A Pico-Hydro Plant in Duble?

Introduction
In this report I present my findings concerning the viability of a pico-hydro electrical plant in Duble. Its purpose is to be a first evaluation of the proposed project. Much more work has to be done if the community in Duble concludes that it is worthwile to proceed.

Conclusions
1. the most cost effective option is the generation of about 3 kW electric power
2. the site has two drawbacks:
   a) a long penstock is needed for the realisation of a moderate head
   b) most of the houses are outside the radius of 1 km from the optimum place of the powerhouse.

Extra money is needed to compensate for the drawbacks. Therefore the plant will be relatively expensive.

Acknowledgements
Two articles were very valuable to master the knowledge concerning pico-hydro power plants:

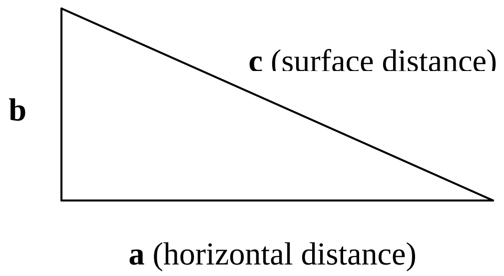
a. Nepal Case Study, parts 1, 2 and 3
   by Nigel Smith, Ghanashyam Ranjitkar and Bhola Shrestha.
   (http://www.eee.nottingham.ac.uk/picohydro/documents.html)
b. Pico-Hydro for Village Power – a Practical Manual for Schemes up to 5 kW in Hilly Areas,
   by Phillip Maher and Nigel Smith
   (http://www.eee.nottingham.ac.uk/picohydro/documents.html).

Both articles can be printed from the internet.
Reading is strongly advised.

Nepal Case Study is based on a project at Kushadevi, a small community close to Kathmandu. According to my information Kushadevi is at the right side of the road from Kathmandu to Panauti, some kilometers before Panauti.
I advise to contact the User Committee in Kushadevi to discuss the management of such a project.

Terminology

- intake	point where the water enters the pipe to the turbine,
- forebay	structure at the start of the penstock to ensure that the water is sufficiently deep.
- head/drop	altitude of the intake minus the altitude of the spot for which you state the head.
- penstock	pipe from intake/forebay to turbine.
- turbine	device to convert fluid (water/steam) power to mechanical (rotating) power.
- generator	device to convert rotating power to ac electrical power.
- horizontal distance	distance in a direct line between a first point and a point directly above or below a second point (this distance is given by a GPS).
- surface distance	distance when you walk from one point to the other (calculated).



$$\mathbf{c}^2 = \mathbf{a}^2 + \mathbf{b}^2$$

- load control	system to keep the load on the generator constant.
- electrical load	device driven by electricity, e.g. a lamp.
- load limiter	device preventing that too much load is taken by a consumer. Necessary to prevent overloading of the system. In an overloaded system fluorescent lamps might not work properly and might be damaged by voltage drop.
- voltage drop	loss of voltage across an electrical load in the distribution system, because of the cable resistance.

Potential of the site

The site was visited in the beginning of March 2008. This is not the end of the dry season, so the all year flow of the river will be less then the flow measured.
Close to the village there are watermills, driven by the water of the Kopche Khola. So a section between two mills was explored. In this section no water is used for irrigation or is diverted for making drinking water. Some meters upstream the first mill we measured a flow of more than 20 l/s. Just downstream the second mill the measurement of the flow was more difficult. We could not catch all the water. Here we measured over 10 l/s and I estimate a total flow of about 15 l/s at that point. The accuracy of our measurements is poor as we used the bucket method, which is only suitable for flows less than about 10 l/s. Further we couldn’t catch all the water.
Considering this I assume an all year flow of between 10 and 15 l/s.

The course of the river and a series of points were measured with a GPS (Garmin GPSmap60 CSx). Accuracy, as stated by the apparatus was better than ±10 m. According to my experience, the accuracy of altitude differences is much better.
The course of the river and the points of interest are shown in figure 1.

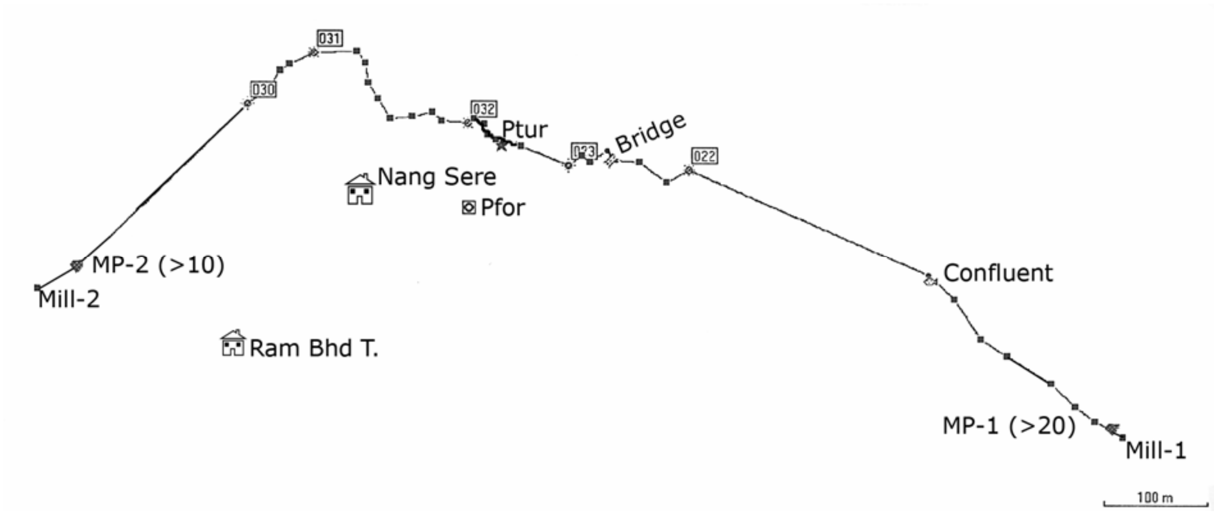


Figure 1

The height between the two mills is 122 m and the length of the track is 1200 m.
Along the riverbank there is a spot where the riverside is steep and where a penstock could be constructed easily. The head at this point is 47 m. The proposed position for the penstock is between the marks ‘Pfor’ and ‘Ptur’.
The height between mark ‘Pfor’ and the water intake, close to Mill-2, is 5 meter. The distance, as the crow flies, being 380 m.
Considering the terrain between these two points, the accuracy of the measurements and the fact that seepage should be avoided a canal is not a viable option to bring the water to mark ‘Pfor’. A pipe of about 430 m. could do the job.
Choosing a pipe for this section, it is obvious that we do not build the forebay at mark ‘Pfor’ but just below Mill-2.
If we want more power (head) than which is available at mark ‘Ptur’ we can make an extension of the penstock by following the course of the river. Waypoint ‘022’ is a good location for building a powerhouse. According to my recollection this should also be possible at mark ‘Confluent’. At that point a small stream joins the river.
The floor of the powerhouse should be higher than the monsoon level of the river. In my calculations I assume that this is not more than 2 m. above the level during our visit.

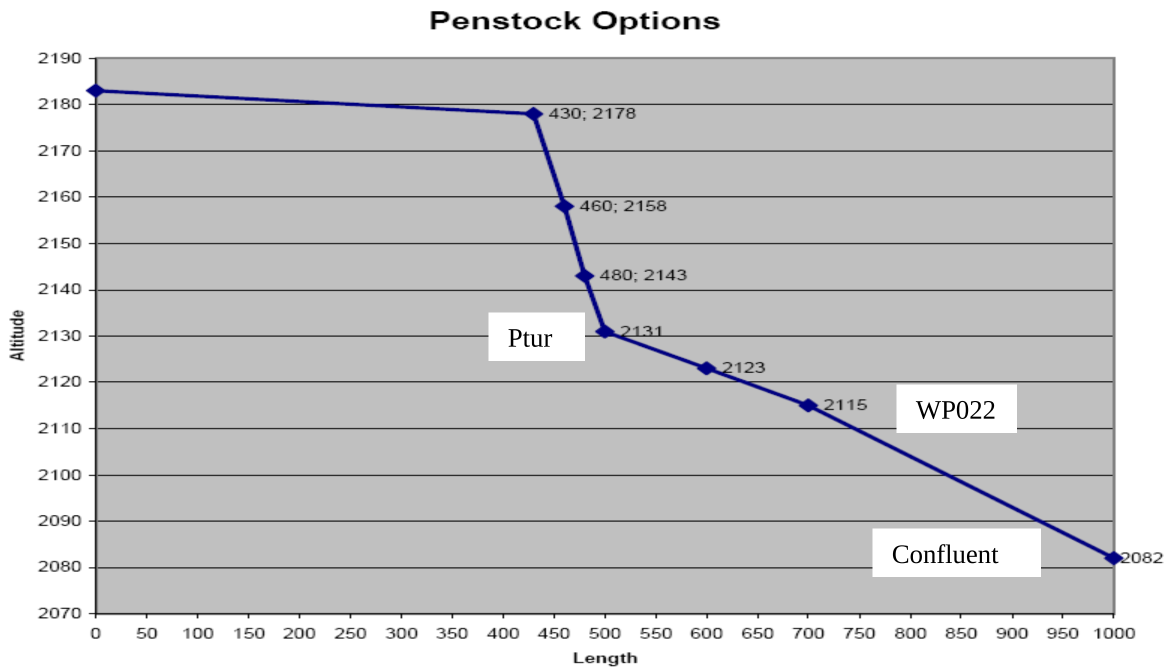


Figure 2

Figure 2 shows the head profile for different penstock options with marks where the powerhouse could be located. The material chosen for the penstock is high density polyethylene (HDPE). For different sections a pipe of proper pressure rating and diameter is chosen.

Figure 3 shows the pipe cost up to specific points and how much power that can be expected at these points.

Pipe sections, power and cost at specific points

Altitude (m)	Section length (m)	Section drop (m)	Pressure rating (bar)	Head loss at 13 l/s (m)	Total Effective drop (m)	Waterpower (watt) at Flow 10 l/s	Electric power (watt) at Flow 10 l/s	Waterpower (watt) at Flow 15 l/s	Electric power (watt) at Flow 15 l/s	Section Cost ($)	Cumulated Cost ($)	Position Power-house
2183												Forebay/Reservoir
2158	468	25	2,5	3,56	21,40	2097		3146		1769	1769	
2143	27	15	4	0,46	35,90	3518		5277		123	1892	
2131	24	12	6	0,50	47,40	4645	2002	6968	3003	157	2049	Mark 'Ptur'
2123	96	8	6	2,00	53,40	5233	2267	7850	3400	628	2677	Max. for 6 bar pipe
2115	100	8	10	4,00	57,40	5625	2443	8438	3665	986	3663	Waypoint 022
2082	260	33	10	10,40	80,00	7840	3440	11760	5160	2564	6226	Confluent
									Total	6226		

Overall efficiency of the Scheme (%): 45
Monsoon level (m above present level): 2

Pipe data

Pressure rating (Bar)	Outside diameter (mm)	Inside diameter (mm)	Weight per 6 m (kg)	Price in 2000 ($/m)
2,5	140	132	10	3,78
4	125	113	13	4,55
6	125	107	20	6,54
10	125	94	32	9,86

Figure 3

Evaluating these figures, my choice is a 3 kW plant at mark ‘Ptur’. For this plant a flow of 15 l/s is needed. As it is not proven that this flow is available during all the months of the dry season I would construct a large intake reservoir just below Mill-2.
More accurate measurements might show that the reservoir is not needed.
A reservoir of 10 x 10 and 1,5 m deep will ensure at least 5 hours of operation in case the flow reaches a low mark of 5 l/s. At a flow of 10 l/s the availability of electrical power can be compared with the situation in Kathmandu nowadays.
In addition to the cost for the pipe we also need to pay for:

- construction of the powerhouse,
- extra cement to construct the reservoir and some supports for the penstock,
- professional help for welding the pipe (at least one week),
- a set consisting of turbine, generator and electronic load controller (ca. $ 3.000,-). This set should also include a lightning arrestor and an earth leakage circuit breaker.

I guess that the total cost for generating the 3 kW will be about $ 7.000,-. However remember that details are copied from a project finalized in 2000. Availability and prices have to be checked and actualised.
Compared with plants already in use in Nepal we have a long penstock. Especially the high-pressure part of the penstock should be as short as possible to keep costs low.

Alternative location of the penstock and powerhouse

When we were approaching Duble from the South, Kame Sherpa showed me a gully where the construction of a penstock would be advantageous. It was a steep spot, where a head of more than 50 m could be possible. It is a pity that I did not arrange for measurements at this location. This was due to the fact that I did not see any water.
However, it would be interesting to explore how much water can be brought here and where a powerhouse could be constructed.
Disadvantage of this site is that it is far away from the houses. The problem of long cables is part of the discussion of the distribution system in the next part of this report.

Figure 4 shows the amount of electrical power which can be expected for combinations of flow and head. The formula for this calculation is:
Power (Watt) = head (m) x flow (l/s) x 9,8 (gravity force) x 0.45 (efficiency factor).

Hydro Electric Chart

How much electric power (kWatt) can be expected from a stream

Head (m) \ Flow (l/s)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	0,44	0,53	0,62	0,71	0,79	0,88	0,97	1,06	1,15	1,23	1,32	1,41	1,50	1,59	1,68	1,76
25	0,55	0,66	0,77	0,88	0,99	1,10	1,21	1,32	1,43	1,54	1,65	1,76	1,87	1,98	2,09	2,21
30	0,66	0,79	0,93	1,06	1,19	1,32	1,46	1,59	1,72	1,85	1,98	2,12	2,25	2,38	2,51	2,65
35	0,77	0,93	1,08	1,23	1,39	1,54	1,70	1,85	2,01	2,16	2,32	2,47	2,62	2,78	2,93	3,09
40	0,88	1,06	1,23	1,41	1,59	1,76	1,94	2,12	2,29	2,47	2,65	2,82	3,00	3,18	3,35	3,53
45	0,99	1,19	1,39	1,59	1,79	1,98	2,18	2,38	2,58	2,78	2,98	3,18	3,37	3,57	3,77	3,97
50	1,10	1,32	1,54	1,76	1,98	2,21	2,43	2,65	2,87	3,09	3,31	3,53	3,75	3,97	4,19	4,41
55	1,21	1,46	1,70	1,94	2,18	2,43	2,67	2,91	3,15	3,40	3,64	3,88	4,12	4,37	4,61	4,85
60	1,32	1,59	1,85	2,12	2,38	2,65	2,91	3,18	3,44	3,70	3,97	4,23	4,50	4,76	5,03	5,29
65	1,43	1,72	2,01	2,29	2,58	2,87	3,15	3,44	3,73	4,01	4,30	4,59	4,87	5,16	5,45	5,73
70	1,54	1,85	2,16	2,47	2,78	3,09	3,40	3,70	4,01	4,32	4,63	4,94	5,25	5,56	5,87	6,17
75	1,65	1,98	2,32	2,65	2,98	3,31	3,64	3,97	4,30	4,63	4,96	5,29	5,62	5,95	6,28	
80	1,76	2,12	2,47	2,82	3,18	3,53	3,88	4,23	4,59	4,94	5,29	5,64	6,00	6,35		
85	1,87	2,25	2,62	3,00	3,37	3,75	4,12	4,50	4,87	5,25	5,62	6,00	6,37			
90	1,98	2,38	2,78	3,18	3,57	3,97	4,37	4,76	5,16	5,56	5,95	6,35				
95	2,09	2,51	2,93	3,35	3,77	4,19	4,61	5,03	5,45	5,87	6,28					
100	2,21	2,65	3,09	3,53	3,97	4,41	4,85	5,29	5,73	6,17						
105	2,32	2,78	3,24	3,70	4,17	4,63	5,09	5,56	6,02							
110	2,43	2,91	3,40	3,88	4,37	4,85	5,34	5,82								
115	2,54	3,04	3,55	4,06	4,56	5,07	5,58	6,09								
120	2,65	3,18	3,70	4,23	4,76	5,29	5,82									
125	2,76	3,31	3,86	4,41	4,96	5,51	6,06									
130	2,87	3,44	4,01	4,59	5,16	5,73										
135	2,98	3,57	4,17	4,76	5,36	5,95										
140	3,09	3,70	4,32	4,94	5,56	6,17										
145	3,20	3,84	4,48	5,12	5,76											
150	3,31	3,97	4,63	5,29	5,95											

Figure 4

Distribution system

When you connect an electrical load to a cable, the voltage over the load will drop at the moment you switch it on. How much depends on the line current and the cable resistance. The cable resistance depends on the material of which the cable is made, the thickness of the cable and the length of the cable.

Line current = load connected / nominal voltage.
Cable resistance = length of the cable x specified value for that cable.
Voltage drop = line current x cable resistance.

We want a distribution system suitable for ordinary Fluorescent tubes and Compact Fluorescent Lamps (CFL's).
In that case the voltage drop should be no more than 6% from the design voltage. These lamps perform well between +6% and -6% from the nominal voltage. When we adjust the voltage from the generator at +6% we can accept 12% voltage drop over our load.

That is all you need to know about the calculations needed to design a simple distribution system. You calculate the voltage drop for each load (house). Variables are the cables chosen

for each section and the length of each section. It will be obvious that you have to perform a lot of calculations for finding a scheme optimized for cost.
I determined the location of only some houses and even for these houses I do not know if they should be connected or not.
Therefore I cannot make the calculations.

For an economic viable pico power distribution system all loads should be within 1 km from the powerhouse.
In Duble the proposed location of the powerhouse is far away from most of the houses and the houses are scattered over the hill. Even concentrations of 2 or 3 houses are seldom. Standard cables will show too much voltage drop.
The problem caused by this situation can be solved by constructing a cable backbone with sections of (very) thick cable to points where a number of houses is within a distance of for instance 200 meters.
A very speculative (worst case?) price for such a backbone could be $ 4000,-(excluding the poles). A good estimate can only be calculated when we know the location of all participating houses. There are places where we cannot go with cables, so it is necessary to make a detailed map of the area. Otherwise we are not able to choose the most cost effective tracks for the backbone and the house connections.

If each house is at a distance of 200 meter from the backbone, the additional costs for each connection would be about $60,- for the insulated copper wire and about $ 10,- for the connection box with a fuse and load limiter. Depending on distances between houses it is possible to share copper cable.

Running cost

The running costs are the minimun costs that have to be paid for by the participants.
The running costs are the maintenance costs and the salary for one or two part-time operators.

Usually the annual maintenance costs are calculated as 6% of the capital cost.
The capital cost can be calculated after we know more about the distribution scheme.

Let us assume $ 14.000,- capital cost, an operator salary of $ 35,- per month, two operators and the possibility to subscribe to packages of 25, 50 or 75 Watt.
When all electricity is sold, the monthly cost for a 25 Watt package would be about $ 1,17.
That is for:
- maintenance 14.000 x 0,06 / 3000 x 25 / 12 = $ 0,583 and
- for the operators 35 / 3000 x 25 x 2 = $ 0,584].

Next steps

At the moment we do not have sufficient information to decide.
Important open questions are:

1. What is the potential of the alternative site?
2. Is somebody planning to use the power which is produced in day-time and which normally would be wasted? – any plans for industrial activities?
   [The largest motor, which can be connected to the 3kW generator, provided it is not switched on under load, is 560 Watt or 0,75 horse power].

3. Check materials. Is HDPE pipe still cheaper then PVC pipe in Nepal?
   Can we buy a cheaper brand of pipe for the first section (almost 500 m)?
   Can we buy ABC cable in stead of ACSR cable? (ABC = Aerial Bundle Conductor, ACSR = Aluminium Conductor Steel Reinforced)
4. What are the current prices for the pipes and the cables?
5. Is the community prepared to provide labour force for the construction of the reservoir, penstock, powerhouse and distribution system?
6. Can the community afford to pay the running costs?
7. Can the community afford to pay a percentage of the capital cost? Perhaps as a (bank) loan?
8. Can we get governmental or other subsidies?
9. How much money do sponsors contribute?
10. Position of the houses of the participants and peculiars of the area to calculate an optimised distribution system

Most of these questions have to be answered by the community of Duble and its representatives. If they conclude that it is worthwile to proceed I will start looking for sponsors (point 9). Further, I can help with point 10.

Ton van der Kop

Appendixes:

1. Waypoints in Duble

Appendix-1

Waypoints in Duble