CHAPTER 8
FIGURES

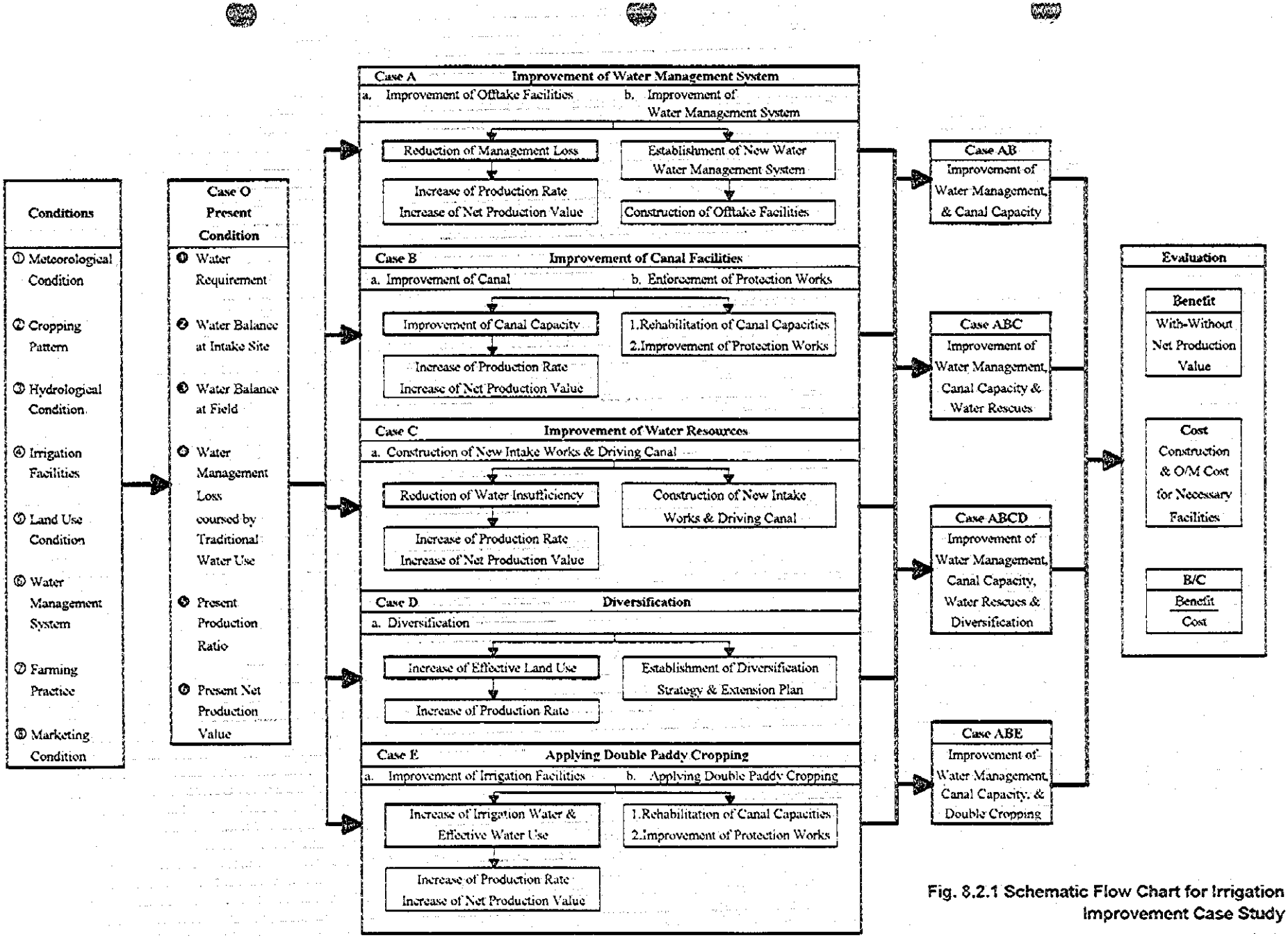


Fig. 8.2.1 Schematic Flow Chart for Irrigation Improvement Case Study

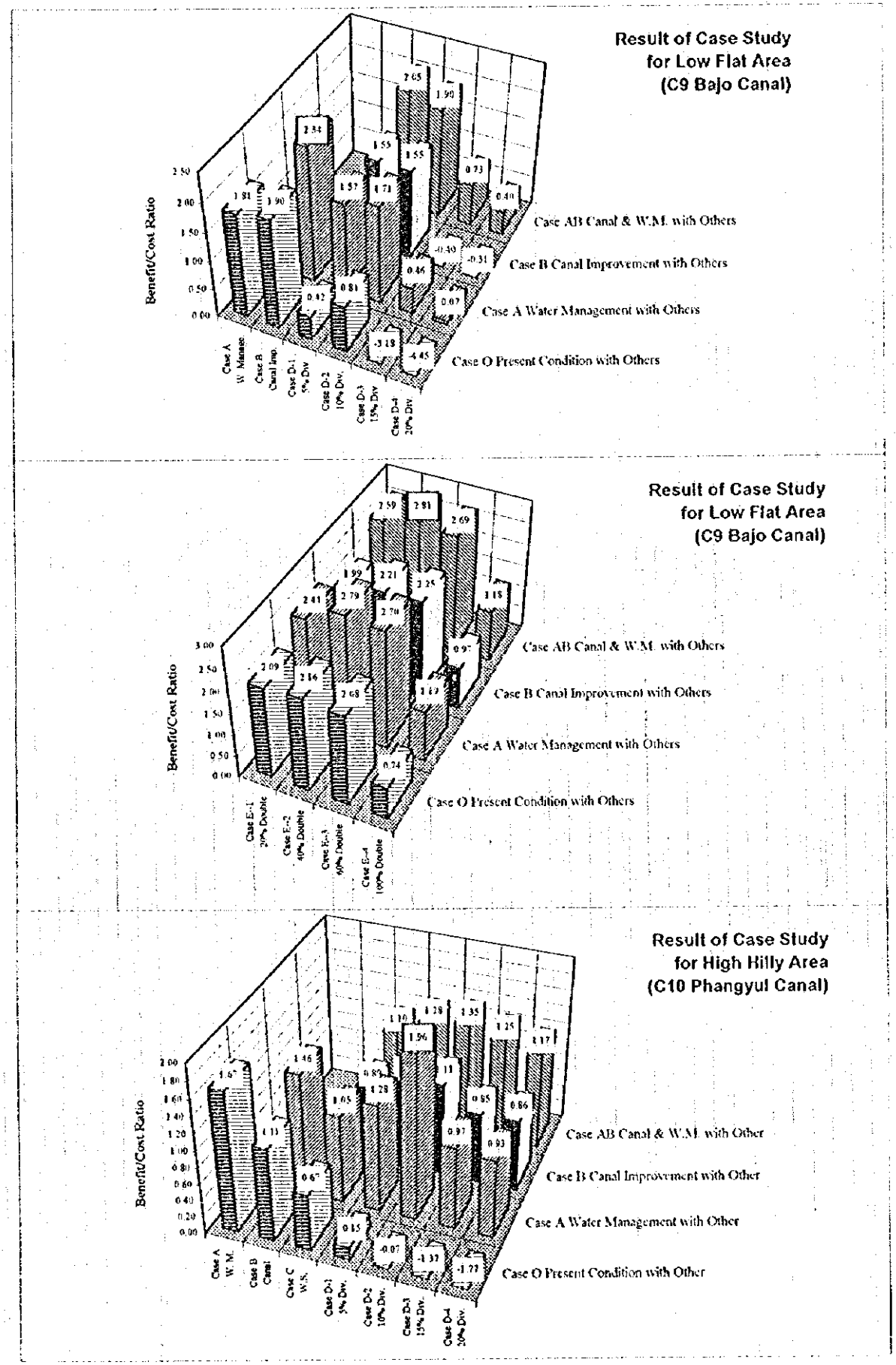
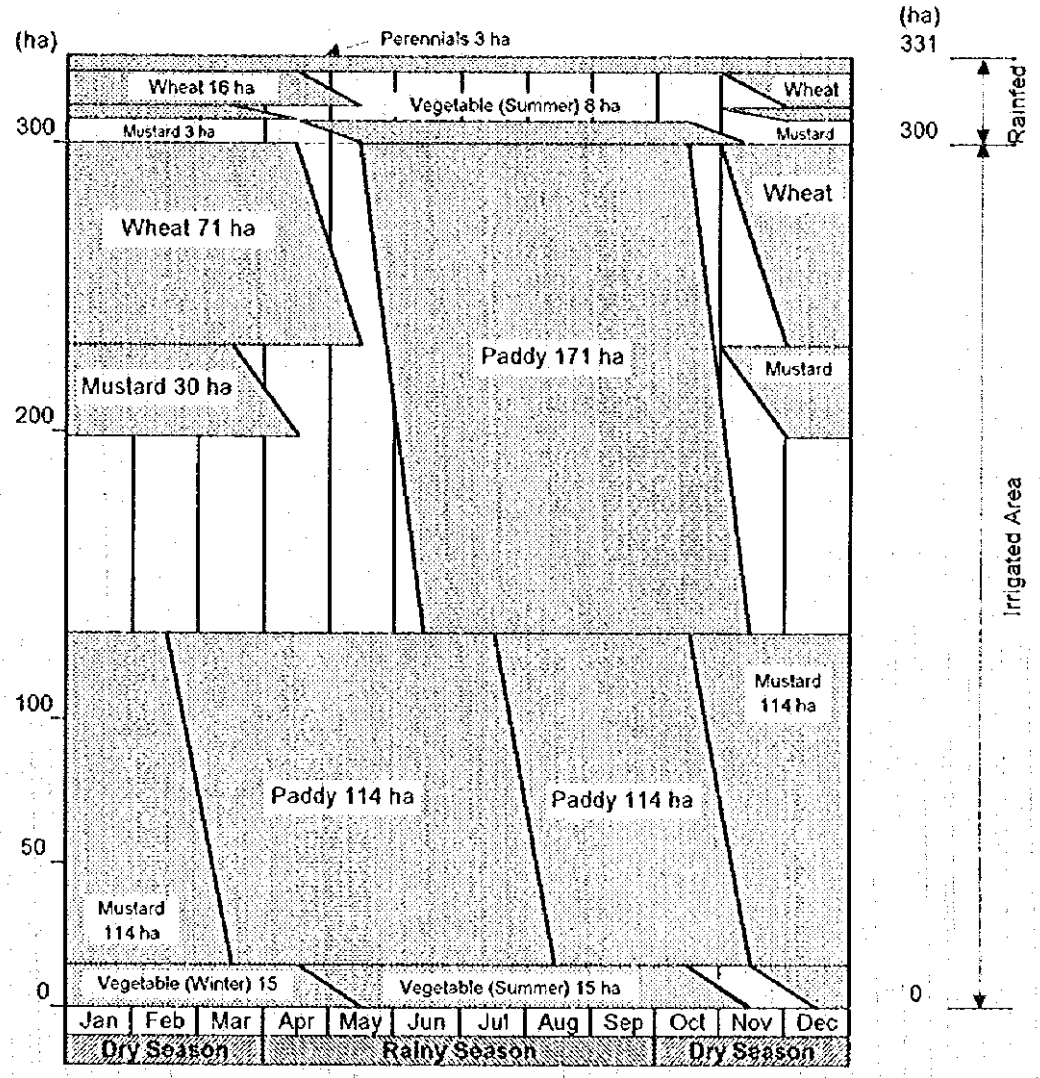
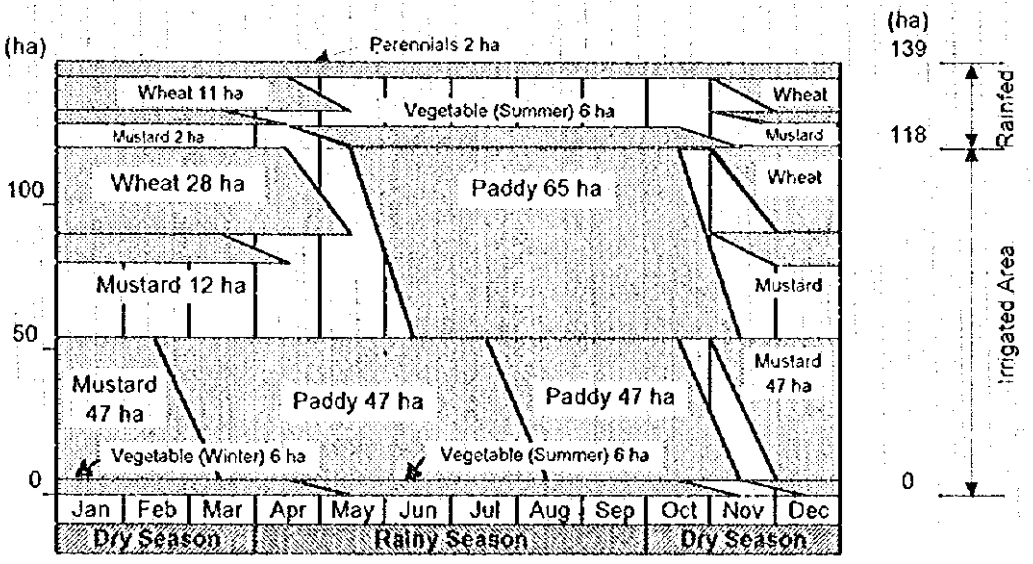


Fig. 8.2.2 Result of Case Study

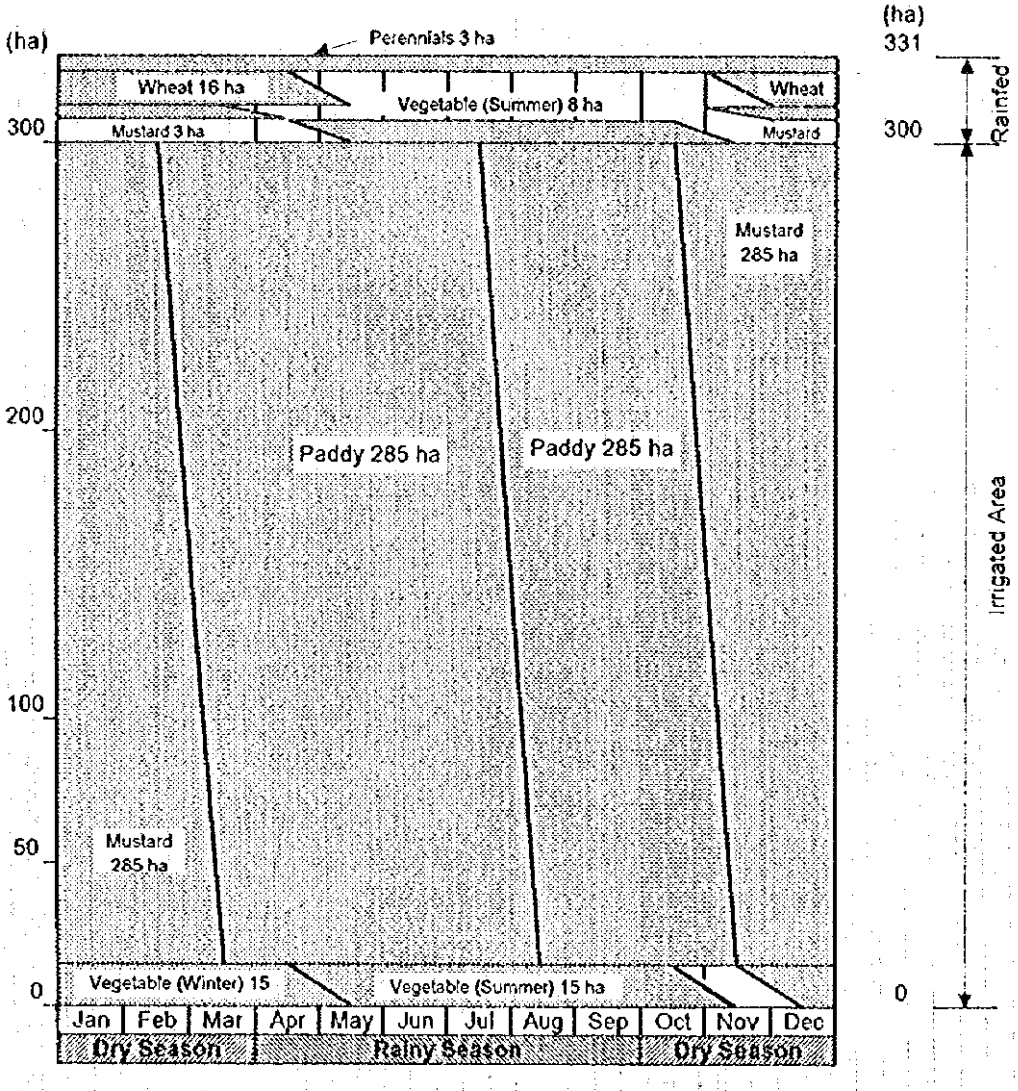


Lobeysa Sub-area (Applying 40% of Paddy Double Cropping)

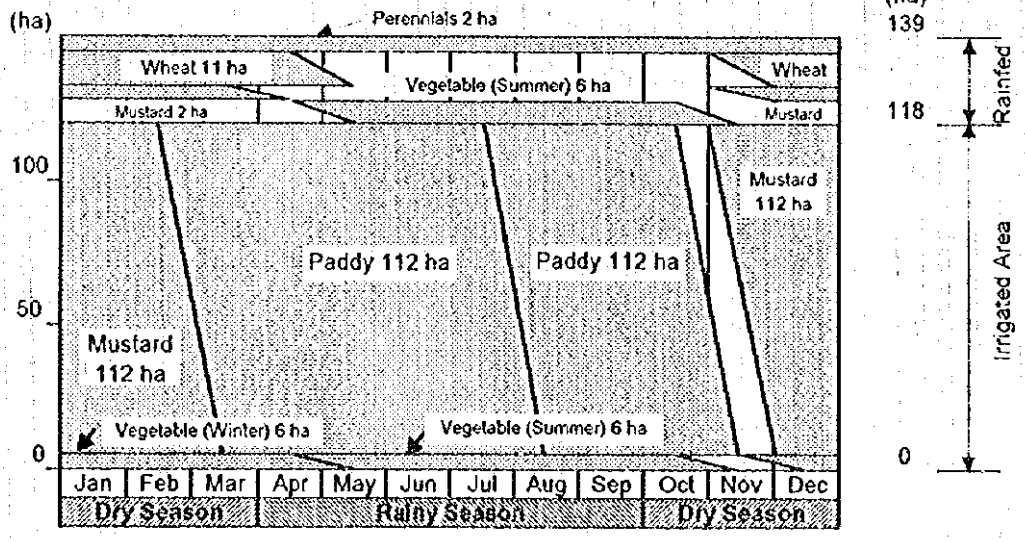


Bajo Sub-Area (Applying 40% of Paddy Double Cropping)

Fig. 8.2.3 Proposed Cropping Pattern (1/3)

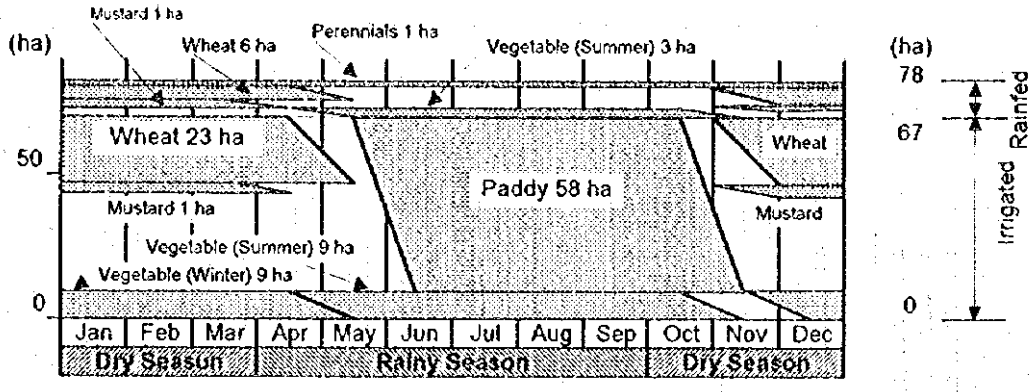


Lobeysa Sub-area (Applying 100% of Paddy Double Cropping)

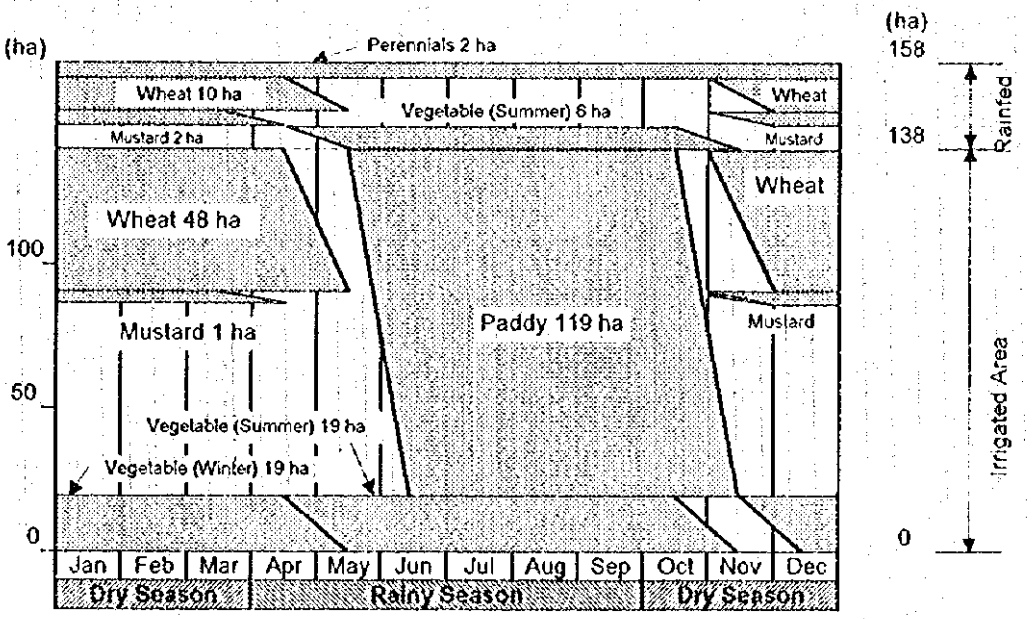


Bajo Sub-Area (Applying 100% of Paddy Double Cropping)

Fig. 8.2.3 Proposed Cropping Pattern (2/3)



Phangyul Sub-Area (Applying 10% of Diversification)



Rubeysa Sub-Area (Applying 10% of Diversification)

Fig. 8.2.3 Proposed Cropping Pattern (3/3)

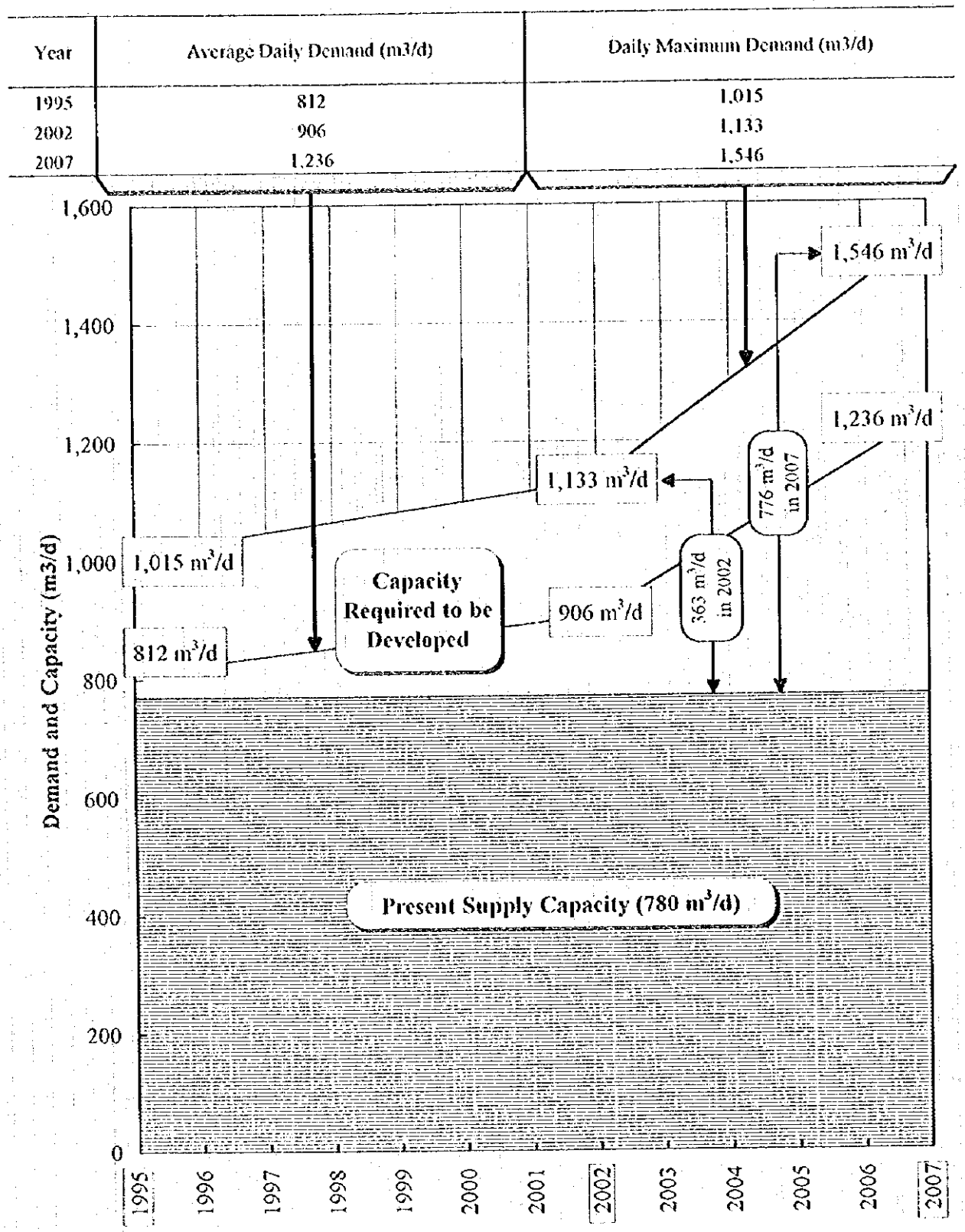


Fig. 8.3.1 FUTURE WATER DEMAND FOR WANGDUEPHODRANG TOWN

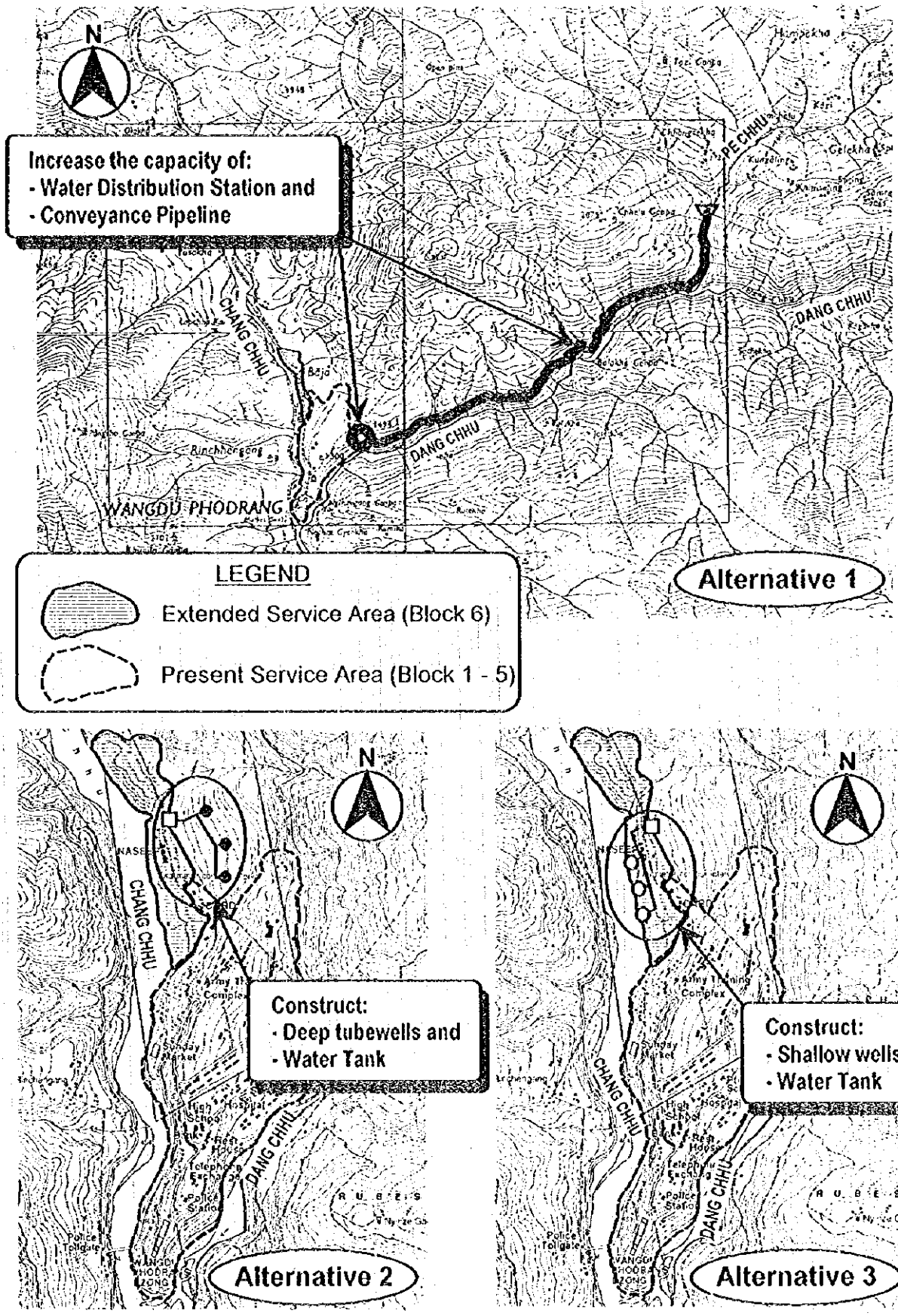


Fig. 8.3.2 ALTERNATIVES FOR URBAN WATER SUPPLY SYSTEM

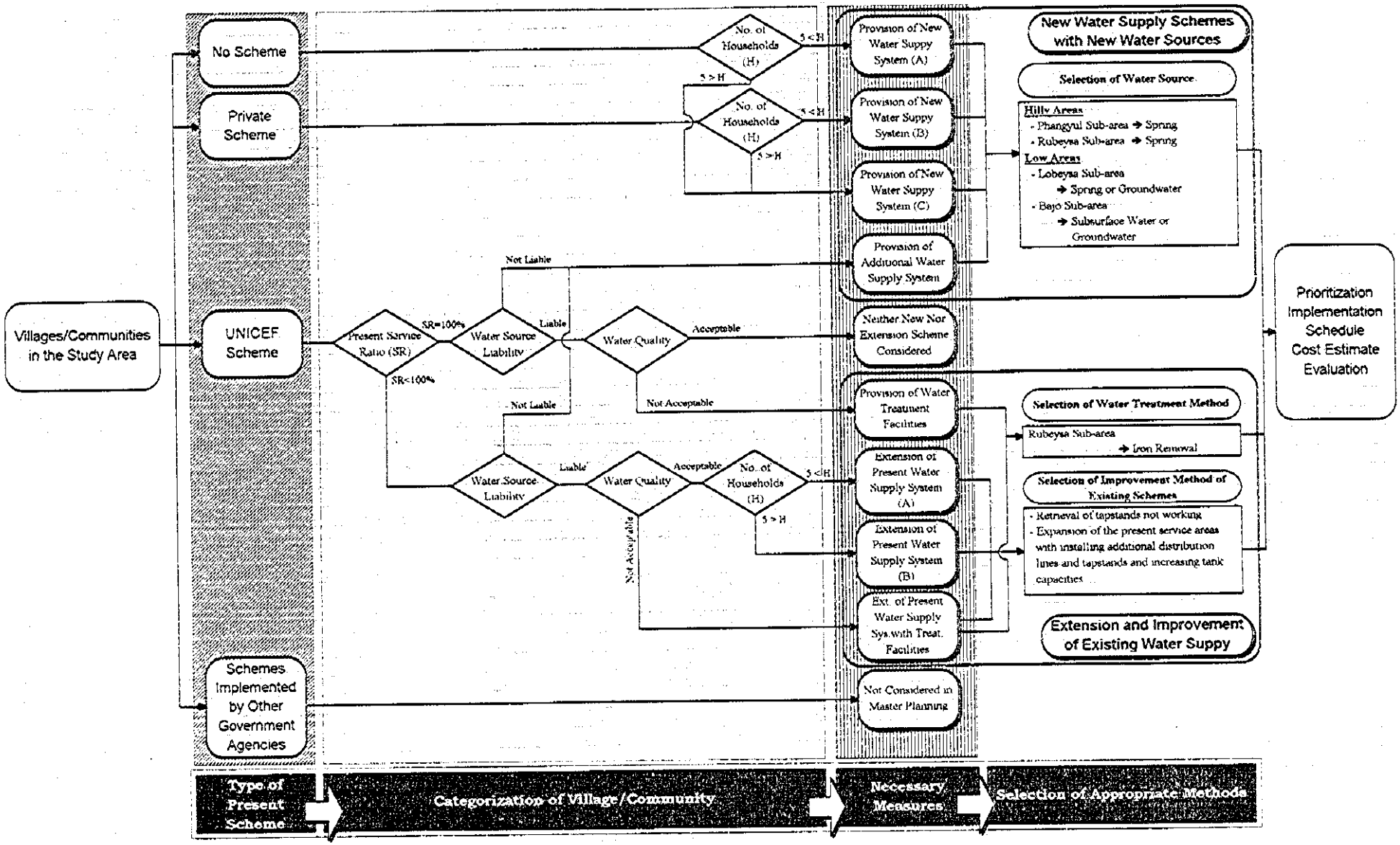
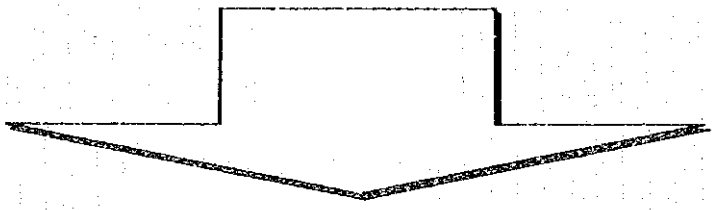


Fig. 8.3.3 SCHEMATIC FLOW FOR SELECTING MEASURES TO BE TAKEN

Sub-areas	Available Water Sources: Spring Water	Sub-surface Water	Groundwater	Stream/River Water**	Water Sources Considered in Alternative Study
Lobeysa	⊙	●	⊙	×	→ Spring Water & Groundwater
Bajo*	●	⊙	⊙	×	→ Sub-surface Water & Groundwater
Phangyul	⊙	×	×	×	→ Spring Water
Rubeysa	⊙	×	×	×	→ Spring Water

Note:
*: Spring water source is considered partly in hilly area.
**: Stream and river water is not considered in the study since they may easily be contaminated biologically.



Sub-areas	Item	New Scheme (A)	New Scheme (B)	New Scheme (C)	Additional Scheme	Extension Scheme (A)	Extension Scheme (B)	Extension with Treatment	Water Treatment Scheme
Lobeysa	No. of Village	L-1 2	0	L-2 2	0	0	S-4 1	0	0
	Average Population	253	0	24	0	0	67	0	0
Bajo	No. of Village	B-1 3	0	1	1	0	0	0	0
	Average Population	128	0	B-2 6	B-1 185	0	0	0	0
Phangyul	No. of Village	3	1	7	0	3	0	0	0
	Average Population	S-1 120	49	18	0	S-3 76	0	0	0
Rubeysa	No. of Village	2	0	S-2 2	0	1	S-4 2	0	1
	Average Population	93	0	21	0	169	27	0	T-1 123
Whole Area	Total No. of Village	9	1	12	1	4	3	0	1
	Average Population	131	49	24	185	99	40	0	123

Case S-1:	Spring Development - New (Large)	Case B-1:	Groundwater vs Subsurface Development (Large)
Case S-2:	Spring Development - New (Small)	Case B-2:	Groundwater vs Subsurface Development (Small)
Case S-3:	Spring Development - Extension (Large)	Case L-1:	Spring vs Groundwater Development (Large)
Case S-4:	Spring Development - Extension (Small)	Case L-2:	Spring vs Groundwater Development (Small)
Case T-1:	Water Treatment - Iron Removal		

Fig. 8.3.4 CASES SIMPLIFIED FOR EACH CATEGORY

CHAPTER 9
URBAN WATER SUPPLY PLAN FOR WANGDUEPHODRANG TOWN

9. URBAN WATER SUPPLY PLAN FOR WANGDUEPHODRANG TOWN

9.1 Planning Condition

9.1.1 Target Year

The target year is set considering the implementation period, hence the final target year is set at 2007 taking into account of the implementation period of about 15 years and the period covered by a regular five year plan of the country. The year of 2002 is also taken as a milestone for implementing the basic plan for about 10 years later and five (5) years before the final target year. The water resources development basic plan for the rural and urban water supply is prepared in accordance with this basic time frame. The whole plan is first figured out for the final target year of 2007, and then it is divided into some steps of implementation considering priority, importance, urgency, etc.

9.1.2 Served Area and Population

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 not 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.

As mentioned in the previous chapter, the future population increase projected for the target year of 2002 and 2007 is set as shown in the table taking the growth rate of two (2) % per year.

Projected Population in Wangduephodrang Town Area

Categories	1995	2002	2007
Resident	6,035	6,979	7,856
Day Visitors	2,293	2,867	3,356
Total	8,328	9,847	11,212

9.1.3 Water Consumption and Required Productivity

The previous sections, the present productivity of the existing water supply system is considered to be 780 m^3/day mainly because of the limited conveyance capacity of the existing conveyance pipeline from the Pe Chhu.

The domestic water demand is estimated at 1,133 m^3/day and 1,546 m^3/day in 2002 and 2007, respectively. It is, therefore, necessary to increase the water supply capacity accordingly. The capacity to be increased is calculated to be 363 m^3/day and 776 m^3/day in 2002 and 2007, respectively. The proposed capacity of the facilities are set as follows:

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

- 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

9.2 Facility Plan

9.2.1 Bajo Canal and Intake Facilities

(1) Intake and Sediment Removal Facilities

The raw water is diverted directly from the Pe Chhu at present with 1,000 mm (w) x 500 mm (d) open channel by gravity on the right bank of the river, and the diverted water is conveyed through the open channel together with irrigation water. The water for the urban water supply is separated at the point of 65 m downstream from the intake structure, and the separated water flows into the sediment removal structure made of a grit chamber of 70 m^3 capacity located beside the open channel for irrigation.

The existing intake facilities of the open canal and the sediment tank is found to be functioning well at present, and is considered still functionable 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.

(2) Conveyance Pipeline

The flow capacity of the existing pipelines is estimated as eight (8) l/sec, 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.

Route of New Conveyance Pipeline

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 considering the following findings.

- The former route has a mild and constant slope to reach the distribution station, resulting in rather moderate pressure variation, while the latter route's profile reveals sudden and frequent changes of pressure due to its topography.

- The latter route runs geologically more stable zones than the former one, and many gullies are formed along the route. Hence the latter route looks to be safer, and less construction costs are expected.

- There is no space for construction and placing the piping materials along the existing Bajo canal. Therefore, the latter route is recommended to enable easy operation and maintenance as well as easy and smooth construction.

Type of Piping Materials

The following three (3) types of piping materials are considered as options for materials of the new conveyance pipelines.

- PVC pipe

- Steel pipe

- Ductile iron pipe

Among the above piping materials, the ductile iron pipe is judged to be the most suitable for the construction of new conveyance pipeline after the following considerations.

- The geological situation in the Study area like Himalayan region is considered as still unstable. In the areas along the proposed route, many land sliding are found, and many efforts have been taken to prevent the national road from damages induced by such land sliding. According to the results obtained through the geological hazards assessment, the vulnerability in this area is the highest. It is, therefore, necessary and essential to adopt such materials which are considered as strong and bearable against excessive pressures and stresses caused by unstable geological conditions.

- In order to proceed with the construction works smoothly as scheduled under the condition that the availability of construction equipment is limited and skilled laborers are found scarce, it is necessary to apply the materials that make joint works easy, because such pipe joints are considered to be the most important to avoid unexpected leakage of water, etc.

- The materials which are strong and bearable against the deterioration and weathering is recommended to be adopted in order to reduce the replacement costs after the completion of construction as much as possible.

- The PVC materials are considered to last a long time, but are weak in bearing the inner and outer stresses and pressures. The steel pipe is rather strong and bearable, but the welding work requiring skilled welders is essential to joint these materials. The ductile iron pipe is considered stronger against such stresses and pressures and easily jointed and last for a long time.

The principal features of the proposed new conveyance pipeline are summarized below.

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

The longitudinal profile of the proposed conveyance pipeline is presented in Fig. 9.2.1.

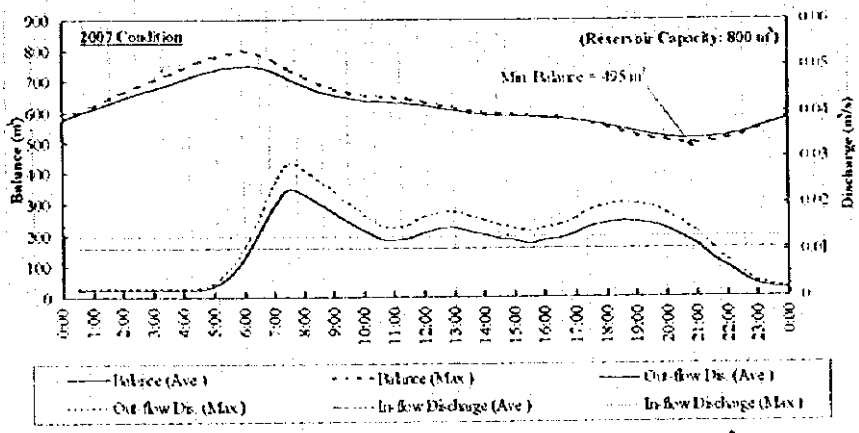
9.2.2 Water Distribution Station

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

(1) Daily Productivity of Distribution Station

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 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.

Therefore, it is proposed to increase the capacity of distribution reservoir from present 600 m^3 to 800 m^3 so as to reserve the capacity for storing 11 hr of distribution water. The variation of water levels in the reservoir tanks are illustrated in the following graph.



WATER BALANCE IN DISTRIBUTION TANKS (800 M^3)

As shown in the graph, 495 m^3 of water is stored even in case of the minimum water level, and this volume is translated to about seven (7) hr of water storage is considered possible.

(2) Water Treatment

Since the turbidity frequently raises over 20 particularly during and after the flood in the Pe Chhu especially in the wet season, it is recommended to apply some water treatment for improving such high turbidity and reducing bad color content.

Based on the above discussions, the existing distribution station is proposed to be improved as itemized below.

- The high turbidity should be resolved by improving and enhancing the present treatment system. A rapid filtration system is applied to improve the station, taking into account that there is only a limited area where the system expansion is able to be allowed as shown in Fig. 9.2.2.

- To facilitate the effects of rapid filtering, a flocculator should be provided before sedimentation tank, and some coagulant materials like aluminum surfeit should be applied to accelerate such coagulation effects as expected.

- Chlorination is recommended to distribute safe and clean water to the service area. It is given at the last stage of treatment.

- The existing water reservoir tanks are proposed to be expanded to some extent, because the present capacity of 600 m^3 is considered rather short to meet the requirement.

- Sludge and drain water treatment systems should also be provided in order to make the sludge dry for disposal and to process the washing water for draining out of the station yard within a permissible level of water quality.

- A piping galley is proposed to be provided to spare the space necessary for smooth operation of valves.

The flow chart of the proposed improved distribution station is illustrated in Fig. 9.2.3, and the elevation of each component is confirmed since some of the additional processes require much fall of water head as presented in Fig. 9.2.4.

The principal features of the proposed system components are summarized below, and its plot plan is presented in Fig. 9.2.5.

- Raw water receiving pit: 5.5 m (L) x 1.5 m (W) x 1.5 m (H) of reinforced concrete box with V-shape notch, butterfly type valves, flow meter and turbidity meter.

- Flocculator: 0.7 m (W) x 10.0 m (L) x 4 Nos. of concrete canal with baffles.
- Aluminum dosing system: 1,5 m (W) x 1.5 m (L) x 1.2 m (D) reinforced concrete solution tank with diaphram constant injection pump (1,400 cc/min.).
- Sedimentation tanks: The existing tanks whose capacity is measured to be 950 m^3 is utilized with some extent of reinforcement and supporting with frames and tapers
- Rapid sand filter: Gravity type rapid filter of 24 m^2 filter area with filtered water transfer pumps of 1.2 m^3/min (Filtered water basin is attached to the rapid filter).
- Distribution reservoirs: The present capacity of 600 m^3 is proposed to be increased by about 200 m^3 and the piping galley is proposed to be attached to the tank.
- Chlorination: 0.8 m dia. x 1.0 m (D) of tank made of plastics with a diaphram constant injection pump (1,400 cc/min.) and the necessary equipment such as level gauge, drain pipe, etc.
- Operation house: Wooden operation houses of 90 m^2 area
- Approach road: About 80 m of approach road from the national road to Tongsa.
- Other miscellaneous works: Wet masonry walls, fencing works, electricity connection works, etc.

9.2.3 Distribution Networks and Relating Facilities

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

(1) Main Pipelines

The present distribution networks were constructed in 1969, and since then no substantial improvement has been made so far. Then, the pipe material is deteriorated in many parts of the networks, resulting in continuous leakage of water. Many extension pipelines have also been placed at random with HDPE pipe materials as

the town area expands. Such HDPE pipes are easily connected to the illegal supply lines, which causes unbalanced load of demand.

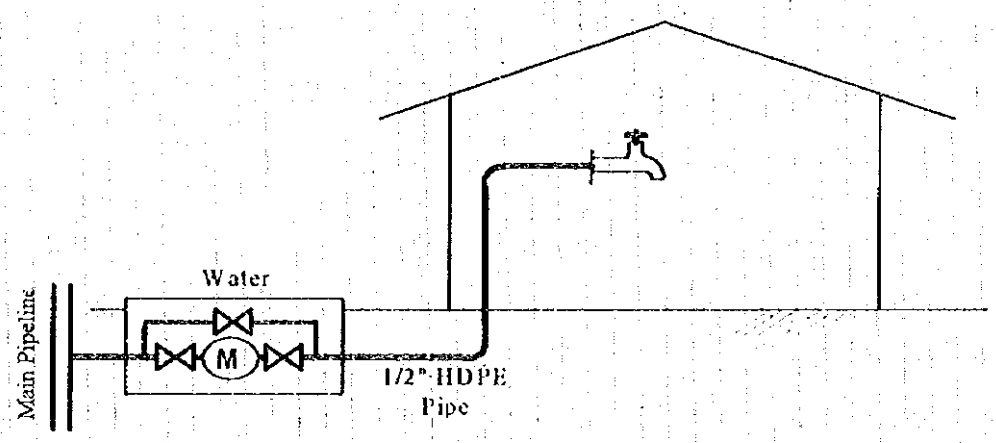
Therefore, it is proposed to replace such HDPE pipe materials with galvanized steel pipes to avoid illegal connection and reduce the leakage. To mitigate such unbalanced load of demand by traversing long main pipelines, etc., it is proposed to construct new main lines.

Since the service area is scheduled to be extended in the Bajo sub-area, a new main line is proposed to be constructed to distribute the water to such extended areas also.

The existing main pipelines and the proposed new pipelines are presented in Fig. 9.2.6.

(2) House Connections

To introduce the metered system, the house connection pipeline should be constructed as illustrated below.



TYPICAL HOUSE CONNECTION

9.3 Implementation Schedule and Project Cost Estimate

9.3.1 Implementation Schedule

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

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

IMPLEMENTATION SHCEDULE OF URBAN WATER SUPPLY SYSTEM

9.3.2 Project Cost Estimate and Disbursement Schedule

(1) Project Costs

The project costs for implementing urban water supply schemes are estimated based on the above implementation schedules as shown in the table. The total costs consisting of direct costs, engineering fees, administration fees, and physical contingency are estimated at Nu. 231,200,000 for the urban water supply system for Wangduephodrang town area. The details of estimated costs are explained in Appendix-J including the proportion between the local and foreign costs.

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

(Unit : Nu. 1,000,000)

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

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

The operation and maintenance costs consist of the following items:

- the salary and other necessary expenditures for the operation and maintenance staff,
- the costs for electric charge to operate the distribution station,
- costs for the chemicals which are applied for treating the distributed water such as chlorine and coagulant, and
- repairing and replacement costs for the distribution station and networks.

The calculated operation and maintenance costs are summarized below, and the details of these costs are explained in the Appendix-J.

Annual Operation and Maintenance Costs

(Unit: NU.1,000)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Urban Water Supply	526.2	526.2	526.2	526.2	2,219.5	2,312.4	2,312.4	2,312.4	2,312.4	2,628.9	2,667.9

(3) Annual Disbursement Schedule

The annual disbursement schedule is also set as shown below based on the implementation schedules prepared in the previous section.

Annual Disbursement Schedule for Implementing Urban Water Supply Scheme

(Unit: Nu.1,000,000)

Work Items	Year										
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1. Direct Construction Costs	0.0	0	60.1	95.4	9.3	0	0	0	3.9	3.9	0
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	0.0	10.7	72.0	108.4	14.6	0.0	0.0	0.0	4.0	4.0	0.0
4. Physical Contingency			6.0	9.5	0.9				0.4	0.4	
Total	0.0	10.7	78.0	117.9	15.5	0.0	0.0	0.0	4.4	4.4	0.0

9.4 Project Evaluation

9.4.1 Economic Evaluation

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

The flow of project cost, operation and maintenance cost and the project benefit of only the urban water supply plan for the Wangduephodrang town are presented in Appendix-K. EIRR of the Plan is 11.1 % and at discount rate of 10%, ENPV is Nu. 20.9 million at price for July 1995, and E.B/C is 1.11 at the same discount rate. Project evaluation has proven that EIRR exceeds the opportunity cost of capital 10%, ENPV is positive and E.B/C exceeds 1. It is judged that the implementation of this Plan is economically sound.

The EIRR is a little larger than the opportunity cost of capital of 10%. However, this Plan is considered profitable in case that such intangible benefits as health conditions and living standards in the Wangduephodrang town are taken into account.

(2) Sensitivity Analysis

The result of sensitivity analysis is shown as follows:

SENSITIVITY ANALYSIS OF URBAN WATER SUPPLY PLAN

Item	EIRR (%)	ENPV (1,000 Nu.)	E.B/C
Base	11.1	20,867	1.11
Project cost increased by 10%	10.2	3,122	1.02
Project benefit decreased by 10%	10.0	11	1.00
Construction delayed for 1 year	10.0	567	1.00

Sensitivity analysis has proven that a change in the construction period has stronger influence on economy of the 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 10.9 % and at discount rate of 11.7 %, ENPV is Nu. million, and E.B/C is 1.17 at the same discount rate.

9.4.2 Financial Evaluation - Water Charge Analysis -

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.

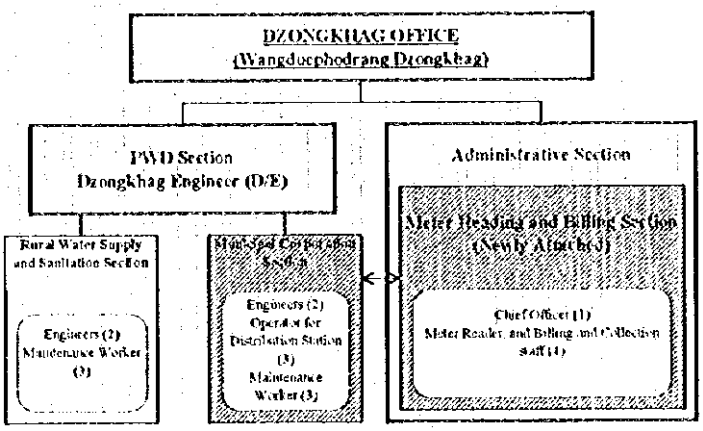
If Wangduephodrang Dzongkhag would apply the same water tariff system, after the completion of the Plan Dzongkhag or City Corporation could charge Nu. 564 thousand which values approximately 21% of the whole operation and maintenance cost.

9.5 Organisation and Institutional Arrangement

(1) Necessity of Introducing Metered System in Urban Water Supply System

Water charge is not collected at present for the urban water supply except a service charge of Nu. 9 - 40 a month depending on the class of beneficiary's house, and most of the expenditures necessary for operation and maintenance of the present urban water supply system have been managed by the Dazongkhag's own budget allocated by the government so far.

The operation and management costs for the future supply system is considered to increase comparing with the present ones, because more number of staff and engineers as well as tools and equipment are required to manage such systems in the future. In addition, the present low morality of the beneficiaries should also be improved at least to reduce such high rate of physical losses. It is, therefore, proposed to introduce a systematic water collection system with a



PROPOSED ORGANIZATION CHART FOR URBAN WATER SUPPLY IN WANGDUEPHODRANG TOWN AREA

proper water tariff before the water production reaches to the full stage as proposed. The metered system is also required to be introduced the new water supply system in order to measure correctly the volume of water used by a beneficiary. The tariff rate should be set considering those being applied to the other cities such as Thimphu, Phuntholing, etc.

(2) Proposed Future Organization

As mentioned in the previous chapter, 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 in the previous page is proposed.

The number of staff required for the operation and maintenance services are mentioned in the parentheses in the figure.

CHAPTER 9
FIGURES

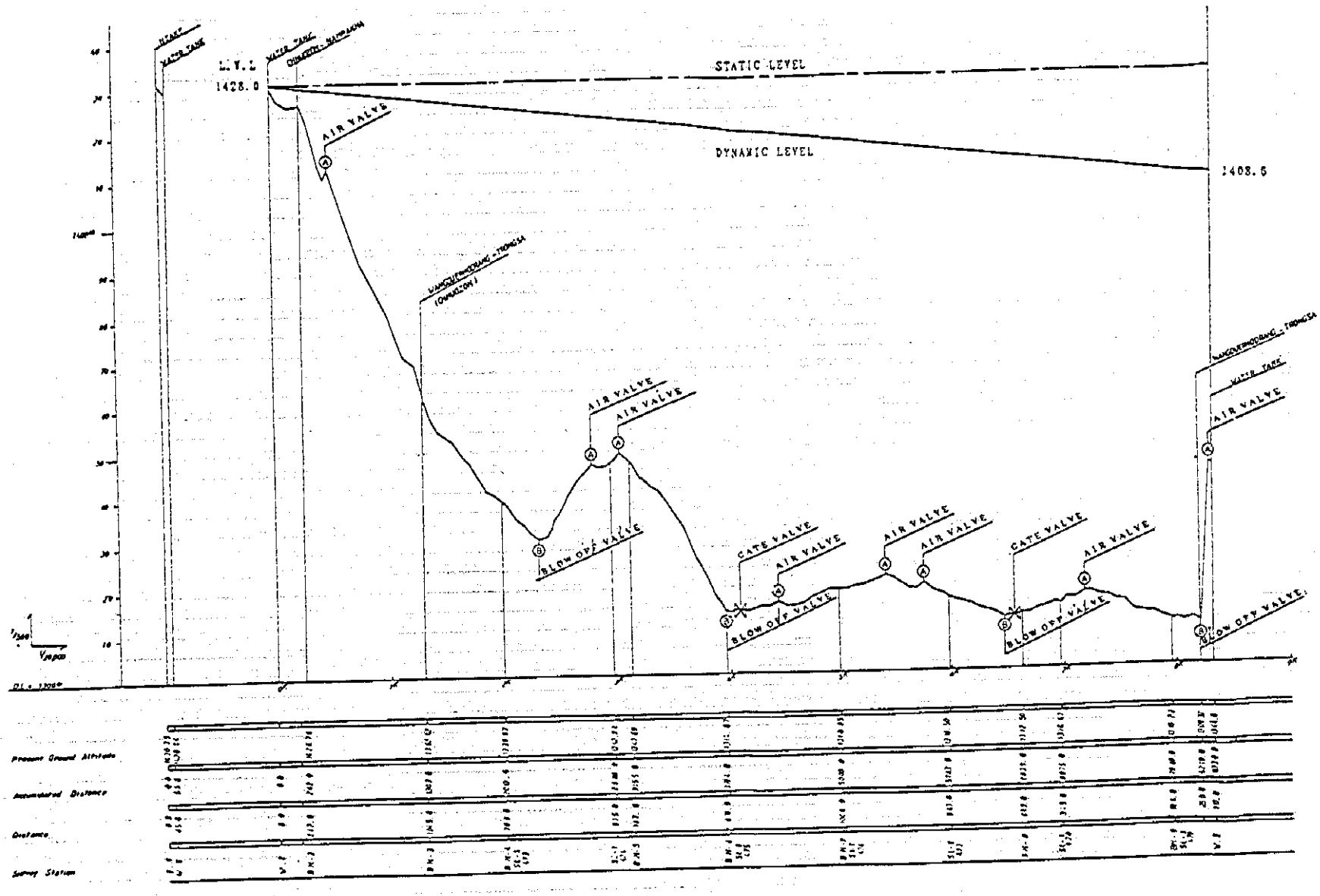


Fig. 9.2.1 HYDRAULIC PROFILE OF CONVEYANCE PIPELINE

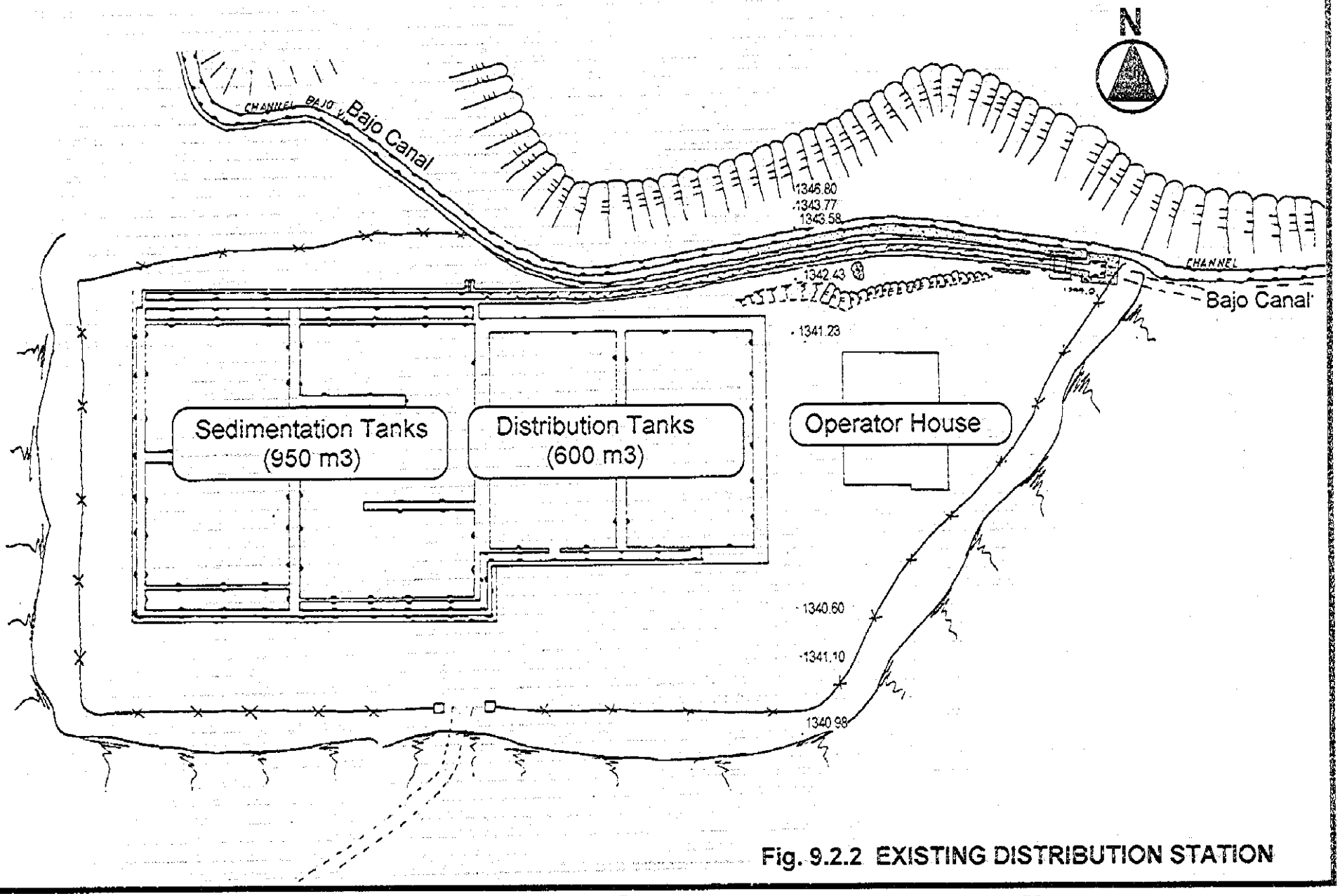


Fig. 9.2.2 EXISTING DISTRIBUTION STATION

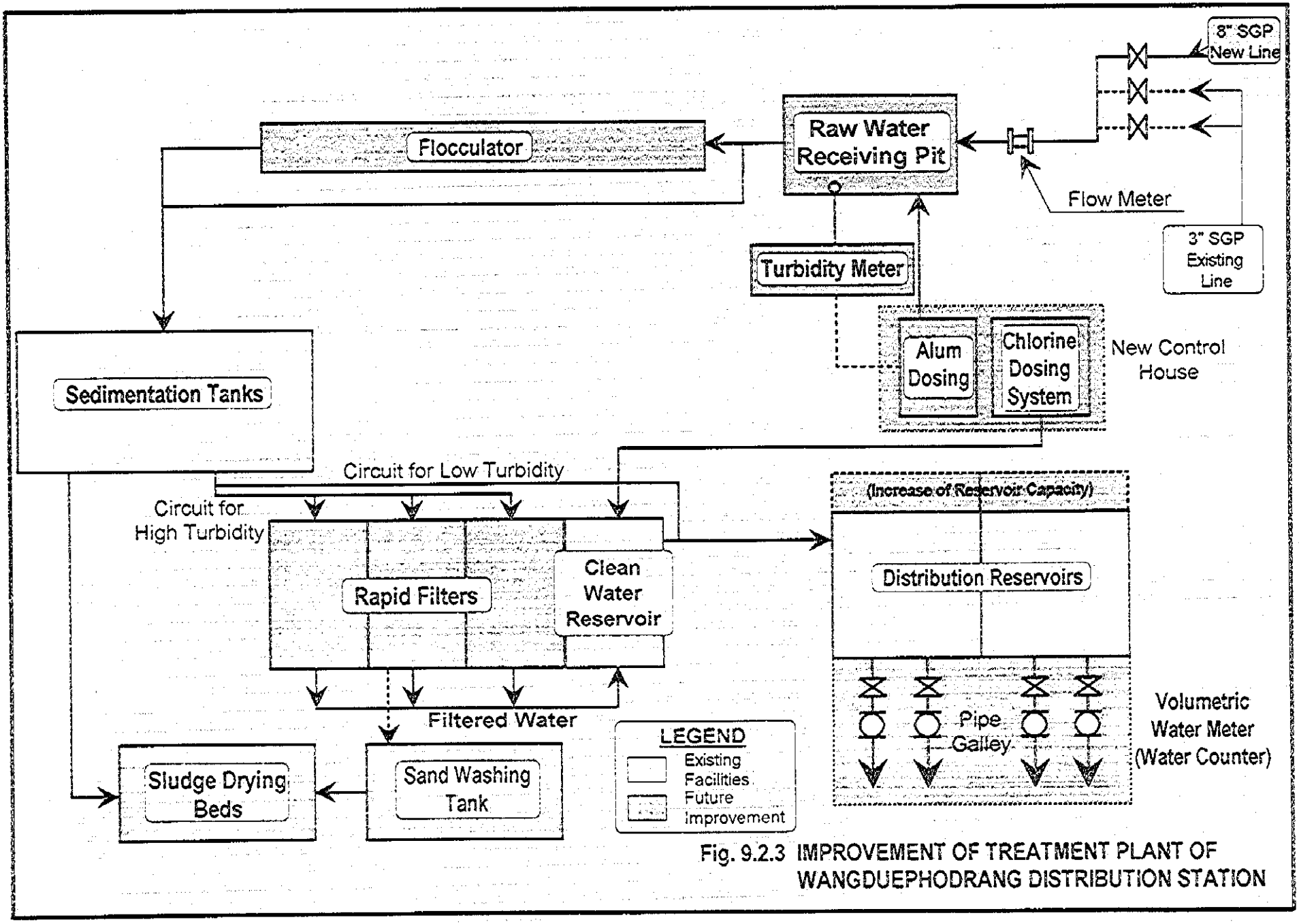


Fig. 9.2.3 IMPROVEMENT OF TREATMENT PLANT OF WANGDUEPHODRANG DISTRIBUTION STATION

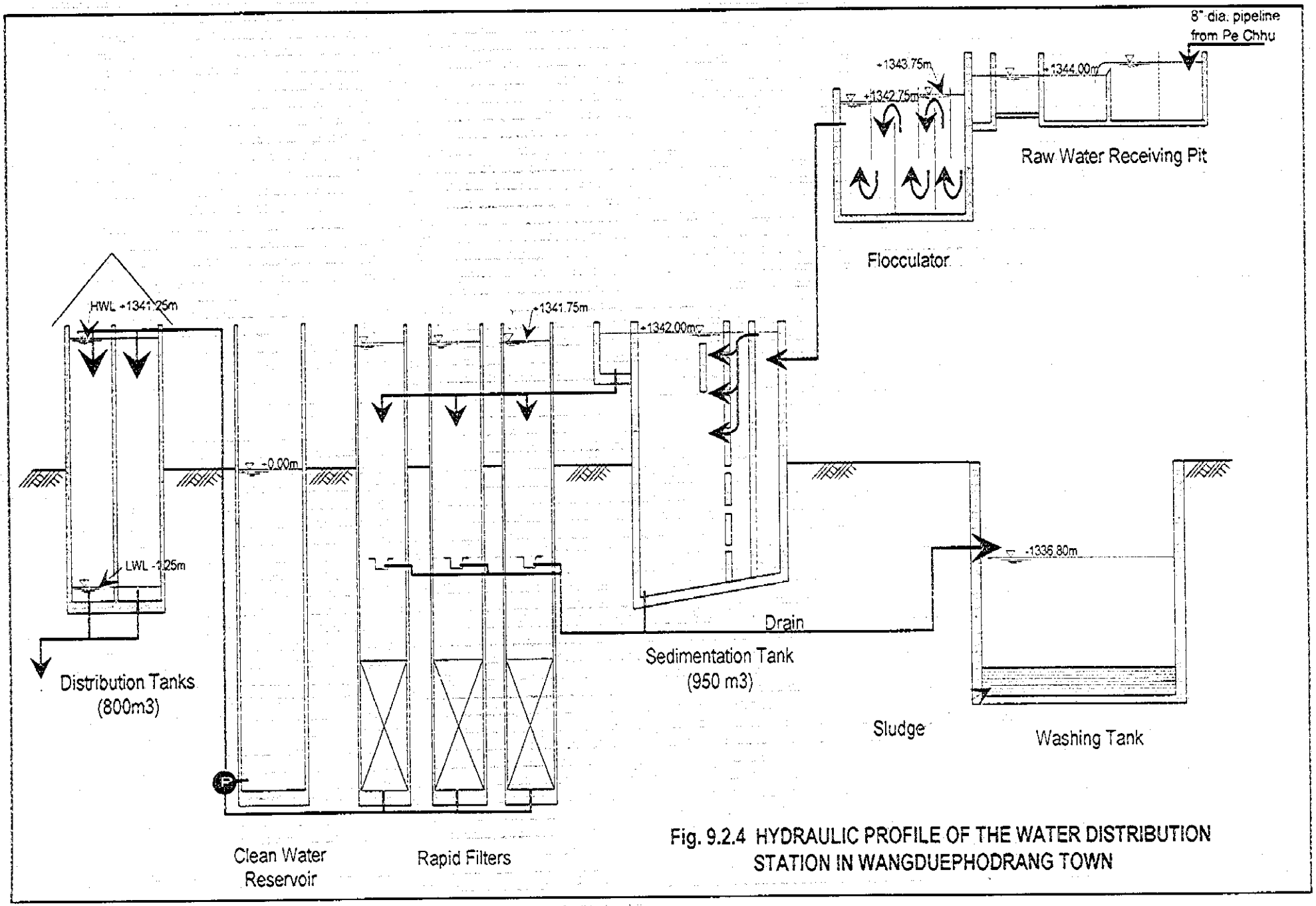


Fig. 9.2.4 HYDRAULIC PROFILE OF THE WATER DISTRIBUTION STATION IN WANGDUEPHODRANG TOWN

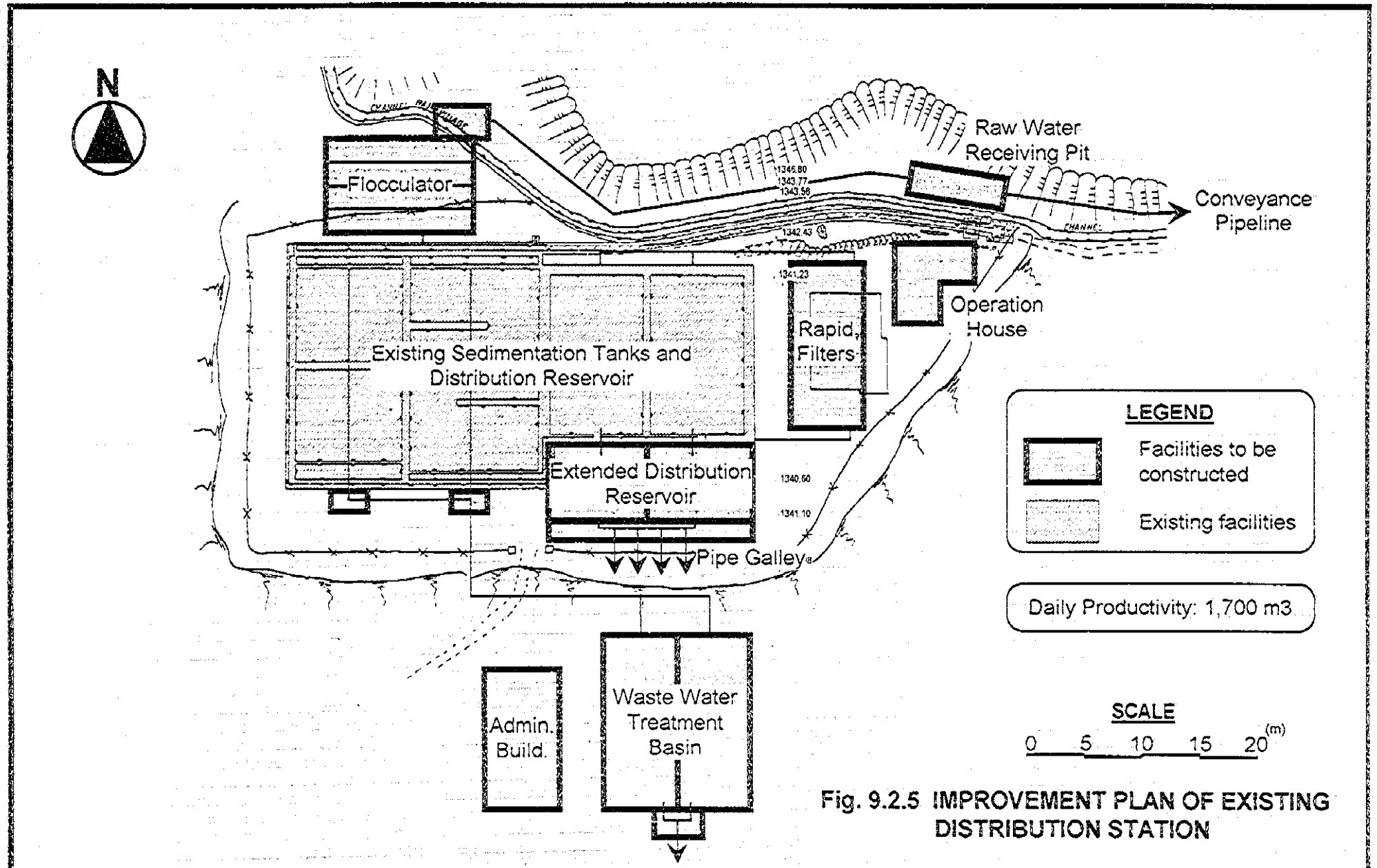


Fig. 9.2.5 IMPROVEMENT PLAN OF EXISTING DISTRIBUTION STATION

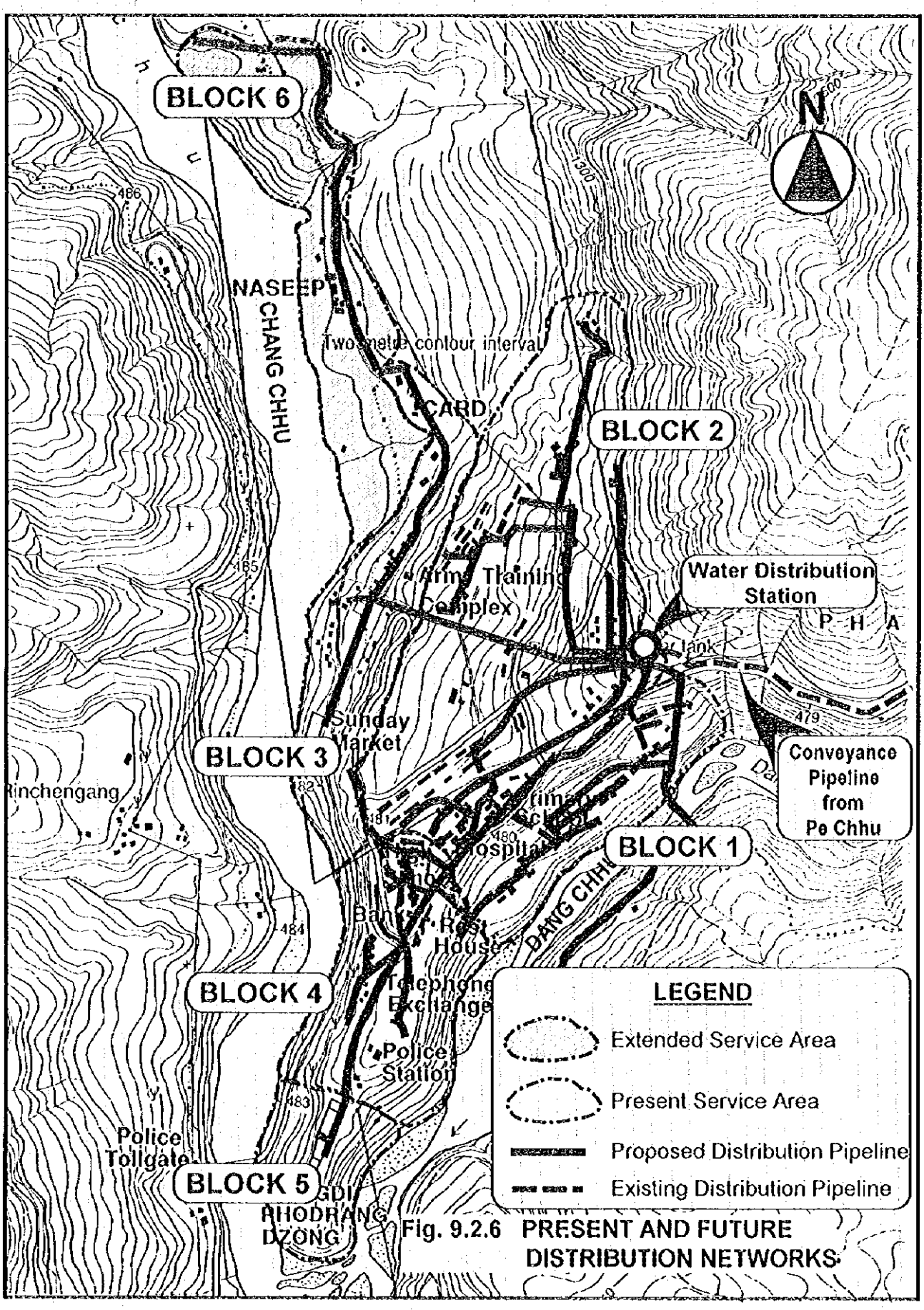


Fig. 9.2.6 PRESENT AND FUTURE DISTRIBUTION NETWORKS

CHAPTER 10
IRRIGATION IMPROVEMENT PLAN

10. IRRIGATION IMPROVEMENT PLAN

10.1 General

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

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

Based on the basic concept and strategies described in Chapter 8, the irrigation improvement projects for these schemes are proposed to include the following countermeasures.

(1) Bajo Canal Project

a) Rehabilitation of present irrigation canals (totally 15 km, 35 unit of offtake structures) with improvement of the protection works in the hazard areas to supply the sufficient irrigation water
b) Establishment of new water management system for effective use of irrigation water
c) Introduction of the double paddy cropping for 40 % of present paddy fields to attain the effective use of agricultural lands

(2) Phangyul Canal Project

a) Establishment of new water management system with providing new offtake facilities to attain effective use of irrigation water
b) Introduction of 10 % of diversification to the present paddy fields to attain the effective land use

10.2 Irrigation Improvement Plan

The proposed irrigation improvement projects are formulated considering the following items.

(1) Design Conditions

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

Proposed Cropping Pattern

(ha)

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

The water requirement for five (5) year return period is calculated as shown in the Data Book V, and the maximum

water requirements are also calculated as shown in the table.

Maximum Water Requirement

(l/sec)

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

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

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

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

Summary of Design Conditions

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

(2) Preliminary Design

The Bajo canal is preliminarily designed for the improvement as shown in Fig. 10.2.1. The structures are designed as shown in the Data Book V, and the construction costs are estimated based on the results of such preliminary design. The results of the cost estimate are summarized below.

Summary of Cost Estimation for Offtake Works of Phangyul Canal

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

Summary of Estimated Costs for Bajo Canal Improvement

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

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

Summary of Estimated Annual O/M Costs

Description	Amount (Nu./year)
Bajo Canal	
Canal O/M Cost	5,016
O/M Cost for Water Management	37,500
Additional O/M Cost for double Cropping	5,468
Total	47,983
Phangyul Canal	
O/M Cost for Water Management	37,416
Additional O/M Cost for Diversification	20,160
Total	57,576

10.3 Implementation Schedule

The implementation schedule of the irrigation improvement plan is proposed as shown below according to the basic irrigation water resources development plan.

Proposed Implementation Schedule

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

Based on the implementation schedule, the annual disbursement schedule of the project and O/M cost are estimated as summarized 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	Bajo	Bajo	C9	2,257	1,756	1,003								
High Hilly Area	Phangyul	Phangyul	C10	257	29									
Annual Total				2,515	1,785	1,003								

Proposed O/M Cost 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	Bajo	Bajo	C9				48	48	48	48	48	48	48	48
High Hilly Area	Phangyul	Phangyul	C10			58	58	58	58	58	58	58	58	58
Annual Total						58	106	106	106	106	106	106	106	106

10.4 Project Evaluation

10.4.1 Economic Evaluation

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

The flow of project cost, operation and maintenance cost and the project benefit of only the irrigation improvement plan of the agricultural development plan are presented in Appendix-K. EIRR of the Plan is 11.2% and at discount rate of 10%, ENPV is Nu. 525 thousand at price for July 1995, and E.B/C is 1.09 at the same discount rate. Project evaluation has proven that EIRR exceeds the opportunity cost of capital 10%, ENPV is positive and E.B/C exceeds 1. It is judged that the implementation of this Plan is economically sound. The EIRR is a little larger than that of the whole agricultural development plan of 10.7%.

(2) Sensitivity Analysis

The result of sensitivity analysis is shown below.

SENSITIVITY ANALYSIS OF IRRIGATION IMPROVEMENT PLAN

Item	EIRR (%)	ENPV (1,000 Nu.)	E.B/C
Base	11.2	525	1.09
Project cost increased by 10%	10.1	28	1.00
Project benefit decreased by 10%	10.2	76	1.01
Construction delayed for 1 year	10.0	-13	1.00

Sensitivity analysis has proven that a change in the construction period has stronger influence on economy of the 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 17.0% and at discount rate of 10%, ENPV is Nu. 2.6 million, and E.B/C is 1.59 at the same discount rate.

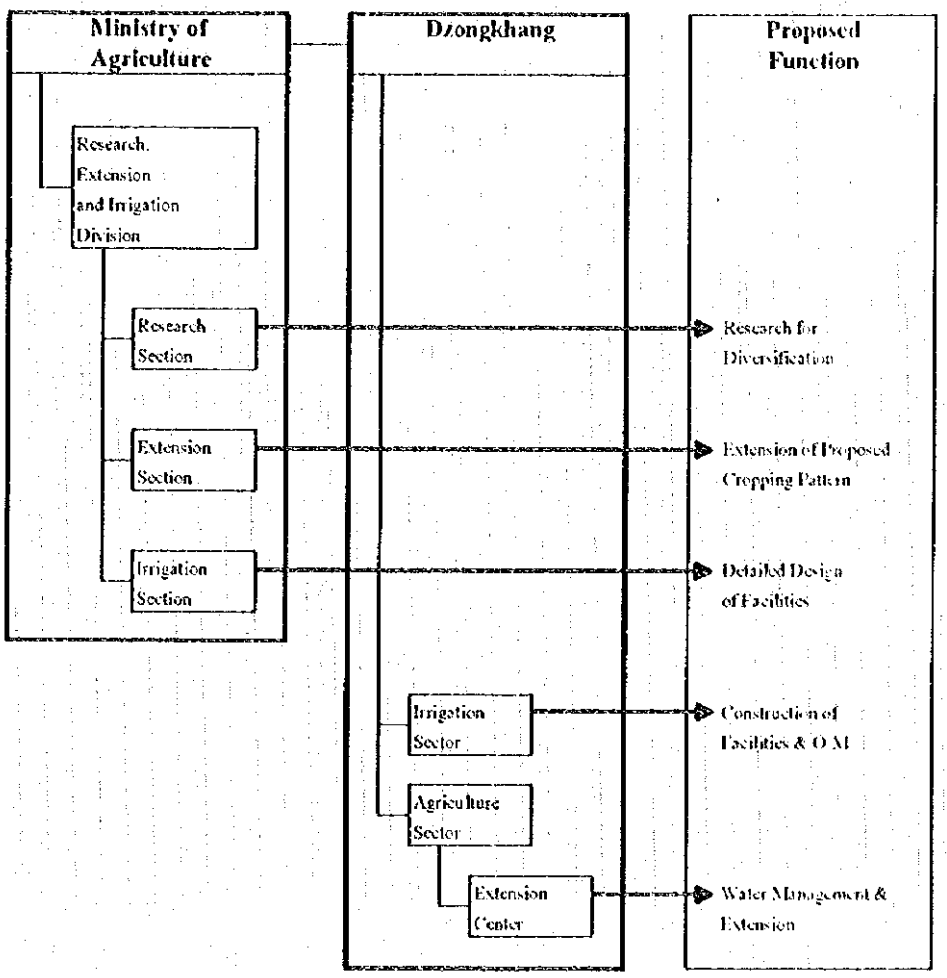
10.4.2 Financial Evaluation - Farm Household's Economic Analysis

After the completion of the Irrigation Improvement Plan which includes the Bajo Canal-9 Improvement Plan and the Phangyul Canal-10 Improvement Plan, the expected annual agricultural net returns are increased by 1.29 and 1.26 times respectively in comparison Without Project. Increased values of agricultural net returns are calculated to be Nu.8,548 and Nu. 2,642, which are equivalent to 6.11 and 1.89 man-month of the minimum wages (Nu. 1,400).

10.5 Organizations for Implementation

Considering the characteristics and the annual cost for the project, it is judged to be possible to implement the project under the present organizations without any establishment of new organizations.

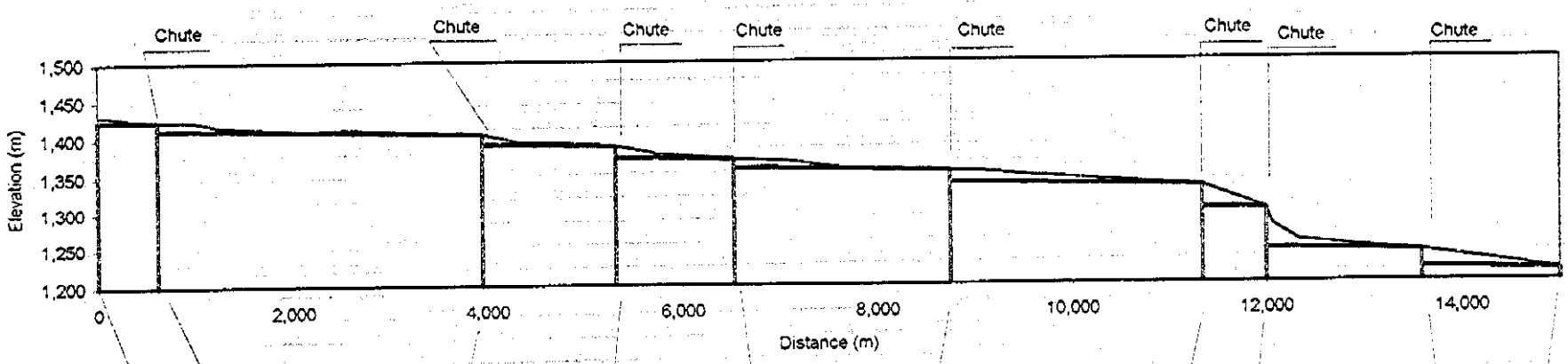
The functions to be assigned for such present organizations are proposed as shown below.



PRESENT ORGANIZATION AND PROPOSED FUNCTIONS FOR THE PROJECT

CHAPTER 10
FIGURES

Canal Code	Name	Command Area (ha)	Canal Length (km)	Design Discharge (l/s)
C9	Bajo Canal	143	15	210



Ground Elevation	1,431.56	1,423.22		1,404.03	1,388.59	1,370.77	1,354.43	1,333.38	1,301.78	1,240.88	1,214.04
A. Distance (m)	614	3,947		5,316	6,531	8,757	11,337	11,997	13,592	15,000	
Distance (m)	614	3,333		1,369	1,215	2,226	2,580	660	1,595	1,408	
D. Elevation (m)	8.34	19.19		15.44	7.761	16	21.05	31.60	60.91	26.83	
Canal Type	M	S		S	S	S	S	S	S	S	
Slope (%)	0.143	0.250		0.250	0.250	0.250	0.250	0.250	0.250	0.250	
Bottom Width	0.800	0.500		0.500	0.500	0.500	0.500	0.500	0.500	0.500	
Side Slope	1 : 0	1 : 1		1 : 1	1 : 1	1 : 1	1 : 1	1 : 1	1 : 1	1 : 1	
Roughness	0.025	0.035		0.035	0.035	0.035	0.035	0.035	0.035	0.035	
Flow Depth (m)	0.566	0.472		0.472	0.472	0.472	0.472	0.472	0.472	0.472	
Velocity (m/s)	0.575	0.567		0.567	0.567	0.567	0.567	0.567	0.567	0.567	
Free Board	0.234	0.228		0.228	0.228	0.228	0.228	0.228	0.228	0.228	
Canal Depth	0.800	0.700		0.700	0.700	0.700	0.700	0.700	0.700	0.700	
Bottom Elevation	1,430.76	1,429.88	1,411.66	1,403.33	1,391.31	1,387.89	1,373.10	1,370.07	1,359.99	1,354.43	1,339.83	1,333.38	1,303.43	1,301.78	1,244.17	1,240.18	1,217.56	1,214.04

Fig. 10.2.1 Proposed Canal Profile of the Bajo Canal

CHAPTER 11
CONCLUSIONS AND RECOMMENDATIONS

11. CONCLUSION AND RECOMMENDATION

11.1 Conclusion

(1) Importance of the Projects

Various constraints were identified in the existing irrigation and domestic water supplies through the surveys, investigations, and analysis as summarized in Chapter 8. These constraints are itemized below.

Identified Constraints in Existing Water Supply

Water Supply	Identified Constraints
❶ **Domestic Water Supply**	**Urban Water Supply System** Shortage of Supply Capacity Inadequate Distribution Capacity Risk to Bacteriological Infection **Rural Water Supply System** Low Service Ratio Risk to Bacteriological Infection
❷ **Irrigation Water Supply**	Insufficient Canal Capacity Impractical Water Management Insufficient Water Resources

In order to realize the ideal social conditions, it is essential to solve and/or mitigate the above constraints as soon as possible. The proposed Basic Water Resources Development Plan is prepared to fulfill this objective focusing on two (2) major components; the domestic water supply consisting of the urban and the rural water supplies, and the irrigation water supply.

The inhabitants in rural areas have to take their water from the nearby rivers, and such use of the surface water may sometimes cause waterborne diseases. In this aspect, RGOB is implementing various schemes to improve rural sanitation and to provide safe water to the inhabitants. In the urban area of the Wangduephodrang town, the shortage of water is considered quite serious. The irrigation water which is normally infected by animal wastes etc. is frequently used for the domestic supply purpose.

The Wangduephodrang district is considered as one of the most potential granaries in the country, and then most of the farmers' lives depend on the agricultural production. In order to increase farmers' income and to rise their living standard, it is indispensable to promote the increase of agricultural productivity. The proposed irrigation improvement plan is prepared to play an important role in increasing the productivity utilizing limited land and water resources.

(2) Water Resources Development Basic Plan

The Basic Plan consists of i) the urban and rural water supply schemes, and ii) the irrigation improvement plans. The irrigation water is planned to be supplied

utilizing mainly surface water resources. The domestic water is planned to be supplied utilizing mainly the groundwater and the sub-surface water resources, except for the urban water supply for Wangduephodrang town areas which utilizes the river water of the Pe Chhu.

The results of project evaluation indicates that the Basic Plan is worth to implement and no negative impact is confirmed in the Study. Therefore, the Basic Plan is considered sustainable and feasible from the technical, economical and social viewpoints.

(3) Priority Projects

The following two (2) projects are given the first priority for further implementation.

1) Urban Water Supply Plan for Wangduephodrang Town Area

The Urban Water Supply Plan for Wangduephodrang Town Area is to improve the existing urban water supply schemes for Wangduephodrang town areas. The daily productivity is increased from the present 780 m^3/day to the future 1,700 m^3/day. The total project costs are estimated in Nu. 231.2 million. Based on the results of project evaluation, it is confirmed that the plan would be economically and technically sound, and will create no adverse effect.

2) Irrigation Improvement Plan for Bajo and Phangyul Canals

The Irrigation Improvement of the Bajo and the Phangyul canals are also selected as the priority projects. The total project costs are estimated as Nu. 5.3 million. According to the results of project evaluation, the proposed project is viable economically and technically, and the implementation does not induce any adverse effects.

11.2 Recommendation

(1) Immediate Implementation

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

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

(2) Method of Implementation

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

(3) Exploitation and Utilization of Water Resources

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

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

(4) Consideration Necessary for Implementation

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

1) Urban Water Supply Plan in Wangduephodrang Town Area

a) Beneficiaries' Well Awareness on Saving Water

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

make them become aware of the value of such supplied water through various opportunities.

b) Introduction of Metered System

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

2) Irrigation Improvement Plan for Bajo and Phangyul Canals

a) Application of Latest Basic Data and Information

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

b) Understanding of Actual Site Condition

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

c) Understanding and Cooperation of Beneficial Farmers

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

d) Improvement of Supporting System

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