DEPARTMENT OF AGRICULTURE
MINISTRY OF AGRICULTURE AND FORESTS
THE KINGDOM OF BHUTAN

DATA COLLECTION SURVEY ON IRRIGATION DEVELOPMENT IN THE KINGDOM OF BHUTAN

FINAL REPORT

MARCH 2017

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
SANYU CONSULTANTS INC.

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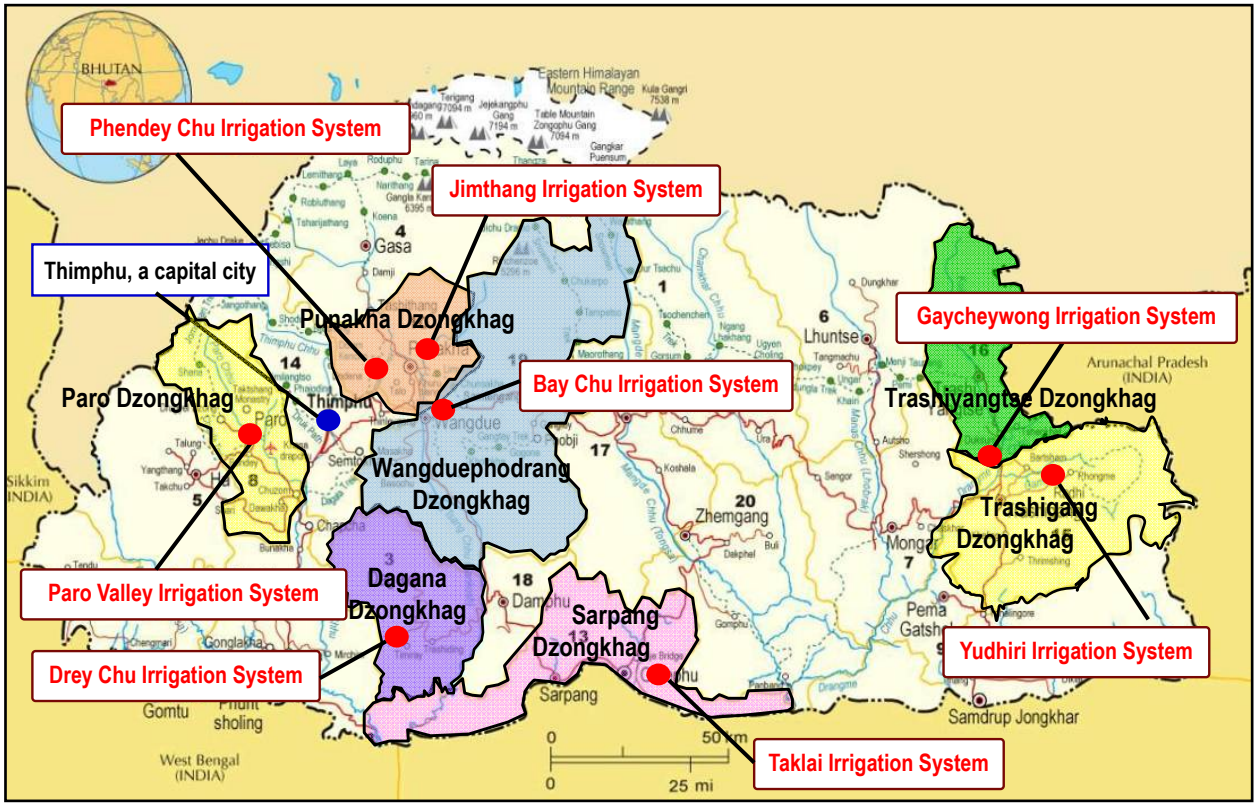
Location Map of the Survey Area



Taklai Irrigation System

Taklai Irrigation System is categorized into the Foot Hill Scheme. The command area is spread over a flat area near the border with India.

Yudhiri Irrigation System

Yudhiri Irrigation System is categorized into the Hilly Scheme. Farmers cultivate terraced paddy fields.

※In addition to the Taklai and Yudhiri Irrigation systems, six more irrigation systems were surveyed.

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Abbreviations

ADB	Asian Development Bank
AIDP	Agriculture Infrastructure Development Programme
ALOS	Advanced Land Observing Satellite
AMC	Agriculture Machinery Center
ARDC	Agriculture Research and Development Center
CMU	Central Machinery Unit
CST	College of Science and Technology
DAO	Dzongkhag Agriculture Office
DoA	Department of Agriculture
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GNH	Gross National Happiness
GNHC	Gross National Happiness Commission
IFAD	International Fund for Agricultural Development
IWMS	Integrated Water Management Section
IWRM	Integrated Water Resources Management
JAXA	Japan Aerospace Exploration Agency
JNEC	Jigme Namgyel Engineering College
MDGs	Millennium Development Goals
MoAF	Ministry of Agriculture and Forests
MoEA	Ministry of Economic Affairs
MoF	Ministry of Finance
MoLHR	Ministry of Labour and Human Resources
MoWHS	Ministry of Works and Human Settlement
NCHM	National Center for Hydrology and Meteorology
NEC	National Environment Commission
NFCCDP	National Field Crop Commodity Development Programme
NHCDP	National Horticulture Commodity Development Programme
NIIS	National Irrigation Information System
NIMP	National Irrigation Master Plan
NSB	National Statistics Bureau
OJT	On the Job Training
O&M	Operation and Maintenance
RIWaM	Regional Integrated Water Management
RNR	Renewable Natural Resource
RGoB	Royal Government of Bhutan
UNESCO	United Nations Educational, Scientific and Cultural Organization
WB	World Bank
WUA	Water Users Association
WUG	Water Users Group

Exchange Rate (JICA Exchange rate as of February 2017):

1 BTN = 1.691	JPY
1 USD = 115.144	JPY
1 USD = 68.097	BTN
1 BTN = 0.01469	USD

CHAPTER 1 BACKGROUND AND OBJECTIVES OF THE SURVEY

1.1 BACKGROUND OF THE SURVEY

Agriculture is the key industry of the Kingdom of Bhutan (hereinafter referred to as Bhutan), which occupied 16.67% of the Gross Domestic Product (GDP) in 2015[1] and employed 62.2% of Bhutan's working population in 2012[2]. However, self-sufficiency rate in rice was only 51.3% in 2011[3] because of low crop productivity and small and fragmented farmlands due to mountainous geography in most of the land in Bhutan. Although constant increase of farmers' income requires appropriate farming practices and increase of crop yield, a delay in irrigation development and abandoned farmland hampers stable or growing agriculture production.

The poverty ratio in Bhutan had decreased from 31.7% in 2003 to 12.0% in 2012. The GINI index, measuring inequality of the income distribution of the country's residents, had also decreased from 0.42 in 2003 to 0.36 in 2012. Meanwhile, about 95% of the poor live in rural areas and the poverty ratio in the eastern area remains high. In fact, 40.3% of the poor are from the six Dzongkhags of the eastern region (Lhuentse, Mongar, Pemagatshel, Samdrup Jongkhar, Trashigang and Trashiyangtse Dzongkhag) among all of the twenty Dzongkhags[4]. Thus, agriculture development should be addressed to alleviate such an inequality and poverty among the areas. The Eleventh Five Year Plan (2013 to 2018) aims to overcome the inequality and reduce Bhutan's poverty ratio to less than 5% by 2018.

Under these circumstances, the Royal Government of Bhutan (RGoB) put higher priority in irrigation development. The Eleventh Five Year Plan aims to increase rice production by 26%, which is from 78,730 MT/year in 2012 to 98,894 MT/year, and emphasizes the necessity of irrigation development for it. Furthermore, the National Irrigation Master Plan (NIMP), developed in 2016 under the support of the Asian Development Bank (ADB), is positioned as one of the reference documents for preparing the Twelfth Five Year Plan and annual budgets.

The RGoB requested the Government of Japan "The Project for the Improvement of Yudhiri Irrigation System in Radhi Gewog, Trashigang District" for the Japanese Grant Aid. This irrigation system[5] covers the largest command area and is the highest-priority candidate system among the 108 systems targeted within the period of the Eleventh Five Year Plan. It is expected that the improvement of Yudhiri Irrigation System shall contribute to an increase in food production and thus farm household incomes in the less developed eastern area. Additionally, during the needs assessment survey in 2016, RGoB requested the Government of Japan "Capacity Development Project for Irrigation Engineers in Bhutan" as a technical cooperation project to enhance technical skills and knowledge of the irrigation engineers on survey, planning, design and construction of irrigation facilities.

However, since it is located in a steep area of eastern Bhutan, design and construction of the facilities

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1 National Accounts Statistics 2016, National Statistics Bureau (NSB)

2 Labour Force Survey 2012, Ministry of Labour and Human Resources (MoLHR)

3 Renewal Natural Resource (RNR) Statistics 2012, Ministry of Agriculture and Forests (MoAF)

4 Poverty Analysis 2003 and 2012, NSB
Poverty Ratio: Lhuentse (31.9%), Mongar (10.5%), Pemagatshel (26.9%), Samdrup Jongkhar (21%), Trashigang (11.5%), Trashiyangtse (13.5%)
The proportion of the overall poverty rate in each Dzongkhag: Lhuentse (6.5%), Mongar (5.8%), Pemagatshel (8.6%), Samdrup Jongkhar (9.1%), Trashigang (7.2%), Trashiyangtse (3.1%)

5 In this survey, the word "irrigation system" comprehends irrigation facilities, command area,operation and maintenance of the facilities.

for Yudiri Irrigation System may be technically complicated and the project costs including Operation and Maintenance (O&M) cost would also be high. Therefore, validity of the cooperation to Yudhiri Irrigation System should be, first of all, examined through a detailed survey, including geological survey. Then, the entire cooperation programme to the irrigation subsector should be comprehensively evaluated, consisting of hard component cooperation, such as construction and/or rehabilitation of irrigation facilities, and also soft component cooperation, such as technical cooperation in O&M of the facilities and farming activities.

Although necessity of the cooperation to the irrigation subsector of Bhutan by the Government of Japan has been recognized, there remains the need to study appropriate directions of the cooperation on the entire irrigation subsector, prior to the formulation of individual projects. Therefore, JICA conducted this Data Collection Survey on Irrigation Development (hereinafter referred to as the Survey) to collect and analyze necessary information for the investigation, and then examine appropriate cooperation approach for the irrigation subsector of Bhutan.

1.2 OBJECTIVES OF THE SURVEY

The Survey aims to collect basic data and information on the irrigation development in Bhutan and examine directions of future cooperation to the irrigation subsector by the Government of Japan in collaboration with other related subsectors in the field of agriculture. More precisely, the Survey aims to make recommendations on cooperation programmes for the irrigation subsector. Particularly, it examines the feasibility of the improvement of Yudhiri Irrigation System, for which RGoB made a request for the Japanese Grant Aid.

1.3 TARGET AREAS OF THE SURVEY

While the target area of the Survey covers the entire Bhutan, field survey was implemented mainly in the east and west central areas because the southern part was already studied in the previous survey, "Data Collection Survey on Strategic Agricultural Water Supply and Management in Southern Bhutan (2012)". However, Taklai Irrigation System in the south was also surveyed on site as a case study of completed cooperation projects.

1.4 SURVEY TEAM AND SURVEY PERIOD

Team members of the Survey are shown in the tables below. In principle, the consultant team was responsible in main data and information collection. In addition, the JICA team was engaged in the field surveys at the launching and ending stage of the Survey so that they could discuss and made an agreement on a detailed approach for Yudhiri Irrigation System with the counterpart organization of Bhutan. The experts in "Geological Investigation" and "Intake Structures Investigation" were also engaged in the field survey at the launching stage, and made suggestions from their own expertise.

JICA Team

Title	Name	Period of Field Survey
Team Leader	Kazuo Shimazaki	First: Nov. 27 to Dec. 15, 2016 Second: Feb. 13 to 21, 2017
Geological Investigation	Takeshi Kusumoto	First: Nov. 27 to Dec. 10, 2016
Intake Structures Investigation	Michihiko Kojima	First: Nov. 27 to Dec. 10, 2016
Cooperation Planning	Mahomi Masuoka	First: Nov. 27 to Dec. 15, 2016 Second: Feb. 13 to 21, 2017

Consultant Team

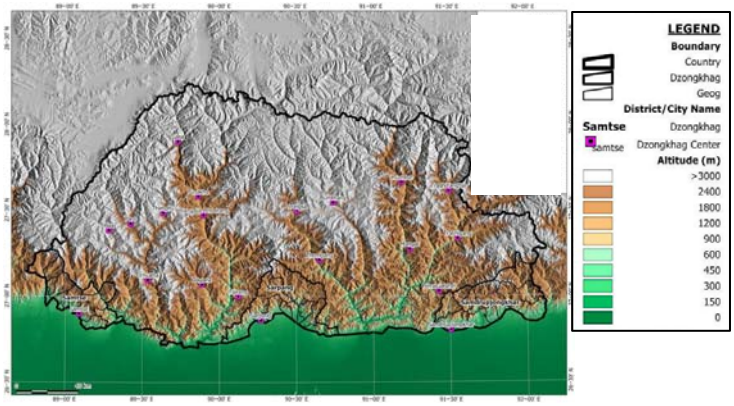
Title	Name	Period of Field Survey
Chief Consultant/ Irrigation Policy/Irrigation Planning	Toru Nakagawa	First: Nov. 27 to Dec. 30, 2016 Second: Jan. 10 to Feb. 25, 2017
Irrigation Planning (2)	Motoyoshi Hikasa	First: Jan. 15 to 24, 2017 Second: Feb. 12 to Feb. 25, 2017
Irrigation Farming/Water Users Association/ Operation and Maintenance	Shohei Natsuda	First: Nov. 27 to Dec. 30, 2016 Second: Jan. 10 to Feb. 25, 2017
Geological Analysis	Ryoichi Kawasaki	First: Nov. 27 to Dec. 30, 2016
Coordinator/Irrigation Farming (2)	Miho Hanamura	First: Nov. 27 to Dec. 30, 2016 Second: Jan. 10 to Feb. 25, 2017

CHAPTER 2 OUTLINE OF BHUTAN

2.1 NATURAL CONDITIONS

(1) Topographical Condition

Bhutan's land area is 38,394 km^2 almost the same as Kyushu, an island in the southern region of Japan[6]. The mountainous and hilly areas of over 2,000 m above sea level account for 85% of the land area in Bhutan. Whereas distance from the south to the north of the country is only 170 km, elevation ranges from 100 m in the south to 7,561 m in the north (Gangkhar Puensum, the highest mountain in Bhutan) (Figure 2.1.1). Accrodingly, slopes of the mountains and gradient of the river beds in Bhutan are very steep.

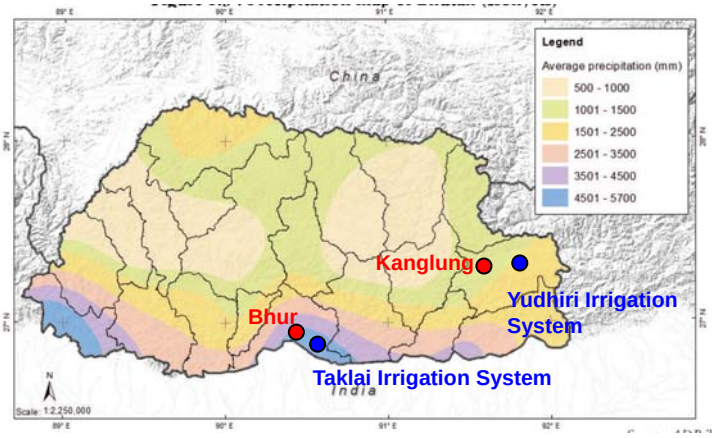


Source: The Survey Team (based upon data from SRTM 90m DEM)

Figure 2.1.1 Altitude Distributions in Bhutan

(2) Meteorological and Hydrological Condition

Depending on altitude zones, Bhutan is covered by several climatic zones such as Subtropical in the south, Warm Temperate in the central and Alpine (the tundra) in the north. The average annual precipitation also varies from 5,000 mm in the south to below 500 mm in the north, depending on the areas. Most of precipitation is recorded in the rainy season from June to September (Figure 2.1.2).



Source: NIMP, MoAF

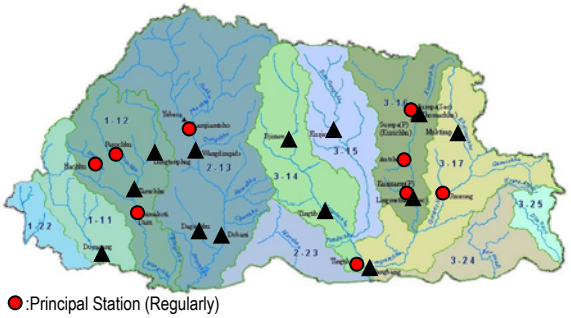
Figure 2.1.2 Annual Average Precipitation

Although Bhutan has such diverse natural conditions, the meteorological/hydrological observation data are limited. There are only twenty meteorological stations in Bhutan, located in the center of Dzongkhags and transport hubs in urban areas (Figure 2.1.3). Besides, river discharge is mainly measured for planning of hydropower projects and therefore the stations are only found at main rivers. Only nine stations regularly measure the discharge (Figure 2.1.4).

Source: The Survey Team (based upon data from National Center for Hydrology and Meteorology (NCHM))

Figure 2.1.3 Location of Meteorological Stations

Additionally, only daily data are available at the meteorological and the river discharge stations.



●:Principal Station (Regularly)
▲:Secondary Station (Temporary)

Source: Surface Hydrological data of Bhutan 2009, Department of Energy, Ministry of Economic Affairs (MoEA))

Figure 2.1.4 Location of River Discharge Stations

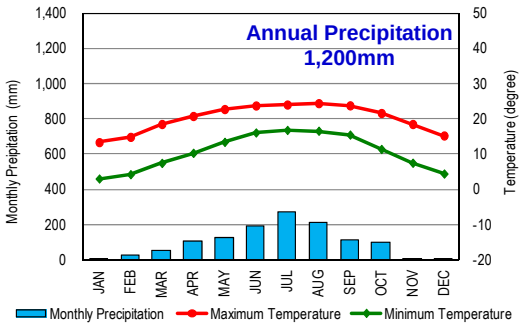
[6] Bhutan Land Cover Assessment 2010, MoAF

Consequently, sudden changes (torrential downpour, rapid water discharge, etc.) cannot be recognized from the data.

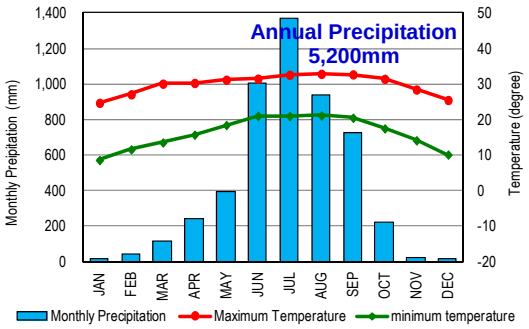
Figure 2.1.5 shows monthly precipitation and temperature in Kanglung near Yudhiri Irrigation System, and in Bhur near Taklai Irrigation System. Although Kanglung and Bhur are the nearest meteorological stations to each of the irrigation systems, they are 22 km and 18 km away from the beneficiary areas, respectively.

(3) Geological Condition

The national land of Bhutan is located near around the plate boundary between India Semi-Continental and Eurasian Continental Plates, thus the upheaval of the land is quite active. Due to such active upheaval, there exist many faults, and the major fault lines divide the country into three main geological zones (Table 2.1.1 and Figure 2.1.6). It is clear from the table and figure below that almost all parts of the country are occupied by fragile geological zones.



Kanglung (nearest to Yudhiri Irrigation System)



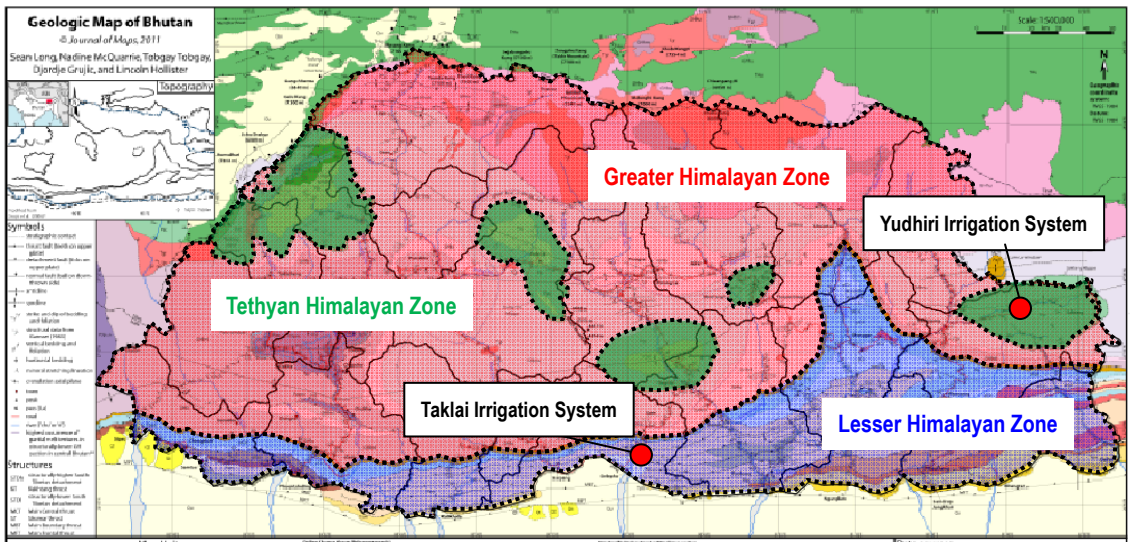
Bhur (nearest to Taklai Irrigation System)

Source: The Survey Team (based upon data from NCHM)

Figure 2.1.5 Monthly Precipitation and Temperature

Table 2.1.1 Outline of Bhutan Geology

Geological Zone	Description
Tethyan Himalayan Zone (Green)	Distributing from the west to east like five islands. Originally, marine deposits but lifted by upheaval activity, undergone by heavy heat and pressure. The rock type is mainly an alternation of Sandstone and Mudstone, and the portion of Mudstone is heavily metamorphosed. Such metamorphosed rock is easily eroded.
Greater Himalayan Zone (Red)	Occupying most of the land area of the country. Rock type is mainly massive and hard Cristaline Schist. However, it includes many faults caused by the upheaval activities, and portion along the faults are crashed and quite fragile.
Lesser Himalayan Zone (Blue)	Distributing in the southern end of the country. Rocks are mainly sedimentary rocks and metamorphic rocks. The zone is located near the major boundary of Indian and Eurasian Plates, and therefore, many huge faults exist. Rocks near the faults are crashed to sand or sand gravel, and easily eroded.



Source: The Survey Team (based upon Geological map of Bhutan, Long, S, 2011)

Figure 2.1.6 Main Geological Zones

From conditions (1) to (3) above and due to the steep mountain slope and river bed, as well as the fragile geological conditions, huge volume of rocks/stones/sands are produced by rainfall. The peak flows during floods, usually heavy and containing rocks/stones/sands, looks like an avalanche, causing depression of the river bed and/or bank erosion.

(4) Soil Condition

The Food and Agriculture Organization (FAO) in cooperation with the United Nations Educational, Scientific and Cultural Organization (UNESCO) created soil maps of the South Asia region[7]. However, a more accurate soil map of Bhutan is being created by the National Soil Services Center, the Department of Agriculture (DoA), MoAF[8].

2.2 SOCIOECONOMIC CONDITIONS

(1) Ethnic Groups

Bhutanese people can be generally categorized into the following groups: the Ngalops (Tibetan origin), the Sharchops (aboriginal inhabitants of the eastern region of Bhutan), the Lhotshampas (Nepal origin), and other minority groups are refugees from Tibet, indigenous peoples of Sikkim, etc[9]. While the Ngalops have settled mostly in the western region of Bhutan such as Thimphu and Paro Dzongkhag, the Sharchops are commonly inhabitants of the eastern region of Bhutan such as Trashigang and Trashiyangtse Dzongkhag. The Lhotshampas have settled in the southern foothills of Bhutan near the border with India[10].

Such differences in the ethnicity lead diversified religions, cultures, languages and livelihoods of people. As for religions, the Ngalops mainly believe in the Drukpa Kagyu sect of Buddhism, the state religion; the Sharchops believe in the Nyingmapa (the ancient or the older) school of Buddhism; and many of the Lhotshampas practice Hinduism. Regarding languages, while the national language is Dzongkha[11], one of the native languages of the southern region of Tibet, and spoken in the whole of Bhutan, English is also recognized as the official language. The Sharchops speak Tshanglakha, while Nepali is the native language of the Lhotshampas. In addition to many other dialects spoken depending on the area, many people speak Hindi because of the past education policy taught in Hindi and the dispatch of government-sponsored students to India.

(2) Politics

Although an absolute monarchy had continued after Bhutan's first hereditary King, the House of Wangchuck established in 1907, the Fourth King crowned in 1972 had let transition from an absolute monarchy to a constitutional one. After the current Fifth King was crowned, a new democratic form of parliament was established in April 2008 through general elections of the National Council (the upper house) in December 2007 and the National Assembly (the lower house) in 2008. In the same year, since the first joint sitting of parliament was held and a new constitution was enacted, Bhutan shifted from absolute monarchy to constitutional monarchy based on parliamentary democracy.

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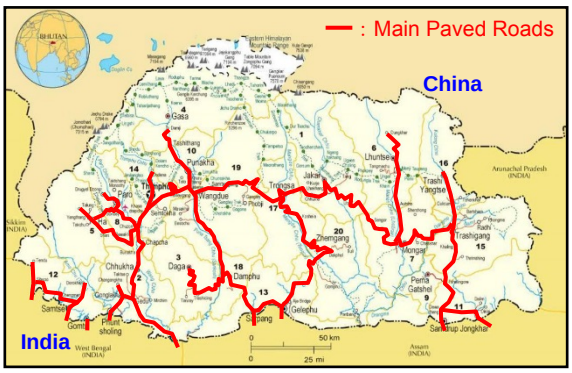
[7] FAO-UNESCO Soil map of the world 1:5,000,000 Volume VII South Asia, 1977
[8] The Status of National Soil Resource of Bhutan, National Soil Service Center, DoA, MoAF,2015
[9] 60 chapters to know contemporary Bhutan (published in Japanese), Shuichi Hirayama, 2005
[10] Formulation of the Bhutan in contemporary period, self-portrait politics from the view point of culture and environmental policy (published in Japanese), pp. 77-100, No. 94, Cultural Sciences Bulletin, Institute for Research in Humanities, Kyoto University, Mari Miyamoto, 2007
[11] Dzongkhag consists of "Dzong (castle)" and "kha (word) and includes the meaning of "word."

(3) Foreign Policy

After the Treaty of Friendship signed by Bhutan and India in 1949, India had remained influential over Bhutan's foreign policy until this treaty was amended in 2007. Besides, Indian Army has been operating on the border between Bhutan and China. Thus, Bhutan is important as a part of India's strategic defence plan to China. Additionally, all the main roads in Bhutan lead to India (Figure 2.2.1) so that India can be the largest trading partner for Bhutan. Thus, the bilateral relations between Bhutan and India have been politically, militarily, and economically close.

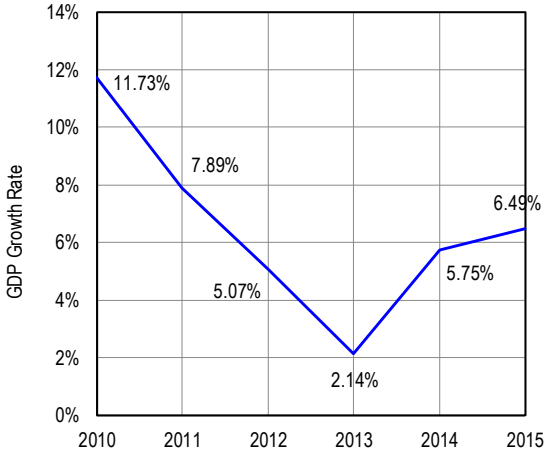


Source: The Survey Team

Figure 2.2.1 Main Paved Roads

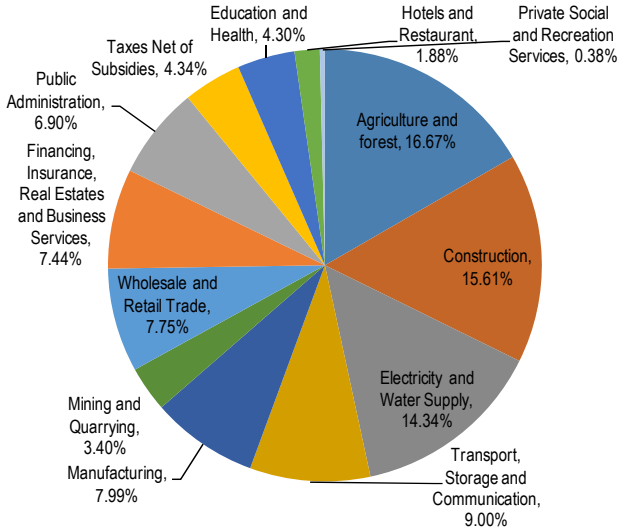
(4) Economic Trends

The Five Year Plan, the national plan of Bhutan, was initiated by the Third King in 1961, with which Bhutan has promoted modernization along with the long-term development of infrastructure. The country has transformed its economy from self-sufficient into market-oriented one. GDP growth rates in recent years were 11.73% in 2010, 7.89% in 2011, 5.07% in 2012, 2.14% in 2013, 5.75% in 2014 and 6.49% in 2015 (Figure 2.2.2). While GDP in 2015 was 2,058 billion USD, GDP per capita was 2,719.11 USD. GDP composition by sector in 2015 was: agriculture and forest; 16.67%, construction; 15.61%, electricity and water supply; 14.34%, transport, storage and communication; 9.00% and manufacturing; 7.99% (Figure 2.2.3). Regarding infraction rate, while Implicit Deflator was 3.70%, Consumer Price Index was 4.58%[12].



Source: The Survey Team (based upon data from National Accounts Statistics 2016, NSB)

Figure 2.2.2 GDP Growth Rate



Source: The Survey Team (based upon data from National Accounts Statistics 2016,NSB)

Figure 2.2.3 GDP Composition by Sector (2015)

As regards to trade, the exports in 2015 were 517 million USD and the imports were 999 million USD, generating a trade deficit of 482 million USD (Table 2.2.1). The main export partners were India,

[12] Bhutan Trade Statistics 2015, Ministry of Finance (MoF)

Bangladesh, Netherlands, USA and Germany in order of the exports, while the main import partners were India, France, Japan, Singapore, and China. The country's export is reliant on electricity, alloy, ironware, cement and cardamom, and it mainly imports diesel, aero-planes, hydraulic turbines, metal products, towers and lattice masts, petrol, wood charcoal and rice[13].

Table 2.2.1 Balance of Trade in Bhutan

	2011	2012	2013	2014	2015
(1) Export (million USD)	462	417	468	523	517
(2) Import (million USD)	715	780	782	835	999
(3) Balance (=(1)-(2)) (million USD)	-253	-363	-314	-312	-482

Source: The Survey Team (based upon data from Bhutan Trade Statistics 2015, MoF)

Since Bhutan depends largely on commodities and capital goods imported from India and other countries, balance of the trade has always been deficit. In January 2012, the parliament discussed an issue on deficits of Bhutan's foreign reserves in Indian Rupee and established a task force to work out a policy for the issue under the initiative of the Finance Minister. Whereas India accounts for a large share of Bhutan's trade, abundant tourist resources in Bhutan can be alternative source of the foreign reserves in other currency rather than Indian Rupee. Development tourism is becoming a key strategy.

(5) Unemployment Rate

The unemployment rate in the whole Bhutan was 2.1% in 2012, while in urban areas remained around 3.5% because of increased number of young people looking for working opportunities. The unemployment rate in rural areas was 1.5%. The unemployment rate of people between the ages of 15 to 24 was particularly high, at 7.3%[14].

(6) Education

The literacy rate in Bhutan was 63.0% in 2012. While that in urban areas was 79.2% and in rural areas was 55.9%. Women's literacy rate was 54.7%, while men's rate was 71.6%. Total enrolment in primary education was 116.3% in 2012 due to grade retention[15].

(7) Poverty

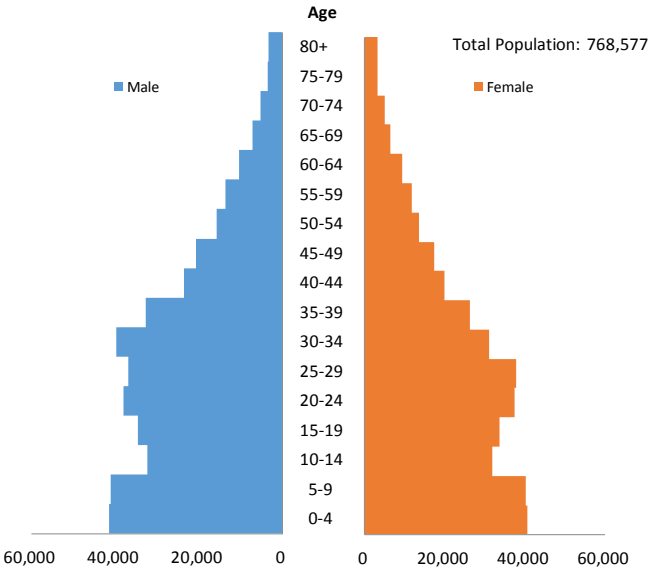
The poverty ratio in Bhutan had decreased from 31.7% in 2003 to 12.0% in 2012; with the target of the Tenth Five Year Plan (2008 to 2013) at 15% was achieved. The GINI index had decreased from 0.42 in 2003 to 0.36 in 2012. Thus, social inequality in Bhutan seemed to be alleviated. However, whereas poverty reduction and social equality have been achieved in whole of Bhutan, the poverty ratio remains high in rural areas at 16.7% in 2007[16]. Accordingly, the Eleventh Five Year Plan (2013 to 2018) aims that regional social inequality is to be improved and the poverty ratio in the whole of Bhutan is to be reduced to less than 5% by 2018.

(8) Demography

The total population of Bhutan was 672,425 in 2005. Since 37,443 was floating population, the number of actual residents was 634,982. Male accounted for 52.5%, while female for 47.5%. The urban population shared 30.9% as compared to the rural population, 69.1%. Average population density was about 17 per km^2 derived from the total land area of 38,294 km^2 and the actual residents

[13] World Integrated Trade Solution, World Bank (WB)
[14] Labour Force Survey 2012, MoLHR
[15] Bhutan Living Standards Survey 2012, NSB
[16] Poverty Analysis 2012, NSB

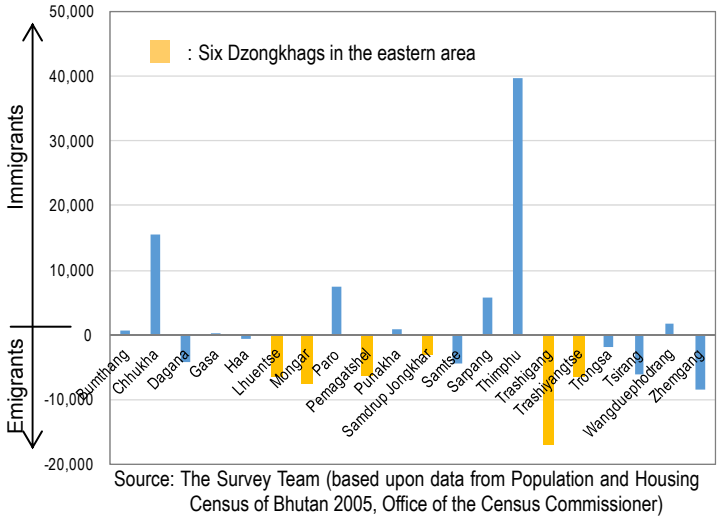
of 634,982. Population density in Thimphu, 54 per km^2, was the highest in Bhutan, to which population was 98,786[17]. Although statistics of population in 2016 is not available, the total population is estimated to be 768,577. The population aged 30 years old or younger is estimated to be about a half and that aged 65 years old or older is about 5% (Figure 2.2.4). The population growth rate was 1.3% and the Crude Death Rate (CDR) was 7.1 out of 1,000 in 2005[18].



Source: The Survey Team (based upon data from Statistic Year Book 2016, NSB)

Figure 2.2.4 Population Composition by Ages

Figure 2.2.5 indicates demographic movement in 2005 (number of immigrants/emigrants was calculated based on the number of people whose birthplace and settlement is different). It is found that all the six Dzongkhags in the eastern area sent emigrants. Emigrant population from the six Dzongkhags was 45,694 and accounted for 64% of Bhutan's total number of emigrants, which were 71,706. Additionally, emigrant population from Trashigang Dzongkhag was remarkable, which was 16,697. Meanwhile, Thimphu Dzongkhag where the capital is located had accepted the largest immigrants of 39,770. This tendency reflects concentration of the population in the cities of Bhutan.



Source: The Survey Team (based upon data from Population and Housing Census of Bhutan 2005, Office of the Census Commissioner)

Figure 2.2.5 Demographic Movement in 2005

(9) Transportation

Bhutan is a landlocked country located at the east end of Himalaya and most of the lands are in steep mountainous areas. The road traffic is the major transportation in Bhutan and thus the establishment of effective and safety roads and bridges is essential for social development. Strategic infrastructure development is one of the strategic thrust areas of the Eleventh Five Year Plan (2013 to 2018). The plan is to develop transport infrastructure, including construction and improvement of national highways and expansion and pavement of roads have been in progress according to the Plan.

(10) Other Infrastructure

Access to electricity (% of population) had reached 99% in 2015 and water supply (% of population with access) had achieved 100% in 2014[19].

[17] Population and Housing Census of Bhutan 2005, Office of the Census Commissioner
[18] Statistical Yearbook of Bhutan 2016, NSB
[19] WB Open Data

2.3 AGRICULTURE CONDITIONS

(1) Land Use

As Table 2.3.1 shows, forest covers 70.46%, while shrubs and meadows covers 14.53%, snow cover and water bodies 8.17%, built up areas 0.17% and cultivated agricultural land 2.93% the land area of Bhutan.

Table 2.3.1 Land Use and Land Cover in Bhutan

Land Use and Land Cover	Area (km²)	%
Forest	27,052.91	70.46%
Shrubs and Meadows	5,580.95	14.53%
Cultivated Agricultural Land	1,125.55	2.93%
Snow cover and water bodies	3,133.67	8.17%
Built up areas	64.81	0.17%
Bare areas	1,229.74	3.20%
Degraded areas	206.36	0.54%
Total	38,394	100.00%

Source: Bhutan Land Cover Assessment 2010, MoAF

(2) Situation of Cultivation

As aforementioned in "2.1 NATURAL CONDITIONS", 85% of the land in Bhutan is covered by mountainous and hilly areas, and the slope gradient is very steep. Flat lands are only found on terraces along the rivers and alluvial fan in the southern region, which are mainly used for agriculture. Meanwhile, farmers in mountainous and hilly areas practice crop production on the lands where slope gradient is relatively moderate. Those gradual slope lands are often formed on landslide-prone areas. Landslides are mainly caused by instabilities of soils attributed to increase of uplift force with rising ground water level. Therefore, ground water and spring water generated from groundwater is often available on former landslide-prone areas. Thus, farmers generally cultivate rice at terraced paddy fields on such alluvial fans, river terraces and landslide-prone areas. On the other hand, in steep slope area or moderate slope area where water is not sufficient, people use these areas as slope farmlands, cultivating mainly maize and vegetables.

Terraced Paddy Field (Chhuzhing)

Slope Farmland (Kamzhing)

Source: The Survey Team

Figure 2.3.1 Situation of Cultivated Land

Cultivated land in Bhutan is categorized into wet land, dry land and orchard. Regardless of the availability of irrigation facilities, wet land is defined as terraced paddy fields. Dry land, on the other hand, is defined as cultivated lands without irrigation facilities, meaning rain-fed farming. Orchard is defined as a fruit farm[20]. Table 2.3.2 summarizes the status of land use by Dzongkhag. Total cultivated areas in Bhutan is around 113,000 ha and wet land accounts for around 32,000 ha (approx. 28%), dry land around 68,000 ha (approx. 61%) and orchard around 12,000 ha (approx. 11%).

[20] RNR Census 2009, MoAF

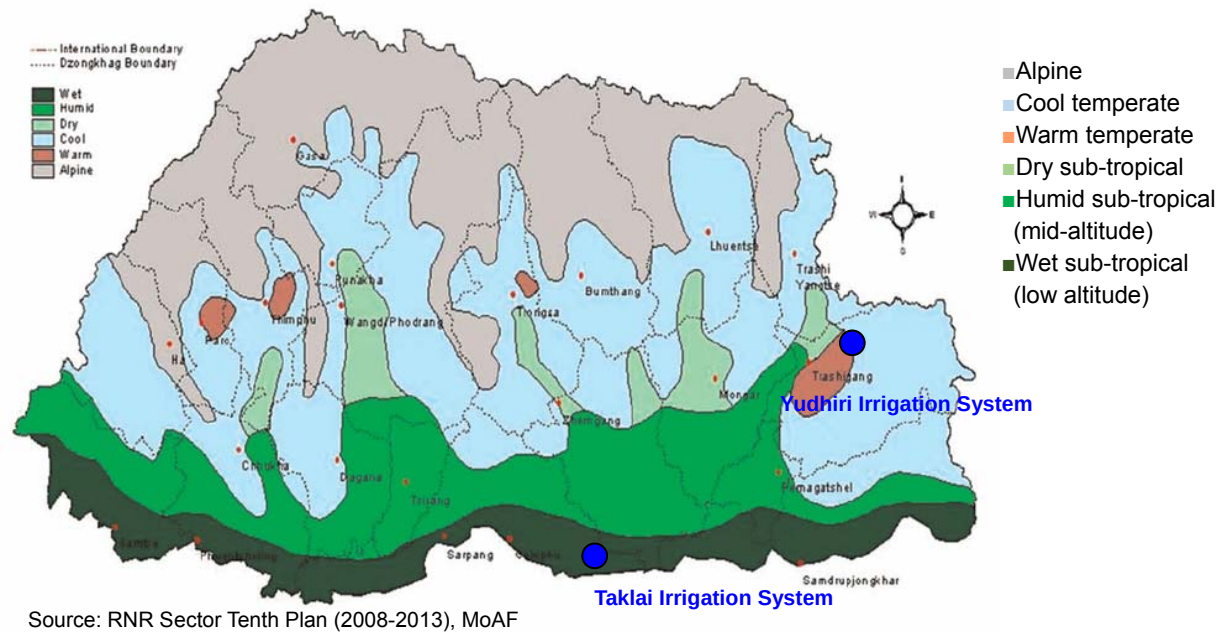
Table 2.3.2 Status of Land Use by Dzongkhag

Dzongkhag	Wet Land (ha)	Dry Land (ha)	Orchard (ha)	Total (ha)
Bumthang	24.7	2,883.8	11.5	2,920.0
Chhukha	1,779.2	5,119.2	2,322.7	9,221.1
Dagana	1,492.8	4,588.4	1,455.5	7,536.7
Gasa	143.6	386.3	0.0	529.9
Haa	88.5	2,067.8	624.6	2,780.9
Lhuentse	1,575.6	4,328.7	0.9	5,905.2
Mongar	431.7	5,304.4	3.2	5,739.3
Paro	1,753.0	3,561.6	1,025.6	6,340.2
Pemagatshel	302.3	4,333.4	620.4	5,256.1
Punakha	5,074.3	262.0	16.7	5,353.0
Samdrup Jongkhar	1,147.7	6,732.4	249.2	8,129.3
Samtse	5,682.4	8,150.5	3,533.4	17,366.3
Sarpang	2,087.6	3,472.7	1,092.5	6,652.8
Thimphu	458.3	913.6	902.1	2,274.0
Trashigang	1,448.5	4,974.4	0.0	6,422.9
Trashiyangtse	949.3	2,110.6	0.0	3,059.9
Trongsa	1,082.3	1,204.9	0.0	2,287.2
Tsirang	1,527.1	2,867.4	314.4	4,708.9
Wangdue Phodrang	4,202.3	1,742.0	0.1	5,944.4
Zhemgang	639.6	3,250.7	211.2	4,101.5
Total	31,910.8	68,254.8	12,384.0	112,549.6[21]

Source: Statistical Yearbook of Bhutan 2016, NSB

(3) Cropping Pattern

Bhutan's national land is classified into six agro-ecological zones: Alpine, Cool temperate, Warm temperate, Dry sub-tropical, Humid sub-tropical (mid-altitude) and Wet sub-tropical (Low-altitude) (Figure 2.3.2). Five zones are arable except for Alpine.



Source: RNR Sector Tenth Plan (2008-2013), MoAF

Figure 2.3.2 Agro-Ecological Zones

[21] Since data is aggregated by Dzongkhag and the figures are rounded, there are small differences between the total area in Table 2.3.1 and that in Table 2.3.2.

Cropping patterns which combine representative crops and their cropping intensity are proposed for the respective arable five agro-ecological zones (Figure 2.3.3). Paddy-fallow is mainly proposed in zones with altitude below 2,600 m, while vegetables, chilli, maize and paddy (double cropping) are preferable as altitude decreases[22].

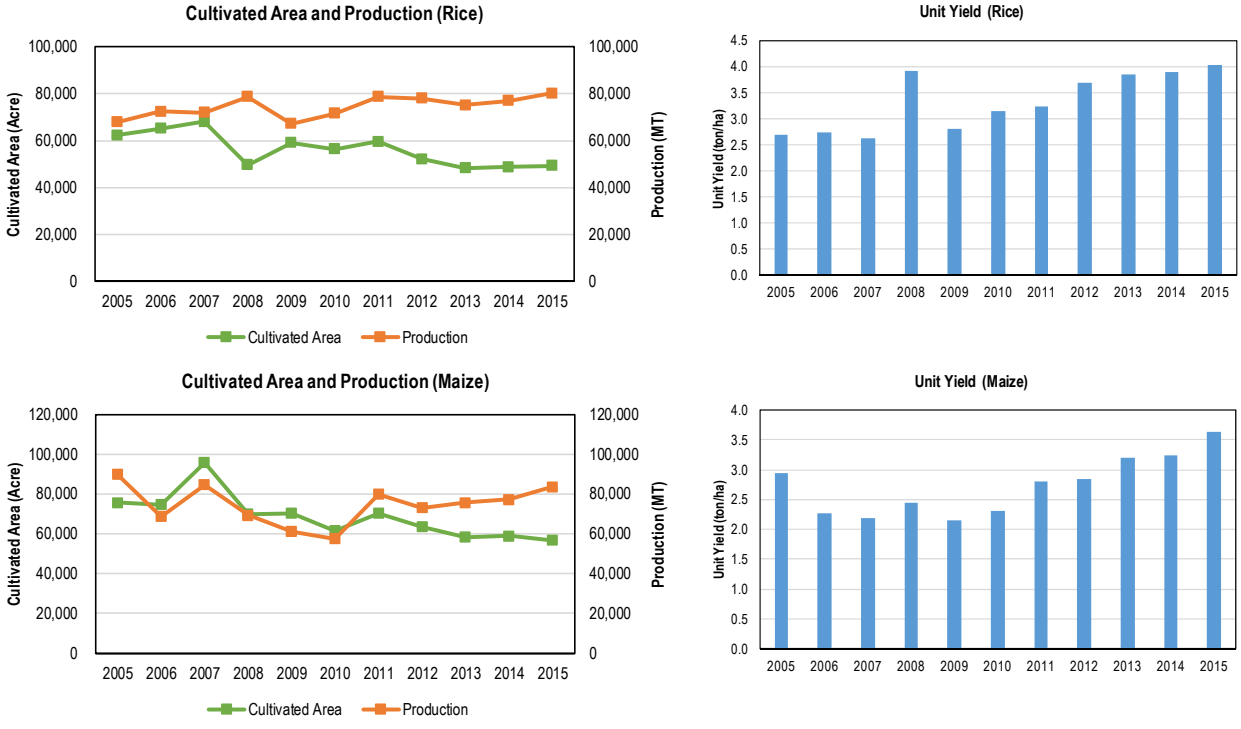
Agro-Ecological Zone	Altitude (m)	Cultivated Area (%)	Proposed area Cultivated %)												
			Spring maize-paddy	Paddy-vegetable, chili	Paddy-winter potato	Orchard	Paddy-fallow	Paddy-wheat	Paddy-oil seed, legumes, pulses	Paddy-paddy	Potato-fallow	Maize-fallow	Wheat-fallow	Buckwheat-fallow	Summer potato-off season vegetable
Cool temperature	2600-3600	8								15	5	15	15		
Warm temperature	1800-2600	20				15	40	15	15						15
Dry sub-tropical	1200-1800	33		10	15	10	40	15	10						
Humid sub-tropical (mid-altitude)	600-1200	22	25	10	15	10	20	10	10						
Wet sub-tropical (low altitude)	100-600	17	25	10	15	10	10	10	10						

Source: The Survey Team (based upon data from NIMP)

Figure 2.3.3 Proposed Cropping Intensity by the Respective Agro-Ecological Zones

(4) Crop Production

Figure 2.3.4 shows annual changes of cultivated area, production and unit yield of rice (paddy - unless specified, production data of rice is based on paddy in this report) and maize, which are main cereals in Bhutan.



Source: The Survey Team (based upon data from RNR Statistics 2012, Agriculture Statistics 2012, 2013, 2014 and 2015, MoAF)

Figure 2.3.4 Annual Changes of Rice and Maize Cultivated Area, Production and Unit Yield

[22] Although Figure 2.3.2 defines Yudhiri Irrigation Systems as cold temperature to warm temperature, actual cropping pattern is likely to be the one for warm temperature shown in Figure 2.3.3.

Trends of each cereal can be summarized as below.

Rice: The cultivated area of rice had decreased from 62,363 acre in 2005 to 49,325 acre in 2015. Despite the decrease of the cultivated area, the production had been levelled off between 70,000 MT/year to 80,000 MT/year. It mainly attributed to the unit yield which had increased from 2.7 MT/ha in 2005 to 4.0 MT/ha in 2015.

Maize: The cultivated area of maize had decreased from 75,805 acre in 2005 to 56,805 in 2015. Although the unit yield rose from 2.9 MT/ha in 2005 to 3.6 MT/ha in 2015, the production had decreased from 89,959 MT/year in 2005 to 83,714 MT/year in 2015 due to the decreased cultivated area.

Table 2.3.3 shows cultivated areas, production and unit yield of main crops in 2015. Rice and maize accounted for 87% of the total harvested area and 94% of the total cereal production in Bhutan.

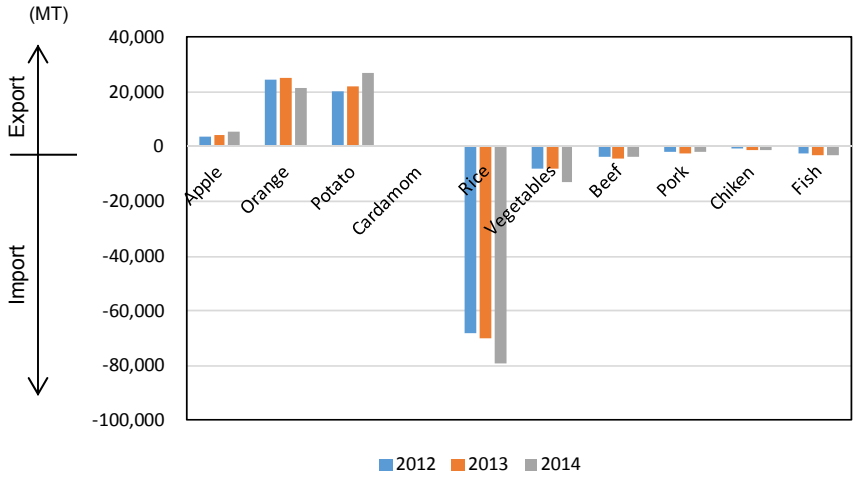
Table 2.3.3 Cultivated area, Production and Unit Yield of Main Cereals (2015)

Crop Name	Cultivated Area (acres)	%	Production (MT)	%
Paddy	49,325	40.4%	80,261	46.0%
Maize	56,805	46.6%	83,714	48.0%
Wheat	4,845	4.0%	3,730	2.1%
Barley	2,520	2.1%	1,800	1.0%
Buckwheat	5,147	4.2%	3,234	1.9%
Millet	3,360	2.8%	1,811	1.0%
Cereal Total	122,002	100.0%	174,550	100.0%

Source: Agriculture Statistics 2015, MoAF

(5) Trade of Agricultural Commodity

Figure 2.3.5 shows annual change of main commodity trade in Bhutan: import of rice, which is a staple food in Bhutan, had rose sharply.



Source: The Survey Team (based upon data from RNR Statistics 2015, MoAF)

Figure 2.3.5 Annual Change of Main Commodity Trade

CHAPTER 3 LEGAL FRAMEWORKS, NATIONAL POLICY AND DEVELOPMENT PLAN IN AGRICULTURE SECTOR AND IRRIGATION SUBSECTOR

3.1 LEGAL FRAMEWORKS, NATIONAL POLICY AND DEVELOPMENT PLAN IN AGRICULTURE SECTOR AND IRRIGATION SUBSECTOR AND THEIR LINKAGE

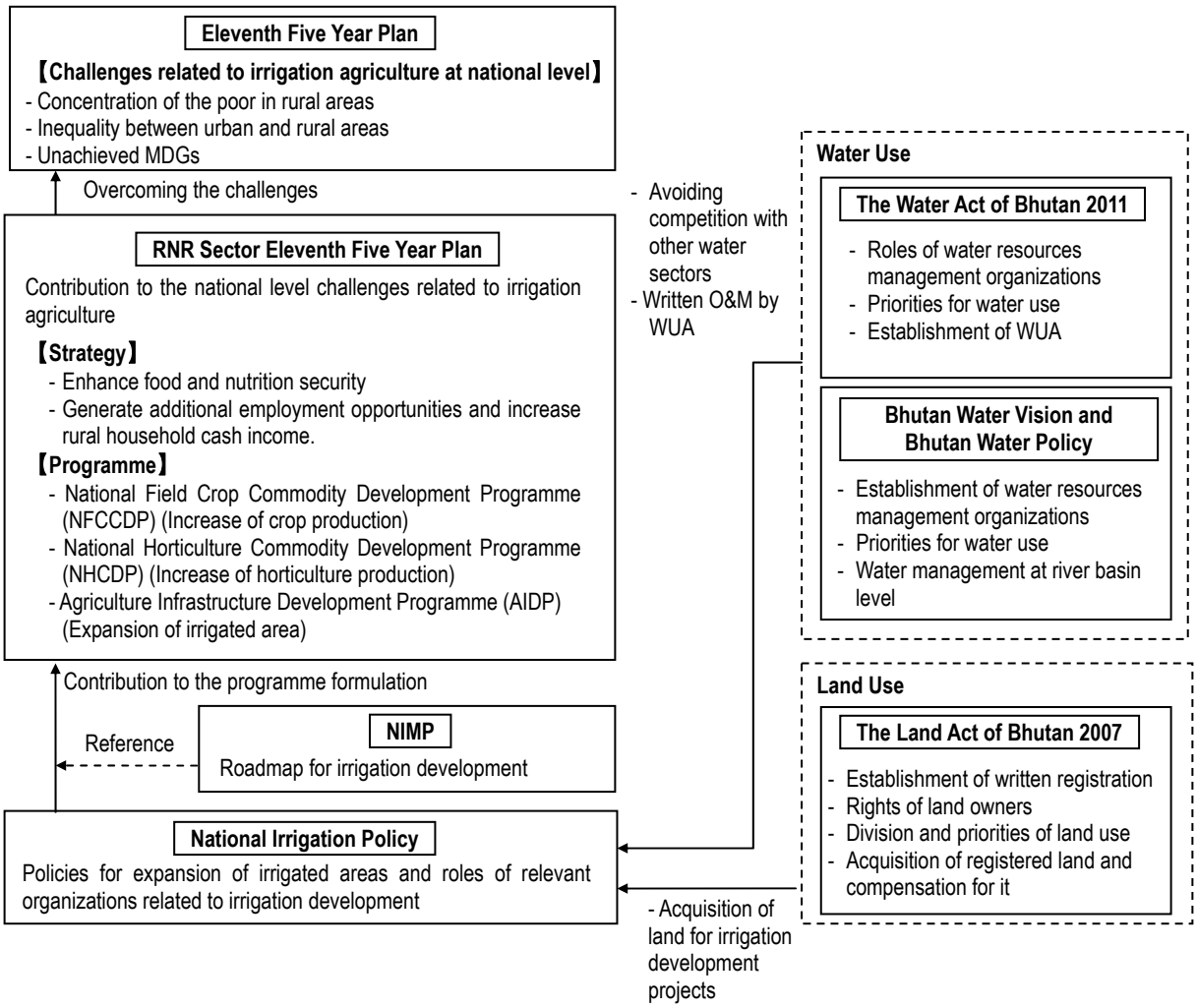
Main legislations, policies, and development plans in Bhutan's agriculture sector and irrigation subsector are summarized in Table 3.1.1 with the following categories: 1) the Five Year Plan identifying the national level challenges; 2) the Five Year Plan in the agriculture sector to overcome the national level challenges; 3) a policy and a master plan related to irrigation development; and 4) legislations and a policy related to water and land use. Figure 3.1.1 illustrates their relations with each other.

Table 3.1.1 Legislation, Policies, Development Plans in the Agriculture and Irrigation Sector

Category		Name	Outline
National Development Plan		Five Year Plan	Target 5-year's challenges and key issues at the national level (the current eleventh plan)
Agriculture Sector	Development Plan	RNR[23] Sector Five Year Plan, MoAF	Strategies and programmes in the agriculture sector to overcome challenges identified on the Five Year Plan
Irrigation Subsector	Policy	National Irrigation Policy (2012)	Policies for expansion of irrigated areas and roles of relevant organizations related to irrigation development
	Master Plan	NIMP (2016)	Road map for irrigation development
Water Use	Legislation	The Water Act of Bhutan 2011	Roles of water resources management organizations, priorities for water use and establishment of Water Users Association (WUA)
	Policy	Bhutan Water Vision and Bhutan Water Policy (2003)	Establishment of water resources management organizations, priorities for water use and water management at river basin level
Land Use	Legislation	The Land Act of Bhutan 2007	Establishment of written registration, rights of land owners, categorization and priorities of land use, acquisition of registered land and compensation for it

Source: The Survey Team

[23] Since RNR sector includes agriculture, livestock and forest, the RNR Sector Five Year Plan corresponds to the Five Year Plan of MoAF.



Source: The Survey Team

Figure 3.1.1 Linkage of Legal Frameworks, National Policy and Development Plan in Agriculture Sector and Irrigation Subsector

Outlines of respective legislation, policies, and development plans are as follows:

3.2 FIVE YEAR PLAN

Bhutan's development planning framework continues to be guided by development philosophy of Gross National Happiness (GNH), which was conceived by His Majesty the Fourth King in 1972. The constitution of Bhutan also states that the nation pursues realization of GNH and the philosophy is the foundation for national plan and formulation of policies. GNH broadly encompasses four pillars: 1) sustainable and equitable socio-economic development, 2) preservation and promotion of culture, 3) conservation and sustainable environment management, and 4) strengthening good governance.

The Five Year Plan has been formulated based on such GNH philosophy and has approved by the Cabinet. The plan sets out the national level challenges and key result areas and is stated as the national primary development plan.

The Five Year Plan was initiated by His Majesty the Third King in 1961 and the First Five Year Plan (1961 to 1966) promoted modernization of the country through mainly centrally planned public work projects. Whereas the Second Five Year Plan (1966 to 1971) and the Third Five Year Plan (1971 to

1976) had continued to guild the national government-led development. The Fourth Five Year Plan (1976 to 1981) launched promotion of decentralization, in which development initiatives have been transferred to local governments. Particularly, the decentralization has been widely progressed since the Ninth Five Year Plan (2003 to 2008).

Meanwhile, as all the budgets for the First Five Year Plan was disbursed by India, achieving self-reliance without foreign supports has been one of the main objectives since the first Plan. Since this objective has not been met, the current Eleventh Five Year Plan (2013 to 2018) also regards economic self-reliance as one of its main objectives.

Contents of the Ninth to the Eleventh Five Year Plan, which were implemented recently or is still on-going, as well as the progress of formulating the Twelfth Five Year Plan (2018 to 2023), are summarized below.

3.2.1 Ninth Five Year Plan (2003 to 2008)

The Ninth Five Year Plan aimed at decentralization and transferred authority of development projects from the central government to the local governments (Dzongkhags and Gewogs). Although enhancement of food security and rural economy were still recognized as a national challenge, the Plan focused more on development of farm roads and power generations. As a result, development of irrigation systems was quite limited during this period.

Because of the above situation, MoAF officers, who used to be engineers of irrigation development, were transferred to the Dzongkhag Engineer Division under the Ministry of Works and Human Settlement (MoWHS) and engaged in engineering works such as road, bridge and buildings constructions aside from irrigation.

3.2.2 Tenth Five Year Plan (2008 to 2013)

The Tenth Five Year Plan targeted poverty reduction. Since development of infrastructure enhances not only socio-economic development but also promotion of employment and thus income generation, it was regarded as one of precious key result areas. Although development of irrigation systems was one of target infrastructures, the Plan mainly focused on road construction with a budget of 5,766 million BTN. The budget for irrigation system development was only 35 million BTN or 0.6% of that for road construction. This allocation for irrigation system development was limited only to the rehabilitation of irrigation facilities under urgent priority.

3.2.3 Eleventh Five Year Plan (on-going, from 2013 to 2018)

With the worldwide food crisis that occurred in 2008, Bhutan government came to concentrate on food security policy. Poverty reduction and food and nutrition security are set as the serious issues of Bhutan in this Five Year Plan. The on-going Eleventh Five Year Plan summarizes Bhutan's current situation and challenges along with each of the respective GNH's four pillars. Main current situation and challenges are detailed below.

Sustainable and equitable socio-economic development

Current Situation
- The poverty rate became less than 15 % that was targeted by the Tenth Plan.
- Most of indicators of the Millennium Development Goals (MDGs) were already satisfied.

Challenges
- Concentration of the poor in rural areas

- Inequality between urban and rural areas
- Some of MDGs indicators were not achieved: malnutrition, female enrolment in tertiary education, maternal and under five mortality rates, spread of HIV/AIDS and youth unemployment

Preservation and promotion of culture

Current Situation - Promotion of traditional arts, craft, Bhutanese film and music industry and cultural tourism contributes to: enhancement of Bhutan's cultural value, increase opportunity for employment and cash income, leading to poverty reduction.

Challenges - Further promotion of culture

Conservation and sustainable environment management

Current Situation
- Abundant natural resources
- Frequent occurrence of natural disasters such as earthquakes, cyclone, flood, and landslide.

Challenges
- A sustainable balance between economic development with increasing use of natural resources and environment conservation
- Improving disaster resilience and management

Promotion of Good Governance

Current Situation - Improved legislation toward anti-corruption

Challenges - Elimination of corruption

National key results areas are defined to overcome the aforementioned challenges (Table 3.2.1). Among those areas, agriculture sector is especially required to contribute to: "2) Poverty reduced and MDG Plus achieved"; "3) Food secure and sustained"; and "4) Employment". Budget of agricultural infrastructure, especially irrigation system, increased from 35 million BTN in Tenth Five Year Plan to 1,600 million BTN in the Eleventh Five Year Plan, recognizing that overcoming the national challenge through development of agriculture infrastructure is an important issue.

Table 3.2.1 GNH Main Challenges and Key Results Areas in each Pillar

GNH Pillars	Main Challenges	Key Results Area
1) Sustainable and equitable socio-economic development	- Concentration of the poor in rural areas - Inequality between urban and rural areas - Unachieved MDGs	1) Sustained economic growth 2) Poverty reduced and MDG Plus achieved 3) Food secure and sustained 4) Employment
2) Preservation and promotion of culture	- Further Promotion of culture	5) Strengthened Bhutanese identity, social cohesion and harmony 6) Indigenous wisdom, arts and crafts promoted for sustainable livelihood
3) Conservation and sustainable environment management	- A sustainable balance between economic development increasing use of natural resources and environment conservation - Improving disaster resilience and management	7) Carbon neutral/green and climate resilient development 8) Sustainable utilization and management of natural resources 9) Water security 10) Improved disaster resilience and management mainstreamed
4) Strengthening good governance	- Elimination of corruption	11) Improved public service delivery 12) Democracy and Governance strengthened 13) Gender friendly environment for women's participation 14) Corruption reduced 15) Safe Society 16) Needs of vulnerable group addressed

Source: The Survey Team (based upon Eleventh Five Year Plan)

3.2.4 Twelfth Five Year Plan (future, from 2018 to 2023)

The Gross National Happiness Commission (GNHC) published a guideline for the Twelfth Five Year Plan in January 2017 and respective ministries and agencies are going to prepare their five year plan based on the guideline.

According to interview with GNHC staff, main national objectives of the Twelfth Five Year Plan will be "establishment of industry structure independently from the hydropower projects" and "enhancement of employment (decrease of unemployment rate)". With these objectives, the agriculture sector will focus on "promotion of agribusiness (enhancement of value addition)" and "strengthen collaboration with the tourism industry".

3.3 MoAF FIVE YEAR PLAN

3.3.1 RNR Sector Eleventh Five Year Plan (2013 to 2018)

The ministries including MoAF formulate their own Five Year Plans for overcoming the national level challenges, and those plans are also approved by the Cabinet.

(1) Current Situation of the Agriculture Sector

As the agriculture sector supplies substantial food, contributes to the GDP, and shares 62.2% of employed population, agriculture is positioned as a key industry in Bhutan. Despite its importance, national challenges related to the sector such as poverty reduction, enhancement of food security and economic growth in Bhutan are not fully achieved. It might be caused mainly by a delay in commercialization and diversification of agriculture.

Regarding creation of employment, the following challenges are also identified: aging of farmers, an increased proportion of women in agriculture, and significantly skewed distribution of the farmers' population by sex and age group, etc.

(2) Challenges of the Agriculture Sector

Given the above, seven challenges are identified (Table 3.3.1), which cover various topics such as loss of agriculture land, farm labour shortage, lack of irrigation, human-wildlife conflicts and lack of credit opportunity.

Table 3.3.1 Challenges in the Agriculture Sector

Challenges	Outlines
1) Decreasing public investment	The proportion of budgets of the agriculture sector in the overall national budget has declined since the Sixth Five Year Plan (1987 to 1992)[24]。
2) Loss of agriculture land	Due to urbanization and land use for other sectors, agriculture land has decreased. Besides, increase in abandoned farmland depressed agriculture productivity.
3) Farm labour shortage	Emigration to urban areas causes farm labour shortage. While the proportion of female in the agriculture sector increases, population of male farmers is decreased.
4) Lack of irrigation	Malfunctioning of irrigation facilities and depletion of water resources lead to increase in abandoned farmland at paddy terrace.
5) Human wildlife conflicts	Since large populations of mega-fauna living in close proximity to human communities, conflicts arise between humans and wildlife. Farmers in areas where the conflict frequently happens stop growing crops.
6) Lack of credit opportunities	High interest rates and stringent condition discourage financial institutions to invest for the agriculture sector.

[24] As compared to the budget of agriculture sector accounts for 15.6% on the Sixth Five Year Plan, that on the Eleventh Five Year Plan decreases to 5.6%.

Challenges	Outlines
7) Cross cutting issues	In addition to the aforementioned challenges, challenges on gender, environment, climate change and disaster disturb the growth of the agriculture sector.

Source: The Survey Team (based upon RNR Sector Eleventh Five Year Plan, MoAF)

(3) Key Results Areas to Overcome the Challenges

As same as the key results areas at the national level, those in the agriculture sector are defined with respect to the four GNH pillars in order to overcome the aforementioned challenges (Table 3.3.2).

Table 3.3.2 Key Results Areas in the Agriculture Sector

GNH Pillars	Key Results Areas
(1) Sustainable and equitable socio-economic development	1) Enhanced food and nutrition security 2) Generate employment and increase mean annual cash income 3) Accelerate RNR sector growth
(2) Preservation and promotion of culture	4) Enhance sustainable management of biodiversity resources
(3) Conservation and sustainable environmental management	5) Enhanced conservation of plant and animal genetic resources
(4) Strengthening good governance	6) Enhanced effectiveness of RNR service delivery

Source: RNR Sector Eleventh Five Year Plan, MoAF

Among these key results areas, "1) Enhanced food and nutrition security" and "2) Generate employment and increase mean annual cash income" are described as follows:

Enhanced food and nutrition security

According to a survey implemented by MoAF in 2011, Bhutan was food secure with national average energy consumption, exceeding 2,500 Kcal/person/day. However, most foods were made available through import and food security from nutritional aspect has not been well considered. Therefore, the Eleventh Five Year Plan aims to enhance food and nutrition security through improved productivity and diversified production.

Generate employment and increase mean annual cash income

Agriculture is Bhutan's key sector, which employs 62.2% of the employed population and they are mostly living in rural areas. Through introduction of micro credit and commercial agriculture, the country aims at promotion of small-scale enterprises based on agriculture in rural areas, which may further lead to increase in employment and cash income.

(4) Strategies for Overcoming the Challenges

In order to overcome the aforementioned challenges, the agriculture sector focuses on the following 14 strategies:

1) Optimization and effective utilization of resources to enhance productivity and production, 2) Farm mechanization, 3) Strengthening commercialization and agriculture marketing, 4) Land development and consolidation, 5) Water resource management and irrigation, 6) Participation in commodity value chain and compacts, 7) Sustainable management and utilization of natural and biodiversity resources, 8) Contract farming and private sector participation, 9) Enhance investment in RNR sector, 10) Adapting to climate change and disaster risk reduction, 11) Encouraging research, innovation and technology, 12) Farmer group and cooperatives, 13) Infrastructure development, and 14) Governance and service delivery

Priority for "5) water resource management and irrigation" is described as follows: construction of new irrigation schemes ranks as the highest priority, and is followed by renovation of non-functional

irrigation channels. To this end, the NIMP would be fully utilized as discussed later in this report.

1st priority: Construction of new irrigation schemes for potential production site
2nd priority: Renovation of non-functional irrigation channels
3rd priority: Put groundwater and water harvesting schemes in place
4th priority: Make available drip and sprinkler irrigation facilities in places where high value crops are grown
5th priority: Build water storage structures
6th priority: Establish water users groups

(5) Key programmes

Based on the above strategies, sixteen programmes are planned for the respective key results areas of agriculture sector. Table 3.3.3 summarizes linkages between the programmes and the key results areas. The table also refers to linkages between the programmes and the national key results areas.

Table 3.3.3 Linkages between Programmes and, the National and the Agriculture Sector Key Result Areas on the Eleventh Five Year Plan

Name of Programmes	National Key Results Area										Agricultural Sector Key Results Area					
	2)	3)	4)	5)	6)	7)	8)	9)	10)	12)	1)	2)	3)	4)	5)	6)
	Poverty reduction	Food security	Employment	Bhutanese identity promotion	Indigenous wisdom etc	Carbon neutral and climate resilience	Sustainable natural resource	Water utilization	Improved disaster resilience	Democracy and governance	Food security	Additional employment	RNR sector growth	Biodiversity management	Natural Resources conservation	RNR Service Deliver
1) National Field Crop Commodity Development	✓		✓									✓				
		✓									✓					
2) National Horticulture Commodity Development	✓												✓			
		✓	✓								✓	✓				
3) Agriculture Infrastructure Development		✓									✓					
4) National Organic Development	✓		✓									✓				
							✓								✓	
5) National Livestock Commodity Development	✓		✓									✓	✓			
		✓									✓					
6) Targeted Highland Development	✓		✓									✓				
		✓									✓					
7) Agriculture Marketing and Cooperative Development	✓		✓									✓	✓			
8) RNR Research and Extension Services	✓		✓									✓	✓			
9) Biodiversity Conservation and Sustainable Utilization					✓									✓		
10) National Biosecurity and Food Safety	✓		✓									✓	✓			
11) Rural Development Training	✓		✓									✓				
12) Sustainable Management of State Forests				✓												✓
			✓				✓					✓			✓	
13) Sustainable Management of Forest Landscapes and Conservation of Biodiversity	✓		✓									✓				
				✓												✓
						✓									✓	
			✓				✓					✓				
14) Integrated Watershed Management								✓							✓	
15) School Agriculture	✓		✓									✓				
									✓							
16) Coordination and Support Services										✓						✓

Source: The Survey Team

As Table 3.3.3 shows, the agriculture sector plans multifaceted programmes such as increase of cultivated farmlands, improvement of crop productivity, development and improvement of agriculture infrastructure, dissemination of agricultural mechanization, improvement of marketing, and research and development. These programmes are expected to contribute to the national key results areas of "2) Poverty reduced and MDG Plus achieved", "3) Food secure and sustained" and "4) Employment" by addressing the sector key results areas of "1) Enhanced food and nutrition security" and "2) Generate

employment and increase mean annual cash income".

Table 3.3.4 summarizes outlines, major indicators for evaluation and budgets of programmes related to irrigation agriculture. Among the irrigation related programmes, "3) Agriculture Infrastructure Development" is regarded as a key area. Indeed, it is budgeted 1,600 million BTN, accounting for 40% of the total budget of 3,966 million BTN for the agriculture sector. Meanwhile, there is no particular programme as to enhance capacity of the Agriculture Engineering Division of DoA, MoAF (hereinafter referred to as "Engineering Division") and the Agriculture Research and Development Centers (ARDC), MoAF in irrigation planning[25] and irrigation facility design/construction/O&M.

Table 3.3.4 Outlines, Major Indicators for Evaluation and Budgets of Programmes related to Irrigation Agriculture

Programme	Major Indicators			Capital (million BTN)
1) National Field Crop Commodity Development Programme (NFCDPP)	**Outline**	i. Commercialization for potential crops such as rice, maize, wheat and oil seed ii. To achieve the volume for commercialization, land intensification through assured irrigation water and mechanization services		430
	Major Indicators	*Outcome* **[Annual Paddy Production]** 78,730 MT→98,894 MT **[Annual Maize Production]** 79,826 MT→88,365 MT	*Output* **[Area under-assured Irrigation]** 67,676 Acre→77,827 Acre **[Area under Farm Mechanization]** 1,271 Acre→5,000 Acre	
2) National Horticulture Commodity Development Programme (NHCDP)	**Outline**	i. To strengthen the commodity chains of (i) vegetables, (ii) citrus, (iii) potato, (iv) fruits & nuts, (v) medicinal, aromatic & spice and (vi) mushrooms with greater emphasis on increasing production for meeting domestic requirement and enhancing income through internal trade and export ii. Not only to increase productivity but also expanding area under cultivation and improving product		230
	Major Indicators	*Outcome* **[Annual Vegetable Production]** 44,650 MT→65,2004 MT	*Output* **[Area under Vegetable Cultivation]** 33,532 Acre→38,532 Acre	
3) Agriculture Infrastructure Development Programme (AIDP)*	**Outline**	To construct new irrigation schemes, to improve existing irrigation infrastructure and to construct and improve farm roads to enhance productivity and production of agriculture crops		1,600
	Major Indicators	*Outcome* **[Paddy Field Area under Functional Irrigation System]** 19,200 ha→32,000 ha **[Horticulture crops area under irrigation]** 0 Acre→300 Acre **[Percentage of households living more than one hour walking distance from a road head]** 31 %→15 %	*Output* **[New irrigation system development]** 0 Nos→10 Nos **[Existing irrigation system improvement]** 0 Nos→20 Nos **[New farm road construction]** 0 Nos→10 Nos	

Source: Eleventh Five Year Plan

*In the description of this programme, justification, strategy, risk assessment and direct beneficiaries of the irrigation system development are shown as in the table below. In addition, it is described that engineers of DoA and ARDCs shall be in charge of design of the irrigation facilities.

Justification	Owing to inadequate maintenance, use of inappropriate technology and technical design, considerable numbers of irrigation systems have low water delivering efficiency.
Strategy	DoA including ARDCs will plan and implement all major new and rehabilitation projects. Detailed design of the systems will be carried out by the engineers of Engineering Division and ARDCs while actual construction will be outsourced to local contractors. Also, DoA implements the survey related to water management.
Risk assessment	The main risk is whether the required additional engineers especially at the ARDCs can be recruited.
Beneficiaries	The direct beneficiaries of the programmes related to irrigation agriculture will be the farmers in Chhuzing

[25] In this survey, "irrigation planning" is used as a word, meaning planning of individual irrigation facilities, and "irrigation development plan" as a word, meaning development plan targeting whole Bhutan such as establishment of the target value, prioritization of the irrigation system development.

	(wetland).

(6) Target Indicators

According to interview with DoA, although the RNR Sector Eleventh Five Year Plan aims to expand the irrigated areas from 19,200 ha to 32,000 ha through development of ten new irrigation systems and rehabilitation of twenty irrigation systems as Table 3.3.4 shows, detail roadmaps for the achievement of the goal, such as target irrigation systems to be developed/rehabilitated, were not determined when formulating the Plan. After the Five Year Plan was approved, DoA selected 108 target irrigation systems to be developed and/or rehabilitated to achieve the target of 32,000 ha irrigated area.

3.3.2 RNR Sector Twelfth Five Year Plan (2018 to 2023)

According to the Policy and Planning Division of MoAF, as of December 2016, draft outlines of the RNR sector Twelfth Five Year Plan are as presented below. The Twelfth Plan aims to further increase food self-sufficiency and transition from subsistence to commercial agriculture following the on-going Eleventh Plan.

1) Development of new irrigation systems
2) Promotion of agriculture mechanization
3) Improvement and dissemination of farming techniques
4) Increase of crop cultivated areas and productivity through 1) to 3), which is improvement of food self-sufficiency
5) Transition from subsistence to commercial agriculture
6) Development of rural areas as food suppliers to urban areas

3.4 LEGISLATION, POLICIES AND DEVELOPMENT PLANS OF THE IRRIGATION SUBSECTOR

3.4.1 National Irrigation Policy (2012)

This Policy is a revised version of National Irrigation Policy in 1992 by MoAF and approved by the GNHC. Moreover, the government does not formulate legislation in the irrigation subsector and this Policy is the primary document for the sector as of February 2017.

(1) Objective

The Policy aims to increase the irrigated area, to improve irrigation water management, and optimal utilization of national water resources for crop production.

(2) Challenges on the Irrigation Development

Challenges on the irrigation development are described as follows.

- Irrigation development and management is characterized by low levels of investments, lack of clear long term development plans and lack of water storage systems to enable temporal availability of irrigation water. These lead to low production levels and low productivity of agriculture crops.
- Support by the DoA in capacity building for scheme management is inadequate and hence many water user associations are not well organized resulting in poor management of irrigation schemes and early scheme failure.
- Due to limited time and technical capacity of engineers, irrigation structures are not perfectly designed and constructed without proper planning; and due to shortage of manpower, schemes are

not thoroughly supervised.
- Due to limited resources allocated for catchment management, there are conflicts of interest among conjunctive water users/uses from a common source.
- Water at the channel and on-farm are not managed efficiently, resulting in land degradation and lower irrigation efficiency.

(3) Vision and Objectives

The vision of the Policy to overcome the challenges listed above is "A stable and productive agriculture sector with dynamic and sustainable irrigation systems that enhances food security and stimulates economic growth". The Policy also clarifies its means to be taken to attain those objectives under the aforementioned vision (Table 3.4.1). The development of the NIMP is also counted as one of the means to be taken.

Table 3.4.1 Summary of the Objectives and Activities in National Irrigation Policy

Objectives	Activities
To accelerate investment based on identified needs in the irrigation sector for the achievement of national food self-sufficiency and food security goals	- Development of irrigation development master plan - Funds mobilization through demand creation by Dzongkhag and Gewog level - Development of alternative water resources including linking up with future hydropower projects
To empower beneficiaries through a farmer-centered approach	- Facilitation and support for the WUA by DoA - Monitoring of the status and functioning of WUAs by DoA with Department of Marketing & Cooperatives, through Dzongkhag and Gewog authorities
To pursue new approaches to sustainable irrigation infrastructure development and maintenance	- Test and promotion of appropriate irrigation technologies - Conduction of feasibility studies one year before implementation - Cost covering for all new constructions by RGoB - Covering wages for skilled labour, materials, and their transportation to construction sites for renovation of schemes by RGoB - Labour force provision by beneficiaries - Taking up of routine maintenance by WUA - Covering of emergency funds by the Ministry for schemes damaged by Force Majeure, and which are beyond the capacity of WUA to repair
To pursue environmentally sustainable Integrated Water Resources Management (IWRM) approach in irrigation development	- Catchment management - Development of irrigation water quality standards - Implementation of IWRM approach in irrigation development - Environmentally-friendly measures in planning, construction and management of irrigation schemes
To ensure reliable and efficient water use system for intensification and diversification of irrigated crop production	- Promotion of appropriate conveyance technology to reduce water wastage - Carrying out of water management research by ARDCs
To strengthen institutional capacity at all levels for the planning, implementation and management of irrigation development	- Establishment of Regional Irrigation and Water Management (RIWaM) unit under ARDCs to co-ordinate, facilitate and support irrigation development in the Dzongkhags - Assignment of sufficient, qualified and trained staff
To strengthen technical support services and to develop, promote and disseminate new practices, innovation and technologies that are appropriate, manageable and affordable	- Capacity development of engineers - Research, development and promotion of more efficient and appropriate technologies
To strengthen implementation of Monitoring & Evaluation system.	- Creation of maintenance of a comprehensive inventory of irrigation in the country - Monitoring and evaluation of the irrigation schemes and the functional status of WUA in Dzongkhags by RIWaM

Source: National Irrigation Policy, MoAF

(4) Roles of Responsibilities of Stakeholders

MoAF is positioned as the responsible organization for irrigation development, and collaboration with other institutions is required to undertake projects. The main roles of each institution are defined as shown in Table 3.4.2. The lead organization for irrigation development shall be Dzongkhag offices, while DoA shall be in charge of the development of overall plans, provision of technical backstopping to Dzongkhag offices, and the implementation of large-scale irrigation development projects which cannot be managed by Dzongkhag offices on their own capacity. Gewog Agriculture Extension

Officers support Dzongkhag offices by involving communities.

Table 3.4.2 Roles and Responsibilities of the Stakeholders in Irrigation Development

Institutions	Roles and Responsibilities
GNHC	- Overall national planning - Monitoring & evaluation of irrigation policies, plans and programs
National Environment Commission (NEC)	- Provide guidance and coordinate integrated water management - Coordinate with MoAF to frame and disseminate rules and regulations - Provide standards and guidelines on agricultural effluents in water - Mediate conflicts related to irrigation water if referred to the Commission
MoAF	- Lead and coordinate irrigation policy formulation and strategic planning - Strategic planning of watershed management (IWRM principles) at national level
DoA – Engineering Division	- Plan and coordinate implementation of the irrigation programme - Initiate and promote appropriate irrigations systems and approaches to enhance crop productivity - Promote IWRM approaches - Plan and implement all large irrigation schemes including those that the Dzongkhags do not have the capacity for. - Provide technical support to Dzongkhags for irrigation development - Issue Environmental Clearance for construction of irrigation schemes
DoA – ARDC	- Research and Development of appropriate irrigation technologies - Develop extension manuals - Planning and development of all large irrigation schemes and centrally executed irrigation projects in the region - Provide technical support to Dzongkhags for irrigation development - Provide training to Dzongkhags based on a capacity needs assessment
Dzongkhag Agriculture Office (DAO)	- Promote appropriate irrigation technologies and good water management practices in the Dzongkhag - Coordinate skill development activities for staff and farmers related to irrigation in the Dzongkhag - Take lead coordination role in preliminary investigations and multi-disciplinary feasibility studies - Facilitate registration of WUAs - Monitor and evaluate the irrigation programme in the Dzongkhag - Create and maintain an inventory of irrigation schemes in the Dzongkhag
Dzongkhag Engineering Division	- Provide technical inputs in preliminary investigations and multi-disciplinary feasibility studies - Carry out detailed survey, design, drawings, estimates and bill of quantities of feasible irrigation schemes - Tendering and contract administration of new irrigation system constructions - Constructions supervision and quality control - Monitor and evaluate irrigation system construction programs
Gewog Agriculture Extension Office	- Assist communities in identification of irrigation schemes for construction/renovation - Promote appropriate irrigation technologies and good water management practices - Collaborate with ARDCs in research activities on irrigation and water management - Coordinate skill development activities for farmers and WUA members - Take lead role in preliminary investigations and multi-disciplinary feasibility studies - Process for environmental clearances - Facilitate the drafting and finalization of WUA Constitution & By-laws by WUA - Facilitate registration of WUAs - Create and maintain an inventory of irrigation schemes of the Gewog - Monitor and evaluate the irrigation programme - Assist in the day-to-day supervision of irrigation construction and renovation works

Source: National Irrigation Policy, MoAF

3.4.2 National Irrigation Master Plan (NIMP) (2016)

NIMP was developed by MoAF based on the National Irrigation Policy with the support from ADB aiming at "1) attaining public concerns to irrigation development which used to be low in priority in Bhutan" and "2) presenting a road map for future irrigation development". NIMP has been a reference document of long-term irrigation development in MoAF since its formulation.

(1) Objective

The objective of NIMP is "To develop irrigated agriculture to help attain broad agriculture sector goals of food and nutrition security and enhanced rural incomes".

(2) Current Status and Challenges of Irrigation Development

In NIMP, irrigation systems are classified into three categories in accordance with the natural characteristics of its farmland. Though development approach and standard specifications for each category are useful for future irrigation development, development plans are not described by these categories.

Table 3.4.3 Categories of Irrigation Systems Defined by NIMP

Category	Characteristics
(1) Hill Scheme	Hill schemes are located on the hill slopes much higher from the rivers flowing in the deeply incised valley floor. Command areas of these schemes are relatively steep, and they are heavily dissected by natural gullies into smaller patches. In such slopes, series of levelled and bounded terraces (referred to as Chhuzhing) are well-constructed and managed by the farmers, especially for the cultivation of the monsoon paddy. These terraces are the most striking features of irrigated agriculture in the hills of Bhutan. The difference in elevation between the command areas and the main rivers flowing down the hills is so great that the water from the main river cannot be conveyed for irrigation. For this reason, water from the first or second order tributaries located higher up from the command areas is tapped and conveyed for irrigation. As a result, these schemes have relatively less water.
(2) Valley Bottom Scheme	Valley bottom schemes are found on the floors of wide valleys formed by main rivers in the mid hills. Their command areas are located on the relatively wide and gently sloping river banks, which are slightly elevated from the main rivers. As diverting water from the main rivers is difficult, water is tapped from tributaries and conveyed to irrigate the command areas. As these schemes are located at lower elevation, they enjoy relatively large and reliable flows. Depending on the elevation, two crops of paddy can be grown in these schemes.
(3) Foot Hill Scheme	Foot hill irrigation systems are located in the southern most narrow strips of the southern foot hills bordering India and exhibit considerable differences with the valley bottom and hill schemes: foot hill schemes have relatively large and flat areas; located in lower altitude; high rainfall; unstable source rivers; rapidly changing river morphology; and frequent flash foods. So, these schemes face major challenges for diverting river water to their respective irrigation canals.

Source: NIMP, MoAF

NIMP identifies major challenges for irrigation development as follows, but detail measures are not specified.

- Lack of irrigation and weakening public sector irrigation development capacity
- Decease in areas under crop cultivation
- Labour shortage for agricultural activities
- Low agricultural productivity
- Crop depredation by wildlife
- Competition with cheap rice imported from India
- Poor access to agricultural credit
- Climate change

(3) Target Years and Indicators

Self-sufficiency in cereals was 64% in 2014 nearly as much as that in 2011, suggesting that it is difficult to attain the target of 75% by 2018 stipulated in the Eleventh Five Year Plan. Therefore, NIMP resets the target of self-sufficiency in rice to be 80% and in cereals 75% by 2032, though details of the calculation criteria are not reported. As already described, MoAF recognizes NIMP as a reference document and does not follow the target year and indicators of NIMP.

Table 3.4.4 Target Year and Indicator Set by the NIMP

Items		Target	Remarks (in Eleventh Five Year Plan)
Target Year		2023	2018
Food Self Sufficient	Cereal	80%	75%
	Paddy only	75%	
Production	Cereal	267,000MT	
	Paddy only	145,000MT	
Yield	Paddy	1.93 t/Acre	2 t/Acre
	Non paddy	1.43 t/Acre	
Additional Irrigated Area for paddy		24,000 Acre	

Source: NIMP, MoAF

For crops other than rice, almost 30,000 acres needs to be newly irrigated. However, it is analyzed in NIMP that once irrigation systems for paddy are developed, these crops can be cultivated as second crops on the same farmlands, and there will be no need to newly develop irrigated areas separately.

(4) Roadmap

In order to meet the aforementioned targets of Table 3.4.4, a roadmap of irrigation development for the next 15 years is described. The roadmap consists of three phases: 1) Survey, Planning and Design; 2) Implementation; and 3) O&M.

i) Data collection and analysis of current situation and challenges
ii) Examination of lands suitable to irrigation, water resources, selection of crops and appropriate irrigation techniques
iii) Prediction of climate change, analysis of socio-economy, needs of institutional set-up
iv) Planning of investments (proposal of candidate projects and their prioritization)

1) Survey, Planning and Design

This phase covers the process of survey, planning and design from the feasibility study until the detailed design of the irrigation systems. Further, institutional analysis, study on groundwater, the development of topographic maps of the command areas, and hydro-meteorological analysis of the watersheds where no observation data are available are required at this phase. However, details are not specified.

2) Implementation

At this phase, target value of the increase in irrigated areas, 24,000 acres, is attained by two approaches, 1) Existing Irrigation Improvement Project and 2) Development of new irrigation system (Table 3.4.5). At the same time, land consolidation, farm road development and agricultural mechanization are also planned as a part of the roadmap.

The target value for the expansion of irrigated area is set in accordance with the existing irrigated area in each Dzongkhag. In addition, the long list of the irrigation systems to be developed/ rehabilitated is created based on the requests made by Gewog offices, the development target of 108 irrigation systems in the Eleventh Five Year Plan and results of previous studies. In NIMP, it is required to create short list through the prioritization of the systems listed in the long list. Also it is generally accepted to include those 108 systems proposed by the Eleventh Five Year Plan into the short list, since RGoB has already confirmed their feasibility.

Table 3.4.5 Projects Planned in NIMP and Their Targets of Irrigated Areas to be Expanded

Planned Projects		Objectives and Contents	Irrigated Areas to Be Expanded (Acre)
1.Existing Irrigation Improvement Project		1) Modernization 2) Renovation 3) Bottleneck repair	8,000
2.Development of new irrigation systems	2-1.Dry Land Irrigation Development Project	Participatory small-scale water resource development for Kamzhing (Dry Land) in the upper watershed not only for irrigation but also for domestic water. *Catchment area management, Treatment of gully erosion and landslide stabilization, Construction of water collection chambers, Construction of irrigation canals and water conservation facilities, Development of irrigation systems like drip, sprinkler and pipelines	4,000
	2-2. New Hilly Irrigation Development Project	To develop new irrigation systems by tapping water from new water sources for irrigating both the Kamzhing (Dry Land) and Chhuzhing (Wet Land), except Subtropical area at low elevation. *To switch water source from seasonal rivers to perennial rivers, and so forth	4,000
	2-3. Wet Subtropical irrigation Development	To shift from the rain-fed agriculture to irrigation agriculture by developing new irrigation systems in Chhuzhing (Wet Land) of sub-tropical areas in southern part of the country or by revitalizing long-time dysfunctional irrigation systems	11,000
		TOTAL	27,000 (Projected 24,000 ＋Reserve 3,000)

Source: NIMP, MoAF

3) O&M

The needs for i) Institutional Strengthening and ii) Capacity Building are emphasized.

i) Institutional Development

- Establishment of the Irrigation and Water Management Section (IWMS) under Engineering Division
- IWMS will consist of the three units of: Planning and Designing unit (Feasibility Study, Detailed Design and cost estimation); Project Implementation unit (Procurement, Planning and Supervision of construction works); Operation, Maintenance and Research unit (Capacity development of WUAs, Collection and Analysis of data).
- IWMS will mainly perform the following three functions: the development of guidelines for survey, planning, designing, construction works and maintenance; the development of various databases: the training to local government institutions and WUAs.

ii) Capacity Development

- Analysis of fields for which the capacity development of government officers is required together with methodologies of such capacity development.
- Transfer of human resource among institutions, as well as for the outsourcing of some tasks

3.5 LEGISLATION AND POLICY FOR WATER USE

3.5.1 Bhutan Water Vision and Bhutan Water Policy (2003)

This legislation was established by NEC and approved by GNHC to realize the vision of overcoming challenges for water use. This legislation consists of Bhutan Water Vision, and Bhutan Water Policy. Since the Water Act of Bhutan 2011, as discussed later, was enacted later than this policy, the Water Act of Bhutan 2011 is the primary policy for water use as of February 2017.

(1) Objective

Before enacting the Bhutan Water Vision and Bhutan Water Policy, several legislations/policies had existed with respect to water use. As a result, it was necessary to make ad hoc coordination among water users which relied on the same water resource. Therefore, both the Vision and the Policy aim to realize equal water use through unifying the coordination mechanism related to water use.

(2) Bhutan Water Vision

This Vision shows strategies and challenges for water resource problems caused by population growth and socio-economic development in the future.

1) Vision

Water is the most important natural, economic and life-sustaining resource and we must ensure that it is available in abundance to meet the increasing demands. Present and future generations will have assured access to adequate, safe and affordable water to maintain and enhance the quality of their lives and the integrity of natural ecosystems.

2) Strategies

In order to realize the above vision, necessary strategies are raised as follows:

- Sustainable, efficient and equitable water use and management
- Accumulating and sharing knowledge to value and protect water in all forms and uses by all water users, planners and decision-makers
- Participation and involvement of all people in Bhutan

3) Challenges

In order to realize the vision and implement the strategies, challenges faced by Bhutan are described as follows; however, details of current situation are not specified.

- Conserving the quantity and protecting the quality of water resources as a national asset
- Managing growing demands for water and energy at high service levels
- Improving productivity and viability of rural livelihood support base in the face of increasing urbanization
- Achieving adequate institutional and human resources capacity
- Anticipating, preventing and managing conflicts between competing uses and users of water resources
- Nurturing representative, responsive and transparent governance at all levels

4) Priorities for the water use and future goals

The priorities for the use of water resources and future goals are indicated as shown in Table 3.5.1. The use in the agriculture sector is given lower priority than human consumption, health and hygiene, and therefore the Vision set the increase in agriculture productivity through effective water use as the future target of agriculture sector.

Table 3.5.1 Priorities for Use of Water Resources and Future Goals on the Bhutan Water Vision

Priority	Purpose	Goal and Target
1	Human Consumption, Health and Hygiene	Rural: 100% coverage of safe water supply and sanitation Urban: 100% coverage of safe water supply and sanitation Health: Reduction of water-related diseases
2	Agriculture	Increased agriculture productivity and production through improved water use efficiency
3	Energy	Tap is vast potential for socio-economic development and self-reliance
4	Industry	Complying with pollution preventing standards
5	Tourism and recreation	Develop water bodies for recreation, fishing and tourism
6	Other uses	Aquaculture: Identify and incense water bodies/courses for fish farming Disaster Management: Forecast and prevent disasters caused by water such as floods and landslides

Source: Bhutan Water Vision, NEC

(3) Bhutan Water Policy

This is a policy to realize the Bhutan Water Vision and its necessity is described as follows:

- Water is a precious natural resource, basic human needs for survival. The development and management of water resources must be therefore guided by national conservation and sustainable development policies.
- Water is finite, Socio-economic development inevitably leads to increasing demand of water for diverse purposes: domestic, agriculture, hydropower, industrial, recreational etc. Water is a crucial element in all these development areas. Therefore, conservation, development, utilization and management of this important resource have to be guided by national goals.

Thus, the Policy states the priorities of water use, water resource management at every river basin, economic evaluation of water, and institutional and human development for water resource management (Table 3.5.2). As with the Bhutan Water Vision, priority of irrigation follows drinking and sanitation.

Table 3.5.2 Priorities for Use of Water Resources on the Bhutan Water Policy

Item	Outline
Allocation (Priority) of Water Use	1. Drinking and Sanitation, 2. Irrigation, 3. Hydropower Generation, 4. Industrial Use, 5. Recreation, 6. Other use
Water Resources Management	- Since the upstream-downstream relationship has impact on the management of water resources, water resources management takes place at the river basin level. - Conflicting uses interests shall be resolved in a river basin context.
Value of Water	- Water has an economic and social value. - Economic instruments are efficient in modifying demand, and this shall be applied with care.
Institutional Development for Water Resources Management	- The State shall act as the trustee of water resources and shall be responsible for overall regulation and management. - NEC as the Designated National Authority shall ensure effective co-ordination of water resources management at national level. - The line ministries, departments, divisions and other organizations shall implement their respective functional responsibility within the policy and legal framework. - Operation and management of water resources shall be carried out at the regional and local level.
Human Resources Development	- Priority trainings shall be imparted on information systems, cross-sectoral and integrated planning, multi-purpose project planning and formulation, project management, conservation, watershed hydrology, operations and maintenance of physical infrastructure.

Source: Bhutan Water Policy, NEC

The Policy also describes the importance and the challenges of agriculture on the water sector as follows:

Importance

- Sustainable agriculture development is an important component of socioeconomic development.

- Adequate water allocation to the agriculture sector is indispensable for achieving overall national food security.

Challenges

- Agriculture consumes the highest percentage of water. Higher efficiency ("more crop per drop") has to be achieved[26].
- As agriculture production has the potential to pollute water resources through use of fertilizers and pesticides, efforts will be made to manage soil and pests without using management without using excessive chemicals to avoid pollution of water resources from non-point agriculture sources.

3.5.2 The Water Act of Bhutan 2011

The Water Act of Bhutan 2011 was enacted based on the aforementioned the Bhutan Water Vision and the Bhutan Water Policy. The legislation to be applied for all the issues related to water resource management was established by NEC and approved by the Parliament.

(1) Objective

The purpose of the Act shall be:

- To ensure that water resources are protected, conserved and/or managed in an economically efficient, socially equitable and environmentally sustainable manner
- To establish suitable institutions

(2) Responsible Organization for Water Resource Management

The Act describes that water resources are the property of the State and the rights over water resources are given to the State. The NEC is established to manage water related issues. Following the Bhutan Water Policy, water resources are managed at every river basin and river basin committees shall be established under the NEC[27]. The Act also states about the formation of a WUA for the purpose of management of water resources and maintenance of water supply system as described below. Here, WUA is not only for irrigation but also all the uses such as for drinking and industry.

- Any group of beneficiaries using a particular water source for their needs may form a WUA to maintain the water source and to manage water supply services.
- A WUA shall be registered with the Competent Authorities within six months from the date of its formation.
- Functions of a WUA shall be 1) To maintain a water source and protect it against vandalism and other damages, and 2) To coordinate and oversee the activities and management of water supply services by its member.

The Act defines water use priorities as same as the Bhutan Water Vision and the Bhutan Water Policy, namely: 1) drinking and sanitation, 2) agriculture, 3) energy, 4) industry, 5) tourism and recreation, and 6) other uses. Besides, the following issues are specified for the irrigation development:

[26] This sentence seems to suggest the water loss during intake, delivering and distribution. According to the interview with DoA, they have never applied this view point, more crop per drop.
[27] As of December 2016, although NEC has been established, only one river basin committee was organized on trial.

i) Water from an irrigation channel shall be allocated either through mutual understanding or in accordance with existing practices, depending on the size of land holdings and the quantity of water in the channel, and subject to the constitution and bye-laws of the relevant WUA.
ii) Labour contribution by the beneficiaries of an irrigation channel shall depend on the size of their land holding.
iii) If a new plot is terraced nearer to the water source, water for the old plot shall flow through the new plot provided there is no other way of bringing water to the old plot.
iv) If there is sufficient water and capacity in the irrigation channels, the existing beneficiaries shall provide access to a new user or to an existing user that requires additional water, including a user who wants to convert Kamzhing (Dry Land) to Chhuzhing (Wet Land).
v) If the water resource for irrigation is deemed insufficient, a water user shall not initiate any activities that would require additional water, including conversion of Kamzhing (Dry Land) to Chhuzhing (Wet Land).
vi) If water has not flown through old irrigation channels and no repair has been done on the embankments for the last five years then renovation and repairs on the existing alignment will be treated as new construction.

According to the interview with DoA on ii), the actual level of labour contribution among the beneficiaries is the same regardless of land holding size, and the principle of vi) is seldom applied. As Bhutan has a tradition to organize group works, activities in relation to the other principles of i), iii), iv) and v) are smoothly carried out in accordance with this Act.

3.6 LEGISLATION FOR LAND USE

3.6.1 The Land Act of Bhutan 2007

This Act defines the category of land, its registration and right of land owners; it was approved by the Parliament.

(1) Objective

The Act is envisaged to manage, regulate, and administer the ownership and use of land for socio-economic development and environmental well-being of the country through efficient and effective land administration, security of land tenure, equal opportunity to the access to land, facilitation of operation of land market, effective use of land resources and conservation of the ecosystem.

(2) Responsible Organization for Land Management Objective

The Act describes that RGoB shall establish a National Land Commission as the implementing agency of land management. The commission lays down the policies, programmes, regulations, and guidelines, etc., related to land management, and approves compensation for land acquisition.

(3) Registration of Land, Land Owners and Their Right

A cadastral map shall be established based on cadastral survey and Thram, a sole authoritative document which shall record and establish the legitimacy of title to land of a person in the country. It includes name of the landowner, total area of the land, coordinates of boundary points, etc. The landowner shall be an individual person or a company and has rights to transact and inherit lands. In case landowner would like to change title holder, landowner shall report change of title holder in the

Thram to local government administrations.

(4) Category of Land and Its Change

Thram defines land categories as follows: 1) Chhuzhing (wet land), 2) Kamzhing (dry land), 3) Cash crops land, 4) Residential land, 5) Industrial land, 6) Commercial land, 7) Recreational land, 8) Institutional land, and 9) Any other category.

A landowner shall apply conversion of the land categories to local government administration except for Chhuzhing (wet land), which is precious for sustainable food supply and change in use shall be applied by another designated form in accordance with MoAF regulation. Local government administration and MoAF assess the applied land based on the submitted form. Only if the land is assessed as no longer functional as Chhuzhing (wet land) due to depletion of water resources or condition of pervious soils, etc., the owner can convert Chhuzhing to another category.

(5) Acquisition of Registered Land and Compensation for Public Work

Although the government can acquire a registered land for public interests, it should provide substitute land or cash payment, or both, as compensation.

3.7 RELEVANT DEVELOPMENT PROJECTS IN OTHER SECTORS

The National Irrigation Policy describes development of alternative water resources in collaboration with hydropower projects. This seems to specify construction of multi-purpose dams or use of discharge water from hydropower plants for irrigation. Therefore, interview surveys about development of alternative water resources in collaboration with other sectors such as hydropower, domestic water and disaster prevention (flood control) sectors were conducted in the Survey. Results of the interview are summarized in Table 3.7.1. So far, such a multi-sectoral water resources development is only found in collaborative watershed management with flood control projects.

Table 3.7.1 Relevant Development Projects in Other Sectors

Sectors	Hydropower	Domestic Water	Disaster Prevention (Flood Control)
Authority (Responsible agency)	Department of Hydropower and Power System, MoEA	Water Supply and Sanitation Division, Department of Engineering Services, MoWHS	Flood Engineering Management Division, Department of Engineering Services, MoWHS
Present Projects	- Construction of nine hydropower stations with funding from India to generate 10,000MW, - Construction of one hydropower station with RGoB budget to generate 118MW	- Improvement of the facilities in Tsirang, Mongar, Paro, and Phuentsholing in accordance with the Master Plans of Water and Sewage formulated with the funding from the Government of India	- Calculation of the volume and the height of flooding water, and implementation of river bank protection works (countermeasures for erosions) based on the results of calculation
Future Projects	- Construction of 76 hydropower stations (including the sites for project with Indian Fund above) to generate 23,000MW	- Development of water and sewage supply facility at satellite cities which were established around the center of each Dzongkhag in accordance with the decision made by the RGoB - Rehabilitation of existing facilities	- Development of flood hazard maps - Flood evacuation planning based on developed hazard map
Collaboration Projects with Irrigation Development	- As of December 2016, there is/was no plan of collaboration projects, such as the construction of multi-purpose dams, between the two sectors of irrigation and of hydropower.	- As of December 2016, there is/was no plan of collaboration projects between the two sectors of irrigation and of domestic water.	- There is a planned joint collaboration project for the watershed management with MoAF. The intention of MoAF is to protect water resources (river water) for irrigation. Meanwhile, the intention of MoWHS is to reduce the volume of rocks/stones/sands to be produced by rain.

Sectors	Hydropower	Domestic Water	Disaster Prevention (Flood Control)
Others	- If irrigation facilities are constructed in upper reaches than a hydropower station, there is a possibility that the station cannot obtain necessary volume of water for generation, due to the irrigation facilities. In order to avoid conflict over the limited volume of water resources, stakeholder meetings are organized prior to the construction of important hydropower stations. - There is a plan to generate 10,000MW of electricity through the implementation of nine projects with finance from the Government of India. In order to secure to generate additional 13,000MW with the remaining 67 projects to be implemented, it is planned to construct not only large-scale hydropower stations on the main rivers, but also small-scale ones on tributaries.	- At the beginning of water source survey, interview of residents if target source is already utilized for the other purpose is conducted to avoid conflict with the other water sectors. - The usual water resources for domestic use are tributaries, not the main rivers. The three major reasons for this are: 1) the water volume in tributaries is enough for the population of cities in Bhutan; 2) the quality of tributary water usually meets hygienic requirements; 3) tributary water can be delivered by gravity (the main river normally runs lower places than the cities to where water should be delivered).	

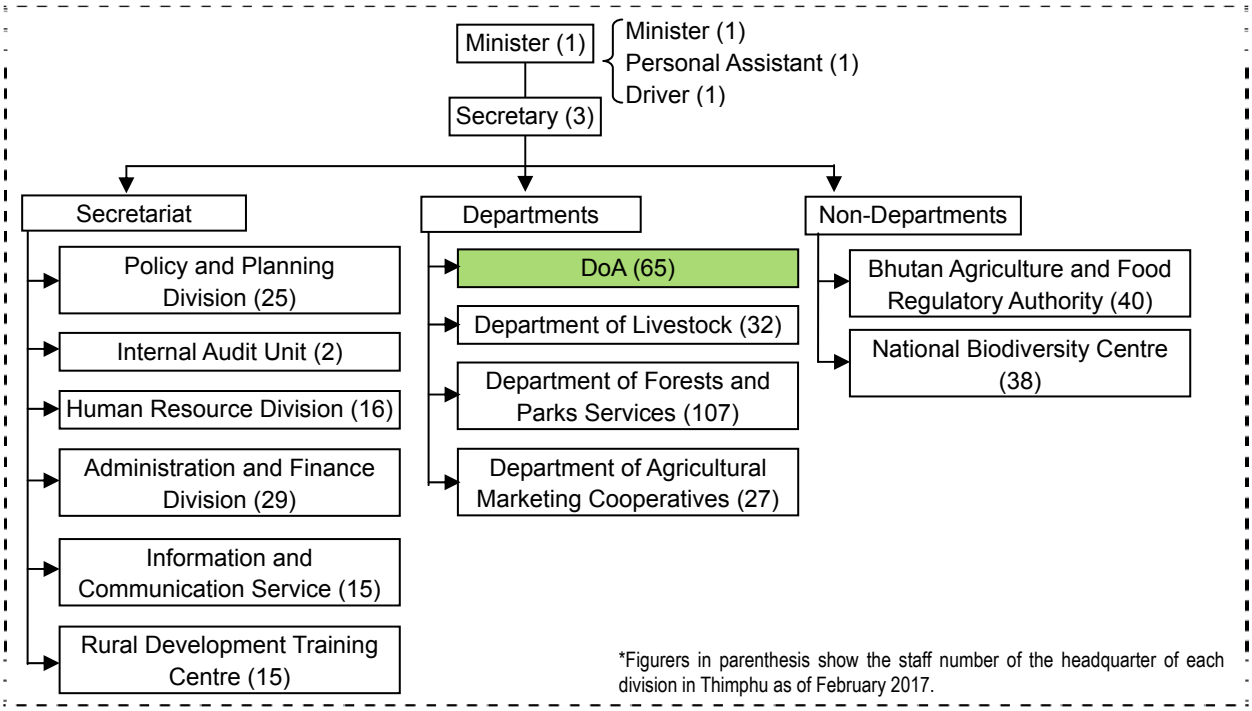
Source: the Survey Team

CHAPTER 4 INSTITUTIONAL ARRANGEMENTS OF THE AGRICULTURE SECTOR AND IRRIGATION SUBSECTOR

4.1 CENTRAL GOVERNMENT INSTITUTIONS

4.1.1 Ministry of Agriculture and Forests (MoAF)

MoAF consists of the i) the Secretariat, ii) the four Departments in charge of works related to agriculture and forestry, together with iii) the Non-Departments (Figure 4.1.1).



Source：the Survey Team (based upon the results of interview with MoAF).

Figure 4.1.1 Organizational Structure of MoAF

The RNR Sector Eleventh Five Year Plan (2013 to 2018) describes following five responsibilities as mandate of MoAF.

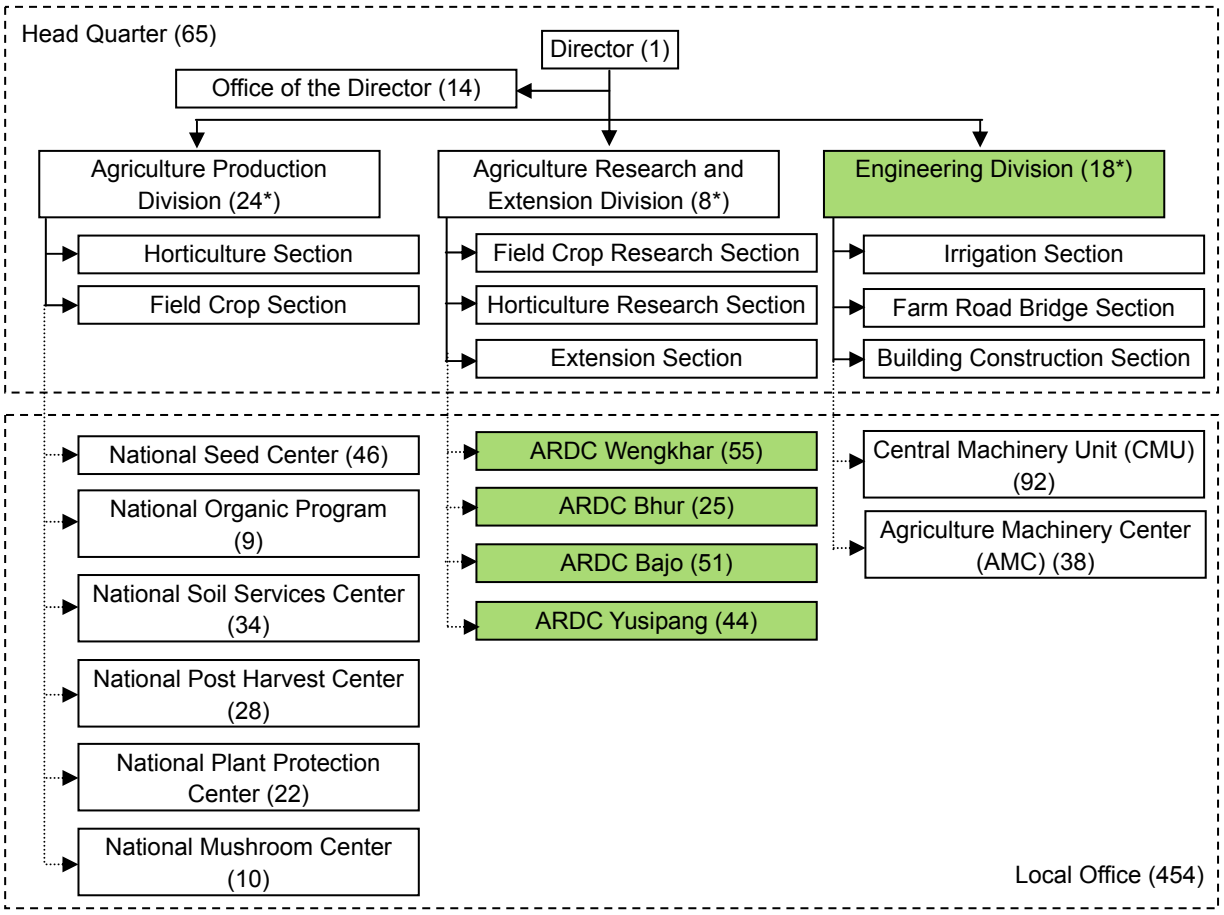
- -To develop agriculture, livestock and forests for the benefit of the Bhutanese people through continuous research and development process;
- -To raise the living standard of rural people through the promotion of income generating agro-based enterprises, reduction of drudgery and improvement of nutrition and health, access to services, market and information;
- -To protect the country's natural environment through the sustainable and judicious use and management of its land, water, forest and biological resources;
- -To ensure food safety through preventive and mitigation measures including quality control of all RNR based consumer products and produces and regulatory measure
- -To represent the interest of the rural people of the country in the functions of the government.

The National Irrigation Policy prescribes the main role of MoAF in the irrigation subsector as follows.

- - Lead and coordinate irrigation policy formulation and strategic planning
- - Strategic planning of watershed management (IWRM principles) at national level

4.1.2 Department of Agriculture (DoA), MoAF

DoA is one of departments of MoAF, consisting of three Divisions: the Agriculture Production Division, the Agriculture Research and Extension Division, and Engineering Division. The engineers of Engineering Division are in charge of works related to irrigation with engineers of ARDCs. ARDC is one of local offices under the Agriculture Research and Extension Division but the engineers of ARDCs belong to Engineering Division.



( ): No of Person as of February 2017
* The number of staff by the sections is not defined
Source : the Survey Team (based upon the results of interview with MoAF)

Figure 4.1.2 Organizational Structure of DoA

4.1.3 Agriculture Engineering Division of DoA (Engineering Division), MoAF and Agriculture Research and Development Center (ARDC)

(1) Roles of each Agency in the Irrigation Subsector

The National Irrigation Policy prescribes the main roles of Engineering Division in the irrigation subsector as follows.

- Plan and coordinate implementation of the irrigation programme
- Initiate and promote appropriate irrigation systems and approaches to enhance crop productivity
- Promote IWRM approaches
- Plan and implement all large irrigation schemes including those that the Dzongkhags do not have the capacity for
- Provide technical support to Dzongkhags for irrigation development

- Issue Environmental Clearance for construction of irrigation systems

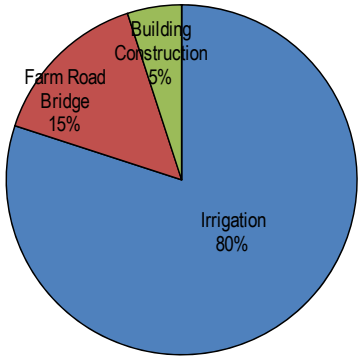
Meanwhile, main roles of the engineers of ARDC are as follows.

- Research and development of appropriate irrigation technologies
- Develop extension manuals
- Planning and development of all large irrigation systems and centrally executed irrigation projects in the region
- Provide technical support to Dzongkhags for irrigation development
- Provide training to Dzongkhags based on a capacity needs assessment

(2) Number of the Project in Charge of the Engineers

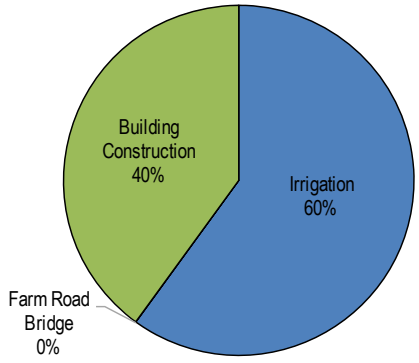
According to the interview with Engineering Division, one engineer of the division oversees an average of four to five works. Although there is the Irrigation Section, the Farm Road Bridge Section, and the Building Construction Section under Engineering Division, engineers are not assigned to a specific section and share all the sections' works. Of all the Division's works, about 80% are irrigation, 15% are farm road bridge, and 5% are building construction (Figure 4.1.3).

Meanwhile, according to the interview with engineers of ARDCs, one engineer oversees an average of seven to eight works. As same as Engineering Division, engineers are not assigned by the sections but they share all sections' works. Irrigation accounts for about 60% of the ARDCs' works, while building construction accounts for about 40%. No one is in charge of works related to the farm road bridge in ARDCs (Figure 4.1.4).



Source: the Survey Team (based upon the results of Interview with Engineer Division)

Figure 4.1.3 Percentage of the Engineering Division Works



Source: the Survey Team (based upon the results of Interview with ARDCs)

Figure 4.1.4 Percentage of ARDC works

(3) Formation of Staff

Engineering Division consists of 18 officers, namely: one Chief Engineer, two Principal Engineers, four Executive Engineers, three Deputy Executive Engineers, seven Engineers and one Drafter. Sixteen engineers, excepting for the Chief Engineer and one of the Deputy Principal Engineers in charge of CMU, oversee works of the irrigation, farm road bridge, and building construction. There is no supporting staff, who corresponds to a Technician of the Dzongkhag Engineering Division as discussed later, and therefore the respective engineers conduct survey, planning, design, cost estimation, tendering, construction supervision, and O&M of their responsible works.

There are four ARDCs in Wengkar, Bhur, Bajo and Yusipang. Engineers are deployed at three ARDCs except for the ARDC Yusipang. They are engaged in engineering works for agriculture in the

respective target areas[28]. Five engineers are working for ARDC Wengkar, three for ARDC Bhur, and three for ARDC Bhur, respectively. Similarly, for Engineering Division, no supporting staff is working in ARDCs, who corresponds to a technician of the Dzongkhag Engineering Division as specified later. Each engineer takes charge of survey, planning, design, cost estimation, tendering, construction supervision, and O&M of their responsible works.

As mentioned above, a total of twenty nine engineers are currently working either at Engineering Division or ARDCs as of February 2017. Four from Engineering Division, two from ARDC Wengkar, one from ARDC Bhur, one from ARDC Bajo are newly employed engineers in recent years. Though freshers learn their responsible works at assigned places through on the job training (OJT), Engineering Division also offers a six-month OJT to freshers of the ARDC Wengkar as there are no engineers who are able to teach[29]. According to the interview with the Human Resource Division of MoAF, it was approved to increase the total number of engineers of Engineering Division and ARDCs up to thirty one.

Table 4.1.1 Position of Engineer from Engineering Division and ARDCs

Position	Engineering Division, DoA	ARDC Wengkar	ARDC Bhur	ARDC Bajo	Total
Chief Engineer	1	-	-	-	1
Principal Engineer	2	3	2	1	8
Executive Engineer	4	-	-	-	4
Deputy Executive Engineer	3	-	-	-	3
Engineer	7	2	2	2	12
(Fresher among Engineer)	(4)	(2)	(1)	(1)	(8)
Drafter	1	-	-	-	1
Total	18	5	3	3	29

Source: the Survey Team (based upon the results of Interview with Engineering Division)

(4) Academic Background and Work Experiences

Table 4.1.2 shows the latest academic background of twenty nine engineers working at either Engineering Division or ARDCs. One master's degree holder studied civil engineering at a university in Bhutan and took postgraduate courses in environment studies and water resource management overseas. Of the eleven bachelor's degree holders, one studied mechanical engineering, while the rest majored in civil engineering. About a half of them studied in Bhutan and the rest studied in India. The diploma holders[30] studied civil engineering at universities in Bhutan except for two who majored in electrical engineering and architecture respectively. While there are many engineers in Engineering Division who earned bachelor's or master's degree, many engineers of the ARDCs are diploma holders.

Table 4.1.2 Latest Academic Background of Engineers at Engineering Division and ARDCs

Latest Academic Background	Engineering Division, DoA	ARDC Wengkar	ARDC Bhur	ARDC Bajo	Total
Master	2	-	-	1	3
Bachelor	11	1	-	-	12
Diploma	5	4	3	2	14
Total	18	5	3	3	29

Source: the Survey Team (based upon the results of Interview with Engineering Division)

[28] Because the ARDC Yusipang is close to Thimphu, Engineer Division is engaged in the engineering works for the area covered by ARDC Yushipang.
[29] Average age of engineers in ARDC Wengkar is relatively high and they cannot design using PC.
[30] Diploma is also called associate degree and qualification, which defines completion of specific course and earn credits.

Furthermore, Table 4.1.3 summarized working experiences of the twenty nine engineers (years after being assigned at either Engineering Division or ARDCs). Engineering Division has engineers ranging from those who are working less than five years to working more than twenty years. Meanwhile, more than a half of engineers working at ARDCs, particularly in Bhur and Bajo, have more than twenty-year experience. Among them, four engineers who are working more than thirty years are supposed to retire within a few years. Since those ARDCs will come to have only less experienced engineers, it is an urgent matter to prepare systems of OJT for freshers.

Table 4.1.3 Working Experiences of Engineers at Engineering Division and ARDCs

Working Experiences	Engineering Division, DoA	ARDC Wengkar	ARDC Bhur	ARDC Bajo	Total
More than 30 years	0	2	2	-	4
20 to 30 years	1	1	-	-	2
15 to 20 years	4	-	-	1	5
10 to 15 years	5	-	-	1	6
5 to 10 years	4	-	-	-	4
Less than 5 years	4	2	1	1	8
Total	18	5	3	3	29

Source: the Survey Team (based upon the results of Interview with Engineering Division)

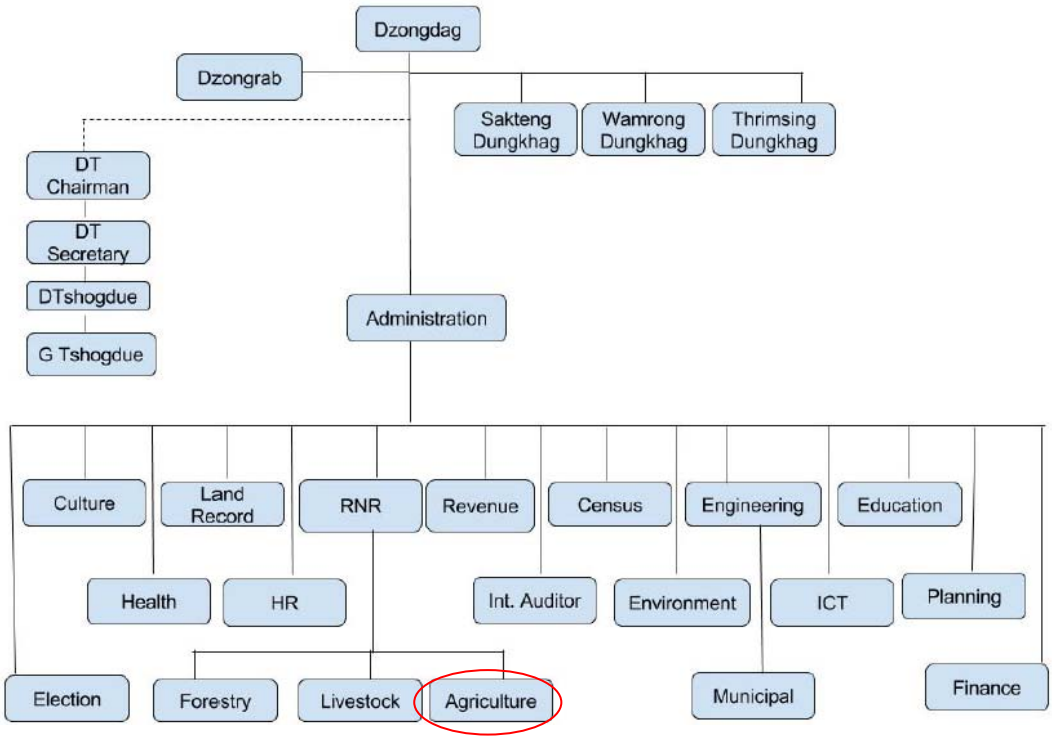
As aforementioned, there are many engineers having longer years of experience in civil engineering in the Engineering Division and ARDCs. However, their practical experience in development of irrigation systems (irrigation planning and irrigation facility design/construction/O&M) is maximum three years only.

The reasons are as follows: 1) while maintenance of existing irrigation systems has been mainly carried out by the central and the local governments, they have not implemented new construction and/or rehabilitation since 1980s; 2) Since the Ninth Five Year Plan (2003 to 2008) promoted decentralization and engineers of each ministry were gathered at the Dzongkhag Engineering Division under MoWHS, the central government hardly directed development projects; 3) since the Eleventh Five Year Plan (2008 to 2013), the central government (engineers of Engineering Division and ARDCs) has initiated irrigation development projects (new construction and rehabilitation) again because Bhutan faced food crisis in 2008 and has recognized the importance of the development of irrigation systems.

4.2 LOCAL GOVERNMENT INSTITUTIONS

4.2.1 Dzongkhag Agriculture Office (DAO)

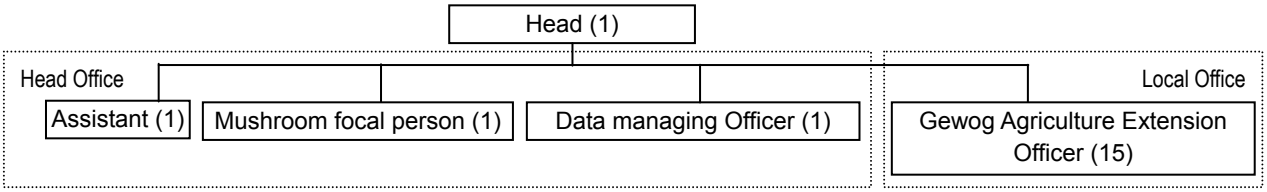
The government institutions at the Dzongkhag level consists of the human resource division, the environment division, the education division, the engineering division, the RNR division and so forth under the administration department, of which DAO is included in the RNR division. As an example of the Dzongkhag administrative institution, the organization chart of Trashigang Dzongkhag is shown in Figure 4.2.1.



Source: the Survey Team (based upon the results of Interview with DAO of Trashigang Dzongkhag

Figure 4.2.1 Government Institutions of Trashigang Dzongkhag

DAO of Trashigang Dzongkhag has a total of nineteen staffs consisting of four officers including the head of office and one extension officer from each of the fifteen areas, as of January 2017 (Figure 4.2.2).



( ) : No of Person as of January 2017
Source: the Survey Team (based upon the results of Interview with DAO of Trashigang Dzongkhag

Figure 4.2.2 DAO of Trashigang Dzongkhag

DAO Head Office is engaged in overall agriculture support at the Dzongkhag level. Its duties in detail are as follows: 1) to disseminate farming techniques, 2) to provide technical service in the planning and monitoring to offices at the Gewog level, 3) to coordinate between the central and local government institutions in the implementation of projects, 4) to collaborate with ARDCs and the National Seed Center at the Dzongkhag level for the projects in agriculture sector, 5) to communicate and coordinate with AMC and CMU, 6) to support offices at the Gewog level in the development of plans of project implementation, 7) to provide advice or assistance to prepare plans of Gewogs, and 8) to rehabilitate/develop rural roads.

The National Irrigation Policy prescribes the main roles of DAO in the irrigation subsector as follows.

- Promote appropriate irrigation technologies and good water management practices in the Dzongkhag
- Coordinate skill development activities for staff and farmers related to irrigation in the Dzongkhag
- Take lead coordination role in preliminary investigation and multi-disciplinary feasibility studies
- Facilitate registration of WUAs
- Monitor and evaluate the irrigation programme in the Dzongkhag
- Create and maintain an inventory of irrigation schemes in the Dzongkhag

4.2.2 Gewog Agriculture Extension Office

In principle, one Gewog Agriculture Extension Officer is assigned to each Gewog and engaged in overall agriculture activities including irrigation at the Gewog level. In fact, some officers are taking care of several Dzongkhags. For instance, an extension officer of Radhi Gewog in Trashigang Dzongkhag also takes care of the activities in Phongmey Gewog in the same Dzongkhag as of January 2017. In addition, while an officer is not assigned in Merag Gewog, two officers are assigned in Sakteng Gewog. Thus, the Gewog Agriculture Extension Officers are assigned to meet the needs of agriculture support in each Gewog despite its principle.

The National Irrigation Policy prescribes the main roles of the Gewog Agriculture Extension Officer in the irrigation subsector as follows.

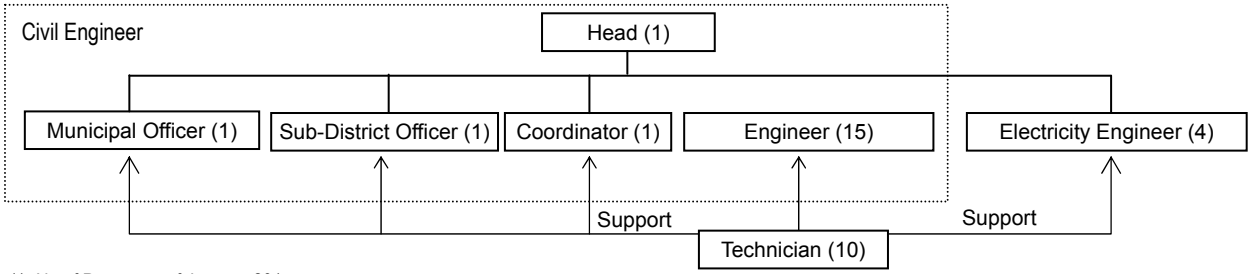
- Assist communities in identification of irrigation schemes for construction/renovation
- Promote appropriate irrigation technologies and good water management practices
- Collaborate with ARDCs in research activities on irrigation and water management
- Coordinate skill development activities for farmers and WUA members
- Take lead role in preliminary investigations and multi-disciplinary feasibility studies
- Process for environmental clearances
- Facilitate the drafting and finalization of WUA Constitution & By-laws by WUA
- Facilitate registration of WUAs
- Create and maintain an inventory of irrigation schemes of the Gewog
- Monitor and evaluate the irrigation programme
- Assist in the day-to-day supervision of irrigation construction and renovation works

4.2.3 Dzongkhag Engineering Division

The Dzongkhag Engineering Division belongs to MoWHS and is engaged in the overall activities[31] related to engineering works at the Dzongkhag level under the supervision of Administration Department. This arrangement mainly attributes to the fact that engineers, including irrigation engineers, were gathered at the Dzongkhag Engineering Division from the central government through the decentralization promoted by the Ninth Five Year Plan (2003 to 2008) as already discussed.

For instance, the Division in Trashigang Dzongkhag employs a total of thirty three staff as of January 2017, composed of four electrical engineers, nineteen civil engineers and ten technicians supporting the engineers' works. Out of nineteen civil engineers, one is the head, one is a municipal officer, one is a sub-district[32] officer, one is a coordinator and remaining fifteen are engineers. An engineer covers a Gewog and transfers to another Gewog in every two years in principle.

[31] Water supply facilities, farm roads, bridges, irrigation facilities, religious facilities, etc.
[32] A governmental unit consists of some Gewogs



( ): No of Person as of January 2017
Source: the Survey Team (based upon the results of Interview with the Engineering Division of Trashigang Dzongkhag)

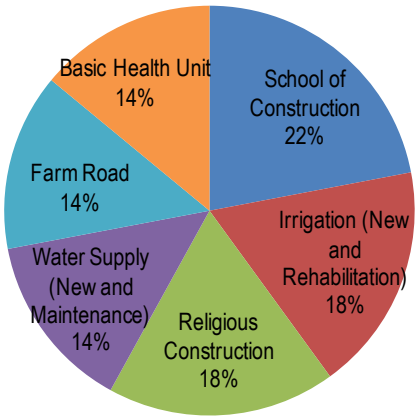
Figure 4.2.3 The Dzongkhag Engineering Division of Trashigang Dzongkhag

The National Irrigation Policy prescribes the main role of the Dzongkhag Engineering Division in the irrigation subsector as follows. O&M of the irrigation systems are out of the mandate of the Dzongkhag Engineering Division.

- Provide technical inputs in preliminary investigations and multi-disciplinary feasibility studies
- Carry out detailed survey, design, drawings, estimates and bill of quantities of feasible irrigation schemes
- Tendering and contract administration of new irrigation system constructions
- Constructions supervision and quality control
- Monitor and evaluate irrigation system construction programs

One civil engineer oversees fifteen to thirty seven projects. Works of civil engineers in irrigation including both construction and rehabilitation account for 18% of the Division's works (Figure 4.2.4).

Table 4.2.1 and Table 4.2.2 show the latest academic background and working experiences (years after being assigned at the Division) of nineteen civil engineers of Trashigang Dzongkhag. Whereas no one earned a master's degree, academic field of bachelor and diploma holders are civil engineering. Their practical experience in development of irrigation system (new construction and rehabilitation) is maximum three years only because only maintenance works have mainly been conducted. However, the engineers are expected to improve their skills through acquisition of further practical experiences on irrigation development because they already have considerable experiences on civil engineering.



Source: the Survey Team (based upon the results of Interview with the Engineering Division of Trashigang Dzongkhag

Figure 4.2.4 Composition of Projects for which Civil Engineers in the Engineering Division of Trashigang Dzongkhag

Table 4.2.1 Latest Academic Background of Civil Engineers in the Engineering Division of Trashigang Dzongkhag

Latest Academic Background	Trashigang Dzongkhag
Master	0
Bachelor	4
Diploma	15
Total	19

Source: the Survey Team (based upon the results of Interview with the Engineering Division of Trashigang Dzongkhag)

Table 4.2.2 Working Experiences of Civil Engineers in the Engineering Division of Trashigang Dzongkhag

Working Experiences	No.
More than 20 years	2
15 to 20 years	0
10 to 15 years	6
5 to 10 years	7
Less than 5 years	4
Total	19

Source: the Survey Team (based upon the results of Interview with the Engineering Division of Trashigang Dzongkhag)

4.2.4 Demarcation of Roles between the Central Government and the Local Government

There is no legislation specifying the demarcation of the central government (DoA and ARDCs) and the local government (Dzongkhags and Gewogs) in the agriculture sector. Meanwhile, according to the interview with Engineering Division, there are two patterns for the implementation of policies and programmes prepared by the central government: 1) central government implements by themselves, and 2) DAO and Gewog Agriculture Extension Office are main implementation body and ARDCs act as a coordinator between them and DoA. As for 2), DoA, ARDCs and each DAO discuss allocation of the roles every year. Other local level policies and development programmes in the agriculture sector are implemented by DAO and Gewog Extension Office with their own budget.

Regarding allocation of roles in irrigation subsectors, engineers of Engineering Division and ARDCs conduct planning and implementation of irrigation systems, for which local governments (Dzongkhags and Gewogs) are unable to manage new construction and/or rehabilitation in terms of technologies and cost. They also provide technical support for the Dzongkhag Engineering Division.

4.3 TRAINING OF ENGINEERS

Engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions can participate in trainings such as freshman training, refresher training, and project-based training,

Freshman training, targeting newly employed engineers, takes six months through OJT.

Refresher training is a series of short-term trainings for engineers from the government, companies and industrial circle and is irregularly conducted at two technical colleges in Bhutan, College of Science and Technology (CST) and Jigme Namgyel Engineering College (JNEC). In detail, they take three to five days theoretical training on design of civil structure including irrigation facilities, construction supervision, quality assurance, earthquake-resistant design, environment consideration, etc. An engineer from Engineering Division, ARDCs and the Dzongkhag Engineering Divisions usually take the refresher training once a year.

Project-based training is carried out either in Bhutan or foreign countries (Thailand, Nepal, Philippines, South Korea, etc.) for seven to ten days where the participants join site visit to farm roads, bridge, water supply and irrigation facilities, etc. Since project-based training depends on implementation status and beneficial areas of the projects, frequency of the participation differs from office to office. Engineers from Engineering Division or ARDCs take one project-based training once a year or every two years, while those from the Dzongkhag Engineering Divisions take it every three to four years.

Table 4.3.1 Training of Engineers from Engineering Division, ARDCs and the Dzongkhag Engineering Divisions

Type of Training	Outline	Situation	
		DoA/ARDC	Dzongkhag Engineering Division
Freshman training	Six-month OJT	If an adequate trainer is unavailable at ARDC, Engineering Division implements the training.	
Refresher training	Venue: Technical colleges in Bhutan Period: 3 to 5 days Content: Theoretical training on design, construction supervision, quality assurance, earthquake-resistant design, environment consideration, etc	One engineer participates once a year.	
Project-based training	Venue: Bhutan or foreign countries (Thailand, Nepal, Philippines, South Korea, etc.) Period: 7 to 10 days Content Site visit to farm roads, bridge, water supply and irrigation facilities, etc.	One engineer participates once a year or every two years.	One engineer participates once every three to four years.

Source: the Survey Team (based upon the results of Interview with Engineering Division, ARDCs and the Dzongkhag Engineering Division in Trashigang, Dagana and Wangdue Phodrang Dzongkhags)

Based on the interview with engineers of each institute, while they recognize the importance of training and require more opportunities to participate, there are limitations of time and budget. Additionally, regular participation and acquisition of comprehensive knowledge and experiences are difficult if only through project-based trainings because it depends on the implementation status of projects. Thus, they would like to take such trainings which are designed depending on technical levels of the participants. They are interested in the subjects of design of irrigation facilities, earthquake-resistant design, and measures against land sliding.

4.4 INSTITUTION OF HIGHER EDUCATION IN TECHNOLOGIES

From the interview with Engineering Division, capacity building of engineers in charge of on-going projects and training for future irrigation engineers are required for further development of irrigation systems initiated by the central government (Engineering Division and ARDCs), which is stipulated by the Eleventh Five Year Plan (2013 to 2018). Additionally, there are two technical colleges that carry a training course in civil engineering to educate irrigation engineers in Bhutan. Engineering Division considers that collaboration with them is important in terms of provision of refresher training and education of future irrigation engineers.

4.4.1 College of Science and Technology (CST)

CST is located in Phuntsholing Gewog, Chhukha Dzongkhag, southwest region of Bhutan, and offers Bachelor of Engineering in Civil Engineering, Engineering in Electrical Engineering, Engineering in Electronics and Communication Engineering, Engineering in Information Technology, and Architecture[33]. Number of enrolees in 2013 was199, 210 in 2014, and 260 in 2015, while the number

[33] Website of Royal University of Bhutan

of students reached 730 in 2013, 788 in 2014 and 865 in 2015[34].

Since annual admission quota of Bachelor of Civil Engineering programme in the CST is 120, about a half of students of the entire college learn at this programme. Curriculum of the Civil Engineering programme refers to that of Indian Institute of Technology. The students must earn 48 credits in Engineering Mathematics, Engineering Mechanics, Strength of Materials, Design of Concrete Structures, etc.

Credits of Hydraulics, Hydrology, Irrigation Engineering, Hydraulic Structures and Water Power Engineering, Principles of Surveying, Photogrammetric and Remote Sensing, etc. are related to irrigation development and account for about 10 to 20% of total credits. Besides, the Civil Engineering programme offers a 6-week internship as a credit during winter holidays. Most of the subjects in the internship are related to the works of road and bridges and internship for the irrigation project has not been conducted.

Graduates of the CST working at Engineering Division mention that if a class on Irrigation Engineering provides design of irrigation facilities such as water intake, canal and distribution structure, it would be an advantage for actual works. Also, the class on Photogrammetric and Remote Sensing offers only theoretical lessons and the students do not operate actual software and analyze data. According to the graduates, they would be able to apply what they learn to their actual works if the classes are more practical.

4.4.2 Jigme Namgyel Engineering College (JNEC)

JNEC is located in Dewathang about 18 km apart from Samdrup Jongkhar Gewog, Samdrup Jongkhar Dzongkhag, southeast region of Bhutan and offers diploma courses of Department of Civil Engineering and Surveying, Electronics and Communication Engineering, Electrical Engineering, Humanities and Management, Information Technology, and Mechanical Engineering and a bachelor course of Engineering in Power Engineering. Number of enrolees in 2013 was 317, 360 in 2014, and 381 in 2015 and the number of students reached 594 in 2013, 733 in 2014 and 846 in 2015.

Since annual admission quota of Department of Civil Engineering and Surveying in the JNEC is 120, about a quarter of students of the entire college learn at this Department. Curriculum of the Department of Civil Engineering and Surveying is basically same as that of the Bachelor of Civil Engineering in the CST and focuses more on the basics because the diploma course is only three years.

About 60% of the graduates of civil engineering course in these technical colleges became supervisors of hydropower projects. The rest (40%) are employed at the central and local governments, such as MoWHS and MoAF, and private construction and consulting companies.

4.5 OTHER RELEVANT INSTITUTIONS

Although hydro-meteorological analysis and geological survey are indispensable in the irrigation planning and irrigation facility design, there is no section within MoAF that is responsible for the aforementioned surveys. Therefore, it is necessary to collaborate with the NCHM for hydro-meteorological analysis and with the Geological Survey of Bhutan Division of the Department of Geology and Mines, MoEA for the geological survey.

[34] Annual report 2013, 1014, 2015, Royal University of Bhutan

4.5.1 National Center for Hydrology and Meteorology (NCHM)

This Center is the only institution in Bhutan to administer hydro-meteorological data. It used to belong to MoEA, however, as of December 2016, it is under the process of becoming independent. RGoB made decision for the independence of the Center, by recognizing that not only MoEA (especially the sections related to hydropower generation) but also all the institutions which require hydro-meteorological data should have equal access to the Center. The Center will not remain financially independent, and the budget required for the Center is allocated from the national budget.

Major functions of the Center are: 1) to build observation stations and their O&M, 2) to provide hydro-meteorological data collected and 3) to coordinate with projects in the procurement of equipment, when the projects are to introduce new observatory facilities. According to officers at the Center, there is no plan to increase drastically the number of observation stations, since it might lead to a reduction of reliability on the data by the reduced maintenance time in each of the stations. Besides, the Center is putting more emphasis on the provision of services such as weather forecasting.

There is no university in Bhutan having faculty in hydrology, meteorology or related area, and the current staffs of the Center have various backgrounds. For example, for the establishment of observation stations, staff with a bachelor degree in electrical engineering was employed. After they started working in the Center, staffs are trying to strengthen knowledge on hydrology or meteorology through studying abroad and in-service training.

4.5.2 Geological Survey of Bhutan Division, Department of Geology and Mines, MoEA

The Department of Geology and Mines of MoEA consists of the following four Divisions: 1) the Geological Survey of Bhutan Division, 2) the Glaciology Division, 3) the Seismology Division and 4) the Mining Division. The Geological Survey of Bhutan Division is the only authority in Bhutan on issues associated with geology.

70% of the geological surveys conducted by Geological Survey of Bhutan Division are requested by MoEA and have higher priorities, while the remaining 30% of the surveys are requested by other ministries and agencies. The main works are assessment of building foundations, road stabilities, and landslides. Those surveys requested by other ministries and agencies are conducted on a first-come, first-served basis. The expenses incurred by the survey (such as personnel expenses, daily allowances and accommodation fees, expenses for the transportation) are covered by the ministries and agencies which requests the survey.

Majority of staff of the Geological Survey of Bhutan Division studied geology outside of Bhutan, such as in India, as there is no university in Bhutan that has faculty in geology. Since experience is the most important thing for a geological survey, staffs are strengthening their knowledge and skills through OJT by being involved in the surveys on the ground for at least six months per year after entering the Division.

4.6 BUDGETS FOR IRRIGATION DEVELOPMENT

Budget for the RNR sector in the fiscal year of 2016/2017 is 6,605 million BTN, which accounts for 12% of the national budget, 54,828 million BTN. Budget related to irrigation development is 434 million BTN and accounts for 0.8% of the national budget. Out of that, budget for irrigation development and rehabilitation allocated to MoAF is 205 million BTN and almost equally shared by the local governments (Dzongkhags and Gewogs) (Table 4.6.1).

Budget allocated to the local governments is fixed amount calculated based on its population, area, poverty, and transportation cost etc. Local governments can decide the allocation of the budget for each sector according to the importance of the sectors. Table 4.6.1 shows the budget for irrigation development and the amount of "Irrigation Projects of Local Government" is the accumulated amount of each local government's budget for irrigation development.

Table 4.6.1 Budget for the RNR Sector and Irrigation Development and Improvement in 2016/17

Sectors	Million BTN	Percent (%)
Social Services	15,430	28.1
Economic and Public Services	18,973	34.6
RNR	(6,605)	(12.0)
Development and improvement of irrigation	(434)	(0.8)
Irrigation Projects of MoAF	(205)	(0.4)
Irrigation Projects of the Local Governments	(229)	(0.4)
Mining and Manufacturing Industries	(1,235)	(2.3)
Roads	(5,818)	(10.6)
Urban development, housing and public amenities	(3,514)	(6.4)
Communication	(1,383)	(2.5)
Energy	(419)	(0.8)
Religion and Culture Services	2,331	4.3
Law and Order Services	2,456	4.5
General Public Services	10,702	19.5
National Debt Services	4,936	9.0
Total	54,828	100.0

Source: NATIONAL BUDGET FINANCIAL YEAR 2016 - 2017, MoF
SCHEDULE OF BUDGET APPROPRIATIONS, FISCAL YEAR 2016 - 2017, REVISED ESTIMATES, MoAF

Table 4.6.2 indicates MoAF budget for projects and trainings related to irrigation development in the past three years. Out of the MoAF budget for irrigation projects, which was 205 million BTN, budget for training related to irrigation planning and irrigation facility design/construction/O&M was 15 million BTN (7.3% of the irrigation project budget), while the budget for O&M training was 0.8 million BTN (0.4% of the irrigation project budget).

Table 4.6.2 MoAF Budget for Irrigation Projects and Training related to Irrigation Development from 2014/2015 to 2016/2017

	Fical Year	2014/15	2015/16	2016/17
Irrigation Project of MoAF	Million BTN	281	381	205
Training budget for irrigation planning and irrigation facility design/construction/O&M	Million BTN	9.29	13.90	14.99
	Percent (%)	3.3	3.7	7.3
Training Budget for O&M	Million BTN	0.44	0.90	0.80
	Percent (%)	0.2	0.2	0.4

Source: The Survey Team (based upon data from NATIONAL BUDGET FINANCIAL 2016 - 2017, MoAF and the interview with Engineering Division

According to the interview with Engineering Division, they considered that the budget for construction and rehabilitation of irrigation systems is prioritized higher, while the budget for training for irrigation planning and irrigation facility design/construction/O&M is lower. Considering the needs of improving technical skills of the present engineers of Engineering Division and ARDCs, they think that not only the budget for newly construction/rehabilitation of irrigation facilities, but also the training budget including O&M training, has to be increased.

CHAPTER 5 CURRENT SITUATIONS AND CHALLENGES S OF THE IRRIGATION SYSTEMS AND IRRIGATED AGRICULTURE

5.1 CURRENT SITUATIONS AND CHALLENGES OF THE IRRIGATION SYSTEM DEVELOPMENT

5.1.1 Current Situation of the Implementation of Legal Instruments, Policies and Development Plans

Based on the interviews with Engineering Division regarding the implementation status of legal instruments, policies and development plans mentioned in Chapter 3, the current status can be classified into the following four (4) categories: 1) already implemented properly, 2) partially implemented, 3) not implemented but the objective is achieved by alternative means, and 4) not implemented yet. The results of analysis by Engineering Division of possible reasons why some legal instruments, policies and development plans have been partially implemented (category 2) above) or not implemented yet (category 4) above) are summarized in Table 5.1.1. The said division identified i) inappropriate understanding and limited experience of engineers in irrigation planning and irrigation facility design/construction/O&M, and 2) shortage of opportunities for them to improve their technical skills.

Table 5.1.1 Implementation Status of Legislation, Policies and Development Plans

Legislation, Policies and Development Plans	Contents	Implementation Status*		Identified Challenges
National Irrigation Policy	Development of alternative water resources	2)	River water has remained as a major water source for most cases. There are engineers with limited experience and technical skills to identify possible alternative water sources, and therefore, a limited number of surveys have been conducted, except those cases when water volume of main source was not enough.	The engineers are not familiar with the advantage to utilize alternative water sources.
	Test and promotion of appropriate irrigation technologies	2)	There are engineers who are interested in improving their technical skills in irrigation planning and irrigation facility design/construction/O&M.	Opportunities for engineers to acquire new technology are limited.
	Carrying out of water management research by ARDCs	4)	There is no expert of water management research in ARDCs.	The development of relevant technology is delayed, since the priority has not been given to it but to the construction of irrigation facilities.
	Assignment of sufficient, qualified and trained staff	2)	The number of staff is not sufficient, and the current staffs do not have enough experience and technical skills for irrigation planning and irrigation facility design/construction/O&M.	The experience in irrigation development of engineers is limited.
	Research, development and promotion of more efficient and appropriate technologies	2)	The development and promotion of efficient and appropriate technology have been limited, as advanced technical skill is required for them.	Engineers are improving their technical skills of irrigation planning and irrigation facility design/construction/O&M.
Bhutan Water Policy	Operation and management of water resources shall be carried out at the regional and local level.	2)	Engineers of the Dzongkhag Engineering Division and Gewog Agriculture Extension Officers have limited capacity in O&M of irrigation systems. They are accustomed to repair but not to provide preventive maintenance.	Measures to improve lifecycle cost of the facilities need to be taken in the daily operation.

*2): partially implemented, 4): not implemented yet
Source: the Survey Team (based upon the interview with DoA)

5.1.2 Functional Status of the Irrigation Systems

Engineering Division conducted an inventory survey of all the irrigation systems in the country in 2013 and its results were compiled into the National Irrigation Information System (NIIS), though it has not been updated since then. According to this database, there are 1,212 irrigation systems in Bhutan, and 111 systems out of them are dysfunctional (Table 5.1.2).

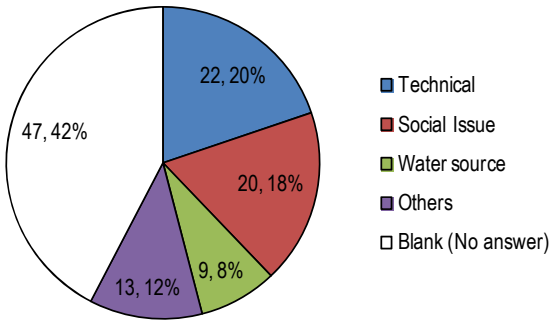
Table 5.1.2 Irrigation Systems in Bhutan

		Number of Systems	Accumulated command area (acre)
Irrigation systems with more than 15 acres of command area	Functional	851	61,748
	Dysfunctional	111	-
Irrigation systems with less than 15 acres of command area		250	2,500
Total		1,212	64,248

Source: National Irrigation Information System (NIIS)

The reasons for dysfunction can be attributed to the following four items: 1) Technical 20%; 2) Social issue 18%; 3) Water Source 8%; and 4) Others 12% (Figure 5.1.1). However, since there is no further information on each of the dysfunctional cases, concrete reasons for dysfunction are unknown. Additionally, the reasons for dysfunction were not provided for 47 irrigation systems in NIIS.

During the interview, Engineering Division stated that it seemed to them that engineers of Engineering Division and of local consultants who conducted the survey had limited knowledge and experience in the irrigation system development and they could not specify the reasons for dysfunction.



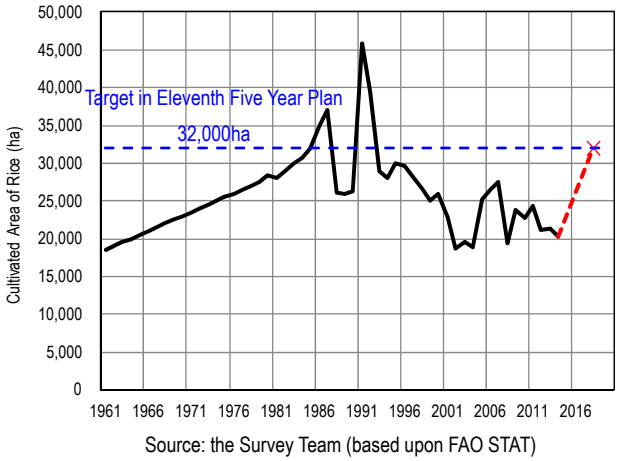
Source: the Survey Team (based upon NIIS)

Figure 5.1.1 Reasons of Dysfunctional

5.1.3 Progress in the Development/Rehabilitation of Irrigation Systems Targeted in the Eleventh Five Year Plan

(1) Transition of Irrigated Area and Possibility to Achieve the Target

As already described in Chapter 3, the Eleventh Five Year Plan (2013 to 2018) aims to expand irrigated area from 19,200ha to 32,000ha through the development/rehabilitation of irrigation systems. The data which shows the transition of irrigated area are not available; however, the harvested area of rice, including both the areas of rain fed rice and of irrigated rice, marked its peak of 46,000 ha at 1991, and since then, the area has decreased as shown in Figure 5.1.2. On the other hand, experience in irrigation system development of the engineers



Source: the Survey Team (based upon FAO STAT)

Figure 5.1.2 Harvested Area of Rice

of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions is limited and there are no skilled engineers who can provide them with practical advices.

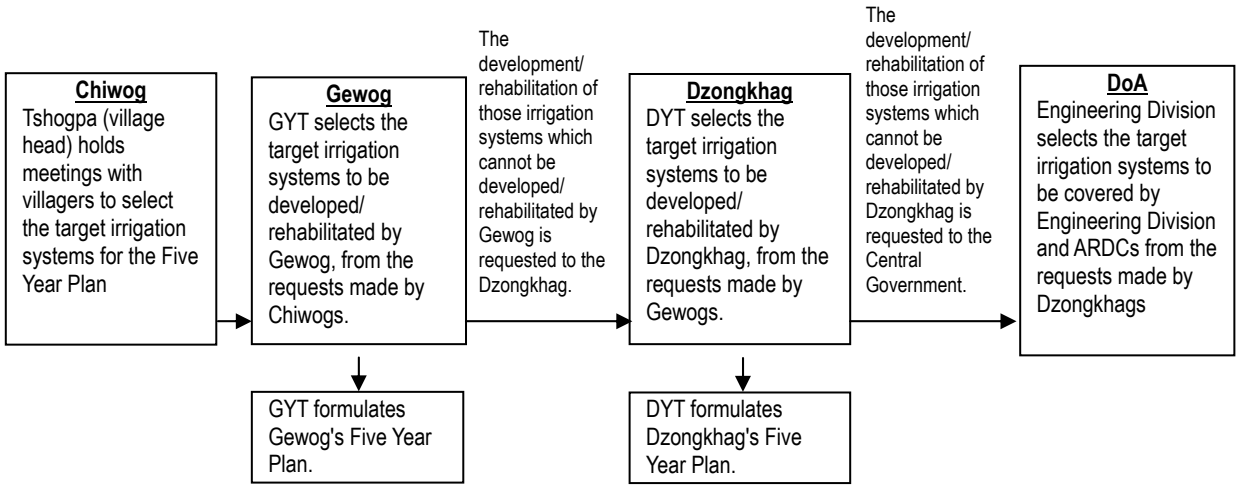
Under these conditions, it seems not feasible to achieve in time not only the target of 32,000ha of irrigated area but also the target of 32,000ha of harvested area of rice, including the area of rain fed cultivation.

(2) Progress in the Irrigation System Development/Rehabilitation and Possibility to Achieve the Target

The target of 32,000ha of irrigated area for rice cultivation would be achieved, according to the Eleventh Five Year Plan through development/rehabilitation of irrigation systems by all the Engineering Division, ARDCs and Dzongkhags.

The development/rehabilitation of irrigation systems is mainly led by Dzongkhags, while Engineering Division and ARDCs deal with those irrigation systems at a large scale, which goes beyond the implementation capacity of Dzongkhags. The distribution procedure of the development/rehabilitation projects of irrigation systems among institutions at different levels is illustrated in Figure 5.1.3. Based on the requests made by to-be-beneficiaries, Gewogs and Dzongkhags respectively, irrigation systems to be developed/rehabilitated are selected at their levels. Subsequently, Dzongkhags make requests to Engineering Division and ARDCs to develop/rehabilitate those irrigation systems with large command area, which Dzongkhags themselves cannot develop/rehabilitate due to technical or financial requirements. There are no technical/financial requirements for the requests to be made to Engineering Division and ARDCs, and even detailed surveys and cost estimation of the requested projects are not required.

Engineering Division has selected and worked on 108 irrigation systems for them and ARDCs, from the requests made by Dzongkhags to them in order to achieve the target set by the Eleventh Five Year Plan, that is to achieve 32,000 ha of the irrigated area for rice cultivation. These target irrigation systems were selected after approval of the Eleventh Five Year Plan. The selection criteria were: 1) the scale of command Area, 2) the number of beneficiary households, 3) the length of main canals, and 4) the number of officers assigned from the central government. However, the technical feasibility to develop/rehabilitate the facilities and economic impact which could be brought about by the expansion of irrigated area was not taken into account for the selection. According to Engineering Division, they have identified so far, among the 108 target irrigation systems, two (2) irrigation systems whose development/rehabilitation requires technical assistance from development partners, since their technical requirements go beyond the planning, design, implementation, and O&M capacity of Engineering Division and ARDCs. These systems are: Yudiri Irrigation System in Trashigang Dzongkhag and the irrigation canal extended from the Tharay River to the Hath River in Samtse Dzongkhag. There is also the possibility that there are actually more irrigation systems that require technical support from development partners in its development/rehabilitation. The Engineering Division of DoA does not have detailed information on all the 108 target irrigation systems, since they have not yet conducted the field surveys for all of them.



*GYT: Gewog Yargye Tshochung: a committee headed by Gup (Gewog head).

*DYT: Dzongkhag Yargye Tshochung: a committee headed by a Gup selected at the beginning of the meeting.

Source: the Survey Team (based upon the interview with Engineering Division)

Figure 5.1.3 Distribution Procedure of Target Irrigation Systems among Different Levels

The status of development/rehabilitation as of February 2017 by Engineering Division and ARDCs of the 108 target irrigation systems is shown in Table 5.1.3. After three and a half years from the launch of the Eleventh Five Year Plan, only the construction works for 14 irrigation systems have been completed. This means that only about 13% of the total 108 target irrigation systems have been done. The records of the number of irrigation systems which were annually developed/rehabilitated by Engineering Division and ARDCs earlier than July 2013 are not available, therefore it is difficult to estimate the average number of irrigation systems the Engineering Division and ARDCs can develop/rehabilitate annually without such evidences. However it seems that it is not feasible to complete the construction of the remaining 95 systems within next 1.5 years, if the current pace of construction works is maintained.

Table 5.1.3 Implementation Status of the Construction works of the 108 Target Irrigation Systems implemented by Engineering Division and ARDCs

Status	Construction completed	Construction on-going	Surveys, Planning and Designs completed	Surveys, Planning and Designs on-going	Nothing implemented	Total
Number of Irrigation Systems	14	2	34	6	52	108

Source: the Survey Team (based upon the interview with Engineering Division)

As shown in Table 5.1.3, the surveys, Planning and designs are completed for 34 irrigation systems out of the 108 target irrigation systems (equivalent to 31%), and the cost estimation for the same 34 systems have also been done. They are ready for tender and just waiting for the allocation of budget for the construction. However, the construction works for some of them may not be able to take off, even when the cost estimations are already prepared. Due to low accuracy in the designs and cost estimations, some previous construction works experience shortage in budget during construction period. To complete these works, the budget gaps are filled with the budget approved for other construction works that have not commenced yet. Therefore, it is confirmed that construction works of irrigation systems whose budget are reduced, would not be able to commence because their remaining budget is not enough to carry out the works.

The budget for the implementation of the 108 target irrigation systems was approved by the parliament, with the assumption that part of the approved budget would be always covered with financial support from development partners. Therefore, the actual amount of budget allocated to MoAF from RGoB every year has been much less than the amount approved. In addition to the capacity shortage of engineers of Engineering Division and of ARDCs, in the irrigation planning and irrigation facility design/construction/O&M, the budget shortage has been also affecting the implementation pace of the construction works of target irrigation systems.

5.1.4 Procedure of Irrigation System Development and the Performance of Each of the Related Institutions

(1) Survey, Planning, Design and Construction Supervision

According to Engineering Division, each of the engineers who belong to their division, ARDCs or the Dzongkhag Engineering Divisions is assigned to one of the irrigation systems, and in principle, the assigned engineer shall take the responsibility alone for the development/rehabilitation of the irrigation system by conducting survey, planning, design, cost estimation, tendering, construction supervision, supporting beneficiary farmers in the establishment of WUA, and completing the transferring procedure of the completed irrigation system to WUA. There is no legislation which stipulates the functions of the engineers, and thus, the above-mentioned functions are not officially obligated to the engineers. They are fulfilling all the functions alone in accordance with the custom.

An engineer shall conduct survey, planning, design, cost estimation, tendering and make the construction works started within a year, because the government budget allocated to those activities shall be executed within the same fiscal year. Each engineer handles some irrigation systems which are distant from one to another at the same time, and therefore, the frequency of field visits for survey or construction supervision remains low. Meanwhile, a project supported by development partners can be managed in accordance with the rules and procedures set by the development partners, and the procedure of the development/rehabilitation of irrigation systems can be undertaken over multiple years.

(2) O&M

According to the Engineering Division, once the construction works are completed, all the developed/rehabilitated irrigation systems should be handed over to WUA, and O&M to the systems after such a transfer should be given under the responsibility of the WUA as stipulated in the Bhutan Water Act 2011. Main actor to provide governmental support to WUA in its establishment and in the provision of O&M to the systems is Gewog Agriculture Extension Officers, as described in the National Irrigation Policy. However, for the 108 target irrigation systems, engineers of Engineering Division and of ARDCs also support the establishment of the WUA.

For the establishment of WUA in the 108 target irrigation systems, a series of training is given according to the O&M training manual by the engineers in charge of O&M of Engineering Division, and in collaboration with the engineers of the same division or of ARDCs who are in charge of the target irrigation system. This manual explains how to operate the irrigation system, how to establish WUA, how to maintain the system, and so on (Table 5.1.4). There are two different ways to provide the training to beneficiary farmers at the establishment of WUA 1) direct training to beneficiaries in collaboration with the Gewog Agriculture Extension Officers; or 2) through the training to Gewog Agriculture Extension Officers, so that the trained Gewog Agriculture Extension Officers can

subsequently provide the training to the beneficiary WUAs. In the O&M training, the engineers explain the functions and the structure of the irrigation system by utilizing concrete instructions. For example, the engineers explain that washing clothes at upper stream by storing water flow temporarily may cause shortage of water at lower stream or in order to protect the surface of canals in good conditions, it is necessary to keep water flow at a certain volume even during non-irrigation period.

Table 5.1.4 Contents of the O&M Manual

Module	Contents
1: AWARENESS ON GENERALITIES	1: Introduction to Objectives and Training Sessions 2: Awareness on Policy and Acts
2: IRRIGATION OPERATION AND MAINTENANCE, AND BENEFICIARIES' ROLES	3: Identification of Problems 4: Maintenance Types and Beneficiaries Roles 5: Water Distribution and Supply System 6: Catchment Management and Beneficiaries Roles
3: FORMATION OF WUAS OR ALTERNATIVE INSTITUTION	7: Identification of Solutions and the Responsible 8: Identification of Key Responsible Persons and their Roles
4: SCHEME MAINTENANCE FUND AND BANKING	9: Scheme Maintenance Fund Accumulation 10: Accounting and Banking
5: MONITORING AND REPORTING	11: Monitoring and Reporting
6: CONFLICT MANAGEMENT	12: Conflict Resolution
7: CONSTITUTION AND BY‐LAWS FORMULATION	13: Annual Working Calendar 14: Formulation of Constitution and By‐laws 15: Nomination and Election of Key Responsible Persons
8: SUSTAINABILITY	16: Dependency and Sustainability 17: Evaluation Tools

Source: Training Manual Operation and Maintenance of Irrigation Scheme by Water User Associations and Beneficiaries, Engineering Division, 2013

Among the 14 irrigation systems whose construction works have been already completed, as shown in Table 5.1.3, only WUAs of 3 irrigation systems were given the training in O&M by the engineers of Engineering Division and/or of ARDCs (Table 5.1.5). This situation has been caused by the shortage in the number of engineers who can provide the training as well as shortage in the budget for training. According to an engineer in charge of O&M of Engineering Division, he is currently the only engineer assigned to be in charge of O&M within the division. It will be required to assign at least one focal person in O&M to each of the three ARDCs in addition to himself, so that there will be four engineers in total. They could provide necessary training in O&M effectively in tandem with the development/rehabilitation of the irrigation systems.

*Hereinafter in this report, the term "WUA" is applied to mean a group with its own regulations covering all the items instructed by the O&M Manual. On the other hand, the term "traditional Water Users Group (WUG)" is applied to mean a group without any regulations or with its own regulations which do not cover such items.

Table 5.1.5 O&M Training Implementation Status in the 14 irrigation systems

O&M Training Implementation Status by Engineering Division and/or ARDCs	Status of WUA	Number of Irrigation Systems
Direct Training to WUA	Not established yet	0
	Already Established	1
TOT through the Training to Gewog Agriculture Extension Officers	Not established yet	2
	Already Established	0
Not Implemented	Already Established*	1
	NA	10

*WUA was established in this irrigation system without training by Engineering Division and/or ARDCs or Gewog Agriculture Extension Officer
Source: the Survey Team (based upon the interview with Engineering Division)

In order to develop irrigation systems, the challenges in O&M should be identified and analysed so that such challenges can be addressed by modification of facility structure. The activities of WUA are annually reported to DAO and the Dzongkhag Engineering Divisions by Gewog Agriculture Extension Officers, and DAO reports it to the Engineering Division. However, the Engineering Division has no responsibility and there is no officer in charge to give a follow-up to the O&M of each irrigation system. Thus, Engineering Division does not have a clear picture of the situation of O&M in each irrigation system.

5.2 CURRENT SITUATION AND CHALLENGES OF THE IRRIGATED AGRICULTURE

(1) Advantages of the Irrigated Agriculture in Bhutan

The main purpose of irrigation in Bhutan is to provide supplemental water supply to paddy rice cultivation in the rainy seasons. Any data which shows the comparison of the unit yield of rice under rain fed conditions with that under irrigated conditions in Bhutan are not available. As a reference, the results of a similar comparison in Malaysia are shown in Table 5.2.1. In this experiment, the unit yields of rice in different depths of inundation were compared, and the results show that unit paddy yield increased by 24 - 40 % when irrigated. In addition, as described in "2.1 Natural Conditions", rainfall during the dry season in Bhutan is too little, thus cultivation of crops is impossible without irrigation in the dry season. Irrigation is therefore the key to increase the crop productivity in Bhutan.

Table 5.2.1 Results of Experimental Rice Cultivation in Different Depth of Inundation in Malaysia

Division	Depth of Inundation (cm)	Yield (g /Tank)	Percent (W/N) (%)
Non-irrigation (N)	0	495	100
Irrigation (W)	6	695	140
	13	671	136
	26	613	124
	Average (6 - 26)	660	133

Source: *Kaigai Kyouryoku Hyakkou*, editied by Kenichiro Kamimura, et al, Japanese Institute of Irrigation and Drainage (JIID), August 1998

(2) Situations of the Double Cropping of Rice

The Eleventh Five Year Plan (2013 to 2018) describes the possibility of the implementation of the double cropping of rice in Samtse Dzongkhag, as well as the importance of its implementation in Wangdue Phodrang Dzongkhag. The implementation will be limited to low-altitude area since warm climate in winter is one of the requirements for the double cropping of rice. The NIMP indicates one of the possible cropping patterns in wet sub-tropical zone at low altitude (100 – 600m of altitude) of the two-times rice cultivation: the first cycle with transplanting in July - harvesting in November and the second cycle with transplanting in February - harvesting in June. The two Dzongkhags mentioned above meet this climate conditions.

On the other hand, actual implementation of the double cropping of rice is limited to a small part of the southern area only, although the total area which meets the climate conditions covers a much larger area. According to Engineering Division, main obstacles for expanding the double cropping area are: 1) river discharge in the rainy seasons is insufficient to irrigate all the command area and it leads to un-equity among the beneficiaries (some farmers can implement the double cropping while others cannot); 2) the early-ripening variety for the double cropping has been promoted, but not yet available for many farmers. Regarding 2), early-ripening variety was developed exclusively for the double cropping and no farmer has used this variety for single cropping.

(3) Production of Rice, Maize and Vegetables

As already described in "2.3 Situation of Agriculture", the planted area of maize has also decreased along with the decrease of the planted area of rice. Likely, the planted areas of other major staple cereals have also decreased, although their total production have increased thanks to an improvement on the unit yield. The Eleventh Five Year Plan (2013 to 2018) sets the target production of rice, maize and vegetables. The Table 5.2.2 shows the results of the comparison between the target production for 2015, which was regressively projected based on the 2018 target, and their actual production in 2015. Although maize has almost achieved the projected target production as of 2015, rice and vegetable fall behind with almost10 % less production.

Table 5.2.2 Target Production and the Achievement of Major Crops

Major Crops	Base of the Production (MT)	Target Production (MT) at 2018	Regressive Target at 2015 (MT)	Actual Production in 2015 (MT)	Production in 2015/ Regressive Target (%)
Rice	78,730	98,894	90,828	80,261	88
Maize	79,826	88,365	84,949	83,714	99
Vegetable*	44,650	65,204	56,983	52,063	91

Note*: Asparagus, Chilli, Cabbage, Cauliflower, Carrot, Radish, Turnip, Beans, Peas, Tomato, Broccoli, Eggplant, Ladyfinger, Green leaves, etc,
Source: the Survey Team (based upon the Eleventh Five Year Plan and the Agriculture Statistics 2015, MoAF)

5.3 CURRENT SITUATION OF IRRIGATION SYSTEMS

5.3.1 Target Irrigation Systems for Field Survey

In order to confirm the current situation and challenges on individual irrigation systems, field surveys for existing irrigation systems were conducted. The target systems were selected based on the combination of the conditions shown in Table 5.3.1 and such combination shall be made by conditions as much different as possible. Finally, eight irrigation systems shown in Figure 5.3.1 and Table 5.3.2 were selected through the discussion with Engineering Division.

Table 5.3.1 Conditions to Select Target Systems for Field Survey

Items	Condition
1) Category of irrigation systems in NIMP	Hilly Scheme / Valley Bottom Scheme / Foot Hill Scheme
2) Contents	New construction / Rehabilitation
3) Progress	Construction completed / Construction on-going / Survey, Plan and Design completed

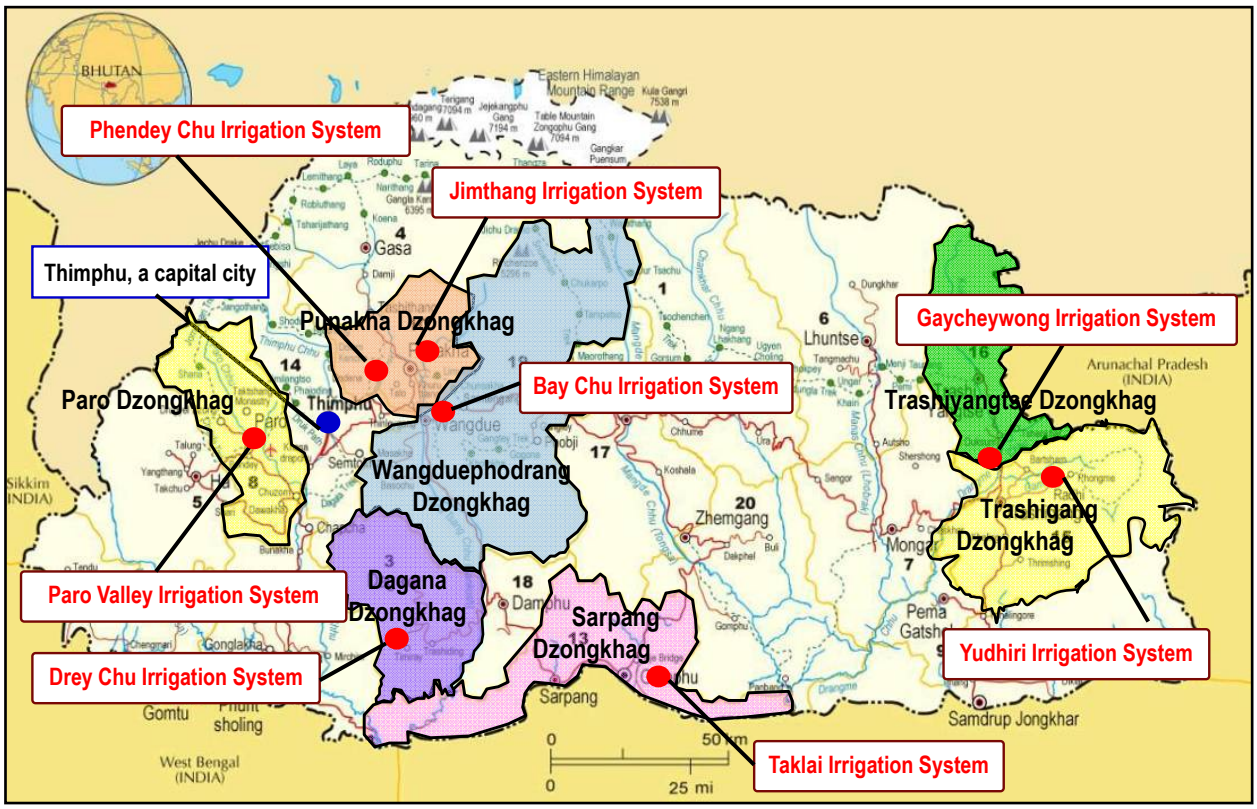


Figure 5.3.1 Target Irrigation Systems for the Field Survey

Table 5.3.2 Target Irrigation Systems for the Field Survey

Name of System	Dzongkhag	Gewog	Category	Command Area (acre)	House holds	Water Source	Main Crop		Contents New: New construction Re: Rehabilitation		Progress*	WUA	Main implementation Agency	Reason for selection
							Rainy Season	Dry Season						
(1) Yudhiri Irrigation System	Trashigang	Radhi	Hilly Scheme	1,304	652	Yudhiri River (Perennial)	Rice	Vegetables	Re	- Headworks (new) - Canal (Re)	*Field survey is conducted in the Survey	Traditional WUG	-	1
(2) Taklai Irrigation System	Sarpang	Sershong and Chuzagang	Foot Hill Scheme	3,308	530	Taklai River (Perennial)	Rice	Rice Maize	Re	- Headworks (new) - Headrace canal (Re) - Sedimentation Pond (new)	1	Established	Japanese Government	2
(8) Paro Valley Irrigation System	Paro	Tsento, Lango, Dotey, Shari, Wangchang, Hore, Luni, Shaba	Valley Bottom Scheme	1,032	-	Paro River Dotey River (Perennial)	Rice	NA	New	- Headworks (new) - Canal (Re) - Farm road (new) - River bank protection (new) - Bridge (new)	1	Established	Japanese Government	3
(4) Drey Chu Irrigation System	Dagana	Kana	Hilly Scheme	300	70	Drey Chu River (Perennial)	Rice Cardamom	Maize Cardamom	New	- Intake facility (new) - Canal (New)	2	Under Establishment	RGoB (ARDC Bajo)	4
(3) Bay Chu Irrigation System	Wangdue phodrang	Thedtsho	Valley Bottom Scheme	420	40	Bay Chu River (Perennial)	Rice	Vegetables	Re	- Intake facility (new) - Canal (Re)	2	Under Establishment	RGoB (ARDC Bajo)	5
(7) Phendey Chu Irrigation System	Punakha	Talog	Hill Scheme	351	400	Teobae_rongchhu River (Perennial)	Rice	NA	Re	- Intake facility (new) - Canal (Re)	3	Established	RGoB (ARDC Bajo)	6
(5) Jimthang Irrigation System	Punakha	Dzomi	Valley Bottom Scheme	365	200	Shanga Phoju River (Perennial)	Rice	Wheat Vegetables	Re	- Canal (Re)	3	Traditional WUA	RGoB (ARDC Bajo)	7
(6) Gaycheywong Irrigation System	Trashiyangtse	Jamkahr	Valley Bottom Scheme	30	50	River (Perennial)	Rice	NA	Re	- Canal (Re)	Plan completed	Traditional WUA	Beneficiaries	8

*1.Construction Completed, 2. Construction on-going, 3.Survey, Plan and Design Completed

** 1. Having highest priority among 108 irrigation systems in Eleventh Five Year Plan, 2. Foot Hill Scheme (Construction completed), 3. Valley Bottom Scheme (Construction completed), 4. Hilly Scheme (New construction on-going), 5. Valley Bottom Scheme (Rehabilitation on-going), 6. Hilly Scheme (Survey, Plan and Design completed), 7. Valley Bottom Scheme (Survey, Plan and Design completed), and 8.Rehabilitation woks by beneficiaries

5.3.2 Current Situation of each Irrigation System

The following are the current situation and challenges of individual irrigation systems confirmed through field surveys. Considering the possible identification of challenges for future irrigation development, confirmed situation and challenges are summarized according to the viewpoints below.

(1) Points to be noted on the development of irrigation systems (identified through investigation of existing irrigation systems)
(2) Survey, Planning and Design situations of the existing irrigation systems
(3) Construction/Construction supervision situations of the existing irrigation systems
(4) O&M situations of the existing irrigation systems
(5) Development situations of agriculture environment in the existing irrigation systems

On this Chapter, descriptions are made on the result of the field surveys on targeted irrigation systems except for Yudhiri Irrigation System which is described in Chapter 6.

(1) Points to be Noted on the Development of Irrigation Systems (Identified through the Investigation of Existing Irrigation Systems)

Points to be noted on the development of irrigation systems in Bhutan are confirmed through field surveys. Target irrigation systems are Taklai and Paro Valley Irrigation Systems where construction have been completed, and Gaycheywong Irrigation System where renovation activities are conducted by the beneficiaries.

1) Taklai Irrigation System

Taklai Irrigation System was rehabilitated in 2015 by Japanese Grant Aid aiming to supply supplemental irrigation water in the rainy season and to realize rice double cropping.

Beneficiaries have constructed temporary guiding dike by rocks/stones/sands to take water from the Taklai River. However, this dike was being washed away by flood year after year. Beneficiaries had to construct this dike every year but construction cost was high. Under these conditions, construction of a permanent intake (headworks) was requested.

Before Rehabilitation　　After Rehabilitation

Figure 5.3.2 Intake Structure of Taklai Irrigation System

Since box culvert canal is blocked by rocks/stones/sands, beneficiaries take water through manholes installed at the top of the box culvert canal.

At the headworks and its apron part, erosion is observed by maximum of about 12 cm.

Figure 5.3.3 Water Intake through Manhole

Figure 5.3.4 Erosion on the Apron Concrete

River bed slope at headworks is steep, about 1/60. Furthermore, it is confirmed through the interview with the beneficiaries and the Engineering Division that the period from the beginning of rain to the occurrence of a flood is short, and flow amount and water level increase rapidly. Additionally, it can be assumed that river bed materials consisting of large rocks are delivered by middle/large-scale flood.

From the interview with the person in charge of design of headworks and canals in the basic design stage, he confirmed in the basic design stage that the Taklai river flow became muddy in case rainfall continued for a few days through the interview with the beneficiaries. Furthermore, since some bare lands were confirmed within the catchment area through the examination of satellite images, it was suspected that rocks/stones/sands were produced from those bare lands by heavy rain and delivered by flood. Therefore durability of the facilities and measures to mitigate damage by the rocks/stones/sands were set as key points for the design.

Durability of the facilities

- In order to avoid damages on the facilities caused by floods and rocks/stones/sands delivered by flood, no projection is designed. If heading up of the facilities is required to intake and deliver water, heights of the heading up shall be as minimum as possible.
- In order to avoid damages on the facilities caused by floods and rocks/stones/sands delivered by flood, high strength concrete is adopted to the headworks and its apron part where impact by the rocks is expected to become serious.
- Steel train rails are adopted at the surface of the apron part of the headworks, where impact by the rocks/stones/sands delivered by flood is expected to become serious.
- Slopes along the canal have weak geological condition and can easily collapse due to heavy rain. It is suspected that damage on the canal and block of the canal by rocks/stones/sands will happen if the canal type is open. Therefore, box type instead of open type is adopted to the canal structure.

Measures to mitigate damage by rocks/stones/sands

- Slope gradient of the collection ditch under the bar screen is enough to wash out the stones and sands flowing into through the bar screen.
- Sand discharge facility, including sand discharge gate and sedimentation pond, is effective. However change of topographic conditions by excavation to construct these facilities may lead

the drastic change of the flood stream conditions. While even if sand discharge gates are installed, gate keepers cannot approach to the gates due to the topographic condition. Therefore, torrent intake structure, which does not require any operation at headworks point, is selected and sand discharge structures and sedimentation ponds beside headworks are not planned.

- Slope gradient of the box culvert canal bed is enough to deliver stones and sands flowing from the collection ditch.

Meanwhile, the said person in charge of design of headworks and canals in the basic design stage evaluated the situations of the System as of February 2017 as follows.

- Local erosion is confirmed on the concrete of the headworks and its apron part, but not on the bar screen and steel rails. Erosion is inevitable on the concrete, even if it has high strength, thus continuous maintenance activity to cast concrete is required after erosion proceeds to a certain extent.

- Bar screen works well to prevent big stones from flowing into the collection ditch, but deposition at the collection ditch and canal blocking by stones and sands is confirmed. It can be estimated that the following phenomenon, which is different from the condition considered at the design stage, are suspected: i) huge volume of stones and sands flew into momentary, ii) disturbance of water flow and speed lowering happened at the curve portion of the canal. These events might lead the deposition and blocking of the canal.

- At the basic design stage, there were no meteorological stations within the catchment area and no river discharge and water level data were observed as well. Therefore the flow condition of the Taklai River was assumed based on the interview with beneficiaries and data of another river having similar natural conditions to the Taklai River. As a result, these assumptions did not coincide with actual flow situation of the Taklai River. However it was difficult to evaluate flow condition quantitatively without any observed data, and qualitative evaluation was the only way.

- Beneficiaries construct guiding dike to take water. Based on the interview with them, the stream becomes stable and easy to guide after construction of the headworks. The headworks might act as drop structure and work to stabilize the stream flow.

As already described in “2.1 Natural Conditions”, in general, river bed is steep and land is in weak geological structure in Bhutan. Additionally the meteorological and discharge measurement stations are limited. Therefore, there may be many rivers which conditions are similar to the Taklai River, hence, to take water from a river with these conditions, the following examinations are required to mitigate damage by rocks/stones/sands delivered by flood.

i) Long term meteorological/hydrological observation

Assumption of hydrological conditions of the target river by applying data observed at the other river in similar natural condition may cause differences with actual condition of the target river. It shall be made by reflecting long term observation of the discharge, water depth, and delivered rocks/stones/sands conditions at intake point as well as rainfall within the catchment area. And planning and design of the facility shall also reflect such long-term observation.

ii) Layout of intake facility

Headworks of Taklai Irrigation System was constructed at the location where river width is narrow and

basement rock appears. Such condition of location is suitable to construct the facilities because scale of facility can be small and that is economically effective. However, flood and rocks/stones/sands delivered by flood are concentrated also on this kind of narrow point. Meanwhile, in order to avoid damage by rocks/stones/sands delivered by flood, layout of headworks shall be required in a location where river width is relatively wide and riverbed slope is gentle. However the scale of the facility will become larger in such condition.

To prevent rocks/stones/sands flowing into the canal with flood, installation of intake gate for intake facility is effective. However, gate can be installed in case 1) running off by flood will not happen, 2) damage by the rocks/stones/sands delivered by flood is limited, and 3) proper gate operation can be done even during flood.

iii) Measures to mitigate rocks/stones/sands volume delivered by flood

In order to lessen damage on the facility by rocks/stones/sands delivered by flood, considerable measures such as slope protection works on the mountain slopes, river bed protection to control the movement of rocks/stones/sands, check-dam to capture delivered rocks/stones/sands, river banks protection works to prevent river bank from erosion, and those combination should be effective. However, to deal with huge volume of rocks/stones/sands, huge scale facilities are also required.

iv) Implementation of continuous O&M

Implementation of O&M on the premise of the construction of the guiding dike and repairing erosion on the facilities is considered as an effective measure instead of measures by permanent facilities. Activities such as 1) construction of the guiding dike, 2) dredging of stones and sands in every year, and 3) periodic rehabilitation of facilities can be considered as concrete O&M activities. Furthermore, the following are considered as measures to simplify these maintenance activities: 1) construction of the drop structures to stabilize the stream flow; 2) installation of the screen at the intake facility to control the amount of stones flow into canals; and 3) adoption of the high resistant material to expand the durable years of the facilities. However, huge amount of maintenance cost would be required to deal with the huge volume of intake water, stones and sands, and serious erosion.

v) Intake water from the other water sources

Taklai irrigation system once became dysfunctional due to the blockage of box culvert canal. An existing intake facility was not removed by the rehabilitation works because beneficiaries requested to retain the existing intake facility. They would like to use this intake facility in case water volume provided from new headworks was not sufficient. When box culvert canal is blocked, this existing intake facility could act as the alternative intake facility and delivered water to some parts (lower area) of the command area. Without this intake facility, the System might have been dysfunctional totally.

Therefore, several intake sources may work to avoid the total dysfunction of the system. The combination of some water sources such as tributaries, spring and groundwater might be effective to mitigate the risk of the System of being dysfunctional totally.

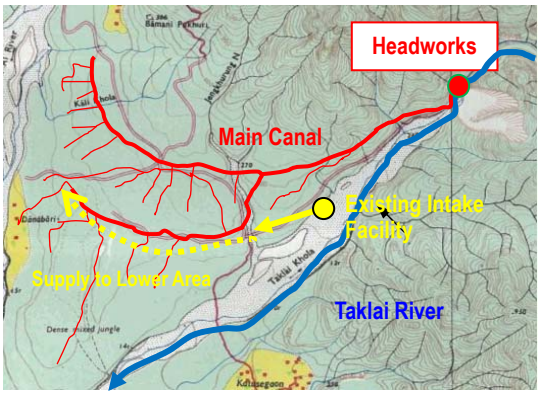


Figure 5.3.5 Situation of Intake through Existing Intake Facility

Figure 5.3.6 shows the pumping station of domestic water for Gelephu city as sample of an alternative water source. This pumping station is located 150 m far from the Mao River, which the Taklai River joins, and pumps up the groundwater. This pumping station has not been damaged by flood or rocks/stones/sands delivered by flood because the location of that is far from the main stream

Figure 5.3.6 Pumping Station for Domestic Water

vi) Structure which can be locally rehabilitated

In Bhutan, all the developed irrigation systems are transferred to WUA, which in turn shall manage the systems. However, repair for damages on the facilities which WUA cannot address is requested to Gewog, Dzongkhag and Engineering Division (National Government). During the rehabilitation works of Taklai Irrigation System, O&M training for the beneficiaries (soft component of the Grand Aid) by a Japanese expert was conducted. During the training, the ways to decide institute to repair damage, (WUA done by themselves, request to Gewog, Dzongkhag and Engineering Division) was lectured.

Although blockage of the box culvert canal and erosion on the headwoks and its apron part were not assumed at the training, WUA identified that the repair works are beyond their capacity and requested the repair to be handled by Gewog, Dzongkhag and the Engineering Division. However the said government agencies also could not repair due to technical and financial difficulties.

Likewise, if there is damage that is beyond the repair capacity of WUA, and Gewog, Dzongkhag and Engineering Division cannot deal with it as well, that irrigation system will be left with problems. In this case, irrigation water cannot be delivered and deterioration of the system will continue. Therefore, to avoid such situation, immediate repair works is required after identification of the damage. To realize this, the structure of irrigation system shall be kept within technical range of Bhutan, or capacity range of maintenance by WUA as much as possible.

For each of the aforementioned six countermeasures, initial costs to develop facilities and maintenance costs are required. Those amounts are much different depending on the scale of facilities and the contents of maintenance activities. Therefore, combination of aforementioned countermeasures, including implementation by single countermeasure, shall be examined based on the situation of water

source. To select the appropriate combination, lifecycle cost can be an effective criterion.

2) Paro Valley Irrigation System

Paro Valley Irrigation System was constructed from 1989 to 1995 as a part of Paro Valley Integrated Agriculture Development project under the Japanese Grand Aid. Total ten (10) intake weirs were constructed. Field survey was conducted on three out of ten weirs.

i) Intake weir-1

This intake weir was constructed by concrete at about 5.5 km downstream of the junction of the Paro River and the Dotey River. The river width at intake point is about 30 m and river bed slope is about 1/140. After construction, this weir was washed away and beneficiaries constructed another weir by gabions. However, this gabion weir was also washed away, and beneficiaries constructed temporary guiding dike to take water. According to the satellite images, it is assumed that the original concrete weir was washed away during the period between 2006 and 2012. Since cyclone Aila attacked Bhutan in 2009 and caused serious damage including twelve deaths, the original concrete weir might have been washed away by this cyclone. The gabion weir constructed by beneficiaries was washed away during the period between 2012 and 2014.

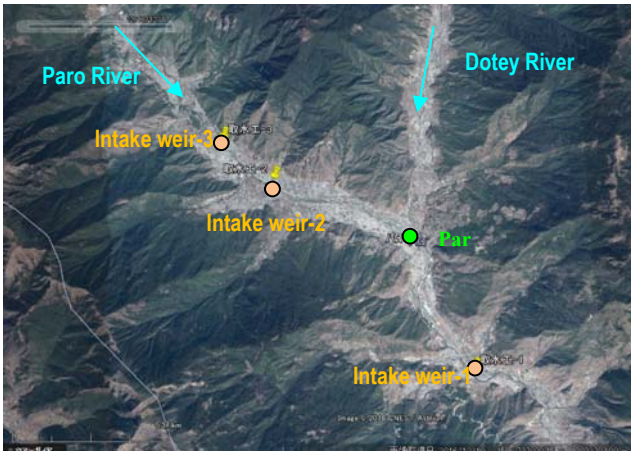


Figure 5.3.7 Location of Intake Weirs

4th of March 2006 12th of December 2012 10th of April 2014

Figure 5.3.8 Satellite Images at Intake Point

Figure 5.3.9 Past Gabion Weir (Intake Weir-1)

Figure 5.3.10 An Example of Gabion Weir

According to the interview with Engineering Division, the reasons why the original concrete weir was washed away were flood and illegal sediment collection at the downstream side of the intake point. However, any surveys or analysis to identify the actual reasons have not been conducted. Also original weir was completely washed away and the actual reasons cannot be identified from the present situation.

Temporary guiding dikes were always being washed away by flood and beneficiaries had to construct this dike more than one time per year. Since construction of this temporary dike requires high cost, the WUA has requested Gewog, Dzongkhag and Engineering Division to construct permanent weir.

While from the interview with Engineering Division, engineers of the Division cannot construct weir like the original one because they do not have appropriate technical knowledge on how to construct weir across the river.

ii) Intake weir-2

The location of intake weir is about 5 km upstream of the junction of the Paro River and the Dotey River. The river width at intake point is about 30 m and river bed slope is about 1/75. As of February 2017, beneficiaries construct temporary guiding dike and take water. According to the satellite images, it is assumed the original weir was washed away before 2006 because no weir is captured on the image of 2006.

Figure 5.3.11 Guiding Canal (Intake Weir-2)

From the interview with Engineering Division, the reason why it was washed away was illegal sediment collection at downstream of the weir, same as with Intake weir-1. However any surveys or analysis to identify actual reasons have not been conducted. The original weir was completely washed away and the actual reasons cannot be identified from the present situation.

Same as with Intake weir-1, WUA has requested Gewog, Dzongkhag and Engineering Division to construct permanent weir but the engineers of Engineering Division cannot construct weir like the original one because they do not have appropriate technical knowledge on how to construct weir across the river.

iii) Intake weir-3

A concrete weir with fish passage was constructed at about 2.5 km upstream of Intake weir-2. The river width is about 20 m at intake point and river bed slope is about 1/30.

The right side of weir does not exist and mainstream is located at right side. Sedimentation is confirmed in front of inlet located at the left river side. It is assumed that this sedimentation is caused by low flow velocity on the left side of river, and some dredging activities would be required in future. Serious damages on the weir are not confirmed.

Based on the interview with Engineering Division, this weir has worked properly and they have no plan for rehabilitation. However it is difficult to judge from the present situation if there would be any problems, such as washing away in the future like what happened to Intake weir-1 and 2.

Figure 5.3.12 Weir and Inlet (Intake Weir-3)

According to Figure 5.3.7, Intake weir-1 is located downstream of the junction of the Paro River and the Dotey River and others are located upstream side of the junction. This implies the flood volume at Intake weir-1 point is bigger than that at Intake weir-2 and 3 points. This might be the reason that Intake weir-1 was washed away but Intake weir-3 does not have serious damage even if the river bed slope at the point of Intake wier-3 is steeper than at the point of Intake weir-1.

While both Intake weir-2 and 3 are located upstream side of junction, only Intake weir-2 with more moderate river bed slope was washed away. In general, flood damage on the weir becomes small as its river bed slope becomes moderate. Since this general situation cannot be confirmed, it is assumed the flow condition changes drastically even if its river bed slope is moderate.

Thus, for the rehabilitation of damaged irrigation systems, it is required to analyze the reason for its damage/dysfunction and to adopt facility structure to avoid re-occurrence of same damages. However, Engineering Division has not collected any information related to the damage/dysfunction on the irrigation system.

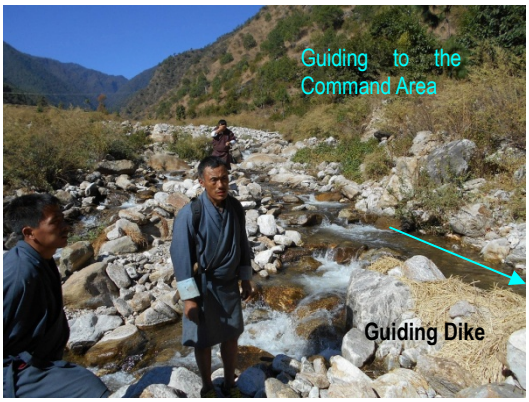
3) Gaycheywong Irrigation System

The beneficiaries of Gaycheywong Irrigation System have renovated intake facility and canals by themselves.

The river width at intake point is about 90 m and beneficiaries construct temporary guiding dike to take water from the river. According to the interview with Engineering Division, if huge flood occurs, this temporary dike is washed away, river bank erosion occurs, and alignment of the main river stream changes.

Beneficiaries have constructed temporary guiding dike every year according to the changes of natural situation by flood, such as change of the mainstream of the river, and have never constructed any permanent structure at intake point. Although intake structure is a temporary one, it can still take and deliver sufficient water to the command area.

In case river width at intake point is wide or target command area is small (= required water volume is small), this kind of intake structure which is easy to construct and easy to repair may have economical advantage as compared to the permanent structure. Thus the conditions of water sources and command area shall be taken into account for the planning and design of the irrigation facilities.



Intake point

Command Area

Figure 5.3.13 Condition of Gaycheywong Irrigation System

(2) Survey, Planning and Design Situations of the Existing Irrigation Systems

Items to be considered for survey, planning and design are regulated in Japanese standard, Plan and Design Standard for Land Improvement Project (hereinafter referred to as "Japanese standard"). In order to confirm the situation of survey, planning and design in Bhutan, each activity is assessed in comparison with the items stipulated in Japanese standard.

1) Survey

In Japanese standard, items to be surveyed are i) items related to planning, ii) items related to design and construction, iii) items related to O&M and iv) the others (Table 5.3.3).

Table 5.3.3 Items to be Surveyed Stipulated in Japanese Standard

Survey Items	i) Items related to planning	ii) Items related to design and construction	iii) Items related to O&M	iv) The others
Outline	Outline of basic plan, Command area, Necessary information to formulate farming and land use plan, water supply plan and water resources plan	Basic natural condition information necessary for design and construction	Maintenance way and location of maintenance facilities	- Environmental impact by the construction etc.
Main Target	- Range of Command Area - Discharge of water source - Cropping pattern	- Topography - Geological condition	- Maintenance way after handing over	- Forest area - Target for resettlement

i) Items related to planning

To decide the range of command area, topographic map is required, however there are no irrigation systems on which the range of command area is decided by topographic map. The range of command area of some irrigation systems are assumed by 1) Google Earth, 2) through interview with beneficiaries, and 3) utilizing cadastral map.

As for the discharge of water source, as already described in "2.1 Natural Conditions", the number of meteorological observation stations is limited and there is no irrigation system with catchment area having meteorological observation station. For some systems, rainfall data utilized for planning is data of the station located a dozen of km far from the command area. While discharge observation stations in Bhutan are located at big rivers only and there is no irrigation system with a water source having past discharge records. Even if discharge measurements are conducted, the frequency is only one time during the dry season except Phendey Chu Irrigation System where discharge measurement has never been conducted.

Within the command area of Drey Chu Irrigation System, some springs can be confirmed. Since water

amount in the dry season of Drey Chu River, which is the main water source of the System, is small, ARDC Bajo engineer decided to use these spring waters for irrigation and decided the alignment of main canal to capture these spring water. However, discharge measurement of springs has not been conducted and the canal does not have structures to capture spring water.

Cropping pattern has been confirmed through the interview with beneficiaries at the initial meeting to explain the contents of a project but cultivated area of each crop have not been confirmed.

ii) Items related to design and construction

Facilities are laid out without utilizing topographic map so that modification of facility layout occurs sometimes during construction (such as in Drey Chu Irrigation System). Furthermore, according to the interview with Engineering Division, a canal was constructed by lot but design modification happened at an upstream point (elevation of structure was changed lower than designed one). As a result, some part of the canal bed have negative slope and cannot deliver water properly.

Geological survey was conducted for only Taklai Irrigation System to identify the thickness of river bed materials. From the interview with Engineering Division, sinking of bridge feet happens at an irrigation system because any geological survey was not conducted and the bridge feet were constructed on the soft base rock.

iii) Items related to O&M

At the beginning stage of the project, engineers in charge conduct public consultation with beneficiaries. At that meeting, they explain about the contents of the project, consult with beneficiaries about the way to maintain the system, and decide the location and size of facilities especially distribution structures. In Taklai Irrigation System, a Japanese expert instructed how to identify the flow volume to the WUA.

Meanwhile, at Drey Chu, Bay Chu and Phendey Chu Irrigation Systems, scale (cross section) of distribution structures is designed as same as main canal aiming to guide all the water from main canal. This is because rotation irrigation plan was designed through consultation, so as the water to be supplied to each distribution structure according to the decided order (= only one distribution structure would be opened and the others would be closed)

iv) The others

For the new construction project, location of forest area and residential area are identified and facilities are laid out to avoid those areas as much as possible.

2) Planning

In Japanese standard, items to be planned are i) project objective ii) command area, iii) regional condition, iv) farming, land use, water supply and drainage plan, v) main construction works, vi) new construction/rehabilitation plan and construction method, vii) construction period, viii) construction cost and its detail break down, ix) management agency after handing over and x) economic evaluation.

Among the items above, situation of iv) farming, land use, water supply and drainage plan and vi) new construction/rehabilitation plan and construction method are summarized as below.

Farming plan, land use, water supply and drainage plan

In addition to the fact that the range of command area is decided by assumption, expected expansion

of irrigated area and its locations are also decided by assumption.

At Jimthang and Phendey Chu Irrigation System, although the volume of water source is assessed as insufficient to irrigate whole the existing command area, planned irrigated area to be expanded was 20% more than present one. Therefore, the designed structure may have more capacity than what is appropriate for the command area. Also, those systems may not provide planned water volume because water source may not have enough volume to irrigate all the command area.

At Drey Chu Irrigation System, target area for irrigation includes dry land for cardamom, and same water requirement for rice is adopted to cardamom because the ARDC Bajo engineer who in charge of the System do not have appropriate knowledge on the crop water requirement for cardamom. Therefore, facilities are overspecified because actual water requirement is less than designed one.

New construction/rehabilitation plan and construction method

For the rehabilitation project of Drey Chu, Bay Chu, Phendey Chu Irrigation Systems, the analysis of the reasons for problems on the existing facilities have not been conducted. For example, at Bay Chu Irrigation System, sedimentation flowing into canal is one of the main problems, however, analysis to identify the source of the sedimentation has not been conducted. Also, any countermeasures against the sedimentation are not taken into account for facility design.

3) Design

Japanese standard describes that design shall be made according to the standard with items to be followed, concrete contents, and also its explanation and sample design.

In Bhutan, design standard or design procedure manual to be followed are not developed. The latest manual is the "Irrigation Engineering Manual" developed under ADB in 2016. However, this latest manual is also positioned as a reference document. Manuals/standards utilized for design differs by engineers, and they have difficulties in understanding if the selected formula and coefficient are suitable to Bhutan’s natural condition or not when they apply such manuals/standards.

The interview with the Engineering Division reveals that, if an engineer has questions on design matters, he/she discusses with their colleagues. However, the work experience for irrigation development of the engineers is limited to maximum three years, and sometimes the questions remain unsolved. Although design review committee has been conducted for all of the design done by engineers of Engineering Division or ARDCs, items to be checked and its check sheet have not been developed. Additionally, work experiences for irrigation development of the reviewers are also limited, therefore, the function of the review committee is limited. As a result, a structure without any stability calculation has been constructed at Drey Chu and Bay Chu Irrigation Systems.

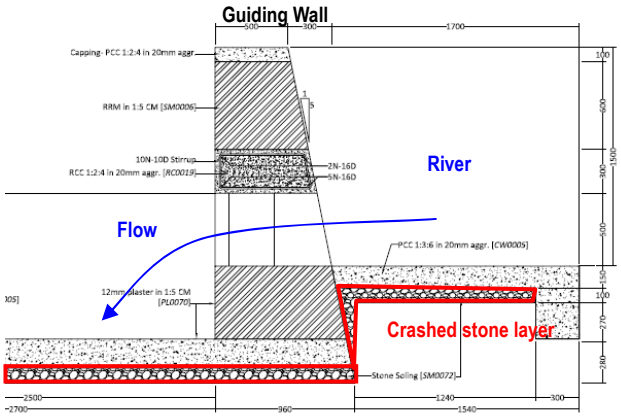
Engineers of Engineering Division and ARDCs have the capacity to design general civil structures and can design intake structure, canal and the other facilities independently. However, it is confirmed that they do not have appropriate technical knowledge on design from the view point of total water flow, intake - delivering - distribution.

Landslides are commonly observed almost all areas in Bhutan and damage on the canals by landslides can be confirmed in not only the target irrigation systems of this Survey but in many irrigation systems throughout the country. However, it is confirmed that engineers of the Engineering Division and ARDCs do not have technical knowledge about the countermeasure for landslides such as slide check works, which fix landslide by piles and anchors, and subsurface drainage works, which decrease

groundwater not to slide clod. Therefore, countermeasures for landslides itself have not been conducted. When landslide destroys canals, only pipes have been substituted for those broken parts.

Confirmation-1: Water proofing function of facility (Drey Chu Irrigation System)

At the basement of the guiding wall, crashed stone layer is designed. However, since crashed stone layer might be a water way and uplift force will affect the facilities, crashed stone layer cannot be adopted to the basement of the hydraulic facility. Additionally, base rock appeared from the shallow depth, and the contractor arranged crashed stone layer on the base rock according to the design drawings. The water proofing function of the base rock is relatively high and it is recommended to construct hydraulic facilities directly on the base rock. Furthermore, guiding wall is designed to touch the rock at the edge of upstream side but no treatment, such as chipping, at the touched point is arranged. Thus, it is confirmed that both ARDC Bajo engineer and the contractor do not have adequate knowledge on the importance of water proofing.



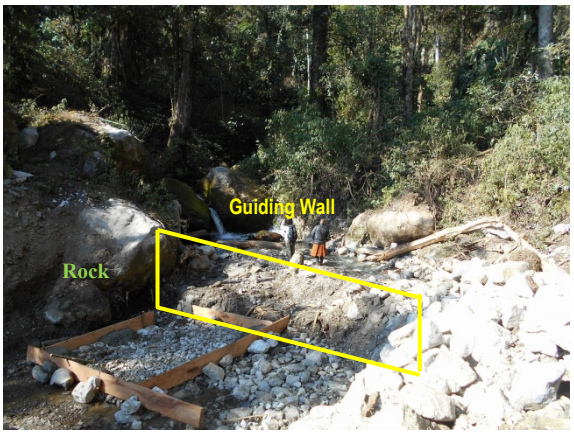


Figure 5.3.14 Structure of Guiding Wall (Drey Chu Irrigation System)

Confirmation-2: Facility design from the view point of flow (Bay Chu Irrigation System)

The size of the end point of main canal is bigger than that of the intake point. Canal cross section was designed according to the hydraulic calculation and original cross section of the end point was smaller than present one.

There is a siphon at the end point of main canal but it wasn't taken into account when the original canal cross section was designed. Therefore, once water was delivered to the end point of main canal, there was an overflow from canal because water head at the inlet of siphon was not enough. The canal walls were made higher after that. Thus, appropriate viewpoints of intake - delivering – distribution as the total water flow, and idea on keeping water head from intake to downstream terminal is required for the engineers of ARDC Bajo.

.

Intake point

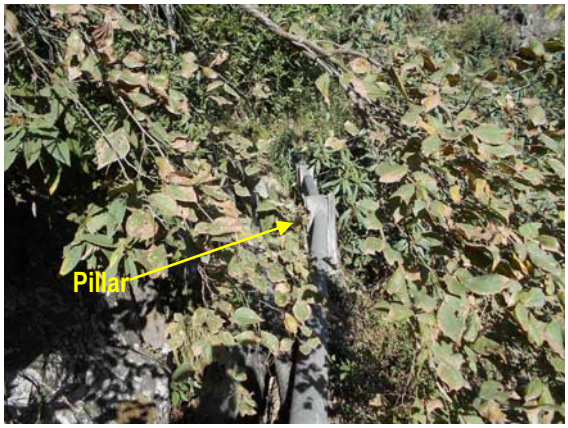
End Point

Figure 5.3.15 Canal Cross Section (Bay Chu Irrigation System)

Confirmation-3: Rehabilitation of canal damaged by landslides (Bay Chu and Gaycheywong Irrigation System)

Some parts of canal were damaged by landslides and pipes are substituted for the damaged parts at Bay Chu and Gaycheywong Irrigation Systems.

In Bay Chu Irrigation System, pipes are supported by pillars but they are unstable because basement of pillars are in the area of a landslide. While at Gaycheywong Irrigation System, since pipes are not supported by any structures, it tears by its self-weight and water leaks from the pipes. Although leaking causes additional landslide, no measures are arranged to address the leakage. Arrangement of soil bags or gabions as a basement for the pipes may be effective to mitigate the leakage, however there are no irrigation systems adopting those kinds of measures. According to the interview with Engineering Division, pipe tearing might be caused by not only the self-weight but also the low quality of the pipes.



Bay Chu Irrigation System

Gaycheywong Irrigation System

Figure 5.3.16 Pipes at Landslides Point

(3) Construction/Construction Supervision Situations of the Existing Irrigation Systems

Among the target irrigation systems for field survey, only Drey Chu and Bay Chu Irrigation Systems were under construction and the construction of Bay Chu has just started. Therefore, in this section, confirmed situations at Drey Chu Irrigation System and those confirmed through interview with Engineering Division are summarized.

1) Supervision frequency

An engineer of ARDC Bajo is the person in charge of Drey Chu Irrigation System. From Bajo to the site of Drey Chu Irrigation System is 56 km by direct distance and it takes two days to go from one site to the other. Therefore, at least three days are required for site visits including one day site investigation. Furthermore, since this engineer handles three more irrigation systems, he can go to the sites for the construction supervision less than 1 time/month.

2) Items for the quality management, its management methods and management standard values

No manuals/guidelines for the items for the quality management, its management methods and management standard values are developed. Since the engineer in charge decides the items to be managed and its method, items beyond the engineer's knowledge/capacity cannot be managed. Moreover, there is no check list of the items to be managed. The engineer in charge points out the items to be managed to the contractor only in case he/she finds any notice points at the site.

As already described, the frequency of supervision by the engineer in charge is very low. Therefore many structures are constructed without supervision of the engineer in charge. While the contractor does not record any results of quality management, the engineer in charge cannot confirm the quality of the structure constructed during his/her absence.

Confirmation-1: Additional water volume for concrete manufacturing

In the design drawings, volume ratio of cement, sand and gravel was mentioned for each concrete structure, such as 1:2:4. In Bhutan, concrete is managed not by the strength but by the ratio of materials like the aforementioned way.

Figure 5.3.17 Concrete Manufacturing Condition

Although, additional water volume largely affects the strength of the concrete, the contractor measures the volume of materials only by bucket but does not measure the volume of additional water. Additional water volume according to the volume ratio of cement, sand and gravel is regulated in Bhutan's standard; however, both ARDC Bajo engineer and the contractor are not aware of that. Based on the interview with the contractor, they set the additional water volume in accordance with the workability of constructions. In case of usage of machines such as a vibrator for concrete consolidation, they set additional water somewhat below. In case of usage of work force such as a trowel for concrete consolidation, they set more additional water. Thus, it is confirmed that both ARDC Bajo engineer and contractor do not fully recognize the importance of water volume to be added for the concrete manufacturing.

Confirmation-2: Waste containing to the gravel

Uniform sand is utilized for concrete manufacturing but gravel contains many wastes. From the interview with the contractor, those wastes were produced during manufacturing gravel by crushing, but the contractor utilizes the gravel without removing the wastes. Furthermore, the volume of gravel is measured without removing the wastes. Therefore, sand portion contained in the concrete is more than designed one and the strength of manufactured concrete might be less than expected. Thus, it is

confirmed that both ARDC Bajo engineer and contractor do not have appropriate understanding on that the containing of sand portion largely affects the strength of concrete.

Sand

Gravel

Figure 5.3.18 Sand and Gravel for Concrete

3) Construction Method

For the concrete, it is required to consolidate after casting to make its strength high. However, consolidation works for the concrete are not observed.

Figure 5.3.19 Concrete Casting

It is confirmed that both ARDC Bajo engineer and contractor know the importance of consolidation but do not have appropriate understanding on the strength/ weakness if no consolidation would be made.

(4) O&M Situations of the Existing Irrigation Systems

O&M situations of Bay Chu, Drey Chu, Jimthang and Gaycheywong Irrigation Systems where O&M is conducted by a traditional WUG, and those of Taklai Irrigation System where O&M is conducted by WUA are summarized as follows:

Confirmation-1 : O&M activities of traditional WUG

Before the beginning of irrigation water distribution, general assembly is conducted and all the members get together to clean canals, cut glasses around the facilities and discuss about the schedule of water distribution and its order. However, the memorandum of the meeting is not made. During irrigation season, canal managers called “water guards” operate facilities for water distribution, check the condition of the facilities through monitoring, and conduct minor renovation that can be managed by themselves.

When minor renovation needs work force, beneficiaries provide their manpower; however, if cost of material/machine is required, they request Gewog or Dzongkhag to provide necessary material/machine. Therefore, they collect water fee form the members only for the wedge of water guards. They manage accounting, but they do not audit nor report on the amount. According to the interview with a traditional WUG leader, the statute of the traditional WUG is not written and the rule of water distribution is not clear. Therefore, although arbitration on conflicts of O&M is managed by WUG, the arbitration sometimes takes long time to solve those problems.

According to the interview with Gewog Agriculture Extension Officers and water guards of the

traditional WUGs, they conduct O&M activities itemized in the Table 5.3.4.

Table 5.3.4 State of O&M Practices by Traditional WUG

Organization for O&M	General Assembly	Cleaning	Operation	Inspection	Repair	Water fee	Account	Audit	Report	Statute
Traditional WUG	△	○	○	△	△	△	△	×	△	△

Legend: ○Practiced ×Not practiced △Partially practiced
Source: the Survey Team (based upon the interview with Gewog Agriculture Extension officers and water guards in the surveyed irrigation systems)

Confirmation-2 : O&M activities of WUA

It has been a year since the transfer of the facilities to WUA of Taklai Irrigation System, and is now going into its second year of operation.

In Taklai Irrigation System, the former two WUAs were united into one WUA before transferring irrigation system to WUA. Engineering Division trained the WUA on O&M and prepared their constitution as well. Water fee has been collected from the members and the repair costs including the materials and machinery, excluding damage by disaster, has been covered from the collected fee.

According to the interview with Gewog Agriculture Extension Officers and water guards in Taklai Irrigation System, they practice the items of the Table 5.3.5.

Table 5.3.5 State of O&M Practices by WUA

Organization for O&M	General assembly	Cleaning	Operation	Inspection	Repair	Water fee	Account	Audit	Report	Statute
WUA	○	○	○	○	○	○	○	○	○	○

Legend: ○Practiced ×Not practiced △Partially practiced
Source: the Survey Team (based upon the interview with Gewog Agriculture Extension officers and water guards in Taklai Irrigation System)

Confirmation-3 : Issues to be addressed on O&M activities by traditional WUG

Table 5.3.6 shows issues to be addressed on O&M activities by traditional WUGs in the surveyed irrigation systems, which are recognized through the interview with Gewog Agriculture Extension Officers and beneficiaries.

Table 5.3.6 Issues to be Addressed on O&M in Each Irrigation System

Organization of O&M	Irrigation System	Issues to be addressed on O&M
Traditional WUG	Bay Chu	- Water conflict between upper stream and downstream - WUG does not grasp past repair cost
	Drey Chu	- WUG does not grasp past repair cost
	Jimthang	- Water conflict between upper stream and downstream
	Gaycheywong	- Ex post facto repair of irrigation facility

Source: The Survey Team (based upon the Interview with Gewog Agriculture Extension Officer in each irrigation system)

Bay Chu, Drey Chu, Jimthang Irrigation Systems are under construction or to be constructed, and existing traditional WUGs are to be reorganized into new WUAs before the completion of the construction.

"WUG does not grasp past repair cost" is an issue related to the fund of WUA establishment. According to the interview with Engineering Division, seed money for establishment of WUA is O&M cost for the moment including repair cost of the facilities and its amount can be decided by WUA. Also WUA can decide whether laying money aside before the expenditure is fixed or collecting money after the expenditure is fixed. The collection procedure is decided through discussions in each WUA.

Therefore, yearly cumulative data of repair cost is required to estimate the seed money. However, the

WUGs of Bay Chu and Drey Chu Irrigation Systems do not grasp the cost of repair because they have relied on their Gewog or Dzongkhag to provide such costs. The engineer of ARDCs in charge of the system is to support the reorganization of WUA including the provision of such kind of basic information.

In Gaycheywong Irrigation System, pipes are substituted for the parts of open canal damaged by landslides, however no supports for the pipes are installed. Without any supports such as by sandbags or gabions, the pipes may be broken by its self-weight and the replacement of a part of pipe would be required.

Confirmation-4 ： Necessity of O&M training for traditional WUG

Gewog Agriculture Extension Officers consider that knowledge or skills on O&M of the traditional WUG shown in Table 5.3.7 should be developed.

Table 5.3.7 Knowledge or Skills on O&M of the Traditional WUG Necessary to be Developed in each Irrigation System

Irrigation System	Dzongkhag	Knowledge / Skills on O&M
Bay Chu	Wangdue Phodrang	- Systematization of water distribution - Making facility repair plan and water fee collecting plan
Drey Chu	Dagana	- Making facility repair plan and water fee collecting plan
Jimthang	Punakha	- Systematization of water distribution
Gaycheywong	Trashiyangtse	- Preventive maintenance of facilities

Source: The Survey Team (based upon the interview with Gewog Agriculture Extension Officer in each irrigation system)

If there is no development/rehabilitation plan for an irrigation system, which O&M is conducted by traditional WUG, O&M trainings are not held for traditional WUGs. However, actual problems on O&M are confirmed; water conflict occurs since rules of water distribution are not clearly decided (Bay Chu and Jimthang Irrigation System); the delay of a minor maintenance causes a major repair (Gaycheywong Irrigation System). About the knowledge or skills described in Table 5.3.7, aforementioned O&M Training Manual shows their training methods, and Engineering Division recognized that O&M trainings for the traditional WUGs are also necessary.

(5) Development Situation of Agriculture Environment in the Existing Irrigation Systems

According to the interview with Gewog Agriculture Extension Officers and beneficiaries of Taklai, Bay Chu, Drey Chu, Jimthang, and Gaycheywong Irrigation Systems, four common problems related to the improvement of farming environment are identified; 1) shortage of irrigation water, 2) shortage of farming labour, 3) shortage of sales opportunity of agriculture produce, and 4) shortage of extension of developed farming skills.

Meanwhile, the Eleventh Five Year Plan shows farming situation and farming issues in each Dzongkhag including some countermeasures to address those issues. The farming situation and the problems of the Dzongkhags where five irrigation systems are located are cited in Table 5.3.8. All the five Dzongkhags raise the problem of 1) Shortage of irrigation water. 2) Shortage of farming labour, including agriculture mechanization, is the problem of four Dzongkhags. 3) Shortage of sales opportunity of agriculture produce is the problem of all the five Dzongkhags as shortage of marketing facilities/skills. 4) Shortage of extension of developed farming skills, including a countermeasure of human-wildlife conflict, is the problem of all the five Dzongkhags.

Thus, those issues related to agriculture environment development are not indigenous but common issues in the area where each irrigation system is located.

Table 5.3.8 Farming Situation and Farming Issues Addressed in each Dzongkhag

Irrigation System	Dzongkhag	Farming Situation	Farming Issues Addressed
Taklai	Sarpang	Paddy, maize wheat and millet are the major crops grown in the Dzongkhag. Whereas orange, areca nut, cardamom and ginger are the principal cash crops grown by the farmers.	Agriculture productivity is challenged by human-wildlife conflict, lack of adequate irrigation facilities, and lack of storage and marketing facilities.
Bay Chu	Wangdue Phodrang	Rice farming or Chhuzhing (irrigated paddy field) is the predominant agricultural activity in the Gewogs of lower altitude, followed by Kamzhing (dry land), and mixed farming and a few patches of Tseri (slash and burn) cultivation are also practiced. Paddy fields mostly exist along the Dangchhu and Punatsangchhu, with double cropping of rice as an important agricultural feature. Potato is an important cash crop for the Gewogs of Phobji, Gangtey and Sephu and there is increasing citrus production in the Gewogs of Daga, Bjena, Phangyul and Rubeisa and ginger production in Daga and Athang Gewogs as a source of income generation. The lower valley towards the southern belt is best suited for sub-tropical horticulture crops such as oranges, mangoes, pineapples, guavas etc. With rich agricultural land and favourable climatic conditions, most Gewogs have potential for increased and diversified agriculture production. It has good internal road network with all of its Gewogs connected by farm and feeder roads which provide relatively easy accessibility to the markets.	While agricultural opportunities exist, the Dzongkhag is also confronted with the challenge of human-wildlife conflict, loss of agricultural land to urbanization, and small and fragmented land holdings. Given the Dzongkhag's high potential for increased and diversified agricultural production, agriculture will be promoted by addressing issues of human wildlife conflict, farm labour shortages, water shortages, and storage and marketing facilities. Production of cash crop will also be increased through training of farmers, encouraging the establishment of rural agro-based enterprises and cooperatives, and promoting better farming techniques and practices.
Drey Chu	Dagana	Agriculture farming is the main source of income for majority of the population. The fertile land and suitable climatic conditions make Dagana one of the major producers of mandarin and cardamom in the country. Other crops and vegetables like broccoli, cauliflower, cabbage, potato, chillies, tomatoes and horticulture crops like banana, passion fruit, pear and avocado are also grown. The high levels of poverty (25%) is attributed to remoteness of the Dzongkhag and poor agricultural productivity due to human wildlife conflict, farm labour shortages and lack of adequate irrigation, storage and marketing facilities.	The Dzongkhag will focus on enhancing agriculture. Support in the form of land terracing, rehabilitation and plantation of citrus and cardamom, supply of high quality disease resistant seeds and seedlings, supply of labour saving farm machinery, irrigation and capacity development such as group formation, awareness, advanced training on farming and marketing skills will be provided. Measures to address human wildlife conflict will be pursued aggressively.
Jimthang	Punakha	Punakha Dzongkhag is well known for rice, vegetables and fruits owing to its favourable location, soil and climatic conditions. The Dzongkhag basically grows all crops, though amount is limited, but the main crops are paddy, wheat, maize and mustard. Though citrus fruits are among the main fruits grown in the Dzongkhag, other fruits like persimmon, guavas, peaches, plums, pears and apples are also grown. The Dzongkhag also grows a variety of vegetables such as chillies, radish, cabbages, brinjals, green-leaf vegetables and tomatoes. The conducive climatic condition enables the people to produce surplus rice, fruits and vegetables which are sold in neighbouring Dzongkhags i.e. Thimphu and Wangduephodrang. The Dzongkhag is one of the largest producers of rice in the country.	The Dzongkhag will ensure that issues of human wildlife conflict, water shortages both for drinking and irrigation purposes, storage and marketing facilities for agricultural products, disaster preparedness and management will be addressed in close coordination with the relevant central agencies.
Gaycheywong	Trashiyangtse	Agriculture is the main source of livelihood for majority of the population. Rice, maize, millet, buckwheat and wheat are the major cereal crops grown. While orange, potatoes and chilly are the main cash crops of the Dzongkhag. Trashiyangtse is endowed with Cordyceps in the pastoral areas which fetches a very high price through exports.	The fragmented land-holdings, farm labour shortage, human wildlife conflict, lack of storage and marketing facilities pose constraint to enhancing agricultural productivity. Trashiyangtse Dzongkhag will focus on enhancing agricultural productivity by investing in agriculture infrastructure, farm mechanization to address farm labour shortages, overcoming human wildlife conflict, and constructing irrigation, storage and marketing facilities.

Irrigation System	Dzongkhag	Farming Situation	Farming Issues Addressed
			Possibilities of establishing small food processing units will be explored. In addition, farmers will be encouraged to form groups to avail better market and rural credit.

Source: Eleventh Five Year Plan

The identified four common issues are summarized below.

1) Shortage of irrigation water

The main role of irrigation facilities in Bhutan is supplemental irrigation for rice cultivation in the rainy season. Needs for the peak period of water requirement, land preparation period, is confirmed. Water needs for rice cultivation in the dry season is limited only in Taklai Irrigation System while water needs for mainly vegetable cultivation in the dry season are confirmed in other irrigation systems.

Table 5.3.9 Needs for Irrigation in each Irrigation System

Irrigation System	Dzongkhag	Needs for Irrigation	Reason of the Shortage of Irrigation Water
Taklai	Sarpang	- Supplemental irrigation for rice cultivation in rainy season - Irrigation in dry season including partial double cropping of rice	- Box culvert canal is blocked by stones and sands and cannot deliver irrigation water. - Discharge volume of water source is enough in through the rainy season. - Discharge volume of water source is insufficient in the dry season if whole the command area conducts paddy double cropping.
Bay Chu	Wangdue Phodrang	- Supplemental irrigation for rice cultivation in rainy season - Irrigation in drought blocks - Irrigation in dry season	- Discharge volume of water source is insufficient in both the rainy and dry season. - Sedimentation blocks the canal and it is difficult to deliver irrigation water.
Drey Chu	Dagana	- Supplemental irrigation for rice cultivation in rainy season - Irrigation in dry season - Irrigation for Cardamom cultivation	- Discharge volume of springs, present water source, is insufficient in both the rainy and dry season.
Jimthang	Punakha	- Supplemental irrigation for rice cultivation in rainy season - Irrigation in dry season	- Discharge volume of water source is enough in both the rainy and dry season. - Water loss due to the leakage from the canal is huge.
Gaycheywong	Trashiyangtse	- Supplemental irrigation for rice cultivation in rainy season	- Discharge volume of water source is enough in both the rainy and dry season. - Water loss due to the leakage from the canal, especially from pipes, is huge.

Source: The Survey Team (based upon the interview with Gewog Agriculture Extension Officer in each Irrigation System)

2) Shortage of farming labour

It is confirmed that many farmers mainly make a living by temporary works, such as road/building construction in the dry season after harvesting rice, not by farming. If those construction sites are near the villages they live, they commute there every day. However, in case farmers cannot find such job around their villages, they leave their homes for a few months to be engaged in these temporary works. Their destinations for the temporary works are not only cities, e.g. Thimphu, Paro, Phuntsholing, Sarpang, etc but all over the country.

According to the interview with farmers in Yudhiri Irrigation System, which is located in Trashigang Dzongkhag in the eastern region, and the detail survey is conducted for this Survey (the results of the survey are shown in Chapter 6), almost all men in their prime go for migrant work for 2-3 months, around from November till February. During the absence of men, crop cultivation on field and kitchen

garden in the dry season is works of women. However, there seems to be big gap in the ratio of migrant worker among areas. For example, in case of Drey Chu Irrigation System which location is far from the cities, it is confirmed that the ratio of migrant worker is comparatively low because cardamom, a cash crop and a perennial, is widely cultivated in the command area.

Short-term countermeasure for the shortage of farming labour is the mechanization of farming works. Traditional animal traction has changed to power tiller (hand tractor) gradually in Bhutan. Although extension of power tillers in an alluvial fan of southern area and in a river terrace of inland is progressed as compared to other areas, there is a big regional difference. Bay Chu Irrigation System has introduced power tillers more than ten years ago, and animal traction is a minor way of plowing nowadays. While in Drey Chu Irrigation System, animal traction is more commonly used than utilization of power tillers.

3) Shortage of sales opportunity of agriculture produces

Although most of agriculture markets are concentrated on cities, huge amount of cheap agriculture produce are supplied from India through highways. In rural areas/towns, there are just a few groceries under private management but even there, a lot of Indian products, which are comparatively cheaper than Bhutan's, are brought in and sold.

Safe and traditional-taste local rice is cultivated without much application of agricultural chemical and supported by consumers who can afford to buy even on a comparatively higher price as to imported rice. Consequently, rice buyers visit farmhouse directory to purchase surplus rice. In addition to rice, the demand of Bhutanese semi-staple food, potato and chilli, are growing steadily, but other vegetables' market scale is limited as present demand. In addition to that, it is confirmed that their sales opportunities are taken by cheap imported agriculture produce.

Under such circumstances, Department of Agricultural Marketing Cooperatives, MoAF addresses export agriculture produces to India and Bangladesh in changeover periods, supplying them to schools/hospitals/military camps, and development of small-scale market along roads/farmers' shops. Also, Bhutan Agro Industries Limited, a state-owned company, plans to build new food processing factory of fruits and vegetables in Mongar Dzongkhag, and to produce high value- added juice, jams, pickles, and preserved in syrup, etc.

4) Shortage of extension of developed farming skills

In the case of farming skills, wide-ranged research and development has been carried out in ARDCs. However, it is necessary for the future to introduce developed farming skills to actual farming fields as soon and smooth as possible. Therefore, establishment of speedier extension system than existing one managed by DAO is required. Also, within a Gewog, especially in sloping lands and mountainous area, natural conditions are different on each block; hence, Gewog Agriculture Extension Officers have to grasp the outline of the situation of whole Gewog to provide agricultural skills suitable to the natural conditions in each block.

Based on the interview in Taklai Irrigation System, it is confirmed that a short-period variety for double cropping of rice has been developed, and this new variety is required to be introduced/extended. Also researchers in ARDC Wengkhar have succeeded to make electric fence system, preventing human-wildlife conflict by about half the cost of those currently in use. They also addressed replacing

sandy soil by mountain soil, and experimental cultivation and extension of bulb onion[35]. As for paddy rice cultivation, they address fertilizing, transplanting timing, transplanting interval, utilizing herbicide, prevention of harmful insects, renewal of seed, etc. Thus new skill development, which can be applied to the current cultivation system, is ongoing but these developed farming skills have not yet been extended.

5.4 CURRENT SITUAION OF SUPPORT FOR RELATED SUBSECTORS BY JICA

The Eleventh Five Year Plan considers the RNR Sector as an important sector as it plays a vital role in bringing about a sustainable development and an improvement on incomes by enhancing well balanced rural development. The Plan shows the issues to be addressed for the development, the strategy of countermeasures to address the identified issues, and the programmes to be implemented as stated in Chapter 3.

Meanwhile, the Rolling Plan for Bhutan of Japan (Issued as annex of the Country Assistance Policy in April 2016) states its basic policy of assistance as "Assistance for self-reliant and sustainable nation building with a good balance of rural and urban areas". The said plan has two Priority Areas: "Sustainable economic growth" and "Reduction of vulnerability".

Under the first priority area, the assistance from Japan to Bhutan aims to contribute to an "Improvement of Standard of Living in Rural Areas" by implementing different programmes. Out of such programmes, there are: "Agriculture and Rural Development Programme" and "Rural Basic Infrastructure Development Programme". Within the framework of the former programme, Japan supports the promotion of farm mechanization, the introduction and dissemination of horticultural crops to add more value to produce, and the development/rehabilitation of irrigation facilities. On the other hand, within the framework of the latter programme, Japan supports the development/rehabilitation of basic infrastructure, such as roads/bridges and the rural electrification.

Based on the basic assistance policies, priority area and programmes mentioned above, Japan supports the following four subsectors under the agriculture sector: "Horticulture"; "Agriculture machinery"; "Irrigation" and "Farm roads". Such supports are expected to contribute to the programmes and strategies of the MoAF Eleventh Five Year Plan, which aims at addressing issues of the agriculture sector in this country, as shown in Figure 5.4.1. The first three programmes out of the listed five programmes, which are related to each of the subsectors mentioned above, fall under the jurisdiction of DoA.

[35] Bulb onion was cultivated only in a part of southern area though leaf onion was cultivated throughout the country. ARDC Wengkhar introduced the variety of bulb onion from India and conducted the experimental cultivation and the extension to farmers.

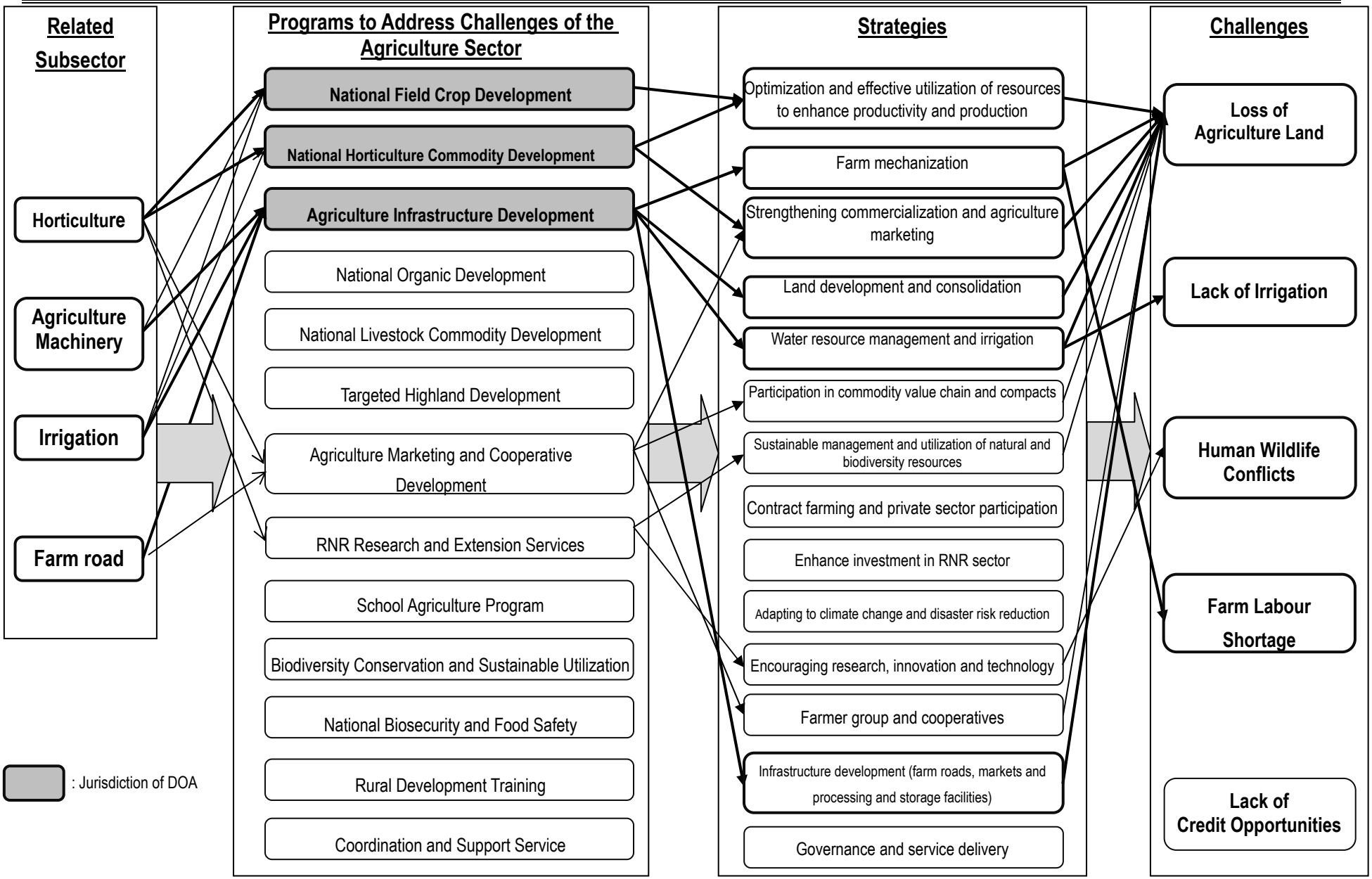


Figure 5.4.1 Linkages among the Related Subsectors and the Challenges, Strategies and Programs of the MoAF Eleventh Five Year Plan

Table 5.4.1 shows the list of the projects which are either already completed or currently under the implementation in the Horticulture, Agriculture Machinery, Irrigation and Farm road subsectors to which Japan has provided its support. Among these projects, there are seven projects which would be implemented in collaboration with other projects of the irrigation subsector, or which could bring about a synergy effect to other projects of the same subsector (highlighted in Table 5.4.1.). The outline of these seven projects and their possible linkages to the irrigation subsector are also described below.

Table 5.4.1 Previous and Ongoing Projects implemented with Japanese Cooperation in the Agriculture Sector

Subsector	Year	Scheme	Projects	Outline	
Horticulture	1964-1992	Dispatch of Experts		Agricultural extension services (Introduction and dissemination of Japanese rice variety and cultivation of cash crops) in Paro and Zhemgang Dzongkhags	
	1986-1987	Grant Aid	Agriculture Development Plan	Establishment of the National Seed Center	
	2004-2009	Technical Cooperation Project	Agricultural Research and Extension Support Project in Lhuentse and Mongar	Development of appropriate cultivation technologies for fruits and highland vegetable in the selected two Dzongkhags	
	2010-2015	**Technical Cooperation Project**	**Horticulture Research and Development Project**	**Promotion of horticulture in the selected six Dzongkhags**	**(1)**
	2016-2021 (on-going)	**Technical Cooperation Project**	**Integrated Horticulture Promotion Project in the West Central Region**	**Promotion of horticulture in the selected four Dzongkhags**	**(2)**
Agriculture Machinery	1983-1986	Grant Aid	Construction of Agriculture Machinery Center	Establishment of AMC	
	1984-2004	**Grant Aid**	**Grant Aid Program to Boost Agricultural Productivity (2KR)**	**Provision of agriculture machinery to improve agricultural productivity**	**(3)**
	2008-2011	**Technical Cooperation Project**	**Strengthening Farm Mechanization Project**	**Support to promote appropriate and safe operation/O&M of agriculture machinery**	**(4)**
	2006-2008 2010、2013	**Grant Aid**	**Grant Assistance for Underprivileged Farmers (2KR)**	**Provision of agriculture machinery (e.g. power tillers)**	**(3)**
	2014-2018 (on-going)	**Technical Cooperation Project**	**Strengthening Farm Mechanization Project Phase II**	**1) Establishment of evaluation criteria for agriculture machinery and 2) Promotion of agriculture machinery provision service model**	**(5)**
	2016-2018 (on-going)	**Grant Aid**	**The Project for Improvement of Farm Machinery for Hiring Services of Tillage**	**Provision of power tillers**	**(6)**
Irrigation (including Farm road)	1986-1988	Development Survey	Lhuentse and Mongar Integrated Agricultural Development Project	1) Preparation of development plan and 2) Validation of the plan from the technical, economic and financial point of view	
	1989-1995	Grant Aid	The Paro Valley Agricultural Development Project (Phase1~3)	Agricultural infrastructure development in the Paro valley which was selected among the 5 priority area in Bhutan	
	1993-1995	Development Survey	Groundwater Development Plan in Wangduephodrang District	Preparation of a water resource (especially groundwater) development plan for the capital of Wangduephodrang Dzongkhag and its peripheral area which is known for its agriculture production	
	2013-2015, additional work 2016	Grant Aid	The Project for the Rehabilitation of Taklai Irrigation System in Sarpang District	The construction/rehabilitation of irrigation facilities which can provide supplemental irrigation water during the rainy seasons and irrigation water for double copping during the dry seasons	
Farm Road	2001-2002	Development Survey	The Study on Agriculture and Farm Road Development in the Lhuentse and Mongar District	Preparation of the master plan (regional agricultural development plan and farm road development plan) and an action plan aimed to improve food self-sufficiency, farmer's income and the living standard in Lhuentse and Mongar Dzongkhags	
	2011-2014	**Technical Cooperation Project**	**Technical Cooperation Project for Farm Road Bridge Design and Implementation**	**To improve the engineering capacity of DoA/Dzongkhag for survey, design, construction and O&M of farm road bridges**	**(7)**

Subsector	Year	Scheme	Projects	Outline
	2005-2006	Grant Aid	The Project for Improvement of Machinery and Equipment for Construction of Rural Agricultural Road	Provision of machineries to construct farm roads in the selected six Dzongkhags
	2010-2011	Grant Aid	The Project for Improvement of Machinery and Equipment for Construction of Rural Agricultural Road （Phase2）	Provision of construction machineries to accelerate the construction of farm roads
	2016-2018 (on-going)	Grant Aid	The Project for Improvement of Machinery and Equipment for Construction of Rural Agricultural Road （Phase 3）	Provision of machineries for the construction and O&M of farm roads
Others	2011	Grant Aid	Non-project Grant Aid	Provision of agricultural equipment from overseas countries

Source：The Survey Team (based upon the Website of Ministry of Foreign Affairs of Japan)

(1) Horticulture Subsector: Horticulture Research and Development Project (HRDP) (Technical Cooperation Project) (Completed / 2010-2015)[36]

In the eastern area of Bhutan, subsistence farming was predominant and in general, the area was less developed, compared to the western area. Although MoAF considered the promotion of commercial farming of fruits and vegetables as one of the important issues, progress in the dissemination of appropriate cultivation skills for the topographic and geographical features of the area as well as in the commercialization of those cash crops was not confirmed. Therefore, from 2004, JICA supported the implementation of the "Agricultural Research and Extension Support Project" in Lhuentse and Mongar Dzongkhags to develop appropriate cultivation skills for these Dzongkhags.

In order to promote horticulture and rural development through the demonstration of applicability of outputs of the "Agricultural Research and Extension Support Project" to other areas, JICA supported the implementation of this “Horticulture Research and Development Project” in selected six Dzongkhags of the eastern area. The project aimed at improving the agricultural income of the model farmers and their neighbouring framers, and its main contents were: 1) technical assistance in the production, processing and marketing related to horticulture; 2) development of guidelines and manuals of horticulture development; 3) support in the trainings and extension activities; and 4) strengthening of the provision system of seeds/seedlings.

As a result of the project, horticulture farming practices and crops suitable to the target area were identified. Additionally, some measures to develop horticulture farming were also identified thorough the trial marketing activities. The quality of the technical training in horticulture at the ARDC Wengkhar was improved. Also the system to provide seeds/seedlings to the trainees at the ARDC Wengkhar and the places of seed/seedling farmers was established.

(2) Horticulture Subsector : Integrated Horticulture Promotion Project in the West Central Region (IHPP) (Technical Cooperation Project) (On-going, from 2016 to 2021)[37]

With the support from JICA in the horticulture development, including the project mentioned above (1), the research and development in horticulture have made progress, and the extension systems on horticulture farming was developed in the eastern area. Meanwhile, it was confirmed that the cultivation of cereals, such as rice, is predominant in the west central region, although the region has a

[36] JICA Website “Horticulture Research and Development Project” Outline of the Project
[37] JICA Website “Integrated Horticulture Promotion Project in the West Central Region” Outline of the Project

high potential for horticulture development. Also a shortage in the development/rehabilitation of basic infrastructure for horticulture promotion has been seen. It is against this background that this "Integrated Horticulture Promotion Project in the West Central Region" has been under implementation based on the experience and lessons learned from the project implemented in the eastern region.

The purpose of this project is to establish the system to promote horticulture in the west central region. In order to achieve this purpose, the project is implemented in the ARDC Bajo with the following contents: 1) the development/rehabilitation of experimental field and facilities to develop appropriate cultivation techniques, 2) the selection and introduction of the appropriate varieties for commercial horticulture in the project area in collaboration with other ARDCs including ARDC Wengkhar, 3) the development of the management methods of horticulture, including appropriate planting, pest control, post-harvest processing, soil management, water management, etc, and 4) the development of extension material by integrating outputs of the project.

The relationship between the horticulture subsector and the irrigation subsector

The Eleventh Five Year Plan aims at increasing horticulture production and establishing irrigation systems for horticulture. To achieve these targets, not only the development of irrigation systems, but also the development and promotion of horticulture cultivation skills and the establishment of marketing methodologies are indispensable. Through the implementation of continuous projects for the horticulture subsector supported by JICA, including the projects mentioned above (1) and (2), the cultivation skills have been developed and promoted, while the marketing methodologies are also established. Thus, the collaboration between the horticulture subsector and the irrigation subsector can produce a synergy effect of an increase in the irrigated area and in the production of horticulture, through the combination of the development and promotion of cultivation skills and the establishment of marketing methodologies by the horticulture subsector and stable water supply by the irrigation subsector. Thus such collaboration can largely contribute to the achievement of the targets of the Eleventh Five Year Plan.

(3) Agriculture Machinery Subsector: Grant Aid Program to Boost Agricultural Productivity / Grant Assistance for Underprivileged Farmers (2KR) (Grant Aid) (Completed / 1984-2004, 2006-2008, 2010, 2013)

The production of major cereal did not meet the demand by domestic consumption, and one of the reasons for it could be low production efficiency in farming. Bhutan is a mountainous country and the farm land area per farmer household is quite limited. In addition, many farmers rely on animal traction. Another possible reason could be the shortage of farm labour due to the aging population and the increasing immigration of youth to urban areas along with the increased opportunities for children of farmer households in education.

As a countermeasure to the labour shortage and the population aging, Japan through its 2KR assistance scheme (Grant Aid Program to Boost Agricultural Productivity and Grant Assistance for Underprivileged Farmers) has provided farming machineries in a total of twenty-five occasions and the total costs has been amounted to 5,955 million Japanese yen. Almost 3,000 units of power tillers (two-wheeled hand tractor) have been granted so far[38].

[38] Report of preparatory survey on agriculture machinery service improvement plan（simple binding）（2016）

(4) Agriculture Machinery Subsector : Strengthening Farm Mechanization Project (Technical Cooperation Project) (Completed / 2008 - 2011)[39]

Since Bhutan belongs to the mountainous zone and farming field area is so small, it was considered necessary to increase unit yield by improving the efficiency of farming practices. Additionally, the shortage of farm labour became a challenge to be addressed, as young people migrated to urban areas to seek employment there instead of being engaged in farming, thus resulting to an aging rural population. In order to improve the living standard of farmers by addressing such challenges, it has been considered important to improve efficiency of farming practices and agricultural productivities through farm mechanization.

Based on what mentioned above, this "Strengthening Farm Mechanization Project" implemented the following activities with its base in AMC Paro: 1) To strengthen the farmer support service through the revision and improvement of the training modules and materials, the capacity development of the extension workers and farmers; 2) To provide quality and safety management of agriculture machinery through the establishment of security standards as well as inspection methods and formats; 3) To prepare a draft farm mechanization plan for future, 4) To develop and design appropriate agriculture machinery to local conditions; and 5) To do research and development of agricultural machinery through the preparation for the handing-over of agricultural machinery from AMC to a private manufacturer.

(5) Agriculture Machinery Subsector: Strengthening Farm Mechanization Project Phase II, (Technical Cooperation Project) (On-going / 2014 - 2018)[40]

The project mentioned above (4) left two challenges, although it has brought about some positive impacts. First one was to develop the national standard to certify the quality and safety of agriculture machinery. Second one was to enhance the hiring service of agriculture machinery so that even those farmers who cannot afford their own machinery can benefit from farm mechanization. To address these problems, this project was to be conducted as the second phase of the project mentioned above (4). The project is promoting the agricultural development to attain high-productivity in agriculture through farm mechanization in Paro and Sarpang Dzongkhags. It was assumed that the effectiveness of farm mechanization could be well proved because these Dzongkhags have relatively flat terrain and irrigation facilities in these Dzongkhags were comparatively well developed/maintained.

The activities of the project are: 1) to develop the certification mechanism of the quality and safety of agriculture machinery; 2) to promote the quality and safety of agriculture machinery; 3) to adjust the functions and work patterns of machine operation according to the conditions of the target sites; and 4) to develop and recommend a model of agriculture machinery hiring service. Through the implementation of these activities, it is expected that farmers' access to appropriate agriculture machinery will be improved in the project site.

(6) Agriculture Machinery Subsector: The Project for Improvement of Farm Machinery for Hiring Services of Tillage (Grant Aid) (On-going / 2016 - 2018)[41]

MoAF plans to increase the ratio of mechanized farming works from about 7.8 % as of June 2013 to

[39] JICA Website "Strengthening Farm Mechanization Project" Basic Information of the Project
[40] JICA Website "Strengthening Farm Mechanization Project Phase II" Outline of the Project
[41] Preliminary Project Evaluation Table of the Project for Improvement of Farm Machinery for Hiring Services of Tillage, 2016

about 16.6 % before June 2018. Improvement of the ratio by the expansion of the agriculture machinery hiring services for tillage throughout the country was sought. They distributed one power tiller each to 205 Gewogs of all the 20 Dzongkhags by the end of December 2015 and began the machinery hiring services for tillage. However, it was recognized that more agriculture machineries are required to achieve the target of the mechanized farming work ratio and to respond the demand from farmers. In addition, RGoB has pledged to spread agriculture machinery throughout the country under the slogan; "One Village, One Power Tiller". RGoB requested Gant Aid from the Japanese government to fulfil such commitment, and the Japanese government is to provide 355 power tillers based on the extension plan of the agriculture machinery hiring service and the implementation arrangements of the service.

The past 2KR supported farm mechanization mainly through the promotion of possession of agriculture machineries by farmers. But this project aims to prepare the enabling environment for the agriculture machinery hiring service which allows those farmers who cannot afford the purchasing cost to have access to agriculture machinery. Thus, this project of the Grant Aid will complement the past 2KR. The results of the establishment of a hiring service model for tillage which is done under the project aforementioned in (5) are planned to be utilized in this project.

Relationship between the agriculture machinery subsector and the irrigation subsector

Increase of irrigated area and agricultural productivity are the targets set by the Eleventh Five Year Plan. To achieve these targets, not only the development of irrigation systems but also an improvement on the effectiveness in farming which may address the shortage of labours, are required. An improvement on the effectiveness and the productivity in farming has been achieved through the distribution of agriculture machinery including power tiller and the preparation for the agriculture machinery hiring service by implementing the Grant Aid and technical cooperation projects aforementioned in (3) – (6). Thus, the collaboration between the agriculture machinery subsector and the irrigation subsector might greatly contribute to the achievement of the targets of the Eleventh Five Year Plan by bringing about an increase in the irrigated area as well as in the agricultural production as results of a synergy effect between the improved effectiveness in farming and the stable water supply.

(7) Farm Road Subsector: Technical Cooperation Project for Farm Road Bridge Design and Implementation (Technical Cooperation Project) (Completed / 2011-2014)[42]

For economic development in the rural area, the shift from subsistent agriculture to market-oriented agriculture was required, and therefore, the development/rehabilitation of farm roads which allow farmers to have better access to markets was considered essential. The development/rehabilitation of farm roads was expected to increase access not only to markets but also to other social services, such as rural electrification, health care, education, etc. The Government of Japan, taking into account possible multiple impacts, provided the Grant Aid for the development plan of farm roads. With this Grant Aid, RGoB has developed farm roads with the purchased machinery and equipment for the road construction. Meanwhile, wooden bridges were built for river-crossing parts of such farm roads, taking into account the bridge building technique available so far in this country. Among the wooden bridges built in the whole country, it was recognized that 24 bridges require to be renewed due to deterioration, etc.

[42] JICA Website "Technical Cooperation Project for Farm Road Bridge Design and Implementation" and interview with counterpart of this project

The Department of Road under MoWHS has been in charge of the design of all the bridges in the country, including the bridges on farm roads. However, part of the bridges on farm roads to be built under the Tenth Five Year Plan and the Eleventh Five Year Plan should be designed by DoA, in accordance with the "Guidelines on Road Classification System and Delineation of Construction and Maintenance Responsibilities" (MoWHS, March 1, 2009) and "Guidelines for Farm Roads Development" (DoA, March 1, 2009).

To implement this "Technical Cooperation Project for Farm Road Bridge Design and Implementation", the Japanese side dispatched two long-term experts and three short-term experts. On the other hand, the Bhutanese side assigned two engineers from Engineering Division, and some engineers from the Dzongkhag Engineering Divisions. Through the construction of three model bridges of the project, the step-by-step technical transfer to the counterpart officers in the process of survey, planning, design, construction supervision, and O&M was given. After the completion of the project, the trained counterpart engineers designed about 30 bridges.

The relationship between the farm road subsector and the irrigation subsector

The project mentioned above provided the technical transfer to the counterpart officials through the process of survey, planning, design, construction supervision, and O&M. RGoB has requested the provision of technical transfer along all the process of development/rehabilitation of irrigation facility in their official request for support to the Government of Japan. Due to this similarity, the project mentioned above can be referred to at the examination of the contents of future cooperation of Japan in the irrigation subsector.

5.5 CURRENT STATUS OF ASSISTANCE FROM OTHER DEVELOPMENT PARTNERS IN IRRIGATED AGRICULTURE AND THE IRRIGATION SYSTEMS

Supports in the agriculture sector from other development partners are summarized in Table 5.5.1 to seek possible collaboration/coordination or a synergy effect for the prospective assistance programme in the irrigation sub-sector, also at the same time, to avoid unnecessary overlap. Now, the on-going projects supported by the Government of India, WB and International Fund for Agricultural Development (IFAD) have a component of support for the irrigation subsector. On the other hand, RGoB has already made requests for further projects to support the irrigation subsector to the Government of India, the Government of the Netherlands, WB, etc.

Table 5.5.1 shows that it is confirmed that the Government of India has provided financial support to the construction of irrigation facilities, and WB and IFAD have supported the capacity development of communities, including the rehabilitation of small-scale irrigation systems by themselves. However, there is no development partner who supports the capacity development in the irrigation planning and irrigation facility design/ construction/O&M.

Table 5.5.1 Supports in Agriculture Sector by Other Development partners

Project Name	Implementation Agency	Geographic Coverage	Total Budget	Funding Source	Project duration
(1) Adapting Integrated Crop Management technologies to commercial citrus enterprises in Bhutan and Australia [On-going]	Horticulture Division, DoA & New South Wales Department of Primary Industries (NSWDPI)	Nation wide	AUD$ 161,500 (Grant)	Australian Centre for International Agricultural Research	September 2012 - October 2017

	[Project Outline]
	1) To improve the quality of Bhutanese citrus planting material through germplasm collection, mother tree establishment and improved nursery production practices. 2) To improve knowledge and management of key citrus pests and diseases. 3) To improved citrus orchard management practices, nutrition and evaluation of water supply options 4) To build additional citrus research, development and production capacity of Bhutanese scientists and extension agents and citrus farmers

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(2) Commercialization of Vegetable Production [On-going]	DoA & Dzongkhag/Gewog	**[Winter Vegetable]** Sarpang, Samtse, Samdrup jongkhar and lower foothills of Tsirang, Chhukha, Dagana, Trongsa, Punakha and Wangdue **[Summer Vegetable]** Thimphu, Paro, Punakha and Wangdue	BTN 40 million (Grant) BTN 9.1 million	Government of India RGoB	July 2014 - June 2018
	[Project Outline]				
	1) Adequate supply of quality seeds and seedlings on cost sharing scheme 2) Promotion of protected cultivation technologies for off-season vegetable production in mid and high altitude area on cost sharing scheme 3) Promotion of integrated plant nutrient management technologies (bio-fertilizers, green manures, etc) 4) Pest and disease management through IPM method 5) Strengthened skills and knowledge of researchers and extension personnel 6) Capacity building o farmers on improved methods of vegetable production				

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(3) Cereal and Vegetable Oil Seed Crop Intensification Project [On-going]	DoA & Dzongkhag/Gewog	**[Maize]** Eastern & low lying plains of southern region **[Wheat]** Western & low lying valleys of warm temperate region **[Mustard & Vegetable oil]** Warm temperate region and low lying regions	BTN 60 million (Grant) BTN 12 million	Government of India RGoB	July 2014 - June 2018
	[Project Outline]				
	[Maize Intensification]	- Quality seed production and supply of OP varieties - Introduction of hybrid seed technologies - Soil fertility and nutrient management - Pest and disease management (GLSS & HLB) - Maize processing and marketing			
	[Wheat Intensification]	- Quality seed production and supply - Introduction and adaptation of new varieties - Pest and Pest managed (rust) - Wheat processing and marketing			
	[Vegetable oil seed intensification]	- Quality seed production and supply - Introduction and adaptation of oil seed varieties - Mustard oil processing and marketing			

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(4) Improvement of Irrigation Infrastructure and Arable Land Development [On-going]	Department of Agriculture (DoA)	Samtse, Lhuentse, Chhukha, Trashiyangtse, Haa, Lhuentse Mongar, Paro, Pemagatshel, Thimphu, Trashigang, Trongsa and Zhemgang	BTN 350 million (Grant) BTN 20 million	Government of India Project Tied Assistance RGoB	July 2014 - June 2018

[Project Outline]

Construction of 14 new irrigation schemes out of the 108 major irrigation schemes planned to be centrally executed by the department during the 11FYP
Total Command Area: about 5,000 acre
Total Number of benefited households: about 2,000

Target Irrigation Systems:

	Scheme Name	Dzongkhag	Gewog	Command Area (Acre)	Beneficiary HH	Canal Length (km)
(1)	Baychuyuwa	Wangdue	Thedtsho	300.60	70	14.0
(2)	Dreychhu	Dagana	Thedtsho	200.00	120	8.0
(3)	Kuchidinia	Samtse	Yetsholtse	962.15	256	7.4
(4)	Thakuri Kholsi	Samtse	Ugyentse	142.78	32	0.9
(5)	Hangay	Samtse	Tashicholing	252.50	95	3.231.0
(6)	Kalikhola-Kamigaon	Samtse	Norgaygang	600.00	250	8.8
(7)	Khandothang	Samtse	Samtse	500.00	110	1.0
(8)	Thargom/chokpagang Irri, channel	Tashiyangtse	Yallang	610.00	314	8.0
(9)	Mantichu Irri, channel	Tashiyangtse	Tongmajangsa	129.91	15	1.0
(10)	Gudari Irri channel	Mongar	Chaskhar	145.23	300	9.0
(11)	Thunmari Irri. channel	Shongphu	Yobenang	700.00	400	5.0
(12)	Phawangchu Irrigation channel	Lhuntse	Domkhar	151.67	55	8.0
(13)	Ngarigang chu Irrigation channel	Lhuntse	Jalang	200.69	84	6.1
(14)	Ngarchu/Serchu Irri channel	Lhuntse	Minjey	362.43	72	5.5

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(5) Strengthening Agricultural Marketing & Trade [On-going]	Department of Agricultural Marketing Cooperatives (DAMC)	Nation Wide	INR 50 million (Grant)	Government of India	July 2013- June 2018

[Project Outline]

1) Construction and strengthen Sales Counters, urban market sheds, cluster centers, cooperative shops and collection depots and supply of equipments and inputs
2) Support to contact farming, PPP, FDI and commercial farming enterprises based on priorities of commodities and linking of
3) Facilitate the improved delivery of credit services through institution of Cooperative Development Fund
4) Linking of groups and cooperatives with markets both domestic and export

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(6) Remote Rural Communities Development Project (RRCDP) [On-going]	Policy and Planning Division (PPD), DoA, Department of Livestock (DoL), Department of Forests and Park Services (DoFPS) & 6 project Dzongkhags	6 Dzongkhags (Chhukha, Dagana, Haa, Samtse, Trongsa, Wangdue) and 24 Gewogs of these 6 Dzongkhags	USD 9.0 million	WB the International Development Association	November 2012 - May 2018

	[Project Outline]
	Component A **Rural Infrastructure**	*Rural accessibility* Farm road new construction, landslide protection structures *Irrigation* Irrigation infrastructure rehabilitation of about 67 schemes, modernization, high efficiency irrigation development, water storage structures, engineering support and water user association training support.
	Component B **Community, Marketing and Productive Infrastructures**	- Establishing community and marketing infrastructure - Improving Productive asset of existing producer groups
	Component C **Project Management and Institutional Strengthening**	- Project management and institutional strengthening

Target Irrigation Systems:

	Scheme Name	Dzongkhag	Gewog	Command Area (Acre)	Beneficiary HH	Canal Length (m)
(1)	Karmaling Lift Irrigation	Dagana	Karmaling	3.0	102	400.0
(2)	Kunchey Khola to Gairi Gaon	Samtse	Dungtoe	15.0	250	200.0
(3)	Chungkha(Yuenengpo)	Chukha	Bongo	8.0	30	90.0
(4)	Ketokha	Chukha	Bongo	7.0	52	77.3
(5)	Chungkha(Pamikha)	Chukha	Bongo	7.0	30	150.0

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(7) Market Access & Growth Intensification Project (MAGIP) [Completed]	Project Coordination Unit (PCU), MAGIP	Lhuentse, Tashiyangtse, Trashigang, Mongar, Pemagatshel and Samdrup Jongkhar	USD 8.490 million (Loan)	IFAD	May 2011 - December 2016
			USD 2.000 million (Grant)		
			USD 2.000 million	RGoB	
			USD 0.147 million	SNV	
			USD 0.860 million	Beneficiaries	

[Project Outline]

1) Support some 3,600 producers organized in groups or cooperatives with the necessary inputs, training and services so as to intensify production of cash crops and dairy products
2) Reaching the necessary economies of scale production, transportation, processing, storage and marketing
3) Construction or rehabilitation of strategically selected marketing and storage infrastructure, farm roads and irrigation schemes

Target: Some 37 Gewogs with good road access and the necessary agro-ecological potentials
Target Irrigation Systems:

	Scheme Name	Dzongkhag	Gewog	Command Area (Acre)	Beneficiary HH	Canal Length (m)
(1)	Wangringmu Lift Irrigation	Tashiyangtse	Ramjar	0.6	344	127.0
(2)	Reeb Irrigation channel	Lhuntse	Kurtoed	4.1	90	181.1
(3)	Mindrupling Irri.channel	Samdrup Jongkhar	Samdrup Choling	5.0	33	80.0
(4)	Mohannelnphu Irri.	Pemagatshel	Nanong	1.6	52	80.0

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(8) Commercial Agriculture and Resilient Livelihoods Enhancement Programme	PCU, 6 eastern Dzongkhags/Gewogs, FCBL, RAMCO Mongar, ARDC Wengkhar, RLDC Kanglung	Eastern 6 Dzongkhag Trashigang, Trashiyangtse, Lhuentse, Mongar, Pemagatshel, Samdrup Jongkhar	USD 17.256 million	IFAD	July 2015 - June 2022

(CARLEP)

[On-going]

[Project Outline]

1) Sustainably increase agricultural production
2) Enhance agricultural production systems to absorb climate induced shocks
3) Institute value chain and marketing systems for vegetable and dairy products
The programme will benefit 28,975 smallholder households, of which 7,115 households

Target Irrigation system

	Scheme Name	Dzongkhag	Gewog	Command Area (Acre)	Beneficiary HH	Canal Length (km)
(1)	Rangshikhar Irri. Channel	Trashigang	Samkhar	79.56	64	4.4

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(9) Green Climate Fund (GCF) [Applying]	DoA(Technical) DPA DDM(Finance)	8 Dzongkhag Punakha Wangdue Trongsa Sarpang Tsirang Zhemgang Samtse Dagana	BTN 10.15 million	Green Climate Fund	-

[Project Outline]

GCF is a fund for supporting reduction of greenhouse gases (mitigation) and addressing impacts of climate change (adaptation) in developing countries.

Proposed Irrigation systems:

	Scheme Name	Dzongkhag	Gewog	Command Area (Acre)	Beneficiary HH	Canal Length (m)
(1)	Phenday yuwa	Punakha	Talog	25.0	430	1000.0
(2)	Jimthang yuwa	Punakha	Dzomi	13.5	200	604.0
(3)	Domsimo	Punakha	Shenga-Bjemi	3.0	35	80.0
(4)	Lhachu yuwa	Wangdue	Dangchhu	5.1	49	113.0
(5)	Pangkabjiyuwa	Wangdue	Nyishog	14.9	67	207.9
(6)	Mangchuka	Wangdue	Gangtey	5.5	110	200.0
(7)	Ngawang Sechuyuwa	Wangdue	Ruebisa	30.0	90	450.0
(8)	Narikachu to Bagaythang via Thomgang	Dagana	Khebisa	6.0	95	150.0
(9)	Tsainzigosa	Dagana	Lhamoizingkha	3.7	35	70.0
(10)	Kari Lum Irri.Channel	Dagana	Tseza	18.0	167	350.0
(11)	Buddichhu to Thangna and Pangna	Dagana	Drukjeygang	12.0	250	200.0
(12)	Budeychu - Tsangkhatar	Dagana	Tsangkha	13.0	222	210.0
(13)	Creedigang (Cardigang)	Trongsa	Korphu	5.0	100	180.0
(14)	Yurmungtshangchu	Trongsa	Langthil	13.0	180	180.0
(15)	Lamitar	Samtse	Yetsholtse	2.7	72	145.8
(16)	Lower Balbotey	Samtse	Tashicholing	3.2	58	368.4
(17)	Lingtey=3km, Hariyakhola=2km	Samtse	Sangachholing	5.0	150	300.0
(18)	Tharaykhola-Bimtar	Samtse	Norbugang	15.0	270	450.0
(19)	Gambadara	Samtse	Samtse	2.5	23	129.0
(20)	Juprey	Sarpang	Samtenling	5.00	26	125.0
(21)	Juprey	Sarpang	Samtenling	5.00	26	135.0
(22)	Thewar	Sarpang	Sershong	5.0	60	205.0
(23)	Pakhey	Sarpang	Shompangkha	7.0	45	200.0
(24)	Rejuk	Sarpang	Umling	2.0	27	86.0
(25)	Dungkharchoeling	Tsirang	Kilkhorthang	3.0	12	80.0
(26)	Tahispang & Pemashong	Tsirang	Mendelgang	1.5	18	66.0
(27)	Tashiling toe, Tashibi, Salangpong	Zhemgang	Phangkhar	5.0	40	100.0

	(28)	Takabi	Zhemgang	Trong	3.5	30	100.0
	(29)	Samcholing Kasa meh	Trongsa	Drakten	4.4	150	377.0
	(30)	Khomshar	Zhemgang	Bardo	4.5	131	425.0

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(10) Global Environmental Fund (GEF) [Applying]	DoA	Undecided	Undecided	Global Environmental Fund	-
	[Project Outline]				
	GEF mission is to be the premier alternative asset management firm in the domain of energy, environment, and natural resources by delivering favourable risk-adjusted investment returns to our investors over multiple vintage years and through varied macroeconomic climates. Proposed Irrigation Systems: undecided				

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(11) Food Security and Agriculture Productivity Project (FSAPP) Former The Global Agriculture and Food Security Program (GAFSAP) Applying	DoA	Samtse, Sarpang	BTN 118.50 million	WB	2017-2022

[Project Outline]

The Project Development Objective is to increase agricultural productivity and enhance access to markets for farmers in selected Gewogs in south-west Bhutan. The project supports the RGoB, which efforts to reduce rural poverty, food insecurity, and high levels of malnutrition, increase resilience to climate change through climate smart agricultural productivity enhancement for food security and nutrition, and increasing farmers' access to local and export markets.
Proposed Irrigation Systems:

	Scheme Name	Dzongkhag	Gewog	Command Area (Acre)	Beneficiary HH	Canal Length (m)
(1)	Dangdungay-Manigang	Samtse	Dophuchan	20.0	300	1000.0
(2)	Ratay	Sarpang	Dekiling	5.3	187	338.0

Project Name	Implementation Agency	Geographic coverage	Total Budget	Funding Source	Project duration
(12) Development-Related Infrastructure Investment Vehicle (DRIVE) [Applying]	DoA	Undecided	Undecided	Government of Netherlands	Undecided

[Project Outline]

The overall objective of DRIVE is to contribute to inclusive and sustainable growth in developing countries. DRIVE supports investments in expansion and/or quality improvement of public infrastructure, which improve the development of the private sector by promoting entrepreneurship, productivity, employment opportunities, and lifting wages.
Proposed Irrigation Systems:

	Scheme Name	Dzongkhag	Gewog	Command Area (Acre)	Beneficiary HH	Canal Length (m)
(1)	Lamitar	Samtse	Yetsholtse	2.7	72	145.8
(2)	Lower Balbotey	Samtse	Tashicholing	3.2	58	368.4
(3)	Lingtey=3km, Hariyakhola=2km	Samtse	Sangachholing	5.0	150	300.0
(4)	Tharaykhola-Bimtar	Samtse	Norbugang	15.0	270	450.0
(5)	Gambadara	Samtse	Samtse	2.5	23	129.0
(6)	Takabi	Zhemgang	Trong	3.50	30	100.0
(7)	Kheshingri Irri channel	Tashiyangtse	Toetsho	6.5	250	236.5
(8)	Masangdaza irri channel	Mongar	Saling	3.3	21	93.3
(9)	Yangbari Irri channel	Mongar	Gongdue	3.1	21	113.5
(10)	Yabrang Irri. Channel	Tashigang	Phongmay/Bidung	10.0	170	500.0
(11)	Satshalo Irri. Channel	Pemagatshel	Nobugang	3.0	63	81.0
(12)	Bahudar irri.channel	Pemagatshel	Chokhorling	2.8	74	200.0

Source: The Survey Team (based upon A Profile of Development Partners Supporting Projects in the RNR Sector, MoAF and an interview with the Engineering Division of DoA)

CHAPTER 6 CURRENT SITUATION, CHALLENGES AND COUNTERMEASURE FOR YUDHIRI IRRIGATION SYSTEM

6.1 OUTLINE OF TRASHIGANG DZONGKHAG

Yudhiri Irrigation System is located in Radhi Gewog, Trasigang Dzongkhag. Trashigang Dzongkhag is bordering Mongar Dzongkhag to the west, Pemagatshel and Samdrup Jongkhar Dzongkhag to the south, Trashiyangtse Dzongkhag to the north, and Arunachal Pradesh of India to the east. Elevation widely ranges from 600 m to 4,500 m.

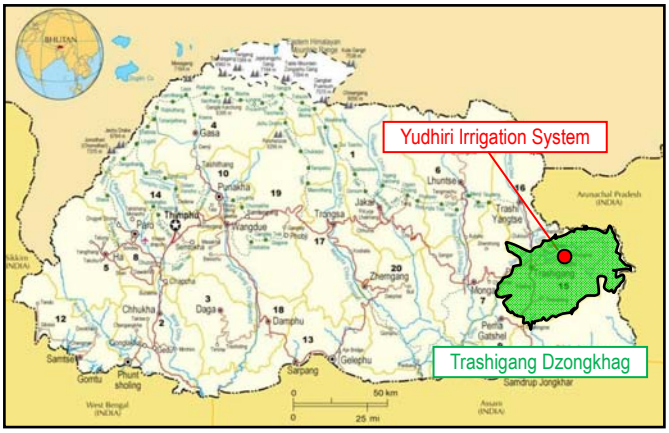


Figure 6.1.1 Location of Trashigang Dzongkhag

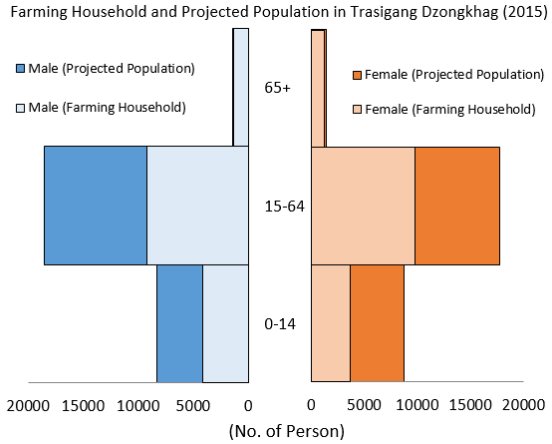
The main economical features of Trashigang Dzongkhag are shown in Table 6.1.1. The poverty incidence is less than the national average (12%), however, areas of high poverty levels exist in parts of the Dzongkhag.

In Trashigang Dzongkhag, 52% of people with age from 15 to 64 years (male: 50%, Female: 55%) are engaged in farming activities (Figure 6.1.2), thus agriculture is an important industry in Trashigang Dzongkhag. The main cereals cultivated in the Dzongkhag are maize and rice (Table 6.1.2).

Table 6.1.1 Main Economical Features of Trashigang Dzongkhag

Number of Dungkhags	3
Number of Gewogs	15
Area	2,204 km^2
Forest cover (2012)	81.65%
Population (2012)	67,271
Households(2012)	8,610
Poverty incidence (2012)	11.5%
Unemployment (2012)	1.6%

Source: Eleventh Five Year Plan (1st July 2013 – 30th June 2018) Local Government Plans–Volume III Trashigang Dzongkhag



Source: the Survey Team (based upon data from
Annual Dzongkhag Statistics 2016, NSB for the population
Agriculture Statistics 2015, MoAF for number of people engaging in agriculture

Figure 6.1.2 Population Composition by Ages and Number of People Engaging in Agriculture Activities

Table 6.1.2 Main Cereals Planted in Trashigang Dzongkhag

	Wheat	Barley	Rice	Maize	Buck Wheat	Millet
Cultivated Area (acre)	203.5	852.9	2,246.5	7,837.6	752.2	-
Production (kg)	193,002.0	344,311.0	4,015,636.0	19,446,098.0	537,241.0	231,500.0
Yield (kg/acre)	862.0	636.6	1,412.0	1,757.8	703.0	-

Source: Annual Dzongkhag Statistics 2016, NSB

6.2 OUTLINE OF RADHI GEWOG

Radhi Gewog, where Yudhiri Irrigation System is located, is in the north center of Trashigang Dzongkhag. The main economical features of Radhi Gewog are shown in Table 6.2.1.

Radhi Gewog has the second highest ratio of irrigation sector budged against total Gewog's budget among Gewogs in Trashigang Dzongkhag (Figure 6.2.2). Radhi Gewog puts emphasis on the irrigation and has the second highest ratio.

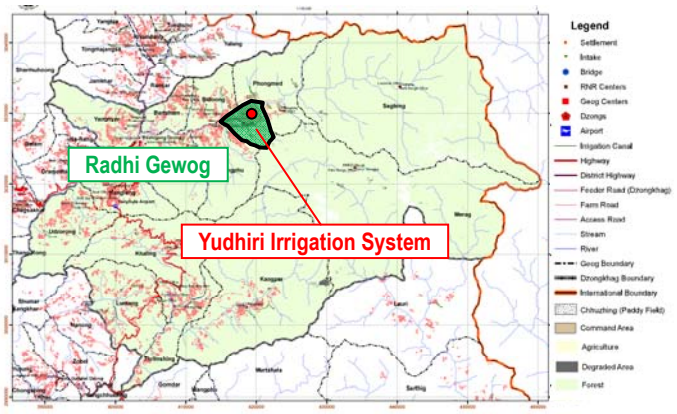
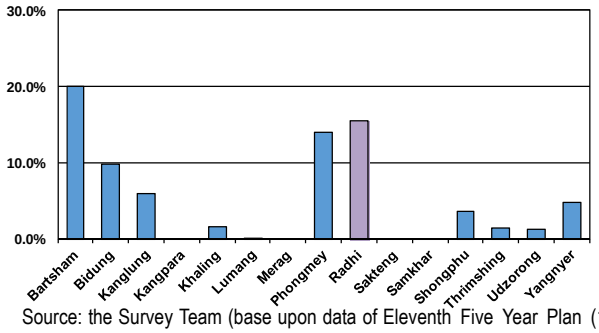


Figure 6.2.1 Location of Radhi Gewog

Table 6.2.1 Main Economical Features of Radhi Gewog

Number of Chiwogs	5
Area	28.2 km^2
Forest cover	51.26%
Population	5,598
Households	758

Source: Eleventh Five Year Plan (1st July 2013 – 30th June 2018) Local Government Plans–Volume III Trashigang Dzongkhag



Source: the Survey Team (base upon data of Eleventh Five Year Plan (1st July 2013 – 30th June 2018) Local Government Plans–Volume III Trashigang Dzongkhag)

Figure 6.2.2 Ratio of Irrigation Sector Budget against Total Gewog's Budget

6.3 PREPARATORY WORKS (CREATION OF TOPOGRAPHIC MAPS)

In general, topographic map with scale 1:5,000 is required for irrigation development to decide the range of command area and to examine the layout of facilities. As of February 2017, the scale of topographic map can be obtained in Bhutan is 1:50,000 in maximum and it is difficult to decide the range of command area and select the location of intake facilities by this scale of topographic map. Moreover, although it was confirmed in the past survey that main canal was damaged by landslides, the formation and distribution of the landslides cannot be identified by the map with such scale.

Therefore prior to the field survey, topographic maps with scale 1:5,000 for 65 km^2 including the whole catchment area of the Yudhiri River was created to identify the range of command area, alignment of rivers and distribution of landslides. As for topographic maps, 1) contour map, 2) red relief map[43] and 3) Advanced Land Observing Satellite (ALOS) image were created.

To create the ALOS image, satellite image taken by ALOS managed by Japan Aerospace Exploration Agency (JAXA) was utilized. While, to create contour map and red relief map, Digital Elevation Model created through analysis of ALOS image were utilized.

For the field survey, contour map, red relief map with contour map and ALOS image with contour map were mainly utilized (Figure 6.3.1 to Figure 6.3.3).

[43] Patented technology of the Asia Air Survey Co., Ltd

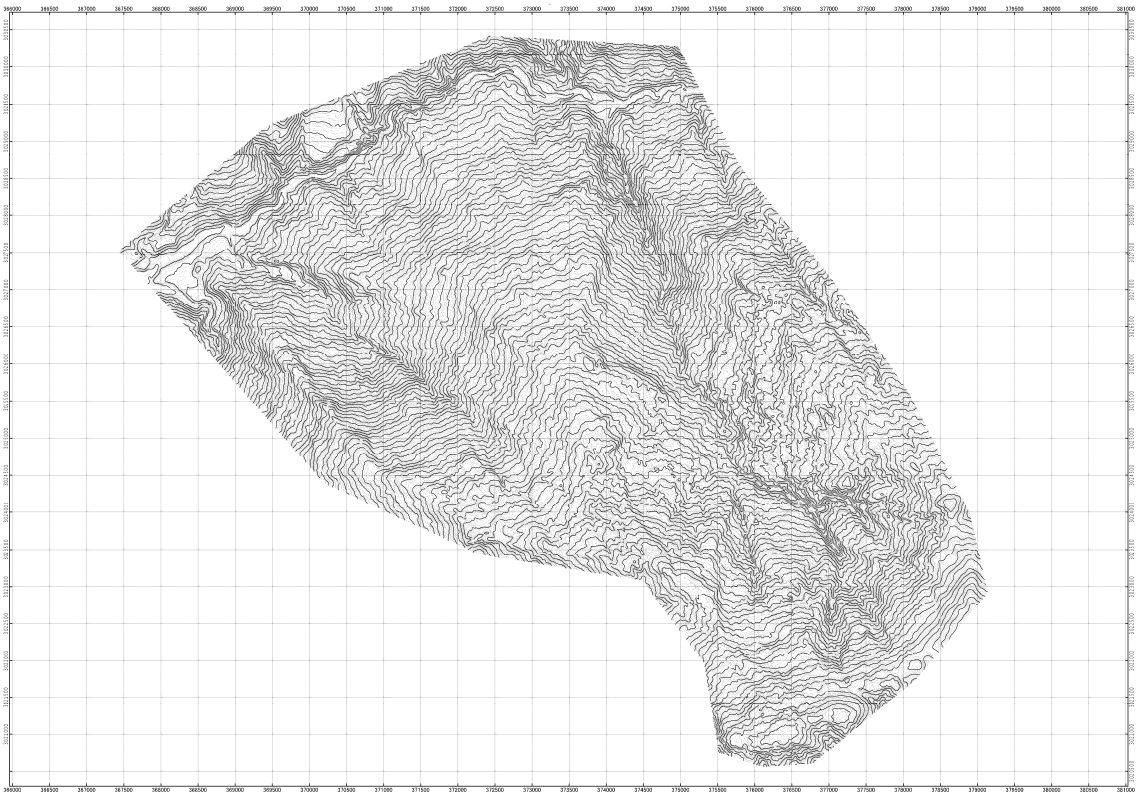


Figure 6.3.1 Contour Map

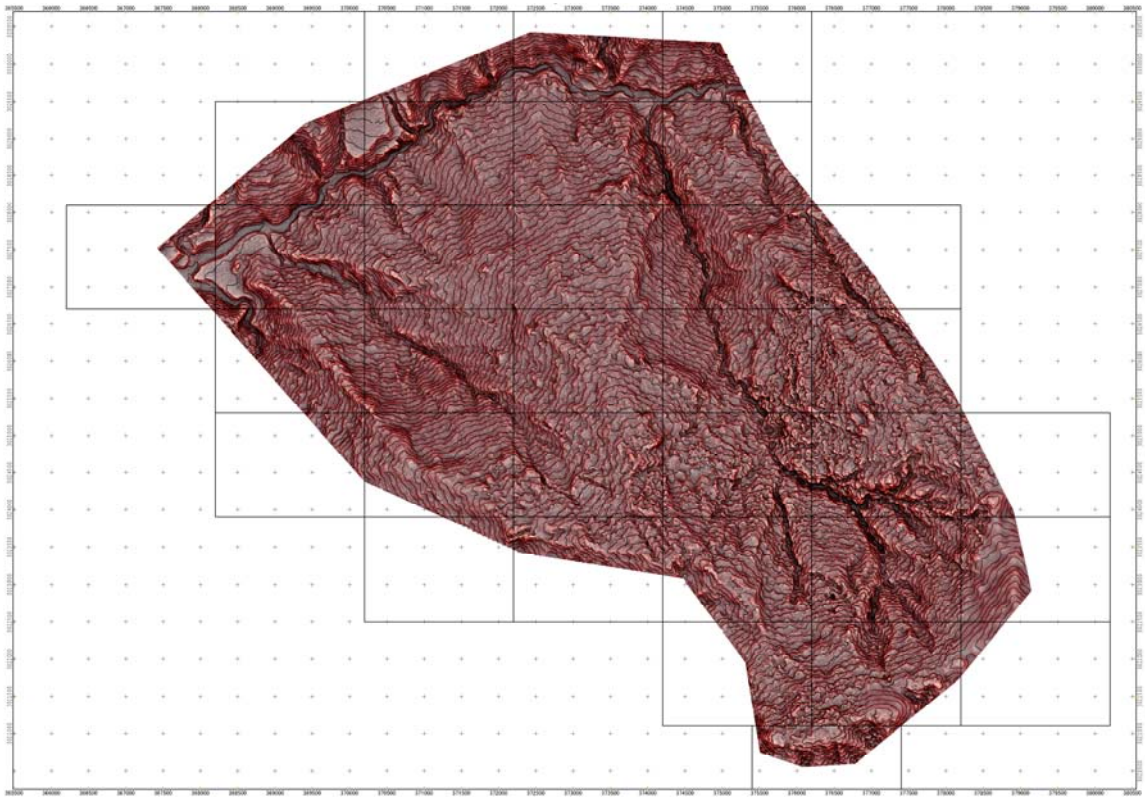


Figure 6.3.2 Red Relief Map with Contour Map

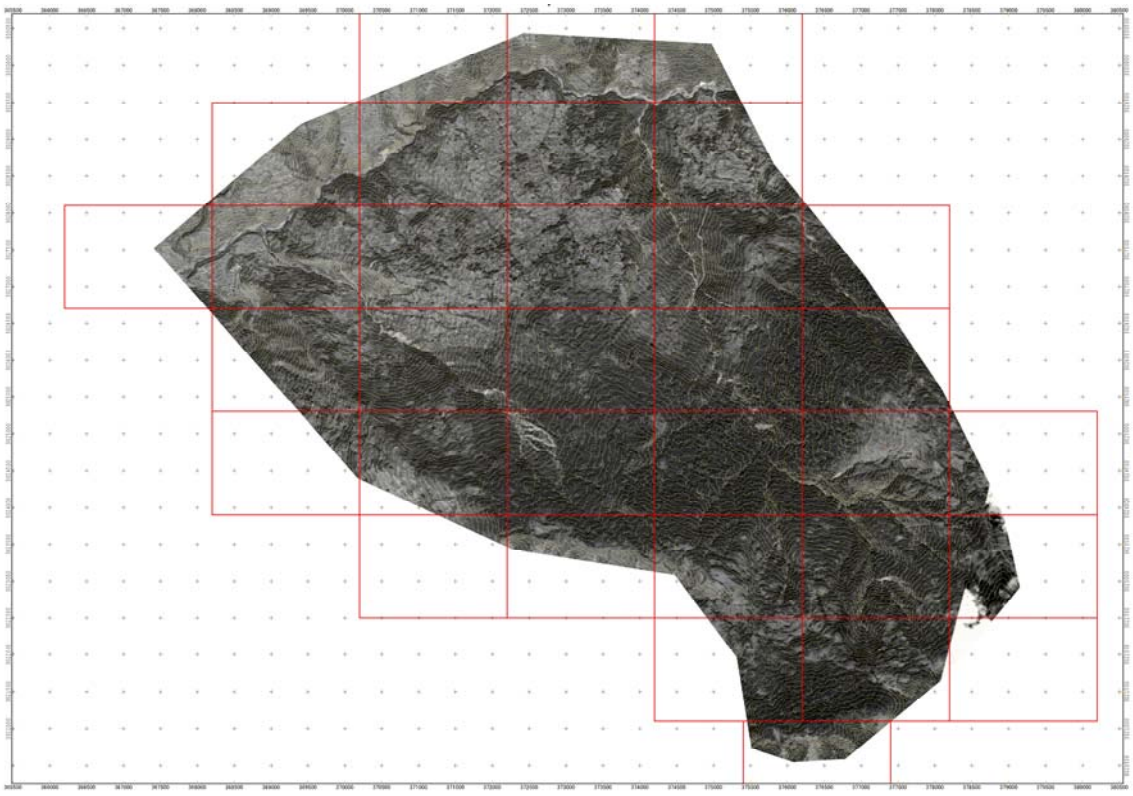


Figure 6.3.3 ALOS Image with Contour Map

Through the terrain interpretation of the red relief map with contour map, many landslide formations were identified (Figure 6.3.4). Since landslides mainly occur by the increase of uplift force with rising groundwater level, it was implied that the command area would have groundwater potential and spring points within.

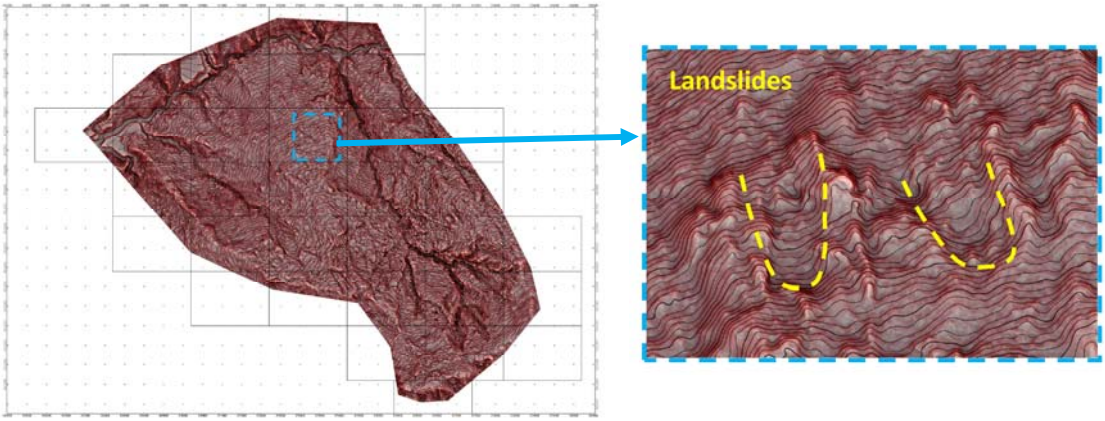


Figure 6.3.4 A Sample of Landslide Formations within the Command Area

While, the followings were identified through the analysis of the contour maps. Additionally, physical relationship of existing facilities became clear as well (Figure 6.3.5).

- The command area is located between the Yudhiri River and the Gamri River.
- Elevation of the command area ranges from 1,100 m to 2,000 m
- General slope of the command area is about 1:3.0.

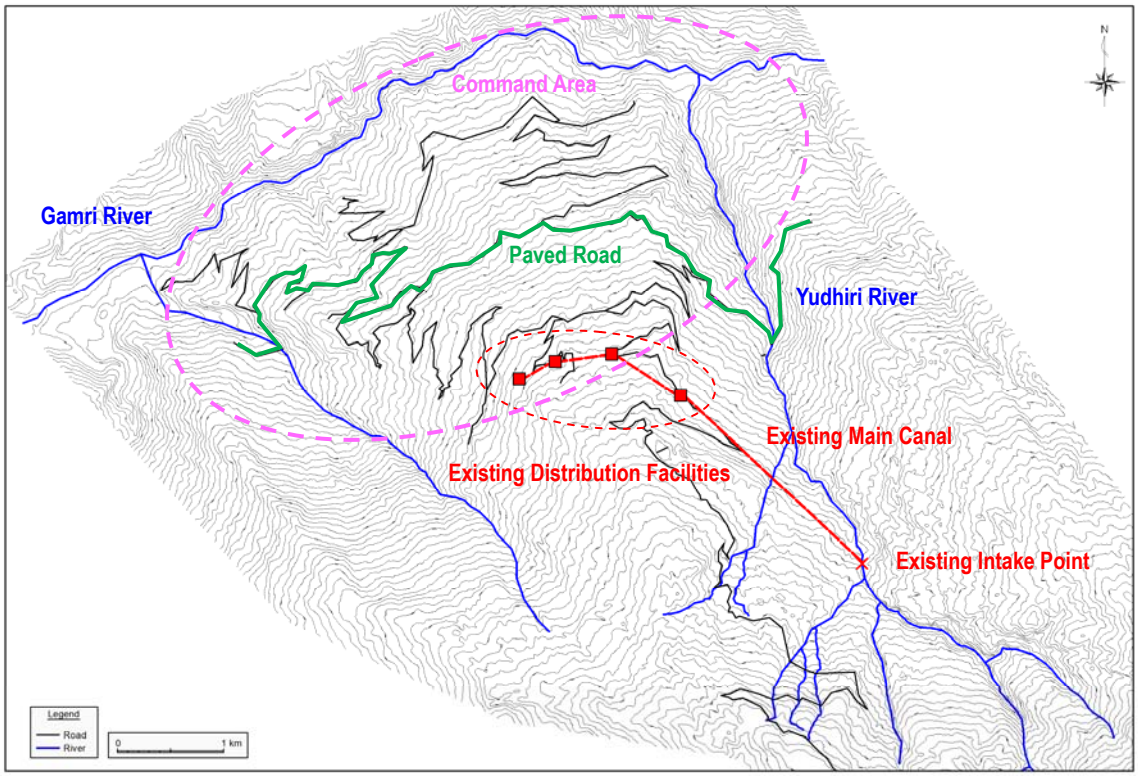


Figure 6.3.5 Contour Map with Existing Facilities Distribution

The maps were very useful for the field survey because it showed detail topographic features such as small landslides and small tributaries.

6.4 PRESENT SITUATIONS OF YUDHIRI IRRIGATION SYSTEM

6.4.1 Farming Situation

(1) Cultivated Area

Farmers in the command area mainly cultivate rice in paddy terrace (Figure 6.4.1 and Figure 6.4.2).

Figure 6.4.1 Overview of the Command Area

Figure 6.4.2 Paddy Terrace within the Command Area

Based on the interview with Gewog Agriculture Extension Officers, the following situations of the cultivated area are confirmed.

- The rainy season is from June to September, and the dry season is from October to May.
- Cultivated wet land during the rainy season is 378 ha, according to the results of the aerial photo analysis (Figure 6.4.3).
- Double cropping of rice is conducted in the limited area along the Gamri River where the temperature is relatively high (but information of the range of double cropping area is not available).
- Cultivated dry land during the rainy season is 68 ha while 43 ha during the dry season.
- Fallow area of wet land is 10% of total wetland, calculated as 37.5 ha.
- The number of households within the command area is 652 so that wet land is estimated 0.6 ha per household.

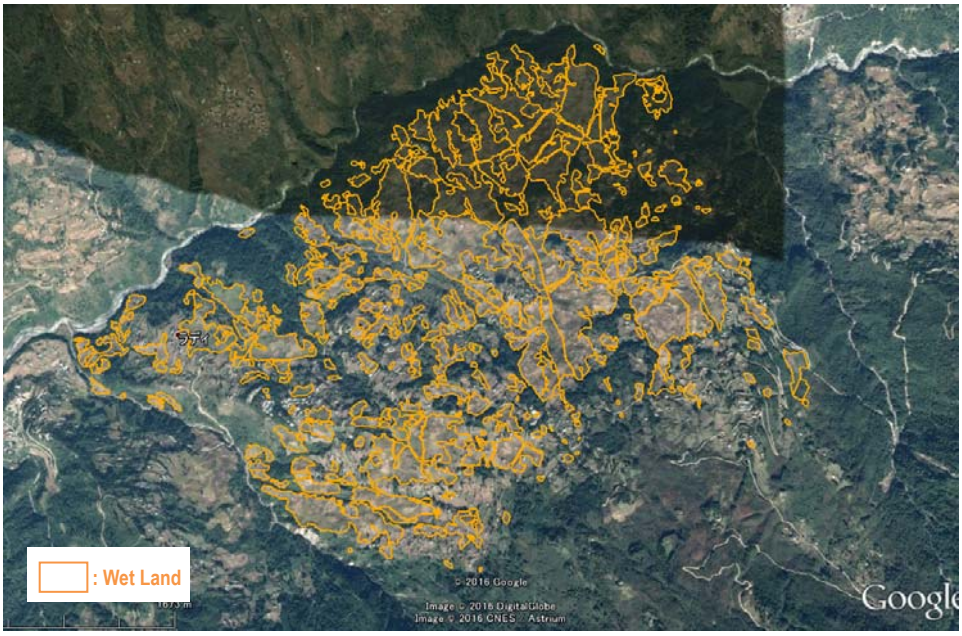


Figure 6.4.3 Wetlands (Result of the Aerial Photo Analysis)

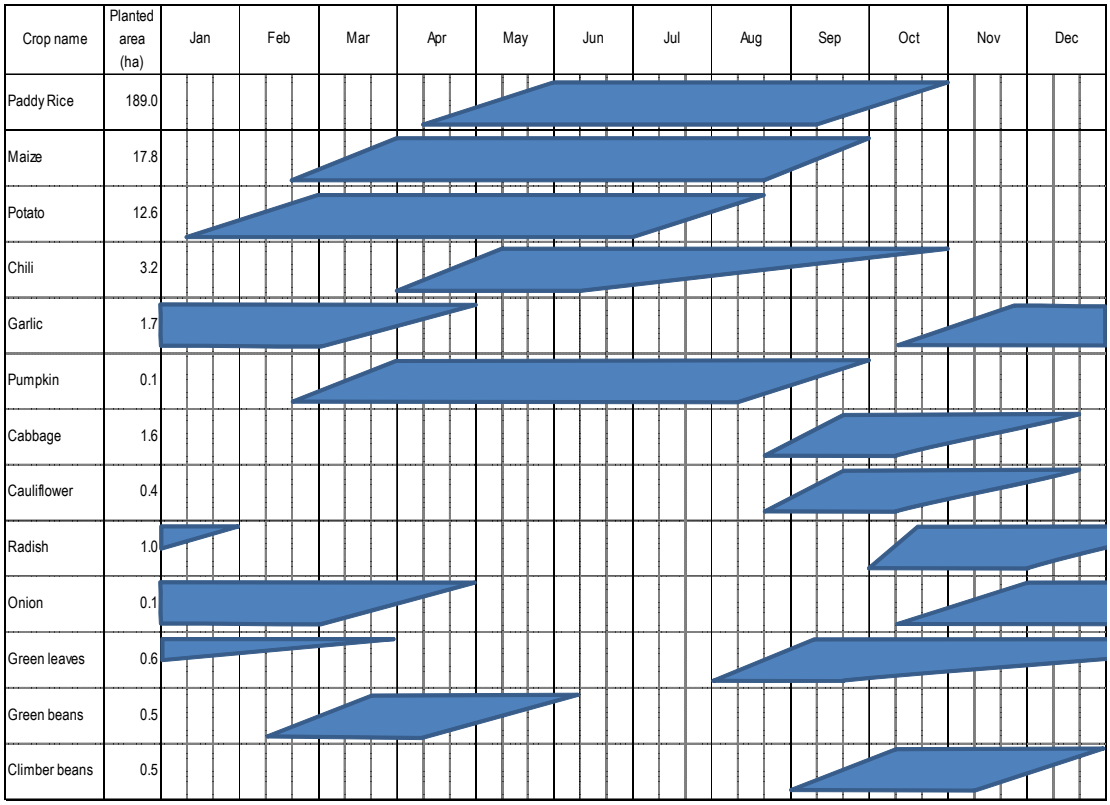
(2) Planting Situation

From the interview with Gewog Agriculture Extension Officers, present cropping pattern is categorized into two patterns, namely Upper part and Lower part (Figure 6.4.4), and its border is almost along the paved road across the command area from the west to east (Figure 6.3.5). Basically, these two patterns are almost same but with little difference according to the temperature. In the upper part, start of land preparation for paddy and planting of vegetable are being made earlier than in the lower part. This difference is made since temperature at the upper part is relatively low, and low temperature injury is likely to happen if planting would be delayed.

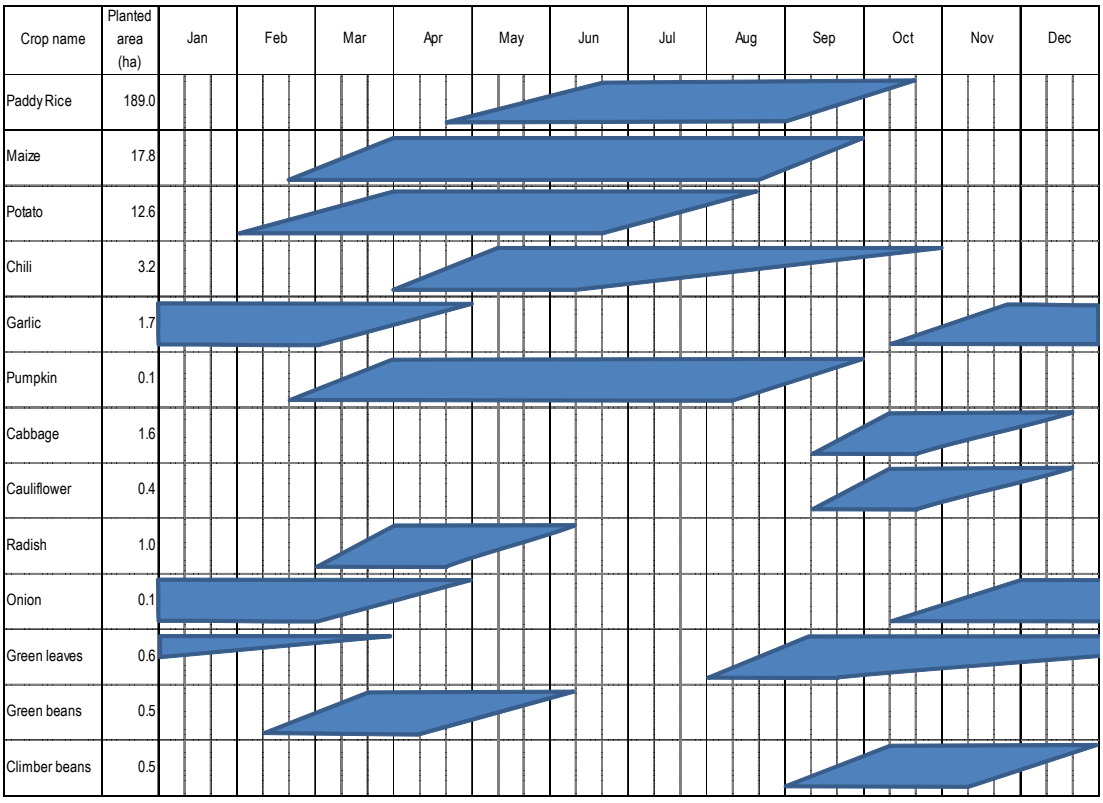
(3) Unit Yield

From the interview with Gewog Agriculture Extension Officers, unit yield of paddy in Radhi Gewog was 4.4 MT/ha in 2015 and 5.4 MT/ha in 2016. Also, based on the interview with the beneficiaries, unit yield of paddy at upper part is 4.08 MT/ha and 4.63 T/ha at lower part. While the average unit yield records of Trashigang Dzongkhag was 3.6 MT/ha in 2014 and 3.5 MT/ha in 2015[44]. Unit yield of Radhi Gewog was higher than the average of Dzongkhag but the basis of the values are not available because there are no records of calculation procedure for those values.

[44] Annual Dzongkhag Statistics 2016, Trashigang, NSB



Upper Part



Lower Part

Figure 6.4.4 Present Cropping Pattern

6.4.2 Facility, Water Intake and Distribution, Springs, and Geological Situations

(1) General Situation of Yudhiri Irrigation System (Figure 6.4.5)

Yudhiri Irrigation System, which consists of an intake facility at the Yudhiri River, main canal and four (4) distribution structures, was developed by IFAD in 1988. From the interview with the beneficiaries, since the intake facility was washed away by the flood completely soon after the completion of construction, water has never been distributed to the command area through this system. Some parts of main canal were damaged by landslides. Water could not be delivered from distribution structure DP-2 to DP-3 due to damage on the pipe connecting these two distribution structures.

In 2008, beneficiaries tried to construct intake facility at almost the same site as the original intake by IFAD, under support for material by RGoB. However, this intake facility was also washed away by flood.

(2) Present Water Intake and Distribution Situation (Figure 6.4.6 and Figure 6.4.7)

Water intake situation

Beneficiaries do not take water directly from the Yudhiri River but from its tributaries namely: the Brag Daza Stream, the Rebligmin Stream, the Daniri Stream and the Phagpari River. River flow of the Brag Daza Stream, the Rebligmin Stream and the Daniri Stream are gathered for the Phagpari River through pipes and taken by three intake facilities. One of intake facilities is located at the upstream side and the remaining two are at the downstream side. Among the two downstream side intake facilities, one that is located relatively at the upstream side is the main facility and the one located relatively downstream works to collect river flow which cannot be caught by the main intake.

Beneficiaries have constructed temporary weir at each tributary by stones and sands to divert river flow to the intake facilities.

Water distribution situation

River water taken at the upstream intake facility on the Phagpari River is discharged for a gully at the upstream of PD-3. This water is delivered to the command area once covered by DP-3 and DP-4 in the past. Thus, for the command areas covered by DP-3 and DP-4 in the past, water is distributed through gullies, and DP-3 and DP-4 do not act as distribution facilities.

Meanwhile, river water taken at the downstream intake facilities on the Phagpari River is delivered to the command area by pipes through two routes; 1) delivered to DP-2 through DP-1 and 2) directory delivered to lower part of the command area covered by DP-1. As already mentioned, water could not be delivered from DP-2 to DP-3 due to damage on the pipe, all the water delivered to DP-2 is discharged to the DP-2 branch canal (Detail of DP-5 is described in (3))).

The types of canals are earthen canal, concrete lining canal and pipe, and combination of their materials. Pipe type is mainly utilized on the steep slope or landslide prone areas where concrete canal is difficult to be constructed.

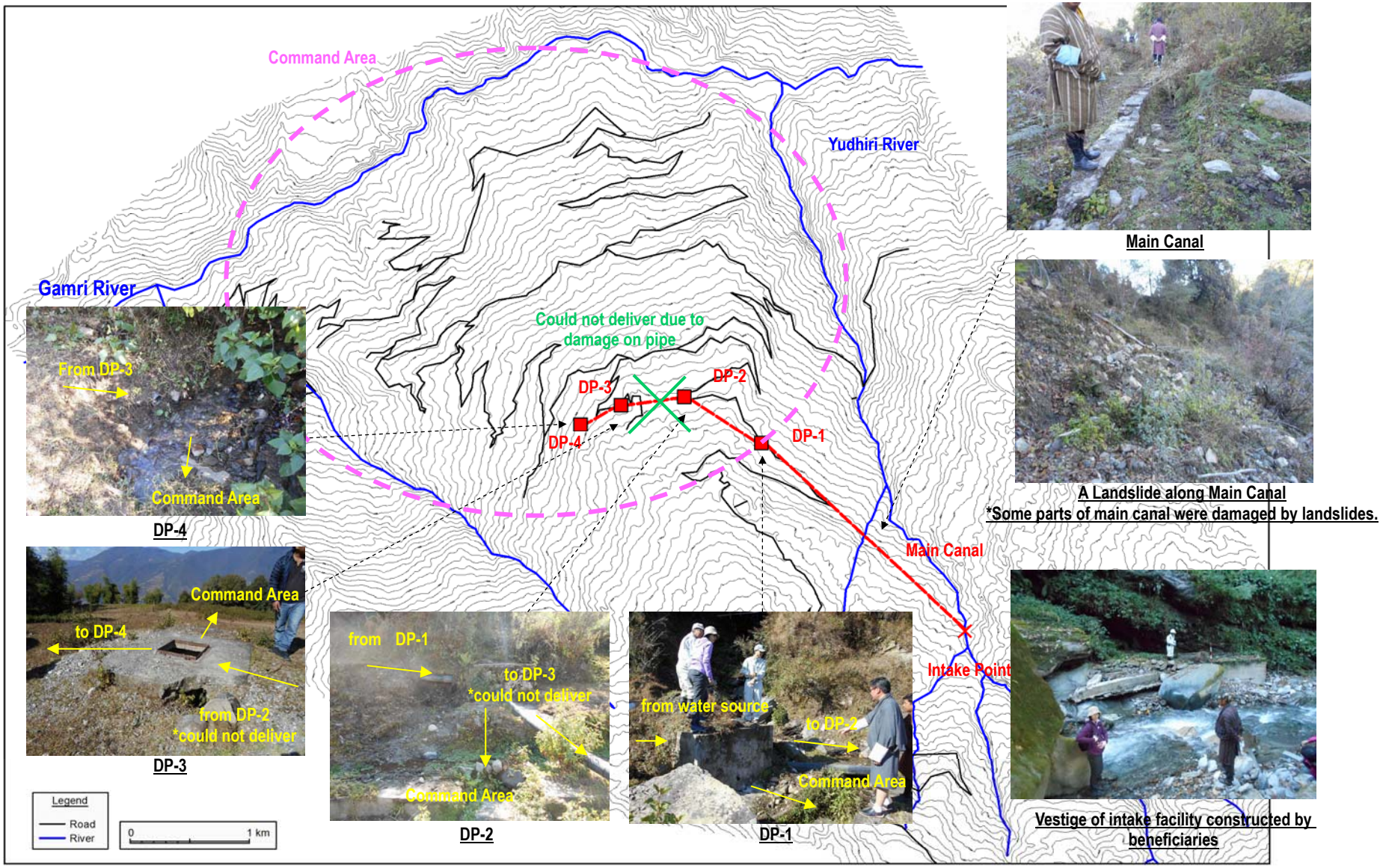


Figure 6.4.5 General Situation of Yudhiri Irrigation System

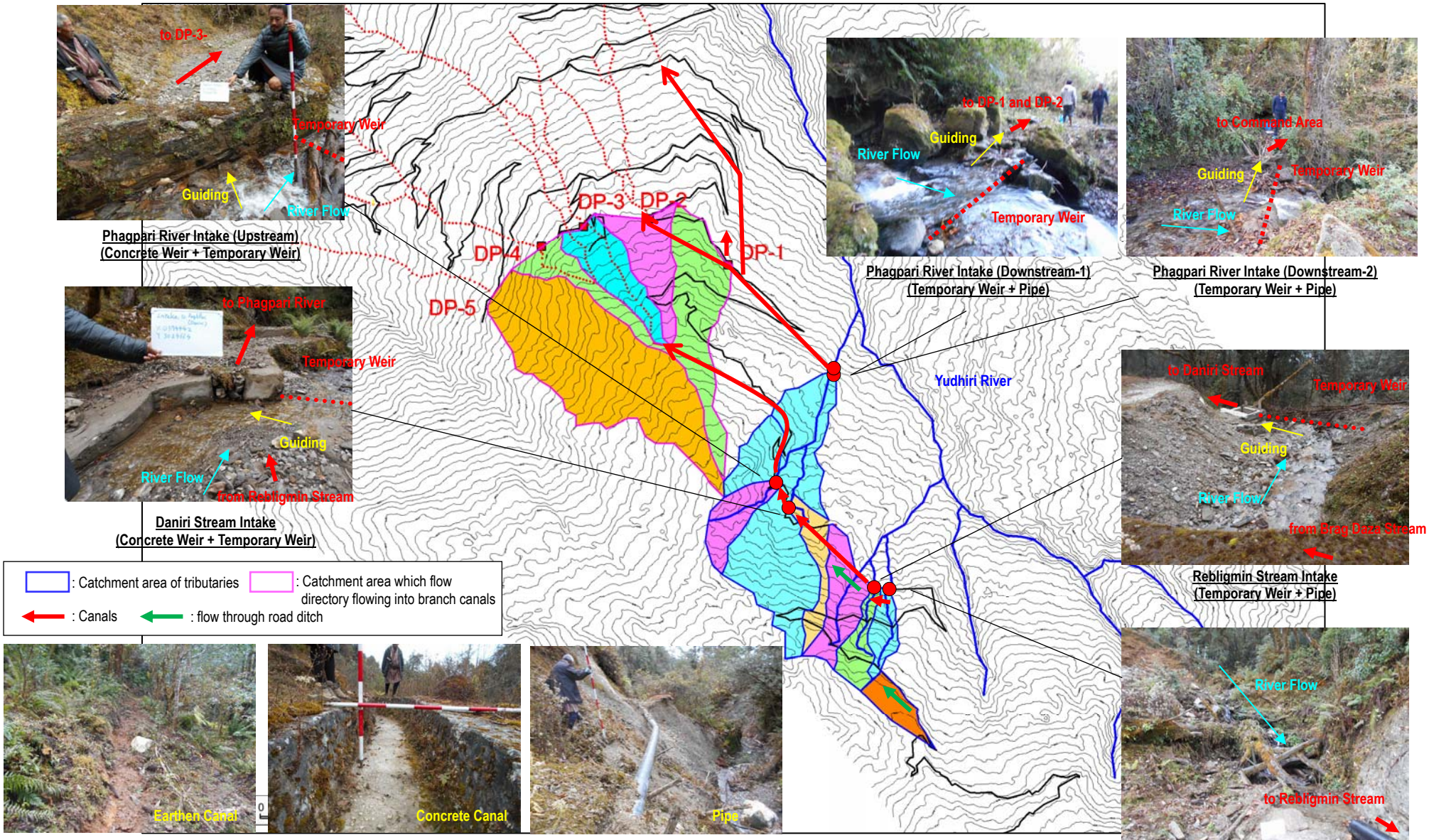


Figure 6.4.6 Water Distribution Situation of Yudhiri Irrigation System-1

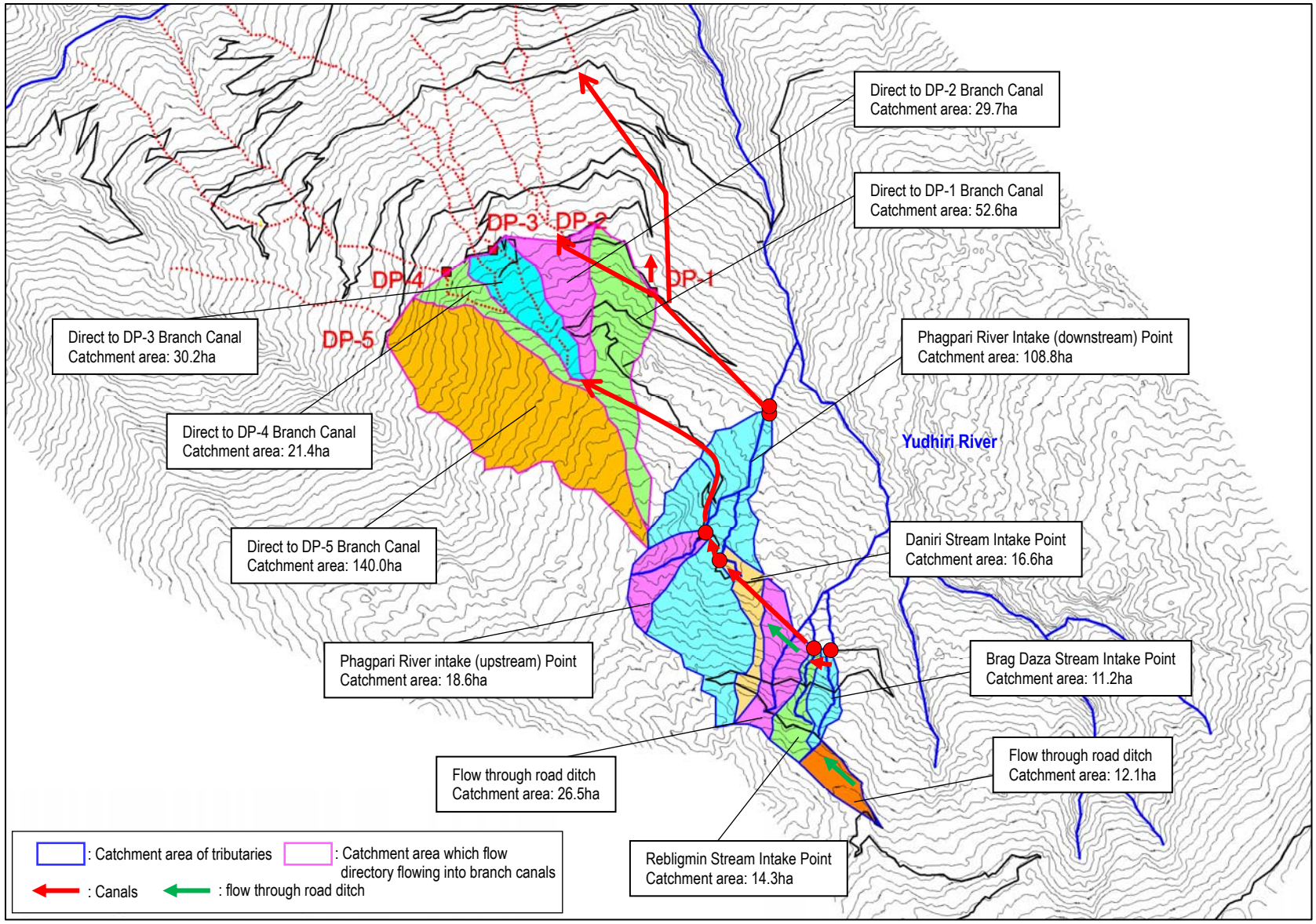


Figure 6.4.7 Water Distribution Situation of Yudhiri Irrigation Ssytem-2

(3) Water Distribution Situation within the Command Area

1) Situation of water distribution from water sources to the command area

All the distribution facilities (DPs) are located at the top of gullies which are stated as branch canals. Water delivered to each DPs (for DP-3 and DP-4, gullies near DPs) are discharged to branch canals and distributed to the command area.

In addition to branch canals, there are many identified gullies within the command area. To clarify gullies stated as branch canals, gully survey was conducted. As a result, alignment of branch canals becomes clear and many gullies, of which water source is spring, are identified (Figure 6.4.9). Since this survey was conducted on December 2016 and no water was taken from Phagpari River, the water source of gully with water may be spring. While at the south-east area of the command area, some gullies are identified but almost all are without water. The reason for this may be attributed to that there is only one spring point but water form this spring is guided to lower area by pipe.

Through the gully survey, it is identified that there is an area at the south-west area of the command area where water source is only spring DP-5. DP-5 also has its branch canal, however it drops about 8 m at 300 m downstream of DP-5. Based on the interview with the beneficiaries, the elevation gap between the branch canal and the command area at the downstream side of this drop point is too big to guide water from branch canal to the command area. Therefore, the spring water from DP-5 is supplied to only a limited upstream area and remaining flow is discharged to the downstream as disable release.

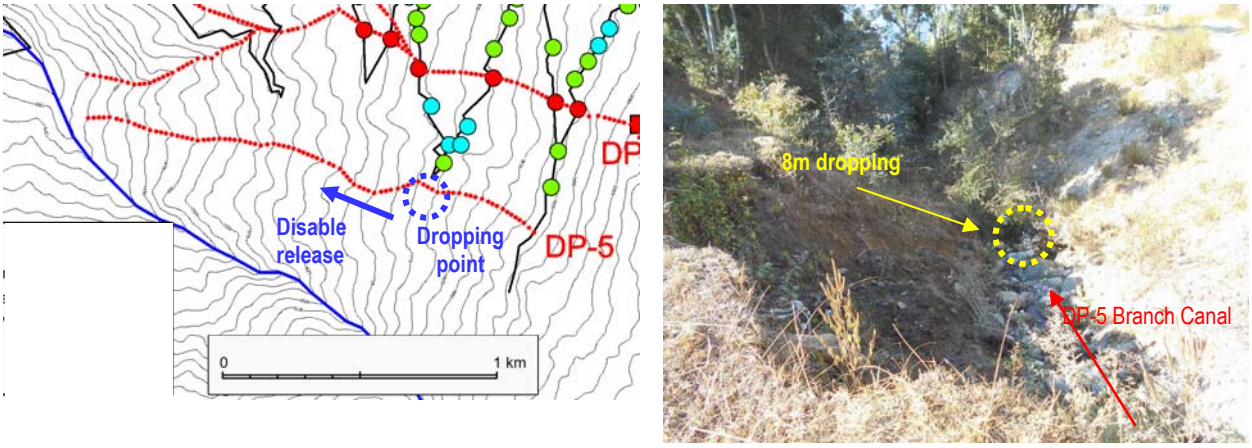


Figure 6.4.8 Dropping Point of DP-5 Branch Canal

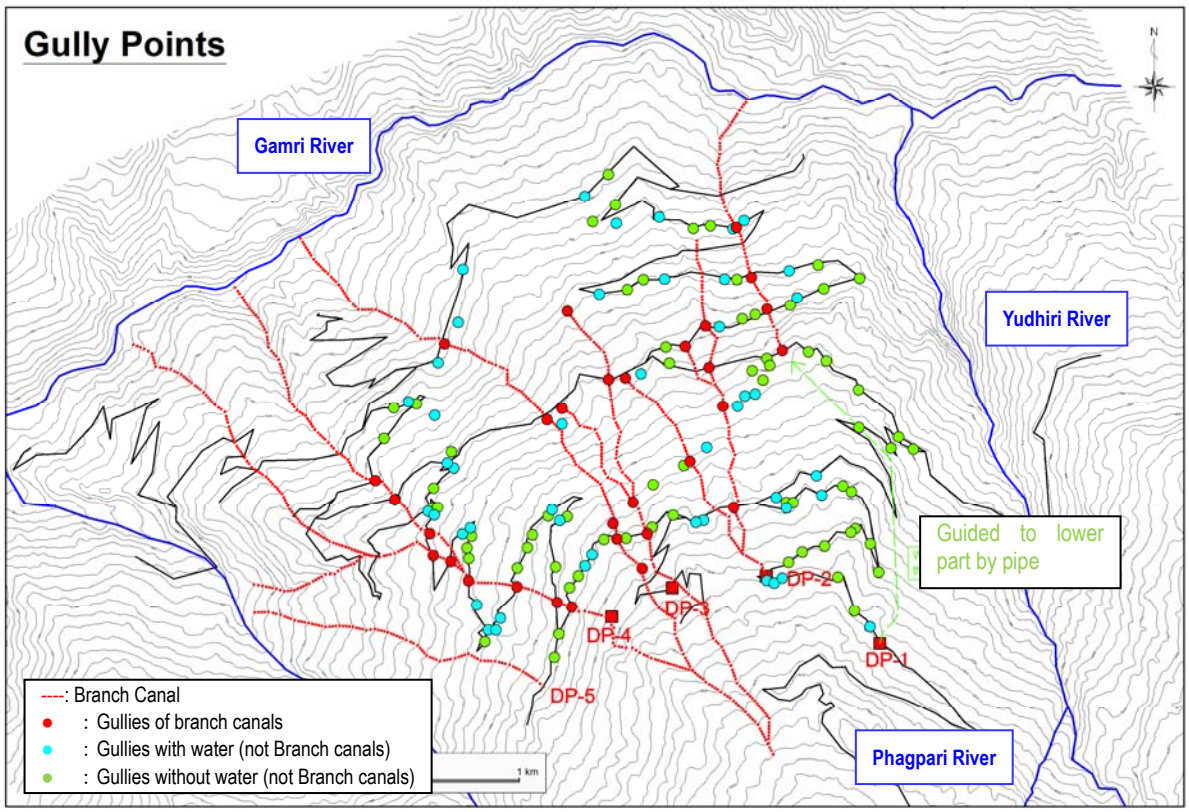


Figure 6.4.9 Gullies within the Command Area

2) Situation of water distribution from the branch canals to the individual command areas

Water discharged to the branch canals is guided to the individual command areas through pipes (Figure 6.4.10). From the interview with the beneficiaries, each beneficiary has their own pipe and never shares with the others.

Flow distributed from DPs (or gullies near DPs) could not reach the end of the branch canals because the flow amount decreased gradually as it goes down due to high seepage of the branch canals. Meanwhile, when it rains, flow is gathered for the branch canals and flow within the branch canals becomes like flood. This flow causes erosion on the edge of farmlands.

It is suspected that the individual command area might be affected by sedimentation delivered through pipe connecting the branch canals and the individual command areas. Also pipe might be closed by dead leaves. However, these kinds of situations are not confirmed.

Branch canal (DP-3)

Intake pipe from branch canal

Figure 6.4.10 Intake Pipe (from the Branch Canals to the Individual Command Areas)

6.4.3 Springs within the Command Area

As assumed through preparatory works, many spring points are identified within the command area.

Spring survey was conducted to identify the location, discharge and utilized purpose of the springs. As a result, almost all the springs are already utilized for drinking or irrigation.

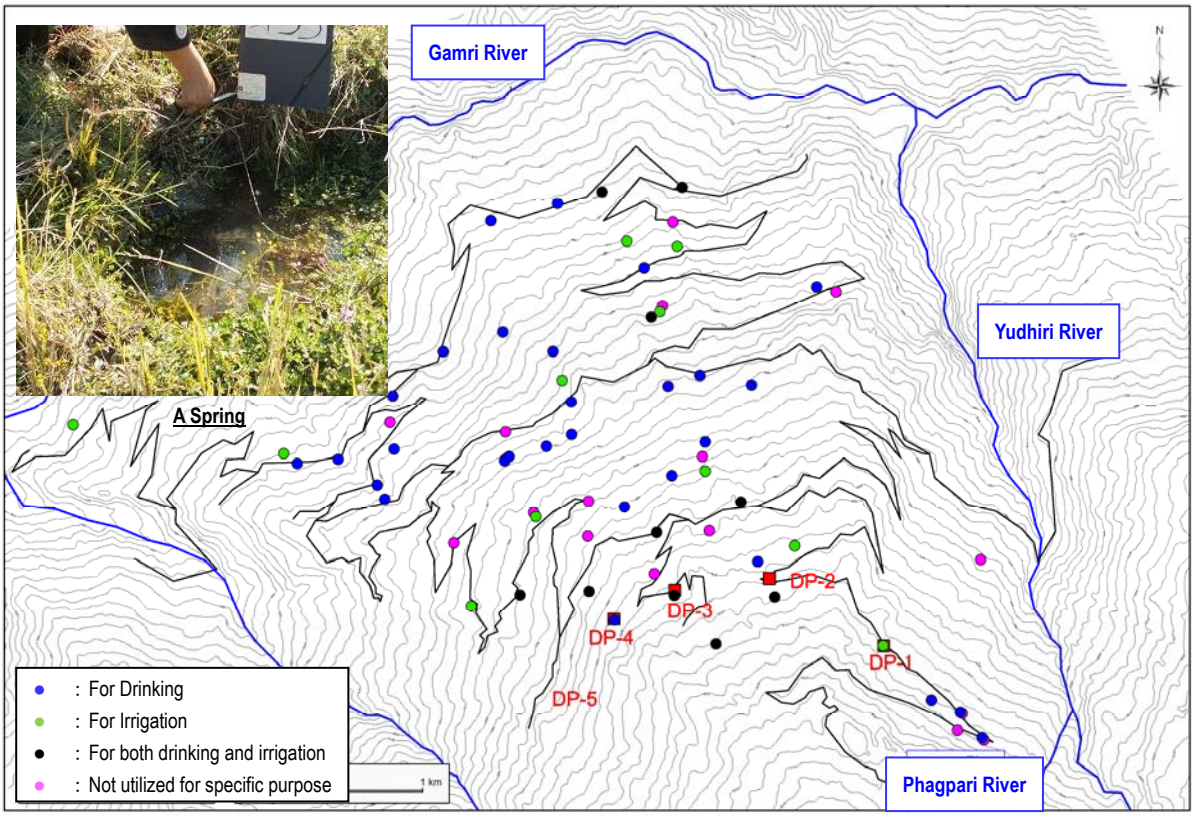


Figure 6.4.11 Springs within the Command Area

6.4.4 Geological Conditions

(1) Results of Outcrop Survey

As any existing geological survey targeting the command area was not available, outcrop survey was conducted to confirm general geological condition of the command area. The results of the survey are illustrated as Figure 6.4.12. The base rocks of the command area are “Crystalline Schist”, mostly “Biotite Schist” and usually consist of rhythmical alternations with meta-sandstone or quartzite, and Pegmatite veins intrudes into them at every pace.

Outcrop of base rocks, mainly the alternations of sandy rocks and schist, can be observed in the eastern and western edge of the command area. Those are mostly weathered and disturbed by faults or any other geological movements.

Almost no outcrops of base rocks can be observed at the central portion of the command area, while outcrops of huge rolling stones or accumulations of large boulders can be observed in almost all the protrusion zones. These stones' and boulders' outcrops consist of metasandstones, quartzite, and pegmatite or gneisses belonging to the basement rocks in this area. However, boulders of Amphibolite, Diabase, and Diorite which are not included in the base rocks in this area are also often observed. Since outcrops of these melanocratic (blackish) rocks cannot be observed within the command area,

these rocks are supposed to be brought from rather far (upper) area to the current portions by landslides.

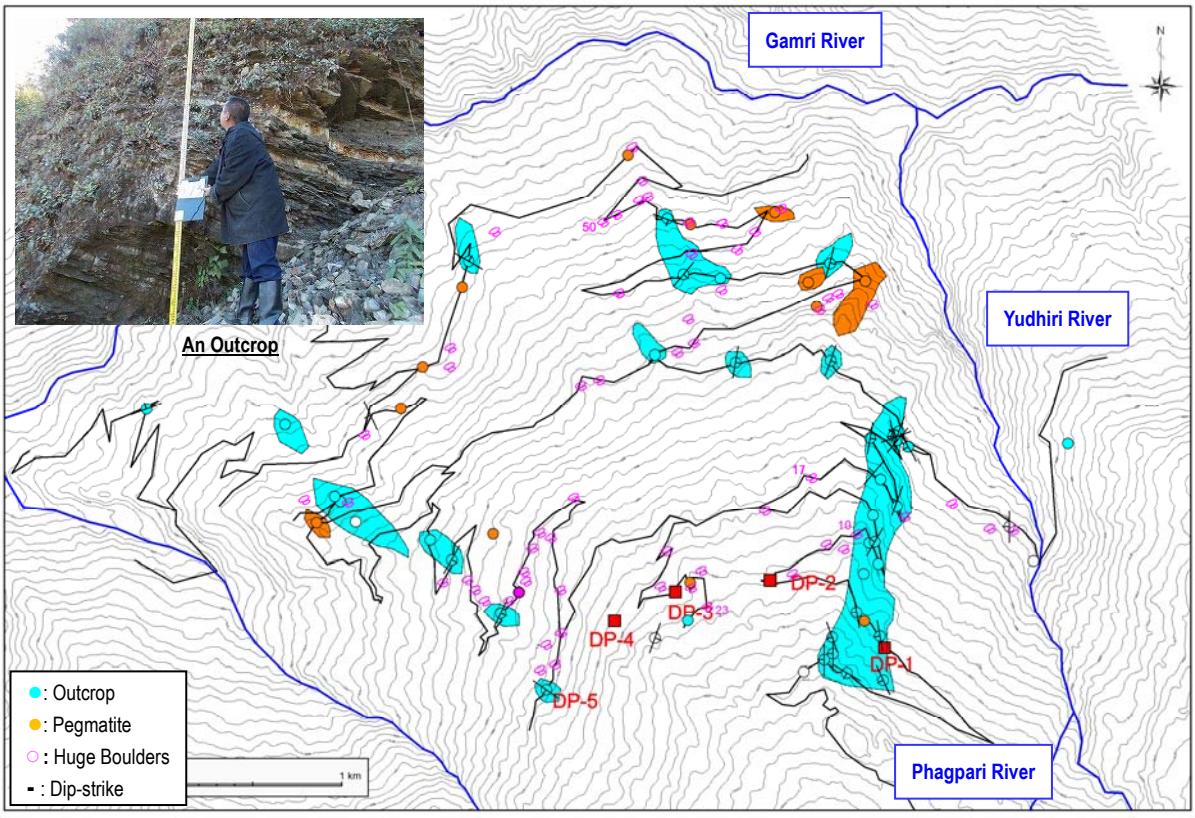


Figure 6.4.12 Results of Outcrop Survey

(2) Results of Boring Survey (refer to annex for detail results)

As many landslide formations were identified through preparatory works and any existing geological survey targeting the command area was not available, boring survey was conducted to grasp the thickness of landslides and geological formation of the command area. A total eight vertical and two horizontal borings were drilled (Figure 6.4.13).

The boring core observation identifies two geological layers at Bv16-2, Bv16-3, and Bv16-5, Colluvial Deposit I (Lower deposit) and Colluvial Deposit II (Higher deposit) according to the rock type included in the each layer.

Colluvial Deposit I includes only whitish to grayish rocks such as Pegmatite, Gneiss, and Quartzite, and those are base rock of the command area. While Colluvial Deposit II includes blackish plutonic rocks such as Amphibolite, Diabase, and Diorite, and those are not base rock of the command area.

This result is one of the proofs of supposition identified through outcrop survey that blackish rocks were brought from rather far (upper) area to the current portions by landslides.

The borings with maximum depth of 35 m are Bv16-2 and Bv16-3 but those cannot reach the landslide surface of Colluvial Deposit I. After drilling, groundwater level measurement was conducted utilizing the drilled holes.

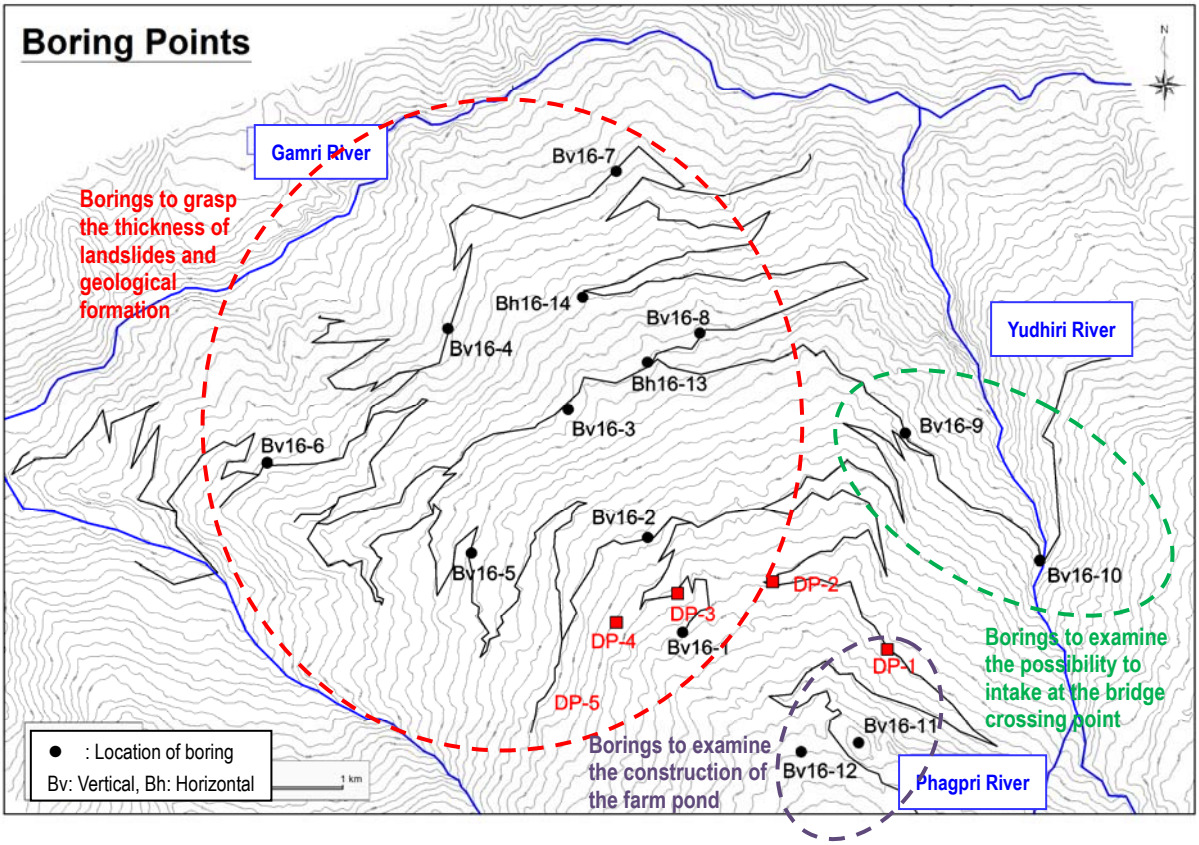


Figure 6.4.13 Location of the Boring Survey

6.5 IRRIGATION DEVELOPMENT PLAN

6.5.1 Planning Procedure

In the Survey, irrigable area is calculated according to the balance of water requirement amount based on the farming plan and water supply amount based on the selection of water source(s). For the calculation of the balance, measure(s) to reduce water delivering loss is also taken into account if necessary.

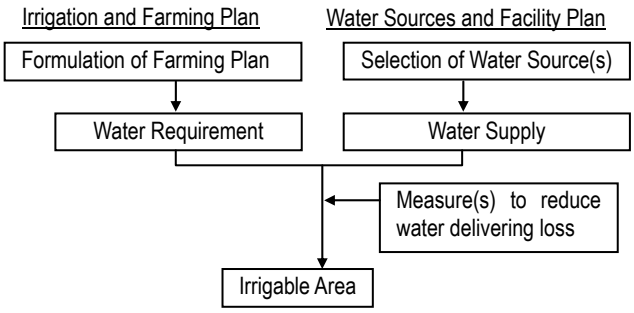


Figure 6.5.1 Flow of Survey and Examination

6.5.2 Irrigation and Farming Plan

(1) Challenges on Farming

Based on the interview with Gewog Agriculture Extension Officers and beneficiaries, current challenges to be addressed on farming are: 1) shortage of irrigation water, and 2) human-wildlife conflict.

Shortage of irrigation Water

a) Water for land preparation

The period of land preparation in the upper part is from middle of April to late May, and in the lower part is from late April to middle of June. Land preparation is conducted before the beginning of the rainy season from the upper part to the lower part in order. If the transplanting is delayed, growing

disorder occurs due to low temperature in planting and harvesting period. Hence, it is necessary to finish land preparation during the above period. Therefore, if the beginning of rain is delayed, land preparation work would be concentrated on a later period, thus shortage of water occurs.

b) Incremental water for rice cultivation
In the lower part, there are blocks that suffered from shortage of irrigation water because irrigation water is taken from the upper part.

c) Water for the dry season cultivation
Cultivated dry land area in the dry season is limited to about 10%* of that in the rainy season since farmers cannot expect rain during the dry season. Field cropping in the dry season is limited in blocks where it can address spring water.

*Cultivated dry land area in the dry season 43 ha / (Cultivated wet land in the rainy season 378 ha + Cultivated dry land in the rainy season 68 ha) = 9.6%

Human-wildlife conflict

Through a year, human-wildlife conflict occurs especially during the dry season when wild animals (wild boar, dear, porcupine, monkey, etc.) try to seek food in the command areas due to the lack of food in their habitat. These conflicts often get serious. In addition, livestock animals such as cow, ox and horses are pastured in the command area. Hence, cultivated areas in the dry season have set about 2 m simple fence, made of wood and bamboo. However, it has been difficult to protect the field from all animals by fencing and not all conflicts are prevented. On the other hand, conflicts also occur during the rainy season, but the number of animals enter the command area is usually small and the damage is limited. Farmers cultivating only in the rainy season have not set fences for their fields.

Other than the two problems mentioned above, there are two more general farming problems as mentioned in Chapter 5; "shortage of farming labour" and “shortage of extension of developed farming skills.” As for the shortage of farming labour, 69 power tillers (hand tractors) were supplied three years ago by Japanese Grant Aid. In addition, RGoB added two power tillers to the 69 by their own budget. So, a total of 71 power tillers have been introduced, and presently one power tiller is being used by nine households in average. According to the Gewog Agriculture Extension Officers, farmers can finish land preparation within the planned period using the current owned number of power tillers if farmers have enough water during planned land preparation period.

As for the shortage of extension of developed farming skills, the short period rice variety for double cropping is already developed. However, the command area of Yudhiri Irrigation System is not suitable for double cropping because the system is located in an altitude of 1,000 m to 2,000m, which is higher than the 700 m altitude condition necessary for double cropping. These are confirmed from the interview with ARDC Wengkhar.

(2) Future Farming Plan

Based on the interview with DAO and Gewog Agriculture Extension Officers, they have not prepared concrete farming plan of the command area. Meanwhile, it is confirmed through the interview with the beneficiaries that if they can secure enough additional irrigation water, they would like to expand rice planted area in the rainy season and vegetable planted area in the dry season. As example of expansion crops, radish, garlic, spring onion, green leaves, cabbage, potato, etc. are raised in the upper part, and wheat, oats, potato, etc are raised in the lower part. However, they do not have any information about expected expansion area. Therefore, the following are set as future farming plan in the Survey.

- Current rice planted area: 378 ha (measured from aerial photo)
- Expanding rice planted area: 37.5 ha (fallow land area)[45]
- Expanding planted area in dry season: 50.2 ha (200% of current potato planted area)[46]

When planted area is increased in accordance with the farming plan above mentioned, three other challenges; a) expansion of human-wildlife conflict, b) shortage of farming labour in the dry season, c) shortage of sales opportunity, would occur. However, it can be considered that the following on-going/to be implemented countermeasures/improvement of situations prevent the occurrence of or mitigate the damage by those challenges.

a) Expansion of human-wildlife conflict

There is possibility that the existing conflict would expand, especially in the dry season. However, the DAO has a plan to introduce electric fences into the command area if the irrigation facilities are improved.

b) Shortage of farming labour in the dry season

From November to February, during the period from the end of rice harvest to traditional New Year, men of 20's - 30's in almost all farmhouses go for migrant work. The income and the profit are 10,000 - 20,000 BTN and 7,000 - 10,000 BTN per month, respectively. The farmers would plant crops during the dry season when irrigation facilities are improved because they wish to reduce migrant work, and the planned profit of crop cultivation during the dry season would exceed the profit of migrant work[47].

c) Shortage of sales opportunity

Self-consumption ratio of rice in Bhutan was 51.3 % in 2011 and the remaining of about 49 % was covered by imported rice. Basically, the demand of local rice is bigger than demand for import. Bhutanese rice buyers visit the command area to buy surplus rice. From the viewpoint of the current situation of rice market in Bhutan, it is considered that there are enough sales destinations even if they increase rice planted area.

On the other hand, almost all surplus vegetables and fruits cultivated in the command area are sold in nine groceries in Radhi and Rangjung, nearest town to the command area. Based on the interview with the groceries, demand of vegetables is increasing. Also, from the interview with ARDC Wengkhar, a project to construct a processing factory and a cold storage house of agriculture produce in Saling, Mongar Dzongkhag is proceeding. In order to supply agriculture produce to this project, cold storage houses are to be constructed into Trashigang and Rangjung and those would have high potential to become a future sales destination for Yudhiri Irrigation System.

6.5.3 Water Sources and Facility Plan

Through the site survey of the command area, items listed in Table 6.5.1 seem to be candidates for water sources.

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[45] It is assumed that improvement of irrigation facilities would cause re-planting in the fallow land.

[46] Vegetables cultivated in the command area are sold in groceries in Rangjung, which is 6 km from Radih. Expanding planted field area in the dry season is set by 200 % of current potato planted area because demand of potato is increasing and about three times would be available to sell, which is confirmed by the interview with the groceries.

[47] Profit of migrant work: 2.5 month x 8,500 BTN = 21,250 BTN
Profit of additional crop cultivation in the dry season: 0.128 ha (incremental planted area per household) × 11,894 kg/ha (unit yield of potato) × 0.7 (profit ratio) × 20 BTN (sales price) = 21,314 BTN

Table 6.5.1 Candidates for the Water Source[48]

Candidates for Water Source	Reason to be judged as water source
(1) Yudhiri River	Discharge volume of river is biggest around the command area.
(2) Tributaries of Yudhiri River	These tributaries are present water sources.
(3) Springs	Many springs are identified within the command area
(4) Groundwater	Many springs are identified within the command area and groundwater surface is identified within the boring holes.
(5) Water Guided from DP-5	Total available water volume within the command area would increase by utilizing disable release.
(6) Concrete Lining for Branch Canals	Total available water volume within the command area would increase by reducing water delivery loss.
(7) Farm Ponds	Flat areas are identified at the higher portion of the command area and farm ponds constructed in these areas would store river flow during night time and increase usable water volume during day time.

The following are the results of the examination for each water source if it can be water source(s).

(1) Yudhiri River

1) Intake at same point where IFAD and beneficiaries constructed intake facility (Feasibility of Yudhiri Irrigation System)

Since the Yudhiri River has the biggest amount of discharge among the candidates, an examination to evaluate the feasibility of the rehabilitation of existing Yudhiri Irrigation System is conducted.

In order to examine the possibility to take water from the same point (hereinafter referred to as "existing intake point") as IFAD's and beneficiary's intake facilities, it is essential to analyze the reasons why intake facilities constructed by IFAD and beneficiaries were washed away - with the intake facility constructed by IFAD totally washed away and the intake facility constructed by beneficiaries washed away with a remaining part. Although these damages might happen due to flood and rocks/stones/sands delivered by flood, it is difficult to identify actual reasons because any facility design drawings and hydrological/meteorological data are not available. Therefore, the potential of taking water at the existing intake point is evaluated by the analysis of topographic map and by the field survey only. The examined results are shown as below;

Figure 6.5.2 Condition of Existing Intake Point

- Base rock at the existing intake point is fresh and tough. This can be the basement of concrete structure.

- River bed slope of the Yudhiri River is steep (almost 1/5) (Figure 6.5.3) with huge amount of water

[48] To take water from the Gamri River by pumping up can be considered as one of the candidates because flow of the Gamri River seems stable. However even if target area for irrigation is only lower part, at least pumping up for 600 m is required. Therefore, multistep pumping is required and the cost of the facilities becomes expensive. Additionally, not only pump itself but also its spare parts are not available in Bhutan. Furthermore there is no technician who can repair pump in Bhutan. Therefore, pump will be dysfunctional by even small trouble. Therefore to take water from Gamri River by pumps seems difficult

even during the dry season. This implies the huge flood volume during the rainy season.

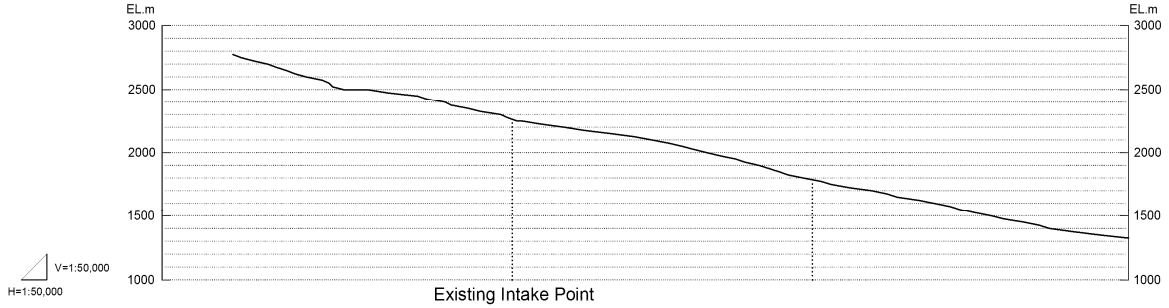


Figure 6.5.3 Longitudinal Profile of Yudhiri River Bed

- According to the analysis of red relief maps, some deep and steep gullies are identified at the upstream area of existing intake point. In addition, bare lands along the gullies are confirmed through the field survey (Figure 6.5.4). When it rains, many rocks/stones/sands may be produced from these bare lands and delivered to the existing intake point by flood. Additionally, big stones with diameter of more than 1 m are confirmed at both the existing intake point and near bare land. This kind of big stones might also be produced from bare lands as well.

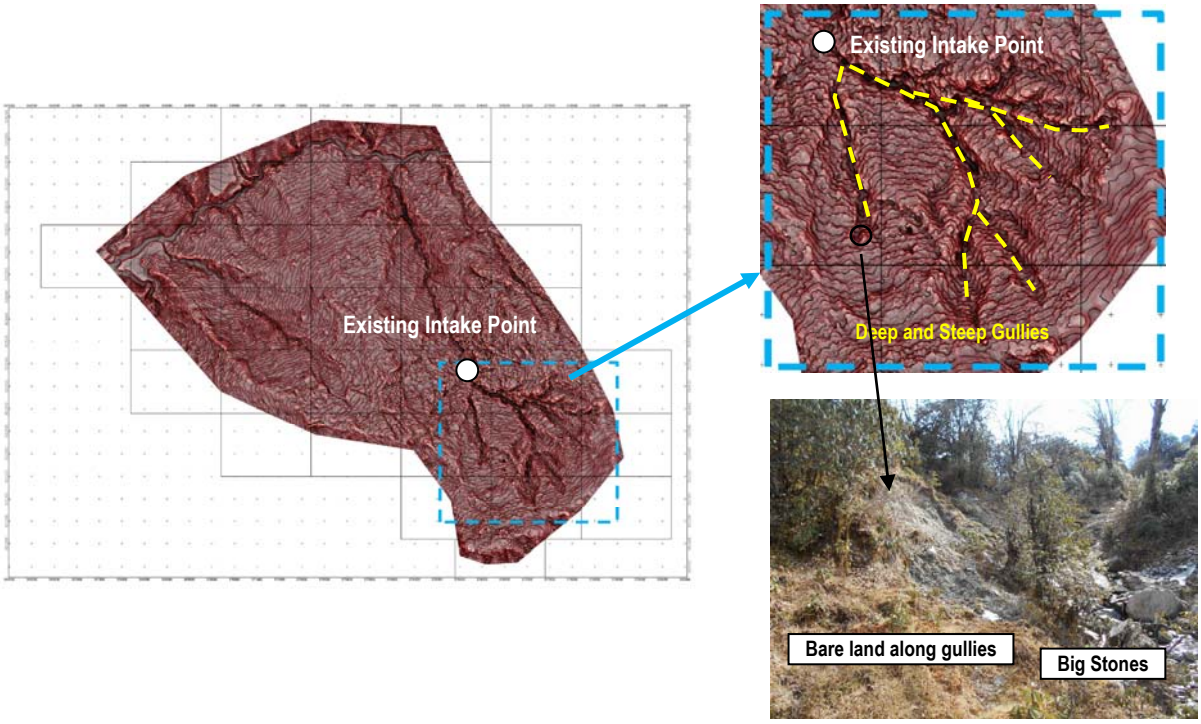


Figure 6.5.4 Gullies at the Upstream Area of Existing Intake Point

- From the analysis of red relief maps, many landslide formations are identified along the existing main canal constructed by IFAD. Additionally, springs and wet part are also identified outside of landslides through the field survey. These can imply future landslides.

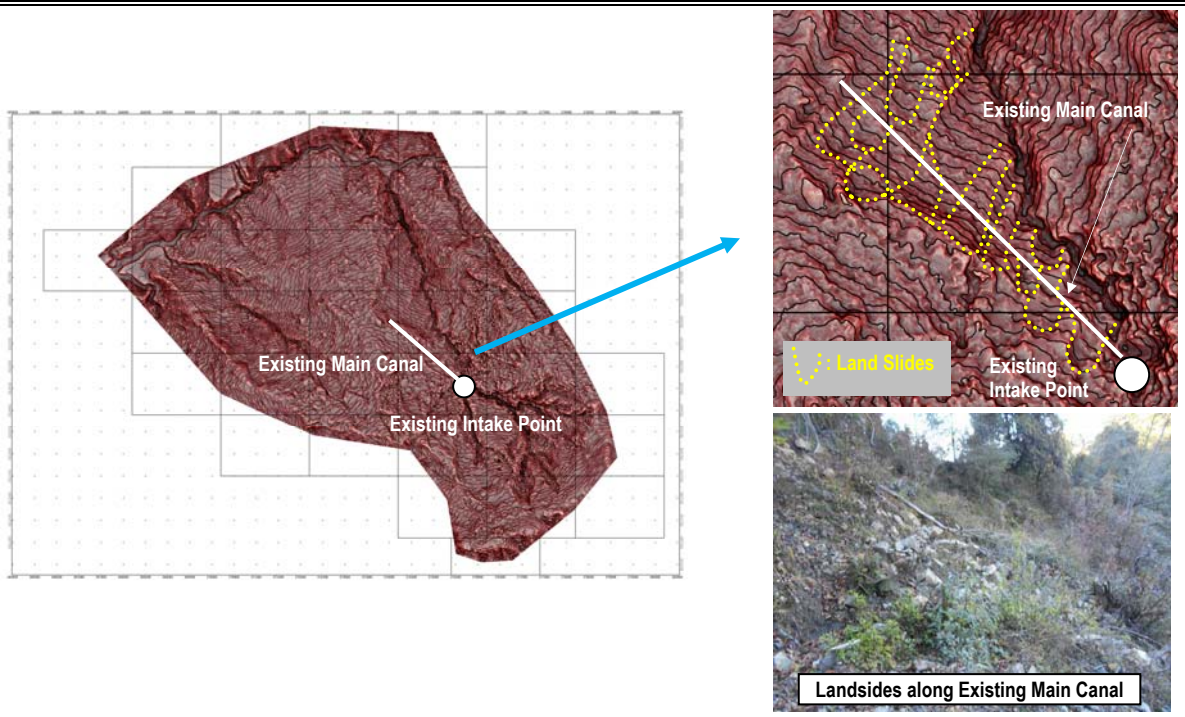


Figure 6.5.5 Landslides along the Existing Main Canal

Based on the results examined above, it is presumed difficult to construct intake facility at the existing intake point because intake facility will be damaged by flood and rocks/stones/sands delivered by flood. If intake facility is constructed independently, it might be washed away as the previous intake facilities constructed by IFAD and beneficiaries. Therefore, to construct intake facility at the existing intake point, construction of check-dams at the upstream side of intake facility is required. Check-dams contribute to catch rocks/stones/sands delivered by flood, to make river bed slope moderate and to reduce the strength of the flood[49].

As for the main canal, to change the alignment of the canal is the best alternative to avoid damage by landslides. However, landslides are identified everywhere along the existing main canal and to set alignment so as to avoid landslides is difficult. To construct main canal as the same alignment as existing one, landslide protection works such as slope protection works and groundwater lowering measures are required. However, since landslides are identified everywhere along the existing main canal as already mentioned above, it is difficult to adopt protection works to all the area where landslides are expected. To address these problems, water delivery by tunnel can be selected[50].

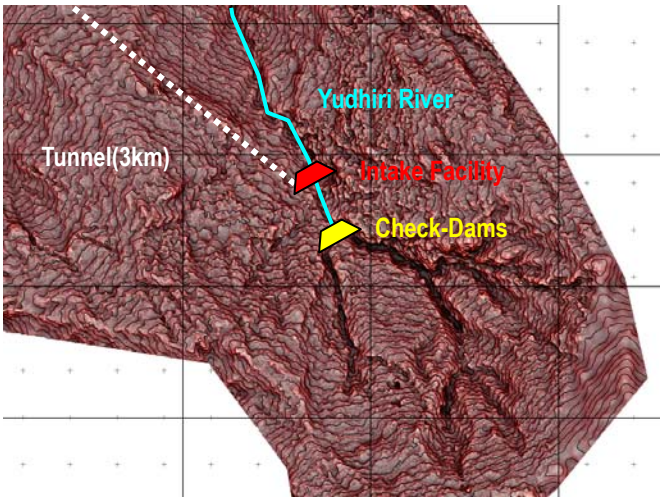


Figure 6.5.6 Rough arrangement of Intake Facility, Check-Dams and Tunnel

[49] To moderate river bed slope by check-dams certainly, multi check-dams shall be arranged cascadingly.
[50] Diameter of the tunnel shall be selected by not only the water delivering capacity but also from the

Rough arrangement of intake structure with check-dams and water delivery by tunnel is indicated in Figure 6.5.6. In addition to check-dams and tunnel, some related facilities such as river bed stabilization structures and river bank/bed protection works are also required. Thus, to draw water from the existing intake point, some facilities and related facilities are required, and the project cost to develop those facilities can be very huge.

Therefore, to construct intake facility at the existing intake point, rehabilitation of Yudhiri Irrigation System is difficult from the both the technical and economical view points.

*As already mentioned, rehabilitation of Yudhiri Irrigation System is judged difficult, examination to find alternative water sources are conducted. To differentiate from Yudhiri Irrigation System, an irrigation system examined below is named as "Radhi Area Irrigation System".

2) Intake from bridge crossing point at the Yudhiri River

If there is a point with mild river bed slope or stagnation along the river, that point might be the intake point because flood velocity is relatively low and rocks/stones/sands would sink due to low flood velocity. These factors cause relatively less damage on the intake facility. However, according to the longitudinal profile of the Yudhiri River bed, the slope is almost same at any points, so most points will have the same difficulty to construct intake facility as the existing intake point.

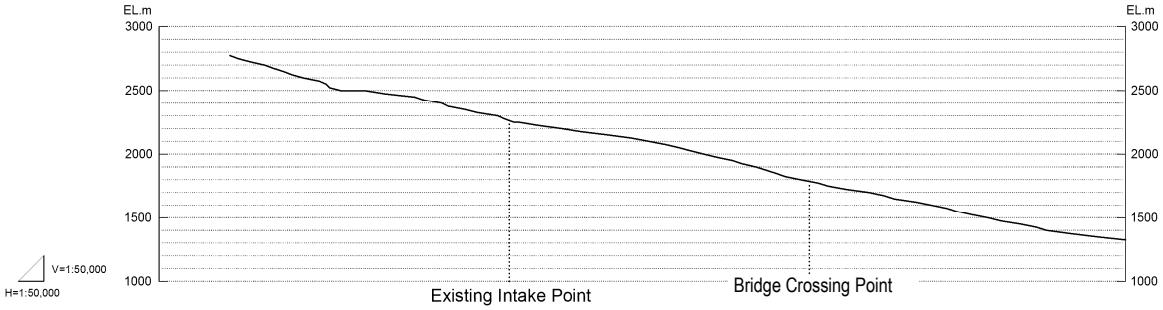


Figure 6.5.7 Longitudinal Profile of Yudhiri River Bed

Meanwhile, about 2.3 km downstream of the existing intake point, there is a road passing the Yudhiri River. A bridge construction is planned at this point (hereinafter referred as “bridge crossing point”.)

Intake from this point is examined because river flow seems stable at this point and to construct intake facility seems possible.

Present situation of bridge crossing point

There is a paved road across the center of the command area from the west to east. To deliver water through a canal constructed along this paved road can be considered. However, by this measure, water could be delivered only to lower part of the command area (Figure 6.5.9).

Figure 6.5.8 Bridge Crossing Point

viewpoints of maintenance. If the diameter is small, it will be blocked by soil or debris.

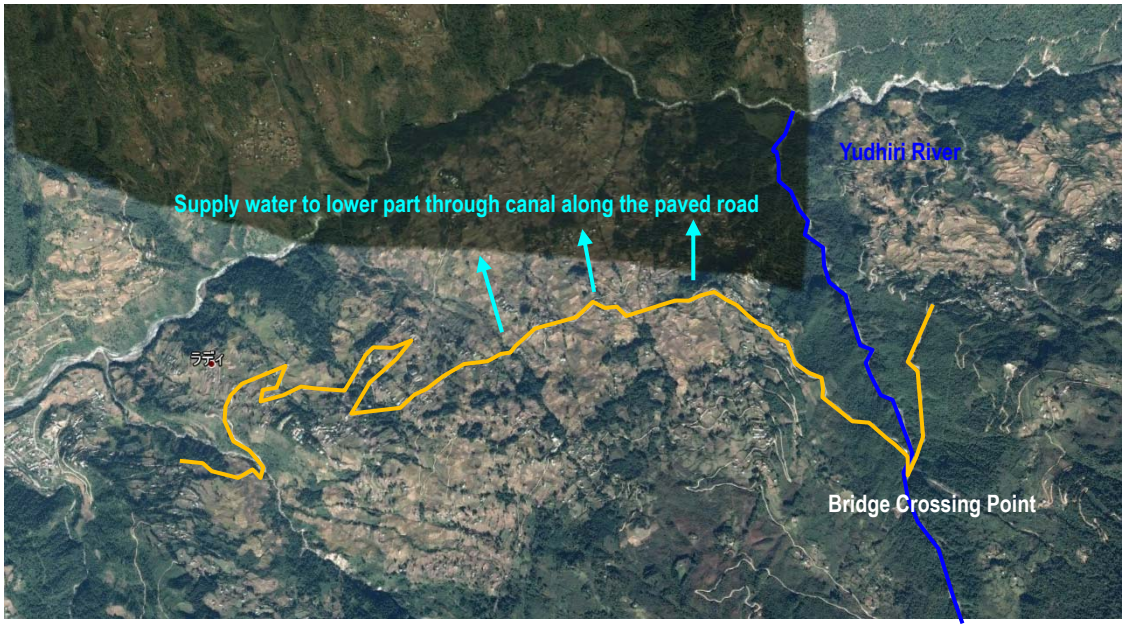


Figure 6.5.9 Outline of Water Distribution from Bridge Crossing Point

According to the longitudinal profile of the paved road, a part of this road has negative slope and the elevation of highest point is 30 m higher than the bridge crossing point (Figure 6.5.10). Therefore, to draw water at the bridge crossing point and deliver through the canal along the road by gravity is impossible.

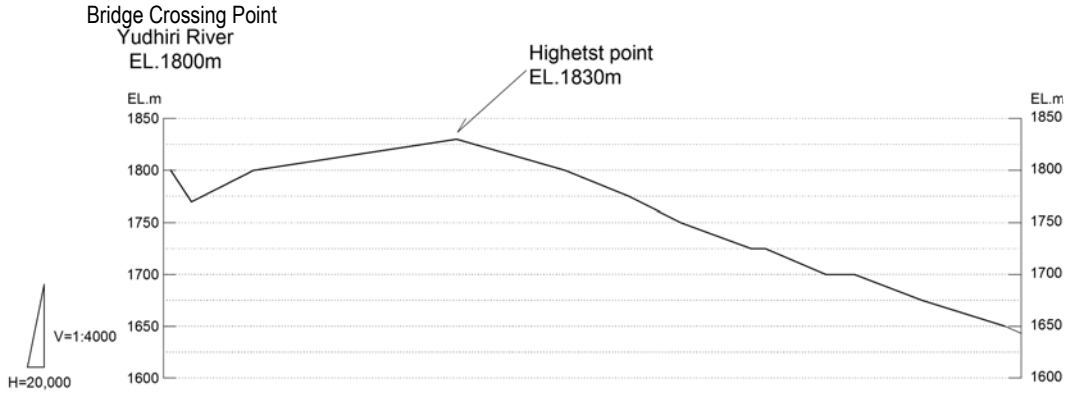


Figure 6.5.10 Longitudinal Profile of the Paved Road

Intake structure

Taking into account the situation of bridge crossing point and longitudinal profile of the paved road, the following three intake structures can be considered:

i) To intake water from upstream side of bridge crossing point
Intake point with higher elevation than the highest point of the paved road is selected and water is delivered to the highest point of the paved road.

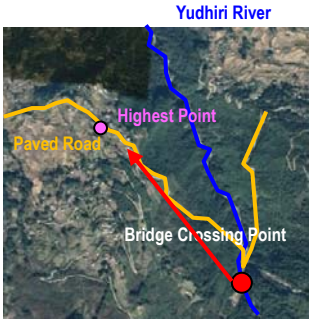
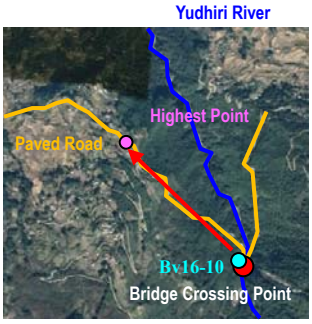
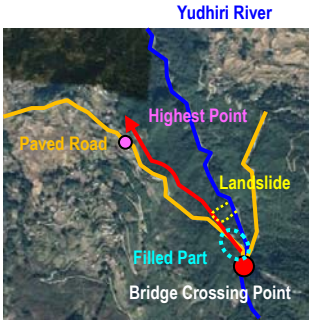
ii) To install pump station at bridge crossing point
River flow is pumped up to the highest point of paved road.

iii) To construct canal along the slope that is lower than the paved road
River flow is delivered through canal constructed on the slope where is lower than the paved road.

Possibility to intake water from bridge crossing point

Results of comparison examination of the three intake structures above are shown in Table 6.5.2. Based on the results, intake from bridge crossing point is difficult because all three structures have technical difficulty to be adopted.

Table 6.5.2 Results of Comparison Examination of Intake Structure from Bridge Crossing Point

Intake Structure	a) To intake water from upstream side of bridge crossing point	b) To install pump station at bridge crossing point	c) To arrange canal along the slope where is lower than the paved road
Outline	 Intake Point (150m upstream of bridge crossing point)	 Intake Point (Bridge Crossing Point)	 Intake Point (Bridge Crossing Point)
Evaluation	There is no point with mild river bed slope or stagnation around this point. Also, river bed slope is almost same as existing intake point. Therefore to draw from this point is difficult because difficulty to construct intake facility is almost same as the existing intake point.	Based on the results of the boring survey conducted just beside the bridge crossing point, base rock appears at 2 m depth from the ground surface. There is also a fault fracture zone from 6 to 10 m depth and N values of this zone are 8 to 11. Therefore, it is judged difficult to install pump station because a fault along the Yudhiri River is suspected and the bearing capacity of fault fracture zone is not enough for pump station.	Slope that is lower than the paved road is very steep, 1:1 or less, and some parts are constructed by filled material. This filled part is not consolidated well (soft) and it might be difficult to construct structures on it. Also, there is a landslide on the alignment of canal. Additionally, a part of canal will be 30 m lower than the paved road and it is difficult for the person to reach there for maintenance works. Therefore, to arrange canal on the slope that is lower than the paved road is difficult.

(2) Tributaries of the Yudhiri River

As of February 2017, water is taken from the tributaries of the Yudhiri River and delivered to the command area. At the intake points of these tributaries, beneficiaries have constructed temporary weir or installed pipe to guide/intake river flow.

Since improvement of intake structures seems to contribute to increase in water volume to be taken, the possibility of the improvement of intake structures is examined.

Present condition of tributaries

From the interview with the beneficiaries, among the tributaries utilized as present water source, the Brag Daza Stream, the Daniri Stream and the Phagpari River have discharge even during the dry season. Discharge volume of those streams/rivers varied according to the season but does not drastically change each year. However, the Rebligmin Steam dries up and acts as only via point from the Brag Daza Stream to the Daniri Stream during the dry season. Also, Phagpari River have had flood only once in these forty years.

Discharge of each tributary

In order to identify discharge condition of each tributary, discharge measurement was conducted two times during the Survey, December 2016 and January 2017. As for the Rebligmin Stream, it already dried up in December 2016.

Discharge was calculated according to the measured depth and width of flow at the point forming like weir. Since there are two formulas to calculate discharge, suitable formula was selected by tributary first and later discharge was calculated by the selected formula.

i) Depth and width of flow at the point forming like weir was measured,

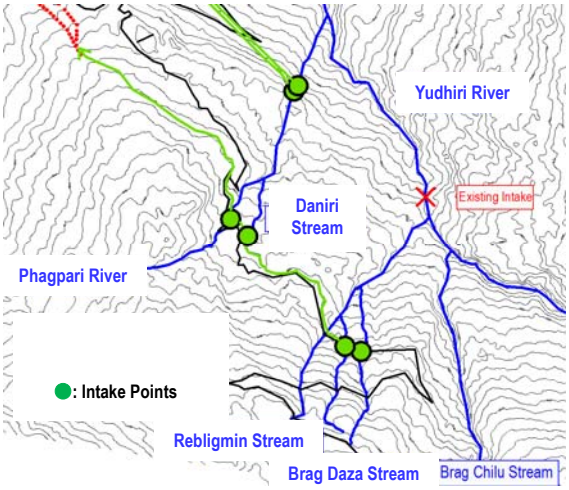
ii) According to the measured depth and width, discharge was calculated according to the two formulas below,

Critical Depth Formula: $Q=\sqrt{}(h^3 \times g \times B^2)$

Weir Formula: $Q=1.7 \times B \times h^{3/2}$

Where;
Q: Discharge (m^3/s),
h: Flow depth (m),
g: Gravitational acceleration ($=9.8m/s^2$),
B: Flow width (m)

iii) Width, depth and velocity were measured at the point where flow was stable (different point from a point forming like weir) and discharge was calculated.



Intake Points at each Tributary

Delivered to the command area through Rebligmin Stream, Daniri Stream and Phagpari River

Figure 6.5.11 Intake Condition of Tributaries (Brag Daza Stream)

iv) A formula with the result almost the same as the results of iii) was selected.

v) From the second measurement, only the width and depth were measured at the point forming like weir and discharge was calculated according to the selected formula.

Figure 6.5.12 Depth and Width Measurement

Seasonal discharge

Depth and width as of September (end of the rainy season) and the end of May (end of the dry season = minimum discharge) are assumed based on the interview with the beneficiaries, and discharge are calculated by the aforementioned selected formula. While, seasonal discharge is calculated by inter/extrapolation of the measured/calculated discharge (Figure 6.5.13).

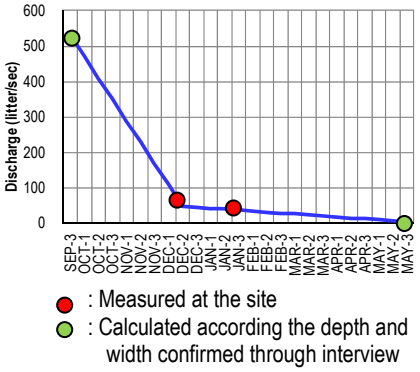


Figure 6.5.13 Seasonal Discharge

Seasonal discharges of each tributary calculated according to the procedure above are shown in Figure 6.5.14. As already mentioned, since the Rebligmin Stream does not have discharge during the dry season, this stream is out of the target for calculation.

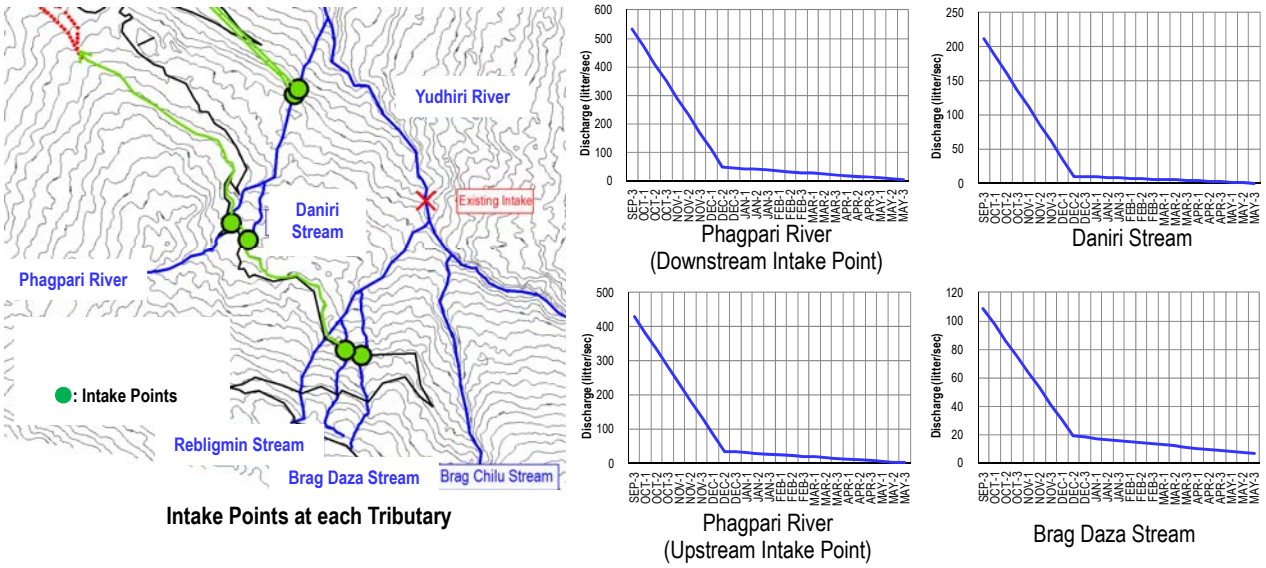


Figure 6.5.14 Seasonal Discharge at Intake Point

Possibility to increase water taken from tributaries by improvement of intake facilities

As compared to the flow conditions of the Yudhiri River, its tributaries have advantages such as 1) flow is more stable, 2) flood volume is smaller and 3) volume of rocks/stones/sands delivered by flood is smaller. Furthermore, existing concrete weirs such as the weir at the Daniri Stream intake point has almost no damage. Therefore, to construct intake facility at the tributaries could be possible and effective. By the arrangement of permanent weirs, the volume of water taken form tributaries might increase.

(3) Springs

Many springs are identified within the command area. Since spring water can be delivered to the command area easily, the possibility to utilize spring water for irrigation is examined.

From the results of the spring survey, almost all the springs are already utilized for drinking and irrigation (Figure 6.5.15). Therefore, springs are difficult to be a new water source.

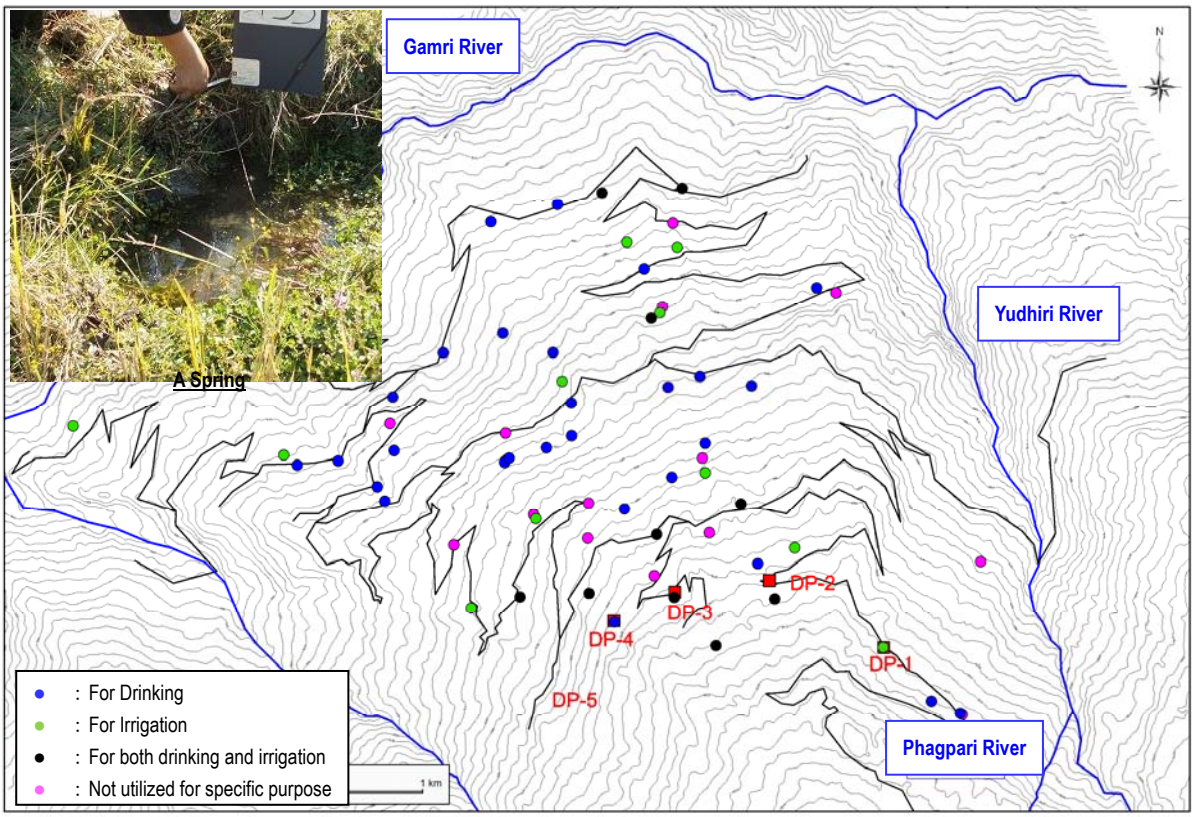


Figure 6.5.15 Springs within the Command Area

(4) Groundwater

Since many springs were identified within the command area, it was assumed that the command area had groundwater potential. Furthermore, groundwater surface was identified within the borehole. Therefore, the possibility to utilize groundwater for irrigation is examined.

Results of groundwater level in the vertical boreholes

At eight vertical boreholes (Bv16-1 to 8) to identify the geological conditions of the command area, groundwater level has been measured before beginning and after completion of daily drilling works (Table 6.5.3 and Figure 6.5.16).

Table 6.5.3 Groundwater Level (Depth from the Ground Surface)

Boring No.	Bv16-1	Bv16-2	Bv16-3	Bv16-4	Bv16-5	Bv16-6	Bv16-7	Bv16-8
Groundwater Level	Nil	1 to 2m (Higher Deposit) 14m (Lower Deposit)	1 to 2m (Higher Deposit) 27m (Lower Deposit)	3 to 6m	0m	11m	2 to 3m	3m

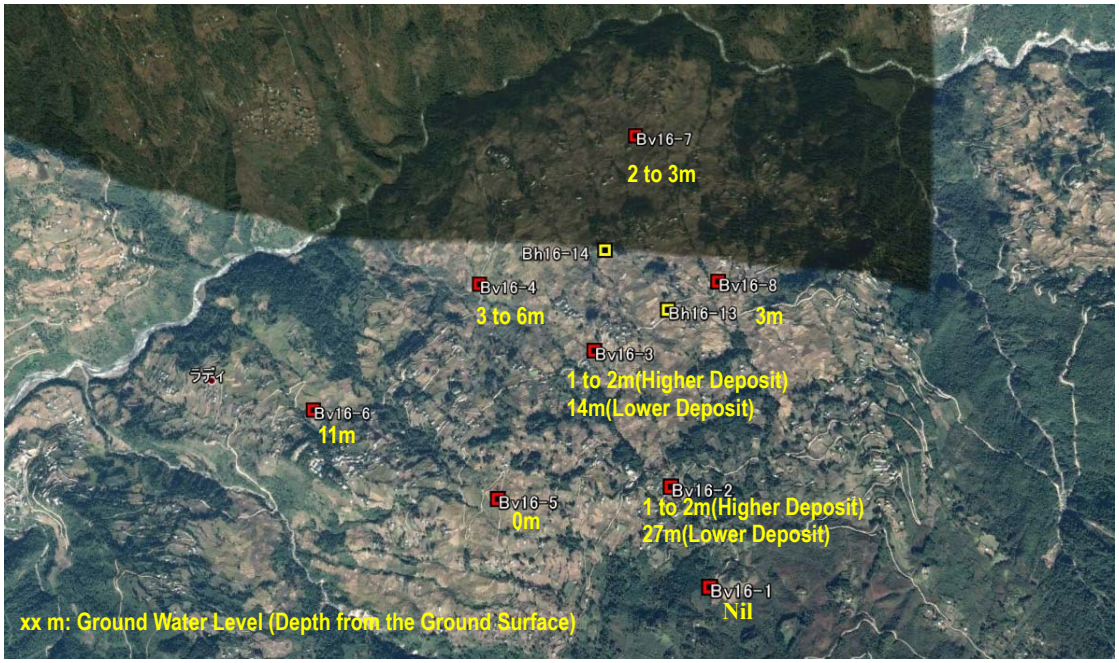


Figure 6.5.16 Location of Boring and Groundwater Level

Target groundwater

As already mentioned, two geological layers, Colluvial Deposit I (Lower deposit) and Colluvial Deposit II (Higher deposit) were identified. From the results of groundwater level measurement, groundwater surfaces were formulated for each layer. It was supposed that the border of layers had relatively low permeability and this caused the two groundwater surfaces.

To utilize groundwater, two methods could be considered, 1) pumping up from vertical borehole and 2) divert through horizontal borehole by gravity. Taking into account the easy O&M, horizontal borehole method was selected. Although deep groundwater might be stable, groundwater formulated within the Colluvial Deposit II (Higher deposit) was selected for the target to be assessed due to easy development in future (length of horizontal boring would be relatively short).

Location of horizontal borings

At almost all vertical boreholes, groundwater surface was identified within 3 m depth from ground surface. However, only Bv16-6 had 11m depth, deeper than the others. It was supposed that groundwater level of the western part of the command area was relatively lower than that of the eastern part.

Therefore, eastern part of the command area was selected for the target of horizontal boring. Locations that are more than 200 m far from the springs were selected for boring site to avoid drying up the springs by collecting groundwater. In particular, one target (Bh16-13) was located between Bv16-3 and Bv16-8 and another (Bh16-14) was between Bv16-4 and Bv16-7.

Results of horizontal boring

Both Bh16-13 and 14 were drilled up to 35 m. Since gradient of the command area was almost 1:3.0 and it was expected that boring would reach

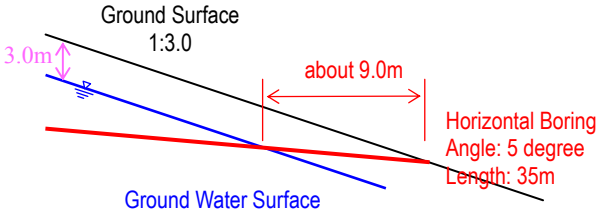


Figure 6.5.17 Relation of Ground Water and Horizontal Boring

enough to the groundwater (Figure 6.5.17). However, no discharge was confirmed at both boreholes.

Possibility to utilize groundwater

At almost all vertical boreholes, groundwater surface was identified within 3 m depth from ground surface. However, no discharge was confirmed from the horizontal boreholes.

Since these horizontal boreholes are located far from the springs, groundwater level only near the spring might be relatively high. However, if groundwater development is planned, horizontal boring shall be located far from the springs to avoid drying up.

Thus, groundwater potential around the spring might be high but horizontal boring shall be constructed far from the spring, to utilize groundwater for irrigation seems difficult.

Meanwhile, lowering of groundwater surface contributes to making it stable from landslides. As already mentioned, since there are many landslides within the command area, to lower the groundwater is effective from the view point of farmland conservation. Therefore, in case the necessity of groundwater level lowering is identified according to the results of groundwater level measurement by DoA utilizing groundwater level gauge procured in the Survey, this kind of horizontal boring will be effective.

(5) Water Guided From DP-5

According to the field survey, disable release was identified at the dropping point. Therefore, possibility to utilize this disable release for irrigation is examined because its utilization would contribute to increase usable water volume.

There is a mild ridge between DP-4 branch canal and DP-5 branch canal. Construction of tunnel under this ridge to connect DP-4 branch canal and DP-5 branch canal will work to guide water from DP-5 to DP-4 branch canal.

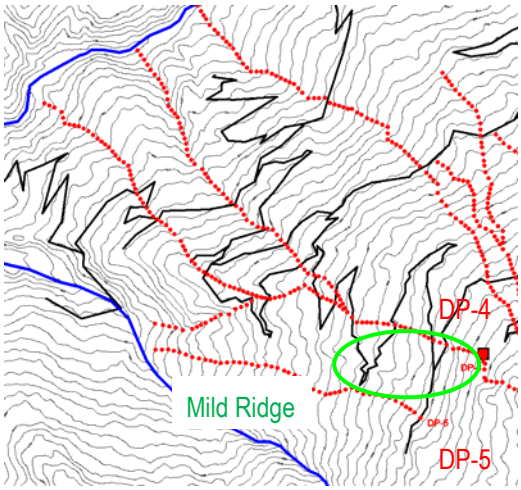


Figure 6.5.18 Mild Ridge between DP-4 and DP-5 Branch Canal

(6) Concrete Lining for Branch Canals

Based on the interview with the beneficiaries, flow distributed from DPs (or gullies near DPs) to the branch canals could not reach the end of the branch canal due to high seepage. Thus, the possibility to reduce water delivery loss by concrete lining is examined.

Figure 6.5.19 Condition of a Branch Canal

Lining Structure

Concrete lining for branch canals causes increase of flow velocity. In this case, to intake/guide water from branch canals to the individual command areas becomes difficult and disable discharge to the Gamri River will increase. Thus, available water volume will be less than present in some cases, even if water delivery loss is improved. In order to take water effectively from the lined branch canals, some energy dissipation structures such as drop structures

or boxes are required additionally.

Efficiency of concrete lining

A water distribution network is created based on the present water distribution system (Figure 6.5.20). The effectiveness of concrete lining to the branch canals are examined utilizing this network. As a result, even if all the 17.7 km of branch canals are lined by concrete, the increase of available water would be limited, only 3% more than present one.

Problems lead by concrete lining

Seepage from branch canal seems to contribute to recharge the groundwater. If branch canals are lined by concrete, recharge volume will decrease and some springs might dry up.

Possibility to adopt concrete lining

Since effectiveness of concrete lining to increase available water volume is limited and lining will cause another problem, concrete lining to the branch canals seems difficult.

Meanwhile, erosions of the edge of the farmlands along the branch canals are confirmed. Lining works to these parts will contribute to prevent farmlands from erosion. Thus, concrete lining is effective from the view point of farmland conservation.

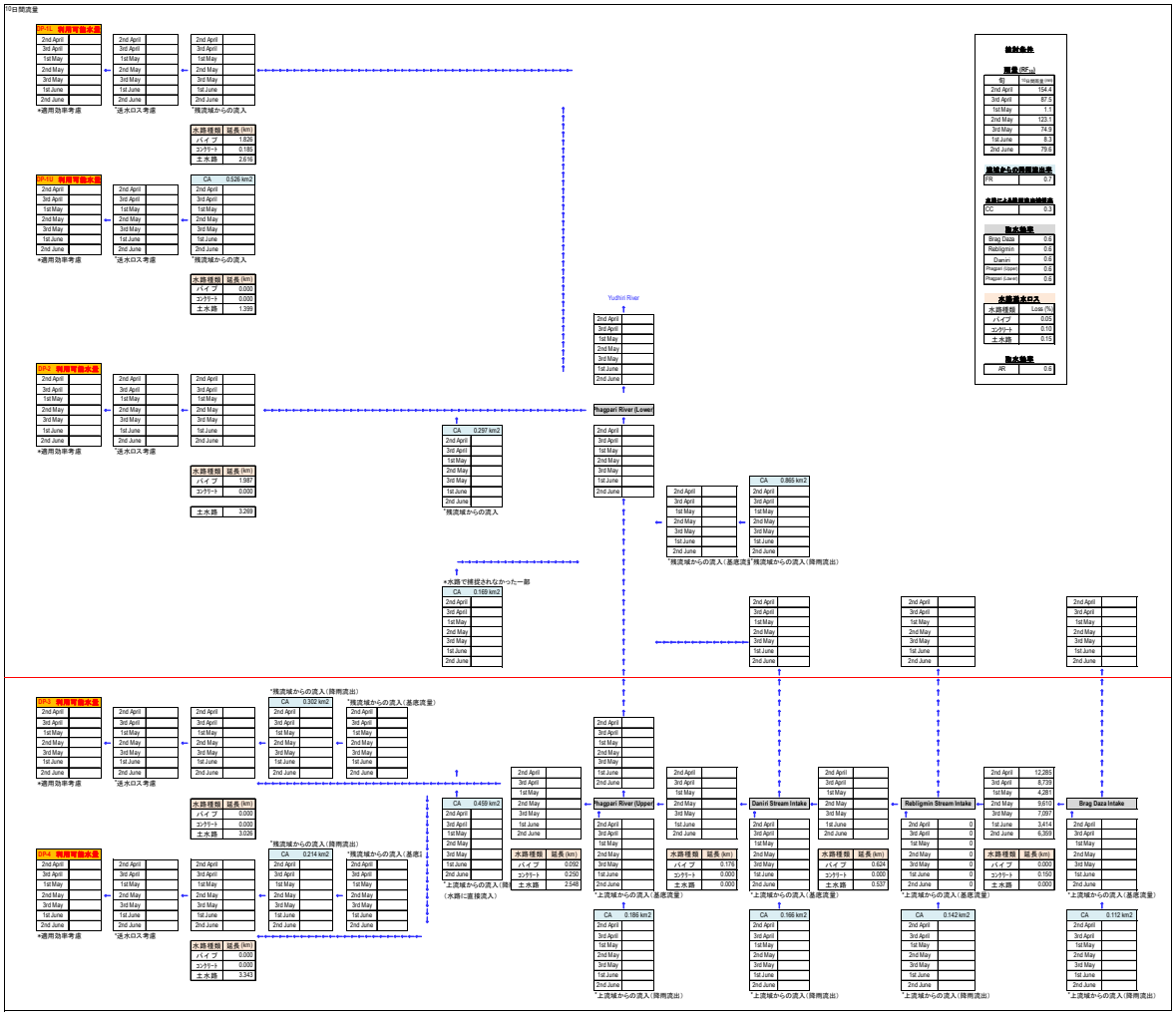


Figure 6.5.20　Water Distribution Network

(7) Farm Ponds

Through the site survey, some flat areas were identified at the high elevation area of the command area. Therefore, possibility of construction of farm ponds is examined because farm ponds would store river flow during night time and available water volume during daytime would increase.

Candidate sites for the farm ponds

The required conditions for construction site of farm ponds are: 1) located at the high elevation area to enable distributing water by gravity, and 2) relatively flat. These conditions can be identified by the analysis of the topographic map. The area with wide gap of contour lines or circled contour line implies the flat area and this kind of area can be a construction site for farm pond. The latter, that is the area with circled contour, is better for the construction site.

According to the analysis of the topographic map, two circled contour lines were identified and only one site was selected as a candidate site (Candidate-1) because the another area was also flat but too narrow to construct a farm pond. Meanwhile some areas with wide gap of contour lines were identified and one site was selected as another candidate site due to its accessibility (Candidate-2).

Figure 6.5.21 Flat Area at High Elevation Area

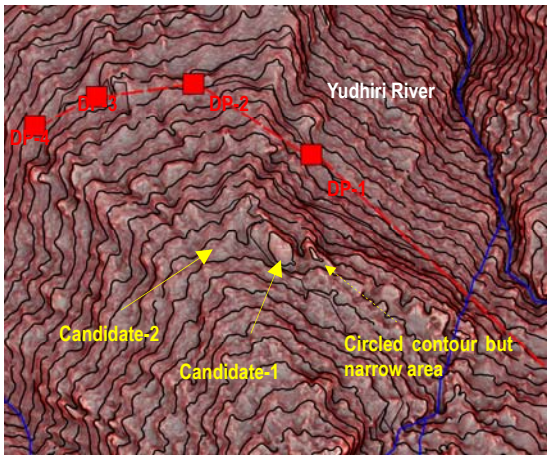


Figure 6.5.22 Candidate Sites for Farm Pond

Results of Boring Survey

Two boring surveys (Bv16-11 and Bv16-12) to confirm the bearing capacity of the ground were conducted at the two candidate sites. Boring logs of both boreholes are shown in Figure 6.5.23. All the N values are less than 10.

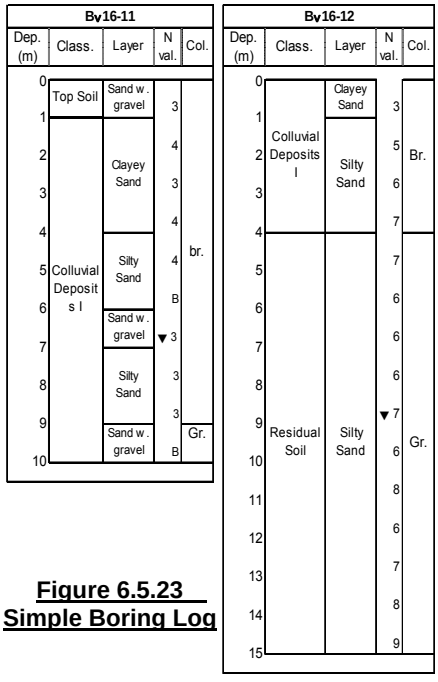


Figure 6.5.23 Simple Boring Log

Farm Ponds Structure

For the concrete structure, N value of more than 30 is required in general. Therefore to select concrete type pond is difficult but digging type pond can be adopted.

Impervious material

For the digging type pond, the surface of dug pond shall be covered by imperious material to reduce seepage volume from the pond. In general, clay soil is utilized for impervious material. However, such soil is not available within/near the command area. Therefore, rubber sheet is considered as an

adoptable impervious material. However, due to technical difficulties stated below, adopting of rubber sheet for impervious material seems difficult.

- Rubber sheet tears easily by the projection. Therefore, all the stones on the surface of dug pond shall be removed completely and levelling of the surface is necessary. Careful construction works are required.
- It is reported that seepage through the rubber sheet happens due to deterioration by the ultraviolet rays and cracks by drying shrinkage. It is possible to prevent rubber sheet from ultraviolet rays by arranging soil layer on the rubber sheet. However, it is difficult to keep the pond to be always in wet condition especially during the dry season.
- From the interview with ARDC Wengkhar and the beneficiaries, rubber sheet is not available in Bhutan and shall be imported from India. Therefore, it is difficult to conduct repair work immediately if trouble happens on the rubber sheet, such as tearing or cracks.
- These candidate sites are located at the head of landslides. If a huge leakage results from the farm pond, these landslides might be unstable. There is also a road beside the landslides, and this road will be blocked if landslides move.

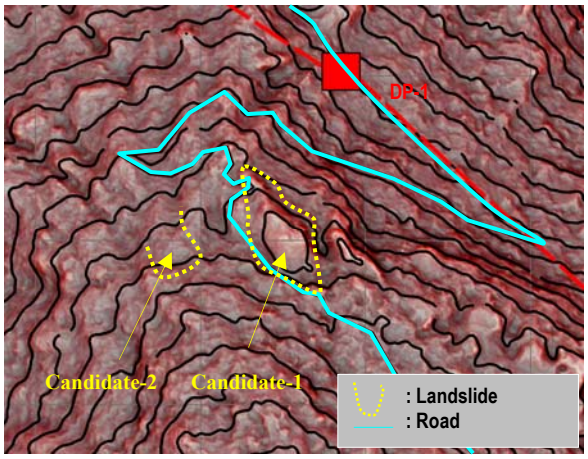


Figure 6.5.24 Landslide Formation at Candidate Sites

Possibility to construct farm pond

Since both concrete type and digging type farm ponds are difficult to be adopted, construction of farm ponds seems difficult.

Based on the examinations above, tributaries of the Yudhiri River and guiding tunnel from DP-5 to DP-4 branch canal can be the water sources of Radhi Area Irrigation System. Meanwhile, concrete lining for branch canal is effective from the view point of farmland conservation.

6.6 MEASURES TO EXAMINE THE BALANCE BETWEEN WATER REQUIREMENT AND SUPPLY

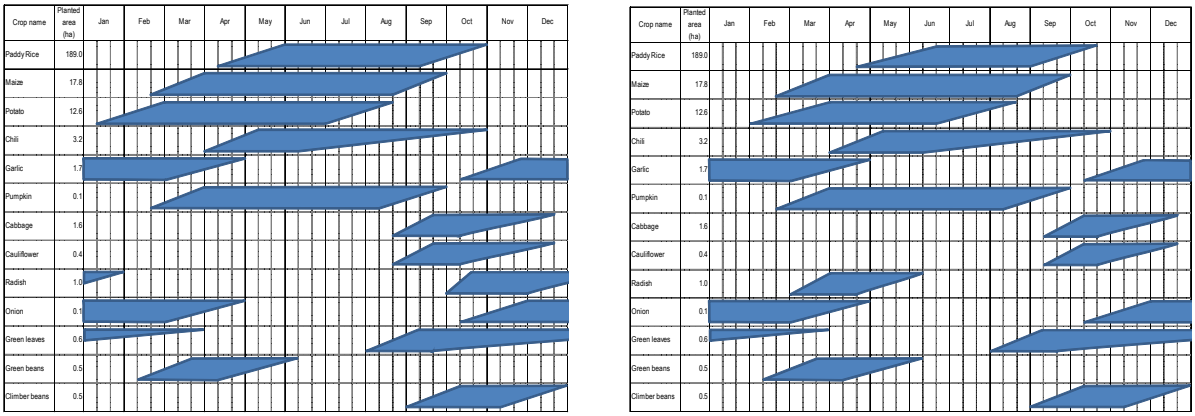
6.6.1 Trial to Identify Coefficients through Present Situation Reproducing Calculation

At Radhi Area, some data necessary to examine water requirement such as water requirement in depth and water requirement for preparation of paddy field are not available. Also data necessary to examine water supply such as tributaries' discharge and water delivery loss are not available as well. Meanwhile, from the interview with Gewog Agriculture Extension Officers and beneficiaries, there was enough rain during land preparation in 2016 and were able to conduct all the land preparation in proper duration. Therefore, it is considered that it might be possible to identify some coefficients through by reproducing calculation.

Water requirement is calculated for every 5 days according to the present cropping pattern as of February 2017 (Figure 6.6.1 same as Figure 6.4.4). While water supply volume is calculated by the

water distribution network model (Figure 6.6.2 same as Figure 6.5.20).

Since available data are limited to only topographic map, command area and rainfall data at Kanglung observation station, only this network model can be created.



Upper Part Lower Part

Figure 6.6.1 Present Cropping Pattern

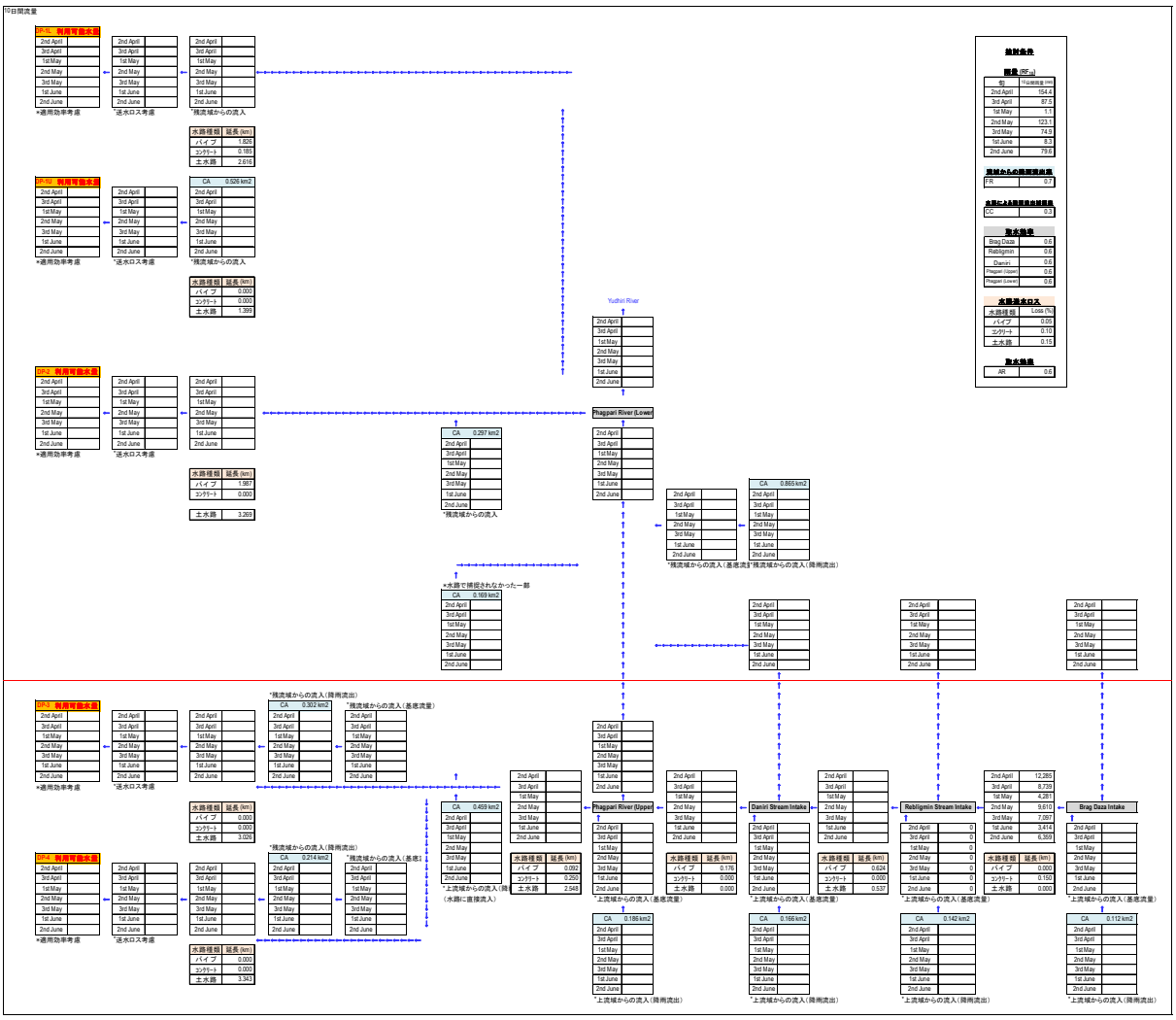


Figure 6.6.2 Water Distribution Network Model

Trial computation by adapting rainfall data from Kanglung observation station cannot succeed because water supply cannot cover the water requirement in 2016. Although the following are supposed as the reasons, these matters cannot be more accurate due to the limitation of available data at the site. Therefore, examinations by this model seem difficult.

- Rainfall data is from Kanglung observation station but this station is located 18 km away from the command area of Radhi Area Irrigation System. Also there is no record of rainfall within the command area.
- Water requirement in depth and for preparation of paddy field are assumed figures.
- If it rains, the open canal catch the flow from the mountainous side but this volume has not been recorded and cannot be taken into account.
- According to the cropping pattern, land preparation is planned to be conducted in order. However, it is actually conducted mainly after rain.

6.6.2 Examination Utilizing Total Rainfall Amount during Land Preparation Period

From the interview with Gewog Agriculture Extension Officers and beneficiaries, water shortage happens during land preparation period only. Water for land preparation is dependant volume to rainfall, such as rainfall itself and increased discharge of tributaries by rainfall. Therefore, examination utilizing total volume of rainfall during land preparation period seems to be acceptable.

Increase volume of water requirement is calculated based on the actual situation that land preparation was done properly in 2016, in particular, by calculating how much is the shortage of rainfall at the target year compared to 2016. In addition to that requirement, future farming plan is also taken into account.

Meanwhile, increased volume of water supply is calculated according to the gap of water volume that can be taken by the present facility and after development of new facilities.

Comparing these water requirement and water supply, irrigable area is calculated.

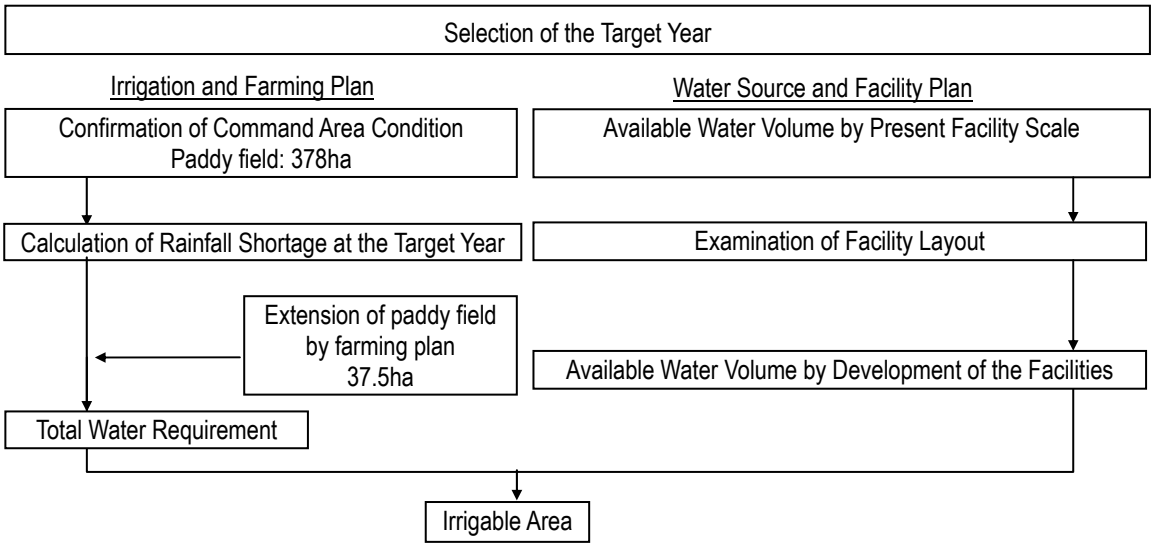


Figure 6.6.3 Flow of Examination

6.7 RESULTS OF EXAMINATION

6.7.1 Selection of the Target Year for Planning

In general, target year for planning is 1/5 to 1/10 drought year. According to the probability analysis of total effective rainfall of Kanglung station during land preparation period, year 2007 is selected as the target year because that year was almost 1/5 drought year.

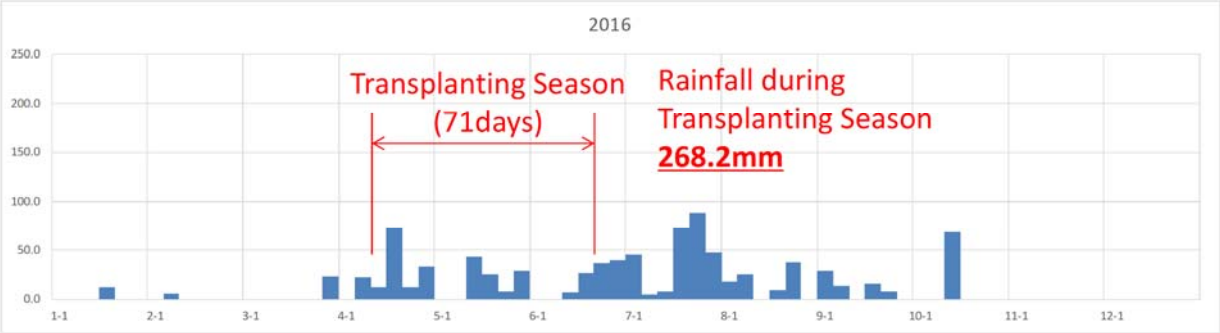


Figure 6.7.1 Effective Rainfall Pattern (Kanglung Station 2016)

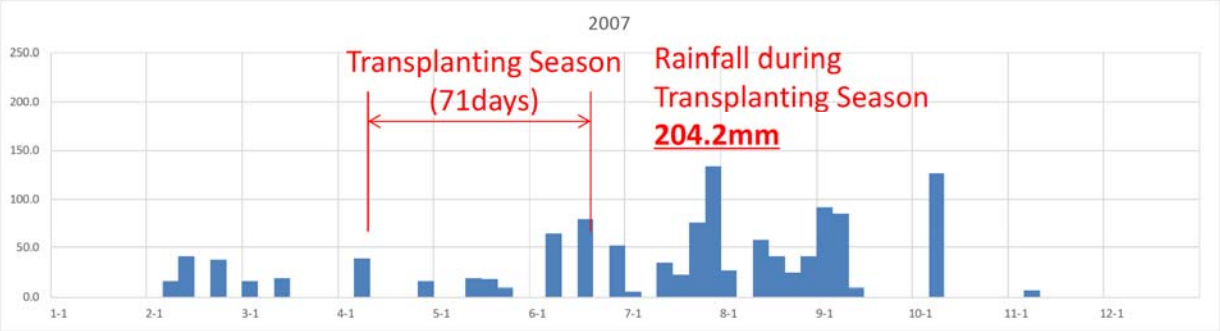


Figure 6.7.2 Effective Rainfall Pattern (Kanglung Station 2007)

6.7.2 Calculation of Increase Amount of Water Requirement

According to Figure 6.7.1, Figure 6.7.2 and Table 6.7.1 below, effective rainfall during land preparation period in 2007 was 76% of that of 2016. Taking into account a situation that no water shortage happened in 2016, 24% of the command area could not be irrigated in 2007.

Table 6.7.1 Rainfall during Land Preparation Season

Year	Draught year	Total Rainfall During Land Preparation Season (Data of Kanglung Observation station)	Total Effective Rainfall During Land Preparation Season (Data of Kanglung Observation station)	Ratio against 2016's Rainfall
2016	-	293.8mm	268.2mm	
2007	1/5	236.4mm	204.2mm	76%

Additionally, according to the future farming plan, paddy field will increase 10% more (37.5ha).

Therefore in the target year, 1/5 drought year, total increase of 34% of water (24% less than 2016 and 10% by increase of paddy field) will be necessary.

6.7.3 Calculation of Increasing Amount of Water Supply

(1) Present Condition of the Facilities

At the tributaries of the Yudhiri River, beneficiaries have constructed temporary weir by stones and sands, and guided water to pipes. The diameter of the pipes is 225 mm in maximum, the largest size available in Bhutan. Figure 6.7.3 is intake situation of a tributary in the dry season (January 2017). All the discharge could be delivered because discharge volume was small. But according to the beneficiaries, all the water cannot be captured by the pipe and disable release to the Yudhiri River happens in the rainy season.

Figure 6.7.3 Intake Structure at the Tributaries (Brag Daza Stream)

(2) Calculation of Increasing Amount of Water Supply

Catchment areas of each tributary

Disable release can be captured by development of the facilities and can be utilized for irrigation.

In order to calculate the disable release volume from each tributary, catchment areas of each tributary are measured. Total area is 208.1 ha including indirect area which flow is transferred to the tributaries through road ditch (Figure 6.7.4).

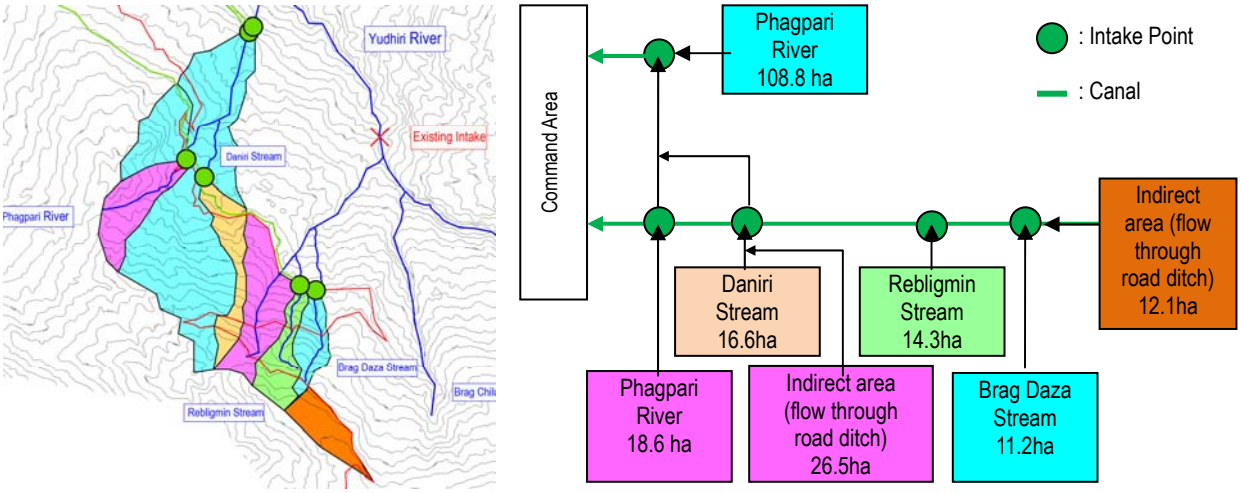


Figure 6.7.4 Catchment Area of Each Tributary

Discharge from tributaries when it rains

Assuming that 70%[51] of total rainfall during land preparation period flowed out from the catchment area, 56 litter/sec is calculated as average flow volume from tributaries in 2007.

[51] Japanese standard for rational formula is applied. This coefficient means the flow ratio and can be utilized to calculate peak volume of flood. Since the flow ratio may be less than 70% at the beginning of the rain or for short time rain, the flow volume varies according to the patter of rain even if total rainfall volume during land preparation period is same. In order to conduct the detail examination, rainfall within the catchment area of each tributary and flow of tributaries shall be measured and actual flow ratio of each tributary shall be examined.

Average flow from tributaries during land preparation period:
= Total rainfall during land preparation period (236.4mm/1,000) x Catchment area (208.1ha x 100 x 100) x flow ratio (70%) / Land preparation days (71days) /86,400 x 1,000
= 56 litter/sec

The maximum water volume can be delivered by one pipe is estimated at 20 litter/sec according to the field survey. Because the diameter of pipes is small and the scale of the existing canal is also small[52]. At present, river flow is taken at two points on the Phagpari River and disable release in 2007 is calculated as 16 litter/sec (56 litter/sec - 20 litter/sec x 2 points).

Additionally, 38 litter/sec is calculated as flow from DP-5's catchment area.

Average flow from DP-5's catchment area during land preparation period:
= Total rainfall during land preparation period (236.4mm/1,000) x Catchment area (140ha x 100 x 100) x flow ratio (70%) / Land preparation days (71days) /86,400 x 1,000
= 38 litter/sec

Total of these two discharge volumes, 54 litter/sec (16 litter/sec + 38 litter/sec) is calculated as the increase in volume to be taken from the tributaries by development of the facilities.

(3) Facility Layout Plan

To be able to take the above 54 litter/sec effectively, the following facility layout is recommended.

i) Construction of five permanent intake facilities
Concrete weirs shall be constructed at intake points of the Brag Daza Stream, the Rebilgmin Stream, the Daniri Stream and two points on the Phagpari River. By these weirs, possible volume of water to be taken will increase. At present, there are two intake facilities at the downstream of the Phagpari River but these will be complied as one.

ii) Tunnels connecting each tributary
At present, tributaries are connected by pipes and canals, however some parts are damaged by landslides. Additionally, maximum diameter of the pipe is 225 mm so the delivery capacity of the pipe is limited. To avoid damage by landslides and to be able to set the diameter to more than 225 mm, tunnels connecting each tributary with diameter 400 mm shall be constructed.

iii) Improvement of existing canals
By the development of intake facilities, possible volume of water to be taken would increase, however water delivery capacity of existing canal is not enough against the increased volume. Therefore, the scale of existing canals shall be improved.

iv) Tunnel connecting DP-5 and DP-4 branch canals
A tunnel to connect DP-5 and DP-4 branch canals with diameter 400mm shall be constructed under the mild ridge to guide water from DP-5 to Dp-4.

v) Concrete lining to some parts of branch canals
For the farmland conservation, concrete lining shall be constructed for some parts of branch canal where erosion is serious (10% of total length).

[52] During the Survey, there was a chance that a farmer took water from tributaries through pipes and canals. At that time, canal was full of flow and discharge was about 20 litter/sec.

The outline of recommended facility layout is illustrated as Figure 6.5.1.

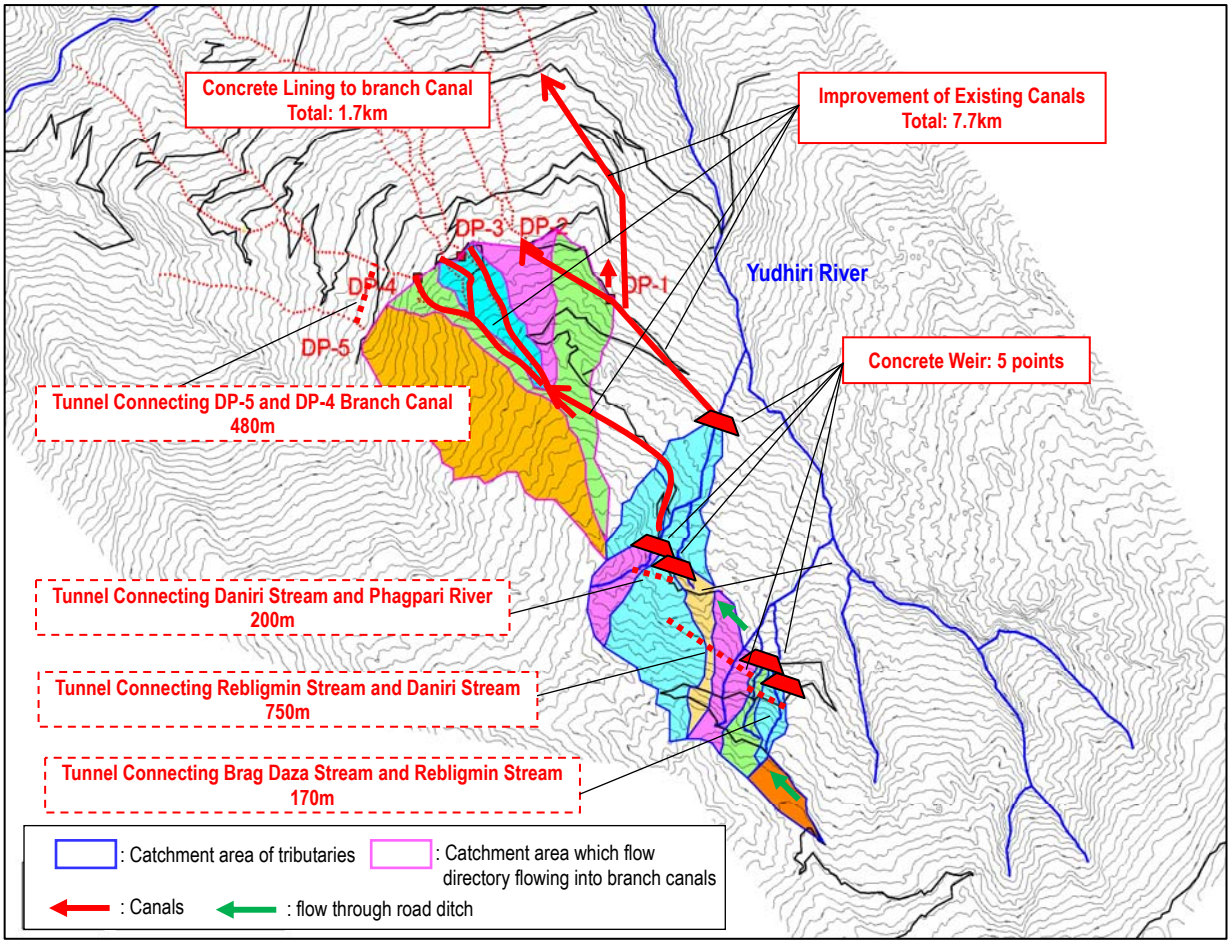


Figure 6.7.5 Outline of Facility Layout

(4) Calculation of Increasing Amount of Irrigated Area by Development of Facilities

Increasing volume of water supply

i) Increasing volume by the development of the facilities

By the development of the facilities, water supply volume would increase. However, to calculate available water volume at the command area, intake efficiency, water delivering efficiency and application efficiency (loss in the farmland) shall be considered. Assuming intake efficiency at 90%, water delivery efficiency at 90%, and application efficiency at 60% after development of the facilities, 26.2 litter/sec through land preparation period is calculated as average increase volume at the command area.

Average increase volume at the command area
= Increase volume to be taken from tributaries (54 litter/sec) x Intake efficiency (90%) x Water delivering efficiency (90%) x Application efficiency 60%
= 26.2 litter/sec

ii) Increasing volume by improvement of canals

Existing water volume to be taken is 40 litter/sec from the Phagpari River and direct flow to DP-3 and DP-4 branch canal from those catchment areas. This volume will increase by reducing water delivery loss by improving the canals from earthen to concrete. Assuming water delivery efficiency at 85%

before development of facilities, at 90% after development, and application efficiency at 60%, 1.9 litter/sec is calculated as increased volume of available water at the command area.

Average flow during land preparation period (Direct flow into DP-3 branch canal):
= Total rainfall during land preparation period (236.4mm/1000) x Catchment area (30.2 ha x 100 x 100) x Flow ratio (0.7) / 71 days/ 86,400 x 1,000
＝8.1 litter/sec

Average flow during land preparation period (Direct flow into DP-4 branch canal):
= Total rainfall during land preparation period (236.4mm/1000) x Catchment area (21.4 ha x 100 x 100) x Flow ratio (0.7) / 71 days/ 86,400 x 1,000
＝5.8 litter/sec

Increase volume:
＝(Existing intake from the Phagpari river＋Direct flow into DP-3 branch canal + Direct flow into DP-4 branch canal) x (Water delivering efficiency (after development of facilities) / water delivering efficiency (before development of facilities -1) x application efficiency
＝(40 litter/sec + 8.1 litter/sec + 5.8 litter/sec) x (0.9/0.85-1) x 0.6 =1.9 litter/sec

iii) Total increase volume for water supply

According to the calculation above, the total increase in volume at the command area by the development of facilities and improvement of the canals is 28.1 litter/sec (=26.2 litter/sec + 1.9 litter/sec).

Average supply volume assuming that all the water requirement is covered by river flow

Assuming that all the water for land preparation was supplied from the tributaries in 2016, 99litter/sec (taking into account application efficiency) is calculated as the average supply volume through land preparation period in 2016 as below.

Average water supply during land preparation period in 2016:
= Total effective rainfall during land preparation period (268.2mm/1,000) x Command Area (378ha x 100 x 100) / Land preparation days (71days) /86,400 x 1,000 x application efficiency (60%)
= 99 litter/sec

This means that 378 ha can be irrigated by 99 litter/sec water supply through land preparation period.

Increasing area of irrigable area

As already mentioned, at the target 1/5 drought year, 24% of water shortage will occur and 91 ha (=378 ha x 24%) of the command area will not be irrigated. Additionally, 10% shortage will also occur because 37.5 ha (about 10% of 378 ha) of wet land will be expanded which is planned in the future farming plan. Therefore, total 34% of the command area, 128.5 ha (378ha x 34%), cannot be irrigated at the 1/5 drought year under the present facilities.

Meanwhile by the development of the facilities, 28.1 litter/sec of supply water volume will increase and this can irrigate about 28.3% (=28.1 litter/sec / 99 litter/sec) of the command area,107.3 ha.

As a result, water shortage condition is improved by the development of the facilities, however irrigation water shortage of 5.7% (=34% - 28.3%) of the command area, 21.2 ha cannot be addressed at the target 1/5 drought year.

6.8 CONSIDERATION FOR THE RESULTS, AND NECESSARY SURVEYS AND EXAMINATIONS

Through the analysis of the topographic maps in the preparatory works, confirming of present farming, facility, water distribution, springs, and geological situations through field survey, and examination of water balance and facilities layout, it is concluded that rehabilitation of Yudhiri Irrigation System is not feasible. Meanwhile, the effectiveness to draw from multiple small water sources, in particular increased volume of water possibly taken from tributaries of the Yudhiri River is confirmed.

By the examination of future farming plan and the results of water balance calculation, it is established that irrigation water shortage at 21.2 ha which is about 5.7% of the command area may occur in the target 1/5 drought year, even if facilities are developed and possible water volume to be taken from multiple tributaries would be increased. However, some conditions applied for the examination are by assumption, such as 1) for the irrigation and farming plan: future farming plan, water requirement in depth, water management conditions during land preparation period, and meteorological conditions and 2) for water source and facility plan: discharge of tributaries and water delivery loss. Therefore, additional surveys are required to make these assumed conditions accurate. Additionally, project feasibility shall be re-evaluated according to the results of the additional surveys. Also, water conservation measures from the viewpoints of farming and water management, such as land consolidation and water-saving farming, shall be taken into account for the re-evaluation.

Even if the results may become more accurate through the additional surveys, there is a possibility that irrigation water shortage cannot be addressed completely due to insufficient discharge at the tributaries. Moreover, although permanent weirs and tunnels are recommended in the Survey, geological surveys at weir sites and along the alignment of tunnels are required to evaluate the technical feasibility of these facilities. As for the tunnels, maintenance measures shall be examined as well. In case the tunnels are validated as not feasible from these additional surveys and examinations, possibility of connecting tributaries by the open canals shall be explored. Furthermore, countermeasures against landslides shall be examined as well based on the groundwater level measured by gauges installed in the Survey.

The necessary additional survey and examinations are summarized in the Table 6.8.1.

Table 6.8.1 Necessary Additional Surveys and Examinations

Items		Contents of Surveys/Examinations
Irrigation and Farming plan	Future farming plan	- Formulation of future farming plan based on the requests from beneficiaries, re-planting in the fallow area, and marketing
	Water requirement in depth	- Survey to identify soil condition and its distribution within the command area - Measurement of water requirement in depth by soil type
	Water requirement for land preparation	- Confirmation of water management situations during land preparation period - Calculation of water requirement during land preparation period
	Meteorological conditions	- Observation of the meteorological conditions within the command area such as rain fall, temperature, humidity, wind direction, and wind velocity - Observation of the rain fall within the catchment area
Water source and facility plan	Discharge of tributaries	- Observation of tributaries' discharge
	Groundwater condition	- Measurement of groundwater level
	Water delivering loss	- Measurement of water delivering loss
	Geological condition	- Geological survey at the weir sites and along the alignment of the tunnels
Measures to reduce water requirement for land preparation		- Examination of measures to reduce water requirement during land preparation period, such as land consolidation and introducing water-saving farming, based on the water management conditions during land preparation period, meteorological conditions within the command area, and discharge of the tributaries

CHAPTER 7 RECOMENDATIONS FOR COOPERATION BY JICA

7.1 CURRENT SITUATIONS AND ISSUES IDENTIFIED

7.1.1 Current Situations and Issues Identified in each Chapter

The current situation and issues that have been identified in Chapter 1 - Chapter 6 are listed in Table 7.1.1.

Table 7.1.1 Current situation and Issues Identified in each of the Chapters

CHAPTER1 BACKGROUND AND OBJECTIVES OF THE SURVEY	
【1.1】	Agriculture is one of the key industries.
【1.2】	The self-sufficiency rate of rice is only 51.3%.
【1.3】	About 95% of the poor lives in the rural areas and 40.3% of the poor is from six Dzongkhags in the eastern region.
【1.4】	The RGoB requested the Government of Japan for its Grant Aid for "The Project for the Improvement of Yudhiri Irrigation System in Radhi Gewog, Trashigang District".
【1.5】	The RGoB requested the Government of Japan for a technical cooperation project, "Capacity Development Project for Irrigation Engineers in Bhutan" to enhance technical skills and knowledge on surveys, planning, design and construction of irrigation facilities.
【1.6】	Yudhiri irrigation system is the most prioritized system to be improved among the target systems of the Eleventh Five Year Plan.
CHAPTER 2 OUTLINE OF BHUTAN	
Natural Conditions	
【2.1】	The mountainous and hilly areas account for 85% of the national territory.
【2.2】	The slope of the mountains and the gradient of river beds are very steep.
【2.3】	Bhutan consists of several climatic zones.
【2.4】	The average annual precipitation varies by region and the maximum precipitation was recorded in the rainy season from June to September.
【2.5】	The number of meteorological/river observation stations is limited.
【2.6】	Only daily data are available at the meteorological and the river observation stations.
【2.7】	Almost the whole country is in fragile geological zones.
【2.8】	The peak flows during floods are usually quite heavy.
【2.9】	Because of rain, huge volume of rocks/stones/sands is produced.
【2.10】	Floods contain rocks/stones/sands and look like an avalanche.
【2.11】	Floods cause depression on the river bed and/or bank erosion.
【2.12】	A soil map of Bhutan is being created.
Socioeconomic Conditions	
【2.13】	The ratio of agriculture and forest industry in GDP is the largest among all the sectors.
【2.14】	The unemployment rate in urban area is higher than that in rural area.
【2.15】	The poverty ratio in rural area is high.
【2.16】	The population flow from rural area to urban area is confirmed.
Agriculture Conditions	
【2.17】	The cultivated agricultural land covers 2.93% of the entire territory of Bhutan.
【2.18】	Flat lands are only found on terraces along the rivers and alluvial fan in the southern region.
【2.19】	Many landslides have occurred.
【2.20】	Farmers generally cultivate rice at terraced paddy fields on the alluvial fans, river terraces and those lands whose slope gradient is relatively moderate in mountainous and hilly areas.
【2.21】	In steep slope area or moderate slope area with insufficient water, farmers cultivate mainly maize and vegetables.
【2.22】	The cultivated area of main cereals tends to decrease.
【2.23】	The unit yield of main cereals tends to increase.
【2.24】	The volume of import rice tends to increase.
CHAPTER 3 LEGAL FRAMEWORKS, NATIONAL POLICY AND DEVELOPMENT PLAN IN AGRICULTURE AND IRRIGATION SECTOR	
Five Year Plan	
【3.1】	Achieving economic self-reliance without foreign supports has been one of the main objectives since the First Five Year Plan.
【3.2】	MoAF officers who used to be irrigation engineers were transferred to the Dzongkhag Engineer Divisions under MoWHS during the period of the Ninth Five Year Plan.
【3.3】	Only urgent rehabilitation was allowed to be done for the Irrigation system development under the Tenth Five Year Plan.
【3.4】	Poverty reduction and food and nutrition security are given weight in the Eleventh Five Year Plan.
【3.5】	Solution of the national level challenges through the development/rehabilitation of agriculture infrastructure is considered

important in the Eleventh Five Year Plan.

【3.6】 Irrigation is given importance in the Eleventh Five Year Plan, and the budget for irrigation related projects was significantly increased from that in the Tenth Five Year Plan.

【3.7】 One of the objectives of the agriculture sector of the Twelfth Five Year Plan will be the "promotion of agribusiness".

MoAF Eleventh Five Year Plan

【3.8】 The paddy field area under functional irrigation system is aimed to be expanded from 19,200ha to 32,000ha.

【3.9】 The development of new irrigation systems is given higher priority than the rehabilitation of dysfunctional irrigation systems.

【3.10】 The number of ARDC engineers is insufficient.

【3.11】 There is no programme to enhance the capacity of irrigation engineers from Engineering Division and ARDCs in irrigation planning and irrigation facility design/construction/O&M.

【3.12】 DoA selected 108 target irrigation systems to be developed and/or rehabilitated to achieve the target of 32,000 ha irrigated area of the Eleventh Five Year Plan, after the same plan was approved.

National Irrigation Policy

【3.13】 Support by DoA in capacity building for scheme management is inadequate and hence many WUAs are not well-organized resulting in poor management of irrigation systems, causing early system failure.

【3.14】 Technical capacity of the engineers is limited.

【3.15】 Structures are designed and constructed without responding to the realities on the ground.

【3.16】 Due to manpower shortage, irrigation systems are not adequately supervised and the quality of irrigation systems has declined.

【3.17】 There are conflicts among water users who share the same water source.

【3.18】 Land degradation and water wastage lead to low irrigation efficiency.

【3.19】 The lead agency for irrigation development shall be the Dzongkhag offices.

【3.20】 Engineering Division and ARDCs shall be in charge of the implementation of irrigation development projects which cannot be managed by the Dzongkhag offices in their capacity.

【3.21】 Engineering Division and ARDCs shall also be in charge of the provision of technical backstopping to the Dzongkhag offices.

NIMP

【3.22】 NIMP is taken as a reference document for irrigation development planning by MoAF.

【3.23】 The Irrigation systems are classified into three categories in accordance with the natural characteristics of its farmland.

【3.24】 The development of the topographic maps of the command areas is required.

【3.25】 The Hydro-meteorological analysis of the watersheds for that observation data have not been collected is required.

Bhutan Water Vision and Bhutan Water Policy

【3.26】 Coordination among water sectors which share the same water resource is required.

【3.27】 Regarding the purposes of water use, the use for agriculture is the second priority following to the use for drinking and hygiene purpose.

The Water Act of Bhutan 2011

【3.28】 Water users should compose WUA.

【3.29】 Regarding the purposes of water use, the use for agriculture is the second priority following to the use for drinking and hygiene purpose.

The Land Act of Bhutan 2007

【3.30】 The Act allows the government to obtain the lands necessary for public works from their land owners for appropriate compensation.

Relevant Development Projects in Other Sectors

【3.31】 There has been no case of water resource development so far by the irrigation sector together with other related sectors.

【3.32】 There is a plan for joint watershed management by the irrigation sector with the disaster prevention (flood control) sector.

CHAPTER 4 INSTITUTIONAL ARRANGEMENTS OF THE AGRICULTURE AND IRRIGATION SECTOR

Central Government Institutions

【4.1】 Engineers of Engineering Division and ARDCs are in charge of works related to irrigation.

【4.2】 An increase in the number of engineers of Engineering Division and ARDCs from 29 to 31 is planned.

【4.3】 Many engineers of Engineering Division and ARDCs have academic degrees in civil engineering.

【4.4】 The work experience in the irrigation planning and irrigation facility design/construction/O&M of the engineers of Engineering Division and ARDCs is for three years at maximum.

Local Government Institutions

【4.5】 The DAO Head Office provides agriculture service in general at the Dzongkhag level.

【4.6】 Gewog Agriculture Extension Officers provide agriculture service in general to WUAs.

【4.7】 In principle, one Gewog Agriculture Extension Officer is assigned to each Gewog.

【4.8】 The Dzongkhag Engineering Division is responsible for the development/rehabilitation of irrigation facilities.

【4.9】 The O&M of irrigation systems is not part of the mandate of the Dzongkhag Engineering Division.

【4.10】 One engineer of the Dzongkhag Engineering Division is assigned to each Gewog.

【4.11】 All the engineers of the Dzongkhag Engineering Divisions have academic degrees in civil engineering.

【4.12】 The work experience in the irrigation planning and irrigation facility design/construction/O&M of the engineers of Engineering Division and ARDCs is for three years at maximum.

Training of Engineers

【4.13】 Engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions usually take theoretical lectures at

technical colleges once a year as refresher training.

【4.14】 Engineers of Engineering Division and ARDCs take the training in third countries on a project basis once a year or every two years, while engineers of the Dzongkhag Engineering Divisions have similar opportunities every three to four years.

【4.15】 Continuous and systematic training has not been implemented.

Institution of Higher Education in Technologies

【4.16】 The credits for irrigation planning and design of irrigation facilities account for about 10% of the total credits required at technical colleges.

【4.17】 Irrigation related projects have not accepted interns from technical colleges.

Other Relevant Institutions

【4.18】 NCHM has no plan to increase significantly the number of observation stations.

【4.19】 The Geological Survey of Bhutan Division of MoEA conducts surveys in the order of requests.

Budgets for Irrigation Development

【4.20】 A large portion of budget is allocated to the construction or rehabilitation of irrigation facilities.

【4.21】 The budget for training in irrigation planning and irrigation facility design/construction/O&M is insufficient.

CHAPTER 5 CURRENT SITUATIONS AND CHALLENGES S OF THE IRRIGATION SYSTEMS AND IRRIGATED AGRICULTURE

Situations of the Implementation of Legal Instruments, Policies and Development Plans

【5.1】 The engineers of Engineering Division are improving their technical skills of irrigation planning and irrigation facility design/construction/O&M.

【5.2】 There are not so many opportunities for engineers of Engineering Division on irrigation planning and irrigation facility design/construction/O&M.

【5.3】 There are not so many opportunities for engineers of Engineering Division on acquisition of technical skills in irrigation planning and irrigation facility design/construction/O&M.

【5.4】 Engineers of Engineering Division are not familiar with the advantages to utilize alternative water sources.

Functional Status of Irrigation Systems

【5.5】 NIIS has not been updated since 2013.

【5.6】 There is no information in NIIS on actual causes of the dysfunction of irrigation systems.

【5.7】 Engineering Division does not analyze the cause for dysfunction of irrigation systems.

Progress in the Development/Rehabilitation of Irrigation Systems Targeted in the Eleventh Five Year Plan

【5.8】 Technical feasibility of the development/rehabilitation of irrigation systems and economic efficiency of the same considering an increase of the irrigated area to be brought about were not taken into account at the selection and prioritization of irrigation systems to be developed/rehabilitated under the Eleventh Five Year Plan.

【5.9】 According to Engineering Division, among the 108 target irrigation systems to be developed/rehabilitated under the Eleventh Five Year Plan, only two irrigation systems require technical assistance from development partners at the development/rehabilitation. They are: Yudiri Irrigation System in Trashigang Dzongkhag and another irrigation system in Samtse Dzongkhag which is called an irrigation canal from Tharay River to Hath River.

【5.10】 Engineering Division has not yet conducted the field surveys for all the 108 target irrigation systems.

【5.11】 One of the targets set in the Eleventh Five Year Plan of achieving 32,000 ha of irrigated area does not seem feasible, taking into account the current pace of the development/rehabilitation of irrigation systems.

【5.12】 To complete the target of development/rehabilitation of 108 irrigation systems of the Eleventh Five Year Plan does not seem feasible taking into account the current pace of the development/rehabilitation of irrigation systems.

【5.13】 The amount of budget actually allocated to MoAF for the development/rehabilitation of the 108 target irrigation systems has been smaller than the approved amount for the implementation of the Eleventh Five Year Plan.

Procedure of Irrigation System Development and the Performance of Each of the Related Institutions

【5.14】 Each engineer of Engineering Division and ARDCs takes care of all the process of the development/rehabilitation of irrigation systems (surveys, planning, design, cost estimation, tendering, construction supervision, support to establish WUA, and system transfer of an irrigation system).

【5.15】 An engineer of Engineering Division and ARDCs has to get the construction works started within a year after setting out the process with surveys in principle.

【5.16】 As each engineer of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions handles some irrigation systems at the same time, the frequency of their visits to each of the irrigation systems for field survey and/or construction supervision is low.

【5.17】 All the developed/rehabilitated irrigation systems are handed over to each WUA.

【5.18】 The engineers of Engineering Division and ARDCs support the establishment of the WUA in the irrigation systems that are allocated to them.

【5.19】 A personnel in charge of O&M in Engineering Division, together with other engineers, is responsible to train WUAs on O&M after the transfer of the irrigation systems.

【5.20】 Since there is only one personnel in charge of O&M in Engineering Division, that personnel cannot directly train all the WUA.

【5.21】 Engineering Division does not have means to be informed on the O&M situation of each irrigation system.

Current Situation and Challenges of the Irrigated Agriculture

【5.22】 Double cropping of rice is put into practice only in a limited part in southern area.

【5.23】 The early-ripen variety of rice was already developed but seeds distribution has not been done completely.

Points to be Noted on the Development of Irrigation Systems (Identified through the Investigation of Existing Irrigation Systems)

【5.24】 Meteorological and hydrological observations need to be conducted and their results shall be reflected in the planning and design of irrigation systems.

【5.25】 The facility layout, structure and O&M methods of irrigation systems need to be examined with the assumption of a huge amount of rocks/stones/sands.
【5.26】 The structure of the facilities shall be examined considering the effectiveness of O&M.
【5.27】 It is effective to get water from plural small scale water sources.
【5.28】 The structure of facilities should be defined based on technique for repair, available in the context of current Bhutan.
【5.29】 The selection of facility structure can be done more effectively in consideration of the life cycle cost of each option.
【5.30】 Engineering Division has not made the causal analysis of damages on the existing facilities.
【5.31】 There is always the possibility that the flow condition could drastically change, even if the slope of the river bed is not steep.

Survey, Planning and Design Situations of the Existing Irrigation Systems

【5.32】 Topographic maps have not been created and utilized.
【5.33】 Meteorological data observed at the nearest observatory station is used for planning and design of irrigation systems, although sometimes it is located dozens of kilometres far away from the command area.
【5.34】 The frequency of discharge measurement of the water source is insufficient.
【5.35】 The cropping pattern is confirmed but the cultivated area of each crop is not surveyed.
【5.36】 The facility layout is made without utilizing topographic maps.
【5.37】 The geological survey is not carried out through the survey, planning and design process.
【5.38】 The facility layout and design taking into account the O&M procedure are confirmed.
【5.39】 The beneficiary area is defined by assumption, not by analysis or simulation, and therefore there have been cases when the scale of irrigation plan is much larger than what should be.
【5.40】 The design of irrigation facilities is made without analyzing causes of challenges faced by the existing facilities.
【5.41】 The standards and the procedural manual of design to be followed are not yet developed.
【5.42】 Each of the engineers refers to technical manuals and applies formulas without having any criterion to evaluate whether they are suitable to Bhutan's natural conditions.
【5.43】 The design review committee is not fully functional.
【5.44】 The engineers of Engineering Division and ARDCs have the general knowledge and experience in civil engineering.
【5.45】 The knowledge and experience required for the prevention of landslides are not available to the engineers of Engineering Division and ARDCs.
【5.46】 Engineers and contractors do not have adequate knowledge on the importance of water proofing of the hydraulic facilities.
【5.47】 Appropriate view points of intake - delivering - distribution as the total water flow is required for the engineers.
【5.48】 There is a possibility that low-quality construction materials are distributed.

Construction/Construction Supervision Situations of the Existing Irrigation Systems

【5.49】 The frequency of construction supervision by engineers of Engineering Division and ARDCs is low.
【5.50】 There are no manuals/guidelines of construction supervision items, methods, and standard values.
【5.51】 Contractors do not leave the quality management records.
【5.52】 The correlation between the volume of water added and the concrete strength is not familiar among engineers and contractors.
【5.53】 The correlation between the mixing portion of sand and the concrete strength is not familiar among engineers and contractors.
【5.54】 The importance of concrete consolidation is not familiar among engineers and contractors.

O&M Situations of the Existing Irrigation Systems

【5.55】 WUAs collect irrigation service fee from their members which is necessary to provide O&M to the irrigation systems, as far as the members are not affected by natural disasters.
【5.56】 Traditional WUGs do not have a concrete idea on the annual costs required for the repair of their irrigation facilities.
【5.57】 It will be effective to provide training in O&M for traditional WUGs.

Development Situation of Agriculture Environment in the Existing Irrigation Systems

【5.58】 The shortage of irrigation water is seen.
【5.59】 The shortage of farming labour is seen.
【5.60】 There is not enough opportunity to sell agricultural produce.
【5.61】 ARDCs are doing the research and development of farming skills.
【5.62】 The extension of developed farming skills has not been adequately done.

Current Situation of Support for Related Subsectors by JICA

【5.63】 The cooperation between the horticulture subsector and the irrigation subsector may lead to an increase in both the irrigated area the production of horticulture produce.
【5.64】 The cooperation between the agriculture machinery subsector and the irrigation subsector may lead to an increase in both the irrigated area and the production of agricultural produce.
【5.65】 The contents of the technical transfer implemented in an OJT manner through technical cooperation project under the farm road subsector are similar to the contents of the technical cooperation project requested by RGoB to the Government of Japan.

Current Status of Assistance from other Development Partners in Irrigated Agriculture and the Irrigation Systems

【5.66】 The financial support for the construction of irrigation facilities is mainly from the Government of India.
【5.67】 There is no development partner that supports the capacity development in irrigation planning and irrigation facility design/construction/O&M.

CHAPTER 6 CURRENT SITUATION, CHALLENGES AND COUNTERMEASURE FOR YUDHIRI IRRIGATION SYSTEM

【6.1】 A topographic map is very useful for field survey and irrigation facilities' layout.

【6.2】	Many locations prone to landslides are identified through the entire command area.
【6.3】	The information source of the unit yield of paddy in Radhi Gewog is not available.
【6.4】	The shortage of irrigation water is seen in the land preparation periods as well as in the dry seasons.
【6.5】	Damages caused by wildlife on crops are serious.
【6.6】	There is no farming plan for the command area.
【6.7】	The rehabilitation of Yudhiri Irrigation System is un-feasible from both the technical and economical points of view.
【6.8】	The water intake from plural and dispersed small scale water sources are effective.
【6.9】	The water intake from tributaries is effective, since their flow is stable and they have less damage caused by rocks/stones/sands.
【6.10】	Utilization of groundwater is effective from the point of view of farmland conservation.
【6.11】	Utilization of water of disable discharge at DP-5 is effective.
【6.12】	The concrete lining in branch canals is effective from the point of view of farmland conservation.
【6.13】	Data necessary to calculate water required, such as water requirement in depth, the volume of water required during land preparation periods, the actual situation of land preparation, and meteorological data are not available.
【6.14】	Data necessary to calculate available water supply, such as discharge in tributaries, water volume actually taken from the tributaries, and water delivering loss of canals are not available.
【6.15】	In the target 1/5drought year, there is a possibility that irrigation water cannot reach all the command areas, even if the irrigation facilities are developed.
【6.16】	It is necessary to evaluate the project efficiency, by conducting additional surveys on irrigation and farming plans, as well as water source and facility plans, and by analysing measures to be taken to reduce the water volume required in land preparation periods.

The current situations and issues confirmed in each chapter are listed in Table 7.1.1 and they can be summarized by theme as follows. They can be further classified into different categories of "Irrigation Development Planning", "Irrigation Development Budget and Expenses", "Irrigation Planning and Irrigation Facility Design/Construction Technology", "O&M of Irrigation Facilities", and "Farming Improvement".

(1) Necessity for the Combination of Solutions to the Challenges in Farming and the Development/Rehabilitation of Irrigation Systems (Irrigation Development Planning, Farming improvement)

The self-sufficiency rate of rice, the staple food of Bhutan, is 51.3% and about 95% of the poor lives in rural areas where the rice is produced. An increase in the production of agricultural produce and in farming income are considered as important in the Eleventh Five Year Plan from the viewpoint of food security and poverty reduction. An improvement on the self-sufficiency rate of rice also is expected to contribute to "economic self-reliance without foreign supports", which has been a long-time target from the First Five Year Plan through reducing the volume of import rice which is currently increasing.

Due to its steep topographic condition, the cultivated area is limited to 2.93% of the national territory and the effective utilization of limited farmland is the key to improve agricultural productivity. Needless to say, irrigation is considered as one of the important keys to this end, and the ratio of the expansion of the irrigated area through development/rehabilitation of the irrigation systems for the agricultural production increase is regarded as crucial. In line with such direction, the budget for the irrigation system development/rehabilitation under the Eleventh Five Year Plan is significantly increased, compared to that under the Tenth Five Year Plan. In addition, in the priority of water use, irrigation purpose occupied the second place following the drinking purpose. Thus, this also indicates that irrigation systems are considered as an essential infrastructure to utilize limited farmland effectively.

On the other hand, as challenges to enhance an improvement on the agriculture productivity along with the expansion of the irrigated area, the shortages of farming labour and shortage of sales

opportunity of agriculture produce, as well as a shortage of extension of developed farming skills are confirmed. In addition, to address these challenges, it is necessary to prepare farming plans, and to improve those elements directly affect the agricultural productivity, such as seeds, soil, etc. Causes of the decline of the cultivated areas and the increased unit yield of main cereals as well as reasons for abandonment of terraced paddy field should be identified so that farming plans can be developed based on addressing such causes and reasons appropriately.

In short, as mentioned above, to realize an increase in the production of agricultural produce, it is required not only to develop/rehabilitate irrigation systems but also to address those challenges in farming (farming improvement).

(2) Weak justifications for the establishment of targets of the irrigated area and the development/rehabilitation of irrigation systems (Irrigation Development Planning, Irrigation Development Budget and Expenses)

The target irrigated area and the development/rehabilitation of irrigation systems can be set based on the total calculated value from the data indicated in the development plan of individual irrigation systems. However, for the target setting of the Eleventh Five Year Plan, Engineering Division, first, sets the target irrigated area, and then selected the 108 irrigation systems to achieve the target irrigated area. At the selection of the target irrigation systems, field surveys were not conducted for all the 108 irrigation systems. Additionally, the technical feasibility and economic efficiency of the expansion of the target irrigated area were not either confirmed at that moment. As a result, sometimes the construction works face technical problems after its commencement, thus an increase also in construction costs. To confirm the technical feasibility and economic efficiency of the expanded area, NIIS could be utilized. However, NIIS has not been updated since 2013 and it is almost not used now.

On the other hand, it seems also difficult to achieve the development/rehabilitation of the 108 target irrigation systems in time. This is due to the limited capacity of engineers in irrigation planning and irrigation facility design/construction, in addition to the budget shortage for facility construction. The approved budget amount for the implementation of the Eleventh Five Year Plan includes the expected amount of financial support from development partners (The Indian Government has provided the most part of financial assistance to the construction of irrigation facilities). Nonetheless, the amount of financial support provided so far is less than what planned, and every year, the amount actually allocated to MoAF from the consolidated fund of RGoB has been less than the approved amount. Moreover, the budget for some irrigation systems was reduced to meet the emergent financial gaps of the construction works under the implementation, due to an increase in the construction costs. This also contributes to the slow-down of the pace of the development/rehabilitation of irrigation systems.

(3) Natural Conditions with high risk (Irrigation Planning and Irrigation Facility Design/Construction Technology)

85% of the national territory remains in the mountainous or hilly areas and flat area is limited to terraces along the rivers and alluvial fan in the southern region. The cultivated and occupies only 2.93% of the country. A topographic map may help to better understand topographic conditions, but the scale of the most accurate topographic maps available in Bhutan is 1:50,000. It is, indeed, difficult to develop irrigation planning, to select water intake sites from water sources, and to define irrigation facilities' layout by using maps with such a small scale. Although Bhutan is a landslide prone country and there have been many incidences, it is difficult to identify their locations and scales with the

current topographic maps available.

Since most part of the country is covered by weak geological conditions, and mountain slopes and river beds slopes are steep, the flood discharge is quite heavy and contains a large amount of rocks/stones/sands. Due to such flood characteristics, river bed depression and river bank erosion occur nationwide. In addition, since the precipitation and climate vary widely depending on the area, the flow volume of river also varies greatly depending on the location. Flood discharge may vary greatly from time to time, even those rivers which have similar moderate slope in their river beds. Thus, the natural condition of Bhutan, which varies greatly depending on location and time, provides very difficult challenges for irrigation planning and irrigation facility design.

The influence of the rocks/stones/sands delivered by flood is serious, as it has blocked box culvert canals and has caused erosion on the facilities in Taklai Irrigation System. There are many rivers in Bhutan, which have similar natural conditions as the Taklai River, and when developing/rehabilitating facilities on those rivers, it is necessary to integrate, among others, the following structures and layout, by assuming that a huge volume of rocks/stones/sands are delivered by floods. They are: 1) the facility layout prepared based on possible physical damages and economic impact to be brought about; 2) sediment runoff prevention works; 3) facility structure which require continuous O&M, and; 4) structure that can be repaired with Bhutan's technical capabilities. In particular, Weir shall not be constructed without any protection works in large stream with deep river bed due to high risk of severe damage on the constructed weir. While, it is effective to take water from plural small scale water sources. In line with this, for example, in case of the study of Radhi Area Irrigation System, the construction of permanent weirs in the natural tributaries where flow condition is relatively stable is considered effective. Moreover, pumping of underflow groundwater in the vicinity of Taklai Irrigation System is also considered effective. Taking water from plural small scale water sources makes it possible to avoid the risk of the complete dysfunction of the irrigation system, because even if one of the water sources cannot provide water, other water sources can still supply water.

On the other hand, to examine whether the options proposed above are effective, it is necessary to understand the meteorological characteristics of the target area and the hydrological characteristics of the target river. However, the number of meteorological and river discharge observation stations from which necessary data could be acquired is insufficient. Unfortunately, NCHM, which is responsible for meteorological and hydrological observations of Bhutan, does not have plans to significantly increase the number of observation stations. In addition, the observation frequency is also not sufficient, being only once a day. For example, even if the total daily rainfall is the same, the measures to be taken, including facility structure design, etc. can vary depending on the rain intensity; i.e. how many hours it has been raining in the day. However, the current observation frequency does not allow identifying such changes in rainfall in a short-term. For this reason, it is difficult to prepare an irrigation planning and irrigation facility design/O&M, in accordance with the natural conditions pertinent to each location.

(4) Insufficient Analysis of the Causes of Dysfunction of Irrigation Systems (Irrigation Development Planning, Irrigation Planning and Irrigation Facility Design/Construction Technology, O&M of Irrigation Facilities)

To rehabilitate the existing irrigation systems that fell into dysfunction, first, it is necessary to analyze the causes of dysfunction and to adapt the facility structure so as not to be dysfunctional again over the same reason.

Although NIIS requires the selection of reasons for dysfunction of the irrigation systems, among various options, those options pre-set by NIIS are not specific enough to prepare concrete rehabilitation planning. In addition, NIIS does not provide a space where the users can describe in details, the information on specific reasons for each of the dysfunction of irrigation systems cannot be collected by NIIS.

Meanwhile, activities status of WUAs has been reported to DoA every year through DAO, but since DoA has no personnel who is in charge of WUAs, the information on the challenges in O&M, irrigation facilities, etc. with which WUAs have faced is not consolidated and analysed by DoA.

(5) Limited Capacity in Irrigation Planning and Irrigation Facility Design (Irrigation Development Budget and Expenses, Irrigation Planning and Irrigation Facility Design/Construction Technology)

At the central level, Engineering Division and ARDCs, and at the district local level, the Dzongkhag Engineering Divisions are in charge of the projects related to irrigation. Most of the engineers in each organization have academic degree in civil engineering and have general knowledge and experience in planning and design of civil works. However, the experience of irrigation planning and irrigation facility design is at most for three years. This is attributed to the background of: 1) the irrigation engineers were transferred to the Dzongkhag Engineering Divisions under MoWHS due to the decentralization process which was implemented under the Ninth Five Year Plan; 2) the Dzongkhag Engineering Division mainly have been implemented since then only those projects on hydropower generation, farm road development, and only the urgent rehabilitation of priority irrigation systems; and 3) irrigation related projects including the development of new irrigation systems were resumed just recently under the Eleventh Five Year Plan.

Each of the engineers is not utilizing all necessary information to prepare an irrigation planning. To mention a few, they do not make topographic maps, they measure the flow discharge of water source only once, they confirm only the cropping pattern but not the cultivated area, and so forth. Such practice sometimes leads to the development of an irrigation planning with an excessive scope. At the design of irrigation facilities, the importance of considering the water flow, intake - delivering - distribution, as an integrated system, and the importance of water proofing of hydraulic facilities were not appreciated adequately. In addition, since the maximum experience in irrigation planning and irrigation facility design among the engineers is only about three years as described above, and senior engineers who can provide technical directions are also absent. Although the design review committee is put into place, the committee does not function sufficiently, because the engineers who are the members of the committee also have only limited experience in irrigation planning and irrigation facility design.

In addition to the situation mentioned above, the design standards/procedure manuals are not well developed and utilized. Each engineer has his/her own reference of design standards/procedure manuals, which he/she obtained through his/her own experience. However, they cannot judge properly whether the chosen design standards/procedure manuals, including the formulas are relevant to the natural conditions of Bhutan.

In spite of the fact that most engineers in Bhutan have only a few years of experience in irrigation planning and irrigation facility design, the Eleventh Five Year Plan does not include the capacity building programme in irrigation planning and irrigation facility design/construction/O&M. There are

a few development partners supporting the capacity building of engineers in these fields. As the budget for training is limited, engineers currently take in-classroom lectures once a year at a technical college as refresher training. In addition, the project-based third country training is conducted once every 1 - 2 years for Engineering Division and ARDCs, and once every 3 - 4 years for the Dzongkhag Engineering Divisions. However, these training courses are not regularized and systematized enough.

On the other hand, it is also urgent to train human resources for next generation in irrigation development. The lectures on the irrigation planning and irrigation facility design at technical colleges can issue only about 10% of the total credits required and most of them are in-classroom lectures and opportunities for practices are very limited. Also, the internship system undertaken in other projects such as projects in the road sectors, etc. is not carried out in irrigation projects, so opportunities for students to experience irrigation projects are limited.

(6) Inadequate Capacity in the Construction and Construction Supervision (Irrigation Planning and Irrigation Facility Design/Construction Technology)

In principle, each of the engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions carries out alone all the tasks of surveys, planning, design, cost estimation, tendering, construction supervision and handing over of the particular irrigation system to farmers. However, each engineer is responsible for several irrigation systems at once, and therefore, the frequency of construction supervision on the site is low. While the engineers in charge are absent, the construction is continued by the contractor alone. Contractors do not keep records for quality management, so the engineers in charge cannot confirm at a later stage the quality of the works done during their absence.

In addition, the knowledge of how the volume of water added for concrete manufacturing, the portion of sands mixed and the concrete consolidation can affect the concrete strength as well as the knowledge of materials of concrete is not well communicated among engineers and contractors. The quality and quantity of knowledge and experience on the construction and materials to be used are very important for the development/rehabilitation of irrigation facilities by determining life cycle costs of facilities.

Despite the situations mentioned above, the engineers in charge have to conduct the construction supervision based on his/her own knowledge and experience, as there are no developed manuals/guidelines on construction supervision to clarify items to be supervised, methods of supervision and standard values.

(7) Necessity of O&M Training to WUAs and Traditional WUGs (O&M of Irrigation Facilities)

When the irrigation systems are developed, WUAs to manage a system shall be established, and the facilities are transferred to the WUAs after the completion of construction works. Engineers of Engineering Division and ARDCs are supporting the establishment of WUAs in the irrigation systems they are in charge, together with the personnel in charge of O&M of Engineering Division. However, Engineering Division has only one personnel in charge of O&M, and the pace of the training to WUAs has been compromised.

On the other hand, the need for the training to the traditional WUGs has been also identified. For instance, there have been reported cases where conflicts have taken place, due to the absence of the rules of water use for the members, and other cases where a large scale of repair is required, as WUGs missed the timing for repair, when the problem was still small enough at an early stage.

(8) Evaluation of the Development of Radhi Area Irrigation System (Irrigation Planning and Irrigation Facility Design/Construction Technology)

The poverty rate in eastern Bhutan is high, and the development of this irrigation system is expected to lead to an increase in food production and income in the eastern region.

Based on the results of the field survey conducted, the rehabilitation of Yudhiri Irrigation System requested by RGoB to the Government of Japanese seems un-feasible. Meanwhile, the development of irrigation system which takes water from plural small scale water intakes established on different tributaries of the Yudhiri River seems to be an effective alternative. Even if a permanent structure is constructed in a tributary, damages which would be caused by floods or rocks/stones/sands delivered by floods are estimated to be limited because at the tributaries, the water flow is stable and load discharge is relatively small. In addition, the volume of rocks/stones/sands delivered by the flood is also limited.

From the point of view of farmland conservation, it is effective to carry out the lining to those parts of the branch canals where currently affected by erosions. In addition, it is also effective to lower the groundwater level to suppress the landslides, when necessary.

On the other hand, according to the results of the irrigable area examination through the development of the farming and irrigation plan as well as the water source and facility plan, the irrigation water cannot reach the entire command area at the target year (the planned 1/5 drought year), even if the planned facilities are developed. However, since this examination was conducted under some assumed conditions, it is necessary to further examine the feasibility of the project in the future after conducting additional surveys on those conditions for which no data were available.

(9) Others

1) Unavailability of knowledge of countermeasures for landslides

There are many irrigation systems with main canals which were damaged by landslides. The preventive maintenance has not been provided and only repairing, including the replacement of damaged parts with pipes, has been given to such systems. Since the knowledge of countermeasures for landslides is not available in Bhutan, slide control works, such as lowering of groundwater level, etc, and slide prevention works, such as protection works for slopes, etc have not been implemented. Also there is a possibility that low-quality construction materials are distributed in markets and attention should be given to the quality of pipes before they are used to replace the damaged parts of irrigation systems.

2) Water source development in collaboration with other sectors

Water source development in collaboration with other sectors has not been done so far. Such collaboration may lead to reduce the land area required for the project and the project costs, but on the contrary, may increase project efficiency. Therefore, it is worthy to study the possibility to develop water source in collaboration with other sectors in future.

7.1.2 Extraction, Categorization and Prioritizing of the Key Issues by DoA

Based on the confirmed current situations and issues (), a workshop with the participation of engineers of Engineering Division, includes the chief engineer and the technical staff was conducted. In the

workshop, current issues that were considered important in the irrigation development in the future of Bhutan were extracted from the issues from each of the chapters of this report (Table 7.1.1). Furthermore, the integration of similar issues was done among the extracted ones, and the result is shown in Table 7.1.2

Subsequently, in order to put the priority to the extracted issues, a problem tree was created in the same workshop (Figure 7.1.1). The core issue of the problem tree, (the objective tree) was set as an "increase in production of agricultural produce" which is one of the targets of the Eleventh Five Year Plan. The numbers given to the left side of each issue in Figure 7.1.1 are the priorities given by the staff of Engineering Division by layer of the problem tree.

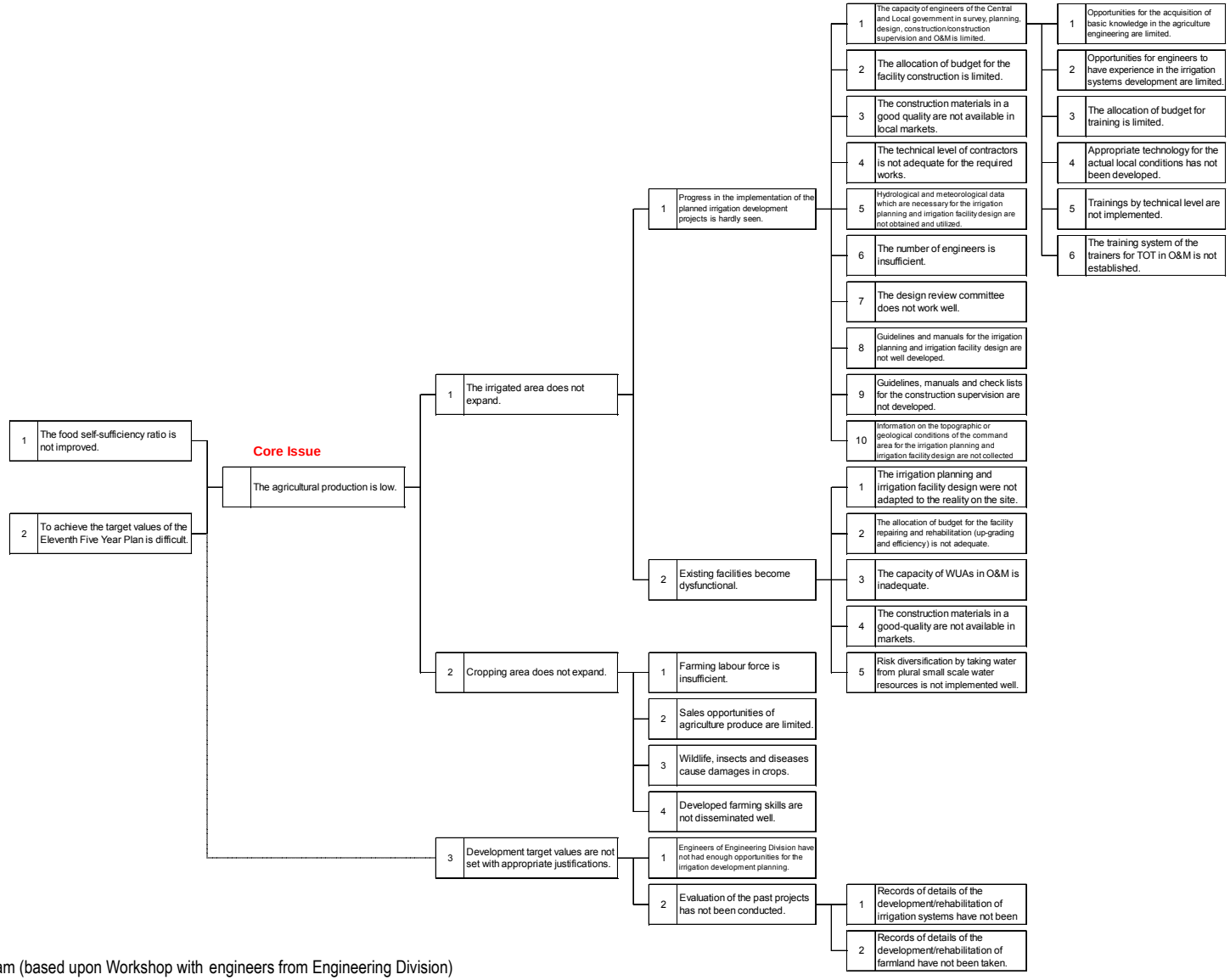
From the Figure 7.1.1, it is shown that DoA puts more weight on the development of new irrigation facilities rather than on the rehabilitation of existing irrigation facilities. Importantly, the issue, "The capacity of engineers of the Central and Local government in survey, planning, design, construction/construction supervision and O&M is limited" which is located in the second row from the right of the problem tree was given the top priority among all the problems identified. Thus, engineers of Engineering Division, although they also acknowledged the importance of the construction works for the development/rehabilitation of irrigation system as well, have prioritized their needs for capacity development in irrigation planning and irrigation facility design/construction/O&M.

On the other hand, the participant engineers put lower priorities to the issues that “Information on the topographic or geological conditions of the command area for the irrigation planning and irrigation facility design are not collected and utilized” and that “Risk diversification by taking water from plural small scale water resources is not implemented well.", although the importance of these issues was recognized by the Survey Team through field survey to Taklai and Radhi Area Irrigation Systems. The reason why Engineering Division considered that the priority of the exploration of alternative water sources is low, may be that the irrigation system development/rehabilitation by themselves has been started only three years ago and so far, they have worked on the irrigation systems which have a sufficient flow volume in their water sources. Furthermore, the number of irrigation systems implemented so far was small and the engineers might have no experience of failure in water intake due to the shortage in water volume at water sources.

Table 7.1.2 Summary of the Current Issues Identified by the Engineering Division of DoA

Common Issues						Current situations and issues confirmed in each chapter (Number in Table 7.1.1)
The food self-sufficiency ratio is not improved.	The agricultural production is low.	The irrigated area does not expand.	Progress in the implementation of the planned irrigation development projects is hardly seen.	The capacity of engineers of the Central and Local government in survey, planning, design, construction/construction supervision and O&M is limited.	Opportunities for the acquisition of basic knowledge in the agriculture engineering are limited.	【3.15】【3.16】【5.4】【5.18】【5.34】【5.37】【5.38】【5.42】～【5.44】
					Opportunities for engineers to have experience in the irrigation systems development are limited.	【4.3】【4.10】【5.4】
					The allocation of budget for training is limited.	【3.9】【3.11】【4.18】【4.19】【5.55】
					Appropriate technology for the actual local conditions has not been developed.	【2.1】～【2.4】【2.7】～【2.11】【2.18】【3.16】【3.24】【5.1】【5.4】【5.19】～【5.23】【5.35】【6.6】
					Trainings by technical level are not implemented.	【3.10】【3.11】【4.11】【5.55】
					The training system of the trainers for TOT in O&M is not established.	【5.15】～【5.17】
				The allocation of budget for the facility construction is limited.		【5.11】【5.56】
				The construction materials in a good quality are not available in local markets.		【5.39】
				The technical level of contractors is not adequate for the required works.		【5.37】【5.41】～【5.44】
				Hydrological and meteorological data which are necessary for the irrigation planning and irrigation facility design are not obtained and utilized.		【2.5】【2.6】【4.16】【5.25】【5.26】【6.13】
				The number of engineers is insufficient.		【3.10】【3.17】【5.12】【5.13】【5.36】
				The design review committee does not work well.		【5.32】
				Guidelines and manuals for the irrigation planning and irrigation facility design are not well developed.		【5.31】
To achieve the target values of the Eleventh Five Year Plan is difficult.				Guidelines, manuals and check lists for the construction supervision are not developed.		【5.40】
				Information on the topographic or geological conditions of the command area for the irrigation planning and irrigation facility design are not collected and utilized.		【3.25】【3.26】【4.16】【5.24】【5.28】～【5.30】【6.1】【6.3】【6.12】【6.13】
			The existing facilities become dysfunctional.	The irrigation planning and irrigation facility design were not adapted to the reality on the site.		【2.1】~【2.4】【2.7】～【2.11】【2.18】【3.16】【3.24】【5.1】【5.4】【5.18】～【5.23】【5.35】【6.6】
				The allocation of budget for the facility repairing and rehabilitation (up-grading and efficiency) is not adequate.		【5.11】【5.56】
				The capacity of WUAs in O&M is inadequate.		【3.14】【5.14】～【5.16】【5.45】～【5.47】
				The construction materials in a good-quality are not available in markets.		【5.38】
				Risk diversification by taking water from plural small scale water resources is not implemented well.		【5.1】【6.8】～【6.10】
		Cropping area does not expand.	Farming labour force is insufficient.			【2.16】【5.49】
			Sales opportunities of agriculture produce are limited.			【5.50】
			Wildlife, insects and diseases cause damages in crops.			【6.5】
			Developed farming skills are not disseminated well.			【5.27】【5.51】～【5.53】
		Development target values are not set with appropriate justifications.	Engineers of Engineering Division have not had enough opportunities for the irrigation development planning.			【5.9】【5.10】
			Evaluation of the past projects has not been conducted.	Records of details of the development/rehabilitation of irrigation systems have not been taken.		【3.12】【5.8】
				Records of details of the development/rehabilitation of farmland have not been taken.		【3.7】【5.7】

Source: the Survey Team (based upon Workshop with engineers from Engineering Division)



Source: the Survey Team (based upon Workshop with engineers from Engineering Division)

Figure 7.1.1 Problem Tree by Engineering Division

7.2 COOPERATION NEEDS IN THE IRRIGATION SUBSECTOR

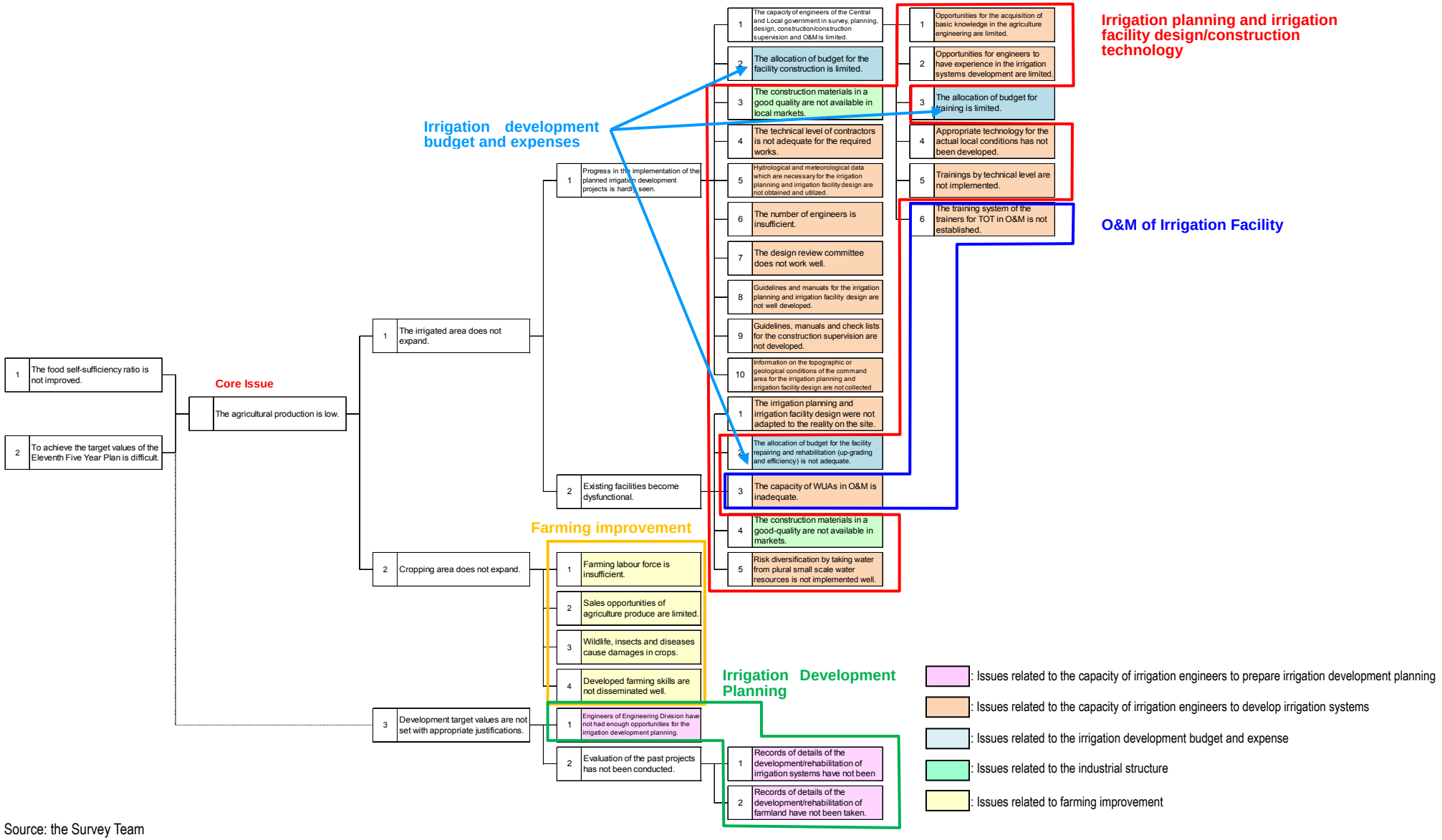
7.2.1 Cooperation Needs Identified through the Problem Tree making

The contents of the issues at the rightmost layer which has no further subsequent layer, in the problem tree developed at the workshop with the engineers of Engineering Division (See Figure 7.1.1.), can be broadly classified into the following five categories.

- Issues related to the capacity of irrigation engineers to prepare irrigation development planning
- Issues related to the capacity of irrigation engineers to develop irrigation systems
- Issues related to the irrigation development budget and expense
- Issues related to the industrial structure
- Issues related to farming improvement

Figure 7.2.1 shows the problem tree coloured according to the classifications above. As Figure 7.2.1 clearly shows, most of the issues at the rightmost layer can be classified into the category of "issues related to the capacity of irrigation engineers to develop irrigation systems". This implies that Engineering Division considers that improving the capacity development (=human resource development) of irrigation engineers is an effective means to solve the core problem, "The agricultural production is low".

On the other hand, these issues can be re-classified into other five categories: "1) Irrigation Development Planning"; "2) Irrigation Development Budget and Expenses"; "3) Irrigation planning and Irrigation Facility Design/Construction Technology"; "4) O&M of Irrigation Facility"; and "5) Farming Improvement", which are the categories utilized in "7.1.1 Current Situations and Issues Identified in each Chapter" above. It shows that the present situations and issues confirmed by the Survey Team and the current situations and issues that Engineering Division considers important are almost the same. Therefore, it can be considered that these five items are the current needs in the irrigation subsector.



Source: the Survey Team

Figure 7.2.1 Classification of Problem Tree by Engineering Division

7.2.2 Implementation Priority of the Cooperation Needs

As indicated in the previous section, the needs in the irrigation subsector can be divided into five categories: "1) Irrigation Development Planning", "2) Irrigation Development Budget and Expenses", "3) Irrigation Planning and Irrigation Facility Design/Construction Technology", "4) O&M of Irrigation Facility", and "5) Farming Improvement". In the problem tree of Figure 7.2.1, the higher the level in the tree structure the issues are located, the higher the priority given to those issues. So, the priority among the five needs that Engineering Division considers is as follows. The above five needs almost conform to the number of the following items from high level to low level. It can be said that Engineering Division puts more weight on facility development.

i) Irrigation Planning and Irrigation Facility Design/Construction Technology
ii) Irrigation Development Budget and Expenses
iii) O&M of Irrigation Facility
iv) Farming Improvement
v) Irrigation Development Planning

As mentioned earlier in "7.1.1 Current Situations and Issues Identified in each Chapter", among the above five needs, "iv) Farming Improvement" should be carried out in conjunction with the development of the irrigation systems to solve the core problem "The agricultural production is low". Thus, among the remaining needs of i), ii), iii), and v) mentioned above, the implementation priority for the irrigation subsector can be established by going through the following processes. The prioritization shall be done from the point of view of the facility development, since it is the focus of Engineering Division.

The development of irrigation facilities is usually carried out in the following order. After each of the following sub-headings, the number of corresponding needs mentioned above is shown in parentheses.

1) Identification of the current situation of each irrigation system (v) Irrigation Development Planning)

The collection of basic information (the range of command area, the number of beneficiaries, the conditions of water source, the meteorological condition, the conditions of facilities, the farming condition, the status of O&M, etc.) and field survey

2) Information analysis and the prioritization of irrigation facilities development (v) Irrigation Development Planning)

The examination of technical feasibility and economic efficiency of the irrigation facility development based on collected information, and the prioritization of the irrigation facilities development/rehabilitation, based on the results of such examinations.
* Including the cause analysis in case there is damage on existing facilities

3) Establishment of development target values and the selection of irrigation systems to be developed (v) Irrigation Development Planning)

Establishment of development target values (such as the value of increased irrigated area, etc.) based on national plans, and so forth, and the selection of irrigation systems to be developed/rehabilitated to achieve the established target values.

4) Preparation of annual development planning of irrigation systems and the request for the approval

and the allocation of the estimated budget (ii) Irrigation Development Budget and Expense)

The breakdown of Irrigation Development Planning into annual development planning, and the submission of the estimated annual budget for approval and allocation

5) Implementation of irrigation planning and irrigation facility design/construction (i) Irrigation Planning and Irrigation Facility Design/Construction Technology)

The irrigation planning and design and construction of irrigation facilities in the selected irrigation systems

6) Irrigation facility transfer and O&M (iii) O&M of Irrigation facility)

The transfer of the completed irrigation facility to the WUA, and the provision of the O&M training to the same WUA

Engineering Division recognizes that "i) Irrigation Planning and Irrigation Facility Design/Construction Technology" of individual irrigation facility is the most important issue. However, in consideration of the identified needs, "v) Irrigation Development Planning" is required, to identify the current situation of each irrigation system, to examine technical feasibility and the economic efficiency of facility development, and to prioritize irrigation systems to be developed, prior to irrigation facility development. In addition, even if irrigation systems to be developed are selected, the development target values cannot be achieved unless the "ii) Irrigation Development Budget and Expenses" for the implementation of the construction are secured. Based on the recognition mentioned above, the priority in the implementation of the above needs for the irrigation subsector has been set as follows.

1) Irrigation Development Planning
2) Irrigation Development Budget and Expenses
3) Irrigation Planning and Irrigation Facility Design/Construction Technology
4) O&M of Irrigation Facility
- Farming Improvement * Conducting in parallel with the irrigation system development

7.3 POSSIBILITY OF JICA'S COOPERATION IN LINE WITH THE CONFIRMED NEEDS FOR ASSISTANCE

This section illustrates the results of the analysis of the possibility of JICA's cooperation for the need for assistance, which were confirmed by the Survey Team and with results of the workshop with Engineering Division.

7.3.1 Irrigation Development

(1) Irrigation Development Planning

The Eleventh Five Year Plan sets the target number of irrigation systems to be developed/rehabilitated and the target irrigated area to be achieved through irrigation system development, although the justifications for these target values are not clarified and it seems difficult to achieve both the target values in time. Therefore, the cooperation from JICA may be provided in order to improve the target setting in the future. More concretely, the implementation of relevant surveys and the development of necessary capacity to prepare the irrigation development planning may be supported under the

cooperation. Those activities to be supported are: 1) to understand the current situation of each of the irrigation systems; 2) to examine the technical feasibility and the economic efficiency of the development/rehabilitation of irrigation systems based on the current situation identified in 1) above, as well as to prioritize irrigation systems for the development/rehabilitation; 3) to set the target values and to select irrigation systems for development/rehabilitation. In addition, the cooperation for the capacity development in the setting of feasible target values for the Twelfth Five Year Plan onwards, would be also provided.

Meanwhile, as an individual activity, the cooperation to update the NIIS, where the basic information on each irrigation system is stored, can be considered. The data stored in NIIS has not been updated since 2013, and with the types of the data currently NIIS has, it is difficult to examine the technical feasibility as well as the economic efficiency of the development/rehabilitation of irrigation facilities. Therefore, the technical cooperation to Engineering Division could be provided on the collection of information for NIIS, so that NIIS can provide the necessary information to analyse the technical feasibility and economic efficiency of the development/rehabilitation of irrigation facilities. In line with this, the technical cooperation could be also provided to identify the current situation of damages on the existing facilities, and causes for such damages, as well as to equip NIIS with the collected information and the results of their analysis.

Furthermore, the technical cooperation to the following issues could be considered. They are: 1) the prioritization of the irrigation systems to be developed/rehabilitated in accordance with the technical feasibility under irrigation engineers' technical capacity and economic efficiency of such development/rehabilitation; 2) the preparation of annual irrigation development plan in consideration of the capacity of each of the engineers to manage workload and budget estimated through the data analysis on their previous performance, and 3) the establishment of feasible target values based on 2) above.

Indeed, inadequate allocation of the budgets to the irrigation related projects (construction, O&M, training, etc.) has been one of the challenges for the implementation of such projects. As a coping strategy, in addition to the technical cooperation on the aforementioned feasible target value setting, it would be important to develop capacity through technical cooperation to revise plans according to the allocated amount of budget, by prioritizing the planned projects of facility construction, O&M, training of irrigation engineers, etc.

(2) Irrigation Development Budget and Expenses

What are confirmed as needs are: 1) the budget for irrigation facility construction, repair and rehabilitation (up-grading and improvement on the efficiency) to address challenges in hard component; and 2) the budget for capacity development training in irrigation planning and irrigation facility design/construction/O&M to address the challenges in soft component.

1) Budget for irrigation facility construction, repair and rehabilitation (up-grading and improvement on the efficiency)

The budget for the construction of irrigation facilities under the Eleventh Five Year Plan was approved in the process of the preparation of the same national mid-term plan, but the actual amount allocated as budget for the irrigation facility development annually to DoA is less than the approved amounts. This is because the approved amount as budget during the preparation of the Eleventh Five Year plan included the amount expected to be financed by development partners, but funding from development

partners have not flown in as planned. Mainly, the Government of India is the major development partner which provides financial assistance to the construction of irrigation facilities, but the amount of its assistance is not sufficient to develop all the 108 target irrigation systems under the Eleventh Five Year Plan. Therefore, financial assistance from other development partners including JICA would be sought for the construction of irrigation facilities. In light of the enormous technical challenges identified through this Survey, however, every proposal for financial support should have a well-developed plan with solid technical/economic feasibility based on detailed survey.

2) Budget for capacity development in the irrigation planning and irrigation facility design/construction/O&M

RGoB puts an emphasis on the construction of irrigation facilities, and the budget for the training in irrigation planning and irrigation facility design/construction/O&M accounts for only about 7.3% of the total irrigation-related projects budget. As the irrigation system development restarted with the Eleventh Five Year Plan, and the development/rehabilitation of the 108 target irrigation systems under the same national plan is being delayed, it seems that the policy of RGoB to put more weight on the development of irrigation facilities will remain for now. Therefore, a significant increase in the training budget cannot be expected for a while. Also, for the time being, there is no development partner that plans to support a training for capacity development in a continuous and systematic manner.

Since both the construction of irrigation facilities and the capacity development training in irrigation planning and irrigation facility design/construction/O&M to the engineers are important for the irrigation development in Bhutan from now onwards, they could be supported by JICA as part of its cooperation to Bhutan. .

(3) Irrigation Planning and Irrigation Facility Design/Construction Technology

The following six detailed needs were identified under the "Irrigation Planning and Irrigation Facility Design/Construction Technology".

1) Capacity development in irrigation planning and irrigation facility design/construction to engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions
2) Provision of observation and survey equipment
3) Improvement of the functions of the design review committee
4) Development of guidelines, manuals, etc
5) Capacity improvement of contractors
6) Quality improvement of construction materials

1) Capacity development in irrigation planning and irrigation facility design/construction to engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions

Many engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions have academic degree in civil engineering and general knowledge of civil engineering. However, it seems that they have not had enough opportunities to acquire the knowledge and education on agriculture engineering such as the necessity of water proofing for hydraulic structures, and on irrigation facility design taking into account the entire water flow (intake - delivering - distribution) as a system, etc. In addition, knowledge concerning landslide countermeasure works, and construction materials such as quality of concrete, etc. seem to be not fully available to the engineers. To supplement the knowledge

and education, in addition to in-classroom lectures, study tours to irrigation systems in Japan and third countries would be useful. For the site visit, it is desirable to visit those facilities taking water from plural small scale water sources as the Survey Team confirmed its advantages and importance through the Survey.

To apply the knowledge acquired through the lectures and study tours on the real works is important in terms of capacity development. Therefore, it would be extremely effective to actually conduct survey, planning, design, construction supervise in the actual irrigation facilities as practices. At the selection of irrigation system for such a practice, it is recommended to select those facilities taking water from plural small scale water sources.

There is no senior engineer who could provide lectures and guidance on the ground through the process of the irrigation facility development. As a part of the findings of the Survey, it was confirmed that the experience in irrigation planning and irrigation facility design/construction of engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions is at most for three years. Therefore, the dispatch of lecturers and instructors for those themes mentioned above could be considered as part of cooperation of JICA. In the future, it is desirable that some engineers of Engineering Division will become senior engineers by meeting the requirements. To achieve this, the cooperation of JICA can support some engineers to meet the requirements by offering them opportunities for study tours/training in Japan or in third countries, or study abroad.

The Survey Team interviewed a deputy executive engineer (with 5-10 year work experience) of Engineering Division, and a principal engineer (with 15-20 year work experience) of ARDC Bajo, on their capacity in irrigation planning and irrigation facility design/construction/O&M. Since there are younger engineers than the two interviewed engineers at Engineering Division and ARDCs, the capacity assessment to all the 29 engineers of these institutions need to be carried out to identify their training needs and their actual technical levels. In addition, technical capabilities of engineers of the Dzongkhag Engineering Divisions, which was not identified in the Survey, shall be assessed as well.

2) Provision of observation and survey equipment

The number of existing meteorological and river discharge observatory stations is limited, and NCHM does not have a plan to increase the number of stations drastically. Therefore, the existing observatories are not often found within/near the command area of the target irrigation systems. It is possible to request geological survey to the Geological Survey Division of the Geology and Mining Department, MoEA, but the requested survey may not be carried out at an opportune timing. Since the collection and analysis of meteorological and river discharge data and geological surveys are indispensable for irrigation system development, the provision of observation equipment and simple equipment for geological survey instruments, together with the guidance on how to use them could be considered as part of the cooperation of JICA.

3) Improvement of the functions of the design review committee

The design review committee has the task to review the design of irrigation facilities prepared by engineers of Engineering Division and ARDCs by organizing meetings. However, since the experience in irrigation planning and irrigation facility design/construction of the engineers of Engineering Division, who forms part of the judge in the committee, is at most for three years, not many technical comments and advice are made by the committee. In addition, items to be reviewed by the committee have not been defined and no checklist for the committee has been developed. This situation affects

the quality of irrigation facilities. For instance, there was a case where the construction of major structures was done without structure calculations. Considering this situation, JICA could cooperate by dispatching observers to the design review committee and/or by assisting the development of checklist for the committee. In the long run, it is desirable that some engineers of Engineering Division will become senior engineers with the examination ability required for the design review committee members. Therefore, JICA as part of its cooperation could provide opportunities for training in Japan/ third countries and study abroad to engineers of Engineering Division.

4) Development of guidelines, and manuals, etc.

Guidelines and manuals on surveys, planning, design and construction supervision for irrigation system development are not well developed. Therefore, each engineer refers technical documents based on his/her own experience. Therefore, they cannot deal with matters beyond their own experience. In addition, each engineer designs irrigation facilities without knowing whether selected technical documents referred, mathematical formula to be applied, etc. are appropriate for Bhutan's natural conditions. This has created gaps in the quality among different designs. Engineering Division has recently publicized “Irrigation Engineering Manual” with support from ADB, but there remains a room to make it highly practical and adapted to local conditions.

The development of guidelines, manuals, and other resources requires experience in irrigation planning and irrigation facility design/construction. As mentioned above, since the experience of engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions for these fields is at most three years, and they may need technical advice to develop the guidelines, manuals, etc. Therefore, JICA as part of its cooperation could provide assistance in the development of guidelines, manuals, etc. Since the natural conditions of Bhutan is harsh for the irrigation planning and irrigation facility design, these guidelines, manuals, etc. shall be adapted to such conditions, while referring to the existing standards established for other countries. The contents of the cooperation is not only to develop guidelines, manuals, etc, but also for periodical revising of those documents, taking into account the results of continuous monitoring of the facilities planned, designed and constructed according to the those documents. JICA’s cooperation might consider the dispatch of experts to assist the development of guidelines, manuals, etc, to monitor the condition of the constructed facilities, and to revise the documents. Since Bhutanese engineers need to be able to develop and revise guidelines, manuals, etc alone in future, in the cooperation, actual works shall be implemented by Bhutanese engineers, while, the dispatched experts will support them.

The Survey Team interviewed only one engineer, the Deputy Executive Engineer of Engineering Division with 5-10 years work experience, about referential technical documents, among other issues. Therefore, it is necessary to confirm referential technical documents and the applied methods with other engineers.

5) Capacity improvement of contractors

It can be said that the construction capacity of contractors is inadequate in Bhutan, because, among others: 1) they are not aware of the importance of water proofing of the hydraulic facilities; 2) they do not leave any record of quality management works; 3) they are not aware of the effect of water volume to the concrete strength; 4) they are not aware of the effect of the volume of sands to be mixed to the concrete strength; and 5) they are not aware of the importance of consolidating concrete.

In case that technical assistance is provided to contractors in Bhutan to improve their construction

capacity, the capacity of the trained contractors may be improved, but the extension of positive impact to other contractors cannot be expected. Therefore, instead of providing direct technical assistance to them, the capacity improvement of the contractors in Bhutan in general could be attained with the instructions and guidance on the ground given repetitively by the engineers trained through "1) Capacity development in irrigation planning and irrigation facility design/construction to engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions". In other words, for this need, the Bhutanese side could remain responsible for the capacity improvement of contractors, instead of seeking for further cooperation from JICA on the matter.

6) Quality improvement of construction materials

It is confirmed that there are cases where water leakage occurs due to splits or cracks in the pipes, which were installed to replace the canals damaged by landslide. This may be attributed to low quality of the pipes.

The establishment of industrial standards such as JIS in Japan, of a mechanism to certify companies that satisfy industrial standards, or of inspection institutions for manufactured products, etc would address this issue. However, this issue is not only pertinent to the irrigation subsector but also to the entire industrial sector of Bhutan. Actual countermeasure which can be taken is to create a list of products identified as inferior goods through actual utilization, and to share it among Engineering Division, ARDCs and the Dzongkhag Engineering Divisions. Since Bhutanese engineers have the knowledge of inferior goods, the Bhutanese side can address the issue without JICA's cooperation.

(4) O&M of Irrigation Facility

The confirmed needs under this theme are: 1) to foster trainers for TOT in O&M; and 2) to provide O&M training to traditional WUGs.

1) To Foster trainers for TOT in O&M

Now, there is only one trainer for TOT in O&M in Engineering Division. The actual number of engineers of Engineering Division and ARDCs is 29 and there is a plan to increase it to up to 31 engineers in the future. However, the objective of that is to increase personnel for survey, planning, design, construction supervision of the irrigation system; hence, there is no plan to increase the number of O&M experts for the time being.

Meanwhile, in the irrigation systems handled by Engineering Division and ARDCs, support to establish WUAs and O&M training to WUAs are given by the engineer in charge and above-mentioned personnel specialized in O&M. It is expected that the engineers in charge of the irrigation system will acquire the knowledge and techniques required to provide the O&M training to WUAs and become a new trainer for TOT, if the O&M training to WUAs are continuously carried out for a while in a collaborative manner. Therefore, the Bhutanese side alone could address this need.

2) O&M training for traditional WUGs

It was confirmed that issues for O&M by the traditional WUGs' are mainly the issues of the transformation of WUGs into WUAs. For example, WUGs don't remember past repair costs to examine water costs after establishment of WUA.

Meanwhile, though DoA has been informed the activity situation of WUA, DoA has no personnel in

charge to consolidate the information, so DoA does not know the actual situation of O&M in each irrigation system.

Therefore, first, it is necessary to confirm the activity status of WUAs reported to DoA and whether problems in O&M exist or not. Subsequently, it is desirable to examine again the need to provide training to WUA together with the traditional WUGs, as well as the possibility for further cooperation from JICA.

7.3.2 Farming Improvement

The confirmed needs are the "Resolution of labour shortage", the "Expansion of sales opportunities of agricultural produce", the "Countermeasures against crop damages caused by wildlife, insects and diseases" and the "Extension of developed farming skills". Cooperation for farming improvement by addressing these needs is indispensable because even if irrigation systems are developed and irrigation water is supplied stably, an increase in agricultural production cannot be attained unless these needs are addressed.

As a measure for the "Resolution of labour shortage", JICA has been promoting farm mechanization as its support to the agriculture machinery subsector. For the "Expansion of sales opportunities of agricultural produce", JICA has improved access to markets through the construction of farm road bridges as its support to the farm road subsector. Meanwhile, for the "Countermeasures against crop damage caused by wildlife, insects and diseases", a research by ARDCs, and the supply of electric fences to farmers by RGoB, among other measures, are underway. Thus, the Bhutanese side can respond to this need by continuously taking this and other similar measures. Furthermore, regarding the "Extension of developed farming skills", ARDCs has conducted research and development of farming technologies for rice, while farming technologies for horticultural crops are being established with JICA's support to the horticulture subsector. Regarding the dissemination of the developed technology, RGoB can assume the responsibility, based on the results of the horticulture subsector's activities in eastern Dzongkhags. As seen above, The Bhutanese side through relevant subsectors can address these needs related to farming improvement.

On the other hand, the information gathered in the Survey revealed that the cultivated area of main cereals tends to decrease and that the abandonment of rice terraces occurred. However, the reasons for these situations were not described in the collected documents. Reasons for these situations shall be confirmed, to prevent the abandonment of rice terraces, and to expand the cultivated area. Furthermore, although the cultivated area of main cereals has decreased, their unit yields have increased, although reasons for that could not be identified either. The reasons for increased unit yield may be useful to develop possible measures for increased unit yield, therefore, it is necessary to confirm the reasons for this as well.

Additionally, soil conditions and seed status (situation of improved seeds and seeds distribution, etc.) are the matters directly contributing to the increase in agricultural production, but were not fully confirmed by this time Survey. Therefore, they should be confirmed further, and to examine the possibility for JICA’s cooperation on these matters.

7.4 RECOMMENDED COOPERATION FOR THE IRRIGATION DEVELOPMENT

Based on the results of the analysis of the possibility for JICA's cooperation on each of the confirmed needs, the recommendation of cooperation approach for future irrigation development in Bhutan

(draft) is shown in Figure 7.4.1. This recommended approach is in conformity with the contents of the Minutes of Discussion signed by RGoB and JICA in February 2017, which puts an emphasis on the importance of capacity development of irrigation engineers (= human resource development) and of the water intake system with multiple water sources for the irrigation development in Bhutan. This recommendation remains as draft and shall be finalized through further concrete discussions between RGoB and JICA.

As shown in Figure 7.4.1, the complex and multi-phased approaches combining the hard component cooperation and soft component cooperation can be recommended. Through the implementation of these approaches, it can be expected that Bhutan becomes to implement the irrigation development without any support from development partners and the irrigated area is expanded. In the end, all the approaches link to capacity development (human resource development), because human resource development is considered as the most important and the centre pillar for irrigation development. In addition, in order to improve agricultural productivity, it is necessary to implement the cooperation on both the farming improvement and the irrigation system development. As the synergy effect produced by the irrigation system development and farming improvement, which are the two wheels to accelerate agriculture development, it is anticipated that agriculture production will be increased, and such an increase will contribute to the attainment of the targets set by the Eleventh Five Year Plan or its successors.

Hereafter, the concrete contents of some items shown in Figure 7.4.1 for which JICA's cooperation could be provided are described. It is considered to implement these approaches by classifying them into two large groups to improve the effectiveness of cooperation, rather than implementing each of them individually. Moreover, the cooperation approach to the irrigation development planning is considered to be the most imminent need at the moment in the irrigation development in Bhutan.

(1) Cooperation Approach to the Irrigation Development Planning

Cooperation on the soft components

Capacity Development (Human Resource Development)-1

- Support for the analysis of causes of damages on the existing irrigation facilities to take into account the results of analysis in the preparation of future irrigation development planning
- Support for the organization of basic information on irrigation systems through an improvement on NIIS
- Support for the collection of meteorological and hydrological data for Radhi Area Irrigation System, including the establishment of the mechanism for the continuous observation of groundwater level, etc.

Capacity Development (Human Resource Development)-2

In view of the strengthening of irrigation development planning capacity:

- Support for capacity development in the prioritization of irrigation systems for the development/rehabilitation
- Support for capacity development in the establishment of development target values

Under the "Capacity Development (Human Resource Development)-2", the selection of irrigation systems which could be developed/rehabilitated through Grant Aid or ODA loan scheme of Japan may

be included. Additionally, the support to select the model irrigation systems which will be the sites for capacity development in the implementation of survey, planning, design, construction/construction supervision, under the "Capacity Development (Human Resource Development)-3", may be included as well. It is desirable that the model irrigation systems are selected from each of the Hilly Scheme, Valley Bottom Scheme and Foot Hill Scheme, as indicated in NIMP in accordance with the features of farmland in Bhutan. Since these topographic divisions by features are common between Bhutan and Japan, it is expected that irrigation technology accumulated in Japan can work in Bhutan as well. Additionally, it is expected that the selected model irrigation systems have plural small scale water sources, as the effectiveness of the system with water intake from plural small scale water sources was confirmed by this time Survey.

Cooperation on the hard components

Radhi Area Irrigation System was studied by this Survey, and to do so, values for several conditions had to be estimated. The project for the development of Radhi Area Irrigation System should be formulated and its efficiency should be analysed through the validation of the estimated values. Therefore, the project components will be studied and evaluated through the implementation of the "Capacity Development (Human Resource Development)-1 and 2", and based on the results of their implementation of the same “Capacity Development -1 and -2”, the contents of cooperation need to be revisited. When an irrigation system, that can be the target of Grant Aid or ODA loan scheme of Japan, is identified in "Capacity Development (Human Resource Development)-2”, another survey will be conducted, if necessary.

(2) Cooperation Approach to Irrigation planning and Irrigation Facility Design/Construction Technology, including the Cooperation for O&M of Irrigation Facility

Cooperation on the soft components

Basic Information Collection

- Technical capacity assessment of engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Division to confirm their strengths and weaknesses in terms of job performance
- Survey to identity the utilization status of technical guidelines, manuals, etc.
- Survey on the current status of O&M of irrigation systems to examine the possibility for further cooperation
- Survey on the current status of farming to examine the possibility for further cooperation

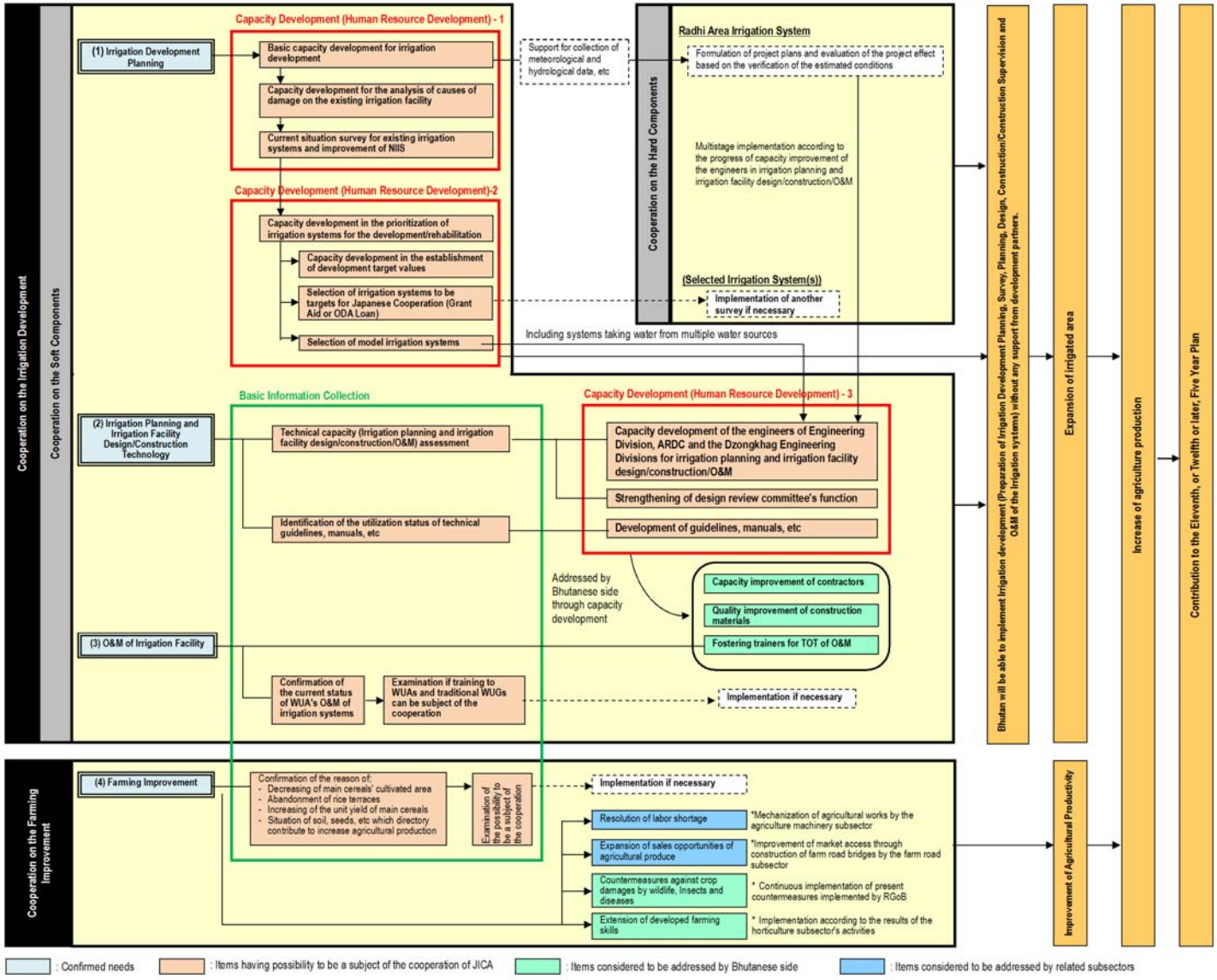
Capacity Development (Human Resource Development)-3

- Support for the capacity development of irrigation engineers in irrigation planning, irrigation facility design/construction/O&M
- Support for the strengthening of design review committee's function
- Support for the development of guidelines, manuals, etc

The confirmed issues of the farming improvement would be addressed by the Bhutan side or through cooperation with different subsectors. Meanwhile, for those issues of the farming improvement, details of which were not fully identified, a further detailed survey (the information collection and analysis) will be required. Therefore, as cooperation for farming improvement, these further detailed surveys shall be included in aforementioned "Basic Information Collection."

Cooperation on the hard components

The model irrigation systems selected through the implementation of the "Capacity Development (Human Resource Development)-2" are considered to be the targets for the implementation of survey, planning, design, construction/construction supervision through the implementation of the "Capacity Development (Human Resource Development)-3". The concrete contents and methods of the development/rehabilitation of the model irrigation systems will be examined through the implementation of the same "Capacity Development (Human Resource Development)-3."



Source: the Survey Team

Figure 7.4.1 Cooperation Approach (Draft)

(3) Others: Consideration of issues in the "Capacity Development (Human Resource Development) -3" (Supplementary notes for future considerations)

1) Analysis of the feasibility of capacity development of engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions in the irrigation planning and the irrigation facility design/construction/O&M, in which Engineering Division has shown its interesting

The experience and knowledge on agriculture engineering of engineers of Engineering Division, ARDCs, and the Dzongkhag Engineering Divisions is still at the preliminary stage. Therefore, the implementation of a technical cooperation project which provides lectures, OJT on the model irrigation systems, and training opportunities is recommended. It is also recommended to give the priority in the project to the development of basic capacity in the irrigation planning and the irrigation facility design/construction/O&M. Therefore, the project structure should allow engineers to acquire advanced technology phase by phase over a long term.

Hereafter, the possible activities of the technical cooperation project are presented with their beneficiaries.

i) Capacity development of engineers of Engineering Division and ARDCs

Engineers of Engineering Division and ARDCs are the major beneficiaries of this project, which is considered as core for the irrigation related projects. Along with the development procedure of the acquisition of new technology, the project will be implemented by dividing itself into the three phases: “Phase I: Acquisition of basic capacity”; “Phase II: Acquisition of advanced capacity”; and “Phase III: Technology development” (Table 7.4.1).

Each phase is composed of lectures, OJT on the model irrigation systems, and training.

Lectures

The lecturers who are in charge of the lectures are professors of technical colleges in Bhutan or others who have similar qualifications to them and the engineers shall acquire the knowledge on the irrigation planning and the irrigation facility design/construction/O&M. In addition, project experts will also assume the role of lecturer on the irrigation system with water intake from small-scale dispersed water sources. In the Phase I, the project experts also give the lecture about the methodology and the budget allocation on the joint water source development with other sectors related to water,

OJT on the model irrigation systems

In the OJT, the survey, planning, design, construction supervision through applying the knowledge acquired in the lectures are implemented, In addition, guidelines/manuals are developed base on the implementation experience through OJT. As for the method of OJT, it is considered that the method applied in the farm road subsector is effective. At the same time, technical backstopping system such as the design review committee, etc. is established/strengthened, including the development/update of the checklist for the committee. In addition, when necessary, the cooperation project accepts interns from the technical colleges for the development of human resources for future irrigation development projects.

Trainings

The trainings are conducted in third countries or in Japan. In the third country training, study tours to the irrigation systems in such a country, whose natural conditions are similar to those of Bhutan, would be implemented. The study tours aim to deepen the technical knowledge on issues to be considered at the planning and design, through the site visits to both the functional/dysfunctional systems. The training in Japan focuses on deepening knowledge especially on O&M methods after the completion of facility construction. In Phase II, a study tour to advanced structures, such as reservoir, etc., which has not been constructed in Bhutan, shall be also conducted. Multipurpose dams for which water sources have been jointly developed by some related sectors are recommended to visit as an advanced facility to be surveyed. Also those candidates for senior engineer who is in charge of the design review, etc., opportunities for study abroad to master advanced skills will be given in Phase II, after acquiring the basic capacity at Phase I.

In Phase III, the development of technologies ascertained through the implementation of Phase I and II, which are required to be developed in Bhutan is conducted.

(Development of Radhi Area Irrigation System)

Engineering Division sees Radhi Area Irrigation System as too complicated to make it a model irrigation system for OJT. Taking this into account, the development of this system is conducted separately from other model irrigation systems selected under the "Capacity Development (Human Resource Development)-2".

In order to raise the accuracy in the planning and design, it is necessary to plan and design after some meteorological and hydrological data are accumulated through the support for data collection which will be implemented separately. Meanwhile, it is also necessary to address issues such as the lining of branch canals, the reinforcement of pipes passing through landslide area, etc. which do not require long-term data and advanced planning/design techniques.

In consideration of the above situations, the lining of the branch canals, the reinforcement of pipes passing through landslide area, and the accumulating meteorological and hydrological data, etc are carried out in Phase I. In Phase II, the engineers of Engineering Divisions and ARDCs, who have acquired basic capacity in Phase I, plan and design the system based on the accumulated meteorological and hydrological observation data.

Table 7.4.1 Capacity Development in the Irrigation Development of the Engineers of Engineering Division and ARDCs (Draft)

	Stage	Period	Outline of Activities		
Phase I	Acquiring Basic Capacity	5 years	Lectures	Theme	Fundamental matters for the irrigation development
				Contents	Irrigation planning, methods to design individual facilities (canal, intake facility, etc.), methods to design water flow system (intake - delivering - distribution), countermeasure works for landslides, etc * The contents are to be finalized according to the results of technical capacity assessment in the "Basic information Collection", which would be conducted at a later stage.
				Lecturers	Professors of technical colleges in Bhutan or specialists equivalent to them
				Theme	Irrigation system taking water from plural small-scale water sources (simple)
				Contents	Concept of the risk diversification by using plural small scale water sources, survey and evaluation methods of alternative water sources, the design methods, etc
				Lecturers	Experts of the technical cooperation project

	Stage	Period	Outline of Activities	
			OJT	- Survey, planning, design and construction supervision of basic structures (canals, intake facility, etc) * Including procurement of survey equipment when necessary - Development of guidelines for survey, planning, design and construction supervision - Development of the check list for construction supervision - Establishment of the technical backstopping mechanism (Development of the check list to the design review committee) **[The target irrigation systems to be developed]** (1) Radhi Area Irrigation System Lining to some parts of branch canals, reinforcement of pipes by sandbags or gabions (2) Model Irrigation Systems Three irrigation systems with one alternative water source * Irrigation systems selected from Hilly Scheme, Valley Bottom Scheme, and Foot Hill Scheme respectively
			Trainings	[Third Country Training] Study tour to irrigation systems in those countries with similar natural conditions to Bhutan *Study tours to both functional/dysfunctional irrigation systems [Training in Japan] Study tours to irrigation systems where O&M is carried out without problems
Phase II	Acquiring Advanced Capacity	5 years	Lectures	Theme: Advanced matters for the irrigation development Contents: Reservoir planning, survey and design method, joint water source management, etc * The contents are to be finalized according to progress in the capacity development in Phase I. Lecturers: Experts of the technical cooperation project, professors of technical colleges in Bhutan or specialist equivalent to them Theme: Irrigation system taking water from plural small-scale water sources (complex) Contents: Connection method of plural small scale water sources, etc Lecturers: Experts of the technical cooperation project
			OJT	- Survey, planning, and design of advanced structures (reservoir, etc) * Construction is not included - Development of manuals for survey, planning, design and construction supervision - Revision and finalization of the check list for construction supervision - Strengthening of the technical backstopping mechanism (Revision and finalization of the check list to the design review committee) - Preparation of irrigation development planning **[The target irrigation systems to be developed]** (1) Radhi Area Irrigation System Examination and implementation of the intake system from plural small scale water sources based on accumulated meteorological and hydrological data and groundwater level data (2) Model Irrigation Systems Three irrigation systems with plural small scale alternative water sources * Irrigation systems selected from Hilly Scheme, Valley Bottom Scheme, and Foot Hill Scheme, respectively
			Trainings	[Third Country Training] Study tour to irrigation systems in those countries with similar natural conditions to Bhutan * Study tours to both functional/dysfunctional irrigation facilities [Training in Japan] Study tours of irrigation facilities where O&M is carried out without problems and advanced structures (multipurpose dam, etc)
			Study abroad	Opportunities for study abroad for those candidates for senior engineer
Phase III	Technology Development	5 years	* Identification and development of technologies through Phase I and Phase II, which are required to be developed in Bhutan	

ii) Capacity development of engineers in the Dzongkhag Engineering Divisions

The capacity development of the engineers of the Dzongkhag Engineering Divisions would be conducted in the following two phases, "Phase I: Acquiring Basic Capacity" and "Phase II: Acquiring Advanced Capacity". Items to be addressed in each stage are shown in Table 7.4.2. Lectures are carried out in each stage and its contents are the same as those for the engineers of Engineering

Division and ARDCs. However, the lecturers of these lectures for engineers of the Dzongkhag Engineering Divisions are the engineers of Engineering Division and ARDCs who have already acquired the capacities required at each stage.

The OJT through the development of the model irrigation systems for the engineers of the Dzongkhag Engineering Division may need to be given the second priority for now. It may be difficult to allocate personnel of the technical cooperation project to the OJT of the engineers of the Dzongkhag Engineering Division until the OJT for the engineers of Engineering Division and ARDCs is done at the same time. Regarding the training, study tours are conducted in Bhutan. The targets of the study tours are the irrigation systems developed by the engineers of Engineering Division and ARDCs through the OJT of this technical cooperation project.

Table 7.4.2 Capacity Development in the Irrigation Development of the Engineers of the Dzongkhag Engineering Divisions (Draft)

	Stage	Period	Outline		
Phase I	Acquiring Basic Capacity	5 years	Lectures	Theme	Fundamental matters for the irrigation development
				Contents	Irrigation planning, methods to design individual facilities (canal, intake facility, etc.), method to design the system along water flow (intake - delivering - distribution), countermeasure works for landslides, etc * The contents are to be finalized according to the results of technical capacity assessment in the "Basic information Collection" to be conducted at a later stage.
				Lecturers	Engineers of Engineering Division and ARDCs
				Theme	Irrigation system taking water from plural small-scale water sources (simple)
				Contents	Concept of the risk diversification by using multiple water sources, survey and evaluation methods of alternative water sources, the design methods, etc
				Lecturers	Engineers of Engineering Division and ARDCs
			Training	[Domestic Training] Study tours to the irrigation systems developed by the engineers of Engineering Division and ARDCs through OJT	
Phase II	Acquiring Advanced Capacity	5 years	Lectures	Theme	Advanced matters for the irrigation development
				Contents	Reservoir planning, survey and design method, joint water source management, etc * The contents are to be finalized according to progress of the capacity development in Phase I.
				Lecturers	Engineers of Engineering Division and ARDCs
				Theme	Irrigation system taking water from plural small-scale water sources (complex)
				Contents	Connection method of plural small scale water sources, etc
				Lecturers	Engineers of Engineering Division and ARDCs
			Training	[Domestic Training] Study tours to the irrigation systems developed by the engineers of Engineering Division and ARDCs through OJT	

Figure 7.4.2 is a diagram which shows the image of the improvement of skills of each engineer and its dissemination in the above mentioned technical cooperation project. Through the implementation of a series of activities, Bhutan will become to implement the irrigation development without any support from any development partners. Thus, it is expected to contribute to the attainment of the target value of the Eleventh or Twelfth or later Five Year Plan.

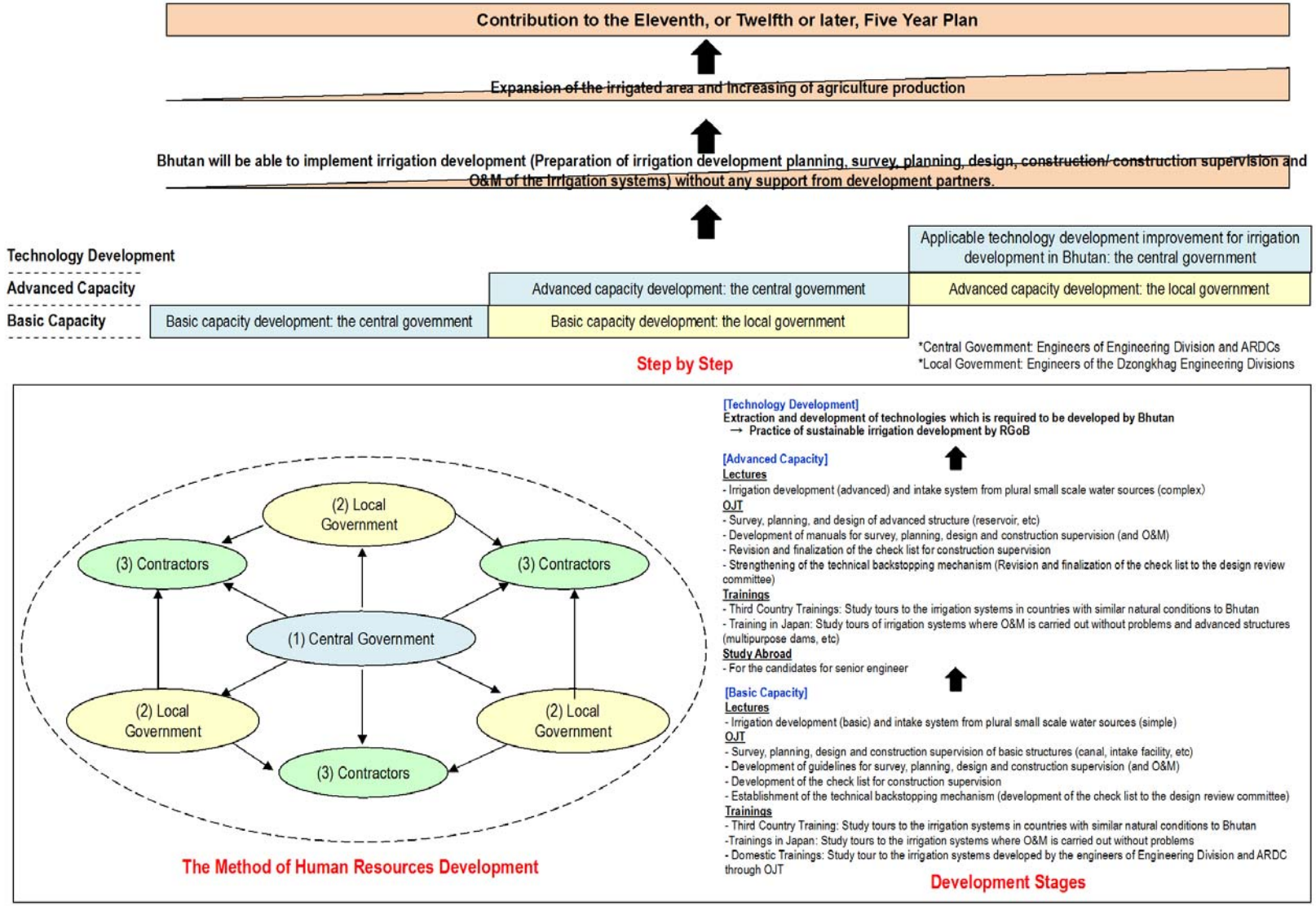
2) Strengthening of the design review committee's function

The development of the checklist to be used in the design review committee is carried out as a part of "Analysis of the feasibility of capacity development of engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions in the irrigation planning and the irrigation facility design/construction/O&M, in which Engineering Division has shown its interesting". Meanwhile, for candidates for senior engineers of Engineering Division, who have judging ability for the design review committee, opportunities for study abroad for further capacity development is conducted at

Phase II after acquiring basic capacity.

3) Development of guidelines, manuals, etc

Preparation of guidelines, manuals, etc is carried out as a part of "Analysis of the feasibility of capacity development of engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions in the irrigation planning and the irrigation facility design/construction/O&M, in which Engineering Division has shown its interesting".



Source: the Survey Team

Figure 7.4.2 Capacity Development of each Engineer by the Technical Cooperation Project and Its Development Image

7.5 RELEVANCE OF THE RECOMMENDED COOPERATION APPROACH TO BHUTAN'S NATIONAL POLICIES AND JAPAN'S ASSISTANCE POLICY

(1) Relevance of the Recommended Cooperation Approach to Bhutan's National Policies

The Eleventh Five Year Plan puts the weight on the development/rehabilitation of agriculture infrastructure as a means to achieve the following three National Key Result Areas: "Poverty reduced and MDG Plus achieved", "Food secure and sustained" and "Employment". In accordance with this policy, DoA is implementing three programmes related to irrigated agriculture as shown in Table 7.5.1.

Table 7.5.1 Programmes under the implementation by DoA, related to Irrigated Agriculture

Programme	Primary Output
National Field Crop Commodity Development Programme (NFCCDP)	**[Area under-assured Irrigation]** 67,676 Acre → 77,827 Acre **[Area under Farm Mechanization]** 1,271 Acre → 5,000 Acre
National Horticulture Commodity Development Programme (NHCDP)	**[Area under Vegetable Cultivation]** 33,532 Acre → 38,532 Acre
Agriculture Infrastructure Development Programme (AIDP)	**[New irrigation system development]** 0 Nos → 10 Nos **[Existing irrigation system improvement]** 0 Nos → 20 Nos **[Newly farm road construction]** 0 Nos → 10 Nos

Source: Eleventh Five Year Plan

Among the programmes listed in the table above, AIDP has the component of development of new irrigation systems and rehabilitation of existing irrigation systems. Because of such a component, it can be said that the cooperation approach which is recommended earlier is in line with AIDP, which includes the development of Radhi Area Irrigation System and the model irrigation systems. Incidentally, AIDP does not include the capacity development of the engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions in the irrigation planning and irrigation facility design/construction/O&M. Nevertheless, such component is essential to effectively develop/rehabilitate irrigation systems. Therefore, even the capacity development component may be taken as part of this approach, in accordance with AIDP.

(2) Relevance of the Recommended Cooperation Approach to Japan's Assistance Policy

The "Country Assistance Policy for Bhutan" of Japan sets "Assistance for self-reliant and sustainable nation building with a good balance of rural and urban areas" as basic policy of assistance (major target). To this end, "Bearing in mind the basic philosophy of GNH and the consolidation of democracy, Japan will provide assistance for self-reliant economic growth as well as improvement of standard of living through revitalizing rural communities, strengthening social infrastructure, and delivery of services in rural areas, which enables people to earn their own living" is required.

The development/rehabilitation of irrigation systems in rural areas is in line with this aid policy, and also with one of the strategies adopted to the Rolling Plan for Bhutan (April, 2016), namely, "From the point of view of increasing food supply, Japan provides assistance for developing irrigation facilities aiming to increase the production of main crops such as rice and vegetables with low self-sufficiency". Thus, the capacity development in the development/rehabilitation of irrigation systems of engineers of Engineering Division, ARDCs and the Dzongkhag Engineering Divisions is meeting with the Country Assistance Policy of Japan.

ANNEX

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Mr. Sangay Wan	Senior Extension Service III
Ms. Deki Pem	Agriculture Extension Supervisor

(9) Dagana Dzongkhag

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Mr. Jamyang Dorji	Principal Engineer
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(10) Integrated Horticulture Promotion Project in the West Central Region

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Minutes of Discussions on
JICA – RGoB Cooperation for Irrigation Sub-sector in Bhutan
between
Japan International Cooperation Agency
and
The Royal Government of Bhutan

Date: February 20th, 2017
Place: Thimphu

The Japan International Cooperation Agency (hereinafter referred to as "JICA") has been conducting the Data Collection Survey on Irrigation Development (hereafter referred to as "the Survey") and its mission headed by Eng. Kazuo Shimazaki (Executive Technical Advisor to the Director General, Rural Development Department) had detailed discussions with the Royal Government of Bhutan (hereafter referred to as "RGoB") represented by the officials of Ministry of Agriculture and Forests (hereinafter referred to as "MoAF") from February 14th to 20th, 2017 about a way forward of JICA-RGoB cooperation in the irrigation sub-sector of Bhutan.

The JICA mission and the RGoB officials hereby confirmed the preliminary findings of the summarized as in the attached document.

For Japan International Cooperation Agency	**For Royal Government of Bhutan**
島崎和夫	
Kazuo Shimazaki	Kinlay Tshering
Executive Technical Advisor to the Director General , Rural Development Department	Director Department of Agriculture, Ministry of Agriculture and Forests

THE ATTACHED DOCUMENT

I. Background of the Data Collection Survey on irrigation Development

Agriculture is the essential industry of Bhutan, which employs 56.7% of Bhutan's working population and occupies 16.8% of GDP in 2014. The irrigation subsector plays an important role in agriculture development especially for increasing and securing rice production. However, self-sufficiency rate of rice was only 51.1% in 2011. The 11th Five Year Plan (2013 - 2018) articulates the expansion of irrigated area and the increase of agriculture production through the construction of irrigation facilities, conducted by the central and the local governments.

Against the backdrop of importance of irrigation development mentioned above, Japan International Cooperation Agency (JICA), in collaboration with Ministry of Agriculture and Forests (MoAF), has conducted Data Collection Survey on Irrigation Development (hereafter referred to as "the Survey") with the objective of collecting necessary information and data to identify focused area of JICA's future cooperation in this sector.

II. Preliminary Findings from the Survey

1. It is confirmed that weir construction without any protection works in large stream with steep river bed, such as Yudhiri, has a high risk of severe damage on the constructed weir by flood.

2. Contrarily, small branch streams having stable discharge is identified in the upstream side of Yudhiri; it is considered that those small branch streams are potentials of alternative water resources.

3. By the findings mentioned above and also the lessons learnt from the preceding irrigation projects, it is confirmed that examination of alternative water resources such as small streams, ground water, springs, and small water storage facilities is important while considering future irrigation development.

4. Both sides confirmed that irrigation development requires deep consideration of natural condition of Bhutan.

5. It is recognized that irrigation development status in Bhutan is still at the preliminary stage. Therefore human resource development shall be positioned as the high-priority issue in JICA's cooperation in irrigation subsector.

End.

Annex-3: Progress of Construction of 108 Irrigation Systems as of End of February 2017

No	Dzongkhag	Gewog	Name of Scheme	L(km)	HH	Command area (ac)	Constructed				Under Construction	Ready to Tender (Survey, Planning, Design finished.)	Under Survey or Planning or Design Phase	Not Started Yet
							2013-2014	2014-2015	2015-2016	2016-2017				
1	Punakha	Kabisa	Naglachen	3.0	34	128.8	✓							
2	Punakha	Barp	Lobesa	1.2	-	200.0		✓						
3	Punakha	Talog	Phenday yuwa	25.0	430	1000.0						✓		
4	Punakha	Chhubu	Yebisa and Bali	10.0	63	275.0							✓	
5	Punakha	Dzomi	Jimthang yuwa	13.5	200	604.0						✓		
6	Punakha	Lingmukha	Omtakha Scheme	6.1	40	197.4								✓
7	Punakha	Toepisa	Chuzomsa	0.3	9	130.0								✓
8	Punakha	Shenga-Bjemi	Domsimo	3.0	35	80.0						✓		
9	Wangdue	Darkar	Mukuchu yuwa	7.0	25	90.0								✓
10	Wangdue	Dangchhu	Lhachu yuwa	5.1	49	113.0							✓	
11	Wangdue	Gase-tshogom	Gase yuwa	6.8	90	443.0								✓
12	Wangdue	Kazhi	Dechengoenpa	12.0	100	100.0								✓
13	Wangdue	Nyishog	Pangkabjiyuwa	14.9	67	207.9								✓
14	Wangdue	Darkar	Bashey yuwa	5.0	30	90.0								✓
15	Wangdue	Gangtey	Mangchuka	5.5	110	200.0								✓
16	Wangdue	Ruebisa	Ngawang Sechuyuwa	30.0	90	450.0							✓	
17	Wangdue	Thedtsho	Baychuyuwa	14.0	70	300.6					✓			
18	Bumthang	Chhoekhor Thromde	Chamkharthang	1.1	60	70.0								✓
19	Dagana	Karna	Dreychhu	8.0	120	200.0					✓			
20	Dagana	Karna	Jabalum	6.0	92	85.0								✓
21	Dagana	Khebisa	Narikachu to Bagaythang via Thomgang	6.0	95	150.0						✓		
22	Dagana	Lhamoizingkha	Tsainzigosa	3.7	35	70.0								✓
23	Dagana	Tseza	Kari Lum Irri.Channel	18.0	167	350.0						✓		
24	Dagana	Tsenda-Gang	Suntalay Kulo	5.0	50	72.0								✓
25	Dagana	Karmaling	Karmaling Lift Irrigation	3.0	102	400.0				✓				
26	Dagana	Drukjeygang	Buddichhu to Thangna and Pangna	12.0	250	200.0						✓		
27	Dagana	Tsangkha	Budeychu - Tsangkha tar	13.0	222	210.0						✓		
28	Trongsa	Draagteng	Longchu Irrigation	7.0	145	300.0								✓
29	Trongsa	Korphu	Creedigang (Cardigang)	5.0	100	180.0						✓		
30	Trongsa	Langthil	Yurmungtshangchu	13.0	180	180.0								✓
31	Thimphu	Maedwang	Pungzi	12.0	178	280.0								✓
32	Samtse	Yetsholtse	Kuchidinia	7.4	256	962.2				✓				
33	Samtse	Yetsholtse	Lower Kuchidiania	3.2	74	285.7								✓
34	Samtse	Yetsholtse	Lamitar	2.7	72	145.8						✓		
35	Samtse	Ugyentse	Thakuri Kholsi	0.9	32	142.8								✓
36	Samtse	Ugyentse	Diana-Ugyentse	25.0	230	340.0								✓
37	Samtse	Tashicholing	Hangay	3.2	95	252.5		✓						
38	Samtse	Tashicholing	Sipsu Khola(penjorling)	2.8	150	118.8								✓
39	Samtse	Tashicholing	Lower Balbotey	3.2	58	368.4						✓		
40	Samtse	Tashicholing	Sipsu khola	3.7	60	156.6								✓
41	Samtse	Sangachholing	Depheling Meth Kha	3.0	60	120.0								✓

No	Dzongkhag	Gewog	Name of Scheme	L(km)	HH	Command area (ac)	Constructed				Under Construction	Ready to Tender (Survey, Planning, Design finished.)	Under Survey or Planning or Design Phase	Not Started Yet
							2013-2014	2014-2015	2015-2016	2016-2017				
42	Samtse	Sangachholing	Lingtey=3km, Hariyakhola=2km	5.0	150	300.0						✓		
43	Samtse	Sangachholing	Tharphu	16.0	80	200.0								✓
44	Samtse	Norgaygang	Kalikhola-Kamigaon	8.8	250	600.0			✓					
45	Samtse	Norbugang	Tharaykhola-Bimtar	15.0	270	450.0						✓		
46	Samtse	Dungtoe	Kunchey Khola to Gairi Gaon	15.0	250	200.0								✓
47	Samtse	Dophuchan	Dangdungay-Manigang	20.0	300	1000.0								✓
48	Samtse	Samtse	Khandothang	1.0	110	500.0			✓					
49	Samtse	Samtse	Gambadara	2.5	23	129.0						✓		
50	Samtse	Samtse	Mechitar	1.1	18	246.7								✓
51	Samtse	Beru	Sipsoo khola-Baraney	10.0	235	200.0						✓		
52	Chukha	Getana	Bachu	3.7	35	60.0								✓
53	Chukha	Getana	Bachu	2.6	35	80.2							✓	
54	Chukha	Geling	Om chhu	4.1	39	211.8								✓
55	Chukha	Darla	Sillangsa	4.0	31	82.0								✓
56	Chukha	Darla	U/L Saurani	4.2	18	86.9								✓
57	Chukha	Darla	Rinchentse	2.5	25	103.6								✓
58	Chukha	Bongo	Chungkha(Yuenengpo)	8.0	30	90.0						✓		
59	Chukha	Bongo	Ketokha	7.0	52	77.3						✓		
60	Chukha	Bongo	Chungkha(Pamikha)	7.0	30	150.0						✓		
61	Sarpang	Dekiling	Ratay	5.3	187	338.0						✓		
62	Sarpang	Samtenling	Juprey	5.0	26	125.0						✓		
63	Sarpang	Samtenling	Juprey	5.0	26	125.0						✓		
64	Sarpang	Samtenling	Roadline	3.5	40	80.0								✓
65	Sarpang	Sershong	Thewar	5.0	60	205.0						✓		
66	Sarpang	Shompangkha	Pakhey	7.0	45	200.0						✓		
67	Sarpang	Umling	Rejuk	2.0	27	86.0						✓		
68	Tsirang	Kilkhorthang	Dungkharchoeling	3.0	12	80.0						✓		
69	Tsirang	Mendelgang	Tahispang & Pemashong	1.5	18	66.0						✓		
70	Tsirang	Sergithang	Phuentenchu	5.0	-	100.0								✓
71	Tsirang	Tshilingkhar	Fetay Canal	5.0	32	73.0								✓
72	Zhemgang	Nangkhor	Tali	10.0	24	80.0								✓
73	Zhemgang	Phangkhar	Tashiling toe, Tashibi, Salangpong	5.0	40	100.0							✓	
74	Zhemgang	Trong	Takabi	3.5	30	100.0						✓		
75	Zhemgang	Trong	Trong, Dangkhar, Tingbi, Pam, Krashiply	12.0	171	178.0								✓
76	Tashiyangtse	Ramjar	Wangringmu Lift Irrigation	0.6	344	127.0		✓						
77	Tashiyangtse	Yallang	Thargom Irri, channel	8.0	-	-								✓
78	Tashiyangtse	Yallang	Jamaling Irri, channel	2.5	-	80.0							✓	
79	Tashiyangtse	Khamdang	Tshotsang Irri channel	4.5	89	67.1								✓
80	Tashiyangtse	Khamdang	Rabkhar Irri channel	7.0	-	100.0						✓		
81	Tashiyangtse	Toetsho	Kheshingri Irri channel	6.5	250	236.5						✓		
82	Tashiyangtse	Tongmajangsa	Mantichu Irri, channel	1.0	15	129.9			✓					
83	Mongar	Chaskhar	Gudari Irri channel	9.0	300	145.2		✓						

No	Dzongkhag	Gewog	Name of Scheme	L(km)	HH	Command area (ac)	Constructed				Under Construction	Ready to Tender (Survey, Planning, Design finished.)	Under Survey or Planning or Design Phase	Not Started Yet
							2013-2014	2014-2015	2015-2016	2016-2017				
84	Mongar	Challi	Wangla Irri channel	2.5	30	87.2								✓
85	Mongar	Challi	Challi irri channel	6.0	286	220.5								✓
86	Mongar	Saling	Changchu Irri	5.0	60	80.0								✓
87	Mongar	Saling	Masangdaza irri channel	3.3	21	93.3						✓		
88	Mongar	Gongdue	Yangbari Irri channel	3.1	21	113.5						✓		
89	Tashigang	Shongphu	Thunmari Irri. channel	5.0	400	700.0			✓					
90	Tashigang	Radhi	Yudiri Irri. Channel	4.5	430	1252.0								✓
91	Tashigang	Samkhar	Rangshikhar Irri. Channel	4.4	64	79.6								✓
92	Tashigang	Phongmay/Bidung	Yabrang Irri. Channel	10.0	170	500.0						✓		
93	Lhuntse	Tshengkhar	Phawangchu Irrigation channel	8.0	55	151.7				✓				
94	Lhuntse	Tshengkhar	Khepachu Irri. Channel	6.3	45	113.2								✓
95	Lhuntse	Maenbi	Shungkhar Irri. Channel	3.0	84	116.1								✓
96	Lhuntse	Maenbi	Serchu Irri. Channel	8.9	20	315.5								✓
97	Lhuntse	Minjey	Ngarigang chu Irrigation channel	6.1	84	200.7				✓				
98	Lhuntse	Minjey	Bomatang Irri. Channel	3.5	23	103.6								✓
99	Lhuntse	Minjey	Ngarchu/Serchu Irri channel	5.5	72	362.4				✓				
100	Lhuntse	Kurtoed	Reeb Irrigation channel	4.1	90	181.1								✓
101	Samdrup Jongkhar	Pemathang	Omshari Irri. Channel	6.0	140	576.0						✓		
102	Samdrup Jongkhar	Langchenphu	Langchenphu toe Irri. Channel	6.0	82	100.0								✓
103	Samdrup Jongkhar	Samdrup Choling	Mindrupling Irri.channel	5.0	33	80.0								✓
104	Samdrup Jongkhar	Samdrup Choling	Warrangkhola Irri. channel	2.0	35	107.0								✓
105	Samdrup Jongkhar	Samrang	Samrang Irri.channel	2.5	54	80.0								✓
106	Pemagatshel	Nanong	Mohannelnphu Irri.	1.6	52	80.0								✓
107	Pemagatshel	Nobugang	Satshalo Irri. Channel	3.0	63	81.0						✓		
108	Pemagatshel	Chokhorling	Bahudar irri.channel	2.8	74	200.0						✓		
				Total			1	4	4	5	2	34	6	52

RESULTS OF BORING SURVEY

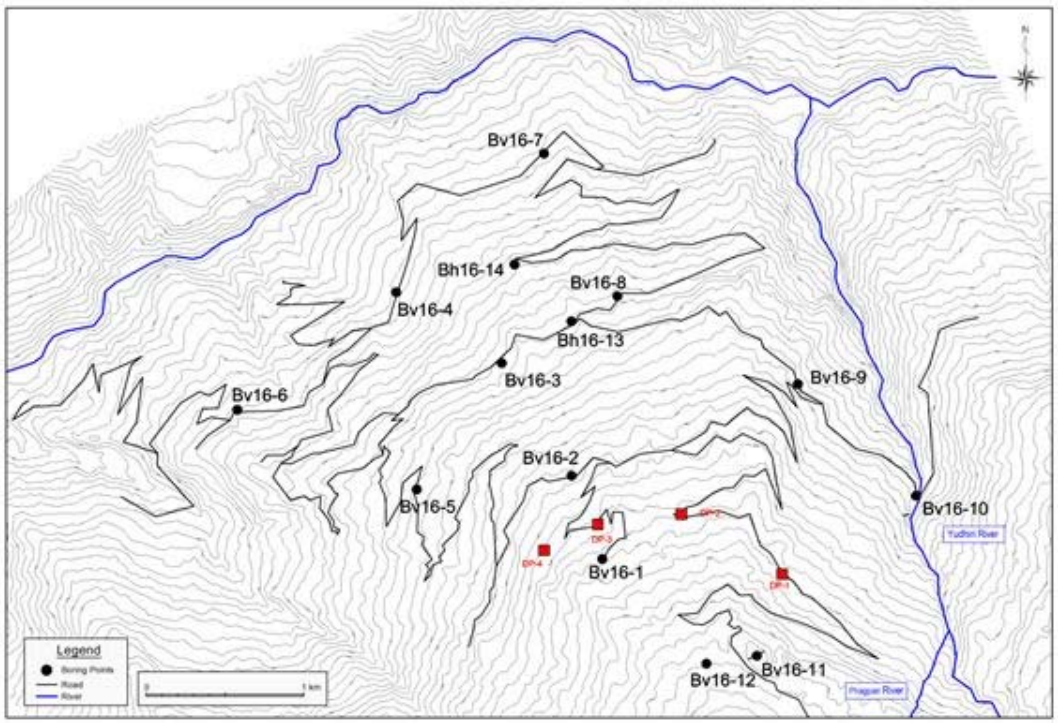
Objective

The objective of the boring survey is to assess the feasibility of the water sources alternative to Yudhiri River.

The targets and items to be investigated by the boring survey are listed in the following table.

Target	Items to be investigated
(1) Groundwater	- Thickness of the major landslide blocks - Groundwater level fluctuation - Available water volume
(2) Downstream of the existing intake point at the Yudhiri River ※Intake from the bridge crossing point	- Basement condition (bearing capacity) of the intake point (Especially, the basement with high bearing capacity: N value >30) - Basement condition along main canal (condition of the landslide)
(3) Farm Pond	- Basement condition of the proposed points of facilities(Especially, the basement with high bearing capacity: N value >30)

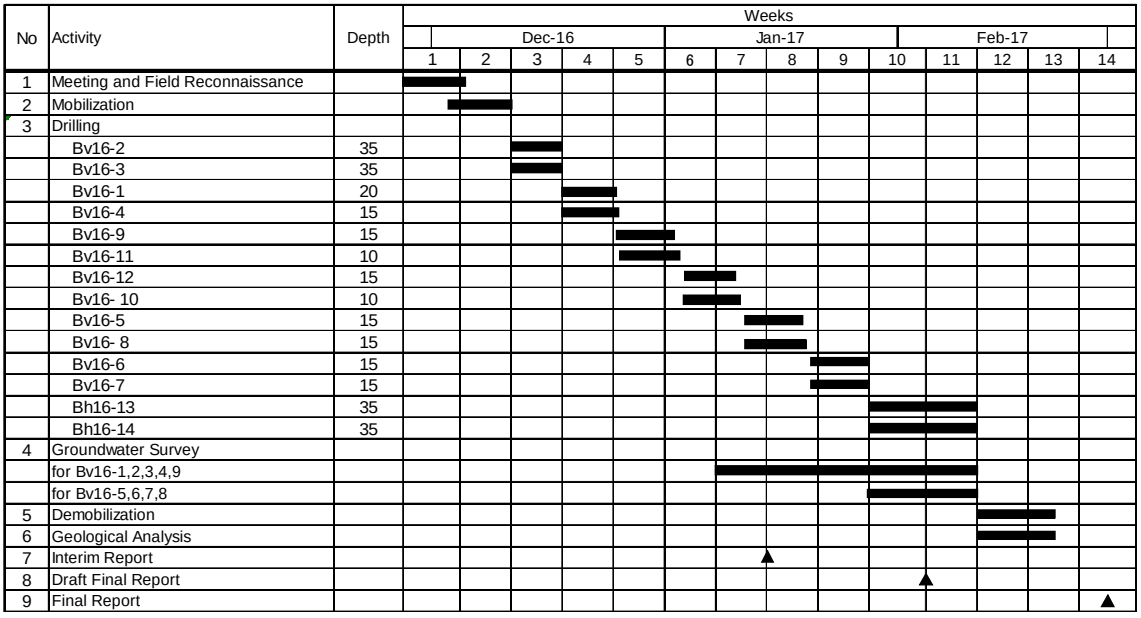
Location Map



Quantity and Purposes

Priority	Name	Depth(m)	Objective
1	Bv16-2	35	To grasp the thicknesses of major landslides within the command area and the groundwater level fluctuation
2	Bv16-3	35	ditto
3	Bv16-1	20	ditto
4	Bv16-4	15	ditto
5	Bv16-9	15	To confirm the conditions of basement along main canal *in case of intake from bridge crossing point
6	Bv16-11	10	To confirm the basement of for farm ponds
7	Bv16-12	15	ditto
8	Bv16-10	10	To confirm the conditions of basement for facility *(in case of intake from bridge crossing point
9	Bv16-5	15	To grasp the thicknesses of minor landslides within the command area and the groundwater level fluctuation
10	Bv16-8	15	ditto
11	Bv16-6	15	ditto
12	Bv16-7	15	ditto
13	Bh16-13	35	To grasp available groundwater volume
14	Bh16-14	35	ditto

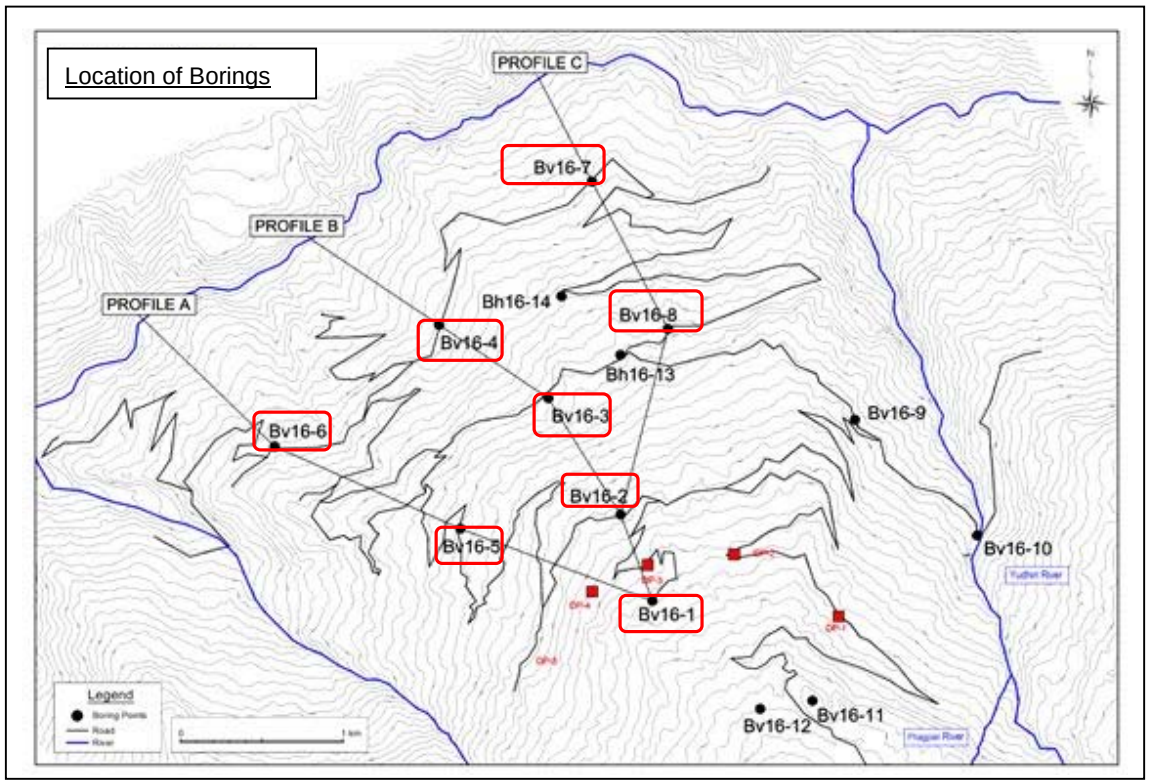
Survey Schedule

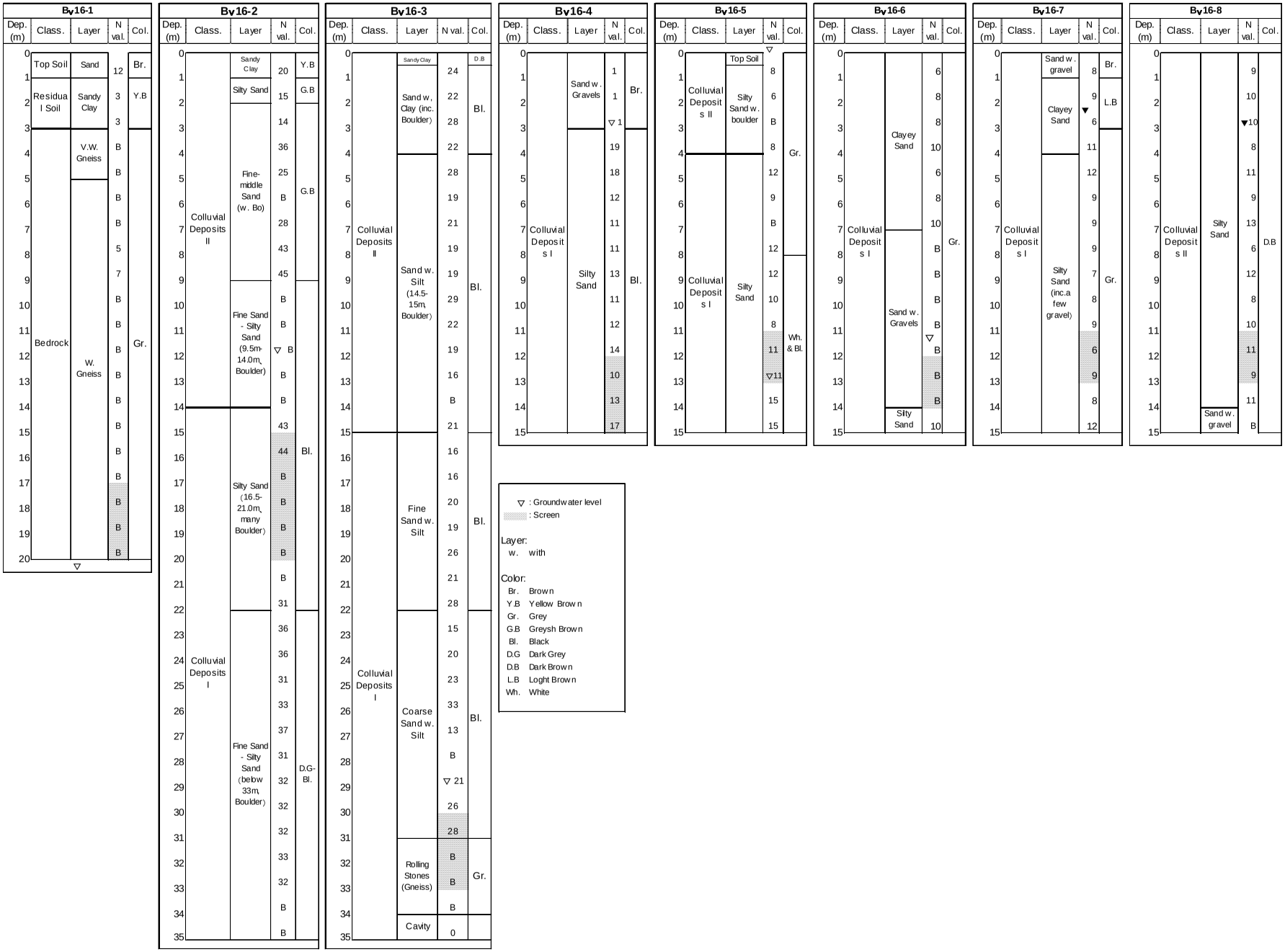


Results of the Survey-1: Groundwater

Results of the Survey-1-1: Thickness of Major Landslide Blocks within the Command Area and Groundwater Level Fluctuation (Bv16-1 - 8)

Since no existing geological survey results targeting the command area are not confirmed, the borings are arranged widely in the site in almost same distances each other to grasp the general geological condition of the command area. Also boring points are selected near the paved road running at the center of the command area from west to east or several farm roads for convenience on the transporting of the rigs and measuring of the groundwater level.




Bv16-1
Dep. (m)
Class.
Layer
N val.
Col.
Top Soil
Sand
Br.
Residual Soil
Sandy Clay
Y.B
V.W. Gneiss
W. Gneiss
Bedrock
Gr.
Bv16-2
Sandy Clay
Silty Sand
Fine-middle Sand (w. Bo)
Fine Sand - Silty Sand (9.5m-14.0m, Boulder)
Silty Sand (16.5-21.0m, many Boulder)
Fine Sand - Silty Sand (below 33m, Boulder)
Colluvial Deposits II
Colluvial Deposits I
G.B
Bl.
D.G-Bl.
Bv16-3
Sandy Clay
Sand w. Clay (inc. Boulder)
Sand w. Silt (14.5-15m, Boulder)
Fine Sand w. Silt
Coarse Sand w. Silt
Rolling Stones (Gneiss)
Cavity
D.B
Bv16-4
Sand w. Gravels
Silty Sand
Wh. & Bl.
Bv16-5
Top Soil
Silty Sand w. boulder
Gr.
Bv16-6
Clayey Sand
Sand w. Gravels
Silty Sand
Bv16-7
Sand w. gravel
Clayey Sand
Silty Sand (inc.a few gravel)
L.B
Bv16-8
Sand w. gravel
▽ : Groundwater level
: Screen
Layer:
w. with
Color:
Br. Brown
Y.B Yellow Brown
Gr. Grey
G.B Greysh Brown
Bl. Black
D.G Dark Grey
D.B Dark Brown
L.B Loght Brown
Wh. White

(1) Geological Condition

Bv16-1 (Depth 20m): The hole reached to the bedrock at the depth of 3.0m and the rock formation continued up to the fixed length 20m. Rock type was "Pegmatite". The span from 3.0m to 9.0m was heavily weathered rock (D class in the weathering grade), from 9.0m to 14.0m was weathered rock (CL class), and from 14m to the bottom of the hole (20m) was slightly weathered rock (CH class). Thus, this point was judged as out of landslide.

Bv16-2 (Depth 35m): The hole did not reach to the bedrock. Soil type was "Silty Sand" or "Fine Sand" with black color. The drilled layer included many large boulders (or rolling stones), and was regarded as "Colluvial Deposits" as a total. Then the rock types of the boulders included among the upper 14.0m and lower than 14.0m were different. Boulders in the upper portion included blackish plutonic rocks such as Amphibolite, Diabase, and Diorite, those are not distributing within/near the command area. While, the boulders included in the lower portion (deeper than 14m) were only whitish to grayish rocks such as Pegmatite, Gneiss, and Quartzite, those are outcropping near/within the command area. The situation suggested that the Colluvial deposits must be divided into two layers by the depth of 14m, and the upper deposits came from rather far (higher) area carried by landslides. Thus, the layer drilled through this hole was divided into two large categories of "Colluvial Deposits I and II", the lower deposits I came from near site and deposits II came from far area. The depth of 14.0m might be one of the landslide boundaries.

Bv16-3 (Depth 35m): As same with Bv16-2, the hole did not reach to the bedrock. The soil type was "Silty Sand" and including some large boulders or gravels. Same with Bv16-2, the layer drilled was divided into two layers by the depth of 15.0m through the kinds of boulders included. The upper layer till 15m was Colluvial Deposits II and the layer from 15m to the bottom was Colluvial Deposits I.

At the bottom of hole, there was a cavity more than 1.0m size below large boulders, and it suggested the bottom of the Colluvial Deposits I in this hole might not be so far from this depth.

Bv16-4 (Depth 15m): The hole did not reach to the bedrock. The soil type was totally rather loose “Sand” or “Silty Sand” with grayish color with N values from 10 to 16. Large boulders were not included but it could be classified to “Colluvial Deposits I” from the rock types of small gravels included.

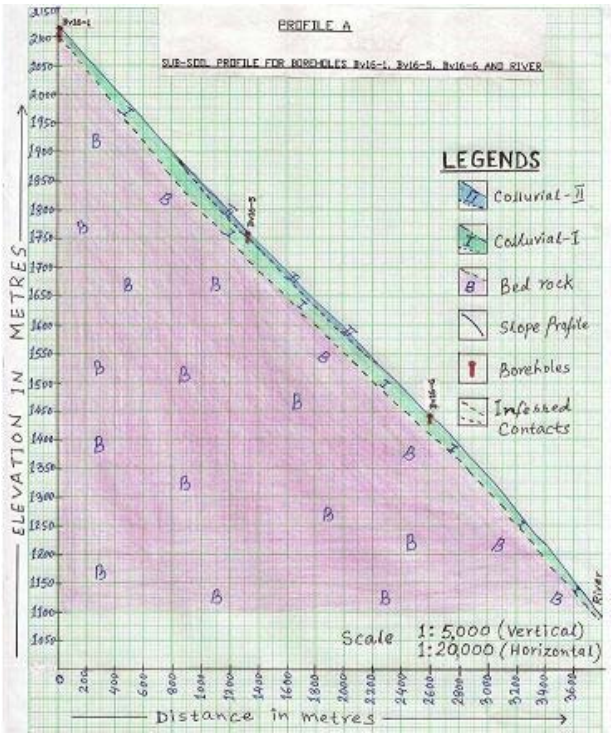
Bv16-5 (Depth 15m): The hole did not reach to the bedrock. Excluding the surface 0.5m of “Top Soil”, the following layer was “Silty Sand”, but the portion above 4.0m included large boulders and the portion lower than 4.0m was loose layer with N values from 10 to 16. According to the rock types of boulders, the upper potion above 4.0m was judges as Colluvial deposits II and the lower was deposits I.

Bv16-6 (Depth 15m): The hole did not reach to the bedrock. The soil type from the ground surface to the depth of 7.0m was “Silty” or “Clayey Sand” with almost no gravels. The soil type from 7.0m to the bottom was large “Rolling Stones” or “Boulders with Sand”. Rock types of the lower layer were mostly “Schists” and “Gneiss.” It was judged that whole the depth is classified to “Colluvial Deposits I.”

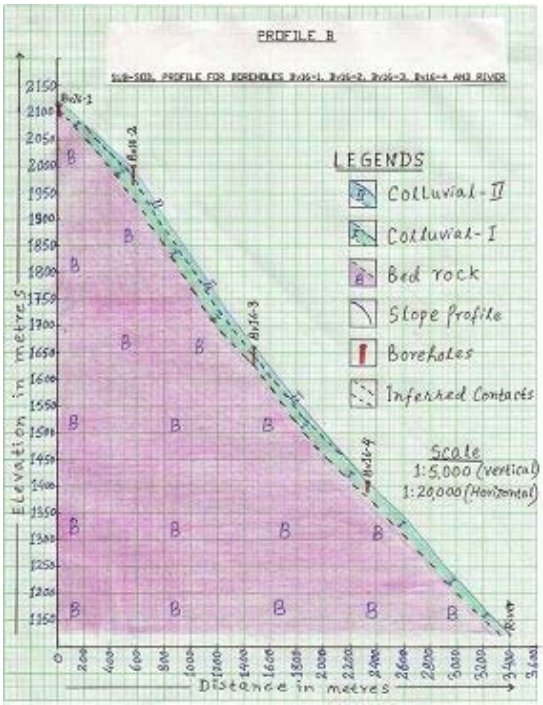
Bv16-7 (Depth 15m): The hole did not reach to the bedrock. The soil type from the ground surface to the depth 1.0m was “Top Soil” with brown color and from 1.0 m to the bottom was grayish “Silty” or “Clayey Sand”. Whole of the layer was rather loose with N values less than 10. Whole the depth was judged as “Colluvial Deposits I."

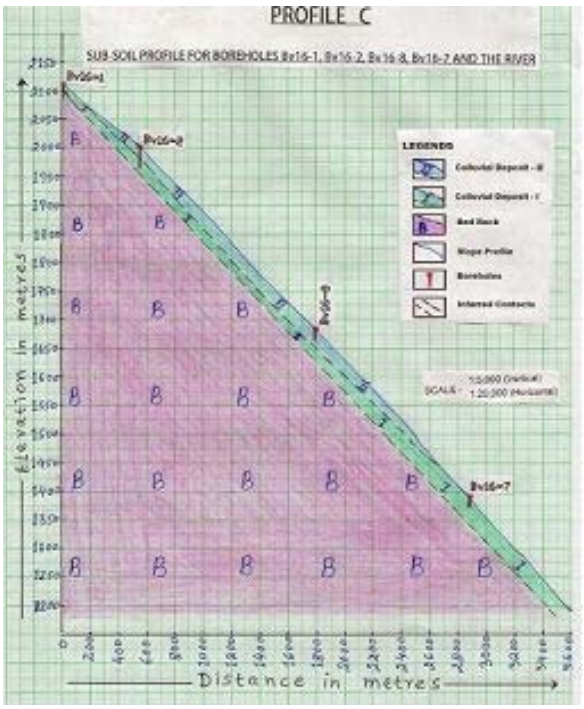
Bv16-8 (Depth 15m): The hole did not reach to the bedrock. The soil type from the ground surface to the depth 1.0m was “Top Soil” and from 1.0m to the bottom was “Silty” or “Clayey Sand” with dark grey color with N values from 9 to 11. However, the lowest portion of the hole (lower than 14.0m) included large boulders with dark green color (possibly “Diabase”), and thus, whole the depth was judged as “Colluvial Deposits II.”

Geological profiles drawn based on the results of investigation boring are shown as PROFILE A to PROFILE C below. Location of the profiles is shown together in the figure: “Location of Borings”, fore-cited. PROFILE A shows geological condition of the line from the portions of Bv16-1, Bv16-5, Bv16-6, and the river bed, along the south-west edge of the command area. PROFILE B shows the geological condition along with line cutting almost center of the site, from Bv16-1, Bv16-2, Bv16-3, Bv16-4, and the river bed. Then, PROFILE C shows the condition along with the line in the eastern side of the command area, started from Bv16-1 and passing through Bv16-2, Bv16-8, Bv16-7, and to the river bed at the extension of the line.



The boring which drilled through the boundary between Colluvial deposits I and II were only three holes, Bv16-2, Bv16-3 (both were 35m depths), and Bv16-5 (15m depth). The depths of the boundary were 14, 15, and 4m from the ground surface respectively. Besides those, the borehole drilled through Colluvial deposits II only, not reached to the boundary, was only Bv16-8. According to the fact that there





were no other boring drilled the Colluvial deposits II, it is suggested that deposits II distributes only in the central portion of the command area, in the elevations between 1,500m to 2,100 with thickness about 14 to 15m.

All the boreholes did not reach to the bottom of the Colluvial deposits I. However, there was a cavity at the bottom of Bv16-3 hole (lower than 34m) and it suggests the bottom of the Colluvial Deposits I in this hole may not be so far from this depth. Additionally, it was found through the outcrop survey conducted at the same time that the depths of bedrock surfaces are shallow in both east and west margins of the command area. Thus, it is considered that the lower landslide blocks (Colluvial deposits I) also distributes in the central zone of the command area with the thickness from 15 to 25m, underlain the Colluvial deposits II.

(2) Groundwater Conditions

To grasp the groundwater condition of the command area, water level in each borehole was measured every day, two times a day at before starting any work in the morning and after completion of all work in the evening. Further, a measurement pipe was installed to the boreholes from Bv16-1 to Bv16-9 for a continuous groundwater measurement after completion of drilling works.

Continuous groundwater measurement (measurement of water level inside the borehole) had been conducted at almost same time every day. Measurement was started at the holes from Bv16-1 to 16-4 and Bv16-9 from 24th December in 2016. Then, that at the holes from Bv16-5 to Bv16-8 were started from 12th January 2017. All measurements were completed by 6th February 2017. However among them, the boreholes of Bv16-4 and 16-9 were blocked so that groundwater measurement in these two holes could not be conducted.

Bv16-1(Depth 20m): Groundwater did not appear in this hole during drilling works (drilling water was completely lost circulation). For the possibility that groundwater level recovers in the wet season, the measurement pipe with screen was installed at the bottom 3 meters.

Continuous groundwater measurement had been conducted from 25th December 2016. Groundwater level in this hole was detected at the depth of 12.0m until 17th January 2017 (24 days), but the water level was dropped to lower than the boring depth (20m) from 18th January 2017 and it never recovered till the end of measurement, 6th February 2017. The detected groundwater level of 12m during the early period may not be actual ground water level.

Bv16-2 (Depth 35m): During the drilling of the Colluvial deposits II layer, the groundwater level as steadily at less than 1.0m depth from the ground surface. Then, after the drilling progressed more than 14m depth and furthermore, the water level in the hole dropped gradually and finally reached to nearly 12m depth. At the depth of 14m, there may be the boundary between the Colluvial deposits I and II. Although there could not be found clear impervious layer such as clay layer, permeability of this part may be low. The situation suggests the relative aquitard formed a small scale groundwater body, like a perched groundwater. Further, it can be considered that the Colluvial deposits I had somewhat higher permeability than the deposits II, and therefore, the water table in the hole dropped down when the boring drilled through the boundary of I and II.

Continuous groundwater level measurement had been conducted from 17th December 2016. The groundwater level was quite stable at the depth of 9.68m during the early one month and more, however, it fluctuated between 10.00m and 10.28m after 24th January 2017.

Bv16-3 (Depth 35m): During the early drilling period, the groundwater level was almost steady at high level around 1 or 2m depth from the ground surface. However, after the boring passed through the depth of 18m, the water level in the hole began dropping and finally downed to the depth of 29m. At the depth of 15m, there may be a boundary between Colluvial deposits I and II, and around the boundary seemed to be an aquitard relatively, although a clear impervious layer such as clay had not found. Such relative aquitard formed a groundwater body in the Colluvial deposits II, forming rather high water table. Because of a little high permeability of deposits I, the high water table in the deposits II was dropped down when the aquitard was penetrated by boring.

The screen in this hole was set at the portion from 30 to 33m depth because the water table in the hole was already dropped to the depth of 28m.

Continuous groundwater level measurement had been conducted from 24th January 2016. The groundwater level in this hole was, however, fixed at the depth of 27.00m with no any fluctuation during whole the

measurement period until 6th February 2017. The groundwater level at this point may be near around this depth (27m from the ground surface), considering from the groundwater level observed during its drilling work.

Bv16-4 (Depth 15m): Observed groundwater level was 5.7m when the hole was drilled through 9.0m depth and 2.65m when it was drilled through 15m (bottom of the hole).

The water level measuring pipe was blocked before starting the continuous groundwater level measurement so that any measurement after completion of the drilling works could not be conducted.

Bv16-5 (Depth 15m): Observed groundwater level was 5.0m when the hole was drilled through from 3.0m to 6.0m, however, the water level had not been observed after that.

Continuous groundwater measurement had been conducted from 12th January 2017, and the groundwater level fluctuated from 11.25m to 12.87m.

Bv16-6 (Depth 15m): Observed groundwater level in the hole was near 5m depth during the drilled depth was rather shallow but shifted to 11.15m depth when the hole was drilled to 15m (bottom of the hole).

Continuous groundwater measurement was commenced from 8th January, 2017. The observed water level in the hole was almost fixed at the level of 11.14m for the beginning time but showed fluctuation between 11.14m and 11.95m after 24th January.

Bv16-7 (Depth 15m): Observed groundwater levels during the drilling work were no water level before start the work and 2.0 – 2.56m after the work.

Continuous groundwater level measurement had been conducted from 15th January 2017. During the beginning 9 days, the groundwater level was steady at the depth of 7.50m, however, the groundwater level fluctuated in between 11.50 to 11.95m depths after that.

Bv16-8 (Depth 15m): This hole was totally drilled through within one day (on 10th January, 2017). Therefore, the water level measurement in the hole during boring work had not conducted.

Continuous groundwater level measurement had been conducted from 18th January 2017. Groundwater level was fixed at 7.10m depth for the beginning one week, and steady also at the depth of 8.00m for the later 10 days.

Bv16-9 (Depth 15m): During the drilling work, no water level was observed in the hole.

The water level measuring pipe was blocked before starting the continuous groundwater level measurement so that any measurement after completion of the drilling works could not be conducted.

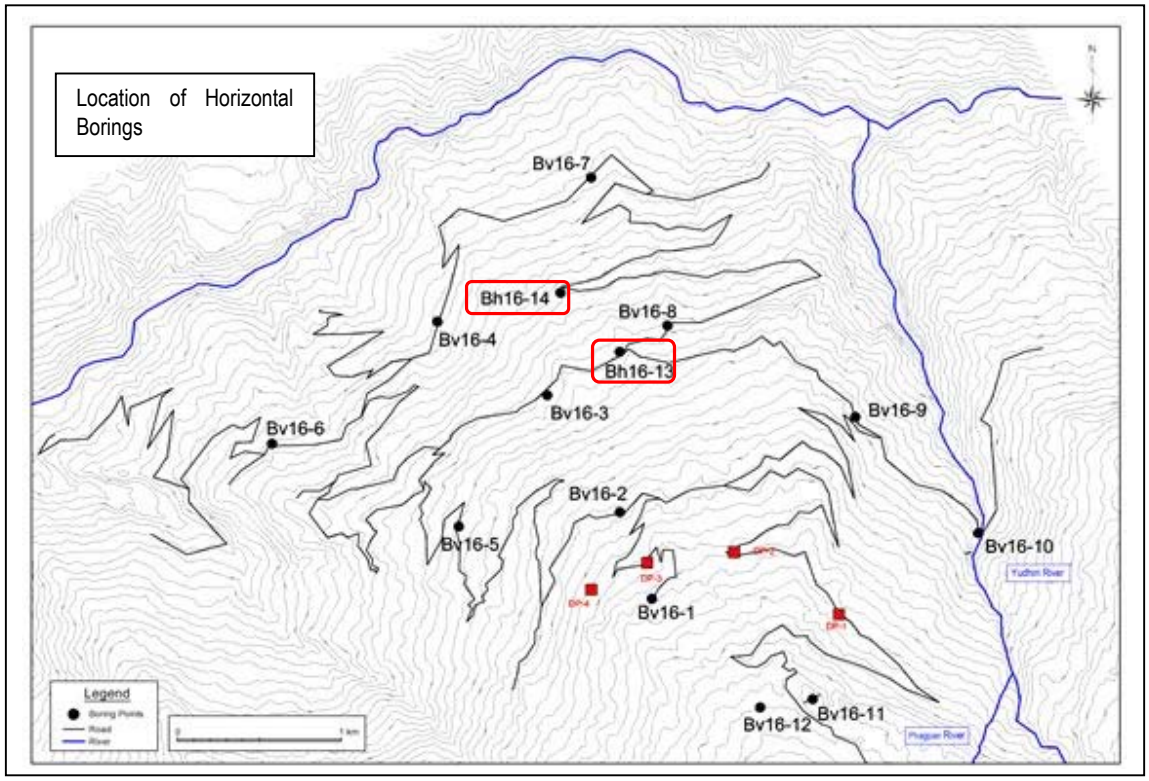
(3) Groundwater distribution within the command area

As described so far, the groundwater levels measured though the relevant boreholes were rather varying. Especially, the groundwater levels in Bv16-2 and 16-3, both are penetrating Colluvial deposits I and II, showed large different such as around 10.3m (Bv16-2) and 27m (Bv16-3) depths. The other holes drilled only Colluvial deposits I or II. Groundwater levels in these holes were also varying but distributing in between 7.1 to 11.9m depths. Furthermore, the most of water levels in their holes were observed in rather shallow depths during in the beginning and shifting to deep depths on the course of further deep drilling. Such tendency was remarkable in Bv16-3: water levels in the hole was quite shallow as at 1 – 2m during it drilled through Colluvial deposits II but the water level dropped down to 19 – 20m depth abruptly when it drilled through Colluvial deposits I. It is considered that the zone near the boundary between deposits II and I was, not so clear though, formed an aquitard, and shallow groundwater contained in the deposits II infiltrated into the lower zone when the boundary was penetrated through.

Through examination on these matters totally, it can be considered that a) the Colluvial deposits II of the upper layer and the deposits I of the lower layer were separated loosely and having each individual groundwater body, b) groundwater body contained in those layers were small scale “perched groundwater” underlain by thin aquitard as an impervious bed, in each numerous landslide blocks, and c) groundwater springs out to the ground at the cross points between the each perched groundwater table and the ground surface, forming many small springs in the command area.

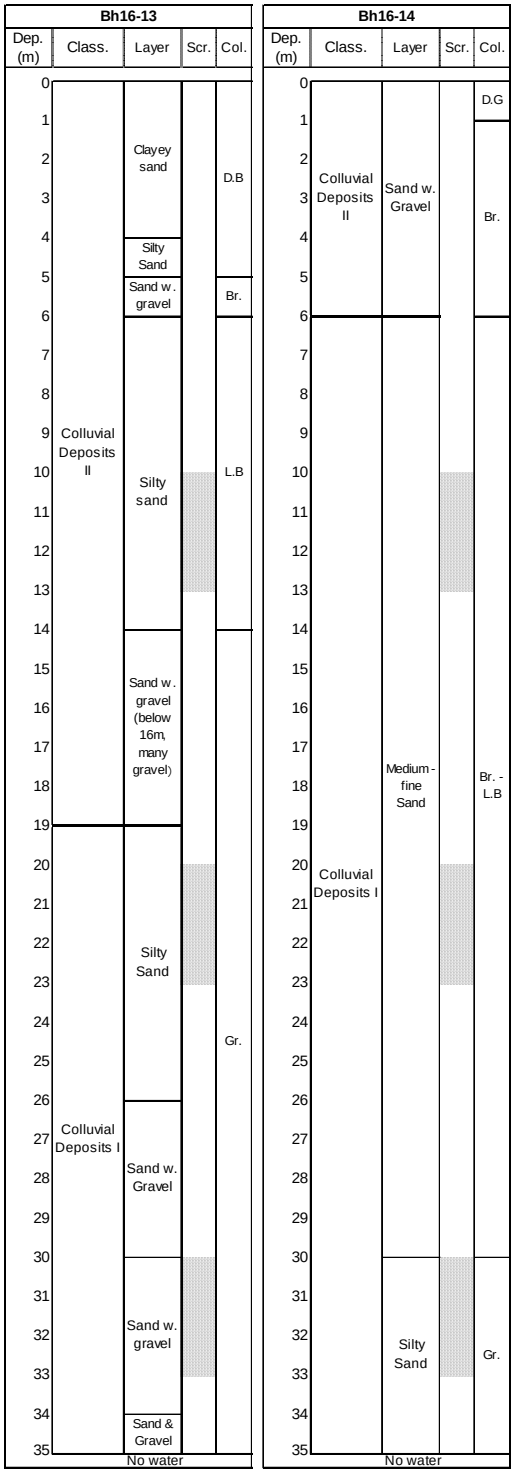
Results of the Survey-1-2: Available Water Volume (Bh16-13 - 14)

After completion of all vertical boring, two horizontal boring were conducted to measure spring water volume and to estimate available groundwater volume. The location of one horizontal boring was set in between Bv16-3 and 16-8 holes and another in between Bv16-4 and 16-7, and at the middle elevation (Bh16-13, EL.1,707m) and lower elevation (Bh16-14, EL. 1,394m) of the command area. Both locations had no spring at just upstream, and the boring directions were vertical to the slope.



(1) Geological and Groundwater Level Conditions

Bh16-13 (Depth 35m): From the boring mouth to the depth of 14m was "Silty Sand" with some small gravels having light brown color. From 14 to 19m was "Sand and Gravels" of grey color. Rock types of these gravels were weathered "Biotite Schists", "Gneiss", and "Quartzite", which were major component of Colluvial deposits I. 19m to the depth of 35m (bottom of the hole) was "Silty or Clayey Sand" with gray color, as same as the upper layer. Among it, the spans from 26 to 29.5m and lower than 34m were likely "Sand and Gravels". Rock types of these gravels were also



heavily weathered "Biotite Schists", granitic "Crystalline Schists", and "Quartzite", which were the components of Colluvial deposits I.

Throughout the boring work period, water and wetness of the hole were carefully checked, and the hole (casing) was clogged by a cap after finished the daily work and opened it in the next morning to check the spring water. As the results, no groundwater was detected, for not only the drilling period but through continuous groundwater measurement period after completion of the boring work.

Bh16-14 (Depth 35m): The uppermost span above 6.0m depth was brownish "Sand and Gravels" with some large boulders. Rock types were mainly weathered granitic "Crystalline Schists" and "Biotite Schists". These are components of Colluvial deposits I. Lower than 6m, till 30m depth, the layer was almost homogenous middle to fine grain "Sand" with brown to light brown color. It had few gravel but it included some weathered "Gneiss" gravel only at the portion from 17.0 to 17.5m. The bottom portion of the hole, the layer from 30 to 35m depth was gray "Silty Sand" with few gravels. Most of the hole, lower than 6.0m, should be Colluvial deposits I based on the few gravels.

In this hole also, any existing water or wetness was carefully checked during the drilling period. And, during in the continuous groundwater measurement period, the hole was clogged after the daily measurement and opened in the same time in the next day to check the yielding of spring water during the 24 hours. Through the measurement, no groundwater was observed.

(2) Possibility to utilize ground water for irrigation

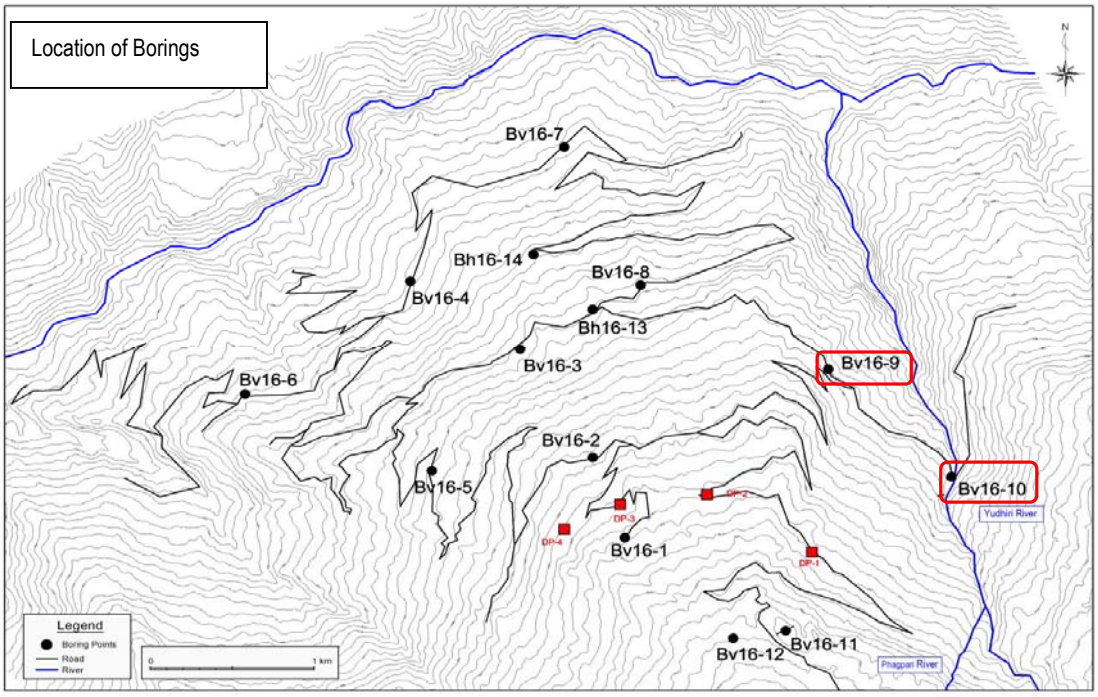
Near around two horizontal borings, many sprigs were confirmed, especially in the eastern side of them. And, in the boreholes near around them (Bv16-8 and Bv16-7), groundwater levels were observed at rather shallow depth of 7.1 to 8.0m. Nevertheless, groundwater level from these two horizontal boreholes could not be observed completely, both in drilling period and in continuous measuring period.

Supposedly, it come from that the groundwater in this area are distributing as thin perched water bodies underlain by relative aquitard. The facts that groundwater levels were observed in the range from 7.1 to 12.9m in the boring from Bv16-5 to 16-8 with drilled depths of 15m, and the depth of boundary between Colluvial deposits I and II was 14 – 15m, suggests the thickness of these perched groundwater bodies shall be only from 2, 3m to around 7m at maximum. Further, so many horseshoe shape depressions (traces of landslide) are distributing in the command area but the widths (or scale) are not large. And, when thinking about that every these depressions have perched groundwater body respectively, regardless it spring out or not, the scale of groundwater body are not large, rather small. Thus, the groundwater bodies distributing everywhere in this command area are thin and small, so that it is rather difficult to penetrate directly by a few boring.

Results of the Survey-2: Downstream of the Existing Intake Point at the Yudhiri River (Bv16-9, 10)

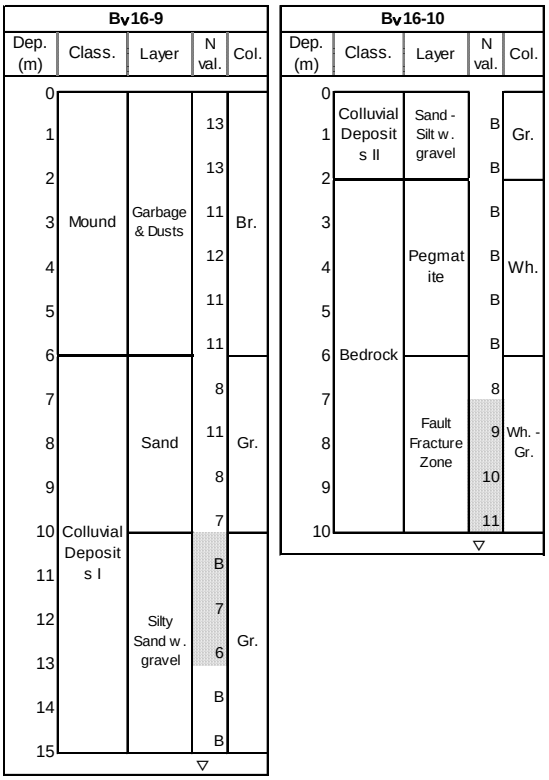
※Intake from the bridge crossing point

These two borings were conducted to grasp the basement conditions in case to take water from the downstream of existing intake point at the Yudhiri River, at the bridge crossing point. One of them was drilled at the planned intake point at the bridge crossing point and another was drilled along with the canal at the middle portion.



(1) Geological and Groundwater Conditions

Bv16-9 (Depth 15m): Borehole Bv16-9 was drilled at just beside the paved road so that it's needed to get an approval for drilling work from Department of Road, Trashigang Dzongkhag. The hole was, however, drilled at artificial filling portion for road construction.



Uppermost 6.0m portion of the hole was filling materials, brownish color and including many garbage and dusts. The portion from 6 to 10m was middle to course "Sand" with grey color. It's includes almost no gravels and very loose with N value from 6 to 13. From 10m to the bottom (15m), it was

"Silty Sand with Gravels". Gravels were mainly "Quartzite", "Gneiss", and "Pegmatites". The whole depth was judged as Colluvial deposits I based on the rock type of the gravels but totally very loose with N values from 6 to 8.

This hole was one of the targets for a continuous groundwater level measurement, however, the groundwater measuring could not conducted because the measuring pipe was blocked before starting the measurement.

Bv16-10 (Depth 10m): This hole reached to the bedrock at the depth of 2.0m. The portion from the ground surface to 1.0m depth was "Top Soil" with grey color, then from 1 to 2.0m was "Silty Sand with Gravel" having grey color also. These gravels included some plutonic rocks with deep green color, so the layer from the surface to 2.0m depth might be Colluvial deposits II. The layer from 2 to 6.0m was slightly weathered "Pegmatite" with white color, and this might be bedrock considering from the outcrops near around the hole. Lower than 6.0m to the bottom (10m) was also "Pegmatite" but completely crushed into sand or fine sand and gravels with white color. The layer was considered as a fault fracture zone. It N values were low from 8 to 11.

This hole was not a target for continuous groundwater measurement but a water level measurement pipe was installed. Water level during the drilling period was observed only one time at 5.3m depth after drilling work. In all of the other days, all drilling water was lost and no return, with no water level detected.

(2) Evaluation for the basement of a facility

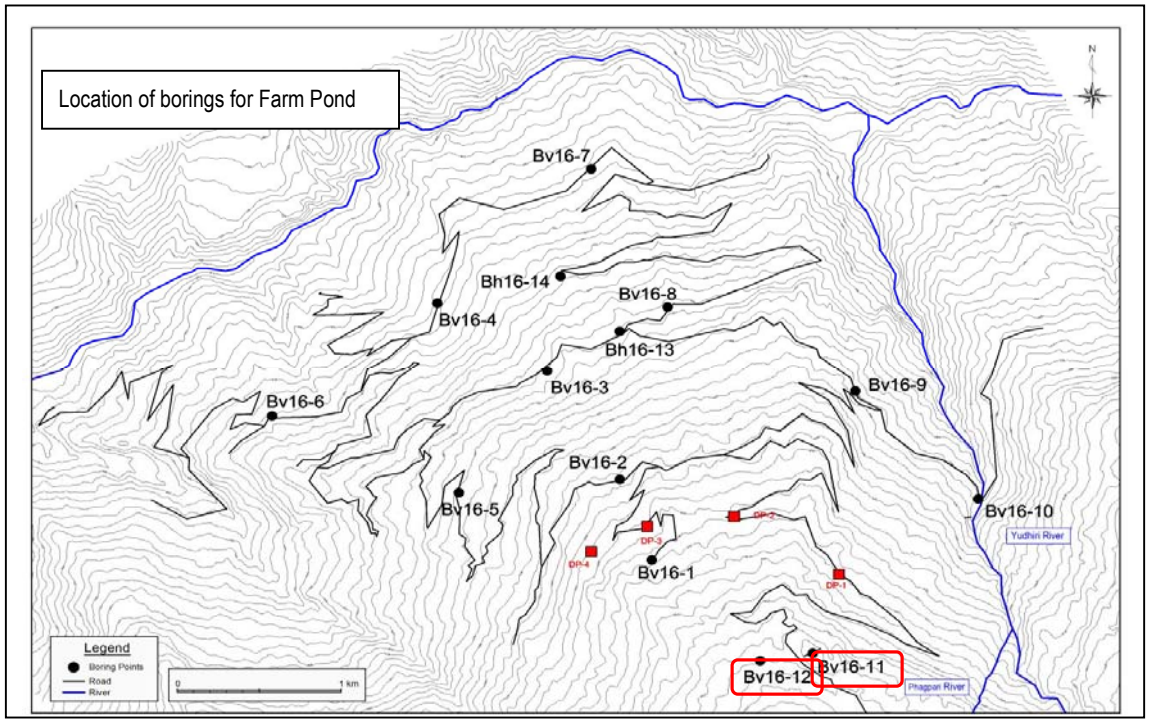
Borehole Bv16-10 reached to hard bedrock (Pegmatite) at the depth of 2.0m, but its thickness was only 4m and it met to fault fracture zone soon (at 6.0m). The fracture zone was completely crushed to almost sand and loosen to show N value less than 10. Supposedly the fault fracture zone runs along the Yudhiri river, and it may outcrop to the ground or underlay near the surface. Depending upon the location of the structure, it was supposed that the fracture zone underlain beneath its basement. Thus, to build any permanent structure near bridge crossing point is considered difficult.

Bv16-9 had very loose sand layer with 10 to 11 N values, even though the portion lower than 6.0m. Generally N value more than 30 is required for the basement of the structure, such loose

layer cannot be the basement for structures due to insufficient bearing capacity.

Results of the Survey-3: Farm Pond (Bv16-11, 12)

Required conditions to be a site for farm pond are 1) there must be higher than the command area and 2) there must have enough bearing capacity. Two of flat (or very gentle slope) zones seemed to be the candidate as the site for farm pond were found at the high potion topographically, and thus, two borings (Bv16-11 and 12) were drilled at each flat zone, to grasp the geological conditions and the bearing capacity.



(1) Geological and Groundwater Conditions

Bv16-11 (Depth 10m): The hole did not reach to the bedrock. The whole the depth was brownish "Sandy Clay", excepting the surface 1.0m of "Top Soil". The layer had a few weathered gravels from 5 to 6m and 9 to 10m depths. Gravels were mainly "Pegmatite". The layer of the hole was wholly granitic and quite loose with N value from only 3 to 4. Thus this point is located on a huge landslide block of Colluvial deposits I.

The drilling works of this hole was completed within one day, so water level in the hole was measured only one day: at the depth of 7.1m after finished the daily work.

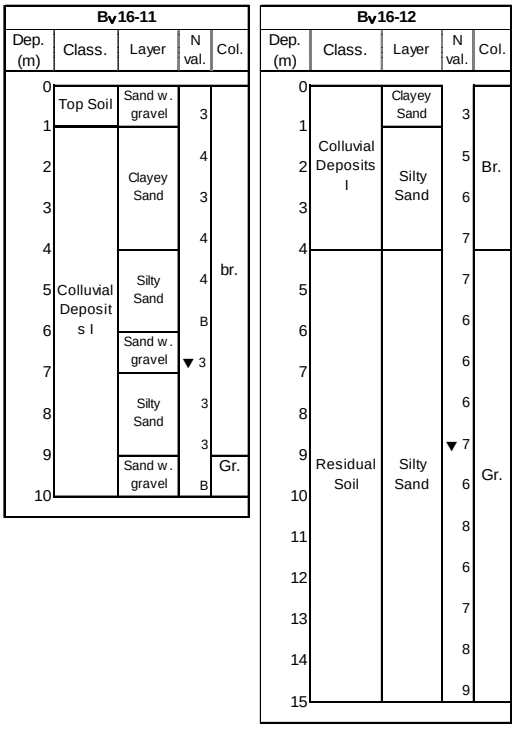
Bv16-12 (Depth 15m): The hole did not reach to the bedrock. The layer from the mouth to the

depth of 4.0m was "Silty Sand" with brown color. The portion from 4.0m to the bottom (15m) was also "Silty Sand" but grey color. The hole was very loose totally with N value less than 10, 9 at maximum, and having almost no gravels. The hole may drill through Colluvial deposits I in its upper portion (till 4.0m) and then drilled through in-situ residual soil for its lower portion.

Continuous groundwater level measurement was not conducted in this hole but water levels in the hole, during drilling work, were around 8.6m to 9.0m at after the daily works.

(2) Evaluation for the basement of farm pond

These two points fit as the location for the farm pond only in the aspect of the elevation. However, the bearing capacity is quite low with N value less than 10, and it cannot be the basement of concrete pond. Additionally, the upper portion of Bv16-12 and whole layer of Bv16-11 may be landslide block. This landslide block has a severe risk of movement in case a pond was broken and huge volume infiltrated into make landslide unstable. Therefore, to construct farm pond at these two points are considered difficult.



OTHER REMARKS

(1) Discussion with the members belonging to the local consultant engaged for drilling work

1) Recovery percentage of boring cores

Since recovery percentage of the boring core was low, discussion about the low percentage was conducted. As the major reason, it was confirmed that there was problem on the storing method of cores into the core-box. The boring in the study includes Standard Penetration Test (SPT) at every one meter, and therefore, the drilled core shall be stored at the beginning 0.5m span, and SPT sample shall be stored in the lower 0.5m span, because SPT itself needs 0.5m span (15cm of the preliminary blow, 10cm x 3 times of the main blow and 5cm of the after blow), as shown in the following picture.

However, the boring surveyor stored the SPT sample (in the plastic bag) at the end of tested one meter span (right edge of the box), and stored the boring core along with all remaining span, as shown in the following picture. Therefore, the boring core taken from the upper 50cm was stored in the almost 80cm span excepting the SPT sample bag. When the core taken from the upper 50cm layer was exactly contained along with the true 50cm span in the core-box, the core recovery percent was improved to more than 70%. The Survey Team instructed the boring team to set the boring core as the upper picture after now.

While, most of the target layers of the boring are loose Sand under the groundwater table, which is one of the most difficult layers to take core sample, as a general. Therefore, the boring team paid their utmost care to improve the core recovery percentage, such as using a very few drilling water, slow and calm drilling feed, and applying a double core tube which is the most suitable coring tool they can provide.

2) Classification of Colluvial deposits

Through the boring core observation and discussions between the geologists of the Survey Team

and the boring team, it was concluded that the Colluvial deposits widely covering the grand surface of the study area should be landslide block and it might be divided into two layers as Colluvial deposits I of the lower layer and Colluvial deposits II of the upper layer, based on the large boulders (or rolling stones) contained respectively. The Survey Team requested to the boring team to make clear the classification of these deposits I and II, in the boring log besides the geological zoning.

3) Triple core tube

The boring team had been tried to improve the core recovery percentage using a double core tube and very careful and tender drilling method, however, the core recovery percentage, especially on the loose sand layer, could not be improved. Then, the boring team decided to utilize a triple core tube which was the most sophisticated and costly coring tool available in Bhutan. The triple core tube was introduced in the No.1 rig on 5th January 2017 and in the No.2 rig on 9th January 2017. Due to the introduction of the triple core tube, the core recovery percentage for rolling stones or huge boulders were improved somewhat but the recovery condition on loose sand layer under water was almost same as previous one.

To improve the core recovery percentage on such loose sand under water table, a special kind of boring technique such as HB Boring, using a chemical foam instead of drilling water, which is already introduced in Japan for a high quality boring project.

(2) Overview of Groundwater Level Measuring Pipes

Material	Polyethylene
Inner/Outer Diameters	25.4mm/ 31.4mm
Structures of the mouth and Bottom	Clogged by Wooden Plug
Structure of Screen	φ4mm circular holes: 100 holes/1.0m Open Ratio： Around 1.6%。
Treating of the holes	Clay sealing at the upper 50cm span
Protective sheet for Screen	None

Information related to boring survey stored in the Appendix

Appendix 2: Results of Boring Survey

2-1: Boring Log

2-2: Boring Core Photos

2-3: Geological Profile

2-4: Groundwater-Level Measurement