No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

DEPARTMENT OF POWER MINISTRY OF TRADE AND INDUSTRY
THE KINGDOM OF BHUTAN

FEASIBILITY STUDY
ON
THE DEVELOPMENT
OF
PUNATSANGCHHU HYDROPOWER PROJECT
IN
THE KINGDOM OF BHUTAN

FINAL REPORT

Vol. Ⅱ

ENVIRONMENTAL IMPACT ASSESSMENT

FEBRUARY 2001

ELECTRIC POWER DEVELOPMENT CO.,LTD.

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CONTENTS

ABBREVIATIONS

ADB	ASIAN DEVELOPMENT BANK
BOD	DIOCHEMICAL OXYGEN DEMAND
℃	DEGREES CELSIUS
COD	CHEMICAL OXIGEN DEMAND
DOP	DIVISION OF POWER
EIA	ENVIRONMENTAL IMPACT ASSESSMENT
GLOF	GLACIER LAKE OUTBUST FLOOD
ha	HECTARE
HWL	HIGH WATER LEVEL
IEE	INITIAL ENVIRONMENTAL EVALUATION
JICA	JAPAN INTERNATIONAL COOPERATION AGENCY
kg	KILO GRAM
km	KILO METER
kV	KILO VOLT
m	METER
μ m	MICRO METER
MW	MEGA WATTS (1000 KILO WATTS)
NEC	NATIONAL ENVIRONMENT COMMITTEE
NOx	NITROGEN OXIDES
SOx	SULFUR DIOXIDES
SPM	SUSPENDED PARTICULATE MATTERS
TOR	TERMS OF REFERENCE
WAPCOS	WATER AND POWER CONSULTANCY SERVICES, LTD
WB	WORLD BANK

EXECUTIVE SUMMARY

Preparation of Environmental Impact Assessment Report

The environmental impact assessment report of this project was prepared by the Department of Power (DoP) of Bhutan and Japan International Cooperation Agency (JICA). The report is prepared in detail on the basis of the results of Initial Environmental Examination (IEE) and pursuant to Terms Of Reference (TOR) (Table 13.1) agreed by DoP and National Environment Commission (NEC) through consultation.

For the purpose to investigate impacts from the project implementation and to prepare an environmental impact assessment report, the JICA study team surveyed the natural and social environment around the project site from May, 1999 to March, 2000. An Indian consulting firm, WAPCOS is conducting and co-ordinating surveys including field surveys under contract, and its subcontractor in Bhutan is in charge of surveys on social environment.

The Study Team completed filled survey of environmental impact assessment by March, 2000, and submitted draft report of all results of this filled survey after compilation.

Then, the study team submitted "Punatsangchhu Hydropower Project in the Kingdom of Bhutan, Draft Final Report, Environmental Impact Assessment" to DoP on July, 2000.

DoP carried out public consultation for people living in the project area and the surrounding area. Outline of these explanations and opinions of people in the areas related to are contained in Annex 2 as attached.

Outline of the Project

It is essential to develop energy sources through abundant hydro power in order to vitalize the industry, and improve the socio-economic and standard of living of the Kingdom of Bhutan. The government of this country has decided to adopt a policy of reducing its dependency on oil and giving priority to the development of hydroelectric power generation. In addition, it is one of the important measures for Bhutan to acquire foreign currencies by exporting electric power to neighboring countries.

This project is to construct the facilities of the run-of-river type hydropower, which are included dam, headrace tunnel, penstock, underground powerhouse and tailrace outlet, that can generate power at a peak load in the midstream of the Punatsangchhu, which runs through the Wangdue

Phondrang in the middle west of Bhutan. Its planned maximum output and annual plant capacity are 870 MW and 4,330 GWh, respectively. This will contribute to the improvement of the socio-economic and standard of living of Kingdom of Bhutan.

A 80-m high from riverbed concrete gravity type dam body is planned. Because of run-of-river type, the reservoir area at a high water level is 53 ha. Water is carried about 8 km downstream through an headrace tunnel and power is generated by six generators installed in the underground powerhouse.

Since generated power is for export, it is transmitted to India through transmission lines by a route having less impact on environment.

Current environmental condition

The proposed site is located in the midstream of the Punatsangchhu. It is approximately 10 to 18 km south of Wangdue Phodrang, a town in Wangdue Phodrang region.

The proposed dam site is about 1,090 m above sea level while the proposed tailrace outlet site of the powerhouse is approximately 840 m above sea level. The distance between these two sites is about 8 km. The site of this project and its surroundings, which are surrounded by relatively high mountains, have steep topographic features. As for climate, the annual rainfall is about 550 to 800 mm and the monthly average temperature ranges from 6 ℃ to 28 ℃.

The survey area on nature characteristic for the environmental impact assessment stretches from 10 km upstream from the proposed dam site to 20 km downstream from the proposed powerhouse site and extends to 2.5 km each from both of the banks of the Punatsangchhu. According to the survey results, because of no large pollution source existing, air around the proposed site and water in the river are in good condition. As for terrestrial flora, existence of a broadleaf forest is noted along the river sides near the riverbed. Pine groves are dominant on the halfway up of the mountain. Many kinds and peculiar species of terrestrial fauna are reported and, according to visual survey, footprint survey and hearing survey results, it is considered that several species designated as endangered and protected species live around the proposed site. Three of fish species are found in the river and Asala as a kind of Carp family is dominant species.

The survey on the social characteristic extends to 2.5 km each from both of the banks along the river from a point about 2 km south of the Wangdue Bridge to a point near Pinsa Village about 38 km down to the south. The survey area has 35 small villages and a population of about 4,200. Almost all the inhabitants are Bhutanese who speak Dzongkha and many of them are engaged in agriculture.

Predicted environmental impact

(1) Geophysical Environment

When the powerhouse and related facilities are constructed, soil erosion and slope collapse may occur due to the collection of ballast and the site preparation. It is necessary to stabilize the soil by reclamation and afforestation.

Since there is no big air pollution source around the proposed powerhouse site, air is clean. The environment may be affected by the generation of dust from the construction work in the process of construction. In order to minimize this impact, various measures including the installation of a cyclone filter and the sprinkling of water will be taken. After the powerhouse is put into operation, nothing will generate air pollutants.

Water may become muddy due to the construction. The impact can be reduced by taking action including the installation of a settling basin. After the powerhouse is put into operation, there will be about 8-km long river sections affected by river diversion. This impact can be reduced by providing an appropriate minimum flow for river condition conservation. Also, since water circulates relatively quickly in the proposed reservoir, there is little possibility that the water quality may deteriorate.

The noise from the construction needs to be minimized by taking measures such as the use of low-noise type machines and standard-conforming vehicles, regulation of traffic, etc. Nighttime construction should be avoided wherever possible.

(2) Biological Environment

Deforestation and submergence involved in the construction and operation of the powerhouse and reservoir were planned so that the area to be affected is as small as possible. A muck disposal site and other construction sites, which are reinstated as a vacant lot after the completion of the work, will be afforested with trees of the same type as that of the neighborhood.

Although the noise from the construction work may affect animal inhabiting near the powerhouse, this is a temporary impact and may not be a menace to the preservation of species. Nevertheless, great care should be taken to carry on the construction.

After the powerhouse is put into operation, there will be about 8-km long river sections affected by river diversion. This impact can be reduced by providing an appropriate minimum flow for river condition conservation.

(3) Economic, Social, and Cultural Characteristics

The resettlement of inhabitants and the acquisition of a construction site are required to construct the powerhouse. Six households will be required to resettle and 27.1 ha of private land need to be acquired. In order to have understanding of residents, it is advisable to make appropriate compensation for the resettlement and land acquisition and move inhabitants based on a carefully thought-out resettlement plan.

Impact mitigation measures

The main mitigation measures to remove, reduce, or lessen the impact of this project on the environment are shown below.

Item	Impact mitigation measures
Physiography, geology and soil	Reclamation of slopes and afforestation for stabilization.
Air quality	Reduce dust from the construction work by installing a cyclone filter and frequently sprinkling water.
Water quality	Carry out proper water treatment such as the installation of a settling basin.
Noise	In order to reduce the noise generated from the construction, employ low-noise type machines whenever possible and at the same time use standard-conforming vehicles and regulate traffic. Avoid nighttime construction.
Biology	Afforest a vacant lot after the completion of the work with trees of the same type as that of the neighborhood. Secure an appropriate minimum flow for river condition conservation in the river sections affected by river diversion. Set up an observation station to prevent trees from illegal deforestation and watch out for poaching and other offenses.
Social characteristics	Make appropriate compensation for the resettlement and at the same time resettle inhabitants based on a carefully thought-out resettlement plan.

Cost for Environmental Mitigation

Cost for environmental mitigation is included the cost required for implementation of the measures for environmental impact mitigation and the cost required for implementation of the environmental monitoring program.

The total cost required for implementation of the measures will be Nu 211.56 million (approx. US$ 5.04 mil.) which includes measures for flora and fauna, air, water and soil and cost for resettlement and rehabilitation.

The cost required for implementation of the environmental monitoring program will be Nu 1.92 million / year (approx. US$ 0.046 mil. / yr) which includes monitoring program for water, ecology and public health.

Conclusion

In case that the project is carried out, it is possible to develop an energy source through abundant hydro power, which is essential to the improvement in the socio-economic and standard of living that Bhutan is aiming at by vitalizing the domestic industry. It is estimated that the implementation of this project will generate an annual electric power of 4,330 GWh and bring in revenues of approx. 6,900,000,000 Nu/year (in terms of 1.5 Nu/kwh) from the sales of electric power. In addition, it will contribute to the local economy by creating employment, roads maintenance, and stimulating the growth of other sectors such as manufacturing industry.

In addition, environmental impact caused by this project will be minimized and mitigated by the state-of-the-art technology. The impact in the process of construction is estimated at a minimum. All the required mitigation measures will be taken.

On the other hand, if this project is not carried out, Bhutan may lose an opportunity to acquire foreign currencies from export of electric power to India.

CHAPTER 1

POLICY,LEGAL AND ADMINISTRATIVE FRAMEWORK

CHAPTER 1. POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

1.1 Power Development Policy of the Royal Government of Bhutan

At present, development of energy resources and their utilization are important issues of Bhutan. Until now, people of the nation have mainly utilized firewood as energy source. Use of petroleum fuel and natural gas for domestic fuel and transportation is being popularized currently. However, all of these energy sources have to be imported and therefore are imposing economic burden to the society. In order to activate industrial activity and upgrade social economy and living conditions, development of the abundant hydropower resource of the nation becomes indispensable. Recognizing the energy resource issue, Bhutan government gives first priority now to the development of the nation's hydropower energy.

In 1995, electric power supply capacity of the nation was 360 MW. Output of Chhuka hydropower plant, which started commercial operation in 1988, is 336 MW. This output shared about 93% of total power capacity of the nation. On the other hand, electricity peak demand in 1996 of the nation was about 70.4 MW, which occupied only about one fifth of available total power capacity. Therefore, most of electricity output of Chhuka H.P. plant has been expoted to India. Relying on import from foreign countries for the supply of various agricultural products and the necessities of life requires export of the national products from the nation for earning foreign currency. Therefore, export of electricity becomes an important policy of the nation. There are four main river basins in the nation, namely Amochhu, Wangchhu, Sankoshchhu and Manachhu. Potential total hydropower capacity of the nation is estimated to be over 20,000 MW. Therefore, it is reasonable and understandable that development of hydropower is a key subject for developing social economy of the nation.

Division of Power, The Ministry of Trade and Industry of the government is responsible for planning and development of energy and electric power resources. Table 1.1 shows the electric power development plan of the nation in 1998.

1.2 Environmental Considerations for Hydropower Development and Institutional Framework

Bhutan is in a unique position for a developing country in that most of its natural environment remains virtually intact. Because of the great variety of plants and animals within Bhutan , the nation has been identified as one of ten global biodiversity hotspots by Norman Myers since 1988. Moreover, Bhutan has been identified to be located at the center of 221 global regional endemic species of birds of the world. There are more than 50 species of rhododendron, various medicinal herbs inhabit in Bhutan. Blue poppy (Meconopsis grandis) which is the national flower and inhabits in high mountainous area is

unique and vary famous around the world. The rare animals Takin (Burdorcas taxicolor), snow leopard, golden langur, tiger, elephant and so on also inhabit in Bhutan.

The Royal Government of Bhutan adopted Rio Declaration on Environment and Development and became a signatory to both the Rio Convention on Biological Diversity and the United Nations Framework Convention on Climate Change. The National Assembly of the government has rectified both the Conventions in 1995. Thereby the nation has made commitment that the process of developments will be proceeded in consistent with maintaining environmental and cultural integrity of the country.

In 1995, the National Environmental Commission (NEC) was founded in the central government to be responsible for national environmental management which will enable to achieve sustainable development of the country. Establishment of institutional framework and strengthening of the environmental management capabilities have been made under the leadership of the NEC, and under the technical and financial assistance from The Asian Development Bank and various foreign countries to date. Through such efforts, various environmental laws, ordinances and guidelines have also been formulated. Final versions of environmental guidelines for various industrial sectors were adopted in February 1999. The guidelines covers those for hydropower, power transmission lines, mining and mineral process9ing, high ways and roads, forestry, etc. The guidelines have been established with making references to those formulated by the World Bank and ADB, and also those of India, Thailand, Norway and Canada. It is required that the guidelines have to be utilized in conjunction with the "Institutionalization and Strengthening of the Environmental Assessment Process in Bhutan - Reference Document (NEC, 1999)". The following is the list of various regulations and guidelines which are related with hydropower development projects:

1) "Strategic Environmental Assessment", NEC, February 1999
2) "Environmental Assessment Process Manual", NEC, February 1999
3) "Hydropower, Sectoral Guidelines", NEC, February 1999
4) "Power Transmission Lines, Sectoral Guidelines", NEC, February 1999
5) "Forestry, Sectoral Guidelines", NEC, February 1999
6) "Ambient/Discharge Standards and Environmental Sampling Manual", NEC, February 1999
7) " Land Act, Volume KA", 1991, Royal Government of Bhutan
8) "Bhutan Fishing Rules", 1992, Royal Government of Bhutan
9) "Biodiversity Action Plan for Bhutan", 1998, Ministry of Agriculture

The document of above item 2) "Environmental Assessment Process Manual" has classified various development projects into the following four categories depending on the extent of their potential environmental impacts:

- **Category A** : Proposals, which have potentially significant impacts, those will require a full environmental assessment to establish the extent and magnitude of potential impacts. For example, major hydropower development projects belong to this category.

- **Category B** : Proposals which have potentially significant impacts, however management and treatment options are well developed and understood. These projects can be adequately managed through application of detailed management measures and monitoring plans. For example, industrial emissions control facilities belong to this category.

- **Category C** : Proposals that have moderate impacts which tend to be repetitive. For example, certain aspects of road construction, forest harvesting practices, etc. belong to this category.

- **Category D** : Proposals that have moderate and easily managed impacts. For example, certain waste disposal and hygiene practices for restaurant business belong to this category.

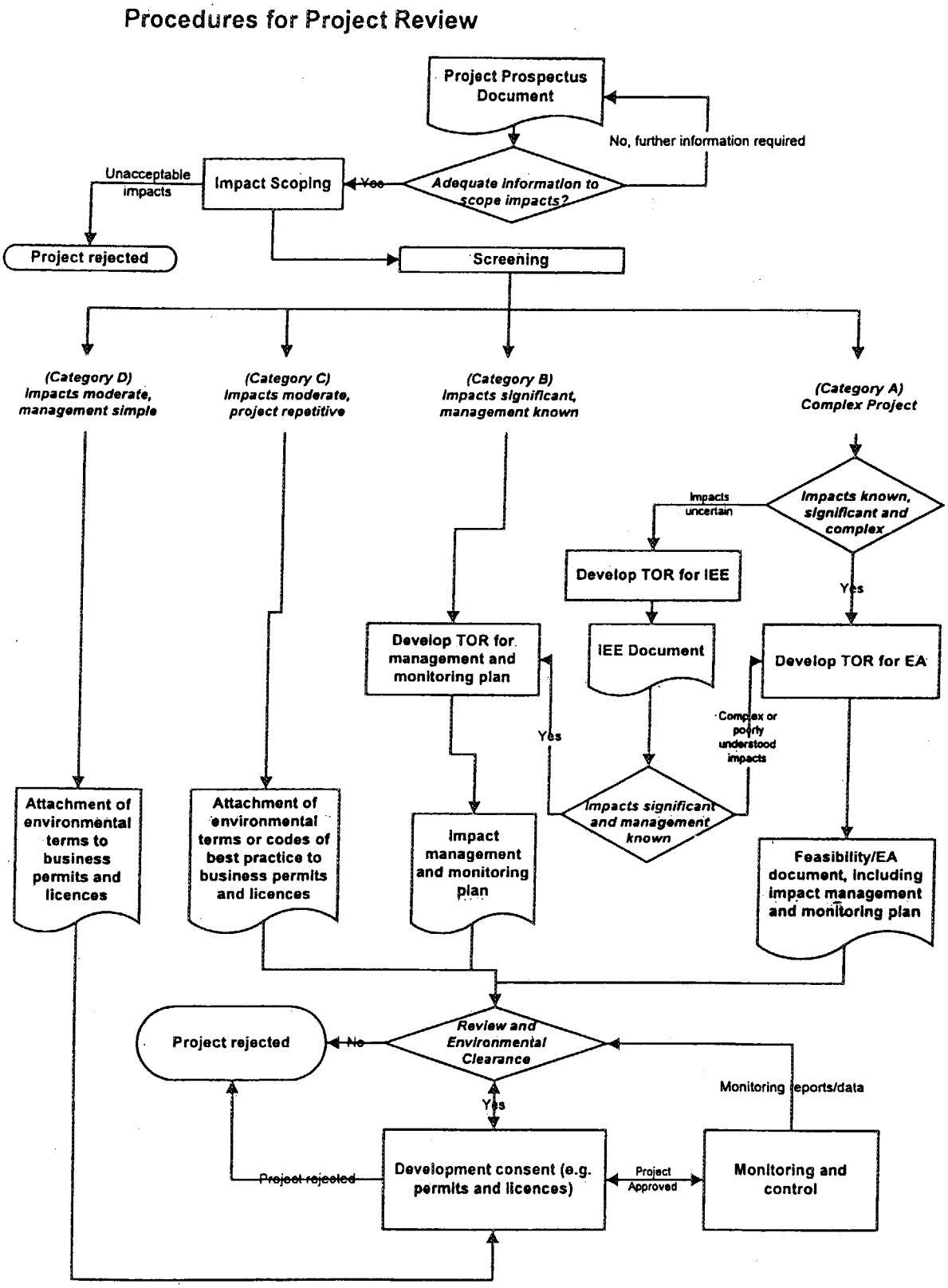
Category A, B and C projects will require environmental clearance by the NEC before development consent is provided by the competent authority. Development consent of Category D projects can be issued by the competent authority without obtaining an environmental clearance by the NEC. On the other hand, the "Reference Document" listed above has provided a clear procedure for various development projects review (see Fig. 1.1). From this procedure, it is clear that a major hydropower development project will require a full environmental assessment.

Regarding details of concerned regulations and guidelines, descriptions will be provided in the following sections as needed.

Table 1.1 Power Development Plan of DoP

Status	Project Name	District	Description	Scheme type
Under Construction	Basochu	Wangdue Phodrang	Installed Capacity: 61 MW Firm Capacity: 12 MW Energy: 291 GWh Completion: 2000/01	Run of River
	Kurichu	Mongar	Installed Capacity: 60 MW Firm Capacity: 24 MW Energy: 322/400 GWh Completion: 2001/02	Run of River
	Tala	Chhukha	Installed Capacity: 1,020 MW Firm Capacity: 168 MW Energy: 3,962 GWh Completion: 2006/07	Run of River
Planned and Studied	Bunakha Reservoir	Chhukha	Installed Capacity: 180 MW Firm Capacity: - MW Energy: 688 GWh Completion: 9FYP	Storage
	Mangdechhu	Trongsa	Installed Capacity: 425 MW Firm Capacity: - MW Energy: 1,800 GWh	Run of River
	Punatsangchhu	Wangdue Phodrang	Installed Capacity: 760 MW Firm Capacity: 125 MW Energy: 3,305 GWh	Run of River

Source: Division of Power, 1998



Source: Institutionalizing and Strengthening of the Environmental Assessment Process in Bhutan, Reference Document

Fig. 1.1 Procedures for Project Review

CHAPTER 2

DESCRIPTION OF THE PROPOSED PROJECT

CHAPTER 2 - DESCRIPTION OF THE PROPOSED PROJECT

2.1 Location of Project-related Development Sites

This project is planned to be constructed in the middle square area of the Punatsangchhu (Sankosh River) which originates in the Himalayas, runs from the north to the south of the western central part of Bhutan, and join the Brahmaputra River in India. The proposed site is located to the south of Wangdue Phodrang town in Wangdue Phodrang Region. The scope of the Environmental Impact Assessment ranges from 10 km upstream of the proposed dam site, from 20 km downstream of the proposed power station site, and 2.5 km wide from either shore of the river. Figs. 2.1 to 2.3 show the proposed sites and the scope of the surveys.

Two access routes are available to the proposed project site, i.e. the route of Phuentsholing – Chhukha - Simtokha – Wangdue – Phodrang and the route of Geylephung – Damphu route.

2.2 General Layout of Facilities at Project-related Development Sites

This project is to construct a run-of-river power station which is able to adjust to peak generation at the site approximately 10 to 18 km to the south of Wangdue Bridge which is built over the Punatsangchhu. Expected generating capacity of the proposed power station will be 859 MW as the maximum output and 4,330 GWh as the total yearly output.

The dam body will be of concrete gravity type, 80 m high from riverbed, and the area of its reservoir on the high water level will be 53 ha. The water in the reservoir will be carried approximately 8 km downward through the underground tunnel and power generation will be conducted with 6 generators installed underground. Table 2.1 and Fig. 2.4 indicate the specifications of the project and the layout of facilities respectively.

2.3 Main Design Specifications of the Project

The purposes of the project are to conduct Feasibility Study (F/S) on Punatsangchhu Hydropower Project based on the international standards which can be examination materials of international financial institutions, to investigate into methods of financing and repayment of the raised fund so that activities of the Bhutan Government toward the project may be supported.

2.4 Pre-construction Activities

Details about the contents of pre-construction activities are determined at the future detail design stage. Activities started at the first stage are reform of the existing roads, construction of bypass tunnel at

dam site, temporary bridge, newly established road at the left bank, foundation and construction activities at laborer's camp, public buildings, arrangement of telecommunication, electric facility for construction, etc. Next to these activities, foundation of motor pool and repair factory, gas station, construction activities at laborer's camp, medical treatment center, water supply and drainage systems, sewage management system, gunpowder storage place, other construction facilities will be constructed.

2.5 Construction Activities

Major structures are dam, tunnel, head tank, penstock and power station. Layout of these structures are shown in Fig.2.4. Approximately 72 months of period and 5,000 of technicians and workers will be required for these construction.

Transportation of construction materials is scheduled to be used a road from Phuntsholing through Thimphu as a major route. Since heavy and large materials are transported by larger vehicles, it is planed to reinforce existing roads if it necessary.

Aggregate required for construction work will be prepared from borrow area at Hesothangkha and muck generated from dam and tunnel excavation work. The borrow area for excavation is located on riverbed at the upper stream from the proposed dam site. The thickness of ancient sediments at the area seem to reach 50-60m.

2.6 Project Schedule

Project schedule is shown in Fig2.5.

2.7 Staffing and Support System for Construction and Operation

Approximately 5,000 engineers and general laborers will be employed per year for the construction work. It is assumed that around 150 engineers would aggregate in the operation phase after completion.

2.8 Facilities and Services

Major facilities required by construction and operation workers are construction office, camp facilities, hospital, etc. Appropriate drainage and waste treatment systems will be established to the construction office. The office will be scrapped after the construction. Camp facilities will be constructed at 3 places, and reuse of these facilities after when the construction work is finished will be discussed later . The hospital will have proper equipment to cope with regular health check and accident.

Details will be decided at future detail design stage.

Table 2.1 Salient features of Punatsangchhu Hydro-Power Development Project

Reservoir	
Catchment Area, km^2	5796
High Water Level, ELm	1161.5
Low Water Level, ELm	1147.0
Available drawdown depth hd, m	14.5
Sedimentation level SWL, ELm	1142.0
Gross storage capacity, 10^6m^3	12.49
Effective storage capacity Vg, 10^6m^3	4.39
Dam	
Type	Concrete gravity
Crest length, m	265
Dam height from river bed hdam, m	81
Dam height from foundation Hdam, m	141
Dam volume Vdam, 10^3m^3	830
Headrace	
Type	Circular/pressure
Inner diameter D(v=4m/s), m	7.4
Tunnel length L, m	7053 / 6989
Penstock (main part)	
Type	shaft
Inner diameter D(v=7m/s), m	5.6
Penstock length L, m	2x438
Powerhouse	
Type	Underground
Number of unit	6
Size, m	20Wide, 38High, 114Long
Tailrace (main part)	
Type	Circular/pressure
Inner diameter D(v=4m/s), m	7.4
Tunnel length L, m	360 / 320
Development plan	
NWL, ELm	1154.3
TWL, ELm	845.0
Gross head Hg, m	309.3
Effective head hl, m	286.3
Loss of head hl, m	23.0
Peaking time Tp, hr	4
Maximum discharge Qmax, m3/s	348
Installed capacity Pmax, MW	870
Turbine type	Fransis
Firm output Pf, MW	859
Firm energy Ef, GWh	1268
Secondary energy Es, GWh	3062
Total energy Etotal, GWh	4330
Economic evaluation	
Project cost (price in 2000 year), 106$	813
Unit construction cost per kW (*1), $/kW	934
Nu/kW	41.754
Unit construction cost per kWh (*2), $/kW	0.188
Nu/kW	8.4
B/C	1.35
B-C, $10^6$$	1.98

*1: Unit construction cost per kW = Project cost/Pmax

*2: Unit construction cost per kWh
= Project cost x Annual cost ratio / (Effective annual average energy)
=Project cost x 12% / (Annual average energy x(1-0.02)x(1-0.003)x(1-0.003)x(1-0.02))

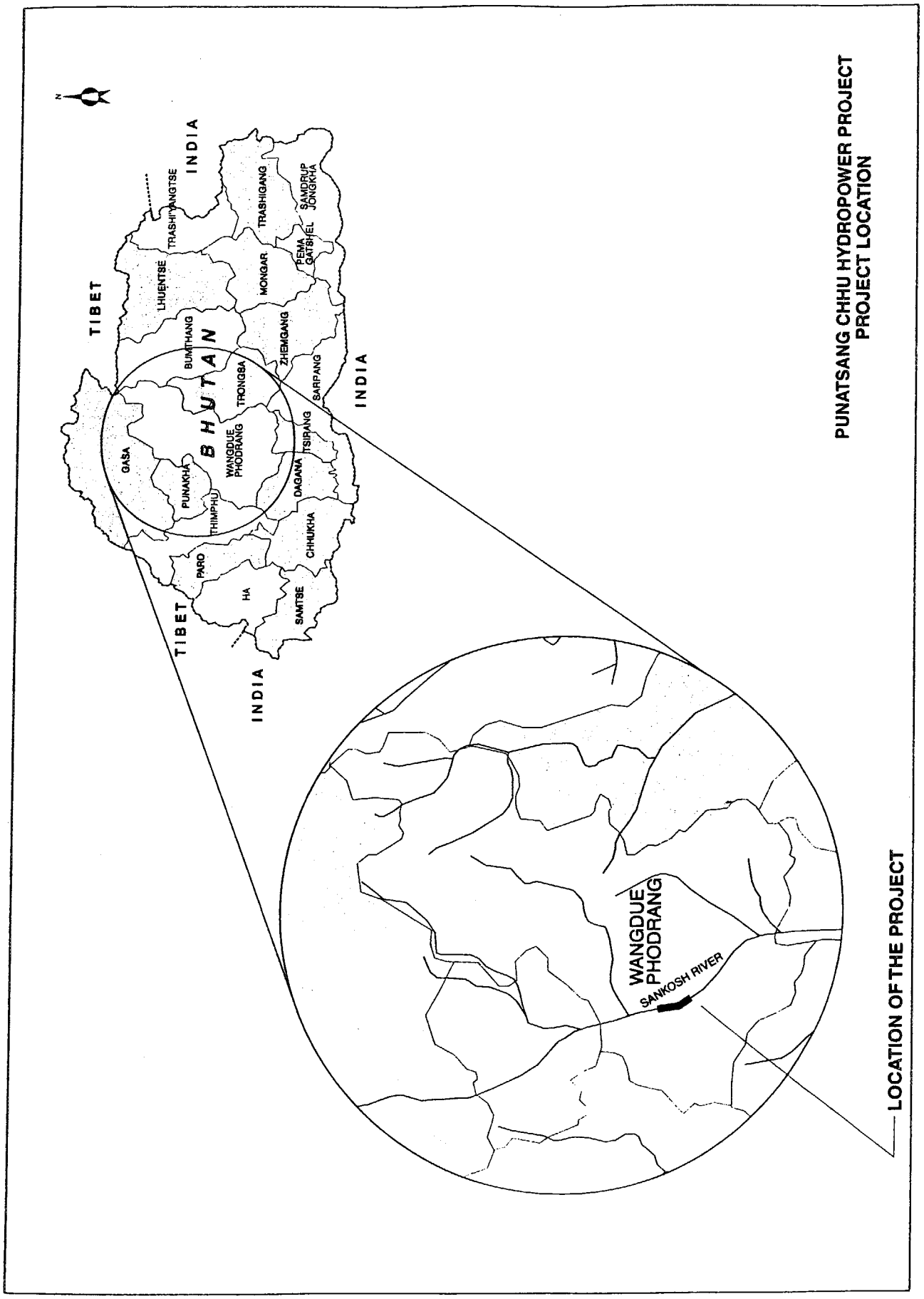
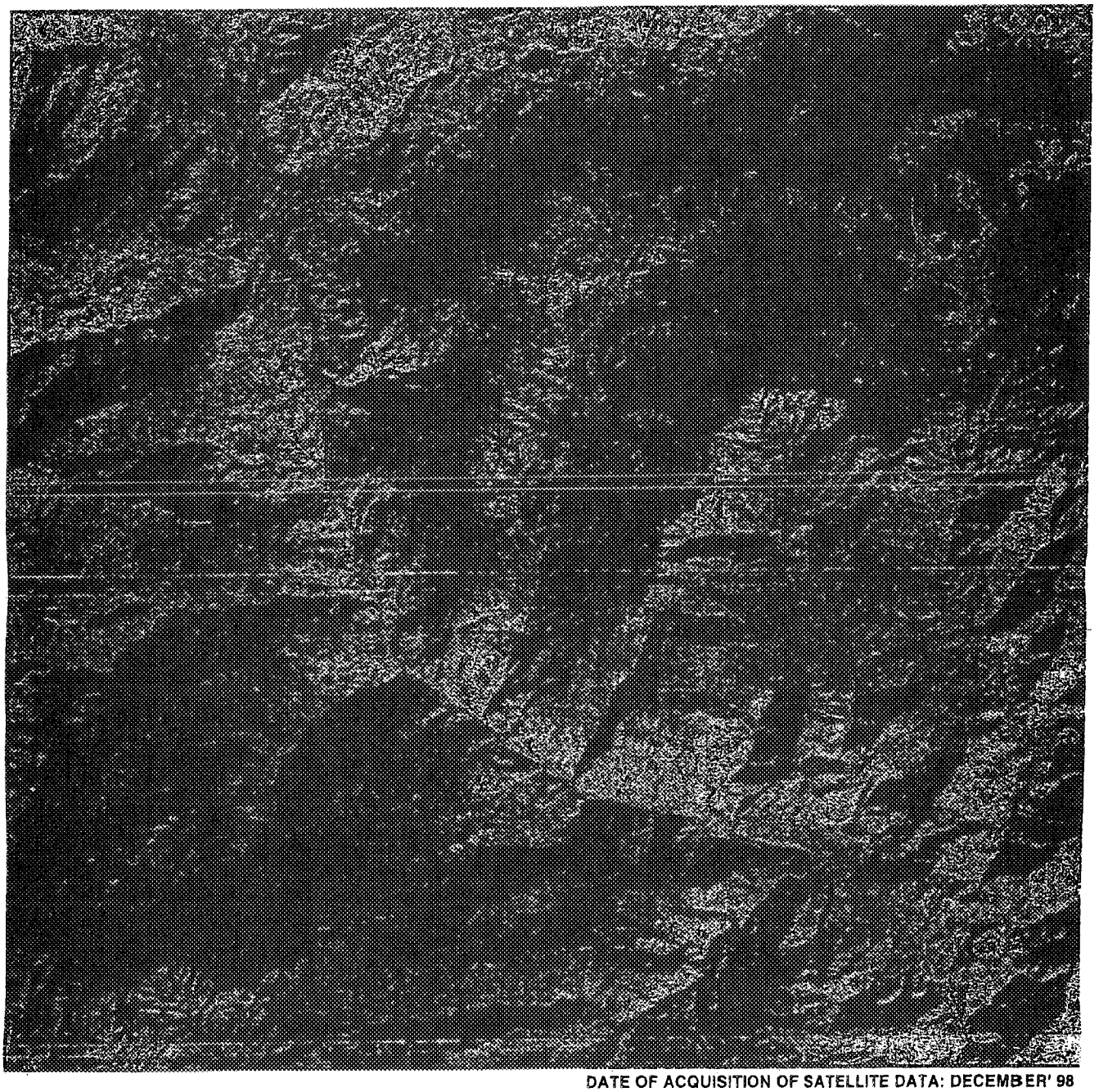


Fig. 2.1 Location of the Project Area

SATELLITE IMAGERY OF THE STUDY AREA AS SEEN BY IRS-1C (LISS III SENSOR)



DATE OF ACQUISITION OF SATELLITE DATA: DECEMBER' 98

Fig. 2.2 Satellite Imagery of the Study Area as Seen by IRS-1C (LISS III SENSOR)

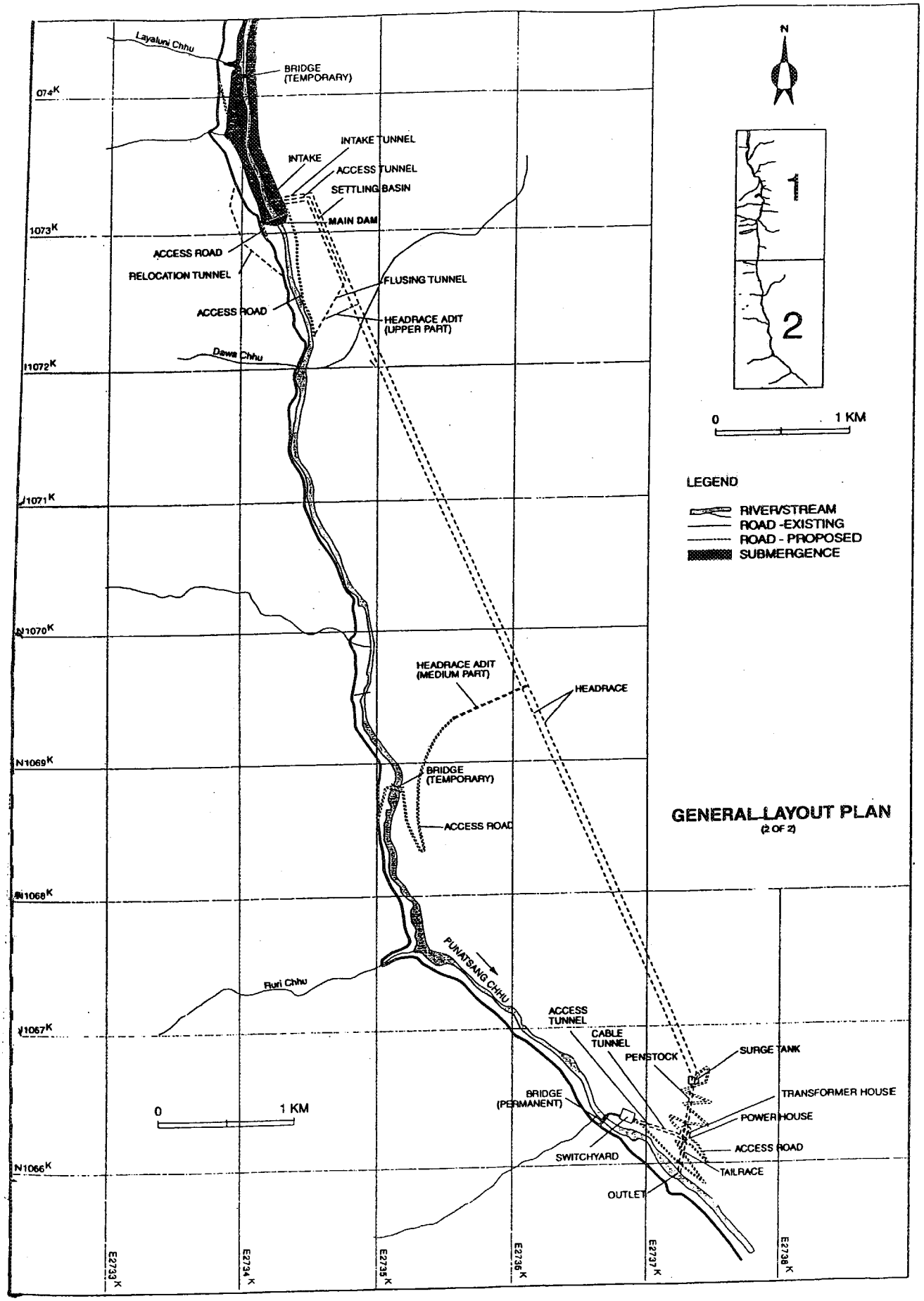


Fig. 2.3 (1) General Layout Plan

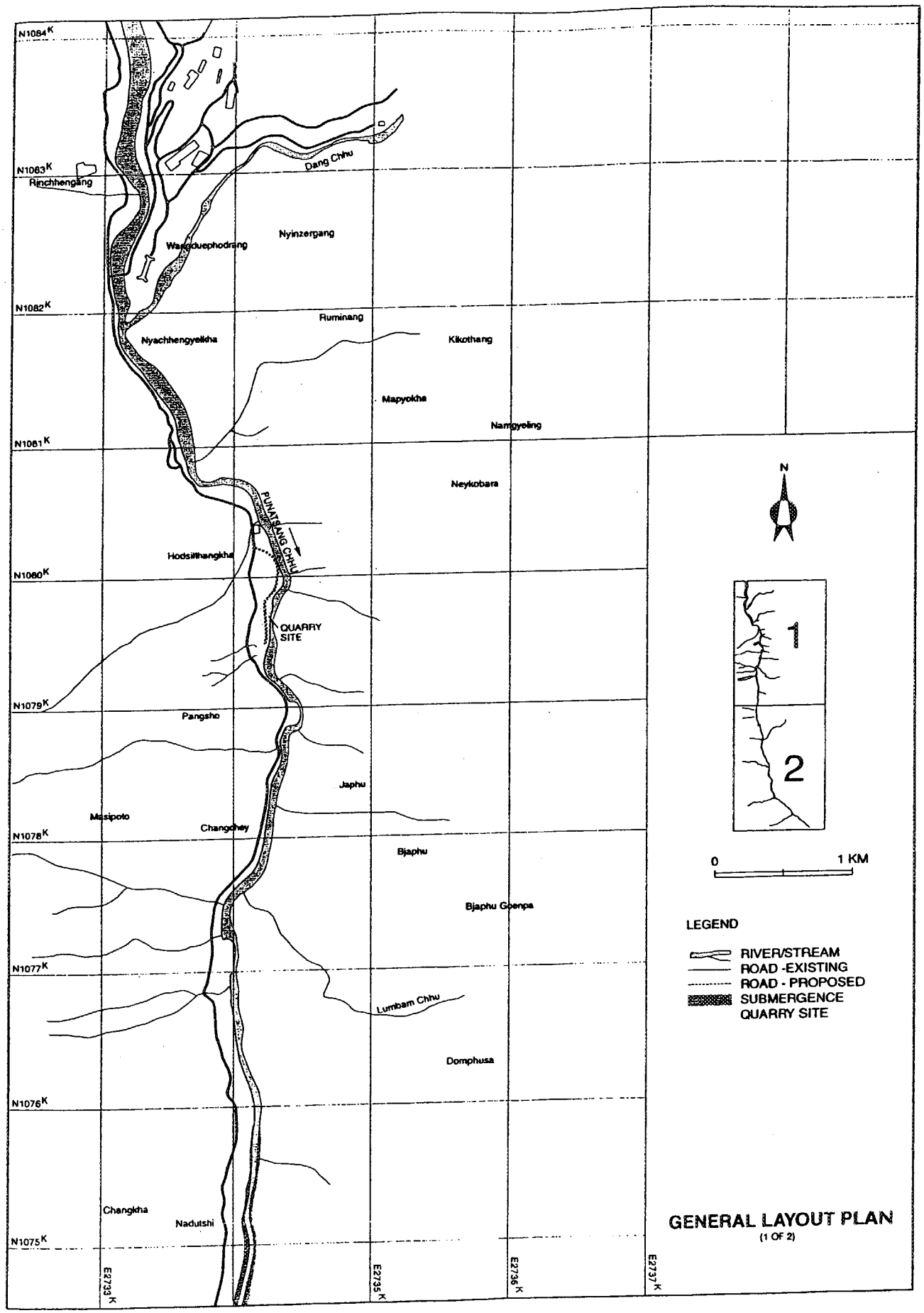
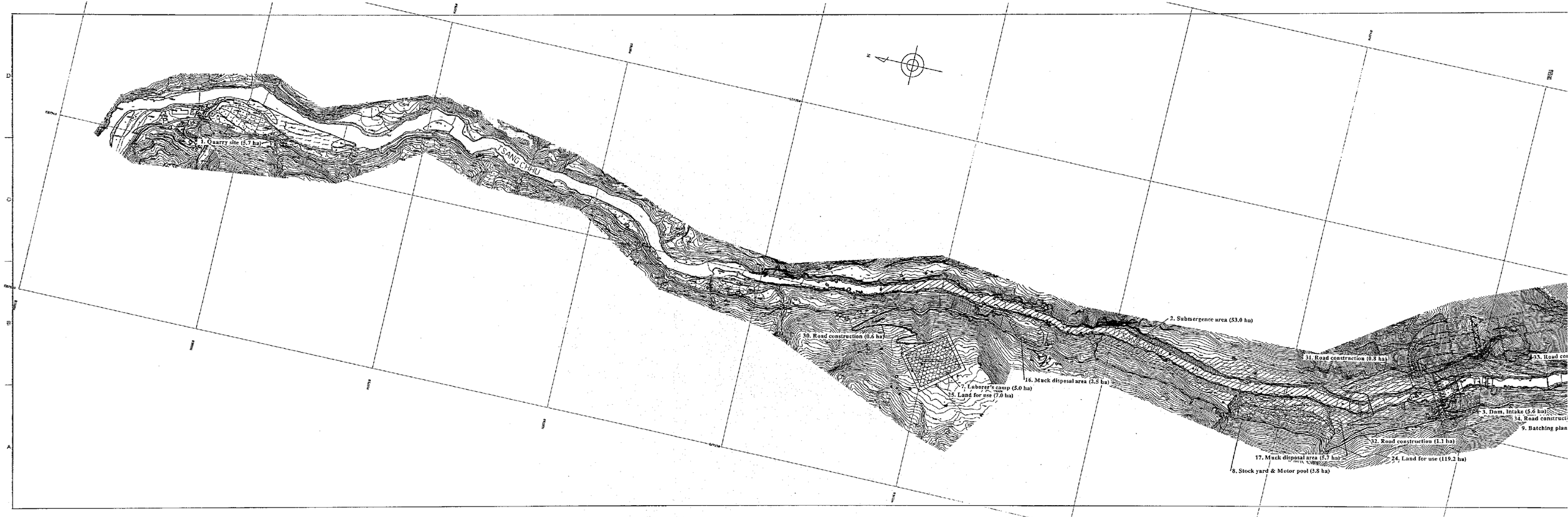


Fig. 2.3 (2) General Layout Plan


1. Quarry site (5.7 ha)
TSANG CHHU
2. Submergence area (53.0 ha)
30. Road construction (0.6 ha)
31. Road construction (0.8 ha)
16. Muck disposal area (2.5 ha)
7. Laborer's camp (5.0 ha)
25. Land for use (7.0 ha)
3. Dam, Intake (5.6 ha)
9. Batching plan
32. Road construction (1.1 ha)
17. Muck disposal area (5.7 ha)
24. Land for use (119.2 ha)
8. Stock yard & Motor pool (3.8 ha)

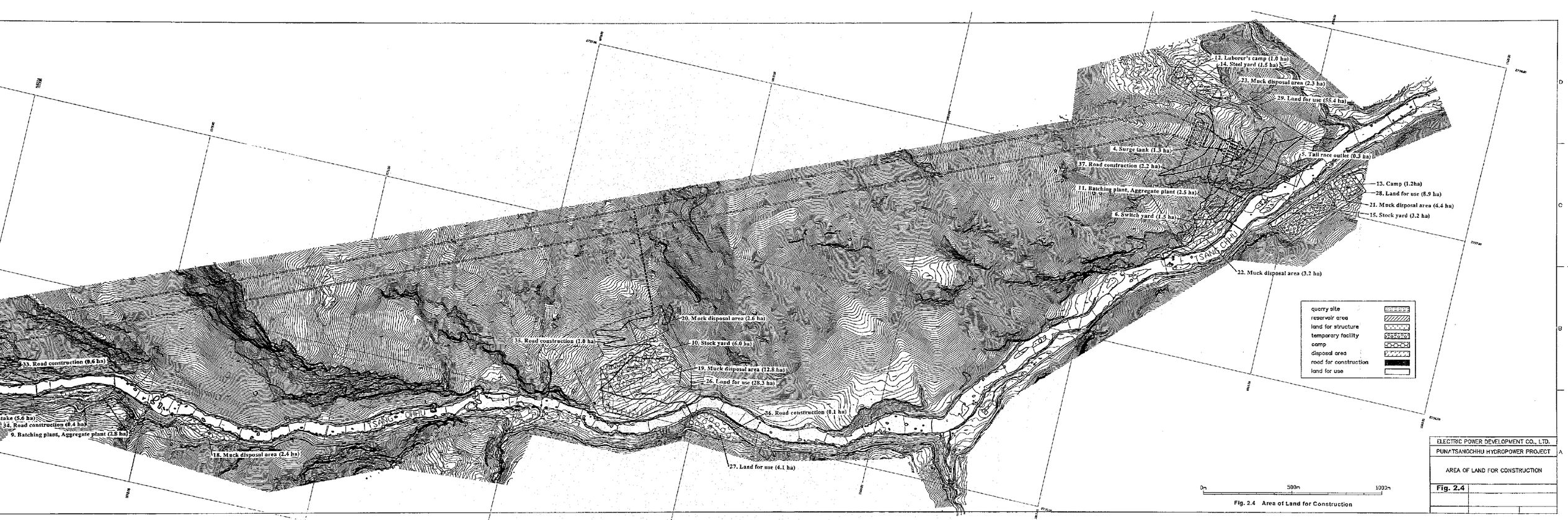
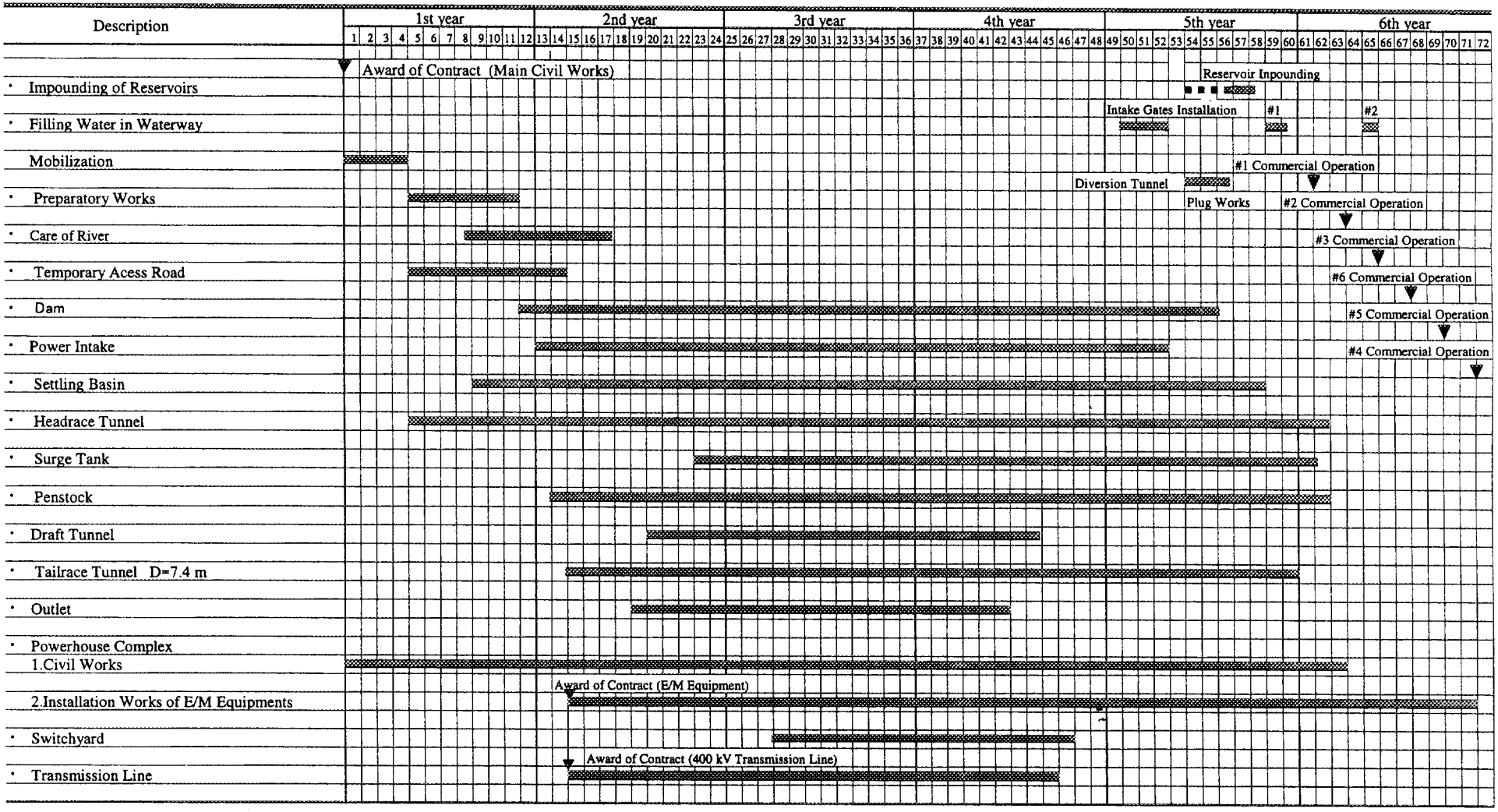


Fig. 2.4 Area of Land for Construction

ELECTRIC POWER DEVELOPMENT CO., LTD.	
PUNATSANGCHHU HYDROPOWER PROJECT	
AREA OF LAND FOR CONSTRUCTION	
Fig. 2.4	

Fig. 2.5 CONSTRUCTION SCHEDULE, DAM AND WATERWAY, PUNATSANGCHHU PROJECT



CHAPTER 3

DESCRIPTION OF THE ENVIRONMENT

CHAPTER 3 - DESCRIPTION OF THE ENVIRONMENT

3.1 Physical Environment

3.1.1 Geology, Topography and Soils

3.1.1.1 Geology

The country of Bhutan is situated among India, Tibet and Nepal with its northern side adjacent to Himalayas, the southern side to Assam and West Bengal division in India about several hundred meters above the sea. Therefore, the physiography of the entire country of Bhutan goes downward for about 150 km in the south to north direction from the northern mountainous high land of more than 5,000 m above the sea to several hundred meters above the sea, and four main rivers (Amochhu, Wangchhu, Sankoshchhu and Manaschuh) are running through the country each having a relatively steep incline. The proposed site of Pnatsangchhu hydropower project is located in the middle drainage basin of the Punatsangchhu and approximately 10 km downstream of Wangdue Phograng town. The proposed dam site is approximately 1,120 m above the sea level, and the proposed tailrace outlet position of the powerhouse is about 880 m above the sea level. The distance between them is approximately 8 km. As indicated in Figs. 2.1 – 2.3, this proposed site and its vicinity is of steep physiography.

3.1.1.2 Topography

The Himalayas are said to be one of the youngest orogenic zones in the world. The Bhutanese Himalayas are subdivided into the following four orogenic districts:

* Sub Himalayas
* Lower Himalayas
* Higher Himalayas
* Tethys Himalayas

This project is located in Lower Himalayas district. The geological structure of Himalayas is complicated having a intersection of many faults and thrusts. The entire zone of the proposed site is classified as Zone-V out of Indian aseismatic classes (IS: 1893 (1984), Bureau of Indian Standards). The proposed dam site is located approximately 10 km down the river from Wangdue Bridge. A lot of traces of landslides in the past are found in the entire zone and boulders scatter along the riverbed. On the both sides of the dam site, a lot of rocks are exposed. Ancient sediments are found in the riverbed down the river from the proposed dam site, whose thickness seem to reach 50 – 60 m. These sediments mostly consist of conglomerates weakly bonded with one another. The location of the underground powerhouse is assumed to be approximately 8 km down the river from the proposed dam site covered with hard and yet folded igneous rocks whose surface has been weathered.

3.1.1.3 Soils

Soil of the vicinity of the river, or the proposed site mostly consists of talus and detrital conglomerates which fell down from precipices on both sides of the river. The soil along the river often includes detrital conglomerates, gravels and pebbles formed through actions of the river flow. Soil sediments of colluvial deposits (mixture of round alluviums and rock fragments) are also recognized in this zone. These sedimentary seams are considered to be 50 – 60 m thick and formed through soil erosion by the river water during a long period of time.

Since chemical fertilizer or insecticide is seldom used in the farms along the river, no soil pollution with chemical substance may have occurred.

In the field survey, soil was sampled from 4 points indicated in Fig. 3.1. Tables 3.1 and 3.3 show the quality and grain-size distribution of sampled soil. Soil is either neutral or alkaline containing extremely small quantities of organic substances. Heavy metal contents are in average densities.

3.1.2 Meteorology

3.1.2.1 Climate

The proposed site is situated at 27°20' – 27° 23' of the north latitude and 89°55' of the east longitude and approximately 880 – 1,120 m above the sea. It may be classified as a tropical to subtropical zone from its longitude. However, owing to its height of around 1,000 m above the sea level and cold air blowing down from Tibet across Himalayas in winter, the temperature there is often below zero.

3.1.2.2 Temperature

According to the data obtained by Wangdue Meteorological Observatory, the closest observatory from the proposed site, from 1990 to 1998 (see Table 3.4), the average monthly temperature is 28.1℃ at maximum in August, while 5.7℃ at minimum as observed in December and January.

3.1.2.3 Precipitation

Table 3.5 shows the records of precipitation at the proposed site and in its periphery from 1990 to 1998 as obtained by the Wangdue Meteorological Observatory, the nearest observatory station from the proposed site. The total annual precipitation is about 550 – 800 mm. The dry season is from October to May, while the rainy season is from June to September.

3.1.3 Hydrology

3.1.3.1 Physical Characteristics of River

With many glacial lakes in the Luna La area of northern part as its source, the Punatsangchhu runs almost straight from the north to the south of Bhutan, passes Assam District in India and joins the Brahmaputra River running through Bangladesh. Two rivers, the Mochhu and the Phochhu, cross with

each other near the town of Punakha situated at approximately 30 km up the river from the proposed site. The jointed river further joins the Tangchhu running from the east at a point near the town of Wangdue Phodrang Approximately 20 km downstream. The proposed dam site is approximately 10 km down the river from the town of Wangdue Phodrang, and the proposed powerhouse site is further downward at approximately 8 km down the river. Between the two sites, three branch rivers, i.e. the Dawachhu, the Basochhu and the Rurichhu join one another. The proposed dam site is about 1,120 m above the sea, while the proposed tailrace outlet position of the powerhouse is about 880 m above the sea, and the difference between the two heights is about 240 m.

The river inclination at the proposed site is about 1/30, and both shores of the river are steep valleys.

3.1.3.2 Flow Rate

Wangdue Flow Gaging Station which is the nearest observatory station from the proposed powerhouse site is about 10 km up the river from the proposed dam site. The flow rate of the proposed dam site was calculated based on the flow rate observed at this observatory.

Table 3.6 shows the record of flow rates for the period from 1991 to 1999. The average annual flow rate was in the range of about 222 – 386 m3/s, and the minimum flow rate was 62.3m3/s. With regard to the average monthly flow rate, the maximum is 791.3m3/s recorded in August, while the minimum is 65.7 m3/s in February.

Table 3.7 shows the record of observed flow rate (1990-1998) of the Basochhu, a branch of the Punatsangchhu. According to this, although a general characteristic was noted that its flow rate was large in summer and small in winter, the actual record sometimes deviated from the above pattern as seen in the record of 1994.

Table 3.8 shows the result of the trial calculation of flood occurrence probability conducted in Wangdue Flow Gaging Station by using the data of 1992-1997.

3.1.3.3 Square Area of River Stream

The total square area of the river stream of the Punatsangchhu was 12,061 km2, while the square area of the proposed dam site was 5,796 km2.

3.1.3.4 Utilization of River

The population of the vicinity of the proposed site was extremely small. The town of Wangdue Phodrang about 10 km up the river from the proposed dam site is the closest district whose population is intensified. Only a few houses of farmers scatter in the district between the proposed dam site and the proposed powerhouse site. The farmers use spring water coming from the mountainside as their living water. They are practicing a small-scale agriculture utilizing the slope on the mountain mainly for their self-sufficiency. Since they use spring water or water of the branch rivers for irrigation, they do not use

water of the Punatsangchhu in a large scale. Further, they do not seem to practice any fishery or raising fish in the river. Moreover, neither large-scale factories/field offices are operated nor ships are sailing as a traffic means in the entire district.

3.1.4 Air Quality

There is no large factories nor field offices around the proposed site as a large-scale air pollution source except a vehicle repair shop. A national highway runs along the Punatsangchhu as the major trunk road in this district. However, since vehicles drive in a low frequency, the highway is considered as a relatively small pollution source. Consequently, atmospheric condition around the proposed site is in a good condition.

Table 3.9 shows the measurement results obtained through the field survey conducted in December, 1999 and January, 2000. The values of SOx, NOx and SPM revealed clean.

3.1.5 Water Quality

There are towns of Punakha and Wangdue Phodrang upstream of the proposed site and sewage of the residents is exhausted into the river without treatment. However, in view of the large amount of the river water, drainage of such waste water is considered not to be beyond natural purifying capacity of the river. Since population around the proposed site was extremely small and no factory existed there to act as a large water pollution source, river water is in good quality.

As the field survey, analysis of water quality by sampling river water was conducted at three points as indicated in Fig. 3.1. The analysis result of river water sampled in August, 1999 (during the rainy season) is indicated in Table 3.10. According to the survey result, pH was almost neutral and both BOD and COD values were low. Consequently, the quality of the river water is considered as clean.

3.1.6 Noise

Since population around the proposed site was extremely small and as no existence of a factory as a large noise source was recognized, noise level was quite low there. Moreover, since traffic density was low in the national highway running along the Punatsangchhu, no continuous noise was generated.

In a field survey, noise was measured around the proposed site, and the result revealed an extremely low noise level of 37 – 48 dBA (see Table 3.11).

3.1.7 Sediments

The river deposits found in the district between the proposed dam site and the proposed powerhouse site mainly consisted of conglomerates weakly bonded with one another, and the seam thickness seemed to reach 50 to 60 m.

Also, since existence of floats having diameters of 1-2 m was identified here and there, a lot of earth & sand and boulders may possibly move when a flood occurs.

Moreover, because of the steep river inclination (the average inclination is approximately 1/30), suspended matters contained in the water flow is considered to flow downward without being precipitated.

At the time of the field survey, river deposits were sampled at two points as indicated in Fig. 3.1 for examination of soil quality and grain size distribution. The results are as shown in Tables 3.2 and 3.3. The river deposits were either neutral or alkaline with extremely small amounts of organic contents. Concentration of heavy metals were average.

3.2 Biological Environment

The national land of Bhutan is considered as one of the ten hot spots on the earth from a viewpoint of biodiversity, having biogeographic characteristics of both Paleartic and Indo-Malayan districts. Its physiography varies in a distance of about 150 km from the north to south ranging from Himalayan mountainous region of 5,000 m or more above the sea to the low land of only several hundred meters above the sea, and a number of rivers with Himalayas as their source flow through the distance forming a deep valley. Consequently, climate varies depending on the variety of longitudes and altitudes and being affected by seasonal winds blowing from Tibet. Because of these variable physiography and climate, diversified and peculiar fauna and flora live and grow in the environment. This diversified biology has been conserved also because of the lifestyle of the people there to co-exist with natural environment.

3.2.1 Terrestrial Flora and Fauna

3.2.1.1 Terrestrial Flora

Climate of Bhutan consists of three climate; subtropical, warm monsoon, and alpine monsoon. Owing to the diversification of climates and large differences in heights above the sea level, the entire land is covered with complicated vegetation. The national land varies including paddy, banana and citrus fruit production zones (up to 1,300 m above the sea), deciduous tree forests and alpine forest zone. The florae are diversified in full variety including Rhododendrons, Junipers, Mango, Carnivorous plants,

Blue poppies, Leontopodium alpinum, Gentiana, Daphne odora, Rhubarb, tropical plants, pine trees, oak trees, etc.

Around the proposed site, existence of a broadleaf forest is noted along the river sides near the riverbed. Pine groves (Chir pine; pinus roxburghii) were dominant on the halfway up of the mountain.

Vegetation ranging from Wangdue Bridge build in the upstream of the proposed site to the tail-end of the reservoir was confirmed by field surveys at August, 1999 and January, 2000. According to the results obtained, main trees identified to exist in this range were Pinus roxburghii, Sapium insignii, Zizyphus incurva, etc. Through a survey conducted at the reservoir and around the proposed dam site, existence of 16 species of trees including Pinus roxburghii, Dalbergia sericea, etc. was identified (see Table 3.12). Further, in the range from the proposed dam site to the proposed powerhouse site, existence of 28 species of plants including Grewia sapida, Pterospermum acerifolium, Maccaranga palustris, etc. was identified (see Table 3.13). In the district of the proposed powerhouse site and its downstream, existence of 38 species of trees, 28 species of bushes, 30 species of herbs and 17 species of grasses was identified as indicated in Table 3.14.

Distribution density of trees at proposed site is more than 200/ha of mixed forest. Density of Pine woods distributed entire the proposed site is 100 - 200/ha, but there are places where Pine woods next to residential area has less than 100/ha of its density.

Distribution characteristic is shown below.

Location of the study area	Diversity Index
Up to the tailend of submergence area	1.20
Submergence area	2.40
Dam site to power house	1.52
Power house to end of study area	2.77

3.2.1.2 Terrestrial Fauna

The Forestry Bureau of the Bhutanese Government has reported the list of terrestrial faunae living around the proposed site (see Table 3.15). The report informs the existence of 15 species of the Mammalia including a kind of deer (Barking deer), Wild boars, Jackals, 3 species of the Reptilia including Python, etc. and 30 species of Aves such as White capped redstart, a kind of a dusky thrush (Whistling thrust), a kind of a Japanese cormorant (Brown dipper), etc. Out of the fauna included in this list, Barking deer was declared as endangered species in the Forest and Nature Conservation Act (1995). As protected species, a kind of deer (Serow), Himalayan Black Bear, a kind of leopard (Leopard Cat), and Leopard are named. However, in view of the facts that many years have passed

since this list was prepared and that the national highway was constructed afterwards, the above list does not necessarily reflect the current state of the district.

Through visual survey, footprint survey and enquiry conducted at the site, existence of fauna around the proposed site was observed. Consequently, Barking Deer, Black mouth langoor, Jackal, Wild boar as well as the Aves as indicated in Table 3.14 was confirmed. Although the existing documents refer to the Leopard, Himalayan Black Bear, etc. also living there, their existence was not identified by this survey. Also, existence of the Reptilia such as Python, Cobra and King cobra is reported. King Cobra is a rare species. Table 3.17 represents a list of migratory birds in Bhutan.

A natural protection officer in Wangdue town said that Spotted deers (Axis axis) were once artificially left around the proposed site in the Punatsangchhu. All the fauna as indicated in Table 3.15 were reported to inhabit Dhikchhu National Park located down stream of the proposed site.

3.2.2 Aquatic Flora and Fauna

3.2.2.1 Aquatic Flora

Since the river in the proposed site flows rapidly and most of the riverbed is covered with sand, detrital conglomerates and rocks, the surface of the stones and rocks on the riverbed have been eroded with the rapid flow to show bare rocks. At the time of visual survey as a part of a site reconnaissance, few weeds and other aquatic flora were noted.

3.2.2.2 Aquatic Fauna

Up to now, no detailed survey has been seem not to conduct on aquatic fauna inhabiting in the Punatsangchhu.

(1) Benthic Organism

Although no information was obtained on plankton or benthos living in the Punatsangchhu, those of the same species as inhabiting East Himalayas of India are considered to inhabit in the river. Based on the above knowledge, 8 orders of benthos such as Plecoptera, Odonata, Ephemeroptera, Trichoptera, Diptera, Coleoptera, Hemiptera and Lepidoptera seem to live in the Punatsangchhu.

From the samples extracted only once in the field survey, existence of various benthos including the genus of Epeorus, Baetis, Rithrongena and Psephenus.

(2) Fish Species

No complete survey has been conducted concerning the fish species inhabiting the Punatsangchhu. In 1976, Dr. G. P. Dubey of Food and Agriculture Organization(FAO) of the United Nations conducted a preliminary survey on fish species living in several rivers running through Bhutan and made a research

on a possibility of inland fishery. According to the report compiled in 1993 from the results of his research, fish species whose existence in the Punatsangchhu was identified were as shown in Table 3.18. 10 species of fish species including Tor *putiotora* and *Schizothorax progastus* of Carp family and brown trout (*Salmo trutta fario*) are referred to in it.

At the time of our field survey, obtaining a special permit from the Bhutanese Government, sampling of fish species with a catching net was carried out at a total of 18 points around the proposed site. Fig. 3.2 and Table 3.19 indicate the survey points and results in October, 1999. Two species, i.e. brown trout (*Salmo trutta fario*) and Asala (*Schizothorax progastus*) as a kind of Carp family were sampled, with Asala accounting for 90% of the total samples. As a result of enquiry from the local residents, we knew that a species called Kabray / Badbala in their local language inhabits there. However, we could not identify its existence in the field survey.

Fishery is forbidden in Bhutan, although sports fishing only is allowed in the limited area. Fishing is interdicted at the place where the Kamechhu and the Dhikchhu join, approximately 23 km down the river from the proposed dam site since that place is located in Dhikchhu National Park. Only the family members of the King of Bhutan are privileged to use this place for fishing. It is said that Mahseer (*Tor putitora*), a kind of the Carp family, appears during the period from the middle of February to the middle of September. This species having nature of travelling go southward when the water temperature is low and come up again when it becomes warm. However, we were unable to identify the existence of this species in the survey. The boundary for Mahseer's eggs laying and going upward is considered to be far down the river from the tailrace outlet.

3.2.3 Rare, Endangered or Protected Species in the Project Areas and its Vicinity

The Ministry of Agriculture of the Bhutanese Government announced its "Biodiversity Action Plan" in 1998 designating protected biology in the country (see Table 3.20). Also in the Forest & Nature Conservation Act (1995), endangered species and protected fauna were designated. As a result of the visual survey, footprint survey, and enquiry conducted in the field survey, it is considered that several species designated as endangered and protected species live there.

In 1994, Rebecca Pradhan & Tandin Wangdi and others reported the endangered species in Aves in the country. Table 3.21 and Fig. 3.3 show the endangered species in Aves and the districts of their distribution, respectively. By examining the distribution chart of the Aves endangered, it was that such species were not distributed around the proposed site.

According to the above distribution chart, a kind of eagle, i.e. Palla's Fishing Eagle (*Haliacectus*), a kind of White-bellied Heron (*Ardea insignus*) and Satyr tragopan (*Tragopan Satyra*), which were designated as endangered species, seem to inhabit the district ranging northwestward from the area approximately 10 km up the river from the proposed dam site and eastward from the area

approximately 20 km down the river from the proposed powerhouse site. With regard to the district surrounding the proposed route of transmission lines, a kind of Hornbill i.e. Rufous-necked Hornbill (*Aceros nipalensis*) and Yellow Rumped Honey Guide (*Indicator xanthonotus*) seem to live in the area ranging approximately 25 km eastward from Phipsoo Wildlife Sanctuary near the border between Bhutan and India.

Further, in 1999 WWF of the Bhutanese Government proposed biological corridors connecting the national parks and wildlife sanctuary (see Fig. 3.4) According to this chart, although the proposed site and its vicinity are not designated as a national park, a wildlife sanctuary, nor its biological corridors but surrounded by them.

3.3 Socioeconomic and Cultural Environment

Table 3.22 shows the outline of economic, social and cultural characteristics of Bhutan.

The economic, social, and cultural characteristics of Wangdue Phodrang Region to which the proposed site belongs and villages in its periphery are as detailed below. We limited the scope of our survey as both of the river sides within 2.5 km wide each, (5 km wide in total) ranging from the spot approximately 2 km down from Wangdue Bridge to near Pinsa Village going southward for approximately 38 km from that point. 35 villages (hereinafter referred to as "Particular Villages") are included in this scope. Table 3.23 represents the list of these particular villages. Survey was conducted through forwarding questionnaires to 164 households covering all of the particular villages.

3.3.1 Population Characteristics and Demographics

Tables 3.24 and 3.25 show the demography of Wangdue Phodrang Region. Population there for 1998 was about 28,792 consisting of 14,387 males (49.97%) and 14,405 females (50.03%). Since there was about 2,793 households, around 10 family members are considered to be involved in a household.

The demography of 35 particular villages is indicated in Table 3.26. With the approximate population of 4,241 and the approximate number of households of 379, about 11 members are considered to be involved in a household. Results of the survey conducted by fowarding questionnaires to 162 households out of the above total number of households are as indicated in Table 3.27. According to these results, the total number of family members of the 162 households was 1,352 consisting of 665 males and 687 females, and 8 members were considered to be included in a family.

Most of the persons living in this are Bhutanese people speaking Dzongkha Language. Their religion is Buddhism. Out of all those surveyed, only one family was from East Bhutan and no family from South Bhutan was found.

3.3.2 Occupation/Economic Activities

Approximately 90% of the residents of Wangdue Phodrang Region are engaged in agriculture, growing paddy, wheat, corn, buckwheat, barley, millet, potatoes, apples, oranges and mustard. Table 3.28 shows the areas under tillage and outputs. Many of the farmers also raise cattle, pigs and domestic fowls.

In this region, 30 industrial license owners and 180 commercial license owners exist. In addition to 10 constructors, woodworkers and paper manufacturers are also operated.

Many residents in particular villages are also engaged in agriculture, and their main crops are paddy and wheat. Most of the households own small-scaled vegetable gardens for consumption by household and as a source of their income. Some of the families grow oranges, bananas, pairs, apples, peaches, guavas, walnuts, etc.

Not fishery nor fish raising is practiced in the Punatsangchhu. There is neither large plant nor field office in this area except a repair shop of vehicles used for road works which is located at about 5 km upstream of the proposed dam site.

3.3.3 Land Use Pattern

According to the Land Utilization Chart (Fig. 3.5)covering the regions from Thimphu to Wangdue Phondrong Dzongkhags prepared by Land Utilization Planning Dept. under the Ministry of Agriculture, 92% of the land in these regions is covered by forests occupying 63,206 ha where Fir, Mixed conifers, Blue pines, etc. grow. The remaining 8% other than the above forests consists of stock farms (2%), farmland (5%) and wasteland (1%). The residential areas and orchards where apples and oranges grow were extremely small, only 103 ha and 5 ha respectively.

The entire farmland consists of irrigated farmland of 2,085 ha accounting for 65% of the entire farmland mentioned above.

A large portion of the proposed site is covered by forests of broadleaf trees, and conifer forests are distributed in part along the valley beside the target river.

Farmland exists on the slope of the valley, and irrigated land out of the farmland were intensively distributed on the slope on the side of the branch river (the Laya lume chan) where it joins the Sankoh River. In the downstream of the joining point, only small-scaled irrigated lands are distributed on a relatively upper part of the valley.

A small-scaled apple orchard exists on the river shore of the point where the Hdochhu joins the main stream.

On the other hand, the slope of the right-hand river shore from Wangdue Phodrang town which is upstream of the proposed dam site to about 3 km downstream is utilized for plantation.

According to the result of the survey by questionnairing conducted in particular villages, most of the residents in this area possess their own houses and small vegetable gardens for household use and several fruit trees. The average area of the land possessed by a household is 3.15 acre (approximately 12,600 m^2) used as a paddy field or dry field, a stock farm and an orchard.

3.3.4 Community Structure

Bhutan is considered in general as consisting of 4 large racial groups. First, Bhutanese of Nepal ancestry living in lowland and speaking Nepalese is said to account for about 25% of the total population. Bhutanese of Tibet ancestry living in middle to high lands is further classified into three groups forming approximately 60% of the total population.

Extremely limited traffic means are used in particular villages. Although bus service is available, frequency of its operation is very low. Most of the villages are located far from the main road. From some of the villages, it takes about 3 – 4 hours on foot to reach the main road. Table 3.29 shows distances from particular villages to post offices, bus stops, etc. which are necessary for exchange with the outside world.

Frontier villages have been organized into Gweog. Those representing individual households are females in general. Villagers are closely connected to their community, and they are not discriminated depending on differences in their incomes and occupations. Crime occurrence ratio is low, and people think they are safe.

Traditionally, succession to a house is practiced in the maternal line, and the eldest daughter of a family succeeds most of the assets such as residence, farmland and cattle. She is supposed to remain in her parent's house and look after her aged parents raising her own family. Even if an adult male is included in a household, the eldest daughter (or his wife) is often regarded as the head of the family. The right of decision making is held by women in general, and women are considered as more capable than their husbands.

In general, women are regarded as occupying the same ranking and rights as men. Only in a far remoter village covered by the survey, women's social position was regarded as low. Women participate in various activities taking place from villages to the central government. However, although without any legal or social hindrance, women who attach importance to their responsibilities within their households seldom advance into local or central political circles.

3.3.5 Employment and Labor Market

Table 3.30 indicates the state of employment in particular villages. Approximately 38% of the target persons are engaged in agriculture. As other occupation, some are engaged in commercial activities and others are government officers, etc. Breakdowns of their cultivated land ownership is as indicated in Table 3.31.

Incomes obtained from these occupations were around Nu.400 – Nu. 30,000 per month. About 40% of the total households live on their monthly income of Nu. 2,000 or under. Although no poverty level has been officially established in Bhutan, that established by ADB is Nu. 504 per capita (as of December, 1998). The average monthly income per capita in particular villages is Nu. 526.5, which is scarcely in excess of the poverty level. Table 3.32 shows the data on the average monthly income and expenditure of the target persons covered by the survey.

3.3.6 Recreation

No recreation facilities were noted around the proposed site.

3.3.7 Public Health

A hospital, 9 Basic Health Units and 20 outreach clinics are established in Wangdue Phodrang Region and 61 educated village health workers work in the these facilities. In this region water-works is available for 1,746 households forming about 63% of the total households.

Only limited number of medical facilities exist in particular villages. Most of the villagers have to walk for several hours to go to the nearest Basic Health Unit (BSU). Distances between the individual villages and their nearest medical facilities are shown in Table 3.33. Water-works are available for approximately 63% of the households out of the total households surveyed. Other households can use water source within a sphere of ten minutes' walk. Table 3.33 also shows their state of access to drinking water.

3.3.8 Education

The number of children who go to school in Bhutan is said to be approximately 70,000 which accounts for a little more than 40% of the those who are 6 to 18 years old. As educational facilities, a high school, 3 middle schools, 9 primary schools and 4 community schools are established in Wangdue Phodrang Region. In addition, Natural Resource Training Institute exists approximately 9 km away from Wangdue Phodrang town.

The data on the education level of the people in particular villages are as shown in Table 3.34. Out of 1,352 persons subject to the survey, 1,079 persons forming about 80% of the total villagers were illiterate. People accounting for about 17% of the total people either completed or being given education of VII class level or over. Since only community schools and primary schools are established within the scope of the survey, they have to go to Wangdue town, etc. to receive higher education. They have to walk for 45 minutes or more even to go to community schools or primary schools. Table 3.33 shows the distance between the individual villages and their closest educational facilities.

3.3.9 Cultural Properties

No archaelogical component was found to exist in the district required for the project.

3.3.10 Indigenous or Ethnic Peoples

Multiple racial groups having independent cultures live in Bhutan. However, their entire images have not been clarified yet.

Most of the residents in particular villages are Bhutanese speaking Dzongkha Language, and existence of only one household from East Bhutan was identified.

Table 3.1 Analysis of Soil Samples from the Study Area

Parameters	Sampling Stations			
	S1	S2	S3	S4
pH	6.8	6.7	7.9	8
Organic matter, (wt %)	4.64	2.31	0.5	0.84
Amm. Nitrogen, mg/kg	1	3	2	4
CEC in meq/100 gm soil as KCl	13.64	9.622	8.139	6.856
Copper, µg/g	21	12	22	23
Zinc, µg/g	31	53	68	72
Cadmium, µg/g	7	10	15	15
Chromium, µg/g	36	28	63	41
Lead, µg/g	11	18	23	23
Mercury, µg/g	<0.001	<0.001	<0.001	<0.001

S1 Above dam site

S2 Near dam site

S2 6 km downstream of dam site

S4 10 km downstream of dam site

Table 3.2 Analysis of Sediment Samples from the Study Area

Parameters	Sampling Stations	
	D1	D2
PH	8.6	8.8
Organic matter (wt %)	0.31	<0.1
Amm. Nitrogen, mg/kg	<1.0	<1.0
CEC in meq/100 gm soil as KCI	6.452	6.504
Copper, µg/g	10	9
Zinc, µg/g	39	29
Cadmium, µg/g	8	5
Chromium, µg/g	25	20
Lead, µg/g	15	9
Mercury, µg/g	<0.001	<0.001

D1 8 km upstream of the dam site
D2 Submergence area

Table 3.3 Grain Size Evaluation of Soil and Sediment Samples in the Study Area

Parameters/Station No.	Soil Sampling Stations (%)				Sediment Sampling Stations (%)	
	S1	S2	S3	S4	D1	D2
>0.25 mm	35.58	34.05	36.5	23.7	7.25	21.25
0.25 to 0.149 mm	47.15	41.2	16.7	28.1	67.45	68.9
0.149 to 0.088 mm	10.65	12.65	11.9	15.35	17.7	7.7
0.0088 to 0.074 mm	0.25	2.8	4.9	5.05	0.45	0.6
0.074 to 0.0625 mm	0.1	0.1	0.3	0.15	0.05	0.15
<0.053 mm	2.85	5.15	18.7	16.65	2.25	0.7

Table 3.4 Average Meteorological Conditions in the Study Area

Month	Temperature (°C)		Relative Humidity (%)	Rainfall (mm)
	Maximum	Minimum		
January	17.1	5.7	73.3	12.7
February	18.3	7.9	71.6	14.1
March	22.5	10.6	68.2	20.4
April	27.7	13.4	70.0	48.0
May	27.9	17.4	69.5	38.6
June	29.1	19.7	74.9	103.0
July	28.0	19.6	79.5	140.1
August	28.1	20.0	79.8	153.2
September	27.2	19.3	81.6	85.5
October	22.8	14.7	76.8	18.2
November	22.6	9.7	73.7	10.6
December	17.0	5.7	75.2	7.7
Total				805.3

Note: Based on data for the period 1990-1998.
Source: Meteorological Department, Thimphu, Bhutan.

Table 3.5 Rainfall Data of Wangdi Weather Station

Unit : mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1990	0.7	23.1	20.1	79.7	34.1	12.42	207.7	95.1	138.1	66.0	0.0	14.5	803.3
1991	22.9	18.9	17.7	16.9	106.7	151.1	110.9	189.3	119.1	3.0	0.0	11.4	767.9
1992	5.7	0.3	1.2	62.1	25.2	103.2	223.2	102.3	23.4	11.5	0.0	1.5	559.6
1993	31.2	16.7	18.4	64.1	13.9	68.4	24.0	189.6	107.5	7.8	10.5	0.5	552.6
1994	31.0	17.7	15.5	40.2	30.3	119.1	133.8	166.9	39.7	1.0	0.3	0.0	595.5
1995	15.2	17.5	13.8	4.9	21.7	102.9	154.5	112.0	123.0	6.4	86.0	6.2	664.1
1996	30.1	0.0	7.6	44.8	38.6	93.6	117.8	152.9	85.3	30.8	2.0	0.0	603.5
1997	4.3	17.3	19.5	68.4	23.5	100.1	135.4	177.7	94.8	8.9	0.0	37.1	687.0
1998	0.0	1.0	70.0	51.3	53.0	64.6	153.7	192.6	38.9	28.0	0.4	0.0	653.5
Mean	15.7	12.5	20.4	48.0	38.6	103.0	140.1	153.2	85.5	18.2	11.0	7.9	654.1
Max	31.2	23.1	70.0	79.7	106.7	151.1	223.2	192.6	138.1	66.0	86.0	37.1	803.3
Min	0.0	0.0	1.2	4.9	13.9	64.6	24.0	95.1	23.4	1.0	0.0	0.0	552.6

Table 3.6 Monthly Discharge at Dam Site

Unit : m^3/s

Y/M	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX	MIN	AVE
1991	-	-	-	-	-	-	-	-	696.9	256.2	133.3	92.3	696.9	92.3	294.7
1992	71.7	62.3	91.3	123.7	168.4	325.2	602.9	727.0	447.9	229.2	126.5	87.3	727.0	62.3	255.3
1993	71.1	67.9	62.9	104.7	232.2	239.3	546.9	831.9	546.5	297.6	150.8	103.5	831.9	62.9	271.3
1994	78.9	67.2	78.2	103.0	206.5	418.6	447.8	621.4	474.9	304.1	125.5	89.3	621.4	67.2	251.3
1995	71.0	67.1	87.7	115.5	255.4	532.3	773.2	697.8	486.0	295.7	173.7	95.9	773.2	67.1	304.3
1996	78.0	66.1	81.5	124.8	228.9	449.3	833.8	730.8	678.5	326.5	156.0	103.9	833.8	66.1	321.5
1997	77.4	66.5	87.2	104.8	212.1	463.7	663.5	693.8	603.0	237.4	132.1	95.2	693.8	66.5	286.4
1998	74.4	64.0	69.0	119.4	238.1	577.1	956.1	1128.8	516.8	298.3	147.3	99.1	1128.8	64.0	357.4
1999	75.8	64.8	63.5	108.2	226.2	501.5	749.3	899.2	631.4	369.5	174.4	111.9	899.2	63.5	331.3
MAX	78.9	67.9	91.3	124.8	255.4	577.1	956.1	1128.8	696.9	369.5	174.4	111.9	1128.8	67.9	386.1
MIN	71.0	62.3	62.9	103.0	168.4	239.3	447.8	621.4	447.9	229.2	125.5	87.3	621.4	62.3	222.2
AVE	74.8	65.7	77.7	113.0	221.0	438.4	696.7	791.3	564.6	290.5	146.6	97.6	791.3	65.7	298.2

Table 3.7 Discharge data at Maza Falls on Basochhu (cumecs)

Month	1990	1991	1992	1993	1994	1995	1996	1997	1998
January	2.33	2.91	2.46	1.98	1.77	1.47	3.62	3.45	3.01
February	1.94	2.38	N.A.	1.88	1.60	N.A.	4.00	3.03	2.64
March	1.89	2.14	2.38	1.69	N.A.	1.45	3.75	3.05	2.80
April	2.33	2.05	2.08	1.83	1.43	1.47	3.24	3.36	3.48
May	2.92	2.38	2.35	2.37	1.64	2.46	3.61	3.56	3.28
June	6.85	10.41	4.91	3.54	3.02	10.19	7.55	6.38	9.79
July	12.58	13.33	13.59	5.65	4.40	20.95	20.72	12.38	26.77
August	13.62	22.25	12.52	10.90	5.78	14.30	16.92	14.56	95.76
September	10.54	17.14	N.A.	9.16	6.79	16.07	22.48	14.02	20.41
October	8.41	6.69	7.60	5.95	N.A.	9.60	N.A.	7.97	9.39
November	4.40	4.05	4.01	N.A.	2.11	N.A.	6.50	5.07	4.96
December	3.27	3.07	2.86	2.48	N.A.	4.21	4.64	3.89	3.58

Note : N.A. – Data Not Available.

Source : Division of Power, Thimpu.

Table 3.8 Probable Flood for Various Return Periods

Return Period (year)	Dry season (cumecs)	Rainy season (cumecs)
5	563	1,326
10	644	1,444
20	722	1,557
50	823	1,704
100	898	1,813
200	974	1,923
1,000	1,148	2,176

Source : Pre-Feasibility Study Report.

Table 3.9 Ambient air Quality in the Study Area

Unit : ug/m^3

Station	Parameters		
	SPM	SO_2	NO_x
November, 1999			
Dam site	24.2	BDL	17.2
	21.7	BDL	18.1
	22.4	BDL	17.9
Quarry site	21.2	BDL	17.9
	29.2	BDL	18.4
	31.2	BDL	17.1
December, 1999			
Dam site	19.2	BDL	18.1
	21.1	BDL	19.1
	19.4	BDL	19.0
Quarry site	24.1	BDL	19.1
	26.2	BDL	17.9
	29.4	BDL	18.0

BDL : Below Detectable Limits.

Table 3.10 Analysis of Water Samples from the Study Area

Parameters	Stations			
	W1	W2	W3	Permissible limits for drinking water in Bhutan*
pH	7.6	7.5	7.8	6.5-8.5
TSS	268.2	112.5	360.6	-
Chlorides	25	17	17	250
Sulphates	<0.01	<0.01	<0.01	500
Phosphates	<0.01	<0.01	<0.01	-
Nitrates	<0.01	<0.01	<0.01	45
Sodium	1.53	1.01	1.12	-
Potassium	0.864	0.508	0.639	-
Calcium	13.1	12.9	12.1	-
Magnesium	2.93	2.82	2.53	-
Copper	<0.1	<0.1	<0.1	2
Lead	<0.1	<0.1	<0.1	0.1
Zinc	<0.1	<0.1	<0.1	5.0
Chromium	<0.05	<0.05	<0.05	0.05
Mercury	<0.001	<0.001	<0.001	0.001
Cadmium	<0.01	<0.01	<0.01	0.01
BOD	3	3	3	-
COD	7	6.5	7	-
DO	10	10	9.5	-

Note : Unit of all parameters except pH is mg/l. pH has no unit.

W1 - 8 km upstream of the dam site.

W2 - Near Dam site.

W3 - 6 km downstream of the dam site.

* Recommended by National Environmental Commission.

Table 3.11 Noise Levels in the Study Area

S. No.	Location	Noise Level (dBA)
1.	Wangdue town	48
2.	Uma	42
3.	Changche	39
4.	Baso	37
5.	Zawa	37
6.	Pinsa	37
7.	Jala	41
8.	Dima	41
9.	Jala	38
10.	Khamina	42
11.	Dingthi	40
12.	Mesesa	38
13.	Gamsab	40
14.	Bay	38
15.	Gikha	39

Table 3.12 Major Floral Species in the Submergence Area

Botanical name	Common / local Name	Economic Importance
Pinus roxburghi	Chir pine/dhup	Timber
Toona ciliata	Tooni / Rawa shing	Timber, Furniture
Sapium insignii	Shoshi	Fire wood
Mallotus philipinesis	Rohini	Medicine
Celtis terandra	Khari / Phantang Shing	-
Rhus chinesis	Bhakimlo	Edible fruit, medicine
Dalbergia sericea	Pchang	Timber
Dalbergia pinnata	Olla shema	Timber & Furniture
Solanum turvium	Ashetu	-
Zizyphus incuvra	Bayer	Edible fruit, Medicine
Syzygium cummi	Jamun / Naysse shing	Edible fruit, Medicine
Aesiandra buteraceae	Cheuri	Edible fruit, oil from seeds.
Bombax cieba	Pema Geysar	-
Ficus semicordata	Khaniun/honaiyo	Fodder
Albizia julibrissin	Patpate siris	-
Altingia exelsa	Seti	Timber

Table 3.13 Tree Species in the Power House Area on the Left Bank of the River

Botalnical Name	Common/Local name	Use
Grewia sapida	Dopta/Tsu tsu shing	Fodder
Petrospermum acerifolium	Hattipaile	Medicine
Maccaranga paltata	Bomchu	Fodder
Caseria glomerata	Barkaunle	Fire wood, batten
Litsea monopetala	Scychhanglu shing/ Bansum	Siek worm reared on the leave
Alnus nepalensis	Utis/Gama	Fire wood, furniture
Ficus benjamina	Kabra	Shade tree
Celties tetrandra	Khari,/ Phantang Shing	Fodder
Eurya cerasifolia	Khuberbu shing/ Bara jhingni	Fencing
Sapium baccatum	Ankhataruwa	Fencing
Rhus chinensis	Bhakimlo	Edible fruit, medicine
Taulama hodgsoii	Chiuri	-
Zanthozyllum armatum	Thingney/ Bale Timur	Medicine
Brassaiopsis hainla	Chuletro	-
Bombax cieba	Pema Geysan	Cotton, medicine
Sapium insigni	Shoshi	Fire wood
Dalbergia pinnata	Olla shema	Timber
Ficus semicordata	Khanillan, Honaiyo	Medicine
Syzygium cumini	Jamun / Nyasse shing	Medicine, fruit, timber
Solanum turvium	Ashetu	-
Sapindus rarak	Kiling shing / Soap nut	Medicine
Bridelia sp.	Kasreto	Fodder
Calicarpa arborea	Ghiwali	-
Dalbergia sericea	Pchang	Timber
Caesalpina decepeltala	Tatse tsang	-
Rhus paniculata	Khai Roptang Shing	Medicine
Cycas pectinata	Bongo	Stem pith used to produce sago
Wood fordia fruticosa	Dhaero	Fire wood, medicine

Table 3.14 (1) Floral Species Observed in the Study Area

No.	Botanical Name	Common/Local Name	Economic Importance
Tree			
1	*Pinus roxburgii*	Chir pine / dhup	Timber
2	*Sapium insigni*	Shoshi	Fencing
3	*Sapindus rarak*	Kiling shing/ soap nut	Medicine
4	*Toona ciliata*	Rawa shing/ Tooni	Timber / Furniture
5	*Eurya accuminata*	Sanu jhingni / jipgane	Timber, Fuel wood
6	*Grewia sapida*	Dopta/ Tsu Tsu Shing	Foddar
7	*Altingia exelsa*	Seti	Timber, resin used as perfume
8	*Pterospermum acerifolium*	Hattipaile	Medicine
9	*Maccaranga peltata*	Bomchu	Fodder
10	*Caseria glomerata*	Barkaunle	Fire wood, batten
11	*Litsea monopetala*	Bonsum / Seychhanglu shing	Silk worm are reared the leaves of this tree
12	*Alnus nepalensis*	Utis / Gama	-
13	*Ficus benjamina*	Kabra	Cultivated as shade plant
14	*Celtis tetrandra*	Kharil / Phantang shing	Foddar
15	*Sauraya nepaulensis*	Mingdormu shing	-
16	*Syzygium cuminii*	Nyasse shing/ Jamun	Fire wood/ edible fruit medicine
17	*Albizia procera*	Seto siris	-
18	*Macaranga pustulata*	Maltata	-
19	*Albizia julibrissin*	Patpate siris	-
20	*Brassaiopsis hainla*	Chuletro	Fodder
21	*Ficus semicordata*	Khaniun /honaiyo	Medicine
22	*Mallatus phillipinensis*	Rohini	Dye
23	*Sapium baccatum*	Ankhataruwa	Fencing
24	*Rhus succedina*	Say shing/ Rani Bhalayo	Medicine (fruit)
25	*Eurya cerasifolia*	Bara Jhingni/Khuberbu shing	Timber valuable for fence post.
26	*Bombax ceiba*	Pema Geysar	Cotton / medicine
27	*Zizyphus incuvra*	Tsangshing Karmo	Cultivated as a host plant for the lac inseet
28	*Zauthojyllum acanthopodium*	Boke timur	Spice (Bhutanese) Medicine
29	*Bridelia sp.*	Kasreto	Fodder
30	*Rhus chinensis*	Pok pokpa shing	Medicine
31	*Zanthozyllum armatum*	Thingney / Bale timuer	Medicine
32	*Dalbergia sericea*	Pchang	
33	*Calicarpa arborea*	Ghiwali	
34	*Dalbergia pinnata*	Olla shema	Timber, Fire wood
35	*Caesalpina decepebtata*	Tats tsang	
36	*Taulama hodgsonii*	Chiuri	-
37	*Rhus paniculata*	Khyr khobtang	Medicine
38	*Phyllunthus emblica*	Omala / churu	Edible fruit, medicine
SHRUBS			
1	*Indigofera dosua*	Kumchingma shing	Fire wood
2	*Datura suaveolens*	Dhatura	Medicine
3	*Dalbergia sp.*	Tatebiri	
4	*Rubus ellipticus*	Tshema Tshelu	Edible fruit
5	*Murraya Koenigii*	Ngebtang shing / Mechia sag	Leaves used in curries, medicine
6	*Cordia sp.*		
7	*Desmodium elegans*	Tatur shi	Fire wood
8	*Sida sp.*	Khareto	
9	*Zanthozyllum sp.*	Dretsang	

Table 3.14 (2) Floral Species Observed in the Study Area

No.	Botanical Name	Common/Local Name	Economic Importance
SHRUBS(Continued)			
10	*Mesia chisia*	Bilaune	
11	*Casealpinia decapetala*	Tatse tsang	
12	*Bauhinia purpurea*	Tanki / Pegpeyposhing	Fodder, fire wood, gum
13	*Ricinus communis*	Castor	Medicine
14	*Jatropa curcus*	Punging nut	Medicine
15	*Woodferdia fruticosa*	Dhaero	Fire wood, medicine
16	*Jasminium sp.*	Chameli	Insect
17	*Srephania sp.*	Chechu Robji	
18	*Calicarpa arborea*	Ghiwali	
19	*Solanum turvium*	Ashetu	
20	*Zyzyphus incuvra*	Tsangshing Karmo	Host free for lac insect
21	*Coffea bengalensis*		
22	*Phyullunthus emblica*	Omala / churu	Medicine
23	*Celastrus sp.*	Bhaisa lahara	
24	*Citrus medica*	Lemon tree	Medicine
25	*Justica adatoda*	Basaka	Medicine
26	*Dioscorea bulbifera*	Yan (Wild potato)	Food
27	*Pueraria sp.*	Birali lahara	-
28	*Argyreia sp.*		-
HERBS			
1	*Amaranthus*	Lasomo	Edible leaf & fruit
2	*Ipomea purpurea*	Morning glory	Ornamental value
3	*Pteracenthus sp.*	-	Medicine
4	*Laportea terminalis*	Sisnoo	Medicine
5	*Artemesia vulgaris*	Indian worm wood	Medicine
6	*Asparagus racemosa*	Satmuli	Vegetable
7	*Barleria cristata*	Jhiniti	Medicine
8	*Jasminium sp. (Shrub)*	Chameli	Perfume
9	*Canabis sativa*	Phagpa Nam, Bhang, Hemp	Medicine, Fibre
10	*Biden bipinnata*	Kuro	-
11	*Galinsoga parviflora*	-	-
12	*Conyza floribunda*	Ban maro	
13	*Eupatorium adenophorum*	Black weed kalijar	
14	*Pilea sp.*		
15	*Zanthum indicum*		
16	*Clematis sp. (Shrub)*		Ornamental value
17	*Mikaria micrantha*		
18	*Tagetes minuta*		
19	*Curcuma sp.*		
20	*Cynoglosum sp.*	Forgetmenot	
21	*Pauzolzia hirta*	Yongiba	
22	*Solanum khasianum*		Medicine
23	*Crassocephalum crepidiodes*		
24	*Impatients sp.*	Door gonang	Ornamental value
25	*Hedychium sp.*		Medicine & ornamental value
26	*Coleus barbatus*	-	-
27	*Colocasia fallaxi*	-	-
28	*Girardiana diversifolia*	Bhangre Sisnoo	Rope

Table 3.14 (3) Floral Species Observed in the Study Area

No.	Botanical Name	Common/Local Name	Economic Importance
HERBS (Continued)			
29	*Abelmoschus manihot*	Sayr metog Wild cotton	Medicine &
30	*Eriocripus cosmosus*	Pule	Rope
BAMBOOS			
1	*Bambusa cupilata*	Malbans	Fencing, bow basket
2	*Bambusa nutan*	Malbans	Basket
GRASS			
1	*Eragrostis Unioloides*	Vibangoti (sp)	Fodder
2	*Dactyloctenium algyptium*	Grass (Ghans)	Fodder
3	*Sporobolus fertilis*		
4	*Chloris virgata*		
5	*Cynodon dactylon*	Burmuda grass	
6	*Oplismenus compositus*		
7	*Sacciolepsis indica*		
8	*Echinochloa colonum*		
9	*Axonopus compressus*		
10	*Paspallum scrobiculatum*		
11	*Cymbopogon Khasianum*	lemon grass Sorbanana (D)	Medicine
12	*Arundenella hookeri*	Grass	
13	*Digitaria stricta*		
14	*Pennisetum flaccidium*		
15	*Saccharum spontaneum*	Khans	
16	*Themeda triandra*		
17	*Chrysopogon gryllus*		
AGRICULTURE CROPS			
1	*Origa sativa*	Paddy (Kharif season)	Food grain
2	*Psidium guajava*	Guava	Fruit
3	*Citrus sinensis*	Orange	Fruit
4	*Carica papaya*	Papaya	Fruit
5	*Zea mays*	Maize	Food grain
6	*Phaseolus vulgaris*	Bean	Vegetable
7	*Cucurbita masehata*	Pumpkin	Vegetable
8	*Manihot esenlenta*	Cassava	Vegetable
9	*Tritucum sativum*	Wheat (Rabi season)	Food grain
10	*Brassica Nigra*	Sarson (Rabi season)	Oil used as cooking media

Table 3.15 List of Fauna Reported in the Study Area

No.	Botanical Name	Common/Local Name
MAMMALS		
1	*Muntiacus muntjak (E)*	Barking Deer
2	*Sus scrofa*	Wild boar
3	*Canis aureus*	Jackal
4	*Nemiorhaedus goral*	Ghoral
5	*Hyatrix sp.*	Indian Porcupine
6	*Cervus unicolor*	Sambhar
7	*Capricornis sumatraenis (P)*	Serow
8	*Selenarctor thibetainus (P)*	Himalayan Black Bear
9	*Pataurista sp.*	Common Giant Flying Squirrel
10	*Cunon alpinus*	Wild dog
11	*Hurpestis sp.*	Crabeating Mangoose
12	*Falis benagalensis (P)*	Leopard Cat
13	*Panthera pardus (P)*	Leopard
14	*Presbytis entellus*	Black mouth Langoor
15	*Mus domesticus*	Mouse
REPTILES		
1	*Pylton molurus*	Python
2	*Naja naja*	**Cobra**
3	*Naja hannah*	**King cobra**
BIRDS		
1	**Chaimarrornis leucocephalus**	White capped redstart
2	*Rhyacornis fuliginosus fuliginosus*	Plumbeous redstart
3	*Myiophoneus caeruleus temmenckii*	Whistling thrush
4	*Encicurus schistaceus*	Slaty backed porktail
5		Green tailed sunbird
6	*Cinclus pallasii tenuirostris*	Brown dipper
7	*Hypsipetes madagascariensis psaroides*	Black bulbul
8	*Phylloscopus magbirostris*	Large billed leaf warbler
9	*Seicercus xanthoschistes xanthoschistes*	Grey headed flycatcher
10		Chestnus bellied nuthatch
11	*Perierocotus brevirostris brevirostris*	Scarlet minivet
12	*Phoenicurus hodgsoni*	Hodgson's redstart
13		Himalayan swiftler
14	*Heterophasia capistrata bayleyi*	Black capped sibia
15		Eurasian jay
16	*Pomatorhinus erythrogenys*	Rusty cheeked scimitar babbler
17	*Garrulax albogularis albogularis*	White throated laughing thrush
18		Hoary barwing
19	*Arborophila torqueola*	Hill patridge
20	*Garrulax striatus sikkimensis*	Striated laughing thrush
21	*Tichodroma muraria nepalcusis*	Wall creeper
22		Oriental White eye
23	*Aegithalos nived*	White throated tit
24	*Lophura leucomelana*	Kaleej
25		White eye
26	*Parus monticolus monticolus*	Green backed tit
27	*Dendrocitta formosae himalayensis*	Himalayan tree pie
28		Rufous bellied woodpecker
29	*Saxicola torquata indica*	Collared bush chat
30	*Paradoxornis nepalensis humii*	Nepal parrotbill
31	*Prinia criniger*	Hill prini

P- Denotes protected species, as per Schedule-I of the Forest and Nature Conservation Act, 1995.

E- Endangered species.

Table 3.16 Avi-fauna sighted during field studies

No.	Birds	Numbers
1	Large billed Leaf warbler	3
2	Grey headed flycatcher	1
3	Turtle dove	1
4	Grey bulbul	6
5	Slaty backed forktail	2

Table 3.17 Migratory birds observed in the project area

No.	Scientific Name	Local Name
1	*Anser indicus*	Bar-headed Goose
2	*Tadorna ferruginea*	Ruddy Shelduck
3	*Tadorna tadorna*	Common Shelduct
4	*Anas strepera*	Gadwall
5	*Anas penelope*	Aurasian wigeon
6	*Anas platyrhynchos*	Mallard
7	*Anas poecilorhyncha*	Spot-billed duck
8	*Anas acuta*	Northern Pintail
9	*Anas crecca*	Common Teal
10	*Aythya ferina*	Common Pochard
11	*Aythya baeri*	Baer's Pochard
12	*Aythya fuligula*	Tufted Duck
13	*Mergus merganser*	Common Merganser (Goosander)
14	*Tringa nebularia*	Common Greenshank
15	*Tringa ochropus*	Green Sandpiper
16	*Charadrius placidus*	Long-billed Plover
17	*Charadrius dubius*	Little Ringed Plover
18	*Larus ichthyaetus*	Pallas's Gull
19	*Haliacectus leucoryphus*	Pallas's Fishing Eagle
20	*Haliaeetus albicilla*	White-tailed Eagle
21	*Accipiter nisus*	Eurasian Sparrowhawk

Table 3.18 Fish Species reported in Punatsangchhu

No.	Zoological Name	Common/Local Name	Elevation range (m above mean sea level)
1.	*Tor putitora (M)*	Mahsheer	200-350
2.	*Schizothorax progastus*	Snow trout/Asala	210-2700
3.	*Salmo trutta fario*	Brown trout	1200-2800
4.	*Puntius titius*	Punti	326-600
5.	*Cirrhina lata*	Gauma	-
6.	*Barilius shaera*	Hill trout/Koksa	200-225
7.	*Labeo pangasia (M)*	Pangusia/Termass	400-610
8.	*Barilius vagra*	Koksa	-
9.	*Barilius barna*	Puti	200-600
10.	*Garra gotyla*	Pattar chat/Lohari	213-610

M - Migratory species

Source : A preliminary annotated list of fish by P. Tamang (1993)

Table 3.19 Fish Statistics as Observed at Different Spots During Survey in the Study Area in Punatsangchhu

Number of fishing spot	Scientific Name of species	Common/ Local Name	Number of Specimens Caught	Length range (mm)	Minimum weight (kg)	Sex
1	2	3	4	5	6	7
1	*Schizothorax progastus*	Snow trout/Asala	1	300	1.000	Female
			2	150	0.250	-
			1	100	0.150	-
2	*Schizothorax progastus*	Snow trout/Asala	2	250	0.800	Male
			2	150	0.250	-
			1	100	0.150	-
3	*Schizothorax progastus*	Snow trout/Asala	2	300	1.000	Female
			2	200	0.600	Male
			1	150	0.250	
			3	100	0.150	
4	*Schizothorax progastus*	Snow trout/Asala	2	375	1.500	Female
			4	150	0.250	-
			1	100	0.150	-
5	*Schizothorax progastus*	Snow trout/Asala	1	150	0.250	-
6	*Schizothorax progastus*	Snow trout/Asala	1	150	0.250	-
7	*Schizothorax progastus*	Snow trout/Asala	1	600	2.000	Female
			2	300	1.000	Female
			1	150	0.250	-
8	*Salmo trutta fario*	Brown trout	1	300	1.000	Female
9	*Schizothorax progastus*	Snow trout/Asala	2	150	0.250	-
10	*Schizothorax progastus*	Snow trout/Asala	1	200	0.600	Male
11	Not seen	N.A.	N.A.	N.A.	N.A.	
12	*Schizothorax*	Snow trout/Asala	1	100	0.150	-
13	*Schizothorax progastus*	Snow trout/Asala	1	300	1.000	Female
			1	150	0.250	-
	Salmo trutta fario	Brown trout	1	250	0.800	Female
14	*Schizotorax progastus*	Snow trout/Asala	1	200	0.600	-
15	*Schizothorax progastus*	Snow trout/Asala	1	100	0.150	-
16	*Schizothorax progestus*	Snow trout/Asala	1	100	0.150	-
	Salmo trutta fario	Brown trout	1	250	0.800	Female
			1	100	0.150	-
17	*Schizothorax progastus*	Snow trout/Asala	1	300	1.000	Male
			1	150	0.250	-
18	*Schizothorax progastus*	Snow trout/Asala	1	250	0.800	Male
			2	150	0.250	-
	Salmo trutta fario	Brown trout	1	100	0.150	-

N.A. : Not applicable,
: Immature specimen gonad not fully developed

Table 3.20 Protected Biological Species in Bhutan

I. Protected fauna (Schedule-IA)

Sl. No.	Common Name	Scientific Name
1	Asian elephant	*Elaphus maximus*
2	Clouded leopard	*Neofelis nebulosa*
3	Golden langur	*Presbytis geei*
4	Musk deer	*Moschus chrysogaster*
5	Pangolin	*Manis crassicaudata*
6	Pigmy hog	*Sus sylvanicus*
7	Snow leopard	*Panthera uncia*
8	Takin	*Budorcas taxicolor*
9	Tiger	*Panthera tigris*
10	Wild buffalo	*Bubalus bubalis*
11	Black-necked crane	*Grus nigricollis*
12	Monal pheasant	*Lophophorus impejenus*
13	Peacock pheasant	*Polylectron bicalcaratum*
14	Raven	*Corvus corax*
15	Rufous-necked hornbill	*Aceros nepalensis*
16	Golden masheer	*Tor tor*
17	Spotted deer	*Axis axis*
18	Gaur	*Bos gaurus*
19	Leopard	*Panthera pardus*
20	Leopard cat	*Felis bengalensis*
21	Himalayan black bear	*Selenarctos thibetanus*
22	Red panda	*Ailurus fulgens*
23	Serow	*Cappricornis sumatraensis*
24	Chinese caterpillar	*Cordyceps sinensis*

II. Protected flora (Schedule-IB)

Sl. No.	Local Name	Common Name	Scientific Name
1	Agar/agaru	Eagle wood/Indian Aloe wood	*Aquilaria malaccensis*
2	Pang-gen metog		*Gentiana crassuloides*
3	Snowdown Lily		*Llyodia yunnanensis*
4	Tsher-ngeon	Blue poppy	*Meconopsis grandis*
5	Kirang-shing	Yew	*Taxus baccata*
6	Bhreeng-gee ra dza	Ginseng	*Panax pseudo-ginseng*

Source: The above were defined to be protected species by the Ministry of Agriculture, Royal Government of Bhutan in 1998, under its "Biodiversity Action Plan for Bhutan".

Table 3.21 Threatened Birds in Bhutan

No.	Scientific Name	Common Name
1	*Ardea insignis*	White-bellied Heron
2	*Haliacectus*	Palla's Fishing Eagle
3	*Tragopan Satyra*	Satyr Tragpan
4	*Tragopan blythii*	Gray-bellied Tragopan
5	*Grus nigricollis*	Black-necked Crane
6	*Gallinago nemoricola* Hodgson	Wood Snipe
7	*Harpactes Wardi*	Ward's Trogon
8	*Alcedo herculis* Laubmann	Blyth's King Fisher
9	*Aceros nipalensis*	Rufous-necked Hornbill
10	*Indicator xanthonotus* Blyth	Yellow-rumped Honeyguide
11	*Cochoa purpurea*	Purple Cochoa
12	*Spelaeornis caudatus* Blyth	Rufous-throated Wren Babbler
13	*Paradoxornis ruficeps* Blyth	Red-headed Parrotbill
14	*Prinia cinereocapilla*	Gray Crowned Prinia
15	*Sita formosa* Blyth	Beautiful Nuthatch
16	*Apus acuticauda*	Dark-rumped Swift

Source: A book titled "THREATENED BIRDS IN BHUTAN" published by Rebecca Pradhan & Tandin Wangdi. Based on the book, the above sixteen different species of birds have been included as threatened birds in Bhutan by Coller,N.J. etc. in 1994. These species have also been included in the World List of Threatened Birds, Birdlife Conservation Series, No.4, Birdlife International. The book also provided the habitat map of the birds. (see attached map)

Table 3.22 Country Performance Indicators for Bhutan

Population Indicators	Latest year
Total population (thousands)	638 (1998)
Annual Population Growth Rate (% change)	3.1%
Age composition(%)	
0-14	42.1%
15-49	44.0%
50-59	6.7%
60+	7.2%
Population density	13.7
Median age	19.4 yrs
Life expectancy (1999) Male	65.9 yrs
Life expectancy (1999) Female	66.1 yrs
Crude Birth Rate (per '000 population)	39.9
Crude Death Rate (per '000 population)	9.0
Social Indicators	
Total Fertility Rate (births per woman)	5.6 (1994)
Maternal mortality rate (per thousand live births)	380.0 "
Infant Mortality Rate (below 1 year, per thousand live births)	70.7 "
Adult Literacy	54% (1996)
Female Literacy	28% "
Primary School Enrolment (% of school age population)	72% "
Female	60% "
Child Malnutrition (% children< 5 yrs)	39.1% "
Population with safe access to water	58% "
Population with safe access to sanitation	90% "
Hospitals	28
Indigenous Units	12
Training Institutes	3
Basic Health Units	145
Malaria Centres	19
Outreach Clinics	454
Universal child immunisation	90%
Rural Water Supply Schemes	1768
High Schools	18
Junior High Schools	44
Primary Schools incl. Community Schools	243
Private Schools	7
Degree College	1
Other institutes	9

Source: Compiled and Verified by Central Statistical Office, Bhutan 1999

Table 3.23 List of Village in the Study Area

Village	Gewog	Dzongkhag
Uma	Daga	Wangdue Phodrong
Baso	Tshowoma	Wangdue Phodrong
Rurichu	Daga	Wangdue Phodrong
Hebesa	Tshowoma	Wangdue Phodrong
Baychu	Dagana	Wangdue Phodrong
Jareygang	Ada	Wangdue Phodrong
Zawa	Ada	Wangdue Phodrong
Kamichu	Daga	Wangdue Phodrong
Yeuthama	Ada	Wangdue Phodrong
Pinsa	Daga	Wangdue Phodrong
Bjaphu	Rupesa	Wangdue Phodrong
Namgelam	Tshowoma	Wangdue Phodrong
Gikha	Tshowoma	Wangdue Phodrong
Pasakha	Tshowoma	Wangdue Phodrong
Tapchekha	Tshowoma	Wangdue Phodrong
Mesesa	Tshowoma	Wangdue Phodrong
Khatokha	Tshowoma	Wangdue Phodrong
Masekha	Tshowoma	Wangdue Phodrong
Changkha	Tshowoma	Wangdue Phodrong
Yemtalou	Tshowoma	Wangdue Phodrong
Khamina	Tshowoma	Wangdue Phodrong
Pangsho	Tshowoma	Wangdue Phodrong
Shinghoe	Tshowoma	Wangdue Phodrong
Gamsab	Tshowoma	Wangdue Phodrong
Ula	Rupesa	Wangdue Phodrong
Jala	Rupesa	Wangdue Phodrong
Ruchekha	Rupesa	Wangdue Phodrong
Metshepokto	Tshowoma	Wangdue Phodrong
Hesothangkha	Tshowoma	Wangdue Phodrong
Dima	Rupesa	Wangdue Phodrong
Lawakha	Tshowoma	Wangdue Phodrong
Dingthi	Rupesa	Wangdue Phodrong
Changchey	Tshowoma	Wangdue Phodrong
Khempajichu	Tshowoma	Wangdue Phodrong
Merapokotokha	Tshowoma	Wangdue Phodrang

Source: Primary Survey

Table 3.24 Dzongkhag Population Data, 1998

Dzongkhag	Population		Number of households	Total Urban Population	Total Rural Population	Household size
	Males	Females				
Wangdue Phodrang	14,387	14,405	2,793	4,000	24,792	10.30

Table 3.25 Demographic Profile and Health Indicators for Wangdue Phodrang Dzongkhag

CATEGORY		TOTAL
Population: 28,792	Male	14,387
	Female	14,406
Infants below 1 year		725
Children 1 – 4 years		3,085
Women 15 – 45 yrs		5,415
No. of pregnancies		808
No. of deliveries		711
No. of abortion		13
Total births		711
Still births		5
Child 1 – 4 deaths		26
Maternal deaths		0
Neonatal deaths		15
Infant death		14

Table 3.26 Population details of the study area villages

Village Name	Households	Total Population
Uma	33	160
Baso	6	50
Rurichu	4	25
Hebesa	18	175
Baychu	2	17
Jareygang	13	120
Zawa	17	67
Kamichu	7	50
Yeuthama	5	35
Pinsa	7	250
Bjaphu	17	48
Namgelam	1	9
Gikha	4	32
Pasakha	5	52
Tapchekha	4	40
Mesesa	5	55
Khatokha	8	95
Masekha	17	220
Changkha	15	198
Yemtalou	8	100
Khamina	10	150
Matshepoto	4	35
Pangsho	12	125
Shinghoe	17	250
Gamsab	6	50
Ula	20	300
Jala	30	300
Ruchekha	12	115
Merapoktokha	4	23
Hesothangkha	55	1000
Dima	2	20
Lawakha	2	8
Dingthi	1	7
Changchey	6	40
Khempajichu	2	20
Total	**379**	**4241**

Source: Primary Survey

Table 3.27 Demographic Details of the Sample Population in Study Area Villages

Village Name	Households	Males	Females	Total	Avg. Family Size
Uma	18	66	68	**134**	7.44
Baso	4	20	24	**44**	11.00
Ruri	4	14	11	**25**	6.25
Hebesa	6	25	21	**46**	7.67
Bay	2	8	9	**17**	8.50
Jareygang	6	23	17	**40**	6.67
Zawa	8	28	20	**48**	6.00
Kamichu	7	19	18	**37**	5.29
Yeuthama	1	3	7	**10**	10.00
Pinsa	3	8	12	**20**	6.67
Bjaphu	6	33	36	**69**	11.50
Namgelam	1	5	4	**9**	9.00
Gikha	4	16	16	**32**	8.00
Pasakha	5	23	31	**54**	10.80
Tapchekha	4	19	21	**40**	10.00
Mesesa	4	18	17	**35**	8.75
Khatokha	5	22	24	**46**	9.20
Masekha	5	36	28	**64**	12.80
Changkha	7	26	29	**55**	7.86
Yemtalou	4	13	18	**31**	7.75
Khamina	5	24	30	**54**	10.80
Matshepoto	2	14	8	**22**	11.00
Pangsho	7	27	31	**58**	8.29
Shingoe	7	36	38	**74**	10.57
Gamsab	3	8	13	**21**	7.00
Ula	6	15	21	**36**	6.00
Jala	6	18	37	**55**	9.17
Ruchekha	6	29	23	**52**	8.67
Merapokto	4	21	10	**31**	7.75
Hesothangkha	4	17	20	**37**	9.25
Dima	2	12	8	**20**	10.00
Lawakha	2	2	6	**8**	4.00
Dingthi	1	6	1	**7**	7.00
Changche	1	2	4	**6**	6.00
Khempajichhu	2	9	6	**15**	7.50
Total	**162**	**665**	**687**	**1352**	**8.33**

Table 3.28 Cropping pattern in Wangdue Phodrang

Crop	Area (acres)	Average yield kg/acre
Paddy	3,388	1,570
Wheat	1,640	1,900
Mustard	310	360
Barley	445	895
Buckwheat	178	220
Chilli (green)	155	2,200
Other vegetables	213	-
Potato	460	4,000
Orange	58	1,007
Apple	56	1,800

Table 3.29 Distance of villages to Transport & Communication facilities/services

Village Name	Distance from road (km)	Distance from Post Office (km)	Distance from Bus Stop (km)	Distance from Telephone (km)
Uma	3 hrs. walk	35	3 hrs. walk	11
Baso	2	12	5	12
Ruri	Road passes through village	19	0	16
Hebesa	7	23	7	23
Bay	Road passes through village	24	0	10
Jareygang	6	30	6	30
Zawa	2 hrs. walk	36	6	36
Kamichu	Road passes through villages	31	0	31
Yeuthama	7	30	15	30
Pinsa	6	38	6	13
Bjaphu	5	7	4	7
Namgelam	8	9	9	9
Gikha	11.5	25	21	21
Pasakha	2	15	15	0
Tapchekha	0.2	25	25	25
Mesesa	0.3	25	25	25
Khatokha	1	26	26	26
Masekha	0.5	2.5	16	1
Changkha	0.4	2.5	16	2
Yemtalou	0.6	3.5	19	5
Khamina	1	20	16	16
Matshepoto	1	3	11	13
Pangsho	2	16	6	16
Shingoe	1	8	16	5
Gamsab	2	19	19	19
Ula	6	27	8	27
Jala	9	30	10	30
Ruchekha	12	35	14	35
Merapoktokha	4	14	12	12
Hesothangkha	Road passes through villages	5	0	0
Dima	1	16	3	16
Lawakha	0.3	9	5	9
Dingthi	1	20	1	20
Changche	0.2	7	3	7
Khempajichhu	0.3	8	4	8

Table 3.30 Occupational profile in study area villages

Village Name	Unemployed	Students	House Holders	Cultivation	Trade & Business	Private service	Govt. service	Total
Uma	16	25	28	63	0	0	4	136
Baso	6	7	7	13	1	0	0	34
Ruri	4	6	8	5	0	0	1	24
Hebesa	3	8	7	16	0	1	0	35
Bay	3	2	3	2	0	0	0	10
Jareygang	6	11	21	21	0	0	0	59
Zawa	3	5	12	20	0	0	2	42
Kamichu	2	8	8	3	6	0	3	30
Yeuthama	1	0	1	3	0	0	0	5
Pinsa	2	1	3	6	0	1	0	13
Bjaphu	8	11	7	18	2	1	2	49
Namgelam	1	2	1	4	0	0	1	9
Gikha	6	6	7	9	0	0	0	28
Pasakha	9	16	7	23	1	0	0	56
Tapchekha	7	9	4	12	0	0	1	33
Mesesa	4	4	7	13	0	0	1	29
Khatokha	7	6	7	17	0	0	0	37
Masekha	12	11	13	16	0	0	2	54
Changkha	5	15	14	19	5	4	2	64
Yemtalou	4	11	6	12	0	0	2	35
Khamina	4	13	5	15	1	0	1	39
Matshepotokha	3	3	3	6	0	1	2	18
Pangsho	9	6	9	18	2	0	1	45
Shingoe	6	15	9	18	0	1	1	50
Gamsab	2	6	6	11	1	0	1	27
Ula	3	4	8	16	0	0	3	34
Jala	4	15	6	15	0	0	1	41
Ruchekha	5	7	15	18	0	0	1	46
Merapokto	2	10	11	11	1	0	1	36
Hesothangkha	2	8	5	5	1	1	2	24
Dima	1	0	7	16	0	0	0	24
Lawakha	0	0	5	3	0	0	0	8
Dingthi	0	2	2	2	0	0	0	6
Changche	0	3	3	2	1	0	0	9
Khempajichhu	1	1	2	7	0	0	0	11
Total	**151**	**257**	**267**	**458**	**22**	**10**	**35**	**1200**

Table 3.31 Land Ownership Details (Study Area Villages)

(Area in Acres)

Village Name	Dry land	Wet land	Total
Uma	21.5	35.2	56.7
Baso	1.5	10.8	12.8
Ruri	2.5	0.5	3.0
Hebesa	3.6	15.9	19.5
Bay	0.0	6.0	6.0
Jareygang	2.0	6.5	8.5
Zawa	2.0	10.2	12.2
Kamichu	14.0	0.0	14.0
Yeuthama	0.3	2.2	2.5
Pinsa	5.2	4.4	9.6
Bjaphu	3.5	15.1	18.6
Namgelam	0.0	0.6	0.6
Gikha	2.1	7.5	9.6
Pasakha	3.4	23.4	26.8
Tapchekha	3.8	13.0	16.8
Mesesa	1.0	7.8	8.2
Khatokha	3.0	13.6	16.6
Masekha	14.5	27.3	41.8
Changkha	9.3	30.7	40.0
Yemtalou	0.0	13.3	13.3
Khamina	3.6	24.0	27.6
Matshepotokha	1.0	10.0	11.0
Pangsho	2.5	12.7	15.2
Shingoe	10.3	24.7	35.0
Gamsab	3.3	7.0	10.3
Ula	1.6	12.7	14.3
Jala	3.8	13.6	17.4
Ruchekha	1.9	7.0	8.9
Merapokto	0.6	12.5	13.1
Hesothangkha	2.0	9.5	11.5
Dima	0.0	0.0	0.0
Lawakha	2.0	12.5	14.5
Dingthi	1.0	4.0	5.0
Changche	0.0	0.0	0.0
Khempajichhu	0.6	2.3	2.9
Total	**126.8**	**395.9**	**522.7**

Table 3.32 Average Monthly Income and Expenditure in the Study Area

Village Name	Average household income (Nu/month)	Average household expenditure (Nu/month)
Uma	3261	2906
Baso	1980	1700
Ruri	3425	2325
Hebesa	2833	2567
Bay	6625	5250
Jareygang	950	817
Zawa	1288	1100
Kamichu	3357	2214
Yeuthama	1200	1000
Pinsa	1733	1333
Bjaphu	6000	4333
Namgelam	4000	3000
Gikha	3000	2450
Pasakha	3600	3160
Tapchekha	1475	1300
Mesesa	2375	1875
Khatokha	2400	1940
Masekha	6700	4280
Changkha	11571	4929
Yemtalou	4125	2950
Khamina	5400	4060
Matshepoto	4350	3850
Pangsho	2371	1957
Shingoe	4686	3257
Gamsab	4833	2933
Ula	4367	2917
Jala	2750	2417
Ruchekha	2033	1333
Merapoktokha	6875	4500
Hesothangkha	6500	4750
Dima	3560	3250
Lawakha	3500	2100
Dingthi	4500	3000
Changche	4500	4000
Khempajichhu	2100	1750

Source : Sample Survey.

Table 3.33 (1) Access to Amenities and Facilities

Village	Uma	Baso	Rurichu	Hebesa
Drinking water	At doorstep	At doorstep	Tap	At doorstep
Irrigation	Channel	River, stream, rain	Natural, channel	Natural channel
Electricity	No	No	Yes	12 of 18 houses have electricity
Sanitation	Pit latrine all	Pit latrine all	Pit latrine all	Pit latrine all
Rural Credit	Available	Available	No	Available
Access to Health	Kamechu BHU @10 km	Wangdue BHU @12 km	Kamechu BHU @ 14 km	Wangdue BHU @23 km, Bajo BHU @ 25km
Access to Education	Gaseloo Pry sch Wangdue Jr H.S Bajo High S	Gaseloo Pry Sch Wangdue Jr H.S Bajo High S	Gamela Pry Sch Wangdue Jr H.S Bajo High S	Gaseloo Pry Sch Wangdue Jr H.S Bajo High S
Local Market	Wangdue Phodrang	Wangdue Phodrang	Wangdu Phodrang	Wangdue Phodrang
Village	**Baychu**	**Jareygang**	**Zawa**	**Kamichu**
Drinking water	Tap	5 – 10 mts	At doorstep	At doorstep
Irrigation	River	Natural, stream	Natural , drain	Rain, river
Electricity	No	No	No	No
Sanitation	Pit latrine all	Pit latrine all	Pit latrine all	Pit latrine all
Rural Credit	No	Available	Available	No
Access to Health	Kamechu BHU @ 10 km	Uma BHU @ 15 km	Kamechu BHU @ 6 km	Kamichu BHU, 0 km
Access to Education	Uma community S Gaseloo Pry Sch Bajo High Sch	Uma community S Wangdue Jr H.S Bajo High Sch	Ada community S Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch
Local Market	Wangdue Phodrang	Wangdue Phodrang	Wangdue Phodrang	Wangdue Phodrang
Village	**Yuethama**	**Bjaphu**	**Namgelam**	**Gikha**
Drinking water	5 – 10 mts	Tap	5 mts	5 mts
Irrigation	Rain, river	Channel	Natural, rain	Stream channel
Electricity	No	No	No	No
Sanitation	Most have Pit ltr	Almost all have latrine inside	Pit latrine all	Pit latrine all
Distance from road	7 km	5 km	8 km	11.5 km
Rural Credit	Available	Available	No	Available
Access to Health	Kamichu BHU @ 7 km	Wangdue BHU @ 9 km	Wangdue BHU @ 11 km	Gaseloo BHU @ 11 km
Access to Education	Ada Pry Sch Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch

Table 3.33 (2) Access to Amenities and Facilities (Cont.)

Village	Pasakha	Tapchekha	Mesesa	Khatokha
Drinking water	Tap	Tap	5 – 10 mts	5 mts
Irrigation	Channel	River, stream	Rain, stream	Channel
Electricity	Yes	No	No	No
Sanitation	Most houses have latrines inside	Pit latrine all	Pit latrine all	Pit latrine all
Rural Credit	Available	Available	Available	Available
Access to Health	Bajo BHU @ 15 km	Tapchekha BHU @ 0.2 km	Tapchekha BHU @ 5 km	Bajo BHU @ 28 km
Access to Education	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch
Village	**Masekha**	**Changkha**	**Yemtalou**	**Khamina**
Drinking water	Tap	Tap	Tap	Tap
Irrigation	River, stream, rain, drain	Natural, channel	Channel	Channel
Electricity	Half the households do not	Yes	No	Yes
Sanitation	Most houses have latrine inside	Most houses have permanent latrines	Pit latrine all	Most houses have permanent latrines
Rural Credit	Available	Available	Available	Available
Access to Health	Gaseloo BHU @ 2.5 km	Gaseloo BHU @ 2 km	Gaseloo BHU @ 3.5 km	Bajo BHU @ 25 km
Access to Education	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch	Gaseloo Pry Sch Wangdue Jr H. S Bajo High Sch	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch	Gamina Pry Sch Wangdue Jr H.S Bajo High Sch
Village	**Matshepokto**	**Pangsho**	**Shinghoe**	**Gamsab**
Drinking water	Tap	Tap	5 mts	Outside house
Irrigation	Channel	Rain, channel	Stream, channel	Stream, drain
Electricity	Yes	Yes	No	No
Sanitation	Pit latrine all	Most houses have permanent latrine	Most houses have permanent latrine	All houses have latrines inside
Rural Credit	Available	Available	Available	No
Access to Health	Gaseloo BHU @ 5 km	Bajo BHU @ 18 km	Gaseloo BHU @ 6 km	Bajo BHU @ 21 km
Access to Education	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch	Gomina Pry Sch Wangdue Jr H.S Bajo High Sch	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch

Table 3.33 (3) Access to Amenities and Facilities (Cont.)

Village	Ula	Jala	Ruchekha	Merapokotokha
Drinking water	5 mts	Tap	Tap	Tap
Irrigation	Stream, channel	Natural, stream	Channel	Channel
Electricity	No	No	No	No
Sanitation	Pit latrine all	Pit latrine all	Most have pit latrine, few have inside	Most houses have permanent latrine
Rural Credit	Available	Available	Available	Available
Access to Health	Jala BHU @ 9 km	Jala BHU @ 1 km	Jala BHU @ 9 km	Gaseloo BHU @ 5 km
Access to Education	Jala community S Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	Jala community S Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	Jala community S Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	Gaseloo Pry Sch Wangdue Jr H.S Bajo High Sch
Village	**Hesothangkha**	**Pinsa**	**Dima**	**Lawakha**
Drinking water	Tap	Tap	5 – 10 mts	Outside house
Irrigation	Channel	Rain, river, stream	Rain, river, stream	River, stream, drain
Electricity	Yes	No	No	No
Sanitation	Almost all houses have permanent latrines	Pit latrine all	Pit latrine all	1 Pit latrine and 1 permanent latrine
Rural Credit	Available	Available	No	Available
Access to Health	Bajo BHU @ 5 km	Bajo BHU @ 38 km	Bajo BHU @ 18 km	Bajo BHU @ 10 km
Access to Education	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	Uma community S Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch
Village	**Ding Thi**	**Changchey**	**Khempajichu**	
Drinking water	5 mts	Tap	5 – 10 mts	
Irrigation	Natural, river, stream, rain	Rain, river, stream	Rain, river, stream	
Electricity	No	No	No	
Sanitation	Pit latrine	Pit latrine all	Pit latrine all	
Rural Credit	Available	Available	Yes	
Access to Health	Jala BHU @ 5 km	Bajo BHU @ 38 km	Bajo BHU @ 18 km	
Access to Education	Jala community S Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	Wangdue Pry Sch Wangdue Jr H.S Bajo High Sch	

Table 3.34 Educational profile amongst study area villages

(Undergoing or having completed)

Village Name	Below VIII	Above VIII	Degree	Total Literates	Illiterates
Uma	39	1	2	**42**	92
Baso	7	0	0	**7**	37
Ruri	5	0	1	**6**	19
Hebesa	8	0	0	**8**	38
Bay	2	1	0	**3**	14
Jareygang	11	0	0	**11**	29
Zawa	5	0	0	**5**	43
Kamichu	8	1	0	**9**	28
Yeuthama	0	1	0	**1**	9
Pinsa	1	0	0	**1**	19
Bjaphu	11	0	0	**11**	58
Namgelam	2	0	0	**2**	7
Gikha	3	4	2	**9**	23
Pasakha	10	7	3	**20**	34
Tapchekha	9	0	0	**9**	31
Mesesa	4	0	0	**4**	31
Khatokha	6	1	0	**7**	39
Masekha	8	2	1	**11**	53
Changkha	13	1	1	**15**	40
Yemtalou	8	3	1	**12**	19
Khamina	17	1	0	**18**	36
Matshepoto	3	0	0	**3**	19
Pangsho	8	0	0	**8**	50
Shingoe	2	0	0	**2**	72
Gamsab	4	0	1	**5**	16
Ula	5	0	0	**5**	31
Jala	15	0	0	**15**	40
Ruchekha	1	1	0	**2**	50
Merapoktokha	3	2	1	**6**	25
Hesothangkha	4	6	0	**10**	27
Dima	0	0	0	**0**	20
Lawakha	0	0	0	**0**	8
Dingthi	2	0	0	**2**	5
Changche	3	0	0	**3**	3
Khempajichhu	0	0	1	**1**	4
Total	**227**	**32**	**14**	**273**	**1079**

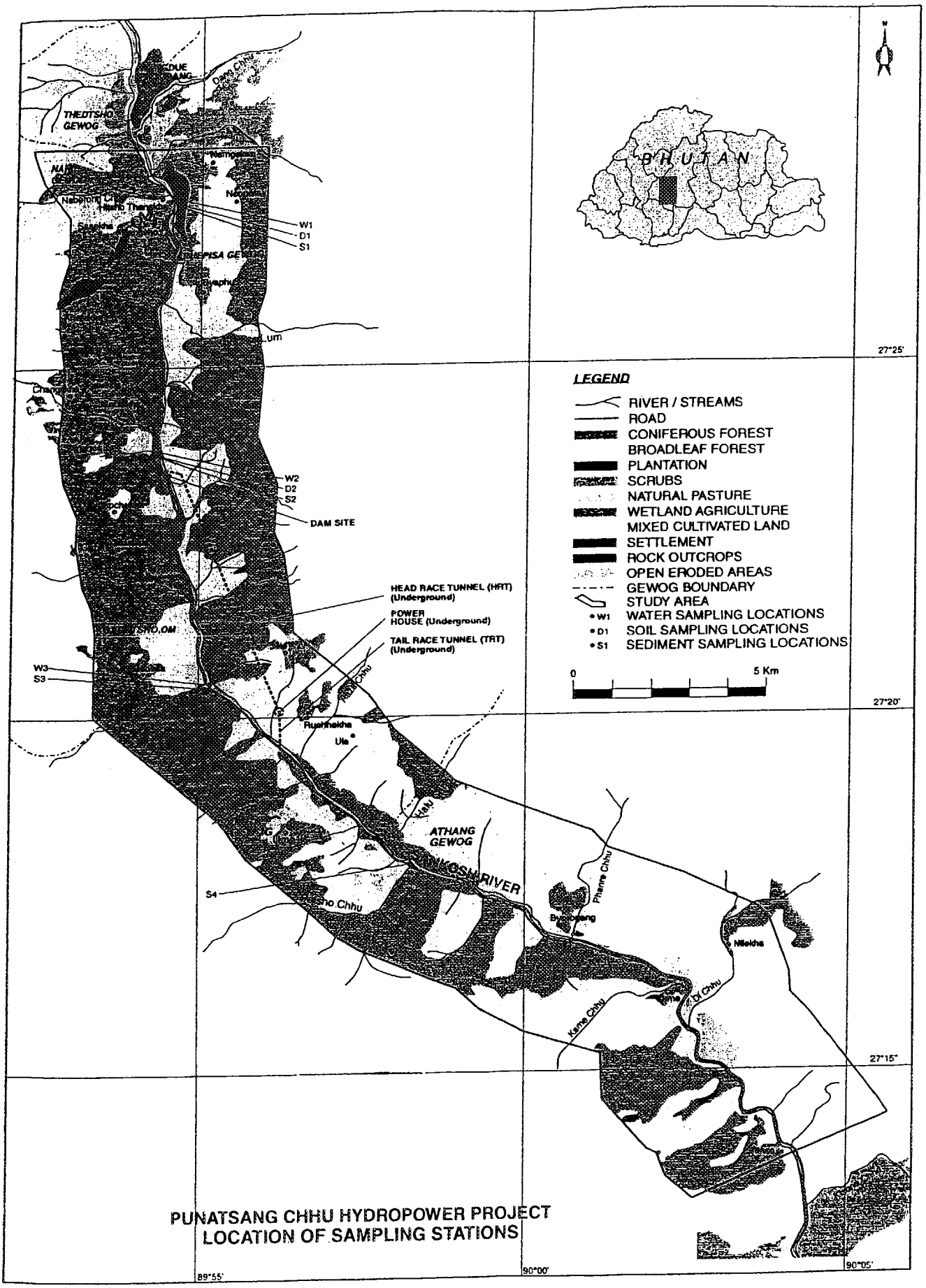
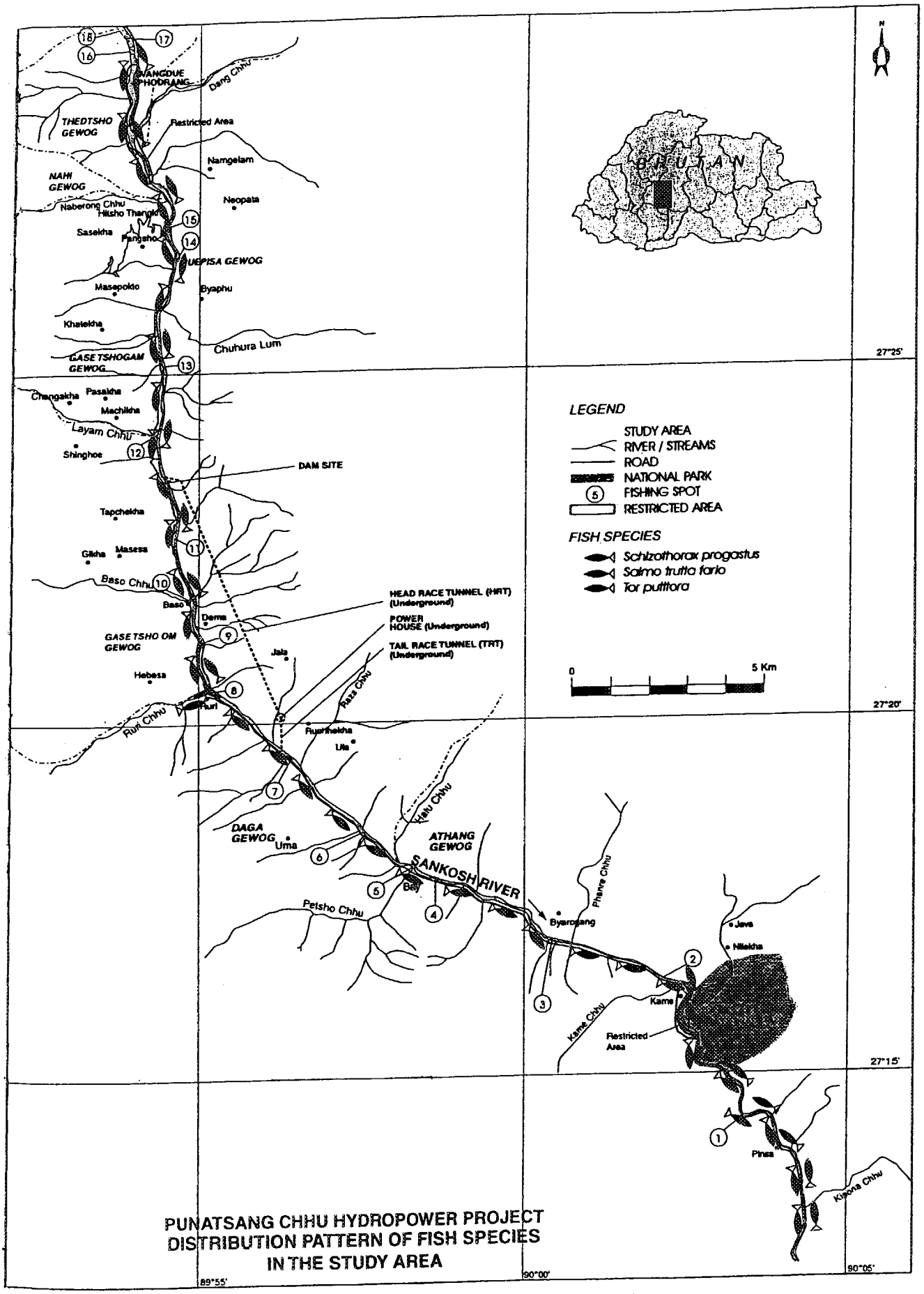


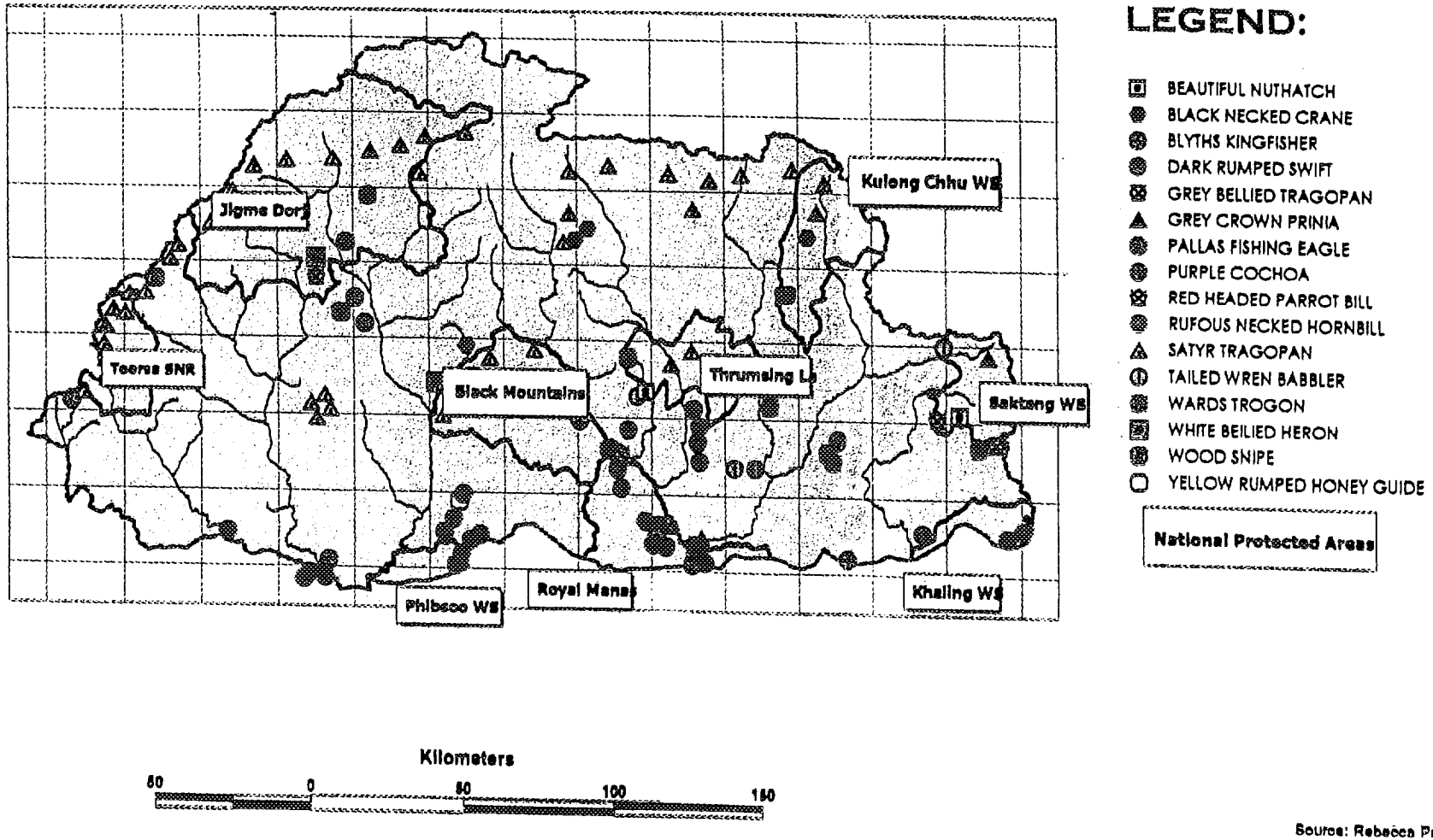
Fig. 3.1 Location of Sampling Stations



PUNATSANG CHHU HYDROPOWER PROJECT
DISTRIBUTION PATTERN OF FISH SPECIES
IN THE STUDY AREA

Fig. 3.2 Distribution Pattern of Fish Species in the Study Area

THREATENED BIRDS IN BHUTAN



Source: Rebecca Pradhan, Taba

Fig. 3.3 Threatened Birds in Bhutan

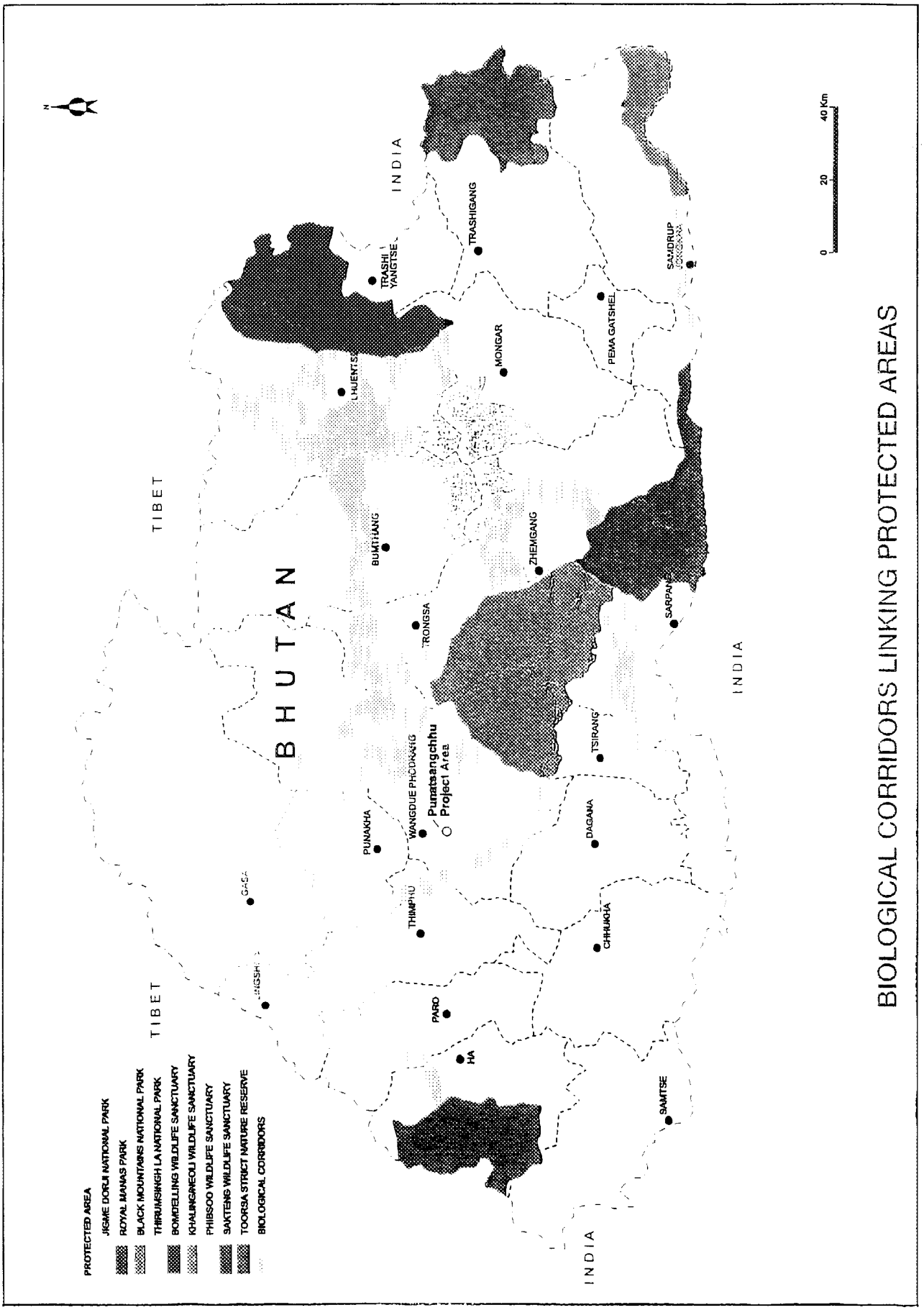


Fig. 3.4 Biological Corridors linking Protected Areas in Bhutan

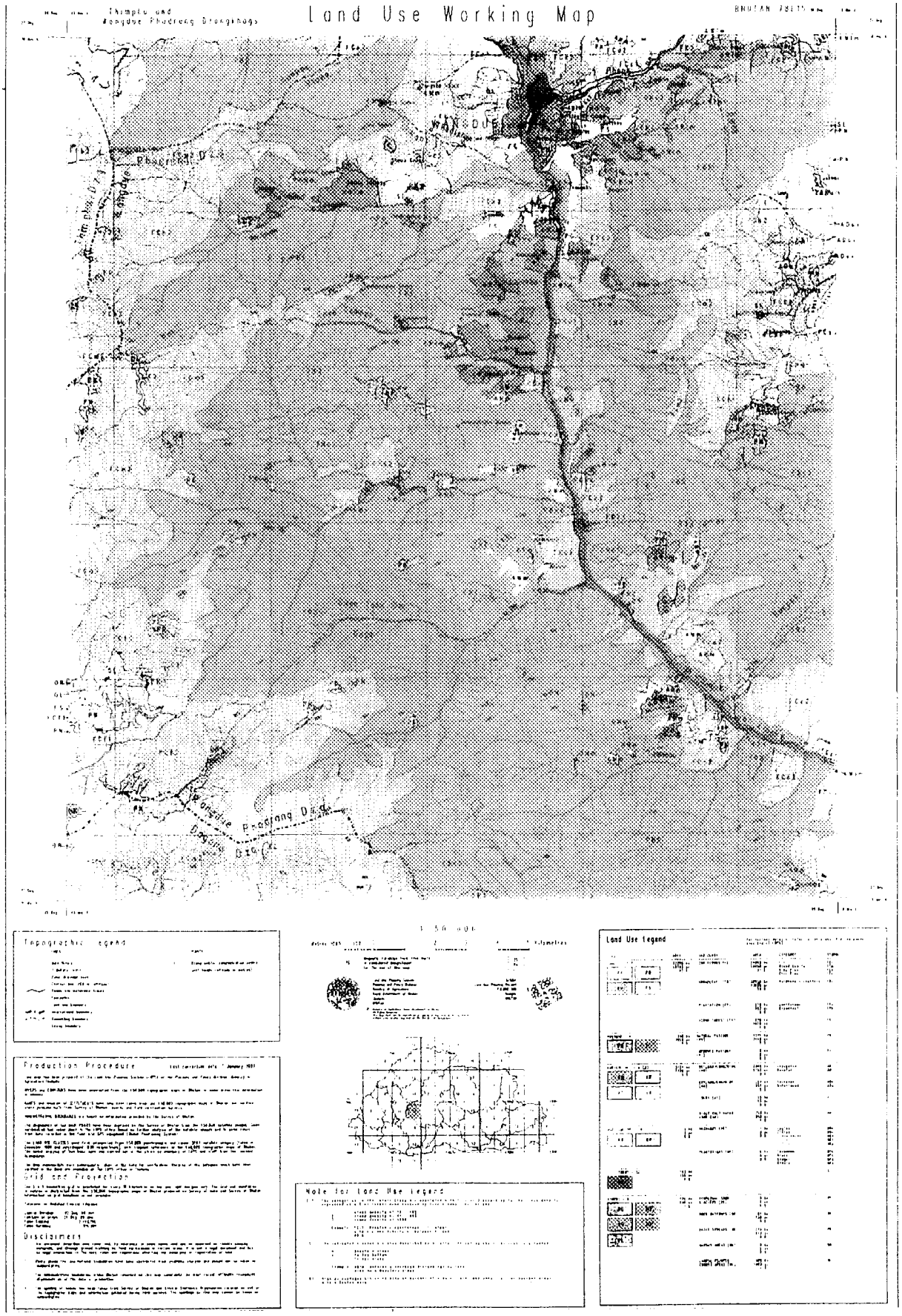


Fig. 3.5 Land use Map

CHAPTER 4

ANTICIPATED ENVIRONMENTAL IMPACTS

CHAPTER 4 - ANTICIPATED ENVIRONMENTAL IMPACTS

Environmental impact assessment of this Project was conducted in two phases of construction and operation, and the following results were obtained:

4.1 Construction Phase

Major works during the construction will include road preparation, construction of the workers' accommodations, excavation and land preparation, gravel extraction, dam body construction, headrace tunnel excavation and construction of the powerhouse, switch yard and transmission lines.

4.1.1 Physical Environment

4.1.1.1 Geology, Topography and Soil

Purposes and square area of geological changes during the construction work are as elaborated in Table 4.1 and Fig. 2.4. The total square area of the construction work will be about 137 ha. About 223 ha is estimated for the land for use included the area of construction work.

(1) Permanent Facilities

Square areas of the individual sites where permanent facilities are to be constructed will be very small, such as 5.6 ha for the proposed dam body site, 1.3 ha for the surge tank work site, 0.3 ha for the tailrace outlet work site of the underground headrace tunnel exit and 1.5 ha for the switch yard work site. Since soil erosion or slope collapse may occur during their construction, face of slope should be secured for stabilization.

(2) Temporary Facilities

27.0 ha is estimated for the sites of temporary facilities such as the place to put construction machinery and materials and workers' accommodations which will be required only for the construction period. Since soil erosion and slope collapse may occur, face of slope should be secured for stabilization.

(3) Muck Disposal Site

Excavation muck to be generated from the construction work taking place at headrace tunnel and the proposed powerhouse site will be broken into fine grains with crushers and disposed in a total of 8 muck disposal sites (35.9 ha). Relatively gentle slopes have been selected for these disposal sites. However, a part of damped muck may be taken into the river and washed down, therefore, muck disposal sites should be stabilized.

(4) Extraction of Gravel

Gravel is to be extracted from the flood plain along a river near Thitosangkha approximately 7 km upstream of the proposed dam site. The river deposits of this site are estimated to have thickness of about 50-60 m. The square area for excavation is required 5.7 ha. In gravel recovery, soil erosion and slope collapse should be prevented through stabilization of the slope. A part of the excavation muck generated from the other construction work will be also used by the project.

4.1.1.2 Air Quality

There is no large factory nor business place around the proposed site and the number of vehicles passing by is limited. Therefore, air pollution source is quite limited, provided that vehicles used for excavation, land preparation and construction work will result in certain amounts of exhaust gas and dust accompanying the work and transport of construction materials.

Dust to generate from operation of two rock drills installed at the proposed dam and powerhouse sites are sometimes scattered for a distance of around 2 km depending on the wind direction. Since there is no village within the scope of 2 km from each proposed site, there will be no impact on the locality. However, since workers' accommodations to be built within the sphere of 2 km may be affected, necessary measures should be taken to avoid possible issues.

With regard to exhaust gas, vehicles in conformity with the standards established by the Bhutanese Government should be used for construction. Impacts on air quality to be caused by other works may vary to a large extent depending on details of construction and weather. Such impacts on the peripheral environment may be minimized through sufficient watering during work period to prevent dust.

4.1.1.3 Hydrology and Water Quality

Water will be used to clean and cool rock drills for the proposed dam and powerhouse sites. 0.1 m3 of water is estimated to be necessary to crush 1 ton of earth and soil. Since much suspended substances may be contained in the water used, measures should be taken to drain it after removal of such substances.

Approximately 5,000 laborers required for the construction work will stay in their accommodations which will be constructed at 3 points. The amount of BOD generating from their sewage is estimated as 225 kg/day. Streeter-Phelp's models are used in general to predict the purifying capacity of the river. However, since the flow rate of the Punatsangchhu is extremely high and its sufficient self-purifying capacity is ensured, no problem may occur. However, the sewage must be processed by taking appropriate measures.

4.1.1.4 Noise

Accompanying construction of the main and associated facilities, noise will be generated as indicated in Table 4.2. However, in view of the facts that population around the proposed site is extremely small, that such noise will not occur continuously and that the night work will be minimized, only small impact will be given on residents.

Although the current noise level is about 40 dBA, the level will increase, though intermittently, when vehicles for construction begin to pass. However, since houses are not clustered together along the road and vehicles for construction will pass there only temporarily, rise in the noise level may not give serious impacts to the residents.

4.1.2 Biological Environment

4.1.2.1 Terrestrial and Aquatic Biology

(1) Terrestrial Flora and Fauna

The places where submergence or felling of trees will be required are construction sites mainly for the reservoir, dam, muck disposal sites and access road. The area required for construction of transmission lines is estimated as 323.4 ha.

In construction of the facilities associated with this project, the number of trees felled should be minimized. The kinds and numbers of the trees to be felled are as indicated in Tables 4.3 – 4.6. In view of the facts that no rare plants are included in the trees to be felled and that similar vegetation grow around the proposed site, no significant impact to cause conspicuous changes of the peripheral flora will result in.

The land used for muck disposal sites, for other construction sites, etc. which will be returned to naked land after completion of the construction should be replanted with similar florae to those growing nearby.

Approximately 5,000 laborers will be required for the intended work, and if they fell trees for their fuel purpose, it may give impacts on the vegetation around the proposed site. As a measure against this, appropriate heating source should be provided in the workers' accommodations.

With regard to faunae, noise to be generated from operation of power saws for land preparation and tree transportation, and noise/vibration from construction vehicles may temporarily affect the faunae inhabiting there. Although no accurate distribution of faunae inhabiting around the proposed site has been clarified, according to the documents available, rare faunae may also inhabit there. Since the proposed site is not included in any biological corridor, preservation of species will not be threatened by

the construction. However, the construction works should be proceeded by paying careful attention through appropriate preventive measures. Measures should be taken to refrain from constructing transmission lines during the season of birds' breeding, since transmission lines may pass the place inhabited by rare Aves. Detailed preventive measures should be examined through discussion with the Bhutanese Government as soon as such detail designing is prepared.

(2) Aquatic Flora and Fauna

Accompanying the construction of the dam and its power intake and tailrace outlet, the district inhabited by aquatic biology may be decreased in part. However, the scope of such decrease will be limited.

Muddy water to result from the construction may affect aquatic biology. However, its impact will be limited since muddy water can be minimized through provision of a setting basin, etc.

At the peak of the construction work, drainage from the workers' accommodations will increase. However, no issue of water quality degradation may occur since a lot of river water there will dilute the drainage.

Since many laborers will lead their life around the proposed site during the construction period, regulations and control measures should be intensified against their possible attempts to catch fish species for securing foods by using explosives which is prohibited in Bhutan so that no adverse impacts may be given on a lot of fish species at a time.

In construction of the dam, a detour will be provided on the left-hand shore of the proposed dam site to let the river water flow down below the dam site. Therefore, the condition of the downstream will not change during the construction period.

4.1.3 Socioeconomic and Cultural Environment

4.1.3.1 Villages Affected

Exhaust gas, dust, noise, vibration, etc. generated from the construction work and the vehicles used for construction may affect peripheral residents. However, since houses do not cluster together within the scope of the construction or along the nearby roads, the construction period is limited, and appropriate countermeasures will be taken, serious impacts may not be given on the residents.

Public consultation meetings for people living around the project site was held by Dop during 20th~ 21st July, 2000. The objectives of this consultation meetings is as below. 232 households from 23 villages participate in the meetings which were held three times during the period. Detail of these meetings are shown in ANNEX II .

Objectives

- Inform the local people about the project details and present environmental and social findings.
- Invite views and suggestions on the project in order to minimize the negative impacts and enhance the positive impacts.

The public consultation could give full understanding of details of the project for participants. Given the immense benefits the project would bring for the general benefit of the government and the people using this river, the people were supportive of the project and even expressed their readiness to help the project in any forms that may be required.

4.1.3.2 Employment

Approximately 5,000 laborers will be required for construction of the intended powerhouse (see Table 4.7). As many laborers as possible should be employed out of local people. A central heating system is provided to provide hot water to the labourers. This is necessary because of low temperature throughout the year, otherwise, workers will be forced to cut trees for heating the water to meet their requirements. A community kitchen is provided where workers have their meals. The fuel used in the kitchen is LPG or diesel. The water for drinking purpose is collected from the rivers or streams flowing upstream of the labour camps. The water is stored in tanks and supplied for use. The water quality in general is good and does not require any elaborate treatment. Only filtration is adequate. However, if some problems are anticipated as a result of bacteriological contamination, then suitable treatment units can be installed at a later date. Efforts should be made that water sources and septic tanks are placed far from each other. It is recommendable to consider about preparation of their life bases including their accommodations when detailed employment plan is decided.

4.1.3.3 Economic Activities

Through creation of their employment, incomes of local villagers will increase. Stores to supply meals and daily necessities will be opened, and this will also lead to increase in their income.

In addition, as many construction materials as possible should be purchased from the local villages.

Further, as a result of road preparation accompanying the implementation of the project, access to this area will be improved and movement of the people and circulation of materials will be facilitated. Thus, local economy can be animated and villagers' income will be increased.

4.1.3.4 Utilization of Land

The area where changes in land conditions will be required accompanying construction of the powerhouse is designed to be the minimum of approximately 137 ha. Therefore, utilization of land in the vicinity will not be changed.

4.1.3.5 Public Health

As a result of laborers flowing in the area from outside, water-related diseases may spread among local residents. Therefore, in employing the workers, health checks should be performed in general, and a schedule should be settled to ensure adequate intake of vaccine.

With regard to the wastes to be disposed from the working site and workers' accommodations, by installing appropriate treatment facilities or establishing an appropriate treatment system, impacts on the vicinity will be minimized.

4.1.3.6 Recreation and Archaeological Components

Since no recreation facilities or archaeological component is noted to exist around the proposed site, no impact will be caused.

4.2 Operation Phase

4.2.1 Physical Environment

4.2.1.1 Geology, Topography and Soil

As elements to give impacts on physiography, geology and soil in the operation phase, possible soil submergence caused by forming the reservoir and soil erosion surrounding the reservoir caused by its operation should be considered.

The area of the reservoir will be 53 ha when the water level is high. Out of this, the farmland including residential areas will be 6 ha. With regard to possible collapse of brittle parts of protection shore through operation of the reservoir, unstable ground part should be examined and necessary reinforcing measure should be taken in advance. In addition, a system should be established to ensure periodical examinations of the protected shore and to cope with anticipated issues.

In addition, an issue of erosion at the toe of tailrace outlet may occur. However, since the riverbed consists of rocks, etc., no serious issue will arise.

4.2.1.2 Hydrology

(1) Flow Rate

The river water flowing into the reservoir will be sent to the powerhouse through the underground tunnel connected to the dam, and it will be returned to the river after being used for power generation. Therefore, although river level variation may be leveled downstream of the powerhouse, no conspicuous change in the flow rate will result in.

On the other hand, approximately 7.5 km extent from just under the dam to the tailrace outlet of the powerhouse is the river section affected by river diversion. Because of the appearance of this river section affected by river diversion, the number of biology inhabiting in this section may decrease, irrigation water may lack and water quality may be degraded. By setting the minimum flow for river condition conservation for this section, possible impacts may be minimized.

In Bhutan, no regulation on setting the minimum flow for river condition conservation has been legislated. Consequently, in deciding the minimum flow for river condition conservation, the actual states of natural and social environments of the Punatsangchhu should be taken into account.

(2) Minimum flow for river condition conservation

In establishing the minimum flow for river condition conservation, natural and social environments of the proposed site were examined. The examined items were; utilization of river water, fishery, protection of biology, water quality, scenery and sight seeing, etc.

- Utilization of river water

As results of the field survey, water is not used for river traffics or living water in the river section affected by river diversion. Further, residents living in the vicinity do not use the underground water for their life. Although irrigated farmlands are distributed in some part of relatively gentle slopes, water from branch rivers and spring water is used as water for agriculture. Moreover, since no factory and the like exists here, river water is not used for industrial purposes.

- Fishery

According to the results of the field survey, no fishery, fishing nor marine substance raising is practiced in the river section affected by river diversion.

- Biology

As a result of the Aves survey and enquiry, existence of three fish species of brown trout (*Salmo trutta fario*), Asala as a kind of carp (*Schizothorax progastus*) and Kabrat were identified, while

existence of rare Fish species was not identified. However, the minimum flow for river condition conservation should be decided from the viewpoint of natural protection.

As to florae, since the flood plain along the river consisted of relatively large stones, aquatic florae were scarcely found and, therefore, no serious impacts will be given on aquatic florae.

- Water quality

  Since the operation of this project will not cause any additional contamination source, water quality will not be degraded much.

- Views and sightseeing

  Reduction in the river width which may be caused by decrease in the amount of river water may give impacts on views of the vicinity. However, no place for sightseeing was found around the proposed site and few people pass.

ANNEX I shows the results of the examination of the minimum flow for river condition conservation taking the above into account. The following is its outlines:

The flow rate of the Punatsangchhu was very high and estimated minimum flow rate was 64 m3/sec. which was determined referring to the data obtained at the groundwater-level observatory located farther upstream of the proposed dam site. If we were to take the usual method, the minimum flow for river condition conservation in the river section affected by river diversion should have been estimated by obtaining the river section. However, since no information on the actual river section is available at present, the minimum flow for river condition conservation was calculated by setting certain conditions on the river section and flow velocity and based on the relations between given flow rates on several stages and river sections. The final minimum flow will be decided when the actual measurement of the river section is available.

Based on the above, in case the flow velocity is 0.5-1.0 m/sec and a tentative flow rate is 3 m^3/sec, the river depth would be around 20-40 cm for the river width of 15 m provided that the river section is in the shape of a rectangular. For tentative flow velocities of 6 m^3/sec and 9 m^3/sec, the river depths would be 40-80 cm and 60-120 cm, respectively. Here, 6 m^3/sec is set as a standard for the flow rate, with the river width and depth being 15 m and 40-80 cm, respectively.

It is known in general that a shape of the section (relation between the depth and the width of the river) varies much depending on locations of the river even if the flow rate is the same. Therefore, a post-survey for adjustment should be conducted upon completion of the construction when measurement of the section is available.

4.2.1.3 Water Quality

In some cases, water quality degradation by eutrophication may arise as an issue. However, in view of the facts that water quality of the Punatsangchhu is clean and that the water in the reservoir will be replaced at a high rate of 0.5 - 2.2/day, an issue of water quality degradation will scarcely arise.

Owing to the minimum flow for river condition conservation and the fact that no large contamination source exists in the section, water quality degradation in the river section affected by river diversion will seldom occur, either.

Approximately 150 persons will be stationed as the staff to operate the powerhouse and to control the facilities. Since their living sewage will be drained into the river through a simple treatment facilities, and in consideration of the high self-cleaning capacity of the river, few impacts will be given to the water quality at downstream.

4.2.1.4 Sediment

It is concerned that the amount of sands going down the river will be decreased by the construction of the dam. As the riverbed of downstream from the proposed site also consists of relatively large rocks, no conspicuous impact will be caused. The river water having passed the powerhouse will return to the river. However, since the place right below the proposed tailrace outlet site of the dam consists of large rocks, and since they are in a stable condition against large flow rate before the dam construction, it is judged that no conspicuous impact will be given by excavation with the water to be discharged.

4.2.2 Biological Environment

4.2.2.1 Terrestrial and Aquatic Biology

(1) Terrestrial Biology

In the operation phase, residents' passage on extended or newly constructed roads may augment, which may give a certain impacts on terrestrial biology. However, since the area where residents can enter will be limited for physiographic reasons, no significant impact will be given on the distribution of biology around the proposed site.

Muck disposal sites and the land which will be naked and unused after completion of the construction should not be abandoned but replanted considering peripheral vegetation.

(2) Aquatic Biology

The affect from changes in flow duration will arise most conspicuously in the dry season when aquatic biology inhabiting the river section affected by river diversion are exposed to low flow rates. In the operation phase, most of the river flow will be lost in the river section affected by river diversion ranging for approximately 7.5 km from the dam to the tailrace outlet. It Would be a concern that a large-scaled decrease in water amount may adversely affect the biology inhabiting there.

A trial calculation of the quantity of Fish species inhabiting the river section affected by river diversion was attempted based on the in the field fishing survey on catch. As a result of the survey, 400 g/man-hour per 1 km of the river length for a range of 1 m in the river was recorded. Since the average river width was approximately 50 m, the total catch per 1 km of the river length was assumed as 20 kg/man-hour. Supposing the section of 7.5 km is completely dried up, space inhabited by Fish species of 150 kg/man-hour would be lost.

According to the results of the field survey, two species of Fish, i.e. brown trout (*Salmo trutta fario*) and Asala (*Schizothorax progastus*) were identified in the Punatsangchhu around the proposed site. In addition, as a result of the enquiry, it was found that the species called kabray/badbala in the local language and Mahaseer (*Tor putitora*) also inhabit there. Out of the above Fish species, Mahaseer is known to seasonally travel for a long distance. The upper limit of the area inhabited by it is considered as the vicinity of the Dhikchuu National Park located downstream of the proposed site. On the field survey, existence of Mahaseer was not identified in the river section affected by river diversion and in its upstream. Each of the other three species of Fish is said to have no large mobility.

Some measures should be taken to establish the minimum flow for river condition conservation so that impacts on biology inhabiting the river section affected by river diversion may be minimized.

Through construction of the dam, a new reservoir of 53 ha will come out. Since water in the reservoir is to be replaced at a rate of 0.5 – 2.2/day, the river water will stay in the reservoir only for a short time. The impact from decayed and decomposed organic substances on aquatic biology is not considered to exceedingly degrade water quality because of high flow rate of the river and of extremely high rate of water replacement except for slight increase of nutrient in the early stage.

4.2.3 Socioeconomic and Cultural Environment

4.2.3.1 Local Community

Appearance of a new reservoir may not possibly lead to local disruption because of the fact that no facility (such as a bridge) to cross over the river exist at the present time.

4.2.3.2 Employment

Accompanying operation of the powerhouse, workers will be employed as required for the operation, maintenance and control. The total number of the workers required for operation of the powerhouse will be approximately 150 as indicated in Table 4.8.

4.2.3.3 Economic Activities

Construction of the powerhouse will not only result in power supply to local residents but also stimulate the growth of other sectors including the industrial section, and thus enhance employment opportunities in the locality.

Further, power supply to local households will enable residents to inaugurate new businesses, which in turn will lead to a possible increase in their incomes.

4.2.3.4 Utilization of Land

The total area of the land subject to change because of this project will be approximately 137 ha which belong to the nation or private persons. The land under private ownership will be expropriated in accordance with an appropriate plan. Construction of the transmission lines for this project is designed to keep out of villages in possible range. Moreover, since the land for access road will be relatively small-scaled, no serious impacts will be given on the land use in the vicinity.

4.2.3.5 Public Health

Accompanying the operation of the powerhouse, population around the proposed site may possibly increase. To cope with this, substantiated facilities for treatment of wastes and drainage, hospitals, etc. will be required.

Because of the reservoir to be established, various pathogenic insects may possibly be bred. The scale of the place for breeding of mosquitoes, etc. is directly proportional to the length of the shore. Therefore, as a result of the reservoir's appearance, the length of the shore will become several times as long as that of the original river, and the places where various pathogenic insects are bred may increase. Consequently, appearance of the reservoir may cause an increase in the occurrence of malaria. In addition, workers gathering together, deforestation and excavation are also considered to lead to occurrence of malaria.

With construction of the reservoir, measures against occurrence of pathogenic diseases should be taken while considering its impact on the increase in water-related diseases. Upon excavation of construction materials, goafs are left as they are in general, and water staying in such goafs will be a

serious factor to cause occurrence of malaria. Generally, mosquitoes fly around in the sphere of 1 – 2 km. Since only small number of residents living within such sphere, no large-scaled occurrence of malaria would take place. However, workers' accommodations may be easily attacked by malaria.

4.2.3.6 Recreation and Archaeological Components

No facility related to recreation and archaeological components exist in the area covered by the project.

4.3 Other Impacts During Construction and Operation Phase

4.3.1 Transmission Line

Transmission lines are planned to be forwarded to India from the proposed powerhouse site. As to the route of transmission lines, two plans, Plans A and B, are currently examined (see Fig. 4.1). Each plan represents a route designed to keep out of the areas for wildlife sanctuary or residence, but they will pass biological corridors proposed by the Bhutanese Government.

Plan A is to go southward from the proposed powerhouse site, pass the periphery of Sarbhang (Sapang), a town near the borders between Bhutan and India and will be connected with Bongaigaon substation in India. The route of the transmission lines within Bhutan will be approximately 80 km long in total and approximately 200 – 230 steel towers will be constructed along the route.

Plan B is to go southward from the proposed powerhouse site and pass the vicinity of Devitar, a town located near the border between Bhutan and India. The route of the transmission lines within Bhutan will be approximately 108 km long and approximately 270 – 310 steel towers will be constructed along the route.

As presumed from the satellite images, the distance of the forest zones to be passed according to the proposed plans will be as follows:

Type of Forest	Alternative-A (km)	Alternative-B (km)
Dense forest	45.50	60.46
Medium forest	5.61	8.19

No regulation has been established yet in Bhutan to provide the maximum width required for transmission lines to pass the forest zones. Referring to the guideline provided in the Forest Conservation Act (1980) enacted by the Ministry of Environment and Forests, the maximum width required for transmission lines of 440 kv will be 52 m. Based on this value, the areas required for the plans of proposed transmission routes are as follows:

Type of Forest	Alternative-A (ha)	Alternative-B (ha)
Dense forest	236.62	313.82
Medium forest	86.76	42.57
Total	323.38	356.39

Plan A is to pass wasteland of 7.97 ha and cultivated land of 0.93 ha and approximately 80,000 trees are to be felled within the entire route, while Plan B is to pass cultivated land of 13.25 ha and approximately 99,500 trees are to be felled within the entire route.

Further, Plan A may possibly pass the area near the border between Bhutan and India where endangered species in Aves seem to inhabit, while based on Plan B it will be required to pass Buxa Tiger Reserve in India designated to protect tigers.

Most of the routes to be established in Bhutan are possessed by the nation and they are designed to avoid villages and private land as much as possible. Upon decision on the detailed construction plans including the number of steel towers and their positions, locations to establish access roads, etc., compensation for acquisition of the land required for the route of transmission lines should be taken into consideration.

4.3.2 Dwellings and Access Road(s)

(1) Residence

The land to be acquired for implementation of this project will be about 137 ha in total. Out of this, 27.1 ha is private lands for agriculture and residence. Table 4.9 elaborates the outline of private lands subject to acquisition for this project. Resulting from acquisition of such private lands, around 6 homesteads will be affected. Table 4.10 shows details of "Project Affected Households."

The property, which is likely to be affected due to land acquisition, includes land under cultivation, homesteads and other crops, such as fruit bearing trees. The details of the affected landed property is given in Table 4.11. It is clear from Table 4.11, that 2 households that are landless and who share-crop on other's land, while all others are land holders. Among the land owning households, the 2 households in Lawakha own land in another village also, while the other households had land only in the affected villages.

Besides cultivated land, the households would also lose land under vegetable garden and horticulture, i.e., fruit bearing trees. The details of these properties are highlighted in Table 4.12.

In addition to the above properties, the households would also lose their homesteads. The details of the affected homesteads are given in Table 4.13.

In all there are about 6 homesteads for the same number of affected households.

With respect to resettlement, since it is possible for them to resettle to nearby places, their life bases may not be thrown into a commotion. For their resettlement, attention should be paid to ensure maintenance of their living standard taking their occupations, etc. into account. Compensation for land expropriation and resettlement should be reasonable enough to be accepted by the persons concerned. Details of the resettlement and compensation plans are as referred to in Chapter 5.3.

(2) Access Roads

The existing roads should be extended for transportation of construction materials. In addition, it will be necessary to establish new roads to ensure access to the proposed dam sites, the proposed powerhouse site and the site for gravel collection. The total length of these additional roads will be approximately 8 km.

The intended extension and addition of roads may involve slope collapse, land erosion, and outflow of earth and sand. In the phase of settling on the detailed plan for road construction, measures to secure stability of road shoulders and the ground should be examined.

4.3.3 Hypothetical Dam Failure or Overflow due to Extreme Flooding

Some examples of incident related to dam collapse and/or partial damage are shown below.

- Large scale of slope collapses at reservoir and dam failure
- Dam destruction caused by collapse of foundation rock
- Earth dam destruction caused by leakage of water
- Overtopping of large flood
- Damage of dam caused by large earthquake
- Destruction caused by GLOF (include mud slide)

Proposed dam is a concrete gravity type which is constructed on stubborn foundation and safe to overflow consequence on detail geological survey. Because earthquake-proof design is adapted and the structure is secure for flood to flow down in the case of gate operation down, dam collapse is hardly to occur. Response of a dam to GLOF and earthquake are concerned as follows.

Case of GLOF and dam destruction

The proposed dam has 10 m from HWL to the dam crest, and has stricture of flowing down safely with

1168.2 m of the maximum water level even in a case of closed gate. The dam is designed to flow a flood safely, even if the gate operation is disrupted by energy off, accident or quick reach of flood. Consequently, it is concerned that there will be no dam destruction caused by GLOF.

Case of dam destruction caused by large earthquake

There is no case of destruction by earthquake, when a dam is constructed appropriately on a foundation. Experiences, tests and analysis show that 150 m class dam is safe against to M8 class of earthquake. The proposed dam is designed appropriately so that there is no chance of dam destruction caused by earthquake.

Case of hypothetical dam failure

Above all, it is hard to concern a situation a dam destructed catastrophically. Only case that the situation can be imagined is a sudden flow out by destruction of spillway gate.

Suppose a gate destructed in flood situation, the amount of flow out water would be some 2,000 m^3/s. This scale is not far from normal flood scale.

Table 4.1 Area to be Acquired for Various Project Activities

No.in map (Fig. 2.4)	Structure/Activity for which land is required		Area (ha)
1	Quarry site		5.7
2	Submergence area		53.0
3	Land for structures	Dam, intake	5.6
4		Surge tank	1.3
5		Tail race outlet	0.3
6		Switch yard	1.5
		Sub-total	8.7
7	Temporary facility	Laborer's camp	5.0
8		Stock yard & Motor pool	3.8
9		Batching plant Aggregate plant	2.8
10		Stock yard	6.0
11		Batching plant Aggregate plant	2.5
12		Laborer's camp	1.0
13		Camp	1.2
14		Steel yard	1.5
15		Stock yard	3.2
		Sub-total	27.0
16	Muck Disposal area		2.5
17			5.7
18			2.4
19			12.8
20			2.6
21			4.4
22			3.2
23			2.3
		Sub-total	35.9
24	Land for use		119.2*
25			7.0*
26			28.3*
27			4.1*
28			8.9*
29			55.4*
		Sub-total	222.9*
30	Road construction		0.6
31			0.8
32			1.1
33			0.6
34			0.4
35			1.0
36			0.1
37			2.2
		Sub-total	6.8
Total			137.1

NOTE: * Included other appurtenances, hence, have not been included in the estimation of total area.

Table 4.2 Noise Levels due to Operation of Various Construction Equipment

Equipment	Sound Level at 7 m dB(A)
Unsilenced pile diver	110
Unsilenced scraper, grader	94
Unsilenced pneumatic drill	90
Unsilenced compressor	85
Cranes	82
Generator	82

Table 4.3 Details of Loss of Trees in the Dam Site Intake Structure and Temporary Facilities in the Dam Site

Species	No. of trees	Loss of wood (m^3)	Remarks
Pinus roxburghii	104	37.1	Timber
Toona ciliata	22	3.20	Timber
Sapium insignii	63	5.0	Fire wood
Mallotus phillipensis	19	-	Medicinal plant
Celtis tetrandra	39	-	-
Rhus chinensis	66	-	Fruit
Dalbergia pinnata	18	2.6	Timber
Dalbergia sericea	146	20.9	Timber
Solanum turvium	63	-	-
Zizyphus incuvra	46	-	Fruit, Medicinal plant
Asandra buteraceae	6	-	Oil seed
Bombax ceiba	10	-	-
Ficus semicordata	13	-	Fodder
Albizia julibrissin	93	28.4	Timber
Altringia exelsa	20	6.1	Timber
Orange	152	-	Fruits
Banana	8	-	Fruits
Total	906	104.9	

Table 4.4 Details of Loss of Trees Likely to be Affected/Lost Near Adit, Submergence Area for Various Activities

Species	No. of trees	Loss of Wood (m^3)	Remarks
Albizzia procera	32	5.5	Timber
Albizzia julibrissin	56	9.6	Timber
Sapium insignii	29	2.3	Fire wood
Ficus benjamina	21	-	Shade
Celtis tetrandra	2	-	-
Toona ciliata	45	6.5	Timber
Mangifera sp.	12	7.6	Firewood
Alnus nepalensis	10	3.1	Firewood
Dalbergia pinnata	63	9.0	Timber
Phyllanthus enblica	21	-	-
Pinus roxburghii	354	126.2	Timber
Litsea monopstala	22	-	-
Orange	30	-	Fruits
Banana	55	-	Fruits
Bamboo	7	-	Fruits
Guava	15	-	Fruits
Total	774	169.8	

Table 4.5 Details of Loss of Trees likely to be Affected/Lost due to Various Activities Near Power House

Species	No. of Trees	Loss of wood (m^3)	Remarks
Pinus roxburghii	177	30.4	Timber
Albizia julibrissin	52	8.9	Timber
Woodfordia fruction	67	11.5	Fire wood
Ficus senicordata	46	-	Shade
Ficus semicordata	15	-	Shade
Toona ciliata	56	6.2	Timber
Syzygium cuminii	43	4.7	Timber
Solanum turbium	12	-	Wild fruits
Bridella sp.	27	-	-
Sapium insignii	34	2.7	Fire wood
Dalbergia sericea	23	-	-
Bambusa cupilata	27	5.5	Timber
Dalbergia pinnata	23	3.3	Timber
Grewia sapida	42	-	Fodder
Alnus nepalensis	37	11.3	Fire wood
Caseria glomurlata	12	-	-
Eurya cerasifolia	34	2.2	Timber
Zanthogy clumarmatun	24	-	-
Mangifera sp.	17	10.8	Fire wood
Guava	30	-	Fruits
Orange	300	-	Fruits
Banana	62	-	Fruits
Papaya	35	-	Fruits
Rhus chinensis	11	-	Wild fruit
Total	1205	97.5	

Table 4.6 Details of Loss of Trees likely to be Lost/Affected due to Quarrying

Species	No. of Trees	Loss of wood (m^3)	Remarks
Alnus nepalensis	10	3.6	Timber
Eucapyptus sp.	12	3.4	Fire wood
Toona ciliata	8	1.2	Timber
Albizia sp.	7	2.1	Firewood
Bamboo	3	-	Agricultural field
Anacardium	5	-	Agricultural field
Banana	4	-	Fruits
Orange	2	-	Fruits
Total	51	10.3	

Table 4.7 The Estimated Employment Opportunities During Construction

	Construction Stage
Engineers/ Office Workers	450
Labour	4,500
Total	4,950

Table 4.8 Employment Opportunities During Operation and Maintenance

	Operation Stage
Engineers/ Office Workers	150
Labour	0
Total	150

Table 4.9 Cultivated & Settlement land required for the Project

Activity	Village whose land is to be acquired	Area (ha)
Submergence	Lawakha	6.0
Switch Yard	Dingthi	0.8
Temporary Facilities	*	4.7
Adit	Dema	2.4
Disposal Areas	Dema	10.0
	Dingthi	1.2
	**	2.0
Total		27.1

* land may belong to either Rurichhu/ Uma/ Baychhu ** land may belong to Shinghoe

Table 4.10 Households Affected By The Project

Village	Dima	Dima	Lawakha	Lawakha	Ding thi	Uma
Geog	**Rupesa**	**Rupesa**	**Tshowom**	**Tshowom**	**Rupesa**	**Daga**
Household Size	9	11	3	5	7	4
Males	6	6	0	2	6	2
Females	3	5	3	3	1	2
Children below 14	3	2	0	3	2	1
Widows	0	0	0	0	0	0
Migrant Members	1	1	0	0	0	0
Education						
Below VIII	0	0	0	0	2	0
Above VIII	0	0	0	0	0	0
Degree	0	0	0	0	0	0
Students	0	0	0	0	2	0
Household chores	3	4	3	2	2	2
Cultivation	6	10	2	1	2	2
Trade/Business	0	0	0	0	0	0
Private service	0	0	0	0	0	0
Government ser	0	0	0	0	0	0
Avg mly HH Inc	3,300	4,000	5,500	1,500	4,500	2000
Avg mly HH Exp	3,000	3,500	3,000	1,200	3,000	1700
Land owned (acres)	**0**	**0**	**7.5**	**7.5**	**5**	**7.0**
Dry land	0	0	1	1	1	7.0
Wet land	0	0	6	6.5	4	0
Sharecropping	1.6	6.6	1.3	0	0	0
Own land	0	0	1.3	0	0	0
Others land	1.6	6.6	0	0	0	0
Crops cultivated						
Rice yield/acre(kg)	600	600	800	800	500	0
Whet yield/acre(kg)	300	400	500	400	200	0
Fruit trees (Nos.)	37	160	118	150	111	200
Vegetables (acres)	0.1	0.1	0.1	0.1	0.1	0.2
Housing details						
Self owned	Yes	yes	yes	no	Yes	Yes
Rented						
No. of floors	1	2	2	2	1	1
No of rooms	2	2	4	9	2	3
Latrine	Pit	Pit	Pit	inside	Pit	Pit
Irrigation	Nat/riv/strm	nat/riv/strm	nat/riv/str	nat/riv/drai	Nat/riv/str	Nat
Shifting cultivation						
Cows	3	15	5	0	6	4
Bulls	4	2	2	0	2	1
Pigs	4	2	0	0	1	0
Poultry	5	3	4	0	2	4
Horses	1	0	0	0	0	0
Others	0	0	0	0	0	0
Material assets	Radio	radio	radio	radio	Radio	Radio
Project awareness	No	No	Yes	No	Yes	No

Table 4.11 Details of Land Likely to be Affected (acres)

Village	Dima	Dima	Lawakha	Lawakha	Ding thi	Uma
Land owned (acres)	**1.6**	**6.6**	**7.5**	**7.5**	**5**	**7.0**
Dry land	0	0	1	1	1	7.0
Wet land	0	0	6	6.5	4	0
Sharecropping	1.6	6.6	1.3	0	0	0
Own land	0	0	1.3	0	0	0
Others land	1.6	6.6	0	0	0	0

Table 4.12 Details of Horticultural Crops and Vegetable Garden Likely to be Affected

Village	Dima	Dima	Lawakha	Lawakha	Ding thi	Uma
Vegetables (acres)	0.1	0.1	0.1	0.1	0.1	0.2
Fruit trees (Nos.)						
Orange	10	50	55	100	650	200
Mango	3	6		40	60	0
Guava	4	4	3	2	400	0
Banana	20	100	60	10	700	0
TOTAL	37	160	118	152	1810	200

Table 4.13 Details of Affected Homesteads

Village	Dima	Dima	Lawakha	Lawakha	Ding thi	Uma
Housing details						
Self owned	yes	Yes	Yes	No	Yes	Yes
Rented						
No. of floors	1	2	2	2	1	1
No of rooms	2	2	4	9	2	3
Latrine	Pit	Pit	Pit	Inside	Pit	Pit

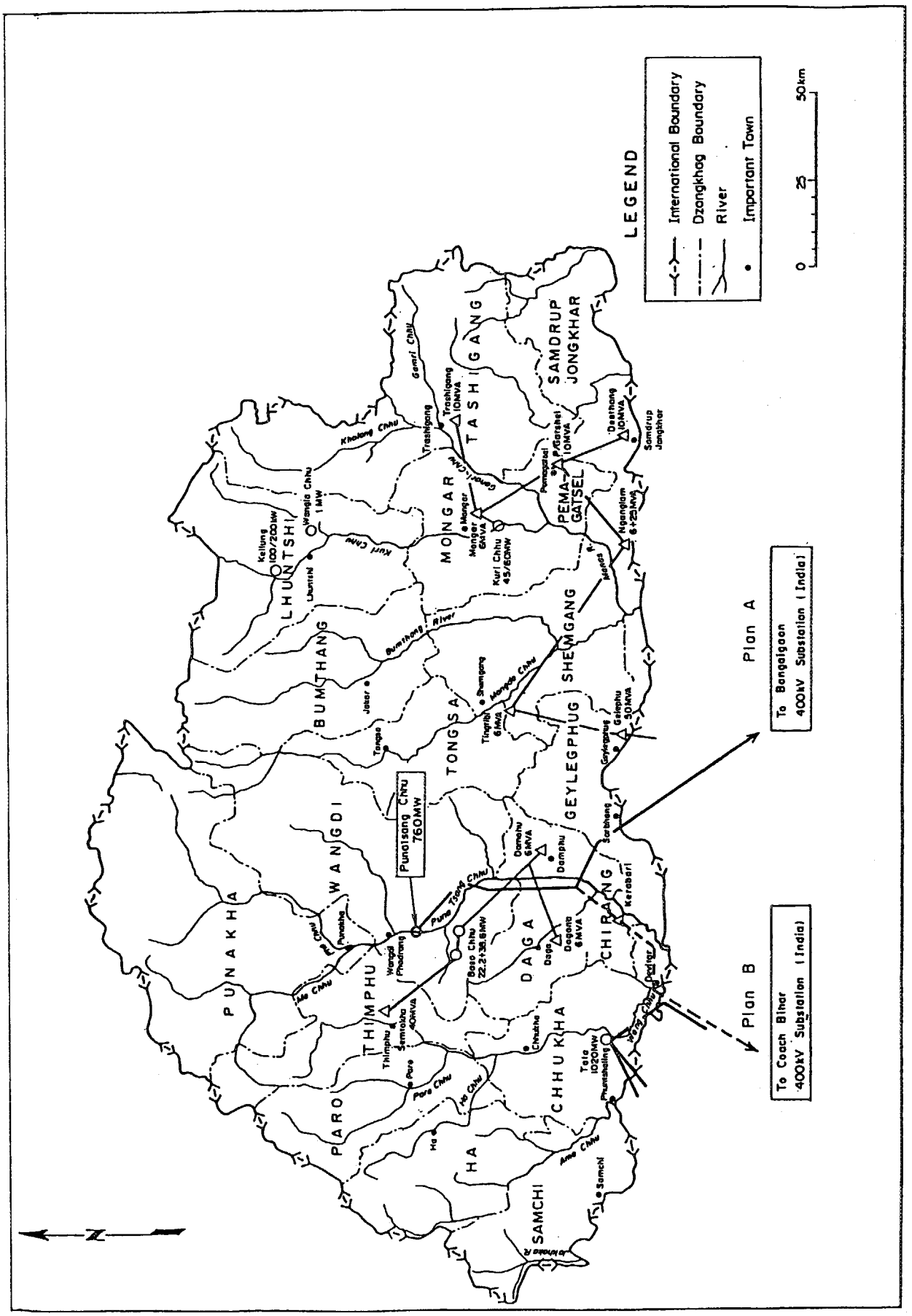


Fig. 4.1 Proposed Transmission Line Route