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MINI-HYDRO GENERATION EQUIPMENT

ANALYSIS AND PROPOSAL FOR DEMONSTRATION MINI-HYDRO POWER PLANT IN GHANA*

Prepared by

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MINI-HYDRO GENERATION EQUIPMENT ANALYSIS OF MINI-HYDRO PLANT IN GHANA

1. Introduction

According to a request of the Ghanaian Government, UNIDO has provided technical support for the evaluation of a techno-economic viability of existing mini-hydro generation equipment and material for the proper erection of a mini-hydro power demonstration plant in Ghana. Furthermore, the possibility for developing Ghana's electricity supply base by preparation of a mini-hydro development program had to be explored.

Electrowatt Engineering Services Ltd. of Zurich, Switzerland was contacted and a contract was signed with UNIDO on December 8th, 1989, to provide the Consultancy Services requested by the Government of Ghana. (Contract No. 89/470)

The services specifically expected were:

- Inspect and evaluate existing mini-hydro equipment supplied by JYOTI Ltd., of India in 1983, which was procured for the Likpe Kukurawtuni Project

- Inspect selected sites for the erection of a demonstration mini-hydro plant and provide a ranking of candidate sites which meets a site's compatibility with the already supplied mini-hydro power equipment.

- Analyse the mini-hydro power potentials and needs of Ghana and prepare a mini-hydro development programme.

Two engineers of Electrowatt Engineering Services Ltd. Mr. Alfonso Krumdieck, a Civil Engineer, and Mr. Helmuth Miller, a Mechanical Engineer, went to Ghana on the second week of March 1990, for the inspection of the turbine and to visit the potential sites for the installation of that turbine.

This report is based mainly on the data provided by the ACRES study on the topic of mini-hydro potential in Ghana, on the inspection of the stored turbine and auxiliary equipment, and on the field trip undertaken to the potential sites where the already purchased equipment could possible be installed.

2. Background

The emphasis on hydro development in Ghana during the past years has been on large scale hydroprojects, somehow neglecting the potentials of small hydro generation, which in some cases could have been appropriate in meriting isolated electrification requirements of remote settlements in which the potential hydropower is available.

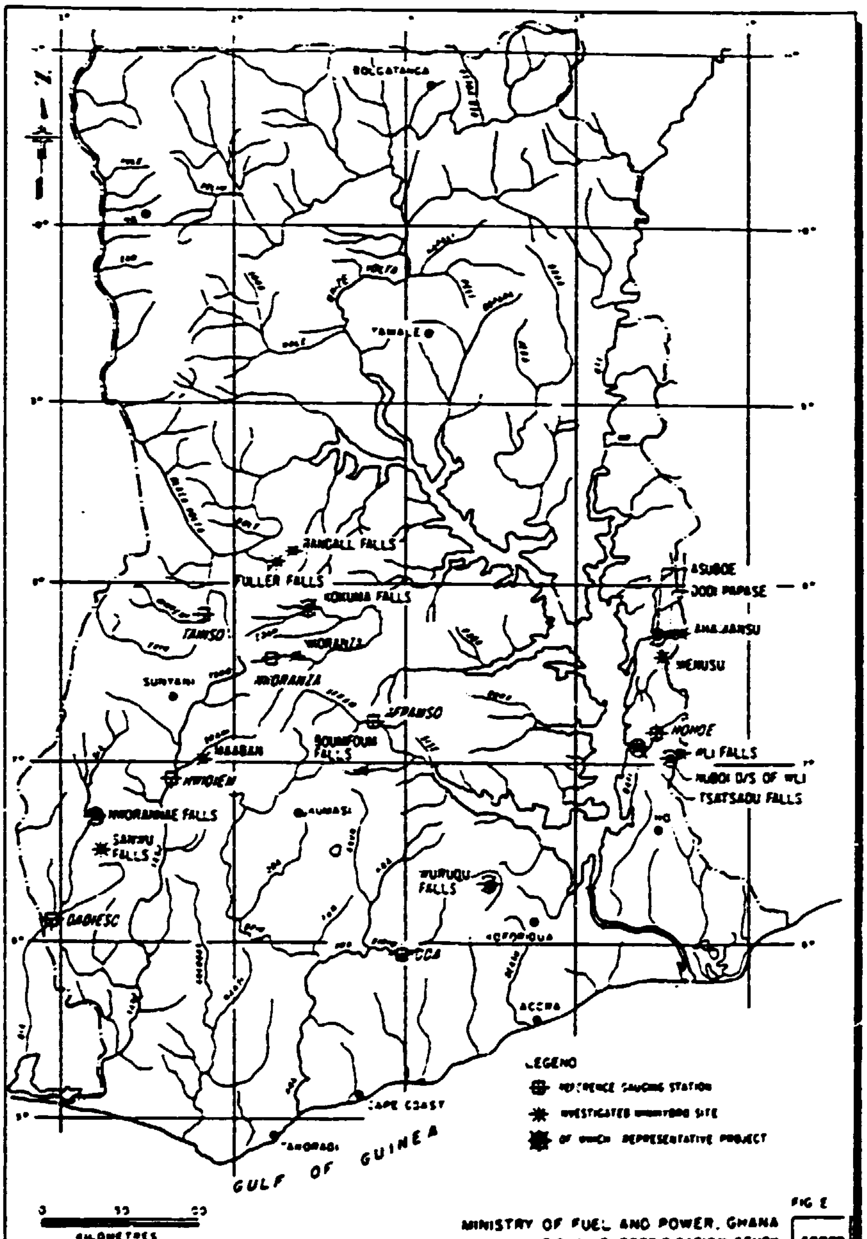
The Architectural and Engineering Services Corporation (AESC) and the Ministry of Fuel & Power / National Energy Board has identified in a previous study forty (40) sites of high potential for mini-hydro development. Out of that number the feasibility study of fifteen (15) sites have proved to be economically viable.

Later on, the Canadian Consulting firm ACRES International Limited in association with the local consultant firm Asare Tsibu & Partners, prepared a report for the National Energy Board called the National Electrification Planning Study Phase 2 Report. In that report they have investigated sixteen (16) sites, fourteen of them as a carryover from the previously ones, and 2 have been newly identified (See Figure 1). Some other sites in separate regions are mentioned in their report, but were abandoned mainly because of the non-perennial character of their watercourses. The ACRES report mentioned a total of 21 sites in all that have been identified and studied.

There is no doubt that there are many other potential sites, but those sites can only be identified and studied in the future. Of the sixteen potential sites studied by ACRES, six have been considered technically and economically viable. Five of those schemas are installations which have small watercourses over concentrated heads which use some natural waterfalls.

The low head projects are however, of a little more cost when compared with high head systems.

ACRES has studied one scheme which is a dam type development conceived to use the existing 100 kW generating unit now available. Next to the Likpe Kukurawtuni site, where the initial installation of this unit was envisaged, the Asuboe site on the Wawa River (Volta Province) has been selected by ACRES as by far the most appropriate site with regard to both, river discharges and site characteristics that would be compatible with the imposed requirements of the available turbine.



LOCATION OF 16 POTENTIAL SITES OF MINI HYDRO INVESTIGATED BY ACRES INTERNATIONAL LTD. AND ASARE TSIBU & PARTNERS IN 1989

Figure 1

3. Available information

The study was based on the following available information:

- National Electrification Planning Study Phase 2 Report, prepared by ACRES International Limited and Asare Tsibu & Partners, October 1989
- Topography sheets in scale 1 : 50 000
- Disposition plan of the planned mini-hydro power plant
- Purchase agreement for the supply of electrical equipments and accessories for Mini-hydro Project of Dec. 16th, 1983.
- List of Delivered Materials (From Contract)
- Packing list and Description of Equipment and Material.(on store house)

4. Inspection of the Stored Equipment

The whole equipment was delivered in 53 boxes by JYOTI Ltd. in 1986, it has been stored in three different places of a Storage House of the Accra Water Supply and Sewerage System:

- The first part has been stored in a closed hangar and it is protected from meteorological influences
- The second part is stored in closed wooden boxes, in an open hangar with a roof, which protects the boxes from direct rain but not from humidity and heat.
- The third part is not packed; it is placed without any protection from climate, mainly the three steel intakes, penstocks and the foundation frames.

It was not possible to check if the delivery is still complete or not. However the fact that the material could be found relatively quickly and that it is enclosed in boxes gave the impression that the delivery is still complete.

A detailed control and check of all parts would take some weeks, it would be necessary to unpile the boxes with a crane or a forklift, to open all the boxes one by one, and to pack them back again in an orderly and professional form.

For that reason it was decided to make only a random check with some of the boxes. The observed material inside of the opened boxes is well preserved in a complete set and can be regarded as practically new.

However, with the rest of material piled outside (intakes and penstock) it could be observed that the corrosion protection has practically disappeared and the penstock and intake material present already heavy rust deterioration.

Further down in numeral 8. are given the limitations in head and discharge of the purchased turbine and its possibilities of installation at a new site.

5. Topography

Only topographical maps on the scale 1:50.000 were available which are not sufficient for a detail design. It is required to make a topographic survey along the river in the areas of the most promising sites and prepare topographic maps at a scale of 1:500, before any other activity can be carried on. Further down in the annex are given some basic specifications for this survey.

6. Hydrology

No gauging station with a sufficient period of record exists at any of the project sites that could be used for the installation of a mini-hydro power station, with the exception already mentioned in the ACRES report of Nkorenza. Gauging measurements have started on the Menu and Wawa rivers, near the mini-hydro project sites of Menusu, Ahamansu, Dodi-Papase and Asuboe, but there are still no meaningful records available.

Therefore, for the time being only data from other gauging stations for catchment areas near the project sites and similar in terms of runoff conditions will have to be considered.

The main hydrologic characteristics can be summarized as follow:

Main Hydrologic Characteristics

Mini-hydro Project Site	Reference Gauging Station	Catchment Area in Gauging Station	Catchment Area in Project Site	Average Discharge Gauging Station	Average Discharge Project Site
		km^2	km^2	m^3/s	m^3/s
Ahamansu	Hohoe	626	1342	4.9	10.6
Dodi-Papase	Hohoe	626	1456	4.9	11.5

The high water discharges are assumed to be 160 m^3/s at Asuboe site. This value has been used for this preliminary report, however because of the lack of more reliable data, this value should be used with caution, with a sufficient margin for much higher floods in the design of the spillway.

7. Field Trip

On March 10, 1990, the Consultants accompanied by Mr. Omane Frimpong Programme Officer of the National Energy Board and Mr. Ebenezer A. Osekre a Civil Engineer of the Water Division of the Architectural and Engineering Services Corporation, made a field trip to the potential sites of Asuboe, (see Figure 2)

Two potential sites were visited, the first one (alternative A), which is a very favorable site is located on the Wawa River (in the Volta Region) near the Village of Asuboe. The damsite is narrow with a river bend which facilitates the implantation of concrete structures. The area upstream of the site that would be flooded is relatively small and will not cause ecological problems.

The site at Asuboe, under consideration, could develop a head of 5 to 6 m which is necessary to allow for the installation of the turbine-generator unit that was acquired by the Ministry of Fuel and Power in 1983 with the intention to install it in the Likpe-Kukurawtuni project.

The second alternative (alternative B), the Dodi-Papase site could develop a somewhat higher head of the order of 9 m, however, this alternative in contradiction to alternative

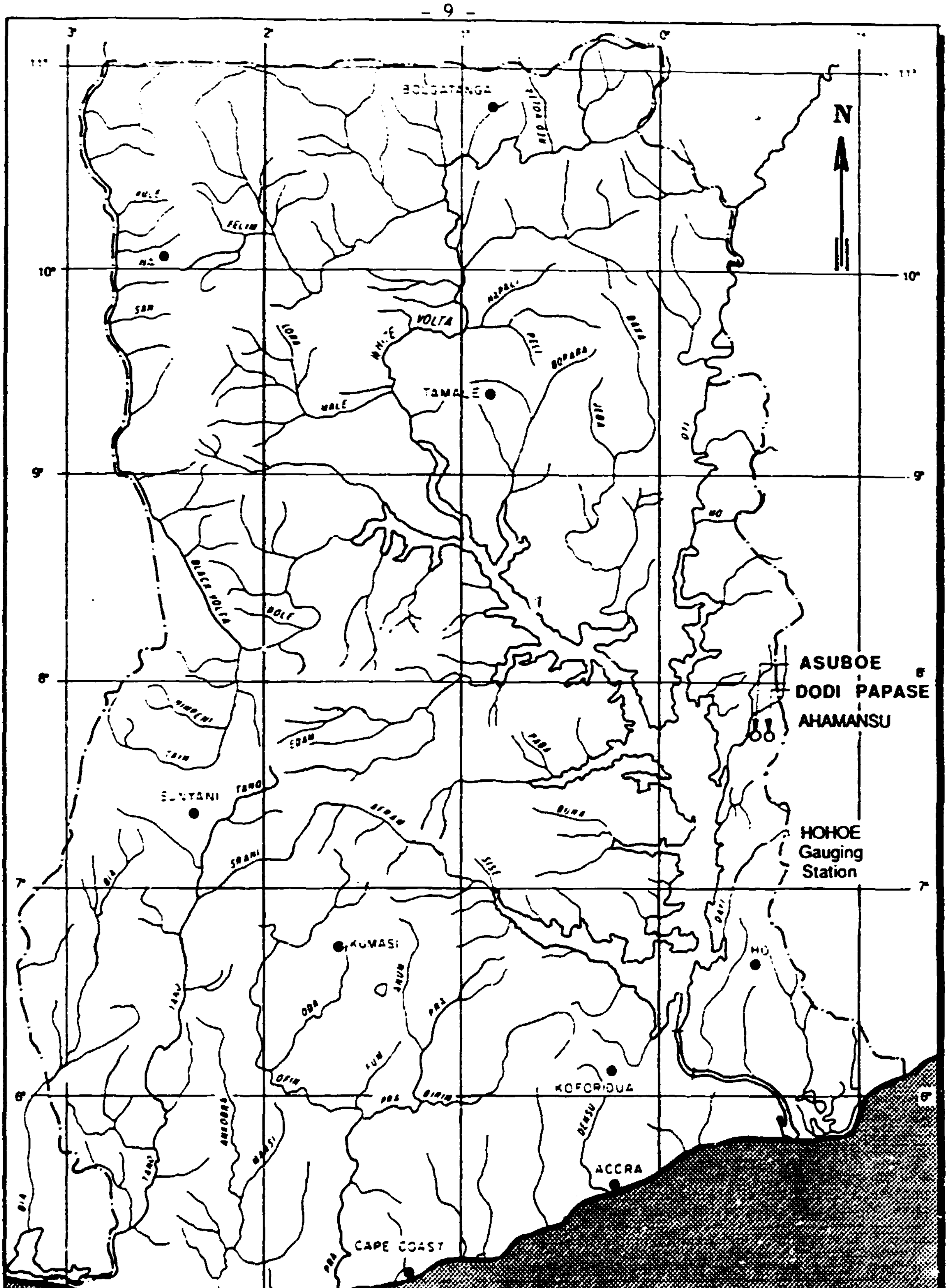


Figure 2

LOCATION MAP OF MINI-HYDRO SITES VISITED

A, visited close to Asuboe, could not make direct use of the existing generator unit. It would require a much stronger generator, but, the rest of the equipment could still be used, however, the site closer to Dodi-Papase has the advantage to be close to the village with an easy access and a simpler general layout (See Figure 3).

Because in both cases, only topographical maps with scale of 1:50,000 are available, it will be necessary to prepare topographical drawings at a scale of 1:500 along a certain length of the river before final design.can be undertaken.

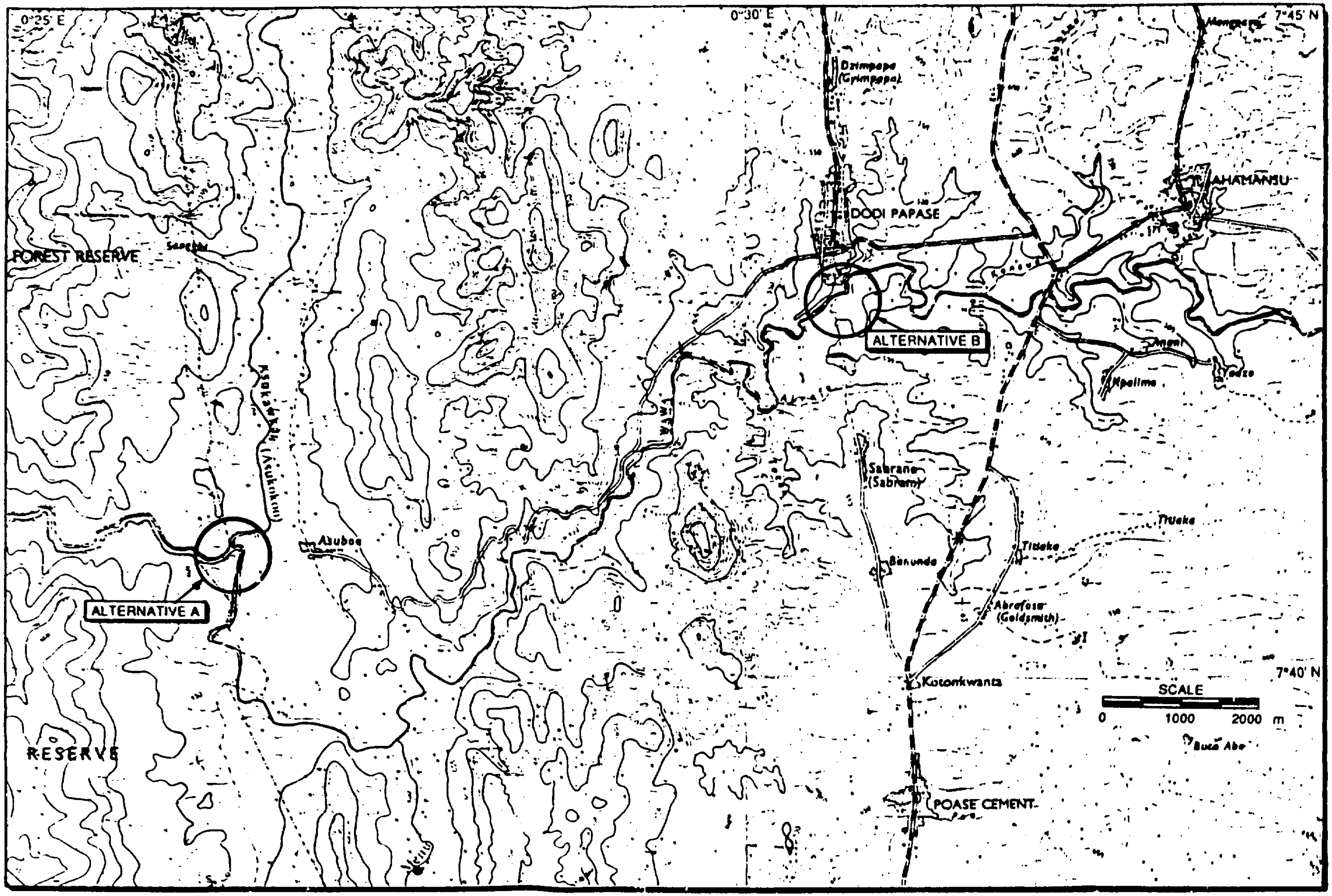
Both, at Asuboe or at Dodi-Papase, the design schemes of the powerhouse are similar (See Figure 4). A dam of about 10 m height will close the central part of the river. The concrete structures consist of an ungated spillway followed by a chute and a stilling basin, a deep sluice with a diversion bay to clean possible sediments in front of the structures, and a power intake connected by a 12-17 m long penstock to the powerhouse, located adjacent to each other at the right bank. The spillway with a width of 20 m could discharge, with a head of 2.50 m, 160 m^3/s which correspond to a 100-year flood. A 0.50 to 1.00 m freeboard to the crest of the dam would allow to pass any flood higher than the one used for the design, however this value seams to be rather low and should be used with a sufficient margin of safety.

The sluice opening could be controlled by a high gate of 2.0 x 2.0 m. This gate would serve as sediment flushing facility as well as a diversion facility during construction or for maintenance.

The power intake, provided with trash racks and a stop log slot, would be located next to the sluice bay. A steel penstock with a 1.20 m diameter will feed the horizontal tube-type turbine located in a conventional type powerhouse. For safety reasons the penstock should be encased in concrete.

The powerhouse of a conventional type will be a simple rectangular box with side walls designed to withstand the external water pressure at high tailwater levels, during the occurrence of floods.

As already noted by ACRES International Ltd., the construction of mini-hydro developments in Asuboe, in Dodi-Papase and in Ahamansu, all three developments in the Wawa River are not mutually exclusive and, potentially, all three sites could be utilized in the future.



ALTERNATIVE SITES VISITED AND INSPECTED

Figure 3

All three sites would have to be equipped with reactive turbines in order to effective utilize the available low head.

8. Equipment

The material and equipment delivered by the Indian Firm JYOTI Ltd. (and other Indian firms), comprise a complete electromechanical set for a Mini-hydro Power Plant of 100 kW installed capacity. it should be possible to expand this power plant in the future to three units.

The price of the equipment at the moment of the signature of the contract in 1983 was Rs. 16.316.126.00 C.I.F.(Indian Rupies) at the Port of Tema, Ghana. The equivalent price today should be about US $ 400.000.

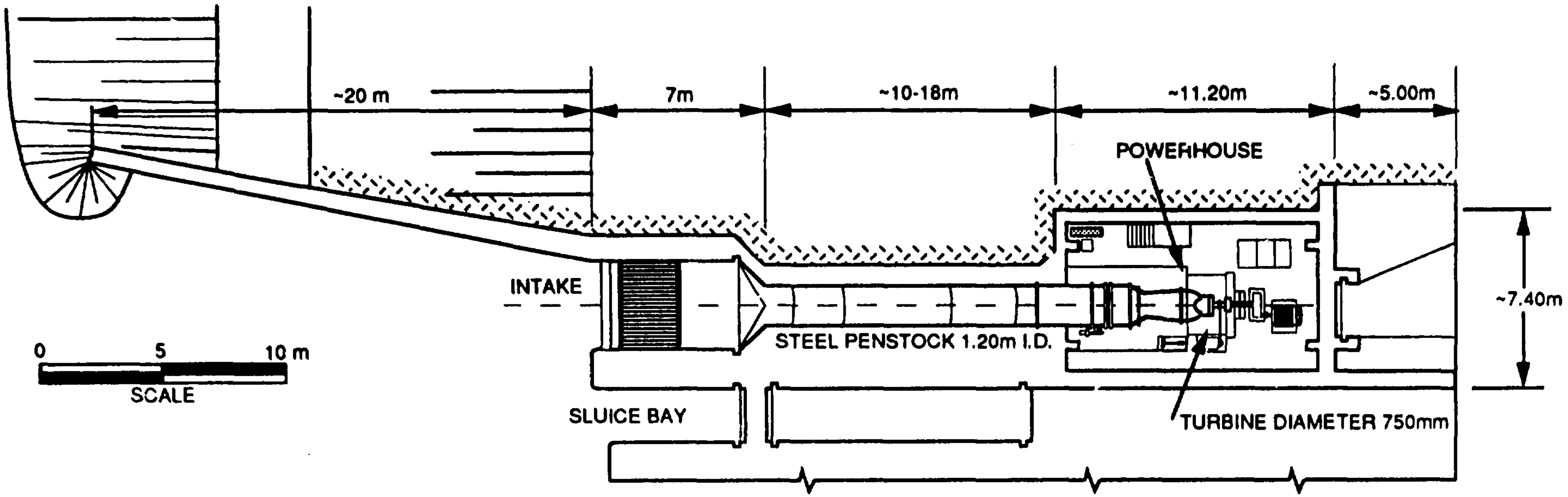
The inspection of the stored material indicates that the tubes of the penstock and the foundation structure are suffering from serious corrosion and that a protection treatment is badly needed and will require a thorough sand blasting to remove all rust from the steel surface, followed by a protection of all inside and outside surfaces with an anticorrosion paint.

it is assumed that all the seals will have to be renewed. The potential danger that the erection and commissioning of the equipment could be delayed as a result of some missing or damaged parts remains. For that reason it is recommended to make an exact check of all materials before assemblage on the site with the purpose to detect any faulty or missing parts and allow sufficient time such that any possible order for replacement parts will not delay the erection and commissioning of the equipment on site.

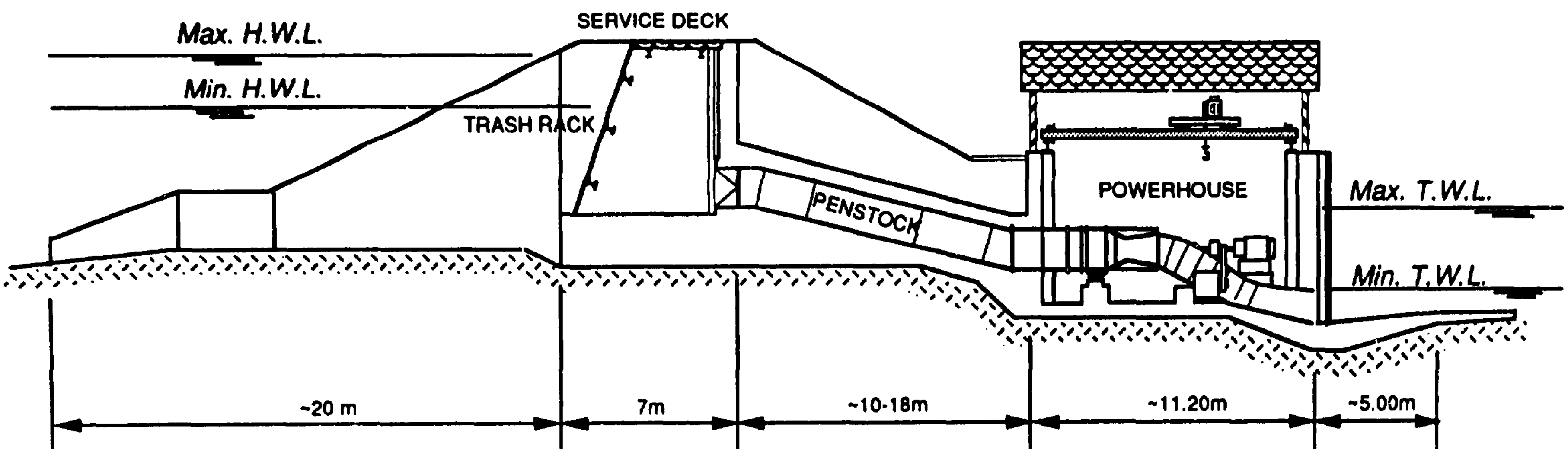
According to the Paragraph 8.01 of the Purchase Agreement, the Guarantee Obligations of the Suppliers expire 12 months after the date of the shipment. For that reason it is recommended that for the montage, erection and some purchase or repair parts to have available some amount of money.

The available data and information of the delivered electromechanical equipment do not give any information on the following points:

SCHEMATIC VIEW OF THE MINI -HYDRO PROJECT



SCHEMATIC VIEW OF PENSTOCK AND POWERHOUSE



SECTION THROUGH INTAKE, PENSTOCK AND POWERHOUSE

Figure 4

- The size of the turbine
- The number of blades
- The type of regulation (if the machine is double or single regulated)

The turbine is of the tubular type (S-turbine). Based on the data given in the Guarantee it was first assumed that the diameter of the runner should be of 750 mm and that the turbine is of a single regulated propeller type with four runner blades (It was later confirmed by a telefax of the manufacturer).

With the above technical information we can confirm that the machine can operate in the following range:

POSSIBLE RANGE OF OPERATION OF THE TURBINE

Head	m	2	3	4	5	6	7	8	9
Discharge	m^3/s	1.15	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Efficiency (Turbine)	%	65.0	79.5	85.3	87.6	89.0	89.5	89.6	89.0
Max. Output (Generator)	kW	13.2	63	90	116	141	165	190	212
Min. Output (Generator)	kW	6	28	40	52	63	73	85	94

If the turbine were of the double regulation type, the difference between the maximum and minimum output of the generator would be bigger, or the minimum output of the generator could be smaller. This point is of significance because the temporary consumption could be very small.

The fact, that the maximum generator output was fixed to be 100 kW means that the existing turbine can only be installed at some specific sites which correspond with the sites proposed in the National Electrification Planning Study prepared by ACRES International Ltd. and Asare Tsibu & Partners.

In the site of the Likpe-Kukurawtuni project the head was 5.0 m with an output of 100 k. In the proposed Asuboe A the head is 5.8 m with an output of 100 kW.

It is possible to gain a wider range of use of the existing turbine if the existent generator could be changed to a stronger one. The extra cost would be of the order of US $ 100,000.

In that case the existing turbine could be used in the following projects:

SITES IN WHICH THE EXISTING EQUIPMENT COULD BE USED

Plant	Max.Head (m)	Output (kW)
Ahamansu	6.0	125
Dodi-Papase	9.0	210
Asuboe A	5.8	100
Asuboe B	9.0	210

In all the above mentioned sites the existing equipment could be used without any changes, if the spillway can be placed in such a way that the relation between the upstream and downstream water level will be a function of the water discharge, i.e., the water head is kept constant for any type of discharge. The advantage of this system is that in case of a high water discharge the turbine can still produce with the maximum installed capacity.

This effect can be achieved by constructing a spillway in which the upper level of the dam crest is not horizontal but inclined.

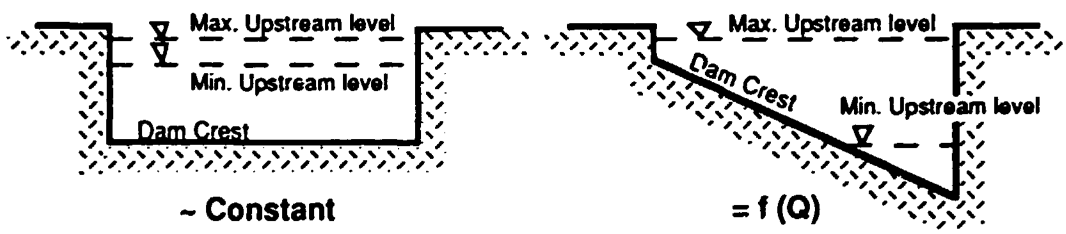


Figure 5 Variable Spillway

Applied to the existing case, it means that the spillway should be shaped in such a way that the total water discharge at any moment can take place under a constant head of about 5 m.

The mentioned solution can eventually in a later phase in which it would be necessary to install the second or the third turbine, accomplish that requirement by solely filling part or all of the inclined spillway section. This will allow to operate the turbine all the time with a maximum upstream water level. The additional machines could be of higher installed capacity. The turbine which was installed first would then only be use for larger discharges. It could be operated with high water heads, of the order of 5 m.

This solution would permit to select the site of Dodi-Papase which is closer to the village and has an easier access. This means that the construction costs will be lower.

9. Cost of the Project

Using the quantities estimated by ACRES for the Asuboe Minihydro Project, a cost estimation can be made which will approximately be the same for both alternatives, given only the approximately order of magnitude.

A final more accurate cost estimation will be only possible when the topographic maps at a scale 1:500 will be available and a detailed project has been developed and located on those maps. Some elementary knowledge of the subsoil conditions must also be available, and a final complete control of the electromechanical equipment has been made.

Dodi-Papase Minihydro Project:

Item	Amount in US $
Access Road	10,000
Civil Works	
• fill dam	24,500
• spillway	87,000
• sluice bay and wing wall	28,500
• powerhouse structures	30,000
Contingencies Civil Works (15%)	30,000
Subtotal Civil Works	200,000
Electromechanical equipment	
• sluice	6,500
• intake and powerhouse, transformer	168,000
Contingencies electromech (10%)	17,500
Subtotal electromechanical equipment	192,000
Direct Cost, Including Contingencies	402,000
Engineering, Surveys, Supervision and	210,000
Total	US $ 612,000

Costs which could be replaced by local contribution:

Access Road (75%)	7,500
Excavation in Overburden (90%)	4,400
Fill (60%)	12,800
Concrete Works (15%)	14,800
Contingencies to Above	5,500
Total Possible Local Contribution	US $ 45,000

10. Mini Hydro Demonstration Power Plant

A Mini Hydro Project in Dodi-Papase or in Asuboe could be used as a demonstration center for a mini-hydro development power plant. However, because of the lack of accommodation facilities and other minor obstacles, it would be necessary to provide a small camp that could be used later as a training facility for other operators to be trained. The cost of the camp has not been included in the cost estimate previously presented.

The Mini-hydro Power Plant will serve to show and demonstrate that it is possible to implant small hydro plants in isolated areas in Ghana in a profitable and economic way and to set the precedent for future developments in other parts of the country.

The ACRES study has already identified 16 sites; however, it is estimated that between 50 and 60 sites could be developed in Ghana as isolated plants in a more or less profitable and economic way. This is a sort of energy that will not overlooked in the future, but will be considered as an alternative source for the isolated areas for which the National grid has not been planned in the near future.

The mentioned mini-hydro potential indicates that Ghana will required sooner or later technical personnel qualified to design, construct and operate the future power stations and that it is advisable to start the training of some personnel with time. The construction of a mini-hydro power plant at Dodi-Papase or any similar location will present the opportunity to integrate some young engineers during the construction period of the plant, and later during the operation of the power plant.

11. Conclusions and Recommendations

The reconnaissance study has shown that there are some existing sites available in Ghana, especially in the Volta Region where the equipment that was purchased by the Ministry of Fuel & Power in 1983 and delivered in 1986, could be installed.

The sites of Dodi-Papase and Asuboe are two possible alternatives, among which the alternative Dodi-Papase is apparently the most promising one.

The equipment stored in Accra could and should be used in one of these alternatives, saving in that way the investment already made. The parts of the intake and penstock stored on the open air yard should be cleaned in all their rusted parts and painted, to avoid further deterioration and eventually total destruction.

A local entity organized by the Ministry of Fuel & Power or the National Energy Board should take care that hydrological measurements and records are systematically made in the future. This would enable to make a better design of further development steps of mini-hydro power plants.

A topographic survey at a scale of 1:500, of the potential sites is recommended, in order to enable a more detailed design and an accurate cost estimation of the proposed power plant.

A first estimation of the cost of the power plant shows that the probable cost of construction made under conservative considerations is economically viable.

The proposed power plant could be used as a demonstration Mini-Hydro Power Plant in Ghana and set a precedent to the future development of mini-hydro in isolated regions of the country where there is potential for hydropower.

Appendix

Recommended Topography Survey to be carried out by the local Ghanaian Authorities befor. a final design.

Only maps at the 1:50,000 scale are presently available for the Asuboe and the Dodi-Papase areas. Those scales are not sufficient for the purpose of a final design. For that reason one of the main activities necessary to determine the definitive location of the powerhouse and of all the other auxiliary structures is the execution of a detailed topographic survey of the project area with the establishment of the basic horizontal and vertical controls. These maps could be prepared already by the Ministry of Fuel & Power or some local specialized firm working under the control of the Ministry.

If possible, all horizontal and vertical controls shall be tied to points of known geographic positions and elevations established by relevant National Geodetic Survey Authorities.

Survey markers should be established ensuring that continuous protection of these points is guaranteed. The benchmarks should be brass rods set in concrete foundations, protruding about 4 mm from the surface.

The field measurements carried out by a professional surveyor fully familiar with the necessary measuring techniques should provide the following :

> Detailed topographic maps, scale 1 : 2 000 up to 1 : 500 with contour lines of 2, 1 and 0.5 m.

The ground controls for the plan and height of the survey markers should be carried out using conventional or electronic distance measuring equipment and a theodolite.

Leveling shall be made as forward and backward running between fixed elevations of basic survey or loop closure on the same bench mark.

Applying a tachymetric method, the density of terrain measurement points should be at least 36 points per ha.

The required accuracy of the maps should be

± 0.3 m in position and
± 0.2 m in elevation.

The expected accuracy of contour lines shall be delineated to represent the true elevation and shape of the ground.

For areas with a slope of less than 1%, the contour intervals should be 0.5 m; for areas with slope of 1%-5%, 0.5-1.0 m and for areas with slope of more than 5%, contour intervals of 1.0 m should be used.

All planimetric features which are well defined on the ground shall be plotted, so that the position on the finished map is accurate to within 0.5 mm of the true coordinate position.

Spot elevations placed in the map shall have an accuracy of at least 1/3 of the basic contour interval.

Eighty-five percent (85%) of all elevations interpolated from the map's contour lines shall be correct within half of the contour interval. Not more than 5% shall show errors in excess of the contour interval.

Any contour line which can be brought within the above-mentioned vertical tolerance, by moving its plotted position by 0.5 mm in any direction, shall be considered acceptable. If, for any part of the area the ground is obscured by vegetation, other obstacles or details, the Surveyor will show contours by broken lines and in those areas additional tolerance will be permitted in regard to the accuracy of the contours.

Coordinates and elevations shall be computed as results from field notes. This includes computations on traverses, triangulations, tide observation (if no bench mark is available), level network, astronomic observations and other computations.

A topographic map shall be plotted in appropriate scale indicating all features of terrain (contour lines), including roads, trails, houses, structures, and rivers, boundaries of wooded areas, etc.

All horizontal and vertical control points located within or near the map area shall be shown and designated by appropriate symbols, number and elevation, wherever applicable.

All maps sheets shall show the following marginal information:

- North arrow
- All important details like lakes, shoreline marks, towns, etc.
- Legend of map and scale bar
- Contour interval
- Projection system used
- Geodetic datum used
- The name of the responsible entity who prepared the map

The surveyor in charge, should provide the following information:

- Field notes and computations on traverses, triangulations, level network and other computations in the establishment of horizontal and vertical ground controls.
- Topographic maps on deformation-proof synthetic paper
- Horizontal and vertical control point descriptions on mylard sheets.