

CHAPTER 4 CURRENT SITUATION ANALYSIS ON AGRICULTURAL WATER SUPPLY AND MANAGEMENT

4.1 ANALYSIS ON THE EFFICIENCY AND FEASIBILITY OF THE EXISTING IRRIGATION SYSTEM

4.1.1 Issues and efficiency of the existing irrigation system

(1) Characteristics of river system

Four (4) major rivers are running in Bhutan originating from Himalayan mountain range. Their relative order from the eastern to the western sides is: Manas River (Dragme Chhu), Sankosh River (Puma Tsang Chhu), Raidak River (Wangchhu) and Amo Chhu/Torsa Chhu River. These rivers run in Himalayan mountain range southward until they merge into Brahmaputra River in Indian territory (see Figure 4.1.1). Hydro-power stations have been constructed or planned along these major rivers. These stations are not reservoirs for storage purpose. If storage dam to regulate river flow largely will be constructed, as the impacts to the river system, it is conceived that the dams make river flow more stable, on the other hand, they may induce a change in the distribution of sedimentation in the watershed.

On the other hand, none of the rivers flowing through the southern three Dzongkhags originates from Himalayan mountains, even such comparatively large scaled ones as Mao River in Sarpang Dzongkhag and Dhansiri River and Boda/Nyera Ame River in Samdrup Jongkhar Dzongkhag run through other Dzongkhags only. No large river runs through Samtse Dzongkhag.

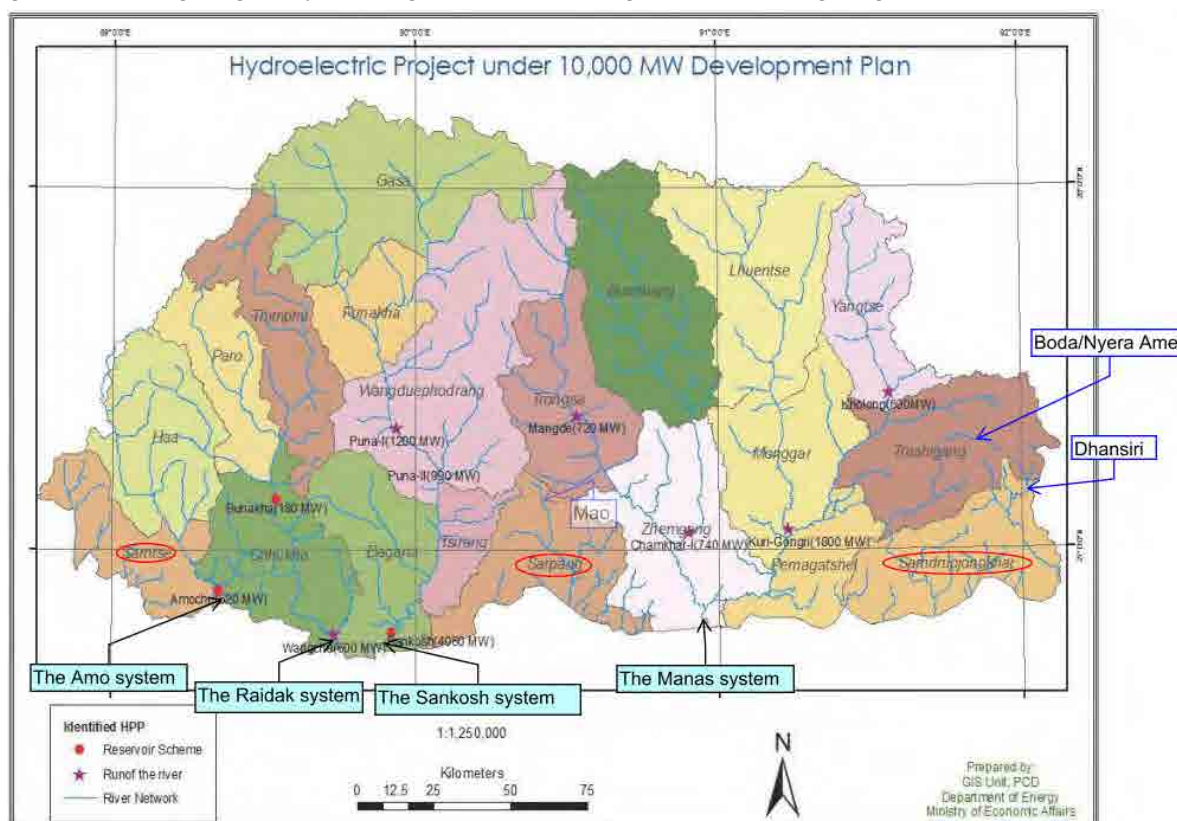


Figure 4.1.1 Major Rivers Running in Bhutan and in the Three Dzongkhags

Since the many rivers flowing in the three Dzongkhags has small catchment area and steep river gradient, rainfall precipitated within their watershed runs off relatively quickly into the rivers. Changes in discharge in these river flows are readily influenced by the pattern of precipitation. The discharges show the same patterns as the rainfall (annually amounting to 4,000 - 5,000 mm, during the period from June to September over 70% of it concentrate precipitates, while no significant precipitation takes place during a dry seasons from November to February). As regards river discharges, they have common characteristics of small rainwater storage capacity inside their watershed areas, with large difference between discharges during rainy and dry seasons, and many drying up rivers are observed, depleting surface flow as dry season progresses.

As for geology of the rivers, vulnerable ground foundation is developed with schistosity and faults zones within faults predominate in southern zone. Besides, rolling stone is often accompanied with heavy discharges in torrential chute rivers. These are the large limiting factors in planning irrigation facilities including river structures.

(2) Rivers and intake method

As to the type of intake, no case of installing head works that regulate stream water level is observed, Agricultural water is taken by natural intake method. Due to this method, intake quantities greatly vary with the fluctuation of water level of the rivers. Many intake facilities fail to take river water once water level draws down. As an issue of water intake facilities, it can be pointed out that the intake points have been shifted to the upstream side of the rivers in order to maintain their water intake as a result that riverbeds are prone to be eroded by flood occurrences and subsequent subsidence of the riverbed at the intake points. Almost no facility is equipped with any gates for regulating intake level or flow quantity or any structural measures to avoid or remove deposited sediments has ever been observed

In the rivers where the riverbed fluctuates as mentioned above, there observed some facilities that ceased to take water from the river (for example, at the headwork of Ratey irrigation system in Dekiling Gewog that diversion canal had been constructed by installing gabions directly under the intake gate to make horizontally traversing way. However, these structures have been destroyed by a flood, thus currently suffering from the difficulty in taking water. Deposit of huge rocks and large sized gravel are observed in the direct upstream part of this intake facility, implying the difficulty in installing permanent structures traversing streams).



Intake of Ratey Irrigation Channel (Gewog:Dekiling)

Photo in the left: showing a state of foundation being scoured at intake mouth by a flood in 2009, Photo in the right: the same intake observed from the upstream side. This type of intake having a division style by backwater in a steep stream is rare. The weir was destroyed by a flood in 2009 that had been installed with gabion nets traversing the whole river. This caused to the loss of intake function.



Intake of Ratey Irrigation Channel (Gewog:Dekiling)

Photo in the right: showing the state located directly upstream side of the intake site where huge rocks and large gravel can be observed. Photo in the right: The state that gabion installed as a weir was destroyed by a flood.

(3) Scale of irrigation farmland

Farmland develops over fans and river terraces formed on relatively flat topography, however, it has been incised by dendritically developed valleys and small rivers/ streams into small pieces of tract parcels. Under such topographic characters, agricultural water is obliged to rely on nearby rivers/ streams. Their farmland takes a dispersed form of distribution. Hence, the irrigation system is typically characterized by small scaled irrigation systems.

According to the inventory of three Dzongkhags, most of the irrigation system in Sarpang was constructed in 1990s. There is the old one which has construction in the 1910s. On the other hand, in Samtse, every system was newly constructed in from 2003 to 2011. Irrigation system has been provided for last ten years (see Table 4.1.1).

Average size of the irrigation sites such as canal length and beneficial area was averaged to compare the scale of the irrigation system of three Dzongkhags. Average size per site shows that in Samtse, canal length is 2.7 km, number of beneficial household is 52.6 and beneficiary area is 47.9 ha., for Sarpang, canal length 1.4 km, 11 households and beneficiary area 10.3 ha, for Samdrup Jongkhar, canal length 2.4 km, 22.8 households and beneficiary area 15.5 ha.

Table 4.1.1 Scale of Existing Irrigation System of Three Dzongkhags

Dzongkaghag	Samtse				Sarpang				Samdrup Jongkhar			
Item	Canal Length	Hous-holds	Beneficiary Area		Canal Length	Hous-holds	Beneficiary Area		Canal Length	Hous-holds	Beneficiary Area	
	Km	Nos.	Acre	ha	Km	Nos.	Acre	ha	Km	Nos.	Acre	ha
Sum	87.9	1,682	3,790.2	1,533.8	429.1	3,267	7,571.7	3,064.3	102.5	956	1,610.0	651.6
Max.	15.0	256	659.0	266.7	7.5	350	700.0	283.3	10.0	70	219.0	88.6
Min.	0.5	6	13.8	5.6	0.01	1	0.5	0.2	0.1	1	2.0	0.8
Average	2.7	52.6	118.4	47.9	1.4	11.0	25.5	10.3	2.4	22.8	38.3	15.5
Number of projects	32				300				42			

Source: Dzongkhag's irrigation system inventory.

Based on the above analysis, scale of irrigation system of each dzongkhag is characterized as follows..

- The total irrigation area of Sarpang is the biggest, beyond 3,000 ha, among the three, but, the number of irrigation site is 300 and the beneficial area of each site is small. It can be said that small scale irrigation site is located dispersedly.
- For Samtse, the number of beneficial households and the beneficial area of one irrigation site are the biggest among the three. Irrigation system in Samtse has comparatively larger scale one.
- Those of Samdrup Jongkhar are the smallest among the three dzongkhags.

4.1.2 Delivery System of Agriculture Water and On-farm Water Use

(1) Current condition of canals

As to canals that deliver water to the beneficial area, there observed some cases of having lost their functions due to collapse of canal sections as well as deposited sand/ mud/ stone caused by collapse of slopes crumbling over the slope surface because they have been constructed on the weak grounds and slopes and sufficient measures have not been taken so far. The following shows examples of what has been surveyed.

Examples of conveyance by pipes are also observed to cope with risks of sediment collapse in open canals and crumbling earthen canals. However, it has been observed that some water leakage takes place from the joints and pipe itself broken by the exterior impacts etc. To cope with these damages, it is required to provide designs as pipelines taking account of burying and protection work. Most canals have been earthen made and many cases observed with leakage. Also, in some cases cross section has been in short of designed water conveyance quantity, and the site survey has revealed that the existing canals have failed to have enough water conveyance capacity.



Ratey Irrigation Channel (Gewog: Dekiling)

Photo in the left: showing the state of having lost the open canal functions due to a serious collapse of canal slopes by a torrential rain. Measures of slope protection have not been taken yet over many canals. Such risk has been brought about by such lack of measures coupled with a steep gradient of their excavation. Photo in the right: This canal has been substituted with a pipe laid along it, but leakage parts are observed from this pipe.

(2) Water supply and management on the farm plots

Farm plots have been developed over alluvial fans covered with fluvial deposits and river terraces, consisting of high permeability soils containing gravel and sand. Hence, it is expected that such soils do not suit to use as paddy fields where requires too large water requirement in depth. Besides, since the farmland forms terraced parcels in inclinatory topography, irrigation is obliged to follow plot-to-plot irrigation with much water loss occurrence.

(3) Current situations for planning/ designing irrigation system

A engineering manual on the planning and design of irrigation facilities have been provided in Bhutan, but it covers homogeneously all the territory as a whole and thus no detail technical guideline including survey of water requirement, estimation of water duty, planning of irrigation facilities etc. have been provided. It is required for southern zone to put the engineering process from planning to design and implementing into a manual taking full consideration of the local natural conditions such as much rainfall, flooding and vulnerable slope and geology.

4.1.3 Efficiency of the Existing Irrigation System

The following are pointed out as the issues showing efficiency of taking water and conveying water by summarizing the points as mentioned above.

- Large percolation rate in plots leads to larger on-farm water requirement, reflecting into larger quantity of intake water requirement. Under such on-farm, water conveyance loss becomes larger because of plot-to-plot irrigation method on small farm plots. Besides, small plots may prevent from leading to farm mechanization.
- Because natural intake method has been adopted at the intake points on the river system and the altitude of river-bed is always instable, it is difficult to construct stable intake structure. Intake

- facility too often loses its function due to damages caused by floods and deposited sediment. It is needed to eliminate such damages by regular operation and maintenance works.
- Leakage in the earth canal section as well as imperfect lining or collapse on slopes may often lead to higher conveyance loss. To cope with these, farmers themselves have been engaged in repairing works every year which is conducted by receiving necessary materials from Dzongkhag and Gewog offices. For large-scaled rehabilitation work, however, it may be required to provide such operation and maintenance as force account work the cost of which is fully borne by the central office.
 - It is said that overall irrigation efficiency of present irrigation system irrigation is not high. But, it is differed in season. During wet season, river flow is much enough to intake, water intake and delivery loss is not affected on the efficiency. But, during less water flow in early and late wet season and dry season, higher efficient irrigation system is needed to prevent intake and delivery water loss.
 - Low efficient and devastated intake facility and delivery canal are repaired by beneficial farmers. Repairing works are generally executed by their labor contribution and using necessary materials such as cement and pipe supplied from by Dzongkhag and Gewog office. But, administration should support their works in case of large repairing works such as heavy machine required.

4.2 PRESENT CONDITION OF IRRIGATION WATER DEMAND AND SUPPLY

Three Dzongkhags are located in the humid sub-tropical and wet subtropical zones where have range of annual rainfall from 2,000 mm to 5,000 mm and altitude around 200 m to 2,000 m. As for cultivating crops and their cropping calendar, those of three Dzongkhags may be regarded as similar ones. Furthermore, Sarpang Dzongkhag may be regarded to be the representative Dzongkhag among the three. Accordingly, by utilizing the data on irrigation system inventory of Sarpang Dzongkhag, situational analysis on agricultural water demand and supply was led as follows.

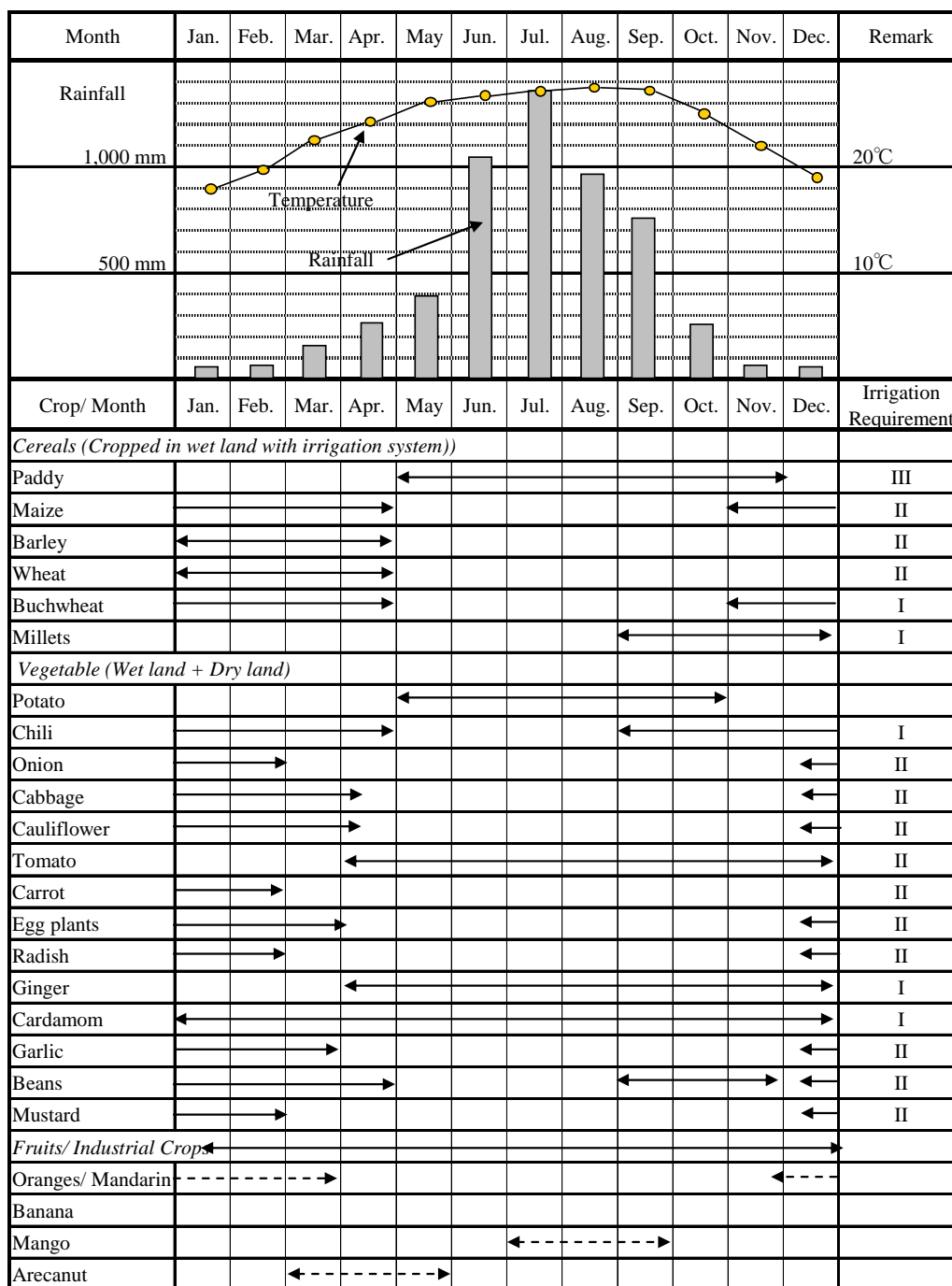
4.2.1 Planting Crops in the Farmland

Small terrace farmland is widely scattered in the range of altitude from around 200 m to 3,000 m. Planting crops and cropping calendar are influenced by natural conditions such as rainfall, soil and temperature and access to irrigation water. According to the interview survey and collected information, subsistence farming is the basic farming style. Subsistent farmers are planting various crops for their food security. Staple food crops are paddy and maize. These crops are planted in all farmland. Planting crops and their cropping season are shown in Figure 4.2.1, although each cropping depends on local conditions as mentioned above.

Among the planted crops, the highest irrigation water requirement crop is the paddy. Paddy is cropping in wet season from June to October, depending on rainfall and irrigation water taking from river. Based on the irrigation site survey, there exist a few farmlands where irrigation water is available

even in dry season. However, double cropping of paddy is not being practiced. According to the interview survey with farmers, they hesitate to plant crops in dry season, since dry season crops are prone to be damaged by intrusion of wild animal. Besides, it also seems that subsistent farming sense remains with them. In order to promote double cropping, various issues such as providing irrigation water supply and management and disseminating farming technology including marketing sense should be solved. Besides the paddy, next irrigation requirement crops are maize and vegetables. But, those crops are normally planted in dry season after the paddy in the present irrigation sites. Their cropping is largely relying on rainfall, since irrigation system is not functional for dry season.

There is some inland fishery ponds constructed in the area where fish-breeding water can be obtained from neighboring irrigation canal. However, the number of active fish pond in dry season is very few due to non-functional irrigation system. Allocating water amount from the canal is not included in this water demand analysis.



Note: Irrigation requirement depending on the local condition III: High II: Moderate I: Low

Cropping is based on the hearing with farmers. It is in the wet land with irrigation system.

←→ Cropping season ←-----→ Harvesting season

Rainfall and temperature data are got from Bhur station of Sarpang Dzongkhag.

Figure 4.2.1 Planted Crops and Cropping Season in Sarpang Dzongkhag

4.2.2 Estimate of Present Irrigation Water Requirement

(1) Estimate method

Irrigation water requirement is calculated by the following method.

$$IWR = (ET_c + Pr + Pd + Nr - Re) / E_f$$

Where,

IWR	:	Irrigation water requirement
ET _c	:	Crop consumptive use
Pr	:	Paddy field percolation
Pd	:	Padding water
Nr	:	Nursery water
ER	:	Effective rainfall
E _f	:	Irrigation efficiency

Crop consumptive use (E_c)

Crop consumptive use (E_c) is calculated by following method.

$$ET_c = ET_o \times K_c$$

Where,

ET _c	:	Crop consumptive use
ET _o	:	Evapo- transpiration
K _c	:	Crop factor

(Based on the FAO guideline "Crop Water Requirement" Irrigation and drainage Paper, it was estimated that the Paddy from 0.8 to 1.4, the Maize/ Vegetable/ Upland crops from 0.7 to 1.0.)

Evapo-transpiration (E_o) is estimated by Penman method that is applied worldwide. Meteorology data for the Penman method was collected from meteorological observation station of each Dzongkhag.

Based on these collected data, Evapo-transpiration (E_o) of the three Dzongkhags was estimated as follows.

Table 4.2.1 Evapo-transpiration (E_o) of the Three Dzongkhags

Dzongkhag: Sarpang

Month	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Rainfall	(mm/month)	20.27	43.39	116.52	246.12	395.28	1005.33	1368.25	939.98	727.79	220.08	22.71	15.36
Potential	(mm/day)	2.56	3.18	3.83	3.85	4.29	3.60	3.42	3.60	3.52	3.64	3.11	2.64
Evapotranspiration (E _o)	(mm/month)	79.50	89.16	118.78	115.43	132.93	107.88	105.99	111.49	105.52	112.69	93.26	81.78

Dzongkhag: Samtse

Month	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Rainfall	(mm/month)	22.24	51.24	120.32	325.81	515.39	974.57	1395.55	1054.40	664.71	220.44	13.68	16.72
Potential	(mm/day)	2.78	3.50	4.67	4.78	4.85	3.90	3.43	3.52	3.70	4.06	3.57	2.77
Evapotranspiration (E _o)	(mm/month)	86.28	97.99	144.68	143.30	150.27	116.94	106.33	108.99	111.02	125.91	106.99	85.99

Dzongkhag: Samdrup Jongkhar

Month	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Rainfall	(mm/month)	13.20	33.35	106.26	352.47	389.57	758.10	958.78	480.58	433.60	176.23	10.95	11.36
Potential	(mm/day)	2.67	3.23	3.83	3.85	4.06	3.39	3.31	3.44	3.55	3.48	3.12	2.67
Evapotranspiration (E _o)	(mm/month)	82.68	90.46	118.74	115.36	125.75	101.72	102.59	106.72	106.36	107.83	93.47	82.69

Source: Calculated by JICA Survey Team based on the meteorological data of each Dzongkhag.

Other items were estimated under the following conditions.

Percolation (Pr) : According to the field survey in Sarpang Dzongkhag, surface soil distributed in the paddy field is generally characterized as a silty and sandy soil containing gravel, although there are a few paddy fields where surface soil contains clayey soil to be desirable for paddy growing. Under such present soil condition, percolation rate is high. For estimating irrigation water requirement, percolation rate was assumed. It was made from the interview survey with farmers on infiltration from pondage water in paddy field, as follows.

Percolation type	Rate (mm/ day)
I	10
II	20
III	50

Padding water (Pd) and Nursery water (Nu) : Assumed 70 mm for Padding water and 20 mm for Nursery water.

Effective Rainfall (Re) : Estimated based on the FAO guideline "Crop Water Requirement" Irrigation and drainage Paper.

Irrigation Efficiency (Ef) : Based on the irrigation system survey in intake and delivery canal, it is assumed at 0.5.

(2) Present cropping pattern

Irrigation water requirement for the long list irrigation sites is provided based on the cropping pattern. Cropping pattern is provided based on the interview survey in the irrigation system sites, as follows.

Wet season Paddy is planted in all command area.

Dry season Maize is the major planted crops in dry season in the command area. Vegetables and upland crops are planted around the dwelling house. Planting area is assumed at around 10 % of the wet paddy cropping area from the survey. However, these crops are not irrigated shortage of irrigation water and non-functional irrigation system.

Monthly gross unit water requirement is estimated from the unit water requirement and cropping area, as follows.

Cropping/ month	Jan.	Feb	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cropping pattern												
Dry season crops												
Wet season crops												
	Gross water requirement (intake water requirement) (lit/sec)											
Wet season crops (paddy)												
Percolation type I 10 mm/day					-	-	-	-	0.565	1.210	0.688	0.159
Percolation type II 20 mm/day					-	2.302	2.670	2.286	2.880	3.062	1.382	0.390
Percolation type III 50 mm/day					2.243	9.663	12.045	9.230	9.825	8.618	3.466	1.085
Dry season crops (maize, vegetables)	0.306	0.524	0.146	-								0.030

Source: Estimated by JICA survey team

Figure 4.2.2 Monthly Gross Unit Water Requirement

(3) Estimate of gross irrigation water requirement (IWR)

Based on the conditions as mentioned above, Gross Irrigation Water Requirement (IWR) of each irrigation command area in Sarpang Dzongkhag was estimated by applying unit irrigation water requirement on each command area (see Table from 4.2.2 to 4.2.4). It can be said that irrigation is

always required even in wet season with much rainfall, due to a large amount of infiltration water loss and other irrigation loss along the canal and on-farm.

According to the interview survey, water shortage sometimes occurs in beginning stage and/or later stage of wet season. Based on the analysis and survey, relationship between irrigation water supply and demand is shown as below Figure.

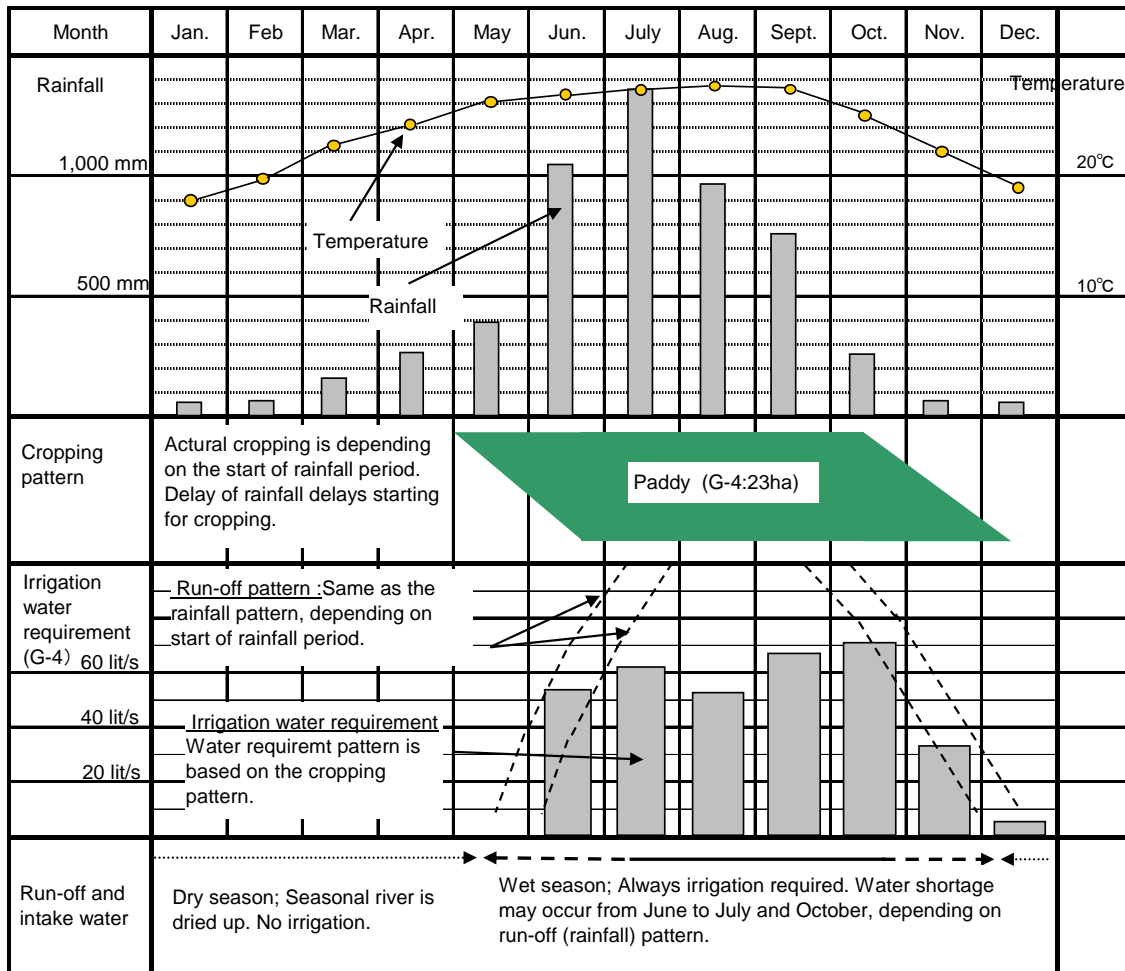


Figure 4.2.3 Relationship between Agricultural Water Supply and Demand

Table 4.2.2 Estimate of Irrigation Water Requirement by Each Command Area (1/3)

Gewog/ No.	Name		Command area (ha)	Cropping area (ha)		Percolation type	Gross water requiremet (intake water requirement) (lit/sec)											
	Channel	Location		Wet	Dry		Jan.	Feb	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.
<i>Senge</i>																		
Sen-1	Baral kulo	Sisty A	23.9	23.9	2.4	III	0.7	1.3	0.3	-	53.6	230.9	287.9	220.6	234.8	206.0	82.8	25.9
Sen-2	Mazan khola	Juphrey	19.0	19.0	1.9	III	0.6	1.0	0.3	-	42.6	183.6	228.9	175.4	186.7	163.7	65.8	20.7
Sen-3	Upper Senghe kulo	Hatikhuar	14.6	14.6	1.5	III	0.4	0.8	0.2	-	32.8	141.2	176.0	134.9	143.5	125.9	50.6	15.9
Sen-4	Koigaon kulo	Koigaon	14.4	14.4	1.4	III	0.4	0.8	0.2	-	32.2	138.9	173.1	132.6	141.2	123.8	49.8	15.6
Sen-5	Rumdali kulo	Sisty B	8.9	8.9	0.9	III	0.3	0.5	0.1	-	20.0	86.2	107.4	82.3	87.6	76.9	30.9	9.7
<i>Hiley</i>																		
H-1	Gurung khola kulo3	Hilley	15.1	15.1	1.5	III	0.5	0.8	0.2	-	33.8	145.4	181.3	138.9	147.9	129.7	52.2	16.3
H-2	Hadzain kulo	Khopitar	8.9	8.9	0.9	III	0.3	0.5	0.1	-	19.9	85.8	107.0	82.0	87.2	76.5	30.8	9.7
H-8	Chuwan khola kulo 1	Hilley	3.8	3.8	0.4	III	0.1	0.2	0.1	-	8.6	36.9	46.0	35.3	37.5	32.9	13.2	4.2
<i>Shompangkha</i>																		
Sho-1	Daoray kulo	Kuencholing	53.4	53.4	5.3	III	1.6	2.8	0.8	-	119.8	516.2	643.4	493.1	524.8	460.4	185.1	57.9
Sho-3	Lower Norbugang	Darjaythang	34.4	34.4	3.4	II	1.1	1.8	0.5	-	-	79.2	91.8	78.6	99.1	105.3	47.6	13.5
Sho-4	Kafley khulo	Darjaythang	20.2	20.2	2.0	III	0.6	1.1	0.3	-	45.4	195.5	243.7	186.7	198.8	174.3	70.1	22.0
Sho-7	Jaidhan Khulo	Pakhay	9.0	9.0	0.9	III	0.3	0.5	0.1	-	20.3	87.4	108.9	83.4	88.8	77.9	31.3	9.8
<i>Dovan</i>																		
Dov-1		Thrulokhola	12.1	12.1	1.2	I	0.4	0.6	0.2	-	-	-	-	-	6.9	14.7	8.4	1.9
Dov-2		Batralkhola	6.1	6.1	3.0	II	0.9	1.6	0.4	-	-	14.0	16.2	13.9	17.5	18.6	8.4	2.5
Dov-4		Batchkhola	5.7	5.7	2.8	II	0.9	1.5	0.4	-	-	13.1	15.1	13.0	16.3	17.4	7.8	2.3
<i>Jigmechoeling</i>																		
J-1	Basghari	Daragaon	42.5	42.5	4.2	II	1.3	2.2	0.6	-	-	97.8	113.4	97.1	122.4	130.1	58.7	16.6
J-2	Panitey Kulo	Saundaley	36.4	36.4	3.6	II	1.1	1.9	0.5	-	-	83.8	97.2	83.2	104.9	111.5	50.3	14.3
J-3	Dharey Kulo	Saundaley	20.2	20.2	2.0	II	0.6	1.1	0.3	-	-	46.6	54.0	46.2	58.3	61.9	28.0	8.0
J-4	Jame Kulo(3)	Daragaon	12.1	12.1	1.2	III	0.4	0.6	0.2	-	27.2	117.3	146.2	112.1	119.3	104.6	42.1	13.2
J-5	Gumi Kulo	Samapagang	12.1	12.1	1.2	III	0.4	0.6	0.2	-	27.2	117.3	146.2	112.1	119.3	104.6	42.1	13.2
J-6	Dawa Kulo	Samapagang	12.1	12.1	1.2	II	0.4	0.6	0.2	-	-	27.9	32.4	27.7	35.0	37.2	16.8	4.8
J-10	Nado Kulo	Samkharn	10.1	10.1	1.0	II	0.3	0.5	0.1	-	-	23.3	27.0	23.1	29.1	31.0	14.0	4.0
J-15	Sepai Kulo	Daragaon	9.2	9.2	0.9	II	0.3	0.5	0.1	-	-	21.2	24.6	21.1	26.6	28.3	12.8	3.6
J-16	Jante Kulo(1)	Daragaon	8.5	8.5	0.9	II	0.3	0.4	0.1	-	-	19.6	22.7	19.4	24.5	26.0	11.7	3.3
J-23	Tharokuloo	Gongdara	7.9	7.9	0.8	II	0.2	0.4	0.1	-	-	18.2	21.1	18.0	22.7	24.2	10.9	3.1
J-24	Tharokulo	Gongdara	7.3	7.3	0.7	II	0.2	0.4	0.1	-	-	16.8	19.4	16.6	21.0	22.3	10.1	2.9

Percolation type: I: 10 mm/day II: 20 mm/day III: 50 mm/day

Table 4.2.3 Estimate of Irrigation Water Requirement by Each Command Area (2/3)

No	Name		Command area (ha)	Cropping area (ha)		Percolation type	Gross water requiremet (intake water requirement (lit/sec))											
	Channel	Location		Wet	Dry		Jan.	Feb	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.
<i>Dekiling</i>																		
Dek-1	Hilley Khora	Juphrey	205.0	205.0	20.5	III	6.3	10.7	3.0	-	459.8	1,980.9	2,469.2	1,892.2	2,014.1	1,766.6	710.5	222.4
Dek-2	Yangchenphu	Yangchemphu	36.4	36.4	3.6	III	1.1	1.9	0.5	-	81.7	351.9	438.7	336.2	357.8	313.9	126.2	39.6
Dek-3	Dekiling	Dekiling	29.4	29.4	2.9	II	0.9	1.5	0.4	-	-	67.6	78.4	67.1	84.5	89.9	40.6	11.5
Dek-4	Bichkolin	Bichpani	28.3	28.3	2.8	III	0.9	1.5	0.4	-	63.5	273.8	341.2	261.5	278.3	244.1	98.2	30.8
Dek-5	Yangchuenphu	Yangchuenphu	22.3	22.3	2.2	III	0.7	1.2	0.3	-	63.5	273.8	341.2	261.5	278.3	244.1	98.2	30.8
Dek-6	Norbuthang	Gawaithang	14.2	14.2	1.4	III	0.4	0.7	0.2	-	31.8	136.8	170.6	130.7	139.1	122.0	49.1	15.4
Dek-7	Rathey Khola	Ratepani	12.1	12.1	1.2	III	0.4	0.6	0.2	-	27.2	117.3	146.2	112.1	119.3	104.6	42.1	13.2
Dek-8	Gawaithang	Gawaithang	10.1	10.1	1.0	III	0.3	0.5	0.1	-	22.7	97.8	121.9	93.4	99.4	87.2	35.1	11.0
Dek-10	Phenley	Trashiling	9.3	9.3	0.9	III	0.3	0.5	0.1	-	20.9	90.0	112.1	85.9	91.5	80.2	32.3	10.1
Dek-11	Rathey	Rathey	8.7	8.7	0.9	III	0.3	0.5	0.1	-	19.5	84.1	104.8	80.3	85.5	75.0	30.2	9.5
Dek-12	Dholkola	Dholkola	8.5	8.5	0.9	II	0.3	0.4	0.1	-	-	19.6	22.7	19.4	24.5	26.0	11.7	3.3
Dek-13	Dholkola	Dholkola	7.3	7.3	0.7	II	0.2	0.4	0.1	-	-	16.8	19.4	16.6	21.0	22.3	10.1	2.9
<i>Bhur</i>																		
B-1	Puchar Kulo	Juphrey	54.6	54.6	5.5	II	1.7	2.9	0.8	-	-	125.7	145.9	124.9	157.3	167.3	75.5	21.3
B-2	Beech Kulo	Juphrey	50.6	50.6	5.1	III	1.5	2.6	0.7	-	113.5	488.8	609.4	467.0	497.0	436.0	175.3	55.0
B-3	Ghalley kulo	Ggalleygoan	36.4	36.4	3.6	III	1.1	1.9	0.5	-	81.7	351.9	438.7	336.2	357.8	313.9	126.2	39.6
B-4	Limbo kulo	Roadline	32.4	32.4	3.2	III	1.0	1.7	0.5	-	72.6	312.9	390.0	298.9	318.1	279.0	112.2	35.2
B-5	Monger kulo	Mongergoan	26.7	26.7	2.7	III	0.8	1.4	0.4	-	72.6	312.9	390.0	298.9	318.1	279.0	112.2	35.2
B-6	Siran kulo	Juphrey	16.2	16.2	1.6	II	0.5	0.8	0.2	-	-	37.3	43.2	37.0	46.6	49.6	22.4	6.4
B-7	Barasan kulo	Jaruwa/Dech.	14.6	14.6	7.3	III	2.2	3.8	1.1	-	32.7	140.8	175.5	134.5	143.1	125.6	50.5	16.0
B-8	Siran kulo	Jaruwa/Dech.	14.2	14.2	7.1	III	2.2	3.7	1.0	-	31.8	136.8	170.6	130.7	139.1	122.0	49.1	15.6
B-11	Puchar kulo	Jaruwa/Dech.	8.1	8.1	4.0	III	1.2	2.1	0.6	-	18.1	78.2	97.4	74.7	79.5	69.7	28.0	8.9
<i>Gelephu</i>																		
G-1	Sonamgatshe &	Raptenling	86.1	86.1	8.6	I	2.6	4.5	1.3	-	-	-	-	-	48.7	104.2	59.2	13.7
G-2	Passangchu	Lower Pelrihang	32.1	32.1	3.2	II	1.0	1.7	0.5	-	-	74.0	85.8	73.4	92.5	98.4	44.4	12.6
G-3	Dhulachu	Lower Pelrihang	25.0	25.0	2.5	II	0.8	1.3	0.4	-	-	57.6	66.8	57.2	72.1	76.6	34.6	9.8
G-4	Dhulachu	Upper Pehihang	22.9	22.9	2.3	II	0.7	1.2	0.3	-	-	52.8	61.2	52.4	66.0	70.2	31.7	9.0
G-5	Tarulay	Dzomlingthang	20.4	20.4	2.0	II	0.6	1.1	0.3	-	-	46.9	54.4	46.6	58.7	62.4	28.2	8.0

Percolation type: I: 10 mm/day II: 20 mm/day III: 50 mm/day

Table 4.2.4 Estimate of Irrigation Water Requirement by Each Command Area (3/3)

No	Name		Command area (ha)	Cropping area (ha)		Percolation type	Gross water requiremet (intake water requirement (lit/sec)											
	Channel	Location		Wet	Dry		Jan.	Feb	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.
<i>Serzhong</i>																		
Ser-1	Lothuen	Lothuen	58.9	58.9	5.9	III	1.8	3.1	0.9	-	132.1	569.1	709.5	543.7	578.7	507.6	204.1	63.9
Ser-2	Norbuling	Norbuling	39.0	39.0	3.9	III	1.2	2.0	0.6	-	87.5	377.0	469.9	360.1	383.3	336.2	135.2	42.4
Ser-3	Pemaling	Pemaling	38.5	38.5	3.8	III	1.2	2.0	0.6	-	86.2	371.5	463.1	354.9	377.8	331.4	133.3	41.8
Ser-4	Pangkhar	Pangkhar	21.0	21.0	2.1	III	0.6	1.1	0.3	-	47.2	203.3	253.4	194.2	206.7	181.3	72.9	22.9
Ser-6	Norbuling	Norbuling	21.0	21.0	2.1	III	0.6	1.1	0.3	-	47.2	203.3	253.4	194.2	206.7	181.3	72.9	22.9
Ser-7	Barshong	Barshong	19.4	19.4	1.9	III	0.6	1.0	0.3	-	43.6	187.8	234.0	179.3	190.9	167.4	67.3	21.1
Ser-8	Kingaling	Kingaling	18.2	18.2	1.8	II	0.6	1.0	0.3	-	-	41.9	48.6	41.6	52.4	55.8	25.2	7.2
Ser-9	Pangkhar	Pangkhar	16.2	16.2	1.6	III	0.5	0.8	0.2	-	36.3	156.4	195.0	149.4	159.1	139.5	56.1	17.6
Ser-12	Barshong (1)	Barshong	10.1	10.1	1.0	II	0.3	0.5	0.1	-	-	23.3	27.0	23.1	29.1	31.0	14.0	4.0
Ser-13	Barshong (2)	Barshong	8.1	8.1	0.8	II	0.2	0.4	0.1	-	-	18.6	21.6	18.5	23.3	24.8	11.2	3.2
Ser-15	Sershong	Sershong	6.1	6.1	0.6	II	0.2	0.3	0.1	-	-	14.0	16.2	13.9	17.5	18.6	8.4	2.4
<i>Chuzargang</i>																		
C-1	Phunsun Low	Low Dawahang	283.3	283.3	28.3	II	8.7	14.8	4.1	-	-	652.1	756.4	647.5	815.9	867.5	391.6	110.6
C-2	Samdrop Choyour	High Dawahang	121.4	121.4	12.1	II	3.7	6.4	1.8	-	-	279.5	324.2	277.5	349.7	371.8	167.8	47.8
C-3	Karbithang	Karbithang	60.7	60.7	6.1	I	1.9	3.2	0.9	-	-	-	-	-	34.3	73.5	41.8	9.8
C-4	Sherab Choling	Chasikher	60.7	60.7	6.1	II	1.9	3.2	0.9	-	-	139.7	162.1	138.7	174.8	185.9	83.9	23.9
C-5	Masimikhola	Chasikher	20.2	20.2	2.0	II	0.6	1.1	0.3	-	-	46.6	54.0	46.2	58.3	61.9	28.0	8.0
<i>Umiling</i>																		
U-1	Rejuk Serchu	Rejuk	34.4	34.4	3.4	II	1.1	1.8	0.5	-	-	79.2	91.8	78.6	99.1	105.3	47.6	13.4
U-2	Dangling Lower	Dangling	33.2	33.2	3.3	II	1.0	1.7	0.5	-	-	76.4	88.6	75.8	95.6	101.6	45.9	13.0
U-4	Dungmin Upper	Dungmin	28.3	28.3	2.8	III	0.9	1.5	0.4	-	63.5	273.8	341.2	261.5	278.3	244.1	98.2	30.8
U-5	Tashithang Karchu	Tashithang	25.9	25.9	2.6	II	0.8	1.4	0.4	-	-	59.6	69.2	59.2	74.6	79.3	35.8	10.2
U-6	Dugmin Lower	Dugmin	21.0	21.0	2.1	II	0.6	1.1	0.3	-	-	59.6	69.2	59.2	74.6	79.3	35.8	10.2
U-7	Chubarhang Seelchu	Chubarhang	19.0	19.0	1.9	II	0.6	1.0	0.3	-	-	43.8	50.8	43.5	54.8	58.2	26.3	7.5
U-8	Thongiazor Karchu	Thongiazor	17.8	17.8	1.8	II	0.5	0.9	0.3	-	-	41.0	47.6	40.7	51.3	54.5	24.6	7.0
U-9	Lingar Dap	Lingar	16.2	16.2	8.1	II	2.5	4.2	1.2	-	-	37.3	43.2	37.0	46.6	49.6	22.4	6.6
U-10	Gadhen Lower	Gadan	15.4	15.4	7.7	II	2.4	4.0	1.1	-	-	35.4	41.1	35.2	44.3	47.1	21.3	6.2
U-11	Rjuk Karchu	Rejuk	12.6	12.6	6.3	II	1.9	3.3	0.9	-	-	28.9	33.5	28.7	36.1	38.4	17.3	5.1
U-12	Dangling Upper	Dangling	9.7	9.7	4.9	II	1.5	2.5	0.7	-	-	22.4	25.9	22.2	28.0	29.7	13.4	3.9
U-14	Pantharey	Dangling	6.9	6.9	3.4	II	1.1	1.8	0.5	-	-	15.8	18.4	15.7	19.8	21.1	9.5	2.8
<i>Taraythang</i>																		
T-1	Yoezergang-Singi Khola Lower	Yoezergang	10.5	10.5	1.1	III	0.3	0.6	0.2	-	23.6	101.7	126.7	97.1	103.4	90.7	36.5	11.4
T-2	Tashichhiling Lower	Tashichhiling	9.3	9.3	0.9	II	0.3	0.5	0.1	-	-	21.4	24.9	21.3	26.8	28.5	12.9	3.7
T-4	Tashichhiling-Singi Khola Upper	Tashichhiling	5.3	5.3	0.5	II	0.2	0.3	0.1	-	-	12.1	14.0	12.0	15.2	16.1	7.3	2.1

Percolation type: I: 10 mm/day II: 20 mm/day III: 50 mm/day

4.2.3 Current Situation for Securing Agricultural Water

Current situation for securing agricultural water is summarized based on the analysis as mentioned above and irrigation site survey in Sarpang Dzongkhag.

- Rivers available as water sources has relatively small catchment area with steep riverbed gradient. Run-off takes place rapidly on the rainfall and small water storage capacity of the catchment area. There are two types of river for irrigation water intake, permanent river and seasonal river. Though no river discharge observation stations exist in those rivers, out of the 79 irrigation sites listed as the rehabilitation candidates sites, 35 sites has permanent river expecting to take water in dry season. Run-off discharges in seasonal river are sharply depleted and often dried up in dry season. As a result, available quantities of intake water are extremely decreased even intake is possible.
- Although annual rainfall is abundant, almost 70% concentrates on during the period from June to September while almost no rainfall occurs during November to February. Total river discharge amount is much enough to intake irrigation water. However, according to interview survey in the irrigation sites, transplanting of paddy is practiced from early June to early July, but in some years shortage of river discharge takes place in that period. It may also occur in October for pre-harvesting season. Such water shortage affects the paddy cropping.
- Natural intake method from river is usually practiced. River-beds often dislocated by fluvial run-off during rainy season and often subsided at the intake points. By this occurrence, improvement necessity would arise to shift the original intake points to any up-stream side in order to maintain the intake water level. Such necessity to do it frequently arises. Also, present situation of natural intake method and decreasing river discharge in dry season often makes intake itself difficult or intake amount short.
- Farmlands have been developed on the fans or terraces containing sands and gravel. Accordingly, water percolation loss comes to a high quantity. So, total water requirement, intake amount itself also becomes large.
- No bank protection like dyke exists along rivers. Water intake efficiency is low owing to large variation of flow and river-bed and sedimentation. As to the measures to prevent such situation, it is required to provide overall watershed management and river structure measures such as torrent control, bank protection and ground sill. To do so, however, large investment is required. Large scale structure measure does not seem practical considering current financial capacity of the country.

4.3 ECONOMIC FEASIBILITY OF EXISTING IRRIGATION SYSTEM

4.3.1 Estimation of Construction Cost and O/M Cost of the Existing Irrigation Facilities

To evaluate economic feasibility, the construction cost and the O/M cost of irrigation facilities was

estimated. It was made based on the collected data; I) on the cost in Takali Project Area in Sarpang Dzongkhag in which comparatively consolidated contents have been obtained, II) rehabilitation work of irrigation canals financially supported by Gewog office, III) on the construction cost of standard of canal sections., and IV) budget and expenditure in Samtse Dzongkhag and

(1) Estimation from Takali irrigation rehabilitation project

1) Outline of Takali Project Area

Project is outlined as shown in Table 4.1.2. Cumulative length of canals are; High Level; L=7.51km, Low Level; L=5.41km, Total length: L=12.92km.

Table 4.3.1 Outline of the Takali Project

Name of the WUA	Phuensum Chhuyur Tshokpa (Low Level)		Samdrup Chhuyur Tshokpa (High Level)	
Geog	Chuzagnag		Serzhong	
No. of household	347		273	
Command area	1,021.45 Ac	413.4 ha	819 Ac	331.4 ha
Dry land	2,207.44 Ac	893.3 ha		
Kitchen Garden	152.5 Ac	61.7 ha		
Total population	3,470			
House Plot	152.5 Ac	61.7 ha		
Average yield	1,108.34 Kg/acre (2,738 Kg/ha)			

Original: RCMU

2) Construction cost and O/M cost

(i) Construction cost

According to the interview survey with CMU (Central Machinery Unit) that is handling Takali Project area, the irrigation facilities have been constructed by financing support from UNCDF (United Nations Capital Development Fund). From the hearing survey, it was reported that the initial investment amounted to approximate Nu.20 millions. The construction was started in 1984 and completed in 1988. The initial investment amount per canal length is calculated at Nu.1,550,387/km, showing comparatively high cost.

(ii) O/M cost borne by the Government (shared by CMU)

By making arrangement of the cost expended by CMU as O/M cost, mean annual expenditure is calculated at Nu. 2,868,000 (see Table 4.3.2). In this regard, a large variance exists from year to year: from Nu. 1,000,000 to Nu.20,064,000/year.

(iii) O/M cost sharing with beneficial farmers

According to the interview survey on O/M cost with chairman and representatives from WUA in the Chuzagan Gewog office who are namely Samdrup Chuyour (High Level) and Phunsum Chuyour (Low Level), membership fee to WUA costs Nu.100/year/household. It is appropriated for O/M cost. Thinking the total amount of this is used as annual O/M cost, and calculating with the afore-tabulated number of the households 620 HH (=347+273), the O/M cost comes to Nu.62,000/household/year (in

which farmer's labor contribution is not included).

(iv) Estimation of annual O/M cost

As the total of (ii) and (iii), annual O/M cost is totaled at Nu.2,930,000/year (=52,740USD/year). This amount is equivalent to Nu.3,934 per irrigation command area (ha) and Nu.226,780/km per unit length of canals.

Table 4.3.2 Annual Maintenance Cost in Takali Irrigation Project Area (share of RCMU)

Financial Year	Budget	Expenditure in Taklai Irrigation Project		Unit: Nu.
		Expenditure	Remarks	Unit cost (Million)
2006-2007	20,064,000	4,844,918	Gaden bank protection(L=820m of 4 layers)	5,908.44
		257,124	For irrigation	
		5,102,041	Sub-total	
2007-2008	4,000,000	339,720	Low level Intake protection work L=48m 4layers	7,077.50
		2,036,705	For irrigation	
		2,376,425	Sub-total	
2008-2009	1,616,000	854,455	Low level Intake protection work L=100.5m 4layers	8,502.04
		20,959	For irrigation	
		875,414	Total	
2009-2010	1,500,000	1,204,171	Reno. High level main canal (Plastering works	523.55
		75,000	Or Steel gates	
		20,000	Labour payment	
		1,299,171	Sub-total	
2010-2011	1,500,000	1,065,957	LL main canal L=2Km	
	1,000,000	399,082	HL Bank protection work L=138m CMU	2,891.90
	5,180,000	5,179,796	River bank protection =283m(7layers of gabion wall),Feeder canal.RRM & PCC=333m(GNH)	
	7,680,000	6,644,834	Sub-total	
2011-2012	1,000,000	910,813	Reno. High level main canal (Plastering works L=1868.5m)	487.46
Grand Total	35,860,000	17,208,698		
Average	5,976,667	2,868,116		

Original: RCMU, Bhur

(2) Estimation from the budget execution in other areas

The record of expenditure at Gewog level in Sarpang Dzongkhag could be obtained. As an example, Table 4.1.4 gives the state of budget execution in Chuzagang Gewog.

Table 4.3.3 State of Budget Execution in Chuzagang Gewog (unit: Nu.millions)

	2005-2006	2006-2007	2007-08 2008-09	2009-2010	2010-2011	2011-2012
S&M-Seeds,Seedlings					0.02	0.02
Demonstration & trial	0.02	0.01		0.01		
Farmer training	0.04	0.01		0.02	0.05	
Procurement of water pump	0.3	CHUYZAGANG Water supply				
Land managemet and soil					0.27	
New Construction on farm road		0.3		0.3	BARTHANG- KARBITHANG	0.69 KARBITHANG- BURTUNG
Improvement of farm road	0.25				1.05	PAGZOR- NIMALING
Small Development				0.3		1.5 PANGZOR- NIMALING
New construction of irrigation channel				0.25	LOWER DAWATHANG (2 km) and KARBITHANG (0.5 km)	0.4 KARBITHANG
Improvement of irrigation channels	0.36	DAWATHANG/ KARBETHANG	0.3	DAWATHAN G/KARBETH ANG	0.2	DAWATHANG
Small Development				0.25	Irrigation	0.5 DAWATHANG
Total	0.97	0.62		1.43	2.67	3.22

Source: Chuzagang Geowg office.

According to the information on the budget execution for provision of agricultural infrastructure from DoA, higher priority has been given for construction of farm road, with comparatively lower priority to repair and rehabilitation of irrigation facility. This table indicates this verbal information. Therefore, it is difficult to estimate the expenditure by each command area from the past budget execution data. However, judging from the state of budget execution shown in above Table 4.1.3, the disbursement for the irrigation channel (Lower Dawatang) is appropriated at Nu.0.25million for the period of 2009-2010, Canal length is 2.5 km. Then, this is equivalent to Nu.100,000/km/year per unit length of canal.

(3) Calculation from canal cross section

Construction cost per unit length of canal is also estimated assuming the cross section of a canal illustrated below at Nu.370,250/km.

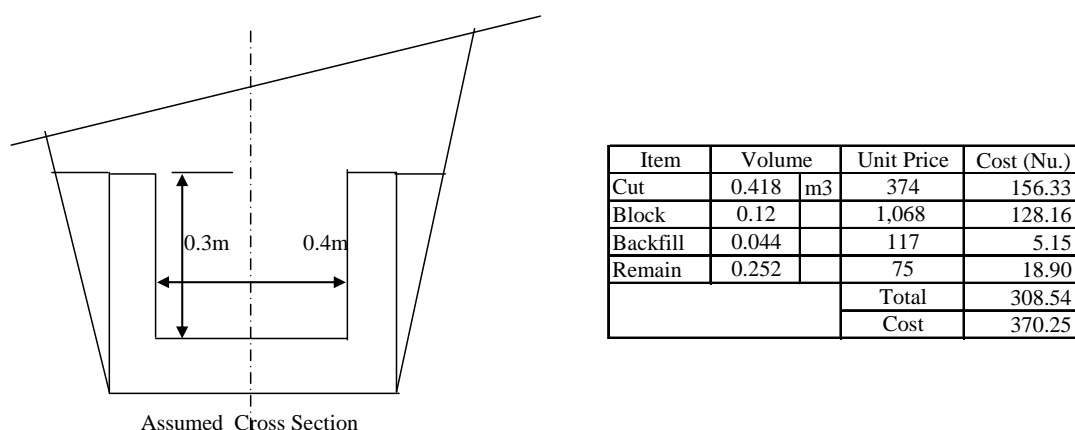


Figure 4.3.1 Typical Canal Cross Section and Construction Cost

(4) Estimation from expenditure for constructed canals in Samtse Dzongkhag

According to the 10th Five Year Plan of Smatse Dzongkhag, actual expenditure and approved budget for construction is accounted as shown in below table.

Table 4.3.4 Budget and Expenditure for Canal Construction in Samtse Dzongkhag

Gewog	Name of irrigation canal	Budget or expenditure (Nu.m)	Length (km)
New constructed till June 2010		Actual expenditure	
Samtse	Lamitar	0.48	1.2
Yoeseltse	Kuchidiana	3.388	3.74
Biru	Hathikharkha A	0.25	0.8
Biru	Khopi	0.8	0.7
Samtse	Sanpla	0.174	3
Sipsu	Gangately-hangay	3.158	7
On-going construction		Approved budget (Nu.m)	
Denchukha	at Nalung-Boribotey and Pungtha	0.350	9
Sipsu	Pinjuli & Bayasi	1.500	5
Tendru	at Jamsatar	0.600	4
Ugyentse	from Khuchidiana to Ngatshang	0.470	1.5
Total		11.17	35.74
Average cost (Nu./ km)		312,534	

Source: 10th Five year Plan, Samtse Dzongkhag

Construction cost per canal length is assumed Nu. 312,534.

By summarizing the above-estimated results, the following construction cost and O/M cost of canals are obtained:

Table 4.3.5 Estimated Cost of Canal Construction and Annual Maintenance

Unit: Nu.

Cost item	I) Takali irrigation rehabilitation project	II) Budget execution (Canal: Lower Dawatang)	III) Calculation from the canal cross section	IV) Budget and expenditure in Samtse
Canal construction cost (per km)	1,550,387*	100,000	370,250	312,534
O/M cost (per km per year)	226,780	(15,000)	(55,500)	(46,800)

Note: *in the case of the Takali Project cost, canal construction cost is calculated in the 1980's. O/M cost is assumed from 10% to 15% of the canal construction cost. In this analysis, the rate of 15% is adopted to apply the estimation of O/M costs of the others II), III) and IV).

Takali Project has a large scale facility with siphon, regulation facility and large scale conduit etc which are not found in other irrigation areas. And, cost is based on the 1980's. Such appurtenant structures certainly escalate the construction costs. Considering these conditions, with reference to the calculated value in the above II), III) and IV), the following cost is to be adopted as the input cost for this economic evaluation.

Canal construction cost Nu. 100,000~370,000/km

O/M cost Nu. 10,000~55,500/km/year

4.3.2 Study on the Benefit of the Existing Irrigation Facilities

(1) Existing irrigation model for the study on the benefit

Situations of irrigation facilities are very different in each facility, which is affected by relationship between landform and rivers, as already mentioned. Irrigation canals are extended from paddy fields to

intake points, which is available to take enough water, because farmers cannot cultivate paddy without irrigation water. Then, canal length, which is related to investment cost including construction cost of canals and the maintenance cost, and command area, which is related to the benefit, are not in direct proportion.

Therefore, nine models of existing irrigation schemes were set up to study the benefit of those schemes, considering the average and the unevenness of the command areas and the canal length of 79 irrigation schemes in Sarpang Dzongkhag. (The average of canal length is 2.6 km and the average of command areas is 29 ha.) Three types of canal length (1.5km/2.5km/5.0km) were combined with three types of command areas (15ha/30ha/60ha) so that total nine models were made.

Table 4.3.6 Setting Up Existing Irrigation Model

Command area		Canal length		
(ha)	(Ac)	(km)		
15	37.0	1.5	2.5	5.0
30	74.1			
60	148.1			

(2) Assumption of costs

The costs of the existing irrigation model are construction costs of canals and the maintenance costs, which depend on the length of canals. In this existing irrigation model, the maximum numbers of the cost estimation in (1) were applied for the cost calculation of the three canal length though the results of the cost estimation in (1) ranged widely.

Table 4.3.7 Construction and Maintenance Costs of the Irrigation Facilities Model

Canal length a (km)	Unit initial cost b (Nu./km)	Initial cost c=a*b (Nu.)	Service life d (year)	Depreciation expense e=c/d (Nu./year)	Annual unit O&M cost f (Nu./km/year)	Annual O&M cost g=f*b (Nu./year)	Total cost h=e+g (Nu./year)
1.5	370,000	555,000	10	55,500	55,500	83,250	138,750
2.5	370,000	925,000	10	92,500	55,500	138,750	231,250
5.0	370,000	1,850,000	10	185,000	55,500	277,500	462,500

Source: Calculated by the JICA Survey Team

(3) Assumption of benefit

The income of the existing irrigation model is calculated by the unit yield of paddy cultivation and the size of the command areas. Using *Agriculture Statistics 2010*, 2.15 ton/ha (870kg/Ac) of Sarpang Dzongkhag was applied to the unit yield of paddy. The average purchasing price of CAFCO at farmers' houses, 17 Nu/kg was applied to the value of paddy produce. Price of milled rice is about 30 Nu/kg. The income of each command area was calculated in the table below.

Table 4.3.8 Income of Paddy Cultivation in Each Command Area

Command area (ha)	Unit yield a (kg/Ac)	Planted area b (Ac)	Paddy production c=a*b (kg)	Selling price d (Nu./kg)	Income amount e=c*d (Nu./year)
15	870	37.0	32,222	17	547,778
30	870	74.1	64,444	17	1,095,556
60	870	148.1	128,889	17	2,191,111

Source: Hearing from WUA in Chuzagang and Agriculture Extension Officers in Gelephu and Dekiling, Sarpang in May 2012

(4) Other assumption

The benefit ratio to the cost (B/C) was calculated on the condition that the service life of the irrigation facilities was 10 years. Working cost of the paddy cultivation was calculated on the assumption of a farmer who cultivated paddy in a hectare. The official minimum wage of 165 Nu/day was applied to the standard of the farming wage. All works were considered to be handwork excluding land preparation by oxen from canal cleaning to threshing work.

Table 4.3.9 Working Cost of Paddy Cultivation in 1.0 Acre (Nu./Ac)

Cleaning canals	Nursery practice	Land preparation	Transplant	Weeding	Field management	Harvesting	Drying	Threshing	Total
1,336	668	900	1,650	2,145	4,008	1,485	330	348	12,870

Source: Hearing from WUA in Chuzagang Gewog and Agriculture Extension Officers in Gelephu Gewog and Dekiling Gewog, Sarpang in May 2012

(5) Result of the calculation of B/C

The result of the calculation of B/C on the existing irrigation model based on the above-mentioned assumption is shown in the next table. In case of a small command area and a long canal, the B/C is tend to be low. Economically speaking, the benefit of the farming is generated through maximumly utilizing labor at a bargain price and drastically reducing the input costs of canal construction and the maintenance.

Table 4.3.10 Benefit Ratio to Cost of the Existing Irrigation Model (B/C)

Command area		Canal length (km)		
(ha)	(Ac)	1.5	2.5	5.0
15	37.0	0.51	0.31	0.15
30	74.1	1.02	0.61	0.31
60	148.1	2.05	1.23	0.61

Source: Calculated by the JICA Survey Team

(6) Sensitive analysis on the case of reducing construction cost and maintenance cost

Though costs influence the economic feasibility of the irrigation model, the range of the costs including construction cost and maintenance cost is wide. Then, to grasp the influence to the economic feasibility by the fluctuation of the costs, trial calculation was made in two cases of cost reducing. The cases of 10 % reduction and 20 % reduction of the costs (90% and 80% of the original costs) indicate that the fluctuation of the costs has a great influence on the economic feasibility.

Table 4.3.11 Benefit Ratio to Cost in Case of Reducing Construction Cost (B/C)

Construction cost (max.)	Command area		Canal length (km)		
	(ha)	(Ac)	1.5	2.5	5.0
90%	15	37.0	0.57	0.34	0.17
	30	74.1	1.14	0.68	0.34
	60	148.1	2.28	1.37	0.68
80%	15	37.0	0.64	0.38	0.19
	30	74.1	1.28	0.77	0.38
	60	148.1	2.56	1.54	0.77

Source: Calculated by the JICA Survey Team

4.4 DATA COMPILATION BY GIS

4.4.1 GIS Sectors in MoAF

In MoAF, GIS is treated in the following sectors:

- Policy and Planning Division (PPD; MoAF main office)
- National Soil Service Centre (NSSC; under the Department of Agriculture (DoA))
- Forest Resources Development Division (FRDD; under the Department of Forest and Park Service)

Nine (9) GIS engineers are presently working in total including ones under training. DoA has no GIS engineers. PPD is responsible for coordination with foreign agencies related to the GIS. Present land cover map 2010 was provided under the leading of PPD with financial support from the World Bank. GIS data is mutually shared among the three sectors. Program "ArcGIS" and PC are commonly used for the GIS work. In this survey, many GIS data has been provided from PPD for JICA survey team.

4.4.2 Standard Coordinates System of Bhutan

Standard coordinates system of Bhutan is called as "DURKREF03", which is based on "Bhutan National Geodetic Datum" defined in 2000 by Department of Survey and Land Records (DSLRL), National Land Commission of Bhutan (NLC). Applied system specification is as follows:

Projection:	Transverse Mercator
False Easting:	250000
False Northing:	0
Central Meridian:	90°East
Scale Factor:	1
Latitude Origin:	0°
Linear Unit:	Meter
Datum:	GRS1980 (almost same as WGS84)

This coordinates system is used in principle for map display showing present survey results.

4.4.3 GIS Layers

GIS data shown in the following table was collected or created (as of May 8th, 2012). They will be compiled and applied to display various theme maps in this survey.

Table 4.4.1 List of GIS Data Collected / Created

Area	Kind	Data	Data Type	Data Source	Remarks
Whole country	Geography	90m DEM - altitude	DEM	http://srtm.csi.cgiar.org/S-ELECTION/inputCoord.asp	
		90m DEM - gradient	-		Crated from DEM with software
		90m DEM - main drainage	Shape file		Crated from DEM with software
		Geog boundaries	Shape file	PPD, MoAF	
		Dhongkhag boundaries	Shape file	PPD, MoAF	
		Dhongkhag centers	Shape file	PPD, MoAF	
	Geology	Geological map of Bhutan	Scanned Image	http://www.tandfonline.com/doi/abs/10.4113/jom.2011.1159	
		Main faults			Degitized from the geological map
	Lond cover	Bhutan Landcover Map, 2010	Shape file	PPD, MoAF	
	Environment Protection	National Protected Area and Biological Corridor of Bhutan	Image	http://www.rspnbhutan.org/about-bhutan/protected-areas-of-bhutan	
Three Dzongkhags	Geography	Bhutan 1:50,000 topographic map	Image	DoA, MoAF	
		Bhutan 1:50,000 topographic map component - Contour lines	Shape file	PPD, MoAF	
		- ditto - land use	Shape file	PPD, MoAF	
		- ditto - drainage	Shape file	PPD, MoAF	
		Roads	Shape file	PPD, MoAF	
		Geog boundaries	Shape file	PPD, MoAF	
		Geog centers	Shape file	PPD, MoAF	
		DoA offices	Shape file	PPD, MoAF	
	Point data with Cheok and village	Shape file	PPD, MoAF		
Geology	Quaternary topography classification	Shape file		Degitized with the Google Earth Image and the Bhutan 1:50,000 topographic maps	
Sarpang Dzongkhag	Irrigation	Taklai irrigation canals	Shape file	DoA, MoAF	Degitized from a map
		Beneficiary area location of irrigation schemes	Shape file	JICA suvey team	
		Source river/stram of irrigation schemes	Shape file	JICA suvey team	
		Beneficiary area of main irrigation schemes	Shape file	JICA suvey team	
		Intake location of main irrigation schemes	Shape file	JICA suvey team	

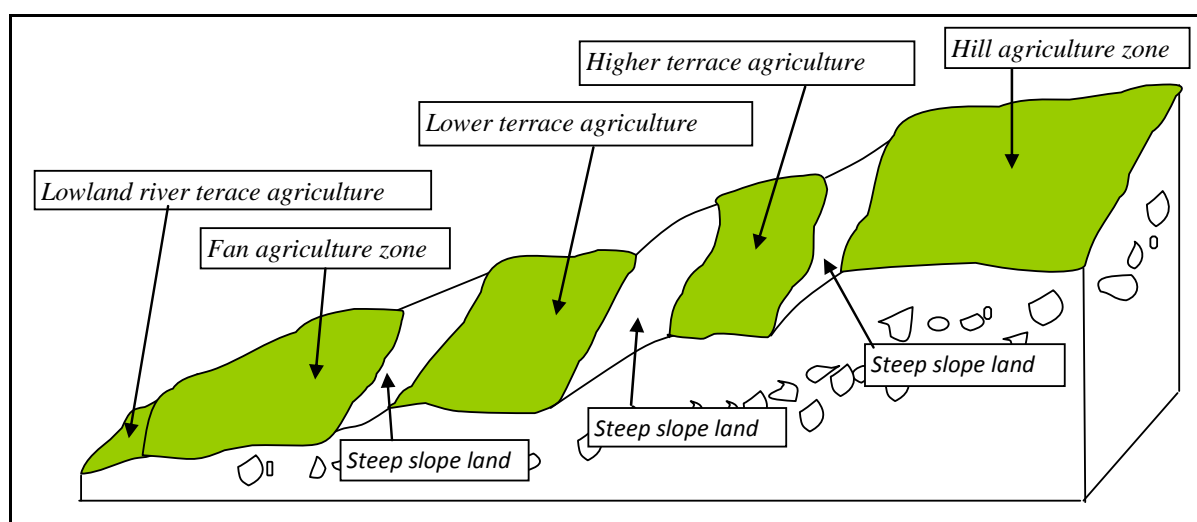
Note - DEM: Digital Elevation Model

CHAPTER 5 ANALYSIS ON VALIDITY OF IRRIGATION AGRICULTURE DEVELOPMENT AND REHABILITATION PROJECT OF IRRIGATION SYSTEM

5.1 CONSIDERATION ON AGRICULTURE DEVELOPMENT DIRECTION

5.1.1 Agriculture Zoning

Southern zone is bordered on the south by India. It lies on almost top range of the gentle alluvial plain ranging from steep mountains. Land use is formed on local natural conditions and agriculture is practiced on the farmland formed by local topographic and geological features. Agriculture zoning is totally made on such natural features. It is roughly classified into three zones on the local topo-geological conditions; hill agriculture zone, terrace agriculture zone and alluvial fan agriculture zone.



Agriculture zone is collectively made from the group of small farmlands provided with irrigation facilities of intake and delivery canal. Scale of the area size of agriculture zone and farmlands are largely dependent on their own local topography and geology of the hill and terrace. According to the irrigation system inventory of Sarpang Dzongkhag, it ranges from 1.0 ha to around 100 ha. Farmlands are scattered in the topographic range. Each agriculture zone is actually mixed in the range. Agricultural feature of the zones is characterized based on their own natural conditions such as rainfall, soil texture and access to agricultural water. It is also affected by social conditions such as access to agriculture infrastructure including market and transportation/ communication. In general, hill agriculture zone is located in higher altitude land in which various crops are cultivated under subsistence farming. Terrace and alluvial fan agriculture zones are located in lower altitude land where wet paddy is cultivated as a major crop. Agricultural and geographical features of the agriculture zone are described as shown in Table 5.1.1.

Surveyed 79 irrigation system sites are classified into the five agriculture zones; Hill, Fan, Higher terrace, Lower terrace and Lowland river terrace. The classification is shown in Tables 5.1.2 to 5.1.3, and Figure 5.1.1 to 5.1.3. Average altitude of the sites was also gotten from the topo-map. Zones located in the northern gewog of Dovan and Jigmecholing are classified into hill agriculture zone

ranged around 900 m to 1,500 m. Those located along the main road in Bhur and Gelephu gewogs are characterized as fan agriculture zone.

Irrigation intake water is obtained from neighboring river/ stream and distributed to farmland through gravity flow. Delivery canal is constructed based on the difference of altitudes between the available river bed and its targeted farmland. Under the altitude difference, irrigation system with intake and canal are located multiply on a same river course.

5.1.2 Development Direction and Expected Project Components of the Agriculture Zones

Strategy to realize agricultural water supply and management should be formulated in line with agriculture development direction of the each zone.

Development direction of the agriculture zones is preliminary formulated considering the country's overall development target, "improving agriculture productivity especially on paddy" and "shifting farming practice style from subsistent farming to market oriented commercial farming". Development direction of each zone is made as shown in Table 5.1.1 In order to materialize the development direction, following development component are required as below.

- Water resources development
- Rehabilitation of irrigation system
- Provision of farm roads
- Promotion of vegetable and cash crop cultivation
- Establishment of farmers organization
- Promotion of processing and marketing of cultivation crops
- Improvement of farm land (soils and soil layers)
- Improvement of paddy cropping technology
- Introduction of double cropping
- Introduction of livestock and inland fishery development plans
- Establishment and strengthening of water users association
- Strengthening on-farm water management
- Value chain improvement of rice and vegetable

Those projects are needed overall for all zones. But, its requirement intensity is differed from each zone on the each development constraint. Therefore, those projects should be applied flexibly based on the local conditions and problems confronted.

Table 5.1.1 Agriculture Feature, Development Direction and Expected Project Component of Each Zone

Zones	Natural Conditions			Agriculture Feature	Development Direction and Expected Project Component	
	Altitude	Rainfall	Topography, Geology, Soil		Development Direction	Expected Project Component
Hill agriculture	Higher ↑	Relatively less ↑	The land lies in higher altitude. Agriculture is practiced on weathering soil in and around the almost top of mountain. Land is suitable for farming.	Agriculture style of this zone is largely characterized as subsistent farming. The land is located in higher altitude zone which has more difficult access to marketing system than in the lower altitude zone. Various crops are cultivated for home consumption. Cropping system is largely dependent on local rainfall and access to irrigation water. Cardamom and orchard are listed as representative commercial crop in this zone.	<ul style="list-style-type: none"> - To strengthen subsistent farming in order to increase surplus agricultural production and ensure stable livelihood through agricultural infrastructure such as irrigation and farm roads. - To promote marketing their produced crops through providing farm roads. 	<ul style="list-style-type: none"> - Small scale water resource development - Rehabilitation of existing irrigation system - Provision of farm roads - Improvement of cash crop cultivation technology - Establishment of farmers organization for cooperative marketing and infrastructure management - Promotion of processing and marketing of cultivating crops
Terrace agriculture	Altitude EL.3,000 m - 200 m ↓	Annual rainfall 3,000 mm - 5,000 mm ↓	Terrace is developed along the river system. It is formed on the range of topographic slope as step farmland. From difference of the altitude between the terrace and its neighboring river, it is classified; higher terrace, lower terrace and lower river terrace. Most higher and lower terraces have sedimentation of rock, stone	Subsistent agriculture is the basic farming style. Agriculture practice is largely constrained by poor soil and shortage of irrigation water. Cultivating crops are mainly paddy in wet season, and maize and vegetables in dry season. Most farmland soil is formed by sandy soil somewhere containing gravel and stone with high infiltration rate. On	<ul style="list-style-type: none"> - To ensure agriculture water supply and improve farmland so as to increase paddy and other crops production. - To improve cropping technology of wet paddy and other crops - To promote market development of surplus rice production and other cultivated crops. 	<ul style="list-style-type: none"> - Small scale water resources development - Rehabilitation of existing irrigation system - Improvement of farm land (soil and soil layer improvements) - Improvement of paddy cropping technology - Introduction of double cropping of paddy - Promotion of vegetable and other cash crops production

Table 5.1.2 Agricultural Zone of the Wet Land (1/2)

Gewog	No.	Name of the Channel	Water Source		Location	Canal Length (Km)	Command Area		Number of Beneficial (HH)	Present Status		Accessibility ^(*)			Catchment Area ^(*) (km ²)	Average Elevation ^(*) (m)	Agricultural Zone ^(*)
			Name	River ^(*)			(Ac)	(ha)		Status ^(*)	Reason of non-functional ^(*)	Distance (km)	Time (min)	Access way			
Bhur	B-1	Puchar Kulo	Aipowali	S	Juphrey	5.00	135.00	54.63	26	F		0.0	0	-	3.4	370	F
	B-2	Beech Kulo	Aipowali	S	Juphrey	5.00	125.00	50.59	26	Non-F	Intake was washed away	0.0	0	-	3.4	397	F
	B-3	Ghalley kulo	Paithakhola	S	Ghalleygoan	5.00	90.00	36.42	29	F		0.0	0	-	4.6	436	F
	B-4	Limbo kulo	Paithakhola	S	Roadline	3.50	80.00	32.38	40	F		0.0	0	-	4.6	418	F
	B-5	Monger Kulo	Paithakhola	S	Mongergoan	3.50	65.90	26.67	30	F		0.0	0	-	4.4	419	F
	B-6	Siran Kulo	Aipowali	P	Juphrey	5.50	40.00	16.19	14	F		0.0	0	-	3.0	415	F
	B-7	Barasau Kulo	Shitakhari	S	Jaruwa/ Dechenpelri	4.50	36.00	14.57	21	F		0.0	0	-	5.9	443	F
	B-8	Siran Kulo	Shitakhari	S	Jaruwa/ Dechenpelri	4.00	35.00	14.16	19	F		0.0	0	-	5.4	489	F
	B-11	Puchar Kulo	Shitakhari	S	Jaruwa/ Dechenpelri	3.00	20.00	8.09	13	Non-F	Intake was washed away	0.0	0	-	6.0	473	F
					Subtotal	39.00	626.90	253.70	218								
Chuzagang	C-1	Phunsum Chuyour (low level)	Takali	P	Dawathang	5.41	700.00	283.28	350	F		0.0	0	-	97.2	236	Tr-H, Tr-L
	C-2	Samdrup Chuyour (high level)	Takali	P	Dawathang	7.51	300.00	121.41	70	F		0.0	0	-	90.0	255	Tr-H
	C-3	Karbitang	Sherabcholing	P	Karbitang	0.36	200.00	80.94	150	F		0.0	0	-	1.8	225	Tr-H
	C-4	Sherab choling	Kalikhola	P	Chasikher	2.00	150.00	60.70	25	Non-F	Supplied from C-2.	0.0	0	-	-	260	F
	C-5	Masinikhola	Masini khola	S	Chasikher	1.00	50.00	20.23	10	F		0.0	0	-	2.0	264	F
					Subtotal	16.28	1,400.00	566.57	605								
Dekiling	Dek-1	Hilley Khola Irri.channel	Hilley Khola	S	Chokorling	3.00	506.55	205.00	36	F		0.0	0	-	2.3	411	F
	Dek-2	Yangchenphu Irri.Channel	Yangchu	S	Yangchenphu	3.00	90.00	36.42	33	F		0.0	0	-	0.4	483	F
	Dek-3	Dekiling Irri.channel	Leo khola	S	Dekiling Derbitang	3.00	72.53	29.35	42	Non-F	Land Slide	0.0	0	-	7.0	296	F
	Dek-4	Bichkhola Irri.channel	Bich khola	S	Bichpani	2.00	70.00	28.33	43	F		0.0	0	-	1.7	486	F
	Dek-5	Yangchuenphu Irri.Channel	Phendey Chu	P	Yangchenphu	5.00	55.00	22.26	30	F		0.0	0	-	1.7	402	F
	Dek-6	Norbuthang Irri.Channel	Phendeychu	S	Gawaiithang	2.50	35.00	14.16	24	F		0.0	0	-	2.9	320	F
	Dek-7	Ratey Khola Channel	Ratepani	P	Ratepani	3.00	30.00	12.14	16	Non-F	Land Slide	0.5	15	On foot	15.5	487	Tr-L
	Dek-8	Gawaiithang Irri.channel	Yangchu	S	Gawaiithang	1.50	25.00	10.12	14	F		0.0	0	-	2.6	350	F
	Dek-10	Phendey Chu Channel	Teen Bhadey	S	Trashiling	1.50	23.00	9.31	10	Non F	Intake was washed away	0.0	0	-	3.4	322	F
	Dek-11	Ratey Irri.Channel	Ratey Khola	P	Ratey	5.00	21.50	8.70	100	Non F	Land Slide & Flood	0.0	0	-	14.3	495	F
	Dek-12	Dhokhola Irri.Channel	Dhokhola	P	Dhokhola	2.00	21.00	8.50	24	F		0.0	0	-	12.5	389	F
	Dek-13	Dhokhola Irri.Channel	Dhokhola	P	Dhokhola	2.00	18.00	7.28	16	F		0.0	0	-	18.4	374	F
						Subtotal	33.50	967.58	391.57	388							
Dovan	Dov-1	-	-	P	Thrukholha	2.50	30.00	12.14	18	F			2days	On foot	1.0	1258	H
	Dov-4	-	Girigang	P	Betchkhola	1.00	14.00	5.67	10	F			3days	On foot	16.9	1260	Tr-L
					Subtotal	3.50	44.00	17.81	28								
Gelephu	G-1	Sonamgatshel & Raptening Irri. Channel	Mouchu	P	Sonamgatshel & Raptening	2.00	212.82	86.13	85	F		0.0	0	-	788.1	207	LLTr
	G-2	Passangchu Irrigation Channel	Passangchu	P	Lower Pelrithang	2.50	79.40	32.13	21	F		0.0	0	-	4.9	259	F
	G-3	Dhulachu Irrigation Channel II	Dhulachu	S	Lower Pelrithang	1.50	61.85	25.03	23	F		0.0	0	-	1.4	308	F
	G-4	Dhulachu Irrigation Channel I	Dhulachu	S	Upper Pelrithang	1.50	56.65	22.93	19	F		0.0	0	-	1.5	276	F
	G-5	Tarulay Irrigation channel	Tarulaychu	S	Dzomlingthang	2.00	50.39	20.39	25	F		0.0	0	-	4.1	387	F
					Subtotal	9.50	461.11	186.61	173								
Hilley	H-1	Gurung Khola Kulo 3	Gurung Khola	S	Hilley	1.50	37.19	15.05	15	F		0.5	20	On foot	2.0	287	Tr-L
	H-2	Hadzari Kulo	Kali Khola	P	Khopitar	2.00	21.95	8.88	10	F		5.0	120	On foot	4.9	722	Tr-H
					Subtotal	3.50	59.14	23.93	25								

*1): P: Permanent river, S: Seasonal river, *2): Based on the field survey, Status; F: Functional, Non F: Not functional, Accessibility; Distance: from area to traffic road, Time: Access time, Access way: Local bus, on foot, etc.

*5) Agricultural Zone

*3) Catchment area at intake site is calculated with SRTM 90m DEM and the intake location.

*4) Average elevation of SRTM 90m DEM data in the estimated beneficiary area.

H: Hill
F: Fan
Tr-H: Higher Terrace
Tr-L: Lower Terrace
LLTr: Lowland River Terrace

Table 5.1.3 Agricultural Zone of the Wet Land (2/2)

Gewog	No.	Name of the Channel	Water Source		Location	Command Area		Number of Beneficial (HH)	Present Status		Accessibility ^{*2)}			Catchment Area ^{*3)} (km ²)	Average Elevation ^{*4)} (m)	Agricultural Zone ^{*5)}		
			Name	River ^{*1)}		(Ac)	(ha)		Status ^{*2)}	Reason of non-functional ^{*2)}	Distance (km)	Time (min)	Access way					
Jigmecholing	J-1	Basghari	Basghari Kholsa	P	Daragaon	1.50	105.00	42.49	12.00	F		1.0	20	On foot	0.5	950	H	
	J-2	Panitey Kuloo	Panitey Kholsa	P	Saundaley	1.00	90.00	36.42	25.00	F		1.0	15	On foot	0.3	1150	H	
	J-3	Dharey Kuloo	Dharey Kholsa	P	Saundaley	0.50	50.00	20.23	12.00	F		1.0	15	On foot	0.5	1140	H	
	J-4	Jante Kuloo(3)	Jantey Kholsa	P	Daragaon	2.50	30.00	12.14	21.00	F		1.0	15	On foot	1.2	950	H	
	J-5	Gumti Kuloo	Gumti kholsa	P	Sampagang	1.00	30.00	12.14	15.00	F		1.0	30	On foot	0.5	1270	H	
	J-6	Dawa Kuloo	Dawa Khola	P	Samapagang	1.00	30.00	12.14	10.00	F		1.0	30	On foot	1.0	1270	H	
	J-10	Nado kuloo	Nado kholsa	P	Samkhara	2.50	25.00	10.12	10.00	F		1.0	20	On foot	1.3	1270	H	
	J-15	Sepai Kuloo	Sepai Khola	S	Daragaon	0.20	22.80	9.23	11.00	F		1.0	15	On foot	0.2	950	H	
	J-16	Jante Kuloo(1)	Jantey Kholsa	P	Daragaon	3.50	21.00	8.50	12.00	F		0.5	15	On foot	-	950	H	
	J-23	Tharokuloo	Tharo Khola	P	Gongdara	3.00	19.50	7.89	13.00	F			2days	On foot	-	1500	H	
	J-24	Hiti kuloo	Hiti kholsa	P	Daragaon	1.50	18.00	7.28	12.00	F		1.0	30	On foot	0.2	950	H	
	Subtotal						18.20	441.30	178.59	153								
Sengye	Sen-1	Baral kulo	Sisty khola	P	Sisty A	4.00	59.05	23.90	24	F		0.0	0	-	16.2	336	Tr-L	
	Sen-2	Mazan kulo	Sisty khola	P	Sisty A	6.00	46.95	19.00	25	Non-F	Under repairing	0.0	0	-	15.8	352	Tr-L	
	Sen-3	Upper Senghe Kulo	Senghe khola	P	Hatikhuar	1.00	36.10	14.61	20	F		0.5	20	On foot	0.8	319	F	
	Sen-4	Koigaon kulo	Tungkhola	P	Koigaon	2.50	35.50	14.37	18	F		0.0	0	-	1.6	320	Tr-H	
	Sen-5	Rumdali kulo	Sisty khola	P	Sisty B	3.00	22.05	8.92	14	F		0.3	10	On foot	15.8	323	Tr-L	
	Subtotal						16.50	199.65	80.80	101								
Sershong	Ser-1	Lothuen irrigation channel	Taklaichhu	P	Lothuen	6.25	145.55	58.90	84	F		0.5	20	On foot	90.0	276	F	
	Ser-2	Norbuling irrigation channel	Norbuling chhu	S	Norbuling	3.00	96.40	39.01	53	F		0.5	20	On foot	2.7	317	F	
	Ser-3	Pemaling irri. channel	Norbulingchhu	S	Pemaling	2.50	95.00	38.45	40	F		1.0	40	On foot	2.4	320	F	
	Ser-4	Pangkhar irrigation channel	Chheojayang chhu	S	Pangkhar	2.50	52.00	21.04	16	F		0.5	20	On foot	0.3	424	F	
	Ser-6	Norbuling irr. channel	Norbulingchhu	S	Norbuling	1.50	52.00	21.04	16	Non-F		0.5	20	On foot	2.8	295	F	
	Ser-7	Barshong irrigation channel	Barthang	S	Barshong	2.00	48.00	19.43	22	F		0.5	20	On foot	24.3	263	Tr-L	
	Ser-8	Kingaling irr. channel	Norbulingchhu	S	Kingaling	1.50	45.00	18.21	22	Non-F	-	1.0	60	On foot	2.7	321	F	
	Ser-9	Pangkhar irrigation channel	Mathangchhu	S	Pangkhar	2.00	40.00	16.19	16	Non-F	Land slide	0.5	20	On foot	0.3	365	F	
	Ser-12	Barshong irrigation channel (1)	Barshongchhu	S	Barshong	3.00	25.00	10.12	14	F		0.5	20	On foot	1.6	319	Tr-H	
	Ser-13	Barshong irrigation channel (2)	Barthang chhuu	S	Barshong	1.00	20.00	8.09	14	F		0.5	20	On foot	1.6	267	Tr-L	
	Ser-15	Sershong irrigation channel	Barshongchhu	S	Sershong	2.00	15.00	6.07	12	Non-F	-	0.5	20	On foot	0.7	290	Tr-L	
	Subtotal						27.25	633.95	256.55	309								
	Shompangkha	Sho-1	Daoray kholo	Doray khola	S	Kuencholing	2.00	132.00	53.42	93	Non-F	River bed dropping	0.0	0	-	2.2	390	F
Sho-3		Lower Norbugang kholo	Tharokhola	S	Darjaythang	1.00	85.00	34.40	12	Non-F		0.0	0	-	3.1	255	F, Tr-L	
Sho-4		Kafley kholo	Kafley khola	S	Darjaythang	2.50	50.00	20.23	24	F		0.0	0	-	3.0	297	F	
Sho-7		Jaidhan Kholo	Jaidhan kholo	S	Pakhay	2.00	22.33	9.04	12	Non-F	Land slide	0.0	0	-	0.6	437	F	
Subtotal						7.50	289.33	117.09	141									
Tarithang	T-1	Yoezergang-Singi Khola Lower Irri. Canal	Singi Khola	P	Yoezergang	1.50	26.00	10.52	14	F		1.5	30	On foot	4.5	215	Tr-L	
	Subtotal						1.50	26.00	10.52	14								
Umiling	U-1	Rejuk Serchu Irrigation channel	Serchu	P	Rejuk	2.00	85.00	34.40	27	F		1.0	20	On foot	2.5	235	Tr-H	
	U-2	Dangling Irrigation channel Lower	Langar chhu	S	Dangling	3.50	82.00	33.18	36	Non-F		0.5	10	On foot	4.1	259	Tr-H	
	U-4	Dungmin Irrigation channel Upper	Langar chhu	S	Dungmin	1.00	70.00	28.33	26	F		0.5	10	Tiller	5.2	260	Tr-H	
	U-5	Tashithang Karchu Irrigation channel	Karchu	S	Tashithang	7.00	64.00	25.90	21	Non-F	Land slide	0.5	10	Tiller	0.5	350	Tr-H	
	U-6	Dungmin Irrigation channel Lower	Langar chhu	S	Dungmin	1.00	52.00	21.04	16	F		0.5	10	Tiller	5.4	261	Tr-H	
	U-7	Chubarthang Seelchu Irrigation channel	Serchu	S	Chubarthang	2.00	47.00	19.02	14	F		0.5	10	Tiller	0.4	266	Tr-H	
	U-8	Thongjazor Karchu Irrigation channel	Karchu	S	Thonjazor	4.00	44.00	17.81	17	Non-F		0.5	10	On foot	0.5	368	Tr-H	
	U-9	Lingar Dap Irrigation channel	Taklai chhu	P	Lingar	3.00	40.00	16.19	15	F		1.0	20	On foot	106.7	218	LLTr	
	U-10	Gadhen Irrigation channel Lower	Taklai chhu	P	Gadhan	1.00	38.00	15.38	48	F		0.5	10	Tiller	112.6	197	Tr-L	
	U-11	Rijuk Karchu Irrigation channel	Karchu	S	Rejuk	1.00	31.00	12.55	27	Non-F		0.5	10	On foot	7.1	202	Tr-L	
	U-12	Dangling Irrigation channel Upper	Langar chhu	S	Dangling	3.00	24.00	9.71	32	Non-F		0.5	10	Tiller	3.7	279	Tr-H	
U-14	Pantharey Irrigation channel	Langar chhu	S	Dangling	1.00	17.00	6.88	15	Non-F		0.5	10	Tiller	0.1	324	Tr-H		
Subtotal						29.50	594.00	240.39	294									

*1): P: Permanent river, S: Seasonal river, *2): Based on the field survey, Status: F: Functional, Non F: Not functional, Accessibility: Distance: from area to traffic road, Time: Access time, Access way: Local bus, on foot, etc.

*3) Catchment area at intake site is calculated with SRTM 90m DEM and the intake location.

*4) Average elevation of SRTM 90m DEM data in the estimated beneficiary area.

*5) Agricultural Zone

H: Hill

F: Fan

Tr-H: Higher Terrace

Tr-L: Lower Terrace

LLTr: Lowland River Terrace

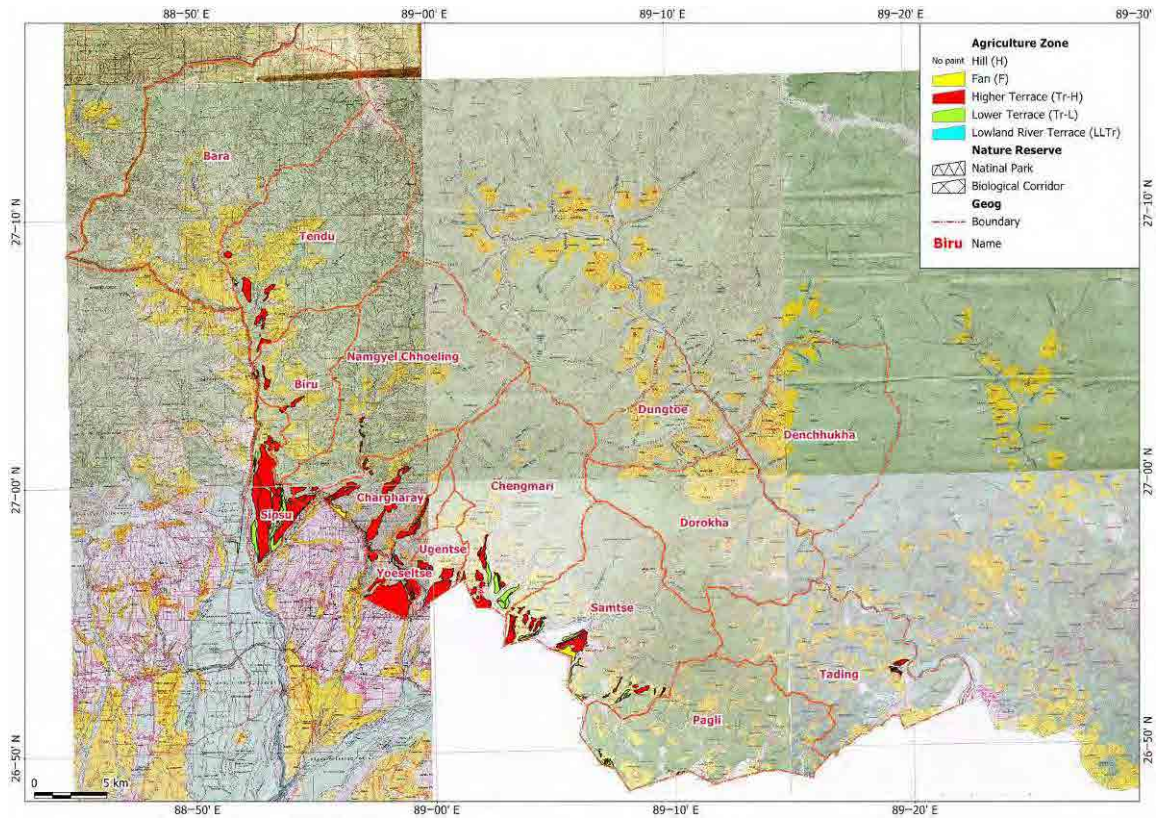


Figure 5.1.1 Agriculture Zone of the Wet Land (Samtse)

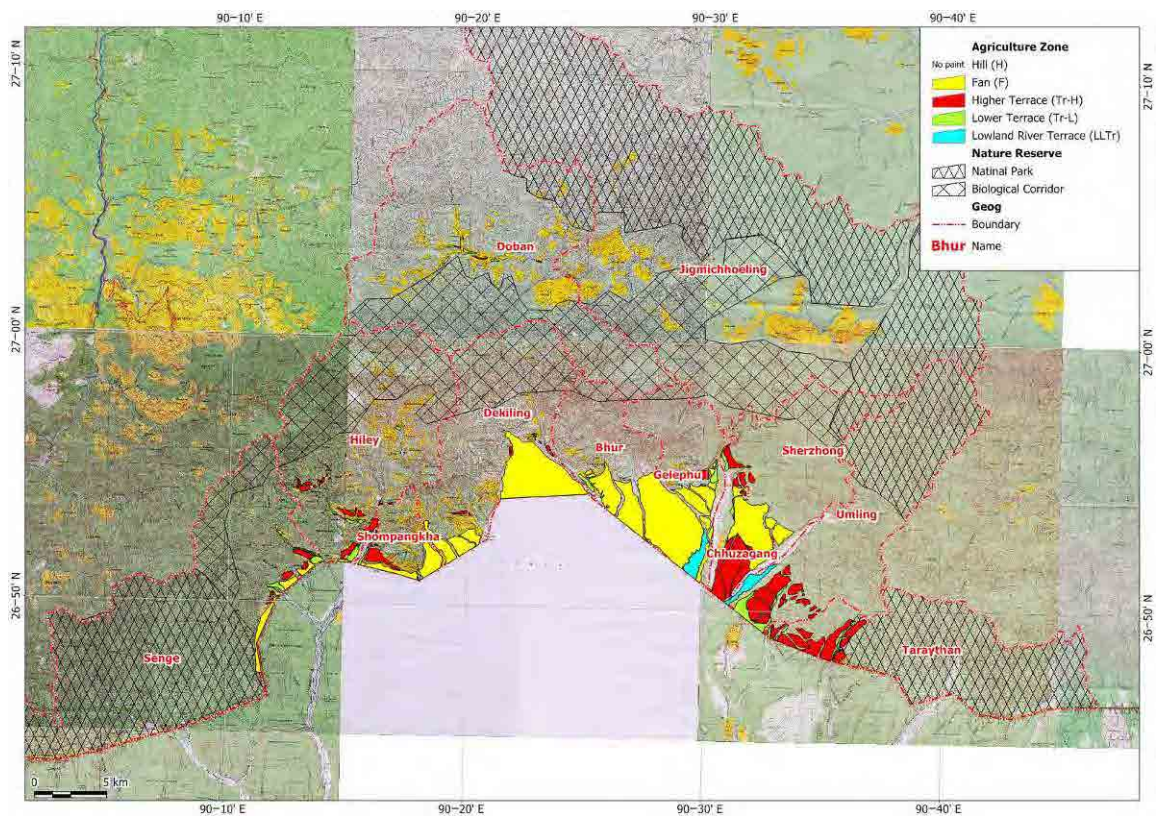


Figure 5.1.2 Agriculture Zone of the Wet Land (Sarpang)

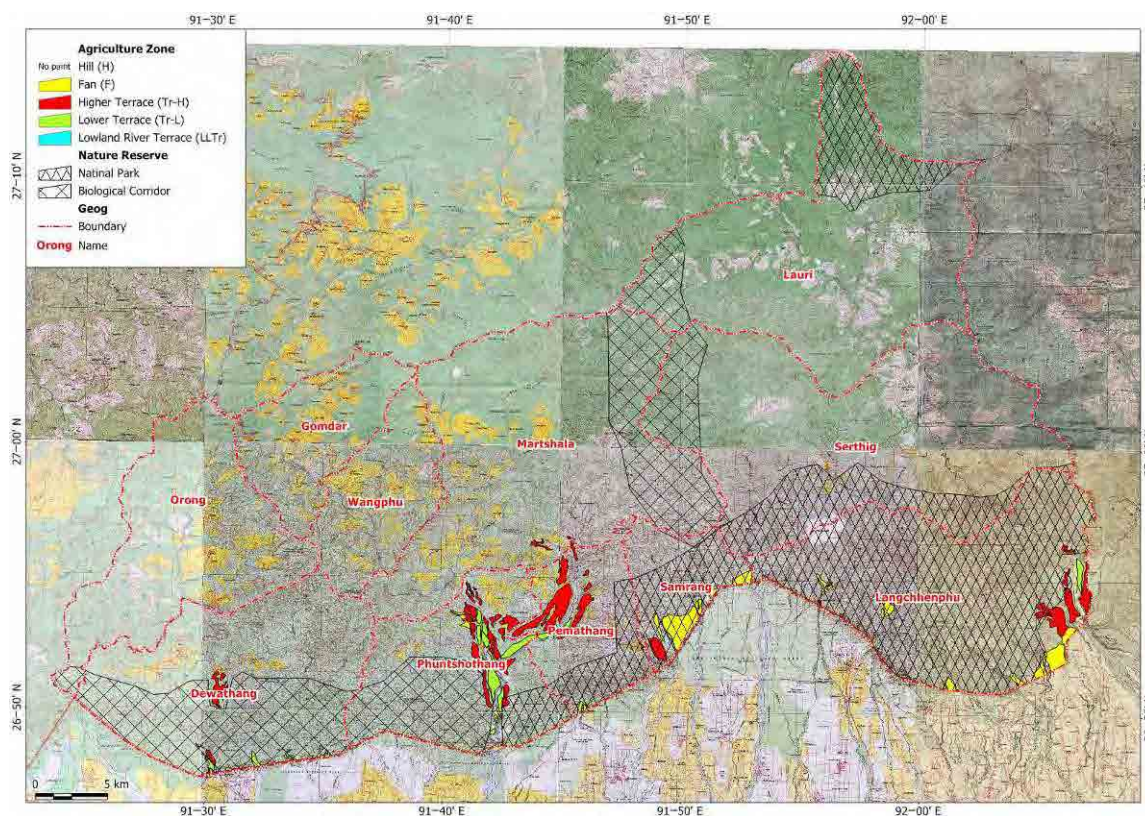


Figure 5.1.3 Agriculture Zone of the Wet Land (Samdrop Jongkhar)

5.1.3 Selection of Priority Project

(1) Selection criteria

Among the project component list mentioned above, development effect of some projects may be generated from mutual linkage in the implementation process of them. Therefore, project implementation should be well designed in the long-term time schedule. To do so, it is required to draw overall development scenario of each zone by conducting more detail study and analysis. On the other hand, it is recommended that priority project may be selected and implemented so that it can generate quick development effect. From development effect generated from the implementation process of priority project, next project and overall project implementation plan may be guided.

Based on the above concept, priority project is preliminary selected in this study stage. Selection criteria items are prepared based on the collected data/ information as follows.

- | | |
|---|--|
| 1) Project effect in short term implementation | ; Can be expected to get quick and certain effect "increase of paddy production" by input in short term? |
| 2) Implementation capacity of administrative body | ; Can administrative implementation body provide enough capacity to lead the project? |
| 3) Readiness of beneficial farmers | ; Are beneficial farmers ready for working with project implementation? |

(2) Selection of priority project

By screening the above mentioned selection criteria, the project "**Rehabilitation of Existing Irrigation System**" is selected as the priority project.

Selection Criteria	Present Condition and Selection Process
1) Project effect in short term implementation	By rehabilitating existing irrigation facilities, it is expected that farmers can increase paddy production to some degree under their present paddy cropping technology and skill conditions.
2) Implementation capacity of administrative body	Administration body in each level of central, dzongkhag and gewog gets some experience and lessons learned from their past rehabilitation works. Implementation capacity to carry out the projects can be provided in short term.
3) Readiness of beneficial farmers	Beneficial farmers have experience to repair the damaged irrigation facilities, intake and irrigation canal. They can contribute their labor force. Repair work can be conducted by using civil work materials supplied from dzongkhag and gewog offices. They can accept to participate in the project.

5.2 APPROACHES TO PROVIDING EFFECTIVE/ EFFICIENT IRRIGATION SYSTEM

In the plan formulation stage of the irrigation rehabilitation project as mentioned above section 5.1, it is required to study for providing effective/ efficient irrigation system.

5.2.1 Agriculture Zoning

The following consideration was taken on the current situation mentioned in the Chapter 4 to study development possibility for ensuring agricultural water source.

(1) Consideration on ensuring agricultural water in terms of meteorological conditions and paddy cropping system

As for beginning stage of paddy cropping, there is a series of water use stage for land preparation, nursery, plowing, bunding, paddling and transplanting, etc. Those stage are practiced during the period from June to July in which July, the peak spell of much rainfall, is the busiest season. The amount of precipitation and rainfall intensity are the highest in this period, on the other hand, the infiltration of rainwater is also fastest in this area located in the top of the alluvial plain. Analyzing this phenomenon from hydrologic point of view, it is evaluated that larger portion of rainwater is fed for recharging groundwater. Thus, large deposit of groundwater is expected to exist in the aquifers. On the other hand, by being coupled with vulnerable geologic and unstable topographic conditions, continuous high intensive rainfall may cause such damages as fluvial floods, avalanche debris flow with earth and rocks and slope collapse, etc. Such natural conditions surely bestows abundant water resource for agriculture, but it also gives at times heavy damages on the irrigation facilities such as intake water from river/ streams and delivery canals. This also serves as a constraint factor making their operation and maintenance difficult.

Paddy cultivation is affected by climatic conditions such as rainfall and hours of sunshine during growing stage of paddy. For example, comparison of monthly rainfall and monthly mean hours of

sunshine between the southern dzongkhags and Paro Dzongkhag in western region (where paddy yield reaches over 4.0 ton/ha) was made as referred to Table 5.2.1 and Figures 5.2.1 and 5.2.2. (It is noted that hours of sunshine are affected by not only location factors as latitude and topography, but also seasonal clouds and precipitations.) Following points are mentioned.

- Share of 60 to 65% of the annual rainfall is precipitated during three months, June to September in three southern dzongkhags. Mean hours of sunshine during this period range as short as 1.9 to 2.6 hr/day and this may be resulted from longer hours of precipitation. The month of the shortest sunshine hours is the July with the highest precipitation amount. Especially, in Samtse the shortest hours have been recorded as only 1.4hr/day. Whereas, the mean annual hours of sunshine in three southern dzongkhags is averaged at from 3.8 to 5.0 hr/day.
- The annual precipitation amount 660 mm recorded in Paro is lower than those in southern dzongkhags, on one hand, but the mean annual hours of sunshine in Paro during the period from June to September comes to 3.4 hr/day that is longer than those in three southern dzongkhags.
- As to the hours of sunshine recorded in India, the adjacent area to Bhutan, it shows 6 to 7 hr/day or around 4 hr/day as an average in July, implying very short hours of sunshine in three southern dzongkhags.

The growing stages of paddy in general consist of transplanting, establishing/rooting, valid tillering, invalid tillering, primordial panicle differentiating, young panicle developing, heading/ flowering, maturing and field draining.

Out of those stages, the stages requiring much water except paddling prior to transplanting, are in the stages; plant establishing, panicle differentiation, panicle developing and heading/ flowering stages followed by grain maturing. Shortage of bright sunshine hours may serve as a limiting factor retarding the plant growth. It is said that insufficient hours of sunshine during the stages of heading/ flowering may cause a sterile state leading later to a poor grain yield.

Conditions including temperature, water supply and hours of sunshine etc. influence on paddy yield. Hence, a cropping pattern considering such salient climatic features as much rainfall during summer and short hours of sunshine is important in southern zone. Based on the long experiences of paddy cultivation, it is quite likely that the currently practiced cropping pattern with transplanting in July and harvesting in mid October to late November (occasionally in December according to the interview survey) has been established in matching with such ambient conditions as rainfall, atmospheric temperature and hours of sunshine, etc.

Table 5.2.1 Amount of Precipitation and Hours of Sunshine in Three Dzongkhags and Paro

Sarpang Observation station: Bhur (EL.375m)		Unit: Rainfall(mm/month) ,Sunshine(hr/day)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
Rainfall	20.3	43.4	116.5	246.1	395.3	1005.3	1368.3	940.0	727.8	220.1	22.7	15.4	5121.1
Sunshine	6.7	5.7	5.0	4.3	4.7	2.3	2.1	3.2	3.9	6.7	7.6	7.3	5.0

Rainfall between June and August 3313.6 mm 64.7 % proportion to annual rainfall
 June and Sep 4041.4 mm 78.9 % proportion to annual rainfall
 Sunshine between June and August 2.6 hr/day

Samtse Observation station: Sibsoo (EL.550)		Unit: Rainfall(mm/month) ,Sunshine(hr/day)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
Rainfall	22.2	51.2	120.3	325.8	515.4	974.6	1395.6	1054.4	664.7	220.4	13.7	16.7	5375.1
Sunshine	4.2	4.4	4.5	4.4	4.2	2.2	1.4	2.1	3.3	6.1	5.7	3.6	3.8

Rainfall between June and August 3424.5 mm 63.7 % proportion to annual rainfall
 June and Sep 4089.2 mm 76.1 % proportion to annual rainfall
 Sunshine between June and August 1.9 hr/day

Samdrup Jongkhar Observation station:Deothang (EL.300)		Unit: Rainfall(mm/month) ,Sunshine(hr/day)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
Rainfall	13.2	33.4	106.3	352.5	389.6	758.1	958.8	480.6	433.6	176.2	11.0	11.4	3724.4
Sunshine	6.6	6.2	5.6	4.5	4.5	2.3	2.3	3.0	3.9	5.6	6.7	6.3	4.8

Rainfall between June and August 2197.5 mm 59.0 % proportion to annual rainfall
 June and Sep 2631.1 mm 70.6 % proportion to annual rainfall
 Sunshine between June and August 2.5 hr/day

Paro Observation station:Paro (DSC)(EL.2406)		Unit: Rainfall(mm/month) ,Sunshine(hr/day)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
Rainfall	6.5	14.2	20.5	31.0	56.4	88.0	175.4	119.4	90.8	55.0	1.9	3.2	662.1
Sunshine	5.9	6.1	6.3	6.1	4.9	3.7	3.2	3.5	3.8	6.0	5.6	4.5	5.0

Rainfall between June and August 382.8 mm 57.8 % proportion to annual rainfall
 June and Sep 473.5 mm 71.5 % proportion to annual rainfall
 Sunshine between June and August 3.4 hr/day

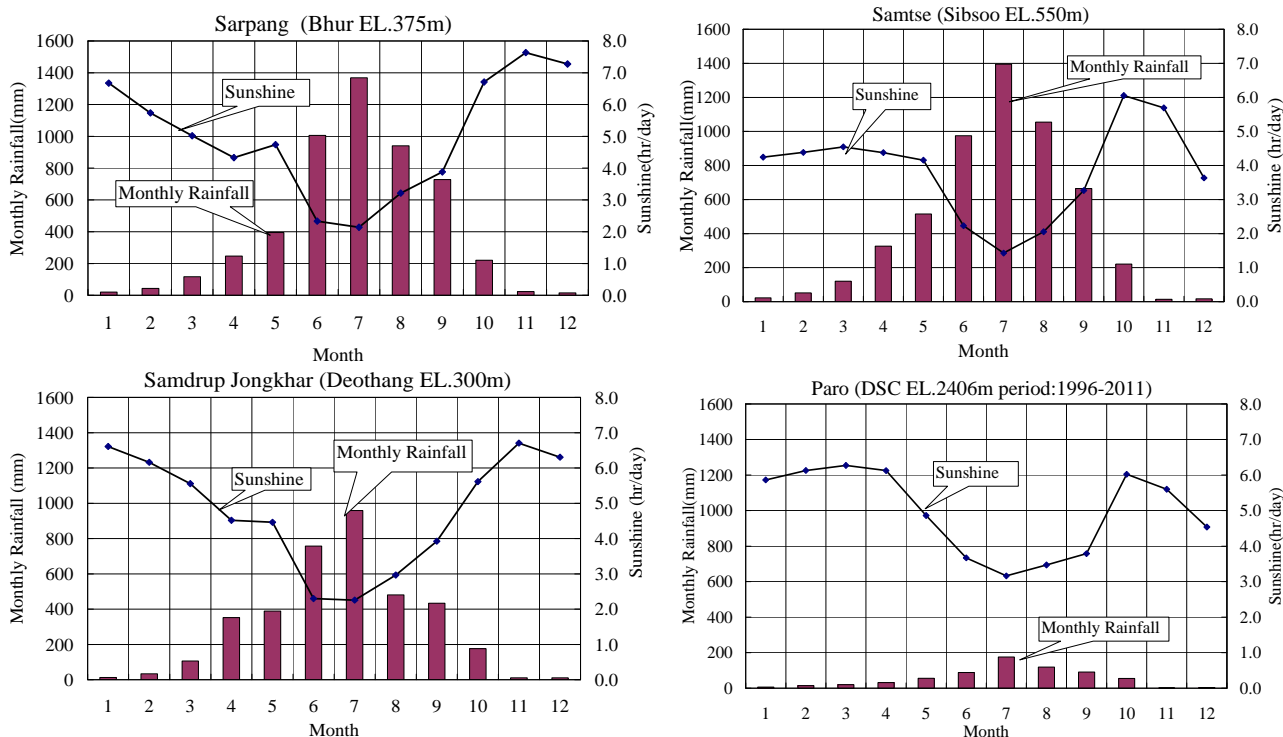


Figure 5.2.1 Fluctuations of Precipitation and Hours of Sunshine in the Three Dzongkhags and Paro

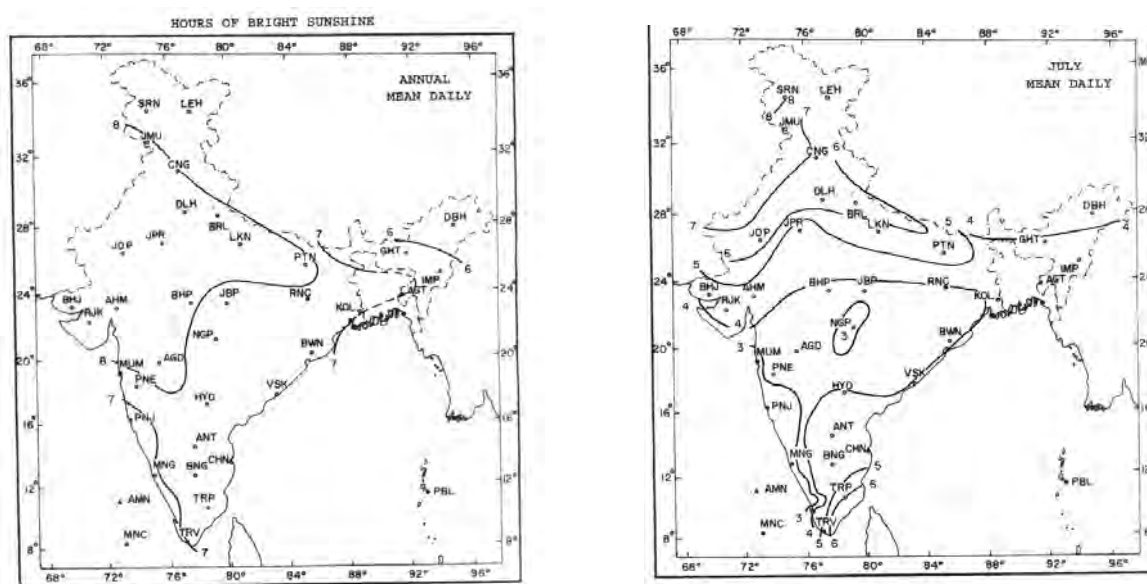


Figure 5.2.2 Distribution of Bright Sunshine Hours in India

(Annual mean is given in the left figure and mean value in July in the right figure)

(Original : India Meteorological Department www.imdagriment.gov.in)

Hydrographic fluctuations of fluvial discharges in the river serving as sources of agricultural water are shown to give a time-sequential pattern similar to the rainfall pattern. According to interview survey, some delay in the entire growing stage of paddy may result from water deficit caused during transplanting period. This condition occurs from delay of onset of rainy season in some years. Water shortage sometimes arises also in the period just before the harvesting stage, from booting stage to maturing stages, by the same reason. In terms of irrigation practice, an essential issue for this area is derived from not only insufficient function of current water intake but also large annual fluctuation in river water resulting from concentrated rainfall period from June to August.

A cropping plan paying due consideration to seasonal climatic fluctuations in southern areas and also to climatic elements (atmospheric temperature, water / moisture, hours of sunshine, etc.) is essential for this area, on one hand. It is also important for ensuring agricultural water by a sustainable way so as to store abundant rainwater and river flow by means of dams and reservoirs (regulation ponds), on the other. In this context, groundwater can be expected as other water source, characterized in comparison with that of surface flow in river.

Furthermore, it is important to ensure water requirement through realizing effective water use in the limitation of available water amount. Here, the necessity arises in introducing such engineering methods as how to control water loss from canal or from field plots. In addition, besides such engineering measures to cope with the issues, non-structural approaches should be introduced as follows.

- Introducing water-saving irrigation coupled with the water storage facilities.
- Establishing rational cropping system with paddy rice in combination with other crops with lower water requirement

In particular, it seems difficult for cultivating paddy in dry season in southern dzongkhags in the same scale in rainy season because of its high water consumption. Thus, it is required to apply suitable cropping system for dry season balancing with the available water amount.

Taking consideration and analysis as mentioned above, the following issues are regarded in ensuring agricultural water in the southern zone.

- Although annual precipitation has a high in the southern zone, its distribution is mainly concentrated in a period from July to September. By coupled with vulnerable geologic formations and topographic conditions, rainfall may cause severe damages to the existing irrigation facilities. It implies a limitation of utilizing river water as a stable water source.
- In terms of ensuring agricultural water, approaches to seeking possibility to construct water storage facilities as well effective use of groundwater.
- Examinations are required to introduce rational dry-season cropping system with limited availability of water sources in which meteorological conditions such as limited hours of sunshine and much rainfall should be reflected on the selection of suitable crops/ cropping seasons and to realize water saving irrigation and cultivation.

(2) Prospect of developing utilization of river water

Great efforts have so far been dedicated to maintain, manage and repair the existing intake facilities and delivery canals. Nevertheless, difficulty has been identified in constructing permanent facilities under the current vulnerable topo-geologic conditions technically and economically so far as river bed has not been stabilized.

However, looking the current structures, some engineering issues such as shallow foundation of intake structure and limited extent of protecting work are observed. Considering this situation, it is necessary to try to improve those shortcoming issues so as to make intake water more stable. By means of this improvement, it may be possible to reduce work frequency in repairing and expand time-interval of repair.

In the long term viewpoint, in order to realize stable intake water, control and management of sediment and introduction of watershed management are required in the river system. Notwithstanding, considering the fact that the existing intake facilities have been kept using, for a short term, it would be more realistic to expand rehabilitation work interval of the facilities by reinforcing the damaged parts. This might bring to alleviate regular heavy operation and maintenance work.

(3) Effect and possibility of creating water storage facilities

Water storage facilities as mentioned in the (1) are effective to procure agricultural water. Based on the roughly classifying, the following types of water storage facilities can be considered (refer to Figure 5.2.3).

- i) Dams to store river water by enclosing the river with a traversing structure
- ii) Regulation ponds installed outside the river course to convey and store surplus river water

in rainy season

iii) Reservoirs installed inside or adjacent to an irrigation area to collect and store rainwater and surface flow from a watershed

iv) Reservoirs to collect and store over flown irrigated water from upper located farmland

Possibility of applying these types to the southern zone is considered as follows.

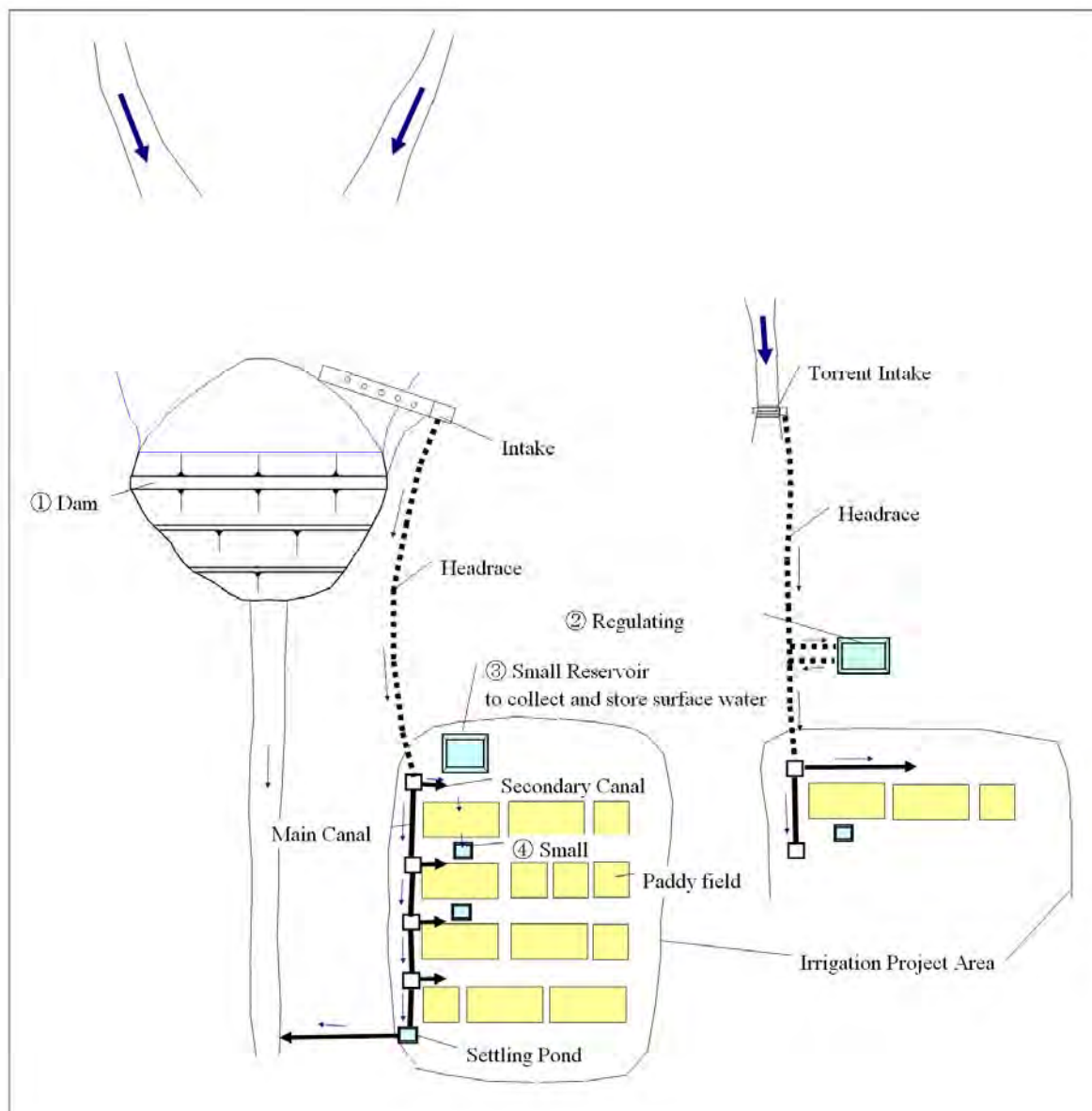


Figure 5.2.3 Types of Water Storage Facilities

i) Dams storing river water

This type storage dam may generate the largest development effect among the four types, but, it is difficult in this data collection survey level to affirm the possibility of constructing them at any sites. It is necessary to provide a longer-term survey/ study/ analysis to study the possibility from viewpoints of geology, topography and characters of the river course, and select any candidate sites based on high accurate topographic maps. Natural and social environmental impact assessment is also indispensable. But, in case of small dams for supplemental irrigation in small river basin, its design and construction

process may be led through short term simple survey and analysis.

ii) Regulation ponds

This is a type to convey and store river water into this regulation pond during the period of large amount of river discharge and utilize the stored water at the time of water scarcity. Water shortage sometimes arises at transplanting and/or harvesting period in a part of the area, according to interview with farmers. The ponds can be served as supplemental irrigation to cope with such water shortage.

As to the storage capacity requirement, for instance, in order to meet water scarcity period 5 days and irrigation area 20 ha, necessary capacity is estimated about 17,400 m³, assuming the unit water requirement 2.0 lit/sec/ha. As regards the area for regulation pond, around 1.0 ha is necessary assuming the depth of water storage at 2.0 m.

In this data collection survey level, any suitable candidate sites for this facility cannot be specified. Detail survey/ study/ analysis on geology and topography are required as mentioned in the i).

iii) Reservoirs storing surface water

Rainwater collection ponds have been introduced in Chuzagang Gewog in a trial basis, though they have small scale to be used for home vegetable gardens in dry season. In future, development effect will be verified through monitoring their irrigation and marketing activities. Aqua cultural ponds have also been constructed and used as reservoirs that collect rainwater and surface river flow. Considering such present situations, it is possible to newly construct reservoirs to strengthen the function of supplemental irrigation. In order to materialize this type of reservoirs, it is essential to select suitable candidate sites based on detail geological and topographic survey. Storability in the candidate sites and possibility of land acquisition are the key survey.



Figure 5.2.4 An Example of Aqua Cultural Pond (Sengye Gewog in Sarpang Dzongkhag)

iv) Reservoirs to collect and store over flown irrigated water from farmland

This reservoir has a function of collecting and storing residual irrigation water over flown from the farm plots located in upper area. Storage water can be used as repeated use for irrigation. Because eroded soil and water loss is significant in plot to plot irrigation system, this type of reservoirs can also function as a settling basin collecting water and eroded soil. In the case that this type is planned to construct within the irrigation area, an issue would arise from land acquisition. And, possibility of land readjustment should be discussed in this case.

(4) Possibility of developing groundwater in Sarpang Dzongkhag

FAO mentions a possibility of developing groundwater in Sarpang Dzongkhag. (Existence of groundwater has not been identified in Samtse Dzongkhag though a test boring was conducted as proposed). From the survey result in Sarpang Dzongkhag by JICA survey team, it is judged that developing groundwater is possible in the surrounding area of an alluvial fan. Founded on the survey result, some case studies for development possibility are introduced as follows.

- As regards intake water from the alluvial fan of Mao River in Sarpang Dzongkhag, regular operation and maintenance work of the existing intake facility has required in the current intake point due to frequent change of water route in the river .
- There exists an intake water point for the Sonamgatshel & Raptenling irrigation areas at the confluence of Dhulachu into Maochu in Gelephu City. Current situation as of July 2012 is shown in Figure 5.2.5.



Figure 5.2.5 Situation of Intake Point in Mao River

- The intake facility has not functioned since the headrace of delivery canal installed at the intake point at Maochu side has been buried by the deposited sediments washed out from Dhulachu. Evacuation work by using heavy machineries needed every year to fix the water route.
- In order to improve such unstable water intake condition, it is possible to collect subsurface underflow. Groundwater use may be the best choice to avoid conducting regular heavy operation and maintenance work caused by the frequent change of river route.
- Also, existence of groundwater aquifers can be expected in northwestern part of Gelephu city because an alluvial fan develops in those areas. It can be judged to be possible to develop new irrigation area plus the existing one through the exploitation of groundwater.
- Comparative advantages of groundwater development are found in the possibility of shortening total length of conveyance canals by lifting groundwater from adjacent sites to the irrigation command area and leading to easier operation and maintenance work of irrigation facilities, and also of flexible planning to adjust number of drilling tube wells in response with demanded amount of water. On the contrary, pumping water cost beneficiary and related administration organizations.
- In Bhutan, since electricity distribution grids have significantly developed in parallel with hydro-power generation development, it is judged possible to use electricity for pumping up groundwater.
- However, in case of agricultural use of groundwater, it is required to establish the cost bearing system for management and operation/ maintenance of the pump facilities and the O/M organization. Hence, it is important to elaborate basic policy related to utilizing groundwater for agricultural purpose in parallel with the survey/ study/ analysis to identify economic/ technical

development possibility.

- Japan has ample experiences of constructing underground dams for irrigation purpose. The Figure 5.2.6 shows an image of underground dam. It is worthwhile to consider its applicability in southern Bhutan.
- Possibility of constructing an underground dam is found in the part of valley where sand and gravel layers have thickly been deposited, with comparatively gentle river-bed gradient, and the least permeable basement rocks / formations are exposed as outcrops or lie in shallow rock mass over both sides of the river banks.

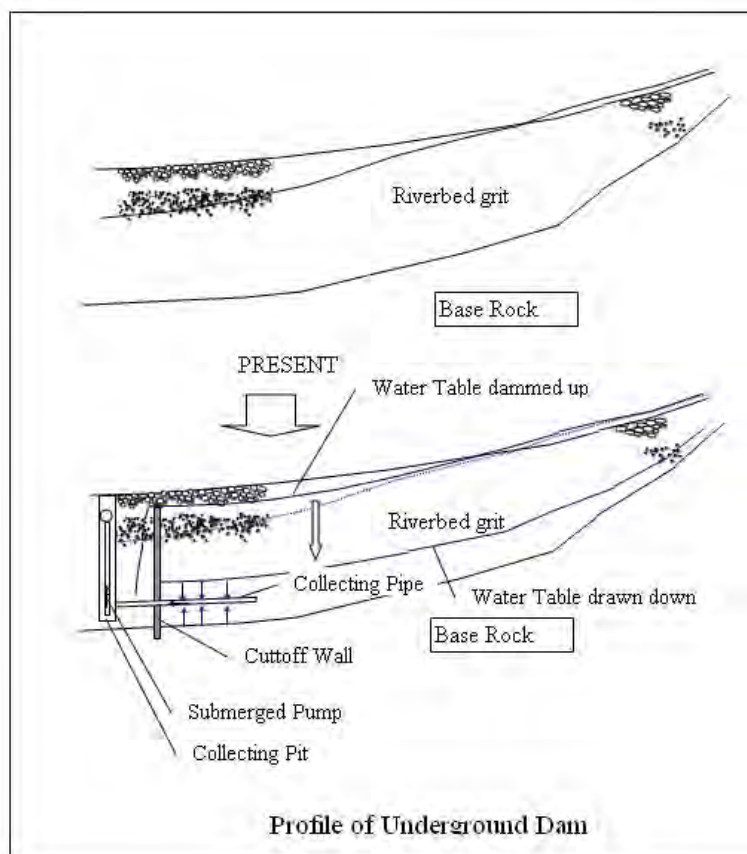


Figure 5.2.6 Image of an Underground Dam

- Figure 5.2.7 gives the possible sites where to construct an underground dam, judging from the survey result in Sarpang Dzongkhag, and Figure 5.2.8 is a photo showing the state of the valley in those sites. In and around sites, sand and gravel have been deposited over the width from 80 m to 120 m and around 1,000 m in length. Fractured rock-mass is observed as an outcrop on the left bank. This fractured rock contains a high percentage of fine particles. Low permeability is presumed. Assuming the mean width of the valley at 100 m, average water depth for use at 5 m and effective porosity at 15%, the volume of 75,000 m³ may be obtained as an effective storage capacity. The catchment area extends as small as 3.4 km², but the basin has high annual precipitation, thus recharging amount to the underground dam is considered sufficient.
- In addition, there find two currently unfunctioning irrigation areas at the left bank of this river (total area: 38.8ha, beneficiary: 52HH) and irrigating to those unfunctioned areas can also be counted.

Since a long-term survey/ study/ analysis is required to identify development possibility of groundwater development and water storage facilities mentioned above, it is inevitable for the time being to rely on river water to ensure agricultural water.

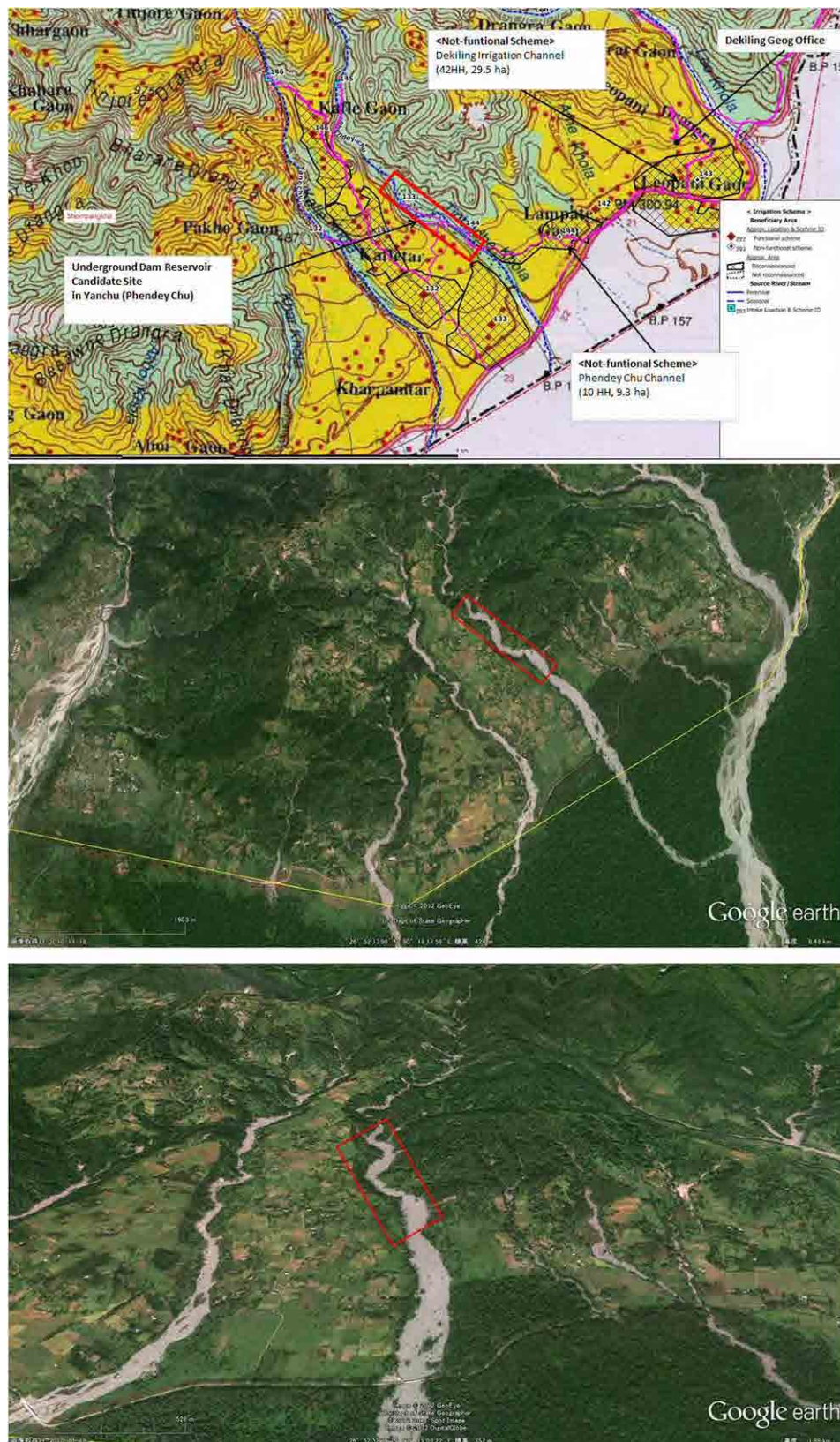


Figure 5.27 Candidate Sites of Developing Underground Dams in Sarpang Dzongkhag

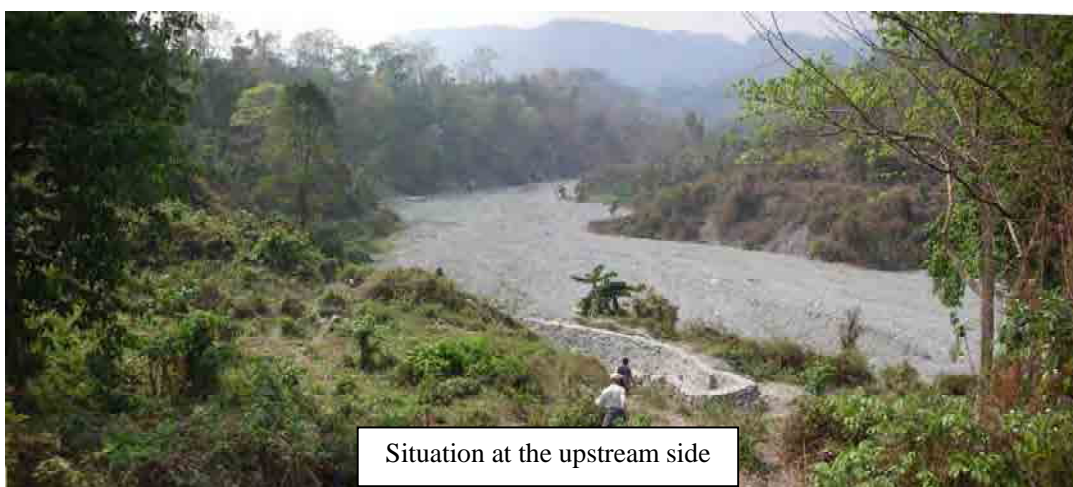


Figure 5.2.8 Current Situation of the Candidate Site of the Underground Dam

5.2.2 Approaches to Providing an Effective/ Efficient Irrigation System

Following approaches were taken to provide effective/ efficient irrigation system on the existing conditions.

(1) Providing efficient intake water

Considering the current development constraints such as steep river-bed gradient with small watershed areas, large fluctuation of river discharges within a short run-off period and a large amount of sand and gravel flushed out from the river basin, it is not easy to plan/ construct intake facilities technically/ economically so as to cope with all of such constraints. In the planning/ designing stages of the facilities, especially, it is required to examine materials of the facilities and construction method against abrasion and/ or breakage caused by flowing sand/ stone.

As to the intake methods adaptable in the areas, seven types as tabulated below are considered (for which detail comparison of each method is shown in Table 5.2.3).

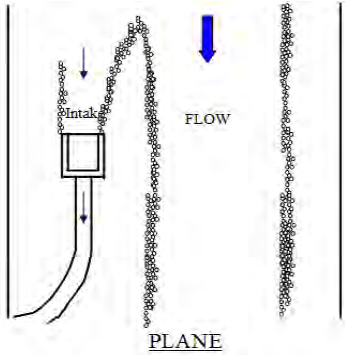
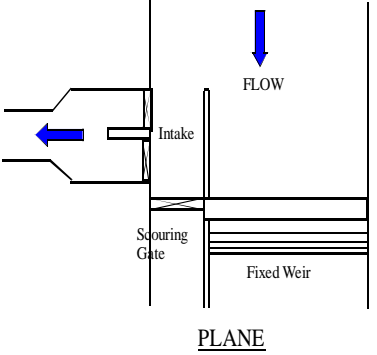
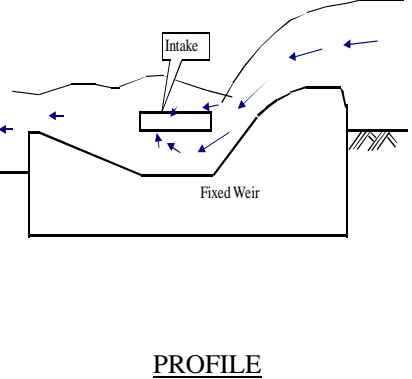
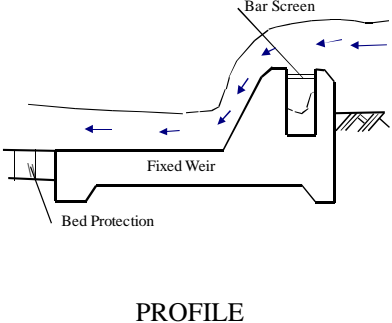
Table 5.2.2 Outline of Comparisons of Intake Method

Method of intake	Stability of intake	Construction cost	Outline
Natural intake	4	1	Though currently this method is the most popularly adopted method in Bhutan, an issue remains in terms of stable intake.
Intake weir	1	4	Though stable intake can be realized, construction cost is expected to be high and higher difficulty in the facility management.
Water cushion type	2	3	These are the intake facilities for torrential river/ streams with construction performances in Japan. (Detail planning/ designing process is referred to in the Japanese Technical Standard.
Bar-screen, intake beneath the bar			
Bar-screen, intake at rear part			
Overflow intake weir at angle of drip type			
Underflow collecting gallery	2	2	Since this facility is constructed underground, less structure part exposed over ground surface, structure itself is stable. It's imperative to judge adaptability at the site because function of the facility is heavily affected by the water holding capacity of aquifers and the fluctuations of surface and sub-surface water level.

Note ; As to the construction cost, cheaper one has lower number, so the "1" in numerical value indicates the cheapest one. As to the intake stability, higher stability has lower ranking, hence the "1" has the highest stability. Mutual comparison is difficult in the case of the construction cost because the cost is highly variable on the local conditions of the sites. Here this ranking was tried to make order, assuming the scale of the facility on the current river flow and topographic conditions.

The adaptability of each method is highly dependent on the topo-geologic conditions including river /bed gradient and water route at the candidate intake sites. Accordingly, in judging the actual adaptation, it is desirable to verify the real effect and function by constructing the possible methods on test-trial basis.

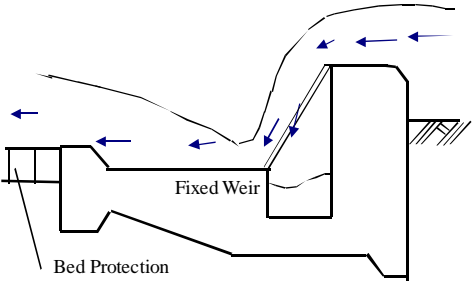
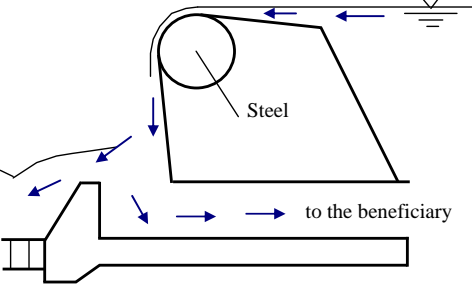
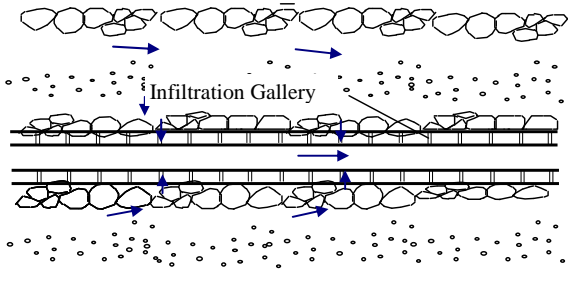
Table 5.2.3 Examination of Conceivable Intake Methods from River (1/2)

Intake type	Natural intake	Intake weir	Water cushion type)	Bar-screen, under-intake type
Structure				
	<ul style="list-style-type: none"> ■ Installing intake inlet making use of stable deep-gut or basin of waterfall to take water by making use of natural gravitational head. ■ In the mid-stream part of Japanese streams, as stream bank revetment has thoroughly been worked, water is taken from the side of the streams by water gates etc. 	<ul style="list-style-type: none"> ■ Water is taken by installing a fixed weir and scouring sluice (sand evacuation gate) in a traversing way to the stream to make back-water. 	<ul style="list-style-type: none"> ■ Installing an overflow weir in a traversing way to the stream consisting of sloped falling chute and downward water cushion, taking water from inlets installed at the side wall by keeping regular, stationary flow inside the water cushion. 	<ul style="list-style-type: none"> ■ Installing an overflow weir in a traversing way to the stream, attaching a bar-screen at the flat overflowing crest of the weir so as to collect water falling in between the slits of the screen.
Advantage	<ul style="list-style-type: none"> ■ Since any facility to traverse the stream is not needed it is possible to make the scale of the structure smaller, so it does not cost much. 	<ul style="list-style-type: none"> ■ The facility can keep necessary intake head, procure the required amount of water in proportion to the scale of beneficiary perimeter. ■ It is possible to mitigate sand/ gravel deposit cause by the installation of the weir through the scouring sluice. 	<ul style="list-style-type: none"> ■ It is possible to make mixing of sand/ gravel in irrigation water comparatively lower level at the intake point. 	<ul style="list-style-type: none"> ■ It enables to procure required water quantity in proportion to the scale of the beneficiary. ■ The structure causes less inhibiting effect to the stream flow and has a high stability of the facility against torrential flow during floods etc.

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Intake type	Natural intake	Intake weir	Water cushion type)	Bar-screen, under-intake type
Dis- advantage	<ul style="list-style-type: none"> ■ In the case of highly variable discharges, stable intake becomes difficult. ■ It becomes necessary to control surplus water flowing into the canal during floods, to take measures to treat surplus flowing. ■ Since huge amount of sand and gravel flow into the facility, methods of prevention and evacuation have to be considered. 	<ul style="list-style-type: none"> ■ Damages of scouring sluice is concerned at the sites where overwhelming floods occur. Also, damages to structures are worried caused by the inhibiting effect to the stream flow section due to resulting back water by the weir. 	<ul style="list-style-type: none"> ■ Water intake become impossible once stones and gravel are deposited at the part of water cushion. 	<ul style="list-style-type: none"> ■ Since mixing of sand/ mud is inevitable at bar-screen cases are arisen that require such sand elimination facility as sedimentation pond. ■ It becomes necessary to provide operation and maintenance work to eliminate clogging at bar-screen.
Adaptability to southern Dzongkhags	<ul style="list-style-type: none"> ■ This method has frequently been employed in southern areas though the stable intake is difficult. Wherever subsidence of the stream bed happens every time flood occurs, such maintenance/ repair is required as re-installation or fixing of gut line, thus difficulty arises from frequent measures to cope therewith. 	<ul style="list-style-type: none"> ■ Structure of this facility has considerable inhibiting part in the flow section of the stream under the condition of floods accompanying with drifting stones/ boulder, thus fairly high strength is needed to make the structure resistant to their impacts. 	<ul style="list-style-type: none"> ■ It is difficult to install this facility at the sites where the influence of sand/ gravel deposit to the area of water cushion is concerned. 	<ul style="list-style-type: none"> ■ Inhibiting action to disturb smooth flow in the stream flow section is rather small, leading to higher stability of the facility. ■ Necessity arises from strengthening resistance against drifting stones etc. Therefore, maintenance is essential, but stability of water intake can be maintained.
Future prospect of development etc	<ul style="list-style-type: none"> ■ The existing facilities have such problems as short penetration or insufficient revetment work. In other words, improvement in the stability of the structure may lead to economization of maintenance cost. Thus, improvement of the facility should be promoted. 	<ul style="list-style-type: none"> ■ Since provision of robust structure requires a high cost though the cost is variable with flow situation of the stream. Hereafter, it will be necessary to verify the compatibility/ feasibility of the facility plan in projects employing this method. 	<ul style="list-style-type: none"> ■ The sites where this facility can be installed are quite confined to those with narrow width of the stream-bed etc. 	<ul style="list-style-type: none"> ■ There is high possibility of adopting this method in taklai area, but generally the sites where this facility can be installed are quite confined to those with narrow width of the stream-bed etc.

Table 5.2.4 Examination of Conceivable Intake Methods from River (2/2)

Intake type	Bar-screen, back stream type	Overflow at angle of drip type	Infiltration Gallery
Structure	 <p style="text-align: center;"><u>PROFILE</u></p>	 <p style="text-align: center;"><u>PROFILE</u></p>	 <p style="text-align: center;"><u>PROFILE</u></p>
	<ul style="list-style-type: none"> ■ Installing an overflow weir in a traversing way to the stream, placing a screen over the chuting slope of the overflowing crest, taking water from the slit of the screen. ■ Outline of the structure is the same as the method shown in the under-intake type, but the difference lies in that the screen is installed over the slope of overflowing phase. 	<ul style="list-style-type: none"> ■ Installing an overflow weir in a traversing way to the stream, making the overflowing edge an arc, along which water chutes and taking it into a receiving ditch placed underneath the arc edge. 	<ul style="list-style-type: none"> ■ Perforated pipes or strainer tubes are buried at the deeper position than the variable floor of the stream-bed for collecting underflow. It has another objective of collecting water efficiently in drought season by installing a staunching wall to cut-off water leakage and to collect underground-stored water into the gallery. This concept is developed into the idea of underground dam. ■ Cases of taking water from the water collecting pipes buried inside erosion and torrent control dam (a facility to store washed out sand) are observed in Japan.
Advantage	<ul style="list-style-type: none"> ■ As the screen is installed over the downward slope, impact damages of the screen can be minimized. 	<ul style="list-style-type: none"> ■ As the overflow edge has been made an arc, a centrifugal force is exerted on the objects overflowing on the arc, so that sand mixing at the time of water intake can comparatively be reduced. 	<ul style="list-style-type: none"> ■ This facility does not make any protruded part inside the stream, risk of suffering from impact damages is limited (however, attention has to be made on the depth of installing collecting pipes).
Dis-advantage	<ul style="list-style-type: none"> ■ The water collecting ditch is placed at lower position, making water head loss equivalent to the lowered height and the construction cost is escalated as the thickness of apron increases. ■ Damages on water cushion is concerned 	<ul style="list-style-type: none"> ■ Quantity of intake depends on the scale of the facility, but it is relatively little as compared with that by other facilities. ■ When the stream discharge increases and flow velocity gets faster, the centrifugal force is also 	<ul style="list-style-type: none"> ■ Quantity of intake is determined by the diameter, laying gradient, length of water collecting tubes, permeability of related aquifers, groundwater level etc. On the other hand, it is needed to select the particle grading of the refilling material to be laid around the

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Intake type	Bar-screen, back stream type	Overflow at angle of drip type	Infiltration Gallery
	where the level of flood discharge becomes enormous.	augmented making intake itself more difficult.	culverts to avoid the possible clogging and choking of perforated holes to absorb groundwater. It follows that in order to procure the planned intake quantity it is required to make the total length of pipes longer.
Adaptability to southern Dzongkhags	■ Because disadvantage of this method lies in inferiority of intake function as compared with under-intake type in hydrological terms as well as from the scale of intake point of view, application of this method is denied.	■ Stable intake is possible by this method while discharge level is limited, but in cases that fluctuation of discharge gets larger, flow velocity in the stream also gets faster, thus making intake more difficult. Since variability of stream discharge is considered larger in the streams of southern areas, the application of this method to these streams seems difficult.	■ This method is worth examining its possibility of application in the sites where enormous amounts of sand and gravel are washed out.
Future prospect of development etc	Possibility of selection remains low.	Possibility of selection remains low.	■ It is desirable to consider the adaptability of collecting channel/ infiltration gallery. Strainer pipes made by Japanese manufacturers are costly but capacity of groundwater collection is also high and they seldom cause clogging. It is therefore desirable to verify the adaptability by means of such materials.

(2) Intake unification

Intake unification is a method of merging dispersed intakes installed in the same river/ stream, in which new water supply system is schemed by planning an integrated irrigation network. This method is effective for not only ensuring intake water but also for beneficial farmers from operation and maintenance point of view (referred to Figure 5.2.9). If the existing intake method is the natural intake, the stability of intake can be enhanced by this intake unification. Besides, it is expected to increase stability of the facility by constructing new intake facility.

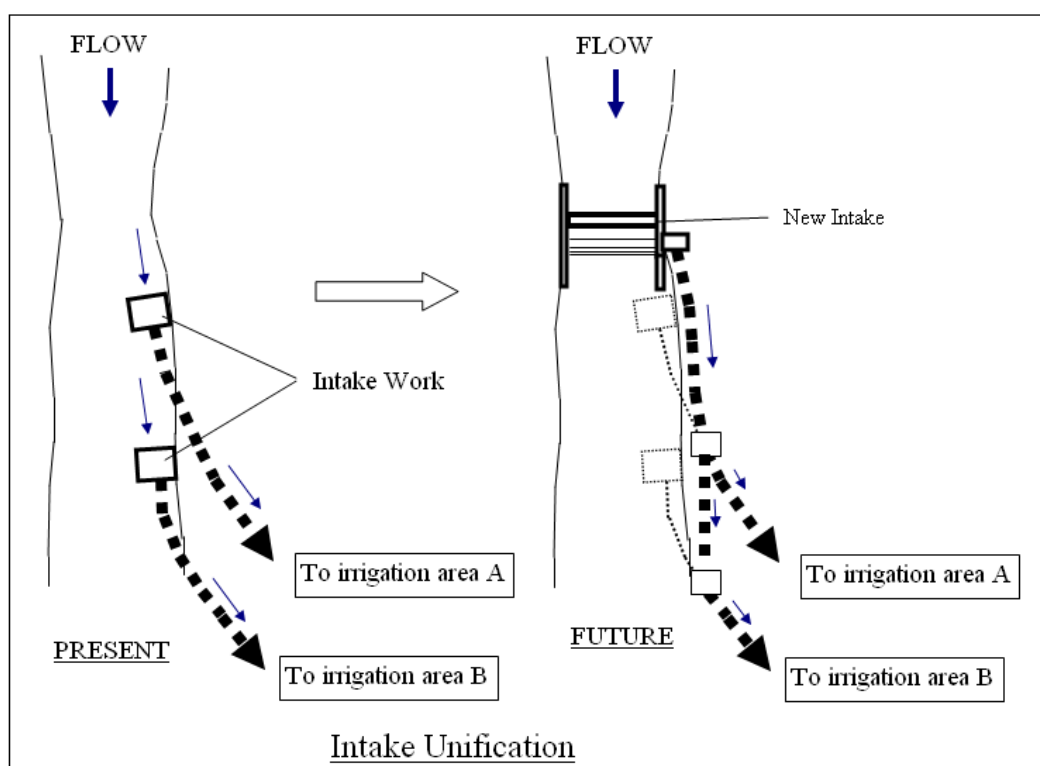


Figure 5.2.9 Illustration of Intake Unification

By extracting from the list of water source rivers in the inventory of Sarpang Dzongkhag, 13 sites are identified as those, which have possibility of intake unification. In the rehabilitation project planning, it is needed to study the unification possibility of each site by means of the topographic maps and survey of river conditions. The area and the number of beneficial farmers under one irrigation system are expected to increase by the unification of intake facilities and irrigation areas. So, need arises in establishing integrated operation and maintenance organization.

Table 5.2.5 Possible Irrigation Areas with Intake Unification in Sarpang Dzongkhag

Gewog	Imaginative United Structure No.	Name of the Channel ¹⁾	Water Source		Location ¹⁾	Canal Length Approx ³⁾ (Km)	Command Area ¹⁾		Beneficiary ¹⁾ (HH)	WUA ¹⁾	Present Status		Catchment Area of Intake ⁴⁾	Average Elevation of Beneficiary Area ⁵⁾	Agricultural Zone ⁶⁾	Expended Water Source after united	Remarks	
			Name ¹⁾	P: Permanent S: Seasonal			(Ac)	(ha)			Status ³⁾ (F: Functional)	Reason of non-functional ³⁾						
Bhur	UB-1	Ghalley kulo	Paithakhola	S	Ghalleygoan	5.00	90.00	36.42	29	No	F		4.6	436	F	Paithakhola		
		Limbo kulo	Paithakhola	S	Roadline	3.50	80.00	32.38	40	No	F		4.6	418	F			
		Monger Kulo	Paithakhola	S	Mongergoan	3.50	65.90	26.67	30	No	F		4.4	419	F			
			Total				235.90	95.47	99									
	UB-2	Siran Kulo	Aipowali	P	Juphrey	5.50	40.00	16.19	14	No	F		3.0	415	F	Aipowali		
		Beech Kulo	Aipowali	S	Juphrey	5.00	125.00	50.59	26	No	F (Non-F)	Intake was washed away	3.4	397	F			
		Puchar Kulo	Aipowali	S	Juphrey	5.00	135.00	54.63	26	No	F		3.4	370	F			
			Total				300.00	121.41	66									
	UB-3	Siran Kulo	Shitakhari	S	Jaruwa/ Dechenpelri	4.00	35.00	14.16	19	No	F		5.4	489	F	Shitakhari		
		Barasau Kulo	Shitakhari	S	Jaruwa/ Dechenpelri	4.50	36.00	14.57	21	No	F		5.9	443	F			
		Puchar Kulo	Shitakhari	S	Jaruwa/ Dechenpelri	3.00	20.00	8.09	13	No	F (Non-F)	Intake was washed away	6.0	473	F			
	Gelephu		Tarulay Irrigation channel	Tarulaychu	S	Dzomlingthang	2.00	50.39	20.39	25	No	F		4.1	387	F		
		Total				91.00	36.83	53										
Sershong		Lothuen irrigation channel	Taklaichhu	P	Lothuen	6.25	145.55	58.90	84	YES	F		90.1	276	F	Taklai	Beneficiary area of Taklai High Level	
Chuzagang	UC-1	Sherab choling	Kalikhola	P	Chasikher	2.00	150.00	60.70	25	No	Non-F	Supplied by C-2	-	260	F			
		Samdrup Chuyour(high level)	Takali	P	Dawathang	7.51	300.00	121.41	70	YES	F		90.0	255	Tr-H			
		Total						595.55	241.01	179								
		Phunsum Chuyour(low level)	Takali	P	Dawathang	5.41	700.00	283.28	350	YES	F		97.2	236	Tr-H, Tr-L	Taklai	Beneficiary area of Taklai Low Level	
		Karbitang	Sherabcholing	P	Karbitang	0.36	200.00	80.94	150	No	F		90.0	225	Tr-H			
		Total				900.00	364.22	500										
Dekiling	UDek-1	Gawaithang Iri.channel	Yangchu	S	Gawaithang	1.50	25.00	10.12	14	No	F		2.6	350	F	Yangchu		
		Yangchenphu Iri.Channel	Yangchenphu	S	Yangchenphu	3.00	90.00	36.42	33	No	F		0.4	483	F			
			Total				115.00	46.54	47									
	UDek-2	Norbuthang Iri.Channel	Phendeychu	S	Gawaithang	2.50	35.00	14.16	24	No	F		2.9	320	F	Phendeychu		
		Yangchenphu Iri.Channel	Phendey Chu	P	Yangchenphu	5.00	55.00	22.26	30	No	Non F (F)		1.7	402	F			
			Total				90.00	36.42	54									
UDek-3	Dhokhola Iri.Channel	Dhokhola	P	Dhokhola	2.00	21.00	8.50	24	No	F		12.5	389	F	Dhokhola			
	Dhokhola Iri.Channel	Dhokhola	P	Dhokhola	2.00	18.00	7.28	16	No	F		18.4	374	F				
		Total				39.00	15.78	40										
Sengye	USen-1	Mazan kulo	Sisty khola	P	Sisty A	6.00	46.95	19.00	25	No	F (Non F)	Under repairing	15.8	352	Tr-L	Sisty khola		
		Baral kulo	Sisty khola	P	Sisty A	4.00	59.05	23.90	24	No	F		16.2	336	Tr-L			
		Total				106.00	42.90	49										
Sershong	USer-1	Barshong irrigation channel (1)	Barshongchu	S	Barshong	3.00	25.00	10.12	14	No	F		1.6	319	Tr-H	Barthang chhuu		
		Barshong irrigation channel (2)	Barthang chhuu	S	Barshong	1.00	20.00	8.09	14	No	F		1.6	267	Tr-L			
		Barshong irrigation channel	Barthang	S	Barshong	2.00	48.00	19.43	22	No	F		24.3	263	Tr-L			
			Total				93.00	37.64	50									
	USer-2	Pemaling irri. channel	Norbulingchhu	S	Pemaling	2.50	95.00	38.45	40	No	F		2.4	320	F	Norbuling chhu		
		Norbuling irrigation channel	Norbuling chhu	S	Norbuling	3.00	96.40	39.01	53	No	F		2.7	317	F			
Norbuling irr. channel		Norbulingchhu	S	Norbuling	1.50	52.00	21.04	16	No	Non-F (F)		2.8	295	F				
		Total				243.40	98.50	109										
Shompangkha	Usho-1	Kafley kholo	Kafley khola	S	Darjaythang	2.50	50.00	20.23	24	No	F		3.0	297	F	Doray khola		
		Daoray kholo	Doray khola	S	Kaencholing	2.00	132.00	53.42	93	No	Non-F	River bed drop	2.2	390	F			
		Total				182.00	73.65	117										
Umling	UU-1	Dungmin Iri. channel Upper	Langar chu	S	Dungmin	1.00	70.00	28.33	26	No	F		3.2	260	Tr-H	Taklai	The present main water source, Langar chu has no sufficient water.	
		Dungmin Iri. channel Lower	Langar chu	S	Dungmin	1.00	52.00	21.04	16	No	F		5.4	261	Tr-H			
		Dangling Iri.channel Upper	Langar chu	S	Dangling	3.00	24.00	9.71	32	No	Non-F (F)		3.7	279	Tr-H			
		Dangling Iri. channel Lower	Langar chu	S	Dangling	3.50	82.00	33.18	36	No	Non-F (F)		4.1	259	Tr-H			
		Rejuk Serchu Irrigation channel	Serchu	P	Rejuk	2.00	85.00	34.40	27	No	F		2.5	235	Tr-H			
		Total				313.00	126.67	137										

1) Posted from inventory "Compiled Irrigation information 2010" obtained from DAO Sarpang.

2) Identified through field survey and interview

3) Status in () is identified through field survey.

4) Calculated with SRTM 90m DEM and the intake location.

5) Average elevation of SRTM 90m DEM data in the estimated beneficiary area.

6) Agricultural Zone

H: Hill

F: Fan

Tr-L: Lower Terrace

LLTr: Lowland River Terrace

Tr-H: Higher Terrace

(3) Effective delivery canal

What has been observed as current situation on the existing delivery canal includes HDPE pipes (High Density Polyethylene Pipe, a kind of flexible pipes that this has increasingly been utilized in Bhutan in recent years) have been used as conventional rehabilitation measures at the points where canal has been collapsed. However, it is observed, due to insufficient protection for the currently installed pipes, water leakage evolves from the coupling parts of them. Similarly, such leakages have been observed as that the foundations of their pipes have readily been scoured by river flow owing to insufficient foot protection in the cross canal structure such as in torrential valleys (see the Figure 5.2.10).



Figure 5.2.10 Aqueduct in Gelephu (Sarpang) Tarulay Irrigation Area

Considering current conditions, the effective measures to prevent water leakage from delivery canal are summarized as follows (see Table 5.2.6).

Table 5.2.6 Possible Measures for Realizing an Efficient Canal Structure

Type of measures	Concrete measures to realize an efficient canal structure	Recommendation
Adoption of pipeline	It is desirable to adopt pipelines instead of open canals for prevention of water leakage. However, from maintaining function of the pipeline, current construction work is still incomplete, and necessity arises to prevent water leakage from joint-couplings and pipe body.	Ample experiences of utilizing the pipe for agricultural water delivery have been accumulated in Japan. Design standard has been prepared. Based on this standard, as a baseline, it is desirable to render technical support on survey, design and construction in the adopting pipe canal.
Improving open canals	This system is inferior from leakage point of view as compared with pipe canal. It also limits land use. However, it turns out to be more economical depending on the design discharge and topographic condition. As to the section of earth canals, cut-off structure is recommended to prevent leakage (wet masonry, concrete structure).	Promoting standardization of canal type and also use of ready-made canal structure manufactured in factory, thereby facilitating construction work, shortening construction period and procuring construction quality.
Canal protection from slope collapse	Adoption of slope face revetment work as well as concrete lining of pipeline work, converting into culvert structure.	Specifying the sections where slopes have been collapsed, converting the canal in those sections into underground structure such as pipeline or culvert.
Traversing work over torrential valleys, etc	Sufficient foot protection of foundations and revetment work are required. It may be possible to make time-interval of rehabilitation work longer.	Preparing design standard and technical manual, etc. Providing systematic procurement arrangement of construction machine.

(4) Effective on-farm conditions

Current terraced paddy fields have higher infiltration. It is important to control irrigation water requirement by preventing water leakage in on-farm level in parallel with ensuring water sources and intake water. Existence of gravel and stone is also a detrimental factor for farming practices. Soil erosion caused by plot-to-plot irrigation is another concern (see Figure 5.2.11).



Figure 5.2.11 Current Conditions of Paddy Fields (Dekiling Gewog in Sarpang Dzongkhag)

(photo in the left: high content of gravel/ stone in the plot. Photo in the right: clayey soil overflows to down plots)

The following measures are necessary to improve conditions of paddy field into productive ones where water leakage can be controlled:

- To investigate current soil conditions in paddy field to elaborate suitable method of soil and soil layer improvement based on the conditions,
- To promote establishment and extension of on-farm water management techniques applicable to the current terraced paddy fields,
- To study possibility of land readjustment, integration of the plots, so as to create an efficient farming toward farm mechanization,
- To eliminate stone/ gravel from the fields so as to provide effective farm practices,
- To promote soil layer improvement by means of soil dressing and soil compaction,
- To construct sedimentation basin in irrigation areas so as to serve as deposits of clayey soil and temporal water source in emergency drought.

(5) Approaches to providing proper water management

Current major issues encountered in the irrigation system are related to the functional problems of intake and delivery facilities and occurrence of much water loss at on-farm level as mentioned above. Review on current water allocation and use, whether irrigation water distribution has been well-operated or not, is also necessary. Invalid water distribution and release are not serious problem in the period of abundant water resources in rainy season. But, it arises as grave issues in less rainfall period and drought season. Proper water management techniques should be diffused among WUA or water users groups in parallel with executing irrigation rehabilitation project.

5.3 PRELIMINARY ANALYSIS ON THE VALIDITY OF REHABILITATING THE EXISTING IRRIGATION SYSTEM

5.3.1 Development Potential of the Existing Irrigation Sites

(1) Possible sites for double cropping of paddy

Dry paddy cropping area can be generally estimated based on the seasonal available water amount in dry season. To estimate its water amount, however, it is needed to measure the river discharge, accumulate its data and analyze them. At present, there is no river discharge measurement in the river running in the dzongkhag. Besides the existing river water, available water can be obtained from other new water resource development such as groundwater, pond and storage dam.

It is hard to estimate dry paddy cropping area in southern zone since no river discharge is measured in the relevant rivers. However, it was tried to calculate from the existing available data in this survey; by assuming seasonal river discharge, dry season cropping area was estimated by the existing irrigation site. (Survey team measured the river discharge by simple method at the existing intake sites with permanent rivers in April 2012. Measurement records are shown in Appendix-B.) Dry paddy cropping area was estimated by simple water balance study between estimated available river discharge amount and irrigation water requirement. The size of area was estimated by the existing site, not includes extendable area brought from new water resources development and unification of intake sites. If such development plans are newly planned, irrigable area should be newly estimated by measuring river discharge and analyzing available water amount.

Out of 79 existing irrigation sites, 35 sites have permanent river as water source where may introduce dry paddy. To estimate possible size of area for those sites, available water amount was estimated from discharge measured in April as mentioned above. On the other hand, making dry paddy cropping pattern, irrigation water requirement was calculated. Irrigable area for dry paddy was calculated from rough water balance study between the estimated available amount and the irrigation water requirement. (Dry paddy cropping area in Taklai irrigation sites of Chuzagang gewog was not estimated since Taklai irrigation system rehabilitation project is under planning.)

Assumption of river discharge

According to the analysis on leaning trend of river discharge in dry season (referred to the (2) Hydrological condition, 3.1.3 Meteorological and Hydrological Condition), river discharge in January may be increased by 30-40% of that in April. Considering this condition, river discharge in January is estimated at 35% increase of April's measurement in this survey.

Calculation of irrigation water requirement for dry paddy

By applying the same method as in the section 4.2.2 "Estimate of Present Irrigation Water Requirement", water requirement for dry paddy is calculated.

Estimate of dry paddy cropping area

Amount of intake water from the river is dependent on intake method. Although some effective intake methods are proposed as mentioned in the section 5.2, suitable intake method would be designed through detail survey and analysis in each intake site. For this study purpose, natural

intake method was applied to each site, as well as in the present one. Amount of intake water was assumed 30% of the river discharge. From rough water balance study between the amount of intake water and the irrigation water requirement, dry paddy irrigable area was estimated. Based on the estimate, dry paddy cropping area is estimated for the 35 irrigation sites whose have a permanent river as water source. Estimated total area is as follows (each area is shown in Table 5.3.1).

Irrigation sites	Command area (ha)	Wet paddy area (ha)	Dry paddy area (ha)
Present (total of 79 sites)	2,328.3	2,328.3	Not cropped
Plan (total of 74 sites)*	1,782.0	1,782.0	220.2

Note; *Except 5 sites in Chuzagang Gewog.

(2) Development potential of the irrigation sites and selection of priority sites

Development potential of the 79 sites including double cropping is evaluated. Based on the evaluation, priority sites for rehabilitation of the existing irrigation system are selected for next development step of the rehabilitation project. In general, development potential of each site should be evaluated based on the overall natural/ socio-economic factors such as geology, soil and water source, size of the irrigable area, degree of damaged irrigation facilities, economic validity, intention of farmers and farmers organization, easiness of marketing access, etc. Besides these, administrative factor should be incorporated in the evaluation process. However, it would be difficult to get all data/ information related to those factors in this survey level. Then, an evaluation is made based on the data/ information collected in this survey. It is conducted by the present irrigation sites in the following process.

Evaluation process is planned 1) items to be screened for evaluation are picked from collected data/ information, 2) criteria is designed to screen the items, 3) items are assessed by the sites based on the criteria, 4) By totaing the assessment, each site is totally evaluated.

- 1) Items to be screened for evaluation are picked from the data/ information items collected in irrigation system inventory and site survey. Picked items are as follows, considering that the items directly influence on the evaluation process and be easy to rate numerically.

Canal length ; It influences direct effects on the working scale of rehabilitation and operation and maintenance. If canal length becomes longer, collapse risk in the route may become higher, and operation and maintenance works comes harder.

Command area ; Total irrigation area including double cropping area directly influences paddy crop production. Larger command area bring larger amount of crop production under the irrigation.

Access to trafficable roads ; Easiness of access to trafficable roads was investigated in each irrigation site by interviewing with gewog extension staff about access method and distance to nearest traffic roads. It influences on access to market channel of produced crops and agricultural input materials. If irrigation site is easy to access to trafficable road, crop production activity would become active, so that, it is expected to increase crop production.

2) Criteria to assess each item are designed as follows. Assessment is made on three levels. Score is given to each level.

Level	Score	Potential	Canal length (km)	Command area (ha)	Access to trafficable road*
I	1	Low	More than 3.5 km	Less than 25 ha	Remote area. One day or more than 1.0 day.
II	2	Moderate	More than 2.5 km, Less than 3.5 km.	Less than 35 ha, More than 25 ha	From 1.0 km to 5.0 km on foot
III	3	High	Less than 2.5 km	More than 35 ha	Adjacent to the road, Less than 1.0 km

Note: *Interviewed by JICA survey team. Criteria are designed on the average: canal length=2.6 km, command area=29 ha.

3) Each site is rated and score is given.

4) Each site is overall rated by adding its score (see Tables 5.3.2 and 5.3.3). The assessment is relative for the existing irrigation site.

The number of high potential site is counted 16 sites. These sites may be considered to be priority site for promoting rehabilitation project of existing irrigation system.

The above evaluation is conducted in the existing irrigation site basis. If new development ideas such as unification of the intake sites and new water resources development will be planned, development potential should be evaluated by designing a new assessment method.

Table 5.3.1 Estimate of Dry Paddy Cropping Area in the Existing Irrigation Site with Permanent River

Gewog	No.	Name		Command area (ha)	Percor-ation type	Water source		Estimated irrigable area (ha)	
		Channel	Location			Status (*1)	Discharge in Apr. (lit/sec) (*2)		
Senge	Sen-1	Baral kulo	Sisty A	23.9	III	P	468	8.1	
	Sen-2	Mazan khola	Juphrey	19.0	III	P	468	8.1	
	Sen-3	Upper Senghe kulo	Hatikhuar	14.6	III	P	2	0.0	
	Sen-4	Koigaon kulo	Koigaon	14.4	III	P	3	0.1	
	Sen-5	Rumdali kulo	Sisty B	8.9	III	P	468	8.1	
Hiley	H-1	Gurung khola kulo3	Hilley	15.1	III				
	H-2	Hadzain kulo	Khopitar	8.9	III	P	90	1.6	
	H-8	Chuwam khola kulo 1	Hilley	3.8	III				
Shompangkha	Sho-1	Daoray kulo	Kuencholing	53.4	III				
	Sho-3	Lower Norbugang	Darjaythang	34.4	II				
	Sho-4	Kafley khulo	Darjaythang	20.2	III				
	Sho-7	Jaidhan Khulo	Pakhay	9.0	III				
Dovan	Dov-1		Thrulokhola	12.1	I	P	2	0.1	
	Dov-2		Batralkhola	6.1	II	P	10	0.4	
	Dov-4		Batchkhola	5.7	II	P	579	5.7	
	J-1	Basghari	Daragaon	42.5	II	P	10	0.4	
Jigmechoeling	J-2	Panitey Kulo	Saundaley	36.4	II	P	2	0.1	
	J-3	Dharey Kulo	Saundaley	20.2	II	P	2	0.1	
	J-4	Jame Kulo(3)	Daragaon	12.1	III	P	10	0.2	
	J-5	Gumi Kulo	Samapagang	12.1	III	P	13	0.2	
	J-6	Dawa Kulo	Samapagang	12.1	II	P	30	1.2	
	J-10	Nado Kulo	Samkharn	10.1	II	P	30	1.2	
	J-15	Sepai Kulo	Daragaon	9.2	II				
	J-16	Jante Kulo(1)	Daragaon	8.5	II	P	10	0.4	
	J-23	Tharokuloo	Gongdara	7.9	II				
	J-24	Tharokulo	Gongdara	7.3	II	P	2	0.1	
	Dekiling	Dek-1	Hilley Khora	Juphrey	205.0	III			
		Dek-2	Yangchenphu	Yangchemphu	36.4	III			
		Dek-3	Dekiling	Dekiling	29.4	II			
Dek-4		Bichkoin	Bichpani	28.3	III				
Dek-5		Yangchuenphu	Yangchuenphu	22.3	III	P	10	0.2	
Dek-6		Norbuthang	Gawaithang	14.2	III				
Dek-7		Rathey Khola	Ratepani	12.1	III	P	808	12.1	
Dek-8		Gawaithang	Gawaithang	10.1	III				
Dek-10		Phenley	Trashiling	9.3	III				
Dek-11		Ratey	Ratey	8.7	III	P	808	8.7	
Dek-12		Dholkola	Dholkola	8.5	II	P	486	8.5	
Dek-13		Dholkola	Dholkola	7.3	II	P	255	7.3	
Serzhong		Ser-1	Lothuen	Lothuen	58.9	III	P	3,390	58.9
		Ser-2	Norbuling	Norbuling	39.0	III			
	Ser-3	Pemaling	Pemaling	38.5	III				

Gewog	No.	Name		Command area (ha)	Percor-ation type	Water source		Estimated irrigable area (ha)	
		Channel	Location			Status (*1)	Discharge in Apr. (lit/sec) (*2)		
Bhur	B-1	Puchar Kulo	Juphrey	54.6	II				
	B-2	Beech Kulo	Juphrey	50.6	III				
	B-3	Ghalley kulo	Ggalleygoan	36.4	III				
	B-4	Limbo kulo	Roadline	32.4	III				
	B-5	Monger kulo	Mongergoan	26.7	III				
	B-6	Siran kulo	Juphrey	16.2	II	P	18	0.7	
	B-7	Barasan kulo	Jaruwa/Dech.	14.6	III				
	B-8	Siran kulo	Jaruwa/Dech.	14.2	III				
	B-11	Puchar kulo	Jaruwa/Dech.	8.1	III				
	Gelephu	G-1	Sonamgatshe & Ratenling	Raptenling	86.1	I	P	1,082	74.3
		G-2	Passangchu	Lower Pelrihang	32.1	II	P	-	
G-3		Dhulachu	Lower Pelrihang	25.0	II				
G-4		Dhulachu	Upper Pehihang	22.9	II				
G-5		Tarulay	Dzomlingthang	20.4	II				
Serzhong	Ser-4	Pangkhar	Pangkhar	21.0	III				
	Ser-6	Norbuling	Norbuling	21.0	III				
	Ser-7	Barshong	Barshong	19.4	III				
	Ser-8	Kingaling	Kingaling	18.2	II				
	Ser-9	Pangkhar	Pangkhar	16.2	III				
	Ser-12	Barshong (1)	Barshong	10.1	II				
	Ser-13	Barshong (2)	Barshong	8.1	II				
	Ser-15	Sershong	Sershong	6.1	II				
Chuzargang	C-1	Phunsun Low	Low Dawahang	283.3	II	P	-		
	C-2	Samdrop Choyour	High Dawahang	121.4	II	P	-		
	C-3	Karbitang	Karbitang	60.7	I	P	-		
	C-4	Sherab Choling	Chasikher	60.7	II	P	-		
	C-5	Masimikhola	Chasikher	20.2	II				
Umiling	U-1	Rejuk Serchu	Rejuk	34.4	II	P	33	1.3	
	U-2	Dangling Lower	Dangling	33.2	II				
	U-4	Dungmin Upper	Dungmin	28.3	III				
	U-5	Tashithang Karchu	Tashithang	25.9	II				
	U-6	Dugmin Lower	Dugmin	21.0	II				
	U-7	Chubarhang Seelchu	Chubarhang	19.0	II				
	U-8	Thongiazor Karchu	Thongiazor	17.8	II				
	U-9	Lingar Dap	Lingar	16.2	II	P	44	1.7	
	U-10	Gadhen Lower	Gadan	15.4	II	P	25	1.0	
	U-11	Rjuk Karchu	Rejuk	12.6	II				
	U-12	Dangling Upper	Dangling	9.7	II				
	U-14	Pantharey	Dangling	6.9	II				
	Taraythang	T-1	Yoezergang-Singi Lower	Yoezergang	10.5	III	P	28	0.5
		T-2	Tashichhiling Lower	Tashichhiling	9.3	II	P	42	1.7
T-4		Tashichhiling-Singi Upper	Tashichhiling	5.3	II				

Note: (*1) Status: P: Permanent river (*2) Discharge was observed in April by JICA survey team

Table 5.3.2 Development Potential in the Existing Irrigation Sites (1/2)

Gewog	No.	Nu. of original list	Name of the Channel	Water Source P or S (*1)	Canal Length (Km)	Command Area		Beneficiary (HH)	Canal Rating	Padding cropping area			Access to road				Total Rating (*5)	Class of IRR (%) (*6)	
						(Ac)	(ha)			Wet	Dry	Total	Rating	Distance (km) (*2)	Access time (*3)	Traveling way (*4)			Rating
Bhur	B-1	297	Puchar Kulo	S	5.00	135.00	54.63	26	I	54.6		54.6	III	0.0	0	-	III	7	IV
	B-2	296	Beech Kulo	S	5.00	125.00	50.59	26	I	50.6		50.6	III	0.0	0	-	III	7	III
	B-3	286	Ghalley kulo	S	5.00	90.00	36.42	29	I	36.4		36.4	III	0.0	0	-	III	7	I
	B-4	291	Limbo kulo	S	3.50	80.00	32.38	40	II	32.4		32.4	II	0.0	0	-	III	7	II
	B-5	292	Monger Kulo	S	3.50	65.90	26.67	30	II	26.7		26.7	II	0.0	0	-	III	7	I
	B-6	295	Siran Kulo	P	5.50	40.00	16.19	14	I	16.2	0.7	16.9	I	0.0	0	-	III	5	I
	B-7	299	Barasau Kulo	S	4.50	36.00	14.57	21	I	14.6		14.6	I	0.0	0	-	III	5	I
	B-8	298	Siran Kulo	S	4.00	35.00	14.16	19	I	14.2		14.2	I	0.0	0	-	III	5	I
	B-11	300	Puchar Kulo	S	3.00	20.00	8.09	13	II	8.1		8.1	I	0.0	0	-	III	6	I
Chuzagang	C-1	130	Phunsum Chuyour (low level)	P	5.41	700.00	283.28	350	II			0.0	III	0.0	0	-	III	8	
	C-2	129	Samdrup Chuyour (high level)	P	7.51	300.00	121.41	70	I			0.0	III	0.0	0	-	III	7	
	C-3	131	Karbitang	P	0.36	200.00	80.94	150	III			0.0	III	0.0	0	-	III	9	
	C-4	128	Sherab choling	P	2.00	150.00	60.70	25	III			0.0	III	0.0	0	-	III	9	
	C-5	127	Masinikhola	S	1.00	50.00	20.23	10	III			0.0	I	0.0	0	-	III	7	
Dekiling	Dek-1	136	Hilley Khola Irri.channel	S	3.00	506.55	205.00	36	II	205.0		205.0	III	0.0	0	-	III	8	V
	Dek-2	146	Yangchenphu Irri.Channel	S	3.00	90.00	36.42	33	II	36.4		36.4	III	0.0	0	-	III	8	IV
	Dek-3	143	Dekiling Irri.channel	S	3.00	72.53	29.35	42	II	29.4		29.4	II	0.0	0	-	III	7	III
	Dek-4	135	Bichkhola Irri.channel	S	2.00	70.00	28.33	43	III	28.3		28.3	II	0.0	0	-	III	8	V
	Dek-5	145	Yangchuenphu Irri.Channel	P	5.00	55.00	22.26	30	I	22.3	0.2	22.4	I	0.0	0	-	III	5	I
	Dek-6	133	Norbuthang Irri.Channel	S	2.50	35.00	14.16	24	III	14.2		14.2	I	0.0	0	-	III	7	I
	Dek-7	139	Ratey Khola Channel	P	3.00	30.00	12.14	16	II	12.1	12.1	24.2	I	0.5	15	On foot	III	6	II
	Dek-8	132	Gawaithang Irri.channel	S	1.50	25.00	10.12	14	III	10.1		10.1	I	0.0	0	-	III	7	I
	Dek-10	144	Phendey Chu Channel	S	1.50	23.00	9.31	10	III	9.3		9.3	I	0.0	0	-	III	7	I
	Dek-11	134	Ratey Irri.Channel	P	5.00	21.50	8.70	100	I	8.7	8.7	17.4	I	0.0	0	-	III	5	I
	Dek-12	137	Dholkhola Irri.Channel	P	2.00	21.00	8.50	24	III	8.5	8.5	17.0	I	0.0	0	-	III	7	I
	Dek-13	138	Dhokhola Irri.Channel	P	2.00	18.00	7.28	16	III	7.3	7.3	14.6	I	0.0	0	-	III	7	I
	Dovan	Dov-1	100	-	P	2.50	30.00	12.14	18	III	12.1	0.1	12.3	I		2days	On foot	I	5
Dov-2		101	-	P	2.00	15.00	6.07	9	III	6.1	0.4	6.5	I				I	5	I
Dov-4		86	-	P	1.00	14.00	5.67	10	III	5.7	5.7	11.4	I		3days	On foot	I	5	II
Gelephu	G-1	226	Sonamgatshel & Raptening channel	P	2.00	212.82	86.13	85	III	86.1	74.3	160.4	III	0.0	0	-	III	9	V
	G-2	227	Passangchu Irrigation Channel	P	2.50	79.40	32.13	21	III	32.1		32.1	II	0.0	0	-	III	8	IV
	G-3	229	Dhulachu Irrigation Channel II	S	1.50	61.85	25.03	23	III	25.0		25.0	II	0.0	0	-	III	8	V
	G-4	228	Dhulachu Irrigation Channel I	S	1.50	56.65	22.93	19	III	22.9		22.9	I	0.0	0	-	III	7	V
	G-5	233	Tarulay Irrigation channel	S	2.00	50.39	20.39	25	III	20.4		20.4	I	0.0	0	-	III	7	III
Hilley	H-1	3	Gurung Khola Kulo 3	S	1.50	37.19	15.05	15	III	15.1		15.1	I	0.5	20	On foot	III	7	II
	H-2	38	Hadzari Kulo	P	2.00	21.95	8.88	10	III	8.9	8.9	17.8	I	5.0	120	On foot	II	6	I
	H-8	4	Chuwan Khola Kulo 1	S	1.00	9.44	3.82	10	III	3.8		3.8	I				II	6	I
Jigmecholing	J-1	175	Basghari	P	1.50	105.00	42.49	12	III	42.5	0.4	42.9	III	1.0	20	On foot	II	8	V
	J-2	184	Panitey Kuloo	P	1.00	90.00	36.42	25	III	36.4	0.1	36.5	III	1.0	15	On foot	II	8	V
	J-3	185	Dharey Kuloo	P	0.50	50.00	20.23	12	III	20.2	0.1	20.3	I	1.0	15	On foot	II	6	V

(*1) P: Permanent S:Seasonal (*2) Distance from irrigation area to adjacent road. (*3) Traveling time (min or days) (*4) Traveling way (on foot or power tiller beneficiary area to road (km) Potential I: Low (score=1), II: Medium (2), III: High (3) (*5) Total score of potential: 3,4(low), 5,6,7(medium), 8,9 (high) (*6) Class of IRR: I: less than 5%, II: from 5% to 10%, III: from 10% to 15%, IV: from 15% to 20%, V: more than 20%

Table 5.3.3 Development Potential in the Existing Irrigation Sites (2/2)

Gewog	No.	Nu. of original list)	Name of the Channel	Water Source P or S (*1)	Canal Length (Km)	Command Area		Beneficiary (HH)	Canal Rating	Padding cropping area			Access to road				Total Rating (*5)	Class of IRR (%) (*6)	
						(Ac)	(ha)			Wet	Dry	Total	Rating	Distance (km) (*2)	Access time (*3)	Traveling way (*4)			Rating
Jigmecholing	J-4	168	Jante Kuloo(3)	P	2.50	30.00	12.14	21	III	12.1	0.2	12.3	I	1.0	15	On foot	II	6	I
	J-5	217	Gumti Kuloo	P	1.00	30.00	12.14	15	III	12.1	0.2	12.4	I	1.0	30	On foot	II	6	III
	J-6	224	Dawa Kuloo	P	1.00	30.00	12.14	10	III	12.1	1.2	13.3	I	1.0	30	On foot	II	6	IV
	J-10	225	Nado kuloo	P	2.50	25.00	10.12	10	III	10.1	1.2	11.3	I	1.0	20	On foot	II	6	I
	J-15	172	Sepai Kuloo	S	0.20	22.80	9.23	11	III	9.2		9.2	I	1.0	15	On foot	II	6	V
	J-16	166	Jante Kuloo(1)	P	3.50	21.00	8.50	12	II	8.5	0.4	8.9	I	0.5	15	On foot	II	5	I
	J-23	148	Tharokuloo	P	3.00	19.50	7.89	13	II	7.9		7.9	I		2 days	On foot	I	4	I
	J-24	165	Hiti kuloo	P	1.50	18.00	7.28	12	III	7.3	0.1	7.4	I	1.0	30	On foot	II	5	I
Sengye	Sen-1	240	Baral kulo	P	4.00	59.05	23.90	24	I	23.9	8.1	32.0	II	0.0	0	-	III	6	II
	Sen-2	239	Mazan kulo	P	6.00	46.95	19.00	25	I	19.0	8.1	27.1	II	0.0	0	-	III	6	I
	Sen-3	234	Upper Senghe Kulo	P	1.00	36.10	14.61	20	III	14.6		14.6	I	0.5	20	On foot	III	7	IV
	Sen-4	236	Koigaon kulo	P	2.50	35.50	14.37	18	III	14.4	0.1	14.5	I	0.0	0	-	III	7	I
	Sen-5	238	Rumdali kulo	P	3.00	22.05	8.92	14	II	8.9	8.1	17.0	I	0.3	10	On foot	III	7	I
Sershong	Ser-1	266	Lothuen irrigation channel	P	6.25	145.55	58.90	84	I	58.9	58.9	117.8	III	0.5	20	On foot	III	8	V
	Ser-2	264	Norbuling irrigation channel	S	3.00	96.40	39.01	53	II	39.0		39.0	III	0.5	20	On foot	III	8	V
	Ser-3	263	Pemaling irri. channel	S	2.50	95.00	38.45	40	III	38.5		38.5	III	1.0	40	On foot	III	7	V
	Ser-4	259	Pangkhar irrigation channel	S	2.50	52.00	21.04	16	III	21.0		21.0	I	0.5	20	On foot	III	7	II
	Ser-6	265	Norbuling irr. channel	S	1.50	52.00	21.04	16	III	21.0		21.0	I	0.5	20	On foot	III	7	V
	Ser-7	257	Barshong irrigation channel	S	2.00	48.00	19.43	22	III	19.4		19.4	I	0.5	20	On foot	III	7	II
	Ser-8	267	Kingaling irr. channel	S	1.50	45.00	18.21	22	III	18.2		18.2	I	1.0	60	On foot	III	7	IV
	Ser-9	258	Pangkhar irrigation channel	S	2.00	40.00	16.19	16	III	16.2		16.2	I	0.5	20	On foot	III	7	I
	Ser-12	255	Barshong irrigation channel (1)	S	3.00	25.00	10.12	14	II	10.1		10.1	I	0.5	20	On foot	III	6	I
	Ser-13	256	Barshong irrigation channel (2)	S	1.00	20.00	8.09	14	III	8.1		8.1	I	0.5	20	On foot	III	7	I
	Ser-15	253	Sershong irrigation channel	S	2.00	15.00	6.07	12	III	6.1		6.1	I				III	7	I
	Shompangkha	Sho-1	112	Daoray kholo	S	2.00	132.00	53.42	93	III	53.4		53.4	III	0.0	0	-	III	9
Sho-3		108	Lower Norbugang kholo	S	1.00	85.00	34.40	12	III	34.4		34.4	II	0.0	0	-	III	8	V
Sho-4		105	Kafley kholo	S	2.50	50.00	20.23	24	III	20.2		20.2	I	0.0	0	-	III	7	I
Sho-7		114	Jaidhan Kholo	S	2.00	22.33	9.04	12	III	9.0		9.0	I	0.0	0	-	III	7	I
Tarithang	T-1	305	Yoezergang-Singi Khola Lower	P	1.50	26.00	10.52	14	III	10.5	0.5	11.0	I	1.5	30	On foot	III	7	I
	T-2	302	Tashichhiling Lower Canal	P	1.50	23.00	9.31	7	III	9.3	1.7	11.0	I				III	7	I
	T-4	301	Tashichhiling-Singi Khola Upper	S	2.50	13.00	5.26	8	III	5.3		5.3	I				III	7	I
Umling	U-1	282	Rejuk Serchu Irrigation channel	P	2.00	85.00	34.40	27	III	34.4	1.3	35.7	III	1.0	20	On foot	III	7	V
	U-2	280	Dangling Irrigation channel Lower	S	3.50	82.00	33.18	36	II	33.2		33.2	II	0.5	10	On foot	III	7	III
	U-4	276	Dungmin Irrigation channel Upper	S	1.00	70.00	28.33	26	III	28.3		28.3	II	0.5	10	Tiller	III	8	V
	U-5	285	Tashithang Karchu channel	S	7.00	64.00	25.90	21	I	25.9		25.9	II	0.5	10	Tiller	III	6	I
	U-6	277	Dungmin Irrigation channel Lower	S	1.00	52.00	21.04	16	III	21.0		21.0	I	0.5	10	Tiller	III	7	V
	U-7	283	Chubarthang Seelchu channel	S	2.00	47.00	19.02	14	III	19.0		19.0	I	0.5	10	Tiller	III	7	II
	U-8	284	Thongjazor Karchu channel	S	4.00	44.00	17.81	17	I	17.8		17.8	I	0.5	10	On foot	III	5	I
	U-9	274	Lingar Dap Irrigation channel	P	3.00	40.00	16.19	15	II	16.2	1.7	17.9	I	1.0	20	On foot	III	6	I
	U-10	272	Gadhen Irrigation channel Lower	P	1.00	38.00	15.38	48	III	15.4	1.0	16.4	I	0.5	10	Tiller	III	7	V
	U-11	281	Rijuk Karchu Irrigation channel	S	1.00	31.00	12.55	27	III	12.6		12.6	I	0.5	10	On foot	III	6	III
	U-12	279	Dangling Irrigation channel Upper	S	3.00	24.00	9.71	32	II	9.7		9.7	I	0.5	10	Tiller	III	7	I
	U-14	278	Pantharey Irrigation channel	S	1.00	17.00	6.88	15	III	6.9		6.9	I	0.5	10	Tiller	III	7	I

(*1) P: Permanent S:Seasonal (*2) Distance from irrigation area to adjacent road. (*3) Traveling time (min or days) (*4) Traveling way (on foot or power tiller beneficiary area to road (km) Potential I; Low (score=1), II; Medium (2), III; High (3) (*5) Total score of potential: 3.4(low), 5.6-.7(medium), 8.9 (high) (*6) Class of IRR: I; less than 5%, II: from 5% to 10%, III: from 10% to 15%, IV: from 15% to 20 %, V; more than 20%

5.3.2 Preliminary Analysis on Economic Validity of Rehabilitation Project of the Existing Irrigation System

Besides the development potential assessment as mentioned in the above section, economic validity is conducted to examine future promotion of the rehabilitation project. It is analyzed for the 79 irrigation sites. This economic analysis is conducted based on the existing irrigation site, not on the new water resource development such as storage facilities/ ponds and large scale changes of the existing system including in integrating irrigation sites/ intake facilities and introducing new canal type.

(1) Cost

Cost consists of construction cost for canal and intake facility and operation and maintenance (O/M) cost for regular maintenance such as cleaning and repair of the intake and canal. In basic cost estimate process, the cost should be estimated by the sites through detail planning and design-drawing process prepared on the local specified conditions of damaged facilities, topography and geology. In this survey level, however, it is difficult to take such processes. So, the cost in this survey is estimated on a canal length basis.

In this analysis, the construction cost is estimated from the unit cost, Nu. 370,000/ km. The value is the same as in the section 4.1.2 "Economic Feasibility of Existing Irrigation System". Besides this, construction cost of intake facility, Nu. 111,000 is added to the construction cost. It is applied into every site as the fixed value.

For operation and maintenance (O/M) cost; Nu. 55,500/ km is basically appropriated as mentioned in the section 4.1.2. But, an idea of efficiency of operation and maintenance works should be introduced to this cost estimate process. In general, amount of the O/M works may be influenced on the canal length, but, work efficiency would be improved on its canal length. (If canal length becomes longer, its O/M cost get higher, but, not straight increase in proportion to the length, since work efficiency will get better.). Considering this, O/M cost may be revised on the canal length, as follows.

Canal length	1.0 km	2.5 km	4.0 km
Applied revise coefficient / Annual O/M cost (Nu.)	1.1/ 61,050	1.0/ 55,500	0.9/ 49,950

Revise coefficient is set based on the average canal length=2.6 km.

(2) Benefit

Benefit is calculated from target of unit yield of paddy production and size of irrigation area. In this analysis, target of unit yield is set 2.28 ton/ ha as the average yield in 2010 of the southern three dzongkhags. According to the past production trend of paddy in those dzongkhags, unit yield is being increased. If improvement technology of paddy cropping will be disseminated into the related wet land, the unit yield is expected to increase up to the national average level. In this analysis, however, it was set conservatively, considering that project effect would be brought from only rehabilitation of the existing irrigation system. If other related projects or activities such as dissemination of paddy cropping technology would be led, the target yield might be designed at higher than in this analysis.

For the average purchasing price at farm gate, Nu.17/ kg (paddy) by CAFCO was applied, same as applied in the section 4.1.2.

Table 5.3.4 Average Yield of Paddy in the Three Dzongkhags (ton/ha)

Year	Samtse	Sarpang	Sumdrop JuJongkhar	Average of the three	Average of Bhutan
2009	2.05	2.01	2.38	2.12	2.77
2010	2.11	2.15	3.18	2.28	3.14

Source: Agriculture statistic 2009 and 2010

Working cost is calculated by the same method/ value as mentioned in the section 4.1.2.

(3) IRR analysis

Project life is set by 20-years on the condition that providing irrigation facilities are the masonry and concrete structures. IRR is calculated for the 74 sites except 5 sites in Chuzagang Gewog.

In general, value of IRR is fluctuated largely depending on the cost and/or benefit. In this analysis, especially, cost is roughly estimated by applying uncertain conditions. Accordingly, calculated IRR should not be directly applied to judge the economic validity of each site. So, in this analysis, value of the calculated IRR is classified into five ranges; I: less than 5%, II: from 5% to 10%, III: from 10% to 15%, IV: from 15% to 20% and V: more than 20%. (see Tables 5.3.2 to 5.3.3).

(4) Consideration on economic validity

Notwithstanding, from the above IRR calculation, sites whose IRR value is relative high can be picked as the sites where may be judged to be economicall feasible. As the result, economic feasible site classified into the III, IV and V (the IRR is more than 10%) are counted 31. The site classified IV and V (the IRR more than 15%) is counted 25. By overlapping those picked sites with the sites evaluated as the relatively high development potential site as picked in the previous section 5.3.1, overlapped sites are counted 13 sites. Those overlapped sites are judged to be higher development potential site and be higher prioritized site in promoting rehabilitation project of the existing irrigation system.

As for the slightly lower IRR value sites, it is important to try to get a feasible value by controlling construction and operation and maintenance costs. For the lower value sites, in order to reach certain feasible level, it may be required to introduce any new schemes such as integration with adjacent feasible site and joining related intake facilities and canal system. Anyhow, to study these ideas, detail survey and analysis are needed in the next project formulation stage.

5.3.3 Validity in Organizing Farmers Participatory Project

Past and current repairing works for damaged intake and canal structures have been conducted by beneficial farmers group/ water users association on their own labor contribution. Considering such working process, it is judged to be easy for farmers group to participate in project implementation process. However, it is limited to the parts of their labor contribution. If materials and machines except labor force will be needed, these should be provided by administration implementation body or

other outside resource.

5.3.4 Validity in Establishing Sustainable Operation and Maintenance System including Water Charge Collection System

The number of the Water Uses Association (WUA) registered in the inventory is limited in; 3 sites in Sarpang, 7 sites (out of total 32 ones) in Samtse, only one site (out of total 42 ones) in Samdrop jongkhar. According to the field survey in Sarpang, in the Takali irrigation site, however, water charge is collected and appropriated for the operation and maintenance works of the irrigation facilities. Furthermore, even in unregistered WUA sites, water use groups are certainly organized although their organization unity is different by each group. The group member of them cooperatively operates and maintains their irrigation facilities. Judging from such on-going situation, it is considered that their groups have readiness to introduce water charge collection system as a next development step.

To fix the water charge collection system in the irrigation site, however, long-term continuous support to the groups is required. Supporting activity should be well designed to link with marketing movement of their produced paddy or other irrigated cash crops. Judging from the current situations that water charge collection system is on-going in one site and water users groups exist in almost all irrigation sites, it is considered feasible to establish operation and maintenance system including water charge collection system in the next coming rehabilitation project.

5.3.5 Social and Environmental Consideration

There are the National Protected Areas in the Sarpang and Sumdrop Jongkhar Dzongkhags and no area exists in the Sumtse (see Figure 3.1.35).

In Sarpang, three National Protected Areas exists in related gewogs. Those are the Royal Manas National Park (Taraythang gewog), Jigme Singye Wangchuck National Park (Jigmechhoeling and Umiling gewogs) and Phipsoo Wildlife Sanctuary (Senge gewog). According to the present national regulation related to the protected area, new development activities are prohibited in these areas. According to the location map of the irrigation sites in the inventory, some irrigation farmlands are located in the delineation of the protected areas. For such farmlands, small scale rehabilitation activity may be allowed, but, large scale development projects such as new water resources development and land development can not be led. Except these farmlands, most irrigation farmlands are not located in the protected area. Development activities may be allowed without environmental assessment.

Three National Protected Areas are located in Samdrop Jongkhar. Some irrigation farmlands may be located within the Protected Areas. In case that any large scale development projects would be planned, existence and location of both irrigation farmlands and Protected Areas should be checked.

CHAPTER 6 STRATEGIC PLAN FORMULATION FOR REALIZING AGRICULTURE WATER SUPPLY AND MANAGEMENT

6.1 PROBLEM ANALYSIS AND POSSIBLE MEASURES FOR ENSURING AGRICULTURE WATER SUPPLY AND MANAGEMENT

6.1.1 Problems and Basic Approach to Solutions and Possible Measures

Overall development target through realizing agriculture water supply and management is to improve agriculture productivity through developing irrigation agriculture. As a basic approach to provide strategic plan for realizing agriculture water supply and management, present situation and problems are analyzed based on the collected data/ information and finding from the irrigation site survey. Problems that may be arisen in realizing water supply and management are analyzed. Based on this analysis, basic approach and possible measures for solutions are considered as shown in Table 6.1.2.

6.1.2 Consideration on Expected Risks and Measures in Irrigation Rehabilitation Project

Project risks including negative impacts that may be caused by promoting rehabilitation project of the existing irrigation system are tabled as below. It is important to deal with those risks in the project formulation. To do so, possible measures to cope with occurrence of the risks should be considered and incorporated into strategic plan formulation process.

Table 6.1.1 Expected Risks and Possible Measures in Promoting Irrigation Rehabilitation Project

Risk items	Expected project risks	Possible measures
Natural/ engineering risk	<ol style="list-style-type: none"> 1. Due to large change of river course/ down of river bed, collapse of canal slope, etc. intake facility and canal become non-functional. 2. Dry season river flow amount drastically decreases and intake water amount also decreases. 	<ol style="list-style-type: none"> 1. Strengthen current non-structural measures such as reinforcement of natural intake, repair of canal. Make budget for them and O/M work regularize. 2. Strengthen on-farm water management (soil and water conservation), Encourage cropping pattern to change from paddy to less water requirement crops.
Social risk	<ol style="list-style-type: none"> 3. Agriculture is abandoned in the sites which not be targeted by the project. Farmers can not get food. 4. Crop damage is often occurred by wild animals. 5. Paddy irrigation agriculture is abandoned in the sites where O/M works becomes large scale so that farmers can not operate with their capacity. 6. Water charge is not collected due to decrease of paddy production. 	<ol style="list-style-type: none"> 3. Prioritize irrigation project as provision of social infrastructure project. Project is led to ensure life security. 4. Promote damage reduction strategy in cropping stage as mentioned in National Development Plan in the project sites. 5. Dzongkhag/ Gewog offices establish O/M organization. And, related administration offices encourage farmers to cultivate other marketable crops except paddy. 6. Through promoting vegetable and other cash crop, other income generation is created, so that it can make the burden of

Risk items	Expected project risks	Possible measures
Economic risk	7. Project cost can not be shared. 8. There exist sites whose economic feasibility is considered to be low.	water charge by paddy lighten. 7. Budget arrangement is made in line with national development policy. If necessary, it is discussed financial support with related donor agencies. 8. Construction cost is reduced by integration of intake facilities and beneficial areas. Irrigation benefit is increased through promoting various farming style such as vegetable and other cash crop cultivation, livestock breeding, inland fishery.
Social and Environmental consideration	9. Large scale water resources development and land development are newly planned in the National Protected Areas. 10. Economic gap widens between farmers provided agriculture infrastructure and settlers living in less development potential area. Security becomes unstable. 11. Large scale water resources development including groundwater development so that river regime is largely changed is planned by related sectors.	9. Organization for environment assessment is organized in the DoA. 10. Provision of agriculture infrastructure for immigrants is prioritized for social security and their stable life. 11. It is discussed with related sectors that feasibility study of irrigation development would be incorporated into new water resources development plan. The issue "Water right" is discussed with India.

Table 6.1.2 Problems and Approach to Solution and Possible Measures

Subjects	Present situation and Problems	Approach to Solution	Possible Measures
Agricultural water supply (Water source and intake)	<p>River/ Stream</p> <ul style="list-style-type: none"> - River in the southern zone is characterized as a fast-flowing river, short run-off duration time and flooding with debris-avalanche. This situation causes the following problems. - Intake structure is damaged every year by sediment and rapid flow with stone and rock. - In order to make intake stable, river structure such as revetment and slope protection is required. - Even in dry season, river flowing throughout the year (permanent river) so that it can be available as water source is limited. Amount of available run-off in dry season can not be estimated since river flow has not been observed so far. - It is judged from the survey conducted by JICA survey team, it is found that few suitable sites for storage dam exist. However, detail investigation along the river should be required for further possibility survey. - Domestic water is also taken for neighboring villages from the same river/ stream as agricultural water source. 	<ul style="list-style-type: none"> - Topography and river conditions are investigated in and around intake sites by irrigation site. - Intake method is studied by the sites based on the present physical conditions of river bed/ slope and sedimentation. Preliminary alternative design plans prepared by this survey is further studied and analyzed. -Structural measures (initial construction is high, O/M cost is relatively low) -Non-structural measures (same as the present natural intake method, regular O/M is required.) - Construction feasibility of water storage facility in and around the irrigation area is studied. - For the permanent river, river flow in dry season is observed to estimate available agricultural water. 	<ol style="list-style-type: none"> 1) Study and analyze suitable intake method by river conditions and provide engineering standard to plan and design intake facility. 2) Study for construction possibility of storage dam in the river classified as the permanent river. 3) Establish river discharge observation system of the permanent river and accumulate observed data and analyze them to estimate available river discharge for dry season irrigation. 4) Investigate present domestic water supply conditions in and around irrigation farmland such as water source, amount of intake water, and number of beneficiary and their consumptive use and study competitive water use between agriculture water and domestic water in the same river basin.
	<p>Groundwater</p> <ul style="list-style-type: none"> - Judging from the investigation and interview survey in the present well sites in Gelephu (for domestic water supply and manufacturing alcohol drink), it is confirmed existence of certain amount of groundwater. However, there is few data on groundwater in Sarpang. 	<ul style="list-style-type: none"> - Data/ information on geology, groundwater and pumping water should be collected by drilling investigation test wells for Sarpang. - Policy and guideline dealing with groundwater use for agriculture 	<ol style="list-style-type: none"> 5) Construct test drilling wells and execute pumping test to clarify the geologic conditions including pumping water. 6) Establish groundwater observation system to analyze

Subjects		Present situation and Problems	Approach to Solution	Possible Measures
		<ul style="list-style-type: none"> - Investigation well has been drilled in Samtse, but, existence of groundwater was not found clearly. - Groundwater development is not suitable at present in Samdrop Jongkhar, according to FAO survey) 	purpose should be provided. It includes sharing method of operation and maintenance cost among beneficiary, how to organize operation and maintenance organization.	<p>available pumping water.</p> <p>7) Provide discussion paper on groundwater use for irrigation purpose for policy maker.</p>
	Rainfall	- Rainwater collection tank using roof has been constructed in a house in Chuzagang Gewog of Sarpang Dzongkhag to irrigate kitchen garden in dry season. Construction has just completed in April 2012. Operation is not begun yet.	- Irrigation activity by using the tank should be monitored to examine promotion possibility in household level.	<p>8) Monitor their irrigation activity by using tank and crop production.</p> <p>9) Provide plan and design standard of rainwater collection tank.</p> <p>10) Study development feasibility of vegetable cropping including by micro irrigation and in green house.</p>
Agricultural water use and management (Canal and on-form)	Distribution canal	<ul style="list-style-type: none"> - If canal is located along the steep slope and weak geology, it is prone to be damaged by the slope collapse. - Sedimentary stone and gravel prevent smooth flow in delivery canal. - Distribution water loss increases by collapse and leakage in earth canal. - Expensive repair work is regularly required before irrigation starts. (Repair and maintenance works are regulated by Dzongkhags/ Gewogs and beneficial farmers groups. But, In case of large scale repairing work with heavy machine, support from the related government offices is required.) 	<ul style="list-style-type: none"> - Collapse risky slope area with weak geology is investigated along the route of canal, and possible slope protection measures is planed and design standard of them is prepared. - Suitable canal type is made on the classified risky section. Its design is standardized. - Operation and maintenance system involved related organization of Dzongkhag, Gewog, village, community and water use group/ beneficiary is provided and strengthened their operation and maintenance capacity. 	<p>11) Prepare the existing irrigation system map delineated canal route and irrigation area.</p> <p>12) Investigate collapse risky section along the route of canal and put them on the map.</p> <p>13) Standardize canal type by local topographic and geologic conditions.</p> <p>14) Provide suitable canal type so as to minimize the delivery loss and leakage, and standardize their plan and design.</p> <p>15) Organize integrated operation and maintenance system involved</p>

Subjects		Present situation and Problems	Approach to Solution	Possible Measures
				related administration and beneficiary for repairing irrigation facilities and support beneficial farmers group in strengthening their operation capacity.
	On-farm water use	<ul style="list-style-type: none"> - Effective thickness of surface soil layer in the paddy field is shallow. In addition, most of its surface soil is formed by gravel, sand and silt whose infiltration rate is very high. Present on-farm water balance is made by much rainfall and irrigation water from river intake and much infiltration loss. In high infiltration paddy fields, it may be difficult to introduce dry season irrigation into whole paddy fields. - Plot-to-plot irrigation among the sloped small plots in the terrace causes surface soil erosion and much water loss. 	<ul style="list-style-type: none"> - Surface soil and thickness of its layer are investigated in the paddy fields and soil and soil layer improvement method should be provided based on the investigated soil texture. - On-farm water management technology should be established so as to be applicable for present small plots and local soil and rainfall conditions. It should be extended to the southern paddy fields. 	<p>16) Prepare soil map.</p> <p>17) Provide soil layer improvement methods, and standardize their planning and design process to make extension easy.</p> <p>18) Train Gewog extension staff on-farm water management in terrace paddy fields, and promote on-farm water management technology for water users groups/ farmers.</p>
	Other agriculture water use	<ul style="list-style-type: none"> - Domestic animal water requirement: domestic animal breeding is done in free-grazing style. Chicken water breeding in the chicken house is directly supplied from tapped household domestic water. - Inland fishery water requirement: inland fishery is practiced in the limited areas where irrigation water is available in dry season. 	<ul style="list-style-type: none"> - Development plan of livestock breeding and inland fishery should be incorporated into irrigation system rehabilitation plan and water requirement of them should be estimated 	<p>19) Prepare livestock breeding and inland fishery development plan and study development feasibility in the area where irrigation water is available in dry season.</p>
	Water use association or water use groups	<ul style="list-style-type: none"> - The number of registered water use association (WUA) is a few, but there exists un-registered water use group (WUG) in an irrigation system (Only one sites whose water charge is collected.) - Member of the WUA or WUG cooperatively 	<ul style="list-style-type: none"> - Supporting system to WUA or WUG should be established in operating repair works. - Technical supporting activities in repairing damaged structures are 	<p>20) Improve extension skill and technology of Gewog extension staff so that they can train WUA or WUG in strengthening operation and management</p>

Subjects		Present situation and Problems	Approach to Solution	Possible Measures
		repairs and maintains their irrigation structures. Materials for repairing such as cement and pipe are brought from Gewog and Dzongkhag offices. Repairing works are done by participative labor contribution. However, in case of large scale repairing work so that it can not be done by member's labor force, repairing works may often be abandoned. Furthermore, if no budgeting by the offices for material supply, necessary works can not be planned. As the result, damaged irrigation structure remains un-functional and as unused facilities. To this end, irrigation agriculture is abandoned.	strengthened for related WUA (or WUG) by Dzongkhag/ Gewog offices. - Repairing activities are regularly patrolled, monitored and reinforced by Dzongkhag/ Gewog offices.	capacity of them. 21) Establish communication system among related government office of Dzongkhag, Gewog and extension staff and WUA or WUG.
Improvement of agricultural productivity	Agricultural land use	- Based on the surface soil and access to irrigation water, agricultural land use type is classified into: i) wet land where cereal crop such as paddy and maize is cultivated, ii) partially agricultural used land iii) abandoned land where crop is not planted due to much rock and stone. Such three land use types are mixed in the agriculture zone.	- Surface soil should be investigated to clarify present conditions of rock/ stone/ gravel distribution. The result is put on soil map. - Feasibility study on agricultural use should be conducted on the classification map.	22) Prepare soil map including sedimentation of rock/ stone/ gravel. 23) Conduct feasibility study for agriculture land use on the soil classification.
	Paddy cropping in wet season	-Infiltration rate is high on sandy soil paddy field. If non-rainfall period is prolonged, paddy growing is damaged unless irrigation water supply. - Small plots and much gravel/ stone make farm mechanization hard. - Surface soil is prone to be eroded in pot-to-plot irrigation.	- Following subjects should be considered; - Soil layer improvement method (removal of gravel/ stone, soil dressing) - Soil improvement method (green manure/ using animal excreta) - Soil and water conservation method (land leveling, improvement of ridge, on-farm water management)	24) Establish suitable soil-layer improvement method and soil improvement method. Standardize their technical issues. 25) Take administrative consideration on possibility of land consolidation in line with present land tenure system

Subjects	Present situation and Problems	Approach to Solution	Possible Measures
		<ul style="list-style-type: none"> - Possibility of land consolidation should be studied. 	
Paddy cropping in dry season	<ul style="list-style-type: none"> - Although there are prospective areas where paddy cropping can be practiced in dry season, no planting is practiced at present. According to the interview survey with farmers, the following constraints are arisen. - Damaged by intrusion of wild animal to the fields - Overlapped harvesting time of dry paddy with land preparation of wet paddy (May to June). <p>In addition,</p> <ul style="list-style-type: none"> - Wet paddy cropping is generally prioritized for farmers' home consumption. Commercial agriculture sense is not fully infiltrated among farmers. 	<ul style="list-style-type: none"> - Development constraints in introducing dry paddy cropping should be clarified by investigating real situations in the prospective areas. Possible measures against the constraints are planned and its feasibility should be studied. - Dry paddy seed is disseminated. - Policy and plan so as to accelerate commercial rice production should be made. - It should be discussed to organize and establish production cooperative so that it can handle commercial activities including purchasing and marketing 	<ul style="list-style-type: none"> 26) Support paddy cultivating farmers in supporting dry paddy cropping such as input of new improved short duration variety and cropping skill. 27) Plan and execute effective measures to prevent from intrusion of wild animal. 28) Demonstrate dry paddy cropping in demonstration plots, to make dissemination of dry paddy cropping technology smooth. 29) Provide administrative supports in organizing production cooperative for paddy cultivation farmers.
Paddy cropping technology	<ul style="list-style-type: none"> - Most farmers utilize homemade seed. - Technical manual "Rice Production in Low Altitude Zone" has been prepared. But, its technology and skill are not fully disseminated yet. 	<ul style="list-style-type: none"> - Model farm of paddy cropping should be provided to display the cropping technology and skill. - Seed distribution system in cooperation with NSC (National Seed Centre) should be strengthened. - Rice production improvement technology should be disseminated through training Gewog extension staff. 	<ul style="list-style-type: none"> 30) Provide model farm to demonstrate farming and disseminate cropping technology by Gewog. 31) Provide learning opportunity for Gewog extension staff so that they can learn cropping technology including on-farm water management, and strengthen cooperation with NSC.
Other related	<ul style="list-style-type: none"> - Farm roads are being provided. Some of farm 	<ul style="list-style-type: none"> - Marketing infrastructures such as 	<ul style="list-style-type: none"> 32) Promote traffic roads

Subjects		Present situation and Problems	Approach to Solution	Possible Measures
	infrastructure	<p>roads are blocked by flooding in wet season.</p> <ul style="list-style-type: none"> - Agriculture cooperative (CAFCO) has been established in Chuzagang Gewog as an advanced organization, operating under support from DoA. • In most Gewog, private rice mill machine is used by neighboring households for milling their home consumption. 	<p>farm roads/ village connection roads should be provided in line with promotion of irrigation agriculture.</p> <ul style="list-style-type: none"> - CAFCO activities should be monitored to seek development possibility to set up similar cooperative in other Gewogs. - Post-harvesting loss should be reduced by improving present threshing and milling technologies. 	<p>construction in parallel with irrigation development and market development.</p> <p>33) Monitor the CAFCO's operation.</p> <p>34) Plan to introduce rice mill machine and establish/ promote post-harvesting technology so as to reduce loss in threshing and milling.</p>
Socio-economy	Industry	<ul style="list-style-type: none"> - Basic industry is agriculture for local people. Provision of agriculture infrastructure is the most important matter for them to stabilize their life. Especially, for immigrants, provision of agriculture infrastructure is the basic requirement. 	<ul style="list-style-type: none"> - Agricultural productivity should be improved through provision of agriculture infrastructure. - Suitable crops on the local land and access to water should be selected. 	<p>35) Draw agricultural development vision for each agriculture zone and formulate development direction on the local conditions and justify the irrigation rehabilitation project as first priority in line with development direction.</p>
	Living infrastructure (Electricity)	<ul style="list-style-type: none"> - According to the data and field survey in Sarpang, almost households in lower altitude area have been electrified. Coverage of household electrification of three Dzongkhags is planned to complete the 100% households by the year 2012-13 by Power Cooperation. - Although there is some permanent river in Sarpang, no suitable site for small scale hydropower generation was found in lower altitude areas. More investigation is required for mountainous area. 	<ul style="list-style-type: none"> - Monitor the progress of electrification plan by Power Corporation. 	<p>36) Investigate current electrified and non-electrified households in remote areas. And, inform the existence of non-electrified ones to Power Corporation.</p>
	(Domestic water supply)	<ul style="list-style-type: none"> - Domestic water is taken from the same river as the irrigation water in the irrigation sites. Intake 	<ul style="list-style-type: none"> - Current situation of domestic water supply should be investigated and 	<p>37) Investigate domestic water use by rivers and incorporate the</p>

Subjects		Present situation and Problems	Approach to Solution	Possible Measures
		way is the same gravity system as the irrigation.	arrange competitive water use.	result into irrigation water supply plan.
	Shift to market oriented agriculture	<ul style="list-style-type: none"> - Commercial agriculture sense is growing in the area with easy access to marketing (for example, chicken breeding in and around Gelephu city and CAFCO). - Degree of access to marketing system differs from Gewogs, villages and farmlands. 	<ul style="list-style-type: none"> - For planning priority area of agriculture development, item of easiness to access to market should be incorporated as selection criteria. 	38) Investigate easiness to access to marketing system on irrigation sites/ agriculture zone and select priority area from easy access sites.
Administration organizations dealing with water supply and management	Execution capacity	<ul style="list-style-type: none"> - Engineering division of DoA, RDC Bhur and Sarpang administration are responsible for planning/ designing irrigation facilities. The number of staff and their capacity are not enough to deal with their roles. In addition, necessary equipment and tool are not provided. - It is required to review and revise country wide "Irrigation Engineering Manual", so that it can be applied to the southern natural conditions. 	<ul style="list-style-type: none"> - Present organization should be improved in quantity and quality. Engineering capacity of the staff is improved - Irrigation engineering manual should be revised so that it deals with local natural conditions such as rainfall, river run-off, topography and geology. 	<p>39) Discuss organization structure including recruitment and allocation of staff required to execute the NIP and train irrigation engineers.</p> <p>40) Revise and update the engineering manual so that it deals with local natural conditions.</p> <p>41) Standardize a series of engineering works; planning/ design/ implementation/ monitoring of irrigation facilities.</p>

6.2 APPROACHES TO STRATEGIC AGRICULTURAL WATER SUPPLY AND MANAGEMENT PLAN FORMULATION

6.2.1 Grouping of Possible Measures for Approach to Project Formulation

Possible measures to cope with the problems and expected risks mentioned in the section 6.1 are grouped into some kinds of project category to form necessary projects for ensuring agricultural water supply and management. As the result of grouping, required projects are categorized into three fields: 1) Study; "Agriculture Development Study in Southern Bhutan" to draw agriculture development vision, 2) Activity; "Irrigation Agriculture Pilot Project in Southern Bhutan" to establish development model in the agriculture and irrigation development fields, 3) Human resources development, "Capacity Development for Irrigation Engineers" to improve irrigation engineering capacity of DoA, as shown in Table 6.2.1. Grouped three projects are proposed to be future prospective projects.

Table 6.2.1 Grouping of the Possible Measures for Project Formation

Grouped projects	Possible measures	Picked from	
		Table 6.1.2	Table 6.1.1
1. Agriculture Development Study in Southern Bhutan			
Objective: <i>Prepare Master Plan for irrigation agriculture in the southern Bhutan. Formulate development component and prioritize them.</i>	- Study for construction possibility of storage dam in the permanent river.	2)	11.
	- Study and analyze suitable intake method by river conditions.	1)	1.
	- Establish river discharge observation system of the permanent river.	3)	
	- Investigate present condition on domestic water supply such as the amount of intake water and the number of beneficiary and their consumptive use. Study competitive water use between agriculture water and domestic water in the same river basin.	4), 7), 37)	
	- Construct test drilling wells and execute pumping test to clarify the geologic conditions including pumping test.	5), 6)	
	- Monitor the effectiveness of irrigation activity by using rainwater collection tank and cropping conditions.	8), 9)	
	- Investigate collapse risky section along the route of canal. Study to provide canal type for such section.	12)	1.
	- Study for organizing operation and maintenance system consisted of administration and local beneficiary, and establishing technical supporting system for beneficiary.	15)	1.
	- Provide soil layer improvement method and soil improvement method.	16), 17)	
- Prepare livestock breeding plan and inland fishery development plan and study development feasibility in the area where irrigation water is	19)		

Grouped projects	Possible measures	Picked from	
		Table 6.1.2	Table 6.1.1
	available in dry season.		
	- Prepare existing irrigation system map.	11)	
	- Plan to improve extension skill and technology of Gewog extension staff to develop operation and management capacity of WUA or WUG., and establish communication system among Dzongkhag, Gewog, extension staff and WUA or WUG.	15), 20), 21)	1., 5.
	- Prepare soil classification map and conduct feasibility study for agricultural land use on the soil classification.	16), 22), 23)	
	- Study for taking administrative consideration of land consolidation in line with present land tenure system.	25)	
	- Provide administrative supports in organizing production cooperative for paddy cultivation farmers.	29)	
	- Draw agricultural development vision by agriculture zone and formulate development direction and development component.	32), 33), 35), 38)	2., 8., 10.
	- Formulate agricultural land sue plan (cereal, vegetable and cash crops)	27), 34), 35)	2., 6., 8.
	- Prepare irrigation rehabilitation plan	35)	3., 6., 8.
	- Conduct environmental assessment for irrigation rehabilitation plan		9.
	- Investigate current electrified and non-electrified households in remote area.	36)	
2. Irrigation Agriculture Pilot Project in Southern Bhutan			
Objective: <i>Demonstrate irrigation agriculture in southern zone. Establish a development model. Improve technical capacity of Gewog extension staff. Cooperate with RNR center.</i>	- Practice soil layer improvement method and standardize their technology.	17)	
	- Provide plan and design standard of rainfall collection tank. Practice vegetable cropping by micro irrigation system and green house.	9), 10)	
	- Provide learning opportunity for Gewog extension staff to learn on-farm water management in paddy field for building their future extension activity.	18), 31)	2.
	-Improve operation and management capacity of WUA or WUG.	20)	
	- Practice soil layer improvement method for standardizing their technical issues.	17), 24)	
	- Demonstrate dry paddy cropping to make dissemination of dry paddy cropping technology.	26), 27), 28), 30), 31)	4.
	- Practice suitable intake method and verify its effect.	1)	1.
	- Practice and demonstrate engineering fields (intake, delivery and on-farm water management).	1), 18)	5.

Grouped projects	Possible measures	Picked from	
		Table 6.1.2	Table 6.1.1
	- Establish post harvesting technology so as to reduce loss in threshing and milling.	34)	
	- Support in organizing production cooperative for farmers.	15), 29)	
3. Capacity Development for Irrigation Engineers			
Objective: <i>Improve irrigation engineering capacity of DoA and related organizations so as to materialize agricultural water supply and management</i>	- Provide engineering standard to plan and design the intake structure.	1)	1.
	- Observe river flow in the river flowing throughout the year and accumulate observed data and analyze them. Estimate amount of river flow available for dry season irrigation.	3)	
	- Observe ground water table and accumulate the data to clarify the present ground water flow and analyze available pumping water.	6)	
	- Provide discussion paper on groundwater use for irrigation purpose for policy makers.	7)	
	- Provide planning and design standard of rainwater collection tank	9)	
	- Standardize the canal types based on the local topographic and geologic conditions.	13), 14)	
	- Prepare technical guideline for organizing operation and maintenance system of the irrigation facilities.	15)	
	- Develop planning/ designing capacity of related irrigation engineers	39)	
	- Prepare irrigation engineering manual for planning/ designing/ implementation and monitoring/ evaluation of irrigation facilities.	40), 41)	
	- Establish environment assessment organization in the DoA for irrigation system rehabilitation project.		9.

6.2.2 Strategy for Realizing the Proposed Projects

Strategy to realize water supply and management in the southern zone is made considering strategic implementation plan of the proposed three projects.

(1) Approach to strategic plan formulation

Strategy is planned based on the analysis of collected data/ information and finding from the existing irrigation sites survey in Sarpang. It is approached from the following issues.

- 1) Southern zone has high crop production potential including rice and other crops under the tropical and sub-tropical agro-meteorological conditions. Agricultural development projects should be formulated on the crop production potential in the southern zone in line with national policy; "Food security", "Improvement of crop productivity" and "Shifting from subsistence farming to

market oriented one". Therefore, related projects with ensuring agricultural water supply and management should be consistent with agriculture development vision and development direction in national and southern regional levels. Proposed projects should be justified in the agricultural land use plan and farming plan formulated based on the local natural conditions such as land, soil and accessibility to water. Validity and priority of the proposed projects should be analyzed in the proposed "Development Study".

- 2) Development ideas such as storage dam and groundwater development may be firstly drawn to make sure of agriculture water source. However, to realize such ideas, a long-term preparation period will be required to study and analyze local river system, hydro-meteorology, geology and topography. Many engineering, social and administrative fields shall be dealt in the development process. Considering such conditions, short term realistic development target to ensure agricultural water supply may be put on improvement of the existing irrigation system.
- 3) To rehabilitate the existing irrigation facilities in southern zone, it is required to cope with physical constraints characterized as vulnerable foundation/ slope and debris flow with stone and gravel. For realistic plan formulation, method of intake water from the river is the key issue to ensure agricultural water. It is firstly required to apply suitable intake method for promoting irrigation rehabilitation project. For providing this, as an engineering viewpoint, current natural intake method should be reinforced and/or new intake method should be introduced. As a first approach, some applicable typical ideas of the intake methods are shown in this survey. As a next to find suitable method, such ideas should be further studied whether applicable or not on local conditions. For further study and analysis, it may be required to examine its applicability on the real physical conditions. Prospective intake method may be introduced tentatively at any sites, as a trial. Its effect and efficiency would be verified through the trial. Such trial process should be incorporated into the proposed "Pilot Project". This trial should be conducted before promoting full scale rehabilitation project.
- 4) To reach an increase target of paddy production, rehabilitation site of the existing irrigation facilities may be prioritized. But, paddy production cannot be increased by only the rehabilitation of facilities. It is necessary to improve cropping technology so as to be suited to the soil and water conditions and disseminate this technology. Accessibility to water is relied on local river condition. For poor water access sites, it may be proposed to shift from paddy with much water consumptive use to other less water requirement crops that are expected to be profitable. For these sites, it may be encouraged farmers to introduce such crops. In this situation, selection of the suitable crops and dissemination of its cropping technology are the important issue for the sites. To realize this, it is necessary as a first approach to find suitable crops and learn its cropping technology, and provide a learning opportunity for related staff and farmers. Establishment of pilot farm is recommended so that it can be utilized as a trial farm for demonstration and practice of selected crops. Cropping

process can be displayed for related farmers and related staff. They can learn cropping technology from this pilot farm. These activities should be provided in the proposed “Pilot Project” in cooperation with the RNR center. (FAO recommended to conduct a pilot farm applied "An integrated wetland productivity and production approach" program, including rice and other crops.)

- 5) For materializing rehabilitation of the existing irrigation system, project planning should be prepared by present irrigation sites. Rehabilitation project in each site should be formulated based on the detail data/ information of the local river and farmland conditions. In addition to this data collection survey, supplemental data collection and site survey are needed for project planning. These include the river discharge observation and analysis, preparation of topographic map, completion of irrigation system inventory and detail survey of soil and present land use, etc. The survey should be planned for not only rehabilitation project planning, but also preparing overall agricultural development vision and the “Pilot Project”. This survey should be conducted in the proposed “Development Study”.
- 6) Physical and natural conditions in topography, geology, water resources and agro-meteorology of three Dzongkhags are similar to each other. Development process taking in Sarpang may be put on other two Dzongkhags.
- 7) DoA under MoAF is the responsible organization for promoting irrigation development including agricultural water supply and management fields. It is indispensable for the DoA to develop their organization capacity to execute the mandate. Requirement capacity is the engineering fields from the stages of survey, planning, design and implementation. Proposed project "Capacity Development of Irrigation Engineer" should be prioritized to meet with this requirement. This project is desirable to run in parallel with the pilot project activities, especially in rehabilitation of irrigation facilities. If both run parallel, project effect in engineering fields is expected to be high.
- 8) DoA will be able to obtain necessary capacity to materialize related projects with water supply and management. After the proposed three projects, DoA is expected to prepare overall project formulation plan, design and implement each project in the southern zone on their own capacity. On the other hand, considering the government financial limitation, it may be difficult to procure project fund in full scale from the national budget. For this situation, discussion with related donors may be held to seek any financial cooperation.

(2) Expected projects and strategic project implementation plan

Based on the approach mentioned above, it is recommended to implement the following projects including proposed three projects in the two development stages.

The first stage

Proposed three projects are materialized. This stage is considered to be the preparation stage for

developing full scale project formulation for the southern Bhutan. This stage is required to conduct under the technical cooperation with related donor agencies.

1) Agriculture Development Study in Southern Bhutan

Agriculture development direction is formulated for the southern zone and rehabilitation project of the existing irrigation system is justified in the formulated development direction. Overall "Irrigation Agriculture Pilot Project" is schemed and its project site is selected.

- Draw development scenario by agriculture zoning
- Formulate development component and prioritize them
- Prepare long list of irrigation system rehabilitation area and put development priority on them
- Evaluate validity and priority of the irrigation rehabilitation project.

2) Capacity Development Project for Irrigation Engineers

In parallel with the 1), capacity development of DoA's engineering section is conducted.

- Standardize plan and design of irrigation facilities and prepare engineering manual.
- Improve engineering capacity of irrigation engineers especially in irrigation facilities of intake and delivery canal

3) Irrigation Agriculture Pilot Project

Cropping technology and rehabilitation of the irrigation system is practiced on a trial basis. Prospective intake method is examined and verified its effect and efficiency. Learning and experience area accumulated.

- Prospective intake method is constructed and verified its function.
- Practice irrigation agriculture and demonstrate paddy cropping
- Develop skill/ capacity of gewog extension staff

Second stage

Based on the learning and experience obtained from the first stage, full-scale irrigation agriculture development project including rehabilitation of the existing system is formulated and implemented in southern zone. Financial cooperation with related donor agencies is discussed as required.

1) F/S for Communal Irrigation Agriculture Development Project

Feasibility study for "Communal Irrigation Agriculture Development Project (draft)" is conducted, and project implementation plan is provided. Development component includes not only rehabilitation of irrigation system but also related project component such as participatory farm road construction, disseminating cropping technology and strengthening WUA capacity. In case that technical and financial cooperation may be needed for this study, discussion with related agencies is held as required.

- Prepare short list for communal irrigation rehabilitation area
- Conduct feasibility study (project component, project cost estimate, and feasibility evaluation)

2) Communal Irrigation Agriculture Development Project

Based on the feasibility study, formulated project is implemented in the southern zone.

- Improve the existing irrigation system
- Implement other components.
- Follow up project implementation Implement the projects.
- Monitoring project implementation process, evaluate and follow up project activities.

Overall time frame of the project implementation is planned as follows.

Table 6.2.2 Expected Project Implementation Schedule (Draft)

Project	Yearly implementation								
	1	2	3	4	5	6	7	8	9
<i>First stage</i>									
Preparation/ administrative arrangement	■								
1) Agriculture Development Study in Southern Bhutan		■	■	■	■				
2) Capacity Development for Irrigation Engineers		■	■	■	■				
3) Irrigation Agriculture Pilot Project			■	■	■	■			
<i>Second stage</i>									
1) F/S for Communal Irrigation Agriculture Development Project					■	■			
2) Communal Irrigation Agriculture Development Project						■	■	■	■

Project Outline (Draft)

1. Project Name	Agriculture Development Study in Southern Bhutan	
2. Project Scheme	Technical Cooperation	
3. Implementing Organization	MoAF/ DoA	
4. Project Outline		
(1) Overall project target Agricultural production of paddy, vegetables and cash crops in southern Bhutan is increased.		
(2) Project objective Master Plan for irrigation agriculture development in southern Bhutan is formulated.		
(3) Project area Southern three dzongkhags. Among the three, Sarpang is the priority dzongkhag.		
(4) Expected outputs		
<ol style="list-style-type: none"> 1) Agricultural development direction of each zone including agricultural land use plan is formulated. 2) Dry season available river discharge in permanent river is estimated. 3) Possibility of storage facility construction is studied by river basin and irrigation area. 4) Groundwater development potential is evaluated. 5) Water use plan among agriculture (irrigation, inland fishery), livestock and domestic use is provided by river basin. 6) Development components are formulated, and their implementation plan is provided. 7) Pilot project sites are selected. 8) Action plan for pilot project is formulated. 9) Long list of irrigation system rehabilitation sites is prepared. 10) Rehabilitation plan of the existing irrigation sites is formulated, including improvement of intake, delivery canal and on-farm water management. 		
(5) Main activity		
<ol style="list-style-type: none"> 1) Topography map covering southern zone is prepared. 2) Existing irrigation system map is prepared. 3) Investigate suitable construction site of storage facility. 4) Dry season river discharge in permanent river is observed. 5) Test well is drilled and pumping test and geologic data is investigated. 6) Present conditions of the irrigation system long list sites (command area, beneficial farmers, WUA) are surveyed. 7) Soil map is prepared, and soil improvement and soil layer improvement methods are studied. 8) Current situation of water use (agriculture, domestic and livestock) is surveyed by river. 9) Suitable structural types of intake and delivery canal are studied on local topography and geology. 10) Agricultural land use (paddy, vegetable and cash crops) is planned based on water, land and soil conditions. 11) Value chain analysis of planted crops is conducted. 12) Dissemination plan of cropping technology is formulated. 		
5. Major input		
(1) Donor agency	(2) Bhutan government	
<ul style="list-style-type: none"> • Necessary experts • Necessary equipment for study and necessary expenses 	<ul style="list-style-type: none"> • Assignment of counterpart staff • Expenses for counterpart staff activities, arrangement of related local organizations, supply of necessary data 	
6. Implementation term		
Project term; 3.0 years, Start: immediately after this survey		
7. Risk, etc.		
-		

Project Outline (Draft)

1. Project Name	Capacity Development Project for Irrigation Engineers	
2. Project Scheme	Technical cooperation	
3. Implementing Organization	MoAF/ DoA, RDC	
4. Project Outline		
(1) Overall project target Agricultural production of paddy, vegetables and cash crops in southern Bhutan is increased.		
(2) Project objective Engineering capacity for provision of irrigation system in the southern zone is improved.		
(3) Project area Southern three dzongkhags. Among the three, priority is put on irrigation sites of Sarpang.		
(4) Expected outputs		
1) Suitable intake method is established on the river, topography and geology conditions of southern zone.		
2) Suitable canal type is designed by local geological and topographical conditions		
3) River discharge in dry season in permanent river is analyzed.		
4) Groundwater observation system is established and groundwater flow discharge is analyzed.		
5) Agricultural water requirement is estimated by crops.		
6) Engineering manual from planning, design and implementation for intake facility is prepared.		
7) Engineering manual for canal is prepared.		
8) Design process of rain water collection tank is standardized.		
9) Operation and maintenance system of WUA is established.		
11) Planning and design process for small scale storage pond is standardized.		
(5) Main activity		
1) Suitable intake method is studied based on topo-geology and river condition and its standard structure is designed.		
2) Suitable canal type is studied and its standard structure is designed.		
3) River discharge in dry season in permanent river is observed and analyzed.		
4) Available groundwater discharge is analyzed and discussion paper on groundwater use for agricultural use is prepared.		
5) Irrigation activity by rain water collection tank is monitored and planning/ design process is standardized.		
6) Intake method examined in pilot project is analyzed and its engineering process is established.		
7) Irrigation water requirement is estimated by crops.		
8) Existing engineering manual is reviewed and revised based on lessons learned.		
5. Major input		
(1) Donor agency	(2) Bhutan government	
• Necessary experts	• Assignment of counterpart staff	
• Necessary equipment for the project, necessary expense	• Expenses for counterpart staff activities, arrangement of related local organizations	
• Expenses for counterpart training	• Preparation project space	
6. Implementation term		
Project term; 3.0 years, Start: immediately after this survey		
7. Risk, etc.		
-		

Project Outline (Draft)

1. Project Name	Irrigation Agriculture Pilot Project	
2. Project Scheme	Technical cooperation	
3. Implementing Organization	MoAF/ DoA, DAO of Sarpang, RNR center	
4. Project Outline		
(1) Overall project target Agricultural production of paddy, vegetables and cash crops in southern Bhutan is increased.		
(2) Project objective Rehabilitation method of irrigation facilities and cropping technology is demonstrated and established.		
(3) Project area Project site is selected from the present irrigation sites of wet land in Sarpang Dzongkhag.		
(4) Expected outputs		
<ol style="list-style-type: none"> 1) Intake method is tested and verified its function. 2) Suitable crops (paddy, vegetable and other cash crops) are selected and planted. 3) Cropping technology is demonstrated. 4) Suitable cropping technology of selected crops is established 5) Soil improvement method is established. 6) Soil layer improvement method is established. 7) Cropping system of dry paddy is established. 8) Extension capacity of RNR center and Gewog extension staff is improved. 		
(5) Main activity		
<ol style="list-style-type: none"> 1) Proposed intake method is tested and its function is monitored. 2) Crops suited to soil and water availability are selected and cropped. 3) Dry paddy with new seed is planted and constraints are found. 4) Crops and on-farm water management are practiced. 5) Suitable crops met with local conditions are selected. 6) Cropping technology of RNR center is practiced. 7) Existing manual for low land paddy cropping is reviewed and revised based on the activities. 		
5. Major input		
(1) Donor agency		(2) Bhutan government
<ul style="list-style-type: none"> • Assignment of experts • Construction cost for pilot farm and irrigation facilities, procurement of necessary equipment • Necessary expenses for project activities 		<ul style="list-style-type: none"> • Assignment of counterpart staff • Expenses for counterpart staff activities, arrangement of related local organizations • Preparation of land for pilot farm
6. Implementation term		
Project term; 3.0 years, Pilot project is justified in the project "Agriculture Development Study in Southern Bhutan". Pilot project component is formulated in the course of that project implementation.		
7. Risk, etc.		
-		

6.3 FUTURE CANDIDATE PROJECTS LINKED WITH PROSPECTIVE COOPERATION FIELDS WITH JICA

6.3.1 Prospective Cooperation Fields with JICA

Based on the project needs as mentioned above for realizing water supply and management and JICA's accumulated experiences and technology/ lessons learned from other similar projects, future prospective cooperation fields with JICA are identified as follows.

(1) Improvement of agriculture production in unfavorable hilled agricultural land.

Japan has experienced in developing irrigation agriculture in unfavorable remote hilled and sloped land where has difficulty in access to irrigation water. Through developing such farm lands, Japan has accumulated advanced knowledge and technology. For example, these are the way how to develop intake water, operate on-farm water management and develop paddy cropping technology with small scale irrigation pond in terrace farming. JICA have conducted some technical cooperation projects in many countries aiming to provide small scale irrigation system and improve paddy cropping technology in similar farm lands to the southern zone. JICA has accumulated related knowledge and developing technology through such technical cooperation projects. If making full use of accumulated knowledge of JICA and learnings from such past experience in Japan can be provided, it is surely possible to realize increase of paddy production in the southern Bhutan.

In Bhutan, agricultural production is unstable depending on regional natural conditions. Rice and some vegetables are obliged to import from neighboring countries. Accordingly, increase of paddy and vegetable production is the most important policy. To realize stable production, the highest development priority may be put on provision of agriculture infrastructure, especially the irrigation system including in ensuring water supply. However, southern zone have a technical risk in providing irrigation facilities to cope with weak geologic conditions. Economic risk to deal with the technical risk also exists.

Considering present physical and financial difficulties, it is hard to solve both risks. However, an important point is to tackle any prospective measures to avoid the expected risks. Cropping approach is the prospective non-structural measures. Southern zone has various crop production potential except paddy. Considering that paddy requires large amount of irrigation water, it is important to find less consumptive water use crops suited to the local water and soil conditions. Finding crops should be in line with overall agricultural development direction in southern zone, and encouraged farmers to crop and increase its production. JICA has accumulated related knowledge and experiences for drawing agriculture development direction including selection of suitable crops under various natural/ social conditions. By making full use of such JICA's accumulated knowledge and experiences, it is possible to find non-structure measures consistent with overall agricultural development direction suited to the southern zone.

(2) Capacity development for irrigation engineering sector

In Bhutan, personnel change of irrigation engineering staff from MoAF to the "Ministry of Works and

Human Settlement" had been made in the past. As the result, it is said that growing tendency for improving engineering capacity had been stagnant for this personnel change period. In order that the engineering section of DoA and other related administrative organizations materialize a countrywide irrigation system improvement according to the "National Irrigation Policy", it is required to improve their organization capacity and engineering level. This is the urgent need.

JICA has conducted many technical cooperation projects in the developing countries aiming to improve engineering capacity with rehabilitation of irrigation system. Japan has experienced in providing irrigation facilities under the similar topographic, geologic and river conditions to the southern Bhutan. Through the experience, JICA has accumulated related engineering knowledge and technology. It is possible to make use of them for improvement of engineering capacity, technology and skill of related staff.

6.3.2 Support and Cooperation by Related Donors in Agricultural Development Field

A few other related donor country and international agencies are supporting the development activities of Bhutan. The largest donor country is India, Japan, Denmark, Switzerland and Netherlands, and international agency such as WB, ADB, EU and UNDP are also supporting to the RGoB. For RNR sector, the supporting activities focus on the fields of increase of crop production and improvement of marketing through provision of rural access roads access in line with the 10th Five Year Plan (2008-2013). Supporting to the RNR sector by related agencies is summarized as follow.

(1) Support and Cooperation Project by EU

Assistance priorities set out by the EU in the Country Strategy Paper 2007-13 were developed in line with the 10th Five Year Plan (2008-2013). EU-funded cooperation is focused on three main areas: a) Renewable National Resources (RNR), b) Good Governance and Trade Facilitation, and c) Economic Capacity Building. The on-going cooperation project covers: i) Medical Plants Phase II, ii) Support to livestock Sector Project, iii) Agricultural Sector Support Project and iv) Trade Capacity Development Project. Among the four, for agricultural field, the iii) Agricultural Sector Support Project is on going. It envisages supporting the agricultural production through integrated crop management with a view to ensure that subsistence needs are met and income increases can be obtained through sustainable agricultural production methods. The program "Chuzargang Rice Commercialization Programme (CRCP)" is conducted as the part of this project in Sarpang Dzongkhag.

Project Objectives	:	To improve the livelihood of farmers by developing more profitable system of rice production
Project Purpose	:	The conversion of low altitude rice from a subsistence crop into a commercial cash crop
Project Duration	:	3 years (2009-10 to 2011-2012)
Funding Sources	:	EC, KRII, DANIDA, RGoB
Executing Agency	:	DoA
Implementation Agency	:	Dzongkhag Agriculture Sector, Sarpang Dzongkhag

Data source: Working Document, April 2009, EU-AGRICULTURE SECTOR SUPPORT PROJECT
Major capital costs are put on the fields: “Farm Mechanization and Processing/ Milling”. The project supports in establishing and operating the “Chuzagang Agriculture Farmers Cooperative (CAFCCO)” mentioned in the section 3.3.4.

(2) Supporting Program and Project by IFAD

“Agriculture Marketing Enterprise Promotion Program (AMEPP)” (2008-2011)

The overall goal is to enhance the livelihood means of poor rural households living in six dzongkhags of eastern region and reduce their poverty. The objective is to increase the production levels and productivity of farm-based activities and improve farmers and livestock owners’ access to markets on a sustainable basis.

“Market Access and Growth Intensification Project (MAGIP)” (2011-2015)

The project is operated in the six dzongkhags of the eastern region. The overall goal is to reduce poverty and improve food security and the standards of living of poor rural households. The specific objectives are to improve the productivity of subsistence-based farming systems in communities with no road access, and to intensify the production of cash crops and dairy products, while enhancing smallholder access to markets in communities with road access. Related infrastructure development, project activities include the infrastructure development, including road rehabilitation and construction, irrigation development.

(3) Projects by World Bank (WB)

On-going active projects supported by WB are: i) Reports to Conventions - NAP Alignment and UNCCD Reporting 2012, ii) Additional Financing for the Decentralized Rural Development Project, iii) BT: Improving statistical capacity, iv) BT: Urban Development II, v) Bhutan Private Sector Development, vi) Bhutan Second Rural Access Project, vii) Bhutan - Sustainable Land Management Project. Priority area in the agricultural sector is put on the fields: a) Stimulate agriculture and forest sector sustainable growth, b) Improving access to assets for sustainable resource use, and c) Support for community-based rural development. Among the seven projects as mentioned above, the projects that MoAF is the implementing agency, is the ii) and the vii). Out of the two projects, the ii) “Additional Financing for the Decentralized Rural Development Project” is presently executing. (Data source: <http://web.worldbank.org>)

“Bhutan- Sustainable Land Management Project” (2006-2012)

This project was conducted aiming to strengthen institutional and community capacity for anticipating and managing land degradation. The project has been implemented in the nine gewogs of the three dzongkhags of Chhukha, Trashigang and Zhemgang. The project did not cover directly the irrigation field.

“Additional Financing for the Decentralized Rural Development Project” (2010 – 2013 (expected))

This Project is to provide an additional financing for the prior Decentralized Rural Development

Project. The objective is the same as in the prior project, to improve market access and increase agricultural output for rural communities in selected areas. To achieve this, this Project finances rural access subprojects, new and rehabilitated irrigation canals, agricultural productivity-enhancing activities, and capacity building for sustainable natural resource management. The Project consists: i) *Component 1: Rural Infrastructure* (US\$2.42 million) (rural access and rehabilitation of irrigation canals), ii) *Components 2: Renewable Natural Resources Centers and Support for Improved Technologies and marketing of Rice, Maize and Potato* (US\$1.92 million) and iii) *Component 3: Institutional Strengthening, Project Management and Monitoring* (US\$0.66 million). Project target dzongkhag covers the southern three dzongkhags and Mongar Dzongkhag, in addition to the six original project target dzongkhags of Trongsa, Zhempang, Dagama, Tsirang, Wangduephodrang and Chhukha. (Data source: interview with the DoA)

(4) Support and Cooperation incorporated into the National Budget (2011-2012)

According to the grant aid amount list by related donor countries and organizations, the amount shared by India occupies about 60% of the total. Next is the ADB's one. Large share of cooperation field related with infrastructure is the road sector. (see Table 6.3.1). (Grant aid project "Irrigation rehabilitation project in Taklai area" by JICA is not listed since it is on going.)

Some loan projects are on-going. According to the loan project list incorporated into the national budget (2011-2012), "Rural Electrification Project" by JICA occupies the largest amount of total loan. For the agriculture field, there are the "Agriculture Marketing Enterprise Promotion Program (AMEPP)" and the "Market Access and Growth Intensification Project (MAGIP)" by IFAD and the WB' projects. (see Table 6.3.2).

Except the above mentioned ones, there is no support and cooperation with related donor countries and international organizations targeting to agriculture development field.

6.3.3 Candidate for Cooperation Project with JICA

As the above survey results, the following projects are recommended as candidate for cooperation project with JICA.

- Agriculture Development Study in Southern Bhutan
- Capacity Development Project for Irrigation Engineers
- Irrigation Agriculture Pilot Project

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Table 6.3.1 Grant Aid Amount by Related Donor Countries and Organizations (2011-2012)

Nu. in Millions

Agency	Grant amount										Total
	In-cash contributions					In-kind contributions					
	Current	Capital	Lending	Repayment	Total	Current	Capital	Lending	Repayment	Total	
ADB	3.787	458.586	435.987		898.360		19.968			19.968	918.328
Austrain Coordination Bureau		37.189			37.189						37.189
Danish International Development Agency	14.249	44.215			58.464						58.464
Denmark	0.320	5.822			6.142						6.142
European Commision	6.938	15.451			22.389						22.389
FAO	3.152	6.623			9.775						9.775
Global Environment Facility	44.189	109.333			153.522						153.522
Global Fund to Fight Aids, Tuberculosis & Malar	37.855	36.813			74.668						74.668
Australia		1.104			1.104						1.104
Austria	1.014	59.902			60.916						60.916
Canada	1.402	0.840			2.242						2.242
India	34.041	4,112.701			4,146.742						4,146.742
Japan	0.236	2.365			2.601		94.000			94.000	96.601
Kuwait		11.128			11.128						11.128
Norway	2.051	3.000			5.051						5.051
Netherlands, Other	1.265	15.076			16.341						16.341
India 10th Plan		341.110			341.110						341.110
International Development Association	109.161	145.497			254.658						254.658
IFAD	9.695	22.104			31.799						31.799
Kuwait Fund		10.304			10.304						10.304
Korea	1.479	12.008			13.487						13.487
Swiss Association for Technical Assistance	0.280	23.072			23.352	0.133	3.300			3.433	26.785
Swiss Development Cooperation	12.122	70.923			83.045						83.045
The Netherlands		19.126			19.126						19.126
United Nation Capital Development Fund		10.257			10.257						10.257
United Nation Children's Fund	15.142	49.087			64.229	2.438				2.438	66.667
United Nations Development Program	7.222	52.034			59.256						59.256
United Nations Development Program, IPF	4.317	37.702			42.019						42.019
United nations Environmental Program	1.018	52.496			53.514						53.514
United nations Fund for Population Activities	5.825	21.046			26.871	6.975				6.975	33.846
WB	4.003	96.927			100.930						100.930
WFP	10.759	4.640			15.399						15.399
WHO	24.498	40.310			64.808	0.225				0.225	65.033
World Wild Life Foundation - WWF	6.004	21.038			27.042						27.042
Sub-total	362.024	5,949.829	435.987		6,747.840	9.771	117.268			127.039	6,874.879
Others	63.665	212.255			275.920						275.920
Total External Grant Funding	425.689	6,162.084	435.987		7,023.760	9.771	117.958			127.729	7,151.489

Source: Bhutan Administrative Financial Network

Table 6.3.2 Loan Project by Related International Organizations (2011-2012)

Nu. in Millions

Agency/ Project Name	Loan amount										Total
	In-cash contributions					In-kind contributions					
	Current	Capital	Lending	Repayment	Total	Current	Capital	Lending	Repayment	Total	
ADB											
Road Network Project		55.496			55.496						55.496
Urban Infrastructure Development Project		246.075			246.075		0.060			0.060	246.135
Financial Sector Development Project	0.505	17.000			17.505						17.505
Total for ADB	0.505	318.571			319.076		0.060			0.060	319.136
Government of Austria											
The Financing of Rural Electrification			69.107		69.107						69.107
Total for Austria			69.107		69.107						69.107
Internationa Fund for Agricultural Development											
Agriculture Marketing Enterprise Promotion Program	7.076	29.845	13.331		50.252						50.252
Market Access and Growth Intensification Project (MAGIP)	0.768	13.205			13.973						13.973
Total for IFAD	7.844	43.050	13.331		64.225						64.225
JICA											
Rural Electrification Project			400.000		400.000						400.000
Rural Electrification Project (PhaseII)			882.739		882.739						882.739
Total for JICA			1,282.739		1,282.739						1,282.739
World Bank (WB)											
Decentralised Rural Dev. Project		1.150			1.150						1.150
Urban Development Project	1.705	56.268			57.973						57.973
Total for WB	1.705	57.418			59.123						59.123
Total External Loan Funding	10.054	419.039	1,365.177		1,794.270		0.060			0.060	1,794.330

Source: Bhutan Administrative Financial Network