BASIC DESIGN STUDY REPORT

ON

THE PROJECT

FOR

THE CONSTRUCTION OF

MICRO HYDRO POWER FACILITIES

(PHASE-II)

IN

THE KINGDOM OF BHUTAN

MARCH 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Kingdom of Bhutan, the Government of Japan has decided to conduct a Basic Design Study on the Project for The Construction of Micro Hydro Power Facilities (Phase-II) and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Bhutan a survey team headed by Mr. Kenji Nakato, Deputy Director of the Kyushu Agricultural Administration Bureau of the Ministry of Agriculture, Forestry and Fisheries from November 20th to December 29th, 1988.

The team exchanged views on the Project with the officials concerned of the Government of Bhutan and conducted a field survey in the project sites. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Bhutan for their close cooperation extended to the team.

March, 1989

Kensuke Yanagiya
President
Japan International Cooperation Agency

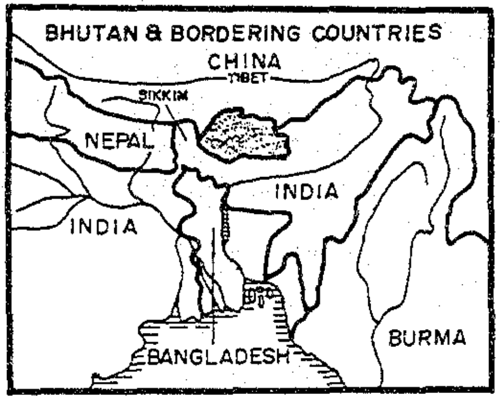
LOCATION OF BHUTAN

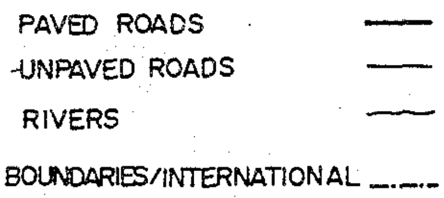
Area: 18,000 square miles

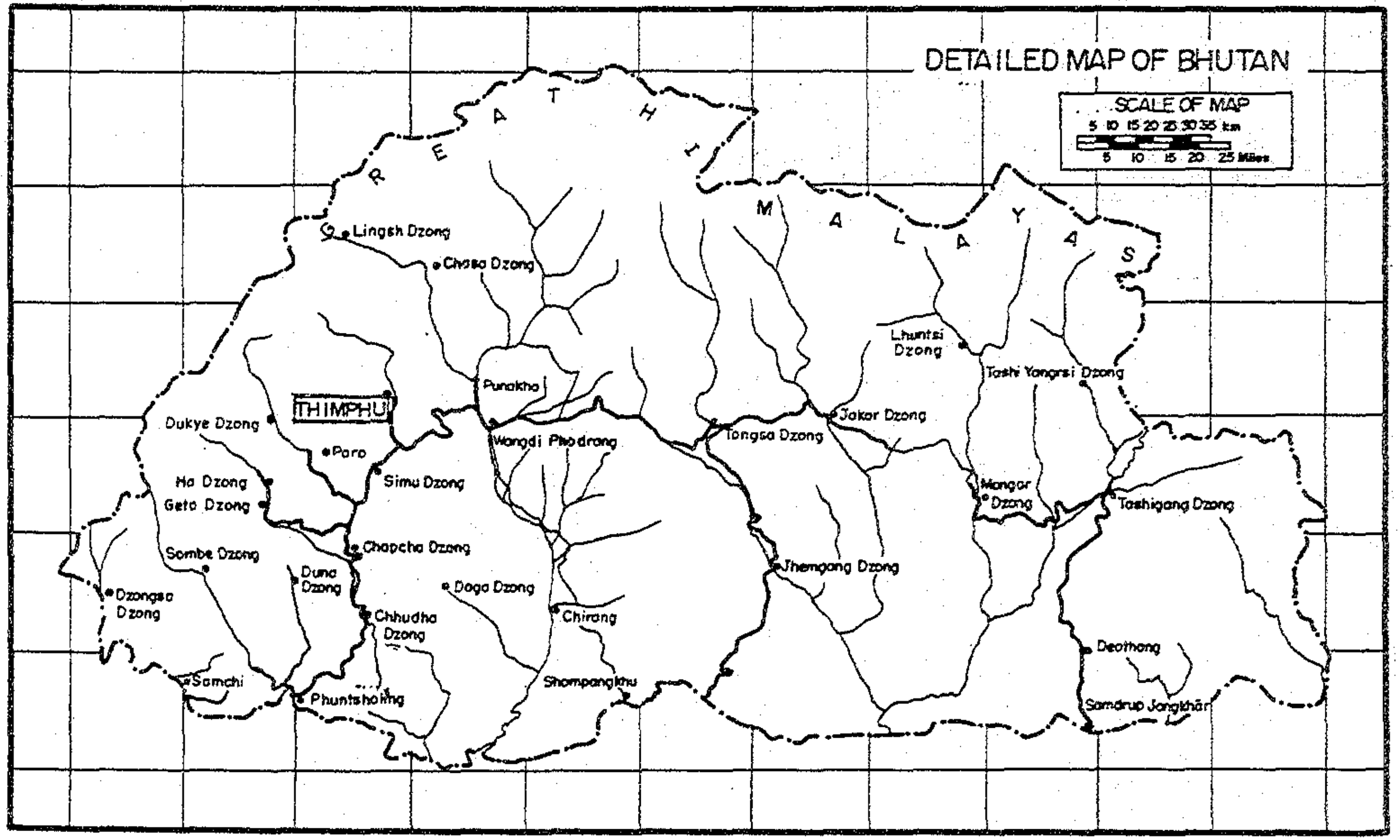
Position: Approximately between 26'45" and 28'10" north latitude and 88'45" and 92'10" east longitude

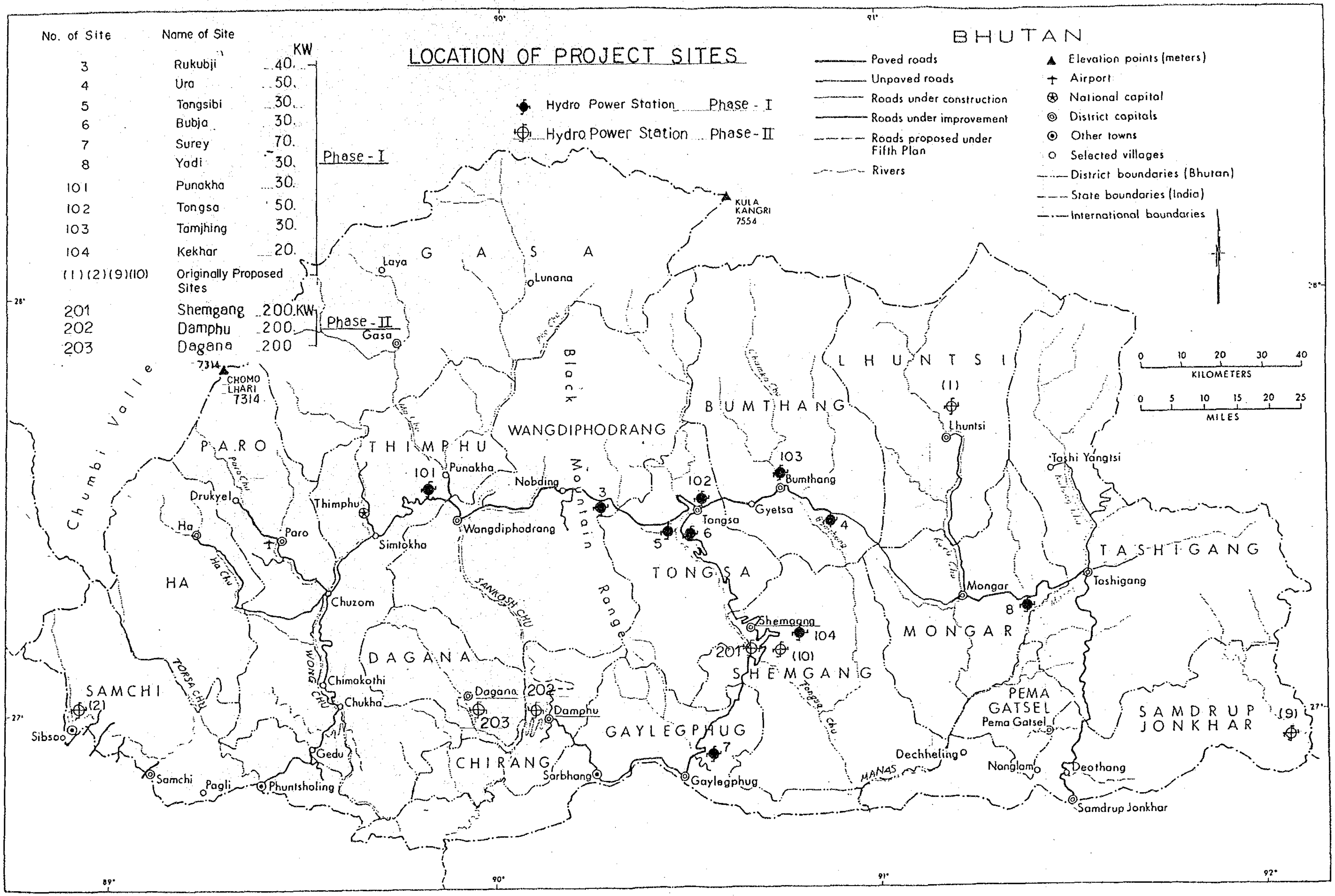
Population: 1,200,000

Capital: Thimphu

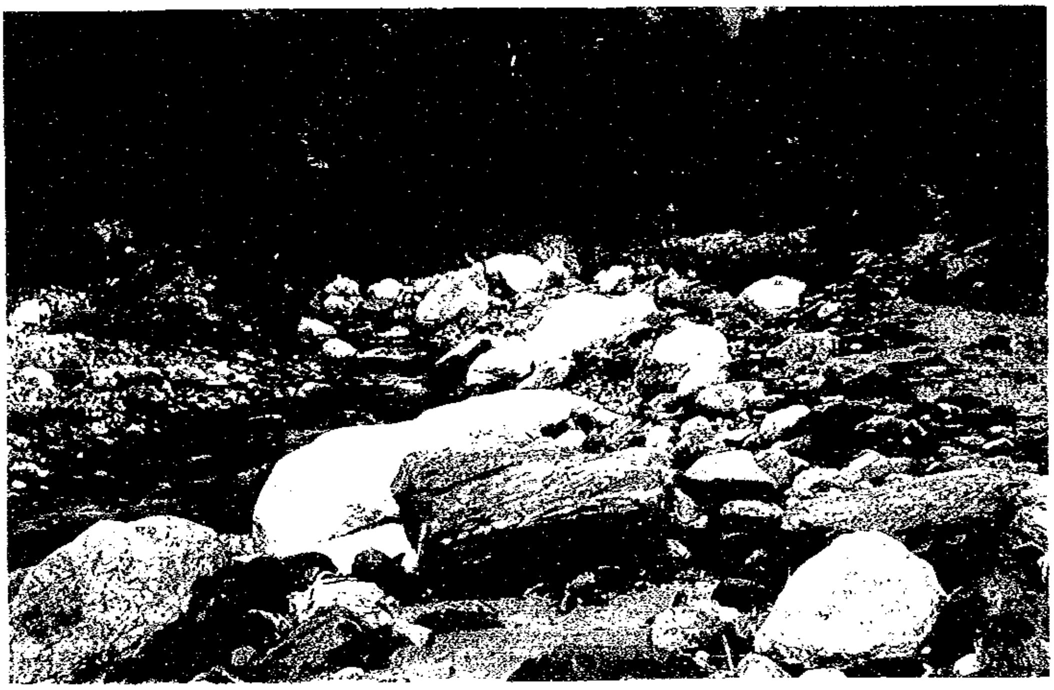






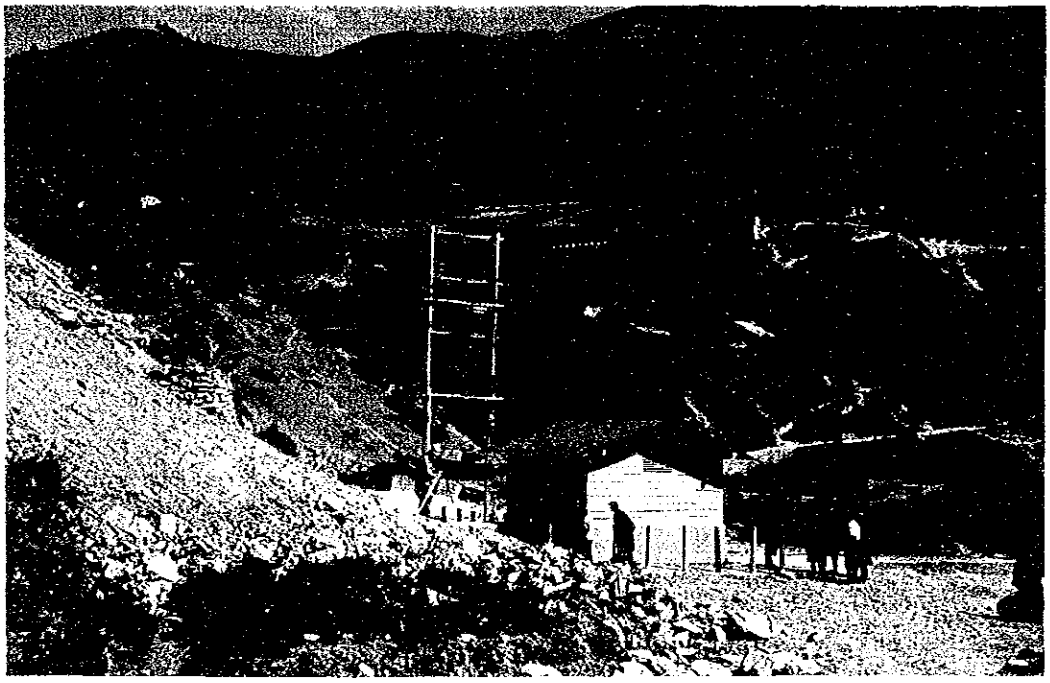

LOCATION OF PROJECT SITES
BHUTAN
No. of Site
Name of Site
KW
3 Rukubji 40.
4 Ura 50.
5 Tongsibi 30.
6 Bubja 30.
7 Surey 70.
8 Yadi 30.
101 Punakha 30.
102 Tongsa 50.
103 Tamjhing 30.
104 Kekhar 20.
Phase - I
(1)(2)(9)(10) Originally Proposed Sites
201 Shemgang 200.KW
202 Damphu 200.
203 Dagana 200
Phase - II
Hydro Power Station Phase - I
Hydro Power Station Phase - II
Paved roads
Unpaved roads
Roads under construction
Roads under improvement
Roads proposed under Fifth Plan
Rivers
Elevation points (meters)
Airport
National capital
District capitals
Other towns
Selected villages
District boundaries (Bhutan)
State boundaries (India)
International boundaries
0 10 20 30 40
KILOMETERS
0 5 10 15 20 25
MILES
KULA KANGRI 7554
CHOMO LHARI 7314
Chumbi Valley
GASA
Laya
Lunana
Gasa
Black Mountain Range
LHUNTSI
Lhuntsi
BUMTHANG
Bumthang
WANGDIPHODRANG
Wangdiphodrang
PARO
Paro
Drukyel
THIMPHU
Thimphu
Punakha
Nobding
Simtokha
Tongsa
Gyetsa
Tashi Yangtsi
TASHIGANG
Tashigang
HA
Ha
Ha Chu
TONGSA
Chuzom
Mongar
MONGAR
Shemgang
SHEMGANG
DAGANA
Dagana
Damphu
SAMCHI
Sibsoo
Samchi
Pagli
Phuntsholing
Gedu
Chimakothi
Chukha
Wong Chu
Torsa Chu
Sankosh Chu
Tongsa Chu
CHIRANG
Sarbhang
GAYLEGPHUG
Gaylegphug
PEMA GATSEL
Pema Gatsel
Dechheling
Nanglam
Deothang
Manas
SAMDRUP JONKHAR
Samdrup Jonkhar
89°
90°
91°
92°
27°
28°

Proposed Site of Shemgang Intake Dam



Proposed Site of Damphu Intake Dam

Proposed Site of Dagana Intake Dam



Rukubji Micro Hydro Power Station
(constructed by Phase I)

SUMMARY

SUMMARY

The Kingdom of Bhutan is a mountainous country located along the southern part of the Himalayas, immediately north of India. The country, surrounded on all sides by India and China, has a land area of about 47,000 km^2. Bhutan's population in 1988 is about 1.3 million, most of whom live in the "Intermediate Zone", which is the area extending from the border with India to the areas below the elevation of 3,000 meters.

Bhutan has a rich natural environment, thus the country's industry is mainly based on agriculture, forestry and animal husbandry. Because, at present, agriculture is practiced on a self-sufficiency basis, income levels are comparatively low, with a GNP of only $160 as of 1988. Industries other than agriculture are newly being introduced but remain undeveloped.

Due to the weakness of the national economy, the country relies on foreign assistance for more than half of its national budget.

In order to be independent from this foreign assistance, the Government of Bhutan has made its Sixth Five-Year National Development Plan (1988 - 1992), and is working to develop an industrial base, improve hygienic conditions and enhance living standard for the citizens.

One of the greatest obstacles to achieving the goals of this Plan, however, is the fact that most areas of the country are still without electricity. Electrification, which is indispensable to the realization of the Plan's goals, is seriously behind schedule for various reasons.

Bhutan is estimated to possess hydro resources sufficient to develop 6,000 MW. Until very recently, however, only 21 sites had been developed, generating a total of 355 MW, or less than 6% of the estimated potential capacity.

In August of 1988, the Chukha hydropower generation plant, built under the assistance of India, was put into operation. This plant has a generating capacity of 336 MW, or about 18 times that of the other existing generating plants throughout the country (19 MW in total including diesel generation).

The main purpose of the Chukha power generation plant, however, is to supply electricity to India. Because Bhutan is so mountainous, construc-

tion of lines and facilities to supply Chukha electricity over a wide area of Bhutan is difficult from technical standpoint and due to budgetary restriction. Therefore, electricity from the Chukha generation plant can be made available only to a limited area of the country.

Therefore, the Government of Bhutan has concluded that the most effective and appropriate way to achieve rural electrification is to utilize the potential generating capability of the relatively small rivers, streams, and irrigation channels which are available at the local sites. The Government of Bhutan has formulated plans for developing micro hydropower facilities at 150 sites.

In view of the difficulties of the limited budget and the shortage of qualified technicians, the Government of Bhutan implemented, under a Japanese Grant Aid program, the construction of micro hydropower facilities at 10 high-priority sites in 1987. These have been contributing to the improvement of the people's lives so far.

Based on this success, the Government of Bhutan has planned the second phase and has requested the Government of Japan for Grant Aid for the electrification based on small-scale hydro power stations of three areas: Shemgana, Damphu, and Dagana. Each of the three sites is located in a center of administration for the respective areas and contains public facilities such as hospitals and schools, to which electricity was supplied by diesel generators. However, operation of these diesel generators was suspended due to the steep rise in fuel costs and a shortage of foreign currency. The Government of Bhutan has resumed the partial operation of diesel generator in Shemgang in June, 1986; presently, the diesel generator works only at night.

The Japanese Government, after considering this request, decided to conduct a Basic Design Study of the proposed project. The Japan International Cooperation Agency (JICA) dispatched a Basic Design Study Team to Bhutan from November 20 to December 29 of 1988.

The objectivs of this study were to investigate the background and content of the request, to study the basic design of the project and to decide the optimum scale thereof.

While in Bhutan, the study team carried out a field survey at the proposed sites and the surrounding towns and villages; field surveys of the rivers to be used for power generation and routing of the transmission lines; and held discussions with the competent Bhutanese Government authorities on matters concerning generating capacities and area to which the Bhutan Government wishes to supply electricity by constructing transmission and distribution lines.

Upon returning to Japan, the study team continued its work. Based on the results of its site investigations and its further work in Japan, the team made a plan of the construction of micro hydro generating facilities at the three sites (Shemgang, Damphu and Dagana). The basic concept to formulate the plans for the generating facilities conforms to the following conditions;

(1) The capactiy of generation facilities shall be sufficient for the consumption of the public institutions in the area. Surplus power will be used to meet the lighting demands of private households.

(2) Rivers and diversion sites used for power generation are chosen to correspond to the scale of demand. Power station are planned to be built close to their load centers.

(3) The facilities shall be safe and easy to maintain.

(4) The facilities are planned for standardization as much as practicable so as to ensure high efficiency and rationalization of construction work of the project.

Outline of Main Facilities to be Provided Under the Grant-Aid

Project Sites		Scale of Hydro Power Plant					No. of Conceivable Consumers		
No.	Name of Site	Max. Installed Capacity (kW)	Max. Dis-charge (m^3/s)	Effec-tive Head (m)	Length of Trans-mission Line (km)	Length of Dis-tribution Line (km)	No. of Public Insti-tutions	No. of House-holds	Popula-tion
1	Shemgang	200	0.9	39.0	18.0	5.0	30	346	3,739
2	Damphu	200	0.9	39.0	9.0	5.0	20	550	4,950
3	Dagana	200	1.4	25.0	33.0	10.0	21	565	3,982
	Total	600	---	---	60.0	20.0	---	---	----

As indicated above, the three power plants, all have similar design conditions. And cross-flow turbines, which are the best suited to these heads, will be applied. Thus the specifications for the facilities in all of the sites will be standardized so as to permit simple operation and maintenance.

For the implementation of this project under the Japanese grant aid, the Government of Bhutan will be responsible for the following: 1) acquisition and provision of the land needed for the facilities and construction, 2) preparation or reinforcement of access roadways needed for bringing in the necessary materials. The expenses borne by Bhutan for the said work are estimated at about 4,320 thousand ngultrums.

Bhutan will also be responbible for the operation and maintenance of the completed facilities. The yearly costs for these activities are estimated at about 575 thousand ngultrums.

The work undertaken by the Japanese party will be separated into two phases in accordance with the accounting system in force in Japan. The first phase will cover the work at Damphu and Dagana, and is expected to require 20 months after the Exchange of Notes (E/N). The second period will cover the work at Shemgang, and is expected to require 19 months after the E/N.

The Department of Power in Bhutan's Ministry of Trade, Industry and Power will be the responsible agency for the implementation of the project. While the Department of Power will conduct periodic patrolling, local residents will play an active role in the daily maintenance and inspection of the completed facilities, so as to provide adequate maintenance and operation.

Income from the sale of the generated electricity to users will be sufficient to cover all necessary operating and maintenance costs.

The direct and indirect benefits arising from the implementation of this project, are expected to be as follows:

(1) Direct Benefits

1) Annual possible power generation is expected to amount to about 5.0 GWh.

2) Electrification to be realized by the project in each area is as follows.

	Shemgang	Dampu	Dagana
Public Institution	30	20	21
Household	346	550	565

3) Regular use of the existing power facilities based on a diesel generator will no longer be required, and fuel oil imports can be reduced, which will in turn save foreign currency.

4) Power will be available all day long in the project areas when the planned power facilities are constructed. This will bring about many benefits to residents, such as: improvement of daily life by use of electric lamps and heaters; improvement of education by prolonged time for learning; improvement of medical services through use of such medical equipment as a X-ray diagnostic devices; boiling sterilizers, and other electric devices; and improvement in public peace and order by installation of street lighting.

(2) Indirect benefits

1) After completion of the power facilities now planned, engineers from the Department of Power will make periodic patrol and check for service and maintenance. Also residents, who are receivers of the benefits, will perform the daily work necessary for operating and maintaining the facilities, which will contribute to enhance their technical skill through the said activities.

2) Use of more electric heaters will reduce consumption rate of firewood used in the project areas; this will prevent devastation of woods and forests, and contribute to resources preservation.

Also small-scale industrial activities will become more active, which will create more opportunities for employment.

3) it will become possible for people to gather in public facilities at night, which will promote communication among residents in the project areas, activate community life, and improve cultural life.

For the above reasons, the implementation of this project promises to have a profound effect on Bhutan's economic development policy. Therefore the project is justifiable for grant aid by the Japanese Government.

It is important, of course, that the Bhutanese Government will rapidly take measures for acquisition of the land necessary for the project construction, to provide the roads for hauling equipment, and to arrange the formalities necessary for prompt unloading and custom clearance of imported materials and the budgeting for required expenses (other than expenses covered by the grant aid).

It is also recommended for the promotion of micro hydro projects that Bhutan should collect data on hydro sources, compile topographical maps, and bring up personnel required for operation and maintenance.

CONTENTS

APPENDIX

PERTINENT DATA AND INFORMATION

NUMBER	DATA NAME
1.	Key Personnel with when the Survey Team Met
2.	Member List of Survey Team
3.	Survey Schedule
4.	Minutes of Discussions
5.	Table and Figure
6.	List of Received Data and Information
7.	Discharge Data
8.	Hydraulic Calculations for Open Channel

CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

Starting from 1961, Bhutanese Government has been carring out a series of National Economic Development Plans. These plans aiming at the greater independence are designed to maintain and promote domestic economic growth and social development. The first plan was launched in 1961; the Sixth Five-Year National Development Plan shall be in force from 1988 to 1992.

These Plans have been aimed at achieving a variety of important and basic objectives: the forging of an economic and social infrastructure, the building-up of human capital, the improvement of administrative capacities, and the betterment of social welfare. Under these Plans, roads, hospitals and clinics and schools have been constructed, and electrification works have been undertaken in some municipalities.

Nevertheless, the majority of villages and towns, which are dispersed throughout the country, remain unelectrified. This is a great impediment to developing social infrastructure and to enhancing education, health care and hygiene, communication, etc. The Government of Bhutan therefore considers the electrification of villages and towns an urgent concern.

Because the country relies on foreign aid for about 60% of its national budget, electrification by means of diesel generator plants, which require the use of imported oil, is inappropriate. Meanwhile the use of large-scale hydropower stations is also inappropriate, as the costs of transmission lines to the scattered remote villages would be extremely high because of very mountainous topographical condition.

On the contrary, the steep and rugged terrain is very well suited to the use of small-scale hydropower stations, as each village and town has access to a river with ample hydro-potential head suitable for hydro power generation. The Government of Bhutan therefore selected 150 sites as candidates for such hydro-power generation, and requested Japanese grant aid to implement 10 of these sites. Electrification of these sites was completed in 1987.

This electrification has brought great benefit to the residents in these towns and villages. Education was enhanced because the lighting of schools and dormitories enabled the hours spent on education to extend. Health and hygiene were enhanced because electrification enabled hospitals and clinics to utilize X-ray diagnosis, sterilizing machinery and refrigerators for storing blood sera. Animal husbandry was enhanced because refrigeration of animal sperm became possible.

As for utilization factor at each of the above 10 sites, ratio of the maximum (peak) load to the maximum capacity of the power facility in the area is 100% in Tongsa, and is between 40% and 70% at the other sites. Considering that operation of the facilities was started just before, it can be considered that the running condition is good. If power is supplied to more houses and small-scale industrial activities, the factor would become higher because more electric devices would be made available.

Bhutan wishes to continue this success by electrifying three new districts (Shemgang, Damphu and Dagana) with a 200 kW hydropower plant at each district together with the transmission and distribution lines necessary to supply the electricity to the demand areas. The Government of Bhutan has therefore requested to the Government of Japan the grant aid for construction of the necessary generating facilities, as well as the supply of materials.

The Government of Japan, based on its initial investigation of this request, decided to carry out a Basic Design Study of the Project. This study was entrusted to the Japan International Cooperation Agency (JICA).

JICA then dispatched a team to Bhutan to carry out this study. The team, headed by Mr. Kenji Nakato (Deputy Director Construction Dept., Kyushu Agricultural Administration Office, the Ministry of Agriculture and Forestry & Fisheries) performed the study and investigation in Bhutan for 40 days from November 20 to December 29 of 1988.

The team conducted discussions with relevant Bhutanese Government authorities regarding the content of the request, and carried out site surveys at each of the three sites. The team visited the rivers which could be used for generation, and performed field investigations of power-line routes. The team also conducted interviews to clarify the actual status of power conditions. As a result of the discussions and the field survey, basic agreements are recorded in the minutes of these discussions which were signed by representatives of both governments and exchanged those on Dec. 1, 1988.

The appendixes attached to this report provide details about the member list of the Japanese team, the itinerary of the investigations, the places visited and the persons interviewed, the minutes of discussions and a list of the data collected in Bhutan.

After returning to Japan, the team continued its work or study on the proposed power scheme, the basic design, the selection of materials, the cost estimate, and operation and maintenance plans. This report incorporating the information, data and the study results too, proposes the most adequate plans satisfactory for the request of Bhutan and appropriate for the implementation of the project.

CHAPTER 2
BACKGROUND OF THE PROJECT

CHAPTER 2 BACKGROUND OF THE PROJECT

2-1 National Economic Development Plan

2-1-1 Circumstances

The government of Bhutan, with the goals of realizing social and economic improvements, and of achieving economic independence, has, from 1961, launched a series of 5-year economic development plans. These plans have focused on improving roads, communication, education, hygiene, and medical conditions. Five such plans have been completed, and the Sixth Five-Year Economic Development Plan is presently in effect.

These plans have been subject to limits based on Bhutan's fiscal difficulties, its shortages of skilled workers and of labor, and its underdeveloped infrastructure, under which transport and communication are at times difficult. Still, the country has invested the greater part of the national budget to its development plans, and through 1987, had built 2,165 km of roads (1,703 km of paved roads), electrified 115 towns and villages, constructed 348.9 km of irrigation canals and repaired or renovated 394.8 km, and established 94 clinics and hospitals, and 177 schools.

Under the First Plan (from 1962), 59% of the country's total national budget was allocated to public works, with particular focus on road construction; 9% was allocated to education. The Second Plan continued its emphasis on public works; education remained the second priority, and agriculture became the third major concern. The portion of plan budgets dedicated to public works declined beginning with the Third Plan; under the Fifth Plan, 16.9% of the budget was devoted to public works; 11.2% to education; 9.0% to agriculture 7.3% to electrification; 7% to mining and manufacturing; and 5.1% to health.

Most of the funds for the First to Fifth five-year plans were supplied by the Government of India. Also, the ratio of financial assistance from international organizations such as UNDP has been increasing, from 3% in the Third plan up to 20% in the Fifth plan.

Bhutan's National Planning Commission was established in 1971, during the implementation of the Third Five-Year Plan, and priorities started to be given to individual projects. Starting with the Fourth Plan, regional authorities were brought into the investigation and planning of product contents. Specifically, the District Development and Planning Committee was established regionally. The Committee drafts projects and proposes them to the relevant organizations, and each Ministry then works in collaboration with the National Planning Commission in investigation and planning these projects.

2-1-2 The sixth national economic development plan (1981 - 1992)

Over the long term, the Government of Bhutan is aiming to maintain and expand its rich national culture; to establish independence in the funding of public services; to achieve self-sufficiency in food production, and particularly in the production of grains; and to develop, within its own population, the technical and specialized skills needed to achieve its developmental goals. In the period before these aims are achieved, the Government is working to increase the proportion of developmental efforts which are funded from within, and is in the process of studying a range of initiatives, such as the introduction of intermediate organizations to work between the central government and the local administrative units, the establishment of a National Urban Development Corporation to administer urban infrastructural development, and the setting up of Development Service Centers to conduct comprehensive services and to generalize regional institutions related to local education, hygiene, agricultural and livestock raising, mail, and radio. The Sixth Five-Year Plan shall move ahead based on the results of the Fifth Plan.

Nonetheless, because almost 60% of yearly expenditures are covered by foreign assistance, the plan contents are subject to large external influences. The result is that each plan is subject to investigation and change, and to continued variability.

Under these circumstances, formal information detailing a full view of the Sixth Five-Year Plan has not been made public. According to the outline the Plan published by the National Planning Commission in its Annual Statistical Report (December, 1987), the value of the Sixth Plan should be about double that of the Fifth Plan, with 29.1% of the funds going to commerce and industry (including electric power); 27.2% going to social services; 15.6% going to Agriculture; and 7.7% to public finance.

2-2 Power Supply Facilities

2-2-1 The Department of Power, and the Chukha Power Station

The Department of Power, which is under Bhutan's Ministry of Trade, Industry, and Power, is in charge of electric power operation, transmission, and distribution throughout all of Bhutan. There are no other public corporations overseeing electric power.

Appendix 5.5 provides a description of the organization of the Dept. of Power.

Generating and transforming facilities are also owned and operated independently, however, by the Chukha Hydropower Project Authority, Peden Cement, the Gedu Wood Manufacturing Corp., Bhutan Carbide & Chemicals, Ltd., and other companies.

Among the independently operated facilities, the Chukha Generating Station, which was built under the Chukha Hydropower Project Authority, and which will be taken over by the Department of Power, is a special case.

The Chukha Project was undertaken to relieve the power shortage in the western region of Bhutan and in eastern districts of India. The station, located in Chukha, generates 336,000 kW, utilizing the power of the Wang-chu River. The power is supplied to Bhutan's western region, and also, through the Birpara Station, into the power grid for the eastern districts of India. Goals also call for supplying any excess power to west Bengal, Sikkim, Bihar, and Orissa.

The Chukha Station was built under the aid of India; accordingly, the Chukha Hydropower Project Authority was set up as a joint venture between the Government of India and Bhutan.

Bhutan is a long and thin country; narrow from north to south, and long from east to west. The only relatively flat area in the country is at the southern tip, by the border with India; northward from this point, mountains rise steeply, until they reach the 6,000 to 7,000 meter heights of the Himalayan Range along the border with China. The rising mountains form deep valleys running north to south, so that the country is divided, east-to-west, into numerous sections.

Because of this topography, the Chukha Generating Station is only able to supply electricity, in Bhutan, to the areas around the transmission lines built along the Wang-chu (and along roadways). In other words, large-scale extension of the lines, from east to west, is not economically possible. The Chukha Station is therefore unable to supply the unelectrified towns and villages scattered in many regions throughout the country.

In addition, less than 5% of the power generated at the Chukha Station is supplied to customers in Bhutan; the remainder is supplied to India. No large change in this proportion is anticipated in the future.

As shown in Table 2.2-1 and Table 2.2-2, which indicate the power supply situation throughout the country in June of 1988, total power generation capacity by both hydro and diesel power stations is 269,505 kW; of this 9,309 kW (3% of the total) is provided by facilities belonging to the Department of Power.

On the other hand, total electric energy generated in the country from April, 1987 until June, 1988, is 1,476.388 GWh, while total electric energy generated by facilities belonging to the Department of Power is 5.693 GWh (0.4%), and the role played by the Department of Power is very low. Chukha Power Station is to be transferred in August, 1989, to the control by the Department of Power, at which time the above values will greatly change. However, it should be noted that most of the power generated by the Chukha Power Station is sent to India.

Table 2.2-1 Capacities of Bhutan's Generating Facilities as of June 30, 1988 (in kW)

	Hydro	Diesel	Totals
Department of Power	4,460	4,849	9,309
Chukha Hydropower Project Authority	252,000	1,696	253,696
Others	---	6,500	6,500
Totals	256,460	13,045	269,505

Table 2.2-2 Amount of Electric Power Generated in Bhutan from April 1, 1987 through June 30, 1988 (in GWh)

	Hydro	Diesel	Totals
Department of Power	5.380	0.313	5.693
Chukha Hydropower Project Authority	1,470.466	0.009	1,470.475
Others	---	0.220	2.220
Totals	1,475.846	0.542	1,476.338

2-2-2 Present situation of power demand and supply

The present power line distribution system in Bhutan is described in Appendix 5.6.

As previously described, much of Bhutan's population live in deep valleys which generally run north-to-south, and are divided by lines of very steep mountains. The land can therefore be considered as being divided, east-to-west, into a number of areas. The transmission line systems that exist in Bhutan are likewise separated, with a separate system running north-to-south along the valleys (and along roads). These systems are generally independent and are not interconnected.

In the western part of the Kingdom of Bhutan, power generated in Chukha Power Station is transmitted through the two 200-kV lines running from the power station in Birpara Power Station in India, through a transmission line running southward in parallel with the above lines to Phuntsholing, and through a line running northward along the Wangchu to Haa in the western district, to Thimphu, the capital of the Kingdom, and to Wangdi-phodrang, in the central district. The power transmitted from Chukha Power Station to these areas is distributed to users via substations controlled by the Department of Power.

As described in the previous section, however, it is impossible to send power generated in the western district to the eastern areas under stable conditions by constructing a long transmission line connecting both districts. We believe that the only effective method is to construct individual and independent power transmission/distribution systems in each area.

The Kingdom of Bhutan purchases electricity generated by the Assam State Electricity Board and supplies it to users in the Gaylegph, Samdrup-Jongkhar, and Daipham areas, which are near the border with India. Also, the Kingdom purchases electric power from the West Bengal State Electricity Board and supplies it to users in the Samchi and Sibsoo areas. The power transmission and distribution systems in these areas are linked with those in India, and we consider that power is supplied under more stable conditions than in the areas where only independent power transmission/distribution systems are available.

For the period April 1987 to June 1988, the maximum power supply was 16.5 MW, which represents a 21% rise over the previous year. In the same period, the amount of power consumed (i.e., sold by Department of Power) amounted to 60.7 GWh, for a 282% rise over the previous year. This growth resulted from the coming on-line of the Chukha power station, which is meeting the previously latent demand in the western region.

Table 2.2-3 shows figures related to the sales of electric power for Bhutan's fiscal years of 1983 (a 12-month period) and 1987 (a 15-month period, from April 1987 to June 1988). The Table shows that, in fiscal 1983, about one-half of the needed power was imported from India. This importation dropped dramatically when the

Chukha plant came on line in September of 1986 (for #1, #2 and #3 operation start in March, 1988; #4 operation start in August, 1988). Activation of this plant allowed the large-consuming areas in the western region, which were within the supply system, to be switched to domestically generated power.

The total amount of power supplied in Bhutan in the sum of power transmitted from all transmitting stations (excluding that send from Chukha Power Station to India: sum of total power by all power stations in Bhutan and that purchased from India, as Appendix 5.7) was 76.2 GWh. On the other hand, the transmission loss was 15.5 GWh or 20.4% of the total supply. But the value in 1983 was 27.4%, and it may be said that the situation has been largely improved. The load factor was 33.5%, which indicates that demand for power during daytime and at midnight is far lower as compared to that at peak time.

As mentioned above, Bhutan's gross sales (i.e., final consumption) of electric power in fiscal 1987 (which was a fifteen-month period) was 60.7 GWh. This consumption can be broken down as follows: industrial consumption, 63.8%; general household consumption, 16.8%; commercial consumption and consumption for public use, 14.6%. The western region, which is located in the south western part of the country, accounted for 70% of the country's total demand. The Samchi district, which is home to a large paper plant, accounted for 61% of the western region's demand.

Table 2.2-3 Sales of Energy (in GWh)

	1983	1987 (15-month period)
Gross Generation	22.622	1476.388
Auxiliary Consumption	0.63	5.913
Amount Imported from India	23.145	4.272
Amount Exported to India	----	1386.657
Gross Energy Available	45.137	88.090
Energy Losses	7.642	16.725
Gross Energy Sold	37.495	71.365
Energy Consumption in Area of Chukha Hydro Project Authority	0	10.712
Net Energy Sold	37.495	60.653

2-2-3 Generating facilities

Bhutan's generating facilities are as shown in Table 2.2-4. At the end of June, 1988, the country had 20 hydropower generating plants (with a total output of 256,460 kW), and ten (10) diesel generating plants (with a total output of 13,045 kW). The total output of both hydro and diesel generation was therefore 269,505 kW.

In August of 1988, the 84,000 kW No. 4 generator at the Chukha power station was started for operation; the following month, the Nos. 1-3 generators (500 kW each) at the Gyetcha power station were also started for operation. The current total generating capacity of Bhutan's power stations is therefore now at 355,005 kW.

The total power generation capacity of the small-scale power facilities at the 10 sites constructed under financial assistance from the Government of Japan (Phase-I, The service operation was started in 1987) is 380 kW. The utilization factor at the 10 sites in December, 1988, is as shown below. Considering that service operation of the facilities was started just before, it may be said that the situation is generally good.

		Installed capacity (KW)	Power generation (actual) (KW)
1)	Tamjhin Power Station	30	20
2)	Punakha Power Station	30	18
3)	Surey Power Station	70	17
4)	kekhar Power Station	20	7
5)	Bubja Power Station	30	11
6)	Tongsa Power Station	50	50
7)	Tangsibji Power Station	30	15
8)	Rukubji Power Station	40	10
9)	Ura Power Station	50	21
10)	Yadi Power Station	30	17

Table 2.2-4 Power Generating Capacity

(1988.6)

Generating Station	Unit No. x Capacity	Installed Capacity	Commissioning Year
Hydroelectric Generating			
Thimphu	4 x 90 kW	360 kW	1967
Cidakom	5 x 250 kW	1,250 kW	1973
Waugdiphodrang	3 x 100 kW	300 kW	1972
Tashigang	3 x 250 kW	750 kW	1972
Mongar	3 x 130 kW	390 kW	1976
Paro	4 x 100 kW	400 kW	1970
Nagu	1 x 10 kW	10 kW	1985
Lhuntshi	1 x 20 kW	20 kW	1986
Khaling	3 x 200 kW	600 kW	1987
Chukha	3 x 84,000 kW	252,000 kW	1988, 88
Micro Hydels (Phase-I)	1 x 20 kW 5 x 30 kW 1 x 40 kW 2 x 50 kW 1 x 70 kW	380 kW	1987
Total 10 power stations			
Sub-Total		256,460 kW (95%)	
Diesel Generating Stations			
Phuntsholing	2 x 128 kW	256 kW	1966
	2 x 248 kW	496 kW	1976
Samchi	1 x 135 kW	135 kW	1982
Paro	1 x 400 kW	400 kW	1986
	1 x 88 kW	88 kW	1977
Thimphu	1 x 500 kW	500 kW	1978
	2 x 225 kW	450 kW	1980
	2 x 150 kW	300 kW	1982
	1 x 1000 kW	1,000 kW	1984
	1 x 1000 kW	1,000 kW	1985
Damphu	1 x 48 kW	48 kW	1969
Tongsa	1 x 56 kW	56 kW	1976
Shemgang	1 x 80 kW	80 kW	1983
Dogana	1 x 40 kW	40 kW	1983
Chukha	3 x 400 kW	1,200 kW	
	2 x 248 kW	486 kW	
Others	-	6,500 kW	
Sub-Total		13,045 kW (5%)	
Total		269,505 kW (100%)	

Note: Chukha #4 1 x 84,000 kW 1988.8 (operation start)
Gyetcha #1 - 3 3 x 500 kW 1988.9 (- ditto)

2-2-4 Transmission and distribution facilities

Appendix 5.6 shows outlines the routes of the existing power lines within Bhutan. Table 2.2-5 shows total line lengths for transmission and distribution lines, classified according to line voltage. Table 2.2-6 indicates total line lengths, for secondary transmission lines and for distribution lines, classified according to regions.

The highest transmission line capacity presently in place is 220 kv; the maximum voltage presently being used, however, is only 66 kv.

Bhutan's power grid is centered around the Chukha Hydro Power Plant, and covers only the western region. The central and eastern regions are served only by independent systems, or by regional systems which receive their power from nearby India.

The distribution lines used are 415 V, 3-phase, 4-wire. Supply to individual consumers is single-phase, 240 V.

Table 2.2-5 Transmission/Distribution Lines (Charged) (Within Bhuntan)
(Line Lengths in K.M.)

SL. No.	Sector	220kV	66kV	33kV	11kV	6.6kV	LT
1.	CHP-Birpara	40.0 (D/C)	-	-	-	-	-
2.	CHP-Singeygaon	35.0*		5.0	460.067	21.16	408.320
					(for whole country)		
3.	CHP-P'ling	-	35.0	-	-	-	-
4.	P'ling-Pasakha	-	8.4	-	-	-	-
5.	P'ling-Gomtu	-	27.0	-	-	-	-
6.	CHP-Confluence	-	39.0	-	-	-	-
7.	Confluence-Simtokha	-	20.0	-	-	-	-
8.	Confluence-Haa	-	33.5	-	-	-	-
9.	Confluence-Paro	-	27.0	-	-	-	-
10.	Simtokha-Wangdi	-	27.0	-	-	-	-
	Total	75.0	216.9	5.0	460.067	21.16	408.320

* charged at 66 kV

CHP: Chukha Hydel Project
D/C: Double Circuit

Table 2.2-6 EXISTING SUB-TRANSMISSION & DISTRIBUTION LINES AS ON 30.6.88 IN KM (upto 33 kV)

System	33 kV O.H.	11 kV O.H.	L.T. Line
Upper Western Region			
Thimphu	13.833*	97.863	96.037
Paro	24.030*	61.934	45.755
W/Phodrang	0.000	33.900	44.300
Total Upper Western Region	37.863	193.767	186.092
Lower Western Region			
Phuntsholing	0.000	65.800	40.900
Samchi	0.000	48.020	35.200
Sibsoo	0.000	11.400	20.000
Total Lower Western Region	0.000	125.220	96.100
Central & South Central Region			
Gaylegphug	0.000	43.750	44.580
Damphu	0.000	3.200	5.550
Tongsa	0.000	0.000	4.348
Shemgang	0.000	0.000	0.500
Total Central & South Central Region	0.000	6.950	54.979
Eastern Region			
S/Jongkhar	0.000	13.900	15.850
Diafam	0.000	4.200	7.800
Tashigang	0.000	52.500	30.000
Mongar	0.000	23.500	17.500
Total Eastern Region	0.000	94.100	71.150
Grand Total	37.863	460.067	408.320

* charged at 11 kV
O.H: Over head Line
L.T: Low Tension Line

2-2-5 Substations

The substations belonging to Bhutan's Department of Power are as summarized in Table 2.2-7. Primary substations are located at 17 sites throughout the country; and 37 transformers (including both step-up and step-down transformers), with a total capacity of 18,885 kVA, are installed at these substations.

In addition, 160 distributional transformers are also installed, with a total capacity of 21,886 kV.

All of the transformers were manufactured in India, and are managed and operated under the supervision of Indian engineers.

2-2-6 Energy tariff and energy sales revenue

The Department of Power's tariff schedule is as shown in Table 2.2-8. In 1982, unit prices were differentiated according to regions and categories. The pricing system was revised, however, and pricing is now uniform on a national basis, with 1 kWh priced at 0.4 Nu. (Approx. ¥4). Pricing is also consistent for households not equipped with watt-hour meters: these households are charged 5 Nu. (Approx. ¥45) per month per light. For electric heaters, households are charged 15 Nu. (Approx. ¥135) per month per "point."

However, for inland areas supplied by diesel generation, and those supplied by Phases I micro hydropower stations, the charge is calculated in order to enable the covering of operating and maintenance costs. Households in areas supplied with diesel-generated electricity are charge 4 Nu. (Approx. ¥36) per month per light; households linked to electricity from micro hydropower stations are charged 2 Nu. (Approx. ¥18) per month per light.

On a national basis, electricity prices in 1988 had dropped to about one-half their 1982 levels.

Table 2.2-9 shows the sales revenue of the Department of Power for the fiscal years 1979 to 1987. Revenue over this period increased, at an average annual rate of 25 percent.

Table 2.2-7 Number of Sub-Stations, Transformers & Their Aggregate Capacity as of 1988.6 (Department of Power)

(1/2)

Area	Step Up/Step Down Main Main Sub-Stations			Distribution Sub-Stations		
	No.	Transfomer Size No/ Capacity (kVA)	Total Capacity (kVA)	No.	Transformer Size No/ Capacity (kVA)	Total Capacity (kVA)
Thimphu	3	2x1600 2x800 5x315 3x125	6,750	55	9x500 1x135 14x250 3x160 1x125 8x100 7x63 6x50 5x25 1x10	10,596
Paro	1	3x125	375	27	2x315 2x250 1x200 4x125 1x100 4x63 10x50 3x25	2,757
W/Phodrong	1	2x125	250	13	1x250 3x100 3x63 6x50	1,039
Phuntsholing	3	1x315 1x500 1x1000 1x500	2,315	14	1x500 1x315 6x250 1x125 4x63 1x50	2,742
Samchi	2	1x315 2x500	1,315	7	1x250 2x125 1x50 3x63	739
Sibsoo	-	-	-	3	1x125 1x63 1x25	213

Area	Step Up/Step Down Main Main Sub-Stations			Distribution Sub-Stations		
	No.	Transfomer Size No/ Capacity (kVA)	Total Capacity (kVA)	No.	Transformer Size No/ Capacity (kVA)	Total Capacity (kVA)
Gaylagphug	1	2x1500	3,000	18	1x500 1x250 8x100 4x63 2x50 2x25	1,952
S/Jonkhar	1	2x250	500	8	1x125 4x100 1x200 1x63 1x25	813
Diafam	1	1x50	50	1	1x250	250
Tashigang	1	2x315	630	9	1x125 2x63 6x25	401
Mongar	1	2x100	200	5	1x125 3x63 1x50	364
Khaling	1	2x500	1,000			
Gyetsha	1	2x1250	2,500			
Total	17	37	18,885	160	160	21,866

Table 2.2-8 Electric Energy Sales Revenue

F.Y. / Description	1979/1980	1980/1981	1981/1982	1982/1983	1983/1984	1984/1985	1985/1986	1986/1987	*1 1987/1988	*3 % of average increase rate
Sold Energy (kWh)										
(1) Domestic	3,200,000	3,827,000	4,014,000	3,840,299	4,156,454.5	4,475,000	4,527,000	5,943,000	10,211,000	12
(2) Commercial	1,244,000	1,430,000	1,494,000	2,624,674	3,274,304	3,887,000	5,568,000	6,179,000	8,882,000	24
(3) Industrial	2,407,000	2,447,000	2,753,000	1,140,136	1,307,613.5	1,572,000	1,945,000	2,605,000	38,720,000	37
(4) Public	203,000	200,000	210,000	41,679	59,915	94,000	120,000	*117,000	140,000	7
(5) Others	-	-	-	1,741,447	1,954,536	2,044,000	2,480,000	2,364,000	2,700,000	4
Total	7,054,000	7,904,000	8,471,000	9,388,235	10,753,823	12,218,000	14,630,000	17,208,000	60,653,000	27
Energy Sales Revenue (103Nu)	3,010	3,918	4,900	6,516	7,512	8,800	10,846	13,913	*2 22,339	25
Increase Rate Over Previous Year (%)	-	30	25	33	15	17	23	28	*3 (28) 61	
Average Unit Price (Nu/kWh)	0.43	0.50	0.58	0.69	0.70	0.72	0.74	0.81	0.37	

*1 15 month from 1974.4 to 1988.6
*2 excluding revenu from sales to India amounting to 870 million Nu.
*3 changing into 12 month

Table 2.2-9 Schedule of Tariff

No.	Category	Year	Tariff (Nu/kWh): Thimphu, Paro	Tariff (Nu/kWh): Phuntsholing, Samchi, Sibsoo, Chargharay	Tariff (Nu/kWh): Tashigang, Khangiung, Mongar, Wangdiphodrang, Pnakha	Tariff (Nu/kWh): Samdrup, Jonkhar, Deothang, Gaylegphug, Sarbhand	Character of Supply
1	Domestic	1982	0.70	0.60 upto 50 kWh 0.80 above 50 kWh	0.65	0.75 upto 50 kWh 0.80 above 50 kWh	AC, 50Hz, 1ϕ, 230V upto 50 kW Ac, 50 Hz, 3ϕ, 400V above 5 kW
		* 1988	0.40	0.40	0.40	0.40	
2	Commercial	1982	0.80	1.00	-	0.90	Same as above
		* 1988	0.40	0.40	-	0.40	
3	Govt. Offices, Hospital, School, Campus, etc.	1982	0.80	0.80	-	0.80	- ditto -
		* 1988	0.40	0.40	-	0.40	
4	Public Lighting	1982	0.70	0.80	-	0.80	- ditto -
		* 1988	FREE	FREE		FREE	
5	Industrial	1982	0.70	0.90	0.45	0.75	L.T upto 5kW, 1ϕ, 230V 50-20kW, 3ϕ, 400V H.T above 20 kW, 3ϕ, 11kW
		* 1988	0.40	0.40	-	0.40	
6	Bulk Supply	1982	0.60 and Demand Charge 20.0 Nu/kVA	0.90	-	0.75	11/33 kW, 11/33 kW, 3ϕ
		* 1988	0.40	0.40	-	0.40	
7	Unmetered Supply	1982	5.00/Lighting Point 20.00/Heating Point 10.00/Connected Load H.P	4.00/Lighting and Fan Point 15.00/Heating Cooling, Pumping, etc. 20.00/Connected Load H.P	Same as Left	Same as Left	-
		* 1988 *	5.00/LP 15.00/HP	5.00/LP 15.00/HP			

Note) Kindly fill in the latest figures in bracket indicated with *.
* JAPAN First Phase Nu 2.00/LP

2-3 Electric Power Development Plans

2-3-1 Power demand forecast

The Department of Power has estimated the supply of electric power and the power consumption based on the economic development program of each sectors for the sixth 5-year national development program which is scheduled for completion by 1991 to 1992, by dividing the country of Bhutan into the following five regions:

1) Northwest region .... Thimphu, Paro, Ha, Wangdiphodrang, Punakha,
2) Southwest region .... Phuntsholing, Penden, Samchi Pana, Gedu,
3) South of central region .. Gaylegphug, Damphu, Dagana, Shemgang
4) Central region .... Tongsa, Biyakar
5) Eastern region .... Tashigang, Mongar, Samdrup Jonkhar

Power consumption in the above regions has been estimated on the basis of the following sectors, and the results have been for final computation:

1) General .... (including general stores, government offices, schools, hospitals and other public facilities)
2) Industries ...... (Large and small industries, both existing and under planning stage)
3) Tourism .... (Department of Tourism and all hotels)
4) Agriculture ..... (Irrigation pump and others)
5) Miscellaneous ... (All other than those mentioned above)

The method used for the demand forecast is based on the following assumptions:

1) General sector: Since the power has not been fully supplied until now, past consumption records reflect usage only for limited areas. Therefore, if power could be made available at a reasonable price, the demand for power would increase with the increased electricity use in the kitchens of private houses, or for heating purpose.

The government is planning to switch from the traditional usage of forest resource to cheap electricity, for fuel/energy. It is planned, for this purpose, to electrify private houses up to a level of 40% by the end of the sixth development program.

2) Industry: It is planned to actively supply much more power for the small industries by connecting the power distribution line with other lines. Based on this plan, the power required by small industries and the consumption by that sector are computed for forecast.

The major power consuming industries are the large industries such as the industries manufacturing calcium, carbide, cement, and caustic soda. The power supply to these consumers is calculated the basis of annual plans.

According to a forecast long-term demand for power, which has been made using the above assumptions, the supply of power will increase by 2.8 times and the power consumption by 3.2 times by 1991-92 when taking 1987-88 as 1. The forecasted increase in demand in terms of the annual average will be 28.9% and 33.8%, respectively.

2-3-2 Power facilities improvement and expansion plan

The topography and the abundant precipitation in Bhutan indicate a high potential for hydraulic power generation, and the utilization of water power resources of the country as a whole is estimated to yield 6,000 MW.

However, the resources developed at 21 locations to date total 355 MW, (as already described in Paragraph 2-2-3), being no more than 6% of the total water power resources.

Table 2.3-1 shows the power generation, substation and transmission projects for which the budget has been appropriated in the sixth 5-year program.

The Government of Bhutan has examined various power facility improvement and expansion projects. Because users are scattered over an extremely mountainous topography, and demand per location is low, it is not economically feasible to construct a large power plant, and long transmission lines, to service this demand. Large power-plant generation, however, is appropriate for generating power for export, and for supplying limited high-demand areas.

A reasonable way to introduce electricity to the many areas not yet electrified is to construct small-scale power facilities, in each area, with capacity sufficient to meet local demand. The facilities should be constructed along rivers with large heads. For this reason, the Government of Bhutan selected 150 sites for such development, and started construction of such facilities under assistance from foreign countries including Japan.

Table 2.3-1 shows the power generation, substation, and transmission projects which have been budgeted under the Sixth 5-year Project. Presently under way are the construction of micro hydropower facilities at Shemgang, Damphu, and Dagana (the objective of the present project), and the Kuri-chu power generation project, to be constructed at Gyopshing, in the Mongar area.

The feasibility study for the Kuri-chu project, which has a planned capacity of 45 MW, has just been completed. When the project is finished, the power can be supplied to the cement factory (Dangsu Cement Authority) with a production capacity of 1,500 megatons, which is planned to be constructed at Manglam, and also to Pemagashel, Dothong, S/Tongkhar along the transmission line connecting with India. Surplus power shall be transmitted to India.

Table 2.3-1 Power Development Plan (1987 - 1992)

	Project Name	Capacity/Volt, Length	Estimated Cost during the Sixth Plan
Generation	* Gyetcha Hydro Project	1.5 MW	3 Million Nu.
	Kurichu Hydro Project	45 MW	560 Million Nu.
	** Shemgang Hydro Project	200 KW	5 Million Nu.
	** Damphu Hydro Project	200 KW	6 Million Nu.
	** Degana Hydel Project	200 KW	5 Million Nu.
	Micro Hydro	50 kW x 5	40 Million Nu.
Substation	Nanglam	132 kV/66 kV 10 MVA x 2	30 Million Nu.
	Pemagatshel	66 kV/11 kV 3 MVA x 2	10 Million Nu.
	Deothang	66 kV/33 kV/11 kV 5 MVA x 2	13 Million Nu.
Transmission	Kurichu-Nanglam	132 kV, 60 km	48 Million Nu.
	Nanglam-Pemagatshel -Daothang	55 kV, 70 km	35 Million Nu.

* Service operation started in September, 1988
** Grant aid from the Government of Japan

2-4 Contents of Request

2-4-1 Background of request

As stated in the introduction, the Government of Bhutan has been executing its sixth 5-year national economic development program.

As a specific goal, the program aims at improving the quality of life.

As a means of achieving this goal, the governemnt is planning to construct and expand public facilities for education, medical care, communication, etc. in the regional towns and villages scattered over the whole of the country, and to have them play a central role in each region.

However, the majority of these towns and villages are deprived of electric light. The power supply is indispensable for achieving this goal.

It is claimed, that the power supply is particularly essential to the school dormitories, for diagnosis and treatment equipment and the refrigerators for preserving serum of hospitals, refrigerators in the veterinary clinics for the preservation of seed sperm for livestock breeding, etc.

In order to redress this situation, a plan was devised calling for the construction of micro hydropower generating facilities at 150 sites across the country. The power plants would make use of small and medium size rivers.

As the first step toward this goal, generating facilities were constructed, under Japanese grant-in-aid, at 10 of the 150 sites.

Each of the three sites selected for the present project from the 150 sites is a provincial capital with public facilities such as a hospital and a school, but power supply by diesel generators in these areas was stopped in march, 1986, because of the rise in fuel cost and shortage of foreign currency. (Note that the Government of Bhutan allowed diesel generation to resume, only in Shemagang, in June of 1986; power is supplied there only at night.) But the people living in these areas once received electricity generated by diesel generators there and experienced comfort realized by electricity. so the Government of Bhutan wants to resume use of the X-ray photographing device, boiling sterilizer, and dental equipment, which are currently not used, in the hospital there, and also hopes to install advanced devices and facilities including refrigerators for storing serum and sperms used by veterinarians for husbandry, to raise living standards in the areas.

Following the success of the previous projects, the Government of Bhutan requested grant aid from Japan for procurement of equipment required for electrification in these three areas.

2-4-2 Details of the request for Cooperation

The Government of Bhutan have requested to construct 200 kW hydroelectric power generating facility each at three provincial capitals of Shemgang, Damphu and Dagana of the provinces of Shemgang, Chirang and Dagana, together with the power transmission and distribution facilities for the purpose of supplying stable power to respective provincial capitals and towns and villages in their vicinity.

Shown below are the details of the request for each site:

	Shemgang	Damphu	Dagana
Location	Shemgang Prov. Shemgang	Chirang Prov. Damphu	Dagana Prov. Dagana
Power generation type	Run-off-river type	Run-off-river type	Run-off-river type
Generator capacity (kW x unit)	100 x 2	100 x 2	100 x 2
Water flow (m^3/s)	1.0	0.86	1.3
Head (m)	35.0	35.0	25.0

CHAPTER 3
OUTLINE OF THE PROJECT

CHAPTER 3 OUTLINE OF THE PROJECT

3-1 Location and topography

Shemgang project site

Shemgang is the capital of Shemgang Province (pop. 44,516), and is located, roughly in the center of Bhutan's populated zone, at Long. 90'40'E, Lat. 27'13'N.

Public facilities, which are in the proximity of the government offices and private houses, are concentrated on a narrow strip of hill which runs east-to-west at an altitude of 1600 - 2200 meters. The province's second largest community, Tintibi, is located on a slightly open hilly zone, at an altitude of 600 - 800 meters, about 8 km south (in a straight line) of Shemgang.

The area's main rivers are the Mangde chu, and its two tributaries, the Wangdi chu and the Burumda chu, which flow from its left bank. The altitude, at a site where a bridge crosses the Wangdi chu, is about 800 m. Upstream of this site, the river banks are steep, with considerable outcropping of rocks, and signs of landslides at a number of places. The west bank of the Burumda chu, in contrast, has many gentle slopes, and stabilized vegetation. The altitude, at a bridge site near the confluence of the Burumda chu and Mangde chu, is about 600 m, which is relatively very low for the Shemgang region.

Although the straight-line distance from Shemgang to nation's capital of Thimphu (Long. 89'40'E, Lat. 27'29'N) is about 100 km, the road distance is 315 km. The road runs north from Shemgang to Tongsa, then west, meandering through the mountains. The road running from Shemgang to Gaylegphug, which is on the sourthern border with India, is roughly 130-km long. These roads, which are maintained and managed by the Indian army, are in fairly good condition.

Damphu project site

Damphu (Long. 90'08'E. Lat. 27'13'N), the capital of Chiran Province (pop. 108,807), is located close to the Indian border. The area is open, and the altitude ranges from 1000 - 1600 meters. The number of houses, and the amount of cultivated land, are greater here than in either Shemgang or Dagana. Public facilities, and a shopping district, are presently expanding around a core of government offices. Active trading is carried out, centering on the area's market.

The Chache chu runs, through the center of this area, joining the Sankosh chu. Upstream of the river's confluence with its tributary, the Damphu, are signs of scattered and fairly violent landslides. The downstream banks, however, appear relatively stable, though there are outcroppings of rocks, as well as signs of smaller landslides. A 100-km road connects Damphu with Gaylegphug, at the border; the road, maintained and managed by the Indian army, is in fairly good condition. The road from Damphu to Thimphu, which runs via Gaylegphug, Shemgang, and Tongsa, is about 545 km in length, and two days are required to drive over this length.

Dagana project site

Dagana (Long. 89'54'E, Lat. 27'04'N) is the capital of Dagana Province (pop. 28,352), Public facilities, serving government offices and private houses, are scattered over a narrow, mountain-ridged are at an altitude of approximately 1600 m. In Gosi, 24 km further south by road, the slop of the land is much more gentle, and there are many private houses and much cultivation. The public facilities in Gosi are similar those in Danaga.

The Dara chu flows through this region. Both banks are steep, and there are many outcroppings of rock. At the site selected for the Dara chu power facility, where a bridge crosses the river, the altitude is approximately 1000 m, or about 600 m lower than Dagana and Gosi, which are to be electrified.

The road connecting Damphu and Dagana, which terminates at Dagana, is about 100 km in length. About 30 km of this road --the portion between the Sankosh chu bridge and the Dara chu bridge -- crosses through a landslide zone; the road surface had collapsed in a number of area, and the road is in poorer condition than most others. During the July-September rainy season, vehicular traffic is often paralyzed. Repair and rehabilition of this road area sometimes cause the road to be closed for five or six months out of the year. The road is maintained and managed by the Government of Bhutan. To drive from Dagana to Thimphu, a considerable detour must be taken; the trip, via Damphu, Galegphug, Shemgang, Tongsa, and Wangdiphodrang, is 645 km in length. Because most of the road meanders through the mountains, its takes three days to cover this distance.

Locations and road networks described above are shown on the project location maps attached at the beginning of this report.

3-2 Power Demand Forecast of Proposed Site

3-2-1 Present situation of power and supply

The three areas of Shemgang, Damphu and Dagana selected this time under the project are towns and villages representing qualifying areas. They either have public facilities such as the schools, hospitals, veterinary clinic, drug dispensaries and post offices, or are scheduled to have them in the near future.

These three areas were supplied with electricity from diesel power generators until March 1986. Later, however, the use of diesel generators has been suspended due to the high fuel cost, to save foreign exchange, and for other reasons. Under special exemption, the Shemgang area alone has been receiving power during the limited time zone (5:30pm to 9:00pm) since June 1986. The two other areas, however, have since been deprived of electric lighting.

The Shemgang area has a power supplying facility with a capacity of 100 KVA (80 kW with power factor of 0.8), which can supply power to a very limited area centering around the government quarters and is completely inadequate for supplying power to the neighboring towns and villages.

The Damphu and Dagana areas have facilities for power generation, transmission and distribution. However, as they have been left unattended since the suspension of the use of power generators, they will require some major repair work, if they are to be used again. In particular, the power transmission and distribution lines are apparently unserviceable for the practical use.

As described above, most of the project areas have not been electrified, or if electrified, the facilities for power supply are insufficient.

Under the circumstances, residents in the areas strongly expect that electricity will be supplied to public facilities there, such as schools and hospitals, as well as to general houses for lighting. Especially, improvement of medical services by using electric medical equipment such as an X-ray photographing device, a boiling sterilizer, or a refrigerator is indispensable for raising living standards of people in these areas.

At present, in the Shemgang area, electricity is generated by a 100 KVA (80 kW) diesel generator, and supplied to about 120 houses and 16 public facilities, including those in the adjacent village of Tong.

In the present project, diesel generators will be switched to small-scale hydro power facilities (200 kW) to enhance the capacity to supply power to 346 houses, including those in neighbor villages such as Dakphei, Tintibi, and Pam, and to 30 public facilities in the areas.

In Damphu, electricity generated by a 60 KVA (48 kW) diesel generator was supplied to 13 public facilities, including the building for the local government, as well as to only 60 houses for lighting.

The present project aims to supply power, generated by small-scale hydro power facilities (200 kW), to 550 houses throughout the Damphu area and in the adjacent Sarami area. Power would also be supplied to 20 public facilities in the areas.

In Dagana, electricity was generated by a 50 KVA (40 kW) diesel generator and was supplied to 5 public facilities as well as to only about 20 houses in the adjacent area. The present project aims to generating power with small-scale hydro power facilities (200 kW), and to supplying it to 20 public facilities and 565 houses, including those in the adjacent areas such as Tashigan and Gosi.

After the completion of small-scale hydro power facilities under this Project, present diesel generators installed in the avove mentioned three (3) areas will be kept as the emargency power generating fasilities.

3-2-2 Power demand forecast

(1) Method of Estimating Demand

Since the project sites are towns and villages without light except for the Shemgang area, the demand for electricity has been estimated, taking into consideration the present conditions of the public facilities, the number of households, the population and the regional industries as well as the plans for the future development of these selected areas.

(2) Result of Estimating the Demand for Electricity

The demand has here been estimated by the following method:

1) The demand arising in the Shemgang area, an area that has already been electrified has been closely examined to serves a reference case in estimating demand in general for areas currently without electric lighting.

2) With respect to the areas without electric lighting, field investigations were conducted jointly with the staff of the Department of Power to establish the present conditions in terms of the number of households, the size of the population, the existing public facilities in the selected project, areas and the presence of future development plans. Information has also been collected by word-of-mouth inquiries from local government agencies.

3) Based on the results of the foregoing investigations, the demand has been aggregated for the places under consideration, and the peak demand estimated by taking into account the demand factors associated with the particular loads and the spread factor. The basic calculation formula used for estimating the maximum demand is as follows:

Where

$$P \geq \left(\frac{\Sigma P.\ell}{\text{Cos } \Theta} \times d \times \frac{K_2}{K_1}\right) + \left(\frac{\Sigma \text{ Pm}}{\eta \times \text{Cos}} \times d \times \frac{K_2}{K_1}\right) \text{ (kVA)}$$

P : Maximum demand

$\Sigma P\ell$: Sum total electric lighting load

Σ Pm: Sum total motive power load
η: Average efficiency of motive power load (0.8)
Cos Θ: Average power factor (fluorescent lighting strip 0.8, incandescent bull 1.0, motive power 0.8)
d : Demand factor (electric lighting load 0.75, motive power load 0.5)
K_1 : Spread (diversity) factor (electric lamp load 1.2, motive power load 1.1)
K_2 : Spread (diversity) factor for combining electric lamp and motive power loads (1.1)
Figures in parentheses ( ) are the values used for this particular case.

The capacity of facilities as used for estimating the demand of each points is roughly as follows:

(i) For public facilities, hospitals, schools, village offices, agricultural education centers, veterinary clinics, forestry centers and cooperative's offices have been considered.

(ii) Lighting fixtures for hospitals, and schools have been taken as fluorescent lighting strips and those for other public facilities and private houses incandescent bulbs.

(iii) Lighting fixtures for public facilities have been taken as 3 to 5 bulbs per room and those for private houses about 6 lamps per house.

(iv) Refrigerators, heaters, and sterilization lamps, have been considered as the electricity users in hospitals and veterinary clinics, and X-ray units have been allowed for if their presence is known.

(v) For areas with plans for the construction of public facilities, such plans have been taken into consideration for estimating power demand.

Shown in the next table are the results of the total estimated demand:

	Estimated demand (KVA)
Shemgang	200
Damphu	220
Dagana	200

3-3 Hydrological Analysis

3-3-1 Hydrological and meteorological data

The project sites are located in Shemgang in the central mountainous regions and in Damphu and Dagana in the central and southern mountain regions with altitudes ranging from 700 to 1,600 m. These regions have relatively large rainfall levels in Bhutan; Shemgang and Dagana have annual rainfalls of 1,580 mm (two year average) and 1,620 mm (three year average), respectively.

The observatories in Gaylegphug (Aie river) and Dobani (Sankosh river) are located at low altitude in the vicinity and their records show annual rainfalls of 4,550 mm (five-year average) and 1,427 mm (two-year average), respectively.

The rainy season proper in these areas usually lasts from June to September, and the period of light rain is from May to October.

Air temperature data show that the lowest temperature of 3°C (January) and the highest of 30°C (August) are recorded at the weather observatories of Shemgang and Dagana. It has been noticed, however, that the meteorological (rainfall, air temperature, humidity) and hydrological (river flow) data collected by observatories throughout Bhutan frequently have periods without observation so that no complete records are available. Therefore, records essential for working out a power generation plan, that is, records covering a sufficiently long period of time (more than ten years) with continuous observation, are practically non-existent. Consequently, records of continuous observations for over one year for relatively recent year had to be resorted from data as many observatories as practicably possible.

3-3-2 Flow data of project site

As for the data showing the flow in the project sites, the only available records are those covering a three-year period (1986 to 1988) at Dagana. No measurements have been made at Shemgang and Damphu as there are no observatories in these areas.

Due to the lack of river flow data, the amount of flow at the project sites has been estimated from proportional flow data taken from the flow data covering nearby area of the same river basin.

The calculations for Shemgang have been made from the flow data of the Refe Observatory at Mangde river in the same river basin, and similarly for Damphu from the flow data of the Dagana Observatory in the same river basin.

3-3-3 Monthly average discharge and specific discharge

As described in the preceding paragraph, 3-3-1, the flow data kept by observatories have gaps (no-data periods) when no records of measurement covering a long duration are available, so that the monthly lowest flow at each water intake point (daily average lowest flow ...) has been calculated by using flow data from observatories, with continuous coverage for relatively recent years. Shown in Appendix 5.21 and 5.22 are the results of such calculations. According to these, the lowest daily average flows for the respective water intake points (minimum flow) are as follows:

Shemgang point	1.0 m^3/s
Damphu point	1.0 m^3/s
Dagana point	4.3 m^3/s

The catchment areas of the respective project sites and observatories used for the calculation of the proportional flow are as liested below:

	Catchment area (km^3)
Shemgang intake dam	108
Damphu intake dam	53
Dagana intake dam	230
Refe Observatory (Sankosh chu)	1,266
Dagana Observatory (Dara chu)	255

3-3-4 Flow-duration curve

The flow-duration curves in the minimum flow year (1986) of Sankosh chu (Refe Observatory) and Dara chu (Dagana Observatory), used for the calculation of flow at each water intake point, are shown in the Appendix 5.23 and 5.24.

3-3-5 Examination of design-flood discharge

Observatory data for the flow of the project sites covering a long period of time are not available and records of rainfall are scarce, as stated above.

It is not appropriate, therefore, to examine the flood discharge with the probability technique due to the presence of many uncertain factors.

Consequently, it has been decided to calculate the flood discharge for the project from the evidence of past flooding patterns verified by the field investigations. Table 3.3-1 shows the flood level and the flood discharge of respective points.

Table 3.3-1 Flood discharge of project sites

	Shemgang	Damphu	Dagana
Past flood water level (EL)	793.0	887.0	1,033.0
Flood discharge (m^3/s)	430.0	390.0	520.0
Catchment area (km^3)	108.0	53.0	225.0

Enumerated below are the daily maximum flow data on a yearly basis obtained from the flow data collected by the investigation team.

	Refe (Mangde river) (m^3/s)	Dagana (Dara river) (m^3/s)
1983	392.6	-
1984	209.9	-
1985	344.3	-
1986	308.5	52
1987	307.2	283.6
1988	-	160.3

3-4 Results Reconnaissance of the Project Site

3-4-1 Results of examination on development scale for the project sites

The development scale of the facilities for each project site was examined by paying attention to the following points and by taking into account the results of field investigations by the investigation team and consultations with the government agencies concerned:

(1) Examination of maximum turbine discharge

In the examination of the maximum turbine discharge to be used, a survey has been conducted on the existing irrigation facilities and the presence of irrigation plans so as to ensure the absence of impediments to these facilities and plans.

(2) Efforts have been made to raise the facility's utilization factor since the facilities to be constructed at project sites in this context can not expect to receive electricity from other facilities and the power supply must be assured independently. In other words, the plans has been drawn up so as to ensure that the maximum turbine discharge used will not exceed the annual minimum flow.

(3) Maximum turbine discharge used and annual minimum flow of project sites

The maximum turbine discharge levels to be used by each project site have been calculated by applying the following formula, based on the electricity required for each site from the estimated power demand for towns and villages in the project sites and the available head as verified by field investigations:

$$P = \eta \cdot g \cdot Q \cdot H \text{ (kW)}$$

$$Q = \frac{P}{\eta \cdot g \cdot H} \text{ (m3/sec)}$$

Where P : Generator power (kW)

η : Combined efficiency of water turbine, generator and speed increaser (60%)

g : Acceleration of gravity (9.8 m/sec^2)

Q : Amount of water used (m^3/sec)

Further, a comparison has been made of the annual minimum flow estimated for each project site on the past flow data, the maximum turbine discharge obtained from the above formula and the results of field measurements by the investigation team, which is shown in Table 3.4-1. This table reveals that the calculated maximum turbine discharge used by the majority of power generation plants are less than the values estimated from the past flow data so that the facility's utilization factor becomes nearly 100%. The maximum turbine dishcarge to be used, therefore, would appear almost appropriate.

Table 3.4-1 Estimated Annual Minimum Flow and Maximum Turbine Discharge Used

Name of Project	Minimum flow estimated from past data (m^3/s)	Measured value by field investigation (m^3/s)	Maximum turbine discharge used (m^3/s)	Maximum output (kW)	Effective head (m)	Remarks
Shemgang	1.0	1.5	0.9	200	39	
Damphu	1.0	1.1	0.9	200	39	
Dagana	4.3	8.5	1.4	200	25	

(4) Results of examination of development scale

The development scale for each site was planned, based on the estimated demand for power as described in Paragraph 3-3, results of examination for flow discharge in each respective river, topographical and geographical conditions, in each project area. The results are shown in Table 3.4-2.

Table 3.4-2 Future of Development Scale

Item	Unit	Shemgang	Damphu	Dagana
1. Power House Site (Name of River)	-	Shemgang (Burumda river)	Damphu (Chanche river)	Dagana (Dara-river)
2. Catchment Area	km^2	108	53	225
3. Max. Discharge	m^3/s	0.9	0.9	1.4
4. Power Generating Plan				
- Intake water level	m	790	884	1,029
- Head tank water level	m	789	882	1,028
- T/G center	m	749	842	1,002
- Gross head	m	40	40	26
- Effective head	m	39	39	25
- Max. discharge	m^3/s	0.9	0.9	1.4

3-4-2 Selection of power generation facilities locations and intake dam site

The survey team selected locations for the power generation facilities and water intakes after collecting the data and conducting the field investigations necessary for the planning and design.

Easy access from the public roads presently in use has been assumed on the primary condition applicable to all sites.

Described below are the reasons for the selection for each site:

(1) Shemgang project site

Reconnaissance was made of the project site along the basin of the Wangde river and the Burumda river, tributaries of the Mangde river. As for the Wangde river, the reconnaissance was made of the vicinity of the road bridge crossing the river, as the project site. However the topography of the vicinity is generally steeple, with the entire left bank marked with the signs of large landslide, the topography and geological condition are not suited for the construction site of power generation facilities. As for the Burumda river basin adjoining the Wangde river basin, the reconnaissance was conducted by selecting an area approximately 4 km upstream from the confluence with the Mangde river as the project site. Unlike the Wangde river basin, the topography of this area is made up of a gentle slope and free from the signs of landslide, with the outcrop of rockbed seen in the vicinity and easy access to the existing road. The area was selected as the site of project since it is suited for the construction of power generation facilities in terms of topographic feature, geological condition and the ease of maintenance and management after completion. Further, the site of intake dam was selected at a location within the project site where the river width is relatively narrow and the slopes of both banks are stabilized.

(2) Damphu project site

The project site is located in the vicinity of confluence between the midstream section of the Chanche river basin and its tributary, the Damphu river. The area upstream of the confluence are marked with the signs of landslide on both banks, and both the topography and geological condition are not suited for the construction of power generation facilities. As for the area downstream of the confluence, the left bank side is unsuitable for the construction of power generation facilities as this side is marked with scattered signs of landslide similarly with the upstream area, although the site should be selected when considering the construction of access road and the transport of materials and equipment since the existing road is on this side. To the contrary, the majority of the right bank side consist of cultivated land, and both of topographic and geological conditions are stabilized so that the side was chosen as the project site. Further, the site of intake dam was selected at a location within the project site where the river width is relatively narrow and the slopes of both banks are stabilized.

(3) Dagana project site

The project site is located in the vicinity of the road bridge near the Dagana district government office building on the upstream of the Dara river basin. With the outcrops of rockbed seen on both banks, the vicinity is formed of steeple topography. However, the right bank side on the downstream of the road bridge is formed of a little open gentle slope and is suited for the site of the power generation plant (including the penstock and the outlet) so that the place was selected as the project site. The site of intake dam was selected at a place where the coffering and diversion of the river will be relatively easy with a broad river width and stable riverbed since the flow of the Dara river is greater than the above two sites, the topography is steeple and the banks of either side close in. The open slope in the vicinity of the road bridge could be effectively utilized as the storage of construction materials and equipment in an anticipation of interruption of vehicular traffic during the rainy season.

CHAPTER 4
BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4-1 Basic Design Concept and Design Condition

4-1-1 Basic design concept

The design for the project will be promoted under the following conditions.

(1) Examination of plan

The development scale of power generation facilities will be planned on the assumption that no power will be supplied from other systems to the three presently selected sites.

The development scale for each site will be planned by taking into consideration the river flow observed in the field investigation, other flow data topographic condition, and the estimated power demand.

(2) Reliability of facilities

Because the power generation and transmission facilities will be the only facilities servicing their respective sites, they shall be designed to sufficiently withstand natural conditions.

For the power distribution facilities for Shemgang area, attention shall be given to achieving coordination with existing facilities.

(3) Ease of maintenance and operation

Care shall be exercised to ensure ease of maintenance, and safety mechanical units will be kept simple.

(4) Economical design

Economical designs shall be adopted, taking (2) and (3) above into consideration, and paying due regard to the standard of Bhutan. Where such standards are unavailable, the standard specifications and the design techniques of Japan shall be adopted in so far as practically possible. However, adequate consideration shall be also given to the exchangeability of the facilities with Indian products, since the Department of Power presently uses many Indian products.

(5) Application of standardization

Standard products shall be used, so far as possible, for the power generating facilities and for related equipment including, for example, for pole-mounted transformers. Use of standard products will lower products costs, and ease the difficulties of parts replacement.

(6) Restriction of voltage regulation

The voltage regulation on the end of users shall in principle be restricted to be within ±10%.

4-1-2 Design conditions

(1) Design conditions set by the study team from the collected data and the result of field investigation

	Shemgang	Damphu	Dagana
1) Altitude			
i) Site of power generation plant	747 m	840 m	1,002 m
ii) Area to be electrified	2,000 m	1,600 m	1,600 m
2) Climatic conditions			
i) Air temperature (Maximum)	30°C	-	32°C
(Minimum)	3°C	-	3°C
ii) Wind velocity	30 m/s	-	30/ms
iii) Rainfall (annual)	1,580 mm	-	1,620 mm
3) Name of river	Burumda chu : tributary of Mangde chu	Chanche chu : tributary of Sankosh chu	Dara chu : tributary of Sankosh chu
4) Catchment area	108 km^2	53 km^2	225 km^2

5)	Daily average flow (Maximum)	34 m^3/s	65 m^3/s	277 m^3/s
	(1986) (Minimum)	1.0 m^3/s	1.0 m^3/s	4.3 m^3/s
6)	Facility capacity	100kWx2 sets	100kWx2 sets	100kWx2 sets
7)	Maximum turbine discharge	0.9 m^3/s	0.9 m^3/s	1.4 m^3/s
8)	Extension of power transmission line	18 km	9 km	33 km
9)	Extension of power distribution line	5 km	5 km	10 km

(2) Structural design standards used by the department of public works

1) Compressive strength of concrete: σ_{28} = 210 kg/cm^2 (1:2:4)
σ_{28} = 265 kg/cm^2 (1:1.5:3)

2) Tensile strength of steel reinforcing bar: σ_u = 49.5 kg/mm^2 (Yield point strength)

3) Seismic intensity (Seismic coefficient): Horizontal 0.1 G
Vertical 0.05 G

4-1-3 Applicable standards

In designing the project, the following Japanese standards shall be used in principle. Consideration shall be given, however, ensure that use of these standards will not cause inexchangeability with Indian products.

Japan Industrial Standard (JIS)
Standard specification of Japan Electrical Standard Investigation society (JEC)
Standard specification of Japan Electric Industry Association (JEM)
Standard specification of Japan Cable Industry Society
Technical standards concerning electrical facilities

4-2 Civil Structures

The three project sites will have the same generating power, and turbine discharge used will be similar. Efforts were therefore made to standardize the structures, in order to facilitate maintenance and management.

4-2-1 Intake dam and sedimentation basin

(1) Intake dam

It was determined that intake dams would be constructed on relatively stable points of the river beds. Intake dams shall be of overflow-type concrete structures, and the heel sections on the downstream side will be covered with wire cylinders to protect against scourig.

Intake will be through an opening provided at right bank to the dam, and intake discharge will be controlled by a gate installed at underneathof entrance. To prevent the accumulation of sediment in front of the intake, inflow of sediment into the intake, a sediment discharge gate will be provided, with in the body of the dam, below the intake. The gate will be opened at flood times to discharge accumulated sediments.

(2) Sedimentation basin

During flooding season, water mixed with sediment is occasionally introduced into the dam. A sedimentation basin will therefore be constructed close by the intake dam, but where it will be unaffected by flooding.

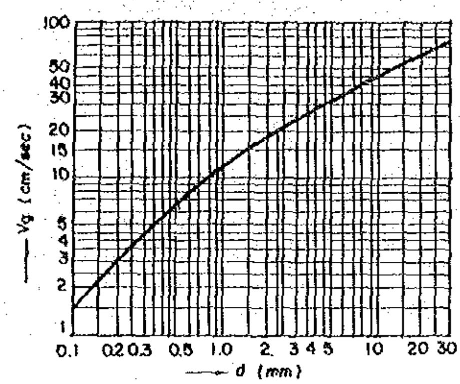
The sedimentation basin is designed that the sediment will settle down due to the deceleration of the water. The precipitated sediment can be removed using the sediment discharging facility provided at the end of the sedimentation basin.

The length required for the sedimentation basin was calculated as follows:

$$L \geq \frac{h}{Vg} \times V$$

L : Minimum required length for sedimentation basin (m)
h : Water depth of sedimentation basin (m)
V : Average flow velocity inside sedimentation basin(m/sec)
Vg: Marginal settling velocity of fine particles (m/sec)

Assuming an average sand particle diameter of 0.5 to 1 mm, the marginal settlement velocity, Vg, will be 0.07 m/sec by the following figure. The average flow velocity inside the grit chamber is assumed to be 0.2 m/sec.



Relations between average diametre of fine sand particles "d" and critical settling velocity "V_g".

4-2-2 Headrace channel

The structural of the headrace channel was determined as follows by giving careful consideration to the flow discharge, inclination, loss of head, geological condition, execution, period of work, etc.

(1) The structure shall be of rectangular open channel and culvert made of reinforced concrete. The open channel shall be covered with precast concrete lid.

(2) Rectangular culverts shall be used for the section below the flood water level on the downstream side of the intake to prevent the intrusion of muddy water.

(3) The flow velocity inside the headrace channel shall be of such range that the internal face of the headrace channel will not be erroded. The velocity for the project shall be regulated to approximately 1 m/sec. The permissible velocity in the range not to errode the internal face of the headrace are as given below:

Type	Flow rate m/sec	Type	Flow rate m/sec
Sandy soil	0.45	Thick concrete	3.00
Sandy loam	0.60	Thin coicrete	1.50
Loam	0.70	Asphalt	1.00
Viscous loam	0.90	Cobble stone dry masonry (achor below 30 cm)	1.50
Clay	1.00	Cobble stone dry masonry (achor over 30 cm)	2.00
Clay mixed with sand	1.20	Cobble stone wet masonry	2.50
Soft rock	2.00	Precast concrete	2.50
Rock with medium hardness	2.50	Pipe	5.00
Hard rock	3.00	Steel pipe	5.00

(4) The inclination of headrace shall be set at 1/1,000, taking into consideration the loss of head between the intake and the head tank, abrasion of internal face of headrace with velocity, settlement of sediment, generation of algae and the safety for the operation and maintenance after the completion of headrace.

(5) Hydraulic calculation of the flow discharge shall be made by employing Manning formulae, and a section which will give the largest hydraulic mean radius shall be selected from cross-sections having the capacity of passing the same flow discharge.

(6) A uniform width (1.2 m) and varying height of 1 m and 1.5 m were adopted for the shape of cross-section, considering the flow discharge at various points are just about the same (0.9 cu.m/sec and 1.4 cu.m/sec), and the benefit of standardization of design and execution.

(7) The water level inside the headrace channel near the head tank will go up by the suspension of power generation. The depth of headrace channel, therefore, shall consist of the value obtained from hydraulic calculation, the additional height equivalent to the rise in water level and an allowance.

4-2-3 Head tank

The head tank shall be constructed at the entrance of the penstock. To avoid the mixing of air into the water admission side of the penstock, adequate depth is allowed for to cover the pipe diameter, plus some allowance.

To handle the flowing when power generation is interrupted, a free overflow type spillway shall be constructed on the side of the head tank. In addition, a sediment discharge gate shall be installed for the discharge of sediments entrained into the tank.

The spillway shall be constructed of concrete. A head tank shall be constructed on the downstream end thereof. This is to reduce the flow of water before being discharged into the river.

4-2-4 Penstock

Ordinary flanged steel pipes have been adopted for the penstock, because welding of pipe joint cannot be well done in the site. Same diameters shall be adopted for ease of producing and etc., since turbine discharges are similar.

The inclination of the penstock shall be made uniform. Every unit length of pipe shall be supported with saddle and an anchor block shall be installed at the end of inclined penstock.

4-2-5 Power house building

The structure of the power house building, the outlet, and the layout of equipment and instruments are as shown in the attached drawings. The space of the power house shall be made wide enough to allow the inspection and disassembling of equipment with safety and ease. All floor surfaces shall be covered with concret.

The draft pit shall be designed so that one pit can be shared by two water turbines by arranging them face to face. Consideration shall also be given to the provision of means to eliminate the possibility of whirlpools, in the water running down from the water turbine, so as to maintain a constant water level.

The building of the power house shall be constructed by wood and concrete blocks. However, the section of the wall from the foundation to a height 1.5 m shall be constructed of concrete to prevent the carry-over of soil into the power house from outside and also to protect the plant from damage by boulders running down.

4-3 Electric Equipments and Facilities

4-3-1 Selection of electric system

In the selection of the electric systems for electric equipments and facilities, consideration should be given to the economic aspects and the level of technology required for maintenance and coordination using the existing facilities.

The following electric systems shall be used for power transmission and distribution lines operation in Bhutan at present:

- Transmission voltage: 6.6 kV, 11 kV, 33 kV, 66 kV, 220 kV
- Distribution system: 400/230 V, 3 phase 4 line
- Frequency: 50 Hz

The type of water turbine and the electric system for the power generating facilities, transmission and distribution lines for the project have been planned based on the following concepts:

(1) Selection of the type of water turbine

The type of water turbine to be used at each site will be decided according to the effective head and quantity of used water.

Types of turbines, and their features and constructions, are described in Appendix 5.25. A selection of a turbine type according to head and quantity of used water is presented in Appendix 5.26.

As seen from data, the Francis turbine and the cross-flow turbine are suited for a medium head.

However, the Francis turbine has a complicated construction and is expensive. Given the same flow rate and the compact size, it will be difficult to manufacture this turbine, and its price will therefore seriously increase. As it has a small size, repair work will become difficult if cavitation and other problems should occur after the commencement of operation.

By comparison, however, the cross-flow turbine has a simple construction and a relatively low price so that it is favorable for medium heads and small amounts of water. This type of turbine shall therefore be adopted for the present project.

Turbine control is generally accomplished by adjusting the water volume and speed to the existing demand (actual load) through the installation of a guide-vane servo-motor.

Given that in the present case the output is around 100kV, the use of this serve motor would complicate the mechanism thereby rendering maintenance more difficult and economically untenable. Therefore, the type described below shall be adopted:

1) Adjustment of water volume:
   The guide vane shall be manually adjusted whenever the need arises to meet demand as much as possible within the range allowable in terms of the inflow rate.

   This adjustment shall be done once a day at most.

2) Adjustment of speed:
   The speed shall be controlled by providing a phantom load in the tailrace to keep the rotational speed constant in accordance with increases and decreases in demand.

3) Entrance valve:
   A hand-operated gate valve shall be installed. No water intake gate shall be installed on the top of the water tank.

When the servoless governor has been decided, the design shall be prepared in such a manner as to eliminate the risk of mechanical damage even when the runaway speed is reached after the occuring of troubles in the governor.

(2) Electric System of Power Generating Facilities

Basically, unmanned control system shall be used for the control of power generation plan since the plant will be unattended at night although operators will attend the plant during daytime.

1) Generator voltage:
AC 400 V, considering the economic advantages

2) Control system:
Equivalent to unmanned power generation plant under intermittent surveillance control. The generator voltage shall be automatically controlled by the automatic voltage regulator (AVR).

4-3-2 Selection of power generation facilities

It has been decided, taking into account the following circumstances, that the power facilities for the above 3 project sites shall each be 200 kW.

. Result of our investigation at the 3 project sites indicates that demand for power at all of the sites is around 200 kW.

. Result of investigation on effective head and stream flow in each respective river indicates that a 200 kW power station can be constructed at each of the three project areas.

. If all the three sites had the same scale, the same specifications could be used for the power generator and penstock for greater economy.

The following outlines the design:

(1) Outline of equipments and facilities

1) Water Turbine

Model: Cross-flow type water turbine (flow through water turbine)

Governor: A stationary-type electronic servoless governor shall be adopted, with an electronic circuit to control the current of the phantom load so as to keep the rotational speed constant

In let valve: Manually operated gate valve

Rating: as shown in Table 4.3-1

2) Power Generator

Model: 3-phase alternating current synchronous power generator

Frequency: 50 Hz

Wiring: 3-phase 4 line type

Rating: As shown in Table 4.3-1

3) Switch Board

Model: Upright front door type

Control protecting unit: One full set consisting of gages, protective relay, AVR and governor control unit, electromagnetic switch, etc.

The speed accelerator shall be installed on the connection of the turbine generator to make the generator as compact as possible by increasing the rotational speed for better economy.

The maximum comprehensive efficiency of the turbine generator of 60% shall be attained by ensuring the appropriate efficiency levels of individual units, i.e., 78% for the water turbine, 97% for the speed accelerator and 80% for the generator.

Table 4.3-1 Summary of Power Plant

Item	Design	Shemgang	Damphu	Dagana
Turbine	No. of unit	2	2	2
	Effective Head (m)	39	39	25
	Maximum Discharge (m^3/s)	0.9	0.9	1.4
	Maximum Output (kW)	131 x 2	131 x 2	131 x 2
	Revolving Speed (rpm)	635	635	510
Generator	No. of unit	2	2	2
	Rated Capacity (KVA)	125 x 2	125 x 2	125 x 2
	Rated Voltage (V)	400	400	400
	Power Factor (Lag)	0.8	0.8	0.8
	Revolving Speed (rpm)	1000	1000	1000
Normal Power House Output (kW)		200	200	200

(2) Outline of power house building

The plan for the power house building to house the generator at each facility, the following points were taken into consideration.

- Protection of machinery from falling objects(stones) and for cattle and horses on the surrounding grazing areas.
- Allowing for operation and maintenance under inclemrent weather conditions
- Safekeeping of spares and consumables
- Protection of equipment and devices from bees and ants.

In view of the above considerations, the foundation of the building shall be constructed of concrete and the wall shall be constructed of concrete blocks. Adequate care shall be taken to ensure proper air ventilation by installing ventilation ports (vents) with insect screens.

A small shed shall be constructed in the power house building. This shall accommodate the office of maintenance crews.

4-3-3 Power transmission and distribution lines

Appendix 5.27 is a typical diagram of power transmission and distribution lines.

The transmission line shall run from the booster transformer, adjoining the power generation plant, to the step-down transformer, installed by the center of the user's area. Power shall be transmitted at high or extra-high voltage.

The distribution line shall run from the step-down transformer to the power box (with knife switch and fuse) installed on light poles erected near the public facilities and general users. For the areas covered by the existing low voltage distribution lines, the power shall be distributed to the connecting points near the existing distribution line.

The basic design shall be prepared on the assumption that the service cable from the public facilities and general users to the power box, the terminal of distribution line and the connection of line from the existing low voltage distribution line to the connecting point shall be the responsibility of Bhutan.

(1) Line length of transmission and distribution lines and selection of route

Length of the transmission/distribution lines in the each project site is as shown in the table below. Also, routes of the transmission/distribution lines in the each site as shown in Figures 4.3-2, 4.3-3, and 4.3-4.

(Unit: km)

	Transmission line	Distribution line
Shemgang	18.0	5.0
Damphu	9.0	5.0
Dagana	33.0	10.0
Total	60.0	20.0

The transmission line from the step-down transformer to the center of the use area shall consist of one line. The distribution line, however, shall be consist of on or two lines, depending on the capacity of user's areas.

The summary of route of the transmisison and distribution lines by sites are as follows:

1) Shemgang area

The transmission line shall supply power from the power generation plant to be constructed on the right bank of the Burumda river to three areas of users. The following three routes shall be constructed:

Fig. 4.3-2 Transmission and Distribution Lines (Shemgang Site)

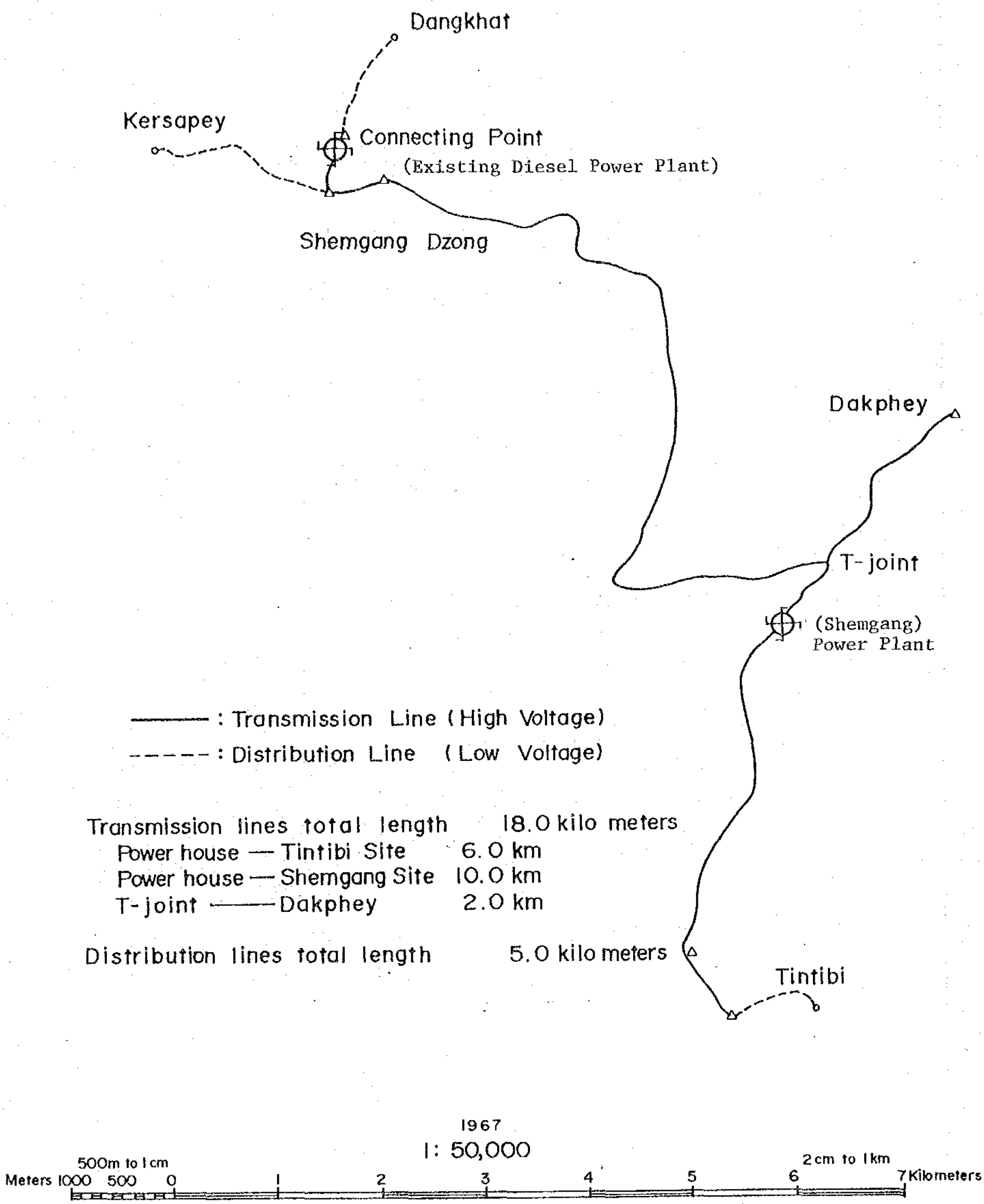
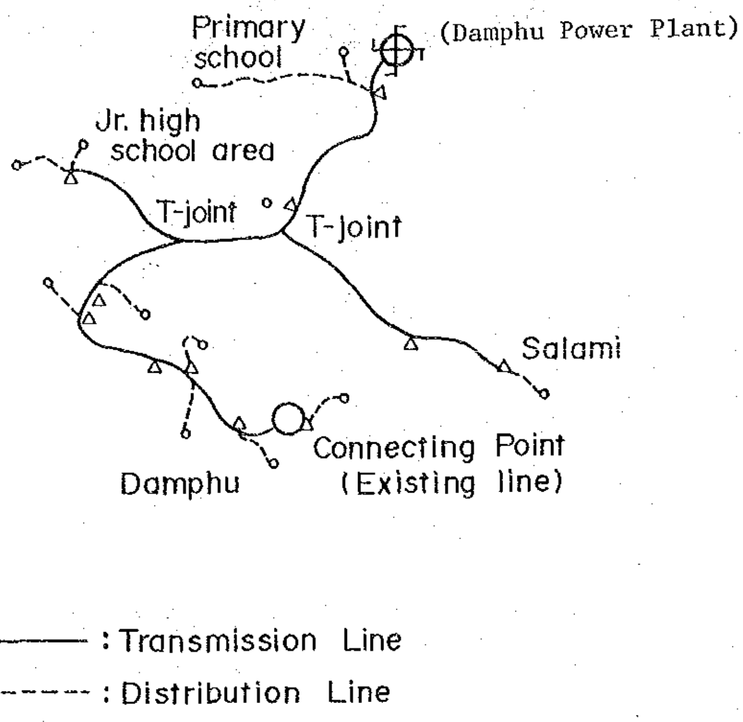


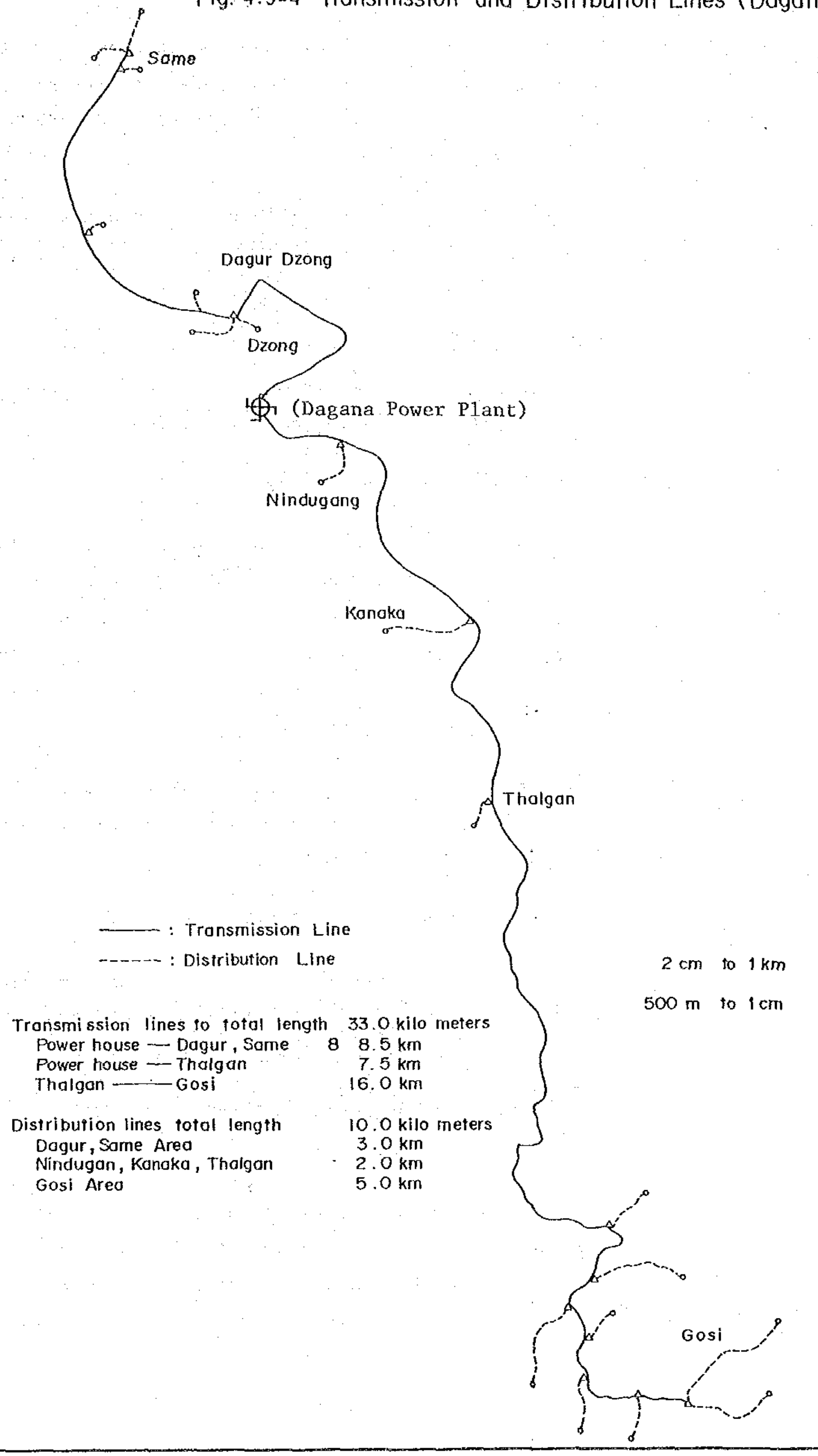
Fig. 4.3-3 Transmission and Distribution Line (Damphu Site)



Transmission lines total length	9.0kilo meters	2cm to 1km
Power house — Connecting point	5.5 km	
T-joint ——— Salami	2.0 km	500m to 1cm
T-joint ——— Jr. high school area	1.5 km	

Distribution lines total length 5.0 kilo meters

Fig. 4.3-4 Transmission and Distribution Lines (Dagana Site)



(i) Power generation plant - Tintibi area

The transmission line shall be constructed from the power generation plant to the center of Tintibi area along the relatively even road with a line length of approximately 6.0 km.

In its route, the line will have to cross the Mande river (span length approximately 200 m) ahead of the center of Tintibi area.

The low-voltage distribution line from the step-down transformer at the center of Tintibi area to the users shall be approximately 1.5 km long.

(ii) Power generation plant - Shemgang area

The transmission line shall be approximately 10km long from the power generation plant to the connecting point adjoining the existing diesel power generation plant at Shemgang. These line will have to traverse mountainous regions with considerable differences in elevation.

The distribution line from the connecting point at Shemgang area to Dankhar area and Kersapey area shall be approximately 3.5 km long.

(iii) Power generation plant - Dakphey area

The transmission line shall traverse mountain forests over a distance of about 2.0 km from the T-branching out point between the power generation plant and Shemgang area to Dakphey area.

2) Damphu area

Transmission lines with a total extension of about 9.0 km shall be constructed, about 5.5 km from the power generation plant to be constructed on the right bank of the Chanche river to the connecting point near the existing diesel power generation plant in Damphu, about 2.0 km to Salami branching out en route by about 1.5 km to the school zone. All shall be laid across the terraced farms to reach the users's areas.

The distribution lines will be constructed to connect from the step-down transformer to be installed at the end of the transmission line to the users.

For the benefit of users scattered along the transmission line, the step-down transformer shall be installed on the way of the transmission line route and the distribution line shall be constructed from there to the users.

The distribution lines to be erected shall total approximately 5.0 km.

3) Dagana area

Two transmission lines shall be laid from the power generation plant to be constructed on the right bank of the Dara chu, one to Dagur and Same on the north and the other to Thalgan and Gosi on the south.

(i) Power generation plant - Dagur and Same

A transmission line with a approximate length of 8.5 km shall be laid from the power generation plant to Dagur Dzong along the road and from there to Same along a mountain path. For the benefit of the users in Dagur Dzong and Same, low-voltage distribution lines shall be laid from the step-down transformers to be installed on the way of the transmission line. The total line length of the distribution line shall be approximately 3.0 km.

(ii) Power general plant - Thalgan and Gosi area

This transmission line shall be erected over a distance of 7.5 km form the power generation plant to Thaigan via Nidgang and Kanakha along the road, except for a mountainous section (about 1.0 km) where the line sill be routed along the mountain path.

For the benefit of the users in Nindugang, Kanakha and Thalgan, low-voltage distribution lines shall be laid from the step-down transformers to be installed on the way of the transmission line. The total line length of the distribution lines shall be approximately 2.0 km.

The transmission line from Thalgan to Gosi shall also be laid along the road. The line length shall be approximately 17 km. The line length of distribution lines to the users in the above two points just shall be approximately 5.0 km.

(2) Design of transmission and distribution lines

1) Electric system of transmission and distribution lines

(i) Transmission voltage

Two voltage classes are conceivable for the transmission lines: 6.6 kV as used for the existing small hydraulic power generating facility and 11.0 kV as standard for Bhutan. If the voltage drop is to be kept below 5%, the use of 6.6 kV will ensure economically acceptable construction costs. However, it will be necessary to consider the use of the 11.0 kV voltage class for the transmission line with a line length exceeding 30 km as it becomes difficult to keep voltage losses below 5%.

Results of examinations of the voltage drop and power losses are given below:

Voltage drop of transmission line by voltage class and distance

(Unit: %)

Voltage	6.6 kV				11.0 kV			
	5.0km	10.0km	20.0km	30.0km	5.0km	10.0km	20.0km	30.0km
ACSR-OE 25 mm^2	1.1	2.2	4.5	6.7	0.4	0.8	1.6	2.4

Annual power loss of transmission line by voltage class and distance

(Unit: kWh)

	6.6 kV			
	5.0 km	10.0 km	20.0 km	30.0 km
ACSR-OE 25 mm^2	4,818	9,636	18,790	28,426

	11.0 kV			
	5.0 km	10.0 km	20.0 km	30.0 km
ACSR-OE 25 mm^2	3,854	7,709	15,418	23,126

(ii) Electric System of Distribution Line

The voltage of the distribution lines shall be the same as that of the existing facility after allowing for the ease of maintenance and the full utilization of available spares. It was decided as follows:

Nominal voltage and distribution system
415 V. (3 phase 4 line type), 240 V (single phase)

2) Determination of safety factor and wind pressure load

The safety factor and wind pressure load to be used in the design of transmission and distribution lines, based on the standard adapted in Chukha project are determined as follows:

(i) Safety factor

Particulars	Design parameter
Pole Conductors Insulators Stay wires, ground wires etc.	2.5 2.0 2.5 2.5

(ii) Wind pressure

Particulars	Design parameter
Pole Conductor	200 (kg/m^3) 50 (kg/m^3)

3) Selection of type of cable

(i) Use of insulated cable

All cables used for the power transmission and distribution lines shall be insulated. The reasons are as given below:

To prevent electric accidents due to contact and/or access between cables and trees and vegetation, seeing that the anticipated routes pass through mountainous zone and hills. To prevent electric shock to the inhabitants of the region on careless contact or approach.

(ii) Use of steel reinforced aluminum cable

Considering the long line length required for power transmission in the entire project area, steel-reinforced aluminum cables shall be used as this is more economical than the use of copper cables. The former also have a superior mechanical strength (tensile strength) and are capable of meeting the electrical requirements (resistance). Any particular considerations not will be required for likely problems (such as electrolytic corrosion) when connecting with the existing aluminum cable distribution lines.

The use of steel-reinforced aluminum cables has thus been decided for the above reasons.

(iii) The type of cable to be used for the transmission and distribution lines shall be as shown below:

Classification	Type and size of cable
Transmission line	ACSR-OE 25 mm^2 (Steel reinforced conductive aluminum cable insulated with polyethylene for outdoor use)
Distribution line	ACSR-OW 25 mm^2 - 58 mm^2 (Steel reinforced conductive aluminum cable insulated with vinyl for outdoor use)

4) Determination of type of support and standard span

(i) Spliced steel pipe pole shall be used for the following reasons:

The construction site of the transmission lines is not totally located along the road. Construction in mountainous regions, however, will require handling by carrying on the shoulders. Steel pipe offer the advantage that they are lighter in weight and, at the sametime, meet the mechanical strength requirements.

(ii) Selection of standard span

The following shall be the criteria for determining the standard span:

. Safety factor of cable

The maximum usable tensile force shall be less than 50% of the minimum tensile load under the worst conditions (lowest temperature), and less than 20% under normal conditions.

. Load condition of cable

The load conditions to be used in the calculation of the cable's safety factor shall be as shown in the table below:

Air temperature	Loading direction		Wind pressure kg/m_2
	Vertical	Horizontal	
High-temperature 40°C	Deadweight of cable	50 kg/m^2 for projected area of cable	50 kg/m^2
Low-temperature -10°C	Deadweight of cable + ice and snow with 3 mm thickness and specific gravity of 0.9	50 kg/m^2 for projected area of cable covered with 3 mm thick	50 kg/m^2
Normal time (average) 15°C	Cable deadweigh	None	0 kg/m^2

. Height of cable

The height of the overhead cables above the ground surface and the road shall be more than the values shown below:

Ground surface	5.0 m
Road	6.0 m

- Minimum spacing between overhead cables and other objects

Building	2.0 m
Telephone line	1.0 m
Low and high voltage lines	1.0 m

- Calculation of cable sag.

  A parabolic approximation formula shall be used for calculating cable sag.

The standard span, assuming the above design conditions and support heights (up to the wire supporting point) of 8.5 m for transmission line and 7.0 m for distribution line, is as shown below.

Transmission line	Mountainous area	60 m
	Flat area	80 m
Distribution line		60 m

Slackness in each case, assuming the above design conditions, is as shown in Appendix 5.28.

5) Type of insulator

The insulator types to be used for the transmission lines shall be the high voltage pin insulator (JIS C3821) and the high voltage tension resisting insulator (JIS C3826), or equivalent insulators of identical or better performance. These shall have a dielectric strength such as to exclude electrical break through over an altitude of 2,000 m. The mechanical perfomance required of the insulators retaining the cable (tension resisting insulator) shall be such as to withstand a load equivalent to 1.5 times the horizontal loads, and for other types of insulators, such as to withstand the estimated load excluding the horizontal loads.

The insulator type to be used for the distribution lines, shall be the low voltage pin insulator (JIS C3844) and the low voltage retaining insulator (JIS C3845), or those having the same or better performance.

6) Mechanical devices

(i) Transformer

The booster transformer shall be installed at the outgoing end of the power generation plant, suiting with the output of the generator, and the step-down transformer with capacity suitable for the users shall be installed on the transmission line. (Switches and overcurrent circuit breakers shall be installed on the primary side of the transformer at the same time). The charging section of the transformer shall not be exposed. Adequate grounding work shall also be executed.

(ii) Switch

The switch shall be installed on the branch-out point of the transmission line or other suitably selected points. The reasons are as described below:

- To operate and control the electric devices and cable circuits safely and accurately.

- It is necessary to suspend transmission of electricity in a specific zone when service work on electric devices and cable circuits is performed. For this purpose, the cable circuits are divided into several zones, and switchs are installed at borders between the zones.

(iii) Overcurrent circuit breakers

The overcurrent circuit breakers shall be installed where required for the protection of the transformer, switch and cable on the electric circuit of the transmission and distribution lines.

(iv) Ground falt protecting device

A ground falt proteciton device shall be installed on the transmission and distribution lines in order to automatically open the circuit when grounded.

(v) Lightning arresting device

. Lightning arrester

The lightning arrester shall be installed on the outgoing end of the transmission line, the end of the electric circuits, switch, installation point of switch and transformer, etc. for the protection of electric devices, instruments and circuits.

The number of days with thunderstorm per annum in Bhutan is assumed to be 60 days/year based on the world standard of IKL (Isokeraunic level)

. Overhead ground line

The overhead ground line shall be installed on the transmission line.

7) Outfitting transmission and distribution line poles

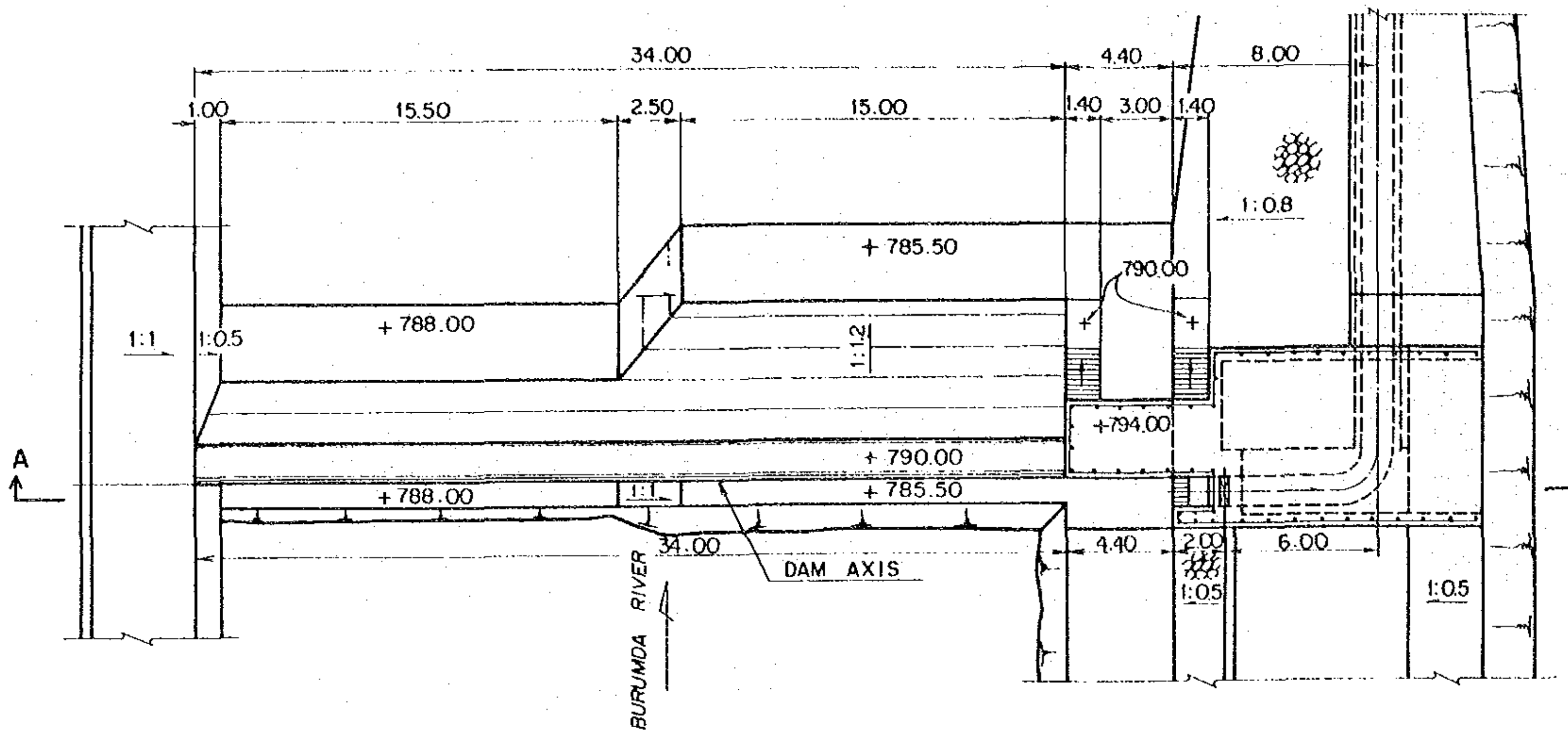
Typical outfitting for transmission and distribution lines is as shown in the basic design drawings No. 10, 11, and 12 in Paragraph 4-4.

4-4 Basic Design Drawings

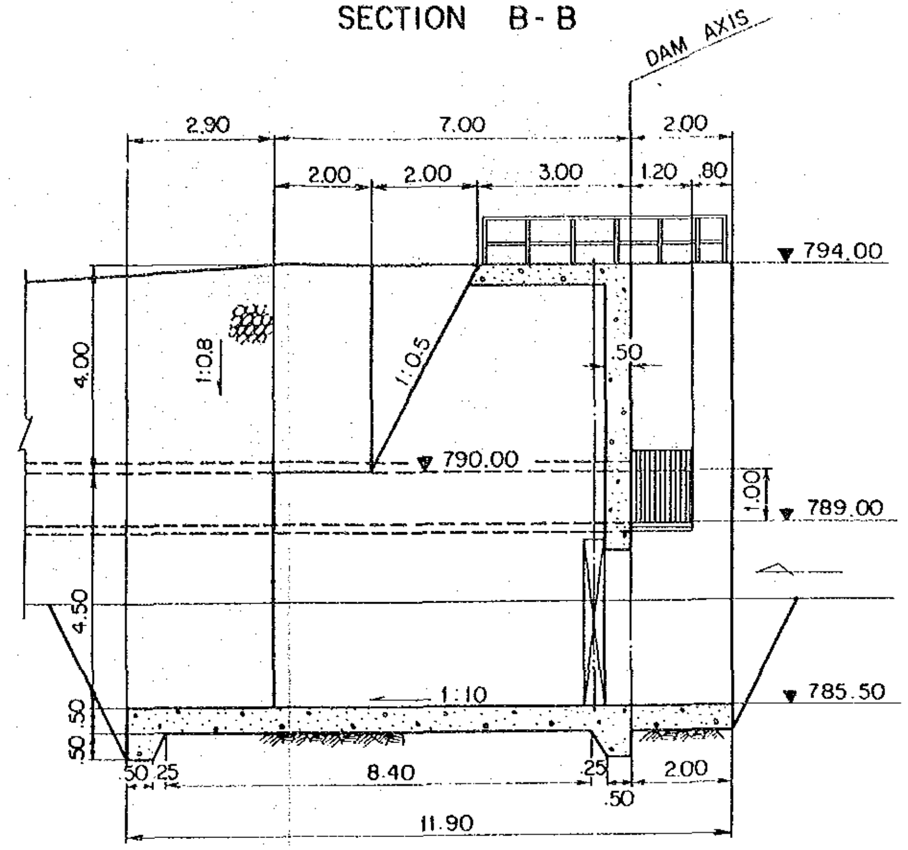
Basic design drawings of civil structures and electrical equipment and facilities designed in accordance with the requirements mentioned hereinbefore in this Chapter 4 are as follows:

Drawing No. 1	Shemgang - Micro Hydro Power Plant Intake Dam
Drawing No. 2	Shemgang - Micro Hydro Power Plant Headrace Channel Sedimentation Basin Head Tank
Drawing No. 3	Shemgang - Micro Hydro Power Plant Penstock, Power House
Drawing No. 4	Damphu - Micro Hydro Power Plant Intake Dam
Drawing No. 5	Damphu - Micro Hydro Power Plant Headrace Channel Sedimentation Basin Head Tank
Drawing No. 6	Damphu - Micro Hydro Power Plant Penstock, Power House
Drawing No. 7	Dagana - Micro Hydro Power Plant Intake Dam
Drawing No. 8	Dagana - Micro Hydro Power Plant Headrace Channel Sedimentation Basin Head Tank
Drawing No. 9	Dagana - Micro Hydro Power Plant Penstock, Power House
Drawing No.10	6.6 kV Transmission Line Post Arrangement (2-1)
Drawing No.11	- Ditto - (2-2)
Drawing No.12	400 V Distribution Line Post Arrangement

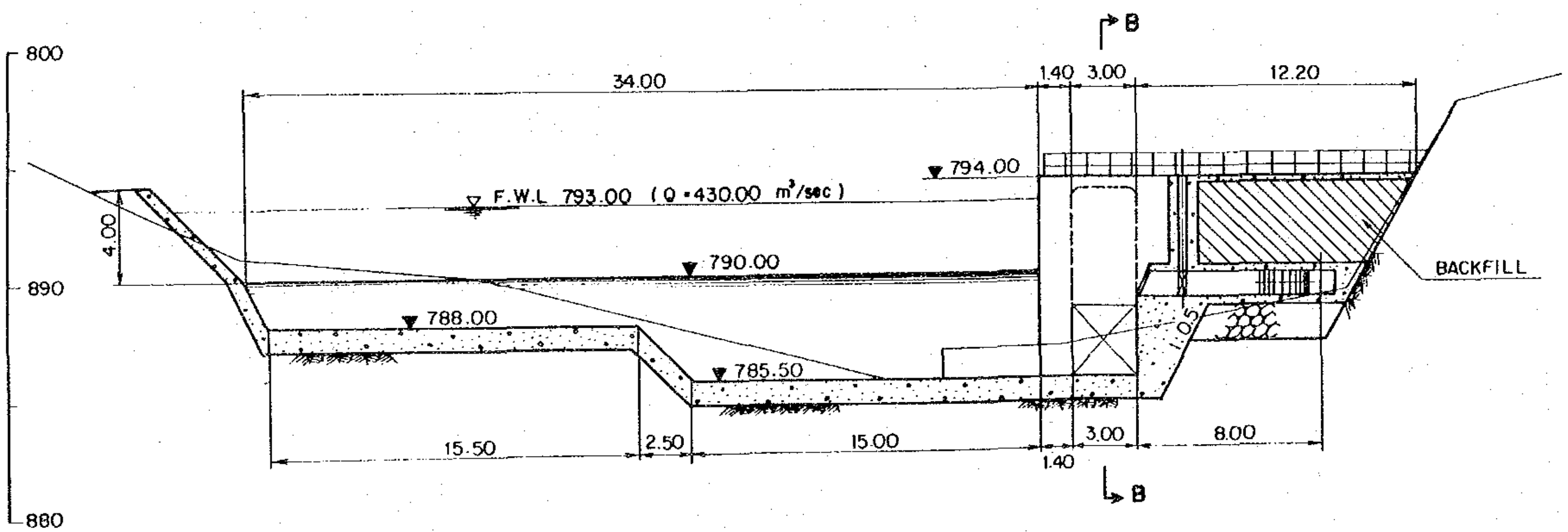
PLAN OF INTAKE DAM



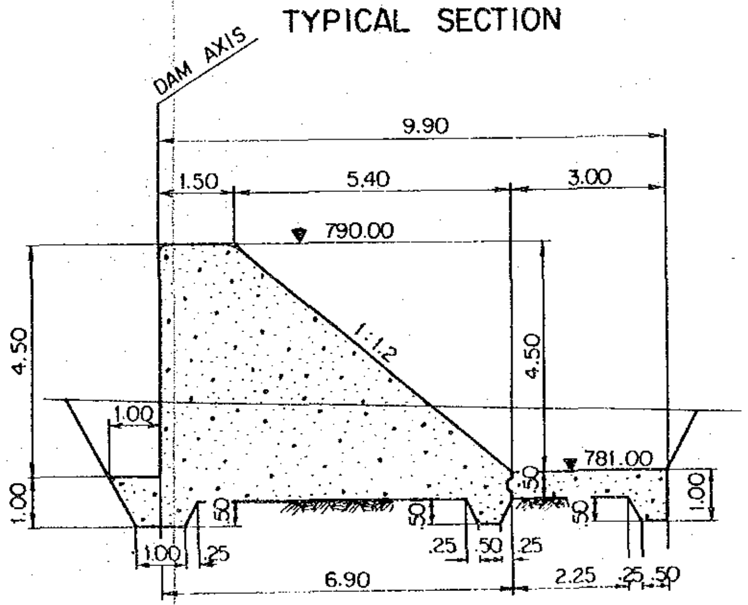
SECTION B-B



SECTION A-A



TYPICAL SECTION

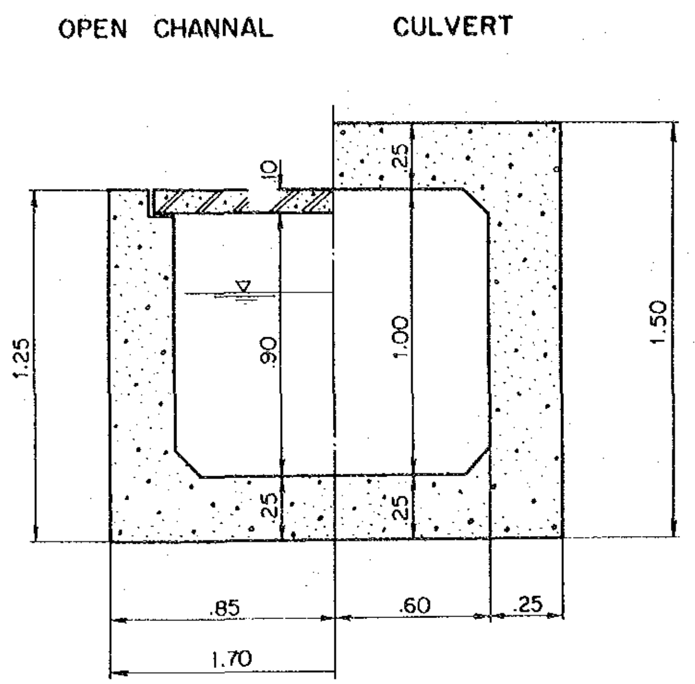


PLAN , SECTION A-A 0 10 m

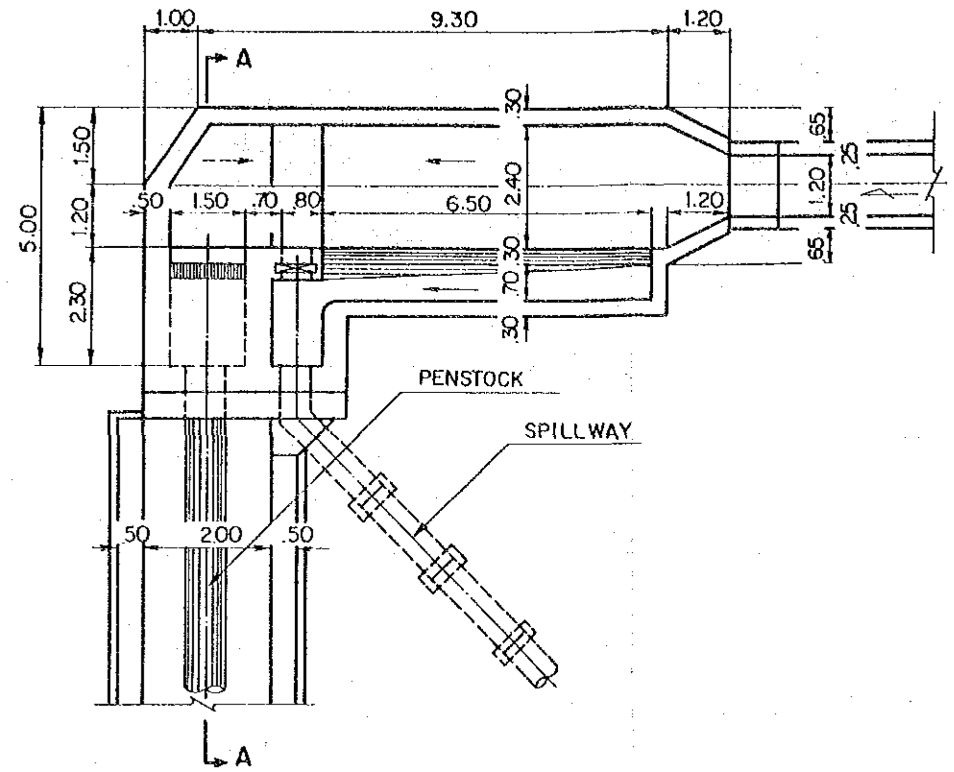
TYPICAL SECTION B-B 0 5 m

JAPAN INTERNATIONAL COOPERATION AGENCY
KINGDAM OF BHUTAN SHEMGANG-MICRO HYDRO POWER PLANT PLAN OF INTAKE DAM
DWG. No. 1

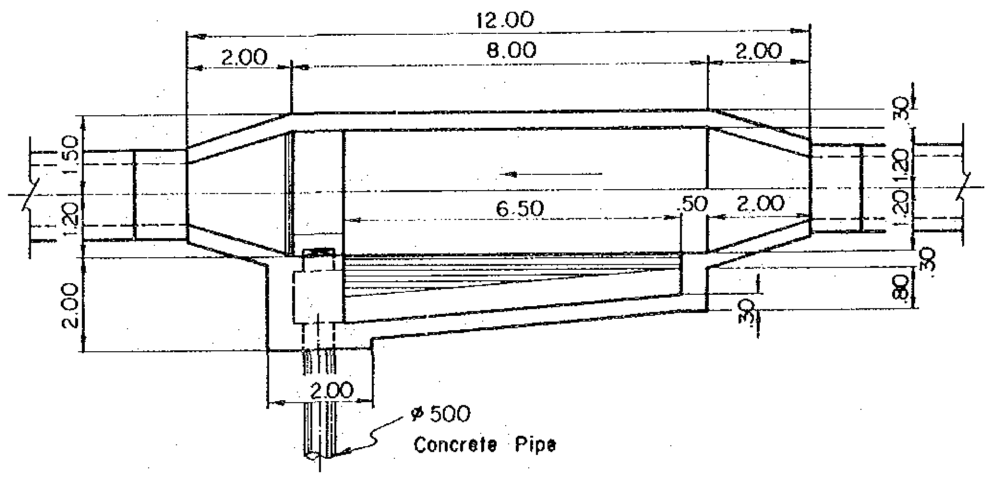
PLAN OF HEADRACE CHANNEL



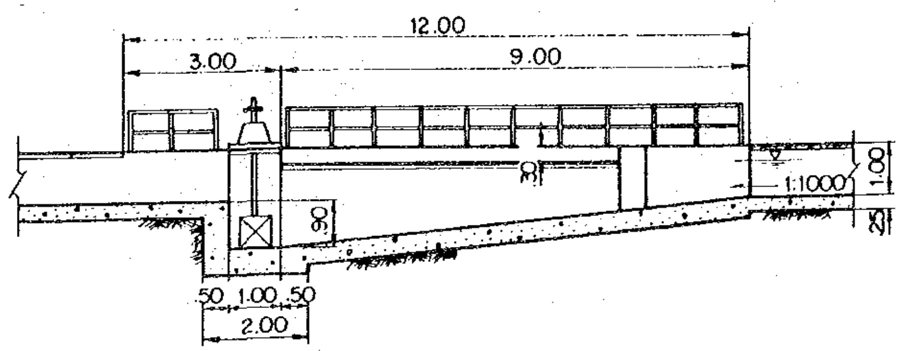
PLAN OF HEAD TANK



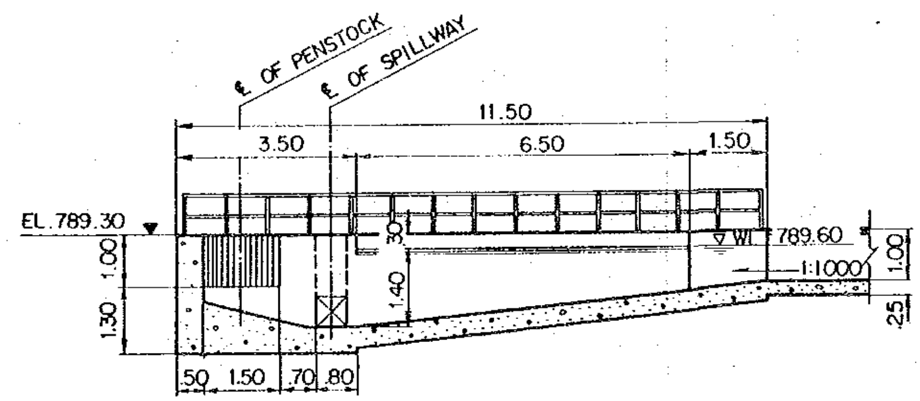
SEDIMENTATION BASIN



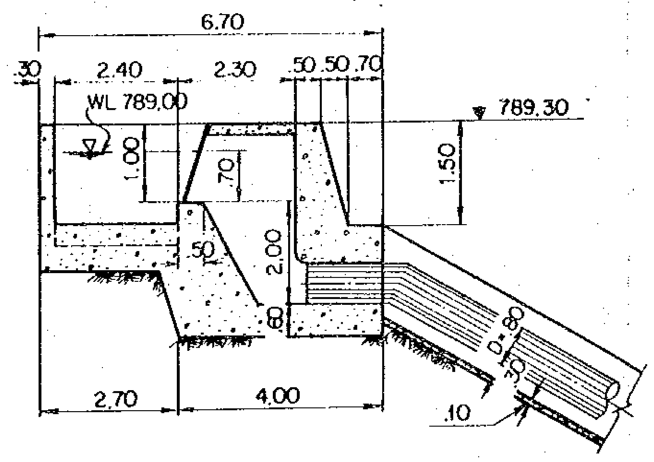
PROFILE



PROFILE



SECTION A - A



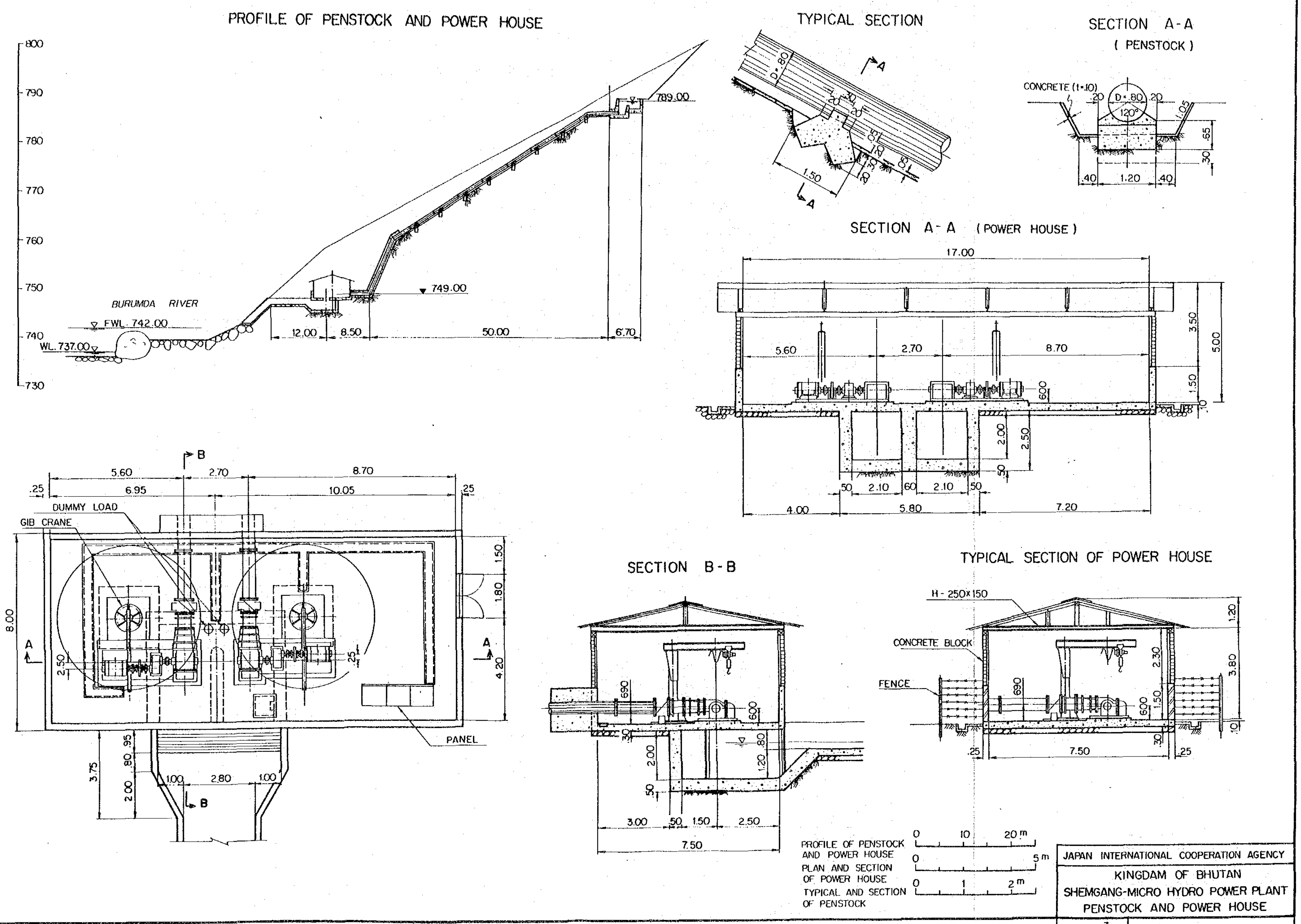
HEADRACE CHANNEL 0 — 1 m

SEDIMENTATION BASIN, HEAD TANK 0 — 5 m

JAPAN INTERNATIONAL COOPERATION AGENCY

KINGDAM OF BHUTAN
SHEMGANG-MICRO HYDRO POWER PLANT
HEADRACE CHANNEL, SEDIMENTATION BASIN AND HEAD TANK

DWG. No. 2



JAPAN INTERNATIONAL COOPERATION AGENCY

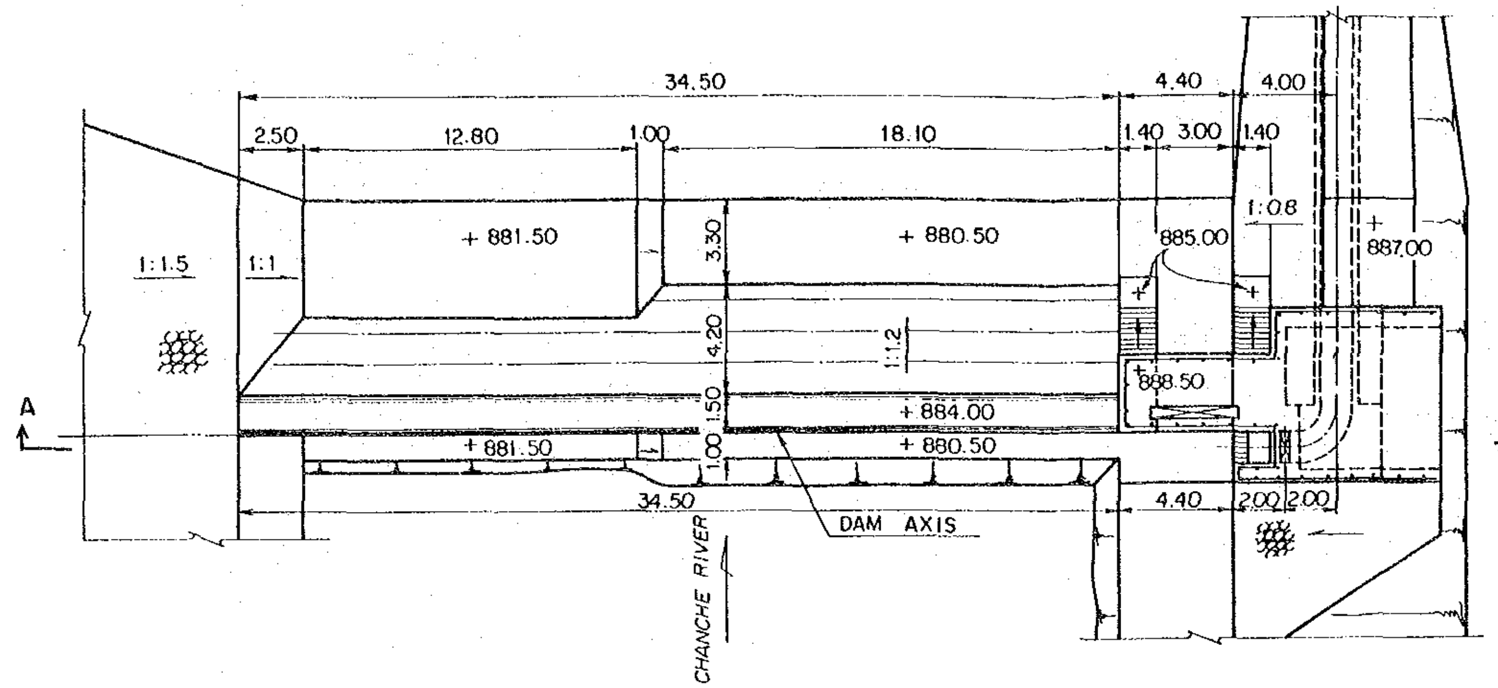
KINGDAM OF BHUTAN

SHEMGANG-MICRO HYDRO POWER PLANT

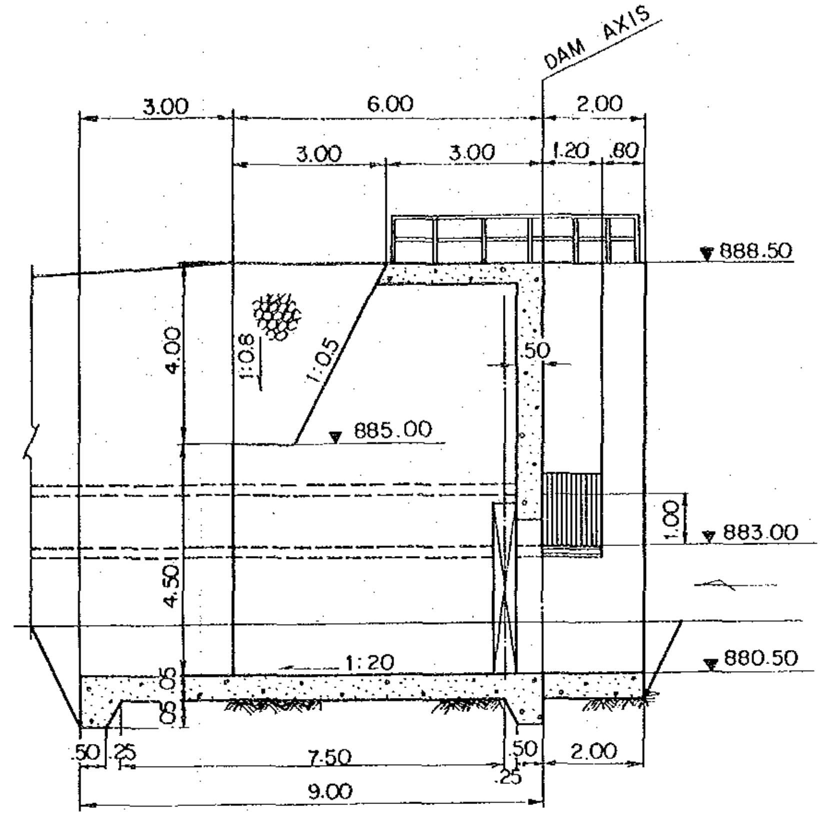
PENSTOCK AND POWER HOUSE

DWG. No. 3

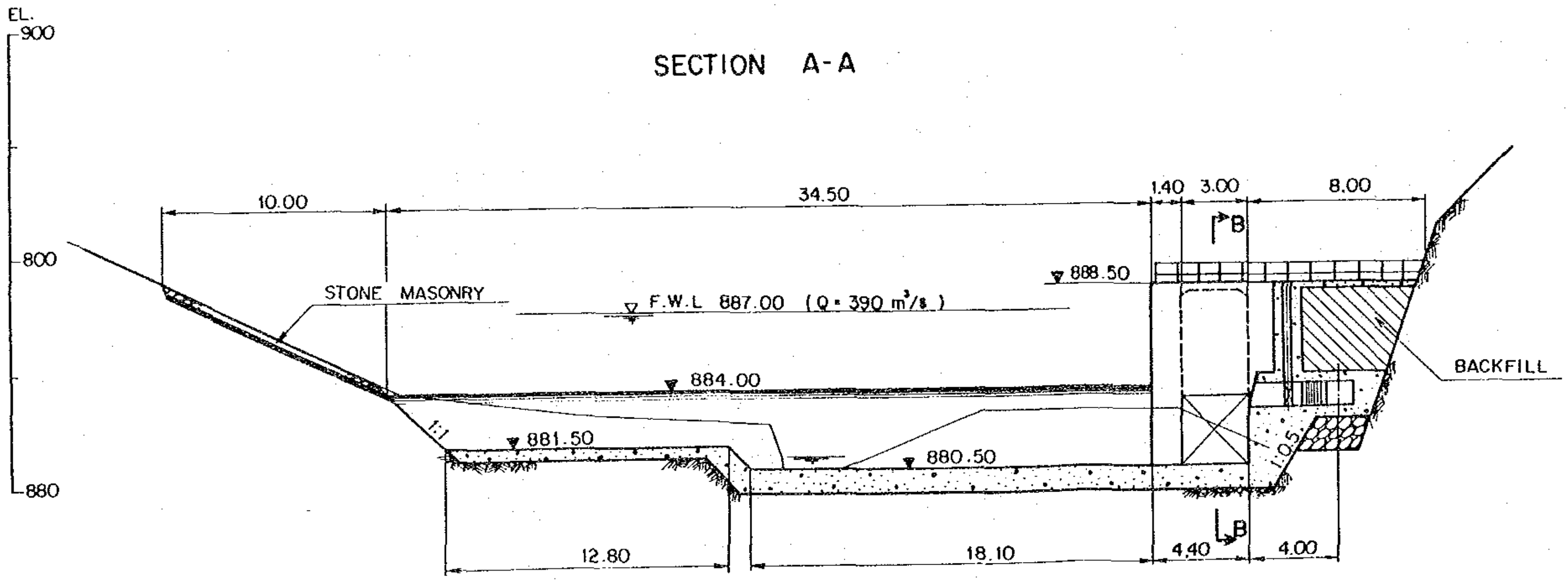
PLAN OF INTAKE DAM



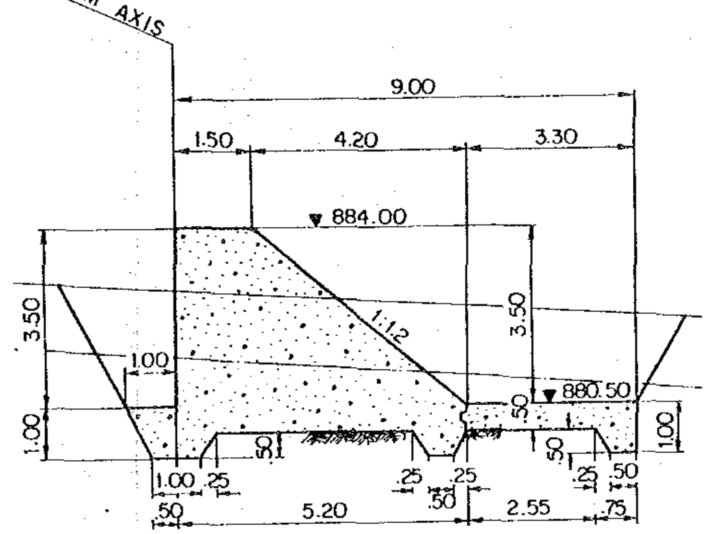
SECTION B-B



SECTION A-A



TIPICAL SECTION



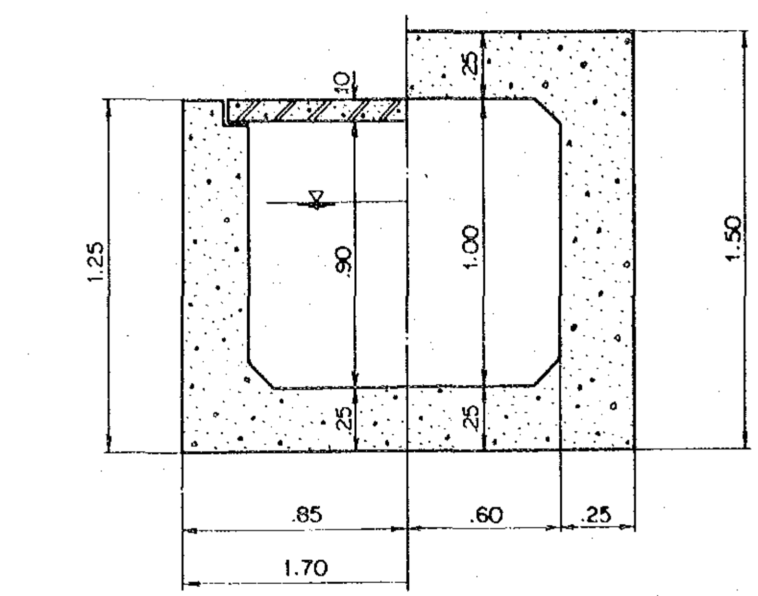
PLAN, SECTION A-A 0 — 10m

TYPICAL SECTION B-B 0 — 5m

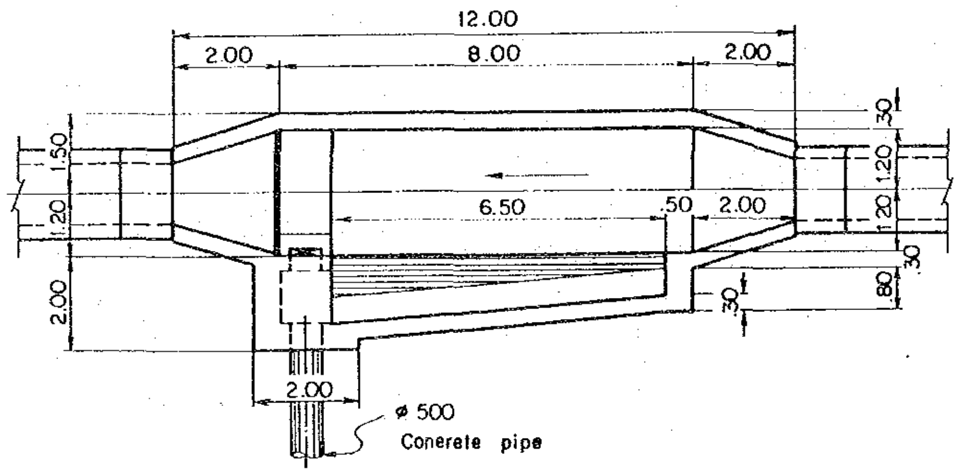
JAPAN INTERNATIONAL COOPERATION AGENCY
KINGDAM OF BHUTAN
DAMPHU-MICRO HYDRO POWER PLANT PLAN OF INTAKE DAM
DWG. No. 4

PLAN OF HEADRACE CHANNEL

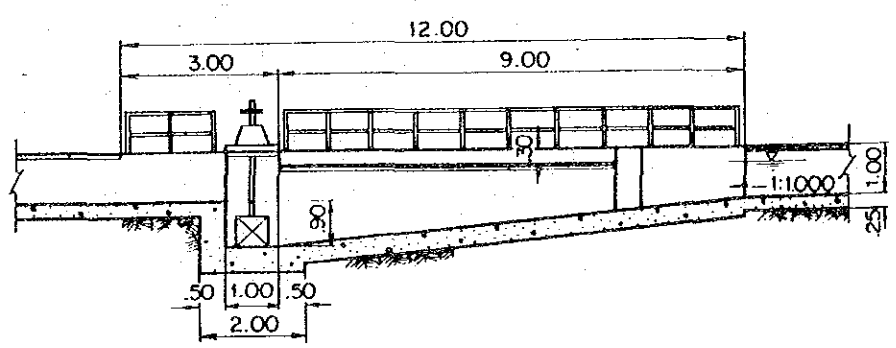
OPEN CHANNEL CULVERT



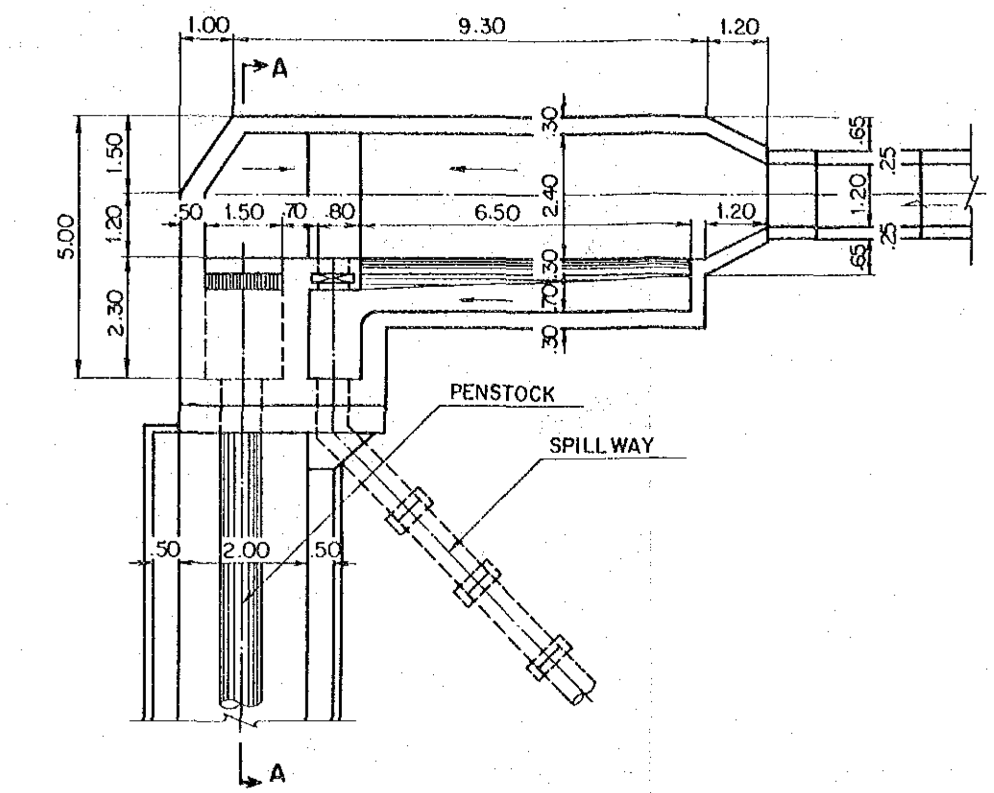
SEDIMENTATION BASIN



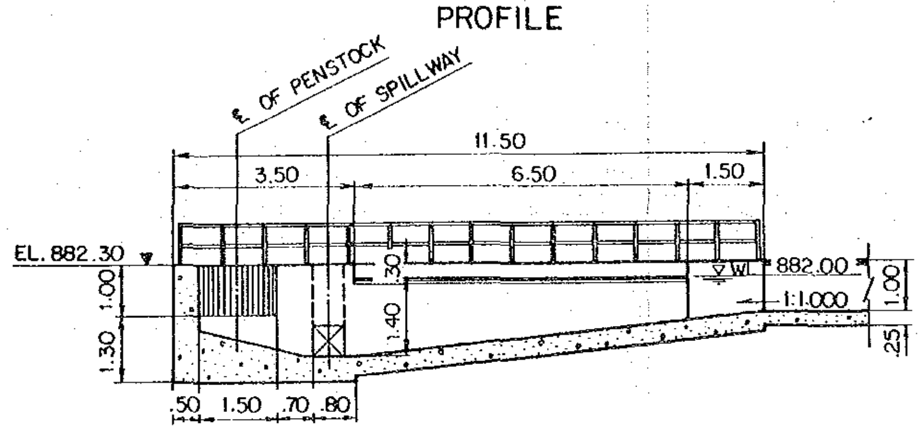
PROFILE



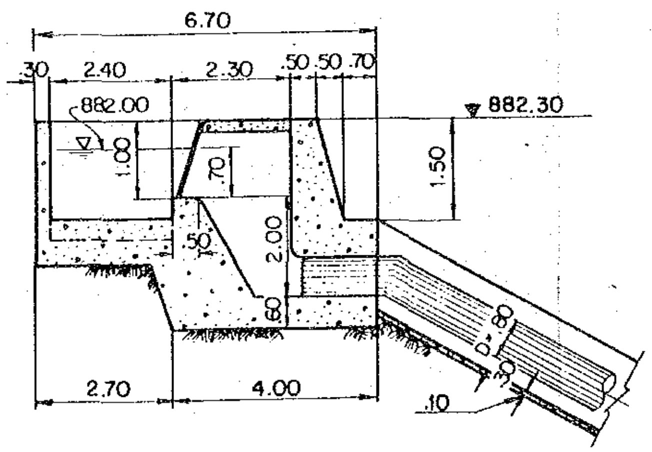
PLAN OF MEAD TANK

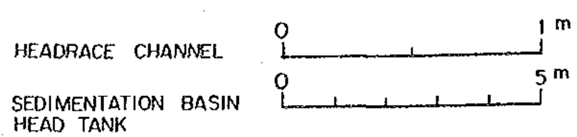


PROFILE

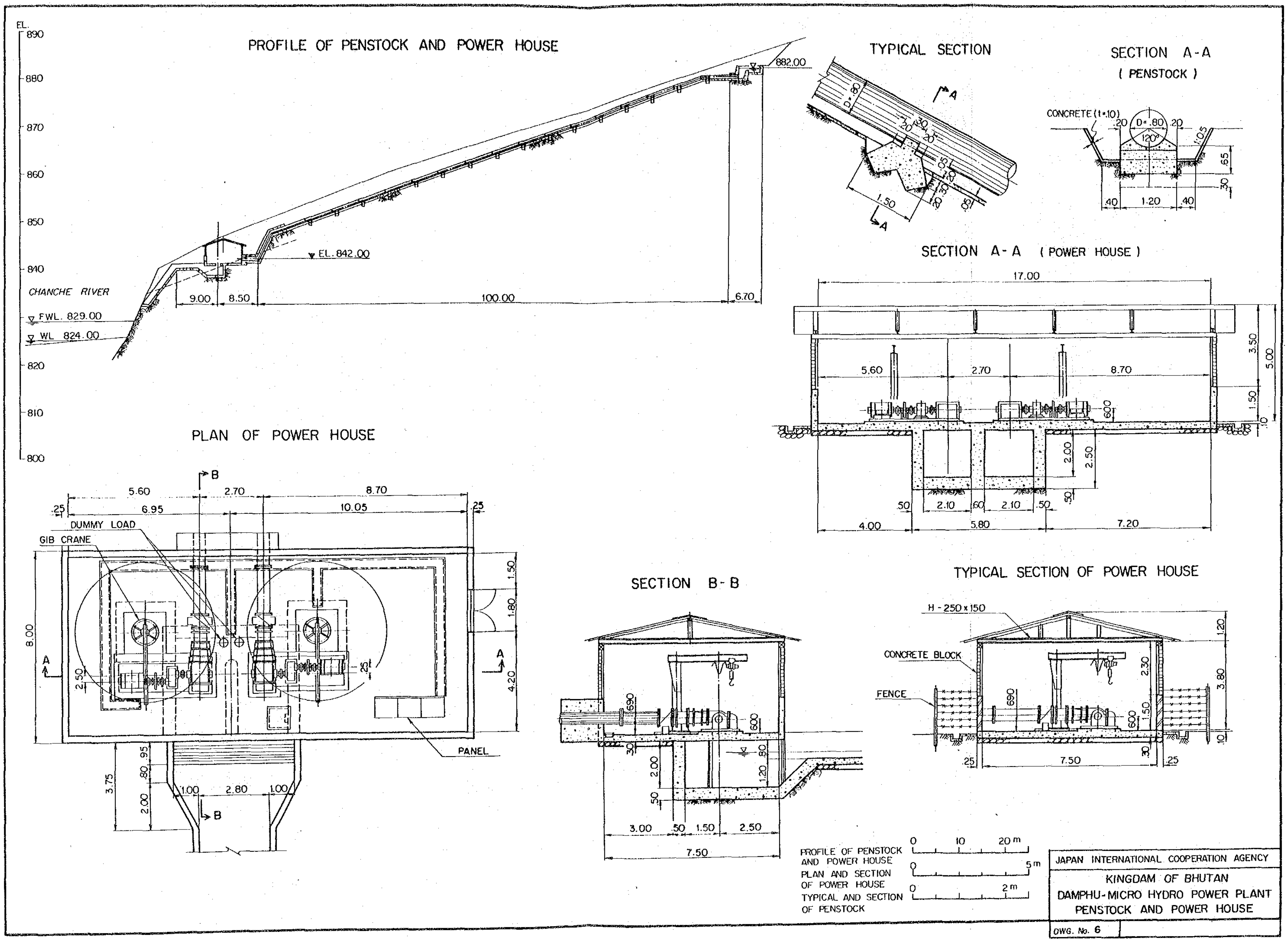


SECTION A-A

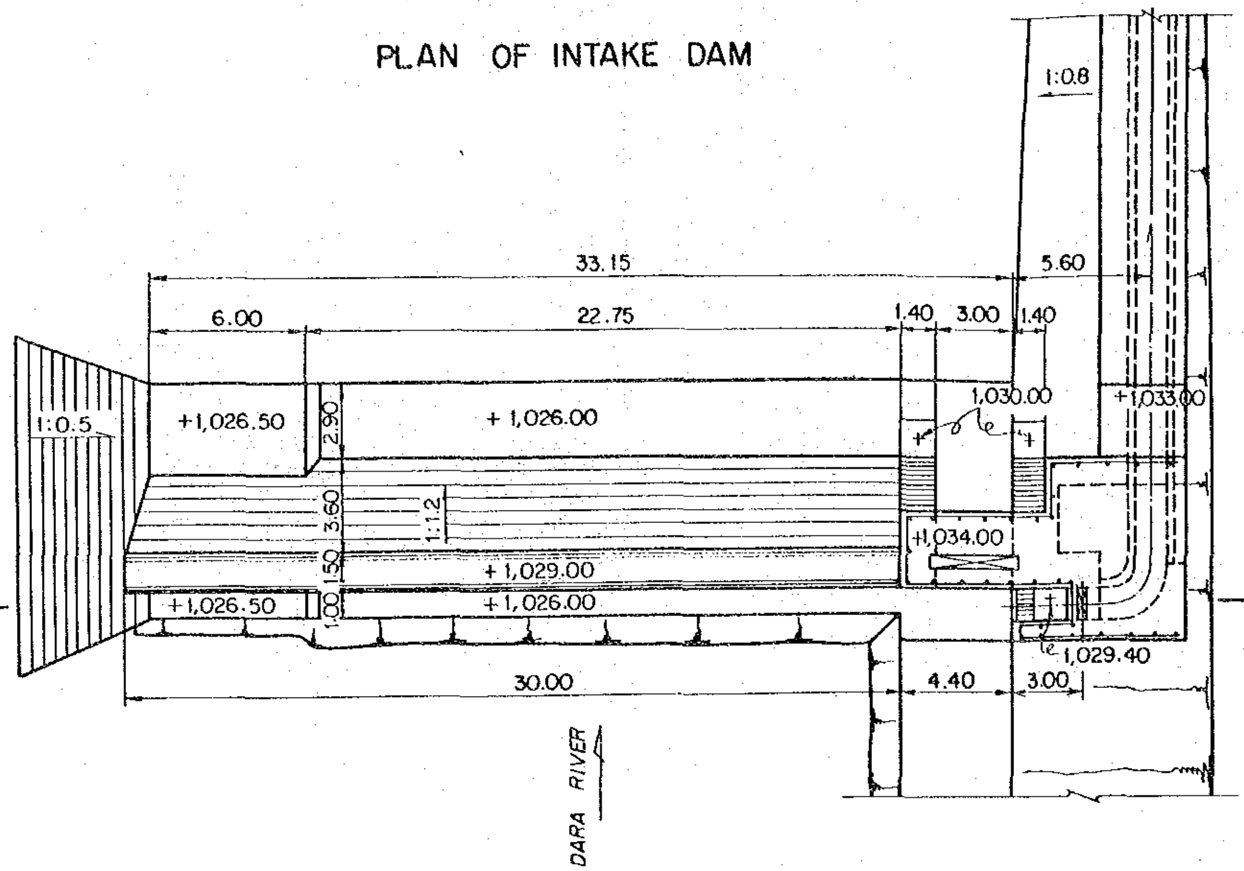




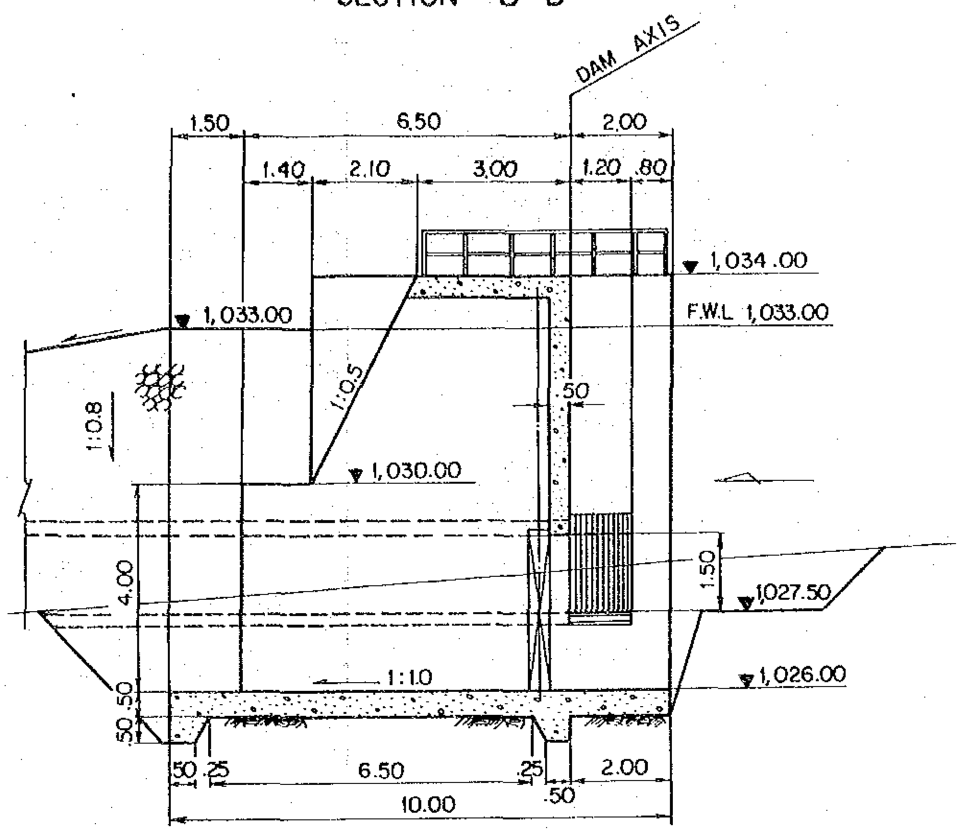
JAPAN INTERNATIONAL COOPERATION AGENCY
KINGDAM OF BHUTAN DAMPHU-MICRO HYDRO POWER PLANT HEADRACE CHANNEL, SEDIMENTATION BASIN AND HEAD TANK
DWG. No. 5


PROFILE OF PENSTOCK AND POWER HOUSE
EL.
890
880
870
860
850
840
820
810
800
CHANCHE RIVER
FWL. 829.00
WL 824.00
EL. 842.00
882.00
9.00
8.50
100.00
6.70
TYPICAL SECTION
D=.80
1.50
SECTION A-A
(PENSTOCK)
CONCRETE (t=10)
D=.80
120°
1.20
SECTION A-A (POWER HOUSE)
17.00
5.60
2.70
8.70
4.00
5.80
7.20
2.10
PLAN OF POWER HOUSE
DUMMY LOAD
GIB CRANE
PANEL
6.95
10.05
8.00
SECTION B-B
3.00
1.50
2.50
7.50
TYPICAL SECTION OF POWER HOUSE
H-250×150
CONCRETE BLOCK
FENCE
7.50
PROFILE OF PENSTOCK AND POWER HOUSE
PLAN AND SECTION OF POWER HOUSE
TYPICAL AND SECTION OF PENSTOCK
JAPAN INTERNATIONAL COOPERATION AGENCY
KINGDAM OF BHUTAN
DAMPHU-MICRO HYDRO POWER PLANT
PENSTOCK AND POWER HOUSE
DWG. No. 6

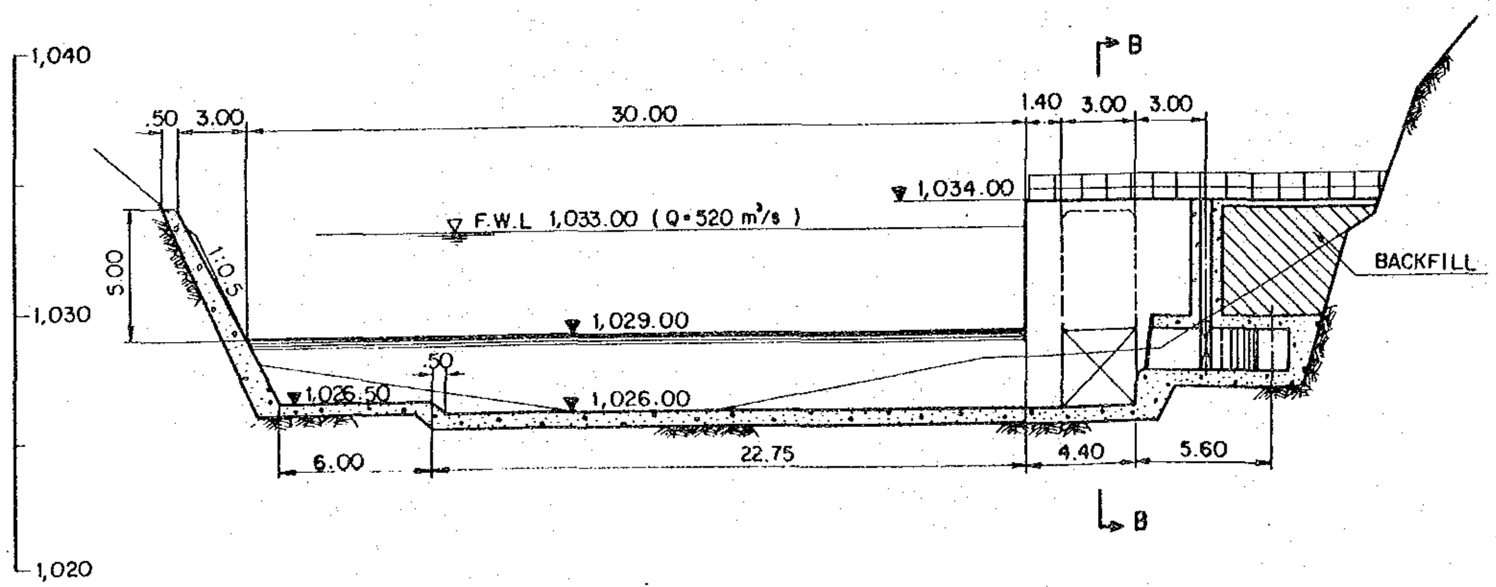
PLAN OF INTAKE DAM



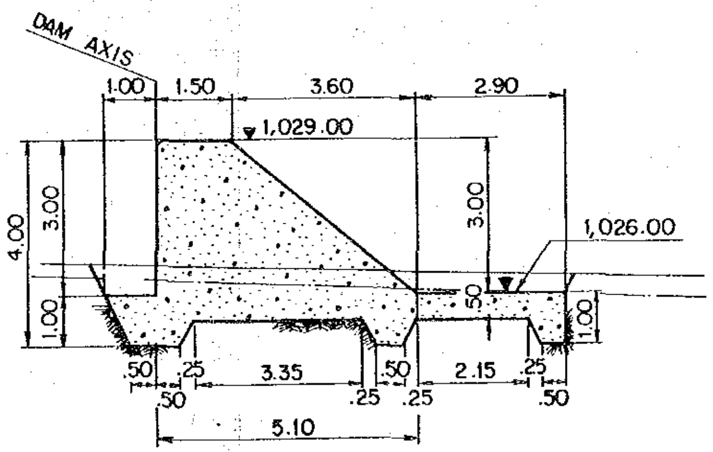
SECTION B-B



SECTION A-A



TYPICAL SECTION

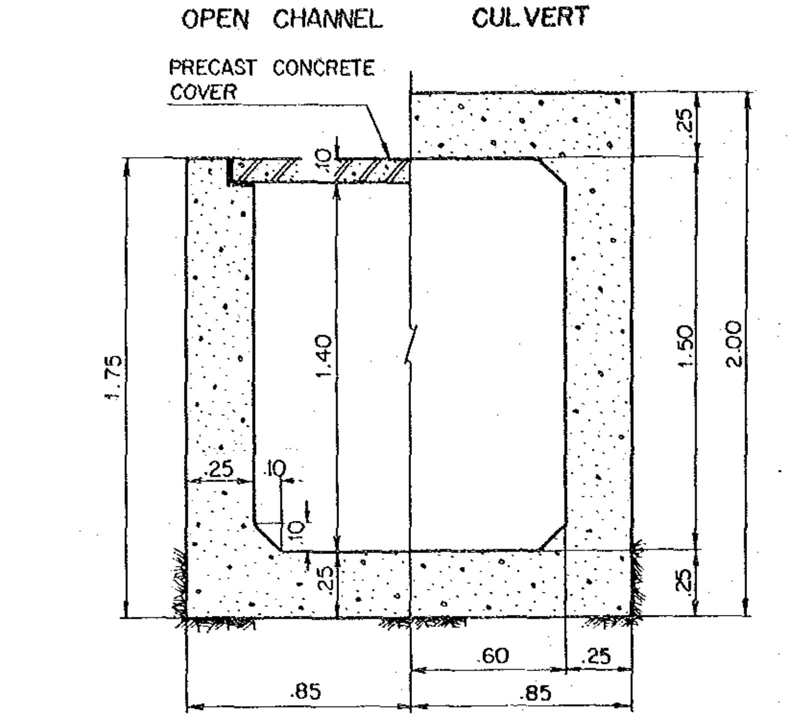


PLAN , SECTION A-A 0 10 m

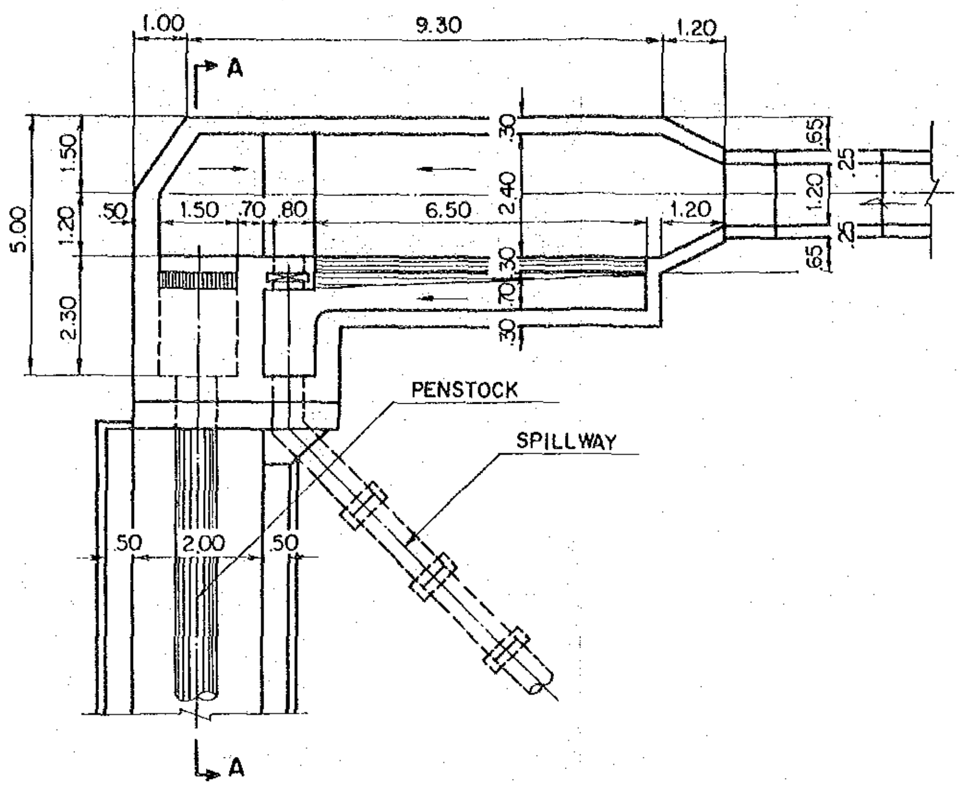
TYPICAL SECTION B-B 0 5 m

JAPAN INTERNATIONAL COOPERATION AGENCY
KINGDAM OF BHUTAN DAGANA-MICRO HYDRO POWER PLANT PLAN OF INTAKE DAM
DWG. No. 7

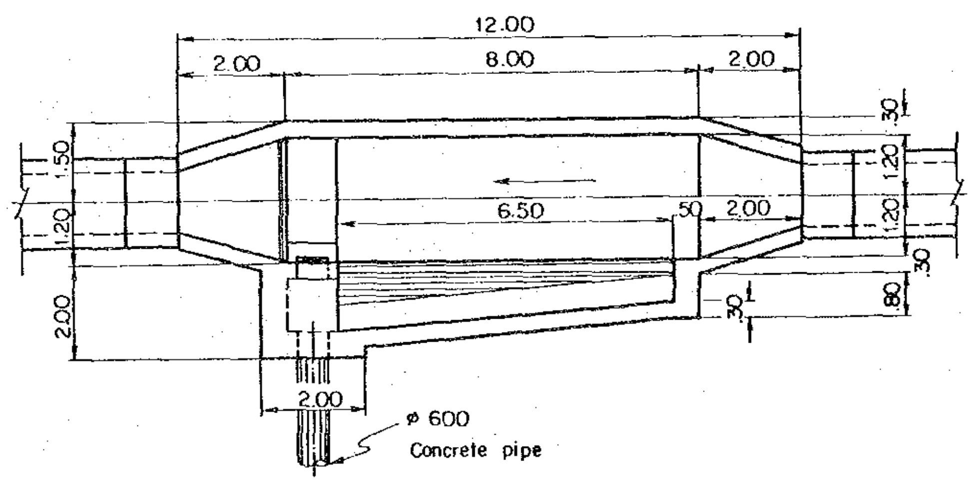
TYPICAL SECTION OF HEADRACE



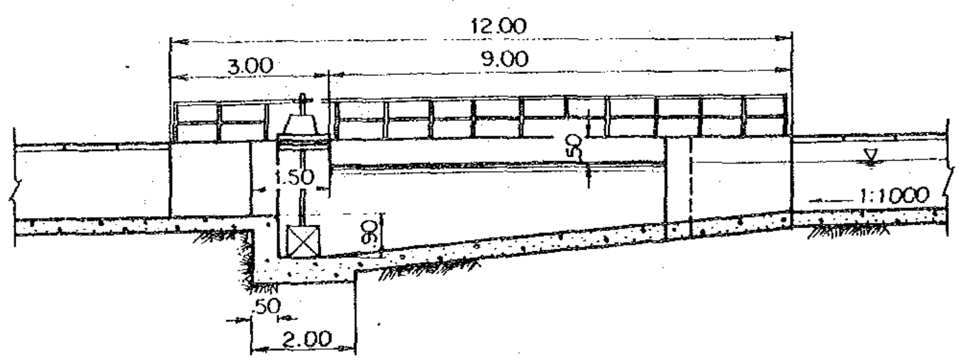
PLAN OF HEAD TANK



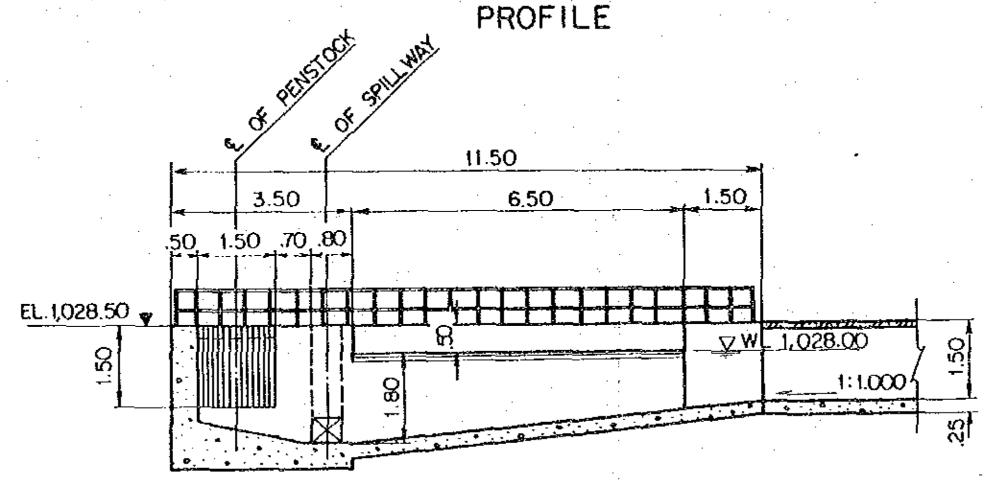
SEDIMENTATION BASIN



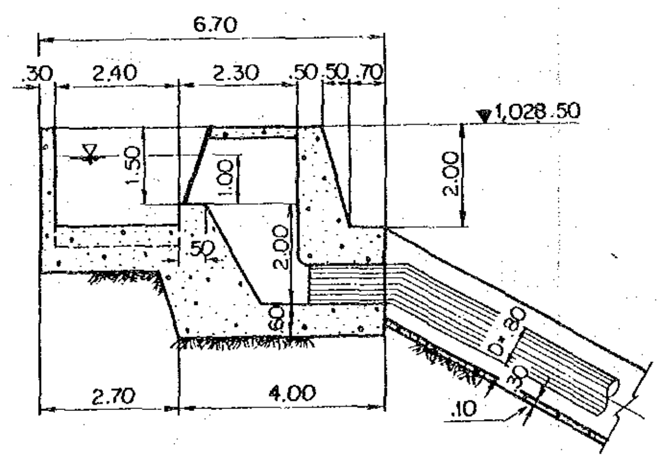
PROFILE



PROFILE



SECTION A-A



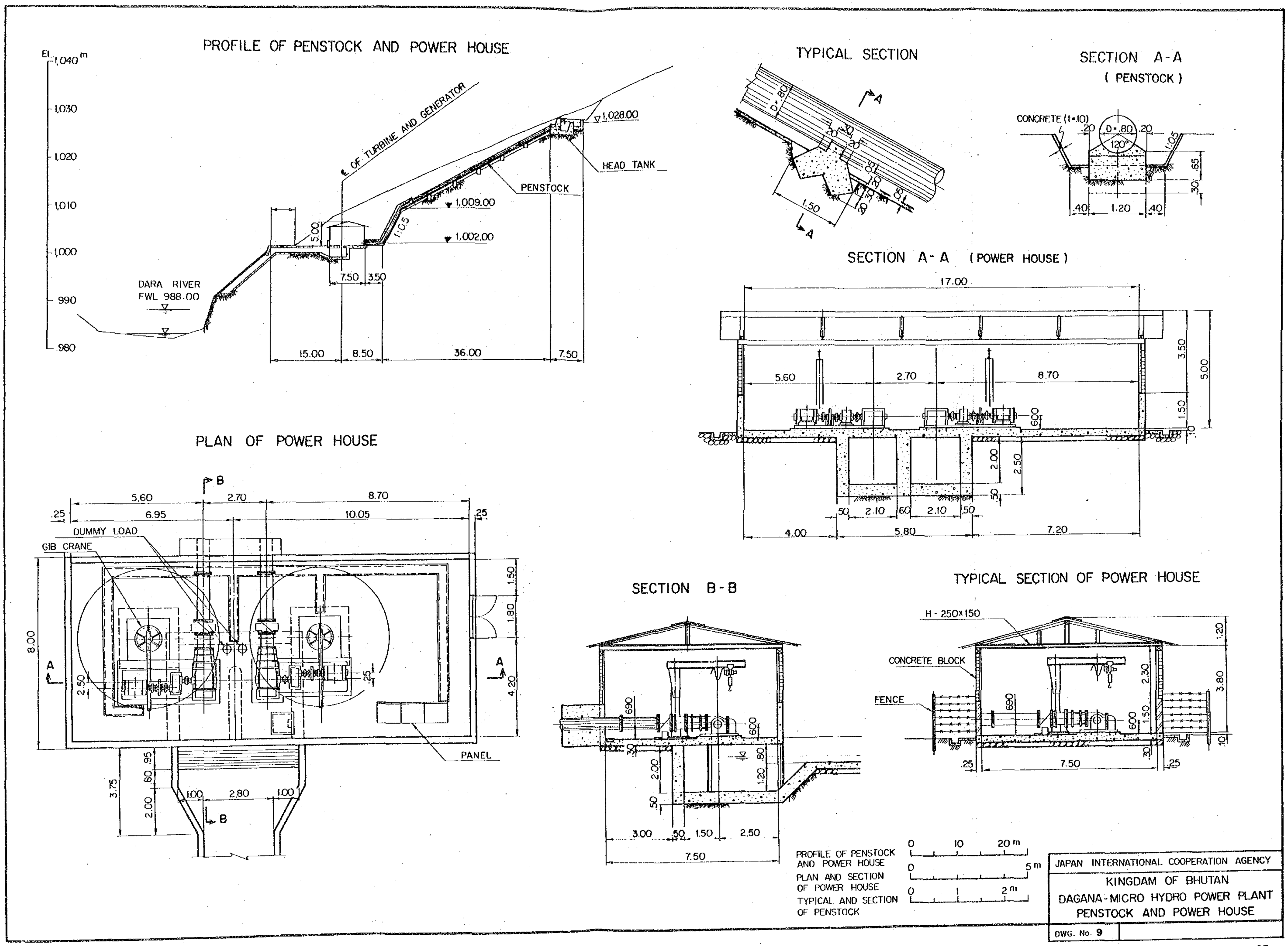
HEADRACE CHANNEL 0 — 1 m

SEDIMENTATION BASIN, HEAD TANK 0 — 5 m

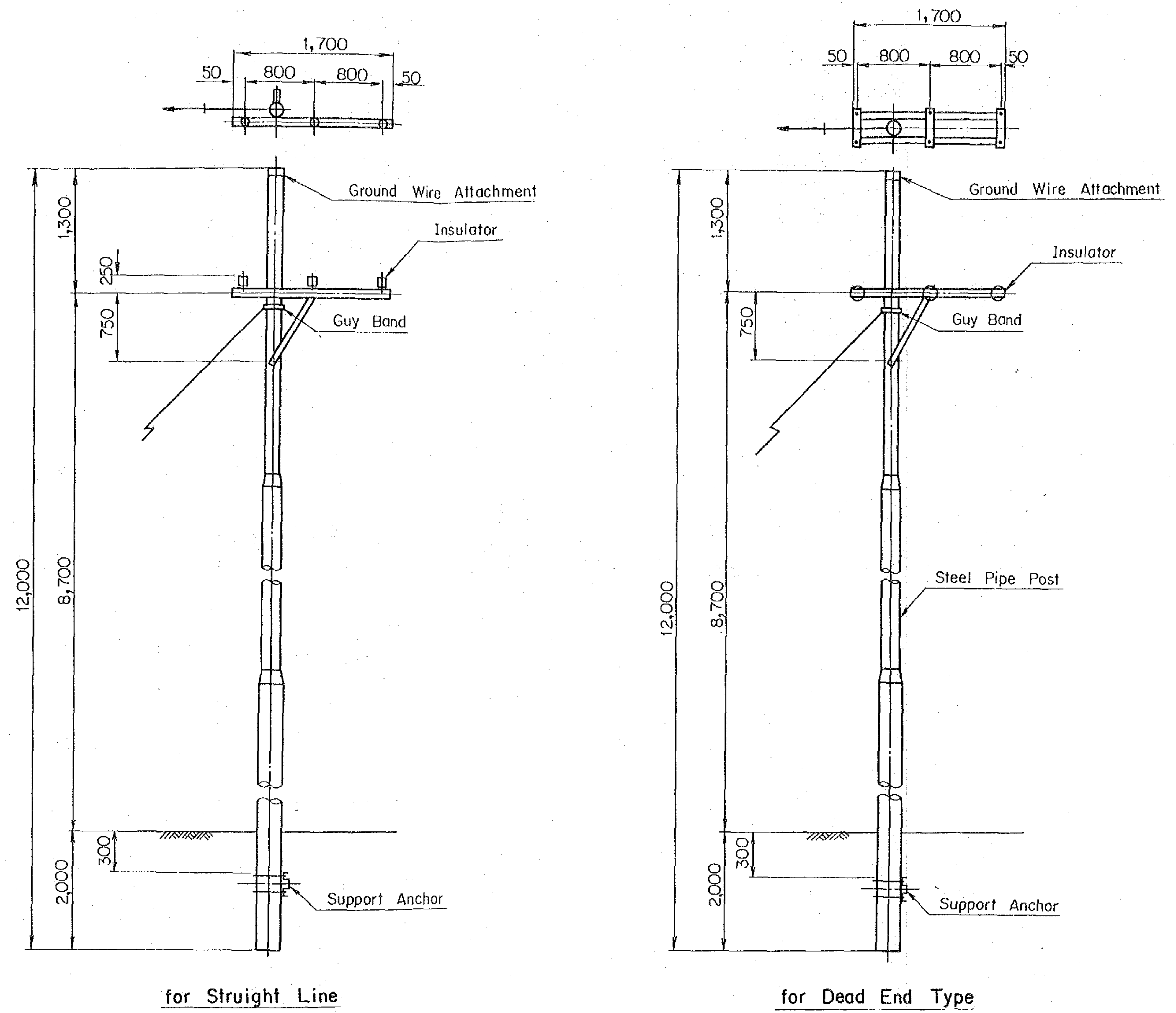
JAPAN INTERNATIONAL COOPERATION AGENCY

KINGDAM OF BHUTAN
DAGANA-MICRO HYDRO POWER PLANT
HEADRACE CHANNEL, SEDIMENTATION BASIN AND HEAD TANK

DWG. No. 8

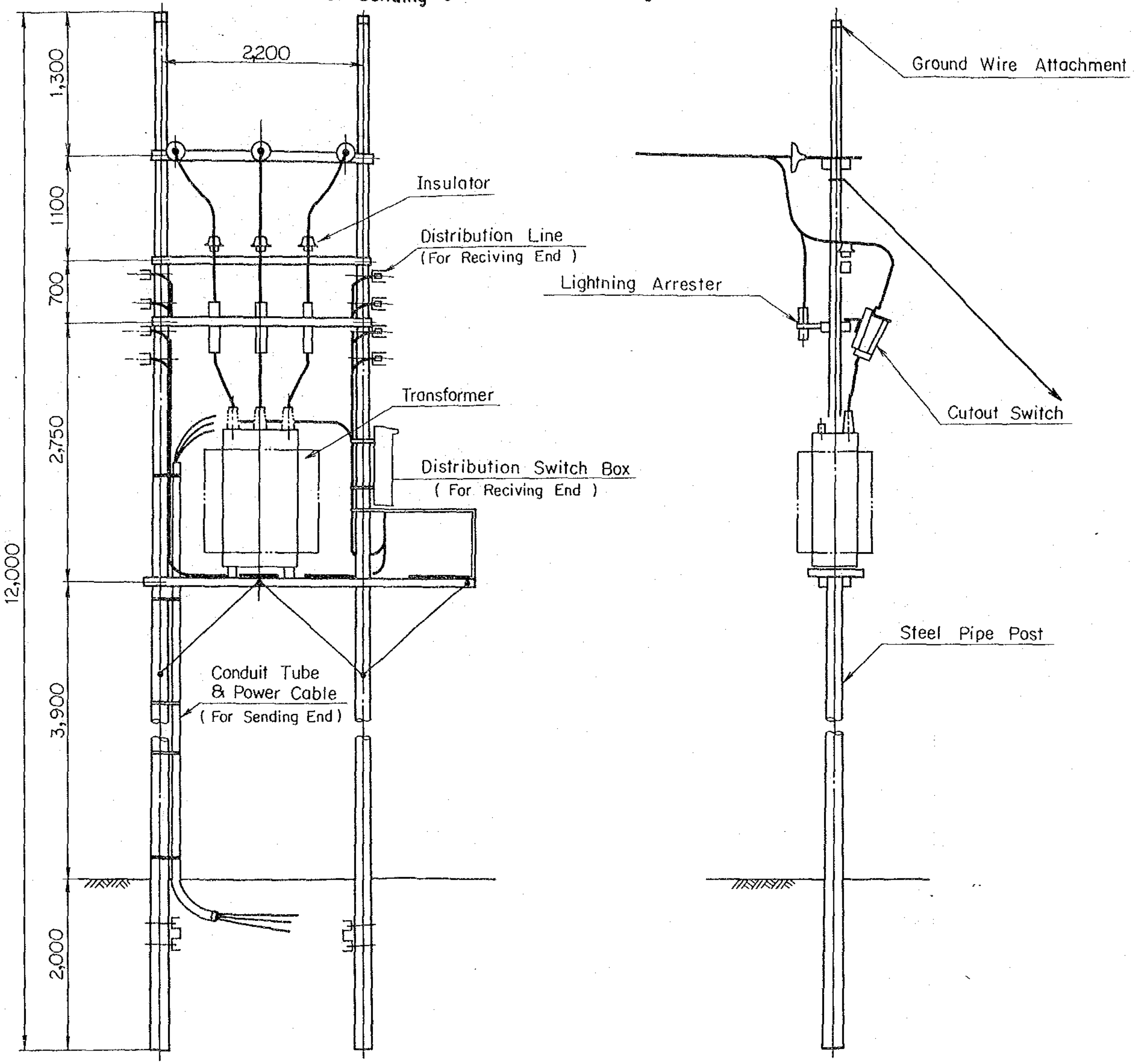

PROFILE OF PENSTOCK AND POWER HOUSE
EL. 1,040 m
1,030
1,020
1,010
1,000
990
980
℄ OF TURBINE AND GENERATOR
1,028.00
HEAD TANK
PENSTOCK
1,009.00
1,002.00
1:0.5
5.00
7.50
3.50
DARA RIVER
FWL 988.00
15.00
8.50
36.00
7.50
TYPICAL SECTION
D=.80
1.50
SECTION A-A
(PENSTOCK)
CONCRETE (t=10)
D=.80
120°
1:0.5
.40
1.20
.40
SECTION A-A (POWER HOUSE)
17.00
5.60
2.70
8.70
3.50
5.00
1.50
600
2.00
2.50
2.10
2.10
4.00
5.80
7.20
PLAN OF POWER HOUSE
5.60
2.70
8.70
6.95
10.05
.25
DUMMY LOAD
GIB CRANE
8.00
1.50
1.80
4.20
2.50
PANEL
3.75
2.00
1.00
2.80
1.00
SECTION B-B
690
600
2.00
3.00
.50
1.50
2.50
7.50
TYPICAL SECTION OF POWER HOUSE
H-250x150
CONCRETE BLOCK
FENCE
1.20
2.30
3.80
1.50
690
600
.25
7.50
.25
PROFILE OF PENSTOCK AND POWER HOUSE
0 10 20 m
PLAN AND SECTION OF POWER HOUSE
0 5 m
TYPICAL AND SECTION OF PENSTOCK
0 1 2 m
JAPAN INTERNATIONAL COOPERATION AGENCY
KINGDAM OF BHUTAN
DAGANA-MICRO HYDRO POWER PLANT
PENSTOCK AND POWER HOUSE
DWG. No. 9

DWG No. 10. 6.6kV T/L Post Arrangment (2-1)

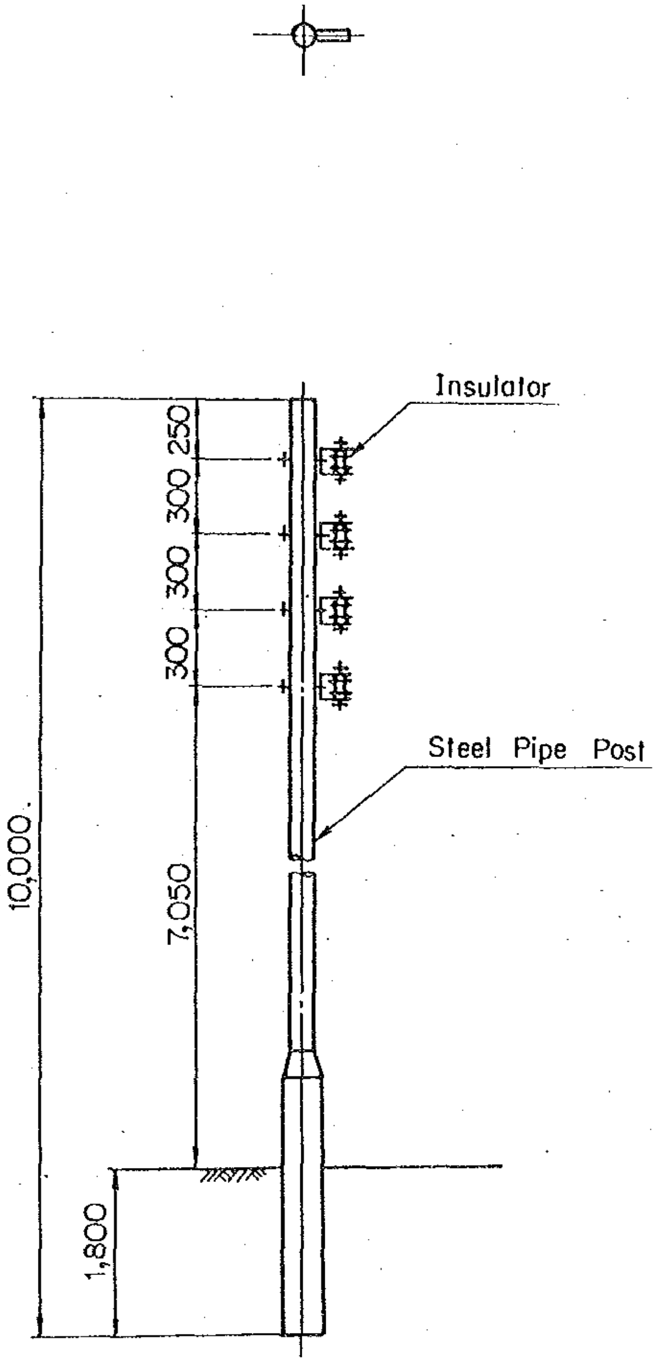


DWG No.11 6.6kV T/L Post Arrangment (2-2)

For Sending end and Reciving end



DWG No.12 400V D/L Post Arrangement



CHAPTER 5
PROJECT IMPLEMENTATION PROGRAM

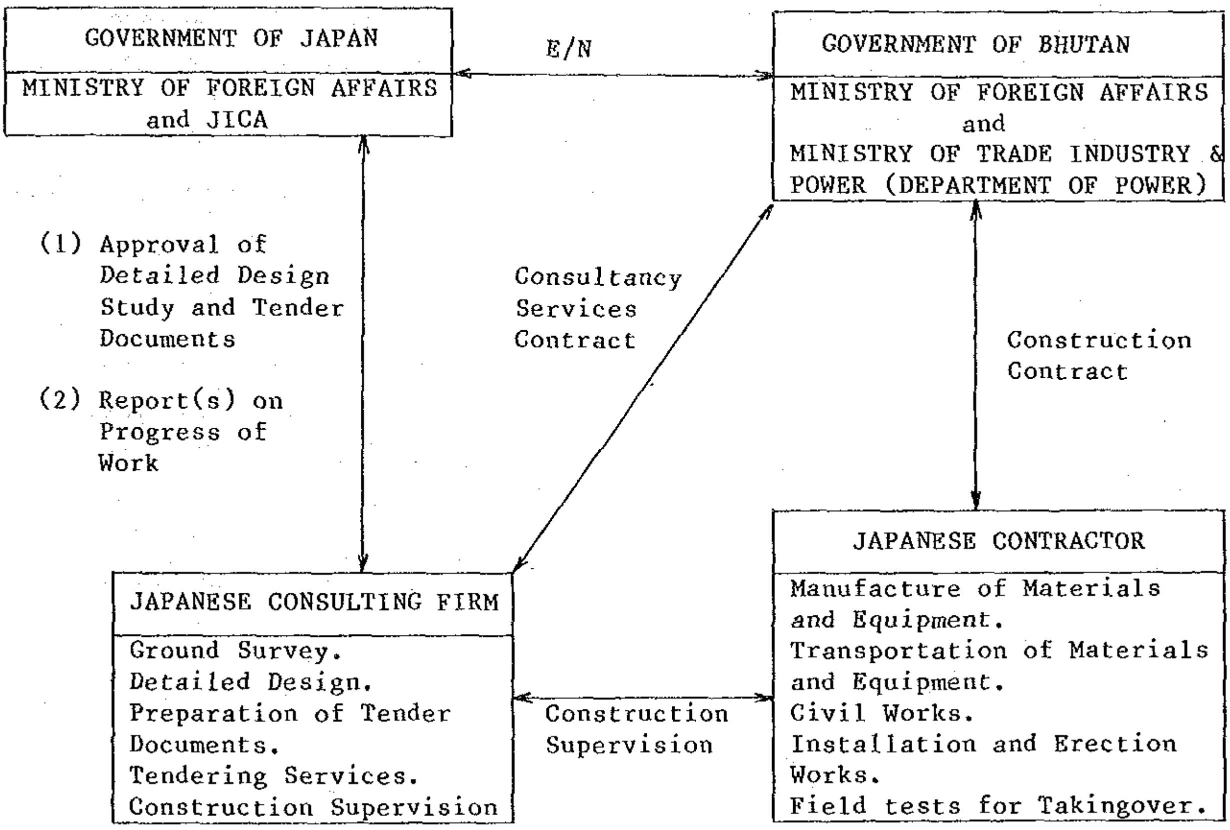
CHAPTER 5 PROJECT IMPLEMENTATION PROGRAM

5-1 System for Implementation

5-1-1 System for grant aid

When the project are implemented on a grant furnished by the government of Japan, the general organization of the system is as shown in Fig. 5.1-1.

Fig. 5.1-1 Project Implementation System



Bilateral negotiation and applications required for this project are to be performed by the Ministry of Foreign Affairs and Ministry of Trade, Industry and Power of Bhutan, while design and installation of equipment, and other such work, will be performed by the Department of Power in the Ministry of Trade, Industry and Power. The organizations of the government of Bhutan and the Department of Power are shown in Appendix 5.30 and Appendix 5.5.

5-2 Scope of Works

The scope of works to be performed for the project by the Governments of Japan and Bhutan is as follows:

5-2-1 Scope of work to be performed by Japanese Government

(1) Provision of equipment and materials as listed in paragraph 4-2 and 4-3, on a grant basis

(2) Sea and land transportation of the above equipment and materials to the project site.

(3) Whole of the related civil works

(4) Whole of the power transmission and distribution line construction works

1) Power transmission line from power generation plants to the transformers for step down voltage at the power receiving end in the power consumption center.

2) Power distribution lines from the step down transformer at the end of the power transmission line to the low-voltage power box installed in the vicinity of public facilities and general consumers.

(5) Installation, adjustment and test run of power generating equipment.

(6) Consulting services related with detailed design, tendering and construction supervision.

5-2-2 Scope of work to be performed by Bhutanese Government

(1) Acquisition of land for sites

(2) Cutting down timbers in work sites, and compensation

(3) Construction and maintenance of road for bringing in equipment and materials

As stated in the minutes of the discussion meeting, the Government of Bhutan shall take necessary measures for the customs clearance and tax exemption of equipment and materials at the port of their landing.

Service cable from the power box to the user shall be the responsibility of user.

5-3 Plan for Detailed Design and Construction Supervision

Upon conclusion of a consultant agreement between a consulting company in Japan and the Kingdom of Bhutan, the consulting company shall start work for designing the systems and for menagement of construction at each site.

5-3-1 Detailed design and tendering

(1) Site survey

Based on the details determined in the basic design and investigation, a detailed topographical survey shall be performed of the sites selected for the construction of civil engineering structures, and the route survey shall be conducted for the power transmission and distribution lines.

(2) Detailed design and preparation of tender documents

Based on the results of detailed investigations performed in paragraph (1) above, the detailed design and tender documents (draft) shall be prepared and consultation shall be held with the Bhutanese organizations concerned.

(3) Tender and conclusion of contract for determination of contractor

The consultant shall advertise for tendering, receive the invitation for participation in tendering, hold orientation for tendering and issue the tender documents. After a lapse of a certain tendering period, the consultant shall evaluate the tenders as soon as he receives them. Then, the executing agency of Bhutan will conclude the contract on behalf of the Government of Bhutan.

5-3-2 Construction supervision

(1) Construction supervision in Japan

Upon conclusion of the agreement, the consultant shall perform work required for authorization of drawings and documents related to fabrication of equipment presented by sub-contractors or for witness tests of the fabricated equipment.

(2) Construction supervision at site

The consultant shall dispatch his personnel to the site at critical points of time, such as the discussions before the commencement of the works, transport of equipment to the site, installation and adjustment, test runs and completion tests for providing guidance to the contractor and his supervision with a view of securely complete the services within the period specified in the Exchange of Note.

5-4 Procurement Plan

The sources of procurement of equipment and materials to be used in the project were decided by comprehensively taking into consideration the result of domestic market survey of Bhutan, price and quality of products manufactured in India and problematical points for construction supervision. The sources of procurement shall in principle be as follows:

(1) Domestic products of Bhutan shall be fully utilized, subject to availability.

(2) Steel materials and minor items manufactured in India, but easily available in the domestic market of Bhutan shall be utilized.

(3) Japanese products shall be used for major equipment and materials other than those listed above.

The specific sources of procurement of equipment and materials are as shown in Table 5.4-1.

(4) Concrete aggregates shall be obtained from the river bed. The states at sites are given below.

1) Shemgang site

The concrete aggregate appears to be available, as the required quantity of gravel can be obtained and screened from the accumulated layer on the river bed of the Burumda river in the vicinity of the project site. However, its sand content is small.

The required quantity of sand will have to be obtained from the accumulated layer on the river bed near the confluence with the Mangde river (approximately 6 km downstream of the project site).

2) Damphu site

As for the concrete aggregates, about half of the required quantity of gravel can be obtained from the accumulated layer at the river bed of the Chanche river near the project site. However, its sand content is small. The shortage in sand and the gravel will have to be made up from the accumulated layer on the river bed near the confluence with the Sankosh river (approximately 20 km by road distance). As the sand available here has a high content of fine particles, these fines will have to be removed.

3) Dagana site

As to the concrete aggregates, the acquisition of both gravel and sand will be impossible from the vicinity of the project site. The required quantity, however, will be obtainable from the accumulated layer on the river bed of the Sankosh river approximately 90 km downstream (road distance).

Table 5.4-1 Source of Procurement of Equipment and Materials

Name of Materials, Equipment, etc.	Source of Procurement			Remarks
	Bhutan	India	Japan	
Construction Materials				
Cement	0			
Steel bar	0			
Steel pipe with small aperture		0		
Shape steel		0		
Nail		0		
Corrugated Iron Plate		0		
Galvanized Wire Mesh		0		
Materials for House	0			
Materials for Form	0			
Penstock			0	
Gate			0	
Screen			0	
Generating Equipment				
Inlet Valve			0	
Turbine			0	
Generator			0	
Control Board			0	
Cable			0	
Materials for Transmission Distribution Lines				
Tubular Steel Pole			0	
Line Conductor			0	
Insulator and Fittings for Stringing			0	
Log for Kicking Block	0			
Pole Transformer			0	
Switching Gear			0	
Lighting Apparatus			0	B.S. standardized goods
Receptacle (plug socket)			0	- do -

5-5 Construction Plan

5-5-1 Construction contract system

The construction work of the project shall be executed under a general contract system, based on the contract to be concluded between the Government of Bhutan and the Japanese juridical person concerned. The contractor shall be selected through tendering and tender evaluation procedures. The construction contract signed between the Department of Power and the Japanese contractor as aforementioned will take effect upon its approval by the Government of Japan.

5-5-2 Outline of execution of works

(1) Preliminary works

The control points shall be established in the vicinity of each structure, and surveys shall be carried out for establishing the reference points necessary for the works. The works shall be started after the establishment of such reference points. Since the construction period is extremely limited, it shall be necessary to carefully work out the plan for the preliminary works for ensuring a smooth progress of the permanent works and to execute the works in the shortest possible period.

For the routing of power transmission lines, a route survey shall be conducted before the commencement of the work to determine the positions where the towers are to be erected. It will be necessary, therefore, to execute these preliminary works in a short period of time immediately after the approval of the contract.

(2) New construction of power generation plant

The work shall be started after careful examination of the timing of bringing in the equipment and materials, and the completion of detailed construction plan as the work sites are scattered. Climatic conditions and other factor shall be taken into consideration when working out the construction plan. In