JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF AGRICULTURE
ROYAL GOVERNMENT OF BHUTAN

THE STUDY ON GROUNDWATER DEVELOPMENT IN WANGDUEPHODRANG DISTRICT

FINAL REPORT

VOLUME I : EXECUTIVE SUMMARY

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).

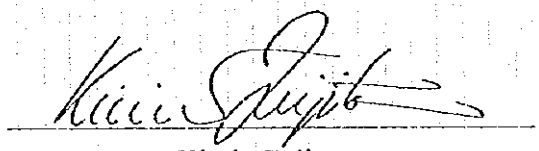
JICA sent to Bhutan a study team headed by Dr. Shoji Kanatsu, Pacific Consultants International and Composed of staff members of Pacific Consultants International and Chuo Kaihatsu Corporation, four times between February 1994 and January 1996.

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

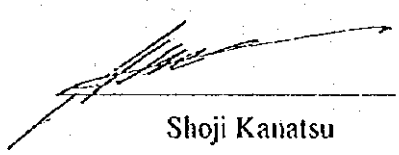
Dear Sir,

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.

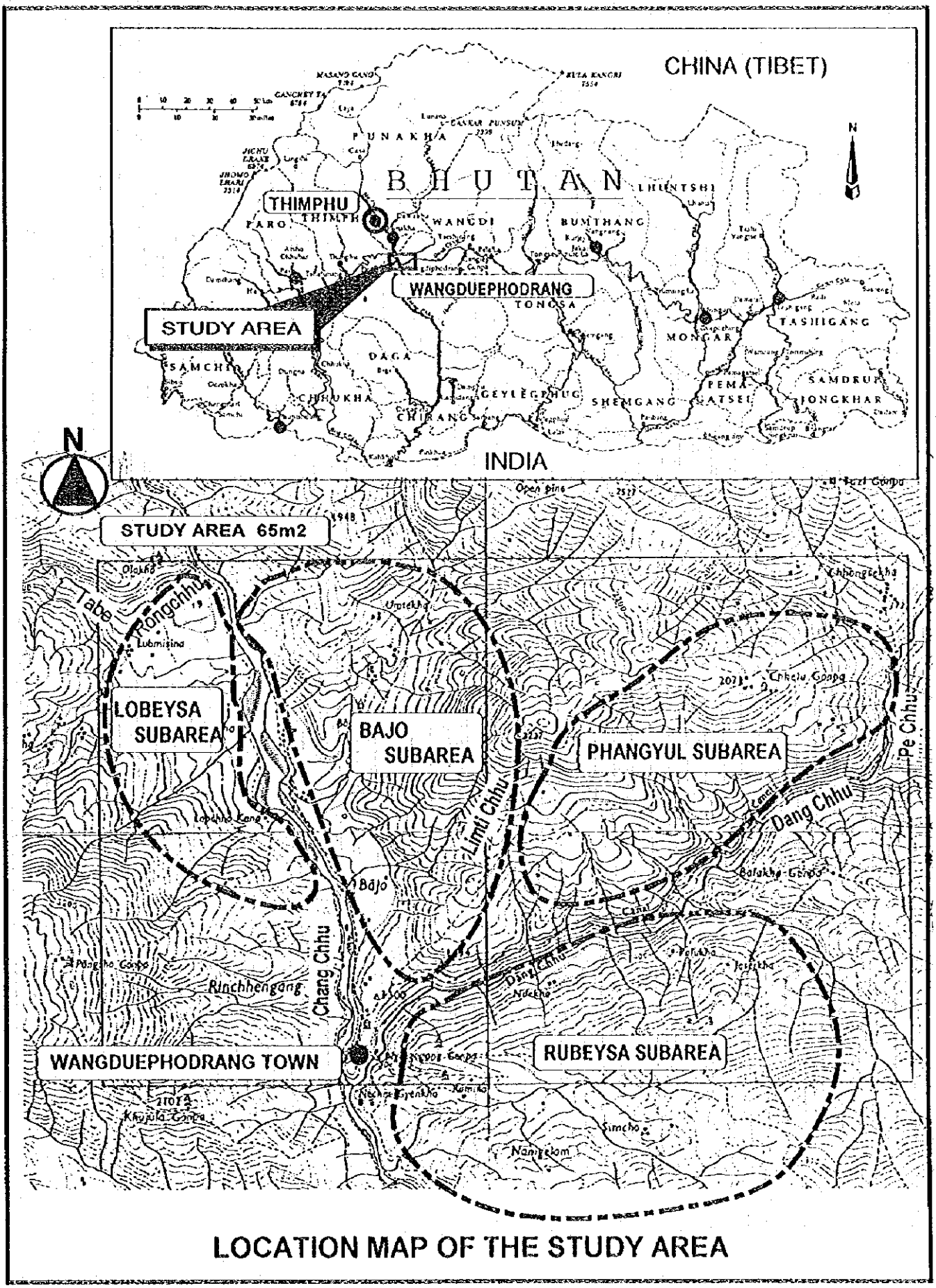
The report consists of Executive Summary, Main Report, and Supporting Report. Executive Summary summarizes the results of all studies. Main Report presents the results of the whole study including water resources potential, water resources evaluation, basic water resources development plan, urban water 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

THE STUDY ON GROUNDWATER DEVELOPMENT IN WANGDUEPHODRANG DISTRICT OF BHUTAN

ABSTRACTS

1. BASIC WATER RESOURCES DEVELOPMENT PLAN

1.1 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

1.2 Objectives of Water Resources Development

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.

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

1.3 Target Years

The target years are set as follows:

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

1.4 Water Resources Development Plan for Irrigation Water Supply

(1) Basic Strategy 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

(2) Summary of Proposed Schemes

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

Summary of Proposed Schemes

Category of land	Low Flat Area	High Hilly Area
Canal Length (km)	30.2	30.6
Command Area (ha)	504	254
Number of Benefited Households	292	266
Number of Offtake Facilities	119	153
Total Construction Cost (1000Nu)	9,195	1,021
Required O/M Cost (1000Nu/year)	102	115

1.5 Water Resources Development Plan for Urban and Rural Water Supply

(1)Urban Water Supply System in Wangduephodrang Town Area

1) Service Area, Future Population and Productivity of Water Supply System

Target year	2002	2005
Service Area	110 ha	130 ha
Future Population	9,847 persons	11,212 persons
Unit Water Consumption	120 l/day/capita	145 l/day/capita
Future Water Demand	1,133 m3/day	1,133 m3/day

2) Proposed Urban Water Supply System

Intake and Conveyance Facilities

-The existing intake facilities are utilized, because their capacity is 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.

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 250 m^3.

-It is recommended to apply some water treatment for improving such high turbidity and reducing bad color content.

Distribution Networks and House Connection

-The distribution networks are improved as provision of house connections, replacement of main pipelines, etc.

(2) Rural Water Supply Systems

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
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

1.6 Cost Estimate

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

Irrigation Water Supply	14.6 Million Nu
Urban Water Supply System	231.2 Million Nu
Rural Water Supply Systems	44.1 Million Nu
Total	289.9 Million Nu

1.7 Economic Evaluation

Economic Internal Rate of Return(EIRR) is estimated to be 15.4 %.. It is judged that the implementation of the Basic Plan is economically sound.

2. URBAN WATER SUPPLY PLAN FOR WANGDUEPHODRANG TOWN

2.1 Facility Plan

(1)Conveyance Facilities

-Design discharge:	1,700 m^3/day (20 l/sec)
-Total distance:	Approximately 8.4 km
-Diameter:	8 inch
-Type of piping materials:	Ductile iron pipe

(2) Water Treatment Facilities

-Raw water receiving pit: 5.5 m (L) x 1.5 m (W) x 1.5 m (H) of reinforced concrete box

-Flocculator: 0.7 m (W) x 10.0 m (L) x 4 Nos. of concrete canal

-Aluminum dosing system: 1,5 m (W) x 1.5 m (L) x 1.2 m (D) reinforced concrete solution tank

-Sedimentation tanks: The existing tanks of which capacity is measured to be 950 m^3 is utilized with some extent of reinforcement

-Rapid sand filter: Gravity type rapid filter of 24 m^2 filter area with filtered water transfer pumps of 1.2 m^3/min

-Distribution reservoirs: The present capacity of 600 m^3 is proposed to be increased with about 200 m^3.

-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.).

-Operation house: Wooden operation houses of 90 m^2

-Approach road: About 80 m of approach road from the national road.

(3) Distribution Networks and Relating Facilities

-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.

2.2 Project Cost Estimate

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

(Unit: Nu. 1,000,000)

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

2.3 Project Evaluation

(1)Economic Evaluation

Economic Internal Rate of Return(EIRR) is estimated to be 11.1%. 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.

(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.

3. IRRIGATION IMPROVEMENT PLAN

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

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

3.1 Irrigation Improvement Plan

(1) Cropping Patterns and Water Requirement

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

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.

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

Maximum Water Requirement

(l/sec)

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

(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

3.2 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				2,490,273
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

3.3 Project Evaluation

(1) Economic Evaluation

Economic Internal Rate of Return (EIRR) is estimated to be 11.2%.. It is judged that the implementation of this Plan is economically sound. The EIRR is a little larger than that of the whole irrigation water supply plan of 10.7 %.

(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).

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FINAL REPORT

VOLUME I: EXECUTIVE SUMMARY

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EXECUTIVE 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).

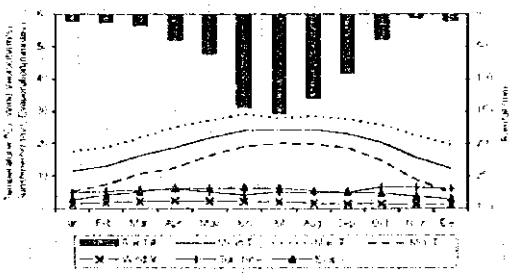
(2) Hydrogeology

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.

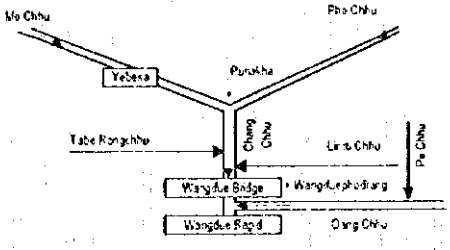
2.3 Meteorology and Hydrology

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%)	444	(50.9%)
2 Agriculture										
Wetland Cultivated	1,099	(16.9%)	216	(52.8%)	151	(85.2%)	151	(13.3%)	215	(25.1%)
Dry land Cultivated	0	(0.0%)	0	(0.0%)	0	(0.0%)	8	(0.7%)	7	(0.8%)
Other Agriculture	471	(7.2%)	132	(32.3%)	5	(2.6%)	115	(10.2%)	45	(4.2%)
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	255	(3.9%)	35	(8.6%)	0	(0.0%)	87	(7.7%)	81	(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	177	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
Linglukha 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
Thangyul	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 mininum 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 Offlake 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, 10% 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	Genikha	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 Offlake Facilities	32	12	20	28
Proposed Counter Measures	New Construction of Offlake 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			
Name of Canal	Maphekha	Naykoyuwa	Rumina	Total
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 Offlake Facilities	25	20	16	153
Proposed Counter Measures	New Construction of Offlake 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 Additional 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.

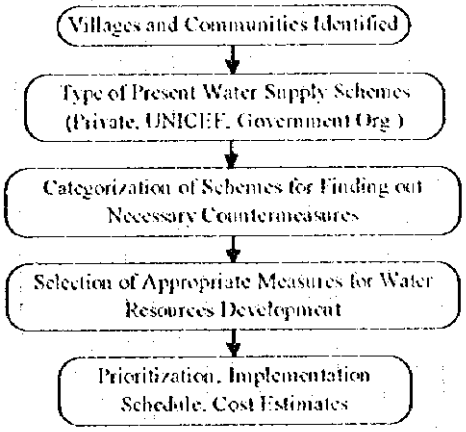
3) Distribution Networks and House Connection

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

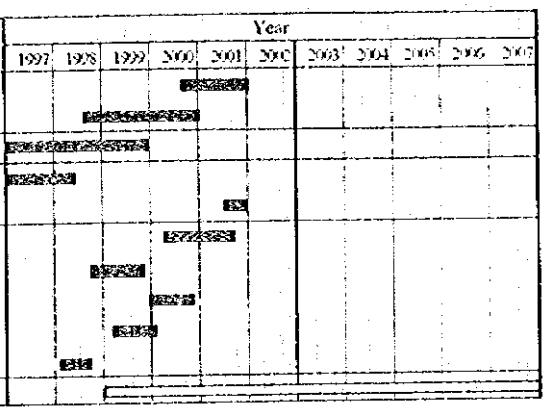
Extension Scheme (A) : More than 6 households
(B) : Less than 5 households

4.4 Implementation Schedule and Cost Estimate

(1) Implementation Schedule

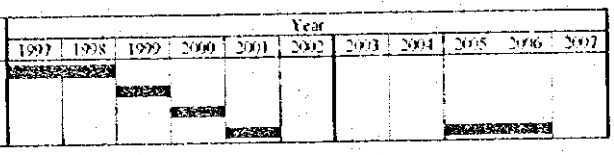
The implementation of the Water Resources Development Basic Plan is proposed as shown below.

Category of Land	Sub-Area	Name of Canal	Code	Priority
Low Flat Area	Lobeysa	Upper Lobeysa	C1	②
		Lower Lobeysa	C2	③
	Bajo	Bajo	C9	①
High Hilly Area	Phangyul	Phangyul	C10	①
		Genikha	C15	⑦
	Rubeysa	Nalakha	C18	⑥
		Rutekha	C19	③
		Maphekha	C20	⑤
		Naykoyuwa	C21	④
		Rumina	C22	②
Research the Optimum Diversification Crop				



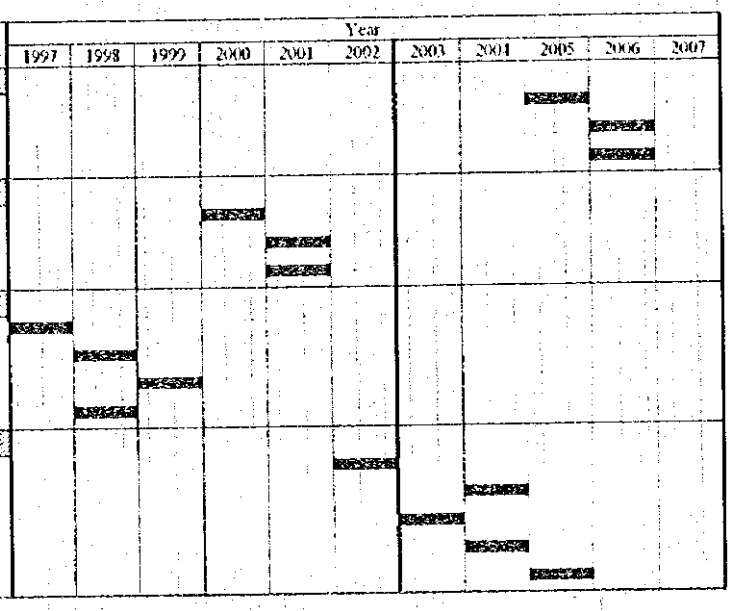
IMPLEMENTATION SCHEDULE FOR IRRIGATION WATER SUPPLY PLAN

Work Items
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
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)	❹-1
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 Wangduephodrang 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	6.3
1.3 Distribution Networks and House Meters	17.1	4 Rubeysa Sub-area	6.7
2 Engineering Service	3.5	5 Research Activities	4.4
3 Administration Costs	6.2	Total (3)	14.6
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 Hat 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
		Maphekha	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						62	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.

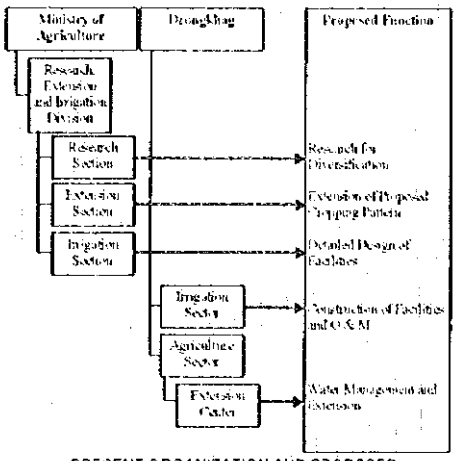
4.5.3 Socio-Economic Evaluation

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

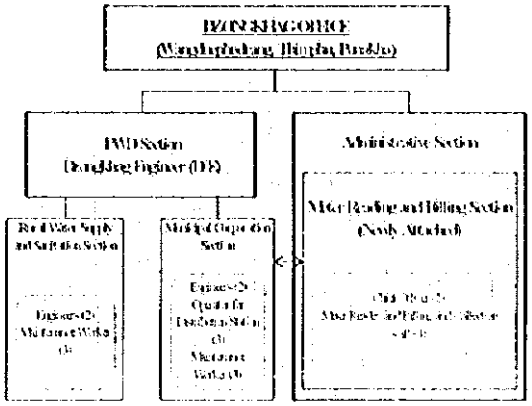
- Contribution to the National Development Plan
- Stable Supply of Food
- Improvement of Living Standard
- Water Quantity and Quality Improvement
- Vitalises Local Commercial Activities
- Improvement of Public Health Environment
- Decrease of Local Women's Work

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

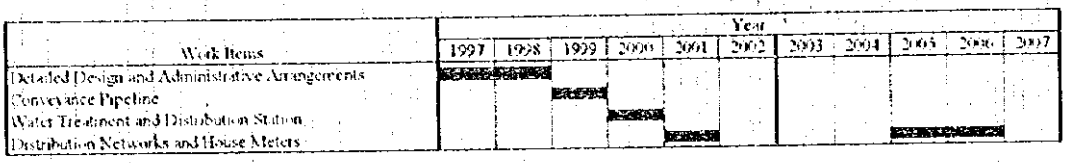
The following improvement works are proposed to be made for the present distribution networks.

- 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



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 Station	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.

Annual Operation and Maintenance Costs

(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	1,683.41	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				8	8	8	8	8	8	8	8
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.

TABLE AND FIGURES

Table. 1 WATER BALANCE STUDY FOR SURFACE WATER RESOURCE

Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)				
Lobeysa	Taberong Chhu				Upper Lobeysa, Lower Lobeysa						361				Taberong Chhu				119.4				
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec
Available River Discharge	2.081	2.081	2.000	2.000	1.862	1.862	2.585	2.585	3.227	3.227	6.423	6.423	9.963	9.963	13.404	13.404	10.862	10.862	4.855	4.855	3.429	3.429	2.423	2.423
Water Requirement for Irrigation	0.165	0.167	0.243	0.257	0.281	0.206	0.152	0.053	0.000	1.133	0.995	0.710	0.616	0.304	0.326	0.302	0.350	0.313	0.108	0.000	0.073	0.117	0.145	0.166
Water Balance	1.916	1.914	1.757	1.763	1.580	1.655	2.453	2.529	3.227	2.094	5.428	5.713	9.346	9.658	13.079	13.103	10.511	10.549	4.745	4.855	3.358	3.312	2.278	2.257
Insufficiency																								

Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)				
Bajo	Pe Chhu				Bajo						145				Pe Chhu				145.7				
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec
Available River Discharge	2.540	2.540	2.440	2.440	2.272	2.272	3.154	3.154	3.938	3.938	7.857	7.857	12.157	12.157	16.357	16.357	13.254	13.254	5.922	5.922	4.184	4.184	2.957	2.957
Water Requirement for Irrigation	0.065	0.066	0.098	0.095	0.111	0.082	0.054	0.023	0.000	0.451	0.398	0.286	0.251	0.127	0.139	0.129	0.144	0.129	0.042	0.000	0.028	0.046	0.057	0.066
for Domestic	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Total	0.083	0.084	0.116	0.113	0.129	0.100	0.072	0.041	0.018	0.469	0.416	0.304	0.268	0.145	0.157	0.147	0.162	0.147	0.060	0.018	0.046	0.064	0.075	0.084
Water Balance	2.457	2.456	2.325	2.327	2.142	2.172	3.083	3.113	3.920	3.468	7.421	7.554	11.889	12.012	16.200	16.210	13.092	13.107	5.862	5.904	4.138	4.120	2.881	2.873
Insufficiency																								

Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)				
Phangyul	Lachhu				Phangyul						91				Lachhu				2.25				
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec
Available River Discharge	0.039	0.039	0.037	0.037	0.035	0.035	0.048	0.048	0.060	0.060	0.120	0.120	0.186	0.186	0.250	0.250	0.202	0.202	0.090	0.090	0.064	0.064	0.045	0.045
Water Requirement for Irrigation	0.043	0.043	0.050	0.048	0.067	0.049	0.024	0.005	0.000	0.256	0.216	0.148	0.127	0.052	0.048	0.043	0.056	0.047	0.028	0.000	0.019	0.030	0.037	0.042
Water Balance	-0.004	-0.004	-0.012	-0.011	-0.033	-0.014	0.024	0.043	-0.060	-0.196	-0.097	-0.029	0.059	0.133	0.202	0.207	0.146	0.155	0.062	0.090	0.045	0.034	0.008	0.003
Insufficiency	-(9%)	-(10%)	-(25%)	-(22%)	-(48%)	-(29%)			-(77%)	-(45%)	-(19%)													

Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)				
Phangyul	Uship				Gemkha						15				Uship				0.84				
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec
Available River Discharge	0.015	0.015	0.014	0.014	0.013	0.013	0.018	0.018	0.023	0.023	0.056	0.056	0.116	0.116	0.187	0.187	0.152	0.152	0.042	0.042	0.024	0.024	0.017	0.017
Water Requirement for Irrigation	0.007	0.007	0.008	0.008	0.011	0.008	0.004	0.001	0.000	0.042	0.036	0.024	0.021	0.009	0.008	0.007	0.009	0.008	0.005	0.000	0.003	0.005	0.006	0.007
Water Balance	0.008	0.007	0.006	0.006	0.002	0.005	0.014	0.017	0.023	-0.020	0.020	0.032	0.095	0.107	0.180	0.180	0.143	0.144	0.038	0.042	0.021	0.019	0.011	0.010
Insufficiency									-(47%)															

Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)				
Ruboysa	Mochuna				Nalakha						29				Mochuna				8.78				
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec
Available River Discharge	0.153	0.153	0.147	0.147	0.137	0.137	0.190	0.190	0.237	0.237	0.472	0.472	0.732	0.732	0.985	0.985	0.798	0.798	0.357	0.357	0.252	0.252	0.178	0.178
Water Requirement	0.014	0.014	0.017	0.016	0.022	0.016	0.008	0.002	0.000	0.082	0.070	0.048	0.041	0.017	0.016	0.014	0.020	0.017	0.009	0.000	0.006	0.010	0.012	0.014
Water Balance	0.139	0.139	0.130	0.131	0.115	0.121	0.181	0.188	0.237	0.155	0.402	0.424	0.691	0.715	0.969	0.971	0.779	0.782	0.348	0.357	0.246	0.242	0.166	0.164
Insufficiency																								

Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)				
Ruboysa	Takarong Chhu				Ruteka, Mapheka, Naykovaka, Rumina						119				Takarong Chhu				6.8				
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec
Available River Discharge	0.119	0.119	0.114	0.114	0.106	0.106	0.147	0.147	0.184	0.184	0.366	0.366	0.567	0.567	0.763	0.763	0.619	0.619	0.276	0.276	0.195	0.195	0.138	0.138
Water Requirement	0.056	0.057	0.069	0.067	0.090	0.066	0.035	0.010	0.000	0.337	0.286	0.198	0.168	0.072	0.066	0.059	0.080	0.069	0.036	0.000	0.024	0.040	0.049	0.056
Water Balance	0.063	0.062	0.045	0.047	0.016	0.040	0.112	0.138	0.184	-0.153	0.080	0.168	0.399	0.496	0.698	0.705	0.538	0.550	0.240	0.276	0.171	0.156	0.089	0.082
Insufficiency									-(45%)															

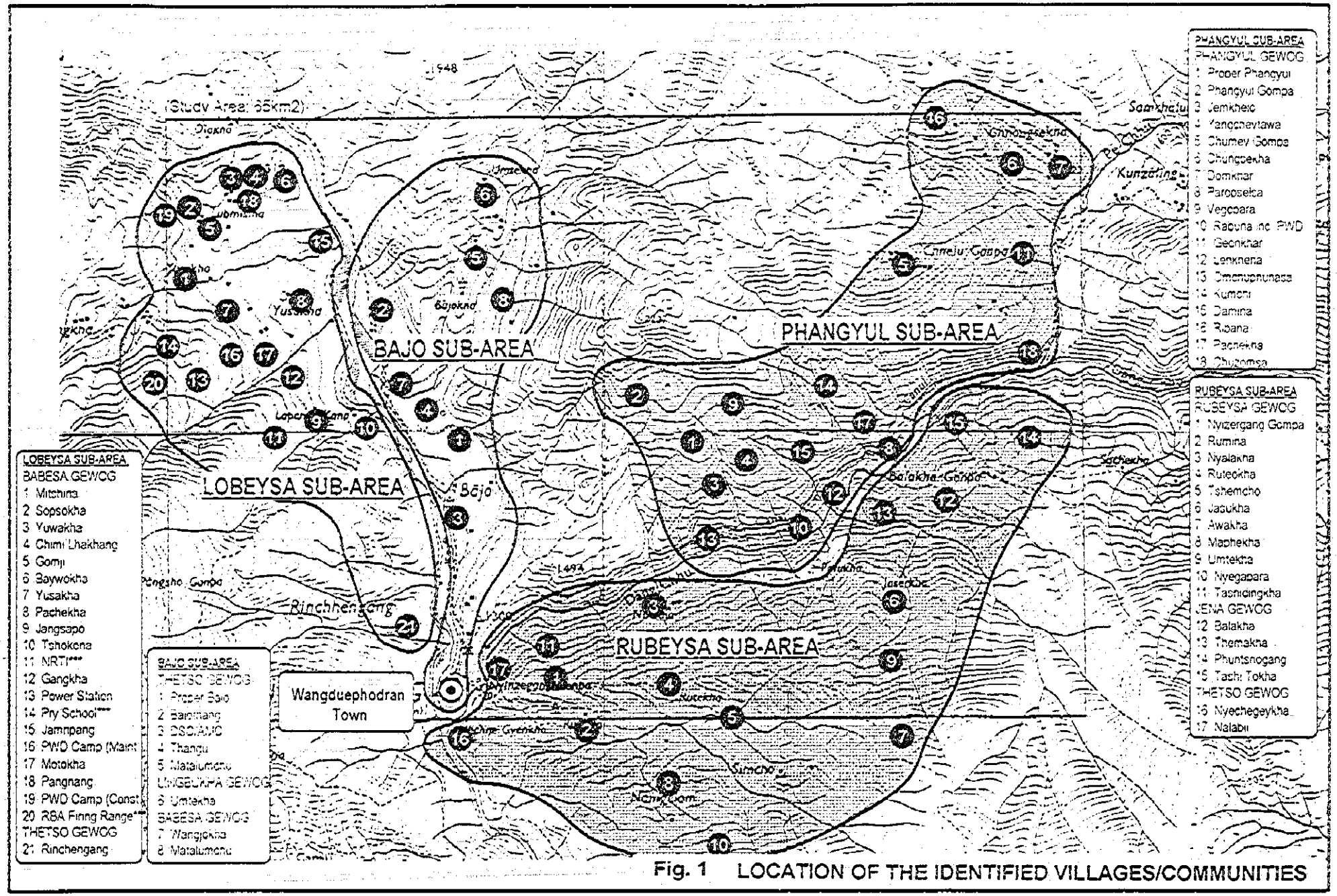


Fig. 1 LOCATION OF THE IDENTIFIED VILLAGES/COMMUNITIES

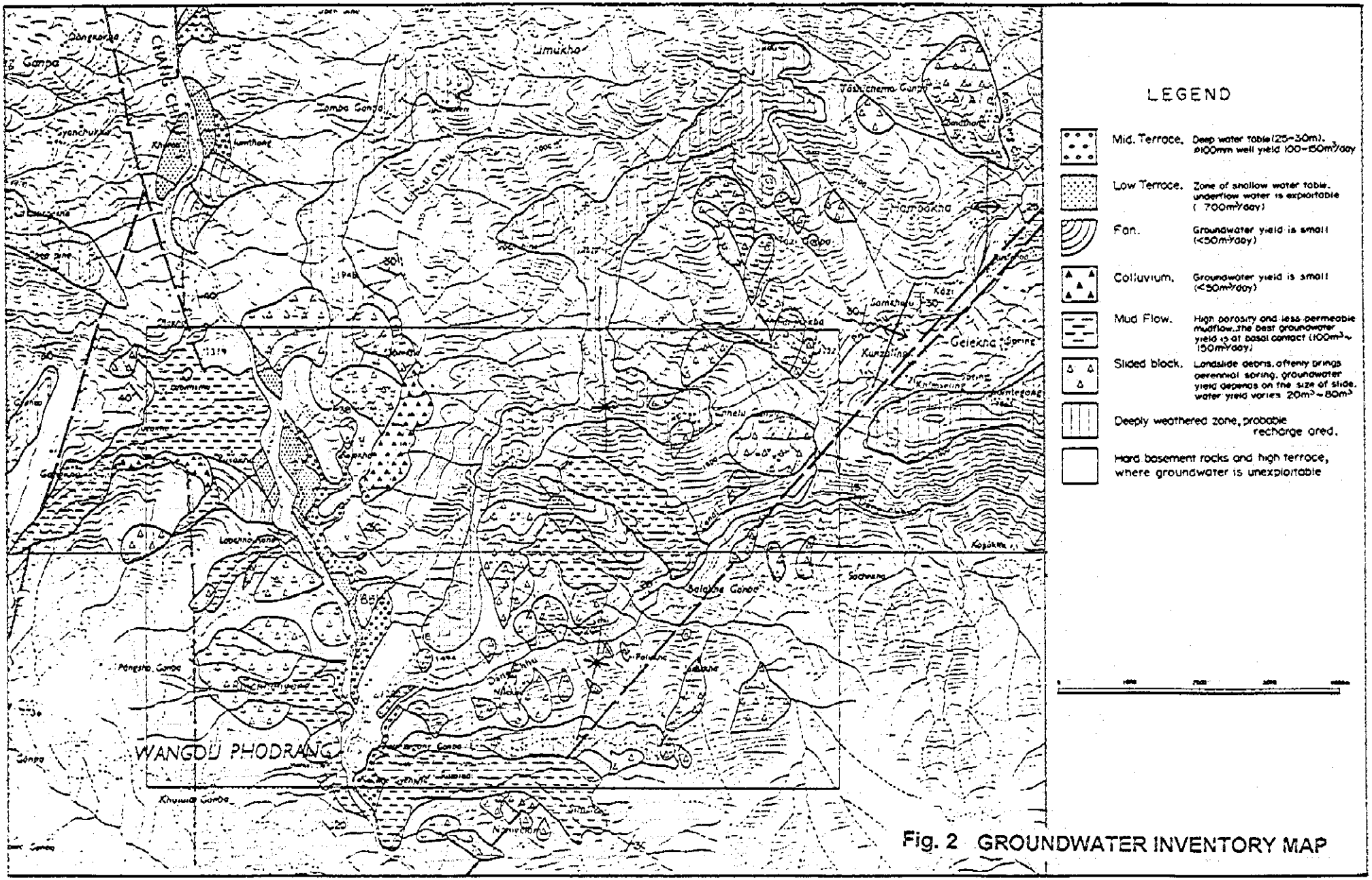
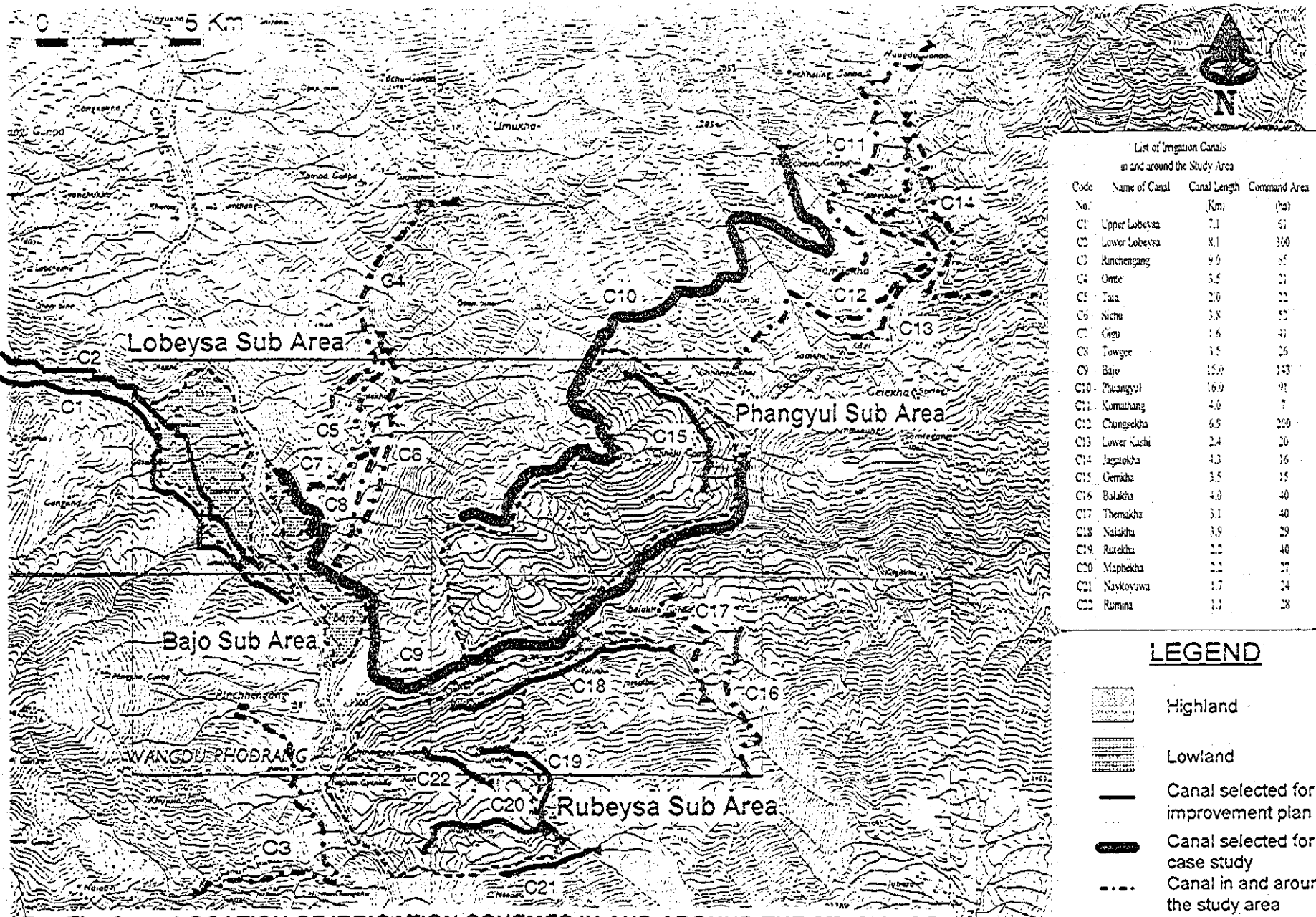


Fig. 2 GROUNDWATER INVENTORY MAP



List of Irrigation Canals in and around the Study Area

Code No.	Name of Canal	Canal Length (Km)	Command Area (ha)
C1	Upper Lobeysa	7.1	61
C2	Lower Lobeysa	8.1	300
C3	Rinchengang	9.0	65
C4	Omte	5.5	51
C5	Tata	2.0	12
C6	Nichu	3.8	12
C7	Gagu	1.6	41
C8	Towgee	3.5	26
C9	Bajo	15.0	143
C10	Phuangyul	16.9	91
C11	Kamathang	4.0	7
C12	Chungekha	6.9	200
C13	Lower Kashi	2.4	20
C14	Jagatokha	4.3	16
C15	Gemdha	3.5	15
C16	Balakha	4.0	40
C17	Themakha	5.1	40
C18	Nalakha	3.9	29
C19	Rutekha	2.2	40
C20	Maphekha	2.2	35
C21	Nawkoyuwa	1.7	24
C22	Rumina	1.1	28

LEGEND

- Highland
- Lowland
- Canal selected for improvement plan
- Canal selected for case study
- Canal in and around the study area

Fig. 3 LOCATION OF IRRIGATION SCHEMES IN AND AROUND THE STUDY AREA

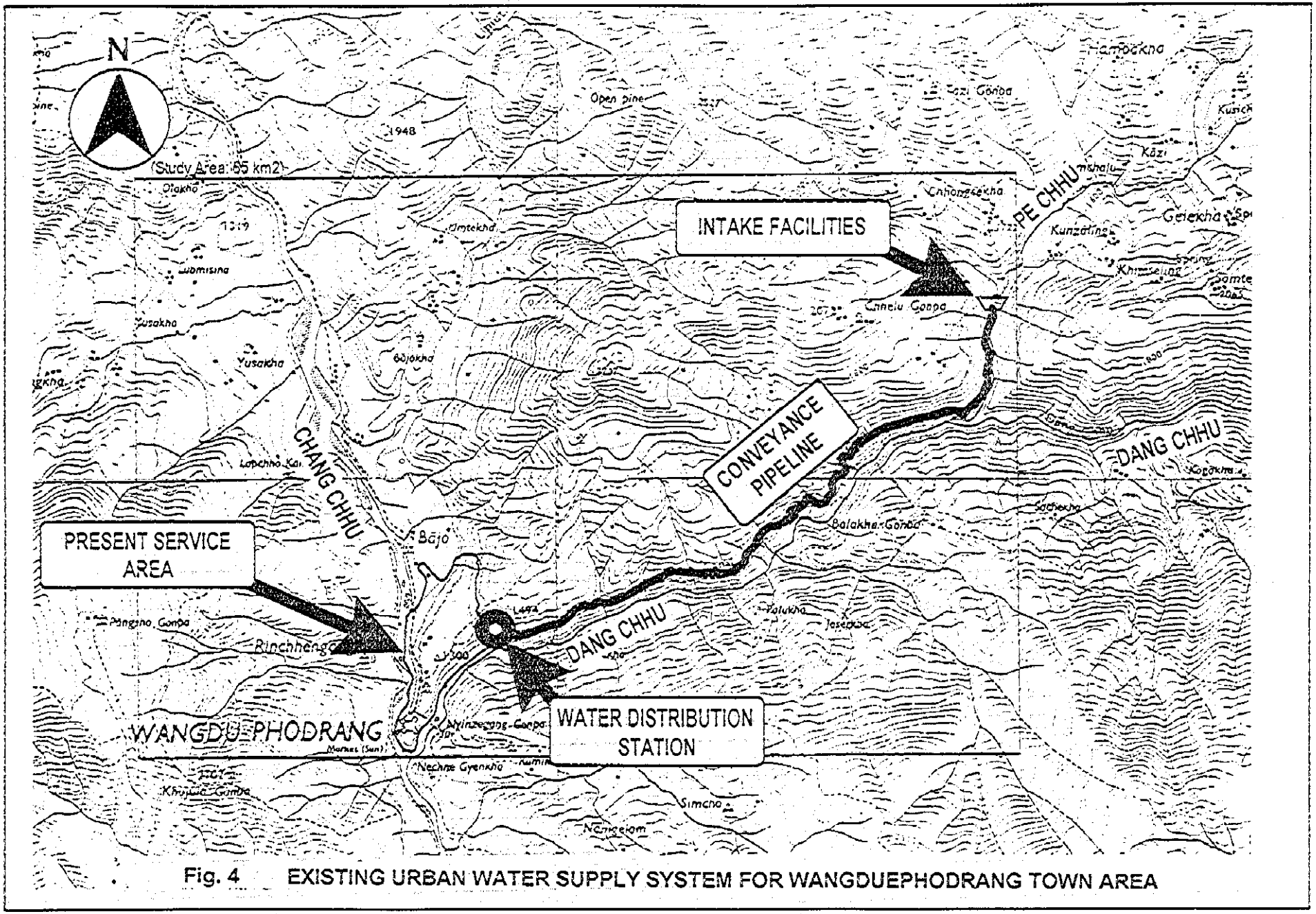


Fig. 4 EXISTING URBAN WATER SUPPLY SYSTEM FOR WANGDUEPHODRANG TOWN AREA

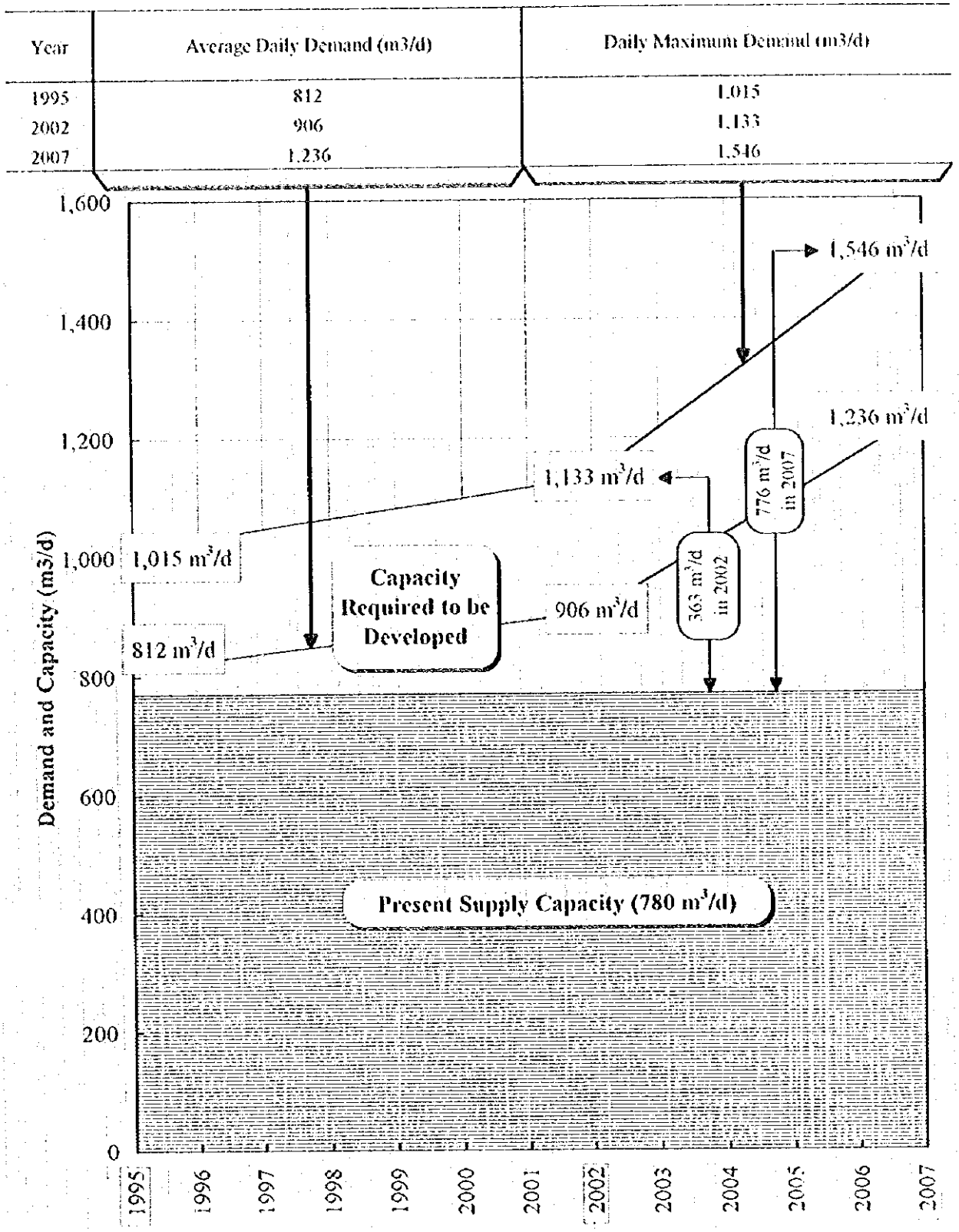


Fig. 5 FUTURE WATER DEMAND FOR WANGDUEPHODRANG TOWN

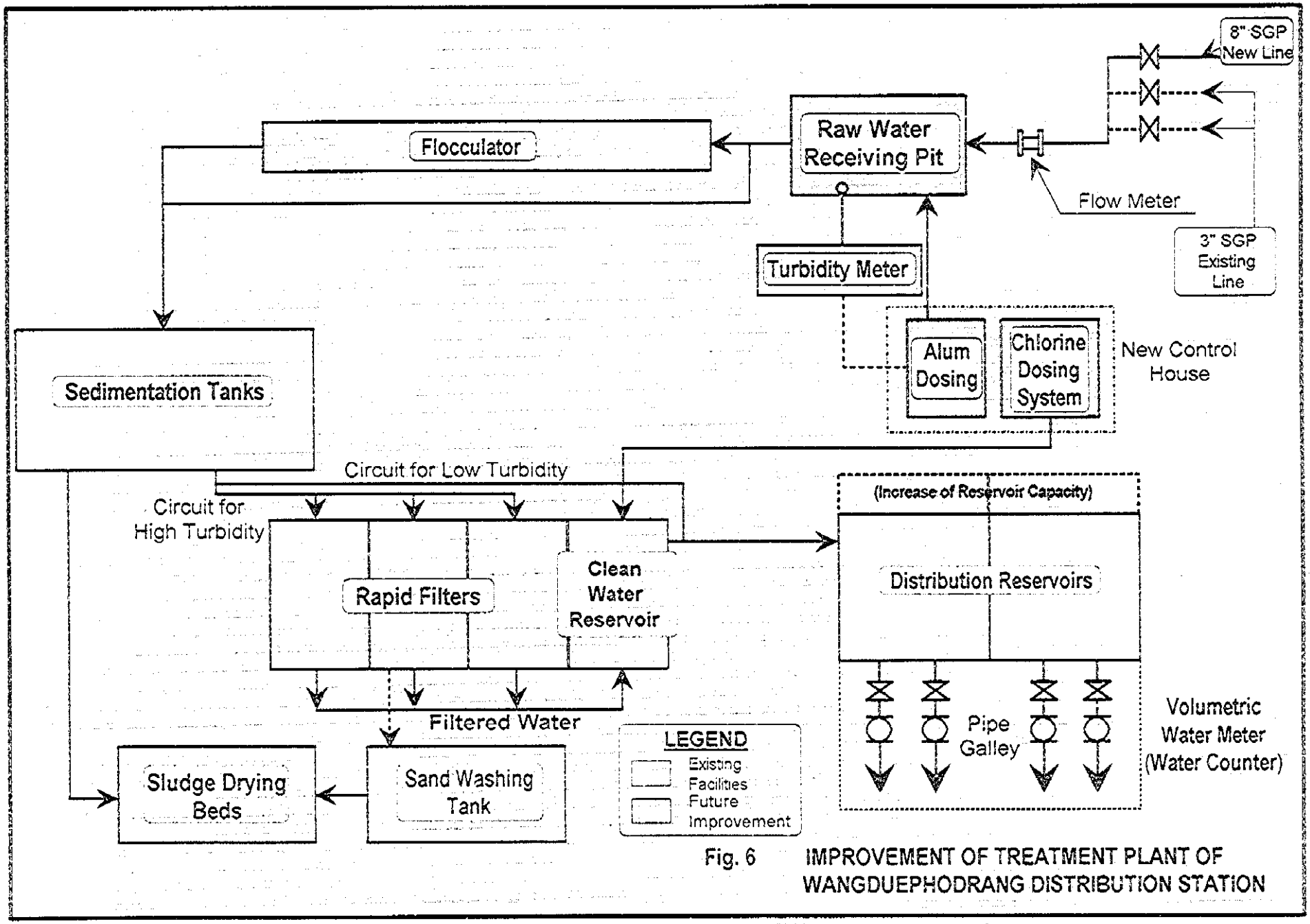
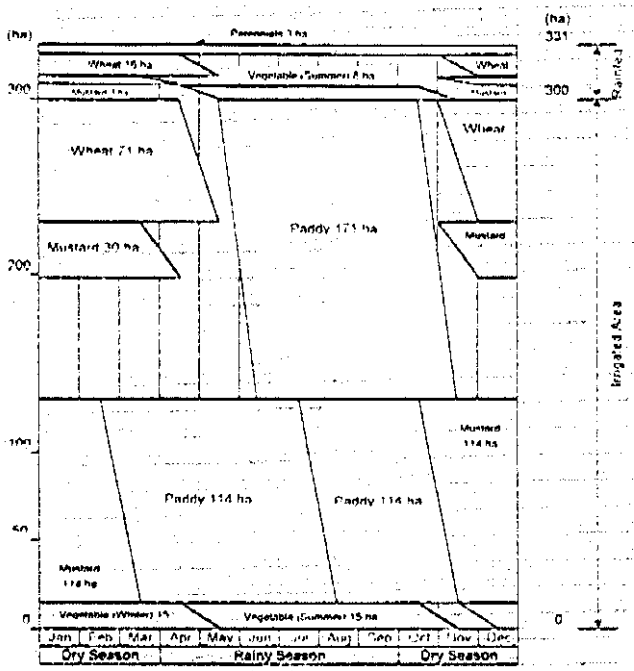
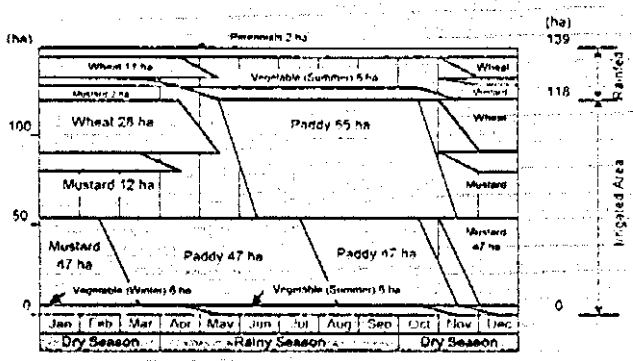


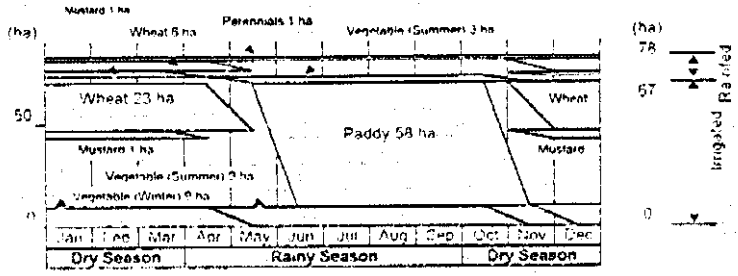
Fig. 6 IMPROVEMENT OF TREATMENT PLANT OF WANGDUEPHODRANG DISTRIBUTION STATION



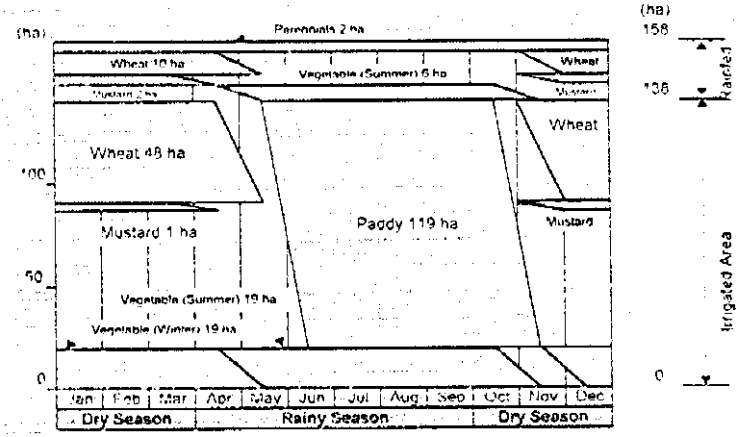
Lobeysa Sub-area (Applying 40% of Paddy Double Cropping)



Bajo Sub-Area (Applying 40% of Paddy Double Cropping)



Phangyul Sub-Area (Applying 10% of Diversification)



Rubeysa Sub-Area (Applying 10% of Diversification)

Fig. 7 PROPOSED CROPPING PATTERN FOR IRRIGATION IMPROVEMENT PLAN