JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF AGRICULTURE
ROYAL GOVERNMENT OF BHUTAN

THE STUDY ON GROUNDWATER DEVELOPMENT IN WANGDUEPHODRANG DISTRICT

FINAL REPORT

VOLUME II : MAIN REPORT

March 1996

PACIFIC CONSULTANTS INTERNATIONAL
CHUO KAIHATSU CORPORATION

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In this report, project costs are estimated based on July 1995 prices with an exchange rate of US$1.00=Nu.30.85=J.Yen100.00

PREFACE

In response to a request from the Royal Government of Bhutan, the Government of Japan decided to conduct a study on Groundwater Development in Wangduephodrang District of Bhutan and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bhutan a study team headed by Dr. Shoji Kanatsu, Pacific Consultants International and Composed of staff members of Pacific Consultants International and Chuo Kaihatsu Corporation, four times between February 1994 and January 1996.

The team held discussions with the officials concerned of the Royal Government of Bhutan, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

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

March 1996

Kimio Fujita
President
Japan International Cooperation Agency

March 1996

Mr. Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

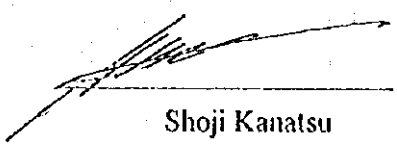
Dear Sir,

We are pleased to submit the final report entitled "The study on Groundwater Development in Wangduephodrang District of Bhutan". This report has been prepared by the Study Team in accordance with the contract signed between Japan International Cooperation Agency and Pacific Consultants International in association with Chuo Kaihatsu Corporation.

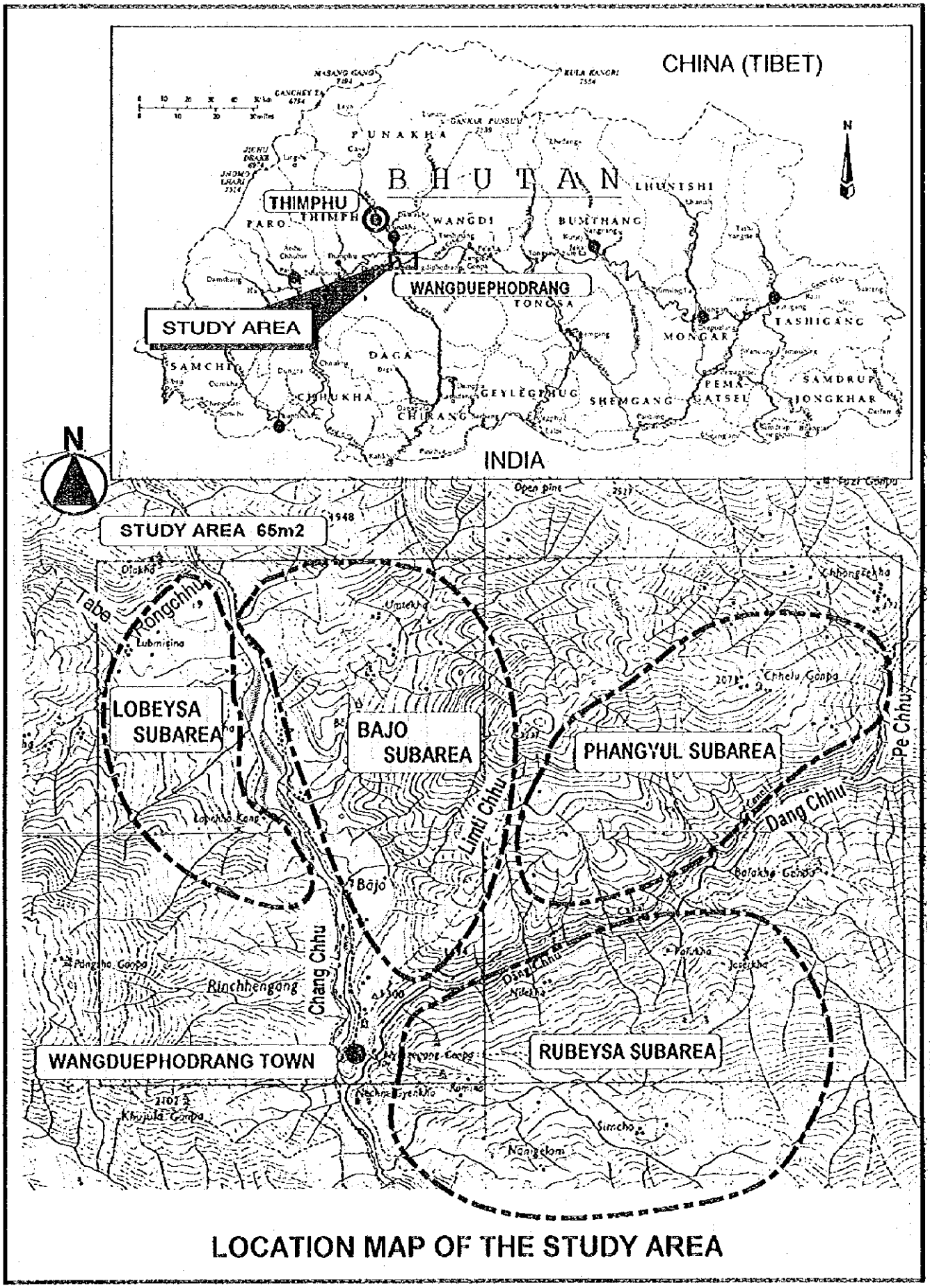
The report consists of Executive Summary, Main Report, and Supporting Report. Executive Summary summarizes the results of all studies. Main Report presents the results of the whole study including water resources potential, water resources evaluation, basic water resources development plan, urban water supply plan for Wangduephodrang town and irrigation improvement plan. Supporting Report describes data and technical details of the entire study. In addition, Drawings and Data Book have been prepared and submitted herewith.

All members of the Study Team wish to express grateful acknowledgments to the personnel of your Agency, the Ministry of Foreign Affairs, the Embassy of Japan in India, JICA India office and JOCV Bhutan coordinator office and also to officials and individuals of the Royal Government of Bhutan for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the improvement of the domestic and irrigation water supply conditions and the social and economic development in Wangduephotrang district.

Your Faithfully,



Shoji Kanatsu
Team Leader



LOCATION MAP OF THE STUDY AREA

SUMMARY

SUMMARY

1. INTRODUCTION

Bhutan is a small country in the eastern Himalaya and its mountainous terrain covers 46,500 km^2. About 90 % of the country's population of 600,000 depends on agriculture which is largely subsistence in nature.

One of the major objectives of the 7th Five Year Development Plan (1992 - 1997) is the development of rural area and the improvement of the living condition of rural inhabitants by means of an effective use of natural and human resources.

The country is 64% self sufficient in food and the target of the Royal Government is to achieve 80-90% self sufficiency by the end of 8th Five Year Development Plan, i.e. year 2002. Therefore, food self sufficiency at the national and household levels has been the major objective during 7th Five Year Development Plan and it would continue to be the major objective in 8th Five Year Development Plan.

Various constraints and problems of insufficient water supplies are found in the present water use of irrigation and domestic water supplies. In order to realize the ideal social conditions to allow inhabitants to lead productive lives in a sustainable manner, it is essential to solve the constraints and problems of insufficient water supplies.

Considering the present situation that many inhabitants both in urban and rural areas are suffering from shortage of water and bacteriological infection, it is necessary to provide the reliable, stable and safe water free of any risk to infection.

The Wangduephodrang district is considered as one of the most potential granaries in the country, and most of the farmers' lives depend on the agricultural production at present. In order to increase the farmers' income and to rise their living levels, it is considered indispensable to promote the increase of agricultural productivity.

The Study was conducted by the Study Team of the Japan International Cooperation Agency (JICA) in cooperation with the Ministry of Agriculture (MOA) and other related organizations from February 1994 to November 1995. The objective of the Study is to conduct a study on water resources development plan with an emphasis on groundwater in Wangduephodrang District of Bhutan. The Study area covers an area of 65 km^2 including the Wangduephodrang township, Lobeysa, Bajo, Phangyul and Rubeysa Sub-areas.

2. PRESENT CONDITIONS OF THE STUDY AREA

2.1 Socio-economic Situation

(1) Household and Population

The number of villages, household etc. of each sub-area is shown in the table.

Number of Villages, Households and Population of Study Sub-areas

Study Sub-area	Village	Household	Population
Lobeysa	21	177	3,086
Bajo	8	115	983
Phangyul	18	156	1,159
Rubeysa	17	179	1,456
Total	64	627	6,684

(2) Regional Economy

The main occupation in the Study area is farming and livestock husbandry. The Punakha - Wangduephodrang valley is one of the largest contiguous paddy areas in Bhutan, accounting for about 18 % of national rice production from about 12 % of the paddy area. Hence, rice production is the most important economic activity in the Study area. Rice is the staple food and is considered as the most important crop in terms of area, production, employment, and as a cash and barter crop. From the viewpoint of the national and regional economy, the Wangduephodrang town is the commercial distribution point between Thimphu and Wangduephodrang Dzongkhag and surrounding areas, acting as a economic service centre of the Study area.

(3) Social Situation and Infrastructure

The Thimphu - Tashigang paved highway is crossing from west to east through the Wangduephodrang town in the Study area. In the greater part of the Study area, villages can only be reached by mule tracks and foot trails, as well as two suspension bridges. Hence, it is a burden for horses and men to transport the luggages and essential items. There are several bus services having daily or sometimes weekly services to Thimphu, Punakha, Phuntsholing, Tashigang, Daga and other places.

2.2 Geology and Hydrogeology

(1) Physiography and Geology

In comparison to other parts of the Himalayas, Bhutan is characterized by the presence of flatlands as peneplain relics at the top of mountain ridges due to the relative gentleness of uplift movement. These support a rich ecosystem. The geology of the region can be broadly classified into:

- Quaternary formation (river terraces, mudflows),
- Chekha series (Mesozoic ~ pre-Cambrian phyllite, meta-sediments),
- Paro series (pre-Cambrian phyllite, schist group), and
- Thimpu series (pre-Cambrian gneiss group).

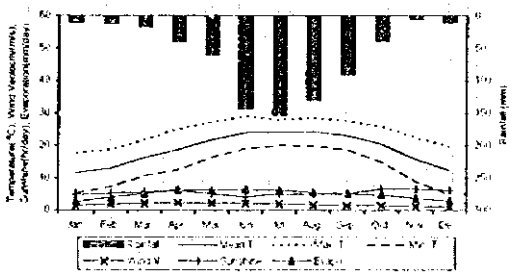
(2) Hydrogeology

Hydrogeological structure is assumed to consist of two layers, i.e. basement rocks of low permeability under Chekha series and porous Quaternary formation with good permeability. In addition to river terraces and mudflow deposits, landslide deposits forming gentle slopes at various locations on mountain sides are significant water bearing strata.

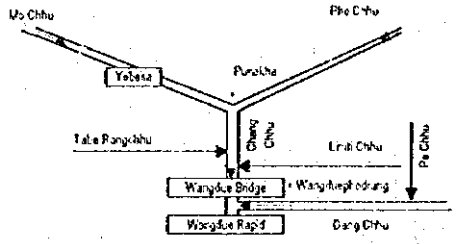
2.3 Meteorology and Hydrology

The climate of the Study area (altitude of 1,200 to 2,800 m) shows both characteristics of the temperate Himalayan and the semi-tropical monsoon. The mean monthly rainfall is higher from April to September than that from October to March, and these two (2) periods are generally referred to as the rainy and the dry seasons, respectively.

The Upper Chang Chhu basin whose catchment area is measured to be 5,640 km^2 consists of the Mo Chhu, the Pho Chhu, the Tabe Rongchhu, the Limti Chhu and the Dang Chhu as shown below.



METEOROLOGICAL CONDITIONS



CHANG CHHU DRAINAGE SYSTEM

2.4 Agriculture

(1) Land Use in the Study Area

The land use in the Study area is measured as shown below.

Land Use in the Study Area

(Unit : ha)

Category	Study Area		Sub-Area							
			Lobeysa		Bajo		Phanguyl		Rubeysa	
1 Forest	4,066	(62.6%)	10	(2.4%)	12	(6.3%)	769	(68.1%)	441	(50.6%)
2 Agriculture										
Wetland Cultivated	1,099	(16.9%)	216	(52.8%)	161	(85.2%)	151	(13.3%)	218	(25.1%)
Dry land Cultivated	0	(0.0%)	0	(0.0%)	0	(0.0%)	8	(0.7%)	70	(8.0%)
Other Agriculture	471	(7.2%)	132	(32.3%)	5	(2.6%)	115	(10.2%)	43	(4.9%)
Sub-Total	1,570	(24.2%)	348	(85.1%)	166	(87.8%)	274	(24.2%)	331	(38.0%)
3 Orchard & Horticulture	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)
4 Pasture	253	(3.9%)	35	(8.6%)	0	(0.0%)	87	(7.7%)	80	(9.2%)
5 Settlement	93	(1.4%)	-	-	-	-	-	-	-	-
6 Others	518	(8.0%)	16	(3.9%)	11	(5.8%)	-	-	19	(2.2%)
Total Area	6,500	(100.0%)	409	(100.0%)	189	(100.0%)	1,130	(100.0%)	871	(100.0%)

Note : Area was estimated based on the data base of the Land Use Planning Project

(2) Present Agricultural Activity

Crop season in the Study area is broadly divided into two (2) seasons; monsoon (rainy) and winter (dry) seasons. The main crop grown in the monsoon season is paddy, followed by winter crop (mainly wheat and mustard). In the upland area which is under rainfed condition, the main crop in the monsoon season is vegetables, but only a few area exists. Recently, some irrigation canals have been improved under the Punakha - Wangdue Valley Development Project financed by IFAD, and in some areas irrigation becomes possible throughout the year. In these areas, it is possible to start land preparation for paddy even in February during the

winter season, and double cropping of paddy is carried out even though such areas are small. Paddy occupies about 95 % of irrigated area during the monsoon season. The production of each sub-area is as follows:

Crop Yield and Production in Each Sub-area

Sub-Area	Paddy			Wheat			Mustard		
	Area(ha)	Yield(t/ha)	Product(t)	Area(ha)	Yield(t/ha)	Product(t)	Area(ha)	Yield(t/ha)	Product(t)
Lobeysa	285	2.67	760	121	1.31	159	33	1.00	33
Bajo	112	3.16	354	52	1.47	76	14	0.80	11
Phangyul	64	3.17	203	29	1.47	43	8	0.83	7
Rubeysa	131	3.16	414	58	1.50	87	16	0.86	14
Total	592	-	1,731	260	-	365	71	-	65

2.5 Water Supply

2.5.1 Urban Water Supply for Wangduephodrang Town Area

(1) Present Population Served and Service Area

The present water supply system covers the whole town area of about 110 ha, and the all areas are served by it with an intermittent operation; three (3) hr in the morning, 2.5 hr in the afternoon, and two (2) hr in the evening, totaling 7.5 hr a day.

Summary of Surveyed Population in Wangduephodrang Town Area

Category	Population in 1995	
	Residents	Day Visitors
Township Area	1,820	0
Commercial and Shopping Area	520	400
Monk Body	65	0
Administrative Organization	60	150
RBA Complex and Outer Quarters	3,140	370
RBA Hospital	175	200
Primary and Junior High School	30	1,200
RNRRC Office	225	0
Total	6,035	2,320

(2) Existing Water Supply System

The present water supply system diverts its raw water from the Pe Chhu, and no other water resource is utilized. The productivity of the existing water supply system is limited to 780 m^3/day only because of the limited conveyance capacity of the existing conveyance pipeline from the Pe Chhu. The system was constructed in 1969 diverting the river water from the Pe Chhu. The intake is situated at right bank of the Pe Chhu, 1.6 km upstream from the Chhuzonsa. The river water flows into the open canal directly by gravity. The Bajo irrigation canal was used for conveying the domestic water also, when the supply system was constructed in 1969. Due to water quality corruption, the pipeline of about nine (9) km was constructed along the national road in 1991, and the raw water is conveyed mainly with the pipelines. The water distribution station for the Wangduephodrang town area consists mainly of plain sedimentation tanks and water distribution tanks. The pipeline networks are also installed in 1969 for distributing the treated water to the service area. The operation and maintenance of the supply system is managed by the PWD section of the Wangduephodrang Dzongkhag.

2.5.2 Rural Water Supply

A total of 64 villages/communities were identified in the whole Study area as shown in the table. There are many villages which have the water supply systems constructed

with the UNICEF's assistance. In the Study area, 31 UNICEF's schemes are found, and most of them are generally operated well though some standpipes are found to be out of order. The system consists of stream or spring intake, transmission pipeline with valves, break pressure tank, clear water reservoir, distribution system, tapstands, and sedimentation tanks.

Summary of Identified Villages/Communities

Villages and Communities	Present Population		Villages and Communities	Present Population	
	House-hold	Popula-tion		House-hold	Popula-tion
Lobeysa Sub-area	127	3,086	Phangyul Sub-area	156	1,159
Babesa Gewog	134	2,604	Phangyul Gewog	156	1,159
Thetso Gewog	43	482			
Bajo Sub-area	115	983	Rubeysa Sub-area	179	1,456
Thetso Gewog	58	496	Rubeysa Gewog	102	744
Lingbukha Gewog	31	250	Jena Gewog	64	616
Babesa Gewog	26	237	Thetso Gewog	13	96
-	-	-	Total	627	6,684

3. WATER RESOURCES POTENTIAL AND EVALUATION

3.1 Outline of Present Water Use

(1) Lobeysa Sub-area

The irrigation water is supplied by the river water of the Tabe Rongchhu through the existing Upper and Lower Lobeysa Canals. The rural water supply by schemes constructed by the Dzongkhag under the UNICEF's assistance contribute the supply of safe water in this sub-area. The UNICEF's schemes take the water from the spring near the villages, and the other systems of the government also take their water from the springs.

(2) Bajo Sub-area

The irrigation water is taken from the Pe Chhu through the existing Bajo canal. The surface water of the Pe Chhu is used for the urban water supply for the Wangduephodrang town area as well. The water supply in this sub-area depends mainly on the spring source in the hilly area. Villagers who do not have any adequate supply system have to take the water from the Chang Chhu or irrigation canals for their domestic and drinking purposes at present.

(3) Phangyul Sub-area

There are some irrigation canals to supply irrigation water in the Phangyul Sub-area, and these canals originate from the perennial streams in higher hilly areas. The rural water supply schemes are also identified as UNICEF's schemes taking the water from nearby springs. The villagers having no scheme take the water from the small seasonal streams or the pools formed beside small springs.

(4) Rubeysa Sub-area

There area some UNICEF schemes in this sub-area, utilizing spring water. The irrigation water is supplied through some irrigation canals in the area taking the water from some perennial streams flowing along the steep valleys in the hilly areas.

3.2 Water Resources Potential

3.2.1 Sub-surface Water and Groundwater Resources

Within the Study area, significant volume of exploitable water resources comprising of sub-surface water and groundwater is explored. On the basis of mode of occurrence, groundwater is classified into i) river terrace related groundwater, ii) landslide related groundwater, and iii) mud-flow related ground-water. The calculated water potential for each sub-area is summarized in the table totaling 7,900 l/min.

Potential of Available Water Resources in the Study Area

Sub-area	Sub-surface Water (l/min)	Groundwater (l/min)			Total (l/min)
		River Terrace	Landslide	Mud-flow	
Lobeysa	Nil	N/A	450	2,450	2,900
Bajo	1,000	800	400	N/A	2,200
Phangyul	N/A	N/A	1,000	450	1,450
Rubeysa	N/A	N/A	450	900	1,350

3.2.2 Surface Water Resources

Considering the environmental effects, the river discharge of at least 20% should flow down as maintenance flow. Consequently, up to 80% of the river discharge is available. The potential of surface water resources is estimated as shown below.

Available River Discharge at Intake Site

(Unit : m^3/s)

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tabe Rongchhu	2.081	2.000	1.862	2.585	3.227	6.423	9.963	13.404	10.862	4.853	3.429	2.423
Pe Chhu	2.540	2.440	2.272	3.154	3.938	7.837	12.157	16.357	13.254	5.922	4.184	2.957
Lachhu	0.039	0.037	0.035	0.048	0.060	0.120	0.186	0.250	0.202	0.090	0.064	0.045
Uship	0.015	0.014	0.013	0.018	0.023	0.045	0.070	0.094	0.076	0.034	0.024	0.017
Mochuna	0.153	0.147	0.137	0.190	0.237	0.472	0.732	0.985	0.798	0.357	0.252	0.178
Taka Rongchhu	0.119	0.114	0.106	0.147	0.184	0.366	0.567	0.763	0.619	0.276	0.195	0.138

As for the river water of the Chang Chhu in the Bajo sub-area, the total amount for exploitable water is determined in accordance with appropriate intake structure and the purpose of utilization.

3.3 Water Resources Evaluation

3.3.1 Water Balance

(1) Sub-surface and Groundwater

1) Sub-surface Water

The sub-surface water resources is abundant in the Bajo sub-area, but it is not recommended to exploit it for irrigation, because of its small potential comparing with the irrigation requirement.

2) Groundwater

a) Groundwater in River Terrace

In the Bajo sub-area, about 800 l/min of the groundwater is considered available in the river terrace along the Chang Chhu. This potential capacity is equivalent to 1,152 m^3/day, and is judged to be quite large comparing with the present and the future water demands of the Bajo sub-area which are estimated to be 44 m^3/day and 66 m^3/sec, respectively. The groundwater in the terrace area is, therefore, considered to be one of the potential water resources for the rural water supply, but not for the irrigation water supply.

b) Groundwater in Landslide Areas

The available water is larger than the future demand of rural water supply in all sub-areas. In the Bajo sub-area, since the area where the groundwater is available is scattered only in the hilly areas, it is recommended to utilize the other type of water resources also for the low flat areas in order to economize the water supply scheme as well as to save and protect such limited groundwater resources.

c) Groundwater in Mud-flow Area

The groundwater in the mud-flow area is not found in the Bajo sub-area according to the results of hydrogeological analyses. The available water is considered to be quite abundant comparing with the future demands for rural water supply in all sub-areas except for the Bajo sub-area. However, since in the hilly areas such as the Phangyul and the Rubeysa sub-areas, it is impossible to carry out drilling works, the utilization of groundwater in mud-flow area is not recommended though the available water is abundant.

(2) Surface Water

At present, surface water is used mainly for the irrigation purpose and Wangdue town water supply. The surface water in low flat areas such as the Lobeysa and the Bajo sub-areas is considered to be sufficient, while that in hilly areas such as the Phangyul and the Rubeysa sub-areas is insufficient even in the present water balance, considering the minimum required discharge of maintenance flow.

3.3.2 Water Quality

The water quality of groundwater is judged to be safe without any infection and contamination, while the surface water requires some treatment of disinfection and filtering. However, it is applicable for the irrigation purpose.

3.3.3 Environmental Impacts

No adverse effects are predicted unless any excessive exploitation is made for the groundwater resources, but for the surface water some consideration may be necessary for reducing the high turbidity which may be caused by the construction of river structures.

4. BASIC WATER RESOURCES DEVELOPMENT PLAN

4.1 Basic Concept and Planning Criteria

4.1.1 Concepts of Basic Water Resources Development Plan

(1) Components of Basic Plan

The major components of the Basic Plan are considered to be the water resources development plan for:

- the irrigation water supply plan, and
- the domestic water supply plan for rural and urban areas.

(2) Basic Concepts

The following items are considered to be the basic concepts of the Basic Plan.

Irrigation Water Supply

- Achievement of the effective irrigation water use
- Achievement of the effective land use

Urban and Rural Water Supply

- Decrease of the risks to various infectious diseases
- Facilitation of the rural and urban development
- Provision of the basic human needs in rural and urban areas

4.1.2 Planning Criteria

(1) Objectives of Water Resources Development

1) Irrigation Water Supply

- Sustainable development of arable production to enable self sufficiency in food production,
- Improvements in the incomes, living and nutrition standards of the rural population, and
- Sustainable utilization of natural resources.

2) Urban and Rural Water Supply

- Provision of the safe domestic water free from any risk to infection
- Realization of the reliable and stable water supply throughout a day as well as a year

(2) Target Years

The target year has to be set taking into account of the following items:

- getting understandings of the beneficiaries,
- coordination among the related government agencies and concerned organizations and people,
- unexpected accidents, and
- delay in financial arrangement.

As a results of discussion with the government officials concerned, the target years are set as follows:

- 2002 for short term plan
- 2007 for long term plan

4.2 Water Resources Development Plan for Irrigation Water Supply

Based on the results of the case study on the various possible countermeasures, the following strategies are proposed for establishing the Water Resources Development Plan for Irrigation Water Supply.

Basic Strategy for Irrigation Water Supply

Areas	Target	Strategy
Low Flat Areas	Short Term	- Supplying the sufficient irrigation water - Applying the double paddy cropping for 40% of present paddy field
	Long Term	- Supplying the sufficient irrigation water - Applying the double paddy cropping for 100% of present paddy field
High Hilly Areas	Short Term	- Establishment of new water management system - Applying the diversification for 10% of present paddy field
	Long Term	- Improvement of the water management system - Research on suitable crops for diversification

The necessary structures are preliminarily designed based on the above strategies, and the irrigation water resources development schemes are proposed as summarized below.

Summary of Proposed Schemes

(Lobeysa and Bajo sub-areas)

Category of land	Low Flat Area			
Sub-Area	Lobeysa		Bajo	
Name of Canal	Upper Lobeysa	Lower Lobeysa	Bajo	Total
Code	C1	C2	C9	
Canal Length (km)	7.1	8.1	15.0	30.2
Command Area (ha)	61	300	143	504
Number of Benefited Households	117	123	52	292
Number of Offtake Facilities	32	52	35	119
Proposed Counter Measures	Rehabilitation of Irrigation Canal with Enforcement of Protection Works Establishment of New Water Management System Applying Double Paddy Cropping (40% for short term, 100% for long term)			
Total Construction Cost (1000Nu.)	1,152	3,027	5,016	9,195
Required O M Cost (1000Nu./year)	21	32	48	102
Estimated Net B C Ratio	2.25	2.21	2.80	-

(Phangyul and Rubeysa Sub-areas)

Category of land	High Hilly Area			
Sub-Area	Pangyul		Rubeysa	
Name of Canal	Phangyul	Gemkha	Nalakha	Rutekha
Code	C10	C15	C18	C19
Canal Length (km)	16.0	3.5	3.9	2.2
Command Area (ha)	91	15	29	40
No. of Benefited Households	42	23	60	44
Number of Offtake Facilities	32	12	20	28
Proposed Counter Measures	New Construction of Offtake Facilities Establishment of New Water Management System Applying Diversification for 10% of Paddy Field			
Total Construction Cost (1000Nu.)	286	47	119	207
Required O M Cost (1000Nu./year)	58	12	15	10
Estimated Net B C Ratio	1.95	1.53	1.57	1.88
Sub-Area	Rubeysa			Total
Name of Canal	Maphekha	Naykoyuwa	Rumina	
Code	C20	C21	C22	
Canal Length (km)	2.2	1.7	1.1	30.6
Command Area (ha)	27	24	28	254
No. of Benefited Households	44	18	35	266
Number of Offtake Facilities	25	20	16	153
Proposed Counter Measures	New Construction of Offtake Facilities Establishment of New Water Management System Applying Diversification for 10% of Paddy Field			
Total Construction Cost (1000Nu.)	148	119	95	1,021
Required O M Cost (1000Nu./year)	9	7	5	115
Estimated Net B C Ratio	1.59	1.74	1.91	-
Research Project for the Diversification				
Required Project Cost (1000Nu./year)	487			

4.3 Water Resources Development Plan for Urban and Rural Water Supply

4.3.1 Present and Future Water Demand

(1) Wangduephodrang Town Area

The future population increase projected for the target year of 2002 and 2007 is set as shown in the table. The consumptive demand per capita is increased from present 75 l/day to 125 l/day in 2007. The total demand per capita will be once decreased from present 125 l/day to 120 l/day in 2002 and will be increased to 145 l/day in 2007

Projected Population in Wangduephodrang Town

Categories	1995	2002	2007
1. Present Service Area			
Resident	6,035	6,932	7,654
Growth Rate (%)	-	(2.00)	(2.00)
Day Visitors (38%)	2,293	2,634	2,908
Sub-total	8,328	9,567	10,562
2. Extended Service Area			
Resident	0	47	202
Day Visitors	0	233	448
Sub-total	0	280	650
3. Total Population			
Resident	6,035	6,979	7,856
Day Visitors	2,293	2,867	3,356
Total	8,328	9,847	11,212

The average daily demand and the maximum daily demand (25 % increased value of the average) are calculated as shown in the table. The required additional capacities are calculated deducting the present capacity of 780 m^3/day from the calculated daily maximum demand as shown in the table.

Present and Future Water Consumption per Capita

(l/day/capita)

Description	Present 1995	Future 2002	Future 2007
Cloth Washing (Laundry)	30	35	40
Latrine	5	10	20
Bathing	30	30	40
Cooking	10	15	25
Consumptive Demand	75	90	125
Physical Loss (% to Total Demand)	50 (40%)	30 (25%)	20 (14%)
Total Water Demand	125	120	145

Estimated Water Demand and Required Additional Capacity for Area

(m^3/day)

Year	Average Daily Demand (m^3/day)	Max. Daily Demand (m^3/day)	Required Addi-tional Capacity (m^3/day)
1995	812	1,015	-
2002	906	1,133	363
2007	1,236	1,546	776

(2) Rural Areas

The future water demand in each sub-area is calculated as shown in table. A total demand of 449 m^3/day is necessary in 2007.

Present and Future Water Demand for Rural Areas

(m^3/day)

Sub-areas	Water Demand 1995	2002	2007
Lobeysa	139	176	207
Bajo	44	56	66
Phangyul	52	66	78
Rubeysa	66	83	98
Total	301	381	449

4.3.2 Urban Water Supply System in Wangduephodrang Town Area

(1) Service Area and Productivity of Water Supply System

The present urban water supply system covers an area of about 110 ha consisting of the Dzongkhag and administrative areas, the commercial and shopping areas, etc. An area of about 23 ha located between the present DSC/AMC yards and the construction sites of the junior high school are additionally included. Then, the total service area of the water supply system will be 133 ha.

The maximum daily demand in 2007 is calculated to be 1,546 m^3/day, and then the capacity of the distribution facilities is set at 1,600 m^3/day. The capacities of the conveyance pipeline and the distribution station are set at 1,700 m^3/day considering the five (5) % of the operation and maintenance requirement such as washing water of the tanks, etc.

(2) Proposed Urban Water Supply System

1) Intake and Conveyance Facilities

- The existing intake facilities consisting of a sedimentation tank and a canal are utilized as they are, because their capacity is measured as more than 0.4 m^3/sec (34,000 m^3/day), sufficient enough to flow the design discharge of pipeline.
- The new conveyance pipeline is constructed increasing the capacity from the present 8 l/sec to the future 20 l/sec.

2) Treatment Facility

- The daily productivity is increased from 780 m^3/sec to 1,700 m^3/sec increasing the capacity of the existing distribution tanks form 600 m^3 to 850 m^3.
- It is recommended to apply some water treatment for improving such high turbidity and reducing bad color content.

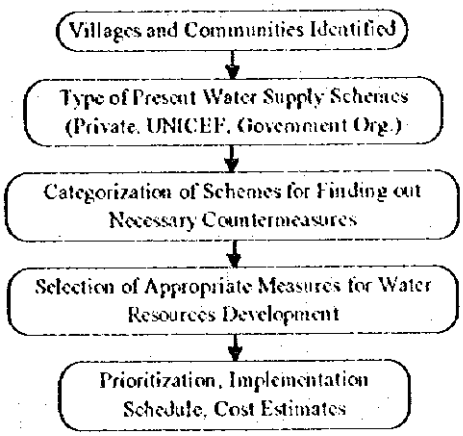
3) Distribution Networks and House Connection

The present distribution networks cover most of the whole service areas in the town, and house connections are made partly to the government offices and the offices and quarters in the RBA complex without any metered system. Therefore, it is necessary to provide such improvement as provision of house connections, replacement of main pipelines, etc.

4.3.3 Rural Water Supply Systems

(1) Planning Methodology

It is found that such villages have different conditions varying village by village, and it is difficult to prepare such plans that are required for each village one by one in the Study. The Study flow presented in the figure is, therefore, applied to find out the necessary countermeasures.



FLOW CHART FOR SELECTING METHODS OF WATER RESOURCES DEVELOPMENT

(2) Necessary Countermeasures

The necessary countermeasures are presented in the table for each categorized villages/communities.

Population and Number of Villages to be Served by New and Extension Schemes

Sub-areas	Item	New Scheme (A)	New Scheme (B)	New Scheme (C)	Additional Scheme	Extension Scheme (A)	Extension Scheme (B)	Water Treatment Scheme
Lobeysa	No. of Villages	1	0	2	0	0	1	0
	Average Population	250	0	29	0	0	67	0
Bajo	No. of Villages	3	0	1	1	0	0	0
	Average Population	128	0	61	185	0	0	0
Phangyul	No. of Villages	3	1	7	0	3	0	0
	Average Population	120	49	18	0	76	0	0
Rubeysa	No. of Villages	2	0	2	0	1	2	1
	Average Population	93	0	21	0	169	27	123
Whole Area	Total No. of Village	9	1	12	1	4	3	1
	Average Population	131	49	24	185	99	40	123

Note : New Scheme (A) : More than 6 households
(B) : More than 6 households with existing private facility
(C) : Less than 5 households

Extension Scheme (A) : More than 6 households
(B) : Less than 5 households

4.4 Implementation Schedule and Cost Estimate

(1) Implementation Schedule

The implementation of the Water Resources Development Basic Plan is proposed as shown below.

Category of Land	Sub-Area	Name of Canal	Code	Priority	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Hat Area	Lobeysa	Upper Lobeysa	C1	②											
		Lower Lobeysa	C2	③											
	Bajo	Bajo	C9	①											
High Hilly Area	Phangyul	Phangyul	C10	①											
		Gimkha	C15	⑦											
	Rubeysa	Nalakha	C18	⑥											
		Rutekha	C19	③											
		Maplekha	C20	⑤											
		Naykoyuwa	C21	④											
		Rumina	C22	⑦											
Research the Optimum Diversification Crop															

IMPLEMENTATION SCHEDULE FOR IRRIGATION WATER SUPPLY PLAN

Work Items	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Detailed Design and Administrative Arrangements											
Conveyance Pipeline											
Water Treatment and Distribution Station											
Distribution Networks and House Meters											

IMPLEMENTATION SHCEDULE OF URBAN WATER SUPPLY SYSTEM

Sub-area Scheme	Priority	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Lobeysa Sub-area	❶											
New Scheme (A)	❶-1											
New Scheme (C)	❶-2											
Extension Scheme (B)	❶-3											
Bajo Sub-area	❷											
New Scheme (A)	❷-1											
New Scheme (C)	❷-3											
Additional Scheme	❷-2											
Phangyul Sub-area	❸											
New Scheme (A)	❸-1											
New Scheme (B)	❸-2											
New Scheme (C)	❸-4											
Extension Scheme (A)	❸-3											
Rubeysa Sub-area	❹											
New Scheme (A)	❹-1											
New Scheme (C)	❹-4											
Extension Scheme (A)	❹-2											
Extension Scheme (B)	❹-3											
Water Treatment Scheme	❹-5											

IMPLEMENTATION SHCEDULE OF RURAL WATER SUPPLY SYSTEM

(2)Cost Estimate

The total project costs for the basic plan for water resources development are estimated as summarized below.

Summary of Project Costs for Basic Plan

(Unit: Nu.1,000,000)

Description	Costs	Description	Costs
I. Urban Water Supply System for Wangdiephodrang Town Area		III. Irrigation Water Supply	
1. Direct Costs	172.6	1. Lobeysa Sub-area	4.2
1.1 Conveyance Pipeline	60.1	2. Bajo Sub-area	5.0
1.2 Treatment and Water Distribution Station	95.4	3. Phangyul Sub-area	0.3
1.3 Distribution Networks and House Meters	17.1	4. Rubeysa Sub-area	0.7
2. Engineering Service	3.5	5. Research Activities	1.1
3. Administration Costs	6.2	Total (3)	11.6
Sub-total	213.9		
4. Physical Contingency	17.3		
Total (1)	231.2		
II. Rural Water Supply Systems			
1. Lobeysa Sub-area	4.2		
2. Bajo Sub-area	18.1		
3. Phangyul Sub-area	14.9		
4. Rubeysa Sub-area	6.9		
Total (2)	44.1	Grand Total	289.9

The operation and maintenance costs are also estimated as summarized below.

Operation and Maintenance Costs for Irrigation Water Supply

(unit : 1,000 Nu.)

Category of Land	Sub-Area	Name of Canal	Code	Year										
				1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Lobeysa	Upper Lobeysa	C1						21	21	21	21	21	21
		Lower Lobeysa	C2					32	32	32	32	32	32	32
	Bajo	Bajo	C9				48	48	48	48	48	48	48	48
High Hilly Area	Phangyul	Phangyul	C10			58	58	58	58	58	58	58	58	58
		Gemkha	C15						12	12	12	12	12	12
	Rubeysa	Nalakha	C18						15	15	15	15	15	15
		Rutekha	C19				10	10	10	10	10	10	10	10
		Msphekha	C20					9	9	9	9	9	9	9
		Naykoyuwa	C21					7	7	7	7	7	7	7
		Rumina	C22			5	5	5	5	5	5	5	5	5
Annual Total						63	120	168	216	216	216	216	216	216

Operation and Maintenance Costs for Domestic Water Supply

(Unit: NU.1,000)

Water Supply Plan	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Urban Water Supply	526	526	526	526	2,220	2,312	2,312	2,312	2,312	2,628	2,667
Rural Water Supply	282	335	406	431	583	704	739	757	772	797	815
Total	808	861	932	958	2,802	3,016	3,052	3,070	3,084	3,425	3,482

The above estimates are made based on the prices in July 1995, with the exchange rates of 30.85 Nu./US$ and 100 yen/US$.

4.5 Project Evaluation

4.5.1 Economic Evaluation

EIRR is 15.4 % and at discount rate of 10%, ENPV is Nu. 127 million at price for July 1995, and E.B/C is 1.53 at the same discount rate. Project evaluation has proven that EIRR exceeds the opportunity cost of capital 10 %, ENPV is positive and E.B/C exceeds 1. It is judged that the implementation of the Basic Plan is economically sound.

4.5.2 Financial Evaluation

(1) Farm Household's Economic Analysis

After the completion of the Basic Plan, expected annual agricultural net returns are increased in the range between 1.16 and 1.33 times (average is 1.28 times) in comparison of Without Project. Increased value of agricultural net returns are in the range between Nu. 804 and Nu.8,548 (average is Nu. 3,270) which result in to be equivalent to 0.57 to 6.11 man-month of the minimum wages (Nu. 1,400). In the Bajo sub-area the effect of the Basic Plan is largest.

(2) Water Charge Analysis

To make the water supply plan successful, at least the operation and maintenance costs should be paid for by the beneficiaries. However, a deep-rooted conviction remained in the minds of the people that water would be provided free of charge by the Government, especially in the rural areas.

1) Water Supply Plan for Rural Areas

The participation of inhabitant would be very important for the development of a water supply plan. The PWD and Dzongkhag are that through participation of the inhabitant, the Water Supply System would be self-supporting.

2) Water Supply Plan for Wangduephodrang Town

Recently, the Urban Water and Sewerage Project in Thimphu is proceeding by the Thimphu City Corporation. This project provides new tariff rates for water supply which are risen after 20 m^3 per month. According to this new rates, a household of five persons using a normal amount of water, will have to pay approximately Nu. 25.0 a month. If Wangduephodrang Dzongkhag would apply the same water tariff system, after the completion of the Plan Dzongkhag or City Corporation could charge Nu. 564 thousand which values approximately 21 % of the whole operation and maintenance cost.

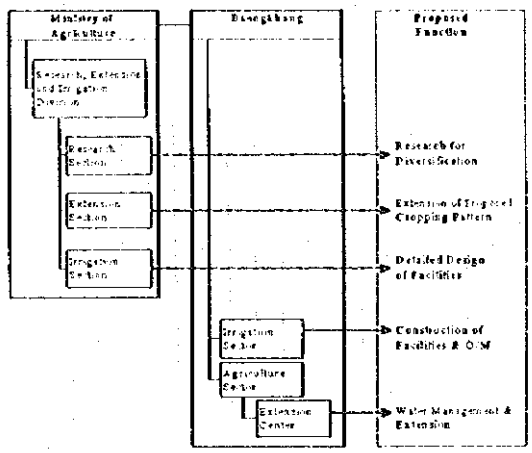
4.5.3 Socio-Economic Evaluation

The Basic Plan is expected to bring about various direct, tangible benefit and secondary or indirect, intangible benefits as stated below.

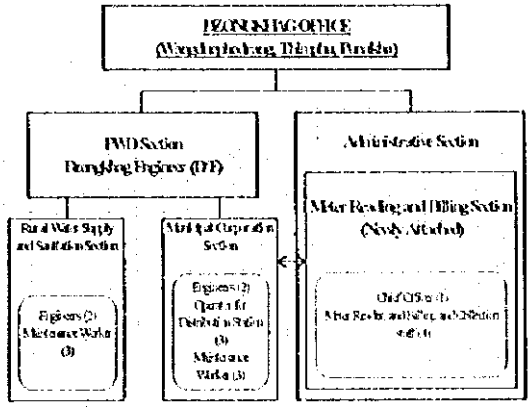
- Contribution to the National Development Plan
- Stable Supply of Food
- Improvement of Living Standard
- Water Quantity and Quality Improvement
- Vitalises Local Commercial Activities
- Improvement of Public Health Environment
- Decrease of Local Women's Work

4.6 Organization

The following organization is proposed to be applied for implementing the Basic Plan.



PRESENT ORGANIZATION AND PROPOSED FUNCTION FOR IRRIGATION IMPROVEMENT



PROPOSED ORGANIZATION CHART DOMESTIC WATER SUPPLY

5. URBAN WATER SUPPLY PLAN FOR WANGDUEPHODRANG TOWN

5.1 Facility Plan

5.1.1 Intake Facilities

It is proposed to utilize the existing intake and sediment removal facilities as they are. Since the flow capacity of the existing pipelines is estimated at 8 l/sec, quite smaller than the design discharge of 20 l/sec, it is recommended to replace the existing one. The principal features of the proposed new conveyance pipeline are summarized below.

- Design discharge: 1,700 m^3/day (20 l/sec)
- Design water levels: Grit Chamber LWL: 1,428 m, HWL: 1,430.5 m
  Raw water receiving tank 1,344 m
- Total distance: Approximately 8.4 km
- Diameter: 8 inch
- Type of piping materials: Ductile iron pipe

5.1.2 Water Treatment Facilities

The principal features of the proposed system components are summarized below.

- Raw water receiving pit: 5.5 m (L) x 1.5 m (W) x 1.5 m (H) of reinforced concrete box with V-shape notch, butterfly type valves, flow meter and turbidity meter.
- Flocculator: 0.7 m (W) x 10.0 m (L) x 4 Nos. of concrete canal with baffles.
- Aluminum dosing system: 1,5 m (W) x 1.5 m (L) x 1.2 m (D) reinforced concrete solution tank with diaphram constant injection pump (1,400 cc/min.).

- Sedimentation tanks: The existing tanks of which capacity is measured to be 950 m^3 is utilized with some extent of reinforcement and supporting with frames and tapers
- Rapid sand filter: Gravity type rapid filter of 24 m^2 filter area with filtered water transfer pumps of 1.2 m^3/min (Filtered water basin is attached to the rapid filter).
- Distribution reservoirs: The present capacity of 600 m^3 is proposed to be increased with about 200 m^3 and the piping galley is proposed to be attached to the tank.
- Chlorination: 0.8 m dia. x 1.0 m (D) of tank made of plastics with a diaphram constant injection pump (1,400 cc/min.) and the necessary equipment such as level gauge, drain pipe, etc.
- Operation house: Wooden operation houses of 90 m^2 at all
- Approach road: About 80 m of approach road from the national road to Tongsa.
- Other miscellaneous works: Wet masonry walls, fencing works, electricity connection works, etc.

5.1.3 Distribution Networks and Relating Facilities

The following improvement works are proposed to be made for the present distribution networks.

- Replacement of the existing HDPE pipes on the main pipelines with GI pipes to reduce water leakage and to avoid illegal connection.
- Placing new pipelines to mitigate unbalanced load of demand by traversing long main pipelines, etc.
- Extending the existing networks to provide water to the extended service areas in the Bajo sub-area.
- Construction of house connecting pipes to each household with water meters.

5.2 Implementation Schedule and Project Cost Estimate

5.2.1 Implementation Schedule

The urban water supply system for the Wangduephodrang town area is proposed to be implemented as shown below

Work Items	Year										
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Detailed Design and Administrative Arrangements											
Conveyance Pipeline											
Water Treatment and Distribution Station											
Distribution Networks and House Meters											

IMPLEMENTATION SHCEDULE OF URBAN WATER SUPPLY SYSTEM

5.2.2 Project Cost Estimate

(1) Project Costs

The project costs for implementing urban water supply schemes are estimated as shown in the table. The total costs consisting of direct costs, engineering fees, administration fees, and physical contingency are estimated at Nu. 231,200,000.

Summary of Project Costs for Urban Water Supply in Wangduephodrang Town Area

(Unit: 1,000,000 Nu.)

Description	Costs
1. Direct Costs	172.6
1.1 Conveyance Pipeline	60.1
1.2 Treatment and Water Distribution Statio	95.4
1.3 Distribution Networks and House Meters	17.1
2. Engineering Service	35
3. Administration Costs	6.2
Sub-total	213.9
4. Physical Contingency	17.3
Total	231.2

(2) Operation and Maintenance Costs

The calculated operation and maintenance costs are summarized below.

Operation and Maintenance Costs for Uban Water Supply

(Unit: Nu.1,000)

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Urban Water Supply	526	526	526	526	2,220	2,312	2,312	2,312	2,312	2,628	2,667

5.3 Project Evaluation

5.3.1 Economic Evaluation

EIRR of the Plan is 11.1 % and at discount rate of 10%, ENPV is Nu. 20.9 million at price for July 1995, and E.B/C is 1.11 at the same discount rate. Project evaluation has proven that EIRR exceeds the opportunity cost of capital 10%, ENPV is positive and E.B/C exceeds 1. It is judged that the implementation of this Plan is economically sound. The EIRR is a little larger than the opportunity cost of capital of 10%. However, this Plan is considered profitable in case that such intangible benefits as health conditions and living standards in the Wangduephodrang town are taken into account.

5.3.2 Financial Evaluation - Water Charge Analysis -

If Wangduephodrang Dzongkhag would apply the same water tariff system as Thimphu, after the completion of the Plan Dzongkhag or City Corporation could charge Nu. 564 thousand which values approximately 21% of the whole operation and maintenance cost.

6. IRRIGATION IMPROVEMENT PLAN

Out of the schemes proposed in the Irrigation Water Resources Development Basic Plan, the following two (2) schemes are selected for the further implementation considering their urgency and importance.

- Bajo canal project for low flat areas
- Phangyul canal for high hilly areas

6.1 Irrigation Improvement Plan

6.1.1 Cropping Patterns and Water Requirement

The improved cropping pattern for the command area of both canals are proposed as shown in the table.

Proposed Cropping Pattern

(ha)

Name of Canal / Canal Code		Bajo C9	Phangyul C10
Paddy-Wheat	(CP1)	34	31
Paddy-Mustard	(CP2)	15	1
Paddy-Paddy-Mustar	(CP3)	55	0
Single Paddy	(CP4)	34	46
Vegetable-Vegetable	(CP5)	7	13
Total		144	91

In the Bajo sub-area, the double cropping of 40 % is proposed to be introduced, and in the Phangyul sub-area, the crop diversification of 10 % is proposed. The water requirement for five (5) year return period is calculated and the maximum water requirements are also calculated as shown in the table.

Maximum Water Requirement

(l/sec)

Name of Canal / Canal Code	Bajo C9	Phangyul C10
For 5 Year Return Period	210	240

The following design conditions are applied for the improvement of the Bajo canal.

- Maximum flow velocity: 0.6 m/sec
- Roughness coefficient : 0.035 (for earth lining canal)
  0.025 (for masonry canal)

6.1.2 Irrigation Improvement Plan

The protection works in the Bajo canal are proposed to be improved taking into account of the vulnerability index. The new offtake facilities are proposed to be constructed to improve water management in the Phangyul sub-area. The design conditions for such improvement are summarized in the table.

Irrigation Improvement Plan

Name of Canal / Canal Code	Bajo C9	Phangyul C10
Canal Length (km)	15	16
Command Area (ha)	143	91
Number of Benefited Household	52	42
Number of Offtake Facilities	35	32
Mean Vulnerability Index	46.8	41.3
Design Discharge (l/s)	210	240

6.2 Implementation Schedule and Project Cost Estimate

6.2.1 Implementation Schedule

The implementation schedule of the irrigation improvement plan is proposed as shown below.

Category of Land	Sub-area	Name of Canal	Code	Year										
				1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Bajo	Bajo	C9											
High Hilly Area	Phangyul	Phangyul	C10											

PROPOSED IMPLEMENTATION SCHEDULE

6.2.2 Project Cost Estimate

The estimated project costs are summarized below.

Summary of Cost Estimation for Offtake Works of Phangyul Canal

Canal Code C10	Name Phangyul		Command Area (ha) 91	Canal Length (km) 16	Design Discharge (l/s) 240
Description	unit	Quantity	Unit Price (Nu.)	Amount (Nu.)	Remark
Offtake Works	unit	32	8,924	285,578	

Summary of Cost Estimation for Bajo Canal Improvement

Canal Code C9	Name Bajo Canal	Command Area (ha) 143	Canal Length (km) 15	Design Discharge (l/s) 210
Description	Unit	Quantity	Unit Price (Nu.)	Amount (Nu.)
Canal Works				
Masonry Canal	m	614.00	1,238.26	760,295
Earth Lining Canal	m	14,386.00	50.92	732,479
Chute for Masonry Canal	m (height)	18.00	2,255.36	40,596
Chute for Soil Canal	m (height)	162.00	1,935.36	313,528
Offtake Works	unit	35.00	9,810.71	343,375
Sub Total				2,190,273
Protection Works				
Protection Work Type PA	m	235.90	7,602.76	1,793,491
Protection Work Type PB	m	39.90	2,790.91	111,357
Protection Work Type PC	m	39.90	6,250.61	249,399
Protection Work Type PD	m	176.70	1,525.61	269,575
Steel Flume Aqueduct	m	39.24	6,708.68	263,249
Pipe Canal	m	82.18	1,683.44	138,345
Sub Total				2,825,416
Total Construction Cost				5,015,689

The operation and maintenance costs are also estimated as summarized below.

Operation and Maintenance Cost for Irrigation Improvement Project

(unit : 1,000 Nu.)

Category of Land	Sub-area	Name of Canal	Code	Year										
				1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Bajo	Bajo	C9				48	48	48	48	48	48	48	48
High Hilly Area	Phangyul	Phangyul	C10			58	58	58	58	58	58	58	58	58
Annual Total						58	106	106	106	106	106	106	106	106

6.3 Project Evaluation

6.3.1 Economic Evaluation

EIRR of the Plan is 11.2% and at discount rate of 10%, ENPV is Nu. 525 thousand at price for July 1995, and E.B/C is 1.09 at the same discount rate. Project evaluation has proven that EIRR exceeds the opportunity cost of capital 10%, ENPV is positive and E.B/C exceeds 1. It is judged that the implementation of this Plan is economically sound. The EIRR is a little larger than that of the whole agricultural development plan of 10.7%.

6.3.2 Financial Evaluation - Farm Household's Economic Analysis

After the completion of the Irrigation Improvement Plan which includes the Bajo Canal Project and the Phangyul Canal Project, the expected annual agricultural net returns are increased by 1.29 and 1.26 times respectively in comparison of Without Project case. Increased values of agricultural net returns are calculated to be Nu.8,548 and Nu. 2,642, which are equivalent to 6.11 and 1.89 man-month of the minimum wages (Nu. 1,400).

7. RECOMMENDATION

(1) Immediate Implementation

The recent growth of the country's economic activities are remarkable and significant both in rural and urban areas. The living conditions of the country is becoming rather worse, because of rapid population increase. In addition, the substantial amount of grains has to be imported from the neighboring countries resulting in an unbalanced trade.

Under these conditions, it is important and essential to provide the inhabitants with safe and liable water supply systems free from any contamination and biological infection. Furthermore, the increase of agricultural productivity is one of the important and urgent issues of the country in order to improve the country's unbalanced trade account. Therefore, it is recommended to implement the Basic Plan as soon as possible.

(2) Method of Implementation

The rural water supply schemes and the irrigation improvement schemes are recommended to be performed under the direct management of the Government, because the construction is so simple that the construction would be able to be carried out by the local engineers without any difficulty. It is, however, recommended to implement the Urban Water Supply Plan for Wangduephodrang Town Area hiring some experienced international contractors, since the facilities to be provided consist of complicated imported plants and materials requiring skilled knowledge and know-how.

(3) Exploitation and Utilization of Water Resources

The potential of groundwater and sub-surface water is not so large comparing with the irrigation water requirement, but enough to supply the demand for rural water supply. It is, therefore, recommended to utilize the groundwater and sub-surface water mainly for the rural water supply. However, a large amount of groundwater and sub-surface water exploitation might have significant impact on the environmental situation of the surrounding areas. It is, therefore, important to establish the most appropriate plan of exploitation considering such effects to the surrounding areas. It is also important to enlighten the higher morality of the beneficiaries on saving supplied water in order to attain effective utilization of the limited water.

The surface water is recommended to be utilized for the irrigation water supply. To realize the effective irrigated agriculture, it is necessary to perform the water management in the most appropriate manner. It is, therefore, important to improve the water management practice as well as the water management facilities. In case that sufficient potential of water source is not expected, it is necessary to diversify the planted crops also in order to utilize the available land resources effectively. It is also necessary to pay attention to the environmental aspects of the surrounding areas to minimize such impacts.

(4) Consideration Necessary for Implementation

The following items are recommended to be considered in the future implementation.

1) Urban Water Supply Plan in Wangduephodrang Town Area

a) Beneficiaries' Well Awareness on Saving Water

The Basic Plan is prepared on conditions that the physical losses would be reduced from present 40 % to future 14 %. Since no water tariff system is introduced, the beneficiaries are able to use water almost free of charge. They may not understand the value of supplied water, and as a result the physical losses may not be reduced as anticipated in the Basic Plan. It is, therefore, recommended to educated the prospective beneficiaries and to make them become aware of the value of such supplied water through various opportunities.

b) Introduction of Metered System

As same as the other cities which have advanced piped water supply systems, it is recommended to introduce the metered system in order to facilitate the collection of water charges. This is considered quite effective for saving water. However, the water tariff should be set properly to be accepted smoothly by the beneficiaries.

2) Irrigation Improvement Plan for Bajo and Phangyul Canals

a) Application of Latest Basic Data and Information

Some of the basic factors such as rainfall, river runoff discharge, soil condition, etc. have to be estimated in the Study. It is necessary to improve and reinforce the basic data and information at the project site such as meteo-hydrological data, geological and hydrogeological data, farming conditions such as soil, unit yield and production cost, economical conditions such as farm gate price and marketing system, and social conditions such as population, etc.

b) Understanding of Actual Site Condition

At present, 2.2 l/s/ha of the design discharge has been applied for the irrigation facilities of most of the projects in Bhutan. However, the agricultural land is distributed from approximately 500 ~ 2,500 m altitude and water requirement should be varied depending upon the site conditions. In some cases, same water requirement has been applied even where there is no sufficient water at the intake site. Therefore, it is necessary to decide the capacity of the irrigation facilities based on the meteo-hydrological condition, cropping pattern, soil conditions, etc. collected at site.

c) Understanding and Cooperation of Beneficial Farmers

According to the results of the Study, the most effective countermeasure for the irrigation improvement is the improvement of the water management system. To establish the effective water management system, it is necessary to get the understanding and cooperation of farmers.

d) Improvement of Supporting System

Improvement of the farmers financial condition is one of the main purposes of the irrigation improvement plan. To implement the project smoothly and to attain the benefit as anticipated, it is necessary to support the farmers financially as well as technically.

THE STUDY
ON
GROUNDWATER DEVELOPMENT
IN
WANGDUEPHODRANG DISTRICT OF BHUTAN

FINAL REPORT

VOLUME II: MAIN REPORT

TABLE OF CONTENTS

Volume I Executive Summary
Volume II Main Report
Volume III Supporting Report
Volume IV Drawings
Volume V Data Book

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

(1) Organization

Bhutan

AMC	Agriculture Mechanization Centre
BHU	Basic Health Unit
CSO	Central Statistical Office
C&LSD	Crop & Livestock Services Division
(DAH)	Department of Animal Husbandry
RE&ID	Research, Extension & Irrigation Division
(DOA)	Department of Agriculture
PD	Power Division
(DOP)	Department of Power
DOS	Department of Survey
FCB	Food Corporation of Bhutan
MOA	Ministry of Agriculture
NASEPP	National Seed and Plant Program
PWD	Public Works Division
(DWH)	Department of Works and Housing
BOB	Bank of Bhutan
BCCI	Bhutan Chamber of Commerce and Industries
BDFC	Bhutan Development Finance Corporation
CSC	Computer Support Centre
RNRRC	Renewable Natural Resources Research Centre
(CARD)	Centre for Agriculture Research and Development
DYT	Dzongkhag Yargay Tshogchung (District Development Committee)
DAO	Dzongkhag Agriculture Officer
DOR	Department of Roads
FSD	Forestry Services Division
(DOF)	Department of Forests
MTI	Ministry of Trade and Industry
NWAB	National Women's Association of Bhutan
NRTI	Natural Resources Training Institute
PPD	Policy and Planning Division
RBA	Royal Bhutan Army
RBP	Royal Bhutan Police
RCSC	Royal Civil Service Commission
RMA	Royal Monetary Authority
RGOB	Royal Government of Bhutan
RPPC	Regional Plant Protection Centre
RNR	Renewable Natural Resource
BOD	Bhutan Oil Distributors
BCCL	Bhutan carbide and Chemical Ltd
BHW	Basic Health Worker
BLC	Bhutan Logging Corporation
BBS	Bhutan Broadcasting Service
NBACD	National Budget & Aid Coordination Division
(DNBA)	Department of National Budget and Accounts
PHED	Public Health Engineering Division
PHD	Public Health Division
RBG	Royal Body Guard
RSPN	Royal Society for Protection of Nature
STCB	State Trading Corporation of Bhutan
TD	Telecommunications Division
(DOT)	Department of Telecommunications
MOC	Ministry of Communication
MOF	Ministry of Foreign Affairs
PC	Planning Commission
TCC	Thimphu City Corporation
CARD	Center for Agricultural Research and Development

International

FAO	Food and Agricultural Organization of United Nations
IBRD	The International Bank for Reconstruction and Development (World Bank)
Helvetas	Swiss Association for Development and Cooperation
IMF	International Monetary Fund
IFAD	International Fund for Agricultural Development
JICA	Japan International Cooperation Agency
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
ADB	Asia Development Bank
ADCA	Agricultural Development Consultants Association
DANIDA	Danish International Development Agency
GSI	Geological Survey of India

(2) Association

Dzong	Fortified monastery housing both civilian administration and monastic institution
Dzongdag	District Administrator
Dzongdag Wagma	Deputy District Administrator
Dzongkhag	District
Dzongrab	Assistant District Administrator
Gup	Head of Block
Mang Gup	Head of Village
TOE	Tons of oil equivalent (1.47 tons of coal equivalent or 43.95 x 109 joules)
Tsheri	Shifting cultivation

(3) Chemistry

EC	Electric Conductivity
PH	Hydrogen Ion Concentration

(4) Economy

B C	Benefit Cost Ratio
E B C	Economic Benefit-Cost Ratio
F. B C	Financial Benefit-Cost Ratio
FIRR	Economic Internal Rate of Return

FIRR	Financial Internal Rate of Return	FNPV	Financial Net Present Value
ENPV	Economic Net Present Value	GDP	Gross Domestic Product

(5) Length

mm	millimeter	m	meter
cm	centimeter	km	kilometer

(6) Area, Volume and Weight

cm^2	square centimeter	m^3	cubic meter
m^2	square meter	g	gram
km^2	square kilometer	kg	kilogram
ha	hectare	t	ton
l	liter		

(7) Derived Measures

m/s, m/sec	meter per second	mm/day	millimeter per day
m3/s, m3/sec	cubic meter per second	l/s, l/sec	liter per second
t/ha, ton/ha	ton per hectare	t/ha	ton per hectare
m3/km2	cubic meter per square kilometer		

(8) Electric Measures

KW	kilowatt	V	volt

(9) Currency

US$	United States Dollar	Nu.	Ngultrum

(10) Temperature, Height, etc.

°C	degree in centigrade	%	percent
EL., GL.	elevation	HP	horsepower

CHAPTER 1
INTRODUCTION

1. INTRODUCTION

1.1 Background of the Study

In response to the request of the Royal Government of Bhutan (hereinafter referred to as "RGOB"), the Government of Japan has decided to conduct a study on the groundwater development project in Wangduephodrang District of Bhutan (hereinafter referred to as "the Study") in accordance with the relevant laws and regulations enforced in Japan.

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, has undertaken the Study in close cooperation with the authorities concerned of RGOB.

In August 1993, JICA dispatched a preparatory study team headed by Mr. Seiji KAIHO to Bhutan to conduct the reconnaissance survey, hold discussions with RGOB's officials and agree on the Scope of Work for the Study (hereinafter referred to as "the S/W") as mentioned in the ANNEX-A.

The S/W, including tentative study schedule, was agreed upon between RGOB and JICA. In accordance with the S/W signed in January 1994, JICA nominated Pacific Consultants International in association with Chuo Kaihatsu Corporation to conduct the Study, and in February 1994, JICA dispatched the Study Team headed by Dr. Shoji Kanatsu to conduct the first field survey.

1.2 Objectives of the Study

The objective of the Study is to conduct a study on water resources development plan with an emphasis on groundwater development in Wangduephodrang District of Bhutan.

1.3 Outline of the Activities of the Study

1.3.1 Member of the Study Team and Counterparts

A total of 13 members of the JICA Study Team were assigned for conducting the Study. The counterparts of RGOB were also assigned and participated in various field works during the period together with the members of the Study Team.

The members of the Study Team and the Counterparts assigned for the Study are listed in Annex B.

1.3.2 Cooperation

During the field work period, the counterpart personnels were assigned to the Study by RGOB in compliance with the request of the Study Team. Especially, a lot of field works including data collection in the respective survey items involved in the Study, topographic survey, installation of new stream gauging stations and rainfall gauging stations, drilling of test wells, sampling for water quality analysis were carried out in collaboration with the counterpart personnels.

In order to formulate the consistent water resources development plan, the Study Team kept the close coordination with various organisations during the Study period as stated below.

- Ministry of Agriculture
- Ministry of Communication
- Ministry of Trade and Industry
- Ministry of Home Affairs
- Wangduephodrang Dzongkhag
- Thimphu Dzongkhag
- Punakha Dzongkhag

1.3.3 Study Progress

Various surveys, investigations, analyses and studies were carried out throughout the three phases of the Study as presented in Fig. 1.3.1. The activities which having been conducted so far are briefed below.

(1) Phase 1 Study

The Phase 1 Field Work was commenced in the early February 1994 and continued for about five and half months up to the end of July 1994. After the submission of Inception Report, the members of the Study Team mobilized to the site and collected the data and information on their respective fields. The data and information collected during the Phase 1 Field Work consist of various reports, publications, statistics, maps, records, etc. In cooperation with many agencies, the necessary data and information were collected successfully for executing the Study. All the field works scheduled in the Phase 1 Field Work were completed and the results were stated in the Progress Report (1) submitted to MOA at the end of July 1994 and were fully utilized in preparing the Interim Report on the Study in the Phase 1 Home Office Work.

(2) Phase 2 Study

In succession to the Phase 1 Home Office Work during which the Interim Report on the Study was prepared to describe the interim results thereof based on the results of the Phase 1 Field Work, the Phase 2 Field Work commenced on arrival of the members of the Study Team at Thimphu on 4 th November 1994. The discussion on the Interim Report was held among various officials concerned including the team members as soon as the Study Team arrived at Thimphu, and consequently the Minutes of Meeting was concluded on November 8, 1994. The field surveys were then commenced, and lasted about nine (9) months till the middle of September 1995.

The Phase 2 Field Survey was divided into two (2) field works, 2nd Field Work (from the beginning of November 1994 to the end of March 1995) and 3rd Field Work (from the middle of June 1995 to the middle of September 1995). At the end of 2nd Field Work , the interim results of the Phase 2 Field Work were compiled in the Progress Report (2) and submitted to MOA at the end of March 1995.

In the course of the Phase 2 Field Work, irrigation improvement study and geological hazards assessment were additionally carried out in response to the request of MOA. Besides,

construction and monitoring works of the experimental facilities, test boring and topographic survey were conducted in addition to the collection of necessary data and information.

(3) Phase 3 Study

Based on the results of the analysis and major findings obtained through the field works and home office works, water resources development plan was formulated and compiled in this Draft Final Report during the Phase 3 Home Office Work.

The Draft Final Report will be submitted to RGOB by JICA with necessary explanation at the beginning of January 1996. After the discussion on the Draft Final Report, the comments from RGOB will be prepared within thirty (30) days after the receipt of the Draft Final Report.

The Final Report will be sent within thirty (30) days after the receipt of the comments on the Draft Final Report from RGOB.

1.4 Composition of the Report

This Draft Final Report comprises the following five (5) volumes of reports.

- Volume I : Executive Summary
- Volume II : Main Report
- Volume III : Supporting Report
- Volume IV : Drawings
- Volume V : Data Book

The Executive Summary briefly describes the results of the whole study. The Main Report describes the summarized results of water resources development plan. The Supporting Report presents the results of the Study and the analyses in detail by the respective survey and study items. The Drawings contain the maps and drawings related to geomorphology, geology, hydrogeology and land use in the Study area. In the Data Book, the basic data and information collected and the results of the analysis of the Study are presented.

CHAPTER 1
FIGURES

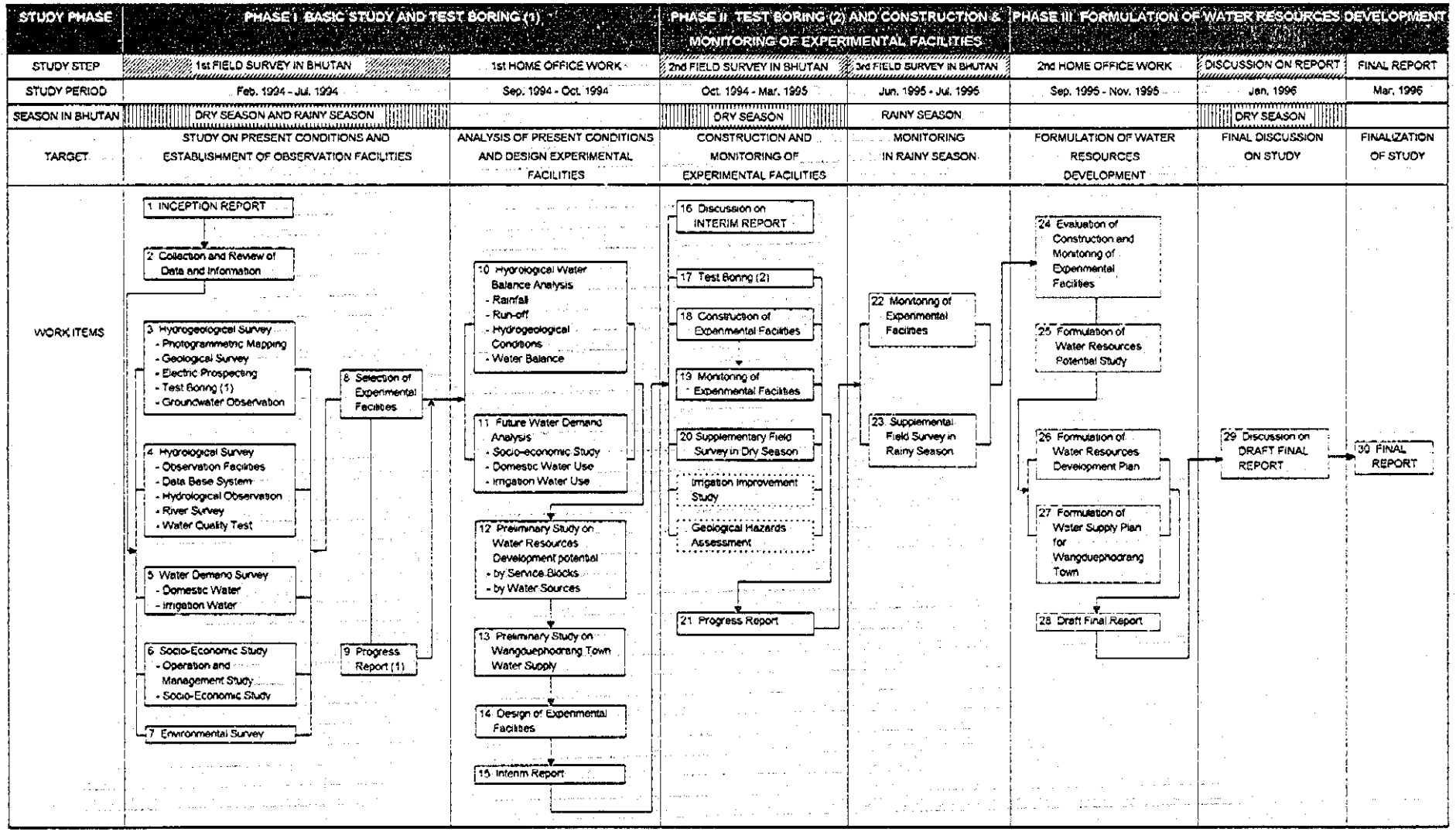


Fig. 1.3.1 WORK FLOW CHART OF THE STUDY

CHAPTER 2
COUNTRY BACKGROUND

2. COUNTRY BACKGROUND

2.1 General Feature of the Kingdom

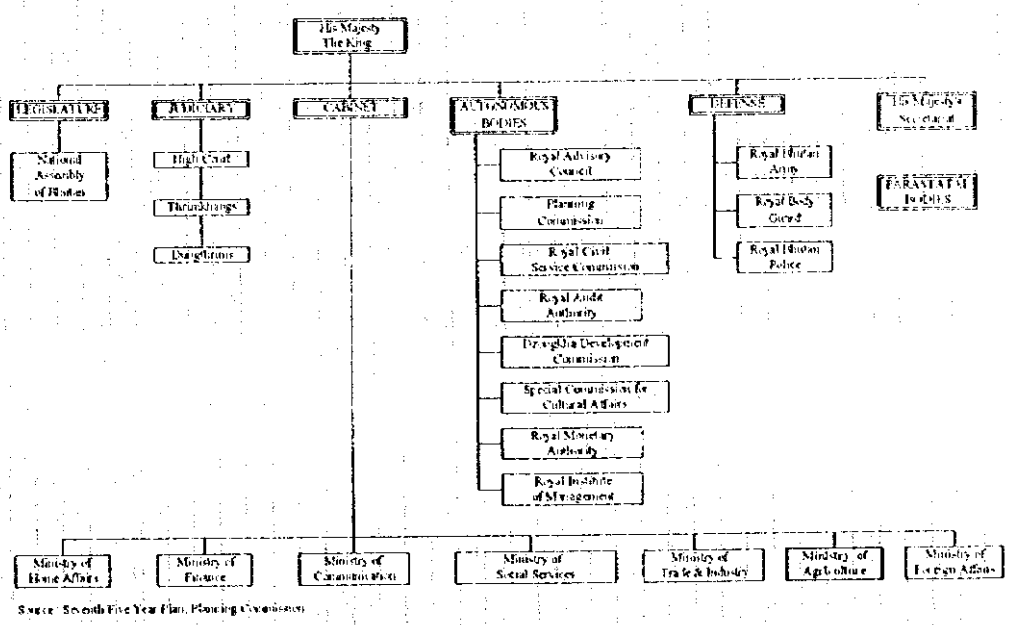
2.1.1 Physical Characteristics

The Kingdom of Bhutan (Druk Yul in Dzongkhag language), which is called Land of Thunder Dragon, lies between latitudes 26° 45' and 28° 10' North and between longitudes 88° 45' and 92° 10' East. The country is relatively compact with a maximum latitudinal distance of 170 km and a maximum longitudinal distance of 300 km, and comprises a land area of approximately 46,500 km^2. Bhutan is a landlocked country situated on the southern slopes of the Eastern Himalayas, bordering the Tibetan Region of China in the north and north-west, and the Indian states of Sikkim, West Bengal and Assam, and Arunachal Pradesh in the west, south and east respectively.

2.1.2 Institutional and Legal Framework

(1) Structure of the Government

The constitution of Bhutann of the Royal Government of Bhutan (RGOB) is based on an enlightened monarch rules through Lhengyel Shungtshog (Cabinet), Tshogdu (National Assembly) and civil service. However, the structure of RGOB of some organisations is changing on in recent years.



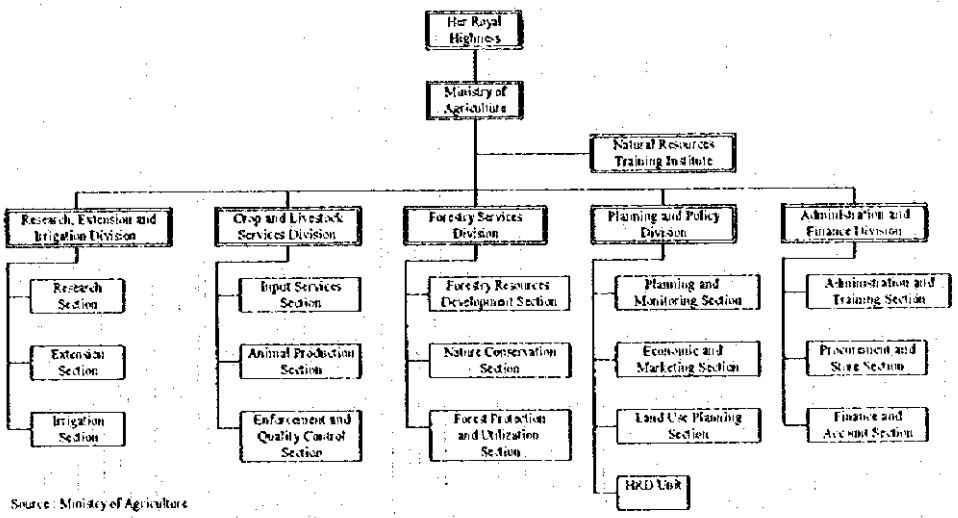
Source: Seventh Five Year Plan, Planning Commission

STRUCTURE OF THE GOVERNMENT (1994)

(2) Structure of the Ministry of Agriculture

According to the document of the "New Renewable Natural Resources (RNR) Structures and Functions", in keeping with the instructions of RGOB to review the organisational structures and functional activities, with a view to strengthen the

Dzongkhag programme planning and implementation capabilities, the Ministry of Agriculture (MOA) had embarked on the process of reorganisation. The MOA has amalgamated the Planning and Policy, and the Administration and Finance functions at the headquarters level in 1990. In 1991/92, further consideration of the Ministry's role in the "Natural Resources Sector Development" led to the formulation of the "Renewable Natural Resources Research Strategy and Plan". As a follow-up to the research and planning exercise, MOA initiated an Extension Review, and Strategy Setting and Planning Exercise in 1992. Finally, MOA was reorganised in November 1993.



STRUCTURE OF MINISTRY OF AGRICULTURE (1994)

With the start of the Seventh Five Year Plan 1992-1997 (7FYP) MOA, guided by PPD, has begun to adopt a wider approach to the development planning process by accepting that the three main activities of MOA, which include crop, livestock and forestry development, as integral parts of the development process, at least in Bhutan where the exploitation of any one resource affects the status of the others. The full practical implications of this co-ordinated RNR approach have yet to be worked out, but at least one of them is that at the dzongkhag level the three sectional heads and the field staff in the three sectors should work closely together under the chairmanship of the Dzongdag.

The MOA's basic structure consists of a Policy and Planning Committee; central functional Divisions; and Dzongkhag RNR Divisions. The co-ordination of the MOA's function at the national level is the responsibility of the Representative of His Majesty the King in MOA, the Deputy Minister and Division Heads. The Policy and Planning Committee, which is composed of the Deputy Minister and Division Heads, is responsible for overall management of Ministry's activities and for ensuring that the RGOB's policy for the RNR sector is efficiently implemented.

As an operational programme of MOA, the activities of the Irrigation Section within the Research, Extension and Irrigation Division (REID; formerly Department of Agriculture) are decentralised to the Dzongkhag Administration. The construction and

maintenance of both major and minor schemes are the responsibility of the concerned Dzongkhag(s).

The major objectives of REID during the Seventh Five Years Plan period comprised of the following:

a. To establish sustainable production systems through increasing soil fertility and improving soil and water conservation;
b. To increase production of cereals and oilseed crops leading to greater self-sufficiency; and
c. To increase production of horticultural and grain legume crops, both for export and domestic markets, leading to high incomes, greater economic growth and export revenues.

2.2 National Socio-economic Situation

2.2.1 Population and Land Use

(1) Population

Until 1990, there had never been a full population census in Bhutan, the demographic data represent rough estimates, for example, the 1990 total population was estimated to be 1.462 million. On the other hand, according to the 7FYP and some other official documents, the 1990 official population of Bhutan has been estimated at 600 thousand. Furthermore, according to the population data which was prepared by the Land Use Planning project in 1994, the total population of Bhutan is approximately 549 thousand.

(2) Land use

The Master Plan for Forestry Development (MPFD Draft 1991) has a more recent assessment. The main finding of the MPFD has been that the total forested area is estimated at 56.9 % of land area. While a large part of the forest area remains un-utilised, forests represent a major source of fuelwood, fodder and construction materials. As livestock graze in forest areas, there is no clear distinction between livestock and forests land uses. Zonal surveys undertaken in 1987/89 have shown that out of total area of land being utilised, more than 50% was accounted for in the others category. This includes, Tsamdok and Sokshin land, i.e. private registered land with forest cover and public land with private grazing rights respectively. Most of temperate pasture areas are subject to year round intense grazing without showing signs of overgrazing except close to population centres (7FYP).

2.2.2 National Economy

(1) Outline of National Economy

Bhutan is predominantly an agriculture oriented country, with about 90 % of labour force engaged in agricultural sector. The sector contributes about 41 % of the Gross Domestic Product (GDP, 1992) and is the backbone of the Bhutanese economy. The

Bhutanese people rely on the land for their food and basic necessities, and the rural economy is based on small, primary subsistence-oriented communities.

(2) Economic Production

The total estimated GDP in 1992 amounted to Nu. 6,178 million or about US$ 238 million (US$ 1 = Nu. 25.92, 1992 annual average) at current price. The GDP per capita referred to the total population estimated of 624,240 (based on 600,000 in 1990 and annual population growth rate of 2.0 %) is Nu. 9,897 or about US$ 380 (for reference, it was estimated at US$ 370 by 1991, 7FYP). This means that Bhutan is not the lowest per capital income in the world which Bhutan have been classified.

(3) Economic Growth

During the 1987-1992 period, the annual growth rate of GDP was estimated at 4.0 %, a very high rate of growth compared with most developing countries during the same period. The major inputs for GDP growth was not from increases in aid, but was largely based on the expansion of the electricity and mining / manufacturing sectors.

RNR sector at 1.7 % was one of the slower growing sectors. Even a 3 % growth rate is rapid by most standards, and would allow a considerable improvement in average agricultural incomes despite the growth of the rural population. While these estimates were based on limited data, it has been assumed that the growth in the agricultural sector was the result of both increases in area planted and in productivity. The relatively slow growth of the forestry sector, was the consequence of RGOB policy restricting the level of logging to prevent un-sustainable utilisation of the forest resources. This policy resulted in a decline in commercial logging in the early 1980s, when responsibility for logging was handed over to the Bhutan Logging Corporation (a public sector enterprise). The output increased from this sector increased in the mid 1980s, but mainly because of the need to fell trees infested with bark beetle disease (7FYP).

(4) Foreign Trade

The major export commodities to India were electricity, minerals, especially calcium carbide, cement, timber and wood products, which accounted 82 % of total export amount in 1990. Electricity generated by Chukha Hydro Power Corporation has been occupying first position from 1987 (Nu. 374 million 97 % in 1990, Nu. 397 million 96 % in 1991 and Nu. 355 million 95 % in 1992). The major import commodities from India were varied from consumer goods like a rice, diesel oil, fabrics, etc. to capital goods like truck chassis, petrol, iron rods, etc. From 1987 the rice has been the highest imported good in Bhutan.

(5) Balance of Payment

The value of merchandise exports was estimated to have increased by Nu. 261 million during the fiscal year 1993/94. Nevertheless, the decrease in imports of Nu. 407 million has borough about a large trade deficit of Nu. 966 million. The trade balance deficits

were accelerated, rising from a deficit of Nu. 217 million in 1990/91 to Nu. 1,634 million in 1992/93, but decelerated in 1993/94.

Further to the trade deficit, the service and transfer payments have been greater than the service and transfer receipts with a deficit of Nu. 455 million. This resulted in a further deterioration of current account balance by deficit of Nu. 1,421 million from deficit of Nu. 1,953 million of the previous period.

Foreign aid has contributed to offset the current account deficits. During 1993/94, Bhutan's Balance of Payments consisting of balance of payments with India and rest of the world had an overall surplus of Nu. 647 million, but it has increased about 70 % from the previous year. These years the economic relation to India has been increasing in comparison with the third countries.

(6) International Reserves and External Debt

The total international reserves were stable in these years. The gross international reserves has been increased by US$ 12.5 million to US$ 107 million during 1993/94. The growth in reserves was a result of a strong increase in convertible currency reserves. The convertible currency reserves increased by 12 % and amounted to US$ 103 million as on June 30, 1994, as compared to US$ 92 million of the previous period. Bhutan has successfully avoided the foreign debt trap into which many countries have fallen. As a result, it has not been forced to mortgage its natural resource base in an un-sustainable fashion to pay off outstanding loans.

At the end of June 1992, Bhutan's convertible currency loan outstanding amounted to US$ 71 million. There was a decline of 12 % comparison with the dept outstanding of the previous period. Total repayments during the period amounted to US$ 4.9 million containing US$ 3.3 million of principal and US$ 1.7 million of interest. There was an increase of 12 % in total debt service payments during the period. The Indian Rupee debt at the start of 1991/92 of Rs. 980 million rose to 1,266 million due to additional borrowing of Rs. 286 million. Total repayment at the end of 1992 was Rs. 3.14 million.

(7) Foreign Exchange

The exchange rate of the Ngultrum against the US$ and other major currencies experienced a significant change in the beginning of 1991/92 as a consequence of the Reserve Bank of India's move to adjust the external value of the Indian Rupee. As a result of this exercise, the Ngultrum weakened further against the dollar and its average exchange rate against one dollar depreciated to Nu. 31.37 of 1994 average from Nu. 30.49 of 1993 average, experiencing a depreciation of about 2.9 %. The currency equivalents of the Ngultrum against the US$ in July 1995 is US$ 1 = Nu. 30.85.

(8) Financial Investment

The domestic investment by the Bank of Bhutan, Royal Insurance Corporation of Bhutan, Bhutan Development Finance Corporation and Unit Trust of Bhutan, has been increasing remarkably. In comparison with the financial investment in 1987 (Nu. 374.3 million), during these five years that on 1992 raised over 600 %. The investment ratio

towards all economic activities has been increased from 11 % of GDP in 1987 to 38 % of that in 1992. The RNR sector occupied only 3.4 % of all financial investment in 1992.

(9) National Budget and Balance of Government's Account

The Fiscal Year of RGOB is from 1 July to 30 June. The total national budget of RGOB for 1994/95 was Nu. 5,010 million and the projected budget outlay for 1995/96 jumped to a record of Nu. 5,212 million.

(10) Price Index

During 1991/92, inflation rate as measured by the rate of change of the Consumer Price Index (CPI), accelerated to 16.0 % as compared to 13.3 % in the previous year. The major factors behind this acceleration was the increase in aggregate demand, increase in food prices, and a strong growth in total liquidity during the year. However, in 1993 and 1994 inflation rates were decelerated to 8.9 % and 8.2 %, respectively. The average increase rates (price index at June) from 1979 to 1994 on food, non-food and total were 8.7 %, 11.6 % and 9.6 %, respectively.

Because of close trade and monetary links, price developments in Bhutan largely follow those in India; however, price levels in Bhutan tend to be considerably higher than in India due to higher transportation cost and less competitive market.

2.2.3 Social Situation and Infrastructure

(1) Transport Network System

The majority of the people in Bhutan lives at least half a day walking distance from a motor road. Some communities are even more remote, 4-5 days from a motor road. These communities have to rely on mule tracks and foot trails in conjunction with suspension bridges, cantilever bridges and in a few places ropeways to reach the nearest large settlement. Rural communities are responsible for the maintenance of foot trails and bridges on a self-help basis. Suspension bridges provide short-cut links between stretches of foot paths and mule tracks and save much time in reaching one's destination. Thus they increase the accessibility to markets, educational, health, agricultural facilities.

(2) Road Network and Condition

The country has a lateral west-east highway from the capital Thimphu to Tashigang (546 km). The west-east highway is connected to southern Bhutan by three north - south highways: Thimphu - Phuntsholing highway (179 km), Tongsa - Gaylegphug highway (244 km) and Tashigang - Samdrup Jongkhar highway (180 km). Further, new Wangduephodrang - Chirang highway is under construction. The highways have 8 tonnes axle capacity and were built according to Indian Hill Road Standard and Specification by Project Dantak, an organisation of the Government of India.

(3) Health and Sanitation

Lack of hygiene and poor sanitation cause many infectious diseases. Diarrhoea and respiratory tract infections remain by far the most frequent diseases treated by the health services. Worm infestations are estimated to occur up to 80 % of the population. The majority of the diseases treated are seasonal and there is a marked fluctuation in the out-patient department attendance between summer and winter. Respiratory diseases are a major cause of morbidity and constitute approximately 20 % of all cases in Basic Health Units. After auto respiratory diseases, diarrhoea disease is the second largest cause of morbidity. Approximately 40 % of deaths of children under five are caused by diarrhoea and 15 % of all patient seen in health centres in 1989 suffered from diarrhoea diseases. To reduce the incidence of this disease, access to safe drinking water and sanitary disposal of human excreta is vitally important (7FYP).

2.2.4 Agriculture

(1) Present Situation of Agricultural Sector

The agricultural sector, newly called as the Renewable Natural Resource (RNR) sector has three sub-sectors: agriculture, livestock and forestry, represents the single largest and the most important sector in the Bhutanese economy. However, based on the comparison with share of agricultural labour force (over 90 %), agriculture land covers of the country (16 %) and its production such as the agricultural GDP (40 % of total in 1992), it is clear that productivity of the RNR sector is unsatisfactorily low and rural economy is kept in subsistence level.

(2) Agricultural Land Use

While a large proportion of the country is covered by forest, the area suitable for agricultural production is limited by the topography and low soil fertility in some areas. The river valleys and the flatlands in the southern foothills account for most of the fertile cultivable lands whereas the northern alpine belt below the snow line is suitable only for pasture. Land is usually terraced for paddy production, while rainfed crop lands and most of the orchards are not terraced. The most recent estimates suggest that 16 % of total land is used for intensive agricultural production, including dryland and irrigated crop production and orchards (7FYP).

(3) Land Tenure

The RNR sector of all country consists of 65,000 farm households with an average farm size of 1.5 ha., and farm distribution is highly skewed: 45 % of farmers with less than 1 ha, cultivating 16 % of the total. Conversely 16% of farmers with holding of more than 2.5 ha, hold 42 % of the total area. Average farm size is substantially higher in the west. Under existing legislation farm households may only plant an area of up to 10 ha, excluding horticultural crops. Farm size has been decreasing as farms are sub-divided between children, and many small farmers are unable to meet their food requirements. A study in the Punakha-Wangduephodrang area during 1990, showed that 40 % of all farmers operated as part owners/tenants. A small number of land less tenants were also identified, accounting for 3 - 5 % of the total. Generally, it is said that

there is no land-lessness in Bhutan, although the rapidly growing population could lead to the emergence of marginal farmers (7FYP).

(4) Agro-ecological Zones

Bhutan has extremely diverse agro-climatic conditions due to major differences in altitude and rainfall as well as in slope and soil characteristics. Climatic conditions in the four physiographic regions (the southern foothills, the middle mountains, the high mountains and the Himalaya) range from hot and humid sub-tropical conditions in the south, to the ice and glacial conditions of the high Himalayas in the north (Masterplan for Horticulture Development, 1994).In an attempt to simplify the diverse climatic conditions and to delineate agricultural areas with similar growing conditions, six agro-ecological zones have been identified based on temperature (determined by altitude) and rainfall.

(5) Production

A wide range of crops are grown depending on cropping conditions and food self sufficiency requirements. Paddy and maize are the principal cereals grown in all country, on 77 % of all cultivable land. Maize covers the largest crop area, but is relatively more important in sub-tropical area of the south. In the temperate area the major crops produced are wheat, buckwheat, potatoes, mustard and barley. Paddy is the principal wet land crop in the monsoon season, and where irrigation water is available wetland winter crops include wheat, mustard and potatoes. Dryland crops in the warm temperate area include wheat, potatoes, mustard.

Oranges, cardamom and other tropical fruits production is concentrated in the south, apples are produced mainly in the temperate area and potatoes are produced in the mid elevation areas. Substantial areas of dryland have been converted to orchard crops in response to the higher profits obtained from horticultural crops. Paddy is the preferred food crop and many farmers would wish to convert dry land to wet land to produce more paddy (7FYP).

Food grain production has grown slowly and export cash crops have grown rapidly in recent years. The main cereal crops are paddy, maize, wheat, barley, buckwheat and millet. Bhutan is 66 % self-sufficient in all cereals. To meet the remaining food needs, cereals are imported from India (Planning Commission).

(6) Farming System

Traditional labour intensive production methods are used, as there is little scope for mechanisation on steep slopes. Water is not a constraint, but management of water in irrigation systems is inefficient. The crop rotation (Tsheri) is widely practised and has traditionally been based on a long fallow period. In most parts of Bhutan traditional soil conservation techniques have appeared to limit soil erosion to a minimum. In the southern foothills high population pressure and steep slope production are beginning to cause erosion in many parts, as the population are originally from plains of India and are unaccustomed to hill farming. Bhutanese farmers practice integrated farming including varied proportions of arable agriculture, livestock and use of products. It

is estimated that over 70 % of the active labour force is engaged in agriculture and related activities.

(7) Agricultural Institutions and Supporting System

Apart from agricultural producers themselves, MOA has the major responsibility for promotion of agricultural development. The MOA provides support services to farmers through three Divisions of Research, Extension and Irrigation (REID), Crop and Livestock Services, and Forest Services. The principal institutions and supporting systems of REID are as follows:

a. Agricultural Extension Centre,
b. Agricultural Research Centre,
c. Seed and Plant Protection Centre,
d. Agricultural Training Centre, and
e. Agricultural Machinery Centre.

The agriculture support services are considered to be one of the most important and essential services to facilitate the various farming practices. Various kinds of centres and institutes have been established in several places and the services provided in these centres and institutes cover various levels of assistance to the farmers with a wide range of knowledge and know-how having accumulated so far.

(8) Problems of RNR Sector

The RGOB has recognised the following as problems confronting sustainable development of the RNR sector:

a. Inability to produce enough cereals to meet the consumption needs of the population;
b. Low productivity of crops;
c. Inadequate technological support;
d. Poor water management;
e. Unbalanced production-mix insufficient to meet the nutritional needs (deficiency in proteins and fat);
f. Predominance of production for subsistence and less for cash income; and
g. Scarcity of cultivated land leading to un-sustainable (suicidal) farming practices on steep slopes.

To address these problems under the overall RNR sector framework, RGOB is presently implementing several activities and has planned options to increase agricultural production on a sustainable basis (Planning Commission).

2.2.5 Water Resources

With the high precipitation and an altitudinal variation of up to 7,000 m above sea level, the water resources are abundant in Bhutan. The high precipitation results in a rich vegetation, natural and cultivated, and the altitudinal difference give many possibilities for use of the

water as a source of energy. Bhutan's water resources are confined in four major river basins: Amo Chhu, Wang Chhu, Sankosh Chhu and Manas Chhu. All four major rivers have their sources in glaciers which cover almost 10 % of the country.

Water has traditionally been used for irrigation, and the availability of water resources has determined the sitting of settlements. Irrigation channels, often running over great distances, have been an integral part of agricultural practices and such channels are still built and maintained. The quality of the water in stream is threatened by pollution from towns and other large communities. This pollution is small and mainly caused by organic matter which will be oxygenated further downstream, nevertheless this constitutes a health hazard of Bhutan's inhabitants (Planning Commission).

2.2.6 Water Supply

Between 1974 and 1990, a total of 1,387 rural water supply schemes were constructed in rural areas. The 6FYP set a target of constructing 600 new schemes but only 258 were completed as of January 1991. Beneficiary communities contributed labour for the construction and maintenance of water supply schemes. A total of 35,000 households (estimated total household number is 70,000) or 305,000 people would benefit from rural water supply programmes if all of them were functioning. However, many of the older schemes are no longer functioning. Thus, the numbers of households benefiting in 1991 was estimated to be about 26,000 or 225,000 people (7FYP).

A study undertaken in 1989 revealed that 21 of the 24 urban areas studied had a piped water supply and distribution system. at that time 5 urban centres had treatment plants and 4 centres had been provided with treatment plants that were no longer functioning. The survey established that in general the water supplies were sufficient, but that only 5 systems were able to provide a 24 hour service. The distribution systems in Thimphu, Phuntsholing, Paro, Gaylegphug, Tashigang and Samdrup Jongkhar been repaired and extended during the 6FYP (7FYP).

2.3 Development Plan

2.3.1 Background

Since the 1960s, RGOB has recognised that Bhutan's economic future is linked to its neighbours and to the world economy. Having abandoned a strategy of self-isolation, Bhutan now looks to increasing economic interaction with other countries as an avenue for development. The development of Bhutanese economy is however constrained by several factors (7FYP):

a. Bhutan is geographically isolated from other countries in the region being a landlocked country, and is distant from the nearest sea port in Calcutta, India. This isolation makes the transport of goods into and from Bhutan costly;
b. Because of the extremely mountainous terrain, the area of land which is suitable for agricultural production is relatively small. This limits the potential for increasing output from the agricultural sector and increases the risks of environmental degradation;
c. The population is distributed in remote scattered settlements, to take advantage of the limited land suitable for agricultural production;

d. The above factors have made the provision of roads and communication networks difficult, and the delivery of health and education services costly;
e. Unlike most other developing countries, Bhutan has a relatively small population and the supply of manpower is a major constraint. The fairly recent introduction of western education means that there is a shortage of manpower with the necessary skills for a developing economy; and
f. As most of the population have been subsistence farmers until recently, the level of monetization has remained low. This has restricted the Government's ability to raise domestic revenues, and Bhutan has relied on external assistance for the funding of development programmes.

His Majesty the King also places much importance on environmentally sound sustainable development. Within the Renewable Natural Resources (RNR) sector the integrated approach to managing the renewable resource base of the country relies heavily on having personnel who have been trained and are capable of implementing the concept of sustainable natural resources management and use.

Bhutan's development is based on co-operation with bilateral and multilateral partners. This international co-operation is essential for the development of the country (Planning Commission).

2.3.2 Five Year Plans and Their Emphasis

The process of social and economic development began late in Bhutan. The Five Year Plans have been the instrument of modern development. The first and second Five Year Plans (1961/67, 1967/72) were totally financed by India and largely implemented with Indian administrative and technical assistance. These plans emphasised the building of basic infrastructure, first and foremost roads, education and human resource training. From the first to the fourth Five Year Plan, there was a shift toward education, health and agriculture. The 4FYP emphasised agriculture, industry and forestry which accounted for 59 % of the plan. The 5FYP and 6FYP (1981-1992) marked a further shift toward decentralisation of development planning and a concerted effort toward economic self-reliance. Total expenditure has more than doubled in each successive plan (Planning Commission).

2.3.3 Seventh Five Year Plan 1992-1997

The overall aim of development is to raise the living standards of all the population, with due emphasis given to the quality of life as well as increasing incomes. While this is the usual objective of development as pursued by all developing countries, there are many means of achieving this goal. The RGOB, in consultation with the people and levels of Government, has developed an overall approach based on six principles:

The Seventh Five Year Plan (7FYP) which came into effect in July 1992 has as its main emphasis:

a. Self reliance: Increased self-sufficiency in financial resources. This will mean increasing the efficiency of domestic taxation, but the country will still be heavily dependent on international assistance both from India and other aid partners;

b. Human resource development: High priority to further development of human resources;
c. Regionally balanced development: Pursuing self reliance, by limiting the amount of foreign technical assistance so that it matches the capacity of the institutions to absorb aid without becoming perpetually dependent on outside funds and experts;
d. Sustainability: Sustainability in development will continue to be a high priority both in relation to the capacity to maintain facilities and services, and in relation to the environment;
e. Efficiency and development of the private sector: Reducing the role of the government and emphasising the private sector as an instrument for further growth; and
f. People's participation and decentralisation: Strengthening decentralisation and popular participation. as part of this initiative development committees will be established at the sub-district (block) levels.

2.3.4 Development Plan in Sectors

(1) Development Plan on Agriculture and Irrigation Sectors

The underlying strategy to achieve the implementation of on-going and planned activities of the 7FYP are (Planning Commission):

a. The development of appropriate and sustainable packages of technologies for each agro-ecological zone and farmer;
b. Improvements in the effectiveness of the technology delivery system through strengthening extension activities, by expanding coverage and the distribution of yield increasing inputs such as fertilisers and improve seeds;
c. Improved access to inputs and credit;
d. Expanding cropping area for irrigated cultivation of crops;
e. Strengthening community organisation for the sustainable management of irrigation and other inputs;
f. Ensuring a stable market and better prices for fruit and cash crops;
g. Implementation of land use planning activities; and
h. Promotion of conservation ethics and environmentally sound sustainable farming by extending training, incentives and grants.

The principal project in the 7YFP related to the Study is the Irrigation Support Project with total cost of Nu. 10.835 million.

Within the frame work of the national development strategy which is guided by the principle objectives of Self-reliance, Sustainability, Environmental Preservation, Efficiency and Decentralisation of Government, Privatisation, Institutional Strengthening, Manpower Development and Regionally balanced Development, the specific RNR Sector Policy Objectives are as follows:

(2) Development Plan on Rural Water Supply Sector

Water supply schemes for rural areas are being established in all major towns and in 962 villages. These water schemes will reduce the incidence of water borne diseases and will provide clean drinking water.

The principal projects in the 7FYP related to the Study are the Support to the Rural Infrastructure Programme with total cost of Nu. 234.186 million and the Support to the Urban Infrastructure Programme with total cost of Nu. 138.662 million.

2.3.5 Relevant Studies and Projects

The relevant studies and projects related to the agricultural, water rescues and water supply developments, especially for the Study and the Study Area are as follows:

a. Punakha - Wangduephodrang Valley Development Project (PWVDP; Bajo)
b. Renewable Natural Resources Research Centre (RNRRC; Bajo)
c. National Seed Production Programme (NASEPP; Bajo)
d. Regional Plant Protection Centre (RPPC; Bajo)
e. Regional Agricultural Machinery Centre (RAMC; Bajo)
f. Natural Resources Training Institute (NRTI; Lobeysa)
g. Irrigation Action Plan
h. National Plan for the Drinking Water Supply and Sanitation
i. Rural Water Supply Project
j. Urban Centres Water Supply and Sanitation Project
k. Seven Towns Water Supply Project
l. Urban Centres Water Supply Consolidation Project

2.3.6 Laws, Regulations and Customary Practices related to Water Resources Development and Water Use

(1) Irrigation Agricultural Development

According to MOA, there is no special regulation of the water resources development on the international rivers for the purpose of irrigated agricultural development. It is said that in case of the water resources development with dams, some international regulations exist between RGOB and India and/or Bangladesh, but they are not clear.

(2) Water Supply

The standardisation of designs on construction of rural water supply schemes has been established in 1988. On average, the beneficiary communities contribute 15 % of the cost of the schemes in the form of labour. Schemes are designed for a 20 year service period.

(3) Water Tariff Structure

Until now, Thimphu and Phuntsholing have been the only towns where consumers are required to pay for water. Consumers are not billed (Nu./month) but pay at the offices of City Corporations according to a ledger. For example, water services charge of Thimphu is as 50 % of the service charges, ranging from Nu. 9.00 to Nu. 40.00 a month according to housing category.

2.3.7 Problems in Development

Problems are caused by the large number of projects. Their growing complexity and inter-dependence combined with the lack of skilled manpower in Bhutan and the limited size of the civil service makes it increasingly difficult to ensure that proposed projects and activities genuinely fit into the priorities of Bhutan's own forward planning, and to prevent the country being donor-driven.

In the matter of aid utilisation, RGOB faces problems similar to those of the past, namely an acute shortage of trained and experienced personal and of local resources to finance development activities. The former is expected to improve with continuing efforts at administrative reform and decentralisation, use of automation, improved communications, more emphasis on in-country training and devolving government operations to the private sector (Planning Commission).

A second aspect of manpower and financial shortages is its impact on plan implementation. Much emphasis will be put on maintenance and consolidation of existing successful programmes, with high priority on health and education and in further strengthening basic institutions (planning, statistics, survey and mapping, census, management training) including participatory development at the local level. Nevertheless the lack of experienced personnel and of finance will restrict the speed and quality of implementation of projects.

2.4 Women in Development (WID)

2.4.1 Status of Women in Bhutan

Women in Bhutan constitute 48 % of the population. Bhutanese women enjoy considerable freedom and are treated equal to men under the law. There is no overt discrimination on the basis of gender. Some women play as vital a role as men in the rural and urban economy. A few women hold managerial positions in the public and private sectors. Married women who are not employed in the formal sector can often generate as much income as their husbands, in addition to being housewives. Actually in urban areas, women are active in marketing and real estate speculation, and as managers of shops and small-scale enterprises.

2.4.2 Organisation

The National Women's Association of Bhutan (NWAB) is a non-governmental organisation established with the purpose of motivating both rural and urban women and to bring them into the mainstream of national development, a goal which is instrumental for the harmonious, sustainable development of the country. The NWAB activities consist of workshops on health, sanitation, basic literacy and nutrition. They have established several weaving-centres and credit facilities specifically for women (Planning Commission).

CHAPTER 3
THE STUDY AREA

3. THE STUDY AREA

3.1 Definition of the Study Area

The Study area of 65 km^2 is broadly divided into four (4) sub-areas, namely Lobeysa, Bajo, Phangyul and Rubeysa by the Chang Chhu, the Dang Chhu and the ridge of the hilly land north to the Wangduephodrang township.

As shown in Fig. 3.8.2, a lot of villages/communities were found and identified in the field survey scattering along the valleys and the hills in the Study area. Generally, boundaries of the villages are not defined under any law or regulation in the country. The Gewog boundaries also run in the Study area from east to west and from north to south without any relation to the existing natural conditions, resulting in a quite complicated situation in delineating the sub-areas exactly.

As for the irrigation aspect, many long and short irrigation canals run in the Study area, and some of them flow from the water source area where their intakes are located. Such intake sites are located rather far away from the Study area. It is considered necessary, in some cases, to include such irrigation areas out of the Study area, because irrigation canals have to be treated as a system covering whole of the command areas from the upstream of intake to the small lateral canals. Therefore, it is quite difficult to delineate the exact areas and boundaries of such sub-areas.

To facilitate the surveys and analyses for the Study in both aspects of the irrigation and domestic water supply plans, the Study area is considered as such areas that include the areas outside the irrigation canals also as required, which is interpreted that the areas and boundaries of sub-areas considered in the Study on irrigation and domestic water supply may be different from each other case by case. As a result, each sub-area is generally defined as stated below.

- Lobeysa Sub-area: The areas located west of the Chang Chhu.
- Bajo Sub-area: The low flat areas which extend east of the Chang Chhu and include some surrounding hilly areas.
- Phangyul Sub-area: The hilly areas which extend north of the Dang Chhu and east of the Pe Chhu.
- Rubeysa Sub-area: The hilly areas located south of the Dang Chhu.

3.2 The Land

3.2.1 Location and Physical Characteristics

The Study area is located in the inner Himalayas of west-central Bhutan. The Wangduephodrang town is the capital of Wangduephodrang Dzongkhag and the economic and urban center of the Study area, and is located at about 27 km east of Thimphu. However, the road distance from Thimphu to the town is about 85 km, and it takes 1.5

hours driving. East-west distance and north-south distance of the Study area are 10 km and 6.5 km respectively, and the total area is approximately 65 km^2.

The elevation of the Study area, as defined, varies from 1,200 m to 2,400 m above sea level, but the ridge lines defining the main river watershed reach 3,000 m above sea level or more. There is a little flat land, except for a limited area of low terraces which are subject to flooding during the monsoon seasons. Ground slopes generally range from 10° to 40°, with the most of the agriculture practices carried out on slopes of 15°-30°. Within the Study area, the rivers and main tributary streams are in general not steeply incised and cultivation is often possible at very near the water courses.

Wangduephodrang town is situated at an elevation of 1,350 m above sea level and located on a ridge overlooking the confluence of the Chang Chhu and the Dang Chhu. This is one of the oldest human settlements of Bhutan, and it is the important district headquarters.

3.2.2 Administrative Unit

The Study area is situated in the three (3) contiguous Dzongkhangs (districts) of Punakha, Thimphu and Wangduephodrang from north to south. This area is limited as shown in the map which includes Lobeysa, Bajo, Phangyul and Rubeysa such as the Study sub-areas and Wangduephodrang town from north to south. Administratively, three (3) Dzongkhangs and six (6) Gewogs (blocks) are related to the Study area, and the Study sub-areas are under the Dzongkhag and Gewog as follows:

Study Sub-areas and Administrative Unit

Study Sub-area	Dzongkhag (District)	Gewog (Block)
Lobeysa	Thimphu	Babesa
	Wangduephodrang	Thetso
Bajo	Wangduephodrang	Thetso
	Punakha	Lingbukha
	Thimphu	Babesa
Phangyul	Wangduephodrang	Phangyul
Rubeysa	Wangduephodrang	Rubisa
	Wangduephodrang	Jena
	Wangduephodrang	Thetso
Wangduephodrang town	Wangduephodrang	Thetso
Others	Wangduephodrang	*Nisho
	Punakha	*Guma

Note: * means very few areas.

3.3 Socio-economic Situation

3.3.1 Household and Population

The numbers of villages, household and population which correspond to the four (4) Study sub-areas such as Lobeysa, Bajo, Phangyul and Rubeysa, are as follows:

Number of Villages, Households and Population of Study Sub-areas

Study Sub-area	Village	Household	Population
Lobeysa	21	177	3,086
Bajo	8	115	983
Phangyul	18	156	1,159
Rubeysa	17	179	1,456
Total	64	627	6,684

The total number of household for the four (4) Study sub-areas which includes schools, public offices and institutes, RBA firing range, temples, etc., is estimated at 627 in 1995. 70 % of the total is in the Wangduephodrang Dzongkhag, 25 % in the Thimphu Dzongkhag and 5 % in the Punakha Dzongkhag. The total population of the Study sub-areas is estimated at approximately 6,700. The average number of family members excluding public organisation is counted approximately as 8.2.

According to the Seven Towns Water Supply Study (1989), the Wangduephodrang town's population (exc. RBA) was 3,800 at 1989 and was expected to grow at a rate of 4.0 % per year. This projection translate into future population, the estimated populations was approximately 4,630 at 1994, and the population projections at 1995 and 2000 were 4,820 and 5,770, respectively. However, the field survey results of 1995 conducts that the numbers of residents and dayvisitors of Wangduephodrang town are estimated at 6,035 and 2,320, respectively setting a moderate growth rate of two (2) %.

3.3.2 Land Use and Land Tenure

(1) Land Use

The land use map of the country is being prepared by the Planning and Policy Division (PPD) of MOA with the assistance of DANIDA. The present land use in the Study area is measured on this map which is called as land-use working map (draft map), and is confirmed during the site survey. As a result, it is clarified that the Study area of 65 km^2 consists mainly of the following four (4) categories:

Land Use of the Study Area

Category	Area (km^2)	%
Forest	40.66	62.5
Agricultural Land	15.70	24.2
Pasture	2.53	3.9
Settlement	0.93	1.4
Others	5.18	8.0
Total	65.00	100.0

Source: PPD/DANIDA

(2) Land Tenure

The agricultural land in three Gewogs; Thetso, Rubeysa and Phangyul, in Wangduephodrang Dzongkhag is calculated to be about 1,180 ha with 475 farmers household. An average size of land holding in these Gewogs calculated to be about 2.5 ha. The small holders less than 0.49 ha in size is more predominant in the three Gewogs than in whole of the district.

3.3.3 Regional Economy

The main occupation in the Study area is farming and livestock husbandry. The Punakha - Wangduephodrang valley is one of the largest contiguous paddy areas in Bhutan, accounting for about 18 % of national rice production from about 12 % of the paddy area. Hence, rice production is the most important economic activity in the Study area and rice is the most important crop in terms of area, production, employment, as a food staple, and as a cash and barter crop.

From the view point of the national and regional economy, the Wangduephodrang town is the commercial distribution point between the Thimphu, the capital of the country and Wangduephodrang Dzongkhag and surrounding areas, acting as a economic service centre of the Study area. The Punakha - Wangduephodrang valley is situated in a fertile soil and its products are brought to the market of the town. A small bazaar with many permanent small structures is situated in the town center. At present, there are a few industries, such as small sawmill and manufacture of furniture in the Study area.

3.3.4 Social Situation and Infrastructure

The Thimphu - Tashigang paved highway is crossing from west to east through the Wangduephodrang town in the Study area. This all-weather macadam road is connected to Thimphu and linked to the main east-west settlements. Three paved roads are extended from this highway to south and north: Wangduephodrang - Chirang road, Lobeysa - Punakha road and Chuzomsa - Sha Slate Mine road which run along the Pe Chhu. Another motor road is Wangduephodrang - Punakha road passing on the left bank of the Chang Chhu, but it is unpaved road. The main flow of traffic is oriented toward Thimphu, and there are limited flows toward Tongsa and points further east.

In the greater part of the Study area, villages can only be reached by mule tracks and foot trails, as well as two suspension bridges. Hence, there is a burden of transporting luggages by horses and by men. There are several bus services having daily or sometimes weekly services to Thimphu, Punakha, Phuntsholing, Tashigang, Daga and other places. In the Wangduephodrang town some jeep taxies are serving from the town to surrounding areas.

Wangduephodrang town has piped water supply system at present, but it is not adequate. The water source is very far away, from the Pe Chhu by pipeline, and the water was diverted in an irrigation channel till it reaches the piped scheme. In the Study sub-areas many rural water supply schemes were constructed by UNICEF programme. However, many of the older schemes are not well functioning and also face insufficient supply in the dry season.

3.3.5 Women's Situations in the Study Area

According to the IFAD study report (1987) and field survey results, the overall situations of rural women in the Study area are as follows:

(1) Household

A feature of farming household is that the head of the household is female, and she preside over the household. It is common for women over 60, especially if widowed, to hand over the responsibilities to one of their daughters. A household consists of about eight (8) people on average. The women live in household with their children, married daughters, unmarried brothers, and their father and mother (if still alive). Matrilocality is a tradition. The husband will after move to his wife's mother's house when married.

(2) Women's Work

The rural women are involved in a host of family chores and activities in the house and farm. The domestic tasks they perform include, on a daily basis: food preparation and processing, washing clothes, fetching water and fuel wood, feeding animals, cleaning the house and the compound. The women in the Study area scarcely weave. The rural women make local liquor from wheat and another cereals for home consumption.

All the women are engaged in agricultural work, and they have a claim on the land, due to matrilineal inheritance of land. Rice farming is the most important farm work in the Study area and gender role on main works is as follows:,

Division of Labour in Rice Farming

Kind of Work	Male	Female
Transporting	X	-
Ploughing	X	-
Manuring	-	X
Rice Sowing	-	X
Rice Transplanting	-	X
Weeding	(X)	X
Harvesting	X	X
Threshing	X	(X)
Winnowing	-	X
Milling	X	-

From the above mentioned, it is seen that the women have the major labour contribution in rice farming. However, recently some part of the division of labour by gender is being not clear, because of introducing of power tiller.

3.4 Geology and Hydrogeology

3.4.1 Physiography

(1) General

The land-locked mountainous kingdom of Bhutan constitutes an important segment in the geology of the Eastern Himalaya. It is flanked in the south-west, south and east respectively by the states of Sikkim, West Bengal-Assam and Arunachal Pradesh of India and in the north by Tibet of China. Bhutan is believed to have derived its name from Sanskrit word "*Bhutan or Bhot-ant*". The former means sudden rise in elevation, while the latter conveys end of Tibet. For locals the name of this spectacularly beautiful country is Druk Yul --- *Land of the Thunder Dragon.*

Geometrically it is roughly an oval shaped country and lies between latitude 26°45' to 28°10' north and longitude 88°45' to 92°10' east. The east-west length is approximately 320 km and the north south width is about 175 km.

Bhutan is compartmentalized into different units by north-south flowing rivers. However, the entire terrain rises abruptly from the Indo-Bhutan border and reaches different elevations in different parts.

Elevation-wise Bhutan can be classified into three (3) units:

- Southern foot hill region (South)
- Mountain and valley belt (Middle)
- Himalayan chain (North)

In the mountain and valley belt where the Study area is situated, nature has made deep gorges in the southern part and wide river valleys in the northern part like Paro, Thimphu, Wangduephodrang etc., of elevation 1300 m to 2500 m. The elevation of the Study area ranges from 1200 m to 2500 m above sea level.

(2) Geomorphological Study

The following geomorphological maps have been prepared.

- Drainage system map	1:50,000 and 1:10,000
- Geomorphological land classification map	1:50,000 and 1:10,000
- Summit level map	1:50,000
- Relative relief map	1:50,000
- Drainage density map	1:50,000

These maps may be of service for the study on geological structure, geological hazards as well as hydrogeology. Geomorphological land classification map (Fig. 3.4.1) revealed gently sloped broad plane on the crest suggesting slow uplifting of the area.

(3) Photogrammetric Mapping

A new map on the scale of 1:10,000 made by photogrammetric map drawing for the study was prepared by the Survey of Bhutan. The aerial photograph used is a part of the 848-A series which was taken in 1978 with approximate scale of 1:35,000. The photogrammetric mapping instruments used are:

- AMH TA-Table and/or AGI for drawing
- EK 22 for coordination and elevation measurement

All of these instruments are products of the Wild Heerbrug of Switzerland. Symbols and marks were adopted as per the topographic map of Bhutan. During the field verification, theodolite (RKI) with staves, sight rule and plane table with tripod were used. Contour line interval is 10 m on steep terrain and two (2) m on the flat terrain. Thick contour line (index contour) was drawn every 50 meters.

3.4.2 Geology

(1) General

The first geological information pertaining to Bhutan came from Godwin-Austin (1868) in connection with mineral assessment. He was followed by Maliet (1875) and Pilgrim (1906). Lahiri (1941) provided details of the foot-hill geology especially of his 'Buxa Series". The geological investigations got an impetus after 1961 when the Geological Survey of India set up a unit at Samtse (old spelling Samchi). Results of the early geological survey were published by Nautiyal et al, (1964). This was followed by a crisp account of Bhutan geology by Gansser (1964), Jangpangi (1974, 1978) and Jangpangi et al, (1975) which dealt in detail with the regional geology of parts of Bhutan.

After Nautiyal et al, (1964), except for the publication of a geological map (Anon, 1984) no attempt has been made to synthesize divergent views contained in numerous unpublished reports of the Geological Survey of India. The emphasis had shifted to mineral exploration. The results of mineral investigations have been summarized by ESCAP (Anon, 1991) under United Nations in an Atlas of Mineral Resources of Bhutan along with a map.

Those existing geological data, although limited, are accessible at the library of the Geology and Mine Division, Ministry of Trade and Industry, Bhutan. The publication of the Indian Geological Survey often contains field reports on the Bhutan geology and these are available in Japan.

Among the physiographic belts mentioned above, the Himalayan Chain as well as the Mountain and Valley belt belong geologically to the Greater Himalayan zone. As is mentioned above, the geology of the Greater Himalaya is mainly composed of highly metamorphosed crystalline rocks with the Tethys sediments distributed to the north.

The Study area is physiographically situated in the Mountain and Valley belt of the metamorphosed crystalline rocks accompanied by thin cover of weathered blanket and the Quaternary river terrace deposits at places.

The Bhutan Himalayas are composed of a sequence of major geo-tectonic units which express themselves geomorphologically as the following three zones; namely Sub Himalayan zone mainly composed of Siwalik Formation, Lesser Himalayan zone mainly composed of Midland Meta-sediments and Greater Himalayan zone composed of the Himalayan Gneiss and the Tethys sediments. These zones are separated from each other by major faults.

Structurally the Bhutan Himalaya presents an extremely complicated picture. Each formation is not only thrust bound but is also traversed by subthrusts. The southern most tectonic belts show maximum imbrications and constitutes a schuppen zone, though the horizontal translation involved seems to be limited and deformational history simple. The northern tectonic belts apparently seem to have simple regional structure but have suffered large scale horizontal translation and show a complicated deformational history. In contrast to the western Himalaya, the Tethyan rocks in the Bhutan Himalaya seem to be involved in complicated deformation.

Based on rock types and tectonic style, the Bhutan Himalaya can be broadly divided into two geological zones: below and above the Main Central Thrust which is being called Thimphu Thrust in Bhutan Himalaya.

As described by Molnar (1986) the Main Central Thrust is not a clearly defined plane separating two different kinds of rocks but instead is a wide zone of ten or more kilometers where all of the rocks have been severely sheared. In other words, the Main Central Thrust is a series of thrusts and each sliced sheet has apparently slid over the one below.

The highly metamorphosed sequence above the Main Central Thrust is the Thimphu Series and the weakly metamorphosed sequence below the thrust is named as the Paro Series. The Thimphu Series was referred to as the Takhtsang Gneiss by Gansser (1983).

(2) Field Works and Map Prepared

During Phase I, II, and III, ranging from February 1994 to September 1995, a field geological survey program has been performed.

The crystalline rock sequence in the Study area has been tentatively classified into two series, namely the Thimphu Series and Paro Series. The Thimphu Series is composed of highly metamorphosed rocks such as garnet gneiss, para-gneiss and schists, marbles and quartzites with granitic intrusives. The Paro Series is composed of less metamorphosed pelitic and psammitic rocks such as phyllite and schist with minor showings of stratabound copper layers.

In the field, the highly metamorphosed Thimphu Series lies as a vast sheet covering the less metamorphosed rocks of the Paro Series. This reversed metamorphism is a well known fact with regards to other parts of the Himalaya mountains but still remains a major future research item. The petrographic study indicates a great break in continuity of the metamorphic grade suggesting fault contact of the two geological series.

In spite of the survey area being situated in mountainous area, many river terraces are distributed in a wide range. Accordingly, the Quaternary system, not only river terraces and mud flow deposits as described before but also some landslide blocks, is also an important element of the geology in the area.

The landslide blocks are situated in the mountainous or hilly areas, and small scale but perennial springs exist in the slide blocks. Because the landslide blocks are geologically important units, therefore these are marked as an independent geological unit in our geological map.

Maps created in this survey are as follows:

- Geological Map : scale 1:50,000 (Fig. 3.4.2) and 1:10,000
- Geological Profile : scale 1:50,000 (Fig. 3.4.3) and 1:10,000

Details of the geological units are described as follows:

1) Thimphu Series

The vast sheet of highly metamorphosed sequence, structurally located above the Main Central Thrust and comprising garnet-kyanite-sillimanite-para-gneisses and schists, augen gneiss, and flaggy quartzites with granitic intrusions, and occupying about half of the country, is named the Thimphu Series after the capital of Bhutan. In the Study area, the biotite gneiss interbedded with garnetiferous schistose gneiss, augen gneiss with minor quartzite band and quartz veins, pegmatites and granite constitute the Thimphu Series. The stratigraphy of the Thimphu Series is repeating alternation of biotite-gneiss, garnetiferous schistose gneiss and augen gneiss.

Judging from the great discontinuity in the metamorphic grade with the underlying Paro Series, the Thimphu Series is considered as a thrust-up sheet on the Paro Series but no definite field evidence of fault contact has been found so far.

2) Paro Series

Below the Main Central Thrust Sheets, largely unfossiliferous Lesser Himalayan formations are present. The Lesser Himalayan sequences, so well developed as distinct tectonic belts in the western Himalaya, have been reduced to a narrow width in the Bhutan Himalaya. The reduction in width is due to more southward translation of the Main Central Thrust Sheet and tremendous tectonic telescoping suffered by the Lesser Himalayan rocks. The

intense tectonics has completely disrupted the original stratigraphic order of these unfossiliferous sequences.

In the studied area, the stratigraphic succession of the less metamorphosed sequence below the thrust consist of phyllitic schist, quartzite and quartz-biotite schist (quartzose member herein after), green schist and thin bed of marble in ascending order.

Although the ground check on the continuity of the proper Paro Series has not been conducted the less metamorphosed stratigraphic sequence observed in the Study area is tentatively by named the Paro Series.

(3) Quaternary Geology

The Quaternary system in the Study area is limited in the scattered river terraces and mud flow deposits of the slope. These two types of Quaternary system, river terraces and mud flow deposits, form gentle sloped terrain utilized as farmland.

1) River Terraces

a) High Terrace

The high terraces are divided into two categories, H1 and H2. H1 is the oldest terrace in the area, and its relative height is 130 m from the present river bed. H2 has its relative height of 70 m to 100 m, and a large portion is being used for the nation's army training center.

H1 is underlain by mud flow deposits containing many cobbles of around 50 cm in diameter. On the other hand, H2 is underlain by a mud flow deposit layer, 10 m in thickness, in the upper part and a boulder layer in the bottom.

So far observed, the high terraces are developed mainly in and around the Wangduephodrang town. The facies change, appearing as huge boulders in the down-stream and fine sand facies in the upper-stream, is significant in the area.

b) Middle Terrace

The middle terraces are distributed in several places of both sides of the Chang Chhu, and are the largest in size. The terraces are divided into two categories, M1 and M2.

M1 has a relative height of 30 m to 50 m from the present river bed, and is distributed in the area from the foot hill of the eastern mountains to the proper Bajo sub-area.

M2 has a relative height of 10 m to 20 m from the present river bed. The top horizon of the terrace is composed of well-sorted fine sands, 30 meters in