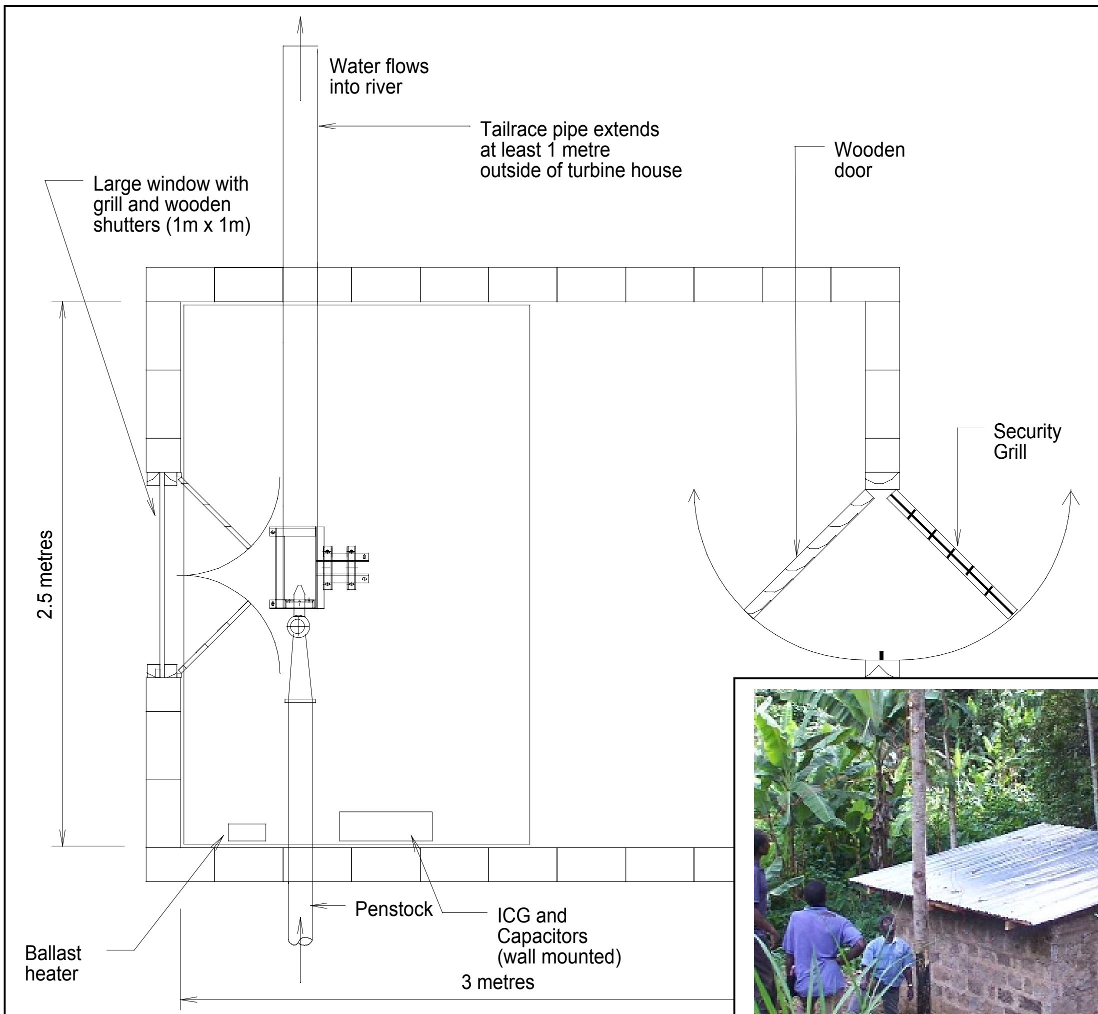
Turbine house.

The location for the turbine house was chosen to give the maximum available head whilst still being high enough away from the river at the bottom of the valley to avoid flooding during the rains. The building was constructed using local stone and timber to minimise material and transportation costs.The farmer who owned the land where the powerhouse was constructed was given a free light as a concession by the local community in return for the land which was used.

Collecting hardcore for the foundations

Digging out the footing for the walls.



Turbine house layout and completed building (right)

Turbine

A Pelton turbine runner was used to convert the hydraulic power into rotating mechanical power. This was connected directly to an induction generator and housed inside a metal casing.

The Pelton runner is defined in terms of its p.c.d. (pitch circle diameter). Runner p.c.d.'s of 120mm, 160mm and 200mm were available. Different sizes of runner operate best with different combinations of head and flow. The runner had to rotate at the correct speed to drive the induction generator. The speed range of these is limited because electricity at 50 Hz is required for the electrical loads connected in the system. For this site, a 6 pole generator coupled to a 200mm p.c.d runner is suitable. This is shown by the following equations:

The operating speed of a six pole induction generator is given by the following:

rpm = $\frac{120 \times frequency}{6}$ x (1+ % generator slip)

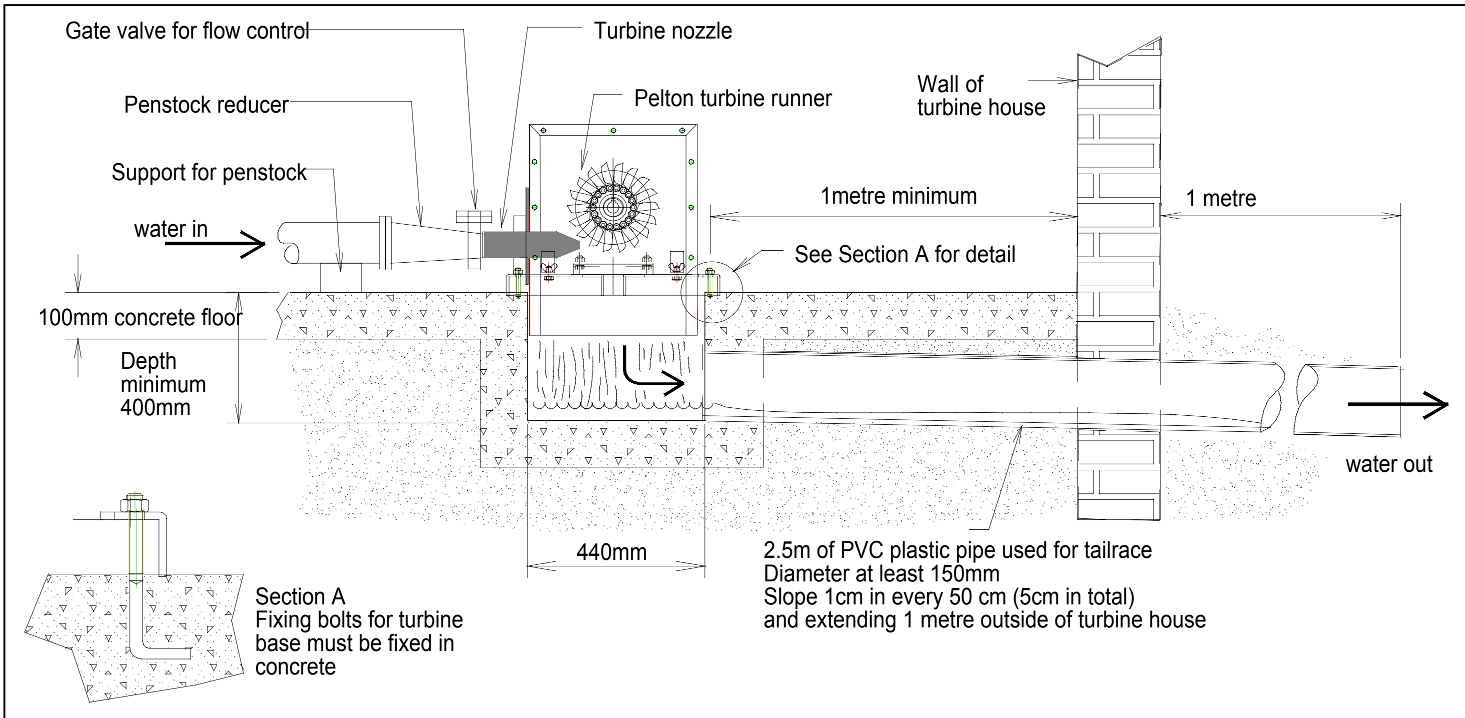
Assuming a typical slip of 3% then the speed (rpm) = (120 x 50 / 6) x 1.03 = 1030 rpm

The equation for selecting the correct turbine runner for this speed and 28m net head is as follows:

Ideal p.c.d = $\frac{38\sqrt{H_{net}}}{rpm} = \frac{38 \times \sqrt{28}}{1030} = 195mm$

The design flow for this turbine is 8.4 l/s (0.0084 m^3/s)

Jet Diameter = $\sqrt{\frac{Flow}{3.43 \times \sqrt{H_{net}}}}$ = 22mm



Section view through turbine house

Local Manufacture

Turbine components were fabricated by Kenyan Electrical Distributors who received training during a 2 week course for African manufacturers of pico hydro equipment held by the Micro Hydro Centre near Nairobi in February 2001. Another Kenyan firm, Rodson Electronics, who also participated in the training, fabricated the load controller, the enclosure and made the internal connections to the capacitors and protection equipment.

Generator

An IP55 1.5 kW 3phase induction motor with 240V delta connection was selected for use as the generator. As shown above, the required number of poles was 6. In addition, the IP rating for the selected motor was IP55 to ensure maximum protection from entry of water and dust inside the machine.

The connection of capacitors to the motor is required in order for it to operate as a generator. By connecting the capacitors in a C-2C arrangement it is possible to produce single-phase power efficiently from a 3-phase induction motor.

200 p.c.d. Pelton Turbine and Nozzle

1.1 kW Induction Generator (6 pole)

An IGC (Induction Generator Controller) ensures that the voltage and frequency of the electricity produced remain constant by sending excess power to a ballast heater during times of changing consumer load. A 2kW electric cooker is used as a ballast at this site. The controller and capacitors are housed together in a lockable enclosure. In addition to these components, an RCD (Residual Current Device) is connected for consumer safety and a motor protection switch is used to protect the generator windings from overheating due to excessively high currents.

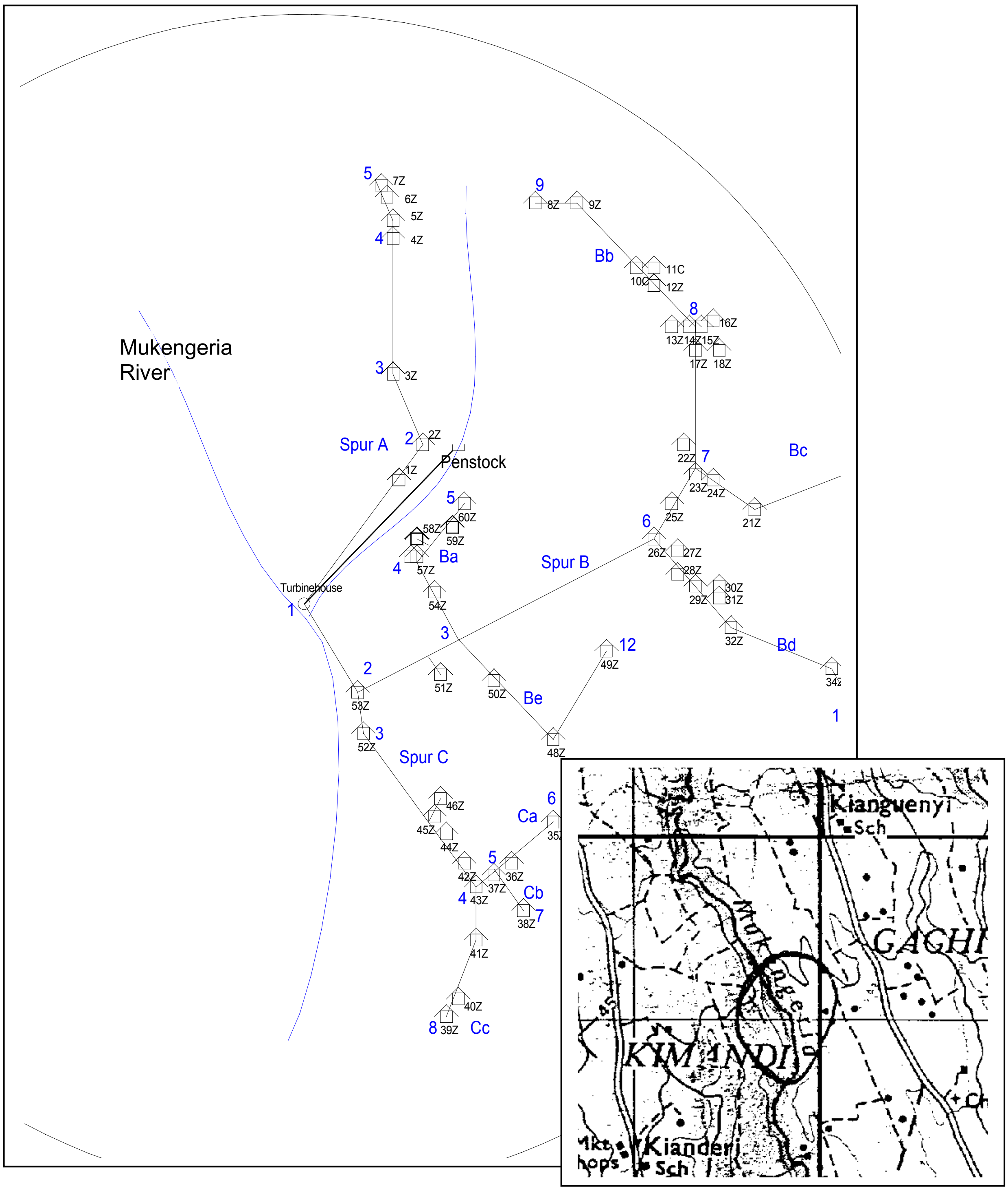
Operator Training

Sufficient training for key individuals was essential to ensure that the scheme will continue to be operated and maintained successfully in the future. Local electricians were involved from the beginning of the turbine and generator installation. They were given on-the-job training to ensure that they could locate faults and replace damaged components. This was particularly important as these are the first schemes of their kind in Kenya. The training was back up with comprehensive documentation including complete circuit diagrams and a maintenance schedule. The new internet facility in Kerugoya town (1hr walk from the site) provides a route to a further source of technical back-up; the operators are now able to request advice directly from pico hydro specialists in Nairobi or the UK if a problem arises which cannot be solved locally. The consumers are charged a fixed monthly tariff depending on whether they have two lamps or one. This is used to pay the operators wages and to contribute to a maintenance fund to replace worn components and keep the scheme operating.

Trained pico hydro installers and operators, Peter Kinyua Mbui and David Kinyua with the IGC enclosure and ballast.

The Distribution System

The plan below shows the position of the consumers relative to the generator. The large circle represents a radius of 500m from the turbine house. The location of the houses was recorded using a widely available and relatively low-cost hand-held GPS system. This allowed the length of cable required to reach all the houses to be accurately calculated and then sized to ensure that even consumers at the furthest points in the system received a supply which was within an acceptable voltage range without excessive cost. This was important as the entire cost of the distribution system and house-wiring was met by the electricity consumers. Local trees were used for distribution poles after basic treatment to reduce damage by termites and weathering. The installation of the distribution system initially required a considerable degree of co-ordination to collect, treat and erect a sufficient number of poles. Guidance was given on the required pole height, methods of treatment, the d buried depth and the spacing. Every consumer contributed one or two poles to the scheme.



The first few houses were connected under supervision from the project implementers, particularly with regard to pole positioning, cable tensioning and service wire connection. The final phase of the project, to connect the remaining houses, continued under the direction of the local electricians and committee members without the need for much external support. The immediate prospect of electric lighting and connection of small electrical loads such as radios and, in some cases, mobile phone chargers, rapidly encouraged the payment of the remaining connection fees. This allowed the final cables and house wiring components to be purchased. In addition, the electricians were paid on a per consumer basis for the house wiring and therefore were keen to keep up the pace of installation of the final poles and conductors.

The first house is connected to the generator

This picture on the right was taken through the front door of a house in Kathamba a few minutes after the first energy saving lamps had been installed and the generator switched on. Despite only drawing 8 watts of power, these lamps give out a bright light. This is particularly apparent in homes that have only previously been lit with kerosene lanterns.

After months of anticipation, the lights were finally switched on (6th November 2001).

Project Costs

A cost breakdown for the scheme components is given in the table below. The hydro potential at this site was limited by the small flow. Due to the limited power available and the relatively large number of consumers living nearby, the power per house is sufficient only for one or two lamps and a radio. This however, had the advantage that the cost of the distribution was divided amongst more people and so households at all income levels were able to benefit. Consumers paid for a 1 lamp or 2 lamp connection depending on how much they were able to afford.

Scheme Components	Cost (US$)
1. Civil works (intake and turbine house)	250
2. PVC penstock	425
3. Turbine, Generator, Controller and Protection	1,200
4. Distribution system, house wiring and energy saving bulbs (65 houses / 100 bulbs)	1,750
5. Labour costs (electrical wiring:200 shillings per house, other labour provided at no cost)	163
Total	**$3,788**

The total cost was $58 per house. This is particularly reasonable 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. A solar home system, providing a similar amount of power as the pico hydro has the same disadvantages as a battery only system and would have cost at least 5 times more per house.

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 Kathamba Self-Help 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.