

# **Mini Hydro Power in Ghana**

## **Prospects and Challenges**



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## **1 Introduction**

The prospects of harnessing the hydro-electric potential of small rivers in Ghana have been investigated in Ghana for over 20 years, leading to the identification of many potential mini hydro sites in the country. Since the 1970's new surveys have been carried out systematically whilst information of existing reports have been updated. In spite of the existence of the numerous reports and an apparent interest in the development of the mini-hydro technology in the country, not a single small hydro plant has been constructed so far. The Likpe Kukurantumi mini-hydro project which was initiated in the 1980's was abandoned midway for unexplained reasons.

Until a few years ago, there was little economic interest in generating electricity from mini-hydro plants, as cheap power from the Akosombo and Kpong hydro plants has been available in excess. This situation however, has changed considerably in recent times. Many of the sites that were found suitable for development to electrify adjoining rural communities were not built and as of now a greater proportion of the villages such plants could have served have been connected to the national grid.

In 1999 the Energy Foundation initiated a programme to assess the prospects for the development of mini-hydro potential of the country by gathering all existing reports and information and reviewing the sites under present technical and economical conditions. The Foundation has received technical assistance from GTZ/CIM of Germany and has been supported financially by DANIDA through the Renewable Energy Development Project (REDP) to undertake detailed reviews of the existing reports, gather site specific flow and topographic data, and re-evaluate the socio-economic potential of the sites for eventual development. This report covers some of the most known sites in the Southern part of the country. Data has been gathered in the dry season and in the rainy seasons in 2001 and 2002.

## **2 Executive Summary**

Studies and research initiatives, aimed at harnessing the power generation potential of small rivers in Ghana to supplement the large Akosombo and Kpong power plants have been undertaken in Ghana for over two decades. At the peak of such studies, mini hydro power plants were regarded not only as supplementary sources of power but also as alternatives for grid extension to rural areas which were far from the national grid. Although a lot of effort and resources have been expended on numerous such studies, not a single mini-hydro plant has been developed in the country, although Ghana has gone through several years of uncertainties in power generation and has now resorted to thermal power generation as a supplement to the traditional hydropower sources.

As part of its mandate to promote the commercialization of renewable energy resources in Ghana, the Energy Foundation has updated all the information on the well-known mini-hydro power generation sites in the country. The aim of this report is to bring to the notice of the government and potential investors, all available information on potential Mini Hydro Sites in the country reviewed under the present climatic, regulatory and economic conditions. The main studies that have been used as the basis for this update are the surveys carried out by the then Architectural and Engineering Services Corporation (AESC) in 1985/86 on 16 mini-hydro sites in Ghana and a review conducted by ACRES International in 1991. Studies on other rivers conducted by ESMAP/ World Bank have also been reviewed and the Energy Foundation has conducted on the spot reviews and taken measurements between September 2000 and October 2002.

The review has enabled the Energy Foundation to report as follows:

1. The villages located within a reasonable distance to justify the development of the identified sites for rural electrification are either grid connected today or at least within a distance of a few kilometers from the grid. Consequently the justification to develop the sites for rural electrification has been weakened considerably.
2. Comparing recently observed flow data with data from the 1960s and 1970s, it has been noticed that flows have considerably decreased in the last decade to the extent that some of the rivers completely dry out for up to 7 months a year. This is the result of massive deforestation in the catchment areas of the rivers. Run offs after rains are heavy and flow sustainability is non-existent due to the absence of forest cover.
3. The Likpe Kukurantumi site, where construction started in 1984, but was not completed, has been reviewed. The village is now connected to the grid for several years now and the equipment purchased from India is almost rotten.
4. For the reasons described in (2) the technically feasible size of plant that can be developed at Likpe Kukurantumi is now a maximum of 150 kW. This is by far lower than the 400 kW previously estimated. The development of Likpe will

require a 5 metre-high dam, which could cause flooding considering the terrain at the site and the massive nature of run-offs after heavy rains. Compared to other locations, the Likpe Kukurantumi site is not the best to be developed as a pilot project.

5. As a result of the present reach of the national grid, many of the sites would have to be developed as grid connected plants. This however requires a power purchase regulation to be developed by the Government of Ghana and the relevant authorities.
6. The economic calculations show that with a power purchase tariff of around US\$0.08/ kWh high height sites such as the Randall and Fuller water falls located in the Brong Ahafo region and the Tsatsadu Falls in the Volta Region, might be economically sustainable. However more recent flow data would have to be collected for a detailed economical analysis as part of detailed feasibility studies for particular sites.
7. The low height sites, most of them in the Volta Region, would only be worth considering as integrated power and irrigation infrastructure. In that case, it should be considered to include a mini hydropower plant to provide power to pump the water to the farms and supply the excess energy to the national grid.
8. Realistically, the quite modest mini hydropower potential in Ghana cannot make a considerable contribution to the national power requirement. This is not only due to the limited number of sites with reasonably high heads, but also due to the extremely unfavorable flow duration curves with a long dry season and high variations in river flows.

### **3 Overview of previous Reports and Surveys**

Since the beginning of the 1980s various studies have been carried out analyzing the small hydro potential of the country and evaluating several sites. The following reports have been available to the Energy Foundation and have been used, in conjunction with the Foundation's own survey data in arriving at some of the conclusion in this report:

1. In January-February 1984 the UN Department of Technical Co-operation for Development evaluated several small hydro sites. It follows up surveys carried out by the Architectural and Engineering Services Corporation<sup>1</sup> (AESC) since the end of the 1970s as well as the University of Science and Technology (UST), Kumasi.
2. The AESC carried out site surveys on about 16 sites in 1985-1986. The Interim Report on phase I from December 1985 as well as main parts of the report from 1996 that probably refers to phase II, include more detailed feasibility studies such as flow measurements and topographic surveys. (Phase III which involved the implementation of pilot schemes, was not carried out.) All these studies have been carried out for rural electrification through local grids.
3. In March 1991 ACRES International reviewed the AESC studies as part of the "National Electrification Planning Study" by the Ministry of Fuel and Power.
4. In 1994 the French firm "Coyne et Bellier" contracted by VRA, carried out a study on the Pra river, analyzing the Hemang and Awisam dam sites. Even though this report focuses on two big hydro sites, its findings are of importance for further development of small hydro on this river.
5. In 1995/96 the Ministry of Energy evaluated potential sites on the western rivers Pra, Tano and Ankobra. The study was carried out by consultants from India and was financed by the World Bank/ESMAP. No copy of the report is available.
6. In the beginning of the 1980s work started on the Likpe Kukurantumi site. This was abandoned midway and has not been completed. This site has been further evaluated and is discussed in detail in this report.
7. In the middle of the 1980s the German turbine manufacturer Ossberger conducted a feasibility study on a site in the Volta Region, contracted by the Ministry of Energy. Although the site turned out feasible and funds were provided by the World Bank, the contract was never awarded. The manufacturer has in the meantime removed the data from its archive, so it is unclear which site was concerned.

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<sup>1</sup> The AESC is now called the Architectural & Engineering Services Limited (AESL).

8. In 2000 the Hydro Department (Ministry of Works and Housing) prepared an overview of potentially interesting small hydro sites in the country, containing about 70 locations. This list has been incorporated into other reports since then. It has to be considered that this list was solely based on topographic maps and flow data of the rivers to indicate possible interesting sites. The authors did not indicate which of the sites were technically and economically feasible.
9. In April 2001 the Kumasi Institute of Technology and Environment (KITE) analyzed the situation of Renewable Energy Technologies in Ghana. The report summarizes some of the information available from the above-mentioned surveys, however it had not been the aim of the report to verify or review the information.
10. In August 2001, the Energy Foundation held a workshop in Accra to review the economic potential of mini hydro plants in Ghana. The workshop proceedings is available at the Energy Foundation. The workshop concluded that since the installed unit cost of mini hydro plants for electricity generation was high, the development of such sites should be considered in tandem with irrigated agriculture, tourism and water supply to improve the cost effectiveness of such investments.

## **4 Maps and Flow Data**

### **4.1 Flow data**

Flow data from several rivers are available with the Hydro Department of the Ministry of Works and Housing. These were taken since beginning of the 1960s. However, mainly during the 1980s and early 1990s data are scanty, probably due to equipment and transport problems encountered during that time.

### **4.2 Topographic sheets**

Topographic maps of scale 1:50,000 are available at the Survey Department for a fee. They are suitable for the calculation of catchment areas and have been used in this review.

## **5 The present condition of the evaluated sites**

### **5.1 Volta Region**

The Volta region is perhaps the best-endowed region in terms of potential mini-hydro sites. The sites in the Volta Region can basically be divided in two groups. The low head sites on the rivers in the northern part of the region, namely the Mensu, Wawa and Dayi as well as the high head sites on the waterfalls on the plateau along the Togo border as well as the “Togo Plateau” west of Hohoe.

As at October 2002, the VRA/ECG grid has been extended to all the sites or to the nearby village settlements which would have been served from these sites if they had been developed into local mini grids. Under the present circumstances, the development of these sites would be considered only as grid connected sites. Some potentially feasible sites have been evaluated in detail.

#### **5.1.1 Wli Falls**

**River:** Nuboi

**Location:** Afegame, Volta Region

**Catchment Area:** 30 km<sup>2</sup>

**Head:** about 2 x 250m

**Proposed installed capacity:** 300 kW isolated  
1,000 kW grid connected

**Annual energy generation:** 3,500,000 kWh grid connected (estimated)

Nuboi River drops on the Wli Falls in two cascades of about 250m each. The upper falls would be quite difficult to realize due to difficult access that is likely to be encountered, during construction as well as for operation and maintenance.

The lower falls is technically the most feasible for the construction of a high head plant fitted with a Pelton turbine. A simple intake structure would divert the water from the pond existing at the middle level into a steel penstock of about 350m in length. A powerhouse could be located on the left bank of the waterfalls. The construction of even a small storage at the intake at the middle level will probably not be possible due to limited space.

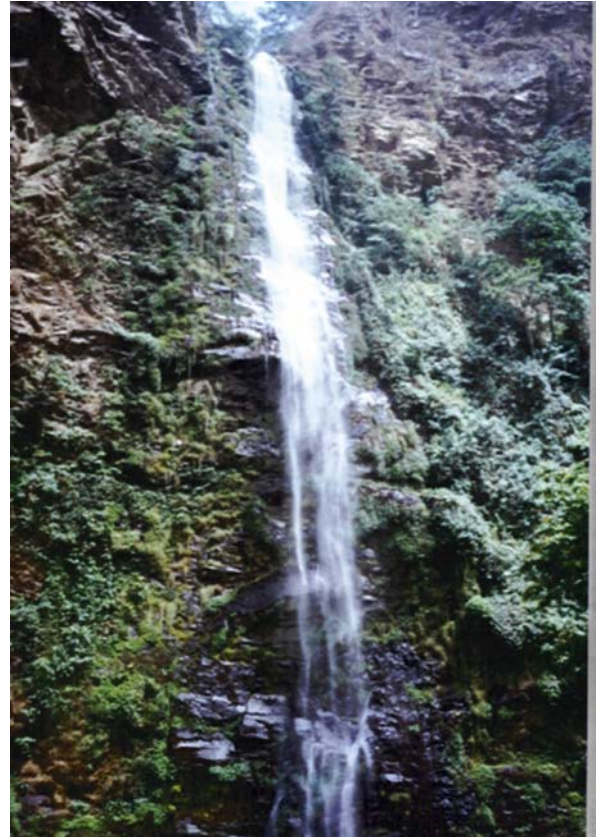
The maximum firm power that can be derived, if the site is developed in isolation would be just about 300 kW. The exact determination of the optimum capacity of a grid-connected site is difficult, because the topo-sheets available do not cover the Togo side of the border, where the catchment area is located.

However, it has been established that detailed information on flow data over the past 40 years might be available from Compagnie Electrique du Togo, which operates the Kpimé site on the Togo side of the mountain.

It should be taken into consideration that the Wli Falls are of an extraordinary natural beauty and the location has been declared a natural protection area. The falls have become one of Ghana's most famous tourist attractions.

The nearby villages are grid connected. Therefore there is no justification for developing the site for rural electrification purposes.

Due to its unique beauty and touristic importance to the local community as well as the country, no priority should be given to the development of this site unless there are no other options to ensure sufficient power generation.



**Photo 1: Upper Wli Falls, Dry Season**



**Photo 2: Lower Wli Falls, Rainy Season**

### 5.1.2 Tsatsadu Falls

**River:** Tsatsadu

**Location:** Alavanyo-Abehensi, Volta Region

**Catchment Area:** 40 km<sup>2</sup>

**Head:** 43m falls + 37m rapids

**Designed flow:** 0,5 m<sup>3</sup>/s

**Proposed installed Power:** 320 kW (grid connected)

**Annual energy generation:** 1,220,000 kWh

The Tsatsadu River is a tributary of the Dayi, located south-west of Hohoe. North of the Alavanyo-Abehensi village it drops by about 43m through some waterfalls and further 37m over a distance of about 1,000 m.

Visits during the dry season show that there is practically no flow during that time. A flow duration curve has been created using flow data from Dayi River at Hohoe gauging station.

The site could be developed with a 170 kW unit on the waterfalls and 150 kW downstream or one unit using the total drop of 80m. A total of 1,220,000 kWh per year could be generated.



**Photo 3: Tsatsadu Falls, Rainy Season**

On the top of the mountain, right over the Waterfall, a religious group has constructed a pilgrimage house, the “Foyer de Charité”. This gives good access to the site for construction, however any development of the site will probably have to be done in cooperation with the religious group. The nearby village Alavanyo-Abehense, a few hundred meters from the proposed location of the powerhouse, is connected to the ECG

grid as well as the Foyer. Therefore the site will have to be developed as a grid-connected plant.

On the proposed location of the powerhouse two ruins of water pumping stations can be found. It is unclear whether they have been closed due to the drying out of the river or due to lack of maintenance. Although water can be conducted to the village downstream through pipes, using the natural head, this has not been done. Perhaps this possibility is not known to the local authorities.

It would be possible to integrate an irrigation system into this site. This would require the construction of some storage facility either on the top of the waterfalls or between the waterfalls and the rapids. That would, however cause losses in energy production and water supply for both activities would be limited to the rainy season, when irrigation would not be needed anyway. On the other hand, this opportunity, together with the option to supply power directly to the centre on the mountain, makes the site a feasible location for development.

### **5.1.3 Likpe Kukurantumi**

**River:** Dayi

**Location:** Likpe Kukurantumi, Volta Region

**Catchment Area:** 477 km<sup>2</sup>

**Head:** up to 5m by dam

**Designed flow:** 2 – 3.8 m<sup>3</sup>/s

**Proposed installed Power Capacity:** 100 – 150 kW (grid connected)

**Annual energy generation:** 420,000 – 500,000 kWh

The only Small Hydro Site on which a feasibility study as well as a detailed design has been done is the Likpe Kukurantumi plant on the Dayi River, upstream of Hohoe in the Volta Region. Likpe Kukurantumi was thought as part of a cascade of several sites on the Dayi river.

The location has no natural head. Head would be created entirely through a 5.2 m high dam. The plans, dating back to 1982, had foreseen a 400 kW plant with an annual output of 876,000 kWh.

Construction started in 1984 and had been ongoing for 11 months with labour supplied by local population, who organised communal labour sessions to assist in the project development. Fifty (50) wooden crates containing the first 100 kW unit of electro-mechanical equipment had been shipped in from India in 1985.

Unfortunately, work stopped at this point for unexplained reasons after the project engineer from India, Mr. Chelvaraj, had left the country.

### **5.1.3.1 Available Information**

Only parts of what had probably been the original feasibility study could be found. A set of drawings from the first revision of the project in 1985 as well as a case study on the project conducted in April 1999 by the engineering firm SECSD from Bangalore is available from ECG.

ECG has reviewed the project in a report compiled in June, 1999.

Flow data of Dayi river (Hohoe gauging station) are available for the period 1962-1973 with the Hydro Department, Ministry of Works and Housing. In 1973 the gauging station had been moved. Since then the water level is still recorded, however no rating table has been generated, so the data cannot be used for our purposes.



**Photo 4: Likpe Kukurantumi, Dry Season**

### **5.1.3.2 Present condition**

As can be seen in the picture above (photo 4.) some concrete work has been done in the riverbed, however neither the dam, nor intake structure or channel has been constructed. The asbestos pipes have deteriorated considerably due to weathering and mechanical damage.

The crates with the equipment supplied are standing under the open sky in the Ring Road ECG yard in Accra for almost 15 years now. The wooden crates have been destroyed by termites. The equipment is rusty. (Photo 5)

The people of Likpe Kukurantumi are still highly interested and are looking forward to their site being completed one day. The village is however connected to the ECG grid and

justification for reviving the project will definitely exclude power production from an isolated mini-hydro plant. The site would have to be developed as a grid connected plant.



**Photo 5: Wooden crates with equipment for Likpe Project at ECG yard in Accra**

### **5.1.3.3 Site development**

The review study of the project in 1999 by SECS from Bangalore, India is quite detailed. The study also has to refer to the old flow data from the 1960s and 1970s. Based on these data, the consultants suggested a 150 kW site with an annual output of 640,000 kWh. Construction cost is estimated at US\$300,000 bringing the unit capacity cost to US\$2,000/kW installed.

Using the existing flow data at Hohoe, the flow duration curve (FDC) for the Dayi at Likpe Kukurantumi has been developed by the Energy Foundation. Taking this FDC as the basis and assuming an available head of 5m, a 150 kW plant (flow 3.8 m<sup>3</sup>/s) would generate around 500,000 kWh/annum. A 100 kW plant (2.0 m<sup>3</sup>/s) would generate 420,000 kWh/a. This still assumes that a 5 m dam would be built.

These figures however do not take into consideration the changes in the flow that has been observed over the last 20 years, as new flow data is not available. The tendency seen on this and on other rivers is that rainfall and consequent river flow has considerably decreased in recent years, meaning that the annual power generation would be less than calculated. Another phenomenon that need to be considered is the annual occasional high water levels, as they had been reported by villagers of Kukurantumi and staff of the water works at Hohoe.

## Investment calculation for: Likpe Kukurantumi

|         |                 |     |          |        |               |          |
|---------|-----------------|-----|----------|--------|---------------|----------|
| cash in | planned outflow |     |          | net    | pres. Worth   | Increase |
|         | Investment      | O&M | cash out | In-Out | of net in-out | of NPV   |

|                     | year  | tUSD  | tUSD   | tUSD   | tUSD    | factor | tUSD    | tUSD    |         |
|---------------------|-------|-------|--------|--------|---------|--------|---------|---------|---------|
|                     |       |       |        |        |         |        |         |         |         |
| construction period | -3    |       |        |        |         |        |         |         |         |
|                     | -2    |       |        |        |         |        |         |         |         |
|                     | -1    |       |        |        |         |        |         |         |         |
|                     | 0     |       | 525.00 | 525.00 | -525.00 | 1      | -525.00 |         |         |
| operation period    | 1     | 40.00 | 3.60   | 3.60   | 36.40   | 0.909  | 33.09   | -491.91 |         |
|                     | 2     | 40.80 | 3.67   | 3.67   | 37.13   | 0.826  | 30.68   | -461.22 |         |
|                     | 3     | 41.62 | 3.75   | 3.75   | 37.87   | 0.751  | 28.45   | -432.77 |         |
|                     | 4     | 42.45 | 3.82   | 3.82   | 38.63   | 0.683  | 26.38   | -406.39 |         |
|                     | 5     | 43.30 | 28.98  | 3.90   | 32.88   | 10.42  | 0.621   | 6.47    | -399.92 |
|                     | 6     | 44.16 |        | 3.97   | 3.97    | 40.19  | 0.564   | 22.69   | -377.23 |
|                     | 7     | 45.05 |        | 4.05   | 4.05    | 40.99  | 0.513   | 21.04   | -356.20 |
|                     | 8     | 45.95 |        | 4.14   | 4.14    | 41.81  | 0.467   | 19.51   | -336.69 |
|                     | 9     | 46.87 |        | 4.22   | 4.22    | 42.65  | 0.424   | 18.09   | -318.61 |
|                     | 10    | 47.80 | 32.00  | 4.30   | 36.30   | 11.50  | 0.386   | 4.43    | -314.17 |
|                     | 11    | 48.76 |        | 4.39   | 4.39    | 44.37  | 0.35    | 15.55   | -298.62 |
|                     | 12    | 49.73 |        | 4.48   | 4.48    | 45.26  | 0.319   | 14.42   | -284.20 |
|                     | 13    | 50.73 |        | 4.57   | 4.57    | 46.16  | 0.29    | 13.37   | -270.83 |
|                     | 14    | 51.74 |        | 4.66   | 4.66    | 47.09  | 0.263   | 12.40   | -258.43 |
|                     | 15    | 52.78 | 35.33  | 4.75   | 40.08   | 12.70  | 0.239   | 3.04    | -255.39 |
|                     | 16    | 53.83 |        | 4.85   | 4.85    | 48.99  | 0.218   | 10.66   | -244.72 |
|                     | 17    | 54.91 |        | 4.94   | 4.94    | 49.97  | 0.198   | 9.89    | -234.84 |
|                     | 18    | 56.01 |        | 5.04   | 5.04    | 50.97  | 0.18    | 9.17    | -225.67 |
|                     | 19    | 57.13 |        | 5.14   | 5.14    | 51.99  | 0.164   | 8.50    | -217.17 |
|                     | 20    | 58.27 | 39.01  | 5.24   | 44.25   | 14.02  | 0.149   | 2.08    | -215.09 |
|                     | 21    | 59.44 |        | 5.35   | 5.35    | 54.09  | 0.135   | 7.31    | -207.78 |
|                     | 22    | 60.63 |        | 5.46   | 5.46    | 55.17  | 0.123   | 6.78    | -201.00 |
|                     | 23    | 61.84 |        | 5.57   | 5.57    | 56.27  | 0.112   | 6.28    | -194.72 |
|                     | 24    | 63.08 |        | 5.68   | 5.68    | 57.40  | 0.102   | 5.83    | -188.89 |
| 25                  | 64.34 |       | 5.79   | 5.79   | 58.55   | 0.092  | 5.40    | -183.48 |         |

### Parameter Box

|                               |           |            |           |
|-------------------------------|-----------|------------|-----------|
| Inflation Rate                | 2.00%     | Lifetime   | 25 years  |
| Interest Rate                 | 10.00%    | Investment | 525 tUSD  |
| Operation & Maintenance (O&M) |           |            | 3.60 tUSD |
| Reinvestment                  | 5%        | Capacity   | 150 kW    |
| from purchase                 | 8 US cent |            |           |

**NPV**     **-183.48 tUSD**

Investment/kW     **3.50 tUSD**

**cost per kWh/a**     **10.53 US cent**

|                               |            |
|-------------------------------|------------|
| energy production per year    | 500 MWh    |
| annual investment cost        | 22.8 tUSD  |
| present worth of reinvestment | 44.6 tUSD  |
| annual interest cost          | 26.25 tUSD |



**Table 1: Investment Calculation for Likpe Kukurantumi**



**Photo 6: Likpe Kukurantumi, Rainy Season**

#### **5.1.3.4 Construction cost**

Low head sites are relatively more expensive to construct than high head sites. The figure of 2,000 USD/kW seems much too low. An amount of around 3,500 USD/kW would be more realistic.

#### **5.1.3.5 Conclusion**

The Likpe Kukurantumi Project is technically feasible, however several aspects might limit its economic viability. The formally proposed size of 400 kW is completely unrealistic considering reduced annual inflow and the fact that a bigger dam will flood a wide area. An economic size would be between 100 kW and 150 kW.

Hydrological calculations would have to be performed to verify whether a weir of 5.2 m head is feasible, taking into consideration the threat of flooding during occasional heavy rains. Any reduction in the size of the dam would cause considerable reductions in power generation. The measurement data from Hohoe gauging station since 1973 have to be re-evaluated and a new rating curve has to be generated by the Hydro Department. Likpe Kukurantumi is connected to the ECG grid. The development of the site would depend on a power purchase agreement with ECG.

Taking into consideration all above mentioned aspects it is not advisable that Likpe Kukurantumi is used as a site for a pilot small hydro power in Ghana. Other sites with an existing head would be much easier to develop and to be operated without the risk of flooding. The Likpe Kukurantumi site would have to be considered alongside an integrated irrigation and water supply scheme.

#### **5.1.4 Dzolo and New Ayoma**

These sites are located further upstream of the Likpe Kukurantumi site. No natural head is available. Head would therefore entirely depend on the construction of dams, similar to the Kukurantumi site. The area is connected to the ECG grid.

As the Dayi river has a dependable flow of about 500 l/s, all these sites would have been feasible for construction with limited head and size just to supply some power to the villages.



**Photo 7: Dayi at New Ayoma, Rainy Season**

### **5.1.5 Hohoe Water Works (GWC)**

The Ghana Water Company (GWC) operates its headwork for the water supply system to the town of Hohoe at a site north of Hohoe, downstream of Kukurantumi on the Dayi river. Water is taken out on the left bank of the river. The head created by the overflow weir is about 3 m. Depending on the water requirements of GWC during dry season, it might be possible to install a power generation unit on the right river bank, supplying the power directly to GWC.



**Photo 8: GWC Headworks at Hohoe, Dayi River**

### 5.1.6 Low head sites on Wawa, Menu, Asuakwakwa and Jelem

| <u>Site</u>          | <u>River</u> |
|----------------------|--------------|
| <b>Menusu</b>        | Menu         |
| <b>Ahamansu</b>      | Wawa         |
| <b>Dodo Papase</b>   | Wawa         |
| <b>Asuboe</b>        | Wawa         |
| <b>Dodo Tamale</b>   | Asuakawkaw   |
| <b>Dodo Amanfron</b> | Jelem        |

All these rivers are located in the northern part of the Volta Region. There is no natural head available. Plans for the construction of mini hydro plants on these rivers would involve the construction of dams of up to 12 m head.

All villages in the vicinity of those sites are presently connected to the ECG grid. Sites would therefore have to be connected to the grid. As these rivers have a permanent flow throughout the year, there might be an interest in setting up small irrigation dams, combined with small turbines to provide enough power for some pumping. For this purpose much lower dams could be built than would have been necessary for power generation only.



**Photo 9: Wawa River at Dodo Papase, Dry Season**

## 5.2 Eastern Region

### 5.2.1 Wurudu Falls

**River:** Wurudu

**Location:** Moseaso ,Eastern Region

**Catchment Area:** 3.9 km<sup>2</sup>

**Head:** 40 m in two drops

**Designed flow:** 80 l/s

**Proposed installed Power:** 25 kW

This is one of many sites in the eastern region. The river however dries out completely throughout the entire dry season from November to May. The nearby village Moseaso is grid connected. There is therefore not much interest in construction of this site for the moment.

## 5.3 Ashanti Region

### 5.3.1 Boumfoum Falls

**River:** Ongwam

**Location:** Kumawu, Ashanti Region

**Catchment Area:** 223 km<sup>2</sup>

**Head:** 23m

**Designed flow:** 0,8 m<sup>3</sup>/s (isolated)

**Proposed installed Power:** 150 kW (isol.)

The river dries out completely throughout the entire dry season. The next village is about 10 km away and is grid connected. The waterfall is located in the middle of a game reserve, being a small tourist attraction and source of income for the wildlife department.

It is not recommended that this site serves as a pilot grid connected site.

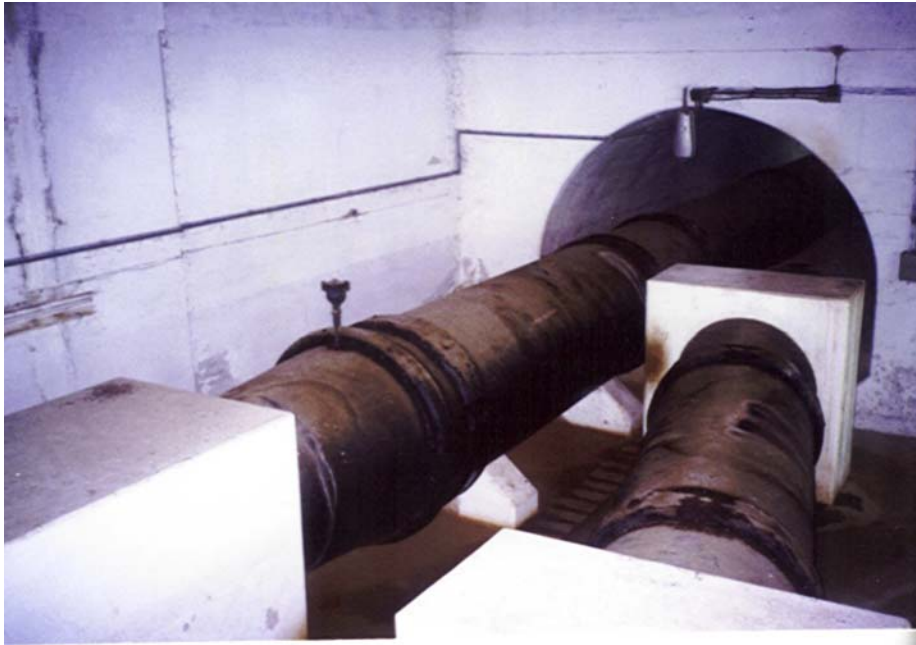


**Photo 10: Boumfoum Falls, Dry Season**

### **5.3.2 Ghana Water Company- Barekese Water Supply Dam, Kumasi**

The Barekese site is one of two dams used by the Ghana Water Company to supply water to the city of Kumasi. The dam was built in 1970.

The design of the dam incorporates a penstock and a platform for the installation of a power generation turbine. A 60" pipe has been installed, leading out of the reservoir into the pumping station. A head of about 12 m is available.



**Photo 11: The 60" pipe coming out of the reservoir at Barekese dam**

At the time of construction there was no economic justification for additional expenditure on a power plant due to the low electricity tariffs at the time and the availability of hydro power from Akosombo. This situation has changed and Ghana Water Company may want to revisit the project.



**Photo 12: Barekese Dam in Rainy Season**

The population of Kumasi has increased considerably compared with 1970. As a result of deforestation in the catchment area of the dam inflow has reduced whilst the rate of evaporation has increased. There is no longer excess water available throughout the year as it used to be in 1970. The operation time of the turbine might be limited to as few as 2 - 4 months a year.

The question whether the installation of a turbine might still be economically feasible depends on a detailed analysis of GWCs records on flow, water consumption and electricity prices.

## 5.4 Brong Ahafo

Potential locations of Mini Hydro Sites are located around Kintampo. The sites are mainly waterfalls which are suitable for mini hydro plants.

### 5.4.1 Nkoranza

**River:** Fia

**Location:** Nkoranza, Brong Ahafo

**Catchment Area:** 353 km<sup>2</sup>

**Head:** 3m by dam

**Designed flow:** 1.5 m<sup>3</sup>/s (isolated)

**Proposed installed Power:** 35 kW (isolated)

The potential site on Fia River is located north of Nkoranza at the bridge of the Kintampo road. Flow data from the 1960s and 70s as well as observations from the early 1980s indicate a dependable flow of more than 1 m<sup>3</sup>/s. This situation has however changed considerably due to deforestation in the catchment area.

Present observations as well as information from the local people indicate that the river dries out completely in the dry season. According to information from the local citizens, the water level has consistently been falling over the last years. An old GWC pumping station has been abandoned; the civil structure of a new station has been erected during the last years. It has however never been completed. The town of Nkoranza is electrified. This site may not be considered technically and economically feasible anymore.



**Photo 13: A GWC Pumping Station on Fia River at the site. It has never been in operation**

## 5.4.2 Kokuma Falls

**River:** Edam

**Location:** Kokuma, Brong Ahafo

**Catchment Area:** 78 km<sup>2</sup>

**Head:** 23 m

**Designed flow:** 0.4 m<sup>3</sup>/s

**Proposed installed Power:** 75 kW (grid)

**Annual energy generation:** 375,000 kWh (grid)

The Edam River, a tributary of Dum, is located about 20 km south of Kintampo. The site is in the forest about 2 km from Kokuma village. The river drops by about 23m in several steps and has dependable flow of around 100 l/s. Access to the bottom is quite difficult by foot due to dense vegetation. The village is presently looking to get connected to the VRA grid. The site is at a distance of about 6.5 km from the main road from Techiman to Kintampo. Several concrete poles have already been purchased for connection to the grid and are stored in the village. The construction of an isolated mini-hydro plant at the site is therefore not to be considered anymore.

A flow duration curve based on flow data from Fia River at Nkoranza gauging station in the same region, recorded from 1970 till 1996 has been generated. A Micro Hydro plant of 75 kW generating a total of 375,000 kWh/annum is feasible.



**Photo 14: Some rapids of Edam River at Kokuma (Dry Season)**

### 5.4.3 Fuller Falls

**River:** Oyoko

**Location:** Yabraso, near Kintampo, Brong Ahafo

**Catchment Area:** 465 km<sup>2</sup>

**Head:** 18 m

**Designed flow:** 2.6 m<sup>3</sup>/s

**Proposed installed Power:** 380 kW (grid)

**Annual energy generation:** 1,900,000 kWh (grid)

The Fuller Falls are located about 7 km west of Kintampo where the Oyoko River has a sudden drop of 18 m. The falls have recently been developed into a "prayer camp", a beautiful tourist site operated by the nearby village.

The national grid passes nearby. Even though the sudden drop of the river makes the site ideal for development into a mini-hydro plant the embankment of the river on the top of the falls would be difficult due to the nature of the area. It is a plain area. As per local information, nearby plots of land have been bought by three different parties to build hotels. As the area is connected to the grid, there is no interest in constructing the site for electrification purposes.

No priority should be given to this site for grid-connected operation. It could become interesting, if a potential investor of the hotels is interested in "clean" energy, e.g. operating the turbine on full power in the night and leaving some water on the falls during the daytime. The development of the site integrated as part of the hotel could be considered as a project under the Clean Development Mechanism.



**Photo 15:**  
**Fuller Falls,**  
**Rainy Season**

#### 5.4.4 Randall Falls (“Kintampo Falls”)

**River:** Pumpum

**Location:** Kintampo, Brong Ahafo

**Catchment Area:** 87 km<sup>2</sup>

**Head:** 40 m in two drops

**Designed flow:** 0.5 m<sup>3</sup>/s

**Proposed installed power:** 160 kW (grid)

**Annual energy generation:** 810,000 kWh (grid)

The Randall Falls, also known as Kintampo Falls, are located on the Pumpum River, a few kilometres north of Kintampo. The River falls about 40m over two steps (“upper and lower falls”).



**Photo 16: Upper Randall Falls, Rainy Season**

There is a dependable flow of about 200 l/s throughout the year. A plant of about 160 kW could be built by constructing a simple diversion weir and intake structure somewhere before the upper falls. Water would be moved through an open channel for about 250 m and through a 200 m steel penstock to the powerhouse located on the left bank of the river. Based on old flow duration curves an annual plant output of about 810,000 kWh can be calculated, based on the flow data from Fia River at the Nkoranza gauging station. However it is feared that flow has considerably in recent years. More recent data will have to be measured at site.

The Randall Falls site is perhaps the most feasible site that can be considered for immediate development. It would not only be easy to develop, the distance of only

4-5 km to the medium voltage line in Kintampo, would be of a big advantage for grid connection.

Randall Falls was developed into a tourist site in the past. A guest house which was operated by the Kintampo local administration is now in ruins.

A detailed economic analysis will have to take into consideration that for aesthetic reasons some water would have to remain on the waterfalls. However this might only affect power generation during the weekends in the dry season, when tourists are coming to the site and no excess water is available. On the other hand the construction of the hydro power plant might encourage the government, NGOs or private investors to further develop the site. The site may be developed into an environmental centre or an ecologically orientated guest house. The town of Kintampo is big enough for some local tourism and the waterfalls are in a walking distance from the main road to northern Ghana and Burkina Faso.



**Photo 17: Lower Randall Falls, Dry Season**

## Investment calculation for: Randall Falls

|         |                 |     |          |        |               |          |
|---------|-----------------|-----|----------|--------|---------------|----------|
| cash in | planned outflow |     |          | net    | pres. Worth   | Increase |
|         | Investment      | O&M | cash out | In-Out | of net in-out | of NPV   |

|                     | year   | tUSD  | tUSD   | tUSD   | tUSD    | factor | tUSD    | tUSD    |         |
|---------------------|--------|-------|--------|--------|---------|--------|---------|---------|---------|
|                     |        |       |        |        |         |        |         |         |         |
| construction period | -3     |       |        |        |         |        |         |         |         |
|                     | -2     |       |        |        |         |        |         |         |         |
|                     | -1     |       |        |        |         |        |         |         |         |
|                     | 0      |       | 450.00 | 450.00 | -450.00 | 1      | -450.00 |         |         |
| operation period    | 1      | 64.80 | 3.60   | 3.60   | 61.20   | 0.909  | 55.64   | -394.36 |         |
|                     | 2      | 66.10 | 3.67   | 3.67   | 62.42   | 0.826  | 51.59   | -342.77 |         |
|                     | 3      | 67.42 | 3.75   | 3.75   | 63.67   | 0.751  | 47.84   | -294.94 |         |
|                     | 4      | 68.77 | 3.82   | 3.82   | 64.95   | 0.683  | 44.36   | -250.58 |         |
|                     | 5      | 70.14 | 24.84  | 3.90   | 28.74   | 41.40  | 0.621   | 25.71   | -224.87 |
|                     | 6      | 71.54 |        | 3.97   | 3.97    | 67.57  | 0.564   | 38.14   | -186.73 |
|                     | 7      | 72.98 |        | 4.05   | 4.05    | 68.92  | 0.513   | 35.37   | -151.36 |
|                     | 8      | 74.43 |        | 4.14   | 4.14    | 70.30  | 0.467   | 32.80   | -118.56 |
|                     | 9      | 75.92 |        | 4.22   | 4.22    | 71.71  | 0.424   | 30.41   | -88.15  |
|                     | 10     | 77.44 | 27.43  | 4.30   | 31.73   | 45.71  | 0.386   | 17.62   | -70.53  |
|                     | 11     | 78.99 |        | 4.39   | 4.39    | 74.60  | 0.35    | 26.15   | -44.38  |
|                     | 12     | 80.57 |        | 4.48   | 4.48    | 76.09  | 0.319   | 24.25   | -20.14  |
|                     | 13     | 82.18 |        | 4.57   | 4.57    | 77.62  | 0.29    | 22.48   | 2.35    |
|                     | 14     | 83.83 |        | 4.66   | 4.66    | 79.17  | 0.263   | 20.85   | 23.19   |
|                     | 15     | 85.50 | 30.28  | 4.75   | 35.03   | 50.47  | 0.239   | 12.08   | 35.28   |
|                     | 16     | 87.21 |        | 4.85   | 4.85    | 82.37  | 0.218   | 17.93   | 53.20   |
|                     | 17     | 88.96 |        | 4.94   | 4.94    | 84.01  | 0.198   | 16.62   | 69.82   |
|                     | 18     | 90.74 |        | 5.04   | 5.04    | 85.69  | 0.18    | 15.41   | 85.24   |
|                     | 19     | 92.55 |        | 5.14   | 5.14    | 87.41  | 0.164   | 14.29   | 99.53   |
|                     | 20     | 94.40 | 33.43  | 5.24   | 38.68   | 55.72  | 0.149   | 8.28    | 107.81  |
|                     | 21     | 96.29 |        | 5.35   | 5.35    | 90.94  | 0.135   | 12.29   | 120.10  |
| 22                  | 98.22  |       | 5.46   | 5.46   | 92.76   | 0.123  | 11.40   | 131.49  |         |
| 23                  | 100.18 |       | 5.57   | 5.57   | 94.61   | 0.112  | 10.57   | 142.06  |         |
| 24                  | 102.18 |       | 5.68   | 5.68   | 96.51   | 0.102  | 9.80    | 151.86  |         |
| 25                  | 104.23 |       | 5.79   | 5.79   | 98.44   | 0.092  | 9.09    | 160.94  |         |

### Parameter Box

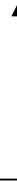
|                               |           |            |           |
|-------------------------------|-----------|------------|-----------|
| Inflation Rate                | 2.00%     | Lifetime   | 25 years  |
| Interest Rate                 | 10.00%    | Investment | 450 tUSD  |
| Operation & Maintenance (O&M) |           |            | 3.60 tUSD |
| Reinvestment                  | 5%        | Capacity   | 160 kW    |
| kWh grid                      | 8 US cent |            |           |

**NPV 160.94 tUSD**

Investment/kW **2.81 tUSD**

cost per kWh/a **5.63 US cent**

|                               |           |
|-------------------------------|-----------|
| energy production per year    | 810 MWh   |
| annual investment cost        | 19.5 tUSD |
| present worth of reinvestment | 38.2 tUSD |
| annual interest cost          | 22.5 tUSD |



**Table 2: Investment Calculation for Randall Falls (Kintampo)**

## 5.5 Western Region

The potential Mini Hydro sites known in the Western Region are located in the Krokosua Hills in the north-west, between Brong Ahafo and Ivory Coast. Some of these sites would have been interesting for rural electrification. However, since about 1996 the region has been connected to the national grid.

Looking at the rivers and streams in the Western region, it is obvious that they still carry water during the dry season. As the forest is still quite dense in that region, its importance becomes obvious when we compare these rivers with the ones in other regions of Ghana, where rivers have completely dried out during the past decades.

### 5.5.1 Sanwu Falls

**River:** Sanwu

**Location:** Sefwi Boinzah, Western Region

**Catchment Area:** 3.4 km<sup>2</sup>

**Head:** 150m

**Designed flow:** 50 – 100 l/sec (isolated)

**Proposed installed Power:** 60 kW (isol.)

The Sanwu Waterfalls had been a perfect location for the implementation of a Micro hydro plant for power supply to the nearby village of Sefwi Boinza. This has been known since the AESC study conducted around 1985. In 1994 the village of Boinzah with the assistance of engineers from Accra started to take flow measurements. However, in 1996, VRA extended the grid up to the village.

The location may not be suitable for the construction of a grid-connected plant, because of the long distance from areas where technical assistance could be sought for maintenance and repairs. It will require the training of local inhabitants to operate and maintain the plant.



**Photo 18: Samwu Falls, Dry Season**

### **5.5.2 Nworanae Falls**

**River:** Nworanae

**Location:** Asampanaye, Western Region

**Catchment Area:** 12.4 km<sup>2</sup>

**Head:** 50 – 100 m

**Designed flow:** 100 l/s (isolated)

**Proposed installed Power:** 40 kW (isolated)

The Nworanae River drops on several rapids by about 50 to 100 m of head. Due to dense vegetation in the rain forest, the top of the hills could not be reached. The dependable flow is about 100 l/s. Construction of the plant would not be so easy like on the Sanwu Falls, however by diverting the water in a channel, a micro plant could be constructed a few Kilometers away from the village of Asampanaye. The village is connected to the WCG grid since 1996. Therefore the site could be developed as a grid-connected site.

### **5.5.3 The “Western Rivers”**

The three big rivers Tano, Ankobra and Pra in the Western Region are known as the “Western Rivers”

A study conducted by Coyne et Bellier in 1994 analyzes the potential Hydro dam sites at Awisam and Twifo Hemang on the Pra river. It shows, that, mainly for the Awisam site, the construction of big dams would have a major environmental impact and demand the resettlement of tens of thousands of people.

A study done for the Ministry of Energy and financed by the World Bank/ESMAP around 1995 on the other western rivers is not available.

However it is clear that any development of these rivers with big hydro dams would have major effects on the environment and cause resettlement of people. Big areas of valuable land in one of the most fertile areas in the country would be flooded. The alternative would be the construction of several small run-of-river hydro plants.



|    |                                    |            | Former Reports |                  | Present Estimation               |                     |   |
|----|------------------------------------|------------|----------------|------------------|----------------------------------|---------------------|---|
|    |                                    |            | Isolated Grid  |                  | Grid Connected                   |                     |   |
|    | Location                           | River      | Size           | Power Generation | Size                             | Power Generation    | remarks   |
|    | <b>Volta Region</b>                |            |                |                  |                                  |                     |   |
| 1  | Wli Falls, Afegame                 | Nuboi      | 300 kW         | 2,600,000 kWh    | (1,000 kW)                       | (3,500,000 kWh)     | should not be developed due to touristic attraction   |
| 1a | Downstream Wli Falls               | Nuboi      | 45 kW          | 145,000 kWh      | 80 kW                            | 300,000 kWh         | <b>grid connected development possible</b>            |
| 2  | Alavanyo-Abehensi "Tsatsadu Falls" | Tsatsadu   | 200 kW         | 1,752,000 kWh    | 320 kW                           | 1,200,000 kWh       | <b>interesting site for development</b>               |
| 3  | Likpe Kukurantumi                  | Dayi       | 400 kW         | 876,000 kWh      | 100-150 kW                       | 400,000-500,000 kWh | based on old flow data; still assuming a 5 m high dam |
| 4  | Dzolo                              | Dayi       | no information |                  | no natural head                  |                     | similar to Kukurantumi                                |
| 5  | New Ayoma                          | Dayi       | no information |                  | no natural head                  |                     | similar to Kukurantumi                                |
| 6  | Menu                               | Menu       | 500 kW AESC    | 4,380,000 kWh    | 13 m high weir is unrealistic    |                     | not recommended for further consideration             |
|    |                                    |            | 65 kW (ACRES)  | 209,000 kWh      |                                  |                     |   |
| 7  | Ahamansu                           | Wawa       | 125 kW (ACRES) | 403,000 kWh      |                                  |                     | not recommended for further consideration             |
| 8  | Dodi Papase                        | Wawa       | 500 kW (AESC)  | 4,380,000 kWh    | 14-16 m high weir is unrealistic |                     |   |
|    |                                    |            | 210 kW (ACRES) | 676,000 kWh      |                                  |                     |   |
| 9  | Asuboe                             | Wawa       | 100 kW (ACRES) | 322,000 kWh      | 10 m high dam was required       |                     |   |
| 10 | Dodo Tamale                        | Asuakawkaw | unknown        |                  |                                  |                     | 13 m high irrigation dam was foreseen                 |
| 11 | Dodo Amanfron                      | Jelem      | unknown        |                  |                                  |                     | 13 m high irrigation dam was foreseen                 |
|    |                                    |            |                |                  |                                  |                     |   |
|    | <b>Eastern Region</b>              |            |                |                  |                                  |                     |   |
| 12 | Wurudu Falls Moseaaso              | Wurudu     | 25 kW          | 219,000 kWh      | dries out completely             |                     | not recommended for further consideration             |

**Table 3: Summary comparison of former data and present condition (continued next page!)**

|    |   |           | Former Reports |                  | Present Estimation               |                  |   |
|----|---|-----------|----------------|------------------|----------------------------------|------------------|---|
|    |   |           | Isolated Grid  |                  | Grid Connected                   |                  |   |
|    | Location                                      | River     | Size           | Power Generation | Size                             | Power Generation |   |
|    | <b>Ashanti Region</b>                         |           |                |                  |                                  |                  |   |
| 13 | Boumfum Falls<br>Kumawu                       | Ongwam    | 225 kW         | 1,970,000 kWh    | Dries out completely             |                  | not recommended for further consideration                                     |
| 14 | Barekese Dam (GWC)                            |           |                |                  | to be evaluated                  |                  | <b>see report!</b>  |
| 15 | Maabang                                       | Kwasu     | 200 kW         | 1,75,000 kWh     | has not been located             |                  | requires 25 m high flood control dam  |
|    | <b>Brong-Ahafo Region</b>                     |           |                |                  |                                  |                  |   |
| 16 | Nkoranza                                      | Fia       | 60 kW          | 525,000 kWh      | Dries out completely             |                  | not recommended for further consideration                                     |
| 17 | Kokuma Falls                                  | Edam      | 45 kW          | 390,000 kWh      | 75 kW                            | 375,000 kWh      | <b>interesting site for isolated plant, grid connection possible</b>          |
| 18 | Fuller Falls                                  | Oyoko     | 90 kW          | 788,000 kWh      | 380 kW                           | 1,900,000 kWh    | <b>grid connected development possible</b>                                    |
| 19 | Randall Falls<br>"Kintampo Falls"<br>Kintampo | Pumpum    | 80 kW          | 700,000 kWh      | 160 kW                           | 810,000 kWh      | <b>interesting site for development</b>                                       |
|    | <b>Western Region</b>                         |           |                |                  |                                  |                  |   |
| 20 | Sanwu Falls<br>Sefwi Boinzah                  | Sanwu     | 60 kW          | 525,000 kWh      | not suitable for grid connection |                  | interesting location for isolated site, however the village is grid connected |
| 21 | Nworannae Falls<br>Asampanaye                 | Nworannae | 40 kW          | 350,000 kWh      | not suitable for grid connection |                  | possible site for isolated plant, however not suitable for grid connection    |
| 22 | Sefwi Asanwinso                               | Benchema  | 45 kW          | 394,000 kWh      | could not be located             |                  | area is grid connected  |

**Table 3 (continued): Summary comparison of former data and present condition**

## **6 Conclusions**

1. The national electricity grid is now at almost all the known potential mini hydro sites in Southern Ghana or within a distance of at least 10 km. Of all the known potential mini hydro sites only a few remain to be of any interest for an isolated grid for rural electrification.  
Two options remain for the construction and operation of the sites: i.e. either power is fed into the national grid or a commercial enterprise is operating the power plant to generate electricity to meet its power demand.
2. The economically usable potential of the rivers has reduced considerably as a result of deforestation.
3. About 50% of the sites dry out completely during the dry season. Power generation will be limited to not more than five months in the year.
4. Several sites could become economically viable if they are considered alongside irrigation and water supply projects or the tourism development of the area.
5. The viability of grid-connected plants depends on power purchase agreements with the utility companies or a power purchase tariff established by the PURC.

## **7 Recommendations**

1. To implement the first mini hydro pilot projects in Ghana, middle or high head sites should be considered rather than low head sites. Low head sites are relatively more expensive to construct and bear the risk of flooding.

It is recommended that as a pilot project either the Tsatsadu Falls in the Volta region or the waterfalls around Kintampo in Brong Ahafo should be considered. At Randall Falls (Kintampo) the opportunity should be considered to use the available power to initiate tourism projects at the location.

2. The low head sites in the Volta Region, especially Likpe Kukurantumi, could be reconsidered if there are plans to set up irrigation projects in that area. As all those rivers have a permanent flow throughout the year, this would be possible. An additional hydro power plant could generate some power to pump the water. However, before going ahead with plans to construct dams of 5 to 14 m of head on those rivers, as foreseen in some proposals, detailed analyses of the effect on flooding should be undertaken by experienced hydrologists.

3. The Ghana Water Company is advised to systematically review the potential for Mini Hydro Plants on their dams and weirs, taking into consideration the recent flow data as well as the present power tariffs they have to pay.
4. To attract the private sector to invest into power generation with small hydro sites as well as other renewable energy sources and to allow a clear basis for further planning of small hydro projects, the Government of Ghana through the Energy Commission and the Public Utilities Regulatory Commission (PURC) should provide a clear regulation and attractive price for power supply into the national electricity grid.