7. EVALUATION OF GROUNDWATER RESOURCES

7.1 Water Balance Analysis

Storage must be taken into account in the water balance equation which is given as:

$$SdH/dt = (Q_1 - Q_2)/F + W$$

where, SdH/dt : Change in groundwater storage, S: Storage coefficient,
dH : Change in water level, dt: Time increment, F : Water balance area
$(Q_1 - Q_2)/F$: Groundwater flow, W: Groundwater recharge

Results of water balance calculations for shallow groundwater are shown in Fig 15.

The estimated balance is as follows.

Rainfall	525 mm	(100%)
Runoff	105 mm	(20%)
Evapotranspiration	325 mm	(62%)
Groundwater Recharge	94 mm	(18%)

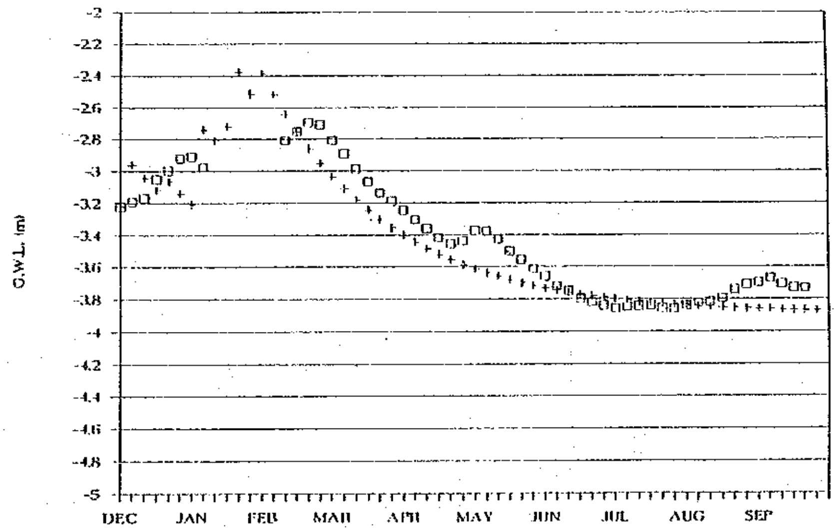
Using appropriate formulas, rough water balance of each basin is calculated. Areal rainfall is calculated from annual isohyet. Evapotranspiration and annual runoff is calculated by the ratio of rainfall, i.e., 65% for evapotranspiration and 20 % for annual runoff.

The next table shows the results of spot discharge measurement (as a baseflow) considered as recharge potential.

unit:(l/min/km2)

Basin	A (km2)	Baseflow	Water Balance
Manombo	508	150	217
Fiherenana	6755	30	223
Sakanavaka	3070	360	214
Isahena	1870	144	231
Malio	2040	378	248
Sakondry	730	66	214
Taheza	1600	924	220

The result of spot measurement is constrained by some site condition, and the above water balance calculatin is based on the average basin condition. From these results, the re charge condition of these basins is roughly estimated as 100 - 300 l/min/km2. However, it is necessary to consider local hydrogeological conditions.



□ Observed water level
+ Calculated water level

Fig. 15 Water Balance

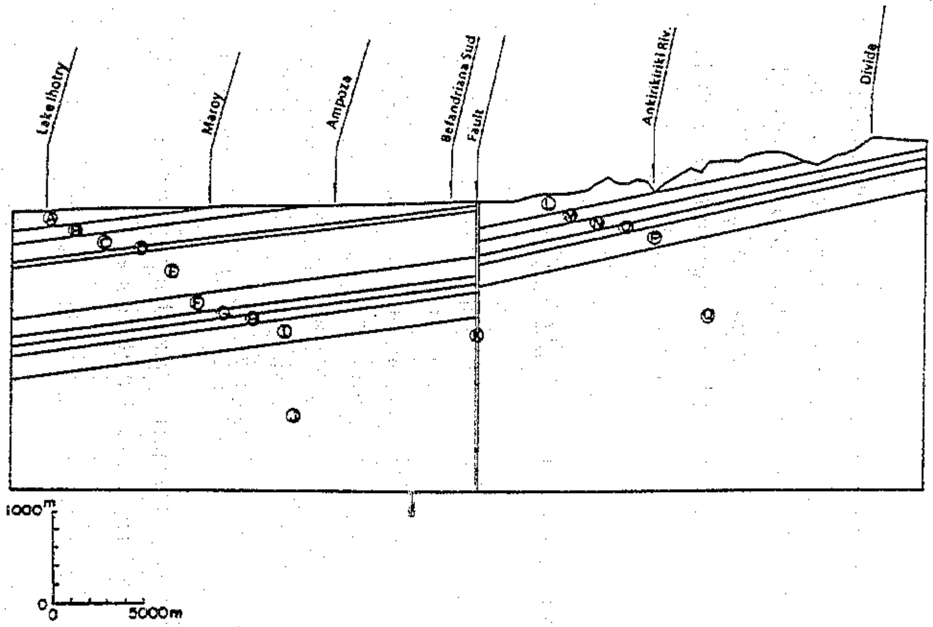
7.2 Groundwater Model Simulation

In order to recognize groundwater flow patterns, a two dimensional simulation model is applied to the Study Area.

Fig. 16 shows results of model simulation assuming typical conductivities which are given to each zone.

The Befandriana - Lake Ihotry section is drawn with the fault system and different hydraulic conductivities. It is very clear that the regional flow from the eastern side is dammed up by the existence of fault.

Two intermediate flow systems are shown in mountainous zone. Flow systems in mountainous area and flat area are basically separated now. The existence of artesian well in Antanimieva is explained by this condition. Two faults with N-S direction are located on the western and eastern sides of this well. The eastern fault is the one considered in the model section. For the Antanimieva well, the influence of the eastern fault is not so severe. On the other hand, the western fault has a big role to stop and dam up groundwater flow.



		Hydraulic Conductivity(m/day) Case 1	Case 2			Hydraulic Conductivity(m/day) Case1	Case2
A	Sandstone	0.864	0.864	J	Basalt	0.864	0.273
B	Sandstone	0.864	0.864	K	fault	0.864	0.864
C	Sandstone	0.864	0.864	L	Limestone	0.864	8.64
D	Marl	0.864	0.273	M	Marl	0.864	0.273
E	Limestone	0.864	8.64	N	Marl	0.864	0.273
F	Marl	0.864	0.273	O	Sandstone	0.864	0.864
G	Marl	0.864	0.273	P	Mudstone	0.864	0.273
H	Sandstone	0.864	0.864	Q	Basalt	0.864	0.273
I	Mudstone	0.864	0.273				

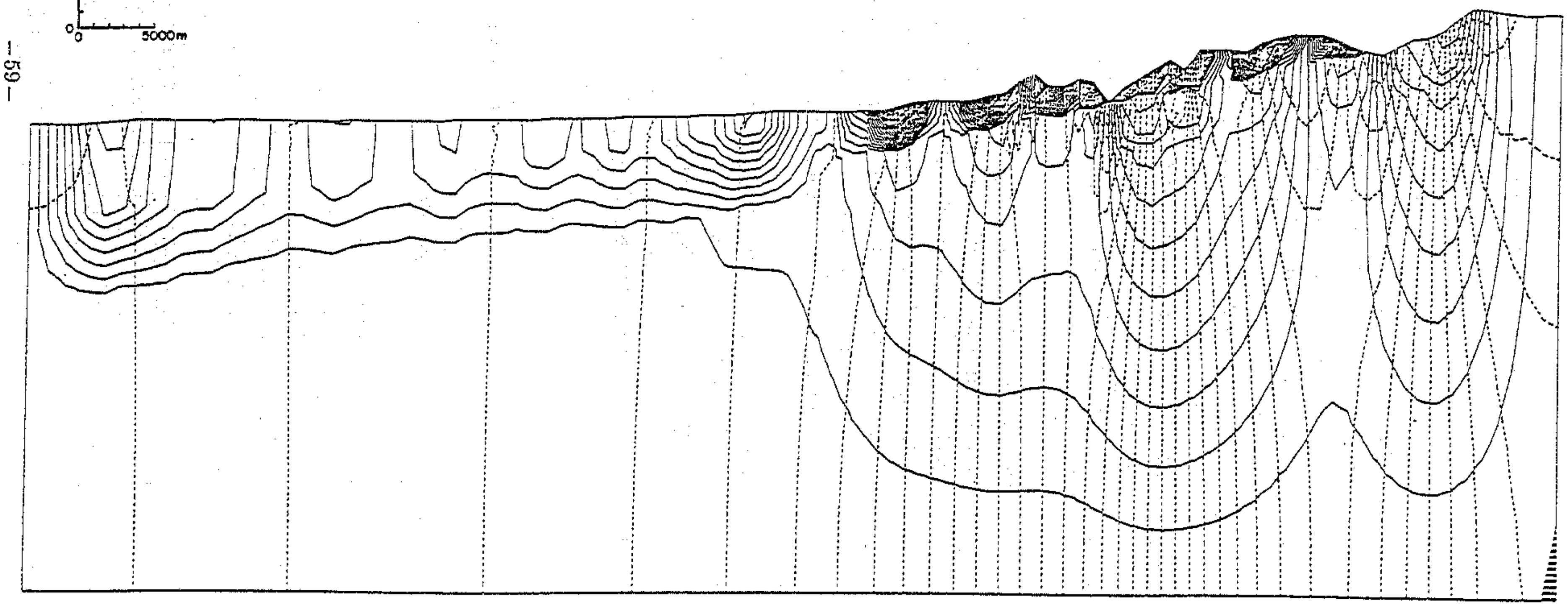


Fig. 16. Simulation Results

7.3 Potential for Groundwater Development

In order to evaluate potential of groundwater resources, a hydrogeological map (1/250,000) was prepared, including hydrogeological cross sections. This map embodied the potentiality for groundwater development from the standpoint of comprehensive analysis based on the results of satellite image and aero-photo analysis, geological field survey, geophysical prospecting, test drilling, pumping test and water quality analysis.

Analysis of groundwater balance and groundwater model simulation described in the above subsections used and verified the hydrogeological map and hydrogeological cross sections.

As shown in Table 7, the potential for groundwater development in the Study Area is generally high, except some areas which are composed of submarine sediments of the Middle to the Upper Jurassic and the Lower to the Middle Cretaceous that occupy the central portion of the Study Area, and other locally poor potential areas due mainly to their unsuitable water quality.

The groundwater potentiality in the Study Area is expected to be sufficient in capacity, not only to overcome existing shortages of drinking water, but also to develop local agricultural or industrial activities in some high potential areas. Main high potential areas which were confirmed from the results of test drilling in this Study are as follows.

Area	Specific capacity(m^3/day/m)
Befandriana	438.58
Sihanaka	232.26
Analatelo	7224.00
Mangotroka	281.35
Soahazo	173.33
Manombo Atm	609.23
Toliara*	3057.00

* Limestone aquifer in the eastern area of Toliara such as Miary and Manoroka

Table 7. Groundwater Development Potential by Region (1)

Area	Geology (Aquifer)	Groundwater Development Potential					Remarks
			Water Level (G.L.)	Discharge (l/min)	Specific Capacity (l/min/m)	Water Quality	
Mangoky Delta	Sand layer of Alluvium	Groundwater from this layer is widely used in this area	1.5-3.0	Tanandava 200	(D=29 m) 26.46	No problem But, there are some cases in the coastal area where chlorine ion concentration is rather high	The static water level of the well shallower than 10 m goes down remarkably in the dry season
	Middle & Upper Eocene	There is little possibility that the productive confined aquifer is found in it					This system mainly consists of marl and marly clay
	Limestone bed of Upper Cretaceous	Highly possibility of confined groundwater					Neighborhood of Nosy-Ambositra where Mangoky river cuts Mikoboka massif
Lake Ihotry Basin	Sand layer of Alluvium	The unconfined groundwater is used for irrigation	1.5-3.0			"Salinity"	Around Lake Ihotry
	Sandstone bed of Middle & Upper Eocene	This aquifer is widely used in this area	3.57-14.49	7 test drilling 200-340	holes 23-304	Good	The aquifer lays 30 meters below the ground surface In areas where Middle and Upper Eocene systems accompany marly sediments, the specific capacity is relatively small and water is salty
	Limestone bed of Lower Eocene		Artesian flow	Antanimieva artesian well 110 l/sec Mandery spring 620 l/sec	2,621 3,061		The artesian groundwater springs out in the 3 Km wide zone extended from NE to SW that links Befandriana with Mandery The static water pressure becomes low toward the northwest
Manombo Basin	Sand dune in the coastal area	As the aquifer is like a lens, its quantity is very limited and not in stable condition					
	Sandstone or limestone bed of Middle & Upper Eocene	Generally productive aquifer	3.40-36.17	12 test drilling 130-360	holes 14-423	"Good"	When the thickness of sandstone bed intercalated in marl is less than 3 m, the water is salty The groundwater quality of the Upper portion not exceeding GL-30 m is frequently bad
	Limestone bed of Lower Eocene	Very highly productive aquifer		Amboboka spring 3,100 l/sec	Sakamaka fan 32.4-139.2	No problem	Its distribution is very deep in the west of Toliara fault, so its utilization is very difficult

Table 7. Groundwater Development Potential by Region (2)

Area	Geology (Aquifer)	Groundwater Development Potential	Water Level (G.L.)	Discharge (l/min)	Specific Capacity (l/min/m)	Water Quality	Remarks
Fiherenana Basin	Continental coarse sandstone bed of Middle Isalo Formation	Highly productive aquifer	16.29 11.0	Test drilling hole 360-480	43.95	Good	Eastern side of Ilovo fault
	Continental sandstone bed of Lower Cretaceous	It is considerd as good aquifer, but it is difficult to utilize it since this layer is mostly covered by marine deposit of the Middle Jurassic System					Water quality is bad (salinity) The groundwater quality of the Upper portion not exceeding GL-30 m is frequently bad Western side of Ilovo fault, eastern area of Analavelona massif
	Marine deposit of Middle Jurassic					It is probable that the water quality is inferior in the portion that is covered by the middle Jurassic	The Middle Jurassic System is accompanied by marl
Sakondry Basin	Talus deposit	It is expected to contain unconfined water, but its quantity is limited					Steep cliff on the western margin of the plain Narrow recharge area
	Medium to coarse sandstone in the middle to upper portion of Isalo Group	It is expected to be good aquifer					The mountain west of Sakondry river Lower part of mountain side is covered by the Jurassic marine deposit Borehole must go through this hard Jurassic marine deposit in order to reach a good aquifer in the mountainside
Taheza Basin	Middle Isalo Group composed mainly of continental sandstone	This bed has high productivity But it is not expected to contain good aquifer because it has a small recharge area					West side of Taheza river — It is recommended that a sufficient investigation on hydrogeological structure be conducted for a successfull groundwater development, due to the complicated geological environment in this area
	Sandstone bed of the Middle Isalo Group	Productive aquifer	35.00	Test drilling hole (Analamary) 360-600	41.76	Good	East side of Tahezo river
	Lower Isalo Group composed mainly of coarse-grained gravely sandstone	This bed is generally assumed to be not necessarily of high productivity due to probable silicified matrix of its highly consolidated sandstone					

Table 7. Groundwater Development Potential by Region (3)

Area	Geology (Aquifer)	Groundwater Development Potential					Remarks
			Water Level (G.L.)	Discharge (l/min)	Specific Capacity (l/min/m)	Water Quality	
Fiherenana Delta	Sand layer of Alluvium	Productive aquifer					
	Limestone bed of Middle & Upper Eocene	Highly productive aquifer	5.10-20.75		Miary (3 wells) (D = 41-42m) 217.5 874.0 408.3	Good except for the coastal area (salinity)	Main water source of Toliara
	Marl bed of Upper Eocene	It is not expected to contain good aquifer					
Belomotra -Vineta Plateau	Basalt (the lower portion exceeding GL-15m, thickness:115m)	This aquifer has high utility from the view point of its depth and yield	16.57	Test drilling hole 110	11.65	It is probable that the water quality is inferior where marl bed lies on this sheet	Groundwater from fracture reservoir The productivity of this aquifer may be different by places because of the irregularity of fissure density
	Sandstone bed of Upper Cretaceous	This bed plays the role of aquifer, but its distribution area is limited	116.0	Andranovory 150		Good	Margin of Vineta plateau
	Limestone bed of Lower Eocene	Productive aquifer This groundwater is not confined	178.56 207.0	Test drilling hole (Befoly) 110 Andranohinaly 166		Good	Belomotra plateau As this groundwater level is more than 200 m below the ground surface, submersible pumps are necessary to pump it up
	Limestone bed of Middle Eocene (accompanied by sandstone bed)	Productive aquifer	5.23	Manoroka 158 (without drawdawn)		Good	Around the western margin of Belomotra plateau

Table 7. Groundwater Development Potential by Region (4)

Area	Geology (Aquifer)	Groundwater Development Potential					Remarks
			Water Level (G.L.)	Discharge (l/min)	Specific Capacity (l/min/m)	Water Quality	
Sakanavaka Basin	Continental sandstone bed of the upper Isalo Group (the lower portion exceeding GL-50m)	Highly productive aquifer	32.72	Test drilling hole 360-100	(Tandrano) 41.76	Good Partially poor in some area where upper layer of this aquifer consists mainly of marine deposit	The aquifer capacity is low in some areas where marine deposits with clayly material are dominant in the upper layer It is generally difficult to expect the presence of highly productive aquifer at the shallow portion in the western side of an imaginary line that links Ankazoabo with Tandrano
Isahena Basin	Middle Isalo Group	Many layers of sandstone intercalated in this group can be aquifer, but this basin is evaluated to have a low potentiality for groundwater development in terms of quantity and quality	15.54	Test drilling hole	(Berenty-Betika)	"Salty"	Though continental sandstone that has coarse-grained lithofacies & high permeability is mainly distributed in the western side of Isahena River, it is not productive aquifer because it has a small recharge area

8. CANDIDATE VILLAGES AND PRIORITY ASSIGNMENT

8.1 Needs for Water & Community Potential

A detailed survey was performed to prepare a ranking of the candidate villages according to the degree of priority. This detailed survey on existing conditions of individual communities had the purpose of confirming and appraising the following:

- real community need for safe water, to justify a new supply system;
- community commitment to the future operation and maintenance of the proposed supply facility; and
- community capacity and potential concerning its physical, financial, institutional, and human resources, which may assure their commitment.

(1) Villages with absolute supply shortage

An absolute shortage of the domestic water is observed in several villages on route 7. Those villages with scarce conventional water sources such as river, canal and shallow groundwater, solely depend on the delivery from water vendors who charge unimaginable high prices.

The majority of villages have several traditional water sources, natural and artificial, within their living area or in the neighborhood. A considerable number of villages have access to both traditional dug wells and rivers or canals. However,the water is not necessarily safe for domestic use, mainly due to probable bacteriological contamination. In particular, schistosomiasis and other prevalent water-borne diseases are feared as a serious epidemic by the villagers taking water from river or canal. Therefore, most of existing water sources, except a few protected dug wells, have not satisfied the community need for safe water supply.

(2) Community commitment

In the Study Area, regardless of the type of water supply facility, community participation was never encouraged in its operation and maintenance.

As the example of existing facilities, there are wells with handpumps built with the assistance of foreign organizations in the villages along route 9, several small community water works by SAMANGOKY, a semi-governmental corporation for plantation (rice, cotton, etc.) in villages of Morombe prefecture, and some community water works observed in Befandriana, Ankazoabo and Sakaraha.

Through interviews with villagers, it has become quite obvious that involvement or participation of the community users were not designed from the beginning of project planning. This neglect of an effort to awaken user's positive commitment is strongly correlated to the present deteriorated and abandoned state of pumps, even though other causes also might be involved. Only two handpumps and water works of SAMANGOKY remain in working condition.

The study team, through repeated dialogues with villagers to set up the maintenance system for pilot water supply facilities, has been convinced that rural dwellers have keen interest and enthusiastic willingness to participate in the maintenance activity.

(3) Community capacity and potential

The villages existing in the Study Area can be characterized into 4 categories on the basis of their location and state of development.

- Large communities on main roads 7 and 9 : Befandriana, Ampasikibo 55, Ankaraobato 65, Benetsy 68, Ankilimalinika 101.

- Medium size communities on main roads 7 and 9 or near the roads : Andranomanitsy 11, Belitsaka 54, Namaboha 56, Ampihamy 59.

- Large communities in remote places : Ambiky 16, Ankilivalokely 47, Tanandava-Antanifotsy 49, Beroroha 61, Manombo Atm 63, Ambohimahavelona 80, Ankilivalo 100, etc.

- Medium and small communities in remote places

One of the important factors for water supply planning is a judgment on the community capacity for the long-term maintenance of a water supply system. In the appraisal of such a community capacity, assessing the various kinds of resource constraints in the community will be more realistic and efficient. The resources required to maintain the introduced water supply system include four kinds, namely, physical, financial, institutional and human resources.

(a) Physical resources

Conditions for using handpumps, which are the preferred means for rural water supply, are not necessarily available everywhere in the Study Area. Inevitable recourse to motorized pumps in many places will result in greater capital investment and will require well-designed maintenance systems.

Energy required for the water supply system will have to rely on imported petroleum products, because electrification has not reached the rural area. The price of petroleum products, for example gas oil and petrol, can be considered as being reasonably acceptable for community users. However, a difficult problem for rural communities is availability of the products. Because of the low degree of motorization in the area, oil distribution system is not yet established in the rural area. Rural community users will have to make time-consuming trips to service stations located far from their living places. For the village located in a remote place, if they need fuel oil for pump operation, the burden is not the price of fuel oil but difficult access to suppliers. In this respect, communities on roads 7 and 9 have a relative advantage.

(b) Financial resources

At first sight, it might appear that financial constraints found commonly in beneficiary communities hamper the recovery of operation and maintenance costs of the water supply. In fact, community water services installed in the past in this region did not rely on beneficiary's contribution at all. However this should not be the case.

FIVONDRONANA (prefecture) and FIRAISAM-POKONTANY (district) offices do not have enough financial capacity to contribute money to a beneficiary village. Local taxes, consisting of land tax, sales and slaughter of cattle, market tax etc., are in principle, to be collected by the government representative (DELEGUE) who is stationed in individual offices. Collected taxes are sent to the FARITANY (province) office, and only a limited small amount of tax money is distributed back to FIRAISAM-POKONTANY and FIVONDRONAM-POKONTANY offices.

On the other hand, individual community users might be reasonably solvent, with rather positive willingness to pay for a water supply service, as the study team has found through their field survey and actual establishment of several maintenance systems for the pilot water supply facilities. As a whole, solvency of villagers is roughly estimated as below :

- Large communities on route 9 may have sufficient solvency to cover not only recurrent costs but also a portion of capital costs.

- Large communities in remote places can bear recurrent costs of motorized pump-based community water works.

- Small, poor communities in remote places can bear recurrent costs of handpump-based water points.

- Medium size communities on route 7, which have to rely an water vendor's supply at the moment, can bear recurrent costs plus a portion of capital costs.

(c) Institutional resources

Prevailing weakness in the existing institutional structure, as confirmed by the field survey,is probably the heart of the difficulty for maintaining water supply facilities in long-term working order.

- FOKONTANY (village)

The average FOKONTANY cannot afford a proper office nor a permanent staff, so that essential records on the FOKONTANY'S present and past depend on personal recolections.

- FIRAISAM-POKONTANY (District)

Although the office has a small ordinary budget and is responsible for some activities for the sake of FOKONTANY which hierarchically depend from the office, data and information on FOKONTANY are hardly available in the District office.

- MIEM Toliara branch

MIEM (Toliara) has a role to provide technical assistance to FOKONTANY in the maintenance of rural water supply facilities. Within the MIEM (Toliara) organization, the Department of Garage and Workshop is in charge of technical services for FOKONTANY. This Department is staffed with an assistant engineer, a technician and 15 workers.

If a rural water supply project is implemented in the Toliara area, the branch capability for managing, coordinating and planning will have to be considerably strengthened to satisfy the expected increase in technical services for FOKONTANY.

(d) Human resources

Skilled or trained manpower to support the operation and maintenance of rural water supply facilities is presently scarce in rural communities.

Members of rural societies in the Study Area earn a living by farming on rather sterile land. The farming tools are limited to two or three primitive types and therefore, there is no real demand to repair or manufacture those tools in the community.

As transportation means, a few carts are used in the community and the bicycle has not yet been introduced. A typical house in the community is made of logs and clay, simple enough to be built by laymen without any skill.

Under these circumstances, the rural community has had no pressing needs to encourage formation of craftsman in the society. However, the situation might be rapidly changing, starting from big communities on main roads where a wave of motorization and energy innovation, from firewood to charcoal, have taken place in the past one year.

8.2 Priority Assignment

Phase I field work and subsequent analyses in Japan resulted in the selection of 48 potential villages for detailed survey and 8 villages for rehabilitation survey. These villages were selected on the basis of groundwater availability, village accessibility, community needs and the community willingness to participate in the operation and maintenance of the water supply facilities. Further, based on the results of the site survey in Phase II, and hydrogeological investigations in Phase I and Phase II, a comprehensive analysis was conducted to define the process and criteria for the selection of priority villages for detailed survey in Phase III.

As shown in Fig. 18, the procedure and criteria for assigning priority order to candidate villages were based on the following considerations.

1) Hydrogeologically, the availability of groundwater in the site must be promising in terms of quantity and quality.

2) The need for groundwater development in the site must be strong. Development investment must promise a significant gain for the general welfare of the inhabitants.

3) The inhabitants must be capable to pay at least the operation and maintenance cost and be organized to manage the water supply system by themselves.

The following table shows the resulting order of priority villages.

Priority	No. of Village	Population(in 1990)	
Aa	19	42,545	
Ab	12	15,124	
Sub-total	31	57,669	(56.6 %)
Ba	4	4,718	
Bb	15	13,629	
Sub-total	19	18,347	(18.0 %)
Ca	12	7,292	
Cb	6	6,250	
Sub-total	18	13,242	(13.3 %)
D	26	12,308	(12.1 %)
Grand-Total	94	102,566	

Table 9 provides details on the degree of overall priority assigned to each village, as a result of evaluations conducted under different criteria.

Table 8. Priority Order of Candidate Villages (1)

No	Village Name	Potential for Groundwater Development (Natural Conditions)					Social and Economic Conditions					Comprehensive priority for groundwater development
		Availability of Groundwater (in terms of quantity/quality)		Accessibility/Conditions for Construction Activities		Potential for Groundwater Development	Population	Existing Water Source	Community Needs	Community Capacity and Potential	Social and Economic Potential	
1	Ankazomanga	-Local aquifer in delta deposits. -Dug well (5-10m depth)	C	Very poor/poor particularly in wet season	Ⅲ	C - Ⅲ	600	River	Ⅲ	C	Ⅲ - C	D
2	Beadabo	Ditto	C	Ditto	Ⅲ	C - Ⅲ	600	River	Ⅲ	C	Ⅲ - C	D
3	befasy	Ditto	C	Ditto	Ⅲ	C - Ⅲ	600	Dug Well	Ⅲ	C	Ⅲ - C	D
4	Ankilifolo(1)	Ditto	C	Ditto	Ⅲ	C - Ⅲ	400	Dug Well	Ⅲ	C	Ⅲ - C	D
5	Ambalamoa	-Moderately productive aquifer in Neritic sediments of the Upper Eocene. -6" Borehole 150m (150 l/min)	B2	Generally good but poor in wet season	Ⅱ	B2 - Ⅱ	1,000	Protected Dug Well	Ⅱ	B	Ⅱ - B	Bb
6	Tsianhy	Ditto	B2	Ditto	Ⅱ	B2 - Ⅱ	1,389	Dug Well	Ⅱ	B	Ⅱ - B	Bb
7	Namatoa	Ditto	B2	Ditto	Ⅱ	B2 - Ⅱ	750	Protected Dug Well	Ⅱ	A	Ⅱ - A	Bb
8	Mangolovolo	-Highly productive aquifer in swampy area. -6" Borehole 30m (350 l/min)	A1	Ditto	Ⅱ	A1 - Ⅱ	1,500	River	Ⅰ	A	Ⅰ - A	Aa
9	Ankida	Ditto	A1	Ditto	Ⅱ	A1 - Ⅱ	15	Spring	Ⅲ	C	Ⅲ - C	D
10	Vorisy	-Productive aquifer in Neritic sediments of the Upper Eocene	A2	Ditto	Ⅱ	A2 - Ⅱ	0	—	—	—	—	—
11	Andranomanintsy	-Highly productive aquifer in Neritic sediments of the Upper Eocene. -6" Borehole 200m (350 l/min)	A3	Ditto	Ⅱ	A3 - Ⅱ	1,400	Dug Well Canal	Ⅰ	A	Ⅰ - A	Ab
12	Berantala	Ditto	A3	Ditto	Ⅱ	A3 - Ⅱ	506	Protected Dug Well	Ⅲ	C	Ⅲ - C	D
13	Tanandava	Ditto	A3	Ditto	Ⅱ	A3 - Ⅱ	620	Canal	Ⅰ	C	Ⅰ - C	Ca
14	Antsakoabe	Ditto	A3	Ditto	Ⅱ	A3 - Ⅱ	800	Canal	Ⅰ	B	Ⅰ - B	Ab
15	Talatavalo	-Moderately productive aquifer of the Neritic sediments of the Upper Eocene. -6" Borehole 200m (100 l/min)	B2	Ditto	Ⅱ	B2 - Ⅱ	642	Canal	Ⅱ	C	Ⅱ - C	Ca
16	Ambiky	Ditto	B2	Ditto	Ⅱ	B2 - Ⅱ	1,360	Dug Well River	Ⅰ	A	Ⅰ - A	Bb

Table 8. Priority Order of Candidate Villages (2)

No	Village Name	Potential for Groundwater Development (Natural Conditions)					Social and Economic Conditions					Comprehensive priority for groundwater development
		Availability of Groundwater (in terms of quantity/quality)		Accessibility/Conditions for Construction Activities		Potential for Groundwater Development	Population	Existing Water Source	Community Needs	Community Capacity and Potential	Social and Economic Potential	
17	Marovato	Ditto	B2	Ditto	II	B2 - II	375	Unprotected Spring	III	B	III - B	D
18	Andranoboka	Ditto	B2	Ditto	II	B2 - II	600	Dug Well Canal	III	B	III - B	D
19	Satrambondro	Ditto	B2	Very poor/poor particularly in wet season	III	B2 - III	0	–	–	–	–	–
20	Mahavozokely	Ditto	B2	Ditto	III	B2 - III	0	–	–	–	–	–
21	Antranosatra	Ditto	B2	Generally good but poor in wet season	II	B2 - II	570	Dug Well	II	C	II - C	Ca
22	Manoy	-Drilled depth 42m (4"). -pumping rate 280 (-309)l/min. SWL 8.37m, DWL 29.53m, EC 1.600 μs/cm, pH 7.0.	A2	Ditto	II	A2 - II	540	Protected Dug Well	I	A	I - A	Aa
23	Ampoza	-Drilled depth 50m(4"). -pumping rate 283(-310)l/min. SWL 5.28m, DWL 15.20m, EC 440 μs/cm, pH 7.2.	A2	Ditto	II	A2 - II	700	Dug Well	II	B	II - B	Bb
24	Ankilifolo(2)	6" Borehole 50m (250 l/min)	A2	Ditto	II	A2 - II	450	Dug Well	III	C	III - C	D
25	Sihanaka	-Drilled depth 41m (4"). -P/Rate 300(-307)l/min, SWL 5.74m, DWL 7.8m, EC 350 μs/cm, pH 7.6.	A2	Ditto	II	A2 - II	700	Dug Well	I	B	I - B	Ab
26	Bemoka	Difficult site for G/Water development due to poor water quality.	D	Very poor all year round	III	D - III	–	–	–	–	–	–
27	Basibasy	-Drilled depth 83.0m (4"). -P/Rate 201(-222)l/min, SWL 14.49m, DWL 44.27m, EC 2,740 μs/cm, Salty taste.	D	Poor in wet season	II	D - II	1,000	Canal	I	B	I - B	D
28	Analatelo	-Drilled depth 35m (4"). -P/Rate 301(-321)l/min. SWL 3.18m, DWL 3.24m, EC 362 μs/cm, pH 7.4.	A2	Ditto	II	A2 - II	400	Dug Well	II	B	II - B	Completed
29	Mangotroka	-Drilled depth 41m (4"). -P/Rate 336 l/min. SWL 3.57m, DWL 5.29m, EC 145 μs/cm, pH 7.2.	A2	Ditto	II	A2 - II	600	Dug Well	I	B	I - B	Ab
30	Nosy-Ambositra	-Highly productive aquifer of porous limestone. -6" Borehole 50m (350 l/min).	A2	Very poor all year round	III	A2 - III	1,000	Canal	I	B	I - B	Cb
31	Tsiarmpioke	Ditto	A2	Ditto	III	A2 - III	800	River	II	C	II - C	Cb
32	Betaratsy	-Highly productive aquifer of Isalo III F. -6" Borehole 150m (300 l/min).	A3	Ditto	III	A3 - III	–	–	–	–	–	–

Table 8. Priority Order of Candidate Villages (3)

No	Village Name	Potential for Groundwater Development (Natural Conditions)					Social and Economic Conditions					Comprehensive priority for groundwater development
		Availability of Groundwater (in terms of quantity/quality)		Accessibility/Conditions for Construction Activities		Potential for Groundwater Development	Population	Existing Water Source	Community Needs	Community Capacity and Potential	Social and Economic Potential	
33	Andranomanintsy	Ditto	A3	Poor in wet season	II	A3 - II	780	Dug Well	II	C	II - C	Ca
34	Tandrano	-Drilled depth 150m(6"). -P/Rate 300(-860) l/min, SWL 32.72m DWL 39.52m, EC 400 μs/cm, pH 7.1	A3	Ditto	II	A3 - II	3,500	River Dug Well	I	A	I - A	Ab
35	Ampandramitsetaky	-6" Borehole 150m (300 l/min).	A3	Ditto	II	A3 - II	800	Unprotected Spring	I	B	I - B	Ab
36	Andranomafana	-Moderately productive aquifer in Isalo III² F. -6" Borehole 100m (120 l/min).	B1	Very poor all year round	III	B1 - III	600	River	III	B	III - B	D
37	Mamakiala	Ditto	B1	Ditto	III	B1 - III	300	River	III	B	III - B	D
38	Berenty-Ankilimasy	Ditto	B1	Ditto	III	B1 - III	108	Dug Well	III	C	III - C	D
39	Betsinefo	Ditto	B1	Poor in wet season	II	B1 - II	34	River	III	C	III - C	D
40	Tanandava	Ditto	B1	Ditto	II	B1 - II	400	Dug Well River	I	B	I - B	Ba
41	Ampoza	-Highly productive aquifer of Isalo III² F. -6" Borehole 150m (250 l/min).	A3	Ditto	II	A3 - II	320	River	II	C	II - C	Ca
42	Ipetsa Atm	-Highly productive aquifer of Isalo II F. -6" Borehole 150m (250 l/min).	A3	Ditto	II	A3 - II	120	River	II	C	II - C	Ca
43	Mondabe Atm	-Local aquifer in river bed. -Dug well (5~10m depth).	C	Very poor in wet season	II	C - II	100	River	III	C	III - C	D
44	Soatanimbary	Ditto	C	Ditto	II	C - II	70	Dug Well River	III	C	III - C	D
45	Sahanory Atn	Ditto	C	Ditto	II	C - II	200	Dug Well River	III	C	III - C	D
46	Berenty-Betsileo	-Drilled depth 140m(6") 30(~60) l/min, EC 2,300 us/cm -Dug well (5m)(500 l/min).	(A3) A1	Ditto	II	A1 - II	2,340	River	I	A	I - A	Aa
47	Ankilivalokely	-Highly productive aquifer of Isal II F. -6" Borehole 200m (200 l/min).	A3	Ditto	II	A3 - II	1,230	River	I	A	I - A	Ab
48	Ilemby	Ditto	A3	Very poor all year round	III	A3 - III	–	–	–	–	–	–

Table 8. Priority Order of Candidate Villages (4)

No	Village Name	Potential for Groundwater Development (Natural Conditions)					Social and Economic Conditions					Comprehensive priority for groundwater development
		Availability of Groundwater (in terms of quantity/quality)		Accessibility/Conditions for Construction Activities		Potential for Groundwater Development	Population	Existing Water Source	Community Needs	Community Capacity and Potential	Social and Economic Potential	
49	Tanandava-Antaifasy	-Highly productive aquifer of Isalo II F. -6" Borehole 100m (200 l/min).	A2	Poor in wet season	II	A2 - II	2,010	Dug Well River	I	A	I - A	Aa
50	Anjamitikitra	Ditto	A2	Ditto	III	A2 - III	0	–	–	–	–	–
51	Anaviary	Ditto	A2	Very poor all year round	III	A2 - III	–	–	–	–	–	–
52	Soahazo	-Drilled depth 76m(4"). -P/Rate 130(-293) l/min, SWL 36.17m DWL 37.25m, EC 1,040 μs/cm, pH 7.3.	A2	Generally good but poor in wet season	II	A2 - II	2,837	Dug Well	I	A	I - A	Aa
53	Analamisampy	-Drilled depth 71m(4"). -P/Rate 30(-39) l/min, SWL 3.11m DWL 23.30m, EC 1,400 μs/cm, pH 7.0.	A2	Ditto	II	A2 - II	756	Well with Hand punp	I	A	I - A	Aa
54	Belitsaka	-Drilled depth 66m(4"). -P/Rate 200(-270) l/min, SWL 12.78m DWL 24.13m, EL 2,050 μs/cm, pH 7.0	A2	Ditto	II	A2 - II	1,315	Protected Dug Well	I	A	I - A	Aa
55	Ampasikibo	-Drilled depth 50m(4"). -P/Rate 280 l/min, SWL 9.16m DWL 18.12m, EC 840 μs/cm, pH 7.0.	A2	Ditto	II	A2 - II	2,000	Well with Hand punp	I	A	I - A	Aa
56	Namaboha	-Drilled depth 83m(4"). -P/Rate 250(-268) l/min, SWL 16.50m DWL 33.17m, EC 990 μs/cm, pH 7.1.	A2	Ditto	II	A2 - II	1,505	Dug Well	I	A	I - A	Aa
57	Antseva	-Productive aquifer of the Upper Eocene (Neritic Sed). -4" Borehole 70m (200 l/min).	A2	Ditto	II	A2 - II	800	Protected Dug Well	II	B	II - B	Bb
58	Ankatrakatra	Ditto	A2	Ditto	II	A2 - II	460	Dug Well	I	B	I - B	Ab
59	Ampihamy	-Drilled depth 53m(4"). -P/Rate 296(-315) l/min, SWL 8.30m DWL 15.33m, EC 996 μs/cm, pH 7.2.	A2	Ditto	II	A2 - II	1,468	Dug Well	II	A	II - A	Ba
60	Ambondro	-Productive aquifer of the Upper Eocene (Neritic Sed). -4" Borehole 50m (200 l/min).	A2	Very poor all year round	III	A2 - III	1,000	Canal	II	B	II - B	Ba
61	Beroroha	Ditto	A2	Very poor in wet season	II	A2 - II	2,270	Canal	I	B	I - B	Ab
62	Antsomarify	Ditto	A2	Ditto	II	A2 - II	1,200	Canal	II	B	II - B	Bb
63	Manombo-Atm	-Drilled depth 27m(6"). -P/Rate 420 l/min, SWL 4.53m DWL 5.53m, EC 1,000 μs/cm, pH 7.2.	A2	Ditto	II	A2 - II	5,000	Protected Dug Well	I	A	I - A	Aa
64	Antandroka	-Productive aquifer of the Upper Eocene (Neritic Sed). -4" Borehole 50m (200 l/min).	A2	Very poor all year round	II	A2 - II	700	Dug Well	I	C	I - C	Ca

Table 8. Priority Order of Candidate Villages (5)

No	Village Name	Potential for Groundwater Development (Natural Conditions)					Social and Economic Conditions					Comprehensive priority for groundwater development
		Availability of Groundwater (in terms of quantity/quality)		Accessibility/Conditions for Construction Activities		Potential for Groundwater Development	Population	Existing Water Source	Community Needs	Community Capacity and Potential	Social and Economic Potential	
65	Ankaraobato	-Drilled depth 75.5m(4") -P/Rate 345(450) l/min, SWL 4.30m DWL 12.30m, EC 670 μs/cm.	A2	Generally good but poor in wet season	Ⅱ	A2 - Ⅱ	1,850	Canal	Ⅱ	A	Ⅱ - A	Ba
66	Andoharano	-Highly productive aquifer of limestone -4" Borehole 50m (350 l/min).	A2	Poor in wet season	Ⅱ	A2 - Ⅱ	300	Canal	Ⅲ	C	Ⅲ - C	D
67	Tsefanoka	-Drilled depth 45m(4") -P/Rate 280 l/min, SWL 24.30m DWL 30.40m, EC 802 μs/cm, pH 7.2.	A2	Ditto	Ⅱ	A2 - Ⅱ	880	Canal	Ⅰ	C	Ⅰ - C	Bb
68	Benetsy	-Drilled depth 72m(6") -P/Rate 300 l/min, SWL 13.51m DWL 17.51m, EC 977 μs/cm, pH 7.4.	A2	Generally good but poor in wet season	Ⅱ	A2 - Ⅱ	2,000	Protected Dug Well	Ⅰ	A	Ⅰ - A	Aa
69	Andrevo	-Local aquifer in the coastal area (poor W/Q) -Dug well (5~10m depth).	C	Ditto	Ⅱ	C - Ⅱ	2,200	Canal Dug Well	Ⅱ	B	Ⅱ - B	Ca
70	Anjamala	-Highly productive aquifer of porous limestone -4" Borehole 50m (300 l/min).	A2	Very poor all year round	Ⅲ	A2 - Ⅲ	150	River	Ⅲ	C	Ⅲ - C	D
71	Ampihalia	Ditto	A2	Ditto	Ⅲ	A2 - Ⅲ	1,000	Canal	Ⅱ	B	Ⅱ - B	Cb
72	Behompy	Ditto	A2	Ditto	Ⅲ	A2 - Ⅲ	1,000	River	Ⅱ	B	Ⅱ - B	Cb
73	Ambolonkira	-Highly productive aquifer of porous limestone. -4" Borehole 50m (300 l/min).	A2	Ditto	Ⅲ	A2 - Ⅲ	450	River	Ⅱ	B	Ⅱ - B	Cb
74	miary	Ditto	A2	Generally good	Ⅰ	A2 - Ⅰ	2,000	JIRAMA'S Public Hyd	Ⅲ	B	Ⅲ - B	D
75	Befanamy	Ditto	A2	Ditto	Ⅰ	A2 - Ⅰ	700	JIRAMA'S Public Hyd	Ⅲ	B	Ⅲ - B	D
76	Tsivonoabe	-Local aquifer in the coastal area (poor W/Quality) -Dug Well (5~10m depth).	C	Ditto	Ⅰ	C - Ⅰ	30	Dug Well	Ⅲ	C	Ⅲ - C	D
77	Andranovory	-Moderately productive aquifer of fissured basalt. -6" Borehole 150m (150 l/min).	B2	Good/Excellent	Ⅰ	B2 - Ⅰ	3,000	Water vendor Rain water	Ⅰ	A	Ⅰ - A	Aa
78	Befoly	-Drilled depth 226.5m -P/Rate 110 l/min, SWL 178.56m, EC 403 μs/cm -6" Borehole 250m(200 l/min).	A3	Ditto	Ⅰ	A3 - Ⅰ	864	Water vendor Rain water	Ⅰ	B	Ⅰ - B	Ab
79	Ankororoka	-Productive aquifer of fissured limestone. -6" Borehole 250m (200 l/min).	A3	Ditto	Ⅰ	A3 - Ⅰ	100	Water vendor Rain water	Ⅱ	C	Ⅱ - C	Ca
80	Ambohimaha-Velona	-Highly productive aquifer of porous limestone. -Existing much spring water.	A2	Very poor in wet season	Ⅱ	A2 - Ⅱ	2,000	Spring	Ⅲ	B	Ⅲ - B	D

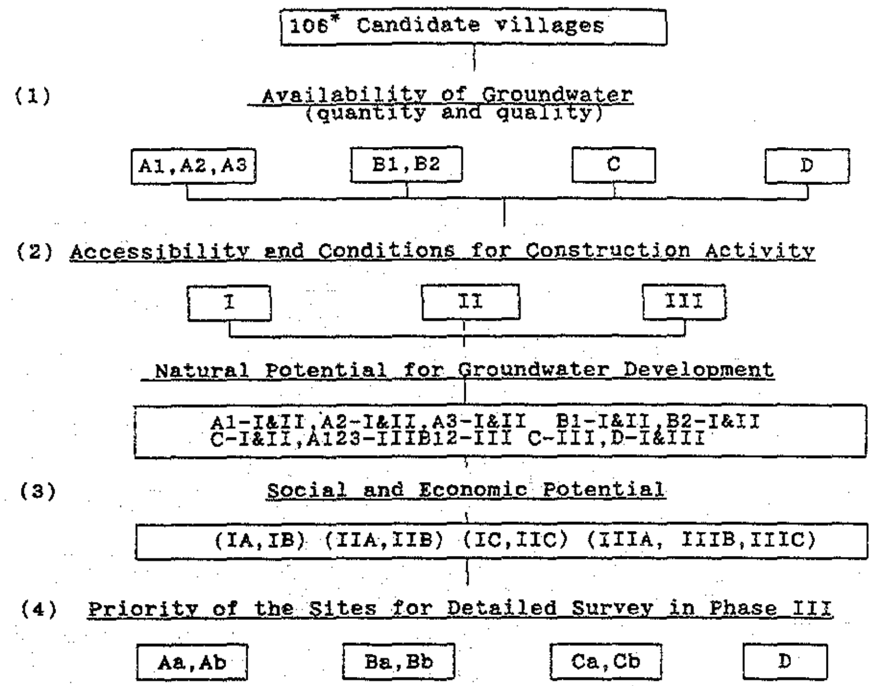
Table 8. Priority Order of Candidate Villages (6)

No	Village Name	Potential for Groundwater Development (Natural Conditions)					Social and Economic Conditions					Comprehensive priority for groundwater development
		Availability of Groundwater (in terms of quantity/quality)		Accessibility/Conditions for Construction Activities		Potential for Groundwater Development	Population	Existing Water Source	Community Needs	Community Capacity and Potential	Social and Economic Potential	
81	Manoroka	-Drilled depth 58m(4"). -P/Rate more than 300 l/min, SWL 5.25m, DWL 5.25m(s:0m), EC 1,150 μs/cm	A2	Ditto	II	A2 - II	1,000	Protected Dug Well	II	B	II - B	Bb
82	Laborana	-Productive aquifer of Isalo II F. -6" Borehole 200m (200 l/min).	A3	Poor in wet season	II	A3 - II	240	Protected Dug Well	I	C	I - C	Ca
83	Andranolava	-Highly productive aquifer of Isalo II F. 4" Borehole 100m(250 l/min).	A2	Very poor in wet season	II	A2 - II	1,500	River	I	B	I - B	Ab
84	Lambomakandro	Ditto	A2	Ditto	II	A2 - II	200	Dug Well River	II	C	II - C	Ca
85	Besakoa(1)	Ditto	A2	Ditto	II	A2 - II	0	–	–	–	–	–
86	Besakoa(2)	Ditto	A2	Poor in wet season	II	A2 - II	1,200	Dug Well	II	B	II - B	Bb
87	Ampandra	Ditto	A2	Good/Excellent	I	A2 - I	0	–	–	–	–	–
88	Maninday	-Drilled depth 73.50(6"). -P/Rate 360(-480) l/min, SWL 16.37m, DWL 24.56m, EC 110 μs/cm.	A2	Ditto	I	A2 - I	700	Canal	II	B	II - B	Bb
89	Bevoalavo	-Highly productive aquifer in the river bed. -Dug Well (10m depth).	A1	Very poor in wet season	III	A1 - III	240	Dug Well	III	C	III - C	D
90	Tanambao	Ditto	A1	Poor in wet season	II	A1 - II	800	Dug Well River	II	B	II - B	Bb
91	Ambahimalitsy	Ditto	A1	Ditto	II	A1 - II	800	River	II	C	II - C	Ca
92	Mahaboboka	-Ditto -6" Borehole 30m (300 l/min)	A1	Good/Excellent	I	A1 - I	2,000	Dug Well River	I	A	I - A	Aa
93	Mahasoa	-Moderately productive aquifer in fissured basalt. -6" Borehole 150m (100 l/min)	B2	Ditto	I	B2 - I	30	River	III	C	III - C	D
94	Andamasiny-Vineta	Ditto	B2	Ditto	I	B2 - I	550	River	I	B	I - B	Bb
95	Tranokaky	-Drilled depth 181m(6") -P/Rate 110 l/min. SWL 16.24m, DWL , EC 970 μs/cm.	B2	Ditto	I	B2 - I	1,180	Water vendor Hand pump	I	A	I - A	Completed
96	Analamary	-Drilled depth 204m(6") -P/Rate 360(-720) l/min, SWL 39.0m, DWL 47.68m, EC 270 μs/cm, pH 6.4	A2	Poor in wet season	II	A2 - II	1,000	Canal	I	B	I - B	Ab

Table 8. Priority Order of Candidate Villages (7)

No	Village Name	Potential for Groundwater Development (Natural Conditions)					Social and Economic Conditions					Comprehensive priority for groundwater development
		Availability of Groundwater (in terms of quantity/quality)		Accessibility/Conditions for Construction Activities		Potential for Groundwater Development	Population	Existing Water Source	Community Needs	Community Capacity and Potential	Social and Economic Potential	
97	Antanimora	-Highly productive aquifer of Isalo II F. -6" Borehole 150m (250 l/min).	A3	Ditto	II	A3 - II	300	Dug Well	III	C	III - C	D
98	Bereketa	-Highly productive aquifer in the river bed. -4" Borehole 50m (250 l/min).	A1	Ditto	II	A1 - II	500	Dug Well River	II	B	II - B	Bb
99	Ankilimitraloka	-Local aquifer -Dug Well (10m depth)	C	Ditto	II	C - II	800	River	II	B	II - B	Bb
100	Ankilivalo	-Highly productive aquifer of Isalo II F. -4" Boreholle 100m (250 l/min).	A2	Very poor all year round	III	A2 - III	2,000	Dug Well	II	B	II - B	Cb
101	Ankilimalinika	-Drilled depth 66m(4") -P/Rate 152(-155) l/min, SWL 14.35m, DWL 10.02m, EC 2,485 μs/cm, pH 7.5	A2	Poor in wet season	II	A2 - II	3,845	River and Dug well	I	A	I - A	Aa
a	Befandriana	-Drilled depth 53m(6") -P/Rate 300 l/min, SWL 12.39m, (S) 0.985m, EC 565 μs/cm, pH 7.2	A2	Poor in wet season	II	A2 - II	3,000	River	I	A	I - A	Aa
b	Betsioky Nord	-Borehole depth 90m, -P/Rate 144 l/min, (S)9.98m, SWL 59.35m, EC 2,800 μs/cm. -6" Borehole 150m (200 l/min).	A3	Ditto	II	A3 - II	2,000	Dug well	I	A	I - A	Aa
c	Andranohinaly	-Highly productive aquifer of limestone. -6" Borehole 250m (250 l/min).	A3	Good/Excellent	I	A3 - I	1,800	Water Vendor	I	A	I - A	Aa
d	Sakaraha	-Borehole depth 30.8m(6") -P/R 144 l/min, SWL 10.86m, (S)10.97m, EC 184 μs/cm. -6" Borehole 100m (300 l/min).	A2	Ditto	I	A2 - I	3,935	River and Dug well	I	A	I - A	Aa
e	Ankazoabo	-Borehole depth 27.25m(6"), -P/R 50 l/min, (S)1.08m, SWL 12.22m, EC 840 μs/cm. -6" Borehole 100m (150 l/min).	B1	Poor in wet season	II	B1 - II	3,000	Dug well and Canal	I	A	I - A	Aa

The process and details of criteria are as follows.



* Including 5 candidate villages for rehabilitation survey and one additional site (Ankilimalinika(101)) which was proposed by MIEM.

< Criteria >

1. Availability of groundwater

A1 : Existence of highly productive aquifer is expected at a depth of less than 20 m

A2 : Existence of highly productive aquifer is expected between 20 m and 100 m

A3 : Existence of highly productive aquifer is expected between 100 m and 250 m

(A1–A3) Expected pumping discharge: more than 200 l/min.

B1 : Existence of moderately productive aquifer is expected at a depth of less than 100 m

B2 : Existence of moderately productive aquifer is expected between 100 m and 200 m

(B1–B2) Expected pumping discharge 50-200 l/min

C : Local and discontinuous aquifer exists within 20 m, including Herzberg's lens aquifer in coastal area.

D : No significant aquifer exists within 250 m (difficult site for groundwater development).

2. Accessibility

I : Excellent or good in both dry and rainy seasons

II : Generally good in dry season (II-1)
Poor in rainy season (II-2)
Very poor in rainy season (II-3)

III : Very poor in both dry and rainy seasons

3. Social and Economic Potential

This potential is evaluated based on the following viewpoints.

3.1 Need for safe water in terms of quality (taste, disease), quantity and distance

I ----- High
II -----Medium
III-----Low

3.2 Community's positive participation in maintaining the water supply facility, financially and institutionally

A ----- High
B ----- Medium
C ----- Low

4. Lay out of the priority criteria

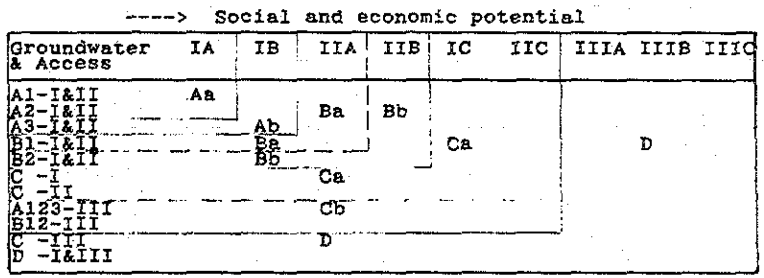


Fig. 17. Criteria and Procedure for Assigning Priority Order to Candidate Villages

8.3 Water Supply System

Detailed survey was conducted in 91 accessible candidate villages for water supply planning, and in 5 villages for rehabilitation survey. Monitoring results from pilot facilities are utilized profitably in order to consider the village's capacity for operation and maintenance.

8.3.1 Water Supply Planning Criteria

(1) Water supply district

In the Study Area, rural population tends to settle in a concentrated community, separated from others. Normally, the distance between communities is a few or several tens kilometers. A community is a few hundred square meters. Accordingly, a community can be identified as the unit water supply district.

(2) Beneficiary

Community residents are the primary beneficiaries of water supply, but cattle raised by the inhabitants is also taken into consideration as beneficiary. The population of a community is estimated by the number of existing houses, since reliable statistics are not available. The number of cattle is also estimated for the cattle kept in the community dwelling area or neighboring land.
Public institutions existing in the community are small in scale, and are not counted as beneficiaries.

(3) Level of service

Appropriate levels of service, adaptable to the community, will consist of two lower types.

- A single or a few water points, such as a well with a handpump or a motorized pump, without a distribution system

- A simple gravity distribution system with several public hydrants, supplied from a single water source.

(4) Population served and water consumption

Since the target year for the national rural water supply plan has been set as the year 2000, the design year for the water supply planning conforms to that year.

The population served in 2000 will be estimated based on the latest population data in 1990 or 1989, which was confirmed in the field survey, and projected using the national population growth rate (yearly 2.76%).

The cattle raised within the village dwelling area are, at most, several tens of heads, and their effect on the design of community water consumption is negligible. Water needs of cattle grazing on land surrounding the village are taken into consideration in separate supply systems for 13 villages, where no sufficient or convenient cattle watering places exist.

The actual daily per capita water consumption in the rural area is estimated as follows.

- Communities on road 7: 8-12 lcd (liters per capita per day)
- Communities on road 9: 10-15 lcd

- Community with pilot water supply facility: 10-15 lcd

An analysis of answers to interview questions gave the consumption pattern of 6-8 lcd for cooking and drinking, 0.5-1 lcd for personal hygiene, and 3.5-6 lcd for washing clothes. The national water consumption target of 20 lcd is, in this context, considered as a practical and appropriate value.
For cattle consumption, 16 -30 liters per head per day is used for the planning.

The water consumption in individual communities to be supplied by a new supply plan is estimated by the difference between the gross community water consumption and existing water sources.

8.3.2 Outline of the proposed water supply system

(1) Expected water supply plan

Sub-projects identifiable in the candidate villages to supply safe water will be classified into three categories as described below.

- Improvement of existing traditional water sources. A dug well, one of the most prevalent traditional water sources, can supply reasonably safe water when it is properly protected from contamination from surface ground.

- Deep tube well installation is the most popular type for modern rural water supply and widely applicable in the Study Area. In this type of project, sufficient attention must be given to the post-investment maintenance. A community which is looking forward to something better than subsistence, and many villages in the Study Area fall into this category, deserves to introduce this type of water supply instead of dug well-based water supply.

- Comprehensive regional water supply system

This system for more than ten communities is considered in certain areas where no dependable water source is available. For instance, the long area along road 7 between Tranokaky and Toliara would be the case (population : 23,000). Also Basibasy and 12 small communities on the 32 km road between Analatelo 28 and Basibasy 27 can be provided with safe water if a transfer main is installed from Analatelo to Basibasy (total population : 6,000).

In this study, however, the planning concentrates on tube well projects. For the dug well projects, the necessary technical recommendation is to be prepared for executing projects with self-help efforts of beneficiary communities.

(2) Adaptable water supply facility or system

The water supply facility or system adaptable to the candidate villages are determined depending mostly on water tables and the scale of beneficiary community. The adaptable facility or system is shown in the following Table.

Table 9. Adaptable Water Supply Facilities

Facility	Supply	Installation	Application	Symbol
Protected dug well or infiltration gallery	Well	New or modification	- Shallow groundwater or underflow - Small village in remote place	WP
Tube well with handpump	Handpump	New	- Shallow groundwater - Concentrated population (200-800)	W.HP
Tube well with motorized pump and simple distribution	Public hydrant	New	- Deep groundwater - concentrated population (500-2000)	W.HP
- do -	- do -	Modification of pilot facility	- Village with pilot facility	MP
- do -	- do -	Rehabilitation and extension of existing facilities	- Village with rehabilitation survey	W.MP .RH
Community Water work	- do -	New	- Only for Berenty-Betsileo	W.W
Separate cattle watering	Watering place	New	- Village with water shortage for cattle	C.T

Berenty-Betsileo is a large community in a remote place, and a test boring carried out during this study has confirmed that the groundwater is salty, to the extent of being unsuitable for drinking. The only alternative is to pump up underflow water that is collected in a shallow well located near the river shore.

8.3.3 Approach to operation and maintenance system

1) Findings through the operation and maintenance of pilot water supply facilities

Prior to the completion of works for the rehabilitation and 19-pilot facilities, preparation of community-level (user-level) organization for the operation and maintenance of the facilities has started. An organization of community members for the purpose has been developed step by step through some meetings (kick off, action plan) held between representatives from each village and those representity the MIEM Toliara office and the Survey team.

The proposed maintenance system for pilot facilities consists of the following:

- user side : a water committee and care-takers
- back up side : MIEM (Toliara)

During these meetings, essential issues with respect to operation, maintenance and management system were discussed and adopted.

- Beneficiaries sharing the costs and labor services
- Spare parts control
- Recording and regular patrol for preventive maintenance

Findings through those activities are summarized below.

<u>Community side</u>

- A willingness to pay for the recurrent cost is clearly indicated by the village people. A positive approach to self-help schemes for the maintenance of the facility is recognized.

- Lack of technician or skilled worker, although doubtlessly important, can be overcome with proper communication and coordination with the back-up organization.

- Almost all water committes are organized based on the existing community hierarchy. A positive community participation is indicated by a strong custom to gather community members' opinions whenever new issues are to be decided. However, one weakness that should be urgently addressed was the absence of women in those community meetings organized to set up the village water committee. Women should have protogenic roles in matters concerning water supply, given the fact that women and children shoulder the bulk of the heavy task of securing water for the family.

Supporting side (MIEM, Toliara)

- The branch does not have sufficient staff. Transportation means and equipment/tools required for the support service are not enough.

- In order to provide technical services, particularly to remote rural communities, strengthening of the branch is urgently required.

Besides, means to manage the collected money and logistic problems concerning acquisition of fuel oil and spare parts are both indirect but important problems for operation and maintenance.

(2) Approach to a new maintenance system

The only way to establish a workable maintenance system tailored to meet actual conditions of the Study Area will be to start a trial system for the pilot water supply facility, and then make adjustments as the results dictate, expanding it according to a set timetable if specified results are achieved. On the other hand, MIEM (Toliara) should test the soundness of the approach with monitoring, analyzing and appraising the operational results of the pilot supply facilities.

There is no particularly difficult problem for the community-oriented self-help scheme in operating and maintaining the community water supply system. MIEM (Toliara) branch, for the time being, must assume the responsibility for training local care-takers and for providing technical services and logistic support before required local organization can improve its ability. Accordingly, strengthening its management ability, technical capacity and equipment/tools availability is most urgently required.

In a long-term prospect, rural community water supply facilities will steadily increase, thereby expanding technical services demanded from MIEM. Then, the maintenance system, with MIEM (Toliara) providing the main support activity, would become a rather questionable system. The right course for the long term building of a real workable support system in the area would be strengthening of the middle-level local administrative offices, such as FIVON-DRONANA and FIRAISAM-POKONTANY offices to the extent that they can back up beneficiary communities. Putting a new "water section" in their organization would be the first step, and start to support handpump-based supply facilities would be the second step.

The following figure illustrates a proposed development plan for the overall operation and maintenance system.

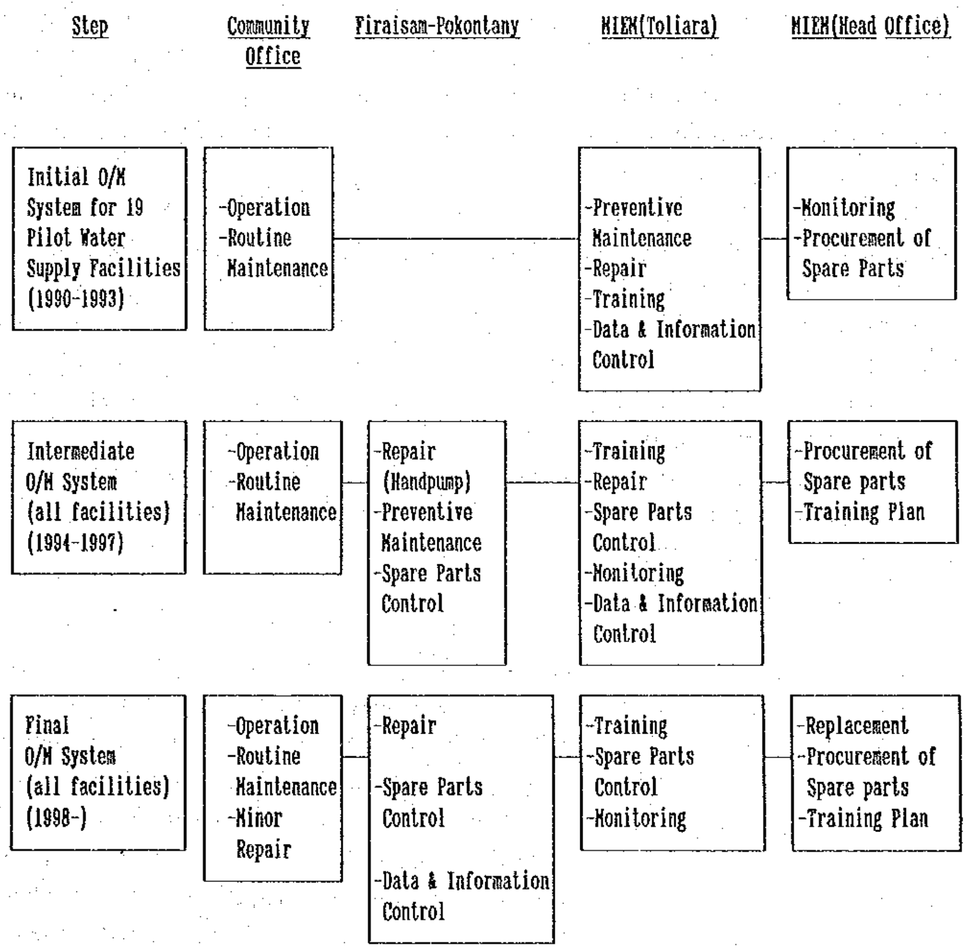


Fig. 18. Proposed Development Plan for Operation and Maintenance

8.3.4 Monitoring of Operation and Maintenance

Once the pilot facilities were in operation, the Study Team took every opportunity to observe real performance of the equipments and the maintenance practice by villages and MIEM(Toliara Office). Table 10 shows status of pilot water supply facilities in March 1991.

In short, as of late March 1991, the handpump (total 16 units) are not considered as completely satisfactory since troubles which began arising in December 1990, still remain to be solved. Handpumps have been observed to be affected by considerable mechanical troubles. The common defect of the locally manufactured handpump is poor check mechanism against downward leak of water column in the riser main through the piston and foot valve.

On the other hand, no problem has been observed in the 3-motorized pumping systems, not because of successful maintenance efforts, but thanks rather to strong and reliable mechanism in the pump and engine-generator. However, it should be pointed out that the three motorized pumping systems have been operated for a short period, each with less than 200 hours.

The potentiality of a solar pump system was evaluated based on the performance of the pilot facility up to now, as discussed in Supporting Report(1).

Water consumption was measured at the pilot facility in Tranokaky in November 1990 and March 1991 in order to estimate water demand. Total water consumption volumes were 16,000 l/day and 15,200 l/day on 10 and 11 November 1990, respectively. Based on these amounts and the estimated number of people, per capita water consumption is calculated as 6 and 16 l.day/person for Mahatsa and all Tranokaky, respectively. The storage tank of this system is designed for 16 cubic meters, and a full tank can satisfy one-day consumption.

In march 1991, after the rainy season, water consumption drastically decreased in reference to November 1990. Pump was operated every other day, and a half tank(8 m3/day) was enough for their consumption. Interviews with villagers show their increased dependence on traditional water sources like dug wells and/or rainfall water stored during the rainy season.

Since the same outcome was observed in Soahazo, water consumption appears to depend on such factors as season, i.e., rainfall amount, water level of the dug well and villagers perception of sanitation and drinking water quality.

Availability of appropriate water sources is expected to accelerate the change of their water utilization pattern from traditional to improved sources. Accordingly, a design water consumption of 20 lcd is deemed appropriate for water supply planning.

Table 10. Status of 19-Pilot Water Supply Facilities (1)

Village	Pump	Status Dec. 1990	Findings in Mar. 1991
Befandriana	Motorized Pump	Working	Working; 155 Hrs operation; periodic patrols by MIEM are continued; good O/M data recording.
52 Soahazo	Motorized pump by Solar battery	Working	Working; Back up engine generator is scarcely used, periodic patrols by MIEM are continued; good O/M data recording.
95 Tranokaky	Motorized pump	Working	Working; No O/M data recording due MIEM patrol, trouble may occur any day.
23 Ampoza	Local Handpump	Working	Working; No patrol by MIEM; around 10 to 20 idle swings (empty cycles) are required after interrupting operation for several ten seconds; probable cause is foot valve leakage
22 Manoy	Local Handpump	Working	Ditto
29 Mangotroka	Local Handpump	Working	Ditto
25 Sihanaka	Local Handpump	Working	Working; no patrol by MIEM; villagers have opened the pump casing without any consultation with MIEM; 3-fixing bolt/nuts on the casing are lost.
54 Belitsaka	Jap. Handpump	Working	Working; No patrol by MIEM; Touch-up painting on the pump casing is required.
53 Analamisampy	Jap. Handpump	Working	Working; No patrol by MIEM.

Table 10. Status of 19-Pilot Water Supply Facilities (2)

Village	Pump	Status on Dec. 1990	Findings in Mar. 1991
101 Ankilimali -nika	Local Handpump	Working	Working; No patrol by MIEM.
68 Benetsy	Local Handpump	Out of order	Out of order since Dec. 1990; MIEM was informed but did not repair it; Probable cause of trouble may be the piston.
59 Ampihamy	Local Handpump	Out of order	Out of order since Dec. 1990; MIEM was informed and took off the piston to repair, but no result until now.
56 Namaboha	Jap. Handpump	Working	Working; No patrol by MIEM; Touch-up painting is required
55 Ampasikibo	Jap. Handpump	Working	Ditto
63 Manombo	Local Handpump	Out of order	Out of order; No action by MIEM.
96 Analamary	Local Handpump	Working but extraordinary force is required due to pump internal friction.	Still working with same difficulty, no action and no improvement.
81 Manoroka	Local Handpump	Working	Working; no patrol by MIEM; touch-up concrete work is required on the foundation.
28 Analatelo	Jap. Handpump	Working	Working; no patrol by MIEM.
27 Basibasy	Local Handpump	Out of order	Could not reach it, but it is assumed to be still out of order without actual repair.

9. THE PROJECT

9.1 Groundwater Development Plan

As stated in previous sections, the potential for groundwater development in the Study Area is generally high, except some poor areas due to their hydrogeological conditions and water quality. Groundwater is an important and a limited resource in this area, where annual rainfall of 400-800 mm makes it the driest area in Madagascar. Therefore, it is required to utilize this resource as efficiently as possible. From this viewpoint, the approach to develop groundwater is summarized as follows.

1) It is advantageous to employ handpump for lifting of groundwater from the viewpoint of construction cost, operation and maintenance and saving of discharge.
According to the results of yield investigation, 2 or 3 handpumps can be utilized simultaneously in the same village without causing drawdown.

2) When submersible motor pump is employed, it is necessary to keep a distance of more than 500 m between wells in order to avoid drawdown.

3) It is necessary to decide well location, depth and drilling method based on comprehensive hydrogeological analysis. Detailed hydrogeological structure is investigated by electric prospecting, after reviewing seasonal variation of groundwater level, water quality, yield and hydraulic information of existing wells.
The groundwater development potential indicated on the hydrogeological map, and the development scale described in the next sub-section are based on the above mentioned detailed research of local conditions.

4) Development of limestone plateau along route 7 requires 250-300 m of drilling because of low groundwater level at 170-220 m below ground surface. Additionally, the aquifer exists in the porous, fault and/or fracture zone in limestone, requiring the detailed research mentioned in 3) above.

5) It is necessary to consider water quality before the development, especialy in the area along route 9.
The problem of "salty water", caused by fossil salt water in dolomitic marl of marine deposit, exists within 30 m below ground surface. Therefore, deep drilling is required in order to get confined aquifer with good water quality, even for handpump equipped wells.

9.1.1 Aquifer and development scale

This subsection describes the general development scale of groundwater in each aquifer zone, as classified in the hydrogeological map, according to the groundwater potentiality.

(1) Class A1 aquifer zone

Aquifer is generally composed of unconsolidated sandy deposits of the Quaternary, such as river-bed deposit and sand dune deposit.
In this Class A1 aquifer zone, groundwater pumping at 250-600 l/min per well is expected in a borehole with a depth of 30-50 m and a diameter of 150 mm(6").

(2) Class A2 aquifer zone

This Class A2 aquifer zone is distributed in both the western region and the eastern region of the Study Area.
The Class A2 aquifer zone distributed in the western region is composed of neritic sediments of the Middle to the Upper Eocene, and divided into three(3) districts of Befandriana, Soahazo and Benetsy, based on detailed hydrogeological conditions.
From the results of the comprehensive analysis on hydrogeology, in particular the results of test drilling and pumping test, the following development scale of groundwater is expected in these districts.

a) Befandriana district

- Target depth and diameter of a borehole : 50 m, 100-150 mm
- Expected pumping discharge per borehole : 200-600 l/min

- Specific capacity of 5 test drillings in this district:
  23.03-304.57 l/min/m (average 142.60)

b) Soahazo district

- Target depth and diameter of a borehole : 50-100 m, 100-150 mm
- Expected pumping discharge per borehole : 200-360 l/min
- Specific capacity of 6 test drillings in this district :
  13.61-120.37 l/min/m (average 43.39)

c) Benetsy district

- Target depth and diameter of a borehole : 50-100 m, 100-150 mm
- Expected pumping discharge per borehole : 230-580 l/min
- Specific capacity of 4 test drillings in this district :
  46.56-115.70 l/min/m (average 82.92)

The Class A2 aquifer zone distributed in the eastern region of the Study Area is mainly composed of continental deposits of the Lower Jurassic, and the following development scale of groundwater is expected from the results of comprehensive analysis on hydrogeology.

- Target depth and diameter of a borehole : 70-100 m, 150 mm
- Expected pumping discharge per borehole : 300-600 l/min
- Specific capacity of 2 test drillings in this district :
  41.76-43.53 l/min/m (average 42.65)

(3) Class A3 aquifer zone

As shown in the hydrogeological map, the Class A3 aquifer zone is distributed in both the western region and eastern region of the Study Area, and its distribution pattern is similar to that of the Class A2 aquifer zone.

Hydrogeologically, the Class A3 aquifer zone distributed in the western region is divided into two districts of western side and eastern side of route 9.

The Class A3 aquifer zone in the western side district of route 9 is composed of neritic sediments of the Middle to the Upper Eocene, and groundwater pumping at 200-600 l/min per well is expected in a borehole with a depth of 100-200m and a diameter of 150 mm.
On the other hand, the Class A3 aquifer zone in the eastern side district of route 9 is mainly composed of porous or fissured limestone of the Lower to the Middle Eocene, and the following development scale of groundwater is expected from the results of comprehensive analysis on hydrogelogy. It is, however, strongly recommended to drill a borehole of more than 250 m for groundwater development in the area of limestone plateau along route 7.

- Target depth and diameter of a borehole : 150-250 m, 150 mm
- Expected pumping discharge per borehole : 200-600 l/min
- Specific capacity of 2 test drillings and 3 existing boreholes of JIRAMA at Miary :
  217.50-5,016.67 l/min/m (average 2,122.92)

The Class A3 aquifer zone distributed in the eastern region of the Study Area is composed of continental and neritic sediments of the Lower to the Middle Jurassic, and pumping discharge of 300-600 l/min per well is expected in a borehole with a depth of 120-200 m and a 150 mm diameter.

(4) Class B1 and B2 aquifer zone

The Class B1 aquifer zone is distributed in three districts of Sikily, Sakanavaka and Menamaty river basins, while the Class B2 aquifer zone is distributed mainly in four districts of Ambahikily of Mangoky River side, central part of Fiherenana River basin, Rezoky and Mangitraky River basins and Berenty-Betsileo of Isahena River basin.

Based on the results of comprehensive analysis on hydrogeology, in particular the results of geophysical prospecting, test drilling and pumping test, Table 10 shows the groundwater development scales which can be expected in those districts of the Class B1 and B2 aquifer zones.

Table 11. General Development Scale of Groundwater in Class B1 and B2 Aquifer Zones

Class	District	Aquifer	Expected P/Discharge per a borehole	Target depth & diameter of borehole	
				Depth	Diameter
			l/min	m	mm
B_1	Sikily River basin	Neritic or submarine sediments of the Lower to Upper Cretaceous with basaltic rocks.	80-120	100	150
B_1	Sakanavaka River basin	Neritic & continental sediments of the Middle Jurassic.	80-120	100	150
B_1	Menamaty River basin	Continental deposits of the Lower Jurassic with Schistose sandstone.	50-100	100	150
B_2	Ambahikily of Mangoky River side	Neritic Sediments of the Middle to Upper Eocene.	80-150	200	150
B_2	Central part of Fiherenana River basin	Neritic or submarine sediments of the Lower to Upper Cretaceous with basaltic rocks.	80-120	150-200	150
B_2	Rezoky and Mangitraky River basins	Neritic & continental sediments of the Middle Jurassic.	80-120	150-200	150
B_2	Berenty-Betsileo of Isahena River basin	Neritic & continental sediments of the Lower Jurassic.	50-100	150-200	150

(5) Class C aquifer zone

In the Class C aquifer zone, local and discontinuous aquifer exists at less than 20 m in depth, including Herzberg's lens aquifer in the coastal area. Therefore, for groundwater development in Class C aquifer zone, it is recommended to dig protected shallow wells with a depth of 5-15 m.

9.1.2 Standard Drilling Method and Well Design

(1) Standard drilling method

The two drilling methods which were used in this study consisted of mud drilling and air hammer drilling.
Judging from the results of test drillings, in the area which is mainly composed of limestone or basaltic rocks, the air hammer drilling method is strongly recommended because of the speed of drilling works and to avoid troubles of frequently lost circulations.
On the other hand, in the areas consisting of sandstone, such as neritic sediments of the Middle to Upper Eocene, neritic or submarine sediments of the Lower to Upper Cretaceous and continental or neritic sediments of the Lower to Middle Jurassic, the mud drilling method is principally recommended.

(2) Standard tubewell design

a) Target depth and diameter of wells

The target depth of 6" diameter wells is 30-250 m and that of 4" diameter wells is 40-100m. This well drilling plan was made mainly on the basis of hydrogeological conditions obtained from the results of test drilling and electrical prospecting, as well as the population in each candidate site.

b) Logging

In order to identify the aquifer and decide on the screen position and length, spontaneous logging, resistivity and natural gamma ray logging is carried out after the drilling.
During drilling, in particular in the case of mud drilling, drill cuttings must be carefully observed for a complete geologic log.
In the area which is composed of limestone or basaltic rocks, geophysical logging alone is generally ineffective in detecting aquifers and aquifuges. The air hammer drilling method is, therefore, recommended not only to avoid troubles of frequently lost circulations, but also to speed up drilling works and to decide on the accurate screen position and length.

c) Casing

FRP (Fiberglass Reinforced Plastic) pipe is recommended for well casing in both 4" and 6" diameter boreholes, mainly because of water quality.

d) Screen

FRP pipe is also recommended for well screen in both 4" and 6" diameter boreholes, with a 5% ratio of openings and a slot size of 1.0 mm (horizontal slot screen). Based on test drilling experience, screen positions are set at multiple layers, and total screen length is principally designed as follows.

Borehole depth (m)	Screen length (m)
30	16
40 - 50	20
60 - 100	24 - 32
110 - 250	32 - 40

e) Gravel packing

It is not always necessary to carry out a sieve analysis for the selection of packing gravel.
Around the screen, gravel of a grain size of 2-3 mm is empirically used as filter.

f) Well completion

In the completion of a filter-packed well, except for the screen area, the annulus of the well between the borehole wall and casing is backfilled with drill cuttings. Moreover, in the top 5 m from the surface of the ground, cement grout is placed for prevention of contamination.

(3) Protected dug well

Protected dug wells are proposed as a self-help construction scheme by the communities. These protected dug wells can be excavated by hand by villagers using picks and shovel. The well is permanently lined with a curb consisting of brick or rock. The curb should be perforated or contain openings for entry of water, and must be firmly seated at the bottom. Dug wells must be deep enough to be several ten centimeters below the water table. Ground should be backfilled around the curb lining and the bottom of the well to control sand entry and possible cave in. All materials and manpower required for the dug well construction would be contributed by villagers.

9.2 Water Supply Plan

9.2.1 Objective

The main objective of the Project is to provide a safe water supply to satisfy domestic and cattle watering needs in the proposed 94-communities up to the year 2000, when the total population in the communities is projected to be 154,000.

9.2.2 Approach to Planning

The approach adopted in formulating the Project follows the basic policy and criteria of this Study.

(1) Selection of deep groundwater as a safe water source

Until recently, water resource development efforts for rural population in Toliara Province, which have been sporadic and limited, focused on the utilization of shallow groundwater (less than 10 meters in depth).
However, shallow groundwater is not commonly available in the area and, in a large community, it hardly satisfies the water demand. Due to the limitations of shallow groundwater, a priority has been given on the development of deep groundwater, which is of better quality and comparatively plentiful in the area.

(2) Maximum convenience for users

In a rural water supply project, it is justifiable to employ plain and simple system as much as possible, in order to minimize capital investment and operation/maintenance costs, on consideration of the low income level and lack of trained technicians in the rural society.

(3) Alternative plan

Though the choice range for a rural water supply project in the Study Area is relatively restricted depending on availability of water resources and community potential and capacity, there are still a few important alternative considerations worthy to be examined in the planning stage. These include selection of proposed villages and the choice of equipments.

9.2.3 The Proposed Project

(1) Project description

The basic criteria for planning and design of the water supply project are summarized as follows.

- Design year	:	2000
- Water supply districts	:	the community, FOKONTANY or KOMITY regarded as a unit of water supply district.
- Beneficiary	:	All community residents and cattle kept in 13 villages
- Service level	:	Handpump and public hydrant
- Population served	:	Population in 2000 estimated from the present population with average yearly growth rate of 2.76% Cattle to be watered between 400 to 800 head per community (13 villages)
- Design daily water consumption	:	20 lcd for people 18 lhd for cattle

Separate water supply sub-projects for 94 candidate villages were prepared. Other candidate villages are left without planning because they are abandoned, non-accessible, or completly satisfied by pilot water supply facilities.

The following Table is a summary of project classification.

Table 12. Classification of Water Supply Plans

Classification		Type of project			
		Improvement	Handpump	Motor Pump	
Priority	Population	of dugwell		Existing	New
Aa	55,733	0	2	8	9
Ab	19,813	0	3	2	7
Ba	6,181	0	2	2	0
Bb	17,856	2	4	1	8
Sub-total	98,583	2	11	13	24
C	17,740	2	7	0	9
D	16,124	10	11	1	4
Sub-total	33,864	12	18	1	13
Total	132,447	14	29	14	37

Descriptions of 94 sub-projects are shown in Table 12.

(2) Water supply facilities

(a) Pump discharge rate

The discharge rate of a motorized pump is designed according to community daily water consumption and duration of pumping cycles of 6 hours. The discharge rate of a handpump is assumed as 4 m^3/day -7m^3/day.

The hourly peak load is designed based on 9 hours of daily water service period, and the ratio between peak load and average load (for 9 hours) is 1.4 to 1.0.
The capacity of the reservoir is planned based on the daily pumping hours increased by 3 hours. For standardization, one of 10, 15, 30, 40 m3 reservoirs is selected when needed.
The number of public hydrants will be decided based on the average capacity of the hydrant, i.e. 8m^3/day.

The equipment required for individual community water supply subprojects is listed in Table 13.

(b) Typical design

Typical installation pictures of handpump and motor pump are shown in Figures 19 and 20. Additionally, schematic drawings of typical water supply facilities with handpump and motor pump are shown in Fig 21.

Table 13. Description of Water Supply Subprojects by Village (1)

No	Village Name	Priority	Gross Water Consumption: Domestic Use (m3/Day)	Gross Water Consumption: Cattle Watering (m3/Day)	Gross Water Consumption: Total (m3/Day)	Existing Safe Water Supply (m3/Day)	Net Water Required (m3/Day)	Proposed Type of Facility	Schistoscolasis	Community Characteristic	Water Source Characteristic	Project Characteristic
8	Mangolovolo	Aa	39.0	—	39.0	—	39.0	W·HP	YES	Large village near main road	High water table	Well & motorized pump-based system
22	Manoy	Aa	14.0	7.0	21.0	4.0 (P)	17.0	W·HP-CT	NO	Medium, well off village, near main road	High water table, slightly turbid	Well with handpump, one for cattle watering
46	Berenty-Betsileo	Aa	61.0	—	61.0	—	61.0	WW	YES	Large, well off village in remote place, center of distribution	Salty groundwater, underflow water is more suitable for drinking water	Simple water work system including slow sand filtration
49	Tanandava-Antaifasy	Aa	53.0	—	53.0	—	53.0	W·HP	YES	Large village in remote place, center of distribution	High water table by confined aquifer, requires deep well	Well & motorized pump-based system, long distribution piping is required
52	Soeharo	Aa	74.0	14.0	88.0	20.0 (P)	68.0	HP-CT	NO	Large, well off village on road-9, commerce is developing	Shallow groundwater is salty	Replace solar pump with conventional pump system, wide distribution piping required
53	Analamisampy	Aa	20.0	7.0	27.0	4.0 7.0 (P)	16.0	W·HP-CT	NO	Medium, well off village on road-9, commerce is developing	High water table	Well with hand pump, one for cattle watering
54	Belitsaka	Aa	34.0	14.0	48.0	7.0 (P)	41.0	HP-CT	NO	Large, well off village on road-9, commerce is developing	High water table	Replace handpump system with motorized pump system
55	Ampasikito	Aa	52.0	14.0	66.0	4.0 7.0 (P)	55.0	HP-CT	NO	Large, well off village on road-9, commerce is developing	High water table	Replace handpump system with motorized pump system
56	Manamboha	Aa	39.0	14.0	53.0	7.0 (P)	46.0	HP-CT	NO	Large, well off village on road-9, commerce is developing	High water table by confined aquifer, requires deep well	Replace handpump system with motorized pump system
63	Manombo-Ata	Aa	122.0	—	122.0	4.0 (P)	118.0	HP	NO	Large, well off village in remote place, center of distribution and culture	High water table	Replace handpump with motorized pump system, wide distribution required
66	Benetsy	Aa	52.0	14.0	66.0	4.0 (P)	62.0	HP-CT	YES	Large, well off village on road-9, commerce is developing	High water table by confined aquifer, requires deep well	Replace handpump with motorized pump system; wide distribution piping required
77	Andranovory	Aa	40.0	—	40.0	—	40.0	W·HP	YES	Medium village on road-7, relies on water vendors	Very low water table	Well & motorized pump-based system
92	Mahaboboka	Aa	52.0	—	52.0	—	52.0	W·HP	YES	Large, well off village on road-7, commerce is developing	Very high water table	Well & motorized pump-based system; wide distribution piping requird
101	Ankilimalinika	Aa	101.0	14.0	115.0	4.0 (P)	111.0	HP-CT	NO	Large, well off village on road-9, commerce is developing	High water table, slightly salty	Replace handpump with motorized pump system, wide distribution required
a	Befandriana	Aa	79.0	—	79.0	24.0 (P)	55.0	HP-RH	NO	Large, well off village on road-9, commerce is developing	High water table	Expansion of capacity & distribution of existing system
b	Betsioky Nord	Aa	52.0	—	52.0	—	52.0	W·HP-RH	YES	Large village near road-9	Low water table, confined water, requires deep well	Rehabilitation including new well drilling & pumping system
c	Andranohinaly	Aa	47.0	—	47.0	—	47.0	W·HP-RH	NO	Medium, well off village on road-7, relies on water vendors	Very low water table	Rehabilitation, existing facility is useless
d	Sakaraha	Aa	103.0	—	103.0	—	103.0	W·HP-RH	YES	City on road-7	High water table by confined aquifer, requires deep well	Rehabilitation, large expansion in capacity and distribution is required
e	Ankazoabo	Aa	79.0	—	79.0	—	79.0	W·HP-RH	NO	City in remote place	High water table by confined aquifer, requires deep well	Rehabilitation, existing facility is useless
11	Andranomanintsy	Ab	37.0	—	37.0	—	37.0	W·HP	YES	Medium village near road-9, with promising farming	High water table by confined aquifer, requires deep well	Well & motorized pump-based system
14	Antsakoabe	Ab	21.0	14.0	35.0	—	35.0	W·HP-CT	YES	Medium village on road-9, with promising farming	High water table by confined aquifer, requires deep well	Well & motorized pump-based system
25	Sihanaka	Ab	18.0	—	18.0	4.0 (P)	14.0	W·HP	NO	Small village near road-9, with promising farming	Very high water table	Well with handpump
29	Mangotroka	Ab	16.0	—	16.0	4.0 (P)	12.0	W·HP	NO	Small village on road-9, with promising farming	Very high water table	Well with handpump
34	Tandrano	Ab	92.0	—	92.0	—	92.0	HP	YES	Large village in remote place, with promising farming	High water table by confined aquifer, requires deep well	Install motorized pump system on existing well
35	Ampandramitsetaky	Ab	21.0	—	21.0	—	21.0	W·HP	YES	Medium village in remote place, with promising farming	High water table by confined aquifer, requires deep well	Well & motorized pump-system
47	Ankilivalokely	Ab	32.0	—	32.0	—	32.0	W·HP	NO	Medium, well off village in remote place	High water table by confined aquifer, requires deep well	Well & motorized pump-system
68	Ankatrakatra	Ab	12.0	7.0	19.0	—	19.0	W·HP-CT	NO	Small, cattle breeding village, near road-9	High water table by confined aquifer, requires deep well	Well with handpump, one for cattle watering
81	Beroroha	Ab	59.0	—	59.0	—	59.0	W·HP	YES	Large village in remote place with promising farming	Very high water table	Well & motorized pump-system, wide distribution piping is required
78	Befoly	Ab	23.0	7.0	30.0	—	30.0	W·HP-CT	NO	Medium village on road-7, relies on water vendors	Very low water table, confined water, requires deep well	Well & motorized pump-system
83	Andranolava	Ab	39.0	—	39.0	—	39.0	W·HP	NO	Large vilage in remote place, with promising farming, center of district	High water table by confined aquifer, requires deep well	Well & motorized pump-system
93	Analamary	Ab	26.0	—	26.0	4.0 (P)	22.0	HP	NO	Medium village in remote place, with promising, farming	Medium water table, confined aquifer, requires deep well	Replace handpump with motorized pump-system
40	Tanandava	Ba	10.0	—	10.0	—	10.0	W·HP	YES	Small village, close to ANKZOABO city	High water table by confined aquifer, requires deep well	Well with handpump

Table 13. Description of Water Supply Subprojects by Village (2)

No	Village Name	Priority	Gross Water Consumption: Domestic Use (m3/Day)	Gross Water Consumption: Cattle Watering (m3/Day)	Gross Water Consumption: Total (m3/Day)	Existing Safe Water Supply (m3/Day)	Net Water Required (m3/Day)	Proposed Type of Facility	Schistosomiasis	Community Characteristic	Water Source Characteristic	Project Characteristic
59	Ampihavy	Ba	38.0	14.0	52.0	4.0 (P)	48.0	HP-CT	NO	Medium, cattle breeding village near road-9	Very high water table	Replace handpump with motorized pump-system
60	Ambondro	Ba	26.0	—	26.0	—	26.0	W-HP	NO	Medium village in remote place, with promising farming, difficult access	Very high water table	Well with handpump
65	Ankaraobato	Ba	48.0	—	48.0	—	48.0	MP	NO	Large, well off village on road-9	High water table by confined aquifer, requires deep well	Install motorized pump-system on a test well
5	Ambalamoa	Bb	26.0	—	26.0	—	26.0	W-MP	NO	Medium, poor village near road-9, with farming potential	High water table by confined aquifer, requires deep well	Well & motorized pump-system
6	Tsianihy	Bb	36.0	—	36.0	—	36.0	W-MP	NO	Medium, poor village near road-9, with farming potential	High water table by confined aquifer, requires deep well	Well & motorized pump-system
7	Bazatoa	Bb	20.0	—	20.0	—	20.0	W-MP	YES	Small, poor village near road-9, with farming potential	High water table by confined aquifer, requires deep well	Well & motorized pump-system
16	Ambiky	Bb	36.0	—	36.0	—	36.0	W-MP	NO	Small, poor village near road-9, with farming potential	High water table by confined aquifer, requires deep well	Well & motorized pump-system
23	Ampoza	Bb	18.0	—	18.0	4.0 (P)	14.0	W-HP	NO	Small, poor village near road-9, with farming potential	Very high water table	Well with handpump
57	Antseva	Bb	21.0	—	21.0	—	21.0	W-HP	NO	Small, poor village on road-9, with traditional wells	High water table by confined aquifer, requires deep well	Well & motorized pump-system
62	Antsoamarify	Bb	31.0	—	31.0	—	31.0	W-MP	YES	Medium, poor village in remote place	High water table	Well & motorized pump-system
67	Tsefanoka	Bb	23.0	—	23.0	7.0 (P)	16.0	W-HP	NO	Medium, poor village, easy access from road-9, with farming potential	High water table	Well with handpump
81	Manoroka	Bb	26.0	—	26.0	4.0 (P)	22.0	MP	NO	Medium village, difficult access, with promising farming	Very high water table	Install motorized pump system, must supply to elevated place
86	Besakoa(2)	Bb	31.0	—	31.0	—	31.0	W-MP	YES	Medium village in remote place	High water table by confined aquifer, requires deep well	Well & motorized pump system, distribution piping required
88	Manindsy	Bb	18.0	—	18.0	4.0 (P)	14.0	W-HP	NO	Small village, easy access from road-7	High water table by confined aquifer, requires deep well	Well with handpump
90	Tanambao	Bb	21.0	—	21.0	—	21.0	DW	YES	Small village in remote place, with farming potential	Very high water table	Protected dug well
94	Andamasiny-Vineta	Bb	14.0	—	14.0	—	14.0	W-MP	YES	Small village on road-7	High water table by confined aquifer, requires deep well	Well & motorized pump system
98	Bereketa	Bb	13.0	—	13.0	—	13.0	W-HP	NO	Small village in remote place	High water table	Well with handpump
99	Ankilimitraika	Bb	21.0	—	21.0	—	21.0	DW	NO	Medium village in remote place, difficult access, with farming potential	Very high water table	Protected dug well
13	Tanandava	Ca	16.0	—	16.0	—	16.0	W-MP	YES	Small village on road-9 very poor, origin of big TANANDAVA near it	High water table by confined aquifer, requires deep well	Well & motorized pump system
15	Tsiatavalo	Ca	17.0	—	17.0	—	17.0	W-MP	NO	Small, poor village, separated small settlements	High water table by confined aquifer, requires deep well	Well & motorized pump
21	Antranosatra	Ca	15.0	—	15.0	—	15.0	W-MP	NO	Small, poor village, 2 separated settlements	High water table by confined aquifer, requires deep well	Well & motorized pump
33	Andranomanintsy	Ca	20.0	—	20.0	—	20.0	W-MP	YES	Medium, poor village in remote place	High water table by confined aquifer, requires deep well	Well & motorized pump
41	Ampoza	Ca	8.0	—	8.0	—	8.0	W-HP	YES	Small, poor village in remote place	High water table by confined aquifer, requires deep well	Well & motorized pump
42	Ipetsa Ata	Ca	3.0	—	3.0	—	3.0	W-MP	NO	Small, poor village in remote place	High water table by confined aquifer, requires deep well	Well & motorized pump
64	Antandroka	Ca	18.0	—	18.0	—	18.0	W-MP	NO	Small, poor village in remote place	High water table	Well & motorized pump
69	Andrevo	Ca	58.0	—	58.0	—	58.0	DW	YES	Large fishing village, well off	Fresh water lies on top of salty water	Protected dug well to controll drawing
79	Ankororoka	Ca	3.0	—	3.0	—	3.0	W-MP	NO	Tiny, poor village on road-7, subsistence farming	Very low water table	Well & motorized pump system
82	Iaborana	Ca	6.0	—	6.0	—	6.0	W-MP	NO	Small village in remote place	Low water table	Well & motorized pump system
84	Lambomakandro	Ca	5.0	—	5.0	—	5.0	W-HP	YES	Small, poor village in remote place	High water table by confined aquifer, requires deep well	Well with handpump
91	Ambahimalitsy	Ca	21.0	—	21.0	—	21.0	DW	YES	Medium village in remote place, promising farming far from consumers	Very high water table	Protected dug well
30	Mosy-Ambositra	Cb	26.0	—	26.0	—	26.0	W-HP	YES	Medium village in remote place, difficult access, good farming potential	Very high water table	Well with handpump
31	Tsiarimpioke	Cb	21.0	—	21.0	—	21.0	W-HP	NO	Medium village in remote place, traditional water source is abandoned, good farming potential	Very high water table	Well with handpump
71	Ampihalia	Cb	26.0	—	26.0	—	26.0	W-MP	NO	Medium village along FIHERENANA river, difficult access, good farming potential	Underflow water	Well & motorized pump system

Table 13. Description of Water Supply Subprojects by Village (3)

No	Village Name	Priority	Gross Water Consumption Domestic Use (m3/Day)	Gross Water Consumption Cattle Watering (m3/Day)	Gross Water Consumption Total (m3/Day)	Existing Safe Water Supply (m3/Day)	Net Water Required (m3/Day)	Proposed Type of Facility	Schistosomiasis	Community Characteristic	Water Source Characteristic	Project Characteristic
72	Behompy	Cb	26.0	—	26.0	—	26.0	W-MP	NO	Medium village along FIHERENANA river, difficult access, mountainous	Underflow water	Well & motorized pump
73	Ambolonkira	Cb	12.0	—	12.0	—	12.0	W-HP	NO	Small poor village along FIHERENANA river, difficult access, mountainous	Underflow water	Well with handpump
100	Ankilivalo	Cb	52.0	—	52.0	—	52.0	W-MP	NO	Large, well off village in remote place, center of distribution, difficult access	High water table	Well & motorized pump system, wide distribution
1	Ankazomanga	D	16.0	—	16.0	—	16.0	DW	YES	Small poor village in northern part, subsistence farming	Very high water table	Protected dug well
2	Beadabo	D	16.0	—	16.0	—	16.0	DW	YES	Small poor village in northern part, subsistence farming	Very high water table	Protected dug well
3	befasy	D	16.0	—	16.0	—	16.0	DW	YES	Small poor village in northern part, subsistence farming	Very high water table	Protected dug well
4	Ankilifolo(1)	D	10.0	—	10.0	—	10.0	DW	NO	Small poor village in northern part, subsistence farming	Very high water table	Protected dug well
9	Ankida	D	0.4	—	0.4	—	0.4	W-HP	NO	Tiny village, poor, subsistence farming	High water table but deeper drilling necessary	Well with handpump
12	Berantala	D	13.0	—	13.0	—	13.0	W-MP	YES	Small village, poor, subsistence farming	In spite of high water table, deeper drilling is required	Well & motorized pump system
17	Marovato	D	10.0	—	10.0	—	10.0	W-HP	NO	Small village, poor, subsistence farming	In spite of high water table, deeper drilling is required	Well & motorized pump, no distribution pipe
18	Andranoboka	D	16.0	—	16.0	—	16.0	W-MP	NO	Small village, poor, subsistence farming	In spite of high water table, deeper drilling is required	Well & motorized pump
24	Ankilifolo(2)	D	12.0	—	12.0	—	12.0	W-HP	NO	Small village, poor, subsistence farming	High water table	Well with handpump
27	Basibasy	D	26.0	—	26.0	4.0 (P)	22.0	Supply from Analatelo	YES	Large village in remote place, center of district	Available but poor quality not suitable for drinking	Transfer pipeline from ANALATELO
36	Andranomafana	D	16.0	—	16.0	—	16.0	W-HP	NO	Small, poor village in remote place, subsistence farming	In spite of high water table, deeper drilling is required	Well with handpump
37	Mamakiala	D	8.0	—	8.0	—	8.0	W-HP	NO	Small, poor village in remote place, subsistence farming	In spite of high water table, deeper drilling is required	Well with handpump
38	Berenty-Ankilimasy	D	3.0	—	3.0	—	3.0	W-HP	NO	Tiny, poor village in remote place, subsistence farming	In spite of high water table, deeper drilling is required	Well with handpump
39	Betsinefo	D	0.9	—	0.9	—	0.9	W-HP	YES	Tiny, poor village in remote place, subsistence farming	In spite of high water table, deeper drilling is required	Well with handpump
43	Mandabe Ata	D	3.0	—	3.0	—	3.0	DW	YES	Tiny, poor village in remote place, subsistence farming	Very shallow aquifer	Protected dug well
44	Soatanimbary	D	2.0	—	2.0	—	2.0	DW	NO	Tiny, poor village in remote place, subsistence farming	Very shallow aquifer	Protected dug well
45	Sahanory Ata	D	5.0	—	5.0	—	5.0	DW	YES	Tiny, poor village in remote place, subsistence farming	Very shallow aquifer	Protected dug well
68	Andoharano	D	8.0	—	8.0	—	8.0	W-HP	NO	Small, poor village far from road-9, subsistence farming	In spite of high water table, deeper drillling is required	Well with handpump
70	Anjamala	D	4.0	—	4.0	—	4.0	W-HP	NO	Tiny, poor village along FIHERENANA river, difficult access	Underflow water	Well with handpump
74	Miary	D	52.0	14.0	66.0	—	66.0	W-MP-CT	NO	Large village near TOLIARA City, supplied by JIRAMA	High water table	Well & motorized pump system
75	Befanamy	D	18.0	—	18.0	—	18.0	W-HP	NO	Medium village near TOLIARA City, supplied by JIRAMA	High water table	Well & motorized pump system
78	Tsivonoabe	D	0.8	—	0.8	—	0.8	DW	NO	Tiny, poor village on road-9, subsistence farming	High water table	Protected dug well
80	Ambohimahavelona	D	52.0	—	52.0	—	52.0	Spring	NO	Large village, center of district, good farming potential	Spring can be used	Piping from spring
89	Bevoalavo	D	6.0	—	6.0	—	6.0	DW	NO	Small, poor village in remote place, subsistence farming	High water table	Protected dug well
93	Mahasoa	D	0.8	—	0.8	—	0.8	W-HP	YES	Tiny, poor village on road-7, subsistence farming	In spite of high water table, deeper drilling is requird	Well with handpump
97	Antanimora	D	8.0	—	8.0	—	8.0	W-HP	NO	Small, poor village in remote place, subsistence farming	In spite of high water table, deeper drilling is requird	Well with handpump

Table 14. Water Supply Facilities by Village (1)

No.	Village Name	Priority	Proposed Type of Facility	Well Dimension	Well Static/Dinamic Water Level	Well Quantity Exist	Well Quantity New	Handpump Capacity x Head	Handpump Q'ty	Submerged Motor Pump Capacity x Head	Submerged Motor Pump Q'ty	Engine Generator Output (KVA)	Engine Generator Q'ty	Reservior Tank (m3)	Water Supply Point Public Hydrant	Water Supply Point Watering Place
8	Mangolovolo	Aa	W·MP	φ6" × 30.0 m	(5.00 m/ 10.00 m)		1	−		100 l/min× 16 m	1		1	15	5	
22	Manoy	Aa	W·HP-CT	φ4" × 40.0 m	(9.50 m/ 9.50 m)	1	3	20 l/min×10 m	3	−						1
48	Bereniy-Betsileo	Aa	MW	φ8" × 30.0 m	(3.00 m/ 10.00 m)		1	−		169 l/min× 16 m	1		1	30	8	
49	Tanandava-Antaifasy	Aa	W·MP	φ6" ×100.0 m	(15.00 m/ 25.00 m)		1	−		147 l/min× 31 m	1		1	30	7	
52	Soahazo	Aa	MP-CT	φ4" × 76.0 m	(36.70 m/ 39.60 m)	1		−		244 l/min× 45 m	1		1	30	10	1
53	Analamisampy	Aa	W·HP-CT	φ4" × 71.0 m	(13.11 m/ 18.60 m)	1	2	20 l/min×19 m	2	−						1
54	Belitsaka	Aa	MP-CT	φ4" × 66.0 m	(12.78 m/ 33.00 m)	1		−		133 l/min× 39 m	1		1	15	6	1
55	Ampasikibo	Aa	MP-CT	φ4" × 50.0 m	(9.16 m/ 15.12 m)	1		−		172 l/min× 22 m	1		1	30	8	1
56	Manaboha	Aa	MP-CT	φ4" × 83.0 m	(16.50 m/ 34.00 m)	1		−		147 l/min× 40 m	1		1	30	6	1
63	Manombo-Atm	Aa	MP	φ6" × 27.0 m	(4.53 m/ 5.53 m)	1		−		339 l/min× 12 m	1		1	30	16	
68	Benetsy	Aa	MP-CT	φ6" × 72.0 m	(13.51 m/ 17.30 m)	1		−		183 l/min× 24 m	1		1	30	8	1
77	Andranovory	Aa	W·MP	φ6" ×150.0 m	(115.00 m/125.00 m)		1	−		111 l/min×131 m	1		1	15	5	
92	Mahaboboka	Aa	W·MP	φ6" × 30.0 m	(5.00 m/ 10.00 m)		1	−		144 l/min× 16 m	1		1	30	7	
101	Ankilimalinika	Aa	MP-CT	φ4" × 66.0 m	(14.35 m/ 17.70 m)	1		−		319 l/min× 24 m	1		1	40	14	1
a	Befandriana	Aa	MP-RH	φ6" × 53.0 m	(12.30 m/ 13.28 m)	1		−		219 l/min× 20 m	1		1	30	10	
b	Betsioky Nord	Aa	W·MP-RH	φ6" ×150.0 m	(60.00 m/ 80.00 m)		1	−		144 l/min× 86 m	1		1	30	7	
c	Andranohinaly	Aa	W·MP-RH	φ6" ×250.0 m	(207.00 m/220.00 m)		1	−		131 l/min×226 m	1		1	15	6	
				φ6" ×100.0 m	(12.00 m/ 20.00 m)		1			186 l/min× 26 m	1		1			
d	Sakaraha	Aa	W·MP-RH	φ6" × 30.8 m	(10.66 m/ 21.60 m)	1		−		100 l/min× 28 m	1		1	30	24	
e	Ankazoabo	Aa	W·MP-RH	φ6" ×100.0 m	(27.50 m/ 38.00 m)		1	−		150 l/min× 44 m	1		1	30	10	
11	Andranomanintsy	Ab	W·MP	φ6" ×200.0 m	(30.00 m/ 40.00 m)		1	−		103 l/min× 46 m	1		1	15	5	
14	Antsakoabe	Ab	W·MP-CT	φ6" ×200.0 m	(30.00 m/ 40.00 m)		1	−		97 l/min× 46 m	1		1	15	4	1
25	Sihanaka	Ab	W·HP	φ4" × 40.0 m	(6.00 m/ 6.50 m)	1	2	20 l/min× 7 m	2	−						
29	Mangotroka	Ab	W·HP	φ4" × 40.0 m	(3.60 m/ 3.60 m)	1	2	20 l/min× 4 m	2	−						
34	Tandrano	Ab	MP	φ6" ×150.0 m	(25.56 m/ 32.76 m)	1		−		258 l/min× 39 m	1		1	40	12	
35	Ampanihaitsetaky	Ab	W·MP	φ6" ×150.0 m	(25.00 m/ 33.00 m)		1	−		58 l/min× 39 m	1		1	10	3	
47	Ankilivalokely	Ab	W·MP	φ6" ×200.0 m	(20.00 m/ 40.00 m)		1	−		89 l/min× 46 m	1		1	15	4	
58	Ankatrakatra	Ab	W·HP-CT	φ4" × 70.0 m	(10.00 m/ 15.00 m)		3	20 l/min×15 m	3	−						1
61	Beroroha	Ab	W·MP	φ4" × 50.0 m	(15.00 m/ 25.00 m)		1	−		184 l/min× 31 m	1		1	30	8	
78	Befoly	Ab	W·MP-CT	φ6" ×250.0 m	(178.66 m/185.00 m)		1	−		83 l/min×191 m	1		1	10	3	1
83	Andranolava	Ab	W·MP	φ4" ×100.0 m	(20.00 m/ 27.00 m)		1	−		108 l/min× 33 m	1		1	15	5	
96	Analamary	Ab	MP	φ6" ×204.0 m	(35.00 m/ 43.62 m)	1		−		72 l/min× 50 m	1		1	10	4	
40	Tanandava	Ba	W·HP	φ6" ×100.0 m	(20.00 m/ 25.00 m)		1	20 l/min×25 m	1	−						
59	Ampihamy	Ba	MP-CT	φ4" × 53.0 m	(8.30 m/ 16.33 m)	1		−		144 l/min× 22 m	1		1	30	8	1
60	Ankondro	Ba	W·HP	φ4" × 50.0 m	(10.00 m/ 15.00 m)		3	20 l/min×15 m	3	−						
65	Ankaraobato	Ba	MP	φ4" × 75.0 m	(3.40 m/ 5.40 m)	1		−		133 l/min× 13 m	1		1	15	5	
5	Ambalanoa	Bb	W·MP	φ6" ×150.0 m	(20.00 m/ 30.00 m)		1	−		72 l/min× 36 m	1		1	10	4	
6	Tsianihy	Bb	W·MP	φ6" ×150.0 m	(20.00 m/ 30.00 m)		1	−		100 l/min× 36 m	1		1	15	5	
7	Mangatoa	Bb	W·MP	φ6" ×150.0 m	(20.00 m/ 30.00 m)		1	−		58 l/min× 38 m	1		1	10	3	
16	Ambiky	Bb	W·MP	φ6" ×200.0 m	(25.00 m/ 35.00 m)		1	−		100 l/min× 41 m	1		1	10	5	
23	Ampoza	Bb	W·HP	φ4" × 60.0 m	(5.50 m/ 6.20 m)	1	2	20 l/min× 7 m	2	−						
57	Antseva	Bb	W·HP	φ4" × 70.0 m	(15.00 m/ 20.00 m)		3	20 l/min×20 m	3							
62	Antsomarify	Bb	W·MP	φ4" × 50.0 m	(15.00 m/ 20.00 m)		1	−		86 l/min× 26 m	1		1	15	4	
67	Tsefanoka	Bb	W·HP	φ4" × 45.0 m	(25.60 m/ 28.00 m)	1	2	20 l/min×26 m	2	−						
81	Manoroka	Bb	MP	φ4" × 58.0 m	(5.25 m/ 6.25 m)	1		−		72 l/min× 12 m	1		1	10	4	
86	Besakoa(2)	Bb	W·MP	φ4" ×100.0 m	(20.00 m/ 28.00 m)		1	−		88 l/min× 32 m	1		1	15	4	

Table 14. Water Supply Facilities by Village (2)

No.	Village Name	Priority	Proposed Type of Facility	Well: Dimension	Well: Static/Dinamic Water Level	Well Quantity: Exist	Well Quantity: New	Handpump: Capacity x Head	Handpump: Q'ty	Submerged Motor Pump: Capacity x Head	Submerged Motor Pump: Q'ty	Engine Generator: Output	Engine Generator: Q'ty	Reservior Tank	Water Supply Point: Public Hydrant	Water Supply Point: Watering Place
88	Menindry	Bb	W·HP	φ6" × 73.5 m φ4" × 70.0 m	(16.37 m/ 16.90 m) (16.50 m/ 17.00 m)	1	2	20 l/min×17 m	2	–						
90	Tananbao	Bb	DW	10.0 m	(8.00 m/ 9.00 m)		4	–		–						
94	Andasasiny-Vineta	Bb	W·MP	φ8" ×150.0 m	(20.00 m/ 30.00 m)		1	–		39 l/min× 36 m	1		1	10	2	
98	Bereketa	Bb	W·MP	φ4" × 50.0 m	(5.00 m/ 10.00 m)		1	–		36 l/min× 16 m	1		1	10	2	
99	Ankilimitraloka	Bb	DW	10.0 m	(8.00 m/ 9.00 m)		4	–		–						
13	Tanandava	Ca	W·MP	φ6" ×200.0 m	(15.00 m/ 20.00 m)		1	–		44 l/min× 26 m	1		1	10	2	
15	Talatavalo	Ca	W·MP	φ6" ×201.0 m	(16.00 m/ 25.00 m)		1	–		47 l/min× 31 m	1		1	10	3	
21	Antranosatra	Ca	W·MP	φ6" ×200.0 m	(15.00 m/ 25.00 m)		1	–		42 l/min× 31 m	1		1	10	2	
33	Andranomanintsy	Ca	W·MP	φ6" ×150.0 m	(15.00 m/ 25.00 m)		1	–		56 l/min× 31 m	1		1	10	3	
41	Ampoza	Ca	W·HP	φ6" ×150.0 m	(35.00 m/ 40.00 m)		1	20 l/min×40 m	1	–						
42	Ipetsa Atm	Ca	W·HP	φ6" ×150.0 m	(35.00 m/ 40.00 m)		1	20 l/min×40 m	1	–						
84	Antandroka	Ca	W·HP	φ4" × 50.0 m	(15.00 m/ 20.00 m)		3	20 l/min×20 m	3	–						
69	Andrevo	Ca	DW	10.0 m	(8.00 m/ 9.00 m)		6	–		–						
79	Ankororoka	Ca	W·MP	φ8" ×250.0 m	(210.00 m/215.00 m)		1	–		8 l/min×221 m	1		1	10	1	
82	Iaborana	Ca	W·MP	φ6" ×200.0 m	(73.00 m/ 80.00 m)		1	–		17 l/min× 88 m	1		1	10	1	
84	Lamboeakandro	Ca	W·HP	φ4" ×100.0 m	(15.00 m/ 20.00 m)		1	20 l/min×20 m	1	–						
91	Ambahiealitsy	Ca	DW	10.0 m	(8.00 m/ 9.00 m)		4	–		–						
30	Nosy-Ambositra	Cb	W·HP	φ4" × 50.0 m	(10.00 m/ 15.00 m)		3	20 l/min×15 m	3	–						
31	Tsiariampicke	Cb	W·HP	φ4" × 50.0 m	(10.00 m/ 15.00 m)		3	20 l/min×15 m	3	–						
71	Ampihalia	Cb	W·MP	φ4" × 50.0 m	(10.00 m/ 15.00 m)		1	–		72 l/min× 21 m	1		1	10	4	
72	Behompy	Cb	W·MP	φ4" × 50.0 m	(10.00 m/ 15.00 m)		1	–		72 l/min× 21 m	1		1	10	4	
73	Ambolonkira	Cb	W·HP	φ4" × 50.0 m	(10.00 m/ 15.00 m)		2	20 l/min×15 m	2	–						
100	Ankilivalo	Cb	W·MP	φ4" ×100.0 m	(15.00 m/ 20.00 m)		1	–		144 l/min× 26 m	1		1	30	7	
1	Ankazomanga	D	DW	7.0 m	(5.00 m/ 6.00 m)		3	–		–						
2	Beadabo	D	DW	7.0 m	(5.00 m/ 6.00 m)		3	–		–						
3	befesy	D	DW	7.0 m	(5.00 m/ 6.00 m)		3	–		–						
4	Ankilifolo(1)	D	DW	7.0 m	(5.00 m/ 6.00 m)		2	–		–						
9	Ankida	D	W·HP	φ6" × 30.0 m	(5.00 m/ 10.00 m)		1	20 l/min×10 m	1	–						
12	Berantala	D	W·MP	φ6" ×200.0 m	(30.00 m/ 40.00 m)		1	–		36 l/min× 46 m	1		1	10	2	
17	Marovato	D	W·HP	φ6" ×200.0 m	(30.00 m/ 35.00 m)		1	20 l/min×35 m	1							
18	Andranoboka	D	W·MP	φ6" ×200.0 m	(30.00 m/ 40.00 m)		1	–		44 l/min× 46 m	1		1	10	2	
24	Ankilifolo(2)	D	W·HP	φ4" × 50.0 m	(15.00 m/ 20.00 m)		2	20 l/min×20 m	2	–						
27	Basibasy	D	Supply from Analatelo					–		72 l/min× 6 m	1		1			
36	Andranomafana	D	W·MP	φ6" ×100.0 m	(15.00 m/ 25.00 m)		1	–		44 l/min× 31 m	1		1	10	2	
37	Mamakiala	D	W·HP	φ6" ×100.0 m	(15.00 m/ 20.00 m)		1	20 l/min×25 m	1	–						
38	Beronty-Ankilimasy	D	W·HP	φ6" ×100.0 m	(15.00 m/ 20.00 m)		1	20 l/min×20 m	1	–						
39	Betsinefo	D	W·HP	φ6" ×100.0 m	(15.00 m/ 20.00 m)		1	20 l/min×20 m	1	–						
43	Mandabe Atm	D	DW	7.0 m	(6.00 m/ 8.00 m)		1	–		–						
44	Soatanimbary	D	DW	7.0 m	(6.00 m/ 8.00 m)		1	–		–						
45	Sahanory Atn	D	DW	7.0 m	(5.00 m/ 8.00 m)		1	–		–						
66	Andoharano	D	W·HP	φ4" × 50.0 m	(10.00 m/ 15.00 m)		1	20 l/min×15 m	1	–						
70	Andamala	D	W·HP	φ4" × 50.0 m	(10.00 m/ 15.00 m)		1	20 l/min×15 m	1	–						
74	Miary	D	W·MP·CT	φ4" × 50.0 m	(8.00 m/ 12.00 m)		1	–		183 l/min× 18 m	1		1	30	8	1
75	Befanamy	D	W·HP	φ4" × 50.0 m	(8.00 m/ 12.00 m)		2	20 l/min×12 m	2	–						
76	Tsivonoabe	D	DW	7.0 m	(5.00 m/ 6.00 m)		1	–		–						
80	Ambohimahavelona	D	Spring					–		–						
89	Bevoalavo	D	DW	10.0 m	(8.00 m/ 9.00 m)		1	–		–						
93	Mahasoa	D	W·HP	φ4" ×150.0 m	(20.00 m/ 25.00 m)		1	20 l/min×25 m	1	–						
97	Antanimora	D	W·HP	φ6" ×150.0 m	(30.00 m/ 35.00 m)		1	20 l/min×35 m	1	–						

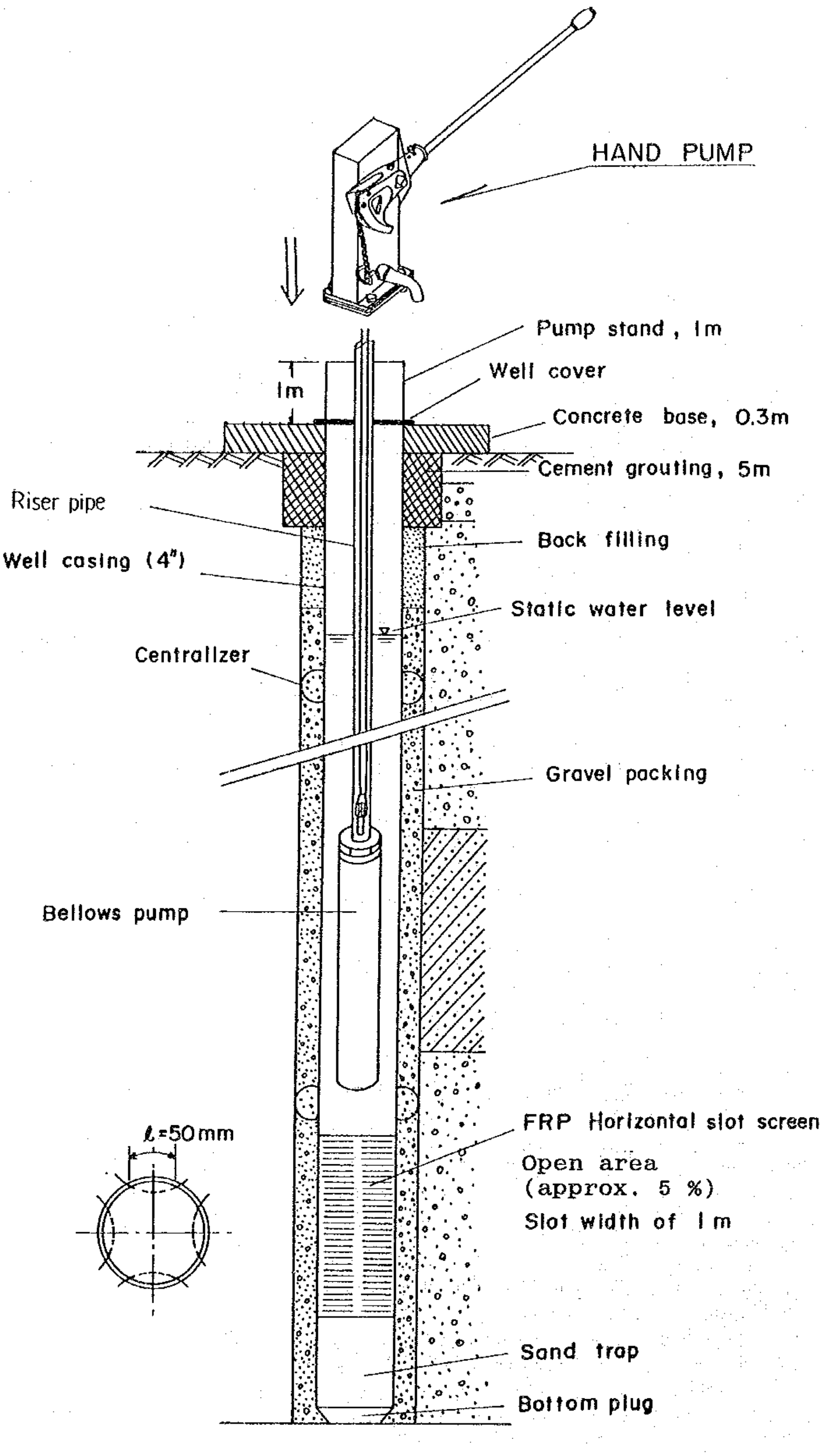


Fig. 19. Standard Well Design for Hand-pumped Well

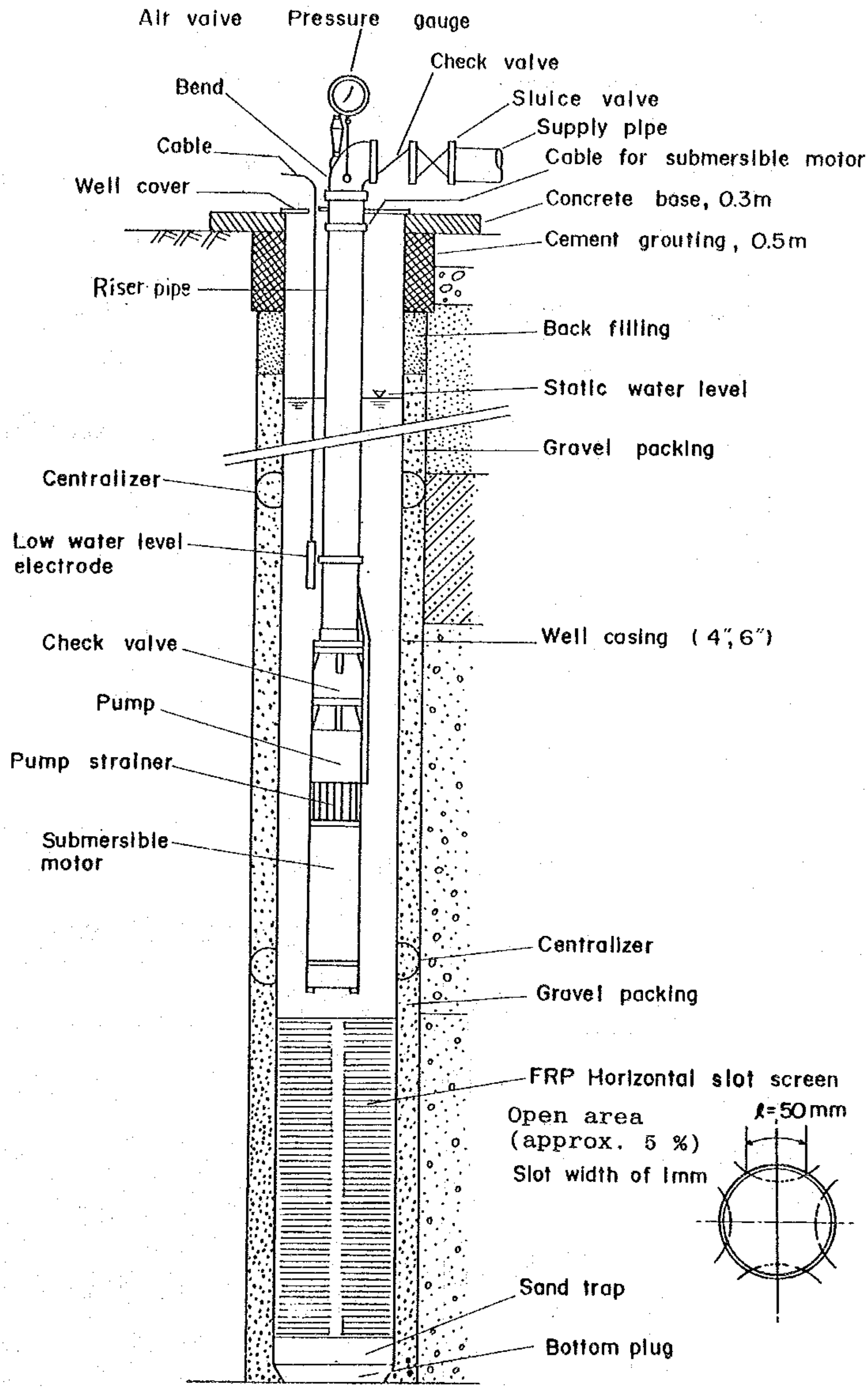


Fig. 20. Standard Well Design for Motor-pumped Well

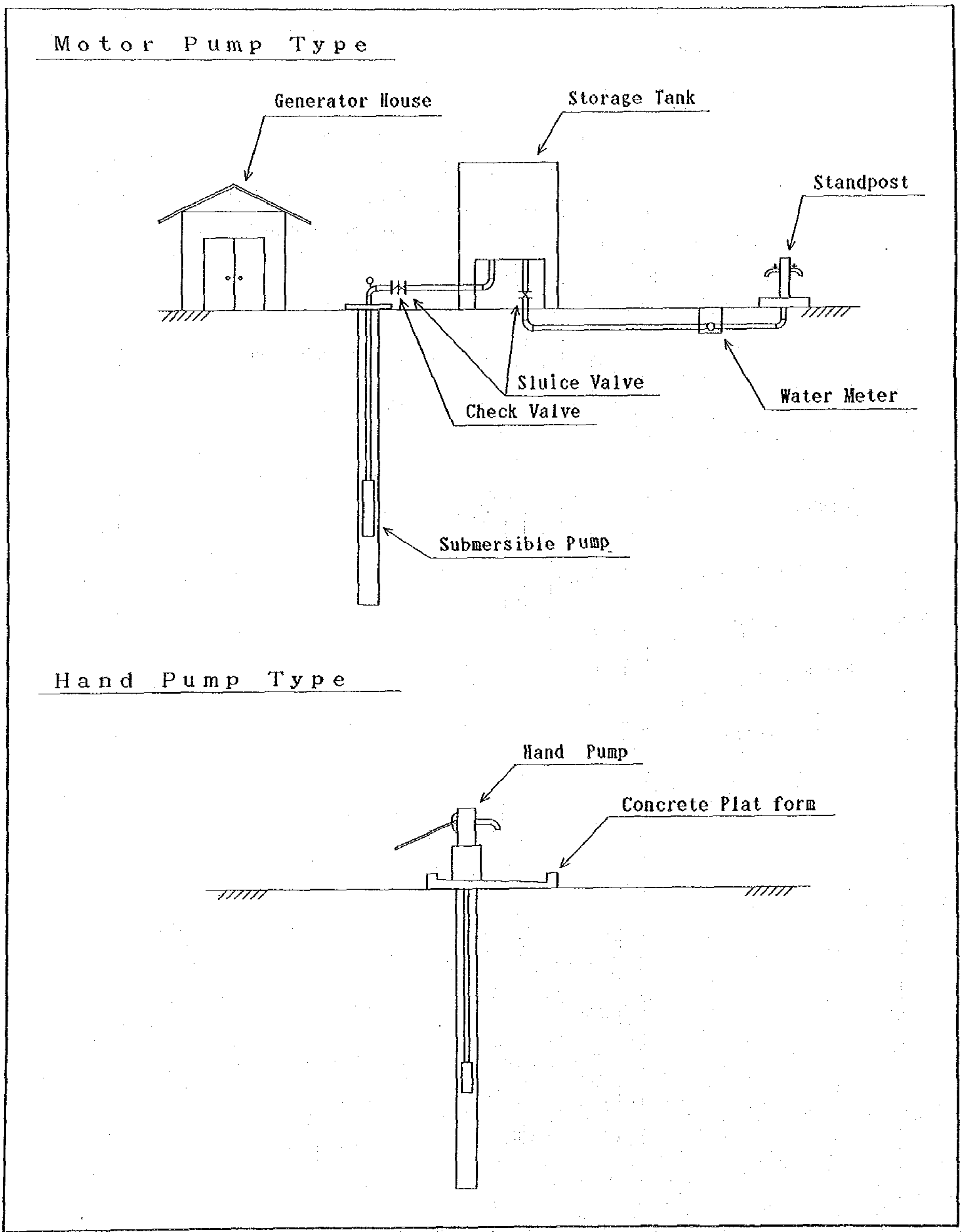


Fig. 21. Schematic Drawing of Water Supply Facilities

9.3 Project Implementation

9.3.1 Basic concept

As already discussed, candidate villages are classified into 6 ranks according to their natural potential for groundwater development and socio-economic conditions.
Priority areas for project implementation consist of villages classified as Aa, Ab, Ba and Bb, for which project implementation plan was prepared.
Although water supply plans were prepared for villages with C and D rankings, implementation plan for C and D ranked villages should be formulated only after giving due consideration to other medium to large size villages existing in the Study Area.

9.3.2 Implementation Plan

(1) Implementing Agency

The Ministry of Industries, Energy and Mines(MIEM) would be the implementing agency of the Project, and the Bureau of Water and Hydrogeology of MIEM will be in charge of actual project management and coordination. The MIEM Toliara branch will assist project implementation, particularly in field construction supervision.

(2) Basic policy

Implementation of the proposed project is urgently required to solve safe water supply problems in the Study Area. At present, however, lack of financial and technical resources in the rural water supply sector hinders prompt self reliant implementation of the project, and assistance by external aid agencies is strongly required.
Circumstances are gradually becoming favorable now for self-help schemes. For instance, rural people begin to show willingness to participate in the project implementation and its operation and maintenance, accepting to share the necessary expenses.

MIEM possesses three drilling rigs with trained crews and supporting equipment/vehicles, enough to drill relatively shallow wells, of less than 150m. However, for the imple-

mentation of the proposed project, still the role of international aid, financially and technically, is of great importance and quite indispensable.
Therefore, it is recommended that most design, procurement and construction activities be carried out by foreign contractors hired and supervised by MIEM, utilizing funds from multilateral or bilateral cooperation.
However, certain field activities such as construction of waste water drainage ditches and fences around well will be undertaken by rural beneficiaries.

Considering the national target year of 2000, a short implementation period would be rather desirable for urgency of water demand. A period of 2 to 3 years may be a realistic minimum period required to provide a sufficient lead time for establishing a maintenance system and a strong back-up capability of MIEM.
A hasty implementation of the project is not wise from the viewpoint of keeping resource allocation balanced among several human or social oriented sectors.

Total implementation period consists of 2-phases as indicated in the next paragraph.
The sub-projects to be implemented in the first phase were selected from the high priority group, placing emphasis on regional urgency of water demand and difficulty of exploiting groundwater. Villages in Fiv. TOLIARA II, Fiv. SAKARAHA and Fiv. ANKAZOABO satisfy the above mentioned conditions, namely, scarcity of traditional water sources and quite deep aquifers.
The majority of handpumps installed on test wells are to be replaced with motorized pumps, so that testwells will become production wells. The replacement of pumps will be completed during Phase 1 and Phase 2 of project implementation.

(3) Implementation schedule

A timetable with a likely duration of 32 months over 2 phases would be proposed for completing 50 sub-projects.

Although preparation for the project implementation is not mentioned in the schedule, the implementation cannot begin until the proposed project has been approved by the Mada-

gascar Government, financial resources have been secured, and a consultant engaged to prepare basic design and tender documents for selection of a contractor.
In the schedule, realistic allowance is provided for each step of the implementation process, design, preparation and approval period, tender evaluation, recommendation, negotiation and contract signature.

Critical activities throughout project implementation are those concerning deep tube well construction as follows.

- Procurement of a drilling rig and necessary equipment capable of boring deeper than 200m.

- Marine and inland transportation of equipments.

- Drilling work in predetermined fields.

- Well casing installation and well development.

Following table 14 and Fig. 22 shows the proposed project implementation schedule.

Table 15. Summary of Project Implementation Schedule

Phase	Phase 1	Phase 2
Duration	18 months	14 months
No.of villages (priority)	17(Aa-Bb)	33(Aa-Bb)
Beneficiary		
-inhabitants	37,689	61,894
-cattle	6,000	2,000
No.of tube wells to be bored (Total depth)	6"x9;1280 m 4"x4; 320 m	6"x11;1560 m 4"x22;1180 m
No.of facilities per category		
- DW	-	2
- W.HP	2	9
- MP	4	9
- W.MP and RH	11	12
- W.W	-	1

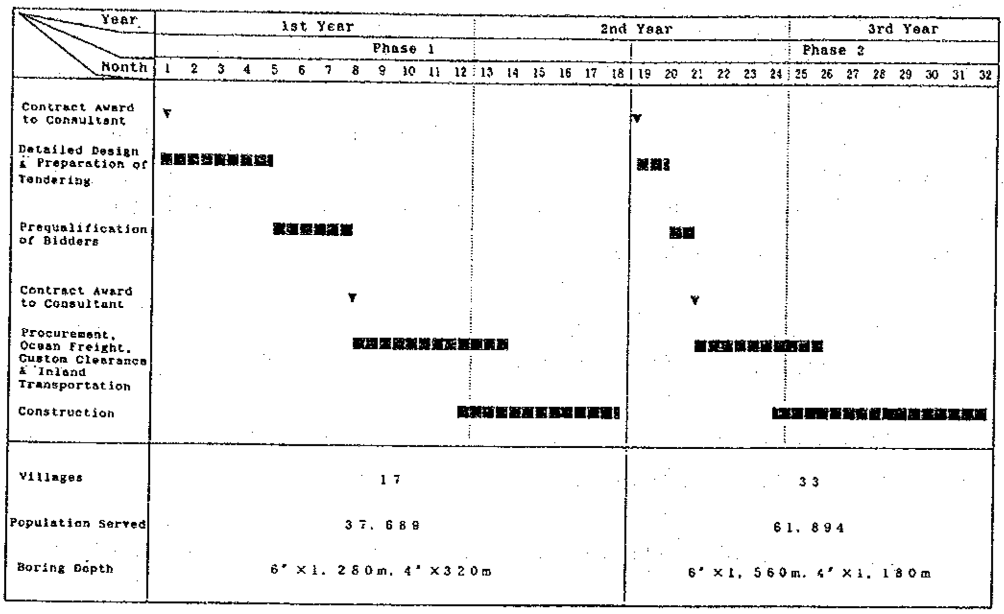


Fig. 22. Project Implementation Schedule

(5) Operation and Maintenance Program

(a) Organization and responsibility

As discussed in the water supply planning study, it is desirable that the operation and maintenance (O&M) system, which is a centralized system at first, be gradually shifted to the local, decentralized systems through three stages.
In the beginning system, beneficiary communities would organize water commitees and assign caretakers, mainly to operate the facilities and carry out routine, rather minor maintenance work.
The central organization, MIEM(Toliara), would technically back up water commitees with their mobile maintenance teams, particularly in major repairs.
Individual responsibility of the organizations involved in the O&M system would be as follows.

Table 16. Organization for Operation and Maintenance

Organization and/or Agency	Responsibility and task
Village-level:	
Village-wise Water Commitee and Caretakers	- Operation of facilities - Routine maintenance such as site cleaning, visual inspection of leak on pipe and reservoirs, maintenance of drainage, touch-up painting etc. - Management of pump operation and water service - Keeping a log-book - Emergency notification, if any, to MIEM as well as regular reporting - Collection of O&M fees from users
Central-level: (regional level) MIEM (Toliara Branch)	- Preventive maintenance by regular inspections - Repair work in the field and work-shop - Inventory control of spare parts - Data and information control - Training of caretakers
National-Level: MIEM (Head office)	- Monitoring of operation and mainte nance activities - Overseas procurement - Training planning

(b) O&M cost and its allocation

An example of working capital which must be borne by beneficiary villages is as mentioned below.

Table 17. Sample of Annual Recurrent Cost

Case	Cost Item	FMG/year
1. For hand pump-based supply system	Salary of caretaker	6,000
Estimation basis: population 300	Pump spare parts	70,000
	Transportation	20,000
	Other cost	10,000
	Total	106,000
	Cost per capita	353
2. For motorized pump-based supply system	Salary of caretaker	12,000
Estimation Basis: population 1000	Fuel oil	1,500,000
	Spare parts	500,000
	Transportation	40,000
	Other cost	50,000
	Total	2,102,000
	Cost per capita	2,102

The rural population is estimated to have the capacity to pay the cost estimated above.

(c) Investment and budget for support activity

A government agency, MIEM(Toliara Branch) would play an essential role to assist rural communities for maintaining water supply facilities. However, its support would be limited as it is assigned only a modest ordinary budget. The most important and urgent action to be taken by the government is strengthening the Garage and Workshop Department in MIEM(Toliara Branch).

(i) New mobile maintenance teams should be established in the Department.
One team should start their service within 1991, while the second team would start by 1994, following the proposed project implementation schedule.
Staffing and operating cost requirements of a team are shown below.

Team member	Person
- Mechanic	1
- Assistant Mechanic	1
- Clerk	1
- Driver	1

Operating cost (a year)

	FMG/Year
- Salaries of staff	2,700,000
- Fuel oil (for regular patrol)	720,000
- Vehicle maintenance	1,000,000
- Stationery and others	20,000
- Insurance	300,000
Total	4,740,000

(ii) Investment for workshop

For metal work, installation and assembly work, the following machinery, equipment and tools should be provided to the workshop.

Machinery and Tools	Quantity
- Centre Lathe	1
- Hack Sawing Machine	1
- Upright Drilling Machine	1
- Electrical Bench Grinder	3
- Portable Electric Drill	2
- Hydraulic Jack	3
- Meter Testing Boards	1
- Electricians Tool Set	3 sets
- Mechanics Tool Set	3 sets
- Plumbing Tool Set	3 sets
- Work Benches with Vice	3
- Miscellaneous Hand Tools	3 sets
- Manual Oil Pump	3

9.3.3 Project cost and financing

Anticipated investment cost for 50 sub-projects for A-B ranked villages is estimated as shown in the following Table.

Table 17 Project Investment Cost

Unit: thousand US$

Component	Phase I	Phase II	Total
Civil Work	701	992	1,693
Boring Work	643	1,136	1,779
Equipment & Installation	745	769	1,514
Piping & Installation	422	450	872
Sub-total	2,511	3,347	5,858
Drilling Rig and Supporting Equipment/Vehicle	2,591		2,591
Engineering Service	408	268	676
Price Contingency	371	327	698
Total	5,881	3,942	9,823

9.4 PROJECT EVALUATION

9.4.1 Beneficiary Villages

Implementation of this project would increase provision of safe water supply to beneficiary villages by 1,995 cu.m per day. Since safe water supply in 1990 is estimated at only 131 cu. m per day, the benefits from this increased safe water supply is quite significant.

The beneficiary population is estimated at 76,016 in 1990, growing to 99,583 in the year 2000. The 1990 beneficiary population amounts to 21.4% of the population of five Prefectures, which totally or partially comprised the project objective area. These five Prefectures consisting of Toliara II, Morombe, Sakaraha, Ankazoabo and Beroroha had a combined population of 337,158 in 1988, which was estimated to have grown to 356,025 in 1990. The population of Toliara Province was estimated at 1,650,000 in 1990, and if the population served with water supply in Toliara I is estimated at 100,000, then the implementation of this project would bring the water supply served population up to around 10% of the entire Toliara Province population.

9.4.2 Willingness to Pay (WTP)

Financial contributions from 50 villages were calculated on the basis of results obtained from interviewing 223 families in 12 villages on the subject of willingness to pay for water services. It should be pointed out that "willingness to pay" presupposes "ability to pay", due to the survey method of obtaining question replies directly from respondents. In other words, it is assumed that respondents give their WTP answers by taking into account their financial capabilities.

The interview survey showed WTP to be a function of village size, ranging from 200 FMG/family/month in "small" villages (under 1,000 people or 143 families) to 400 FMG/family/month in "medium" size villages (1,000-2,000 people or 143-357 families) and 500 FMG/family/month in "large" villages (over 2,500 people or 358 families).

The resulting financial contributions from villagers are estimated at US$44,000 per year, and would cover operation and maintenance costs of the Project which are estimated at US$38,000 per year. This assumes 100% contribution from village households. Being more realistic, assuming 10% of households cannot make financial contributions, the Project would still cover operation and maintenance costs.

Although the proposed maintenance system envisages increasing participation of local administrative offices and residents, their responsibilities would be mostly for operation and maintenance. Accordingly, the Government of Madagascar, through appropriations in the MIEM budget, should be responsible for the replacement of water supply facilities, which are viewed as social infrastructure of the country.

9.4.3 Other Benefits

(1) Human health improvement

Health data indicate that Toliara Province is worse off than the whole country as far as water-borne and water-related diseases are concerned. Although the productivity effects of improved health are difficult to quantify, there is no question that provision of safe drinking water will result in lower incidence of water-borne and water-related diseases, leading to better health, and consequently to improved well being and more productive life.

The incidence of diarrhea and other digestive ailments in 1987 was higher in Toliara Province than in the country as a whole under the categories of outpatient consultation (9.0% and 8.4%), hospitalization (7.9% and 6.6%), and mortality in hospitals (7.4% and 7.0%). In addition, of 35 villages reporting as being affected by schistosomiasis, 19(54%) will benefit from improved water supply facilities to be provided by the Project.

(2) Time saving

If conveniently located water supply facilities are installed, time saving will benefit housewives and children, who shoulder the bulk of water hauling task for the family. It is entirely possible that children are sacrificing study time, or completely giving up going to school for the sake of hauling water. The time saving can help to improve the social status of women if appropriate education programs are set up to encourage increased women participation in community affairs. Education programs can also be designed to induce women to assume a leadership role in hygiene matters.

The actual benefits of time saving can only be ascertained on an ex-post evaluation, that is, some time after the water supply facilities are in operation. This implies the need for a detailed ex-ante evaluation, so that a careful comparative study can be conducted on the time use pattern of women and children before and after operation of water supply facilities.

(3) Reduced expenses

Some villages along Route 7 (Befoly, Andranovory, Andranohinaly) do not have water sources at a reasonable distance, having to depend completely on water sold at 2,500 FMG to 4,000 FMG per 200 liter drum. A typical family reportedly buys a drum of water every two or three days, or at the very least once a week. Then, a typical family will have to spend between 10,000 FMG and 40,000 FMG per month just on water. It appears that the household expense on water comprises an inordinately high proportion of the household total income.

If deep tube wells are drilled in Befoly, Andranovory and Andranohinaly, even if the village residents pay for the operation and maintenance costs instead of purchasing water, a considerable amount of money can be saved. These savings from reduced expenses could be used for productive purposes. Direct benefits will accrue to the estimated 700 to 800 households in Befoly, Andranovory and Andranohinaly. Assuming they contribute 1,000 FMG per month for the operation and maintenance, instead of spending 10,000 FMG per month on water purchased during 6 months of the dry season, the savings for the residents of the three villages are estimated at around 40,000,000 FMG per year.

(4) Community development

During the field work of the Study, a great deal of time and effort were put into explaining the role of the village water committees so that the villagers could actively participate in the operation and maintenance of water supply facilities. This kind of endeavor has no precedence in the Study Area, and if the villagers acquire enough experience and confidence, it may turn into an engine of growth through the undertaking of similar self-help projects.

(5) Development of the rural water supply sector

As explained elsewhere, the rural water supply sector is unfortunately weak in terms of financial, technical and institutional capabilities. This project may become the means to shed light on the urgent needs of the rural water supply sector, thereby helping to appropriate the resources required to strengthen the sector financially, technically and institutionally.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

10.1.1 Groundwater Potential

As the final results of comprehensive analysis and evaluation on hydrogeology, a hydrogeological map of the Study Area was completed in Phase III of the study, with a particular focus on the potentiality of groundwater resources.

As shown in this hydrogeological map, the potential of groundwater resources in the Study Area is generally high, except in some areas where hydrogeological conditions and water quality are poor. The groundwater potentiality in the Study Area is expected to be sufficient in capacity, not only to overcome existing shortages of drinking water, but also to develop future agricultural or industrial activities in some high potential areas. Main high potential areas which were confirmed from the results of test drilling in this study are as follows.

Area	Specific capacity (m^3/day/m)
Befandriana	438.58
Sihanaka	232.26
Analatelo	7,224.00
Mangotroka	281.35
Soahazo	173.33
Manombo Atm	609.23
Toliara*	3,057.00

* Limestone aquifer in the eastern area of Toliara as Miary and Manoroka

10.1.2 Social and Economic Potential

In this study, a detailed survey on existing conditions of individual communities was conducted in order mainly to understand and investigate the community need for safe water and the community's positive participation in maintaining the future water supply facility, financially and institutionally.

As a conclusion, this detailed survey confirmed the following.

1) In general, the majority of candidate villages in the Study Area have several traditional water sources, natural and artificial, within their living area or in the neighborhood. However, the water is not necessarily safe for domestic use mainly due to probable bacteriological contamination.

2) More than 30 candidate villages reported as suffering from schistosomiasis, which is hard to wipe out in practice because of the difficulty to effectively control the snail population in the stagnant water.

3) In several villages on route 7, an absolute shortage of water for domestic use is observed. These villages depend solely on the delivery from water vendors who charge unimaginable high prices, i.e. 2,500 to 4,000 FMG per drum (200 liters).

4) Because of the above mentioned existing conditions of water sources for domestic use, the resulting order of priority for community need for safe water was as follows.

Degree of priority	No. of village	Population
I (High)	40 (41.7%)	64,719(62.6%)
II(Medium)	31 (32.3%)	27,419(26.5%)
III(Low)	25 (26.0%)	11,308(10.9%)
Total	96	103,446

5) In villages with I(high) and II(medium) rankings in the above mentioned community need for safe water, the majority of inhabitants have keen interest and enthusiastic willingness to participate in maintaining water supply facilities, and also they might be reasonably solvent, with rather positive willingness to pay for a water supply service.

6) Large communities on route 9 and medium size communities on route 7 may have sufficient solvency to cover not only recurrent costs but also a portion of capital costs.

7) The accuracy of these considerations were confirmed through several field survey and actual establishment of operation and maintenance systems for the pilot water supply facilities.

10.2 Recommendations

10.2.1 Groundwater Development and Management

(1) Effective Data Collection and Utilization

Basic data for the evaluation of groundwater resources are meteorological data, hydrogeological data, groundwater level records and borehole data (geological maps, logging records, pumping test records, hydrological data). These data should be collected continuously in the future and be input into the data base system established at the MIEM Toliara Branch Office. The necessary cooperation from governmental and other agencies concerned are desirable and hereby requested. In addition, in the future, legal and regulatory investigation is desired for groundwater management on a national level.

(2) Continued Observation of Discharge and Water Level

It is necessary to continue the observation of river system discharge and groundwater level carried out in this study. The facilities for discharge observation are not functioning well at many stations. In order to continue these observations, it is necessary to basically examine and assess the facilities of the entire Study Area.

(3) Groundwater Exploration

The success of well drilling depends on the results of the groundwater exploration. The drilling sites must be chosen based on the results of detailed hydrogeological survey and geophysical prospecting. This procedure offers positive results in drilling and is effective by its low cost. It is strongly recommended to drill boreholes of more than 250m for the success of groundwater development in the area of limestone plateau along route 7.

(4) On-the-Job-Training

Groundwater development has its own comprehensive technology with complex and far-reaching components, thereby making vast knowledge and experience essential. Consequently, a necessary condition for the groundwater engineer is that he/she possess the technology which corresponds to the specialized fields of groundwater exploration, well drilling, pumping test, quantitative analysis, development and monitoring. In the future, it is expected that the concerned agencies choose the proper personnel for the detailed design stage and the construction stage of the Project, in order to bring up the level of the engineering staff through on-the-job-training.

10.2.2 Implementation of the Water Supply Project

(1) Management of groundwater resources

Groundwater is a precious natural resource for the area in which it exists. It is a resource which might be developed and managed by experienced and knowledgeable inhabitants of the area. It is desirable that research and discussions on utilization and management of groundwater resources be conducted throughout the project implementation.

(2) Project implementation

It is judged that the proposed project is feasible from technical and socioeconomic viewpoints. It is also judged that the project has a high priority considering the natural and socioeconomic condition of the area. Therefore, early implementation of the project is strongly recommended.

(3) Operation and maintenance

It is recommended that the daily operation and maintenance be carried out by the water committee composed of the village inhabitants. It is also desirable that the MIEM Toliara Office strengthen its financial and technical base in order to be able to provide the necessary assistance for the operation and maintenance of water supply facilities in the medium to large size villages.

10.2.3 Women Participation in Development

(1) Water for the family

Securing adequate water supply for the family demands tremendous amounts of time and energy, especially in the semi-desertic area of southern Madagascar. The heavy task of fetching water for the family is usually the responsibility of women and children. Construction of easily accessible water points has the potential to give women plenty of free time, which can be effectively utilized to increase women's participation in social and economic activities.

(2) Training and education programs

It is recommended that MIEM take the initiative, with the assistance of appropriate government and non government organizations, to set up training and education programs in beneficiary villages. These training programs should be designed so as to take advantage of the potentially free time, which the project implementation would make available to women. Suggested areas of training are women participation in community affairs, leadership role of women in sanitation and hygiene matters, and craft and cottage industries for women. Effective training programs in these areas will mobilize powerful, and so far untapped resources for socioeconomic development of rural communities.

10.2.4 Sanitation

(1) Status of village sanitation

Implementation of the Project will require continued monitoring and actions on the following sanitation aspects:

- consumption of water from new improved sources;
- drainage of water spilled around wells; and
- in the long-run, as water consumption increases, disposal of domestic waste water.

One finding from monitoring pilot water supply facilities showed that water consumption from improved sources decreased to half in the rainy season. This implies that villagers go back to traditional water sources, when these are plentiful, rather than using better quality water. This regrettable outcome reflects lack of awareness on sanitation, and will diminish the expected benefits from implementing the Project.

Likewise, a common sight of the few remaining US AID built wells with handpumps was the pool of mud surrounding the base of the pump. Villagers faced not only the inconvenience of having to step into the mud to get water, but also running the risk of contaminating the just-pumped-up well water by splashing or dropping mud into the water container. Worse yet, seepage of polluted mud water over the long-run may end up contaminating the aquifer. The same problem may arise in connection with domestic waste water, when water consumption increases sufficiently.

(2) Improvement of village sanitation

Wells to be built through the Project will be designed with appropriate pump bases so as to minimize the chances of mud pools being formed around wells. In addition, the village Water Committee and Care-taker should be instructed to keep the drainage around the well in good working condition.

However, the most effective way to deal with the sanitation matters described above is to improve the population awareness on sanitation. Then, a widespread education campaign is called for, targetting school children, patients of health-care centers, housewives and the general population.

The education should focus on the importance of clean water, avoidance of contaminated drinking water, actions that individuals can take to prevent water contamination, simple measures applicable before using unsafe water, and methods for appropriate disposal of waste water. The content of the required education implies the need for a cooperative effort between MIEM, Ministry of Education and Ministry of Public Health.

Sanitation is an integral component of water supply projects. Accordingly, full benefits from water supply projects can be expected only when sanitation matters are given due considerations, and appropriate countermeasures are taken.