Leigh, P.; Aggidis, G.; Howard, D.. 2007 Investigation of barriers against the development of hydro power schemes in Northwest England. In: *BHA Annual Conference - "Hydro - the Next Generation", Birnam, Perthshire, 10-11 October 2007*.

Investigation of barriers against the development of hydro power schemes in Northwest England

P. A. Leigh[1,3], G. Aggidis[1] & D. Howard[2]

1. Engineering Department, Centre, Lancaster University, Lancaster, LA1 4YR
2. Centre for Ecology and Hydrology, Lancaster, LA1 4AP
3. (Since September 2007) Crichton Carbon Centre, Rutherford McCowan, Crichton University Campus, Bankend Road, Dumfries, DG1 4ZL

Email: p.leigh@carboncentre.org

Abstract

This paper describes the development of a sequential decision support system to promote hydroelectric power in North-West England. The system, composed of a series of integrated models, addresses barriers to the installation of hydroelectric power schemes. Information is linked through an economic assessment which identifies different turbine options, assesses their suitability for location and demand; and combines the different types of information in a way that supports decision making.

The system is structured into five components: the hydrological resource is modelled using Low Flows software, the turbine options are identified from hydrological, environmental and demand requirements; and the consequences of different solutions will be fed into other components so that the environmental impacts and public acceptability can be assessed and valued.

Key words: Flow duration curve, Hydro-electric power, North-West England, Sequential decision making.

1. Introduction

In this current political climate the option of reliance on coal, oil and gas is non sustainable; nuclear is an option many people would prefer to avoid and doesn't provide the full answer – where does that leave us? Much recent sustainable energy generation has focused on wind power; this article explores the potential capacity of an often overlooked renewable energy source, namely small scale hydro power. DEFRA has stated that if many streams and rivers in the UK could be tapped it would be possible to produce around 10,000 GWh per year – enough to meet over 3% of our total energy requirements; making a significant contribution to the Governments renewable energy target of 10% by 2010 [1]. Additionally, as a clean power source hydro can help attain national targets for CO_2 reduction.

One key element of weather in the UK is rain; especially on the western side of the UK. We receive reliable annual precipitation rates of ~1m – 3m (depending on location and altitude);

this coupled with a complex array of mountain streams through to lowland rivers, has the potential to convert moving water into electricity via a turbine for both low (<1m) and high heads (>20m). In the UK our largest energy demands occur during autumn through to spring. In general, this coincides with the period of highest water flow; making hydro often more attractive than other sources such as solar power. However, the ultimate way forward may be the installation of a '*suite*' of renewables incorporated into new build and in the regeneration of existing buildings [2].

Lancaster University on behalf of the Joule Centre (http://www.joulecentre.org/) has been awarded a grant to investigate the potential of hydro power in North West England. The project entitled "North West Hydro Resource Model" is building a web based tool; which will enable the user to pose queries that arise when an interested party inquires whether hydro power could be harnessed to provide all or a proportion of their individual or community electricity requirements.

2. Sequential decision making

A number of leading Lancaster academics across many departments in partnership with the Centre for Ecology and Hydrology (CEH) and Hydrological Solutions (HS) in Wallingford have come together in an attempt to address this problem. The model will be an iterative process and Lancaster University is approaching it from a systems and informatics standpoint. Any energy system, whether sustainable or not has a fundamental requirement to be economically viable after a pre-determined period of time – the payback time? Thus, the main driver of any hydro power scheme is economics. This key driver will ultimately decide if a project moves from conception to completion. In-between there are many other phases and steps.

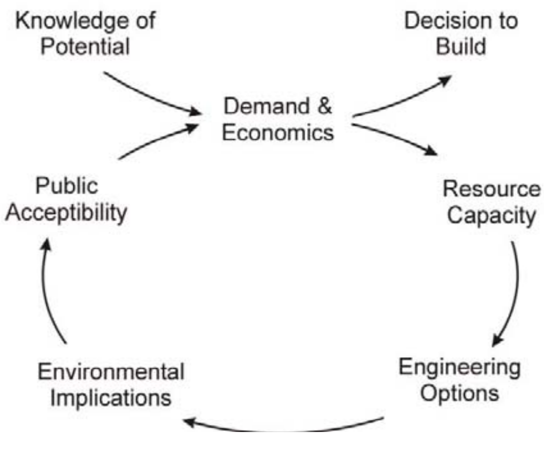

Figure 1: Sequential decision making loop for hydro power schemes.

In figure 1 above, there is a circuit that takes linked information around an iterative loop in a "Sequential Decision Making" (SMD) process. This process requires the user to ask a number of questions at each of the main topic headings within the sequence before moving to the next topic or level. Within this project topics are defined as work packages (http://www.engineering.lancs.ac.uk/REGROUPS/LUREG/home.htm). It is envisaged the user will progress round the loop several times, resulting in a multi level sequential decision making process (figure 2); questioning the strength and confidence at the end of each loop. This process allows refinement of questioning in order to obtain a higher level of sophistication and accuracy in the answers, and permits the user to short circuit the loop where applicable in order to move their individual project forward [3]. The SDM process is designed to develop a generic and fundamental understanding of the barriers to the deployment of hydro electric schemes in North-West England.

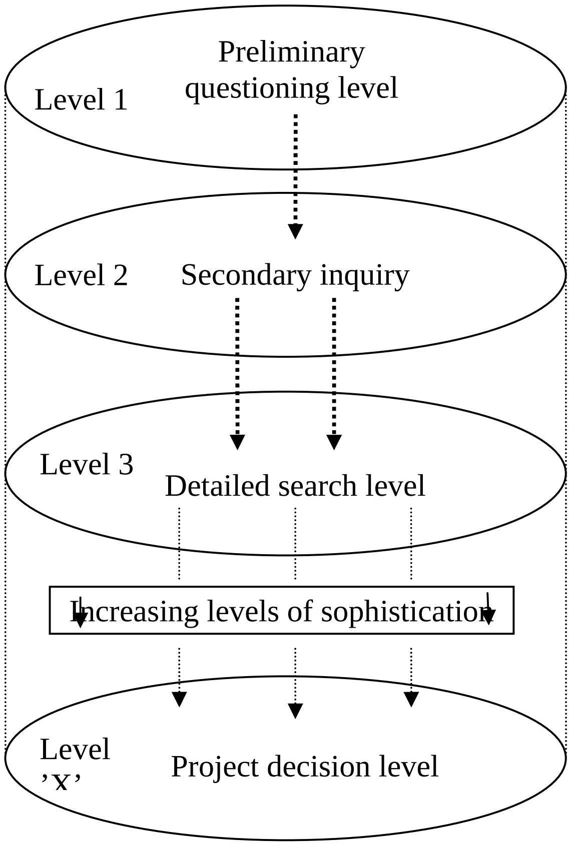

Figure 2: Multi level sequential decision making process.

3. Work packages

The hydro resource project comprises of 6 main Work Packages (WP's). These are:

3a (WP1) ***Demand and economics***: this will address identified costs and revenues associated with various turbine technologies. Cost per kilowatt hour produced (p/kWh) is a key element of any proposed hydro power system [4]. WP1 will also investigate costs and benefits for a community, e.g. loss of amenity, degradation of the physical environment etc.

3b (WP2) ***Resource capacity***: here we will utilise expertise from HS Wallingford and Low Flows software to estimate flow duration curves for different river and stream reaches and identify sub catchments (figures 3 and 4). Uncertainty in the prediction of flow duration curves will be constrained to minimise uncertainty in projected energy production in order to demonstrate the viability of a scheme [5, 6].

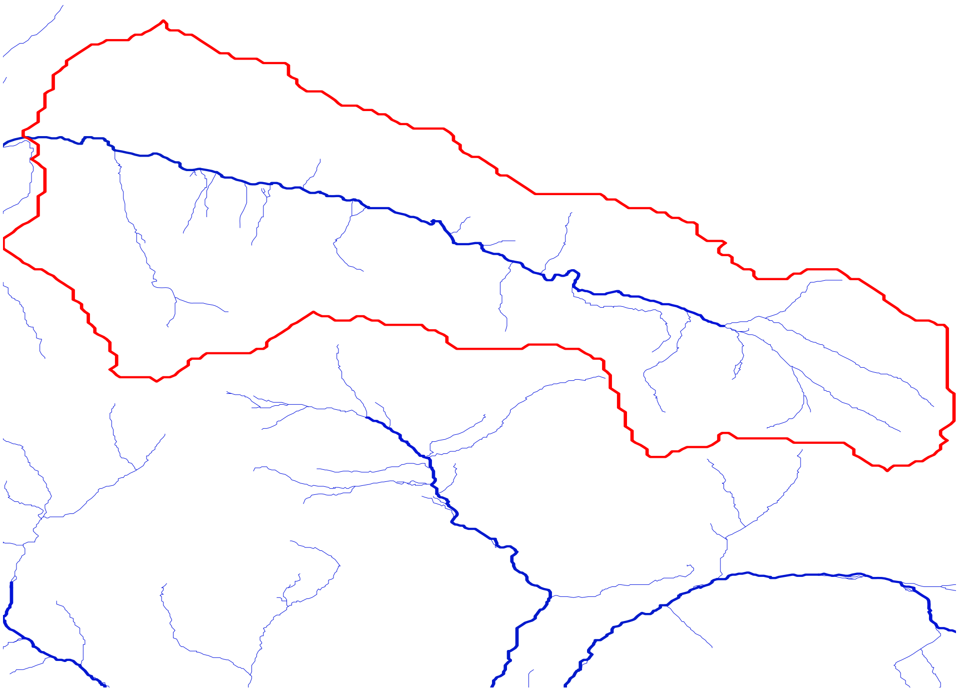

Figure 3: Low Flows 2000 plot of a North West Stream with a sub catchment defined (red outline) for flow estimation.

3c (WP3) ***Engineering options***: Modern hydro turbine design allows for small turbine units to be installed directly into a small stream or water course. GIS data combined with flow data established from WP2 will feed into advanced software tools to optimise the engineering options on cost and annual generated power; all latest engineering innovations will be incorporated in this model (figure 5) [7-9]. Each design will have its own specific characteristics and components including storage, culvert, penstock, turbine house and tailrace system, whose values will be adjusted for each location.

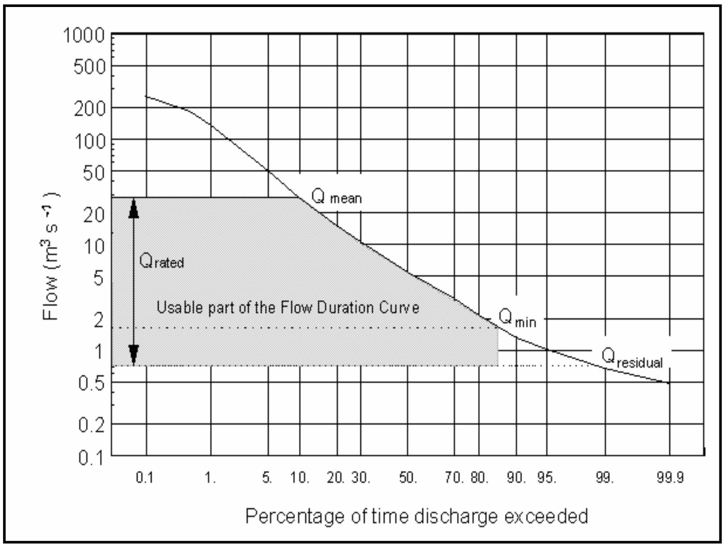

Figure 4: Example of a typical flow duration curve.

3d (WP4) ***Environmental implications***: The often *ad hoc* and *ill defined* approaches to defining impacts of hydro power schemes on a water course are currently being reviewed by various bodies. This WP is an opportunity to ensure the environmental implications of a hydro scheme, such as a water abstraction licence are at one with current environmental legislation. To this end the project is in consultation with the Environment Agency (EA) and British Hydro Association (BHA) to help ensure all parties are considered (figure 6).

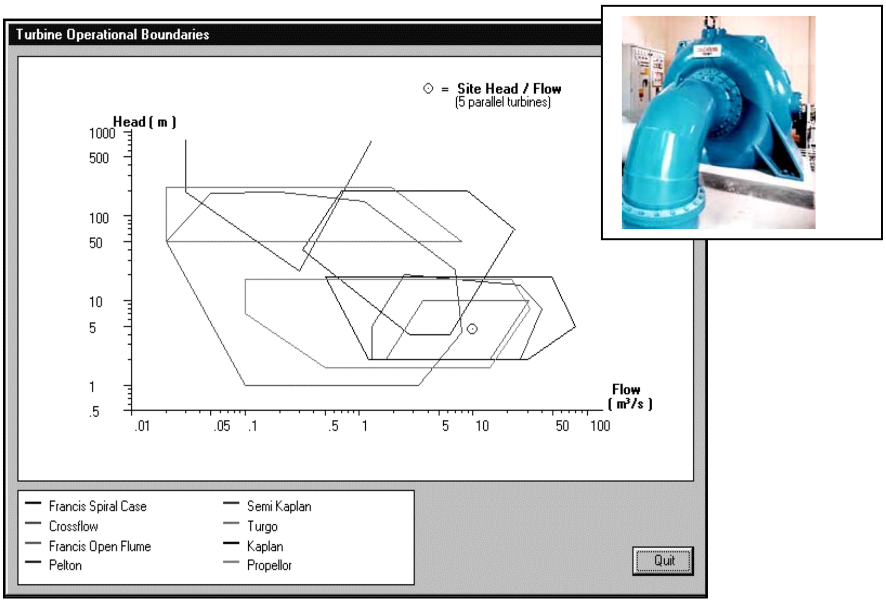

Figure 5: Example of the turbine operational boundaries.

3e (WP5) *Public engagement*: how the public engage with hydro technology is a crucial question this WP is seeking to address. Ordinary people are potential adopters of the technology at a micro household and community level and may be concerned about the local impacts of the installation (visual, ecological, noise etc.). The research here is focusing on recognising the diversity of public and stakeholder group who may have an interest in the installation and impacts of small scale hydro technologies.

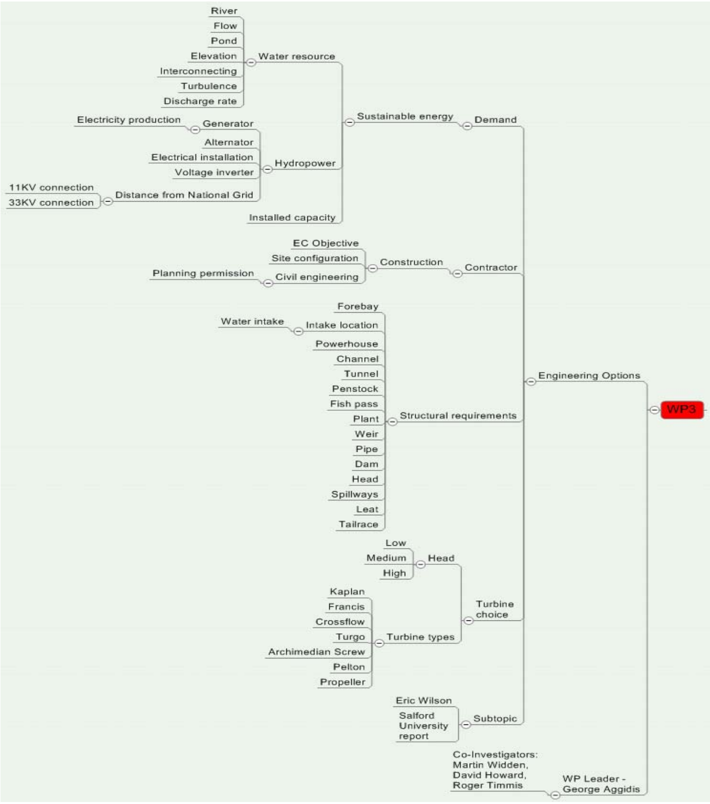

Figure 6: Illustration of part of the thought process before a hydro power system is approved in a particular location.

3f (WP6) *Dissemination and exploitation*: the final work package will ensure the project delivers its objectives and outputs and identifies future work on technologies and legislation that can smooth the path for potential hydro power designers, installers and end users, [10]. The novelty of this project is its ability to identify appropriate solutions to different situations and locations. The outputs will not be a "one size fits all" approach, but offer a range of options that will have different values and costs.

4. Core hydro sites

The Joule hydro project has selected three core sites with which it works closely. These sites are geographically situated in the northern, central and southern parts of the NWDA region (figure 7). In the north Black Sail youth hostel in the remote Ennerdale valley is a potential off grid scheme that will be fed by a pristine stream running straight off a steep sided Lakeland mountain. By contrast the sites within the Bury council on the rivers Irwell are within an 'urban' environment. Here the water has passed off the hillsides of greater Manchester through housing and industry; the project collected water samples here and contrasted them with the almost pure rainfall collected in Ennerdale. Unsurprisingly while the water here is far from polluted it is also less pure than a mountain stream in the Lake District. The final core site is situated close to the middle of the NWDA region at Beetham near Lancaster. Heron Corn Mill has been a very interesting scheme with regard to the need to overcome a wide range of barriers and supplying information into the Joule hydro model. A full account of this scheme will be published once the project is completed in 2008.

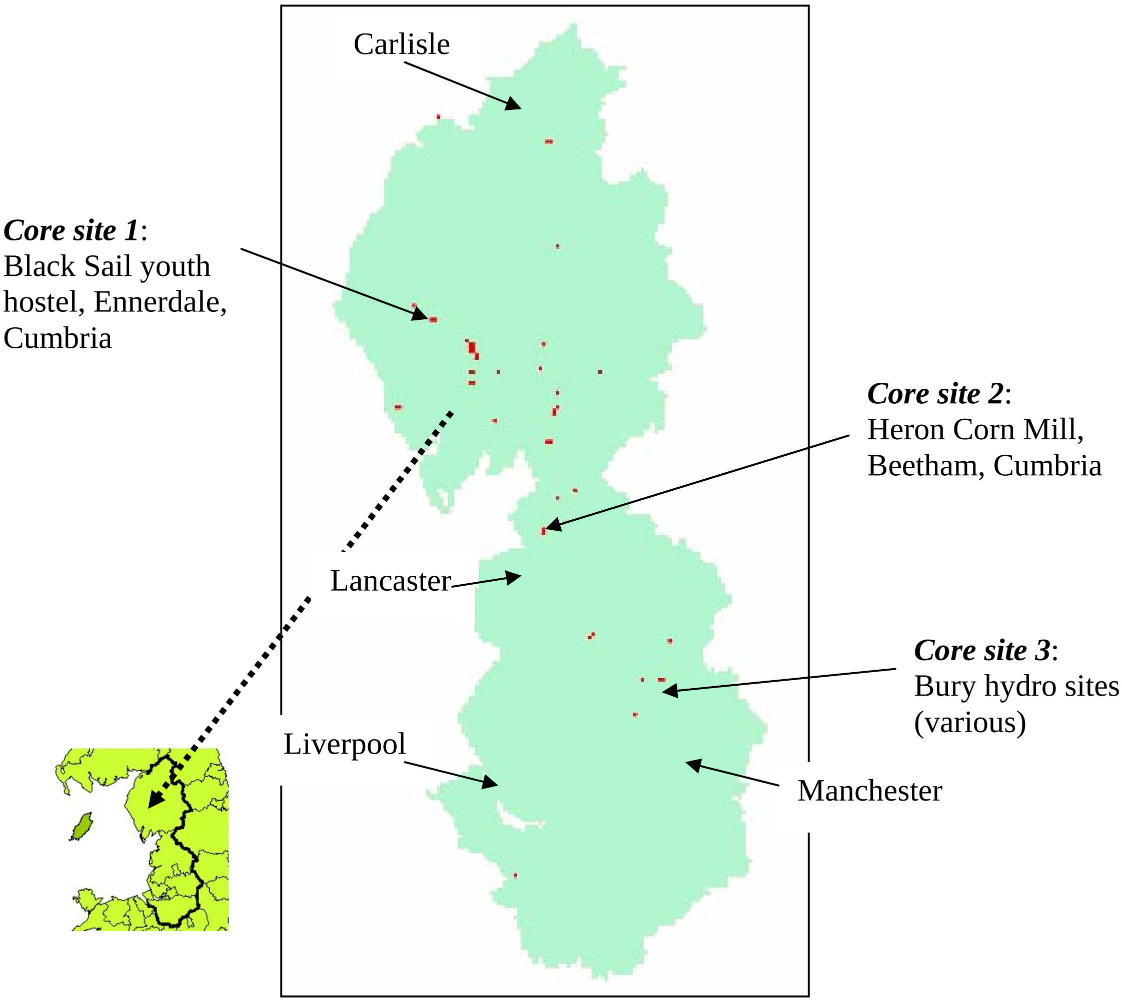

Figure 7: Map of NWDA region showing a number of hydro and potential hydro sites including three ‘core’ sites that are contributing information to the Joule hydro model.

5. Full circle

Historically water power was utilised for centuries to drive machinery in mills and factories. It determined the location of industry, supported the industrial revolution and shaped the landscape of North West England along with many other regions throughout the UK; but since the end of the 19th century its importance declined as fuel powered engine technology flourished. However, perhaps it is time to revisit the potential of this overlooked resource that is literally flowing past our front doors! This project is developing in one corner of England, but has potential to be applied throughout the UK.

6. Acknowledgments

The authors wish to express their appreciation of the support of the North West Development Agency (NWDA) through the Joule Centre for Energy, Manchester, for the research reported in this paper via Joule Grant Reference: JIRP106/07.

7. References

[1] U K Department of Trade and Industry,: "*The Energy Challenge*: The Energy Review Report, July 2006 Cm 6887.

[2] Leigh, P. A.: *Time to go with the flow*, Water & Environment Magazine, vol. 12, No. 3, March 2007 pp. 24-25.

[3] Read, P. & Lermit, J.: *Bio-energy with carbon storage (BECS): A sequential decision approach to the threat of abrupt climate change*. Energy, 30, 2005, pp. 2654-2671.

[4] Aggidis, G. A., Howard, D. C., Rothschild, R., and Widden, W. B.: *Maximising the benefits of hydropower by developing the North-West England hydro resource model*, Proceedings of the International Hydro Power and Dams Construction Journal, Paper 7.01, HYDRO 2006 – Maximising the benefits of Hydropower, Porto Carras, Greece, 25-27 September 2006.

[5] Holmes, M. G. R, Young, A. R., Gustard A .G., and Grew R.: *A Region of Influence approach to predicting Flow Duration Curves within ungauged catchments*. Hydrology and Earth System Sciences 6 (4), 2002, pp. 721-731.

[6] Young, A R, Grew, R & Holmes, M. G. R.: *Low Flows 2000: a national water resources assessment and decision support tool*. Water Science & Technology Vol.48 No.10, 2003, pp 119-126.

[7] Aggidis, G. A.: *Technological Developments on Small Hydro*, Invited Paper, IMechE", Fluid Machinery Group, London, May 2001.

[8] Aggidis, G .A., Graves, C. P., and Porter, N. I.: "*Experience of Innovation & Technological Developments Meeting Small Hydro Needs Today*", Proceedings, International Conference on Small Hydro, Athens, Greece, November 1998.

[9] Nechleba, M.: "*Hydraulic Turbines, Their Design and Equipment*", Constable London 1957.

[10] Leigh, P. A., Aggidis, G. A., Howard, D, & Rothschild, R., May 2007 *Renewable energy resources impact on clean electrical power by developing the north-west England Hydro Resource Model*. International Clean Electrical Power Conference, Capri, Italy. May 2007.