Only the Nalakha canal has no problem because the water available at intake site is considered sufficient.

Since the irrigation improvement plan is of the one to decrease the present water demand, the above-mentioned future water balance is improved accordingly as explained in Appendix-H.

7.1.2 Groundwater and Sub-surface Water

(1) Sub-surface Water

Sub-surface water is defined as large-scale flowing water in sand and gravel layers, formed in buried ancient river channels, nearby present river flows. Hydrogeologically, it is generally connected with river water, and impossible to divide it from river water in quantitative calculation. Accordingly, groundwater tables of subsurface water generally coincide with those of river water.

As mentioned above, sub-surface water is basically considered same as river water. The Chang Chhu, which has about 4,800 km^2 of catchment area and 270 m^3/sec of mean annual discharge, runs in the study area. The Bajo sub-area, about 1.9 km^2, exists beside the Chang Chhu. Sub-surface water runs in this sub-area, but the water volume of precipitation, surface run-off, infiltration, and evapotranspiration in the sub-area is negligible compared with the total volume of the river.

Judging from this point of view, the water balance of sub-surface flow in the sub-area is negligible in terms of the large-scale water recharge of the Chang Chhu. Rough calculation on exploitable quantity of subsurface flow was made, and one (1) m^3/min was estimated in the low terrace area of the Bajo sub-area.

In the Bajo sub-area, the present and the future water demands for the rural water supply are projected to 44 m^3/day and 66 m^3/day, respectively as explained in Chapter 6. Since 1,000 l/min of potential capacity is interpreted in 1,440 m^3/day, the above demands for rural water supply is judged to be negligible small, less than five (5) % of the recharge capacity. However, it is difficult to utilize it considering that the expected potential capacity is able to command as small area as 10 ha only. Therefore, the sub-surface water resource is considered as one of the resources to be anticipated to provide the rural water in the Bajo sub-area.

(2) Groundwater

1) Groundwater in River Terrace

The groundwater in the river terraces is unconfined, and its water table level is observed five (5) m higher than the river water level of the Chang Chhu.

The chlorine contents of the groundwater in the terrace are as follows:

- 46 ppm in the Umtekha spring water in the background mountain

- 15 ppm in the Limti Chhu river water originated from the eastern mountain and draining the terrace area

- 30 ppm in the water from the groundwater in the terrace, that is the average of above two

These contents are much higher than that of water from other areas. Judging from the above-mentioned fact, the groundwater in the Bajo sub-area is most likely composed of one portion of fracture water from the eastern background mountains and another one portion of the surface water from the Limuti Chhu, a tributary of the Chang Chhu.

In the background mountain area in the north and northeast of the Bajo sub-area, the groundwater run-off from the fissure water into the terrace has been investigated. In this case, the 355 days' specific discharge is set to 7.6 l/km^2/sec, and the area of background mountain is about two (2) km^2. Then, the run-off is calculated to be 15 l/sec as stated below.

Run-off = 7.6 l/km^2/sec × 2.0 km^2 = 15 l/sec (900 l/min)

This is the recharge volume of the groundwater in the river terrace from the eastern mountains, assuming the fracture water of the eastern mountain is diluted by the same amount of river water from the Limti Chhu. The water supply of the groundwater in the area is, therefore, 2,592 m^3/day or 1,800 l/min.

In addition, the infiltration water in the terrace of 0.9 km^2 in area is able to be expected. Assuming the annual precipitation is 1,000 mm and 20 % of the precipitation water percolates into the ground, the volume of 180,000 m^3/year, 493 m^3/day or 340 l/min, of water is added. If recharge from paddy fields in the area is added, then total flow-in volume would roughly be calculated to be about 3,000 m^3/day or 2,000 l/min.

In the following section, exploitable groundwater is considered as 40% of recharge volume. Therefore, 800 l/min of groundwater will be exploitable in the river terrace in Bajo sub-area.

As for the water balance in the Bajo sub-area, about 800 l/sec of the groundwater is considered available in the river terrace along the Chang Chhu. This potential capacity is equivalent to 1,152 m^3/day, and is judged to be quite large comparing with the present and the future water demands which are estimated to be 44 m^3/day and 66 m^3/sec, respectively. The groundwater in the terrace area is, therefore, considered to be one of the potential water resources for the Bajo sub-area.

2) Groundwater in Landslide Areas

The groundwater in the landslide areas is stored in the fractured landslide debris, and small perennial springs yielding 5 to 20 l/min are scattered in the landslide areas.

In Chapter 4, it is discussed that the annual infiltration amount to the landslide areas is 200 mm from precipitation and 240 mm from the background mountains. Accordingly, the recharge amount in an area of 300 m × 300 m is estimated as follows:

300 m × 300 m × 0.44 m = 39,600 m^3/year

On the other hand, the volume of the natural discharge of spring from the similar size of landslide is estimated in 10 l/min or 5,250 m^3/year. Accordingly, if the intake facilities are improved and double or triple amount of water is taken from the springs, only 30 to 40 % of total recharge amount is utilized safely. On the Geological Map 1:10,000, all landslide areas are measured. Then, the recharge volume is calculated for each slided blocks and in turn, 40 % of the recharge volume, which is considered exploitable is calculated as shown on the Groundwater Inventory Map of 1:10,000. Above listed volume is the sum of those figures for each sub-area.

The following table shows the balance of the present and the future water demands and the available capacity of the groundwater in landslide areas.

Water Balance of Groundwater in Landslide Areas

(Unit: m^3/day)

Sub-area	Water Demand Present (1995)	Water Demand Future (2007)	Available Water	Share of Future Water Use (%)
Lobeysa	139	207	450	46
Bajo	44	66	400	17
Phangyul	52	78	1,000	8
Rubeysa	66	98	450	22

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

3) Groundwater in Mud-flow Area

As discussed in the previous chapters, the mudflow deposits are highly porous but less permeable. Judging from the comparison of yielding quantity of the two drill holes, TB-4 and TB-5, the size of catchment area is more significant controlling factor for groundwater volume than the area or volume of mudflow. Applying the values set out in the previous section, specific discharge of metamorphic rock is roughly 7.6 l/sec/km^2 (450 l/min/km^2) that will be recharged to the mudflow area. if 40% of recharge volume is considered exploitable, then the volume will be :

450 x 0.4 = 180 l/min/km^2

In the mudflow area, 180 l/min of groundwater is exploitable for every one (1) km^2 of catchment area of the mudflow. Those catchment areas for each mudflow are measured in the Geological Map and the exploitable volume is calculated using the factor of 180 l/min/km^2. Those calculated volumes are shown on the map of "Groundwater Inventory Map" (1:10,000), and the potential for each sub-areas are summed up and shown on the table in previous section.

The following table presents the present and the future water demands and the calculated potential groundwater in mud-flow areas for each sub-area.

Water Balance of Groundwater in Mud-flow Areas

(Unit: m^3/day)

Sub-area	Water Demand Present (1995)	Water Demand Future (2007)	Available Water	Share of Future Water Use (%)
Lobeysa	139	207	2,450	8
Phangyul	52	78	450	2
Rubeysa	66	98	900	11

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

Consequently, the available groundwater and sub-surface water resources in the Study area are summarized as stated below.

- The sub-surface water is available in the Bajo sub-area, but it is not recommended to utilize it for the irrigation purpose except emergency or supplemental purpose, but for the rural water supply, because its potential is quite small comparing with the irrigation demand.

- The groundwater resources are not recommended to be utilized for the irrigation purpose because of their limited potential comparing the irrigation water demand.

- In the hilly areas such as the Phangyul and the Rubeysa sub-areas, two (2) types of groundwater (groundwater in mud-flow and landslide areas) are considered available. To exploit those in mud-flow area, it is required to conduct drilling works applying heavy equipment. Therefore, it is recommended to utilize those in landslide areas as much as possible.

- The groundwater resources in landslide and river terrace are available in the Bajo sub-area, while those in landslide and mud-flow are available in the Lobeysa sub-area.

7.2 Water Quality

The water quality is one of the important factor to evaluate whether the water envisaged to be utilized is suitable and applicable for any purpose. In this Study, since sub-surface water is directly connected with river water hydrogeologically, it is considered as river water which has similar characteristics in view of water quality. To evaluate such suitability and applicability, water sampling and analyses were carried out in the points shown in Fig. 7.2.1, and their results are summarized in Table 7.2.1 and Table 7.2.2. Fig. 7.2.2 indicates the hexadiagram of the selected samples.

7.2.1 Surface Water

The water qualities were analyzed with the samples listed as follows:

- Pe Chhu — Intake of the Bajo canal
- Dang Chhu — Downstream of the Pe Chhu
- Mo Chhu — Punakha Valley
- Pho Chhu — Punakha valley
- Tabe Rongchhu — Near Thinleygang village
- Chang Chhu — Inflow in the center of the study area
- Limti Chhu — Inflow in the Tedtsho gewog
- Takana Chhu — Inflow in the Rubeysa gewog
- Dongkhar Chhu — Inflow in the Phangyul gewog

The locations of the above-listed sampling points are indicated in Fig. 7.2.1, and the results of the analyses are summarized in Table 7.2.1.

As a result, the surface water is judged to be satisfactory physically, but the results of chemical and biological analyses suggest the necessity of

- iron removal by filtration, and

- disinfection treatment by chrolination.

The characteristics of major parameters of sampled surface water are summarized below.

(1) Physical Examination

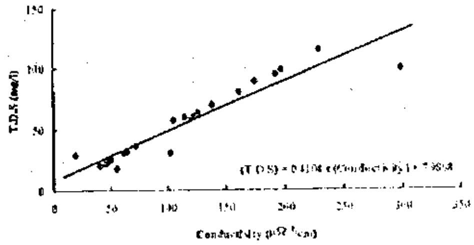
The water quality is observed to be stable and judged to be physically satisfactory except in rainy season. The water is kept low turbidity, normal taste, low color unit as summarized below.

- Appearance is clear in dry season, but turbid and hazy during rainy season

- Temperature widely varies from 15 C° to 25 C°, and approximately 10 C° lower than the atmospheric temperature

- Turbidity is higher in rainy season, and the value often exceeds 100 mg/l especially during and after the flood time.

- Conductivity is observed to vary moderately in accordance with T.D.S. Apparent relation is found between turbidity and T.D.S as presented in the right table. The relationship of these parameters is expressed as follows:



RELATIONSHIP BETWEEN CONDUCTIVITY AND T.D.S.

$$\{T.D.S\ (mg/l)\} = 0.4104 \times \{Conductivity\ (\mu\Omega/cm)\} + 7.9868$$

- Color unit is observed to be lower than five (5) normally in dry season, but it frequently raises during the flood times in the rainy season exceeding 10.

- Taste and Odor are considered generally normal at the measured temperature of 40 C°, except for a few samples.

- Generally turbid and hazy substances are caused by extremely fine choroidal particles of clay or silts. Those choroidal substances might not settle within 24 hr observation.

(2) Chemical Examination

The water is considered chemically satisfactory though moderate ion contents are found as stated below.

- pH value indicates rather high values. The value shows in a range of 7.5 - 8.5 It is considered to be almost the upper limitation of the requirement for drinking water.

- Total Dissolved Solids (T.D.S) moderately varies with a linear regression as shown in the above-presented figure.

- Alkalinity detected on a level of hundred sometimes, which is considered good enough for reacting with Aluminum coagulant.

- Hardness is also detected on a quite low level.

- Chloride is extremely low measured 1-5 mg/l in all samples.

- Sulfate and phosphor are also detected in small values.

- Some small amounts of iron ion is detected, but it is considered within an allowable level.

- Ammonium nitrogen and nitrite nitrogen are detected simultaneously suggesting a contamination by wastes of animals, etc.

(3) Bacteriological Test

Bacterial counts and the bacterial coliform groups are detected in all of the samples, suggesting some degree of contamination caused by both animal and human activities.

7.2.2 Groundwater and Sub-surface Water

The groundwater quality is also examined taking samples in various points in the Study area. The results indicate that the groundwater generally judged to be satisfactory including spring water. The details are discussed below.

(1) Seasonal Fluctuations

The spring water in Phangyul, the observation point S-5 (assay sample S-7), was chemically assayed four (4) times from the end of the dry season to the wet season. The results are as shown in the table presented below.

Seasonal Fluctuation of Spring Water Quality in Phangyul (S-5)

Date Weather		Apr.25 cloudy	May 30 fine	June 4 fine	June 19 fine
1) Physical Exam.					
Appearance		clear	clear	clear	clear
Temperature		15.8	19.1	–	24.2
Conductivity	μΩ/cm	116.9	125.0	123.4	189.1
Turbidity	mg/l	3	3	3	2
Color	degree	<5	<5	<5	<5
Taste		normal	normal	normal	normal
Odor	at 40°C	none	none	none	none
2) Chemical Exam.					
Ph	mg/l as NaCl	8.21	7.60	6.91	7.54
T.D.S	mg/l	58.7	65.0	61.6	95.0
Alkalinity	mg/l	64.0	63.0	62.0	87.0
Hardness	mg/l	38.0	34.0	42.0	41.0
Chloride	mg/l	2	3	6	2
Sulfate	mg/l	<1	<1	<1	<1
Phosphate	mg/l	0.1	0.1	0.2	0.2
Nitrogen					
-Ammonium		nil	nil	nil	nil
-Nitrite		nil	nil	nil	nil
-Nitrate	mg/l	nil	0.8	0.5	0.5
Dissolved Oxygen		5.3	4.8	4.2	5.1
$KMnO_4$	mg/l				
Residual Chlorine					
Iron	mg/l	0.2	0.3	0.05	trace
Manganese	mg/l	nil	nil	nil	nil
Heavy Metal					
-Cu	mg/l	nil	nil	nil	nil
-Cr	mg/l	nil	nil	nil	nil

The reason why the electric conductivity of the water increases from time to time, is attributed to the fact that salts accumulated on the ground surface in the dry season would dissolve and run off in the wet season.

On the other hand, the pH values decreased from 8.21 to 6.91, then increased to 7.54. This phenomenon is interpreted that the iron sulfide minerals (pyrite; F_eS_2) in the black clay layers would be oxidized in the dry season because the groundwater level is lowered. The sulfuric acid water occurring there would subsequently flow out in the wet season, after which the groundwater level would be rise over the black clay layers, sealing the zone of oxidation.

The content of iron ion decreases from April to June, and nitrogen or nitrate appears in May, however this content is very little. These phenomena should be discussed in relation with other factors such as volume of water pouring out at measurement time.

(2) Characteristic Spring Water and Groundwater in Drilled Well

Three (3) water samples from chemically characteristic springs and four groundwater samples from drilled wells have been assayed. As shown in the table, chlorine in the samples from Umtekha spring and Bajo drill hole (TB-2) show high values, and both are genetically related to each other. This is discussed in the previous chapter. Other geochemical characteristics are that a small amount of iron ions are commonly contained in all samples from the wells and phosphate content in all samples is generally high, from 0.1 to 0.45 ppm.

Water Quality of Some Characteristic Springs and Groundwater Sources

Sample No. Date Weather		No.1 June 4 fine	No.2 May 11 fine	No.3 May 30 fine	No.4 Apr.18 fine	No.5 May 9 fine	No.6 May 23 fine	No.7
1) Physical Exam.								
Appearance	clear	clear	clear	turbid	clear	clear	clear	
Temperature		23.0	25.4	19.1	–	24.0		
Conductivity	μΩ/cm	266.0	137.2	125.0	257.0	34.1	0	71.6
Turbidity	mg/l	3	2	3	7	28	10	0
Color	degree	<5	<5	<5	<5	<5	<5	<5
Taste		normal	normal	normal	normal	normal	normal	normal
Odor	at 40°C	none	none	none	none	none	none	slight
2) Chemical Exam.								
pH	mg/l as NaCl	7.23	6.53	7.60	6.96	7.35	7.47	7.00
T.D.S	mg/l	133.0	68.7	65.0	128.8	116.0	153.2	0.353
Alkalinity	mg/l	177.0	57.0	63.0	119.0	96.0	121.0	–
Hardness	mg/l	148.0	30.0	34.0	106.0	81.0	132.0	96.0
Chloride	mg/l	2	46	3	30	0	1	5
Sulfate	mg/l	<1	3	<1	0.5	<1	<1	nil
Phosphate	mg/l	0.1	0.3	0.2	0.1	0.45	0.2	N.A
Nitrogen								
-Ammonium		nil	nil	nil	nil	nil	nil	nil
-Nitrite		nil	nil	nil	nil	nil	nil	0.2
-Nitrate	mg/l	1.5	0.5	0.8	0.5	0.8	nil	nil
Dissolved Oxygen		5.0	4.7	4.8	2.2	5.5	2.3	nil
$KMnO_4$	mg/l							
Residual Chlorine								
Iron	mg/l	nil	nil	0.3	0.45	0.75	0.3	nil
Manganese	mg/l	nil	nil	nil	nil	nil	nil	
Heavy Metal								
-Cu	mg/l	nil	nil	nil	nil	nil	nil	N.A.
-Cr	mg/l	nil	nil	nil	nil	nil	nil	nil

Note;

Sample No.1 S-1, Upper Mitsina
No.2 S-4, Umtekha
No.3 S-7, Proper Phangyul
No.4 W-2, Bajo (TB-2)
No.5 W-3, CARD (TB-3)
No.6 W-4, Mitshina (TB-4)
No.7 Lobeysa (TB-5)

N.A; not assayed

7.3 Environmental Impact

7.3.1 Surface Water

The exploitation of surface water sometimes induces various environmental impacts to upstream as well as downstream areas. It is, therefore, quite essential to forecast extent and magnitude of such adverse effects through the adequate scale of assessment before implementing the water resources development in order to prevent inhabitants, fauna and flora, etc. therein from such effects as much as possible. Nevertheless to say, the costs and expenses necessary for taking remedial measures should be considered in studying and evaluating the envisaged water resources development plans to minimize such adverse effects.

The following adverse effects are considered to be induced by implementing the surface water resources development.

Water Rights and Fishing Rights

Excessive water intake from rivers and lakes may change river flow conditions. In particular, the shortage of a maintenance flow will decrease the river functions. The lowering of river levels will cause difficulty in obtaining irrigation water, reduce the size of fish catch, discourage tourism, and also will affect the water supply, the fishery industry, and the lives of inhabitants.

Hydrological Situation

Excessive water intake from rivers and lakes will result in the decrease of discharge and transportation rate. Such change of flow situation may obstruct the growth and propagation of aquatic lives in downstream area.

Effects during Construction of River Structures

The construction of river structures often causes the effect to the fauna and flora as well as the characteristics of the ecosystem in the downstream area. Such construction increases the turgidity of river water and transports lots of sediment loads giving unexpected adverse effects to the inhabitants and the endemic fauna and flora as well as the ecosystem in the downstream areas.

The adverse effects to be considered for each sub-area are described below.

(1) Lobeysa Sub-area

In the Lobeysa sub-area, the irrigation water is taken from the Tabe Rongchhu, a tributary of the Chang Chhu. The diverted water is conveyed for the irrigation of about 360 ha of farm lands through two (2) irrigation canals; the Upper and Lower Lobeysa Canals. The mean discharge of about 4.0 m^3/sec is available in this river in May according to the hydrological studies. the maintenance discharge of about 0.8 m^3/sec at least should be kept even when the irrigation requirement is increased in the future plan. There are some small streams in the Lobeysa sub-area, but it is rather difficult to utilize such stream water since the flow is observed poor and unstable.

(2) Bajo Sub-area

The irrigation water for the Bajo sub-area depends mainly on the Pe Chhu, a tributary of the Dang Chhu, and the Limti Chhu, a tributary of the Chang Chhu. The Limti Chhu is mainly used for the irrigation for the farm lands in the upstream area, and then for the Bajo sub-area it functions as a supplemental water source. Hence, they use the river water of the Pe Chhu for the irrigation of the Bajo sub-area at present. The river water of the Pe Chhu is utilized for supplying the domestic water for the Wangduephodrang town ship too. The mean river discharge of the Pe Chhu is observed to be about 4.9 m^3/sec, and hence the discharge of about 1.0 m^3/sec is required to be kept for maintaining the perennial river flow in good condition.

(3) Phangyul Sub-area

In the Phangyul sub-area, the rural water supply is made by mainly utilizing spring water, and only the irrigation water depends on the surface water of some perennial streams tributaries flowing into the Pe Chhu. However, since the stream flows in these small streams are observed to be small, it is proposed to take adequate measures to keep the sufficient discharges of stream flow in the streams.

(4) Rubeysa Sub-area

The stream flow is found to be quite scarce in the Rubeysa sub-area, and even the irrigation water being diverted from the small streams in the area is considered insufficient. Therefore, no further development increasing the water requirement is proposed to be implemented without any proper measure. Most of the present rural water supply schemes utilize the spring water at present.

7.3.2 Groundwater and Sub-surface Water

In this survey, the water in the underground is classified into two types; subsurface water and groundwater.

Subsurface water is present in the low terraces, and water table is about two (2) m from the ground surface. Its flow speed in some ancient river channels is significantly high. The sub-surface water is directly supplied from rivers, and exploitation may have no impact on the physical and ecological environment.

The groundwater is hosted in the middle terraces and landslide areas. The middle terraces are utilized as cultivated ground or residential areas, and some irrigation water channels are constructed for rice fields. It is estimated that the groundwater in the middle terraces, being hosted below 25 m to 30 m from the surface, is supplied and recharged in a rate of about 2,000 l/min.

Accordingly, as far as a smaller amount than the above-mentioned figure is pumped up, no environmental impact such as change of soil moisture in farmlands is expected on the surface in the terrace area.

As previously mentioned, there are two (2) types of recharge patterns for the groundwater in landslide areas, i.e. penetration (infiltration) from precipitation and infiltration from fracture water in the background mountain.

The amount of infiltration from the precipitation of about 1,000 mm/year is estimated at 200 mm/year, and that from the fracture water in the background mountain is about 240 mm. Therefore, the total quantity of annual recharge for each landslide block is calculated as follows:

Area (m^2) × 0.44 (m) = Annual recharge (m^2)

For example, if the area is 300 m × 300 m, the quantity of the recharge would be:

90,000 m^2 ×0.44 m = 40,000 m^3/year (76 l/min)

At present, the yield from springs in landslides of such scale is about 10 l/min, and hence no adverse impact on the groundwater system would occur even if the yield volume is increased up to three (3) times by improving the existing facilities.

In conclusion, the groundwater in the landslide areas can be utilized as much as two (2) or three (3) times of the present yield by improving existing facilities without any adverse environmental or ecological impact. The water in the middle level terraces can also be utilized within the recharge volume of 2,000 l/min as estimated before.

CHAPTER 7
TABLES

Table 7.1.1 Result of Water Balance Study for Surface Water Resources

Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)					
Lobevsa	Taberong Chhu				Upper Lobevsa, Lower Lobevsa						361				Taberong Chhu				119.4					
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Available River Discharge	2.081	2.081	2.000	2.000	1.862	1.862	2.585	2.585	3.227	3.227	6.423	6.423	9.963	9.963	13.404	13.404	10.862	10.862	4.853	4.853	3.429	3.429	2.423	2.423
Water Requirement for Irrigation	0.165	0.167	0.243	0.237	0.281	0.206	0.132	0.055	0.000	1.133	0.995	0.710	0.616	0.304	0.326	0.302	0.350	0.313	0.108	0.000	0.071	0.117	0.145	0.166
Water Balance	1.916	1.914	1.757	1.763	1.580	1.655	2.453	2.529	3.227	2.094	5.428	5.713	9.346	9.658	13.079	13.103	10.511	10.549	4.745	4.853	3.358	3.312	2.278	2.257
Insufficiency																								
Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)					
Bajo	Pe Chhu				Bajo						143				Pe Chhu				145.7					
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Available River Discharge	2.540	2.540	2.440	2.440	2.272	2.272	3.154	3.154	3.938	3.938	7.837	7.837	12.157	12.157	16.357	16.357	13.254	13.254	5.922	5.922	4.184	4.184	2.957	2.957
Water Requirement for Irrigation	0.065	0.066	0.098	0.095	0.111	0.082	0.054	0.023	0.000	0.451	0.398	0.286	0.251	0.127	0.139	0.129	0.144	0.129	0.042	0.000	0.028	0.046	0.057	0.066
for Domestic	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Total	0.083	0.084	0.116	0.113	0.129	0.100	0.072	0.041	0.018	0.469	0.416	0.304	0.268	0.145	0.157	0.147	0.162	0.147	0.060	0.018	0.046	0.064	0.075	0.084
Water Balance	2.457	2.456	2.325	2.327	2.142	2.172	3.083	3.113	3.920	3.468	7.421	7.534	11.889	12.012	16.200	16.210	13.092	13.107	5.862	5.904	4.138	4.120	2.881	2.873
Insufficiency																								
Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)					
Phangyul	Lachhu				Phangyul						91				Lachhu				2.23					
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Available River Discharge	0.039	0.039	0.037	0.037	0.035	0.035	0.048	0.048	0.060	0.060	0.120	0.120	0.186	0.186	0.250	0.250	0.202	0.202	0.090	0.090	0.064	0.064	0.045	0.045
Water Requirement for Irrigation	0.043	0.043	0.050	0.048	0.067	0.049	0.024	0.005	0.000	0.256	0.216	0.148	0.127	0.052	0.048	0.043	0.056	0.047	0.028	0.000	0.019	0.030	0.037	0.042
Water Balance	-0.004	-0.004	-0.012	-0.011	-0.033	-0.014	0.024	0.043	0.060	-0.196	-0.097	-0.029	0.059	0.133	0.202	0.207	0.146	0.155	0.062	0.090	0.045	0.034	0.008	0.003
Insufficiency	-(9%)	-(10%)	-(25%)	-(22%)	-(48%)	-(29%)				-(77%)	-(45%)	-(19%)												
Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)					
Phangyul	Uship				Gemkha						15				Uship				0.84					
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Available River Discharge	0.015	0.015	0.014	0.014	0.013	0.013	0.018	0.018	0.023	0.023	0.056	0.056	0.116	0.116	0.187	0.187	0.152	0.152	0.042	0.042	0.024	0.024	0.017	0.017
Water Requirement for Irrigation	0.007	0.007	0.008	0.008	0.011	0.008	0.004	0.001	0.000	0.042	0.036	0.024	0.021	0.009	0.008	0.007	0.009	0.008	0.005	0.000	0.003	0.005	0.006	0.007
Water Balance	0.008	0.007	0.006	0.006	0.002	0.005	0.014	0.017	0.023	-0.020	0.020	0.032	0.095	0.107	0.180	0.180	0.143	0.144	0.038	0.042	0.021	0.019	0.011	0.010
Insufficiency										-(47%)														
Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)					
Rubevsa	Mochuna				Nalakha						29				Mochuna				8.78					
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Available River Discharge	0.153	0.153	0.147	0.147	0.137	0.137	0.190	0.190	0.237	0.237	0.472	0.472	0.732	0.732	0.985	0.985	0.798	0.798	0.357	0.357	0.252	0.252	0.178	0.178
Water Requirement	0.014	0.014	0.017	0.016	0.022	0.016	0.008	0.002	0.000	0.082	0.070	0.048	0.041	0.017	0.016	0.014	0.020	0.017	0.009	0.000	0.006	0.010	0.012	0.014
Water Balance	0.139	0.139	0.130	0.131	0.115	0.121	0.181	0.188	0.237	0.155	0.402	0.424	0.691	0.715	0.969	0.971	0.779	0.782	0.348	0.357	0.246	0.242	0.166	0.164
Insufficiency																								
Sub-Area	Name of River				Name of Canal						Total Command Area (ha)				Name of River				Catchment Area (km2)					
Rubevsa	Takarong Chhu				Ruteka, Mapheka, Naykoyuka, Rumina						119				Takarong Chhu				6.8					
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Available River Discharge	0.119	0.119	0.114	0.114	0.106	0.106	0.147	0.147	0.184	0.184	0.366	0.366	0.567	0.567	0.763	0.763	0.619	0.619	0.276	0.276	0.195	0.195	0.138	0.138
Water Requirement	0.056	0.057	0.069	0.067	0.090	0.066	0.035	0.010	0.000	0.337	0.286	0.198	0.168	0.072	0.066	0.059	0.080	0.069	0.036	0.000	0.024	0.040	0.049	0.056
Water Balance	0.063	0.062	0.045	0.047	0.016	0.040	0.112	0.138	0.184	-0.153	0.080	0.168	0.399	0.496	0.698	0.705	0.538	0.550	0.240	0.276	0.171	0.156	0.089	0.082
Insufficiency										-(45%)														

Table 7.2.1 Results of Water Quality Analysis (Surface Water) (1/2)

Items		Sampling Point	R-4 Pe Chhu Intake	R-4 Pe Chhu Intake	R-4 Pe Chhu Intake	R-6 Tacksasew Chhu Source of Irrigation	R-14 Metshina	R-3 Dang Chhu H Bridge	R-3 Dang Chhu H. Bridge	R-3 Dang Chhu H. Bridge	R-7 Lunn Chhu Wangokha	R-9 Pho Chhu Punakha	R-9 Pho Chhu Punakha	R-12 Domkhar Chhu
		Sampling Date	18 Aprill, 1994 Fine	9 June, 1994 Fine	18 June, 1994 Rainy	19 May Fine	4 May Fine	3 May Fine	9 June Fine	18 June Rainy	18 April Cloudy	18 June Rainy	25 June Fine	May 9 Little Rain
1) PHYSICAL EXAMINATION		Recommended Allowable Value												
Appearance		Clear	clear	clear	slightly turbid	slightly turbid	clear	have some S.S	clear	slightly turbid	muddy high turbid	white turbid	white turbid	brownish
Temperature			14.8	27.8	18.3	15.0	24.9	24.0	26.9	16.3	17.0	15.5	17.5	21.0
Conductivity	s/cm		196.5	298.0	192.1	72.0	161.5	126.3	114.8	119.9	138.5	46.4	40.5	138.1
Turbidity	mg/l	5 or less as Silica	5	2	22	9	1	2	4	19	3,640	120	102	23
Colour	degree	5 or less	< 5	< 5	< 5	< 5	< 5	< 5	< 5	10	Redish brown	7	5	18
Taste		Normal	normal	normal	normal	normal	normal	normal	normal	normal	soil	normal	normal	soily
Odour	at 40 C	Odourless	odourless	odourless	odourless	odourless	odourless	odourless	odourless	odourless	soil small	odourless	odourless	odourless
2) CHEMICAL EXAMINATION														
pH		7.0 - 8.5	8.45	8.49	8.55	7.85	7.87	8.17	8.34	8.37	7.45	7.85	7.83	8.2
T.D.S	mg/lasNaCl	500 or less	98.6	99.1	95.7	36.1	80.8	63.2	59.9	59.6	70.0	23.3	20.5	69.1
Alkalinity	mg/l		100.0	108.0	92.0	31.0	68.0	48.5	60.0	62.0	72.0	29.0	25.4	60.0
Hardness	mg/l	300 or less as CaCO3	91.0	96.0	89.5	2.2	72.0	31.0	52.0	50.0	51.0	25.0	20.0	48.0
Chloride	mg/l	200 or less	2	< 1	< 1	1	1	2	2	2	15	5	4	2
Sulfate	mg/l	200 or less	3.0	< 1	< 1	< 1	2	< 1	< 1	< 1	-	< 1	< 1	< 1
Phosfate	mg/l		0.3	0.1	0.1	0.1	< 0.1	0.05	0.1	0.1	-	0.02	0.01	0.5
Nitrogen														
- Ammonium		not detected	Nil	Nil	Nil	Nil	Nil	0.02	Nil	0.1	-	Nil	Nil	0.02
- Nitrite		simultaneously	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	-	Nil	Nil	Nil
- Nitrate	mg/l	45 or less	1.5	0.5	0.5	2.0	1.5	0.5	0.5	0.45	-	0.3	0.45	0.2
Dissolved Oxygen	mg/l	saturated	9.8	4.7	7	6.6	7.0	7.1	5.2	7.8	5.6	8.1	7.9	5.7
KMnO4 Consumption	mg/l	10 or less												
Residual Chlorine	mg/l													
Iron	mg/l	0.3 or less	Nil	trace	trace	trace	0.25	Nil	Nil	Nil	-	0.2	0.1	0.25
Manganese	mg/l	0.1 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	-	Nil	Nil	Nil
Heavy Metal	mg/l													
- Cu	mg/l	1.0 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	-	Nil	Nil	Nil
- Cr	mg/l	0.05 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	-	Nil	Nil	Nil
3) BACTERIAL EXAMINATION (Qualitative)														
Bacterial Count		100/1ml or less	+	++	+	+	[illegible]	+	+	++		++		++
Coliform Index		0/100 ml	++	++	++	[illegible]	++	++	+	++		++		+
Health Risk Assessment		Safe water - Low Risky water + Risky Water ++ Grossly polluted water +++												
Luxuary of Water Use		1) Comfortable 2) Comfortless 3) Unendurable	1	1	2	2	1	2	2	2	2	2	2	2

Table 7.2.1 Results of Water Quality Analysis (Surface Water) (2/2)

Items		Sampling Point	R-2 Chang Chhu	R-2 Chang Chhu	R-2 Chang Chhu	R-13 Tamluchu (Geonkha)	R-5 Tekama Chhu	R-1 Mo Chhu Punakha	R-1 Mo Chhu Punakha	R-1 Mo Chhu Punakha	R-1 Mo Chhu Punakha	R-11 Tabe Rongchhu	R-11 Tabe Rongchhu	R-11 Tabe Rongchhu	R-11 Tabe Rongchhu
		Sampling Date	May 3 Fine	June 19 Fine	June 18 Fine	May 30 Fine	May 28 Fine	June 9 Fine	June 15Rainy	June 18 Rainy	June 25 Fine 29.5 C	April 20 Fine	June 9 After Rain	June 18 Little Rain 27.0 C	June 25 Fine 30 C
1) PHYSICAL EXAMINATION		Recommended Allowable Value													
Appearance		Clear	slightly turbid	white turbid	yellowish turbid	floating matter clear	clear	yellowish turbid	brownish	yellowish turbid	turbid	clear	slightly turbid	slightly turbid	slightly turbid
Temperature		-	22.5	24.4	15.7	20.4	22.0	16.7	16.7	16.5	17.0	18.2	24.0	24.1	25.5
Conductivity	μ/cm	-	63.9	19.1	50.6	229	174.2	61.2	47.4	44.9	40.5	54.9	122.8	102.3	105.0
Turbidity	mg/l	5 or less as Silica	4	55	104	4	1	50	95	68	102	4	9	23	20
Colour	degree	5 or less	<5	<5	15	<5	<5	15	20	10	15	<5	<5	10	15
Taste		Normal	normal	soily	soily	normal	normal	soily	soily	soily	soily	normal	normal	normal	normal
Odour	at 40 C	Odourless	odourless	soily	soily	odourless	odourless	soily	soily	soily	soily	odourless	odourless	odourless	odourless
2) CHEMICAL EXAMINATION															
pH		7.0 - 8.5	7.64	8.01	7.79	7.85	8.19	8.18	7.73	7.78	7.22	7.98	8.89	8.11	8.22
T.D.S	mg/lasNaCl	500 or less	31.9	29.4	25.3	115.0	89.2	30.7	23.5	22.5	20.3	18.5	61.1	31.1	58.0
Alkalinity	mg/l	-	24.5	28.0	20.0	91.0	114.0	23.0	118.0	24.0	20.1	16.0	51.0	35.0	48.0
Hardness	mg/l	300 or less as CaCO3	21.0	22.0	24.0	89.0	87.0	18.0	14.0	21.0	20.0	14.0	50.0	30.0	40.0
Chloride	mg/l	200 or less	1	2	2	2	5	2	1	3	2	3	10	15	18
Sulfate	mg/l	200 or less	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Phosfate	mg/l		0.1	0.1	0.01	0.02	<0.5	0.01	0.05	0.02	0.01	0.2	0.02	0.02	0.02
Nitrogen															
- Ammonium		not detected	0.25	Nil	Nil	0.5	Nil	0.3	0.5	0.05	0.03	0.05	0.05	0.15	0.2
- Nitrite		simultaneously	trace	Nil	Nil	0.01	Nil	Nil	Nil	Nil	Nil	0.01	Nil	Nil	Nil
- Nitrate	mg/l	45 or less	2.0	1.5	0.8	0.45	Nil	1.0	1.0	Nil	Nil	0.25	Nil	0.15	0.3
Dissolved Oxygen	mg/l	saturated	4.3	4.6	6.2	7.8	5.4	7.6	7.4	7.9	7.3	8.3	4.7	5.9	5.8
KMnO4 Consumption	mg/l	10 or less													
Residual Chlorine	mg/l														
Iron	mg/l	0.3 or less	0.3	0.25	0.2	0.1	trace	0.8	1.0	0.15	0.2	Nil	0.2	0.35	0.3
Manganese	mg/l	0.1 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Heavy Metal	mg/l														
- Cu	mg/l	1.0 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
- Cr	mg/l	0.05 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
3) BACTERIAL EXAMINATION (Qualitative)															
Bacterial Count		100 /ml or less	+	++	++	++	++	+	+	++	+	+	+	++	++
Coliform Index		0/100 ml	+	+	+	++	+	+	+	++	+	++	++	++	+
Health Risk Assessment		Safe water - Low Risky water + Risky Water ++ Grossly polluted water +++													
Luxury of Water Use		1) Comfortable 2) Comfortless 3) Unendurable	2	2	2	2	1	2	2	2	2	1	2	2	2

Table 7.2.2 Results of Water Quality Analysis (Groundwater, Spring Water and Tap Water) (1/2)

Items		Sampling Point	S-4 Rinchengang (Holly Water)	S-4 Umetakha	S-9 Hambakha	S-10 Rinchengang	S-7 Proper Phangyul	S-7 Proper Phangyul	S-7 Proper Phangyul	S-7 Proper Phangyul	S-13 Damuna	S-6 Rumina	S-6 Rumina	S-11 Thinleygang	S-5 Mindeygang
		Sampling Date	May 21 Fine	May 11 Fine	April 25 Fine	May 21 Fine	June 4 Fine	May 30 Fine	June 19 Fine	April 25 Cloudy	May 26 Fine	April 19 Fine	June 28 Fine	May 4 Fine	May 4 Fine
1) PHYSICAL EXAMINATION		Recommended Allowable Value													
Appearance		Clear	clear	clear	clear	slight turbid	clear	clear	clear	clear	clear	clear	Yellowish turbid	clear	clear
Temperature		-	20.4	25.4	18.6	19.5		19.1	24.2	15.8	18.5	17.9	22.5	20.0	20.6
Conductivity	g/cm	-	244.0	137.2	13	250.0	123.4	125.0	189.1	116.9	455.0	110.0	114.8	70.8	84.0
Turbidity	mg/l	5 or less as Silica	2	2	2	8	3	3	2	3	4	3	220	< 1	< 1
Colour	degree	5 or less	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	50	< 5	colourless
Taste		Normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	metalic	normal	normal
Odour	at 40 c	Odourless	odourless	odourless	odourless	odourless	odourless	odourless	odourless	odourless	odourless	odourless	metalic	odourless	odourless
2) CHEMICAL EXAMINATION															
pH		7.0 - 8.5	7.72	6.53	7.01	8.01	6.91	7.6	7.54	8.21	7.55	6.46	6.77	7.92	7.84
T.D.S	mg/lasNaCl	500 or less	122.0	68.7	26.5	125.0	61.6	65.0	95.0	58.7	228.0	5.2	57.5	35.4	42.1
Alkalinity	mg/l	-	95.0	57.0	23.0	203.0	62.0	63.0	87.0	64.0	184.0	39.0	38.0	28.0	42.0
Hardness	mg/l	300 or less as $CaCO_3$	88.0	30.0	18.0	193.0	42.0	34.0	44.0	38.0	163.0	39.0	35.0	16.0	27.0
Chloride	mg/l	200 or less	8	46	< 1	3	6	3	2	2	3	3	< 1	1	6
Sulfate	mg/l	200 or less	< 1	3	< 1	0.4	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 0.1	< 1
Phosfate	mg/l		0.8	0.3	0.3		0.01	0.2	0.2	0.1	0.02	0.05	< 1	< 0.1	0.1
Nitrogen															
- Ammonium		not detected	Nil	Nil	0.05	Nil	Nil	Nil	Nil	Nil	0.55	0.05	0.45	0.25	Nil
- Nitrite		simultaneously	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.21	Nil	0.25	1.75	Nil
- Nitrate	mg/l	45 or less	0.3	0.5	0.2	0.3	0.5	0.8	0.5	Nil	0.45	0.45	3	4	Nil
Dissolved	mg/l	saturated	6	4.7	8	4.8	4.2	4.8	5.1	5.3	4.4	8.2	5.1	5.2	6.3
$KMnO_4$	mg/l	10 or less													
Residual	mg/l	-													
Iron	mg/l	0.3 or less	trace	Nil	Nil	Nil	0.05	0.3	trace	0.2	0.1	0.3	> 5.0	0.25	Nil
Manganese	mg/l	0.1 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Heavy Metal	mg/l														
- Cu	mg/l	1.0 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
- Cr	mg/l	0.05 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
3) BACTERIAL EXAMINATION (Qualitative)															
Bacterial Count		100/ml or less		+−	++	+−	+−	—	++	++	+	++	—	++	++
Coliform Index		0/100ml		+	++	++	++	++	++	++	+−	+	+	++	++
Health Risk Assessment		Safe water - Low Risky water +- Risky Water ++ Grossly polluted water +++													
Luxury of Water Use		1) Comfortable 2) Comfortless 3) Unendurable	1	1	1	2	1	1	1	1	1	1	2	1	1

Table 7.2.2 Results of Water Quality Analysis (Groundwater, Spring Water and Tap Water) (2/2)

Items		Sampling Point	S-14 Sopsukha	S-1 Upper Mitshina	S-3 PWD Camp Mitshina	W-3 CARD	D-1 Distribution Station	D-1 Distribution Station	T-4 Bajo Tap	T-1 Wangdue-phodrang Tap	T-1 Wangdue-phodrang Tap	T-5 Gangkha	W-3 CARD	W-2 Bajo	W-4 Mitshina	W-4 Mitshina
		Sampling Date	May 21 Fine	June 4 Fine	May 21 Fine	May 9 Fine	April 18 Fine	24-May	May 11 Fine	June 5 Fine	June 18 Fine	May 3 Fine	May 21 Fine	April 18 Fine	May 20 Fine	May 23 Fine
1) PHYSICAL EXAMINATION		Recommended Allowable Value														
Appearance		Clear	clear	clear	clear	white turbid	clear	turbid	clear	clear	turbid	clear	Yellow turbid	slightly turbid (R.T)	slight turbid	clear
Temperature		-	20.4	23.0	19.5	24.0	18.4	20.4	25.0	25.1	25.0	15.9	25.5			
Conductivity	g/cm	-	229.0	266.0	150.3	34.1	193	201	149.9	199.7	201	145	293	257.0	20	0.0
Turbidity	mg/l	5 or less as Silica	11	3	11	28	7	28	8	< 5	10	6	300	7	26	10
Colour	degree	5 or less	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 10	< 5	90	< 5	< 5	< 5
Taste		Normal	normal	normal	normal	normal	normal	soily	normal	normal	normal	normal	soily	normal	normal	normal
Odour	at 40 c	Odourless	odourless	odourless	odourless	odourless	odourless	soily	odourless	odourless	odourless	odourless	soily	odourless	odourless	slightly
2) CHEMICAL EXAMINATION																
pH		7.0 - 8.5	7.86	7.23	7	7.35	8.47	8.51	8.03	8.33	8.21	8.2	7.39	6.96	8.11	7.47
T.D.S	mg/lasNaCl	500 or less	102.0	133.0	75.0	116.0	93.2	100.5	75.0	101.8	108.0	73.0	146.0	128.8	159.3	153.2
Alkalinity	mg/l	-	110.0	177.0	73.0	96.0	104.0	101.0	69.0	100.0	110.0	62.0		119.0	140.0	132.0
Hardness	mg/l	300 or less as CaCO3	4.0	148.0	69.0	81.0	102.0	79.0	37.0	102.0	102.0	60.0		106.0	129.0	121.0
Chloride	mg/l	200 or less	2	2	2	0	2	2	2	2	2	2		30	6	1
Sulfate	mg/l	200 or less	< 1	< 1	5	< 1	2	< 1	< 1	< 1	< 1	< 1		0.5	< 1	< 1
Phosfate	mg/l		0.1	0.1	0.15	0.45	0.45	0.25	0.1	< 0.1	< 0.1	< 0.1		0.1	0.2	0.2
Nitrogen																
- Ammonium		not detected	Nil	Nil	Nil	Nil	Nil	0.55	Nil	Nil	Nil	0.25		Nil	Nil	Nil
- Nitrite		simultaneously	Nil	Nil	Nil	Nil	1.5	0.5	trace	0.2	0.1	0.75		Nil	0.5	Nil
- Nitrate	mg/l	45 or less	0.5	1.5	0.15	0.8	2.0	1.5	0.025	1.5	1.5	5		0.5	0.45	Nil
Dissolved	mg/l	saturated	7.8	5	6.5	5.5	7	6.9	6.4	6.3	6.8	7.6	5.1	2.2	5.9	2.3
KMnO4	mg/l	10 or less														
Residual	mg/l	-														
Iron	mg/l	0.3 or less	0.2	Nil	Nil	0.75	Nil	Nil	0.45	trace	trace	0.3		0.45	0.25	0.3
Manganese	mg/l	0.1 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil		Nil	Nil	Nil
Heavy Metal	mg/l															
- Cu	mg/l	1.0 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil		Nil	Nil	Nil
- Cr	mg/l	0.05 or less	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil		Nil	Nil	Nil
3) BACTERIAL EXAMINATION (Qualitative)																
Bacterial Count		100 but or less	+++	+++		++			+	+++	+++	++	++	+++	+++	++
Coliform Index		0/100 ml	++	++	+	++	++	++	++	+	-	++	++	++	++	++
Health Risk Assessment		Safe water - Low Risky water + Risky Water ++ Grossly polluted water														
Luxury of Water Use		1) Comfortable 2) Comfortless 3) Unendurable	1	1	1	2	1	2	2	1	2	1	2	2	2	2

CHAPTER 7
FIGURES

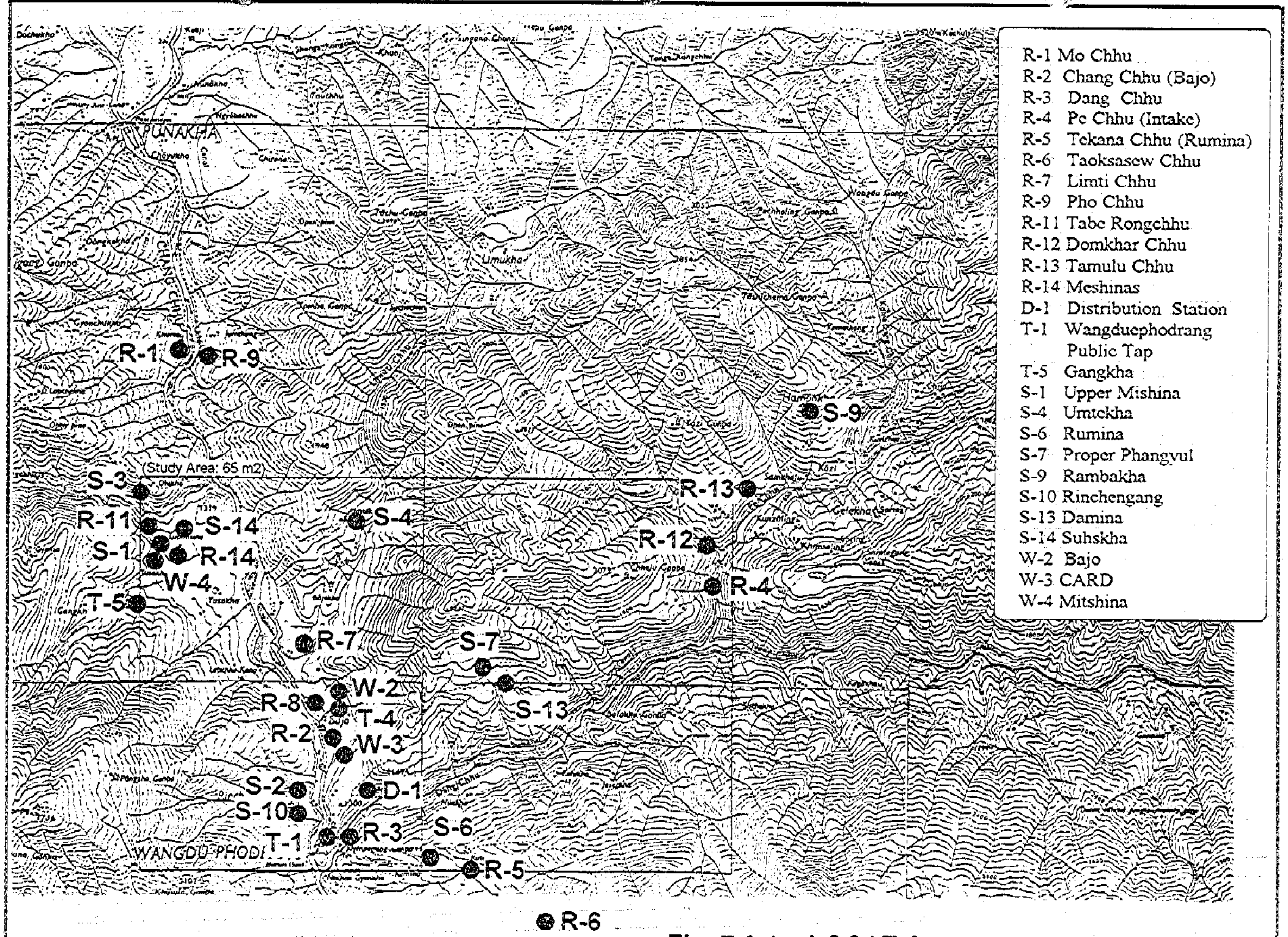


Fig. 7.2.1 LOCATION OF WATER SAMPLING

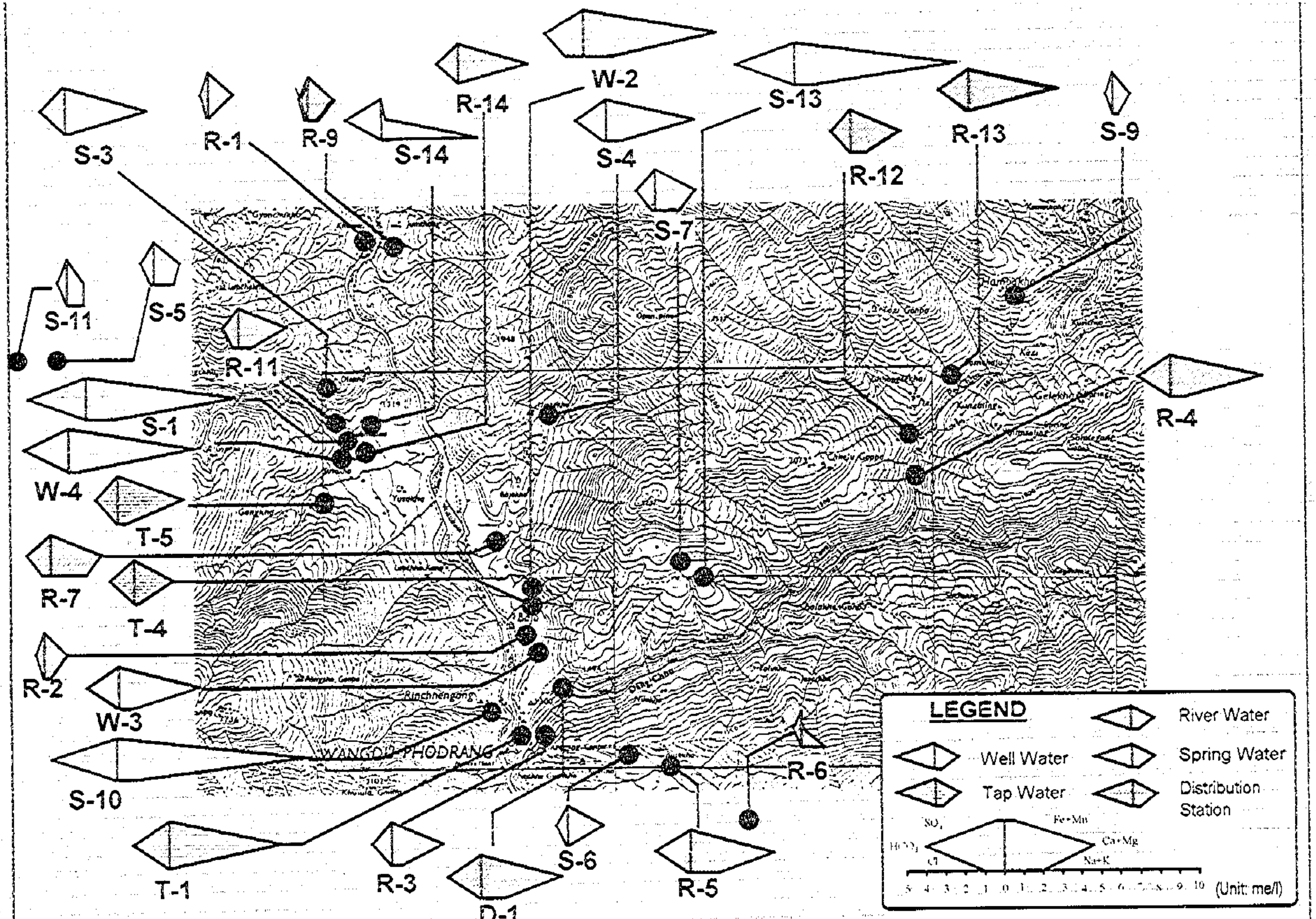


Fig. 7.2.2 HEXADIAGRAM FOR WATER QUALITY SURVEYED IN THE STUDY AREA

CHAPTER 8
WATER RESOURCES DEVELOPMENT BASIC PLAN

8. Basic Water Resources Development Plan

8.1 Basic Concept and Planning Criteria

8.1.1 Constraints in Present Water Use

The following constraints and problems are found and identified in the present water use of irrigation and domestic water supplies through the studies, analyses and field surveys having been conducted so far.

(1) Urban and Rural Water Supply

Urban Water Supply System

- Since the quantity delivered from the Pe Chhu is not sufficient due to lack of supply capacity of the system, the water distribution is made intermittently at present and the irrigation water conveyed by the Bajo canal is also sometimes used for the urban water supply. (Shortage of Supply Capacity)

- The present distribution networks were constructed in 1969. Since then many branch lines have been added and expanded at random resulting in the inadequate and unbalanced distribution networks. (Inadequate Distribution Networks)

- The irrigation water of the Bajo canal is frequently used for the urban water supply during the irrigation season, and such irrigation water is apt to be bacteriologically contaminated by the animal waste and landslide mud. However, no treatment is conducted in the present distribution system except for simple sedimentation. The turbidity data of raw water from the Pe Chhu also indicate higher value than 20 frequently during the rainy season. (Risk to Infection)

Rural Water Supply System

- In rural areas, the service ratio of the existing water supply schemes reaches only 67 %, and the remaining 33 % of dwellers have to take water from irrigation canals, river streams or small spring pools for their domestic use. (Low Service Ratio)

(2) Irrigation Water Supply

- The capacities of the existing irrigation canals are judged to be insufficient in most of the irrigation systems in the Study area causing the decrease of cropping areas. (Insufficient Canal Capacity)

- The present water management system prevailing in most of the irrigation areas is considered impractical to utilize the available water properly. (Impractical Water Management)

- The available water resources at the intake sites are considered insufficient particularly in the high hilly areas such as Phangyul and Rubeysa sub-areas. (Insufficient Water Resources in Hilly Area)

8.1.2 Concepts of Basic Water Resources Development Plan

(1) Components of Basic Plan

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

- the irrigation water supply plan, and

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

Taking into account that all the water resources available in the Study area is at present used for the above two (2) purposes only, and any other use of water resources is neither planned nor scheduled for the future. The water resources are also used separately for these two (2) purposes except for the surface water in the Pe Chhu which is used for both irrigation of the Bajo sub-area and water supply for the Wangduephodrang town area.

(2) Basic Concepts

Considering the results of the discussions made in the previous chapters and sections, the Basic Water Resources Development Plan are considered to be established in order to realize and attain the ideal social conditions so as to allow the inhabitants to lead productive lives in a sustainable and balanced manner as stated below.

Irrigation Water Supply

- Achievement of the effective irrigation water use

- Achievement of the effective land use

Urban and Rural Water Supply

- Decrease of the risks to various infectious diseases

- Facilitation of the rural and urban development

- Provision of the basic human needs in rural and urban areas

8.1.3 Planning Criteria

(1) Objectives of Water Resources Development

Considering the basic concepts stated above, the Basic Water Resources Development Plan for the Irrigation and Domestic Water Supplies is to be established and formulated to fulfill and satisfy the objectives set as stated below.

Irrigation Water Supply

The following items, in conformity with which the RGOB has made efforts to promote agricultural developments under the Seventh Five Year Plan (1992-1997), are considered as the objectives of the Basic Plan.

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

Urban and Rural Water Supply

Under the above basic concepts, the following items are set as the objectives of the basic plan.

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

(2) Target Years

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

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

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

- 2007 for long term plan

- 2002 for short term plan

(3) Necessary Consideration in Planning

The following items are considered necessary for formulating the Basic Water Resources Development Plan for Irrigation and Domestic Water Supplies.

1) Irrigation Water Supply

- To attain the effective use of the agricultural lands and the limited water resources, several countermeasures such as improvement of water management, irrigation canal, diversification, improvement of water resources, etc. should be proposed. The optimum countermeasure will be determined comparing with such countermeasures, and focusing on the net B/C ratios through the case study.

- Considering the topographic characteristics of each sub-area, the Study area is broadly categorized into two (2) groups; one is the high hilly area and the other is the low flat area. The constraints in present irrigation systems differ from sub-area to sub-area, and then the optimum countermeasures is also considered to be different depending on such different constraints of sub-areas. Therefore, the case study is carried out for these two (2) groups.

- As a result of the Study, several development schemes will be proposed. The priority should be given to them according to the net B/C ratio, and the most effective implementation plan will be proposed.

2) Domestic Water Supply

- Considering the present situation that many inhabitants both in urban and rural areas are suffering from shortage of water, the highest priority will be put on the plan to reserve enough volume of domestic water to meet the increasing demands.

- The improved and/or introduced water supply systems should be of the quality and level same as those being implemented in the other similar areas in the country in order to avoid uneven development.

- It is necessary and essential to consider the existing plans related to the water resources development in the Study area as well as municipality and town development plans in order to formulate such basic plans in a most realistic and suitable way.

8.2 Water Resources Development Plan for Irrigation Water Supply

8.2.1 Proposed Countermeasures

Considering the effective use of the agricultural land and limited water resources, the following countermeasures are proposed for the irrigation improvement plan.

- Improvement of water management system (Case A)
- Improvement of irrigation capacity (Case B)
- Improvement of water sources (Case C)
- Crop diversification (Case D)
- Expansion of double paddy cropping (Case E)
- Combination of countermeasures mentioned above

The following two (2) irrigation schemes are selected out of the 10 irrigation schemes in the Study area to determine the optimum countermeasure.

- Bajo canal representing low flat areas
- Phangyul canal representing high hilly areas

The cost and benefit of each countermeasure are estimated in the case study. The flow of the case study is shown in Fig. 8.2.1, and the applied study cases are summarized in Table 8.2.1.

8.2.2 Conditions of Case Study

(1) Water Requirement

Irrigation Efficiencies

Present Condition	Field Efficiency	Conveyance Efficiency	Total Efficiency
Paddy	0.9	0.72	0.648
Upland Crop	0.6	0.72	0.432

Based on the calculation method mentioned in Appendix II, the water requirement are calculated for each 10 schemes. The irrigation efficiencies presented in the table are applied in the study on the improvement of irrigation canal capacities in accordance with the IFAD project.

In the case study, the water requirements are recalculated when the improvement of canal capacities or changing of the cropping area were considered necessary. (See Data Book)

(2) Influence of the Insufficiency of the Irrigation Water

The following influence coefficients are applied for calculating the irrigation insufficiencies considering the results of field investigations.

- For planting area 50% of insufficiency for low flat areas
  40% of insufficiency for high hilly areas

- For cropping yield 13 % of insufficiency

Considering these coefficients, the reduction of yield is estimated for each case.

(3) Conditions of Benefit

Based on the farm gate price and production cost in 1992, the net production value are estimated as shown below;

Estimated Net Production Value

(Nu/ha)

Description	Paddy (Summer)	Double Paddy First	Double Paddy Second	Wheat (Winter)	Mustard (Winter)	Vegetable (Winter)	Vegetable (Summer)
Unit Yield (t/ha)	3.20	2.56	2.56	1.80	0.67	1.50	1.50
Farm Gate Price (Nu./t at 1992)	3,960	3,960	3,960	4,400	7,499	7,430	7,430
Farm Gate Price (Nu./t at 1995)	5,029	5,029	5,029	5,588	9,524	9,436	9,436
Gross Production Value (Nu./ha)	16,093	12,875	12,875	10,058	6,381	14,154	14,154
Production Cost (Nu./t)	8,047	8,626	8,626	3,219	1,021	8,634	8,634
Net Production Value	8,047	4,249	4,249	6,840	5,360	5,520	5,520

In the estimation, 27% of inflation from 1992 is considered. The difference of the total net production value with and without the improvement plan is considered as the benefit of the improvement plan.

(4) Conditions of Cost Estimation

The conditions of cost estimate are summarized as shown below;

- Base year and month : July, 1995
- Exchange rate : US 1 $ = 30.85 Nu.

The basic information for cost estimate for the case study is presented in Table 8.2.2.

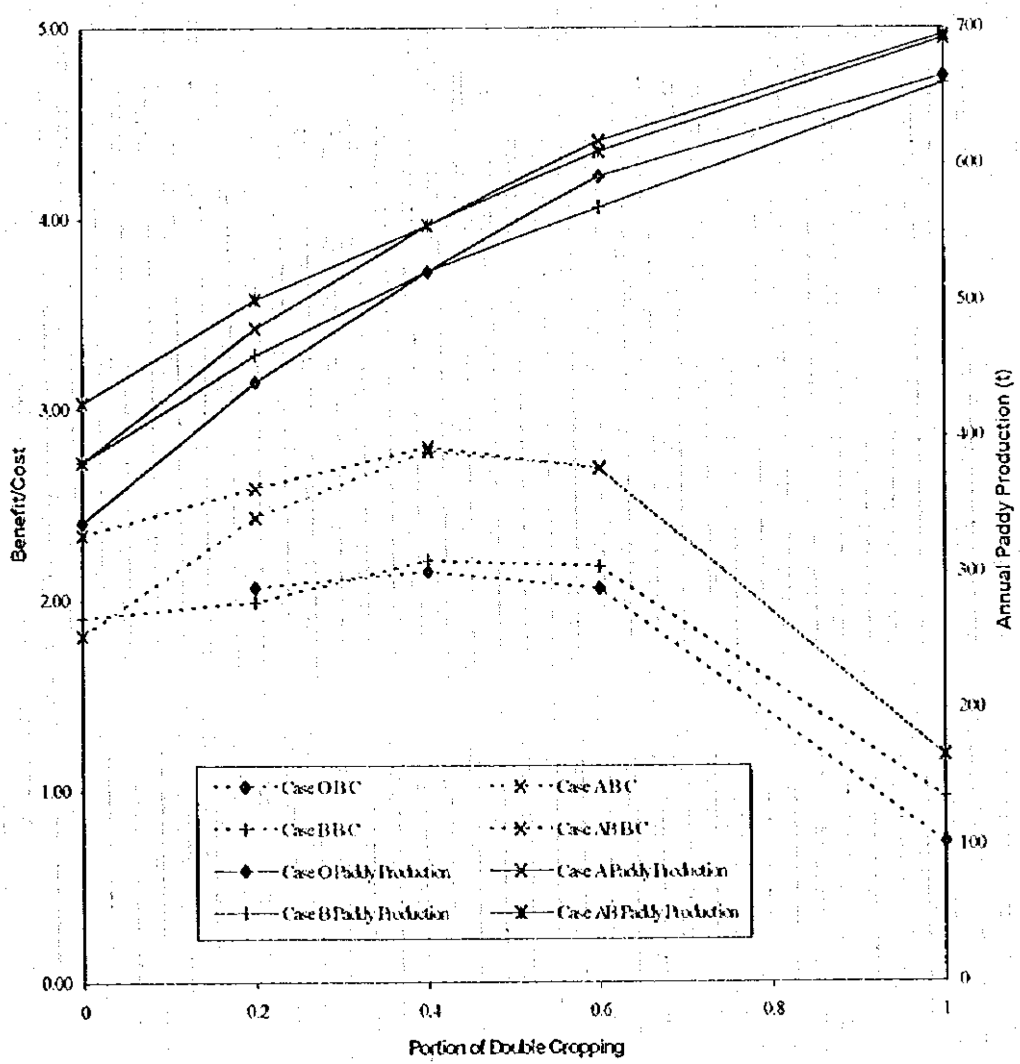
8.2.3 Results of Case Study

The procedure and calculation are shown in Appendix H and the Data Book V. The results are summarized and illustrated in Table 8.2.3 and Fig. 8.2.2, and the following basic strategy for Water Resources Development Plan is suggested.

(1) For Low Flat Area (Lobeysa and Bajo Sub-areas)

Without consideration of the double paddy cropping, the highest benefit/cost ratio is obtained in Case AB (combination of water management and canal capacity improvement), and hence the improvement of canal facilities and establishment of new water management system are proposed for the irrigation improvement plan of the low flat areas.

With consideration of the double paddy cropping, it is technically possible to apply the double cropping to all the present paddy fields. However, Case AB with applying 40% of the double paddy cropping with Case AB shows the highest B/C ratio. This means that it is necessary to consider the proposed portion of double cropping based on the development concept. The relation among B/C ratios, production and portion of the double cropping are presented below.



RELATION BETWEEN DOUBLE PADDY CROPPING AND PRODUCTION IN THE BAJO SUB-AREA

(2) For high hilly Area (Phangyul and Rubeysa Sub-areas)

The highest B/C ratio is obtained in Case AD-2 (combination of water management improvement and diversification of 10 %), and the improvement of water management system with 10% of diversification is proposed. As there is no sufficient irrigation water at intake site in these areas, the high B/C ratio is not expected applying the improvement of canal capacities. Considering the effective use of agricultural lands and limited irrigation water, it is necessary to consider the diversification. In this Study, chili is considered as the diversified crop instead of paddy, and it is necessary to conduct the research for finding out the suitable crop for the diversification.

8.2.4 Basic Water Resources Development Plan

(1) Summary of Basic Plan

As it is necessary to establish the proper implementation plan to prevent the social conflicts caused by the rapid development, the improvement plan should be studied for short and long terms. The following target years are set taking into account of the physical year of the Five Year National Development Plans in the country.

- 2002 year for the short term improvement plan
- 2007 year for the long term improvement plan

Based on the results of the case study, the following strategies are proposed.

1) For Low Flat Areas

i) Short Term

- Supplying the sufficient irrigation water
- Applying the double paddy cropping for 40% of present paddy field

ii) Long Term

- Supplying the sufficient irrigation water
- Applying the double paddy cropping for 100% of present paddy field

2) For High Hilly Areas

i) Short Term

- Establishment of new water management system
- Applying the diversification for 10% of present paddy field

ii) Long Term

- Improvement of the water management system

- Research on suitable crops for diversification

Based on above strategies, the irrigation water resources development schemes are proposed as stated below.

1) For Lobeysa and Bajo Sub-area

i) Short Term

a) Rehabilitation of present irrigation canals (3 schemes, 30 km in all) including the protection works in the hazard areas for supplying the sufficient irrigation water
b) Establishment of new water management system for the effective use of irrigation water
c. Applying the double paddy cropping of 40% of present paddy fields for the effective use of agricultural lands

ii) Long Term

a. Applying the double paddy cropping for 100% of present paddy field to increase the paddy production. (the maximum water requirement is about 5 % less than that for the short term plan, the same facilities are applied for short term plan.

2) For Rubeysa and Phangyul Sub-areas

i) Short Term

a) Establishment of new water management system constructing new offtake facilities for the effective use of irrigation water
b) Applying 10% of diversification for present paddy fields for the effective land use

ii) Long term

a) Research on the suitable crop for diversification to improve the future agricultural activities

Based on these countermeasures mentioned above, the future cropping pattern shown in Fig. 8.2.3 is proposed to be applied, and the necessary structures are preliminary designed as shown in Appendix H and the Data Book V. The project benefits and costs including O/M costs are also roughly estimated based on the results of the case study. The proposed irrigation water resources development schemes are summarized below.

Summary of Proposed Schemes

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

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

8.3 Water Resources Development Plan for Urban and Rural Water Supply

8.3.1 Urban Water Supply System in Wangduephodrang Town Area

(1) Service Area and Required Capacity of Water Supply System

The present urban water supply system covers an area of about 110 ha consisting of the RBA complex and quarters, the Dzongkhag and administrative areas, the commercial and shopping areas, the residential areas, etc. Any extension of the present town area is scheduled at present according to the Town Planning Section of PWD except for the areas where some internal shuffling of land use is scheduled. However, the areas of about 23 ha located between the present DSC/AMC yards and the construction sites of the junior high school are recommended to be included, and then the total service area of the water supply system will be 133 ha.

Estimated Water Demand and Required Additional Capacity

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

The present productivity of the existing water supply system is limited at 780 m^3/day because of the limited capacity of the existing conveyance pipeline from the Pe Chhu.

The table shows the domestic water demand estimated based on the projected future population and the demand per capita. It is necessary to increase the water supply capacity from 780 m^3/day to 1,133 m^3/day and 1,546 m^3/day in 2002 and 2007, respectively. The capacity to be increased is calculated to be 363 m^3/day and 776 m^3/day in 2002 and 2007, respectively. The future demand and the capacity to be increased in future are illustrated in Fig. 8.3.1.

Therefore, the proposed capacity of the conveyance pipeline from the Pe Chhu and the proposed daily productivity of the distribution station are set at the values as stated below, considering the internal requirement of five (5) % for washing tanks.

- Conveyance capacity of the proposed conveyance pipeline: 1,700 m^3/day (including 5 % of the internal requirement for washing, etc.)
- Productivity of the proposed water distribution station: 1,700 m^3/day
- Distribution capacity of the distribution networks: 1,600 m^3/day

(2) Available Water Source

The present water supply system diverts its raw water from the Pe Chhu, and no other water resource is utilized for the said urban water supply. The following water sources are considered possible to be developed to supplement the present resource of the Pe Chhu for the urban water supply system in the Wangduephodrang town area.

- Surface water in the Chang Chhu and the Dang Chhu
- Groundwater in the south of the Bajo
- Sub-surface water in the areas along the Chang Chhu

Spring water is not considered for the urban water supply in the Study, because its potential is expected to be quite less comparing with the estimated demand of water supply and possible source sites are scarce.

The surface water of the Chang Chhu and the Dang Chhu is found to be abundant, but its utilization is judged to be quite difficult, because of the following reasons.

- Since the velocity and depth of river flow in these rivers are fast and shallow in the reaches near the town, it is necessary to provide the intake facilities with sufficient capacity of suction pits which require difficult underwater construction.

- The inlet structure constructed beside the river is easily clogged by the sediment loads of the river, and it is difficult to conduct necessary sediment removal works for the Dzongkhag administration due to the limited budget allocation for it.

- A large lift of pumping facility is required to lift the diverted water up to the existing water distribution station; the necessary height of the lift is measured over 140 m.

- If the supplemental volume to meet the estimated future demand (about 1,000 m^3/day) is served by the river water, a huge capacity of distribution reservoir is required to be constructed since the operation hour of the pumping station is limited.

Furthermore, it is recommended to utilize neither groundwater in the south of the Bajo sub-area nor sub-surface water in the areas along the Chang Chhu for supplementing whole of the future incremental demand of the urban water supply in the following aspects.

- Considering that the present distribution reservoir tank is located at the highest point in the town area over 1,300 m and the both sites of tubewells and shallow wells are in low areas in the south of the Bajo sub-area, it is considered necessary to apply the pumping system to lift the raw water up to the distribution station. However, it is recommended to reduce such application of pumping facilities as much as possible which requires expensive related facilities such as electric supply in order to realize the liable water supply and to achieve an easy operation and maintenance.

- If the whole of the future incremental volume is served by the newly developed groundwater or sub-surface water resources, the pumping facilities are necessary as explained above. Then, a large capacity of distribution tanks is necessary since such pumping facilities are not be able to be operated throughout a day. However, taking into account that the present yard of the existing distribution station is quite limited being situated on the top of hill, it is judged to be difficult to extend the present yard for constructing the additional reservoir tanks.

(3) Alternative Measures to Develop the Supplemental Water Resources for Future Extended Service Area

Based on the discussion made in the above section, in this Study, the alternatives for establishing the most appropriate water resources development plan are to be set so as to consider only the optional plan to cover the extended areas between the school yards being constructed and the DSC/AMC yards in the Bajo sub-area (Block 6) from the following considerations.

- As discussed in the above section, it is recommended to apply the development of neither groundwater nor sub-surface water for supplementing whole of the incremental demand.

- Since the existing water supply network covers whole of the town area as its service area at present, and only the areas along the Chang Chhu in the Bajo sub-area are not covered.

The following three (3) alternatives are consequently considered in this Study to supplement the shortage of supply capacity of the urban water supply system.

Alternative 1 ➡ Increase the present diversion water from the Pe Chhu

The present urban water supply system is basically utilized with some extent of improvement that meets whole of the incremental demand including that for Block 6 which is proposed to be extended.

Alternative 2 ➡ Develop the groundwater resources available in the south of the Bajo sub-area

The groundwater resources available in the farm yards of RNRRC are developed for the additional demand of the extended area (Block 6), and the incremental demand of the other blocks are served by utilizing the existing water supply system. In this case, an isolated supply system is provided for only the Block 6. The present system for the Blocks 1 to 6 has to be improved increasing its supply capacity.

Alternative 3 ➡ Develop the sub-surface water resources available in the area along the Chang Chhu in the Bajo sub-area

The sub-surface water resources expected to be available in the areas along the Chang Chhu are developed for the additional demand of the extended area (Block 6), and the incremental demand of the other blocks are served by utilizing the existing water supply system. In this case, an isolated supply system is provided for only the Block 6 as same as Alternative 2. The present system for the Blocks 1 to 6 has to be improved increasing its supply capacity.

The above-stated alternatives, presented in Fig. 8.3.2, are scrutinized and compared with each other, and consequently it is concluded that Alternative 1 is considered the most appropriate for supplying the water to Block 6.

(4) Proposed Urban Water Supply System

The proposed water supply system for the urban water supply of the Wangduephodrang town area consists of:

- the intake and conveyance facilities,
- the water treatment and distribution station, and
- the distribution networks and house meters.

1) Intake and Conveyance Facilities

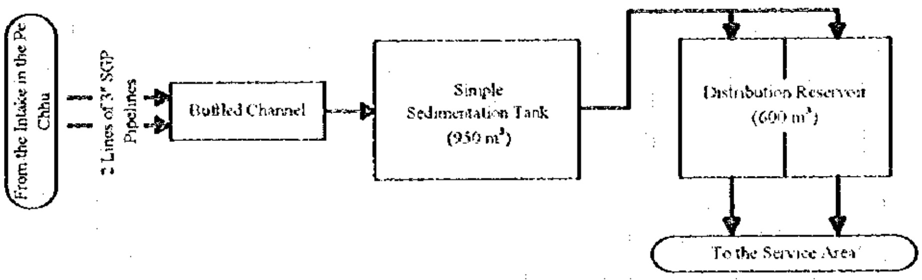
The design discharge of the conveyance pipeline is calculated to be 20 l/sec for the target year of 2002 on the condition that the raw water is diverted continuously from the river for a day (1,700 m^3/day / 86,400 sec = 20 l/sec). The existing open channel is judged to have an enough capacity to flow this discharge, even if the irrigation water requirement of the Bajo canal is considered. The existing sediment tank made of reinforced concrete is found to function well at present, and is considered well functional in the future plan also although some extent of cleaning is required. Therefore, it is proposed to utilize the existing intake and sediment removal facilities as they are utilized now.

As described in the previous chapter on the present condition of the urban water supply, the diverted raw water is conveyed by the pipelines to the existing water distribution station at present. The existing pipelines run mainly along the national road for Tongsa, and their distance is measured to be about 8.5 km according to the topographic survey. The flow capacity of the existing pipelines is estimated at 0.08 l/sec, which is quite smaller than the design discharge of 20 l/sec. The pipelines are made of galvanized steel at the most upstream and downstream portions only, while the middle portion is of 4" HDPE pipes and partly broken causing leakage of water. Therefore, it is recommended to replace the existing one in this Study.

There are two (2) routes which are considered as options for the new conveyance pipeline. One is the route along the existing Bajo canal and the other is along the national road for Tongsa. The existing pipelines run along the latter route. Both routes are scrutinized and compared in detail, and the latter route is recommended to be considered for the new conveyance pipeline. Among the piping materials, the ductile iron pipe is judged to be the most suitable for the construction of new conveyance pipeline.

2) Treatment Facility

As shown in the following flow chart, only simple sedimentation is performed in the present water distribution station.



FLOW CHART OF EXISTING WATER DISTRIBUTION STATION

The water is delivered from the existing intake through two (2) lines of the conveyance pipelines with a maximum discharge of 8 l/sec, and received water passes the baffled channel to the simple sedimentation tank of about 950 m^3 capacity. The distribution reservoir of about 600 m^3 capacity is located adjacent to the sedimentation tank. The flow of treated water is regulated in this tank and distributed to the service areas in the town.

The present distribution station is scrutinized to find out the necessary items of improvement as stated below.

- The daily productivity of the proposed distribution station is set at 1,700 m^3/day as aforesaid. The capacity of the existing sedimentation tank (950 m^3) is considered to be so sufficient that about 13 hr of retarding time is considered enough to allow the required sediment settlement. However, the capacity of distribution reservoir measured to be 600 m^3 is considered insufficient considering that this capacity is translated to only about eight (8) hr of retarding time.

- The results of the water quality examination reveal that no serious bacteriological infection is detected, but turbidity frequently raises over 20 during and after the flood in the Pe Chhu especially in the wet season from June to September. Therefore, it is recommended to apply some water treatment for improving such high turbidity and reducing bad color content.

3) Distribution Networks and House Connection

The present distribution networks cover most of the whole service areas in the township, and house connections are made partly to the government offices and the offices and quarters in the RBA complex without any metered system. The improvement works for the distribution networks are as follows:

- Replacement of the existing HDPE pipes on the main pipelines with GIS pipes to reduce water leakage and to avoid illegal connection.

- Placing new pipelines to mitigate unbalanced load of demand by traversing long main pipelines, etc.

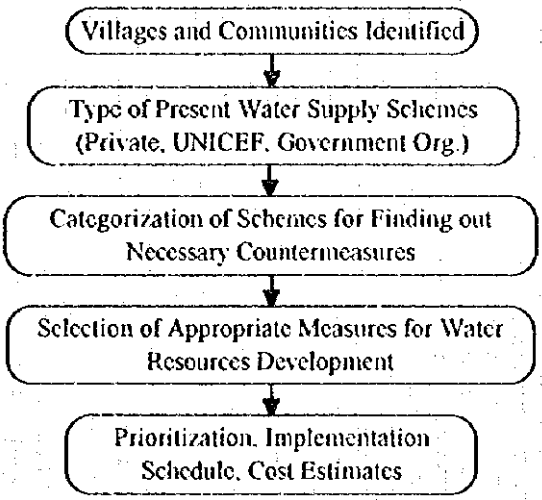
- Extending the existing networks to provide water to the extended service areas in the Bajo sub-area.

- Construction of house connecting pipes to each household with water meters.

8.3.2 Rural Water Supply Systems

(1) Planning Methodology

The conditions such as topography, available water resources, village population served and not-served, present water supply systems, etc. were surveyed for each village/community during the field surveys as summarized in Table 8.3.1. As a result, it is found that such villages have different conditions varying village by village, and consequently it is difficult to prepare such plans which are required for each village one by one in this level of the Study for the basic planning.



FLOW CHART FOR SELECTING METHODS OF WATER RESOURCES DEVELOPMENT

Therefore, as shown in the flow chart, the villages and communities identified during the field survey are categorized depending upon some factors which are considered important in order to find out the constraints and necessary and suitable measures to be taken for respective sub-areas. Some typical scale of villages are, then, assumed for each selected category to facilitate further studies on appropriate measures to be proposed. These assumed villages have the typical constraints. The countermeasures are proposed for these assumed villages including alternative studies, if necessary.

(2) Categorization of Villages/Communities and Necessity of Further Water Resources Development

As illustrated in Fig. 8.3.3, before categorizing the villages/communities identified, the types of the present water supply schemes are considered according to the kind of organization which implemented such water supply schemes; private, UNICEF and other government organizations such as RBA, MOA, MOC, etc. Out of the villages whose scheme is confirmed, those schemes which are implemented by UNICEF and any private sectors and those villages which do not have any scheme are considered for further categorization, taking into account of the following factors which are considered important for finding out constraints and countermeasures.

- Present Service Ratio

- Liability of Water Source
- Water Quality
- Number of Households to be Involved

The villages/communities identified in the field survey are classified into the following categories depending on the above factors.

i) The villages requiring some new schemes involving more than six (6) households (New Scheme (A)),

ii) The villages requiring some new schemes involving more than six (6) households, since there are private water supply schemes but do not function well as expected (New Scheme (B)),

iii) The villages requiring some new schemes involving less than five (5) households (New Scheme (C)),

iv) The villages requiring some additional schemes, since the existing UNICEF's schemes do not satisfy the requirement in some viewpoints of service ratio, liability of water source or water quality (Additional Scheme),

v) The villages requiring some water treatment schemes, because the present raw water does not clear the recommended standard values (Water Treatment Scheme),

vi) The villages requiring some extension schemes involving more than six (6) households to increase the served population (Extension Scheme (A)),

vii) The villages requiring some extension schemes involving less than five (5) households (Extension Scheme (B)), and

viii) The villages requiring both extension and water treatment schemes (Extension with Treatment Schemes).

In the above categories, the first four (4) items from i) to iv) are considered as the group requiring new water resources development and the last four (4) items from v) to viii) require some improvement or rehabilitation works such as water quality treatment, expansion of present water supply system, etc. The results of categorization are summarized below.

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

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

(3) Selection of Appropriate Methods for Water Resources Development

To select the most appropriate method of water resources development for the rural water supply, the categorized villages are further simplified and re-arranged considering the available water resources in each sub-area as presented in Fig. 8.3.4. The water resources available in the Study area are considered and evaluated as stated below.

a) Spring Water

Spring water resources are available predominantly in the hilly areas such as the Phangyul and the Rubeysa sub-areas and some parts of the Bajo and the Lobeysa areas along hilly areas. Many springs have been developed for the rural water supply schemes so far mainly by UNICEF, and villagers who do not have their water supply schemes also take water from such springs available nearby their houses. This source is considered to be the most liable one in the Study area for rural water supply.

b) Sub-surface Water

Sub-surface water resources are available in low lands such as river terraces along the Chang Chhu in the Bajo and the Lobeysa sub-areas. A shallow well has to be constructed on the low lands to utilize this water source. According to the results of the monitoring conducted during the field survey, 8 l/sec of yield is expected in a 3.5 m diameter of well with 1.6 m of drawdown in the Bajo sub-area.

c) Groundwater

The groundwater resource is also considered as one of the most promising source in the low lands like the Bajo and the Lobeysa sub-areas. According to the results of test boring conducted during the field survey, an yield of 150 l/sec is expected for a 10" diameter of borehole with 50 m and 80 m depths in the Bajo and the Lobeysa sub-areas, respectively.

d) Stream/River Water

There are many streams and rivers flowing in the Study area. Among others, perennial streams are found to be a quite few in the Study area except for the Chang Chhu and the Dang Chhu, and such surface water may be infected and contaminated by animal wastes and land sliding soils. If this source is utilized for the use of domestic water supply, it is essential to provide the supply system with treatment facilities to the extent that enables to supply safe water. Therefore, in this Study, this water source is not recommended for rural water supply.

Considering the above discussions, the following cases are extracted for the further study.

Cases to be Considered in the Study

Case	Description	Remarks
Case S-1	Spring Development - New (Large)	New spring development for large group of households of more than six (6) mainly applied for the hilly areas like the Phangyul and the Rubeysa sub-areas
Case S-2	Spring Development - New (Small)	New spring development for small group of households of less than five (5) mainly applied for the hilly areas like the Phangyul and the Rubeysa sub-areas
Case S-3	Spring Development - Extension (Large)	Extension or additional spring development for large group of households of more than six (6) mainly applied for the hilly areas like the Phangyul and the Rubeysa sub-areas
Case S-4	Spring Development - Extension (Small)	Extension or additional spring development for large group of households of less than five (5) mainly applied for the hilly areas like the Phangyul and the Rubeysa sub-areas
Case T-1	Water Treatment	Water treatment scheme of iron removal for the Rubeysa sub-area
Case B-1	Groundwater vs. Sub-surface Development (Large)	Groundwater or Sub-surface water development scheme for large group of households of more than six (6) applied for the Bajo sub-area (Construction costs are compared with each other to determine which resource is to be applied.)
Case B-2	Groundwater vs. Sub-surface Development (Small)	Groundwater or Sub-surface water development scheme for large group of households of less than five (5) applied for the Bajo sub-area (Construction costs are compared with each other to determine which resource is to be applied.)
Case L-1	Spring vs. Groundwater Development (Large)	Spring or groundwater development scheme for large group of households of more than six (6) for the Lobeysa sub-area (Construction costs are compared with each other to determine which resource is to be applied.)
Case L-2	Spring vs. Groundwater Development (Small)	Spring or groundwater development scheme for large group of households of less than five (5) for the Lobeysa sub-area (Construction costs are compared with each other to determine which resource is to be applied.)

The sizes and scales of the typical villages for the study are tabulated below.

Summary of Sizes and Population of Typical Villages for the Study

Case	Water Source	Type of Scheme	Population to be Served	Present Population Served	Required No. of Tap Stands	Distance from Source (m)	Existing Storage Tank Vol (m3)	Distance to Standpipe (m)	Slope Condition
Case S-1	Spring Water	New	103	-	15	1,000	-	1,500	Steep
Case S-2	Spring Water	New	19	-	3	1,000	-	1,500	Steep
Case S-3	Spring Water	Extension	99	120	15	1,000	3	1,500	Steep
Case S-4	Spring Water	Extension	27	22	3	1,000	No Tank	1,500	Steep
Case T-1	-	Deiron	123	-	-	-	4	-	-
Case B-1	Groundwater	New	147	-	20	500	-	1,000	Mild
	Sub-surface Water	New	147	-	20	500	-	1,000	Mild
Case B-2	Groundwater	New	61	-	5	500	-	1,000	Mild
	Sub-surface Water	New	61	-	5	500	-	1,000	Mild
Case L-1	Groundwater	New	250	-	20	1,000	-	1,500	Steep
	Spring Water	New	250	-	20	1,000	-	1,500	Steep
Case L-2	Groundwater	New	29	-	3	1,000	-	1,500	Steep

(4) Selected Development Methods

1) Lobeysa Sub-area

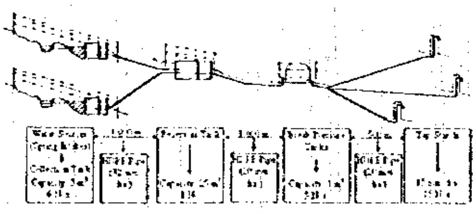
In the Lobeysa sub-area, there are development schemes required to be implemented as shown in the table. Two (2) New Schemes (A) and (C) are considered as Case L-1 and Case L-2, respectively taking into account of the available water resources in this sub-areas. The last Extension Scheme (B) is regarded as Case S-4 because the present scheme depends on the spring water resource.

As for Cases L-1 and L-2, there are two (2) options to be considered; the construction costs are compared for utilizing spring water and groundwater resources. The following typical schemes are considered for the comparative study of Cases L-1 and L-2.

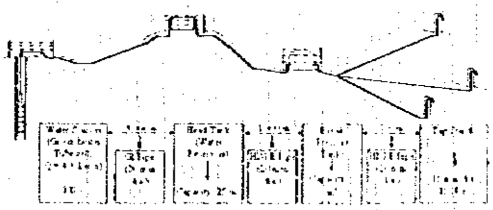
Development Schemes Required in the Lobeysa Sub-area

Item	New Scheme (A)	New Scheme (C)	Ext'sion Scheme (B)
Population	250	58	67
No. of Villages	1	2	1
Average Pop.	250	29	67
Case →	L-1	L-2	S-4

Case L-1

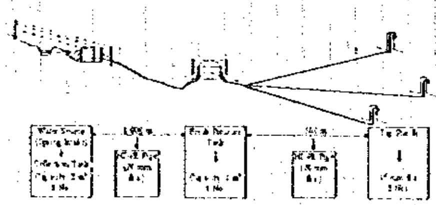


OPTION-1 (SPRING WATER)

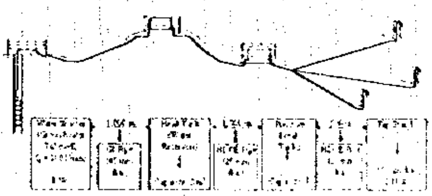


OPTION-2 (GROUNDWATER)

Case L-2



OPTION-1 (SPRING WATER)



OPTION-2 (GROUNDWATER)

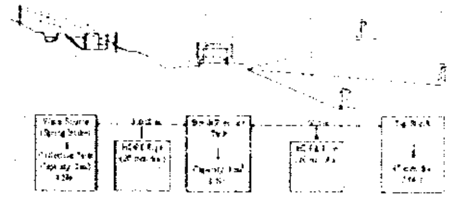
The construction costs are calculated for the above options, and the costs for the Option-1: Utilization of Spring Water are considered lower than those of Option-2: Utilization of Groundwater as summarized in the table. Therefore, utilization of the spring water resources is recommended for Cases L-1 and L-2.

Comparison of Construction Costs for Cases L-1 and L-2

(Unit: 1,000 Nu.)

Case	Option-1 (Spring Water)	Option-2 (Groundwater)
L-1	2,418	3,838
L-2	657	2,608

As for Case S-4: Extension Scheme of the Present Spring Water Source, the water supply system consisting of collection tank, reservoir tank, break pressure tank, etc. is recommended to be applied as shown in the figure.



CASE S-4: EXTENSION OF SPRING WATER SCHEME

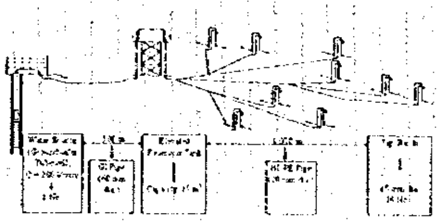
2) Bajo Sub-area

There are three (3) schemes to be implemented for water resources development as summarized in the table. Out of the three (3) New Schemes (A), one (1) scheme is located away from the potential area of groundwater and sub-surface water, and hence it is considered as Case S-1: the new development scheme of spring water. The other schemes are located in the potential areas of either groundwater or sub-surface water, and then are regarded as Cases B-1 or B-2, which include two (2) optional water sources of groundwater and sub-surface water. The necessary construction costs of these two (2) options are compared with each other to determine which option is more suitable and appropriate for the basic plan. The following two (2) typical schemes are considered for the comparative study.

Development Schemes Required in the Bajo Sub-area

Item	New Scheme (A)	New Scheme (C)	Additional Scheme
Population	384	61	185
No. of Villages	3	1	1
Average Pop.	128	61	185
Case →	B-1 & S-1	B-2	B-1

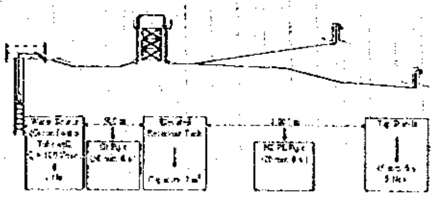
Case B-1



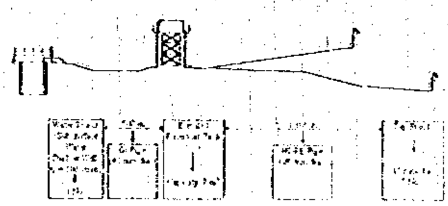
OPTION-1 (GROUNDWATER)

OPTION-2 (SUB-SURFACE WATER)

Case B-2



OPTION-1 (GROUNDWATER)



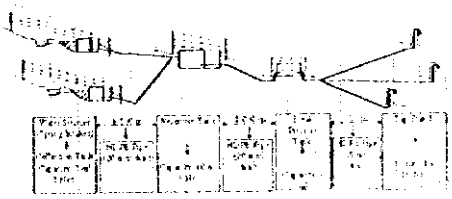
OPTION-2 (SUB-SURFACE WATER)

The construction costs are calculated for the above options, and the costs for the Option-1: Utilization of Groundwater are considered lower than those of Option-2: Utilization of Sub-surface Water as summarized in the table. Therefore, the groundwater resources are recommended to be utilized for Cases B-1 and B-2.

Comparison of Construction Costs for Cases B-1 and B-2

(Unit: 1,000 Nu.)

Case	Option-1 (Groundwater)	Option-2 (Sub-surface Water)
B-1	4,275	4,341
B-2	3,066	3,317



CASE S-1: NEW SPRING WATER SCHEME

As for Case S-1: New Scheme of the Spring Water Source, the water supply system consisting of collection tank, reservoir tank, break pressure tank, etc. is recommended to be applied as shown in the figure.

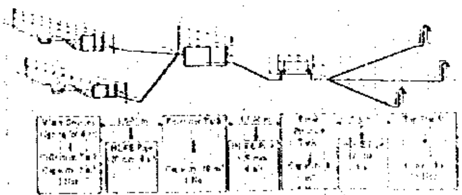
3) Phangyul Sub-area

In the Lobeysa sub-area, there are the development schemes required to be implemented as shown in the table. Two (2) New Schemes (A) and (B) are considered as Case S-1, and New Scheme (C) is considered as Case S-2 taking into account that the available water resource is only spring water in this sub-area. The Extension Scheme (A) is regarded as Case S-3 because the present scheme fully depends on the spring water resource.

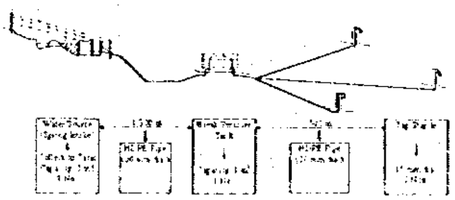
Development Schemes Required in the Phangyul Sub-area

Item	New Scheme (A)	New Scheme (B)	New Scheme (C)	Ext'sion Scheme (A)
Population	361	49	128	227
No. of Villages	3	1	7	3
Average Pop.	120	49	18	76
Case →	S-1	S-1	S-2	S-3

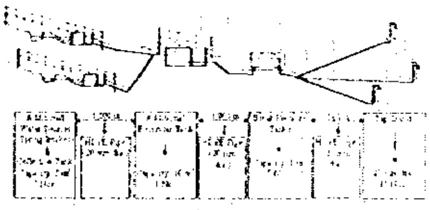
As for Cases L-1 and L-2, there are two (2) options to be considered; the construction costs are compared for utilizing spring water and groundwater resources. The following typical schemes are considered for the comparative study of Cases L-1 and L-2.



CASE S-1 NEW SPRING WATER SCHEME (LARGE)



CASE S-2 NEW SPRING WATER SCHEME (SMALL)



CASE S-3 EXTENSION OF SPRING WATER SCHEME (LARGE)

It is considered as unnecessary to conduct any cost comparison between different water sources, because only the spring water source is available for the rural water supply in this sub-area. The water supply systems indicated in the above figures consisting of collection tank of spring water, reservoir tank, break pressure tank, etc. are recommended to be applied for the spring water development schemes in this sub-area.

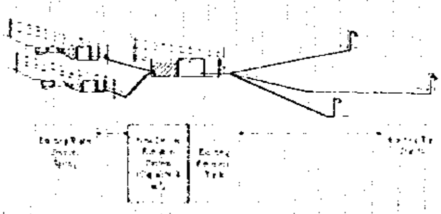
4) Rubeysa Sub-area

In the Rubeysa sub-area, there are development schemes required to be implemented as shown in the table. Two (2) New Schemes (A) and (C) and two (2) Extension Schemes (A) and (B) are considered as Cases from S-1 to S-4 taking into account that the available water resource is only spring water in this sub-area. Water Treatment Scheme is considered as Case T-1, because this scheme includes only the component of water treatment for iron removal.

Development Schemes Required in the Rubeysa Sub-area

Item	New Scheme (A)	New Scheme (C)	Ext. Scheme (A)	Ext. Scheme (B)	Water Treat. Scheme
Population	186	42	169	53	123
No. of Villages	2	2	1	2	1
Average Pop.	93	21	169	27	123
Case →	S-1	S-2	S-3	S-4	T-1

It is considered as unnecessary to conduct any cost comparison between different water sources, because only the spring water source is available for the rural water supply in this sub-area. The water supply systems indicated in the previous sub-section for the Phangyul sub-area consisting of collection tank of spring water, reservoir tank, break pressure tank, etc. are recommended to be applied for the spring water development schemes in this sub-area. The treatment scheme proposed to be implemented is considered only for one (1) existing scheme in this sub-area, and it is recommended to be composed of a iron removal tank beside the existing tank as shown in the figure in previous page.



CASE T-1 WATER TREATMENT SCHEME

8.4 Implementation Schedule and Cost Estimate

8.4.1 Implementation Schedule

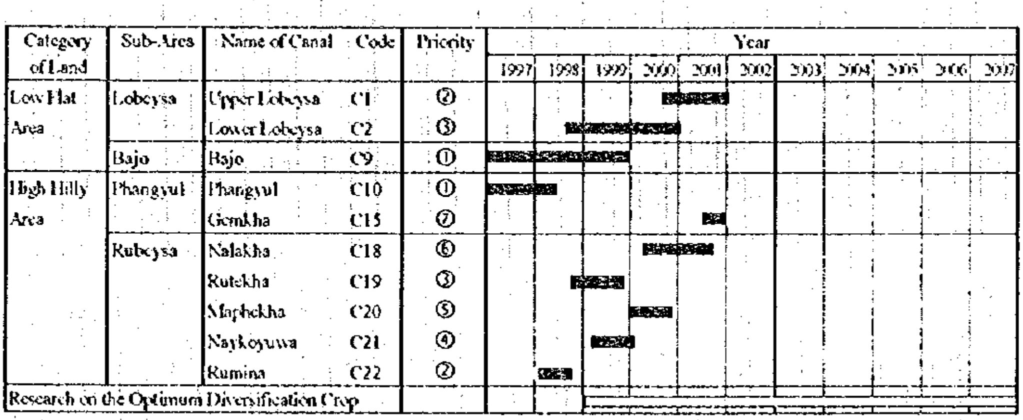
(1) Irrigation Water Supply Plan

Based on the estimated B/C ration of the projects, the priority was considered for the implementation of the irrigation improvement plan. The inventory and priority of the projects is tabulated as shown below;

Inventory of the Irrigation Water Resources Development Project

Category of Land	Sub-Area	Name of Canal	Code	Command Area (ha)	Construction Cost (1000 Nu.)	O/M Cost for 1 year (1000 Nu.)	Estimated B/C Ratio	Priority
Low Flat Area	Lobeysa	Upper Lobeysa	C1	61	1,152	21	2.25	②
		Lower Lobeysa	C2	300	3,027	32	2.21	③
	Bajo	Bajo	C9	143	5,016	48	2.80	①
High Hilly Area	Phangyul	Phangyul	C10	91	286	58	1.95	①
		Gemkha	C15	15	47	12	1.53	⑦
	Robeysa	Nalakha	C18	29	119	15	1.57	⑥
		Rutekha	C19	40	207	10	1.88	③
		Maphekha	C20	27	148	9	1.59	⑤
		Naykoyuwa	C21	24	119	7	1.74	④
		Rumina	C22	28	95	5	1.91	②

Based on the priority of the project, the implementation schedule of the irrigation improvement plan is proposed as shown below considering the target year and total construction cost.



PROPOSED IMPLEMENTATION SCHEDULE FOR IRRIGATION WATER SUPPLY PLAN

(2) Urban and Rural Water Supply Plan

Prior to setting the implementation schedules for the Basic Water Resources Development Plan both for the urban and the rural water supplies in the Study area, the following items are considered in order to make the implementation schedule more effective and more suitable for the Study area.

Urban Water Supply Plan

- The present urban water supply system faces the constraints both in quantity and quality of the supplied water as aforesaid. To achieve the maximum effects of the project implementation, the quantity of supplied water should be increased as soon as possible in accordance with the projected future demand.

- The planned scale of the water supply system is set at 1,700 m^3/sec only, which is considered so small that it is difficult to construct the proposed water distribution station and the conveyance pipeline separately based on efficiency and economic aspects.

- Therefore, the construction of the proposed conveyance pipeline and distribution station is recommended to be implemented by the first target year of 2002, and the improvement works of distribution networks and the introduction of metered system are implemented later by the final target year of 2007.

Rural Water Supply Plan

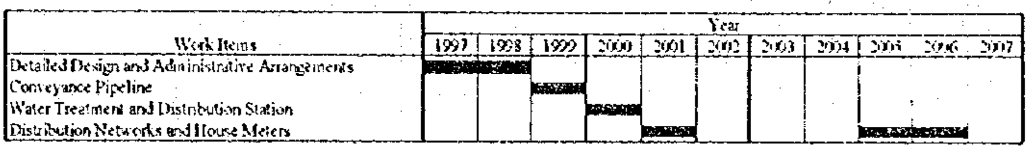
- The present service ratios of the sub-areas are considered to be one of the important factors to determine the priorities for implementing the schemes in each sub-area. The priority of the area-wise implementation is proposed to be set i) Phangyul sub-area, ii) Bajo sub-area, iii) Rubeysa and iv) Lobeysa, according to the present service ratios of the respective sub-areas; 88 %, 36 %, 36 % and 69 % for the Lobeysa, the Bajo, the Phangyul and the Rubeysa sub-areas, respectively.

- There are eight (8) categories of schemes proposed to be implemented. Among these schemes, the first priority is recommended to be given to the schemes for villages which are considered to have no supply system at present and more population to be served.

- Water treatment scheme is proposed to be given the last priority, because the quantity of supplied water is judged to be the most important and essential in planning.

- Extension schemes are proposed to be implemented after the new schemes which are proposed to be implemented in the villages having no supply system.

The urban water supply system for the Wangduephodrang town area is proposed to be implemented as shown below based on the above-mentioned items.



IMPLEMENTATION SHCEDULE OF URBAN WATER SUPPLY SYSTEM

The rural water supply systems for the sub-areas are proposed to be implemented as shown below taking into account of the above-mentioned items.

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

IMPLEMENTATION SHCEDULE OF RURAL WATER SUPPLY SYSTEM

8.4.2 Cost Estimate

(1) Project Costs

The project costs for implementing the rural and urban water supply schemes as well as the irrigation improvement schemes are estimated based on the above implementation schedules as shown in the table presented below.

Summary of Project Costs

(Unit: Nu 1,000,000)

Description	Costs	Description	Costs
I Urban Water Supply System for Wangduephodrang Town Area		III Irrigation Water Supply	
1 Direct Costs	172.6	1. Lobeysa Sub-area	1.2
1.1 Conveyance Pipeline	60.1	2. Bajo Sub-area	5.0
1.2 Treatment and Water Distribution Station	95.4	3. Phangyul Sub-area	6.3
1.3 Distribution Networks and House Meters	17.1	4. Rubeysa Sub-area	0.7
2 Engineering Service	35.1	5. Research Activities	1.4
3 Administration Costs	6.2	Total (3)	14.6
Sub-total	213.9		
4 Physical Contingency	17.3		
Total (1)	231.2		
II Rural Water Supply Systems			
1. Lobeysa Sub-area	4.2		
2 Bajo Sub-area	18.1		
3 Phangyul Sub-area	14.9		
4 Rubeysa Sub-area	6.9		
Total (2)	44.1	Grand Total	289.9

The total costs consisting of direct costs, engineering fees, administration fees, and physical contingency are estimated at Nu. 14,600,000 for the irrigation improvement schemes, and Nu. 275,300,000 for the domestic water supply schemes consisting of Nu. 231,200,000 and Nu. 44,100,000 for the urban and the rural water supply schemes, respectively. The details of estimated costs are explained in Appendix-J including the proportion between the local and foreign costs.

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

(2) Operation and Maintenance Costs

Annual operation and maintenance costs are calculated for the irrigation improvement schemes and the domestic water supply schemes as tabulated below.

Operation and Maintenance Costs for Irrigation Water Supply

(unit : 1000 Nu.)

Category of Land	Sub-Area	Name of Canal	Code	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Lobeysa	Upper Lobeysa	C1						21	21	21	21	21	21
		Lower Lobeysa	C2					32	32	32	32	32	32	32
	Bajo	Bajo	C9				48	48	48	48	48	48	48	48
High Hilly Area	Phangyul	Phangyul	C10			58	58	58	58	58	58	58	58	58
		Gemkha	C15						12	12	12	12	12	12
	Rubeysa	Nalakha	C18						15	15	15	15	15	15
		Rotekha	C19				10	10	10	10	10	10	10	10
		Maphekha	C20					9	9	9	9	9	9	9
		Naykoyuwa	C21					7	7	7	7	7	7	7
		Rumina	C22			5	5	5	5	5	5	5	5	5
Annual Total						62	120	168	216	216	216	216	216	216

Operation and Maintenance Costs for Domestic Water Supply

(Unit: NU.1,000)

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

(3) Annual Disbursement Schedule

Based on the above implementation schedule, the annual disbursement schedule of the project and O/M cost were estimated and summarized as shown below.

Proposed Disbursement Schedule for the Irrigation Improvement Project

(unit : 1000 Nu)

Category of Land	Sub-Area	Name of Canal	Code	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Lobeysa	Upper Lobeysa	C1				230	922						
		Lower Lobeysa	C2		605	998	1,514							
	Bajo	Bajo	C9	2,257	1,756	1,003								
High Hilly Area	Phangyul	Phangyul	C10	357	29									
		Gemkha	C15					47						
	Rubeysa	Nalakha	C18				71	48						
		Rutekha	C19		41	166								
		Maphekha	C20			15	133							
		Naykoyuwa	C21			83	36							
		Rumina	C22		95									
Research for the Optimum Diversification Crop						487	487	487	487	487	487	487	487	487
Annual Total				2,515	2,526	2,662	2,471	1,503	487	487	487	487	487	487

Annual Disbursement for Implementing Rural Water Supply Schemes

(Unit: Nu 1,000,000)

Sub-area Scheme	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Lobeysa Sub-area											
New Scheme (A)									2.5		
New Scheme (C)										1.4	
Extension Scheme (B)										0.4	
Bajo Sub-area											
New Scheme (A)				10.6							
New Scheme (C)					3.2						
Additional Scheme					4.4						
Phangyul Sub-area											
New Scheme (A)	5.3										
New Scheme (B)		1.8									
New Scheme (C)			2.5								
Extension Scheme (A)		5.3									
Rubeysa Sub-area											
New Scheme (A)						3.5					
New Scheme (C)								0.7			
Extension Scheme (A)							1.8				
Extension Scheme (B)								0.7			
Water Treatment Scheme										0.1	
Total	5.3	7.1	2.5	10.6	7.6	3.5	1.8	1.5	2.5	1.9	0.0

Annual Disbursement Schedule for Implementing Urban Water Supply Scheme

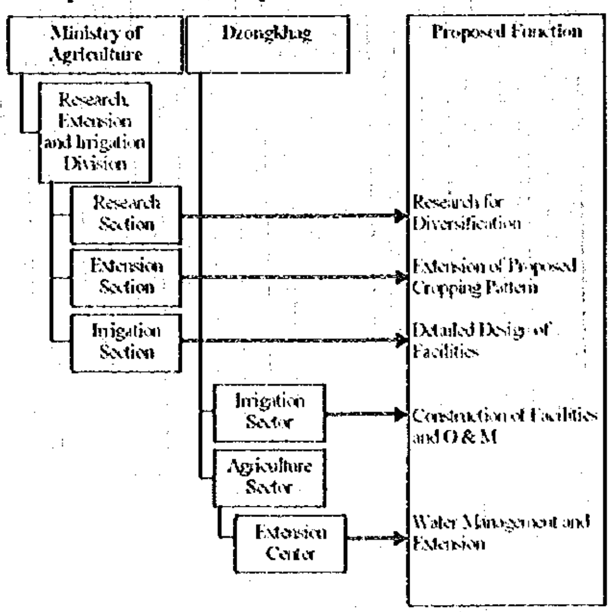
(Unit: Nu 1,000,000)

Work Items	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1. Direct Construction Costs			60.1	95.4	9.3				3.9	3.9	
1.1 Conveyance Pipeline			60.1								
1.2 Water Treatment and Distribution Station				95.4							
1.3 Distribution Networks and House Meters					9.3				3.9	3.9	
2. Engineering Service		10.4	9.8	9.8	4.9						
3. Administration Costs		0.3	2.1	3.2	0.4				0.1	0.1	
Sub-total		10.7	72.0	108.4	14.6				4.0	4.0	
4. Physical Contingency			6.0	9.5	0.9				0.4	0.4	
Sub-total		10.7	78.0	117.9	15.5				4.4	4.4	

8.5 Organizations and Institutional Consideration

8.5.1 Organization for Irrigation Improvement Project

Considering the characteristics and annual cost for the project, the project is implemented by present organizations, and it is not necessary to establish any kind of new organization. The function of present organizations is proposed as shown below.



PRESENT ORGANIZATION AND PROPOSED FUNCTION FOR THE PROJECT

8.5.2 Organization for Domestic Water Supply Schemes

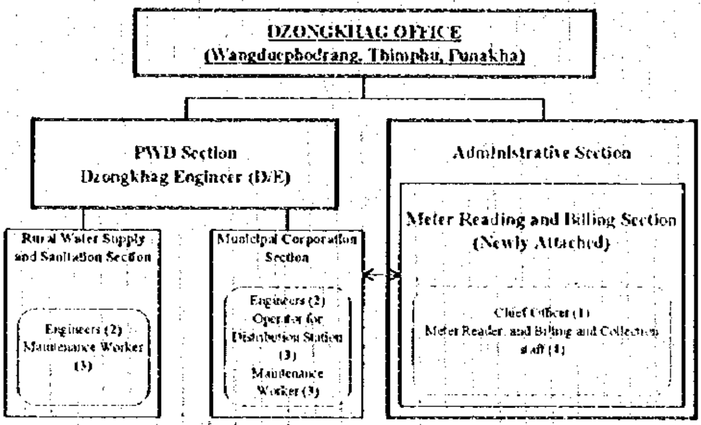
No new organization is recommended to be established to implement the proposed urban and rural water supply schemes, because it is consequently judged as follows:

- the present Dzongkhag's organization is considered to have functioned so far well enough to proceed with its implementation of various schemes as well as operation and maintenance services at least in view of the rural water supply, since most of the daily and routine maintenance works are basically to be managed by the beneficiaries themselves,

- on the other hand, it is considered to involve some constraints in operating and managing the urban water supply system as stated in the above section, which requires some extent of the reinforcement and enhancement of the present organization particularly in the human and material resources aspects, and

- taking into account the scale of town and the served population, it is not necessary to establish such new independent organization only for operating and managing the water supply system in order to reduce the costs and expenditures necessary for such management.

Therefore, it is proposed to maintain the present Dzongkhag's organization with a little enhancement and reinforcement in human and material resources, and the organization presented in the figure is proposed for the operation and management of the future urban water supply system.



PROPOSED ORGANIZATION CHART

Only the sub-section for meter reading and billing is proposed to be attached to the Administrative Section of the Dzongkhag Office in order to enhance and facilitate the services directly connected to the beneficiaries.

8.6 Project Evaluation

8.6.1 Basis of Evaluation

(1) Approach

The project evaluation method to assess a Water Resources Development Plan for validity of its implementation includes economic evaluation, financial evaluation and socio-economic evaluation (effect). Emphasis is placed on the economic evaluation since the main objectives of the Basic Plan are agricultural development by irrigation water supply and urban and rural water supply development, and public profitability is also emphasised. The financial evaluation is oriented to the farm household economic analysis and water charge. The basic approach of the project evaluation confirms to the methodology and guide line adopted by the international financial organisations and the adopted parameters are related to MOA of Bhutan.

(2) Conditions of Evaluation

The evaluation criteria used in the estimation of economic and financial evaluations are as follows:

a. The project life is set as 30 years from the commencement of the Basic Plan including detailed design period and construction works period, considering the working life periods of the main facilities.
b. The currency used for the estimation is the money of the Bhutan Ngultrum (Nu).
c. The foreign exchange rate used set as US$ 1.00 = Nu 30.85 as monthly average rate of the official foreign exchange rate of the Royal Monetary Authority of Bhutan (RMA) as of July 1995.
d. The prices of agricultural products are farm-gate prices and the prices of agricultural production input materials and construction materials are prices on delivery at the production and construction sites.
e. The economic discount rate applied in the evaluation is 10%. This figure represents the opportunity cost of capital for the country, as estimated in recent studies (Study on Promotion of Export Oriented Industries, 1991; Bhutan Power System Master Plan, 1993; An Analysis of Comparative Advantage and Development Policy Options in Bhutanese Agriculture, 1995; etc.).

8.6.2 Benefit and Cost of the Plan

The project evaluation is made on the Water Resources Development Plan in the Study Area which comprises of the following plans:

a. Agricultural Development Plan including Irrigation Improvement Plan
b. Urban and Rural Water Supply Plans including Wangduephodrang Town Plan

(1) Estimation of Benefit

The benefit of the Basic Plan refers to a difference of net profit expected between With Project and Without Project conditions under the water resources development plan through the whole project life. The project benefits consist of tangible benefits; i.e. an increase in agricultural production, supply of safe and stable water, a saving effect of operation and maintenance cost of irrigation and/or urban and rural water supply systems, an increase of returns of farmers, etc. and intangible benefits such as a stabilised food supply, a creation of employment opportunities, an improvement of living standard of inhabitants, etc. Tangible benefit is directly subjected to economic and financial evaluations, while intangible benefit is analysed for socio-economic effects.

(2) Agricultural Production Benefit

AGRICULTURAL PRODUCTION BENEFIT

(Unite: 1,000 Nu.)

Item	With Project	Without Project	Increased Value
Gross Production Value	14,800	11,500	3,300
Production Cost	6,900	5,300	1,600
Net Production Value	7,900	6,200	1,700

Annual net production value on the With Project condition is about Nu. 7.9 million and about 1.28 times as on the Without Project condition, and the annual agricultural production benefit is about Nu. 1.7 million

Actual operation and maintenance cost which value Nu.325 thousand per year is considerable a project benefit because of saving effect by canal improvement.

(3) Urban and Rural Water Supply Benefit

URBAN AND RURAL WATER SUPPLY BENEFIT

(Unite: 1,000 Nu.)

Item	With Project	Without Project	Increased Value
Urban Water Supply	112,800	71,100	41,700
Rural Water Supply	41,100	18,500	22,600
Total	153,900	89,600	64,300

Total annual net water value on the With Project condition is about Nu. 154 million and about 1.72 times as on the Without Project condition, and the annual water supply benefit is about Nu. 64 million.

(4) Project Costs

Capital cost for the Basic Plan totals Nu. 290 million, over the 10 year construction period and agricultural research activities, as summarised as shown below. The project costs include the cost of construction of irrigation facilities and water supply facilities.

Annual operation and maintenance (O & M) costs after the completion of the construction works are included during the operation period, Nu. 216 thousand and Nu. 2,674 thousand on irrigation facilities and water supply facilities, respectively. With the project evaluation period applied, 30 years, no replacement of equipment is included. Salvage values at the end of the evaluation period are not included.

PROJECT COST

(Unite: 1,000 Nu.)

Year order	Irrigation Facilities	Water Supply Facilities	Total
1	2,515	5,308	7,823
2	2,526	17,820	20,346
3	2,662	80,629	83,291
4	2,471	128,506	130,977
5	1,503	23,116	24,619
6	487	3,539	4,026
7	487	1,769	2,256
8	487	1,455	1,942
9	487	6,898	7,385
10	487	6,263	6,750
11 -	487	0	487

8.6.3 Economic Evaluation

(1) Evaluation Criteria

The evaluation uses three relevant indexes: economic net present value (ENPV), economic benefit-cost ratio (E.B/C) and economic internal rate of return (EIRR). The benefit and cost of the Basic Plan which are estimated based on the implementation schedule of the Basic Plan are discounted by the opportunity cost of capital through the project life. The term ENPV is a difference between accumulated benefit and accumulated cost, and E.B/C is the ratio of the former to the latter. The term EIRR means a discount rate by which accumulated benefit is equalised to accumulated cost.

The criteria to economically validate the implementation of the Plan are that ENPV is positive, E.B/C is more than 1 and EIRR exceeds the opportunity cost of capital. The opportunity cost of capital (discount rate) is social marginal productivity of capital input in the Basic Plan, and the discount rate is considered to be 10%.

(2) Price Conversion

Standard conversion factor and shadow prices are not applied for this economic evaluation because of obtainable difficulty on basic and adequate economic data. As a sensitivity analysis, however, a standard conversion factor (SCF) of 0.8 is applied to local costs.

(3) EIRR, ENPV and E.B/C

The flow of project cost, operation and maintenance cost and the all project benefit of the whole Basic Plan are shown in Appendix-K. Where EIRR is 15.4 % and at discount rate of 10%, ENPV is Nu. 127 million at price for July 1995, and E.B/C is 1.53 at the same discount rate. Project evaluation has proven that EIRR exceeds the opportunity cost of capital 10 %, ENPV is positive and E.B/C exceeds 1. It is judged that the implementation of the Basic Plan is economically sound.

(4) Sensitivity Analysis

Sensitivity analysis is carried out to estimate for variation of the main factors of the project evaluation, and made under the following conditions: 1) 10% increase of the project cost, 2) 10% decrease of the project benefit and 3) 1 year delay of the completion of the construction works.

SENSITIVITY ANALYSIS OF ECONOMIC EVALUATION

Item	EIRR (%)	ENPV (1,000 Nu.)	E.B/C
Base	15.4	126,849	1.53
Project cost increased by 10%	14.2	104,528	1.40
Project benefit decreased by 10%	14.0	90,264	1.38
Construction delayed for 1 year	13.7	91,390	1.38

Sensitivity analysis has proven that a change in the construction period has stronger influence on economy of the Basic Plan than a change in project cost and project benefit.

A standard conversion factor (SCF) of 0.8 has been applied to local cost components, resulting in an EIRR of 16.8 % and at discount rate of 10%, ENPV is Nu. 149 million, and E.B/C is 1.68 at the same discount rate.

8.6.4 Financial Evaluation

(1) Farm Household's Economic Analysis

Direct beneficiaries of the Water Resources Development Plan are farmers in the Study area through the implementation of the agricultural development plan. Agricultural net returns have been calculated deducting production costs from gross production values.

AGRICULTURAL NET RETURNS

(Unite: Nu.)

Sub-Area	Condition	per Farm Household	per hectare
Lobeysa	Without Project	14,450	9,607
	With Project	18,622	12,380
Bajo	Without Project	25,762	9,368
	With Project	34,310	12,476
Phangyul	Without Project	8,141	4,992
	With Project	10,202	6,256
Rubeysa	Without Project	5,111	5,807
	With Project	5,915	6,719
Average	Without Project	11,814	8,178
	With Project	15,084	10,442

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

(4) Water Charge Analysis

Charging of water has the dual purpose to reduce excessive consumption and to cover the costs involved in operating, maintaining and renewing the system. To make the water supply plan successful, at least the operation and maintenance costs should be paid for by the beneficiaries. However, a deep-rooted conviction remained in the minds of the people that water would be provided free of charge by the Government, especially in the rural areas.

1) Water Supply Plan for Rural Areas

The participation of inhabitant would be very important for the development of a water supply plan. Without their participation, the chances of a successful plan would be slim. It is possible to utilise the inhabitant's labour services in the construction works. The inhabitant would also be allowed to participate in the operation and maintenance works with a view to promoting their enthusiasm for the Basic Plan. Also, the PWD and Dzongkhag are that through participation of the inhabitant, the Water Supply System would be self-supporting.

2) Water Supply Plan for Wangduephodrang Town

After the completion of the Plan, annual operation and maintenance cost is increased in 5.07 times in comparison Without Project from Nu. 526 thousand to Nu. 2,667 thousand. Until now, Wangduephodrang town has not charged water tariff for water supply service. Thimphu and Phuntsholing have been the only towns where consumers are required to pay for water. Recently, the Urban Water and Sewerage Project in Thimphu is proceeding by the Thimphu City Corporation. This project provides new tariff rates for water supply which are risen after 20 m^3 per month. According this new rates, a household of five persons using a normal amount of water, will have to pay approximately Nu. 25.0 a month.

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

8.6.5 Socio-Economic Evaluation

As stated before, the Basic Plan brings about direct, tangible benefit as well as the secondary or indirect, intangible benefit, which is important in reviewing validity of the implementation of the Plan.

(1) Contribution to the National Development Plan

Implementation of the Plan contributes to the national development in ensuring accomplishment of many objectives of the agricultural development and water supply plans, which are ones of the important political terms on the agricultural and water supply sectors of the national development plan.

(2) Stable Supply of Food

Bhutan is 66% self-sufficient in all cereals. It is virtually self sufficient in maize, barley, millet and buckwheat, but it is only 52% self-sufficient in rice and only 24% self sufficient in wheat. To meet the food deficits cereals are imported from India.

Productions of rice and wheat, which are basic major crops, are maintained and become stable with irrigation agricultural method. Furthermore, agricultural production become diversity because of new crop introduction such as vegetables, answers stable supply of food for people and contributes to improve of self-sufficiency rate.

(3) Improvement of Living Standard

As evidently proven by the financial evaluation, farmer's economic surplus is increased to a great extent by the implementation of the Plan. A rapid increase in funds in farmer's economy by far exceeds cost of improving living environments.

(4) Water Quantity and Quality Improvement

Improvement of drinking water supply has two aspects, quantity and quality. The former is by far the dominant factor, as quality is always attained by the treatment of water. Increase of water supply would give tremendous impact on the domestic users.

Increase of the water supply to the existing distribution system would reduce the area and time of suppressed use and it will result in reduction of a chance for the poor who will suffer from water-borne diseases like diarrhoea, typhoid, cholera, worm infestations (hepatitis), especially in the hot rainy season when water is contaminated.

Expansion of the water supply area would result in the overall improvement of the marginal areas of the town economically and ecologically. The effects two folds. This is the area where quality aspect of the drinking water would need keen attention. It would reduce the incidents of epidemics of water-borne diseases by enhancing the standard of hygiene. This would contribute to build-up of better human resources in the area. At the same time it would liberate may womenfolk and children from the labour of carrying water from sources some distance away.

(5) Economical Stimulation

As stated, the implementation of the Plan increases the income of local farmer and improves the living standard to a great extent. Improved income further increases purchase power of the local farmer and vitalises local commercial activities. Increased purchase power and vigorous commercial activities are expected to promote local industries. In this way, the implementation of the Basic Plan will bring about significant repercussive effect to Wangduephodrang district and finally to the economy of Bhutan, not limited to the Study area.

(6) Environmental Consideration

The environmental impacts and influence on the confirmed environmental elements which is especially ground water is summarised as follows: Ground water potential is rather poor in the Study area except for limited areas. Therefore the ground water resources are scarcely used as a source of drinking water. Presently, there is no health hazards connected to the contamination of the ground water resources. The Water Resources Development Plan in the Study area involves no ground water development plan on a grand scale. Accordingly, it is considered that the environmental impact on ground water would be insignificant.

(7) Gender Issue

According to the previous studies, generally in the rural area of Bhutan, women are the predominant proprietors whether it concerns the house, land or livestock. Ownership gives women a stronger position than men at the household level. Women most often decide about household labour mobilisation, selling of livestock and cash expenditure.

In paddy cultivation, women provide more than 60% of the labour. Irrigation Implementation Plan which increases the wetland area or cultivation ratio could bring relatively more work for women than for men. In other words, irrigation development would affect women more than men.

On the other hand, one of the important and hard household works by the rural women is fetching water, traditionally carried from streams or springs on long distance. Water supply for rural area could get water on near houses. A part of women's work would be decrease about fetching water.

8.6.6 Comprehensive Evaluation

The implementation of present Water Resources Development Plan is judged as valid with the result of economic evaluation and financial evaluation as computed from tangible benefit. In addition, socio-economic impact evaluated from intangible benefit is also judged as sufficiently expectable. Large negative impact from the implementation the Basic Plan is not confirmed on the environmental evaluation and the Basic Plan is evaluated as a sustainable water resources development plan considering the environment. Moreover, the implementation of the Plan is justified to be feasible from technical and organic operation view points. Accordingly, it is recommended that a high priority should be given to the present Plan be implemented in the early stage.

CHAPTER 8
TABLES

Table 8.2.1 Summary of Study Case

No.	Case Code	A Water Management	B Canal Capacity	C Water Resource	D Crop Diversification	E Double Paddy Cropping	Remark
1	O	(Present Condition)					
2	A	●					
3	B		●				
4	C			●			
5	D-1				●		5% Diversification
6	D-2				●		10% Diversification
7	D-3				●		15% Diversification
8	D-4				●		20% Diversification
9	AB	●	●				
10	AC	●		●			
11	AD-1	●			●		5% Diversification
12	AD-2						10% Diversification
13	AD-3						15% Diversification
14	AD-4						20% Diversification
15	BC		●	●			
16	BD-1		●		●		5% Diversification
17	BD-2		●		●		10% Diversification
18	BD-3		●		●		15% Diversification
19	BD-4		●		●		20% Diversification
20	CD-2			●	●		5% Diversification
21	CD-3			●	●		10% Diversification
22	CD-4			●	●		15% Diversification
23	CD-5			●	●		20% Diversification
24	ABC	●	●	●			
25	ABD-1	●	●		●		5% Diversification
26	ABD-2	●	●		●		10% Diversification
27	ABD-3	●	●		●		15% Diversification
28	ABD-4	●	●		●		20% Diversification
29	ACD-1	●		●	●		5% Diversification
30	ACD-2	●		●	●		10% Diversification
31	ACD-3	●		●	●		15% Diversification
32	ACD-4	●		●	●		20% Diversification
33	BCD-1		●	●	●		5% Diversification
34	BCD-2		●	●	●		10% Diversification
35	BCD-3		●	●	●		15% Diversification
36	BCD-4		●	●	●		20% Diversification
37	ABCD-2	●	●	●	●		10% Diversification for Phangyul
38	ABE-1	●	●	●		●	20% Double Cropping for Bajo
39	ABE-2	●	●	●		●	40% Double Cropping for Bajo
40	ABE-3	●	●	●		●	60% Double Cropping for Bajo
41	ABE-4	●	●	●		●	100% Double Cropping for Bajo

Note ● : With Improvement Plan

Table 8.2.2 Unit Construction Cost for Irrigation Improvement Plan

Work Item	Unit	Cost (Nu.)	Code
1 Earthwork			
Excavation, manual	m3	30.61	E-1
Excavation, machine	m3	45.92	E-2
Backfill, manual	m3	15.38	E-3
Backfill, machine	m3	23.07	E-4
Embankment, manual	m3	34.56	E-5
Embankment, machine	m3	51.84	E-6
Earth lining	m2	8.75	E-7
Gravel surfacing	m2	367.96	E-8
Gravel foundation	m3	206.60	E-9
Sand fill	m3	61.22	E-10
2 Concrete Works			
Reinforced concrete (1:2:4)	m3	1,330.73	C-1
In-situ precast concrete (1:2:4)	m3	2,358.20	C-2
Foundation concrete (1:3:6)	m3	994.38	C-3
Plain concrete	m3	1,483.75	C-4
Concrete mortar for plastering	m2	56.45	C-5
Wet masonry	m3	917.08	C-6
Cement Masonry (1:4)	m3	818.54	C-7
Dry masonry	m3	313.39	C-8
Form, type-1	m2	54.83	C-9
Form, type-2	m2	43.86	C-10
3 Metal Works			
Steel Flume for Aqueduct (t=4)	m2	55.13	M-1
4 Timber Works			
Wooden plunk for stop log (t=50)	m2	231.33	T-1
Timber beams	m3	4,512.18	T-2
Wooden cross tai (t=20)	m3	4,626.63	T-3
5 Other Works			
Gabion	m3	561.76	
Concrete pipe placing (D=1,200)	m	1,685.09	P-1
Concrete pipe placing (D=900)	m	1,136.04	P-2
Concrete pipe placing (D=700)	m	859.78	P-3
Concrete pipe placing (D=500)	m	540.00	P-4
Concrete pipe placing (D=400)	m	436.03	P-5
Concrete pipe placing (D=300)	m	306.49	P-6

Table 8.2.3 Summary of Case Study Result (1/3)

Canal Code	Name of Canal	Command Area (ha)	Canal Length (km)
C9	Bajo Canal	143	15

Case	Improvement Item	Irrigation Efficiency		Maximum W.R. (l/s)	Canal Capacity (l/s)	Production Ratio		Net Production Value (1000 Nu.)	Expected (1000 Nu)		B/C Ratio
		Paddy	Upland			Summer	Winter		Benefit	Net Cost	
Case O	Present Condition	0.36	0.24	452	378	77%	100%	1,340			
Case A	only Management	0.36	0.24	452	378	87%	100%	1,454	114	63	1.81
Case B	only Canal	0.65	0.43	251	261	87%	100%	1,454	114	60	1.90
Case AB	Canal & Management	0.65	0.43	251	261	97%	100%	1,568	228	97	2.34
Case D-1	only 5% Diversification	0.36	0.24	434	378	79%	100%	1,349	9	22	0.42
Case AD-1	Management & 5% Div.	0.36	0.24	434	378	90%	100%	1,472	133	85	1.57
Case BD-1	Canal & 5% Diversification	0.65	0.43	241	250	89%	100%	1,461	122	79	1.55
Case ABD-1	Canal, Management & 5%	0.65	0.43	241	250	99%	100%	1,574	234	114	2.05
Case D-2	only 10% Diversification	0.36	0.24	416	378	81%	100%	1,357	18	22	0.81
Case AD-2	Management & 10% Div.	0.36	0.24	416	378	92%	100%	1,479	139	82	1.71
Case BD-2	Canal & 10% Diversification	0.65	0.43	231	240	90%	100%	1,457	117	76	1.55
Case ABD-2	Canal, Management & 10%	0.65	0.43	231	240	99%	100%	1,556	217	114	1.90
Case D-3	only 15% Diversification	0.36	0.24	397	378	83%	100%	1,271	-69	22	-3.18
Case AD-3	Management & 15% Div.	0.36	0.24	397	378	94%	100%	1,378	39	85	0.46
Case BD-3	Canal & 15% Diversification	0.65	0.43	220	235	87%	100%	1,310	-30	74	-0.40
Case ABD-3	Canal, Management & 15%	0.65	0.43	220	235	98%	100%	1,417	78	106	0.73
Case D-4	only 20% Diversification	0.36	0.24	379	378	85%	100%	1,244	-96	22	-4.45
Case AD-4	Management & 20% Div.	0.36	0.24	379	378	96%	100%	1,345	5	75	0.07
Case BD-4	Canal & 20% Diversification	0.65	0.43	210	221	93%	100%	1,317	-22	73	-0.31
Case ABD-4	Canal, Management & 20%	0.65	0.43	210	221	100%	100%	1,382	42	104	0.40

Table 8.2.3 Summary of Case Study Result (2/3)

Canal Code	Name of Canal	Command Area (ha)	Canal Length (km)
C10	Phangyul	91	16

Case	Improvement Item	Irrigation Efficiency		Maximum W.R. (l/s)	Canal Capacity (l/s)	Production Ratio		Net Output	Expected (1000 Nu)		B/C Ratio
		Paddy	Upland			Summer	Winter		Benefit	Cost	
Case O	Present Condition	0.36	0.24	255	240	38%	51%	421			
Case A	only Management	0.36	0.24	255	240	42%	71%	508	86	52	1.67
Case B	only Canal	0.65	0.43	142	149	51%	76%	587	166	150	1.11
Case AB	Canal & Management	0.65	0.43	142	149	57%	98%	694	272	187	1.46
Case C	only Water source	0.36	0.24	255	240	46%	69%	531	110	164	0.67
Case AC	Management & Water source	0.36	0.24	255	240	53%	95%	656	235	223	1.05
Case BC	Canal & Water source	0.65	0.43	142	149	59%	95%	699	278	314	0.89
Case ABC	Management. Canal & W.S	0.65	0.43	142	149	72%	100%	808	387	351	1.10
Case D-1	only 5% Diversification	0.36	0.24	243	240	39%	51%	424	3	20	0.15
Case AD-1	Management & 5% Div.	0.36	0.24	243	240	43%	72%	513	92	72	1.28
Case BD-1	Canal & 5% Diversification	0.65	0.43	135	143	52%	77%	591	170	162	1.05
Case ABD-1	Canal. Management & 5%	0.65	0.43	135	143	59%	98%	702	280	218	1.28
Case D-2	only 10% Diversification	0.36	0.24	232	240	39%	51%	420	-1	20	-0.07
Case AD-2	Management & 10% Div.	0.36	0.24	232	240	49%	76%	562	141	72	1.96
Case BD-2	Canal & 10% Diversification	0.65	0.43	129	136	53%	77%	593	171	155	1.11
Case ABD-2	Canal. Management & 10%	0.65	0.43	129	136	60%	98%	702	281	208	1.35
Case D-3	only 15% Diversification	0.36	0.24	220	240	40%	51%	394	-28	20	-1.37
Case AD-3	Management & 15% Div.	0.36	0.24	220	240	46%	72%	491	70	72	0.97
Case BD-3	Canal & 15% Diversification	0.65	0.43	122	130	53%	77%	549	127	150	0.85
Case ABD-3	Canal. Management & 15%	0.65	0.43	122	130	63%	99%	674	252	202	1.25
Case D-4	only 20% Diversification	0.36	0.24	209	240	41%	51%	385	-36	20	-1.77
Case AD-4	Management & 20% Div.	0.36	0.24	209	240	47%	72%	481	60	64	0.93
Case BD-4	Canal & 20% Diversification	0.65	0.43	116	124	56%	77%	548	126	147	0.86
Case ABD-4	Canal. Management & 20%	0.65	0.43	116	124	63%	99%	652	230	197	1.17
Case CD-2	Water source & 10% Div.	0.36	0.24	232	240	49%	70%	544	123	184	0.67
Case ACD-2	Management. W.S & 10% Div	0.36	0.24	232	240	62%	95%	707	286	243	1.18
Case BCD-2	Canal. W. source & 10% Div.	0.65	0.43	129	136	56%	96%	668	247	334	0.74
Case ABCD-2	W.M.. Canal. W.S & 10% Div.	0.65	0.43	129	136	76%	100%	820	399	371	1.07

Table 8.2.3 Summary of Case Study Result (3/3)

Canal Code	Name	Command Area (ha)	Canal Length (km)
C9	Bajo Canal	143	15

Case E Applying Double Paddy Cropping

Case	Improvement Item	Irrigation Efficiency		Maximum	Canal	Estimated Production Ratio					Net Production	Expected (1000 Nu)		B/C	Paddy
		Paddy	Upland	W.R. (l/s)	Capacity (l/s)	Summer	Winter	1st Paddy	2nd Paddy	Winter	Value (1000 Nu.)	Benefit	Net Cost	Ratio	Product (t)
Case O	Present Condition	0.36	0.24	452	378	77%	100%	-	-	-	1,340				338
Case A	only Management	0.36	0.24	452	378	87%	100%	-	-	-	1,454	114	63	1.81	381
Case B	only Canal	0.65	0.43	251	261	87%	100%	-	-	-	1,454	114	60	1.90	381
Case AB	Canal & Management	0.65	0.43	251	261	97%	100%	-	-	-	1,568	228	97	2.34	425
Case E-1	only 20% Double Paddy C.	0.36	0.24	434	378	82%	100%	92%	100%	100%	1,408	68	33	2.09	441
Case AE-1	Management & 20% D.P.C	0.36	0.24	434	378	92%	100%	95%	100%	100%	1,502	162	66	2.44	480
Case BE-1	Canal & 20% D.P.C.	0.65	0.43	234	240	87%	100%	95%	100%	100%	1,454	114	57	1.99	461
Case ABE-1	Canal, Management & 20%	0.65	0.43	234	240	97%	100%	98%	100%	100%	1,550	210	81	2.59	501
Case E-2	only 40% Double Paddy C.	0.36	0.24	416	378	87%	100%	95%	100%	100%	1,458	118	55	2.16	522
Case AE-2	Management & 40% D.P.C	0.36	0.24	416	378	97%	100%	98%	100%	100%	1,532	192	69	2.79	555
Case BE-2	Canal & 40% D.P.C.	0.65	0.43	210	210	87%	100%	95%	100%	100%	1,458	118	53	2.21	522
Case ABE-2	Canal, Management & 40%	0.65	0.43	210	210	97%	100%	98%	100%	100%	1,532	192	69	2.81	555
Case E-3	only 60% Double Paddy C.	0.36	0.24	397	378	92%	98%	95%	100%	100%	1,476	136	66	2.08	591
Case AE-3	Management & 60% D.P.C	0.36	0.24	397	378	100%	100%	100%	100%	100%	1,528	188	69	2.70	617
Case BE-3	Canal & 60% D.P.C.	0.65	0.43	186	190	87%	95%	89%	99%	100%	1,436	96	43	2.25	568
Case ABE-3	Canal, Management & 60%	0.65	0.43	186	190	97%	100%	98%	100%	100%	1,514	174	65	2.69	610
Case E-4	only 100% Double Paddy C.	0.36	0.24	379	378	98%	93%	91%	99%	100%	1,396	56	77	0.74	665
Case AE-4	Management & 100% D.P.C	0.36	0.24	379	378	100%	99%	98%	100%	100%	1,424	84	71	1.19	695
Case BE-4	Canal & 100% D.P.C.	0.65	0.43	205	210	97%	92%	90%	98%	100%	1,392	52	53	0.97	660
Case ABE-4	Canal, Management & 100%	0.65	0.43	205	210	100%	99%	97%	100%	100%	1,422	82	69	1.18	692

Table 8.3.1 Evaluation Sheet of Each Village/Community (1/4)

(Lobeysa Sub-area)

Village/Community	Implemented Scheme	Water Source: Type of Water Source	Water Source: Liability of Water Source	Water Source: Capacity per Capita (l/d)	Water Source: Capacity > or < 67 l/s	Water Source: Present Source Capacity	Water Quality	Present Service: Service Ratio (%)	Present Service: Number of Household Not Served	Measures to be Taken: Proposed Measures	Measures to be Taken: Population to be Served
BABESA GEWOG											
1 Mitshina	No Scheme	* Irri./Spring	Low	-	-	-	NG	0	18	X New Scheme (A)	250
2 Sopsokha	UNICEF**	Spring	High	102	OK	OK	OK	100	0		
3 Yuwakha	UNICEF**	Spring	High	102	OK	OK	OK	100	0		
4 Chimi Lhakhang	UNICEF	Spring	High	-	-	OK	OK	100	0		
5 Gomji	UNICEF**	Spring	High	102	OK	OK	OK	100	0		
6 Baywokha	No Scheme	* Spring	Low	-	-	-	OK	0	5	X New Scheme (C)	40
7 Yusakha	UNICEF	Spring	High	-	-	OK	OK	100	0		
8 Pachekha	UNICEF	Spring	High	-	-	OK	OK	100	0		
9 Jangsapo	UNICEF	Spring	High	-	-	OK	OK	100	0		
10 Tshokona	UNICEF	Spring	High	-	-	OK	OK	100	0		
11 NRTI***	MOA	Stream	High	-	-	-	OK	100	0		
12 Gangkha	UNICEF	Spring	High	-	-	OK	OK	100	0		
13 Power Station	MOI	Spring	Low	-	-	-	OK	100	0		
14 Pry School***	UNICEF	Spring	High	508	OK	OK	OK	100	0		
15 Jamripang	UNICEF**	Spring	High	102	OK	OK	OK	100	0		
16 PWD Camp (Maint.)	GREF*	Spring	Medium	-	-	-	OK	100	0		
17 Motokha	Private	Spring	Low	-	-	NG	OK	100	0	X New Scheme (C)	18
18 Pangnang	UNICEF**	Spring	Medium	102	OK	OK	OK	100	0		
19 PWD Camp (Const.)	MOC	Spring	Medium	-	-	-	OK	100	0		
20 RBA Firing Range**	RBA	Spring	Low	-	-	-	OK	100	0		
Sub-total	-	-	-	-	-	-	-	89	23	-	-
THETSO GEWOG											
21 Rinchengang	UNICEF	Stream	Medium	104	OK	OK	OK	86	5	X Extension Scheme (B)	67
Sub-total	-	-	-	-	-	-	-		5	-	-
Total	-	-	-	-	-	-	-	88	28	-	-

Table 8.3.1 Evaluation Sheet of Each Village/Community (2/4)

(Bajo Sub-area)

Village/Community	Implemented Scheme	Water Source					Water Quality	Present Service		Measures to be Taken	
		Type of Water Source	Liability of Water Source	Capacity per Capita (l/d)	Capacity > or < 67 l/s	Present Source Capacity		Service Ratio (%)	Number of Household Not Served	Proposed Measures	Population to be Served
THETSO GEWOG											
1 Proper Bajo	UNICEF	Stream	Low	-	-	NG	OK	26	20	X Additional Scheme	185
2 Bajothang	No Scheme	* River	High	-	-	-	NG	0	5	X New Scheme (C)	61
3 DSC/AMC	MOA	Subsurface	High	-	-	-	OK	100	0		
4 Thangu	No Scheme	* Spring	Low	-	-	-	OK	0	11	X New Scheme (A)	59
5 Matalumchu	No Scheme	* Spring	Low	-	-	-	OK	0	8	X New Scheme (A)	75
Sub-total	-	-	-	-	-	-	-	23	44	-	-
LINGBUKHA GEWOG											
6 Umtekha	No Scheme	* Spring	Low	-	-	-	OK	0	31	X New Scheme (A)	250
Sub-total	-	-	-	-	-	-	-	0	31	-	-
BABESA GEWOG											
7 Wangjokha	UNICEF	Spring	High	-	-	OK	OK	100	0		
8 Matalumchu	UNICEF	Spring	High	432	OK	OK	OK	100	0		
Sub-total	-	-	-	-	-	-	-	100	0	-	-
Total	-	-	-	-	-	-	-	36	75	-	-

Table 8.3.1 Evaluation Sheet of Each Village/Community (3/4)

(Phangyul Sub-area)

Village/Community	Implemented Scheme	Water Source: Type of Water Source	Water Source: Liability of Water Source	Water Source: Capacity per Capita (l/d)	Water Source: Capacity > or < 67 l/s	Water Source: Present Source Capacity	Water Quality	Present Service: Service Ratio (%)	Present Service: Number of Household Not Served	Measures to be Taken: Proposed Measures	Measures to be Taken: Population to be Served
PHANGYUL GEWOG											
1 Proper Phangyul	UNICEF	Spring	Medium	407	OK	OK	OK	37	15	X Extension Scheme (A)	118
2 Phangyul Gompa	No Scheme	* Spring	Medium	-	-	-	OK	0	2	X New Scheme (C)	5
3 Jemkhelo	UNICEF	Spring	High	-	-	OK	OK	100	0		
4 Yangcheytawa	UNICEF	Spring	High	-	-	OK	OK	100	0		
5 Chumey Gompa	UNICEF	Spring	Medium	-	-	OK	OK	100	0		
6 Chungsekha	UNICEF	Spring	High	839	OK	OK	OK	59	10	X Extension Scheme (A)	72
7 Domkhar	No Scheme	* Irrigation	High	-	-	-	NG	0	14	X New Scheme (A)	123
8 Paropselsa	No Scheme	* Irrigation	High	-	-	-	NG	0	1	X New Scheme (C)	9
9 Vegopara	Private	Spring	Medium	-	-	OK	OK	100	0	X New Scheme (C)	5
10 Rabuna inc. PWD	No Scheme	* Spr./Irr.	Medium	-	-	-	OK	0	4	X New Scheme (C)	70
11 Geonkhar	UNICEF	Stream	High	557	OK	OK	OK	81	6	X Extension Scheme (A)	37
12 Lenkhena	No Scheme	* Irrigation	High	-	-	-	NG	0	1	X New Scheme (C)	5
13 Omchuphunasa	No Scheme	* Irrigation	High	-	-	-	NG	0	1	X New Scheme (C)	22
14 Kumchi	No Scheme	* Spring	Low	-	-	-	OK	0	21	X New Scheme (A)	146
15 Damina	UNICEF	Spring	Medium	-	-	OK	OK	100	0		
16 Ribana	No Scheme	* Spring	Low	-	-	-	OK	0	19	X New Scheme (A)	92
17 Pachekha	No Scheme	* Spring	Low	-	-	-	OK	0	1	X New Scheme (C)	12
18 Chuzomsa	Private	Spr./Riv./Irr	High	-	-	OK	NG	31	4	X New Scheme (B)	49
Total	-	-	-	-	-	-	-	36	99	-	-

Table 8.3.1 Evaluation Sheet of Each Village/Community (4/4)

(Rubeysa Sub-area)

Village/Community	Implemented Scheme	Water Source					Water Quality	Present Service		Measures to be Taken	
		Type of Water Source	Liability of Water Source	Capacity per Capita (l/d)	Capacity > or < 67 l/s	Present Source Capacity		Service Ratio (%)	Number of Household Not Served	Proposed Measures	Population to be Served
RUBEYSA GEWOG											
1 Nyizergang Gompa	UNICEF	Spring	Medium	415	OK	OK	OK	100	0		
2 Rumina	UNICEF	Spring	High	237	OK	OK	NG	100	0	X Treatment Scheme	123
3 Nyalakha	UNICEF	Spr./Irr.	High	237	OK	OK	OK	45	4	X Extension Scheme (B)	41
4 Ruteokha	UNICEF	Spring	Medium	404	OK	OK	OK	100	0		
5 Tshemcho	UNICEF	Spring	High	237	OK	OK	OK	100	0		
6 Jasukha	UNICEF	Spring	High	576	OK	OK	OK	100	0		
7 Awakha	UNICEF	Spring	High	518	OK	OK	OK	45	1	X Extension Scheme (B)	12
8 Maphekha	UNICEF	Stream	High	608	OK	OK	OK	100	0		
9 Umtekha	No Scheme	* Spring	Low	-	-	-	OK	0	4	X New Scheme (C)	33
10 Nyegapara	No Scheme	* Stream	High	-	-	-	OK	0	7	X New Scheme (A)	45
11 Tashidingkha	No Scheme	* Spring	Low	-	-	-	OK	0	1	X New Scheme (C)	9
Sub-total	-	-	-	-	-	-	-	81	17	-	-
JENA GEWOG											
12 Balakha	UNICEF	Stream	Medium	3,086	OK	OK	OK	100	0		
13 Themakha	UNICEF	Spring	Medium	237	OK	OK	OK	47	8	X Extension Scheme (A)	169
14 Phuntshogang	UNICEF	Stream	High	864	OK	OK	OK	100	0		
15 Tashi Tokha	No Scheme	* Spring	High	-	-	-	OK	0	11	X New Scheme (A)	141
Sub-total	-	-	-	-	-	-	-	50	19	-	-
THETSO											
16 Nyechegeykha	UNICEF	Spring	Medium	508	OK	OK	OK	100	0		
17 Nalabji	UNICEF	Stream	Medium	617	OK	OK	OK	100	0		
Sub-total	-	-	-	-	-	-	-	100	19	-	-
Total	-	-	-	-	-	-	-	69	36	-	-