SVP/1/010302811 – West Harris Crofting Trust - Appendix A

WESTERN ISLES HYDRO POWER FEASIBILITY STUDY

For Highlands & Islands Community Energy Company

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Reference:
Date created: 01-06-2007
Telephone: 0131 311 4000
Fax: 0131 311 4090
Website: http://www.fabermaunsell.com
Dunedin House
25 Ravelston Terrace
Edinburgh EH4 3TP

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HIGHLANDS & ISLANDS COMMUNITY ENERGY COMPANY
WESTERN ISLES HYDRO POWER FEASIBILITY STUDY

Prepared by: .... Approved by:
Debbie Hay-Smith Ken Turnbull
Principal Engineer Regional Director
Rev No Comments Date
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EXECUTIVE SUMMARY

The hydropower development potential of the initial eleven sites brought to Faber Maunsell by the Highlands and Islands Community Energy Company varied significantly.

The sites at ******, the reservoirs above ****** and Losgaintir are not recommended by Faber Maunsell as preferred sites for development. The eight remaining sites do have development potential and initial scheme designs have been prepared. These initial scheme designs are displayed in the table below:

		Intake						
	Scheme	Easting	Northing	Area (km2)	Standard average annual rainfall (mm)	Potential evaporation (mm)	BFI	Mean Flow (m3/s)
5	Gleann Dubhlinn	108000	895400	4.75	1,939	489	0.2	0.218

Findings from modelling the hydropower resource have indicated that the greatest efficiencies of operation are likely to be gained by sizing the hydro turbine to the mean flow. By sizing the turbine to the mean flow the following estimated plant capacity, efficiency and annual energy output for each of the ten hydro power schemes may be achieved.

Scheme no.	Plant capacity (kW)	Efficiency %	Annual energy output (MWh)
5	117	45%	467

From the information displayed in the table above, using an approximate power purchase agreement of £70/MWh and indicative estimates of development costs the simple pay back period of each of the sites may be calculated. These pay back periods and estimated annual gross revenue of each of ten schemes are displayed in the table below.

Scheme no.	Estimated Simple Pay Back Period	Estimated Annual Gross Revenue
5	3.1 – 7.2 years	£32,690

Faber Maunsell would recommend that the Highlands and Islands Community Energy Company consider the information contained in this report and then carry out site specific feasibility studies on any sites they wish to develop further.

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1. Introduction

1.1 Background to the Project

This report results from an instruction from Highlands and Islands Community Energy Company to provide a feasibility appraisal of potential small hydro power sites in the Western Isles as part of their objective for all communities across the Highlands and Islands to be able to generate and use renewable energy for their long term and collective benefit.

1.2 Scope of Report

The location of a number of potential sites has been identified, and preliminary calculations completed to give a guide to their viability for development. The scope of this report is therefore limited to:-

- Site Identification
- Hydrology
- Power Generation
- Land ownership
- Planning & environmental issues
- Grid connection Issues

It is envisaged that following review of this report above issues can be addressed in a Feasibility Report for selected sites.

1.3 Hydro Development in Scotland

On a historical note, large scale hydro power was developed in Scotland in Galloway in the 1930's, and in the Highlands in the post war period up to about 1962 when public disquiet about the environmental impact halted this type of scheme. Since that time there has been little hydro development. Small scale schemes have been developed over the past 15 years, for example Scottish & Southern Energy's 3.5MW Kingairloch HSD scheme in Morven, completed in 2005. The one exception is that SSE is currently developing an 80MW scheme at Glen Doe near Loch Ness.

Faber Maunsell has been involved in small hydro developments for many years, including the identification of sites for various developers, and this report exploits that experience. An important reference document on this subject was produced by Salford University in the late 1980's, '*Small Scale Hydro Electric Generating Potential in the UK*', identifying 823 potential sites in Scotland alone, and others in England and Wales. This report states that there is 236MW of developable small hydro in Scotland, however environmental and grid issued will reduce that figure.

1.4 Potential sites

11 potential hydro power sites were brought to Faber Maunsell by the Highlands and Island Community Energy Company and the associated interested community groups. Each of these potential hydro sites was visited by a Faber Maunsell engineer to better assess the technical feasibility of the project and to identify constraints to development.
The sites brought to FM are as follows:

- Site 6: Gleann Dubhlinn

2. Site Visits and Site Descriptions

2.1. Site Visits
The site visits were undertaken by George Baillie (Faber Maunsell) between 5 and 11 May 2008. George Baillie was accompanied on some of the site visits by Rona Womersley (Highlands & Islands Community Energy Company), Kathleen MacLennan (Highlands & Islands Community Energy Company) and representatives from community groups with vested interests in the projects.
The purpose of the site visits was to assess the development potential of the site, to inform the scheme design. In addition information of any potential on or near site constraints was also gathered during the visits. Descriptions of the sites, observations of on site resource and information on any potential constraints to development are provided in the following subsections of this report.

2.7. Site 6: Gleann Dubhlinn
The Gleann Dubhlinn site visit was carried out 8 May 2008. Attending on the site visit were George Baillie (Faber Maunsell) and Murdo MacKay (Local Community Group). The grid reference of the proposed turbine house for the Gleann Dubhlinn site is at OS National Grid **108,170; 896,360**.
The land comprising the site is believed to be in private ownership; however proposals for the potential purchase of an area of land that includes the site are being discussed by the community. Ownership of the site may be transferred to the community through a special purpose vehicle that may be known as the South Harris Trust.
The site is located on the Isle of Harris and has been proposed to the Highlands and Islands Community Energy Company by a local community group (**Map 6**). The site of the proposed turbine house is located approximately five hundred metres from the township of Seilebost.
The Gleann Dubhlinn site is made up of a series of watercourses, including the Glen Dubhlinn and Abhainn Gil an Tailleir rivers. There is also a loch within this site, Loch Heileasbhal, which was formerly used by the local water authority to supply the nearby township. The site has since passed into the ownership of Scottish Water who are, it is believed, negotiating the sale of the site at present.

2.8. Site 7: Losgaintir
The Losgaintir site visit was carried out on 8 May 2008. The grid reference of the Losgaintir site outlet to the sea is at OS National Grid **106,860; 999,010**. The site visit on 8 May 2008 was carried out by George Baillie (Faber Maunsell) and Murdo MacKay (Local Community Group). The site is located on the western coast of the Isle of Harris.
The land ownership of the site has not been established. The land comprising the site is believed to be in private ownership; however proposals for the potential purchase of an area of land that includes the site are being discussed by the community. Ownership may be transferred to the community group through a special purpose vehicle, known as the South Harris Trust.
This site is comprised of three waterbodies and a series of watercourses that are all located in close proximity to the village of Losgaintir. Only one of the four watercourses have been named; the Abhainn an Tighe which flows from the north of the village for approximately a kilometre. The site also includes Loch na Caorach and several man-made lochs.
Flows in the river systems in this area are very flashy as there is virtually no vegetation cover on the rock within the catchment. Estimations made during the site visit suggest that approximately ten percent of the catchment includes some vegetation cover.
The two small lochs, one with an inflow into Loch na Caorach and one with an outflow from Loch na Caorach, are man-made. The watercourses running into the village of Losgaintir have been controlled and/or diverted so that the majority of the flow on the site feeds these manmade lochs. The bi-furcation till functions in very heavy rain with waves of water washing down the hills and causing some damage to the man-made walls. The lochs comprising this site are at approximately 30 metres AOD.

3. Site Development Potential

During the site visits information on the resource and development constraints of the site were gathered to assist with the geographical information systems (GIS) assessment of the development potential of each of the 11 sites. This information was used in turn to assess development potential, recommend generating plant and produce initial scheme layouts for each site. These layouts are modelled in the hydrological modelling process reported in Section 4 of this document. Sites where there were 'show stopping' constraints to development are also reported in the following section of this report. Any sites where potential show stopping constraints existed have been ruled out for further study in this report.

3.2. Main Elements of a Hydropower Scheme

The main elements of a small scale hydropower scheme, with a medium or high head, are illustrated below in Figure 2.

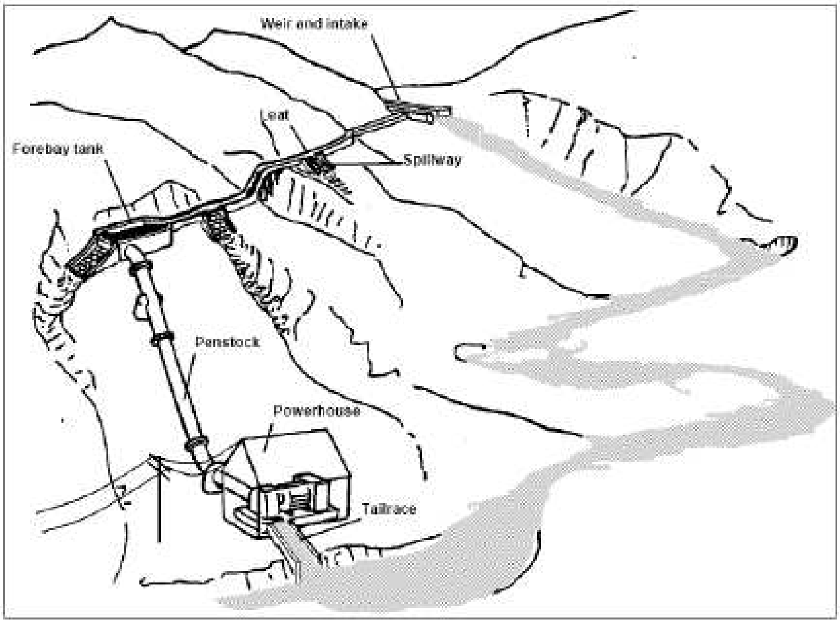


Figure 2: Typical Medium-to-High Head Hydropower Schemes

This scheme can be summarised with the following bullet points:
• Water is taken from the river by diverting it through an intake at a weir;
• In medium or high-head installations water may first be carried horizontally to the forebay tank by a small canal or 'leat';
• Before descending to the turbine, the water passes through a settling tank or 'forebay' in which the water is slowed down sufficiently for suspended particles to settle out;
• The forebay is usually protected by a rack of metal bars (a trash rack) which filters out water-borne debris;
• A pressure pipe, or 'penstock', conveys the water from the forebay to the turbine, which is enclosed in the powerhouse together with the generator and control equipment;
• After leaving the turbine, the water discharges down a 'tailrace' canal back into the river.

There is a large variation in scheme design between sites that are suitable for small-scale hydro power projects. Variations to the scheme design of the 'canal-and-penstock' layout for medium and high-head schemes include using only a penstock without a canal. In situations where the terrain of some sites would make canal construction difficult or in environmentally-sensitive locations where a buried penstock is required such a variation in scheme layout has been used. The typical layout for low head schemes usually consists of one of two designs; barrage or canal. In many cases the design of a small scale hydropower scheme is influenced by existing infrastructure and economical aspects of a project.

Figure 3 illustrates some alternative hydropower scheme designs.

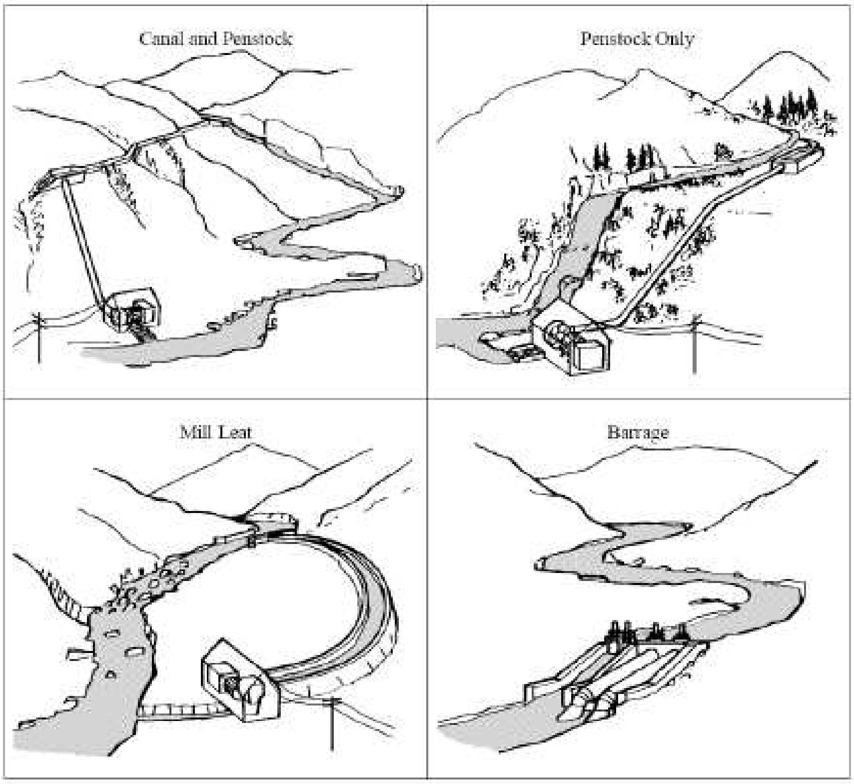


Figure 3: Variations to Hydropower Scheme Designs

3.3. Turbine Options & Scheme Design
The following sections of this document report on the most suitable generating plant and scheme design for each of the 11 Western Isles sites visited by Faber Maunsell. Hydropower turbines can be classified as high-head, medium-head, or low-head machines. Hydropower turbines can also categorised as either impulse or reaction turbines, depending on their design. The rotor of the reaction turbine is fully immersed in water and is enclosed in a pressure casing. The runner blades are profiled so that pressure differences across them impose forces which cause the runner to rotate. In contrast an impulse turbine runner operates in air, driven by 'jets' of water.

Four principal hydropower turbines are referred to in the following sub-sections of this report. These are:

• Pelton Turbine (high head);
• Crossflow Turbine (high, medium & low head);
• Kaplan Turbine (low head);
• Screw Turbine (low head).
3.3.1. Pelton, Crossflow, Kaplan & Screw Turbines

Pelton turbines (Figure 4) consist of a wheel with a series of split buckets set around its rim; a high velocity jet of water is directed tangentially at the wheel. The jet hits each bucket and is split in half, so that each half is turned and deflected back almost through 180º. Nearly all the energy of the water goes into propelling the bucket and the deflected water falls into a discharge channel below.

The Crossflow turbine (Figure 4) has a drum-like rotor with a solid disk at each end and guttershaped "slats" joining the two disks. A jet of water enters the top of the rotor through the curved blades, emerging on the far side of the rotor by passing through the blades a 2nd time. The shape of the blades is such that on each passage through the periphery of the rotor the water transfers some of its momentum, before falling away with little residual energy.

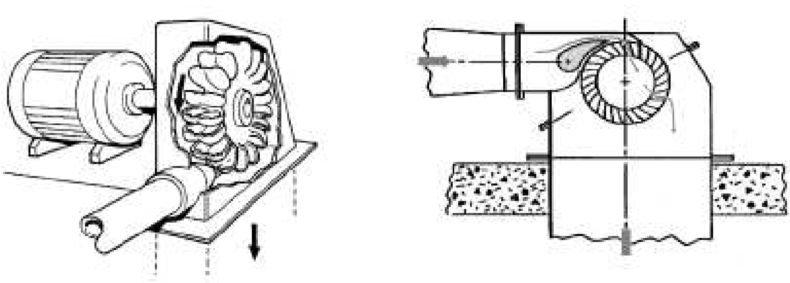


Figure 4: Typical Pelton (left) & Crossflow (right) Turbine Design
The Kaplan turbine (Figure 5) is a 'propeller-type' turbine that has adjustable blades. The Kaplan turbine is an 'inward flow reaction turbine', with this design the working fluid entering the turbine changes pressure as it moves through the turbine and releases kinetic energy.

A typical design of a Screw turbine (Figure 6) is displayed in Figure 5. The flow passing through the screw is determined by the volume of 'chambers' filling per second. The volume of each chamber is related to the diameter of the screw and its shaft, the angle of inclination of the screw, the number of blades on the screw and the water level at the inlet to the turbine. The number of chambers filling per second is then dependent on the rotational speed of the screw.

Figure 5: Typical Kaplan Turbine Design

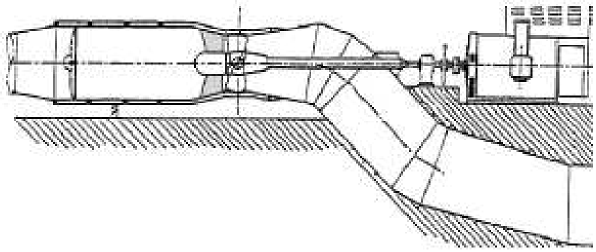
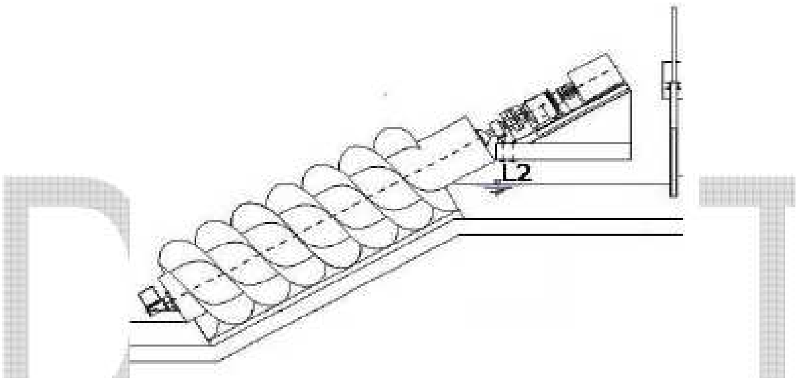


Figure 6: Typical Screw Turbine Design



3.9. Site 6: Gleann Dubhlinn

The intake for this site would be located at a low weir built at approximately 80 metres AOD with a buried 150 millimetre plastic pipe connecting to the mainly underground water treatment building via a route cut through a rock ridge. A possible location for the control building has been identified at about 75 metres AOD. The abandoned pipeline existing on site is then in a direct route to the bottom of the hill

This is an excellent site offering a head of potentially 90 metres, a weir (which requires an increase in height) and a pipeline route. Faber Maunsell do not anticipate any problems with plant and vehicle access to the weir site and the pipeline. The turbine house could be located near the road and a potential grid connection point on the 33 kV distribution circuit.

The turbine most suitable for generation at this location is a Pelton turbine. This site does appear at this stage to have a reasonably good development potential. In addition a potential grid connection point into the 33kV distribution network is also located in close proximity to the site. A site specific technical feasibility study would need to be carried out in order to confirm the initial observations and calculations.

3.10. Site 7: Losgaintir

The low vegetation cover on the land within the catchment of the site makes the river systems in this area very flashy. The electricity distribution network located in close proximity to this site appears to be at between 6kV, which will be difficult to connect to. Damage to the man-made walls of the two lochs was observed during the site visit. If a hydro power project was to proceed at this site then repairs to these walls would need to be carried out. The cost of the repairs to these man-made walls combined with the low head and flashy nature of the flows in this area would most likely make the site uneconomic for development. No further consideration to this site has been given in this report.

3.15. Scheme Descriptions
Following the desk based assessment of the sites and the site visits the following scheme descriptions have been taken forward for further assessment:

Scheme no	Location	Description
5	Gleann Dubhlinn	Intake at site of Scottish Water water treatment unit at OSNGR 108000 895400, turbine 1km downstream to the north.

4. Hydro Resource

4.1. Hydrology

This element of the study provides the baseline hydrological data, i.e. the flow regime in the river from which power estimation calculations can be made. The flow regime is generally described by a *flow duration curve*, which gives the percentage of time during which any selected discharge is equalled or exceeded.

4.2. Methodology

The flow regime for a watercourse can either be determined directly from gauged flow data, or estimated using catchment characteristics such as area, rainfall and soil data. Since there were no flow records at any of the potential sites, and the sites were not close to any gauged catchments, the flow regime of the watercourse was determined using the catchment characteristics.

Catchment parameters for the sites were estimated from the FEH CD-ROM[1]. Catchment area plans for each scheme are shown in Appendix A, along with potential intake and turbine house locations.

The flow duration curves from which potential power production figures can be estimated were calculated using the following

• FEH catchment descriptors were exported from the FEH-CDROM.
• The catchment area was checked and manually adjusted where required.
• BFI was taken from the Base Flow Index Map for Scotland (IOH report 101).
• Potential evaporation (PE) was estimated from Hydra software (1941-70 figures) and converted to actual evaporation (AE) using the SAAR dependent factor “r” given in IOH Report 101[2].
• These descriptors were then used to estimate mean flow (MF) as described in Report 101.
• Q95(1) was estimated using equation 6.2 in Report 108[3].
• Q95(1) was then used to determine the appropriate pooled curve type in IOH Report 126 (updates part of IOH 108) and the full flow duration curve estimated.

A summary of the flow calculations and flow duration figures for each scheme are given in Table 4.1 and in Appendix A of this report.

Two possible intake sites at ****** have been investigated. In addition, this scheme and the scheme at ***** includes indirect catchments being directed to the main intake to increase the available flow. In such cases, the flow conveyance structures e.g. intake and pipe or ditch, will be sized to carry a maximum flow. It has been assumed at this stage that the flow from these indirect catchments will be sized to carry mean flow from the indirect catchment (MF), and multiples of 1.5, 2 and 2.5 times MF. The flow duration curves for the indirect catchments are derived, capped at the maximum figure, and added to the flow duration curve for the direct catchment for the power generation analysis.

Table 4.1 : Flow Calculation Summary

		Intake						
	Scheme	Easting	Northing	Area (km2)	Standard average annual rainfall (mm)	Potential evaporation (mm)	BFI	Mean Flow (m3/s)
5	Gleann Dubhlinn	108000	895400	4.75	1,939	489	0.2	0.218

4.3. Compensation Flow

From 1st April 2006, abstraction from surface water is subject to a CAR (Controlled Activities Regulations) licence, issued by SEPA. The licence allows for site-specific conditions to be set to protect the water environment. This will include compensation or "hands-off" flow that must be left in the river, and therefore cannot be used for generation. At this feasibility stage, the level of compensation flow that would be set by SEPA is not known; however historically this has been in the region of Q90 (the flow exceeded 90% of the time), and the power generation calculations in the following section have therefore been based on this figure. Present compensation flows may well be higher, in the region of Q85 to Q90 if migratory fish are present.

5. Environment

5.1. Introduction
A desk-based study has been undertaken to identify the potential environmental constraints that exist in the vicinity of the sites of the 8 hydro schemes being considered. Various sources of information have been reviewed in order to identify environmental constraints including:

- SNH – Records of designated sites
- Historic Scotland – Records of designated sites; and
- SEPA –Water Quality / Water Framework Directive Characterisation

It should be noted that no consultation with Comhairle nan Eilean Siar, SNH, SEPA or Historic Scotland has been undertaken at this stage.

5.6. Gleann Dubhlinn, South Harris Estate (Scheme 5)
The potential scheme comprises a single intake on the Abhainn Gil an Tailleir with a turbine house further downstream. The hydro-scheme is not located within any environmental designations but the Abhainn Gil an Tailleir flows northwards into Luskentyre Banks and Saltings, a Site of Special Scientific Interest (SSSI).
The SSSI is important for its physiographic and botanical features as well as for feeding, breeding, wintering and migrating birds, especially waders and waterfowl. The grid connection would be required to be sensitively routed to ensure that potential impacts on birds are minimised.
It is also possible that protected species such as otters (*Lutra lutra*) may be present in the area. Further consultation with SNH and local wildlife groups would provide more information on the potential presence of protected species.
Water quality within the Abhainn Gil an Tailleir is not monitored. Downstream of the turbine house, the coastal areas have been identified as 1a definitely at risk of not achieving “good status”.

6. Hydro Power Generation

6.1. Power Generation

A preliminary assessment of the potential annual energy output of each scheme has been made based upon the hydrology of the catchments as calculated in Section 2 above. The results are summarised in Table 3 below. The calculations are based on the following assumptions:

- Gross head estimated from OS maps and site visit, based on outline intake and turbine locations. Note that this gives only an approximate figure at this stage. Topographic survey will be required to confirm the figures.
- Four design flows were tested: mean flow, 1.5 x mean flow, 2 x meanflow, and 2.5 x mean flow
- Compensation flow equal to Q90.
- Various turbines were tested for some of the schemes. The results in Table 6.1 show the results of turbine giving the maximum power output.

Table 6.1: Summary of Power Generation Calculations

		Turbine Grid ref		Design flow = mean flow				Design flow = 1.5x mean flow				Design flow = 2 x mean flow				Design flow = 2.5 x mean flow			
Scheme no.	Gross Head (m)	Easting	Northing	Max flow to turbine (m3/s)	Plant capacity (MW)	Capacity factor %	Annual energy output (MWh)	Max flow to turbine (m3/s)	Plant capacity (MW)	Capacity factor %	Annual energy output (MWh)	Max flow to turbine (m3/s)	Plant capacity (MW)	Capacity factor %	Annual energy output (MWh)	Max flow to turbine (m3/s)	Plant capacity (MW)	Capacity factor %	Annual energy output (MWh)
5	75	108168	896362	0.22	0.117	45%	467	0.33	0.177	39%	607	0.44	0.238	34%	711.71	0.55	0.299	30%	792.40

7. Development Potential of Sites

7.1. Introduction
Eleven sites on the Western Isles were visited. Pressure heads at these sites varied from around 3 metres to 90 metres. Catchment size also varied from 5 square kilometres to 10 square kilometres. The development potential of the ten schemes assessed in this study varied from 9kW to 155kW when turbines were sized to the mean flow, to 23kW to 394kW when turbines were sized at 2.5 times the mean flow. Efficiencies of any potential installed plant varied similarly between the sites. The most efficient developments from the hydrological modelling assessment indicate that turbines sized to the mean flow for each of the sites would prove to be most efficient.

The following section of this report addresses environment development issues that need to be considered if taking any of these projects forward. This section of the report also provides an estimation of likely development costs associated with each of the ten schemes and simple payback periods associated with them.

7.2. Environmental Constraints

In order to make a formal planning application to Comhairle nan Eilean Siar, there are a number of procedures which it is necessary to follow. In general the need for an Environmental Impact Assessment (EIA) should be considered for hydroelectric schemes with an operational capacity of more than 0.5MW.

Given the operational capacity of the eight schemes considered in detail varies from 0.009MW to 0.155MW; none of the developments should require Environmental Impact Assessment (EIA) under either:

- The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2000; or
- The Environmental Impact Assessment (Scotland) Regulations 1999.

However, whilst it is likely that there will be no requirement for EIA to be undertaken it is recommended that a screening opinion is requested from the Comhairle nan Eilean Siar to formally identify what environmental information would be required to support a formal planning application. In addition consultation with SEPA, SNH and Historic Scotland should be undertaken to ascertain their views on the potential hydro schemes.

It should be noted that as a result of the introduction of the Water Environment (Controlled Activities) (Scotland) Regulations 2005 (CAR) all hydro schemes, by virtue of their potential impact on the water environment, require authorisation from SEPA.

Draft guidance on the supporting information required for hydropower applications has been produced by SEPA and it recommends that developers of schemes generating less than 15kW should contact them for further advice. The information requirements will differ according to the type of hydro scheme i.e. run-of-river or water storage, however, it is likely that it would be required to include:

- Flow duration curves for impacted watercourses, pre and post construction;
- Compensation arrangements, river flows or loch levels;
- River habitat or morphology data; and
- Ecology data.

7.3. Economic Aspects

The following sub-sections provide estimates for the overall project costs and simple pay back periods for each of the proposed schemes using turbines sized at mean flow in order to maximise efficiencies. The figures used in these cost estimations come from industry accepted guidelines produced by the British Hydropower Association for small-to-medium hydropower schemes.

Turbine availability has not been factored into this assessments. Similarly, estimations of civil and electrical works costs are based only on indicative hydropower schemes of similar ratings. External costs include items such as engineering design, licences and costs associated with making a planning application. External costs are estimated from Faber Maunsell's internal hydropower development database.

Faber Maunsell would stress that the costs associated with each of the developments should be investigated in more detail in full site-specific technical feasibility studies.

7.8. Gleann Dubhlinn, South Harris Estate (Scheme 5)

Table 7.7 provides estimated high and low overall project costs for Scheme 5, with a turbine sized to the mean flow in order to maximise efficiency. Scheme 5, when sized at mean flow is likely to generate approximately **467 MWh** of electricity per annum. Assuming a conservative Power Purchase Agreement of **£70/MWh**, the annual gross income from this project would likely be in the region of **£32,690**.

Table 7.7: Scheme 5 Overall Project Cost Estimates

Overall Project Cost Estimates		
	Low Estimate (£ 000's)	**High Estimate (£ 000's)**
Machinery	38	70.2
Civil Works	34	93.6
Electrical Works (not including grid connection)	17.6	31
External Costs	11.7	39
Total Cost	**£101.3**	**£233.8**

Assuming that the total development cost of the Scheme 5 project was **£101,300** the project would have a simple pay back period of **3.1 years**. If the total development cost of the project was **£233,800** then the simple pay back period of the Scheme 5 project would be approximately **7.2 years**.

8. Conclusions & Recommendations

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Scheme no.	Plant capacity (kW)	Efficiency %	Annual energy output (MWh)
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Faber Maunsell would recommend that the Highlands and Islands Community Energy Company consider the information contained in this report and then carry out site specific feasibility studies on any sites they wish to develop further.