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Site Selection and Installation of Small Hydropower Equipment in Mozambique

(ORIGINAL)

FINAL REPORT

Submitted by:
International Network on Small Hydropower

Final Report

I. Background

Reliable and affordable sources of energy are pre-requisites for economic and social development. Currently, some 2 billion people, one third of the world's population have no access to electric power. In addition, the major sources of commercial energy in developing countries rely on imported fossil fuels giving rise to both high import bills and environmental problems. Small hydropower potential exists in most developing regions and if this renewable and clean energy resource can be harnessed it could provide economic and environment benefits to developing countries. In China it has been estimated that some 300 million people depend on small hydropower for electric power and that annually there is an increase of about 1,200 small hydro power stations with an installed capacity of around 2 million KW.

Throughout the world, opportunities are abundant for the development of SHP schemes. Thanks to the active role SHP technology has been playing in the supply of rural energy, environment protection and poverty alleviation, the international community is paying more attention to the potential of SHP in developing countries and countries with economies in transition. As a technology with excellent social, economic and environmental benefits, SHP systems have been widely used in rural areas in many countries. As an environmentally sound and affordable energy technology it has become an effective way of stimulating the economy of rural and remote areas.

Mozambique is a country in southern Africa with increasing energy demand and large SHP potential. Many rivers originating in neighbouring countries pass through Mozambique before flowing into the Indian Ocean. These rivers are rich in hydraulic resources. In the mountainous areas, many potential SHP sites remain untapped, while a handful of SHP stations are discarded due to either war damage or bad management. On the other hand, only 15 percent of the population in Mozambique has access to electricity and most of them live in cities. Almost all rural areas are non-electrified. SHP can play a key role in rural electrification in Mozambique, leading to poverty alleviation and social change.

The Government of Mozambique, through the Ministry of Industry and Commerce (MIC) approved the UNIDO reformulated Integrated Programme matrix which includes an output on the provision of hydro power through a pilot demonstration project. The Ministry of Mineral Resources and Energy (MIREME) is the direct counterpart for this output.

The work which has been performed could be summarized as Site Selection, Field Consultation Mission and the homework of Designing and layout of civil works.

II. Consultation mission and Site Selection

On 8th Dec 2003, the consultation team arrived Maputo on around 15:00 hours and then directly went to site on Mutivaze river of Malema town in Nampula province of Mozambique after 39 hours trip by air and on road. The Mission members include:

Prof. Tong Jiandong, Director General, and Mr. Li Zhiming, Chief Engineer, International Network/Center on Small Hydro Power (IN-SHP), Hangzhou, China
Mr. Steven Dils, Programme Officer, UNIDO office Mozambique

Counterpart:
Mr. Remos Mucatar, Administrator, Malema District
Mr. Manuel da Costa, Technician of Public works and housing, Malema District.

The site selection has been conducted based on the following technical criteria, mainly:

1) Suitable water head
2) Required diversion channel length
3) Required penstock length (to be less than 40m)
4) The slope of the location of the powerhouse to be not more than 20 degree
5) The availability of the ram material locally

Requirement for the selection of the site, as agreed upon with MIC and MIREME, were as follows:

- Promote local development
- Simple technology and local maintenance
- Joint UNIDO- Government budget
- Quick implementation and impact

Prior to the team's field visit, the Directorate of Energy (DNE), Directorate of Industry (DNI) and UNIDO Mozambique made a preparatory mission visiting 6 sites to inform the local authorities and do a first site assessment for recommendation to the technical assessment by UNIDO International Center on Small Hydro Power (IN SHP), China.

The mission team collected local data and made technical assessment on field. According to the analysis and comparison, the team recommended installing one 75 kW axial flow turbine unit instead of turgo turbine, as previously proposed to maximize the benefits, based on the field conditions.

The need for electricity has been well justified. The existing local power needs has been mainly met through the diesel generator, with 200 kVA output among a total of 250 kVA. Annually around USD 54,500 will be consumed for diesel and maintenance cost. But the scarcity of electricity has hindered the local development and with provision of electricity service, lots of agro-produce will generate local agro processing, local tourism infrastructure - site is earmarked for tourism, illumination, hospital, school etc – and next year evening classes, telephone lines to come by February 2004, television transmission, new local industries development etc are in focus.

Here is a brief account of the project parameters:

- Water head : 7 m
- Discharge : 1.5 m^3/s on 9-12-03
- Capacity : 75 kW

Accordingly, the most cost-effective equipment for the site parameters identified above has been selected as follows:

Project Tech Parameters	Equipment	Specifications
H =7m Q =1.5m3/s N =75 kW Hz =50 Voltage = 415 V	Turbine	Type = ZD_{560} - LH-60 Speed n = 750 Efficiency y= 80.8% N = 84 kW Weight = 5 Ton
	Generator	Type = SF_{75} – 8/590 Speed n = 750 Power factor= 0.8 Output current: I = 135.3 A Excitation current= 119 A Efficiency y = 89.7% Output N = 75 kW Output Voltage: V=0.4 kV Frequency f= 50Hz Excitation voltage: V= 24 V Weight: 1.32 Ton
	Governor	Type: YT-3000 N-m Machinery hydraulic
	Control Panel	Type: 13KSF-42(H) Could be used for excitation regulation, control, measurement and protection and distribution

III. Follow up actions and relevant Cost /Task sharing as proposed below:

1) UNIDO HQ: overall coordination. Inform timely, one-month notice, future missions to Mozambique with clear TOR

2) UNIDO International Center on Small Hydro Power (IN-SHP):
   - Technically assess site selection
   - Selection and manufacturing of equipment
   - Supply equipment to Maputo port
   - Training for local operators on operation and maintenance

3) UNIDO office in Mozambique jointly with DNE/DNI
   - implementation and supervision of the project
   - relation Local/ Provincial/ Central Government
   - Receive mission from UNIDO IN SPH to Mozambique

4) Local Government of Malema:
   - Construction of dam according to technical specifications to be sent by UNIDO/ IN-SHP to UNIDO Mozambique by end of December 2003, to be forwarded to Malema.
   - Including: increase of dam wall by 1 metre (with local stones and cement), intake canal, fore bay, powerhouse, penstock (0.6m in diameter in metal)
   - Transmission from site to local distribution less than one Km.

5) Central Government
   - Approval of site (urgent)
   - Provision of budget to local government for civil works

IV. Proposal second site

Should be proposed soon and preferably in Maputo area for promotional purposes of small hydro power, easier logistics and a minimum of 8 m water head on a dam to limit the civil works, and thereby the contribution of the local government.

UNIDO Mozambique proposes a site on Pequenos Lebombos dam for Central Government consideration.

The potential beneficiary is a recently privatised local company, CITRUM, currently struggling with an electricity bill of USD 4000/month for irrigation pumps. The living conditions of the surrounding community, currently very much engaged within the company, would be enhanced by provision of electricity and water. It is also suggested that a financial contribution for the civil works, normally the local government contribution, could be negotiated with the company.

V. The second consultation mission to Mozambique

The sites proposed by the first mission were denied by local government because of non-technical reasons. The second consultation mission was then conducted to evaluate the alternative sites proposed by local government. The UNIDO delegation consisting of three experts from the International Network on Small Hydro Power (IN-SHP) as well as two engineers from M/s Powermate International, where the Sub-center of IN-SHP for Africa is functioning, covered four sites in Mozambique from 18 January to 27 January 2005 and the team was guided by the UNIDO Mozambique, Ministry of Energy and Ministry of Industry. The sites visited are in the order of visit Rotanda, Maue, Majaue and Kazula.

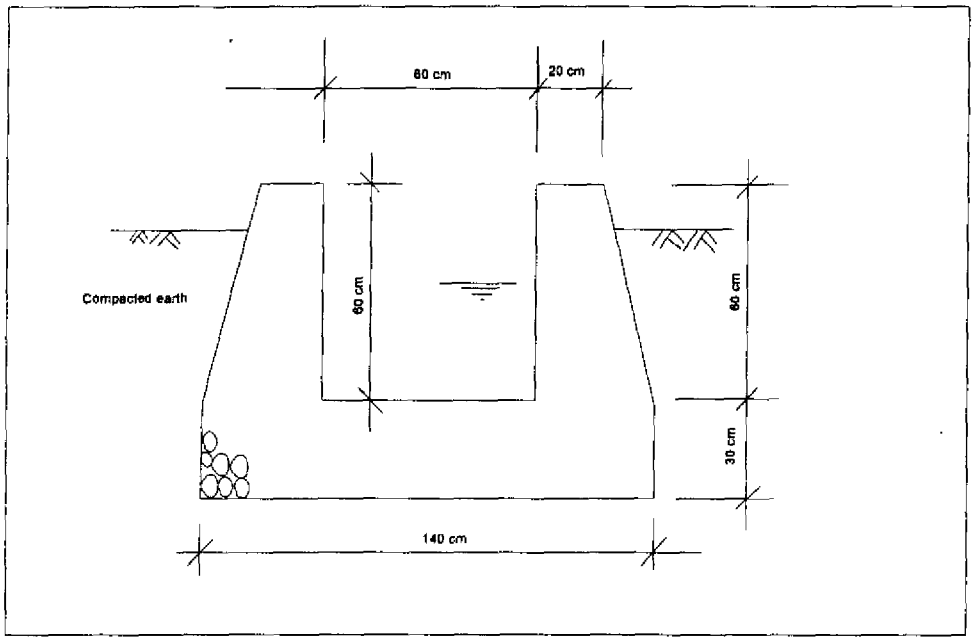
1. ROTANDA

The power distribution grid has already been set up in the town of Rotanda, which is only 7 km away from Mozambique-Zimbabwe border. There is a hospital, a school and some retail shops in the town. The construction of a 70 kW diesel generation powerhouse is almost complete. There are 4260 people as part of 885 families living in the area. Initially, the town and 45 families only will get electricity, according to the local administrator. Due to the high price of diesel, a SHP station is planned as the main power source and the diesel generator is expected to remain as the standby.

The proposed location for the SHP station is about 3.5 km from the town. There is a maze mill now with grinder driven by a Pelton turbine. A 17 cm diameter metal pipe of 165 m length connects the turbine with a pond on the mountain, which serves as a fore bay. A 5 km long canal diverts water from the river to the pond with most of the water being released for irrigation purposes along the way.

We suggest that a 30-kW micro hydro unit be installed at this site using the existing fore bay and pipeline. Our measurement indicates that about 80 m water head will be available. Other suggestions are:

1. The current powerhouse together with the equipment inside should be removed, because the powerhouse is in bad shape and the tail water canal is not big enough.
2. The whole penstock should be thoroughly checked and the rusted portions should be replaced, ensuring that there is no leakage. It should be ensured that the wall thickness of the pipe is not less than 6 mm. Anchor blocks should be added where the penstock bends. And the whole penstock should be properly supported.
3. The canal from the river intake to the fore bay needs rehabilitation. 0.063 m^3/s water is needed for a 30 kW turbine to function.
4. The cross section of the canal is as shown in the following sketch.



The material suggested for the canal is rubble masonry in cement lined with cement mortar of 1.5 cm thick for preventing seepage. The longitudinal slope of the canal should be ensured not to be less than 1:1000, in order to guarantee enough water flow and speed.

The existing fore bay needs to be cleaned and any leakage from the fore bay plugged. Before the penstock inlet, a trash rack should be added.

2. MAUE

Generally the civil works are in good condition and it would not be difficult to restore the power station to its original capacity. The slope of the existing canal is insufficient - approximately 35 cm over the 750 m length and the penstock is quite small, with 800 mm diameter only. With some minor improvements, the capacity could be increased to 280 kW. The improvement suggested are: increasing the area of the trash rack; or moving it and increasing the dam crest and canal walls in the vicinity of the dam, to increase the effective canal slope. The capacity of the transformer would also need to be upgraded.

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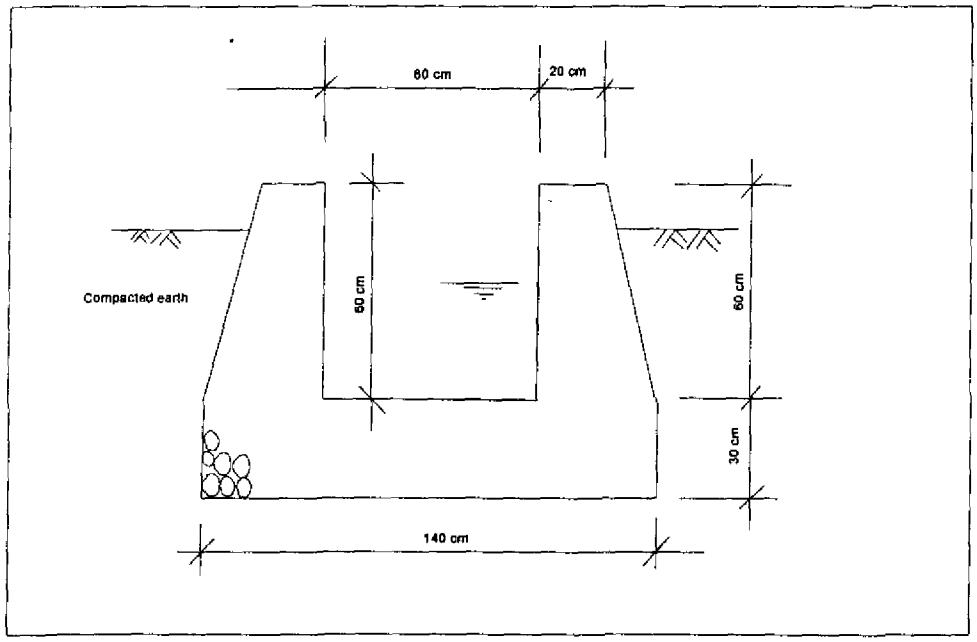

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It is observed that the powerhouse was flooded twice in the past 20 years. Therefore, the flood prevention for the powerhouse should be a key issue to be considered while refurbishing the station. Flood protection measures should also be included - such as blocking the low level windows and raising the elevation of the door. Waterproof door and windows can be used. However, this is subject to checking the strength of the building and making sure that it can withstand the flood pressure. Enough drainage equipment and reliable standby power supply should be available during the flood season.

Because of the limited size of the canal and penstock diameter, increasing the capacity beyond 300 kW would require more extensive canal modifications and the use of a larger penstock. For example, the original 200 kW plant required a flow of 1.3 m^3/s with an assumed head loss of 1.3 m. If we double the flow, the head loss will increase to 5 m or 25% of the gross head available will be lost, resulting in only a 320 kW capacity, suggesting that there is no corresponding increase in power.

Given the conditions at the site, we would propose to complete a detailed survey and develop a restoration plan without delay. The existing transformer can be either replaced or altered appropriately.

As discussed with the EDM and Ministry staff at the site, bush clearing below the flood line in the proximity of the power station would lower the flood levels and it is an inexpensive and uncomplicated exercise before restoration planning.

The diesel backup may not be required as the grid connection from Malawi can be used for emergency back up purposes.

LONG TERM PLANS FOR MAUE

The watershed appears to have great variation in flow. This could be getting worse, if there is much environmental degradation upstream. A long-term strategy would be to begin a process of flow monitoring with a view to constructing a storage reservoir upstream.

Based on site observations of the existing conditions, the following preliminary calculations were made, all of which are subject to modification after a detailed site survey and hydrologic investigation is over:

Max plant flow:	2.0 m^3/s
Capacity:	280 kW
Gross Head:	20 m
Net Head:	17 m
Turbine:	Horizontal Francis with 650 mm dia runner

It would not be complicated exercise to replace the penstock with a larger diameter one and to increase the canal height in the event of a higher capacity being required. This would still be a much cheaper option than the construction of a new generating station.

3. MAJAUE

This former generating station provides an excellent opportunity to incorporate a Rural Electrification Project while offsetting current power imports for the town of Milange. The civil works are in good shape and some minor improvements can be made to improve capacity to, perhaps 1 MW. The powerhouse appears to be sound and the penstock is in good condition, only requiring a coat of paint and replacement of the expansion seals.

The access road will require improvement before equipment can be brought to site.

The supply from Malawi appears to be very erratic, so it appears advisable to construct this as an **isolated system** where the Malawi side is connected only when long term shut down of the hydro station is encountered.

We would propose a 33 kV transmission line from the site to Milange with intermediate step-down transformers along the line for the local villages, schools and shops. This line would be approximately 60 km long, linking with the existing distribution lines in Milange.

The Dept of Energy in conjunction with the local EDM staff should advise on what is the current demand and IN-SHP can then advise on the most appropriate size, factoring in the proposed increased demand from the new line and future growth in demand.

Local knowledge suggests that flow levels are quite low in October. So, additional civil works may be required at that time to ensure that all of the low flow is diverted into the intake.

Civil works improvements would include a course trash rack at the intake and a gate to permit drainage of the canal. The existing trash rack, as well as the existing gates and valves require replacement. The powerhouse appears structurally sound, but will require some restoration work.

Based on site observations, the following preliminary calculations are made, all of which are subject to modification after a detailed site survey and hydrologic investigation is completed:

Max plant flow:	7 m^3/s
Capacity:	1.0 MW
Gross Head:	20 m
Net Head:	18.3 m
Turbine:	Horizontal Francis of 1.2 m dia. runner & scroll case 4.2m high

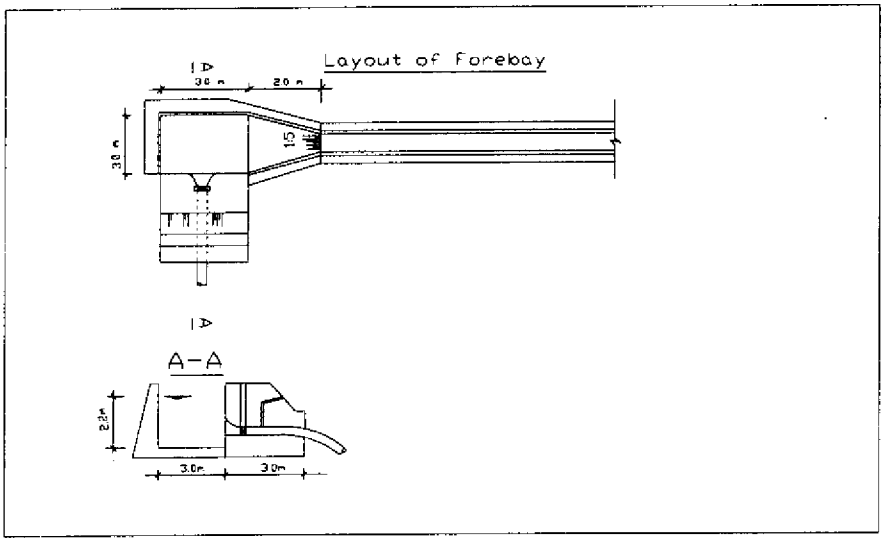
The penstock intake will have to be checked for adequate submergence for the proposed increased flow

4. KAZULA

Kazula is an ideal site for "hydro for rural electrification". The team visited two sites for the proposed 30 kW micro hydropower site. Of them, the one where there used to be a small dam is considered the best.

A small dam can be built at the same place where the old damaged dam stands. The fore bay shall be constructed on the left side hill - where a relatively plain terrain is available - as close to the dam as possible. A canal then will divert water from dam site to the fore bay. The powerhouse shall be constructed on the downstream of the waterfall, but not far from it. The flood level at both the dam and powerhouse sites should be ascertained by consulting with local people, to take necessary measures for protecting the intake and the powerhouse. Water head of about 50 meters can be had.

The same cross section for the canal of the Rotanda site can be applied to this case also, and the slope of the canal should not be more gentle than 1/1000.



The penstock diameter shall be 20 cm.

Topographic maps and aerial photos would be the best means to develop this concept further, followed by a detailed topographic survey based on the concept drawings.

The gravel road access to the site is in good condition.

VI. SUMMARY OF THE SECOND CONSULTATION MISSION

All the four sites visited offer good opportunities for small hydro station development in rural Mozambique, each with slightly different conditions and benefits. The two former generating stations can be restored reasonably quickly, as very little civil works are required. The other two sites (Rotanda and Kazula) can also be constructed quickly due to its small size.

The recommended capacities of the sites are as shown below:

- Maue 280 kW
- Majaue 1000 kW
- Rotanda 30 kW
- Kazula 30 kW

The most important conclusion from this field trip is the need to validate the appropriate size of other proposed sites, as data on the two available (Maue and Majaue) were extremely off the mark.

Hydrological information appears to be very sketchy on these sites and we would assume that it is so generally throughout Mozambique. A long-term goal should be to establish a network of flow gauges to establish reliable flow data to develop watershed utilization plans as per the Chinese model. In the short term, the lack of hydrological data will mean that the determination of most economical plant size will be less accurate, than would normally be possible and desired.

The IN-SHP Sub-Centre in Africa at Powermate International is capable of conducting the required further studies and to undertake construction and management of the recommended SHP sites. The Nyafaru Project completed by Powermate in Zimbabwe about ten years ago, is still in good condition and is benefiting the local people. The IN-SHP headquarters can be a back up institution to offer any assistance to the speedy implementation of the recommended activities, if the government so desires. This arrangement will also make it possible for completing the projects in a reasonable time, with guaranteed quality and at the lowest cost possible.

VII. THE FOLLOW-UP ACTIVITIES

1. First of all, the Mozambique government should decide upon the capacity of the different sites. For Rotanda, the capacity can go up to 70 kW, but larger and longer canal is needed in such a case. And penstock should also need to be changed. Therefore, the expense could be much higher than the 30 kW scheme.
2. Once the capacity is finalized, the process of equipment purchase can be started. The equipment supplier will provide necessary data for civil construction, like the powerhouse dimension, etc.
3. Local counterparts can start civil construction with professional supervision or a qualified contractor should be employed for civil construction. The IN-SHP Sub-Centre can undertake the work, if so needed.
4. Once the civil structure is ready, the equipment supplier will send people to install the equipment, if this is needed. The training of operators can be carried out at this time.