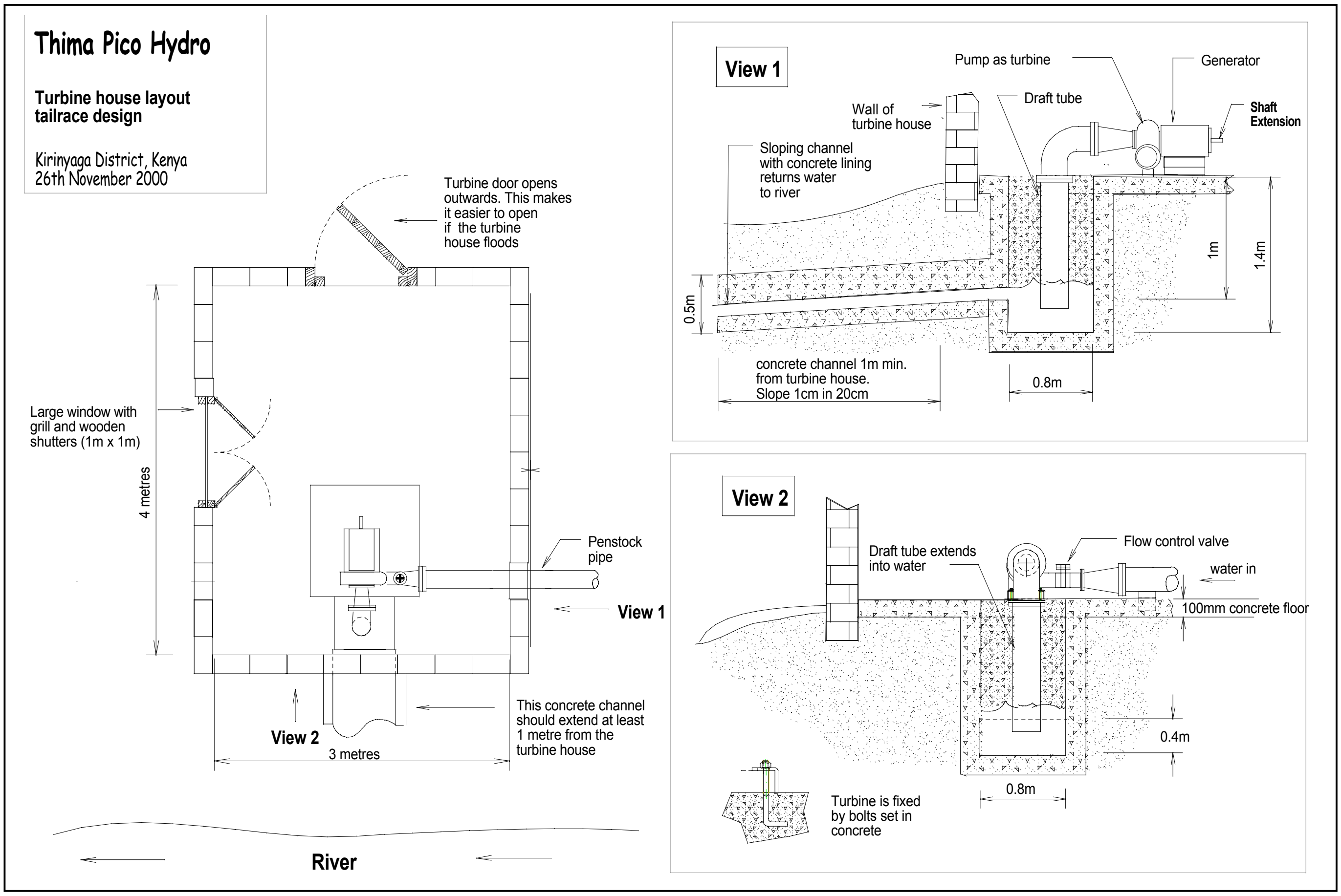
Turbine House

This building houses the pump-as-turbine and generator equipment and ensures that the water is returned directly to the river. It is built above flood level but otherwise close to the riverbank. The location was chosen to maximise the available head whilst minimising the penstock length. A draft tube was added to the outlet of the pump to obtain and extra 1metre of head. Extra floor area was added to the building since the intention is to use the fan end of the generator shaft to drive a 'posho' (maize) mill. Double-ended generators such as this can sometimes be requested from the supplier or otherwise a shaft extension can be fabricated in a workshop and welded in position.



This scheme was installed in 10 days at a cost of $2,600 (excluding distribution and house wiring).

The induction motor as generator produces 2.2kW but a shaft extension provides a 3kW drive for mechanical loads.

Pump-as-Turbine

Since the head at this site was not sufficient for a Pelton turbine, another low-cost and robust solution was selected. Standard centrifugal pumps can be used as turbine generator units if carefully matched to the site. In this case a 'mono-bloc' type was used which is supplied with a directly-coupled induction motor. The pump impeller becomes the turbine runner and the motor is used as an induction generator. The difficulty lies in predicting precisely how a particular pump will perform as a turbine at a given site. Performance prediction equations can be used to select a particular machine if the site conditions are known. The Indian manufacturer Kirloskar Brothers supplied the pump used for this project since they have a sales outlet in Nairobi. To calculate the power output from this pump when it is used as a turbine, it is necessary to look at the pump best efficiency data which was obtained from the manufacturer. The following equations can then be used which take into account the speed increase necessary when operating the pump connected directly to an induction motor which is used as a generator.

$$Q_t = \frac{N_t}{N_p} \times \frac{Q_{bep}}{\eta_{\max}^{0.8}} \qquad H_t = \left(\frac{N_t}{N_p}\right)^2 \times \frac{H_{bep}}{\eta_{\max}^{1.2}}$$

Where:

Q_t = Flow rate using pump as turbine (litres per second)

H_t = Head using pump as turbine (metres)

Q_{bep} = Flow rate at best efficiency point (litres per second)

H_{bep} = Head at best efficiency point (metres)

N_t = Speed of turbine (rpm)

N_p = Speed of pump (rpm)

η_{max}= maximum efficiency (%)

Using data for a Kiloskar 515+ pump, Q_t and H_t were calculated and found to approximately match the site conditions allowing for approximately 2 metres of head loss in the penstock. Despite the prediction, the pump as turbine output was not as high as expected at the speed required for 50Hz. The diameter of the impeller was reduced on a lathe to tune it more exactly to the site conditions. A stuffing box type seal was specified rather than a mechanical seal as replacement parts for the mechanical seal are more difficult to obtain. A bronze impeller was selected instead of cast iron because of the improved resistance to corrosion.

A draft tube increases the head by 1m whilst ensuring that the turbine remains above flood level.

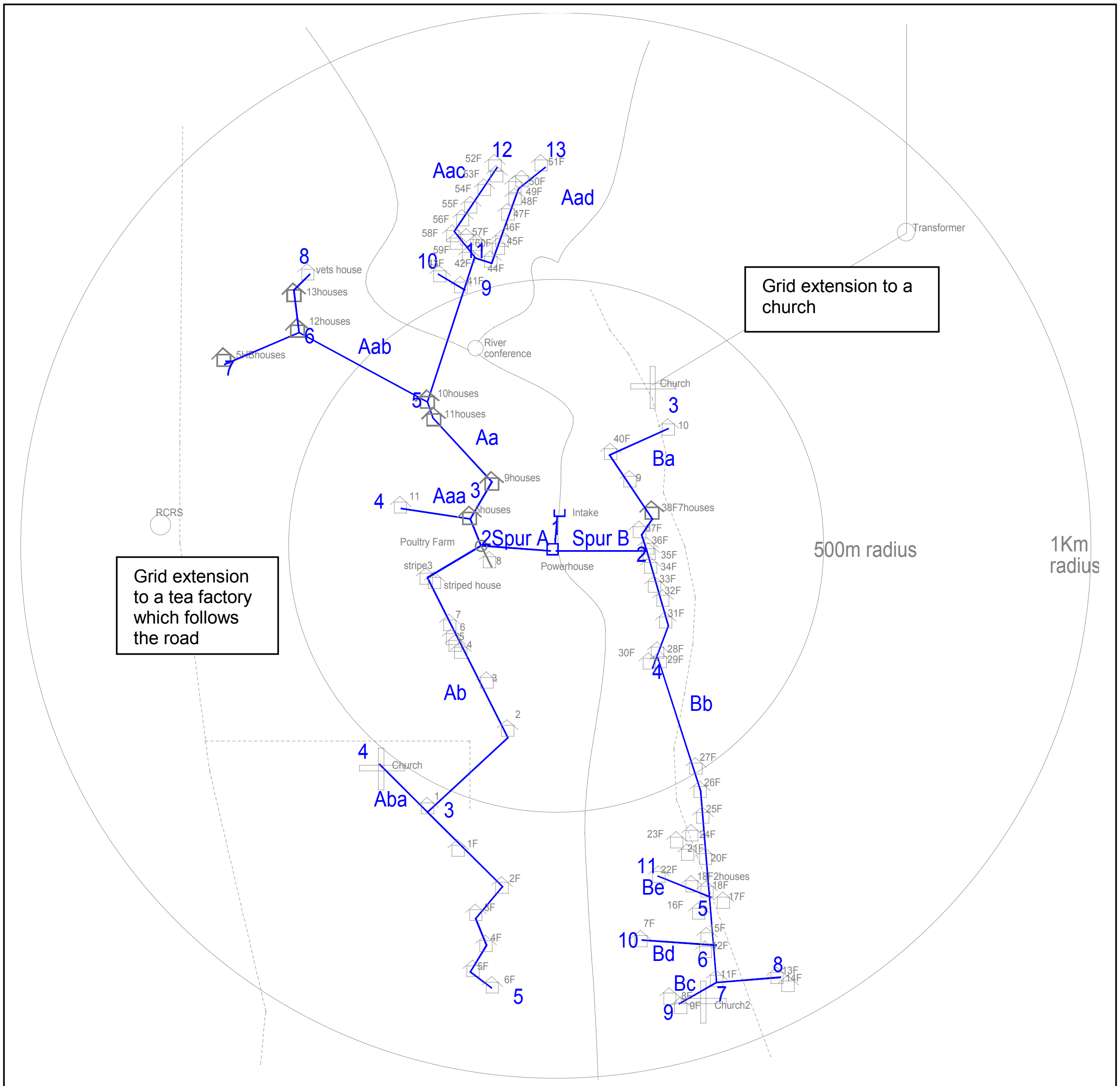
Two 1.8kW cooking rings have been used as a ballast load. An RCD (left) improves consumer safety by minimising the risk of dangerous electric shocks.

Generator

The KDS 515+ pump is fitted with a 3.7kW (5h.p.) induction motor. This produces 2.2kW of electrical power when driven by the turbine (pump impeller). The motor voltage was specified from the manufacture to be 260V rather than 240V and the winding insulation Class F rather than Class B which is standard on machines of this size. Both of these measures help to prolong the life of the windings by ensure that they operate at a much lower temperature than their rated temperature. A 3kW induction generator controller (IGC) provides voltage and frequency regulation by diverting excess power to a ballast load (two 1.8kW cooking rings). A residual current device (RCD) with 30mA tripping current maximises consumer safety by disconnecting the generator if an earth fault develops, either because of a faulty appliance or due to someone accidentally touching a live wire.

Distribution System Planning Using GPS Data

The locations of the houses shown on the plan were recorded with a relatively inexpensive GPS unit (Global Positioning System). This uses satellite technology to triangulate a precise position by 'tuning in' to 3 or more satellites (accuracy of +/-15m). The position is then referenced and stored. Downloading these points to a CAD (Computer Aided Design) program allows a map of the site to be generated. Using the CAD system, the routes for the distribution cables was worked out and drawn in to ensure that all the consumers were connected. A spreadsheet program was used tp determine the minimum cable diameters which could be used whilst still ensuring that all consumers would receive a connection with an acceptable voltage, no matter if their house lies at the end of the cable furthest from the generator. This helped to keep the connection costs for the consumers as low as possible.



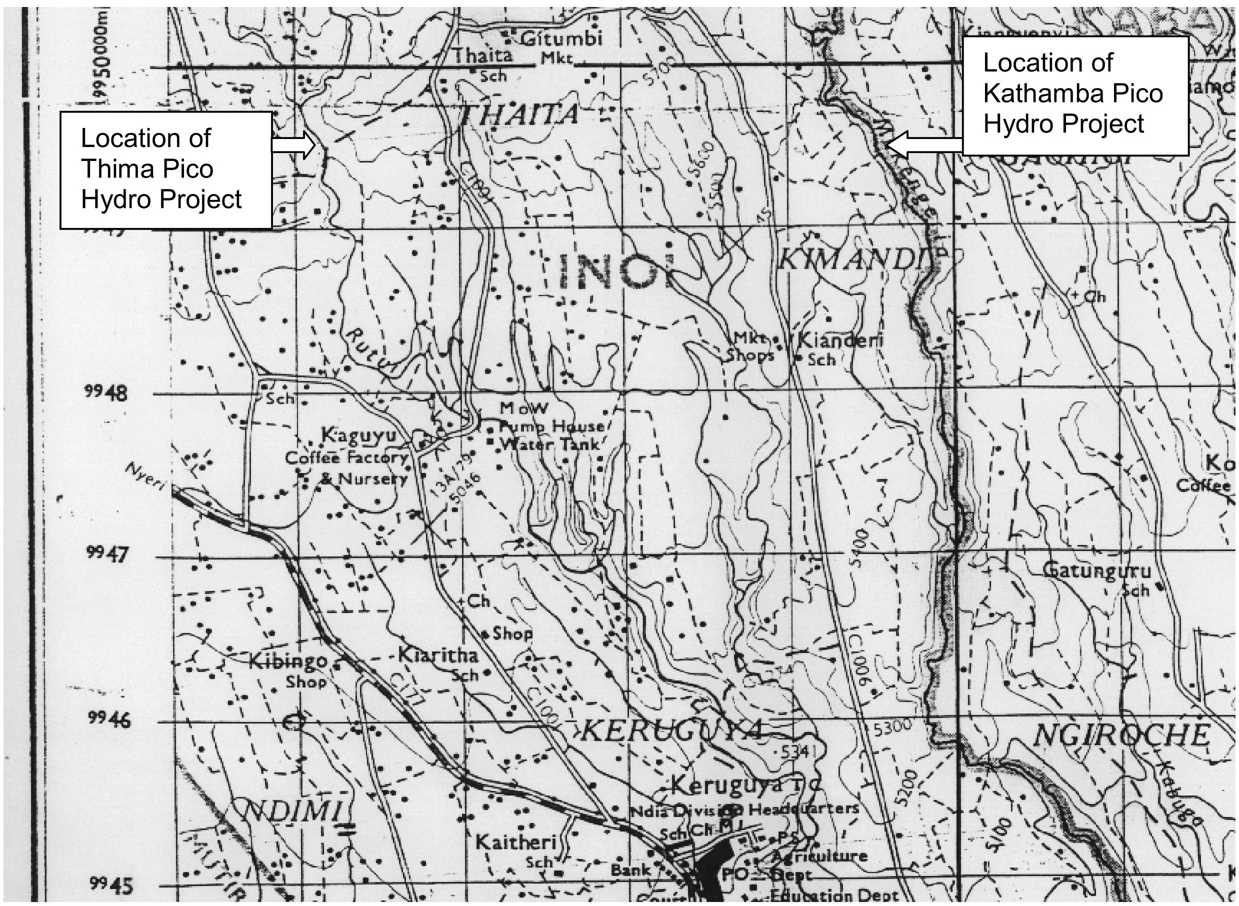
Consumer houses were surveyed using a GPS unit. Using this data a map was drawn and the network planned out. Houses which are not connected have not been shown.

Project Costs

A cost breakdown for the scheme components is given in the table below.

Scheme Components	Cost (US$)
1. Civil works (turbine house)	250
2. PVC penstock	600
3. Turbine, Generator, Controller and Protection	1,750
4. Distribution system, house wiring and energy saving bulbs (110 houses / 200 bulbs)	3,365
5. Labour costs (electrical wiring:200 shillings per house, other labour provided at no cost)	400
Total	**$6,365**

The total scheme cost averages $58 per house. This makes pico hydro very cost-effective when compared to a lead acid battery which, when bought new, not only costs more but requires regular charging, provides DC power only and has a useful life of 2 years or less. Nevertheless, batteries are still used extensively in many parts of Africa. A solar home system, providing a similar amount of power as the pico hydro, suffers the same drawbacks as battery only systems and costs at least 5 times more per house. Clearly pico hydro is limited to areas where suitable hydro potential exists, but given that the flows required are small, an extremely large number of people stand to benefit from this very affordable technology in many parts of Kenya and more broadly in Sub Saharan Africa.



Both demonstration sites are located quite close to each other and convienient for vehicle access. Travelling time is approximately 2.5hrs from Nairobi (Topographical Map: Sheet 121/4 Embu North)

Acknowledgements

The Micro Hydro Centre at Nottingham Trent University would like to thank all the project partners who have worked hard to make this scheme a success. They are Stephen Gitonga and Patrick Balla from the Energy Program at ITDG Kenya; James Muriithi and Theuri Daniel Kahiga from the Renewable Energy Department at the Kenyan Ministry of Energy and the committee and community members of Thima Micro Hydro Group 2000. The Micro Hydro Centre also gratefully acknowledge the funding provided by the European Commission for making this program of demonstration and training possible.