4.2 Categorization and Prioritization

4.2.1 Categorization by Water Requirement

The categorization of the accessible villages by water requirement is one of the critical aspects in judging the effectiveness of investment for groundwater development. There are two criteria to judge the effectiveness of investment for the groundwater development by water requirement.

The first criterion is the kind of existing water sources and the observers' evaluation in the inventory survey. All the accessible candidate villages were categorized into Category A (higher water requirement), Category B (moderate water requirement) and Category C (lower water requirement). As a result, as Table 4.1.1 shows, 56 villages were classified into Category A, 24 villages into Category B and one village into Category C, respectively. Figure 4.2.1 illustrates the distribution of candidate villages by Category of water requirement in the map of the Study Area.

The second criterion is the number of population who will benefit from the groundwater development. In order to obtain the total ranking by water requirement, all of the accessible 81 candidate villages have been ranked in accordance with the ranking of population in each category. Table 4.2.1 also indicates the details of the ranking of candidate villages by water requirement, indicating that the top 5 villages in the total ranking by water requirement are Malaimbandy (No. 106), Ankilizato (No. 103), Mandabe (No. 104), Befasy (No. 25) and Analaiva (No. 67).

4.2.2 Classification by Socio-Economic Capacities

Even if the need for development by water requirement is high, the socio-economic capacities are other important aspects necessary in assessing the effectiveness of investment for the groundwater development in terms of the socio-economic capabilities to operate and maintain the facilities.

(1) Economic Capacity

The economic capacity is related to the operation and maintenance in the financial aspect. It assesses the affordability to pay for the operation and maintenance cost for facilities. The economic capacity was gauged by three criteria available. The first criterion is the number of population. The second criterion is the cash income. The level of cash income is available by the socio-economic survey and some estimation based on the correlation analysis, which has proved that the cash income level is highly correlated with population. The amount of asset is the third criterion. Since village people is willing to transform their financial balances into cattle, the number of cattle per capita given by the inventory data is the most reliable value to assess the amount of assets in the Study Area.

In summary, the accessible 81 candidate villages have been ranked in descending order in accordance with the sum of each ranking of the above three criteria, and the ranking by economic capacity has been decided. The details of ranking by economic capacity is as per Table 4.2.2.

(2) Social Capacity

The social capacity of village is another important aspect related to operation and management level of individual village. The operation and maintenance requires the understanding of the long-term management of water associations. The social capacity were gauged by two criteria available. The census 1993 gives the village-wise data for adult literacy rate and primary school enrollment rate, where 81 candidate villages were ranked in ascending order in accordance with these two criteria. It has been found that the maximum adult literacy rate and primary school enrollment rate are 81.9 % in Androvakely (No.53) and 89.5 % in Androvakely (No.53), respectively, and the minimum rates are 0.5 % in Antaly (No.3) and 3.1 % in Mitsitily (No.27).

In summary, the 81 candidate villages have been ranked in descending order in accordance with the sum of each ranking of the above two criteria, and the ranking by social capacity has been decided. The details of the ranking by social capacity is as per Table 4.2.3.

(3) Institutional Capacity

The institutional capacity of villages is related to supporting environment for operation and maintenance. Even if the level of the people is socially high, without proper socio-economic infrastructure and environment, the operation and maintenance will not function well. The inventory gives the data for 1) availability of village organization, 2) level of hygiene habit, 3) availability of medical services, 4) availability of educational services and 5) level of women's status. The points to be allocated in each category are shown in the following Table.

Points for Institutional Capacity

Point	Organization	Hygiene	Medical Service	Education	Women
0	None	Poor	None	None	Poor
1	1 Association	Fair	Health Care Center	Primary	Fair
2	2 Associations	Good	Clinic	Secondary	Good
3	3 Associations	Excellent	Hospital	Both	Excellent

All 81 accessible villages have been ranked in ascending order in accordance with the total points to be gained, and the ranking by institutional capacity has been decided. The details of the ranking by institutional capacity is shown in Table 4.2.4.

In order to obtain the total ranking by socio-economic capacities, all of the accessible 81 candidate villages have been ranked in descending order in accordance with the sum of each ranking of the above economic, social and institutional aspects, considering their weighting ratios shown in the following Table, and the total ranking by socio-economic capacities has been decided. Table 4.2.5 shows the total ranking by socio-economic capacities, indicating that top 5 villages in the total ranking by socio-economic capacities are Analaiva (No.67), followed by Ankilizato (No.103), Ankilivalo (No.94), Ambatolahy (No.114) and Tsimafana (No.112).

Weighting Ratios to be Allocated on Each Capacity.

Items	Economic	Social	Institutional	Socio-economic Total
Weighting Ratio	50.0%	25.0%	25.0%	100.0%

As a result, the ranking 1-30 villages were classified into Category A (higher priority for socio-economic capacities), the ranking 31-60 villages into Category B (moderate priority) and the ranking 61-81 villages into Category C (lower priority), respectively. Figure 4.2.2 illustrates the distribution of candidate villages by Category of socio-economic capacities in the map of the Study Area.

4.2.3 Total Ranking and Categorization

The important point here is that how much weighting ratios should be put on each dimension. It is reasonable that 50 % of weighting ratio should be put on both water requirement and socio-economic capacities, considering the well-balanced planning of development priorities in the Study Area. Table 4.2.5 indicates the total ranking of all of the 81 villages by water requirement and socio-economic capacities.

Weighting Ratio of Criteria for Ranking

Items	Water Requirement	Socio-economic Capacities	Total
Weighting Ratio	50.0%	50.0%	100.0%

Apart from the total ranking, the combination of categories by ranking of water requirement and socio-economic capacities gives the final combined category of water requirement and socio-economic capacities, as shown in the following Table. While Category AA means that both priorities by water requirement and socio-economic capacities are highly ranked, Category CC means both priorities are poorly ranked. Category AA, AB, BA and BB includes 60 candidate villages, which should be urgently developed. This classification is given in the right end column of Table 4.2.5, and Table 4.1.1.

Distribution of Candidate Villages
by Ranking of Water Requirement and Socio-economic Capacities

	Water Requirement		
Socio-Economic Capacity	A (Rank 1-30)	B (Rank 31-60)	C (Rank 61-81)
A	18	21	17
B	11	10	3
C	0	0	1

Figure 4.2.3 illustrates the distribution of candidate villages by categories of both water requirement and socio-economic capacities, indicating that Category AA (higher water requirement and higher socio-economic capacities) includes 18 villages, Category AB includes 21 villages, Category AC includes 17 villages, Category BA includes 11 villages, Category BB includes 10 villages, Category BC includes 3 villages and Category CC includes one village, respectively.

Table 4.2.1 **Ranking of Candidate Villages by Water Requirement** (1/3)

No.	Fivondronana	Firaisana	Village	Water Requirement				Total Point	Total Ranking
				Data		Ranking			
				Requirement	Population	Requirement	Population		
1	Manja	Andranopasy	Andranopasy I	2	623	57	9	66	65
2	Manja	Andranopasy	Andranopasy II	3	226	1	42	43	42
3	Manja	Andranopasy	Antaly	3	327	1	31	32	31
4	Manja	Andranopasy	Darika	3	327	1	31	32	31
5	Manja	Andranopasy	Befamonty	3	450	1	23	24	23
6	Manja	Andranopasy	Anbatobe	3	220	1	43	44	43
7	Manja	Andranopasy	Nositonga	3	260	1	37	38	37
8	Manja	Andranopasy	Nosibe	3	600	1	18	19	18
9	Manja	Andranopasy	Ankoba	3	410	1	25	26	25
10	Manja	Andranopasy	Antseranandaka Nord	3	342	1	29	30	29
11	Manja	Andranopasy	Tsaramandroso	3	237	1	41	42	41
14	Manja	Manja	Tanambahiny	2	131	57	23	80	79
15	Manja	Manja	Miary	2	365	57	18	75	74
16	Manja	Ankiliabo	Ambivy I	3	130	1	51	52	51
17	Manja	Ankiliabo	Ambivy II	3	500	1	20	21	20
18	Manja	Ankiliabo	Ambahia	2	200	57	21	78	77
19	Manja	Ankiliabo	Besatrohaka	3	210	1	44	45	44
20	Manja	Ankiliabo	Marolafila Atsimo	3	500	1	20	21	20
23	Beroroha	Beroroha	Marerano	3	1,100	1	6	7	6
25	Morondava	Befasy	Befasy	3	2,000	1	3	4	3
26	Morondava	Befasy	Antevamena	3	360	1	28	29	28
27	Morondava	Befasy	Mitsitily	3	340	1	30	31	30
28	Morondava	Befasy	Andranovorisosotra	3	40	1	55	56	55
29	Morondava	Befasy	Ankitatamahavelo	3	190	1	47	48	47
30	Morondava	Befasy	Bekininy Soarano	3	400	1	26	27	26
31	Morondava	Befasy	Beleo	3	800	1	12	13	12
32	Morondava	Befasy	Anadabo	1	36	81	1	82	81
33	Morondava	Befasy	Misokotsa	2	800	57	7	64	63
34	Morondava	Laijoby	Croisement Besotroka	3	200	1	46	47	46
35	Morondava	Laijoby	Amanga	3	400	1	26	27	26
36	Morondava	Manomentinay	Namakia	2	400	57	15	72	71
39	Morondava	Manomentinay	Antsamaka	3	150	1	48	49	48
40	Morondava	Manomentinay	Manomentinay	2	436	57	14	71	70

Table 4.2.1 **Ranking of Candidate Villages by Water Requirement** (2/3)

No.	Fivondronana	Firaisana	Village	Water Requirement				Total Point	Total Ranking
				Data		Ranking			
				Requirement	Population	Requirement	Population		
41	Morondava	Manomentinay	Farateny	3	250	1	38	39	38
43	Morondava	Manomentinay	Andrananja	3	70	1	53	54	53
46	Morondava	Belo-Sur-Mer	Marofihitsa	3	750	1	15	16	15
47	Morondava	Belo-Sur-Mer	Ambararata	2	500	57	12	69	68
48	Morondava	Belo-Sur-Mer	Ankevo	2	300	57	19	76	75
50	Morondava	Lavaravy Tsimaliha	Bevantaza	2	150	57	22	79	78
52	Morondava	Androvabe	Antsakamirohaka	2	1,600	57	2	59	58
53	Morondava	Androvabe	Androvakely	2	550	57	11	68	67
55	Morondava	Androvabe	Ampananiha	3	420	1	24	25	24
56	Morondava	Androvabe	Antseranambondro	3	60	1	54	55	54
58	Morondava	Bemanonga	Bemanonga	2	1,250	57	4	61	60
59	Morondava	Bemanonga	Marovoay	2	1,247	57	5	62	61
60	Morondava	Bemanonga	Tandrokosy	3	238	1	40	41	40
61	Morondava	Bemanonga	Bekonazy	3	40	1	56	57	56
64	Morondava	Bemanonga	Andranomena Atsimo	3	210	1	44	45	44
65	Morondava	Bemanonga	Tanandava	3	250	1	38	39	38
66	Morondava	Bemanonga	Croisement (BST)	2	204	57	20	77	76
67	Morondava	Analaiva	Analaiva	3	1,520	1	5	6	5
68	Morondava	Analaiva	Betsipotika	3	120	1	52	53	52
69	Morondava	Analaiva	Amboloando	3	150	1	48	49	48
70	Morondava	Analaiva	Ampandra	2	600	57	10	67	66
72	Morondava	Analaiva	Antevamena II	2	100	57	24	81	80
74	Morondava	Analaiva	Tsinjorano	2	450	57	13	70	69
76-1	Morondava	Laijoby	Laijoby Avaratra	3	150	1	48	49	48
79	Morondava	Laijoby	Ambonio	3	270	1	36	37	36
80	Morondava	Laijoby	Analalava	3	300	1	33	34	33
81	Morondava	Befasy	Malandirano	2	400	57	15	72	71
82	Morondava	Marofandiliha	Marofandiliha	2	370	57	17	74	73
83	Morondava	Marofandiliha	Ampataka	3	695	1	17	18	17
89	Morondava	Marofandiliha	Ankaraobato	2	800	57	7	64	63
93	Morondava	Marofandiliha	Boraboka Atsimo	3	783	1	14	15	14
94	Mahabo	Ankilivalo	Ankilivalo	2	2,960	57	1	58	57
95	Mahabo	Ankilivalo	Ambohibary	3	300	1	33	34	33

Table 4.2.1 Ranking of Candidate Villages by Water Requirement (3/3)

No.	Fivondronana	Firaisana	Village	Water Requirement				Total Point	Total Ranking
				Data		Ranking			
				Requirement	Population	Requirement	Population		
97	Mahabo	Ankilivalo	Bezezika	3	855	1	11	12	11
99	Mahabo	Ampanihy	Ankilimida	3	1,400	1	18	19	18
100	Mahabo	Ampanihy	Ampanihy	3	742	1	16	17	16
101	Mahabo	Ampanihy	Benato	3	500	1	20	21	20
102	Mahabo	Ampanihy	Anolotsy	3	300	1	33	34	33
103	Mahabo	Ankilizato	Ankilizato	3	4,200	1	2	3	2
104	Mahabo	Mandabe	Mandabe	3	2,000	1	3	4	3
106	Mahabo	Malaimbandy	Malaimbandy	3	7,000	1	1	2	1
107	Mahabo	Malaimbandy	Ampanotoka	3	900	1	10	11	10
109	Belo sur Tsiribihina	Tsianaloka	Tsianaloka	3	1,000	1	7	8	7
110	Belo sur Tsiribihina	Tsianaloka	Kiboy	3	930	1	8	9	8
112	Belo sur Tsiribihina	Tsimafana	Tsimafana	2	1,500	57	3	60	59
113	Tsiribihina	Tsimafana	Mananjaky	2	1,170	57	6	63	62
114	Miandrivazo	Ambatolahy	Ambatolahy	3	800	1	12	13	12
115	Miandrivazo	Ankotrofotsy	Ankotrofotsy	3	908	1	9	10	9

Table 4.2.2 Ranking of Candidate Villages by Economic Capacity (1/3)

No.	Fivondronana	Firaisana	Village	Economic Capacity							Total Ranking
				Data			Ranking			Total Point	
				Population	Income	Assets	Population	Income	Assets		
1	Manja	Andranopasy	Andranopasy I	623	875,000	12.8	26	4	2	32	4
2	Manja	Andranopasy	Andranopasy II	226	468,400	3.5	61	54	16	131	45
3	Manja	Andranopasy	Antaly	327	481,700	3.7	49	42	15	106	36
4	Manja	Andranopasy	Darika	327	481,700	0.6	49	42	58	149	57
5	Manja	Andranopasy	Befamonty	450	550,000	6.7	35	22	5	62	8
6	Manja	Andranopasy	Anbatobe	220	467,600	0.5	62	55	65	182	70
7	Manja	Andranopasy	Nositonga	260	472,900	2.7	56	48	18	122	41
8	Manja	Andranopasy	Nosibe	600	517,700	2.0	27	27	22	76	15
9	Manja	Andranopasy	Ankoba	410	492,700	4.9	39	35	13	87	21
10	Manja	Andranopasy	Antseranandaka Nord	342	483,700	5.8	47	40	10	97	31
11	Manja	Andranopasy	Tsaramandroso	237	469,800	10.5	60	53	3	116	40
14	Manja	Manja	Tanambahiny	131	455,900	1.5	73	64	30	167	62
15	Manja	Manja	Miary	365	325,000	0.5	45	78	65	188	73
16	Manja	Ankiliabo	Ambivy I	130	575,000	3.1	74	18	17	109	38
17	Manja	Ankiliabo	Ambivy II	500	504,500	0.4	31	30	72	133	48
18	Manja	Ankiliabo	Ambahia	200	465,000	1.8	66	57	25	148	54
19	Manja	Ankiliabo	Besatrohaka	210	466,300	0.5	63	56	65	184	72
20	Manja	Ankiliabo	Marolafila Atsimo	500	504,500	0.8	31	30	50	111	39
23	Beroroha	Beroroha	Marerano	1,100	583,700	1.1	12	17	36	65	9
25	Morondava	Befasy	Befasy	2,000	650,000	0.4	4	11	72	87	21
26	Morondava	Befasy	Antevamena	360	486,100	2.2	46	39	21	106	36
27	Morondava	Befasy	Mitsitily	340	483,400	5.9	48	41	9	98	32
28	Morondava	Befasy	Andranovorisosotra	40	443,900	0.8	79	70	50	199	76
29	Morondava	Befasy	Ankitatamahavelo	190	463,600	0.4	68	59	72	199	76
30	Morondava	Befasy	Bekininy Soarano	400	491,300	2.0	40	36	22	98	32
31	Morondava	Befasy	Beleo	800	544,100	0.9	18	23	44	85	19
32	Morondava	Befasy	Anadabo	36	443,300	0.6	81	72	58	211	80
33	Morondava	Befasy	Misokotsa	800	470,000	2.5	18	51	20	89	24
34	Morondava	Laijoby	Croisement Besotroka	200	465,000	5.0	66	57	11	134	50
35	Morondava	Laijoby	Amanga	400	240,000	0.3	40	80	76	196	75
36	Morondava	Manomentinay	Namakia	400	491,300	5.0	40	36	11	87	21
39	Morondava	Manomentinay	Antsamaka	150	458,400	2.7	69	61	18	148	54
40	Morondava	Manomentinay	Manomentinay	436	680,000	0.9	37	10	44	91	26

Table 4.2.2 Ranking of Candidate Villages by Economic Capacity (2/3)

No.	Fivondronana	Firaisana	Village	Economic Capacity							Total Ranking
				Data			Ranking			Total Point	
				Population	Income	Assets	Population	Income	Assets		
41	Morondava	Manomentinay	Farateny	250	471,600	1.4	57	49	31	137	53
43	Morondava	Manomentinay	Andrananja	70	447,800	6.5	77	68	7	152	59
46	Morondava	Belo-Sur-Mer	Marofihitsa	750	650,000	0.9	23	11	44	78	16
47	Morondava	Belo-Sur-Mer	Ambararata	500	450,000	1.2	31	66	34	131	45
48	Morondava	Belo-Sur-Mer	Ankevo	300	370,000	0.7	51	76	55	182	70
50	Morondava	Lavaravy Tsimaliha	Bevantaza	150	458,400	0.5	69	61	65	195	74
52	Morondava	Androvabe	Antsakamirohaka	1,600	649,600	0.8	6	14	50	70	11
53	Morondava	Androvabe	Androvakely	550	511,100	0.4	30	29	72	131	45
55	Morondava	Androvabe	Ampananiha	420	494,000	0.6	38	34	58	130	43
56	Morondava	Androvabe	Antseranambondro	60	446,500	1.7	78	69	28	175	67
58	Morondava	Bemanonga	Bemanonga	1,250	603,400	0.8	9	15	50	74	14
59	Morondava	Bemanonga	Marovoay	1,247	603,000	1.0	10	16	39	65	9
60	Morondava	Bemanonga	Tandrokosy	238	470,000	0.5	59	51	65	175	67
61	Morondava	Bemanonga	Bekonazy	40	443,900	0.8	79	70	50	199	76
64	Morondava	Bemanonga	Andranomena Atsimo	210	450,000	1.0	63	66	39	168	63
65	Morondava	Bemanonga	Tanandava	250	471,600	0.5	57	49	65	171	64
66	Morondava	Bemanonga	Croisement (BST)	204	380,000	1.2	65	75	34	174	66
67	Morondava	Analaiva	Analaiva	1,520	820,000	6.1	7	6	8	21	2
68	Morondava	Analaiva	Betsipotika	120	325,000	0.6	75	78	58	211	80
69	Morondava	Analaiva	Amboloando	150	225,000	0.7	69	81	55	205	79
70	Morondava	Analaiva	Ampandra	600	420,000	1.3	27	74	32	133	48
72	Morondava	Analaiva	Antevamena II	100	451,800	1.0	76	65	39	180	69
74	Morondava	Analaiva	Tsinjorano	450	360,000	1.1	35	77	36	148	54
76-1	Morondava	Laijoby	Laijoby Avaratra	150	458,400	1.3	69	61	32	162	61
79	Morondava	Laijoby	Ambonio	270	474,200	0.6	55	47	58	160	60
80	Morondava	Laijoby	Analalava	300	478,100	0.7	51	44	55	150	58
81	Morondava	Befasy	Malandirano	400	491,300	1.8	40	36	25	101	34
82	Morondava	Marofandiliha	Marofandiliha	370	460,000	1.8	44	60	25	129	42
83	Morondava	Marofandiliha	Ampataka	695	530,200	0.9	25	26	44	95	29
89	Morondava	Marofandiliha	Ankaraobato	800	544,100	0.9	18	23	44	85	19
93	Morondava	Marofandiliha	Boraboka Atsimo	783	650,000	3.8	22	11	14	47	7
94	Mahabo	Ankilivalo	Ankilivalo	2,960	950,000	1.0	3	3	39	45	6
95	Mahabo	Ankilivalo	Ambohibary	300	478,100	0.3	51	44	76	171	64

Table 4.2.2 Ranking of Candidate Villages by Economic Capacity (3/3)

No.	Fivondronana	Firaisana	Village	Economic Capacity							Total Ranking
				Data			Ranking			Total Point	
				Population	Income	Assets	Population	Income	Assets		
97	Mahabo	Ankilivalo	Bezezika	855	750,000	0.2	17	8	80	105	35
99	Mahabo	Ampanihy	Ankilimida	600	517,700	0.3	27	27	76	130	43
100	Mahabo	Ampanihy	Ampanihy	742	536,400	0.9	24	25	44	93	28
101	Mahabo	Ampanihy	Benato	500	504,500	1.6	31	30	29	90	25
102	Mahabo	Ampanihy	Anolotsy	300	478,100	1.0	51	44	39	134	50
103	Mahabo	Ankilizato	Ankilizato	4,200	1,050,000	6.6	2	2	6	10	1
104	Mahabo	Mandabe	Mandabe	2,000	435,000	0.6	4	73	58	135	52
106	Mahabo	Malaimbandy	Malaimbandy	7,000	1,250,000	0.1	1	1	81	83	18
107	Mahabo	Malaimbandy	Ampanotoka	900	557,300	1.1	16	21	36	73	13
109	Belo sur Tsiribihina	Tsianaloka	Tsianaloka	1,000	500,000	1.9	13	33	24	70	11
110	Belo sur Tsiribihina	Tsianaloka	Kiboy	930	561,200	0.6	14	19	58	91	26
112	Belo sur Tsiribihina	Tsimafana	Tsimafana	1,500	780,000	0.5	8	7	65	80	17
113	Tsiribihina	Tsimafana	Mananjaky	1,170	720,000	0.3	11	9	76	96	30
114	Miandrivazo	Ambatolahy	Ambatolahy	800	850,000	15.0	18	5	1	24	3
115	Miandrivazo	Ankotrofotsy	Ankotrofotsy	908	558,300	7.3	15	20	4	39	5

Table 4.2.3 Ranking of Candidate Villages by Social Capacity (1/3)

No.	Fivondronana	Firaisana	Village	Social Capacity					Total Ranking
				Data		Ranking		Total Point	
				Literacy	School Enrollment	Literacy	School Enrollment		
1	Manja	Andranopasy	Andranopasy I	13.5	51.2	39	20	59	29
2	Manja	Andranopasy	Andranopasy II	1.5	4.6	77	78	155	80
3	Manja	Andranopasy	Antaly	0.5	6.1	81	71	152	78
4	Manja	Andranopasy	Darika	6.5	5.9	56	72	128	65
5	Manja	Andranopasy	Befamonty	0.5	9.3	80	66	146	76
6	Manja	Andranopasy	Anbatobe	7.8	3.2	52	80	132	68
7	Manja	Andranopasy	Nositonga	3.8	7.2	67	70	137	74
8	Manja	Andranopasy	Nosibe	4.7	5.2	61	75	136	72
9	Manja	Andranopasy	Ankoba	4.8	12.8	60	55	115	57
10	Manja	Andranopasy	Antseranandaka Nord	2.9	10.1	71	64	135	71
11	Manja	Andranopasy	Tsaramandroso	3.4	9.8	68	65	133	69
14	Manja	Manja	Tanambahiny	10.3	8.4	46	67	113	56
15	Manja	Manja	Miary	21.6	54.5	28	18	46	21
16	Manja	Ankiliabo	Ambivy I	9.7	25.1	49	39	88	40
17	Manja	Ankiliabo	Ambivy II	10.4	12.7	45	56	101	50
18	Manja	Ankiliabo	Ambahia	3.8	19.5	66	46	112	55
19	Manja	Ankiliabo	Besatrohaka	4.9	18.5	58	47	105	54
20	Manja	Ankiliabo	Marolafila Atsimo	3.2	12.7	69	57	126	63
23	Beroroha	Beroroha	Marerano	7.6	16.9	54	49	103	51
25	Morondava	Befasy	Befasy	41.1	43.9	9	28	37	18
26	Morondava	Befasy	Antevamena	1.4	5.9	78	74	152	78
27	Morondava	Befasy	Mitsitily	2.5	3.1	74	81	155	80
28	Morondava	Befasy	Andranovorisosotra	5.3	3.3	57	79	136	72
29	Morondava	Befasy	Ankitatamahavelo	4.8	5.2	59	75	134	70
30	Morondava	Befasy	Bekininy Soarano	3.1	5.0	70	77	147	77
31	Morondava	Befasy	Beleo	2.1	14.2	75	53	128	65
32	Morondava	Befasy	Anadabo	2.9	7.8	71	69	140	75
33	Morondava	Befasy	Misokotsa	1.6	16.1	76	51	127	64
34	Morondava	Laijoby	Croisement Besotroka	15.6	5.9	32	72	104	52
35	Morondava	Laijoby	Amanga	8.8	14.0	50	54	104	52
36	Morondava	Manomentinay	Namakia	7.8	20.0	53	45	98	48
39	Morondava	Manomentinay	Antsamaka	16.6	12.4	31	59	90	43
40	Morondava	Manomentinay	Manomentinay	12.1	25.4	41	38	79	39

Table 4.2.3 Ranking of Candidate Villages by Social Capacity (2/3)

No.	Fivondronana	Firaisana	Village	Social Capacity					Total Ranking
				Data		Ranking		Total Point	
				Literacy	School Enrollment	Literacy	School Enrollment		
41	Morondava	Manomentinay	Farateny	17.6	29.1	30	36	66	33
43	Morondava	Manomentinay	Andrananja	11.2	16.8	42	50	92	45
46	Morondava	Belo-Sur-Mer	Marofihitsa	14.6	15.9	36	52	88	40
47	Morondava	Belo-Sur-Mer	Ambararata	30.9	44.7	19	25	44	20
48	Morondava	Belo-Sur-Mer	Ankevo	7.1	10.4	55	62	117	58
50	Morondava	Lavaravy Tsimaliha	Bevantaza	10.6	18.3	44	48	92	45
52	Morondava	Androvabe	Antsakamirohaka	50.5	78.5	7	4	11	4
53	Morondava	Androvabe	Androvakely	81.9	89.5	1	1	2	1
55	Morondava	Androvabe	Ampananiha	22.9	22.7	26	42	68	35
56	Morondava	Androvabe	Antseranambondro	23.0	21.3	25	44	69	36
58	Morondava	Bemanonga	Bemanonga	59.4	66.8	2	7	9	3
59	Morondava	Bemanonga	Marovoay	32.5	68.7	16	6	22	10
60	Morondava	Bemanonga	Tandrokosy	32.0	38.1	17	32	49	23
61	Morondava	Bemanonga	Bekonazy	3.8	10.3	65	63	128	65
64	Morondava	Bemanonga	Andranomena Atsimo	15.1	49.4	34	23	57	27
65	Morondava	Bemanonga	Tanandava	14.3	42.1	37	29	66	33
66	Morondava	Bemanonga	Croisement (BST)	38.0	55.2	11	16	27	12
67	Morondava	Analaiva	Analaiva	32.5	74.5	15	5	20	8
68	Morondava	Analaiva	Betsipotika	53.6	59.4	4	11	15	6
69	Morondava	Analaiva	Amboloando	37.3	44.7	12	24	36	15
70	Morondava	Analaiva	Ampandra	40.4	50.2	10	21	31	13
72	Morondava	Analaiva	Antevamena II	36.1	34.6	14	34	48	22
74	Morondava	Analaiva	Tsinjorano	2.9	44.4	73	27	100	49
76-1	Morondava	Laijoby	Laijoby Avaratra	15.6	36.0	32	33	65	32
79	Morondava	Laijoby	Ambonio	13.2	32.5	40	35	75	38
80	Morondava	Laijoby	Analalava	9.7	23.4	48	41	89	42
81	Morondava	Befasy	Malandirano	4.2	12.3	63	60	123	61
82	Morondava	Marofandiliha	Marofandiliha	31.4	57.0	18	14	32	14
83	Morondava	Marofandiliha	Ampataka	25.5	40.4	22	30	52	24
89	Morondava	Marofandiliha	Ankaraobato	23.6	8.0	24	68	92	45
93	Morondava	Marofandiliha	Boraboka Atsimo	26.0	38.9	21	31	52	24
94	Mahabo	Ankilivalo	Ankilivalo	42.6	59.2	8	12	20	8
95	Mahabo	Ankilivalo	Ambohibary	10.0	22.4	47	43	90	43

Table 4.2.3 Ranking of Candidate Villages by Social Capacity (3/3)

No.	Fivondronana	Firaisana	Village	Social Capacity					Total Ranking
				Data		Ranking		Total Point	
				Literacy	School Enrollment	Literacy	School Enrollment		
97	Mahabo	Ankilivalo	Bezezika	51.7	65.7	6	8	14	5
99	Mahabo	Ampanihy	Ankilimida	18.0	44.4	29	26	55	26
100	Mahabo	Ampanihy	Ampanihy	0.7	24.2	79	40	119	59
101	Mahabo	Ampanihy	Benato	15.1	28.4	35	37	72	37
102	Mahabo	Ampanihy	Anolotsy	3.9	12.3	64	60	124	62
103	Mahabo	Ankilizato	Ankilizato	53.0	55.1	5	17	22	10
104	Mahabo	Mandabe	Mandabe	25.2	58.8	23	13	36	15
106	Mahabo	Malaimbandy	Malaimbandy	27.1	53.0	20	19	39	19
107	Mahabo	Malaimbandy	Ampanotoka	4.6	12.6	62	58	120	60
109	Belo sur Tsiribihina	Tsianaloka	Tsianaloka	37.1	85.4	13	2	15	6
110	Belo sur Tsiribihina	Tsianaloka	Kiboy	10.9	55.9	43	15	58	28
112	Belo sur Tsiribihina	Tsimafana	Tsimafana	54.2	82.3	3	3	6	2
113	Belo sur Tsiribihina	Tsimafana	Mananjaky	14.3	49.6	38	22	60	30
114	Miandrivazo	Ambatolahy	Ambatolahy	21.8	64.5	27	9	36	15
115	Miandrivazo	Ankotrofotsy	Ankotrofotsy	8.1	63.2	51	10	61	31

Table 4.2.4 Ranking of Candidate Villages by Institutional Capacity (1/3)

No.	Fivondronana	Firaisana	Village	Institutional Capacity						Total Ranking
				Data					Total Point	
				Organization	Hygiene	Medical Service	Education	Women		
1	Manja	Andranopasy	Andranopasy I	1	2	3	3	1	10	2
2	Manja	Andranopasy	Andranopasy II	0	1	0	0	1	2	68
3	Manja	Andranopasy	Antaly	0	2	0	1	1	4	38
4	Manja	Andranopasy	Darika	0	1	0	0	1	2	68
5	Manja	Andranopasy	Befamonty	0	3	3	1	1	8	16
6	Manja	Andranopasy	Anbatobe	0	2	0	0	1	3	47
7	Manja	Andranopasy	Nositonga	0	2	0	0	1	3	47
8	Manja	Andranopasy	Nosibe	0	1	0	0	1	2	68
9	Manja	Andranopasy	Ankoba	0	3	0	1	1	5	32
10	Manja	Andranopasy	Antseranandaka Nord	0	1	0	0	1	2	68
11	Manja	Andranopasy	Tsaramandroso	0	1	0	0	1	2	68
14	Manja	Manja	Tanambahiny	0	1	0	0	1	2	68
15	Manja	Manja	Miary	1	2	0	2	1	6	23
16	Manja	Ankiliabo	Ambivy I	0	1	0	0	1	2	68
17	Manja	Ankiliabo	Ambivy II	0	1	0	1	1	3	47
18	Manja	Ankiliabo	Ambahia	0	3	0	0	1	4	38
19	Manja	Ankiliabo	Besatrohaka	0	2	1	1	1	5	32
20	Manja	Ankiliabo	Marolafila Atsimo	0	1	0	1	1	3	47
23	Beroroha	Beroroha	Marerano	1	2	3	3	1	10	2
25	Morondava	Befasy	Befasy	1	1	3	3	2	10	2
26	Morondava	Befasy	Antevamena	0	2	0	0	1	3	47
27	Morondava	Befasy	Mitsitily	1	3	0	1	1	6	23
28	Morondava	Befasy	Andranovorisosotra	0	1	0	0	1	2	68
29	Morondava	Befasy	Ankitatamahavelo	0	2	0	0	1	3	47
30	Morondava	Befasy	Bekininy Soarano	0	0	0	0	1	1	81
31	Morondava	Befasy	Beleo	0	2	1	2	1	6	23
32	Morondava	Befasy	Anadabo	0	2	0	0	1	3	47
33	Morondava	Befasy	Misokotsa	2	0	1	2	1	6	23
34	Morondava	Laijoby	Croisement Besotroka	1	1	0	0	2	4	38
35	Morondava	Laijoby	Amanga	0	2	0	0	1	3	47
36	Morondava	Manomentinay	Namakia	0	1	0	0	1	2	68
39	Morondava	Manomentinay	Antsamaka	0	2	0	0	1	3	47
40	Morondava	Manomentinay	Manomentinay	1	3	3	2	1	10	2

Table 4.2.4 Ranking of Candidate Villages by Institutional Capacity (2/3)

No.	Fivondronana	Firaisana	Village	Institutional Capacity						Total Ranking
				Data					Total Point	
				Organization	Hygiene	Medical Service	Education	Women		
41	Morondava	Manomentinay	Farateny	0	1	0	1	1	3	47
43	Morondava	Manomentinay	Andrananja	0	2	0	0	1	3	47
46	Morondava	Belo-Sur-Mer	Marofihitsa	1	2	0	2	1	6	23
47	Morondava	Belo-Sur-Mer	Ambararata	0	1	0	1	1	3	47
48	Morondava	Belo-Sur-Mer	Ankevo	1	3	1	2	2	9	9
50	Morondava	Lavaravy Tsimaliha	Bevantaza	0	3	1	2	1	7	19
52	Morondava	Androvabe	Antsakamirohaka	1	0	0	3	1	5	32
53	Morondava	Androvabe	Androvakely	1	2	1	2	1	7	19
55	Morondava	Androvabe	Ampananiha	2	2	0	2	1	7	19
56	Morondava	Androvabe	Antseranambondro	0	2	0	0	1	3	47
58	Morondava	Bemanonga	Bemanonga	1	0	3	3	2	9	9
59	Morondava	Bemanonga	Marovoay	0	2	0	2	2	6	23
60	Morondava	Bemanonga	Tandrokosy	0	1	0	1	2	4	38
61	Morondava	Bemanonga	Bekonazy	0	1	0	0	1	2	68
64	Morondava	Bemanonga	Andranomena Atsimo	1	2	0	2	1	6	23
65	Morondava	Bemanonga	Tanandava	0	1	0	1	1	3	47
66	Morondava	Bemanonga	Croisement (BST)	1	2	0	2	1	6	23
67	Morondava	Analaiva	Analaiva	2	1	3	3	1	10	2
68	Morondava	Analaiva	Betsipotika	1	0	0	2	1	4	38
69	Morondava	Analaiva	Amboloando	0	2	0	0	1	3	47
70	Morondava	Analaiva	Ampandra	0	1	0	2	1	4	38
72	Morondava	Analaiva	Antevamena II	0	0	0	1	1	2	68
74	Morondava	Analaiva	Tsinjorano	3	2	0	2	1	8	16
76-1	Morondava	Laijoby	Laijoby Avaratra	2	3	1	2	1	9	9
79	Morondava	Laijoby	Ambonio	0	0	0	1	1	2	68
80	Morondava	Laijoby	Analalava	0	1	0	0	1	2	68
81	Morondava	Befasy	Malandirano	1	0	0	1	1	3	47
82	Morondava	Marofandiliha	Marofandiliha	1	3	3	2	1	10	2
83	Morondava	Marofandiliha	Ampataka	1	0	0	0	2	3	47
89	Morondava	Marofandiliha	Ankaraobato	1	0	0	1	1	3	47
93	Morondava	Marofandiliha	Boraboka Atsimo	2	1	0	2	1	6	23
94	Mahabo	Ankilivalo	Ankilivalo	0	3	1	3	2	9	9
95	Mahabo	Ankilivalo	Ambohibary	0	2	0	1	1	4	38

Table 4.2.4 Ranking of Candidate Villages by Institutional Capacity (3/3)

No.	Fivondronana	Firaisana	Village	Institutional Capacity: Data: Organization	Hygiene	Medical Service	Education	Women	Total Point	Total Ranking
97	Mahabo	Ankilivalo	Bezezika	2	2	0	2	1	7	19
99	Mahabo	Ampanihy	Ankilimida	1	1	0	2	1	5	32
100	Mahabo	Ampanihy	Ampanihy	0	2	0	2	1	5	32
101	Mahabo	Ampanihy	Benato	0	1	0	1	1	3	47
102	Mahabo	Ampanihy	Anolotsy	1	1	0	0	1	3	47
103	Mahabo	Ankilizato	Ankilizato	1	3	1	3	1	9	9
104	Mahabo	Mandabe	Mandabe	3	3	3	3	1	13	1
106	Mahabo	Malaimbandy	Malaimbandy	0	0	3	3	2	8	16
107	Mahabo	Malaimbandy	Ampanotoka	0	2	0	2	1	5	32
109	Belo sur Tsiribihina	Tsianaloka	Tsianaloka	0	1	0	2	1	4	38
110	Belo sur Tsiribihina	Tsianaloka	Kiboy	0	1	0	1	1	3	47
112	Belo sur Tsiribihina	Tsimafana	Tsimafana	1	2	3	3	1	10	2
113	Tsiribihina	Tsimafana	Mananjaky	1	1	0	1	1	4	38
114	Miandrivazo	Ambatolahy	Ambatolahy	2	0	3	3	1	9	9
115	Miandrivazo	Ankotrofotsy	Ankotrofotsy	1	1	3	3	1	9	9

Table 4.2.5 Total Ranking of Candidate Villages (1/3)

No.	Fivondronana	Firaisana	Village	Rank						Categorization		
				E (25%)	S (12.5%)	I (12.5%)	W (50.0%)	Total	Total Ranking	E+S+I (50%)	W (50%)	Final Category
1	Manja	Andranopasy	Andranopasy I	4	29	2	65	37	32	6	65	BA
2	Manja	Andranopasy	Andranopasy II	45	80	68	42	51	59	73	42	AC
3	Manja	Andranopasy	Antaly	36	78	38	31	39	34	47	31	AB
4	Manja	Andranopasy	Darika	57	65	68	31	46	48	74	31	AC
5	Manja	Andranopasy	Befamonty	8	76	16	23	25	17	20	23	AA
6	Manja	Andranopasy	Anbatobe	70	68	47	43	53	65	77	43	AC
7	Manja	Andranopasy	Nositonga	41	74	47	37	44	40	57	37	AB
8	Manja	Andranopasy	Nosibe	15	72	68	18	30	23	41	18	AB
9	Manja	Andranopasy	Ankoba	21	57	32	25	29	21	29	25	AA
10	Manja	Andranopasy	Antseranandaka Nord	31	71	68	29	40	35	55	29	AB
11	Manja	Andranopasy	Tsaramandroso	40	69	68	41	48	53	65	41	AC
14	Manja	Manja	Tanambahiny	62	56	68	79	71	80	75	79	BC
15	Manja	Manja	Miary	73	21	23	74	61	73	49	74	BB
16	Manja	Ankiliabo	Ambivy I	38	40	68	51	49	56	45	51	AB
17	Manja	Ankiliabo	Ambivy II	48	50	47	20	34	26	51	20	AB
18	Manja	Ankiliabo	Ambahia	54	55	38	77	64	75	55	77	BB
19	Manja	Ankiliabo	Besatrohaka	72	54	32	44	51	59	72	44	AC
20	Manja	Ankiliabo	Marolafila Atsimo	39	63	47	20	34	25	47	20	AB
23	Beroroha	Beroroha	Marerano	9	51	2	6	12	8	14	6	AA
25	Morondava	Befasy	Befasy	21	18	2	3	9	3	12	3	AA
26	Morondava	Befasy	Antevamena	36	78	47	28	39	33	53	28	AB
27	Morondava	Befasy	Mitsitily	32	80	23	30	36	29	39	30	AB
28	Morondava	Befasy	Andranovorisosotra	76	72	68	55	64	77	81	55	AC
29	Morondava	Befasy	Ankitatamahavelo	76	70	47	47	57	70	78	47	AC
30	Morondava	Befasy	Bekininy Soarano	32	77	81	26	41	36	68	26	AC
31	Morondava	Befasy	Beleo	19	65	23	12	22	15	24	12	AA
32	Morondava	Befasy	Anadabo	80	75	47	81	76	81	79	81	CC
33	Morondava	Befasy	Misokotsa	24	64	23	63	48	55	31	63	BB
34	Morondava	Laijoby	Croisement Besotroka	50	52	38	46	47	50	49	46	AB
35	Morondava	Laijoby	Amanga	75	52	47	26	44	42	76	26	AC
36	Morondava	Manomentinay	Namakia	21	48	68	71	55	68	37	71	BB
39	Morondava	Manomentinay	Antsamaka	54	43	47	48	49	57	54	48	AB
40	Morondava	Manomentinay	Manomentinay	26	39	2	70	47	49	16	70	BA
41	Morondava	Manomentinay	Farateny	53	33	47	38	42	37	46	38	AB

Table 4.2.5 Total Ranking of Candidate Villages (2/3)

No.	Fivondronana	Firaisana	Village	Rank						Categorization		
				E (25%)	S (12.5%)	I (12.5%)	W (50.0%)	Total	Total Ranking	E+S+I (50%)	W (50%)	Final Category
43	Morondava	Manomentinay	Andrananja	59	45	47	53	53	64	63	53	AC
46	Morondava	Belo-Sur-Mer	Marofihitsa	16	40	23	15	19	12	18	15	AA
47	Morondava	Belo-Sur-Mer	Ambararata	45	20	47	68	54	66	36	68	BB
48	Morondava	Belo-Sur-Mer	Ankevo	70	58	9	75	63	74	59	75	BB
50	Morondava	Lavaravy Tsimaliha	Bevantaza	74	45	19	78	66	78	64	78	BC
52	Morondava	Androvabe	Antsakamirohaka	11	4	32	58	36	30	10	58	BA
53	Morondava	Androvabe	Androvakely	45	1	19	67	47	52	21	67	BA
55	Morondava	Androvabe	Ampananiha	43	35	19	24	30	22	32	24	AB
56	Morondava	Androvabe	Antseranambondro	67	36	47	54	54	67	65	54	AC
58	Morondava	Bemanonga	Bemanonga	14	3	9	60	35	28	7	60	BA
59	Morondava	Bemanonga	Marovoay	9	10	23	61	37	31	9	61	BA
60	Morondava	Bemanonga	Tandrokosy	67	23	38	40	44	43	52	40	AB
61	Morondava	Bemanonga	Bekonazy	76	65	68	56	64	75	80	56	AC
64	Morondava	Bemanonga	Andranomena Atsimo	63	27	23	44	44	41	43	44	AB
65	Morondava	Bemanonga	Tanandava	64	33	47	38	45	46	60	38	AC
66	Morondava	Bemanonga	Croisement (BST)	66	12	23	76	59	72	39	76	BB
67	Morondava	Analaiva	Analaiva	2	8	2	5	4	2	1	5	AA
68	Morondava	Analaiva	Betsipotika	80	6	38	52	52	62	58	52	AB
69	Morondava	Analaiva	Amboloando	79	15	47	48	52	62	67	48	AC
70	Morondava	Analaiva	Ampandra	48	13	38	66	51	61	34	66	BB
72	Morondava	Analaiva	Antevamena II	69	22	68	80	69	79	71	80	BC
74	Morondava	Analaiva	Tsinjorano	54	49	16	69	56	69	42	69	BB
76-1	Morondava	Laijoby	Laijoby Avaratra	61	32	9	48	44	43	38	48	AB
79	Morondava	Laijoby	Ambonio	60	38	68	36	46	47	69	36	AC
80	Morondava	Laijoby	Analalava	58	42	68	33	45	45	69	33	AC
81	Morondava	Befasy	Malandirano	34	61	47	71	58	71	43	71	BB
82	Morondava	Marofandiliha	Marofandiliha	42	14	2	73	49	58	19	73	BA
83	Morondava	Marofandiliha	Ampataka	29	24	47	17	25	16	55	17	AB
89	Morondava	Marofandiliha	Ankaraobato	19	45	47	63	48	54	28	63	BA
93	Morondava	Marofandiliha	Boraboka Atsimo	7	24	23	14	15	9	11	14	AA
94	Mahabo	Ankilivalo	Ankilivalo	6	8	9	57	32	24	3	57	BA
95	Mahabo	Ankilivalo	Ambohibary	64	43	38	33	43	38	61	33	AC
97	Mahabo	Ankilivalo	Bezezika	35	5	19	11	17	11	17	11	AA
99	Mahabo	Ampanihy	Ankilimida	43	26	32	18	27	20	33	18	AA
100	Mahabo	Ampanihy	Ampanihy	28	59	32	16	26	18	34	16	AB

Table 4.2.5 Total Ranking of Candidate Villages (3/3)

No.	Fivondronana	Firaisana	Village	Rank						Categorization		
				E (25%)	S (12.5%)	I (12.5%)	W (50.0%)	Total	Total Ranking	E+S+I (50%)	W (50%)	Final Category
101	Mahabo	Ampanihy	Benato	25	37	47	20	27	19	30	20	AB
102	Mahabo	Ampanihy	Anolotsy	50	62	47	33	43	38	61	33	AB
103	Mahabo	Ankilizato	Ankilizato	1	10	9	2	4	1	2	2	AA
104	Mahabo	Mandabe	Mandabe	52	15	1	3	17	10	23	3	AA
106	Mahabo	Malaimbandy	Malaimbandy	18	19	16	1	9	4	14	1	AA
107	Mahabo	Malaimbandy	Ampanotoka	13	60	32	10	20	13	22	10	AA
109	Belo sur Tsiribihina	Tsianaloka	Tsianaloka	11	6	38	7	12	7	13	7	AA
110	Belo sur Tsiribihina	Tsianaloka	Kiboy	26	28	47	8	20	14	25	8	AA
112	Belo sur Tsiribihina	Tsimafana	Tsimafana	17	2	2	59	34	27	5	59	BA
113	Tsiribihina	Tsimafana	Mananjaky	30	30	38	62	47	51	26	62	BA
114	Miandrivazo	Ambatolahy	Ambatolahy	3	15	9	12	10	5	4	12	AA
115	Miandrivazo	Ankotrofotsy	Ankotrofotsy	5	31	9	9	11	6	8	9	AA

Notes: 1) E means 'Economic Capacity'.
2) S means 'Social Capacity'.
3) I means 'Institutional Capaity'.
4) W means 'Water Requirement'.

Fig. 4.2.1 Distribution of Villages by Water Requirement

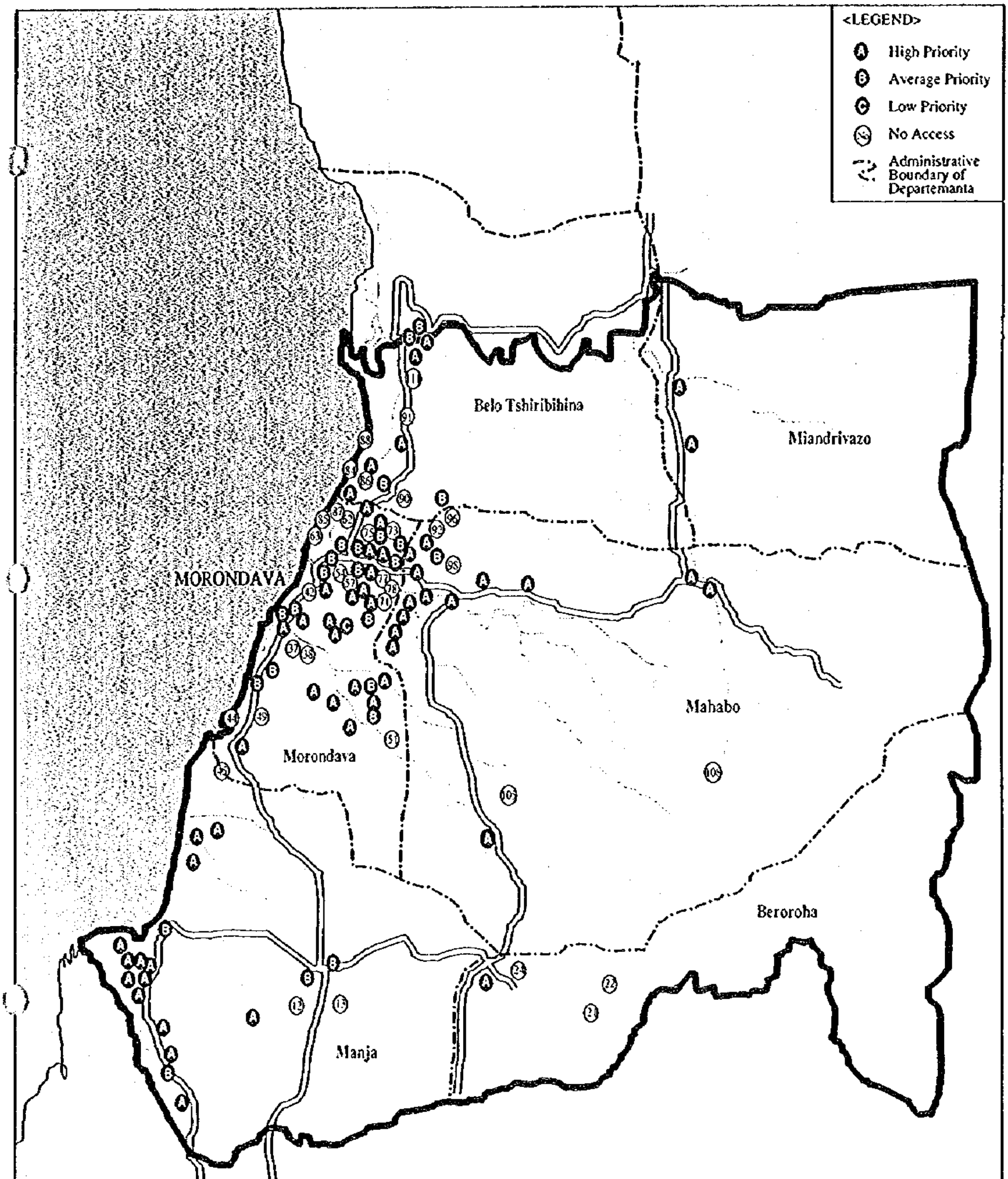


Fig. 4.2.2 Distribution of Villages by Socio-economic Capacity

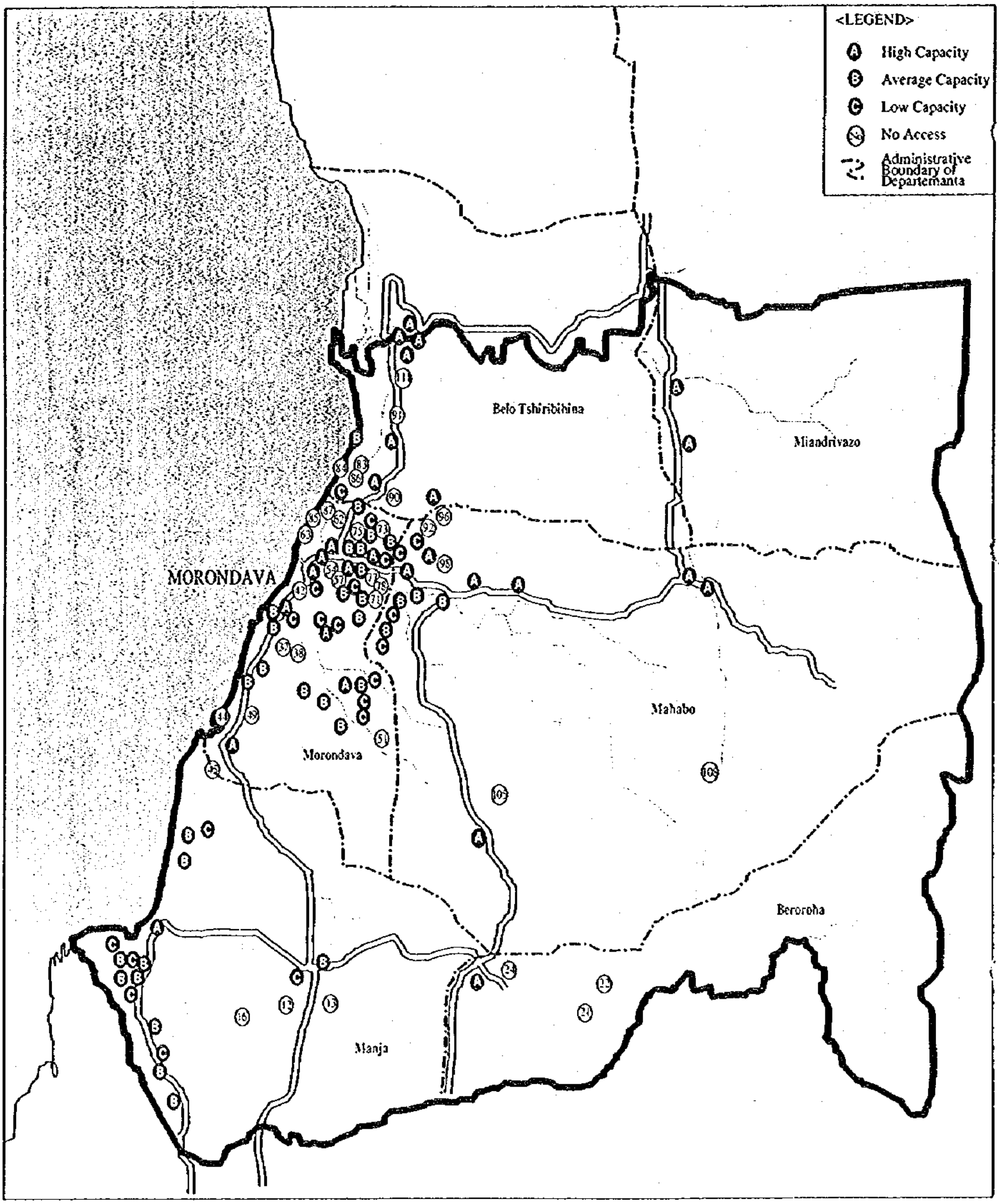
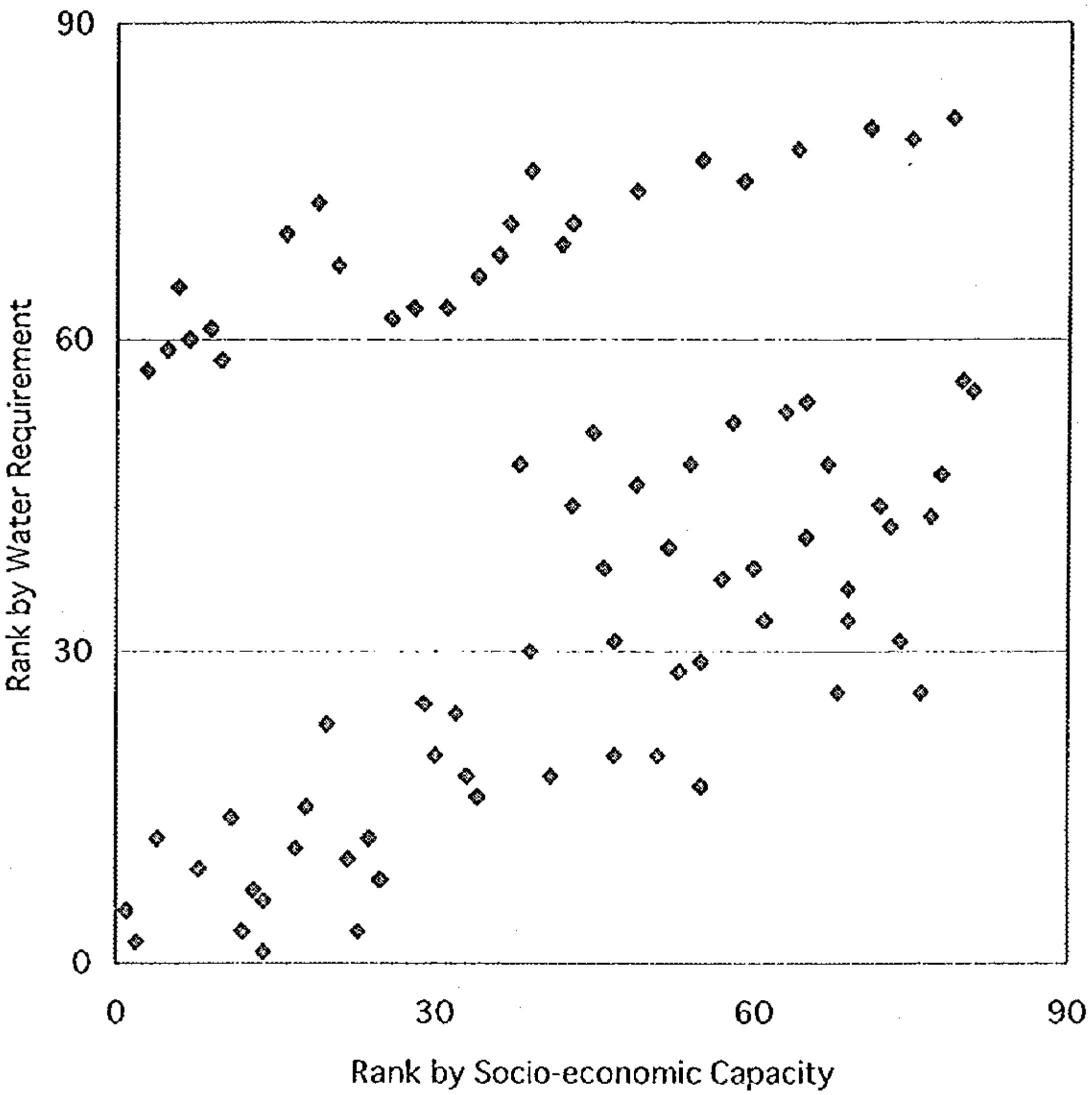


Fig 4.2.3 Distribution of Candidate Villages by Rank of Water Requirement and Socio-economic Capacity



Number of Villages in Each Category

Water \ Socio-economy	A(1-30)	B(31-60)	C(61-81)
A	18	21	17
B	11	10	3
C	0	0	1

5. SURVEY FOR GROUNDWATER DEVELOPMENT

5.1 Hydrology

In order to estimate the macroscopic water balance in the main areas of the Morondava groundwater basin, existing records of precipitation, evaporation, stream (river) flow and groundwater level were collected and processed. By verifying and classifying the main river basins for the evaluation of water resource potential, the discharge measurement was carried out at 17 sites in June 1995. Table 5.1.2 presents the results of measurement and the locations are given in Fig. 5.1.1.

5.1.1 Precipitation and Evapotranspiration

(1) Existing Stations

The required meteorological data of the Study Area were obtained from the Directorate of Meteorology in Antananarivo.

The meteorological stations used for the data collection in this Study are as follows:

Table 5.1.1 Location of Meteorological Stations

Stations	Latitude	Longitude	Altitude	Period	Type
1. Morondava	20° 17' S	44° 19' E	7 m	1961-1990	A
2. Morombe	21° 45' S	43° 22' E	4 m	1961-1990	A
3. Mahabo	20° 22' S	44° 41' E	75 m	1960-1980, 90	B
4. Manja	21° 26' S	44° 20' E	267 m	1951-1962 1961-1970	B
5. Beroroha	21° 40' S	45° 10' E	180 m	1961-1969	B
6. Miandrivazo	19° 34' S	45° 27' E	71 m	1974-1983 1977-1980 1988-1993	B

Type A stations deal with temperature, rainfall, relative humidity, hours of sunshine, mean wind velocity, evaporation, while Type B stations record only temperature and rainfall.

Although these stations are well located at reasonable points as shown in Fig. 5.1.1, they are insufficient in number for understanding local variations of climate in the Study Area.

(2) Precipitation

Fig. 5.1.2 represents the monthly average rainfall at the 6 stations mentioned above. As shown in this figure, the Study Area has a five-month rainy season from November to March, and a seven-month dry season from April to October.

In Fig. 5.1.1, isohyets on the hydrological map show the average annual rainfall distribution represented by the 6 stations, which indicates that rainfall decreases gradually from the north-east to the south-west, excluding the area of Beroroha. The hilly and mountainous areas have a higher rainfall (1,400 mm) than the coastal plains (600 mm).

Fig. 5.1.3 shows the relationship between the annual rainfall and the altitude of the stations. From this figure, it can be roughly assumed that rainfall seems to increase with elevation even at the station of Miandrivazo, because the station of Miandrivazo is located in the intramountain basin enclosed by the Bemahara massif (500-550m) in the west and the western ridge of the Central High Lands (450-700m) in the east.

(3) Evapotranspiration

Daily evaporation is measured at two stations, Morombe and Morondava, by Piche evaporimeters (see Fig. 5.1.4 and 5.1.5). Basically, the Piche evaporimeter is not designed to make actual measurement of evaporation and is not recommended for hydrology in arid zones.

Evapotranspiration is usually estimated by empirical formulas. Using the climatic records from the said two stations, the monthly potential evapotranspiration was, thus, calculated by the Thronwaite method (Fig. 5.1.4 and 5.1.5).

As shown in these tables, the calculated potential evapotranspiration is not adaptable for water balance analysis. The evapotranspiration value used for the water balance analysis is discussed in the section of "Hydrogeology".

5.1.2 River System and Discharge

As shown in Fig. 5.1.1, the Study Area is composed hydrologically of 8 river basins and 3 coastal plains. The area of these river basins and plains are as follows:

- Morondava Plain	6,006	km²
- Mangoky Delta	855	
- Tsiribihina Delta	245	
- Tsiribihina River Basin	2,485	
- Andranomena River Basin	1,529	
- Morondava River Basin	5,535	
- Sakény River Basin	2,521	
- Maharivo River Basin	4,328	
- Kirindy River Basin	1,956	
- Maintapaka River Basin	1,904	
- Mangoky River Basin	9,165	

The Tsiribihina and Mangoky rivers are the third and fourth largest rivers in Madagascar. The Tsiribihina River bounds the Study Area at the north, and the Mangoky River at the south.

Between the Tsiribihina and Mangoky rivers, 6 perennial rivers flow N-W, WNW and westward, and many seasonal rivers are present. The Morondava River is the biggest of the 6 perennial rivers and its annual streamflow observed at the Dabara dam is as follows:

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
141	138	94.1	19.1	12.2	11.0	10.4	9.3	8.7	8.1	19.1	107

Q in m^3/s (average year)

In the coastal area, no water flow has been observed during the dry season in the Maharivo, Andranomena, Kirindy or Maintapaka rivers. The absence of water flow in these 4 rivers is accounted for by the recharge to the groundwater sub-basin of the Morondava Plain.

The discharge measurement were made at 16 sites in June, 1995. The sites are shown in Fig. 5.1.1, and the results are given in Table 5.1.2. The hydrogeological analysis on the results of discharge measurement is discussed in the section of "Hydrogeology".

5.1.3 Springs

Manja and its surrounding area is composed of sandstone and alternating facies of limestone and marl of the Cretaceous System, and limestone, marl, marly sandstone and sandstone of the Eocene Series. There are many springs discharged from the above facies, as shown on the hydrogeological map.

According to the results of spot discharge measurement, the specific discharge from springs is estimated at 0.76 - 1.56 ℓ /sec/km². A part of the springs are utilized for domestic water and agricultural use in the town of Manja and its neighboring villages.

Tab. 5.1.2 Résultats des Mesures de Débit
Results of Discharge Measurement

Sites	River Basin	Discharge Measurement		
		Area (km^2)	Discharge (m^3/sec)	Discharge ($\ell/sec/km^2$)
A	Morondava	4,562	12.24	2.72
B	〃	474	0.60	1.27
C	Andranomena	213	1.00	4.69
D	〃	291	0.10	0.34
E	Sakeny	135	1.60	11.85
F	〃	203	2.50	12.32
G	〃	533	6.30	11.82
H	〃	1,650	2.10	1.27
I	Maharivo	2,901	7.85	2.71
J	〃	317	0.93	2.93
K	〃	214	1.17	5.47
L	〃	388	0.33	0.85
M	Kirindy	1,050	1.30	1.24
N	Maintapaka	397	0.30	0.76
O	〃	292	0.46	1.56
P	〃	72	0.08	1.11
Q	〃	163	0.19	1.17

Station météorologique
Meteorologic Station

763.9 Pluviométrie annuelle moyenne (mm)
Mean Annual Rainfall (mm)

--700-- Isohyètes (mm)
Rainfall Contour Line (mm)

Bassin fluvial
River Basin

13.21 Débit de base (m³/sec)
Base Flow (m³/sec)

(1) Plaine de Morondava
Morondava Plain

(2) Delta de Mangoky
Mangoky delta

(3) Delta de Tsiribihina
Tsiribihina Delta

(4) Bassin du fleuve Tsiribihina
Tsiribihina River Basin

(5) Bassin du fleuve Andranomena
Andranomena River Basin

(6) Bassin du fleuve Morondava
Morondava River Basin

(7) Bassin de la rivière Sakény
Sakeny River Basin

(8) Bassin du fleuve Maharivo
Maharivo River Basin

(9) Bassin du fleuve Kirindy
Kirindy River Basin

(10) Bassin du fleuve Maintapaka
Maintapaka River Basin

(11) Bassin de la rivière Mangoky
Mangoky River Basin

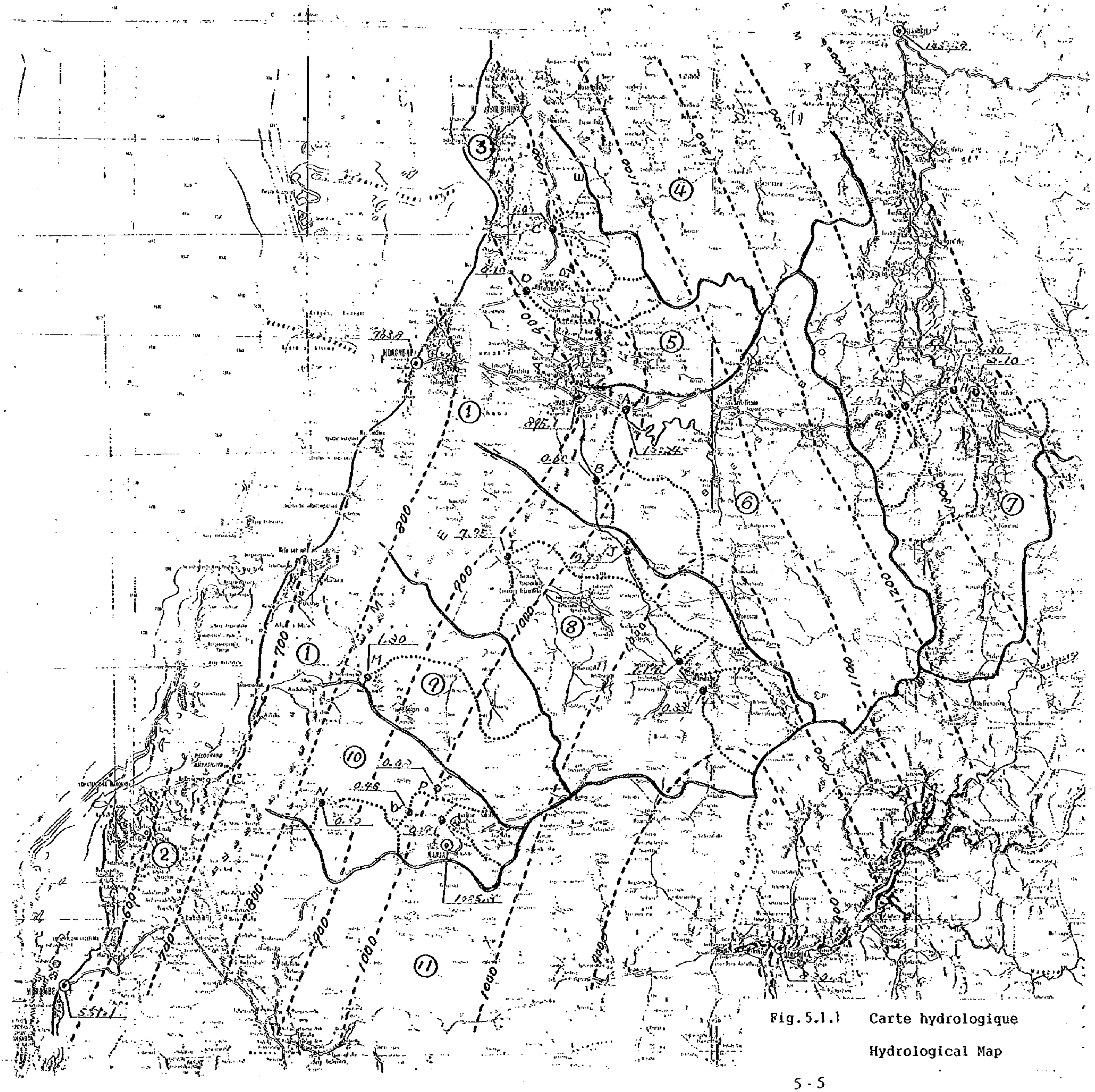


Fig.5.1.1 Carte hydrologique

Hydrological Map

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	Total
Morondava	241.6	200.2	89.5	14.8	1.4	2.4	2.3	2.2	3.6	11.9	20.6	163.3	753.8
Morombe	94.8	141.9	59.5	30.7	26.6	33.8	2.2	5.8	7.2	23.4	8.5	126.7	561.1
Mahabo	197.2	175.7	86.5	15.1	27.5	3.2	15.9	0.0	23.9	71.7	42.0	236.4	895.1
Manja	295.5	190.9	196.0	28.0	28.2	0.0	4.3	17.0	38.8	23.5	79.4	183.7	1,085.3
Beroroha	205.7	144.6	93.4	16.1	14.5	5.0	3.7	4.2	4.3	44.2	88.8	196.1	820.6
Miandrivazo	274.0	340.8	260.2	65.9	18.9	0.8	5.5	1.8	13.7	66.7	114.9	271.5	1,434.7

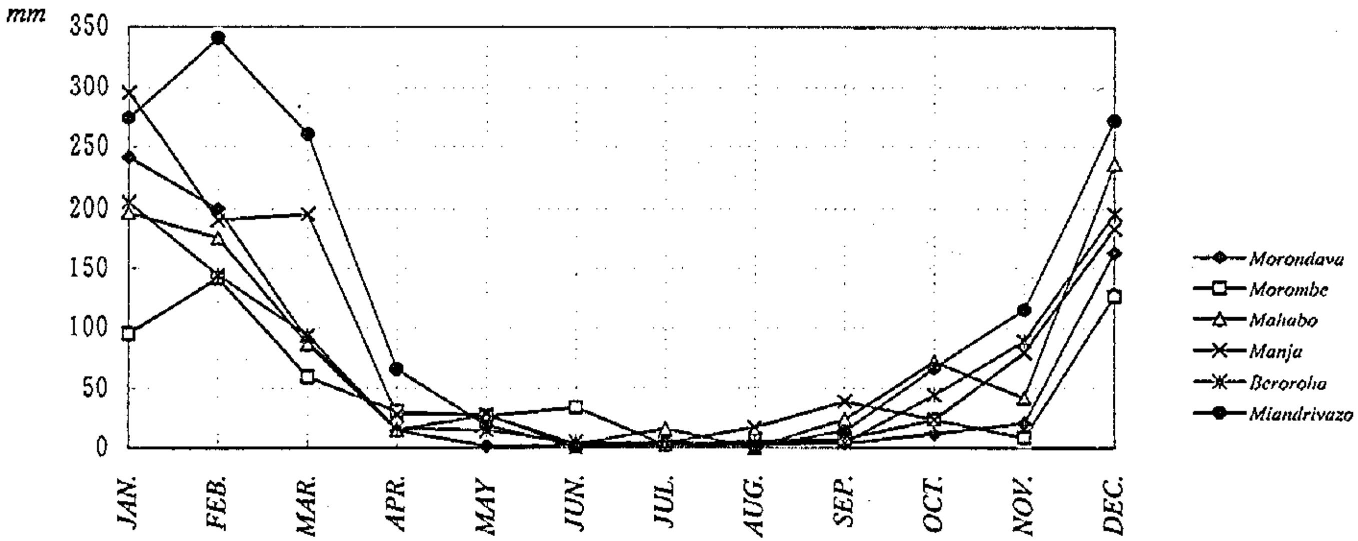


Fig. 5.1.2 Monthly Mean Rainfall of 6 Station

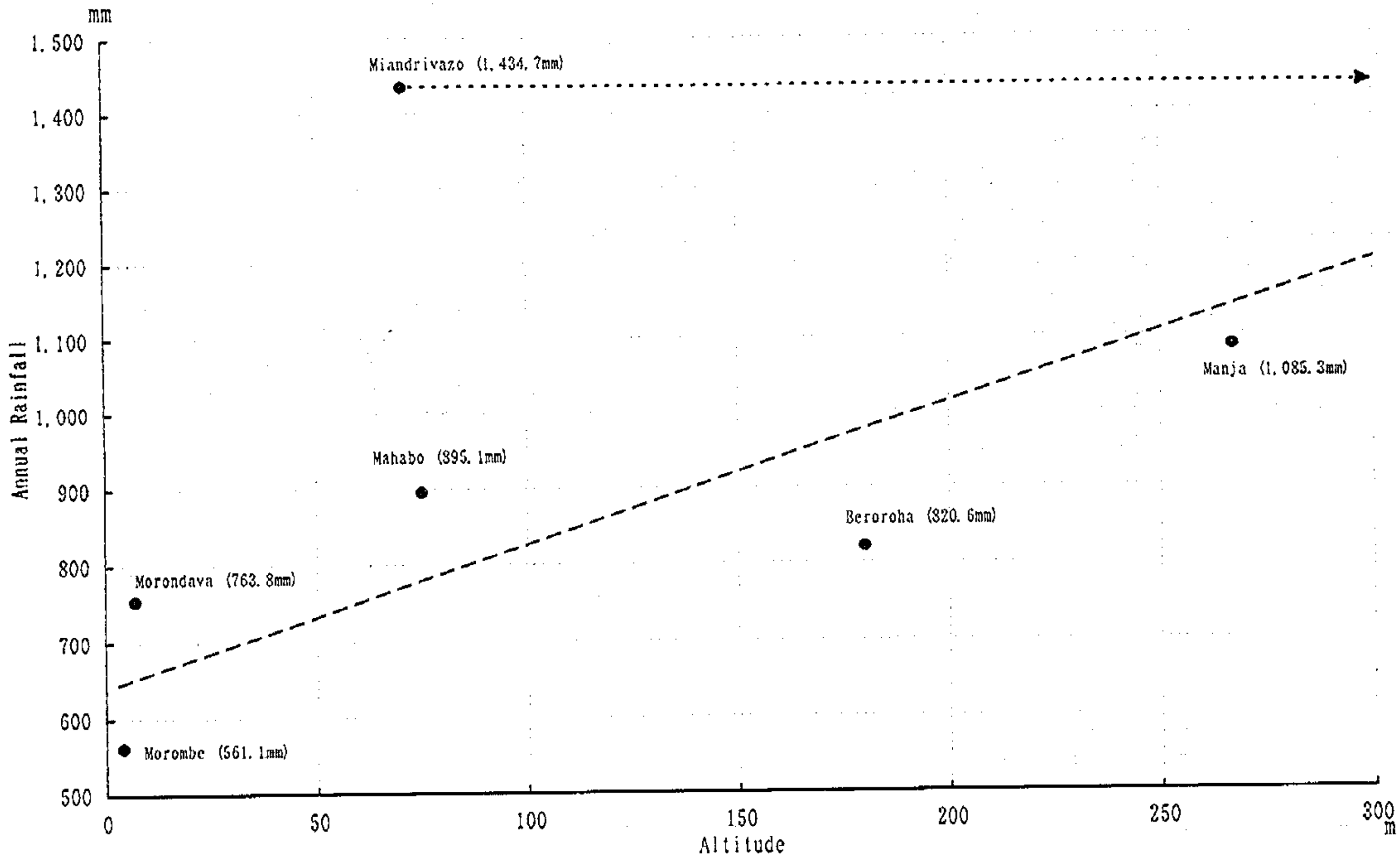
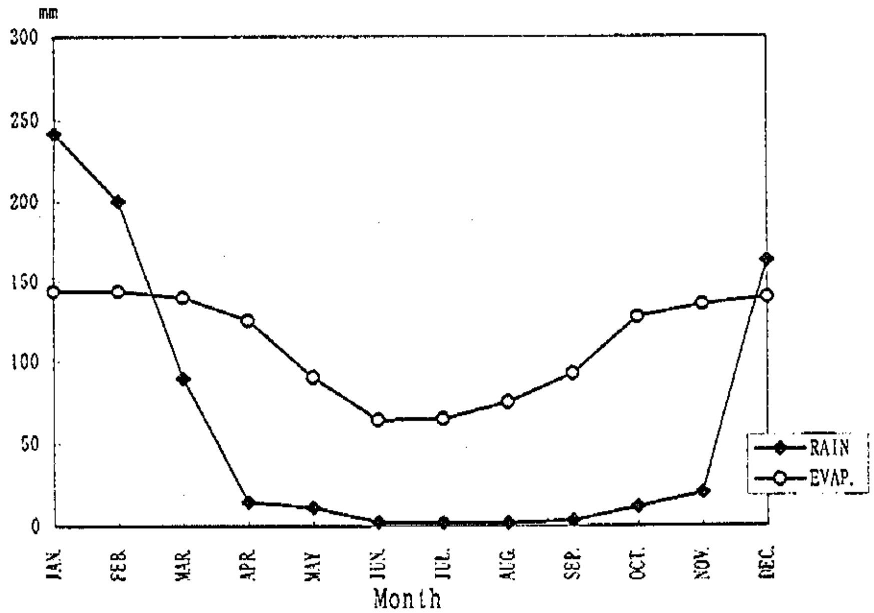


Fig. 5.1.3 Altitude - Annual Rainfall Curve

Station : MORONDAVA   Latitude : 20° 17' S   Longitude : 41° 19' E   Altitude : 7m

YEAR	ITEM	UNIT	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1961-90	RAIN	(mm)	241.6	200.2	89.5	14.8	11.4	2.4	2.3	2.2	3.6	11.9	20.6	163.3
	TEMP.	Max.	31.9	31.8	32.2	31.8	30.4	29.0	28.7	29.1	29.7	30.7	31.6	31.9
		Min.	23.4	23.2	22.6	20.5	17.0	14.5	14.3	15.3	17.6	20.1	21.6	22.9
		Ave.	27.6	27.5	27.4	26.1	23.7	21.7	21.5	22.2	23.6	25.4	26.6	27.4
	HUN.	(%)	80.0	82.0	81.0	79.0	77.0	74.0	74.0	74.0	76.0	76.0	75.0	78.0
	SUN.	(h & 1/10h)	267.9	239.9	286.6	288.4	301.2	287.5	295.7	308.5	296.5	320.3	315.1	282.0
		(h & 24h/M)	8.9	8.6	9.2	9.6	9.7	9.6	9.5	10.0	9.9	10.3	10.5	9.1
	EVAP.	(mm/M)	143.7	143.7	139.5	124.8	90.0	63.9	64.7	74.9	92.5	127.1	135.0	139.5



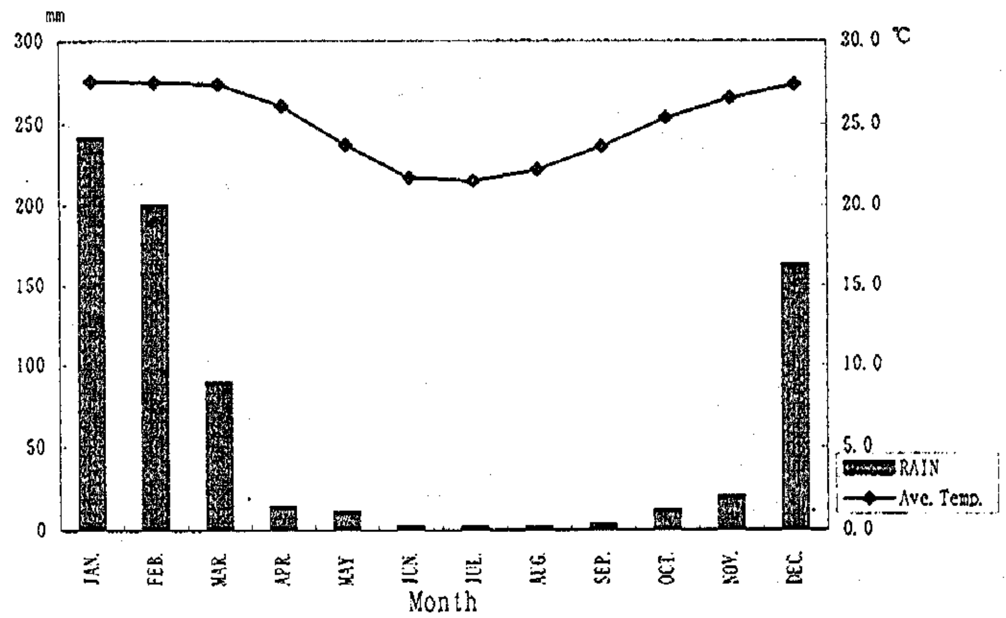
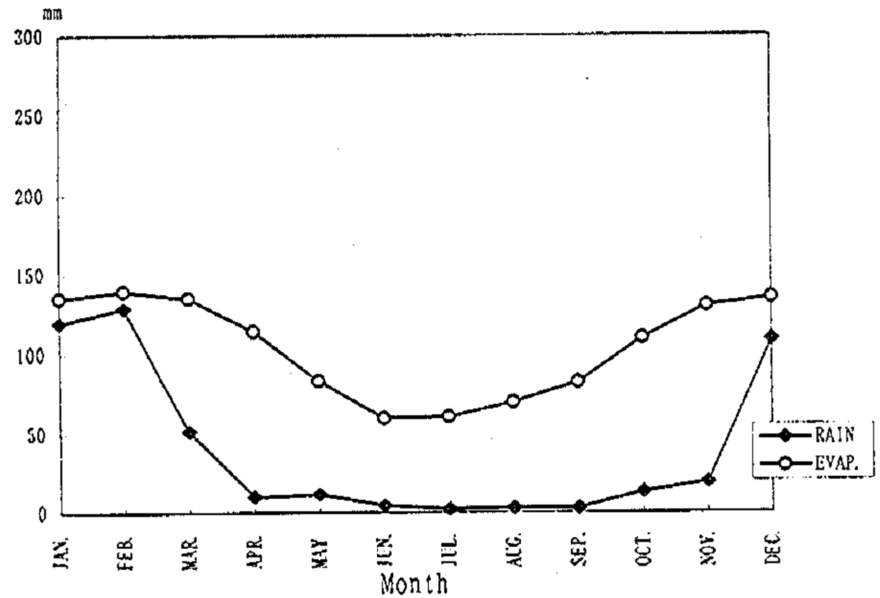


Fig. 5.1.4 General Climatic Condition (Morondava)

Station : MORONBE　　Latitude : 20° 45' S　　Longitude : 43° 22' E　　Altitude : 4m

YEAR	ITEM	UNIT	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1961-90	RAIN	(mm)	119.4	128.7	51.7	9.9	11.6	4.3	2.0	2.8	2.6	12.6	18.8	108.8
	TEMP.	Max.	31.7	31.6	32.0	30.9	29.3	27.6	27.5	28.1	28.8	29.7	30.6	31.2
		Min.	22.9	22.9	21.8	19.7	16.5	14.2	14.0	14.6	16.2	18.5	20.2	22.1
		Ave.	26.8	27.2	26.9	25.3	22.9	20.9	20.7	21.4	22.5	24.1	25.4	26.6
	HUN.	(%)	80.0	81.0	78.0	77.0	76.0	75.0	74.0	74.0	76.0	76.0	77.0	80.0
	SUN.	(h & 1/10h)	292.9	254.8	299.6	292.5	303.9	289.6	298.3	316.5	306.6	317.8	319.7	297.7
		(h & 24h/M)	9.5	9.1	9.7	9.8	9.8	9.7	9.6	10.2	10.2	10.3	10.7	9.6
	EVAP.	(mm/M)	135.0	139.5	135.0	114.3	83.5	59.9	60.8	70.1	82.4	109.7	130.0	135.0



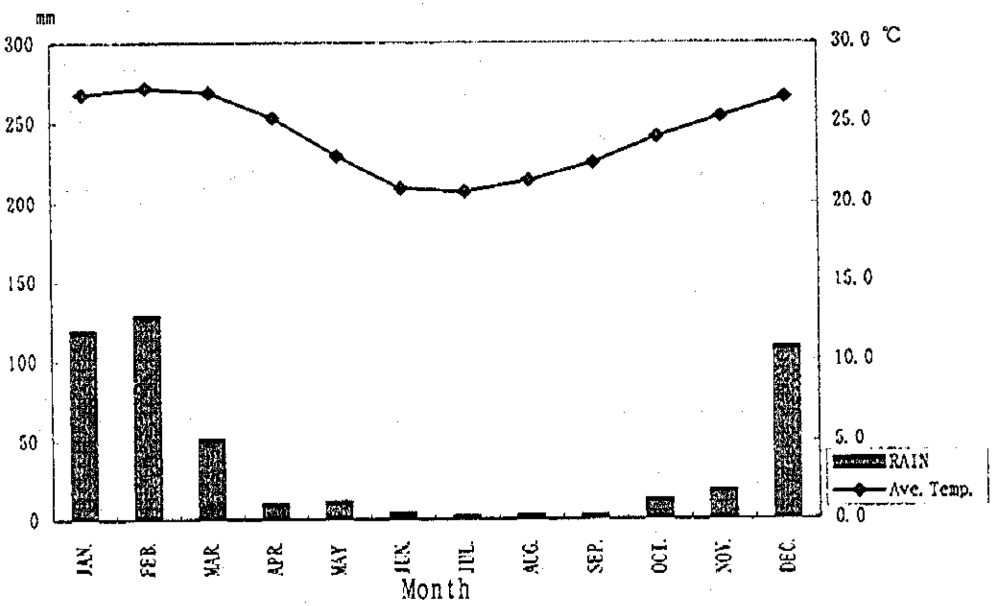


Fig. 5.1.5 General Climatic Condition (Moronbe)

5.2 Hydrogeology

In order to evaluate the groundwater resource potential in the Study Area, a hydrogeological map (1/250,000) was prepared, accompanied by the hydrogeological cross sections and vertical sections. The map represents the groundwater development potential by area based on the comprehensive analysis of existing relevant data and materials, satellite image and aerial photographs, geological and hydrogeological field surveys, geophysical prospecting, test drilling and pumping test, water quality analysis, and macroscopic water balance analysis.

As shown in this hydrogeological map, the potential for groundwater development in the Study Area is generally high, except some portion of the particular lithological or topographical conditions.

Groundwater potential in the Study Area is expected to be sufficient in capacity not only to supplement water supply shortages but also to meet the demand for the development of local agricultural or industrial activities, particularly in the Morondava plain.

5.2.1 General Hydrogeological Features of the Study Area

The Study Area is situated in the Morondava groundwater basin that is enclosed by the seashore of the Mozambique Channel in the west, the Tsiribihina and Mangoky rivers in the north and south and the western edge of the Central High Land of Madagascar in the east.

The geological structure of the groundwater basin is presented in the regional geological cross sections (Fig. 2.1.6) and hydrogeological cross and vertical sections (Fig. 5.2.1 and 5.2.2). Its outline is described in "Geology and Geological Structure".

As shown in these figures, the groundwater basin is basically composed of low permeable basement rocks of the Precambrian and the Paleozoic (Sakoa and Sakamena Groups) and water-bearing formations of the Jurassic to the Quaternary. Regarding the basic groundwater flow mechanism in the Morondava groundwater basin, it is considered that groundwater, which is mainly recharged by rainfall in the rainy season, infiltrates into aquifers and moves from high potential zone located in the east (recharge area) toward low potential zone in the west. Groundwater is partly and perennially discharged into the sea, and is discharged into rivers in dry season.

Although the main part of the Sakoa and Sakamena groups of the Paleozoic is considered to be low permeable basement rocks, a part of these groups exposed in the eastern marginal area of the basin is generally weathered, and so is the same for the Isalo Group. The weathered portion of the Sakoa and Sakamena groups is assumed to be a fairly good aquifer. The results of test drilling conducted in the Sakamena Group at Ambatolahy (114) are as follows:

Discharge : 504 m³/day

Specific capacity : 46.4 m³/day/m

Of the Isalo Group, the Lower Isalo Group (I_I) consists mainly of continental gravelly coarse-grained sandstone with conglomerate, a cross bedding and low solidity, and is habitually evaluated as a good aquifer. Productivity of this aquifer evaluated from the result of discharge measurement is 1,020 m³/day/km².

The Middle Isalo Group (I_{II}) is the continental sediments with a cross bedding and low solidity, and it is lithologically divided into 3 formations of the Lower, Middle and Upper formations.

The Lower formation consists of fine to medium-grained sandstone and mudstone (red clay), and its productivity of groundwater is relatively low compared with that of the Middle and Upper formations. The Middle and Upper formations consist principally of medium to coarse-grained sandstone and evaluated to have a good aquifer, similar to the Lower Isalo Group. Groundwater productivity of the Middle and Upper formations, estimated from the discharge measurement, is 1,044 m³/day/km².

The Upper Isalo Group (I_{III}) shows mixed facies of continental and marine origins. This group is composed of the Lower formation that consists essentially of medium to coarse-grained sandstone of continental origin and the Upper formation comprising of medium to fine-grained sandstone, mudstone and calcareous deposits of mixed facies. Of the Upper Isalo Group, the Lower formation is evaluated to be a good aquifer, whereas the Upper formation is assumed to contain an aquifer of relatively low productivity. Productivity of groundwater of the Upper formation, estimated from the discharge measurement, is 268 m³/day/km², and the results of test well drilled into this Upper formation at Mandabe (104) are as follows:

Discharge : 504 m³/day

Specific capacity : 122.3 m³/day/m

The Lower Jurassic System shows the characteristics of mixed facies contemporary with the Upper Isalo Group, being composed mainly of limestone and calcareous sandstone, containing sandstone of continental origin. The exposed area of this system in the intramountain basin is evaluated to have a good aquifer. On the other hand, the Upper Jurassic system is composed of thick marl with marly limestone (Ankilizato marl) and alternating facies of calcareous deposits, generally regarded as the confining layer, except the portion of porous marly limestone and calcareous sandy beds.

The test well at Ankilizato (103) was drilled in the Upper Jurassic System consisting of marl and sandy marl (0-110m), and alternating layers of marl, mudstone and sandstone (110-161m), and the result are as follows:

Discharge : 432 m³/day

Specific capacity : no available data

Although the Cretaceous System is geologically and paleontologically divided into the Upper and Lower subsystems, the main part of the Cretaceous System is occupied by the Upper Cretaceous System. The Lower Cretaceous System is negligible hydrogeologically since it consists of thin and discontinuous calcareous sediments. The Upper Cretaceous System is composed of thick medium to coarse-grained sandstone with thin muddy layers and basalt sheets, overlain by alternating facies of limestone and marl. The exposed areas of the Upper Cretaceous System generally form cuestas of high elevation, the massifs of Ankilizato and Manja, where groundwater development is difficult due to deep groundwater table resulting from the high permeability of the Upper Cretaceous System. According to the existing borehole records near the Dabara dam, there are 3 flowing wells of 14 to 19 ℓ/sec, drilled on the Upper Cretaceous System.

The Eocene Series is divided into the Lower Eocene Series, that consists mainly of limestone and marly limestone, and the Middle and Upper Eocene Series made of limestone, marly limestone, marl, marly sandstone, etc. Most of the exposed areas of hard and compact limestone of the Eocene Series show isolated hills (horsts) as observed in the Manja limestone plateau area. Other areas, estimated to be composed of weathered and porous limestone, marly limestone, marl, marly sandstone, etc., are generally covered by thick soil. The groundwater potential of the Eocene Series is evaluated to be fairly high, excluding the above mentioned hard and compact limestone.

The specific discharge in the hilly area consisting mainly of limestone, observed in this Study, is 65-135 m³/day/km².

As described in "Geology and Geological Structure", the hydrogeological features of the Neocene and Quaternary systems in the Morondava plain have been gradually revealed by geophysical survey, test drilling and hydrogeological analysis in this Study. The hydrogeological vertical section of the Morondava plain (Fig. 5.2.2) was prepared based on the results of those surveys and analysis, and shows a lithological composition and hydrogeological structure of the Neocene and Quaternary Systems in the Morondava plain.

The main aquifers of the area are in the layers of fine conglomerate, gravelly coarse sandstone (gravelly coarse sand) and sandstone (sand). The groundwater potential of the Morondava plain is evaluated to be of high level, as shown in Fig. 5.2.2.

5.2.2 Local Hydrogeological Features and Aquifer Characteristics

In order to evaluate the local hydrogeological features and aquifer characteristics, geophysical survey, test drilling and pumping test and water quality analysis were conducted in this Study.

(1) Geophysical Survey

Two types of the geophysical survey method were initially planned to be conducted. One was the VLF-Electro Magnetic method intending to detect the fault fractured zone for the development of fissure groundwater, and another was the electrical resistivity sounding method especially for classification of the layers by depth. However, since the following points were found through topographic and geological surveys, the VLF-EM method was substituted by additional electrical resistivity method surveys.

a) All of the candidate villages are situated in the areas mostly of intergranular aquifers (aquifers of bedded layers).

b) Many dykes of basaltic rocks dating back to the Pre and Post Eocene ages are observed in the Study Area. These dykes are inferred to control the occurrence of hot springs. The fissure groundwater in these dykes and in accompanied fault zone probably is not potable because of the high content of dissolved substances related with hot springs. Therefore, the research for fissure water in this study is somewhat useless.

The electrical resistivity sounding conducted in this Study is as follows:

- Number of survey sites (candidate villages): 46 sites
- Number of survey points: 140 points
- Sounding depth: 100m to 300m (total: 26,812m)

The electrical resistivity sounding was conducted with the equally spaced 4-electrode arrangement, and by use of a McOHM-type resistivity meter. The field data obtained from this survey, which are incorporated in Data Book, have been hydrogeologically analysed and are presented in the Supporting Report as the hydrogeological sections.

Geophysical survey by VLF-EM method was performed at the 3 sites of Andranomena, Dabara and Ankilizato, just to examine the suitability of this method for the localisation of faults or faulted zones. The results of analysis are shown in the Supporting Report.

(2) Test Drilling and Pumping Test

Test wells were constructed by the drilling team of MEM under the instruction and technical advice of the JICA Team. The works had two purposes: to confirm the local hydrogeological feature and aquifer characteristics and to construct productive wells for use in the pilot project.

Although the scope of work entailed the drilling of 13 boreholes with a total drilling depth of about 1,500 meters, drilling achieved by the time limit was 13 wells with total depth of 1,250 meters, and 12 series of geophysical logging and pumping test. The results of test well and pumping test are summarized in Tables 5.2.1 and 5.2.2.

The drilling works were carried out by use of MEM's three rigs: a TOP-500, TOP-200 and FSW-ST-S19. Since the submersible motor pump of OKAMOTO Model "OPD4-50-3-7-15EC" provided by JICA was for the use of the 4-inch casing of FRP pipe, it could not be used in the 4-inch casing of PVC pipe because the diameter of the submersible motor pump was 1.5 mm bigger than the inner diameter (94 mm) of the 4-inch casing of PVC pipes. Therefore, only the recovery test by air-lifting was conducted on the 9 wells drilled on the coastal plain.

1) Tsianaloka (Tsiribihina Delta)

The drilling site at Tsianaloka is located near the apex of Tsiribihina delta and lies between lakes and swampy areas. Tsiribihina Town and villages located in this delta are using the surface water from rivers, lakes and swampy areas for their domestic water supply.

In this drilling site, two test wells (No.1-73m, and No.2-22m) were drilled, considering its geological and hydrogeological conditions. As shown in the hydrogeological vertical section of the Morondava plain (Fig. 5.2.2), it is considered that the No.1 well was drilled in the alluvial deposits of the Tsiribihina delta, consisting of gravel, sand, silt and clay layers, that is, the present river-bed deposits (26m thick), and dark black clay beds with peat and boulders of porous limestone, that is the lower facies (26-73m) of the Alluvium. The screen casing was installed between 43m and 67m deep.

Resulting from the above geological conditions, the No.1 well was a dry borehole whose discharge ratio is several liters/min, and the electric conductivity value is 5,230μs/cm.

Therefore, the No.2 well was drilled to investigate the usefulness of river-bed water, and results are as follows:

- Discharge rate:	67 ℓ/min.
- Static water level:	13.22m B.G.L.
- Dynamic water level:	14.40 m
- Electric conductivity:	2,335 μs/cm

2) Beroboka Sud (Northern area of the Morondava plain)

As shown in Fig. 5.2.2, the area is situated on a gentle isolated hill consisting of alternating layers of fine conglomerate, gravelly coarse sandstone, sandstone, siltstone, sandy marl and marl, which are considered to be Pliocene sediments. Resulting from these lithological features, the upper facies of the Pliocene series is presumed to be continental sediments and the lower facies is shallow marine sediments.

The main aquifers of the area are in the upper layers of fine conglomerate, gravelly coarse sandstone and sandstone, and the results of test drilling at Beroboka Sud are as follows:

- Discharge rate: 501 ℓ /min.
- Static water level: 6.27 m B.G.L.
- Dynamic water level: 13.52 m B.G.L.
- Specific capacity: 69.10 ℓ/min./m
- Transmissivity: 101.5 m^2/min.
- Electric conductivity: 646 μs/cm

3) Andranomena, Analaiva and Bezezika (Central area of the Morondava plain)

The area is situated along the lower reaches of Morondava and Andranomena river systems, and is composed of alternating layers of gravelly coarse sand, medium to fine sand, sandy silt and silt, which is considered to be the Pleistocene series (see Fig. 5.2.2).

The main aquifers of the area are located in the layers of gravelly coarse sand and medium to fine sand, and they are of unconfined and/or confined condition. The results of test drillings are as follows:

	Andranomena	*Analaiva*	*Bezezika*
- Discharge rate (ℓ/min.)	402	715	930
- Static water level (GL-m)	+ 1.80 *	3.70	7.80
- Dynamic water level (GL-m)	1.53	4.81	8.64
- Specific capacity (ℓ/min./m)	198	644	1,107
- Transmissivity (m^2/min.)	147.3	785.8	1,353.9
- Electric conductivity (μs/cm)	846	214	250

** Flowing well (discharge rate of 120 ℓ/min.)*

The existing borehole data listed below were obtained from the Analaiva irrigation project in 1991. In this area, SIRANALA (sugar factory of Analaiva) has 13 production wells whose discharge rate falls between 267 and 168 m³/h.

These existing borehole data indicate that the north-western area of the Analaiva village is composed of thick gravelly coarse sand layer and has a groundwater development potential of very high level.

Table 5.2.3 Existing Borehole Data at Analaiva Area

	FS.1	FS.2	FS.4	FS.5
Drilled Depth (m)	65.50	67.00	72.00	71.00
Screen position (GL-m)	23.95 ~ 55.98	21.96 ~ 63.98	24.77 ~ 63.96	23.54 ~ 66.96
Static water level (GL-m)	4.38	3.97	6.02	6.41
Discharge (m³/h)	350	363	350	338
Drawdown (m)	9.60	8.30	7.80	9.20
Transmissivity (10^{-2}/sec)	2.7	2.6	2.5	2.9

4) Befasy (Central area of the Morondava plain)

The drilling site at Befasy is located along the lower reaches of Maharivo River. The area is composed of alternating layers of gravelly coarse sand, medium to fine sand, and they are of unconfined and/or confined. The result of test drilling is the following:

- Discharge rate (ℓ/min.) 477
- Static water level (GL-m) 5.57
- Dynamic water level (GL-m) 9.98
- Specific capacity (ℓ/min./m) 108.16
- Transmissivity (m²/min.) 154.9
- Electric conductivity (μs/cm) 364

5) Ambararata and Marofihitsa (southern area of the Morondava plain)

The drilling site at Ambararata is located at about 3.5 km north of a dried-up bay of Belo-sur-mer, and that of Marofihitsa is situated at the side of the dried-up bay.

The area is composed of secondary deposits of marl with limestone gravel of the Eocene, gravelly coarse sand, medium to fine sand and sandy silt of the Pleistocene layers. Although the main aquifers of the area are in the layers of gravelly coarse sand

and medium to fine sand, in the area of the Marofihitsa, groundwater affected by the sea water intrusion.

At the drilling site of Marofihitsa, two boreholes (No.1: 87m and No.2: 38m) were drilled to prospect for a fresh water zone. However, the test drilling did not bring about with good results. There are two salty water zones: very salty water zone of EC 18,890 µs/cm and salty water zone of EC 6,840 µs/cm (brackish water). The boundary of two water zones lies between 40 and 50 m (See Fig. 5.2.2). The existing water source of Marofihitsa comes from dug wells (6.8 m deep) and water quality is considered unsuitable for drinking purpose ($Cr6^{+}$: 0.14 mg/ℓ; $N0_3^{-N}$ 98.0 mg/ℓ; Cu: 2.18 mg/ℓ; Cl^{-}: 770 mg/ℓ, and EC: 4,020 µs/cm). Therefore, a new water source shall be developed at the eastern of the village, about 3 km far from the center of the village.

On the other hand, the test drilling at Ambararata could provide good results, as shown below.

		Ambararata	*Marofihitsa No.1*	*Marofihitsa No.2*
- Discharge rate (ℓ/min.)	:	767	480	524
- Static water level (GL-m)	:	2.95	4.50	4.12
- Dynamic water level (GL-m)	:	5.21	-	4.48
- Specific capacity (ℓ/min./m)	:	268	-	1,455
- Transmissivity (m^2/min.)	:	414	-	1,775.8
- Electric conductivity (µs/cm)	:	751	18,890	6,840

6) Andranopasy and Befamonty (Mangoky delta)

The drilling site at Andranopasy is located on the northeastern edge of the Mangoky delta. Since the dwelling area of Andranopasy is situated on the bay mouth bar where development of fresh water source is very difficult, the selected drilling site was therefore situated about 5 km east of the village center. The drilling site of Befamonty is located on a central part of the Mangoky delta and was selected as a representative drilling site to investigate the hydrogeological feature and groundwater development potential in the Mangoky delta. However, the accessibility by drilling machine and its equipment, between Andranopasy and Befamonty, became partially very bad after the end of November , especially where soft clay bed is exposed in the dried-up bay. Therefore, the test drilling at Befanonty could not be conducted.

As shown in the Fig. 5.2.2, the area at the drilling site of Andranopasy consists of gravel and gravelly coarse sand of the Pleistocene and marl and marly layer of the

Eocene, and the main aquifer of the area is allocated in the layer of gravel and gravelly coarse sand of the Pleistocene. The result of test drilling are as follows:

- Discharge rate (ℓ/min.) 137
- Static water level (GL-m) 7.16
- Dynamic water level (GL-m) 12.49
- Specific capacity (ℓ/min./m) 25.70
- Transmissivity (m^2/min.) 31.4
- Electric conductivity (μs/cm) 2,000

7) Ankilizato area (Morondava river basin)

The area of Ankilizato is located in an intramountain basin consisting of so called Ankilizato marl of Jurassic and intrusive rocks of basalt and/or gabbroic basalt.

Although groundwater development is inferred to be difficult in areas consisting of Ankilizato marl in terms of water quantity and quality (salty and bitter taste), the test drilling was executed in order to investigate a possibility of groundwater development by drilling deep boreholes, because the present population of Ankilizato is about 4,000 and the villagers are suffering from water borne diseases caused mainly by drinking water (canal water).

The findings of this test well are:

a) Lithological features

0 - 10m:	reddish brown-brown sandy marl
10 - 18 m:	brown fine to medium sand and gravelly sand
18 - 30 m:	brown marl and sandy marl
30 - 58 m:	grey - dark grey sandy silt (partially clayey)
58 - 78 m:	grey - dark grey marly mudstone with marly limestone
78 - 100 m:	grey fine sandstone with sandy marl and marl
100 - 110 m:	brownish grey - grey marl with gravelly sandstone
110 - 132 m:	frequent alternating layers of grey marl, mudstone and sandstone
132 -143 m:	grey - dark grey marly mudstone
143 - 156.6 m:	frequent alternating layers of marl, mudstone and sandstone
156.6 - 161m:	grey marly limestone
161 - 170 m:	dark black hard gabbro - gabbroic basalt

b) As shown in the well log in Supporting Report, since the electric conductivity value of circulating mud-water, between 20 and 110 m, was of high level (1,570 to 2,115 μs/cm) and that of lower part sharply changed to 1,110 - 1,325 μs/cm, the screen casing was installed between 110 and 162 m, to avoid salty water of bitter taste.

The main aquifers of the site are distributed in thin beds of sandstone in frequent alternating layers and in layers of marly limestone, and are characterized as follows:

	First Airlifting	*Pumping test*	*2nd Airlifting*
- Discharge rate (ℓ/min.)	80-100	40	300*
- Static water level (GL-m)	22.00	22.08	22.29
- Dynamic water level (GL-m)	-	43.13	-
- Specific capacity (ℓ/min./m)	-	1.90	-
- Transmissivity (m^2/min.)	-		
- Electric conductivity (μs/cm)	168-250	2,210	2,150

** Resulting from second airlifting works, it was confirmed that this test well can not be used unfortunately as a production well because a part of the screen at about 121 m deep was broken at the time of installation, and the main part of the screen (about 83%) was filled up with sand and gravels (Ø max. 3 cm) coming from the aquifer (See the well log in Data Book).*

8) Mandabe area (Upper reaches of Maharivo river basin)

This area is located in an intramountain basin and is composed of fine conglomerate, gravelly coarse sandstone, medium to fine sandstone, sandy marl and marl of the Isalo III Group.

The main aquifers of the drilling site are allocated in weathered layers of fine conglomerate, gravelly coarse sandstone and medium to fine sandstone, and are characterized as follows:

- Discharge rate (ℓ/min.)	320
- Static water level (GL-m)	9.80
- Dynamic water level (GL-m)	13.90
- Specific capacity (ℓ/min./m)	78.0
- Transmissivity (m^2/min.)	95.2
- Electric conductivity (μs/cm)	324

Although this test well was drilled up to 103 GTL-m, the screen casing was installed in the weathered zone between 12 and 39 m, because the lithofacies between 39 and 193 m is composed of grey to white grey and very hard compact sandstone (39 - 49.50 m), grey marl with thin sandstone beds (49.50 - 57 m) and grey hard compact sandstone with marl and marly mudstone (57 - 103 m), and its productivity for groundwater is considered to be low in terms of water quantity and quality (see well log in Supporting Report).

9) Ambatolahy

The area of Ambatolahy is located on the eastern bank of the Sakény river, and consists of brownish grey gravelly coarse sandstone with siltstone of the Isalo Group (I_I) and chocolate color, purplish green and pale greenish grey mudstones with sandstone and siltstone of the Sakamena Group.

The main aquifers of the area are allocated in layers of gravelly coarse sandstone and sandstone of the Isalo and Sakamena Groups, and the results of test drilling at Ambatolahy are as follows:

- Discharge rate (ℓ/min.)	350
- Static water level (GL-m)	13.41
- Dynamic water level (GL-m)	24.24
- Specific capacity (ℓ/min./m)	32.2
- Transmissivity (m^2/min.)	39.3
- Electric conductivity (μs/cm)	343

10) Malaimbandy area (Sakény river basin)

The area of Malaimbandy is located on the eastern bank of Manampandy River, a branch of the Sakény river, and is mainly composed of the Sakamena Group.

The area at the drilling site consists of:

0 - 13 m:	Brownish grey to white grey gravelly coarse sandstone with mudstone and siltstone
13 - 41 m:	Bluish grey to pale greenish grey clayey mudstone
41 - 74 m:	Bluish grey to pale greenish grey clayey sandy siltstone with sandstone and coarse sandstone (61-64 m)
74 - 170 m:	Pale greenish grey to greenish chocolate color mudstone and siltstone with thin calcareous beds and fine sandstone (113-116m)
170-186 m:	Greenish grey to grey schistose mudstone
186-187 m:	Chocolate color to dark green schistose mudstone
187-194 m:	Purplish green schistose mudstone and coarse mudstone

194-196 m: Chocolate color coarse sandstone

196-200 m: Chocolate color schistose mudstone

200-201 m: Grey coarse sandstone

201-204 m: Grey schistose siltstone with coarse sandstone

204-210 m: Grey coarse sandstone

210-213 m: Green schistose siltstone with grey coarse sandstone

213-222 m: Grey coarse sandstone

The main aquifers of the site are believed to be in layers of coarse sandstone and schistose siltstone with coarse sandstone which are probably of the Sakamena Group. Since the drilling work was forced to be delayed, the pumping test could not be carried out, and the aquifer parameters of this well could not be confirmed. However, it is assumed that the productivity of this well is high enough to cover the water demand of 340 ℓ/min. or more. This is suggested by a remarkable rise of the static water level from -180m to -30m during the well development work.

(3) Water quality of groundwater

The water quality of groundwater samples taken from newly drilled boreholes is generally good as drinking water, as shown in Table 5.2.4. However, some water samples have high ion contents exceeding the maximum limit of the standards for drinking water. These items are as follows:

1) Physical condition

a. Electric conductivity (less than 1500 μs/cm)

Tsianaloka (2,335), Marofihitsa (7,310), Andranopasy (2,090), Ankilizato (2,150)

2) Toxins

a. Cr^{6+} (0.05 mg/ℓ)

Tsianaloka (0.08), Beroboka Sud (0.09), Andranomena (0.05), Bezezika (0.05), Analaiva (0.05), Befasy (0.05), Ambararata (0.06), Marofihitsa (0.13), Andranopasy (0.06), Ankilizato (0.08), Mandabe (0.08), Ambatolahy (0.07).

b. NO_3^- (10 mg/ℓ)

Tsianaloka (590), Mandabe (37).

3) Chemical condition

a. TDS (500 - 1,500 mg/ℓ)

Marofihitsa (3,640)

b. Mn (0.05 - 0.5 mg/ℓ)

Ankilizato (0.1)

c. Cu (0.005 - 1.5 mg/ℓ)

Marofihitsa (1.58)

d. Ca (75 - 200 mg/ℓ)

Ankilizato (299), Tsianaloka (171), Marofihitsa (193), Andranopasy (152)

e. Cl^- (200 - 600 mg/ℓ)

Marofihitsa (2,032)

f. SO_4^{2-} (200 - 400 mg/ℓ)

Ankilizato (1,150)

Of the 13 groundwater samples, the groundwater from the test well of Marofihitsa is considered to be not potable and water from test wells of Tsianaloka and Andranopasy is not considered to be suitable for drinking.

As shown above, all groundwater samples have a high value of chrome (Cr^{6+}) ion exceeding the drinking water standard. A quantity of chrome (Cr^{6+}) in the water sample taken from the Marofihitsa test well shows a value similar to that of sea water. However, it is generally said that when the presence of chrome in water exceeds 0.1 mg/ℓ. it can cause nausea and, in severe cases, seriously affects intestines and kidneys and eat away the skin. On the other hand, a quantity of chrome (Cr^{6+}) less than 0.1 mg/ℓ is harmless.

Recently in Japan, nickel has been additionally listed among the toxic items to be examined, and its recommended permissible value is less than 0.01 mg/ℓ. However, it is said that oral absorption of nickel has little toxic effect, and if absorbed much, it is evacuated by vomiting and diarrhea.

In this connection, nickel has been examined as one of the toxic items in this Study. The analyzed results on nickel showed its value ranging from 0.19 to 0.92 g/ℓ. Since it was unbelievably high, the samples were brought back in Japan for re-analysis. The results were all lower than 0.001 mg/ℓ.

5.2.3 Discharge of existing wells

The tables in the Data Book display the well inventory prepared in this Study. Data on wells were collected at the MEM, the JIRAMA and during the field survey. The location of wells was represented in the hydrogeological map.

Discharge data on existing wells were used for the hydrogeological analysis, and the relerant explanations are given in sections "General Hydrogeological Features of the Study Area" and "Local Hydrogeological Features and Aquifer Characteristics".

Present groundwater use by borehole in the Study Area is limited to the central area of Morondava, and detailed explanations are given in the "Macroscopic water Balance Analysis and Groundwater Development Potential" Section.

5.2.4 Macroscopic Water Balance and Groundwater Development Potential

(1) Macroscopic water balance analysis

In the Morondava groundwater basin of the Study Area, little experience has been accumulated on the groundwater development, and insufficient data on hydrogeological information such as drilling logs (aquifer unit), results of pumping tests (aquifer constant) and continuous monitoring of the groundwater level preclude the detailed evaluation of groundwater resource potential by mathematical water balance analysis.

In this Study, macroscopic water balance was therefore analyzed by groundwater sub-basin from a standpoint of the amount of annual groundwater recharge from rainfall into the aquifer systems, based on the results of water balance analysis of the Phase-I study as well as hydrological and hydrogeological surveys conducted in this Study.

According to the results of the water balance analysis carried out in the study of Phase-I, the estimated water balance by river basin was as follows:

Table 5.2.5 Factors Used for Water Balance Analysis in Phase I Study

Basin	Area (km^2)	P (mm) (100%)	ET (mm) (65%)	RO (mm) (20%)	WR (mm) (15%)
Manombo	508	760	494	152	114
Fiherenana	6,755	780	507	156	117
Sakanabaka	3,070	750	488	150	113
Isahena	1,870	810	527	162	122
Malio	2,040	870	566	174	131
Sakondry	730	750	488	150	113
Taheza	1,600	770	5,501	154	116

In this analysis, the input of water from precipitation (P) is being equated to the outflow of water by evapotranspiration (ET), surface runoff (RO) and groundwater recharge (WR).

$$P = ET + RO + WR$$

The lithological conditions observed in the geological formations in the Study Area are very similar to those of the study area of Phase-I. It is, therefore, considered that the above mentioned groundwater recharge ratio (W) of 15% is adaptable in the river basins of the Study Area. On the other hand, about 70% of the Morondava plain is covered by dense mixed forest which has very good condition for groundwater recharge. Hence, the following factors were used for the macroscopic water balance analysis in this Study.

Table 5.2.6 Factors Used for Macroscopic Water Balance Analysis

	P (%)	ET(%)	RO (%)	WR (%)
- River basin in the hilly area	100	65	20	15
- Morondava plain (average)	100	58.0	9.5	32.5
Forest area (70%)	(100)	(55)	(5)	(40)
Grass or bare area (30%)	(100)	(65)	(20)	(15)

The annual precipitation (P) by area of water balance analysis was estimated from the rainfall records, as shown in the hydrological map.

The value of a river baseflow and spring discharge in the dry season is generally regarded as groundwater development potential, as well as the value of groundwater recharge.

In this Study, the productivity of groundwater was empirically evaluated by the values of specific groundwater recharge ($m^3/day/km^2$), resulting from the macroscopic water balance analysis and specific baseflow ($m^3/day/km^2$) obtained from discharge measurement, because 1 km^2 is generally regarded as the unit of recharge area for one well.

(2) <u>Results of macroscopic water balance analysis and groundwater development potential</u>

1) Morondava Plain

The Morondava plain can be hydrologically divided into 5 sub-areas: a), b), c), d), and e), as shown in Fig. 5.2.3.

In these hydrological sub-areas, the following groundwater recharge from the baseflow are perennially expected in addition to the groundwater recharge volume from the precipitation, resulting from discharge measurement in the dry season of 1995.

a): 86,400 m^3/day (from local river)

b): 224,600 m^3/day (from Morondava river)

c): 758,600 m^3/day (from Maharivo river)

d): 198,700 m^3/day (from Kirindy and Lampaolo rivers)

e): 72,600 m^3/day (from Maintakapa river)

In the sub-area b), the groundwater volume used for domestic water supply, industry and irrigation is 61,800 m^3/day, and its breakdown is as follows:

- Domestic use:	Morondava City (JIRAMA)	2,400 m^3/day (from 3 boreholes)
	Mahabo City (JIRAMA)	150 m^3/day (from 1 borehole)
	35Villages (average 6.6 ℓ/p/d)	130 m^3/day (from dug wells)
- Industrial use:	SIRANALA (sugar factory)	32,056 m^3/day (from 5 boreholes)
	SAGRIM (alcohol factory)	551 m^3/day (from 1 borehole)
- Irrigation use:	SIRANALA (sugar cane)	26,511 m^3/day (from 8 boreholes)

The analyzed result of the macroscopic water balance in the Morondava plain is shown in the Table 5.2.7.

Table 5.2.7 Macroscopic Water Balance of Morondava Plain

Water Balance \ Sub Area		a)	b)	c)	d)	e)	Total
Recharge Area (km²)		752	1,935	1,535	989	795	6,006
Annual Rainfall (mm)		936	863	822	747	730	825
Recharge (m³/day)	from rainfall	626,735	1,486,496	1,123,209	657,820	516,572	4,410,832
	from baseflow	86,400	224,600	758,600	198,700	72,600	1,340,900
Pumping discharge (m³/day)		-	61,800	-	-	-	61,800
Groundwater Development Potential	(m³/day)	713,135	1,649,296	1,881,809	856,520	589,172	5,689,932
	(m³/d/km²)	948	852	1,224	866	741	947
Results of test Drilling (m³/day/well)		721	1,339 - 806	1,105	755	(197)*	

** Andranopasy: shallow well of 30 m depth*

2) Tsiribihina and Mangoky Deltas

It has been revealed by the results of electrical resistivity sounding and test drilling that the Tsiribihina and Mangoky deltas are composed of gravelly sand (10 to 20 meters thick), clay beds of very low resistivity values (0.8 to 1152 m, 35 to 55 meters thick) and silt or sand beds, descending order. Although gravelly sand is highly permeable in aquifer of shallow groundwater, its water quality is not good for domestic use due to its salty taste and contamination by toxins and bacteriological items. The clay beds of very low resistivity values are confining layers of groundwater which are partially saturated by salty water. Therefore, groundwater development in these deltas should be conducted in silt or sand beds that underlie the clay beds.

Resulting from the above mentioned hydrogeological conditions, direct groundwater recharge from the rainfall into the silt or sand beds of confined aquifer, through thick clay beds, is not expected in these deltas. Besides, the quantitative estimation of water balance is difficult.

3) Andranomena River Basin

In this river basin, water balance analysis was conducted in the sub-area f), which is represented by the Izalo village (Fig. 5.2.3). Since this sub-area is covered by paddy fields (about 55 km²) and mixed forest (about 105 km²), the infiltration ratio used for the calculation of water balance was 19.65 %.

- Recharge area	882 km²
- Annual rainfall	1,051 mm
- Groundwater development potential	499,151 m³/day or 566 m³/day/km²

4) Morondava River Basin

In the Morondava River basin, water balance calculation was conducted in the 2 areas of Ankilizato north (g) and Ankilizato south (h). The obtained results are as follows:

	North Ankilizato	*South Ankilizato*
- Recharge area (km²)	677	3,885
- Annual rainfall (mm)	1,178	1,098
- Groundwater recharge (m³/day)	327,883	1,750,829
- Discharge from baseflow (m³/day)	156,900	900,600
- Groundwater development potential		
(m³/day)	170,983	850,229
(m³/day/km²)	253	219

The above areas are mainly composed of marine sediments of the Jurassic System and marine and continental sediments of the Isalo Group, and specific baseflow is 235 m³/day/km².

5) Sakeny River basin

In the lower reaches of Sakeny River, there are big swampy areas even in the dry season. The hydrological survey included discharge measurement and was, therefore, carried out in the upper reaches of the Sakeny River basin (Fig.5.2.3).

The results of the water balance calculation in the upper reaches of the Sakeny River basin (I) is as follows:

- Recharge area	2,183 km²
- Annual rainfall	1,304 mm
- Groundwater recharge	1,169,568 m³/day
- Discharge from baseflow	725,760 m³/day
- Groundwater development potential	443,808 m³/day or 203 m³/day/km²

In the upper reaches of the Sakeny River basin, the eastern half area is composed of the Precambrian rocks and the Sakoa and Sakamena Groups of the Carboniferous and Permian Periods, and the western half area consists of the Isalo Group of the Jurassic Period.

According to the results of spot discharge measurement, the specific baseflow by geologic formation is as follows:

- the area consists of the Precambrian rocks, the Sakoa and Sakamena Groups and the Isalo Group: 110 $m^3/day/km^2$

- the area is mainly composed of continental sandstone of the Isalo Group: 1,020 - 1,064 $m^3/day/km^2$

6) Maharivo river basin

In the Maharivo River basin, water balance calculation was conducted in the 2 sub-areas of Mandabe (k) and Lavaravy Tsiamaliha (j) as shown in Fig. 5.2.3. The obtained results are shown below.

	Mandabe (k)	*L. Tsiamaliha (j)*
Recharge area (km^2)	602	2,299
Annual rainfall (mm)	953	969
Groundwater recharge (m^3/day)	235,685	960,205
Discharge from baseflow (m^3/day)	129,600	548,640
Groundwater development potential		
(m^3/day)	106,085	411,565
($m^3/day/km^2$)	176	179

The above areas are mainly composed of marine sediments of the Upper Isalo Group, the Jurassic System and the Cretaceous System (sandstone and calcareous sediments), and the specific baseflow in the sub-areas is 73 - 253 $m^3/day/km^2$.

7) Kirindy River Basin

In the Kirindy River basin, water balance calculation was conducted in the upper reaches of the basin (l) where the spot discharge measurement was carried out, and the results are the following:

- Recharge area	1,050 km^2
- Annual rainfall	960 mm
- Groundwater recharge	414,247 m^3/day

- Discharge from baseflow 112,320 m³/day

- Groundwater development potential 301,927 m³/day or 287 m³/day/km²

The area is mainly composed of thick marl and calcareous sediments of the Jurassic and Cretaceous systems and limestone and marl of the Eocene series. The specific baseflow in the area is 107 m³/day/km².

8) Maintapaka River Basin

In this river basin, water balance calculation was conducted in the 2 sub-areas of West Manja (m) and Manja (n). The obtained results are as follows:

	West Manja (m)	*Manja (n)*
- Recharge area (km²)	397	364
- Annual rainfall (mm)	909	991
- Groundwater recharge (m³/day)	149,804	149,743
- Discharge from baseflow (m³/day)	25,920	47,256 *
- Groundwater development potential		
(m³/day)	123,884	102,487
(m³/day/km²)	312	281

** Including the water supply volume of about 600 m³/day from springs at Manja City area*

The western area of Manja (m) consists of limestone and calcareous sediments of the Eocene (specific baseflow: 66 m³/day/km²) and the Manja area (n) is composed of thick marl of the Jurassic limestone and marl of the Cretaceous and Eocene (specific baseflow: 230 m³/day/km²).

9) Mangoky River Basin

In this river basin, water balance calculation was conducted in the 2 sub-areas of Ankiliabo (o) and Beroroha (p), and the following results were obtained:

	Ankiliabo (o)	*Beroroha (p)*
- Recharge area (km²)	1,301	3,173
- Annual rainfall (mm)	918	1,033
- Groundwater development potential		
(m³/day)	490,816	1,347,004
(m³/day/km²)	377	424

The area of Ankiliabo (o) is mainly composed of limestone, marly limestone and marl of the Eocene and Cretaceous, and the sub-area of Beroroha (p) consists mainly of continental sediments of the Isalo Group and the Sakamena Group.

Table 5.2.1 Result of Test Drilling Wells

No.	Village	Drilling Depth (m)	Well Depth (m)	Static Water Level (m)	Dynamic Water Level (m)	Draw Down (m)	Total Screen length (m)	Pumping Rate (ℓ/min.)	Specific Capacity (ℓ/min./m)	Transmi-ssibility T=1.22Sc (ℓ/min.)	EC (25) (μs/cm)
109	Tsianaloka	73	71.67	17.180	-	-	60.00	-	-	-	5,230
		22	20.82	13.175	14.490	1.315	3.95	69	52.5	64.1	2,335
93	Beroboka Atm.	75	75.00	6.220	12.230	6.010	23.70	500	83.2	101.5	650
64	Andranomena A.	78	74.00	+1.800	1.530	3.330	27.65	402	120.7	147.3	846
67	Analaiva	73	70.90	3.700	4.810	1.110	35.55	715	644.1	785.8	214
97	Bezezika	48	41.75	7.802	8.640	0.838	23.70	930	1,109.8	1,354.0	210
25	Befasy	63	63.00	5.570	9.980	4.410	39.50	560	127.0	154.9	364
47	Ambararata	73	72.00	2.950	5.210	2.260	35.55	767	339.4	414.1	751
46	Marofihitsa	87	73.50	4.500	-	-	51.35	480	-	-	18,890
		38	37.20	4.120	4.480	0.360	19.75	524	1,455.6	1,775.8	6,840
1	Andranopasy I	30	29.50	7.160	12.485	5.325	15.80	137	25.7	31.4	2,000
103	Ankilizato	170	170.00	22.080	-	-	36.00	300	-	-	2,150
104	Mandabe	103	44.00	9.800	13.900	4.100	21.00	320	78.0	95.2	324
106	Malaimbandy	222	-	-	-	-	-	-	-	-	-
114	Ambatolahy	96	93.00	13.410	24.270	10.860	21.00	350	32.2	39.3	343

Table 5.2.2 Result of Pumping Test Analysis

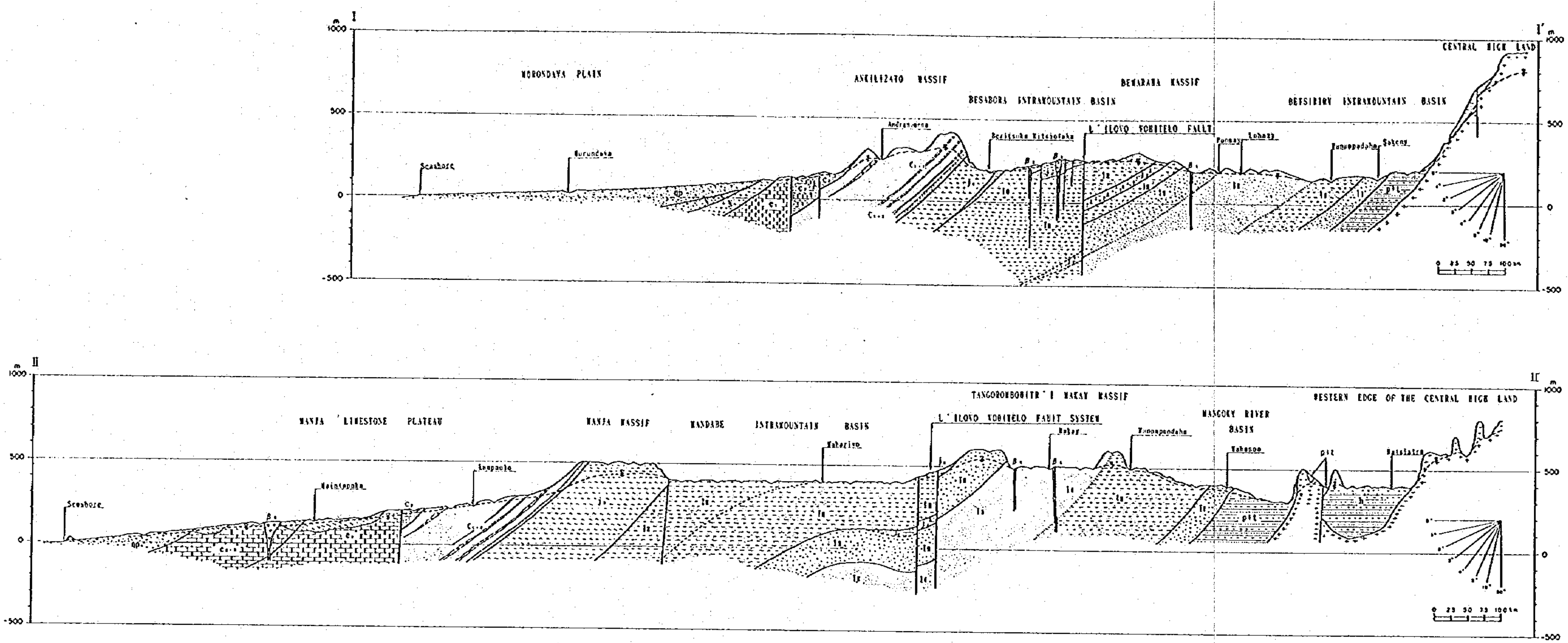
No.	Village	Transmissibility (m^2/day)				Specific Capacity	T=1.22Sc
		Jacob	Theis	Recovery	Average		
						(m^3/day/m)	(m^2/day)
109	Tsianaloka	-	-	106.00	106.00	75.60	92.23
93	Beroboka Atm.	-	-	34.70	34.70	119.81	146.17
64	Andranomena A	-	-	-	-	173.81	212.05
67	Analaiva	-	-	897.00	897.00	927.50	1,131.55
97	Bezezika	-	-	1,256.00	1,256.00	1,598.11	1,949.69
25	Befasy	-	-	1,109.00	1,109.00	182.88	223.11
47	Ambararata	-	-	898.00	898.00	488.74	596.26
46	Marofihitsa	-	-	738.00	738.00	2,096.06	2,557.19
1	Andranopasy I	-	-	347.00	347.00	37.01	45.15
103	Ankilizato	1.33	3.17	1.07	1.86	2.63	3.21
104	Mandabe	68.70	229.00	109.00	135.50	112.32	137.03
106	Malaimbandy	-	-	-	-	-	-
114	Ambatolahy	19.20	29.18	19.20	22.50	46.37	56.57

Table 5.2.4 Water Quality of Groundwater (1/2)
Qualité des eaux souterraines (1/2)

No.	Localités	Analyses sur terrain				Analyses en laboratoire										
		T (℃)	Conductivité (ms/cm)	pH	T (℃)	Conductivité (ms/cm)	pH	TDS (mg/l)	Acidité (mg/l) en $CaCO_3$	Alcalinité (mg/l) en $CaCO_3$	Dureté totale (mg/l) en $CaCO_3$	Dureté (mg/l) en Ca	Dureté (mg/l) en Mg	Chloride (mg/l) en Cl	CO_2 (mg/l)	ClO_2 (mg/l)
109	Tsianaloka (I)				28.5	2.280	6.69	1,128	7.5	18	780	171.2	85.9	292	8	11
109	Tsianaloka (II)				29.1	2.333	6.54	166	82	32	632	196.8	34.2	310	16	7
93	Beroboka				28.7	0.613	7.03	306	35	138	220	32	34.2	104	56	0
64	Andranomena				28.8	0.778	6.56	420	42	94	12	4.8	0	180	32	12
97	Bezezika				28.6	0.232	7.18	116	14	76	690	16	4	20	24	13
67	Analaiva	27.8	0.218	6.5	28.6	0.199	7.22	99.2	12	94	54	15	3.9	8	8	6
25	Befasy				28.5	0.399	7.02	199	20	92	110	23.2	12.6	42	16	5
47	Ambararata	28.4	0.760	6.5	28.6	0.779	7.04	389	34.5	94	168	23.2	26.8	112	24	4
46	Marofihitsa				29.3	7.310	7.18	3,640	40	164	1,012	193.6	128.9	2,032	28	7
1	Andranopasy				29.5	2.090	5.07	1,040	92	282	490	152	26.3	392	48	3
103	Ankilizato (forage)	30.3	2.190	-	28.7	2.230	6.71	1,120	87	276	784	299.2	8.8	44	24	4
104	Mandabe	27.8	0.228	6.28	29.3	0.178	6.57	89.5	34	40	100	32	4.9	28	16	1
114	Ambatolahy				29.5	0.341	6.82	171	32	96	10.4	26	0	10	0	0
106	Malaimbandy															
	JIRAMA(forage) (Morondava)	-	-	-	29.2	0.548	6.68	273	35	94	80	12.8	11.7	72	24	0
	Dabara (artésien)	31.0			29.3	0.272	7.57	134	18	110	104	24	10.7	24	8	8
	Manamby (artésien)				29.4	0.553	7.32	277	32	64	56	11.2	6.8	25	20	2
	Ankilizato (puits)	29.8	0.309	-	28.7	0.309	6.79	153	40	146	112	16.8	17.1	16	56	5
	Morondava (rivière)				29.1	0.637	7.37	315	40	212	176	44.8	15.6	36	24	3
	Eau de mer				29.4	62.650	7.49	31,100	34	124	6,390	387.2	1,329.9	19,200	32	1

Table 5.2.4 Water Quality of Groundwater (2/2)
Qualité des eaux souterraines (2/2)

No.	Localités	Analyses en laboratoire																	
		Na_2CrO_4 (mg/l)	So_4^{2-} (mg/l)	PO_4^{3-} (mg/l)	NO_3^- (mg/l) en N	NH_3^- (mg/l) en N	NO_2^- (mg/l) en N	Cl_2 (mg/l)	SiO_2 (mg/l)	S^{2-} (mg/l)	Cu (mg/l)	Fe (mg/l)	Mn (mg/l)	$KMnO_4$ (mg/l)	Cr^{6+} (mg/l)	Zn (mg/l)	I_2 (mg/l)	Br_2 (mg/l)	F^- (mg/l)
109	Tsianaloka	16	95	0.29	545	2.05	0.010	0.04	0.482	0.010	0.81	0.11	0.4	1.152	0.07	0.00	0.24	0.15	0.44
109	Tsianaloka II	1	80	0.33	590	1.9	0.007	0.02	0.754	0.001	0.29	0.21	0.3	0.864	0.08	0.50	0.12	0.07	0.38
93	Beroboka	0	8	0.34	2.3	0.03	0.007	0.05	0.423	0.000	0.60	0.05	0.2	0.576	0.09	0.02	0.17	0.10	0.42
64	Andranomena	20	34	0.31	1.7	2.34	0.002	0.06	0.315	0.008	0.36	0.39	0.1	0.288	0.05	0.00	0.23	0.14	0.48
97	Bezezika	21	20	0.38	1.9	0.06	0.017	0.06	0.506	0.029	0.34	0.29	0.2	0.576	0.05	0.00	0.21	0.13	0.41
67	Analaiva	9	13	0.30	2.1	0.02	0.006	0.04	0.363	0.010	0.40	0.07	0.1	0.288	0.05	0.86	0.08	0.05	0.39
25	Befasy	7	54	0.33	2	0.09	0.004	0.03	0.458	0.011	0.35	0.11	0.2	0.576	0.05	0.08	0.07	0.05	0.46
47	Ambararata	7	110	0.29	3.9	0.02	0.005	0.05	0.709	0.034	1.19	0.06	0.2	0.576	0.06	0.00	0.02	0.01	0.44
46	Marofihitsa	11	330	0.23	5	0.89	0.001	0.05	0.798	0.002	1.58	0.09	0.2	0.576	0.13	0.00	0.74	0.06	0.47
1	Andranopasy	7	230	0.32	4.1	0.82	0.005	0.03	0.786	0.006	1.48	0.07	0.2	0.576	0.06	0.08	0.11	0.07	0.45
103	Ankilizato (forage)	8	1,150	0.26	2.6	0.00	0.003	0.07	0.605	0.000	1.47	0.36	0.1	0.288	0.08	1.04	0.15	0.10	0.43
104	Mandabe	2	20	0.38	37	0.01	0.003	0.03	0.859	0.005	0.44	0.08	0.1	0.288	0.08	0.00	0.16	0.13	0.43
114	Ambatolahy	2	11	0.53	27	0.04	0.006	0.01	0.539	0.006	0.38	0.10	0.1	0.288	0.07	0.56	0.08	0.02	0.41
106	Malaimbandy																		
	JIRAMA(forage) (Morondava)	0	50	0.30	3.8	0.05	0.005	0.04	0.571	0.001	0.36	0.05	0.0	0.000	0.08	0.16	0.43	0.06	0.48
	Dabara (artésien)	11	20	0.26	1.7	0.05	0.005	0.02	0.569	0.002	0.36	0.25	0.2	0.576	0.07	0.10	0.30	0.04	0.43
	Manamby (artésien)	3	8	0.25	4.1	0.08	0.002	0.05	0.476	0.005	0.32	0.05	0.1	0.288	0.08	0.06	0.38	0.12	0.42
	Ankilizato (puits)	8	2	0.28	2	0.17	0.005	0.04	0.419	0.002	0.33	0.09	0.1	0.288	0.08	1.92	0.10	0.07	0.44
	Morondava (rivière)	12	49	0.35	2.2	0.02	0.016	0.06	0.749	0.003	0.33	0.05	0.3	0.864	0.07	0.06	0.10	0.05	0.45
	Eau de mer	1	3,100	0.29	4.7	3.10	0.004	0.04	0.077	0.006	1.00	0.08	0.1	0.288	0.13	0.00	0.07	0.05	0.39



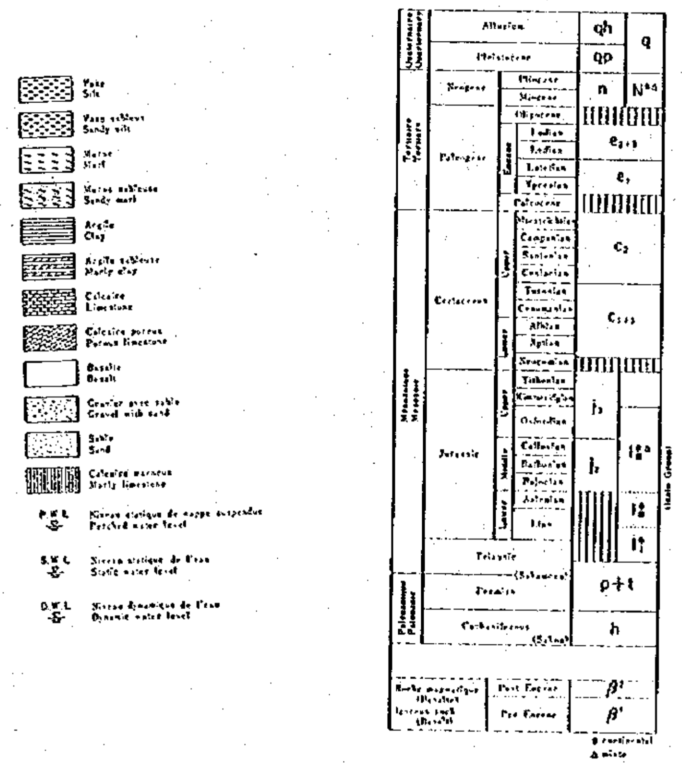


Fig. 5.2.1 Coupe Hydrogéologique Transversale
Hydrogeological Cross Section

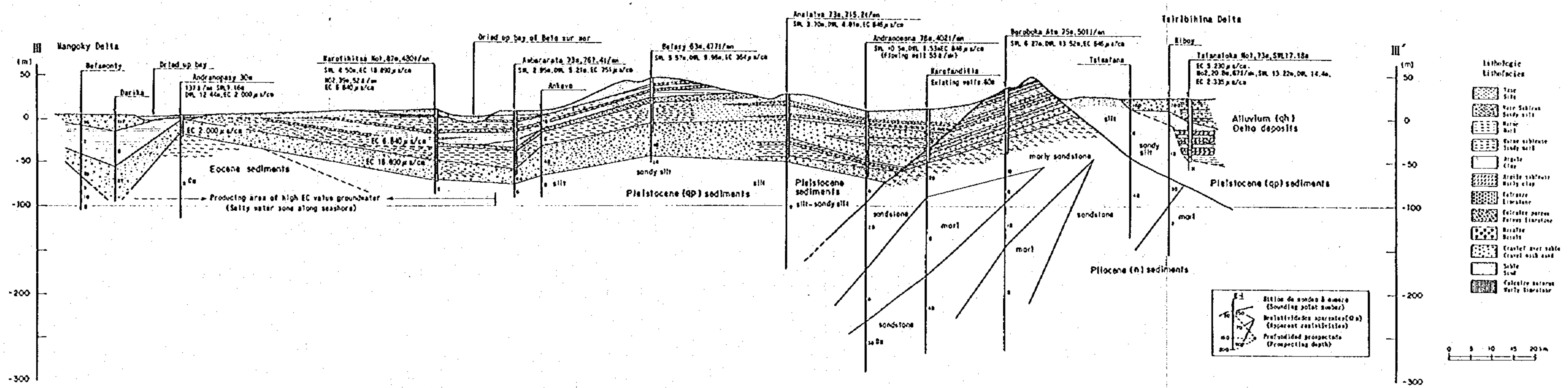


Fig. 5.2.2 Coupe Hydrogéologique Verticale de la Plaine de Morondava
Hydrogeological Vertical Section of the Morondava Plain

Station météorologique
Meteorologic Station

763.8 Pluviométrie annuelle moyenne (mm)
Mean Annual Rainfall (mm)

---700--- Isohyètes (mm)
Rainfall Contour Line (mm)

Bassin fluvial
River Basin

13.34 Débit de base (m³/sec)
Base Flow (m³/sec)

(1) Plaine de Morondava
Morondava Plain

(2) Delta de Mangoky
Mangoky delta

(3) Delta de Tsiribihina
Tsiribihina Delta

(4) Bassin du fleuve Tsiribihina
Tsiribihina River Basin

(5) Bassin du fleuve Andranomena
Andranomena River Basin

(6) Bassin du fleuve Morondava
Morondava River Basin

(7) Bassin de la rivière Sakény
Sakeny River Basin

(8) Bassin du fleuve Maharivo
Maharivo River Basin

(9) Bassin du fleuve Kirindy
Kirindy River Basin

(10) Bassin du fleuve Maintapaka
Maintapaka River Basin

(11) Bassin de la rivière Mangoky
Mangoky River Basin

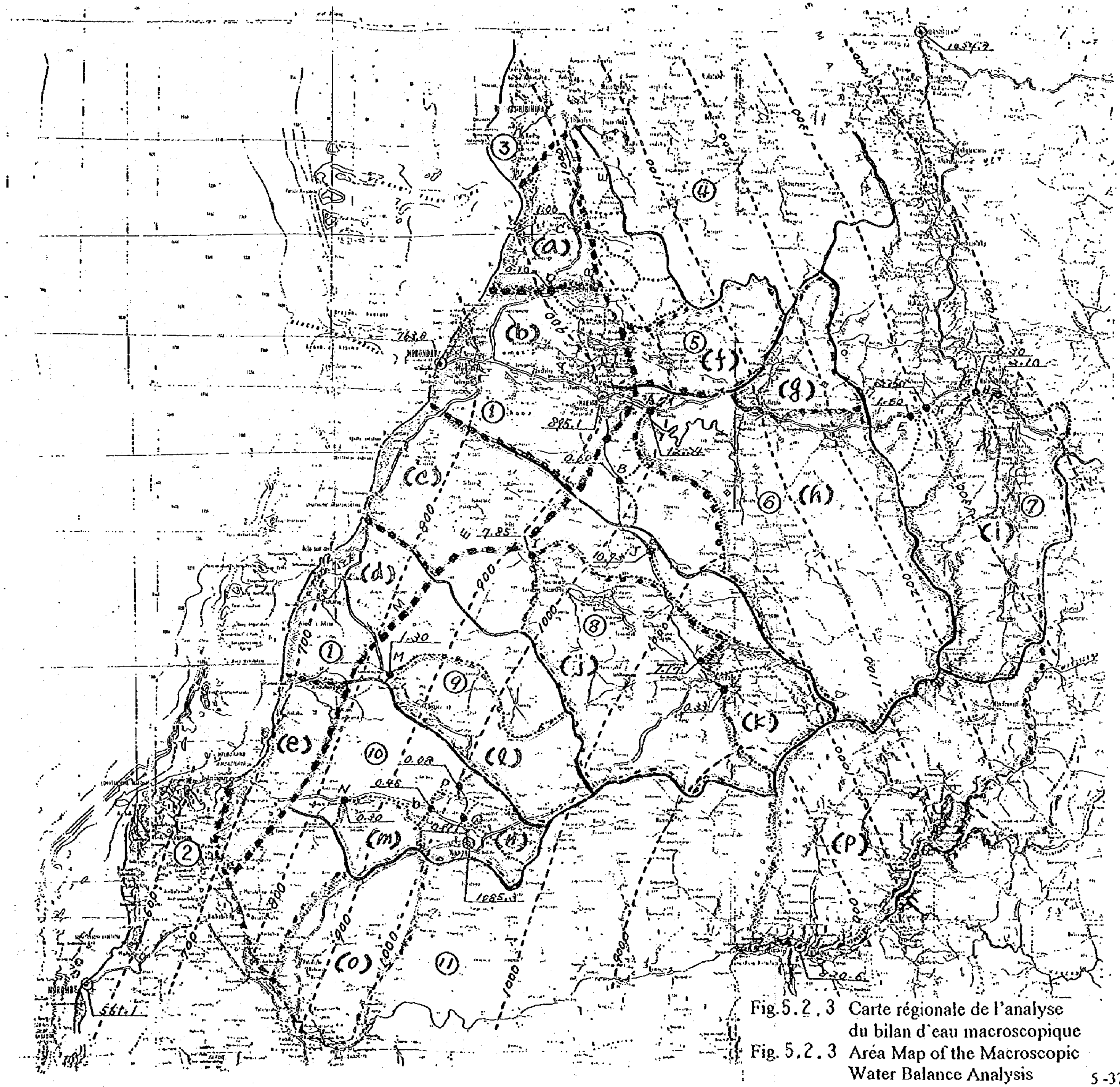


Fig.5.2.3 Carte régionale de l'analyse du bilan d'eau macroscopique
Fig. 5.2.3 Area Map of the Macroscopic Water Balance Analysis

6. SURVEY FOR DETAILED SOCIO-ECONOMY

6.1 Overall Socio-economic Survey

6.1.1 Objective of the Survey

The comprehensive socio-economic survey was conducted in the previous stage of the study in order to obtain basic socio-economic data for project evaluation. The basic method employed was direct interviews held with 60 households randomly sampled in 30 selected villages. The list of surveyed villages is as per Table 6.1.1. The survey was conducted on various socio-economic indicators: *1)* basic profiles, *2)* revenue and expenditure, *3)* water requirement and *4)* sanitation and medical services. Details of the questionnaires and a summary of the survey in each field is shown in the Supporting Report. The major findings of the survey are as follows.

6.1.2 Basic Profile

The basic profiles include the number of family members, adult literacy, and primary school enrollment. The number of family members ranges from 3 to 13, and the average is 6.0 persons. The average adult literacy rate is 25.6 % in Malagasy, and the average primary school enrollment is 38.6 %, indicating that the education level of the Study Area is much lower than the national average.

6.1.3 Revenue and Expenditure

The level of the economy is measured by three criteria. The first criterion is the cash revenue per household per annum. The average of the samples is FMG 587.8 thousand per household per annum. A major part of this amount derives from the cash income from the marketing of agricultural products. The adjusted average income per capita per annum of FMG 195.9 thousand, after counting the same amount of non-cash income and being divided by the average size of a family of 6.0, is much lower than the average GDP per capita of FMG 532.3 thousand in Madagascar.

The second criterion is the expenditure per household per annum. It is observed that 95.6 % of all the annual expenditure is for the daily necessities, and very little is invested on farming to improve agricultural productivity. It is clearly shown that the Study Area remains a subsistence economy.

The third criterion is the cash balance per household per annum. The sample households with positive cash balances are only 11.7 %, and the average amount being only FMG 55,200 per annum. The balance, if any, is usually not invested on farm improvements but saved for future purchases of cattle.

In order to estimate the cash income level of all the accessible villages, the correlation between the level of cash income and population was analysed, as shown in Table 6.1.7 and Figure 6.1.1. The result shows that the level of cash income highly correlates to population, with a correlation coefficient (R) of 0.7577.

6.1.4 Water Requirement

In connection with the kinds of existing water sources, 23.3 % of the sample households answered that their water source was inadequate, such as rivers, canals and ponds. As regards to the amount of water available, the average amount of water shortage, which is expressed in the form of the difference between the necessary amount of water and the actual amount of water available, is estimated at 35.5 liters per household per day, indicating that there are difficulties to meet the demand for water, especially during dry seasons.

As for the quality of water, 45.0 % of sampled households complained that the quality of water is poor, 35.0 % responded that it is fair, and only 20.0 % regarded the quality as good. However, it is often the case that villagers evaluate the quality of water only in terms of its taste.

The average distance to the nearest water source is 350 m, which forces villagers to be inconvenienced by fetching water. The maximum distance to an existing water source is 1 km. In summary, the statistics show that the development of water resources is urgently needed in the Study Area in every aspect.

6.1.5 Sanitation and Medical Services

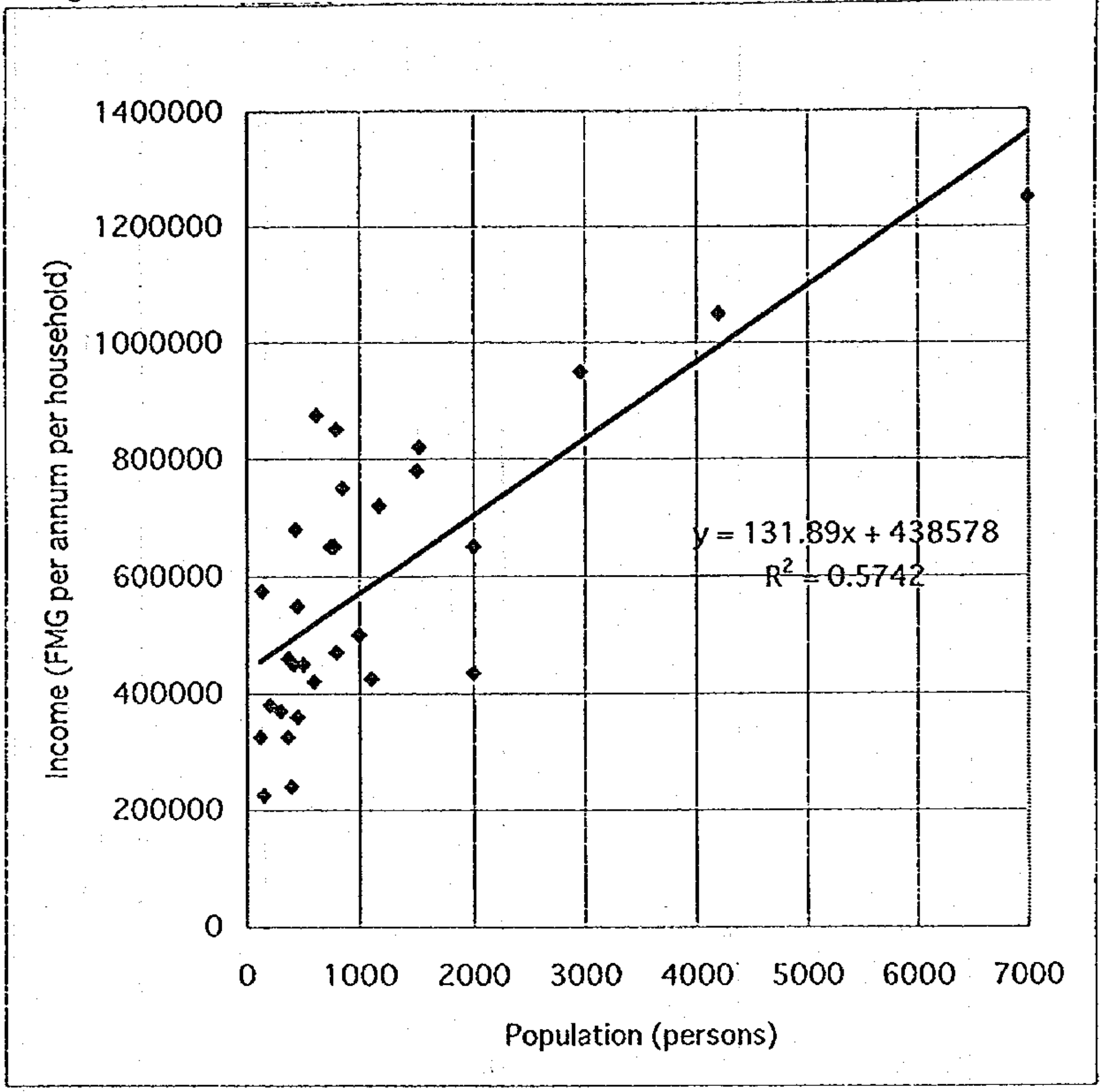
The onset rates of the major waterborne diseases such as diarrhea, typhoid, amebiasis, hepatitis and other parasitic diseases were collected to obtain the information for the disease impact analysis in the economic evaluation. For example, the average onset rate of diarrhea, one of the major waterborne diseases, is an alarming 73.3 %, indicating that the poor quality of water in the Study Area causes the diarrhea.

The access to hospitals with doctors is very poor with the average distance to the nearest hospital being 10.5 km. Even if hospitals are accessible, there is an insufficient amount of medicines available, further, villagers cannot afford to buy medicines that are available. The sanitary education in the Study Area is lax. The data shows that only 23.4 % of the sample households responded that sanitary education had been conducted by some official organizations.

Table 6.1.1 Correlation between Population and Income in Selected Villages

No.	Fivondronana	Firaisana	Village	Population	Income
1	Manja	Andranopasy	Andranopasy I	623	875000
5	Manja	Andranopasy	Bafamonty	450	550000
15	Manja	Manja	Miary	365	325000
16	Manja	Ankiliabo	Ambivy I	130	575000
25	Morondava	Befasy	Befasy	2000	650000
33	Morondava	Befasy	Misokotsa	800	470000
35	Morondava	Laijoby	Amanga	400	240000
40	Morondava	Manomentinay	Manomentinay	436	680000
44	Morondava	Belo-Sur-Mer	Belo-Sur-Mer	1100	425000
46	Morondava	Belo-Sur-Mer	Marofihitsa	750	650000
47	Morondava	Belo-Sur-Mer	Ambararata	500	450000
48	Morondava	Belo-Sur-Mer	Ankebo	300	370000
64	Morondava	Bemanonga	Andranomena Sud	414	450000
66	Morondava	Bemanonga	Croisement (BST)	204	380000
67	Morondava	Analaiva	Analaiva	1520	820000
68	Morondava	Analaiva	Betsipotika	120	325000
69	Morondava	Analaiva	Amboloando	150	225000
70	Morondava	Analaiva	Ampandra	600	420000
74	Morondava	Analaiva	Tsinjorano	450	360000
82	Morondava	Marofandiliha	Marofandiliha	370	460000
93	Morondava	Marofandiliha	Boraboka Sud	783	650000
94	Mahabo	Ankilivalo	Ankilivalo	2960	950000
97	Mahabo	Ankilivalo	Bezezika	855	750000
103	Mahabo	Ankilizato	Ankilizato	4200	1050000
104	Mahabo	Mandabe	Mandabe	2000	435000
106	Mahabo	Malaimbandy	Malaimbandy	7000	1250000
109	Belo sur Tsiribihina	Tsianaloka	Tsianaloka	1000	500000
112	Belo sur Tsiribihina	Tsimafana	Tsimafana	1500	780000
113	Belo sur Tsiribihina	Tsimafana	Mananjaky	1170	720000
114	Miandrivazo	Ambatolahy	Ambatolahy	800	850000

Figure 6-1-1 Correlation between Population and Income in Selected Villages



Revolution Stastics		Revolution Analysis			
R	0.7577	Y=aX+b	Coefficient	Standard Error	t Value
R2	0.5742	b Value	438577.7832	38619.7235	11.3563
Revised R2	0.5589	a Value	131.8900	21.4656	6.1443

6.2 Survey on the Villages for Pilot Projects

6.2.1 Objectives of the Survey

In the latter stage of the Study, a more precise socio-economic survey was conducted in the 6 pilot project villages (Ambararata, Andranomena, Analaiva, Beroboka Sud, Bezezika and Tsianaloka). The objective of this specific survey was to collect statistically meaningful information on the willingness to pay and the affordability to pay for the operation and maintenance of the facilities.

The willingness to pay (hereinafter referred to as WTP) is the maximum amount of operation and maintenance fee which villagers are willing to pay without sacrificing present expenditure. On the other hand, the affordability to pay (hereinafter referred to as ATP) is the minimum amount which villagers are capable of paying with sacrificing present expenditure.

Direct interviews were conducted for the survey. In order to obtain statistically accurate data, 15 sample households in each village, totaling 90 samples, were interviewed. The interviews were conducted individually so that interviewees could not be influenced by other interviewees.

6.2.2 Willingness to Pay and Affordability to Pay

Table 6.2.1 summarizes WTP and ATP in the 6 villages of the pilot project, and Figure 6.2.1 to 6.2.6 illustrates their distribution in each village. WTP ranges from FMG 500 to 10,000 per household per month with the average figures of FMG 2000 in Ambararata, FMG 2433 in Andranomena, FMG 2067 in Analaiva, FMG 1967 in Beroboka Sud, FMG 2167 in Bezezika and FMG 2067 in Tsianaloka. On the other hand, ATP ranges from FMG 250 to FMG 3000 per household per month with the average figures of FMG 1033 per household per month in Ambararata, FMG 1167 in Andranomena, FMG 867 in Analaiva, FMG 967 in Beroboka Sud, FMG 970 in Bezezika and FMG 1017 in Tsianaloka.

In some cases, villagers are likely to give a higher ATP amount than they can actually pay. In an attempt to identify the accuracy of ATP, an analysis on the correlation between WTP and ATP was conducted. Figure 6.2.7 illustrates the correlation between WTP and ATP in 6 pilot project villages, indicating that WTP highly correlates to ATP with the correlation coefficient (R) of 0.8713, and their ATP is in line with their WTP without exaggerating the level of ATP.

6.2.3 Results of the Analysis

Table 6.2.2, Figure 6.2.8 and Figure 6.2.9 summarize the statistical data for the willingness to pay and the affordability to pay in the 6 pilot project villages. The mean ATP of the whole group of villages was estimated as shown below as well as the 95% interval of the mean.

Mean and 95% Confidence Interval of ATP in 6 Pilot project Villages

Unit: FMG per household per month

Name of Village	Minimum Mean	Mean ATP	Maximum Mean
Ambararata	484.85	1033.33	1581.81
Andranomena	863.05	1166.67	1470.29
Analaiva	486.20	866.67	1247.14
Beroboka Sud	507.90	966.67	1425.44
Bezezika	563.62	970.00	1376.38
Tsianaloka	596.53	1016.67	1436.81

It could be observed that while the mean ATP of the sample households ranges from FMG 866.7 to FMG 1166.67 per household per month, it is 95% probable that in the whole group of villages the mean ATP would range from FMG 484.85 at minimum to FMG 1581.81 at maximum per household per month. In other words, it is highly probable that the mean ATP exists at a certain point between FMG 484.85 and FMG 1581.81. Thus, it can be safely concluded that villagers can pay at least about FMG 500 per household per month as the operation and maintenance fee for water supply facilities.

Table 6.2.1 Willingness to Pay (WTP) and Affordability to Pay (ATP) for 6 Pilot project Villages Unit: FMG

Village	Anbararata		Andranomena		Analaiva	
	WTP	ATP	WTP	ATP	WTP	ATP
Household 1	1000	500	2000	1000	500	250
Household 2	1000	500	1000	750	1000	250
Household 3	500	250	2000	1000	10000	2000
Household 4	5000	2500	3000	1500	500	250
Household 5	6000	3000	5000	2500	1000	500
Household 6	500	250	2000	1000	5000	2000
Household 7	1500	750	5000	1000	1000	500
Household 8	500	250	3500	2000	500	500
Household 9	1000	500	2500	1500	500	250
Household 10	1000	500	2500	1500	500	250
Household 11	1500	500	2000	1000	1000	750
Household 12	1000	500	1000	500	1500	1000
Household 13	5000	3000	1500	500	2500	1500
Household 14	2000	1000	2000	750	1500	1000
Household 15	2500	1500	1500	1000	4000	2000
Average	2000	1033.33	2433.33	1166.67	2066.67	866.667
Village	Beroboka Sud		Bezezika		Tsianaloka	
	WTP	ATP	WTP	ATP	ATP	WTP
Household 1	5000	2500	2000	500	5000	2500
Household 2	1500	500	500	500	1250	750
Household 3	500	500	2500	500	2500	1000
Household 4	500	250	3000	1000	2000	1000
Household 5	5000	2500	1000	500	2000	1000
Household 6	2000	1000	5000	2500	500	250
Household 7	5000	2500	2000	1000	500	250
Household 8	2500	1000	3000	1000	5000	3000
Household 9	1000	500	500	250	2000	1000
Household 10	1000	500	2500	1500	2000	1000
Household 11	1500	500	1000	500	1000	500
Household 12	2000	1000	2000	1500	2000	1000
Household 13	500	250	2000	500	1000	500
Household 14	500	500	5000	2500	3000	750
Household 15	1000	500	500	300	1250	750
Average	1966.67	966.667	2166.67	970	2066.67	1016.67

Table 6.2.2 Stastical Summary for WTP and ATP in Pilot Project Villages

Stastical Items	Ambararata		Andranomena		Analaiva	
	WTP	ATP	WTP	ATP	WTP	ATP
Mean	2000.00	1033.33	2433.33	1166.67	2066.67	866.67
95% Confidence Interval	1009.26	548.48	685.20	303.62	1426.79	380.47
Standard Error	470.56	255.73	319.47	141.56	665.24	177.39
Median	1000.00	500.00	2000.00	1000.00	1000.00	500.00
Mode	1000.00	500.00	2000.00	1000.00	500.00	250.00
Standard Deviation	1822.48	990.43	1237.32	548.27	2576.45	687.04
Variation	3321428.57	980952.38	1530952.38	300595.24	6638095.24	472023.81
Range	5500.00	2750.00	4000.00	2000.00	9500.00	1750.00
Minimum	500.00	250.00	1000.00	500.00	500.00	250.00
Maximum	6000.00	3000.00	5000.00	2500.00	10000.00	2000.00
Number of Samples	15	15	15	15	15	15
Stastistical Items	Beloboka Sud		Bezezika		Tsianaloka	
	WTP	ATP	WTP	ATP	WTP	ATP
Mean	1966.67	966.67	2166.67	970.00	2066.67	1016.67
95% Confidence Interval	932.94	458.77	794.73	406.38	766.32	420.14
Standard Error	434.98	213.90	370.54	189.47	357.29	195.89
Median	1500.00	500.00	2000.00	500.00	2000.00	1000.00
Mode	500.00	500.00	2000.00	500.00	2000.00	1000.00
Standard Deviation	1684.66	828.44	1435.10	733.83	1383.79	758.68
Variation	2838095.24	686309.52	2059523.81	538500.00	1914880.95	575595.24
Range	4500.00	2250.00	4500.00	2250.00	4500.00	2750.00
Minimum	500.00	250.00	500.00	250.00	500.00	250.00
Maximum	5000.00	2500.00	5000.00	2500.00	5000.00	3000.00
Number of Samples	15	15	15	15	15	15

Figure 6.2.1 WTP and ATP in Ambararata

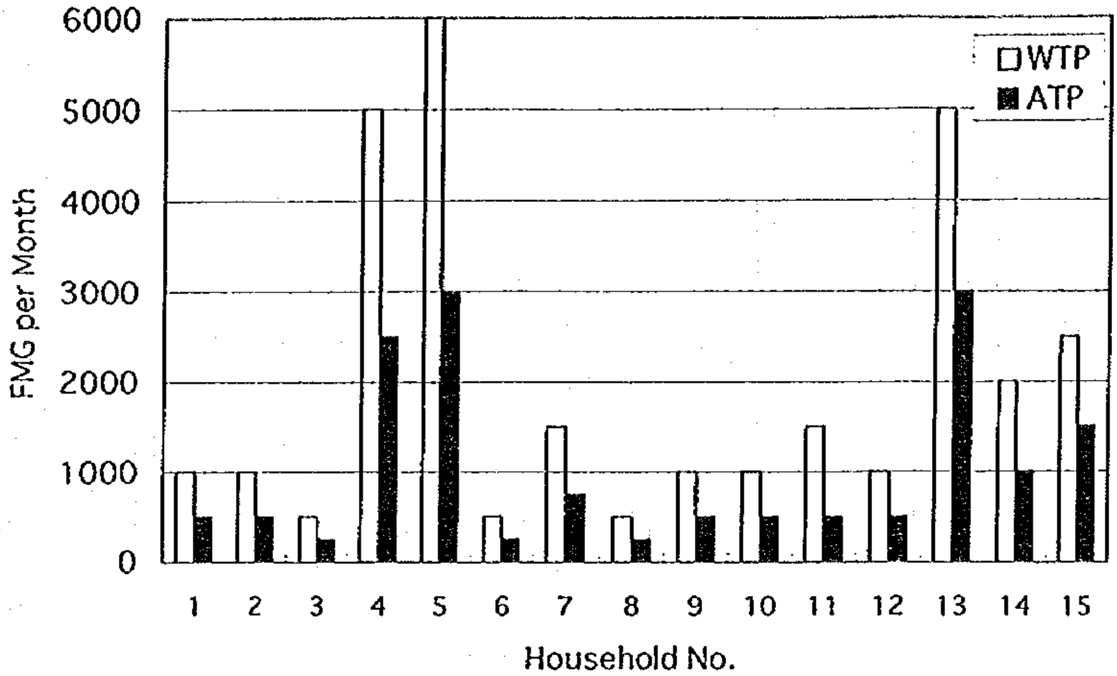


Figure 6.2.2 WTP and ATP in Andranomena

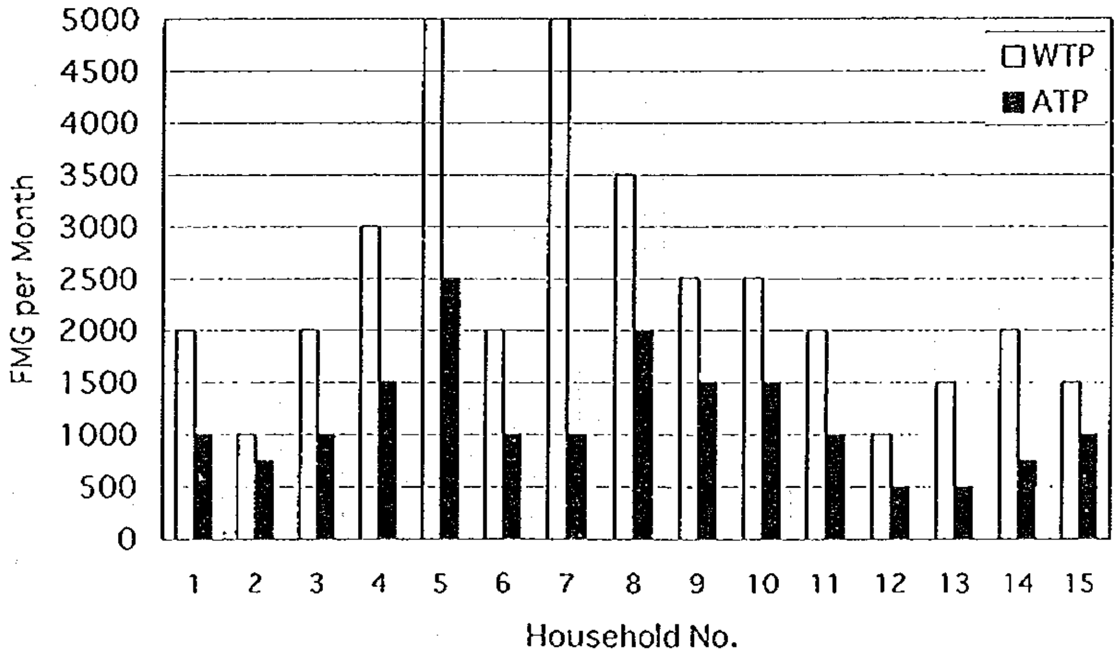


Figure 6.2.3 WTP and ATP in Analaiva

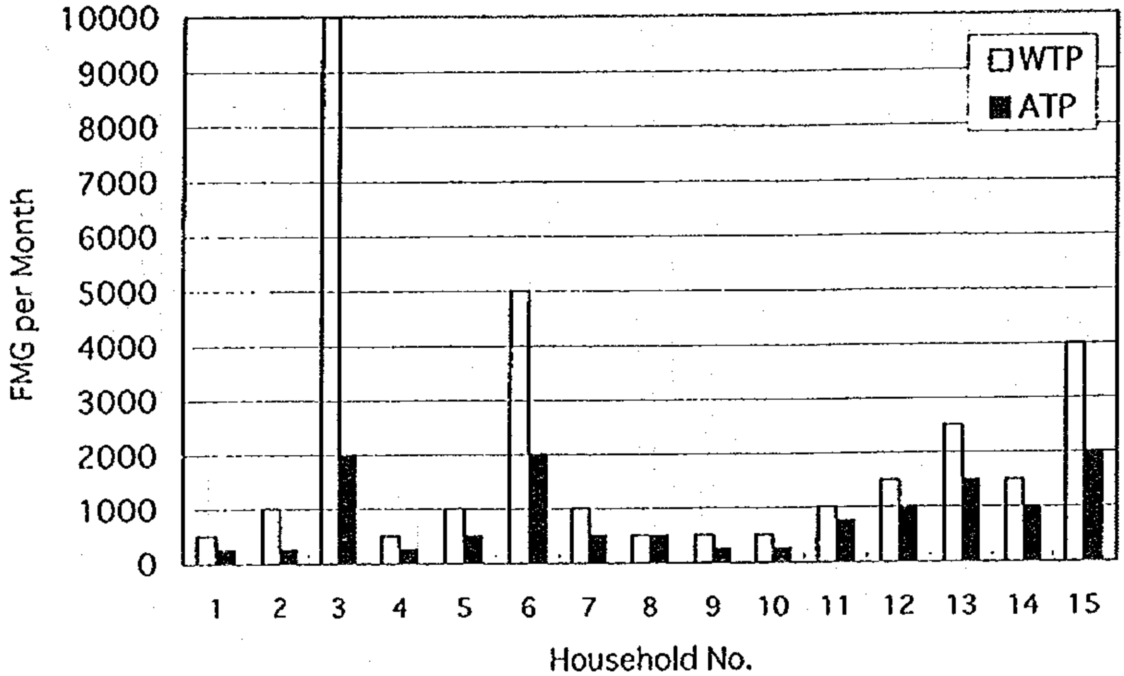


Figure 6.2.4 WTP and ATP in Beroboka Sud

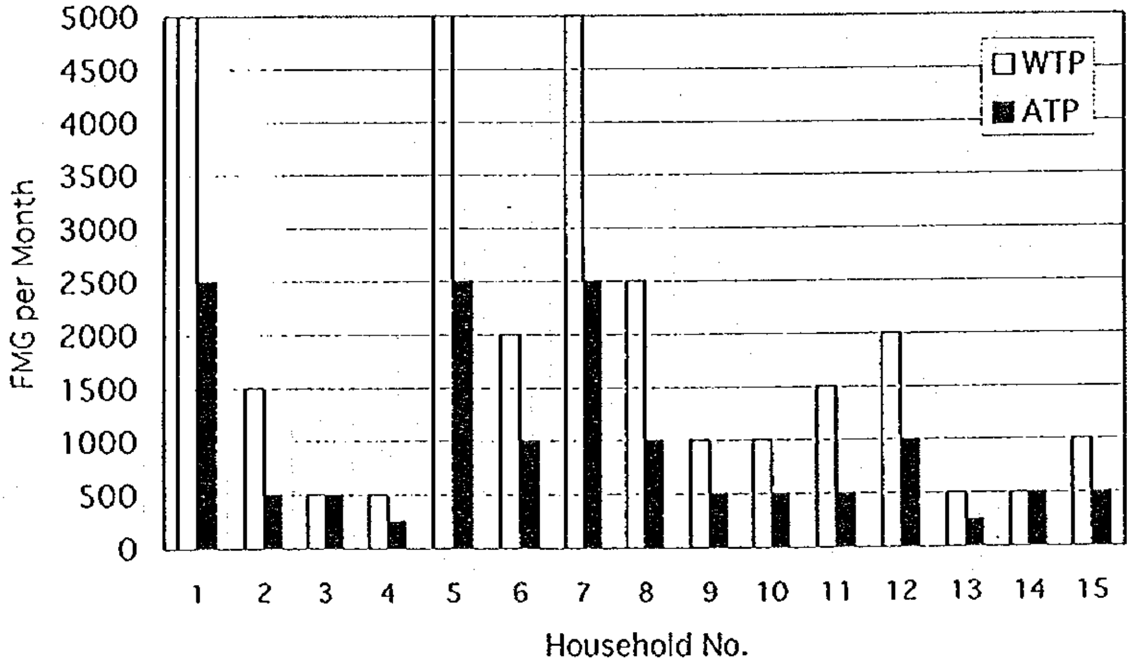


Figure 6.2.5 WTP and ATP in Bezezika

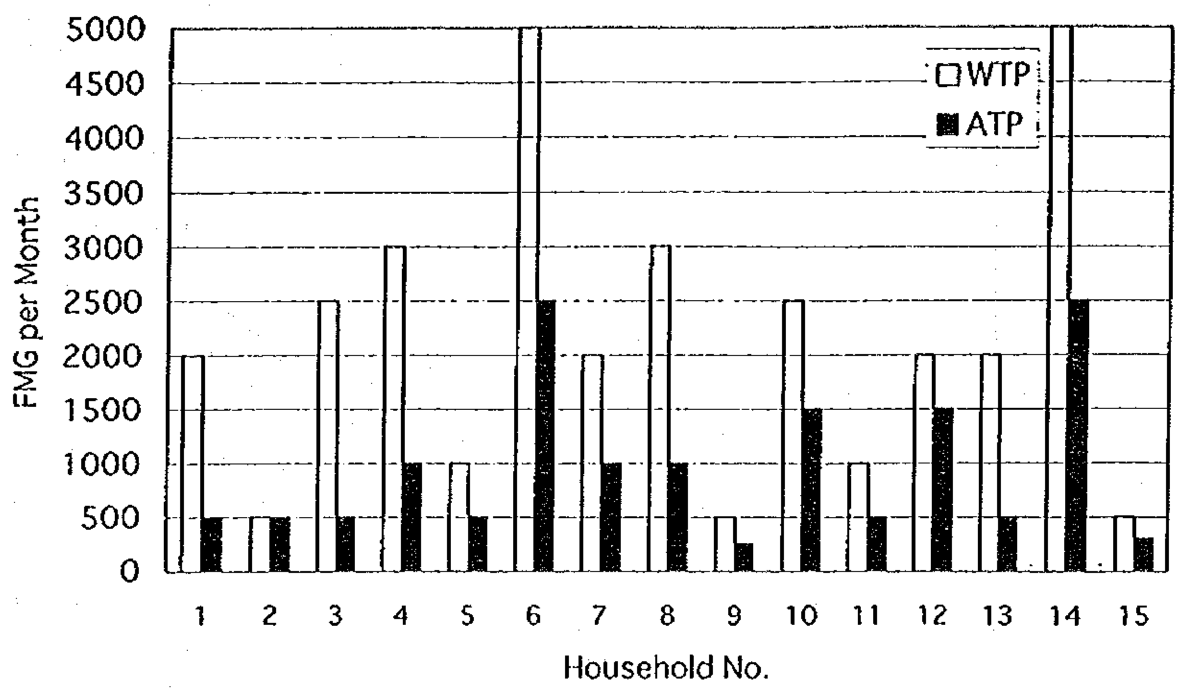


Figure 6.2.6 WTP and ATP in Tsianaloka

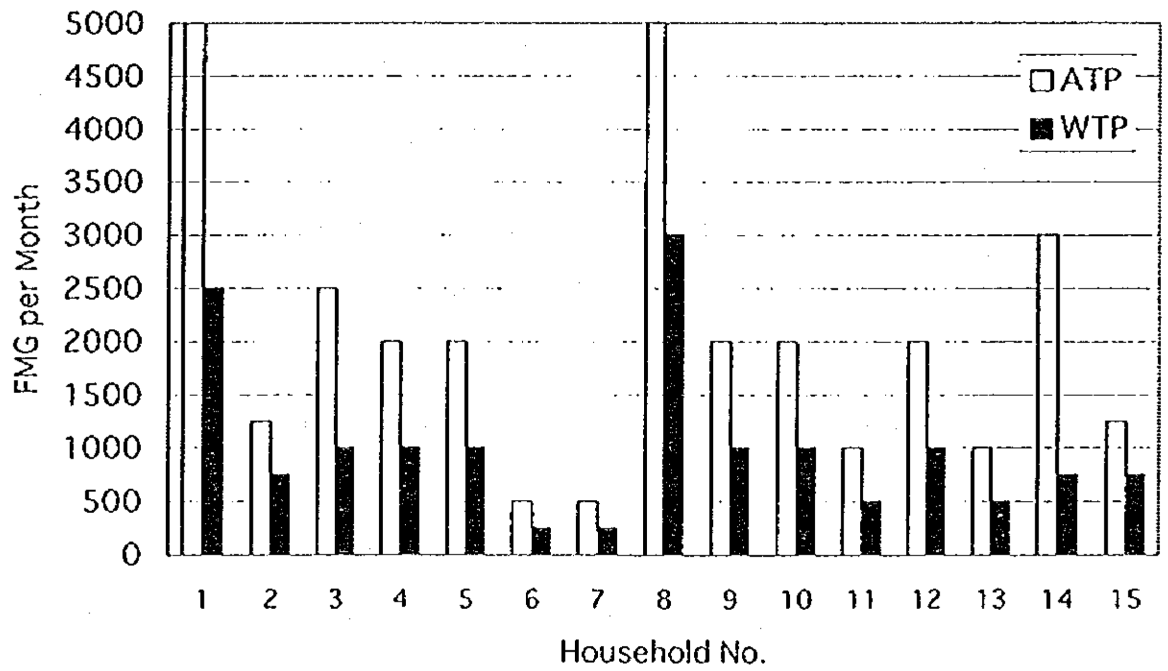
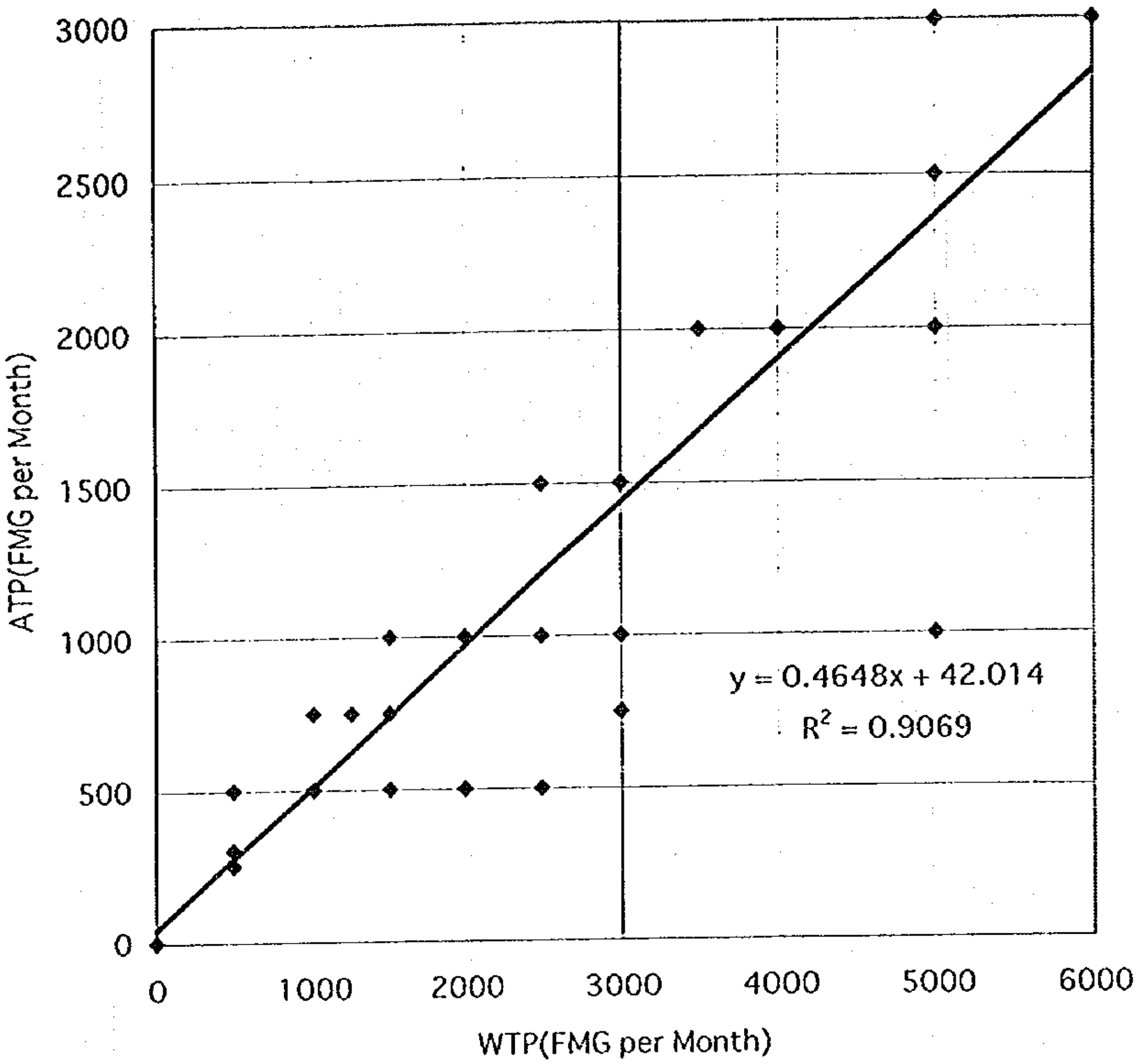


Figure 6.2.7 Correlation between WTP and ATP



Correlation Stastistics			Correlation Analysis		
R	0.8713	Y=aX+b	Coefficient	Standard Error	t Value
R2	0.7591	b Value	188.1627	62.7092	3.0006
Revised R2	0.7563	a Value	0.3851	0.0231	16.6513

Figure 6.2.8 Estimated WTP based on 95% Confidence Interval

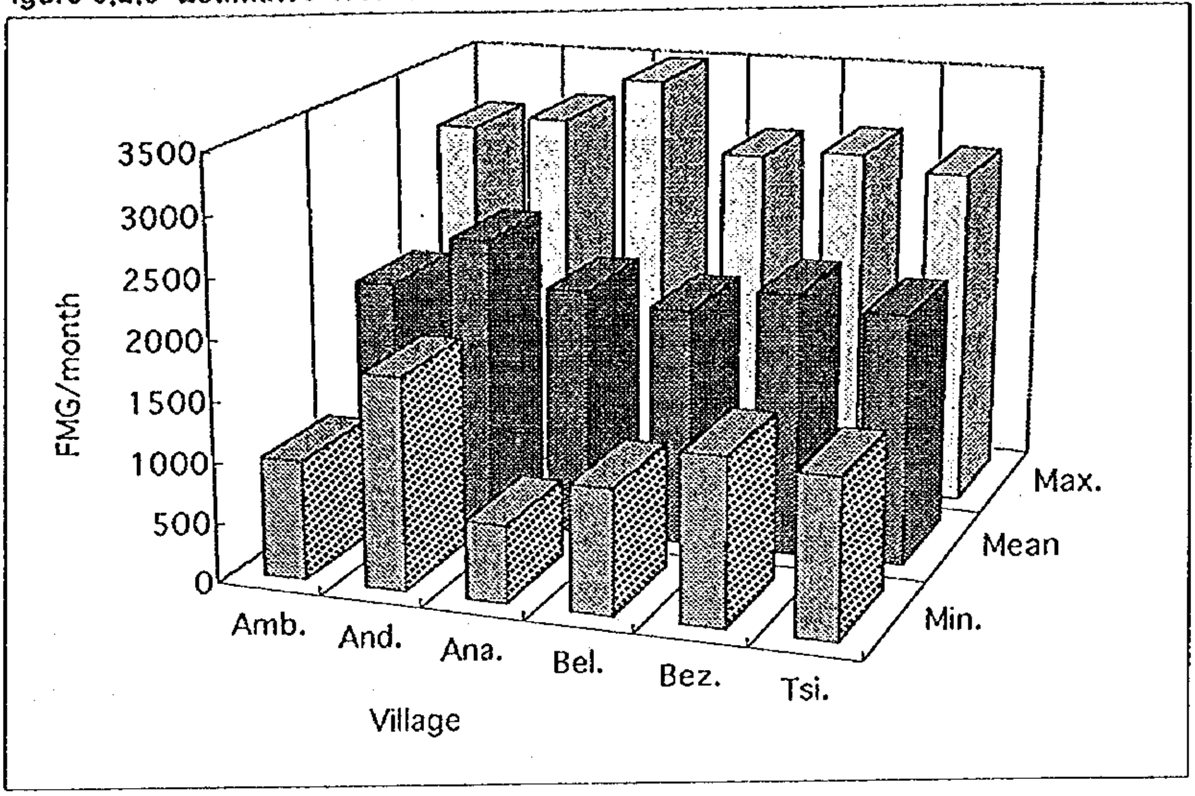
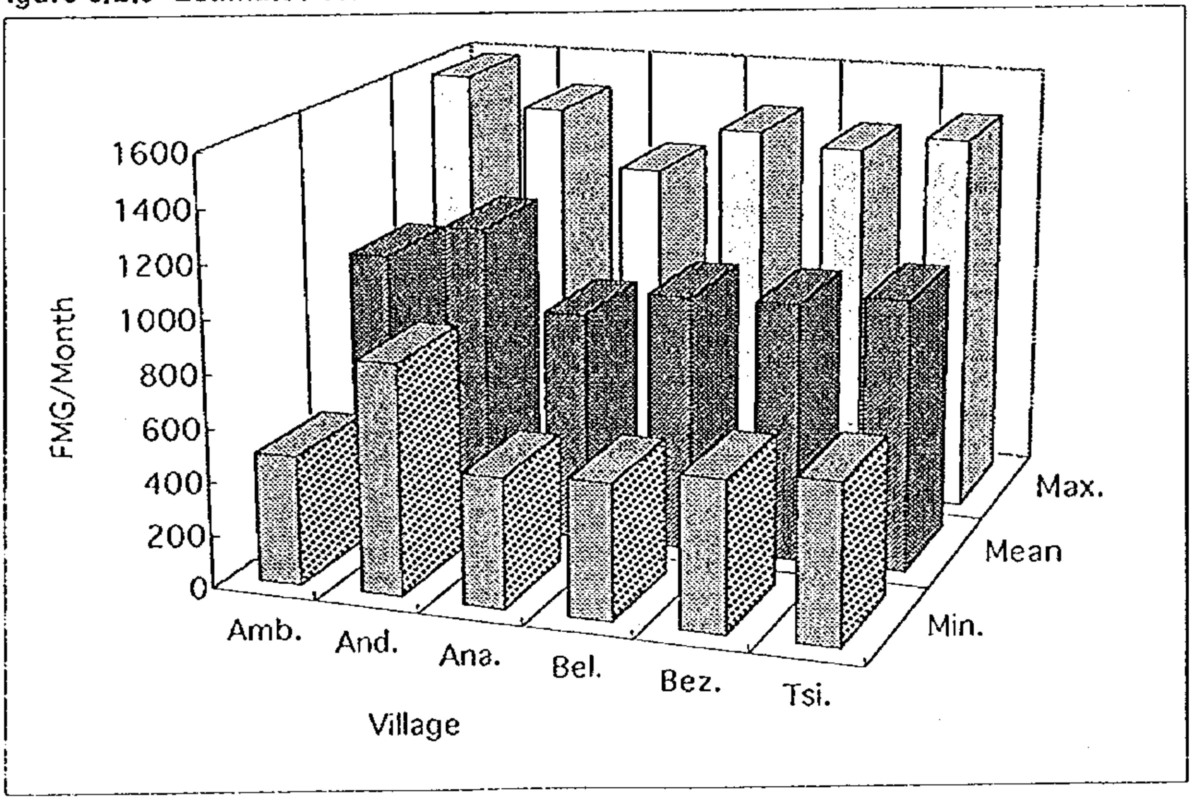


Figure 6.2.9 Estimated ATP based on 95% Confidence Interval



7. EVALUATION SURVEY ON PHASE - I PROJECT

The purpose of the evaluation survey on the Phase I Project was to draw lessons from the following for the Phase II Study:

- Whether the type and scale of the supply facility is appropriate, especially for the villages where water supply facilities have never existed.
- Whether the willingness to pay for the supply services has been fully established in this area.
- Whether the water association established in each of the project implemented village is functioning adequately (technically and administratively).
- Whether the sanitary environment as well as the sense of sanitation have been improved by the service of potable water supply.
- Whether the regional office of MEM and the local authorities have extended sufficient facility maintenance services.
- Whether the women's social status has improved in this area through participation of water associations as administrative members.

7.1 Existing Condition of the Phase I Project Facilities

In the Phase I Project area, that is the southern half of the proposed project area, 50 sets of water supply facilities were constructed in the selected 50 villages from 1993 to 1995 under the Japan's grant aid program.

The facilities constructed are :

- 2 or 3 borehole wells in each village with a hand pump in 12 villages, and
- Simple water supply systems comprising of a borehole well with motorized pump, generator house, distribution tank, branch type distribution pipeline, and communal faucets in 38 villages.

Of the 50 villages, 28 villages were visited during the early stage of the Study in order to observe the facilities in operation, functioning of the water association, and how the facilities are being maintained.

The apparent operation and maintenance condition of each village is tabulated in Table 7.1, and the typical findings are as follows:

a) The general trend of water use indicates little increase in the water consumption rate. In many of the villages, the inhabitants seem to prefer to consume smaller amounts of water and thus make smaller payments rather than the amount they would like to use. Whereas the supply systems are designed to distribute 20 liters per capita per day by 6-hours pumping, the majority of motor pumps are operated only 1 to 2 hours a day, in order to save the cost of diesel. This means that the average daily supply amount per person is limited to only 3 to 7 ℓ/c/d, resulting in little improvement in water use, so far as quantity is concerned.

b) The technology transfer on how to operate the diesel engine generator to the person in charge of daily facility operation has been done well, and there is little problem with the facility operation, so far as the technical aspects of the daily operation are concerned.

c) With regard to the facility maintenance, however, some problems have appeared a short time after the facility construction. For example, damaged taps or broken down hand pumps have not been immediately repaired due to the difficulty in obtaining parts, and probably due to the old habit of fetching water from distant water sources, therefore, they do not mind collecting water from further taps or wells so long as the remaining taps or wells are present in the village.

d) The maintenance services from the Toliara regional office of MEM or from the local authorities are not adequate. The periodical patrol service of the MEM Toliara office has not been extended to cover the whole Project area.

Moreover, countermeasures are not taken immediately, ignoring the request of the villagers for the inspection or repair of the troubled parts. This is due to a lack of man - power and budget of MEM for O/M.

e) In some of the villages, the water supply operation was suspended during the rainy season because there was plenty of water in the streams and ponds nearby.
Many inhabitants preferred to use water as before refusing the burden for operation costs, thus operation of supply facilities was forced to be suspended during the rainy season. This fact suggests that the sense of sanitation has not been fully established in these areas, due to lack of continuous efforts on extension activities.

f) Women's participation in the management of water associations is believed to be very effective in the improvement of the status of women. Based on this, vigorous efforts to enlighten women were done during the course of the study and the construction period. However, only 4 of the 28 water associations have female executive members. Such a low female participation as executive members was simply explained by the fact there were "no requests for candidacy from women".

7.2 Lessons for Phase II Study

Taking due consideration of the findings in the Phase I Project, special attention was paid to improving the study methodology and approach especially for the Pilot Project and the detailed socio-economic survey of the Phase II Study. Also, in formulation of the Phase II Project, the type of supply facility was determined while carefully considering low-cost and easy maintenance. The following lessons are applied to the Phase II Study.

1) The willingness to pay and the amount the villagers are able to pay, declared by the villagers before implementation of the project, are not always the same after provision of the water supply facility. The actual ability to pay was surveyed through a detailed socio-economic survey. Trials on the establishment of the willingness to pay were made through repeated discussions with the villagers in the Pilot Project.

   The importance of safe water use even in the rainy season was emphasized in these discussions.

2) Through the village inventory survey and the Pilot Project, women's participation in the water supply management was strongly suggested from the viewpoints of better management, and improvement of women's social status.

3) In order to achieve independent operation by the villagers, and to make maintenance easier and the costs lower, the hand pump well facilities have been planned for all villages with a population smaller than 800. Also, solar powered systems are planned to be introduced in the villages where fuel supply is difficult.

4) A reinforcement of the maintenance service organization of MEM, including the establishment of a Morondava branch office, has been strongly suggested to MEM.

Table 7.1 Condition of Water Supply in Phase I Project Area

Name of Village (Population 1995)		Facility type and Number of H/P wells or Communal faucets		Condition of the facilities, as of May 1995			
				NO. of damaged wells or faucets	Generator operation hours per day	Water charge collection rate (%)	Remarks
Ambalamoa	1,180	M/S	6F	3F	0	0	Totally not working caused by battery exhaustion
Tsianihy	1,630	M/S	10F	0	4~5	100	Fairly good O/M
Namatoa	880	M/S	6F	3F	2~3	80	Damaged faucets are left unrepaired
Mangolovolo	1,760	M/S	10F	2F	2	70~80	No money collection during rainy season
Andranomanintsy	1,650	M/S	10F	3F	1(2h/2d)	60~70	Very short operation period
Analamisampy	890	H/P	3W	1W	—	100	No spare parts for damaged pump
Antseva	940	H/P	3W	0	—	100	Fairly good
Ankatrakatora	540	H/P	2W	0	—	100	Fairly good
Ambondro	1,170	H/P	3W	3W	—	0	No countermeasures until the last well stopped working
Andranohinary	2,070	M/S	12F	0	1~2	100	Comparatively good
Sakaraha	4,510	M/S	18F 26F	0 10	Zone(1) 1.5 Zone(2) 2	75 100	(1) Fairly good (2) Frequent tap damages
Ankazoabo	3,440	M/S	24F	2F	3	90	No saving for maintenance cost due to small charge of FMG1000
Belitsaka	1,510	M/S	8F		1(2h/2d)	100	Small amount of water is equally shared
Ampasikibo	2,290	M/S	12F	2F	3.5	100	Fairly good
Namaboha	1,730	M/S	10F	0	1.5	75	Partial supply
Ampihamy	1,680	M/S	10F	0	1.5	100	Partial supply
Beroroha	2,600	M/S	14F	3F	1(2h/2d)	100	Fund shortage for longer operation (FMG 1000)
Antomarify	1,380	M/S	8F	0	0.5(1h/2d)	100	Fund shortage for longer operation (FMG 1000)
Manombo-Atm	3,440	M/S	18F	8F	1.5(3h/2d)	100	Poor maintenance caused by fund shortage (FMG 500)
Ankaraobato	2,120	M/S	12F	0	0.8(2.5h/3d	80	Shortage of O/M fund
Benetsy	2,290	M/S	12F	0	2	100	2 taps have been extended by the villagers themselves
Ankiliberengy	1,700	M/S	10F	0	0.3(1.5h/5d	100	Intentional small supply
Befoly	990	M/S	6F	0	2	100	Fairly good
Anjapirahalahy	500	M/S	2F	0	4	100	Fairly good
Besakoa (2)	1,380	M/S	8F	1F	0.7(2h/3d)	100	Insufficient supply
Andamasiny-Vineta	630	M/S	4F	0	0.4(2.5h/week)	100	Insufficient supply
Analamary	1,150	M/S	6F	6F	2	100	Water use by operating valves without repair of faucets
Ankilimalinika	4,410	M/S	24F	8F	0	0	No operation as battery was stolen

M/S : Motorized System, H/P : Hand Pump Wells

8. PILOT PROJECT

8.1 Objectives and Contents of the Pilot Project

The Pilot Project was carried out with the following objectives:

1) Promotion of the participation of women

As is generally the case with water supply projects including the construction of wells, water associations are organized by the local inhabitants. However, the selected association members consist solely of men in many cases, though most of the water is used by women. Even if women are included, their role is usually limited to sanitation and cleaning around the well. There are many pumps which remain broken without any maintenance work. It is considered that women should be deeply involved with the maintenance work, since collecting water is their work and they benefit most from safe water, thus the participation of women in the water associations is crucial. Therefore, this point was emphatically promoted during the Pilot Project.

2) Education of the inhabitants on sanitation issues

What is important is not only to supply potable water, but to improve the inhabitants knowledge of sanitation. A sound knowledge of the importance of safe potable water will make them move positive about operation and maintenance of the water supply facilities.

3) Technical transfer for the operation and maintenance of the water supply facilities

Ideally, troubles with the facilities should be repaired by the villagers while receiving technical assistance from MEM. In order to repair simple troubles by themselves, the villagers should understand the workings of their water supply facility in order to be able to deal with it.

Six villages were previously selected for the Pilot Project from the 13 villages where test drilling was carried out. The 6 villages were divided into two groups: Group A (Tsianaloka, Beroboka Sud and Andranomena) and Group B (Bezezika, Analaiva and Ambararata). However, pilot facilities were constructed in four villages only. In Andranomena, the test drilling hit a confined aquifer, resulting in a self-flowing well. Though a concrete base was constructed, a pump was not installed. In Ambararata, the construction work was postponed until the next dry season, because the water level rose in Kabatomena River and made crossing impossible.

In the two villages of Group A, Tsianaloka and Beroboka Sud, the villagers prepared materials such as gravel, sand and water for the concrete base, then installed the pump to the well under the instructions of the Study Team. In the two villages of Group B, Bezezika and Analaiva, the facilities were installed by the Study Team without full participation of the villagers but only with the mechanics from the Water Association.

Enlightenment of inhabitants to organize a water association for the management of water supply was conducted with sanitary education in six villages by means of two posters and a cartoon donated by UNICEF: a poster on cleanliness and operation of the pump, a poster showing the future of the village with a pump, and a cartoon on the organization of the villagers and sanitary education.

8.2 Activities for the Pilot Project

Activities undertaken by the Study Team in the villages during the Pilot Project are as follows:

1) Discussion with the village chief (called "president")

a. Fixing a date for the meeting with women, men and the villagers' conference.
b. Promotion of water association activities.
c. Fixing a date for the meeting with the water association.
d. Water quality test for bacterial contamination of existing water sources. (litmus paper, KYOWA TPA-CG and TPA- BG).
e. Delivery of questionnaires on sanitary conditions and gender related issues. (Form is presented in the Supporting Report)

2) Meeting with the village primary school teachers

a. Request to hold a sanitary seminar for children and fixing of date.
b. Distribution of a questionnaire format for sanitation, a copy of cartoon and a picture book "Water and health in the village" both donated by UNICEF. (The cartoon was translated into Malagasy, and attached in the Supporting Report)
c. Request to monitor the health conditions of children over a two months period. (one month before and one month after the completion of the facility)

3) Meeting with women

a. Presentation by a representative of local authority and introduction of the Study Team.
b. Explanation of the actual conditions of the hand pumps and motor pumps in the Phase I Project implemented in the area south of the Mangoky River.
c. Explanation of the Project (Phase II).
   - Period of the study in the Project.
   - Explanation of the results of water analysis.

- Discussions on sanitation issues.

d. Discussion with the villagers:

- Organization of a water association
- Collection of monthly charges towards a "Fund", for the management of the facility.
- Discussion on the practical use of the Fund for other purposes.
- Discussion on the use of the drained water .
- Participation in the construction of the facility.

(in Tsianaloka, Beroboka Sud and Andranomena villages)

e. Discussion with the villagers about the following points:

This Project is a case study on how the villagers operate and maintain their own facility and how they can improve their health conditions with potable water.

The most important issues are:

- Firstly, to convince them of the importance of potable water
- Secondly, to raise funds for the maintenance of the facility.

f. Explanation to the villagers that the implementation of future water supply projects may depend on the results of this Pilot Project.

g. Presentation of posters donated by UNICEF.

- A poster on cleanliness and maintenance of a pump
  "A well in the village. Water = Health - Cleanliness - Happiness - Life"
- A poster on the future of the village with a pump.
  "A well in the village - An Asset for everyone"

4) Meeting with men

a. - g. The same as above

h. Distribution of draft regulations for the Water Association, in Malagasy, to the president of the village.

i. Explanation of the construction work of the pump base.

5) Sanitary seminar for school children

a. Questionnaire on sanitation.

b. Cartoons on the training of villagers and sanitary education donated by UNICEF.

6) Meeting with the village president after the villagers' conference

a. Announcement of the results of the villagers' conference and the list of selected board members of the Water Association

b. Modification of the draft regulations of the Water Association for the village.

c. Fixing a date for discussion with the Water Association

7) Discussion with the Water Association

a. Confirmation of the articles of the Water Association, and signing by the executive members.
b. Explanation of the roles of each Water Association member.
c. Open a hearing concerning remuneration of the Water Association members.
d. Open a hearing of the decision of the villagers' conference about the use of draining water and use of a portion of the Fund for other purposes
e. Explanation of the requirement for the participation in the installation of the pump (in Tsianaloka, Beroboka Sud and Andranomena villages)
f. Explanation on bookkeeping for the Fund for facility maintenance accompanied by a sample of future estimation of accounting.
g. Inform the Water Association about monitoring works, assessing the functioning of the Water Association, to be carried out by a consultant at least a month after the completion of the facilities.

The meeting with women was held first to show that the role of women in this Project is very important. In the meetings with women and men, the Study Team encouraged the villagers to select women at least as accountant and sanitary coordinator. The Study Team also informed the villagers that, with the regular collection of charges for the Fund, there would be sufficient reserves not only to repair the pump but to contribute towards the welfare of the village. Therefore, it was proposed to use a portion of the Fund for other things for the village; for example, a loan system and a pharmacy system.

The posters donated by UNICEF were very effective in explaining the concept of sanitation and to illustrate an ideal life with a hand pump well. Villagers showed great interest in them and the presidents of the villages requested copies. Demonstration of microbe analysis of water using litmus papers was also effective in exemplifying the contamination of water from rivers, marshes and dug wells. Villagers were interested in the results of analysis, especially in the results of dug wells.

Microbes including coliforms were detected in all water sources of the six villages. Particularly, more microbes were found in most of the dug wells than in rivers and streams. The surroundings of dug wells must be kept clean in order to impede the intrusion of microbes.

The results of the questionnaire on sanitation are in the Supporting Report. It is difficult to judge from these figures, but the villagers of Ambararata seem to be less educated on sanitation than other villages, considering the following answers:

Q-2. Do you know what is a microbe?

Five people out of 10 answered by "No", while the response in other villages were mostly "Yes".

Q-6. Do you boil water from rivers and springs before drinking it?

Four people answered "Sometimes", and 6 people out of 10 answered "Never".

The details of the meeting with the villagers are in the Supporting Report. Most of the villagers agreed to pay FMG 500 a month per family or person over 18 years old. Some villagers proposed to pay more than FMG 500, saying that it was for the benefit of the village to use the Fund for other purposes. The most common opinion among the villagers for the use of a portion of the Fund was to establish a health center. Most of the villagers also wished to build a basin for vegetable gardens or cattle.

The sanitary seminars in primary schools were effective. Children reacted well to the seminar, listening in good manners, expressing their opinions actively and understanding well. It was also very easy to get many participants compared with the seminars for adults.

The ratio of the attendants in the meetings mentioned above, the meeting with women and that with men in the Pilot Project are shown in Table 8.2.1. Andranomena provided the biggest percentage of the attendants. The reason of this high participation was the good leadership of the village president and it seemed that the village was well-organized because of the small population. In Bezezika, the ratio of women attendants was high because of good communication between the six Water Associations of the dug wells.

Table 8.2.1 Ratio of Attendants in the Meetings in the Pilot Project

	Tsiana-loka	Beroboka Sud	Andra-nomena	Bezezika	Analaiva	Ambara-rata
Population of village	1,000	783	210	855	1,520	500
Female attendants	20	8	25	50	19	42
Male attendants	10	12	35	16	27	15
Total attendants	30	20	60	66	46	57
Percentage of population	3.0%	2.6%	28.6%	7.7%	3.0%	11.4%

The results of the villagers' conference concerning the board members of Water Association and the uses of drained water and a portion of the Fund for other purposes are in the Supporting Report. In the villages of Tsianaloka, Ambararata and Bezezika, all the board members are women except the mechanics. In Tsianaloka, the president of the Water Association is the wife of the village president. The sanitary coordinator at Andranomena is a primary school teacher. In Bezezika, the president and the accountant are primary school teachers. In Analaiva, the secretary and one of the mechanics are secondary school teachers. All accountants and sanitary coordinators in six villages are women except in Analaiva where one of the sanitary coordinators is a man, and all accountants are good at reading, writing and arithmetic.

Table 8.2.2 Board Members of the Water Associations

	Tsiana-loka	Beroboka Sud	Andra-nomena	Bezezika	Analaiva	Ambara-rata
Gender of the President	woman	man	man	woman	man	woman
Number of women	4	2	2	8	3	4
Number of men	2	4	4	2	4	1
Total number	6	6	6	10	7	5

Each Water Association has made a members list of the Association. The number of members is shown in Table 8.2.3. Not all households in each village are members, but the Fund raised by the members would be sufficient for the maintenance of the facility if the collection rate is at a reasonable level.

Table 8.2.3 Joining Ratio and Fund in the Water Associations as of November 1995

	Tsiana-loka	Beroboka Sud	Andra-nomena	Bezezika	Analaiva	Ambara-rata
Population of village	1,000	783	210	855	1,520	500
Households	109	120	85	143*	411	108
Population over 18 years old	327*	--	--	--	--	--
Members (persons over 18 years old or households)	109 persons	56 houses	34 houses	24 houses	172 houses	30 houses
Ratio of participation	33.3%	46.7%	40.0%	16.8%	41.8%	27.8%
Fund (FMG/month/member)	500	500	1,000	500	500	500
Total amount of the Fund as of November 1995 (FMG)	27,000	6,000	51,000	0	0	0

* *estimated*

The pilot facility in each village was not constructed immediately after the completion of the well due to the delay of the delivery of hand pumps. In some villages, however, the villagers started the Fund raising just after organizing the Water Association before the construction of the pilot facility. In Andranomena, the constructed well was a self-flowing well and people could use the new water source without a pump. They constructed a wooden fence surrounding the source voluntarily and dug a canal to lead water to the planned vegetable garden for irrigation.

8.3 Monitoring of the Pilot Project

Monitoring work of the Pilot Project, including activities such as the observation of water use, inquiry on how the new facilities are maintained, etc. was scheduled to be conducted during Stage 2 of the survey . However, monitoring had to be postponed until February 1996 due to the delay of the delivery of the hand pump sets. Construction of the facilities in the Pilot Project was one to two months behind the schedule as shown below.

Table 8.3.1 Completion date of the installation of the hand pump

Village	Tsianaloka	Beroboka Sud	Andranomena	Bezezika	Analaiva	Ambararata
Date	29/11/95	24/11/95	25/11/95	30/11/95	30/11/95	-- *

** delayed until the next dry season*

8.3.1 Contents of Monitoring

The monitoring work for the Pilot Project was conducted by a local engineer 2 months after the completion of the facilities, and dealt with the following contents:

1) Interview with the board members of the Water Association
   a. Number of the households taking water from the facility?
   b. How far is the furthest house from the facility?
   c. Did they prepare the list of the members paying the Fund?
   d. Have the villagers agreed to use the pump and continue to pay their contribution fees for the Fund even during the rainy season?
   e. In case the Project is further implemented in this village, is it possible to maintain several similar facilities?

2) Observation and measurement
   a. Is the surrounding area of the facility clean?
   b. Do the villagers use the drained water, and for what purpose?
   c. Measurement of water consumption

3) Interview with pupils of primary schools and collection of the list of sick pupils checked for one month.

4) Evaluation of the Water Associations
   a. Are they properly organized, and do the presidents of the Associations show good

leadership skills?

b. Do the villagers acknowledge the importance of safe drinking water, as advocated by the Water Association?

c. Do they keep accounts?

d. Do they know how to contact MEM or the local authorities in case of troubles with the pump?

5) Comparison of the two groups: two villages where the hand pump was installed with the participation of the villagers (Group A) and two villages where the hand pump was installed by the Study Team (Group B).

8.3.2. Results of Monitoring in Andranomena

Andranomena has an artesian well and the water consumption from the well was measured for information before the installation of the hand pump. The result showed that daily consumption was 21 liters per person. Water consumption for washing and bathing is not included in the results. Estimated water consumption is about 27 - 40 liters per family a week for washing, and about 28 liters per person a day for bathing. Water consumption in the primary school is about 40 liters a day.

The representatives of the Agency for Flood Control and Forests live in the village and come to collect more than 67 liters per person a day. One company comes to collect 245 liters of water every four days for its workers. Moreover, one family who lives in the center of Morondava comes to get 1,200 liters of water twice a week. This means that the well of Andranomena is widely known in Morondava and used by many people even from outside of the village.

The wife of the pastor began to cultivate vegetables in a garden as a demonstration, in a village where the villagers are not used to growing vegetables. After sowing, she collected 200 liters of water per day. Then, the president of the village also made a fenced vegetable garden near the well. It is expected that other villagers will follow and grow vegetables, and that they will improve their diet. The villagers are thinking of cultivating rice paddies around the well.

In the village of Andranomena, it is apparent that the villagers have become more active. If they make good use of the flowing well for public benefit, the village will develop gradually.

In February, the villagers cultivated rice on land near the well. The total amount of the Fund has decreased from FMG 51,000 in November 1995 to FMG 25,000.