Japan International Cooperation Agency
The Republic of Cameroon
Ministry of Mines, Water and Energy

Feasibility Study on Rural Electrification Project

in

The Republic of Cameroon

Main Report

December 1999

Electric Power Development Co., Ltd.

PREFACE

In response to a request from the Government of the Republic of Cameroon, the Government of Japan decided to conduct the Feasibility Study on a Rural Electrification Project in the Republic of Cameroon and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a study team led by Mr. Shozo Yuzawa of the Electric Power Development Co., Ltd. to the Republic of Cameroon six times from March 1998 to November 1999.

The team held discussions with the officials concerned of the Government of the Republic of Cameroon, and conducted related field surveys. After returning to Japan, the team conducted further studies and compiled the final results in this report.

I hope this report will contribute to the promotion of the plan and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Cameroon for their close cooperation throughout the study.

December 1999

Kimio Fujita
President
Japan International Cooperation Agency

December 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita,

LETTER OF TRANSMITTAL

The Feasibility Study Report on the Rural Electrification by Small Hydroelectric Power Development Project in the Republic of Cameroon is herewith submitted. This Report has been prepared according to the advice received from the authorities concerned of the Japanese Government and your Agency and, further, taking into consideration comments of our counterparts on the Cameroonian side in technical discussions held in Yaounde during field investigations made by the survey team.

This Report contains a summarization of feasibility studies made on the small hydroelectric power development projects at three sites, namely, Ngambe-Tikar, Ndokayo, and Olamze, proposed from among candidate sites for small hydroelectric power development existing in the Republic of Cameroon. As a result of the feasibility studies, it is judged that the Ndokayo Small Hydroelectric Power Development Project, in particular, is a promising project from technical and economic viewpoints as small hydroelectric power development with the purpose of enhancing the people's livelihood in the districts of Garoua Boulai, Ndokayo, and Betare Oya in Eastern Cameroon.

It is recommended that the Government of the Republic of Cameroon, starting with Ndokayo Small Hydroelectric, will next continue with the two other projects, to implement as quickly as possible the rural electrification policy based on the new Electric Law revised in December 1998.

It is desired to express our heartfelt thanks to your Agency, the Ministry of Foreign Affairs, and the Ministry of International Trade and Industry for the opportunity to carry out this survey. Further, it is wished to extend our sincere gratitude to the Ministry of Public Investment and Regional Development, the Ministry of Mines, Water and Energy, and SONEL of the Republic of Cameroon for their close cooperation and advice during the period of surveys in Cameroon.

Very truly yours,

Shozo Yuzawa
Team Leader
Feasibility Study on Rural Electrification Project
in the Republic of Cameroon

CONCLUSIONS AND RECOMMENDATIONS

Conclusions and Recommendations

The Republic of Cameroon ("Cameroon") made a drastic revision of its Electric Power Sector Law by Law No. 98/022 on December 24, 1998, and inaugurations of an Electric Power Sector Regulating Agency and a Rural Electrification Agency as of June 15 and September 8, 1999, respectively, were approved by President Paul Biya. This means that, along with introduction of privatization of the electric enterprises, on the other hand, financial and technical aid from the Cameroonian Government for promotion of rural electrification is now ensured, indicating in essence that eliminating the chronic shortage in supply of electric power to rural areas, thus improving the livelihood of the people is considered indispensable for Cameroon to become economically self-sustaining.

The Survey Team, in view of such a situation and based on a total of six field investigation trips and the results of discussions with various government agencies, conducted studies for a program of rural electrification by means of small hydroelectric power stations.

The Survey Team carried out investigations in the field regarding Ngambe-Tikar, Ndokayo, and Olamze which had been named by the Cameroonian Government as prospective sites for small hydro-electric power generation projects. Hydroelectric power development plans were formulated based on investigations of topographical and geological features of the localities, and technical and economic studies were made. The resulting conclusions and recommendations are as follows.

Conclusions

1. It is technically possible for an intake dam and power station to be constructed at each of the proposed sites, while socio-economically, electrification of neighboring rural communities through construction of a hydroelectric power station will contribute extremely to improvement of the livelihood of local people. However, as for the Ngambe-Tikar site, the civil structures are excessive due to 10 m^3/s of power station water discharge and about 1,000 m^3/s of flood discharge to be considered in design. As for the Olamze, the Woro river flows in gentle slope through the flat lands, and an upstream road-bridge site was inundated in the recent flood so that further inundation of the surrounding villages are feared by new intake-dam implementation. The Ndokayo site, particularly, is favored with optimum conditions for a power station of the scale contemplated, and is a superb site for hydro power.

2. Peak demand (kW) is forecasted in the assumption that an annual increase of population is 3 percent, and one half of house-holds receive the electricity, with 500 W each, in the environs, plus expected demand of local industries. In the meantime, the maximum scale of installed capacity is found for the 3 sites based on the usual way in the central Africa that a 180 days river discharge is set up as a standard against which the max. discharge of the power station is selected, as follows:

	Projected Installed Capacity	Forecasted Demand in 2010
Ngambe-Tikar	530 kW (2 units)	560 kW
Ndokayo	4,530 kW (3 units)	4,620 kW
Olamze	400 kW (2 units	1,145 kW

3. Ngambe-Tikar Hydro-Project

There is few suitable site for the mini-hydro project in the vicinity of Ngambe-Tikar village. The present project is found on the Kim river six kilometres south from the village. The headrace canal of 500 m long is constructed on the left bank, the generators of 530 kW of installed capacity produce 3.92 GWh of energy per year by the water head of 7 m and the max. water discharge of 10 m^3/s. It will be sent to the village of Ngambe-Tikar and its environs by the 30 kV transmission of 25 km long. The intake dam could be made inexpensive by good use of the rock outcrops in the riverbed, however, only a few head available, a large and long canal needed, and the structure shall be built to withstand about 1,000 m^3/s of flood discharge.

The project costs amount to 1,852 x 10^6 F.CFA for the civil works, 2,475 x 10^6 F.CFA for the electromechanical works, 335 x 10^6 F.CFA for the transmission lines, and 5,203 x 10^6 F.CFA in total inclusive of the engineering costs. The project cost per kWh and kW is, respectively, 138 F.CFA and 9.8 x 10^6 F.CFA, and the hydro-project could not be justified in comparison with the diesel power station if based on such ordinary or commercial method of economic evaluation as so far made. (100 F = 17.6 Japanese Yen for reference)

4. Ndokayo Hydro-Project

1) The Ndokayo Project, approximately 10 km from Betare Oya, is a hydroelectric power development scheme which would make use of the head of 91 m provided by the waterfalls of Mari. Intake of 4 m^3/s of water to be used would be done in the right bank with a wet masonry concrete dam 4.5 m in height, with this water conducted to a power station by a headrace tunnel (length 133 m) and a steel penstock (length 306 m, inside

diameter 1.4 m), with electric energy of 30.6 GWh produced annually using three Francis turbines and generators (output 4,530 kW). The electric power generated would be supplied by 30 kV transmission lines 152 km in length to the Betare Oya and Ndokayo districts, of course, and to Garoua Boulai District and the districts of Monbal, Borongo Garga, and Sarali as well.

2) Construction of the Ndokayo Project would be carried out in two phases in consideration of the power demand in the district. That is, two generators (output 3,020 kW) would be installed by 2003 with the remaining one unit installed by the end of September 2010. The construction period for the first phase would be 18 months extending over two dry seasons. Materials and equipment for civil works would be mostly procured inside Cameroon, and electrical and mechanical equipment for the power station and surroundings would be imported. However, with regard to transmission lines, the system employed in Cameroon up to the present is to be preserved in aiming for convenience of maintenance and control.

3) The construction cost of Ndokayo Hydroelectric Power Station would be as given below.

(Unit: 10^6 F.CFA)

i) Hydro Power Project	1st Phase Construction (3,020 kW)	2nd Phase Construction (1,510 kW)	Total
Civil Construction Cost	2,540	16	2,556
Electrical Construction Cost	3,360	1,185	4,545
Engineering and Administration Cost	738	150	888
Sub-total	6,638	1,351	7,989
ii) Transmission Line (152km)			
Construction Cost	1,630		1,630
Engineering and Administration Cost	432		432
Sub-total	2,062		2,062
Total	8,700	1,351	10,051

(100F = 17.6 Japanese Yen)

4) The generating cost of Ndokayo Hydroelectric Power Station, for ultimate output of 4,530 kW, is extremely cheap at 39 F.CFA/kWh. When compared with the alternative thermal (diesel plant), the economic internal rate of return, for development in two phases, is 11.5%, and with benefit/cost ratio and benefit-minus-cost 1.27 and 2.22 x 10^6 francs CFA, respectively, the economics is amply favorable.

5) Ndokayo Hydroelectric Power Station would make use of the waterfalls of Mari having a head as much as approximately 90 m. With intake of 6 m^3/s, there is slight fear that the falls may be drained up temporarily in the dry season, however, it could be prevented by the daily regulation of water in the pond. The project site including the intake pond is in the state land, not inhabited and no rare biota has been confirmed.

6) Today, in Cameroon, almost all of the meager existing facilities for rural electrification have become antiquated and, because of shortage of funds, repairs are not being made promptly. Work on new electrification projects is faced with extreme trouble in getting started due to difficulties in procurement of funds. However, with the new Electric Enterprise Law enacted, it is necessary to start new rural electrification projects using hydro power, and Ndokayo Hydroelectric Power Station would be an answer to this demand.

Income from sales of electric power in operation after completion of Ndokayo Hydroelectric Power Station will indicate a high rate of return, and with repayment of all or part of the amount to the abovementioned Rural Electrification Agency, it will be possible for funds to be furnished other rural area hydro power projects. A considerable effect is expected of the project in this way, while at the same time, since it will contribute to improvement in the livelihood of local residents, implementation of this project will have a tremendous significance.

5. Olamze Hydro-Project

As in the case of Ngambe-Tikar, there is few suitable site for the mini-hydro project on the Woro river near the village of Ata'antem. The present project is to build a compact structure of so-called dam-type power station on the rock outcrop portion of the Woro riverbed. It will produce 2.64 GWh of energy per year through the generators of installed capacity of 400 kW, by the use of 6 m of water head created and 9 m^3/s of max. water discharge. The energy will be sent on the 30 kV transmission line of 47 km long, and respond to the demand of Ambam and Olamze area in close connection with the existing diesel power stations of 900 kVA.

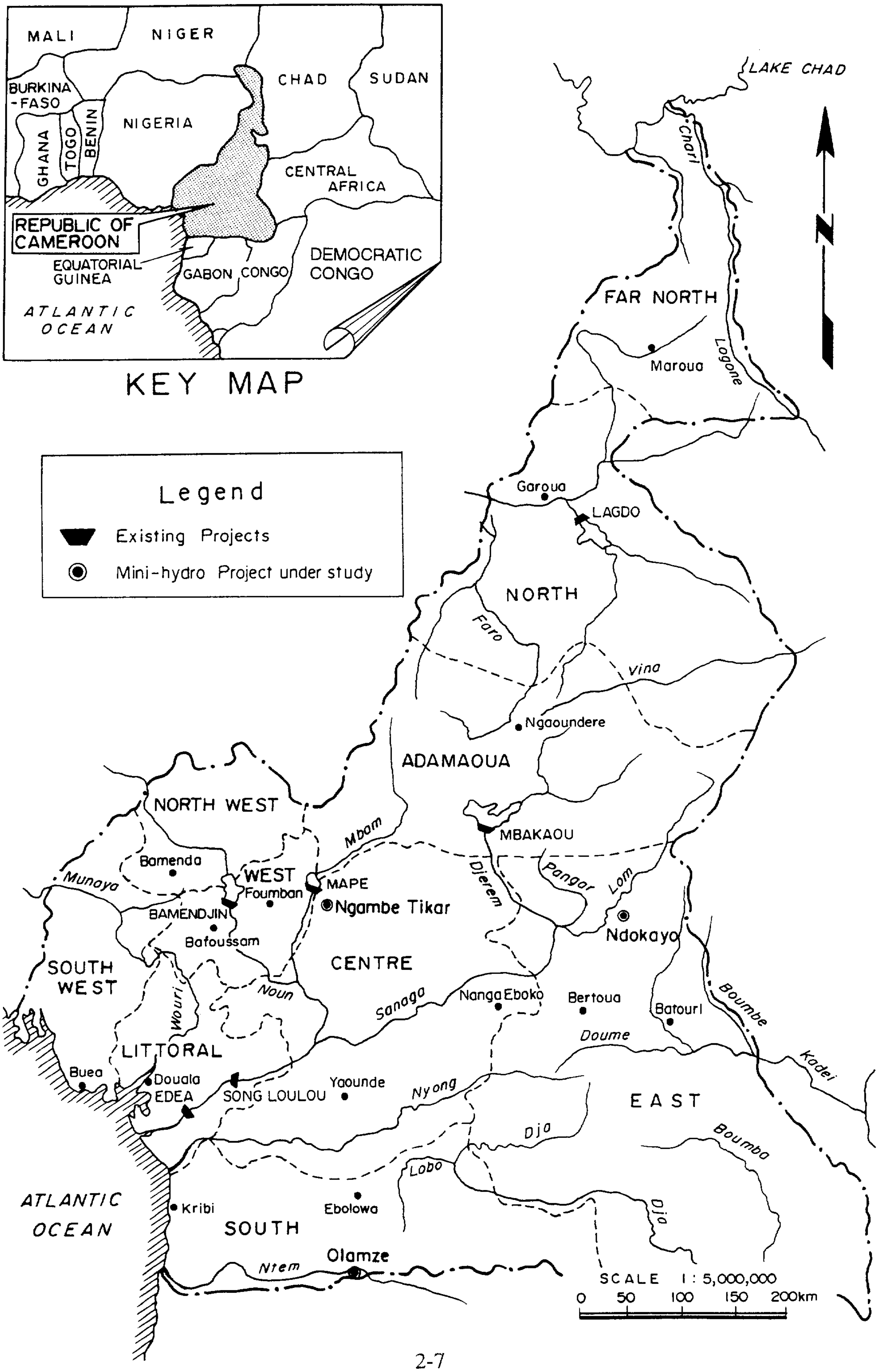
The project costs amount to 1,409 x 10^6 F.CFA for the civil works, 2,535 x 10^6 F.CFA for the electromechanical works, 615 x 10^6 F.CFA for the transmission lines, and 5,055 x 10^6 F.CFA in total inclusive of the engineering costs. The project cost per kWh and kW is 197 F.CFA and 12.6 x 10^6 F.CFA, respectively, and the hydro-project could not be justified in comparison with the diesel power station if based on such an ordinary or commercial method of economic evaluation as so far made.

Recommendations

1. Ndokayo Hydro, according to this present investigation, is judged to be a technically and economically feasible development project. It is desirable for this project to be planned for completion of its first phase (power station output 3,020 kW) by 2003 in consideration of the demand in this district. Taking into account preparations and the construction period, it is recommended that preparations for realization such as arrangements for development funds and execution of definite design work be carried out promptly.

2. With regard to the two projects of Ngambe-Tikar and Olamze, if going by conventional evaluation techniques, hydro will not be economically advantageous in comparison with alternative thermal. However, when the calls for realization of hydroelectric power stations from the local residents are considered, it is desirable for studies concerning these projects to be continued. However, with respect to the Olamze Project, it is first necessary to ascertain what effects will be brought about by backwater upstream from the pond resulting from construction of the intake dam on bridges and roads, residential areas and cultivated fields.

3. The Ndokayo hydro-project would be first rural electrification which is to be implemented under the new Electric Power Sector Law. For this reason, prior to the start of construction, the concrete set-up should have been made, by the cooperation of the ministries concerned and SONEL, not only of the frame-work but also of the definite plan, which will cover the details of management, organization and operation of the power station.


MALI
NIGER
CHAD
SUDAN
BURKINA -FASO
NIGERIA
GHANA
TOGO
BENIN
CENTRAL AFRICA
REPUBLIC OF CAMEROON
EQUATORIAL GUINEA
GABON
CONGO
DEMOCRATIC CONGO
ATLANTIC OCEAN
KEY MAP
Legend
Existing Projects
Mini-hydro Project under study
LAKE CHAD
Chari
FAR NORTH
Maroua
Logone
Garoua
LAGDO
NORTH
Faro
Vina
Ngaoundere
ADAMAOUA
NORTH WEST
Mbam
MBAKAOU
Bamenda
WEST
MAPE
Munaya
Foumban
Ngambe Tikar
Djerem
Pangar
Lom
BAMENDJIN
Bafoussam
Ndokayo
SOUTH WEST
CENTRE
Noun
Wouri
Sanaga
Nanga Eboko
Bertoua
Batouri
Boumbe
LITTORAL
Doume
Kadei
Buea
Douala
EDEA
SONG LOULOU
Yaounde
Nyong
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Boumba
Lobo
ATLANTIC OCEAN
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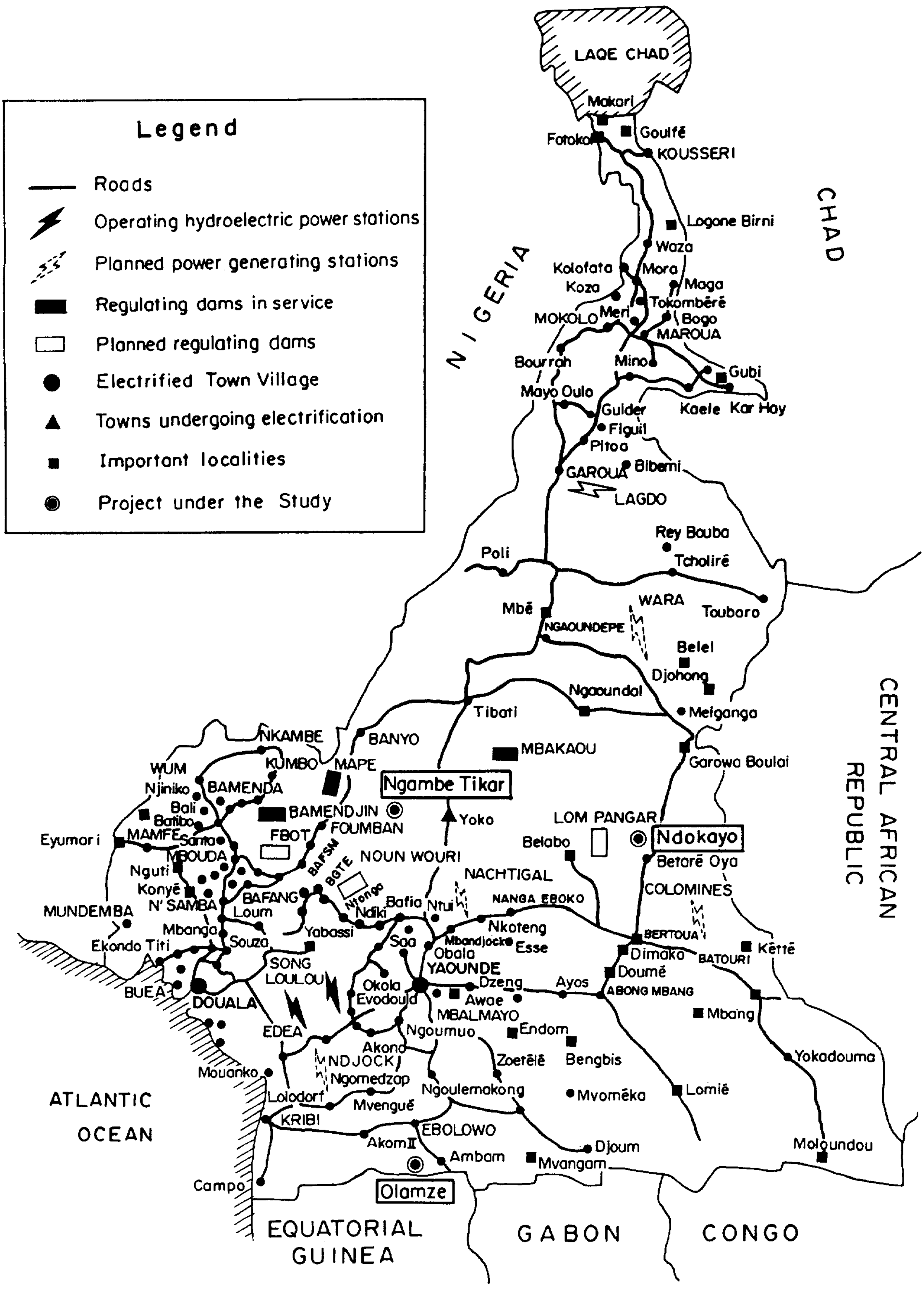
REPUBLIC OF CAMEROON



Summary Description of Studied Projects

1. Ngambe-Tikar mini-hydro power station

Ngambe-Tikar hydro-electric project, located in left abutment of the Kim river, extends 500 m long to create a head of 7 m. Annual energy production is 3.92 GWh with an installed capacity of 530 kW.
Principal structures which constitute the project are:

- trapezoidal-shaped overflow dam, 517.5 m long and 2 m of max. height, having 3 bottom outlets.

- an intake of 4 spans to flow 10 m^3/s of nominal discharge

- an open canal of 17.4 m^2 of section, 515 m long, leading to a water chamber of 540 m^3

- a powerhouse having 2 unit of Kaplan turbine of S-curve in upstream, 295 kW each

- a restitution canal of 41 m long to protect sedimentation of sand by the use of wall deflector of 200 m long

- 30 kV main transmission line of 25 km

Total project cost of 5,203 MF.CFA, and price cost of 138 F.CFA per kWh with a discount rate of 8% per year.

2. Ndokayo mini-hydro power station

Ndokayo hydroelectric power station utilizes 91 m of natural head on the Mari river. By the use of this head, the project is able to produce an annual energy of 30.6 GWh with an installed capacity of 4,530 kW.
Principal structures which compose it are:

- trapezoidal-shaped masonry dam, maximum height of 4.5 m, and a total length of 36 m, of which 21 m is overflowed

- an intake of two spans in right abutment for a discharge of 6 m^3/s

- a pressure tunnel of 8 m^2 section in rock, 133 m long, 0.05% in slope, concreted, inner dia. of 2.20m

- a steel penstock with expansion joints, 307 m long and 1.4 m in diameter

- a powerhouse having 3 units of Francis turbines, horizontal axis, 1,600 kW each, resulting in a total powerhouse capacity of 4,530 kWe

- a short restitution canal with downstream weir of EL 697 crest which guarantees non-cavitation

- 30 kV main transmission line of 152 km long

Total project cost of 10,051 MF.CFA and price-cost of 39 F.CFA per kWh with a discount rate of 8% per year.

3. Olamze mini-hydro power station

Olamze Project closes the Woro river, creating a total head of 6 m. Annual energy production is 2.64 GWh with an installed capacity of 400 kW.
Principal structures are:

- a dam of 138 m long, 8.95 m max. high, having spillway of 46 m long and 6.3 m high in central portion

- in right abutment, next to spillway, a powerhouse of 12 m long houses 2 units of Kaplan turbine, horizontal axis, of a discharge of 4.5 m^3/s

- 30 kV main transmission line of 47 km

Total project cost of 5,055 MF.CFA, and price-cost of 197 F.CFA per kWh with a discount rate of 8% per year.

Summary Table

HHP Project	Ngambe-Tikar	Ndokayo	Olamze
Net output	530 kW	4,530 kW	400 kW
Length of transmission line	25 km	152 km	47 km
Net annual generation with outage	3.5 GWh	26.3 GWh	2.4 GWh
Total Project Cost	5,203 MF.CFA	10,051 MF.CFA	5,055 MF.CFA
Generation Cost	138 F.CFA/kWh	39 F.CFA/kWh	197 F.CFA/kWh

Main Features
Ngambe-Tikar Mini Hydroelectric Power Project (530 kW)

1)	Location	6 km from Ngambe-Tikar village, 2 km upstream of bridge on Kim river
2)	Hydrology	
	Catchment Area	5,820 km^2
	Average Discharge	59.3 m^3/s
	Specific Average Discharge	10.2 $l/s/km^2$
	Low Discharge	1.6 m^3/s
	Flood Discharge (100 years)	898 m^3/s
	Flood Discharge (1000 years)	1,050 m^3/s
3)	Pond	
	Surface Area	9 ha
	Effective Volume	45,000 m^3
	Normal Water Level	EL. 712.00
	Low Water Level	EL.711.50
4)	Dam	
	Type	Trapezoidal-shape Spillway
	Weir Crest	EL. 712.00
	Dam Crest	EL. 712.85
	Weir Length	509 m
	Dam Height from Riverbed	2 m
5)	Intake	
	Intake Area	4 spans of 4 m^2 : 16 m^2
	Floor Level	EL. 710.00
	Intake Ceiling	EL. 712.00
6)	Headrace Canal	
	Length	515 m
	Section	17.4 m^2
7)	Head Tank	
	Dimension	20 x 8.7 m : 174 m^2
	Volume	540 m^3
	Floor Level	EL. 709.72
8)	Powerhouse	
	Number of Unit	2
	Net Head	6.9 m
	Installed Capacity	530 kW - 625 kVA
	Production (effective)	3.5 GWh/year
	Floor Level	EL. 702.00
	Dimension	13 m x 6.70 m

9) Turbine

Type	Kaplan S-curved upstream
Normal Discharge	5 m^3/s
Diameter	0.85 m
Unit Capacity	295 kW
Rotation Speed	600 r/mn

10) Generator

Type	3-phase alternative, synchronous
Number	2
Rotation Speed	1,000 r/mn, multiplicater
Nominal Capacity	267 kW - 315 kVA
Frequency	50 Hz
Voltage	400 V
Power Factor	0.85

11) Transformer

Type	Indoor, 3-phase, oiled, air-cooled
Quantity	1
Nominal Capacity	630 kVA
Voltage	400 V / 30 kV

12) Transmission Line

Voltage	30 kV 3-phase
Length	25 km

13) Construction Cost (Engineering fee & Contingency included)

Civil Works	1,852 MF CFA
Equipment	2,475 MF CFA
Transmission Line	335 MF CFA
Engineering	541 MF CFA
Total	5,203 MF CFA

14) Economic Cost-price

Discount Rate	8%
Cost per kWh	138 F CFA/kWh
Cost per kW	9.8 MF CFA/kW

Main Features
Ndokayo Mini Hydroelectric Power Project (4,320 kW)

1)	Location	On cascade of 10 km from Betare Oya on Mari river, which is affluent of Lom river
2)	Hydrology	
	Catchment Area	640 km^2
	Average Discharge	10.1 m^3/s
	Specific Average Discharge	15.8 $l/s/km^2$
	Low Discharge	1 m^3/s
	Flood Discharge (100 years)	45 m^3/s
	Flood Discharge (1000 years)	54 m^3/s
3)	Pond	
	Surface Area	7.5 ha
	Effective Volume	90,000 m^3
	Normal Water Level	EL. 790.80
	Low Water Level	EL. 789.60
4)	Dam	
	Type	Trapezoidal-shape Spillway
	Weir Crest	EL. 790.80
	Dam Crest	EL. 792.10
	Weir Length	21 m
	Dam Height from Riverbed	4.50 m
5)	Intake	
	Intake Area	9.12 m^2
	Floor Level	EL. 787.20
	Intake Ceiling	EL. 790.00
6)	Headrace Tunnel	
	Length	133 m
	Section	Concrete lined, Horse-shoe type, 3 x 3 m exterior D = 2.2m interior
7)	Penstock	
	Unit	1
	Length	306 m
	Diameter	1.40 m
	Thickness	11 mm
8)	Powerhouse	
	Number of Unit	3
	Net Head	91 m
	Installed Capacity	4,530 kW - 5,330 kVA
	Production (effective)	26.3 GWh/year
	Floor Level	EL. 697.00

	Dimension	22.80 m x 5.00 m
9)	Turbine	
	Type	Francis, axis horizontal
	Normal Discharge	2 m^3/s
	Diameter	0.58 m
	Unit Capacity	1,600 kW
	Rotation Speed	1,000 r/mn
10)	Generator	
	Type	3-phase alternative, synchronous
	Number	3
	Rotation Speed	1,000 r/mn
	Nominal Capacity	1,535 kW - 1,805 kVA
	Frequency	50 Hz
	Voltage	5,500 V
	Power Factor	0.85
11)	Transformer	
	Type	Indoor, 3-phase, oiled, air-cooled
	Quantity	3
	Nominal Power	1,800 kVA
	Voltage	5.5 kV / 30 kV
12)	Transmission Line	
	Voltage	30 kV 3-phase
	Length	152 km
13)	Construction Cost (Engineering fee & Contingency included)	
	Civil Works	2,556 MF CFA
	Equipment	4,545 MF CFA
	Transmission Line	2,062 MF CFA
	Engineering	888 MF CFA
	Total	10,051 MF CFA
14)	Economic Cost-price	
	Discount Rate	8%
	Cost per kWh	39 F CFA/kWh
	Cost per kW	2.2 MF CFA/kW

Main Features
Olamze Mini Hydroelectric Power Project (400 kW)

1)	Location	3 km upstream of Ata'antem on Woro river
2)	Hydrology	
	Catchment Area	840 km^2
	Average Discharge	12.8 m^3/s
	Specific Average Discharge	15.2 $l/s/km^2$
	Low Discharge	0.7 m^3/s
	Flood Discharge (100 years)	69 m^3/s
	Flood Discharge (1000 years)	80 m^3/s
3)	Pond	
	Surface Area	18.3 ha
	Effective Volume	110,000 m^3
	Normal Water Level	EL. 553.90
	Minimum Water Level	EL. 555.35
4)	Dam	
	Type	Fill-Type in wing portion with spillway in Center
	Weir Elevation	EL. 553.90
	Crest Elevation	EL. 555.35
	Total Length / Spillway	138.10 m / 46.10 m
	Dam Height from Riverbed, Crest / Weir	7.75 m / 6.30 m
5)	Intake	
	Intake Area	29.12 m^2
	Floor Level	EL. 546.00
	Intake Ceiling	EL. 547.40
6)	Powerhouse	
	Number of Unit	2
	Net Head	6 m
	Installed Capacity	400 kW
	Production (effective)	2.4 GWh
	Floor Level	EL. 545.50
	Dimension	22.80 x 5.00 m
7)	Turbine	
	Type	Kaplan horizontal with angle gear
	Normal Discharge	4.5 m^3/s
	Diameter	0.9 m
	Unit Capacity	225 kW
	Rotation Speed	400 r/mn
8)	Generator	3- phase synchronous
	Number	2
	Rotation Speed	750 r/mn, multiplicator

Nominal Capacity	204 kW - 240 kVA
Frequency	50 Hz
Voltage	400 V
Power Factor	0.85

9) Transformer

Type	Indoor, 3-phase, oiled, air-cooled
Quantity	1
Nominal Capacity	500 kVA
Voltage	400 V / 30 kV

10) Transmission Line

Voltage	30 kV 3-phase
Length	47 km

11) Construction Cost (Engineering fee & Contingency included)

Civil Works	1,409 MF CFA
Equipment	2,538 MF CFA
Transmission Line	615 MF CFA
Engineering	493 MF CFA
Total	5,055 MF CFA

12) Economic Cost-price

Discount Rate	8%
Cost per kWh	197 F CFA/kWh
Cost per kW	12.6 MF CFA/kW

Contents

CHAPTER 1. INTRODUCTION

Chapter 1 Introduction

1.1 Background of Project

The Republic of Cameroon is providing approximately 98% of the electric power generated within its boundaries by means of water power. The electric energy production during one year in 1994-1995 was 2,735 GWh, while in 1995-1996 it was 2,823 GWh. Of these amounts, thermal power made up no more than 30 and 33 GWh, respectively. Approximately 50% of the electric power is consumed by the largest industrial group of Cameroon which is engaged in aluminum refining based on the abundant bauxite reserves of the land, production of pulp and cement, and petroleum refining.

The power transmission distribution structure of the country is divided into the Southern System with its power sources Edea and Song-Loulou Hydro Stations, and the Northern System with its source Lagdo Hydro. Areas not serviced by these power transmission and distribution systems are supplied from independent diesel power plants maintained by the country's electric power corporation, Société Nationale de Electricité du Cameroun (SONEL). As of 1994, the electrification ratio of the country as a whole was an average of 24% of the total population of 12,900,000. Compared with the electrification ratio in areas centered at large cities such as Yaounde and Douala, the ratio of 46% in other areas is only 4%, so that electrification in regions other than metropolitan areas lags far behind. Independent-system diesel power plants are burdened with many problems such as rising fuel costs, difficulty in maintenance and parts replacement, antiquation of the distribution network, uncollected electricity bills, etc., and unless thoroughgoing remedial measures are set up, improvement of the present situation cannot be expected.

It was with such a background that the Government of Cameroon requested the Government of Japan to carry out a feasibility study on rural electrification through development of small hydro power stations.

1.2 Objectives and Scope of Study

This Study, the "Study on Rural Electrification Project in the Republic of Cameroon through Small Hydroelectric Development" has the objectives of formulating the optimum plan for electrification through development of small hydro power stations at three sites, namely, 1) Ngambe-Tikar, 2) Ndokayo, and 3) Olamze, sites which had been conformed in the scope of work agreed upon between the Japan International Cooperation Agency and the Government of the Republic of Cameroon on December 19, 1997, namely, “Scope of Work for Feasibility Study on Rural Electrification Project in the Republic of Cameroon”, and the minutes, “Minutes of Meeting on the Development Study of Rural Electrification Project in the Republic of Cameroon”, and to evaluate the technical, economic, and financial feasibilities thereof.

In formulation of the plan, operation of the small hydros that would be done by local people was kept in mind and, along with carrying out studies of the two aspects of economics and finance, investigations were made under the principle of giving consideration to impact on the environment also. With regard to the feasibility of the Project from economic and financial standpoints, it was decided to make evaluations by means of cash flow analyses and by examining internal rates of return.

Meanwhile, technology transfer to engineers of government agencies concerned and SONEL is considered as an important objective in carrying out the Study. As methods for achieving this may be cited technical discussions and examinations at work sites in Cameroon, including investigation sites, and joint operations carried out on inviting engineers to Japan and France.

1.3 Progress of Study

The investigations proceeded divided into three stages: 1) Preliminary Study, 2) Detailed Study, and 3) Feasibility Study. The work schedule is shown in Fig. 1-1.

The Preliminary Study was carried out from February to October 1998 with the objective of obtaining adequate information for making the Detailed Study. The details of the work done in the Preliminary Study are described in the Progress Report submitted in October 1998.

In succession to the Preliminary Study, the Detailed Study was carried out from November 1998 to March 1999. The results of the Detailed Study were submitted by the end of March 1999 from the local firms LANA CAMEROUN and GEOFOR S.A. regarding topographic surveying and geological investigations, respectively.

Feasibility study work, the final stage of investigation, was commenced from April 1999. The ultimate objective of the feasibility study work was to make clear the appropriateness of the abovementioned three small hydro power development projects, and initial studies were completed by June 1999. The results of these initial studies were submitted in July 1999 in the form of an Interim Report. The comments ensuing from the explanations and discussions at the time of submission of the Interim Report further examined in detail have resulted in this Final Report.

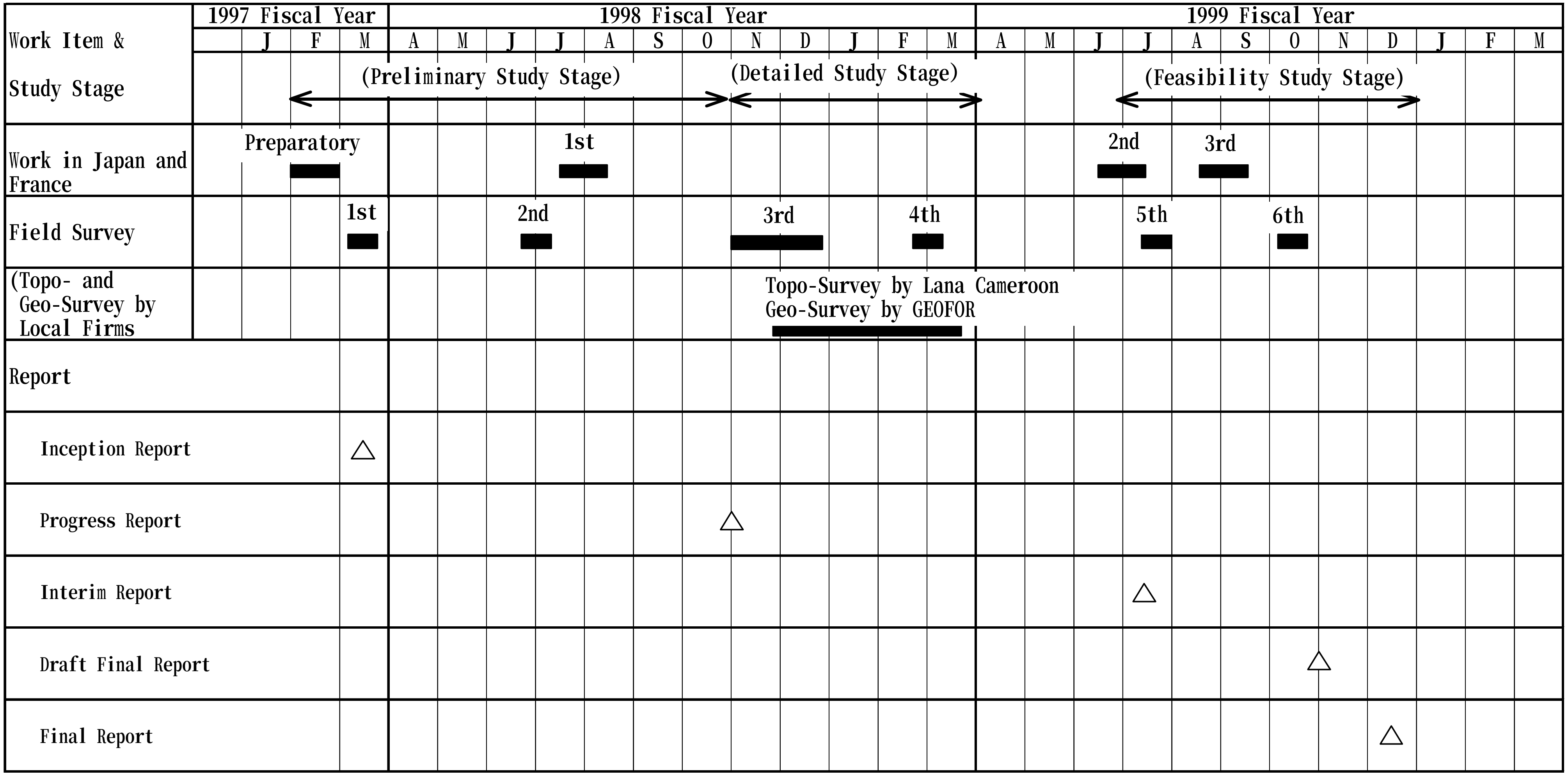
1.4 Survey Work

This Study, as previously described, was executed in the three stages of Preliminary Study, Detailed Study, and Feasibility Study, each stage consisting of work in Japan and work in Cameroon. Survey team members at the various stages are listed below. Members with (EDF) after their names were those from Electricité de France who participated in carrying out the studies.

Shozo Yuzawa	General Supervision/ Power Generation Planning	1st - 6th Field Surveys
Gerard Chassard (EDF)	Civil Works Design	1st – 6th Field Surveys
Estienne Deliry (EDF) and Roger Pivat (EDF)	Electrical Equipment	1st – 3rd, 5th – 6th Field Surveys
Toshihiko Mitsuta	Hydrological Analysis	1st – 4th Field Surveys
Yukio Koike, Kazuhiro Ishizuka	Topographic Surveying	1st – 3rd Field Surveys
Jean Paul Blais (EDF), and J.S. Vaast (EDF)	Geological Investigations	1st – 4th Field Surveys
Nobuyuki Hamano	Environmental Assessment	1st – 3rd Field Surveys
Makoto Nakamura,	Organizations & Institutions	2nd – 3rd Field Surveys
Gerard Malenge (EDF)	Economics & Finance	2nd, 5th Field Surveys
Yoichi Harada	Interpreter	1st – 6th Field Surveys

Messrs. Nomo Protais of the Ministry of Mines, Water and Energy and Mr. Justin Ntsama of Société Nationale de Electricité du Cameroun participated in the training program in Japan. During the period from September 29 to October 28, 1998, they toured hydroelectric power stations including those of EPDC and public institutions in addition to taking part in discussions concerning the Project. Mr. Essouma Akono Clemente of the Ministry of Mines, Water and Energy participated in the training program in Japan during a period from 13 September to 27 October in 1999, as well.

Fig. 1-1 Study & Survey Schedule



CHAPTER 2. OUTLINE OF THE REPUBLIC OF CAMEROON

Chapter 2 Outline of the Republic of Cameroon

2.1 Geography

Cameroon is on the west coast of the African continent and, situated from 2 to 12 degrees north latitude and from 8 to 16 degrees east longitude, it faces the North Atlantic Ocean positioned between Nigeria to the north and Equatorial Guinea to the south. Its total area covers 475,000 km^2, of which the land area is 469,000 km^2. This size is approximately 1.4 times that of Japan. The total length of its border line is 4,591 km, consisting clockwise from the north of 1,690 km with Nigeria, 1,094 km with Chad, 797 km with Central Africa, 523 km with Congo (Brazzaville), 298 km with Gabon, and 189 km with equatorial Guinea. Besides the above, there is 402 km of coastline facing the Atlantic Ocean.

The land has diverse features with tropical rain forests in the southern and western regions, savanna in the central region, and semi-arid desert in the north. The terrain is also varied with a coastal plain in the southwest, development of eroded canyons on a central plateau, a high mountainland in the west, and a plateau gently sloping down to Lake Chad in the north. As a consequence, vegetation and the living environment are extremely varied, and the diverse features of the African continent are all contained in this one country.

As the principal natural resources of the country may be cited petroleum, bauxite, iron ore, lumber, and besides, hydroelectric potential. The land is made up of 13% arable land, 2% agricultural land, 18% grassland and pasture, 54% forest, and 13% other, and there is much possibility left for development, there being only about 280 km^2 of agricultural land now under irrigation.

2.2 Climate

The climate in Cameroon, as described in detail in Chapter 5, is influenced by the country's topographical features, the generation and movement of hot, dry air from the Sahara Desert and the humid air from the Gulf of Guinea. That is, from November to March, high atmospheric pressure originating in the Sahara Desert to the north cause fronts to move south, along with which, dry, hot winds called "harmattan" blow into Cameroon to result in a dry atmosphere of high temperature. On the other hand, from April to October, when these air masses from the Sahara quiet down, Atlantic highs generated in the Gulf of Guinea become active, and pushing up the fronts north, bring in extremely humid air, and Cameroon's rainy season sets in.

The climate of Cameroon may be broadly divided according to (1), a two-season tropical climate zone north of a line connecting Bertoua and Bafia, and (2), a four-season equatorial climate zone south of the line. To describe the climate of the country in outline, the coastal area along the Gulf of Guinea in the southwest has high temperatures, much rain, and high humidity, while there is a trend for this to change to higher temperatures, less rain, and dryer air the farther inland on the continent for a great degree of diversity.

2.3 Population

The population of Cameroon in mid-1996 was approximately 13,000,000 and young, consisting 46% of those aged 14 and under, 51% aged 15 to 64, and 3% aged 65 and over; the population growth rate was extremely high at 2.89%. According to the estimate in 1996, the average life expectancy of males was 51.55, while that of females was 53.68, and the birth rate per female was 5.99. The school attendance rate is on the high side for Black Africa and the literacy ratio of those 15 and over was 63.4% according to a 1995 survey.

There are more than 200 tribes living in Cameroon. As the so-called Bantu Line (the northern extreme of inhabitation by Bantu-speaking peoples) runs east-west through the middle of Cameroon, Bantu tribes live in the south, while in the west live many Bamileke who are a Bantu subgroup people. From the eastern region to the north, the terrain is that of savanna and desert, and besides pastoral tribes such as the Fulani, Hausa, and Sudanic peoples, there are also Arab peoples, thus comprising a complex population distribution.

With regard to languages, besides the official languages of French and English, there are as many as 24 tribal languages spoken locally. As for religion, 33% of the population is Christian, and 16% is Muslim, while traditional animistic faiths are predominant among the others.

2.4 Government

A president elected by direct vote to a seven-year term appoints a prime minister. Other cabinet members are appointed upon being nominated by the prime minister. The current president is Paul Biya, who has been in office for 17 years since 1982.

The legislature is bicameral with 180 members, and a plural political party system was legalized in 1990.

Cameroon has 10 provinces, and local government consists of the 10 provinces divided into 58 divisions, each of the divisions made up of subdivisions which are further subdivided into districts. Under these districts are towns and villages. The sites which are the objects of this Study, Ngambe Tikar, Betare Oya, which is near Ndokayo, and Olamze, are all centers of subdivisions.

The Government of Cameroon has set June 30 as the end of the fiscal year. Accordingly, fiscal year is a period of one year from July 1 of a calendar year to June 30 of the following calendar year.

2.5 Economy

The economy is based on agriculture, but there are petroleum reserves along the coast, and favored with a diverse terrain and climate, the Cameroonian economy may be counted as that of one of the most favored primary resource producing countries of Subsaharan Africa. With the development of oil production, the country experienced a rapid economic growth from 1970 to 1985. However, because of falling prices of the principal export products of coffee, cocoa, and petroleum since 1986, one third of export income has been lost, and combined with problems of financial management, there has been a rapid turnaround to minus growth. In 1990, the country agreed to implementation of the reform program prescribed by the IMF and the World Bank, and embarked on a structural reorganization consisting of expedition of private investment, privatization of state-run industries, and reforms in the banking system. However, due to the political unsettlement following the general elections of 1992, the IMF-World Bank drastically cut back aid and structural reorganization practically came to a stop. On January 12, 1994, a 50% devaluation of the currency was carried out and inflation occurred temporarily, but the international balance of exchange improved. During the period from 1990 to 1996, both imports and exports indicated minus growth, and the economy has remained stagnant. A drastic structural reorganization is presently underway as required by the IMF and the World Bank.

Cameroon is a participant in Union Douanière et Economique de l’Afrique Centrale, a customs and economic alliance formed with Gabon, Central Africa, Equatorial Guinea, Congo (Brazzaville), and Chad, having a central bank and currency in common. The currency, the CFA franc, or Communaute Financière Africaine franc, had been linked to the French franc at a rate of 50 CFA to 1 since 1948, but with the devaluation in 1994, it dropped to 100 to 1, where it is to date.

The estimated national revenue in the 1992/93 fiscal year was $1.6 billion and the outgo $2.3 billion. The principal industries are petroleum extraction and refining, and aluminum refining, while hardly any food processing, light industry, textile manufacturing, or lumber milling is to be seen. Export items are crude oil and petroleum products, lumber, aluminum, cocoa beans, coffee, and cotton. Countries exported to are EU members headed by France, which take up 50%, followed by African countries. Imports consist of machinery, electrical equipment, foodstuffs, consumer goods, vehicles, and petroleum products, 38% coming from EU countries, again headed by France, followed by African countries, while imports from the United States and Japan are both 5%.

The gross domestic product of Cameroon as of 1993-1994 corresponded to US$680 per capita, and the average annual growth rate from 1985 to 1994 was –6.9%. The average annual growth rate of GDP indicating growth of the economy, which was +1.9% during 1980-1990, fell to –4.1 during 1990-1994, and has been 3.0% since 1997. Foreign debt, which was US$2,513 million in 1980, increased to US$1,215 million in 1994, the ratios to GDP being 36.8% and 107.0%, respectively.

2.6 Energy Resources

Cameroon is an oil-producing country, and along with being rich in natural gas reserves, it is favored with a hydroelectric potential which is the second greatest in Africa. Cameroon has a leading position in the continent with regard to forestry also. Consequently, the country is self-sufficient in energy.

Of these natural resources, oil, particularly, made an important contribution to development of the country’s economy and society from 1978 to 1985. Revenues from oil exports and oil-related industries propelled the economy of the country during this period to sustain its development. Exports of crude oil reached its peak of 8.9 million tons in 1985-1986. Export and petroleum products made up 18% of GDP, and comprised roughly 53% of the entire amount of exports including products and services.

In 1986, however, oil-well drilling slowed down and production declined, while from 1985 to 1988, the price of oil dropped from US$25 per barrel to US$15. The economic situation abruptly worsened due to such circumstances and equilibrium was lost. With the economic activity of Cameroon having contracted in this way, the government has temporarily adopted a recovery program. Although the economic outlook is gray, oil has continued to play an important role in the country's economy. Of primary energy products, 95% is oil and the remainder is hydroelectric power generation. Approximately 80% of all energy consumption comprises petroleum products. The amount of this energy consumption had gradually increased since 1980, but with 1985 as the turning point, it has been declining. On the other hand, electric power consumption continued to increase up to 1989, and since then, it has been stable in the neighborhood of 2,300 GWh.

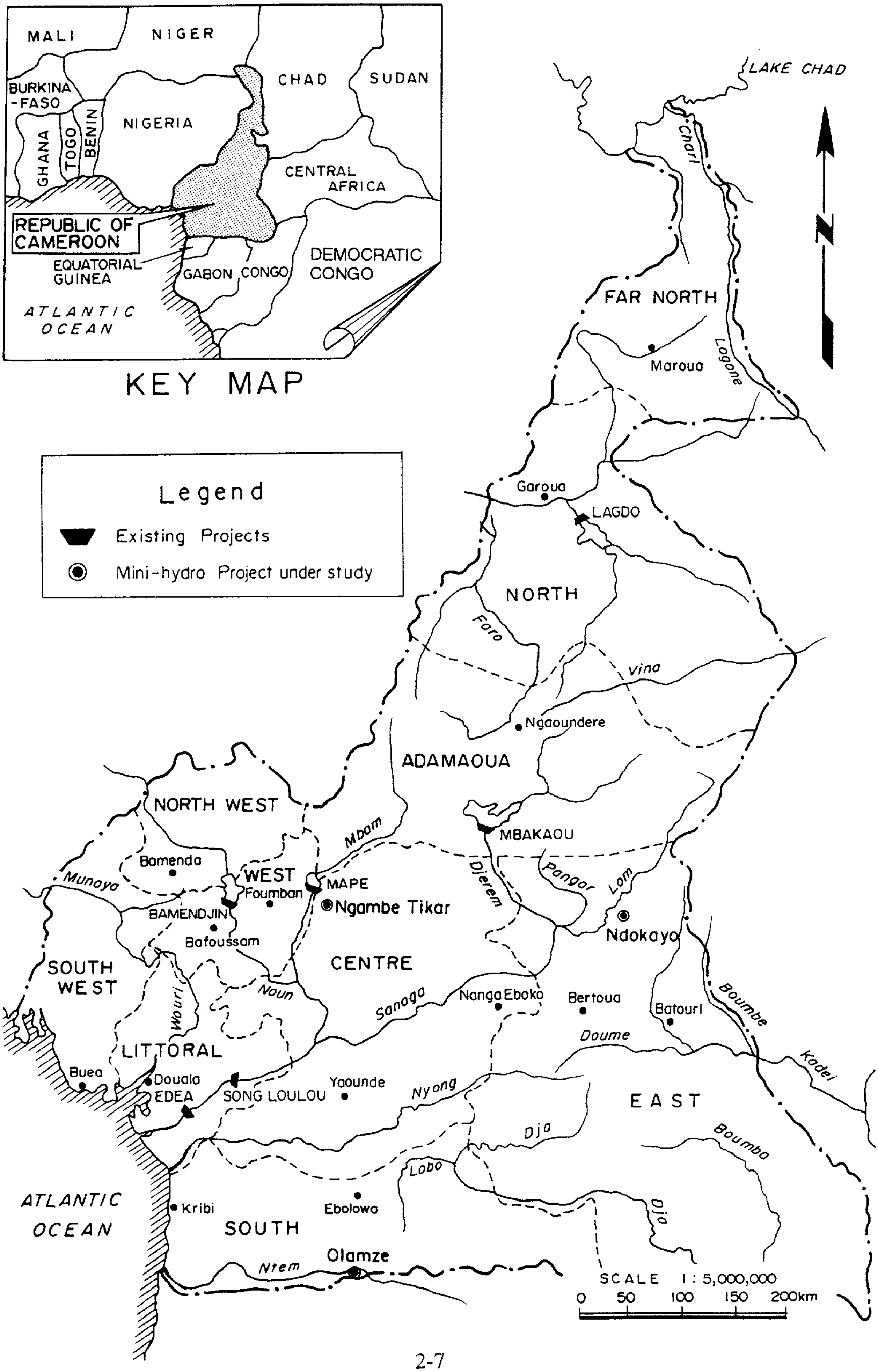
Cameroon is first in electric power production among franc-economy countries of Africa. The electric power corporation, SONEL, established in 1974 carries out power generation, transmission, and distribution of the entire country, and also is responsible for street lighting and traffic lights. SONEL is capitalized at 30 billion FCF francs, of which the Cameroonian government holds 93.1% and Agence Francaise de Developpement most of the remaining 6.9%. Approximately 95% of the country's electric power since the 1980s has been hydroelectric power, and imports of diesel thermal fuel amount to only 1% of all imports. Of new types of energy, utilization of solar energy is barely managing to pay, a total of 50 kW being used for lighting and air conditioning, and heating and cooling of water at medical clinics in remote areas.

As previously mentioned, the oil sector played a leading role in the national economy in the 1980s, but oil fields are now drying up and crude oil production is continuing to fall. As a consequence, the country has become an oil importer, and as export revenues dropped, the Cameroonian government, while encouraging oil-well drilling, adopted a policy of diversification of energy sources. Promotion of natural gas extraction, development of the hydroelectric potential, and agreement on laying of a Chad-Cameroon oil pipeline are in lien with this policy.

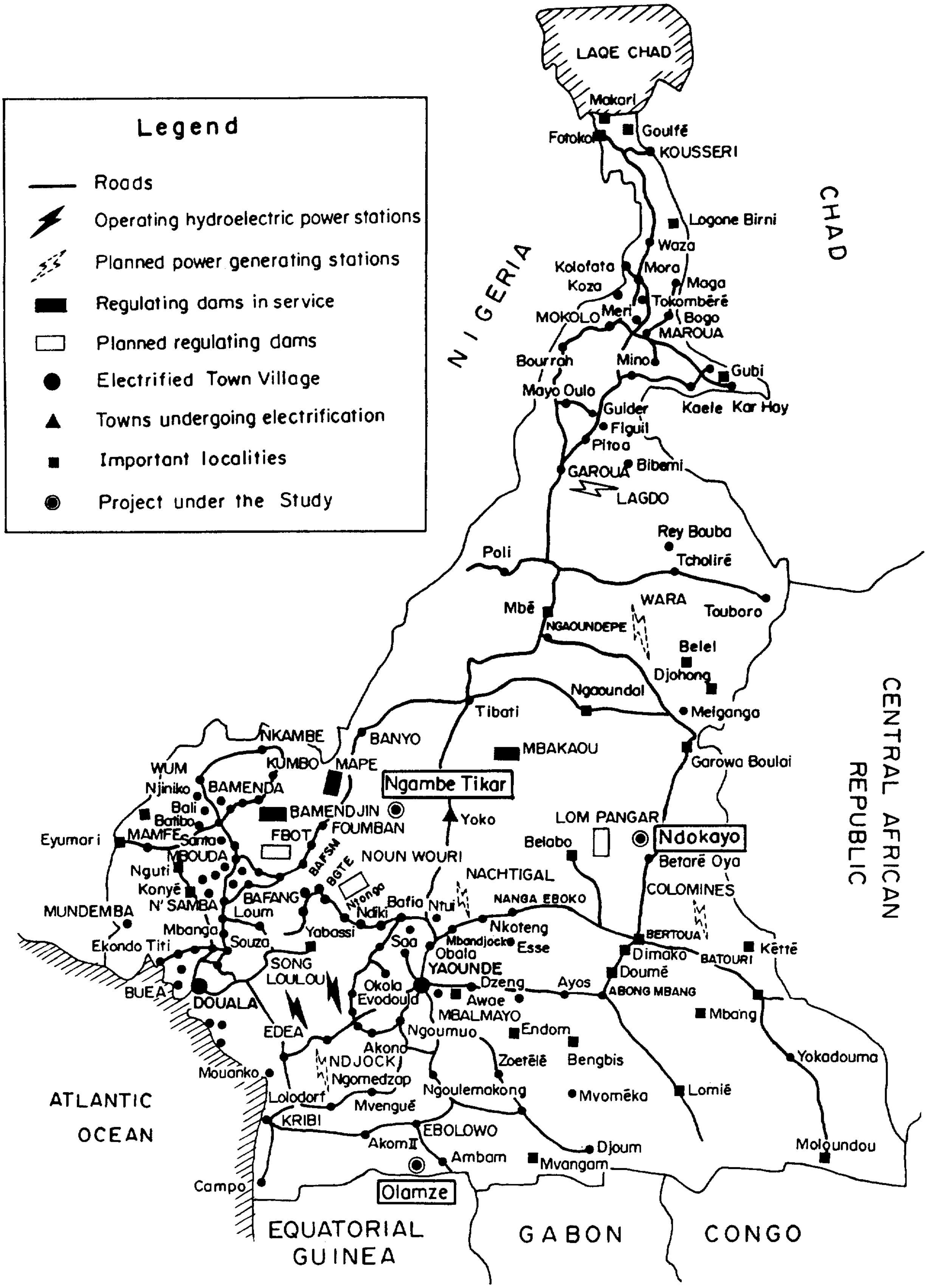
In regard to natural gas, the government previously had not included it in planning, but now, development is being pushed to obtain butane and propane, and long-term plans are for exports to Europe of natural gas in the form of LNG.

In the electric power energy sector, SONEL has been placing emphasis on development of consumption or distribution rather than generation. At present 24% of the population enjoys the benefits of electric power, but whereas the electrification rate in urban areas is 46%, the rate in rural areas is only 4%. It was targeted for the electrification rate of the rural population to be brought up to 30% in the year 2000.

SONEL's plans, up to 2005, are not to introduce any new hydro, but to continue to extend power distribution lines. In 1983, a hydroelectric potential survey of entire Cameroon was carried out aided by Electricite de France (EDF). A middle- and long-term development program was formulated based on this, while a survey of small hydroelectric sites in Adamaoua Department was also carried out. In 1996, EDF, under the auspices of JICA, carried out a preliminary study of small and mini hydro sites for rural electrification in four West Sub-saharan countries including Cameroon.


MALI
NIGER
CHAD
SUDAN
BURKINA -FASO
GHANA
TOGO
BENIN
NIGERIA
CENTRAL AFRICA
REPUBLIC OF CAMEROON
EQUATORIAL GUINEA
GABON
CONGO
DEMOCRATIC CONGO
ATLANTIC OCEAN
KEY MAP
Legend
Existing Projects
Mini-hydro Project under study
LAKE CHAD
Chari
FAR NORTH
Maroua
Logone
Garoua
LAGDO
NORTH
Faro
Vina
Ngaoundere
ADAMAOUA
NORTH WEST
Mbam
MBAKAOU
Bamenda
WEST
MAPE
Foumban
Djerem
Pangar
Lom
Munaya
BAMENDJIN
Ngambe Tikar
Ndokayo
Bafoussam
CENTRE
SOUTH WEST
Noun
Wouri
Sanaga
Nanga Eboko
Bertoua
Batouri
Boumbe
Doume
LITTORAL
Kadei
Buea
Douala
EDEA
SONG LOULOU
Yaounde
Nyong
EAST
Dja
Boumba
Lobo
ATLANTIC OCEAN
Kribi
Ebolowa
SOUTH
Olamze
Ntem
SCALE 1 : 5,000,000
0 50 100 150 200km

REPUBLIC OF CAMEROON



CHAPTER 3. ORGANIZATION AND SYSTEM OF THE REPUBLIC OF CAMEROON

Chapter 3 Organization and System of the Republic of Cameroon

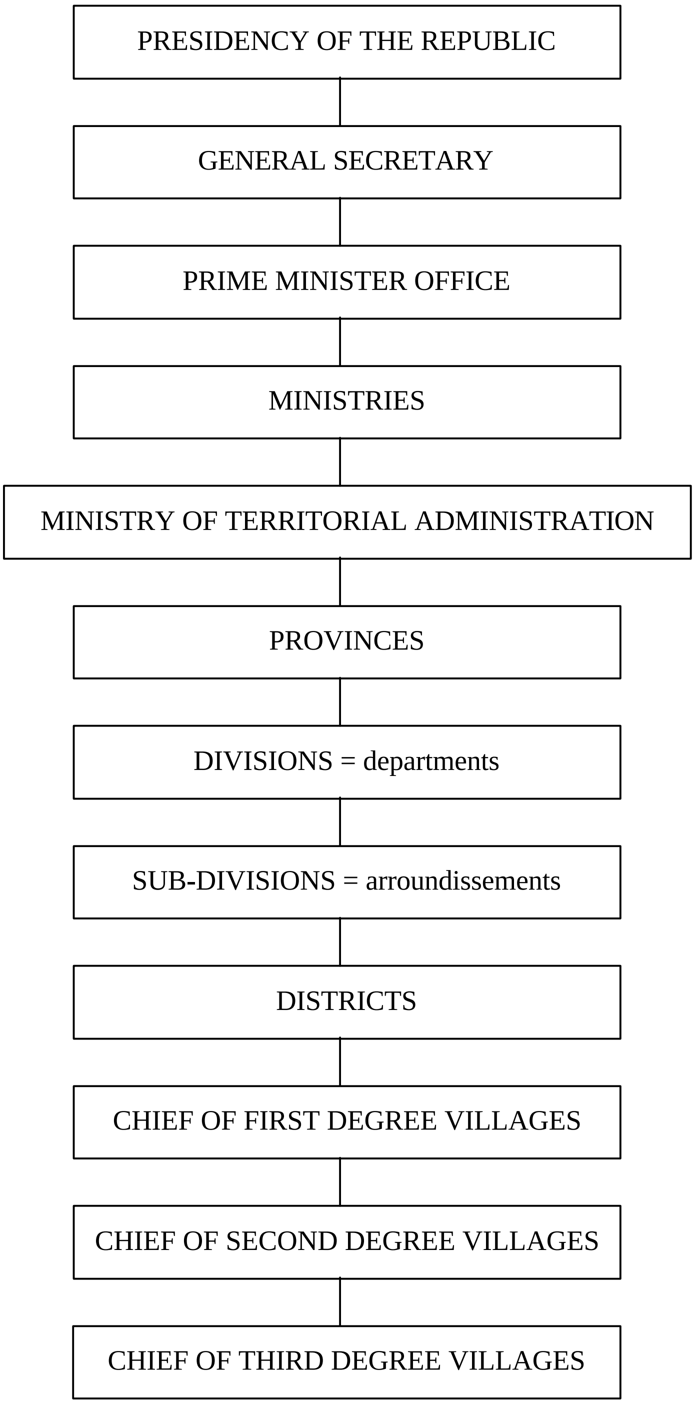
3.1 Administrative System

Due to the past history of colonization by French and England, Cameroon has dual practices of jurisdiction and administration. The administrative division of the country made in 1983 has made the country into 10 Provinces (two of them are Anglo-phone provinces) and 58 Divisions. These departments are divided into 269 Subdivisions and into 53 Districts. The number of basic administrative units amount to 322 and these administrative division make the general public of Cameroon very close and familiar with the public administration.

Two languages are used in Cameroon, namely, French and English as the official languages. The use of two foreign languages as the official languages in Cameroon is the legacy from the colonial time.

As the specific features of the public sector of Cameroon, the centralization of administrative authorities and political rights are pointed out. For the purpose of ruling out the concentration and centralization of the rights and powers, the new fundamental laws have been started to be elaborated and examined with the spirit of democracy and freedom which started in 1990. By the constitution proclaimed by the President on January 18, 1996, the decentralization of power and authorities to the rural areas is stipulated. Through this decentralization policy, transfer of some rights and authorities from the central authorities to the local autonomous bodies and to the counties and prefectures have been undertaken. Actually, by the general election conducted on January 21, 1996, local assemblies on the level of county and prefectures have been established. However, these local assemblies are to be supervised by the representatives appointed by the central government. Table 3-1 shows the administrative system of the government of Cameroon.

Table 3-1 The Administrative System of the Government of Cameroon



3.2 Society

3.2.1 Population and Number of Households

The Republic of Cameroon conducted the National Census in 1987 and since that time no national census has been conducted. By the national census conducted in Cameroon in 1976, the population of Cameroon was found to be approximately 7.5 million, but by the national census conducted in 1987, the population was found to be 10.5 million. In 1997, the national census was planned to be conducted, but due to the budgetary constraints of the central government, the census was not conducted. However, according to the statistic materials compiled by UNDP, the population of Cameroon in 1996 is estimated to be 13.2 million.

In regard to the population and homeholds in the proposed project site, though information and data are relatively old, the present study is based on the National Census conducted in 1987 as to estimating the approximate number of households in Cameroon, and the data and information on population and households in the areas from SONEL. Also, the first hand information on population and households in the proposed project sites were obtained through the site visits of Ndokayo, Ngambe-Tikar and Olamze by the Study Team.

3.2.2 Present Situation of Society

According to the Human Development Indicator (L'indicateur de developpement humain = IDH), which is shown in Table 3-2, Cameroon is ranked at 127th in the world and its IDH is indicated to be 0.48. The indicator illustrates the present situation of social development of Cameroon very precisely and faithfully. The indicator covers the indices on health, medical service, education, food, availability of public transportation means by the general public, housing and etc., however, a part of details is given in Cameroon.

Table 3-2 Human Development Indicator

	Cameroon	Sub-Sahara Africa	Industrialized Countries	The entire world
Human Development Indicator	0.468	0.380	0.911	0.764
Average life cycle at birth	55.1 yrs	50.0 yrs.	74.1 yrs.	63.2 yrs.
Education				
Literacy ratio of adult people	62.1%	55.9%	98.5%	77.1%
School Attendance Ratio				
Female	42.0%	38.4%	83.9%	57.1%
Male	51.0%	46.6%	81.5%	63.9%
Total	46.0%	42.0%	83.0%	60.0%
Economy (by the use of exchange rate of 1987)				
GDP per capita in US dollar				
1960	601	495	6,448	2,049
1994	661	507	14,473	3,402
Growth rate 1960 ~ 1994	0.3%	0.1%	1.6%	1.2%

3.2.3 Health and Medical Service

The Infant Mortality Ratio still remains at a level of 62 children against 1,000 children in Cameroon. The ratio was 163 in 1960. As to the average life cycle at birth in Cameroon is 55 years against the figures in the entire world of 63 years and in the industrialized countries of 74 years. The mal-nutrition of infant children and other difficult problems related to health result as the 5th major causes of death in Cameroon.

Besides, it is to be noted that such infectious diseases as malaria, meningitis and yellow fever still remain as the major diseases causing death of the people in Cameroon.

In addition to the fact that medical facilities and equipment in the public hospitals and clinics are extremely poor in their quality as well as in their quantity, the maintenance of these facilities are not organized and clean. Though the area where the medical services are being extended gradually in its coverage, sharp gaps still remain among different regions of the country. In the Provinces situated in the utmost northern areas of Cameroon, the number of medical doctor against 100,000 people is only 2 (two). Though the number of medical doctors against 100,000 people in the provinces in the central part of Cameroon is 15 (fifteen), there exist some gaps between the urban areas and rural areas in the same central zones of Cameroon. Namely, the number of doctors in rural areas is only one tenth (10%) of the number of doctors in the urban areas of the Central Cameroon. In particular, in some specified medical sector including dental medicine, medical doctors are extremely in short in its number.

On a national level, there is 1 (one) medical doctor against 12,500 inhabitants and 1 (one) qualified nurse against 1,852 inhabitants in Cameroon. The figures are not necessarily inferior to the average numbers of medical doctors and nurses in the African countries in Sub-Sahara region, where average number of inhabitants who are looked after by a medical doctor is 18,514 and the average number of inhabitants who are looked after by a qualified nurse is 6,548 respectively.

In Cameroon, the role being played by the private medical institutions are very significant in terms of rendering medical services for the Camerounian citizens. FEMEC (Protestant Church Association) has, among 122 facilities owned by the Association, 24 hospitals, employing 2,623 people. A Non Profitseeking Organization (NPO) named Catholic Health Agency has 8 hospitals among 179 facilities owned by the Agency, and the hospitals employ 1,315 people.

Though quite a good number of projects of developing the water-supply are being implemented, only 100 districts out of 322 districts are favoured of using the water supply-system in Cameroon. In terms of number of persons who can drink safe water, only one person out of two persons are in the position to drink the safe potable water from the water supply system.

3.2.4 Housing and Clothing

Due to such reasons as economic recession, reduced annual income of the general public and cutting down of the national budget, domestic consumption of families in the general public and purchases of the durable goods by the consumers in the country have been remarkably decreasing. Accordingly, the general public people Cameroon are trying to minimize their household expenditures as low as possible just to meet the minimum domestic requirements. For instance, though the imports of the secondhand clothes are considered to impede the promotion of textile industry of the country, the government has been obliged to legalize the import of the secondhand clothes from foreign countries.

The problem of poor housing situation of the people of Cameroon still remains unsolved. The main reasons for this is that construction of the housing for the poor people in the country has been suspended and the loan to be extended by the commercial banks to the developers have also been suspended. Despite the policy efforts exerted by central and local governments to promote the utilization of the economic materials locally produced, the living conditions, in terms of housing, of the medium-low income people are hardly improved.

3.2.5 Education and Employment

Based on statistics, the literate ratio of the adult people in Cameroon is 62.1% in 1997. The figure was 31% in 1970. Though it is evident that educational development has been observed on a nation-wide basis, there still remain diverse inequalities and gaps in the country. As the gap derived from the different sex; male or female, the literate ratio of male in 1994 was 73.1%, whereas the literate ratio of female in the same year was only 49%. The average school attendance ratio throughout the nation in 1997 attained to 48%. However, there is also a gap between male and female; male's school attendance ratio is 53.5% and for female only 42.7%. There also exist gaps among different regions of Cameroon with respect of the school attendance ratio of youths. Though the average school attendance ratio of youths throughout the nation is 71%, but the school attendance ratio of youngsters in the northern regions is extremely low. The reasons which account for the above phenomena are not necessarily due to the economic situations, namely low income per households commonly observed in the northern regions. Major reasons for the above are derived from cultural practices which have been observed in the northern regions since the remote past time. In particular, school attendance ratio of girls in the northern regions are lower compared with the others.

Gaps and differences are also observed, among different regions, with respect of the school facilities. School buildings and facilities in the northern and eastern regions are poor in their quality and quantity and it is evidently observed that these regions are lagging behind from other regions of the country. Private Educational Institutions are making substantial contributions in a continued manner to the establishment of school facilities for secondary education and for technical education including higher education. Also, private institutions are active in establishing kindergartens and primary schools. Religious organizations are also active in all levels of education with respect of enhancement of education in Cameroon.

One of the most serious problems which are observed toward the final stage of school education in Cameroon is the unemployment problem, namely, the school leavers are positioned as the unemployed. The unsatisfactorily coordinated relation between the employment sector and education sector accounts one of the major reasons for the above. However, the current economic recession does not indicate any bright future for the increase of employment opportunities in general and this affects very seriously to the unemployment issues of the school leavers. In the labour market where new graduates gather together, new jobs are mostly obtained by those people who lost their previous jobs in government or private offices due to the downsizing or so called 'restructuring' of the private firms or government organizations. The present employment situation in Cameroon can be expressed as the decrease of the number of the salaried employees and the demand for the labour force is very low. As the result of the above unemployment issues which is in the trend of deterioration for the future, some social crisis is about to occur in the country. The fact that the people of younger generation and adult female are in very difficult position in finding their jobs in the formal sector is consequently causing the economic development in the informal sector.

As already stated, the population of Cameroon was estimated to be 13.2 million in 1996, according to UNDP and the average life cycle of the Camerounians is 55 years. It is pointed out that the female are advancing and very active in the economic activities in the informal sector. In particular, Camerounian women are active in the small & micro industries. Most of women, 82%, are engaged in the primary industries, out of which 92% are engaged in the agriculture contributing the agricultural production of the entire country by about 90% in the output. In other words, women play the role of social foundation of the country, however, they face the various problems as indicated below:

- More than half of women who are in the age group of marriage are not educated.
- In every education level, young women in Cameroon are much fewer than men in number and young girls are treated unequally in having the opportunities of education.
- Many social, cultural and legal factors refuse the active social and economic participation of woman in the communities. Indeed, it is very difficult for Camerounian women to take part in the real estate and monetary businesses.
- Political participation by women are very inactive, as shown in the fact that only 5% of the Members of National Assembly are women.

3.3 Economy

3.3.1 Primary Industry

In the beginning of this century, favoured by the fertile soil land and the climate which varies by different seasons, agriculture in the country was very active and Cameroon was the exporting her agricultural products to the neighbouring countries. Production of such primary industry products as rubber, oilpalm, banana were active in the coastal areas while the production of coffee and cocoa made its increase in the forestry and highland areas in the western regions of the country. After the end of the World War II, production of tobacco leaves and cotton flowers were begun and this initiated the rural development of northern and eastern parts of the country.

These agricultural products are categorized into two, namely, agricultural products developed by the private entrepreneurs are coffee and cocoa. On the other hand, other agricultural products are produced by the agricultural enterprises and agro-industry enterprises. In these enterprises, the farming people are either salaried workers, or farmers are well organized. However, the business depressions have been observed in the coffee and cocoa production in recent years due to the main reason that the Cameroonian market share of these items are drastically decreasing in recent years. The production of tobacco leaves also went down. On the other hand, production of other agricultural products has made a remarkable increase. In particular, the production of banana has changed its depressing trend to increasing trend in 1992 and consequently banana production recovered its market share in Cameroon as it used to be.

<u>Agricultural production</u>

Nowadays, farmers in Cameroon realized to market their agricultural products to urban and other rural areas whereby they are able to earn cash money. Substantial quantity of such grains as millet and maize are produced in northern regions and in the areas close to Sahel. In the areas where the irrigation of water from the rivers are possible, production of rice and onions are added to the production of millet and maize. Production of peanuts and fruits are considered possible to increase, but its realization is still slow. Increased production is envisaged possible in the coastal areas and forestry areas since Cameroon is favoured with vast areas of land which are suitable for the production of maize.

Livestock and fisheries

Northern region is one of the areas where raising different size of domestic animals are possible. The annual production of cattle is estimated to be around four (4) million and they are exported to the neighbouring countries. In particular, Nigeria is the major import country of Cameroonian cattle. Production method of livestock is yet organized and that of cattle are not done in a systematic way by the livestock farmers. In the forestry areas, small size domestic animals and poultry are produced.

Fisheries conduced by the enterprises were begun by the shipping companies in order to supplement their financial deficiencies. Fisheries practiced by the fishing people in the coastal areas are stagnant in developing its productivity due to the insufficient financial capability of the fishermen. Fishing industries in the reservoir of Ragdo has shown a drastic development in recent years contributing remarkably to the export of fish products.

Though the agricultural productivity in Cameroon might be able to be enhanced by general methods, there are many impeding factors. Bad road conditions, most of the arable land are situated in the remote areas of the country, and shortage of seeds of various agricultural plants and materials can be cited as the main reasons which impede the agricultural development. The share of agricultural production in GDP is presently around 27%.

3.3.2 Secondary Industry

The total products from the secondary industry occupy the share of 25% of GDP of Cameroon. Handicraft industries of Cameroon are very diversified whereby most of the daily necessities of the Camerounian nationals are manufactured at agricultural enterprises or at the genuinely private handicraft factories. Though these micro industries have been suffering from low productivity over many years in the past, but nowadays they have reached the stage where they export some items of their products to the neighbouring countries.

Owing to the establishment of hydro-power stations of large scale in the country, the electro-refinery of alminium has been made possible and alminium thus refined is one of the most important mineral items for export. Though most of the secondary industries in Cameroon have been monopolized by either colonial or states-owned enterprise groups over many years in the past, the growth of the secondary industries in Cameroon is the results of efforts made by the entrepreneurs of the medium size industries.

Oil is one of the main items of industrial products in Cameroon, which occupies more than 30% of export amount of the country. Most of the oil are exported in crude oil but there is quota system for domestic consumption. Crude oil supplied to the local oil refineries where 1.5 million tons of crude oil are refined meeting the domestic needs.

But the cross-sector wise coordination between agriculture and secondary industry are not smoothly practiced whereby most of the food manufacturers in the country have to depend upon import for the acquisition of the raw materials. Whereas, the processing of the agricultural products remain at the stage of the semi-finished products. Other specific features of the secondary industries in Cameroon is that textile industries are not promoted in a concentrated manner and that the inter-trade relations among the different industries are extremely rare.

Forestry industry is always practised along the coastal areas of Cameroon, though forestry resources in the sea-shore areas are almost fading away. Forestry development in the eastern region and at the remote areas of Mbam have been strengthened recently. Timbers and logs occupy the share of 13% of export of the nation, which is ranked at the second place next to the oil-export in earning foreign currencies. By the new regulation on environmental protection, it is stipulated that the forestry development should be done on the basis of sustainability and environmental protection. Though the construction business and other public enterprises had flourished until recently, they are almost collapsed due to the economic recession. The business in this sector would not be revived unless the policy of the national economic recovery is clearly shown.

3.3.3 Tertiary Industry

Tertiary industry composes more than half of GDP. In this industrial sector, besides the conventional economic activities in the process of marketing the daily necessities, modern type of service industries have come into the picture. Tertiary industries in Yaounde and Douala are the biggest resources which provide the employment opportunities to the people.

Among the tertiary industries, it should be pointed out that the monetary system is not appropriately implemented. Though the Government implemented various policy programmes for the management crises of banks and security firms, hopeful and dynamic recovery are yet reached in this sector.

As to the transportation sector, there is an issue of privatization of national shipping enterprise 'CAMSHIP'. On the other hand, no decision has not been made as to maintain the national air lines 'Air Cameroun'. City Bus Corporation has been abolished since there has been no alternative policy to maintain the corporation. Inhabitants who live in the distant places from Yaounde and Douala are obliged to suffer inconvenience caused by the lack of public transportation.

3.3.4 Basic Infrastructure

Road network in Cameroon is not so developed as to cover the distant places in rural areas. Besides, the road network illustrates the present conditions of the Camerounian economy which is oriented to the external trade. Actually, most of the major trunk highways and roads are running toward sea and there are almost no rural areas where road network is well developed whereby the marketing of the domestic products could be made in easier ways. The same situation is observed with railway system in Cameroon, and considering the competitiveness with highways or roads, railway fares are extremely high. Generally speaking, under-developed railway network mal-functions as a major factor to impede the economic development of the nation.

Utilization of water resources for hydro-power generation is just the partial utilization of water resources which are abundant in Cameroon. As to the telecommunications sector, due to the inappropriate organization and poor management in the past year, serious shortcomings are observed.

3.4 Policy of Rural Electrification

As to the rural electrification, ER in short from the view points of organization and system, the Government of the Republic of Cameroon has adopted a policy to promote the rural electrification in decentralized way, which is called ERD in short. By implementing the policy, the government intends to improve the living standard of the farming people in rural areas and enhance the socio-economic development in the village.

3.4.1 Economic Condition and Rural Electrification

In the economy of Cameroon, the farming areas hold very high importance. In terms of the statistics of population, the population in the rural farming areas occupies nearly 70% of the total population of the country. In 1970, the farming areas contributed to GDP by about 30% and export of agricultural products corresponded 80% of the total export amount. Today, contribution of the economic activities of the farming villages to GDP lowered down to 25% and the export amount of the agricultural products are also lowered down to 50%.

The Government of Cameroon started its policy of implementation of rural electrification for the purpose of enhancing the socio-economic conditions of rural areas. The present rural electrification ratio remains still at 5%. Heightening the rural electrification contributes not only to the improvement of the living conditions of the inhabitants in the rural areas but it also serves the social purpose of diminishing the population outflow from rural areas to urban areas.

In the declaration of economic policy and economic promotion promulgated in 1989, Cameroon set up a number of objectives for the electric enterprise sector and, particularly, economic planning policies concerning energy were established. A concrete policy arrived at by December 1990 was that the rural electrification ratio is to be raised to 15% by the year 2010.

However, the economic crises which struck Cameroon from around 1987 was further aggravated by devaluation of the CFA Franc, and such an economic situation has been hindering expansion of the electric power transmission and distribution network owned by SONEL to rural areas and the smooth progress of various projects such as electric power development.

Utilization of renewable energy, ENR in short, and remote area rural electrification, ERD, are short- and middle-term solutions. In other words, the Cameroonian Government has placed great emphasis on mini-hydropower development along with renewable energy utilization such as solar energy power generation and wind power generation as items of its short- and middle-term energy policy.

3.4.2 Progress of Rural Electrification

(1) Progress of Provincial Electrification

At present, the state sets electricity rates by the per capita system based on the voltage level of use and the amount of electric power. This system does not take into consideration the actual cost of production and transportation of electric power. Consequently, it is a system under which the economic burden is great on both enterpriser and beneficiary.

When electrification of a certain specific district was the issue, what was done in the past had been first of all to interconnect with SONEL. The strategy in rural electrification and initially been to electrify villages where medium-voltage lines supplying large cities passed by. The policy of SONEL was to electrify on a priority basis districts of investment recovery periods 10 years (Western Region) and 15 years (other regions). These rural electrification programs are called programs implemented by SONEL, and through these programs it has become possible for 100 to 200 districts in rural areas to be electrified annually. Five rush programs are presently underway with four of them more or less completed. On the other hand, MINMEE implemented a social rural electrification program by which it has been made possible for approximately 50 districts to be electrified annually.

Meanwhile, SONEL made the following choices to lower installation costs of medium- and low-voltage lines. In effect,

- Electrification using grounded single-phase current. This is a model which had been introduced from the Canada.
- Accelerated use of electric poles and accompanying forestation with eucalyptus.
- Construction of electric pole processing facilities.
  There is a possibility for surplus poles to be exported.

Through SONEL's rush programs and MINMEE's social rural electrification program, it was possible to electrify approximately 1,200 out of about 13,000 districts overall. In effect, it is a coverage rate of 8%. As a result of the abovementioned programs, the rate of it having become possible to use electricity in rural areas, namely, the electrification ratio, has become 5%, but that is still too low.

Therefore, efforts should be made to raise this figure, the necessity for a new rural electrification program to be implemented can be clearly seen.

(2) Potential Power Demand in Rural Areas

A demand for electric power does exist in rural areas of Cameroon, but it is not an easy matter to try to forecast it. To forecast demand, it must be discerned what kind of energy source can be economically utilized along with the growth in population and the future of regional industry, upon which, referring to that of already electrified districts, the growth in power demand of the district in question needs to be grasped beforehand.

The needs for electric power in rural areas of Cameroon are generally comprised of 1) domestic demand, 2) water utilization of the village, 3) processing of agricultural products, and 4) handicrafts.

On top of these, it is necessary to add long distance telecommunication facilities or group demand of school and health-and-sanitation centers. Within these demands, demand for lighting of higher quality, and demand for visual and audio learning apparatus have come to the fore. Expenses for batteries and kerosene add up to 5 to 10% of family budgets. Therefore, power demand for such specific uses exist as potentials. Increases in demand registered with MINMEE and SONEL average 100 annually, which may be said to show how earnest rural inhabitants are with regard to the use of energy.

(3) Problematic Points of Rural Electrification

1) Payability

The costs of power transmission and distribution works are extremely high. For example, the construction cost of a low voltage line is 5 to 7 million CFA francs per kilometer. The facts that demand is low and that huge investments cannot be quickly amortized by selling make the financial status of SONEL even more unstable. As it is necessary to obtain permits for electrification projects that pay, it is unavoidable for SONEL to give priority only to areas with large populations which are closest to existing power system networks where social capital has been invested to some degree. Such areas are scarce in Cameroon, and the heat majority of districts needing to be electrified are located far away from power system networks. Because of such a situation, rural electrification programs by the conventional method of system extension has gradually become difficult to achieve. Added to such a factor as the above, the limits and constraints to rural electrification need to be in step with the characteristics of the rural society, the reality of the provinces, and the constraints of existing administrative organs and regulations.

2) Rural Society

The reasons why the rural areas of Cameroon are lacking in economic attractiveness are because they are remotely separated and the purchasing power of the people living in the areas is weak. The population densities of the areas are low, particularly, in the eastern and western regions where dispersion is of a high degree. This is a great handicap in new construction or expansion of the electric power network. Even in individual villages, the abodes of the rural people are scattered apart and the density of potential electric power users in relation to the length of distribution lines to be constructed is low.

The demand for electricity in rural areas mostly consists of domestic demand, and, according to SONEL, average consumption of household in rural area is 0.5 kW and, kW in urban area.

- The imbalance between expenses and revenues accompanying increase in power generating cost.
- Securing of maintenance and repairs of power generation, transmission, and distribution facilities.
- Non-payment of electricity bills, and expenses required in clerical handling of bills and documents of contracted electricity users.

3) Administrative Organs and Laws

The regulatory and statutory frameworks up till now cannot be said to have been suited to rural electrification. However, in case such conditions as cited below are in order, it may be said that fund procurement for rural electrification will be on a realistic basis.

- Construction of facilities through financial assistance, in effect, production and supply of cheap electric energy.
- Commercial operation of autonomous management system by beneficiaries.
- Price deregulations suited to respective rural electrification cases.

As previously described, the rural electrification policy of Cameroon had essentially been based on interconnection with the electric power network of SONEL, and not to mention economic reasons, that other energy sources (renewable energy) were not positively taken up in rural electrification and promotion of electric power production activity was lacking had constituted a bottleneck to furthermost of rural electrification.

3.4.3 New Rural Electrification Works Policy

The new rural electrification policy of the Cameroonian Government lies in combining rural electrification through interconnection with the electric power network of SONEL, which is ER, and remote area rural electrification, which is ERD. The aims of this policy comprise the following:

1) Expedite ERD while protecting the environment.
2) Establish clear targets for the electrification ratios of rural autonomous bodies and attain 4 times the present ratios in 20 years.
3) Improve the living conditions of residents through further raising of the energy consumption ratio. The energy consumption ratio is an index of the level to which society has developed, and therefore, is a criterion for evaluation of the energy policy.
4) Expand means of production, that is, create medium- and small-scale enterprises (Petites et Moyenne Entreprises: PME) and medium- and small-scale factories (Petites et Moyenne Industries: PMI), by which stop the population drain from rural areas.

ERD means electrification of a district far away from the electric power network without connecting to the network. However, in order to guarantee the technical and economic success of its implementation, it is important for all necessary factors to be complete.

The districts that Cameroon considers as possible beneficiaries of ERD are all districts 50 km or more distant from the electric power network of SONEL. The economic appropriateness of this distance is examined judging which is more economical on comparison with the investment required for interconnection with a transmission line of the existing electric power network.

As types of electric power sources for isolated districts, there are diesel engines for private power generation, mini- or small-scale hydroelectric power plants, solar power generating systems using solar energy, and wind power generating systems using wind energy.

Electric power production and demand in isolated areas are generally closely related to each other. In setting up the generating output, along with examining stream runoff and head, ease or difficulty of obtaining fuel, and solar and wind power potentials from among these choices, in the aspects of demand, the location and size of the village, public facilities, and scales of industries must be considered. Cameroon has large and small rivers throughout its territory, and it is thought that by making use of the large potential, development of ERD, and as a result, development of rural areas can be activated.

A rich hydroelectric power development potential exists in the network of waterways spread throughout Cameroonian land. This potential is calculated as 1,115 TWh annually, mainly considering the provinces of East, Adamaoua, West, and South-west. Installations that can be termed small-scale hydroelectric power stations are all hydroelectric power generation facilities where stable outputs of about 1,000 kW are possible with runoffs of several hundreds of liters to several tens of cubic meters per second. There are two small-scale hydroelectric power stations now in operation, and more than 700,000 kWh of electric power is being produced annually. As for small-scale power stations such as Yoke and Malale near Mayuka, and Nchi near Foumban, they have outputs of about 500 ~ 800 kW, and though civil structures are still sound, power generating equipment all need to be exchanged. According to the survey made in 1996 by Electricite de France (EDF), there are further approximately 40 districts with hydroelectric potentials that have been confirmed.

After it has been decided or contemplated to carry out electrification by ERD of an area where population density is fairly high or increase in population is prominent, the payability of the electrification becomes the issue from the point of view of selecting the type of energy. The decision should be made upon comparing the various energy sources, and based on the costs per kWh of electric power from different sources, especially, the future promise of each type of energy source. Contemplating solution of the problem by private diesel power generation should be limited to cases where energy sources of the region, such as solar energy, very small hydroelectric power station do not exist, or they are not able to satisfy demand.

3.5 Socioeconomic Situation in Project Areas

3.5.1 Ngambe-Tikar

(1) Ngambe-Tikar Area

Ngambe-Tikar as an administrative organization is a sub-division (arrondissement), higher administrative organizations being the division (department) of Mbam and Kim, main administration seat Ntui, and above that, the province of Centre. Villages concerned in the project will be Ngambe-Tikar, Mansouh, Gah, and Gwenge, etc. The population in the National Census of 1987, in 1988 from SONEL, estimated for 2010 on the assumption of 3 percent increase per year, and number of households of individual villages of the Ngambe-Tikar area are respectively as given in the table below.

Village	Population (National Census in 1987)	Population (1998 from SONEL)	Population (Estimated for 2010)	Number of household (in 2010)
Ngambe-Tikar	2,556	3,500	4,990	942
Mansouh	200	274	391	74
Gah	750	1,027	1,464	276
Gwenge	250	342	488	92
Total	3,756	5,143	7,333	1,384

(2) Regional Economy and Society

i) Population: Approx. 5,500

ii) Number of households: 1,000

iii) Annual income by household:

The monthly incomes of the middle class (provincial public servants, Socierie de la Societe Forestiere HAZIM employees) average CFA

35,000 (approximately CFA 420,000 annually), but the monthly average income by inhabitant is approximately CFA 20,000 to 25,000.

iv) Principal industries:

- Lumber milling: Lumber mill of HAZIM
- Agriculture: Main agricultural crops are cocoa and maize, but being an agricultural form without irrigation facilities and with manual work using no fertilizer, the productivity is extremely low.
- Fisheries: The average monthly income of fishermen is CFA 35,000 and comparatively high.
- Other: Hunting, raising of small-size livestock, and handicrafts

(3) Health and Sanitation

- Hospitals and clinics: There is one hospital at Ngambe-Tikar, with the World Bank carrying out an expansion project on the hospital. One doctor and four nurses presently staff the facility. Other than this, there are three clinics in operation.
- Most widespread diseases: Malaria, onchocerciasis, and measles occur at extremely high rates and exceed the national averages. Other than these, the rates of malnutrition and infant diseases are high.

Groundwater is used as drinking water and appears to be comparatively safe.

(4) Education

i) Number of schools:

Number of schools:	Elementary school	6
	Middle school	1
	Private school	6 (5 Protestant, 1 Catholic)

ii) Literacy rate: Although not a problem in urban districts, extremely low in rural areas.

iii) School facilities: Of the total of 48 classrooms, 23 are of durable construction, 13 are of semi-durable construction, and 12 are of temporary construction.

iv) Teachers: The public schools have four elementary school teachers with qualifications, and volunteer and part-time teachers in addition, but there is an extreme shortage of teaching personnel. To fill the necessary positions, at least 25 teachers at elementary schools and 10 at middle schools are required.

(5) Local Residents' Organizations

A regional autonomous group, or Groupe d'Initiative Commune (GIC), exists at the Kong District, and has cleared 10 ha and planted maize.

For local residents' organizations to be made stronger, it is necessary for mutual assistance between cooperative members to be encouraged, income sources of regional autonomous bodies to be created, and latitude provided in the livelihood of the people. A type of regional savings association called "ontine" is organized locally. A tontine is organized strictly of women. There are two tontines of large scale in the Ngambe-Tikar area. Small tontines appear to be made up of family members and relatives.

(6) Expectations of Local Residents Regarding Project

As results of construction of the hydroelectric power station, the local residents have expectations that Ngambe-Tikar will emerge from its status as a remote district, that the drain of people from rural areas to the cities will be braked through creation of jobs, that a degree of latitude will be born in the livelihood of many residents, that children will be able to receive better education, and that as it becomes possible to preserve medicines such as vaccines, great contributions can be made towards improvement in health and sanitation conditions.

The local authorities, particularly the headman of the sub-division, and the chief of the Ngambe-Tikar administration support the new construction of a hydroelectric power station by the Ministry of Mines, Water and Energy (MINMEE), SONEL, and the JICA Study Team, and are calling for residents to cooperate positively with the construction. The same comments can be made regarding the two other sites.

(7) Necessity and Demand for Small Hydroelectric Power Generation at Ngambe-Tikar

There are a number of individuals at Ngambe-Tikar who own diesel generators and are using them in accordance with their financial capabilities. These individuals are the ten of sub-division headman, police squad chief, doctor, forestry office chief, Ngambe-Tikar town mayor, La Famile Goula, Mr. Mgbatou Pierre, Mr. Soule, a bar owner, the supervisor from the Forestry Ministry, and Mr. Taskin.

According to the sub-division headman, he uses the generator he owns from 1,800 to 2,300 daily (Monday ~ Friday), and 1,100 to 1,700 and 1,800 to 2,300 on Saturdays and Sundays.

Fuel consumption is 10 liter/day of gasoline (the price of gasoline: CFA 450 franc/liter), while 5 liter/mo of oil (the price of oil: CFA 1,200 franc/liter) is used. The sub-division headman has used a generator from 5 years ago and has changed generators four times due to trouble, Yamaha 600 (price: 200,000 CFA francs) and Yamaha 1800 (price: 450,000 CFA francs) have been used. Fluorescent lamps have also been changed four times in 5 years. The price of one fluorescent lamp is said to be roughly 3,000 CFA francs. As a result of such maintenance, the cost of running the generator described here was 300,000 CFA francs, and the price of the generator itself, and its operation and maintenance are far beyond the reach of Ngambe-Tikar residents. Consequently, providing a small hydroelectric power station will bring about great benefits to the people of Ngambe-Tikar.

The generating facilities supplying energy to the lumber mill of Socierie de la Societe Forestiere HAZIM (SFH) amount to 2 x 400 kVA.

On Sunday every week, only one 400 kVA generator is operated for lighting and drying, and the amount of kerosene used is 600 to 900 liters depending on the load. In maintenance, oil is changed every week on Sunday. Production of sawed lumber was 1,400 to 2,000 cubic meters per week when there were 3 days of trouble with machinery. As is clear from the above, the energy being produced at the lumber mill is excessively high in cost.

Accordingly, the construction project for a small hydroelectric power station is a welcome thing for regional industry, and by filling the demand of the lumber mill, collection of electricity charges will become certain, and this is thought will contribute to stable management of the power station itself. Provision of a plywood factory in Ngambe-Tikar Sub-division is being studied, and for this to go into operation, a large amount of energy will be required. In this way, the small hydroelectric power station construction project will make a great contribution, not only socially, but also in promotion of the regional economy.

3.5.2 Ndokayo

(1) Ndokayo Area

Ndokayo is a third degree village in Betare-Oya Sub-division, Bertoua Division, East Province. In regard to the Ndokayo area where the projected hydro-power station is to cover, the population and the number of households of the individual towns and village are shown in the table below. The figures in 2010 are based on the same assumption as in Ngambe-Tikar.

Village	Population (National Census in 1987)	Population (1998 from SONEL)	Population (Estimated for 2010)	Number of household (in 2010)
Mari village	200	274	391	74
Lom	209	286	408	77
Betaré Oya	4,271	5,849	8,339	1,573
Ndokayo	1,778	2,435	3,472	655
Bongo	318	2,268	3,234	610
Borongo	1,656	1,020	1,454	274
Mombal	745	1,020	1,454	772
Nadongwe	2,095	2,869	4,091	772
Botila	334	457	652	123
Badzéré	1,804	2,471	3,523	665
(Garoua Boulai)	(14,125)	(19,345)	(27,581)	(5,204)
Oudow	276	378	539	102
Kongolo	498	682	972	183
Garga Sarali	1,092	1,496	2,133	402
Total	15,276 * (29,401)	20,921 (40,266)	29,830 (57,411)	5,627 (10,831)

* Figures in (   ) included Garoua Boulai

(2) Regional Economy and Society

The principal industries are agriculture in which maize, carrot, yam, and banana are produced and fishery at the Lom River and the Mari River, with the greater part of the fish caught sold to villagers. Approximately 2,000 women are engaged in agricultural production, and the annual average income per household is CFA 700,000/year at the high level, CFA 300,000/year at the middle level, and CFA 100,000/year at the low level.

Further, in this area, many small scale peddlers sell foodstuffs and clothing on an informal basis. At the river beds of the Bali and Mbal Rivers, alluvial gold mining has been going on from a fairly long time ago, and it is said there are some who make as much as CFA 100 million in a year. There are also tontines as savings associations in this area.

(3) Health and Sanitation

There is one clinic with only two nurses, but no doctor in Ndokayo area. A doctor comes as necessary from neighboring Betare-Oya. Although not limited to this area, malaria, migraine, and stomach ace are widespread. It appears that malaria-preventive medicine is taken only when stricken with the illness. The infantile death rate appears not to be so high as in the other African area because the vaccines are plentiful.

(4) Education

There is one elementary school with six classes and approximately 700 pupils. Of the teachers, three are saud to be paid salaries by the government, and three by the village. The majority of the villagers in this area are able to read and write French.

(5) Expectations of Local Residents Regarding Project

Expectations of local residents with regard to realization of the hydroelectric power generation project are as high if not higher than at the two other sites, namely, Ngambe-Tikar and Olamze, since there is a site favorable for hydropower development nearby: the waterfalls of Mali. Ten persons in this area presently own diesel generators, but all are of high operation and maintenance costs, out of reach for the ordinary local resident. Accordingly, hydroelectric power generation making possible nighttime illumination and lighting, enjoyment of radio and television, and supply of electric power for agricultural machinery and irrigation, will be especially welcome, like blessed rainfall on a parched land.

In the near future, the oil pipe-line from Chad to Douala is to be installed in the distance of only about 40 km from Betare-Oya, and an improvement work has been recently started of the existing road from Bertoua to Ndokayo. It is for this reason that Ndokayo hydro-power project is expected not only by the government organizations and private industries but also the local communities.

3.5.3 Olamze

(1) Olamze Area

In regard to the Olamze area where the projected hydro-power station is to cover, the population in the National Census of 1987, in 1988 from SONEL, estimated for 2010 on the assumption of 3 percent increase per year, and number of households of the individual town and village are respectively as given in the table below.

Village	Population (National Census in 1987)	Population (1998 from SONEL)	Population (Estimated for 2010)	Number of household (in 2010)
Olamze	537	735	1,048	198
Meko' Ossi	567	777	1,108	209
Eyinantoun	381	522	744	140
Meko' Omengona	453	620	884	167
Ebangon	725	993	1,416	267
Nsana	342	468	667	126
Ngoasik	476	652	930	175
Nkoumebé	239	327	466	88
(Amban)	(5,843)	(8,002)	(11,409	(2,153)
Total	3,720 * (9,563)	5,094 (13,096)	7,263 (18,672)	1,370 (3,523)

* Figures in (   ) include Ambam.

(2) Regional Economy and Society

The annual average income per household in Olamze area of Ntem river southern bank is CFA 300,000. The main products are the cash corps of cocoa, coffee, and oil palm. As for subsistence type industries, there are the following:

Agricultural products: Peanut, banana, manioc, maccaboy, pistachio, maize

Fishery: Manual fishing at streams such as the Ntem River

Hunting: Chimpanzee, gorilla, small primates, crocodile, antelope, other small bovines and deer

Livestock: Raising of small livestock such as, sheep, poultry, boar

Factors hindering improvement in productivities of agriculture and fisheries are that operations in agriculture are manual, that irrigation facilities do not exist, that fertilizer is not used, while in fisheries also, the work is performed manually. As an economic activity in Olamze, trading with neighboring countries such as Equatorial Guinea and Gabon is pursued very actively, and with Kye-Ossi as the base, all kinds of commodities are handled.

Agricultural cooperative associations and mutual benefit groups do not exist in this region. However, in each village, there is an average of two tontine cooperatives, each a group consisting of at least 10 persons. The memberships are mixed male and female, the main purposes of the tontines being to increase savings and to improve communications.

(3) Health and Sanitation

i) Hospitals and clinics: There are two hospitals and a number of small health care clinics.

ii) Doctors and nurses: There are 7 doctors and a number of nurses, and 6 nurses at a Protestant clinic.

iii) Most widespread diseases: Malaria, diarrhea, measles.
Malnutrition and infant diseases (no vaccines) occur at a higher rate than the overall national average.

(4) Education

i) Number of schools: 20 elementary schools and kindergartens in all of Olamze. 1 middle school

ii) School facilities: Except for roofs of galvanized iron, buildings are made of local materials. (boards, calcined earth)

iii) Teachers: 8 teachers with baccalaureat qualifications, 6 with achievement certifications, and 3 with middle school education 1st phase achievement certification, and there is an absolute shortage of teachers.

iv) School age: 5 (kindergarten)

v) Number of schoolchildren: 949 (elementary school), 250 (middle school)

vi) Number of dropouts: 1st ~ 3rd grade elementary school (40.26%), 3rd ~ 6th grade (52.4%)

(5) Expectations of Local Residents Regarding Project

The residents have high expectations regarding the hydroelectric project which will change their mode of living. That by a degree of latitude to be gained in their livelihood, and that by using refrigeration facilities it will become possible to store medicines and vaccines, health will be maintained. And with nighttime lighting made possible, efficiency in the pursuit of knowledge will be improved and studying to enter schools of higher learning and studying to take various qualification tests can be done.

The local authorities, namely, the headman of the sub-division and the chief of the local tribe, have expressed their readiness to cooperate with MINMEE, SONEL, and the JICA Study Team, and eagerly look forward to the early commencement of work on the hydroelectric power generation project.

CHAPER 4.   ELECTRIC POWER SITUATION

Chapter 4 Electric Power Situation

4.1 Electric Power Sector

As mentioned previously, Cameroon is a major electric power producer among countries in the franc-economy zone of Africa, and the state-run electric power company, SONEL, has carried out power generation, transmission, and distribution for all of Cameroon. The legal framework for electric enterprises in the Republic of Cameroon has for a long time been based on Law 83/20 enacted on December 26, l983, this law being applied to power generation, transmission, and distribution, sales, export-import, and supply of electric power carried out as public utilities. However, a drastic revision was made with Law 98/022 of December 24, 1998, and especially, with respect to furthering of rural electrification, aid from the state came to be promoted in both technological and financial aspects. With this new law, private commercial enterprise techniques were taken up and what had been recognized as a monopolistic concession to SONEL ceased to be such.

SONEL was established in 1974 through the merger of ENELCAM and EDC, while in 1975, POWERCAM was merged into SONEL. ENELCAM was a company established in 1948 in step with construction of Edea Hydroelectric Power Station for the aluminum refining company, ALUCAM. POWERCAM was established in 1961 to supply electric power generated by ENELCAM to the western pat of the country, while EDC was a company established in 1963 to supply the eastern part. In effect, SONEL was established for smooth power generation, transmission, and distribution throughout all of Cameroon. SONEL, besides carrying out its normal operations, has been engaged in education of the population with the aim of spreading the use of electric power.

The Cameroonian government owns 93.1% of the capital shares of SONEL, while CFD, Caisse Francaise de Developpement, owns the greater part of the remaining 6.9%. The board of directors consists of twelve members, of whom nine are representatives of the Cameroonian government and two are representatives of CFD, while the remaining one is a representative of ALUCAM. The term of a director is for 3 years. According to a government proclamation in June 1995, SONEL is included in a plan for future privatization.

SONEL had 3,802 employees as of March 31, 1997. Of these employees, 54% were in the sales and operations sectors, while 21% were in the power generation and transmission sectors. The remaining 25% were in the administration and information processing sectors. By grade, approximately half were staff and workmen, approximately 35% junior executives, and 14% senior executives.

Regarding administrative organs and their roles, the Office of the President decides the country's overall policy, the Ministry of Mines, Water and Energy (MINMEE) formulates, executes, and coordinates the country's energy policy, along with which, it controls and inspects work execution, and prepares regulations concerning electric power. As for electricity rates, they are set by the Ministry of Industrial and Commercial Development. Negotiations with regard to loans from foreign countries are carried out by the Ministry of Public Investment and Regional development, and financial affairs are managed by the Ministry of Economics and Finance. Supervision of construction work is handled by the Ministry of Public Works and the Ministry of Transport.

4.2 Electric Power Facilities

The Direction of Equipment of SONEL manages all new equipment installation projects including design and construction. Meanwhile, the Direction of Production and Transport manages operation and maintenance concerning supply of electricity including reservoir operation, all management of hydroelectric power stations and transmission lines, and diesel generators. The Direction of Exploitation manages distribution networks, and the Direction of Commerce handles all commerce-related matters.

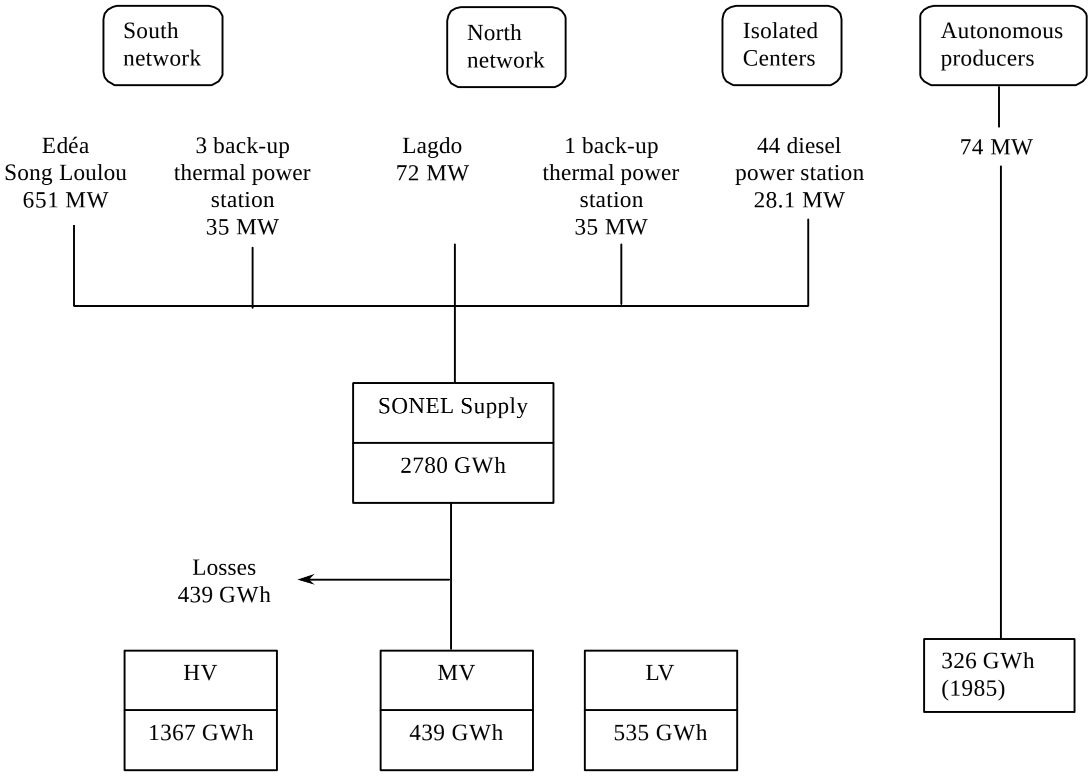
Presently, there are two power transmission networks in Cameroon. One is the Southern Power Transmission Network, or, the Sanaga System, and the other the Northern Power Transmission Network, or, the Lagdo System. As for demand areas isolated from these system, direct supply is being carried out generally through diesel generation. Power generation facilities of the electric system as of 1993/94 figures are shown in Fig. 4-1.

These two power transmission systems possess diesel generating facilities as reserve capacities. There are also independent generating facilities for the purpose of supplying power to areas outside transmission networks. The load dispatching center of the Southern Power Transmission System is inside Mangombe Substation in the city of Edea. This load dispatching center controls all facilities in the Southern Power Transmission System, while on the other hand, control in the Northern Power Transmission System is by Garoua Load Dispatching Center.

The operating patterns in these power transmission networks are for hydro stations to operate in accordance with power demand, while when power from hydro stations is insufficient, or in an emergency, diesel power plants go into operation.

The operation plans of individual hydroelectric power stations are prepared by the Direction of Production and Transport of SONEL based on estimated annual inflows to regulating reservoirs, and adjustments are made periodically based on discharge records.

Fig. 4-1 THE ELECTRIC SYSTEM
(1993/94 figures)



The Southern Power Transmission Network which supplies electric power to Littoral Province, Center Province, West Province, South-west Province, South Province, and North-west Province has the two large hydroelectric power stations of Edea and Song-Loulou.

As previously mentioned, SONEL, at the time it started operations in 1974, received capital investment from Electricite de France (EDF) and POWERCAM, and along with operation of Edea Power Station which had been run by EDC, it was also entrusted with management of power distribution network facilities which EDC had managed.

The Northern Power Transmission Network which supplies electric power to Adamoua, North, and Far-north Provinces, has Lagdo Hydroelectric Power Station as its generating facility. This was constructed with the cooperation of the Chinese government and was commissioned in May 1983.

Meanwhile, a new power transmission system had been planned for the eastern region, but construction of transmission and transformation facilities accompanying the construction of Lom Pangor and Nachtigal-Amont Hydroelectric Power Stations has been suspended and commencement of work in the near future is awaited.

The total installed power generating capacity of Cameroon, as given below, is 804 MW. The composition is 90% hydro and 10% thermal. The ratio of the installed capacity of the Southern Transmission Network to the total installed capacity is 87.2% (701 MW), while on the other hand, that of the Northern Transmission Network is 12.8% (103 MW).

The first two units of Edea Hydroelectric Power Station went into operation in 1953, after which, expansion was completed by 1976. The total installed capacity is 263.2 MW, while the electric power of Edea No. II Power Station is being consumed by ALUCAM, and depending on the situation, the No. III Power Station makes up any shortage.

The first-stage commercial operation of Song-Loulou Power Station in the Sanaga River System located 55 km upstream of Edea City was started in 1981. Expansion work on the station was completed in 1988, and the total installed capacity is 387.6 MW. The power stations of the two transmission networks are as follows.

1) Southern Power Transmission Network

(a)	Edea I, II, III Hydro		263.2MW	
	Song-Loulou Hydro		387.6MW	
	Sub-total		650.8MW	(92.8%)
(b)	Diesel plants (reserve)	14 sites	43.3MW	(6.2%)
(c)	Diesel plants (independent)	15 sites	6.7MW	(1.0%)
	Total		700.9MW	(100%)

2) Northern Power Transmission Network

(a)	Lagdo Hydro (18MW x 4)		72.0MW	(69.8%)
(b)	Diesel plants (reserve)	4 sites	23.2MW	(22.5%)
(c)	Diesel plants (independent)	8 sites	7.9MW	(7.7%)
	Total		103.1MW	(100%)

In the Southern Power Transmission Network there are three large reservoirs at upstream parts of the Sanaga River system, and regulation of annual discharge is being done in order that the downstream Edea and Song-Loulou will fully perform their functions even in the droughty season. These are Mbakaou Reservoir (storage capacity 2,600 million m^3) on the Djerem River, Bamemdjin Reservoir (storage capacity 1,800 million m^3) on the Noun River, and Mape Reservoir (storage capacity 3,300 million m^3) on the Mbam River.

Many of the diesel generating facilities are being maintained, but efficiencies are poor, and there are some that have become inoperative. The dependable outputs of these diesel generators are 52% and 70% of the reserve and independent diesel generating capacities installed, respectively. They are either to be abandoned in the near future, or as they are of small unit capacities compared with hydroelectric generating facilities, many are considered to be inconsequential, and are not expected to fulfill roles as electric power supply sources. However, even then, they are generating approximately 33 GWh annually, indicating an annual average growth of approximately 8.5%.

The present power transmission and distribution network is as given in Tables 4-2 and 4-3, there being 16 substations incorporated in the Southern Power Transmission Network. However, the substations for ALUCAM, SOCATRAL, CELLUCAM, and CIMENCAM, all large-capacity consumers listed in 4.3, are not indicated. As for the Northern Power Transmission Network, it has 3 substations other than that of one high-voltage consumer. The total transformer capacity of these substations is 1,086 MVA including that for 30 kV power distribution.

The total length of existing high-voltage transmission lines as of 1990/1991 was approximately 1,881.6 km. This consisted of 480.4 km of 225 kV transmission lines, 337.2 km of 110 kV transmission lines, and 1,064 km of 90 kV transmission liens. Besides these, there were approximately 7,570 km of medium-voltage transmission lines. Also, there were 33 high-to-medium-voltage substations, and 5,077 medium-to-low-voltage substations.

Power line carrier telephone systems are being used for telephone communications and data transmission from the load dispatching center. Furthermore, the headquarters of SONEL has a radio communication system as a means of communicating with distant locations.

4.3 Power Demand and Supply

The annual energy productions in 1995-1996 by hydro and by diesel thermal were 2,790 GWh and 33 GWh, which were increases of 3.1% and 8.5% respectively. However, with respect to annual growth rates during the past 10 years, whereas hydro has shown growths of approximately 5%, thermal has declined approximately 10% annually.

On the other hand, looked at by region, the amount transmitted in the Southern Power Transmission Network was 1,427 GWh in 1994-1995 for an increase of 2.5% compared with the previous year, while in contrast, in the Northern Power Transmission Network, it was 147 GWh, a 12% increase compared with the previous year. These are in regard to medium-voltage and low-voltage consumers in the Southern Network estimated to amount to approximately 1,400 GWh annually, however, ALUCAM of alminum manufacture, which consumes the electric energy the most, CELLUCAM of paper manufacture, SOCATRAL which manufactures aluminum and zinc products, CIMENCAM which manufactures cement, and SONARA which refines oil, and by CICAM in the Northern Network being separate. There were approximately 1,080 medium-voltage customers and approximately 368,300 low-voltage customers.

The southern end of the area covered by the Southern Power Transmission Network is at Eboloua, the eastern end is at Ayos and Foumban, the northern end is at Nkambe, close to Nigeria, and thus, tends to be one-sided toward the west where Douala and Yaounde are located. The southern end of the area covered by the Northern Power Transmission Network is at Meiganga. Consequently, there is a large empty space in the central region and the eastern part of the southern region, where there are Ngambe-Tikar and Ndokayo.

Small, independent systems are individually supplied by diesel, but the total capacity does not reach 20 MW. Besides these, there are private diesel generating facilities of food processors, lumber mills, etc., and these amount to approximately 74 MW.

The energy consumption of Cameroon doubled from 1976 to 1989, after which, the increase up to 1995 was not very much. As one of the main reasons for this may be cited the trends at ALUCAM, which accounts for 60% of the energy sales of SONEL. The situation of being influenced by which way ALUCM goes will continue into the future, but the increase in electric energy from hydroelectric power stations which produce the greater pat of annual electric energy indicates a steady growth of around 5% annually, and this situation is thought will continue in the future.

The table which follows shows the recent transitions in electric energy production and electric energy sales of SONEL. As this table indicates, the power transmission and transformation losses including non-technical losses make up as much as 16%.

Transitions in Annual Electric Energy

（Unit：GWh）

Year	88~89	91~92	92~93	93~94	94~95	95~96
Hydro generation	2,649	2,659	2,778	2,748	2,705	2,790
Thermal generation	41	38	29	32	30	33
Total generation	2,690	2,697	2,807	2,780	2,735	2,823
Total sales	2,393	2,330	2,274	2,340	2,310	—
High voltage（HV）	1,399	1,322	1,373	1,367	1,266	—
Medium, low voltage (MV・LV)	994	1,008	1,001	973	1,044	—

The electrification ratio, which was approximately 20% in 1990-91, had improved to slightly less than 25% in 1995-96, but it can be seen that the necessity for electrification is still very high in the provinces.

4.4 Electricity Rates

SONEL separates electric power customers according to Distribution Publique and Clients Speciaux. Distribution Publique corresponds to general customers whose electricity rates are set by statute, while Clients Speciaux correspond to large-volume customers under special contract. As of the year 1995-96, there were five customers headed by ALUCAM as Clients Speciaux, while among Distribution Publique customers were 1,105 medium-voltage users and approximately 400,000 low-voltage users.

Distribution Publique rates are set according to ministry ordinances issued by the Ministry of Industrial and Commercial Development and the following rates are applied to all low-voltage and medium-voltage users regardless of whether urban or rural. As a consequence, the burden on SONEL of the rural diesel generation areas where operation and maintenance costs of facilities are high will be increasingly heavy.

(1) Low-Voltage Users

1) Lighting and Residential

Group 1: Monthly consumption 90 kWh or less 50 CFAF/kWh

Group 2:

Division 1: Monthly consumption up to 90 kWh 50 CFAF/kWh

Division 2: Portion of monthly consumption over 90 kWh 58.15 CFAF/kWh

2) Public Lighting

For use from 1830 to 0600 hours 32 CFAF/kWh

(2) Medium-Voltage Users

1) Set rate of electric power applied for 8,690 CFAF/kWh

2) Proportional Rates for Energy Consumed

As per monthly hours of use applied for:

Division 1: 0 to 200 hours 38.5 CFAF/kWh

Division 2: 201 to 325 hours 35.2 CFAF/kWh

Division 3: 326 to 450 hours 31.9 CFAF/kWh

Division 4: over 450 hours 29.7 CFAF/kWh

The electric energy sold and the power sales amounts in 1995-96 were as given below.

	Distribution Publique			Clients Speciaux	Total
	Low Voltage	High Voltage	Sub-total		
Energy sold (MWh)	468,589	444,320	912,909	1,310,049	2,222,958
Revenue (million CFAF)	28,191	18,098	46,289	9,322	55,611

4.5 Present Condition of Rural Electrification and New Law

4.5.1 Present Condition

The objective of the electrification policy of Cameroon had been to raise living standards in rural areas, but today, using electric power for production has become an additional major objective of rural electrification. In rural areas electrified through small hydro and diesel generation, not only do people living there need to have sufficient economic strength to be able to pay electricity charges, but they also have to take part in management of the facilities through means such as by setting up people's cooperatives. In addition, from a technical point of view, it will be necessary for guidance and management to be provided by SONEL.

In 1971, EDC, the predecessor of SONEL, constructed a 30 kV transmission line of 69 km from Nkongsamba northeast of Douala to Mbanga. A number of rural communities are located along this transmission line and electric power was supplied to various factories, coffee processing plants, and private homes. This corresponds to the initial stage of rural electrification of Cameroon. Since then, electrification progressed at a pace averaging 20 or more villages annually.

Rural electrification in Cameroon proceeded with supply from two large power systems, north and south, but as a result of review of the government's national land development policy, there has been a change to a dispersed electrification strategy by which electrification of areas located geographically distant from the major power transmission networks is being done. At present, consolidating the minimum bases for electrification including power supply facilities at areas called secondary centers has become one of the basic principles of rural electrification.

By secondary centers is meant centers of provincial government such as of provinces, departments, and districts not interconnected with either the Southern or Northern System. Many such secondary centers exist in the departments of Adamoua, Est, and Sud which are blank areas of the two systems. Ordinary rural electrification projects mainly consisting of diesel generation are chronically in the red, and provision and operation of high-cost independent systems only serve to worsen SONEL's finances. SONEL considers promotion of rural electrification to be one of its principal duties, while at the same time, since it must keep in mind the aspect of income as an independent electric power corporation, new rural electrification projects make resolution of the problem even more difficult.

The master plan for rural electrification set up by SONEL had been for expansion of the distribution system from the existing interconnected system or independent systems supplied from diesels and to raise the utilization rates of generators, along with which, efficiency was to be improved in maintenance and operation of facilities.

The Ministry of Mines, Water and Energy, which is responsible for water and energy, had worked from an early time on realization of a management system in supply of drinking water participated in by rural residents for which the residents would be responsible. In this way, in rural areas where previously the state had borne all costs, management systems of types participated in by local residents are now functioning effectively. Both the Ministry of Mines, Water and Energy and SONEL, to introduce this trend into the electricity sector, have begun to make investigations in order to carry out studies on rural electrification cooperatives managed by beneficiary residents.

When electrified, the manner in which the electric power is to be used will be 20% to 50% for industries supplied with medium-voltage power, the remainder being for low-voltage demands. Of low-voltage demands, 80% will be for lighting and residential uses, 10% for equipment motive purposes, and 10% public purposes such as street lighting.

Rural electrification by independent systems in Cameroon has already been realized at Kousseri, Yokadouma, and Tibati. It is said that the peak demand per household contracted to receive power is 283 W, and this is large, but it is not that all households are receiving electricity, so per resident, it will be less than 10 W. Generally speaking, in case of residential use, the average load per household is approximately 150-300 W, but since ordinary contract households are less than one half the entire number of households, it is thought to be sufficient to estimate based on such status for peak system load in case of electrification in areas long distances away from urban districts.

Rural electrification where load density is low and the area is economically poor is extremely disadvantageous costwise, and SONEL has been endeavoring to lower various costs. In this respect, single-phase, medium-voltage distribution and domestically-produced electric poles of wood have been adopted fairly conspicuously in Cameroon. Fundamentally, however, it may be said that the method of resolving the rural electrification problem most suited to the present circumstances would be for amortization costs of facilities to be made zero through grants from advanced nations with only operation and maintenance costs borne locally, SONEL providing technical guidance and control.

4.5.2 New Electric Power Sector Law

(1) New Electric Power Sector Law

The legal framework for electric power sector in the Republic of Cameroon has for a long time been based on Law 83/20 enacted on December 26, 1983, this law being applied to power generation, transmission, and distribution, sales, export-import, and supply of electric power carried out as public utilities. However, a drastic revision was made with Law 98/022 of December 24, 1998, and especially, with respect to furthering of rural electrification, aid from the state came to be promoted in both technological and financial aspects. With this new law, private commercial enterprise techniques were taken up and what had been recognized as a monopolistic concession to SONEL ceased to be such.

According to Article 1 of the law, all activities related to power generation, transmission, and distribution, and sales export-import, and supply beginning with hydroelectric power development, are subject to the statutory system below.

- la concession
- la license
- l'autorisation
- la declaration
- la liberte

In order to be able to carry out power generation, transmission, and distribution as a public utility, it is necessary to pay royalties. The rates, and the system for levying and collection are as prescribed in separate regulations.

This law also stipulates that an "Electric Power Sector Regulating Agency" is to be established with its principal responsibilities to regulate, supervise, and follow up regarding activities of operators and enterprisers of electric power sector. The Electric Power Sector Regulating Agency is to be concerned with promotion and development of electric energy enterprises in a competitive environment which should come into being in the future, and will be setting up the tariff system in light of the procedures prescribed by the authority with jurisdiction over the electric power industry and conforming with various statutory regulations.

The statutory regulations as prescribed by this law are as listed below.

- The “la license” regulation concerns independent power generation and sales of medium-voltage electric power.
- The “l’autorisation” regulation concerns private power generation facilities larger than 1 MW and electric power distribution and operation facilities of output less than 100 kW.
- The “la declaration” regulation concerns private power generation facilities of outputs from 100 kW to 1 MW.

and

- The “la liberte” regulation concerns hydroelectric power plants of outputs less than 100 kW and distribution lines strung out on private land.

Particularly, with regard to rural electrification work, all activities are to be subject to the “l’autorisation” regulation as prescribed in Article 62 of this law.

This law also stipulates establishment of a “Rural Electrification Agency” under the jurisdiction of the electric power administration authority. The Rural Electrification Agency expedites and secures technological and financial aid necessary for development of rural electrification. Such aid is based on subsidies from the state, various royalties, or technical cooperation and donations from friendly foreign countries.

(2) Management of Electric Power Facilities

Hereafter, management of electric power facilities is to be done independently by rural communities, public initiative organizations, and provincial autonomous bodies with technological and financial aid from the Rural Electrification Agency.

Until the time that the Rural Electrification Agency is established, technological aid concerning studies, construction, and management of small hydroelectric power stations and their electric power networks will be provided by the electric power administration authority.

A Small Hydroelectric Power Station Management Committee (CGMHE) is to be established in accordance with the new law regulating the electric power industry. This is composed of a group of economic beneficiaries within the framework of the current regulations and corresponding statutory system (GIE), common initiative group (CIG), and cooperatives.

Even in case of a facility given a concession, the ownership is retained by the state.

The abovementioned Management Committee, which is a juridical person and is financially self-sustaining, receives cooperation from local councils supplied with electric power, the electric power administration authority providing technological assistance, various organizations concerned with rural area development such as the Agricultural Engineering & Regional Development Bureau of MINAGRI (Ministry of Agriculture), FEICOM, and small-scale financial institutions.

Details of the management agreement and related conditions are to be set up with the electric power administration authority, Electric Power Sector Regulation Bureau, Rural Electrification Bureau, and selected enterprises as the parties concerned.

The hydroelectric projects presently being carried out as parts of technical cooperation by JICA, namely, Ngambe-Tikar, Ndokayo, and Olamze, all cover plural numbers of districts or departments, these projects are to be carried out based on the “l’autorisation” regulation in accordance with Law No. 98/022 of December 24, 1998 and its enforcement regulations which regulate electric power sector.

Regarding the respective authorizations, the Cameroonian Government, along with the administration authority, wishes to regulate the operating conditions and forms according to the particulars below.

– Participate in the Management Committee, picking up organizations or communities to work as committee members.

- Pick up enterprisers with possibilities of engaging in operation on being commissioned by the Management Committee.
- Provide one small hydroelectric power station management committee (CGMHE) and one enterpriser for each territory.
- Set up an authorization contract between Regulating Bureau and Management Committee and distinctly delineate the territory to be covered.
- Select the enterpriser (provincial autonomous body, civilian enterprise, GIF, GIE, cooperative).
- Transfer facilities and equipment to Management Committee in accordance with management agreement.
- In order to bring financial responsibility to facilities management, invest the enterpriser's or administration committee's own funds (acceptable even if limited).
- Decide the final form of operation and provision of electric power public utility work.
- In order to enhance the attractiveness of prior projects and to immediately secure the source of funds for rural electrification over the middle term, the enterpriser repays the capital furnished by the state within the period of authorization (whole amount or partial, no interest).
- Set up a special electric power tariff system which will have rates commensurate with incomes of the rural population and at the same time make possible repayment of the funds provided by the state, payment of annual maintenance and administration costs, renewal of equipment at the end of the authorized period, and securing of technical and financial assistance.

(3) Rural Electrification Agency

Thus, based on the new Electric Power Sector Law enacted on December 24 of last year, establishment of the Rural Electrification Agency came to be approved as of September 8, 1999 by President Paul Biya to break the various bottlenecks to rural electrification. This electrification agency was placed under the supervision of various government agencies concerned with electric power that decide national policies in the electric power sector, and together with promoting rural electrification works and providing technical assistance to electric power enterprisers and utilizers, also can provide financial aid. The principal items of the corporation's business are considered to be as follows:

- Based on approved criteria and standards, carry out investigations and studies for technological and economic measures applicable to rural areas.
- On behalf of rural communities, join with government agencies concerned and enterprisers in the electric power sector to study technical problems in procurement of funds for rural electrification work.
- Joining with the supervising government agency, negotiate with investors regarding procurement of funds required for rural electrification work.
- In the event necessary, provide aid in accordance with conditions prescribed in current laws and regulations to rural electrification enterprisers for generation, transmission, distribution, and sales of electric power, beginning with small hydroelectric power stations.
- Provide financial aid to enterprisers and rural communities in accordance with conditions set by the minister in charge of electric power and the minister in charge of finance.
- Provide guidance regarding management and maintenance to rural communities where rural electrification facilities are installed.
- Carry out all public service works entrusted the Electrification Bureau by the government concerning rural electrification undertakings.

The earliest possible establishment of the Electrification Agency is presently being called for in Cameroon, and probably, operation will be started in the year 2000, with management of existing power generating facilities assumed on being commissioned by the supervisory agency concerned with electric power. The director general of the Rural Electrification Agency would be appointed by the national President, while the board of directors would be made up of representatives of ministers such as those concerned with electric power, finance, and public investment and regional development, representatives of provincial autonomous bodies, and users of electric power. The source of funds for the Electrification Agency is public money, while it is also possible for rural electrification funds to be set up separately. The Electrification Agency, besides receiving national government subsidies and grants, can collect royalties according to laws regulating the electric power sector, and can be apportioned a share in the event the newly set up Electric Power Sector Regulating Agency should turn a profit.

The Electric Power Sector Regulating Agency, as previously described, will have the principal task of regulating and supervising activities of operators and enterprisers concerned with electric power, and will be engaged in promotion and development of the electric power industry in the competitive environment coming into existence with future privatization of the electric power industry.

(4) Ngambe-Tikar Hydro

The structure is to be the same as for Olamze Hydro described in (5). The administrative authorities of Ngambe-Tikar, FEICOM, Hazim Lumber Co. are conceivable as cooperators in the enterprise. The “l’autorisation” system prescribed by law is to be followed.

In case of Ngambe-Tikar, in view of the size of the company and its weight in the regional economy, the Hazim firm is to be asked to cooperate with the management committee as an enterprise from the private sector.

(5) Ndokayo Hydro

The structure given below is conceivable as the management system for Ndokayo Hydro. The revenue would be shared by the various economic entities taking part in operation and management and the state.

- Transfer the diesel generating facilities and electric power networks existing at Betare Oya and Garoua Boulai to the management committee.
- Fund procurement: Based on the grant from the country providing aid, the state makes an interest-free loan.
- Management committee: Provincial autonomous bodies (Garoua Boulai and Betare Oya administrative authorities), FEICOM, private enterprises.
- Own capital ratio: 10%
- Authorized period: 20 years
- Repayment of 80% of capital furnished by the state within the authorized period.
- Electricity rate for general household: An amount commensurate with household expenses in case of using other energy (petroleum, batteries, etc.), and at the same time an amount making possible repayment of funds furnished by the state, along with covering maintenance and administrative expenses, fuel costs, equipment renewal costs, profit, and technical assistance.
- Fixed rate system of tariff
- If any profit is made, distribution of the profit, while it is conceivable for a set-up where a certain percent of annual income is paid to the electric

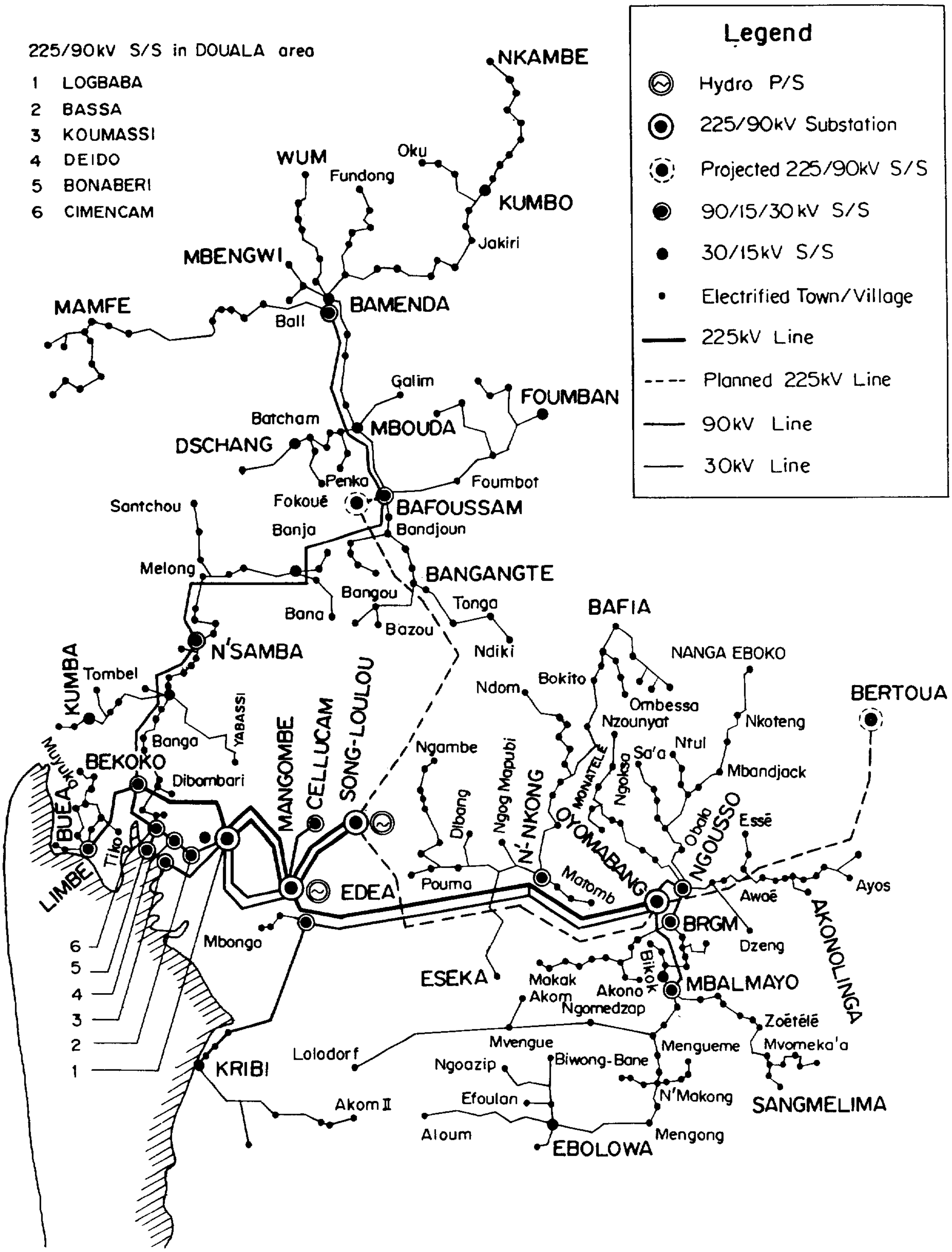
power enterprise regulating authority as a royalty for subsidizing projects running deficits.

(6) Olamze Hydro

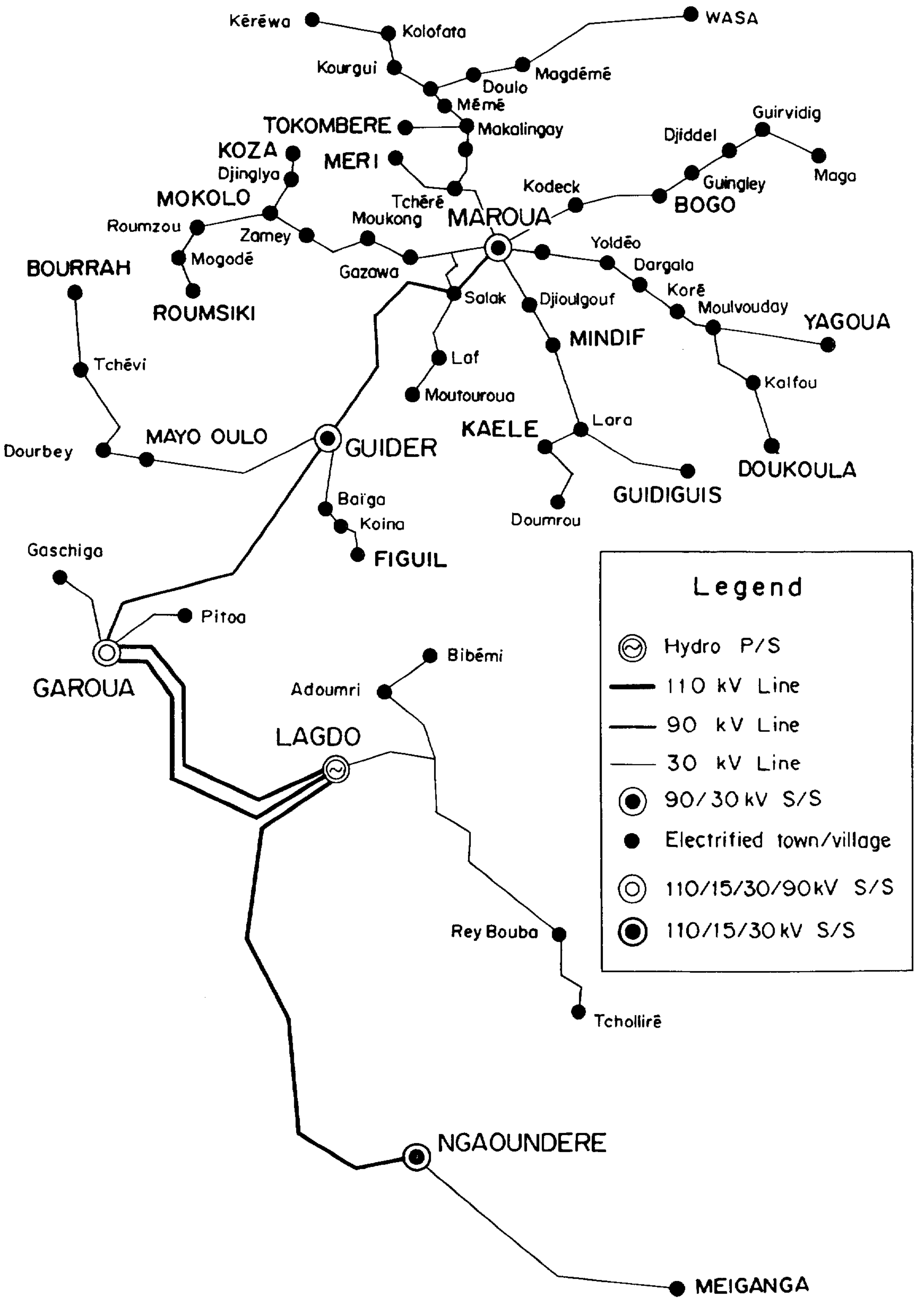
As a decentralized management system for Olamze Hydro the simple structure below is conceivable. Profit would be shared by various economic entities participating in management and the state.

- Transfer the diesel power generating facilities and electric power networks existing at Olamze and Ambam.
- Fund procurement: Based on the grant from the country providing aid, the state makes an interest-free loan.
- Management committee: Provincial autonomous bodies (Olamze and Ambam administrative authorities), FEICOM, GIE, GIC, and in cases, private enterprises, cooperatives.
- Own capital ratio: 5%
- Authorized period: 20 years
- In the case of this project, repayment to the state during the authorized period is to be 20% of the capital furnished in view of the low profitability.
- Electricity rate for general household: An amount commensurate with household expenses in case of using other energy (petroleum, batteries, etc.) and at the same time an amount making possible repayment of funds furnished by the state, along with covering maintenance and administration expenses, fuel costs, equipment renewal costs, profit, and technical assistance.
- Fixed rate system of tariff
- Decide among enterprise cooperators of national government level subsidies to cover anticipated deficits (some discount of repayment amounts of capital furnished).

Southern Interconnected System



Northern Interconnected System



CHAPTER 5. HYDROLOGIC ANALYSIS

Chapter 5 Hydrologic Analysis

5.1 General Topography, Meteorology, and Hydrology

5.1.1 Topography

Cameroon is on the west coast of the African continent and is situated from 2º to 12º north latitude and 8º to 16º east longitude, the total area of the country being 475,440 km2 (approximately 1.3 times the area of Japan).

The total length of the country's borders not include the 402 km of coastline facing the Atlantic Ocean is 4,591 km, clockwise from the north, 1,690 km with Nigeria, 1,094 km with Chad, 797 km with Central Africa, 523 km with Congo, 298 km with Gabon, and 189 km with Equatorial Guinea.

The land is of diverse character with tropical rain forest in the southern and western regions, savanna in the central region, and semi-arid desert in the northern region. Topographically, too, there is a coastal plain in the southwest, a central plateau where many ravines are developed, a high mountainous area in the south, and a plateau in the north sloping gently down toward Lake Chad for great variety. Consequently, vegetation and customs in daily life vary exceedingly according to climate and terrain, and having the various features of the African continent within the boundaries of one country, it is called "Mini-Africa" at times.

5.1.2 Meteorology and Climate Zones

The climate of Cameroon is created by the geomorphological features of the country mentioned in the preceding paragraph, the hot, dry air from the Sahara Desert, and the moist air generated and moving in from the Gulf of Guinea. That is, from November to March, anticyclones generated in the Sahara Desert cause fronts to move south and dry, hot winds called "Harmattan" blow into Cameroon bringing in dryness and high temperatures. On the other hand, from April to October, when the anticyclones from the Sahara quiet down, Atlantic highs generated in the Gulf of Guinea to the south become active, and push up fronts north bringing in low-temperature high-humidity atmosphere from the south for the rainy season of Cameroon to set in (see Fig. 5.1).

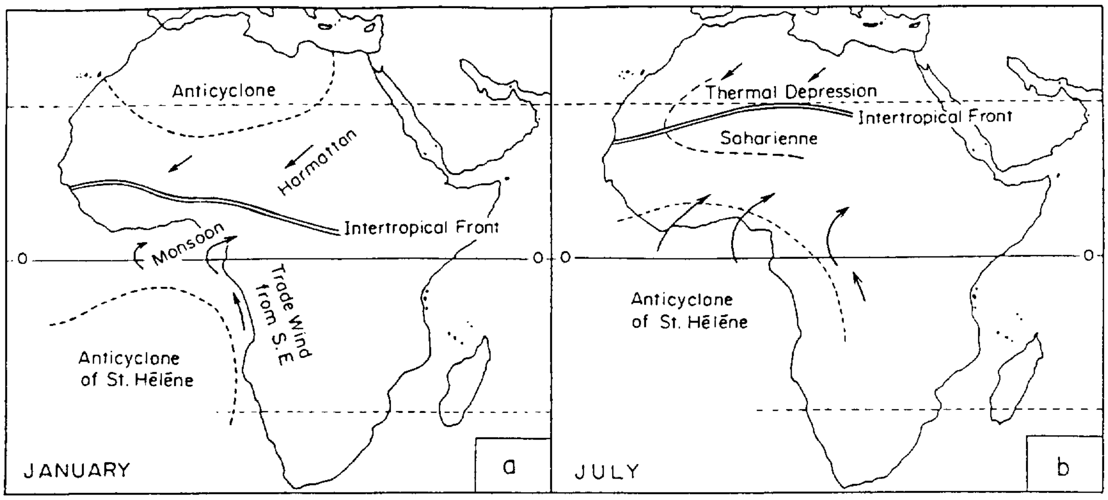


Fig. 5-1 Typical Weather Map in Two Seasons

The climate of Cameroon may be broadly divided according to the two climatic zones below:

(1) A two-season tropical climate zone north of a line connecting Bertoua and Bafia.

(2) A four-season equatorial climate zone south of the abovementioned line.

Even though belonging to either of these two climatic zones, there are variations according to district, coastal, inland, or according to elevation, and subdivision into the following 8 zones may be done (see Fig. 5.2):

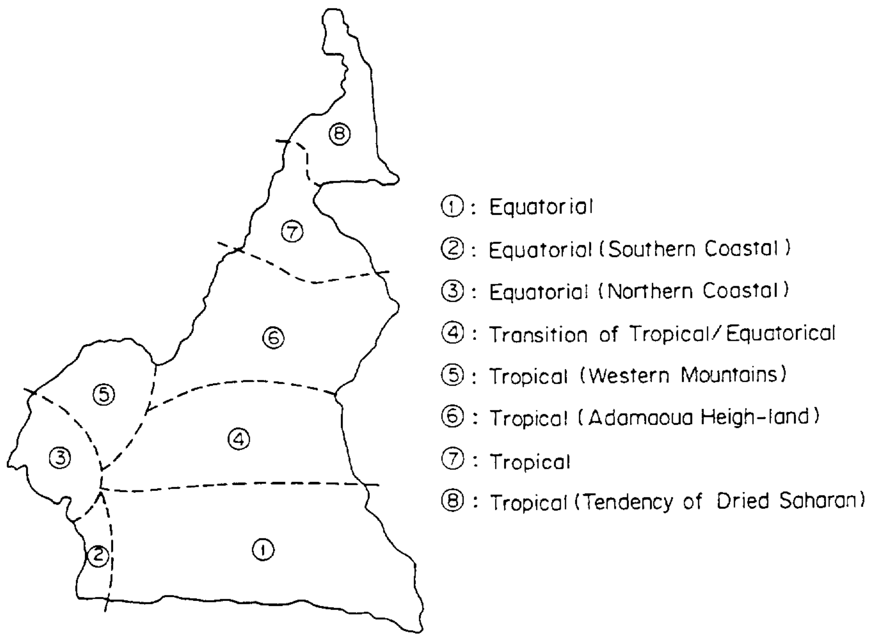


Fig. 5.2 Typical Climates in Cameroon

Zone ① : Entire southern part. Very distinct four-season tropical climate covering Yaounde, Yokadouma, Ebolowa, Ambam, Moloundou, and Ouesso.

Zone ② : Southwestern coastal region. Although there are four seasons, a southern coastal tropical climate with very much rain and high humidity. A minor dry season in July and August.

Zone ③ Northern coastal tropical climate, two seasons only. The modifier of "tropical" remains only because of abundant rainfall, and no minor dry season even in July and August. Douala and Mt. Cameroon districts included in this zone.

Zone ④ : From Bafia to Bertoua. A transition zone between equatorial and tropical covering Batouri, Yoko, and Betare-Oya.

Zone ⑤ : Western mountainous tropical climate. Two seasons. The feature of this region, from Dschang to Founban and from Bamennda to Ngambe-Tikar, is that, compared with regions of similar terrain and elevation in the country, air temperature is clearly lower, in addition to which, influenced by the Atlantic Ocean, the climate is a tropical one with much rain and high humidity.

Zone ⑥ : Highland tropical climate of Adamaoua. Two seasons. A region covering the entire Adamaoua Highland from Banyo to Ngaoundera and Meiganza. The feature of this region is that, in spite of the elevation averaging 1,000 m, temperatures are high with abundant precipitation, and the climate is a humid, tropical one but accompanied by a dry season of at least 4 months.

Zone ⑦ : Tropical climate of Benoue Basin. Featured by annual precipitation of more than 900 mm and a dry season of 6 months.

Zone ⑧ : A dry tropical climate of northern Cameroon. Covers the entire northern region from Kaele to Maroua, and from Mora and Yagoua to Kousser and Makary, and also Lake Chad. Annual precipitation varies between 400 mm and 900 mm. July is the dry season.

5.1.3 Air Temperature, Humidity, and Evaporation

With regard to the meteorology and climatic zones of Cameroon, as described in the preceding section, in addition to factors of topography and elevation of the country, the influences of monsoons from the Sahara Desert and the Gulf of Guinea are deeply involved. To express the climate of the country in general terms, the Gulf of Guinea coastal area of the southwestern region is of high temperature, much rain, and high humidity, while there is a trend for higher temperature, less rain, and more dryness the further inland into the African continent.

Mean annual temperatures, means annual relative humidifies, and annual evaporation potentials are shown in Figs. 5.3, 5.4 and 5.5.

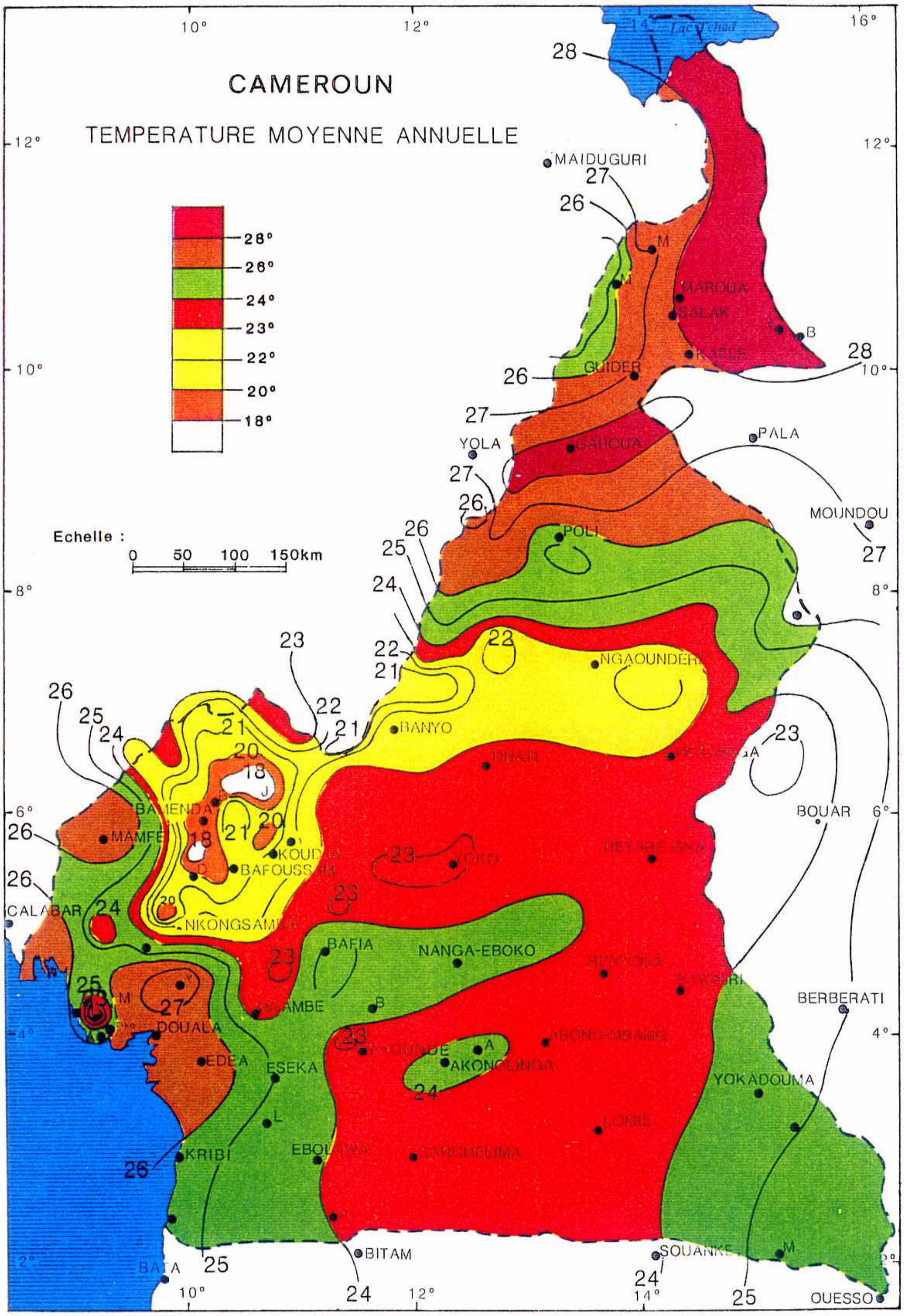


Fig. 5.3 Mean Annual Temperature

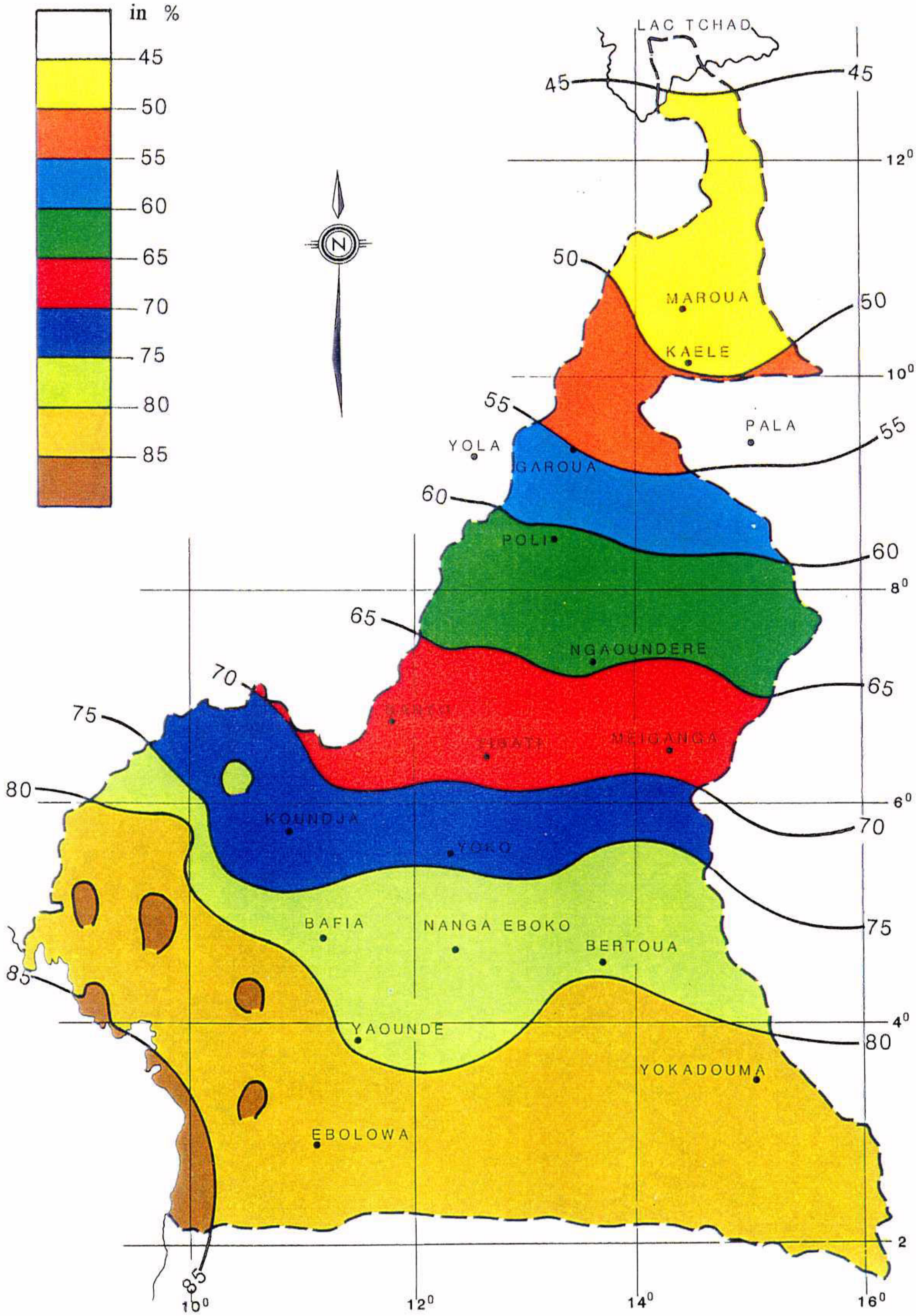


Fig. 5.4 Mean Annual Relative Humidity

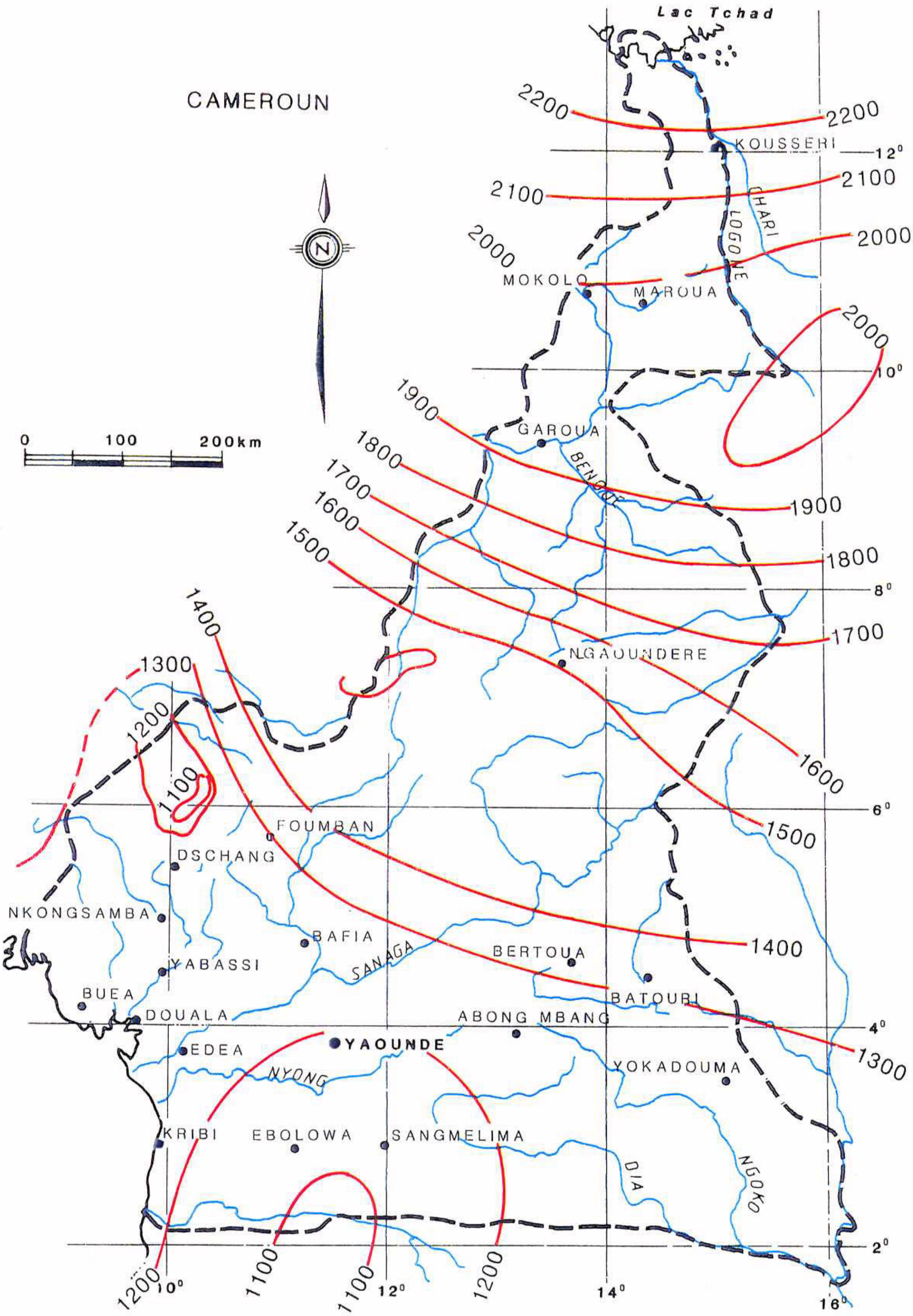


Fig. 5.5 Annual Evapotranspiration Potential (in mm)

5.1.4 Precipitation

An isohyetal map showing the annual mean precipitation is presented in Fig. 5.6. Trend-wise, it is as described in the preceding section, but especially, rainfalls in the Gulf of Guinea coastal areas, the northern region, and the Adamaoua Highland are abundant. Typical patterns of annual precipitation by region are shown in Fig. 5.7 and variations in precipitation by latitude in Fig. 5.8.

It is seen from these two figures that in the southern region below 6º north latitude and the western region, a minor rainy season (dry season) occurs from June to August. From 9º north latitude and above, the period of the rainy season is short, while annual precipitation is less than 1,000 mm.

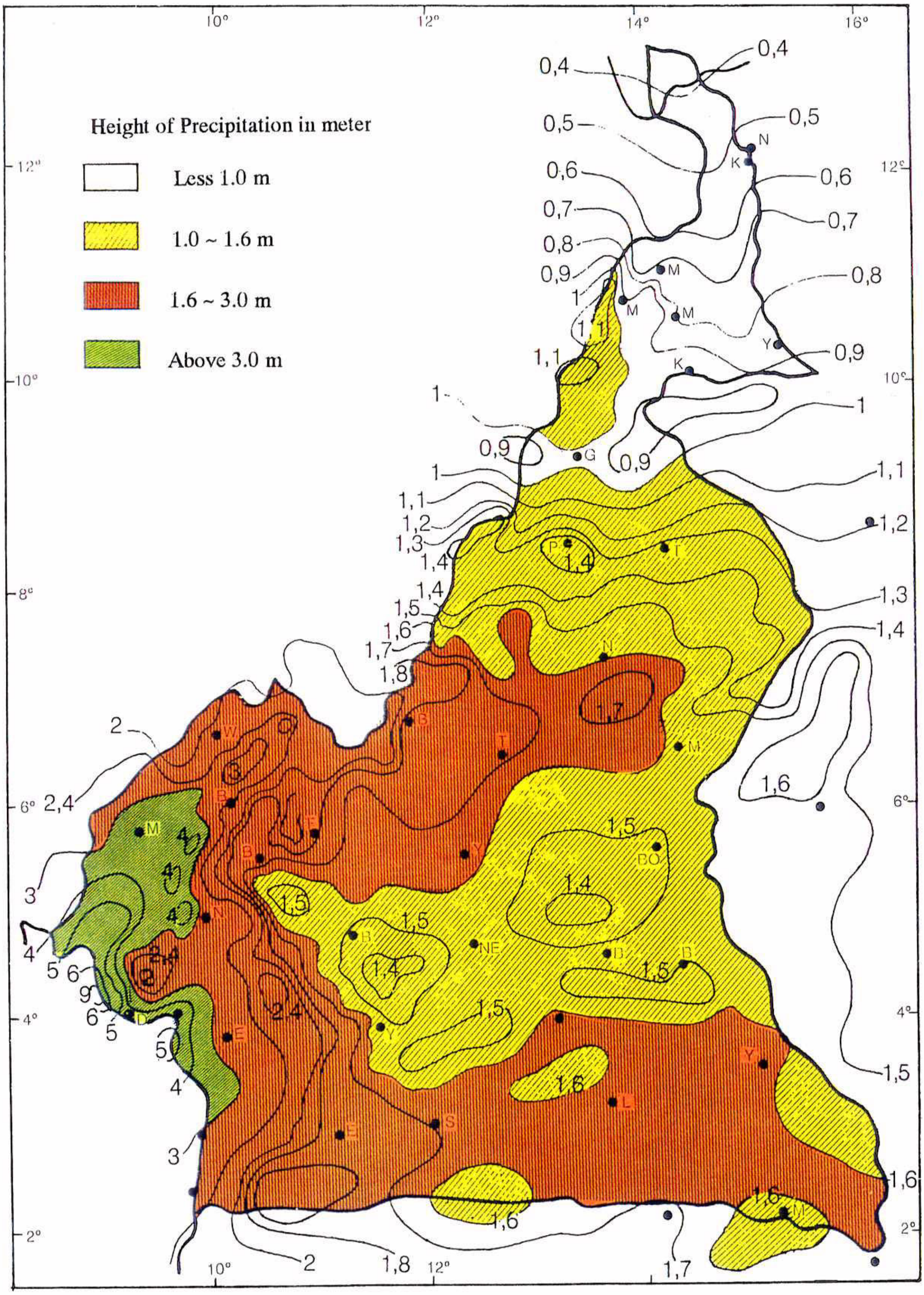


Fig. 5.6 Annual Precipitation (in m)

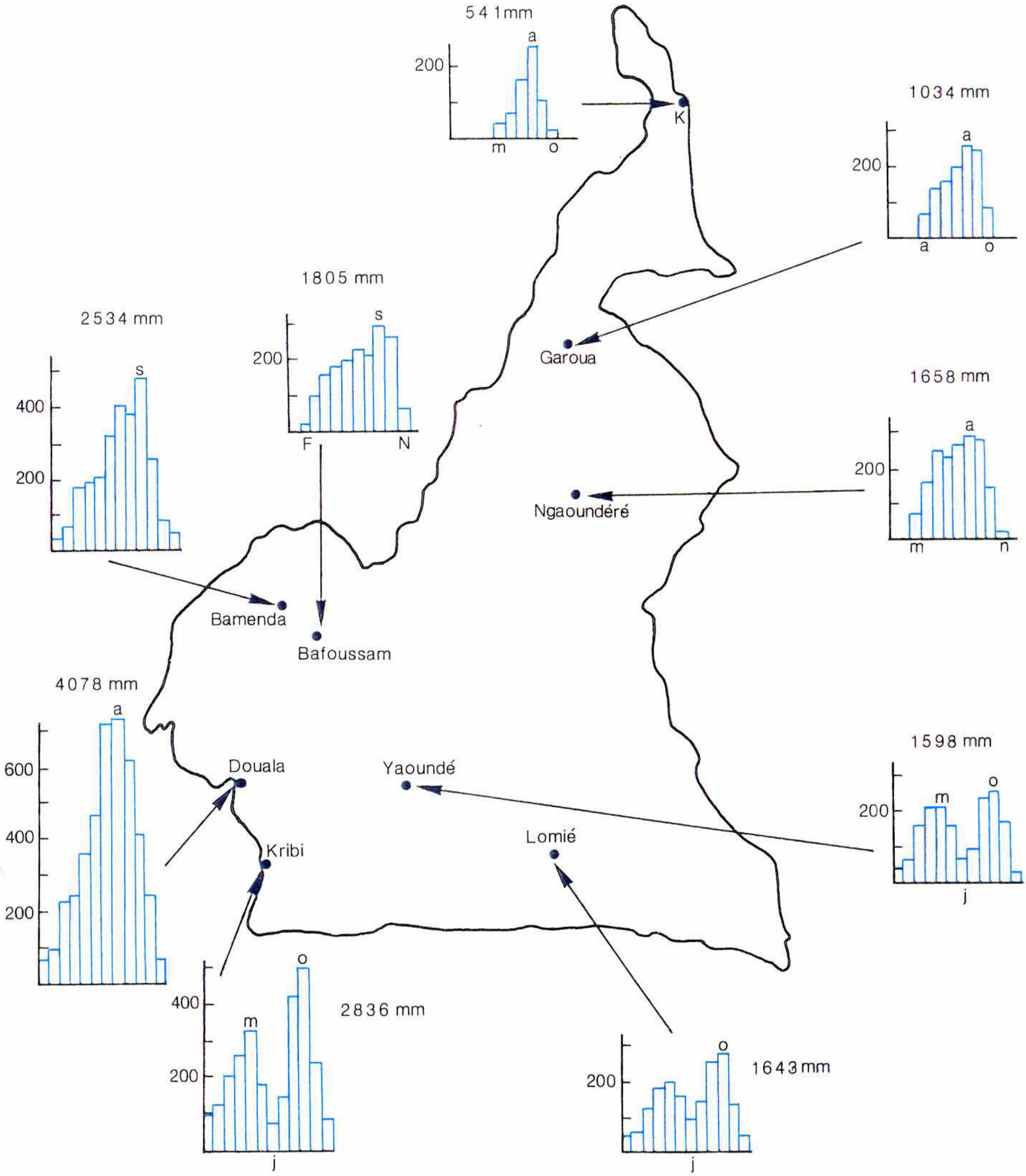


Fig. 5.7 Typical Patterns of Monthly Precipitation in Regions

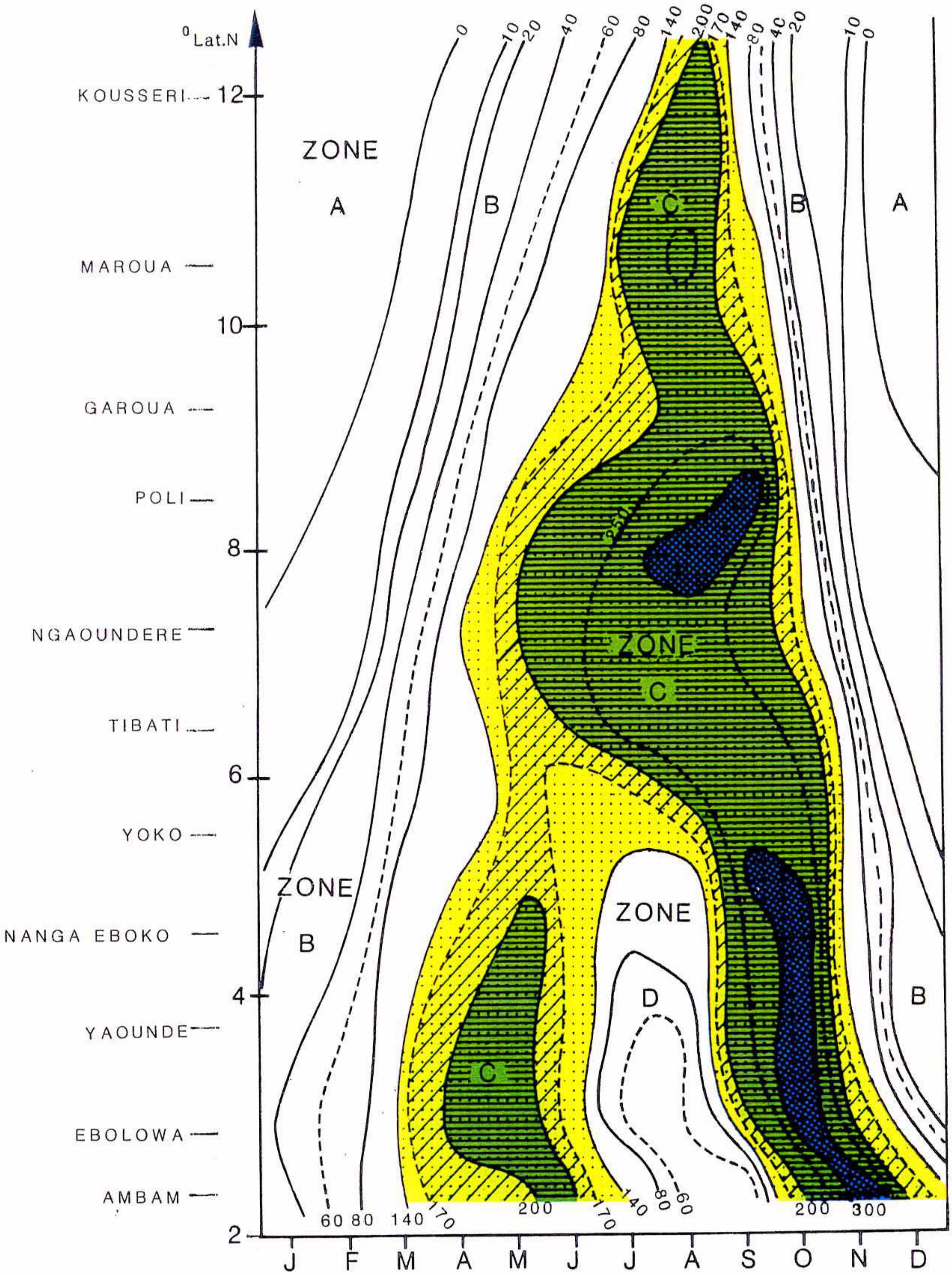


Fig. 5.8 Variations of Monthly Precipitation by Latitudes

5.1.5 Rivers and Streams

The rivers and streams of Cameroon, excepting the Sanaga River, Nyong River, and Ntem River which empty into the Atlantic Ocean, all belong to three out of the five great discharge basins of Africa. (Rivers and streams, and basins are shown in Figs. 5.9 and 5.10.)

These basins are:

- Niger River Basin
- Lake Tchad Basin
- Zaire River Basin

The proportions of the national territory of Cameroon that the abovementioned four discharge systems take up are as follows:

1)	Coastal river basins of Cameroon beginning with the Sagana River, directly flowing into the Atlantic Ocean	Approx. 50%
2)	Niger River Basin: Benoue River	Approx. 20%
3)	Lake Tchad Basin: Vina River, Nbere River, tributaries of the Logone River	Approx. 10%
4)	Zaire River Basin: Sangha River, tributary of Congo River	Approx. 20%

The three sites under consideration in this Project are all located inside 1).

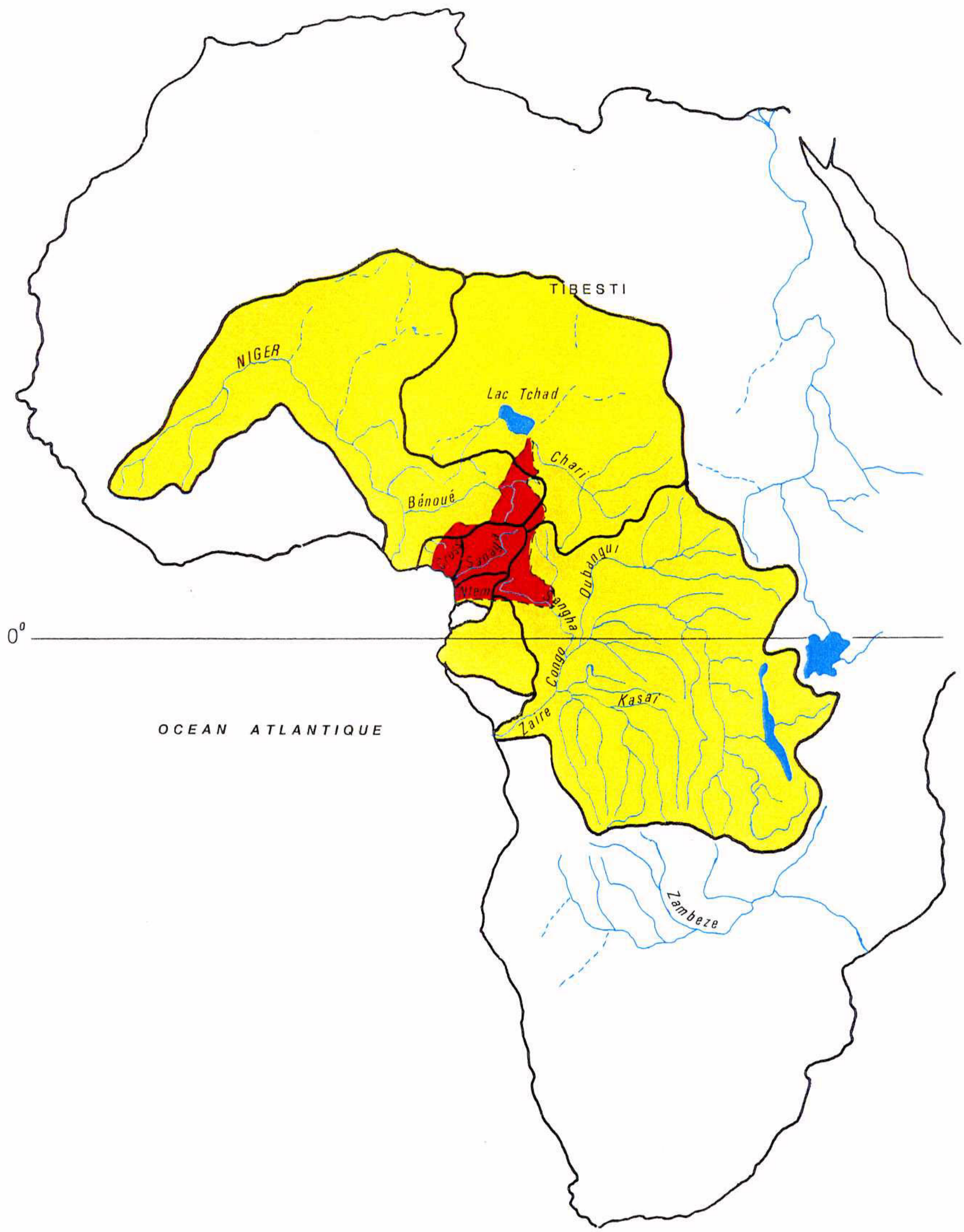


Fig. 5.9 Related River Basin in Cameroon

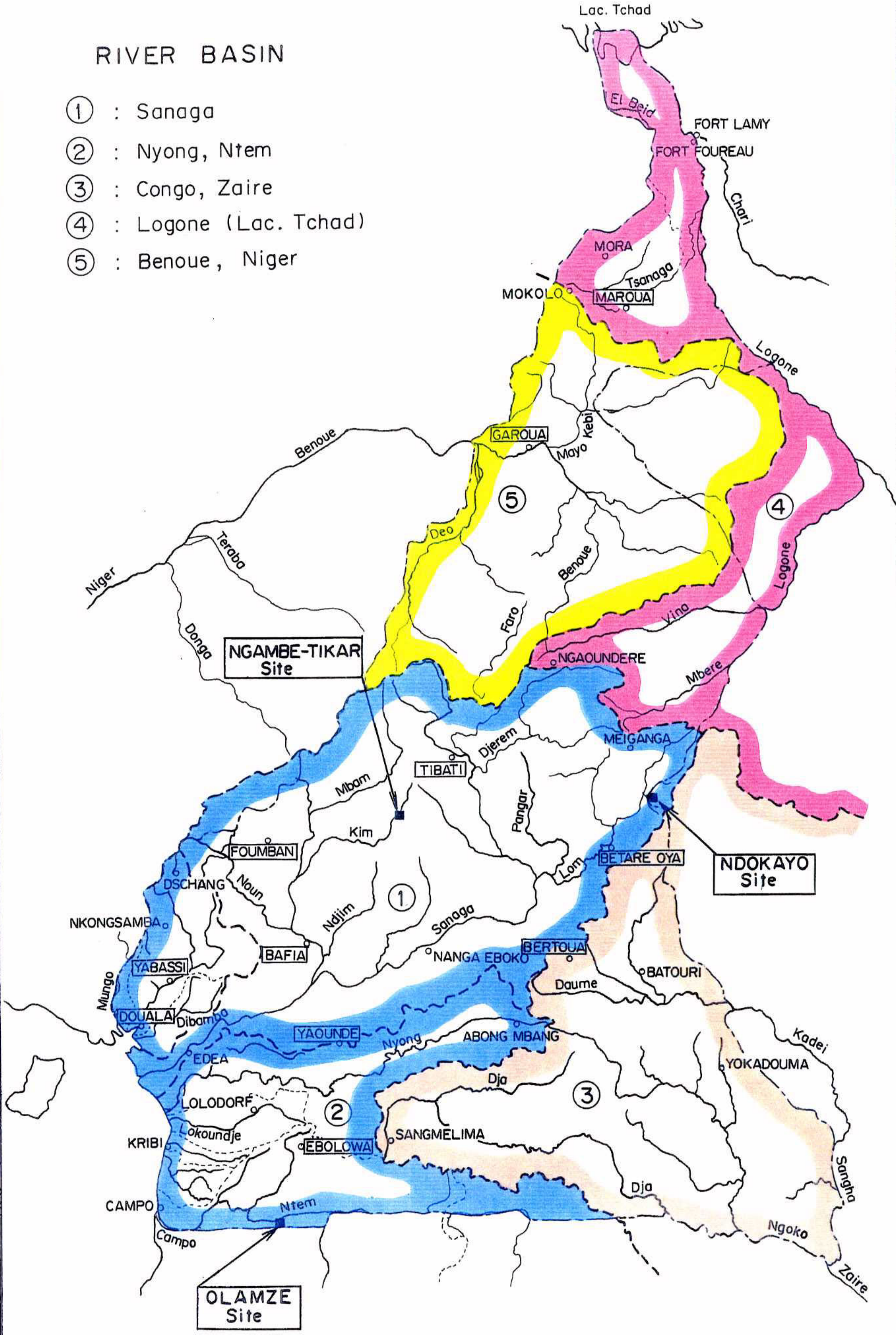


Fig. 5.10 Related River and River Basin in Cameroon

5.2 Terrain, Meteorology, and Hydrology of Project Area

5.2.1 Ngambe-Tikar Site

The Ngambe-Tikar site is located at 5º45’ north latitude and 11º30’ east longitude on the midstream stretch of the Kim River, a branch of the Mbam River, a tributary of the Sanaga River, the largest river in Cameroon.

The Kim River runs down southward from its fountainhead, the southern slope of the Adamaoua Highland of elevation 900 m to 1,500 m, which runs east-west through the central part (7º north latitude) of the country, and with a length of approximately 220 km, it joins the Mbam River. The elevation at the project site is approximately 710 m and the catchment area is approximately 5,820 km^2.

The climate in the project area is tropical and wet, annual precipitation being from 1,600 mm to 1,700 mm, but the mean temperature is 23ºC, low comparison with other areas in the country of similar terrain and elevation. The rainy season is from April to October, the dry season from November to March. The vegetation in the basin is mainly thin shrubbery, but at banks of the river, there are some jungle growths including tall trees remaining. The runoff of the Kim River at the project site is an annual average 59.3 m^3/sec with minimum monthly average 6.3 m^3/sec (February). The river at the project site forms rapids with heads of 3 to 5 m, but the river width is large, from 50 to 70 m, even at the narrowest stretch, while both banks are flat, and topography suitable for intake-dam abutment construction cannot be found. Judging the water level during flood by traces left in the past, it is assumable that there will be a rise of approximately 2 m above the water level of the driest period and, beginning with the intake dam, special consideration will be necessary regarding layouts and design elevations of various power generation structures.

5.2.2 Ndokayo Site

The Ndokayo site is located at 5º40’ north latitude and 14º10’ east longitude, at the downstream most stretch of the Mari River, a branch of the Sanaga River tributary Lom River. Both the Lom River and the Mari River have their fountainheads at the southern slope of the Adamaoua Highland, the same as the Ngambe-Tikar site, the Mari joining the Lom immediately downstream of the project site, following which, it flows down southwest to merge into the Sanaga River. The Mari River on which the powerhouse is planned has a length of approximately 50 km, a catchment area of

640 km^2, and elevations at the project site of 700 to 790 m. This plan is for the head of approximately 80 m of a natural waterfall to be used for power generation, the topographical conditions being the best compared with the other two sites.

The climate in the project area is tropical, the same as the Ngambe-Tikar site, precipitation, temperature, and rainy and dry seasons being roughly identical. The vegetation in the basin is similar to that at the Ngambe-Tikar site also, although the degree of thinning has progressed. The river discharge at the project site is an annual average 10 m^3/sec with minimum monthly average 2.6 m^3/sec (March).

This project site possesses ideal topographical conditions for a hydroelectric power station project, the intake dam site immediately above the waterfall, the penstock, and the powerhouse site immediately downstream of the waterfall.

5.2.3 Olamze Site

The Olamze site is located at 2º15’ north latitude and 11º00’ east longitude at the downstream most part of the tributary Woro River which joins the midstream part of the Ntem River. The Woro River springs inside Equatorial Guinea and flows north approximately 60 km to merge into the Ntem River. Therefore, more than 90% of the catchment area of 840 km^2 lies within Equatorial Guinea.

The climate in the project area is equatorial, but being approximately 140 km inland from the Atlantic Ocean, there is influence of the southern coastal equatorial climate, and it is hot and humid, with much precipitation. A minor dry season occurs in July and August. The annual mean temperature is 24 to 25º and precipitation 1,800 to 2,000 mm/yr. The vegetation within the basin comprises a broad equatorial rain forest. The river discharge at the project site is an annual average 12.8 m^3/sec with minimum monthly average being 5.3 m^3/sec.

At this project site, rapids with low heads of 2 to 3 m would be used, similarly to the Ngambe-Tikar site, but since there is only a very small river gradient on the whole (about 1/1,000), head will have to be gained relying on the height of the intake dam. Since the topography of the project area is flat and provides little river gradient, special consideration will be required concerning layouts and design elevations of various power station structures.

5.3 Hydrologic Analysis of Project Area

5.3.1 Analysis Technique

(1) Meteorological and Hydrological Data

Regarding the meteorology and hydrology of Cameroon, Institut Francais de Recherche Scientifique pour le Developpement en Cooperation (ORSTOM) had in 1986 arranged and analyzed data obtained and accumulated up to that time, and the results were published under the title "Fleuves et Rivieres du Cameroun".

In the hydrologic analysis to be made in the present project survey, the data arranged and analyzed in the abovementioned report and the precipitation and runoff data obtained independently in the present survey will be used.

A list of existing meteorological observation stations is given in Table 5.1 and the precipitation by month observed at each station in Table 5.2. A location map of stream runoff gauging stations and a list of the stations are shown in Fig. 5.11 and Table 5.3, respectively.

(2) Analysis Technique

The locations of the three sites taken up in this project survey and their basins, stream runoffs useful in hydrologic analysis, and positioning of precipitation observation stations are shown in Fig. 5.12. The analysis technique used for the individual sites is described below.

Table 5.1 List of Meteorological Stations

No. Station	Lat. (N)	Long. (E)	Alt. (m)	Observation Items Other than Precipitation
North-West Regions				
1. Mamfé	5°42	9°18	126	T. H. Ap. Ev. ETP. I.
2. Dschang	5°27	10°03	1382	W. T. H. Ap. Ev. ETP. I
3. Nkongsamba	4°57	9°56	877	W. T. H. Ap. Ev. ETP
4. Nkondjock	4°52	10°15	200	
5. Loum	4°42	9°43	242	
6. Kumba	4°38	9°27	236	
7. Mbanga	4°30	9°34	115	
8. Idenau	4°12	8°59	10	
9. Buea	4°09	9°14	700	I.
10. Ekona	4°08	9°15	380	
11. Débundscha	4°06	8°59	18	
12. Bota	4°07	9°12	10	
13. Tiko	4°05	9°21	46	T. H. Ap. Ev. ETP. I
14. Yabassi	4°27	9°58	30	T.
15. Douala	4°04	9°41	12	W. T. H. Ap. Ev. ETP. I.
16. Yingui	4°32	10°18	200	
17. Edéa	3°48	10°08	31	W. T. H. Ap. Ev.
18. Dizangué	3°45	10°00	50	
South Regions				
19. Eséka	3°38	10°47	423	W. T. H. Ap. Ev.
20. Lolodorf	3°14	10°44	440	
21. Makat	3°33	11°02	600	
22. Yaoundé	3°50	11°32	782	W. T. H. Ap. Ev. ETP. I.
23. Mbalmayo	3°31	11°30	641	
24. Akonolinga	3°46	12°15	671	T. H. Ap. Ev.
25. Ayos	3°54	12°31	693	
26. Abong Mbang	3°58	13°12	694	W. T. H. Ap. Ev.
27. Doumé				
28. Sangmélima	2°56	11°59	713	W. T. H. Ap. Ev.
29. Ebolowa	2°55	11°09	603	T. H. Ap. Ev.
30. Nkoemvone	2°49	11°08	10	
31. Kribi	2°56	9°54	18	W. T. H. Ap. Ev.
32. Campo	2°22	9°50	25	
33. Nyabessan				
34. Ambam	2°23	11°16	602	W. T. Ev.
35. Djoum	2°40	12°41	684	
36. Ditam (Gabon)	2°05	11°29	600	ETP.

W.:	Wind	T.:	Temperature	H.:	Humidity
Ap.:	Air Pressure	Ev:	Evaporation	ETP.:	Evapotranspiration potential
I.:	Insolation				

Table 5.2 Monthly Mean Precipitation

(mm)

Station	J	F	M	A	M	J	J	A	S	O	N	D	Year
Edéa	41	59	149	236	275	248	240	340	472	374	153	41	2 628
Yaoundé	26	53	149	190	211	159	59	75	225	304	122	27	1 600
Manoka	202	195	358	384	507	683	725	624	721	541	330	197	5 467
Sakbayeme	22	39	141	218	262	229	200	315	414	343	152	23	2 358
Evodoula	11	44	160	218	253	107	49	56	215	303	129	23	1 568
Obala	17	62	135	163	201	148	47	55	169	275	141	25	1 438
Ngambe	21	55	168	191	246	283	361	552	556	455	128	24	3 040
Batschenga	23	48	119	204	209	148	67	65	239	296	132	20	1 570
Nachtigal	19	37	112	177	191	128	49	74	161	270	120	17	1 355
Saa	13	44	124	176	185	137	40	51	159	288	106	13	1 336
Ndom	9	33	122	131	176	96	86	148	267	297	100	9	1 474
Ntui	13	33	126	195	172	148	53	68	188	307	94	9	1 406
Yingui	19	21	133	184	236	225	196	287	325	362	137	23	2 148
Bertoua	24	54	124	155	178	186	106	147	243	311	111	35	1 674
Nanga-Eboko	24	40	114	177	212	153	93	127	269	302	103	26	1 640
Bafia	12	33	117	163	182	140	102	136	231	280	86	11	1 493
Ndikinimeki	15	39	119	167	169	153	85	112	262	286	86	12	1 505
Bombi	13	53	80	131	185	193	114	101	149	243	130	19	1 411
Nkongjock	46	52	169	224	241	288	417	504	539	371	133	19	3 004
Mankim	13	34	140	207	190	182	113	110	285	385	140	10	1 809
Bangangté	8	25	102	141	138	146	133	151	257	256	69	15	1 441
Dschang	15	50	138	198	184	231	223	250	340	242	52	13	1 936
Bafoussam	10	30	105	176	185	191	231	234	292	278	65	9	1 806
Foumbot	8	26	94	142	163	171	230	258	303	253	65	11	1 723
Yoko	11	25	83	124	181	165	151	186	299	295	73	11	1 604
Betare-Oya	12	25	71	137	173	179	166	229	276	249	56	11	1 584
Koundja	5	31	111	165	199	202	319	314	365	265	64	10	2 050
Mantoum	3	12	90	169	192	147	224	191	266	317	80	13	1 704
Kounden	6	30	109	160	194	228	356	313	355	270	60	16	2 097
Babadjou	15	28	93	165	183	223	220	222	285	253	59	12	1 758
Foumban	4	25	94	146	190	175	275	304	327	268	73	10	1 891
Baboua	7	26	79	111	171	197	188	240	261	219	92	8	1 549
Bamenda	22	52	166	185	194	303	426	367	477	246	74	26	2 537
Bouar	5	20	71	117	130	157	188	293	270	178	39	6	1 474
Bambui	14	41	144	194	221	276	365	348	398	296	54	13	2 364
Ndop	10	26	127	160	175	194	195	221	268	171	39	6	1 592
Jakiri	8	40	122	159	172	240	278	337	305	260	51	6	1 978
Bansoa	10	31	128	144	184	215	291	294	336	252	57	11	1 953
Mayo-Darle	11	27	91	176	207	220	269	283	353	269	54	11	1 971
Tibati	3	11	63	129	180	203	280	266	292	242	46	5	1 720
Meiganga	5	10	68	124	195	215	296	275	307	222	39	7	1 763
Banyo	4	21	86	170	226	230	295	268	310	230	39	10	1 889
Sarki	0	5	31	81	128	208	272	285	247	153	13	0	1 423
Ngaoundere	2	2	44	154	223	243	276	292	257	151	12	2	1 658
Tignere	0	4	46	115	179	193	230	258	248	140	19	1	1 433

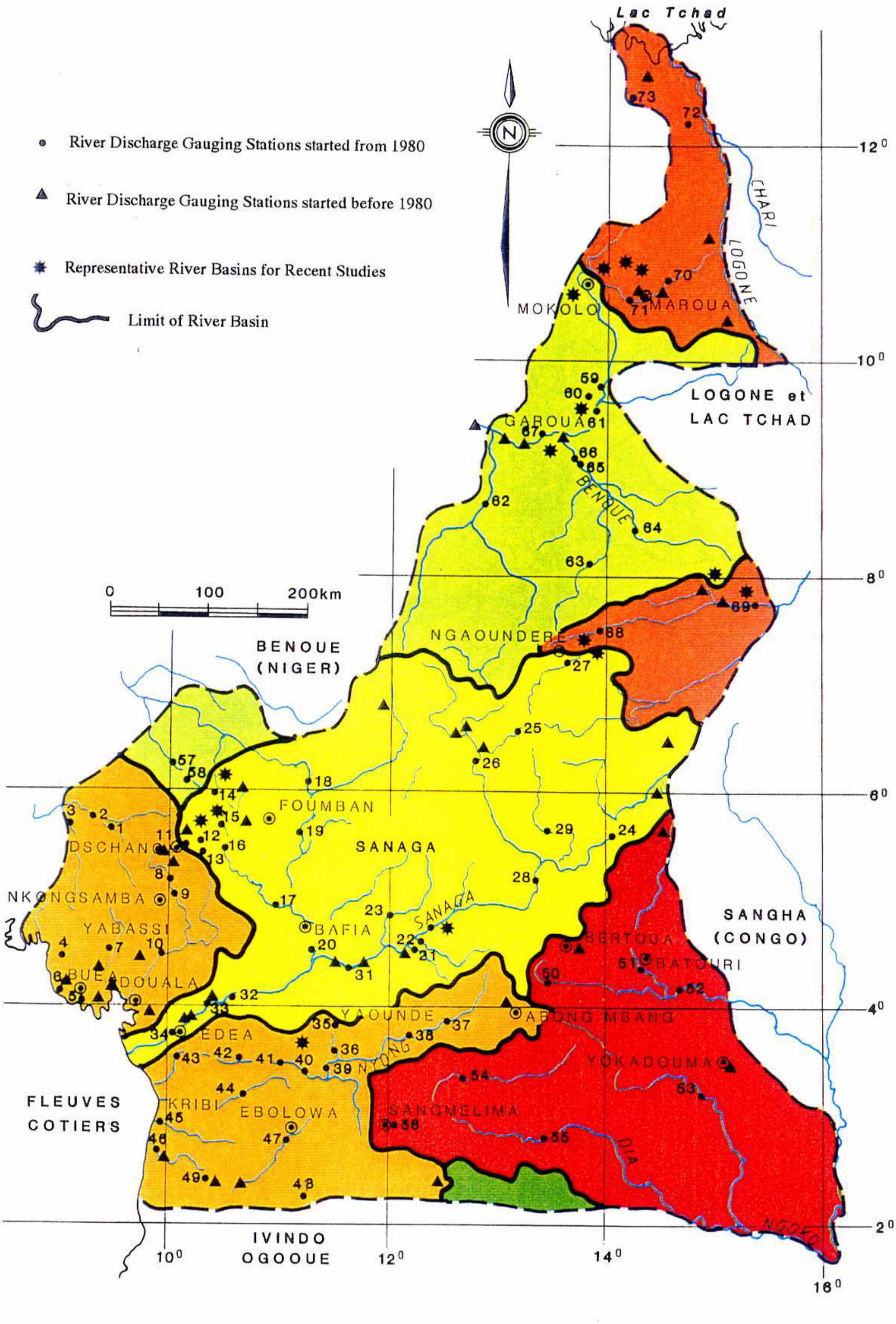


Fig. 5.11 Location Map of River Discharge Gauging Stations

Table 5.3 List of River Discharge Gauging Stations (1/2)

N°	River	Station	Lat.	Long.	Altitude m	Catch. Area km2
1	Bassin de la Cross-River	Mainyu	5°43'	9°30'	69.22	4 050
2	Cross-River	Manfe	5°43'	9°19'	44.32	6 810
3	Munaya	Akwen	5°46'	9°04'	38.59	2 770
4	Bassin de la Meme	Bai	4°29'	9°07'	12	975
5	Bassin de l'Ombe	Pont	4°05	9°17'	*150*	92
6	Bassin de la Sanje	Idenau	4°14'	8°58'	29.10	77
7	Bassin du Mungo	Mundame	4°34'	9°32'	*30*	2 420
	Bassin du Wouri					
8	Nkam	Melong	5°09'	10°00'	699.23	2 275
9	Nkam	Ekom	5°04'	10°02'	*620*	2 440
10	Wouri	Yabassi	4°28'	9°58'	12	8 250
	Bassin de la Sanaga					
11	Choumi	Banock	5°29'	10°17'	1385 env	360
12	Metchié	Chutes	5°22'	10°20'	1297.11	480
13	Mifi-Sud	Bamoungoum	5°31'	10°21'	1264.38	306
14	Monkie	Bamessing	5°57'	10°25'	1158.73	180
15	Noun	Bamendjing (éch. aval)	5°42'	10°30'	1131.10	2 190
	Noun	Bafoussam E1	5°28'	10°33'	992 env	4 740
16		E2	5°28'	10°33'	986.75	4 740
17	Noun	Bayomen	4°55'	11°05'		8 850
18	Mape	Magba (éch. amont)	5°59'	11°16'	683.89	4 020
	Mape	Magba (éch. aval)	5°59'	11°16'	683.73	4 020
19	Mbam	Mantoum	5°37'	11°11'	660 env	14 700
20	Mbam	Goura	4°34'	11°22'	392.00	42 300
21	Nianiang	Megangme	4°36'	12°14'	567.19	224
22	Tere	Ndoumba	4°38'	12°17'	568.16	1 730
23	Njeke	Ngongon	4°48'	12°00'	560 env	3 720
24	Lom	Bétaré-Oya	5°55'	14°08'	662 env	11 100
25	Djerem	Bétaré-Gongo	6°35'	13°12'	837.93	11 000
26	Djerem	Mbakaou E2	6°20'	12°49'	823.69	20 200
27	Vina-Sud	Lahoré	7°15'	13°34'	1056.32	*1 680*
28	Sanaga	Goyoum	5°12'	13°22'	616.71	50 500
29	Pangar	Mbitom	5°44'	13°19'		2 934
30	Sanaga	Nanga-Eboko	4°42'	12°23'	566.92	65 100
31	"	Nachtigal	4°21'	11°38'	425.91	76 000
32	"	Sakbayeme	4°02'	10°33'		129 500
33	"	Song-Loulou	4°07'	10°27'		130 000
34	"	Edéa éch. 0	3°46'	10°04'	25 env	131 500

Table 5.3 List of River Discharge Gauging Stations (2/2)

N°	River	Station	Lat.	Long.	Altitude m	Catch. Area km2
	Bassin du Nyong					
35	Mefou	Etoa	3°46'	11°29'	672 env	235
36	Mefou	Nsimalen	3°44'	11°32'	650 env	425
37	Nyong	Ayos	3°53'	12°31'	645.60	5 300
38	Nyong	Akonolinga	3°47'	12°15'	642.85	8 350
39	"	Mbalmayo	3°31'	11°30'	633.47	13 555
40	"	Olama	3°26'	11°17'	628.30	18 510
41	"	Kaya	3°32'	11°05'	617 env	19 985
42	"	Eséka	3°41'	10°42'	146.42	21 600
43	"	Dehane	3°34'	10°07'	35 env	26 400
44	Bassin de la Lokoundje	Lolodorf	3°14'	10°44'	436.62	1 150
45	Bassin de la Kienké	Kribi	2°56'	9°54'	10 env	1 435
46	Bassin de la Lobe	Kribi	2°52'	9°53'	7 env	2 305
	Bassin du Ntem					
47	Seng	Assosseng	2°50'	11°09'	570 env	440
48	Ntem	Ngoazik	2°18'	11°18'	535 env	18 100
49	Ntem	Nyabessan	2°24'	10°24'	385 env	26 350
	Bassin du Congo					
50	Doume	Doume	4°14'	13°27'	610 env	515
51	Kadéi	Batouri	4°14'	14°19'	587.96	8 974
52	Kadéi	Pana	4°12'	14°41'	570 env	20 372
53	Boumba	Bewala	3°13'	14°55'	467 env	10 335
54	Dja	Somalomo	3°22'	12°44'	603 env	5 380
55	Dja	Bi	2°48'	13°21'	533 env	19 500
56	Afamba	Sangmélima	2°54'	11°59'	660 env	191
	Bassin de la Bénoué					
57	Metchem	Gouri	6°17'	10°02'	560.02	2 240
58	Mezam	Bengwi	6°00'	10°01'	1260 env	360
59	Mayo-Louti	Figuil	9°46'	13°56'	250 env	5 540
60	Mayo-Oulo	Golombe	9°39'	13°53'	240 env	1 160
61	Mayo-Kébi	Cossi	9°37'	13°52'	195 env	25 000
62	Faro	Safaï Djelepo	8°39'	12°49'	230 env	24 000
63	Bénoué	Buffle Noir	8°07'	13°50'	360 env	3 220
64	Mayo-Rey	(M. Galké) Tchollire	8°24'	14°15'		5 240
65	Bénoué	Lagdo (amont)	9°03'	13°41'	186.88	30 650
		Lagdo (aval)	9°03'	13°41'	186.88	30 650
66	Bénoué	Riao	9°03'	13°41'	185.80	30 650
67	Bénoué	Garoua	9°18'	13°23'	173.37	60 500
	Bassin du Lac Tchad (Logone)					
68	Bini	Berem	7°33'	13°57'	810 env	1 585
69	Vina-Nord	Touboro	7°45'	15°20'	472 env	12 200
	(Nord-Cameroun)					
70	Mayo-Tsanaga	Bogo	10°44'	14°36'	344 env	1 535
71	Mayo-Tsanaga	Maroua	10°34'	14°17'	407 env	845
72	El Beid	Tilde	12°09'	14°44'	284 env	
73	El Beid	Fotokol	12°22'	14°13'	282	12 500

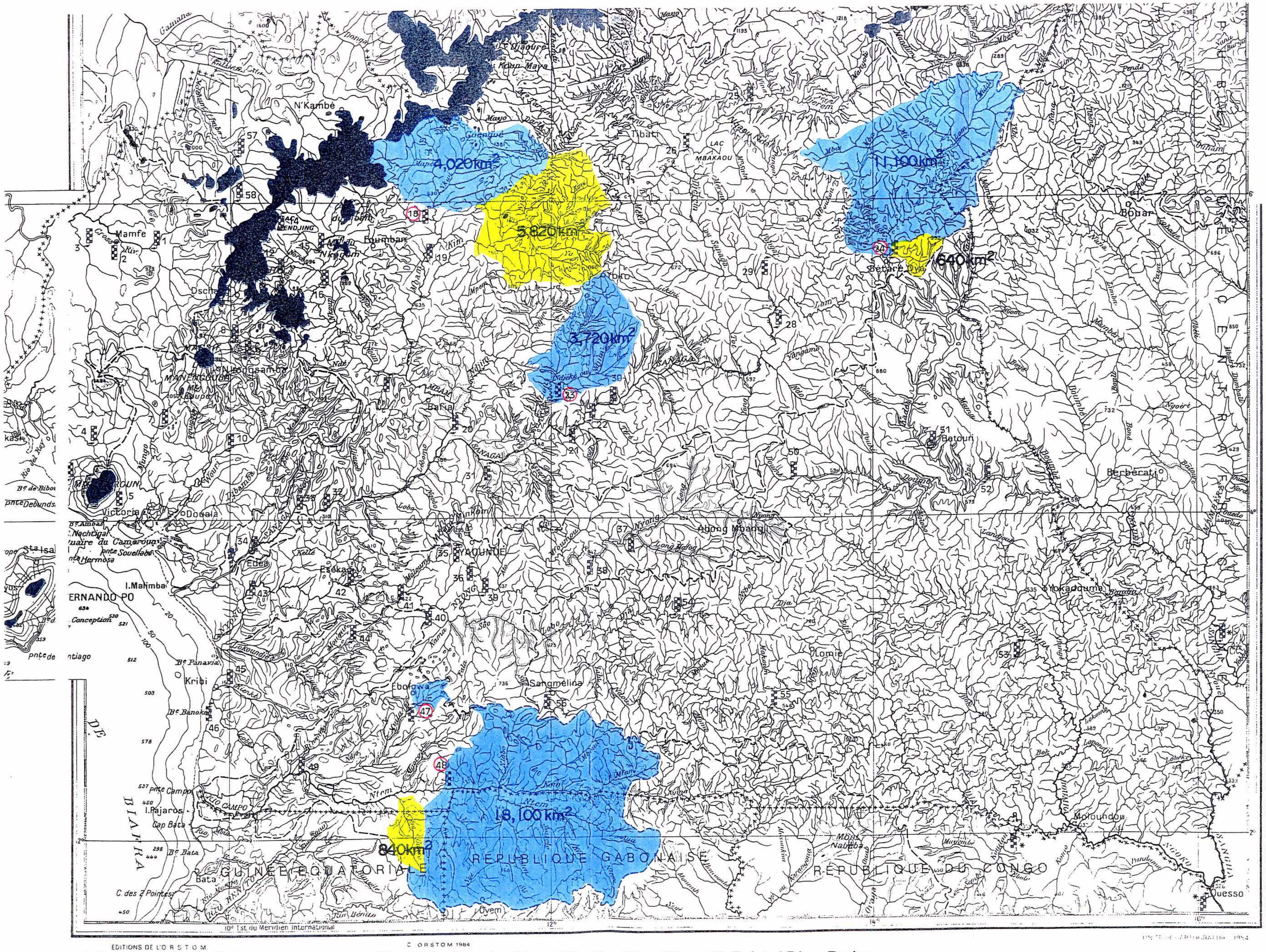


Fig. 5.12 Location Map of the Candidate Sites with Related River Basins

(a) Ngambe-Tikar Site

This project site is located at the midstream stretch of the Kim River, a tributary of the Sanaga River. This Kim River has a channel length of 220 km and the catchment area of the project site is 5,820 km^2, but there is no runoff gauging station, while one precipitation observation station is located at Ngambe-Tikar Village approximately 4 km distant from the project site.

On the other hand, there are the following four runoff gauging stations in neighboring areas of the project site or on neighboring streams, and data from them are available.

- Magba Gauging Station (No.18) : Mape River
  Catchment area 4,020 km^2
- Mantoum Gauging Station (No.19) : Mbam River
  Catchment area 14,700 km^2
- Goura Gauging Station (No.20) : Mbam River
  Catchment area 42,300 km^2
- Ngongon Gauging Station (No.23) : Njeke River
  Catchment area 3,720 km^2

In view of the above situation, the analysis for this project site is to be made by catchment area ratio and runoff ratio based on the available runoff data.

(b) Ndokayo Site

This project site is located at the downstreammost part of the Mari River, a tributary of the Sanaga River. The Mari River has a channel length of approximately 50 km and the catchment area at the project site is 640 km^2, but there is no runoff gauging station, while one precipitation observation station is located at Betare Oya Village approximately 12 km distant from the project site. On the other hand, there are three runoff gauging stations on the Lom River into which the Mari River merges and on neighboring streams.

- Betare Oya Gauging Station (No.24) : Lom River
  Catchment area 11,100 km^2
- Goyoum River (No.28) : Sanaga River
  Catchment area 50,500 km^2

- Mbitom Gauging Station (No.29) : PangarRiver
  Catchment area 2,934 km^2

In view of the above situation, the analysis for this site is also to be made by catchment area ratio and runoff ratio based on the runoff data available.

(c) Olamze Site

This project site is located at the downstreammost part of the Woro River, tributary of the Ntem River. The Woro River has a channel length of approximately 60 km and the catchment area of the project site is 840 km^2, but neither a runoff gauging station nor a precipitation observation station exists in its basin. However, there are the three runoff gauging stations below on neighboring streams, and data from them are available.

- Ngoazik Gauging Station (No.48) : Ntem River
  Catchment area 18,100 km^2
- Nyabessan Gauging Station (No.49) : Ntem River
  Catchment area 26,350 km^2
- Assosseng Gauging Station (No.47) : Seng River
  Catchment area 440 km^2

In view of the above situation, the analysis for this project site, similarly to the other two sites, is also to be made by catchment area ratio and runoff ratio based on the data available.

5.3.2 Runoff Analyses of Ngambe-Tikar Site

As described in the previous clause, 5.3.1 (2) (a), data of runoff gauging stations existing in four neighboring basins can be used in runoff analysis for this project site. Here, topographies, elevations, precipitation characteristics in the surroundings of the project site, and catchment area are to be taken into consideration, and analysis performed with data of Magba and Ngongon Gauging Stations in the two basins adjacent at north and south of the project site’s basin. The monthly average runoffs and annual runoff characteristics of the two gauging stations are given in Table 5.4 and Table 5.5. Runoff data available are for 31 years from 1951 to 1981 in case of Magba Gauging Station and 15 years from 1967 to 1981 in case of Ngongon Gauging Station.

The results of calculating runoffs of the project site by catchment area ratio based on data of these two gauging stations are given in Table 5.6 and Table 5.7.

Meanwhile, the runoffs calculated from water-level records gathered from July to October 1998 by an automatic water gauge installed at the project site in this present survey are given in Table 5.8.

Table 5.4 (1/2) Monthly Mean River Discharge

Gauging Station: Magba, Mape River

C.A. = 4,020 km^2, (m^3/sec)

Year	A	M	J	J	A	S	O	N	D	J	F	M	Module
1951-52										25.5	15.7	4.41	
52-53	23.7	32.9	61.4	115	174	216	217	105	42.0	18.7	11.6	27.1	87.5
53-54	11.5	30.0	54.8	86.5	124	207	231	82.0	40.1	25.1	12.0	11.5	76.7
54-55	27.4	45.2	97.4	161	136	285	360	129	48.7	24.9	12.2	16.7	113
55-56	10.7	41.6	80.7	112	197	232	213	97.1	38.4	16.1	12.1	36.1	90.8
56-57	21.9	64.3	80.6	157	147	242	164	93.0	50.8	24.4	9.20	3.75	88.6
57-58	13.7	50.2	98.2	174	152	238	333	174	68.8	30.7	12.4	5.75	113
58-59	31.1	72.4	121	128	148	240	163	149	63.6	29.7	10.8	5.44	97.1
59-60	22.9	48.6	71.6	133	150	210	273	108	44.5	19.3	6.18	4.55	91.3
60-61	27.3	35.9	73.1	171	239	238	358	173	58.1	29.4	11.3	2.38	119
61-62	15.9	16.8	44.8	141	166	313	337	86.3	37.2	14.8	5.33	9.69	99.6
62-63	35.4	50.1	69.0	172	205	257	333	184	98.6	35.7	17.9	9.48	123
63-64	16.7	52.2	73.1	84.4	113	168	266	92.3	33.7	13.9	4.31	9.89	77.6
64-65	39.4	51.4	79.2	150	178	202	328	154	81.6	38.0	11.7	10.2	111
65-66	43.5	50.4	69.6	129	204	225	291	94.8	36.7	15.5	4.64	2.32	97.8
66-67	7.56	55.6	137	179	236	289	258	147	50.0	23.6	7.87	2.74	117
67-68	8.04	25.6	42.5	118	241	277	401	154	49.3	20.5	5.00	9.37	113
68-69	14.5	28.8	61.8	121	173	285	258	141	47.5	19.4	5.54	13.3	97.8
69-70	24.4	48.2	67.5	177	212	234	277	234	72.7	21.7	5.75	2.51	115
70-71	12.7	43.7	64.0	106	168	190	271	131	34.1	11.4	3.15	4.85	87.2
71-72	10.7	8.44	48.3	131	125	187	134	46.9	26.3	8.0	2.46	5.11	61.3
72-73	23.5	28.0	79.0	93.3	136	209	255	72.1	29.2	10.5	2.57	0.94	78.7
73-74	7.35	29.7	46.8	92.6	147	177	165	72.0	31.0	10.3	2.04	0.82	65.5
74-75	22.0	34.2	77.2	150	175	296	295	147	48.0	19.5	6.61	4.70	107
75-76	11.5	26.4	54.9	103	108	176	231	103	47.2	19.1	9.57	7.05	75.0
76-77	14.7	40.5	78.3	158	210	224	257	157	50.4	23.2	6.47	1.29	102
77-78	2.93	17.6	44.1	144	162	254	226	65.7	24.8	8.3	2.92	2.43	80.1
78-79	19.3	34.9	77.0	110	147	305	309	179	47.1	17.4	4.56	3.09	105
79-80	9.96	54.9	62.8	158	207	231	200	139	51.0	22.1	5.40	2.33	95.6
80-81	3.56	30.2	63.2	92.5	142	311	353	161	48.1				
Mean 52-70	*21.9*	*47.0*	*80.6*	*138*	*179*	*242*	*289*	*136*	*53.6*	*23.3*	*9.20*	*10.5*	*102*
MID.	15.9	40.5	69.6	131	166	234	266	131	47.5	19.5	6.47	4.85	
ET.	10.3	14.6	21.5	29.7	37.5	42.3	67.3	43.3	16.5	7.6	4.22	7.84	
MEAN	18.4	39.6	71.7	133	170	239	267	127	48.3	20.6	7.84	7.58	95.7
Q_1	24.0	50.3	79.1	158	204	281	330	155.5	50.9	25.0	11.6	9.80	
Q_3	10.7	29.2	58.1	108	144	208	221	92.6	36.9	15.1	4.60	2.50	

Table 5.4 (2/2) Characteristics of River Discharge Duration

Gauging Station: Magba, Mape River

(m³/sec)

Year	Minimum		Characteristics							Maximum	
	Date	Discha.	355	330	270	180	90	30	10	Discha.	Date
1952-53	06/2	4.82	6.25	9.37	19.0	54.1	140	219	264	273	11/10
53-54	04/3	6.39	6.96	9.72	24.8	45.4	103	211	>273	273	09/10
54-55	-	-	-	-	19.0	68.9	151	316	406	465	28/09
55-56	19/2	3.60	7.57	11.8	41.8	57.5	157	220	251	316	29/09
56-57	29/3	1.26	2.75	-	19.0	74.1	136	186	208	220	10/10
57-58	23/3	2.75	4.94	7.88	21.4	88.9	173	294	338	471	01/10
58-59	15/3	2.93	3.70	6.11	25.6	87.7	151	191	274	355	24/09
59-60	11/3	2.11	2.75	4.13	20.9	61.6	143	233	281	462	16/10
60-61	26/3	0.80	1.12	5.05	17.3	61.6	207	315	383	467	12/10
61-62	03/3	3.11	3.70	5.59	19.0	44.4	161	314	458	536	25/09
62-63	27/3	5.06	6.11	10.3	24.6	75.9	198	301	356	389	12/10
63-64	06/3	1.36	1.59	3.70	22.0	54.1	112	209	326	375	12/10
64-65	31/3	4.58	7.26	9.20	22.2	80.1	168	249	389	449	02/10
65-66	29/3	1.59	1.97	2.75	10.3	58.2	167	266	329	375	15/10
66-67	22/3	1.84	1.97	2.93	12.5	85.4	203	283	311	375	21/09
67-68	04/3	2.26	2.75	4.35	15.5	43.9	201	308	453	551	12/10
68-69	25/2	2.75	4.13	7.11	20.0	50.5	161	257	335	483	30/09
69-70	06/4	0.93	1.12	2.58	17.5	77.0	196	283	398	499	02/10
70-71	07/3	1.42	1.77	3.05	12.0	53.6	156	227	305	376	31/10
71-72	27/2	1.17	1.53	3.11	7.42	31.1	110	170	201	228	17/09
72-73	11/3	0.66	0.67	1.47	14.0	46.2	110	230	268	384	07/10
73-74	25/2	0.66	0.66	0.86	8.20	39.3	121	173	199	281	24/09
74-75	16/3	1.97	2.75	5.31	18.0	59.0	172	285	360	390	02/09
75-76	10/3	3.81	5.11	7.26	13.3	49.0	114	202	238	285	09/10
76-77	26/3	0.66	0.86	2.42	17.0	66.6	193	251	273	308	18/10
77-78	08/3	0.93	1.47	2.75	5.84	29.1	147	240	283	341	25/09
78-79	21/3	1.36	1.84	3.11	14.8	57.2	153	316	380	444	15/09
79-80	19/3	1.36	1.84	2.75	13.5	60.5	182	226	273	311	29/08
MID.		1.84	2.75	4.59	18.0	57.2	156	247	311	376	
Q1		3.11	3.81	6.67	24.6	74.1	182	294	380	465	
Q3		0.93	1.53	2.93	13.5	46.2	136	210	273	308	

Table 5.5 (1/2) Monthly Mean River Discharge

Gauging Station: Ngongon, Njcke River, C.A.= 3,720 km^2

(m^3/sec)

Year	A	M	J	J	A	S	O	N	D	J	F	M	Module
1967-68												2.20	
68-69	4.46	18.5	41.4	32.8	35.8	92.8	112	117	43.2	17.2	9.96	40.7	47.3
69-70	19.3	43.7		70.2	76.6	98.1	136			9.03	6.88	5.12	
70-71	35.8	32.4	38.2	35.4	46.5	79.5	155	102	18.5	7.79	2.62	7.02	46.9
71-72	12.0	9.30	41.7	48.2	53.1	66.4	79.6	24.5	7.89	3.12	1.23	2.99	29.2
72-73	4.9	44.7	67.6	20.5	24.9	68.0	159	97.8	18.7	11.5	3.23	1.41	43.7
73-74	7.6	31.4	31.7	28.8	36.6	116	182	97.7	42.3	10.7	8.58	4.69	50.0
74-75	5.8	18.7	22.8	9.33	34.9	77.4	117	77.2	11.4	4.76	2.50	1.87	32.1
75-76	4.50	5.43	8.07	20.8	31.9	31.2	160	110	44.1	6.84	5.90	4.88	36.3
76-77	23.4	30.4	19.0	6.39	36.2	60.8	100	46.5	25.1	9.29	3.07	1.43	30.3
77-78	4.90	5.83	13.7	10.2	10.6	56.7	77.9	16.9	4.14	1.22	0.74	0.64	17.0
78-79	8.15	20.6	8.81			84.0			20.9	8.05	2.93	3.75	
79-80	5.28	13.0	31.6	18.0	17.1	43.0	80.9	64.6	13.6	2.50	0.97	0.73	24.3
80-81	1.55	14.4	37.3	9.64	26.1	67.2	242	145	26.3				
MID.	5.84	18.7	31.6	20.6	35.3	68.0	126.5	97.7	19.8	7.92	3.00	2.99	
ET.	9.85	13.3	17.0	18.8	17.3	22.7	49.1	40.0	13.8	4.45	3.05	5.96	
MEAN	10.6	22.2	30.2	25.9	35.9	72.4	133	81.7	23.0	7.67	4.05	5.96	37.7
Q1	15.6	31.9	39.8	34.1	41.5	88.4	159.5	110.0	34.3	10.0	6.40	5.00	
Q3	4.70	11.1	16.3	9.92	25.5	58.7	90.4	46.5	12.5	3.94	1.86	1.42	

Table 5.5 (2/2) Characteristics of River Discharge Duration

Gauging Station: Ngongon, Njeke River

(m³/sec)

Year	Minimum		Characteristics							Maximum	
	Date	Discha.	355	330	270	180	90	30	10	Discha.	Date
1968-69	23/2	4.02	5.93	9.00	25.9	62.3	76.4	110	151	185	11/11
69-70	10/4	1.43	2.64	3.84	9.00	60.4	81.6	115	145	201	04/10
70-71	09/3	1.71	1.92	2.64	10.3	25.9	65.5	118	202	275	22/10
71-72	25/2	0.73	0.82	2.14	3.67	15.3	52.2	76.8	84.6	103	07/10
72-73	24/3	0.20	0.69	2.03	6.95	20.0	62.3	114	205	261	25/10
73-74	13/4	1.35	2.26	4.02	9.00	20.5	64.7	142	216	275	08/10
74-75	08/3	1.35	1.61	2.14	4.40	14.1	40.8	106	136	155	08/10
75-76	25/3	2.26	2.77	3.84	5.23	9.97	40.8	118	173	222	17/10
76-77	19/3	1.27	1.35	1.81	6.95	21.1	42.9	91.1	91.5	91.6	30/09
77-78	28/2	0.56	0.56	0.65	1.52	8.08	14.5	68.2	92.4	122	23/10
78-79	16/2	2.26	2.38	2.91	6.68	17.0	39.7	170	237	265	09/11
79-80	08/3	0.60	0.63	0.69	2.91	13.3	33.0	77.7	97.3	113	30/10
MID.		1.35	1.76	2.39	6.81	18.5	62.3	114	151	201	
Q1		2.09	2.98	4.91	10.1	29.1	71.4	118	203	268	
Q3		1.00	1.08	2.08	4.81	14.7	41.8	98.5	114	129	

Table 5.6 (1/2) ESTIMATED RIVER DISCHARGE

Site: NGAMBE-TIKAR
River: KIM
Catchment Area 5,820 km²

(m^3/sec.)

	4	5	6	7	8	9	10	11	12	1	2	3	Module
Mid.	23.02	58.63	100.76	189.66	240.33	338.78	385.10	189.66	68.77	28.23	9.37	7.02	136.61
ET.*	14.91	21.14	31.13	43.00	54.29	61.24	97.43	62.69	23.89	11.00	6.11	11.35	36.52
Mean	26.64	57.33	103.80	192.55	246.12	346.01	386.55	183.86	69.93	29.82	11.35	10.97	133.97
Q1	34.75	72.82	114.52	228.75	295.34	406.82	477.76	225.13	73.69	36.19	16.79	14.19	166.40
Q3	15.49	42.27	84.11	156.36	208.48	301.13	319.96	134.06	53.42	21.86	6.66	3.62	112.29

ET.: Ecart Type

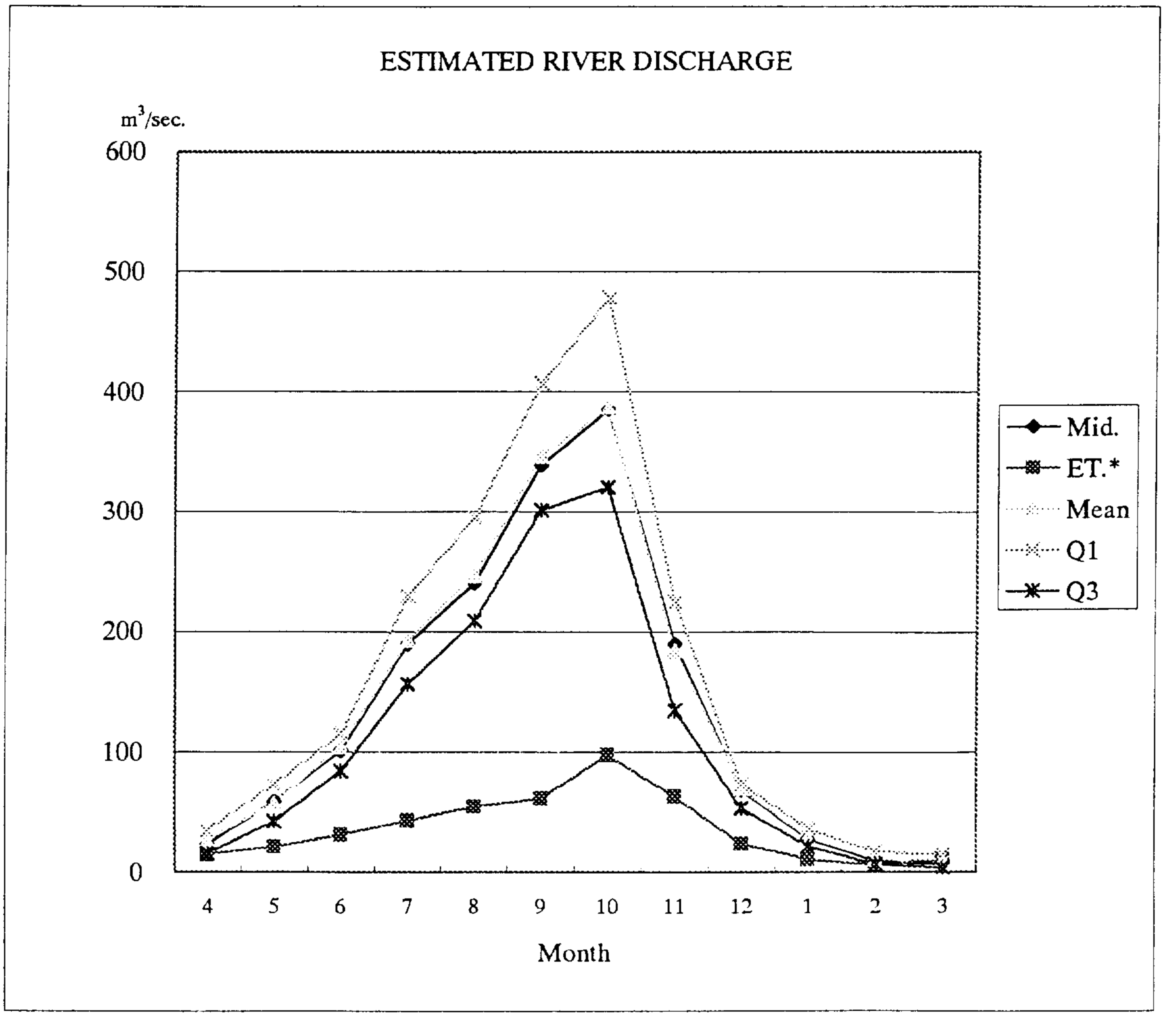
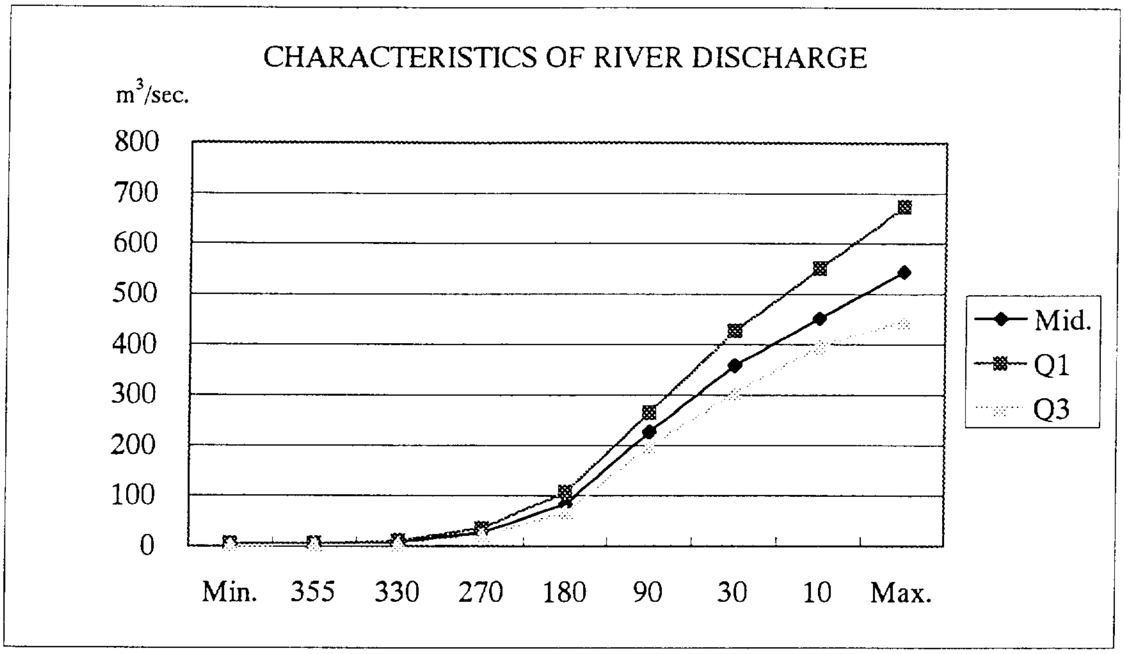


Table 5.6 (2/2) CHARACTERISTICS OF RIVER DISCHARGE

(m^3/sec.)

	Min.	355	330	270	180	90	30	10	Max.
Mid.	2.66	3.98	6.65	26.06	82.81	225.85	357.60	450.25	544.36
Q1	4.50	5.52	9.66	35.61	107.28	263.49	425.64	550.15	673.21
Q3	1.35	2.22	4.24	19.54	66.89	196.90	304.03	395.24	445.91



Note: Estimated river discharge is calculated based on the records at "Mape au Pont de Magba Amont" Gauging Station in Mbam River.

Table 5.7 (1/2) ESTIMATED RIVER DISCHARGE

Site: NGAMBE-TIKAR
River: KIM
Catchment Area 5,820 km²

(m^3/sec.)

	4	5	6	7	8	9	10	11	12	1	2	3	Module
Mid.	9.14	29.26	49.44	32.23	55.23	106.39	197.91	152.85	30.98	12.39	4.69	4.68	63.93
ET.*	15.41	20.81	26.60	29.41	27.07	35.51	76.81	62.58	21.59	6.96	4.77	9.32	28.07
Mean	16.58	34.73	47.25	40.52	56.17	113.27	208.08	127.82	35.98	12.00	6.34	9.32	59.26
Q1	24.41	49.91	62.27	53.35	64.93	138.30	249.54	172.10	53.66	15.65	10.01	7.82	75.16
Q3	7.35	17.37	25.50	15.52	39.90	91.84	141.43	72.75	19.56	6.16	2.91	2.22	36.88

ET.: Ecart Type

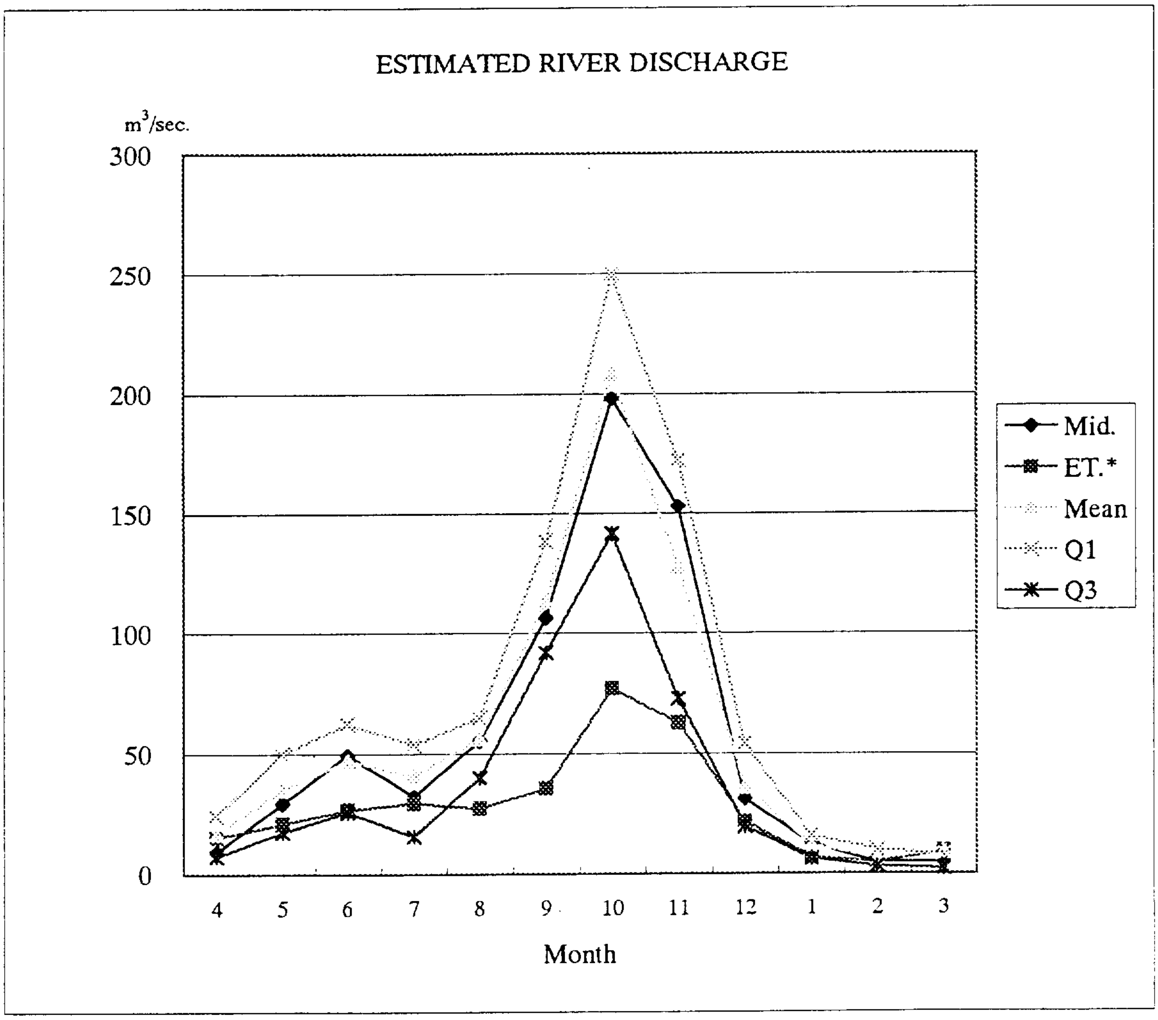
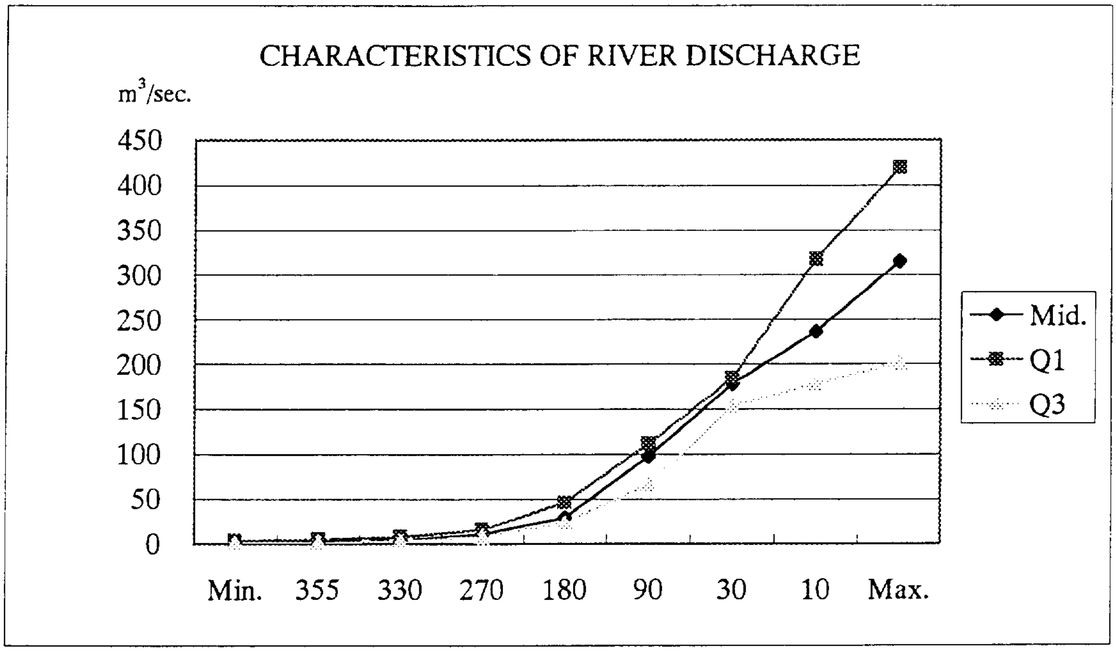


Table 5.7 (2/2) CHARACTERISTICS OF RIVER DISCHARGE

(m^3/sec.)

	Min.	355	330	270	180	90	30	10	Max.
Mid.	2.11	2.75	3.74	10.65	28.94	97.47	178.35	236.24	314.47
Q1	3.27	4.66	7.68	15.80	45.53	111.71	184.61	317.60	419.29
Q3	1.56	1.69	3.25	7.53	23.00	65.40	154.10	178.35	201.82



Note: Estimated river discharge is calculated based on the records at "Ngongon" Gauging Station in Njeke River.

ESTIMATED RIVER DISCHARGE

Table 5.8 (1/2)

River Name: Kim
Name of Observation Station: Kim Bridge, Ngambe-Tikar

(m^3/sec.)

Date	1998							
	July	August	September	October	November	December	January	February
01		95.2	118	161.0				
02		98	122.5	158.0				
03		95.2	136.5	155.0				
04		101.0	139.5	154.0				
05	70.6	104.5	147	156.0				
06	71.5	105.0	148	156.0				
07	70.6	104.0	143	149.0				
08	69.5	104.5	138.5	146.0				
09	69.7	105.5	133.5	144.5				
10	69.0	106.5	130.5	144.0				
11	68.5	107.5	131	147.0				
12	76.0	107.0	130	156.5				
13	76.5	105.0	129.5	157.0				
14	73.5	115.0	128.5					
15	72.0	115.0	127					
16	73.0	116.0	122					
17	83.0	117.5	127.5					
18	80.3	126.0	132.5					
19	80.5	120.0	135.5					
20	77.5	115.50	136					
21	73.0	116.0	144					
22	73.0	124.0	144.5					
23	76.0	126.5	135.5					
24	78.0	125.5	137.5					
25	81.0	120.0	136.5					
26	78.5	11.8	158					
27	75.0	117.0	161.5					
28	77.5	129.5	167					
29	76.0	124.5	162.5					
30	78.0	120.0	157.5					
31	92.0	117.5	–					
	2,038.4	3,502.4	4,161.00	1984.00				
Mean	75.5	112.98	138.7	152.62				

OBSERVATION RECORDS ON RIVER WATER LEVEL

Table 5.8 (2/2)

Recorder 0.00 = EL. 697.35 m
Reading: 9.00 AM

River Name: Kim
Name of Observation Station: Kim Bridge, Ngambe-Tikar

W.L.: (m)

Date	July		August		September		October	
	Reading	W.L.	Reading	W.L.	Reading	W.L.	Reading	W.L.
01			0.66	698.01	1.16	698.51	2.10	699.45
02			0.72	698.07	1.26	698.61	2.05	699.40
03			0.66	698.01	1.57	698.92	1.98	699.33
04			0.78	698.13	1.63	698.98	1.96	699.31
05	0.10	697.45	0.86	698.21	1.81	699.16	2.00	699.35
06	0.12	697.47	0.87	698.22	1.83	699.18	2.00	699.35
07	0.10	697.45	0.84	698.19	1.71	699.06	1.85	699.20
08	0.07	697.42	0.86	698.21	1.61	698.96	1.78	699.13
09	0.08	697.43	0.88	698.23	1.51	698.86	1.75	699.10
10	0.06	697.41	0.9	698.25	1.44	698.79	1.74	699.09
11	0.05	697.4	0.93	698.28	1.45	698.80	1.80	699.15
12	0.22	697.57	0.91	698.26	1.43	698.78	2.01	699.36
13	0.23	697.58	0.87	698.22	1.42	698.77	2.02	699.37
14	0.18	697.53	1.1	698.45	1.39	698.74		
15	0.13	697.48	1.1	698.45	1.36	698.71		
16	0.16	697.51	1.12	698.47	1.25	698.60		
17	0.37	697.72	1.15	698.50	1.37	698.72		
18	0.31	697.66	1.33	698.68	1.48	698.83		
19	0.32	697.67	1.2	698.55	1.55	698.90		
20	0.25	697.60	1.11	698.46	1.58	698.93		
21	0.17	697.52	1.12	698.47	1.74	699.09		
22	0.12	697.47	1.29	698.64	1.75	699.10		
23	0.22	697.57	1.35	698.70	1.57	698.92		
24	0.27	697.62	1.32	698.67	1.60	698.95		
25	0.32	697.67	1.24	698.59	1.90	699.25		
26	0.28	697.63	1.16	698.51	2.07	699.42		
27	0.2	697.55	1.14	698.49	2.11	699.46		
28	0.25	697.60	1.42	698.77	2.26	699.61		
29	0.22	697.57	1.3	698.65	2.16	699.51		
30	0.27	697.62	1.21	698.56	2.04	699.39		
31	0.57	697.92	1.15	698.50	—	—		

On comparing the two groups of runoffs calculated by catchment area ratios and runoffs calculated from results of investigations in the present survey, the values calculated from the data of Magba Gauging Station is the largest and those from data of Ngongon Gauging Station are the smallest. The values from measurements made during the present survey are in between the above two.

The correlations of these three groups of calculated values for the observation period during this present survey are as follows:

Data Used	Jul.	Aug.	Sept.	Oct.
Magba (A)	192.55	246.12	346.01	386.55
Ngongon (B)	40.52	56.17	113.27	208.08
Present Survey (C)	75.50	112.98	138.70	152.62
(C) / (A)	0.392	0.459	0.401	0.385
(B) / (C)	0.537	0.497	0.817	1.370

According to the abovementioned results, values calculated from observations in the present survey are from 38.5% to 45.9% of values calculated from runoff data of Magba Gauging Station and are more or less constant. On the other hand, the values of Ngongon Gauging Station are scattered from 49.7% to 137% and the data of Magba Gauging Station have better correlations with values calculated from observations in the present survey. Regarding runoff calculated from water levels measured in this survey, comparisons and evaluations cannot be made because the observation period was short, while the observation data of Magba and Ngongon Gauging Stations during the above period are presently being sorted and analyzed by the Hydrologic Research Center of Cameroon and are not available. Therefore, these observation results will be used only for confirmation of correlations with existing gauging station data to be adopted, and for the monthly average runoffs of this project site, runoffs calculated from data of Magba Gauging Station are to be adopted.

With regard to the probability flood at this project site, 898 m^3/sec is obtained converted by catchment area ratio from the 100 year return period flood of 620 m^3/sec calculated according to analysis by ORSTOM.

As for 1000 year return period flood, it is 1,050 m^3/sec. The figure for the 100 year return period flood may be judged to be reasonable from the results of investigating traces remaining from past floods at the project site.

5.3.3 Runoff Analyses of Ndokayo Site

Data of runoff gauging stations in three neighboring basins can be used in runoff analyses for this project site. Of these gauging stations, Betare Oya Gauging Station located at the upstreammost part of the Lom River has in its basin the Mari River on which a power station is planned, and data of this gauging station are to be used in runoff analyses for this site.

Monthly average runoffs and annual runoff characteristics from 1951 to 1981 are given in Table 5.9.

Runoffs at the project site calculated by catchment area ratio based on these data are given in Table 5.10.

The results of runoff observations made during the three field surveys carried out up till the present are as follows:

- 20 Mar. 1998 (First Field Survey) 2.0 m^3/sec
- 17 Nov. 1998 (Second Field Survey) 25.0 m^3/sec
- 11 Dec. 1998 (Third Field Survey) 18.8 m^3/sec

These values roughly coincide with the calculated values in the previously-mentioned Table 5.10 and, thus, these calculated values will be adopted as the runoffs at this project site.

Regarding the probability flood at this project site, 45 m^3/sec is obtained through conversion by catchment area ratio from the 100 year return period flood of 760 m^3/sec at Betare Oya Gauging Station calculated in analyses by ORSTOM. As for the 1000 year return period flood, it is approximately 54 m^3/sec.

5.3.4 Runoff Analyses of Olamze Site

Data from runoff gauging stations in two neighboring basins are available for use in runoff analyses for this project site.

Monthly average runoffs and annual runoff characteristics are given in Table 5.11 and table 5.12.

The results of calculating runoffs at the project site by catchment area ratio based on data of these two gauging stations are given in Table 5.13 and Table 5.14.

On the other hand, runoffs calculated from water level records obtained from June to September 1998 with an automatic water gauge installed at the project site in the present project survey are given in Table 5.15.

The results of runoff observations made in three field surveys carried out up till the present are as follows:

- 29 Jun. 1998 (Second Field Survey) 7.3 m^3/sec
- 13 Nov. 1998 (Third Field Survey) 34.0 m^3/sec
- 07 Dec. 1998 (Third Field Survey) 23.3 m^3/sec

Comparing the two groups of runoffs from catchment area ratios and measured values from the abovementioned field surveys, the following may be said:

(i) The monthly average runoffs of the project site calculated from data of the two gauging stations of Ngoazik and Assosseng are more or less in agreement, but there are some differences in the minor rainy season of July-August and in the low-water period. Judging from results of field surveys, it may be said that the values calculated from Ngoazik Gauging Station data in which droughty runoff comes out larger are in better agreement with the discharge duration at the site.

(ii) Looking at the measurements made during the field survey and values calculated from data of the two gauging stations, the trends are in rough agreement, but there are some differences in runoffs, and so judgments cannot be made based on measured values.

As a consequence of the above considerations, the values calculated from data of Ngoazik Gauging Station where droughty runoff is shown to be large are to be adopted.

Regarding the probability flood at this project site, 69 m^3/sec is obtained on conversion by catchment area ratio from the 100 year return period flood at Ngoazik Gauging Station of 1,480 m^3/sec as calculated in analyses by ORSTOM. As for 1000 year probability flood, it is approximately 80 m^3/sec.

Table 5.9 (1/2) Monthly Mean River Discharge

Gauging Station: Betare Oya, Lom River

C.A.= 11,100 km², (m³/sec.)

Year	A	M	J	J	A	S	O	N	D	J	F	M	Module
1951-52	36.4	62.7	70.6	137	329	471	398	294	142	94.5	86.6	41.5	180
52-53	48.1	104	110	162	327	444	448	264	146	95.9	74.2	64.0	191
53-54	45.7	80.2	90.9	215	176	365	450	241	135	91.6	71.0	61.1	169
54-55	72.5	80.5	202	214	187	426	576	324	171	112	76.2	70.1	210
55-56	71.3	84.0	133	277	347	450	522	290	160	109	81.0	89.0	218
56-57	93.3	84.2	134	205	194	314	482	231	148	97.8	65.1	46.9	175
57-58	60.9	78.3	120	196	189	354	369	260	152	97.3	64.4	47.9	166
58-59	55.5	68.9	208	218	284	320	409	279	158	107	70.0	49.1	186
59-60	62.5	81.1	167	181	223	378	414	234	114	80.0	59.9	44.4	170
60-61	62.4	76.7	84.5	207	248	465	460	221	135	85.2	51.3	25.8	177
61-62	47.5	57.9	95.8	220	163	415	405	180	108	76.2	51.1	55.7	157
62-63	61.4	57.8	94.8	169	227	440	373	240	138	89.2	69.7	55.0	168
63-64	68.7	78.0	78.1	132	326	352	434	205	118	83.7	55.7	41.0	165
64-65	65.0	97.2	90.6	233	234	317	350	228	127	87.2	60.9	42.9	162
65-66	32.0	49.9	72.2	176	368	311	323	154	92.5	60.8	33.8	17.3	142
66-67	48.2	84.5	157	195	342	429	374	260	127	84.5	57.1	32.7	183
67-68	29.4	51.4	82.2	167	353	454	479	253	120	80.3	51.3	45.8	181
68-69	56.3	70.0	130	239	352	389	375	254	135	91.1	61.1	111	189
69-70	62.7	127	162	342	503	607	410	315	164	104	81.3	63.2	245
70-71	79.9	93.7	153	276	321	440	441	186	119	85.2	55.6	74.7	195
71-72	90.1	66.1	94.9	218	253	369	354	147	94.7				
72-73				128	233	251	286	128	73.3	51.2	22.8	14.9	
73-74	33.5	85.6	81.5	151	277	323	305	147	89.6	52.0	25.2	16.5	133
74-75	41.0	55.5	126	164	322	418	417	205	108	67.0	43.2	30.9	167
75-76	45.4	56.1	168	221	243	334	457	192	115	70.6	53.9	35.6	166
76-77	41.8	71.1	139	158	243	311	445	312	140	86.9	53.4	22.6	169
77-78	26.6	64.7	170	189	204	454	376	152	73.5	46.2	24.4	14.3	150
78-79	72.3	98.4	148	300	338	386	328	190	104	63.2	36.0	30.0	175
79-80	51.7	79.7	113	278	372	493	441	260	123	76.7	44.7	22.7	197
80-81	72.5	112	216	242	278	470	559	251	121				
Mean51-70	56.8	77.6	120	204	283	405	424	249	136	90.9	64.3	52.9	181
MID.	56.3	78.3	126.0	205	278	389	410	237	125	85.2	56.4	43.6	
ET.	17.4	18.4	42.0	52.3	77.1	73.9	69.5	53.6	25.3	17.4	17.3	23.2	
MEAN	56.4	77.8	127	207	282	398	416	230	125	83.1	56.5	45.2	175
Q_1	70.0	85.0	159.5	236	340	447	449	260	142	95.2	69.8	58.4	
Q_3	43.6	63.7	90.7	165	225	328	371	190	108	73.4	47.9	27.9	

Table 5.9 (2/2) Caracteristics of River Discharge Duration

Gauging Station: Betare Oya, Lom River

(m³/sec.)

Year	Minimum		Characteristics							Maximum	
	Date	Discha.	355	330	270	180	90	30	10	Discha.	Date
1951-52	05/04	31.7	37.0	42.1	83.7	117	286	421	536	681	24/09
52-53	17/04	33.4	41.2	50.6	72.2	128	265	487	535	559	05/10
53-54	09/03	46.3	49.7	55.7	75.8	117	255	428	492	541	18/10
54-55	02/05	48.0	60.9	64.4	84.6	166	264	509	620	690	13/10
55-56	12/05	55.7	59.2	73.1	92.6	145	335	508	561	672	12/10
56-57	30/03	37.0	43.8	53.2	69.6	141	225	357	545	656	08/10
57-58	23/03	≤38.7	47.2	51.7	63.7	133	222	372	385	421	07/09
58-59	12/03	43.8	46.3	53.2	74.9	160	281	390	423	470	10/10
59-60	23/03	34.3	40.4	48.9	69.6	136	224	390	505	526	30/09
60-61	25/03	20.3	22.4	32.1	54.5	120	-	-	-	-	-
61-62	25/05	38.3	42.1	50.2	60.1	101	208	422	502	576	22/09
62-63	23/03	43.8	47.2	57.5	71.4	115	239	400	512	572	29/09
63-64	09/03	28.4	34.3	46.3	74.0	101	247	437	465	525	11/10
64-65	09/04	23.8	26.8	87.0	53.2	117	239	354	393	467	22/09
65-66	27/03	12.8	15.7	21.7	51.4	83.7	257	366	395	404	24/10
66-67	24/03	23.4	25.7	29.2	56.6	135	282	430	503	554	31/09
67-68	13/04	25.3	31.7	42.1	62.7	98.9	300	471	520	549	14/10
68-69	29/04	52.7	55.7	60.1	86.4	134	305	398	450	484	31/10
69-70	04/04	45.9	57.5	63.1	98.1	173	385	604	630	690	07/09
70-71	06/06	26.0	42.1	51.4	71.8	116	314	452	492	577	29/09
71-72		-	-	-	-	106	242	353	454	485	07/10
72-73	14/03	10.9	12.0	19.4	56.2	100	173	287	331	401	18/08
73-74	25/03	11.6	15.2	19.7	44.2	96.7	213	319	375	462	03/10
74-75	08/03	21.7	23.1	30.4	51.4	122	270	406	490	634	03/10
75-76	01/04	22.7	25.3	33.4	57.5	134	241	386	494	517	17/10
76-77	22/03	14.9	19.4	26.3	56.6	133	278	-	-	-	
77-78	03/03	11.6	12.5	17.2	35.2	84.1	239	432	504	513	21/09
78-79	02/03	19.0	25.3	31.7	56.2	107	304	377	421	468	28/08
79-80	17/03	15.2	19.0	26.8	61.8	117	309	480	514	572	01/10
MID.		27.2	35.6	47.6	63.2	117	260	406	494	541	
Q1		38.3	45.5	54.0	79.3	136	300	452	520	577	
Q3		17.8	22.4	32.1	56.6	99.0	239	370	421	468	

Table 5.10 (1/2) ESTIMATED RIVER DISCHARGE

Site: NDOKAYO
River: Mari, LOM
Catchment Area 640 km^2

(m^3/sec.)

	4	5	6	7	8	9	10	11	12	1	2	3	Module
Mid.	3.25	4.51	7.26	11.82	16.03	22.43	23.64	13.66	7.21	4.91	3.25	2.51	10.04
ET.*	1.00	1.06	2.42	3.02	4.45	4.26	4.01	3.09	1.46	1.00	1.00	1.34	2.34
Mean	3.25	4.49	7.32	11.94	16.26	22.95	23.99	13.26	7.21	4.79	3.26	2.61	10.11
Q1	4.04	4.90	9.20	13.61	19.60	25.77	25.89	14.99	8.19	5.49	4.02	3.37	11.59
Q3	2.51	3.67	5.23	9.51	12.97	18.91	21.39	10.95	6.23	4.23	2.76	1.61	8.33

ET.: Ecart Type

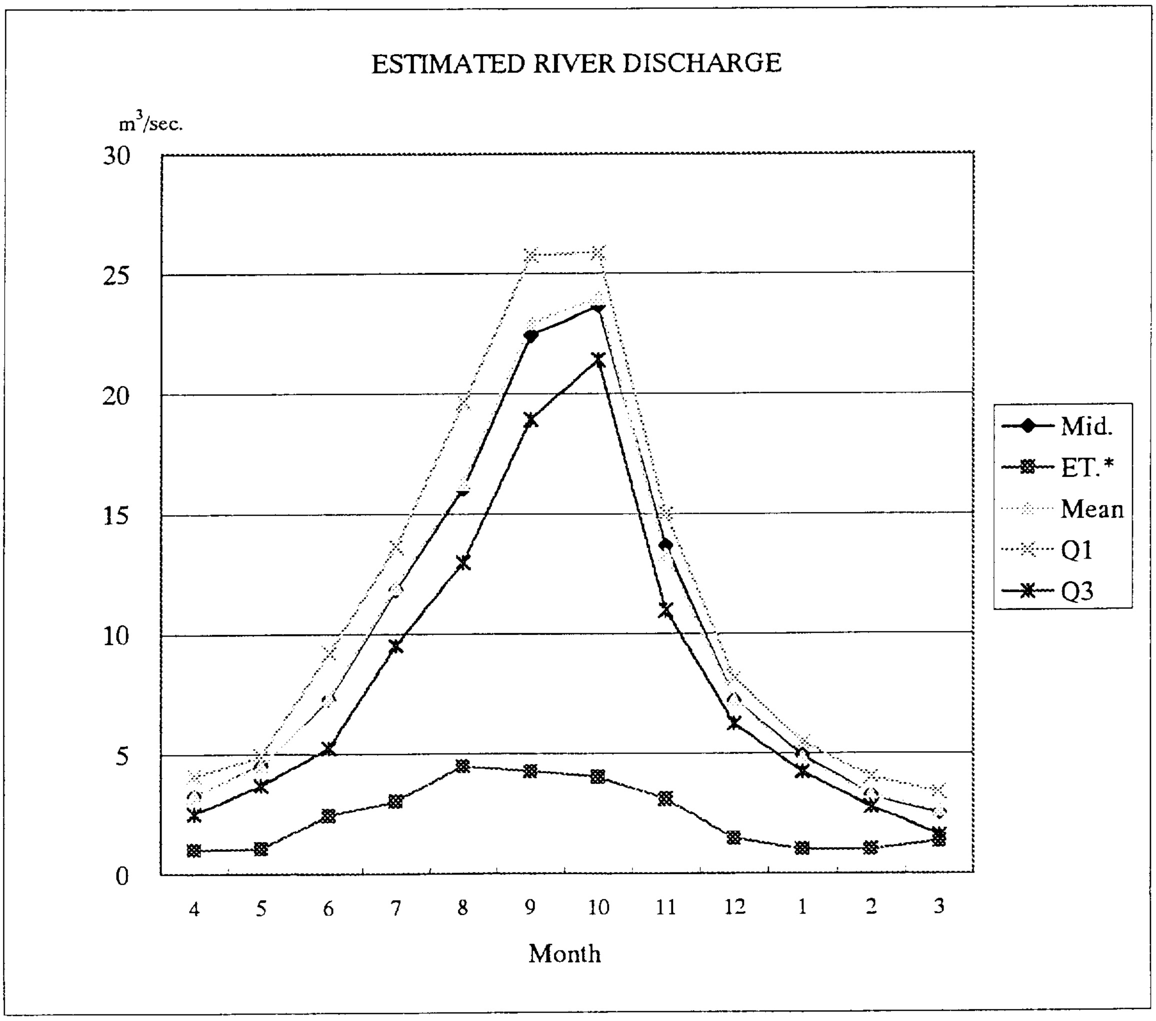
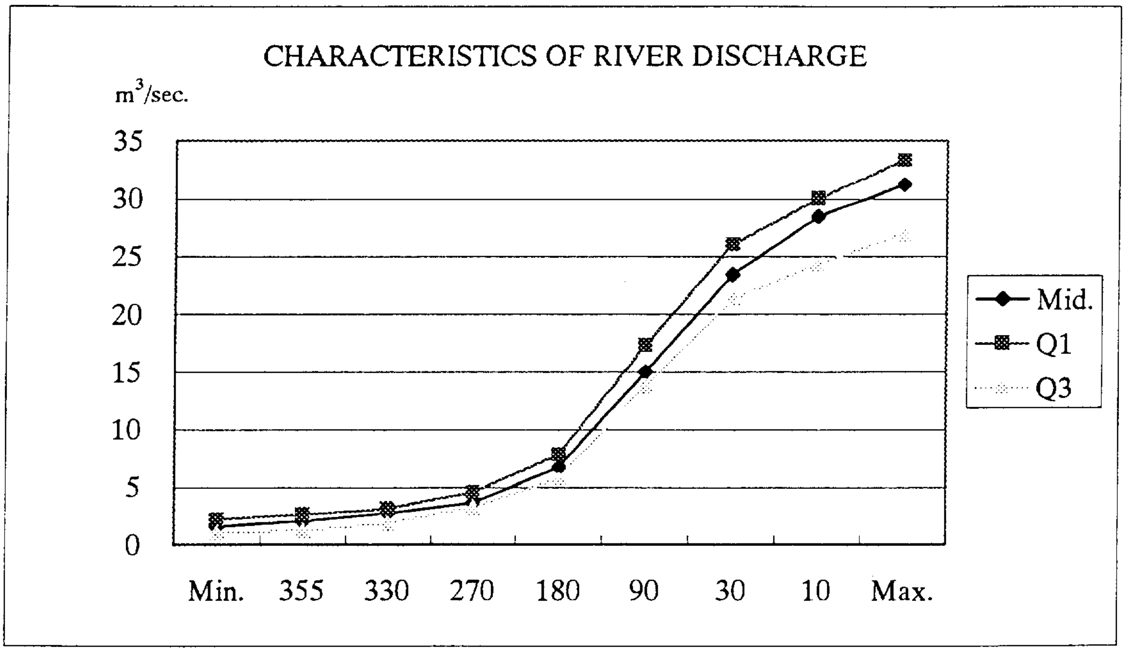


Table 5.10 (2/2) CHARACTERISTICS OF RIVER DISCHARGE

(m^3/sec.)

	Min.	355	330	270	180	90	30	10	Max.
Mid.	1.57	2.05	2.74	3.64	6.75	14.99	23.41	28.48	31.19
Q1	2.21	2.62	3.11	4.57	7.84	17.30	26.06	29.98	33.27
Q3	1.03	1.29	1.85	3.26	5.71	13.78	21.33	24.27	26.98



Note: Estimated river discharge is calculated based on the records at "Betare-Oya" Gauging Station in Lom River.

Table 5.11 (1/2) Monthly Mean River Discharge

Gauging Station: Assosseng, Seng River, C.A.= 440 km^2

(m^3/sec.)

Year	A	M	J	J	A	S	O	N	D	J	F	M	Module
1955-56	2.83	4.75	8.27	3.49	2.40	6.21	20.7	19.2	5.60	1.91	3.15	8.80	7.40
56-57	12.9	13.7	10.30	8.04	2.00	6.68	24.7	20.6	8.47	1.14	3.65	4.00	9.68
57-58	8.77	8.72	10.94	8.39	3.36	6.81	17.0	19.6	8.63	2.36	1.64	2.21	8.29
58-59	6.07	9.41	2.25	-	-	-	12.0	10.4	6.91	2.57	1.21	1.18	
59-60	4.79	9.43	5.09	2.41	2.91	11.1	19.8	17.2	6.25	1.93	1.60	6.75	7.44
60-61	9.47	9.61	8.32	2.78	1.57	7.97	20.5	21.3	11.2	9.38	3.43	2.79	9.04
61-62	6.71	6.82	6.39	2.23	0.54	7.46	16.7	20.5	6.79	1.72	1.33	7.86	7.09
62-63	13.7	10.9	9.94	5.49	2.43	6.72	9.15	13.0	6.13	2.19	2.19	5.40	7.27
63-64	6.27	6.36	11.62	13.20	3.67	6.04	11.6	11.6	4.5	1.90	1.34	2.99	6.81
64-65	9.59	9.90	8.22	2.53	7.01	3.03	17.2	16.7	5.7	2.56	3.28	7.25	6.02
65-66	6.28	13.2	13.9	5.01	5.43	8.85	17.6	10.0	3.21	1.31	1.20	1.64	7.33
66-67	7.63	13.9	18.6	11.07	5.03	7.80	17.4	25.7	8.89	4.49	1.91	2.01	10.4
67-68	3.50	12.3	16.5	4.98	2.12	21.2	20.5	15.5	8.68	3.02	2.18	3.13	8.48
68-69	5.73	8.42	9.41	-	1.24	6.30	12.4	-	8.59	2.91	1.94	11.49	-
69-70	8.38	9.66	8.23	6.55	6.10	19.6	15.7	20.6	5.35	2.42	2.89	10.41	9.66
70-71	13.1	13.28	11.6	4.94	6.98	12.7	22.0	21.2	6.26	2.67	1.60	3.30	9.84
71-72	3.28	3.44	5.21	3.62	1.31	7.38	27.1	12.0	5.07	1.16	0.68	5.61	6.32
72-73	4.80	6.57	7.05	1.40	1.19	9.12	22.4	17.9	4.37	2.00	0.61	3.23	6.74
73-74	5.68	8.78	14.0	6.09	4.33	6.35	11.7	4.94	1.82	1.02	1.31	2.17	5.69
74-75	4.66	8.43	4.86	0.66	1.79	9.60	14.0	15.8	3.38	0.81	2.34	1.90	5.72
75-76	7.41	5.60	7.18	8.39	0.73	3.40	15.4	25.5	6.36	2.10	2.10	3.64	7.00
76-77	7.80	6.00	10.0	4.00	0.80	2.30	16.2	22.8	11.40	8.45	1.60	1.50	7.74
MID.	6.27	9.09	8.86	4.99	2.43	7.46	17.3	17.9	6.26	2.14	1.77	3.26	7.37
ET.	8.14	2.98	3.92	8.40	2.27	5.45	3.12	4.63	2.40	2.16	0.86	3.02	1.41
MEAN	7.02	9.05	9.45	7.06	3.35	9.39	17.35	17.24	6.44	2.73	1.96	4.51	7.70
Q1	8.38	10.9	11.6	8.22	5.23	10.3	20.7	20.9	8.47	2.67	2.34	6.75	8.76
Q3	4.79	6.57	7.05	2.65	1.44	6.32	14.00	12.50	5.07	1.72	1.33	2.17	6.77

Table 5.11 (2/2) Characteristics of River Discharge Duration

Gauging Station: Assosseng, Seng River, (m^3/sec.)

Year	Minimum		Characteristics							Maximum	
	Date	Discha.	355	330	270	180	90	30	10	Discha.	Date
1955-56	01/2	0.73	0.92	0.98	3.56	6.20	8.18	20	29.7	30.9	08/11
56-57	12/3	0.92	0.92	1.04	2.40	7.64	14.60	23.0	31.4	32.1	22/10
57-58	01/3	0.92	0.92	1.08	2.64	4.05	12.90	20.0	22.1	30.5	07/11
58-59	11/3	0.35	0.57	0.75	0.92	2.40	6.02	12.3	19.4	28.0	21/11
59-60	03/3	0.57	0.73	0.90	2.46	4.26	15.50	19.0	22.6	29.7	06/09
60-61	24/8	0.90	1.10	1.39	2.88	5.21	13.20	21.9	29.5	30.9	05/11
61-62	31/8	0.14	0.42	0.73	1.95	4.05	10.35	20.6	25.1	30.9	
62-63	14/2	0.64	1.21	1.59	2.70	5.75	10.62	15.3	18.8	24.4	22/04
63-64	18/2	0.75	0.87	1.10	2.82	5.03	8.90	16.4	20.6	30.9	02/07
64-65	27/8	0.50	0.59	1.04	3.21	5.48	10.44	17.5	25.3	43.2	04/11
65-66	04/3	0.48	0.67	0.87	2.58	4.40	10.71	17.6	24.7	29.7	31/05
66-67	08/3	0.64	0.84	1.59	3.91	7.64	14.30	26.1	29.4	36.9	29/10
67-68	04/2	0.75	0.90	1.27	2.70	4.67	13.00	21.8	26.2	37.9	02/11
68-69	27/8	0.57	0.78	1.38							
69-70	16/2	0.59	1.15	2.13	3.56	7.64	13.60	22.2	27.8	33.4	06/11
70-71	12/3	0.75	1.10	1.95	3.49	7.82	15.20	21.6	28.9	35.7	04/11
71-72	16/2	0.38	0.53	0.90	1.38	3.33	7.37	23.1	28.4	31.9	06/10
72-73	07/2	0.38	0.55	0.70	1.27	3.84	7.91	22.0	26.6	29.5	07/11
73-74	09/1	0.29	0.48	0.73	1.95	3.84	7.46	15.0	18.0	24.4	19/06
74-75	12/8	0.10	0.38	0.50	1.10	3.42	7.55	16.1	21.0	25.6	10/10
75-76	17/9	0.23	0.35	0.57	1.95	4.58	10.08	18.6	28.5	35.1	15/11
76-77	10/3	0.40	0.55	0.78	1.86	5.21	11.25	17.7	28.6	31.5	18/11
MID.		0.57	0.75	1.01	2.58	4.67	10.6	20.0	26.2	30.9	
ET.		0.24	0.26	0.43	0.85	1.56	2.89	3.33	4.07	4.5	
Q1		0.75	0.92	1.35	3.05	5.97	13.4	12.9	28.7	33.4	
Q3		0.38	0.55	0.75	1.90	3.94	8.05	16.9	21.5	29.6	

Table 5.12 (1/2) Monthly Mean River Discharge

Gauging Station: Ngoazik, Ntem River, C.A.= 18,100 km^2

(m^3/sec.)

Year	A	M	J	J	A	S	O	N	D	J	F	M	Module
1953-54				95.1	40.2	139	321	523	152	61.2	122	141	-
54-55	190	294	256	121	31.7	133	442	505	209	77.5	66.3	173	208
55-56	359	264	287	131	76.0	248	342	521	218	177	72.6	250	245
56-57	402	506	481	181	71.1	178	577	670	424	207	97.3	111	325
57-58	213	315	347	197	77.0	188	709	584	419	134	82.6	67.3	278
58-59	129	241	146	31.9	15.9	59.2	409	347	197	87.7	85.2	56.8	151
59-60	120	345	209.	99.8	67.0	294	737	687	471	304	213	127	306
60-61	266	311	350	170	138	479	664	826	382	207	218	144	346
61-62	255	163	214	100	102	127	430	529	253	72.3	65.1	196	209
62-63	519	520	384	165	80.7	168	563	523	418	152	137	432	338
63-64	270	418	254	323	169	419	738	503	294	159	112	161	318
64-65	415	439	270	143	74.2	175	594	790	792	199	163	279	324
65-66	363	335	340	165	123	281	704	639	302	124	116	125	301
66-67	420	624	717	534	247	360	564	674	363	137	108	90.1	405
67-68	122	173	407	186	72.0	219	784	729	377	155	146	186	305
68-69	273	579	419	157	88.0	254	533	546	640	108	180	410	355
69-70	514	336	275	157	121	301	654	581	280	106	85.0	176	307
.70-71	195	233	440	199	117	264	659	957	262	132	67.0	105	303
71-72	232	168	131	890	80.9	225	558	556	242	71.4	71.3	108	211
72-73	290	230	206	88.3	76.8	205	597	639	202	143	97.7	115	241
73-74	204	292	384.	148	111	182	411	412	177	79.4	84.3	114	217
74-75	188	434	303	111	125	228	506	572	268	84.2	115	115	254
75-76	334	259	172	156	54.0	84.2	430	646	385	120	115	136	241
76-77	260	278	355	173	79.7	135	583	583	336	233	112	84.1	268
MID.	260	311	287	156	78.3	212	570	583	298	135	109	131	288.5
ET.	109.	125	135	96.4	48.0	101	130	133	112	59.9	43.5	95.2	62.1
MEAN	267	342	307	163	92.4	224	563	610	318	142	114	163	276
Q1	359	434	384	177	119	272	661	677	383	187	129	181	321
Q3	190	259	209	105	69.5	153	436	523	230	35.9	83.4	109	229

Table 5.12 (2/2) Characteristics of River Discharge Duration

Gauging Station: Ngoazik, Ntem River, (m^3/sec.)

Year	Minimum		Characteristics							Maximum	
	Date	Discha.	355	330	270	180	90	30	10	Discha.	Date
1953-54	27/8	29.5	33.1	42.8	-	-	-	478	523	616	19/11
54-55	27/8	23.0	24.0	47.6	74.0	163	299	455	560	665	05/11
55-56	03/9	50.0	61.2	70.2	115	242	325	448	597	635	11/11
56-57	28/2	51.6	57.6	69.3	118	299	496	642	695	729	13/11
57-58	02/3	47.6	58	63	96.3	208	414	624	784	877	17/10
58-59	12/9	14.4	14.8	15.6	45.5	102	205	368	523	627	22/10
59-60	13/8	33.1	40.4	88.5	111	173	382	769	861	896	01/12
60-61	14/7	82.0	108	121	171	273	463	784	920	978	14/11
61-62	27/8	33.1	35.2	50	78	171	292	534	612	646	10/11
62-63	24/8	55.8	68.4	100	141	251	496	612	650	672	14/10
63-64	11/2	108	111	114	152	283	410	654	758	830	18/10
64-65	31/8	48.8	65.7	107	150	261	410	605	939	1034	06/11
65-66	03/9	78.0	85.9	95	128	236	421	683	758	799	11/10
66-67	28/3	65.7	98.9	163	429	616	725	766	834	882	25/06
67-68	24/8	55.8	62.1	76	128	196	429	773	908	1006	31/10
68-69	27/8	48.4	63	85.9	152	396	545	665	695	717	14/05
69-70	17/2	53.2	66.6	91.1	130	219	429	717	747	815	06/11
70-71	10/2	49.2	58.7	78	114	139	371	799	1074	1318	11/11
71-72	21/2	35.2	48.4	58.5	72	145	248	597	740	807	28/10
72-73	21/8	50.0	63	72	104	161	305	654	758	799	24/10
73-74	27/1	63.0	67.5	74	97.6	176	302	425	538	593	05/11
74-75	22/1	64.8	70.2	78	105	183	398	560	654	702	06/11
75-76	03/9	26.0	28.5	46	112	181	299	597	695	710	20/11
76-77	16/8	55.8	57.6	72	105	242	389	597	657	710	24/11
MID.		50.0	61.6	75.0	114	208	389	618	717	764	
ET.		20.5	23.4	24.8	31.2	76.1	97.3	119	141	167	
Q1		59.4	67.9	93.0	141	261	429	700	775	855	
Q3		34.1	44.4	60.7	97.6	173	302	547	631	668	

Table 5.13 (1/2) ESTIMATED RIVER DISCHARGE

Site: OLAMZE
River: Woro, UTEM
Catchment Area 840 km²

(m³/sec.) (m³/sec.)

	4	5	6	7	8	9	10	11	12	1	2	3	Module
Mid.	12.07	14.43	13.32	7.24	3.63	9.84	26.45	27.06	13.83	6.27	5.06	6.08	13.38
ET.*	5.06	5.80	6.27	4.47	2.23	4.69	6.03	6.17	5.20	2.78	2.02	4.42	2.88
Mean	12.39	15.87	14.25	7.56	4.29	10.40	26.13	28.31	14.76	6.59	5.29	7.56	12.81
Q1	16.66	20.14	17.82	8.21	5.52	12.62	30.68	31.42	17.96	8.68	5.99	8.40	14.90
Q3	8.82	12.02	9.70	4.87	3.23	7.10	20.23	24.27	10.67	1.67	3.87	5.06	10.63

ET.: Ecart Type

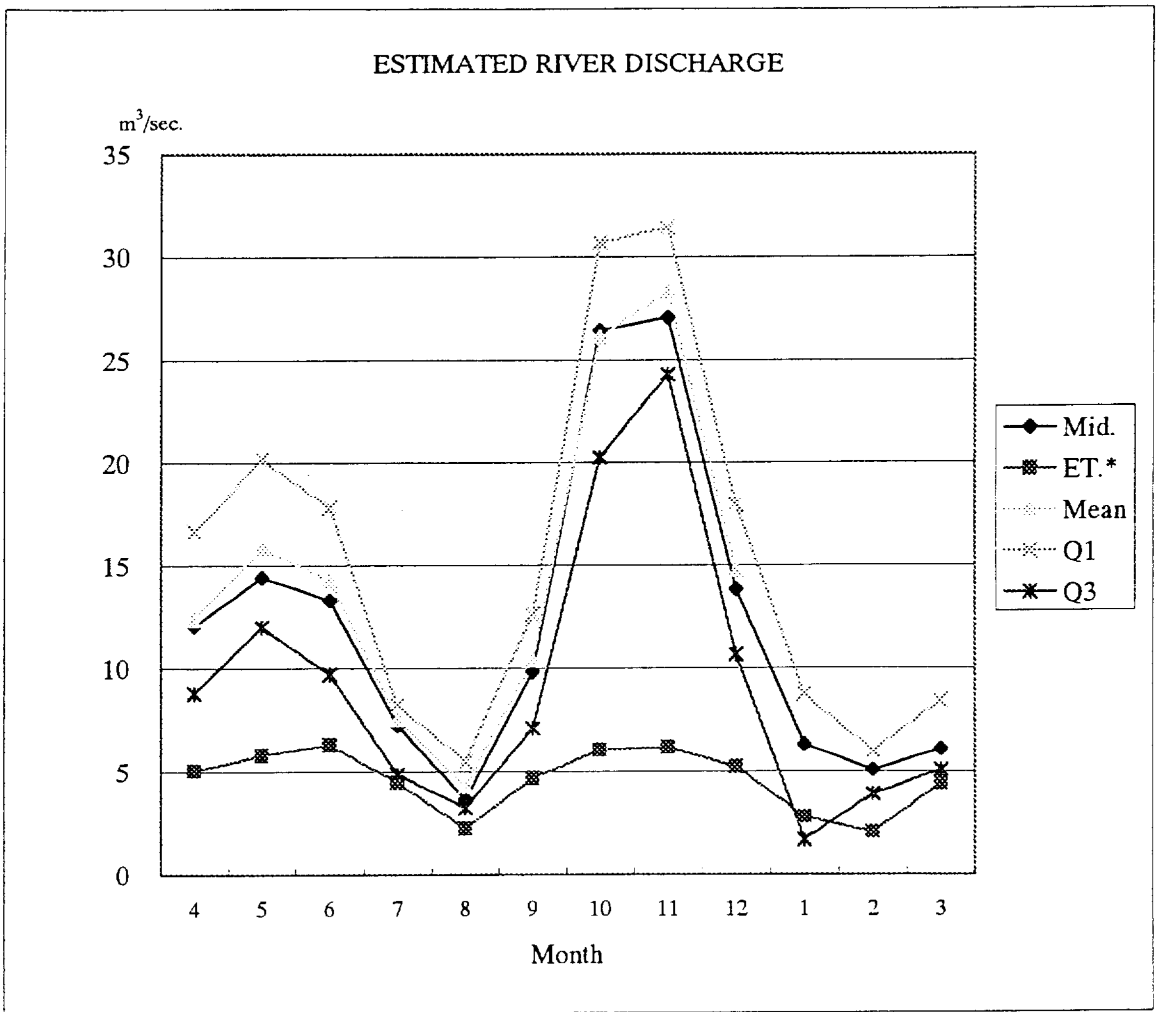
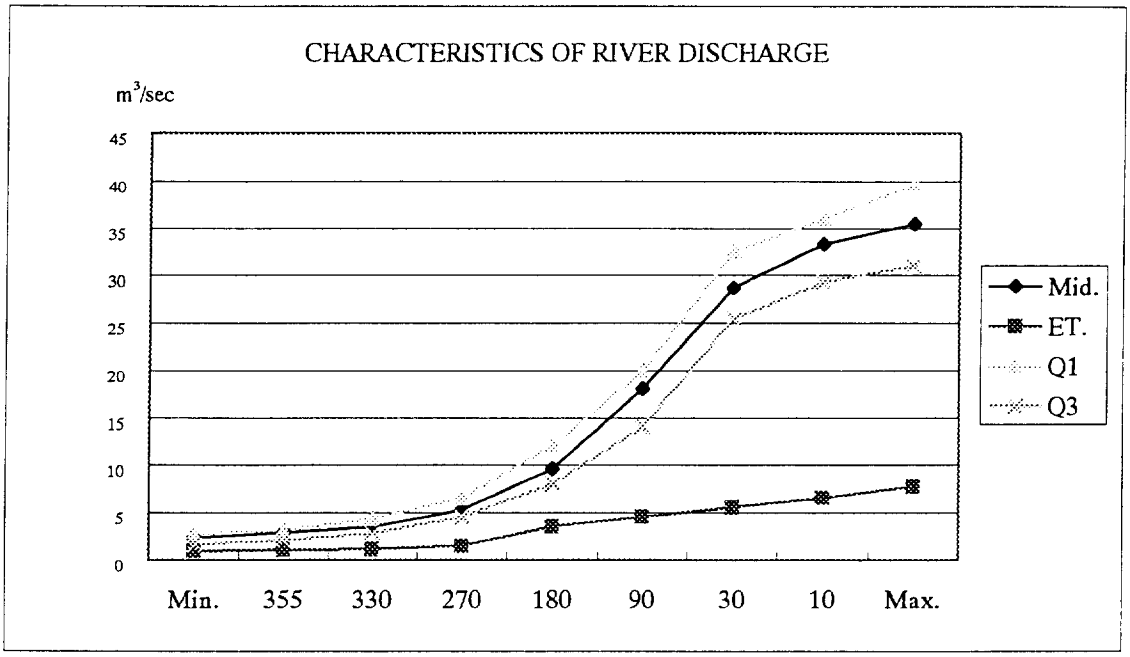


Table 5.13 (2/2) CHARACTERISTICS OF RIVER DISCHARGE

(m^3/sec.)

	Min.	355	330	270	180	90	30	10	Max.
Mid.	2.32	2.86	3.48	5.29	9.65	18.05	28.68	33.28	35.46
ET.	0.95	1.09	1.15	1.45	3.53	4.52	5.52	6.54	7.75
Q1	2.76	3.15	4.32	6.54	12.11	19.91	32.49	35.97	39.68
Q3	1.58	2.06	2.82	4.53	8.03	14.02	25.38	29.28	31.00



Note: Estimated river discharge is calculated based on the records at "Ngoagik" Gauging Station in Ntem River.

Table 5.14 (1/2) ESTIMATED RIVER DISCHARGE

Site: OLAMZE
River: Woro, UTEM
Catchment Area 840 km²

(m^3/sec.)

	4	5	6	7	8	9	10	11	12	1	2	3	Module
Mid.	11.97	17.35	16.91	9.53	4.64	14.24	33.03	34.17	11.95	4.09	3.38	6.22	14.07
ET.*	15.54	5.69	7.48	6.49	4.33	10.40	5.96	8.84	4.58	4.12	1.64	5.77	2.69
Mean	13.40	17.28	18.04	16.04	6.40	17.93	33.12	32.91	12.29	5.21	3.74	8.61	14.70
Q1	16.00	20.81	22.15	15.69	9.98	19.66	39.52	39.90	16.17	5.50	4.47	12.89	16.72
Q3	9.14	12.54	13.46	5.06	2.75	12.07	26.73	23.86	9.68	3.28	2.54	4.14	12.92

ET.: Ecart Type

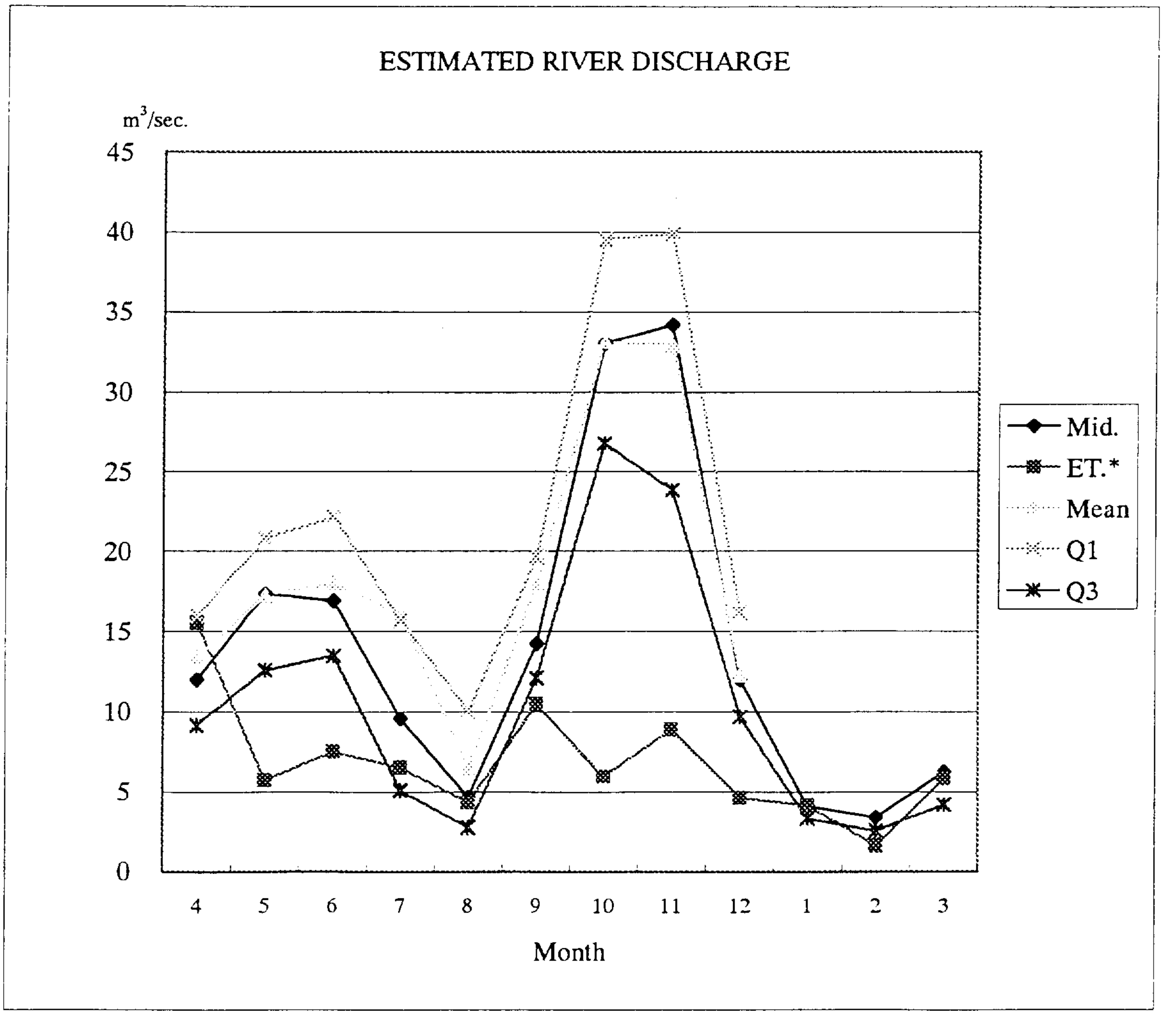
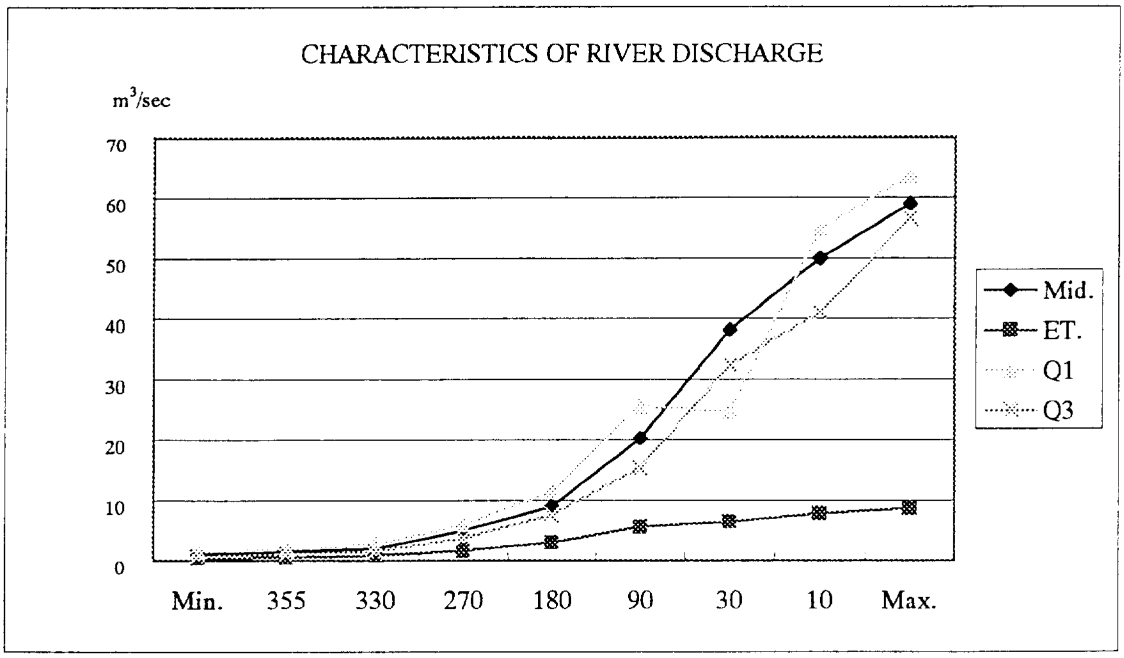


Table 5.14 (2/2) CHARACTERISTICS OF RIVER DISCHARGE

(m^3/sec.)

	Min.	355	330	270	180	90	30	10	Max.
Mid.	1.09	1.43	1.93	4.93	8.92	20.24	38.18	50.02	58.99
ET.	0.46	0.50	0.82	1.62	2.98	5.52	6.36	7.77	8.59
Q1	1.43	1.76	2.58	5.82	11.40	25.58	24.63	54.79	63.76
Q3	0.73	1.05	1.43	3.63	7.52	15.37	32.26	41.05	56.51



Note: Estimated river discharge is calculated based on the records at "Assosseng" Gauging Station in Seng River.

ESTIMATED RIVER DISCHARGE

Table 5.15 (1/2)

River Name: Woro
Name of Observation Station: Woro Bridge, Olamze

(m³/sec.)

Date	1998							
	June	July	August	September	October	November	Desember	
01		13.5	3.3	5.4				
02		11.6	3.6	11.9				
03		12.6	3.3	16.1				
04		10.0	4.1	15.5				
05		9	5.4	11.5				
06		11.7	5.4	9.0				
07		11.9	5	8.2				
08		15.7	11.6	7.5				
09		19.2	13.1	9.0				
10		19.4	10	9.6				
11		16.9	7.2	9.0				
12		14.7	5.5	6.2				
13		16.3	4.3	5.4				
14		21.2	5	6.2				
15		20.9	8.2	8.4				
16		15.5	10.3	13.70				
17		11.2	9.6	17.10				
18		9.0	8.4	20.00				
19		8.2	7.3	19.20				
20		8.4	7	15.50				
21		7.3	6.2	13.10				
22		6.20	7	13.50				
23		5.4	8.6	14.50				
24		5.0	8.6	12.30				
25		4.1	8.2	15.50				
26		3.3	5.6	17.10				
27		3.1	5	17.10				
28	7.3	2.4	4.4	17.10				
29	7.8	2.1	3.1	20.90				
30	10.8	2.4	2.9	19.80				
31	-	3.3	2.5	-				
	25.9	321.5	199.70	385.30				
Mean	8.63	10.37	6.44	12.84				

OBSERVATION RECORDS ON RIVER WATER LEVEL

Table 5.15 (2/2)

Recorder 0.00 = EL. 145.78 m
Reading: 9.00 AM

River Name: Woro
Name of Observation Station: Woro Bridge, Olamze

W.L.: (m)

Date	June		July		August		September	
	Reading	W.L.	Reading	W.L.	Reading	W.L.	Reading	W.L.
01			0.72	146.50	0.22	146.00	0.32	146.10
02			0.63	146.41	0.23	146.01	0.64	146.42
03			0.68	146.46	0.22	146.00	0.85	146.63
04			0.55	146.33	0.26	146.04	0.82	146.60
05			0.50	146.28	0.32	146.10	0.62	146.40
06			0.63	146.41	0.32	146.10	0.50	146.28
07			0.64	146.42	0.30	146.08	0.46	146.24
08			0.83	146.61	0.63	146.41	0.43	146.21
09			1.00	146.78	0.70	146.48	0.50	146.28
10			1.01	146.79	0.55	146.33	0.53	146.31
11			0.89	146.67	0.41	146.19	0.50	146.28
12			0.78	145.56	0.33	146.11	0.36	146.14
13			0.86	146.64	0.27	146.05	0.32	146.10
14			1.09	146.87	0.30	146.08	0.36	146.14
15			1.08	146.86	0.46	146.24	0.47	146.25
16			0.82	146.60	0.56	146.34	0.73	146.51
17			0.61	146.39	0.53	146.31	0.90	146.68
18			0.50	146.28	0.47	146.25	1.02	146.80
19			0.46	146.24	0.42	146.20	1.00	146.78
20			0.47	146.25	0.40	146.18	0.82	146.60
21			0.41	146.19	0.38	146.16	0.70	146.48
22			0.38	146.16	0.40	146.18	0.72	146.50
23			0.32	146.10	0.48	146.26	0.77	146.55
24			0.30	146.08	0.48	146.26	0.66	146.40
25			0.26	146.04	0.46	146.24	0.82	146.60
26			0.22	146.00	0.33	146.11	0.90	146.68
27			0.21	145.99	0.30	146.08	0.90	146.68
28	0.42	146.20	0.18	145.96	0.27	146.05	0.90	146.68
29	0.44	146.22	0.16	145.94	0.21	145.99	1.07	146.85
30	0.59	146.37	0.18	145.96	0.20	145.98	1.03	146.81
31	-	-	0.22	146.00	0.18	145.96	-	-

CHAPTER 6. POWER DEMAND FORECAST AND SUPPLY PLAN

Chapter 6 Power Demand Forecast and Supply Plan

6.1 Power Demand Forecast

6.1.1 Methodology

The objective of the study is to optimise and to find the best use of the potential energy of the 3 hydroelectric sites of Ngambe-Tikar, Ndokayo, Olamze to cover the close vicinity and the power requirements of the rural population for the years 2005-2010.

The main locations to be supplied from these three MV isolated systems (30 kV) are primarily non-electrified centres and partially electrified larger centres such as Betare Oya, Ambam and Garoua Boulai, or under electrification such as Olamze.

Power demand is characterised by 3 types of use:

- domestic uses (dwelling areas),
- industrial uses (commercial or craft areas),
- administrative uses or public lightning uses.

The consumption in rural areas will primarily depend on the importance and distribution of day time industrial uses.

In Cameroon, the principles of estimation of LV power demand in rural areas and peak load demand have been, for each type of use, as follows:

<u>Domestic Uses</u>

The total power demand for a given year in kW is as follows, considering that the consumption occurs mostly between 6 and 10 p.m.:

$$\text{Capacity (in kW)} = \frac{P \times D}{T} \times \frac{Cs}{N}$$

with P = estimated population at a given date

D = distribution rate

T = number of people per household

Cs = specific consumption per household and per year in kWh (600 to 1200 kWh)

N = number of equivalent operating hours per year during the peak period (1500 to 2000 hours) with a $\frac{Cs}{N}$ ratio comprises between 250 W and 500 W.

For the study, a population growth rate of 3% per year from 1998 to 2010, 5.3 people per household and a supply rate in rural areas of 50%, with 75% for the town of Garoua Boulai were used.

SONEL considers that the maximum capacity to be taken into account for rural electrification studies is approximately 500 W per electrified household in the year 2010. This value corresponds to the power required to meet peak demand from approximately 6 to 11 p.m., including technical and non technical losses.

Industrial Uses

Industrial or craft uses from 7.30 a.m. to 6 p.m. are estimated on a case by case basis depending on the possible kinds of industry (wood industry, trade, etc.).

Administrative Uses or Public Lightning Uses

This consumption was considered relatively low and already included in the domestic consumption data.

6.1.2 Forecast And Results

The maximum power demand was estimated on a domestic consumption basis, which peaks between 6 and 11 p.m.

The daily load curve in rural areas (excluding industry) for administrative centres is given by SONEL in the table below:

Daily load curve in rural areas excluding industry for 1 kW

hours	1	2	3	4	5	6	7	8	9	10	11	12
P/Pp*	0.400	0.325	0.300	0.285	0.250	0.225	0.200	0.185	0.175	0.175	0.175	0.175
hours	13	14	15	16	17	18	19	20	21	22	23	24
P/Pp*	0.175	0.175	0.175	0.175	0.420	1.0	1.0	1.0	1.0	0.850	0.750	0.70

* : Load (P) in Peak load (Pp)

As shown in the table above, the 0.43 kW average power demand for domestic uses corresponds to a daily consumption of 10.3 kWh for a peak load of 1 kW.

The average annual consumption per household in 2010 would be approximately 1150 kWh [500 W x 0.80 (losses) x 0.4 (load factor) x 7000 h] for 1100 kWh consumed in 1998. The average domestic consumption, is forecasted in Cameroon, is 5% average growth and 7% in rural areas.

For industrial areas, we integrated the various existing consumption potentials (for example, the SF HAZIM in Ngambe-Tikar) or the industrial or commercial development in some large centres such as Garoua Boulai (principal road junction to the Central African Republic) whose consumption between 7 a.m. and 6 p.m. should increase strongly after electrification.

The estimated number of households in 2010 and the power demand (excluding industrial needs) for the 3 sites are given in Appendix 1. This data determines the maximum capacities to be installed 30 kV networks. Each one is made up of:

- a principal network to supply approximately 75% of the electrical requirements,
- a possible extension whose construction is not planned within the frame of this project.

The lengths of the associated lines are given in Appendix 2.

The estimations for the year 2010 based on SONEL hypotheses are summarised in the table below:

Areas to be supplied by the sites of:	Population in 1998	Population in 2010	Number of households in 2010	Households electrified in 2010	Maximum power demand (in kW)
Ngambe-Tikar	8 300	11 800	2 235	1 117	560
Ndokayo	44 500	63 500	11 984	7 293	4 620
Olamze	17 000	24 200	4 574	2 287	1 145
Total	69 800	99 500	18 793	10 697	6 325

In order to meet peak demand at the 3 studied sites in 2010, it will therefore be necessary to have a total available installed capacity of approximately 6.3 MW, including the existing production means (Diesel units) and the prospected hydroelectric projects (5.5 MW).

However, this capacity does not take into account the specific case of SFH Hazim, which operates using 3 units according to the demand (350 kVA) and thereby increases peak power between 6 to 11 p.m.

By integrating the consumption of SF Hazim, the total capacity for the whole of the works would be 6.6 MW.

6.2 Future Load Pattern (kWh)

The analysis of demand depends upon the whole of the areas to be supplied in the long term (2010) and therefore includes the main network distribution and possible extensions.

6.2.1 Ngambe-Tikar Network

The estimated maximum capacity to be installed in order to meet only domestic and public lightning requirements of the main 30 kV network and the extensions of the Ngambe-Tikar area is 560 kW. The total estimated maximum capacity (not including extensions) is 350 kW.

By integrating the consumption of the SF Hazim, peak demand would increase from 560 kW to 860 kW (or from 350 kW to 650 kW excluding network extensions).

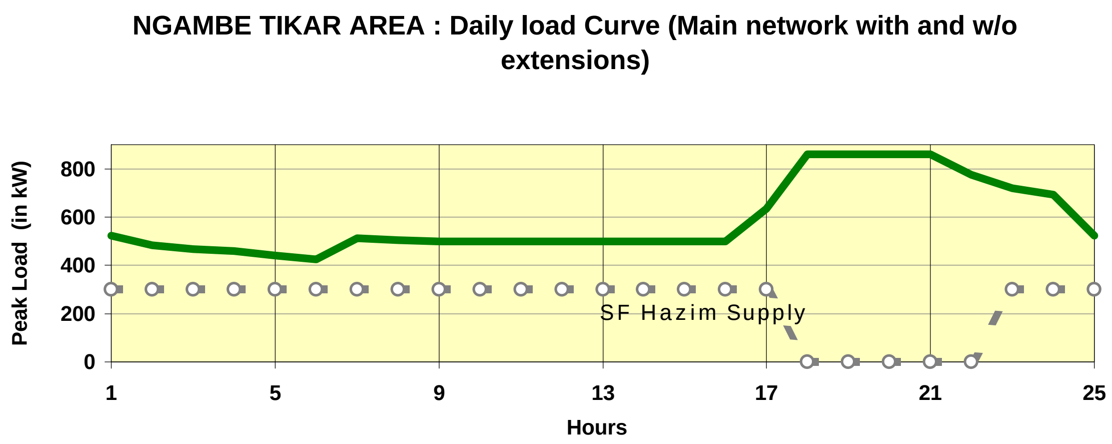
For the main network, the estimated annual consumption for the year 2010 is approximately 1300 MWh for domestic and public uses and approximately 3000 MWh for industrial uses corresponding to a demand of approximately 300 kW over 24 hours and 100 kW between 8 a.m. and 6 p.m or 2400 MWh for industrial uses, which corresponds to a demand of approximately 300 kW over 19 hours and 100 kW between 8 a.m. and 6 p.m

For the extensions of the Ngambe-Tikar area, the supplementary annual consumption for the year 2010 is estimated to 800 MWh for domestic and public uses.

Ngambe-Tikar (560 kW) : Demand – Typical daily load curve in 2010							
Hours	P/Pp(*) x 560	Industry (in kW) 300/400	Demand (in kW) 560	Hours	P/Pp(*) x 560	Industry (in kW) 300/400	Demand (in kW) 560
1	0.400	300	524	13	0.175	400	498
2	0.325	300	382	14	0.175	400	498
3	0.300	300	468	15	0.175	400	498
4	0.285	300	460	16	0.175	400	498
5	0.250	300	440	17	0.420	400	635
6	0.225	300	426	18	1.0	300	860
7	0.200	300	412	19	1.0	300	860
8	0.185	400	504	20	1.0	300	860
9	0.175	400	498	21	1.0	300	860
10	0.175	400	498	22	0.850	300	776
11	0.175	400	498	23	0.750	300	720
12	0.175	400	498	24	0.70	300	692

* : Installed capacity (P) in Peak load (Pp)

The 490 kW average power demand, excluding extensions, is corresponding to a daily consumption of 12 MWh.



6.2.2 Ndokayo Network

The estimated maximum capacity to be installed in order to supply the main 30 kV network and the extensions of the Ndokayo – Garoua Boulai area is 4600 kW.

The estimated annual consumption for the year 2010 is approximately 17 400 MWh for domestic and public uses and approximately 8 100 MWh for the industrial and craft sectors, corresponding to an approximate demand of 2100 kW between 8 a.m. and 6 p.m.

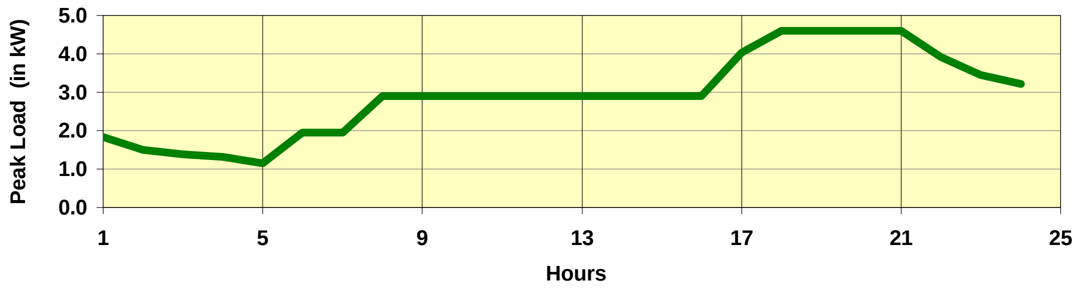
Ndokayo Network (4.6 MW) :
Demand – Typical daily load curve in 2010

Hours	P/Pp(*) x	Industry (in kW)	Demand (in kW)	Hours	P/Pp(*) x	Industry (in kW)	Demand (in kW)
	4 600	2 100	4 600		4 600	2 100	4 600
1	0.400	0	1 840	13	0.175	2 100	2 905
2	0.325	0	1 495	14	0.175	2 100	2 905
3	0.300	0	1 380	15	0.175	2 100	2 905
4	0.285	0	1 311	16	0.175	2 100	2 905
5	0.250	0	1 150	17	0.420	2 100	4 032
6	0.225	900	1 935	18	1.0	0	4 600
7	0.200	1 000	1 920	19	1.0	0	4 600
8	0.185	2 000	2 851	20	1.0	0	4 600
9	0.175	2 100	2 905	21	1.0	0	4 600
10	0.175	2 100	2 905	22	0.850	0	3 910
11	0.175	2 100	2 905	23	0.750	0	3 450
12	0.175	2 100	2 905	24	0.70	0	3 220

*: Installed capacity (P) in Peak load (Pp)

The 2900 kW average power demand corresponds to a of 70 MWh daily consumption.

Ndokayo Area : Typical daily load curve



6.2.3 Olamze Network

The maximum capacity to be installed by the year 2010 in order to supply the main 30 kV network and the Olamze site extensions is estimated at 1150 kW.

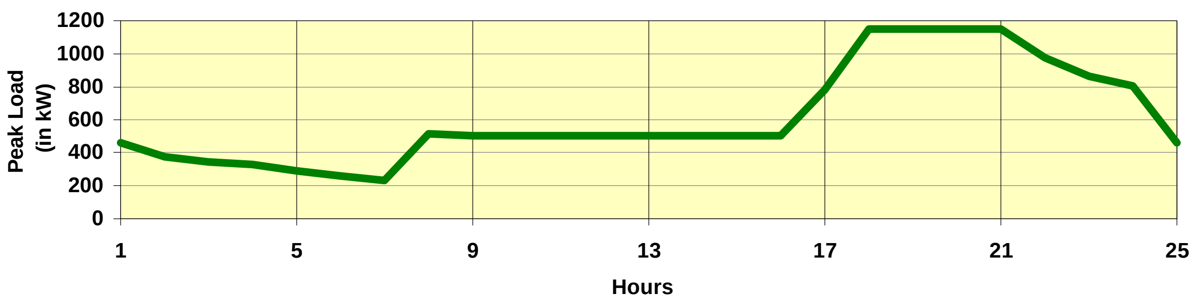
At that point in time, annual consumption is estimated at 4300 MWh for domestic and public uses and approximately 1100 MWh for industrial uses, which corresponds to a demand of about 300 kW between $7^{1/2}$ a.m. and 6 p.m.

Olamze Network (1 150 kW) : Demand – Typical daily load curve in 2010							
Hours	P/Pp(*) x 1 150	Industry (in kW) 300	Demand (in kW) 1 150	Hours	P/Pp(*) x 1 150	Industry (in kW) 300	Demand (in kW) 1 150
1	0.400	0	460	13	0.175	300	501
2	0.325	0	374	14	0.175	300	501
3	0.300	0	345	15	0.175	300	501
4	0.285	0	328	16	0.175	300	501
5	0.250	0	288	17	0.420	300	783
6	0.225	0	259	18	1.0	0	1 150
7	0.200	0	230	19	1.0	0	1 150
8	0.185	300	513	20	1.0	0	1 150
9	0.175	300	501	21	1.0	0	1 150
10	0.175	300	501	22	0.850	0	978
11	0.175	300	501	23	0.750	0	863
12	0.175	300	501	24	0.70	0	805

* : Installed capacity (P) in Peak load (Pp)

The 620 kW average power demand corresponds to a daily consumption of 15 MWh.

Olamze Area : Typical daily load curve



6.3 Power Supply Plan (estimation of power resources development plan)

6.3.1 Potential Production

Potential production has been calculated from the most unfavourable classified discharge curves "Q3" (see Chapter 5 Hydrologic Analysis) for the 3 hydropower plants, each one with a capacity sufficient to allow daily or weekly modulations during dry periods. Each power station's output is that of Chapter 8. Power Generation Project.

The storage capacities of the 3 reservoirs have been dimensioned so as to provide a 95% guarantee of maximum capacity over the 5 daily peak hours from 6 to 11 p.m. However, the power stations guarantee about 70 to 80% of the production over the 19 off-peak and working hours.

The table below gives the corresponding potential production (excluding unavailability) with the distribution over peak hours from 6 to 11 p.m.:

Generation per Power Station		Average potential production in GWh and Load factor		Potential production: 19 off-peak and working hours		Potential production: 5 Peak hours	
Ngambe-Tikar	(530 kW)	3.92	(85%)	3.04	(80%)	0.88	(90%)
Ndokayo	(4.5 MW)	30.6	(78%)	22.4	(70%)	8.2	(95%)
Olamze	(400 kW)	2.64	(77%)	1.91	(70%)	0.73	(95%)
Total	(5.4 MW)	37.2		27.3		9.8	

Note:

By using the classified discharge curve " Mid " of average hydrology, the potential production would increase by 8% for a design flow of 8.8 m^3/s. Uprating the Olamze power plant with three 200 kW unit for a design flow of 12.2 m^3/s would improve the classified discharge curve " Mid " by 38% relative to the classified discharge curve " Q3 ".

HPP Olamze	Average potential production in GWh	Potential production: 19 off-peak and working hours	Potential production: 5 Peak hours
2 x 200 kW (8.8m3/s)	2.85	2.12	0.73
3 x 200 kW (13.4 m3/s)	3.65	2.56	1.09

6.3.2 Ngambe-Tikar Network Expansion Plan

The gross production available at the Ngambe-Tikar power station (530 kW), which is estimated at 3.9 GWh, cannot be absorbed by the 30 kV main network (Station-Ngambe-Mbam 25 km axis) whose needs in 2010 have been estimated at 4.0 GWh, of which 2.6 GWh for the Société Forestière Hazim (SFH) and at 0.3 GWh for other industries.

The SFH possesses two 800 kVA diesel generating sets that operate alternatively at half-load at high costs (300 to 350 FCFA per gas oil litre) with a base consumption of approximately 2 to 2.5 GWh per year. The selling of power to the SFH during working hours at a lower price than diesel would enable the use of the production excesses from Ngambe-Tikar. Negotiations must be opened to supply 200 to 400 kVA during working hours from 7.30 a.m. to 6 p.m. and possibly during night peak hours from the Ngambe-Tikar power station and in return, to have available peak hour power to ensure peak hour demand between 6 and 11 p.m. in low flow periods. The SFH plans to extend its activities in the coming years.

The industrial, agricultural and forestry development on the Ngambe-Tikar plain could also enable to absorb part of the production surplus (100 kWA). The extension of the 30 kV main network (80 km) should be rapidly undertaken, despite low profitability, in order to use the power surplus provided by the Ngambe-Tikar power station.

6.3.3 Ndokayo Network Expansion Plan

The 30 GWh gross production available at the Ndokayo power station (4.5 MW) cannot be totally absorbed by the main 30 kV network (Site-Ndokayo & Garoua Boulai 150 km axis) whose estimated needs for 2010 will be approximately 20 GWh, for a peak load of 4.6 MW.

In the short term, it would therefore be possible to limit the construction of the Ndokayo power station to 2 units for an installed capacity of 3.5 MVA.
The existing diesel generating sets at Garoua Boulai (400 kVA) and at Betare Oya (156 kVA) will complete the production.

In 2010, the Ndokayo hydropower station, which could be equipped with three 1.5 MW units, could supply 85 to 90% of the consumption, i.e. 30 GWh. The peak complement must be ensured by the diesel generating sets.
The extension of the 30 kV main network by 45 km could therefore be undertaken quite rapidly to use the additional production of the third unit.

6.3.4 Olamze Network Expansion Plan

Almost all the gross production (2.6 GWh) from the Olamze power station (400 kW) may be absorbed by the main 30 kV MV network (45 to 50 km long OOlamze-Ambam axis) whose estimated needs for 2010 are approximately 4 GWh.

The existing capacity of the diesel generating sets being 855 kVA will facilitate the meeting of demand in 2010, this especially after the 3 Ambam's units rehabilitation.

Prior to undertaking the extension of the 30 kV main network by approximately 60 km, it will of course be necessary to consider new production means.

6.4 Optimum Power Development Plan

6.4.1 Transmission Line

For each of the 3 projects, the 30 kV MV main network is limited to:

- 25 km for Ngambe-Tikar, with an 81 km extension difficult to justify in its totality.
- 153 km for Ndokayo, with a possible 43 km extension,
- 47 km for Olamze, with a possible 59 km extension, but which will require the construction of other production means,

This will enable an economical supply to approximately 75 and 90% of the identified towns from the sites of Ngambe-Tikar and Ndokayo respectively.

Concerning the main network of Olamze, the choice between the Olamze-Ambam axis (47 km) presenting too high a demand compared to the hydro-electric power station's capacity (400 kW) and the Olamze-Ndoakik axis (35 km) having, in the opposite case, too low a demand in 2010 (300 kW), it is deemed preferable to build the Olamze-Ambam connection that will in particular absorb a production surplus of 200 kW until 2010 and 100 kW afterwards.

The costs for the possible extensions have not been taken into account in the projects costs or in LV distribution.

6.4.2 Supply-Demand Assessment

The table below gives a summary of the analysis of supply and demand for the 3 sites. The potential productions of the 3 power stations are compared to the forecasted consumption in 2010.

in GWh

Hydropower Station	Average potential production*	Maximum demand in 2010	Production % in 2010
Ngambe-Tikar (530kW)	3.72	5.1	72.9%
Ndokayo (4.5 MW)	28.3	25.6	110.5%
Olamze (400 kW)	2.51	5.4	46.5%
TOTAL	34.53	36.1	95.7%

(*) : excluding losses on the network

Note that:

- for the Ngambe-Tikar power station, the production surplus will be sold to the SFH and to new companies in the immediate vicinity of the Ngambe-Tikar township in order to absorb the totality of the production.
- for the Ndokayo power station, the production from the two (3 MW) units will be absorbed quite rapidly by the Garoua Boulai development axis, and that the commissioning of a third unit (1.5 MW) will require the extension of the network in order to supply the additional production,
- for the Olamze power station, the totality of the production will be absorbed by the main network.

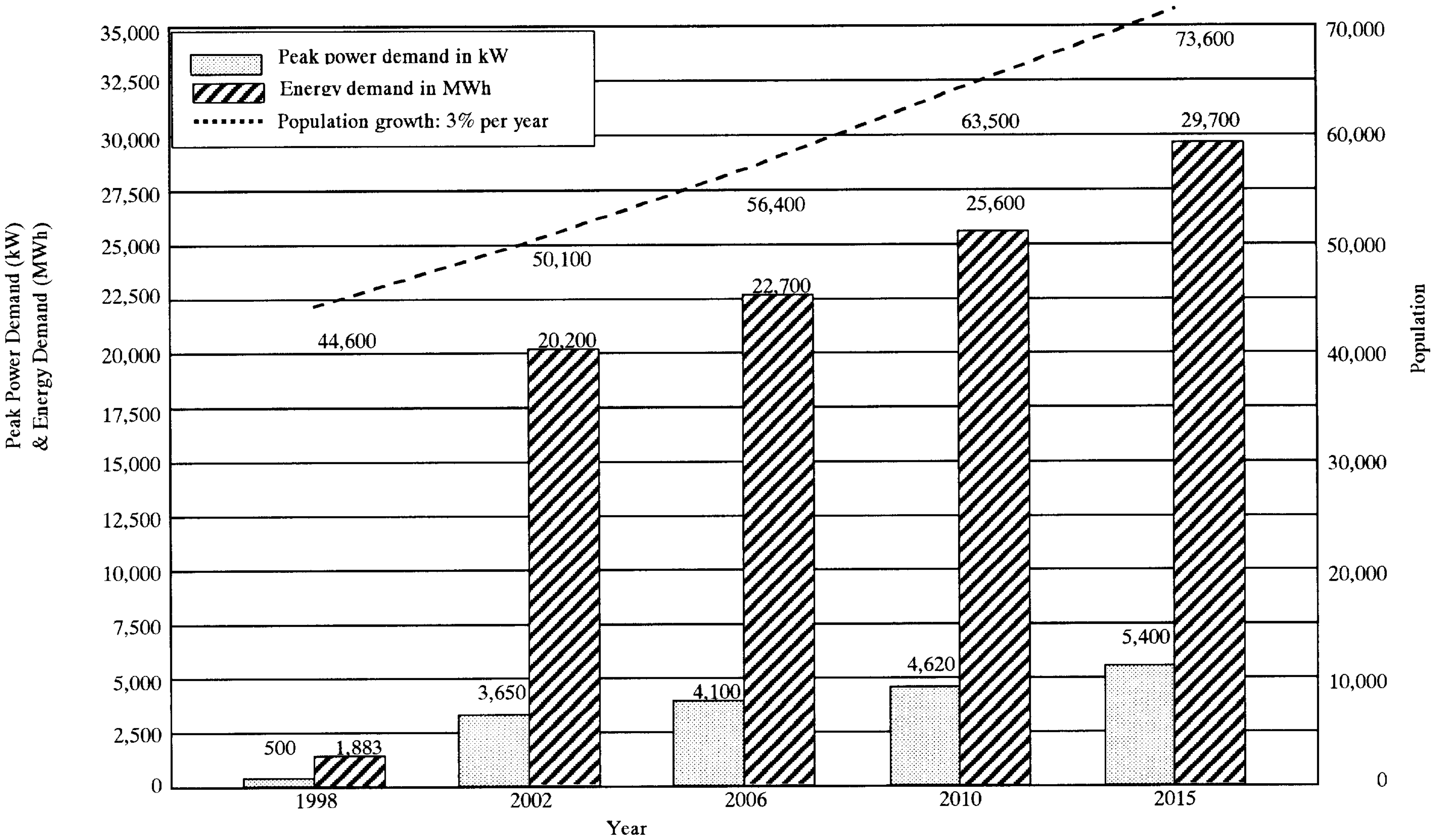
Decentralized Rurale Electrification 30 kV Network in Cameroon
for the sites of Ngambe-Tikar, Ndokayo and Olamze
Estimation of the population and capacity to install

Axes et Centres	Population in 1987	Population in 1998	Evaluation of the population in 2010 (3% growth rate per year)	Nbr. of households (5.3 people per household)	50% supply (*)	Puissance Max. capacity to install 500W per household (*)
1. Ngambe-Tikar site (Kim river)						
Axe Ngambe-Tikar - Mbam						
Ngambe-Tikar	2,556	3,500	4,990	942	471	235
Mansouh	200	274	391	74	37	18
Ga	750	1,027	1,464	276	138	69
Gwenze	250	342	488	92	46	23
Sub-total 1	3,756	5,143	7,333	1,384	692	346
Axe Ngambe-Tikar - Kpwala						
Gandie	200	274	391	74	37	18
Mboutou	200	274	391	74	37	18
Mbondé	200	274	391	74	37	18
Sub-total 2	600	822	1,172	221	111	55
Axe Mbambe - M'bomena						
M'bomena	250	342	488	92	46	23
Ndjonkou	250	342	488	92	46	23
Sub-total 3	500	684	975	184	92	46
Axe Ngambe-Tikar - Nga						
Benbeng	250	342	488	92	46	23
Nga	250	342	488	92	46	23
Sub-total 4	500	684	975	184	92	46
Axe Ngambe-Tikar - We						
Wawe	250	342	488	92	46	23
We	250	342	488	92	46	23
Sub-total 5	500	684	975	184	92	46
Axe Ngambe-Tikar - Mandjambo						
Mangon	212	290	413	78	39	20
Sub-total 6	212	290	413	78	39	20
Total Network 1	**6,068**	**8,307**	**11,844**	**2,235**	**1,117**	**559**
2. Ndokayo site (Mari-river)						
Axe Bétaré Oya - Garoua Boulai						
Mari Village	200	274	391	74	37	18
Lom	209	286	408	77	38	19
Bétaré Oya	4,271	5,849	8,339	1,573	787	393
Ndokayo	1,778	2,435	3,472	655	328	164
Bongo	318	436	622	117	59	29
Borongo	1,656	2,268	3,234	610	305	153
Mombal	745	1,020	1,454	274	137	69
Nadongwé	2,095	2,869	4,091	772	386	193

Axes et Centres	Population in 1987	Population in 1998	Evaluation of the population in 2010 (3% growth rate per year)	Nbr. of households (5.3 people per household)	50% supply (*)	Puissance Max. capacity to install 500W per household (*)
Botila	334	457	652	123	61	31
Badzéré	1,804	2,471	3,523	665	332	166
Badang	912	1,249	1,781	336	168	84
Yoko Sire	833	1,141	1,627	307	153	77
Ganko	345	472	673	127	63	32
Garaoua Boulai (*)	14,125	19,345	27,581	5,204	3,903	2,927
An overvaluation of 50% has been applied for the calculation of supply and capacity						
Sub-total 1	29,625	40,572	57,846	10,914	6,758	4,355
Axe Ndokayo - Tongo						
Oudou	276	378	539	102	51	25
Kongolo	498	682	972	183	92	46
Garga Sarali	1,092	1,496	2,133	402	201	101
Ngaoundere	280	383	546	103	52	26
Tongo	759	1,039	1,481	280	140	70
Sub-total 2	2,905	3,978	5,672	1,070	535	268
Total Network 2	**32,530**	**44,550**	**63,518**	**11,984**	**7,293**	**4,622**
3. Olamze site (Woro river)						
Axe Olamze - Ngoasik - Ambam						
Olamze	537	735	1,048	198	99	49
Meko'Ossi	567	777	1,108	209	105	52
Eyinantoum	381	522	744	140	70	35
Meko'Omengona	453	620	884	167	83	42
Ebengon	725	993	1,416	267	134	67
Nsana	342	468	667	126	63	31
Ngoasik	476	652	930	175	88	44
Nkoumeké	239	327	466	88	44	22
Ambam	5,843	8,002	11,409	2,153	1,076	538
Sub-total 1	9,563	13,096	18,672	3,523	1,761	881
Axe Ngoasik - Kyé Ossi						
Konofossi	320	438	624	118	59	29
Meyo Nkoulou	200	274	391	74	37	18
Kyé Ossi (frontere Guinée)	531	727	1,037	196	98	49
Subtotal 2	1,051	1,439	2,052	387	194	97
Axe Ambam-Abang Minko						
Minyim	338	463	660	125	62	31
Mekomo	510	698	995	188	94	47
Nlono	275	377	538	101	51	25
Bilessi	230	315	449	85	42	21
Abang Minko	450	616	878	85	42	21
Sub-total 3	1,803	2,469	3,520	664	332	166
Total Network 3	**12,417**	**17,004**	**24,244**	**4,574**	**2,287**	**1,144**

Ndokayo Main Network

Forecast of Energy & Peak Power Demand



CHAPTER 7.   GEOLOGY

Chapter 7 Geology

7.1 General (Ref. Fig. 7.1)

Almost all of the bed rock of Cameroon is characterised by formations from the Precambrian called “basic complex”. This basic complex is divided in several parts:

- so-called “mobile” zone or granitized and migmatitized zone from the pan-African period,
- septentrional ending of the Congo Craton (or Ntem’ group) from the archean period and partially rejuvenated, along its borders, during the Eburnean and pan-African period,
- charnockitic cores from the liberian period (2,900 million years) enclosed in the “mobile zone”.

The Ngambe Tikar and Ndokayo sites are located in the so-called mobile” zone affecting most of the metamorphic ground in Central Africa, which covers practically the entire country of Cameroon. The Olamze site is located in the Congo Craton (Ntem’ group).

The most common rock of the mobile zone are granite and migmatite from the pan-African period (550 ±100 million years) underlying Pre-Cambrian formations called “intermediate” formations, which may or may not be in discordance.

The mobile zone is in opposition to the Craton zone, which is considered to have been stable for at least the past 2,500 million years. In the widest sense of the term, the mobile zone in Cameroon includes all the rock placed during the pan-African orogenesis. The contact between the mobile zone and the Congolese craton is apparently a line of overthrust, similar to the one at the eastern edge of the West African craton.

The lithological sets in the mobile zone can be broken down into:

- epimetamorphic cover formations,
- gneiss formations, possibly resulting from ancient, totally recrystallised overburden formations,
- migmatite posterior to the cover formations,
- two groups of granite, either circumscribed or not,

- various types of plutonic rocks.

The region of Ngambe-Tikar (Ref. Fig. 7.3) belongs to the migmatite set that covers almost two-thirds of Cameroon. This group of migmatite (commonly called granito-gneiss by Anglo-Saxon authors) is very heterogeneous. It is a complex hybrid formation wherein all the lithological terms may be represented. It is a highly varied set from the standpoints of texture, chemical composition and mineralogical make-up, composed of diadysites, embrechites, anatexites and anatexic granites.

The site studied at Ngambe-Tikar is marked by outcrops of embrechites and amphibolitic gneiss.

The region of Ndokayo (Ref. Fig. 7.8) belongs to a volcano-sedimentary formation called the LOM formation, after the river crossing it. It covers a surface area of approximately 2500 km^2. That formation has undergone regional metamorphism; it is probably structurally discordant on a granito-gneiss base that was rejuvenated in the pan-African period. It is a set composed of schist, greywacke and quartzite.

The site studied at Ndokayo features the presence of quartzite outcrops in the form of compact beds that are resistant to erosion and weathering, forming crests above the surrounding schists.

The Craton zone or NTEM group is caracterised by the different lithological formations:

- intrusive rocks (granite, diorite, syenite, charnockite, gabbro),
- ribbon series (gneiss, migmatite, amphibolite),
- ribbon series (gneiss, migmatite, amphibolite),
- iron formations locally.

The region of Olamze (Ref. Fig. 7.15) belongs to the ribbon series of the Ntem' unit, and the site studied is marked by outcrops of amphibolitic gneiss.

7.2 Ngambe-Tikar Site

The site is located on the Kim river, approximately 2 km upstream from the bridge over that river and 6 km from the village of Ngambe Tikar (Ref. Fig. 7.2 & 7.3). The local topography is a little complex (Ref. Fig.7.6). The site is very flat with very little relief. The slopes of the river banks are very gentle. A 300 metres long rock sill creates a series of small falls in the river, divided into a number of branches or channels. The river has a very wide flood plain (approximately 200 m), and a 2m high bench marks the limit of the flood plain and the bank. Its longitudinal profile is very gentle, with very little drop in elevation between the beginning of the "falls" and the downstream part.

7.2.1 Geology

The almost entire riverbed for a distance of 300 m is formed of outcropping rock, very high quality amphibolitic gneiss, sound and with no weathering, forming small jumps. In places it has been severely eroded by the running water. All of the rock is covered over with dried algae that in places hides its geology. The rock seems to be foliated parallel to the river (N100 ° E). A few seams of quartz (strike N100°E and with a vertical dip) affect the rock.

The rock is marked by:

- 2 main groups of fracturing, with a perpendicular strike:
  - group A: strike: N110°E – 130°E, dip: 70°SW to the vertical, i.e. parallel to the river: the fracture planes show openings of several centimetres in places;
  - group B: strike N60° - N80°E, dip: 60° to 85° towards the South-East, i.e. perpendicular to the river and towards the left bank.

- A secondary group of fracturing:
  - group C: strike N170° to N20°E, dip: 60° to 80° towards the East.

No major fault is visible on the site.
The riverbed is marked by the presence of many alluvial deposits, consisting of fine sand that in places forms small islands (in dry season), boulders of varying sizes, and a sort of agglomeration of small boulders cemented together by a hardened agglomerate binder that locally "fills in" hollows in the rock.

Both river banks are covered by a primary gallery-forest. The riverbanks consist of loose formations resulting from laterite weathering, which is a classic formation in equatorial Africa.

A ridge 2 to 3 m high separates the river's flood plain from the feet of the river banks. No rock outcrop or boulder were observed on the banks during the site tour.

7.2.2 Geological Investigations

The geological investigations were carried out by GEOFOR on February to March, 1999, and location of geological investigations is shown on Fig. 7.4A & 7.4B.

Irregularities of execution and interpretation of the geological investigations (boreholes, water tests, and geolphysics) from GEOFOR, have been displayed and immediately pointed out, geological investigations are, now, exploitable, and the results of the geophysical investigations were interpreted and used carefully.

The seismic data were collected on each line by using a 24 channels seismic recorder, with signal display. Each spread was 115 m long; 24 geophones were planted at 5 m (or less) intervals (slope distance) to pick up refracted waveforms. The layout of blasting points should be for a minimum of five points one each spread (one on the centre, one of each extremity, one offset on each side).

Height pits (called Pu1 to Pu5) were completed at regular intervals between the intake site to the future power station, along the river bank (on seismic profiles). The description of the 8 pits is available in appendix 1. The pits were stopped when the means used did not allow to dig them deeper, especially when encountering: either numerous 50 cm to 100 cm blocks at the bottom of most pits, or the groundwater level.

Two boreholes were carried out with a rotary drilling machine (78 mm diameter). The description of the boreholes is available in appendix 1.

6 field permeability tests (Lugeon test) had been conducted at boreholes.

7.2.3 Structure Sites

The characteristics for development at the site are:

- dams of one or two meters high: masonry and overtoppable dams with three bottom gates, (length to be dammed at the upstream sill: approx. 480 m, in 5 river branches or channels),
- an headrace canal, 515 m long, with a maximum natural head: about 7 m,
- an above ground power station with an installed capacity of: about 500 kW.

The estimated discharge is about: 4m^3/s.

Since access to the scheme will be possible only on the left bank, the headrace structure and the power station must be built on this bank. It should be emphasised that both banks have the same topographical and geological characteristics.

(1) Dams

There is a possibility of damming the river at the sill located the farthest upstream (beginning of the "falls") in the area under study. Topographical structure close off the site on both banks. The layout of the dams use the presence of the succession of rocky islands between right bank and left bank. It is why this layout is not rectilinear; it use for the best, the local geological and topographical conditions. The outcrops in the bed of the river are very fresh and are good geological qualities. The rock (amphibolitic gneiss), is a little weathered, and is affected by several closed cracks.

But unfortunately, the outcrops, in the bed of the river, are not continuous; and between different islands, as any geological investigations have been carry out, it is difficult to expect the level of the rock. So, we can, properly consider that between rocky islands the river flows on the rock, with perhaps little "pockets" of sand.

The borehole S2, is located on the left river bank, at a few meters from the river water level, just near the old establishment of the intake (now, the intake is 200 metes downstream). The results of this investigation show, from the top to the bottom of the borehole:

- about 4.75 meters of grey fine and medium alluvial sand,
- about 3 meters of weathered rock (gneiss), with a lot of joints, enough permeable: about 32 Lugeon units,
- about 2 meters of lightly weathered rock, with a permeability of 19.5 Lugeon units,
- under 10 meters depth, a very fresh rock, with a permeability of 9.3 Lugeon units.

The 5 river branches could be dammed by a series of concrete or masonry structures, and the structures could rest directly on the outcropping rock, after a good cleaning; an anchorage of 0.50 m could be consider. No special stripping seems required at the sills except perhaps, the sand pockets between the rocky islands. The present, irregular bottom of the rock, would improve the structures hold. Since those structures would be overstopped quite often, they would have to have a fairly wide base (3 to 4 m) in order to resist the thrust of the water. Any grouting of the rock appears not necessary, as it is quite impermeable and faintly fractured. The materials for construction could be taken on the site (boulders and sand).

(2) Water Intake

The water intake, planned on the left bank, must also be founded on the rock in place. The seismic profile SP2 could give some informations that the rock, in this part could be in about 2 meters depth. The foundation of the intake will be guaranteed on the fresh rock, which will meet an essential condition.

(3) Headrace

Six seismic refraction profiles and height hand pits have been completed on bank where the headrace is considered. We don't found any rocky outcrop on this bank.

Bedrock is 2 m below the ground surface at the low points and highly to softly weathered (quarzitic and amphibolitic gneiss) 5 to 10 meters thick, with a lot of oxidised and iron rusted, oblique and horizontal joints; locally the joints are little clayed; the dip of the shistosity is near 45°. This formation is quite permeable between 19.5 to 32 Lugeon units.

A very fresh rock (gneiss) is near 10 to 15 meters deep, with a permeability near 7 to 9 Lugeon units (permeability of cracks).

The foundation grounds of the headrace lined canal, are essentially overburden clay and sand, after stripping off the topsoil (between 10 to 20 cm). But it would seem that the canal could be set directly on the very compact laterite clay layers directly, for the main part.

However, the crossing of a sandy part is possible on about few meters long. So, on this part, some specific adaptations might be consider about possible settlements of the canal.

The headrace must be protected from erosion due to the river and be set at an elevation that is higher than the maximum water level; it must be lined to avoid leekages through the concrete which could scour the foundation. The layout of the canal must avoid the area near the river where the riverbank show a steep slope.

(4) Power Station & Tailrace

As for the power station site, the level of the top of the weathered rock must be identified, but we can properly suppose that this level will be located at 701, conservatively, even if it is weathered.

It is possible that during the earthworks of the power station, some water inflows come from the water river level. So the earthworks must be realised during the dry season, when the river level is low.

The same comments as in the foundations of the headrace canal could be emitted as for the tailrace canal, and the side slope in lateritic clay should be about 45° : 1 vertical for 1 horizontal.

7.3 Ndokayo Site

The Ndokayo site is in the east of Cameroon, 180 km north-east of Bertoua, and about 10 km north of the village of Betare Oya, on the Mari river (Ref. Fig. 7.7 and 7.8). The region is gold bearing (alluvial placers) and is still being mined on a small scale.

In comparison to the Ngambe Tikar site, the Ndokayo site is essentially marked by the hills that the Mari river must cross perpendicularly to the strike of the main crest, via major falls the height of which ranges over 100 m. The river’s longitudinal profile at the falls is very steep. The river banks also have steep slopes (45° to 50°) and vertical cliffs in some places. These banks have reached their angle of natural equilibrium.

7.3.1 **Geology** (Ref. Fig. 7.7)

The entire riverbed is very hard rock that has created a natural obstacle to the course of the river: it is quartzite with seams of quartz. The quartzite is strongly micaceous (muscovite) in places; the rock is white and powdery when weathered, but at clean breaks it is dark blue with fine grains.

The quartzite zone forms the backbone of the hills overlooking the falls; the river has formed a path through this barrier by hollowing out a miniature canyon in it.

The main strike of the fracturing in the quartzite is N30°E. That strike corresponds to that of the crest line of the two hills overlooking the falls. It is perpendicular to the river at the falls. This main fracturing has a subvertical dip. The "benches" of quartz and quartzite are 20 to 50 cm thick. Spaces between "benches" are wide open in places (20 cm or even more).

The N30°E strike is the main strike of the weakness in the rock. Two groups of fracturing are associated with it:

- one group with strike parallel to the river in the area of the falls: strike N140°E and dip 70° towards the West,
- a subhorizontal group.

The three fracture planes that affect the rock have perpendicular strikes and dips; the combination of these planes has the effect of cutting the rock into large parallelepipedal blocks.

No alluvial deposit is visible at the falls. On the other hand, downstream from them the riverbed is cluttered with many boulders of varying sizes and with finer deposits. The gold-mining activity is in these zones. In the downstream part, a ridge several metres high separates the river's flood plane from its banks.

The river banks above the falls are very steep and very rocky. the rocky skeleton is formed by the lateral extension of the quartzite zone on either side of the falls.

The top of both banks shows many outcrops of severely (vertically) fractured quartzite "benches" that form cliffs in places. On the other hand, the middle and lower part of both banks are covered with quartzite and quartz debris mixed with topsoil. In fact a certain number of quartzite and quartz "benches" at the top of the hills have tipped over towards the foot of the slope under the effect of gravity and imbalance (toppling), creating significant zones with a chaos of parallelipipedal blocks. Those boulders are very large (often more than 1 m^3). The thickness of this talus seems variable; a rough estimation before investigations could be 4 to 8 m. The thickness should be greater at the feet of the banks.

The top of the hill on the right bank, overlooking the falls, has a double crest; the hollow between the two crests – which is continued in the subjacent cliff over the falls – could correspond to a fault or more extensive fracture zone, with a N30° to 40°E strike or a level more erodible. Regarding that hill, a certain lack of symmetry between the banks is noticeable; the southern bank, the one that is visible as the visitor arrives at the site, has no plant cover and most notably has been covered by rock falls, as noted above; the northern bank, on the other hand, has very thick plant cover (forest) and the debris or boulders of quartz and quartzite are relatively rare.

Another phenomenon – that is relatively rare in equatorial Africa – is the presence on the southern slope of the hill on the right bank of a spring of clear water (with low flow); that spring is located halfway up the slope, approximately 300 m from the river's centreline. The existence of a spring that does not dry up in low flow periods proves that water flows within the rock via the fracture planes and also that this source may be fed from the river.

7.3.2 Geological Investigations

The geological investigations were carried out by EOFOR on February to March 1999. The location of geological investigations is shown on Fig. 7.9.

Irregularities of execution and interpretation of the geological investigations (boreholes, water tests, and geophysics) from GEOFOR, have been displayed and immediately pointed out, the geological investigations are, now, exploitable, and the results of the geophysical investigations were interpreted and used carefully.

The seismic data were collected on each line by using a 24 channels seismic recorder, with signal display. Each spread was 115 m or 70 m long, 24 geophones were planted at 5 m (or less) intervals (slope distance) to pick up refracted waveforms. The layout of blasting points should be for a minimum of five points on each spread (one on the centre, one of each extremity, one offset on each side).

Five pits (called Pu1 to Pu5) were completed at regular intervals between the foot of the hill and the future outlet in the river. The pits had been hand-made with a hand-shovel down to the bedrock. The description of the 5 pits is available in appendix 2. The pits were stopped when the means used did not allow to dig them deeper, especially when encountering: either numerous 50 cm to 100 cm blocks at the bottom of most pits, or the groundwater level.

Three boreholes were carried out with a rotary drilling machine (78 mm diameter). The description of the boreholes is available in appendix 2.

Four field permeability tests (Lugeon test) had been conducted at boreholes.

7.3.3 Structure Sites

(1) Intake Dam (Ref. 7.10 & 7.11)

There is a possibility of damming the river in the area upstream of the falls. topographical structures to close off the site exist on both banks. The sill is approximately 12 m long at the water level, and for a dam 5 m high the crest length can be estimated at about 30 m.

The riverbed is rocky at the centreline of the proposed dam; that rock is of excellent quality, very sound quartzite type. It is affected by the main fracturing pattern with a N30° to 40°E strike, and subvertical dip. The rock crops out on the left bank of the envisaged centreline and forms a small cliff.

On the right bank, at the level of the envisaged dam centreline, no rock outcrops are visible; that rock is covered with large slabs of quartzy rock from rock slides. However, outcrops of the rock can be observed about 10 m upstream and downstream of the proposed centreline. Within the outcrops upstream from that point, one or two metres above the level of the river, fractures with a subhorizontal (or close to it) dip of 10° to 20° towards the inside of the bank can be noted; those fractures are open (from 5 cm to several dozen cm) and even form overhanging.

We noted the presence of some fine alluvial sand, in very limited quantity, about 50 m upstream the future dam location on the right bank, near the river bed, where the water flow must be locally sloved down on the river edge.

We noted, as well, a main rocky dissymmetry between each bank: the rock of the right bank should be more weathered than the rock of the left bank. But the thickness of debris and alluvial deposits, on the left bank should be a little more important than these of the right bank. We don't have any information about the quality and the permeability of the rock in-depth. But we must certainly, have all the degrees of rock weathering, from the outside to the depth: highly weathered rock, moderately weathered rock, slightly weathered rock.

The planned dam could rest directly on the outcropping rock in the riverbed, or anchored of 0.5 meter in the rock.

In the same manner the talus at the feet of the banks must be stripped off when the excavations begin, as the dam must abut on sound existing rock on both banks (about two meters of excavation). The geophysical investigations completed on the abutments allows to determine with a certain inaccuracy the thickness of the debris and the level of the top of weathered rock. In the light of the field observations, high permeability of the rock (permeability of horizontal cracks and vertical joints) in the abutments could be feared.

The results of the borehole S3, completed near the cabin, in the same rock, give a relative fresh rock (5.00 m depth) and the result of the water test (between 6 to 8 meters depth) give an absorption of 43 1/m/mm under 7.2 bars, that is to say 70 Lugeon units (extrapolated value). This result allows to say that this rock: quartzite, is permeable.

Nevertheless, in this stage of study it is already reasonable to believe that the foundation' dam rock will have to be treated by grouting.

The water intake is to be planned on the right bank; it must also be founded on the sound rock in place.

(2) Headrace (Ref. Fig. 7.12 & 7.13)

The headrace is the structure with the greatest geological risks. It must be built at the right bank hill, and must include a first section of tunnel after the water intake in order to across the hill, and then steeper section along the bank.

Like the left bank hill, the right bank hill has:

- very steep slopes (45° to 50°),
- small subvertical rock cliffs at the top; those cliffs are highly disorganised and unstable, made up of quartzite and seams of quartz that

are "pushed up" vertically and widely cracked; some hollows can be observed (passage of a fault or more severely fractured zones) in places,

- in the middle and lower parts, a chaotic zone formed by rockslides of "slabs" of quartz or quartzy materials (blocks of widely varying sizes, from a dozen litres to several hundred litres), mixed with topsoil and all at the limit of stability.

The layout of the headrace structure must take into account the geological constraints on the site:

- instability of the outcropping rock that is highly disorganised with wide cracks,
- a great thickness of debris over a very steep slope at the limit of instability,
- major falls of boulders, of varying sizes.

The bank must be generally stripped when the works begin; some unstable blocks will have to be blasted and others anchored with bolts; in some places it will be essential to install safety wiremesh.

A small diameter tunnel, (diameter of 3 meters) would eliminate any concern with outside rockfalls. This tunnel could be lined with reinforced concrete with an circular interior section (2 meters diameter).

However, excavation in such a severely cracked and disorganised rock mass could prove very difficult. The upstream and downstream working faces will be delicate to carry out. The rock blasting design will be adapted to this bad rock; and it should be very "light" to not disorganised the rocky surroundings.

The second part of the structure (along the bank), steel penstock, must be laid out perpendicular to the contour lines (approximately 150 m long). As the thickness of the debris is important (more than 8 meters), it is impossible to place the penstock on stable rock.

For the hill part and for the plain part, each 10 meters, on large foundation footings (minimum 2.00 x 2.00 x 0.70 ht) built in reinforced concrete, and several anchor blocks (concrete support: 5.00 x 3.00 x 3.00 ht) might be considered, at least one at the level of the head gate, one at the bottom of the hill, and one just before the power station. The penstock might have a few of expansion joints.

There are many possible locations for the power station in the alluvial plain at the foot of the bank. From a geological standpoint the layout conditions are identical at any location in the plain.

A pit dug during the first site tour gave a global view of the foundation conditions for this structure. The pit showed a depth of 1.40 m with very compact clay layers, grayish blue at the top and reddish at the bottom, with large blocks inside those clayey layers.

As the bedrock is enough depth (minimum 15 meters), it would be impossible to found the power station on the rock. So the foundations will be necessary in lateritic clays, quartzitic blocks and alluvial sand. Calculation of bearing capacity will have to be realised.

7.4 Olamze Site

The site is on the Woro river, one of the big tributary of the Ntem river. (Ref. Fig. 7.1, 7.15 & 16), and located 2 km from the small village of Andok (Ref. Fig. 7.15). The site is flat, with very little relief, the slopes of the river banks are very gentle. The river get over a small rocky sill, 20 m long. The flood plain of the river is 40 m wide and is separated from the side by a little step of 2 m high. Its longitudinal profile is very gentle, and a little relief (between 1 and 1.5 meters – high to be defined) exists between the upstream and the downstream of the sill.

7.4.1 **Geology** (Ref. Fig. 7.17)

At the sill location, the riverbed is rocky. The rock outcrops at the bottom of the banks, in the middle of the river, and in the small branch located on the right bank. It is an amphibolitic gneiss, slightly quartzitic, sound, with locally a soft weathering.

The strike of the rock foliation is N90°E (approximately perpendicular to the flow of the river) and the dip is subvertical. The planes are locally open (mm to cm). This rock is marked by a main group of fractures: strike: N170°E (parallel to the river), dip: 70°E (towards the right bank). No major fault is visible on the site.

Banks are covered by forest. The riverbanks consist of clayey formations resulting from laterite weathering. The thickness of this formation is probably relatively important, on the top of the bank. No rock outcrop or boulder were observed during the site tour.

7.4.2 Geological Investigations

The geological investigations were carried out by GEOFOR in March 1999, and the location of geological investigations is shown on Fig. 7.17.

Irregularities of execution and interpretation of the geological investigations (boreholes, water tests, and geophysics) from GEOFOR, have been displayed and immediately pointed out, the geological investigations are, now, exploitable; and the results of the geophysical investigations were interpreted and used carefully as in the other two sites.

The seismic data were collected on each line by using a 24 channels seismic recorder, with signal display. Each spread was 115 m long, 24 geophones were planted at 5 m (or less) intervals (slope distance) to pick up refracted waveforms. The layout of blasting points should be for a minimum of five points one each spread (one on the centre, one of each extremity, one offset on each side). The seismic source was explosives.

Seven pits (called P1 to P7) were completed at regular intervals on the dam axis and on the power station site. The pits had been hand-made with a hand-shovel down to the bedrock. The description of the 7 pits is available in appendix 3. The pits were stopped when the means used did not allow to dig them deeper, especially when encountering: either numerous 50 cm to 100 cm blocks at the bottom of most pits, or the groundwater level.

Three boreholes were carried out with a rotary drilling machine (78 mm diameter). The description of the boreholes is available in appendix 3.

Seven field permeability tests (Lugeon test) had been conducted at boreholes.

7.4.3 Structure Sites

According to the local topographical conditions (flood plain quite narrow, natural closure of the banks), geological (river floor rocky) and hydrogeological (low discharge, longitudinal profile very gentle) the following sketch for the scheme of the site will be considered:

- dam of few meters high, to the rocky sill, with a central part (stream bed) in concrete, and two lateral wings in tight and homogeneous earth,
- water intake and power station located in right bank and at the heel of the dam.

(1) Intake Dam (Ref. Fig. 7.18)

Two boreholes (S2 and S3), with four water tests, six pits (P1 to P6), and two seismic refraction profiles (SP1 and SP2) have been completed on the dam' axis. We found there a classical geological cross section in this kind of country with:
- an important weathering under the banks,
- a rocky river bed.

Each bank is constituted by lateritic clay. This formation is plastic, locally sandy, and can be mixed with some rocky blocks. The colour is variable: yellow, brown or red. The thickness is also variable: 1 ~ 2 meters at the bottom of the bank to 5 ~ 10 meters at the top.

The thickness of the weathered rock is very variable. In the river bed the rock is very fresh and we found only a few rare weathered outcrops. On the other hand under each bank the thickness increase with the altitude (about 6 meters or more on the altitude 555). This is composed of all the degrees of chemical weathering: from highly weathered rock to slightly weathered rock.

The fresh rock has been seen in the boreholes S2 and S3. It is a very fresh amphibolitic gneiss, with some joints locally weathered. The RQD is near 100%. The results of the water tests show a variable permeability of the rock under the bottom of the right bank: between 3 to 16 Lugeon units. The top of the right bank is more permeable: 35 Lugeon units (absorption of 28.5 l/mm/m under 9.2 bars of pressure).

According to the quite high intensity of the opening of the joints, and to the values of permeability a grouting of the rock seems necessary. On this part of the dam the permeability of the foundation is characterised by a fracture' permeability of the rock. So the grouting of the rock, could be carried out by vertical grout holes of 5 meters deep, under the excavation line. The distance between two holes could be 2.5 meters, and the grout could be a bentonite-cement grout. Contact grouting between concrete and rocky foundation should be carried out. Not far from the site, the possibilities to open a rock quarry (rockfill, sand, aggregate) seem restricted (lack of outcropping rock).

The lateral structures (two wings in tight and homogeneous earth) could rest, after stripping of the vegetal cover, directly on the clayey laterite weathering formations which form the skeleton of the banks. The possible sandy levels in the clayed superficial formations would be stripped.

At this level of study we don’t have information about the water content and the permeability coefficient of the lateritic lay. We can suppose that this formation is tight.

One of the solution of water tightness can be considered: putting a clayed upstream blanket after verification of the permeability coefficient of the local clay. In order to provide a good watertightness at the basis of the structure, an anchor trench at the upstream toe could be considered.

The materials for construction of these structures: tight clay, could be taken on the site, after quantitative and qualitative studies, in the loose weathering lateritic clayed layers. The impermeability of the materials and the compaction aptitude should be checked before beginning works.

These materials would be set by successive lifts (30 cm high), and compacted. The slope of the faces would be about 3 (H) for 1 (V).

(2) Power Station (Ref. Fig. 7.18)

One borehole (S1), one pit (P7) and one seismic refraction (SP3) have been completed near the power station location.

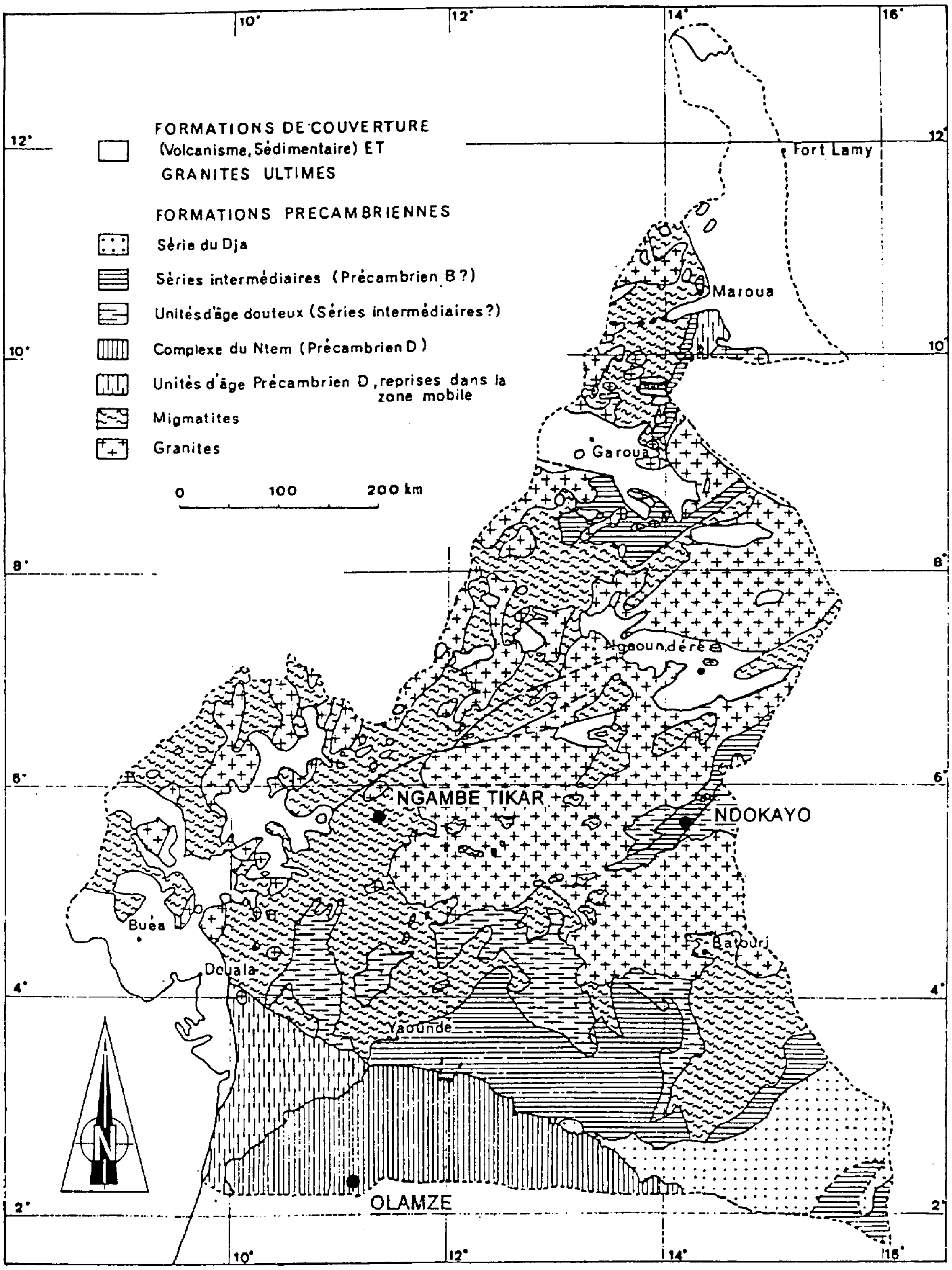
These geological investigations show the geological cross section:

- a few meters of superficial alluvial deposits; sandy clay and yellow-brown clay (5 meters to the borehole S1),
- about five meters of weathered rock, with locally debris of gneiss, very tight (absorption of 57 l/mm/m under 5.8 bars),

- a deep fresh rock: amphibolitic gneiss, around 10 meters of depth; the water test give a permeability of 13 Lugeon unit.

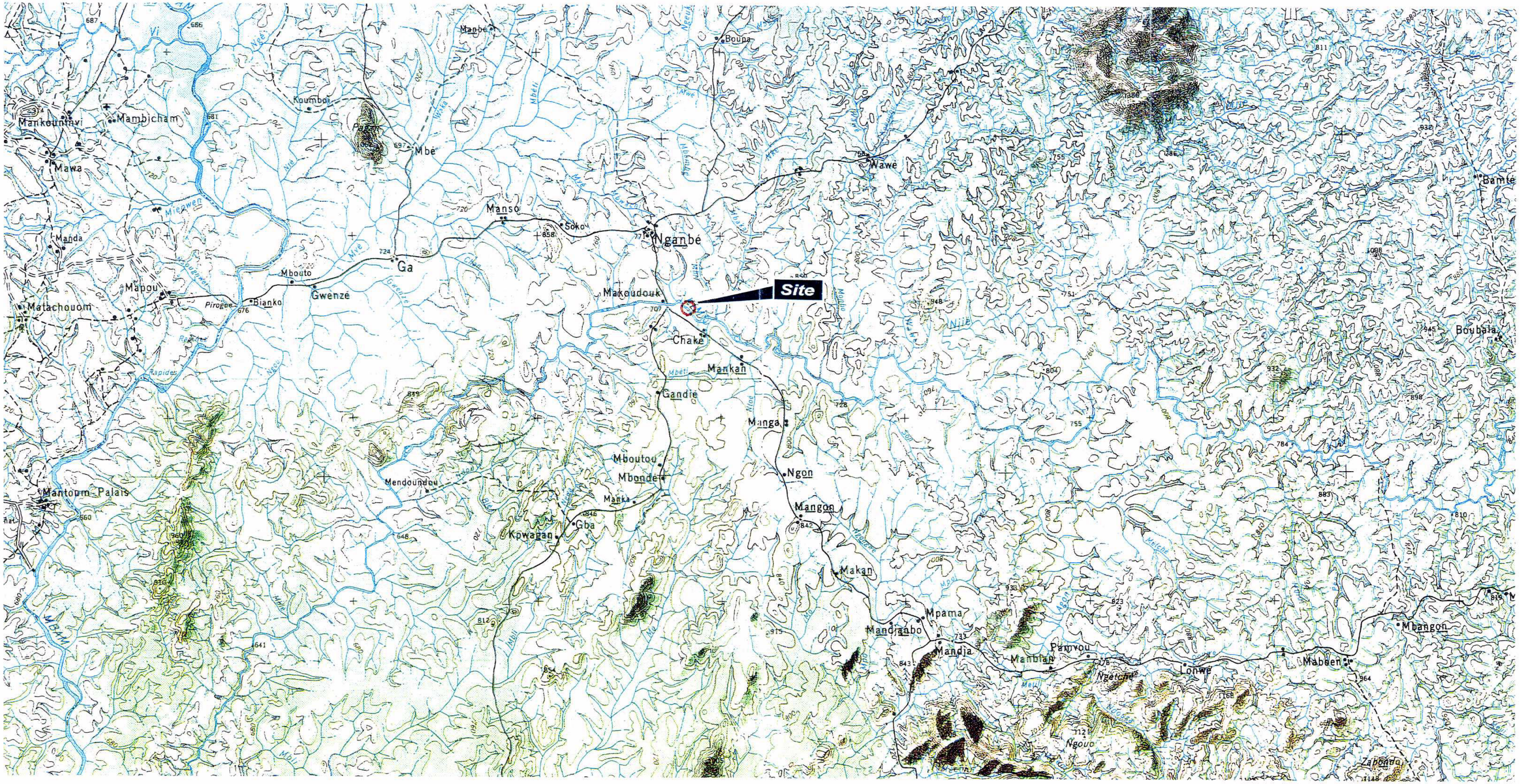
In this area, on the right bank, the geological investigations show the possibility to found the rock (in the area of the borehole S1, weathered to 5 m, and fresh to 10 m) enough deep, the setting out of the power station seem a little difficult on the right bank.

The conditions of the excavation level could be considered to be bad superficial important loose deposits, and ground water near the river level, so the hydrogeological and foundation conditions should be defined in advance with precision.



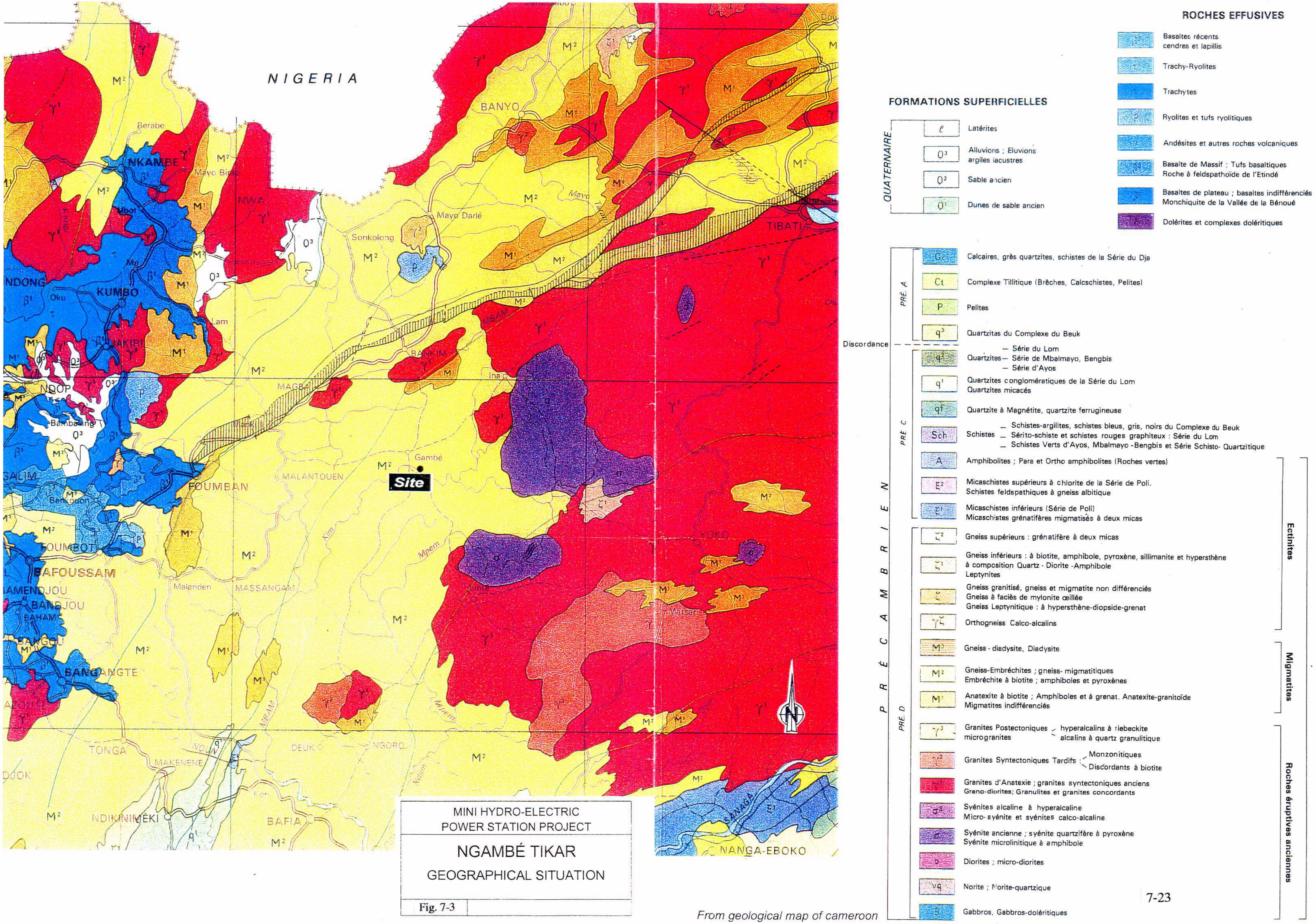
From : Memoire du B.R.G.M. n°92 (R. Bessoles et al. 1977)

MINI HYDRO-ELECTRIC POWER STATION PROJECT	
GEOLOGICAL MAP OF CAMEROON WITH THE LOCATION OF THE SITES UNDER STUDY	
Fig.7-1	



MINI HYDRO-ELECTRIC POWER STATION PROJECT
NGAMBÉ TIKAR
GEOGRAPHICAL LOCATION
Fig. 7-2

Scale 1/200 000



MINI HYDRO-ELECTRIC POWER STATION PROJECT

NGAMBÉ TIKAR

GEOGRAPHICAL SITUATION

Fig. 7-3

From geological map of cameroon

MINI HYDRO–ELECTRIC POWER STATION PROJECT

NGAMBE TIKAR SITE

GEOLOGICAL INVESTIGATIONS AND GEOLOGICAL MAP

Fig. 7-4A

MINI HYDRO-ELECTRIC POWER STATION PROJECT

NGAMBE TIKAR SITE

GEOLOGICAL CROSS SECTION

INTAKE-HEADRACE-POWER STATION

Fig. 7-5

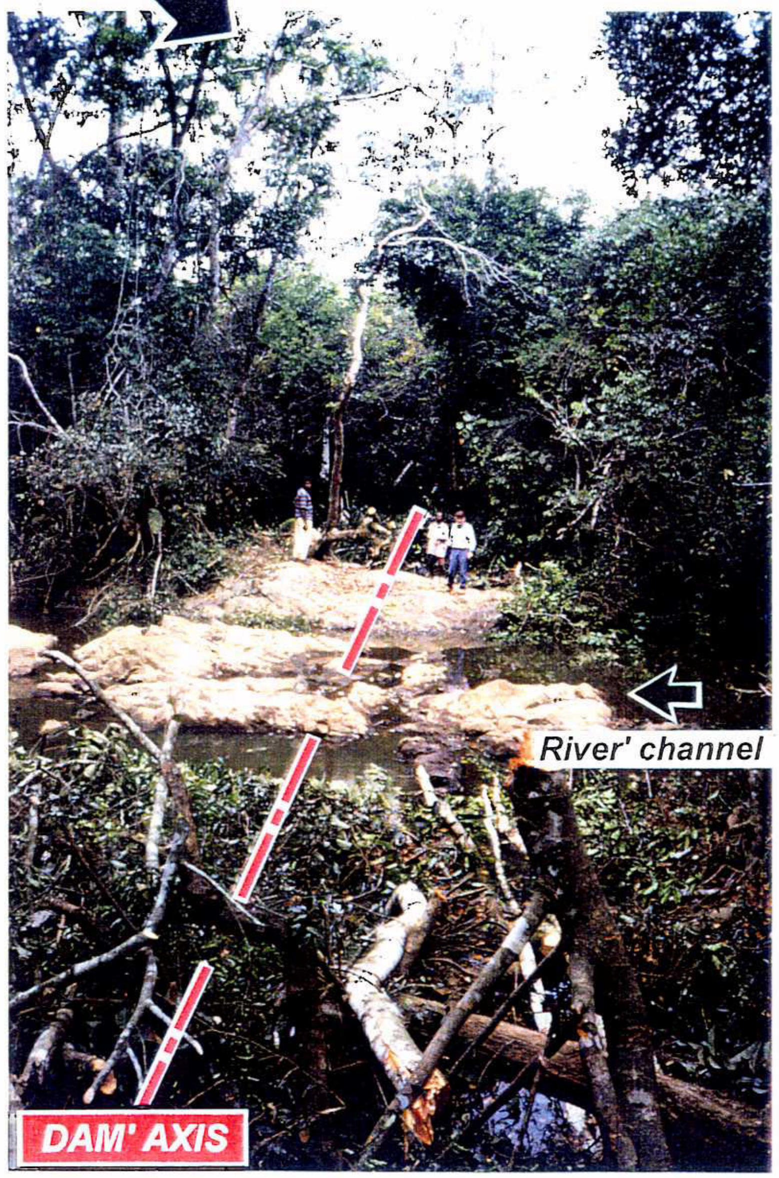
MINI HYDRO-ELECTRIC POWER STATION PROJECT

NGAMBE TIKAR SITE

GEOLOGICAL INVESTIGATIONS AND GEOLOGICAL MAP

Fig. 7-4B

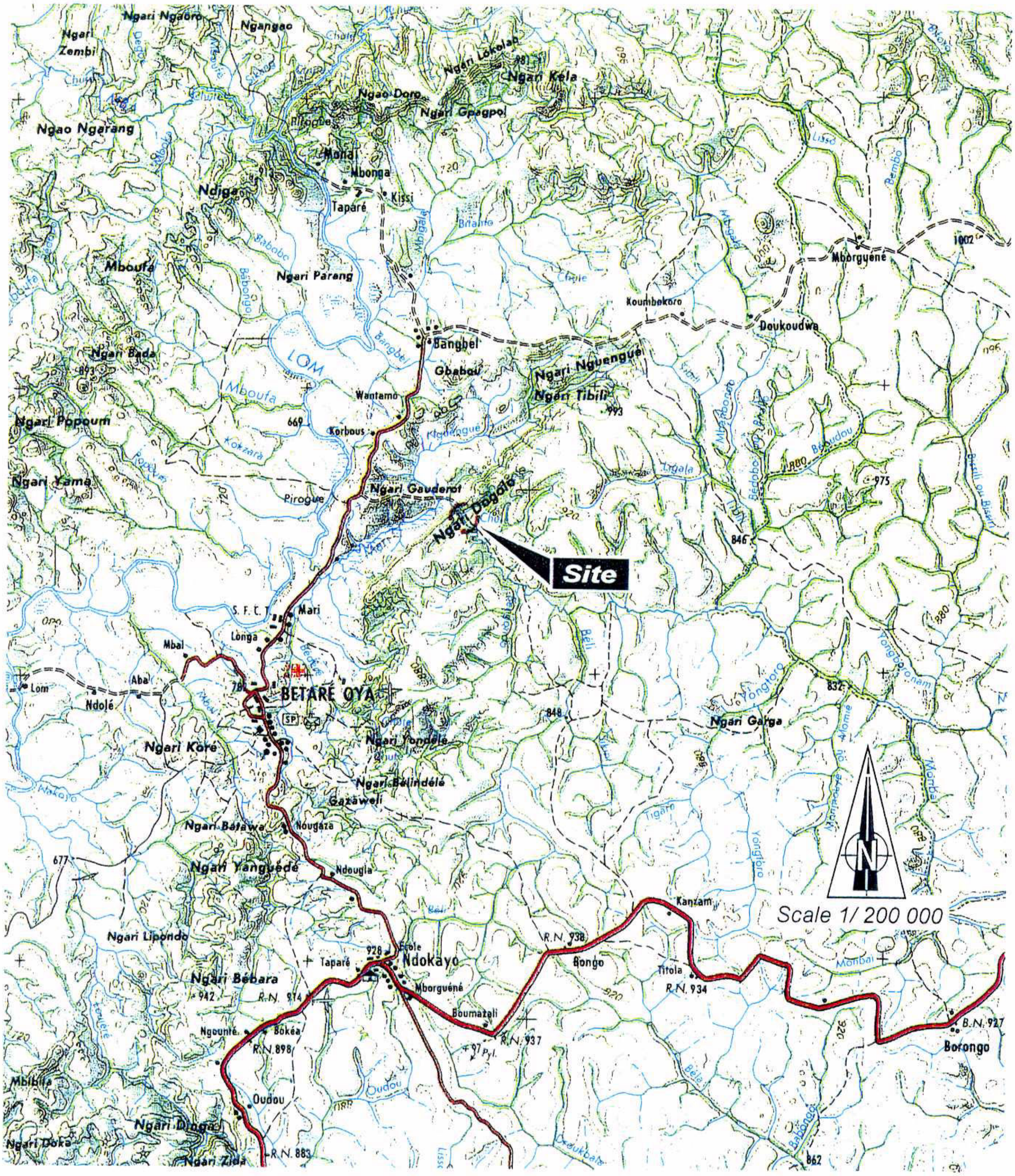
Upstream view



Left bank

Downstream view

MINI HYDRO-ELECTRIC POWER STATION PROJECT	
NGAMBÉ TIKAR PHOTOGRAPHIC ILLUSTRATIONS	
Fig. 7-6	

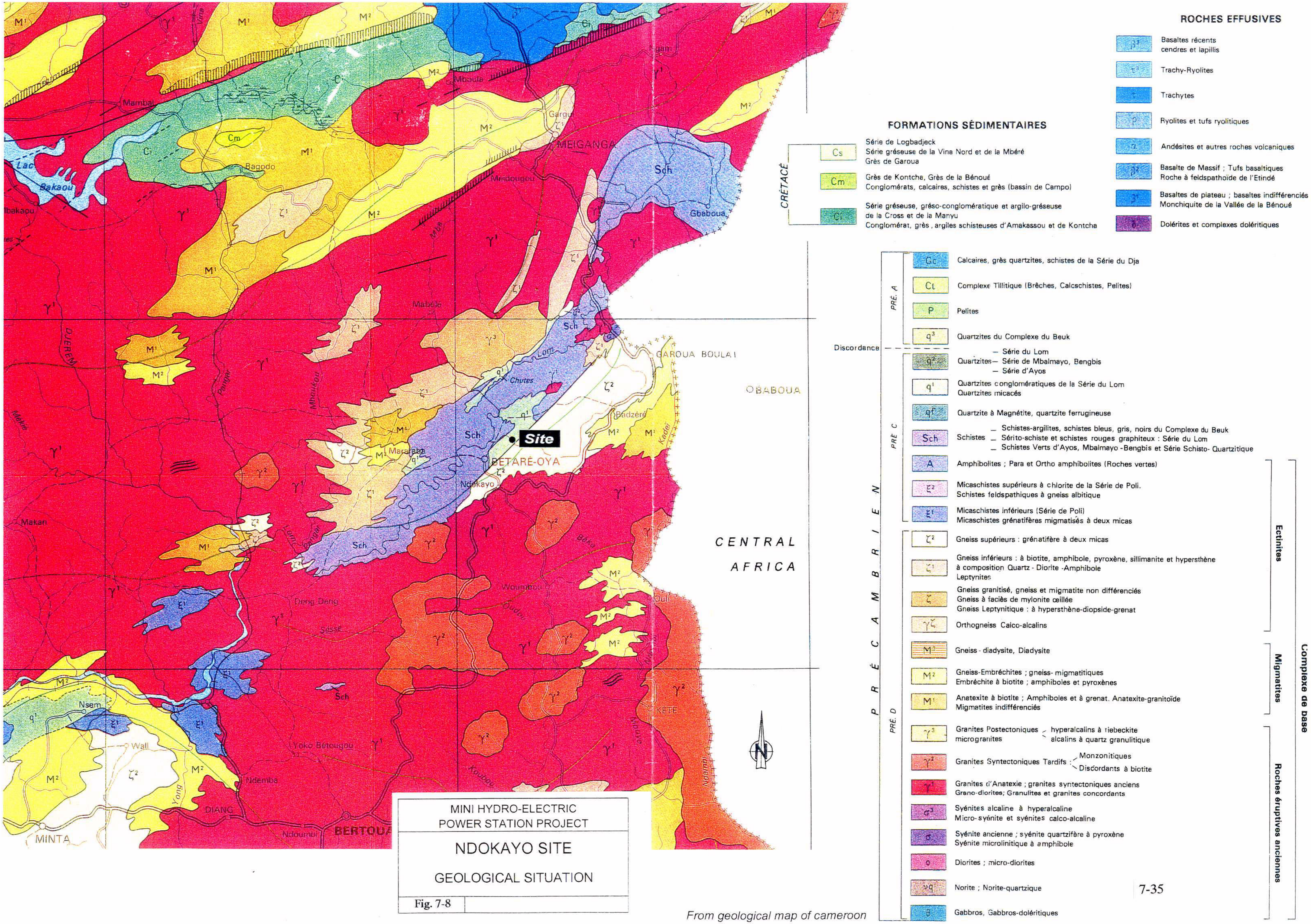


MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NDOKAYO SITE

GEOGRAPHICAL LOCATION

Fig. 7-7



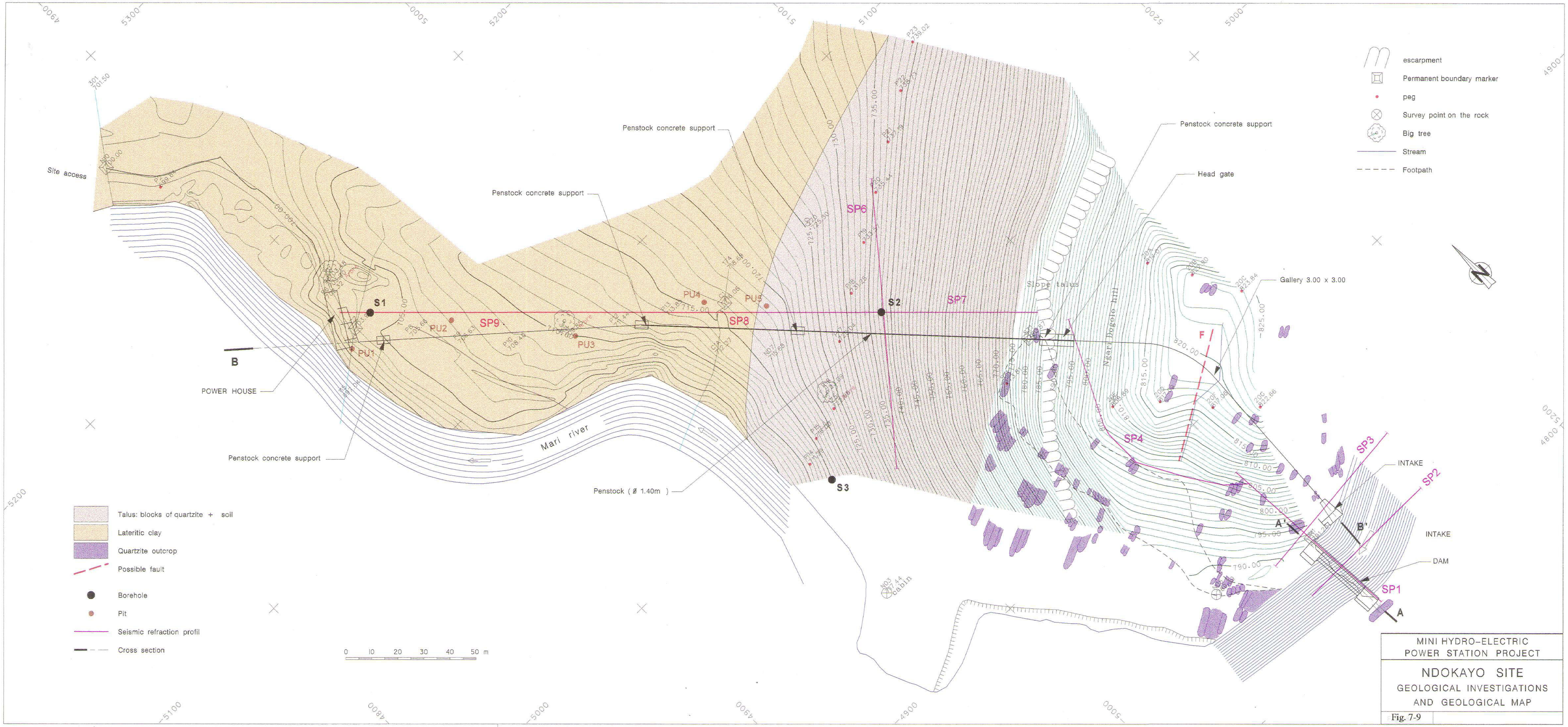
MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

GEOLOGICAL SITUATION

Fig. 7-8

From geological map of cameroon

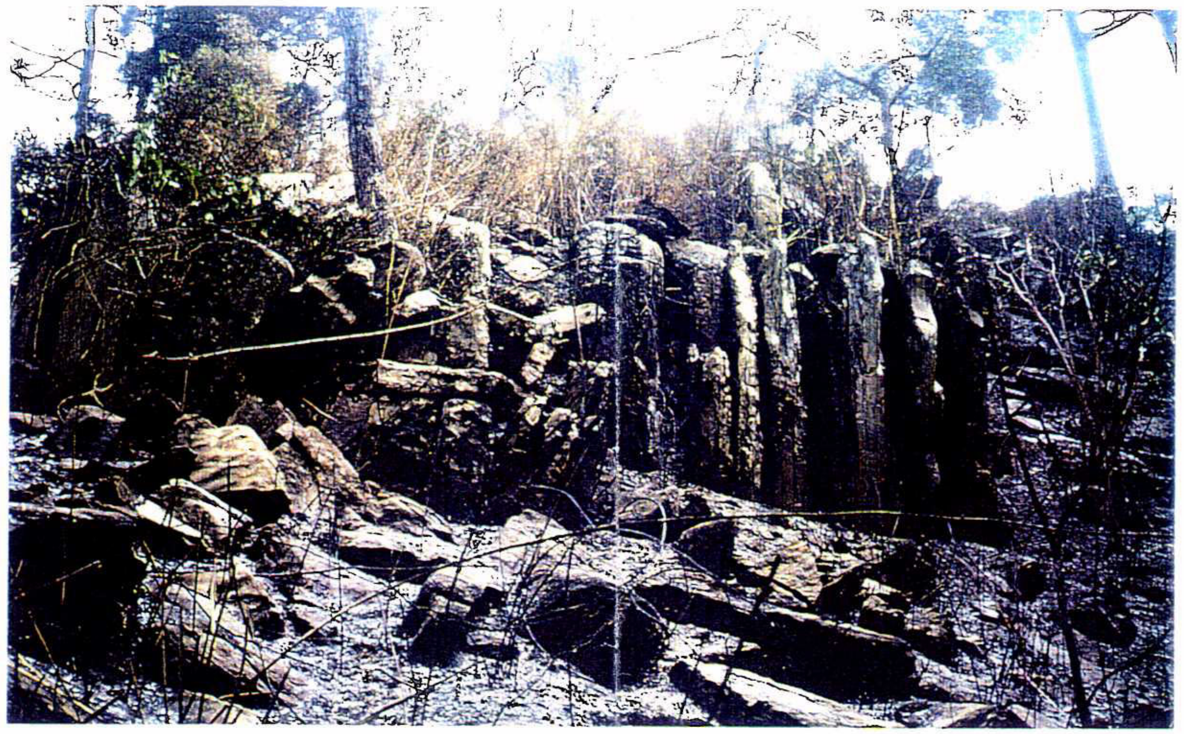


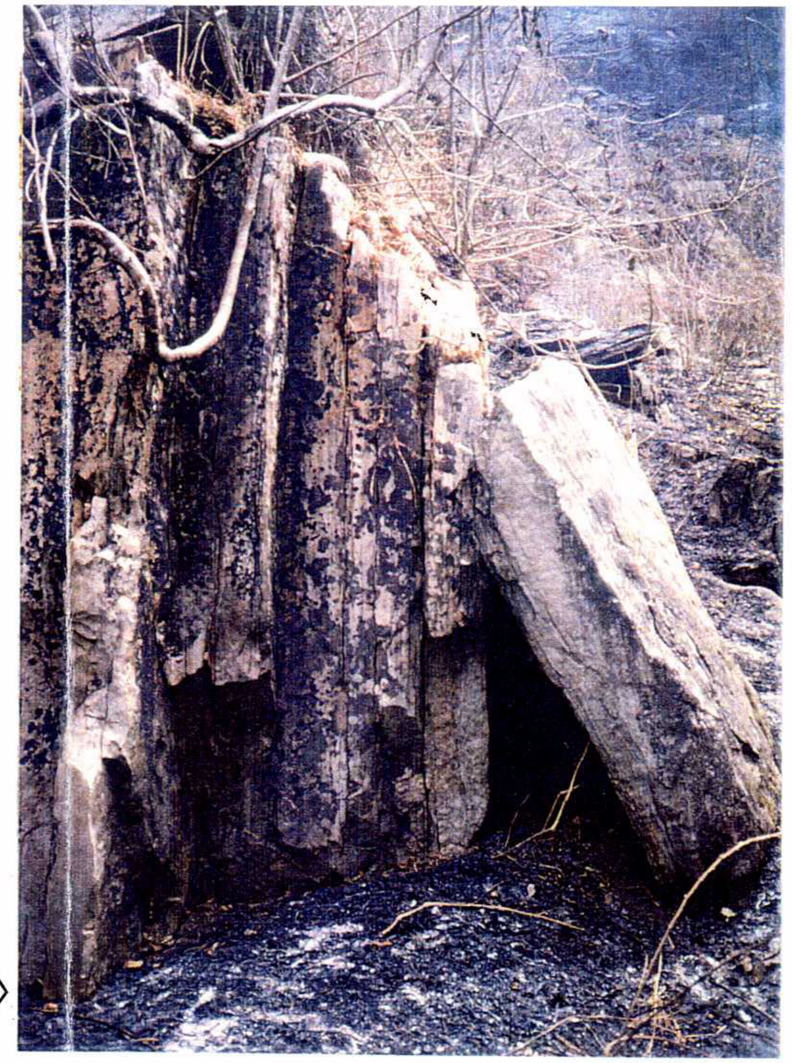
MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE
GEOLOGICAL INVESTIGATIONS AND GEOLOGICAL MAP

Fig. 7-9

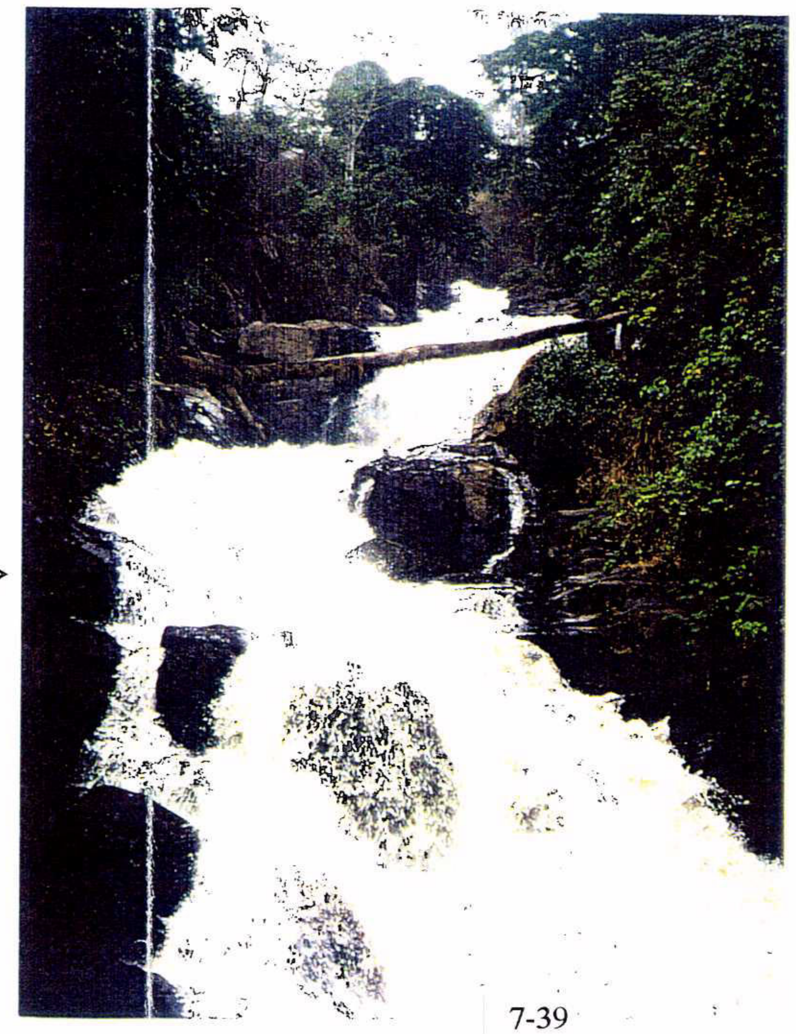
Outcrops of quartzites
(with vertical fracturations)



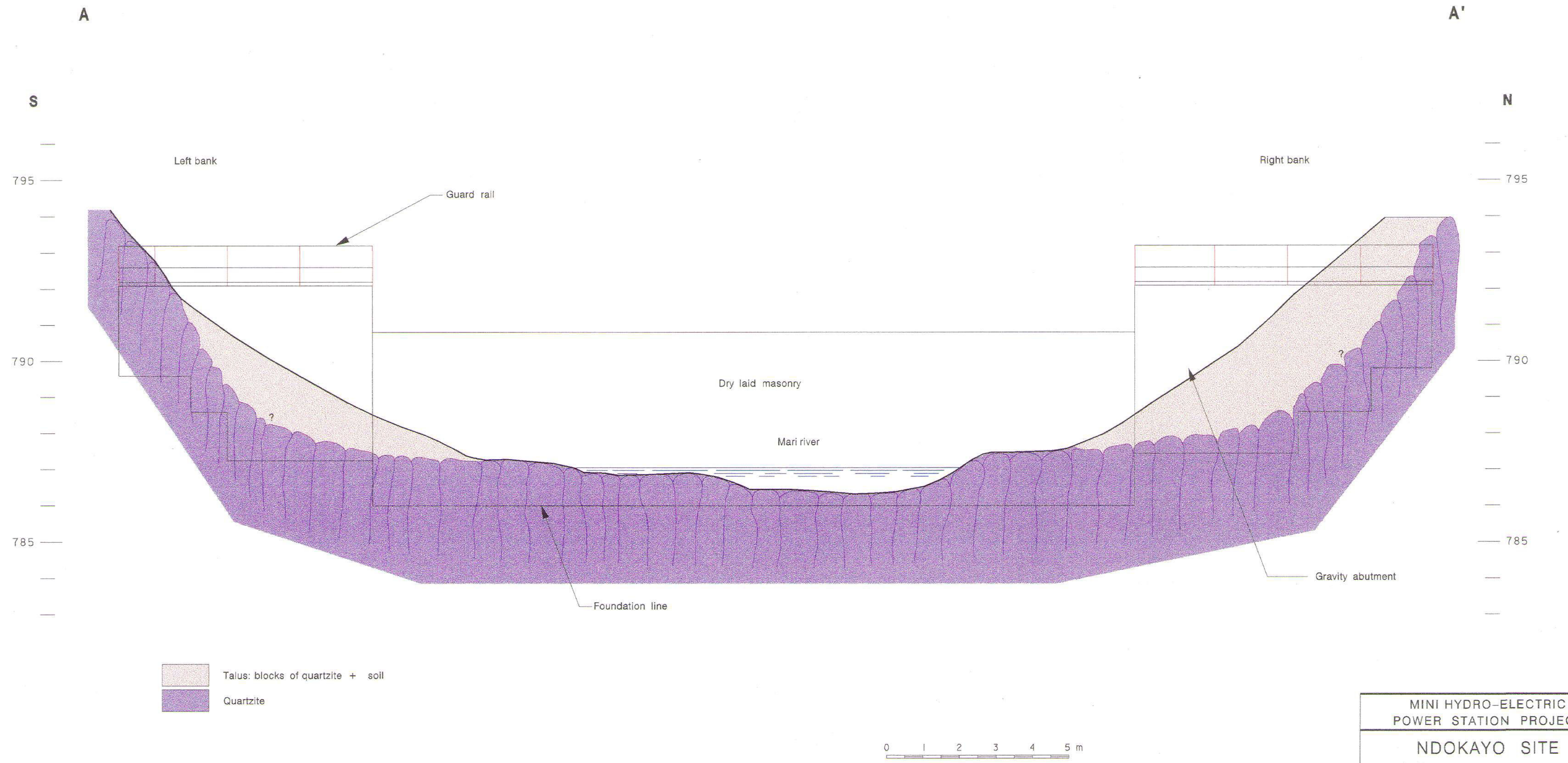


Outcrops of quartzites
(Detail)

Water falls



MINI HYDRO-ELECTRIC POWER STATION PROJECT
NDOKAYO SITE
PHOTOGRAPHIC ILLUSTRATIONS
Fig. 7-10

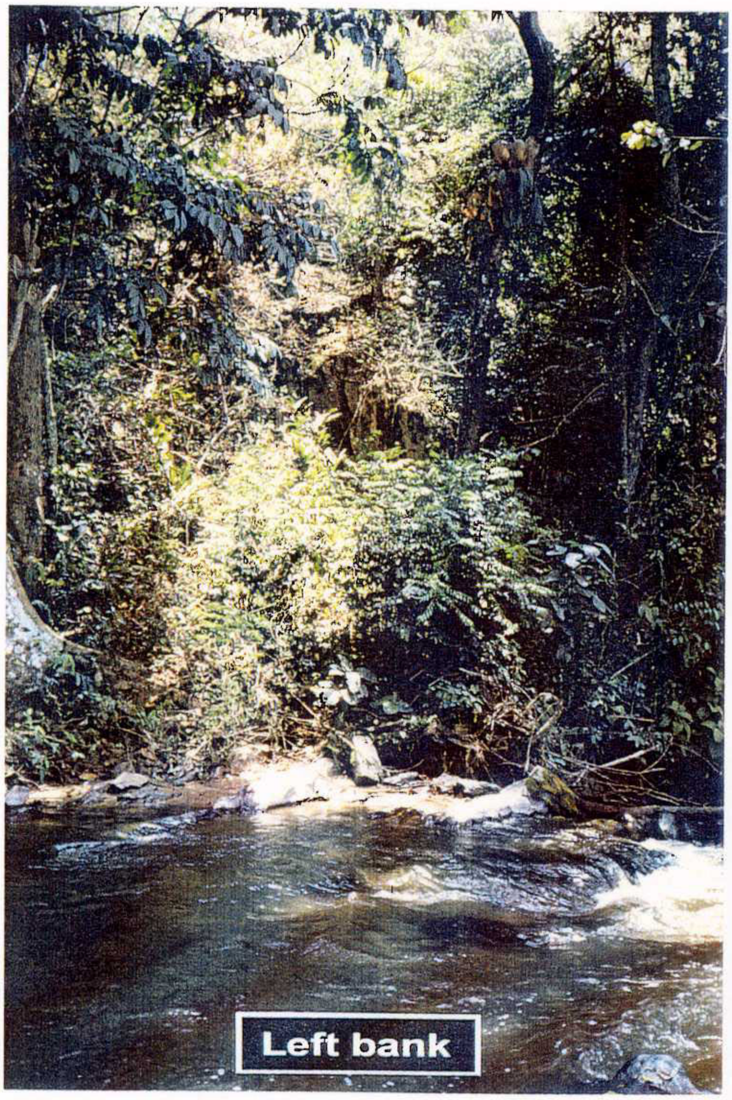


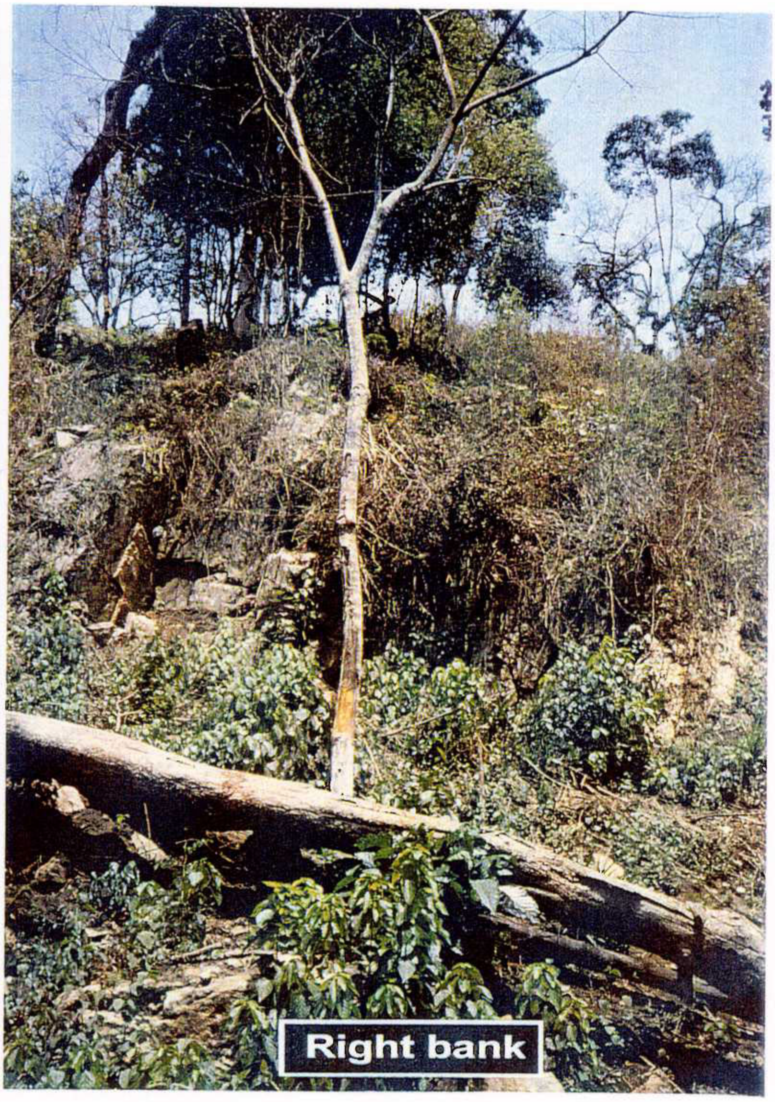
MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

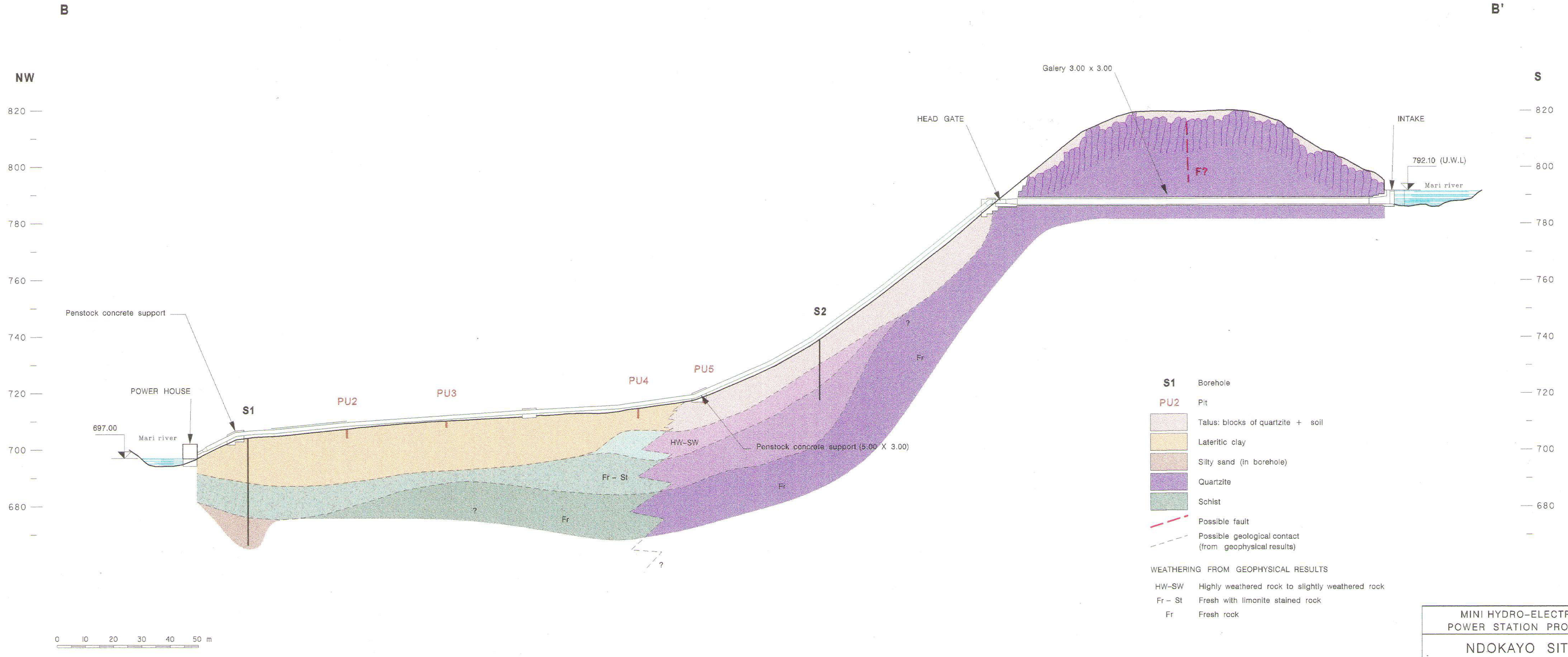
GEOLOGICAL CROSS SECTION DAM SITE

Fig. 7-11





MINI HYDRO-ELECTRIC POWER STATION PROJECT	
NDOKAYO SITE	
PHOTOGRAPHIC ILLUSTRATIONS - DAM SITE -	
Fig. 7-12	



MINI HYDRO–ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

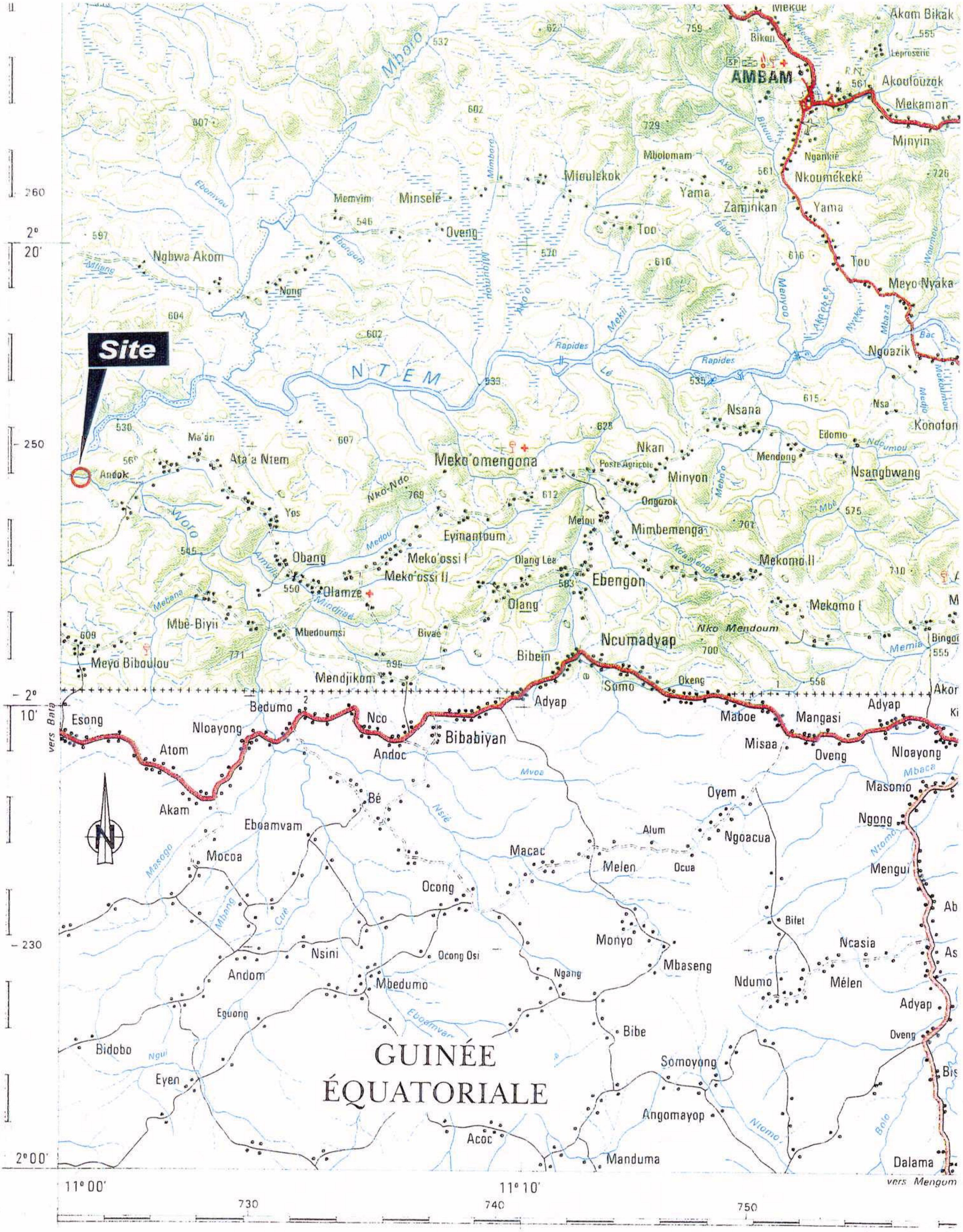
GEOLOGICAL CROSS SECTION PENSTOCK AND POWER STATION

Fig. 7-13

Penstock area

Details of the slope with mass of fallen quartzites

MINI HYDRO-ELECTRIC POWER STATION PROJECT	
NDOKAYO SITE	
PHOTOGRAPHIC ILLUSTRATIONS - PENSTOCK AREA - RIGTH BANK HILL	
Fig. 7-14	

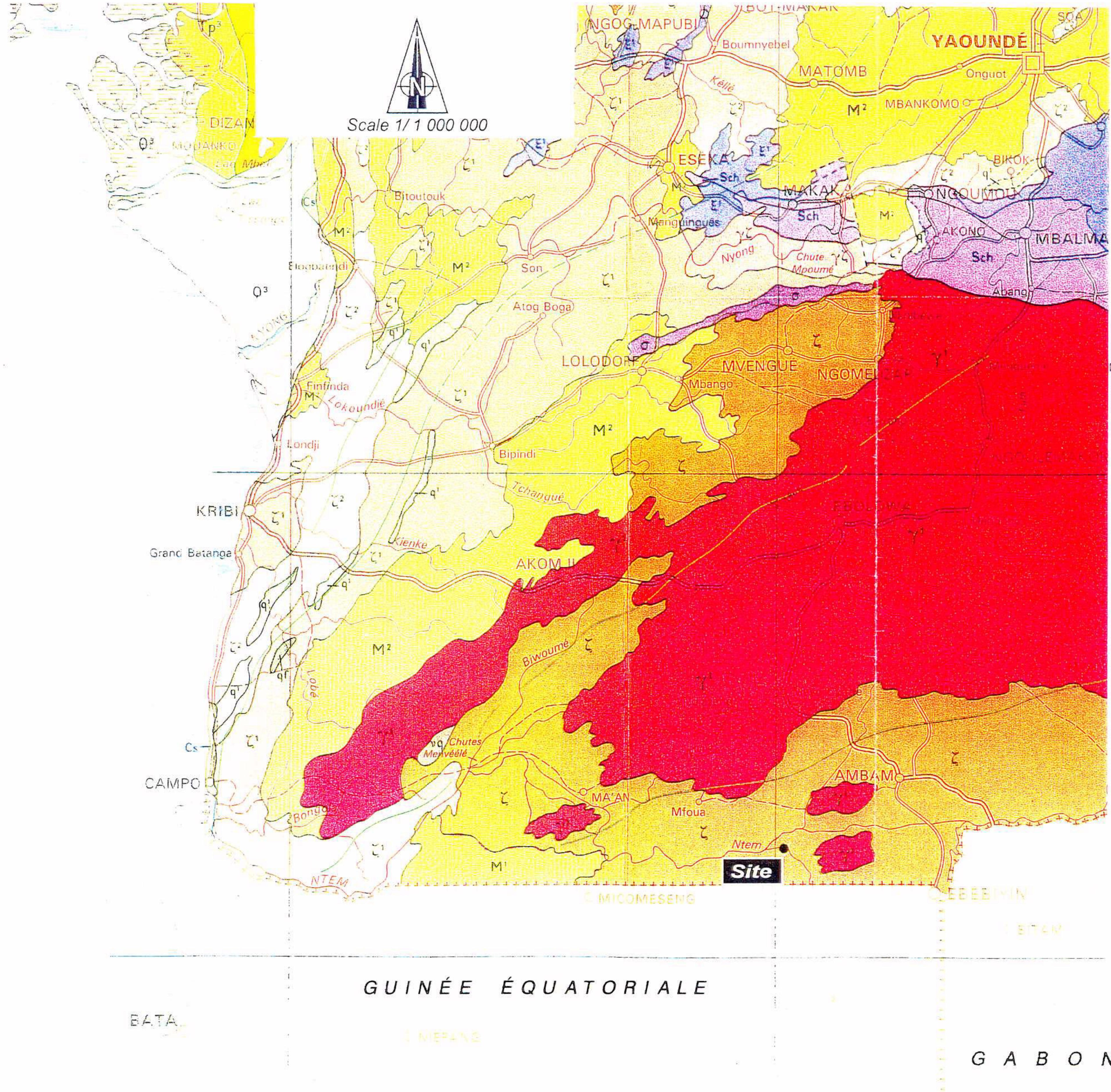


MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZÉ

GEOGRAPHICAL LOCATION

Fig. 7-15



QUATERNAIRE

ℓ	Latérites
Q³	Alluvions ; Eluvions argiles lacustres
Q²	Sable ancien
Q¹	Dunes de sable ancien

TERTIAIRE

T3	Tertiaire avec intercalations basaltiques
T	Tertiaire indifférencié
Tp³	Argile, sable
Tp²	Grès calcaires ou marneux calcaires gris, marnes
Tp¹	Grès ferrugineux marnes noires grès marneux à lignite

PRÉCAMBRIEN

PRÉ. A

Gc	Calcaires, grès quartzites, schistes de la Série du Dja
Ct	Complexe Tillitique (Brèches, Calcschistes, Pelites)
P	Pelites
q³	Quartzites du Complexe du Beuk

Discordance

PRÉ. C

q²	Quartzites – Série du Lom – Série de Mbalmayo, Bengbis – Série d'Ayos
q¹	Quartzites conglomératiques de la Série du Lom Quartzites micacés
qf	Quartzite à Magnétite, quartzite ferrugineuse
Sch	Schistes – Schistes-argilites, schistes bleus, gris, noirs du Complexe du Beuk – Sérito-schiste et schistes rouges graphiteux : Série du Lom – Schistes Verts d'Ayos, Mbalmayo -Bengbis et Série Schisto- Quartzitique
A	Amphibolites ; Para et Ortho amphibolites (Roches vertes)
ξ²	Micaschistes supérieurs à chlorite de la Série de Poli. Schistes feldspathiques à gneiss albitique
ξ¹	Micaschistes inférieurs (Série de Poli) Micaschistes grénatifères migmatisés à deux micas

PRÉ. D — Complexe de base

Ectinites

ζ²	Gneiss supérieurs : grénatifère à deux micas
ζ¹	Gneiss inférieurs : à biotite, amphibole, pyroxène, sillimanite et hypersthène à composition Quartz - Diorite -Amphibole Leptynites
ζ	Gneiss granitisé, gneiss et migmatite non différenciés Gneiss à faciès de mylonite œillée Gneiss Leptynitique : à hypersthène-diopside-grenat
γζ	Orthogneiss Calco-alcalins

Migmatites

M³	Gneiss - diadysite, Diadysite
M²	Gneiss-Embréchites ; gneiss- migmatitiques Embréchite à biotite ; amphiboles et pyroxènes
M¹	Anatexite à biotite ; Amphiboles et à grenat. Anatexite-granitoïde Migmatites indifférenciés

Roches éruptives anciennes

γ³	Granites Postectoniques microgranites – hyperalcalins à riebeckite – alcalins à quartz granulitique
γ²	Granites Syntectoniques Tardifs : – Monzonitiques – Discordants à biotite
γ¹	Granites d'Anatexie ; granites syntectoniques anciens Grano-diorites; Granulites et granites concordants
σ³	Syénites alcaline à hyperalcaline Micro- syénite et syénites calco-alcaline
σ	Syénite ancienne ; syénite quartzifère à pyroxène Syénite microlinitique à amphibole
δ	Diorites ; micro-diorites
νq	Norite ; Norite-quartzique
θ	Gabbros, Gabbros-doléritiques

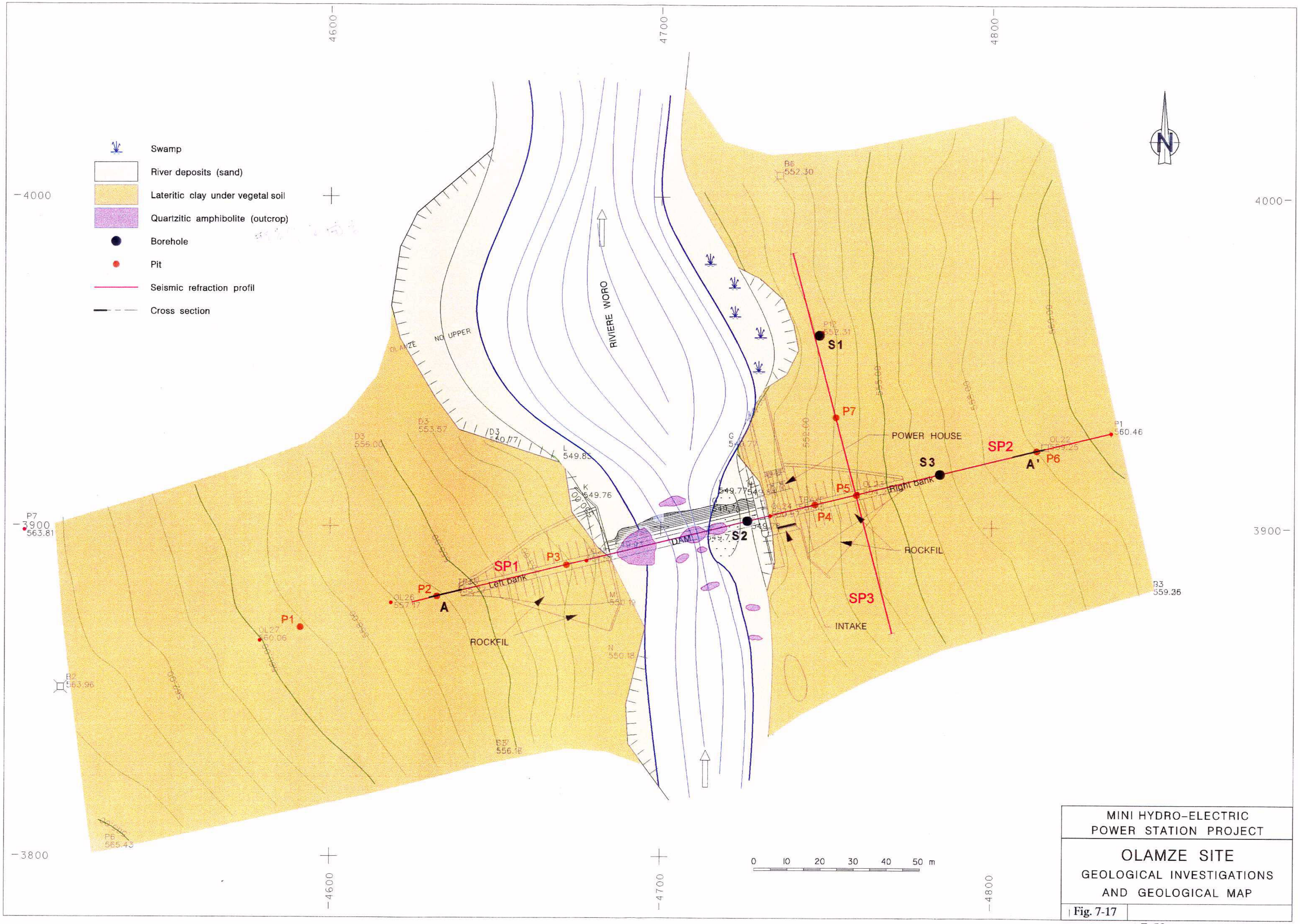
FROM GEOLOGICAL MAP OF CAMEROON

MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZÉ

GEOLOGICAL SITUATION

Fig. 7-16

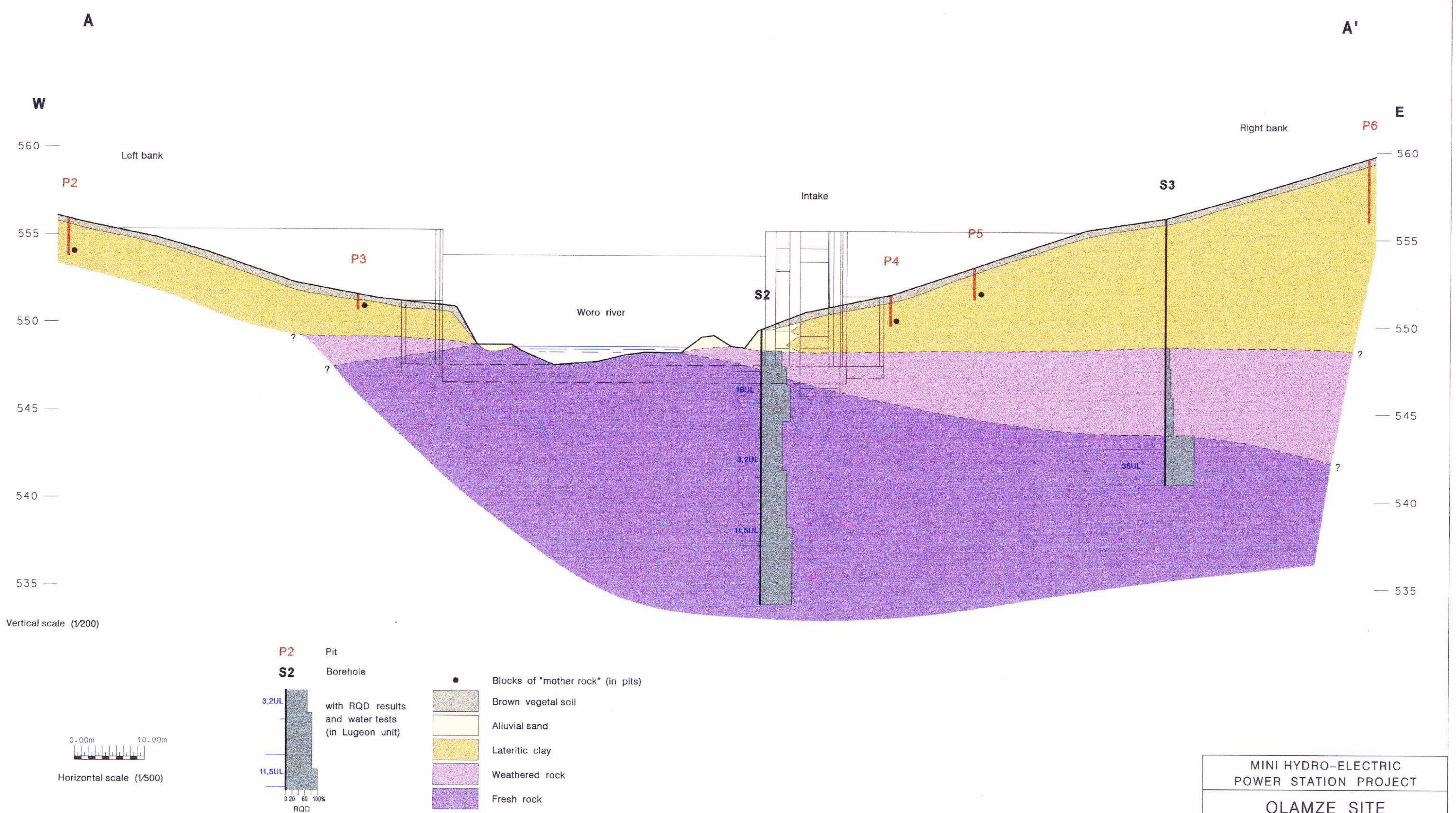


MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZE SITE

GEOLOGICAL INVESTIGATIONS AND GEOLOGICAL MAP

Fig. 7-17



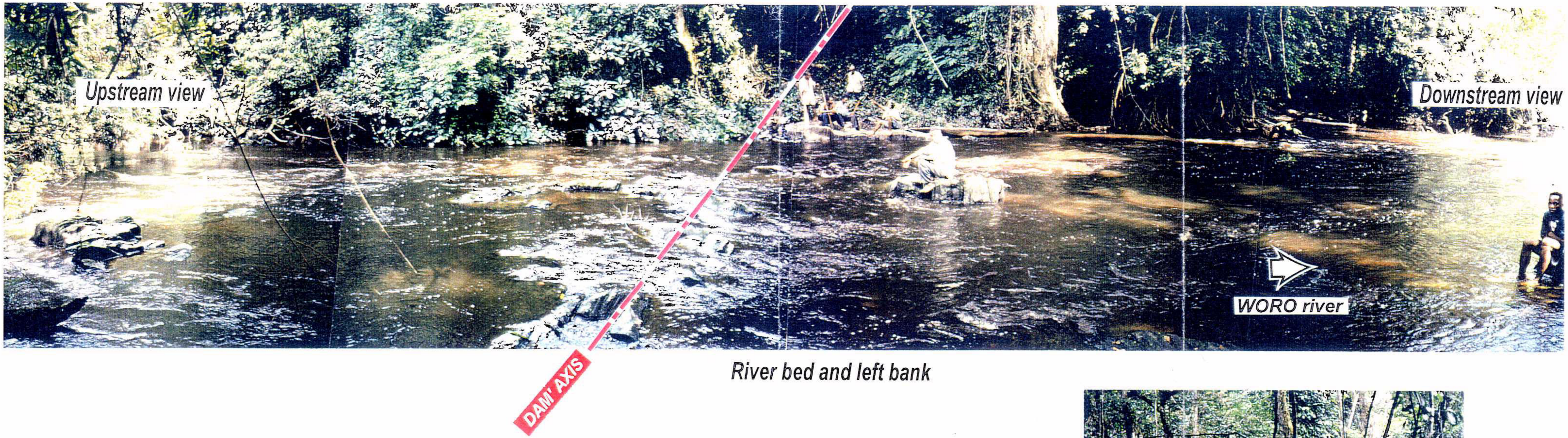
MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZE SITE

GEOLOGICAL CROSS SECTION

DAM SITE

Fig. 7-18



River bed and left bank

River bed and right bank

MINI HYDRO-ELECTRIC POWER STATION PROJECT	
OLAMZÉ	
PHOTOGRAPHIC ILLUSTRATIONS	
Fig. 7-19	

CHAPTER 8. POWER GENERATION PROJECT

Chapter 8 Power Generation Project

8.1 Ngambe-Tikar Site

8.1.1 Outline

As the dam cannot be very high since the slope of the river is relatively low, the head can hardly be higher than 7 m. The only parameter that can be modified is the design flow. It must be chosen according to the hydrology (minimum available inflow) and the future peak demand.

The choice of 10 m^3/s discharge is the most relevant one because it enables the network to be supplied during peak hours, without requiring a prohibitive amount of investment.

The profitability of the scheme depends on the possibility of supplying the energy generated during off-peak hours. The Hazim sawmill represents an interesting opportunity. It is equipped with several diesel generating sets that it uses for its own needs and whose cost price is high. Negotiating an agreement with them would ensure the profitability of the power station and allow the sawmill to economise on diesel oil.

The project includes: a dam, a water intake, a headrace canal, a power house, and a channel. The 6.9 m net head (7 m – 0.10 m of head loss) and the 10 m^3/s flow rate generate a capacity of 530 kW. In order to optimise the project and in consideration of the low head, all the works have been dimensioned in order to reduce the head loss and the costs to the maximum. For example, masonry being the least expensive way of building dams, it is used whenever possible.

The dam is a masonry structure on a rocky weir creating a head.
As the net head is low, the scheme is designed so as to minimise head losses as much as possible. To do this, we tried to reduce the length of the plant's water supply system by building an open-air canal terminating at a starting chamber and a discharge channel into the river.

8.1.2 Civil Structures

8.1.2.1 Dam

The dam closes the water flow of several channels with the aid of rock out-crops, which explains the layout of its various sectors of 517 m in total length. A 50 cm modulation is enough to create a volume of 45000 m^3 (0.5 m x 9.10^4 m^2) and to ensure good daily operation during low flow. This explains the low height of the dam. The height of the dam therefore varies between 50 cm and 2 m above the outcropping weir, so that the elevation of the overtopping part of the weir is at an altitude of 712.0 m over its whole length.

The 100-year flood is approximately 600 m^3/s, which creates a 70 cm increase of the water level above the weir.

Three bottom gates (1 m x 1 m) will be installed at the 3 locations where the rocky weir is the lowest. The force of the water discharged through the gates is then used to clean the trapped sand and gravel deposits.

A screen of approximately 60 m will be placed 200 m upstream of the water intake. It will divert the largest scrap from the canal inlet. Its position and angle have been chosen so as to discharge the waste easily and avoid intake closure.

8.1.2.2 Water Intake

The water intake is in masonry, and it connects the dam to the headrace canal. It is intended to limit head losses, to protect the canal thanks to screens and to provide a hydraulic insulation of the canal during possible repairs.

The elevation of the bottom of the intake is as low as possible, i.e. 710.0 m. It must however be located 50 cm above the river bed to prevent too much sand and gravel from being introduced into the canal. The stone trap located in the middle of the canal has the same function.

In normal conditions, the depth of water at the entrance of the weir is 2 m (712 - 710). In order to obtain a water velocity lower than 0.7 m/s for a flow rate of 10 m^3/s, one could choose an intake length of 8 m. This velocity limit is intended to prevent sand and gravel from entering the canal. This length is divided into 4 parts of 2 m each so that the stoplogs in place can be more easily installed and handled. The 4 stoplogs are supported by 5 pillars 1 m wide each for a total width of 13 m.

The upper deck of the intake is at the 713.00 m level, i.e. 30 cm above the highest water level (calculated from the 100-year flood).
The angle in the plane of the side walls is approximately 7° in order to minimise head losses, which gives a total length of 25.50 m to join the intake and the canal widths.

8.1.2.3 Headrace Canal

The headrace canal is an approximately 607 m long and 5 m wide masonry structure. Its location is intended to minimise the volume of masonry, excavation and back fill. Such dimensions have been chosen to optimise the cost of the canal, in consideration of the head loss which increases with water velocity. With a Strickler coefficient of 75, the head loss is 10 cm for a flow rate of 10 m^3/s (1 m/s).

The crest of the canal walls is at the 712.85 m level, which represents a 15 cm freeboard during the 600 m^3/s 100-year flood. The bottom slope is approximately 0.05%, the canal height varies between 2.85 m (712,85 - 710) and 3.15 m.

8.1.2.4 Powerhouse

The power house is located so as to minimise the canal length and avoid the construction of a penstock. On the other hand, in this general design, the power house is nearly underground and requires significant excavation, which however remains less expensive than the installation of a penstock.
Normally, the water level upstream from the power station is 705 m, but one must consider that it decreases by 70 cm during low flow periods. The lowest water level is therefore estimated at 704.30 m. These values are not the result of a comprehensive and accurate investigation, and can therefore be examined prior to the definite design, so that the level of the turbine axis is deduced from the preceding values and from the suction head.

The profile of the turbine, with a small pipe on its upstream side, makes it possible to avoid building a deep reservoir that would require large reinforced concrete walls.
The power house is a 6 m large and 13 m long structure, mainly in reinforced concrete. These dimensions are those required to receive the two turbines, the electrical installations, the generator and the alternating current generator. The

transformer is located in an adjoining room at a higher elevation in order to minimise excavations.

8.1.2.5 Tailrace Channel

A 45 m long tailrace channel is required to reach the river. It is a 5 m wide masonry structure which minimises the head loss in order to obtain the best net head.
The top of the channel walls is at an elevation of 706.00 m, which corresponds to the highest water level downstream of the station. This level is to be defined more precisely in the definite design.

The channel is extended by a small wall whose top is also at the 706.00 m level. It was designed to prevent sand and gravel deposits downstream of the power station during floods. In this way, it prevents the river bed level from rising and the head from decreasing.

8.1.3 Main Electromechanical Equipment

8.1.3.1 Selection of Main Equipment

(1) Turbine

Considering the 7 m gross head, only a Kaplan turbine can be used. The characteristics of the supply system, and essentially the presence of a starting chamber which should not be oversized, require the installation of the turbine at the end of the conduit: An S turbine with an upstream elbow should suit this configuration perfectly.

The analysis of the individual and industrial demand shows that the peak capacity is approximately 550 kW, i.e. a design flow of 10 m^3/s.
The number of units being to be limited to two in order to minimise the investment costs, the nominal flow-rate of the turbine has been chosen equal to 5 m^3/s.

The minimum flow-rate must be approximately 40% of the nominal flow-rate, i.e. 2 m^3/s, in order to maintain acceptable results. During very low flow periods, the flow rate decreases to approximately 1.7 m^3/s. In this case, the reservoir may be used as lockage water to ensure evening peak demand.

It should be noted that the 10 m^3/s flow rate is ensured approximately 260 days per year. One may think that the site is under-equipped, but considering the demand, this is not the case.
The safety element of the turbine is made up of a downstream flat valve.

(2) Alternating current generator

The alternating current generator is a 3-phase type generator rotating at a synchronous speed. The power factor chosen is 0.85.
It is standard make, i.e. of minimum cost, but with an efficiency of the order of 90%.

(3) Unit transformer

The transformer, common to the two units, is installed in a room next to the power station.

8.1.3.2 Essential Characteristics of Main Equipment

Turbine

Type	Kaplan S with upstream elbow
Quantity	2
Position of the axis	Horizontal
Nominal net head	6.9 m
Minimum net head	6.7 m
Nominal unit flow rate	5 m^3/s
Minimum unit flow rate	2 m^3/s
Rotational speed	600 rpm
Rated power	295 kW

Alternating current generator

Type	3-phase alternating synchronous
Quantity	2
Rotational speed	1000 rpm
Rated power	267 kW - 315 kVA
Frequency	50 Hz
Voltage	400 V
Power factor	0.85

Transformer

Type	Interior 3-phase, oil, air-cooled
Quantity	1
Rated power	630 kVA
Voltage	400 V / 30 kV

Total installed capacity of the power station : 530 kWh

8.2 Ndokayo Site

8.2.1 Outline

The hydrology, the power demand and the natural layout of the site are the 3 factors which count in the project design. Another element which must be taken into account is the best use of the capacities of the site.

The 6 m^3/s design flow rate and the 91.20 m net head make it possible to install 4500 kW. Such a dimensioning can meet power demand 93% of the time (during peak hours) as of 2010, and will make the best use of the hydrological capacities of the site, considering the dry period. Given the site layout, the 91.20 m net head is the best that can be obtained.

A 34 m wide weir, a 15 m water intake upstream of the weir, a 133 m long tunnel, a 306 m penstock and a power station comprising 3 turbines are required to operate the site.

Francis turbines, using hydraulic power, will have a maximum capacity of 4500 kW for a production capacity of 30 GWh.

8.2.2 Civil Structures

8.2.2.1 Dam

The dam is a masonry dam of a total width of approximately 34 m that includes a 21 m long overtopping section.

During the low flow period, a volume of 90 000 m^3 is required for a daily optimal control. This can be obtained by increasing the height of the weir. This solution, which makes it possible to increase power generation during low flow periods, is the most economical. Given the upstream slope and the valley width (27 m at the weir), the control volume may be obtained by modulating the water height over 1.20 m.

Since the tunnel 2.20 m in diameter must always be under pressure, the overtopping section of the weir must be located 3.60 m (2.20 + 1.20 +0.20 m for safety) above the bottom of the tunnel.
The 100-year flood is approximately 60 m^3/s, which corresponds to a 1.30 m increase of the water level above the weir. This level then corresponds to the position of the abutments.

The dam is supported by the bedrock which was found at an altitude of 786.50 m and the spillway crest is positioned at an altitude of 790.80 m. As already mentioned in Section 1, the crest height is directly linked to the modulation height. Since the data regarding the upstream reservoir is not precise, the weir height could be modified following more accurate investigations prior to the definite design.

8.2.2.2 Water Intake

Given the position of the tunnel, a lateral intake upstream of the dam seems preferable and is not an expensive solution.
The intake has been calculated in order to connect the reservoir, whose level may decrease by 1.20 m below the crest level, to the tunnel which must always be under pressure. The intake is a reinforced concrete structure whose top is at the level of the highest water level, i.e. 792.10 m.

The bottom of the intake is at 787.20 m. The weir setting being directly linked to intake elevation, this value was therefore chosen to be as low as possible. However, the intake must be high enough to limit the intrusion of sand and gravel into the tunnel.

The width is 3.80 m (1.90 x 2) and the height inside the intake varies between 2.40 m and 3 m so that the inlet velocity is always lower than 0.66 m/s. This velocity limit prevents sand and gravel from being sucked and washed into the intake.

This width is divided into two parts because it is preferable to handle two stoplogs 1.90 m wide each rather than a single 3.80 m stoplog. The total length is 5 m including the walls.
A screen is installed at the inlet. Its cleaning frequency will depend on the inflow of floating debris.
The water intake is 9 m long. This results from the choice of the angle of the side walls which is 7°. Such a slope makes it possible to reduce head losses to the

maximum. The length then makes it possible to link the total 5 m width to the 3 m width of the tunnel, while maintaining the pressure.

8.2.2.3 Headrace Tunnel

A headrace tunnel was preferred to a surface steel penstock in the headrace which follows the intake, because of the bad quality of the ground surface. Given the slope and condition of the ground, the risk of rock fall is high in the right bank slope. Drilling a tunnel is therefore viable and feasible solution.

The level of water in the catchment area may decrease by 1.20 m during the dry period and increase by 1.30 m during the 100-year flood. A non-pressure tunnel would have required a diameter larger than 2.50 m, which explains why a pressure tunnel is preferred.

Considering that the boring is performed through 2 m wide quartzite layers which are not watertight, the tunnel must be built in reinforced concrete.

The inner diameter is 2.20 m and the excavation is 3 m wide. The tunnel has a circular shape while the excavation has a horseshoe shape. A larger excavation would have been more costly while a smaller one, not being big enough for a human, would have been difficult to construct.

The longitudinal slope of the tunnel is 0.05% in order to obtain correct flow and to be able to empty it during the isolation required for inspection or repairs. The length of the tunnel is 133 m to connect the intake to the penstock.

8.2.2.4 Convergent

A convergent rather than a surge tank was chosen to connect the tunnel to the penstock. It was not the economic factor but rather the hydraulic factor that influenced this choice. A surge tank would have created massive oscillations without dampening due to the head losses which are low in the gallery. These oscillations would have disturbed the operations of the plant.

8.2.2.5 Butterfly Valve

A butterfly valve just downstream of the convergent is used to isolate the penstock during repairs. In the case of a ruptured intake, its second function is to close automatically under the effect of the counter weight. Sensors are used to detect flow anomalies so as to order the closure.

Downstream of the valve, a 60 cm in diameter manhole is planned for the inspection of the penstock or the gallery if necessary.

8.2.2.6 Penstock

The penstock connects the tunnel to the power house. It rests on supports placed 10 m apart. The sections between the two elbow anchor blocks are equipped with expansion joints, reducing the thermal forces, which were enormous when the penstock was empty. In this way, only the dynamic pressure is considered in the calculation of the supports.

The diameter of 1.40 m corresponds to the economic optimum between the cost of the tunnel and the head loss. Over a total length of 306.50 m and a roughness of 0.3 mm, the head loss for a flow rate of 6 m3/s is approximately 2.55 m, corresponding to the main project head loss.

The cross-section of the penstock follows the slope of the ground. The upstream section (120 m long) is on a slope of approximately 37.5°, the middle section (170 m long) is on a slope of approximately 5°, and the last section, leading to the power station (15 m long) is on a 27° slope. Five anchoring blocks are necessary and were specifically calculated. The largest block is the first one downstream of the tunnel.

The slope of the first section of the tunnel is as high as possible so that an eventual land slide would occur parallel to the tunnel and would not damage it. This consideration is extremely important as the stability of the ground surface is questionable in the steep part.

The thickness of the tunnel is 11 mm. The details of the calculations are in Appendix X. For this, we considered 24 kg/mm² as an acceptable limit for the steel and a maximum dynamic pressure of 110 m.

8.2.2.7 Powerhouse

The ideal location for the power house would have been on a close part of the river with a gentle slope. Unfortunately, the only ideal location had geological characteristics which prevented the construction of the power house. Another solution would have been to position the power house on a gentle slope farther from the river, which would have necessitated the construction of a downstream weir to avoid cavitation. This solution avoids excavation of a large volume but reduces the load by approximately 10 m.

The best economic solution was to place the power house close to the river on a steeper slope. This requires enormous excavation work but yields a gain in capacity which generates more than the cost of the works.

Given that at low flow all the water passes through the turbines, a small weir must be built approximately 8 m downstream of the power house. Its altitude being the same as the river bed's (696 m), this allows, due to a positive suction height (2.20 m), to place the turbine at 697.85 m. A watertight wall around the power house, whose crest is at 700 m, protects the power house during a flood. All the altitudes mentioned in this paragraph (river bed, turbine axis, crest of the walls) should be re-examined prior to the definite design, considering the fact that the present data on the river bed and the valley are not very precise.

8.2.3 Main Electromechanical Equipment

8.2.3.1 Selection of Main Equipment

(1) Turbine

Given the characteristics of the scheme (90 m head and minimum flow of 1.05 m^3/s), the choice of the turbine is to be made between a single runner Francis turbine and a transverse flow turbine, these two turbines having horizontal axes.

The design of the transverse flow turbine is more simple than of a Francis turbine and its maintenance is therefore easier.

However, the Francis turbine has superior results, 91% at normal flow and 85% at half flow, compared to the transverse flow turbine, which is almost always constant between 60% and 100% of the nominal flow-rate, but limited to the value of approximately 82%.

The studies regarding the requirements of the supplied network show the interest of having the highest peak capacity possible to supply the city of Garoua Boulai. This was the decisive factor that led to the choice of the Francis turbine.

The minimum flow of the turbine must be approximately half of the nominal flow in order to maintain acceptable results at low flow. The nominal flow of the turbine must be approximately 2 m^3/s.

Taking into account that the flow of the river 180 days par year is approximately 6 m^3/s, we decided to install 3 turbines.

It is possible at first to only equip two units, although the supply system and the power house are designed for three units.

The safety element of the turbine consists of a butterfly valve downstream of the case.

(2) Alternating current generator

The alternating current generator is a 3-phase type generator rotating at a synchronous speed. The capacity factor chosen is 0.85, although this value could be reduced if the reactive power absorbed by the Garoua Boulai distribution network is more important.

(3) Unit transformer

The outdoor transformers (one per unit) are installed on a platform downstream of the power house.

8.2.3.2 Essential Characteristics of Main Equipment

Turbine

Type	Francis
Quantity	3
Position of the axis	Horizontal
Nominal net head	91 m
Minimum net head	90 m
Nominal unit flow rate	2 m^3/s
Minimum unit flow rate	1 m^3/s
Rotational speed	1000 rpm
Rated power	1600 kV

Alternating current generator

Type	3-phase alternating synchronous
Quantity	3
Rotational speed	1000 rpm
Rated power	1535 kW - 1800 kVA

Frequency	50 Hz
Voltage	5500 V
Power factor	0.85

Unit transformer

Type	Exterior 3-phase, oil, air-cooled
Quantity	3
Rated power	1800 kVA
Voltages	5.5 kV / 30 kV

Total installed capacity of the power house : 4500 kWh

8.3 Olamze Site

8.3.1 Outline

The power demand was not the principal criterion for the dimensioning. In fact, considering the hydrology and the layout of the site, the energy produced is always inferior to local demand. The project was designed to make the best use of the site capacities, at the lowest cost.
The choice of the design flow takes into account the existence of two diesel power stations on the network. The flow cannot exceed 8.8 m^3/s, which is the minimum value obtained for 45% of the year. The thermal power stations, which must be renovated, make it possible to take such a strong flow since they can supply the missing energy during the periods of low flow. Larger equipment would lead to higher costs and would rarely be in operation, which would reduce the profitability of the project.

The 6 m net head is created solely by the weir and the cost of energy is therefore directly linked to its height. Given the shape of the valley, a higher dam would lead to an increased cost of energy and could cause problems at the end of the reservoir.
This head creates a capacity of 400 kW for an annual power generation of 2.64 GWh that may be entirely consumed by the population and the industries.

8.3.2 Civil Structures

8.3.2.1 Dam

The overtopping section of the weir is a 46 m long and 7 m high masonry structure. Its spillway crest elevation is 553.90 m. Its role is to increase the head and to create a regulating volume in order to create a run-of-river power house located at the heel of the dam. The width of the valley and the relatively low slope of the banks enable the construction of this type of dam. By using the regulating volume, the dam may be operated properly during the dry season by stocking it at night and pouring it during peak hours. Taking into account the hydrology, a volume of 110 000 m3 is necessary for optimum day time regulation. This may be obtained by varying the height of the water by 0.60 m.

The geology of the site was a decisive factor in the choice of the location of the dam. It is built at the only location where it could rest on a rocky weir.

The two abutments have a total length of 90 m and are made of earthfill, as this solution corresponds to the ground surface more than a masonry structure does. They are composed of watertight material, in order to ensure the watertightness of the dam, and of a layer of rockfill, in order to stabilise the watertight material and protect it from erosion. An inner filter layer is planned to reduce pore pressure. Grout injection is also planned in order to reduce the hydraulic gradient under the abutments.

The 100-year flood of the site is approximately 70 m^3/s, leading to an 85 cm increase in the water level. The abutments are however 1.45 m higher than the overtopping section, as a partial obstruction of 50% of the length of the weir was planned. This could be caused by tree trunks or other waste floating in the river. The consideration of this obstruction is very important as the abutments are in earthfill and therefore fragile.

A 1 m^2 bottom valve is installed to evacuate accumulated deposits from the bottom of the dam. It is located near to the intake as this part must be as clean as possible to limit the entry of sand or gravel.

The construction of a bridge was not considered in this study, but one could be added to the dam without changing the dimensions. A 3 m wide small bridge could therefore be built above the weir.

8.3.2.2 Water Intake

As the dam is positioned just downstream of the weir, the intake must be part of the dam. It is built with reinforced concrete. The bottom of the intake is at the 548.15 level, according to the elevation setting of the turbines, i.e. below the ground surface. In order to avoid digging a pit, we created a weir which also protects the turbines against the risk of the washing away of alluvium.

8.3.2.3 Powerhouse

The reinforced concrete power house rests at the water intake. This arrangement is feasible and economical. In addition, due to the site geology with its lack of surface rock downstream of the dam weir, we could not locate the plant elsewhere.

The two Kaplan turbines are positioned to obtain a head of 6 m. The upper part of the runner must be 50 cm below the minimum downstream level in order to avoid cavitation. Consequently, the turbine axis is set at the 546.70 level.

As the main power transmission network is on the right bank, the station must be located on the right bank. The two turbines, the alternators, the transformer, the electrical equipment and the handling hoists are all located in the station.

8.3.3 Main Electromechanical Equipment

8.3.3.1 Selection of Main Equipment

(1) Turbine

Considering the 6 m net head, only a Kaplan turbine can be used. The layout characteristics lead to the use of an angle gear turbine of small dimension, which minimises civil engineering costs.

The design flow was chosen relative to the number of days for which it is guaranteed. We decided on a flow rate of 9 m^3/s, guaranteed 165 days per year, which is inferior to the value normally accepted. In this case, it is accepted as the upstream reservoir has a significant volume capable of supplying the differential between the flow drawn-off and the entering flow, in order to ensure the supply of peak power.

There shall be two units to minimise investment costs while guarantying a minimum supply in case of outages.

The safety element of the turbine is made up of a downstream flat valve.

(2) Alternating current generator

The alternating current generator is a 3-phase type generator rotating at a synchronous speed. The power factor chosen is 0.85.

It is standard made, i.e. of minimum cost but with an efficiency of the order of 90%.

(3) Unit transformer

The transformer for the two units is located in a room above the hydraulic intake of the turbine.

8.3.3.2 Essential Characteristics of Main Equipment

Turbine

Type	Kaplan, angle gear
Quantity	2
Position of the axis	Horizontal
Nominal net head	6 m
Minimum net head	6 m
Nominal unit flow rate	4.5 m3/s
Minimum unit flow rate	1.6 m3/s
Rotational speed	400 t rpm
Rated power	225 kW

Alternating current generator

Type	3-phase alternating synchronous
Quantity	2
Rotational speed	750 t rpm
Rated power	204 kW -240 kVA
Frequency	50 Hz
Voltage	400 V
Power factor	0.85

Transformer

Type	Interior 3-phase, oil, air-cooled
Quantity	1
Rated power	500 kVA
Voltages	400 V / 30 kV

Total installed capacity of the power house : 400 kWh

MINI HYDRO-ELECTRIC POWER STATION PROJECT

NGAMBE TIKAR SITE

GENERAL LAYOUT

Plan view (sheet 1)

Fig.8-1-1

MINI HYDRO-ELECTRIC POWER STATION PROJECT

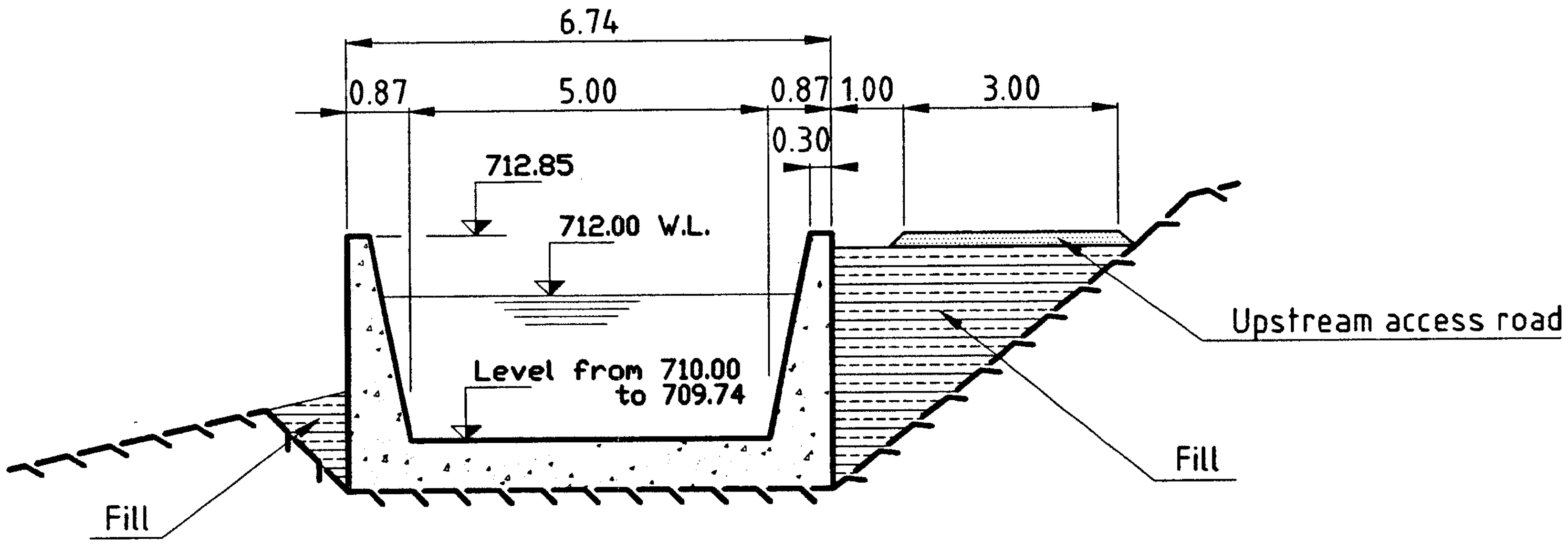
NGAMBE TIKAR SITE

GENERAL LAYOUT

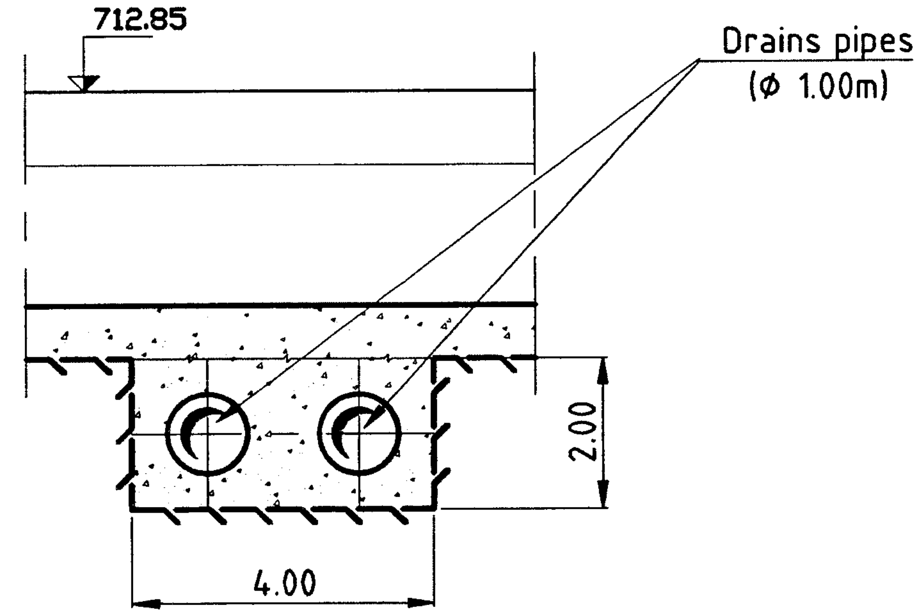
Plan view (sheet 2)

Fig.8-1-2

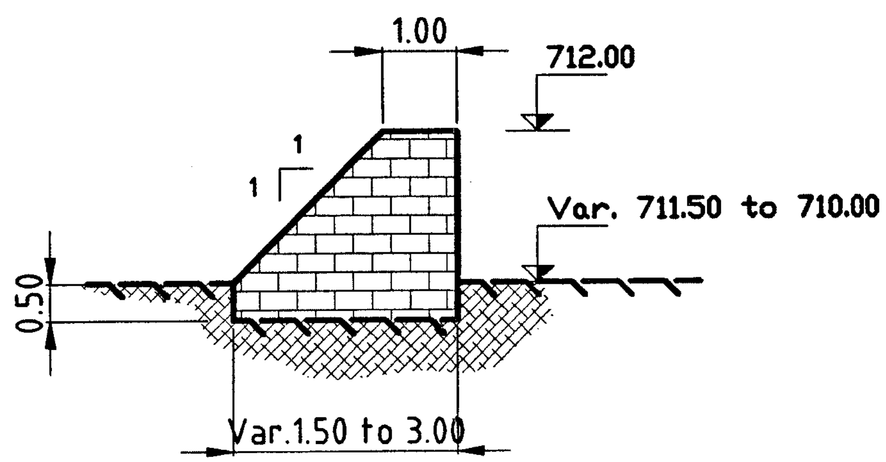
HEADRACE CANAL
Typical section



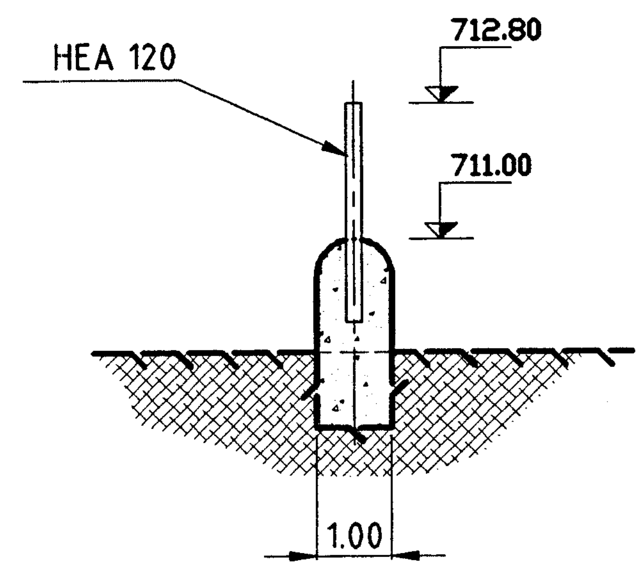
HEADRACE CANAL
Stream recouvery



DAM
Typical section



TRASHRACK SUPPORT
Typical section



MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NGAMBE TIKAR SITE

DAM – TRASHRACK SUPPORT – HEADRACE
Typical sections

Fig.8-1-3

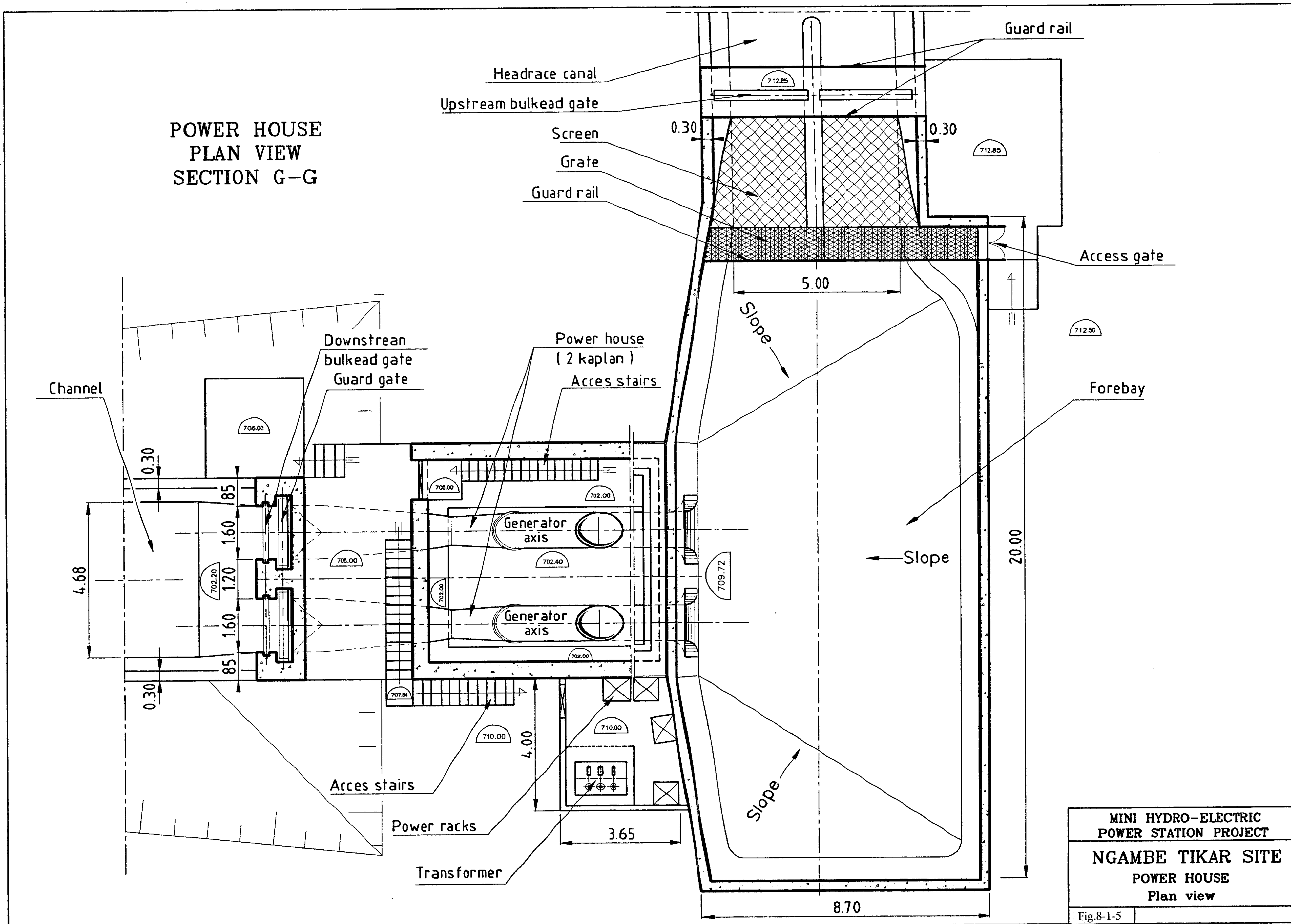
MINI HYDRO–ELECTRIC POWER STATION PROJECT

NGAMBE TIKAR SITE

POWER

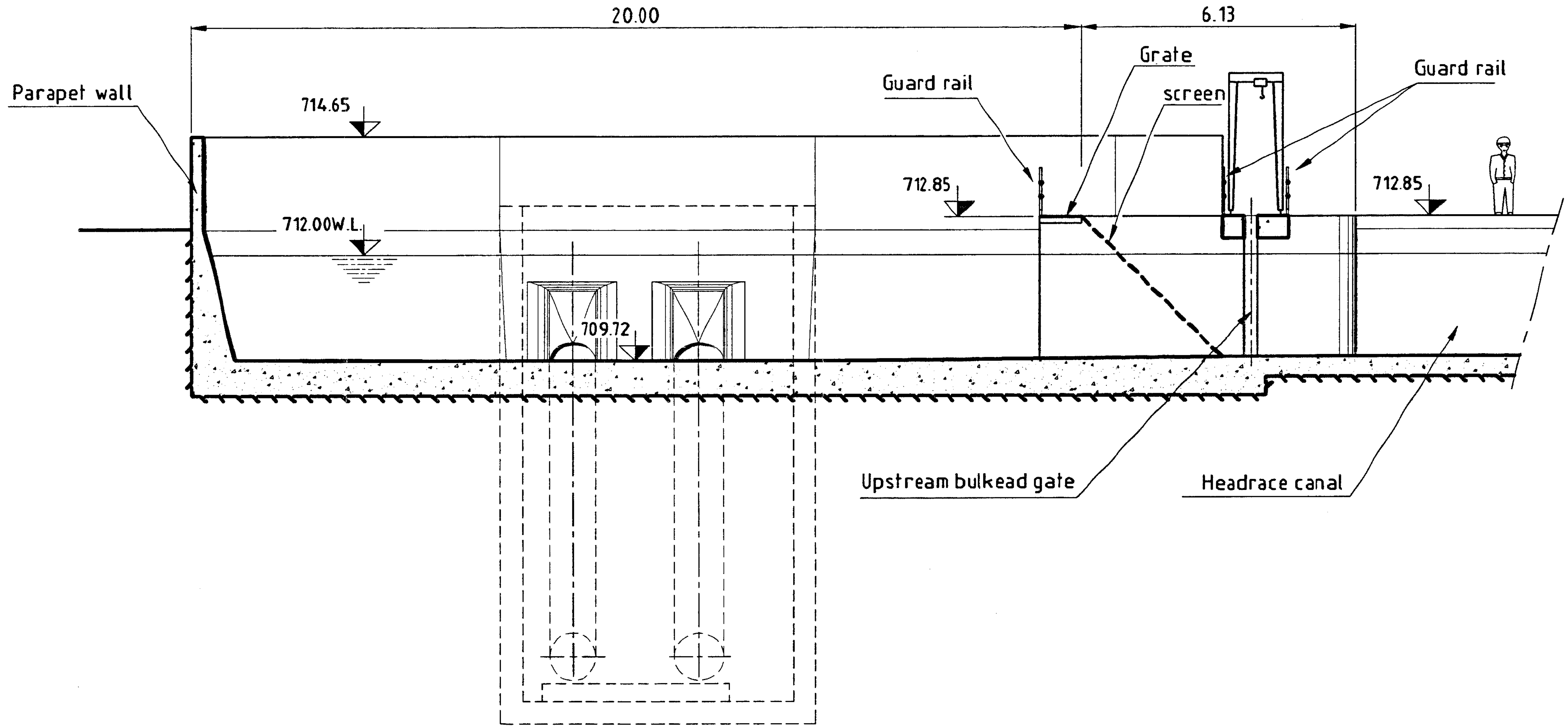
Longitudinal section

Fig.8-1-4

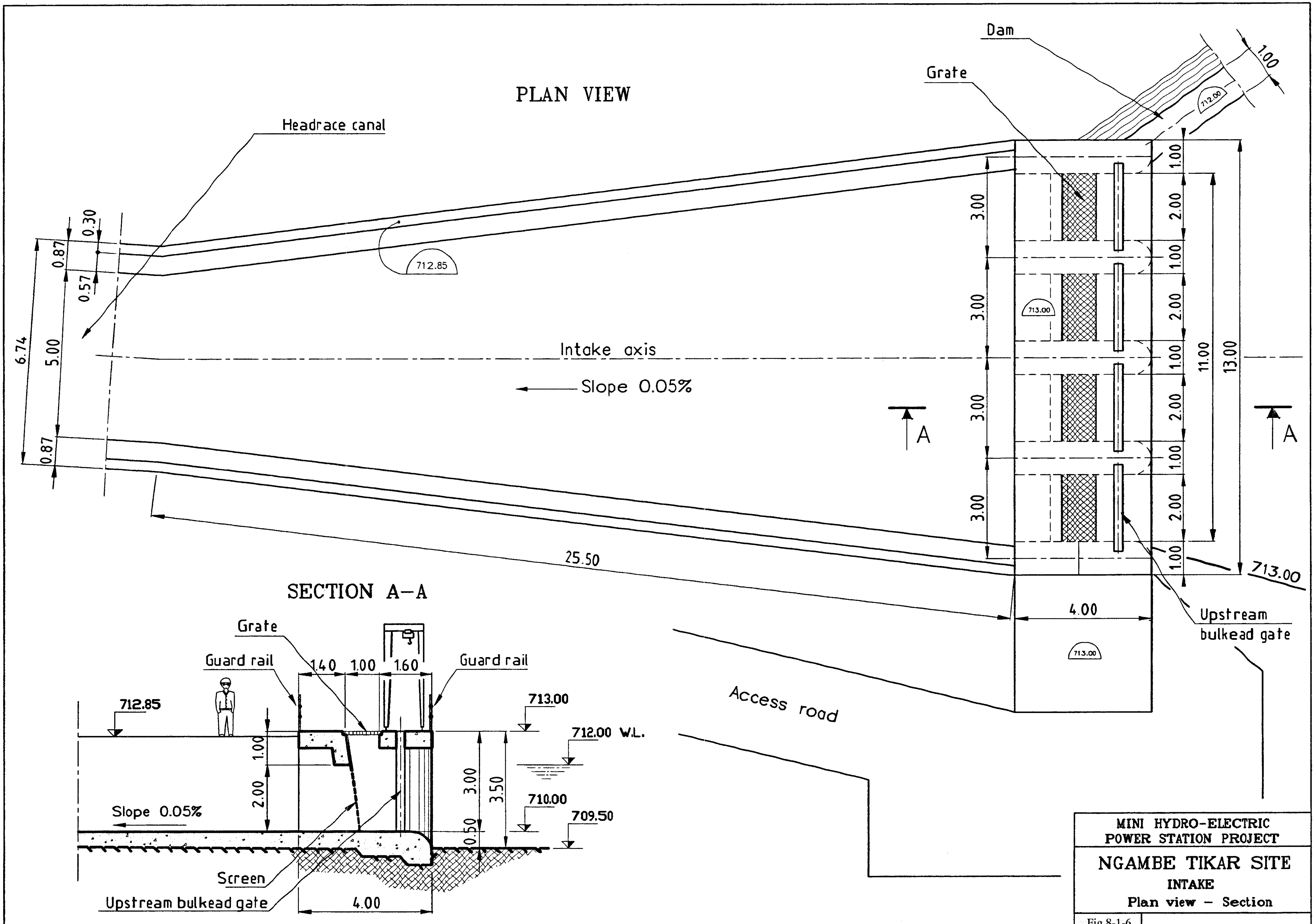


MINI HYDRO-ELECTRIC
POWER STATION PROJECT
NGAMBE TIKAR SITE
POWER HOUSE
Plan view
Fig.8-1-5

FOREBAY
LONGITUDINAL SECTION
SECTION H-H



MINI HYDRO-ELECTRIC POWER STATION PROJECT
NGAMBE TIKAR SITE
FOREBAY Longitudinal section
Fig.8-1-5bis



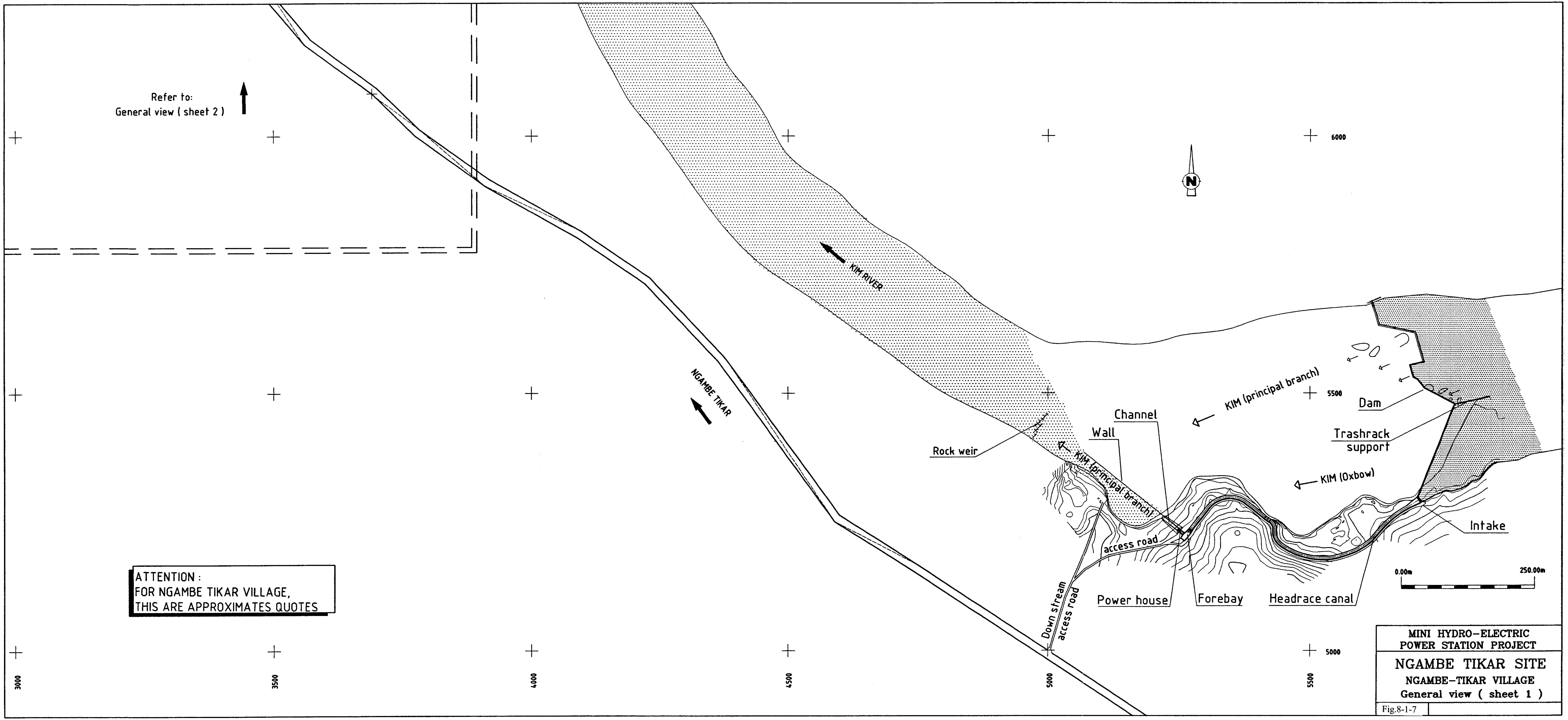
MINI HYDRO-ELECTRIC POWER STATION PROJECT

NGAMBE TIKAR SITE

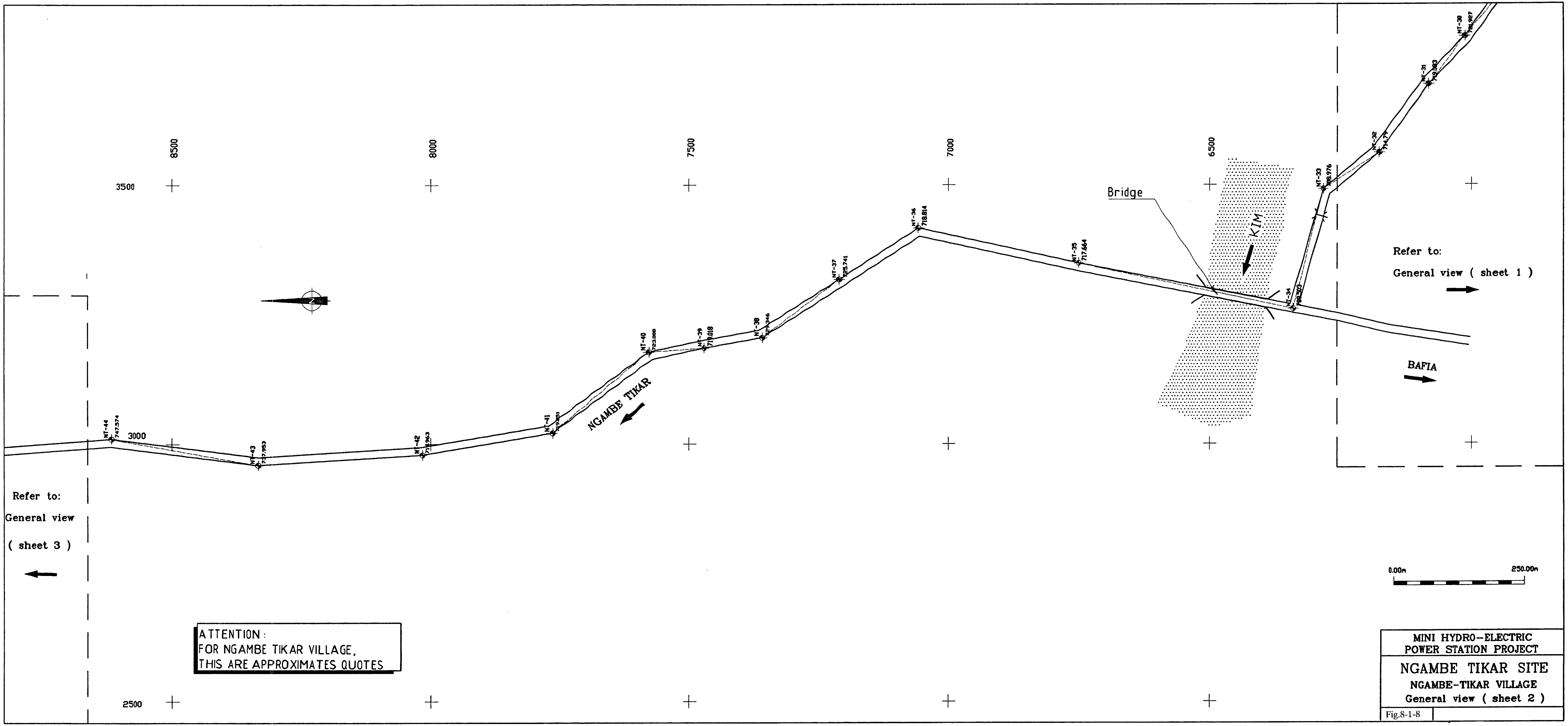
INTAKE

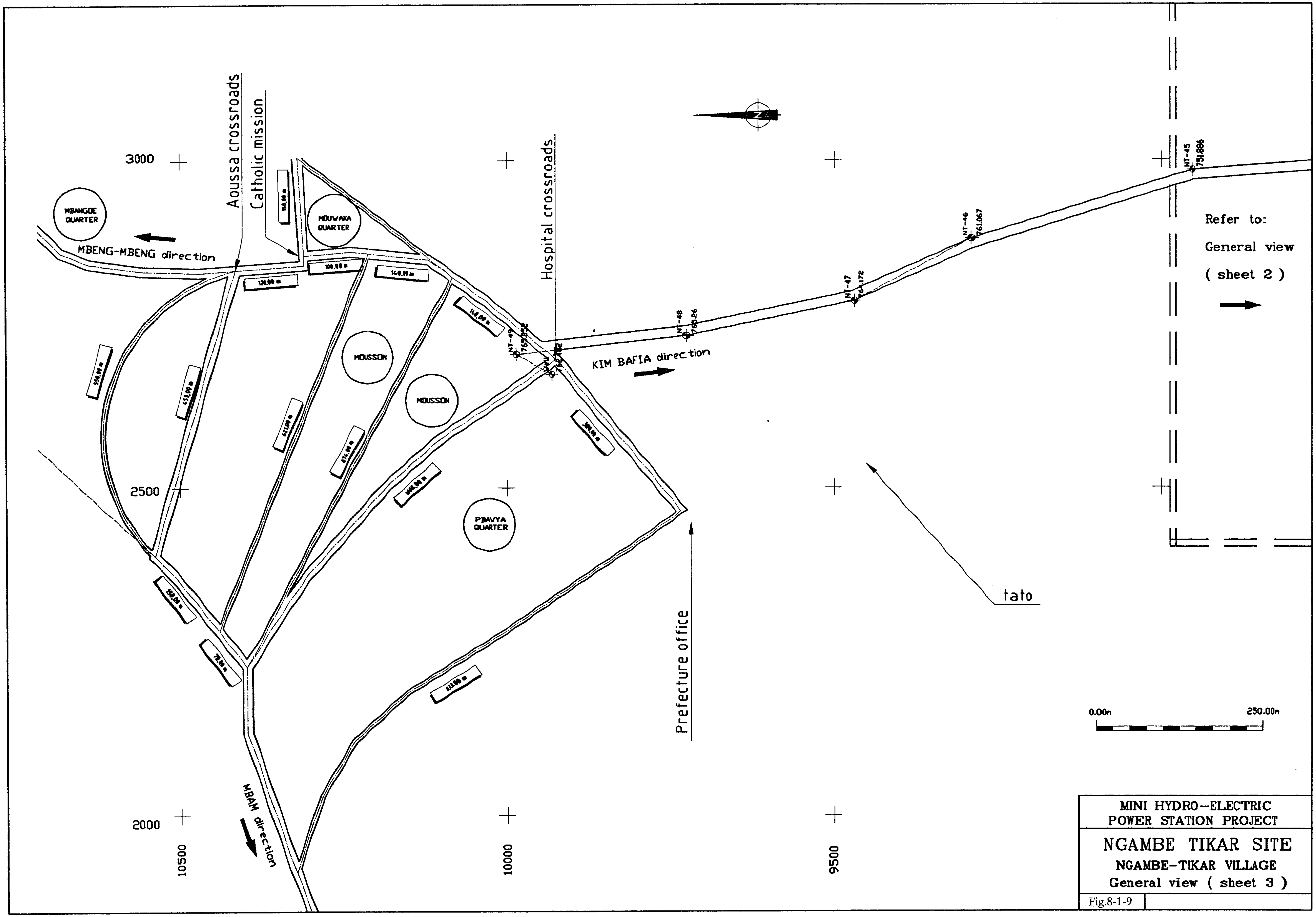
Plan view – Section

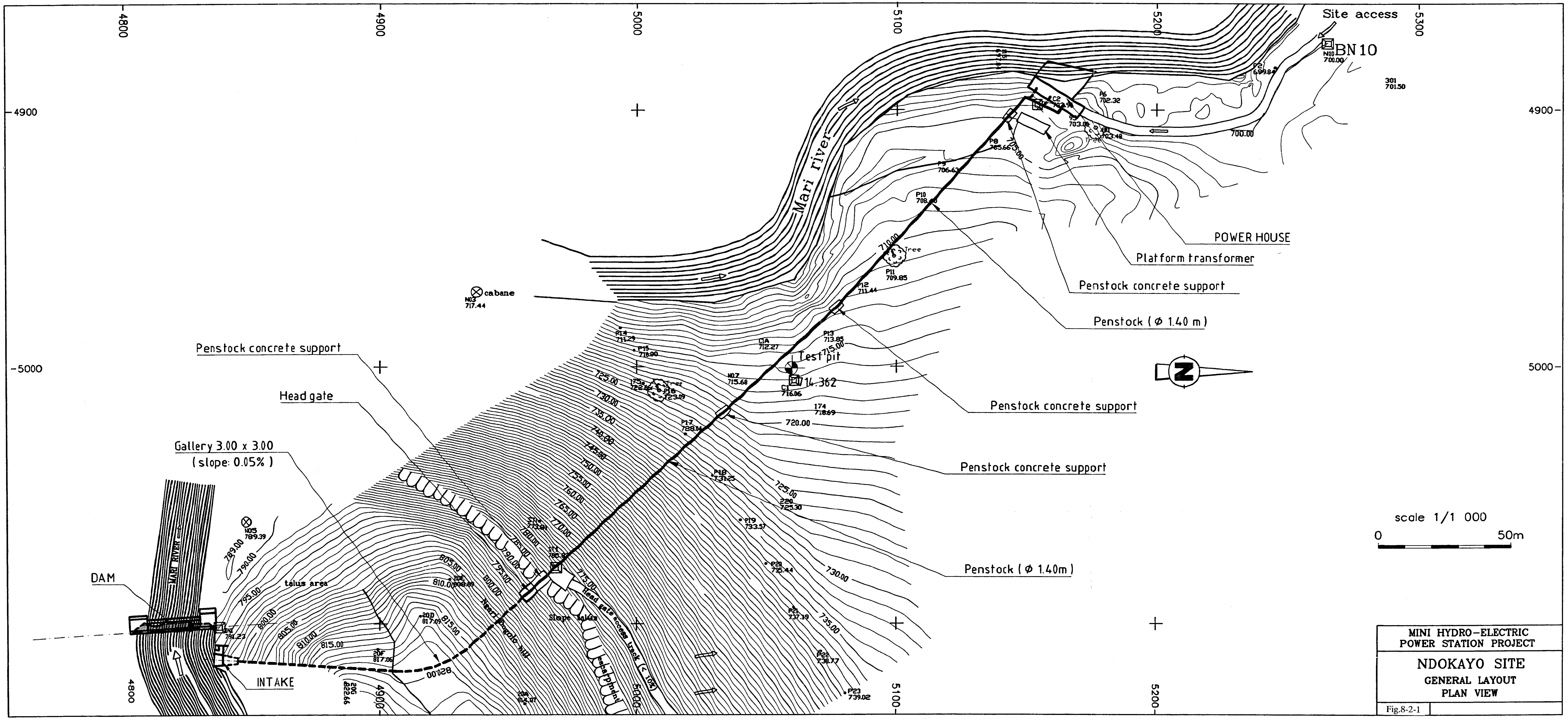
Fig.8-1-6



Refer to:
General view (sheet 2)
KIM RIVER
NGAMBE TIKAR
6000
5500
5000
3000
3500
4000
4500
5000
5500
KIM (principal branch)
Channel
Wall
Dam
Trashrack
support
Rock weir
KIM (principal branch)
KIM (Oxbow)
Intake
access road
Down stream
access road
Power house
Forebay
Headrace canal
0.00m
250.00m
ATTENTION :
FOR NGAMBE TIKAR VILLAGE,
THIS ARE APPROXIMATES QUOTES
MINI HYDRO-ELECTRIC
POWER STATION PROJECT
NGAMBE TIKAR SITE
NGAMBE-TIKAR VILLAGE
General view (sheet 1)
Fig.8-1-7


8500
8000
7500
7000
6500
3500
3000
2500
Bridge
KIM
Refer to:
General view (sheet 1)
BAFIA
NGAMBE TIKAR
Refer to:
General view
(sheet 3)
0.00m
250.00m
ATTENTION:
FOR NGAMBE TIKAR VILLAGE,
THIS ARE APPROXIMATES QUOTES
MINI HYDRO-ELECTRIC
POWER STATION PROJECT
NGAMBE TIKAR SITE
NGAMBE-TIKAR VILLAGE
General view (sheet 2)
Fig.8-1-8


3000
2500
2000
10500
10000
9500
MBANGOE QUARTER
MBENG-MBENG direction
Aoussa crossroads
Catholic mission
MOUWAKA QUARTER
Hospital crossroads
MOUSSON
MOUSSON
PBAVYA QUARTER
KIM BAFIA direction
MBAM direction
Prefecture office
tato
NT-45
751.886
NT-46
761.067
NT-47
NT-48
Refer to:
General view
(sheet 2)
0.00m
250.00m
MINI HYDRO-ELECTRIC
POWER STATION PROJECT
NGAMBE TIKAR SITE
NGAMBE-TIKAR VILLAGE
General view (sheet 3)
Fig.8-1-9



MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

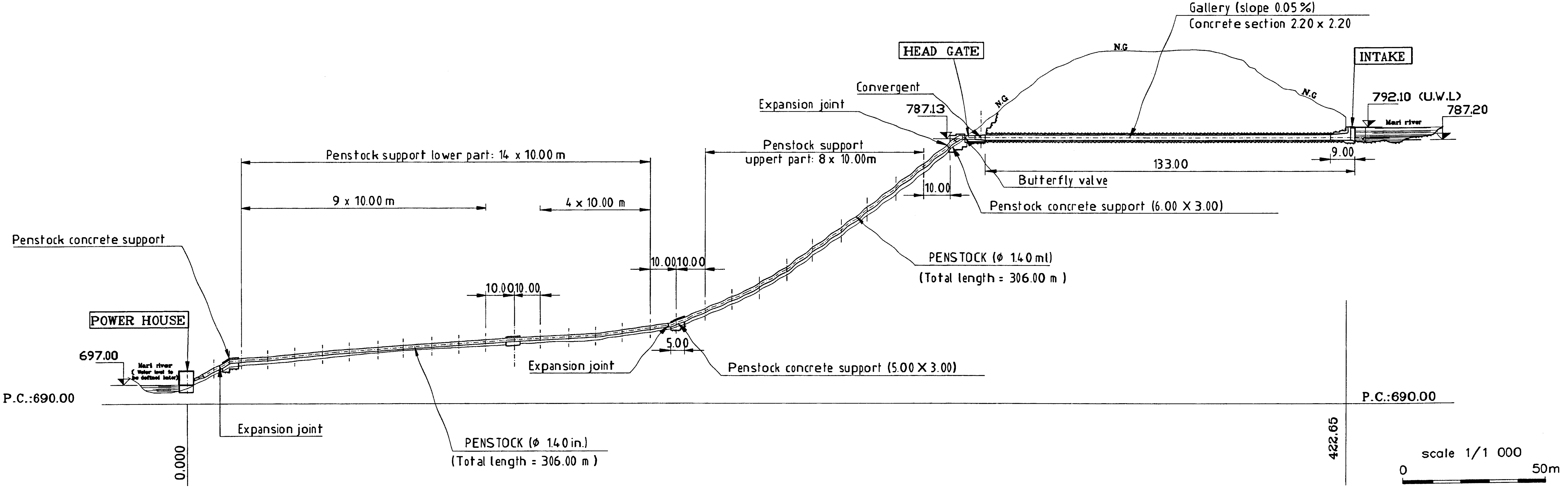
GENERAL LAYOUT

PLAN VIEW

Fig.8-2-1

PROFILE SECTION

(scale 1/ 1 000)



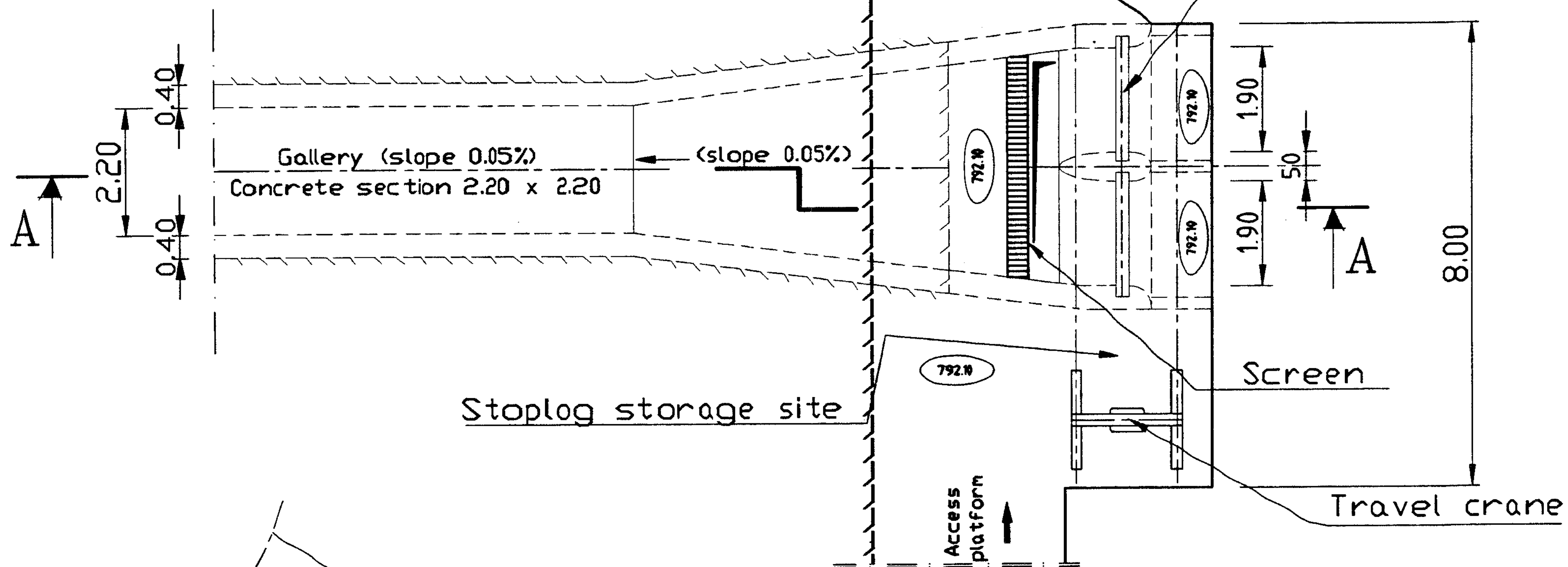
MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NDOKAYO SITE

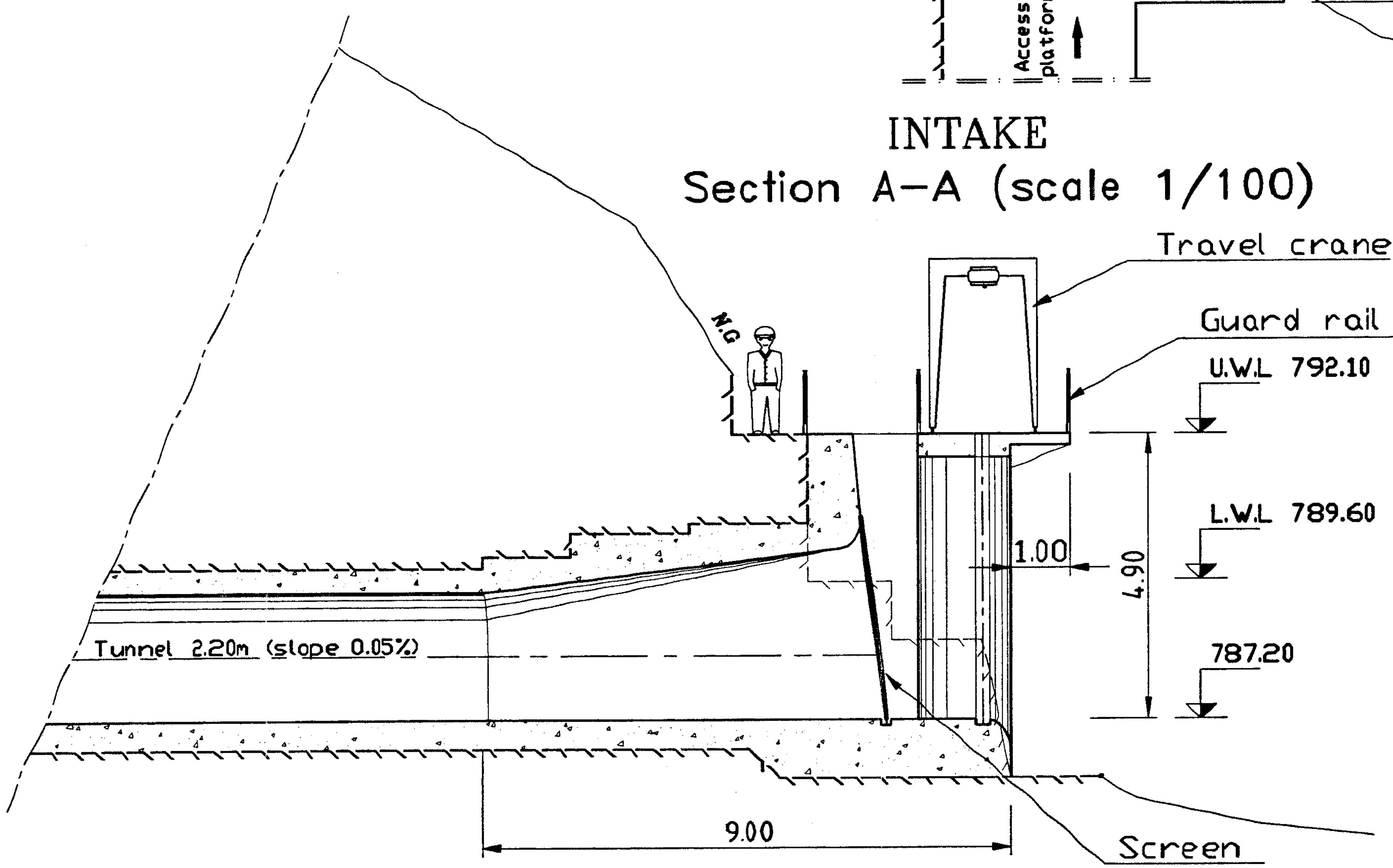
GENERAL LAYOUT
PROFIL SECTION

Fig.8-2-2

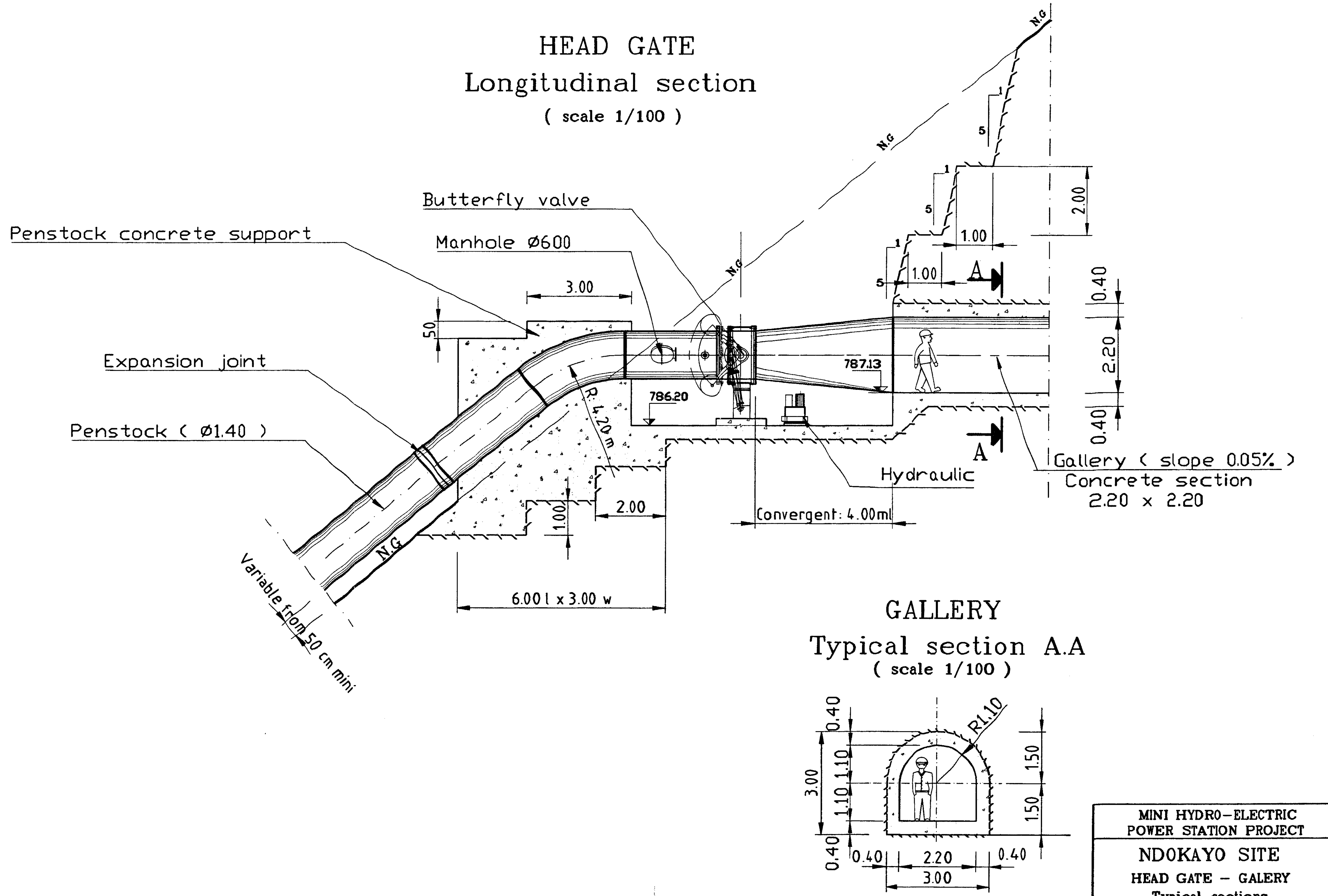
INTAKE
Plan view (scale 1/100)



INTAKE
Section A–A (scale 1/100)



MINI HYDRO–ELECTRIC POWER STATION PROJECT
NDOKAYO SITE INTAKE Plan view – Section A
Fig.8-2-3



MINI HYDRO-ELECTRIC POWER STATION PROJECT

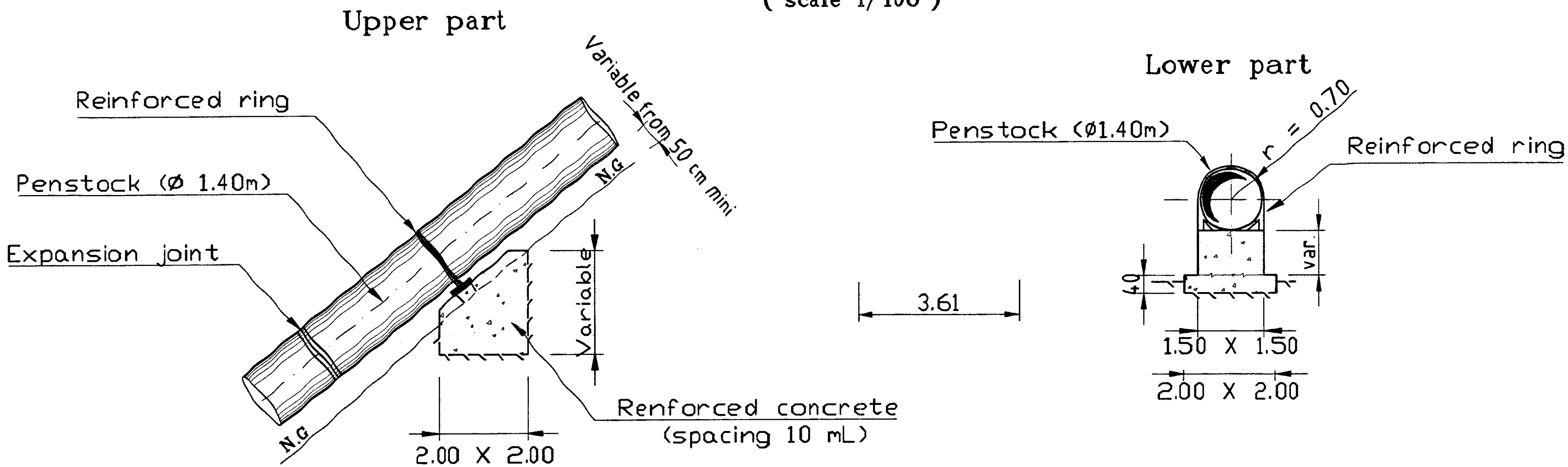
NDOKAYO SITE

HEAD GATE – GALERY

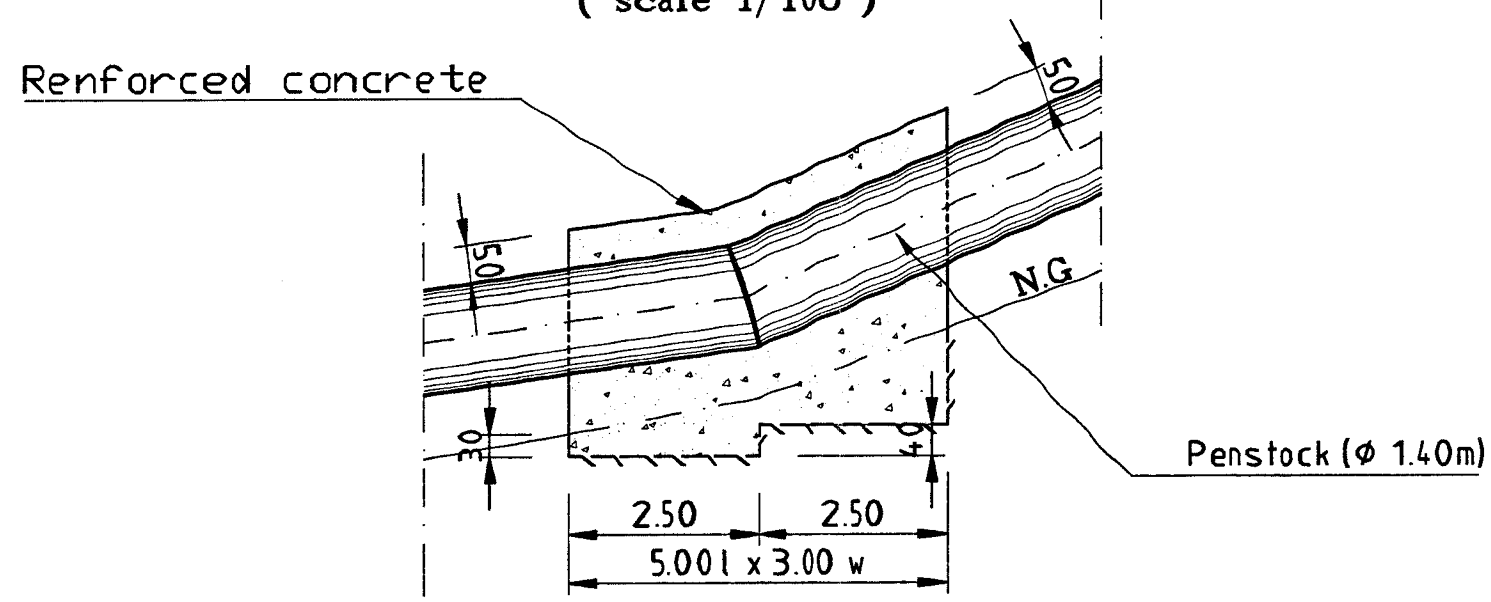
Typical sections

Fig. 8-2-4

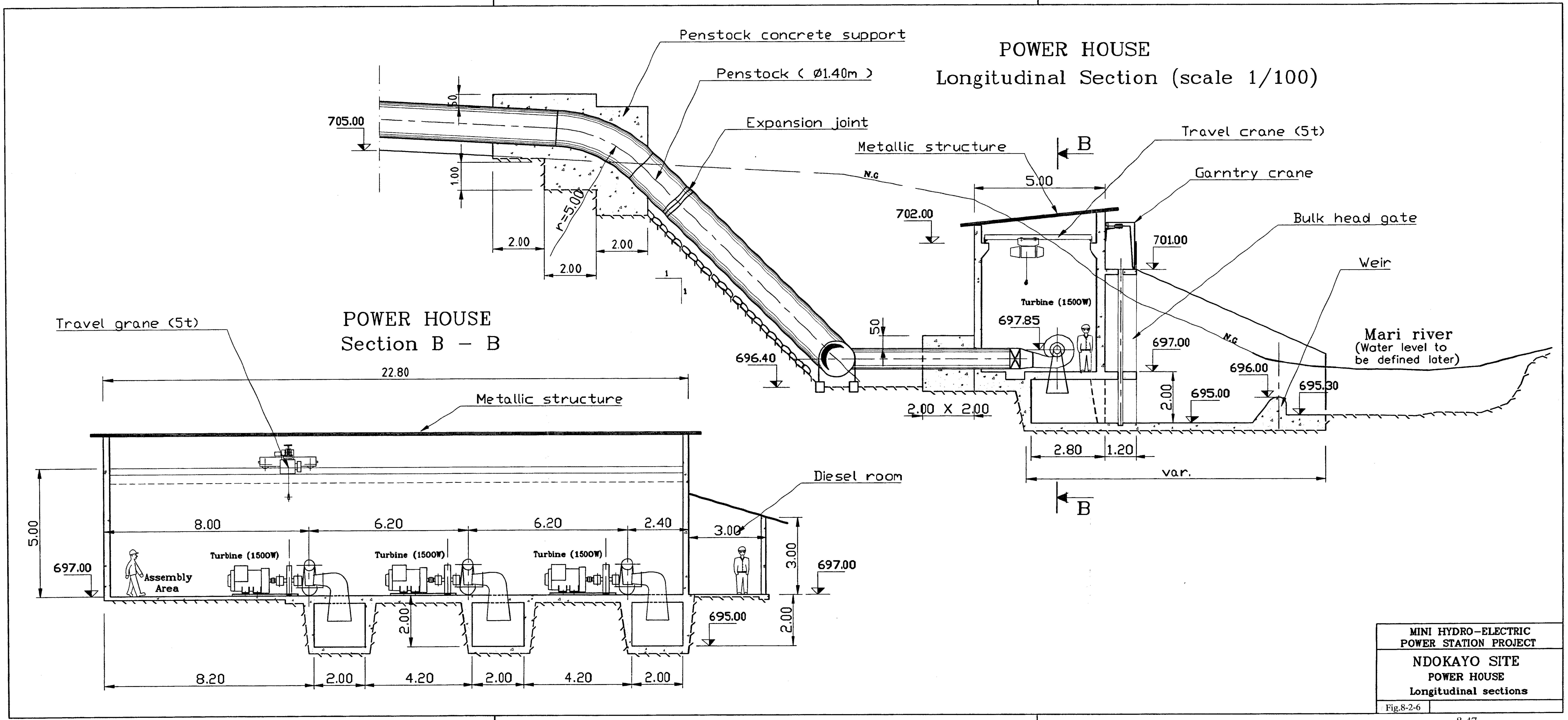
PENSTOCK SUPPORTS
Typical sections
(scale 1/100)



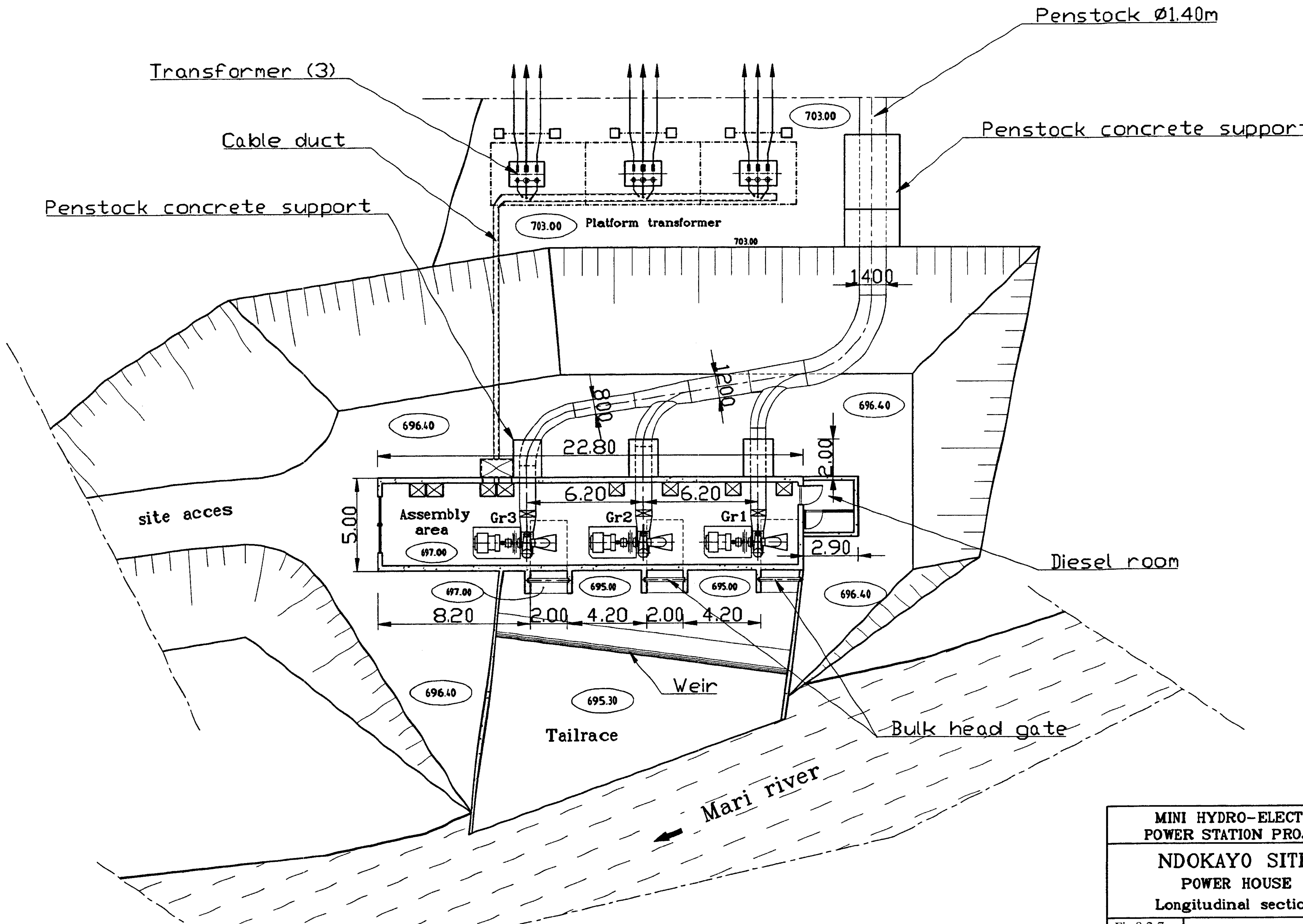
PENSTOCK CONCRETE SUPPORT
Longitudinal section
(scale 1/100)



MINI HYDRO-ELECTRIC POWER STATION PROJECT
NDOKAYO SITE PENSTOCK SUPPORTS Typical sections
Fig.8-2-5


POWER HOUSE
Longitudinal Section (scale 1/100)
Penstock concrete support
Penstock (Ø1.40m)
Expansion joint
Metallic structure
Travel crane (5t)
Garntry crane
Bulk head gate
Weir
Mari river
(Water level to be defined later)
705.00
702.00
701.00
697.85
697.00
696.40
696.00
695.30
695.00
5.00
2.00
1.00
r=5.00
50
2.00 X 2.00
2.80
1.20
var.
B
N.G
Turbine (1500W)
POWER HOUSE
Section B – B
Travel grane (5t)
22.80
Metallic structure
Diesel room
8.00
6.20
6.20
2.40
3.00
5.00
697.00
Assembly Area
Turbine (1500W)
695.00
8.20
2.00
4.20
2.00
4.20
2.00
MINI HYDRO-ELECTRIC POWER STATION PROJECT
NDOKAYO SITE
POWER HOUSE
Longitudinal sections
Fig.8-2-6

POWER HOUSE
Plan view (scale 1/ 200)



MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

POWER HOUSE

Longitudinal sections

Fig.8-2-7

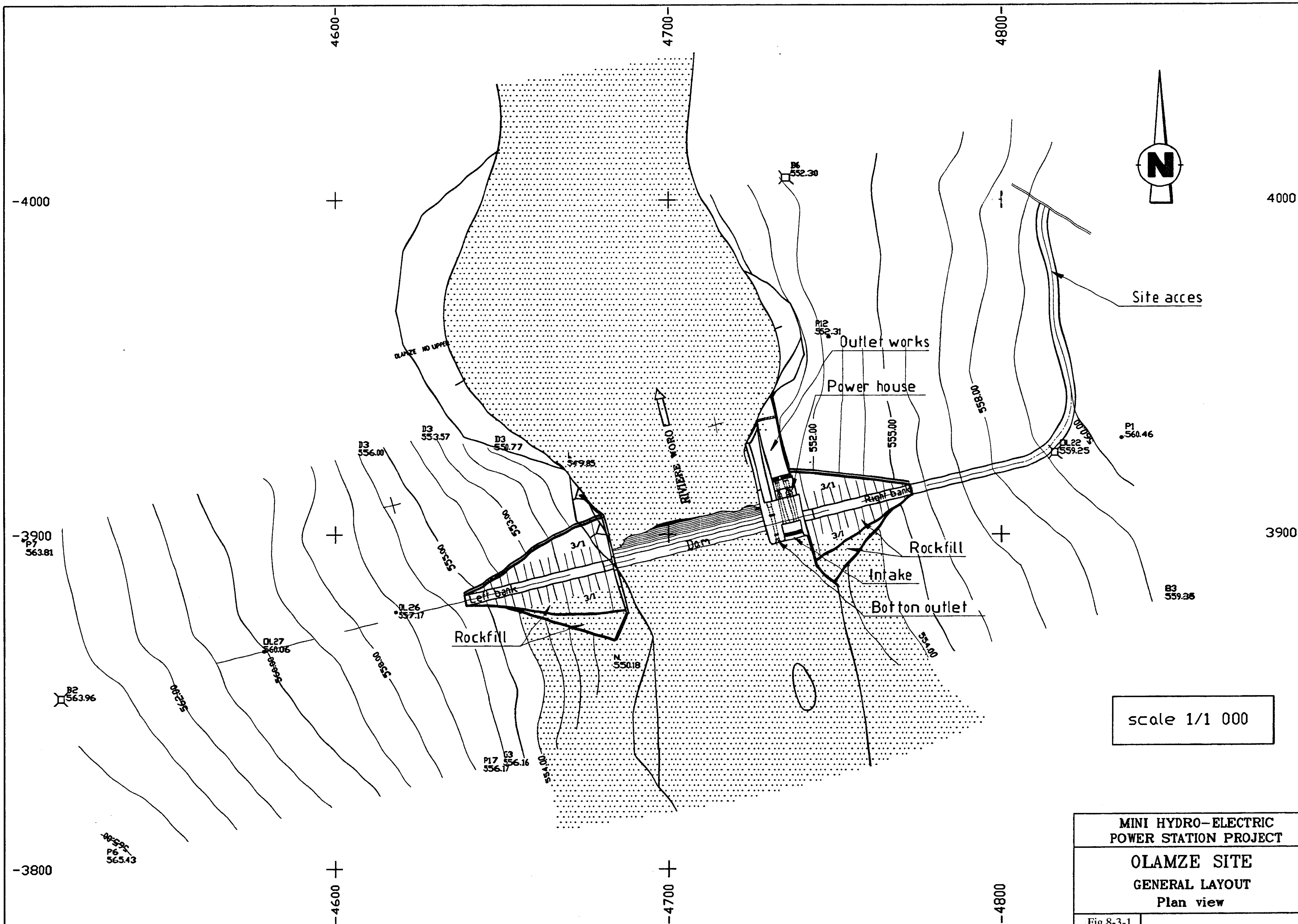
MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

DAM AXIS CROSS SECTION

typical sections: A-B-C-D

Fig.8-2-8



MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZE SITE

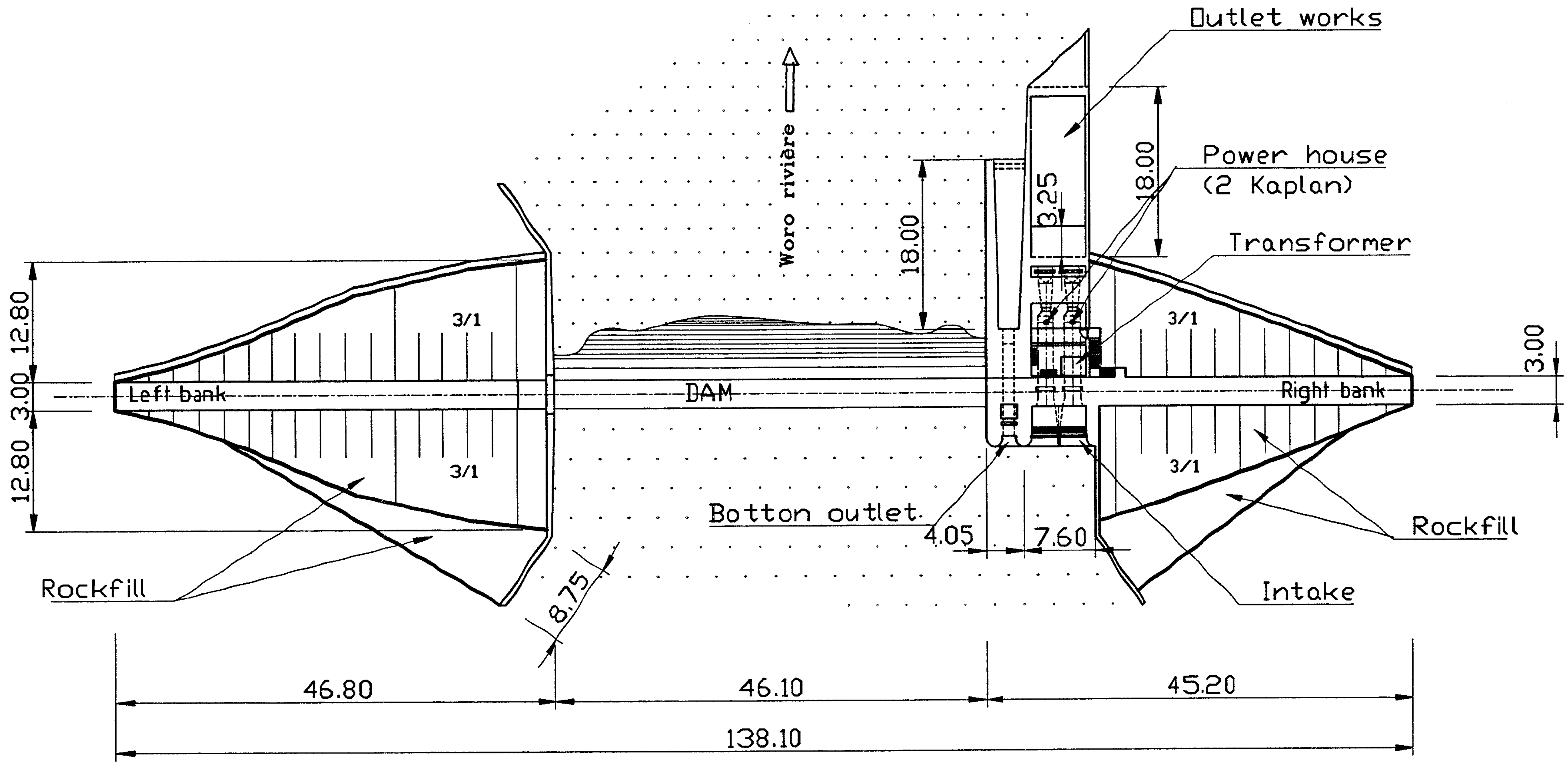
GENERAL LAYOUT

Plan view

Fig.8-3-1

DAM & ANCILLARY WORKS

PLAN VIEW (scale 1/500)



MINI HYDRO-ELECTRIC POWER STATION PROJECT

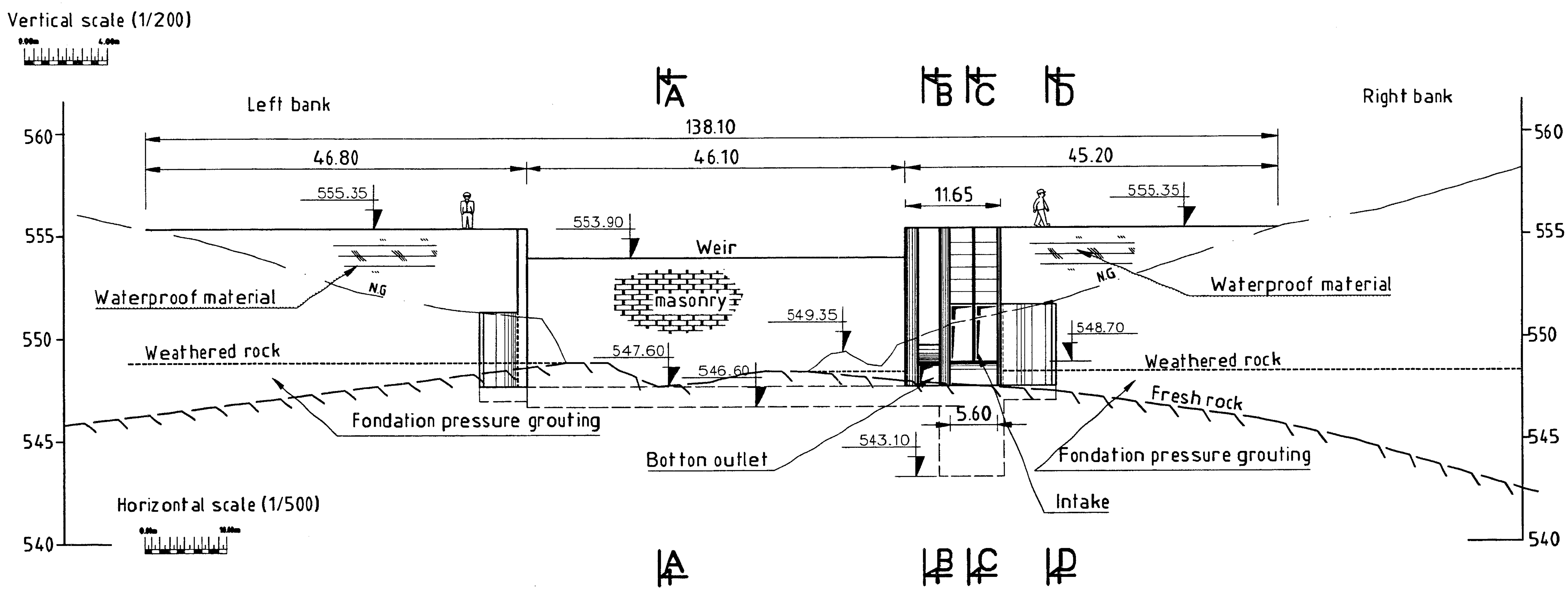
OLAMZE SITE

DAM & ANCILLARY WORKS

Plan view

Fig.8-3-2

UPSTREAM DAM ELEVATION



MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZE SITE

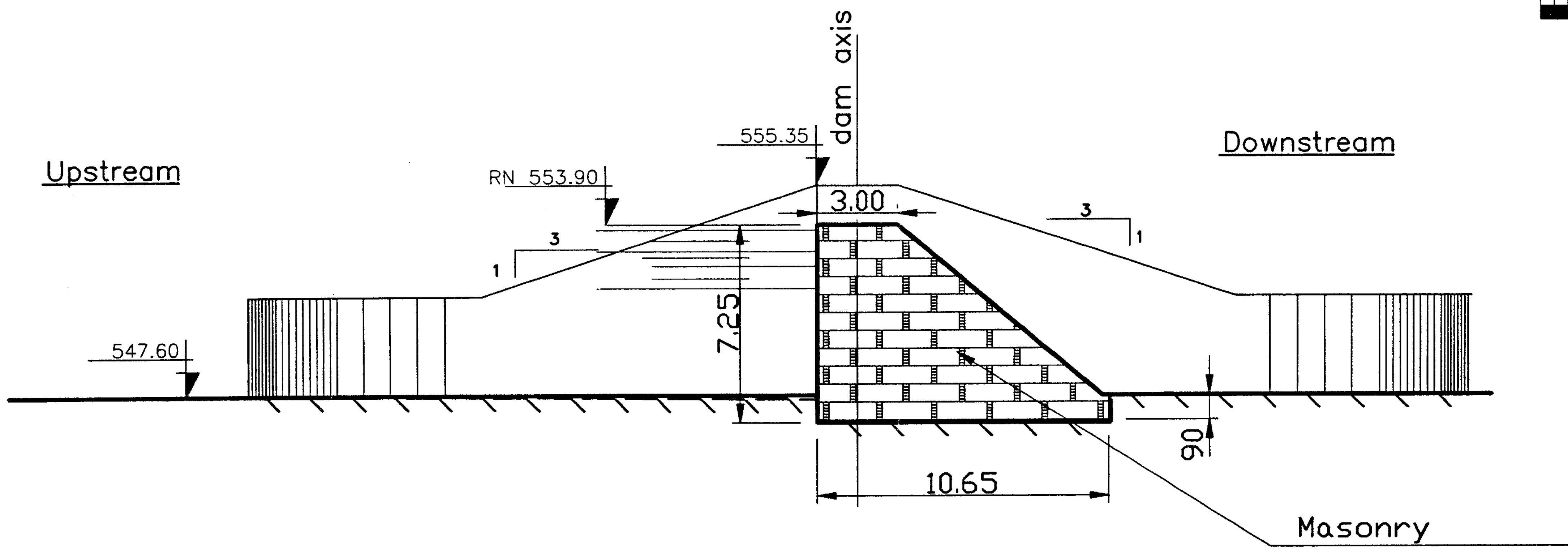
DAM AXIS CROSS SECTION

Fig.8-3-3

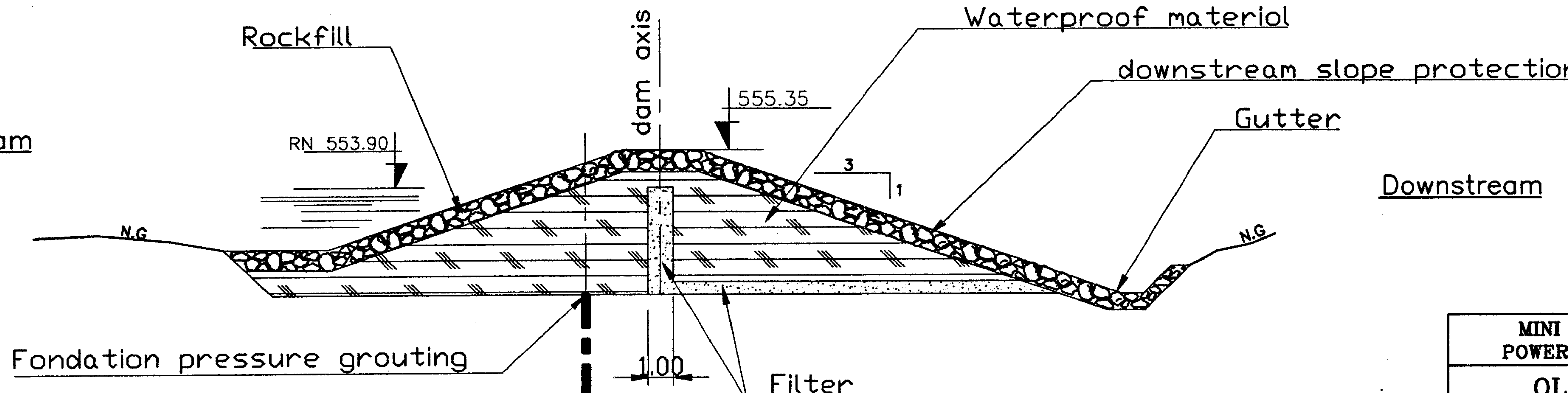
scale = 1/200

0.00m 10.00m

typical section A-A of the dam



typical section D-D of the Embankment



MINI HYDRO-ELECTRIC POWER STATION PROJECT

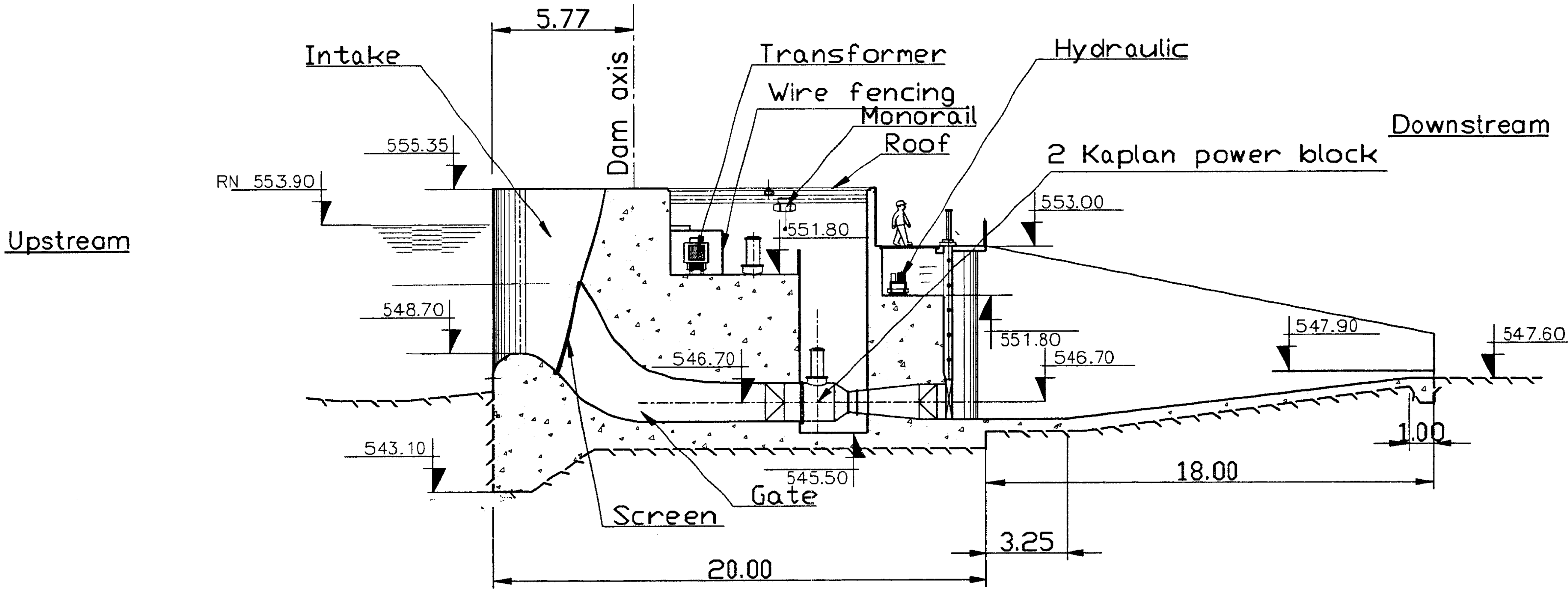
OLAMZE SITE

DAM

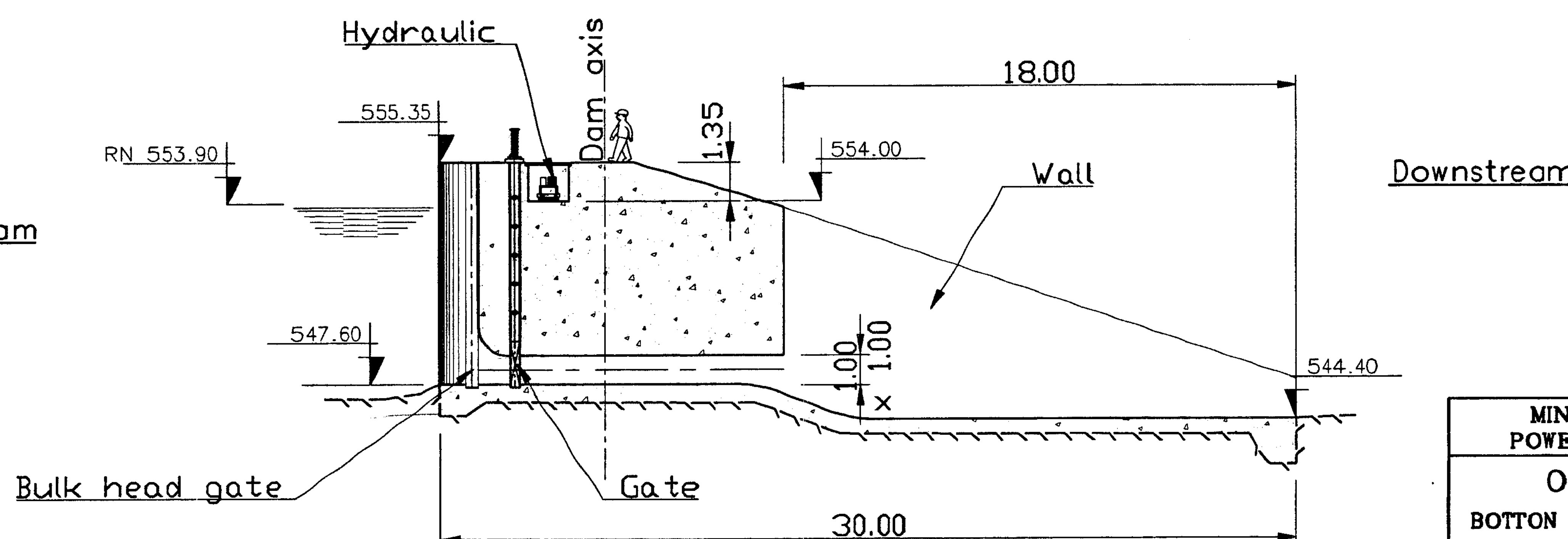
Typical sections

Fig.8-3-4

typical section C–C of the power house



typical section B–B of the bottom outlet



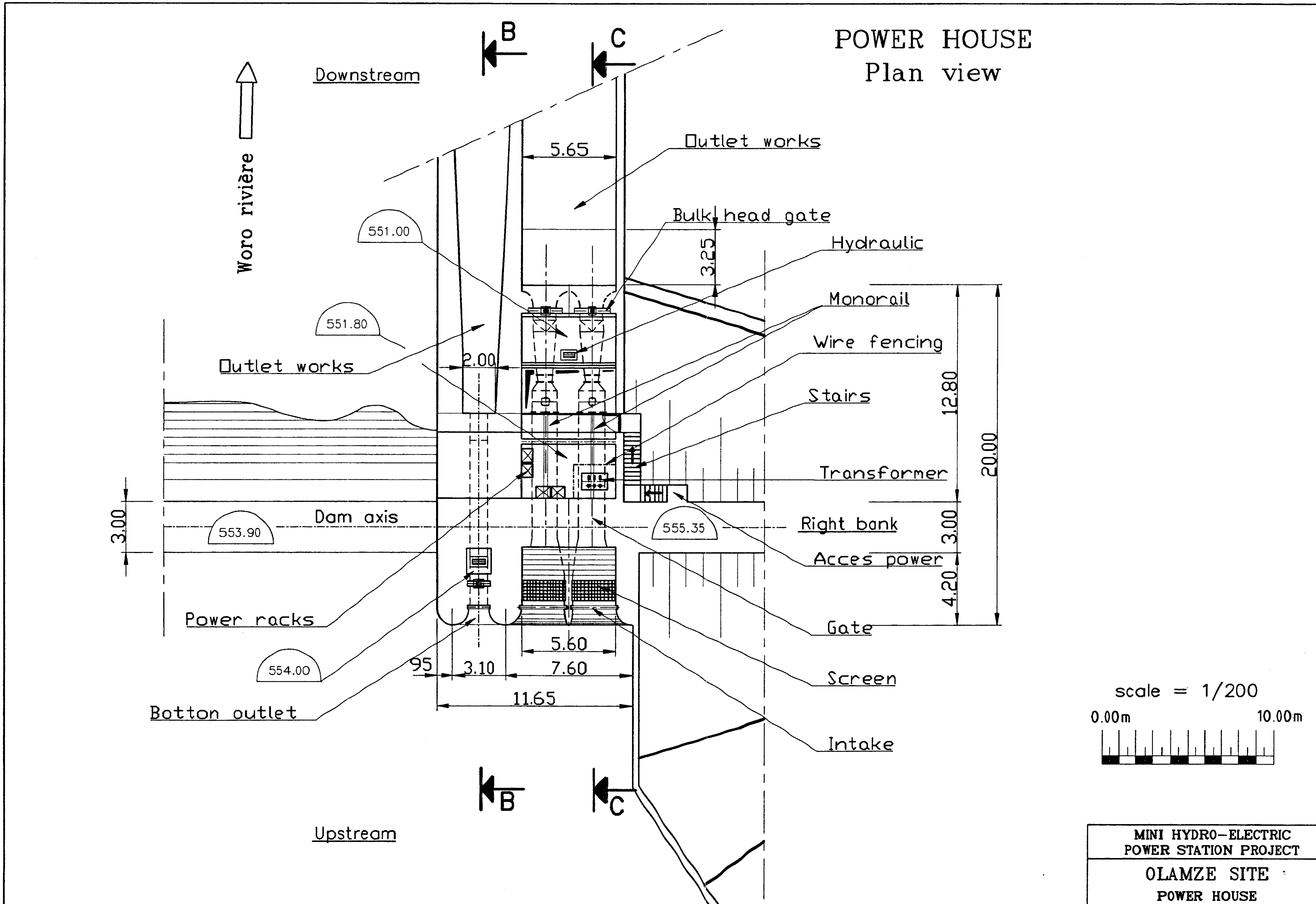
Scale 1/200
0 5m

MINI HYDRO–ELECTRIC POWER STATION PROJECT

OLAMZE SITE

BOTTON OUTLET–POWER HOUSE
Typical sections

Fig8-3-5



MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZE SITE

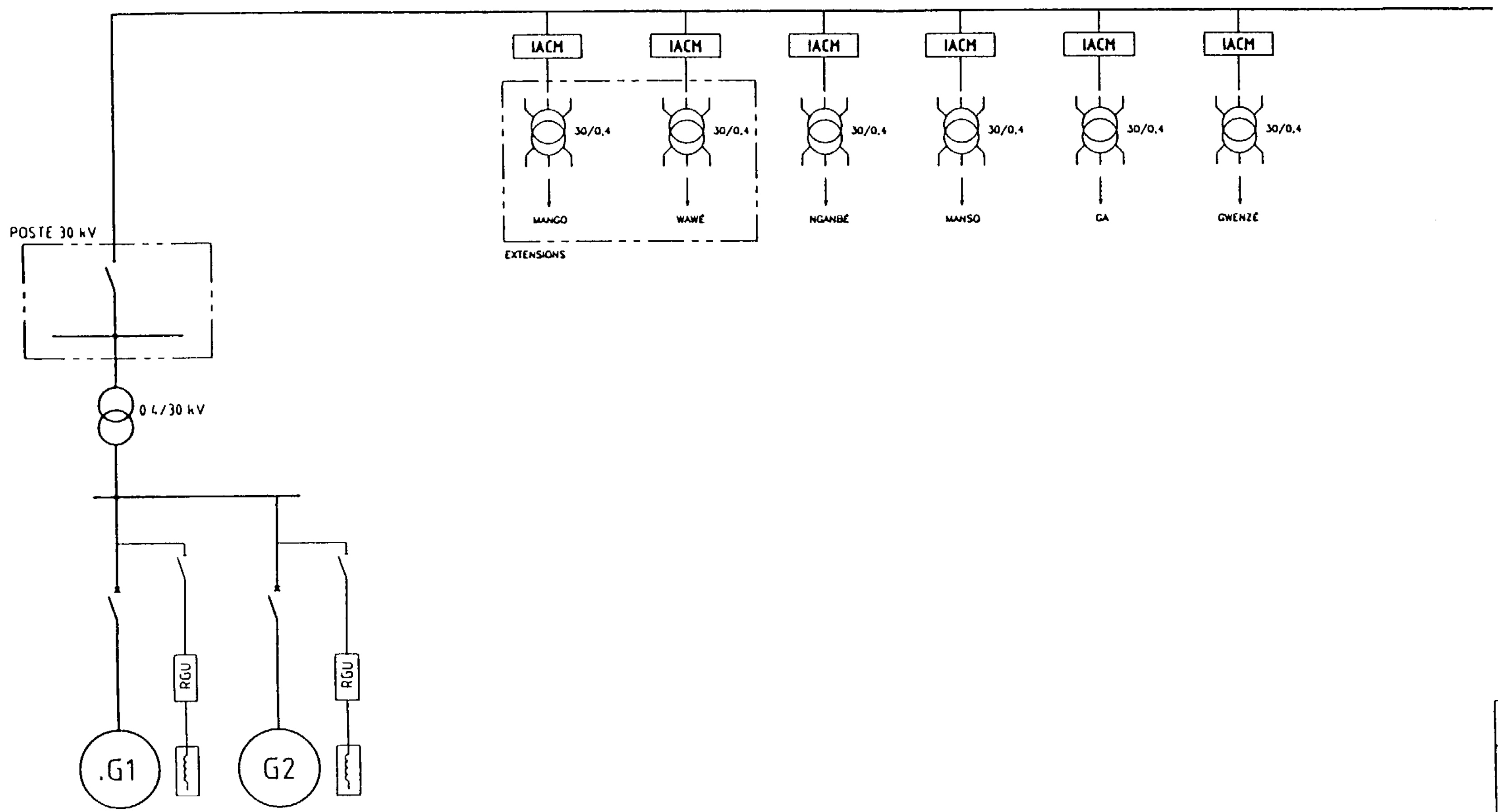
POWER HOUSE

Plan view

Fig.8-3-6

IAT Interrupteur Aérien Télécommandé

IACH Interrupteur Aérien à commande Manuelle

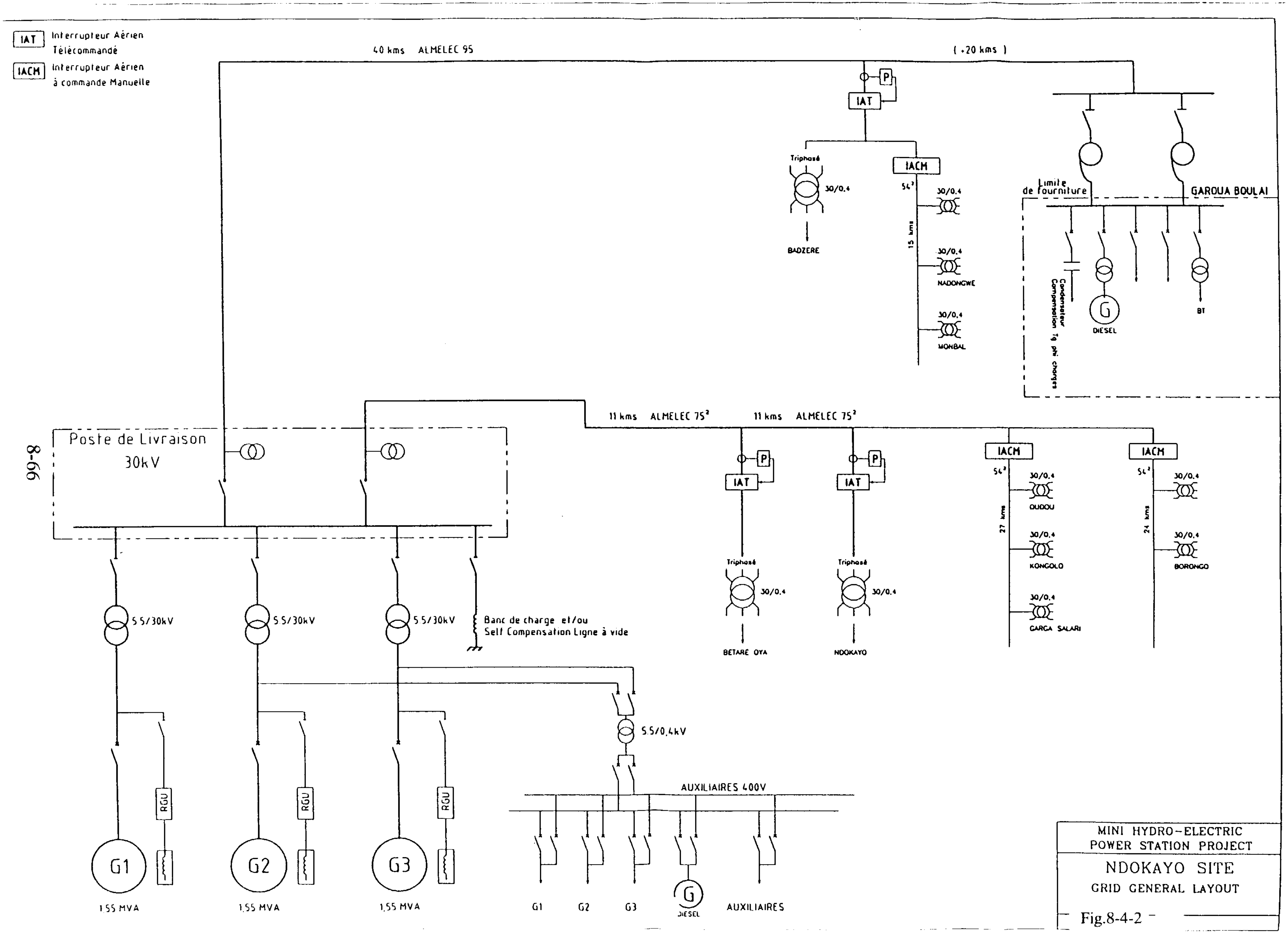


MINI HYDRO-ELECTRIC POWER STATION PROJECT

NGAMBE TIKAR SITE

GRID GENERAL LAYOUT

Fig.8-4-1



MINI HYDRO-ELECTRIC POWER STATION PROJECT

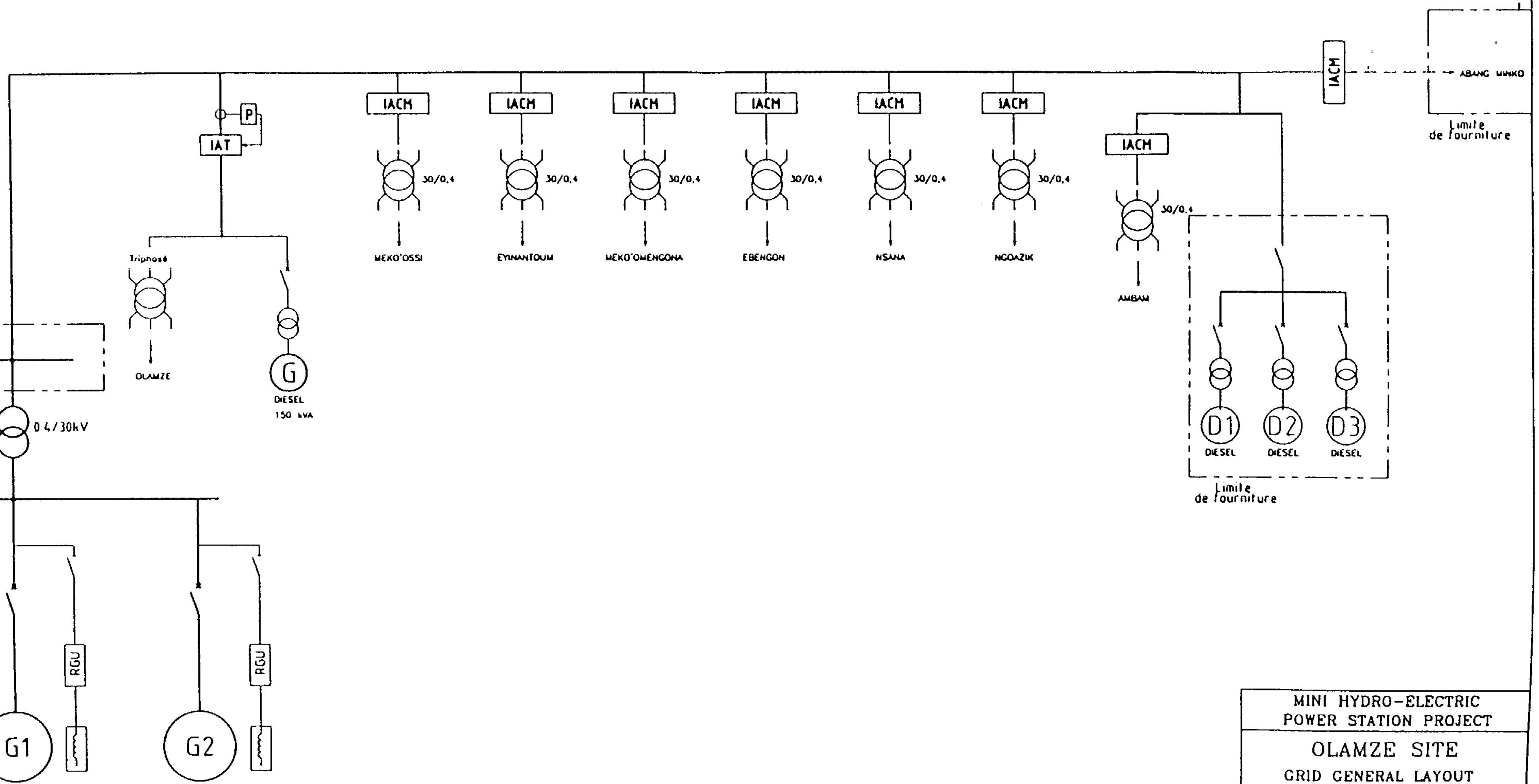
NDOKAYO SITE

GRID GENERAL LAYOUT

Fig.8-4-2

IAT — Interrupteur Aérien Télécommandé

IACM — Interrupteur Aérien à commande Manuelle



MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZE SITE

GRID GENERAL LAYOUT

Fig.8-4-3

CHAPTER 9.   TRANSMISSION LINE

Chapter 9 Transmission Lines

9.1 Presentation of Study

This chapter presents the different preliminary studies for the electrical networks of the three sites. They enable the determination of the evacuation of the produced power and the analysis of the consequences relative to these networks.

This chapter deals with the following points:

- Analysis of the voltage map
- Analysis of the load flow of the electrical system using diverse topologies.
- The calculation of voltage drops in overhead lines and the induced power losses.

The quality of the required service does not necessitate the maintenance and the evacuation of energy while certain works are unavailable, such as the main connection line.

9.2 Hypotheses for the Study

Only the principal data was taken into account in this preliminary study.

9.2.1 Consumption

As the hydraulic units have a relatively slow dynamic behaviour compared to the diesel sets, it will be necessary to analyse the dynamic behaviour of the frequency during the loss of a high capacity unit and the automatic load shedding control equipment which will have to be put into use, when hydraulic and diesel sets function in parallel.

The reactive consumption, essential element in the determination of the voltage map, is considered as a set value in this study: the tangent φ of the load is uniform and equal to 0.5. If this value is very different from the effective value, the reactive compensation energy must be produced at the HVA unit nearest to the loads.

9.2.2 Generation

9.2.2.1 Generation equipment

Ngambe Tikar

The hydraulic unit: The installed capacity is 625 kVA; Maximum deviation of reactive power is of +/- 50 kVAR.

Ndokayo

Hydraulic units: The total installed capacity is 5,330 kVA .
Maximum deviation of reactive power is +/- 0.5 MVAR
The Garoua Boulai diesel sets: The installed capacity is 0,4 MVA with a possibility of a reactive supply of 0,1 MVAR.

Olamze

The hydraulic unit: The installed capacity is 470 kVA; Maximum deviation of reactive power is of +/- 50 kVAR.
The Olamze diesel sets: The installed capacity is 150 kVA. Three units could be connected to Ambam giving a cumulative power of 750 kVA .

9.2.2.2 Accepted generation plan for Ndokayo

In order to ensure the satisfactory operation of the separate network and to limit the load shedding in case of loss of a unit, a spinning reserve at least equal to the operating unit must be maintained. Supposing that the units in operation (n = N -1 of the capacity of the plant) are at 70% of their maximum power, the diesel of Gaoura Boulai producing the complementary power, the spinning reserve is distributed throughout all of the hydraulic units in operation. In the case where the plant is functioning at full production power, should a unit trigger, it will be necessary to shed the loads automatically.

9.2.3 Networks

The networks considered in this study correspond to those which allow the evacuation of power under acceptable service quality conditions for this type of supply, specifically in regard to the voltage and frequency deviations. For this last point, the limit of the possibilities of the production units correspond to:

- Units : +/- 5 % in frequency and +/- 5 % in voltage (at the machine terminals).

9.2.3.1 Level of MV voltage

The structure of Ndokayo - Garoua Boulai is proposed in 30 kV. This voltage level minimises the voltage drops over the 60 km distance separating the two sub-stations with a maximum active load flow of 3,5 MW.

For Ngambe-Tikar and Olamze, where the capacities to be transited are lower and more spread out, the accepted choice was also 30 kV, but the amount to transit only require a voltage of 15 kV .

It should be reminded that these two voltages are well known standards in Cameroon and should not present any problems for their implementation by local companies.

9.2.3.2 Low voltage supply

This type of supply permits, via an MVB or MVA/LV transformation, the supply of LV networks in 220/380 V, according to two very distinct principles. These correspond to practices homogeneous to protection plans for generation systems on one hand, and to distribution on the other hand.

For this project, the economic impact is essential and as the population is very spread out and distant from the production centres, we propose the following solutions:

- the MVB or MVA is a 3-phase type with distribution of only the three phases.
- If the LV load is important and/or near and concentrated, the technique to use is the placement of 3-phase transformers on poles or on the ground, according to the power level to be transported.
- The MV connection is made through a remote control overhead switch (IAT) (Interrupteur Aérien Télécommandé) or a manual control overhead switch (IACM) (Interrupteur Aérien à Commande Manuelle).
- If the LV load is low and distant, we propose to supply these loads from a 3-phase network. However, a more economic system could be set up consisting of a 2-phase network, which are already being tested in countries with scattered housing.

Option : A 2-phase network set up using two phases of the network connected to a transformer substation on a pole. The distances could reach lengths of approximately 30 to 40 km.

The MVB or MVA/LV transformer could supply single phase LV or a not « true » 2-phase, the neutral being grounded near to the customers in order to avoid a mixture of MVA and LV polarity in the presence of faults. The connection to the MV is made through an IACM.

Advantages of this solution :

- Protection for people: the return of high polarity on the LV network from the earthing circuits is very low (it depends on the quality of the earth).
- The protections for generation and distribution equipment are managed independently.
- With a 2-phase network, it is easy to increase power by installing a third phase and by transforming this type of network one by one with extension possibilities by transforming the LV network into a 2-phase MVA network.

9.2.4 Planning

This preliminary study verifies that the networks planned for connection of the Ndokayo site respect the operations criteria relative to voltage and to the load flow in the different works (lines and transformers).

A specific analysis was done by varying the section of the main line in order to deduce the energy losses and their associated economic repercussions. A depreciation analysis of the additional cost of the use of a more costly section was made.

9.2.4.1 Steady state conditions

The verification of the voltage and transit capacity criteria are done in steady state conditions when the totality of the works are available:

- the voltage in the substations must fall within the acceptable range +/- 10 % of U_n
- the current circulating in the lines must not exceed the acceptable maximum limit
- the transit of capacities apparent in the transformers must not exceed their nominal value
- the reactive generation of the units must not exceed their maximum production.

9.2.4.2 Operating condition of n-1 (loss of equipment)

After the loss of a line or transformer, one should check that the voltage in the substations, the current in the lines still in service, as well as the transits in the remaining transformers are still within the accepted limits.

9.3 Operations Outline

9.3.1 Ndokayo

The operations outline corresponds to the use of all the existing works. The loops on the 15 kV urban network were not analysed due to lack of information.

The Ndokayo - Garoua Boulai structure is in 30 kV, a voltage level that minimises voltage drops over the 60 km distance separating the two substations with a maximum active load flow of 3,5 MW. The choice of the cable acts on the energy losses and the table below gives an idea of the size of these losses.

Section of the Cable (Almelec in mm^2)	losses (in %) at maximum load
75	10 %
95	7 %
148	4 %

A double line installation for this line with a section 2 times 75 mm^2 should spread out the investments over time.

Moreover, the two auto-transformers of 30 / 15 kV, with a unit capacity of 2 MVA correspond to those which would be required to be available in the future for the availability of the whole of the hydraulic capacity. This investment could also be spread out over time.

The reactive power generating capacity of the units is only employed when the networks are of acceptable length. Specific studies could be undertaken to examine the installation of condensers at certain source substations.

A device connected to the 30 kV network at a delivery substation enables compensation of the reactive power of the lines without load. The commissioning of charging resistors will enable the realisation of a minimal charge and ensure the correct setting of the frequency, in complement to the setting device for the speed of the units.

9.3.2 Ngambe-Tikar and Olamze

The operations outline corresponds to the use of all existing works. A structure is planned with a connection to the 3-phase antennas, however the use of 2-phase would be possible according to the power level. A specific analysis would have to be undertaken if the connection of the diesels is considered.

9.4 Examination of the Ndokayo Power Transmission

9.4.1 Examination of the Transits

Under normal circumstances, the operation of a mini-system is satisfactory. We do not observe any overload on the network, which is largely dimensioned. After the triggering of an element (line, transformer or unit) the intensities remain inferior to acceptable levels , except in the case of the loss of a 30/15 kV transformer.

9.4.1.1 Loss of a larger unit

After the loss of a hydraulic unit producing 1,8 MVA, generation/consumption imbalance leads to a frequency loss. The re-establishment time should be between 10 to 15 seconds, if the power required is inferior to the maximum potential power or if the load shedding actions are effective in the case of an important imbalance between generation and consumption.

9.4.1.2 Loss of a consumer

9.4.1.2.1 Loss of a consumption antenna

The protections to be put into place near the tapped antennas on the main network or at the departure of a point of supply should rapidly eliminate the faulty section in order to maintain potential production on the main line. In the case of the loss of the main line, the frequency meter protections will trigger one or several surplus units.

9.4.1.2.2 Loss of a 30 / 15 kV transformer

In this configuration, the capacity to be transited is superior to the capacity of each of the auto-transformers, consequently, the dimensioning must correspond to a guaranteed

exchange with a single equipment. An economic analysis should be undertaken in order to distribute the investments over time and to commission the equipment relative to the evolution of the guaranteed transits.
The automatic load shedding control equipment can manage this incident locally and the units react by their frequency/capacity regulation, if necessary, in complement to the load bank.

9.5 Supply of the Site Auxiliaries

9.5.1 Ndokayo

The supply is planned from a diesel set installed on the production site and a capacity of 50kVA seems sufficient. A re-supply from Garoua-Boulai must not be considered, due to the complexity of the exchanges of information . The operation conditions in the case of a re-supply of the de-energised network will require specific operating instructions in order to respect the technological limits of the different equipment.

9.5.2 Ngambe-Tikar and Olamze

The systems are independent and batteries ensure the start-up of each of the units.

9.5.3 Supply of the Distant Loads

Precautions should be taken in order to respect the different technological limits of the equipment used and especially if the energising is abrupt .

9.6 Prolongation of the Studies

The different analyses show that during the loss of works, it is necessary to know the temporal behaviour of different sizes in order to verify their compatibility with the diverse technological limits. It should be done prior to preparation of the technical specifications.

9.6.1 Dynamic Studies

The loss of an element provokes important disruptions, but it is necessary to study the margins of stability of the system. To do this, we can vary the operation time of the protections or the selectivity of its devices, prior to preparation of the technical specifications.

9.6.2 Load Shedding Plan

The studies performed show that the loss of a unit of Ndokayo or the loss of a transformer at Garoua Boulai may cause important frequency deviations. A load shedding should be planned in order to respect these. A specific analysis must be undertaken.

9.7 Overhead line Cost Estimates

The costs of the overhead lines and associated equipment have been established for :

- A main network to be realised in the first stage with the project
- An extension network, not included in this project, to be realised in a second stage by another operator, and dealt with in section 9.7.1.2.3.

The outlines of these networks and their respective costs are included here under.

9.8 Conclusion

The connection of the hydraulic units of Ndokayo, Olamze and Ngambe Tikar to the different networks present the following conditions for supply to consumers:

- located near these sites: no specific problems.
- distant from these sites: the connection shall be made through a 3-phase network when the capacities are important or in an urban zone. However, it shall be made through 2-phase links when the housing is scattered.

As the generation is mostly hydraulic, in all cases, the plans of the voltage and transits induced by the presence of these sites must be compatible with the characteristics of the equipment being used.

During the course of further studies, prior to preparations of the technical specifications, certain themes will have to be looked at in closer detail :

- The refinement of costs with the data received from the local companies and the use of installation standards for HVA and HVB networks.

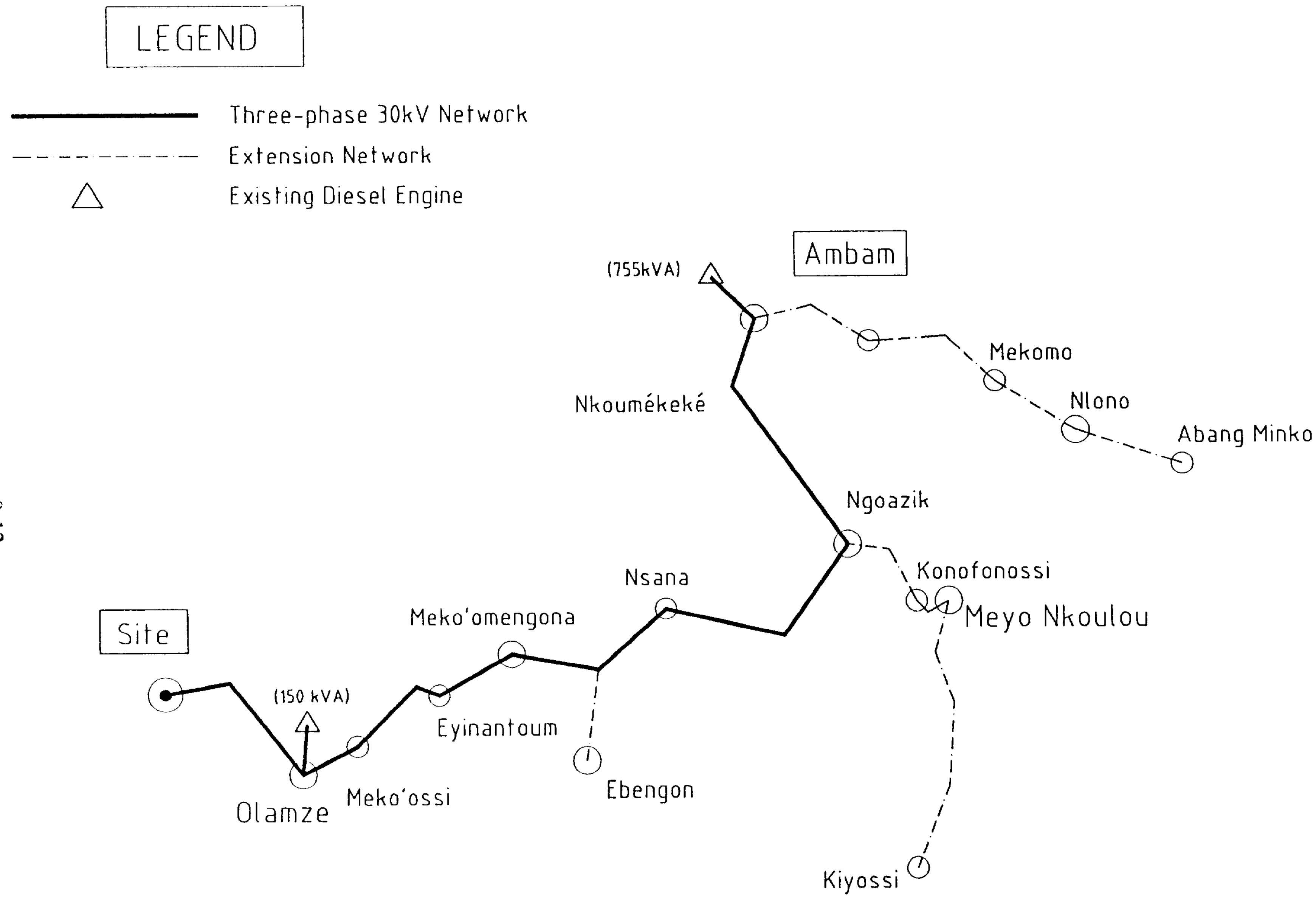
- The installation of 30 / 15 kV auto-transformers; the order of investments should be refined (number and/or unit capacity) relative to the urban network.
- The dynamic behaviour of the equipment in the network. Complementary analyses must be undertaken to better forecast the behaviour after important disturbances, as well as the observed stability margins.

For this last aspect, as a minimum of knowledge of the electrotechnical characteristics is necessary in order to perform these studies, they shall take place in an ulterior phase.

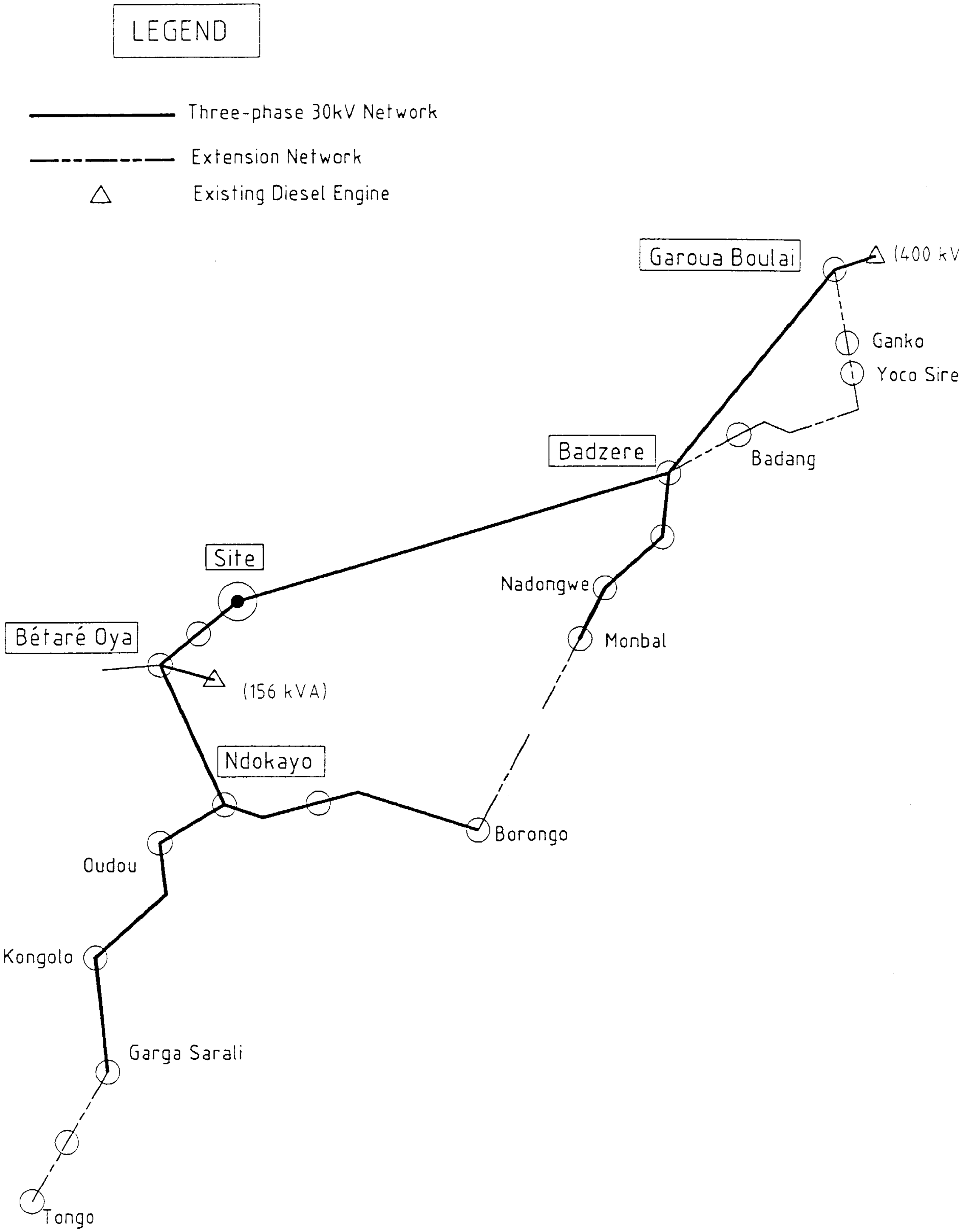
Table 9-1 Decentralized Rural Electrification 30 kV Network in Cameroon for the sites of Ngambe-Tikar, Ndokayo and Olamze

Axes et Centres	Distance to the site in km	Theoritical length of 30kV line to bulidde	Proposed main network in km	Future extension in km
1. Ngambe-Tikar site (Kim river)				
Ngambe Tikar - Mbam axis				
Ngambe-Tikar	7	7	7	
Mansouh	15	8	8	
Ga	20	5	5	
Gwenze	25	5	5	
Sub-total 1		25	25	
Ngambe-Tikar - Kpwala axis				
Gandie	7	7		7
Mboutou	11	4		4
Mbonde	12	1		1
Sub-total 2		12		12
Mgambe - M'bomena axis				
M'bomena	16	9		9
Mdjonkou	21	5		5
Sub-total 3		14		14
Ngambe-Tikar - Nga axis				
Benbeng	26	19		19
Nga	32	6		6
Sub-total 4		25		25
Ngambe-Tikar - We axis				
Wawe	15	8		8
We	25	10		10
Sub-total 5		18		18
Ngambe-Tikar - Mandjambo axis				
Mangon	12	12		12
Sub-total 6		12		12
Ngambe-Tikar Network		**106**	**25**	**81**
2. Ndokayo site (Mari river)				
Bétaré Oya - Garous Boulai axis				
Mari Village	8	8	8	
Lom	22	6		6
Bétaré Oya	16	8	8	
Ndokayo	22	6	6	
Bongo	31	9	9	
Borongo	46	15	15	
Mombal	61	15		
Nadongwé	69	8	8	
Botila	76	7	7	
Badzéré	80	4	4	
Badang	88	8		8
Yoko Sire	98	10		10
Ganko	101	3		3
Garaoua Boulai(*)	106	5	60	
Sub-total 1		112	125	27
(*) ou à 60 km du site en ligne droite				
Ndokayo - Tongo axis				
Oudou	29	7	7	
Kongolo	42	13	13	
Garga Sarali	49	7	7	

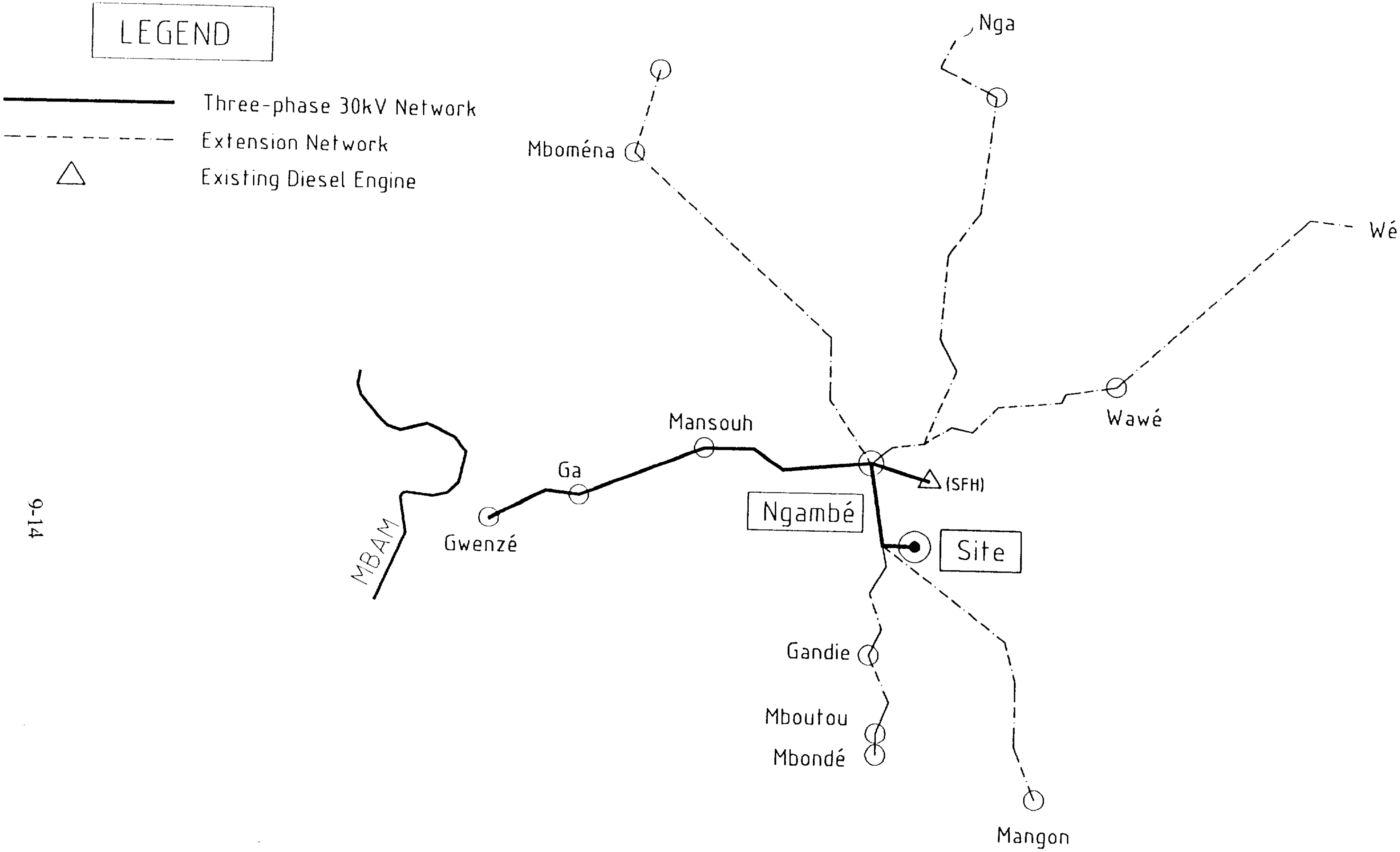
Axes et Centres	Distance to the site in km	Theoritical length of 30kV line to bulidde	Proposed main network in km	Future extension in km
Ngaoundéré	60	11		11
Tongo	66	6		6
Sub-total 2		44	27	17
Ndokayo Network		**156**	**152**	**44**
3. Olamze site				
Olamze - Ngoasik - Ambam axis				
Olamze	15	15	15	
Meko'Ossi	16	1	1	
Eyinantoum	17	1	1	
Meko'Omengona	19	2	2	
Ebengon	24	5		5
Nsana	25	6	6	
Ngoasik	35	10	10	
Nkoumeké	44	9	9	
Ambam	47	3	3	
Sub-total 1		52	47	5
Ngoaslik - Kyé Ossi axis				
Konofossi	38	3		3
Meyo Nkoulou	43	5		5
Kyé Ossi (frontiére Guinée)	66	23		23
Sub-total 2		31		31
Ambam - Abang Minko axis				
Minyim	51	4		4
Mekomo	58	7		7
Nono	63	5		5
Bilessi	68	5		5
Abang Minko	70	2		2
Sub-total 3		23		23
Olamze Network		**106**	**47**	**59**


LEGEND
Three-phase 30kV Network
Extension Network
Existing Diesel Engine
Ambam
(755kVA)
Mekomo
Nlono
Abang Minko
Nkoumékeké
Ngoazik
Konofonossi
Meyo Nkoulou
Nsana
Meko'omengona
Site
(150 kVA)
Eyinantoum
Ebengon
Meko'ossi
Olamze
Kiyossi

OLAMZE Site



Ndokayo Site



NGAMBE TIKAR Site

Table 9-2 Ngambe-Tikar Network Construction Cost
Main Three-phase 30 kV Network in MV & Extension

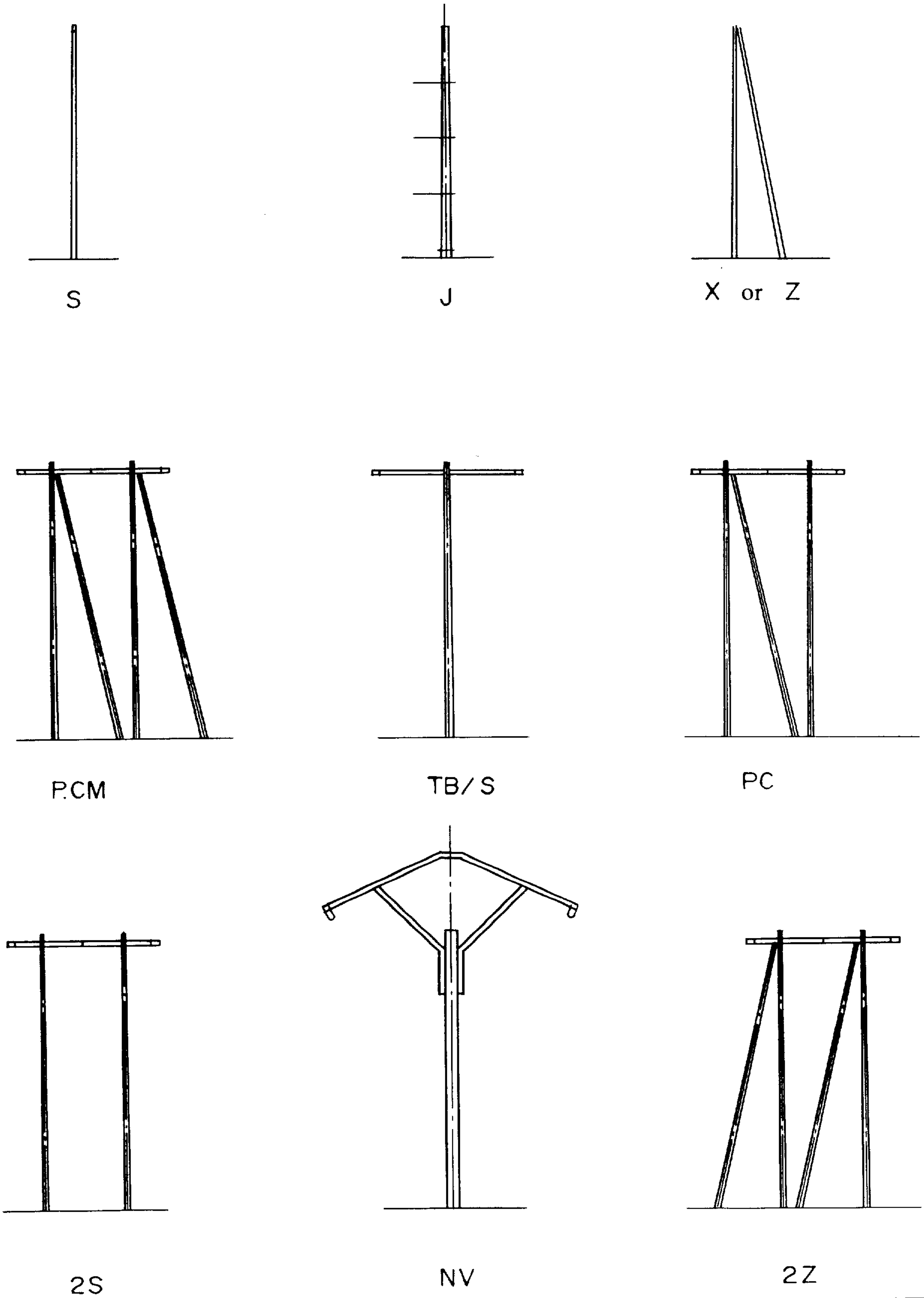
Ngambe-Tikar Network at price level 1999 (w/o Tax)	Unit	Cost (in MF. CFA)		Total Cost in MFFR
		Unit price	Total	
1. Main Network - Three-phase Line in 30 kV (excluding main transformers)				
Line "Site to Gwemze"				
Line in 3 x 54 mm^2	25 km	8.5	213	2.1
Transformers				
Transformer 50/100kVA Three-phase 30/0, 4kV	3	3.5	11	0.1
Transformer 15/25kVA Three-phase 30/0, 4kV	3	3	9	0.1
Equipment				
Automatic Switch 30kV (IACM)	6	2.5	15	0.2
Line Protection	1	5	5	0.1
Sub-total			252	2.5
Engineering & miscellaneous	5%		13	0.1
Contingencies	5%		13	0.1
Total Main Network	25 km	11	278	2.8
Part of Supply (for information only)				
Cables			*121*	
Transformers			*15*	
Switches			*15*	
Total of Supply			*151*	*1.5*
2. Network Extension				
Line MW in 30kV - 3 x 54 mm^2	81 km	8.5	689	6.9
Transformer 15/25kVA Three-phase 30/0, 4kV	10	2.5	25	0.3
Engineering & miscellaneous	5%		34	0.3
Contingencies	5%		37	0.4
Total Extension Network	81 km	10	785	7.9
Total 1 & 2	106 km	10	1,063	10.6

Table 9-3 Nkokayo Network Construction Cost
Main Three-phase 30 kV Network in MV & Extension

Ndokayo Network at price level 1999 (w/o Tax)	Unit	Cost (in MF. CFA)		Total Cost in MFFR
		Unit price	Total	
1. Main Network - Three-phase Line in 30 kV (excluding main transformers)				
Line "Site to Garoua Boulai"				
- Deforestation (30m)	60 km	0.6	36	0.4
- in 3 x 95 mm^2	60 km	9.2	552	5.5
Line "Site to Ndokayo"				
- in 3 x 75 mm^2	22 km	8.7	191	1.9
Line "Garga Sarali to Borongo" & "Badzere to Monbal"				
- in 3 x 54 mm^2	70 km	8.5	595	6.0
Transformers				
Auto-Transformer 2MVA Tri. 30/15kV	2	15	30	0.3
Transformer 100/150kVA Three-phase 30/0, 4kV	6	4	24	0.2
Transformer 75/100kVA Three-phase 30/0, 4kV	2	3.5	7	0.1
Transformer 25/50kVA Three-phase 30/0, 4kV	4	3	12	0.1
Equipment				
Switchyard	4	25	100	1.0
Manual Switch (IAT)	3	4	12	0.1
Automatic Switch 30 kV (IACM)	4	2.5	10	0.1
Line Protection	2	5	10	0.1
Sub-total			1,579	15.8
Engineering & miscellaneous	5%		79	0.8
Contingencies	5%		83	0.8
Total Main Network	152 km	11	1,741	17.4
Part of Supply (for information only)				
Cables			*789*	
Transformers			*55*	
Switches			*99*	
Total of Supply			*943*	*9.4*
2. Network Extension				
Lines: Lom, Tongo, Badang-Ganko				
Line MV in 30 kV - 3 x 54 mm^2	44 km	8.5	372	3.7
Transformer 75/100kVA Three-phase 30/0, 4kV	2	3.5	7	0.1
Transformer 25/50kVA Three-phase 30/0, 4kV	5	3	15	0.2
Engineering & miscellaneous	5%		19	0.2
Contingencies	5%		21	0.2
Total Extension Network	44 km	10	435	4.4
Total 1 & 2	196 km	11	2,177	21.8

Table 9-4 Olamze Network Construction Cost
Main Three-phase 30 kV Network in MV & Extension

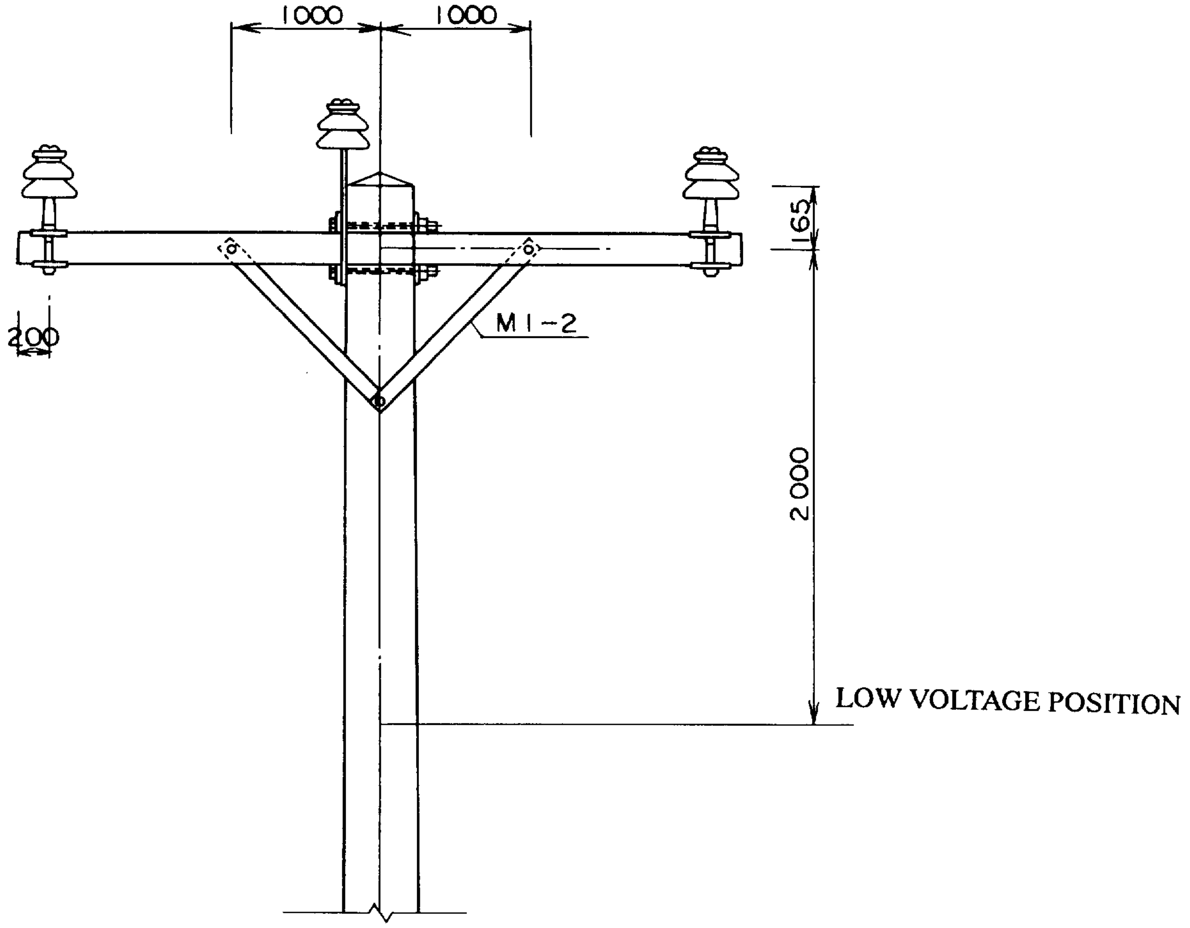
Olamze Network at price level 1999 (w/o Tax)	Unit	Cost (in MF. CFA)		Total Cost in MFFR
		Unit price	Total	
1. Main Network - Three-phase Line in 30 kV (excluding main transformers)				
Line "Site to Ambam"				
Line in 3 x 54 mm^2	47 km	8.5	400	4.0
Transformers				
Transformer 50/100kVA Three-phase 30/0, 4kV	5	3.5	18	0.2
Transformer 25kVA Three-phase 30/0, 4kV	5	3	15	0.2
Equipment				
Manual Switch (IAT)	1	4	4	0.0
Automatic Switch 30kV (IACM)	8	2.5	20	0.2
Line Protection	1	5	5	0.1
Sub-total			461	4.6
Engineering & miscellaneous	5%		23	0.2
Contingencies	5%		24	0.2
Total Main Network	47 km	11	508	5.1
Part of Supply (for information only)				
Cables			*228*	
Transformers			*24*	
Switches			*22*	
Total of Supply			*274*	*2.7*
2. Network Extension				
Line MW in 30kV - 3 x 54 mm^2	59 km	8.5	502	5.0
Transformer 25/50kVA Three-phase 30/0, 4kV	10	3	30	0.3
Engineering & miscellaneous	5%		25	0.3
Contingencies	5%		28	0.3
Total Extension Network	59 km	10	584	5.8
Total 1 & 2	106 km	10	1,093	10.9

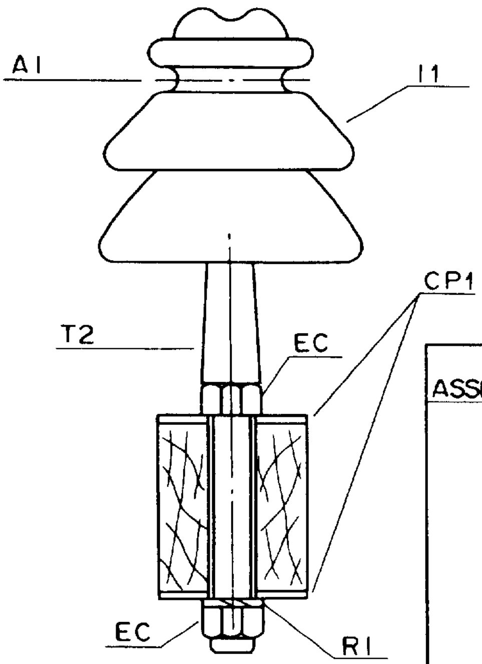


MINI HYDRO-ELECTRIC
POWER STATION PROJECT

TRANSMISSION LINE
SILHOUETTE OF WOODEN POLE

Fig. 9-1



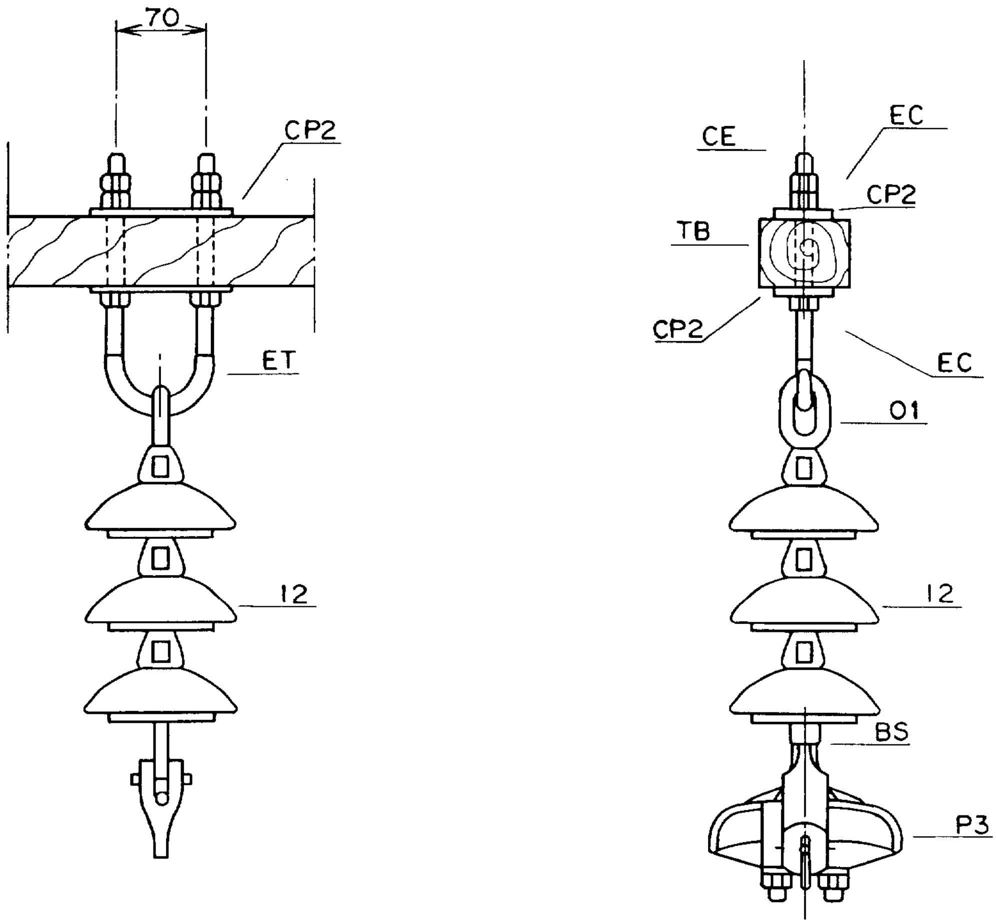


ASSEM	N° ITEM	DESIGNATION	QTE	CODE
		ISOLATEUR RIGIDE SUR TRAVERSE BOIS DE 3.40m		
	A1	Attache pour càble	01	
	I1	Isolateur rigide	01	
	T2	Tige renforcée pour isolateur rigide	01	
	CP1	contre plaque 100X80	02	
	EC	Ecrou	02	
	R1	Rondelle grower	01	
	M1-2	Montant fer plat 1500	02	
	TB	Traverse bois	01	

MINI HYDRO-ELECTRIC
POWER STATION PROJECT

TRANSMISSION LINE (M-VOLTAGE)
RIGID ISOLATER OF
SUSPENSION POLE (3.4 m)

Fig. 9-2

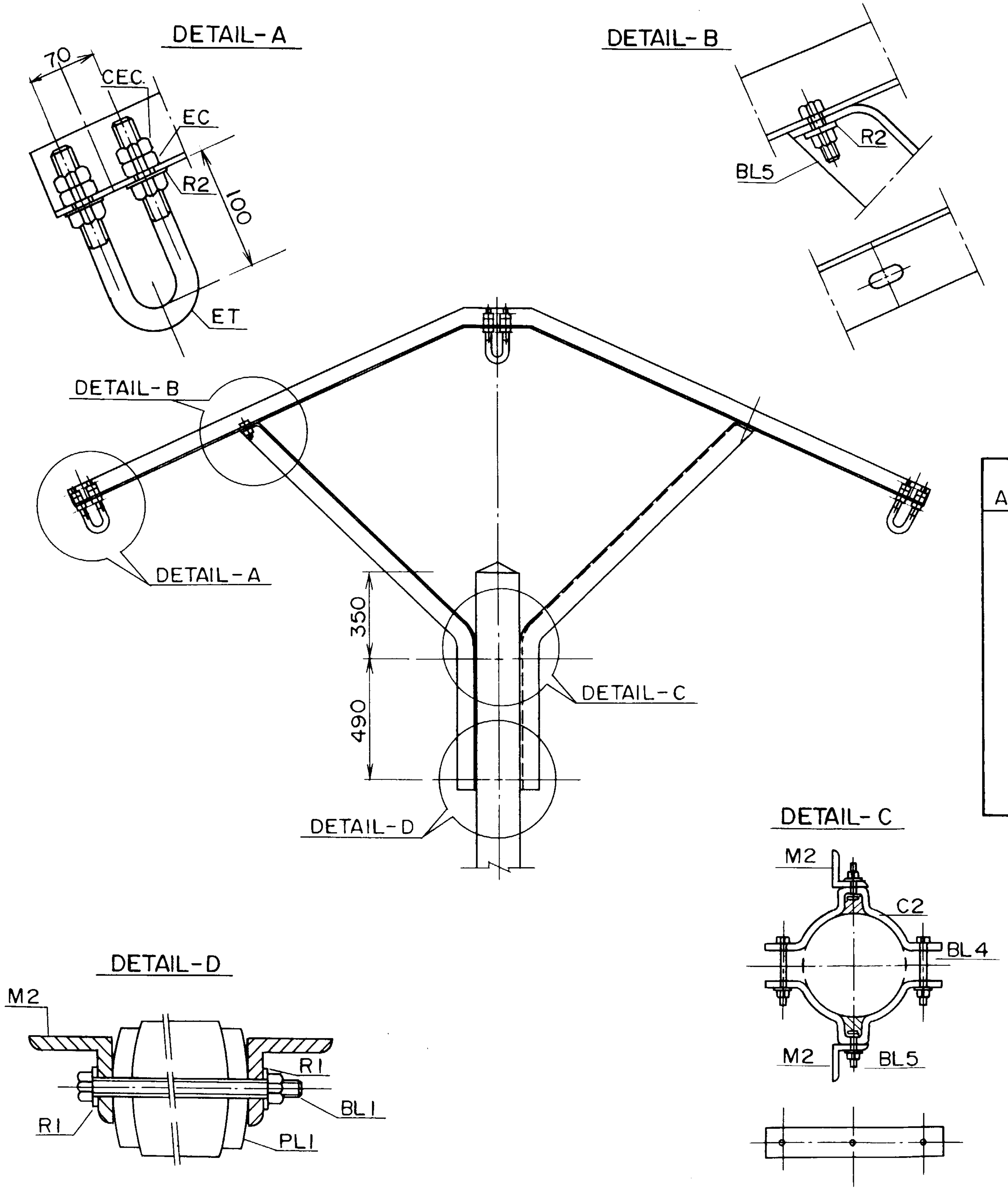


ASSEM	N° ITEM	DESIGNATION	QTE	CODE
		CHAINE A SUSPENSION A VEC ETRIER		
	CP2	Contre plaque 100X80 pour écrier Ø 14	02	
	ET	Etrier en U	01	
	12	Isolateur suspendu	03	
	EC	Ecrou	04	
	O1	Oeillet à rotule	01	
	TB	Traverse bois	01	
	CEC	Contre écrou	02	
	BS	Ball socket	01	
	P3	Pince de renvoi	01	

MINI HYDRO-ELECTRIC POWER STATION PROJECT

TRANSMISSION LINE (M-VOLTAGE)
SUSPENSION CHAINE WITH STRAP

Fig. 9-3

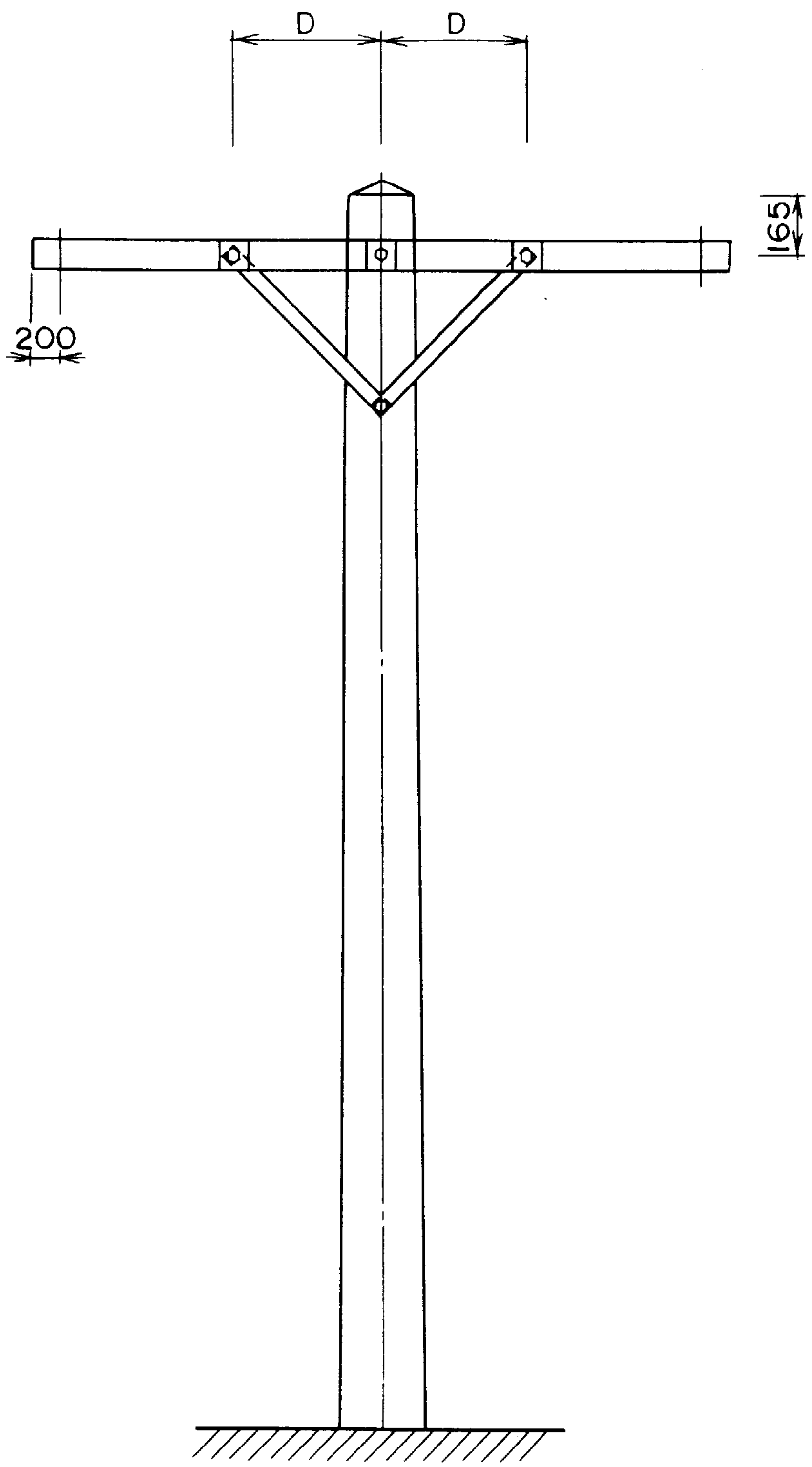


ASSEM	N° ITEM	DESIGNATION	QTE	CODE
		NAPPE VOUTE SUR POTEAU BOIS		
	EC	Ecrou Ø = 10	06	
	R2	Rondelle grower Ø = 12	08	
	ET	Etrier	03	
	BL5	Boulon 10X100	04	
	R1	Rondelle grower Ø = 16	08	
	BL1	Boulon 14X450	01	
	C2	Collier de fixation nape voute	02	
	M2	Montant nappe voute	02	
	BL4	Boulon 10X200	04	
	PL1	Plaquette cylindrique pour poteau bois	02	

MINI HYDRO-ELECTRIC
POWER STATION PROJECT

TRANSMISSION LINE (M-VOLTAGE)
ARCH-TYPE EQUIPMENT

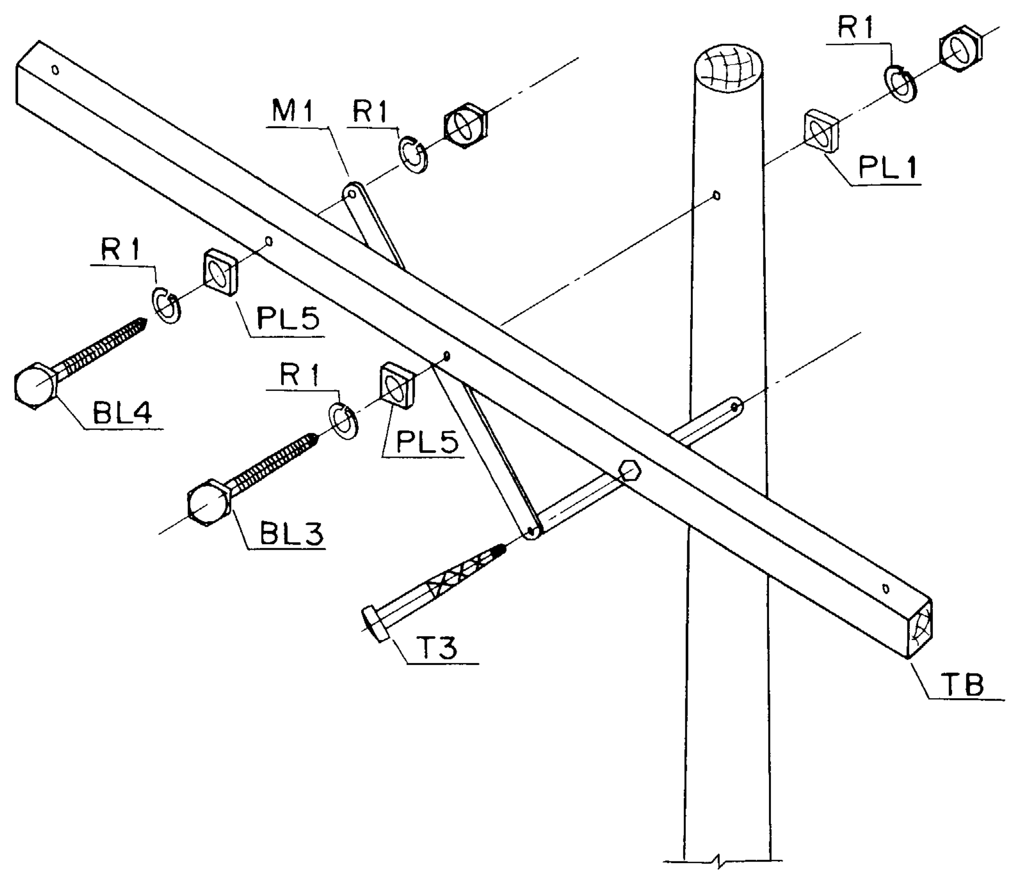
Fig. 9-4



D: -500 POUR TRAVERSE DE 2.40m
-1000 POUR TRAVERSE DE 3.40m

M1: -760 POUR TRAVRESE DE 2.40m
-1500 POUR TRAVERSE DE 3.40m

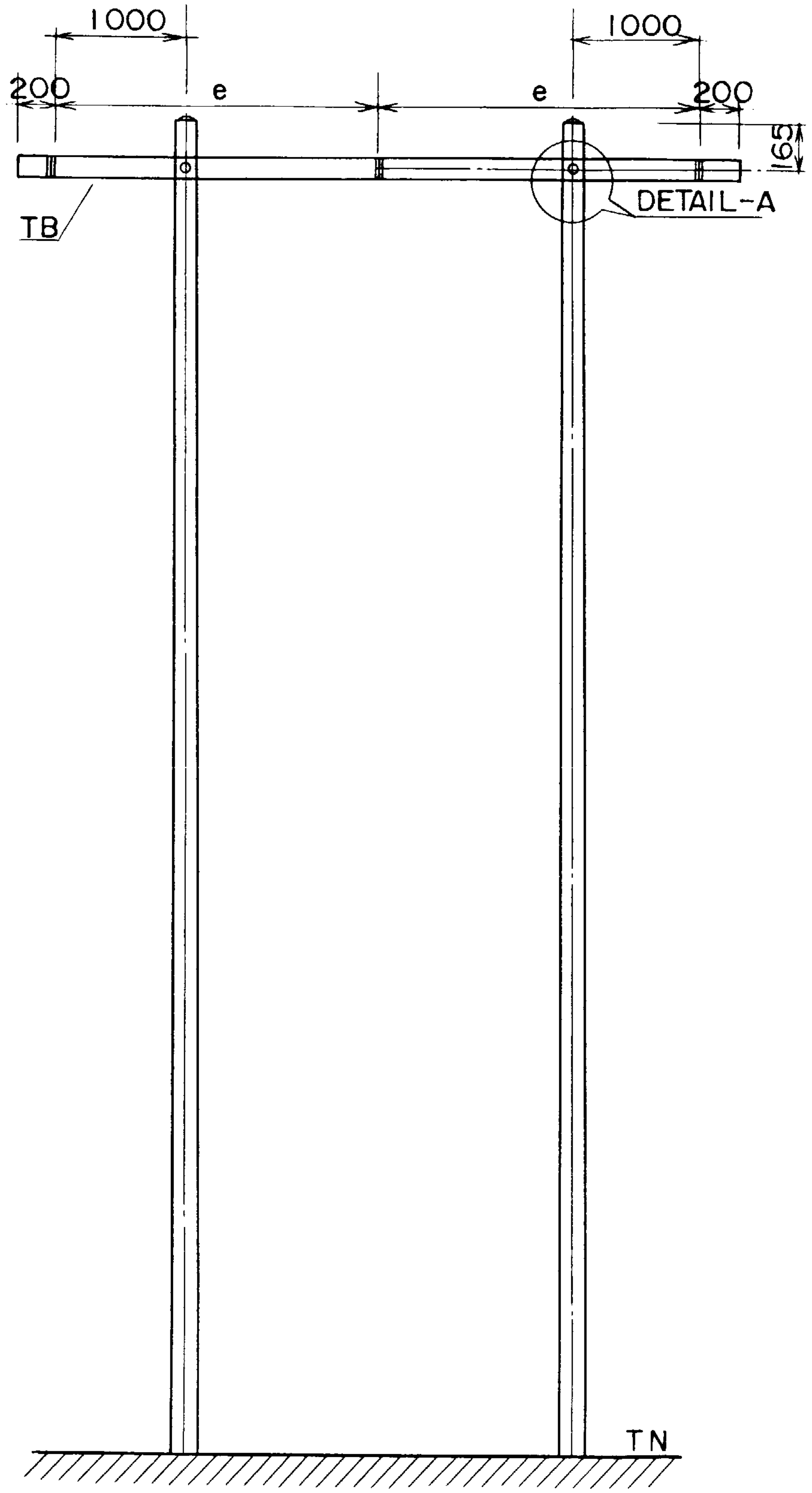
ASSEM	N° ITEM	DESIGNATION	QTE	CODE
		TRAVERSE SUR POTEAU SIMPLE		
	TB	Traverse bois	01	
	T3	Tire fond 14X100	01	
	BL4	Boulon 16X200	01	
	BL3	Boulon 16X350	01	
	PL5	Contre plaque galvanisée 100X80	04	
	R1	Rondelle grower Ø = 18	06	
	M1	Fer plat dimension variable	02	
	PL1	Plaquette galvanisée type PR 35 pour poteau bois	02	



MINI HYDRO-ELECTRIC POWER STATION PROJECT

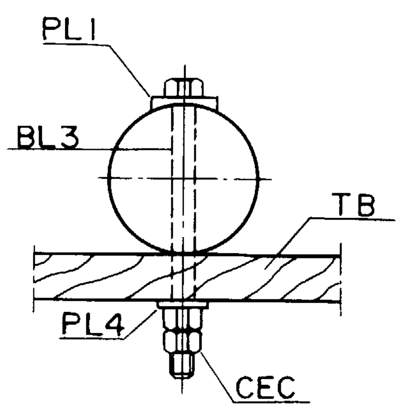
TRANSMISSION LINE (M-VOLTAGE)
SILHOUETTE
WOODEN-ARM OF SUSPENSION POLE

Fig. 9-5



ASSEM	N° ITEM	DESIGNATION	QTE	CODE
		TRAVERSE BOIS SUR PORTIQUE SIMPLE (2S)		
	PL1	Plaquette cylindrique pour poteau bois	02	
	BL3	Boulon 14X350	02	
	TB	Traverse bois	01	
	PL4	Contre plaque galvanisée 100X80	02	
	CEC	Contre écrou	02	
	PB	Poteau bois	01	

DETAIL-A



MINI HYDRO-ELECTRIC POWER STATION PROJECT

TRANSMISSION LINE (M-VOLTAGE)
SILHOUETTE
SUSPENSION GANTRY (2S)

Fig. 9-6

CHAPTER 10. ENVIRONMENTAL SURVEY

Chapter 10　Environmental Survey

10.1　Summary and Contents of Construction Plan

Refer to Chapter 8 and 9.

10.2　Summary of the Area

10.2.1　Social Environment

(1)　Demography

As mentioned before, the population in Republic of Cameroon is about 13 million in 1996 and the population growth rate is as high as 2.89%.

The Ngambe-Tikar as the first proposed site of this project is located near the village named Ngambe-Tikar in Ngambe-Tikar sub-division belonged to Mbam and Kim Division, Centre Province.

Even though detail demographic census has not been reported after 1987, total population of the Ngambe-Tikar area, which will be covered by the studied microhydro-project, is estimated about 6,000.　There are 20 villages belonging to this sub-division such as Gah, Kpaga, Mbeng-Mbeng.

The Ndokayo as the second proposed site is located near the Third degree village, being about 12 km from Betare Oya city, in Batara-Oya sub-division belonged to Bertoua Division, East Province. The population, which will be covered by the studied micro-hydro-project except that of Garoua Boulai, is about 18,000 and nearly 3,400 households are in the site area with an average of 5.3 people in a household.

The third proposed site is located near the village of Andok which is approximately 20km from Olamze village, the center of Olamze sub-division. Olamze village, which will be covered by the studied micro-hydro-project, has population about 5,000 and households about 1,000. About 50 villages are scattered in this sub-division.

(2)　People and Culture

More than 200 tribes reside in Republic of Cameroon. Bantu tribe is living in the area south side of so called Bantu-line which is running from east to west of Republic of Cameroon, and also large number of Bamileke tribe which belongs to Bantu in broad sense is living in the area west side of that line. The area from east to north part has geographical features of savanna and desert. The area has complicated distribution of tribes such as nomads of Furani, Sudan Tribe and Arabic Lineage.

There are 24 native languages spoken beside of French and English as official language. Religious feature includes 33% of Christianity, 16% of Islam and traditional Aminism of others.

(3) Industry

Agricultural products produced in Republic of Cameroon are coffee, cacao, banana and tobacco as export goods, and grain and vegetables such as millet, corn and rice for daily foods for residence. Farmers get their profit from selling these agricultural products at markets. Grains are cropped at the northern part and area near Sahel. Rice, onion and fruits are produced at the area of irrigated firm land. Corn is the main product at the coastal zone and the high land in the western part of the country.

Stock rising is conducted at the northern part of the area and exported to the neighboring country, Nigeria. Fisheries at coastal area is started for supplement of financial difficulties of fishermen and ship builders, but is stagnated now a days. However, fisheries at the lake of Ragudo dam is successfully developed as export industry. Also, small scale fisheries are conducted widely at inland rivers and supply a part of food for residence.

Secondary Industry occupies about one forth of the gross domestic products. Various necessaries of life are produced by companies related to agriculture and household industries, and these days, some of them are exported to neighboring areas. In Republic of Cameroon, it is possible to export not only crude oil, but also refine and electric refine. Although about 13% of exports is occupied by exporting log and lumbering which becomes one of the source of acquisition of foreign currency, protection of forestry resources by regulation has been advocated.

The tertiary Industry is occupied more than half of the gross domestic products. Service industry related to transport of necessaries of life creates employment, especially in the cities of Yaounde and Douala.

In Ngambe-Tikar sub-division, industries such as agriculture producing cocoa, coffee and corn, small fishery scaled 35,000CFA income, hunting targeting small animals, breeding small livestocks, manual industry and commerce are conducted. Agriculture is ineffective because of farmland without irrigation system and lacking fertilizer use. As a big industry making cash income, there is forest development and sawing industry by HAZEM public corporation.

At Olamze sub-division, there are industries such as agriculture producing cassava, banana, corn, tomato and peanut which are exported mainly to Gabon or Guinea, fisheries for local consumption, hunting and raising livestocks.

Main industries conducted at Ndokayo area are agriculture producing corn, carrot, yam, banana, and small scale fishery at rivers of Lom and Mari for local consumption.

Also, there is small scale commercial business, and gold dust collecting at the rivers of Bali and Mbal.

(4) Transportation

The transportation network in Republic of Cameroon is distributed centering around Douala City at coastal area and Yaounde City at inland area.

The road between Douala City and Yaounde City, and Ngambe Tikar point has first class highway paved with asphalt until Foumban City, and most of the part from Foumban to Ngambe-Tikar is second class all-weather road.

It takes about one hour drive from Foumban to Manki. Point kilometric 36km from Manki crossing Mbam river, and 25km more drive takes to Ngambe Tikar point. On the other hand, the another road via Yaounde Bafoussam and Magba in Manki is used for transporting lumber, so that it seems possible to transport some degree of heavy matters. The proposed dam site is located 2km from concrete made bridge crossing the Kim river which is 4km from Ngambe Tikar village. The proposed site has good access from existing road.

It takes about 10 hours to Ndokayo site from Yaounde City via Ayos, Abong Mbang, Bertoua and Betare Oya. The road between Yaounde City and Ayos is a first class highway paved by asphalt. The road after Ayos is all weather first class road but it has problem with traffic jam during rainy season and its road surface.

The road after Ndokaya village becomes second class, a foot path take to the dam site. Private houses are scattered at the area before the foot path, but not found at the proposed site.

For access to Olamze site, the following route has to be followed ; go to Ambam via Ayos, take a ferryboat to go across a river Ntem to Olamze City, go further 20km to Olamze site . The road until Yaounde and Ebolowa is first class highway paved by asphalt. From Ebolowa to Olamze is a second class road which has no problem for use in the dry season, but presents a problem during the rainy season. The road from Olamze village to the proposed dam site is existing on the left side of Woro river but not on the right side.

(5) Land use

According to the land use draft regulation classified by agriculture & forest, fishery and hunting rules examined with Canadian cooperation, Olamze sub-division is mainly divided as a forestry section, an individual and common forestry section, a living space and agriculture & forestry section, an opening space and agricultural section. The proposed site belongs to an opening space and agricultural section, but is not belonged to the prohibited district of forest cutting down, fishery and hunting.

Areas of Ngambe-Tikar and Ndokayo have no land use regulation, but according to hearing survey with the forest bureau, it is given a priority to local intention on land use. Especially, because Ndokayo village is in Savanna zone, it is said that there will be no significant problem found on developing project. Therefor, none of the 3 proposed site is in protection district, and it is required to obtain necessary land space under deliberating with local authorities and land owner.

(6) Inland water

Fishery in Republic of Cameroon is divided into 7 categories such as large scale fishery, medium and small size fishery and traditional or domestic consumption fishery and sports fishing. Inland water fishery is belonged to type of traditional or domestic consumption fishery.

At the rivers of the three proposed sites, small scale fishery purposed to residential consumption is conducted. Aquaculture, however, is not operated.

The rivers around the proposed sites are not used for transportation purpose, because the river shape is not suitable for transportation. Drinking water is supplied by underground water at all 3 proposed site, and direct river water use for drinking purpose is not conducted.

(7) Health and Sanitation

The average span of life in Republic of Cameroon as a whole is 55 years old. The baby mortality rate is 62 out of 1,000 infants, and malnutrition is ranked at fifth of its cause.

The number of medical doctors at the state of the most northern part is extremely limited, as small as 2 doctors for 100,000 people, comparing to 15 doctors at the center states. In this limited situation, the private medical facilities managed by religious bodies contribute great manner, but public hospital has poor facilities. These medical services are spreading to local areas, but still there is big regional difference. Major endemic in Republic of Cameroon is diseases such as malaria and cholera. Moreover, many water supply works has been projected in Republic of Cameroon, but only one third of administrative districts have got benefit from those projects.

(8) Related Laws and Regulations

The environmental basic law（N96/12/05/August) was enacted in 1996, and following general principles related to environmental impact assessment are established as guidelines.

① analysis of the initial environmental condition of the proposed site
② justification of the site selection
③ evaluation of the predicted impacts by the implementation of the proposed project on the site and its natural and social environment
④ summary of the measures by the promoter or owner to eliminate, reduce or, if appropriate, compensate for the negative impacts be the proposed project on environment and the estimation of the expense to be incurred

⑤ project alternatives and the justification of the selected alternative from the environmental protection

Moreover, environmental protection related on atmosphere, inland water and wet land, coast and marine water, soils, waste, hazardous or toxic chemical substances, noise and offensive odor are enacted.

For natural environment :

① regulation on national park and protection area reserves

② regulation on forest reserves

③ regulation on wildlife protection

④ regulation on fishery

Although there are seven designated national parks and six designated reserves for wild animals, none of 3 proposed site is located in these designated area. Regulation on land use is examined on a part of land with Canadian cooperation. According to the examination, Olamze zone which is one of 3 proposed site is the area designated on the regulation on land use. The site is next to production forest（FPX、Fig. 10. 1), and dam site is belong to the residential and agriculture & forestry area.

Wildlife species designated in the regulation on wildlife protection is shown in Table 10.1, Table 10.2 and Table 10.3. Species listed on Class A, Rare or endangered species, have mammals including totally 19 species ; 3 species of Family Bovidae such as gazelle, 3 species including 2 species in a sub-family of orangutans, 2 species of Family Elepantidae, 1 species of Family Giraffidae、3 species of Family Felidae such as lion, 2 species of Family Lorisidae, 1 species of Family Rhinocerotidae, 1 species of Family Orycteropodidae. Birds are included 7 species such as Ostrich and Family Accipitridae.

Class B, partially protected species, include 24 species of mammals such as Superfamily Bovoidea, Underorder Ancodonta, Underorder Suina and 1 species of Viverricula. Birds are included 14 species such as Suborder Ardeae and Order Psittaciformes. Reptiles are included 3 species of Order Crocodilia, 2 species of Family Varanidae and 1 species in a sub-family of Pythoninae. According to information from WWF（World Wild Fund for Nature), there is no regulation on protection of flora.

(9) Landscape

The rainy season is from April to October, and dry season is from November to March in this country. According to the survey conducted in June, the proposed intake dam site at Ngambe-Tikar has relatively flat landscape, and bottom of river is covered by rocks. The area is surrounded by forest and has relatively mild stream. Landscape at the site is not different from that of surroundings.

The proposed intake dam site at Ndokayo has steep geographical features and a waterfall running among forest, but is hard to access from a nearest village. The intake dam site at Olamze is in the dense forest, and no significant difference in landscape is found.

(10) Cultural Asset

There is no cultural asset found in any of 3 proposed sites.

10.2.2 Natural Environment

(1) Geosphere (topography, geology, soil, sand accumulation, etc.)

Ngambe-Tikar site is located 6 km from Ngambe Tikar village, and its topology is very flat. Around 300 m of shallows are formed along a river but with gentle slope to downstream. Base rocks belong to a migmatite layer, which is dominant in Cameroon. The Mari River flows perpendicular to hills at Ndokayo site, bedrock stands steep, and there are some places relatively unstable on both sides of a fall. Riverbed is made of quarzite with thin layers of quartz porphyry. No sediment can be recognized in waterfall basin. Olamze site locates in a very flat area and there is little inclination in the river.

(2) Aquasphere (flow regime, water quality, sediment etc.)

The Kim River belongs to Sanaga river system. It originates in the southern slope of Adamaoua Highland which extends east and west in Cameroon at the altitude of 900 to 1,500 m, and it flows south to join the Mbam River. The proposed site is at about 710 m in altitude and its catchment area is around 5,830 km^2.

Annual average of river flows at the proposed site is 59.3 m^3/sec. Traces of floods there suggest that during floods, water goes up around 2 m above its level in dry season. Since the upstream is forests and the proposed site is far apart from human settlements, it is assumed that water quality there is in natural condition. Riverbed is made of bedrock, and no polluted mud is found at all.

Ndokayo site locates at the downstream end of the Mari River, which is a tributary of the Lom River of Sanaga river system. The Mari River originates in the southern slope of Adamaoua Highland, and it flows southwest to eventually join with the Sanaga River. Total length of the Mari River is about 59 km, and its catchment area is 640 km^2. The proposed dam site locates between 700 to 790 m in altitude. Annual average of river flows at the proposed dam site is 10 m^3/sec. According to the visual observation, water there containes inorganic mud but it appeared to be clean. The upstream to this site occupies a savanna, and no situation of organic pollution is recognized there.

Olamze site locates at the most downstream of the Woro River. The Woro River originates in Guinea and it flows about 60 km to the north to join the Ntem River. More than 90% of its basin is within Guinea. Water at the proposed site is slightly brown in color, but no pollution is recognized. Annual average of river flows at the proposed site is estimated to be 12.8 m^3/sec.

(3) Atmosphere (meteorology, air quality, odor, noise, vibration, etc.)

Climates in Cameroon are divided to two major categories; tropical climate in the area north to the line between Bertoua and Bafia, and equatorial climate in the area south to this line. There are distinct four seasons in equatorial climate. Geographically, the southwestern area adjacent to Guinea is hot and humid, while it becomes hot and dry in inland.

Climate in Ngambe-Tikar area belongs to wet tropical climate, and annual precipitation ranges from 1,600 to 1,700 mm. Average temperature is 23℃ and relatively low. Rainy season is from April to October, and dry season is from November to March. Climate in Ndokayo area is also tropical climate like in Ngambe-Tikar area, and precipitation and temperature there is similar to those in Ngambe-Tikar area. Although the climate in Olamze area is equatorial climate, it is hot and humid and it rains a lot since it is close to the Atlantic Ocean and influenced by south coast-type of equatorial climate. Annual average temperature is 24 to 25℃, and precipitation is 1,800 to 2,000 mm/year.

The three proposed sites are all far from human settlements, and they are in forests or savannas where natural environment is almost preserved. There is no problem of air pollution, odor, noise nor vibration.

(4) Biota

1) Vegetation

Vegetation in Cameroon is generally divided to savannas in the north which Ndokayo area belongs to, semi-deciduous forests in the center which covers Ngambe-Tikar area, succession forests in the south, and evergreen forests along the west coast where Olamze area locates.

In Olamze area, mixed forests of semi-deciduous trees and Atlantic coast-type evergreen trees and semi-deciduous forests are dominant (regions with dark and light green hatches in Fig. 10.2). Ngambe Tikar area is covered by semi-deciduous-type development forests (represented by regions with blue meshes), and there grow cacaos (*Sterculianceae*) and , *Zelkova* and *Ulmaceae* trees.
Northern type semi-deciduous forests (159) are also found there. Ndokayo area is in savannas with small shrubs (138, 172).

According to the distribution map of trees (Arbres des forêts Denses d'afrique Central), there are 127 species in Olamze area, 107 species in Ngambe Tikar area, and 45 species in Ndokayo area (Table 10.4). Number of species in Ndokayo area in savannas is small.

2) Terrestrial animals

As for mammals, general information prepared by WWF is shown in Table 10.5.
According to this information, 67 species were recognized in Ntem Drainage area where Olamze site is located, and 15 of them are protected animals. In Tikar area, 58 species were recognized, and 17

of these are protected. In Betare-Oye area, 51 species were found, and 15 of them are protected.

Among them, occurrences of elephants (*Loxodonta africana*) in Ngambe-Tikar and Betare-Oya areas, and water-deer (*Kobus defassa*) and jackals (*Canis aureus*) in this area are not recognized any more. One the other hand, it is said that aquatic mammals such as otter-screws (*Potamogala velox*, *Ladra maculicollis*, *Anonx capensis*, *Aonyx congica*, *Hymoschus aquaticus*) may be occurring. Especially in Ntem drainage area, a species of amphibians, or frogs (*Conraua golisth*), 3 species of cats (*Gentta vicotria*, *Poiana richardsoni*, *Felis aurata*), 4 species of cercopithecid monkeys (*Mandrillus sphinx*, *Cecocebus torquatus*, *Gercopithcus pogonias*, *Colobus satanus*), gorillas (*Gorilla gorilla*), and chimpanzees (*Pantroglodytes*) may occur.

3) Aquatic organisms

Basins in Cameroon are divided to 5 major basins as shown in Fig. 10.5. Ngambe Tikar site and Ndokayo site are in Sanaga basin, and Olamze site is in the southern basin. Dr. Jacques Vivien recognized the occurrences of 542 species of 179 genera in 53 families of fish in Cameroon. Those which occurred in Sanaga basin and the basins in south coast are summarized in Table 8.6. In Sanaga basin, 185 species were recognized, while additional 6 species are thought to be occurring although they were not found. This makes the total number of species to 191. On the other hand, 211 species were found in the coastal basins in the south while 17 more species are presumed to be occurring, which makes the total number to 228. During the survey by WWF (Table 10.7) at a location along the Ntem River, which is close to Olamze site, 7 species of freshwater anchovies, 6 species of characins, 6 species of cichlids, 5 species of oryziatids, 3 species of spiny eels, 2 species of gobies and 5 species of carps were recognized.

10.3 Present Status of Environment at the Proposed Site

10.3.1 Demography

As stated already, there are about 1,800 households of about 9,000 people in the Ngambe-Tikar area and its labor population is estimated to be about 2,000.

Population in neiboring villages are; 1,050 people in Gah village, 350 people in Gwenze village and 300 people in Mansonh village. Although the population is about 18,000 in the Ndokayo area except Garoua Boulai area and about 5,000 in the Olamze area, there is no human settlement at any of the proposed dam and power station sites.

10.3.2 People and Culture

There are 6 public elementary schools and one junior high school in Ngambe-Tikar area. There are also private schools. Monthly average income of the middle class, such as officials of local governments, is CFA 35,000 and their annual income is around CFA 420,000, but the monthly average income of ordinary people is about CFA 20,000. Although the main agricultural products are cocoas and corns, but their productivity is low since no fertilizer is used. Monthly average income of the local fishermen is CFA 35,000. Cattle-raising, hunting and handicraft manufacturing are also conducted as local industries.
There is an elementary school in Ndokayo village, and most of the people in the village can read and write French.

In this area, there are many small businesses and they sell food and clothes. Although electricity is produced by diesel generators, only 10 people own them. Therefore, there exists a strong demand for electricity supply for lighting at night and the use of electric appliances.

There are 20 elementary schools, one kindergarten and one junior high school in Olamze area, but their facilities are very poor. Annual average income in the area is CFA 300,000. Main products are peanuts, bananas, pistachios and corns for local consumption, and cacaos, coffees and oil palms for commercial purposes. Sheep, poultry and boars are raised. No fertilizer is used in local agriculture, and no machine is used in local fishery.

10.3.3 Topography and Soil

There are rapids of 3 to 5 m in depth at the proposed Ngambe-Tikar dam site, but the river is 50 to 80 m wide at its narrowest part and both sides of the river are flat. This site can not provide an abutment for a large-scale dam. There are forests on both sides of the river, and soil there is thin and poor, which is typical for soils in tropical areas.

Ndokayo site is from 700 to 790 m in altitude, and there is a fall of about 80 m in height. There is no topography against the proposed generation project and it does not prevent locations of a water intake just above the fall and a powerhouse just below it.

Olamze area is in a jungle. Its altitude is 550 m. Topography there is very flat. Although there appear several low rapids during dry seasons, the slope of river is around 1/100 and very slight.

The upstream to the proposed dam for water intake is very flat and there are many tributaries. There are human settlements along them. Soils there seem to be those with humus.

10.3.4 Flow Regime, Water Quality and River Bottom

As is described in Chapter 5 Water quality analyses, annual average of river flows at Ngambe-Ticar is 59.3 m^3/sec with their maximum monthly average of 208.1 m^3/sec in October and their minimum of 6.3 m^3/sec in February. ORSTOM analyses suggest that once-in-hundred years flood level is 898 m^3/sec and once-in-thousand years flood level is 1,050 m^3/sec. Water is clear and no mud is observed during dray seasons. Bottom of the river is conglomerates. There does not appear to be excessive growing of sessile organisms, and the river bottom is not organic.

Annual average of river flows at Ndokayo site is 10 m^3/sec with their maximum monthly average of 24 m^3/sec in October and their minimum of 2.6 m^3/sec in March. ORSTOM analyses suggest that once-in-hundred years flood level is 45 m^3/sec and once-in-thousand years flood level is about 54 m^3/sec. Water is clear and the river bottom is rocks.

Annual average of river flows at Olamze site is 12.8 m^3/sec with their maximum monthly average of 28.3 m^3/sec in October and their minimum of 5.3 m^3/sec in February. ORSTOM analyses suggest that once-in-hundred years flood level is 69 m^3/sec and once-in-thousand years flood level is about 80 m^3/sec. Many brown suspensions, probably humus, were observed, but this seems to be natural characteristics of this river. It is thought that there is an accumulation of silts on the river bottom.

10.3.5 Biota

Main vegetation at Ngambe-Tikar site is scarce bushes, but there remains jungles with tall trees on river banks. During the site survey, only a species of bird, which appeared to be a heron, was observed on a river bank. It was observed that fish, probably carps, were swimming in the river.

Vegetation at Ndokayo site is similar to the vegetation in Ngambe-Tikar site, but somewhat diffused forests remain at Ndokayo site. Although birds were recognized during the site survey, no other animal was observed. Among fish, those which appeared to be carps were observed, but their number was not so large. There extend tropical forests at Olamze site. Due to the poor visibility in jungles, no wild animal could be identified.

10.3.6 Landscape

There is no distinct feature in landscape of Ngambe-Tikar. Although there is a fall at the Ndokayo site, it does not attract tourists. Olamze site is in jungles, and its landscape is similar to the surroundings.

10.4 Predictions and Evaluations of Environmental Impacts

10.4.1 Prediction and Evaluation Processes and the Objectives for Environmental Protection

The present project is a rural electrification project by mini-hydroelectric power generation. A small-scale run-of-river-type power station proposed in the present project would change its surrounding environment, such as its downstream, much less than reservoir-type power stations. Nevertheless, potential impacts by the proposed project have to be reduced as much as possible, and it is necessary to consider environmental protection when details of the project are designed.

The project has to be designed to minimize the area to be impacted, and considerations have to be taken so that potential impacts on social environment of the area by the construction are avoided. Objectives for environmental protection should be determined in accordance with the relevant regulations in Cameroon.

10.4.2 Predictions and Evaluations for Operation

(1) Topography and soil

Topography of Ngambe-Tikar site is flat, and there does not appear to be a suitable location for an abutment of water-intake dam. Although it is necessary to design the dam little higher than the river bottom in order to take water, and the area to be inundated by the intake dam is small and it will occupy only a part of the present wide river bed. No impact is predicted on surrounding environment. Sedimentation is expected to be minimal when the water quality there and the water exchange rate of the intake pond are considered. Land slides are not expected to occur due to the flat topography.

Ndokayo site is in a V-shaped valley which leads to a fall. The water-intake dam is very small and it does not go beyond the valley. No significant impact is predicted on surrounding forests. No scar of landslide is recognized in the area, and its foundation seems to be strong. Degradation of water is not expected there when the water quality and water exchange rate are considered. No erosion is expected on the river bed at the water-discharge point.

Although Olamze site is in jungles, it is extremely flat and large area will be inundated by the trivial height of water-intake dam. The Ntem River is not clear due to humus, but its bottom is covered with a slight layer of silts on bedrock. Sedimentation problem seems to be relatively insignificant there. The foundation of river at the water-discharge point is bedrock, and there will not be a significant problem of erosion in surrounding soils nor river bed.

(2) Flow regime, water quality and river bottom

At Ngambe-Tikar site, the proposed project will create an approximately 500 m section of reduced water in the river during dry seasons, since the water taken for power generation is discharged at 500 m down to the intake. However, since water exchange rate at the water-intake dam is high, and water is discharged back to the river, there will not be a significant change in water quality and sediments down to the discharge point.

At Ndokayo site, a part of the river water will be taken by a very small dam at the upstream to the fall and used for power generation. Like at

Ngambe-Tikar site, river flow will be reduced for around 500 m especially during dry seasons, but there will be no significant change in flow regime nor water quality down to the discharge point.

Since it is flat at the proposed Olamze site, an area to be inundated by the water-intake dam would be wide depending on the river flow, and there would be an impact on human settlements in the upstream. It is necessary to design dam height, taking the river flow into consideration, so that required amount of electricity is produced and, at the same time, no impact is made on human settlements in the upstream. At the moment, sufficient information has not been obtain on detailed topography of the upstream including tributaries. Careful investigations should be conducted at D/D stage, and the project should be implemented after due consideration of possible options. Although the present project is so-called “dam-type power station” and the river flow will not be reduced at any section of the river, it is possible that a pedestrian’s bridge at several kilometer up to the dam would be submerged under backwater even in case of a small-scale and low dam.

At present, water is clean. However, depending on dam height, the reservoir area would enlarge. In a shallow reservoir, water exchange rate would be low, and stagnant water is expected to appear. This may lead to some degradation of water quality, and favorable environment for the propagation of malaria mosquitoes may be created.

As for potential impacts on underground water, no specific impact is likely since the water-intake dam is small at all of the three sites. The present project is to construct a small-scale run-of river-type power station at an inland tributary, and it will not create a significant impact on water balance in the downstream.

(3) Biota

1) Vegetation

At Ngambe-Tikar site, a water intake-dam will create a small reservoir in the area which is presently riverbed of rocks and a part of the surrounding forests. However, the forest area to be inundated is very small, and the forests in this region are not those to be protected by law. There will be little impact on natural environment.

Ndokayo site is in a part of savanna, and there is no jungle. However, some trees will be cleared for the access to the water-intake dam and power house. These trees are also not protected by law, and the area to be cleared is limited. There will be a minimal impact on natural environment.

Olamze site is close to production forests, and some forests have to be cleared for the access. Approval by the Forestry Department would be required for their clearings. Depending on dam height, a large area would be inundated. Consultation with those who represent local interests is required to design the project.

Although small in scale, transmission lines are required. However, they are to run along the existing roads at all sites to reduce the number of trees to be cleared, and the proposed transmission route avoids houses. Operation of the project will not create a problem.

2) Terrestrial animals

According to the survey in Ngambe-Tikar area by WWF, there occur 58 species, but this area is not designated as a nature reserve. Facilities to be constructed for the project are small, and they will be designed as compact as possible. They will not change the habitat greatly. Ndokayo site is also not included in a nature reserve, and only a small area will be modified. Habitats for the animals in this area will not be greatly influenced. Olamze site is not included in a nature reserve. Although the inundated area in the flat upstream may change its shape, its impact on local animals is thought to be insignificant since human houses are already there.

3) Aquatic organisms

As for fish, there does not exist sufficient information on rivers in the project area. Many species in Cameroon are yet to be identified. However, the site survey and literature survey did not reveal the occurrence of anadromous nor catadromous fish in the area, and the present project does not seem to create a problem on fish. Further surveys should be conducted during the period with high water level at D/D stage to consider whether the installation of a fish way for their migration is required or not. At Ndokayo site, where a water-intake dam is to be constructed just above a fall, the fall itself creates a natural barrier against fish migration, and the proposed project does not make an impact on fish.

At Ngambe-Tikar and Olamze sites, a river section with reduced water flow is short, and fish fauna is similar between the upstream and downstream of the proposed dam. Separation of species may occasionally occur during the period with low water level, but this will not lead to their extinction. Nevertheless, it should be considered for Ngambe-Tikar site, after future surveys on fish migration, whether a measure is required for the protection of fish during the period with low water level.

(4) Landscape

The site at Ngambe-Tikar has no significant landscape so that there will be less impact on the landscape. The proposed plan for Ndokayo site takes advantage of its landscape which is a waterfall of Milo running in forest at savanna zone. It is possible to be pointed out the future source of sight-seeing for the waterfall, but it is extremely far from city and in unexplored region, and also nothing valuable for sight-seeing dose exist around the site. The intake point at Olamze site is in forest so that there has no significant landscape. Valuable landscape dose also not find out after the construction.

10.4.3 Estimation and Evaluation during Construction

(1) Resettlement

There is no village around the proposed sites at Ngamb-Tikar and Ndokayo, so that resettlement problem will not occur. Although there is no village at Olamze proposed site, some settlements are existing at the upstream of the site.

Because the river slope at Olamze site is extremely gentle, adoption of appropriate dam height, in order to generate necessary electric power, may cause inundation of a village, farm land and/or road. It is necessary to investigate for further consideration. A plan for Olamze site will be proposed after comparing alternative schemes and it should be a plan not required resettlement.

Moreover, for selecting and transporting construction materials, adjusting access route to construction area and establishing transmission line, a construction plan which gives less impacts on residence will select measures such as choosing area where the project does not give conflict on residential life and industry, extending the width of existing roads, arranging limited space, selecting low noise and vibration machines, and careful selecting of construction hours.

(2) Nation and Culture

Because there is no resettlement problem caused by inundation at the proposed sites at Ngambe- Tikar and Ndokayo, there is no possibility to give negative impacts on residential life and their culture. The construction work of the proposed hydropower plant will make contributions to local economy and residential life in the field of employment of local people as construction workers, establishment of a medical facility and supply of electricity. Construction vehicles are managed appropriately under consideration of residential life pattern. Moreover, it is required to consider employment of local residence for construction work as much as possible.

At the rivers around the 3 proposed site, they are small scale but fisheries for residential consumption are conducted. Therefor, it is required to give careful consideration for safety and support fisherman’s life.

(3) Water Quality and Soil

It is possible to produce mud caused by construction work at the sites. Naturally, organisms living in a river inhabit with tolerate or escape from muddiness caused by flood. However, it is necessary to contrive the way of construction for minimizing impacts on the habitat. It is minimized impact on soil quality by setting measure for construction discharge. General construction waste and waste from lodgings for workers should be treated by following the related regulation of Republic of Cameroon.

(4) Biology

1) Flora

The forest, which may have some impacts by setting access route, constructing intake facility, plant, transmission line and other related works, is considered to cut down after consultation with related organization.

2) Terrestrial Fauna

It is possible to make fauna away temporarily by noise and vibration from construction. Some measures will be introduced such as selecting low noise and vibration machines. The construction period is very short time so that it will be recovered after the construction.

3) Aquatic Organism

It is possible that there are some fish species which escape from the area temporarily during the construction. However, some measures will be introduced such as reducing mud water spread and controlling water quality at construction area so that impacts on aquatic organism will be minimized.

10.5 Environmental Protection Measures and Land Acquisition

(1) Environmental Preservation Measures

1) During Operation

The three hydroelectric power stations of this Project are all to start power generation by 2010, with power transmitted to villages neighboring the respective power stations by 30 kV medium voltage transmission lines. As socio-economic effects, although of small number, local residents will be employed as unskilled technicians or laborers for rises in incomes, while also, opportunities to experience elementary-level power generation and transmission technologies will be increased. Further, the installation of hydroelectric power stations will be useful for improvement of local electrification rates, improvement in livelihood of residents, and promotion of livelihood activities. Still further, since roads from the principal villages to the dams and power stations will be maintained in good condition, the situation will be far better than at present, and the benefit to the regional society and economy will be great. Communications and medical services will also be improved.

The three hydroelectric power stations of this Project are all small hydros and there will be no fear of large amounts of discharge to threaten the safety of residents, and neither will there be risk of slopes collapsing and sedimentation occurring. During flood, however, there will be risk that the surroundings will be inundated by backwater of Olamze Intake Pond, and it is necessary for a separate investigation to be made in this regard for some measure to be taken including changing of plans. Effects on public sanitation and changing of stream water quality will be little since all of the power stations will be small.

When the power stations are operated, stream water will be impounded by the dams and, especially at the Ndokayo site, Mari Waterfalls located between the intake dam and the power station will dry up temporarily. However, this site is at a remote location and is not a place where tourists would come, while local residents will not be affected at all.

Regarding impact on the ecosystem, at Ngambe-Tikar and Olamze, flow of river water will be cut off temporarily due to construction of intake dams and there will be a risk of obstructing migration of fish. However, the existence of fishes with such a habit, especially in this season, has not been confirmed, and it is believed there will be no harmful effect. Concerning land animals also, the dams, power stations, and transmission lines will all have vast wild plains around them and it is thought the animals will not be affected in particular.

At all of the hydro sites, there may be benefits for the residents of the surrounding areas, but it is not conceivable that there will be negative effects with respect to safety and public sanitation. As for negative influences on the ecosystem, there should be none when the existence of the surrounding wilderness is considered. However, if there is to be any exception, it would be the inundation of the surroundings by the backwater of Olamze Intake Pond, and it is thought this is a matter which should be cleared up through flood area surveys in an additional field investigation.

Items to be monitored are listed in (1) of 10.6, Monitoring Program.

2) During Construction

Each of the projects will require a period of approximately 2 years for construction, and laborers will be hired from within and without the project area to carry out works such as clearing, temporary facilities, permanent facilities, access roads, etc. It is thought approximately 30% of these laborers will be mobilized from outside, while the remainder is estimated will be hired from within the project area and immediate surroundings, that is, they will comprise the majority of unskilled workers.

It is estimated that the number of local residents who will be hired during the construction period will be approximately 200 for the respective projects. Thus, the execution of construction will provide employment opportunities for many people living in the project area and surroundings, and bring about increases in income.

As for the case of a laborer who is a carrier of a contagious disease being mobilized from outside the project area, there would be the fear that the disease would be spread among residents of the area, but a contagious disease of a type communicated from person to person is not highly infectious, and it is considered there will be no problem if sanitation of the laborers' quarters were to be maintained.

Regarding effects of transporting materials and equipment during the construction period, carbon monoxide, nitrogen oxide, and particularly, dust in the dry season, may temporarily increase when a vehicle passes by, but it is thought normally regulated values, for example, dust approximately 250 mg/m^3, carbon monoxide approximately 20 ppm, and nitrogen oxide approximately 0.05 ppm will not be exceeded. However, regarding volume of dust, people living along roads will be troubled so that in areas where housing densities are high, measures such as sprinkling of water are to be carried out as suited.

During construction, there is a possibility for traffic accidents to occur in areas where there are many local residents. Measures such as traffic regulation and speed regulation should be taken as necessary, and trouble with local residents must be avoided. In the event trouble does occur, quick medical service and compensation must be provided. Traffic noise will affect wild animals living in forest areas along roads and transmission line rights of way, but this will be in a narrow range, while not very many animals inhabit these parts. Results of investigations indicate that protected animal species do not exist in the project area. A vast wilderness makes up the surroundings and it may said there will be hardly any impact felt.

Items to be monitored are listed in (2) of 10.6, Monitoring Program.

(2) Acquisition of Land

1) Acquisition of Land

All three of the sites will not require any expense for acquisition of land.

2) Compensation

None of the three sites will require any expense for compensation. However, as previously mentioned with regard to the Olamze site, the area upstream of the Olamze site is extremely flat and it is necessary for a study to be made with a detailed topographical map. Under present circumstances, priority should be given to the projects at the Ngambe-Tikar and Ndokayo sites, while regarding the Olamze site, the effects of the backwater of the regulating pond caused by the intake dam should be further examined including possible changing of the dam site, upon which the project should be implemented

10.6 Monitoring Program

The environmental monitoring program to be followed during construction and when the power stations are in operation is as shown in the tables below.

(1) When Operating

Major Impact	Cause	Monitor Item	Monitoring Purpose	Data Collection Method	Data Analysis Method	Object Area	Period & Frequency	Organization Concerned
1) Income increase	· Employment · Electricity tariff · Industry, others	· Labor pool & wages · Industry	Monitoring item at left	Government & local agency data	Data tabulation & trend analysis	Project area (incl. transmission line route)	Bimonthly	Government & local agency
2) Public sanitation	Electric power distribution	Sicknesses	Monitoring sicknesses	Government & local agency data	Data tabulation & trend analysis	Project area (incl. transmission line route)	Bimonthly	Government & local agency
3) Impact of inundation (Olamze only)	Intake pond backwater	· Complaints, disputes · Compensation	· Inundation scale investigation · Monitoring complaints & compensation situation · Improvement works execution	Field investigation, interview	· Data tabulation, illustration · Analysis	Intake pond surroundings	Flood duration	Government & local agency

(2) During Construction

Major Impact	Cause	Monitor Item	Monitoring Purpose	Data Collection Method	Data Analysis Method	Object Area	Period & Frequency	Organization Concerned
1) Income increase	Employment	Locally hired laborers number, wage level	Monitoring item at left	Contractor's data	Data tabulation & trend analysis	Project area (incl. transmission line route)	Bimonthly	· Government & local agency · Contractor
2) Traffic obstruction & traffic accident	· Equipment & materials delivery · Road repair & access road construction	· Complaints · Disputes · Accidents	· Monitoring traffic accidents, number & frequency of interference to transportation traffic · Monitoring complaints, disputes of residents	· Data from contractor and police · Field investigations	· Data tabulation · Trend analysis	· Project site (incl. transmission line route) · Roadside area	Monthly	· Government & local agency · Contractor
3) Noise, air pollution, public sanitation	· Equipment & materials delivery · Road construction, materials collection works · Laborers' quarters	· Complaints · Disputes · Sicknesses · Dust quantity · Noise level	· Monitoring dust quantity, noise level · Monitoring complaints, disputes of residents · Monitoring sicknesses	· Field investigations	· Data tabulation · Trend analysis	· Project site (incl. transmission line route) · Roadside area	Monthly	· Government & local agency · Contractor
4) Impact of inundation (Olamze only)	Inundation	· Compensation · Complaints, disputes	· Inundation scale investigation · Monitoring complaints and disputes situations · Improvement works execution	· Field investigations · Interviews of farmers, land owners	· Data tabulation, illustration, analysis	Intake pond surroundings	Flood period	Government & local agency

10.7 Comparison Studies of Alternative Plans

These small hydros are small-scale run-of-river types, with extremely small impacts on their surrounding areas, and when expenses and convenience of maintenance and inspection are taken into consideration, there can be no alternative plan.

10.8 Evaluation

The project sites of the three hydros are all only several kilometers away from their respective neighboring villages and, since the power generation schemes are all of extremely small scale, there will be hardly any effects on the present natural and social environment. If there are any points in particular requiring attention to be paid, they are (1) the negative effects from backwater of the intake pond at Olamze must be eliminated at the time final plans are made, (2) the waterfalls of Mari at the Ndokayo site will dry up temporarily during the dry season, but this site is in an extremely remote area, hardly ever approached by other than local residents, so this will not be a problem, (3) the works are of small scale, but with regard to increased traffic volume during construction and the resulting dust and noise, it will be necessary for the constructor to give appropriate consideration in village areas with high concentrations of housing. The table below is a summary of the overall assessment on the environmental impacts of the Project.

Environment Affected	Content	Impact	Analysis and Degree of Impact	
1. Industry in power system area	Power generation	Electric energy supply	Society, economy	A+
2. River water use				
When operating	Maintenance and control of dam and power station	Downstream flow reduction when operating	Society, economy	C
During construction	Construction of structures	Water pollution from muddy water	Society, ecosystem	B-
3. Land transportation				
When operating	Access road	Improvement of traffic	Society, economy	B+
During construction	Traffic of vehicles concerned	Traffic safety and dust	Society	B-
4. Esthetics				
When opeating	(Ngambe Tikar, Olamze)	Loss of tourism resources	Society, economy	C
When operating	(Ndokayo)	Loss of tourism resources	Society, economy	B-
5. Public sanitation				
When operating	Pollution of water used	Contamination of drinking water	Hygiene	B-
During construction	Pollution of water used	Contamination of drinking water	Hygiene	B-
	Inflow of laborers, wastes	Outbreak of sickness	Hygiene	B-
6. Land animals				
When operating		Influence of structures, intake ponds	Ecosystem	C
During construction	Clearing and construction	Impacts of noise, air pollution	Ecosystem	C
7. Aquatic animals				
When operating		Change in downstream water flow	Ecosystem	B-
During construction	Construction	Impact of contaminated water	Ecosystem	B-
8. Ecosystem				
During construction	Construction work	Impact due to changes in habitat and restriction of movement	Ecosystem	C
9. Atmosphere				
When operating			Society, economy, ecosystem	C
During construction	Construction work	Pollution due to traffic volume and construction	Society, economy, ecosystem	B-
10. Employment				
When operating	Operation and maintenance	Employment in items at left	Society, Economy	A+
During construction	Construction work	Employment in item at left	Society, economy	A+

A: influential + : plus

B: slightly influential - : minus

C: non influential

Table 10.1 Protected wild animals in class A (Rare or Endangered Species)

Mammals

English Name	Scientific Name
Red-fronted gazelle	Gazella rufifrons
Caracal	Felis caracal
Water chevrotain	Hyemoschus aquaticus
Chimpanzee	Pan troglodytes
Mountain reedbuck	Redunca fulvorufula adamauae
White-mantled black colobus	Colobus guereza
Elephant (less than 5 kg points)	Loxodonta africana
Pygmy elephant	Loxodonta pumilio
Giraffe	Giraffa Camelopardalis
Gorilla	Gorilla Gorilla
Cheetah	Acinonyx jubatus
Manatee	Trichechus senegalensis
Lion	Panthera pardus
Panther	Panthera pardus
Lemur	
Angwatibo (Golden potto)	Arctocebus calabarensis
Potto	Perodicticus potto
Galago (Bush baby)	Galago alleni
Aardvark	Orycteropus afer
Black rhinoceros	Diceros bicornis

Birds

English Name	Scientific Name
Ostrich	Struthio camelus
Shoebill (Whale-headed stork)	Balaeniceps rex
Black stork	Ciconia nigra
White stork	Ciconia ciconia
Secretary bird	Sagittarius serpentarius
African harrier hawk	Polyboroides radiatus
Bateleur	Terathopius ecaudatus

Note:Rare or endangered wild animals are designated in Class A. These animals are to be protected througout the country. Capture or hunting of these animals are permitted only for the development for public interest, scientific study, protection of human health and properties, when the special permission is granted by the representative of the Tourist Bureau.

Table 10.2 Protected wild animals in Class B (Partially protected species)

Mammals

English Name	Scientific Name
Bongo	Boocerus euryceros
Hartbeest	Alcephalus buselaphus major
Water buffalo	Syncerus caffer
Waterbuck	Kobus kob
Colobus other than white-mantled black colobus	Kolobus spp
Bohol reedbuck	Redunca redunca
Korrigum	Damaliscus korrigum
Giant eland	Taurotragus derbianus
Elephant (more than 5 kg point)	Loxodonta africana
Bushbuck	Tragelaphus scriptus
Hippopotamus	Hippopotamus amphibius
Roan antelope	Hippotagus equinus
Mandrill	Papio (Mandrillus) sphinx
Drill	Papio (Mandrillus) leucophaeus
Yellow-backed duiker	Cephalophus silvicultor
Bay duiker	Cephalophus dorsalis
Civet	Viverra vibetta
Giant ground pangolin	Manis gigantea
Sitatunga	Tragelaphus spekel
Defassa waterbuck	Kobus defassa
Swine	
Giant forest hog	Hylocherus meinetzhagenl
Warthog	Phacochoerus aethiopicus
River hog	Potamochoerus porcus

Birds

English Name	Scientific Name
Egret	Egretta (casmerodius) Alba
	Egretta mesophoys
Marabou	Leptoptilos crumeniferus
Deham's bustard	Neotis denhami
Abyssinian ground hornbill	Bucorvus abyssinicus
White-bellied bustard	Eupodotis sengaiensis
Parrots and Prakeets	
- Niam-niam parrot	Poicephalus crassus
- Jardine's parrot, I.e. red-headed parrot	Poicephalus gulielmi
- Meyer's parrot, I.e. brown parrot	Poicephalus meyeri
- Senegal parrot, I.e. yellow-bellied parrot	Poicephalus senegalus
- Gray parrot	Psittacus erithacus
- Red-headed lovebird	Agapornis pullaria
- Black-collared parakeet	Agapornis swinderniana
- Rose-ringed parakeet	Psittacula kramerl

Table 10.3 Protected wild animals in class B (Partially protected species) (continued)

Reptiles

English Name	Scientific Name
Crocodiles	
- Nile crocodile	Crocodylus niloticus
- Long-muzzled crocodile	Cocodylus cataphractus
- Dwarf crocodile	Osteoleamus tetraspis
Snake	
- Python	Python sebae
Monitors	
- Desert monitor	Varanus griseus
- Nile monitor	Varanus niloticus

note1: Wild animals in class B are to be protected in the designated areas. These animals may be hunted, caught or shot when an appropriate permission is granted.

note2: Wild animals in class C are those not listed neither in class A nor class B. Shooting of these animals are controled to maintain a population dynamics.

note3: The protection provision for class A animals shall be applied the the young individuals of the above three classes and to the eggs of the birds in class A and class B.

Table 10.4 Tree species found near the proposed project sites

Species Name	Olamze	Ngambe Ticar	Ndokayo
Dracaena arborea	●		
Antrocaryon klaineanum	●	●	
Antrocaryon micraster	●	●	
Lannea welwitschii	●	●	
Trichoscypha acminata	●		
Anonidium mannii	●	●	
Cleistopholis glauca	●	●	
Cleistopholis patens	●	●	
Enantia chlorantha	●		
Hexalobus crispiflorus	●		
Pachypodanthium staudtii	●	●	
Polyalthia suavelens	●	●	
Xylopia hypolampra	●		
Xylopia staudtii	●	●	
Alstonia boonei	●	●	
Funtumia africana	●	●	●
Funtumia elastica		●	
Picralima nitida	●		
Polyscias fulva			●
Fenandoa asolfi-friderici		●	
Markhamia lutea		●	●
Markhamia tomentosa		●	
Spathodea campanulata		●	●
Bombax buounopozense	●	●	
Ceiba pentandra	●	●	●
Rhodognaphalon brevicuspe	●		
cordia platythyrsa	●	●	●
Canarium schweinfurthii	●	●	●
Dacryodes buettneri	●		
Dacryodes macrophylla	●		
Santiria trimera	●		●
Afzelia bipindensis	●		
Afzelia africana		●	
Amphimas pterocarpoides	●	●	●
Daniellia sp.	●		
Detarium macrocarpum	●		
Didelotia unifoliolata	●		
Distemonanthus benthamianus	●		
Erythropleum ivorense	●		
Erythropleum suaveolens		●	●
Gibertiodendron brachystegioides	●		
Gilletiodendron pierreanum	●		
Gossweilerodendron balsamiferum		●	
Guibourtia tessmannii	●		
Hylodendron gabunense	●	●	●
Julbernardia seretii	●		
Monopetalanthus pellegrinii	●		

Species Name	Olamze	Ngambe Ticar	Ndokayo
Oddoniodendron micranthum	●		
Pachyelasma tessmannii	●	●	
Stemonocoleus micranthus	●		
Swartzia fistuloides		●	
Tessmania anomala	●		
Tessmania africana	●		
Plagiosiphon emaraginatus	●		
Magnisipula tessmannii	●		
Maranthes glabra	●	●	
Maranthes chrysophylla	●		
Maranthes gabunensis	●		
Maranthes kerstingii			●
Parinari hypochrysea	●		
Pteleospsis hylodendron	●	●	
Strephonema pseudocola	●		
Terminalia superba	●	●	●
Erythroxylum mannii		●	
Discoglypremna caloneura	●	●	
Drypetes gossweileri	●		
Keayodendron bridelioides			●
Maragaritaria discoidea		●	
Ricinodendron heudelotii	●	●	●
Sapium ellipticum		●	
Uapaca guineensis	●	●	●
Uapaca paludosa		●	
Allanblackia floribunda	●		
Mmmea africana	●	●	
Pentadesma butyracea	●		
Symphonia globulifera	●		
Desbordesia glaucescens	●	●	
Irvingia gabonenis	●	●	
Irvingia grandifolia	●	●	
Klainedoxa gabonenis	●	●	●
Petersianthus macrocarpus	●	●	
Entandrophragma angolense	●	●	
Entandrophragma candollei	●	●	
Entandropragma cylindricum	●	●	
Entandropragma utile	●	●	
Guarea cedrata	●	●	
Guarea thompsonii	●	●	●
Khaya grandifoliola		●	●
Lovoa trichilioides	●	●	●
Trichilia welwitschii	●	●	
Albizia adianthifolia	●	●	●
Albizia ferruginea	●	●	●
Albizia glaberrima	●	●	●
Albizia zygia	●	●	●
Aubrevillea kerstirgii		●	●
Cylicodiscus gabunensis	●	●	

Species Name	Olamze	Ngambe Ticar	Ndokayo
Fillaeopsis discophora	●		
Parkia bicolor	●	●	●
Pentaclehtra macrophylla	●		
Piptadeniastrum africanum	●	●	
Tetrapleura tetraptera	●	●	●
Antiaris africana		●	●
Chlorophora excelsa	●	●	●
Ficus mucuso	●	●	●
Musanga cecropioides	●	●	●
Treculia africana			●
Trilepisium madagascariense		●	●
Coelocaryon preussii	●		●
Pycnanthus angolensisi	●	●	●
Staudtia kamerunenis	●	●	
Syzygium rowlandii	●	●	
Lophira alatra	●	●	
Coula edulis	●		
Ongokea gore	●	●	
Stombosia grandifolia	●		●
Stombosia pustulatata	●	●	
Strombosiopsisi tetrandra	●		
Ponda oleosa	●		
Angylocalaye pynaerii	●		
Erythrina excelsa	●		
Milletia laurentii	●		
Pterocarpus soyauxii	●	●	
Pterocarpus mildbraedii		●	
Maesopsis eminii		●	●
Anopyxis klaineana	●		
Poga oleosa	●		
Bernania brieyi	●		
Hellea sp.	●	●	●
Nauclea didierrichii	●	●	
Pausinystalia macroceras	●	●	
Fragara heitzii	●		
Fragara tessmannii		●	
Hamalium letestui	●		
Afrosesalisia cerasifera		●	
Aningeria robusta	●		
Aningeria altissima		●	●
Baillonella toxisperma	●		
Gambeya afrricana	●		
Gambeya lacourtiana	●		
Gambeya boukokoensis	●	●	●
Pachystela msolo	●		
Tridesmostemon omplalocarpoides		●	
Kanton guereensis	●		
Odyendyea gabonensis	●		
Cola lateritia		●	

Species Name	Olamze	Ngambe Ticar	Ndokayo
Eribroma oblongum	●	●	
Mansonia altissima	●	●	
Nesogordonia papaverifera		●	●
Pterygota bequaertii	●		
Pterygota macrocarpa		●	
Sterculia rhinopentata		●	
Triplochiton sclenroxylon	●	●	
Duboscia macrocarpa	●	●	
Celtis mildbraedii	●	●	●
Celtis zenkeri		●	●
Celtis philippensisi		●	●
Celits tessmannii	●		
Celtis adolfi-friderici	●	●	
Heloptelea grandis		●	
Vitex grandifolia	●	●	
Vitex ciekowskii			●
Erismadelphus exsul	●		
Total numbers of species	127	107	45

● Indicate species found

Reference : J. VIVIEN ,J.J. FAURE ARBRES DES FORETS DENSED d'AFRIQUE CENTRALE(1985)

Table10.5 Mammalas of the Three Sites (information from WWF)

Species	Sites		
	Ntem Drainage	Ticar	Betare-Oye
Potamogalc vlox	+	+	+
Manis gigantea **	+	+	+
Manis tetradaclyla	+	+	+
Manis tricuspis	+	+	+
Funisciurus isabella	+	+	+
Funisciurus gambianus	+	+	+
Fleliosciurus gambianus	+	+	+
Epixcrus cbii	+	+	+
Heliosciurus rufobrachium	+	+	+
Protoxcrus stangeri	+	+	+
Paraxcrus pocnsis	+	+	+
Myssciurus pumilio	+	+	+
Euxcrus crythropus	0	+	+
Cricctomys cminii	+	+	+
Anomalurus beccrofti	+	+	0
Anomalurus deribianus	+	+	0
Anomalurus pusillus	+	+	0
Zenkerella insignis	+	+	0
Idiuros sp.	+	0	0
Thyronymys seindcrianus	+	+	+
Aterurus africanus	+	+	+
Canis aureus	0	0	+
Mellivora capensia	+	+	+
Aonyx capensis	0	+	+
Aonyx congica	+	0	0
Lotra maculicolis	+	+	+
Viverra civetta +	+	+	+
Nandinia binotata	+	+	+
Genetta tigrina	0	0	+
Genetta scrvalina	+	+	0
Genetta victoriae	+	0	0
Poiana richardsoni	+	0	0
Inchncumonia albicauda	0	0	+
Atilax paludinosus	+	+	+
Bdeogale nigripcs	+	+	0
Herpestcs ichncumon	0	0	+
Herpestcs naso	+	+	0
Herpestcs sanguineas	+	+	+
Crossarchus obscutus	+	0	0
Felis syvestris	0	0	+
Felis aurata	+	+	0
Panthera pardus *	+	+	+
Orycteropus afer *	0	0	+
Loxodonta africa *,**	+	+	+
Dendrohyrax arboreus	+	+	+
Phacochoerus aethiopica **	0	0	+
Potamochoerus porcus **	+	+	+
Hylochaocrus meinzerhageni	+	+	0
Hyemoschus aquaticus	+	+	0
Tragelaphus scriptus **	+	+	+
Tragelaphus spekel **	+	+	+
Kobus defassa **	0	+	+

Species	Sites		
	Ntem Drainage	Ticar	Betare-Oye
kobus kobu **	0	+	+
Cephalophus silvicultor **	+	+	+
Cephalophus dorsalis **	+	+	+
C.Ogibyi	+	0	0
C.callipygus	+	+	0
C.nigrifrons	+	0	0
C.monticola	+	+	+
C.rufilutus	0	+	+
C.grimmia	0	0	+
Neotragus batesi	+	+	0
Neotragus pygnacus	+	+	0
Syncerus caffer **	+	+	+
Perodicticus potto *	+	+	0
Arctocebus calabarensis *	+	+	0
euoticus elegantulus	+	+	0
Galago alleni *	+	+	0
Galago demidovii	+	+	0
Galago senegalensis	0	0	+
Mandrillus sphinx	+	0	0
Papio cynocephalus	0	0	+
Cercocebus torquatus	+	0	0
Cercocebus albigena	+	0	0
Miopithecus talapoin	+	0	0
Cercopithecus cephus	+	+	+
C.nictitans	+	+	0
C.mona	+	+	0
C.pogonias	+	0	0
C.negletus	0	0	+
C.aethiops	0	0	+
erythrocebus patas	0	0	+
Colobus guereza *	+	+	+
Gorilla gorilla *	+	0	0
Pan troglodytes *	+	0	0

*Protected mammals throguout of the country
**Protected mammals in degignated areas

Table 10.6 List of Fish Species in the Sagara and South Coast Basin

Family	Species Name	Sanaga River Basin Ngambe Ticar Ndokayo	South Coast Rvier Basin Olamze
Pristidae	Pristis microdon	●	●
Dasyatidae	Dasyatis margarita	●	●
	Urogymnus africanus	●	
Protopteridae	Calamoichthys calabaricus	●	●
Elopidae	Elops lacerta	●	○
	Elops senegalensis	●	○
Ophichthidae	Dalophis cephalopeltis	●	●
Denticipitidae	Denticeps clupeoides	○	○
Clupeidae	Cynothrissa ansorgii	●	○
	Ethmalosa fimbriata	●	○
	Lisha africana	●	○
	Laeviscutella dekimpei	●	○
	Pellonula afzeliusi	●	●
	Pellonula vorax	●	●
	Saridinella aurita	●	○
	Sierathrissa leonensis	●	○
	Thrattidion nactivagus	●	
Osteolglossidae	Heterotis niloticus	●	●
Notopteridae	Papyrocranus afer	●	○
	Xenomystus nigri	●	
Mormyridae	Brienomyrus asustus		●
	Brienomyrus brachyistius	●	●
	Brienomyrus sphecodes		●
	Campylomormyrus phantasticus	●	
	Hippopotamyrus batesi		●
	Hippopotamyrus castor	●	●
	Isichthys henryi	●	●
	Marcusenius conicephalus		●
	Marcusenius mento	●	
	Marcusenius moorii	●	●
	Marcusenius ntemensis		●
	Marcusenius paucisquamatus		●
	Macrusenius stnleyanus	●	
	Mormyrops bchrachi	●	
	Mormyrops caballus	●	●
	Mormyrops deliciosus	●	
	Mormyrops longiceps	●	
	Mormyrops zanclirostis		●
	Mormyrus goheeni	●	
	Mormyrus rume	●	
	Mormyrus tapirus	●	●
	Petrocephalus ballayi		●
	Petrocephalus guttatus		●
	Petrocephalus microphthalmus	●	
	Petrocephalus sauvagei	●	●
	Petrocephalus simus	●	●
	Pollimyrus adspersus		●
	Pollimyrus kingsleyae	●	●
Hepsetidae	Hepsetus odoe	●	●
	Alestes dentex	●	
	Alestes macrophthalmus	●	●

Family	Species Name	Sanaga River Basin Ngambe Ticar Ndokayo	South Coast River Basin Olamze
	Brycinus batesi		●
	Brycinus brevis	●	
	Brycinus imberi	●	
	Brycinus intermedius		●
	Brycinus kingsleyae		●
	Brycinus longipinnis	●	
	Brycinus macrolepidotus	●	●
	Brycinus nurse		●
	Brycinus opisthaotaenia	●	●
	Brycinus taeniurus	○	●
	Brycinus tessmanni		●
	Bryconaethiops macrops		●
	Bryconaethiops microstoma		●
	Hydrocynus forskalii	●	
	Hydrocynus vittatus	●	
	Micralestes acutinens	●	
	Micralestes occidentalis	●	
	Phenacogrammus major		●
	Phenacogrammus stigmatura		●
	Phenacogrammus urotaenia		●
Distichodontidae	Distichodus hypostomatus		●
	Distichodus kolleri	●	
	Hemigrammocharax ocellicauda		●
	Ichthyoborus monodi		●
	Nannaethiops unitaeniatus		●
	Nannocharax fasciatus		●
	Nannocharax intermedius		●
	Nannocharax micros		●
	Neolebias ansorgii	●	●
	Neolebias trewavasae	●	●
	Xenocharax spilurus		●
Cyprinidae	Barboides gracilis		●
	Barbus batesi		●
	Barbus bourdarieri	●	
	Barbus brevispinnis	●	●
	Barbus callipterus	●	●
	Barbus camptacanthus	●	●
	Barbus foureaui	●	
	Barbus guirali		●
	Barbus jae		●
	Barbus martorelli		●
	Barbus mbami	●	
	Barbus micronema		●
	Barbus miolepis		●
	Barbus progenys	●	●
	Barbus racadasi		●
	Barbus taeniurus		●
	Barbus tegulifer		●
	Barbus trispilomimus		●
	Garra dembeensis	●	
	Labeo annectans		●

Family	Species Name	Sanaga River Basin Ngambe Ticar Ndokayo	South Coast River Basin Olamze
	Labeo hatesi		●
	Labeo parvus	●	
	Lepcocypris weynsii	●	
	Opsaridium ubangense	●	●
	Prolabeops malanhypoptera	●	
	Prolabeops nyongensis		●
	Raiamas buchholzi		●
	Sanagaia velifera	●	
	varicorhinus fimbriatus	●	
	Varicorhinus jaegari	●	
	varicorhinus mariae	●	
	Varicorhinus sanderisi	●	
	varicorhinus steindachneri		●
	Varicorhinus tornieri		●
	varicorhinus werneri		●
Bagridae	Auchenoglanis ballayi		●
	Auchenoglanis guirali	●	●
	Auchenoglanis longiceps		●
	Auchenoglanis monkei	●	
	Auchenoglanis pantherinus		●
	Auchenoglanis piestschmanni		●
	Chrysichthys filamentosus		●
	Chrysichthys furcatus		●
	Chrysichthys longidorsalis	●	●
	Chrysichthys maurus	●	
	Chrysichthys nigrodigitatus	●	
	Chrysichthys walkeri	●	
	Parauchenoglanis guttatus		●
	Parauchenoglanis macrostoma	●	
	Platyglanis depierrei	●	
Schilbeidae	Eutropius brevianalis	●	●
	Eutropius djeremi	●	
	Eutropius grenfelli		●
	Eutropius micropogon		●
	Eutropius multiaeniatus		●
	Eutropius niloticus	●	
	Eutropius nyongensis		●
	Schilbe mystus	●	
Amphilidae	Amphilius brevis		●
	Amphilius longirostris		●
	Doumea typica		●
	Paramphilius goodi		●
	Phractura brevicauda		●
	Phractura intermedia	●	●
	Phractura longicauda		●
Clariidae	Clariallabes longicauda		●
	Clariallabes pietschmanni		●
	Clarias bathupogon		●
	Clarias camerunensis	●	●
	Clarias jaensis	●	
	Clarias longior	●	●

Family	Secies Name	Sanaga River Basin Ngambe Ticar Ndokayo	South Coast River Basin Olamze
	Clarias pachynema	●	●
	Clarias plathcephalus		●
	Clarias submarginatus		●
	Gymnallabes typus		○
	Heterobranchus longifilis	●	
Malapteruridae	Malapterurus electricus	●	●
Mochokidae	Atopochilus savorgnani		●
	Chiloglanis batesi		●
	Chiloglanis cameronensis		●
	Chiloglanis micropogon		●
	Microsynodontis batesi		●
	Synodontis batesi		●
	Synodontis marmoratus	○	○
	Synodontis obesus	●	●
	Synodontis rebeli	●	
	Synodontis steindachnen		●
	Synodontis tessmanni	●	●
Ariidae	Arius heudelotii	●	●
	Arius latiscutatus	●	●
Cyprinodontidae	Aphyosemion ahli	●	●
	Aphyosemion amieti	●	
	Aphyosemion amoenum		●
	Aphyosemion bamilekorum	●	
	Aphyosemion batesii	●	●
	Aphyosemion bualanum	●	
	Aphyosemion cameronense	●	●
	Aphyosemion dargei	●	
	Aphyosemion edeanum	●	●
	Aphyosemion exiguum	●	●
	Aphyosemion franzwerneri	●	
	Aphyosemion heinemanni		●
	Aphyosemion kribianum		●
	Aphyosemion loennbergii		●
	Aphyosemion obscurum		●
	Aphyosemion pascheni		●
	Aphyosemion raddai	●	●
	Aphyosemion riggenbachi	●	
	Aphyosemion splendidum		●
	Aphyosemion splendopleure	●	●
	Aplocheilichtys spilauchen	●	●
	Aplocheilichtys esekanus		●
	Aplocheilichtys grahami		●
	Aplocheilichtys sangmelinensis	●	●
	Aplocheilichtys sexfasciatus	●	●
	Micropanchax camerunensis		●
	Micropanchax scheeli	●	●
	Procatopus nototaenia		●
	Procatopus similis	●	●
Syngnathidae	Enneacampus ansorgii	●	●
	Enneacampus kaupi	●	●
	Microphis brachyurus	●	●

Family	Species Name	Sanaga River Basin Ngambe Ticar Ndokayo	South Coast River Basin Olamze
Channidae	Parachanna obscura	●	●
Centropomidae	Lates niloticus	●	
Serranidae	Epinephelus guaza	●	
Carangidae	Carax hippos	●	○
	Carax senegallus	●	○
	Chloroscombrus chrysurus	●	
	Hemicaranx bicolor	●	●
	Selene dorsalis	●	
	Trachinotus teraia	●	●
Lutjanidae	Lutjanus agennes	●	●
	Lutjanus dentatus	●	●
	Lutjanus endecacanthus	●	●
	Lutjanus goreensis	●	●
Gerridae	Eucinostomus melanoperus	●	●
	Gerres nigri	●	●
Pomadasyidae	Brachydeuterus auritus	●	●
	Plectorhinchus macrolepis	●	●
	Pomadasys jubelini	●	●
	Pomadasys perotet	●	●
Sciaenidae	Pseudotolithus elongatus	●	●
	Pseudotolithus senegalensis	●	●
Monodactylidae	Monodactylus sebae	○	
Ephippidae	Drepane africana	●	●
Nandidae	Polycentropsis abbreviata	●	○
Cichlidae	Chromidotilapia batesi	●	
	Chromidotilapia finleyi		●
	Chromidotilapia guntheri	●	●
	Chromidotilapia kingsleyae		●
	Hemichromis elongatus		●
	Hemichromis fasciatus		●
	Nannochromis caudifasciatus		●
	Nannochromis longirostris	○	●
	Pelmatochromis ocellifer		●
	Pelvicachromis taeniatus		●
	Sarotherondon melanotheron	●	●
	Sarotherondon mvogoi		●
	Sarotherondon sanagaensis	●	
	Tilapia cabae		●
	Tilapia cameronensis	●	
	Tilapia guineensis	●	●
	Tilapia margaritacea		●
	Tilapia mariae	●	●
	Tilapia nyongana		●
	Tilapia zillii	●	
Mugilidae	Liza falcipinnis	●	●
	Liza grandisquamis	●	○
	Mugil cephalus	●	●
	Mugil curema	●	●
	Myxus bananensis	●	●
Sphyraenidae	Sphyraena dubia	●	●
	Sphyraena piscatorum	●	●

Family	Species Name	Sanaga River Basin Ngambe Ticar Ndokayo	South Coast River Basin Olamze
Polynemidae	Galeoides decadactylus	●	●
	Pentanemus quiquarius	●	●
	Polynemus quadrifilis	●	●
Gobiidae	Bathygobius soporator	●	●
	Chonophorus lateristriga	●	●
	Gobioides africans	●	●
	Gobioides ansoraii	●	●
	Gobionellus occidentalis	●	●
	Mauligobius niari	●	●
	Nematogobius ansorgii	●	●
	Nematogobius maindroni	●	●
	Porogobius schlegelii	●	●
	Sicydium brevifile	●	●
	Yongeichtys thomasi	●	●
Eleotridae	Batanga lebretonis	●	●
	Bostrychus africanus	●	●
	Eleotris dagenensis	●	●
	Eleotris senegalensis	●	●
	Eleotris vittata	●	●
	Kribia kribensisi	●	●
Periophthal-midae	Periophtalmus pailio	●	●
Anabantidae	Ctenopoma kingsleyae	●	○
	Ctenopoma maculatum	○	●
	Ctenopoma nanum	●	●
Mastacem-belidae	Caecomastacembelus batesi		●
	Caecomastacembelus brevicauda	●	●
	Caecomastacembelus crypacanthus		●
	Caecomastacembelus goro	●	●
	Caecomastacembelus longicauda	●	●
	Caecomastacembelus sanagali	●	
	Caecomastacembelus sclateri		●
	Caecomastacembelus seiteri	●	
Bothidae	Citharichthys stampflii	●	●
	Heteromycteris proboscidus	●	
Cynoglossidae	Cynoglossus senegalensisi	●	●
Tetraodontidae	Tetraodon pustulatus		
	Total ●	185	211
	Total ○	6	17
	Total	191 Types	228 Types

Legend:
● Fish species founed in the Basin
○ Fish species considered to be living in the Basin

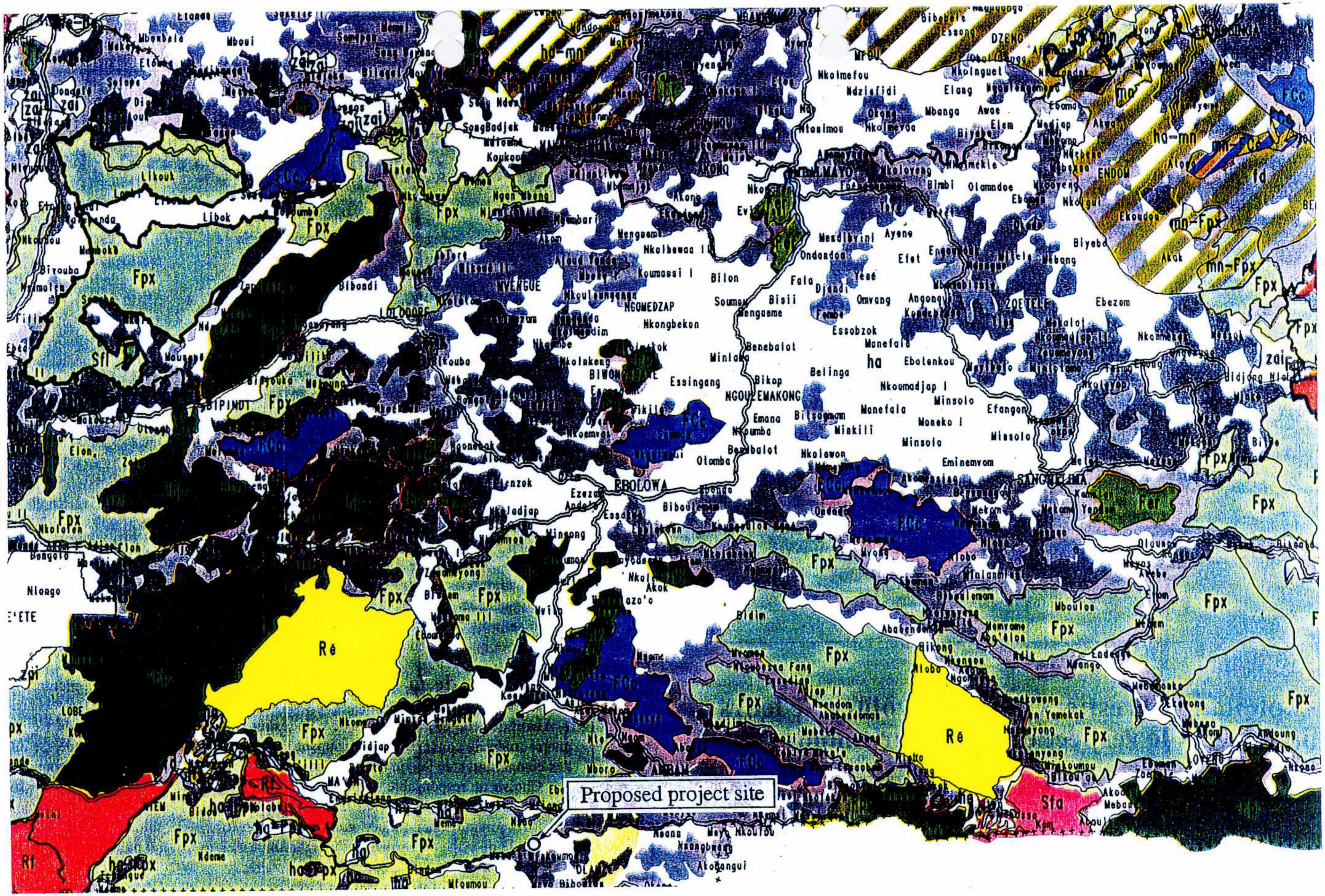


Fig. 10.1 Draft Use Plan for the Olamze Area

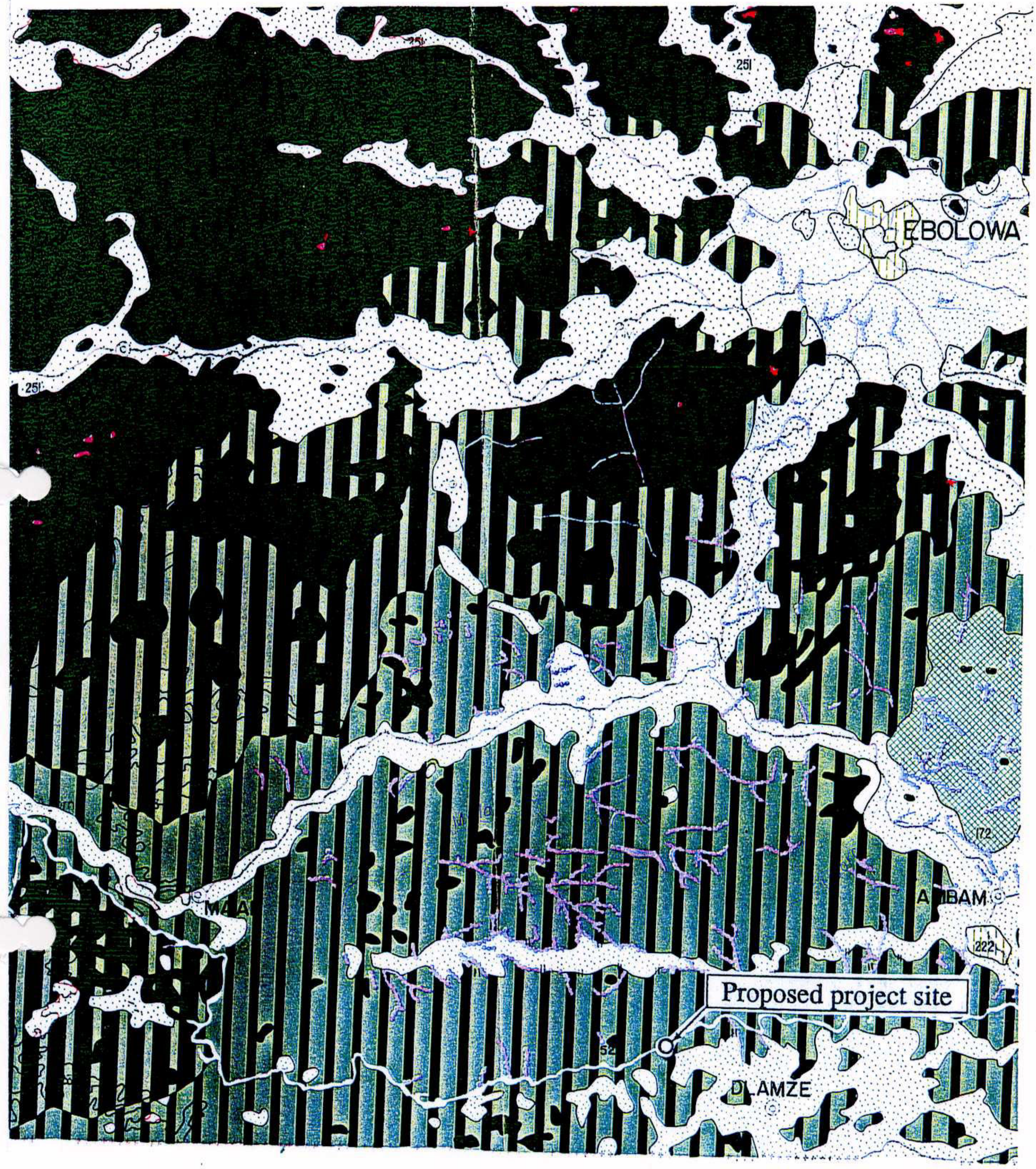


Fig. 10.2 Vegetation in the Olamze Area

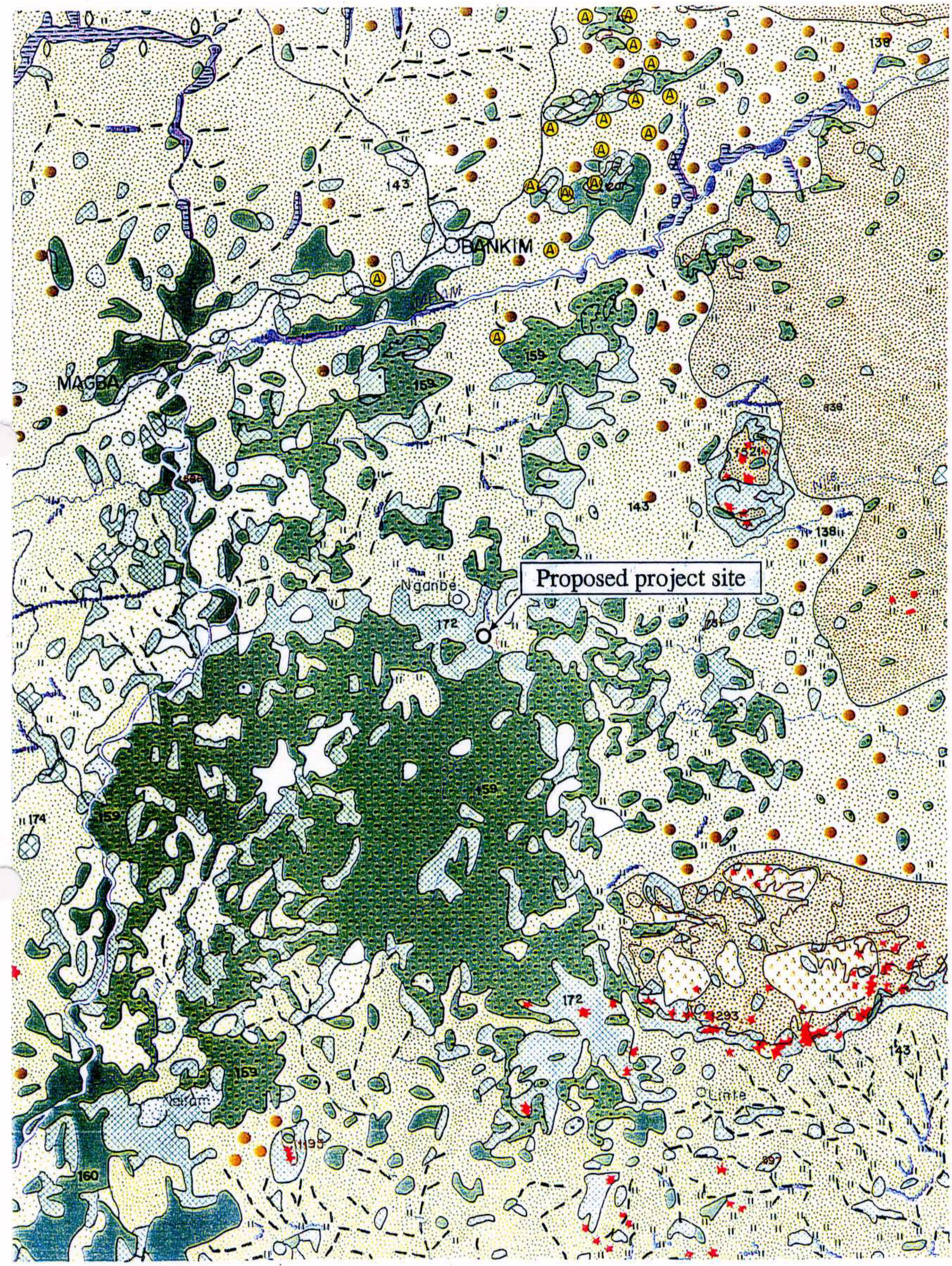


Fig. 10.3 Vegetation in the Ngambe Ticar Area

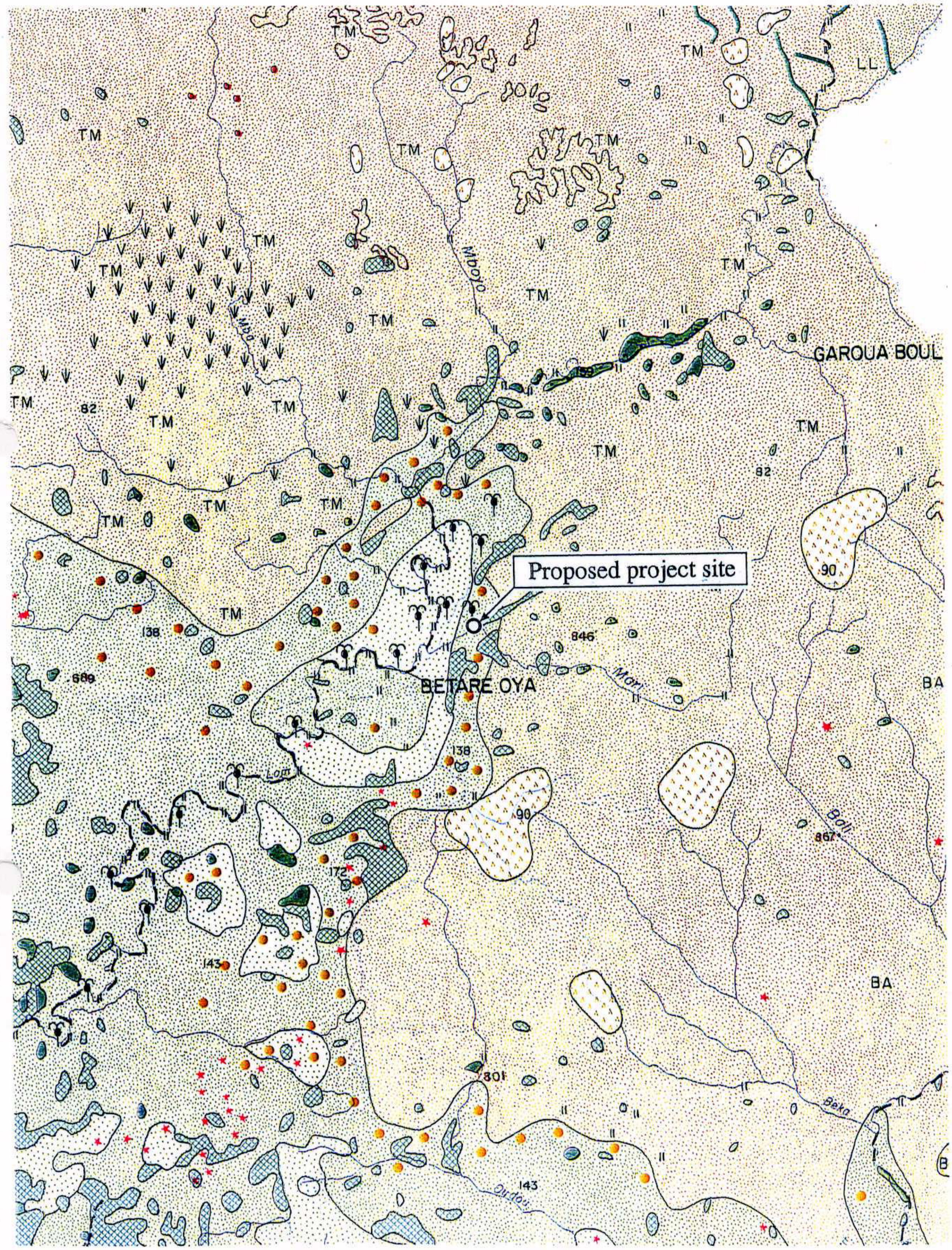


Fig. 10.4 Vegetation in the Ndokayo Area

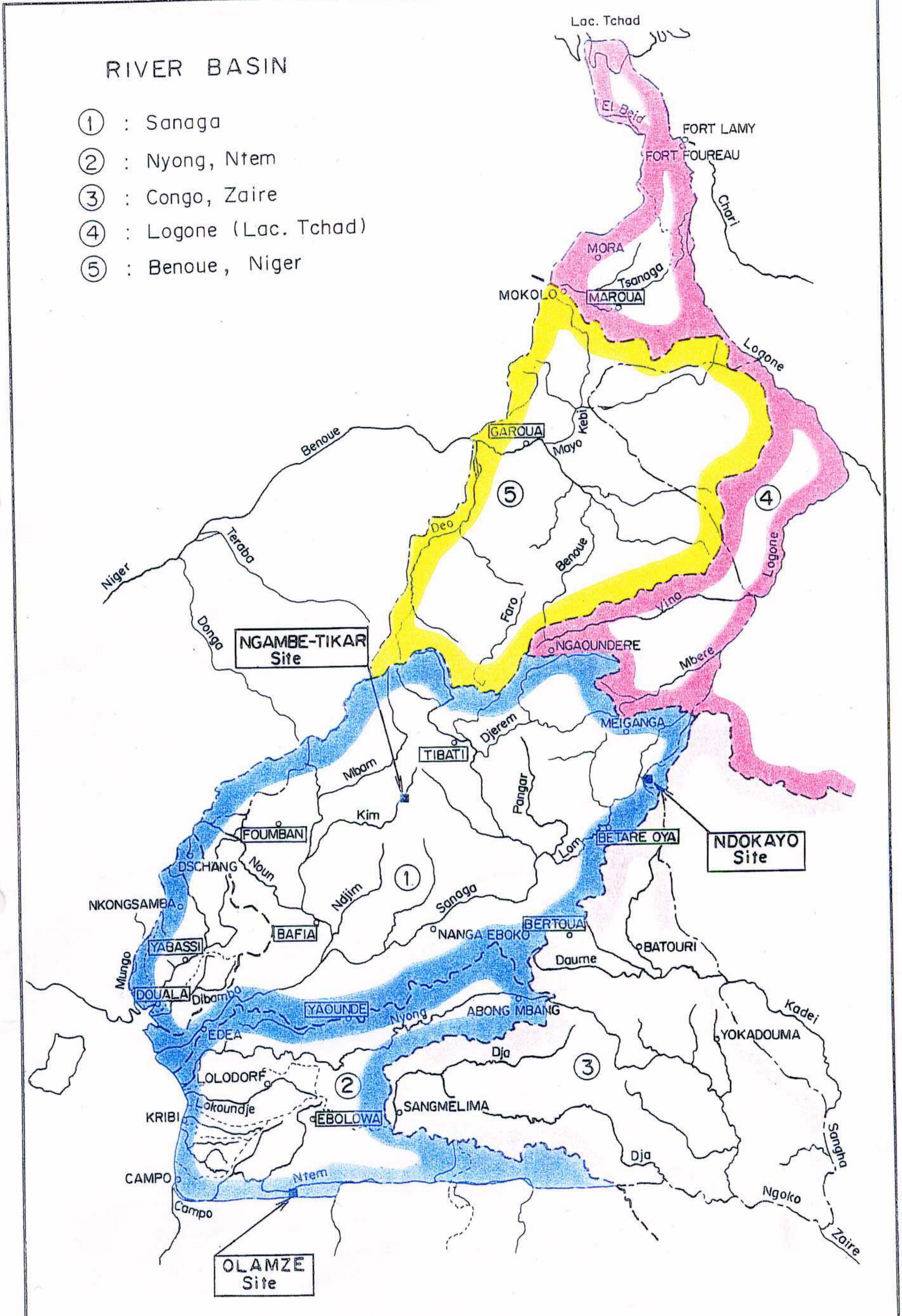


Fig. 10.5 River and Basin in Cameroon

CHAPTER 11. CONSTRUCTION PROGRAM, CONSTRUCTION SCHEDULE, AND CONSTRUCTION COST

Chapter 11 Construction Program, Construction Schedule, and Construction Cost

11.1 Construction Program and Construction Schedule

The quantities of major civil works in the individual projects are as given in Tables 11-4, -5, and -6. These works are as shown in Figs. 11-1, -2, and -3, respectively, and since each requires a construction period straddling two dry seasons, power generation would be started after approximately 18 months from start of construction.

(1) Ngambe-Tikar Project

The annual precipitation at this project site is approximately 1,700 mm, with the rainy season from August to November, and the dry season from January to April. The river runoff is an annual average of approximately 60 m^3/s, with the minimum average of 6.3 m^3/s recorded in February. The water level during flood, judged from traces of past occurrences, rises approximately 2 m above the water level in the driest period, so that it will be necessary for minute attention to be paid when carrying out construction at the river in the rainy season.

In construction, various preparatory works including access roads and temporary works, and waterway work at the right bank are to be carried out as much as possible before the rainy season arrives, while in the dry season following the rainy season, main civil works and electrical works are to be about completed, power generation to be started with the onset of the next rainy season.

(2) Ndokayo Site

The annual precipitation at this project site is roughly the same as at the Ngambe-Tikar site, approximately 1,700 mm, the rainy season being from July to November and the dry season from February to April. The river runoff is an annual average 10 m^3/s, with the minimum monthly average in February at 2.6 m^3/s. In the case of this site, especially with regard to hauling in of heavy articles, road conditions are poor between Bertoua and Betare Oya in the rainy season and thus it should be avoided as much as possible during that time.

In construction, various preparatory works including access roads and temporary facilities are to be completed before the rainy season of the first year sets in, and part of the penstock route is also to be excavated. Even during the rainy season, work on the headrace tunnel is to be continued and is to be brought roughly to completion. Main works such as the dam, penstock, and power generation facilities are to be started as soon as the rainy season of the first year ends, and work in the open is to be finished by the onset of the next rainy season. A part of equipment installation works will extend into the rainy season, but similarly to Ngambe-Tikar, it will be possible for power generation to be started within 18 months.

(3) Olamze Site

The annual precipitation at this site reaches 2,000 mm, with rainy seasons from May to July and from September to November, the month of August in between being a minor dry season. To continue with construction work in the rainy season is not an easy matter due to overlapping of conditions such as flooding of the Waro River and halting of transportation because of overflowing of the Ntem River.

At this site, construction of access roads and temporary facilities would be completed before onset of the rains from May to July. In December, when the rainy season is over, works involving the river bed such as the dam and power station are to be started, and the greater part of open work at the river bed is to be completed before the onset of the rainy season in May. Indoor works such as equipment installation would be done during the next rainy season.

11.2 Construction Materials

The principal civil works materials required in construction of this project, namely, concrete aggregates, cement, reinforcing bars and steel can be procured in Cameroon except for a very small part. Especially, wet masonry concrete structures are specified for facilities such as intake dams, and this, as can be seen in riparian civil structures like Edea Hydroelectric Power Station (installed capacity 263.2 MW) on the downstream part of the Sanaga River, is a technique which has been nurtured by workers of Cameroon over a long period of time, with materials procured locally and, moreover, being cheap.

Power station electro-mechanical equipment such as turbines and generators, and gate equipment such as penstock gates, would be imported from overseas countries, including Japan.

However, with regard to transmission lines, concerning both equipment and installation, planning and estimating were done based on records of actual work recently done by SONEL. Regarding main contractors to perform construction of dams and power stations would be by foreign contractors, Japanese ones included, but for transmission lines, it was considered that local contractors would do the work supervised by SONEL. This is based on the thinking that it would be more convenient to use locally marketable items as facilities required for transmission lines after entering the maintenance stage.

11.3 Construction Cost

(1) Hydroelectric Power Stations

The construction costs of the hydroelectric power stations of Ngambe-Tikar, Ndokayo, and Olamze, not including customs and VAT, in effect, the amounts to be invested, are as given in detail in Tables 11-4 to -9, with summaries given in Tables 11-1 to -3.

Table 11-1 3 Hydro Construction Cost

M.CFA Franc (1999)

	Ngambe-Tikar	Ndokayo	Olamze	Total
Installed Capacity	530 kW (2 units)	4,530 kW (3 units)	400 kW (2 units)	5,460 kW
Civil Works	1,852	2,556	1,409	5,817
Electromechanical Equipment	2,475	4,545	2,538	9,558
Engineering & Administrative	541	888	493	1,922
Total	4,868	7,989	4,440	17,297

Unit prices were all prices in CFA francs under economic conditions as of 1999, and include commodity price slides up to the year 2003, but interest during construction, customs, and VAT are not included. Unit prices used, for medium-voltage transmission line construction, were domestic prices of Cameroon, while for civil works and power station equipment, prices based on work done by Japanese contractors in the region of Africa concerned were taken up, but allowances were provided in consideration of the fact that the design is of the feasibility study level, and the conditions of transportation to remote areas.

Concerning Ndokayo Hydroelectric Power Station, installation of the third generator could be delayed depending on the power demand initially when operation is started. In such case, a reduction in the investment amount of 1,000 to 1,200M F.CFA would result, this amount corresponding to more than 10% of the total project cost.

In case of Olamze, on the other hand, when the average river runoff turns out to be more than expected, then installation of a third generator can be contemplated. In such case, there would be an increase in installation cost of about 800 to 1,000M F.CFA.

(2) Transmission Lines

The construction costs of 3-phase, AC, 30 kV medium voltage transmission lines connecting to the three power stations of Ngambe-Tikar, Ndokayo, and Olamze, not including customs and VAT, are given in Table 11-2. The cost of 224 km of 30 kV main transmission lines is an average of approximately 13M CFA franc/km. No future expansion project cost is included for the 30 kV transmission lines.

Table 11-2 30 kV Line Construction Cost

M.CFA Franc (1999)

	Ngambe-Tikar	Ndokayo	Olamze	Total
Total Length	25 km	152 km	47 km	224 km
Construction Cost	265	1,630	486	2,381
Engineering & Administrative	70	432	129	631
Total	335	2,062	615	3,012

(3) Total Construction Cost

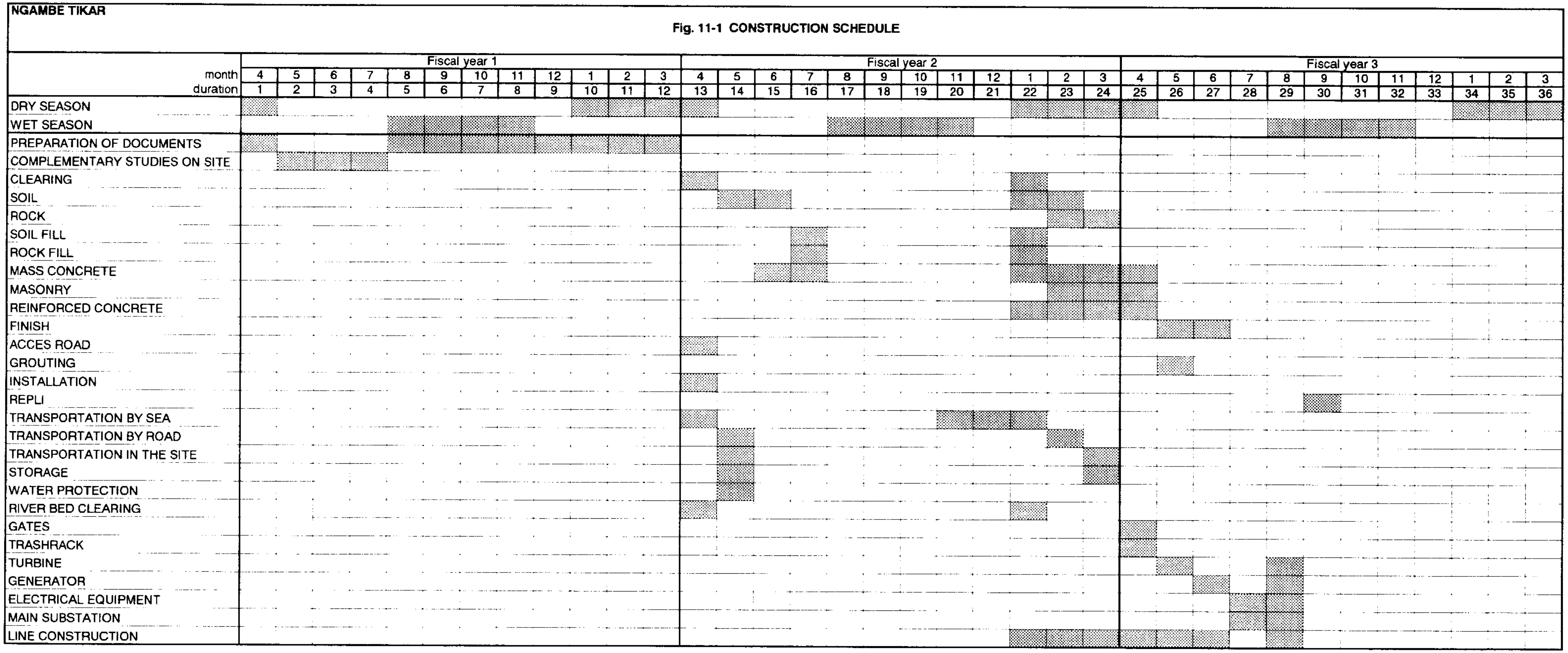
The total construction cost for the three hydroelectric power stations of Ngambe-Tikar, Ndokayo, and Olamze, excluding necessary customs and VAT, is 20,309M CFA francs, the breakdown of which is given in Table 11-3. The construction cost per kilowatt is from 2.2 to 12.6M CFA francs depending on the power station, the average construction cost being 3.7M CFA francs.

Table 11-3 3 Hydro Construction Cost

M.CFA Franc (1999)

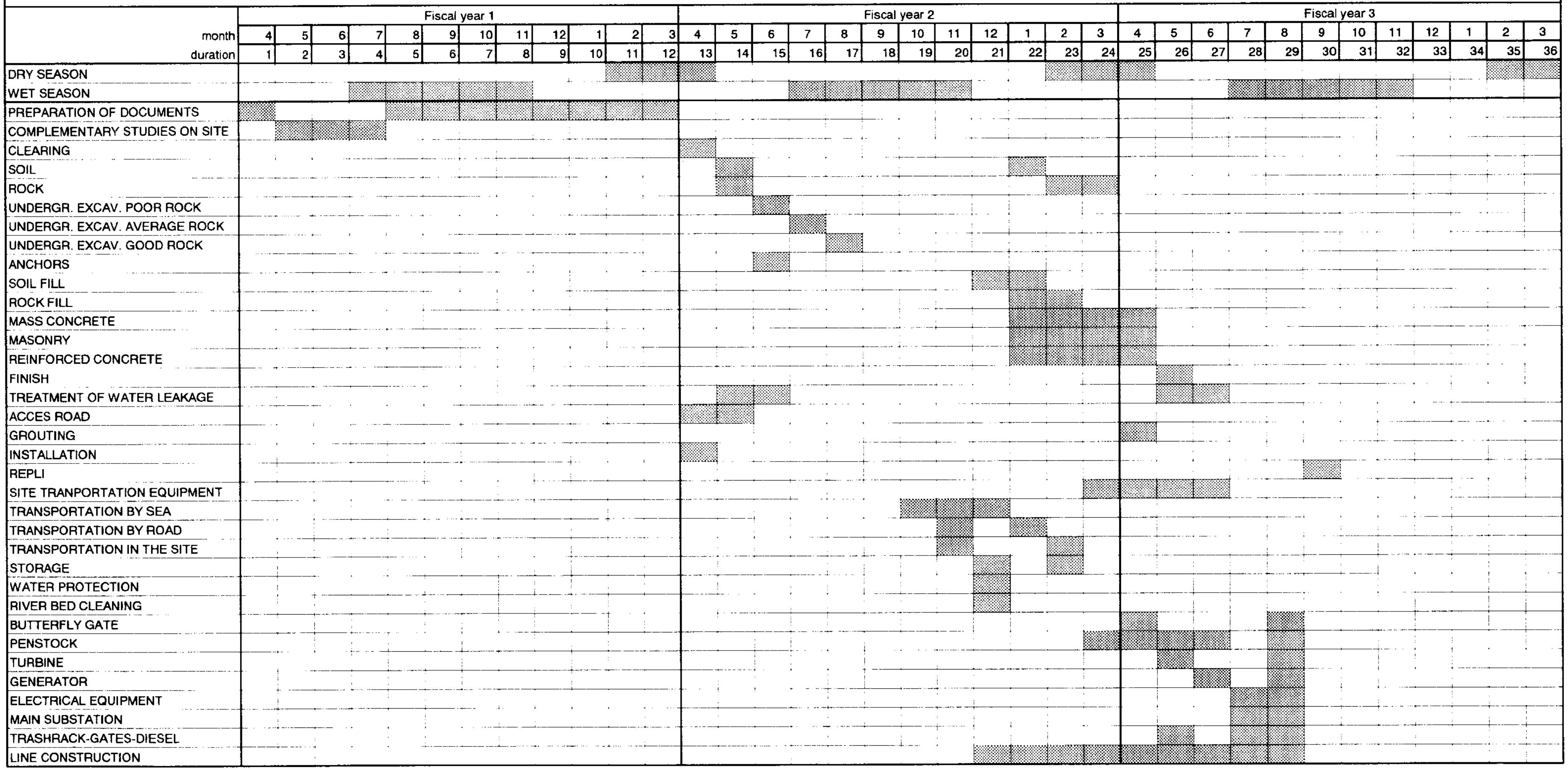
	Ngambe-Tikar	Ndokayo	Olamze	Total
Hydro power Station	4,868	7,989	4,440	17,297
30 kV Transmission Line	335	2,062	615	3,012
Total	5,203	10,051	5,055	20,309
Installed Capacity	530 kW	4,530 kW	400 kW	5,460 kW
Construction Cost per kWh	9.8	2.2	12.6	3.7

Fig. 11-1 CONSTRUCTION SCHEDULE



NDOKAYO

Fig. 11-2 CONSTRUCTION SCHEDULE



OLAMZE

Fig. 11-3 CONSTRUCTION SCHEDULE

	Fiscal year 1											
month	4	5	6	7	8	9	10	11	12	1	2	3
duration	1	2	3	4	5	6	7	8	9	10	11	12
DRY SEASON					■					■	■	
WET SEASON		■	■	■		■	■	■				
PREPARATION OF DOCUMENTS	■				■	■	■	■	■	■	■	■
COMPLEMENTARY STUDIES ON SITE					■					■	■	
CLEARING												
SOIL												
ROCK												
WATERPROOF MATERIAL												
ROCK FILL												
FILTER												
MASONRY												
REINFORCED CONCRETE												
FINISH												
ACCES ROAD												
GROUTING												
INSTALLATION												
REPLI												
TRANSPORTATION BY SEA												
TRANSPORTATION BY ROAD												
TRANSPORTATION IN THE SITE												
STORAGE												
WATER PROTECTION												
RIVER BED CLEANING												
GATES												
TRASHRACK												
TURBINE												
GENERATOR												
ELECTRICAL EQUIPMENT												
MAIN SUBSTATION												
LINE CONSTRUCTION												

	Fiscal year 2											
month	4	5	6	7	8	9	10	11	12	1	2	3
duration	13	14	15	16	17	18	19	20	21	22	23	24
DRY SEASON					■					■	■	
WET SEASON		■	■	■		■	■	■				
PREPARATION OF DOCUMENTS		■	■	■		■	■	■				
COMPLEMENTARY STUDIES ON SITE												
CLEARING	■											
SOIL									■	■		
ROCK											■	
WATERPROOF MATERIAL											■	■
ROCK FILL												
FILTER												■
MASONRY										■	■	■
REINFORCED CONCRETE										■	■	■
FINISH												
ACCES ROAD					■							
GROUTING												■
INSTALLATION	■											
REPLI												
TRANSPORTATION BY SEA							■	■	■			
TRANSPORTATION BY ROAD										■		
TRANSPORTATION IN THE SITE											■	
STORAGE												■
WATER PROTECTION									■			
RIVER BED CLEANING	■				■					■	■	
GATES												
TRASHRACK												
TURBINE												
GENERATOR												
ELECTRICAL EQUIPMENT												
MAIN SUBSTATION												
LINE CONSTRUCTION										■	■	■

	Fiscal year 3											
month	4	5	6	7	8	9	10	11	12	1	2	3
duration	25	26	27	28	29	30	31	32	33	34	35	36
DRY SEASON					■					■	■	
WET SEASON		■	■	■		■	■	■				
PREPARATION OF DOCUMENTS		■	■	■		■	■	■				
COMPLEMENTARY STUDIES ON SITE												
CLEARING												
SOIL												
ROCK												
WATERPROOF MATERIAL												
ROCK FILL	■											
FILTER												
MASONRY	■											
REINFORCED CONCRETE	■											
FINISH		■										
ACCES ROAD												
GROUTING												
INSTALLATION												
REPLI						■						
TRANSPORTATION BY SEA												
TRANSPORTATION BY ROAD												
TRANSPORTATION IN THE SITE												
STORAGE												
WATER PROTECTION												
RIVER BED CLEANING												
GATES	■				■							
TRASHRACK	■											
TURBINE		■			■							
GENERATOR			■		■							
ELECTRICAL EQUIPMENT				■	■							
MAIN SUBSTATION				■	■							
LINE CONSTRUCTION	■	■	■		■							

Table 11-4 Ngambe-Tikar Hydro Power Plant (530 kW) and Main Network in 30 kV

Construction Cost		Unit	Quantity	Unit Cost (F.CFA 99)	Cost (MF. CFA 99)	Total (MFRF 99)	Total (MJPY 99)
A	**HYDRO POWER PLANT**						
	CIVIL WORKS						
1.	**EXCAVATIONS**						
	Clearing-Soil preparations	m^2	30,000	300	9		
	Soil	m^3	24,000	5,612	135		
	Rock	m^3	2,700	21,549	58		
	Sub-total				**202**	**2.0**	**38**
2.	**FILL**						
	Soil fill	m^3	6,300	2,945	19		
	Rock fill	m^3	2,700	4,893	13		
	Sub-total				**31.8**	**0.3**	**6**
3.	**CONCRETE**						
	Mass concrete	m^3	220	164,153	36		
	Masonry	m^3	6,250	130,000	813		
	Reinforced concrete	m^3	320	284,798	91		
	Finish & miscellaneous	%	15%		141		
	Sub-total				**1,081**	**10.8**	**205**
4.	**OTHER CIVIL WORKS**						
	Access road	km	2	50,000,000	100		
	Grouting	L.S.			63		
	Installation & repli	L.S.			80		
	Transportation by sea	L.S.			70		
	Transportation by road	L.S.			30		
	Transportation in site	L.S.			15		
	Storage	L.S.			15		
	Water protection	L.S.			90		
	River bed clearing	L.S.			75		
	Sub-total				**538**	**5.4**	**102**
	TOTAL CIVIL WORKS				**1,852**	**18.5**	**352**
	EQUIPMENTS (including 5% transportation)	kW	530				
	Gates	kg	3,500	10,714	38		
	Trashrack	kg	20,000	6,215	124		
	Equipment (turbine, generator, etc.)	unit	2	825,800,000	1,652		
	Overhead Travelling	-			16		
	Electrical Equipment	-			117		
	Main substation (transformers)	-			137		
	Miscellaneous equipment	%	5%		104		
	Supervision				139		
	Transportation & Storage (in Cameroon)				89		
	Others	%	2.5%		60		
	TOTAL EQUIPMENTS				**2,475**	**24.8**	**470**
	TOTAL CIVIL WORKS & EQUIPMENTS				**4,327**	**43.3**	**822**
	Administration costs	%	5.0%		216		
	Engineering costs	%	7.5%		325		
	TOTAL HYDRO POWER PLANT				**4,868**	**48.7**	**925**
B.	**TRANSMISSION LINE** (Only Main Network)						
	Line construction (30 kV)	km	25	10,580,000	265		
	Engineering costs	%	10%		26		
	Contingencies & escalation price	%	15%		44		
	TOTAL T. LINES				**335**	**3.3**	**64**
	PROJECT COST (A + B)	(excluded Taxes & VAT)			**5,203**	**52.0**	**989**

Table 11-5 Ndokayo Hydro Power Plant (4,530 kW) and Main Network in 30 kV

Construction Cost	Unit	Quantity	Unit Cost (F.CFA 99)	Cost (MF. CFA 99)	Total (MFRF 99)	Total (MJPY 99)
A HYDRO POWER PLANT						
CIVIL WORKS						
1. EXCAVATIONS						
Clearing-Soil preparations	m^2	90,000	300	27		
Soil	m^3	2,570	5,612	14		
Rock	m^3	2,900	21,549	62		
Sub-total				**104**	**1.0**	**20**
2. TUNNEL EXCAVATION						
Underground excavation, good rock	m^3	780	110,011	86		
Underground excavation, average rock	m^3	390	127,258	50		
Underground excavation, poor rock	m^3	130	190,607	25		
Anchors	L.S.			35		
Sub-total				**195**	**2.0**	**37**
3. FILL						
Soil fill	m^3	100	2,985	0.3		
Rock fill	m^3	0	4,893	0.0		
Sub-total				**0.3**	**0.0**	**0**
4. CONCRETE						
Mass concrete	m^3	120	164,153	20		
Masonry	m^3	650	130,000	85		
Reinforced concrete	m^3	1,050	284,798	299		
Finish & miscellaneous	%	15%		60		
Sub-total				**464**	**4.6**	**88**
5. OTHER CIVIL WORKS						
Treatment of water leakage	m^2	60,750	9,000	547		
Access road	km	7.5	50,000,000	375		
Grouting	L.S.			32		
Installation & repli	L.S.			90		
Site transportation equipment	L.S.			375		
Transportation by sea	L.S.			150		
Transportation by road	L.S.			40		
Transportation in site	L.S.			40		
Storage	L.S.			20		
Water protection	L.S.			75		
River bed clearing	L.S.			50		
Sub-total				**1,793**	**17.9**	**341**
TOTAL CIVIL WORKS				**2,556**	**25.6**	**486**
EQUIPMENTS (including 5% transportation)	kW		4,530			
Butterfly Gate	-			43		
Steel for penstocks	kg	122,000	5,634	687		
Equipment (turbine, generator, etc.)	unit	3	907.852	2,724		
Overhead Travelling	-			15		
Electrical Equipment	-			183		
Main transformers	-			224		
Miscellaneous (trashracks, diesel plant, etc.)	%	5.0%		194		
Supervision Cost				139		
Transportation to site & Storage in Cameroon				225		
Others	%	2.5%		111		
TOTAL EQUIPMENTS				**4,545**	**45.4**	**864**
TOTAL CIVIL WORKS & EQUIPMENTS				**7,101**	**71.0**	**1,349**
Administration costs	%	5.0%		355		
Engineering costs	%	7.5%		533		
TOTAL HYDRO POWER PLANT				**7,989**	**79.9**	**1,518**
B. TRANSMISSION LINE (Only Main Network)						
Line construction (30 kV)	km	151	10,793,377	1,630		
Engineering costs	%	10%		163		
Contingencies & escalation price	%	15%		269		
TOTAL T. LINES				**2,062**	**20.6**	**392**
PROJECT COST (A + B)	(excluded Taxes & VAT)			**10,051**	**100.5**	**1,910**

Table 11-6 Olamze Hydro Power Plant (400 kW) and Main Network in 30 kV

	Construction Cost	Unit	Quantity	Unit Cost (F.CFA 99)	Cost (MF. CFA 99)	Total (MFRF 99)	Total (MJPY 99)
A	**HYDRO POWER PLANT**						
	CIVIL WORKS						
1.	**EXCAVATIONS**						
	Clearing-Soil preparations	m^2	2,500	300	1		
	Soil	m^3	300	5,612	2		
	Rock	m^3	1,200	21,549	26		
	Sub-total				**28**	**0.3**	**5**
2.	**FILL**						
	Water proof material	m^3	3,200	22,212	71.1		
	Rock fill	m^3	2,000	4,893	9.8		
	Filter	m^3	800	40,449	32.4		
	Sub-total				**113.2**	**1.1**	**22**
3.	**CONCRETE**						
	Mass concrete	m^3	0	164,153			
	Masonry	m^3	2,500	130,000	325		
	Reinforced concrete	m^3	850	284,798	242		
	Finish & miscellaneous	%	15%		85		
	Sub-total				**652**	**6.5**	**124**
4.	**OTHER CIVIL WORKS**						
	Access road	km	3	50,000,000	150		
	Grouting	L.S.			105		
	Installation & repli	L.S.			80		
	Transportation by sea	L.S.			70		
	Transportation by road	L.S.			30		
	Transportation in site	L.S.			15		
	Storage	L.S.			15		
	Water protection	L.S.			75		
	River bed clearing	L.S.			75		
	Sub-total				**615**	**6.2**	**117**
	TOTAL CIVIL WORKS				**1,409**	**14.1**	**268**
	EQUIPMENTS (including 5% transportation)	kW	400				
	Gates	unit	2	32,900,000	65.8		
	Trashrack	unit	1	306,600,000	306.5		
	Equipment (turbine, generator, etc.)	unit	2	737,600,000	1,475.2		
	Overhead Travelling	-			17.4		
	Electrical Equipment	-			114.9		
	Main substation (transformers)	-			158.5		
	Miscellaneous equipment	%	5.0%		106.9		
	Supervision				138.6		
	Transportation & Storage (in Cameroon)				92.7		
	Others	%	2.5%		61.9		
	TOTAL EQUIPMENTS				**2,538**	**25.4**	**482**
	TOTAL CIVIL WORKS & EQUIPMENTS				**3,947**	**39.5**	**750**
	Administration costs	%	5.0%		197		
	Engineering costs	%	7.5%		296		
	TOTAL HYDRO POWER PLANT				**4,440**	**44.4**	**844**
B.	**TRANSMISSION LINE** (Only Main Network)						
	Line construction (30 kV)	km	47	10,362,473	486		
	Engineering costs	%	10%		49		
	Contingencies & escalation price	%	15%		80		
	TOTAL T. LINES				**615**	**6.1**	**117**
	PROJECT COST (A + B)	(excluded Taxes & VAT)			**5,055**	**50.6**	**960**

Table 11-7 Ngambe-Tikar Transmission Line

Main Three-phase 30 kV Network in MV & Extension

NGAMBE-TIKAR NETWORK at price level 1999 (w/o Tax)	Unit	Cost (in MF.CFA)		Total Cost in MFFR
		Unit price	Total	
1. MAIN NETWORK - THREE-PHASE LINE in 30 kV (excluding main transformers)				
LINE "SITE TO GWEMZE"				
- Deforestation - 30 m	25 km	0.6	15	0.2
- Line in 3 x 54 mm^2	25 km	8.4	210	2.1
TRANSFORMERS				
Transformer 50/100 kVA Three-phase 30/0.4 kV	3	3.5	11	0.1
Transformer 15/25 kVA Three-phase 30/0.4 kV	3	3	9	0.1
EQUIPMENT				
Automatic Switch 30 k (IACM)	6	2.5	15	0.2
Line Protection	1	5	5	0.1
Sub-Total			265	2.5
Engineering & Supervision Costs	10%		26	0.3
Contingencies & Escalation price	15%		44	0.4
TOTAL MAIN NETWORK	25 km	13	**335**	**3.3**
Part of Supply (for information only)				
Cables			*120*	
Transformers			*15*	
Switches			*15*	
Total of Supply			*149*	*1.5*
2. NETWORK EXTENSION				
Deforestation - 30 m	81 km	0.6	49	0.5
Line MV in 30 kV - 3 x 54 mm^2	81 km	8.4	680	6.8
Transformer 15/25 kVA Three-phase 30/0.4 kV	10	2.5	25	0.3
Engineering & Supervision Costs	10%		75	0.8
Contingencies & Escalation price	15%		124	1.2
TOTAL EXTENSION NETWORK	81 km	11	**905**	**9.1**
TOTAL 1 & 2	106 km	12	**1,240**	**12.4**

Table 11-8 Ndokayo Transmission Line

Main Three-phase 30 kV Network in MV & Extension

NDOKAYO NETWORK at price level 1999 (w/o Tax)	Unit	Cost (in MF.CFA)		Total Cost in MFFR
		Unit price	Total	
1. MAIN NETWORK - THREE-PHASE LINE in 30 kV (excluding main transformers)				
THREE-PHASE LINE in 30 kV				
Line “SITE to GAROUA BOULAI”				
- Deforestation - 30 m	60 km	0.6	36	0.4
- in 3 x 95 mm^2	60 km	9.2	552	5.5
Line “SITE to NDOKAYO”				
- Deforestation - 30 m				
- in 3 x 75 mm^2				
Lines “Garga Sarali to Borongo” & “Badzere to Monbal”				
- Deforestation - 30 m	70 km	0.6	42	0.4
- in 3 x 54 mm^2	70 km	8.4	588	5.9
TRANSFORMERS				
Auto-Transformer 2MVA Tri. 30/15 kV	2	15	30	0.3
Transformer 100/150 kVA Three-phase 30/0.4 kV	6	4	24	0.2
Transformer 75/100 kVA Three-phase 30/0.4 kV	2	3.5	7	0.1
Transformer 25/50 kVA Three-phase 30/0.4 kV	4	3	12	0.1
EQUIPMENT				
Switchyard	4	25	100	1.0
Manual Switch (IAT)	3	4	12	0.1
Automatic Switch 30kV (IACM)	4	2.5	10	0.1
Line Protection	2	5	10	0.1
Sub-Total			1,630	16.3
Engineering & Supervision Costs	10%		163	1.6
Contingencies & Escalation price	15%		269	2.7
TOTAL MAIN NETWORK	152 km	14	**2,062**	**20.6**
Part of Supply (for information only)				
Cables			*786*	
Transformers			*55*	
Switches			*99*	
Total of Supply			*940*	*9.4*
2. NETWORK EXTENSION				
Lines: Lom, Tongo, Badang-Ganko				
Deforestation - 30 m	44 km	0.6	26	0.3
Line MV in 30 kV - 3 x 54 mm^2	44 km	8.5	374	3.7
Transformer 75/100 kVA Three-phase 30/0.4 kV	2	3.5	7	0.1
Transformer 25/50 kVA Three-phase 30/0.4 kV	5	3	15	0.2
Engineering & Supervision Costs	10%		42	0.4
Contingencies & Escalation price	15%		70	0.7
TOTAL EXTENSION NETWORK	44 km	12	**508**	**5.1**
TOTAL 1 & 2	196 km	13	**2,570**	**25.7**

Table 11-9 Olamze Transmission Line

Main Three-phase 30 kV Network in MV & Extension

NGAMBE-TIKAR NETWORK at price level 1999 (w/o Tax)	Unit	Cost (in MF.CFA)		Total Cost in MFFR
		Unit price	Total	
1. MAIN NETWORK - THREE-PHASE LINE in 30 kV (excluding main transformers)				
LINE "SITE to AMBAM"				
- Deforestation - 30 m	44 km	0.6	26	0.3
- Deforestation - 60 m	3 km	1.1	3	0.0
- Line in 3 x 54 mm^2	47 km	8.4	395	3.9
TRANSFORMERS				
Transformer 50/100 kVA Three-phase 30/0.4 kV	5	3.5	18	0.2
Transformer 25 kVA Three-phase 30/0.4 kV	5	3	15	0.2
EQUIPMENT				
Manual Switch (IAT)	1	4	4	0.0
Automatic Switch 30 kV (IACM)	8	2.5	20	0.2
Line Protection	1	5	5	0.1
Sub-Total			**486**	**4.5**
Engineering & Supervision Costs	10%		49	0.5
Contingencies & Escalation price	15%		80	0.8
TOTAL MAIN NETWORK	47 km	13	**615**	**6.1**
Part of Supply (for information only)				
Cables			*225*	
Transformers			*24*	
Switches			*22*	
Total of Supply			*71*	*2.7*
2. NETWORK EXTENSION				
Deforestation - 30 m	59 km	0.6	35	0.4
Line MV in 30 kV - 3 x 54 mm^2	59 km	8.4	496	5.0
Transformer 25/50 kVA Three-phase 30/0.4 kV	10	3	30	0.3
Engineering & Supervision Costs	10%		56	0.6
Contingencies & Escalation price	15%		93	0.9
TOTAL EXTENSION NETWORK	59 km	11	**674**	**6.7**
TOTAL 1 & 2	106 km	12	**1,289**	**12.9**

CHAPTER 12. ECONOMIC EVALUATION AND FINANCIAL ANALYSIS

Chapter 12 Economic Evaluation and Financial Analysis

12.1 Generation Cost per kWh

For calculation of cost per kWh, there are the method based on effective energy and the method using the generated power considering the future demand of the power system and hydrology-meteorology, and in this case, the former was used, unit cost per kWh calculated from effective energy. Effective energy was determined based on annual duration curves Q_3 for the various sites. The respective runoffs, outputs, and energy productions are as indicated in Table 12-1 and Figs. 12-1, -2 and -3.

The unit costs per kWh (excluding customs and VAT) of the power stations of Ngambe-Tikar, Ndokayo, and Olamze are given in Table 12-1.

Table 12-1 Generation Cost per kWh

M.CFA 1999

	Ngambe-Tikar	Ndokayo	Olamze	Total
Net Output	530 kW	4,530 kW	400 kW	5,460 kW
Annual Generation	3.92 GWh	30.6 GWh	2.64 GWh	37.2 GWh
Transmission Line Losses	5%	7.5%	5%	
Net Annual Generation	3.72 GWh	28.3 GWh	2.51 GWh	34.5 GWh
Net annual generation with outage	3.5 GWh	26.3 GWh	2.4 GWh	32.2 GWh
HPP Investment Costs	4,869	7,989	4,400	17,298
Transmission Line Costs	335	2,062	615	3,012
Total Project Costs	5,204	10,051	5,055	20,310
Life Duration	50 years	50 years	50 years	
Annuity Costs at @8% (a)	425	822	413	1,660
Annual HPP O&M Costs	31.8	135.9	24	191.7
Annual T. Lines O&M Costs	6.8	41.0	12.7	60.5
Annual Renewable Provisions	25.1	39.4	18.8	83.4
Total Annual O&M Costs (b)	63.7	216.4	55.5	252.2
Total Annual Costs (a)+(b)	489	1,038	469	1,912
Generation Cost in FCFA per kWh (1)+(2)	138	39	197	59.3
with a breakdown in:				
Capital cost per kWh (1)	120	31	173	51.5
O&M cost per kWh (2)	18	8	23	7.8

The main hypotheses used for the calculation of the cost above are:

- Discount rate: 8%
- Generation losses on the main network: between 5 and 7.5%
- Outages: between 3 and 5%
- Economic life: 50 years for the civil structures and 25 years for the equipment and the transmission lines
- HPP O&M costs: from 1.55 to 1.65% of the construction cost
- Transmission Line O&M costs: 2% of the construction cost (260-270 CFA·kF per year)

The cost price of 1 kWh for the 3 projects vary from 39 CFA Francs per kWh to 197 CFA Francs per kWh (excluding taxes and VAT), of which 8 to 23 CFA Francs per kWh is for the operation, maintenance and renovation provisions.

Especially for the Ndokayo site, the cost price is attractive due to the interesting characteristics of head height (90 m) and despite the fact that the transportation network is fairly significant.

Table 12-2 Synthesis

Characteristics and Production:

	Discharge (m^3/s)	Turbine (kW)	Generator (kW)	Net Head (m)	Hypothesis	Generation (GWh)
Ndokayo	6	4,800	4,530	90	Q3	30.54
Ndokayo	6	4,800	4,530	90	mid.	32.76
Ngambe Tikar*	10	590	530	6.7	Q3	3.93
Ngambe Tikar*	10	590	530	6.7	mid.	4.11
Olamze	9	450	400	6	Q3	2.64
Olamze	9	450	400	6	mid.	2.83

* : For Ngambe Tikar, net head varies from 6.70 to 6.90 m.

Hydrology:

Number of day	Olamze		Ndokayo		Ngambe Tikar	
	Q3	mid.	Q3	mid.	Q3	mid.
365	1.58	2.32	1.03	1.57	1.56	2.11
355	2.06	2.86	1.29	2.05	1.69	2.75
330	2.82	3.48	1.85	2.74	3.25	3.74
270	4.53	5.29	3.26	3.64	7.53	10.65
180	8.03	9.65	5.71	6.75	23.00	28.94
90	14.02	18.05	13.78	14.99	65.40	97.47
30	25.38	28.68	21.33	23.41	154.10	178.35
10	29.28	33.28	24.27	28.48	178.35	236.24
0	31.00	35.46	26.98	31.19	201.82	314.47

Figure 12-1 Ngambe Tikar HPP Production (530 kW)
Flow and Power Duration Curves (F&P DC)

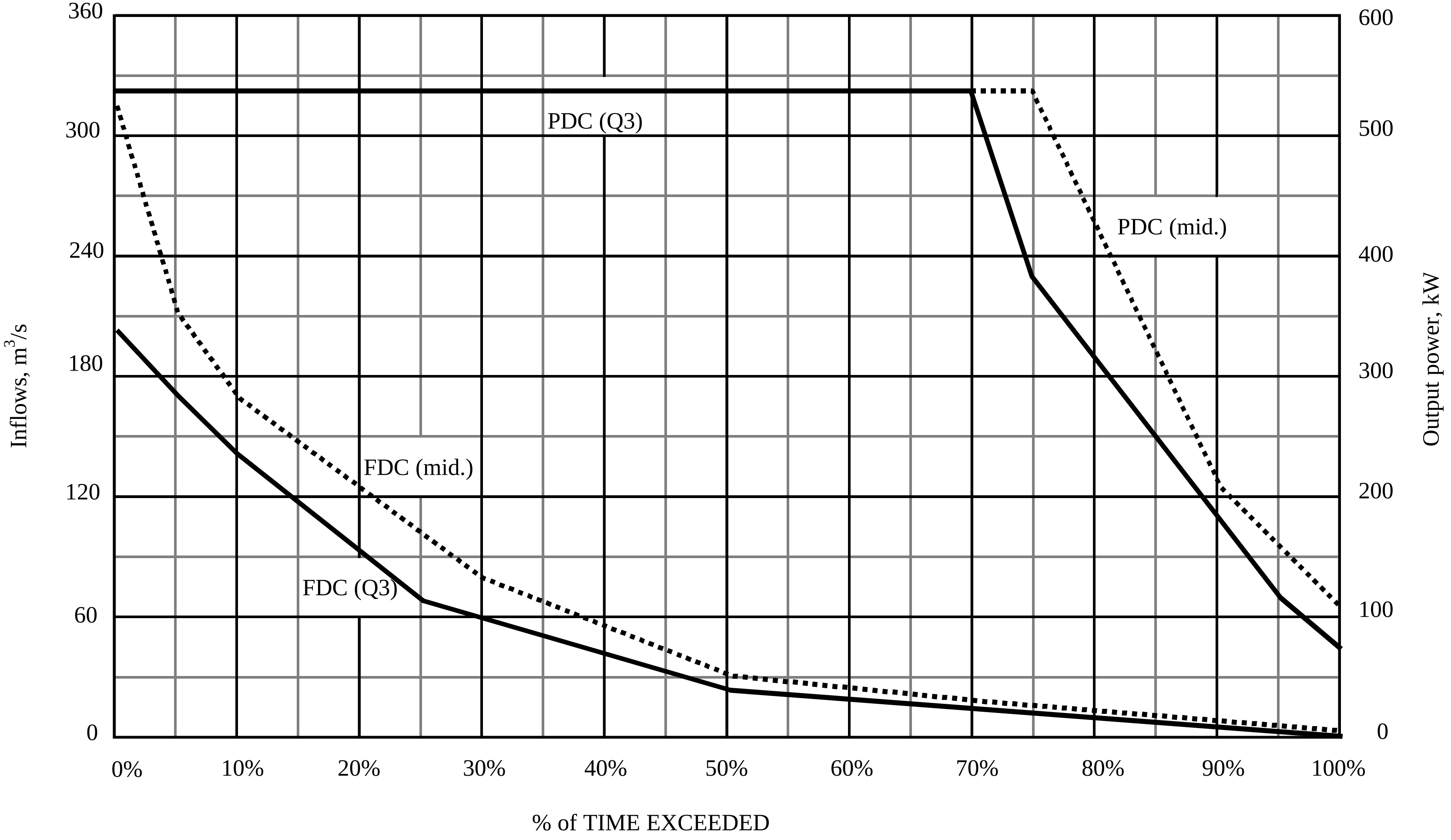


Figure 12-2 Ndokayo HPP Production (4,500 kW)
Flow and Power Duration Curves (F&P DC)

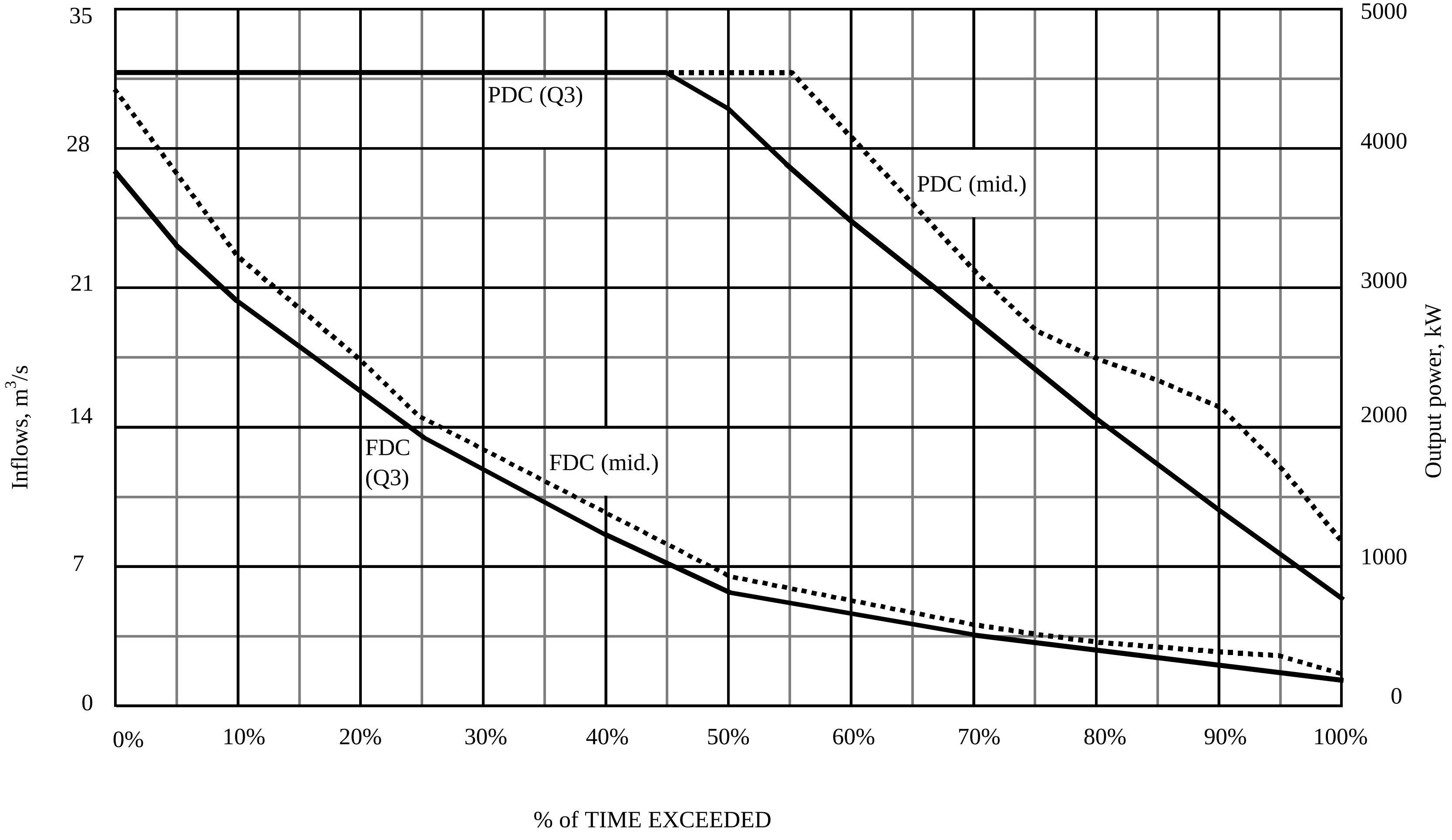
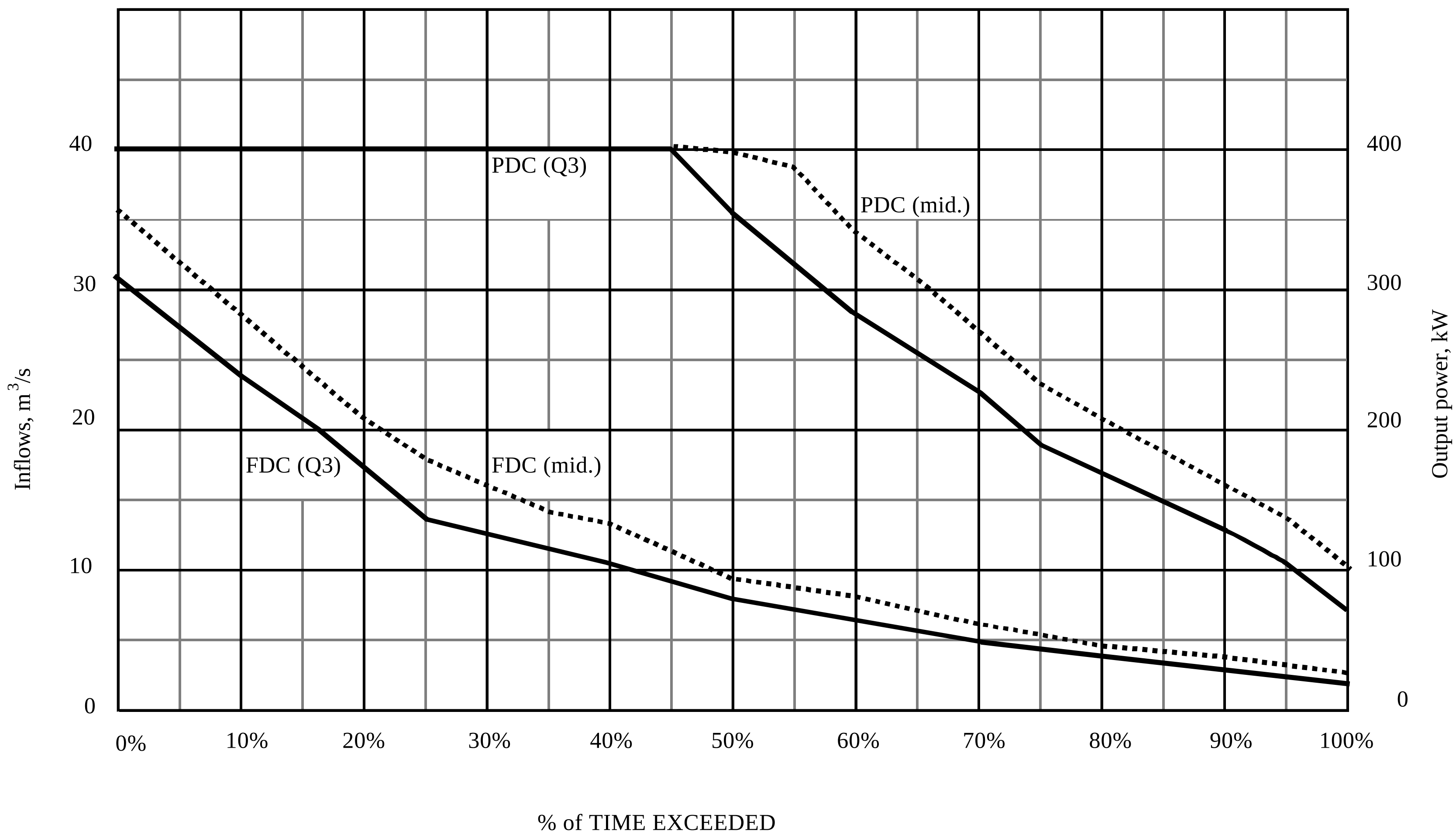


Figure 12-3 Olamze HPP Production (400 kW)
Flow and Power Duration Curves (F&P DC)



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12.2 Economic Evaluation

12.2.1 General

A rural electrification project in a remote area, along with being a public undertaking, is for the purpose of contributing to improvement in the people’ s livelihood, and requires special attention to be paid in comparison with an ordinary project. That is, it must be kept in mind that supplying electric power itself improves rural life and energizes activities in various ways. Accordingly, it is extremely difficult to quantitatively grasp the actual benefit brought about by an electrification project.

The price of a commercial item in a free market is decided by the balance of supply and demand for that item, but especially, in rural electrification, it is quite unlikely that the price can be set simply from the relation with supply and demand. That is, setting of electric power prices will generally be something outside the bounds of free market rules, and prices are normally decided by a government agency. In many cases, prices are held down for political or socie-economic reasons.

In Cameroon, too, there exists latent demand for electric power which would be awakened in response to reduction in the price of electric power, and it is not appropriate to attribute the benefit of a power development project only to power sales.

Accordingly, it is necessary for special consideration to be given in calculation of benefit and evaluation of the economics of a power development project. For hydroelectric power projects, a technique widely employed is the alternative facility method, and the results of study by that method are described below.

The objective of the study is to ascertain whether or not the project set up, in comparison with the various alternative plans conceivable, is in total cost from the stage of beginning of planning to start of operation to the end of service life, “ the project of minimum cost” . The technique of economic analysis conventionally used is either of the following, the analysis for this Project made accordingly.

a) Calculate economic internal rate of return - EIRR - for the respective total costs of the project set up and alternative plans to be equal converted to present worths and compare with the social discount rate reflecting the opportunity cost of capital in the country concerned to evaluate the appropriateness of the project.

b) As a method employed in case the concrete value of the abovementioned social discount rate is officially recognized, determine the ratio between the total costs of the project concerned and the alternative plan considered as "benefit" converted to present worths. In effect, determine the benefit-cost ratio, and evaluate the appropriateness of the project by whether or not be said ratio is 1 or more.

12.2.2 Economic Internal Rate of Return

In calculating economic internal rate of return, adjustment of kW and kWh of the alternative thermal in comparison of hydro and thermal power generating projects was done in the manner below. Parenthetically, there are differences in station power consumption rates, forced outage factors, repair rates, etc. of power stations according to individual modes of power generation. Therefore, in case of making an economic comparison between the project concerned and the alternative project, the capacity and energy production of the alternative project versus the capacity and energy production of the project concerned are adjusted so as to satisfy the condition of "furnishing equal service". Power transmission losses are respectively taken to be zero.

Start of power generation is to be by the year 2003 for all the three hydros, but in case of Ndokayo hydro, and recommended plan is made in consideration of regional demand, in which 2 units, 3,020 kW, would be started up by 2003, with the remaining unit started up in 2010. As given in the figure of the peak demand forecast for a period from 1998 to 2015, which is attached to the end of Chapter 6, Ndokayo net-works will show 3,650 kW of peak demand in the year 2002, and Ngambe-Tikar and Olamze is estimated to be 680 kW and 910 kW, respectively, in the same year's peak.

Service lives were taken to be 50 years for civil facilities and 25 years for electrical and mechanical equipment and transmission lines. Construction periods are all 2 years, but since there would be matters such as engineering required before start of construction, it was considered that expenditures for hydro would be over a period of 3 years.

(1) Ngambe-Tikar Hydropower Project

Alternative power plant: Diesel Power Plant

Installed capacity of Ngambe-Tikar Hydropower Plant: 530 kW (265 kW x 2 units)

1) Installed Capacity: 530 kW

Item	Ndokayo Hydropower	Alternative Thermal (Diesel)
Installed Capacity	530 kW	602 kW (Note 1)
Energy Generation	3.92 GWh	4.107 GWh (Note 2)
Station Service Loss Factor		
- Power loss	0.8%	4.5%
- Energy loss	1.0%	5.5%
Forced Outage Rate	0.5%	3.0%
Scheduled Outage Rate	2.0%	8.0%
Plant Service Life	50 year	20 year
Investment Cost		
- Power plant	4,869,000 x 10^3 F.CFA	457,000 x 10^3 F.CFA
- Transmission line	335,000 x 10^3 F.CFA	335,000 x 10^3 F.CFA
Total	5,204,000 x 10^3 F.CFA	792,000 x 10^3 F.CFA
Investment Cost (Alt. Thermal)	—	760,000 F.CFA/kW (Power Plant)
Heat value of fuel	—	10,200 Kcal/l
Price of fuel	—	105 F.CFA/1
Ratio of O/M Cost to Investment Cost	2.0%	5.0%

Note 1: kW adjustment factor

$$\frac{\text{Ngambe-Tikar Hydro} \quad (1 - 0.008) \times (1 - 0.005) \times (1 - 0.02)}{\text{Alternative Thermal} \quad (1 - 0.045) \times (1 - 0.03) \times (1 - 0.08)} = 1.13500532$$

Therefore, installed capacity of alternative diesel power project is calculated to be:

530 kW x 1.1350053 = 602 kW

Note 2: kWh adjustment factor

$$\frac{\text{Ngambe-Tikar Hydro} \quad (1 - 0.010)}{\text{Alternative Thermal} \quad (1 - 0.055)} = 1.04761905$$

Therefore, energy generation of the alternative diesel power project is calculated to be:

3.92 GWh x 1.047619 = 4.107 GWh

2) Investment Cost

Investment cost of alternative thermal power project is estimated as follows:

Construction cost of power plant	457,000 10^3F.CFA
Construction cost of transmission line	335,000 10^3F.CFA
Investment cost	792,000 10^3F.CFA

Annual disbursement of the investment costs of two alternatives is estimated as follows:

Year	Ngambe-Tikar Hydro (10^3F.CFA)	Alternative Thermal (10^3F.CFA)	
1st year	4,454,000	475,000	60%
2nd year	750,000	317,000	40%
Total	8,700,000	792,000	100%

3) Operation and Maintenance Cost

Annual O/M cost for Ngambe-Tikar Hydropower: 104,080 x 10^3F.CFA
Alternative thermal 792,000 x 0.05 = 39,600 x 10^3F.CFA

4) Fuel Cost of Alternative Thermal

Price of fuel, thermal efficiency for the alternative thermal power project are estimated as follows:

a) Price of fuel

Price of Diesel Oil:	105 F.CFA/l	¥ 20/l
Heat value:	10,200 Kcal/l	
Fuel cost:	0.010 F.CFA/Kcal	

b) Thermal efficiency

Thermal efficiency	38%	860 Kcal = 1 kWh
	2,263 Kcal/kWh	

c) Fuel cost

Fuel cost per kWh	23.30 F.CFA/kWh

The alternative thermal power project generates 32.057 GWh. The annual fuel cost of alternative thermal project is estimated as follows:

Annual fuel cost: F.CFA 23.3/kWh x 4.107 GWh
= 95,693 x 10^3F.CFA

5) Total annual cost

The total annual costs of two alternatives amounts to:

Ngambe-Tikar Hydro:	104,080 10^3F.CFA
Alternative Thermal:	
O/M cost	39,600 10^3F.CFA
Fuel cost	95,693 10^3F.CFA
Total	135,293 10^3F.CFA

6) Adjustment of investment cost of Ngambe-Tikar Hydropower Project

The service life is estimated at 50 years for the Ngambe-Tikar hydro project and 20 years for the alternative thermal project. To evaluate these two projects on the same basis, their operation period must be common. To select such an operation period there are two methods. The one is to adopt the least common multiple, i.e. 50 years of the alternative thermal, and the other is to adopt the shorter one, i.e. 20 years of the alternative thermal. If the latter method is adopted, the investment cost of the hydro power project must be adjusted so as to correspond to the first 20 years period. The results of the economic comparison by these two methods become the same. In this study the latter method is adopted.

7) Equalizing discount rate and Benefit/Cost ratio

The result of calculations given in the table below.

EIRR Calculation, Installed Capacity (530 kW)

(10^3F.CFA)

Discount Rate	Ngambe-Tikar Hydro Power Project			Alternative Thermal			Difference
	Investment Cost	O/M Cost	Total	Investment Cost	O/M Cost	Total	
12%	4,354,564	585,613	4,940,177	639,533	761,235	1,400,768	-3,539,409
11%	4,288,202	638,490	4,926,692	650,375	829,971	1,480,345	-3,446,347
10%	4,204,749	698,227	4,902,976	661,514	907,623	1,569,137	-3,333,839
9%	4,101,563	765,954	4,867,517	672,961	995,660	1,668,621	-3,198,896
8%	3,975,974	843,019	4,818,993	684,729	1,095,837	1,780,566	-3,038,427
7%	3,825,509	931,040	4,756,549	696,829	1,210,255	1,907,083	-2,849,466
6%	3,648,211	1,031,961	4,680,172	709,274	1,341,441	2,050,714	-2,629,458
5%	3,443,048	1,148,125	4,591,173	722,078	1,492,442	2,214,520	-2,376,653
4%	3,210,392	1,282,371	4,492,763	735,254	1,666,949	2,402,203	-2,090,560
3%	2,952,468	1,438,147	4,390,615	748,819	1,869,441	2,618,260	-1,772,355
2%	2,673,671	1,619,656	4,293,327	762,787	2,105,383	2,868,169	-1,425,158
1%	2,380,584	1,832,036	4,212,620	777,175	2,381,455	3,158,630	-1,053,990

In the case of Ngambe-Tikar hydro-project, investment cost of the alternative thermal is about ten percent of the hydro, and, to make matters worse, annual cost is lower in the alternative thermal than in the hydro, so that the hydro-project would not be justified in consideration of the economy only.

(2) Ndokayo Hydropower Project (Stage-1)

Alternative power plant: Diesel Power Plant

Installed capacity of Ndokayo Hydropower Plant: 3,020 kW (1,510 kW x 2 units)

1) Assumed alternative power plant

Item	Ndokayo Hydropower	Alternative Thermal (Diesel)
Installed Capacity	3,020 kW	3,428 kW (Note 1)
Energy Generation	20.4 GWh	21.371 GWh (Note 2)
Station Service Loss Factor		
- Power loss	0.8%	4.5%
- Energy loss	1.0%	5.5%
Forced Outage Rate	0.5%	3.0%
Scheduled Outage Rate	2.0%	8.0%
Plant Service Life	50 year	20 year

Investment Cost		
- Power plant	750,000 x 10^3 F.CFA	1,731,000 x 10^3 F.CFA
- Transmission line	1,650,000 x 10^3 F.CFA	1,650,000 x 10^3 F.CFA
Total	8,700,000 x 10^3 F.CFA	3,381,000 x 10^3 F.CFA
Investment Cost (Alt. Thermal)	—	505,000 F.CFA/kW
Heat value of fuel	—	10,200 Kcal/l
Price of fuel	—	105 F.CFA/1
Ratio of O/M Cost to Investment Cost	2.0%	5.0%

Note 1: kW adjustment factor

$$\frac{\text{Ndokayo Hydro} \quad (1 - 0.008) \times (1 - 0.005) \times (1 - 0.02)}{\text{Alternative Thermal} \quad (1 - 0.045) \times (1 - 0.03) \times (1 - 0.08)} = 1.13500532$$

Therefore, installed capacity of alternative diesel power project is calculated to be:

3,020 kW x 1.1350053 = 3,428 kW

Note 2: kWh adjustment factor

$$\frac{\text{Ndokayo Hydro} \quad (1 - 0.010)}{\text{Alternative Thermal} \quad (1 - 0.055)} = 1.04761905$$

Therefore, energy generation of the alternative diesel power project is calculated to be:

20.4 GWh x 1.047619 = 21.371 GWh

2) Investment Cost (Stage-1)

Investment cost of alternative thermal power project is estimated as follows:

Construction cost of power plant	1,731,000 10^3F.CFA
Construction cost of transmission line	1,650,000 10^3F.CFA
Investment cost	3,381,000 10^3F.CFA

Annual disbursement of the investment costs of two alternatives is estimated as follows:

Year	Ndokayo Hydro (10^3F.CFA)	Alternative Thermal (10^3F.CFA)	
1st year	1,116,000	-	
2nd year	4,808,000	2,028,600	60%
3rd year	2,776,000	1,352,400	40%
Total	8,700,000	3,381,000	100%

3) Operation and Maintenance Cost

Annual O/M cost for Ndokayo Hydropower:		174,000 x 10^3F.CFA
Alternative thermal	3,381,000 x 0.05 =	169,050 x 10^3F.CFA

4) Fuel Cost of Alternative Thermal

Price of fuel, thermal efficiency for the alternative thermal power project are estimated as follows:

a) Price of fuel

Price of Diesel Oil:	105 F.CFA/l	¥ 20/l
Heat value:	10,200 Kcal/l	
Fuel cost:	0.010 F.CFA/Kcal	

b) Thermal efficiency

Thermal efficiency	38%	860 Kcal = 1 kWh
	2,263 Kcal/kWh	

c) Fuel cost

Fuel cost per kWh	23.30 F.CFA/kWh

The alternative thermal power project generates 21.371 GWh. The annual fuel cost of alternative thermal project is estimated as follows:

Annual fuel cost: F.CFA 23.3/kWh x 21.371 GWh
= 497,944 x 10^3F.CFA

5) Total annual cost

The total annual costs of two alternatives amounts to:

Ndokayo Hydro:	174,000 10^3F.CFA
Alternative Thermal:	
O/M cost	169,050 10^3F.CFA
Fuel cost	497,944 10^3F.CFA
Total	666,994 10^3F.CFA

6) Adjustment of investment cost of Ndokayo Hydropower Project

The service life is estimated at 50 years for the Ndokayo hydro project and 20 years for the alternative thermal project. To evaluate these two projects on the same basis, their operation period must be common. To select such an operation period there are two methods. The one is to adopt the least common multiple, i.e. 50 years of the alternative thermal, and the other is to adopt the shorter one, i.e. 20 years of the alternative thermal. If the latter method is adopted, the investment cost of the hydro power project must be adjusted so as to correspond to the first 20 years period. The results of the economic comparison by these two methods become the same. In this study the latter method is adopted.

7) Equalizing discount rate and Benefit/Cost ratio

The result of calculations are given in the table below.

EIRR Calculation, Installed Capacity (3,020 kW)

(10^3F.CFA)

Discount Rate	Ndokayo Hydro Power Project			Alternative Thermal			Difference
	Investment Cost	O/M Cost	Total	Investment Cost	O/M Cost	Total	
12%	6,477,795	979,022	7,456,817	2,730,203	3,752,886	6,483,088	-973,729
11%	6,437,386	1,067,422	7,504,808	2,776,482	4,091,752	6,868,234	-636,574
10%	6,370,489	1,167,290	7,537,779	2,824,030	4,474,575	7,298,605	-239,174
9%	6,272,313	1,280,514	7,552,827	2,872,894	4,908,598	7,781,492	228,665
8%	6,137,843	1,409,352	7,547,195	2,923,123	5,402,469	8,325,592	778,397
7%	5,962,174	1,556,505	7,518,679	2,974,770	5,966,549	8,941,320	1,422,641
6%	5,741,014	1,725,222	7,466,236	3,027,891	6,613,295	9,641,186	2,174,950
5%	5,471,373	1,919,425	7,390,798	3,082,543	7,357,732	10,440,275	3,049,477

As shown in the table above,

a) In the case Ndokayo hydro project is developed in two stages, the EIRR of 1st stage of 2 units of 1,510 kW each is 9.5%, which means that the 1st stage project could be justified in the social discount rate of 8% in Cameroon.

b) The values of Benefit Cost ratio and Benefit minus Cost of the Ndokayo are 1.10 and 778.4 MF.CFA respectively, which duly supports the project economically, as well.

(3) Ndokayo Hydropower Project (Stage-2)

Alternative power plant: Diesel Power Plant

Installed capacity of Ndokayo Hydropower Plant: 1,510 kW (1,510 kW x 1 unit)

1) Assumed alternative power plant

Item	Ndokayo Hydropower	Alternative Thermal (Diesel)
Installed Capacity	1,510 kW	1,714 kW (Note 1)
Energy Generation	10.2 GWh	10.686 GWh (Note 2)
Station Service Loss Factor		
- Power loss	0.8%	4.5%
- Energy loss	1.0%	5.5%
Forced Outage Rate	0.5%	3.0%
Scheduled Outage Rate	2.0%	8.0%
Plant Service Life	50 year	20 year
Investment Cost		
- Power plant	939,000 x 10^3 F.CFA	865,000 x 10^3 F.CFA
- Transmission line	412,000 x 10^3 F.CFA	412,000 x 10^3 F.CFA
Total	1,351,000 x 10^3 F.CFA	1,277,000 x 10^3 F.CFA
Investment Cost (Alt. Thermal)	—	505,000 F.CFA/kW
Heat value of fuel	—	10,200 Kcal/l
Price of fuel	—	105 F.CFA/1
Ratio of O/M Cost to Investment Cost	2.0%	5.0%

Note 1: kW adjustment factor

$$\frac{\text{Ndokayo Hydro}}{\text{Alternative Thermal}} \quad \frac{(1 - 0.008) \times (1 - 0.005) \times (1 - 0.02)}{(1 - 0.045) \times (1 - 0.03) \times (1 - 0.08)}$$

$$= 1.13500532$$

Therefore, installed capacity of alternative diesel power project is calculated to be:

1,510 kW x 1.1350053 = 1,714 kW

Note 2: kWh adjustment factor

$$\frac{\text{Ndokayo Hydro}}{\text{Alternative Thermal}} \quad \frac{(1 - 0.010)}{(1 - 0.055)}$$

$$= 1.04761905$$

Therefore, energy generation of the alternative diesel power project is calculated to be:

10.2 GWh x 1.047619 = 10.686 GWh

2) Investment Cost (Stage-2)

Investment cost of alternative thermal power project is estimated as follows:

Construction cost of power plant	865,000 103F.CFA
Construction cost of transmission line	412,000 10^3F.CFA
Investment cost	1,277,000 10^3F.CFA

Annual disbursement of the investment costs of two alternatives is estimated as follows:

Year	Ndokayo Hydro (10^3F.CFA)	Alternative Thermal (10^3F.CFA)	
8th year	0	-	
9th year	904,000	766,200	60%
10th year	447,000	510,800	40%
Total	1,351,000	1,277,000	100%

3) Operation and Maintenance Cost

Annual O/M cost for Ndokayo Hydropower: 27,020 x 10^3F.CFA

Alternative thermal 1,277,000 x 0.05 = 63,850 x 10^3F.CFA

4) Fuel Cost of Alternative Thermal

Price of fuel, thermal efficiency for the alternative thermal power project are estimated as follows:

a) Price of fuel

Price of Diesel Oil:	105 F.CFA/l	¥ 20/l
Heat value:	10,200 Kcal/l	
Fuel cost:	0.010 F.CFA/Kcal	

b) Thermal efficiency

Thermal efficiency	38%	860 Kcal = 1 kWh
	2,263 Kcal/kWh	

c) Fuel cost

Fuel cost per kWh 23.30 F.CFA/kWh

The alternative thermal power project must generates 10.686 GWh. The annual fuel cost of alternative thermal project is estimated as follows:

Annual fuel cost: F.CFA 23.3/kWh x 10.686 GWh
= 248,984 x 10^3F.CFA

5) Total annual cost

The total annual costs of two alternatives will amount to:

Ndokayo Hydro:	27,020 10^3F.CFA
Alternative Thermal:	
O/M cost	63,850 10^3F.CFA
Fuel cost	248,984 10^3F.CFA
Total	312,834 10^3F.CFA

6) Adjustment of investment cost of Ndokayo Hydropower Project

The service life is estimated at 50 years for the Ndokayo hydro project and 20 years for the alternative thermal project. To evaluate these two projects on the same basis, their operation period must be common. To select such an operation period there are two methods. The one is to adopt the least common multiple, i.e. 50 years of the alternative thermal, and the other is to adopt the shorter one, i.e. 20 years of the alternative thermal. If the latter method is adopted, the investment cost of the hydro power project must be adjusted so as to correspond to the first 20 years period. The results of the economic comparison by these two methods become the same. In this study the latter method is adopted.

7) Equalizing discount rate and Benefit/Cost ratio

The result of calculations are given in table below.

EIRR Calculation, Installed Capacity (1,510 kW) 2nd-Stage

(10^3F.CFA)

Discount Rate	Ndokayo Hydro Power Project			Alternative Thermal			Difference
	Investment Cost	O/M Cost	Total	Investment Cost	O/M Cost	Total	
12%	447,303	68,770	516,073	466,460	796,216	1,262,676	746,603
11%	474,000	79,838	553,838	505,103	924,358	1,429,460	875,622
10%	500,473	93,018	593,491	547,351	1,076,948	1,624,299	1,030,808
9%	526,047	108,777	634,824	593,581	1,259,400	1,852,980	1,218,156
8%	549,865	127,700	677,565	644,209	1,478,487	2,122,696	1,445,131
7%	570,884	150,522	721,406	699,701	1,742,723	2,442,424	1,721,018
6%	587,892	178,172	766,064	760,580	2,062,853	2,823,434	2,057,370
5%	599,571	211,827	811,398	827,427	2,452,508	3,279,935	2,468,537

(4) Ndokayo Hydropower Project (Stage-I + Stage-II)

Alternative power plant: Diesel Power Plant

Installed capacity of Ndokayo Hydropower Plant: 4,530 kW (1,510 kW x 3 units)

Combined EIRR Calculation, Installed Capacity 4,530 kW

(10^3F.CFA)

Discount Rate	Ndokayo Hydro Power Project			Alternative Thermal			Difference
	1st Stage	2nd Stage	Total	1st Stage	2nd Stage	Total	
12%	7,457	516	7,973	6,483	1,263	7,746	-227
11%	7,505	554	8,059	6,868	1,429	8,298	239
10%	7,538	593	8,131	7,299	1,624	8,923	792
9%	7,553	635	8,188	7,781	1,853	9,634	1,446
8%	7,547	678	8,225	8,326	2,123	10,448	2,223
7%	7,519	721	8,240	8,941	2,442	11,384	3,144
6%	7,466	766	8,232	9,641	2,823	12,465	4,233
5%	7,391	811	8,202	10,440	3,280	13,720	5,518

As shown in the table above, in the case Ndokayo hydro project is developed in two stages, the EIRR of the total project is 11.5, and the value of Benefit cost ratio and Benefit minus Cost, in the case of 8% of the social discount rate, are respectively, 1.27 and 2.223 MF.CFA, which duly supports the project economically, as well.

(5) Olamze Hydropower Project

Alternative power plant: Diesel Power Plant

Installed capacity of Olamze Hydropower Plant: 400 kW (200 kW x 2 units)

1) Installed Capacity: 400 kW

Item	Ndokayo Hydropower	Alternative Thermal (Diesel)
Installed Capacity	400 kW	454 kW (Note 1)
Energy Generation	2.64 GWh	2.766 GWh (Note 2)
Station Service Loss Factor		
- Power loss	0.8%	4.5%
- Energy loss	1.0%	5.5%
Forced Outage Rate	0.5%	3.0%
Scheduled Outage Rate	2.0%	8.0%
Plant Service Life	50 year	20 year
Investment Cost		
- Power plant	4,440,000 x 10^3 F.CFA	345,000 x 10^3 F.CFA
- Transmission line	615,000 x 10^3 F.CFA	615,000 x 10^3 F.CFA
Total	5,055,000 x 10^3 F.CFA	960,000 x 10^3 F.CFA
Investment Cost (Alt. Thermal)	—	760,000 F.CFA/kW (Power Plant)
Heat value of fuel	—	10,200 Kcal/l
Price of fuel	—	105 F.CFA/1
Ratio of O/M Cost to Investment Cost	2.0%	5.0%

Note 1: kW adjustment factor

$$\frac{\text{Olamze Hydro} \quad (1 - 0.008) \times (1 - 0.005) \times (1 - 0.02)}{\text{Alternative Thermal} \quad (1 - 0.045) \times (1 - 0.03) \times (1 - 0.08)} = 1.13500532$$

Therefore, installed capacity of alternative diesel power project is calculated to be:

400 kW x 1.1350053 = 454 kW

Note 2: kWh adjustment factor

$$\frac{\text{Olamze Hydro} \quad (1 - 0.010)}{\text{Alternative Thermal} \quad (1 - 0.055)} = 1.04761905$$

Therefore, energy generation of the alternative diesel power project is calculated to be:

2.64 GWh x 1.047619 = 2.766 GWh

2) Investment Cost

Investment cost of alternative thermal power project is estimated as follows:

Construction cost of power plant	345,000 10^3F.CFA
Construction cost of transmission line	615,000 10^3F.CFA
Investment cost	960,000 10^3F.CFA

Annual disbursement of the investment costs of two alternatives is estimated as follows:

Year	Olamze Hydro (10^3F.CFA)	Alternative Thermal (10^3F.CFA)	
1st year	4,305,000	576,000	60%
2nd year	750,000	384,000	40%
Total	5,055,000	960,000	100%

3) Operation and Maintenance Cost

Annual O/M cost for Olamze Hydropower: 101,100 x 10^3F.CFA
Alternative thermal 960,000 x 0.05 = 48,000 x 10^3F.CFA

4) Fuel Cost of Alternative Thermal

Price of fuel, thermal efficiency for the alternative thermal power project are estimated as follows:

a) Price of fuel
Price of Diesel Oil: 105 F.CFA/l ¥ 20/l
Heat value: 10,200 Kcal/l
Fuel cost: 0.010 F.CFA/Kcal

b) Thermal efficiency
Thermal efficiency 38% 860 Kcal = 1 kWh
2,263 Kcal/kWh

c) Fuel cost
Fuel cost per kWh 23.30 F.CFA/kWh

The alternative thermal power project generates 32.057 GWh. The annual fuel cost of alternative thermal project is estimated as follows:

Annual fuel cost: F.CFA 23.3/kWh x 2.766 GWh
= 64,448 x 10^3F.CFA

5) Total annual cost

The total annual costs of two alternatives amounts to:

Olamze Hydro:	101,100 10^3F.CFA
Alternative Thermal:	
O/M cost	48,000 10^3F.CFA
Fuel cost	64,448 10^3F.CFA
Total	112,448 10^3F.CFA

6) Adjustment of investment cost of Olamze Hydropower Project

The service life is estimated at 50 years for the Olamze hydro project and 20 years for the alternative thermal project. To evaluate these two projects on the same basis, their operation period must be common. To select such an operation period there are two methods. The one is to adopt the least common multiple, i.e. 50 years of the alternative thermal, and the other is to adopt the shorter one, i.e. 20 years of the alternative thermal. If the latter method is adopted, the investment cost of the hydro power project must be adjusted so as to correspond to the first 20 years period. The results of the economic comparison by these two methods become the same. In this study the latter method is adopted.

7) Equalizing discount rate and Benefit/Cost ratio

The result of calculations given in the table below.

EIRR Calculation, Installed Capacity (400 kW)

(10^3F.CFA)

Discount Rate	Olamze Hydro Power Project			Alternative Thermal			Difference
	Investment Cost	O/M Cost	Total	Investment Cost	O/M Cost	Total	
12%	4,277,930	568,846	4,796,776	775,213	632,695	1,407,907	-3,388,869
11%	4,163,644	620,210	4,783,854	788,353	689,824	1,478,177	-3,305,677
10%	4,082,761	678,236	4,760,997	801,854	754,363	1,556,218	-3,204,779
9%	3,982,713	744,023	4,726,736	815,728	827,535	1,643,263	-3,083,473
8%	3,860,906	818,882	4,679,788	829,991	910,796	1,740,787	-2,939,001
7%	3,714,935	904,382	4,619,317	844,655	1,005,894	1,850,549	-2,768,768
6%	3,542,897	1,002,414	4,545,311	859,738	1,114,928	1,974,666	-2,570,645
5%	3,343,786	1,115,252	4,459,038	875,256	1,240,432	2,115,688	-2,343,350
4%	3,117,960	1,245,654	4,363,614	891,226	1,385,471	2,276,697	-2,086,917
3%	2,867,577	1,396,970	4,264,547	907,666	1,553,771	2,461,437	-1,803,110
2%	2,596,902	1,573,282	4,170,184	924,595	1,749,872	2,674,467	-1,495,717
1%	2,312,327	1,779,582	4,091,909	942,032	1,979,328	2,921,360	-1,170,549

In the case of Olamze hydro-project, investment cost of the alternative thermal is about ten percent of the hydro, and, to make matters worse, annual cost is lower in the alternative thermal than in the hydro, so that the hydro-project would not be justified in consideration of the economy only.

12.3 Financial Analysis

Based on the discussion made in Yaounde between the JICA study team and the Cameroonian counterparts taking into consideration the recent revision of the electric enterprise law, the financial analysis is made to define generally the appropriate financial and legal package within the framework of the Grant which the government of Cameroon intends to request to the government concerned, for the development of the 3 hydropower projects, and within the framework of the creation of the future “ Rural Electrification Agency” responsible for the totality of the decentralised networks.

12.3.1 Financial and Legal Framework

The framework of development for the 3 projects is described in Chapter 4, as is the decontralised management proposed by the supervisory ministry of Cameroon. As already stated these, the conditions and modes of operation to be defined with the Authorities, in the framework of the concession authorisation, are generally:

- the contractual determination of the concession and of the management committee,
- the choice of the operator or concession holder (local administrations, private companies, etc.) in association or not with the operator of the main network,
- the transfer of the existing equipment from the isolated network of the rural electrification agency to the operator,
- the provision of capital stock (even limited) to commit the operator’ s financial responsibility,
- the beginning of construction work and work supervision by the Ministries concerned prior to be creation of the Agency, if necessary,
- the definition of the final modes of operation and the guarantee of power distribution continuity,
- the total or partial repayment of the capital to the Agency by the operator over the concession duration (with no payment of the interest) for accounting reasons and to constitute funds to finance rural electrification,
- the establishment of special prices for power supply compatible with the existing domestic prices that will enable the repayment of the capital to the Agency, the annual maintenance and operation costs, and the constitution of a reserve to ensure equipment renovation at the end of the concession, as well as technical and financial assistance by the operator of the main network.

Most of the possible services performed by the local inhabitants would be paid for directly by the operator and accounted for.

The package principles currently proposed by the ministry and defined in Chapter 4 for the three sites of Ngambe-Tikar, Ndokayo and Olamze are outlined hereunder:

- transfer of the existing decentralised diesel-generating sets and networks,
- financing: 0% loan from the Rural Electrification Agency following the grant by the Government concerned,
- creation of the management committee: local administrations (town councils), local financing organisations (FEICOM, etc.), private operators,
- share of capital stock: from 5% to 10% depending on the profitability of the project,
- duration of the concession: 20 years,

- domestic price of power production: e.g. 40 CFA francs per kWh to cover capital stock repayment, operating and maintenance expenses, fuel costs, reserve fund for equipment renovation and technical assistance by the operator of the main network,
- fixed connection cost: e.g. 10,000 CFA francs per domestic household with a connection lower than 100 m,
- repayment of the capital stock to the Agency over the duration of concession, totally or partially in case of low profitability of the project.

12.3.2 Results of the Financial Simulations

The objective here was to determine the percentage of capital to be repaid by the Operator to the Agency in order to reach a relatively attractive profitability in the order of 25% to 30% on the capital stock provided by the future concession holder. Total or partial repayment of the capital to the Agency will make it possible to re-finance other projects in rural areas of Cameroon.

The main parameters taken into account and the results of the simulations are summarised in the table below.

Results of the Financial Simulation

in MF.CFA 1999

HPP Projects	Ngambe-Tikar	Ndokayo	Olamze	G. Total
Net output	530 kW	4,530 kW	400 kW	5,460 kW
Network Length	25 km	152 km	47 km	224 km
Net annual generation with outage	3.5 GWh	26.3 GWh	2.4 GWh	32.2 GWh
Total Project Costs	5,203	10,051	5,055	20,309
Annual HPP O&M costs (a)	31.8	135.9	24.0	191.7
Annual TL O&M costs (b)	6.8	41.0	12.7	60.5
Annual renewable provisions (c)	25.1	39.4	18.8	83.4
Total Annual Operation Costs (a + b + c)	63.7	216.4	55.5	335.8
in kF CFA/kW/yr.	120	47.7	138.7	61.5
“ Concession” common basis	Price: 40 FCFA/kWh plus connection fees “ Concession” Period: 20 years Discount rate: 8% interest rate: 0%			
Part of Equity	5%	10%	5%	
Repayment Capital	20%	90 - 80%	10%	-
Results:				
IRR on Equity	25%	25 - 35%	30%	-

According to the hypotheses defined above, and to reach a rate of financial profitability on capital stock in the order of 25% to 30% for a duration of concession limited to 20 years, and for user acceptable prices, repayment of the capital loaned by the concession holder to the Agency would be approximately.

- 20% for the Ngambe-Tikar HPP project with a 5% capital stock contribution by the operator,
- 90% for the Ndokayo HPP project with a 10% capital stock contribution by the operator,
- 10% for the Olamze HPP project with a 5% capital stock contribution by the operator.

The amount unpaid is equivalent to a subsidy covering the deficits of the project. On the other hand, the amount refunded will allow the Agency to constitute a reserve to finance other development projects.

12.3.3 Financial Internal Rate of Return

Financial internal rate of return in Ndokayo power station is calculated to be 6.5%, with 40 F CFA/kWh and on the same assumption as in the economic internal rate of return, of which the evaluation table is shown below.

Table 12-3 FINANCIAL EVALUATION

(Unit: Thousand F CFA)

No.		Ndokayo Hydro Project			Benefit		(B)-(C)
		Construction Cost	O & M Cost	(C) Total Cost	Annual Available Energy	(B) Power Sales Revenue	
					(kWh)		
1		1,116,000		1,116,000			-1,116,000
2		4,808,000		4,808,000			-4,808,000
3		2,776,000		2,776,000			-2,776,000
4	1		174,000	174,000	17,530,000	701,200	527,200
5	2		174,000	174,000	17,530,000	701,200	527,200
6	3		174,000	174,000	17,530,000	701,200	527,200
7	4		174,000	174,000	17,530,000	701,200	527,200
8	5	0	174,000	174,000	17,530,000	701,200	527,200
9	6	904,000	174,000	1,078,000	17,530,000	701,200	-376,800
10	7	447,000	174,000	621,000	17,530,000	701,200	80,200
11	8		201,020	201,020	26,300,000	1,052,000	850,980
12	9		201,020	201,020	26,300,000	1,052,000	850,980
13	10		201,020	201,020	26,300,000	1,052,000	850,980
14	11		201,020	201,020	26,300,000	1,052,000	850,980

No.		Ndokayo Hydro Project			Benefit		(B)-(C)
		Construc-tion Cost	O & M Cost	(C) Total Cost	Annual Available Energy	(B) Power Sales Revenue	
15	12		201,020	201,020	26,300,000	1,052,000	850,980
16	13		201,020	201,020	26,300,000	1,052,000	850,980
17	14		201,020	201,020	26,300,000	1,052,000	850,980
18	15		201,020	201,020	26,300,000	1,052,000	850,980
19	16		201,020	201,020	26,300,000	1,052,000	850,980
20	17		201,020	201,020	26,300,000	1,052,000	850,980
21	18		201,020	201,020	26,300,000	1,052,000	850,980
22	19		201,020	201,020	26,300,000	1,052,000	850,980
23	20		201,020	201,020	26,300,000	1,052,000	850,980
24	21		201,020	201,020	26,300,000	1,052,000	850,980
25	22		201,020	201,020	26,300,000	1,052,000	850,980
26	23		201,020	201,020	26,300,000	1,052,000	850,980
27	24	1,808,000	201,020	2,009,020	26,300,000	1,052,000	-957,020
28	25	894,000	201,020	1,095,020	26,300,000	1,052,000	-43,020
29	26		201,020	201,020	26,300,000	1,052,000	850,980
30	27		201,020	201,020	26,300,000	1,052,000	850,980
31	28		201,020	201,020	26,300,000	1,052,000	850,980
32	29		201,020	201,020	26,300,000	1,052,000	850,980
33	30		201,020	201,020	26,300,000	1,052,000	850,980
34	31		201,020	201,020	26,300,000	1,052,000	850,980
35	32		201,020	201,020	26,300,000	1,052,000	850,980
36	33		201,020	201,020	26,300,000	1,052,000	850,980
37	34	904,000	201,020	1,105,020	26,300,000	1,052,000	-53,020
38	35	447,000	201,020	648,020	26,300,000	1,052,000	403,980
39	36		201,020	201,020	26,300,000	1,052,000	850,980
40	37		201,020	201,020	26,300,000	1,052,000	850,980
41	38		201,020	201,020	26,300,000	1,052,000	850,980
42	39		201,020	201,020	26,300,000	1,052,000	850,980
43	40		201,020	201,020	26,300,000	1,052,000	850,980
44	41		201,020	201,020	26,300,000	1,052,000	850,980
45	42		201,020	201,020	26,300,000	1,052,000	850,980
46	43		201,020	201,020	26,300,000	1,052,000	850,980
47	44		201,020	201,020	26,300,000	1,052,000	850,980
48	45		201,020	201,020	26,300,000	1,052,000	850,980
49	46		201,020	201,020	26,300,000	1,052,000	850,980
50	47	-540,400	201,020	201,020	26,300,000	1,052,000	850,980
51	48		201,020	201,020	26,300,000	1,052,000	850,980
52	49		201,020	201,020	26,300,000	1,052,000	850,980
53	50		201,020	-339,380	26,300,000	1,052,000	1,391,380
Total		13,563,600	9,861,860	23,425,460	1,253,610,000		1,230,184,540
						F.I.R..R.	6.5%