The Directorate General of Water Resources Development
The Ministry of Public Works
The Republic of Indonesia

BASIC DESIGN STUDY REPORT

ON

THE PROJECT FOR CONSTRUCTION OF FACILITY FOR IRRIGATION IN EASTERN AREA

IN

THE REPUBLIC OF INDONESIA

OCTOBER 1999

JAPAN INTERNATIONAL COOPERATION AGENCY

TAIYO CONSULTANTS CO., LTD.

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PREFACE

In response to a request from the Government of the Republic of Indonesia, the Government of Japan decided to conduct a basic design study on the Project for Construction of Facility for Irrigation in Eastern Area and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Indonesia a study team from April 10 to May 19, 1999.

The team held discussions with the officials concerned of the Government of Indonesia, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Indonesia in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Indonesia for their close cooperation extended to the teams.

October 1999

Kimio Fujita
President
Japan International Cooperation Agency

October 1999

Letter of Transmittal

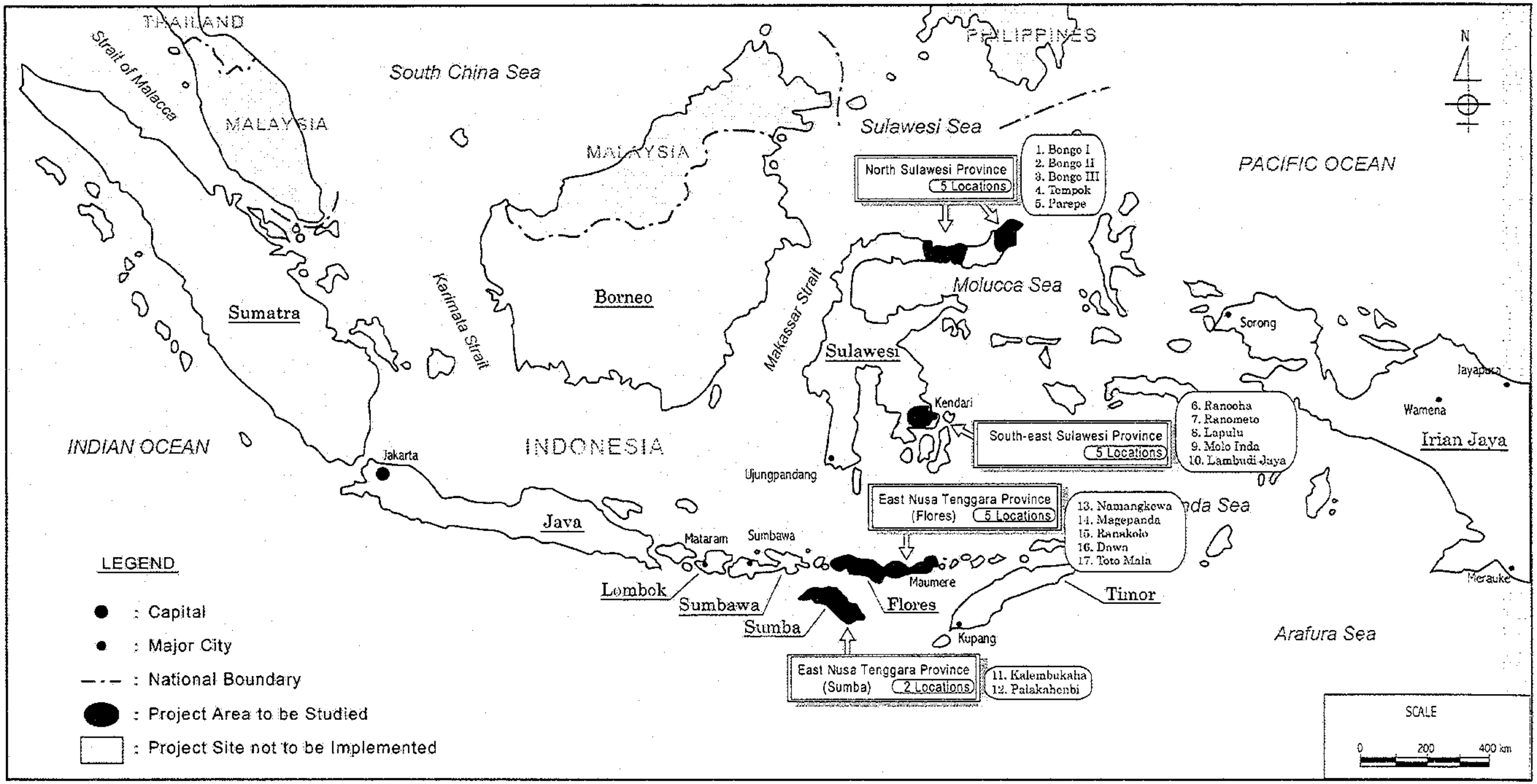
We are pleased to submit to you the basic design study report on the Project for Construction of Facility for Irrigation in Eastern Area in the Republic of Indonesia.

This study was conducted by Taiyo Consultants Co., Ltd., under a contract to JICA, during the period from March 31, 1999 to November 22, 1999. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Indonesia and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

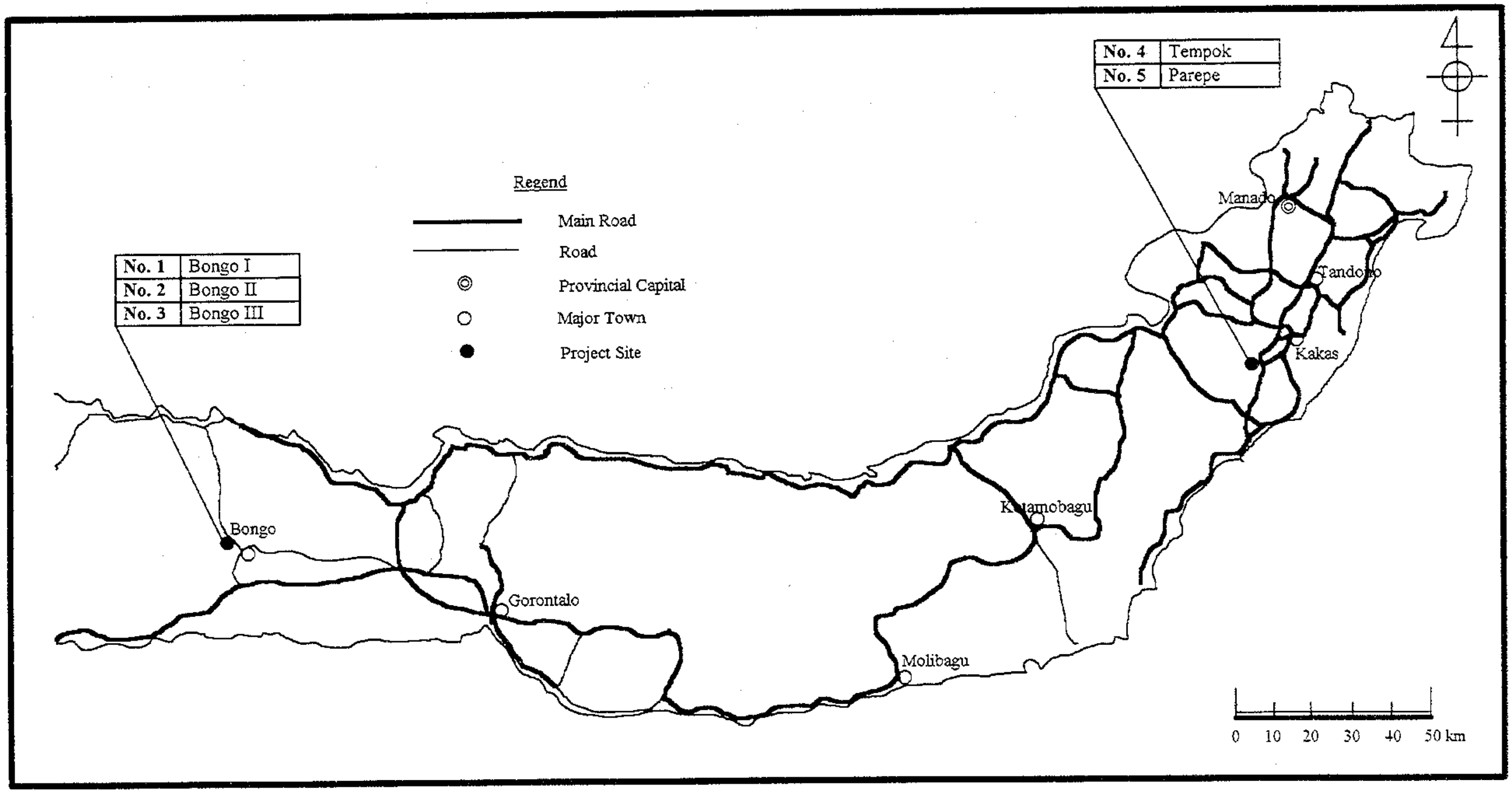
Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours.

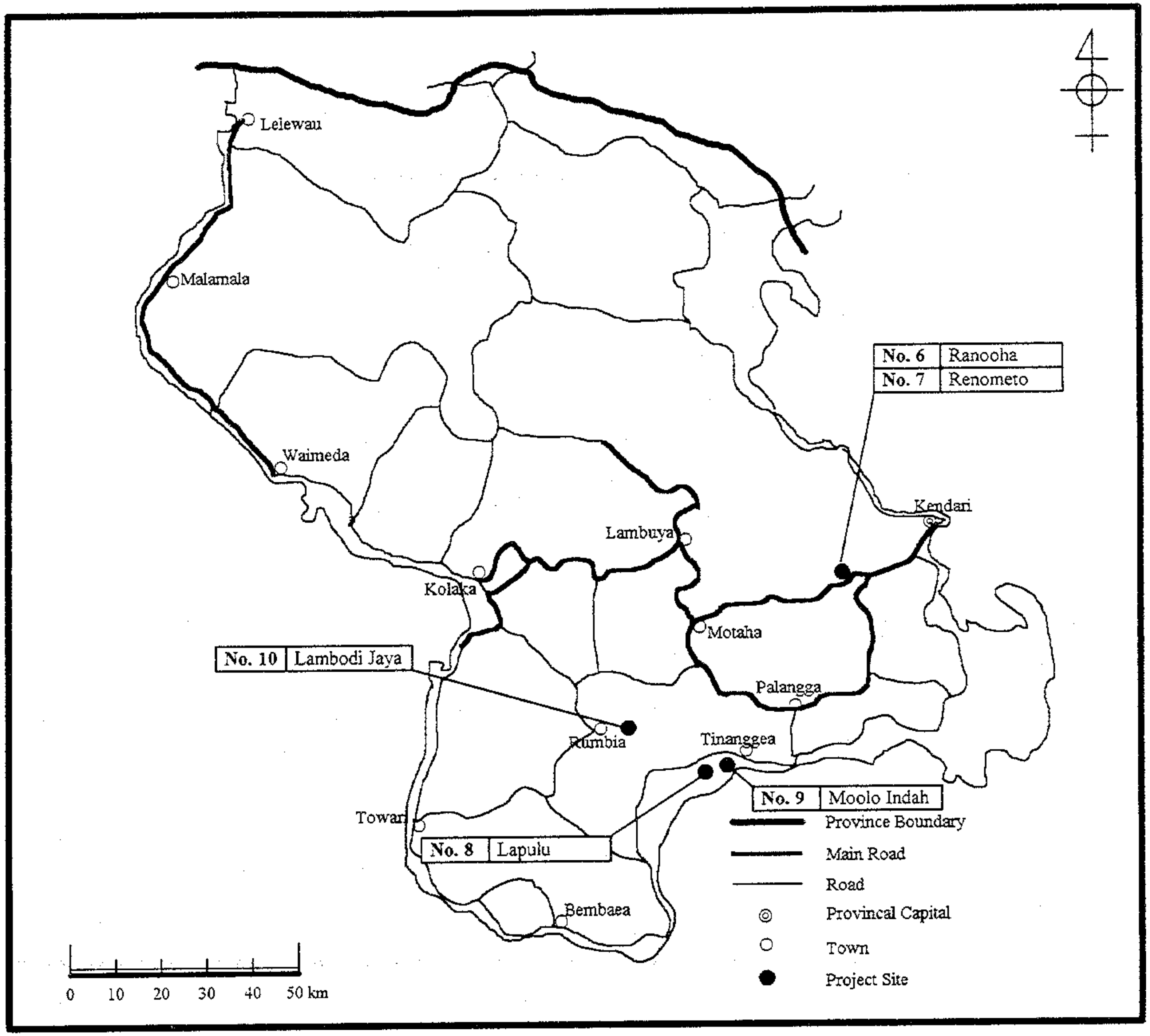
Tsuneo AMANO
Project manager,
Basic design study team on
The Project for Construction of Facility
for Irrigation in Eastern Area
Taiyo Consultants Co., Ltd.



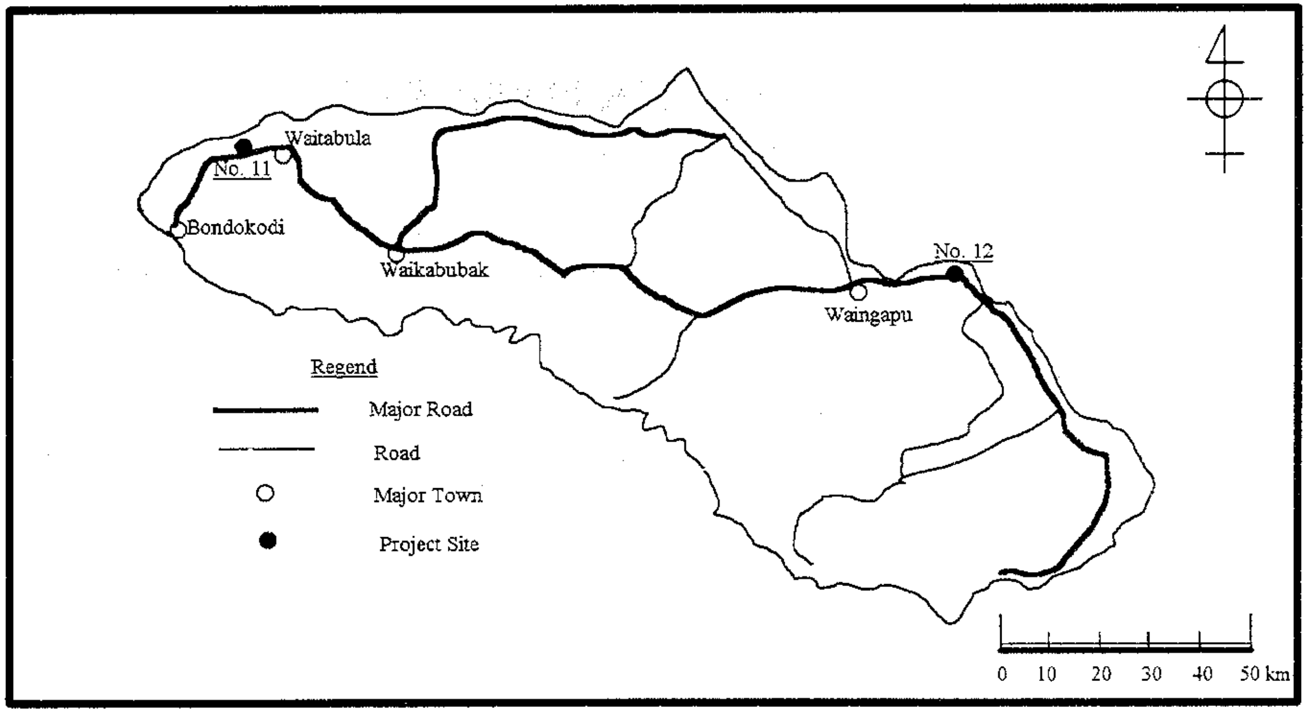
Location Map



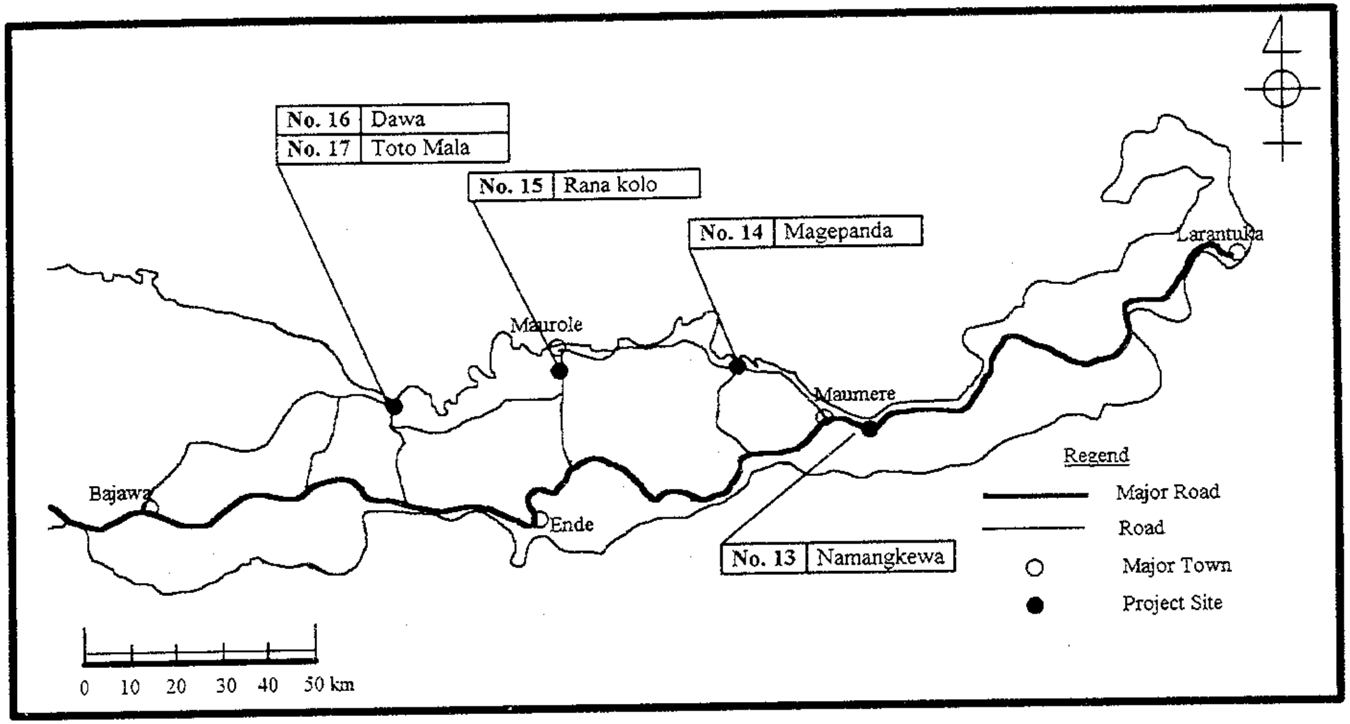
Location Map of North Sulawesi Province



Location Map of Southeast Sulawesi Province



Location Map of NTT Province (Sumba)



Location Map of NTT Province (Flores)

ABBREVIATION

ADB	Asia Development Bank
B/D	Basic Design
BAPPENAS	Badan Perencanaan Pembangunan Nasional -National Development Planning Agency-
BAPPEDA	as above. at the Provicial and Kabupaten levels
BIMAS	Binbingan Massal-Mass Guidance Supervised Credit Program for Food Production
DGWRD	Directorate General of Water Resources Development
EC	Electric Conductivity
EIRR	Economic Internal Rate of Return
E/N	Exchange of Notes
GES	Geo-electric Survey
GDP	Gross Domestic Product
GNP	Gross National Product
GOI	Government of the Republic of Indonesia
GOJ	Government of Japan
IBRD	International Bank for Reconstruction and Development
IMF	International Monetary Fund
JICA	Japan International Cooperation Agency
KUD	Koperasi Unit Desa
MOA	Ministry of Agriculture
MPW	Ministry of Public Works
NTT	Nusa Tenggara Timur
O & M	Operation & Maintenance
P3A/WUA	Water User's Association
PAT	Pengembangan Air Tanah
P 2 AT	Proyek Pengembangan Air Tanah Groundwater Development Project
PJP- II	The 2nd National 25-Year Long Term Development Program
Palawija	Secondary food crops of the primary crop, rice, and consisting mainly of cereals (maize, sorghum), tubers (cassava, sweet poteto) and legumes (soybean, ground nut and mugbean)
PVC	Polyvinyl Chloride
Reperlia-VI	The 6th National 5-Year Development Plan
SSIMP-III	Small Scale Irrigation Management Project- Phase III

MEASURES

mm	millimeter
cm	centimeter
m	meter
km	kilometer
cm^2	square centimeter
m^2	square meter
km^2	square kilometer
ha	hectare
m^3	cubic meter
kg	kilogram
t, ton	metric ton
s, sec	second
min	minute
hr	hour
℃	degree centigrade
%	percentage
kw	kilowatt
mw	megawatt
HP	horse power
PS	0.986HP, 0.7355KW
EL	elevation
MSL	mean sea level
rpm	rotation per minute
bar	1.020 kgf/cm^2, 1.000×10^5Pa
Rp	Rupiah
US$	American dollar
¥	Japanese yen

CONTENTS

CHAPTER 1 BACKGROUND OF THE PROJECT

Chapter 1 Background of the Project

1-1 Background of the Project

In line with the basic policy of the National Development Plan, which set forth food self-sufficiency as main priority, the Republic of Indonesia had actively invested in the agricultural sector, stressing namely the development of irrigation projects. Consequently, self-sufficiency of rice production was achieved for the first time in 1984. However, rice supply at present is unstable due to high population growth and diversion of superior agricultural land to housing and industry.

On the other hand, gaps between the urban and rural areas have been expanding as the result of industrialization. For the above-mentioned reasons, the Government of Indonesia (GOI) has stressed food self-sufficiency, redress of the regional gaps and poverty eradication as prioritized tasks in the 6th National 5-year Development Plan (PELITA VI). Especially to the poorly developed Eastern Area, priority has been given through the promotion of irrigation projects by groundwater development.

The Government of Japan (GOJ) has been assisting GOI's policy which aims at attaining food self-sufficiency through Japan's ODA programs. From 1997 to 1999, GOJ provided GOI with drilling rigs and necessary equipment to develop groundwater irrigation for around 5,200 ha in five provinces of the Eastern Area under the past Japan's Grant Aid Schemes, namely "The Project for Supply of Equipment for Irrigation in Eastern Area (1/2) and (2/2)" and "The Project for Urgent Preventive Irrigation Restoration in the Drought Affected Marginal Areas".

However, the economic crisis that erupted in July 1997 in Southeast Asia affected Indonesian economy as well, inciting GOI to introduce strict monetary policy. As a result, budget allocation to groundwater irrigation projects has become difficult and their smooth progress has been hampered.

To cope with this serious situation, GOI made a request to GOJ for a grant aid for the Project for Construction of Facility for Irrigation in Eastern Area (hereinafter referred to as "the Project"), which consists of the construction of irrigation facilities and wells for 25 sites in four provinces of North Sulawesi, Southeast Sulawesi, Irian Jaya and East Nusa Tenggara located in the Eastern Area.

In response to this request, GOJ conducted a Preparatory Study on the Project in December 1998, which aimed at alleviating the social weak who was the first one affected by the economic crisis and ensuring effective utilization of the drilling rigs and the equipment provided under the said Japan's Grant Aid Schemes. As the result of the study, GOJ decided to conduct a Basic Design Study on 17 sites excluding 8 sites in Irian Jaya and West Timor where public security became unstable.

1-2 Outline of the Request

(1) Objectives of the Project

1) To relieve poor farmers without any irrigation facilities in the Semi-arid Region
2) To provide adequate quantity of irrigation water to the marginal or rain-fed areas where crop intensity and production could be increased
3) To introduce simple irrigation technology to the farmers in the areas that are not served by surface water irrigation system
4) To raise farmers income
5) To support poverty alleviation program
6) To support the Drilling Rig Program procured under Japan's Grant Aide Schemes

(2) Executing Agency

The Directory General of Water Resources Development (DGWRD) in the Ministry of Public Works

(3) Contents of the Request

Items / Site	Site		Well Description				Irrigation Facilities		
	Type	Area (ha)	Discharge (lit./sec)	Well Number	Diameter (inch)	Depth (m)	Pump (set)	Distribution Box	Pipeline (m)
1 North Sulawesi									
1) Bongo I	B	25	30	1	10"-6"	100	1	12	1,500
2) Bongo II	B	25	30	1	10"-6"	100	1	8	1,500
3) Bomgp III	B	25	30	1	10"-6"	100	1	12	1,500
4) Tenpok	B	25	30	1	10"-6"	100	1	12	1,500
5) Parepe	A	25	20	Exist.	10"-6"	100	1	12	1,500
Sub-total		125	140	4		500		56	7,500
2 Southeast Sulawesi									
6) Ranooha	B	20	20	1	12"-8"	110	1	8	1,080
7) Ranometo	B	20	15	1	12"-8"	110	1	8	1,080
8) Lapulu	B	20	20	1	12"-8"	110	1	8	1,080
9) Moolo Inda	B	20	15	1	12"-8"	110	1	8	1,080
10) Lambodi Jaya	B	20	15	1	12"-8"	110	1	8	1,080
Sub-total		100	85	5		550		40	5,400
3 NTT Sunba									
11) Kalembukaha	B	20	15	1	14"-8"	70	1	12	800
12) Palakahembi	B	20	15	1	14"-8"	70	1	12	800
13) Sub-total		40	30	2		140		24	1600
4 NTT Fulores									
13) Nawangkewa	A	10	10	Exist.	12"-8"	75	1	8	800
14) Magepanda	A	12	15	Exist.	12"-8"	75	1	8	800
15) Ranakolo	B	10	10	1	12"-8"	75	1	8	800
16) Dawa	B	10	10	1	12"-8"	75	1	8	800
17) Toto Mala	A	10	10	Exist.	12"-8"	75	1	8	800
Sub-total		52	55	2		375		40	4,000
Total		317	310	13		1,565		160	18,500

Remarks: 1. Type A: D/D is completed with the existing well in the site

2. Type B: no existing well in the site, however availability of ground water is confirmed based on the surrounding existing wells and the existing hydro-geological data

3. Exist: even though an existing well in the site was assumed, new well drilling was judged needed at the beginning of the study

4. Source: the data in the preliminary study report were used

5. Among 25 sites requested, the excluded 8sites are omitted from this table

CHAPTER 2 CONTENTS OF THE PROJECT

Chapter 2 Contents of the Project

2-1 Objectives of the Project

Aiming at improvement of living conditions of farmers, the Government of the Republic of Indonesia (GOI) has been promoting irrigation projects in the Eastern Area by groundwater development in compliance with the 6th National 5-year Development Plan (PELITA VI). Meanwhile, the Government of Japan (GOJ) has extended assistance to these projects since 1980, supporting GOI to procure drilling rigs with appurtenant equipment. However, the economic crisis erupted in July 1997 in Indonesia has affected budget allocation to groundwater irrigation projects hampering their smooth progress. Taking the economic crisis into consideration, this Project has been formulated in order to secure appropriate progress of the groundwater irrigation projects.

The objectives of the Project for Construction of Facility for Irrigation in Eastern Area (the Project) are to construct groundwater irrigation facilities, using effectively the drilling rigs procured under Japan's Grant Aid Scheme, aiming at betterment of weak agricultural structure in the project area, stability of agricultural production and securing and improvement of living standards of the rural weak and poor.

2-2 Basic Concept of the Project

2-2-1 Consideration on the Project Sites

Due to the inconsistency of conditions among the sites scattered in three provinces of the Eastern Area, consideration to judge the appropriateness of the 17 sites for Japan's Grant Aid Scheme was made, based on (1) hydro-geological conditions, (2) access conditions to each site and (3) operation & maintenance of facilities.

(1) Consideration based on Hydro-geological Conditions

Design discharge of each well is calculated on the basis of each requested irrigation area, and possibility of well construction with each calculated discharge is examined. The following flowchart shows the process of the consideration.

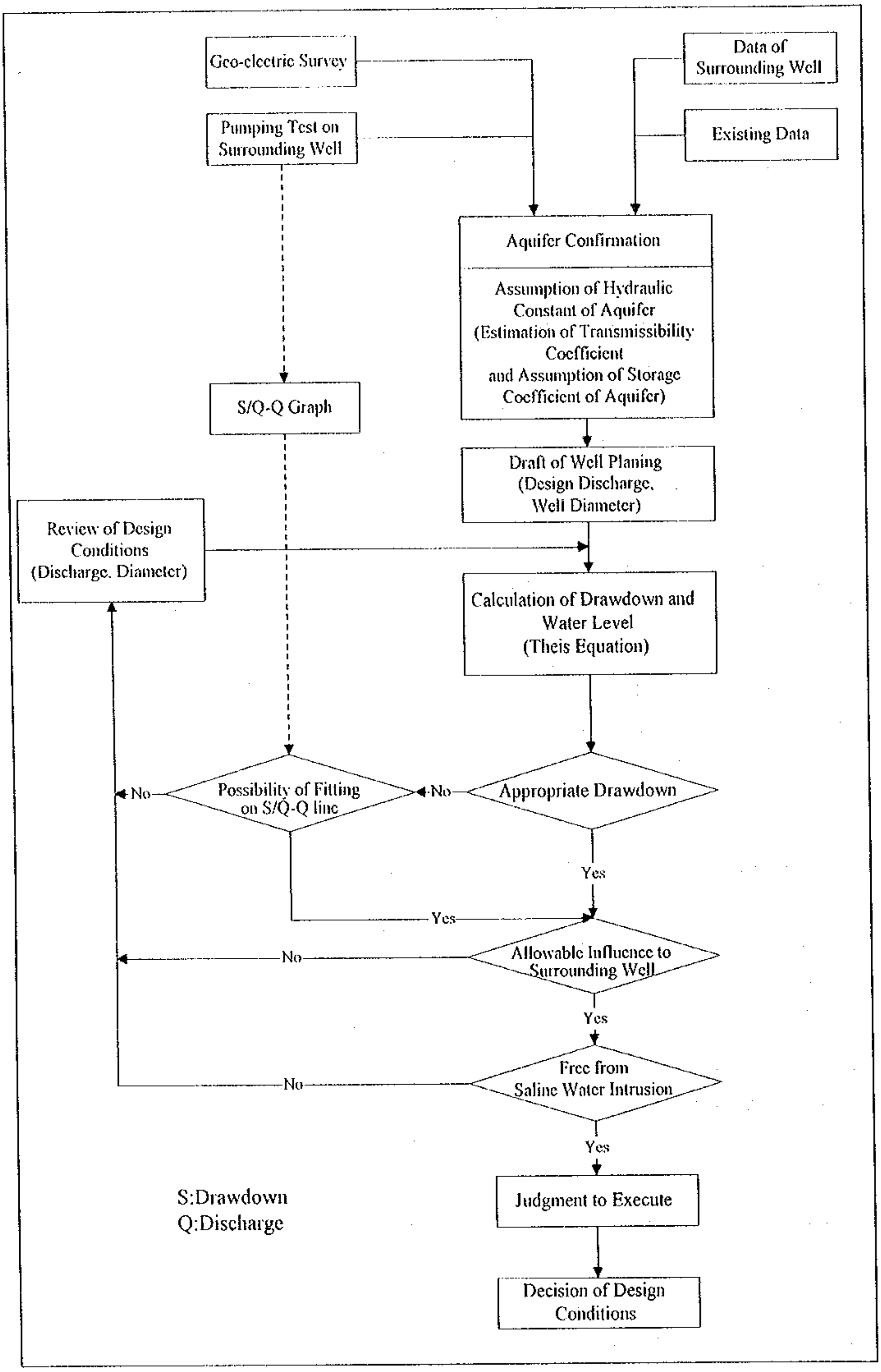


Figure 2-1 Process of Consideration based on Hydro-geological Conditions

Appropriate drawdown shall be judged regarding approximately 20 m as the border.
Allowable influence on surrounding existing wells shall be judged from estimated drawdown at a point of 500m off, since newly constructed wells shall normally be 500 m away from existing wells in Indonesia. Allowance of this estimated drawdown shall be determined less than 2 m, taking into account accuracy rate of hydraulic constant and calculation, that calculated values are generally smaller than those actually measured.
Regarding risk of saline water intrusion, allowable drawdown shall be less than 0.5 m at seashore, taking into account altitude at well points, accuracy of calculation and average pump operating hours. Concerning two sites in Sumba, however, allowable drawdown shall be 0 m at seashore, since Sumba island consists of limestone and the risk of saline water intrusion is judged high.
Risk of land subsidence has been considered calculating rough water balance at 5 sites in North Sulawesi and at Ranooha and Ranometo in Southeast Sulawesi where the groundwater irrigation development is comparatively advanced.

Table 2-1 shows the results derived from the consideration. Brief explanations are made on the sites with some problems as follows.

a. Sites No. 15 Ranakolo and No. 16 Dawa have been judged inappropriate for Japan's Grant Aid Scheme due to lack of data. The judgement was made based on the results of geo-electric survey, which showed estimated potential aquifer too deep and unclear.
b. Site No. 10 Lammbedi Jaya has been judged inappropriate since its drawdown was too big. Even the design discharge was decreased to 10 lit/sec, 40% of the initial design discharge, the drawdown was still 33 m.
c. The design discharge for site No. 8 Lapulu has been decreased from 24 lit/sec, which are needed for the planned irrigation area of 20 ha, to 10 lit/sec so that the drawdown is kept within the border of appropriateness and allowable influence to surrounding wells.
d. The design discharge for sites No. 11 Kalembukaha and No. 12 Palakahembi has been decreased from 24 lit/sec, which are needed for the planned irrigation area of 20 ha, to 12 lit/sec in order to avoid the risk of saline water intrusion. Moreover, a condition that electric conductivity shall be measured at the pumping test and operating time is made.
e. The design discharge for site No. 14 Magepanda has been decreased from 15 lit/sec, which are needed for the planned irrigation area of 12 ha, to 10 lit/sec despite the allowable drawdown of 14 m at the initial discharge, since the nearest existing well was located only 300m away from the site. The change of discharge made the drawdown at the existing well allowable.

Table 2-1 Consideration from Perspective of Hydro-geological Conditions

Region	No.	Site	Proposed Discharge Q (lit/sec)	Static Water SWL(m)	Drawdown s (m)	Dynamic Water Level DWL (m)	Pump Housing d (m)	Well Depth D (m)	Total Screen l (m)	Hydro-geological Evaluation	Remarks
North Surawesi	1	Bongo I	30	8	10	18	27.5	120	66.0	Good aquifers are estimated to be distributed in each site in accordance with the study on the existing data, the geo-electrical sounding and the pumping test results. The proposed discharge can be expected. However, careful selection of the proposed well site will be necessary, because several existing wells give a little yield.	A
	2	Bongo II	30	7	10	17	27.5	135	44.0		
	3	Bongo III	30	11	10	21	33.0	120	44.0		
	4	Tempok	30	4	5	9	22.0	120	44.0		
	5	Parepe	30	2	9	11	22.0	105	38.5		
Southeast Surawesi	6	Ranooha	24	1	23	24	33.0	125	49.5	The pumping test result at the vicinal existing well does not show so good value of the hydro-geological parameter. The hydro-geological conditions of the proposed well site and the ones of the pumping test well site are estimated to be the same in accordance with the geo-electrical sounding results. If the drawdown of 23 m is accepted, the proposed discharge can be expected. Attention to interference in the vicinal existing wells is necessary.	B
	7	Ranometo	24	1	14	15	27.5	120	66.0	The proposed discharge can be expected from the comparative study of the survey results in this project with the existing data.	B
	8	Lapulu	(24)→10	1	(51)→21	22	33.0	85	22.0	The pumping test result at the vicinal existing well does not show so good value in spite of artesian area. The hydro-geological conditions of the proposed well site and the ones of the pumping test well site are estimated to be the same from the geo-electrical sounding results. As the original proposed discharge leads to large drawdown, the reduced discharge of 10 l/s is proposed. The drawdown by the reduced discharge is 21 m. Attention to interference in the vicinal existing well and saline water intrusion is necessary.	C→B
	9	Moolo Indaha	24	1	20	21	33.0	120	55.0	The pumping test result at the vicinal existing well does not show so good value in spite of artesian area. The hydro-geological conditions of the proposed well site and the ones of the pumping test well site are estimated to be the same from the geo-electrical sounding results. If the drawdown of 20 m is accepted, the proposed discharge can be expected. Attention to interference in the vicinal existing well and saline water intrusion is necessary.	B
	10	Lambodi Jaya	(24)→10	3	(78)→33	(81)→36	-	-	-	The pumping test result at the vicinal existing well (test well) shows small value of hydro-geological parameter of the aquifer. The target aquifer of the proposed well and the ones of the pumping test well are estimated to be the same from the geo-electrical sounding. As even the discharge of 10 l/s, 40% of the original one, leads to the drawdown of 33 m, construction of the well is difficult.	D—D
NTT (Sumba)	11	Kalembukaha	(24)→12	52	(6)→3	55	66.0	85	11.0	The pumping test result at the vicinal existing well shows good value. The hydro-geological conditions of the proposed well site are estimated to be the same from the geo-electrical soundings. The proposed discharge leads to little drawdown of 5 m, the DWL reaches to 55 m due to the deep SWL. Although the original proposed discharge can be expected, the reduced one proposed considering the risk of the seawater intrusion. Because the proposed well site is located on the permeable coral limestone near the coast and the SWL is almost the same to the sea level. Moreover, attention to saline water intrusion is necessary.	C—B
	12	Palakahembi	(24)→12	16	(16)→8	24	33.0	50	11.0	Although the distance between the proposed well and the nearest existing well is about 8 km, the target aquifer of the both wells are estimated to be the same, coral limestone. As the pumping test result at the nearest well shows good value, the proposed discharge can be expected. However, the reduced discharge is proposed owing to the same reasons to the "11.Kalembukaha" as described above. Moreover, attention to saline water intrusion is necessary.	C→B
NTT (Flores)	13	Nawangkewa	11	9	2	11	22.0	65	22.0	The proposed discharge can be expected in accordance with the comparative study of the survey results in this project with the existing data. Moreover, attention to saline water intrusion is necessary.	A
	14	Magepanda	(15)→10	1	(14)→9	(15)→10	22.0	120	33.0	The original proposed discharge leads to the large interference to the nearest (300m) well. The reduced discharge of 10 l/s is proposed through the comparison study of survey results of this project and existing data. Moreover, attention to saline water intrusion is necessary.	C—B
	15	Ranakolo	10	-	-	-	-	-	-	Vicinal existing well data are not available. The aquifer which is estimated from the geo-electrical soundings of this project is deep (70-180 m) and the screen position cannot be defined clearly. Therefore, at present, the judgment whether the proposed discharge can be expected or not is very difficult.	D
	16	Dawa	10	-	-	-	-	-	-		
	17	Toto Mala	10	20	2	22	33.0	85	22.0	The proposed discharge can be expected from the comparative study of the survey results in this project with the existing data. Moreover, attention to saline water intrusion is necessary.	A

Note 1.The depth of pump housing, depth of well and total screen length will be changed finally in relation to their fixed length.
2. DWL are rounded off to decimal places.
3. The original proposed discharge are shown in parenthesis
4. A: without any problems, B: small problems, C: problems/counter measure or design alteration is needed, C: inappropriate/impossible to judge

The planned irrigation area will vary following the change of design discharge.

(2) Consideration based on Water Quality Conditions

Concerning water quality, Hydrogen Ion Concentration and Electric Conductivity were measured along with the preliminary pumping test. Table 2-2 shows the summary of the measurement result and collected data.

Allowance of irrigation water quality varies from crop to crop, and the results show that the water quality is appropriate for irrigation use at all sites since they satisfy the Indonesian standard for irrigation (pH: 6.0 - 8.0, EC: less than 2,000 μ S/cm). However, electric conductivity shall be necessarily measured at pumping test and operating time in the sites No. 8, 9, 13, 14 and 17 from the sites No. 11 and 12 on down which are near to the coast. Moreover, the pH values measured satisfy WHO standard as well.

Table 2-2 Summary of Water Quality

No.	Site	Well No.	pH	EC (μ S/cm)	No.	Site	Well No.	pH	EC (μ S/cm)
1	Bongo I	**TWG 14**	7.30	541	10	Lammbodi Jaya	P32KDI	-	(900)
2	Bongo II	**TWG 30**	7.30	567			**P33kDI**	7.90	400/(800)
3	Bongo III	**TWG 31**	7.40	540	11	Kalembukaha	EPI-16	(7.00)	-
4	Tempok	**TWM 03**	7.40	150			EPI-15	7.20	392
5	Parepe	**TWM 12**	7.60	223	12	Palakahembi	WKKI-29	(7.41)	(829)
6	Ranooha	**P28KDI**	7.90	320			**WKKI-30**	7.00/(7.31)	412/(749)
7	Ranometo	P37KDI	(7.10)	(900)			WKKI-31	(7.39)	(895)
		P38KDI	(7.25)	(500)	13	Nawangkewa	**KKI-11**	7.00	420
		P39KDI	7.40/(7.15)	510/(650)	14	Magepanda	KMI-27	(7.05)	(751)
		P42KDI	(7.20)	(900)			KMI-19	(7.05)	(469)
8	Lapulu	**P48KDI**	7.20/(7.50)	600/(391)			**KMI-59**	7.50	915
9	Moolo Indah	**P60KDI**	7.80/(7.00)	410/(325)	15	Ranakolo	-	-	
		P61KDI	(7.40)	(320)	16	Dawa	-	-	
		P62KDI	(7.40)	(328)	17	Toto Mala	**NMI-06**	7.00	315

Note: Bold letters describe the wells on which pumping test was carried out in the Study
pH: Hydrogen Ion Concentration
Letters with ( ) describe values from collected data

(3) Consideration basede on Access Conditions

Sites No. 10 Lammbedi Jaya, No. 16 Dawa and No. 17 Toto Mala have some restrictions caused by access conditions.

Site No. 10 Lammbedi Jaya is located at 128 km south-west of Kendari, the capital city of Southeast Sulawesi Province. In the last 9 km to the site branching off from the trunk road, there are 13 bridges. One of them is a Bailey bridge with 5 ton allowance, and the others are wooden bridges with 3.5 ton allowance. Moreover, some of the wooden bridges are seriously damaged, and one of them is completely washed away and a poor temporary bridge is installed instead. In order to make the drilling rigs pass such damaged bridges, certain reinforcing and temporary works are needed. Therefore, it is difficult to select this site with the present access conditions.

Access to the sites No. 16 Dawa and No. 17 Toto Mala in Flores was damaged by flood this year, so that the Study Team had to choose a detour to reach the sites for the site survey. However, the DGWRD has informed after the study that the access to these sites was already repaired. Therefore, it is judged that there is no restrictions on access conditions for these sites.

(4) Consideration based on Operation & Maintenance Conditions

Operation & maintenance costs of the facilities are subsidized by GOI for the first 2 years of operation. Subsequently, their operation & maintenance is transferred to a water users' association, which has to carry out autonomously its management collecting irrigation service fees from farmers as operation and maintenance costs, and the farmers should be able to shoulder these fees otherwise the project cannot be sustainable. Therefore, operation and maintenance conditions are key items to be considered.

Ratios of operation and maintenance costs to farmer's net incomes are considered, instead of considering simply the amount of operation and maintenance costs. Since the costs and incomes vary from site to site, five typical sites (Bong I and III in North Sulawesi, Ranometo in Southeast Swulawesi, Nawangkewa in NTT Flores and Kalembukaha in NTT Sumba) are selected for consideration. The ratios in the third year, where the perfectly autonomous management starts, are also examined.

As a result, the small irrigation area makes replacement cost relatively high in some sites and the ratio of operation and maintenance costs to the net income becomes big there. However, the farmers in those sites are still judged able to shoulder their operation and maintenance costs. (concerning the incomes and operation and maintenance costs, refer to 2-3-2 (2) and 3-2-2 respectively)

(5) Overall Evaluation as Japan's Grant Aid Scheme

Table 2-3 shows a summary of the consideration for the aforementioned 17 sites.

Table 2-3 Summary of Consideration on 17 Sites

No.	Site	Hydro-geological Conditions	Access Conditions	Operation & Maintenance Conditions	Overall Evaluation	Remarks
1	Bongo I	A	A	A	A	
2	Bongo II	A	A	A	A	
3	Bongo III	A	A	A	A	
4	Tempok	A	A	A	A	
5	Parepe	A	A	A	A	
6	Ranooha	B	A	A	A	
7	Ranometo	B	A	A	A	
8	Lapulu	C/B	A	B	B	decrease of area
9	Molo Inda	B	A	A	A	
10	Lambodi Jaya	D	C	A	D	inappropriate
11	Kalenbukaha	C/B	A	B	B	decrease of area
12	Palakahembi	C/B	A	B	B	decrease of area
13	Nawangkewa	A	A	B	B	
14	Magepanda	C/B	A	B	B	decrease of area
15	Ranakolo	D	A	B	D	inappropriate
16	Dawa	D	B	B	D	inappropriate
17	Toto Mala	A	B	B	B	

* A: Appropriate
B: Small problems
C: Some problems/counter measure or design modification
D: Serious problems/impossible to judge

The followings are the conclusions of the consideration.

a. Sites No. 10 Lammbedi Jaya, No. 15 Ranakolo and No. 16 Dawa have been judged inappropriate for Japan's Grant Aid Scheme and excluded from the Project.

b. Design areas of Sites No. 8 Lapulu and No. 14 Magepanda shall be decreased and design discharges shall be kept less than 10 lit/sec.

c. Design areas of Sites No. 11 Kalembukaha and No. 12 Palakahembi shall be decreased and design discharges shall be kept less than 12 lit/sec.

d. Even all the farmers should understand and deal with the operation and maintenance costs to be shouldered by the farmers, especially the farmers in the sites No. 8, 11, 12, 13, 14 and 17 where such costs are relatively expensive should realize them.

2-2-2 Basic Concept

Among 17 sites, 14 sites exempting Lammbedi Jaya in Southeast Sulawesi and Ranakolo and Dawa in Flores are selected and the groundwater irrigation development project are planned for these sites. Design areas are unchanged from requested area except 4 sites namely Lapulu, Kalembukaha, Palakahembi and Magepanda.

Each project consists of construction of well using the drilling rig procured under Japan's Grant Aid Scheme, procurement of pump equipment and its installation and construction of pump house and irrigation facilities with pipeline. The Project will be implemented in single Japanese fiscal year.

2-3 Basic Design

2-3-1 Design Concept

(1) Irrigation Plan

1) Basic Concept

By means of supplementary irrigation to be realized by the construction of small-scale groundwater irrigation facilities, the weak agricultural structure shall be improved and the stable agricultural production is secured in the Project area where rain-fed agriculture has been carried out.

In paddy cultivating areas, a triple cropping with a stable double cropping paddy and dry season upland crops (cropping intensity: 50%) with proper supplementary irrigation shall be substituted for the existing single cropping with rainy season paddy or double cropping with rainy season paddy and semi-rainy season gambling paddy or upland crops, and annual cropping intensity will be altered to 250%.

In upland crops cultivating areas, a triple cropping with a stable rainy season cropping and additional double cropping in dry season (each cropping intensity: 50%) with proper supplementary irrigation shall be substituted for the existing single cropping only in rainy season, and annual cropping intensity will be altered to 200%.

2) Design Irrigation Area

In principle, the irrigation areas of each site requested by the Indonesian side shall be adopted as design irrigation areas. However, in the case that the yields of well are insufficient for water requirements for the irrigation areas, such areas will be decreased in accordance with their optimum yields.

Table 2-4 shows the requested irrigation areas of each site and each design irrigation area decided from the hydro-geological study.

Table 2-4 Design Irrigation Area

No.	Province	Prefecture	District	Village	Design Irrigation Area Requested (ha)	Design Irrigation Area (ha)
1	North Sulawesi	Gorontalo	Paguyaman	Bongo I	25	25
2				Bongo II	25	25
3				Bongo III	25	25
4		Minahasa	Tompaso	Tempok	25	25
5			Remboken	Parepe	25	25
6	Southeast Sulawesi	Kendari	Ranometo	Ranooha	20	20
7				Ranometo	20	20
8			Tinanggea	Lapulu	20	8
9				Moolo Indah	20	20
10				Lannbedijaya	20	—
11	NTT (Sumba)	West Sumba	Kodi	Kalembukaha	20	10
12		East Sumba	Pandawai	Palakahembi	20	10
13	NTT (Flores)	Sikka	Kewapante	Nawangkewa	10	10
14			Nita	Magepanda	12	8
15		Ende	Mautenda	Ranakolo	10	—
16		Ngada	Assesa	Dawa	10	—
17				Toto Mala	10	10

[shaded box] : alteration was made on the area requested

3) Water Requirements

Water requirements are calculated based on "Irrigation Design Standards: DGWRD, PWD" and "SSIMP: OECF". Upon calculating, the meteorological data of each district are taken into account since the sites are scattered in broad area and each site has different natural conditions.

Maximum daily pump operating hours, which are necessary to calculate design capacity, are determined taking the living practice of each site into account.

4) Irrigation System

The irrigation system is planned based on the method currently adopted in Indonesia. The closed pipeline system directly connecting a pump with distribution boxes at each outlet to which an alfalfa valve is annexed, that realizes effective use of water resources and streamlined water management, is adopted.

Rotational irrigation is adopted for water distribution, and each site is divided into 5 rotation blocks as the aforementioned "Irrigation Design Standards: DGWRD, PWD" defines that the maximum number of rotation block shall be 5. Therefore, the irrigation interval is 5 days and each rotation block is supplied with 5-day irrigation water a day. Each rotation block consists of several small irrigation blocks extended around each distribution box.

(2) Facility Design Concept

1) Well Facilities

a. Drilling diameter and depth

Drilling diameters are determined taking into account the capacity and bit type of the drilling rigs procured under Japan's Grant Aid Scheme, the casing diameter and distribution conditions of aquifer.

Depth is determined based on the result of the geo-electric survey and the existing hydro-geological material. Meanwhile, in the case that there are some existing wells around, the depth is determined so as to include all the target aquifer of the existing wells.

b. Casing and screen diameter, and screen length

Generally, casing and screen diameters are determined based on hydro-geological conditions, which is adopted for this Project. Casing diameters for the existing wells are taken into account for the determination, as well. The types of pump to be used are taken into account to decide pump housing casing diameter,

Screen length is determined based on the result of the geo-electric survey and the screen length for the surrounding existing wells.

c. Type of casing and screen

Types of casing are determined taking into account strength, corrosion-resistance, easy handling and price.

Types of screen are determined taking opening ratio into account, as well.

2) Pump Facilities (Pump/Motor)

Pump facilities are selected taking into account the design discharge, total head, economical aspect and users' ability in operation & maintenance.

In Indonesia, centrifugal pumps are adopted for wells with suction head of less than 7 m

and vertical turbine pumps are generally adopted for the others. The selection is carried out taking adoption of submersible pumps into account.
Diesel engines are normally used in Indonesia, however, the selection is carried out taking the adoption of electric motors into account.

3) Pump House

Pump houses are designed based on "Irrigation Design Standards: DGWRD, PWD", and proper structure and scale are taken into account in order to keep the facilities properly and carry safe and easy operation.

4) Irrigation Facilities

First of all, the system shall allow the irrigation water to reach the very end of the farm land efficiently.
Based on the result of the PCM Workshop which proved that there was difficulty of proper irrigation in the surrounding existing projects as the distribution boxes were far from the very end of the farm land, proper number and location of distribution boxes shall be designed taking topographic conditions into account.
In order for the farmers to make sustainable operation & maintenance, simple and durable facilities shall be designed.
Irrigation facilities are designed based on "Irrigation Design Standards: DGWRD, PWD", and easy construction and future operation & maintenance, corresponding to the local construction technology and materials are taken into account.

a. Pipeline
   Alignments of pipeline are designed along roads or ridges as much as possible, and the soil covering depth is at least 1 m in order to avoid damage by farming.
   Types of pipe are determined taking strength, easy handling and price into account.
b. Distribution box
   One distribution box par one hectare shall be constructed in principle to make irrigation efficient. Each small irrigation block shall be adjusted to the property borders as much as topographic and other conditions allow, otherwise, the block shall be drawn up in accordance with such conditions. Each distribution box shall be located at the highest point of each small irrigation block.
   Simple suppressed rectangular weirs are designed to annex to distribution boxes as water measures in order to realize fair water distribution.

Small on-farm reservoirs shall be designed in order to realize flexible and useful water use corresponding to variation of water demand for horticulture. The reservoir shall be annexed to the distribution box, and shall have function of water supply for miscellaneous use on farm as well. Drain taps are attached in order to prevent the breeding of mosquitoes that transmit malaria.

5) Village Water Supply

Small-scale water tanks are designed besides each pump house for village water supply. Their capacity is determined supposing one day stock of 30 liter/day/person in principle, however, in the case that a village is far from the pump house, small capacity tanks are designed.
The water is not deemed as potable water in principle, however, a water quality survey shall be carried out at the time of pumping test considering that beneficiaries may use it as potable water. As a result, if the water has some problems in quality, instructions shall be made to warn the beneficiaries not to take it as potable water.

2-3-2 Basic Design

(1) General Plan

Based on the results of the consideration on the 17 sites, the groundwater irrigation projects are planned for five sites in North Sulawesi, four sites in Southeast Sulawesi, two sites in NTT Sumba and three sites in NTT Flores.
Each project consists of construction of deep tube well using the drilling rigs procured under Japan's Grant Aid Scheme, procurement of pump equipment and its installation, a pump house and irrigation facilities with pipeline. The Project will be implemented in single Japanese fiscal year.

Table 2-5 shows the outline of each project.

Table 2-5 Outline of the Project

Proposed Items / Site Name		Benefited		Well				Irrigation Facilities		
		Area	Farm Family	Discharge	Number	Diameter	Depth	Pomp House	Distribution Box	Pipeline
		(ha)	(family)	(lit./sec)	(no.)	(inch)	(m)	(unit)	(no.)	(m)
1)	Bongo I	25	31	30	1	12"-8"	120	1	28	1,834
2)	Bongo II	25	32	30	1	12"-8"	135	1	31	2,246
3)	Bongo III	25	25	30	1	12"-8"	120	1	25	2,224
4)	Tempok	25	70	30	1	12"-8"	120	1	25	2,107
5)	Parepe	25	86	20	1	12"-8"	105	1	23	2,385
6)	Ranooha	20	18	20	1	12"-8"	125	1	20	1,870
7)	Ranometo	20	23	15	1	12"-8"	120	1	21	2,234
8)	Lapulu	8	6	20	1	12"-8"	85	1	8	732
9)	Moolo Indah	20	27	15	1	12"-8"	120	1	21	2,531
11)	Kalembukaha	10	11	15	1	12"-8"	85	1	11	929
12)	Palakahembi	10	10	15	1	12"-8"	50	1	10	727
13)	Nawangkewa	10	9	10	1	12"-8"	65	1	12	720
14)	Magepanda	8	14	15	1	12"-8"	120	1	9	765
17)	Toto Mala	10	23	10	1	12"-8"	85	1	11	872
Total		241	385	275	14		1,455	14	255	22,176

Remarks: 1. Each pump house includes one set of pump with diesel engine and a small scale water tank for village water supply.
2. Diameter 12"-8" means diameter of upper housing pipe is 12" and that of lower conduit casing pipe and screen is 8".
Drilling diameter is 17"1/2.

(2) Agricultural Plan

1) Cropping Pattern

Cropping patterns of each site are drawn up based on the result of site survey, taking into account practical and sustainable farming with groundwater irrigation system by the farmers and conditions of the project site. The cropping patterns shall comply with the conditions of each site. Figure 2-2 shows the cropping patterns.

Figure 2-2 Cropping Pattern (1/2)

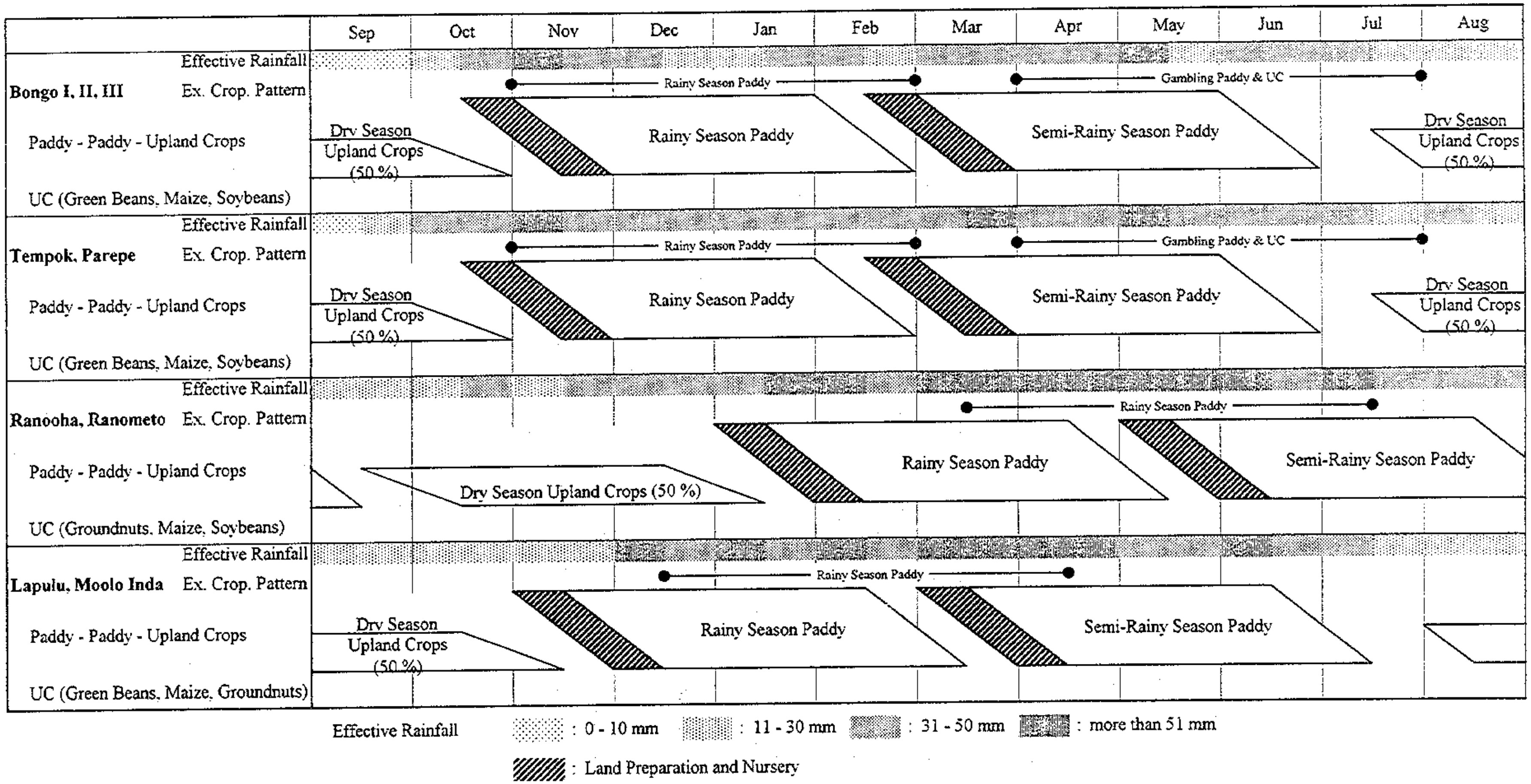
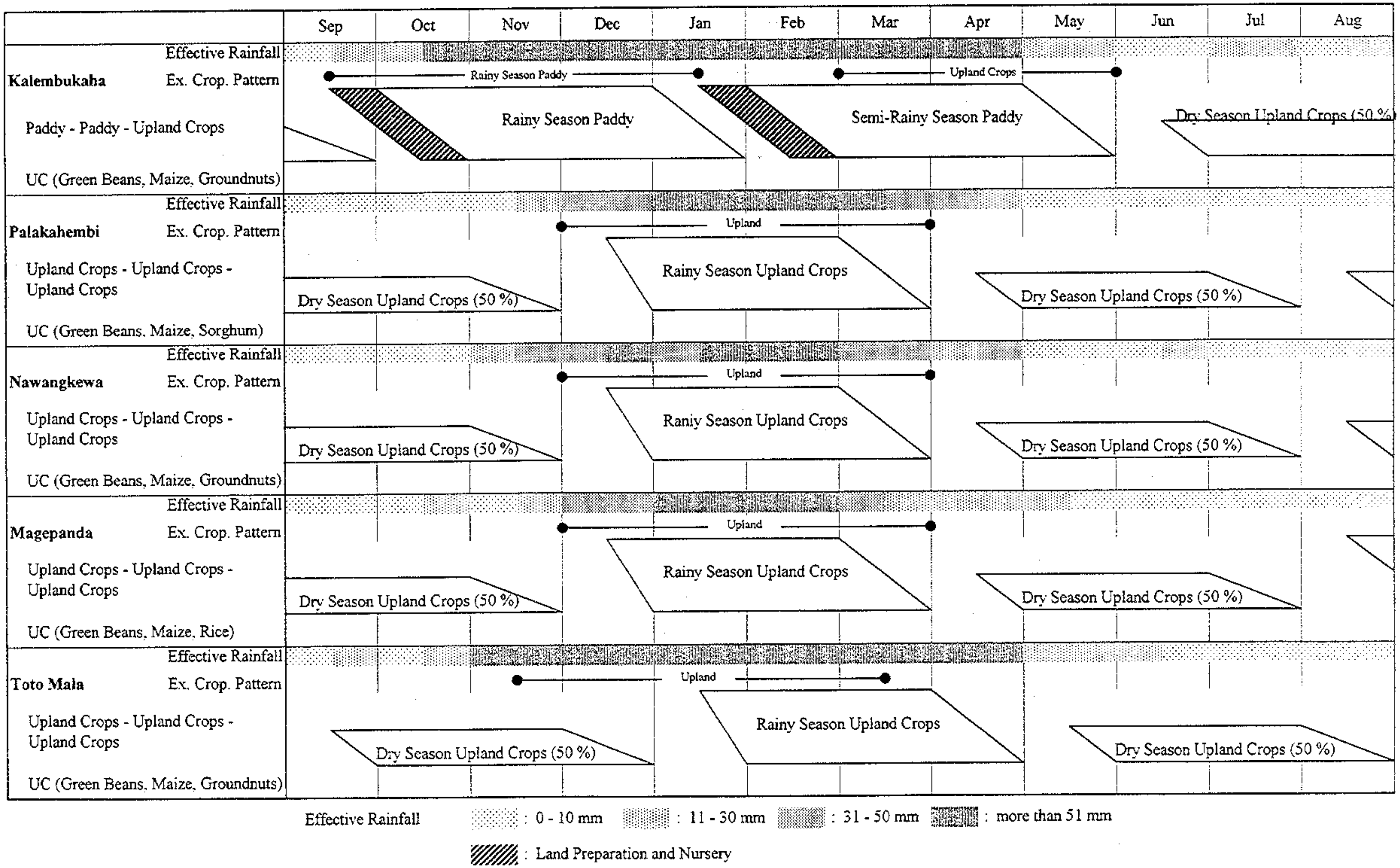


Figure 2-2 Cropping Pattern (2/2)



2) Analysis on Input and Output at Farmer's Level

In order to examine the sustainability of the Project from the perspective of farmer's economy, the current and planned production costs and net incomes are calculated for some typical sites of the Project. Since the perfectly autonomous management starts from the third year of operation, them in the third year are also examined.

Five typical sites are selected taking into account scale of irrigation area, paddy or upland crop area and difference of pump head. They are as follows.

Region	Site	Area	Pump Head
North Sulawesi	Bongo I	rather big paddy area	average pump head
"	Bong III	rather big paddy area	big pump head
Southeast Sulawesi	Ranometo	average paddy area	average pump head
Sumba	Kalembukaha	small paddy area	very big pump head
Flores	Nawangkewa	small upland crop area	average pump head

The project production costs and income of each typical site are calculated based on the cropping patterns. The production costs consist of seeds cost, fertilizer cost, insecticide and pesticide cost, labor wages, O&M cost (including replacement cost) and miscellaneous cost. The results of the consideration is as follows.

Table 2-6 Analysis on Input and Output on Farmer's Level (per 1 ha)

Site	Cropping Pattern	Cropping Intensity (%)	Production Costs (1,000 Rp)	Income (1,000 Rp)	Net Income (1,000 Rp)	Net Income Increase (1,000 Rp)
Current						
Bongo I	P+P+UC	200	3,407	5,773	2,365	-
Bongo III	P+P+UC	200	3,407	5,773	2,365	-
Ranometo	P	100	1,912	3,000	1,088	-
Kalembukaha	P+C	200	3,169	4,463	1,294	-
Nawangkewa	UC	100	1,257	2,138	881	-
Planned						
Bongo I	P+P+UC	250	7,922	16,082	8,160	5,795
Bongo III	P+P+UC	250	8,039	16,082	8,044	5,679
Ranometo	P+P+UC	250	7,946	16,514	8,568	7,274
Kalembukaha	P+P+UC	250	8,557	15,983	7,425	6,131
Nawangkewa	UC+UC+UC	200	4,666	8,730	4,064	3,183
Planned (Third Year)						
Bongo I	P+P+UC	225	6,114	10,935	4,821	2,456
Bongo III	P+P+UC	225	6,221	10,935	4,714	2,349
Ranometo	P+P+UC	175	4,489	8,389	3,899	2,811
Kalembukaha	P+P+UC	225	6,182	9,422	3,240	1,946
Nawangkewa	UC+UC+UC	150	3,121	4,877	1,757	876

* P: Paddy, UC: Upland Crop
Production Cost = Seed + Fertilizer + Insecticide/Pesticide + Labor + O&M

(3) Irrigation Plan

1) Crop Evapotranspiration (ETc)

Crop evapotranspiration is determined by the following formula.

$$ETc = ETo \times Kc$$

Where:

ETc: Crop evapotranspiration (mm)
ETo: Reference crop evapotranspiration (mm)
Kc: Crop coefficient

Penman's Method using meteorological data of Gorontalo and Tondano in North Sulawesi, Palangga in Southeast Sulawesi, Waingapu in Sumba and Maumere in Flores determines reference crop evapotranspiration.

Table 2-7 shows calculated reference crop evapotranspiration.

Table 2-7 Reference Crop Evapotranspiration

(mm/day)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
Gorontalo	4.7	5.3	5.4	5.3	5.0	4.6	4.9	5.5	5.7	5.4	4.8	4.9	5.1
Tondano	4.1	4.6	4.6	4.4	3.8	3.9	4.1	4.8	5.0	4.5	3.9	3.9	4.3
Palangga	4.0	4.1	4.4	4.0	4.2	3.9	4.2	4.7	5.4	5.3	4.8	3.8	4.4
Waingapu	4.2	4.6	5.6	6.3	6.7	6.2	6.1	6.7	6.8	6.8	5.8	4.6	5.9
Maumere	6.0	6.4	6.9	6.9	6.8	6.8	6.7	6.9	6.9	6.8	6.5	5.8	6.6

2) Effective Rainfall (ER)

Half-monthly effective rainfall is adopted at 70% of average half-monthly rainfall with a 5-year return period of non-exceedance probability for paddy and a 2-year return period for upland crops. The effective rainfall is determined using meteorological data of Gorontalo and Tondano in North Sulawesi, Mowila and Palangga in Southeast Sulawesi, Waikabubak and Waingapu in Sumba and Maumere, Magepanda and Welamosa in Flores.
Table 2-8 shows calculated effective rainfall.

3) Net Water Requirements (NWR)

Net water requirements are calculated by the following formula.

NWR = ETc + Paddling water + Percolated water - ER

Where:

NWR: Net water requirements (mm)
ETc: Crop evapotranspiration (mm)
ER: Effective rainfall (mm)

Table 2-8 Summary of Effective Rainfall

Month		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Annual
		I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	
days		15	16	14	14	15	16	15	15	15	16	15	15	15	16	15	16	15	15	15	16	15	15	15	16	365
Bongo I, II, III																										
Paddy (P)	mm	30	34	32	15	35	42	42	34	62	25	32	35	31	25	19	15	5	10	18	36	56	39	41	29	742
Upland Crops (UC)	mm	36	41	38	18	42	50	50	41	74	29	37	42	37	29	22	18	6	12	22	42	66	46	49	34	881
Average	mm	37	42	39	19	43	52	52	42	76	30	39	43	38	30	23	18	6	13	22	43	68	48	50	35	908
Tempok, Parepe																										
Paddy (P)	mm	43	50	36	36	43	56	44	42	56	42	44	38	37	29	31	15	10	20	33	34	60	47	36	42	924
Upland Crops (UC)	mm	55	63	47	47	55	72	56	53	72	53	56	49	48	37	40	20	13	25	43	44	76	61	46	54	1,185
Average	mm	57	66	48	48	57	75	58	55	74	55	58	50	50	39	41	20	13	26	44	46	79	63	48	56	1,226
Ranooha, Ranometo																										
Paddy (P)	mm	42	53	51	39	52	66	65	53	54	67	64	42	61	46	33	37	21	15	16	33	23	42	37	37	1,049
Upland Crops (UC)	mm	52	66	63	48	64	81	81	65	67	83	78	51	75	56	41	45	26	19	20	40	28	51	46	46	1,292
Average	mm	53	67	64	48	64	82	81	66	67	83	79	52	76	57	41	46	26	19	20	41	29	52	46	46	1,305
Lapulu, Moolo Inda																										
Paddy (P)	mm	57	41	54	45	51	53	57	58	50	48	53	33	38	27	23	20	11	17	17	23	20	28	50	42	916
Upland Crops (UC)	mm	72	51	69	57	64	67	71	73	62	60	66	41	47	34	29	25	14	22	22	29	25	35	64	53	1,152
Average	mm	74	53	70	58	66	69	73	74	64	62	68	42	48	35	29	25	14	22	22	30	26	36	65	55	1,180
Lambodi Jaya																										
Paddy (P)	mm	34	40	37	40	45	39	30	30	48	49	53	26	54	25	19	22	22	17	20	10	17	25	36	26	764
Upland Crops (UC)	mm	46	55	52	55	61	53	41	42	65	67	73	36	74	34	26	30	30	24	28	13	23	34	50	36	1,048
Average	mm	49	59	55	58	65	57	43	44	69	71	78	39	78	36	27	32	32	25	29	14	25	36	53	39	1,113
Kalembukaha																										
Paddy (P)	mm	90	171	112	124	155	99	105	69	24	15	9	10	16	22	5	20	5	27	18	61	82	93	128	99	1,559
Upland Crops (UC)	mm	103	196	129	142	178	114	120	80	28	17	10	12	18	25	6	23	6	30	21	70	94	107	147	113	1,789
Average	mm	104	198	130	144	180	116	122	81	28	18	11	12	18	25	6	23	6	31	21	71	95	109	148	115	1,812
Palakahembi																										
Paddy (P)	mm	49	62	53	51	51	37	34	10	4	5	2	4	1	2	0	0	1	1	1	1	5	20	43	44	481
Upland Crops (UC)	mm	56	69	59	57	57	41	38	12	5	6	2	4	1	3	0	0	1	1	1	1	5	22	49	49	539
Average	mm	57	71	60	58	58	42	39	12	5	6	2	4	1	3	0	0	1	1	1	1	6	22	50	50	550
Nawangkewa																										
Paddy (P)	mm	38	44	56	58	36	34	21	24	8	6	4	8	5	4	0	1	1	2	2	4	21	37	33	49	496
Upland Crops (UC)	mm	49	57	72	75	46	44	27	31	10	8	5	11	6	5	0	1	1	3	2	5	27	48	43	64	640
Average	mm	52	60	76	79	48	46	28	33	11	8	6	11	6	6	0	1	1	3	2	6	29	50	46	67	675
Magepanda																										
Paddy (P)	mm	42	54	75	72	30	23	19	15	9	2	5	8	4	6	2	3	3	4	1	12	7	17	39	40	492
Upland Crops (UC)	mm	53	67	94	89	38	28	24	19	11	2	6	10	5	7	3	4	3	5	1	15	9	21	49	49	612
Average	mm	55	69	97	92	39	29	25	20	12	2	6	11	6	8	3	4	4	5	1	15	9	22	50	51	635
Ranakolo, Dawa, Toto Mala																										
Paddy (P)	mm	123	115	96	86	73	75	58	48	17	20	11	6	8	11	1	4	9	19	9	11	47	70	83	78	1,078
Upland Crops (UC)	mm	136	126	105	95	81	83	63	53	19	22	13	7	8	12	1	4	10	21	10	12	51	77	91	85	1,185
Average	mm	137	127	106	95	81	83	64	53	19	22	13	7	8	12	1	4	10	21	10	12	52	78	92	86	1,193

4) Gross Water Requirements (GWR)

Gross water requirements are calculated by the following formula.

GWR = NER/IE

Where:

GWR: Gross water requirements (mm)

NWR: Net water requirements (mm)

IE: Irrigation efficiency

5) Design Water Requirements and Design Discharge

In accordance with the cropping patterns and the gross water requirements, peak water requirements of each site are determined.

Design water requirements of each site are calculated multiplying the peak water requirements and the maximum daily pump operating hours. The pump operating hours are determined taking the operating hours of existing surrounding farms into account. These operating hours are 14 - 16 hours a day for paddy cultivating area and 12 hours a day for upland crops cultivating area.

Design discharge is calculated multiplying the design water requirements and irrigation area at the peak hours.

Table 2-9 shows the results of the calculations.

Table 2-9 Design Water Requirements and Design Discharge

No.	Site	Design Irrigation Area (ha)	Peak Water Requirements (lit/sec/ha)	Maximum Pump Operating Hours (hr/day)	Design Water Requirements (lit/sec/ha)	Irrigation Area at Peak (ha)	Design Discharge (lit/sec)	Crop Intensity in Dry Season (%)
1	Bongo I	25	0.79	16	1.2	25	30	50
2	Bongo II	25				25	30	50
3	Bongo III	25				25	30	50
4	Tempok	25	0.67	14	1.2	25	30	50
5	Parepe	25				25	30	50
6	Ranooha	20	0.66	14	1.2	20	24	50
7	Ranometo	20				20	24	50
8	Lapulu	8	0.69	14	1.2	8	10	50
9	Moolo Indah	20				20	24	50
11	Kalembukaha	10	0.79	16	1.2	10	12	50
12	Palakahembi	10	1.17	12	2.4	5	12	50
13	Nawangkewa	10	1.03	12	2.1	5	11	50
14	Magepanda	8	1.20	12	2.4	4	10	50
17	Toto Mala	10	0.94	12	1.9	5	10	50

(4) Facility Design

1) Deep Tube Well

a. Drilling diameter and depth

Drilling diameters are fixed at 17-1/2" for pump house and conduit, and well depth is fixed at less than 150 m based on the results of the geo-electric survey and the existing hydro-geological material. The depth decided is shown in Table 2-1.

b. Casing and screen diameter, and screen length

Theis Equation is the most common for considering drawdown and well structure. Conduit casing diameter, determined in accordance with the design concept in Anon's figures (refer to Table 2-10), is examined using Theis Equation in order to make it definite. Theis Equation is shown as follows.

$s = (Q \cdot W(u)) / (4\pi \cdot T)$ .... (Theis Equation)

$W(u) = \int (e^{-u}/u) \cdot du$, $u = r^2 \cdot S / 4 \cdot T \cdot t$

Where,

Q	:	Design discharge (m^3/sec)
t	:	Operating hours (sec)
s	:	Drawdown (m)
W(u)	:	Well function of Theis
T	:	Transmissible coefficient (m^2/sec)
r	:	Well radius (m)
S	:	Storage coefficient of aquifer

The following formula gives the drawdown (x: m) at a place R m off from the well.

$$(s - x) = (Q \cdot \ln(R/r)) / 2\pi \cdot T$$

Table 2-10 Minimum Screen Diameter for Design Discharge

(Anon 1997)

Design Discharge : m^3/day (lit/sec)	Minimum Screen Diameter (inches)
Up to 270 (3.1)	2
270 - 680 (3.1 - 7.9)	4
680 - 1,910 (7.9 - 22)	6
1,910 - 4,350 (22 - 50.3)	8
4,350 - 7,650 (50.3 - 88.5)	10
7,650 - 13,600 (88.5 - 157)	12
13,600 - 19,000 (157 - 220)	14
19,000 - 27,000 (220 - 313)	16
27,000 - 38,000 (313 - 440)	18
38,000 - 49,000 (440 - 567)	20

As a result, the selected diameter is 8", and the determined figures are shown in Table 2-1.

Pump housing casing diameters are fixed at 12" similarly to the existing wells for a matter of compatibility in their utilization.

c. Type of casing and screen

There are carbon steel pipe, FRP, UPVC, stainless steel pipe, etc. as casing and screen material. The followings are their specific characters.

Carbon Steel Pipe	:	strong, not easy to keep quality of welding at site, poor chemical and electrical corrosion resistance, rather expensive.
FRP	:	strong, light and easy to install, good chemical and electrical corrosion resistance, expensive.
UPVC	:	light and easy to install, good chemical and electrical corrosion resistance, however insufficient in strength, not expensive.
Stainless Steel Pipe	:	strong, not easy to keep quality of welding at site, good chemical and electrical corrosion resistance, very expensive.

The casing shall be durable as it is a well itself and unchangeable permanent facility. The carbon steel pipe has poor chemical and electrical corrosion resistance and UPVC is insufficient in strength. The stainless steel pipe is very expensive even it is strong and durable. FRP has very good strength, durability and easy installation, therefore, it is selected as casing, even though it is somewhat expensive.

The screen made of FRP has 20% of opening ratio and is sufficient. Therefore, FRP is selected as screen, as well.

A typical outline of well is shown in Figure 2-3.

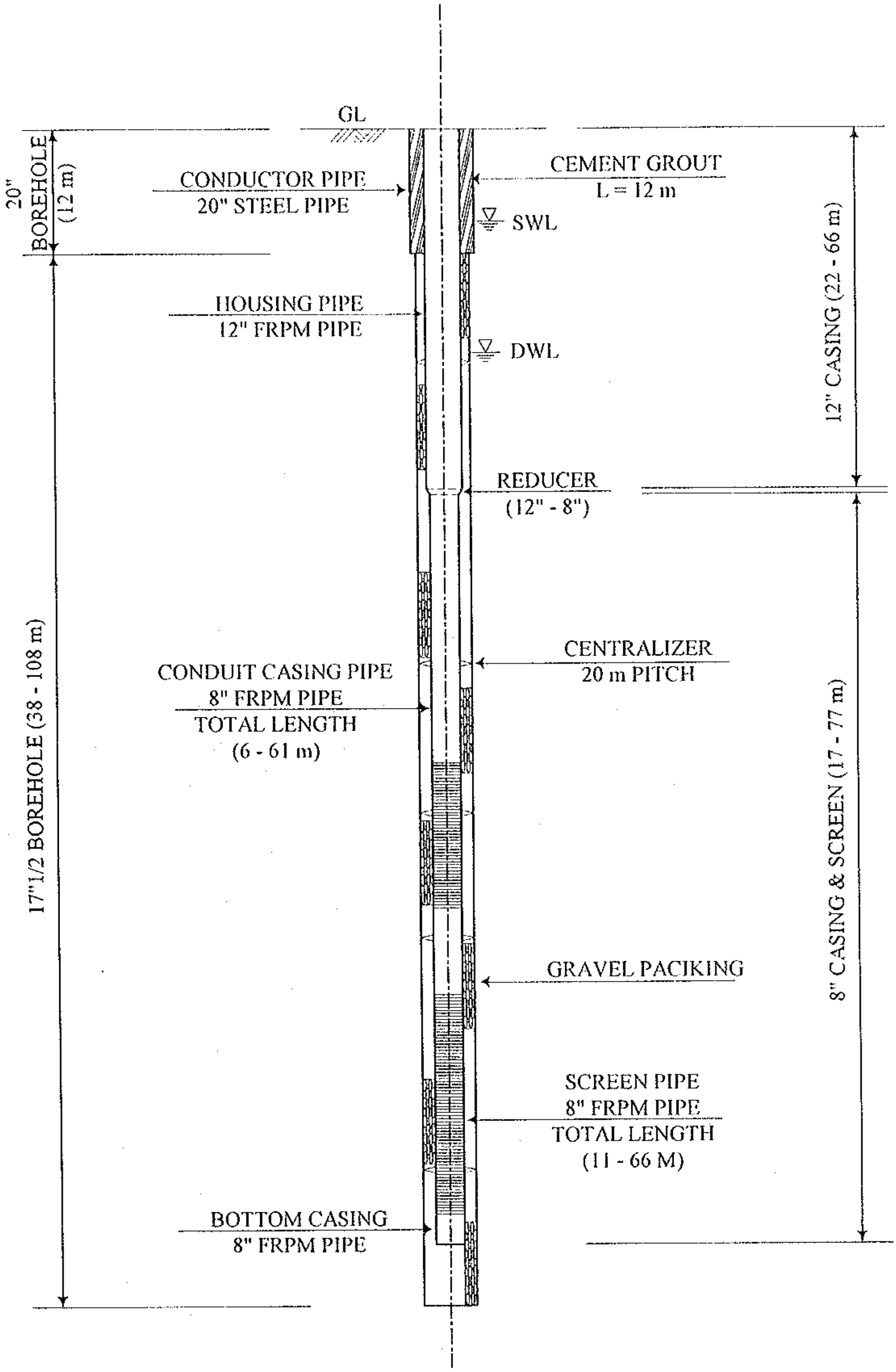


Figure 2-3 Typical Outline of Well

2) Pump Facilities

a. Total pump head

The total pump head of each site is calculated based on design discharge adding actual head, pipe loss and head needed at outlet.

The head needed at outlet is calculated taking effective head of alfalfa valve into account. The effective head of alfalfa valve is calculated using the following formula.

$$Q = C \times A \times (2gh)^{1/2}$$

Where:

Q	:	Discharge (lit/sec)
C	:	Coefficient of discharge
A	:	Area (m^2)
g	:	Acceleration of gravity (9.8 m/sec^2)
h	:	Effective head (mm)

The coefficient of discharge (C) of alfalfa valve varies depending on the types of valves and their opening rates, and the mean values generally vary from 0.35 to 0.40. Therefore, the middle value, 0.375, is adopted. The results of calculation give 2.00 m as the head needed at outlet which includes the effective head of alfalfa valve, height between ground elevation and water level of small on-farm reservoir and allowance. Table 2-11 shows the result of the calculations of the total head.

Table 2-11 Pump Total Head

No.	Site	Design Discharge (lit/sec)	Actual Head (m)	Pipe Loss (m)	Head Needed at Outlet (m)	Total Head (m)
1	Bongo I	30	16.99	3.99	2.00	23
2	Bongo II	30	17.55	1.36	2.00	21
3	Bongo III	30	24.72	4.31	2.00	31
4	Tempok	30	8.34	1.92	2.00	13
5	Parepe	30	13.25	2.00	2.00	18
6	Ranooha	24	25.98	2.78	2.00	31
7	Ranometo	24	14.32	1.68	2.00	18
8	Lapulu	10	22.80	1.30	2.00	27
9	Moolo Indah	24	21.90	2.23	2.00	27
11	Kalembukaha	12	57.07	1.93	2.00	61
12	Palakahembi	12	24.37	1.37	2.00	28
13	Nawangkewa	11	11.00	0.25	2.00	14
14	Magepanda	10	10.85	0.66	2.00	14
17	Toto Mala	10	25.85	0.94	2.00	29

b. Types of pump

There is no site with suction head of less than 7 m, therefore the vertical turbine pumps and submersible pumps are considered to adopt.

The vertical turbine pumps are the most popular pumps for deep tube wells in Indonesia due to their easy operation & maintenance since the main parts of pump are displayed on the ground and their durability on sand. The vertical turbine pumps out of operation due to breakdown have not been seen during the field survey since repair is possible by the mechanics of the groundwater development sub-project offices.

On the other hand, the submersible pumps are not generally used in the Eastern part of Indonesia as it is rather difficult to repair troubles related to electrical system due to shortage of the electricians in the sub-project offices. Two cases of troubled submersible pumps out of operation have been seen during the field survey. Therefore, it is judged that the submersible pumps are not suitable for this Project.

Taking the above-mentioned into account, the vertical turbine pumps are selected for this Project.

Bores of the selected pumps are shown in Table 2-13.

c. Types of Motor

There are diesel engines and electric motors for pump motors.

Even though all the sites have public electric power supply, no site uses it as power source for groundwater irrigation in the project area, as it is expensive and not economy for irrigation.

In accordance with the comparison on operating expenses of diesel engine and electric motor, the operating expenses of electric motor are more than one million Rupia higher than those of diesel engine. Therefore, the diesel engines are adopted for this Project. The following shows the results of the comparison.

Table 2-12 Comparison between Diesel Engine and Electric Motor

Diesel Engine		Electric Motor	
Shaft Power	12.66 ps	Shaft Power	9.31 kw
Fuel Consumption	0.19 lit/ps/hr	Basic Charge	17,000 Rp./kVA/m
Fuel Price	550 Rp./lit	Power Charge	116.5 Rp./kWh
Operating Hours	3,110 hr/year	Operating Hours	3,110 hr/year
Operating Expenses	4,114,437 Rp./year	Operating Expenses	5,272,393 Rp./year

Note: Shaft Power and Operating Hours are from Bongo I

Required power for diesel engine is calculated by the following formula

$$L = (K \cdot Q \cdot H \cdot r)/(n/100)/nt$$
$$P = L \cdot 0.7355$$

Where:

L	:	Shaft power (kW)
K	:	Constant figure (K = 0.163)
r	:	Specific weight of liquid (r = 1.0 for water)
n	:	Pump efficiency (%)
Q	:	Discharge (m^3/min)
H	:	Total head (m)
nt	:	Gear loss (nt = 0.92 for vertical pump)
P	:	Required power (ps)

Required power for diesel engine is shown in Table 2-13.

Table 2-13 Pump Bore and Engine Power

No.	Site	Pump Bore (mm)	Engine Power (ps)	No.	Site	Pump Bore (mm)	Engine Power (ps)
1	Bongo I	150	12.65	8	Lapulu	150	4.95
2	Bongo II	150	11.55	9	Moolo Indah	150	11.88
3	Bongo III	150	17.61	11	Kalembukaha	150	13.43
4	Tempok	150	7.15	12	Palakahembi	150	6.16
5	Parepe	150	9.90	13	Nawangkewa	150	2.82
6	Ranooha	150	13.65	14	Magepanda	150	2.57
7	Ranometo	150	7.92	17	Toto Mala	150	5.32

3) Pump House

Reinforced concrete structure and concrete block wall with mortar finish are adopted. Roof material is corrugated galvanized steel and the roof is pitched. Direct foundation after replacement of surface soil is employed.

A chain block is attached in order to make pump installation and repair easy. The chain block is supported by a H-beam structure.

Outline of pump house and pump allocation are shown in Figure 2-4.

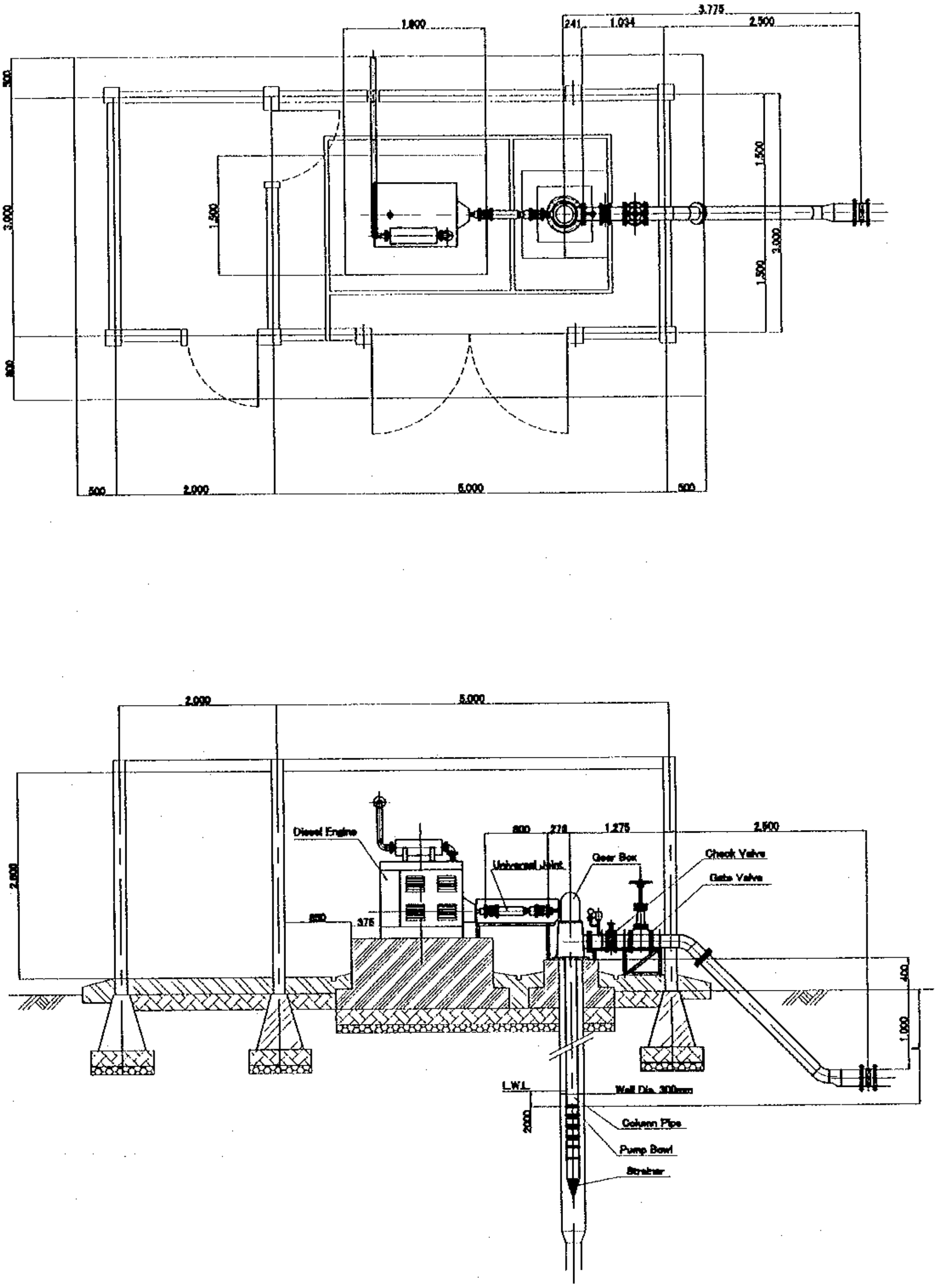


Figure 2-4 Outline of Pump House and Pump Allocation

4) Irrigation Facilities

a. Pipeline

Pipe diameters are selected to provide an economical velocity during pump operation, as shown below.

Pipe Diameter and Economical Velocity

Pipe Diameter	Economical Velocity
ϕ75～ϕ150	0.7～1.0 m/s
ϕ200～ϕ400	0.9～1.6 m/s
ϕ450～	1.2～1.8 m/s

Table 2-14 shows the length and discharge of the pipelines.

Table 2-14 Dimension of Pipeline

	Site	Discharge (m^3/s)	Length (m)	Diameter (mm)	Remarks
1	Bongo I	0.030	1,834	ϕ200	PVC
2	Bongo II	0.030	2,246	ϕ200	PVC
3	Bongo III	0.030	2,224	ϕ200	PVC
4	Tempok	0.030	2,107	ϕ200	PVC
5	Parepe	0.030	2,385	ϕ200	PVC
6	Ranooha	0.024	1,870	ϕ200	PVC
7	Ranometo	0.024	2,234	ϕ200	PVC
8	Lapulu	0.010	732	ϕ150	PVC
9	Moolo Indah	0.024	2,531	ϕ200	PVC
11	Kalembukaha	0.012	929	ϕ150	PVC
12	Palakahembi	0.012	727	ϕ150	PVC
13	Nawangkewa	0.011	720	ϕ150	PVC
14	Magepanda	0.010	765	ϕ150	PVC
17	Toto Mala	0.010	872	ϕ150	PVC
	Total	-	22,176	-	-

Types of pipe are determined taking into account the internal and external pressure, chemical and electrical corrosion resistance, costs and easiness of installation.

There are steel pipe, ductile cast-iron pipe (DCIP), FRP, PVC, etc., and the followings are their specific characters.

Steel Pipe	:	strong, not easy to keep quality of welding at site, poor chemical and electrical corrosion resistance, rather expensive.
DCIP	:	strong, heavy, expensive.
FRP	:	strong, light and easy to install, good chemical and electrical corrosion resistance, expensive.

PVC : not so strong compared with the other pipes, however sufficient for the strength required in this Project, light and easy to install, good chemical and electrical corrosion resistance, not expensive.

PVC, which is available in Indonesia, is selected as it is cheap and has good durability and easy installation.

Water hammer that may possibly occur at the time of pump stoppage is considered and the maximum pressure is 1.2 kgf/cm^2. Proper pipe thickness is calculated in accordance with the design pressure (2.4 kgf/ cm^2) this pressure and dynamic water pressure (max. 1.2 kgf/ cm^2).

Pipe loss that is included in the total pump head, for the pipes chosen above, is calculated using the following Hazen & Williams formula.

$$hf = 10.67 \cdot C^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85} \cdot L \cdot (1+n)$$

Where,

hf	:	Pipe loss (m)
C	:	Coefficient (PVC 150)
D	:	Pipe diameter (m)
Q	:	Discharge (m^3/s)
L	:	Pipe length (m)
n	:	Coefficient of friction by fittings (0.05)

Sluice valves, air stands and air valves are installed for operation & maintenance. The sluice valves are installed on the discharge side of the pump and the main diversion points of the pipeline for repair. The air stands or air valves are installed at 500 m interval on the line and on the longitudinal protrusions. The air stands are normally employed, while the air valves are employed where high dynamic water pressure occurs. Blow-off valves are provided on the longitudinal depressions for operation & maintenance, as well.

b. Distribution box

Brick masonry with mortar finish structure is employed as the water depth is less than 1 m and there is no soil pressure. Locally made simple alfalfa valves are attached to the boxes as outlet valves. The capacity of the annexed small on-firm reservoirs is determined supposing one day stock of 5 mm/day for 400 m^2 horticulture land, and is 2 m^3.

The reservoirs are used as stilling basins for the suppressed rectangular weirs annexed to the boxes, as well.

5) Village Water Supply

The following table shows the capacity of the small-scale water tank for village water supply.

Capacity of Village Water Supply

Type	Capacity (m^3)	Site Number
A	10	5
B	5	1, 2, 3, 8, 9, 11, 14, 17
C	2	4, 6, 7, 12, 13

Reinforced concrete structure with direct foundation is adopted. In order to prevent intrusion of dust and withered leaves, the top of the tank is closed. Taking farmers' convenience into account, taps are installed.

6) Basic Design Drawings

Refer to the attached basic design drawings.

(5) Operation and Maintenance Plan

Project benefit and its sustainability are secured when proper operation & maintenance (O&M) is carried out in the case of irrigation development project. O&M is acknowledged as one of the most important issues in Indonesia, therefore, "Irrigation Management Policy Renewal" was announced in April 1999 by the current government (the President). Taking up this announcement, BAPPENAS has announced the "Policy, Institutional, Legislative and Regulatory Reform Program" of water resources and irrigation sector for the World Bank. In this article, O&M plan for this groundwater irrigation development project are drawn up in accordance with Indonesian policy for irrigation management, and recommended as follows.

1) Concept of O&M

The water users' association (WUA) established after the construction of facilities shall take responsibility for operating and managing the constructed irrigation facilities. WUA consisting of all the farmers benefited from the project shall be established at each site as independent organization.

The establishment of WUA, its management and O&M of the facilities shall be supported by the sub-project of groundwater development (PAT), as main party, and relevant government bodies and organizations. The operating costs of the facilities shall be borne by subsidies from PAT for the first 2 years after construction.

2) Role and Organization of WUA for O&M

WUA, with the support by PAT, will be fully responsible for O&M of facilities and will have the following roles.

- Settlement of seasonal or annual cropping patterns
- Drawing up an irrigation plan and encouraging a fair and proper irrigation to the whole irrigation area
- Daily O&M of the facilities including small repair to keep them in good condition
- Periodical maintenance, overhaul and rehabilitation of the facilities
- Monitoring for groundwater level and water quality
- Drawing up a facility replacement plan and its execution
- Extension of knowledge and techniques concerning irrigation and farming to the member farmers

- Collection of irrigation service fee for the sake of O&M including operating costs of WUA and replacement cost
- Making the member farmers keep to the regulations and restriction (including penal regulations) of WUA

The WUA officers shall be democratically elected from the member farmers, and shall consist of three officers namely president, secretary and accountant. An operator selected by PAT and persons in charge of each block shall be assigned under the WUA officers. The general meeting shall be on the top of the whole association as a decision-making authority. (Refer to Figure 2-5)

Their major duties are as follows.

[President]
- Overall responsibility for operation and management of WUA
- Activity for receiving support from PAT, other relevant government organizations and associations
- Supervising the WUA staff members
- Arbitration of disputes
- Holding monthly and seasonal general meetings
- Drawing up the cropping and irrigation plan
- Responsibility for proper and fair irrigation

[Secretary]
- The whole administration
- Procurement and handling of fuel, oil and other consumable supplies
- Management of spare parts
- Handling the alfalfa valve with the persons in charge of each block
- Supervising the operator

[Accountant]
- Collecting irrigation service fee
- Accounting
- Taking charge of documents

[Operator]
- Pump operating
- O&M of pump facilities

- Monitoring for groundwater level and water quality
- Recording the operation (operating hours, amount of consumed fuel and oil, amount of discharged water, static water level, operating water level, electric conductivity, etc.)
- Management of pump house

3) Practice of O&M by WUA

a. Operation

If the farmers select the crops to grow and cropping time by their own convenience, the whole operation system and water management would be complicated. Therefore, WUA shall draw up annual and seasonal cropping patterns and irrigation plan by the consensus of the member farmers. Rotational irrigation carried out block by block shall be adopted to realize effective and smooth water management. The system of water management shall be as follows.

- The farmers who need irrigation water submit applications of water request to the president via the persons in charge of the block.
- The president gives orders to the secretary to deliver water in accordance with the decided rotation program, making adjustment if necessary.
- The secretary instructs the operator to operate the pump, and handle the alfalfa valves with the persons in charge of the block. In principle, the irrigation is carried out for one block simultaneously.
- The operator informs the record of pump operation (operating hours and amount of discharged water) to the president and accountant.
- The accountant collects irrigation service fee from the farmers who made water request in accordance with the record. The irrigation service fee collection follows the procedures decided by each WUA.

O&M costs shall be borne by all the member farmers. The amount and collecting procedures of irrigation service fee shall be decided by the consensus of the member farmers. The following procedure is conceivable as irrigation service fee collection. In this procedure, financial management of WUA shall be carried out by its own responsibility.

- Member charge or registration charge is collected when farmers are registered as the member of WUA.

- The irrigation service fee that covers O&M costs consisting of pump running cost, operator's wages and maintenance costs of pump and irrigation facilities is collected depending on operating hours at each operating time or after harvest.
- Replacement costs for pump facilities are collected each harvest depending on cropping areas or property areas.

Collection of those fees shall be commenced at the beginning of operation, and a stock fund shall be formed during the first two years, when GOI subsidizes WUA, in order to lay the foundation of WUA. The stock fund may be used as a revenue source for loans to the member farmers.

b. Maintenance of pump facilities

Maintenance of pump facilities (pump and engine) shall be carried out by the operator, in accordance with the operation and maintenance manual supplied with the facilities. Generally, lubricant for vertical turbine pump shall be changed every 2,000 hours, and diesel engine's lubricant, grease and oil filter shall be changed every 120 hours, 8 hours and 240 hours respectively. The operator shall record O&M carried out and, if problems are found, he shall inform to the president and carry out repair with the support of PAT.

c. Monitoring of groundwater

Monitoring for static water level, operating water level and electric conductivity shall be carried out by the operator, at the time of operating. In the case of any irregularities, the operator shall inform to the president without delay.

4) Supporting Organization for WUA

In order for WUA, which consists of farmers who have carried out rain-fed agriculture so far, to realize sustainable O&M of groundwater irrigation facilities and farming with irrigation by WUA's own responsibility, the following support is indispensable.

- Guidance on composing the system including establishment of WUA, selection of the WUA Officers and laying down rules
- Guidance and training on management of WUA
- Subsidies concerning pump operating costs for the first 2 years of operation
- Advice on determination of irrigation service fee and procedure of its collection
- Guidance and advice on making stock fund
- Technical guidance and training on pump operation and its maintenance
- Guidance and advice on cropping planning

- Guidance and advice on water management
- Guidance and advice on dressing fertilizer and pesticide/insecticide
- Guidance and advice on farming technology
- Guidance and advice on post harvest technology
- Support for operating funds
- Support for supply of material and marketing services

The above-mentioned support shall be extended under the coordination of PAT. PAT itself shall bear technical support for the facilities, the agricultural offices shall bear support for the farming technology, PAT and the provincial, prefectural and village government shall bear support for management of WUA and the village level agricultural cooperation (KUD) shall bear support for finance and marketing.
The organization chart of WUA and a relation chart of supporting organizations are described in Figure 2-5.

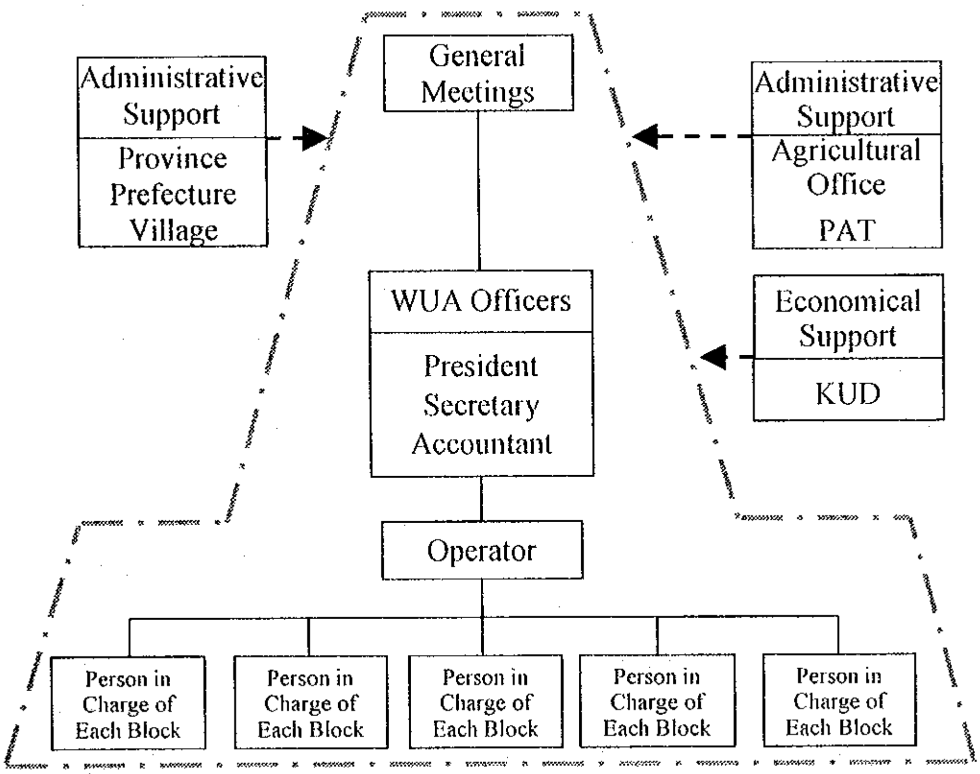


Figure 2-5 Structure of Water Users' Association

5) Other Measures for O&M

In order to make the Project successful, it is judged effective to improve the farmer's sense of participation in the Project as well as the above-mentioned support. Therefore, the followings shall be carried out from the first step of the Project.

- DGWRD and the consultant shall make an explanatory session about the Project with the farmers gathered at each site at the detailed design stage.
- The contractor shall employ the farmers as labors at the construction stage.
- WUA shall be established with the support of PAT and the consultant during the construction stage.

PAT shall make O&M manual with the assistance of the consultant by the completion of facility construction in order to realize proper O&M by WUA. The O&M manual shall include the followings.

- List of members
- Organization chart and roles of each staff
- Rules of WUA
- Irrigation service fee and collection procedure
- General plan describing a well, distribution boxes, pipeline, rotation blocks, property boundary and land owners' names
- Characteristics of well (including safe yield) and important notices for its O&M
- Details of the pump and the diesel engine installed and their O&M manual (including spare parts list)
- Standard cropping plan
- Manners of water management and rotational irrigation, and their schedule
- Manners of utilization and management of water tank for village water supply

The amount and collection procedures of irrigation service fee as well as the rules of WUA shall be decided by the consensus of the member farmers with the assistance of PAT. The establishment of the stock fund shall be strongly recommended as well.