PEAK POWER:

DEVELOPING MICRO HYDRO POWER IN THE PEAK DISTRICT

Friends of the Peak District

This project was principally supported by a grant from the Peak District Sustainable Development Fund (SDF – Defra funded, operated by the Peak District National Park Authority) plus additional grants from the East Midlands Community Renewables Initiative (CRI, administered by the East Midlands Regional Assembly, EMRA) and the Chesterfield Steels Group, corporate sponsors of Friends of the Peak District.

This report was written by Graham Woods and Andy Tickle (of Friends of the Peak District), Paul Chandler and John Beardmore (of T4Sustainability Ltd) with a contribution by Richard Pymm (of the Devon Association for Renewable Energy) on behalf of Friends of the Peak District.

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T4 Sustainability Ltd

PEAK DISTRICT NATIONAL PARK AUTHORITY

Supported by the Sustainable Development Fund

East Midlands Regional Assembly

Chesterfield Steels Group

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Graham Woods, Andy Tickle, Paul Chandler
and John Beardmore
with an additional contribution by Richard Pymm

March 2010

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FOREWORD

BY HILARY BENN, MP, SECRETARY OF STATE FOR THE ENVIRONMENT, FOOD AND RURAL AFFAIRS

In 2009 I was fortunate enough to visit the Peak District National Park, to celebrate the 60th anniversary of the legislation which established England's wonderful National Parks.

While I was there I was delighted to hear about the work which Friends of the Peak District and others are doing to explore the potential of small scale hydro power. The challenges which face us on climate change are huge and will require a global agreement. But they also need small scale answers with individual households and businesses taking responsibility for doing something. And that is where Friends of the Peak District's work fits in. It is striking that in many of our rural areas we were making more use of water power in the 19th century than we did in the 20th.

That needs to change, hence the importance of the work which Friends of the Peak District is doing with its partners. I am delighted that these include the National Park Authority, which I know has also helped with finance from its Sustainable Development Fund. Of course any new idea becomes much more powerful when we can actually see it working in practice and that's why the case studies in this report are so valuable. They show just how viable hydro power is in lots of places.

Hilary Benn

PREFACE

BY NARENDRA BAJARIA CBE,
CHAIR OF THE PEAK DISTRICT NATIONAL PARK AUTHORITY

HARNESSING THE POWER OF WATER

With increasing energy demands, the need to save or generate more energy is a challenge for us all.

Despite awareness of the environmental damage caused by burning coal, oil and gas the vast majority of our energy still comes from fossil fuels.

It was not always like this. Hydro power was once a significant part of the Peak District landscape, powering the Industrial Revolution of the 18th and 19th centuries.

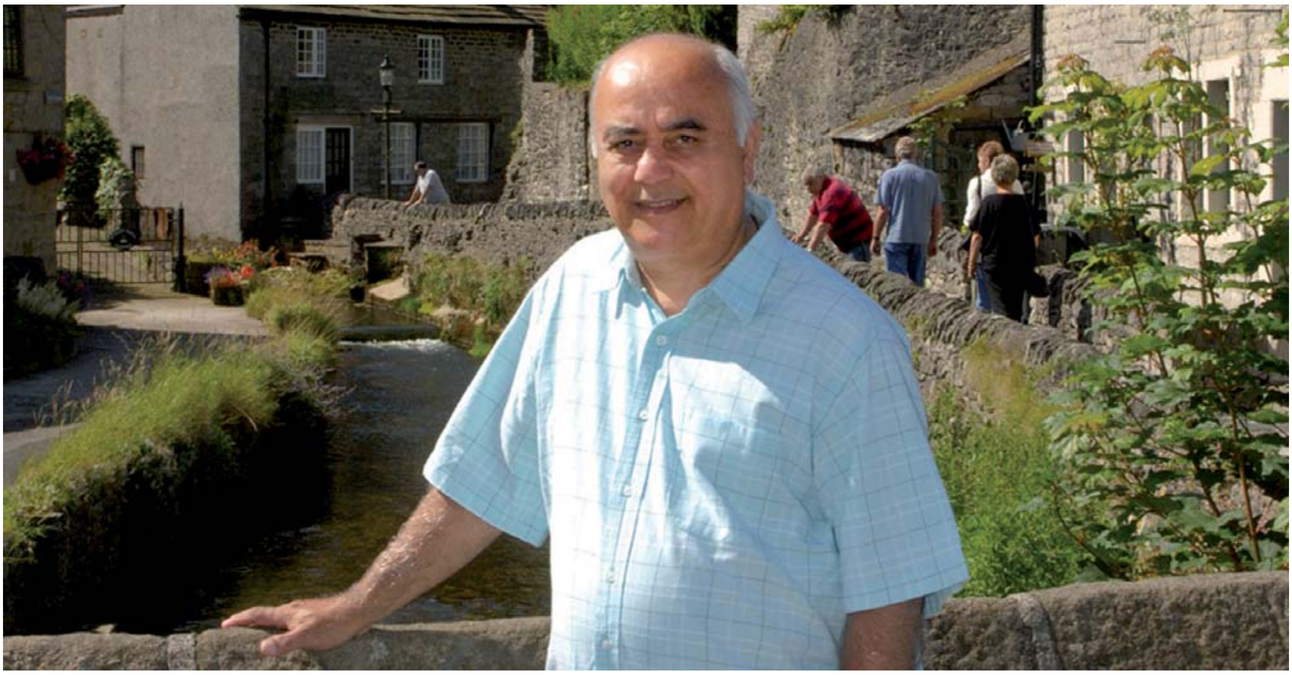
Today the opportunities for creating small scale hydro power sites in the Peak District National Park are again being explored. To do this we have to consider the challenge of using new technologies and structures, as well as the possibilities for restoring old mills. Indeed a hydro plant has already opened at Alport Mill on the Haddon Estate.

This report is an important stepping stone towards more hydro schemes of this type. It looks in detail at the wide variety of available and developing hydro technologies that can be used to create sustainable energy, while still protecting the special features of the National Park.

The report will also encourage local residents, community services, local businesses and others to consider harnessing water power as part of a move towards more sustainable lifestyles.

I hope this is the beginning of a new industrial revolution and that opportunities to re-introduce an ages old technology can be taken forward into the 21st century.

Narendra Bajaria



DISCLAIMER

This report was produced by Friends of the Peak District (with contributions from T4Sustainability and Richard Pymm of the Devon Association for Renewable Energy, DARE) to investigate and promote the potential for renewable energy from micro hydro power installations in the Peak District. Its specific purpose is not to act as an expert feasibility study though clearly we hope that the information collated in the report is of use in helping focus on and resolve site-based issues.

The contents of this report represents the views of Friends of the Peak District, with specialist technical input from T4Sustainability. This report is not binding on the Peak District National Park Authority or neighbouring planning authorities in the determination of any subsequent planning application which would be judged on the merits of any scheme coming forward. Any comments in this report relating to the Environment Agency do not prejudge any decision or guidance on licensing.

All landowners or other interested parties should be fully aware that further assessment will be required before the suitability of a site is fully understood. The content of this report does not constitute legal advice.

ACKNOWLEDGEMENTS

The project team wishes to acknowledge the significant time and input of all the owners and other parties interested in hydro sites in helping with information and access to their land, rivers and weirs. In particular, we acknowledge the access given by the Chatsworth and Haddon estates and dialogue with them and their agents, in particular Jon Needle and Olly Paish at Derwent Hydro Power (DHP) who developed Alport Mill for the Haddon Estate. DHP gave much help and advice throughout the project and also provided a number of illustrations, as did the British Hydropower Association. We are also very grateful to Hilary Benn (and his staff) and Narendra Bajaria for their kind words of support.

We also thank the project advisory group for their input throughout the project and particularly at the inception and mid-term review stages. Richard Pymm of DARE did sterling work from a distance to ensure the HydrA flow studies and the accompanying advice were as accurate as possible. We benefited greatly from the Dartmoor hydro work by DARE which preceded and inspired this report.

Local Environment Agency staff, including Margaret Neal, Jim Finnegan and Steve Tupper, also helped and advised on various issues, and staff from other EA regions helped us understand the hydro implications of relevant elements of their local CAMS documents. We are grateful for the help and assistance of Richard Hall of Yorkshire Water, Martin Dent at Severn Trent Water and various staff at United Utilities in identifying existing and potential schemes within their ownership. Officers at the Peak District National Park Authority, including Judith Fidler, Frances Horsford, John Lomas, Brian Taylor, and Sarah Whiteley, all made helpful comments especially during the project write-up. Dr John Barnatt of the Peak District Mines Historical Society also commented on the use of soughs. However any errors or opinions in this report remain those of the authors on behalf of FPD.

We are indebted to Richard Godley, the SDF officer, for his huge and unwavering commitment to see the project through to completion. We also thank the PDNPA and the East Peak Innovation Partnership (EPIP) for funding the final community workshop which was ably delivered by Steve Welsh of Water Power Entreprises (H_2OPE). We also thank Helen Chadwick and Murray Hunter for their help in delivering the CRI/EMRA funding and Berenice Wilson and Adrian Cole of the Chesterfield Steels Group for their generosity.

Chapter 1 Introduction

1.1 THE PEAK DISTRICT MICRO HYDRO PROJECT

This report has been produced by Friends of the Peak District (FPD) in conjunction with technical input from renewable energy consultants, T4Sustainability (T4S) and the Devon Association for Renewable Energy (DARE). DARE pioneered surveying hydro power potential in a national park (Dartmoor) context (DARE, 2004) and also devised a survey template that could be applied in other designated landscapes (Pymm, 2005), which formed the starting point for the Peak District micro hydro[1] project. This project, spread over more than two years, was funded principally by the Peak District Sustainable Development Fund (SDF – Defra funded, operated by the National Park Authority) with a further contribution from the East Midlands' Community Renewables Initiative (CRI, operated by the East Midlands Regional Assembly) and corporate sponsorship from the Chesterfield Steels Group (CSG).

The micro hydro project deals primarily with the identification and assessment of rivers and streams in the Peak District where micro hydro power (MHP) could be reinstated or developed from new. It draws in part on previous national and regional studies (Salford Civil Engineering Ltd, 1989, usually known as the 'ETSU report'; LUC and IT Power, 2001) which identified a number of potential Peak District sites. The current study attempts to assess further potential for micro hydro power in the Peak, focusing predominantly on opportunities for reinstating old mill sites.

The project team comprised a part-time hydro project officer (water engineer Graham Woods), based with FPD, who oversaw the literature and technology reviews and the site survey work. Technical expertise was provided by Paul Chandler and John Beardmore, directors at T4S, who devised and ran the Geographic Information Systems (GIS) constraints screening model and also advised on case study turbine choices and costs. Technical site assessments for the key case studies (principally modelled flow and power predictions using the HydrA model) were commissioned from Richard Pymm, a DARE director. The project was managed and drawn together by FPD's Head of Planning, Andy Tickle.

The overall progress and direction of the project was steered by a project advisory group (see Appendix F) comprising representatives of the regional water and sewerage companies (Yorkshire Water, United Utilities and Severn Trent); the hydro industry; key PDNPA officers plus a member of the National Park Authority with experience of the water industry; the Environment Agency; English Heritage and two hydro/renewable energy experts drawn from academia.

1.2 THE VISION

The vision for this project was to identify a comprehensive data set of potential micro hydro power sites in the Peak District, paving the way for enhanced uptake of hydro-based renewable energy (RE) schemes by residents, larger landowners and local communities in the National Park and beyond. This should help meet local, regional and national policy targets to offset the damaging impacts of climate change.

By addressing residents, landowners and communities, the project aimed to raise general awareness of the need for increased RE (appropriate to the special characteristics of the National Park). The project should also help to identify how to meet the national need for renewable energy whilst respecting the statutory purposes and duty enshrined in National Park legislation.

1.3 AIMS AND OBJECTIVES

The overall aim of the project was to produce a comprehensive survey of micro hydro power potential in the Peak District National Park (PDNP) area and its immediate surroundings. The results are produced in full in this technical report. A separate popular booklet, summarising the project findings for wider circulation and awareness raising, has also been produced.

[1] *Micro hydro power usually describes schemes with capacities between 10-100 kilowatts (kW); small scale hydro is used to describe schemes between 100 kW-2 megawatts (MW); schemes under 10 kW are sometimes referred to as 'pico'.*

The project has involved the local community, initially via two consultation events (in the north and south of the Peak District: Glossop and Cromford). These were aimed at raising awareness of the opportunities for private or community-led hydro projects (or other RE schemes if more appropriate) and were useful in obtaining feedback on the project at a formative stage, including suggestions of potential sites. At the end of the project, a further workshop (jointly organised by FPD, the PDNPA and Water Power Entreprises, H_2OPE) was held in Low Bradfield, on how to develop a community hydro scheme.

The project's specific objectives were as follows:

- To introduce and overview currently available hydro power technology and to review opportunities and constraints to its introduction in the Peak District
- To set out the policy and legal frameworks associated with gaining permission to develop a micro hydro scheme
- To give practical advice on dealing with site issues such as the water environment, ecology, archaeology, landscape impact, access for civil works, electrical connection etc
- To use appropriate datasets (including GIS information) to identify possible sites for micro hydro installations
- To create accessible databases with site listings that will be available to residents, landowners, communities and other interested parties (e.g. PDNPA planners, statutory agencies, other local authorities)
- To consult and engage with parish councils, local communities and residents to help raise awareness of hydro power potential in the Peak District
- To investigate the opportunities for innovative low head schemes (including modern waterwheel technology) and refurbishment of existing historic mill sites; also to scope the potential use of water flows from lead mine drainage channels (soughs) – a typical and historic Peak District resource
- To encourage and facilitate the assessment of potential hydro power sites with the intention to bring forward new schemes, in particular using a set of key case study sites as exemplars of different types of micro hydro opportunities
- To provide helpful information on recent micro hydro schemes in the Peak District and other UK designated landscapes as potential models for development
- To publish a full report on the project's main findings which will be an authoritative reference source for potential small scale hydro scheme developers and those who assess or comment on such schemes (statutory consultees, planners and interested third parties such as local communities, amenity groups, wildlife trusts etc)
- To disseminate the project findings more widely through an attractive and accessible booklet illustrating hydro power potential and best practice in a National Park perspective

1.4 STUDY APPROACH

To realise the project objectives the following broad approach was taken to gathering the relevant data:

i Literature reviews of current hydro technologies, planning and licensing regimes for micro hydro schemes and gathering information on specialist hydro suppliers and grants currently available for hydro schemes

ii A desk study of all known old mill and other potential micro hydro sites, using specialist publications, databases and map-based resources; this was augmented by wide consultation with local communities, parish councils and key landowners who nominated additional potential sites

iii Walk-over surveys (117) of many of the sites identified in the desk study (162) to assess potential for development/re-development

iv An assessment of the major constraints (planning, environmental, cultural, electrical connection) affecting the sites with the most potential: this involved creating a novel GIS computer model to screen 59 sites

v Undertaking more detailed investigations, in liaison with local landowners and/or stakeholders, of 20 key sites of which 10 were developed into case studies where the feasibility of a scheme was assessed, design options considered and recommendations developed

1.5 THE NEED

1.5.1 Setting the challenge – the national context

In 2003 the UK Government published the Energy White Paper *Our energy future – creating a low carbon economy* (DTI, 2003). This paper highlighted three major energy challenges that face the UK:

- climate change – to help lessen the effects of climate change, there must be a reduction in greenhouse gas emissions
- security of supply – within a few years the UK will no longer be self sufficient in energy and is expected to become a net importer of gas
- ageing energy infrastructure – many conventional and nuclear power stations need massive investment, replacement or closure by 2020.

In October 2006 the Stern Review on the Economics of Climate Change was published[2] and it made clear that action was required quickly to mitigate climate change. The UK Government reacted quickly to the review and soon promoted a UK target of 60% reduction in CO_2 by 2050. More recently, evolving scientific evidence of climate change and increasing domestic and international pressure has led the UK Government to set even more demanding targets for the reduction of greenhouse gas emissions, including CO_2, that cause adverse climate change.

[2] *See http://www.occ.gov.uk/activities/stern.htm (see also Stern, 2007).*

Increasing the proportion of energy generated by renewable technologies is a key part of meeting these targets. The UK Climate Change Act, which passed into law in November 2008, sets a legal target of at least an 80% reduction in greenhouse gas emissions by 2050, with an interim target of a 34% reduction by 2020, both from 1990 levels. Binding European Union (EU) targets also commit the UK to producing 15% of total energy from renewable sources by 2020 (equivalent to a 35% share of electricity from RE). Within the UK Renewable Energy Strategy (RES), published by the Government in July 2009, small scale hydro power (both grid-connected and off-grid) is expected to make a limited, yet significant contribution to these targets.

According to the UK RES, at present 5.5% of the total amount of electricity in the UK comes from renewable sources (DECC, 2009a). Of this electricity generated from renewable sources, small scale hydro only provides 2.6% (DECC, 2009b) though the share for large scale is much higher (21.3%). The proportion of hydro power as part of the renewable mix is currently decreasing because of the stronger growth in other technologies, notably wind power. Although small scale hydro will always be a minor contributor to national renewable energy targets, there is calculated to be between 600-1000 MW of low head[3] hydro power potential in the UK (Muller & Kauppert, 2002). More optimistically the British Hydropower Association (BHA, the hydro industry's trade body) estimates a total resource of 20 GW of hydro power in the UK, including tidal barrages.

1.5.2 Planning for renewables

The Government's *Planning Policy Statement 22: Renewable Energy* (PPS22) states the key principles which regional planning bodies and local planning authorities should adhere to in their approach to planning for renewable energy. PPS22 makes it clear that there should be regional targets for renewable energy which help the Government deliver its objectives. The use of criteria based policies under PPS22 is an essential part of the approach to developing renewable energy resources, with these criteria being used to identify broad areas where development of particular types of renewable energy may be considered important. However, PPS22 also sets out, in paragraphs 11 and 12, the special regard required for development in National Parks in regional spatial strategies and local development documents.

In a further *Planning Policy Statement: Planning and Climate Change*, published in December 2007 as a supplement to Planning Policy Statement 1 (PPS1), the Government clearly states *'In developing their core strategy and supporting local development documents, planning authorities should provide a framework that promotes and encourages renewable and low-carbon energy generation. Policies should be designed to promote and not restrict renewable and low-carbon energy and supporting infrastructure.'* For areas such as the Peak District National Park, this means that the challenge is to find and promote acceptable forms of renewable energy which can be accommodated in the National Park's special landscape.

1.5.3 Regional targets

Although the local authority areas that make up the National Park fall within four Government regions (East Midlands; West Midlands; North West; Yorkshire & Humber), all of the area within the National Park boundaries falls formally within the East Midlands region for the purposes of spatial planning.

In terms of renewable energy, current regional targets are based on previous domestic policy commitments to supply 10% of UK electricity from renewable sources by 2010 and 20% by 2020 (driven by our extant international obligation, under the UN Kyoto Protocol, to cut CO_2 emissions by 12.5% from 1990 levels by 2008-2012). In terms of the proportion of renewable electricity generated, the East Midlands Regional Plan (adopted in March 2009) aims to double 2006 capacity (3%) by 2010 to 6% (a reduction on the previous RSS target of 10% by 2010 but recognising poor recent progress) and sets a target of 20% by 2020. In terms of hydro power, capacity is targeted to rise from 3 megawatts (MW) to 9 MW by 2010, 14 MW by 2020 and 16 MW by 2026 (the end of the plan period).

However, given the scale of ambition in the new national and EU targets for 2020 and 2050, it seems likely that regional RE targets will have to be increased significantly. The scope for further RE capacity is being addressed currently in the partial review of the Regional Plan. A study commissioned by the East Midlands Regional Assembly (Faber Maunsell/AECOM, 2009) suggests that, under a 'business as usual' scenario, the contribution of hydro in the region will be relatively minor in overall terms with current capacity (about 3.5 MW) rising to 12 MW in 2031. However if a 'high growth' scenario was achieved, the study suggests a target of 20 MW by 2031 is feasible. The main potential is seen as being predominantly in Nottinghamshire and Derbyshire which includes contributions from the Peak District National Park.

1.5.4 The local challenge

Although much of the strategic framework for developing sources of renewable energy is set out at regional level, in October 2003 the Peak District National Park Authority adopted its *Supplementary Planning Guidance for Energy, Renewables and Conservation*. This document establishes the

[3] *Low head refers to large quantities of water falling a short distance, typically less than 10m. High head refers to smaller flows of water but falling over greater distance (height), often on mountain streams.*

Figure 1.1 The Torrs Hydro Archimedes screw at New Mills in High Peak (photo courtesy of MannPower)

Figure 1.2 The newly installed crossflow turbine at Alport Mill (photo courtesy of Derwent Hydro)

positive role that renewable energy can play in an area of high environmental quality and offers guidance on the most appropriate opportunities for the future deployment of renewable technologies. It identifies those options most likely to be acceptable within the National Park, including small- and micro-scale hydro generation. Furthermore it emphasises that renewable technologies should be small scale, serving only local needs and achieved in ways which are sensitive to the special character of the Park.

Currently no overall targets for renewable energy generation within the Peak District have been set by the National Park Authority for either 2010 or 2020. However in 2005 the East Midlands Regional Assembly did set targets for the NP as part of its Regional Spatial Strategy (RSS8). These were an overall 2010 target for electricity generation from renewables of 9.73 GWh/yr of which 6.3 GWh/yr, or 1.3 MW installed capacity, should come from hydro power. At present there is approximately 1.6 MW of installed hydro power either within the National Park or immediately adjacent and feeding from catchments within the Park (see Table 5.1).

Finally as part of the process of developing an evidence base for the new Local Development Frameworks (LDFs) for the Peak District National Park, High Peak Borough Council and Derbyshire Dales District Council, a climate change study of the Peak sub-region has been published (NEF & LUC, 2009). Based on landscape sensitivity assessments, figures for RE capacity and targets to 2026 have been estimated which will contribute towards meeting regional targets for the East Midlands. The study has assessed (based largely on data from this project) that hydro power could generate up to 6 GWh/y of energy, thus saving 2580 tonnes of CO_2. In terms of installed capacity, this would be roughly equivalent to 1.2 MW.

1.5.5 Recent hydro developments in the Peak District

Although water power was historically the mainstay of industrial power in the Peak District (principally associated with mineral extraction and processing, grinding cereals and fabric making), very few original working wheels (or latterly turbines) remain. The main exceptions are two low head turbines at Caudwell's Mill at Rowsley (one providing electricity for the mill) and the high head turbines at Chatsworth that power the Emperor Fountain and provide electricity to the House.

In recent decades, water and sewerage companies have utilised water flows between and from reservoirs to provide power, notably in the Longdendale and the Upper Derwent catchments. These installations (totalling about 1.4 MW) now form the backbone of hydro power generated in the Peak District. Latterly, spurred mainly by the need to find new forms of low carbon energy generation, two new schemes have been implemented at New Mills in the High Peak (a 70 kW Archimedes screw installed in 2008 – see Figure 1.1) and Alport Mill (a 30 kW turbine installed in 2009 – see Figure 1.2), near Youlgreave. These schemes readily demonstrate the potential for both private and community-led micro hydro power in the Peak District.

Thus the Peak District is now beginning to mirror the experience of other UK national parks, such as Dartmoor (DARE, 2004), the Brecon Beacons (e.g. the Green Valleys initiative) and the Yorkshire Dales (Inter Hydro Technology, 2009), in focusing on micro hydro power as a sustainable source of renewable energy that does not cause significant landscape or environmental conflicts.

1.6 SCOPE AND STRUCTURE OF THE REPORT

As stated earlier, this report focuses on assessing the potential for developing further micro hydro power capacity within the PDNP, predominantly in relation to old mill sites. As the project has progressed, and in response to local stakeholder feedback, the scope was extended to sites just outside the NP boundary but where the main part of the stream or river's catchment lay within the National Park. A typical example would be Hayfield in the High Peak where the main part of the village and a former weir lie just outside the park boundary. In total 42 sites outside the PDNP were assessed in detail (i.e. assessing local constraints with the GIS model), compared with 120 assessed within the boundary.

The report is divided into six substantive chapters. Chapter 2 introduces and explains the physical principles underpinning the generation of power from water and the main forms of technology and associated infrastructure in use today. Chapter 3 covers the main regulatory issues that affect any substantive form of hydro power development including water licensing, planning permission and other necessary consents. Chapter 4 builds on this and explains – in simple terms – how a hydro scheme can be taken forward from early scoping and assessment, what grants may be available and how income streams can be harnessed.

Chapter 5 reviews the first two elements of the project's survey of potential Peak District sites: the initial resource assessment (all sites) followed by detailed screening of nearly 60 sites with the most potential. This is followed in Chapter 6 by ten key case studies focusing on differing types of micro hydro opportunity in the area with recommendations for next steps.

Overall conclusions and recommendations are then set out in Chapter 7. A series of Appendices contains detailed site data and maps, detailed flow and power data for the key case study sites and information on how to access other hydro-related resources, such as hydro installers, equipment suppliers and sources of grants and other forms of financial assistance.

Chapter 2
Micro hydro power explained

2.1 BACKGROUND

Hydro power is one of the oldest forms of energy generation and for centuries – up to the start of the industrial revolution – was a major source of motive power in the UK. It uses the kinetic energy in water (the energy in its movement) to turn machinery or to turn a generator and produce electricity (usually via a turbine).

It is not known when the first mill was built in the Peak District but the Doomsday Book lists 63 mills in Derbyshire of which six (Ashford, Bakewell, Dovedale, Hope, Tissington and Youlgreave) would lie within the present National Park boundaries. All water mills were driven by waterwheels up to the early part of the 19th century when turbines began to be used. In the later part of the 19th century turbines for hydro electric generation were developed, with the first installation being in Northumberland in 1879. There was a rapid growth of electric power supply during the later part of the 19th century but hydro power was never very important in England as adequate water power was generally remote from towns. However, many mills were converted to supply DC power to the mill and nearby houses by the retro-fitting of turbines and generators.

At present, with 1630 MW of installed capacity (as at 2008: DECC, 2009b), the UK generates about 1.4% of its electricity from hydro electric schemes – mostly from a small number of large scale schemes in the Scottish Highlands. Opportunities to increase large scale hydro in the UK are limited as most commercially attractive and environmentally acceptable sites have by now been utilised.

The situation with the small and micro hydro sector in the UK differs in that there are over 100 schemes but grid connected schemes only total 173 MW capacity (DECC, 2009b). Most of these schemes are in England and Northern Ireland but their total contribution is a tiny fraction (c.0.2%) of the UK's electricity generating capacity. However, as shown in Figure 2.1, the amount of electricity generated by small schemes has risen significantly since 2003. In terms of future development, it has been estimated that if all the rivers and streams in the UK could be tapped for small scale hydro, it would be possible to produce 10,000 GWh/yr (about 2000 MW capacity at 55% capacity factor), enough to meet just over 3% of our total electricity needs (Leigh, 2007).

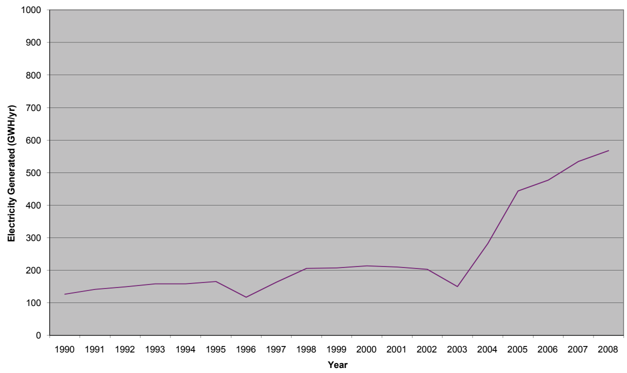


Figure 2.1 Small scale hydro generation in the UK, 1990-2008 (based on data from DECC, 2009b)

However other assessments, already referred to in Chapter 1, have been less optimistic and range from an estimated capacity of 600-1000 MW of low head power (Goring, 2000 quoted in Muller and Kauppert, 2002), to the ETSU report (Salford Civil Engineering Ltd, 1989) which estimated the economically available potential (defined as offering a 10% real rate of return) of small scale hydro in the UK to be in the region of 1312 GWh/yr. This would correspond to 322 MW of installed capacity, with an overwhelming majority of this total (286 MW) being in Scotland.

The ETSU report includes 193 low head sites (2-10m) with capacities between 25-100 kW. These were reported as being able to yield about 10.25 MW but significantly, in relation to this study, ETSU dismissed many sites with either a head less than 2m or power outputs less than 25 kW. In total the ETSU report rejected 25 sites in Peak District catchments, usually on the grounds of very low heads or poor projected power output.

2.2 SMALL SCALE HYDRO POWER

Although there is no internationally agreed definition of small scale hydro, in the UK it is usually taken to mean schemes with an output less than 2 MW. Small hydro power is something of a catch-all category and can be broken down further into three size ranges:

- Mini hydro   schemes from 100 kW-1 MW
- Micro hydro   schemes from 10-100 kW
- Pico hydro   schemes below 10 kW

Similarly, schemes can be divided based on the head of water available at the site, with the normally accepted classifications being:

- High head   > 50m
- Medium head   10-50m
- Low head   <10m

All the potential schemes considered in this project fall outside the mini hydro and high head categories with the majority being low head micro hydro.

It is widely considered that small scale hydro is one of the most effective and reliable energy technologies used for generating clean electricity. Also, as an indigenous renewable source of energy, it helps to reduce dependence on imported fossil fuels, bringing diversity and security of supply to the UK's energy infrastructure, as well as helping to minimise the impact of climate change.

In particular small scale hydro offers the following key features (British Hydropower Association, 2005):

- A high efficiency (70-90%) of the turbine, screw or wheel
- Constant generation over long periods unlike wind and solar power
- A high level of predictability, varying with annual rain patterns
- Slow rate of change; the power output varies only gradually from day to day, not from minute to minute
- A good correlation with demand in that output is greatest in winter (this feature is sometimes described as 'load following')
- It is a long lasting and robust, tried technology; systems can be engineered to last for over 50 years (and many have lasted longer)
- Low maintenance requirements and running costs
- Reasonable payback for grid connected systems, often 10 years or less

A good quality hydro installation will generate electricity for at least 40 years. Assuming an annual saving of 1.6 tonnes per year of CO_2 for a 10 kW scheme (compared with fossil fuel generation), then over the lifetime of the scheme this would amount to a saving of 24 tonnes of CO_2.

2.3 HYDRO POWER BASICS

Hydro power is best described as harnessing the energy of water to do work. The energy can be captured wherever a flow of water falls from a higher to a lower level, such as when a river passes over a waterfall or weir or when a stream flows down a hillside.

The vertical fall of water created either naturally (waterfall, slope) or artificially (weir) is generally considered essential for hydro power generation as fast flowing water on its own has limited applications for power generation. The energy in water is a function of the weight of water and the vertical height through which it falls, usually expressed by the rate of flow, **Q**, and the head, **H**.

The rate of flow (**Q**) is the volume of water passing per second and is usually expressed in **cubic metres per second**, m^3/sec (often called 'cumecs').

The head (**H**), expressed in **metres**, m, is the **net head** applied across the hydro installation and, due to efficiency losses incurred, will be less than the **gross head** which is the maximum available vertical fall across the site.

2.3.1 Power

Energy, measured in **joules**, is defined as an amount of work done or the capacity to do work and power is the rate of work being done measured in **watts** (where 1 watt = 1 joule/sec).

Waterwheels and turbines convert kinetic energy in the water into mechanical power to drive a generator and thereby produce electrical energy. The formula for the output of a hydro scheme is:

P = n p g Q H

where:

- **P** = the mechanical power produced
- **n** = the hydraulic efficiency of the waterwheel, turbine etc
- **p** = the density of water (1000 kg/m^3)
- **g** = the acceleration due to gravity (9.81 m/s^2)
- **Q** = the volume of water (m^3/sec)
- **H** = the net head of water across the waterwheel, turbine etc (m)

To estimate the electrical power produced it is necessary to consider the efficiencies of the various types of plant and generators, which vary depending not only on the type of plant but also on the size of scheme. Efficiency is a measure of how well power is converted from one form (water power) to another (electricity). The water-to-wire efficiency, or system efficiency, of a typical small scale scheme has been variously estimated as 50-70%, with the losses split almost equally between the conversion of water energy into mechanical energy by the turbine and conversion of the mechanical energy into electrical energy by the generator and associated equipment. This then simplifies the above equation to:

P_e (kW) = 5 x H (m) x Q (m^3/sec) (lower estimate)
or
P_e (kW) = 7 x H (m) x Q (m^3/sec) (higher estimate)

where:
P_e = electricity generated (kW)

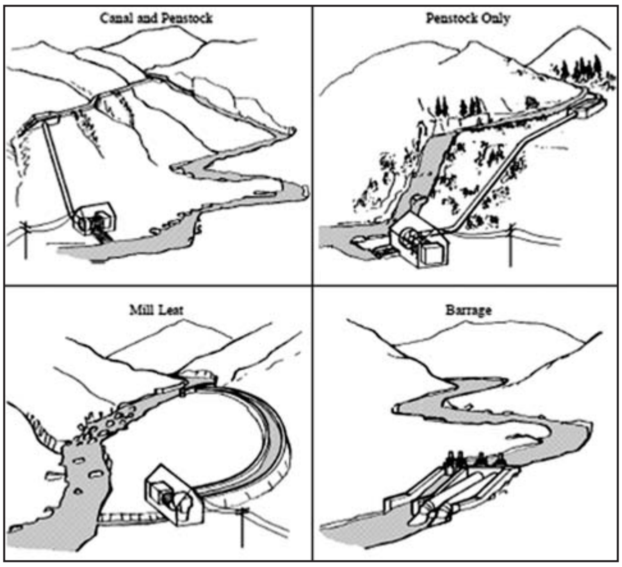
For the power estimates made in this report a value of 6 (x H x Q) has been used throughout (see Appendix C for the full rationale for this choice).

2.3.2 Typical layouts

Although sites available for run of river hydro schemes vary greatly, they can be categorised into four main types (see Figure 2.2):

- for medium head schemes there is the canal and penstock (pressure pipe) layout or,
- where a canal is not acceptable due to terrain or environmental considerations, then a penstock only can be used;
- where a scheme involves the development of an old mill site then the existing channel (often termed a 'leat') can be used thereby reducing the construction costs;
- finally it is possible to use an existing weir by placing turbines or a screw generator in the weir face or immediately adjacent to the weir or by creating a new impoundment in the form of a barrage to create a head.

Figure 2.2 Types of hydro scheme layouts (courtesy of BHA)



In the case of the water distribution network operated by the water and sewerage companies then there are a number of opportunities for the generation of electricity. These include:

- compensation water from reservoirs,
- inlets to water treatment works and
- the effluent discharge from wastewater treatment works.

2.4 TECHNOLOGY

2.4.1 Context

Humans have been using water to generate power for over 4000 years and during that time three main types of technology have been developed:

- Waterwheels
- Archimedes screws
- Turbines

For medium and high head sites (head > 10m), the only realistic power source for the generation of electricity is a turbine and, in the recent past, these have also been seen as the solution of choice for the generation of electricity for low head sites (head < 10m). However, the cost per kW of electricity produced tends to increase with decreasing (power) rating and – partly for this reason – the two oldest methods of energy conversion, the waterwheel and the Archimedes screw have been re-assessed for their use as power generators (Muller and Kauppert, 2004).

A recent study (TV Energy & MWH, 2004) into the use of different types of generator at eight low head sites in the South East of England found that *'the use of waterwheels and Archimedean screws is technically feasible and financially favourable as compared to the low head Kaplan turbine and hence their technologies could be a suitable alternative to modern turbines for hydro electricity generation'.*

The final choice of technology will always be site specific and depend upon a number of unique factors such as environmental, financial, historic and planning. For this reason, the following sections do not make comparisons between different types of machine or recommend choices.

2.4.2 Waterwheels

Waterwheels are the earliest form of hydro technology and are often seen more as historic relics than viable modern hydraulic machines. They provided the power for the start of the Industrial Revolution with an estimated 25,000 to 30,000 wheels in operation in England around 1850. Developments in the design of wheels continued throughout the later part of the 19th century well after the advent of turbines.

There are four basic types of waterwheel (see Figure 2.3) developed and perfected during the 19th century and designed to utilise head differences from 0.5-12m. The first utilises solely the kinetic energy in a moving body of water whereas the other three types utilise the potential energy of the water falling through a given height and are therefore capable of producing more power.

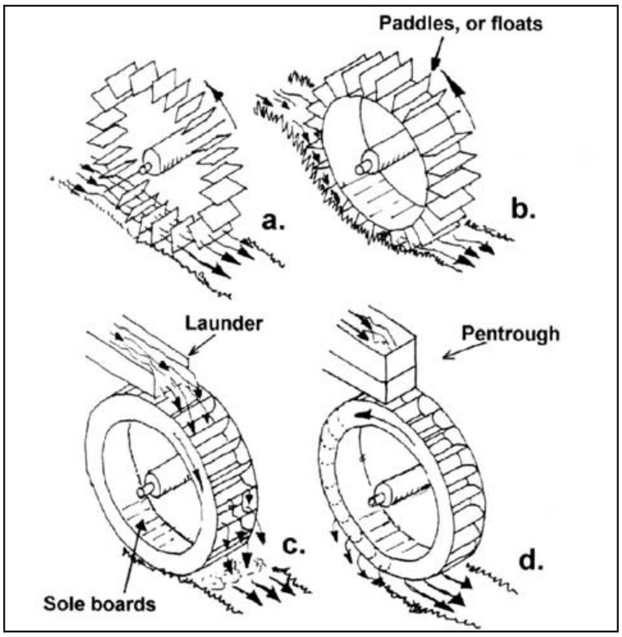


Figure 2.3 Main types of waterwheel: a. undershot; b. breastshot; c. overshot; d. backshot (pitchback) (courtesy of Mrs S. Foreman)

UNDERSHOT
The undershot wheel, see Figure 2.3a, acts like the wheel of a paddle steamer but in reverse. The water enters below the axis and is used for very small heads – 0.5-2.5m. Compared with other types this design is less efficient as it relies purely on the kinetic energy of the water, typically with flows of 0.5-0.95 m^3/sec per metre width of the wheel (Muller and Kauppert, 2004). The Poncelet wheel is a more efficient variation of the undershot wheel with curved metal blades and an upstream sluice gate which directs a jet of water at the wheel.

BREASTSHOT
In the case of this type of wheel (Figure 2.3b) water is admitted to the wheel at approximately the level of the wheel's axis and flows out with the rotation of the wheel. This type of wheel was generally used for head differences of 1.5-4m, and flow rates of 0.35-0.65 m^3/sec per metre width (Muller and Kauppert, *ibid.*).

OVERSHOT
In the case of this type of wheel (Figure 2.3c) water is delivered above the wheel, filling the buckets and making one side of the wheel heavier than the other, which causes the wheel to rotate. This type of wheel was traditionally employed for head differences of 2.5-12m and flow rates of 0.1-0.2 m^3/sec per metre width (*ibid.*).

BACKSHOT
A variation of the overshot wheel is the backshot or pitchback wheel (Figure 2.3d) where the water is added just before top dead centre and the wheel rotates in the opposite direction to the overshot wheel. Whilst the pitchback needs a slightly more complex water supply arrangement it has the advantage that the exhaust water flows away in the direction of the rotating wheel.

STREAM WHEELS
The stream wheel is similar to the undershot wheel in that it converts the kinetic energy of the flow in a stream into mechanical power (see Figure 2.4). They were used to produce mechanical power until the middle of the 19th century; since then they have fallen out of use, probably due to the fact that their efficiencies are low. However, there is renewed interest in this type of wheel for the exploitation of small and very small hydro power sources, with joint research being undertaken by the Universities of Southampton and Berlin into their characteristics (Muller *et al.*, undated). This suggested that modern stream wheels could be employed as an economical converter of the kinetic energy of flowing water with the environmental and ecological advantages that their installation would not constitute a major change to the river.

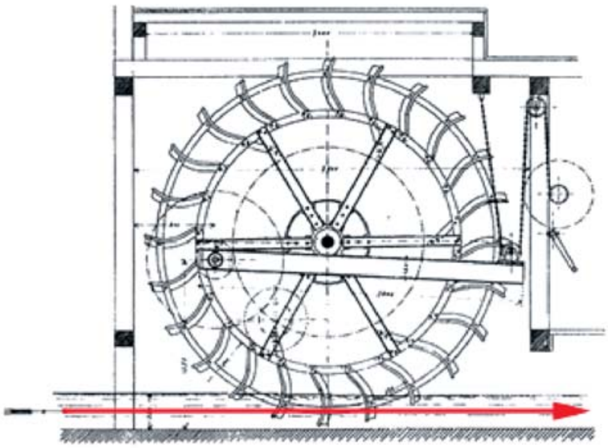


Figure 2.4 Cross section of a stream wheel (courtesy University of Southampton)

Until the 1930s tens of thousands of waterwheels were still in operation in Europe but despite this very little is known about their hydraulic characteristics. In consequence they tend to suffer from a dated and romantic image which leads promoters of hydro power schemes to consider them not worthy of consideration for modern electricity generation schemes.

Figure 2.5 Renovated (but non-working) wheel at Malin Bridge Corn Mill, Sheffield

Figure 2.6 A modern waterwheel in Germany

Indeed, waterwheels are often restored as part of mill conversions (usually to residential use), usually because they are listed, but unfortunately without power generation being re-instated. Recent examples in the area include Bradbourne Mill, near Ashbourne, Bearda Mill near Danebridge and the recently restored Malin Bridge Corn Mill in Sheffield (see Figure 2.5). This is obviously a missed opportunity although it is accepted that noise (from the wheel and gears) can be a problem, especially for residential conversions.

However, some detailed investigations were undertaken in Germany and the USA in the early 20th century and these results, together with some recent research at Queen's University, Belfast, would seem to indicate that waterwheels are efficient energy converters with maximum efficiencies of over 85% for overshot wheels and about 75% for breastshot and undershot wheels. Furthermore waterwheels operate efficiently over a wide flow range, typically from 20% of the designed flow rate (Muller & Kauppert, 2004).

One problem with waterwheels is their slow speed of rotation, typically 7-12 revolutions per minute (rpm). These slow speeds are not sufficient for electricity generation where generator speeds of 650 rpm and above are required to produce alternating current (AC) which can be fed into the electricity distribution network. Therefore a gearing system is required; in the past these have included belt and pulley systems and old tractor gearboxes. It has been estimated that the overall efficiency of a modern waterwheel installation, water to wire, is in the order of 62-69%.

One particular advantage of waterwheels is that they can be considered to be 'fish friendly' due to their low speed of operation and large cells and therefore do not require the fish-screening measures often deemed necessary for turbines. Also, depending on location (whether they are fed by a mill pond), there may not be any need for screening, with resultant savings in capital and operational costs.

Although there has been a number of schemes undertaken in the UK in which an existing wheel has been renovated using traditional materials (see Figure 2.5) there are no UK manufacturers of wheels using modern materials and techniques. An example of a modern design of waterwheel manufactured by HydroWatt in Germany is shown in Figure 2.6.

2.4.3 Archimedes screw

The Archimedes screw has been known since ancient times as a simple and effective machine for lifting water and is still widely used, e.g. for pumping sewage and grain. It is a simple design with only one moving part and two bearings. In the late 20th century it was realised that the Archimedes screw could also be used in a reverse role as an energy converter to produce electricity from water power.

It is claimed that the screw offers a number of advantages over other hydro power machines due to the following factors:

- No complex control system as the screw matches itself automatically to the water supply

Figure 2.7 Screw at River Dart Country Park, Devon (photo courtesy of MannPower)

Figure 2.8 A buried 1 kW screw at Bonfield Ghyll, North York Moors National Park, minimising landscape impact (photo courtesy of MannPower)

- High efficiency across a wide flow range (20 to 100% of design flow)
- Robust simple machinery so little maintenance required
- Fish friendly so no fish screen required
- Floating objects and debris simply pass through the screw negating the need for fine screening

Trials undertaken using the 48 kW Archimedes screw installed at the River Dart Country Park, see Figure 2.7, have confirmed that the screw is indeed fish friendly and no fish screen is required. The operational range of these screws has been stated[1] to be:

- Flow rate 0.1-10 m^3/sec
- Hydraulic head 1-10m
- Hydraulic efficiency up to 87%
- 77% water to wire efficiency
- Satisfactory operation down to 15% of maximum flow
- Power output from 1 kW to 350 kW

Whilst screws do not rotate at anywhere near the rate of turbines their rotation is greater than that of waterwheels, typically 30 to 60 rpm, so fewer gear ratios are needed to achieve the speed necessary for electricity generation. Trials at Prague Technical University have shown that the angle of the screw for optimum performance should be 30 degrees (though most screws installed in the UK have been between 22-26°).

Over the past two years 11 schemes incorporating Archimedes screws have either been constructed or commissioned in the UK, ranging in output from 1.4 kW to 180 kW. The nearest to the Peak District National Park is a 70 kW screw at New Mills constructed in 2008 (see Figure 1.1 in Chapter 1) and the smallest at 1.4 kW is at Bonfield Ghyll in the North York Moors National Park, Figure 2.8, which has been buried to minimise landscape impact.

2.4.4 Turbines

Turbines started to be developed in the mid 19th century and can be classified either according to their operating head or their principle of operation. In terms of the latter, there are two types of turbine: the impulse turbine and the reaction turbine.

The impulse turbine operates in air. The head or water pressure is converted into kinetic energy by a nozzle or nozzles before entering the runner (the rotating part) of the turbine. The resultant high speed jet of water strikes specially shaped cups mounted on the periphery of the runner. Examples of impulse turbines include Pelton, Turgo and crossflow (or Banki) turbines (see Figure 2.9).

The reaction turbine operates fully immersed in water and is enclosed in a pressure casing. Water flows over the runner blades situated in the casing; this causes a pressure drop across the blades which causes the runner to turn in a similar way to a windmill. Examples of reaction turbines include Francis, propeller and Kaplan turbines (see Figure 2.9).

[1] *See http://www.mannpower-hydro.co.uk/benefits.php*

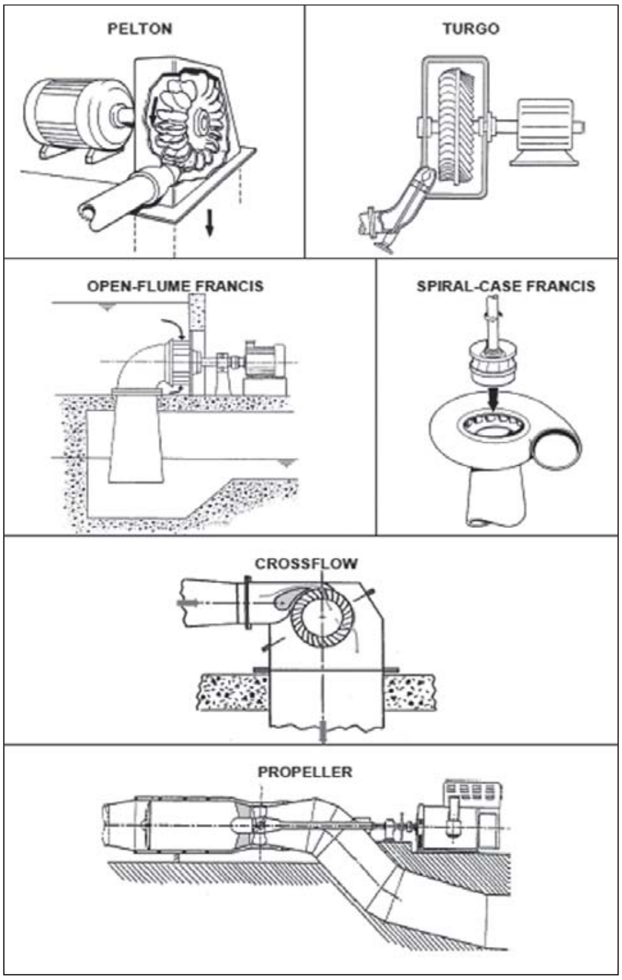


Figure 2.9 The main different type of turbines (courtesy of BHA)

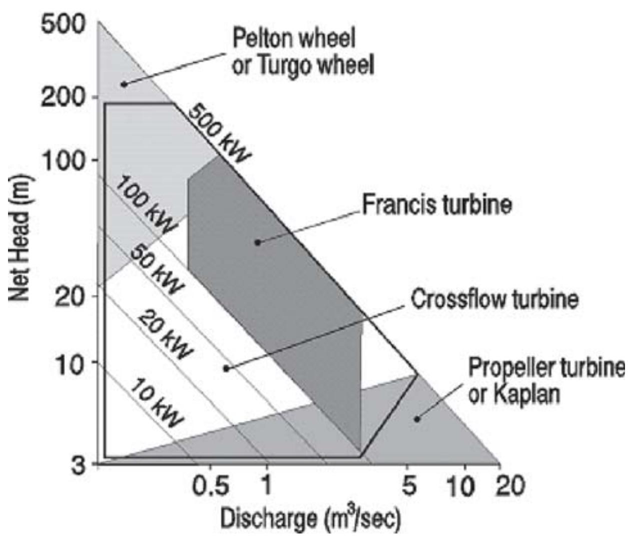


Figure 2.10 Turbine types and operating ranges in relation to head and flow parameters (courtesy Oliver Paish/BHA)

The approximate relationship between head and type of turbine is given in Table 2.1.

Turbine Type	Operating Head		
	High (>50m)	Medium (10-50m)	Low (<10m)
IMPULSE	Pelton Turgo	Turgo Crossflow	Crossflow
REACTION		Francis	Francis Propeller Kaplan

Table 2.1 Operating head and type of turbine

The British Hydropower Association has published a chart giving the approximate operating ranges for different types of turbine and also giving a power output guide for the different combinations of design flow and operating head and this is reproduced in Figure 2.10.

IMPULSE TURBINES

The Pelton turbine is ideally suited to the high heads and low flows from steep mountain streams and consists of a wheel with a series of specially shaped cups set around its rim. A nozzle directs a high velocity jet tangentially at the wheel which rotates at high speed in reaction to the impact of the water jet. The jet hits each cup, is split in half and nearly all the kinetic energy in the water goes into propelling the cup with the deflected water falling into a discharge channel below the wheel.

The Turgo turbine functions like the Pelton except the water jet strikes the plane of the runner at an angle so that the water enters the runner at one side and exits at the other. Blades rather than cups are fixed around the periphery of the wheel and these are shaped so that the water jet imparts nearly all its energy by being diverted through a tight curve. A Turgo machine tends to have a smaller diameter runner than a Pelton machine for an equivalent power output.

The crossflow turbine, also known as the Banki, has only come into widespread use fairly recently due partly to the fact that it is easy to make and hence relatively cheap. It can also operate over a very wide range of heads, from 3-100m. The turbine is drum shaped and uses an elongated nozzle to direct the water jet against curved blades on a cylindrically shaped runner. The water jet enters the top of the drum and flows from the outside to the inside; the second pass is from the inside to the outside. The shape of the blades is such that on each pass the water transfers some of its energy, making the crossflow a very efficient machine. Figure 2.11 illustrates a pairing of Pelton and crossflow turbines (not operating) at Cressbrook Mill in the Peak District.

Figure 2.11 A Pelton turbine (left) and a crossflow (right) at Cressbrook Mill

Figure 2.13 A DIY pico hydro installation in Canada

Figure 2.12 An original Frances turbine in situ at Flewitt's Mill, Ashford in the Water

REACTION TURBINES

Propeller and Kaplan turbines are axial-flow turbines similar in principle to a ship's propeller except that, in the case of the turbine, moving water causes them to rotate rather than *vice versa*. In the propeller turbine the blades are fixed whilst in the Kaplan they can be adjusted to match the flow, i.e. variable pitch. This gives the Kaplan improved efficiency over a wide range of flows but the machine is more complicated and hence more expensive. The water entering these turbines needs to be given some swirl before entering the turbine runner so guide vanes (sometimes adjustable) are mounted upstream of the runner to impart this swirl.

The Francis turbine is basically a modified form of propeller turbine. In this design the water enters the turbine radially, flowing through a pipe which curves around the outside of the turbine (see Figure 2.12). Guide vanes direct the flow onto curved blades which re-direct the water so that it emerges axially. As the water changes direction the runner rotates. Originally designed as a low head machine, thousands were installed from the 1920s to the 1960s. Although an efficient machine, it has been superseded by the propeller turbine which is more compact and faster running for the same flow and head conditions.

LOW COST TURBINES

Turbines tend to be expensive both in terms of capital cost and particularly for sizes below 10 kW (pico hydro). To meet the needs of this market a number of manufacturers, particularly in the USA, Canada and the Far East, have developed small turbines, often plastic, for DIY installation. An example of a small DIY installation in Canada is shown in Figure 2.13.

2.4.5 Screens

For small scale hydro schemes the large majority of operating problems and maintenance costs can be traced back to problems with the screening system. Screens (or trash racks as they are often called) have been used since the early days of waterwheels to filter out waterborne debris before it enters the hydro installation and damages the machinery. In addition, to protect fish, there are guidelines set down by the Environmental Agency (see EA, 2009) regarding the bar spacing of screens (depending upon the type of machinery installed) and these are given in Table 2.2.

Turbine type/screw	Bar Spacing of Screen
Waterwheel or Archimedes screw	100mm or as appropriate
Propeller/Francis/Kaplan turbine (flow greater than 1.5 m^3/sec)	10/12.5mm
Kaplan/Francis turbine (flow less than 1.5 m^3/sec) Crossflow turbine	Default 6mm if evidence of young fry present in summer months otherwise 10/12.5mm
Pelton turbine	3mm Coanda drop through screen

Table 2.2 Suggested bar spacing for inlet screens (Environment Agency, 2009)

Figure 2.14 Mechanically raked bar screen at Barton, near Manchester, showing build up of debris (photo courtesy O. Paish)

The screening of debris from the watercourse can be seen as an additional benefit of hydro schemes. However, the controlled disposal of the debris on land can bring with it charges for waste disposal. Depending upon the location it is sometimes necessary to incorporate a floating boom upstream of the screen to catch large items of floating debris, such as tree trunks, before they reach the screen and cause damage.

RAKED BAR SCREENS

These screens consist of a series of inclined bars spaced across the intake so that a rake can be used to drag the accumulated debris to the top of the screen. Originally this was done by hand but there are now a range of automatic devices available to clean the screen.

Typically a screen will have bars spaced at 20mm with an automatic rake lifting the debris (which can be substantial: see Figure 2.14) onto a conveyor which then deposits it in a skip for disposal to land. There are several designs of rakes, each with advantages and disadvantages. The main types are:

- A robotic rack normally hydraulically powered
- A chain driven rake
- A grab and lift cleaner (usually for larger hydro schemes)

OTHER SCREEN TYPES

Drum screens

A drum screen is in the form of a rotating cylinder of wire mesh (see Figure 2.15) in which the water enters around the periphery of a three quarters submerged cylinder, which is placed across the flow and has one end blanked off. The water exits through the open end and out through a close fitting hole into the turbine intake pipe. A spillway on the downstream side of the drum has a lip that maintains the water level and allows a few centimetres of water to flow outwards from within the cylinder. The cylinder or drum is

Figure 2.15 Self-cleaning drum scheme at the Old Walls scheme, Dartmoor

Figure 2.16 Band screen at Alport Mill, Peak District (courtesy of Derwent Hydro)

slowly rotated by the flow (or an electric motor) and debris is carried over the top and meets the spillwater coming from within the drum and is washed off over the spillway. Drum screens are effective at keeping fish and debris out of the turbine(s) but leave it in the river They are usually only cost-effective for relatively small flows (typically <1 m^3/sec).

Band screens

Similar to the drum screen, a band screen consists of a continuous flexible mesh, set up in a conveyor-belt formation so as to lift the debris into a raised spillway (see Figure 2.16). However, because the mesh is a continuous loop passing up and then down the back of the screen, twice the amount of screen material is needed than the area to be screened. Also the water flows through two layers of screen ('up' and 'down') giving twice the head loss, and the flexible material is easily damaged by large debris so a coarse screen is needed upstream of the band screen.

Wedge-wire or Coanda screens

Wedge-wire screens are the option most favoured by the Environment Agency for excluding all forms of fish from small water intakes because they can accommodate bar spacing down to 3mm. These screens use the Coanda effect to filter out and flush away debris and silt, allowing only clean water into the intake system. They require no raking (see Figure 2.17).

Figure 2.17 A Coanda or 'wedge-wire' screen (courtesy of BHA)

Fish screens

There are also a number of 'behavioural' screen technologies now available for deterring the entry of fish into turbines using vortices, sound waves, bubbles or electric fields, which can be used in combination with a physical trash screen.

For a more detailed review of fish screening options in the UK see Turnpenny, Struthers and Hansen (1998).

Chapter 3
Licensing, environmental and planning issues

3.1 INTRODUCTION

Developing a micro hydro scheme, especially within a National Park, inevitably has the potential to create impacts on sensitive environments: the river, its margins and adjacent land and, of course, the surrounding landscape. Impacts may include changes in river flow, possible alterations to habitats, new structures in a sensitive area or the alteration of existing structures which are historically valued. Connection to the grid may also become an environmental or planning issue as any new connection would be placed underground or on new overhead poles.

The following chapter attempts to offer an introduction to the likely consultations and/or consents that may be required to bring a scheme to fruition – even when all that is proposed is the reinstatement of a disused site where all infrastructure is intact.

There are three main areas that usually need to be addressed, assuming that land, weir and riparian (bankside) rights are under the control of the applicant(s):

- River/water related consents (from the Environment Agency) – see section 3.2
- Planning permission for new structures or changes to land use (from the local planning authority/National Park Authority) – see section 3.3
- Consents for alteration to scheduled monument and/or listed structures (from either English Heritage or the local planning authority, depending on scheduling/grade of listing) – see section 3.4

Of necessity, the following material in this chapter draws heavily on up to date advice given by Environment Agency guidelines and staff plus additional comments provided by planners from the Peak District National Park Authority. However every potential scheme raises different and sometimes unique issues. For this reason, all potential developers are advised to contact the relevant body as early as possible for advice when developing a design for a scheme. Information given here is broadly applicable but cannot necessarily be applied to specific sites nor will be binding upon consequent negotiations with appropriate bodies.

3.2 LICENSING AND THE RIVER ENVIRONMENT – THE ENVIRONMENT AGENCY'S ROLE

Whilst there are aspects of environmental impact dealt with under planning regulations (see Section 3.3), the main body for licensing micro hydro schemes (and hence assessing their impact) is the Environment Agency (EA).

The EA has responsibility for fish protection, water quality and other environmental aspects of riverside developments and hence has regulatory powers which require them to balance the requirements of hydro developments with protection of the environment. The EA is generally sympathetic to renewable energy schemes and has a position statement and policy on hydro power which encompasses three main tenets:

- Strong support for the Government's targets for the use of renewable energy, including hydro power schemes and their role in addressing climate change
- Recognition of the potential benefits of small scale hydro power to rural communities and in meeting local needs for power
- Seeking to work constructively with the hydro power industry to achieve the aspirations of Government, the Agency and the industry

They have produced an internal document *Hydro power - A Handbook for Agency Staff* (EA, 2003 but updated regularly since then) which they will provide upon request to potential developers. The handbook helps to explain the breadth and complexity of the Agency's statutory duties as well as the procedures to be followed in any application for a micro hydro scheme. This document has also been supplemented recently (August 2009) by the *Good Practice Guidelines Annex to the Environment Agency Hydro power Handbook: The Environmental Assessment of Proposed Low Head Hydro Power Developments*. See http://www.environment-agency.gov.uk/static/documents/Business/Low_Head_Hydropower_August_2009.pdf .

Both these documents and related publications stress the importance of an early approach to the Agency, usually via the relevant Area Environment Planning Team (for much of the Peak District (Derbyshire Derwent catchment) this is the EA's Nottingham office).

3.2.1 Environmental assessment

Statutory Environmental Impact Assessments (EIAs) are only required for schemes with an installed capacity of more than 500 kW – well above the capacity of any hydro power scheme likely to be proposed in the Peak District. However, the EA considers that the benefits of an EIA for non-statutory schemes is well established and state that *'...all hydro power proposals need environmental assessment, although in some cases this may be minimal'* (EA *Hydro power Handbook*, section 10).

The new *Good Practice Guidelines* (EA, 2009) also set out an 'environmental site audit' (ESA) approach. This is essential reading for anybody interested in developing or re-instating a micro hydro power scheme. The ESA comprises a check list guide (with a green/red 'traffic light' system) which has been developed to help identify schemes that are not expected to pose environmental problems, those that require more detailed investigations, or may require an EIA.

Any assessment of impact will relate particularly to the EA's conservation function but EA staff are warned not to ask for more than they need to help with determination of the proposal. Appendix A of the *Hydro power Handbook* (*'Guidance to applicants on environmental information required'*[1]) sets out the main areas of impact that need to be considered which include:

- Hydrological information
- Details of structures
- Water resources
- Fisheries
- Conservation (effects on habitats and species, including survey information)
- Recreation
- Navigation
- Water quality
- Flood defence
- Environmental monitoring

It may be necessary to employ specialist consultants to undertake some assessments but a general hydro consultant with the appropriate track record may be able to carry out some of the work.

Also, to ensure that any potential problems are identified at an early stage, it is also wise to have formal and informal consultation with other conservation agencies such as Natural England and amenity/recreation groups such as local angling clubs, boating and water sports associations.

The Environment Agency warns that, due to each site often having unique and complicated environmental impacts which require thorough assessment, the time taken to determine permit applications can be lengthy and significantly exceed the statutory minimum. Consequently, this should be built into any project plan. Pre-application discussion will also help minimise the risk of abortive work.

The local planning authority may also have separate requirements for environmental information, depending on the nature of the development (see section 3.3 below).

3.2.2 Licences

To remove water from a watercourse for a micro hydro scheme requires permission(s) from the EA in the form of water resources permits. There are three different types which can apply to a scheme depending upon its location and design. In addition 'flood defence consent' is likely to be required for all schemes. This involves undertaking a flood risk assessment to ensure there is no adverse impact on flooding in the locality.

ABSTRACTION LICENCE

This licence is required if water is diverted away from the main flow of the watercourse i.e. outside the existing banks of the river or stream. This means that all projects, except barrages where a turbine or Archimedes screw is installed on an existing weir within the existing banks, require an abstraction licence. All new licences are normally for 12 years after which they must be renewed. Some may expire earlier with the Common End Date specified in the local EA Catchment Abstraction Management Strategy (CAMS) document. Although there is a presumption of renewal of the licence by the EA, this is clearly an area of risk for a scheme developer. Schemes extracting less than 20 cubic metres (m^3) per day are exempt from this requirement. Hydro power schemes which return water back to the same watercourse are normally issued with a 'transfer licence', which does not attract an annual charge.

IMPOUNDMENT LICENCE

This licence is required when changes are made to structures which impound water, such as weirs and mill ponds, or if a new structure is to be built. Where a weir already exists it may not be necessary to apply for an impoundment licence – the EA will be able to advise on this.

[1] *Also available as a freestanding handout at EA area offices.*

LAND DRAINAGE CONSENT
This is required for permission to return the abstracted flow back to the watercourse and for any works carried out in the main channel of the watercourse.

3.2.3 Flow control

Micro hydro schemes are deemed to be a non-consumptive use of water, unlike water supply and agricultural uses. However, a certain minimum volume of water, variously termed the 'residual', 'compensation', 'reserve' or 'hands off' flow, must be left in the section of river or stream which by-passes the micro hydro site. This section of watercourse – often referred to as the depleted reach – is between the point of abstraction and the point where the flow is returned. Maintaining a sufficient hands off flow is key to protecting the environment and ecology of the river in the depleted stretch, and is also important for aesthetic reasons.

The EA will prescribe what residual flow must be left in the river and hence what can be used for hydro power. The maximum hydro power flow figure has historically been taken as that in excess of a residual flow of Q_{95} (the flow in the watercourse for over 95% of the time) but recently it has been suggested that this should be varied depending upon the length of the depleted stretch of stream and the type of river (as measured by its Base Flow Index or BFI). The longer the depleted reach and the more 'flashy' the river[2], the greater the residual flow will need to be – up to Q_{85} or greater (see Table 2 and associated text, *Good Practice Guidelines Annex*, pp.30-32: EA, 2009).

3.2.4 Historic rights

The fact that the site may be a former water mill does not mean it has a historic right to extract water, even if shown in title deeds or allied documents. In the late 1970s legislation was passed which required mill owners to take specific and positive action to maintain their abstraction rights. Most did not, so now have no rights and will probably need to re-apply as if for a new site.

3.2.5 Catchment Abstraction Management Strategies

The EA produces a water resource management plan for most river catchments and makes these publically available. The resulting Catchment Abstraction Management Strategies (CAMS) seek to balance the needs of abstractors, the environment and other water users.

CAMS are also the mechanism for managing time-limited abstraction licences by determining whether they should be renewed and, if so, on what terms (through the context of the current and likely future availability of water for abstraction). They are therefore necessary reading for anyone operating an existing hydro scheme or contemplating constructing such a scheme.

CAMS relevant to schemes within the Peak District and adjacent catchments are
- The Derbyshire Derwent CAMS
- The Dove CAMS
- The Don and Rother CAMS
- The Tame, Goyt and Etherow CAMS
- The Weaver and Dane CAMS

Copies of the documents together with details of any proposed revisions can be found at www.environment-agency.gov.uk/cams

Areas of catchments/rivers in CAMS are commonly split into Water Resource Management Units where more specific guidelines are defined and applied, including 'environmental weightings' (EW, from very low to very high, with low, medium and high between, representing the sensitivity of the river to abstraction) which are then developed into river flow objectives. However, although the EW may act as a proxy for environmental factors that may also be a constraint to developing a hydro scheme, the resultant designations such as 'over-licensed' or 'over-abstracted' do not necessarily form a hindrance to a potential hydro scheme (as the use of the water will be non-consumptive). Again the EA will be able to advise.

3.2.6 River Basin Management Plans

In addition to the CAMS are the River Basin Management Plans (RBMPs) which set out the strategies for each of the river basins in England and Wales in order to implement Water Framework Directive (WFD) requirements. At present, consultation drafts for the two main river basins in which the Peak District sits, the Humber and the North West, are available for perusal on the Environment Agency's web site, having been consulted upon in the first half of 2009. The final RBMPs will be published shortly and will be due for review after six years in 2015.

The draft RBMPs also set out protected area objectives (to meet other EU legislation on aquatic environments such as the Freshwater Fish Directive) for particular nature conservation areas (e.g. EU-designated Special Areas of Conservation, SACs, aimed at habitat protection) and other stretches of rivers. In the main, these objectives relate to water quality indices and current compliance status (and measures that may be necessary to improve compliance) should not directly affect the viability of a potential hydro scheme. In due course, these objectives will be subsumed by the more generic target, under the WFD, to reach 'good condition' status.

[2] *'Flashy' rivers are those that respond quickly to rainfall episodes with frequent extremes of high and low flows. A flashy river will also usually have a low Base Flow Index (BFI = ratio of Q_{95}:Q_{mean} <0.1)*

3.2.7 Fish passage

In 2009 the Department for Environment, Food and Rural Affairs (Defra) issued a consultation document concerning the need to improve the free passage of fish and to allow free access to breeding, nursery and feeding grounds for fish in England and Wales. The consultation ended on 10th April 2009.

The proposed regulations intended to extend the powers of the EA to require fish passes (at present limited to new obstructions and enabling the migration of salmon and sea trout) so they could additionally:

– require the installation of a fish pass to facilitate the passage of all migratory and freshwater species;
– require the installation of a fish pass at an extant obstruction whether or not works (e.g. a hydro scheme) are underway.

The deadline for implementation of such powers, required to meet obligations under the WFD, is 2015 but this may be extended up to 2027.

As part of the consultation process the Environmental Agency issued a Statement of Intent (SoI) setting out in principle the way in which they intend to use the new powers that the regulations will provide, with the aim of meeting the WFD obligations by 2027.

The SoI states a number of general principles which will be used by the EA in the future implementation of the regulations, namely:

- New hydro schemes will be required to incorporate appropriate provisions for fish passage
- Installation of fish passes on existing obstructions (weirs) will be phased, based on River Basin Plans, with their need assessed and prioritised in terms of impact on fish populations
- Where the need for a pass is identified at an existing weir then the owner of the obstruction shall pay for the pass. This may be varied where there are other beneficiaries such as fishery owners or where there is a wider public benefit
- The owner of the obstruction shall be responsible for the ongoing repair and maintenance of the pass
- New enforcement powers will enable the EA to serve notice on an owner to take action in respect of a pass or to access land to construct a pass and to recover costs

Late in 2009, after consultation responses had been considered by Defra, it was announced that implementation of the proposed regulations would be set back until at least May 2011. The reason cited was the potential impact on business, in particular in the light of the current financial climate. In the meantime, the Environment Agency will continue its current approach of only targeting critical barriers and working closely with owners and occupiers of barriers to find pragmatic solutions. More detailed advice on when fish passes[3] for hydro schemes are required is given in the *Good Practice Guidelines* (EA, 2009).

3.3 PLANNING

Planning permission is required for most forms of development. Development is defined in section 55 of the Town and Country Planning Act 1990 as follows:-
"The carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change in the use of any buildings or other land."

3.3.1 Initial advice

The National Park Authority's website (www.peakdistrict.gov.uk) has a large section devoted to planning advice and this is well worth consulting. Planners at the NPA should be consulted on the general scope of a potential scheme and they should be able to advise as to which parts (if any) of a scheme may require permission, including listed building consents. Prospective developers should call the NPA's Customer Service Team to initiate contact with their Planning Service. A planning officer can then co-ordinate a response, drawing in other specialist staff as required. An experienced hydro consultant or agent should also be able to give guidance on likely planning issues.

National Park planning policy (currently covered by the PDNP Local Plan, adopted in 2001: see paragraphs 8.14–8.19, page 92 and Policy LU4) allows for small scale energy schemes to meet local needs, subject to the impact on the valued characteristics of the area being acceptable. Any renewable energy schemes need to be acceptable in the landscape and of a scale and output consistent with local demand for power. Size, design, siting, noise generation, impact on wildlife and associated landscaping will all be relevant. Local Plan Policy LU4(b) also states that 'Transmission lines should always be placed underground' (see also section 3.5 below). In due course, the Local Plan will be superseded by a new Local Development Framework (LDF). The LDF Core Strategy, which will cover renewable energy issues (including support for small scale hydro), should be adopted by 2011.

The Local Plan (para. 8.19) also notes that some small scale, normally supplementary, power generation may constitute 'permitted development' (i.e. that formal planning permission may not need to be sought). For micro hydro schemes, which usually have a range of potential impacts, this is unlikely to apply, save on rare occasions. However, the Government is currently consulting on extending such rights for small scale renewable technologies (DCLG, 2009). It recognises, for hydro

[3] *There are basically five types of fish pass: pool and weir; baffled passes; locks and lifts; pre-barrages; and natural type by-passes, rock ramps and easements. Brief descriptions of each type can be found on the EA web site: http://www.environment-agency.gov.uk/business/sectors/37579.aspx*

power, that alterations to river courses and structures (e.g. weirs) should be kept within existing consenting procedures but suggest that planning permission should not be required for turbine houses placed on agricultural or forestry land. The consultation closed in February 2010.

3.3.2 Ecological issues

In relation to potential ecological impacts, the NPA's *Validation of Planning Applications: Guidance Notes* document[4] particularly encourages pre-application on ecological matters for hydro power schemes. Akin to the Environment Agency's scope of potential impacts, the aspects that the NPA would consider during consultation on a hydro scheme include:

- The general watercourse character
- Macrophytes (aquatic plants)
- Fish (including fish passage)
- Invertebrates
- Habitat (those that are protected and those of UK/regional/ local importance, e.g. Biodiversity Action Plan habitats)
- Birds (protected and of local importance)
- Geomorphological (landscape) features

Direct and indirect impacts will be considered, including potential impacts from increased water levels upstream of the site, changes in sediment composition, decreased water levels between the point of water abstraction and discharge, any associated infrastructure, works to banks, tree works, repairs to existing structures etc. Although these aspects will be considered, only surveys relevant to the application will be required and this will be determined on a case-by-case basis. The need for specific surveys will be guided by the scale of the scheme, the type of hydro equipment involved, the method of abstraction etc.

3.3.3 Protected species

If protected species are found during survey, details of measures to avoid, mitigate or compensate for potential harm to these species must be reported. This depends on the species found and the extent of use of the site but generally the report must include recommendations on the timing of any operations, the methods used and how species and habitats can be retained and enhanced as part of the scheme.

It should be noted that the presence of a protected species need not detrimentally affect the potential to gain planning permission. PDNPA planning officers will consider survey recommendations in assessing any application. Changes may have to be made to initial plans and, for example, if species translocation is required, a licence from Natural England may be required to allow some works to proceed. In the majority of cases, protected species can be accommodated within development proposals.

PLANNING CASE STUDY:
ALPORT MILL NEAR YOULGREAVE, RIVER LATHKILL

In 2007 the Haddon Estate, owners of Alport Mill, commissioned local hydro consultants and installers, Derwent Hydro, to scope a micro hydro scheme on the site of the mill on the River Lathkill. Derwent Hydro's report suggested it was feasible to install a 30 kilowatt (kW) turbine, partly using remnant structures (weir, intake, tail race channel) but with a new, buried penstock (see Figure 3.1) leading to a partly buried powerhouse. It was envisaged that the scheme could supply up to 70% of the properties in the adjacent Alport village. It should be noted that the River Lathkill (both upstream and downstream of the proposed scheme) is important for recreational fishing and is controlled by the Estate. The site is also close to important protected habitats.

Figure 3.1a/b Burying the pipe ('penstock') carrying the water from the intake to the powerhouse at Alport Mill, Peak District (photos courtesy of Derwent Hydro)

[4] *Available on the PDNPA website.*

Figure 3.2 The new turbine house at Alport Mill faced with local stone (photo courtesy of Derwent Hydro)

After extensive pre-consultation with a range of bodies, statutory and non-statutory, two applications were made in summer 2008 for i) erection of turbine house and intake; and ii) listed building consent for alteration to walls in the curtilage of a listed building. The main planning issues were considered to be:

- The principle of the proposed development
- The proposed design and external appearance (of the new powerhouse)
- Potential impact on the Alport Conservation Area
- Potential impact on the setting of a listing building
- Potential impact on features of archaeological interest and,
- Potential impact on features of ecological interest

The principle of development was supported by former Structure Plan Policy C17 which allows for small scale local energy generation. The powerhouse was felt to be modest in scale and, with suitable finishing (turf roof, external limestone walls – see Figure 3.2), would be acceptable and not affect either the Conservation Area nor the setting of the listed mill.

Both archaeological and ecological interests were present at the site. An archaeological desk based assessment was prepared for the site to inform the planning application. Subsequently a watching brief on excavations and building recording was carried out as mitigation for the scheme. In relation to ecological concerns, mitigation measures to safeguard local species of special interest were also agreed and implemented.

No objections were registered to the applications and it was recommended for approval subject to relevant conditions. The relevant planning consents were issued in October 2008. The scheme was implemented successfully in spring/summer 2009 and is now operational.

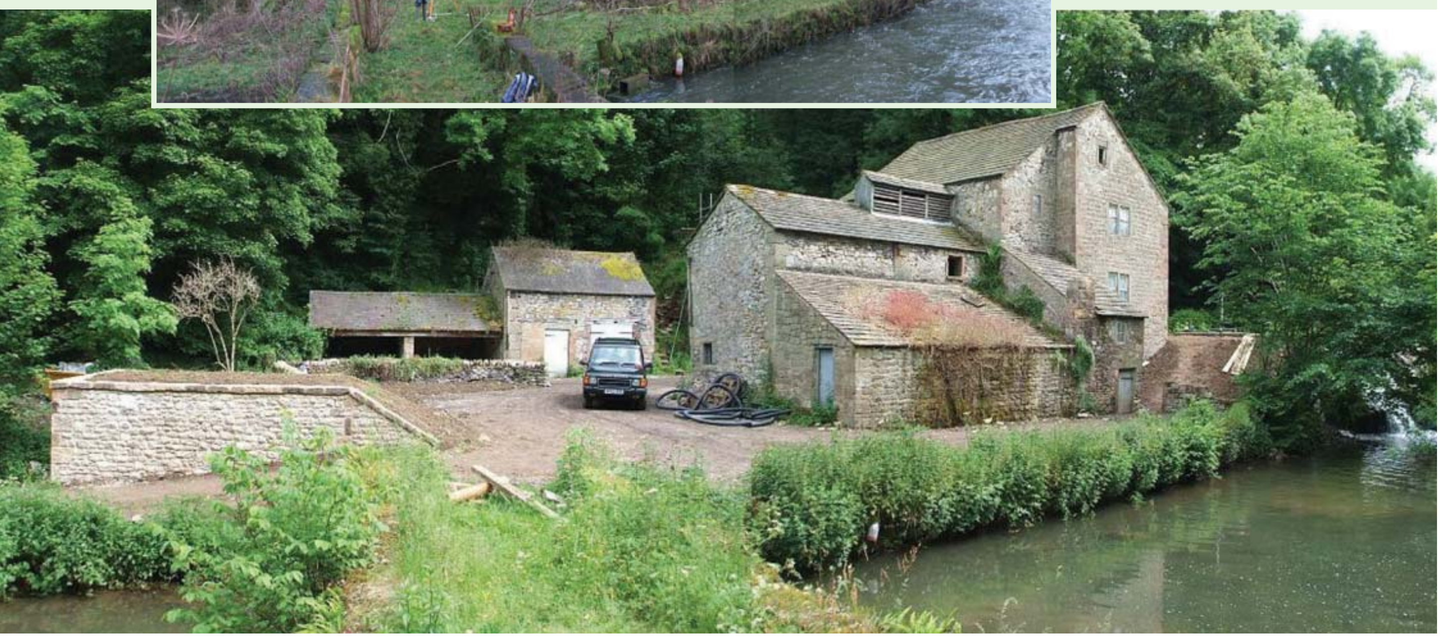


Figure 3.3a/b Before and after pictures of the Alport Mill scheme showing the buried powerhouse at left (photos courtesy of Derwent Hydro)

3.4 CULTURAL HERITAGE ISSUES

All old mill sites have historic value and many may also be listed or scheduled, or be registered in the Historic Environment Record (HER[5]), usually held on a county basis. Proposed works for a micro hydro scheme may either affect the historic fabric or the setting of a site or area. If the site is a Scheduled Monument (sometimes also referred to as a 'scheduled ancient monument') or listed at either grade I or grade II* status, consent for allied works will be required by English Heritage.

Changes to listed structures below grade II* may need 'listed building consent' (as was necessary at Alport Mill, above) and this must be sought from the local planning authority. Applicants should consult the PDNPA (or other planning authority if outside the NP) in order that any archaeological/listed building issues can be identified at an early stage and any necessary investigations and surveys be commissioned. Because of the levels of ground disturbance and the potential modification of existing water management features involved, an old mill site is likely to require the following archaeological input at the pre-application stage:

- Desk-based assessment
- Walkover survey
- Measured survey
- Trial trenching

This work should be undertaken by recognised archaeological contractors to a brief prepared by the National Park's Cultural Heritage team. The costs of archaeological evaluation can be significant (running to several thousands of pounds) and should be budgeted for by applicants so that any grant aid applied for can include these costs.

Often issues identified can be dealt with quite readily by small amendments to plans or by conditions associated with the consents or planning permission obtained. Mitigating measures may be required (usually by condition) and may involve pre-recording of any building fabric affected by the scheme, measured survey of earthwork features and small scale excavation of any ground to be disturbed by the works.

3.5 ELECTRICAL CONNECTION – PLANNING ISSUES

If a micro hydro scheme is going to be grid connected, this may raise some ancillary planning issues (for more detail regarding on site electrical connection, see Chapter 4). These issues arise primarily where a relatively long stretch of new cabling is required, carrying power either by overhead wires and associated poles or – more usually – by underground cabling (particularly in the National Park, see 3.3.1 above).

Policy LU1 of the PDNP Local Plan states that 'Development requiring new or upgraded service infrastructure will be permitted providing that the new infrastructure: (i) does not adversely affect the valued characteristics of the area; and (ii) can be provided before any new land use begins. As stated above, the default position in the National Park is that new utility services (including electricity wires) will be placed underground. On very rare occasions, for example where trenching would cross ground that is ecologically or archaeologically sensitive and where suitable screening is available, an overhead route may be considered.

Planning consents for new electricity connections are handled by the distribution network operator (DNO, also see section 4.4.3). Provision of such connection will also be dependent on successful negotiation of relevant wayleaves and/or easements (types of permission to run wires or cables through adjacent land). Needless to say, the overall costs of providing a new connection over some distance may prove prohibitive at some sites. It is therefore wise to deal with this issue at a relatively early stage in any pre-application scoping process.

3.6 LAND OWNERSHIP ISSUES

Care should obviously be taken to ensure that all areas of a site are either within the ownership or control (via lease or some other form of suitable agreement) of the developer(s) of the scheme. Advice may be necessary from specialist sources (e.g. solicitors, Land Registry) as to ownership (weir ownerships can be difficult to fathom and may not attach necessarily to a mill property/curtilage). Again, early resolution of any contentious matters is a pre-requisite. Lease terms should also be subject to very careful scrutiny as they will be key to the economic viability of any scheme.

[5] *Formerly known as the Site and Monuments Record (SMR). In the GIS analysis data used in Chapter 5 (and the accompanying data in Appendix B), reference is still made to the SMR. See section 5.1.5 for further information.*

Chapter 4
How to scope and implement a micro hydro scheme

4.1 INTRODUCTION

Two of the major barriers to developing a micro hydro scheme are the relatively high cost of site assessment and the large outlay of capital in implementing the project. Detailed feasibility studies are usually undertaken by a consultant to establish the viability of the scheme. The fact that capital costs are more site specific than for any other form of renewable energy unfortunately means that making initial economic estimates is difficult. There are therefore three stages a site owner can progress through (to minimise costs and risk) before deciding to move forward with a scheme.

Stage 1 Initial site assessment
This can be a DIY stage which seeks to answer two basic questions. Approximately how much electrical power can I generate? Are there any major environmental, ecological, cultural heritage, planning or grid connection problems ('show stoppers') which would prohibit the development?

Stage 2 Preliminary site (pre-feasibility) study
This is an interim stage which can be undertaken before a full feasibility study. It would be undertaken by an experienced hydro power professional at a cost of between £500 and £1,000. A list (not exhaustive) of hydro power consultants and installers is given in Appendix E. Some costs towards renewable energy studies can be met by grants, including the BRE Community Sustainable Energy Programme (see 4.3.2).

Stage 3 Feasibility study
This stage, again undertaken by a professional, takes the project forward to the final design stage looking closely at (amongst other items) costs, project finance, sale of electricity generated, and the necessary approvals and licences. The cost of a feasibility study can range from £3,000 for a domestic scale scheme to £10,000 for a commercial scheme.

4.2 INITIAL SITE ASSESSMENT

This assessment seeks to provide a first estimate of the potential electrical power available from the proposed site and ascertain any major constraints, often related to environmental or planning issues (see Chapter 3).

To determine the power potential (**P_e**, electrical power) it is necessary to measure the head (**H**) and the flow (**Q**) available and then use the formula

P_e (kW) = **6 x H** (m) x **Q** (m^3/sec)

This will give a conservative, yet realistic estimate of the electrical power available. If using one of the simpler methods of flow measurement detailed in section 4.2.2 below, then Q should be the summer flow. If flow rates over a year are available then the average over the year (Q_{mean}) should be taken as the value for flow. As an example, varying the key factors of flow and head shows how the same power can be achieved in very different situations of head and flow:

6 x 10 metre head x flow of 1 cubic metre per second = ***60 kW*** or

6 x 1 metre head x flow of 10 cubic metres per second = ***60 kW***

The amount of energy produced per year can then be estimated as follows (with 8760 being the number of hours in a year)

Energy (kWh/yr) = P_e (kW) x **CF** x **8760**

and where **CF** = capacity factor which varies depending upon the flow used for hydro power but can be taken as 0.4 (i.e. that the system will be running for 40% of the year) for the initial assessment. Capacity factors for hydro are usually higher in reality (usually upwards of 0.5) but for initial estimates it is better to be conservative. Using the worked example above, energy capture would be

60 kW power x 0.4 capacity factor x 8760 = ***210,240 kWh per year***

4.2.1 Head

The head available at any site is determined by measuring the height difference in metres between the water levels at the proposed inlet and discharge points. The method used for this will depend to an extent on the height difference and the layout of the site.

An initial estimate for a high head site can be taken from a large scale Ordnance Survey map by simply counting the contours between the inlet and discharge points to give the height difference.

On sites where it is proposed to simply use the head across a weir then a measuring tape can be used for the initial head determination. However, care is needed in these cases as the head will reduce with increasing flow because the level of the water below the weir will rise faster than that above as the flow increases – in extreme cases even drowning out the weir.

Another simple method is to use a water filled hose or tube which is laid along the ground from the intake point to the discharge point. The height of the water level in the tube above the level in the stream is measured at the intake and discharge points and the difference is the head. Generally, the head is measured more accurately using a dumpy or surveyor's level as shown in Fig 4.1.

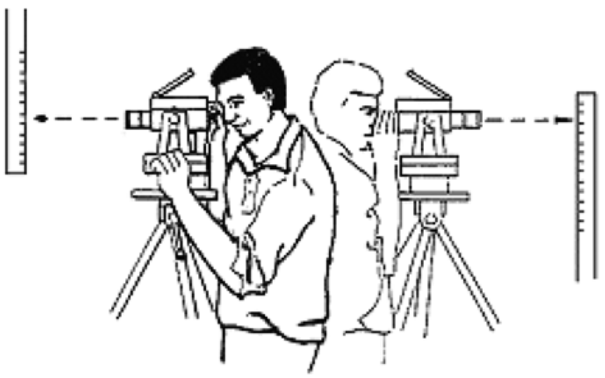


Figure 4.1 Using a dumpy or surveyor's level and staff to measure head (courtesy of BHA)

4.2.2 Flow

FLOW MEASUREMENT

The gross annual flow in a river or stream is the product of the size of the catchment multiplied by the annual rainfall less any water that is removed from the catchment by way of evaporation, transpiration[1] or by abstraction for agricultural, industrial use or public water supply. A certain minimum volume of water, termed the 'residual' or 'compensation' flow must be left in the section of river or stream which bypasses the hydro site, both to protect the ecology of the river in the depleted stretch and for environmental and aesthetic reasons. The Environment Agency will determine what residual flow

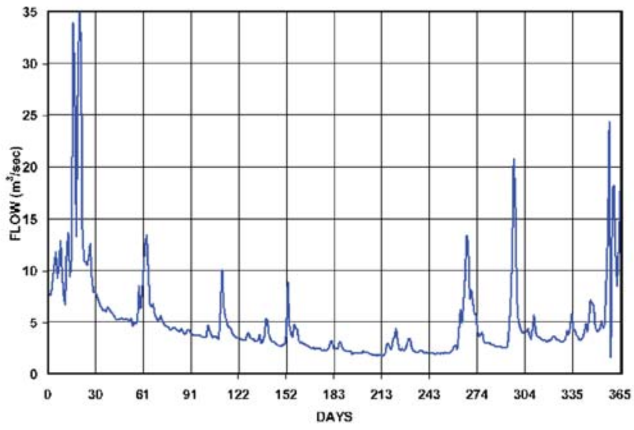


Figure 4.2 An example of an annual hydrograph (courtesy of Oliver Paish/ BHA)

must be left in the river (see section 3.2.3) and hence what can be used for hydro power. Residual flow has historically been taken as Q_{95} (the flow present for 95% of the time) but new guidelines from the EA suggest that where factors such as migratory fish, low base flow or long depleted reaches impinge then residual flow may need to be greater.

The flow in a river or stream varies on a seasonal basis with flows generally being greater in the winter than the summer. Flow also varies on a daily basis. This flow variation can be expressed in two ways – either by an annual hydrograph which shows the day-by-day variation over a year (see Figure 4.2) or by a flow duration curve or FDC (see Figure 4.3). The FDC shows how flow is distributed over a year with the vertical axis giving the flow and the horizontal axis giving the percentage of the year that the flow exceeds the value given on the vertical axis, e.g. Q_{50} indicates that flow which will be exceeded for at least half the year. The FDC is the most useful graph when calculating the flows available for a micro hydro scheme.

There are several methods of calculating the flow in a river or stream and hence the micro hydro potential and these vary in both complexity and accuracy[2]. In the case of a small stream

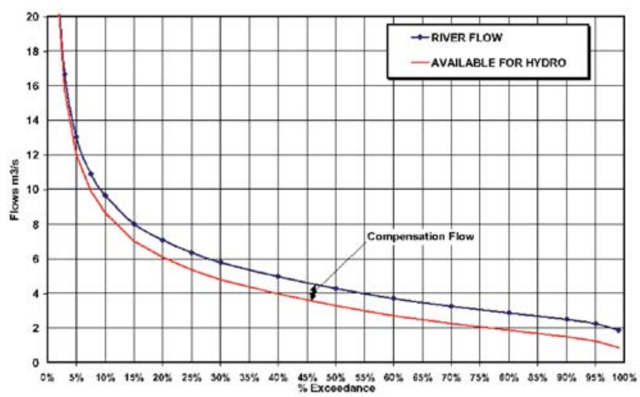


Figure 4.3 An example of a flow duration curve (courtesy Paish/BHA)

[1] *Transpiration is the water absorbed by trees and other forms of vegetation and then re-released to the atmosphere as water vapour.*
[2] *See also http://www.westernrenew.co.uk/estimate.html for a useful summary of DIY approaches.*

one can simply divert the full flow into a container of known volume, time how long it takes to fill and hence calculate the flow rate.

For larger streams, an initial estimate can be made by measuring the perceived average flow – a variation on 'Poohsticks'. The speed of the stream is measured by timing a float over a measured distance (in metres, preferably in a straight line) and multiplying by a factor of between 0.8 (smooth straight channel) and 0.6 (rocky channel). The cross sectional area of the stream can be calculated by measuring the depth at several points across the stream, taking the average and multiplying that by the width. Then speed (metres per second, m/s) x area (m^2) = flow Q (m^3/sec). Alternatively, if available, an electro-magnetic velocity meter or similar device can be used to measure the velocity of flow.

A more accurate method of flow measurement, which also allows the recording of the daily flow rate over a long period and hence the flow variation, is to build a weir (usually of wood) across the stream with a rectangular notch cut in it as shown in Figure 4.4. The simplified formula for the flow over a rectangular weir is:

$\mathbf{Q} = 1.8\ (\mathbf{L} - 0.2\mathbf{h})\ \mathbf{h}^{1.5}$ where

L = width of rectangular notch (m)
h = height of water flowing over the weir (m)
Q = flow rate (m^3/sec)

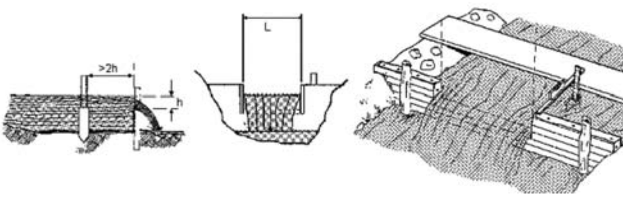


Figure 4.4. The use of a rectangular notched weir for calculating flow (courtesy of the BHA)

An alternative to physical flow measurement, which to be accurate needs to be undertaken over a long period (at least a year and preferably several years), is to run a computer program which will calculate a range of flow values and produce a FDC for a given site based on its grid reference. There are two models commonly used: HydrA and a more modern version of the same program named LowFlows 2000. The latter is more accurate but HydrA has been used successfully to predict flows at potential hydro sites for a number of years.

LowFlows 2000 is offered on a bureau basis by its developers, Wallingford Hydrosolutions Ltd, for those interested only in the development of one or two sites at a cost of £175+VAT per site. It is also available for longer lease periods if ongoing estimation for multiple sites is envisaged. Flow estimates are presented in a simple graphical report format, including estimates of both monthly and annual mean flows and flow duration statistics (Q_{95} for example), as well as giving clear advice on the best way to use this information in evaluating the potential of a particular site. See www.hydrosolutions.co.uk.

HydrA based evaluations are available from the Devon Association for Renewable Energy (DARE) who, upon receipt of basic site information, will produce a desk top report for £75+VAT per site. They can also provide a more detailed service, including a site visit and assessment, at further cost. See www.devondare.org. The format and level of information DARE provide can be seen in Appendix C, where their report on selected Peak micro hydro sites is reproduced.

Finally, the Environment Agency measures the flow in most significant rivers in the UK by means of permanent gauging stations, with records going back over many years. There are a number of such stations in and around the Peak District and their locations, and the data from them (stored in the National River Flow Archive, NRFL) can be obtained at www.ceh.ac.uk/data/nrfa/index.html. These records, which include FDCs, can be used to estimate the flow at a particular site providing allowance is made for the location of the gauging station relative to the proposed hydro site.

4.2.3 Demand assessment

Domestic electrical energy demand varies throughout the year and also varies greatly during each day. For grid connected systems it is therefore important to assess the expected demand in terms of annual consumption and the average demand over 24 hours at different times of the year. This can be achieved by taking regular (daily or at least weekly) electricity meter readings.

Energy efficiency should be investigated to ascertain if it is possible to lower energy consumption as, by reducing local consumption (demand), export potential (grid sales) and revenue can be increased. As a guide, the electrical power demand of a house (excluding heating) is approximately 600 W (i.e. roughly 5,300 kWh per year). This varies widely and depends upon the number of power consuming devices and their useage (houses with electrical heating use substantially more).

Off grid systems require detailed load calculations to specify battery and inverter sizing (see section 4.4).

4.3 FINANCE

4.3.1 Costs

CAPITAL COSTS

It is difficult to give guidance on the estimated costs of micro hydro schemes as hydro power, unlike other forms of renewable energy, is very site specific and hence costs vary enormously from site to site. However, the costs can usually be reduced considerably if the project is the renovation of an old mill site where infrastructure, such as the weir and leat, is still in existence and in good condition.

The costs of a scheme can be divided into four parts:

1 **Civil works** being all physical/engineering works concerned with the abstraction and return of the water, as well as any building costs to house the machinery.
2 **Machinery** being all the machinery (plant) necessary to convert water power into electrical power from a turbine, waterwheel etc. to the generator. This may also include screens, where needed.
3 **Electrical works** which include the control panel and control system, wiring and grid connection and metering if required.
4 **External costs** being the cost of a consultant to design and manage the project plus costs of licences, planning permission etc.

Generally, the cost per kilowatt of installed power increases as the project size reduces due to certain fixed costs and economies of scale. A number of estimates of capital cost have been given which fall in the range of £1,000 to £4,500 per installed kilowatt subject to the amount of civil engineering required. Above £5,000 per kW scheme viability usually diminishes rapidly.

The British Hydropower Association gives the following cost breakdown for a low head 100 kW scheme (see http://www.british-hydro.org/mini-hydro/infopageb5eb.html?infoid=379 but note these prices may be a little dated). Total high head costs for a comparably sized scheme would normally be a little lower (£85,000-£200,000).

Civil works	£30,000 to £100,000
Machinery	£60,000 to £120,000
Electrical works (excl. grid connection)	£15,000 to £30,000
External costs	£10,000 to £30,000
TOTAL COSTS	**£115,000 to £280,000**

The recent High Torrs scheme at New Mills, which involved the installation of an Archimedes screw with a capacity of 70 kW, cost £300,000 or about £4,300/kW. If all the electricity generated at New Mills (c.266,000 kWh/y) were sold at 15p/kWh (c.£39,990) then pay-back would be less than ten years. However the estimation of the pay-back period for a micro hydro scheme is further complicated not only by the proportion of electricity which is exported to the grid and that which is used on site but also by current fiscal incentives for renewable energy (see section 4.3.5).

OPERATING COSTS

The maintenance and servicing of a micro hydro scheme are low as modern machinery is robust and requires little maintenance. The cost of routine inspections and servicing should be about 1-2% of capital costs. To these costs should be added the cost of insurance, rates (business if not part of a domestic property), disposal of screenings and metering if connected to the grid.

4.3.2 Grants

There is a wide range of regional and national funding available for micro hydro schemes. However, these tend to vary in availability in both time and space (region). Furthermore, grants depend upon whether the scheme is a private or community venture, the latter usually attracting more support. Details of some current schemes are given below and further sources of information are given in Appendix E.

LOW CARBON BUILDINGS PROGRAMME

The Government's Low Carbon Buildings Programme (LCBP) Phase 1 offers grants to domestic owners of mini hydro plant up to a maximum of £2,500 per property. The equipment must be chosen from an approved product list, and installed by a registered installer. This scheme will now close in April 2010 due to the introduction of feed-in tariffs.

The LCBP (Phase 2 extended) also offers larger grants to community schemes which are owned and operated by a non-profit organisation for the benefit of the local community. Such organisations can include councils, schools, housing associations, community groups etc. Grants of up to 50% of project costs can be obtained up to a maximum of £200,000. An essential element of these schemes is their ability to raise awareness within the community and improve the national profile of renewable energy schemes.

This scheme will also close in April 2011. It should be noted that any project that obtains funding from central government sources may have to pay back these monies to be eligible for support from the proposed Feed-in Tariff (see below).

BRE COMMUNITY SUSTAINABLE ENERGY PROGRAMME

This Big Lottery funded scheme supports not-for-profit community organisations with funding for studies and project development. Grants are available for studies investigating the feasibility of installing renewable energy and energy conservation systems. The maximum grant available is £5,000 or 75% of the study cost, whichever is smaller.

Capital funding is also available for energy efficiency measures in combination with micro-generation technology. Organisations can apply for up to £50,000 or 50% of the project cost (whichever is lower) for installing renewable energy technologies and energy efficiency measures. At the time of writing, spending in the East Midlands and on hydro has been less than in others areas and technologies, so the probability of receiving funding is relatively good. See www.communitysustainable.org.uk.

COMMUNITY ACTION FOR ENERGY (CAfE)
This is a programme from the Energy Saving Trust that is designed to promote and facilitate local community based energy projects. They offer a community support panel which provides free expertise and advice to CAfE members, including help on grant funding, see http://www.energysavingtrust.org.uk/cafe/Green-Communities/Funding-Advice. After a free consultation, experts provide a review of the proposed project and a short report, including recommendations for action. This may consist of advice over the phone and/or a site visit anywhere in the UK. The total time allocated for each organisation applying for support is limited however to one and a half days.

OTHER GRANTS FROM LOCAL/REGIONAL BODIES
Some planning authorities and the Peak District Sustainable Development Fund (SDF) have been willing to offer small grants towards small scale renewable energy projects in their area on an ad hoc basis. Exceptionally, larger sums may be offered to help support capital expenditure but the norm is for assistance with project development. Local authorities and the SDF should be able to advise on the current availability of grants.

A useful listing of funds available for renewable energy schemes can be found at Future Energy Yorkshire's web site (http://www.co2sense.org.uk/) and follow the funding links. In the North West, grants are available via Envirolink Northwest's Low Carbon Development Programme (http://www.envirolinknorthwest.co.uk/). Unfortunately there appear to be no regionally dedicated funded streams for micro generation (other than national provision) in the East or West Midlands regions but it is suggested that applicants could try to access EU funding streams for rural innovation and diversification (such as LEADER), also available from the regional development agencies (RDAs), especially if the scheme can be linked with the farm-based economy.

TAX BREAKS
In addition to grants there are some tax breaks available. The VAT payable on hydro electric plant installation is reduced to 5% for systems supplying buildings which are either residential or used for charitable purposes.

4.3.3 Loans

A micro hydro project which is constructed solely for community benefit is usually eligible for so-called soft loans. Soft loans are a type of business loan where little or no personal collateral is required by the bank or commercial lender. The main UK providers of such loans are Charity Bank, Triodos Bank and Co-operative Bank, with Triodos having dedicated schemes for renewable energy projects.

4.3.4 Community schemes

There are various funding streams available for community hydro schemes, depending upon the legal structure of the enterprise, which can take several forms, including a
- Trust
- Limited liability company (by shares or guarantee)
- Community interest company
- Industrial provident society
- Charitable incorporated organisation or co-operative

Which of these structures is adopted will depend upon the particular circumstances of the scheme but it is generally considered that the three most appropriate for a non-profit community business activity are a company limited by guarantee, a community interest company or an industrial provident society. These structures allow the use of 'equity' funding (capital raised, usually by a share offer) from social investors who generally consider their investment to be for social and community benefit rather than short-medium term financial gain and therefore do not expect high rates of return.

Water Power Enterprises (H_2OPE), a social enterprise company created to develop community hydro schemes (focusing mainly on Archimedes screw solutions), offers a bespoke model for communities to engage with. In essence, H_2OPE manage scheme development from inception to fruition in return for a fee on completion of the project (or a proportion of subsequent income). Project funding is usually a mixture of grants, soft loans and a share offer. Projects successfully delivered so far include the Torrs hydro scheme at New Mills and at Settle in the Yorkshire Dales National Park, among others. See http://www.h2ope.org.uk/.

Energy4all Ltd is another not-for-profit organisation helping communities own a stake in renewable energy schemes (see www.energy4all.co.uk). Although their main successes have so far been with wind power, they are also interested in helping develop hydro projects.

4.3.5 Revenue

A micro hydro scheme can generate revenue by different methods, many of which can be used in combination:

- On site electricity use (reducing bills)
- Local electricity sales
- Utility company sales
- Renewable Obligation Certificates (ROCs)
- Levy Exemption Certificates (LECs)
- Renewable Energy Guarantees of Origin (REGOs)
- Feed-In Tariffs (FITs)

ROCs are to be replaced by the Feed-In Tariff in April 2010 for projects under 50 kW. The sale of renewable energy is complicated and for most schemes the sale of electricity to a utility to claim income from the Feed-In Tariff and LECs will offer the best income. In this case, any electricity used at the site would reduce electricity bills and still be eligible for income from the Feed-In Tariff.

Each of these sources of income is now described in more detail below:

ON SITE ELECTRICITY USE

If the electricity is used on site, as for example at Chatsworth House and Caudwell's Mill, so displacing electricity bought from the grid, then there is a financial saving and some energy companies will also pay for renewable electricity generated, even if it is consumed on site (e.g. Good Energy, Ecotricity, Green Energy).

LOCAL ELECTRICITY SALES

Alternatively, the electricity generated could be sold to a substantial local user (e.g. the Co-op supermarket in the case of the New Mills/Torrs hydro scheme) at the same price as if it was purchased from the grid. Also, if the customer is a business user they would save having to pay an extra 0.47p/kWh Climate Change Levy with each unit of hydro electricity purchased. Preparing a Power Purchase Agreement contract for such an arrangement can be complicated and expensive, making it easier to sell to a utility company (who may offer reduced rates for purchased energy in return).

UTILITY COMPANY SALES

Most electricity suppliers will buy renewable energy and specialists include Ecotricity, Green Energy (UK) plc and Good Energy. Prices can be in the region of 15p per kWh. These companies will also pay for the ROC (or Feed-in Tariff) and LEC elements as well as the wholesale value of the electricity (around 5p/kWh).

ROCs

Renewable Obligation Certificates (ROCs) are awarded by Ofgem for every 1 MWh of power generated from a renewable source. They are needed by energy supply companies to show that they are meeting Government targets for CO_2 emission reduction and hence can be traded with their value depending upon the supply and demand of ROCs on the open market. ROCs are to be replaced by the Feed-In Tariff in April 2010; the latter offers a less complicated system and better income.

From 1 April 2009 a new Government banding system will mean that schemes of 50 kW installed capacity and less will be eligible for double ROCs. Under this scheme a base price is set, guaranteeing the minimum value of a ROC. However, there are insufficient ROCs on the market at present to satisfy demand which results in a higher value for each ROC. At the end of 2008 ROCs had a base price of about £37.00/MWh and a market value of about £45.00/MWh with estimated future levels based on a growth rate of 2.5% given in Table 4.1, although with the increased construction of wind farms the market value of ROCs could fall.

Table 4.1 Estimated ROC Values 2008/09 to 2013/14

YEAR	£ per MWh
2008/09	45.00
2009/10	46.13
2010/11	47.28
2011/12	48.46
2012/13	49.67
2013/14	50.91

In addition there are monies available from the ROC Buyout Fund Premium, again administered by Ofgem, which are paid to renewable energy generators based on penalties levied on suppliers for missing RO targets.

LEVY EXEMPTION CERTIFICATES

Electricity purchased from micro hydro schemes is exempt from the Climate Change Levy (introduced by the Government in 2001) and hence hydro generators are issued with Levy Exemption Certificates (LECs) by Ofgem. LECs are issued for every MWh and have a price in 2009/2010 of £4.70 each, which is indexed in line with the retail price index (RPI). The current legislation applies until 2011 but it is expected to be extended. However, the revenue received from the sale of LECs through any agreement with an electricity supplier is typically 20-55% of their face value.

REGOs

Renewable Energy Guarantees of Origin are again issued by Ofgem at 1 per MWh of electricity generated but at present they have no market value. This may change in the future if a European renewable energy market develops. Therefore it is worth retaining ownership rights to the certificates or any income from them.

FEED-IN TARIFFS

Feed-in tariffs oblige utilities to buy renewable energy from generators at a price, currently fixed by government. Such schemes have been very successful in countries such as Germany in promoting the installation of renewable generation. In 2009, as part of the UK Renewable Energy Strategy, the Government announced that it will introduce a feed-in tariff (FIT) from April 2010 for projects under 5 MW.

The exact form of the scheme and level of support has been subject to consultation in 2009 with a view to implementation in April 2010. It is understood that the FIT will replace ROCs for small scale schemes (less than 50 kW) after April 2010. The claiming of FITs will require both generation and export metering (see section 4.4.4).

The final details of the FITs scheme are still to be confirmed by the Government but it is anticipated that:

- From April 2010, feed-in tariffs will offer a fixed payment per kilowatt hour generated (generation tariff) plus an additional payment for surplus power exported to the grid (export tariff) with a guaranteed minimum payment per kWh exported to the market for a 20 year period
- FITs will be at levels that will offer projects a 5-8% return on investment, with the aim of delivering 2% of the UK's energy from small scale projects by 2020
- The Government is not proposing to offer financial support for up-front capital costs in the shape of grants to schemes eligible for FITs; it is expecting the market to provide the necessary loans or other finance
- Whilst the Government is not looking to provide finance, this does not preclude others (e.g. local authorities) from offering such schemes
- The tariff structure will vary depending upon the renewable technology used and the installed capacity. Recently the Government announced generation tariffs for micro hydro schemes of 19.9p/kWh for schemes of ≤15 kW installed capacity and 17.8p/kWh for schemes between 16 kW and 100 kW
- Off-grid schemes will be eligible for FITs but, because such generators have no direct relationship with a supplier, there are issues regarding who should make payments of FITs and how they should be made

The Government has indicated that schemes cannot utilise central government funding (e.g. the Low Carbon Buildings Programme) and benefit from the Feed-In Tariff. Funding from other sources (such as local authorities) is not expected to prevent support from the FIT.

Further details of the Government's consultation can be found at www.decc.gov.uk/en/content/cms/consultations/elec_financial/elec_financial.aspx

ADVICE AND HELP

Help in registering for ROCs etc and selling electricity to the grid can be provided by agents or specialist companies such as Tradelink Solutions (www.tradelinksolutions.com). In addition a list of current agents is available on the Ofgem web site (www.ofgem.co.uk) but prospective generators are advised to make their own checks before appointing a representative.

4.4 ELECTRICITY GENERATION

4.4.1 Electrical connection

Hydro plant (turbines, screws, wheels) are usually connected to generators to produce electricity (they can also be used directly for mechanical work such as grinding corn). The generators can be connected to the grid or used to provide stand-alone power. In an off-grid system, the electricity is generally used to charge a bank of batteries to store the energy. In a grid-connected system, power is used locally, with the balance imported from, or exported to, the grid. Figure 4.5 shows the electrical control panel (and generator) for the modern 11 kW waterwheel installed at Lemsford Mill on the River Lea in Hertfordshire, which provides about 60% of day time demand to office premises with 45 staff. Some export to grid occurs at night and weekends when on-site demand reduces.

Figure 4.5 Control panel at Lemsford Mill, Hertfordshire (photo courtesy Ramblers Worldwide Holidays)

4.4.2 Off-grid systems

Most off-grid micro hydro systems are battery based. Batteries can also be connected to wind turbines and solar panels in hybrid systems. Batteries store energy between the time of generation and use. Where stream flow is consistent, it is often possible to use a small battery bank. Battery banks cost a significant amount, require considerable space and have a negative environmental impact due to the lead and acid they contain, as well as the energy required to make and recycle them. As a battery bank can only store a limited amount of energy for a moderate length of time and is damaged by repeated deep discharge, a back-up generator (or alternative sources of renewable energy) might also be required to provide additional energy at times of low water flow.

Batteries can be used to run low voltage direct current (DC) appliances including lights, computers and audio equipment, or used with inverters which convert the low voltage DC to 240 volt alternating current (AC), as used in most homes. When using a battery bank and inverter, the maximum amount of power that can be supplied is limited not by the water flow or turbine but the size of the battery bank and inverter.

A charge controller is also required to ensure that the batteries are not over charged or discharged too deeply. Such appliances divert excess electricity to loads such as space or water heaters when the batteries are fully charged ('shunt regulation' using 'dump loads') or shut down the supply of water to the generating system.

4.4.3 Grid connected systems

In sites that are connected to the grid, power will typically be supplied at 240V AC via the main distribution breaker. Schemes of 10 kW or over usually require connection at 415V AC (three phase), and need to meet the requirements of the G59 standard for grid connection (see box below). The G59 standard also details the requirement for disconnection from the grid (for safety reasons) in the event of a grid fault.

GRID CONNECTION STANDARDS

Any decentralised (sometimes termed 'embedded') generation, including micro hydro, must conform to standards set for connection to an electrical distribution system (the grid). There are two standards that are applicable:

- **G83:** this covers up to 16 amps (A) per phase, equating to an upper limit of 6 kW at low voltage or around 11 kW for three phase connections. Thus if your generator is around 10 kW or lower in power output, this is likely to be the applicable standard. The connecting equipment will need to be certified to the G83 technical specification and the distribution network operator (DNO) only needs to be notified of the connection.
- **G59:** this covers connection upwards of 6/11 kW (to an upper limit of 5 MW at 20 kV). It will require a connection application and potential study by the DNO (which will be charged for) to ensure the local grid has the capacity to absorb new generation. A connection offer should be made by the DNO within 90 days with cost estimates (some of which may be 'contestable': see below).

The amount of generated energy that can enter the grid at a given location depends on the 'strength' of the nearby grid. A weak grid will suffer noticeable voltage increases when even a small amount of generation is added. The strength of the grid can be assessed by consideration of factors such as the size of cable supplying the building, the number of phases[3], the distance to the substation, local loads and the combined effects of hydro and any other local generation. Connecting a generator can increase or decrease local power quality and network stability depending on the local generator and network characteristics.

The cost of connecting to the grid depends on a number of factors including the distance to a suitable connection point and any reinforcement works that need to be undertaken. The cost of three-phase connection varies widely and most costs, including reinforcement, are passed on by the DNO to the customer (hydro developer). Costs include:
- equipment and its installation
- the provision of wayleaves and easements (see section 3.5)
- reinforcement and diversions of the existing grid distribution system
- administrative charges, and
- commissioning

Long connection distances and associated wayleaves or reinforcement works frequently make connection costs prohibitive, especially where cables may need to be placed underground.

Work such as cable laying and installation of sub-stations can be undertaken by approved contractors and then 'adopted' by the DNO. Work which may be carried out by such approved contractors is referred to as 'contestable', whereas non-contestable work covers the design, connection and administration tasks that can only be undertaken by the DNO who will charge for these services.

4.4.4 Electricity sales

As well as the standard electricity import meter, 'generation' and/or 'export' metering is required to sell electricity from a generator. A generation meter measures the total output of the generator, whilst an export meter measures the net generation at the site. A generation meter is normally

[3] Commonly single phase for domestic properties and three phase for commercial, industrial or agricultural premises with heavier loads.

installed as part of an installation, whilst an optional export meter will incur an additional cost, typically around £100. See the revenue section (4.3.5) above for details of the different ways to sell electricity generated.

4.4.5 Heat from hydro

Hydro systems offer a relatively constant power output around the clock, with higher output in winter. This output profile means that hydro is well suited to running heating systems such as heat pumps where energy is required most of the time and particularly in winter.

Hydro systems may be used to provide heat by the use of generated electricity. This may either be achieved by the use of resistive heating (electric fires, fan heaters, storage heaters etc), or the use of heat pumps. In general, the use of resistive heating should be discouraged on efficiency grounds.

In addition to the use of generated electricity, the use of waste heat from generators and gearboxes might be considered. Although more expensive, water cooled generators are available and cooling will help to minimise the energy losses from a generator by reducing the resistance of the internal wiring.

The cooling of gearboxes may also be considered, but the optimum oil temperature should be considered with care and the manufacturer's instructions followed, as cooling the oil excessively will increase energy losses due to oil viscosity, and allowing it to run too hot will shorten the life of the oil and reduce the protection of mechanical components.

4.4.6 Heat pump systems

Heat pump systems use heat at ambient temperatures from the ground, air or water, to drive a high efficiency heating system. Particularly when used in conjunction with under-floor heating, they can deliver three to six times more heat into a building than the amount of electricity they consume. This ratio is known as the coefficient of performance (COP). The higher this value in a given set of circumstances, the better the performance of the heat pump. By modern standards, COP values of three and below are poor and values above five are good. Traditional resistive electric heating can only achieve a COP of one.

The COP that a heat pump can attain depends on the difference in temperature between the heat source and the emitter of the heat within the building. The smaller the difference in temperature the better the COP, thus the use of under floor heating at less than 40°C offers better performance than radiators above 60°C. By the same token, the higher the temperature of the heat source (air, ground or water), the better the COP.

Air source heat pumps have the disadvantage that on the coldest days of winter, condensation may freeze on the heat exchangers, energy has to be used to defrost these, and the net COP may be little above one. Ground source systems need extensive ground works to avoid excessive cooling of the ground and are prone to low input temperatures late in the heating season because the thermal capacity and conductivity of the surrounding soil are limited.

By contrast, water source heat pumps use water as the source of heat which on a hydro site is always being replenished, and water temperatures are higher than air in the depths of winter by a significant margin, making this an ideal space heating technology to exploit at most hydro sites. Water source heat pump systems can offer good efficiency with little infrastructure. Such systems will not necessarily be available 'out of the box' and some bespoke design and construction of heat exchangers will typically be required. This must be undertaken with some care to avoid damage in the event of unusually high flow rates.

More information applicable to water source heat pumps can be found in the T4S report *Peak District Spring Water Source Heat Pump Opportunities,* also produced with funding from the Peak District National Park Authority, available at: http://www.t4sustainability.co.uk/downloads/PeakDistrictHeatingFromSpringWater0123.pdf

4.4.7 Hybrid systems

Hydro can be used in conjunction with other renewable energy sources and this is particularly relevant for off-grid systems where photo-voltaics (solar electrical generators) can be used to complement hydro. Solar and hydro can work well together as solar peak output is in summer, whilst hydro peak output is in winter; thus offering a more constant output throughout the year.

Chapter 5
Surveying hydro power potential in the Peak District

5.1 INTRODUCTION

A core aim of the project was to bring together an up-to-date and comprehensive data set of existing and potential micro hydro schemes and sites in the wider Peak District. This involved data gathering from a variety of sources including: previous studies; old mill records and databases; companies or other owners and organisations operating or implementing hydro schemes; consultation with communities and land owners; and finally, visiting, surveying and assessing potential sites identified by the data gathering process.

Three main categories of sites were noted or investigated: existing (operating) sites (12); old mill sites (131); and non-mill sites (19, including potential high head schemes). A further sub-division of sites inside or just outside the National Park was also recognised (120 inside; 42 just outside). A three stage process was then applied to the potential sites:
1. A 'walk over' visit (117 sites) – see section 5.4
2. Constraint mapping and assessment using a Geographical Information System or GIS (59 sites) – see section 5.5
3. More detailed site investigations (20 sites) – see section 5.6; followed by pre-feasibility studies for 10 key sites (Chapter 6).
The full methodologies for each stage are described below.

Finally, it should be noted that the ten sites taken forward as key case studies (described in full in Chapter 6) were not chosen as being the 'top ten' sites with the best hydro potential, but rather because they represented a good range of typical Peak District sites with reasonable potential. It was felt that exploring the opportunities and constraints of a wide range of sites would be of more utility to site owners and communities whose situations are usually quite varied.

5.2 CONSULTATION WITH KEY STAKEHOLDERS AND LOCAL COMMUNITIES

In addition to forming a project advisory group (see section 1.1 and see Appendix F), early and ongoing discussions also took place with representatives of the three water and sewerage companies with assets within the National Park: United Utilities (UU), Yorkshire Water (YW) and Severn Trent Water (STW). This was to ascertain their existing hydro electric generating capacity and any studies undertaken and/or subsequent proposals for the development of any additional hydro power installations.

In relation to raising public awareness of the project and seeking suggestions for potential sites, a letter introducing the project was sent to every Parish Council within the National Park. Following completion of the initial site visits, a press release was issued to garner further interest and two public consultation meetings were held, a week apart. The first was in Glossop and the second in Cromford, catering roughly for more northerly and southerly communities respectively. These were well attended, especially by those with direct interest in a variety of mill sites.

A key outcome from these events was the recommendation that hydro sites just outside the National Park be included within the study, especially where a community spanned the boundary. This was duly adopted and resulted in an additional 42 sites being assessed, including two as key case study sites (Via Gellia Mills near Bonsall; Millthorpe in North East Derbyshire).

5.3 EXISTING PEAK HYDRO POWER CAPACITY

There are about 1.6 megawatts (MW) of installed mini/micro hydro capacity within (or just outside) the National Park area at present and all sites are listed in Table 5.1. The vast majority of this capacity is situated within water supply networks (see below) with the only other significant installations being at Chatsworth, where a 162 kW turbine is used to provide electricity to the House, and the new 30 kW scheme at Alport Mill, near Youlgreave, installed in 2009 (see section 3.3).

LOCATION	RIVER	GRID REFERENCE	PLANT	INSTALLED CAPACITY (kW)	NOTES
Located wholly within National Park					
Alport Mill	Derwent	SK 222 646	Turbine	30	Commissioned August 2009
Ladybower Reservoir	Derwent	SK 200 854	Turbine	234	Commissioned April 2007
Chatsworth House	Derwent	SK 260 701	Turbine	162	
Hartington Mill	Dove	SK 120 598	Waterwheel	2.5	Not working – noise issues
Bottoms Reservoir, Longdendale	Etherow	SK 023 972	Turbine	130	
Rhodeswood Reservoir, Longdendale	Etherow	SK 043 981	Turbine	170	
Torside Reservoir, Longdendale	Etherow	SK 055 983	Turbine	170	
Errwood Reservoir	Goyt	SK 016 759	Turbine	150	
Caudwell's Mill, Rowsley	Wye	SK 255 657	Turbine	42	Maximum output c.15 kW
PDNP CAPACITY				1090.5	
Catchment area within National Park (powerhouse outside boundary)					
Broomhead/More Hall Reservoirs	Don	SK 299 957	Turbine	200	
Dale Dike/Agden Reservoirs	Don	SK 289 902	Turbine	200	
Rivelin Valley WTW, Sheffield	Don	SK 285 869	Turbine	120	
ADDITIONAL CAPACITY				520	
TOTAL PEAK DISTRICT CAPACITY				**1610.5**	

Table 5.1 Existing hydro power capacity in the Peak District (end 2009)

5.3.1 Water and sewerage companies

The three water and sewerage companies (STW, UU and YW) have substantial assets in the National Park in terms of reservoirs, treatment plants and distribution systems. All three companies are committed to the generation of electricity from renewable resources but it has to be remembered that in each case the National Park only forms a small percentage of their total area and hence resources are often targeted elsewhere. Any investment in new plant must also meet strict market tests for rates of return (governed in part by the Government regulator, OFWAT) and this mitigates against developing some of the more economically marginal sites.

The types of site within these companies' infrastructure which are used (or would be envisaged) for hydro are not 'run of river' but installations within the water supply and sewerage system. Broadly these include break pressure valves on main supply pipes and at the entrance to water treatment works (e.g. the recent installation at YW's Rivelin Water Treatment Works), release valves from reservoirs including compensation water (e.g. at the UU Longdendale reservoirs and STW's Ladybower site) and at outfalls from sewage treatment works.

At present there is 1.37 MW of installed capacity on eight sites either within the National Park or at sites which derive almost all their water supply from reservoirs situated within the NP (see Table 5.1). In addition, the companies have identified a further seven potential sites which are being evaluated: six by Severn Trent Water in the Upper Derwent catchment (total potential c. 700 kW; mostly at Derwent and Howden Dams) and one in Sheffield by Yorkshire Water (c.50 kW at Damflask Reservoir). If fully realisable, these sites – together with those already up and running – would have a total installed capacity of just over 2.1 MW.

5.4 DESK STUDY AND 'WALK OVER' ASSESSMENT

The project commenced by reviewing existing data on hydro power sites within the National Park. Two main reference sources were used initially:

- the Department of Energy ('ETSU') study commissioned in 1989 from Salford University (Salford Civil Engineering Limited, 1989) and
- the relevant county databases of the Mills Archive Trust (Cheshire, Lancashire, West Yorkshire, South Yorkshire, Derbyshire and Staffordshire)

The ETSU study, whilst providing valuable data on a number of sites, was limited in its scope in that it set lower limits of 25 kW of installed power or a 2m head. However, the study did include a list of rejected sites (i.e. those below those limits) which formed a useful starting point.

Additional data on historic watermill sites was obtained from the book *Derbyshire Watermills – Corn Mills* by Alan Gifford (Gifford, 1999) to which was added details of sites obtained from sources such as suggestions from Parish Councils and local historical societies. In all, over 130 old mill sites were identified either within or adjacent to the National Park. These historic sites give a good indication of the overall gross river potential[1] for hydro power in the Peak District and the most likely locations for new/reinstated schemes.

5.4.1 Old mill sites

Most of the old mill sites within the National Park and some (but not all) just outside were visited and a rough 'walk-over' survey conducted (either using adjacent public rights of way or by permission of the owner) to ascertain their potential for development as micro hydro sites. Many were found to be no longer in existence or derelict (some even flooded by later reservoir schemes); some had fallen into disuse but with their original equipment still in place; some have been or are being restored (often as dwellings); and a few have been converted to generate electricity. Excluding the latter category, the rest of the sites were then classified into three categories:

- 'a' – those sites with good potential for micro hydro power (MHP) development
- 'b' – those sites with possible potential for MHP development
- 'c' – those sites with little or no potential

The classification is indicative but took into account the following criteria:

- Whether the site was still in existence
- If the mill building was demolished or converted into dwelling
- The condition and extent of existing mill infrastructure (leats etc)
- The flow in the watercourse available for power
- The head available
- Location and access (e.g. for civil works)
- Any other obvious potential constraints

The main reason for classifying mill sites as 'c' was generally because the mill or its infrastructure had ceased to exist and/or the flow was too low for power generation. In some locations, although the flow would have been sufficient to power a waterwheel and slow moving machinery (often with the aid of overnight storage in a millpond), the 'run of river' flow was generally insufficient to drive a turbine or similar machinery to generate electricity.

Those sites classified as 'a' or 'b', see Appendix A1, were then subjected to detailed GIS analysis (see sections 5.5 and 5.7 below). The 'c' mills, listed in Appendix A4, were not subject to any further analysis but, if the need for rural micro-generation were to increase substantially in the future, some sites may become viable and worth re-examining. Viable locations just outside the National Park, comprising both mill and non-mill sites where the catchment is largely within the NP, are listed in Appendix A2.

5.4.2 Non-mill sites

Due mainly to the likely environmental and ecological problems associated with the construction of new weirs and extraction points on rivers and streams within the National Park, it was decided at the outset of the project not to place a strong focus on investigating potential new hydro sites (including high head sites). However, the ETSU study identified two such sites, one on the Bar Brook at Baslow and one on Burbage Brook (Padley Gorge) and other potential sites have been identified during the study.

Additionally other (non-mill) weir structures (usually owned by one of the water and sewerage companies) were also identified, leading to a total of 18 non-mill sites. All these sites are listed in Appendix A3 to give a more complete picture of the potential for micro hydro in the National Park (if visited, the same classification potential 'a'/'b'/'c' has been applied). Some more information on and assessment of these sites is given in both this chapter (see section 5.7.2) and the next chapter on key case study sites.

5.5 GEOGRAPHICAL INFORMATION SYSTEM (GIS) SCREENING

Roughly 60 sites (classified 'a' and 'b') were investigated using a bespoke computer model specially commissioned for this project from T4Sustainability. The Peak District National Park Authority made its planning constraint data available specially to the project and other spatial information was sourced from MAGIC (Multi-Agency Geographic Information for the Countryside – a publicly-available web-based interactive map service which brings together environmental information from across government – see www.magic.gov.uk).

5.5.1 GIS screening and its limitations

The sites selected for investigation were imported into the GIS to facilitate the identification of potential constraints to development (most of the GIS data supplied by the NPA is that used by their planning service to identify constraints when development proposals are submitted). A constraints map and list was produced for each site studied and these are reproduced in full in Appendix B. It should be noted that

[1] *A crude estimate of all possible power from 'run of river' schemes, i.e. excluding potential high head sites.*

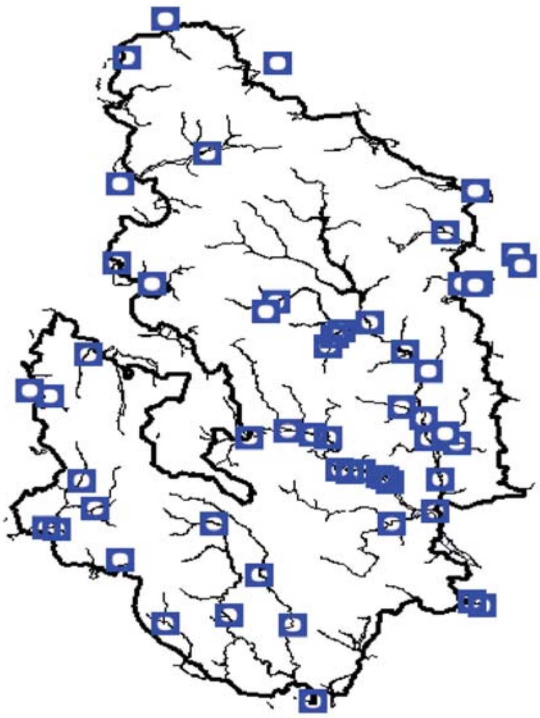


Figure 5.1 The broad distribution of the GIS analysed sites across the Peak District

some of the sites lie outside of the National Park where complete datasets were not available – see Figure 5.2.

It should be noted that the site assessments and maps are intended as initial reviews rather than feasibility assessments and should not be relied upon to prove the viability (or not) of a site. As the data-sets were provided by third parties, T4S cannot be held responsible for any errors or incomplete data. In addition to this, the general limitations of GIS should be recognised as the data sets used may not pick up all constraints.

The PDNPA also hold other data sets in addition to those used here and there may also have been recent updates to the original data. For example some wildlife that have the potential to be affected by hydro schemes (e.g. the fish species brook lamprey) will not be picked up as constraints within PDNPA records, as no distribution data is held for this species. A site visit (and subsequent surveys, if required) is the usual way to pick up issues not identified as part of any desktop study.

Similarly the Historic Environment Record (HER, the successor to the Sites and Monuments Record, SMR) is constantly being developed and enhanced and will often hold other information (e.g. historic landscape character assessments) which is not available on line. HERs should always be seen as a primary data source when working up new schemes.

5.5.2 Data sets used

The following data sets were used to assess the sites within the National Park boundary (source is given in brackets).

GRID CONNECTION

- overhead lines (sourced from PDNPA data)
- cables (PDNPA)
- Central Networks low voltage (LV) overhead network (PDNPA)

NATURAL

- UK Sites of Special Scientific Interest (PDNPA/MAGIC)
- EU Special Areas of Conservation (MAGIC)
- EU Special Protection Areas (MAGIC)
- Derbyshire Red Data Book (RDB) plants (PDNPA)
- English Nature (now Natural England) rare/protected species (PDNPA)
- Ground water protection zone (PDNPA)
- Key ecological area (PDNPA)
- EA flood zones 2 & 3 (PDNPA)

CULTURAL CONSTRAINTS

- Scheduled Monuments (PDNPA/MAGIC)
- Listed Buildings (PDNPA)
- Sites and Monuments Record (now HER) (PDNPA)
- Common Land (PDNPA)
- Conservation Area (PDNPA)

POLICY CONSTRAINTS

- Natural Zone (PDNPA)
- National Park boundary (MAGIC)

5.5.3 Site assessments

The constraints overlapping and adjacent to each site were reviewed and recorded in an assessment table for each site (see Table 5.2). Constraints within approximately 1km of a site have been listed unless there are numerous constraints in the area (e.g. large numbers of listed buildings) in which case the closest constraints have been listed. The following analysis was undertaken for each set of constraints.

GRID DATA

The proximity to electrical cables or lines was determined. The table refers to the distance to the nearest known cable or over-head line which may not be a connection point. e.g. 'less than 500m' means there is a cable within 500m of the site, not that there is a grid connection point within 500m. The grid data is known to be incomplete, therefore detailed data should be sought from the local electricity distribution network operator (DNO) when assessing sites. GIS data was also supplemented by other network data from E.ON/Central Networks East (CNE), United Utilities (UU) and Central Electric –Yorkshire Electricity Distribution Ltd (CE-YEDL) held by FPD.

NATURAL CONSTRAINTS
The names (or reference numbers where names were not available) of relevant local constraints (usually species or habitats) have been given for each constraint except nationally protected species which are confidential. For such protected species, their presence has been noted and where possible an indication of rough location given.

CULTURAL CONSTRAINTS
The names (or reference numbers where names were not available) of relevant local constraints have been given for each site. Where there are numerous listed buildings or scheduled monuments only the closest have been listed. Please note that SMR data was used in the GIS analysis – these records are now part of the HER (see 5.5.1).

POLICY CONSTRAINTS
If the site is within or adjacent to the Natural Zone[2], this was recorded. Sites near or outside the National Park boundary were recorded as such. The relationship to Conservation Areas was also recorded.

5.5.4 Site maps

A map showing potential constraints to development was prepared for each site (see Figure 5.1). The map has a legend and gives a site reference number as well as the site name. The scale of each map was set to best show the relevant constraints as clearly as possible. Each potential hydro site is shown using a blue square symbol and to reduce confusion many are not centred on the page to avoid showing adjacent sites on the same map.

The following should also be noted about the maps prepared:

FLOOD ZONES
The GIS data for EA-designated flood zones 2 and 3 appears to be corrupted and therefore they have not been shown for some sites although the constraint is listed in the accompanying tables.

GROUND WATER PROTECTION ZONE
This constraint is not shown on the maps as it obscures other data layers; again this constraint is listed in the tables.

5.5.5 Sites outside the National Park boundary

As the PDNPA data sets are limited to the National Park boundaries, only limited data (from MAGIC) is available for sites outside the NP boundaries. As all the sites outside the NP were close to the boundary, a combination of PDNPA and MAGIC data sets was used to determine most constraints.

Where PDNPA data showed there were constraints near to the site they have been listed, otherwise the data row has been removed from the table (as it has not been possible to definitively determine whether the constraint is present or not due to a lack of data).

Where constraints have been identified in the vicinity of a site using PDNPA data, it is not possible to establish whether the site is overlapped by other data points in this constraint data set (as the site is outside the NP). In this case the table refers to 'not known' (rather than not applicable, N/A) in the relevant row.

The full set of constraint maps and tables for each 'a' or 'b' site is reproduced in Appendix B. Old mill sites are referenced M1 *et seq.*, non-mill sites N1 *et seq.* and sites outside the NP as O1 *et seq.*

5.6 FURTHER SITE INVESTIGATIONS

Twenty sites were either chosen specifically for further investigation (the key case study sites) or were investigated in more detail at the request of site owners or other interested parties. This usually involved a further site visit, often accompanied by land owners/other parties, to scope issues including: neighbour considerations/riparian rights; extraction rights; other riverine issues; local landscape character and visual impact issues; ground-truthing GIS/MAGIC data including archaeology, ecology and electrical connection; state of infrastructure; and owner ambitions. Head was measured by a dumpy level (Topcon AT-24A), tripod (Topcon) and 5m staff (Stanley). Crude measurements of flow were made if no other local data was available.

The sites looked at in more detail were the ten key case study sites: **Whitelee Mill**; **Lumford Mill** (Riverside); **Bamford Mill**; **Edensor Mill**; **Caudwell's Mill**; **Diggle Mill**; **Millthorpe weir**; **Via Gellia Mills**, Bonsall; **Marsden town weir**; **Grinds Brook**, Edale (see Chapter 6). The further group of ten (investigated in varying levels of detail) were: **Low Bradfield** corn mill; **Ashford Bobbin Mill**; **Magpie Sough**; **Hodgkinson's Mill**, Baslow; **Blackwell Mill**, Wyedale; **Gradbach Mill**; the **Chatsworth** estate; **Greenlands Farm**, Edale; **Alport Bridge** weir, Woodlands Valley; **Ilam Church**.

In addition, other major sites where head, flow and power estimates had already been made (such as **Litton Mill** **Flewitt's Mill**, **Calver Mill** and **Cressbrook Mill**) were also re-visited in the course of the project, usually at the behest of local interested parties. It should be noted that many of

[2] *Areas mapped under provisions in the Wildlife and Countryside Act (1981) whose natural beauty is particularly important to conserve.*

the 'a' and 'b' sites listed in Appendix A1 and A2 will have potential for micro hydro development but limited resources and time prevented their fuller investigation. The issue of overall capacity is dealt with in Chapter 7.

5.7 RESULTS FROM THE GIS ANALYSIS – COMMENTARY

5.7.1 Old mill sites

In total 38 old mill sites (see Appendix A1) within the NP were subject to the GIS constraints analysis. Of these seven (**Whitelee Mill**, **Lumford Mill**, **Bamford Mill**, **Edensor Mill**, **Caudwell's Mill**, **Diggle Mill** and **Low Bradfield**) were selected for further study (including flow modelling, using the HydrA model, where necessary – see Appendix C) and these (bar **Low Bradfield**, see below) are described in full as 'key case study sites' in Chapter 6. For the remaining sites, the GIS analysis is helpful in identifying initial potential constraints, some of which may be 'show-stoppers'.

POLICY AND NATURAL CONSTRAINTS

Major constraints to hydro development include a site falling within the PDNPA's Natural Zone where most forms of development are prohibited. This constraint will often overlap with nature conservation designations such as Site of Special Scientific Development (national level) and EU designations such as Special Protection Area (SPA, under the Birds Directive) and Special Area for Conservation (SAC, under the Habitats Directive). Development within such areas is extremely unlikely and can only occur in exceptional circumstances. However, there may be opportunities for micro hydro power in connection with existing development in the Natural Zone if the National Park Authority and others consider any environmental impact to be minimal.

A good example of a site faced by these constraints would be the **Paper Mill**, near **Crowden** in Longdendale (site ref. no. M18, Appendix B) which overlaps a combination of all these designations (Natural Zone and SSSI/SPA/SAC). However the presence of rare species and valued habitats need not necessarily be a barrier to development as the new Alport Mill scheme demonstrates (see site ref. no. M2, Appendix B and section 3.3).

CULTURAL CONSTRAINTS

Given that all old mill sites have historic value and are often either recorded on the HER (SMR), listed or sometimes scheduled, this is a key constraint that appears for many of the sites examined. The importance of evaluating the real 'on the ground' constraints and early consultation with the appropriate authorities (usually the PDNPA cultural heritage team in the first instance) has already been highlighted in sections 3.3 and 3.4.

However, being valued historically is not necessarily an over-riding barrier – even where a site is nationally scheduled. Reinstating hydro power may, in some circumstances, add interpretive value and context to the historic dimension of the site (hence why the Arkwright Society are redeveloping hydro at **Cromford Corn Mill**, site ref. no. O13, see Appendix A2) or schemes may be designed in such a way as to minimise the impact on features of interest (such as at Alport Mill).

But at some sites, e.g. **Lumford Mill** (site ref. no. M5 and also a 'key case study site' – see Chapter 6 for full detail) where a large proportion of the original water management system is scheduled, the barriers to obtaining the appropriate permissions (in this case, scheduled monument consent) are likely to be significant, time-consuming and costly. Happily however, and as the key case study explains, there are other potential ways of exploiting hydro power at or adjacent to this site.

Some sites however may be more problematic, for example **Edensor Mill** (also known variously as Calton or Pain's Mill) which is situated within the grade 1 listed park and garden of Chatsworth. It is currently unclear whether developing the related weirs, which the case study shows are viable in terms of power available, would have an adverse effect on the listing (see Chapter 6 for more detail). Unusually, at **Caudwell's Mill** – again another key case study site – the historical value of the mill and its working turbines (they are also listed) potentially militates against either their increased use for electricity generation or the addition of more modern equipment.

GRID CONNECTION

The GIS analysis showed that the majority of old mill sites are usually within reasonable distances of grid connection, although distance is not the only connection issue to be addressed (see sections 3.5 and 4.4.3). However, some sites do have a level of remoteness (sometimes combined with landscape sensitivity that would rule out overhead wires and poles) that may act as an overriding deterrent to developing a scheme, unless an off-grid use for the power can be found. These included **Ashford Bobbin Mill** (see below), the **Edensor Mill** weirs and the **Lumford Mill** weir.

An example of this issue is found at **Ashford Bobbin Mill** (site ref. no. M3) which has good (albeit listed) infrastructure (weir, leat, wheels *in situ*), good flow (could power up to 30 kW) yet would probably require about a mile of underground cable to connect it to the grid in Ashford in the Water, which would be very costly. However, on the optimistic assumption that other site issues (e.g. presence of EA gauging station, valuable local game fishery) could be dealt with, and if the mill buildings were to require power for some low-key form of development (e.g. a camping barn, heritage interpretation site), then off-grid hydro power could be an attractive and obvious option (although matching demand with the energy available could be difficult).

CAPACITY OPTIONS

A number of old mill sites were looked at in more detail by the project team or have already had capacity studies (of varying levels of detail) completed. The most obvious major sites for further study and development are those covered by the ETSU study and comprise (with original power estimates): **Hodgkinson's (Old) Mill, Baslow** (35 kW), **Calver Mill** (125 kW), **Cressbrook Mill** (94 kW) and **Litton Mill** (120 kW). Given that ETSU calculated power potential based on residual flows of Q_{95}, which may no longer be permitted by the Environment Agency, the capacity estimates may now be over optimistic. Two old mill sites (**Vincent Works, Brough; Stoney Middleton**) have also had feasibility studies carried out by Derwent Hydro (funded by the PDNPA Sustainable Development Fund). Together these sites would net c.15 kW (11 kW at Brough, 4 kW at Stoney Middleton – see Derwent Hydro, 2007; ibid., 2008).

The project team also examined in some detail the feasibility of the former corn mill site at **Low Bradfield**, including running the HydrA model for this site to gauge flows (see Appendix C for the DARE report on this site). Unfortunately, due to the fact that no statutory compensation flow is released from the reservoirs above the site, the likely power capacity was very low (0.8 kW). This was very disappointing as there was substantial local interest in developing a community scheme and the site itself presented few other constraints.

Acting on *ad hoc* requests, the FPD project team also looked at the weir once associated with **Blackwell Mill** in Wye Dale (c.1m weir only but good flow), **Gradbach Mill** (now YHA site – c.5 kW potential but low flows, little infrastructure and a long depleted reach imply substantial constraints) as well as Ashford Bobbin Mill (see above and also the section below on the nearby Magpie Mine sough). Both Blackwell Mill and Gradbach Mill may also be limited by environmental/ecology issues, either being in/close to sensitive areas (especially Blackwell) or providing very natural river habitat for fish (Upper Dane at Gradbach – see the Weaver and Dane CAMS: EA 2006, p.36).

Figure 5.2 The Frances turbine from Flewitt's Mill awaiting refurbishment in winter 2009 (photo courtesy of R. Griffiths)

In terms of 'a' and 'b' sites outside the National Park (see Appendix A2), at least 20 out of 25 of these were old mill sites and the majority of these have been studied in further detail, notably at **Bollington** (Leigh, 2008) and on the **River Don and its tributaries** in and around Sheffield (IT Power 2006; Zeleznikar, 2008), including power estimates. Three sites (**Via Gellia Mills, Bonsall; Millthorpe; Marsden town weir**) were also assessed in greater detail by the project team and are reported on in Chapter 6. Most of these sites have viable potential in varying degrees but clearly those sites with the greatest potential power output should be prioritised initially for further investigation.

REFURBISHMENT PROJECTS

Two of the 'a' and 'b' mill sites, **Flewitt's Mill** (also known as Ashford Old Mill, site ref. no. M4) on the Wye and **Hodgkinson's Mill** (also known as Old Mill, site ref. no. M9) on the Derwent, have a degree of intact infrastructure possibly only rivalled by **Cressbrook Mill** (M16, where two turbines are still in situ – see Figure 2.11) and therefore are good early options for increasing Peak District micro hydro capacity.

Indeed, during the course of this project, refurbishment began at **Flewitt's Mill** and the 1920s Frances turbine (made by Gilkes) should be reinstated and running by early 2010. Power capacity is expected to be about 18 kW, the maximum rating for the turbine. Reaching this stage has been a long-running project for the owner who commissioned a full feasibility study in 2008 which gave options of refurbishment of the old turbine or installing a new Kaplan turbine which could increase capacity and output significantly. Although a new, larger turbine would offer a significant return on investment in due course, the option of refurbishing and reinstating the existing turbine has been preferred (partly on cost grounds). See Figures 2.12 and 5.2 showing the disused turbine in situ and its removal, respectively.

Figure 5.3 The original turbine in situ at Hodgkinson's Mill in Baslow

Figure 5.4 A modern waterwheel manufactured by Hydrowatt of Germany recently installed at Lemsford Mill, Hertfordshire (photo courtesy of Ramblers Worldwide Holidays)

The FPD project team also looked at the reinstatement potential at **Hodgkinson's (Old) Mill, Baslow** which had already been investigated by the ETSU study. The mill, now converted to a dwelling, was converted to generate electricity in the early part of the twentieth century, providing power for Baslow Hall, home of Dr Sebastian de Ferranti FRS – a renowned electrical engineer and head of Ferranti Ltd. The original Frances-type turbine is still in place (see Figure 5.3) and water still flows through the wheel pit, exiting via a quite lengthy tail race which adjoins several neighbouring properties. The length of the depleted reach is likely to have implications for determining any future design flow, which may mean that the 35 kW estimate by ETSU may not be fully realisable. The rest of the infrastructure is in good condition, although the full details of the weir ownership remain to be resolved. The owner remains interested in developing a scheme, at least in principle and subject to costs.

WATERWHEEL OPTIONS

A subsidiary aim of this project was to scope the option for increased use of modern or restored waterwheels and thus counter, in a very limited way, the almost complete dominance of turbines and Archimedes screws as the modern solution of choice. As described in Chapter 2 (section 2.4.2), a number of old mill sites – often during conversion to dwellings – have had wheels restored for cultural and aesthetic reasons but seldom with electrical power being generated from them. A number of owners (e.g. at **Hartington Mill, Longnor Mill** and **Calver Corn Mill**, the latter unusually fed by water derived from a mine drainage channel, locally called a 'sough') have either completed or are in the process of setting up wheels with some power output but most are rated at less than 10 kW. Unfortunately the Hartington wheel, which was installed to provide power to a holiday let, is no longer used because of noise issues. The new wheel at Calver Corn Mill should be installed in 2010.

Edensor Mill in Chatsworth Park was a key focus for the project in terms of a site where wheel reinstatement might be favoured on several accounts, not least the need not to affect adversely the listed historic park and garden landscape and provide some educational and interpretive context to the history of a building that, in recent times, has become somewhat neglected (see Chapter 6). Although wheels are decidedly fish-friendly and need little screening (thus saving on costs), the need to relocate them in the original wheelpit (usually the easiest solution) may mean reduced design flow if a significant depleted reach were to ensue.

It is also fair to say that, in terms of overall efficiency (and therefore generation and carbon saving), wheels fall slightly short of turbine solutions (including screws), which also have the flexibility to be installed as in- or near-weir solutions, thus addressing the depleted reach issue. Nonetheless, the experience at one UK site, Lemsford Mill on the River Lea in Hertfordshire (see section 4.4.3 and Figure 5.4), has shown that retrofitting a modern (11 kW) waterwheel can be highly successful.

5.7.2 Non-mill sites

Although the main focus of the project was generally on run-of-river old mill sites, 19 non-mill locations for potential micro hydro schemes were identified and a number of them looked at in varying degrees of detail, right up to key case study level (the Grinds Brook site in Edale – see Chapter 6). Sixteen of these sites are within the NP and these are listed in Appendix A3; three sites (Combs Reservoir; More Hall Reservoir, site ref. no. 05; Rivelin Water Treatment Works, 08) fell outside the NP and are listed in Appendix A2. Twelve of these non-mill sites had the benefit of GIS constraint analysis (see Appendix B, sites numbered N1-N15 (incomplete) plus 05 and 08) and general commentary on these and other sites is made below.

POLICY AND NATURAL CONSTRAINTS

Of the 15 sites listed in Appendix A3, the large majority (12) are in reasonably remote, semi-natural locations, where the watercourse is in the upper, and often uppermost, reach of its catchment. Indeed six of the sites (**Swint Clough**; **Bar Brook**, site ref. no. N1, see Appendix B; **Greenlands Farm**, N10; **Grinds Brook**, N15; **Padley Gorge**, N5; and **Manor Farm**) are slated as medium/high head sites.

Potential high head sites, despite the natural attraction of their gradient and their ubiquity in upland areas with high precipitation, often present major barriers to development. Many of those mentioned above, despite clear potential (the ETSU study estimated the **Burbage Brook (Padley Gorge)** scheme at 106 kW and **Bar Brook** at 88 kW) fall within the Natural Zone or strict nature conservation designations and would involve very long depleted reaches to achieve the maximum potential head. This would present severe difficulties for the two ETSU schemes, for example.

Two other non-mill sites, assessed by ETSU but rejected on various grounds, were identified in **Lathkill Dale** (waterfall) and a sizeable weir (c.4-5m) in **Monsal Dale** on the Wye. Both would be severely constrained by ecological issues and would be very remote for grid connection. The potential to develop such sites is very low and they were graded 'c' for this reason. Another site on the River Lathkill, at **Raper Lodge**, has been identified recently in a study commissioned by Sustainable Youlgreave (Clarke, 2009) as potentially the best option remaining (after the implementation of the Alport Mill scheme) on the Lathkill and Bradford rivers. Power was estimated at 10-15 kW.

The project team, at the request of various landowners/ interested parties, were asked to assess two further high head schemes: Swint Clough in Alport Dale and Greenlands Farm in Edale (on an upper tributary of Harden Clough). **Swint Clough** had already been the subject of a scoping study prompted by a nearby local resident and the major landowner in the area, the National Trust. Although a scheme could have potentially generated 2 kW (sufficient for a local property) and the visual and ecological impacts were likely to be manageable, a buried penstock was likely to be at risk of rupture due to locally unstable slopes.

The FPD team also made investigations at **Greenlands** which revealed a c.50m head across the landholding with good layout options including suitable sites for an upper coffer dam and a lower powerhouse, both within the landholding. Visual impact would have been low given that the stream ran in a deep, scrubby clough, although ecologically it is likely to be sensitive and it is in the Natural Zone. However, an instantaneous measurement of winter flow (4.5 litres per second) suggested that maximum power would be about 1 kW or less. The owner was advised that a DIY 'pico' scheme was the only realistic option and that planning and environmental constraints may outweigh viability.

Two medium head sites identified in the course of the study were judged to have much more potential: Grinds Brook in Edale (developed as a key case study site, see Chapter 6 but again likely to be environmentally constrained) and **Manor Farm, Quarnford.** The latter has been scoped and developed as a viable scheme by Western Renewable Energy on behalf of a local landowner/farmer and licences from the Environment Agency are currently being sought. It aims to provide c.12 kW on a 35m head and is intended to help diversify the farm's income.

Finally four sites, mostly being weirs for in-catchment management by water and sewerage companies were identified at **Crowden, Pikenaze Farm** (both in Longdendale), **Dovestone Reservoir** (Chew Valley) and **Alport Bridge** (Woodlands Valley). The former two were judged poor prospects for development, mainly on the grounds of remoteness and naturalness but the 2m weir on the **River Alport** may have some limited potential, although increasing design flow to a turbine/screw would alter the original purpose of the weir which was to divert water along an artificial channel to a further weir on the nearby River Ashop where a larger diversion channel feeds water to Derwent Reservoir. Flow data is currently being sought from the local water company (STW) to estimate likely power.

It is possible that if further water company sites were found but not judged viable enough to meet their own investment criteria, leasing sites to a local community (who might also be in a better position to secure grant aid) might provide a possible development route. This strategy is currently being pursued at the Dovestone site.

CULTURAL CONSTRAINTS

A number of atypical non-mill sites fall broadly into a bracket of facing cultural constraints, including opportunities at Chatsworth, Ilam and Magpie Sough. As has been mentioned previously, **Chatsworth** already has a purpose built high head scheme (where a new turbine was installed in 1988) which provides electricity to the House in winter and some export to grid in the summer. In addition, the project team scoped the potential for re-developing the weirs adjacent to Edensor Mill (see Chapter 6).

However, in discussions with senior Chatsworth staff, further options for either upgrading power or further schemes were identified. These included re-lining the current Emperor penstock so as to increase flow and power output and also capturing energy from the further head between the current turbine exhausts and where the flow re-joins the river. The former option should not necessarily give rise to impacts on the listed park and garden but the latter might. Given the extent of the Chatsworth land holdings in the area, several other mill and non-mill options are also open to the Estate, including **Heathy Lea Saw Mill** (M38), close to Chatsworth, and **Ashford Bobbin Mill** (M3, see section 5.6.1) and the adjacent **Magpie Sough** outfall.

In addition to the special project sub-focus on waterwheels, the original aims also included an objective to investigate the potential of lead mine drainage channels, 'soughs' in Derbyshire parlance, for micro hydro power. This stemmed in part from the observation that some soughs have quite considerable year-round flows, sometimes capturing drainage waters at depth over considerable catchment areas (sometimes even capturing flows from adjacent river catchments).

In addition, in 2004 a hydro power feasibility study for Norchard Drift, a similar mine drainage tunnel near Lydney in the Forest of Dean, Gloucestershire, suggested an 8 kW was feasible and – with then Government grant aid (the 'Clear Skies' programme) – a good payback time (c.7 years) could be achieved (Renewable Heat & Power Ltd, 2004). Also, during the course of the project, our attention was drawn to the unusual example of Calver Corn Mill which derives its water from a local sough (see Willies, 1989). The owners of the mill (now two dwellings) are currently reinstating a wheel, due to be providing power (4 kW capacity) in early 2010.

LEAD MINE SOUGHS – A UNIQUE PEAK DISTRICT MICRO HYDRO RESOURCE?

Mine drainage tunnels were driven to de-water Peak District lead mines all across the South Pennine/Derbyshire orefield, from the sixteenth to the nineteenth centuries. Although they can capture underground drainage over wide areas, their gradient (between the base or 'sole' of a mine and their outfall in an adjacent river valley) is usually very small (usually dropping only several feet in a mile), hence heads are usually somewhat limited.

The larger soughs (see below) usually have strong, year round baseflows and one, Meerbrook Sough, which drains the Wirksworth area and has its outfall on the Derwent near Whatstandwell, is actually under the control of the local water company. An initial investigation of this sough by Derwent Hydro (Paish, pers.comm.) suggested a rough estimate of up to 10 kW power might be obtained.

The larger soughs (and some natural resurgences) in the wider Peak District that may be worth further investigation include: the **Bagshawe Cavern resurgence** in Bradwell (also possibly sough-fed; the resurgence once powered a small wheel linked to the adjacent smelting works); **Magpie Sough; Yatestoop Sough**, near Darley Bridge (which also has an additional small head at its outfall into the Derwent); **Meerbrook Sough; Ridgeway Sough** near Crich; **Hillcarr Sough** near Stanton Lees; **Watergrove Sough** in Stoney Middleton Dale; **Moorwood Sough** in Stoney Middleton; **Stoke Sough** near Froggatt; **Cromford Sough** (which used to feed wheels at Arkwright's Cromford Mill); and **Peakshole Sough/Slop Moll resurgence** in Castleton[3].

It must be borne in mind that the archaeological value of soughs is intrinsically high – tails and portals are often scheduled together with associated features – and this mitigates strongly against their use. Other constraints, such as the lack of head – without creating new structures underground in potentially historically fragile and unstable, restricted environments – also suggest that this option remains a low priority for the future.

The project team also conducted a scoping survey of one of the larger local soughs, **Magpie Sough.** This major sough has its outfall into the River Wye about 400m west of Ashford Bobbin Mill and drains Magpie Mine about 1.5 km to the south. Some drainage that would otherwise flow to the

[3] *We are grateful to Dr Jim Rieuwerts, the leading authority on Peak District soughs, for his advice in compiling this initial list.*

Figure 5.5 Strong flow at Magpie Sough tail in the 1970s (photo courtesy of Richard Bird)

Lathkill, further south, is also captured by the sough. A recent review of historic flow figures combined with estimates made in late 2009 (*pers.comm.* Gunn, 2009) suggest an average flow (based on 1989-1995 data) of c.370 litres per second (L/s). Flow in late 2009 ranged between 370-650 L/s and Gunn suggests assuming a Q_{95} of 350 L/s (0.35 m^3/s) is reasonable.

The FPD site investigation suggested that a 1m head could be achieved by building a small coffer dam at the sough exit (see Figure 5.5) although this would likely flood the sough to roof level in its lower reaches. Assuming design flow would be close to mean flow, this would give a potential power output of some 2 kW. However, a greater head could be obtained, either by moving the intake higher up the sough (i.e. underground) or by running a penstock from the sough to a lower powerhouse nearer to the Bobbin Mill, which could add an extra 3m or so to the head, albeit with a small deprivation of water to the Wye over a 400m or so stretch. Issues associated with such a scheme would include continued accessibility to the sough, impacts on its function and impacts on its setting and underground archaeological features and, as mentioned previously for Ashford Bobbin Mill, lack of grid connection.

However, if any sough sites were to be taken forward for development, it is extremely important that detailed consultations are entered into with both the PDNPA and the Peak District Mines Historical Society (PDMHS). The PDMHS have stated they would potentially welcome any potential micro hydro scheme that fully respected and maintained the historic and archaeological integrity of the structure (and where there were no other legitimate non-mining issues that others raised in objection).

The PDMHS also suggest the best way to ensure this (where possible) would be to place any turbine and/or other equipment in the tail race rather than the sough itself. But in most cases, it is also very important that access up soughs is maintained. These are important underground resources visited regularly by mine historians and archaeologists for research and education purposes and no additional access restraints should be put in place.

Finally a further non-mill site near **Ilam Church** was identified by a local community initiative, Ilam Community Energy (ICE) to address the issue of supplying energy (heat if not power) to Ilam Church by using weirs on the River Manifold. A feasibility study was carried out (Derwent Hydro, 2004) which scoped two options ranging between 8-20 kW. However use of the larger head (option A) was deemed likely to be problematic for a number of reasons (new impoundment and leat, possible effects on local hydrology) but subsequently concerns were also raised that siting a turbine house below the lower weir could affect the setting of the adjacent scheduled bridge.

This was unfortunate given that the feasibility report suggested matching hydro power to a ground source heat pump that would have heated the church over the key winter months. The matter rested there until the National Trust became interested in providing power to a nearby off grid property (Wood Lodge) and asked the FPD hydro team to advise on further options. The only different option FPD were able to suggest was placing either a turbine or screw (the latter could possibly be buried) downstream of the bridge (also nearer to Wood Lodge), thus reducing the impact on its setting of the bridge and Ilam Hall park and garden. However this would also have involved re-instating/raising the upper weir and the 1910 leat (Option A in the Derwent Hydro report) which brought with it other environmental challenges.

GRID CONNECTION

The GIS analysis adds little to what has been described in the above sections, save emphasising that many of the non-mill sites tend to be more remote than old mill sites and may suffer from high connection costs as a result.

CAPACITY OPTIONS

The above analyses suggest, especially in comparison with the old mill sites identified, that non-mill sites offer much less readily developable micro hydro capacity, especially at remote and/or medium/high head sites. This unfortunately confounds the lay perception that the uplands (due to their steep topography) should offer good opportunities for hydro power. Nonetheless, where structures and impoundments already exist, predominantly associated with local water supply networks, there may be reasonable scope for more capacity. A broader assessment of overall future Peak District micro hydro capacity – based on previous studies, the sites identified in this chapter and the key case study sites – follows in Chapter 7.

Chapter 6
Key case study sites

6.1 BACKGROUND

Chapter 5 has already set out how the total data set of 162 sites was refined down – via desktop study, walk over survey, GIS constraints mapping and further site visits and measurement/data gathering (see sections 5.3-5.6) – to a final group of ten key case study sites, chosen to exemplify a characteristic range of Peak District micro hydro opportunities. These are now described in full after a brief description of the selection and data gathering process.

6.2 METHODOLOGY

Site visits to investigate head, flow, GIS-identified constraints and other issues have already been described in section 5.6. This process was applied to all of the key case study sites chosen but in addition flow estimates (using the HydrA model) were commissioned from Richard Pymm at the Devon Association for Renewable Energy (DARE), who offer this site assessment service on an affordable basis (see section 4.2.2 and Appendix C).

6.2.1 Key case study site choice

As has been explained previously, the key case sites were not chosen to be the most developable or highest power opportunities in the Peak District but instead represent a range of typical micro hydro opportunities available to (and hopefully, deliverable by) communities and other site owners. In choosing the sites the following initial primary criteria were used: viability; potential for community involvement; ability of project to add value (i.e. data not already available via previous studies or other sources); and would cover a range of hydro technologies (medium/high head, low head, turbines, screws and wheels). Secondary criteria included seeking a range of sites that achieved a good geographical spread across the Peak District and had varying ownership situations (commercial, landed estate, charitable trusts, small private landowners, farm).

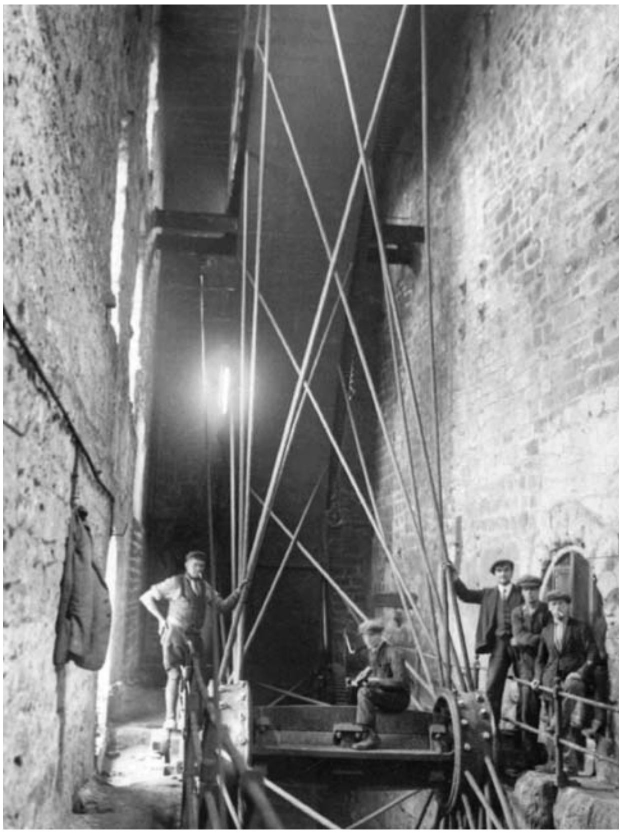


Figure 6.1 The waterwheel at Diggle Mill in 1924 (source: Oldham Standard)

6.2.2 Follow up data gathering and analysis

Following on from further site visits, other data sources were consulted including: planning history (PDNPA files), cultural heritage data (from a variety of sources, including previous planning applications), local landscape character assessments, the relevant Environment Agency (EA) Catchment Abstraction Management Strategy (CAMS) and draft River Basin Management Plan (RBMP), EA flow monitoring data (where available), reference to the EA hydro power handbook and the good practice guidelines, local planning policies (usually the

PDNP Local Plan, 2001), more detailed electricity network data, local (game) fisheries information and other local information on features or species of note. Owners, interested parties and those with neighbouring interests were consulted in the light of the emerging potential scheme options and recommendations.

Input from National Park Authority officers, particularly in relation to ecological and archaeological issues, and EA staff was sought and broad advice was received on a range of potential site-related issues (but not on a detailed site specific basis). Where relevant, this advice is reflected in some of the case studies. Finally, based on both the emerging case study analyses and the HydrA flow and power data, T4S prepared outline overviews of turbine choices and costs and estimates of grid connection costs (cabling only). This analysis has been woven into the case studies and the background material can be found in Appendix D.

6.3 CASE STUDIES: ANALYSIS AND COMMENTARY

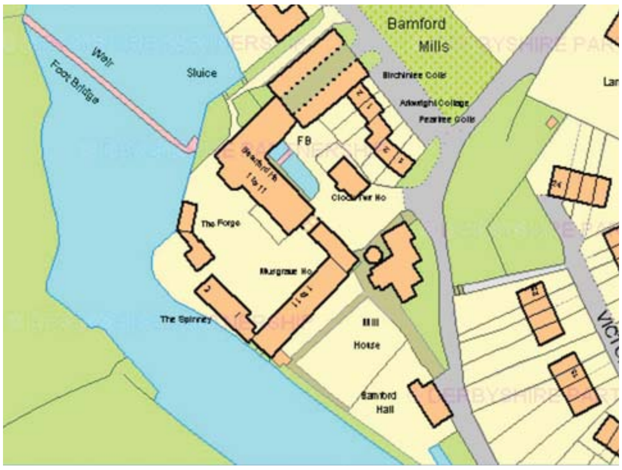
Each of the case studies is presented in a relatively standard format comprising:

- site overview: including location, site history, previous studies (where available) and site ownership/interest
- physical characteristics: current site status including state of hydro-related infrastructure; flow data and power estimates (derived from the DARE report – see Appendix C)
- potential constraints: including landscape and amenity/visual impact issues; cultural, environmental/ecological and grid connection issues
- scheme options: potential site designs outlined with alternate options where constraints may intervene
- recommendations: suggested next steps to explore further feasibility and/or support mechanisms for taking the site forward

6.3.1 Major residential mill conversion

Bamford Mill, Hope Valley, Derbyshire

Grid reference: OS Explorer OL1 SK 204 834



SITE OVERVIEW

Bamford Mill is situated on the River Derwent about 2.5 km below the Ladybower dam wall. A former cotton mill dating from 1820, it produced its own electricity from two Gilkes turbines until the loss in flow (by the reservoir impoundment in the Upper Derwent catchment) forced reliance on a steam engine. The mill closed in 1965 and was converted to residential use in the late 1990s with 26 apartments and a small number of adjacent houses.

A recent hydro capacity study for the East Midlands (commissioned by the Regional Assembly) suggested substantial power may be available at Bamford Mill (upwards of 83 kW with a 6.7m head: LUC/IT Power, 2001). The ETSU study (1989) rejected the site on the grounds that it was operational but this seems likely to be erroneous. However it may be that the Gilkes turbines and leat/tail goyt infrastructure were still intact at that time. The site is now owned freehold by Bamford Mill Residents Ltd. Some residents have expressed a strong interest in re-instating hydro power and have already made initial enquiries with potential installers. The site was originally identified from the county register of the Mills Archive Trust.

PHYSICAL CHARACTERISTICS

The residential conversion partly removed the connection between the former wheel and turbine pits and the tail goyt. However the weir is still intact and in good condition and the long tail goyt is also in existence. Any reconnection between the two would involve finding a new piped route through the development or along the bankside although this latter area has mostly become gardens for the ground floor riverside apartments.

Mean annual flows have been predicted using the HydrA model but, given the presence of an Environment Agency monitoring station just upstream at Yorkshire Bridge (below Ladybower), actual data is preferable for the potential power calculation. The utilisable head was measured on site by FPD, both between the weir top and the tail goyt water level immediately below the mill (5.5m) and at the weir itself (2m on the east bank; 3m on the west). The discrepancy between the previous EMRA study head (6.7m) may either be error by either party or that the larger estimate relates to the maximum head (weir top to final, lower point of discharge from the tail goyt back into the river).

Two potential power options were examined (see the DARE report, p.7, Appendix C). The first would use the larger 5.5m head but at a lower design flow (0.65 m^3/s: leaving a residual flow of Q_{70} because of a lengthy and sensitive depleted reach) resulting in a power output of 21.4 kW. As a second option, an in-weir solution was calculated using a mean head of

2.5m and a higher design flow (1.81 m^3/s) resulting in a power output of 27.1 kW. The earlier power estimate of 83 kW appears to be based on a flow close to the mean annual flow (2.10 m^3/s) with 6.71m head. It is difficult to envisage how such an estimate can currently be realised.

POTENTIAL CONSTRAINTS
The site is situated at the northern edge of the Derwent Valley character area and, although the site itself lies within the built up, residential area of Bamford, it is adjacent to the Riverside meadows landscape character type (LCT) where the priority is to restore the diversity of the river corridor landscape. The site also lies within the Bamford village Conservation Area, controlled by Local Plan policy LC5. Applications for development in a Conservation Area should clearly demonstrate how existing character and appearance of the area will be preserved and, where possible, enhanced. A right of way (footpath) runs between the weir and the overflow channel on the east bank of the river, then crosses the river via stepping stones and a footbridge. This route must be maintained, although minor diversions may be approved.

Bamford Mill itself, though not scheduled, is clearly of strong historic interest and its area (including the weir and the tail goyt) is registered on the county Sites and Monuments Record (now Historic Environment Record). Development of hydro power may alter the setting, if not the fabric, of the mill and its curtilage and this impact will need to be assessed appropriately.

As noted in the DARE report, the river has a 'Very High' environmental weighting (see Derbyshire Derwent CAMS, 2006) which primarily indicates sensitivity to further (consumptive) abstraction. This should not be an issue for hydro development but it does denote a likely high sensitivity of the local ecology to flow variations. The river is known to contain brown trout, pike, grayling and fishing rights on the west bank are with the Derbyshire Fly Fishing Club. The stretch from Yorkshire Bridge to Hathersage Bridge (which includes Bamford Mill) is also designated for protection of salmonid fishery under the EU Freshwater Fish Directive and is currently compliant with 'guideline pass' status, based on water quality criteria (see EA Humber River Basin Management Plan consultation draft, Annex D, p.38). Dippers, wagtails and kingfishers have all been observed locally. Rare and protected species are also adjacent to the site; assessment of impacts on such species would likely be mandatory prior to any development taking place. The Environment Agency have already indicated informally that a proposal for an in-weir solution (such as an Archimedes screw) with a fish pass would be contemplated favourably. Electrical connection should not be problematic. A low voltage (LV) network has been identified as passing through site (based on data from PDNPA). There is a pole mounted transformer just to the north of the site on an 11 kV line and this supply continues to a substation in the village less than 1km away from the Mill (data from CE-YEDL plans). Given the density of housing at the site and nearby it is assumed that the area is supplied by three-phase electricity. Based on the above and assuming 10m of cabling is required, grid connection could cost as little as £4,000 (assuming reinforcement is not required).

SCHEME OPTIONS
Although an option does exist to pipe water from the weir to the beginning of the lower portal of the tail goyt (which itself forms a suitable physical location to install a screw or turbine) to maximise the head, this presents the problems of:
a) finding an acceptable route for a pipe (most likely buried) and
b) creating a significant length of depleted reach downstream of the weir.

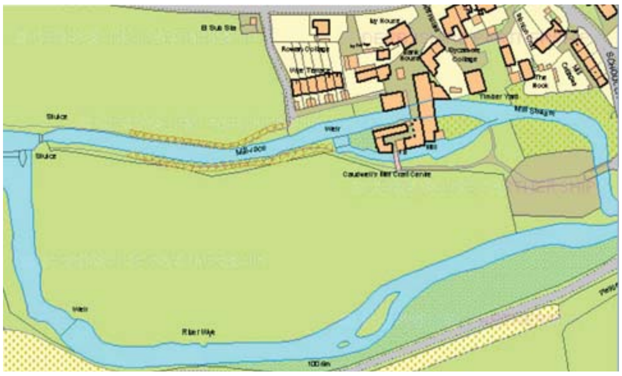
The DARE HydrA flow studies also demonstrate that this option, with a reduced design flow to minimise impacts on the depleted reach, also yields less power (21 kW) and energy capture. This strongly suggests, and this is supported by initial feedback from the Environment Agency, that an in-weir (Archimedes screw) solution is preferable as long as it is accompanied by a suitable fish pass.

RECOMMENDATIONS
- **Further feasibility work should focus on scoping design options (including costs) for an in-weir solution**
- **Site stakeholders, principally Bamford Mill Residents Ltd, need to consider a business model for progressing a scheme and whether participation may need to be widened to include the local community and/or through a share offer**

6.3.2 Working heritage mill with upgrade potential

Caudwell's Mill, Rowsley, Derbyshire
Grid reference: OS Explorer OL24 SK 255 657

SITE OVERVIEW
This mill is situated on the River Wye very close to its confluence with the Derwent. The present corn mill (built by John Caudwell), dates from 1874. Originally powered by water wheels, by the end of the 19th century, these had been replaced by turbines. These are still extant at the site: the 'Little Giant' rated at 56hp (42 kW) which still generates electricity, though only producing c.15 kW; and a Francis turbine rated at 80hp (60 kW) which powers the milling machinery. The mill ceased commercial production of flour in 1978 and now operates as a tourist attraction.



PHYSICAL CHARACTERISTICS
As this is still a working mill (albeit for demonstration purposes only) the necessary infrastructure for power generation is largely in place and in relatively good condition (for example the head and flow could be enhanced by de-silting the mill races). At present only the Little Giant turbine is used to produce electricity but the Francis turbine could also be linked to a generator by a clutch to produce electricity when not being used to power the mill machinery. The option of installing a third turbine for electricity is regarded as requiring extensive additional civil engineering works.

Mean annual flow has been predicted by HydrA at 4.9 m^3/s, although some reservations are expressed regarding modifications to the catchment, both in terms of water abstractions for drinking water and possible underground flows caused by lead mine soughs (principally Hillcarr Sough that takes water from the Bradford and Lathkill catchments to the east and returns it to the Derwent below Stanton Lees). However the figure appears commensurate with gauging station data upstream on the Wye (at Ashford, 3.24 m^3/s) and downstream on the Derwent at Matlock Bath (12.99 m^3/s; summing predicted flow at Caudwells, 4.9 m^3/s and Derwent at Chatsworth, 6.43 m^3/s gives 11.33 m^3/s).

The depleted reach is very long at approximately 500m long and this could seriously affect the design flow which the EA will allow to be removed for power generation. However the extant flow regime will be licensed by the EA though they may wish to vary the level of abstraction in the future in line with targets under the Water Framework Directive. The HydrA/DARE study suggests a design flow of 2.5 m^3/s based on leaving a residual flow of Q_{70} because of the depleted reach issue. It is not known what the currently licensed abstraction at the site is. The indicative design flow suggested by DARE gives a potential power output of 40.5 kW and an annual energy capture of 178 MWh per year.

POTENTIAL CONSTRAINTS
Caudwell's Mill lies in the Riverside meadows landscape character type (LCT) within the Derwent Valley character area (PDNP Landscape Strategy, 2009). The priority for this LCT is to restore the diversity of the river corridor landscape and manage the landscape to provide flood water storage. The strong history of using water as an energy source and the opportunity to develop new forms of hydro electricity schemes is noted as an issue for change and a planning opportunity. Sensitive re-development of hydro power at this site is unlikely to have landscape scale impacts.

The GIS constraints mapping exercise reveals some potentially significant natural constraints in the form of rare and protected species close by the site. These would have to be surveyed by appropriately qualified specialists and advice sought on whether mitigation was possible but bearing in mind that an extant, licensed hydro system is already operating. Cultural constraints also exist in the form of the Mill being listed (grade II* including the existing turbines) and it being within the Rowsley Conservation Area (which also includes the wider water management system: weir, mill races and the course of the river from the weir to just below Wye Bridge).

Grade II* listing means that the mill is nationally important and any changes to the structure would need consent from English Heritage. New development within the Conservation Area is controlled by PDNP Local Plan policy LC5 and any scheme should preserve, and where possible enhance, the character and appearance of the Area. Given that most of the necessary infrastructure is already in existence (and is a positive feature within the Area), the addition of a further turbine and any related infrastructure should not affect the integrity of the Conservation Area. The GIS analysis also notes a SMR entry in the near vicinity ('Rowsley earthwork'); this may need assessment if any works might impinge directly on it or its setting.

Since the potential power output predicted by HydrA is below the rated capacity of the existing turbines, another constraint relates to the potential renovation of both turbines which are listed and if there are any physical constraints preventing the adaption of the Francis turbine to electrical generation. This is a matter for the owners, the Caudwell's Mill Trust Ltd (in reality the trustees), to consider in conjunction with the listing authority.

The stretch of the Wye that Caudwell's Mill takes water from is designated by the Environment Agency (see Annex D, draft River Basin Management Plan for the Humber River Basin District, 2009) as a salmonid fishery whose compliance status is good ('guideline pass/imperative pass'). The EA is now charged, under the Water Framework Directive, to maintain and enhance river quality and fish passage. These mandatory objectives may conflict with either the continued or enhanced use of diverted flow for hydro power at the Mill. A view on the specific short- to medium-term objectives of the EA on this stretch of the Wye should be sought. In addition, fishing rights on the leat are owned by the Haddon Estate and they would also need to agree any changes in the flow regime.

This site is within 100m of 11kV and LV connections at Rowsley and 6km from a 33kV substation at Darley Bridge (CNE). The GIS data shows cable passing through site but this may be single phase. As there are industrial properties nearby it is assumed that the local electricity supply is three phase. Based on the above (assuming the site is 100m from a three phase supply), one can assume a connection cost of roughly £10,000. With c.40 kW (or more) power, the issue of voltage variation on the local network may have to be assessed by the relevant distribution network operator (Central Networks East/E.ON). Some electrical switchgear already exists to allow the Mill's lighting and power circuits to be fed by the Little Giant turbine; this would need alteration if grid export was to occur.

SCHEME OPTIONS

The main options to be considered are either:

- improvements to the current hydro plant (turbine renovation and adaptation to increase electricity production) and infrastructure (dredging of mill races to improve flow and head) and/or
- the installation of a third, modern machine, should a design solution be available that takes into account some very significant natural and cultural constraints.

Both options have their difficulties including the issue of whether antique turbines should be subjected to high capacity factor usage and whether there is the appetite to take forward a planning proposal for complex and expensive new works. Both options also need to be considered in the light of the current, and any future, abstraction rates that the Environment Agency is happy to countenance.

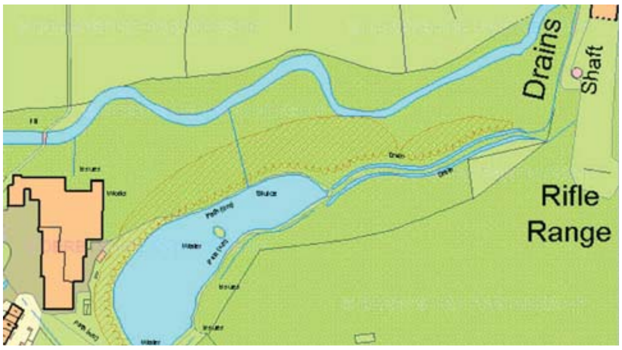
RECOMMENDATIONS

- **Before scoping any potential options, it would be wise to liaise with the Environment Agency and seek their views on the current, and likely future, abstraction regimes for the Mill**
- **More accurate flow data should be obtained for the site and consideration given to undertaking a full feasibility study including either renovation of existing plant and infrastructure and/or design and installation costs for new plant.**

6.3.3 Planned conversion to residential units

Diggle Mill, near Diggle, Oldham

Grid reference: OS Explorer OL1: SE 017 080



SCHEME OVERVIEW

Diggle Mill is situated adjacent to Diggle Brook at approximately 240 metres above sea level. A former woollen mill dating from the mid-19th century, it once housed the largest waterwheel on the British mainland (the Laxey Wheel on the Isle of Man being larger) with a diameter of 64 and a half feet (see Figure 6.1) and a power rating of 130 horsepower (c.97 kW). The mill building (with modern additions) was last used for sheet metal processing and currently lies semi-derelict. Planning permission was granted in 2005 for conversion to residential use but the re-development has not yet begun. The site was identified from the county database of the Mills Archive Trust.

PHYSICAL CHARACTERISTICS

Much of the previous water power infrastructure remains intact (weir, leat and millpond – albeit moribund) but key elements such as the elevated penstock to the wheel (pipe on an aqueduct), the wheel itself and the wheelhouse are either missing or irreparable. A leat (now with very little flow) draws water from a weir some distance upstream from the mill which flows into a sizeable millpond (see location map in HydrA desktop study, p.9, Appendix C).

Mean annual flow within the catchment has been calculated at 0.12 cubic metres per second (m^3/s) but reservations are expressed that catchment modifications may render the prediction unreliable. In this case, flow should be measured on site to get more accurate data. The head was estimated at c.22m based on the size of the former wheel and comparison with elevations found within the re-development plans submitted. It is possible that this may be an underestimate of potential head between the mill pond and the return point to the Brook.

Based on the concern over the predicted flow, a relatively conservative design flow (leaving a residual flow of Q_{70} in Diggle Brook) of 0.088 m^3/s has been assumed. This gives a potential power output of 11.6 kW and an annual energy capture of 58 MWh per year. The former power output of the wheel at 97 kW suggests that a much larger flow was once available. This may indicate that 11.6 kW is also a somewhat conservative estimate of current potential power (i.e. flow in Diggle Brook may be greater than 0.12 m^3/s) but the fact that water is also abstracted at Diggle Reservoir (above the site) will have reduced the flow. Full power on the wheel may also only have been realisable through enhanced flow from the stored water in the millpond. Setting up a temporary gauging station would resolve this issue.

POTENTIAL CONSTRAINTS

In landscape terms the site falls within the Dark Peak Western Fringe character area and the Valley pastures with industry landscape character type. Infrastructure and works associated with re-instating hydro power is unlikely to give rise to significant landscape impacts, especially if any above ground structures were kept close to the curtilage of the existing buildings. The GIS mapping analysis revealed relatively few natural constraints though the source catchment clearly lies within the Dark Peak SSSI/South Pennine Moors SAC and SPA.

One constraint on re-development of hydro power is probably cultural, given the archaeological value of the remaining mill and associated water power system. Re-use and/or alteration of any parts of the system would trigger a need for further archaeological assessment/recording before planning consent could be gained. However, the site is not a scheduled monument and is not nationally important. The remains, however, are of local or regional importance which – if affected – would require appropriate recording to be made (Grimsditch et al., 2008).

Electrical connection (presumably three phase) already exists at the mill, therefore grid connection could cost as little as £4,000. However the local distribution network operator (DNO), United Utilities, would need to be consulted if a G59 connection was sought and a grid connection study may need to be commissioned.

In terms of the water environment, use of the extant leat and mill pond system would mean Diggle Brook having a depleted reach of some 300m or more which the Environment Agency may be resistant to. The Brook lies within the Upper River Tame catchment which attracts a 'Very High' environmental rating and the Tame, Goyt and Etherow CAMS (2004) states that *'there will be a presumption against consumptive abstraction when flows are not meeting the ecological river flow objective'*. However, '*non-consumptive abstractions* [including hydro] *will be considered, provided they do not compromise the current ecological status of the reaches…'*. Diggle Brook also attracts designation for its salmon and trout fisheries and, based on water quality indices, its compliance status is relatively good. This suggests there may also be sensitivity to maintaining stretches of Diggle Brook for fish presence and passage. To address these concerns may require increases in the residual flow. A fish pass at the weir is unlikely to be needed as a large natural barrier (waterfall) to upstream fish passage lies just above the weir.

SCHEME OPTIONS

The most obvious option would be to re-instate flow into the leat and millpond and then drop a buried pipe from the millpond to a discreetly located turbine house between the mill building and the Brook. This would maximise the head but mean that design flow may have to be reduced to ensure the residual (hands off) flow of the Brook is maintained. As noted above, the restoration of the former water system may have archaeological sensitivities. Failing this, a second option could involve an in-weir solution with greater flow but a very reduced head. This latter option has not been investigated in any detail. However, the current weir is some distance from the mill building and both access for civil works and electrical connection could be problematic.

The site has recently changed hands and the new owner is keen to press ahead with the planned re-development. One of the conditions attached to the planning permission stipulates that details of any potential scheme to realise renewable energy be submitted to the National Park Authority. The original proposals did not envisage hydro power being developed as part of the development but this does not preclude any such proposal from coming forward in the future, either by the developer/landowner or future residents of the mill.

RECOMMENDATIONS

- **More accurate flow data should be obtained for the site and consideration given to undertaking a full feasibility study including design and installation costs**
- **National and regional funding regimes for small scale renewable energy generation should be investigated to explore options to offset initial capital expenditure**
- **At the very least, the final design of the re-development scheme should prioritise the safeguarding of infrastructure that can be re-utilised in any future hydro scheme, especially the leat and millpond and associated control sluices etc**

6.3.4 Reinstating hydro in a historic estate landscape

Edensor Mill, Chatsworth, Derbyshire

Grid reference: OS Explorer OL24 SK 259 689

SITE OVERVIEW

Edensor Mill (also known variously as Paine's Mill or Calton Mill) was built in the mid-18th century when the original mill situated upstream on the River Derwent was demolished as part of landscaping improvements. The mill, which worked until the 1950s, was damaged by gales in 1962 though the shell of the building, together with remains of the waterwheel, still stands as a ruin within Chatsworth Park. It is fed by a leat that flows SW from the weir (underground from 'Sluice' to 'Issues' on the plan above), then due south in open channel to the wheelpit, then again underground (ESE) back to the river. A second weir (presumably associated with the original mill) stands some 600 metres upstream and was also assessed by FPD. This upper weir is 1.64 metres high.

The lower weir and mill was assessed as part of the 1989 ETSU report (site no. 028014) where, based on an installed (design) flow of 4.59 m^3/s, they calculated an installed capacity of 88 kW and an energy yield of 357 MWh per year. This was based on a head of 2.8m which presumably represents the maximum head from weir top to either the base of the wheelpit or the point of discharge back into the Derwent below the mill. The head at the weir itself is only 2.1m.

Both weirs were also assessed for potential hydro power as part of a regional study (*Viewpoints on Sustainable Energy in the East Midlands*, IT Power/LUC, 2001, see their Appendix 5.4, Table 5.4D) with the upper weir stated to have a head of 3.0m and the lower (Edensor Mill) weir at 2.2m. It is unclear how these estimates were made. Power outputs were gauged at 49 kW and 35 kW, respectively. Based on an economic model of a 6% discount rate, 5p/kWh and a 20 year life, neither site was seen as being economically viable.

PHYSICAL CHARACTERISTICS

The lower weir is in good condition and there is still some flow in the leat and tailrace though renovation work would be required. The shell of the mill building is still standing together with the wheelpit (at rear) containing remains of the 4.2m diameter by 1.5m wide breastshot waterwheel. The lack of fall on the River Derwent dictates that there is a long depleted reach (c.250m) between the weir to the point where flow is returned to the river at the end of the tailrace. The upper weir was also judged to be in good condition.

The HydrA model was run for this site giving an overall predicted flow of 6.88 m^3/s; however the catchment is heavily modified by both water abstraction and possible underground flows connected with past lead mining, so the predicted value should be treated with caution. Happily, the Environment Agency maintains a flow gauging station on the Derwent situated 1km downstream of the mill where mean annual flow is recorded as 6.43m^3/s. This is less than that predicted by HydrA and confirms concerns that a portion of the flow from the catchment is either abstracted or travels underground. Since the gauging station is only one kilometre from the mill it can be assumed to be accurate for the site.

In determining what portion of the flow may be available for hydro power generation, much will be depend upon how the site is developed. The mill building is a ruin and it appears unlikely that monies will be readily available to renovate the building and associated infrastructure, nor is there likely to be a pressing use for the building. These problems with renovation of the building, coupled with the long depleted reach, points to an in-weir solution using the existing mill weir. In this case – providing sufficient water is left available for a fish pass – there is no reason why all of the remaining flow could not be used for hydro power. Therefore assuming Q_{95} is left in the river for a fish pass ,the flow available for hydro power based on the data from the EA gauging station is (Q_{mean} – Q_{95}) (6.43-1.488) = 4.9m^3/s.

The height of the weir is 2.1m which gives a maximum electrical power output of 61.7 kW and an annual energy capture of about 270 MWh/year. This is lower than the ETSU figure which was probably based on using the additional head through the mill infrastructure and not just the weir. If the same methodology is applied to the upper weir, this yields a slightly smaller output of 48.2 kW (204 MWh/year) on a 1.65m head.

POTENTIAL CONSTRAINTS

The site is within the Riverside meadows landscape character type (LCT) of the Derwent Valley character area (PDNPA, 2009) where the prior use of water power is noted and its re-instatement encouraged in the Landscape Strategy guidelines.

The site (both mill and weir) is also immediately adjacent to the Estatelands LCT where the overall priority is to protect the historic parkland character. Any development at this site, which is very open to medium- and long-distance views within Chatsworth Park, must not detract from this character.

The GIS mapping analysis suggests some significant natural constraints, with rare and protected species at or nearby the site, including red data book aquatic flora (intermediate water-starwort). Their presence and the impact of any hydro development (if proposed) should be surveyed and assessed by an appropriately qualified ecologist. The river is designated both as having a 'Very High' environmental weighting (Derbyshire Derwent CAMS, 2006) and for salmonid fishery (compliance status 'Guideline pass/Imperative pass': Annex D, draft River Basin Management Plan, Humber River Basin District, EA 2009). Non-consumptive water abstraction for hydro should be unproblematic but the EA would likely stipulate the need for a fish pass to accompany any hydro scheme.

The mill site falls between the Edensor and Calton Mills Conservation Areas but the mill building itself is listed. This is a further factor favouring an in-weir solution for hydro development at the site, although re-instating the wheelpit for use (wheel or possibly Archimedes screw) and making good such other parts of the building that would be needed for related infrastructure would more than likely help conserve the building. Chatsworth Park is also grade 1 listed on English Heritage's Register of Parks and Gardens. This means the site is of international importance and EH would need to be consulted at an early stage.

Electrical connection to either an in-weir screw or turbine or to equipment at the mill would be difficult as the nearest link to the grid is at the Bridge House, Calton Lees, some 400-500 metres away (assumed to be three phase). Based on this a connection cost of some £40,000 could be assumed. Cable would have to buried so as not to impinge on the character of the estate parkland (and cable burial may also bring with it other issues). The upper weir presents similar problems: the nearest connection (at Edensor) being some 750m distant. Generating 45-60 kW of power in a relatively remote rural area may also need some form of network reinforcement and Central Networks East (E.ON) would need to be consulted over this issue.

SCHEME OPTIONS

Assuming that the option for the re-use of the wheelpit/renovation of the mill is disregarded then there are two options for an in-weir scheme. The first would be to build a structure in the bank to house a turbine just downstream of the weir with a take-off and fish screen built on the top of the weir (similar to the scheme recently constructed on the Haddon Estate at Alport Mill). The second would be to install an Archimedes screw in the bank at the side of the weir in which case there would be no need for a fish screen. Both options would probably require the construction of a fish pass. The same options apply to the smaller, upper weir where screening for a screw or turbine house would possibly be enhanced by the presence of a plantation on the eastern bank.

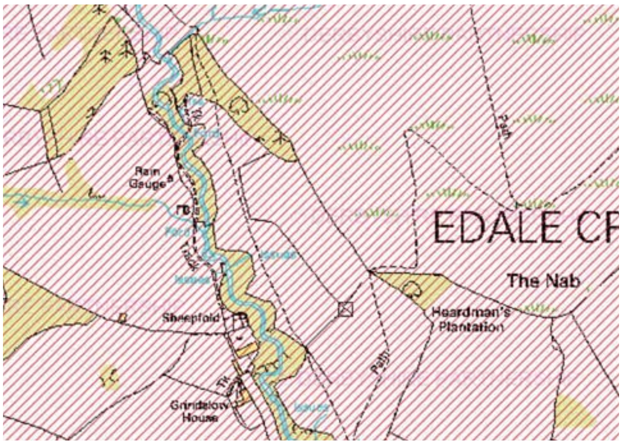
RECOMMENDATIONS

- **Unless there are other factors favouring a need to renovate/restore Edensor Mill, the likely preferred option would be to undertake a feasibility study for an in-weir solution at the lower, larger weir**
- **Given the sensitivity of the Chatsworth parkland landscape to new development, early consultation with English Heritage and the PDNPA planning team is strongly advised**

6.3.5 Non-mill site, high head on natural watercourse

Grinds Brook, Edale, Derbyshire

Grid reference: OS Explorer OL1 SK 121 866



SITE OVERVIEW

This is one of the very few non-mill sites examined by this study and has been brought forward as an example of a potential 'high' head site. Another site in the Vale of Edale (the upper part of Hardern Clough adjacent to Greenlands – see section 5.7.2) had been identified by a landowner interested in exploring high head options but flow appeared to be insufficient, even for a pico/DIY scheme. Through ongoing liaison with a local community energy group, another Edale landowner with an interest in developing hydro power was brought to the project's attention.

The site lies on the Grinds Brook, a fast flowing upland stream draining Edale Moor via a steep valley, Grindsbrook Clough. Although the land ownership extends right up the Clough and onto the Moor, the section of the Brook chosen for study was from just below the junction with Golden Clough to a point adjacent to Grindslow House, a stretch of some 500 metres or so.

PHYSICAL CHARACTERISTICS

From Golden Clough to Grindslow House, the stream drops about 30 metres in height, mostly in a fairly incised and heavily wooded clough with poor access, even for minor civil engineering works. Along most of the western bank, there is a rough farm track which then peters out after reaching the moorland wall (edge of the in-bye land). The track also crosses the Grinds Brook to the eastern bank at a ford. All the clough in which the stream flows is owned by Grindslow House; to the east of the clough, Grindsbrook Meadows (part of the Pennine Way route) is in the ownership of the National Park Authority.

The likely scheme envisaged would involve a take off point just inside the moorland wall with a long leat contouring southwards through grazing pastures before being dropped (in a penstock) to a turbine house, possibly in outbuildings behind Grindslow House. The HydrA model predicted a mean flow of $0.12m^3/s$. In gauging potential power output, a residual flow of Q_{70} was used in deference to the long (over 500m) depleted reach. This gave a potential power output of nearly 15 kW.

POTENTIAL CONSTRAINTS

In landscape terms the site is in the Upper valley pastures sub-type (LCT) of the Dark Peak LCA (PDNP Landscape Strategy, 2009) – priorities for this LCT include protecting the historic settlement and enclosure pattern whilst enhancing habitats within a sustainable farming system. Issues for change include the scope for the development of hydro schemes with appropriate siting, scale and design. A sensitively developed scheme at Grinds Brook need not impact adversely on the local landscape as topography and tree cover could help screen development.

The GIS constraints mapping analysis reveal potentially significant issues relating to the proximity to areas designated nationally and internationally for nature conservation and the proximity of the 'Natural Zone', although the site itself does not appear to impact on red data book, rare or protected species (but two 'key ecological areas' are adjacent). However, it is likely that some form of ecological survey would be required before any development took place, given that the clough comprises predominantly natural, undisturbed habitat.

As the site had no former mill infrastructure, cultural heritage issues should not affect development potential. However the site falls within the Edale Conservation Area which is unusually widely drawn. It should be possible to develop a sensitive scheme that can meet the standards expected by developments in a Conservation Area. Grindslow House is listed and if changes to its structure were proposed, this may need consent. It is unclear if the outbuildings are also listed; it is more likely that these would be used for any hydro infrastructure developed.

The river environment itself is likely to be the largest constraint to development however. The River Noe has a 'Very High' environmental weighting given to it in the Derbyshire Derwent CAMS (EA, 2006) which indicates sensitivity to abstraction (usually consumptive). The Noe to its source is also designated for salmonid fishery with a compliance status of 'Guideline fail/Imperative pass'. The Environment Agency have already made clear the high value of the Grinds Brook as a superb natural small stream habitat for juvenile brown trout and indicated their concern at any scheme that might put this status at risk. The proposal for a long depleted reach on the Grinds Brook would therefore be likely to be strongly opposed (or the design flow reduced severely, making any scheme uneconomic).

Finally, electrical connection could also be problematic. The site appears to be within 100m of LV (based on data from PDNPA) but a long way from higher voltage lines. The nearest connection point is likely to be single phase only and therefore reinforcement of the line from Edale may be required. Based on the above one can assume a connection cost of over £10,000.

SCHEME OPTIONS

The potential scheme envisaged, utilising a long leat and/or penstock to realise some 30m of head, appears to have serious environmental constraints associated with it, not to mention likely difficulties with access and topography in terms of realising the necessary civil engineering works. However a second option of utilising a previous water collection scheme for the local village may provide a more feasible alternative.

Historically Edale was supplied with water from a collection tank buried high on the flank of Grindslow Knoll then piped under the pastures and down to the village. The system is no longer in use as Edale now is on mains supply but the main elements of it could readily be renovated. Initial investigation has revealed a likely flow of some 300 litres per minute (equivalent to 0.005 m^3/s) and a head of 180 metres, giving a potential power output of around 5 kW which would be suitable for Grindslow House. It is suggested that this becomes a preferred option for further investigations.

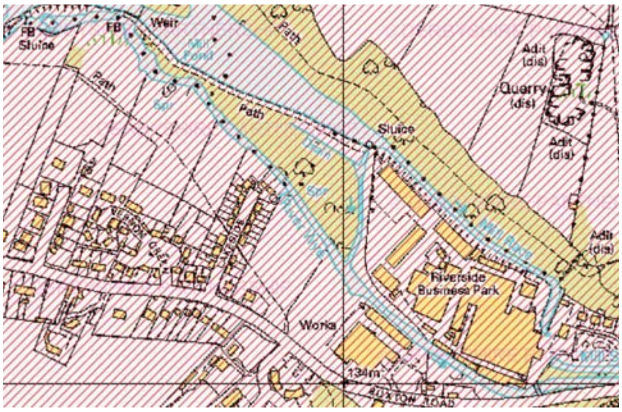
RECOMMENDATIONS

- **A scheme based on the Grinds Brook is unlikely to find favour in regulatory terms, either by the PDNPA or the Environment Agency, due to the high sensitivity of the river and surrounding environment**
- **If sources of sustainable power are being sought for Grindslow House, it is suggested that the former water collection system may prove a more amenable option for a pico DIY/bespoke solution and a full feasibility study should be considered**

6.3.6 Reinstatement of historic site undergoing conversion to major mixed use development

Lumford Mill weir, near Bakewell, Derbyshire

Grid reference: OS Explorer OL24 SK206 695



SITE OVERVIEW

Lumford Mill was originally an Arkwright designed mill on the River Wye, just NW of Bakewell, fed by a very long leat from an upper mill pond contiguous with and below Ashford Lake. The leat originally fed two waterwheels (see Figure 6.2) but these were replaced in the twentieth century by a Gilkes turbine (now off site but owned by a local firm of hydro developers) generating 150 horsepower at 213 rpm (c.112 kW). This provided power for a lead acid battery factory. The site was later owned by Fernehoughs, more recently becoming the Riverside Business Park, owned and managed by Litton Properties Ltd. However the weirs are now in a separate, adjacent ownership. The site was identified through the county register of mills held by the Mills Archive Trust.

The site's potential for hydro power has been assessed previously as part of the University of Salford study for ETSU (1989) but named, in relation to its then ownership, as 'W. Fernehough Ltd, Bakewell' (site ref. no. 028022). The study suggested that an available head of 3.0m with a design flow of 2.19 m^3/s would develop 44 kW of power with an annual energy capture of 255 MWh. Despite the likely accuracy of this data, it was decided to re-investigate the site, both to provide a cross-check on the validity/accuracy of the HydrA model being used in this study and also re-assess the findings in the current (and now much stricter) regulatory environment, twenty years on. It should also be noted that the Riverside Business Park is currently the subject of a major planning application (albeit at outline stage) to convert the site to mixed residential and light industrial uses. The outcome of this study may therefore help inform any options for future renewable energy supply linked to the site.

PHYSICAL CHARACTERISTICS

Lumford Mill and its water management system is probably the most complex site investigated in this report, with over a kilometre of mill-related leats, cross channels and several weirs. In essence a mill pond linked to Ashford Lake feeds, via a 'self-levelling' weir (and a lower bypass weir), a very long and substantial mill race heading SE before turning due south to a wheel/turbine pit on the western edge of the mill buildings, before returning (via an underground goyt) to the river. However, the mill pond was drained in the 1980s to avoid the need to comply with new reservoir regulations and the pond and the leat returned to nature (although much scrub clearance work has been done recently to protect the leat structure). The whole water management system is now a scheduled monument (SAM) and the structure cannot be readily altered without gaining English Heritage's consent. However, the turbine house and the tilting sluice ('self-levelling' weir) at the western end of the millpond are excluded from the scheduling. If the leat was re-instated, the total depleted reach would be c.1km.

The HydrA model predicted a mean annual flow of 3.24 m^3/s at the site which corresponds remarkably well with EA gauging station data some 2km above the site. Assuming the original leat system to be useable (but using a Q_{70} value for residual flow given the long depleted reach) a power output of some 55 kW could be realisable on the full 6.5m head. The discrepancy between this and the rating (112 kW) of the former turbine is probably explained by the (temporarily) larger flows that could have been generated by storage of water in the millpond.

However it is unlikely that such a long depleted reach would now be countenanced by the Environment Agency (or if allowed, design flow may be reduced to a 50:50 leat:river split), so an in-weir solution was instead assessed using a design flow of 2.49 m^3/s, allowing a residual flow of Q_{95} for the weir and any fish pass that may need to be installed. The weir head is 3.0m and power output was calculated at 41 kW with, depending on the technology of turbine/screw, an average mean annual energy capture of 208 MWh.

POTENTIAL CONSTRAINTS
The site is situated in the Riverside meadows character type of the Derwent Valley character area, although it is immediately adjacent to the border with the White Peak LCA. The lower (south eastern) part of the site sits within the built up area of Bakewell. The priority for the Riverside meadows is to restore the river corridor landscape and provide flood water storage. The opportunity for new hydro electric schemes is noted, recognising the strong history of using water power in the Derwent Valley. Several of the landscape character types, including the riverside meadows, are considered suitable for hydro.

The GIS constraints analysis shows a variety of ecological sensitivities nearby, including local red data book species and nationally rare and protected species. If any of these are related to riverine/aquatic habitats, then ecological surveys and appropriate mitigation may be required before any development can be contemplated. There are also a number of key ecological areas (a local PDNPA designation) nearby.

As mentioned above, cultural heritage constraints also exist with the scheduling of the water management system and the listed status of the Mill itself. The scheduling is of the post-1820 hydraulic system and includes the millpond, millrace, dam wall, wheel pits and goyts, tail culverts and race and river bridge (SAM entry no.12010). Unsurprisingly, the site is also on the county SMR (now HER) as both a point and area entry. No changes can be made to the fabric or setting of a scheduled monument without the express consent of English Heritage.

In terms of the river environment, the Wye (see the Derbyshire Derwent CAMS, EA 2006) carries an EA 'High' environmental weighting score (based on its sensitivity to abstraction, usually consumptive) and the stretch (from the A6 road bridge by Shacklow Woods to Rowsley) is also designated as a salmonid fishery with current compliance status of 'Guideline pass/Imperative pass'. It is unlikely that the EA would wish these standards to be threatened and are therefore likely to be concerned about any potential scheme with a long depleted reach.

Assuming an in-weir scheme to be pursued, this does give rise to issues in respect of electrical connection. If the scheme is to be developed in connection with supplying the Riverside Business Park (a possible scenario), this would involve running a connection (probably underground) some 500m to a three phase connection in the industrial site. This could cost as much as £40,000. There may also be archaeological issues with cable burial given the scheduled monument status of much of the leat.

SCHEME OPTIONS
A scheme utilising the former infrastructure and full head of the site seems unlikely to be a feasible option, though a variant of the original scheme has been suggested using a penstock comprising a buried pipe in the old leat feeding the original turbine reinstated on site. However, realising an economic design flow would be very difficult if, as seems likely, the EA wish to minimise impacts on the depleted reach. In this case, the best option would be to look at an in-weir (or just adjacent) turbine or Archimedes screw, though even this scenario is not without its problems: access for civil works, the sensitivity of the scheduled monument and the length of electrical connection.

RECOMMENDATIONS
- **Initial liaison with English Heritage is suggested to explore how any potential hydro scheme may affect the scheduled monument**
- **A full feasibility study should be considered focusing on an in-weir solution, although other options should not be ruled out, at least initially**
- **Land ownership issues may need to be clarified, especially if a scheme were to be linked with the re-development of the Riverside Business Park**

6.3.7 Potential urban community scheme, low flows

Marsden town weir, Marsden, W. Yorks.
Grid reference: OS Explorer OL21 SE 048 116

SITE OVERVIEW
This weir is located in the centre of Marsden adjacent to Argyle Street, on the final stretch of Butterley Brook before it joins the River Colne. The site lies about 1 km outside the National Park boundary but most of the catchment – draining Wessenden Moor – lies within. The previous use of the weir is unknown but a possible route for a mill race is discernible on the western bank on the site (now a residential block: Wessen

Court). There is a bypass sluice on the eastern side of the weir. A grassy area below the weir (and leading to the waterside) is directly accessible from the street and is a popular amenity area. The site was identified by the FPD hydro team in the course of the project.

PHYSICAL CHARACTERISTICS

Wessenden Brook is canalised as it passes through Marsden centre and, in the apparent absence of the former mill race, all flow passes over the weir. The weir, whose ownership is not known, is in reasonable condition and is substantial, possibly based on a natural outcrop of bedrock. Within 50m of the weir, the Brook flows into a revetted section of the Colne, flowing west to east.

Mean flow cannot easily be calculated using the HydrA model because of the presence of a number of reservoirs in the catchment, whose abstraction rates are not known. However Yorkshire Water (YW) have provided flow data including the rate of compensation water release which stands at 8.068 megalitres per day (ML/day) which is equivalent to 0.093 m^3/s. Given the canalised nature of the Brook at the weir site, it is suggested that virtually all of the flow could be utilised for hydro power, especially if an in-weir solution were favoured. However, because the flow is comparatively low, power output is still very small at c. 1.4 kW (see DARE report, Appendix C, p.11). The YW data did however reveal that annual mean daily flows are likely to be higher (at c.0.32 m^3/s) – caused by stronger winter flows. This could increase power output to c.5 kW but this would mean any generating plant may be idle in drier periods (a lower capacity factor) unless two small units were installed, one for summer flows and a further machine to utilise the additional winter flow.

POTENTIAL CONSTRAINTS

As the site is urban, neither the local landscape character analyses nor the natural constraints/designation GIS data will be relevant in assessing any planning constraints.

The site may form a point entry on the county Sites and Monuments Record (SMR) and there may be archaeological constraints to consider. The virtual inclusion of the site as part of the local 'street scene' may be seen as a barrier to development as could any encroachment of hydro infrastructure onto the adjacent amenity area. Conversely, micro hydro development can also be seen as adding interest for the local community and visitors.

The site is within the Marsden Conservation Area where development must conform with policy BE5 of Kirklees Council's UDP which states that new development must respect the architectural qualities of surrounding buildings and contribute to the preservation or enhancement of the Area. Sensitive development of the site should be able to meet these aims.

Electrical connection should be unproblematic as there are low voltage (LV) connection points in the vicinity.

Given that the state of the Brook at this point is far from natural, the potential for damage to the water environment is not a serious concern. The adjacent stretches of the Colne (both upstream and downstream from the confluence) are both designated for salmonid fishery and compliance status is 'Guideline fail/Imperative pass' (see Annex D of the River Basin Management Plan for the Humber River Basin District). This may indicate that the Environment Agency might wish to promote further passage of fish up Wessenden Brook; if this were the case, they may seek to include a fish pass as part of the development. Given that developing the site is likely to be on the margins of economic feasibility, the addition of a fish pass would reduce viability significantly.

SCHEME OPTIONS

If an in-weir solution was sought then an Archimedes screw is the obvious choice and they are available down to 1 kW capacity (see Figure 2.8). There is ready access for civil works although the physical space at the edge of the Brook is somewhat restricted, especially on the eastern side. There is more area available for development adjacent to the curtilage of Wessen Court. However developing this site, especially if a fish pass were required by the Environment Agency, would probably not constitute a 'simple low cost scheme' (see conclusion of the DARE HydrA report) and therefore is questionable in overall terms unless funding options and subsidies for renewably generated electricity were to increase very markedly.

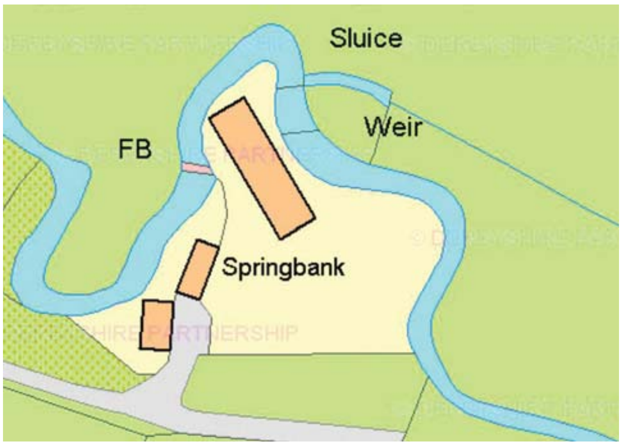
RECOMMENDATIONS

- **Further analysis of annual flow release data (if made available by Yorkshire Water) may reveal opportunities for a (dual unit) scheme that could maximise output from higher winter flows**
- **Ownership of the site should be clarified; further publicity regarding hydro options at the weir may reveal a local community group who may wish to promote a scheme**
- **Further weir sites should be investigated locally, especially downstream on the Colne where the flow is higher**

6.3.8 Pico DIY/bespoke private scheme, low flows

Millthorpe weir, near Millthorpe, NE Derbyshire

Grid reference: OS Explorer OL24: SK 313 764



SCHEME OVERVIEW

This site is situated partly within the curtilage of a private property adjacent to the weir on Millthorpe Brook. Originally the weir, via a long leat edged with oak boards, fed a waterwheel at a corn mill (demolished in 1959) in the nearby village of Millthorpe. Some outlying mill buildings remain but have been converted to other uses. The site was identified after the owner approached FPD seeking advice on options for a DIY pico hydro scheme. The site lies just outside the National Park.

PHYSICAL CHARACTERISTICS

Millthorpe Brook is partly canalised as it passes through the property above the weir and is also culverted below the weir. The weir is in good condition and is maintained by the current owner of the property. The weir ownership is not entirely clear and may be joint with the owner of the land to the north. A leat ran east from a sluice/intake just above the weir for over 0.5 km; for some distance this leat is still legible in the landscape but is now silted up and does not flow. Water does initially pass into the leat but this is soon returned to Millthorpe Brook via a bypass channel. The Brook is very close to the property and has been known to overtop its (artificial) banks. The owner has built solid walls adjacent to the property to reduce the flood risk.

Mean flow within the catchment has been estimated as 0.11 m^3/s but this may be an under-estimate as an underground aquifer is known to augment the flow in the Brook from a point above the site (see DARE report, p.12, Appendix C). The true flow regime should be assessed by setting up a temporary monitoring gauge. The head has been measured at 1.65m. A design flow of 0.092 m^3/s has been assumed (leaving the residual flow at Q_{95}) because an in-weir solution (with no depleted reach) seems the most likely option. Flow might also be increased by minimising the bypass flow through the side sluice/leat/return channel.

POTENTIAL CONSTRAINTS

In terms of landscape character the site is covered by both the recent PDNPA LCA and Landscape Strategy (classified as Derbyshire Peak Fringe character area and part of the character type of Slopes & valleys with woodland) and Derbyshire County Council's (DCC) earlier study (Derbyshire Peak Fringe Character Area 50 and Landscape Type: Wooded Slopes and Valleys). As the site itself is within NE Derbyshire, the PDNPA Landscape Strategy does not apply although its landscape guidelines suggest '*the Slopes and Valleys with Woodland… are suitable for the development of water power*'.

The site itself is adjacent to floodplain pastures with streamside trees. Any built development associated with realising hydro power would be well screened by either topography or the immediately adjacent property. The site may also overlap an adjacent Conservation Area (centred on Cordwell) designated by NE Derbyshire DC under policy BE11 in the 2005 Local Plan. This policy states '*Proposals for development within or adjacent to a Conservation Area should preserve or enhance the character of the Conservation Area*'. A very small scale development, such as envisaged here, should not be threatened by such a policy, especially as it would be linked visually with the relatively modern property adjacent.

In terms of ecology, there seem to be very few constraints although a survey would probably be required to establish a baseline. The owner has reported brown trout both above and below the weir and the presence of herons and kingfishers. The adjacent presence (see GIS analysis, Appendix B, site 015) of rare and protected species – if aquatic or freshwater-related – may be of concern.

The weir, sluice and leat system does not appear to be on the county Sites and Monuments Record (HER) but may be worthy of inclusion, particularly the two fine stone gateposts (stoups) that retained the sluice boards. These would be unaffected by any likely development.

Electrical connection is expected to be unproblematic. The supply is single phase and brought in via low voltage overhead line on poles from the north and, given the size of the output, most power would be consumed on site and connection should be straightforward (G83). For this reason, no grid capacity study was made for this site.

Given the canalised/culverted state of the Brook within the property and the minor size of the stream, any scheme should not pose any serious threat to the water environment, especially given that there will be little or no depleted reach (see below). However, the EA will be keen to maintain a minimum depth of flow over the weir and ensure that the weir pool is not significantly affected. The normal licensing routines will still need to be followed despite the minor nature of the scheme.

SCHEME OPTIONS

If an in-weir solution is sought then an Archimedes screw is a possible option and they are available for 1 kW capacity (see Figure 2.8). However access for civil works is restricted and there is also a question of whether there is sufficient space within the curtilage for a screw. The owner is more interested in taking a simpler (less expensive) DIY approach to an installation and for this reason a turbine (possibly a crossflow) is favoured. An intake would be made in the bank above the weir on the south side of the Brook and a short penstock, by-passing the weir, could be buried in the bank to a small, sunken turbine house (though care would need to be taken regarding flood risk). The length of bypass would be several metres at most.

RECOMMENDATIONS

- **More accurate flow data should be obtained for the site by setting up a temporary monitoring station; obtaining more information on the acquifer input higher in the catchment to determine seasonality of flow would also be useful**
- **Initial contact should be made with the Environment Agency to determine the sensitivity of the stream and the likely design flow constraints**
- **Initial contact should be made with NEDDC planners to scope potential policy constraints, especially in relation to ecology, archaeology and impact on the adjacent Conservation Area**

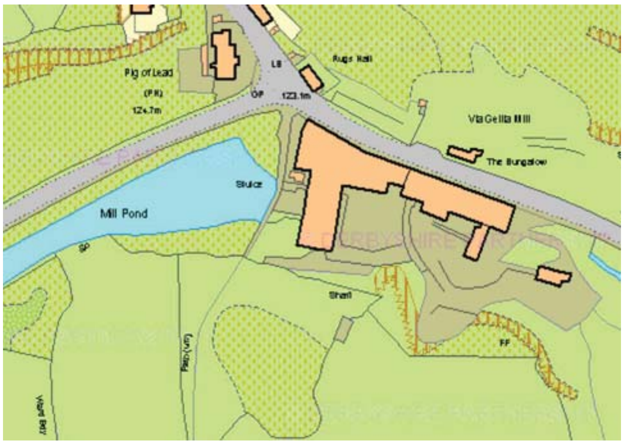
6.3.9 Reinstatement of existing industrial site with low flows

Bonsall (Via Gellia) Mill(s), Bonsall, Derbyshire

Grid reference: OS Explorer OL24 SK 284 574

SITE OVERVIEW

This former mill, now a mixed use/light industrial business park, stands adjacent to the confluence of the Bonsall Brook and the unnamed stream that descends the Griffe Grange Valley/Via Gellia. The current mill was built as a cotton mill in 1867 and is famous as the place where Viyella (a corruption of Via Gellia), a mixed wool/cotton yarn, was first produced. A mill pond, fed by both the Via Gellia stream and a diverted part of the Bonsall Brook flow, fed a waterwheel; the tail race and overflow sluice channels run below the mill complex in



underground goyts then emerge as the main stream below the Mill entrance. It appears that all the Via Gellia stream passes through the millpond and mill races; part of the Bonsall Brook may circumvent the mill pond and enter the stream at a lower point. The site was originally identified from the county register of the Mills Archive Trust. A nearby community interest group (Bonsall Energy Group) have also expressed interest in re-instating hydro power in the locality.

PHYSICAL CHARACTERISTICS

The millpond is in reasonable condition though its volume is now reduced by silting. The sluices are maintained by the site owner. The northerly sluice fed a wheel; additional flow, said to be from the Bonsall Brook, joins the intake to the wheelpit. The southerly sluice (both are joined by a footbridge/footpath that traverse the millpond dam wall) is an overflow channel.

Mean annual flow was predicted as 0.49 m^3/s using the HydrA model (see Appendix C, p.8) but several caveats were made in respect of its results, primarily related to concerns over losses to underground flows. This has been confirmed in relation to the northern edge of the catchment near Winster Bank where a mine drainage tunnel (Winster Sough) diverts flow north eastwards to the River Derwent (*pers.comm.* Rieuwerts, 2009). It is also unclear (see above) whether all of the Bonsall Brook flow enters the millpond. As is stated in the DARE report, confidence in the flow prediction for this site is low.

As virtually all the flow in the catchment is impounded at this point and directed through the mill complex, it is suggested that most (if not all) of the predicted flow could be utilised for hydro power. This would give a maximum potential power output of 11.8 kW. If a residual flow (Q_{95}) was required in the overflow channel, power would reduce to c.8.5 kW.

POTENTIAL CONSTRAINTS

The site's landscape character is classified by both the Derbyshire LCA (DCC, 2003) and the PDNPA Landscape

Strategy (2009) as Limestone Dales character type within the White Peak character area, although the site formally lies some 200m from the National Park boundary. The DCC description notes the extensive urbanisation of the Bonsall Brook and Via Gellia dales whilst the PDNPA landscape guidelines suggest there are localised opportunities in the limestone dales for the development of water power. Landscape sensitivity is unlikely to be a constraint to installing hydro power infrastructure at the site.

The site lies outside both the Bonsall and Cromford Conservation Areas and the building is not listed. The GIS constraints mapping exercise notes that Bonsall Mill is on the county Sites and Monuments Record (SMR, now HER); it is not clear whether this is Via Gellia Mill or the dry colour mill just to the north on the Clatterway (the two mills are shown separately on the 1971 OS 6 inch map SK 25 NE). The site also lays within the buffer zone of the Derwent Valley World Heritage Site. Thus any development within the mill curtilage will probably require some form of archaeological assessment, especially if located within the original water management system. There is also a limekiln recorded very close to the site but it seems unlikely that this or its setting would be impacted adversely.

The site is adjacent to the Via Gellia woodlands which are designated as SSSI and SPA but any scheme is unlikely to have impacts on their biological interest or the integrity of the habitat. There are however rare and protected species in the vicinity; if any of these are dependent on the water environment, then some appropriate form of assessment will be required. However, the stretch of brook is not listed in either the local CAMS or the Humber River Basin Management Plan as having environmental or fishery designations. Initial comments by the Environment Agency suggest that they view the site as highly modified. However further assessment would be required before a concluded view could be given.

Electrical connection should not be problematic: the Mills already have three phase connection for some 25 business units which would consume most of the generated electricity. Even if the maximum power (c.11 kW) was realised, the connection would be unlikely to require a G59 connection. However, this should be confirmed by contacting the local DNO, Central Networks East (E.ON). Cabling costs should be minimal.

SCHEME OPTIONS

The most obvious option would be to install either a turbine (either a propeller or cross flow – see HydrA recommendations) or an Archimedes screw in or immediately adjacent to the former wheelpit. Design flow should be maximised by reducing the second sluice flow to the minimum acceptable to the Environment Agency. Given the highly modified nature of the stream in the Via Gellia, it would seem unlikely that a fish pass would be required though screening would still be needed if a turbine was to be installed. The company that owns the mill are building and civil engineers and have expressed interest in re-instating hydro power. If this were to go ahead, they would take on as much of the work as possible themselves.

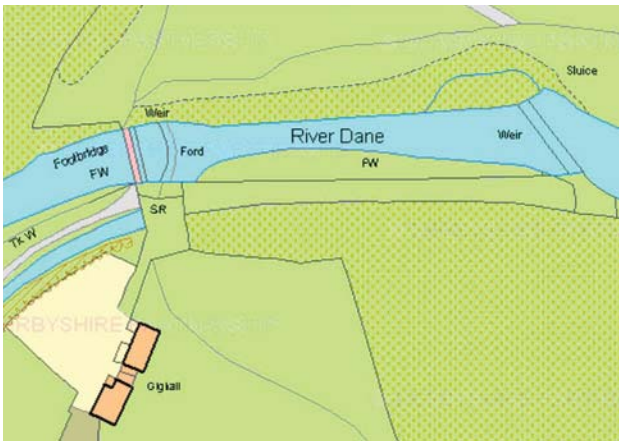
RECOMMENDATIONS

- **A better understanding of the flow regime (volume and seasonality) should be obtained before proceeding with any further feasibility studies**
- **An enhanced knowledge of the physical layout and interconnections of the Bonsall Brook, the mill sluices, and the subterranean drains with the lower river course would also be helpful in fully evaluating any proposed design**
- **The owners may wish to consult with Bonsall Energy Group to see if community interest/involvement might release various forms of capital grant aid that would otherwise be unavailable to a commercial developer**

6.3.10 Potential rural community scheme

Whitelee Mill, Danebridge, Cheshire

Grid reference: OS Explorer OL24 SJ 956 642



SITE OVERVIEW

Nearly all traces of the former Whitelee Mill have disappeared (it was on the bypass stream to the north of the eastern weir – just west of 'Sluice' on the plan above) with the exception of the upper weir on the River Dane. Downstream of this weir a second weir was built to divert flow from the Dane, via a feeder channel, into Rudyard Reservoir which provided water for the Caldon Canal. The feeder is now fed by the upper weir which was renovated recently (a fish pass was installed at the same time). Both weirs plus the land adjacent to the feeder

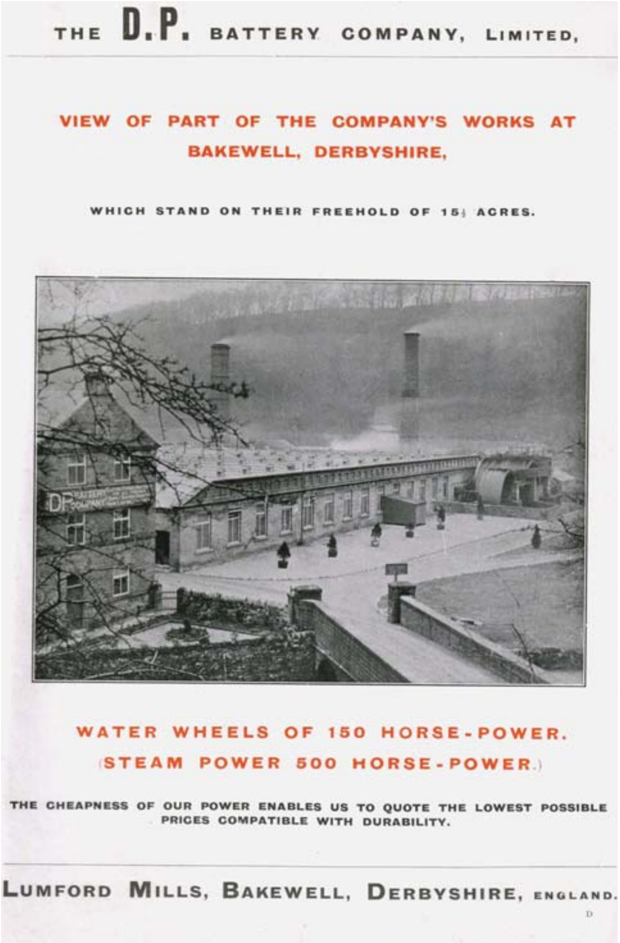


Figure 6.2 An early example of the marketing and economic advantages of hydro power at Lumford Mill (image courtesy of Paul Hudson)

appear to be in the ownership of British Waterways (BW). Adjacent riparian rights are shared between properties to the north and south (Whitelee Farm and Gig Hall, respectively). The site is close to the boundary of the National Park but lies wholly within it. The site was identified through the county register of mill sites held by the Mills Archive Trust.

PHYSICAL CHARACTERISTICS

The two weirs, measuring 2.0m and 2.45m high respectively, are situated about 200m apart with a total head measured between both weirs of 5.1m. Little remains of the leat for the mill at the upper weir but the feeder for Rudyard Reservoir and the associated take-off works and feeder still exist, albeit silted up and seldom used. The feeder channel was designed to take water off the Dane when flow exceeded c.2 m^3/s, via an overflow lip at the side of the upper weir.

The HydrA model gives a prediction of mean annual flow of 1.41 m^3/s for this site. Other catchment data (see DARE report, Appendix C) suggests this may be an underestimate but this can only be resolved by undertaking monitoring at the site itself. The long depleted reach, which would result if a single installation spanning both weirs was adopted, means that a residual flow of Q_{70} would probably be necessary to satisfy Environment Agency concerns. In this case the design flow would be ($Q_{mean} - Q_{70}$) (1.41 – 0.49) = 0.92m^3/s, yielding a power output of some 28 kW and mean energy capture of 120 MWh/year.

There are clearly two options here. Firstly, using the feeder channel as a leat/penstock running from above the top weir to a turbine or screw situated below the bottom weir. This would result in a 200m depleted stretch of river between the two weirs. Secondly, two separate 'in-weir' installations – most probably Archimedes screws – linked to a common grid connection. In both cases a fish pass would be required at the lower weir and in the first case a fish screen at the intake. The final choice would depend on capital costs and revenue though the EA are more likely to favour the in-weir option.

POTENTIAL CONSTRAINTS

The site is part of the Riverside meadows character type within the South West Peak character area (PDNP Landscape Strategy, 2009) where the priority is to protect the diversity of the river corridor landscape and encourage natural river processes to provide flood storage, amenity and biodiversity benefits. The opportunity is noted for small scale hydro-electric schemes within the strategy but in the landscape guidelines for the LCT it is not a priority but may be considered in some locations. Given the BW feeder infrastructure already in place at the site and the well screened nature of the river corridor, it is unlikely that further hydro development would impact negatively on the local landscape.

The GIS constraints analysis reveals that a small strip of Natural Zone land (woodland) is immediately adjacent to the upper section of the feeder (between the two weirs). It is unclear how this may affect the potential to develop the site; a further assessment of any scheme's impact on this area may be needed at some point. The site also falls within the River Dane 'key ecological area' (a local PDNPA designation) although rare and protected species are not recorded. This suggests that an ecological survey may be required before a full proposal could be worked up although the PDNPA may already hold more detailed ecological records for the site. In terms of cultural constraints, there is a SMR (HER) entry for the former watermill site but this should be unaffected by any scheme.

Information from the Environment Agency (the Weaver and Dane CAMS, EA 2006) suggests the site is very sensitive for fish: '*The Upper Dane supports an excellent brown trout fishery. It is valued for its spawning gravels and juvenile refuge areas and therefore supports a diversity of age groups of fish* *ranging from fry to adults*'. This stretch of the Dane is also designated for salmonid fishery under the protected area objectives in the draft River Basin Management Plan, North West River Basin District (Annex D, p.29) with a compliance status of 'Guideline fail/Imperative pass'. Given these factors, it is unlikely that the Environment Agency would allow a depleted reach of any significance (at least without significantly increasing residual flow) and would also want to ensure fish passage through any hydro related barrier.

Electrical connection (low voltage, Central Networks) is closest at Gig Hall, within 50m of the site and 11 kV within 200m but, alternatively, connection could also be sought at Whitelee Farm (LV, probably 3 phase, but on the United Utilities network), but this is c.200m away with difficult ground in between. Costs to connect to Whitelee Farm have been estimated at over £15,000. Given the relative remoteness of the grid in this rural area, an analysis of the strength of the local grid to absorb 30 kW of generation may be necessary.

SCHEME OPTIONS

In terms of civil works and making use of the existing infrastructure, a scheme utilising the full head by way of the extant feeder channel, with a return to river below the lower weir, makes a good deal of sense. However, this study has revealed a likely significant sensitivity of the river to further modification. The second option would comprise an in-weir scheme at both weirs with a residual flow of Q_{95} servicing the weirs (including fish passes). In this case, the design flow could be increased to 1.23m^3/s and the maximum electrical power output would be 32.84 kW (6 x 2.0 x 1.23 + 6 x 2.45 x 1.23) with an mean annual energy capture in the order of 135 MWh/year.

Both weirs and much of the associated infrastructure and land are owned by British Waterways. They have already indicated an in-principle readiness to examine a scheme at this site and possibly lease the site for hydro power generation by the local landowners and/or the local community. The likely mechanism for this would be via a royalty arrangement (percentage of the income from the electricity export) but no terms have been disclosed. These would clearly be crucial to the overall economic case for proceeding with development.

RECOMMENDATIONS

- **More accurate flow data should be obtained for the site and consideration given to undertaking a full feasibility study including design and installation costs**
- **Given the likely sensitivity of the river environment, principally for fish, early contact should be made with the Environment Agency**
- **Negotiations should be undertaken with British Waterways to ascertain likely leasing conditions and costs**
- **Consideration should be given to the formation of an Industrial and Provident Society (IPS) to develop the scheme for the benefit of the local community**

6.4 OVERVIEW ON KEY CASE STUDY SITES

The key case study sites have illustrated an interesting mix of sites varying greatly in the associated constraints and also likely power outputs. Although two (Marsden and Millthorpe weirs) fell squarely into the bracket of 'pico' schemes (less than 10 kW), where economic viability is often marginal, either community involvement or a willingness to do most of the civil and other works without outside contractors, could enhance their developability. The likely enhanced subsidies for sub-10 kW schemes under the Feed-In Tariff may also assist in reducing payback times. However, a similar site at Low Bradfield (output 0.8 kW) was felt to be too marginal and not worth further study (see Table 6.1) and was therefore not developed into a key case study site (see section 5.7.1). The sole 'high' head site, Grinds Brook in Edale, is unfortunately highly constrained by its own high quality natural environment but again an innovative pico scheme (c.5 kW) may be realisable as an alternative.

At the opposite end of the scale, a number of former mill sites on the main Peak District rivers of the Wye and Derwent offer good opportunities, including Bamford Mill (21-27 kW), Lumford Mill weir (50 kW), Caudwell's Mill (50 kW) and Edensor Mill weirs (43 kW and 56 kW) though the latter three sites are likely to have significant historic environment issues to address. The Bamford Mill site appears to be the least constrained and there is significant local interest in progressing a scheme. On the Dane, in the southwest Peak, excellent infrastructure at two weirs at the former Whitelee Mill may afford a good opportunity (34 kW) for a remoter rural scheme.

A number of light industrial sites on the edges of the National Park (Via Gellia Mills and Diggle Mill, although the latter has planning permission for conversion to residences) offer reasonable opportunities for on-site power (both just over 10 kW). Economic viability at these sites may be enhanced by installing smaller turbines that could take advantage of the higher Feed-in Tariffs. Via Gellia Mills is particularly promising given the artificial nature of the river environment; Diggle Mill would be a much more difficult scheme to develop but the key issue here is to protect future options by safeguarding the remaining historic infrastructure.

Finally it should be noted that all the sites (bar Low Bradfield) were recommended as being worth further study. In the final and concluding chapter, all the sites identified and described in Chapter 5 and this chapter are drawn together to estimate, with key caveats, likely future hydro capacity for the Peak District. The total potential capacity of the case study sites is also shown in Table 6.1 showing nearly 300 kW that could be realisable (285 kW within the PDNP).

Table 6.1 Summary table of case study sites subject to HydrA analysis

	SITE NAME	HEAD (m)	DESIGN FLOW (m^3/S)	INSTALLED CAPACITY (RATED POWER) (kW)	MEAN ANNUAL ENERGY CAPTURE (MWh/y)	WORTH FURTHER STUDY?
1	Bamford Mill	2.50	1.81	27.0	216	Y
#1a	Bamford Mill	5.50	0.65	21.0	168	Y
2	Via Gellia Mills, Bonsall	4.00	0.49	10.7*	45*	Y
3	Diggle Mill	22.0	0.09	11.6	58	Y
4	Low Bradfield weir†	2.00	0.07	0.8	4	N
5	Marsden town weir	2.60	0.09	1.4	12	Y
6	Millthorpe weir	1.65	0.07	0.9	3	Inconclusive
7	Whitelee/Gig Hall weirs	5.10	0.92	34.0*	117*	Y
8	Caudwell's Mill	2.70	2.50	49.8*	182*	Y
9	Grinds Brook, Edale	30.0	0.08	12.5	47	Y
10	Lumford Mill weir	3.00	2.26	50.2*	208*	Y
11	Edensor upper weir	1.64	4.90	43.0	204	Y
11a	Edensor (Mill) weir	2.10	4.90	56.0	261	Y
	Total capacity/output	-	-	**297.9**	**1357**	-
	(capacity within PDNP)			*(284.9)*	*(1297)*	

 # alternative scheme
**mean output from range of turbine options*
† not written up as a key case study site (see section 5.7.1)

Chapter 7 Conclusions and recommendations

7.1 OVERVIEW

Through a sequential process of data gathering including desk studies, consultation with parish councils, local community groups and other interested parties, the FPD micro hydro project has identified a total of 162 sites across the Peak District National Park and immediately adjoining areas (120 inside the NP boundary, 42 just outside). At 12 sites (nine within, three just outside – see Table 5.1), there is installed hydro plant (all turbines save one waterwheel at Hartington Mill) totalling 1.6 megawatts (MW) and the potential to upgrade power output exists for at least two of these sites (Chatsworth's Emperor stream and at Caudwell's Mill). Of the 150 potential (currently undeveloped) sites, two (at Flewitt's Mill in Ashford in the Water and Calver Corn Mill) should be producing power in early-mid 2010 and other schemes (e.g. Meadow Farm near Flash) are currently seeking licences from the Environment Agency.

Of the remaining 150 sites, the majority of which are old mill sites, the outlook is variable. This project and other recent studies (for example examining sites around Bollington and on the Peak fringe to the west of Sheffield: see Leigh, 2008 and IT Power, 2006, respectively) have identified 80 or so sites (mill and non-mill sites, both inside and just outside the NP – see Appendix A, Tables A1, A2 and A3) where there is worthwhile scope for further investigation. The majority of these sites (59) were subject to a GIS constraints analysis process (see Chapter 5 and Appendix B).

Ten sites (the key case study sites written up in the preceding Chapter 6) were examined in much greater detail with flow and power output estimated, design options explored and grid connection and turbine choices analysed. Less detailed study of a further ten sites (see Chapter 5) suggested that there will be scope for schemes at many more sites across the Peak District but identifying viability and possible power outputs was beyond the scope and resources of this project. Nonetheless, the issue of wider capacity for new micro hydro development in the Peak District is addressed in this chapter.

Of the remaining 70 sites (see Appendix A, Table A4), the potential for re-development is thought to be low with the main issues being low flow and/or lack of infrastructure. Many low flow streams historically had mills where power could only be generated intermittently by storing water in a millpond and, in general, such sites are unsuitable for 'run of river' electricity generation. However if the pressure for new renewable energy (RE) sources, including micro generation, increases markedly, then some of these sites may become more economically viable, especially if the balance between conservation and the need for RE shifts.

Finally, it should be noted that the list of sites identified should **not** be regarded as fully comprehensive, especially in relation to non-mill sites. Although these seem unlikely to be developed in great numbers (either due to significant environmental constraints in the uppermost parts of river catchments for medium/high head sites or issues relating to creating new weirs), the scope for such schemes was only explored in a relatively minor way. Our coverage of old mill sites has been more exhaustive yet new sites continued to come to light throughout the project (e.g. Calver Corn Mill; Panna Mill near Meltham), most of which have been belatedly included, at least in the site listings (Appendix A).

7.2 ASSESSING FUTURE MICRO HYDRO POWER CAPACITY IN THE PEAK DISTRICT

As has been stated earlier, there is currently just over 1 MW installed capacity of small/micro hydro power within the PDNP boundary and 1.6 MW if schemes that traverse the boundary (catchment within/powerhouse outside – see Table 5.1) are included. Although there are currently no local or regional planning targets for hydro power generation allocated to the PDNP area, the Draft Regional Energy Strategy for the East Midlands (referred to in the Regional Spatial Strategy for the East Midlands (RSS8), 2005) did set a target of 1.3 MW by 2010 which has been largely met. However, strong pressure to provide ever more energy from renewable sources suggests that higher targets will be necessary. A recent study of renewable energy (RE) capacity in the East Midlands (Faber Maunsell/AECOM, 2009) suggests that somewhere between 12-20 MW of hydro capacity by 2031 is feasible for the whole of the region, with the main potential being in Nottinghamshire and Derbyshire, including the National Park area.

A more detailed RE capacity study carried out for the Peak sub-region (which comprises the Derbyshire Dales, High Peak and the Peak District NP), and based largely on interim data from this project, suggested further potential hydro capacity of 2.6 MW generating up to 13.2 GWh/y of energy across the three areas of which c.1-1.2 MW was in the PDNP (NEF & LUC, 2009). Although this current project was not tasked with analysing overall future hydro capacity for the Peak District, at the conclusion of the work we are now in a better position to provide some context and indicative data to finesse the NEF/LUC study, albeit with some major caveats.

7.2.1 Data limitations

The first caveat relates to the fact that this project can only comment (with any confidence) on the potential capacity within the National Park itself, rather than the Peak sub-region. Although sites on or near the boundary of the NP were also examined, there was no corresponding analysis of sites with High Peak or the Derbyshire Dales local authority areas as a whole. Figures for these latter areas were estimated by the NEF/LUC study but the information base was at quite a low level; therefore their figures may be conservative.

Secondly, the capacity estimates are only known (either from this study or previous reports) for a proportion of the more viable sites (about 30 – see Appendix A, Table A5); it is likely that there will be viable schemes within the other 50 or so more developable sites (Appendix A, Tables A1, A2 and A3). Set against this, however, is the fact that most of the major river sites (generally the larger mills on the Wye and Derwent) have already been identified and studied (to varying degrees) and, as other sites get scoped, the 'law of diminishing returns' is likely to operate.

Thirdly, for various reasons – related to both economic, planning and environmental constraints – a number of sites seem unlikely to be developed, at least in the short term. Nonetheless, parallel changes in planning policy and an increasing need to produce renewable energy (usually addressed through fiscal incentives) may offset some of these constraints to differing degrees.

7.2.2 Overall PDNP hydro capacity

Taking these essential caveats into account, and based on this project and other studies' data, we calculate that there is a potential capacity of c.1.8 MW (1840 kW with an output of c.9.2 GWh/y) known about at the current time (end 2009), as shown in Table 7.1 and in more detail (by individual sites) in Table A5 in Appendix A. This improves on the potential capacity in the recent NEF/LUC study which was reported as between 5.1-6.0 GWh/y, equivalent to c.1.0-1.2 MW of installed capacity (the NEF/LUC assessment appears to use a relatively high capacity factor of 0.6/60%). The increase in capacity we report is predominantly due to the addition of

Table 7.1 Potential small/micro hydro sites - additional capacity within the PDNP

Site groupings	Installed capacity (kW)	Sites/locations
New water and sewerage company sites	700	Upper Derwent catchment
Upgrade existing hydro schemes	148	Chatsworth and Caudwell's Mill
FPD key case study sites	235	Excluding Caudwell's Mill and sites outside the NP
ETSU mill sites	374	Calver/Cressbrook/Litton/Baslow
ETSU high head sites	194	Bar Brook and Burbage Brook
Derwent Hydro/Segen/WRE/SY etc	97	Flewitts/Brough Bus. Pk/Stoney Middleton/Ilam/Meadow/ Raper Lodge/Ashford Bobbin Mill/Calver Corn Mill
LUC/ITP sites	92	Leadmill/Lathkilldale
Sub total potential sites	**1840**	**(c.9.2 GWh/year output)**
Existing hydro capacity	**1090**	Excluding water and sewerage company sites just outside the PDNP
TOTAL	**2930**	**(c.14.5 GWh/year output)**

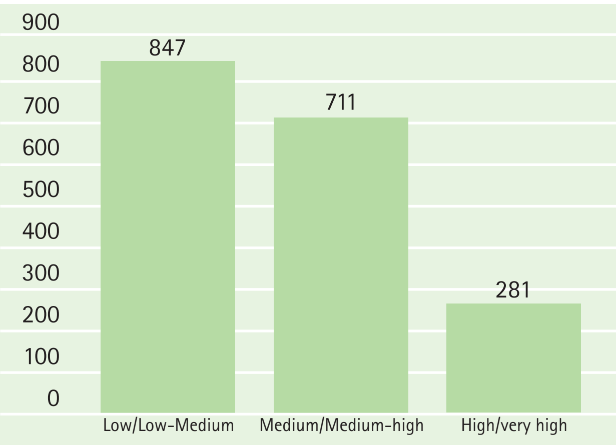
the potential for further schemes in the Upper Derwent catchment, as scoped by Severn Trent Water.

Put together with existing capacity (c.1.1 MW), this gives an overall capacity for the PDNP area of 2.9 MW (2933 kW, c.14.5 GWh/y) which – if realisable - would be a substantial contribution to local and regional hydro capacity. However, this estimate must (again) be strongly hedged with caveats.

In terms of what is usually understood as 'gross river potential' – the total theoretical energy available in all weirs and potential medium-high head sites – the 2.9 MW is probably an under-estimate, especially as our estimate of potential is based on only 30 or so sites from at least 80 of the more viable locations and a further 70 or so less viable sites. However, in relation to what might be readily deliverable in the short-medium term, the 1.8 MW capacity figure must be treated with some caution. This is because licensing/planning issues (often related to environmental constraints), grid connection difficulties and economic viability factors will intervene to varying degrees.

To address this issue, we have allocated an indicative level of constraint (running from 'low' to 'very high') against each of the potential sites listed in Table A5 (in Appendix A). Summing the capacities within broad bands of constraint levels gives a rough indication of the distribution of hydro opportunities and this is shown in Figure 7.1. In crude terms this demonstrates that the majority of potential capacity falls within the lower to middle constraint bands, which is encouraging for future uptake. To realise this potential it would obviously be best to focus most effort on the sites with highest capacity and least constraint.

Figure 7.1 Potential PDNP hydro capacity (kW) versus level of site constraint



7.3 NEXT STEPS

7.3.1 Local engagement and action

As well as identifying a comprehensive data set of potential micro hydro power sites in the Peak District, another key aim was help encourage and enable site owners and/or local community groups to progress sites towards implementation. This has been attempted in a variety of ways, including:

- compiling the advice and 'how to' elements of this report (Chapters 2, 3, 4)
- investigating the comparative viability of a large number of sites and
- producing – via the key case studies – pre-feasibility reports which reduce the need for initial consultants' advice, thus saving developer costs, particularly to interested communities

In addition, throughout the whole project, advice has been dispensed to individuals and groups in a variety of formats (telephone; e-mail; letter; face-to-face discussion; site visits) on developing particular sites or areas, and engagement has occurred with community groups (e.g. Sustainable Youlgreave, Sustainable Bakewell, Sustainable Edale, Dales Association for Integrated Renewable Energy, Sustainable Wirksworth etc) interested in developing micro hydro as part of wider renewable energy or local sustainability initiatives. Much of this engagement led on from the two initial community consultation events (see section 5.2) which were specifically aimed at raising awareness among individuals and communities in and around the Peak District.

To conclude the project, a community workshop (held jointly with Water Power Entreprises – H_2OPE, and sponsored by the National Park Authority and the LEADER-funded East Peak Innovation Project) in Low Bradfield shared the survey results and then focused on showing how an established business model (as used for the Torrs Hydro development at New Mills in High Peak) could be adopted to develop a community hydro site. The workshop was well attended by a range of site owners and community interest groups from all over the Peak District and beyond. However, its true effectiveness can only be judged by schemes progressed in the future. It is also intended to hold at least two further workshops in 2010 to roll out the project results and encourage further action.

Finally it is suggested that a further way forward to facilitate site development would be to form some kind of Peak District micro-hydro 'user group' which could be used as a forum for exchanging advice and experiences and learning from best practice, as demonstrated in the Peak District and other protected landscapes. This model has been adopted in other areas, notably Dartmoor, with some success. The group could also have an informal role in monitoring progress against the site lists produced by this project. If this recommendation is supported, Friends of the Peak District will assist in the group's inception and support it through its initial period of operation.

7.3.2 Political engagement and action

For progress to be made in delivering more micro hydro schemes in the Peak District, other forms of assistance will be required. Grant aid for micro renewable projects is variable across the Peak District and the paucity of dedicated schemes to support small scale generation in the East Midlands region (as compared to those available in Yorkshire & Humber) needs to be remedied. It is also the case that national grant schemes do not appear – as yet (though this may change with the introduction of feed-in tariffs) – to have had a major role in catalysing the growth of micro hydro and a number now seem likely to end prematurely (e.g. the Low Carbon Building Programme – see section 4.3.2) when the Feed-In Tariff starts in April 2010, for fear of 'double-funding'.

The role of the PDNP Sustainable Development Fund has been very valuable in supporting scoping studies for micro hydro (as well as providing a substantial grant towards this project) but none of the sites investigated (Ilam, Brough Business Park, Bakewell, Stoney Middleton, Caudwell's Mill) have progressed much further as yet. However at the end of 2008 the SDF also awarded a much larger grant (£25,000) towards the capital costs of a proposed 10 kW scheme at Cromford Corn Mill by the Arkwright Society. Notably the site lies just outside the National Park but is seen as having an important educational role at a key southern gateway to the NP area.

Elsewhere, for example in the Yorkshire Dales National Park, a YDNPA-commissioned hydro power feasibility study (not dissimilar from this project) has been completed (Inter Hydro Technology, 2009) and is being followed up by:

- holding a one day seminar to gauge local support for new hydro schemes
- YDNPA planning officers (working together with the Environment Agency) doing further scoping work on the most viable sites
- putting in place a programme to provide financial support for full feasibility studies at key sites with the objective of taking some sites through to design and commissioning.

The YDNPA's ultimate aim is to achieve a range of exemplar sites across the YDNP that can be shared with others, illustrating a range of turbine technologies and construction techniques demonstrating best practice.

In Wales, a similar approach has been put into practice in the Brecon Beacons National Park with the Green Valleys Project, part of which has also received SDF grants and NPA assistance. There are already 10 operating schemes, some of which have been brought to fruition by the BBNPA's Renewable Energy Asssistance Programme (REAP). In 2009, community groups identified a further 92 possible schemes with the first 23 having a combined potential capacity of 399 kW. A second phase of surveys is planned (see www.thegreenvalleys.org.uk).

The Peak District National Park Authority's Management Plan (2006-2011) already prioritises the promotion of low carbon technologies to address climate change. It recognises the necessity to promote renewable energy within the National Park context and finding ways to enable a greater level of renewable energy generation. In part, this can be achieved through planning policies and the recent PDNPA consultation document *Preferred Approaches for the Peak District National Park Core Strategy* (2009) which emphasises the PDNPA's aim to be an exemplar of best practice in low impact, low carbon and renewable technologies. To realise this, it is therefore suggested that the Peak District National Park Authority, possibly working in conjunction with adjacent planning authorities in the Peak sub-region, consider enhancing the current level of both policy and financial support so that a greater number of appropriate micro hydro schemes, particularly at a community level, are progressed more quickly.

7.4 OVERALL RECOMMENDATIONS

Based on the findings of this project and the evidence set out in this and preceding chapters (including experiences and good practice noted from other areas, including other National Parks in England and Wales) it is recommended that:

- in the short term, attention should be focused on developing the potential hydro sites identified with the highest capacity (>25 kW) and least constraint. These would include opportunities in the Upper Derwent reservoirs complex, Chatsworth Park and the large mills/weirs on the Wye, Derwent and Dane (Litton Mill, Cressbrook Mill, Lumford Mill, Caudwell's Mill; Bamford Mill, Calver Mill and Hodgkinson's Mill; Whitelee Mill)

- further workshops should be held to promote awareness of local micro hydro opportunities and to engage with site owners and local communities so schemes are progressed. The formation of a Peak District micro hydro users' group to share best practice and monitor progress should be actively considered. Such groups have proved valuable elsewhere

- the National Park Authority should consider making available further resources, both in terms of staff time and grant aid (similar to the Brecon Beacon's Renewable Energy Assistance Programme), to enable the swifter implementation of a range of exemplar micro hydro sites throughout the Peak District, particularly in support of community-led projects

- to fully realise the renewable energy potential in the Peak District and wider Peak sub-region, better grant aid for micro generation (including hydro) should be provided in the East Midlands region

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GLOSSARY OF SELECTED HYDRO TERMS

Abstraction licence	Authorisation from the Environment Agency to remove water from a watercouse
Capacity factor	The ratio of the actual energy output per year to the maximum output if the system runs at full power all day, all year
CAMS	Catchment Abstraction Management Strategy - definitive document issued by Environment Agency as statement of local water resource management
Compensation flow	See residual flow
Compensation water	The flow released from a reservoir to maintain water levels in the watercourse below the impoundment
Design flow	The portion of the river flow that is used to power the hydro electric plant. Also sometimes called the installed flow. Usually calculated by subtracting residual flow from the mean (average) flow
Efficiency	The percentage obtained by dividing the actual power or energy produced by the theoretical power or energy. It represents how efficiently the machinery converts water energy into electrical energy (hence the term 'water-to-wire' efficiency)
Feed-in tariff (FIT)	New payment system for any electricity fed into the grid by micro generation. Will begin in April 2010
Flow duration curve	A graph showing the percentage of time usually a year that the flow at a particular point equals or exceeds a certain value
Gauging station	A site, usually a weir, where the flow of a watercourse is measured
Gigawatt/Gigawatt hour	GW/GWh. See megawatt. 1 gigawatt (hour) = 1000 MW(h)
Hands off flow	See residual flow
Head - gross	The difference btween the upstream and downstream water levels at a hydro power site
Head - net	The head available to generate power after subtracting friction losses in the intake and outlet from the gross head
Impoundment licence	The authorisation from the Environmental Agency to obstruct or impede the flow of a river by a weir/dam
kW	Kilowatt; unit of power, which indicates capacity to generate energy. One kW equals 1000 watts
kWh	Kilowatt hour; unit of electrical energy which is equal to the electicity produced by 1kW working for 1 hour
Leat or goyt	An open channel/canal conveying water from the abstraction point to the powerhouse (see also penstock). Also known as a head race or millrace
Levy Exemption Certificate (LEC)	A LEC proves how the electricity was generated and who generated it. They are are awarded by Ofgem for every 1 MWh of power generated from a renewable source
MW	Megawatt; one megawatt equals 1000000 watts or 1000 kW
MWh	Megawatt hour; unit of electical energy which is equal to the electicity produced by 1MW working for 1 hour. 1000 MWh = 1 Gigawatt hour, GWh
Penstock	A pipe that conveys water under pressure from an intake point to a turbine (see also sluice gate)
Powerhouse	A building housing the generating plant
Renewable Energy Guarantees of Origin (REGOs)	Awarded by Ofgem for every 1 MWh of power generated from a renewable resource, but currently have no market value
Renewable Obligation Certificates (ROCs)	Awarded by Ofgem for every 1 MWh of power generated from a renewable resource. These are tradeable but their value varies each year with market forces
Residual flow	The flow which must be left in the watercourse at the point of abstraction for environmental and ecological reasons; sometimes called compensation flow or 'hands off' flow
Sluice gate	A vertical sliding gate which can be operated either automatically or manually to control the flow of water into a leat. Sometimes called a penstock
Screen	A metal filter that sieves debris prior to water entering hydro plant and prevent ingress of fish. Also called a trash rack
Tailrace	The channel taking the flow back into the watercourse. Also sometimes known as a mill race or tail goyt
Weir	A weir is a low head overflow type dam which is designed to raise the level of a river or stream and thus create head

Appendix A1: Potential old mill micro hydro power sites within the Peak District National Park

County	District or Town	Mill Name	NGR	Ref No	River System	Tributary	Source	Category*	Notes
Cheshire	Danebridge	Whitelee Mill	SJ 960 650	M93	Dane		Mills Trust	a	No mill, upper weir and adjacent feeder owned by British Waterways – see case study
Cheshire	Rainow	Ginclough Mill	SJ 958 764	M1	Dean	Hayes Clough	Bollington Civic Society	a	Ceased production 1890, property renovated, infrastructure still in place
Cheshire	Wildboarclough	Crag Works	SJ 983 687	M99	Dane	Clough Brook	FPD	b	Works demolished, no weirs or infrastructure but mill pond extant
Derbyshire	Ashford in the Water	Ashford Bobbin Mill	SK 182 697	M3	Derwent	Wye	Mills Trust	a	Leats and wheels intact, EA gauging station adjacent to mill
Derbyshire	Ashford in the Water	Comb Mill	SK 190 694	M45	Derwent	Wye	Mills Trust	a	Mill demolished but weirs and some infrastructure in place
Derbyshire	Ashford in the Water	Flewitt's Mill	SK 198 695	M4	Derwent	Wye	Mills Trust	a	Existing turbine being refurbished for re-use (autumn 2009); also called Ashford Old Mill
Derbyshire	Bakewell	Lumford Mill	SK 213 691	M5	Derwent	Wye	Mills Trust	a	Industrial site, original twin wheels generated 90 kW – see case study text
Derbyshire	Bakewell	Rutland Mill	SK 220 685	M6	Derwent	Wye	Mills Trust	a	Now offices, turbine removed but c.1.5-2m head with inlet and tailrace in place
Derbyshire	Bakewell	Victoria Mill	SK 216 688	M7	Derwent	Wye	Mills Trust	a	Converted into flats but leat etc in place; estimates suggest 10-20 kW potential
Derbyshire	Bamford	Bamford Mill	SK 205 833	M8	Derwent		Mills Trust	a	Converted into flats, weir in place, leat/tailrace incomplete – see case study text
Derbyshire	Baslow	Heathy Lea Saw Mill	SK 272 721	M38	Derwent	Heathy Lea Brook	Gifford	b	Derelict mill but weir extant, c.4m head
Derbyshire	Baslow	Hodgkinson's Mill	SK 250 724	M9	Derwent		Gifford	a	Good infrastructure and weir, 1930s turbine still in situ, also called Old Mill, Baslow
Derbyshire	Blackwell	Blackwell Mill, Wye Dale	SK 113 727	M10	Derwent	Wye	Gifford	a	Weir (1.2m) but no other infrastructure apparent
Derbyshire	Bradwell	Butts Mill	SK 173 812	M11	Derwent	Bradwell Brook	Mills Trust	b	Derelict building astride Bradwell Brook, low flows
Derbyshire	Bradwell	Stretfield Mill	SK 178 820	M13	Derwent	Bradwell Brook	Mills Trust	b	Mill pond still there but all other infrastructure lost
Derbyshire	Brough	Brough (Vincent Works) Mill	SK 184 825		Derwent	Bradwell Brook	Mills Trust	a	Now Brough Business Centre; feasibility study by Derwent Hydro estimated 11 kW

Continued...

Appendix A1: Potential old mill micro hydro power sites within the Peak District National Park *(continued)*

County	District or Town	Mill Name	NGR	Ref No	River System	Tributary	Source	Category*	Notes
Derbyshire	Brough	Brough Mill	SK 184 826	M12	Derwent	Noe	Gifford	a	Now Wm Eyre & Sons Country Store but weir and wheel still in place
Derbyshire	Calver	Calver Corn Mill	SK245 743		Derwent	Calver Mill Sough	Gifford	a	Now residential property but infrastructure still in place, low flows
Derbyshire	Calver	Calver Mill	SK 247 745	M14	Derwent		Mills Trust	a	Long depleted reach approx.1km, in weir scheme on renovated weir may be better
Derbyshire	Chatsworth	Edensor Mill	SK 260 688	M15	Derwent		Mills Trust	a	Derelict building but weir and leat still in place – see case study text
Derbyshire	Cressbrook	Cressbrook Mill	SK 173 727	M16	Derwent	Wye	Mills Trust	a	Converted into flats, infrastructure and turbines still in place
Derbyshire	Crowden	Paper Mill	SK 079 990	M18	Etherow	Fair Vage Gutter	Mills Trust	a	Now residential property; low flow but c.8-10m head
Derbyshire	Edale	Edale Mill	SK 133 853	M40	Derwent	Noe	Mills Trust	a	Converted into flats, no infrastructure remaining bar silted up mill pond
Derbyshire	Grindleford	Padley Mill	SK 251 789	M19	Derwent	Padley Brook	Mills Trust	a	Now residential property; no wheel but wheelpit plus most infrastructure intact
Derbyshire	Hathersage	Lead Mill	SK 233 807	M21	Derwent		Mills Trust	a	Now residential property, goyt/ tailrace in place though weir in very poor condition
Derbyshire	Kettleshulme	Lumbhole Mill	SJ 988 804	M22	Goyt	Todd Brook	Mills Trust	a	Derelict medium sized mill but potential for conversion and hydro
Derbyshire	Longnor	Old Saw Mill	SK 085 646	M23	Dove	Manifold	Mills Trust	a	Being renovated; wheel restored plus generator installed
Derbyshire	Millers Dale	Litton Mill	SK 161 729	M24	Derwent	Wye	Mills Trust	a	Inlet works and tailrace in place
Derbyshire	Millers Dale	Millers Dale Meal Mill	SK 142 733	M41	Derwent	Wye	Mills Trust	b	Now sewage pumping station but wheel and leat still there
Derbyshire	Rowarth	Little Mill	SK 011 890	M25	Goyt		Mills Trust	a	Converted to inn (1992) with demonstration 10m breastshot wheel, weir and leat in place
Derbyshire	Rowsley	Caudwell's Mill	SK 255 657	M26	Derwent	Wye	Mills Trust	a	Two historic turbines, options to increase capacity – see case study text
Derbyshire	Stoney Middleton	Stoney Middleton Mill	SK 230 755	M29	Derwent	Stoke Brook	Gifford	a	Subject of Derwent Hydro feasibility study, estimated 4 kW

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Appendix A1: Potential old mill micro hydro power sites within the Peak District National Park *(continued)*

County	District or Town	Mill Name	NGR	Ref No	River System	Tributary	Source	Category*	Notes
Derbyshire	Upper Hulme	Dain's Mill	SK 012 613	M27	Churnet		Mills Trust	a	Renovated wheel in place
Derbyshire	Wetton	Wetton Mill	SK 096 561	M28	Dove	Manifold	Mills Trust	b	Old mill building on site but infrastructure, including weir, lost
Lancashire	Diggle	Diggle Mill	SE 017 080	M30	Tame	Diggle Brook	Mills Trust	a	Derelict mill building, leat and mill pond in place - see case study text
W Yorkshire	Meltham	Panna Mill	SE 088 106		Holme	Meltham Dyke	PitL	a	Weirs intact, remaining mill buildings now residences, power estimate <5 kW
S Yorkshire	Low Bradfield	Low Bradfield Mill	SK 264 918	M31	Don	Loxley	FPD	a	No mill but 2m weir and some infrastructure, low flows
Staffordshire	Gradbach	Gradbach Mill	SJ 993 660	M33	Dane		Mills Trust	b	Now youth hostel, extensive infrastructure but in poor condition, low flow
Staffordshire	Heaton	Bearda Mill	SJ 963 641	M34	Dane	unnamed tributary	Mills Trust	a	Now residential property with non-working breastshot wheel still in place.
Staffordshire	Milldale	Lode Mill	SK 146 551	M36	Dove		Mills Trust	a	Mill subject of planning application to convert without hydro (autumn 2009)
Staffordshire	Onecote	Onecote Mill	SK 047 554	M37	Dove	Hamps	Mills Trust	a	Mill demolished but weir still there

Sources
FPD = identified in course of project
Mills Trust = Mills Archive Trust: www.millarchive.com
Gifford = Gifford A. (1999) *Derbyshire Watermills*, The Midland Wind & Water Mills Group
PitL = Power from the Landscape (see www.powerfromthelandscape.co.uk)
* see section 5.4.1, p.34 for an explanation of categories a, b

Appendix A2: Potential micro hydro sites outside the Peak District National Park

County	District or Town	Mill Name	NGR	Ref No	River System	Tributary	Category*	Source	Notes
Cheshire	Bollington	Ingersley Road	SJ 936 779		Dean	Harrop Brook	a	BCR	BCR estimate 27 kW on 22m head with c.800m depleted reach
Cheshire	Bollington	Ingersley Vale	SJ 936 779		Dean		b	BCR	BCR estimate 3.4 kW on c.2m head with 50m depleted reach
Cheshire	Bollington	Lowerhouse Mill	SJ 921 777		Dean		a	BCR	BCR estimate 9 kW on 3m head with in-weir solution
Cheshire	Bollington	Recreation Ground	SJ 932 779		Dean	Harrop Brook	b	BCR	BCR estimate 3.1 kW on 1.3m head with in-weir solution
Cheshire	Bollington	Waulkmill Farm	SJ 943 770	01	Dean		b	BCR	BCR estimate 27 kW on 16m head but c.1km depleted reach
Derbyshire	Bonsall	Bonsall Mill/Via Gellia Mills	SK 284 574	012	Derwent	Bonsall Brook	b	FPD	Via Gellia Mills now industrial units but infrastructure still in place – see case study
Derbyshire	Chapel-en-le-Frith	Bridgeholm Green	SK 051 818		Goyt			Mills Trust	Not visited
Derbyshire	Chapel-en-le-Frith	Combs Reservoir	SK 034 798		Goyt			FPD	British Waterways reservoir with popular amenity use (sailing)
Derbyshire	Cromford	Cromford Corn Mill	SK 292 570	013	Derwent	Bonsall Brook	a	Mills Trust	11 kW scheme being developed by Arkwright Society
Derbyshire	Hayfield	Hayfield weir	SK 037 870	02	Goyt	Kinder	a	FPD	Old weir 3-3.5m high, possible old mill at side, very poor access
Derbyshire	Millthorpe	Millthorpe weir	SK 312 764	015	Rother	Millthorpe Brook	a	FPD	2m weir for old Millthorpe Mill – see case study text
Lancashire	Hollingworth	Hollingworth weir	SK 013 963	03	Etherow		a	Mills Trust	Stone weir in good condition 3m head
S Yorks	Sheffield	More Hall Reservoir	SK 287 956	05	Don	Ewden Beck	a	SCR/IT Power	IT Power study estimated 41 kW capacity with mean flow 0.29 m³/s on 20m head
S Yorks	Sheffield	Old Wheel Farm 1	SK 297 899		Don	Loxley		SCR/IT Power	No output stated in IT Power study but mean flow estimated as 0.56 m³/s
S Yorks	Sheffield	Old Wheel Farm 2	SK 287 903		Don	Loxley		SCR/IT Power	ditto
S Yorks	Sheffield	Olive Mill	SK 306 894		Don	Loxley		SCR/IT Power	ditto
S Yorks	Sheffield	Rivelin Dams	SK 276 869	06	Don	Rivelin	a	SCR/IT Power	IT Power estimated 19 kW with mean flow 0.11 m³/s on 25m head
S Yorks	Sheffield	Rivelin Mill	SK 291 872	011	Don	Rivelin	a	SCR/IT Power	Just outside NP boundary, very low head (<1.2m)
S Yorks	Sheffield	Rivelin Valley East	SK 323 887	07	Don	Rivelin	a	SCR/IT Power	IT Power study estimated 10 kW with mean flow 1.1 m³/s on 1.3m head
S Yorks	Sheffield	Rivelin Water Treatment Works	SK 287 868	08	Don	Rivelin	a	SCR/IT Power	IT Power study estimated 19 kW on mean flow 0.55 m³/s on 5m head
S Yorks	Sheffield	Loxley River, Wisewood Forge	SK 318 897	04	Don	Loxley	a	SCR/IT Power	IT Power study estimated 11 kW on mean flow 0.56 m³/s on 2.8m head

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Appendix A2: Potential micro hydro sites outside the Peak District National Park *(continued)*

County	District or Town	Mill Name	NGR	Ref No	River System	Tributary	Category*	Source	Notes
Staffordshire	Mappleton	Okeover Mill	SK 162 481	014	Dove		a	Mills Trust	Mill and infrastructure in good condition
Staffordshire	Waterhouses	Caldon Mill	SK 078 502		Dove	Hamps		Mills Trust	Not visited
W Yorks	Holmfirth	Bottoms weir	SE 135 076	09	Holme		a	FPD	Weir needs some repair, 3m head
W Yorks	Marsden	Marsden town weir	SE 048 116	010	Colne	Butterley Brook	a	FPD	Stone weir in centre of town, 2.5m head, low flow - see case study text

Sources

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Sheffield Community Renewables Group (Zeleznikar, 2008), *Small Hydroelectric Schemes*, Sheffield Hallam University, Sheffield
IT Power (2006) *Renewable Energy Scoping and Feasibility Study for Sheffield*, IT Power report for Sheffield City Council
Mills Trust = Mills Archive Trust: www.millarchive.com
FPD = Site identified in course of project
* see section 5.4.1, p.34 for an explanation of categories a, b

Appendix A3 Potential non-mill sites within the Peak District National Park

County	District or Town	Site Name	NGR	Ref No	River System	Tributary	Source	Category*	Notes
Derbyshire	Woodlands Valley	Alport Dale		Derwent	Swint Clough	SK 135 911	NT/community	b	Low flow high head scheme, <5 kW
Derbyshire	Woodlands Valley	Alport Bridge	N7	Derwent	Alport	SK 141 897	FPD/community	b	Weir plus leat belongs to Severn Trent Water
Derbyshire	Baslow	Bar Brook, nr Baslow	N1	Derwent	Bar Brook	SK 263 730 (PH) SK 276 739 (Int.)	ETSU	c	Environmental considerations may rule out; 95/88kW estimated
Derbyshire	Chatsworth	Chatsworth House	N3	Derwent	Emperor Stream	SK 259 699 (PH) SK 267 702 (Int.)	ETSU	a	Upgrade of existing Chatsworth scheme
Derbyshire	Crowden	Crowden	N13	Etherow	Crowden Brook	SK 070 995	FPD	c	Weir complex belonging to United Utilities
Derbyshire	Crowden	Pikenaze Farm	N14	Etherow	Withens Brook	SK 096 004	FPD	c	Weir complex belonging to United Utilities
Derbyshire	Edale	Greenlands Farm	N10	Noe	Harden Clough	SK 125 844	Owner	b	Low flow high head scheme, c.1 kW
Derbyshire	Edale	Grinds Brook	N15	Noe	Grinds Brook	SK 121 863	FPD/owner	b	Low flow high head scheme
Derbyshire	Grindleford	Padley Gorge	N5	Derwent	Burbage Brook	SK 251 789 (PH) SK 257 800 (Int.)	ETSU	c	Environmental considerations may rule out; 100/106kW estimated
Derbyshire	Ilam	Ilam Church	N11	Dove		SK 132 505	Derwent Hydro	a	Feasibility study by Derwent Hydro; 8 kW
Derbyshire	Little Longstone	Monsal Dale		Wye		SK 176 714	LUC/ITP	b	Weir only in sensitive environmental area
Derbyshire	Sheldon	Magpie Sough		Wye		SK 179 686	FPD	b	Could be linked with Ashford Bobbin Mill scheme
Derbyshire	Over Haddon	Upper Lathkill Dale	N6	Lathkill		SK 177 655	ETSU	c	Unlikely site due to environmental constraints
Derbyshire	Over Haddon	Raper Lodge		Lathkill		SK 214 653	SY	b	11-14 kW estimated by study for Sustainable Youlgreave
Lancashire	Greenfield	Dovestone Reservoir		Tame	Greenfield Brook	SE 004 036	Community	a	Compensation water flow from reservoir
Staffordshire	Gradbach	Manor Farm		Dane		SK 004 663	WRE/owner	a	Initial design completed; 12 kW

NT = National Trust
FPD = site identified in course of project
ETSU = Salford University study (1989)
LUC/ITP = capacity study for East Midlands region (2001)
SY = Sustainable Youlgreave
WRE = Western Renewable Energy
PH = Powerhouse
Int. = Intake
* see section 5.4.1, p.34 for an explanation of categories a, b, c

Appendix A4: Old mill sites with little/no micro hydro potential

County	District or Town	Mill Name	NGR	Ref No	River System	Tributary	Source	Category*	Notes
INSIDE NATIONAL PARK									
Cheshire	Pott Shrigley	Pott Mill	SJ 947 796	M42			Mills Trust	c	Small stream, no infrastructure
Cheshire	Rainow	Corn Mill	SJ 949 757		Dean		Heritage	c	Demolished
Derbyshire	Abney	Corn Mill	SK 214 795	M71	Derwent	Highlow Brook	Mills Trust	c	Remote small stream
Derbyshire	Ashford in the Water		SK 181 696	M44	Derwent	Wye	Mills Trust	c	Refers to waterpumping wheel adjacent Ashford Bobbin Mill (site M3)
Derbyshire	Ashford in the Water		SK 193 698		Derwent	Wye	ETSU	c	Very little infrastructure, very low head
Derbyshire	Baslow	Barbrook Smelting Mill	SK 268 734		Derwent	Bar Brook	Heritage	c	Demolished
Derbyshire	Birchover	Birchover Mill	SK 232 626	M46	Derwent	Ivy Bar Brook	Gifford	c	Derelict site, small flow, no potential
Derbyshire	Bradwell	Bump Mill	SK176 817		Derwent	Bradwell Brook	Heritage	c	Demolished
Derbyshire	Castleton	Castleton Mill	SK 151 831	M55	Derwent	Peakshole Water	Mills Trust	c	No infrastructure, now converted to house
Derbyshire	Castleton	Saw Mill	SK 151 831		Derwent	Peakshole Water	Heritage	c	Demolished, was adjacent to corn mill
Derbyshire	Charlestown, Glossop	Gnathole Mill	SK 039 924	M58	Etherow	Bray Clough	Mills Trust	c	Converted into homes; no infrastructure left
Derbyshire	Crowdecote	Crowdecote Mill	SK 100 651	M60	Dove		Gifford	c	Not found
Derbyshire	Curbar	Bar Brook Mill	SK 275 739	M61	Derwent	Bar Brook	Mills Trust	c	Mill foundations plus remains of pond/goyt, intake point for Bar Brook (site N1)
Derbyshire	Froggatt	Slag Mill	SK 247 771		Derwent		Heritage	c	Demolished
Derbyshire	Glutton Bridge	Corn Mill	SK 084 665		Dove		Heritage	c	Demolished
Derbyshire	Grangemill	Grange Mill	SK 243 577	M64	Derwent		Mills Trust	c	Derelict with pond, small feeder stream, no potential
Derbyshire	Green Fairfield	Dale End Mill	SK 085 726	M65	Derwent	Wye	Gifford	c	No potential
Derbyshire	Green Fairfield	Pictor Hall	SK 093 725	M66	Derwent	Wye	Mills Trust	c	Weir left but no potential
Derbyshire	Grindleford	Grindleford Mill	SK 241 790		Derwent		ETSU	c	No infrastructure or weir apparent
Derbyshire	Hartington	Ludwell Corn Mill	SK 124 623	M77	Dove		Mills Trust	c	Demolished
Derbyshire	Hathersage	Dale Mill	SK 235 817		Derwent		Heritage	c	Converted into house
Derbyshire	Hayfield	Bank Vale Mill	SK 031 875	M69	Goyt	Sett	Mills Trust	c	Demolished
Derbyshire	Hope	Hope Mill	SK 174 838	M72	Derwent	Noe	Gifford	c	Converted into homes, no infrastructure left, also known as Kilhill Bridge Mill

Continued...

Appendix A4: Old mill sites with little/no micro hydro potential *(continued)*

County	District or Town	Mill Name	NGR	Ref No	River System	Tributary	Source	Category*	Notes
Derbyshire	Ible	Lode Mill	SK 246 569	M73	Derwent		Mills Trust	c	Completely derelict no potential
Derbyshire	Little Hayfield		SK 031880	M74	Goyt	Sett	FPD	c	Large mill converted into flats, no infrastructure
Derbyshire	Longnor?		SK 000 671	M76	Goyt	Dane	Mills Trust	c	Not found, grid reference incorrect? If correct, site is in Quarnford, Staffs.
Derbyshire	Middleton		SK 199 636	M78	Derwent	Bradford	Mills Trust	c	Derelict site, some infrastructure
Derbyshire	Middleton		SK 199 633	M79	Derwent	Bradford	Mills Trust	c	Derelict site, some infrastructure
Derbyshire	Millers Dale		SK 127 732		Derwent	Wye	ETSU	c	Very remote site, low head and environmental constraints
Derbyshire	Millers Dale	Wormhill Mill	SK 137 732	M80	Derwent	Wye	Mills Trust	c	Now craft shop with all leats etc either demolished or filled in
Derbyshire	Outseats, Hathersage	Green's House Mill	SK 233 837	M81	Derwent	Hood Brook	Mills Trust	c	Remote small stream
Derbyshire	Over Haddon	Carter's Mill	SK 184 657	M82	Derwent	Lathkill	Mills Trust	c	No potential due to environmental constraints and intermittent flows
Derbyshire	Over Haddon	Sough Mill	SK 203 662	M83	Derwent	Lathkill	Mills Trust	c	No potential due to environmental constraints and intermittent flows
Derbyshire	Peak Forest	Dam Dale	SK 115 787	M84	Derwent		Mills Trust	c	No potential
Derbyshire	Stanton-in-the-Peak	Stanton Mill	SK 233 639	M86	Derwent	Ivy Bar Brook	Mills Trust	c	Converted into house; small stream
Derbyshire	Stoney Middleton	Lord's Mill	SK 224 756	M87	Derwent	Dale Brook	Mills Trust	c	Now Rock Mill Business Park, no potential
Derbyshire	Taddington	Old Mill	SK 148 709	M88			Mills Trust	c	Converted into house; no sign of water source
Derbyshire	Thorpe	Thorpe Mill	SK 146 505	M89	Dove		Mills Trust	c	Downstream of Ilam site (N1); no sign of mill
Derbyshire	Tissington	Woodeaves Mill	SK 184 504		Dove	Bentley Brook	Heritage	c	Demolished
Derbyshire	Winster	Cotton Mill	SK 241 605		Derwent		Heritage	c	Not found
South Yorkshire	Bradfield	Damflask Mill 1	Sk 281 908		Don	Loxley	FPD	c	Under Damflask Reservoir
South Yorkshire	Bradfield	Damflask Mill 2	SK 278 908		Don	Loxley	FPD	c	Under Damflask Reservoir
Staffordshire	Allgreave	Folly Mill	SJ 971 664	M43	Dane		Mills Trust	c	Not found; on MAT database as Derbyshire
Staffordshire	Goytsclough		SK 012 733	M63	Goyt		Mills Trust	c	Isolated site no sign of mill; on MAT database as Derbyshire
Staffordshire	Grindon	Ford Mill	SK 067 534	M67	Dove	Hamps	Mills Trust	c	Demolished; on MAT database as Derbyshire
Staffordshire	Hartington Upper Qtr	Fernilee	SK 013 771	M68	Goyt		Mills Trust	c	Flooded by reservoir; on MAT database as Derbyshire

Continued...

Appendix A4: Old mill sites with little/no micro hydro potential *(continued)*

County	District or Town	Mill Name	NGR	Ref No	River System	Tributary	Source	Category*	Notes
Staffordshire		Crossbrook Mill	SK 005 700	M85			Mills Trust	c	Grid reference highly suspect; on MAT database as Derbyshire
Staffordshire	Upper Hulme	Upper Hulme Mill	SK 012 609		Churnet		Heritage	c	Not found; on MAT database as Derbyshire
Staffordshire	Alton	Old Wire Mill	SK 000 742	M92			Mills Trust	c	Grid reference highly suspect
Staffordshire	Fawfieldhead	Ludburn Mill	SK 094 626	M94	Dove	Manifold	Mills Trust	c	No trace of infrastructure
Staffordshire	Meerbrook	Corn Mill	SJ 993 607		Churnet		Heritage	c	Under Tittesworth Reservoir
Staffordshire	Milldale	Milldale	SK 139 547	M95	Dove		Mills Trust	c	No sign of mill; National Trust property on site, goyt visible
Staffordshire	Sheen	Brund Mill	SK 099 613	M96	Dove	Manifold	Mills Trust	c	Converted into house, no infrastructure
Staffordshire	Warslow	Brownlow Mill	SK 075 576	M98	Dove	Warslow Brook	Mills Trust	c	Not found
Staffordshire	Warslow	West Side Mill	SK 101 589	M97	Dove		Mills Trust	c	Mill building now garage for house; otherwise no infrastructure
West Yorkshire	Holme	Holme Mill	SE 105 055		Holme	Rake Dyke	FPD	c	Derelict site
OUTSIDE NATIONAL PARK									
Derbyshire	Bonsall	Calamine Works	SK 275 580	M47	Derwent	Bonsall Brook	Ark. Soc.	c	Very low flow, no potential
Derbyshire	Bonsall	Comb Mill	SK 281 580	M48	Derwent	Bonsall Brook	Ark. Soc.	c	Very low flow, no potential
Derbyshire	Bonsall	Corn Mill	SK 281 578	M49	Derwent	Bonsall Brook	Ark. Soc.	c	Very low flow, no potential
Derbyshire	Bonsall	Paint Mill	SK 278 580	M50	Derwent	Bonsall Brook	Ark. Soc.	c	Very low flow, no potential
Derbyshire	Bonsall	Paint Mill 2	SK 281 579	M51	Derwent	Bonsall Brook	Ark. Soc.	c	Very low flow, no potential
Derbyshire	Bonsall	Stone Mill	SK 282 577	M52	Derwent	Bonsall Brook	Ark. Soc.	c	Very low flow, no potential
Derbyshire	Bradbourne	Bradbourne Mill	SK 201 522	M53	Dove	Havenhill Dale Brook	Mills Trust	c	Residential conversion with non-working wheels
Derbyshire	Cadster		SK 003 801	M54	Goyt	Randal Carr Brook	Gifford	c	Not visited
Derbyshire	Chapel en le Frith		SK 073 798	M57			Mills Trust	c	Query NGR
Derbyshire	Chapel en le Frith	Comb's Mill	SK 045 782	M56	Goyt	Pyegreave Brook	Mills Trust	c	Only mill pond remaining
Derbyshire	Cromford	Slinter Mill	SK 288 572	M59	Derwent	Bonsal Brook	Ark. Soc.	c	Now holiday cottage with demonstration wheel
Derbyshire	Darley Abbey	Warnley Mil	SK 276 625	M62	Derwent	Warney Brook	Gifford	c	Not found
Derbyshire	Hayfield	Phoside Mill	SK 037 859	M70	Goyt	Sett	Mills Trust	c	Not found
South Yorkshire	Sheffield	Rowell Mill	SK 299 895	M91	Don	Loxley	Mills Trust	c	Derelict site, no potential, buildings destroyed by Great Sheffield Flood

Source
FPD = site identified in course of project
Heritage = www.derbyshireheritage.co.uk/Menu/Archaeology/Mills.html
Ark. Soc. = Arkwright Society, Cromford, Derbys.
Mills Trust/MAT = Mills Archive Trust www.millarchive.com
Gifford = Gifford A. (1999) *Derbyshire Watermills*, The Midland Wind & Water Mills Group
* see section 5.4.1, p.34 for an explanation of category c

Appendix A5: Potential hydro sites in the PDNP, ranked by installed capacity (kW)

Site name/location	River/stream	Capacity kW	Output GWh/y#	Study reference	Constraints	Notes/other studies
Upper Derwent catchment	Derwent/Ashop	700	3.4	STW	Low-medium	Six sites including Derwent and Howden dams scoped by Severn Trent Water
Calver Mill	Derwent	125	0.72	ETSU	Medium	Likely to be over-estimate; full head or design flow now unrealisable due to long depleted reach
Litton Mill	Wye	120	0.65	ETSU	Medium	Previous study: ITP/LUC, 2001: 63-157 kW/0.29-0.51 GWh/y; likely to be overestimate re new EA guidelines
Chatsworth upgrade*	Emperor stream	113	0.54	Chatsworth Estate	Low-medium	Current installed capacity 162 kW; suggested total after upgrade: 205-275 kW
Padley Gorge	Burbage Brook	106	0.5	ETSU	Very high	Very high natural constraints - very unlikely to be realisable
Cressbrook Mill	Wye	94	0.52	ETSU	Medium	Previous study: ITP/LUC, 2001: 57-100 kW/0.27-0.39 GWh/y; likely to be overestimates re new EA guidelines
Bar Brook, Baslow	Bar Brook	88	0.39	ETSU	Very high	Very high natural constraints - very unlikely to be realisable
Waterfall, Lathkilldale	Lathkill	75	0.35	LUC/ITP	Very high	Very high natural constraints; low summer flows - very unlikely to be realisable
Edensor lower weir	Derwent	56	0.26	FPD	Medium-high	Previous studies: ETSU, 1989: 88 kW/0.36 GWh/y; ITP/LUC, 2001: 35 kW/0.16 GWh/y
Lumford weir	Wye	50	0.21	FPD	Medium-high	Previous study: ETSU estimate was 44 kW and 0.255 GWh/y
Edensor upper weir	Derwent	43	0.2	FPD	Medium-high	Previous studies: ITP/LUC, 2001: 49 kW/0.23 GWh/y (seems likely LUC/ITP confused the two weirs)
Caudwell's Mill upgrade*	Wye	35	0.18	FPD	Medium-high	Existing turbine produces 15 kW (off grid); 50 kW potential from HydrA study - thus additional capacity = 35 kW
Old Mill, Baslow	Derwent	35	0.25	ETSU	Medium	Full estimate may be unrealisable due to depleted reach and new EA guidelines
Whitelee Mill, Danebridge	Dane	34	0.12	FPD	Medium	Alternative option of 2 in-weir schemes producing 32 kW/0.14 GWh/y
Ashford Bobbin Mill	Wye	30	0.14	Townsend/FPD	Medium-high	FPD estimate based on study (Townsend, 2009) by postgraduate student at CAT, Machynlleth
Bamford Mill	Derwent	27	0.22	FPD	Medium	Previous study: ITP/LUC: 83-187 kW - very unlikely to be realisable
Flewitt's Mill, Ashford	Wye	18	0.14	Segen	Low	Estimate based on existing turbine. Segen also scoped 95 kW with new Kaplan - highly unrealistic
Lead Mill, nr Hathersage	Derwent	17	0.08	LUC/ITP	Medium-high	FPD walk over survey suggested weir in poor condition
Edale	Grinds Brook	12.5	0.05	FPD	High	Difficult to realise due to environmental constraints; 5 kW pico DIY scheme may be possible
Diggle Mill	Diggle Brook	12	0.06	FPD	Medium-high	Former site of 97 kW wheel but fed by long leat/millpond; wheel capacity now unrealisable
Meadow Farm, nr Flash	Dane	12	0.06	WRE	Medium	Currently with EA for licensing; farm scheme/feasibility study by Western Renewable Energy
Brough Business Park	Bradwell Brook	11	0.06	Derwent Hydro	Medium	Study commissioned by Direct Charcoal Ltd with grant aid by PDNP SDF
Raper Lodge, nr Alport	Lathkill	10	0.05	SY/Clarke	Medium-high	Scoping study (Clarke, 2009) for Sustainable Youlgrave re hydro potential on Bradford/Lathkill rivers

Continued...

Appendix A5: Potential hydro sites in the PDNP, ranked by installed capacity (kW) *(continued)*

Site name/location	River/stream	Capacity kW	Output GWh/y#	Study reference	Constraints	Notes/other studies
Ilam	Dove	8	0.05	Derwent Hydro	Medium-high	Significant constraints - cultural heritage and river environment; feasibility study funded by PDNP SDF
Calver Corn Mill	Calver Mill Sough	4	0.02	FPD	Low	Wheel to be re-instated in 2010; low flows on a mine drainage channel; no environmental issues
Stoney Middleton	Stoke Brook	4	0.02	Derwent Hydro	Medium	Pre-feasibility study funded by PDNP SDF
Total		**1840**	**9.24**			

Notes:
* existing sites: capacity noted is additional to current installed capacity
# = where no output/annual energy capture estimated in original study, a capacity factor of 55% has been used
1. Many more sites (40+) examined by FPD desk/GIS constraints study but no head measured nor flow known. Some may provide additional capacity but difficult to estimate
2. Other sites where estimates made include Low Bradfield (0.8 kW), Gradbach Mill (<5 kW), Magpie Sough (2 kW), Harden Clough (1 kW), Swint Clough (2 kW) - all likely to be uneconomic to develop