CHAPTER 2 BACKGROUND OF THE STUDY

2.1 General Socio-economic Condition

Recently, the population of Madagascar has rapidly increased, and after a quarter century it is reported to become two to three times of the current population of 18.84 million in 2005. With such a background, the main targets in the framework of economic policy are in increases in the productivity of the agricultural sector, poverty alleviation and living circumstance improvements in rural areas, as well as decentralization and rationalization of local administration.

The economic growth rate in 2004 reduced from 9.0% in 2003 to 5.3% due to damage by cyclones which occurred twice at the beginning of the year, in addition to the adverse effects of the international market price increases of crude oil and rice, as well as disturbances in monetary stability. In 2005, it was stagnant at 4.6% as economic growth was directly affected by a drastic price increase in the international crude oil market, although booms in construction, public works, export factories in tax-free industrial zones and tourism sectors were continuously sustained from the previous year, coupled with good harvest of rice. The economic development status of Madagascar is classified as Least Development Country (LDC) based on the World Bank's standard and Heavily Indebted Poor Country (HIPC) according to the criteria of the Development Assistance Committee (DAC) under the Organization for Economic Co-operation and Development (OECD). Major economic indicators in 2005 are as shown in Table 2.1.1.

Table 2.1.1 Major Economic Indicators in 2005

Indicator	Value	Indicator	Value
Country area ('000 km^2)	587.0	Consumer price fluctuation rate (% based on 2004)	11.4
Population (million)	18.4	Export value (million USD)	1,127.7
Population growth rate (%/year)	2.7	Export volume (% based on 2004)	46.1
GNI* (nominal price, million USD)	5,685.6	Import value (million USD)	1.936.1
Per capita GNI (USD)	309	Import volume (% based on 2004)	2.9
GDP** (nominal price, million USD)	4,469.7	Trade balance (million USD)	-808.4
GDP real growth rate (% based on 2004)	4.6	Current balance (million USD)	-11.7
Revenue and grant aid (% of GDP)	18.8	Foreign currency reserves (% of monthly import value)	2.9
Expenditure and loan (% of GDP)	24.0	Foreign debt balance (% of GDP)	112.8
Financial balance (% of GDP)	4.3	Total receipt value (net expenditure million USD)	1,236.0

Note: *; Gross National Income **; Gross Domestic Product

Source: JICA Study Team

2.2 Development Policy

2.2.1 Poverty Reduction Strategic Paper

A Poverty Reduction Strategic Paper (PRSP) was prepared in May 2003, which illustrated development strategy and goals of the country for the target year of 2015. The basic target

was set to be the achievement of an annual growth rate of 8% and an investment share of 20% in GDP (12.7% in 2002), and to reduce the poverty rate by half in the next 10 years. Also, the PRSP emphasized capacity building, community participation, and public sector and private sector partnership.

General strategy in the PRSP is summarized as follows:

a. To give priority to regional and local integration, that is, to reinforce the regional and local economy, and strengthen economic relations among the regions;

b. To allow the main sector (e.g. export industry) to operate with maximum efficiency in order to redistribute resources in the region;

c. To emphasize the importance of economic and human environment in project impacts;

d. To consider the regional characteristics and the participation of all related sectors to the projects, which requires the creation of public investment strategy;

e. To find solutions to fight against environment damage by conducting an impact study prior to implementation of any project;

f. To develop the technical capability of communes in order for them to participate in their own development, provide training, and provide equipment;

g. To implement new mechanisms to allow concerned people to participate in the choice of investment to be realized in their area and to be responsible for implementation and operation and maintenance;

h. To encourage private sector operations in the region; and

i. To establish a partnership between the public sector and private sector.

Sector development policy was based on the development strategy of the PRSP. Rural development is the responsibility of MAEP, promoting agricultural-based rural development programs; while watershed management is the responsibility of MINENVEF, promoting forestry-based watershed management.

(1) Agriculture-based rural development

In conformity with the PRSP, an action plan for the rural development (PADR), built upon a participative and evolving approach, was prepared. The PADR is composed of rural development programs and projects. It gives five directions that allow for goals of the rural development policy to be reached, including:

a. Ensuring food security;

b. Contributing to economic growth;

c. Reducing poverty and improving the conditions of life in rural areas;

d. Promoting sustainable use of natural resources; and

e. Promoting education and the spread of information to enhance production in rural areas.

Based on the above directions for rural development, the MAEP was aimed at reducing poverty in rural area, ensuring food security, and optimizing resource use. Its main objectives included:

a. Raising agricultural productivity and increasing the area farmed;

b. Promoting small investments in rural areas and partnership between producers' associations and private sector;

c. Promoting agricultural and food product exports and enhancing their quality;

d. Ensuring a clear and rational use of resources;

e. Facilitating producers and investors access to land; and

f. Promoting the development of producers' organizations via Agricultural Chamber.

The objectives of the MAEP coincided with the strategy for rural development in the PRSP.

(2) Forestry based watershed management

The overall goal of the forestry sector was to promote efficient utilization forestry resources including economical and tourism potential and to create an environment contributing to sustainable economic development. A basic policy of MINENVEF was as follows:

a. Preventing forest deterioration;

b. Improving forest management;

c. Increasing forest area and potential of forest resources; and

d. Improving forestry economy.

Based on the Ministry's policy, strategy of forestry sector was set as follows:

a. Sustainable forestry resource management by considering conservation needs, production demand, and short term/long term needs;

b. Establishment of new relationship among stakeholders (local government, private sector, and other organizations) to solve forestry problems;

c. Administrative reform;

d. Forestry activities at a regional level and decentralized management;

e. Forestry resources managed by the local authority and by community participation;

f. Consistency of forestry policy and other related sector policy; and

g. Creation of a mechanism for financial sustainability.

Based on the PRSP proclaimed in July 2003, various programs were performed in the first year operation of PRSP. The actual results were indicated by the decreasing poverty ratio from 80.1% in 2003 to 73.5% in 2005. Taking into account the performance of each program and Madagascar Naturellement that was set up by the President in November 2004 as a national vision showing the super goal of development concept, PRSP was modified in June 2005 with the revised targets to reduce the number of poor people by half and to realize annual economic growth of between 8% and 10% by 2015 through promotion of agricultural development and privatization. To attain these targets, the following strategies in line with the partnership between government agencies and private sectors:

a. Promotion of economic growth: To achieve an economic growth rate at 8% to 10% level and reduce the poor by accelerating economic growth through increase in domestic investment rate focusing on rural development and infrastructure improvement for road and transport as well as activation of private sector;

b. Promotion of monocracy and sound governance: To attach importance to establishment of sound governance, eradication of corruption, acceleration of democratization paying attention to democracy and assurance of administrative transparency, and to put priority over promotion of decentralization in practicing poverty reduction programs; and

c. Promotion of security network establishment for safe living circumstances: To upgrade basic social services such as education and medical care, and to provide the socially weak with nutrition improvements and rural micro credit services.

It is required to jack up implementation of individual programs under the respective strategies of revised PRSP, because the progress in the initial stage from late 2005 to beginning 2006 was behind the originally planned schedule to some extent.

2.2.2 Madagascar Action Plan

Citing the overall performance of programs of the PRSP in the initial stage from late 2005 to the beginning of 2006 and the extent of the achievements for the respective targets set up for the above three strategies, the GOM re-examined programs scheduled to be implemented from 2007 onward and transferred some of them in an expanded form to the newly drawn up Madagascar Action Plan (MAP).

The vision of the MAP is that people equally make efforts toward prosperity of the nation and enjoy the fruits of their efforts. Challenging targets to realize the vision and approaches for the achievement of these targets are condensed in the following eight commitments;

a. Reasonable governance: Seven challenging targets are set up to provide sufficient security to protect people and property, to strengthen the rule of law, to reduce corruption, to establish an efficient and effective government budgetary process, to strengthen the provision of public services, to decentralize government administration, and to become a learning nation. A total of 44 priority projects and activities are to be performed for the achievement of these challenging targets;

b. Connected infrastructure: Seven challenging targets are set up to prioritize infrastructure development for key growth areas, to efficiently move goods and people from one place to another, to improve access to transport services nationwide, to ensure accessible and adequate energy supplies at an affordable and competitive cost, to ensure an efficient and affordable communication system, to better weather forecasting- and warnings of potential disasters such as cyclones, and to substantially improve access to drinking water and sanitation. A total of 40 priority projects and activities are to be performed for the achievement of these challenging targets;

c. Educational transformation: Seven challenging targets are set up to ensure access of all children to developmental opportunities before official school entry, to create a successful primary education system, to create a successful lower secondary education system, to improve upper secondary school and develop vocational training, to transform higher education, to end illiteracy, and to develop capacities and mindsets of young people through sports and civic participation. A total of 54 priority projects and activities are to be performed for the achievement of these challenging targets;

d. Rural development and a green revolution: Six challenging targets are set up to secure land tenure, to improve access to affordable rural finance, to launch a sustainable green revolution, to promote market oriented activities, to diversify rural activities, and to increase the agricultural value added and promote agribusiness. A total of 42 priority projects and activities are to be performed for the achievement of these challenging targets;

e. Health, family planning and the fight against HIV/AIDS; Eight challenging targets are set up to provide quality health services to all, to eradicate major diseases, to win the fight against HIV and AIDS, to implement a highly successful family planning strategy, to reduce infant mortality, to reduce maternal and neonatal mortality, to improve nutrition and food security, and to provide safe water and widespread use of hygienic practices. A total of 45 priority projects and activities are to be performed for the achievement of these challenging targets;

f. High growth economy: Ten challenging targets are set up to ensure a stable macro economic environment, to increase foreign direct investment, to promote full

employment, to reform the banking and financial system, to strengthen domestic enterprises, SMES and handicraft industry, to enhance international trade competitiveness, to intensively develop the mining sector, to intensively promote and develop the tourism sector, to intensively exploit regional opportunities, and through diplomacy, to develop economic synergies. A total of 73 priority projects and activities are to be performed for the achievement of these challenging targets;

g. Cherish the environment: Four challenging targets are set up to increase the protected areas for the conservation of land, lake, marine and coastal biodiversity, to reduce the natural resources degradation process, to develop the environmental reflex at all levels, and to strengthen the effectiveness of forest management, and to strengthen the effectiveness of forest management. A total of 55 priority projects and activities are to be performed for the achievement of these challenging targets; and

h. National solidarity: To celebrate cultural diversity, understanding and respect, to build social trust and promote civic participation, to promote solidarity and pride, to improve support for the very poor and vulnerable populations, and to promote gender equality and empowerment of women. A total of 23 priority projects and activities are to be performed for the achievement of these challenging targets.

Aiming at the achievement of these eight commitments and 54 challenging targets as mentioned above, 416 priority projects and activities in total under the MAP are planned to be performed in the coming five years up to 2012. In this connection, numerical indexes to indicate the achievement extent of each challenging target are fixed in comparison with the numerical value indicating the current condition as of 2005. Major numerical indexes are as shown in Table 2.2.1.

Table 2.2.1 Major Numerical Indexes of MAP

Main indicators		Numerical target		Main indicators	Numerical target	
		2007	2012		2007	2012
UN Human Development Index (ranking)		146	100	Economic growth	4.6%	8~10%
Poverty rate				GDP (billion USD)	50	120
(% of population living below 2 USD/day)		85%	50%	GDP per capita (USD)	309	476
Family size (fertility rate)		5.4	3~4	Foreign direct investment		
Life expectancy		55.6	58~61	(million USD)	84	500
Literacy		63.5	80%	WB Business Climate Ranking	131	80
Percentage of children	Lower	19%	56%	Corruption Perception Index	2.8	5.2
completing secondary school	Upper	7%	40%	Households having land title	10%	75%

Source: JICA Study Team

At present, detailed sector plans of the MAP are under preparation, and among others irrigation and watershed policy to fulfill the “Rural Development and Green Revolution” commitment and a decentralization policy to fulfill the “Reasonable Governance”

commitment go ahead towards implementation of priority projects. To execute MAP, the GOM has reorganized central ministries including MAEP and MINENVEF as shown in Appendices 2-1 and 2-2, respectively.

In 2005 annual per capita consumption of paddy as the staple food in Madagascar was 146 kg, and 94% of domestic demand was met with 3.4 million tons of paddy produced in the total are of paddy fields of 1.25 million ha throughout the country. However, the increasing rate of rice paddy production for the last 10 years was only 34% being equivalent to about half the population increase rate. With such a background, the target for the agricultural sector in the MAP is to increase rice paddy production from 3.42 million tons in 2005 to 7.00 million tons in 2012 by practicing commitments of the green revolution in order to achieve a self-sufficiency level of rice paddy production and to export the surplus of rice. In this regard, a challenging guideline for attaining this policy target has been set up, which is to raise land productivity by 50% in rice paddy fields and 100% in upland field, to expand upland rice cultivation areas in hilly areas and to promote new land reclamation as shown in Table 2.2.2.

Measures to accomplish the commitment to cherish the environment are: 1) to develop and implement sustainable use plans for land, lake, marine and coastal areas; 2) to promote the development and use of alternative energy resources such as bio-fuels; 3) to manage the clearing of vegetation and the damage caused by fires; 4) to promote reforestation and restore degraded habitats; and 5) to promote private sector financing to assist in environmental management, coupled with the strengthening of forest management administrative capacity that is needed to implement the measures.

Table 2.2.2 Rice Production Doubling Plan under MAP

Farm land	Farm land area (ha)	Current condition in 2005			Target in 2012			
		Cropped area (ha)	Yield (ton/ha)	Production (ton)	Counter-measure	Cropped area (ha)	Yield (ton/ha)	Production (ton)
Irrigated paddy field	1,100,000	1,118,400		2,870,000		1,185,000		4,212,000
GPI*	86,000	230,000	3.5	805,000	Rehabilitation	150,000	5.0	750,000
PPI**	144,000	(18,400)	3.5	(64,400)	Consolidation	(75,000)	5.0	(375,000)
					-	80,000	3.8	304,000
MPI***	500,000	870,000	2.3	2,001,000	Rehab./Conso.	150,000	4.5	675,000
PF****	370,000				-	720,000	2.9	2,088,000
					Drainage	(10,000)	2.0	(20,000)
Rain-fed field	265,000	265,000		546,000		415,000		1,046,000
Shifting cultivation	160,000	160,000	2.1	336,000		160,000	2.1	336,000
					Intensification	50,000	3.0	150,000
Upland field	105,000	105,000	2.0	210,000	-	55,000	2.0	110,000
					Expansion	150,000	3.0	450,000
New reclaimed area	0	0		0	RRI*****	500,000	3.5	1,750,000
Grand Total	1,365,000			3,416,400		2,100,000		7,008,000

Note : * : Large scale irrigation project ** : Middle scale irrigation project *** : Small scale irrigation project
**** : Simple irrigation project ***** : Rapid Result Initiative
Source : Program National Bassins Versants - Périmètres Irrigués, MAEP

2.2.3 Irrigation and Watershed Management Policy

In accordance with the revised PRSP and MAP, the GOM promulgated the BVPI in June 2006 as its new national policy on functional strengthening of production bases for rice that is the national staple food. The main objective of the BVPI is to implement two projects in an integrated manner, one of which aims at irrigation development to cover about 1.0 million ha of paddy field throughout the country and the other targets sustainable water resource fostering by recovering vegetation and promoting reforestation in watersheds of irrigation areas. To contribute long-term and integrated promotion of the BVPI, MAEP is appointed as the main responsible agency among many government agencies concerned. In line with the decision of the GOM cabinet meeting, a new unit named the National Project Coordination Office is established under the Directorate General of Rural Development of MAEP, which is responsible for promoting the BVPI by gathering technical cooperation from related agencies like MINENVEF as the need arises.

The basic strategy of BVPI is to strengthen functions of the existing irrigation schemes that have a large potential for increasing agricultural productivity by investing 940 million USD up to 2022 as shown in Appendix 2-3 for providing necessary facilities with these schemes to command 960,000 ha and recovering the vegetation of watersheds of all the schemes. In formulating this national policy, the GOM has obtained full support from the World Bank and set up short term targets within the framework of MAP to implement the BVPI projects to facilitate 280,000 ha. In response to the request of the GOM, the following financial assistance to individual projects has been committed by the respective donor agencies and country:

a. International Development Association (IDA): BVPI Project Phase I with command area of 21,780 ha and financial assistance of 36 million USD;

b. Agency for French Development (AFD): South-east Highland BVPI Project with command area of 9,350 ha and financial assistance of 18.8 million USD;

c. African Development Bank (AfDB): Manobo Integrated Agricultural Development Project with command area of 5,000 ha and financial assistance of 10 million USD;

d. International Fund for Agriculture (IFAD): Menabe-Melaky Development Assistant Project with command of 3,800 ha and financial assistance of 13.5 million USD; and

e. IDA: BVPI Project Phase II and Phase III with command area of 44,050 ha and financial assistance of 55 million USD.

In addition, the GOM has also requested the GOJ to support functional strengthening of PC23 irrigation scheme in the south-west area of Lake Alaotra.

The following are salient features of BVPI Project Phase I:

a. Sub-project areas: Andapa area in northeast of Madagascar covering 3,650 ha, Marovoay area in northwest of Madagascar covering 6,070 ha, Itasy area in central highland covering 5,650 ha and Sahamaloto area in northwest of Lake Alaotra covering 6,400 ha;

b. Project implementation period: four years from 2007 to 2011;

c. Total project cost: 4.04 million USD comprising an IDA loan of 36 million USD and GOM own budget of 4.4 million USD; and

d. Project components and budget allocation: 17.47 million USD for functional strengthening of irrigation and drainage facilities, 1.68 million USD for farming system modernization, 4.33 million USD for recovery and augmentation of water resource fostering capacity, 4.31 million USD for project management and 1.61 million USD.

For the BVPI Project Phase II and Phase III, the Anony area northwest of Lake Alaotra covering 7,700 ha is selected by the World Bank. Accordingly, agricultural productivity of the existing four large irrigation schemes in the surrounding area of Lake Alaotra will be improved by such donor assistance as AFD for PC15 irrigation scheme of 2,800 ha, Japan for PC23 scheme of 10,070 ha, and IDA for Sahamaloto and Anony of 14,100 ha in total.

2.2.4 Decentralization of Development Administration

The GOM established 22 Regions under six Provinces in 2004 in order to promote its decentralization policy in a concrete manner. These regions function as a promoter and supervisor of regional development administration in conformity with geographical conditions and socio-economic features of each region. After the function of each Region is set on its way, the previous six Provinces were abolished to ensure simplification and prompt local administration. As a result, the authority of general administration is transferred along the lines of nation → region → district → commune → village. In the case of development administration, each Region directly contacts Communes within its jurisdiction in the planning stage of regional development programs and coordinates Districts and Communes in monitoring stage of programs under implementation.

To cope with the decentralization policy at central level, the Ministry of Interior has the authority of general administration of the nation, while other central ministries concerned that are responsible for development administration share only upstream and downstream tasks such as program formulation, program planning and budgetary aspects as well as monitoring, evaluation and problem solution of programs under implementation. The remaining tasks related to program implementation are transferred to their regional offices to which their various branches are united and/or reorganized.

Within the framework of regional development administration, every Commune is assigned

to a function of contacting inhabitants and preparing its five year communal development plan (PCD) through compilation of development issues and countermeasures corresponding to inhabitants' needs. While, the respective Region Offices are responsible for making their five year regional development plans (PRD) by reviewing and condensing all PCD as well as development programs implemented by regional offices of the central administration. To perform such a responsibility, they have already established a monitoring and evaluation system concerning the progress of every program listed up in PRD. This system is operated in order to enable Regions to learn lessons from annual evaluation results in preparing an annual implementation plan of development programs for the following year. Accumulated monitoring results of programs under the on-going PRD will be fed back in preparation of the next PRD. As the Regional Office is responsible for reviewing programs to be implemented by regional offices of the central ministries in preparing its PRD, and also for monitoring progress, pointing out problems and evaluating performance of programs under implementation, the Region Office is actually above regional offices of the central administrations in rank.

2.3 Alaotra-Mangoro Regional Development Plan

The Alaotra-Mangoro Region where the Study Area is located consists of the five Districts of Andilamena, Amparafaravre, Ambatondorazaka, Moramanga and Anosibe An'Ala, 79 Communes and 606 Villages, and its office is established in Ambatondorazaka. This Region has a total population of 1.11 million, entire coverage of 33,054 km² and population density of 34 persons per 1 km². In the Region, cultivated land is around 120,000 ha of which about 100,000 ha are concentrated in the area around Lake Alaotra. A total of 350,000 ha are demarcated for various reserves, comprising two national parks of 51,000 ha, one general nature reserve of 24,000 ha, two specific reserves of 2,000 ha, three forest reserves of 114,000 ha, one forest designated area of 130,000 ha and two wetlands of 29,000 ha registered based on the Ramsar Convention.

The cultivated land of around 100,000 ha in alluvial plains around Lake Alaotra is used as a rice paddy field which is one of the important rice granaries in the country and meets about 10% of rice demand for Madagascar people. However, the indiscriminate deforestation done in watersheds of rivers flowing down to the alluvial plains during the 1950s resulted in the fact that forest resources were almost exhausted, and since then, these exhausted areas have been left without implementation of any countermeasures to recover vegetation. As a result, coupled with the existence of Lavaka originated from the geological conditions specifically prevailing in this area, a lot of earth and sand have been washed away from slopes of mountains and hills in upstream areas and flown into rivers during every rainy season. Such situation has continuously caused frequent occurrence of flooding by sedimentation on river bed, inflow of earth and sand into paddy field, functional deterioration of irrigation facilities,

and a decrease in fish catches by shrinking the water surface area of Lake Alaotra.

The Alaotra-Mangoro PRD has five strategic targets that are: 1) recovery of good governance in local communities; 2) acceleration of growth of the local economy through social infrastructure development; 3) multilateral expansion of social security for inhabitants and community; 4) rationalization of environmental conservation management; and 5) promotion of government policy implementation. The on-going PRD is a four-year plan up to 2008 and consists of 148 development programs which are formed by rearranging and combining various programs proposed in each PCD made by 79 Communes in the Region in accordance with the above five strategic targets. The Directorate of Development of the Alaotra-Mangoro Region Office has estimated 197.8 billion Madagascar Ariary (MGA) to be the necessary budget for implementing these 148 programs during the period of four years as shown in Table 2.3.1.

Table 2.3.1 Necessary Budget for Alaotra-Mangoro PRD

Strategic Target	Necessary Budget	
	('000 MGA)	('000 USD)
1. Recovery of good governance in local communities	17,411,200	8,493
2. Acceleration of growth of local economy through social infrastructure development	106,888,000	52,140
3. Multilateral expansion of social security for inhabitants and community	33,483,500	16,334
4. Rationalization of environmental conservation management	15,815,600	7,715
5. Promotion of government policy implementation	24,192,000	11,801
Total	197,790,300	96,483

Source: Alaotra-Mangoro PRD

The Alaotra-Mangoro Region Office in Ambatondorazaka has already operated a computerized monitoring and evaluation system of program performance as well as a databank compiling various statistical data gathered from the respective District Offices. The said monitoring and evaluation system is built to check the monthly progress of individual program performance based on 18 approaches to attain the five strategic targets and the respective objectives of the 148 programs that are shown in Appendix 2-5. To build this system and train operators, the United States Agency for International Development (USAID) has been providing the Region Office with technical and financial assistance.

2.4 Trend of Assistance by Donors

2.4.1 Assistance to Madagascar

Foreign assistance is composed of multilateral agency oriented assistance to implement programs under PRSP and bilateral assistance to individual programs based on the concept of each donor country.

As for the former, the International Monetary Fund (IMF) takes charge of monitoring macro

economic policy in the budgetary and financial sector, while the World Bank is in charge of assistance to the structural reform. In addition, IDA, United Nations Development Program (UNDP), Food and Agriculture Organization (FAO), African Development Fund (AFD) under the group of AfDB, European Union (EU), USAID, France and Germany share assistance in the establishment of good governance and promotion of decentralization in coordination with each other. With regard to the latter, the respective donor countries in addition to multilateral agencies perform various programs according to their own assistant policy to Madagascar. The results of assistance done by multilateral agencies to Madagascar for the last five years are summarized in Table 2.4.1.

Table 2.4.1 Results of Assistance by Multilateral Agencies to Madagascar

Unit：million USD

Rank	2000		2001		2002		2003		2004 & 2005	
First	IDA	76.8	IDA	92.7	IDA	158.6	IDA	187.6	IDA	289.0
Second	IMF	45.0	CEC	54.7	CEC	48.1	CEC	87.0	CEC	135.0
Third	CEC	19.4	IMF	17.5	IMF	5.5	IMF	8.2	AfDB	35.0
Fourth	AfDB	19.4	AfDB	17.5	UNDP	5.5	AfDB	8.2	IMF	34.0
Fifth	UNDP	5.9	UNDP	5.9	AfDB	5.0	UNDP	4.8		
Others		17.9		23.7		19.4		18.6		
Total		184.6		229.2		247.8		314.5		493.0

Source: ECD/DAC, DAC statistcs

Both the governments of Madagascar and Japan concluded a technical cooperation agreement in October 2003 and completed the arrangements for undertaking comprehensive technical cooperation. Since then, the assistance by Japan has extended to the following priority sectors along with the two strategic directions such as promotion of economic growth and promotion of a secure network establishment for safe living circumstance:

Assistance to poverty reduction through the promotion of economic growth

a. Agriculture sector development aiming at increase in agricultural productivity, environmental conservation, agribusiness promotion, fisheries encouragement, and promotion of Asia-Africa cooperation;

b. Private sector development focusing on acceleration of trade and investment, mining development; and

c. Infrastructure development targeted at construction of logistic infrastructures.

Investment in security network establishment for safe living circumstances and sustainable development

d. Primary education especially for construction of primary school buildings;

e. Health and medical care paying special attention to improvement of maternal and child health as well as rural medical care, and countermeasures for infectious diseases; and

f. Water supply based on improvement of access to safe water.

The results of bilateral assistance made by donor countries for the same period are as shown in Table 2.4.2.

Table 2.4.2 Results of Bilateral Assistance to Madagascar

Unit : million USD

Rank	2000		2001		2002		2003		2004 & 2005	
First	France	46.5	France	41.7	France	46.3	France	128.1	France	299.0
Second	USA	31.6	USA	37.2	USA	41.7	USA	43.2	Japan	108.0
Third	Japan	26.3	Japan	25.5	Germany	8.6	Germany	16.4	Spain	92.0
Fourth	Germany	14.2	Austria	10.1	Japan	7.6	Japan	9.7	USA	61.0
Fifth	Norway	4.5	Germany	10.0	Swiss	6.0	Norway	6.2	Italy	47.0
Others		30.8		25.5		7.6		9.7		
Total		138.7		146.0		125.9		224.9		607.0

Source: ECD/DAC, DAC statistcs

As the assistance to implementation of PRSP programs has been settled for the time being, the respective multilateral agencies and bilateral donor countries are formulating new assistant strategies, apart from the new commitment to assist BVPI projects as described in Sub-section 2.2.3. The on-going, promised and planned assistance is summarized as follows:

a. World Bank: Environmental Program Phase III (PE III) financing 40 million USD for forestry eco-system management, natural protection area management and environmental information system establishment under implementation up to 2009; and promising finance of 10 million USD to Jiro sy Rano Malagasy (JIRAMA) for strengthening of the existing power generation facilities, reduction of electricity and domestic water distribution losses, upgrading of operation and management capacity of JIRAMA and formulation of future power generation expansion plan;

b. AfDB: Extension of the on-going rural infrastructure development project in southern area up to 2009; additional commitment of 145 million USD finance for new programs including support to trawler groups, improvement of rural water supply and sanitation, integrated rural development, and national road rehabilitation;

c. France: Provision of the largest bilateral assistance through AFD as the former suzerain; and commitment of 18.28 million USD finance in 2005 for three projects including BVPI, and 99.68 million USD finance in 2006 for 14 projects including port rehabilitation, educational support and foreign debt cutback; and

d. USA: Contribution of 110 million USD from the Millennium Challenge Account (MCA) focusing on support to land tenure system improvement, financial system rationalization and agribusiness investment.

2.4.2 Foreign Donor Assistant Activities in the Surrounding Areas of Lake Alaotra

Table 2.4.3 shows activities by sector under implementation by donor agencies and countries as well as private sector of Madagascar in the surrounding area of Lake Alaotra including the Study Area.

Table 2.4.3 Development Assistant Activities in Surrounding Area of Lake Alaotra

Sector	World Bank	UNDP	AFD	USA	Japan	Public sector	Private sector
Rural road						XXX	
Water supply		XX					
Rural electrification		X		X			
Rural credit		XXX			XXX*		
Agricultural production			XXX		XXX**		
Agricultural infrastructure	XXX						
Rice mill							XXX
Inland fisheries							
Watershed management	XX			XX			
Environment conservation	XXX						

Note: XXX; Under implementation or completed XX; Under preparation X; Under formulation
*; Micro credit project based on collateral funds of Japanese grant aid
**; Dispatching of Indonesian experts under Asia-Africa cooperation program of Japan
Source: JICA Study Team

As for Japan, apart from this Study, the improved farming practices extension support project was reopened in 2004 and since then, Indonesian experts have been dispatched every year under the Asian-Africa cooperation program, and furthermore the micro credit project was commenced in 2006 by using collateral funds of Japanese Grant Aid as the capital of credit with its nationwide service area covering the surrounding area of Lake Alaotra. Other than Japan, the World Bank, UNDP, France and USA in addition to Japan have been providing technical and financial assistance to the GOM. Main components of on-going and promised projects are summarized as follows:

a. World Bank: Under the PSDR program that is planned to be terminated in 2009, projects so far financed were diversification of agricultural products based on livestock and vegetables as well as rehabilitation of intake facility for a small scale irrigation scheme in response to requests from a farmers' group and non-governmental organization (NGO). Assistance under the on-going PE III is presently concentrated into activities related to the Ramsar Convention. In BVPI Phase I, a rehabilitation project of Sahamaloto wasn commenced, while Anony project will be rehabilitated in Phase II;

b. UNDP: Microfinance project of Caisses d'Epargne et de Crédit Agricole Mutuelles (CECAM) is supported with an interest subsidy. Rural electrification and water supply projects in the surrounding area of Lake Alaotra are under formation;

c. France: AFD through Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) has undertaken technical and financial assistance to watershed management and rural development in PC15 irrigation area located in southeast of Lake Alaotra. Among important programs, CIRAD is promoting extension of new upland rice variety so-called as SEBOTA ("Poly-aptitude" rice varieties) that is tolerant to dry and/or wet weather condition by distributing seeds to farmers. In addition, such programs are practiced as self-management capacity building for farmers groups and NGO, application test of zero tillage practices with leguminous plants and upland crops to devastated grassland, and introduction of milk cows coupled with cultivation of high nutrient value pastures; and

d. USA: USAID in performing a strengthening program for bio-diversification preservation in the whole Toamasina Province, especially focusing on Mangoro area, with initiatives of private sector. Further, USAID assigns local consultants as monitoring staff in the Directorate of Development of the Alaotra-Mangoro Region Office aimed at full support to decentralization of rural development administration. Other assistance backed up by MCA is going to be in his field of agribusiness promotion and land tenure registration system improvement.

Table

Table 2.1 National Irrigation and watershed management programs (BVPI)

Phase			Execution of pilot project		Commencement (2007-2012)		Strengthening of project (2011-2015)		Expansion of project (2015-2022)		Total	
Purpose			Preparation of formulation of BVPI		Execution of integrated project in new project area		Projct continuation based on lessons learned in provious project		Nationwide development of project by irri.&watershed approarch			
	Name of prefecture		Area ha	Cost million USD	Area ha	Cost million USD	Area ha	Cost million USD	Area ha	Cost million USD	Area ha	Cost million USD
	Diana				7,500	10.0	10,000	5.0	31,500	57.2	49,000	72.2
	Sava				8,650	11.0	12,050	8.3	10,000	5.0	30,700	24.3
	Sofia				27,000	38.0	40,000	20.0	49,600	34.1	116,600	92.1
	Boeny				29,070	63.0	24,450	21.4	22,950	18.2	76,470	102.6
	Betsiboka				6,000	6.0	12,000	6.0	12,000	6.0	30,000	18.0
	Melaky				11,300	17.6	10,000	5.0	10,000	5.0	31,300	27.6
	Analanjirofo		1,500	22.2	10,000	15.0	10,000	5.0	10,000	5.0	31,500	47.2
	Alaotra-Mangoro		3,870	10.0	29,400	37.6	27,700	22.2	24,500	19.0	85,470	88.8
	Atsinanana				6,000	8.0	8,000	4.0	8,000	4.0	22,000	16.0
	Analamanga		200	0.3	21,900	34.8	18,000	9.0	29,400	9.0	69,500	53.1
	Itasy		70		12,660	16.4	15,300	9.1	14,000	7.0	42,030	32.5
	Bongolava				11,000	11.0	22,000	11.0	22,000	11.0	55,000	33.0
	Vakinankaratra				9,250	12.0	16,337	12.0	14,000	7.0	39,587	31.0
	Amoron'l Mania				8,400	11.0	14,337	11.0	12,000	6.0	34,737	28.0
	Haute Matsiatra				17,000	25.0	18,000	9.0	18,000	9.0	53,000	43.0
	Ihorombe				3,500	3.5	7,000	3.5	7,000	3.5	17,500	10.5
	Vatovavy-Fitovinany				11,400	14.0	20,338	14.0	18,000	9.0	49,738	37.0
	Atsimo-Atsinanana				8,800	11.5	15,338	11.5	13,000	6.5	37,138	29.5
	Menabe				18,000	31.0	10,000	5.0	10,000	5.0	38,000	41.0
	Atsimo-Anorefana		5,000	19.0	18,000	41.0	0	0.0	1,000	0.5	24,000	60.5
	Androy				0	0.0	0	0.0	500	0.3	500	0.3
	Anosy		5,400	12.6	6,500	9.0	8,000	4.0	8,000	4.0	27,900	29.6
	Wide-Area		2,700	18.6							2,700	18.6
Total			18,740	82.7	281,330	426.4	318,850	196.0	345,450	231.3	964,370	936.4
External assist.	Donors	Name of project	Area ha	Cost million USD	Area ha	Cost million USD	Area ha	Cost million USD	Area ha	Cost million USD	Area ha	Cost million USD
	FAO	Pilot project	270	0.3							270	0.3
	AFD	BV Lac	3,500	16.0							3,500	16.0
		BVPI HP-SE			9,350	18.8					9,350	18.8
	IDA	BVPI 1, 2and 3 phase			21,700	30.0	19,500	25.0	24,550	30.0	65,750	85.0
	GEF					6.0		6.0		6.0		18.0
	AfDB	Bas-Magoky	5,000	11.0							5,000	11.0
		PDA1M			5,000	10.0					5,000	10.0
	KFW	PLAE		5.0							0	5.0
	FIDA	PPRR-Mandrare	6,900	27.1							6,900	27.1
		PDA2M			3,800	13.5					3,800	13.5
	OPEP	PHDM & PRBM		15.7							0	15.7
	Japan	PC23	370	1.5	9,500	10.0					9,870	11.5
	UE	ACORDS	2,700	5.6							2,700	5.6
		Others		0.5							0	0.5
	Total		18,740	82.7	49,350	88.3	19,500	31.0	24,550	36.0	112,140	238.0

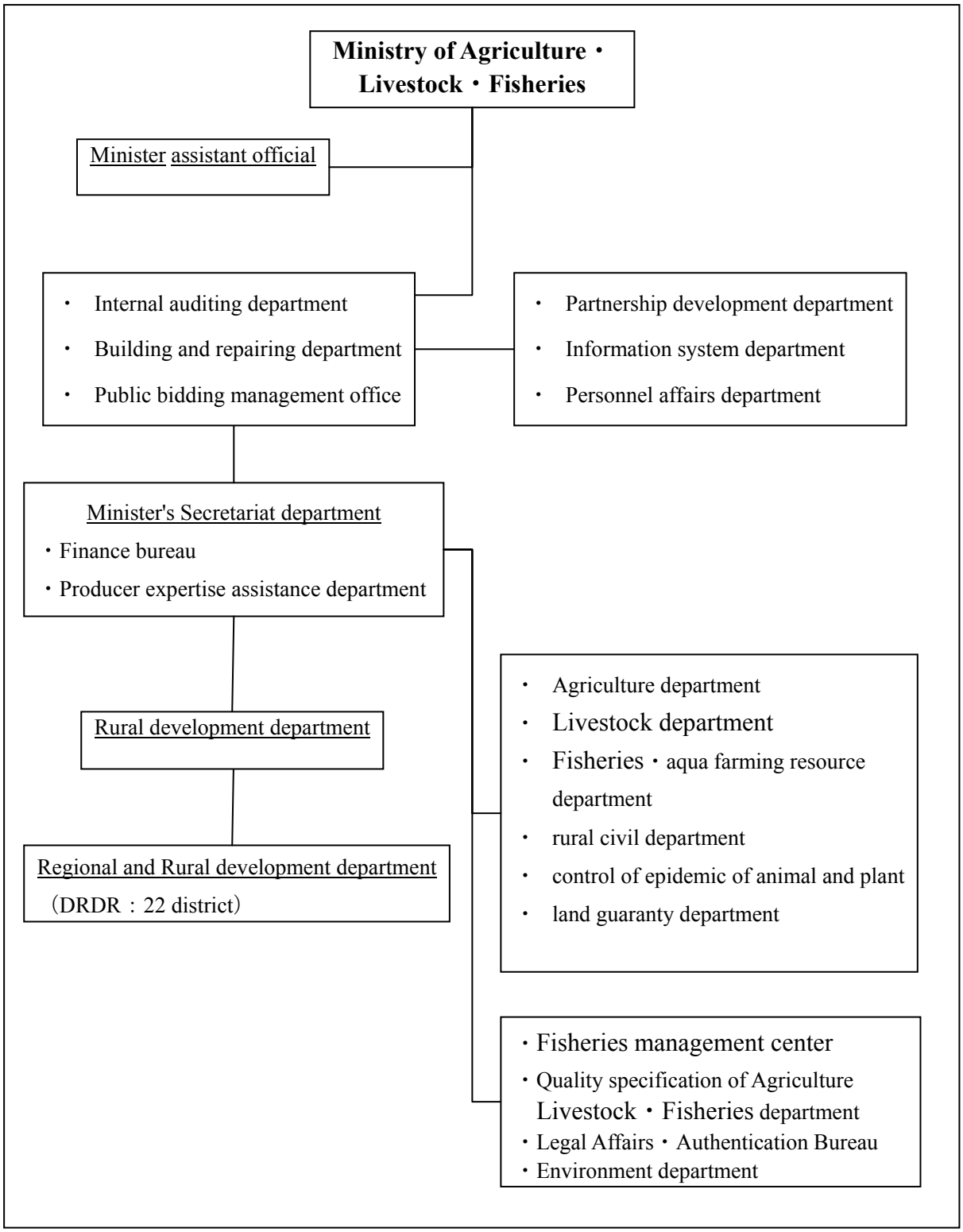
Source : Programme National Bassins Versants - Perimetres Irrigues, 2006, MAEP

Table 2.2 General features of Alaotra-Mangoro regional development plan

strategic target	Approach and individual program for realization of target	relation to this JICA project
Recovery of good and fair governance for local society	1) management of information of the region ・establishment of data bank system regarding development area and commune ・establishment of information broadcast system 2) strengthening capacity for administration organization ・reinforcement of administrative organization ・promotion of reorganization of tax collection ・restoration of reliance between administrative organization and users for administrative service ・improvement of administrative service taking into characteristics of the region 3) increasing performance of implementation of the various plans formulated for improvement ・carrying out monitoring and assessment for projects 4) strengthening safety of life and property ・strengthening functions of police ・strengthening administration of justice and prison affairs ・promotion of law education for local people	Reorganization of the forest administration
Promotion of the regional economic activities along with establishment of social infrastructure	1) performance of cooperative economic activities for development ・formulation of action plan for the regional development 2) development of potentials in the region ・demarcation of development area ・organization of operation relevant to production 3) promotion of economic growth in the regions ・strengthening production capacity and productivity in the region ・increasing purchasing power 4) strengthening capacity of investment in the region ・strengthening capacity of individual producers` investment ・strengthening capacity of investment in the region	Strengthening of building capacity for development administration in commune Reinforcement of water user association and producer's cooperation in the Study area improvement of irrigation systems, increasing land productivity and introduction of income diversification introduction of revolving fund increasing shipment of rice to Antananarivo and urban area by increasing rice production
Enlargement and promotion for human, material, social security	1) improvement of access to basic social service for local people ・improvement of health/medical facilities and replenishment of equipment ・strengthening manpower for health and medical service field ・improvement of health and medical services 2) improvement of access to education services for local people ・improvement of school facilities and teaching materials ・strengthening manpower for education ・improvement of educational services 3) improvement of environment for sports and social culture for local people ・improvement of facilities for sports and culture ・organization of traditional culture and public entertainment	
Streamlining management for environmental conservation	1) conservation of natural resources ・demarcation of environmental conservation area and improvement of management for conservation area 2) streamlining management for natural resources ・guaranteeing for environment and investment 3) increasing added values for tourism resources ・promotion and improvement of tourism resources ・promotion of echo-tourism 4) promotion of natural resources project with added values ・promotion of natural resources project with added values	Demarcation of conservation of swampy land and related area registered by the Ramsar Convention
performance of government policy	1) performance of the government policy ・promotion of control for AIDS ・prevention for natural calamities 2) promotion of reforestation ・demarcation of area for reforestation ・establishment of reforestation areas 3) improvement of life environment and living standard of local people ・promotion of natural resources project with added values ・establishment of facilities for service of electric power and drinking water supply	Overall deployment program for conservation land and water Introduction of reforestation based on RFR Prevention for forest fire improvement of traditional cooking stove

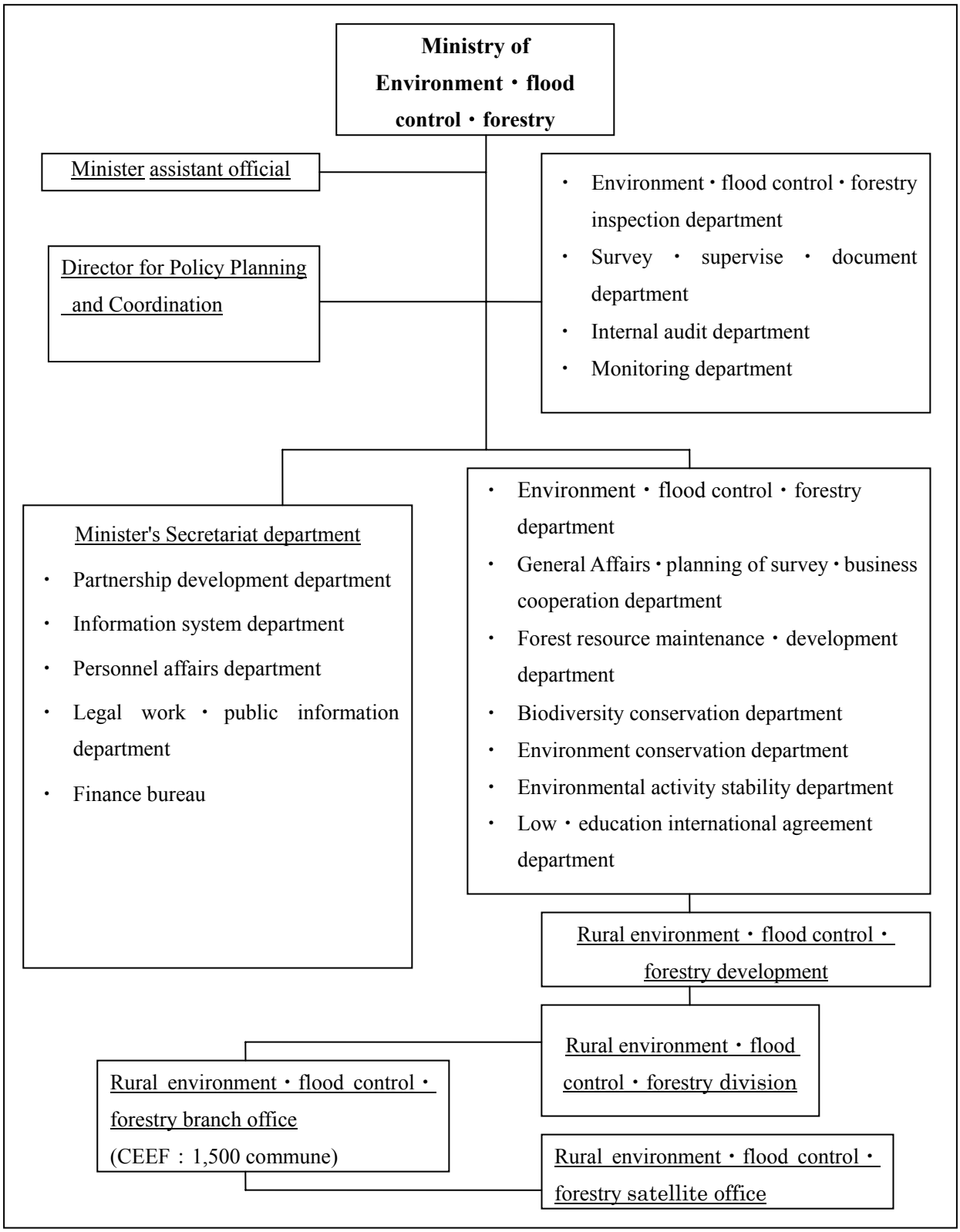
Source：Alaotra-Mangoro regional office

Figure



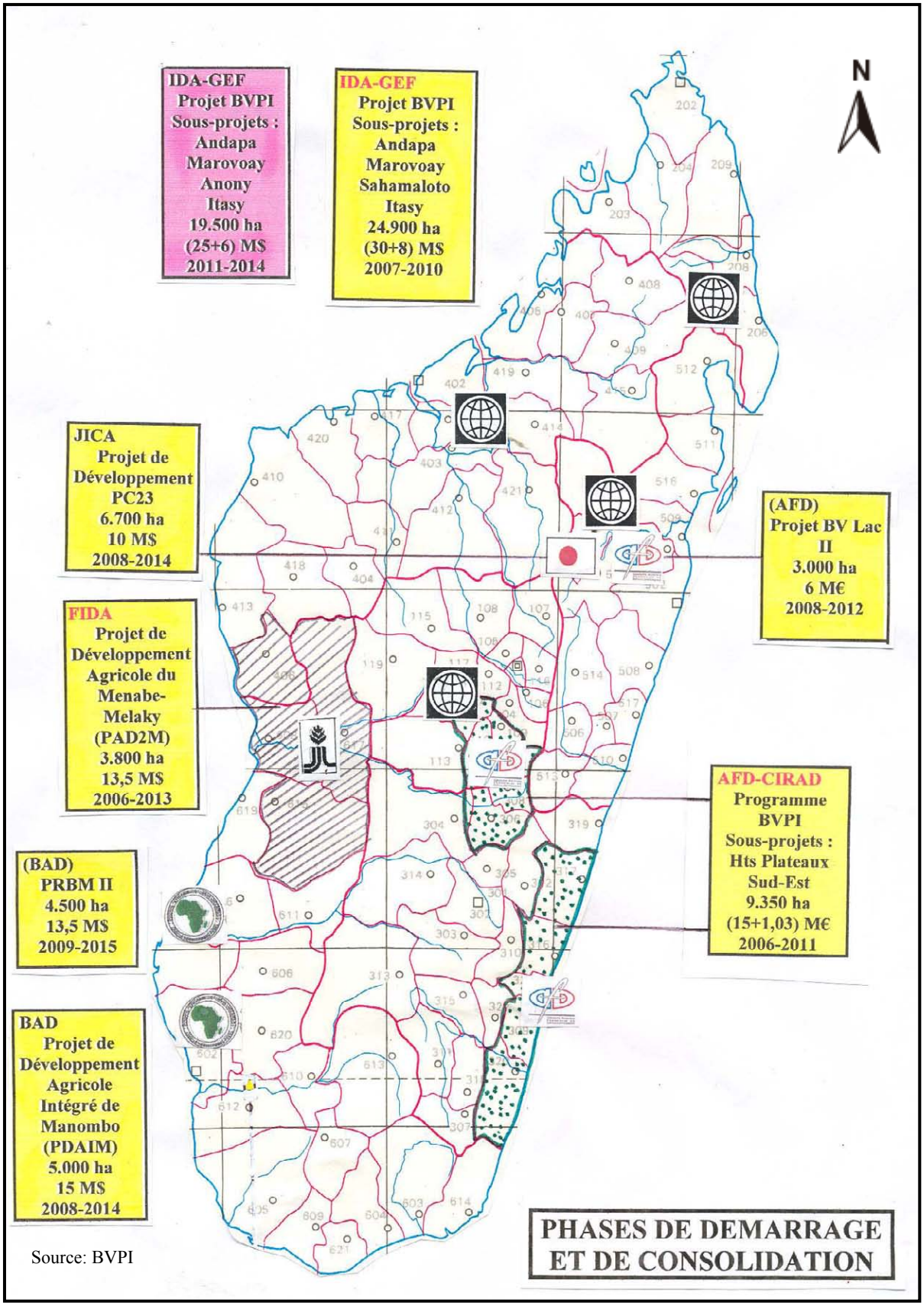
Source: Ministry of Agriculture・Livestock・Fisheries

Fig.2.1 Ministry of Agriculture・Livestock・Fisheries



Source：Ministry of Environment・flood control・forestry

Fig.2.2 Organizational chart of Ministry of Environment, flood control, forestry



Source: BVPI

Fig.2.3 Irrigation and Watershed management program location map

CHAPTER 3 TITLE PRESENT CONDITIONS AND PROBLEMS IN THE STUDY AREA

3.1 Present socio-economic conditions

3.1.1 Administrative system, zone demarcation and population

Administratively, the Study area is under the jurisdiction of the Alaotra-Mangoro region, 2 districts of Amparafaravola and Ambatondrazaka, 9 communes and 52 villages as shown in the following table. Geographically, the Study area consists of Sahabe river basin, Sahamilahy river basin and 4 small/medium river basins and PC23 area. The administrative boundary is illustrated in Fig.3.1.

Table 3.1.1 Administrative units and zone in the Study area

Region	District	Commune	Number of village	Zone
Alaotra-Mangoro	Amparafaravola	Ampasikely	4	4 small/medium river basins
		Andrebakely Sud	6	4 small/medium river basins
		Ambatomainty	9	4 small/medium river basins, PC 23 area
		Morarano Chrome	27	Sahamilahy river basin, Sahabe river basin, 4 small/medium river basins, PC 23 area
		Ranomanity	6	Sahabe river basin
	Ambatondrazaka	Bejofo	2	Sahabe river basin
		Soalazaina	5	Sahabe river basin
		Tanambao Besakay	6	Sahabe river basin
		Andilanatoby	6	Sahabe river basin

Source: Alaotra-Mangoro regional office

According to an additional village interview survey in 2006, the total population in all villages in the Study area is 118,194, the total number of households is 20,631 and the average family size is 5.7. Details are shown in Table 3.1. There are major tribes such as the Sihanaka, Merina, Betsimisaraka and Betsileo in the Study area. Educationally, about a half the people graduate from primary school and there is a literacy rate of about 69%.

3.1.2 Detailed village survey

The JICA study team carried out a detailed village survey in December 2003 in order to understand the present socio-rural conditions of villages in sublet contracts with the local NGO. The detailed village survey was performed by a questionnaire method and an interview survey for key informants (the head of village, head of fokonolona). A questionnaire was conducted by investigative staff that were trained by the NGO. The JICA study team supervised the NGO during the survey period. The 10 objective villages and 500 household samples were selected as follows;

Table 3.1.2 Objective villages for survey

Zone	Commune	Village	Number of households
Sahamilahy river basin	Morarano Chrome	1. Antanimafy	40
		2. Maheriara	40
		3. Morarano Chrome	60
4 small/medium river basins	Morarano Chrome	4. Manakambahinikely	40
Sababe river basin	Ranomainty	5. Ranofotsy	50
	Soalazaina	6. Soalazaina	60
	Tanambao Besakay	7. Besakay	60
	Andilanatoby	8. Sahanidingana	50
PC23 area	Ambatomainty	9. Mahakary	50
	Morarano Chrome	10. Ambohidrony	50

Source: the detailed village survey, JICA study team, 2004

3.1.3 Land tenure

(1) General

In principle all the lands in Madagascar belong to a state. The government recognizes the ownership of the lands of the people. There are two landowner systems of traditional land ownership and modern land ownership. The former is where the parent transfers the rights of the lands of the parents to his children and is traditionally recognized. The latter is that where the rights of the lands are legally recognized based on legal procedures in the governmental land registration office. In the Study area, the branch office of the DRDR land registration office carries out a legal procedure that acknowledges the traditional land rights as the legal rights for the lands. There are two land registrations such 'large scale land registration (Cadastre)' and 'private land registration (immatriculation)'. The former is to register the lands of the local government such as villages and their land boundary. The latter is to register private lands as traditional land ownership.

(2) Average land holding size in the Study area

The detailed village survey conducted by JICA study team indicates the average land holding size in the Study area as shown below;

Table 3.1.3 Average land holding size

Zone	Village	Average land holding size (ha)
Sahamilahy river basin	Antanimafy	9.9
	Morarano Chrome	2.4
	Manakambahinikely	6.2
4 small/medium river basins	Manakambahinikely	3.2
Sahabe river basin	Ranofotsy	1.5
	Sahanidingana	3.8
	Soalazaina	2.3
	T. Besakay	2.4
PC23area	Ambohidrony	2.3
	Mahakary	7.6

Source: Detailed village survey, JICA study team, 2004

(3) Present land registration

The present land registration rate is shown below;

Table 3.1.4 Present land registration rate

Zone	Village	Land Registration land rate (%)	Non-land registration rate (%)
Sahamilahy river basin	Antanimafy	10.8	89.2
	Maheriara	3.3	96.7
	Manakambahinikely	63.1	36.9
4 small/meium river basins	Manakambahinikely	47.5	52.5
Sahabe river basin	Ranofotsy	17.9	82.1
	Sahanidingana	75.0	25.0
	Soalazaina	13.5	86.5
	T. Besakay	72.5	27.5
PC23 area	Ambohidrony	51.5	48.5
	Mahakary	99.9	0.1

Source: the detail village survey, JICA study team, 2004

The land registration rate fluctuates depending on the location. It is apt to increase in the PC23 are and downstream of the river basins and to decrease as the location of the village nears the upper stream. The reasons that local people do not register their lands are: poor capacity of the local government in land register procedure, payment of land tax after registration, the complicated and unclear land registration procedure, the cost necessary for land registration, no understanding of the land registration, etc. Up to now, land registration is not yet properly carried out.

(4) Absentee landlords and land fractionation

Most of the farmers in the upper stream area of the Sahabe, the Sahamilahy and the 4-small/medium have lands near their villages. It is recognized that the land fractionation and land scattering occurs in all the villages because fact that children inherit land from their parents.

On the other hand, about 40% of the land owners live in the areas out of the PC23 areas

according to the land register for Vonona P1, one of the water user associations in the PC23 area. Most of the landowners live in the Sahamilahy basin, Amparafaravola city and Ambatondrazaka city. It is assumed that absentee landlords own a considerable amount of land in the PC23 area. Some landowners live in Antananarivo and Antirave cities. It is also recognized that the land fractionation and land scattering occurs in PC23.

3.1.4 Major occupation and income structure and farmer's income and poverty

(1) Major occupation and income structure

Based on the results of a detailed village survey conducted by JICA study team, the major occupation and share of income source are summarized as in the table below.

Table 3.1.5 Major occupation and income structure of household heads

(%)

Structure	Occupation	Zone	PC23area		Sahamilahy/4 small/medium river basins				Sahabe river basin			
		village *	1	2	3	4	5	6	7	8	9	10
Occupation of household head	1) agriculture		82.0	80.0	87.2	50.0	95.0	71.7	91.8	88.0	57.6	76.7
	2) government officer		0.0	0.0	0.0	2.5	2.5	10.0	2.0	2.0	6.8	1.7
	3) private sector		2.0	2.0	12.8	0.0	0.0	6.7	0.0	0.0	23.7	1.7
	4) merchants		0.0	0.0	0.0	10.0	0.0	6.7	0.0	2.0	1.7	6.7
	5) agri.w/permanent job		0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
	6) agri. w/seasonal job		4.0	4.0	0.0	25.0	2.5	1.7	4.1	4.0	6.8	6.7
	7) no job		4.0	0.0	0.0	0.0	0.0	1.7	2.0	4.0	0.0	0.0
	8) other		8.0	14.0	0.0	7.5	0.0	1.7	0.0	0.0	3.4	6.7
Income structure	1) agriculture		41.4	28.2	55.6	39.5	68.9	38.1	59.1	64.9	19.1	42.8
	2) livestock raising		6.4	11.8	8.2	3.8	1.9	5.6	3.8	2.8	8.3	6.1
	3) fisheries		11.3	21.3	6.7	11.3	11.1	16.2	9.2	10.6	9.0	12.6
	4) firewood selling		9.8	14.8	11.0	14.7	8.2	10.3	7.4	9.7	11.2	6.6
	6) remittance		5.6	5.0	3.3	3.5	1.0	1.3	2.9	1.7	8.9	7.0
	7) other		13.0	9.0	10.9	13.0	5.0	22.0	9.0	6.1	35.0	17.1

*: 1.Mahakary, 2. Ambohidrony, 3. Antanimafy, 4. Maheriara, 5.Morarano Chrome, 6.Manakambahinikely, 7.Ranofostsy, 8. Soalazaina, 9.Besakay, 10.Sahanidingana

Source: Detailed village survey, JICA study team

Though the major occupation of household heads is agriculture, there are household heads that receive non-agricultural income from government offices, schools and merchants in Morarano Chrome, non-agricultural income from the Fanalamanga Corporation in Salazina, and non-agricultural income from farm labor in PC23 area and firewood selling in Maheriara. Though household heads in the village receive income mainly from rice cultivation, household heads receive income from fisheries in Mahakary where nears the lake Alaotra and seasonal job in the area of their village in Manakambahinikely and Besakay where is located in the area having small farm size.

(2) Farm budget

The average farm budget in the Study area that is estimated based on a detailed village

survey is shown in the following table, and details are shown in Table 3.2.

Table 3.1.6 Farm budget of farmers in the Study area

(1,000 MGA/household/year)

Zone	Village	Income	Expenditure	Net revenue
PC23area	1. Mahakary	8,187	3,571	4,616
	2. Ambohidrony	11,046	5,616	5,430
Sahamilahy river basin	3. Antanimafy	8,545	5,058	3,487
	4. Maheriara	4,450	2,191	2,258
	5. Morarano Chrome	9,588	6,726	2,862
4 small/medium river basins	6. Manakambahinikely	5,900	3,257	2,643
Sahabe river basin	7. Ranofotsy	3,691	2,065	1,626
	8. Soalazaina	5,375	2,492	2,884
	9. Besakay	5,918	3,067	2,851
	10. Sahanidingana	5,230	2,380	2850

Source: Detailed village survey, JICA study team, 2004

(3) Poverty

The World Bank prepared a welfare map of Madagascar based on data from the population census of 1993. The result reveals that about 75% of population in rural area in any province is under the poverty line except for Mahajunga and Antsiranana. Poverty rates in Ambatondrazaka and Amparafaravola were estimated as follows.

Table 3.1.7 Poverty rate (%)

province／region*	Whole country	Urban area	Rural area
Toamasina province	74.6	59.9	78.5
Amparafaravola	70.5	43.7	75.0
Ambatondrazaka	79.3	75.3	80.3

Source: World Bank, 2002 *: organization in 2002

The Madagascan government also analyses the poverty conditions in a Poverty Reduction Strategy Paper (PRSP) which was prepared in 2003. In the paper, poverty is defined as "where a person is not able to secure food intake of 2,133 calories per day which is the minimum rate to maintain normal daily life and activities". Based on this definition, the cutting edge for measuring poverty is set at FMG 988,600/year/person at the price levels of 2001 and estimated that about 69.6% of total population is under poverty line in Madagascar.

Applying this definition and the cutting edge income level used in the PRSP using data from the detailed village survey, poverty conditions in the Study area can be roughly estimated. The results of this estimation are shown in the table below.

Table 3.1.8 Poverty rate in the Study area

Zone	Village	Average family size (person/household)	Poverty standard income*1 (FMG/household/year)	Poverty rate*2
Sahamilahy river basin	Antanimafy	6.95	8,826,000	35.1%
	Maheriara	5.38	6,832,000	72.5%
	Morarano Chrome	5.37	6,819,000	26.7%
4 small/medium river basins	Manakambahinikely	5.53	7,023,000	45.0%
Sahabe river basin	Ranofotsy	4.95	6,286,500	63.3%
	Sahanidingana	6.14	7,797,800	70.0%
	Soalazaina	5.55	7,048,500	71.7%
	Besakay	5.87	7,454,900	60.0%
PC23 area	Ambohidrony	6.62	8,407,000	30.0%
	Mahakary	6.80	8,636,000	50.0%
	Average			52.4%

*1: Poverty standard income (FMG9,88,600/person/year)defined in PRSP was converted to poverty standard income (FMG1,270,000/person/year) in 2004 by applying the average inflation rate（8.9%/year：2001～2003year>. Further, poverty standard income was calculated by applying average family size/household.

*2: Income of each farmer was revised by taking into consideration self-consumption of agricultural production. Revised income is estimated by applying the following formula.

Revised income＝agricultural income×1/0.404×（0.404＋0.472）＋other income

Source: the detail village survey, JICA study team

It should be noted, however, that the poverty rate calculated here may be slightly overestimated since farmers usually obtain part of their food directly from their own produce. However, the poverty rate is shown to be a similar figure to the poverty rate estimated in the PRSP and World Bank's poverty map, and it is considered that the figures may not be far from the actual situation. Even if the figures are an overestimation, it can be said that more than 50% of farmers are still in poverty except for several in Fokontany such as Ambohidrony, Antanimafy and Morarano Chrome.

Comparing the average holding size of paddy fields and the average income level per household, it is observed that in Fokontany where the holding size of paddy fields is small people tend to have less income and, hence, a higher poverty rate.

Table 3.1.9 Poverty rate and paddy field area owned by household

Zone	Village	% of household below poverty line	Average holding size of paddy field* (ha/household)	Average annual income level (FMG/household/year)
Sahamilahy river basin	Antanimafy	35.1%	1.91	8,545,000
	Maheriara	72.5%	1.62	4,450,000
	Morarano Chrome	26.7%	1.78	9,588,000
4 small/medium river basins	Manakambahinikely	45.0%	1.47	5,900,000
Sahabe river basin	Ranofotsy	63.3%	0.96	3,691,000
	Sahanidingana	70.0%	1.95	5,230,000
	Soalazaina	71.7%	1.10	5,375,000
	Besakay	60.0%	1.73	5,918,000
PC23 area	Ambohidrony	30.0%	2.86	11,046,000
	Mahakary	50.0%	4.50	8,187,000

*: Holding size is calculated based on the results of a detailed village survey. For the calculation, extreme figures that may affect average values considerably are excluded.
Source: Detailed village survey, JICA study team

Since causes of poverty are more complicated in reality, it cannot be concluded that the holding size of a paddy field is *the* cause of poverty. However, the paddy field size is considered to be one of the important factors in affecting income level.

On the other hand, Ambohidrony and Morarano Chrome show lower rates of poverty even though the holding size of the paddy fields there is not so large. One of the major reasons is the location of their residences. Fokontany is located near a national road and Ambaiboa is an important town for transportation and commercial activities. These facts mean more non-agricultural job opportunities which lead to higher an income level regardless of the land holding size. Another reason may be the location of the paddy field. Morarano Chrome and Ambohidrony are near the main canal of PC 23 and, therefore, productivity could be higher due to the easy availability of irrigation water. They also have the advantage of selling their products since access to their paddy field is easier than other villages.

Mahakary has the largest land holding size but the income there is not as high as expected. The paddy field around Mahakary suffers from a malfunctioning irrigation system and inundation. Besides, large area is still under rain-fed condition due to lack of irrigation facilities. Hence, agricultural productivity is low and this is why the land holding size doesn't contribute much to income in Fokontany.

In the case of the Sahabe river basin, the poverty rate is higher than in other zones. In Sahanidingana, the income level is almost a half of that in Antanimafy, although its land holding size is larger. One of the main reasons is the poor access to market due to poor road conditions and less availability of public transportation. Poor access leads to disadvantages

in marketing and less job opportunities.

From the above observation, the major causes of poverty in terms of income level are considered to be insufficient agricultural income due to low productivity, poor marketing conditions, small land holding size, and little job opportunities in the non-agricultural sector.

3.1.5 Gender Issue and Social Practice

(1) Gender Issue

Daily life in the habitats has farming as a base. A basic daily life calendar of habitat by sex is shown in Figure 3.1.1. The farmers living in PC23 area and going out to fish in Alaotra Lake are fishing and processing fish when the full-time farmers are working in paddy fields and upland fields.

Farming Season	04:00		08:00	12:00	14:00	16:00	17:00	19:00
	Maraina		*Antoandro*		*Tolakandro*	*Hariva*	*Alina*	
Male	Getting up		Work in paddy field	Rest Lunch	Work in paddy field		Dinner	Going to bed
Female	Getting up	Making of breakfast	Making of lunch Housework	Rest Lunch	Housework	Making of dinner	Dinner	Going to bed

Off Farming Season	04:00		08:00	12:00	14:00	16:00	17:00	19:00
	Maraina		*Antoandro*		*Tolakandro*	*Hariva*		*Alina*
Male	Getting up		Work in upland field/Fishing	Rest Lunch	Work in upland field/Fishing	Rest/Processing of fish	Dinner	Going to bed
Female	Getting up	Making of breakfast	Making of lunch Housework	Rest Lunch	Housework	Making of dinner	Dinner	Going to bed

Source: JICA Study Team

Figure 3.1.1 Basic Daily Life Calendar

Thus, the core of daily life for males and females is farming and making meals, respectively. For rich and middle class people, the basic daily life pattern is universal. However, time where there is nothing to do is included in the basic daily life pattern for poor people. The annual farming calendar shown in Figure 3.1.2, especially for the annual rice farming calendar is common to all hierarchies of people.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Male	Irrigation water management				Harvesting of paddy	Threshing		Plowing			Nursery	Trans-planting
	Weeding											
Female	Cultivation of vegetables				Assistance of rice farming and making of meals							Trans-planting
					Making of handicraft (poor people)							

Source: JICA Study Team

Figure 3.1.2 Basic Annual Farming Calendar

In the habitat of hilly to mountainous areas upland crops are also cultivated on the slope in January through April. For rice farming, males are responsible for heavy physical work such as plowing and females are responsible for light physical work such as transplanting, respectively. Moreover, females are carrying out the cultivation of upland crops such as beans, root crops and vegetables. For meal making, females are responsible for cooking and children and/or females are responsible for the collection of firewood and fetching of water from well, spring river, public faucet, etc. for cooking. On the other hand, males are responsible for the making of charcoal for marketing. The making of handicraft goods made from reed and water grass, such as mats, baskets, hats, etc. is limited to females. The females take charge of the family budget management regardless of the economic condition. The husband passes the full amount of his income to the wife. The purpose of spending the money from the obtained income is decided through discussion among them and the income is spent based on mutual agreement of them. The most common household goods are radio-cassettes and bicycles from a convenience point of view.

(2) Social Practices

The consensus of people at the village level is examined in the meeting, the so-called Fivoriam-Pokonolona, in which all men and women of 18 years old or more can participate, and decisions are made by the raising of hands for a majority. Most villages enforce a penalty on absentee of said meeting. In some villages, however, the penalty is in name only.

The social practices in the Study area are “Dina” (the traditional group standard of the village), circumcision, invitation to weddings and the second funeral, “Manala-Voady” (the giving of meals when a promise declared beforehand is accomplished), and “Fady" (the taboo not to work on the paddy fields on a specific day of the week).

3.2 Natural conditions

3.2.1 Topography, geology and soil

(1) Topography and geology

Alaotra Lake originated from a depression basin formed by many fault movements. The Eastern part of the lake approaches steep mountains on which the elevation is 1,000m above sea level. On the other hand, the southern and western area of the lake is distributed on a wide alluvial plain fed by Sahabe, Sahamilahy, Ambolotaramadinika and other small rivers. Formed Especially, the southwestern part of the lake is distributed on a vast wetland which originated from soil transportation and sedimentation by the Sahabe River. The mountainous formation of the western part of Alaotra Lake has gentle slopes compared to the eastern part. Originally, rivers flow in an easterly direction. However, the direction of river accurately changes from an east-west direction to a north-south direction at the point of around 900m above sea level because of the existence of fold structures. The change of the mountain strike suggests that there are these structures at 900m above sea level that extend from a south direction to a north direction. Taking into account this change of river runoff direction and mountain strike, it is supposed one large scale fault crossed towards the north-south direction at a point around 900m above sea level. It is also supposed that the depression basin including Alaotra Lake was formed by this large scale fault. Water from Alaotra Lake flows out from Maningory River, which is located at the northeastern part of the lake towards the Indian Ocean.

The geological structure of the Alaotra Lake region mainly consists of gneiss and biotite schist into which are penetrated by granite. Also, migmatite is formed from metamorphic gneiss by granite intrusion. Metamorphic rocks such as gneiss or biotite schist and plutonic rocks like granite are original materials of lateritic soils. Alkaline feldspar is a mineral composition of granite and granidiorite, which is the main material in kaolinite development. It is supposed that the layer of kaolinite influences the outbreak of lavaka in this area

(2) Soils

Laterite derived from granite and gneiss is widely distributed as the typical soil in this region. The base of laterite without plant cover is highly leached. The soils in the Study area can be divided into four (4) types by the geographical features and geological distribution i.e. the granite origin laterite in the mountainous area, the migmatite or gneiss origin laterite in the hilly area, the old alluvial soil in the river terrace, and the recent alluvial soil in the lowland and valley plain.

Based on the above soil types in the study area, a physio-chemical analysis was undertaken for soil samples collected from the paddy fields and the upland fields. The analysis was requested to and made by the soil laboratory of the National Applied Agriculture Research

Development Center (FOFIFA). The following characteristics can be read from the analysis results as shown in Table 3.3.

(a) The soils in the terrace and hilly areas: The characteristics of soils are low caution exchange capacity (CEC) and base saturation, semi-acid to acid sandy soil with high base leaching, low total carbon content, and low fertile.

(b) The soils of paddy in hilly to mountainous areas: The characteristics of soils in the poor drainage area are high total carbon content, and fertile. On the other hand, the characteristics of soils directly influenced by "Lavaka" are a shallow surface and low fertility.

(c) The alluvial soils in PC23 area: The fertility level and physical characteristics of soils can be distinguished by the differences in the origination of the type of sediments, the duration of utilization as a paddy field, and the drainage condition due to the altitude of the soil surface of the paddy field.

3.2.2 Agricultural climate

The Study area belongs to a semi-wet tropical climate zone and is affected by monsoons. The rainfall records that were observed at FOFIFA Central-Eastern regional agricultural research center（*Centre Regional de Recherche du Moyen Est CRR ME*） in CALA for 14 years are shown in Table 3.2.1. Average annual rainfall is 1,078mm. About 90% of annual rainfall falls in the rainy season that extends for 4 months from December to March. The remainder is the dry season. Furthermore, annual rainfall fluctuates year by year, ranging from 44mm to 1,452mm for 14 years. Such rainfall and rainfall patterns are crucial factors for agricultural production. Also, typhoons usually hit the Alaotra Lake during the period from the end of January to March and inflict serious damage on agricultural production.

Table 3.2.1 Average annual rainfall at FOFIFA Central-Eastern regional agricultural research center

Year/ month	10	11	12	1	2	3	4	5	6	7	8	9	Annual Rainfall	Day of rain
1993/94	66	33	132	433	266	190	5	21	8	23	7	4	1,188	145
1994/95	169	4	110	461	218	78	48	29	10	4	3	1	1,135	122
1995/96	4	3	510	486	129	227	19	4	3	5	2	1	1,393	133
1996/97	0	4	409	481	254	19	42	4	2	10	6	17	1,248	109
1997/98	24	85	149	294	452	17	3	12	5	3	8	36	1,088	116
1998/99	0	1	211	226	35	103	12	39	9	15	6	2	659	100
1999/00	1	7	99	110	185	188	13	3	11	16	7	4	644	112
2000/01	1	19	196	666	106	24	29	3	7	2	11	1	1,065	102
2001/02	16	0	209	103	482	59	14	12	6	6	2	9	1,026	101
2002/03	1	46	390	486	311	136	3	9	4	4	2	8	1,400	128
2003/04	31	76	162	221	130	128	16	5	8	3	3	5	788	125
2004/05	0	7	367	143	485	342	47	7	5	34	8	7	1,452	138
2005/06	0	57	222	139	86	107	13	5	9	7	15	1	661	120
2006/07	1	85	61	514	446	156	50	8	3	14			1,338	116
average	22	30	231	340	256	127	22	19	8	10	6	7	1,078	119
Distribution (%)	2.0	2.8	21.4	31.5	23.8	11.8	2.0	1.8	0.7	0.9	0.6	0.7		

Source: FOFIFA Central-Eastern regional agricultural research center

At present the rice variety MK34 that has a growth period of 180-190 days and photosensitivity is the prevailing crop in the Study area. The MK34 variety enters into young panicle formation at the end of March and heading at the middle of April, and has a long vegetative period. For this reason, it is essential to carry out seeding for nursery beds at the beginning of December. It is also a pre-requisite for higher yields of paddy to have enough rain for young panicle formation period.

In the Study area, rainfall and its distribution pattern are very unstable due to climate change. Severe droughts occurred in the consecutive years from 1998 to 2000 and led to serious crop failure. Shortage of rainfall at the end of March is one of the causes in decreasing the paddy yield. Also rainfall for 2 months from January to February exceeds 600mm, and becomes a serious drainage problem, especially in the PC 23 area.

Table3.2.2 Temperature and evaporation at Anosiboribory seed center

Year/month	Temp.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1991	Min.				18.6	19.4	19.3	17.8	15.9	12.6	10.8	11.2	11.7
	Max.				27.7	27.7	27.8	26.4	25.6	23.5	22.5	23.5	26.8
	Avg.				23.2	23.6	23.6	22.1	20.8	18.1	16.7	17.4	19.3
1991/1992	Min.	15.1	16.9	18.3	19.8	14.5	8.8	17.0	14.2	13.4	9.8	10.9	11.1
	Max.	28.6	29.2	28.9	28.4	27.8	28.5	26.5	26.2	22.6	23.1	23.0	25.3
	Avg.	21.9	23.1	23.6	24.1	21.2	18.7	21.8	20.2	18.0	16.5	17.0	18.2
1992/1993	Min.	12.9	16.6	20.7	18.6	19.1	18.1	17.2	15.6	11.6	19.3	10.4	12.3
	Max.	26.9	28.1	29.1	28.2	27.9	26.9	26.8	25.3	24.0	22.7	23.7	25.2
	Avg.	19.9	22.4	24.9	23.4	23.5	22.5	22.0	20.5	17.8	21.0	17.1	18.8
1993/1994	Min.	13.0	17.5	14.7									
	Max.	27.0	28.6	29.5									
	Avg.	20.2	23.1	22.1									
Avg.	Min.	13.7	17.0	17.9	19.0	17.7	15.4	17.3	15.2	12.5	13.3	10.8	1.7
	Max.	27.6	28.6	29.2	28.1	27.8	27.7	26.6	25.7	23.4	22.8	23.4	25.8
	Avg.	20.7	22.8	23.5	23.6	22.7	21.6	22.0	20.5	18.0	18.0	17.1	18.7
Monthly Avg.		28.0	20.0	241.0	375.0	244.0	104.0	19.0	24.0	7.0	9.0	5.0	8.0
(%)		3.0	2.0	22.0	34.0	22.0	10.0	2.0	2.0	1.0	1.0	0.0	1.0

Monthly evaporation(mm)

year		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1991					133.7	100.6	106.3	87.0	71.0	66.7	59.5	81.4	133.3
1991/1992		120.5	146.5	160.0	140.8	90.3	121.5	68.0	65.2	61.3	74.3	116.9	116.7
1992/1993		147.3	98.7	-	160.3	116.0	106.6	100.5	118.3	72.7	64.3	82.9	112.4
1993/1994		153.0	107.4	150.2									
Avg.		140.3	117.5	155.1	144.9	102.3	111.5	85.2	84.8	66.9	66.0	93.7	120.8

Source: Anosiboribory seed center

Temperature entirely depends on the elevation. As the elevation increases, the temperature decreases. Average monthly temperatures at the Anosyboribory seed center (elevation:769 m) are shown in the following table. Average monthly temperature ranges from 17.1℃ at August to 23.6℃ in January. From June to September, average monthly temperature falls to 20℃. Serious minimum temperature for growth of paddy occurs from June to September. Average annual evaporation is 1,290mm.

3.2.3 Rivers and water resources

(1) Rainfall analysis

(a) Local rainfall pattern in and around the Study area

Annual mean rainfall ranges from 1,000 to 1,800mm in the lake basin. In the lake and the adjacent low-land area less rainfall was observed with more or less 1,000 mm. On the other hand, the mountain area on both of east and west sides of the basin are recorded abundant rainfall of about 1,600 – 1,800mm. It seems that there would be a high relation between altitude and the rainfall amount in the lake basin (The co-relationship between altitude and rainfall is estimated at 0.98 as r^2).

(b) Probability analysis on annual rainfall

Probability analysis of annual rainfall for the basin of lake Alaotra was conducted based on

monthly rainfall records (43 years) at the station of FOFIFA Central-Eastern regional agricultural research center. The results are shown below;

Table 3.2.3 Drought and wet probability

Annual drought probability			Annual wet probability		
Return period	Non-exceeding probability	Annual rain (mm)	Return period	Exceeding probability	Annual rain (mm)
2-year	0.5	1,068	2-year	0.5	1,072
5-year	0.2	898	5-year	0.2	1,281
10-year	0.1	828	10-year	0.1	1,418
20-year	0.05	778	20-year	0.05	1,518
50-year	0.02	729	50-year	0.02	1,655

Remarks: Log person type III was applied for the distribution pattern
Source: JICA Study Team

(2) Condition of rivers

(a) General characteristics

In the Study area, there are 6 rivers flowing into the PC 23 area such as 1) Sahabe river, 2) Sahamilahy river, 3) Ampasimena river, 4) Asahamena river, 5) Behengitra river and 6) Bemarenina. The general characteristics of these rivers are shown below;

Table 3.2.4 General characteristics of rivers

Nos.	Name of river	Area of basin (km^2)	Total length (km)	Gradient
1	Sahabe	903	103.3 (*2)	0.0026 (1/384)
2	Sahamilahy	249 (*3)	37.8 (*1)	0.0136 (1/73)
3	Ampasimena	27	14.8 (*1)	0.0215 (1/46)
4	Asahamena	119	34.0 (*1)	0.0107 (1/93)
5	Behengitra	27	14.8 (*1)	0.0129 (1/77)
6	Bemarenina	45	15.8 (*1)	0.0121 (1/82)

Notes: (*1) From the upstream end to the crossing point of National road A.P.3a
(*2) From the upstream end to the surface edge of Alaotra Lake
(*3) Including residual basin at the south (Ampondra river basin)
Source: JICA study team

River gradient is generally steep at more than 1/100 except the Sahabe River. The rivers originated from Sahamilahy and other 4 small/medium rivers directly flow to the PC-23 irrigation area from the mountain area, and the gradient suddenly changes at the spot with about El.800-900 m, from which to the downstream, sediment is tend to deposit and induced to form fan topography. A steep stretch exists in all the rivers in the Study area, and waterfalls of 20-30m were found in all the steep stretches.

The second flat stretch between water fall sites and the upstream of the Sahabe, Sahamilay and Asahamena rivers, where there are paddy field and swamps, was gentle with more or less 1/300. These seem to have been good retarding/control function of flood and sediment discharge to the downstream.

(b) River run-off condition

Since there is no data on the river flow of all the rivers in the Study area, direct measurements of river flow were conducted at 15 different points. The measurements were carried out at one time at the end of the dry season in 2003, at which irrigation activities had not commenced yet and no major water diversion from the river is observed. Since measurement points were installed at the upper site of the irrigation areas downstream, the discharge measured is not affected by irrigation water diversion. The results are shown in Fig.3.2 and summarized below:

Table 3.2.5 Summary of discharge measurement results

Nos.	Name of river	Location	Area of basin (km^2)	Date of measurement	Discharge (m^3/s)	Specific discharge ($m^3/s/100km^2$)
1	Sahabe	Ambohimitsotra	427	2003/10/8	2.25	0.52
2	Sahamilahy	Maheriara	152	2003/10/9	2.52	1.65
3	Ampasimena	Ambohidray	27	2003/10/9	0.59	2.18
4	Asahamena	Ambohimanjaka	119	2003/10/9	1.84	1.26
5	Behengitra	AP3a bridge	27	2003/10/10	0.39	1.44
6	Bemarenina	Bismangana	45	2003/10/15	0.47	1.04
	Average		823		8.06	0.98

Source: JICA study team

It was found that all the rivers have rather abundant river flow even at the end of dry season with more than 1.5 $m^3/s/100km^2$ of the specific discharge except Sahabe River. The average specific discharge in the Study area is estimated at 0.98 $m^3/s/100km^2$ at the end of dry season in 2003.

The difference in the specific discharge is clear between all the river basin except Sahabe river and the Sahabe river basin from the above figure in the table. On the other hand, there is no big different in annual rainfall between all the river basins except Sahabe river and the Sahabe river basin. This difference of specific discharge is due to the difference in water holding capacity.

The water shortage for PC-23 irrigation area is one of the main issues in the Study area. The availability of the water for PC-23 is estimated based on the results of discharge measurement. The low flow distribution network was prepared for water balance in the Study area.

The total inflow into PC-23 irrigation area at the end of the dry season in 2003 is estimated at 4.62 m^3/s, and the discharge directly to the Alaotra Lake bypassing the irrigation area is estimated at 3.74 m^3/s. In such a situation, the rehabilitation of the intake structure would be highly required for sustainable water diversion for the PC-23 irrigation area.

(c) Sediment and flood

Sediment deposition along the river channel at the downstream portion is remarkable,

particularly the Bemarenina and Behengitra Rivers in the north of the Study area. The primary river terrace in the downstream stretch was fully buried by the sediment deposition and the river is meandering to change course on the fan-formed area downstream. In the other four rivers, Sahabe, Sahamilay, Ampasimena and Asahamena, it is observed that no serious excess sediment is transported from the upstream from the view of the river channel formation at the downstream stretch. The river channel on the primary river terrace is maintained by the river flow.

Flood prone area is spread over the downstream part, particularly in the Sahabe and the Sahamilay River Basins. Paddy fields are fully developed in the flood prone area and the yearly destruction of the paddy field caused by the flooding is raised as one of the major issues in the Study area

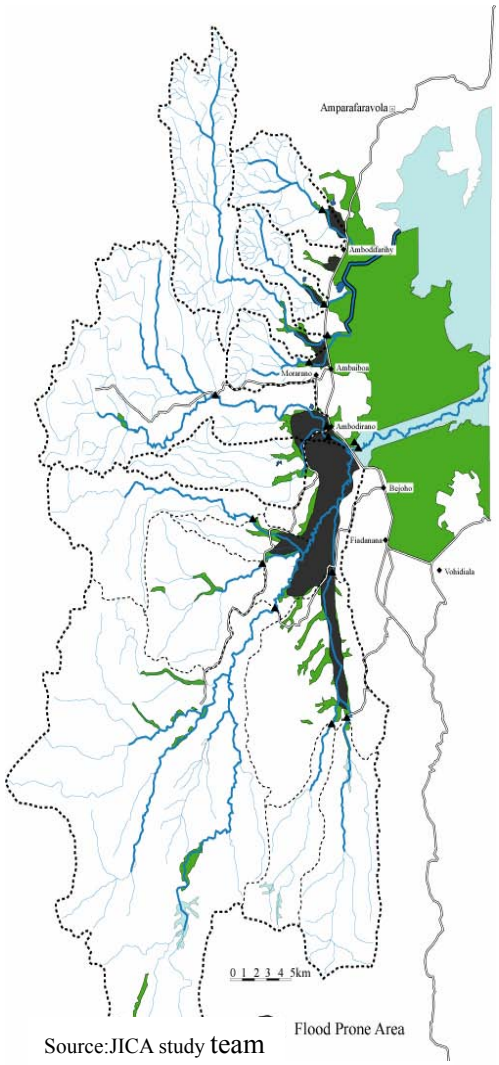
(3) Flood analysis

(a) Flood prone area

The flood prone area is assumed to spread over the low-land area, particularly along the Sahabe and Sahamilay river basins. Also, for the other rivers, the downstream fan-formed area located just above national road 3a is assumed to be damaged by floods because of the flat topography and the insufficient river channel capacity compared with the flood scale. In addition, almost no flood control measures such as dike construction and river training works are provided.

Along the Sahabe river, downstream from the national road bridge, a parallel dike exists to protect the PC 23 irrigation area against the flood.

It seems that downstream from the National road 3a might not be seriously flooded compared with the upstream paddy field. This is because the existing national road is elevated a few meters by an embankment from the adjacent area and the bridges to cross the rivers are rather small. Because of this, the flood flow would be blocked by the bottle neck of the bridges and the elevated national road. As a result, the area of PC-23 might not be flooded as an upstream paddy field from the national road.



Source:JICA study team

Figure 3.2.1 Flood Prone Area in the Study area

(b) Storm rainfall probability analysis

The storm rainfall probability analysis was conducted by using annual maximum daily rainfall records (for 24 years from 1979 to 2002) at FOFIFA Central-Eastern regional agricultural research center. The results are shown below;

Table 3.2.6 Probability of maximum daily rain at FOFIFA central-eastern regional agricultural research center

Return period (year)	Exceeding probability	Probability daily rain (mm)
2	0.500	95.2
5	0.200	124.9
10	0.100	144.0
20	0.050	161.9
50	0.020	184.0
100	0.010	201.7

Remarks: Log-pearson, type-III was applied for the distribution
Source: JICA study team

(c) Probable peak flood estimation

The probable peak flood was estimated based on the probable daily rainfall at the FOFIFA Central-Eastern regional agricultural research center by which probable rainfall for respective river basins is estimated by the adjustment factor. The results are shown below.

Table 3.2.7 Summary of probable peak in the Study area

Name of river	Sahabe	Sahamilahy	Ampasimena	Asahamena	Behengitra	Bemarenina
Area of basin ($km^{2)}$	903	249	27	119	27	45
2-year flood (m^3/s)	1,875	1,071	194	528	192	314
5-year flood (m^3/s)	2,460	1,460	254	692	252	311
10-year flood (m^3/s)	2,837	1,621	293	798	290	474
20-year flood (m^3/s)	3,100	1,771	320	872	317	518

Source: JICA study team

It is noted that the above figure shall be applied just on a tentative basis, and for flood control activities, a detailed survey is highly required including fold measurement and flood damage assessment.

(4) Run-off analysis

(a) Methodology

Generally, low flow analysis is conducted by means of a series of river discharge data. For this, it is necessary to conduct discharge measurement at least once a month for 30 years to accumulate the river discharge data. Daily river flow measurement together with the rainfall measurement is much preferable for conducting more detailed and reliable analysis. The study team conducted discharge measurement in this time it is just once. The same activities should be continued for long-time

Unfortunately, there is so far no river discharge data available, except one measurement record conducted by the study team. This one measurement data is of course not sufficient to conduct low flow analysis. In this case, rainfall records are to be used for low-flow analysis, which is called rainfall-runoff analysis.

To conduct rainfall-runoff analysis, some conversion model for rainfall to river flow is required. In this study, the Tank Model is applied to the rainfall-runoff model, which was developed by Dr. Sugawara in Japan. Details are shown in the attached paper "low flow analysis".

(b) Rainfall and run-off pattern in 5-year drought year and 5-year wet year

The results of probability analysis of annual rainfall were shown in section 3.2.1 (1). The seasonal available flow should be analyzed based on the authorized stochastic theory. In this study, a 10-day series of annual discharge was estimated by means of the developed tank model for 5-year wet year, average year and 5-year drought year. Details are shown in the attached paper 3-1 "low flow analysis".

3.3 Land use

The present land use in the Study area is categorized by (1) forest（natural forest, manmade forest）, (2) grass/shrub land, (3) river vegetation, (4) farm land (upland, paddy field), (5) wet land and (6) water bodies. Based on landsat image (shot in April 2001) analysis, land use conditions in the Study area is shown in Table 3.3.1. MINENVEF made a land image analysis and prepared a land use map in and around the lake of Vallarta in cooperation with the donor that conducted registration work for the protected areas covered by the Ramsar Convention. The land use map in the Study area is illustrated in Fig. 3.3. The features of the land use conditions in the Study area are shown as follows;

Table 3.3.1 Present land use

Land use categories	Sahamilahy river basin		4-small and medium river basin		Sahabe river basin		PC23area		Study area	
	area (ha)	(%)	Area (ha)	(%)	area (ha)	(%)	area (ha)	(%)	area (ha)	(%)
（1） forest										
- natural forest	1,076	5.2	118	0.5	4,140	4,2	0	0.0	5,334	3.4
- manmade forest（pine）	157	0.8	0	0.0	9,117	9.3	0	0.0	9,274	5.9
Manmade forest (Eucalyptus)	441	2.1	1,086	4.8	4,871	5.0	0	0.0	6,398	4.0
(2) grass and shrub land・	15,925	77.3	16,649	74.0	53,787	55.1	1,020	5.8	87,381	55.2
(3) river	1,609	7.8	2,556	11.4	11,552	11.8	172	1.0	15,889	10.0
(4) farm land										
- paddy field	942	4.6	1,401	6.2	7,459	7.6	15,591	88.8	25,393	16.0
- upland	381	1.9	602	2.7	4,790	4.9	710	4.1	6,483	4.1
(5) wet land	0	0.0	0	0.0	784	0.8	0	0.0	784	0.5
(6) water bodies	65	0.3	81	0.4	1,217	1.3	60	0.3	1,423	0.9
Total	20,596	100.0	22,493	100.0	97,717	100.0	17,553	100.0	158,359	100.0

Source: JICA study team

Forest land consists of natural forest and manmade forests (pine and Eucalyptus). The total area is about 21,000ha or 13.3% of the Study area. Especially, forest land in the Sahamilahy river basin and 4 small/medium river basins is very small or 8% and 5% of their basins, respectively. Based on topographic maps prepared by aerial photos in 1957, the natural forests covered with the whole river basin area located in the western part of the Study area. However, most of these forests disappeared for 50 years. At present, the natural forest land remains in the steep lands in the river basin located at the extreme west and south west of the study area. The area of the natural forest is only 5,300 ha or 3% of the Study area. The disappearance of the natural forest was made due to illegal cutting down of the forest and forest fires over the duration of 50-years.

The manmade pine forests were planted in the relatively flat area of the hilly lands on a large scale by Fanalamanga Corporation in 1970's, which played a very important role in soil conservation for the Study area. Eucalyptus is planted in the mountainous and hilly lands near the village areas by the local people.

The total area of the grass and shrub lands is about 87,400 ha or 55% of the Study area. Most of the lands are widely distributed in a remote area from the villages. The grass and shrub lands have been annually fired and used by crop production and grazing for cattle. Though a part of the grass and shrub lands is used as grazing land, vegetation has been deteriorated by repeated field fires and larger evaporation during the dry season, the grass and shrub lands have been deteriorated seriously. The vegetation of the steep hilly lands is damaged by livestock raising activities and the denuded areas are sometime founded, which becomes one

of the serious causes of soil erosion. There are many lavakas in the grass and shrub lands in areas formed by migmatites. Since the grass and shrub land within PC23 area is higher than water level of irrigation canal, it is forced to be used as the grazing land.

The total area of the river vegetation land is about 15,900 ha or 10% of the Study area. It is distributed into the land along rivers. It is densely covered with grasses and trees owing to high moisture content. It plays a very important role in the conservation of levees of rivers.

The farm land is composed of paddy and upland. The total area of paddy and upland is about 25,400 ha (or 16% of the Study area) and 6,500 ha (4% of the Study area), respectively. Paddy area is distributed into the alluvial plain of the downstream of the Sahabe, the Sahamilahy and the 4 small/medium rivers and the low lying land along the tributaries of the main 6 rivers. Upland is distributed into the slope lands near the villages and the river terrace in the downstream of the main rivers. The shifting cultivation on the slope lands is not set as custom use. It is found that the setting of fires is usually conducted to control weeds in paddy fields and ridges at the end of the dry season.

3.4 Agriculture

3.4.1 General

The main crop grown in the Study area is paddy from the income for which is the most important income for the farmers in the study area. The paddy area in the study area is estimated at 25,400 ha that is equivalent to about 27% of the total paddy area (92,700 ha) in the basin of the lake Alaotra and have played an important role in the rice supply base in Madagascar.

Upland, upland crops such as upland paddy, maize, cassava, sweet potatoes, beans, sugarcane, tomatoes and etc. are cultivated. In the area around the villages, banana, coffee, mango, oranges, litchis and pineapple are grown on a small scale.

Single cropping of paddy per year is the major cropping pattern in the PC23 area. Some farmers cultivate beans after the harvest of paddy during the dry season. The eastern parts (about 2,400ha in net) of the PC23 irrigation system are rain-fed/ pasture lands because of the deterioration of the irrigation system, the problem of sedimentation in the system and microrelief in topography. The average farm management size is relatively large and about 3 ha. The farmers take a long time to access the paddy fields in the PC23 area because they live in the villages that are situated in remote plateau areas from the PC23 area. For this reason, the shortage of a farm labor force, especially for land preparation and harvesting seasons, occurs. The farmers in the PC23 area hire seasonal laborers and cultivators in and around the PC23 area. Many zebus that are raised as a symbol of assets play an important role in provision of manure, draft animal for land preparation as well as transportation operations for manure, seedlings, paddy harvested and straw.

Except the middle-scaled irrigated paddy area in the middle stream of the Sahabe, the farmers in the river basin of the Sahamilahy, the Sahabe and the 4small/medium rivers basically cultivate paddy and manage a mixed agriculture with raising of small and large livestock, upland crop cultivation, horticulture, fisheries culture, and so on, taking account of the conditions of location. And additionally, they get cash income from making wood and charcoal from Eucalyptus. However irrigation efficiency is very low owing to poor irrigation systems and poor O&M of them, which result in low yield of paddy in those areas. Since the average farm size of the farmers is below 2ha, the farmers are obliged to eat cassava as a rice substitute when rice production becomes below an average value. Also sometimes, access to paddy field is brought to a standstill and access to the markets becomes difficult owing to poor transportation means.

The upland area is very small in the Study area. It extends over the slope land along the paddy field in upper and mid basins of the rivers. It is used for rice and cassava cultivation without taking case of said erosion control, which becomes one of the big causes of surface soil erosion.

3.4.2 Cropping patter and farming practice

Paddy is planted during about 3 months from the beginning of January to the end of February, and harvested May and June at the PC23 area, and during the end of October to the end of November. A second crop such as haricot beans is practiced after harvesting paddy on the small scale.

The rice variety MK34 with 180-day growth period mainly prevails in the PC23 area and the middle stream of the Sahabe river. The Tesemaka rice variety with a 170-day growth period is mainly spread over the Sahamilahy river basin and the middle stream of the main rivers except the Sahabe. The rice varieties 2787 and 2798 are in some areas. Those above rice varieties have the characteristics of photosensitivity. MK34 rice variety and other rice varieties enter into heading at the middle of April and the end of March, respectively, whenever these varieties are planted at any time. These rice varieties has been used for a long time because they provide a good rice taste, a lot of straw for livestock grazing and a high price of rice. In the recent 2-year, planned rice varieties of the SEBOTA series were tried to practice in the paddy field.

Land preparation in the PC23 area is performed mostly by draft animals though cultivators and tractors are being spread partly in the recent year. In other areas, land preparation entirely depends on manpower and draft animals. However, land preparation such as ploughing, leveling and puddling can not be properly conducted because the total number of cattle (draft animals) is the Study area is small as mentioned in section 3.5.1. Planting methods that prevail in to the Study area consist of (i) the random transplanting method (70%), the direct sowing method (20%) and the improved SRI method (System of Improved

Riziculture). Weeding is seldom practiced in the random transplanting method and the direct sowing method. About 2tons/ha are usually applied into. Chemical fertilizer is not generally provided owing to the high cost of fertilizer. 2,4-D (abbreviation of 2,4 – dichborophenoxacetie acid) for weeding is widely conducted along with manual weeding practice in the Study area and its dosage is one litter/ha. Though there are damages by rice blast, pyralid, case-worm and so forth, chemicals application against pests/diseases are rarely used due to the high cost of chemicals, shortage of knowledge in the use of chemicals and access to chemical shops. Harvesting is generally carried out with sickles. Cutting ears of rice method and mechanical a harvester with engines are seldom. After harvesting paddy, it is dried in the sun for several days on the paddy field. Most residues of paddy are used as feeds for livestock.

Upland crops also are cultivated during the wet season. In the case of tomatoes, cultivation is common in the dry season because there are no serious problems against pest and diseases.

3.4.3 Yield and production

The cultivation area, yield and production for the main crops in both districts of Amparafaravola and Anbatondorazak covered with the Study area for the recent 5 years are shown below;

Table 3.4.1 Cultivation area, yield and production for the main crops

year	Items	paddy	Upland rice	Maize	Cassava	Beans
2001/02	Area (ha)	66,832	2,158	2,524	4,985	2,122
	Yield (ton/ha)	2.95	1.63	1.59	10.42	1.11
	Production (ton)	196,842	3,512	4.010	51,944	2,351
2002/03	Area (ha)	66,320	2,533	3,360	4,918	2,811
	Yield (ton/ha)	2.69	1.81	1.71	11.84	0.98
	Production (ton)	178,460	4,577	5,746	58,226	2,749
2003/04	Area (ha)	80,169	2,800	4,453	4,884	2,198
	Yield (ton/ha)	3.18	2.02	1.83	10.90	1.12
	Production (ton)	255,023	5,656	8,128	53,230	2,458
2004/05	Area (ha)	84,272	4,427	4,801	3,931	1,226
	Yield (ton/ha)	3.37	2.56	1.86	12.22	3.85
	Production (ton)	283,659	11,344	8.922	48,054	4,757
2005/06	Area (ha)	78,510	4,995	4,602	3,944	3,809
	Yield (ton/ha)	3.90	2.60	1.91	12.28	1.40
	Production (ton)	306,115	12,988	8,785	48,456	5,323

Source: Alaotra-MangoroDRDR

Though the yield of paddy is gradually increasing from 2.96tons/ha in 2001/02 to 3.9 tons/ha in 2005/6, it remains low. As mentioned previously, MK rice variety is the major one in the Study area and has as potential yield of 9ton/ha. The causes of the low rice yield are considered as follows.

Among causes, the most serious cause is the delay of seeding on the seedbed because land preparation containing operation of puddling and leveling cannot be made before December due to water shortage. As the rice varieties have photosensitive characteristics, the best

seeding is at the beginning of December. However, seeding on nursery beds is carried out for three months from the beginning of December to the end of February at present. So the vegetative period becomes very short, which results in a low yield. The main causes of water shortage in December and January, is considered as follows: a) Recently, the beginning of the rainy season delays from a half of a month to one month in comparison with previously due to the effect of the recent climate change that occurred prominently from 1990's, b) A shortage of irrigation water because a lot of river waters are used in the paddy fields located in the upper stream of the PC23 area, c) A shortage of irrigation water due to deterioration of irrigation, d) A delay of land operation of puddling and leveling due to lack of animal and mechanical power.

In addition to the delay in seeding, the causes of the low paddy yield are (i) deterioration of paddy seeds, (ii) problems of land leveling, (iii) problems of pests and diseases, (iv) poor internal drainage due to improper drainage system, (v) poor management due to shortage of farming costs, (vi) shortage of farm labor force and (vii) poor agricultural support services. Such as multiplication of certified seed, development and extension of appropriate paddy farming technology, etc.

3.4.4 Agricultural support services

(1) Agricultural government services

The Alaotra Mangoro DRDR office is structured as shown in Fig. 3.4. It consists of 9 divisions composed of (i) Agriculture, (ii) livestock, (iii) fisheries and fresh water resource, (iv) livestock hygiene and veterinary, (v) land registration, (vi) Technical services, (vii) planning and monitoring, (viii) agricultural civil engineering and (ix) general affairs, a 3-branch office for agricultural development at Andilamena, Amparafavavola and Moramanga, a branch office for surveying and a 2-branch office for land registration in Anbatondrazaka and Moramanga. The total prescribed number of staff in the Alaotra Mangoro DRDR office is 210 comprising 27-technical professional officers, 108-technicians, 85-administrative staff. Among those, the positions of 13-technical professionals and 40-technicians are vacant at present. According to the decentralization power policy, the MAEP liquidated the existing local government organization and reorganized DRDR. At the same time, the MAEP revised the existing system for agricultural extension services, and introduced a technical support system on the basis of an on-demand system. As a result, the treatment for the land registration procedure that has taken a long time in the past is being improved by assistance of the donors.

(2) Agricultural research services

The Central-Eastern regional agricultural research center that is located at FOFIFA, Ambohitsilazozana district in the eastern area of the lake Alaotra was one of the 7 regional agricultural research centers established in the French period based on the agricultural

ecological zones. It is making an endeavor to conduct the field of the research studies on food crops, paddy production in the low lying land and a mixed agricultural system with livestock rising on hilly areas (Tanety). The staff of this research center are composed of 6 professional staff, a social scientist, a farming system expert, an entomologist and agronomists, and 25 assistants and administrative staff. The total area of this research is 342 ha. The experimental farm is installed by irrigation facilities. The causes for activities of research studies are considered as follows; (i) shortage of staff necessary for research studies on river basin management and livestock, (ii) no extension service on agricultural proper technology to local farmers owing to no linkage between research and extension works after PNVA, (iii) deterioration of the irrigation facilities of the experimental farm, (iv) deterioration of agricultural machinery and (v) no communication facilities to outsides.

(3) Seed multiplication service

The Anosyboribory seed multiplication center (CMS : *Centre Multiplicateur de Semences*) established 1982, July is the largest seed center that produces paddy seeds. It is under the control of Director General of Agriculture, MAEP. CMS carries (i) paddy multiplication works using No.2 and No.3 irrigation block, (ii) make fruit/flower seedlings in the farm and (iii) produce fries of freshwater fishes in the hatching ponds. The total farm land is 544ha. CMS plays an important role in supply of the improved varieties of paddy, horticultural crops, freshwater fishes and agricultural materials to the Study are as well the central and coastal areas for increasing agricultural production. CMS has been managed under a self-supporting accounting system since 1987. However, CMS continues to be in the red because the main revenue from sale of certified seeds was less than that of operation cost of CMS. Then, a scrutiny study that CMS should be leased to the private sector for a long time was carried out, however, operation of CMS is now continuing under the control of MAEP. The causes of the deficit of budget are considered: (i) a substantial rise of farm inputs such as fertilizer and fuel and (ii) deterioration of agricultural machineries, (iii) low production yield of seeds due to shortage of irrigation water and (iv) low production yield of seed owing land leveling problems

(4) Agricultural training service

The agricultural training service center established （CAF : *Centre d'Appui et Formation*） in 1930's is operated as an independent organization in charge of the training for agriculture and livestock sector under the control of the MAEP. The training programs contain pig raising, poultry raising for egg production, apiculture, vegetable cultivation and general agriculture. The training for farmer's lectures is made based on the programs that lectures want. Charge for training is free except the cost of meals and the accommodation for lecture facilities are available.

(5) Rural credit services

In the Alaotra Mangoro region, there are 2 banks of BNI-CA (*Banque Nationale pour l'Institute - Credit Agricole*) and BOA (*Bank of Africa*) that provide mainly the capital funds of the agricultural credit with the mutual credit cooperatives such as OTIV and CECAM as well as give credit services to the local farmers. On the other hand, OTIVO and CECAM provide the small scaled agricultural credit services with the local farmers.

OTIV started to operate credit services in 1994 in the Alaotra Mangoro. It has a head office at Anbatondrazaka and 11 branch offices under a self-supporting accounting system. In the Study area, there is a branch office at Bejofo, Moraran Chrome and Ambohimandros to where the farmers are able to most easily access. OTIV gives a small scaled credit services to 6 kinds of credit services such as farming, agricultural machineries, cooperative warehouse for grains, commercial affairs, O&M cost for facilities and craft works for women. The financial report of OTIV in 2004 shows below: (i) the total number of customers is 14,000 or 1.5times of those in 2000, (ii) capital: MGA 9 million, (iii) the balance of the account: MGA 29.4 million, (iv) the number of credits for lending: 2,654, (v) the total annual loan repayment: MGA 26.6 million, (vi) the total number of delinquent cases: 186, the total annual delinquent repayments: MGA 1.4 million, (vii) a delinquent rate of repayment: 5%. Though the total number of a nonperforming loans and their amount became 1,600 and MGA 47.7 million at the peak period, respectively, these conditions have been improved. Afterwards, the number of customers and the amount of credit for lending increased to 6,327 and MGA 60.8 in 2006, respectively. At present, an annual interest rate is applied to 5% for the customers who deposit less than MAG 500, 000, 1% for more than MGA 500,000 and 2% for more than MGA one million. A monthly loan rate for the customers is 3% and 2% for the customers having a bank account. Since a monthly loan rate for the customers is reduced to 0.5% because an interest subsidy generated by the collateral funds from the Japanese Government, the number of customers who use a small scale loan increased 30% from the previous figure.

Since May 2003, ECAM has commenced banking work in the Alaotra Mangoro region. It was established at Anbatondrazaka, PC15, Morarano Chrome, Ampafaparavora, Tanabe and Ambohitororibo. It especially provides small scale credit services for the agricultural sector consisting of agricultural machinery, cooperative paddy banks and paddy cultivation. The loan conditions are (i) 3%/month for 60% of the total farm input cost at a maximum, (ii) 2.5%/month for 80% of the total cost of agricultural machinery at a maximum, (iii) 3.3%/month for 75% of the market price of the paddy amount for cooperative paddy banks. As of the end of 2006, the total number of customers is 3,729 that increases 10 times for these 3 years. The balance of the account (MGA 92 million) increased 2.3 times for these 3 years. Since the monthly loan rate for the customers is reduced to 0.5% in 2006 because an interest subsidy generated by the collateral funds from the Japanese Government, the

number of loans and the total loan amount are 2,836 (2 times of that in 2005) and MGA 25.5 million (1.7 times of that in 2005), respectively. Especially, a loan for agricultural machinery prominently increased and occupied about 53% for the loan number and 41% for the loan amount.

BOA merged by 2 national banks according the privatization policy of the Government operates at 3 branch offices in Anbatondrazaka, Anpalafalavola and Tanabe. It provides a small scale credit service for farming, agricultural machinery and cooperative paddy warehouses in the agricultural sector. The credit services are limited to the customers who have a transaction track record or sufficient capability to pass an investigation. Loan conditions for farming of loan amount and rate are determined for an individual farmer of group (more than 7 members) based on the results of investigation regarding their capability of buying farming inputs and hired laborer's cost by themselves. The loan condition for agricultural machineries is: (i) an interest rate: 20-22%/year, (2) repayment period: within 5 years and (iii) loan amount: less than 80% for requested loan from the customers. The loan services for cooperative paddy warehouses are limited to the farmer's cooperative group that has a warehouse. The loan conditions are determined based on a paddy price of MGA 200/kg for the total paddy amount to be stored. Recently, the number of loans and the total loan amount is 99 and MGA 2.8 million.

BNI is the commercial bank that was made by joint investment of the Government of Madagascar and the private local subsidiary having French capital. It started to operate a small scale credit service for the agricultural sector at the branch office at Anbatondrazaka, however, there is no big performance of credit services during the current year..

In additions to those small scale credit services to the local farmers, a large scale development fund that deals with the whole country is invested to the Study area. PSDR that was established in June 2001 is the development funs of which funds, US$ 89 million, is provided by the World Bank. The purposes of PSDR are shown as follows:

1) to increase income of small scale farmers by means of agricultural productivity improvement
2) to train and development agricultural farmer organizations such as agricultural cooperative
3) to conserve the national resources and to reduce poverty in rural area.

PSDR provides grant credit services for activities of the rural development sector that accord with the above purposes.

1) activities for reinforcement of agricultural production
2) agricultural extension and training services for technical transfer to the local farmers

3) competitive applied research program, provision of a scholarship for the master's grade papers regarding to the cooperative regional development program by FOFIFA and FIFAMANOR (Centre de development rural et de recherché appliqué issu d'un project de cooperation bilaterale entre la Norvège et Madagascar), activities to strengthen agricultural cooperative groups and farmers groups

The conditions of application to PSDR's credit services are shown as follows; GTDR (*Groupes de travail de developpements reginaux*) is in charge of assistance of loan applicant form, evaluation of loan applicant and so forth.

1) An applicant deposits 10% of the annual revenue during the past 5 years

2) An agricultural group should have 10 households at least and be formed by cooperative organization.

3) An applicant should levy about 15% of credit amount requested to PSDR fund.

FID (*Fonds d'Intervention pour Développement*) operates by the World Bank funds under control of the Alaotra Mangoro DRDR office. It specifies to provide loan services for the social infrastructure sector such as the construction of medical offices and schools at the beginning. Afterwards construction of ponds for irrigation and rural roads and operation/maintenance costs are added to the services of FOD. FID fund is under the control of Alaotra Mangoro DRDR office. An applicant should have a corporation that has more than 12 members at least.

3.4.5 Problems and their causes for agriculture

Agricultural problems and their causes are shown below;

Table 3.4.2 Agricultural problems and their causes

zone	problems	Causes of problems
PC23area (irrigated area)	Delay of plowing/puddling	Shortage of farming emblems and draft animals
	Delay of seeding on nursery bed	Change of starting time of rainy season due to climate change, shortage of irrigation water during plowing and puddling
	Deterioration of quality of paddy seed	Difficult access to seed center and seed shops, delay of replacement of self-made paddy seed
	Differential operation of paddy culture due to various conditions of irrigation, drainage and fields	Poor drainage condition of paddy field due to poor land leveling condition
	Difficult operation for application of pests and diseases	Difficult access to paddy field during rainy season and high plant density
	Poor agricultural extension services	Shortage of governmental extension services
	Shortage of farming cost	Farmer's poor capacity to pay and difficult access to agricultural credit services
PC23area (rain fed area)	Shortage of irrigation water source	Poor development of irrigation facilities
	Serious risk for rainfed crops cultivation	No selection of proper varieties
Basins of Sahamilahy river, Sahabe river and 4 small/medium rivers	Delay of plowing/puddling	Shortage of farming implement and draft animals
	Difficult access to paddy field	Poor development of road system (Access to paddy field is brought to a standstill)
	Deterioration of quality of paddy seed	Difficult access to seed center and seed shops, delay of replacement of self-made paddy seed
	Poor technology for upland crops, vegetables and horticulture, farmer's indifference for soil conservation technology	Shortage of governmental extension services
	Shortage of farming cost	Farmer's poor capacity to pay and difficult access to agricultural credit services
	Difficult access to markets	Lack of transportation means and a rise of transportation fee
All Study area	Delay of development of paddy seeds having early and medium ripening characteristics and upland rice varieties with drought and wet resistance	Shortage of governmental extension services

Source: JICA study team

3.5 Livestock

3.5.1 General

The main livestock in the Study area is cattle. In addition, swine, sheep, equine, fowl, geese, duck, turkey, and rabbit are bred on a small scale. The total number of cattle is about 37,000 heads and has not been increasing.

According to a detailed village survey conducted by JICA study team, the number of cattle

per household ranges from 0 to 60 and averages 4.4 heads. However, it is estimated that 42 % of the farmers in the Study area have no cattle and 55% occupy less than 2 heads of cattle. Such situations bring about a shortage of draft animals, which results in taking long time for land preparation for paddy cultivation. As a result, transplanting of paddy cannot be performed at the optimum time and that becomes one of the most serious causes on decreasing paddy yield. The farmers in the Study area customarily consider that cattle are raised firstly for use of draft animal power and transportation means, and secondly as social status. They are not concerned with raising cattle for milk production. In such a situation, they play an important role in the provision of meat to the people in the Study area. On the other hand, it is expected that the population increases year by year with about a 3% population increase rate and beef demand will be also required.

The decline in cattle numbers may be led by frequent cattle robberies and traditional cattle sacrifices in cases of funeral ceremonies or marriages. Low reproductive performance of cattle led from poor nutritive grasses in grazing pastures may also cause this decreasing rate as calving interval prolongs

The number of livestock except cattle is estimated to be about 6,000-swine and 0.9 million poultry in both Ambatondrazaka and Amparafaravola districts relevant to the Study area.

Outbreak of African Swine Fever (ASF) in 1999 spread rapidly and brought disastrous economic damage to the swine industry. The number of swine drastically decreases and remains at the same condition at present.

Sheep are the latest animal to be introduced in the Study areas recently. Since the swine industry was hugely damaged by ASF, people have started sheep breeding instead of swine because of its low mortality rate. There are no large scale poultry farms in the Study area. Since farmers extensively rear fowl, geese and duck around the village houses, the yield of their production of meat and eggs is low. The income from poultry rising is very small.

Because at present there are few livestock projects that easily provide appropriate profit. Farm income of the farmers who has a small scale of paddy field and/or cannot conduct appropriate land use, is small. In order to raise income, it is necessary to consider income sources diversification.

3.5.2 Pasture land farming system

Grazing in Study area is basically an extensive method. Incentive raising of cattle is seldom performed. Grazing is conducted around residential areas and in places with suitable grasses such of paddy after harvesting till rice-planting, ridges, road sides and riverbed and is not conducted in harvesting areas or privately owned areas. Grazing type is one day distance that starts grazing in the morning and returns in the evening. The distance of grazing is about 10km. During February to the end of May, grazing is practiced in Kizana areas (pasture land)

that are owned by individuals and blood relation groups

3.5.3 Grazing land and carrying capacity of grazing areas to keep cattle

In the African continent, TAU is used for feeding management and the idea of TAU is as follows:

- Body weight of 250 kg estimates as one (1) TAU
- 1TAU needs 8 kg of Dry Matter (DM) per day

In the Study area, most cattle is Zebu which has a hump on the back , low milk production of 4 liters per day maximum、350 – 400kg of body weight in adult and small body size. Contained from small calves, young calves, heifers , cows、oxen and bulls, we estimate the average of cattle in weight in the Study area is 300 kg. The method to calculate the demand of fodder is:

(300 ÷ 250 ＝ 1.2 TAU)	the unit of one cattle
(1.2 TAU x 8kg ＝ 9.6 kg)	one day requirement of one cattle
(9.6 kg x 365day＝4,088 kg)	total demand of fodder in the are

Since one cattle needs about 4 tons of fodder per year and total cattle in the area is 160,000 heads in Ambatondrazaka and Amfarafaravola districts relevant to the Study area, total requirement of fodder supply is 640,000 tons. On the other hand, 280,000 tons of paddy as well as 340,000 tons of straw are produced in both districts. As a result, required fodder supply from rice straw in the Study area is about 50 %. Fodder supply is 40% from grasses such of ridges, road sides and riverbed.

3.5.4 Balance of fodder supply and fodder consumption

At present, supply of DM seems to be enough but the essential levels of crude protein (CP) is very low in rice straw. It needs to add more protein in fodder component or to provide protein- enriched fodder.

The ingredients of rice straw are 873 g of dry matter (DM), 32 g of crude protein (CP) and 395g of Total Digestive Nutrients (TDN) per 1 kg. Since cattle of 300 kg in weight needs 8 kg of DM, 735 g of CP, 4.2 kg of TDN and 0.175 of the ratio of CP/TDN. The ingredients of rice straw in 9 kg of weight contains 8 kg of DM, 299 g of CP, 3.6 kg of TDN and 0.08 of the ratio of CP/TDN. Requirement of nutritive element for body maintenance is as follows;

Table 3.5.1 Balance of fodder supply and fodder consuming

Body weight 300 kg	DM	CP	TDN	Ratio of CP/TDN
requirement	8.0 kg	735 g	4.2 kg	0.175
Supply	7.9 kg	288 g	3.5 kg	0.08
balance	-0.1 kg	-447 g	-0.7 kg	-0.095

Source: JICA study team

Ground-nut hey has high concentration of CP and is available in the Study area. Although it is the crop residue after its harvesting and, therefore is impossible to supply during the year, the necessity is clear for planting of fodder trees, forages or/and fodder crops.

Although the above mentioned calculation is just for maintenance requirement, it should add excess requirement amounts in cases of productivity activities, labors, pregnant and etc.

3.5.5 Problems and causes of problems for livestock sector

Problems and causes of problems for livestock sector are shown as follow;

Table3.5.2 Problems and causes of problems for livestock sector

Zone	Problems	Causes of problems
Study area	The number of livestock, especially cattle is not increased.	Poor nutritive grasses and shires in grazing lands, frequent cattle robberies, traditional cattle sacrifices in cases of funeral ceremonies or marriages, high maturity of calves
Study area	Low income of farmers	Because there are not proper technical services by the Government and credit services, income diversification including livestock sector is not considered.

Source:JICA study team

3.6 Inland fisheries

The area around the lake of Alaotra is the largest area for inland fishery production in Madagascar. There are about 10,000 people consisting of full-time fishery men, fishery men in farming, men in aquaculture, middleman, retailers and men involved in processing activity. They enter the fishery cooperatives that were established basically on the basis of village units. The member of the cooperative pays MGA 2,400 to the office of the fishery section of Alaotra Mangoro DRDR to get an official registration card for fishery work activity. At present the total number of the cooperatives is 289. The total number of the members is 10,263 consisting of 7,726 -fishery man, 61-acuaculture man and 2,476-men engaged in market and processing work. There is one established federation of the fishery cooperatives in lake Alaotra that is affiliated with 4 regional fishery federations. Funds for activities depend on the carrying out fee of fisheries at a rate of MGA 100/kg for each cooperative and annual fee of MGA 4,000 from each cooperative and a refund of MGA 1,000 at each official registration cardegional federation.

The area of lake Alaotra annually changes due to rainfall, which affects annual production of fisheries. Moreover, production of fisheries has been apt to decrease due to reckless fishing for a long time. Then, the government made a rule to annually prohibit fishing during one month around November and tried to recover fishery resources. It is forecasted that fishing in the lake of Alaotra and swampy area along the lake is more strictly controlled for the conservation of the swamp areas registered in the Ramsar Convention. The present illegal fishing in the irrigation and drainage canals will be controlled after rehabilitation of irrigation

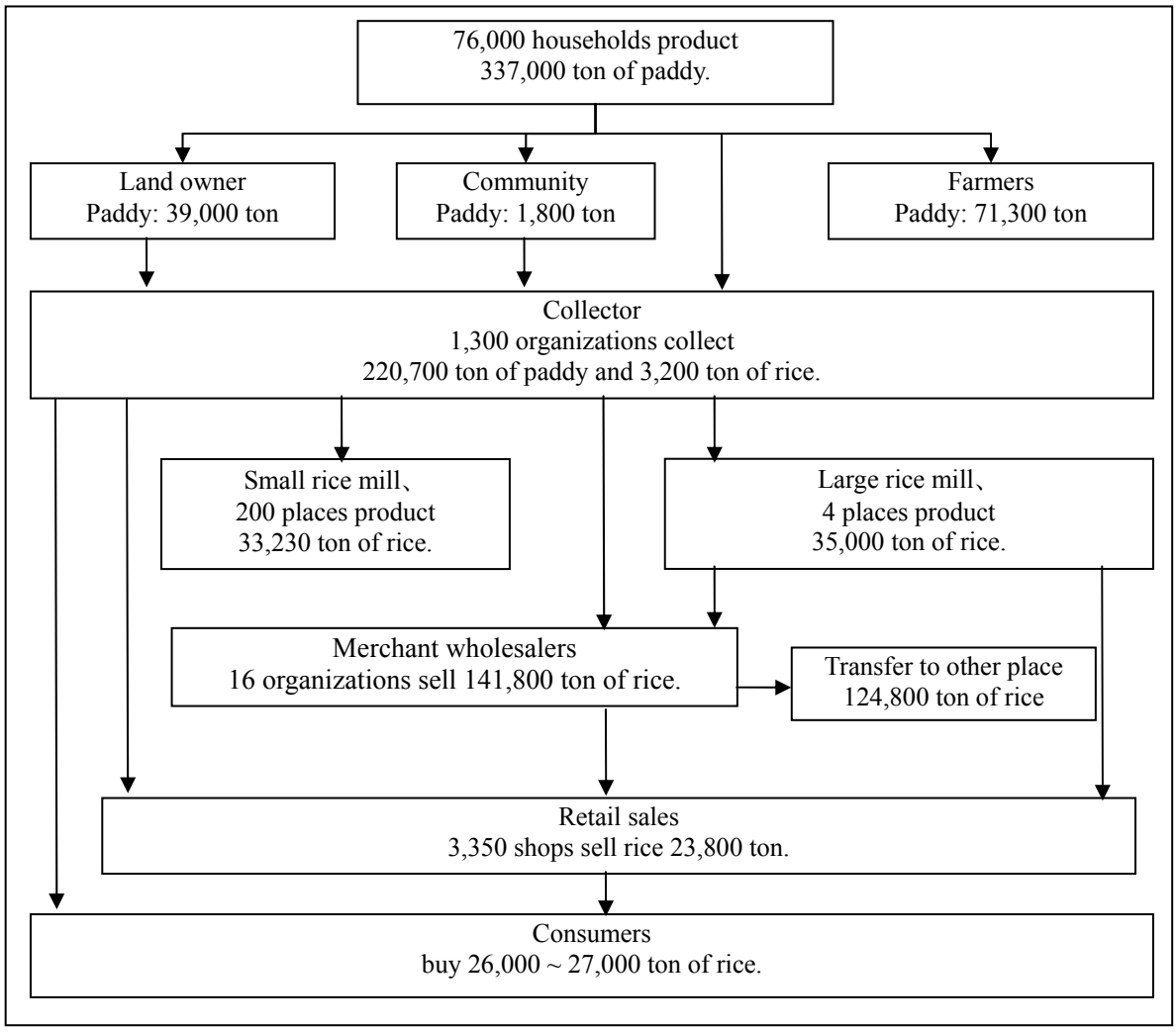
and drainage facilities. In such a situation, aquacultures of tilapia and royal carp were introduced. However technology transfer of fish culture, the management on fish ponds and the government support services are not sufficient and about 70% of fishery men engaged in aquaculture gave up continuing this. It is essential that technical support systems should be established.

3.7 Post harvest and market

3.7.1 Present post harvest

(1) Paddy post harvest practices and handling

Harvesting starts at the middle of May and continues up to the end of July. After harvesting paddy, it is dried on the paddy field for several days and is piled up. Afterwards, threshing is done in the field when man power is available. Threshing is done by treading by cattle for 75% of the paddy, by treading by tractors for 15% of paddy and by beating by hand for 10% of paddy. Plastic sheets are laid in the manual threshing and 30% of threshing by tractors and cattle to save losses. Remaining panicles in the stalks are stripped off by comb-shaped tools. According to the FAO/UPDR study, post harvest losses are low of 2.1% in reaping, hauling and threshing, and 2.4% in transport and storage of rice. Cleaning is done by natural wind. It is considered that there are no serious problems in post harvesting practices and handling.



Source: Analysis of rice market in the Alaotra lake region,
April 2000, FAO / UPDR

Figure 3.7.1 Market condition of Paddy and Rice in Alaotra lake region in 1999

(2) Rice milling conditions

Mortars are used by farmers for milling of paddy for home consumption in the Study area. There are 56 rice mills of which 88% is located in Morarano Chrome and Abmatomainty communes. Small rice mill is operated by generators and the total milling capacity is estimated to be 92,000 ton/year. However, there is no electricity in the remote area and no rice mil is available. Rice milling by mortars is carried out by women in the remote area or farmers in the remote area bringing paddy by an oxcart and/or a bicycle to the rice mills in Morarano Chrome and Abmatomainty communes. Rice milling action requires a long time and a very heavy work load. Moreover, the sale of rice in the form of paddy gives less profit than rice to farmers.

On the other hand, the large scale rice mill was constructed in Vohidiara located 10km south of the Study area. Operation of the mill was started by the food complex company (TIKO) with Madagascar private capital in July 2006. It has silos consisting of 10 units with 2,000

tons and 5 units of 1,500 ton. The maximum storage capacity is 27,500 tons. The milling capacity is 4 tons/hour. TIKO has an own paddy field of 5,000ha near the rice mill site and produces paddy. In addition, it collects paddy from the farmers in the basin of the lake of Alaotra and does not compete with the existing small rice mills on collection of paddy.

3.7.2 Market and prices

(1) Marketing channel of rice

The Alaotra lake region, which includes districts of Ambatondrazaka, Amparafaravola, Andilamena and Moramanga, is a kind of enclave isolated by mountains and limited access roads. Roads such as in PC23 are impassible in the rainy season. Even the trunk roads such as No.44 are not all-weathered and the transportation cost of surplus paddy produced in the basin of the lake of Alaotra to Moramanga is expensive.

Based on the study on the rice market that was conducted by FAO in 1999 I, the rice market in the lake of Alaotra is illustrated in Figure 3.7.1. This table indicates that 20% (71,300 tons of paddy) of the total production of paddy in the basin of the lake of Alaotra is consumed by farmers in the area and the remainder (80% or 192,500 tons of paddy) is marketed. Among the marketed paddy, 124,800 tons of rice (192,500 tons of paddy or 57% of the total production of the basin) is shipped to the urban areas such as Antananarivo and Toamasina. The remainder is consumed by non-farmers in the Alaotra basin.

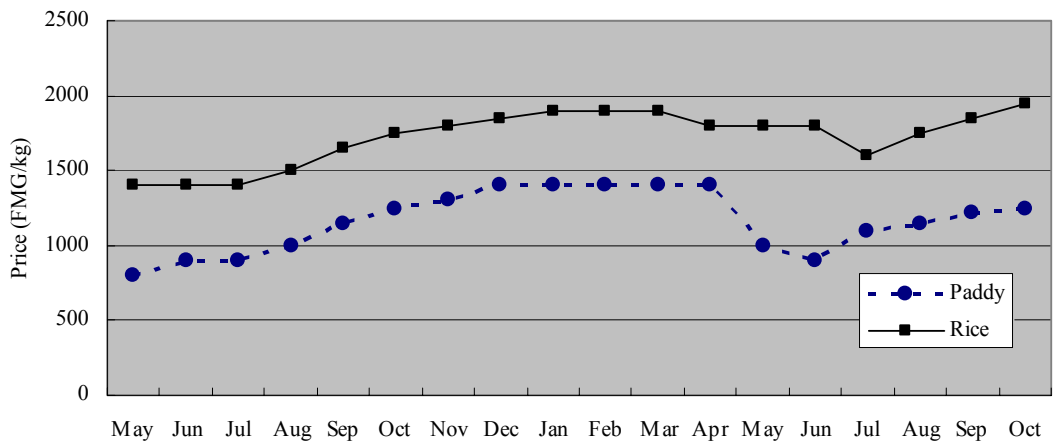
Since TIKO, however, dealt with the rice amount of 40,000 tons in 2006, the present rice market channel will be expected to become double-tracking. While the farmers will have an opportunity due to higher farm gate prices of rice and reduction of transportation costs to rice mills by the effect of the competitive principle, sale of paddy with a higher price will require a high quality of paddy for the farmers.

(2) Rice price

The monthly changes of paddy/rice prices given by a collector in Ambatondrazaka from May 2002 to October 2003 are shown in Figure 3.7.2. The prices show these of mixed varieties. In the local markets quality in rice has not so much significance in price difference. The price difference between head rice and broken rice in MK34 variety is only 25FMG/kg. So, most rice mills mix a different quality of rice. Both prices are lower in the paddy-harvesting season from May to July and are higher in the lean period from December to April. The paddy price increased to 1,400 MGA/kg in January 2003 from 800 MGA/kg in May 2002, which was equivalent to 75% increase. The corresponding increase in prices of white rice was 36%. Afterwards the price of white rice in the lean period of January is MGA 1,000/kg in 2004, MGA 600/kg and MGA and MGA 420/kg in 2006. The price fluctuation is very high.

The price of paddy that was purchased by the small rice millers at the harvest season in 2006

was fixed as MGA 380/kg (US$ 0.20/kg), whatever the quality of paddy and rice varieties are, under the conditions of (i) rice producers should take paddy to the rice millers and (ii) the miller should pay cash. On the other hand, TIKO paid MGA 420/kg by cheque to farmers at TIKO office after 4 days that TIOKO collected paddy. Also TIKO paid MGA 400/kg at maximum and adjusted the price taking into consideration the moisture content of paddy and content of an impurity by cash in the case that rice producers bring paddy to the TIKO rice mill site.



	2002								2003									
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Paddy	800	900	900	1000	1150	1250	1300	1400	1400	1400	1400	1400	1000	900	1100	1150	1225	1250
Rice	1400	1400	1400	1500	1650	1750	1800	1850	1900	1900	1900	1800	1800	1800	1600	1750	1850	1950

Source: JICA study team

Figure 3.7.2 Market rice of paddy and rice at Amvatondrazaka

However poor farmers are obliged to sell their paddy at lower prices at the beginning of the harvesting season in order to repay loans and to get cash for livelihood.

3.7.3 Market information system

There are no systematic agricultural market information services for farmers. Radio and television stations sometimes broadcast sporadically market information on agriculture as news. Farmers can get some agricultural market information in the local markets. The market information services by agricultural extension workers to farmers fortnightly through the T&V system was ceased in 1999. All the DRDR offices monitor the market price of the major agricultural commodities weekly at the main markets and send it to the statistical office in the Ministry of Agriculture at Antananarivo. Also the regional offices of the Ministry of Health monitor and send agricultural commodity price at communes to the statistical office. However, it is very difficult for farmers in the Study area to receive price information due to no communication means and they are obliged to believe the price of the middlemen.

3.7.4 Problems and causes of problems for post harvesting and market sector

Problems and causes of problems for post harvesting and the market sector are shown as follows;

Table 3.7.1 Problems and causes of problems for post harvesting and market sector

Zone	Problems	Causes of problems
All Study area	Lack of agricultural market information	Since farmers get no information except some agricultural market information in the local markets, farmers are obliged to transact with middle men at prices that they propose and do not receive proper profit.
All Study area	No advantageous income of paddy in lean periods	Farmers are obliged to sell most of their paddy at lower prices at the beginning of the harvesting season in order to repay loans and to get cash for their livelihood and are not able to sell paddy in lean periods when the paddy price increases 1.4 times the harvesting time
Sahabe river basin	Shortage of rice mill	Heavy work load of women caused by rice milling by mortars, heavy works of transportation of paddy to the rice mill at Morarano Chrome and Abmatomainty, loss of time, disadvantage of profit for sale in the form of paddy

Source: JICA study team

3.8 Irrigation

3.8.1 Irrigation areas around PC23 irrigation area

There are 14 irrigation systems including PC23 area in the basin of the lake of Alaotra as shown in Table3.8.1. The total of these irrigation systems is about 40,000ha in gross. Among them, 8 systems are installed with dam/reservoir function as irrigation water sources. The agricultural engineering section in the Alaotra Mangoro DRDR office controls all the irrigation systems. Regarding operation and maintenance for 2 irrigation system, the Ambatondrazaka branch office manages 2 irrigation offices for Ambatondrazaka and PC15 system and the Amfarafaravola branch office manages 4 irrigation systems of PC23, Sahamaloto, Anony and Anaiafo.

Table 3.8.1 General features of irrigation systems around PC23 area

Name of irrigation system	Irrigation area (gross, ha)	Type of water source	Intake discharge (m^3/sec.)	River Source	Note (V=Storage capacity)
Andranobe	(750)	R + G	1.15	Andranobe	V=10.0Mm^3
Morafeno	(450)	R + G	0.7	Morafeno	V=6.4 Mm^3
Anony	7,700	R + G	11.7	Anoy	V=40.0 Mm^3
Sahamaloto	6,403	2 R + G	2.0	Sahame	V(2R)=62.0 Mm^3
Sahamamy	(500)	R + G	0.8	Sahamamy	V=2.3 Mm^3
Ivakaka	2,669	R + G	3.0	Ivakaka	V=39.0 Mm^3
Imamba		G	1.33	Imamba	-
Ranofotsy	(650)	R + G	1.0	Maningoro Ranofotsy Ansahamaroloha	V=54.0 Mm^3
PC15	2,800	R + G	4.0	Sasamangaha	V=22.3 Mm^3
Ambohimasina	(350)	G	0.5	Harabe	-
Andingadingana	(200)	G	0.3	Andranobe	-
Mangalaza	(50)	G	0.1	Analaboahangy	-
Manamontana	(900)	G	1.4	Manamontana	-

Name of irrigation system	Irrigation area (gross, ha)	Type of water source	Intake discharge (m^3/sec.)	River Source	Note (V=Storage capacity)
Total (13 area)	23,422	R+G; 8 G; 5	27.98		V total=236.0 Mm^3

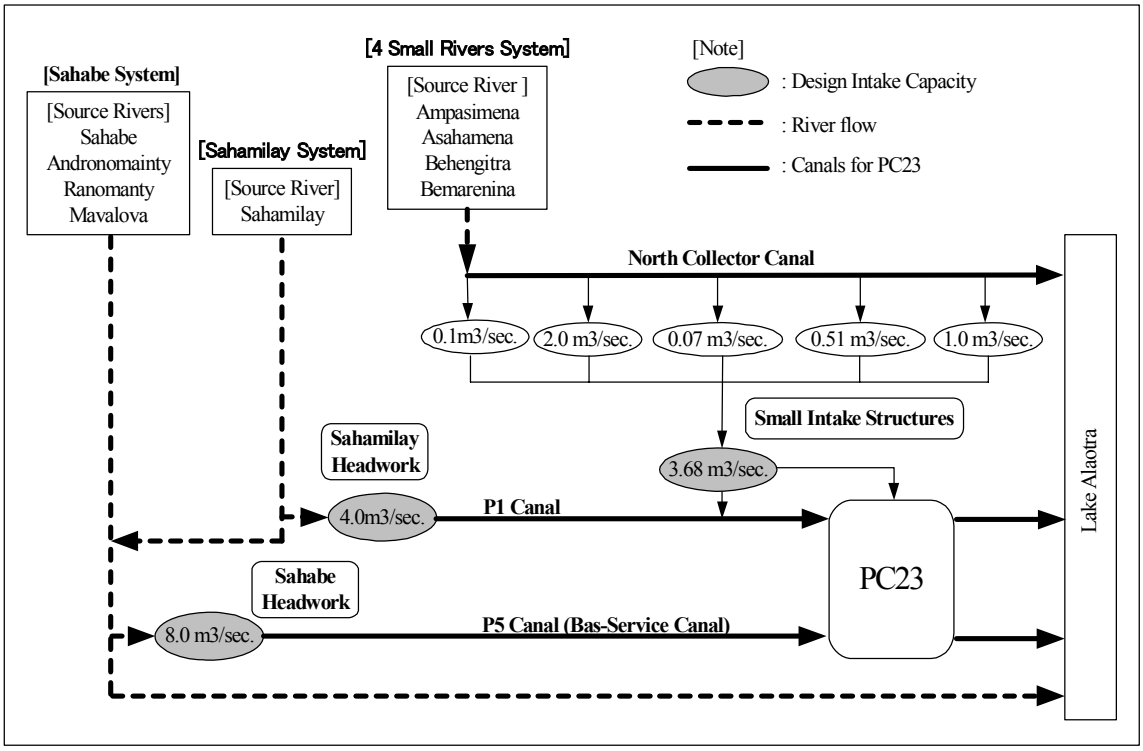
Source：Lemak' Alaotra, May 1994, CIRGR Ambantondrazaka
Remarks: irrigation ares in ( ) are estimated.' Gravity ' is the natural river flow as water source, R: reservoir, G: River water

3.8.2 Irrigation and drainage in PC23 area

(1) Water sources and intake system

There are three major water sources for irrigation in the PC23 area; (a) the Sahabe river and its three major tributaries (the Andronomainty, the Ranomanty, and the Mavalova), (b) the Sahamilay river, and (c) four small rivers flowing into Lake Alaotra from the western hilly areas (the Ampasimena, the Asahamena, the Behengitra, and Bemarenina). Since the PC23 irrigation scheme has no reservoir in the catchment area of source rivers for regulating river runoff, the available water for irrigation seasonally fluctuates in accordance with the hydrological characteristics of the source river. The intake system of the PC23 consists of (a) Sahabe temporary headwork, (b) Sahamilay permanent headwork, and (c) small intake structures provided on the North Collector Canal and P5 Canal.

The Sahabe temporary headwork is located in 100 m downstream of river crossing bridges of National Road No.3a and railway. The headwork is a temporary structure consisting of a low concrete weir with three flush gates and bank protection work by using sheet piles. Since no intake structure is provided, irrigation water is taken in the manner of "free intake" by gravity. The Sahamilay headwork located in 2.5 km north-west of the Sahabe headwork consists of a submerged type bridge-weir and modern intake structures for regulating intake water discharge and sand flushing. The irrigation water is also taken by gravity in the Sahamilay intake system. Regards the intake system on 4 small rivers, the river runoff is firstly collected by the North Collector Canal provided outside of the P5 Main Canal. Then irrigation water is taken through the P5 or directly from the North Collector Canal to the irrigation area of PC23. A schematic diagram of the intake system with the design intake discharge of each intake system is shown below.



Source: JICA study team

Figure 3.8.1 Schematic diagram of intake system for PC23 area

(2) Irrigation area in and around PC23 Area

As a result of the estimation, the extent of total net irrigation area in PC23 is 9,870 ha and 3,500 ha in the upstream areas of the source rivers. Out of 9,870 ha of net irrigation area in PC23, the land of 5,300 ha is commanded by the Sahamilaly intake system combined with 4 small river intake systems and that of 4,570 ha is commanded by Sahabe intake system.

(3) Irrigation and drainage canal system in PC23 area

The irrigation and drainage system in the PC23 area is illustrated on Fig. 3.5 The irrigation and drainage canal system of PC23 comprises (a) two main canals; P1 Canal and P5 Canal (Main Service Canal), (b) ten secondary canal groups with subordinate tertiary canals, (c) field canals and small ditches, (d) five main drains with subordinate tertiary canals, (e) field drains, (f) two catch drains provided in the lower end of the C23 area; South Drain and North Drain, and (g) North Collector Canal (Collecteur Nord) running outside of P5 Canal. The canals are well aligned for separating irrigation and drainage functions and no dual-purposes canal is basically provided in the original canal layout. The main canals as well as the North Collector Canal and tertiary canals are generally aligned in parallel with contour lines and the secondary canals run along the land slope. The main drains are aligned along the land slope and a tertiary canal is provided for formulating a couple with the tertiary irrigation canal and for connecting with the parent drain. The field canals/ditches and field drains are basically provided in accordance with the topography in the manner of separate functions;

supplying canal and receiving canal.

All the canals provided in PC 23 are earth canals having a trapezoidal section as the original design. No lining of concrete or stone masonry is provided. The following table shows the estimated length of the canals and the details are shown in Table 3.4.

Table 3.8.2 Length of canals provided by for PC23 area

Irrigation canal		Drainage canal	
Grade of canal	Length (km)	Grade of canal	Length (km)
P1 canal P5 canal 10 secondary canal Tertiary canal	23.2 6.4 30.1 90.5	5 main drains Tertiary drains	49.8 127.3
Sub-total	150.2	Sub-total	177.1
North collector canal	10.5	2 collector drains 3 tertiary drains	6.6 14.3
Sub-total	10.5	Sub-total	20.9
Total	160.7	Total	198.0

Source: JICA study team

Because of low canal density, the plot to plot irrigation has been executed at present and the field canals/ditches and field drains are to be provided by farmers with complicated alignment

(4) Road network in PC23 area

The road network in PC23 is formulated mainly by the inspection roads running along the main and secondary irrigation canals and main drains. The length of main roads and secondary roads is 29.6 km and 34.9 km, respectively. There are two trunk roads; (a) Inspection road for P5 Canal connecting the villages Antanandava - Ambohidrany - Ambatomanga (south to north) and (b) the road along the D2 drain connecting the villages Ambaibo -Ambohidrany – Mahakary - Antsampananafatra (east - west). The inspection roads might be connected with the others and linked to the two trunk roads. The east - west trunk road connects with the National Road No.3a at Ambaiboho village. The inspection roads are unpaved on all the routes and the effective width of the roads except for two trunk roads is not enough for two cars /tractors passing. Because of unpaved and bumpy road surface, most of the inspection roads are impassable in the rainy season.

(5) Flood protection dike

The flood protection dike on the left bank of the Sahabe was constructed at the beginning of 1970s. The height of the dike is 2.5 t~3.0 m and the total length is 13.5 km. However, a big flood occurred owing to a localized downpour with total rain of 600 mm from the end of February to the beginning of March in 2005 which breached the dike at the meander in the end of the eastern of the PC23 area. The flood water flowed in the D0 main drains along the dike and brought about serious drainage problems for 2 months. At present, the breached

dike was improved by temporary means.

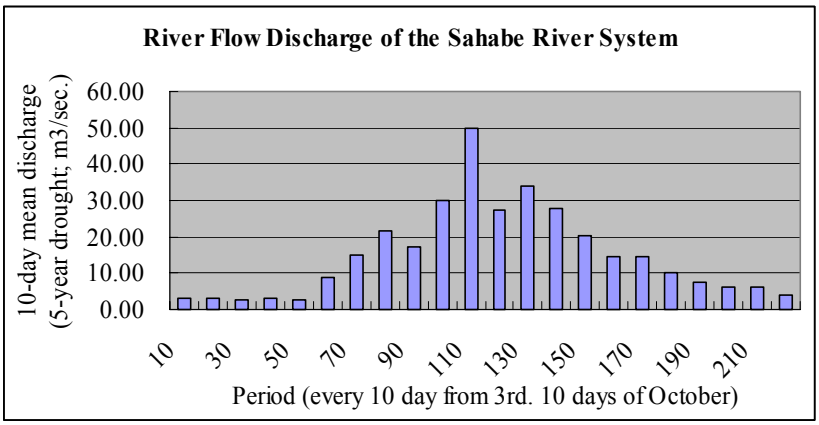
For protecting the western area of PC23 from annual floods of 4 small rivers; the Ampesimena, the Asahamena, the Behengitra, and Bemarenina, the embankment of the right bank of the North Collector Canal functions as the protection dike. The embankment is around 13.0 km long and the bank top is impassable due to insufficient width for vehicle passing and intake structures provided on the right bank

3.8.3 Present water distribution

(1) Basin-wide water distribution in the Study area

There exists irrigated lands of about 3,500 ha (net, total) in the upper catchment of the source rivers. An irrigated area of the PC23 of about 10,000 ha lies downstream of the upper irrigated lands. Farmers in the upper areas generally take the irrigation water for their paddy fields earlier than those in the PC23 area with the geomorphologic advantage in the basin-wide water distribution.

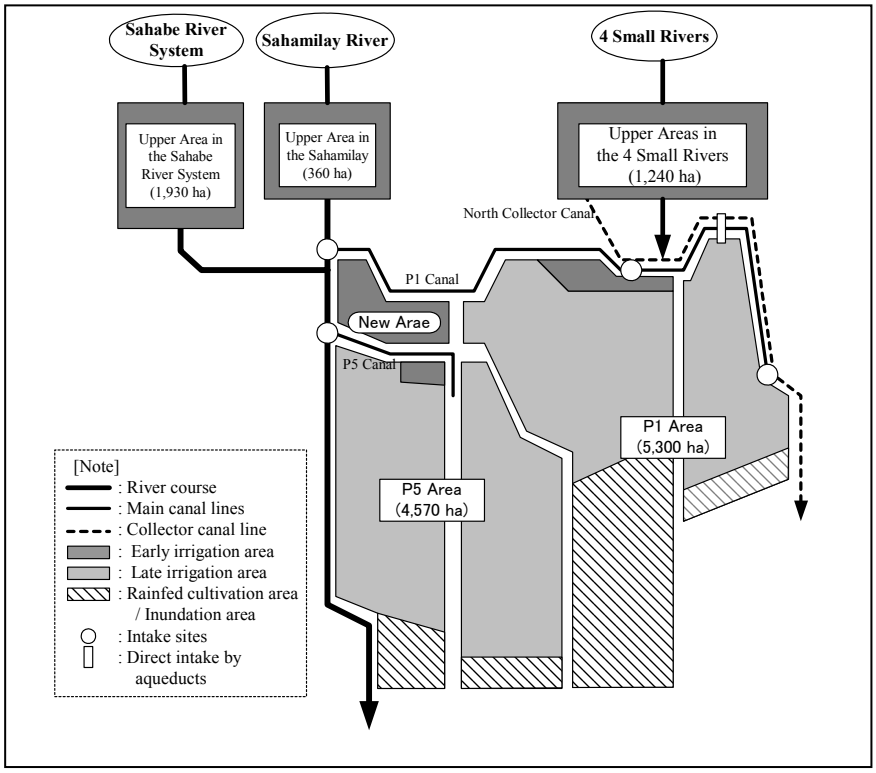
The 10-day mean discharger with 5-year drought for the Sahabe river system is shown in the following figure. The discharge at the commencement of irrigation in October and November is less than 5m^3/sec and afterwards increases up to 10.0m^3/sec at the end of December.



Source: JICA study team

Figure 3.8.2 River flow fluctuation of the Sahabe river system

From the viewpoint of available river discharge, paddy field in the upper stream of the Sahabe river system can be started from October to the beginning of December. As a result, irrigation water supply in the PC23 area located in the lower stream has to be commenced at the end of December. Then, commencement of irrigation water supply in the Study area is decided based on the conditions of hydrological features of the river and geophysical locations of paddy field. General area classification on commencement of irrigation activities is illustrated in the following figure.



Source: JICA study team

Figure 3.8.3 General area classification on commencement of irrigation activities

(2) Water distribution in PC23 canal system

The characteristics of the irrigation canal system in PC23 area is summarized below;

Table 3.8.3 Irrigation water distribution in canal hierarchy of PC23 area

Item	Main Canal (to Secondary)	Secondary Canal (to Tertiary)	Tertiary Canal (to sub-ordinates)
Water diversion	Measured distribution by gate on-off (Sluice gate)	Measured distribution by gate on-off (Module type gate)	Fixed (adjustable) discharge (Diversion box)
Measurement	Orifice (simple operation and low accuracy)	Module type gate (complicated operation and high accuracy)	No measurement
Rotation Irrigation	Gate on-off only (Very hard in low water period)	Possible on tertiary block basis	Very hard
Emergency for drought	Even distribution, Rotation impossible	Rotation possible within diverted water at main canal	Impossible

Source: JICA study team

The irrigation water diagram in PC23 is illustrated in the following figure.

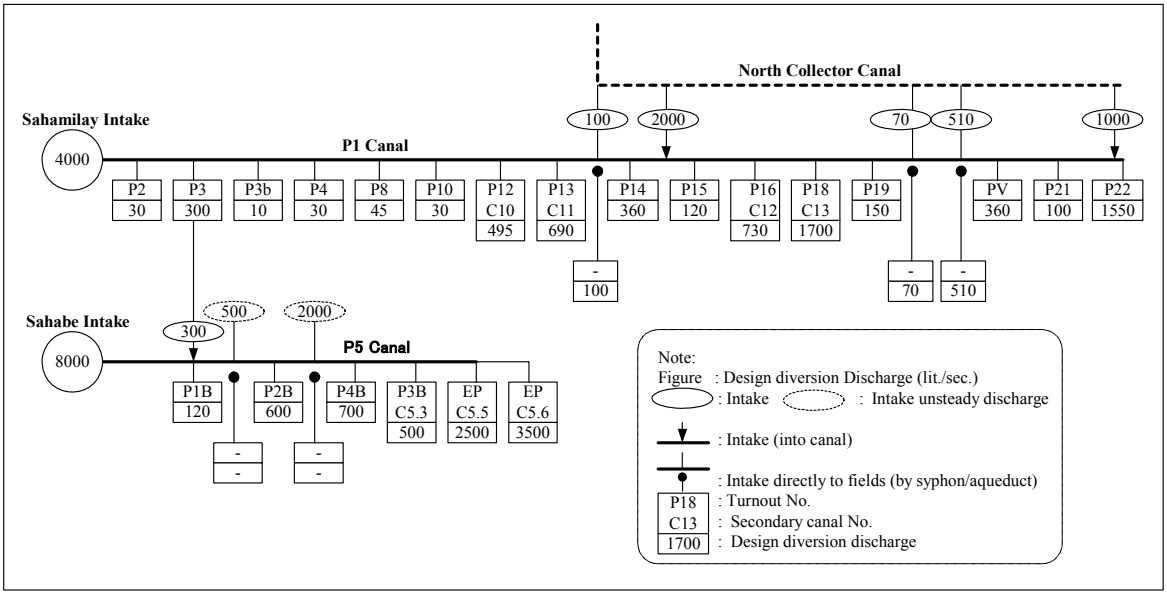


Figure 3.8.4 Irrigation water distribution (irrigation diagram) in PC23 canal system

The irrigation water distribution to the plots of paddy fields is generally carried out through the field canals/ditches generally running along the ground slope. The farmers sometime align and dig the ditches by themselves depending on the topography and the location of their own plots of paddy fields. Since the tertiary plot is vast; max. 280 ha, and the land leveling is not so well done in the tertiary level, a vast plot of the paddy field are divided into small pieces by levees. The irrigation water to the plots is, therefore, distributed by a plot to plot system.

3.8.4 Sedimentation, land subsidence and drainage

(1) Source of sedimentation for PC23

As in the section 3.9.4 in soil erosion in PC23 area, the total annual of soil is estimated at 1,422,000 tons. The Sahabe river systems annually provides 732,000 tons, Sahamilahy 256,000 tons, Asahamena 153,000 tons and the remaining 281,000 tons.

In 2003 the Alaotra Mangoro DRDR office conducted dredging works in the significant parts of the main canal under the contract basis. The dredging works are shown below.

Table 3.8.4 Dredging Works in PC23 conducted by DRDR Ambatondrazaka in 2003

Canal	Location	Length (m) (m)	Volume (m3)
P1	Intake from North Collector Canal to downstream of P1	2,570	20,478
P5	BP (Sahabe Temporary Intake to downstream of P5	3,641	28,942
Total		6,211	49,420

Source: DRDR office in Ambatondrazaka

The sedimentation in the above two portions was significant for heavy sediment transportation by the Sahabe (P5) and the Asahamena (Asahamena – North Collector Canal –P1). Both intake works; the Sahabe temporary intake for P5 and the intake at the North Collector Canal for P1 have no effective structure for preventing from the heavy sediment intrusion into the main canals.

After dredging works, intake water from the Sahabe to P5 main canal increases from 2.0~3.0m^3/secto 5 m^3/sec at present. However Design intake discharge of 8.0m^3/sec has not yet recovered.

(2) Causes of sedimentation in canal systems

The cause to the heavy sedimentation in the canals is primarily heavy sediment loads conveyed by the Source Rivers; the Sahabe, the Sahamilahy, and the Asahamena. Secondly, there is no structure for protecting sediment loads from flowing into the main canals; intake gates, a scoring sluice at the headwork, a stilling basin, and an automatic control gate as AVIO gate in PC23. The Sahabe temporary intake has no intake gate and no stilling basin. Then the sediment loads freely flow into the upper P5 canal. Thirdly, structural malfunction has been the cause of sedimentation in the canal. The intake from NCC at Andranotsimihoatra has an AVIO gate automatically controlling intake water discharge depending on water level in NCC. However, the gate has not been effectively working and the heavy sediment load flowed into the P5 canal. In the case of the upper P1 canal of which the water source is the Sahamilahy river conveying the heavy sediment loads (estimated basin soil erosion of 494,000 ton/year, the AVIO gate provided at the intake may not be working, a slide gate is functional.

In addition to the above causes, the following phenomena also cause heavy sedimentation.

1) The canal base width varies and flow area of canal section varies for the same design discharge even after dredging works: sediment loading capacity of water flow changes and sedimentation occurs at the turning point.

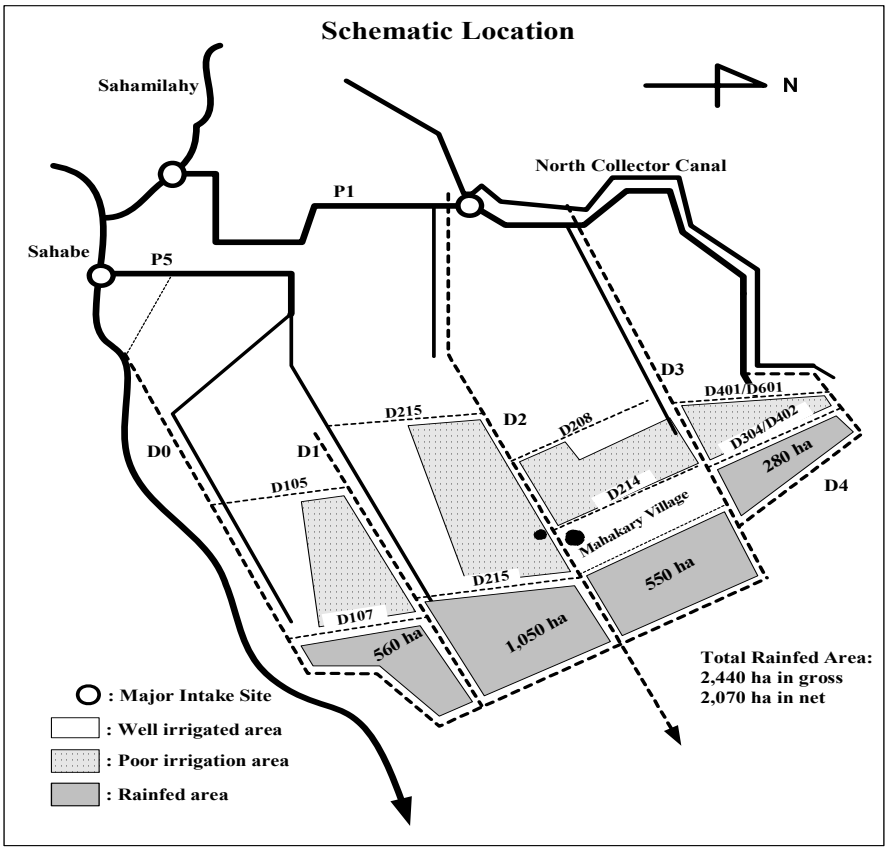
2) Water flow is uneven in the most parts of the canal; backwater of the downstream canal affects the flow of water in the upstream canal

3) Roughness of the canal bottom and side slope varies depending on the vegetation on the slope, water grass in the canal, and bank collapse; loading capacity of water flow changes and water flow is sometime interrupted by gregarious papyrus in the canal.

4) Broken structures or malfunctioning AVIS gates affect water flow in the canals; broken structures of the most AVIS gates in the canals interrupt the irrigation water flow and sediment loading capacity changes at the structures.

In such a situation of canal systems, water shortages of irrigation water occurs in the PC23 area due to the lack of proper supply of water discharge from the tertiary canal to the end of

the paddy field in the PC23 area, as shown in Figure 3.8.5. Moreover, the downstream area of the PC23 area with 1,610 ha where irrigation water does not reach owing to insufficient intake water from the source river are used by (i) rain-fed culture in the low lying part, (ii) direct sowing on dry land in the middle part and pasture land in the higher part. In the remaining area of PI main irrigation canals where dredging works have not yet been performed, a lack of irrigation water occurs in the middle of the area and for rain-fed agriculture in the end area.



Source: JICA Study area

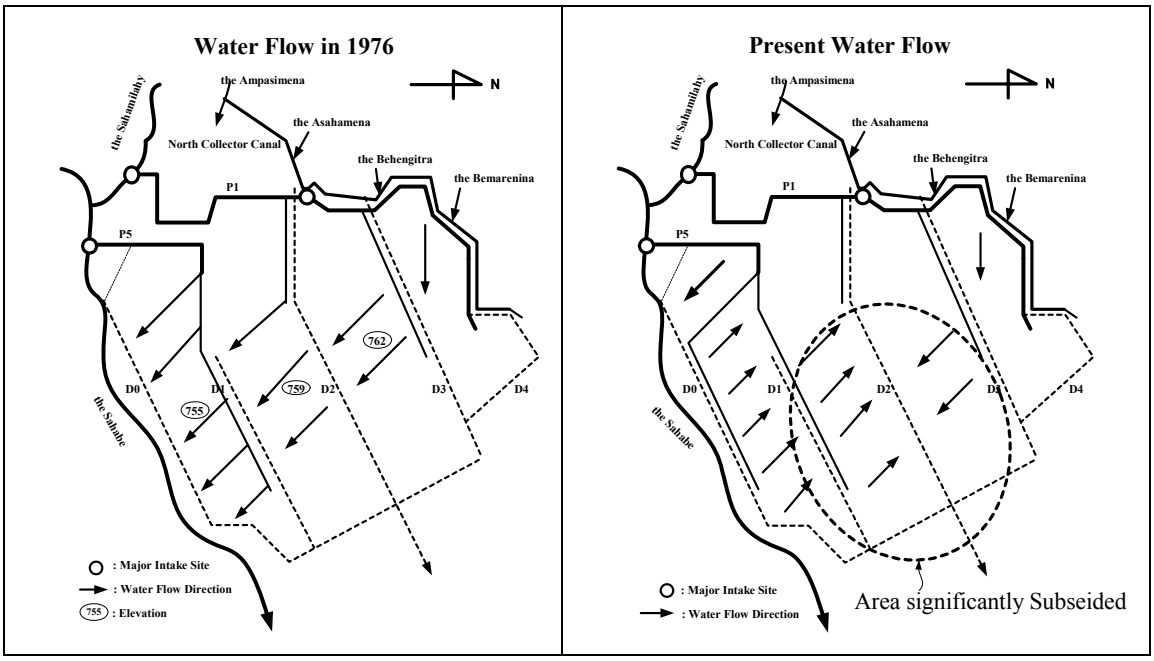
Figure 3.8.5 Present irrigated conditions in PC23 area

(2) Subsidence of PC23 area

In accordance with the Technical Study and Works Division, DIDDR Ambatondrazaka, the PC23 area had subsided in the period between 1960's and early 1980's, of which the subsidence depth was 1.2 m in maximum. After a field survey and design from 1983 to 1985, SOMALAC; the executing agency for management, operation, and maintenance of the irrigation schemes around Lake Alaotra, conducted rehabilitation works consisting of irrigation systems for PC23.

The alignment of canals as well as the structures was changed depending on the new geomorphologic conditions of the PC23 area. The following figures show that the direction

of irrigation water reversed in the southern half of the PC23 area. It shows that the downstream portion of the main drain D2 had been heavily subsided by the period of the middle of 1980s



Source: left Carte de Madagascar ay 1/15,000, right canal alignment map of 1/20000, DRRDR

Figure 3.8.6 Change of water flow direction before and after rehabilitation works in 1980's

Afterwards, the DIDDR office carried out survey to check subsidence in December 2003, of which the results indicated that there was no significant subsidence of the PC23 area from along the D2 main drain that runs from east to west. With regards to the land subsidence in the smaller areas and that of the north – south line, there exists some evidence in the field. In the eastern part of Mahakary village, the canal structures are floating above ground level. In the eastern part of the catchment of D4 drain, the same phenomena caused by land subsidence are observed. The following photos show the floating structures in the north-eastern part of PC23 area.

According to the results of field observations conducted by the JICA Study Team, the land subsidence in PC23 area has progressed after rehabilitation in the north-eastern areas commanded by the D2, D3, and D4 drains. While, there is no serious floating structure in the south and south eastern areas. The turnout structures on C5.5 (secondary canal) are working under the condition that the irrigation water is available in C5.5. The subsiding areas in the east and north-eastern parts of PC23 are generally rainfed cultivation area or used as grassland for cattle.

(3) Inundation areas in PC23 area

(a) Inundation in PC23 area caused by high water of Lake Alaotra

In accordance with the results of a profile survey conducted by DIRDR in December, 2003,

for checking the land subsidence in PC23 area, the approximate ground elevation of the operation road and dike along D2/Mahakary Canal are as follows.

Table 3.8.5 Approximate ground elevation along D2 drain (road surface/.dike crest)

Survey Points	Accumulated Distance (km)	Approx. ground EL (m)
National Road 3A (Antetezampotsy)	0	772.0
P5 Canal (No.2 AVIS gate)	2.3	764.9
Ambohidrony	3.3 3,3	763.7 763,7
Mahakary	10.6 10,6	756.9 756,9
EP of D2/ BP of Mahakary Canal	12.6	756.5
Antsampananefatra	14.8	756.4
East edge of Antsampananefatra	15.6	755.3
EP of profile survey	20.0	753.7

Source:DIRDR

The JICA Study Team investigates the past inundation along the main drain, D2, and the Mahakary Canal by means of interviews with the inhabitants along those canals, especially with regards to the effects of floods caused by the backwater of Lake Alaotra. Annual high-water at the downstream of the PC23 caused by backwater of the lake is at EL755 m in February at the east edge of Antsampananefatra, about 15.6 km east of the National highway 3a. The inhabitants who have houses and living properties on the dike of the Mahakary Canal have never experienced inundation of the living spaces but the upland crop fields and grass lands for cattle scattered outside of the dyke (about 1.5 m below the dyke crest). Since the dike crest elevation is more than EL.756.5 m at the eastern edge of the PC23 (EP of D2), no serious inundation of the living places and paddy fields by high-waters of Lake Alaotra in the PC23 has occurred. However, the bottom elevation of D2 at the EP point is more than 3.0 m below ground elevation (EL.753m), the backwater of the lake has the effect of lowering flow capacity of D2 and branch drains. The lowering of flow capacity of D2 and branch drains can be observed in the area of North Drain running along the east edge of PC23 from north to EP of D2.

(b) Local inundation in PC23 area due to poor drainage

Local inundation due to poor drainage often occurs in PC23 area. Local inundation of paddy fields, roads, and canals is mainly observed in the lower command areas of tertiary drains of PC23. The major causes of inundation are:

(a) The drainage water level is dammed up for use in adjacent paddy fields or leading water to irrigation canals for lower areas

(b) Drainage water flow is interrupted by water grass, canal collapse, sedimentation, and even paddy fields which have developed in the drains.

(c) Drains are intentionally cut for leading drainage water to the paddy fields/ irrigation

canals and the consequent local inundation occurs.

(d) The drains are completely unshaped or malfunctioned due to collapse, erosion and land subsidence.

3.8.5 Operation and maintenance (O/M) irrigation and drainage system in PC23 area

(1) General description on operation maintenance

Until 1990, operation and maintenance of the irrigation facilities in PC23 area had been carried out by SOMALAC (Société malgache d'aménagement du lac Alaotra), the executing agency for irrigation development. SOMALAC formed a water user's associations (AUE : Association des Usagers de l'Eau) to collect water charges for operation from the beneficiaries in 1985 and promoted the joint operation for operation and maintenance by AUE

In 1990 SOMALAC was broken up according to the government policy on downsizing governmental enterprises and privatization. Afterwards, activities for operation and maintenance for PC23 area are carried out by both the Government and AUEs. At present, DRDR is in charge of O&M as the government. Role of DRD and AUE is in the following table.

Table 3.8.6 General Description of Role of DRDR and AUEs in O/M

O/M activities	DIRDR/Irrigation Office	AUEs/Beneficial farmers
Water management planning	- Direction on preparation of irrigation planning to the farmers (AUEs) - Approval of irrigation plan prepared by the farmers (AUEs)	- Preparation of irrigation (water distribution plan for own irrigation block)
Water distribution	- On-off of intake gates at headworks/dams - On-off of diversion gates on the main canals - Approval on on-off of gates on secondary/tertiary canals	- On-off of diversion gates on secondary/tertiary canals - Adjusting the diversion water discharge to field canals/ditches - On-off of the inlet of plot of paddy fields - Alignment and construction of field ditches and drains for own irrigation block
Maintenance of the facilities	- Application for budget for maintenance and repair works on major facilities, - Supervision of maintenance and repair works conducted by the contractors - Approval on repair work of minor facilities to be executed by the farmers (AUEs)	- Maintenance of tertiary canals and drains, field canals/ditches and drains, and related structures
Others	- Managing farmers' meeting on annual water distribution planning and maintenance - Mediation of disputes concerning water distribution between AUEs - Monitoring of irrigation activities and instruction to the farmers, if required - Technical advice to the farmers (AUEs)	

Source: JICA study team

(2) Water user association (AUE) and problems

The general features of present 6-AUE in the PC23 area are shown below; 5 AUEs except Zato P1 was established during the SOMMALC era and all the AUEs have been starting on procedure to secure the legal status of AUE assisted by DRDR. The general profile of AUEs is showed below:

Table 3.8.8 General profile of water user association

AUE		Irrigation area planned (ha)	The number of beneficiaries	Number of irrigation block	Name of source river
1	Amparamanina	1,790	701	8	Sahamena, Behengitra
2	Mahakary	3,460	509	18	Sahamilahy
3	Vohihola	2,790	684	12	Sahabe
4	Vonana P1	780	320	5	Asahamena, Ampasimena
5	Tsaratahimbary	1565	425	12	Sahabe, Sahamilahy
6	Zato P1	250	80	1	Sahamilahy
Total		10,635	2,719	56	

Source: the irrigation branch office in Morarano Chrome (before reorganization) and interview JICA study team

In order to evaluate these AUEs, an analysis was made from 5 aspects, organizational basis, level of activeness, level of participation, management ability, and present financial status. Details are shown in Appendix 3-2, Explanatory note 3-2. In PC 23 area, all the AUEs are not functioning well. Among the 6 AUEs, however, Amparamanina and Vonona P1 are relatively active. On the other hand, almost no activities are observed in Mahakary, Vohibola-Mandroso and Zoto P1. Tsaratambary AUEs conduct some minor maintenance work of irrigation facilities, but not regularly. Although the level of functioning is different from one AUE to another, factors for not functioning can be analyzed as below.

1) lack of irrigation water: A large scale area of the AUE is rain-fed due to an incomplete irrigation system due to poor irrigation facilities. Therefore, most of the farmers do not see any necessity to participate in AUE. Only part of the members who can receive irrigation water conduct maintenance and repair work for their own paddy field.

2) Farmers' skepticism about AUE: AUEs were originally established as organizations responsible for operation and maintenance of irrigation systems during the SOMALAC period. However, management of the AUE had been unclear especially regarding financial and asset management. Besides, AUE has been incapable of managing the irrigation system after the dissolution of SOMALAC. Farmers also think that insufficient distribution of irrigation water is partly because of mismanagement of AUE and do not trust their activities. This tendency hinders farmers from participating in AUE.

3) Lack of organizational basis : no AUE are legally registered except Amparamanina and Vonona P1. Legal registration makes AUEs accessible to governmental and

other donors' support and be allowed to take legal action against those who violate AUE regulations. Apart from legalization of AUE, most of the executive members and water charge collectors do their task on a voluntary basis without receiving any incentives. They have to do many tasks for management of AUE without payment and, therefore, they have less motivation to work. This leads to inactiveness of the AUE.

4) Location of the farmers: Farmers' residences are widely scattered in and out of PC23. Many of the farmers live outside of PC23 and they go to their paddy field in PC23 during cropping season only. In some cases, land owners live in faraway places such as Antananarivo, Antsirabe, etc. and lend their land to farmers living in and nearby PC23. Accordingly, it is quite difficult for AUE to get an understanding of the actual land users. Moreover, farmers have very limited communication ability among themselves, especially for meeting and decision-making and it also makes water charge collection quite difficult.

3.8.6 Present situation of irrigation in the upper area of the source rivers

There exist six (6) major source rivers supplying irrigation water to the PC23 area. The rivers also provide irrigation water to paddy field areas in the upstream of the PC23 area. The total net irrigation area commanded by the main course of the source rivers and its major tributaries is estimated at about 3,500 ha as shown in the following table.

Table 3.8.9 Irrigation Areas in the Upper Area

Source River	Major Branch	Irrigation Area (ha)	
		Gross	Net
Sahabe	main	1, 750	880
Tributary of Sahabe	Mavolava	1, 570	780
Tributary of Sahabe	Andranomainty	210	100
Tributary of Sahabe	Ranomainty	370	180
Sahamilahy		720	360
Ampasimena		600	300
Asahamena		240	120
Behengitra		590	290
Bemarenina		1,050	520
Total		7, 100	3, 530

Source: JICA study team

Most of the paddy fields in the upper area of the resource rivers of PC23 area consist of small spots. The main irrigation canal is provided along the skirt of the hilly area and the drainage water returns to the rivers through the plots of paddy fields. The field canals with a crooked course basically have dual purpose canals; irrigation and drainage. Plot to plot irrigation is dominant in the upper area**.** Most of the irrigation system is commanded by a temporary weir made of wooden planks, reeds, and other materials available in the area. An intake weir commands some 10 ha to 100 ha

The irrigation activities start in the early October after rough plowing of the fields and construction/repairing the intake weir. In the rainy season, the temporary weir is sometime flushed away by floods and reconstruction of the weir in the cropping period is to be regularly executed by the farmers' group with spending over a long period.

3.8.7 Problems of irrigation and water use association and causes of problems

Problems of irrigation and water use association and causes of problems in PC23 area and the upper area of the resource rivers are summarized as shown in the following table.

Table 3.8.9 Problems of irrigation and water use association and causes of problems

Zone	Problems	Causes of the problems
PC23 area (irrigated land)	Decrease of intake discharge for irrigation	Due to sedimentation at 3 main intake sites and in the main irrigation canal, design intake discharge at intake sites and canals cannot be taken.
	Decreases of carrying capacity of irrigation canal	Luxuriant growth of water grass, canal collapse, sedimentation, and damage of structure in irrigation canal.
	Insufficient irrigation water distribution to secondary/tertiary area	Malfunction for irrigation water distribution due to incomplete and/or deteriorated facilities of diversion gates, check gates and measuring devices
	Lack of irrigation water to the paddy field and improper water distribution	Long length of tertiary irrigation canal, decrease of carrying capacity of tertiary irrigation canal, irrational canal alignment on farm
	Inefficient use of limited irrigation water	Poor field water management for irrigation system due to the shortage of government irrigation staff, irrigation application by plot to plot
	Local inundation in paddy field and inspection roads	Interception of drainage water by making weirs in drains for re-use of water ingrains, decrease of carrying capacity of drains owing to luxuriant growth of water grass, canal collapse, cultivation in drains
	Impassable condition on the secondary/tertiary inspection road along drains and hindrance of transportation of commodities	Cutting of inspection road along the secondary and tertiary canals to take illegal diversion of water from irrigation canal to drain, damage of inspection road by tractors and/or ox-cart during the rainy season
	Deterioration of on-farm facilities of Irrigation and drainage	No O&M plan due to incomplete institution for O&M of irrigation facilities, lack of government budget relevant to O&M
	Incomplete O&M for on-farm facilities by farmers' group and farmers themselves	Incomplete function of water user association made on the level of tertiary area, no farmers' systematic O&M of irrigation and drainage facilities for farmers' paddy field.
PC23area (rainfed land)	Rainfed paddy due to incomplete irrigation system	No irrigation water supply due to low carrying capacity of the existing main irrigation canal, no rehabilitation of irrigation facilities for secondary/tertiary irrigation blocks damaged by past subsidence
	Local inundation during the rainy season	Decrees of lowering flow carrying capacity of main drain by back water of the lake of Alaotra during rainy season, luxuriant growth of water grass, canal collapse, sedimentation in drains, unevenness topography made by the past land subsidence, decrease of flow carrying capacity of drains due to deterioration and damages of drainage facilities
	Insufficient of land leveling	Insufficient of puddling operation and ridges
	Decrease of function of operation road for irrigation canal	Suspension of activities for O&M of canal management road due to deterioration of irrigation canal
	Grazing land used on the agricultural land	Farmer's giving up cultivation of crops on the agricultural high land made by affection of the past subsidence
Sahabe river, Sahamilhay river and 4 small/medium rivers	Unstable supply of irrigation water	Change of river discharge during the period for irrigation supply, no supplemental water supply means for emergency of water shortage
	Decrease of irrigation efficiency	Deterioration of intake facilities made by concrete/masonry, poor management of puddling, poor ridges, poor O&M on farm facilities by farmers
	Poor growth of paddy	Lack of supplemental water supply means at drought year

Zone	Problems	Causes of the problems
	and decreasing yield of paddy due to delay of transplanting time at drought year	
	Insufficient technical extension services on design of facility and construction	Lack of technical and extension support services for farmers by the government
	No organization is in charge of O&M of the irrigation facilities on the basis of river basin.	No role regarding procedure for irrigation water use and commencement of irrigation among PC23 area and the upper areas of its resource rivers.

Source：JICA study team

3.9 Present watershed management and soil conservation

3.9.1 Present status of forest

The forest in the Study area consists of natural forest and manmade forest. The rate covered with forest in the basins of the resource rivers to PC23 irrigation area is 19% in the Sahabe river basin, 8% in the Sahamilahy river and 5% in the 4 small/medium rivers, respectively. The forest is prominently found in the Sahabe river basin. Though natural forest that occupies only 3% of the total river basin above PC23 area, it has been remarkably decreased and/or deteriorated due to farmers' disorderly development of the forest and illegal lumbering for commercial purposes. In addition, repeated forest fires in the natural forest have made the natural forest conditions worse. However, the young trees and are grown at a planting density of 10,000 trees/ha in the natural forest area. If there are no external obstacles such as forest fires and artificial lumbering, it is expected that the present natural forest will be able to naturally recover as it was. Though the area of natural forest lands is small, it has fertile and soft soil and plays an important role in provision of water conservation. The manmade forest is mainly composed of the forest with *Eucaluptus robuster* and forest with pine (Pinus *caribaena*, *P.eriotti*). Grevillea is planted on a small scale. Most of the pine forest was reforested by the Fanalamanga Corporation and the other manmade forest was made by local people and the DREEF. Since Eucaluptus robuster is resistant to fire and has a stronger sprouting power after felling, people use the forest at the stage of sprouting as firewood and charcoal. Afterwards, the people leave it without dealing with and wait by the time when sprouting occurs

Eucalyptus that grows faster is a most excellent resource for firewood and charcoal at present. It is said that eucalyptus has a negative impact on fostering ground water recourses in the Study area because eucalyptus absorbs much soil moisture due to its faster growth. However, the results of interviews with local farmers and staff of MINENVEF in the field indicate that their seems to be no such negative phenomena. On the other hand, the Government has been performing Study on the selection of appropriate tree varieties for firewood and charcoal resources and mixed cultures of Eucalyptus and Grevillea.

There is natural forest of about 1,100 ha and manmade forest of 600 ha in the Sahmilahy river basin. Natural forests remain in the slope lands that are more than 30^0 west in the Study area comprising 2nd forests with a medium radius of trees. The manmade forests mainly consisting of Eucaluptus robuster are distributed in the hilly lands near the villages. Especially Eucaluptus robusters are used for firewood and charcoal. Since the rate covered with the forests and shrubs/grass land in the Sahamilahy river basin is 8% and 77%, respectively, the Sahamilahy basin becomes the biggest resource of soil erosion to the downstream area and leads to negative environmental conservation.

In Sahabe river basin there are about 4,100 ha of natural forest and 14,000ha of manmade forest. The natural forest extends over relatively large areas in the very steep lands located near the area of the south west boundary and the edge of the southern river basin. All the natural forest is composed of secondary forest with a medium radius of trees. However, the natural forest near the area of the south west boundary was lost by a large-scale forest fire that occurred outside of the study area in the dry season of 2006 and part of it was devised seriously. Most of the manmade forest with pine was planted by the Fanalamanga Corporation after 1973. However, many forest areas had poor growth due to improper planting performance as well as being damaged by a 2006 forest fire. In addition, the manmade forest with Eucaluptus robuster was made by the local people and/or DREEF in and around the villages. It is extensively planted and used for the firewood and charcoal. The rate covered with the forest is 18% which plays an important role in soil erosion control and river basin conservation.

3.9.2 Watershed management

The activities for the watershed management in the Study area is concentrated to the forest management and is in charge of the Alaotra Mangoro DREEF office after reorganization of the MINENVEF was conducted in April 2007. The present total staff of DREEF including the branch offices is 31 consisting of 3-professional, 21-technician and 7-administrative officers. In addition, there are 13 vacant positions for technicians. The organizational structure of the DREEF is illustrated in Fig. 3.6. Among the forest management activities, activities against the forest fire often are carried out in cooperation with the DREEF and the local governments (prefecture, district, commune and village) and the DREEF carries out reforestation of pines with the Fanalamanga Corporation. However, the number of staff, the budget and motive power for management is so small that the DREEF cannot perform proper forest management in the study area by itself. In addition to the above situation, a farmer's organization necessary for forest management is not yet instituted and there is no support system (including incentive program) for setup of the farmers' organization

3.9.3 Forest fire

The annual forest and shrub/grass land fire that has occurred mostly in the Sahabe, the

Sahamilahy and the 4 small/medium rivers causes deterioration of the natural forest and hindrance of natural recovery power for vegetation. According to the records of DREEF, damage by the forest fires from 1998 to 2005 in the area controlled by the old offices of Ambatondrazaka and Amparfaravola is shown below;

Table 3.9.1 Damage by forest fires within the area controlled by old offices of Ambatondorazaka and Amparafaravola

Forest office	Damage for natural forest (ha)	Damage for mandate forest (ha)	Total (ha)	Present forest area (ha)	Proportional percentage (%)
Ambatondorazaka	389	640	1,029	18,128	5.7
Amparafaravola	376	447	923	2,877	32.1

Source : DREEF

The shrub/grass lands damaged by field fires are larger than that of the forest lands mentioned in the above table. In the Ambatondrazaka forest office (old organization), the area damaged by field fires was 2,516 ha in 2004 and 3,462 ha in 2005. On the other hand, the area damaged by field fires was 2,335 ha in 2005 in the Amparafaravola forest office. The number of these fires for forest and shrub/grass lands occurred in the Sahamilahy river basin were not large, but these in the Sahabe river basin near Soalazaina and Tanambao Besakay communes were large. The Sahabe river basin is far away from the villages and geographically has no advantageous position for engaging in fire protection activities. Also since the pine trees forest land that is subject to fires is extensively distributed in the basin, once a forest fire occurs, the damage is great.

The fires on forest and shrub/grass lands are mainly caused by cigarettes, cooking, charcoal production and so forth that were not extinguished properly. On the other hand, it is said that there are incendiary fires due to religious and/or political reasons. For prevention of these fires, MINENVEF has endeavored to extend a campaign for enlightenment. The CIREF office at Ambatondrazaka tried to carry out enlightenment about forest fires to local people around the forest land owned by Fanalamanga in cooperation with Fanalamanga Corporation in 2003. Recently, some NGOs tried to improve the awareness of the local people against forest fire from the viewpoint of the environmental conservation activities.

On the other hand, the government promulgated an ordinance 60-127 in 2003 that contains embracement and penal servitude, to strictly control fires in forest and shrub/grass lands.

Though there are still some traditional fires fighting customs that all local people should take part in when fire occurs, local peoples' awareness about field and forest fires is low. Moreover, there is no institution at the village level for prevention of field and forest fire as well as no fire-extinguishing equipment

3.9.4 Soil erosion

A lot of sand sediment flows into the down area such as PC23 irrigation area during annual flood season through the Sahabe, the Sahamilahy and 4 small/medium rivers. The main sources of the sand sediment into the rivers are the devastated shrub/grass lands in the upper stream of the rivers and lavakas. The location of lavaka was identified based on interpretation of landsat images shot on April, 2001. There are about 1,300 sites of lavakas in the Study area as shown in the following table. Lavaka is defined as a collapse phenomenon in the surface of the mountainous/hilly area. About 80% of the total number of lavakas in the Study area occurs in the area covered with migmatite. It is considered that occurrence of lavaka is very old and lavaka has been formed for a long time. From the view of the condition of vegetation in lavaka, it is categorized into three; (i) active type: The lavaka is still collapsing and movement of the collapsed soils in lavaka into the downstream is still severely made, (ii) inactive type: Movement of the collapsed soils in lavaka into the down streams is completed by the recovery of vegetation in lavaka and (iii) intermediate type: Movement of the collapsed soils in lavaka into the downstream is apt to be reduced by the recovery of vegetation in lavaka.. Among those, the collapsed soils in the lavaka in active type and intermediate type become a source of the soil erosion.

Table 3.9.2 Present number of lavaka in the Study area

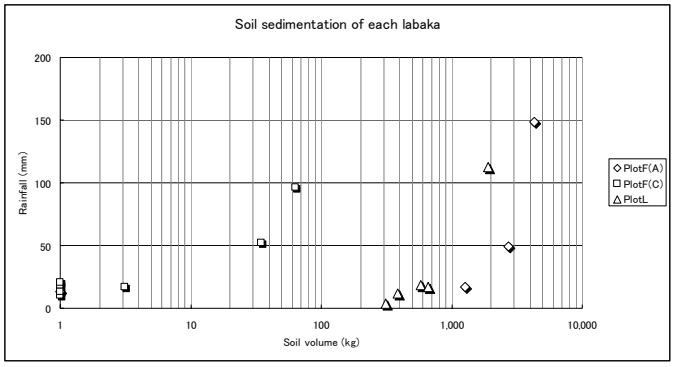
Name of river	Name of tributaries	Catchment (ha)	Number of lavaka	Number per 100ha
Behengitra		2,648	68	2.6
Asahamena		12,433	197	1.6
Ampasimena		2,912	56	1.9
Sahamilahy		20,596	209	1.0
Sahabe	Sahabe (main)	49,066	276	0.6
	Ampondra	5,834	71	1.2
	Ranomainty	9,739	37	0.4
	Andranomainty	8,664	106	1.2
	Mavolava	24,414	310	1.3
Total		136,306	1,330	1.0

Source：JICA study team

In order to grasp the present soil erosion from the upper stream of the rivers, soil loss was measured at four experimental plots consisting of (i) manmade forest with Eucaluptus robuster in the hilly area, (ii) manmade forest with Grevillea in the hilly area, (iii) grass land with high density of grass, (iv) grass land with low density of grass, (v) active type-lavaka, (vi) intermediate type-lavaka and (vii) inactive type-lavaka. Soil loss was measured at occurrence of rain and the result of soil loss is shown in figure 3.9.1 and 3.9.2 as follows;

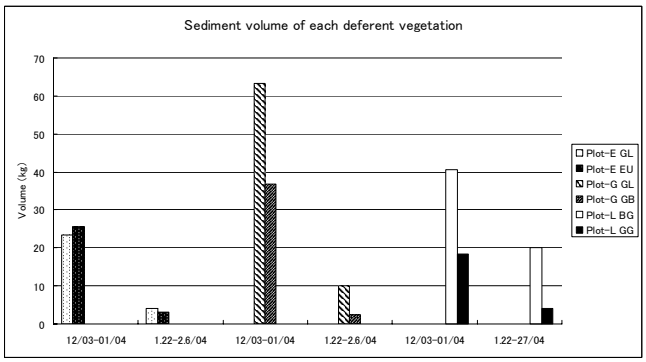
Measurement of soil loss was carried out during one rainy season of 2004/05 for lavaka and three rainy seasons from 2004/05 to 2006/07 for two mandate forest sites. Based on the data of rainfall and soil loss measured, co-relation linear function was made at 7 experimental

sites. Based on this, soil loss from the Study area was estimated as in the following table.



Source: JICA study team

Figure 3.9.1 Soil loss from lavaka



Source: JICA study team

Figure 3.9.2 Soil loss from kinds of vegetation

Table 3.9.3 Soil loss from each river basin

Name of river basins	Catchments area (ha) Ⓐ	Annual soil loss (ton/year)			Unit soil loss (ton/ha) Ⓑ/Ⓐ	devastation class
		lavaka	Hilly area	Total Ⓑ		
Sahamilahy	20,596	4,974	250,557	255,531	12.4	serious
Asahamena	12,433	4,526	148,779	153,305	12.3	
Ranomainty	9,739	805	101,935	102,740	10.5	moderate
Sahabe	49,066	6,150	489,291	495,441	10.1	
Behengitra	2,648	1,339	24,874	26,231	9.9	
Andranomainty	8,664	2,134	82,058	84,192	9.7	
Ampasimena	2,912	1,068	26,260	27,328	9.4	slight
Mavolava	24,414	6,312	221,125	227,437	9.3	
Ampondra	5,834	1,446	47,926	49,372	8.5	
Total	136,306	28,754	1,392,805	1,421,559	10.4	

Source: JICA study team

The total soil loss from the Study area is estimated at 1.4 million tons/year. The total soil loss from lavakas is 29,000 tons/year or 2% of the total soil loss from the Study area. Though soils collapsed in the lavaka rapidly flow into the downstream area and provide considerable sedimentation problems when a big cyclone occurs, it is considered that soil loss from lavakas do not provide serious problems at present. On the other hand, the total soil loss from the mountainous and hilly area occupies 98% of the total soil loss in the Study area of which 80% are mostly provided from the shrub and grass lands.

Soil loss from the grass lands varies depending on the vegetation condition. According to the results of measurement of soil loss, soil loss is 1.5kg/ha/100mm of rainfall in the case of dense grass coverage and 5.5 kg/ha/100 mm of rainfall in the case of thin grass coverage, which indicates a high effect for soil conservation if improvement of vegetation condition is

carried out.

The soil loss from each river basin is varies owing to condition of land use and kinds of vegetation in the Study area.

It is recommended that river basin conservation projects aimed at preventing serious devastation should be performed first from the viewpoint of effectiveness against soil erosion control.

3.9.5 Problems of watershed management and the causes of problems

Problems of watershed management and the causes of problems are summarized in the following table.

Table 3.9.4 Problems of watershed management and causes of problems

zone	Problems	Causes of problems
Sahabe river, Sahamilhay river and 4 small/medium rivers	Lack of proper watershed management activities	Lack of proper forest management due to shortage of governmental staff, luck of budget, luck of motive power for activities
		No local peoples' institution for forest management, no incentives for promotion of institution for forest management
	Fire for forest and shrub/grass lands	Shortage of awareness for control against fire for forest and shrub/grass lands
		No local peoples' institution for control against fire for forest and shrub/grass lands in village level
		No fire-extinguishing equipment for fire for forest and shrub/grass lands in village level
	Soil erosion from the river basin	Decrease of natural forest due to illegal cutting down, illegal cultivation (farming and grazing) by illegal settler
		Decrease of the area of natural forest and manmade forest by firing
		Hindrance of vigorous growth and luxuriance natural vegetation by fire
		Devastation and denudation of shrub/grass cover by field fire
		Devastation and denudation of shrub/grass lands by the extensive use of grazing
		Lack of technical research work for countermeasure for lavaka and forestry

Source: JICA Study area

3.10 Life environmental status

3.10.1 Poverty

As mentioned in section 3.1.3, an annual average net return of the farmers in the Study area is small ranging from MGA 1.63 million (or MGA 4,500/day/household or $0.7/day/household) to MGA 5.43 million (MGA14,900/day/household or $2.2/day/household). Based on the definition of poverty and criteria that were indicated in the PRSP prepared by the Government in 2003, poverty rate in the Study area is roughly calculated. It is estimated that the poverty rate in the Study area ranges from 72.5% to 26.7%, averaging at 52.3%. It is considered from income aspect that the main causes of poverty consist of (i) lower productivities and insufficient of marketing condition, (ii) insufficient

income due to the small paddy land holding size and (iii) very small number of employment opportunities in the non-agricultural sector

3.10.2 Basic living environment

(1) Domestic water supply

JIRAMA does not provide domestic water supply services to the Study area. People who live in the center of Tanambao Besakay commune only receive domestic water supply services through a water pipe from waterworks in water sources. In the remaining 8 communes, water services are provided by a public well in the center of the communes. The present condition of water source is summarized below;

Table 3.10.1 Source of domestic water in the Study area

(%)

Zone	Village	Irrigation canal	Spring	River	Well
Sahamilahy river basin	Antanimafy	2.6	23.1	35.9	38.5
	Maheriara	0.0	40.0	42.5	17.5
	Morarano Chrome	6.7	0.0	0.0	93.3
4 small/medium river basin	Manakambahinikely	5.0	0.0	35.0	60.0
Sababe river basin	Ranofotsy	0.0	61.2	10.2	28.6
	Sahanidingana	4.0	6.0	68.0	22.0
	Soalazaina	0.0	25.0	25.0	50.0
	Besakay	0.0	9.1	68.2	22.7
PC23 area	Ambohidrony	16.0	0.0	0.0	84.0
	Mahakary	0.0	0.0	0.0	100.0

Source : Detailed village survey, JICA study team, 2004

The local people in the Sahamilahy and 4 small/medium river basins use the wells. On the contrary, most of the people in the Maheriara and Antanimafy located upper stream of the Sahamilahy use water of springs and river. In the Sahabe and PC23 area, people mostly use water of rivers and springs. However, the water quality of water source is poor, especially during the rainy season. On the other hand, water level of wells becomes lower in the dry season that results in one of the serious causes of water shortage of domestic water as well as diarrhea for the children

(2) Toilets

The present condition of toilets in the Study area is shown in the following table. Most of the people use a simple pit type toilet in a shed.

Table 3.10.2 Condition of toilet

(%)

Zone	Village	Pit (%)	Non facility (%)
Sahamilahy river basin	Antanimafy	89.7	10.3
	Maheriara	52.5	47.5
	Morarano Chrom	96.7	3.3
4 small/medium river basins	Manakambahinikely	77.5	22.5
Sahabe river basins	Ranofotsy	67.4	22.5
	Sahanidingana	76.0	24.0
	Soalazaina	95.0	5.0
	Besakay	95.0	5.1
PC23 area	Ambohidrony	88.0	12.0
	Mahakary	90.0	10.0

Source: Detailed village survey, JICA study team, 2004

(3) Fuel for cooking

The source of fuel for cooking in the Study area is shown in the following table. Firewood is the main source for cooking though use of charcoal is found in the Morarano Chrome village on the scale. Most of these firewood and charcoal are collected from Eucaluptus robusters planted in the areas around the villages. Since there are few forest resources in the lower reaches of the rivers and PD23 area, firewood and charcoal are carried from the upper stream to the markets along national road 44 and provided to the local people who live in the downstream area and PC23 area. At present, most of the people in the Study area use the traditional cooking stoves. Its thermal efficiency is so poor that the people have to consume a lot of firewood and charcoal. As a result, the forest resources in the Study area have been overconsumed. In addition, women and children are traditionally in charge of collecting firewood. Work for collecting firewood requires a long time puts a hard work on women. In such a situation, women cannot provide care services for children.

Table3.10.3 Sources of fuel

(%)

Zone	Village	Firewood	Charcoal	No-response
Sahamilahy river basin	Antanimafy	100.0	0.0	0.0
	Maheriara	100.0	0.0	0.0
	Morarano Chrome	66.7	31.7	1.6
4-small/medium river basins	Manakambahinikely	85.0	12.5	2.5
Sahabe river basin	Ranofotsy	100.0	0.0	0.0
	Sahanidingana	96.0	2.0	2.0
	Soalazaina	95.0	5.0	0.0
	Besakay	96.7	3.3	0.0
PC23are	Ambohidrony	86.0	12.0	2.0
	Mahakary	84.0	16.0	0.0

Source: Detailed village survey, JICA study team, 2004

(4) Energy for lighting and economic activities

The present condition of lighting in the Study area is shown in the following table. Most of

the people in the Study area use kerosene oil for lighting followed by candles and electric power. It is common that candles are used with kerosene oil. Regarding electric power, JIRAMA (JIRO Sy Rano Malagasy) mainly provides power services with a training school of a religious organization in Morarano Chrome. It does not yet provide power services to the public welfare and business sectors. At present, JIRAMA is carrying out planned power cuts and reduction of power services in operation owing to increases in oil prices. In addition, private entrepreneurs provide power service by diesel engines for relatively large villages such as Ambaiboa and Morarano Chrome (Sahamilahy river basin), Ambohidrony and Amparamanina (PC23 area) and Bejofo and Tsarahonenana (Sahabe river basin). However, the primate entrepreneurs reduce operation hours due to a substantial rise of oil price, beneficiaries (users) change from use of power to lumps.

On the other hand, power demand from the public welfare and business sectors is increasing in the villages, as Morarano Chrome that has developed as an economic center. Due to shortages of power at present, economic activities for rice mill become stagnant, and fisheries and meats without refrigeration facilities cannot be marketed at an optimum price.

Table 3.10.4 Soruce of lighting

Zone	Village	Kerosine (%)	Others (%)
Sahamilahy river basin	Antanimafy	100.0	0.0
	Maheriara	100.0	0.0
	Morarano Chrome	50.0	50.0
4 small/medium river basins	Manakambahinikely	82.5	17.5
Sahabe river basin	Ranofotsy	98.0	2.0
	Sahanidingana	100.0	0.0
	Soalazaina	93.2	6.8
	Besakay	88.1	11.9
PC23 area	Ambohidrony	94.0	6.0
	Mahakary	62.0	38.0

Source: Detailed village survey, JICA study team,

(5) Roads condition

The road system is the Study area is outlined on the location map in the Study area. The area around the lake of Alaotra is connected with Antananarivo, the Capital through 2 national roads and a railroad. Among those, the national road-44 that connects Moramanga with Ambatondrazak, the center of Alaotra Mangoro region, is the most important main road. The distance between Moramanga and Ambatondrazaka is 273 km. Moramanga is located in the way of the national road-2 that connects Antananarivo with Toamasina. Another important road connecting Antananarivo with Ambatondrazaka is the route (Antananarivo-Anjozobe -Ambatondrazaka). It is 40km shorter than that of the first one, but it traverses the river basin in the upper stream of the Sahabe river and is impassible during the rainy season at the steep sections. So it is used as a supplemental traffic road only during the dry season. In the Study area, the national road-44 and the national road-3a form the ring road along lake Alaotra. The

national road-3a reaches Andilamena, that is located in the edge of the northern part of the Alaotra Manroro region. In addition, the national road-33 connecting with the Brieville mine with Morarano Chrome joins with the national road-3a. The national road-3a, the national road-33, 20km of the national road-44 and 24km of the link road along the lake Alaotra are paved. An improvement project for the remainder of the national road-44 was credited by the World Bank. But the implementation of the project is suspended at present, which causes a traffic bottle neck from Moraganga to the area around the lake Alaotra. The rural roads breaching off each national road have been improved successively according to the 10 years development plan for road development.

However, the most serious road problems are that the rural roads to the villages connecting with national roads such as national road-3a, national road-33 are severely deteriorated. Under such situation, Mahakary and Ambohidrony in PC23 area, Ranofotsy, Soalazaina, Sahanigingana and Besakay in the Sahabe sometimes are isolated for a long time. In the Sahamilahy river basin, access to the national roads is relatively easy except Manakambahinikely. In such a road situation, economic activities of these villages are restricted especially in the rainy season. And access to markets are hindered and farmers cannot sell agricultural and livestock products at an optimum price

(6) Health and sanitation

Main diseases in the Study area are malaria and diarrhea. The main hospitals that provide medical and health services with the local people in and around the area of the lake Alaotra are at Ambatondrazaka and Ampasikely. There are 5 clinics and 9 medicine store houses in 9 communes in the Study area. Ministry of health and family planning dispatches a care service team to a village without a doctor that carries out a periodic patrol service for pregnant woman and infant cares. The most serious constraint for health and sanitation services is poor access to hospitals and doctors due to long distance and poor road condition. It takes about 20 km in the remote village. Moreover, lack of medical facilities, lack of doctors and nurses and lack of medicine are the serious problems for local people.

3.10.3 Problems of basic living environment and causes of problems

Problems of basic living environment and causes of problems in the Study area are shown in the following table.

Table 3.10.5 Problems of basic living environment and causes of problems

Zone	Problems	Causes of problems
All the areas	Low income and stagnant economic activities	Poor access to the markets of agricultural/livestock products located along the national roads 3a and 33 at a right time owing to poor local roads connected with national roads
		Poor access to the markets of fisheries and meats in Morarano Chrome at the right time because proper management of fisheries and meats can not be undertaken without refrigerators due to lack of electric power Increase in rice milling charge
	Lack of basic living environment	An outbreak of water born diseases such as diarrhea from intake of water with poor water quality such as wells, irrigation canal, springs and river water due to insufficient domestic water supply facilities
		Poor access to hospital and clinics
		Lack of hospitals, lack of doctors and nurses, lack of medicines
	Overconsumption of forest resources	Overconsumption of manmade forest for firewood and charcoal in the upper stream due to population pressure, Increase in living expense of the people in the down stream area due to increasing transportation charge of firewood/charcoal
		Women's heavy work load and long time needed for collecting firewood, insufficient care for children
		Overconsumption of firewood due to use of a traditional cooking stove having low thermal efficiency

Source: JICA study team

3.11 Natural environment

The swampy area around lake Alaotra is reduced because of land use change from the swamp to farm lands as well as soil loss of the rivers. On the other hand, the area of lake Alaotra consisting of the lake, the swampy area and paddy field has deteriorated and environmental conservation for the swampy area is essential. The features of the natural environment in the Study area are as follows;

(1) Protected area and endangered species

In Madagascar there are 3 kinds of protected area enacted by the Decree' Code of Protected Areas' in 2001/05; (i) National Park (NP), (ii) Integral Natural Reserve (INR) and (iii) Special Reserve (SR). There is no protected area in the Study area.

It seems that endangered species exist in the surrounding Study area such as *Hapalemur griseus alaotrensis, Microcebus rufus, Aythya innotata, and Tachiybaptus rufolavatus.*

(2) Ecology

Globally there area four types of habitats in the wetland of lake Alaotra in the Study area, as follows;

(a) Lakes, ponds, canals and rivers dependent to Alaotra Lake

(b) Marshlands providing a habitat for lemur Hapalemur Alaotrensis

(c) Marshy meadows dominated by herbaceous plants and some dwarf plants providing a

habitat for wild avifauna

(d) Hills and river basins, pasturing place, reforestation zone, mainly covered by Aristida Rufescens and Heteropogon sp

(3) Flora

Vegetation in the Alaotra wetland, which is surrounding the study area, presents 2 stratums. The upper stratum is dominated by Cyperus Madagacariensis "Zozoro", Phragmits communis "Bararata" and Aergyrea vahibora "Vahankelana", However, the lower stratum is populated by Cyperus Latifolius "Vendrana", Polygonum Glabrum "Tamboloana" and Echinochloa Crusgalli "Vilona".

River basins are dominated by the presence of *Aristida rufescens* and *Heteropogon*. The lower bottoms are covered by grasses called *Cynodon dactylon* "Rapanitra" and ponds present a large floristic species such as *Typhonodorum lindleyanum* "Via", *Polygonum Glabrum*, *Learsia hexandra* "Karangy".

(4) Fauna

Alaotra marshlands which are surrounding Study area provide a habitat or a type of lemur called Hapalemut griseus Alaotrensis that is for the moment seriously endangered. It is an endemic sub-species in Madagascar, but also endemic in Alaotra. The population of this animal is presently decreasing as there were more than 10 000 individuals at about 1990 and in 1994, there were only 75 000 individuals remaining; 5 000 to 7 000 individuals in 1999 and at the present time the total population is estimated to 3 000 individuals.

(5) Ramsar Convention

The Lake Alaotra and the swampy area around the lake were designated as a swampy area registered by the Ramsar convention on 9th September 2003. The area registered is 48,916 ha consisting of the lake area of 19,971 ha, the other marshy area of 5,445 ha and the swampy area around the lake of 23,500 ha. The Study area does not overlap with the area registered by the Ramsar Convention except on one site of the other marshy area that has 232 ha

The Alaotra Mangoro DREEF prepared a draft management plan for the registered area in 2005 with the assistance of the environmental program of the World Bank and World Wildlife Fund (WWF). In the above study, zoning was made for the basin of the registered area. The basin of the registered in the Study area is 673,584 ha comprising 117,000 ha of paddy field, 54,088 ha of the area equivalent to paddy field and 502,496ha of the river basin of the rivers that flow into the lake Alaotra. Also a part of the natural forest area in the basin of the registered area was designated as an environmental conservation area but the farm lands in the basin of the registered area not decimated. The register swampy area and land use classification map in the Study area is illustrated in Fig. 3.7.

3.12 Peoples' desire and willingness to participate for development

3.12.1 Peoples' desire

The results of the peoples' desire for the development component that JICA study team conducted is summarized in the table 3.5. Generally the people highly require improvement of infrastructures such as roads, medical service, domestic water supply etc, but desire for improvement of environment issues is low. The results do not always indicate low awareness of the people for environment because in the answers for questions it is requested that the limited number of choice should be selected among the multiple desire choices. In the case of use of such question form, people are apt to apply a shortsighted viewpoint for selection of development components. As a result, people will select the infrastructure components that provide profits in the short-term. On the other hand, it is considered that poverty improvement in this project should be achieved by income improvement, improvement of living environment and environment conservation. Then, it is necessary to take into consideration infrastructure component as well as environment (forestation:3-20%, soil conservation : 8-30%) for development project. Moreover, it is also pre-requisite that the people should be enlightened so as to understand that both the issues of the environment and infrastructure are important to improve of poverty in the study area.

3.12.2 Peoples' willingness to participate for development

The results of the detailed village survey which indicate peoples' willingness to participate in development is shown below;

(1) Awareness of improvement for forest problems

Table 3.12.1 Peoples' willingness to participate for increasing forest areas

Zone	Village	Participation (%)	Non-participation(%)	No-response (%)
Sahamilahy river basin	Antanimafy	89.7	2.6	7.7
	Maheriara	97.5	2.5	0.0
	Morarano Chrome	93.3	5.0	1.7
4-small/medium river basins	Manakambahinikely	92.5	7.5	0.0
Sahabe river basin	Ranofotsy	87.8	10.2	2.0
	Sahanidingana	96.0	0.0	4.0
	Soalazaina	83.3	16.7	0.0
	Besakay	93.3	5.0	1.7

Source: the detail village survey, JICA study team, 2004

(2) Awareness of improvement for irrigation problems

Table 3.12.2 Peoples' willingness to participate for irrigation improvement

zone	Village	Participation (%)	Non-participation (%)
Sahabe river basin	Antanimafy	76.9	2.6
	Maheriara	-	-
	Morarano Chrome	81.7	0.0
4 small/medium river basins	Manakambahinikely	87.5	5.0
Sahabe river basin	Ranofotsy	79.6	4.1
	Sahanidingana	4.0	0.0
	Soalazaina	53.3	1.7
	Besakay	76.7	0.0
PC23 area	Ambohidrony	86.0	4.0
	Mahakary	100.0	0.0

Source: the detail village survey, JICA study team, 2004

Most of the people in the Study area make a living on the basis of agricultural activities. Peoples' willingness to participate in improvement of the forest problems is high in general. They understand that the watershed management in the Study area should be carried out urgently at present. However, they have no idea on' how to realize watershed management' at the present time. On the other hand, people in the upperstream area want to improve the problems concerning deterioration of traditional irrigation systems for paddy cultivation. The people in the PC23 area mostly require improvement of irrigation and drainage systems in the PC23 system and want to participate in development projects for irrigation improvement.

Table

Table 3.1 Number of Commune and Number of House Hold/population in villages in the Study Area

Commune/village	Population	H.H*	Region
1 Ampasikely	3,690	541	
Ampasikely	1,060	157	SM**
Ambodifano	849	133	SM**
Ambodivoandelaka	873	117	SM**
Antanimbaritsara	908	134	SM**
2 Andrebakely Sud	7,237	1,016	
Andrebakely	1,560	160	SM**
Ambodifarihy	1,688	250	SM**
Antanimalalaka	1,877	326	SM**
Amnongabe	987	125	SM**
Andranomnainga	707	110	SM**
Andilambarika	418	45	SM**
3 Ambatomainty	13,849	2,165	
Ambatomainty	1,430	211	PC23
Analakininina	2,088	303	PC23
Antsevabe	900	125	PC23
Antanambao III - IV	3,100	516	PC23
Antanambao I - II	3,250	518	PC23
Mahakary	876	119	PC23
Vohibola	900	103	PC23
Antsapananefatra	1,055	205	PC23
Andrombaza	250	65	PC23
4 Morarano Chrome	52,938	10,484	
Morarano Chrome	10,278	1,713	SM**
Morarano Quest	1,407	396	SM**
Ambahibo	7,110	1,422	PC23
Manakambahinikely	1,494	249	SM**
Analamongy	402	67	SM**

commune/village	Population	H.H	Region
4 Morarano Chrome (continue)			
Mahatsinjo	3,924	654	Sahamilahy
Ambohidrony	1,894	350	PC23
Ambatomanga	1,998	333	PC23
Antanimena	1,673	277	SM**
Maharidaza	1,385	325	SM**
Antanandava	1,200	341	Sahamilahy
Anosiboribory	550	187	PC23
Antsahamanga	350	91	Sahamilahy
Ankoririka	2,000	350	Sahamilahy
Antsarahonenana	1,125	213	Sahamilahy
Ambohimanarivo	1,800	320	Sahamilahy
Tsaralaza	690	115	Sahamilahy
Ambohidelahy	860	215	SM**
Moratelo	1,090	400	Sahabe
Ambodiatafana	1,671	354	Sahabe
Andranofasika	890	148	Sahabe
Maheriara	1,600	270	Sahamilahy
Antetezantany	535	190	Sahamilahy
Antanimafy	4,500	1,000	Sahamilahy
Andoharano	261	87	Sahamilahy
Ambodirano	1,701	230	Sahamilahy
Ambohitromby	550	187	Sahamilahy
5 Ranomainty	10,062	1,535	
Ranomainty	2,472	380	Sahabe
Mahatsara	1,799	300	Sahabe
Ranofotsy	2,130	290	Sahabe
Fidanana	1,839	285	Sahabe
Ambohimanatrika	1,822	280	Sahabe
Amparihivola			Sahabe

Commune/village	Population	H.H	Region
6 Bejofo	1,536	260	
Betambako	1,017	174	Sahabe
Ambohitrandriana	519	86	Sahabe
7 Soalazaina	8,712	1,431	
Soalazaina	3,637	534	Sahabe
Ambatobe	1,758	317	Sahabe
Vohitsoa	1,979	278	Sahabe
Mahatsara	1,338	302	Sahabe
Andranobe			Sahabe
8 Tanambao-Besakay	13,033	2,183	
Tanambao-Besakay	5,080	1,000	Sahabe
Anjiro	2,061	300	Sahabe
Nandanivatsy	2,427	350	Sahabe
Andriambe	2,122	300	Sahabe
Ambohimanarina	691	145	Sahabe
Andilamenakely	652	88	Sahabe
9 Andilanatoby	7,137	1,016	
Ambodifiakarana	570	101	Sahabe
Ambohimiarina	1,607	221	Sahabe
Sahanidingana	2,375	333	Sahabe
Ankasina	850	111	Sahabe
Ambohimasina	1,128	150	Sahabe
Andasibe	607	100	Sahabe
Toltal in the Study Area	118,194	20,631	

Note: **H.H:house hold, **:4 small and medium rivers

Source: Office files of Communnes and villages

Table 3.2 Average Farm Buget in 10 Selected villages

(FMG/household/year)

region	PC23		Sahamilahy river basin			small/mediam river basins	Sahabe river basin			
village	Ambohidrony	Mahakary	Antanimafy	Maheriara	Morarano Chrome	Manakam-bahinikely	Ranofotsy	Sahanidingana	Soalazaina	Besakay
A. Income										
1) agriculture	4,572,000	2,284,000	4,763,000	1,746,000	3,660,000	4,046,000	2,186,000	3,397,000	1,023,000	2,532,000
2) livestock	711,000	970,000	704,000	167,000	537,000	114,000	141,000	148,000	446,000	361,000
3) fisheries	1,253,000	1,737,000	569,000	502,000	1,550,000	650,000	343,000	550,000	485,000	737,000
4) sale of fire wood	1,088,000	1,214,000	949,000	656,000	991,000	478,000	278,000	501,000	602,000	393,000
5) agri.hired labor	1,377,000	812,000	371,000	628,000	620,000	232,000	318,000	222,000	456,000	453,000
6) income from other occupation	799,000	626,000	670,000	548,000	1,707,000	243,000	254,000	302,000	1,360,000	763,000
7) remittance	615,000	411,000	279,000	155,000	128,000	60,000	108,000	87,000	481,000	413,000
8) others	633,000	132,000	241,000	47,000	395,000	78,000	64,000	24,000	522,000	265,000
sub-total	11,046,000	8,187,000	8,545,000	4,450,000	9,588,000	5,900,000	3,691,000	5,230,000	5,375,000	5,918,000
standard deviation	*7,780,000*	*8,032,000*	*5,450,000*	*2,676,000*	*7,925,000*	*6,092,000*	*2,506,000*	*6,105,000*	*3,371,000*	*4,753,000*
maximun	*40,600,000*	*50,625,000*	*23,925,000*	*24,174,000*	*43,340,000*	*38,080,000*	*9,726,000*	*41,200,000*	*19,150,000*	*29,020,000*
minimum	*2,780,000*	*1,788,000*	*1,126,000*	*873,000*	*790,000*	*1,425,000*	*468,000*	*770,000*	*500,000*	*496,000*
B. Expenditure										
1) food	2,298,000	1,937,000	2,540,000	1,627,000	3,836,000	1,602,000	1,094,000	1,150,000	1,596,000	1,419,000
2) clothes	356,000	412,000	348,000	179,000	441,000	353,000	193,000	381,000	193,000	462,000
3) housing expenses	176,000	370,000	406,000	45,000	377,000	191,000	49,000	223,000	198,000	219,000
4) education	366,000	225,000	347,000	83,000	296,000	198,000	91,000	130,000	94,000	207,000
5) medical services	539,000	290,000	264,000	53,000	466,000	172,000	73,000	100,000	93,000	163,000
6) energy	434,000	114,000	172,000	65,000	513,000	150,000	105,000	83,000	111,000	148,000
7) loan repayment	468,000	55,000	375,000	2,000	288,000	205,000	196,000	66,000	64,000	108,000
8) others	980,000	169,000	607,000	138,000	510,000	386,000	265,000	246,000	142,000	342,000
sub-total	5,616,000	3,571,000	5,058,000	2,191,000	6,726,000	3,257,000	2,065,000	2,380,000	2,492,000	3,067,000
standard deviation	*4,156,000*	*1,914,000*	*5,138,000*	*1,282,000*	*9,691,000*	*2,759,000*	*1,469,000*	*2,249,000*	*1,692,000*	*2,685,000*
maximun	*24,765,000*	*10,300,000*	*28,660,000*	*6,163,000*	*70,060,000*	*16,580,000*	*7,103,000*	*15,000,000*	*10,791,000*	*15,240,000*
minimum	*1,230,000*	*1,215,000*	*876,000*	*561,000*	*720,000*	*1,005,000*	*343,000*	*693,000*	*466,000*	*326,000*
C. net reserve	5,430,000	4,616,000	3,487,000	2,258,000	2,862,000	2,643,000	1,626,000	2,850,000	2,884,000	2,851,000

Source: detail village survey by JICSA study team, Feb. 2004

Table 3.3 Soil Analyses

Sample sites	topography	land use	horizon	soil texture	pH water	pH KCl	EC (µmho/cm)	total carbon (%)	total nitrogen (%	C/N ratio	available phospate (ppm	CEC meq/100g	BS %
Antanimafy	hilly	upland	surface	SL	5.85	5.15	250	2.66	0.049	54.3	6.1	2.2	11.8
			sub-soil	Silty C	5.95	4.90	170	1.62	0.035	48.3	1.4	0.9	19.1
Maheriara/Antanetilehibe-1	valley bottom	paddy field	cultivated land	SL	5.70	5.40	450	11.96	0.336	35.6	1.0	8.0	24.9
Maheriara/Antanetilehibe-2	valley bottom	paddy field	cultivated land	SL	5.90	5.60	182	12.83	0.378	33.9	0.7	9.9	68.2
Maheriara/Anosivilona	valley bottom	paddy field	cultivated land	L	6.20	5.90	158	2.04	0.070	29.1	0.2	3.2	184.2
Maheriara/Amabaniatsimo	valley bottom	paddy field	cultivated land	CL	5.65	5.80	300	2.27	0.063	36.0	2.4	4.8	116.2
Ambatomainty	valley bottom	upland	surface	SL	5.60	4.85	650	3.21	0.084	38.2	76.3	2.6	12.3
			sub-soil	SL	5.95	4.85	400	1.56	0.049	31.8	11.8	1.1	19.2
Antsenandrabary	alluvial plain	paddy field	cultivated land	CL	5.90	5.75	150	1.11	0.028	39.6	0.9	2.3	127.7
Anosiboriry	plateau	forst	sub-soil	LS	5.75	5.45	280	2.34	0.070	33.4	18.6	1.9	52.3
			sub-soil	SL	6.00	3.25	80	1.43	0.028	51.1	7.7	1.0	20.9
PC23/Antanandava	alluvial plain	paddy field	cultivated land	SL	5.70	5.20	230	9.31	0.161	57.8	7.0	3.8	37.7
PC23/Lot 4	alluvial plain	paddy field	sub-soil	SL	5.65	5.05	136	9.08	0.168	54.0	4.3	5.6	58.0
			sub-soil	SL	6.20	5.70	100	8.23	0.126	65.3	4.2	5.8	60.9
PC23/Lot 5	alluvial plain	paddy field	cultivated land	C	5.55	5.00	156	1.89	0.098	19.3	9.0	4.1	126.0
PC23/Lot 5	alluvial plain	paddy field	cultivated land	L	5.55	5.20	166	11.30	0.196	57.7	3.1	6.5	39.6
PC23/Lot 6-1	alluvial plain	paddy field	cultivated land	CL	5.65	5.25	176	3.68	0.119	30.9	34.3	3.9	117.3
PC23/Lot 6-2	alluvial plain	paddy field	cultivated land	SL	5.70	4.95	160	10.05	0.210	47.9	5.3	7.1	33.7
Mahakary/PC23 Lot 20-1	alluvial plain	upland	cultivated land	CL	6.10	5.70	344	3.67	0.119	30.8	9.2	3.5	148.1
Mahakary/PC23 Lot 20-2	alluvial plain	upland	cultivated land	SL	6.05	5.70	400	8.41	0.301	27.9	3.6	7.3	73.0
Mahakary/PC23 Lot 28	alluvial plain	upland	surface	L	6.60	6.25	166	5.62	0.119	47.2	1.1	4.5	119.2
			sub-soil	SL	5.85	5.60	210	5.84	0.168	34.8	3.1	8.2	56.8
Mahakary/PC23 Lot 29	alluvial plain	upland	cultivated land	SL	6.25	5.90	234	8.35	0.182	45.9	2.4	5.1	89.5
Bejofo	plateau	upland	surface	SL	5.70	4.55	260	3.41	0.098	34.8	3.1	2.1	15.4
			sub-soil	SL	6.05	5.25	140	2.71	0.084	32.3	1.8	1.5	15.1
Ranofotsy	lavaka	grazing land	surface	SCL	5.45	5.30	114	1.20	0.028	42.9	3.6	1.9	156.2
	fan		sub-soil	SCL	5.50	5.20	64	0.50	0.014	35.7	1.1	2.0	101.7

remarks : soil samples taken by JICA study team, soil analyses done by FOFIFA

EC:electric conductivity, CEC:cation exchange capacity, BS:base saturation

Source: JICA study team

Table 3.4 Total Length of Canals in PC23 Area

(Unit: m)

Irrigation Canals						Drainage Canals			
Main Canal		Secondary Canal		Tertiary Canal		Main Drain		Tertiary Drain	
Name	Length	Name	Length	Name	Length	Name	Length	Name	Length
P1	23,200			C001	2,600	D0	14,700	D001	1,800
				C002	1,000			D002	2,000
				C003	2,300			D003	3,300
				C101	1,700			D004	4,000
				C102	2,200			D005	3,200
		C.1.1	2,000	C111	1,400	D1	8,200	D101	2,000
				C112	2,000			D102	2,400
		C1.2	-	C121	1,500			D103	3,000
				C122	2,800			D104	3,000
		C1.3	5,000	C131	1,000			D105	3,000
				C132	3,000			D106	3,000
				C133	3,000			D107	3,000
				C134	3,000			D108	3,000
				C135	3,000	D2	12,400	D200	4,800
				C136	2,500			D201	4,800
		C1.4	3,200	C141	2,000			D202	3,200
				C142	1,200			D203	1,000
				C143	1,600			D204	1,600
P5	6,400	C5.1	250					D205	4,600
		C5.2	2,200					D206	4,600
		C5.3	650	C531	2,000			D207	3,600
				C532	2,000			D208	4,000
				C533	1,000			D209	3,600
		C5.4	-	C541	3,400			D210	4,000
				C542	4,500			D211	3,600
		C5.5	7,900	C551	1,000			D212	4,000
				C552	1,600			D213	3,600
				C553	2,000			D214	4,000
				C554	2,000			D215	3,600
				C555	2,000			D216	4,000
				C556	2,000			D217	3,600
				C557	2,000			D218	4,000
				C558	4,900			D219	3,600
		C5.6	8,900	C561	2,600			D220	4,000
				C562	2,600			D221	3,600
				C563	2,600	D3	8,700	D301	1,500
				C564	2,600			D302	1,100
				C565	2,600			D303	-
				C566	2,600			D304	1,200
				C567	2,600	D4	5,800	D401	3,400
				C568	2,600			D402	2,000
				C569	1,500	Sub-total	49,800		127,300
Sub-total	29,600		30,100		90,500	South D.	3,000		
N.C.Canal	10,500		-		-	North D.	3,600	ND1	5,000
Total	40,100		30,100		90,500			ND2	4,800
								ND3	4,500
						Sub-total	6,600		14,300
						Total	56,400		141,600

(Note) : The previous study for rehabilitation in 1988 shows the following length;
'- Main Irrigation Canal : 28,930 m
'- Secondary Irrigation Canal: 36,880 m
N.C.Canal: North Collector Canal
D.: Drain

Source:JICA study team

Table 3.5 Farmers' Desire for Development

(%)

Zone	Sahamilahy river basin			small/medium river basins	Sahabe river basin				PC23 area		
village	Antanimafy	Maheriara	Morarano Chrome	Manakambahin ikely	Ranofotsy	Sahanidingan a	Soralazaina	Besakay	Ambohidrony	Mahakary	numver of village*
1- road	25.6	57.5	41.7	92.5	59.2	94.0	86.7	73.3	58.0	100.0	9
2- bridge	35.9	17.5	5.0	12.5	16.3	12.0	11.7	20.0	0.0	2.0	1
3- drainage	0.0	2.5	23.3	12.5	10.2	14.0	20.0	6.7	18.0	6.0	0
4- medical services	51.3	70.0	25.0	60.0	44.9	16.0	10.0	66.7	84.0	10.0	6
5- water supply	28.2	90.0	53.3	15.0	38.8	22.0	41.7	31.7	26.0	84.0	5
6- irrigation system	12.8	2.5	11.7	17.5	24.5	48.0	16.7	35.0	26.0	84.0	3
7- marketing of agri.products	38.5	2.5	28.3	22.5	20.4	10.0	40.0	25.0	14.0	6.0	2
8- services for agricutural technol	33.3	12.5	43.3	10.0	26.5	38.0	15.0	8.3	32.0	0.0	3
9-toilet	2.6	5.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	4.0	0
10- forestation	10.3	17.5	23.3	17.5	16.3	12.0	16.7	3.3	2.0	2.0	0
11- soil conservation	23.1	22.5	10.0	30.0	8.2	32.0	28.3	20.0	4.0	0.0	1
12- others	30.8	0.0	21.7	10.0	16.3	0.0	1.7	5.0	26.0	2.0	0

※answer for question[what development items do you want for development assistance?], 3 items at maximum for selection

development items at largest three desires in village

* : the number of villages that indicates one development items among the largest three desires

Source: the detail village survey conducted by JICA study team, Feb. 2004

Figure

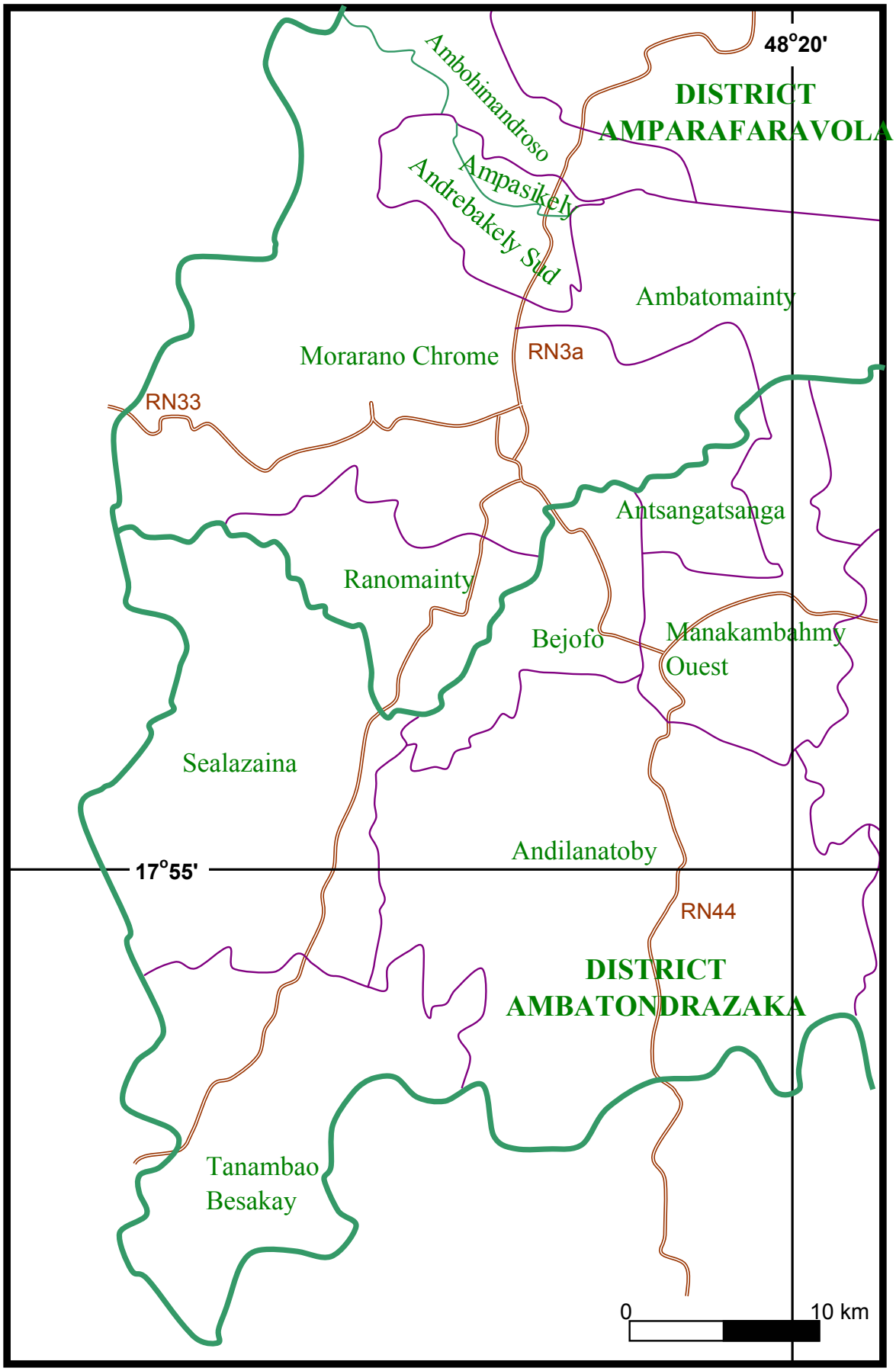


Fig.3.1 Location map of administrative units and zone in the study area

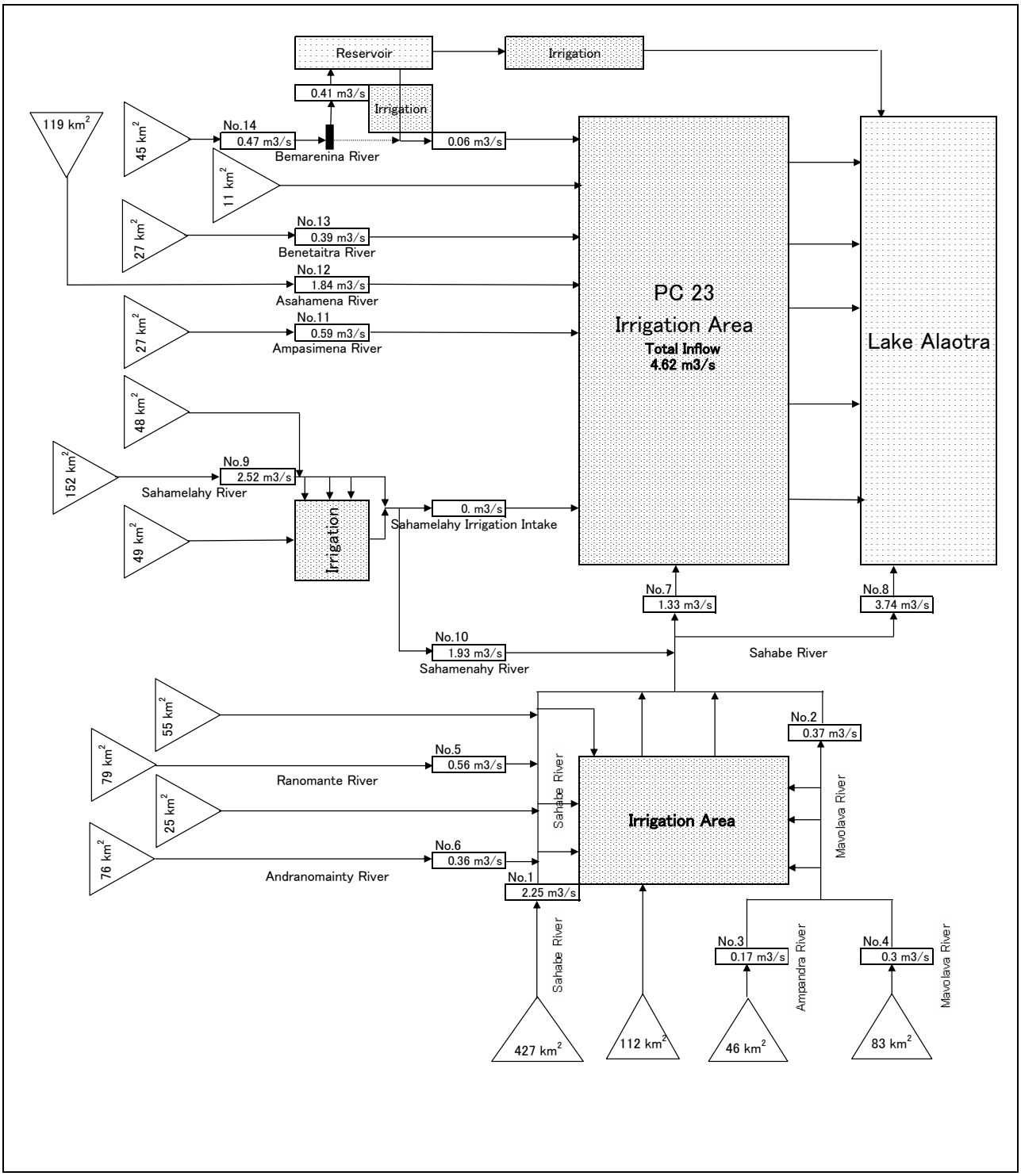
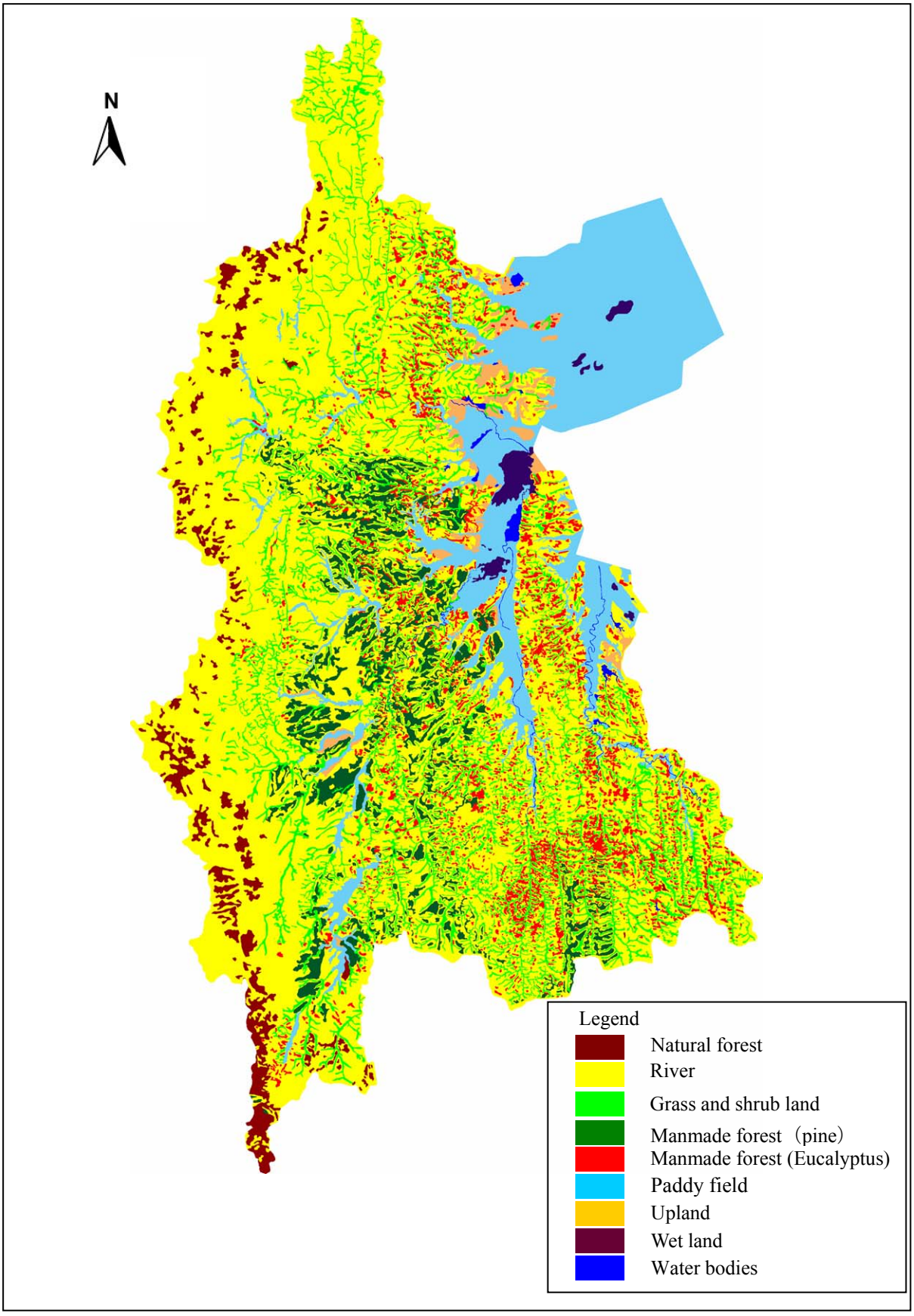


Fig. 3.2 Discharge measurement results in PC23 irrigation area
(Mesurement period: Oct. 8, 2003 - Oct. 11 2003)



Data source：MINENVEF , JICA Study Team

Fig. 3.3 Land use map in the Study area

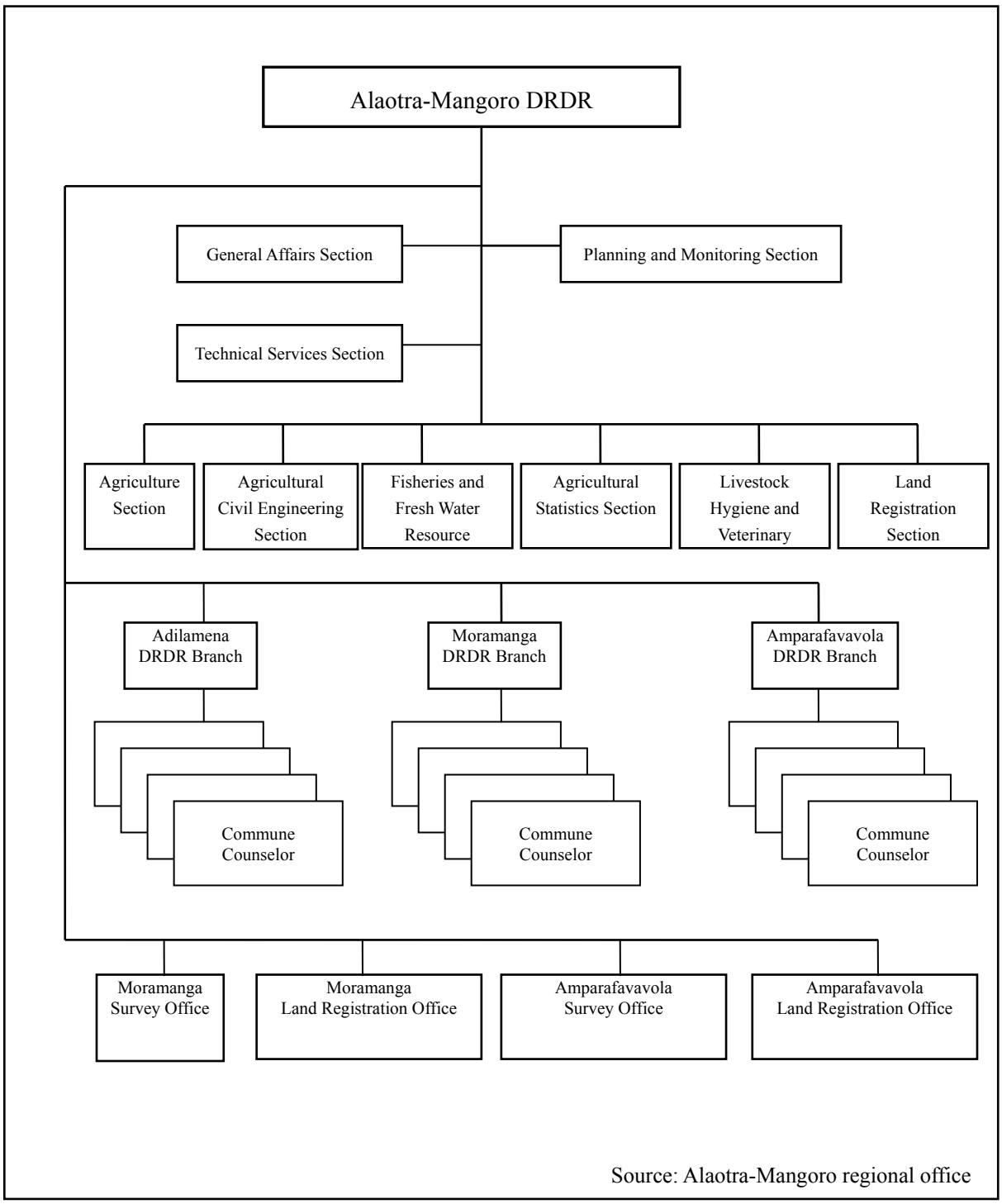
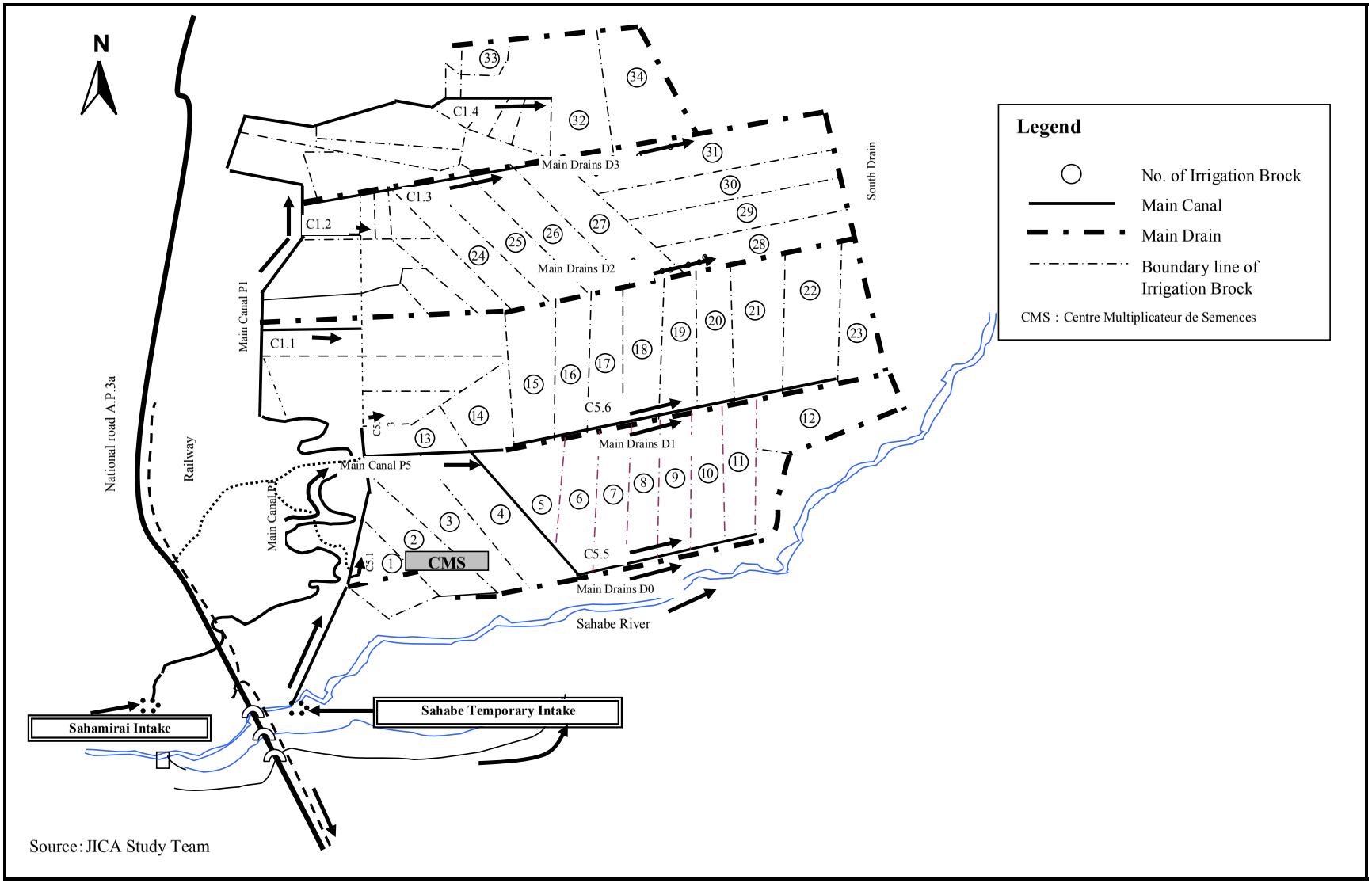
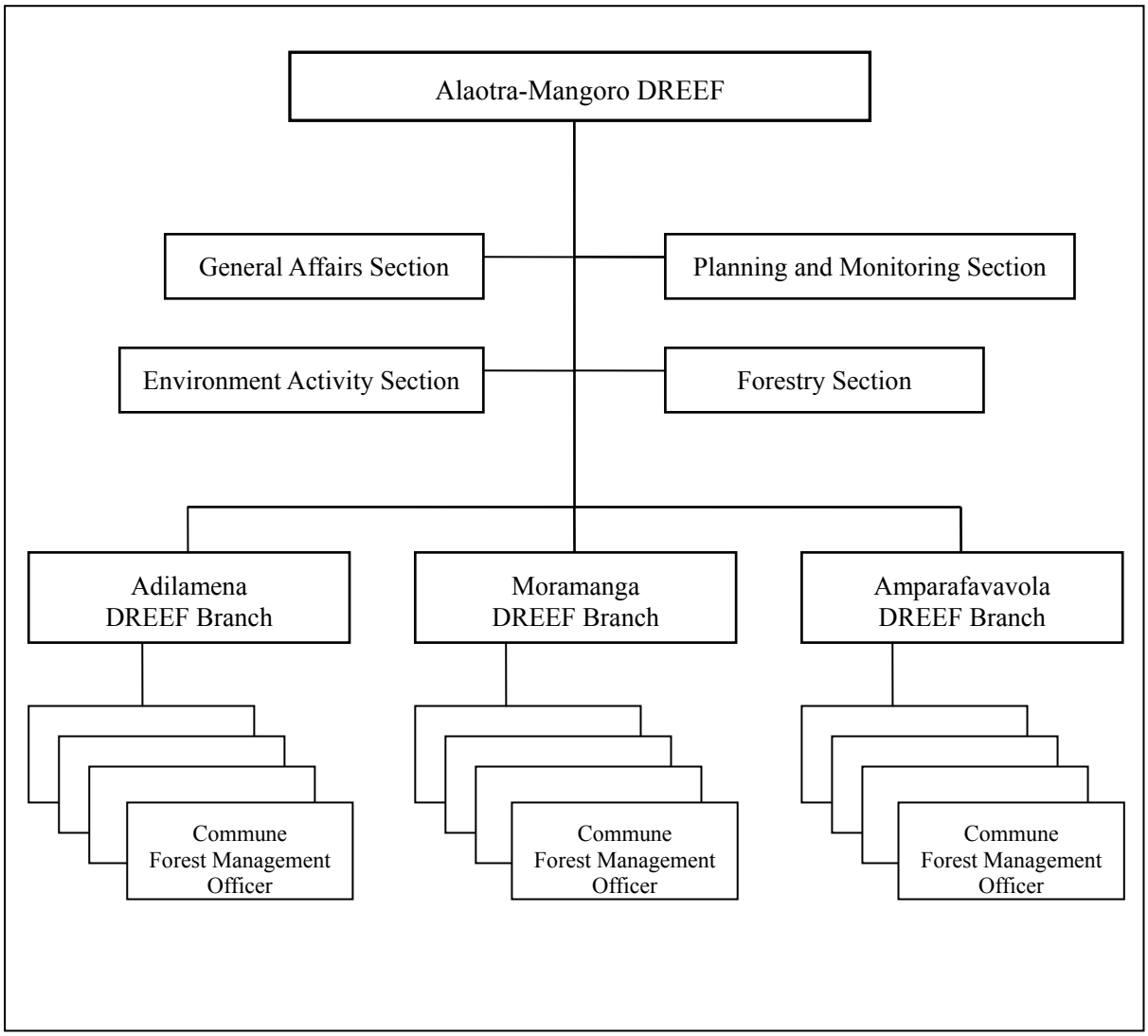


Fig. 3.4 Alaotra-Mangoro DRDR



Source: JICA Study Team

Fig 3.5 Irrigation and Drainage System in PC23



Source: Alaotra-Mangoro regional office

Fig. 3.6 Alaotra-Mangoro DREEF

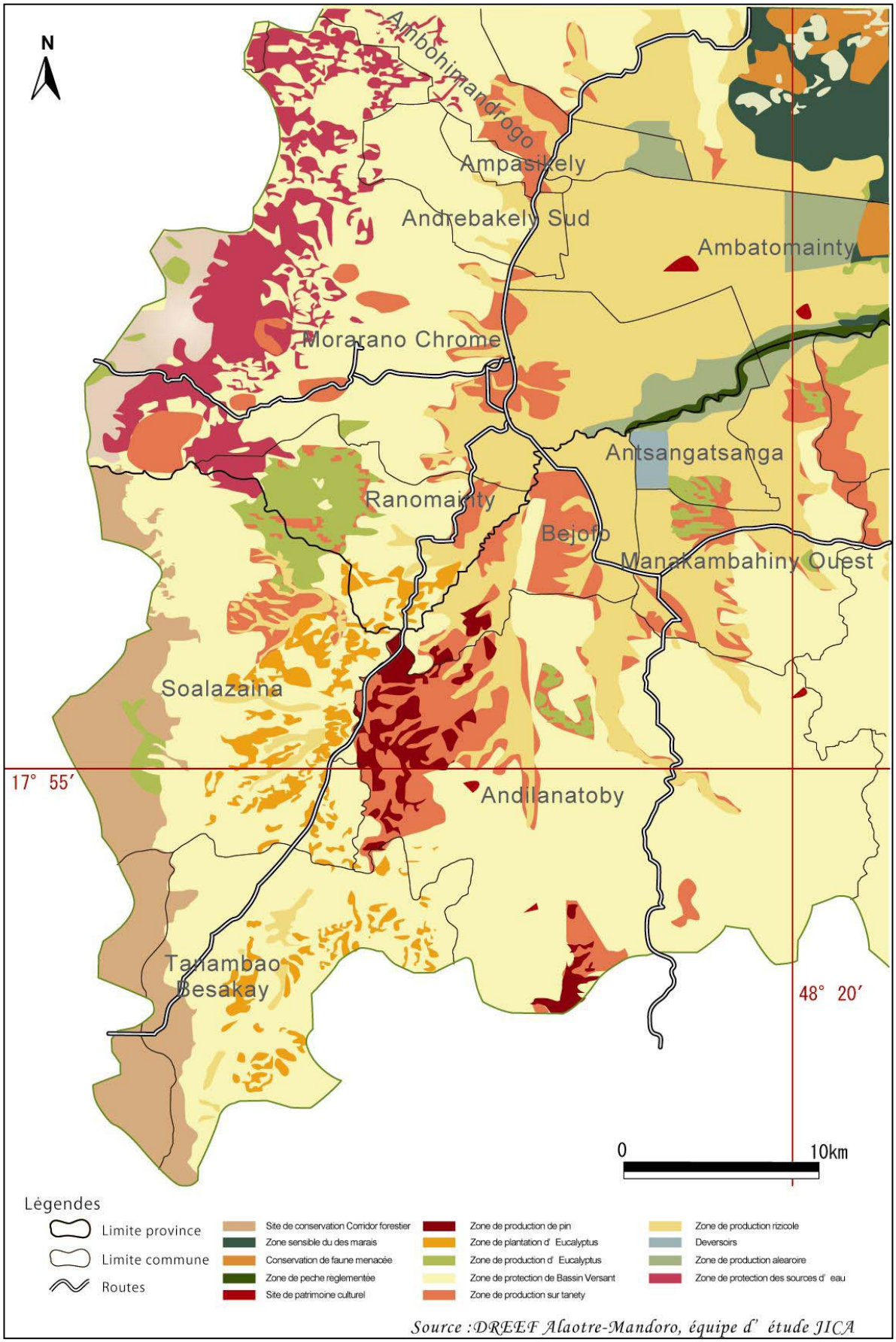


Fig3.7 Map of watershed management

EXPLANATION NOTE 3-1

RUN-OFF ANALYSIS

RUN-OFF ANALYSIS

1 Objectives

Low flow analysis is conducted in this study to estimate the long term series of river flow in the study area. The seasonal distribution of river flow highly affects to the irrigation activities, by which rice productivity is much fluctuated. For example, the severe draught occurred in 1998 and 1999 of hydrological year in the study area, and the most of paddy field in PC-23 irrigation area was dried up without rice production. This is quite serious for the farmers to keep on stable income for their daily livings. Generally, the decrease of income would directly affect to the education condition of children. Many farmers told that if income is upgraded, they want to spend the incremental money to the education for the children. On the contrary, the expenses for the education would be firstly saved if the income is decreased due to drought and flood.

Low flow analysis could not solve such a serious matter, it can be clarified the probability of the draught risk, which could provide some hints to take actions for the disasters such as flood and draught to the water users association and farmers. The disaster preparedness activities, such as rice stock, saving, and emergency insurances system, could be generated by means of the results of low flow analysis, because it can be indicated the probability of the drought risk.

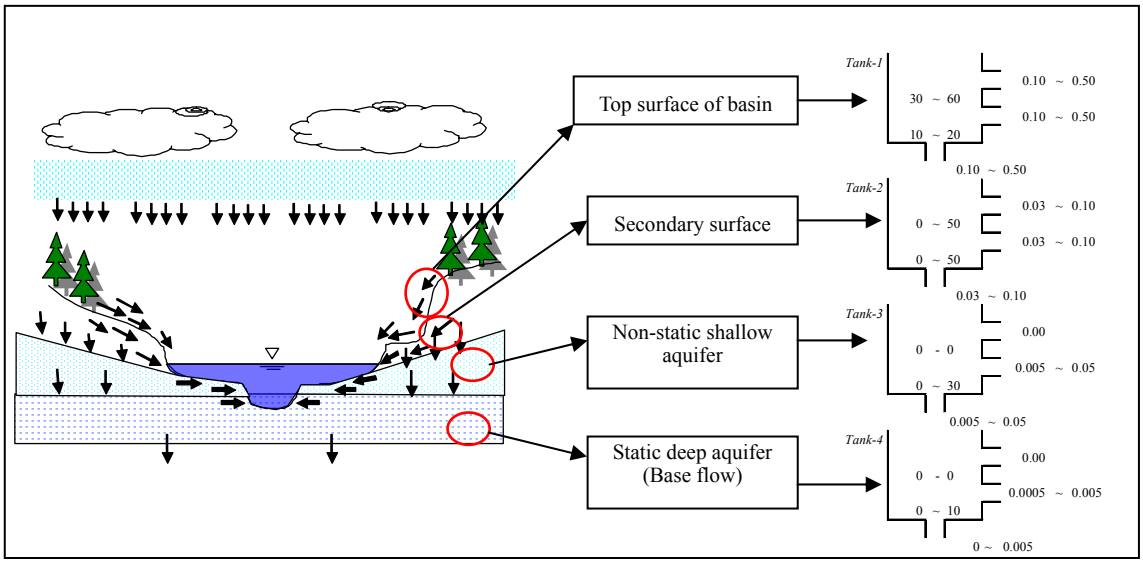
Another objective of lowflow analysis is to review the existing irrigation system of PC-23. The paddy field within PC-23 irrigation system is estimated about 10,000 ha. In addition, there are remarkable area of paddy field both on the upstream and the downstream of PC-23 area. The total paddy field is estimated more or less 15,000 ha. The optimum irrigation area based on the water availability would be revealed by the results of lowflow analysis and the followed water balance study. In addition, water resources development plan, including multi-purpose dam and reservoir, small scale water impounding, water distribution management plans can be proposed based on the low flow analysis.

2. Methodology

Generally, low flow analysis is conducted by means of the series of river discharge data. For this it is necessary to conduct discharge measurement, at least once a month for 30 years to accumulate the river discharge data. Daily river flow measurement together with the rainfall measurement is much preferable to conduct more detail and reliable analysis. The study team conducted discharge measurement in this time it is just once. The same activities should be continued for long-time.

Unfortunately, there is so far no river discharge data available, except one measurement record conducted by the study team. The one measurement data is of course not sufficient to conduct the low flow analysis. In this case, the rainfall record is to be used for low-flow analysis, which is called rainfall-runoff analysis. To conduct rainfall-runoff analysis some conversion model from rainfall to river flow is required. In this study, Tank Model is applied to the rainfall-runoff model, which was developed by Dr. Sugawara in Japan.

Figure2.1 describes the theory of tank model, which is quite simple compared with the other methods. The river basin is divided into four rows of tanks to represent top surface, secondary surface, non-static shallow groundwater aquifer, and static deep groundwater aquifer respectively. Rainfall is put into the top tank, and which is to be allocated for direct runoff to the river, storage in the tank and infiltration to the next tank. All the tanks have outlets to the rivers or the lower layers of the basins. The size and location of the holes is to be determined based on the observed rainfall and river discharge data.



Source: JICA study team

Figure 2.1 General Description of Tank Model

The procedures to develop the tank model for the study area are as follows:

1) To prepare the daily basis rainfall and discharge data for the Antanifotsy dam (74 km^2) in the Sasomangana River Basin (3 years data from 2000-2003 is available)

2) To develop tank model for the Antanifotsy dam and reservoir by trial and error. The developed model is 10-day basis instead of daily basis. Because the daily discharge data is converted from the daily reservoir water level and it is not sufficient to convert daily basis of discharge in its accuracy.

3) To prepare 10-day basis rainfall at Alaotra station for 10 years (1993-2002), and the basin rainfall data to develop by means of adjustment factor of basin mean elevation. The procedures are described in the former Section 1.3.

4) To simulate the 10-day basis discharge for respective river basins in the study area applying the same model developed for the Antanifotsy dam and reservoir.

5) To compare the simulated discharge at the end of dry season 2003 with the observed discharge, and to adjust the coefficient of Tank-3 and Tank-4 to fit the simulated discharge with the observed one.

6) To run the tank model for estimating 10-day basis river discharge for 1993 to 2002, this is to be utilized for water balance study.

It is much better that if the discharge measurement is continued by agriculture department or water users' association even once a month throughout the study period, which can be available to improve the accuracy of the basin run-off model.

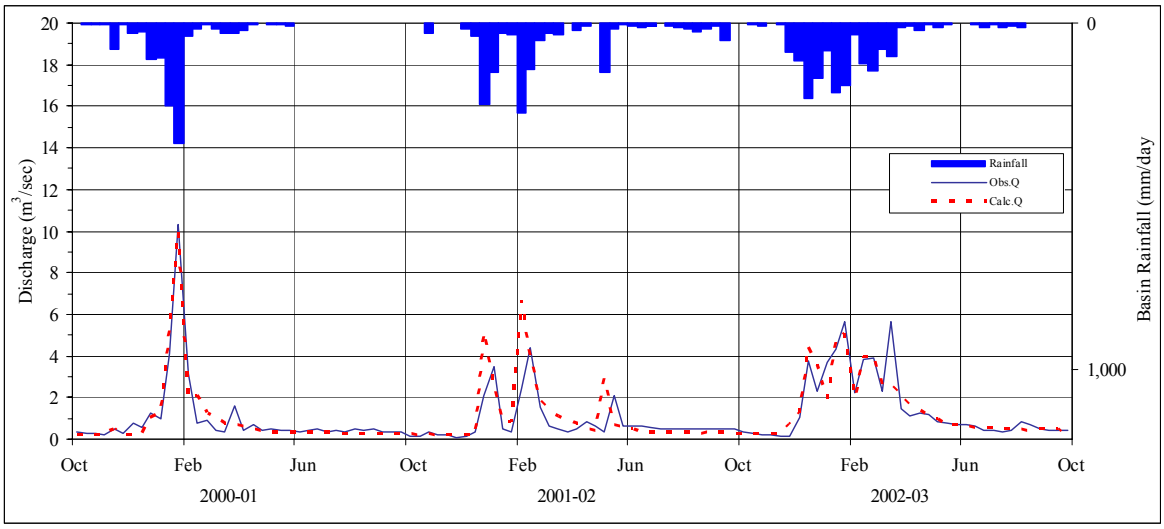
3. Rainfall-Runoff Record at Antanifotsy Dam

Figure 3.1 shows the calibration results of the developed rainfall-runoff model.

The correlation coefficient between the observed and simulated run-off is calculated at 0.725, which is not sufficiently high to justify the model accuracy, but it is judged the model is available in terms of the similarity of lowflow hydrograph as well as run-off coefficient. According to the simulation, the annual average run-off coefficient is estimated at 35.2%, which is almost same as observed one of 33.5%.

Table 3.1 Summary of Simulation Results (Unit:mm)

Year	Rainfall	Run-off (Calc.)	Evapo.	Infiltration	Ratio	Run-off (Obs.)
2000	1,109	397	629	105	0.358	409
2001	1,388	436	826	98	0.314	344
2002	1,629	625	791	99	0.384	633
Average	1,375	486	749	100	0.352	462



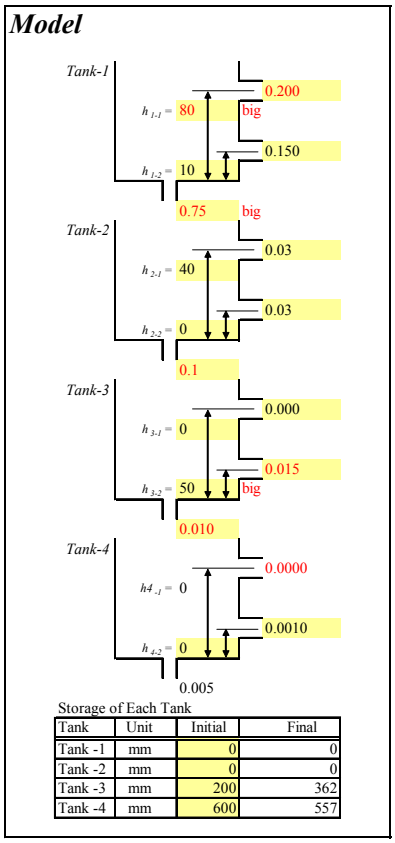
Source: JICA study team

Figure 3.2Comparison of the observed and the simulated hydrograph

It was found that even though the annual rainfall of 2001 is bigger than the one of 2000, the run-off ratio in 2000 is rather higher than the 2001. This is because the rainfall is concentrated in January in 2000/01 and the most them directly flows into the reservoir without evaporation loss. As the results, the annual run-off ratio in 2000 became higher than the 2001 because of the less evaporation volume. On the other hand, the calculated run-off ratio in the 2001 is much lower than the observed value. The reason why the higher run-off ratio is marked is that the observed peak floods in January and February 2002 are much lower than the simulation results. Taking into account the estimated basin rainfall, the simulated peak discharge can not be higher anymore, by which the other flood peak would also become much higher and the correlation would be much decreased. As the results, it is wondered that the actual basin rainfall during the flood in January and February 2002 might be rather lower than the recorded one.

View of Antanifotsy Dam and Reservoir (Storage: 24.65 million m^3 (HWL=El.820m)

Figure 3.3 shows the final developed tank model for the Sasomangana River basin. Since the location of the basin is just adjacent to the study area and the basin conditions, such as topography, geology and forest coverage are quite similar, the same model can be applied to the respective river basin in the study area.



Tank	Unit	Initial	Final
Tank -1	mm	0	0
Tank -2	mm	0	0
Tank -3	mm	200	362
Tank -4	mm	600	557

Source:JICA study team

Figure 3.4 Final Parameters of Tank Model

On the tank-1, the upper and the bottom holes are designed rather bigger than the standard. According to the calibration, it is supposed that the direct flood run-off is rather late up to the depth of 80mm. In fact, no remarkable peak flood can be observed with a rainfall of 40 to 50mm/day. Also, the flood quickly cease just 1-2 days after the rainstorm. These are the reasons why the upper and the bottom holes designed rather big and the height of upper holes is put at the higher place that the standard.

For the small flood, it seems that the discharge is mainly coming from the second tank as the observed flood receding hydrograph is rather gentle, which is not similar as the large scale flood hydrograph.

Parameters in Tank-3 and Tank-4 are determined based on the observed hydrographs from May to September, particularly at the end of dry season, September for three years. But the parameters in Tank-3 and Tank-4 would be adjusted for the respective river basin based on the results of discharge measurement conducted in the end of dry season, October 2003.

4. Development of Rainfall-Runoff Model for the Study Area

Table 4.1 compiled the determined parameters of the tank models of the rivers in the

study area. The calibration is carried out only one data, measured by the study team at the end of dry season 2003.

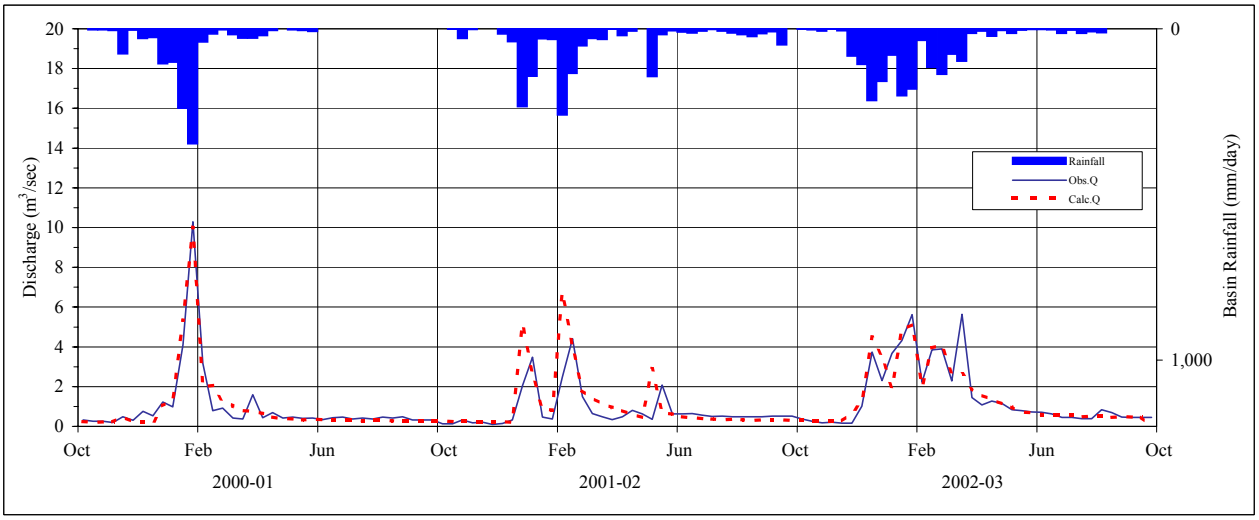
The run-off condition between the Sahabe river basin, and the Sahamilahy River and 4 small/medium basins in the study area is much difference, and the model is also reflected to the differences run-off characteristics between the Sahabe river basin, and the Sahamilahy River and 4 small/medium basins. As the result, the run-off ratio, which is the rate of run-off to rainfall, is about 38% for the Sahabe River, but of which in the Sahamilahy and 4 small/medium river basins is designed about 50%.

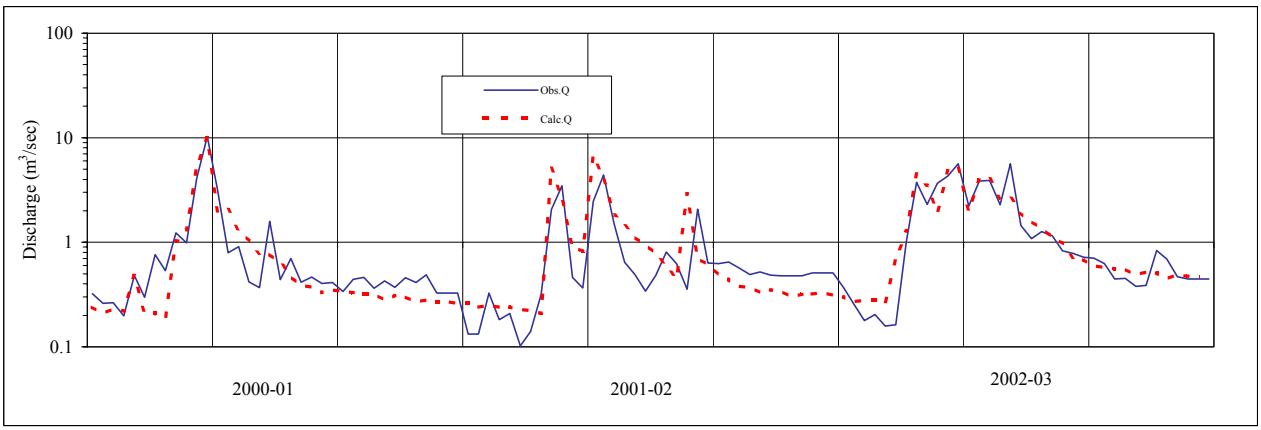
The 10-day rainfall data applied to the tank model simulation for the respective river basin is attached as Tables 4.2 through 4.10, and the simulated 10-day discharge is shown in Tables 4.11 through 4.19 respectively.

5. Probable 10-day Rainfall and Discharge on The Rivers in the study area

As conducted in Section 3.2.3(1) in the main text, the drought probability analysis is required for the plan formulation of irrigation management and development. The seasonal available flow should be analyzed based on the authorized stochastic theory. In this study, 10-day series of annual discharge was estimated by means of the developed tank model for 5-year wet year, average year and 5-year drought year. The irrigation plan is generally formulated based on the water availability under 5-year drought year condition.

The available series of rainfall data is only for 10 years after 1993. Therefore, distribution pattern of probable rainfall and probable discharge was made based on the 10-day average rainfall and simulated discharge for 10 years. For 5-year probable wet year, adjustment factor of 1.2 is multiplied based on the average rainfall as well as discharge (1,281mm/1,068mm). For 5-year probable drought year, adjustment factor of 0.84 (898mm/1,068mm) is applied based on the average 10-day rainfall and discharge. Based on the above adjustment, the simulation was again conducted by means of tank model for respective rivers. The results are compiled in Tables 4.2 to 4.10 for the basin rainfall, and Tables 4.11 through 4.19 for the discharge for respective river basin.





Check of Run-off Ration

Year	Rainfall	Run-off (Calc.)	Evapo.	Infiltration	Ratio	Run-off (Obs.)
2000	1,109	397	629	105	0.358	409
2001	1,388	436	826	98	0.314	344
2002	1,629	625	791	99	0.384	633
Average	1,375	486	749	100	0.352	462

Run-off Ration

Year	Observe.	Calc.	
2000	0.369	0.358	OK
2001	0.248	0.314	-
2002	0.389	0.384	OK
Average	0.335	0.352	OK

4 Co-relation Check

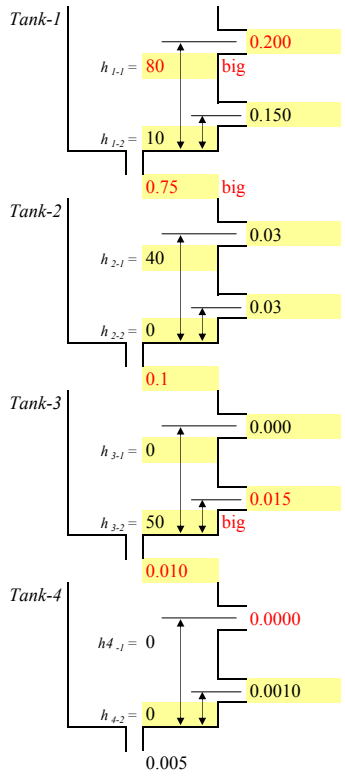
Year	Annual	Oct-Apr.	May-Sep.	
2000	0.621	0.589	0.359	-
2001	0.818	0.800	0.988	OK
2002	0.735	0.648	0.679	OK
3 Years	0.725	0.679	0.676	OK

Figure 3.1 Results of simulation by tank-model at Sasomangana river

Error= 0 **0** (No.of X= 0) Date: 21-Apr-08

R fo Reduced EV (mm/day) **5.0** Coefficient for Evapotranspiration 0.7

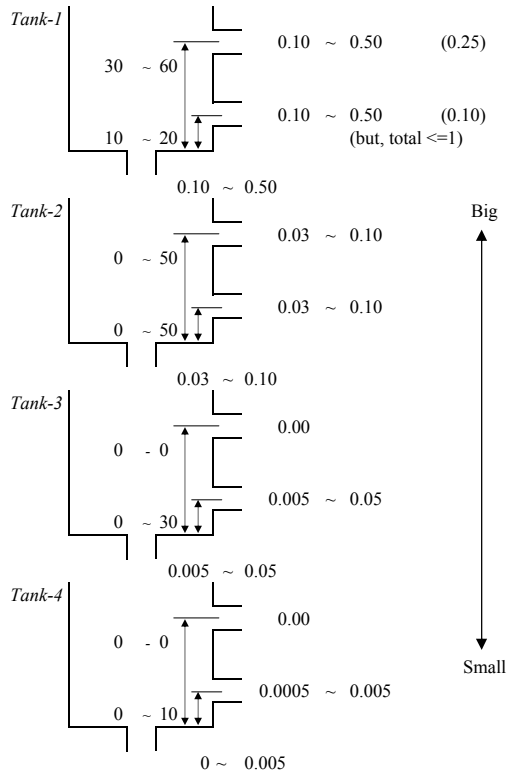
Model



Storage of Each Tank

Tank	Unit	Initial	Final
Tank -1	mm	0	0
Tank -2	mm	0	0
Tank -3	mm	200	362
Tank -4	mm	600	557

Reference of Coefficient for Tank



Initial Storage of Each Tank

Tank -1	mm	0
Tank -2	mm	0
Tank -3	mm	10 ~ 100
Tank -4	mm	100 ~ 1,000

Source: Ministry of Construction, Japan

Conditions of the Tank Model

River System

Sasomangana River

Catchment Area & Calculation Term

Catchment Area	km2	74.00
Discharge Calculation Point at		Antanifotsy Damsite
Calc. Start Year	YYYY	1
Lag Time of U/S to Down Stream (Max = 2days) **ONLY for Daily Calc.**	day	0

Evapotranspiration (ET)

If storage volume of tank-1 is empty (=0), ET from Tank-2 ?	(Y or N)	Y
If storage volume of tank-2 is empty (=0), ET from Tank-3 ?	(Y or N)	N
If storage volume of tank-3 is empty (=0), ET from Tank-4 ?	(Y or N)	N
In a rainy day, will evapotranspiration be reduced ?	(Y or N)	N
(if above yes, how mach rainfall per day when it will be reduced EV ?	mm/day	5.0
(and, how many percentage of reducing for potential EV ?	%	50%

EV from Tank

Tank-1	Y
Tank-2	Y
Tank-3	N
Tank-4	N
(if above y	0.5
(and, how	50%

Figure 3.3 Rainfall-runoff model at Sasomangana river

Table 4.1 Tank-model analysis for the rivers in the Study area

No.				1	2	3	4	5	6	7	8	9
location				Ambohimitsotra	Morarano	Ranofotsy	Sahadingana	Maheriara	Ambohidray	Ambohimanjaka	Hafisea	Bismangana
name of river				Sahabe	Andranomainty	Ranomanty	Mavalova-Ampandra	Sahamilay	Ampasimena	Asahamena	Behengitra	Bemarenina
river system				Sahabe	Sahabe	Sahabe	Sahabe	Sahamilahy	Ampasimena	Asahamena	Behengitra	Bemarenina
catchment area				427 km2	76 km2	79 km2	129 km2	152 km2	27 km2	119 km2	27 km2	45 km2
average elevation of the river asin				El.1031 m	El.937 m	El.1,008 m	El.947 m	El.1,097 m	El.891 m	El.1061 m	El.918 m	El.914 m
Paremeters of Tank Model	Tank-1	Initial depth		0	0	0	0	0	0	0	0	0
		upper hole	height	80	80	80	80	80	80	80	80	80
			dia.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		lower hole	height	10	10	10	10	10	10	10	10	10
			dia.	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
		bottom hole	dia.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	Tank-2	Initial depth		0	0	0	0	0	0	0	0	0
		upper hole	height	40	40	40	40	40	40	40	40	40
			dia.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		lower hole	height	0	0	0	0	0	0	0	0	0
			dia.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		bottom hole	dia.	0.1	0.1	0.1	0.1	0.15	0.35	0.15	0.25	0.15
	Tank-3	Initial depth		200	200	200	200	200	200	200	200	200
		upper hole	height	0	0	0	0	0	0	0	0	0
			dia.	0	0	0	0	0	0	0	0	0
		lower hole	height	50	50	50	50	10	10	10	10	10
			dia.	0.005	0.005	0.005	0.005	0.03	0.03	0.03	0.03	0.03
		bottom hole	dia.	0.05	0.05	0.006	0.05	0.005	0.005	0.005	0.005	0.02
	Tank-4	Initial depth		600	600	600	600	600	600	600	600	600
		upper hole	height	0	0	0	0	0	0	0	0	0
			dia.	0	0	0	0	0	0	0	0	0
		lower hole	height	0	0	0	0	0	0	0	0	0
			dia.	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		bottom hole	dia.	0.006	0.006	0.004	0.007	0.001	0.001	0.001	0.001	0.001
Simulated Resuls												
	annual average rainfall			1453mm	1,311 mm	1,418 mm	1,326 mm	1,553 mm	1,241 mm	1,553 mm	1,282 mm	1,276 mm
	annural average discharge			7.6m^3/s	1.15 m^3/s	1.47 m^3/s	1.96 m^3/s	4.09 m^3/s	0.57 m^3/s	3.04 m^3/s	0.57 m^3/s	0.86 m^3/s
	run-off coefficient			38.30%	36.10%	41.10%	35.70%	54.20%	52.80%	54.20%	51.90%	46.80%

Source: JICA study team

Table 4.2 10-day rainfall at Amohimitsotra (Sahabe river)

River System
Catchment Area: 427 km2
Basin Elevation: 1031 (El.m) Adjustment Factor: 1.343 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.3	34.5	0.0	84.6	271.9	125.7	5.4	0.0	3.8	7.1	2.6	1.7	1,597.5
		11-20	0.0	10.1	66.1	205.5	73.1	22.7	0.3	2.8	4.0	19.9	4.8	4.2	
		21-end	88.8	0.0	111.1	291.2	12.5	107.3	0.4	25.9	2.8	4.0	2.4	0.0	
		Month	89.1	44.6	177.2	581.3	357.4	255.7	6.0	28.7	10.6	31.0	9.8	5.9	
2	1994/95	1-10	43.3	0.0	43.0	14.9	203.6	4.4	33.2	37.1	11.3	0.0	0.4	0.5	1,523.6
		11-20	138.4	0.0	104.4	365.6	81.9	75.2	30.5	0.0	1.9	4.2	2.6	0.4	
		21-end	45.4	4.7	0.4	239.0	7.3	25.1	0.7	1.7	0.1	1.3	1.1	0.1	
		Month	227.0	4.7	147.8	619.5	292.8	104.8	64.3	38.8	13.3	5.5	4.0	1.1	
3	1995/96	1-10	2.4	0.8	210.6	184.6	124.8	105.0	3.6	4.3	0.5	2.1	1.6	0.4	1,869.4
		11-20	0.5	0.0	116.2	240.3	8.9	26.2	1.7	0.7	0.7	0.9	0.7	0.3	
		21-end	2.7	3.5	358.2	228.2	39.4	173.4	19.5	0.0	2.6	3.0	0.7	0.4	
		Month	5.6	4.3	685.0	653.1	173.0	304.6	24.8	5.0	3.8	6.0	3.0	1.1	
4	1996/97	1-10	0.1	0.0	138.9	177.6	146.9	7.5	55.2	4.2	0.0	8.7	7.1	5.2	1,675.9
		11-20	0.1	0.0	316.6	62.7	91.5	16.4	0.5	0.3	1.7	1.2	0.0	0.7	
		21-end	0.0	5.8	93.8	405.3	102.8	1.1	0.0	1.2	1.2	2.8	1.3	17.5	
		Month	0.3	5.8	549.2	645.6	341.2	25.0	55.7	5.6	3.0	12.8	8.5	23.4	
5	1997/98	1-10	1.1	0.5	159.4	94.2	50.9	22.4	0.5	15.9	1.1	1.1	4.4	47.6	1,461.4
		11-20	10.2	85.8	0.7	23.0	168.2	0.0	3.6	0.0	5.0	0.7	3.6	0.5	
		21-end	20.4	28.1	39.9	278.0	388.5	0.3	0.0	0.0	0.8	2.1	2.1	0.8	
		Month	31.7	114.4	200.0	395.2	607.5	22.7	4.2	15.9	6.9	3.9	10.2	48.9	
6	1998/99	1-10	0.0	0.0	76.4	267.3	9.7	25.7	7.3	50.5	9.4	17.1	3.5	0.0	885.6
		11-20	0.0	0.0	86.5	16.4	14.8	111.6	7.9	0.0	0.1	0.0	2.3	1.5	
		21-end	0.0	0.8	120.4	19.9	23.1	1.5	1.1	2.4	3.0	2.8	2.0	0.8	
		Month	0.0	0.8	283.3	303.6	47.6	138.8	16.3	52.9	12.5	19.9	7.8	2.3	
7	1999/00	1-10	0.4	4.4	25.9	61.4	43.9	250.1	17.9	3.4	6.3	11.4	6.3	0.1	865.7
		11-20	0.0	3.5	106.5	69.2	132.0	2.7	0.0	0.4	6.9	3.4	0.8	2.0	
		21-end	1.1	1.1	0.0	17.2	72.8	0.1	0.0	0.0	1.2	6.9	2.7	3.8	
		Month	1.5	9.0	132.4	147.8	248.8	252.9	17.9	3.8	14.4	21.6	9.8	5.9	
8	2000/01	1-10	0.0	0.0	61.3	10.5	138.2	14.4	36.4	0.0	3.0	1.3	11.3	0.0	1,430.1
		11-20	0.3	23.4	21.9	330.7	4.2	4.8	2.4	3.0	0.3	0.3	0.8	1.7	
		21-end	1.2	2.1	180.0	553.8	0.0	13.4	0.0	0.9	6.0	0.4	2.1	0.0	
		Month	1.5	25.5	263.1	895.0	142.4	32.6	38.8	3.9	9.3	2.0	14.2	1.7	
9	2001/02	1-10	0.3	0.1	40.2	76.4	258.6	31.0	0.8	115.5	0.9	0.0	0.4	0.0	1,375.6
		11-20	0.0	0.0	52.8	48.9	267.3	4.6	5.9	39.4	7.7	0.1	1.3	11.6	
		21-end	21.1	0.0	187.2	12.5	121.2	43.3	12.2	5.8	0.0	8.1	0.5	0.0	
		Month	21.4	0.1	280.2	137.8	647.0	78.8	18.9	160.6	8.6	8.2	2.3	11.6	
10	2002/03	1-10	0.0	18.7	35.1	74.5	17.5	55.3	4.2	9.5	0.0	0.0	1.2	3.0	1,878.9
		11-20	0.3	3.8	291.3	308.0	263.0	125.1	0.0	1.5	0.7	5.2	0.0	2.8	
		21-end	0.9	38.7	196.9	270.1	137.5	1.7	0.0	0.5	5.1	0.7	1.1	5.0	
		Month	1.2	61.1	523.3	652.7	418.0	182.1	4.2	11.6	5.8	5.9	2.3	10.7	
	Average	1-10	4.8	5.9	79.1	104.6	126.6	64.2	16.4	24.0	3.6	4.9	3.9	5.9	1,456.4
		11-20	15.0	12.7	116.3	167.0	110.5	38.9	5.3	4.8	2.9	3.6	1.7	2.6	
		21-end	18.2	8.5	128.8	231.5	90.5	36.7	3.4	3.9	2.3	3.2	1.6	2.8	
		Month	37.9	27.0	324.2	503.1	327.6	139.8	25.1	32.7	8.8	11.7	7.2	11.3	
	5-year drought	1-10	4.0	5.0	66.4	87.9	106.3	53.9	13.8	20.2	3.0	4.1	3.3	4.9	1,223.4
		11-20	12.6	10.6	97.7	140.3	92.8	32.7	4.4	4.0	2.4	3.0	1.4	2.2	
		21-end	15.3	7.1	108.2	194.5	76.0	30.8	2.8	3.2	1.9	2.7	1.4	2.4	
		Month	31.9	22.7	272.3	422.6	275.2	117.4	21.1	27.5	7.4	9.8	6.0	9.5	
	5-year wet	1-10	5.7	7.1	94.9	125.5	151.9	77.0	19.7	28.8	4.4	5.9	4.7	7.0	1,747.7
		11-20	18.0	15.2	139.6	200.4	132.6	46.7	6.4	5.8	3.5	4.3	2.0	3.1	
		21-end	21.8	10.2	154.5	277.8	108.6	44.1	4.1	4.6	2.7	3.9	1.9	3.4	
		Month	45.5	32.4	389.0	603.8	393.1	167.8	30.1	39.2	10.6	14.0	8.6	13.5	

Source: JICA study team

Table 4.3 10-day rainfall at Morarano (Andranomainty river)

River System
Catchment Area: 76 km2
Basin Elevation: 937 (El.m) Adjustment Factor: 1.212 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.2	31.1	0.0	76.3	245.2	113.4	4.8	0.0	3.4	6.4	2.3	1.6	1,440.9
		11-20	0.0	9.1	59.6	185.4	65.9	20.5	0.2	2.5	3.6	17.9	4.4	3.8	
		21-end	80.1	0.0	100.2	262.7	11.3	96.8	0.4	23.4	2.5	3.6	2.2	0.0	
		Month	80.3	40.2	159.8	524.4	322.4	230.7	5.5	25.9	9.6	28.0	8.8	5.3	
2	1994/95	1-10	39.0	0.0	38.8	13.4	183.7	4.0	29.9	33.4	10.2	0.0	0.4	0.5	1,374.2
		11-20	124.8	0.0	94.1	329.8	73.9	67.8	27.5	0.0	1.7	3.8	2.3	0.4	
		21-end	40.9	4.2	0.4	215.5	6.5	22.7	0.6	1.6	0.1	1.2	1.0	0.1	
		Month	204.7	4.2	133.3	558.8	264.1	94.5	58.0	35.0	12.0	5.0	3.6	1.0	
3	1995/96	1-10	2.2	0.7	190.0	166.5	112.6	94.7	3.3	3.9	0.5	1.9	1.5	0.4	1,686.1
		11-20	0.5	0.0	104.8	216.7	8.0	23.6	1.6	0.6	0.6	0.8	0.6	0.2	
		21-end	2.4	3.1	323.1	205.8	35.5	156.4	17.6	0.0	2.3	2.7	0.6	0.4	
		Month	5.1	3.9	617.9	589.0	156.0	274.8	22.4	4.5	3.4	5.5	2.7	1.0	
4	1996/97	1-10	0.1	0.0	125.3	160.2	132.5	6.8	49.8	3.8	0.0	7.9	6.4	4.7	1,511.6
		11-20	0.1	0.0	285.6	56.6	82.5	14.8	0.5	0.2	1.6	1.1	0.0	0.6	
		21-end	0.0	5.2	84.6	365.5	92.7	1.0	0.0	1.1	1.1	2.5	1.2	15.7	
		Month	0.2	5.2	495.4	582.3	307.7	22.5	50.3	5.1	2.7	11.5	7.6	21.1	
5	1997/98	1-10	1.0	0.5	143.8	84.9	45.9	20.2	0.5	14.3	1.0	1.0	4.0	42.9	1,318.2
		11-20	9.2	77.4	0.6	20.7	151.7	0.0	3.3	0.0	4.5	0.6	3.3	0.5	
		21-end	18.4	25.3	36.0	250.8	350.4	0.2	0.0	0.0	0.7	1.9	1.9	0.7	
		Month	28.6	103.2	180.4	356.4	548.0	20.5	3.8	14.3	6.2	3.5	9.2	44.1	
6	1998/99	1-10	0.0	0.0	68.9	241.1	8.7	23.1	6.5	45.6	8.5	15.4	3.1	0.0	798.8
		11-20	0.0	0.0	78.0	14.8	13.3	100.7	7.1	0.0	0.1	0.0	2.1	1.3	
		21-end	0.0	0.7	108.6	17.9	20.8	1.3	1.0	2.2	2.7	2.5	1.8	0.7	
		Month	0.0	0.7	255.5	273.8	42.9	125.2	14.7	47.7	11.3	17.9	7.0	2.1	
7	1999/00	1-10	0.4	4.0	23.4	55.4	39.6	225.6	16.1	3.0	5.7	10.3	5.7	0.1	780.8
		11-20	0.0	3.1	96.1	62.4	119.1	2.4	0.0	0.4	6.2	3.0	0.7	1.8	
		21-end	1.0	1.0	0.0	15.5	65.7	0.1	0.0	0.0	1.1	6.2	2.4	3.4	
		Month	1.3	8.1	119.5	133.3	224.4	228.1	16.1	3.4	13.0	19.5	8.8	5.3	
8	2000/01	1-10	0.0	0.0	55.2	9.4	124.7	13.0	32.8	0.0	2.7	1.2	10.2	0.0	1,289.9
		11-20	0.2	21.1	19.7	298.3	3.8	4.4	2.2	2.7	0.2	0.2	0.7	1.6	
		21-end	1.1	1.9	162.3	499.5	0.0	12.1	0.0	0.8	5.5	0.4	1.9	0.0	
		Month	1.3	23.0	237.3	807.2	128.4	29.4	35.0	3.5	8.4	1.8	12.8	1.6	
9	2001/02	1-10	0.2	0.1	36.2	68.9	233.2	28.0	0.7	104.2	0.8	0.0	0.4	0.0	1,240.7
		11-20	0.0	0.0	47.6	44.1	241.1	4.1	5.3	35.5	6.9	0.1	1.2	10.4	
		21-end	19.0	0.0	168.9	11.3	109.3	39.0	11.0	5.2	0.0	7.3	0.5	0.0	
		Month	19.3	0.1	252.7	124.3	583.6	71.1	17.1	144.9	7.8	7.4	2.1	10.4	
10	2002/03	1-10	0.0	16.8	31.6	67.2	15.7	49.9	3.8	8.6	0.0	0.0	1.1	2.7	1,694.7
		11-20	0.2	3.4	262.8	277.8	237.2	112.8	0.0	1.3	0.6	4.7	0.0	2.5	
		21-end	0.8	34.9	177.6	243.6	124.1	1.6	0.0	0.5	4.6	0.6	1.0	4.5	
		Month	1.1	55.1	472.0	588.7	377.0	164.3	3.8	10.4	5.2	5.3	2.1	9.7	
	Average	1-10	4.3	5.3	71.3	94.3	114.2	57.9	14.8	21.7	3.3	4.4	3.5	5.3	1,313.6
		11-20	13.5	11.4	104.9	150.7	99.6	35.1	4.8	4.3	2.6	3.2	1.5	2.3	
		21-end	16.4	7.6	116.2	208.8	81.6	33.1	3.1	3.5	2.1	2.9	1.5	2.6	
		Month	34.2	24.4	292.4	453.8	295.5	126.1	22.7	29.5	7.9	10.5	6.5	10.2	
	5-year drought	1-10	3.6	4.5	59.9	79.2	95.9	48.6	12.5	18.2	2.7	3.7	2.9	4.4	1,103.4
		11-20	11.3	9.6	88.1	126.5	83.7	29.5	4.0	3.6	2.2	2.7	1.3	1.9	
		21-end	13.8	6.4	97.6	175.4	68.6	27.8	2.6	2.9	1.7	2.4	1.2	2.1	
		Month	28.7	20.5	245.6	381.2	248.2	105.9	19.0	24.8	6.7	8.9	5.4	8.5	
	5-year wet	1-10	5.2	6.4	85.6	113.2	137.0	69.5	17.8	26.0	3.9	5.3	4.2	6.3	1,576.3
		11-20	16.2	13.7	125.9	180.8	119.6	42.1	5.7	5.2	3.1	3.9	1.8	2.8	
		21-end	19.7	9.2	139.4	250.6	97.9	39.7	3.7	4.2	2.5	3.5	1.7	3.1	
		Month	41.0	29.3	350.9	544.6	354.5	151.3	27.2	35.4	9.5	12.6	7.8	12.2	

Source: JICA study team

Table 4.4 10-day rainfall at Ranofotsy (Ranomanty river)

River System
Catchment Area: 79 km2
Basin Elevation: 1008 (El.m) Adjustment Factor: 1.311 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.3	33.7	0.0	82.6	265.3	122.7	5.2	0.0	3.7	6.9	2.5	1.7	1,559.2
		11-20	0.0	9.8	64.5	200.6	71.3	22.2	0.3	2.8	3.9	19.4	4.7	4.1	
		21-end	86.7	0.0	108.4	284.2	12.2	104.7	0.4	25.3	2.8	3.9	2.4	0.0	
		Month	86.9	43.5	172.9	567.4	348.9	249.6	5.9	28.1	10.4	30.3	9.6	5.8	
2	1994/95	1-10	42.2	0.0	42.0	14.6	198.7	4.3	32.4	36.2	11.0	0.0	0.4	0.5	1,487.1
		11-20	135.0	0.0	101.9	356.9	80.0	73.4	29.8	0.0	1.8	4.1	2.5	0.4	
		21-end	44.3	4.6	0.4	233.2	7.1	24.5	0.7	1.7	0.1	1.3	1.0	0.1	
		Month	221.6	4.6	144.2	604.6	285.8	102.3	62.8	37.9	13.0	5.4	3.9	1.0	
3	1995/96	1-10	2.4	0.8	205.6	180.1	121.8	102.5	3.5	4.2	0.5	2.1	1.6	0.4	1,824.5
		11-20	0.5	0.0	113.4	234.5	8.7	25.6	1.7	0.7	0.7	0.9	0.7	0.3	
		21-end	2.6	3.4	349.6	222.7	38.4	169.3	19.0	0.0	2.5	2.9	0.7	0.4	
		Month	5.5	4.2	668.6	637.4	168.9	297.3	24.3	4.9	3.7	5.9	2.9	1.0	
4	1996/97	1-10	0.1	0.0	135.6	173.3	143.4	7.3	53.9	4.1	0.0	8.5	6.9	5.1	1,635.7
		11-20	0.1	0.0	309.0	61.2	89.3	16.0	0.5	0.3	1.7	1.2	0.0	0.7	
		21-end	0.0	5.6	91.5	395.5	100.3	1.0	0.0	1.2	1.2	2.8	1.3	17.0	
		Month	0.3	5.6	536.1	630.1	333.0	24.4	54.4	5.5	2.9	12.5	8.3	22.8	
5	1997/98	1-10	1.0	0.5	155.6	91.9	49.7	21.9	0.5	15.5	1.0	1.0	4.3	46.4	1,426.4
		11-20	10.0	83.8	0.7	22.4	164.1	0.0	3.5	0.0	4.9	0.7	3.5	0.5	
		21-end	19.9	27.4	38.9	271.4	379.1	0.3	0.0	0.0	0.8	2.1	2.1	0.8	
		Month	30.9	111.7	195.2	385.7	593.0	22.2	4.1	15.5	6.7	3.8	10.0	47.7	
6	1998/99	1-10	0.0	0.0	74.6	260.9	9.4	25.0	7.1	49.3	9.2	16.6	3.4	0.0	864.3
		11-20	0.0	0.0	84.4	16.0	14.4	108.9	7.7	0.0	0.1	0.0	2.2	1.4	
		21-end	0.0	0.8	117.5	19.4	22.5	1.4	1.0	2.4	2.9	2.8	2.0	0.8	
		Month	0.0	0.8	276.5	296.3	46.4	135.4	15.9	51.7	12.2	19.4	7.6	2.2	
7	1999/00	1-10	0.4	4.3	25.3	59.9	42.9	244.1	17.4	3.3	6.2	11.1	6.2	0.1	844.9
		11-20	0.0	3.4	104.0	67.5	128.9	2.6	0.0	0.4	6.7	3.3	0.8	2.0	
		21-end	1.0	1.0	0.0	16.8	71.1	0.1	0.0	0.0	1.2	6.7	2.6	3.7	
		Month	1.4	8.8	129.3	144.2	242.8	246.9	17.4	3.7	14.0	21.1	9.6	5.8	
8	2000/01	1-10	0.0	0.0	59.8	10.2	134.9	14.0	35.5	0.0	2.9	1.3	11.0	0.0	1,395.8
		11-20	0.3	22.8	21.4	322.8	4.1	4.7	2.4	2.9	0.3	0.3	0.8	1.7	
		21-end	1.2	2.1	175.7	540.5	0.0	13.1	0.0	0.9	5.9	0.4	2.1	0.0	
		Month	1.4	24.9	256.8	873.5	139.0	31.9	37.9	3.8	9.0	2.0	13.9	1.7	
9	2001/02	1-10	0.3	0.1	39.2	74.6	252.4	30.3	0.8	112.7	0.9	0.0	0.4	0.0	1,342.6
		11-20	0.0	0.0	51.5	47.7	260.9	4.5	5.8	38.4	7.5	0.1	1.3	11.3	
		21-end	20.6	0.0	182.8	12.2	118.3	42.2	11.9	5.6	0.0	7.9	0.5	0.0	
		Month	20.8	0.1	273.5	134.5	631.5	77.0	18.5	156.8	8.4	8.0	2.2	11.3	
10	2002/03	1-10	0.0	18.2	34.2	72.8	17.0	54.0	4.1	9.3	0.0	0.0	1.2	2.9	1,833.8
		11-20	0.3	3.7	284.4	300.6	256.7	122.1	0.0	1.4	0.7	5.1	0.0	2.8	
		21-end	0.9	37.8	192.2	263.6	134.2	1.7	0.0	0.5	5.0	0.7	1.0	4.9	
		Month	1.2	59.7	510.8	637.0	408.0	177.8	4.1	11.3	5.6	5.8	2.2	10.5	
	Average	1-10	4.7	5.8	77.2	102.1	123.6	62.6	16.0	23.5	3.5	4.8	3.8	5.7	1,421.4
		11-20	14.6	12.3	113.5	163.0	107.8	38.0	5.2	4.7	2.8	3.5	1.7	2.5	
		21-end	17.7	8.3	125.7	226.0	88.3	35.8	3.3	3.8	2.2	3.1	1.6	2.8	
		Month	37.0	26.4	316.4	491.1	319.7	136.5	24.5	31.9	8.6	11.4	7.0	11.0	
	5-year drought	1-10	3.9	4.8	64.8	85.8	103.8	52.6	13.5	19.7	3.0	4.0	3.2	4.8	1,194.0
		11-20	12.3	10.4	95.3	136.9	90.6	31.9	4.3	3.9	2.4	2.9	1.4	2.1	
		21-end	14.9	6.9	105.6	189.8	74.2	30.1	2.8	3.2	1.9	2.6	1.3	2.3	
		Month	31.1	22.2	265.8	412.5	268.6	114.6	20.6	26.8	7.2	9.6	5.9	9.2	
	5-year wet	1-10	5.6	6.9	92.6	122.5	148.3	75.2	19.3	28.1	4.2	5.7	4.5	6.9	1,705.7
		11-20	17.5	14.8	136.2	195.6	129.4	45.6	6.2	5.6	3.4	4.2	2.0	3.0	
		21-end	21.3	9.9	150.8	271.2	106.0	43.0	4.0	4.5	2.7	3.8	1.9	3.3	
		Month	44.4	31.7	379.7	589.3	383.7	163.8	29.4	38.3	10.3	13.7	8.4	13.2	

Source: JICA study team

Table 4.5 10-rainfall at Sahanidingana (Mavalova-Ampandra river)

(D/S of confluence)

River System Mavalova-Ampandra River, Sahabe River System
Catchment Area: 129 km2
Basin Elevation: 947.07 (El.m) Adjustment Factor: 1.226 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.2	31.5	0.0	77.2	248.1	114.7	4.9	0.0	3.4	6.5	2.3	1.6	1,457.7
		11-20	0.0	9.2	60.3	187.5	66.7	20.7	0.2	2.6	3.7	18.1	4.4	3.8	
		21-end	81.0	0.0	101.4	265.7	11.4	97.9	0.4	23.7	2.6	3.7	2.2	0.0	
		Month	81.3	40.7	161.7	530.5	326.1	233.4	5.5	26.2	9.7	28.3	8.9	5.4	
2	1994/95	1-10	39.5	0.0	39.2	13.6	185.8	4.0	30.3	33.8	10.3	0.0	0.4	0.5	1,390.2
		11-20	126.2	0.0	95.2	333.6	74.8	68.6	27.8	0.0	1.7	3.8	2.3	0.4	
		21-end	41.4	4.3	0.4	218.0	6.6	22.9	0.6	1.6	0.1	1.2	1.0	0.1	
		Month	207.1	4.3	134.8	565.3	267.2	95.6	58.7	35.4	12.1	5.0	3.7	1.0	
3	1995/96	1-10	2.2	0.7	192.2	168.4	113.9	95.8	3.3	3.9	0.5	2.0	1.5	0.4	1,705.7
		11-20	0.5	0.0	106.0	219.3	8.1	23.9	1.6	0.6	0.6	0.9	0.6	0.2	
		21-end	2.5	3.2	326.9	208.2	35.9	158.2	17.8	0.0	2.3	2.7	0.6	0.4	
		Month	5.1	3.9	625.1	595.9	157.9	278.0	22.7	4.5	3.4	5.5	2.7	1.0	
4	1996/97	1-10	0.1	0.0	126.7	162.0	134.1	6.9	50.4	3.8	0.0	8.0	6.5	4.8	1,529.2
		11-20	0.1	0.0	288.9	57.2	83.5	15.0	0.5	0.2	1.6	1.1	0.0	0.6	
		21-end	0.0	5.3	85.6	369.8	93.8	1.0	0.0	1.1	1.1	2.6	1.2	15.9	
		Month	0.2	5.3	501.2	589.0	311.3	22.8	50.9	5.1	2.7	11.6	7.7	21.3	
5	1997/98	1-10	1.0	0.5	145.5	85.9	46.5	20.5	0.5	14.5	1.0	1.0	4.0	43.4	1,333.5
		11-20	9.3	78.3	0.6	21.0	153.5	0.0	3.3	0.0	4.5	0.6	3.3	0.5	
		21-end	18.6	25.6	36.4	253.7	354.5	0.2	0.0	0.0	0.7	2.0	2.0	0.7	
		Month	28.9	104.4	182.5	360.6	554.4	20.7	3.8	14.5	6.3	3.6	9.3	44.6	
6	1998/99	1-10	0.0	0.0	69.7	243.9	8.8	23.4	6.6	46.1	8.6	15.6	3.2	0.0	808.1
		11-20	0.0	0.0	78.9	15.0	13.5	101.9	7.2	0.0	0.1	0.0	2.1	1.3	
		21-end	0.0	0.7	109.8	18.1	21.1	1.3	1.0	2.2	2.7	2.6	1.8	0.7	
		Month	0.0	0.7	258.5	277.0	43.4	126.6	14.8	48.3	11.4	18.1	7.1	2.1	
7	1999/00	1-10	0.4	4.0	23.7	56.0	40.1	228.2	16.3	3.1	5.8	10.4	5.8	0.1	789.9
		11-20	0.0	3.2	97.2	63.1	120.5	2.5	0.0	0.4	6.3	3.1	0.7	1.8	
		21-end	1.0	1.0	0.0	15.7	66.4	0.1	0.0	0.0	1.1	6.3	2.5	3.4	
		Month	1.3	8.2	120.8	134.8	227.0	230.8	16.3	3.4	13.1	19.7	8.9	5.4	
8	2000/01	1-10	0.0	0.0	55.9	9.6	126.1	13.1	33.2	0.0	2.7	1.2	10.3	0.0	1,304.9
		11-20	0.2	21.3	20.0	301.8	3.8	4.4	2.2	2.7	0.2	0.2	0.7	1.6	
		21-end	1.1	2.0	164.2	505.3	0.0	12.3	0.0	0.9	5.5	0.4	2.0	0.0	
		Month	1.3	23.3	240.1	816.6	129.9	29.8	35.4	3.6	8.5	1.8	13.0	1.6	
9	2001/02	1-10	0.2	0.1	36.6	69.7	235.9	28.3	0.7	105.4	0.9	0.0	0.4	0.0	1,255.2
		11-20	0.0	0.0	48.2	44.6	243.9	4.2	5.4	35.9	7.0	0.1	1.2	10.5	
		21-end	19.2	0.0	170.9	11.4	110.6	39.5	11.2	5.3	0.0	7.4	0.5	0.0	
		Month	19.5	0.1	255.7	125.8	590.4	71.9	17.3	146.6	7.8	7.5	2.1	10.5	
10	2002/03	1-10	0.0	17.0	32.0	68.0	15.9	50.5	3.8	8.7	0.0	0.0	1.1	2.7	1,714.4
		11-20	0.2	3.4	265.8	281.0	240.0	114.1	0.0	1.3	0.6	4.8	0.0	2.6	
		21-end	0.9	35.3	179.7	246.5	125.5	1.6	0.0	0.5	4.7	0.6	1.0	4.5	
		Month	1.1	55.8	477.5	595.5	381.4	166.2	3.8	10.5	5.3	5.4	2.1	9.8	
	Average	1-10	4.4	5.4	72.2	95.4	115.5	58.5	15.0	21.9	3.3	4.5	3.5	5.3	1,328.9
		11-20	13.7	11.5	106.1	152.4	100.8	35.5	4.8	4.4	2.6	3.3	1.5	2.3	
		21-end	16.6	7.7	117.5	211.3	82.6	33.5	3.1	3.5	2.1	2.9	1.5	2.6	
		Month	34.6	24.7	295.8	459.1	298.9	127.6	22.9	29.8	8.0	10.7	6.6	10.3	
	5-year drought	1-10	3.7	4.5	60.6	80.2	97.0	49.2	12.6	18.4	2.8	3.7	3.0	4.5	1,116.3
		11-20	11.5	9.7	89.1	128.0	84.7	29.8	4.1	3.7	2.2	2.7	1.3	2.0	
		21-end	13.9	6.5	98.7	177.5	69.4	28.1	2.6	3.0	1.8	2.5	1.2	2.2	
		Month	29.1	20.7	248.5	385.6	251.1	107.2	19.3	25.0	6.7	9.0	5.5	8.6	
	5-year wet	1-10	5.2	6.5	86.6	114.5	138.6	70.3	18.0	26.3	4.0	5.4	4.3	6.4	1,594.7
		11-20	16.4	13.9	127.3	182.9	121.0	42.6	5.8	5.3	3.2	3.9	1.9	2.8	
		21-end	19.9	9.3	141.0	253.5	99.1	40.2	3.7	4.2	2.5	3.5	1.8	3.1	
		Month	41.5	29.6	354.9	550.9	358.7	153.1	27.5	35.8	9.6	12.8	7.9	12.3	

Source: JICA study team

Table 4.6 10-day rainfall at Maheriana (Sahamilay river)

River System
Catchment Area: 152 km2
Basin Elevation: 1097 (El.m) Adjustment Factor: 1.436 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.3	36.9	0.0	90.4	290.6	134.4	5.7	0.0	4.0	7.6	2.7	1.9	1,707.5
		11-20	0.0	10.8	70.6	219.7	78.1	24.3	0.3	3.0	4.3	21.2	5.2	4.5	
		21-end	94.9	0.0	118.7	311.3	13.4	114.7	0.4	27.7	3.0	4.3	2.6	0.0	
		Month	95.2	47.7	189.4	621.4	382.0	273.4	6.5	30.7	11.3	33.2	10.5	6.3	
2	1994/95	1-10	46.2	0.0	45.9	15.9	217.6	4.7	35.5	39.6	12.1	0.0	0.4	0.6	1,628.5
		11-20	147.9	0.0	111.6	390.8	87.6	80.4	32.6	0.0	2.0	4.5	2.7	0.4	
		21-end	48.5	5.0	0.4	255.4	7.8	26.8	0.7	1.9	0.1	1.4	1.1	0.1	
		Month	242.6	5.0	157.9	662.1	313.0	112.0	68.8	41.5	14.2	5.9	4.3	1.1	
3	1995/96	1-10	2.6	0.9	225.1	197.3	133.4	112.3	3.9	4.6	0.6	2.3	1.7	0.4	1,998.0
		11-20	0.6	0.0	124.2	256.8	9.5	28.0	1.9	0.7	0.7	1.0	0.7	0.3	
		21-end	2.9	3.7	382.9	243.9	42.1	185.3	20.8	0.0	2.7	3.2	0.7	0.4	
		Month	6.0	4.6	732.2	698.0	184.9	325.6	26.6	5.3	4.0	6.5	3.2	1.1	
4	1996/97	1-10	0.1	0.0	148.4	189.8	157.1	8.0	59.0	4.5	0.0	9.3	7.6	5.6	1,791.3
		11-20	0.1	0.0	338.4	67.0	97.8	17.5	0.6	0.3	1.9	1.3	0.0	0.7	
		21-end	0.0	6.2	100.2	433.1	109.8	1.1	0.0	1.3	1.3	3.0	1.4	18.7	
		Month	0.3	6.2	587.1	690.0	364.7	26.7	59.6	6.0	3.2	13.6	9.0	25.0	
5	1997/98	1-10	1.1	0.6	170.4	100.6	54.4	24.0	0.6	16.9	1.1	1.1	4.7	50.8	1,562.0
		11-20	10.9	91.7	0.7	24.6	179.7	0.0	3.9	0.0	5.3	0.7	3.9	0.6	
		21-end	21.8	30.0	42.6	297.2	415.2	0.3	0.0	0.0	0.9	2.3	2.3	0.9	
		Month	33.9	122.3	213.8	422.4	649.4	24.3	4.5	16.9	7.3	4.2	10.9	52.3	
6	1998/99	1-10	0.0	0.0	81.7	285.7	10.3	27.4	7.8	54.0	10.0	18.2	3.7	0.0	946.5
		11-20	0.0	0.0	92.5	17.5	15.8	119.3	8.5	0.0	0.1	0.0	2.4	1.6	
		21-end	0.0	0.9	128.6	21.2	24.7	1.6	1.1	2.6	3.2	3.0	2.2	0.9	
		Month	0.0	0.9	302.8	324.5	50.8	148.3	17.4	56.6	13.4	21.2	8.3	2.4	
7	1999/00	1-10	0.4	4.7	27.7	65.6	46.9	267.3	19.1	3.6	6.7	12.2	6.7	0.1	925.3
		11-20	0.0	3.7	113.8	73.9	141.1	2.9	0.0	0.4	7.3	3.6	0.9	2.2	
		21-end	1.1	1.1	0.0	18.4	77.8	0.1	0.0	0.0	1.3	7.3	2.9	4.0	
		Month	1.6	9.6	141.6	157.9	265.9	270.3	19.1	4.0	15.4	23.1	10.5	6.3	
8	2000/01	1-10	0.0	0.0	65.5	11.2	147.7	15.4	38.9	0.0	3.2	1.4	12.1	0.0	1,528.6
		11-20	0.3	25.0	23.4	353.5	4.5	5.2	2.6	3.2	0.3	0.3	0.9	1.9	
		21-end	1.3	2.3	192.4	591.9	0.0	14.4	0.0	1.0	6.5	0.4	2.3	0.0	
		Month	1.6	27.3	281.3	956.6	152.2	34.9	41.5	4.2	9.9	2.2	15.2	1.9	
9	2001/02	1-10	0.3	0.1	42.9	81.7	276.4	33.2	0.9	123.5	1.0	0.0	0.4	0.0	1,470.3
		11-20	0.0	0.0	56.4	52.3	285.7	4.9	6.3	42.1	8.2	0.1	1.4	12.3	
		21-end	22.5	0.0	200.1	13.4	129.5	46.2	13.1	6.2	0.0	8.6	0.6	0.0	
		Month	22.8	0.1	299.5	147.3	691.6	84.3	20.2	171.7	9.2	8.8	2.4	12.3	
10	2002/03	1-10	0.0	20.0	37.5	79.7	18.7	59.2	4.5	10.2	0.0	0.0	1.3	3.2	2,008.2
		11-20	0.3	4.0	311.4	329.2	281.1	133.7	0.0	1.6	0.7	5.6	0.0	3.0	
		21-end	1.0	41.3	210.5	288.7	147.0	1.9	0.0	0.6	5.5	0.7	1.1	5.3	
		Month	1.3	65.3	559.3	697.6	446.8	194.7	4.5	12.3	6.2	6.3	2.4	11.5	
	Average	1-10	5.1	6.3	84.5	111.8	135.3	68.6	17.6	25.7	3.9	5.2	4.1	6.3	1,556.6
		11-20	16.0	13.5	124.3	178.5	118.1	41.6	5.7	5.1	3.1	3.8	1.8	2.7	
		21-end	19.4	9.1	137.7	247.5	96.7	39.3	3.6	4.1	2.4	3.4	1.7	3.0	
		Month	40.5	28.9	346.5	537.8	350.1	149.4	26.8	34.9	9.4	12.5	7.7	12.0	
	5-year drought	1-10	4.3	5.3	71.0	93.9	113.7	57.6	14.8	21.6	3.3	4.4	3.5	5.3	1,307.6
		11-20	13.4	11.4	104.4	150.0	99.2	34.9	4.8	4.3	2.6	3.2	1.5	2.3	
		21-end	16.3	7.6	115.6	207.9	81.2	33.0	3.0	3.5	2.1	2.9	1.4	2.5	
		Month	34.0	24.3	291.0	451.7	294.1	125.5	22.6	29.3	7.9	10.5	6.5	10.1	
	5-year wet	1-10	6.1	7.6	101.4	134.2	162.4	82.3	21.1	30.8	4.7	6.3	5.0	7.5	1,868.0
		11-20	19.2	16.2	149.2	214.2	141.7	49.9	6.8	6.2	3.7	4.6	2.2	3.3	
		21-end	23.3	10.9	165.2	296.9	116.1	47.1	4.3	4.9	2.9	4.1	2.1	3.6	
		Month	48.6	34.7	415.8	645.3	420.1	179.3	32.2	41.9	11.3	15.0	9.2	14.4	

Source: JICA study team

Table 4.7 10-day rainfall at National Road Bridge (Ampasimena river)

River System
Catchment Area: 27 km2
Basin Elevation: 891 (El.m) Adjustment Factor: 1.147 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.2	29.5	0.0	72.3	232.2	107.4	4.6	0.0	3.2	6.1	2.2	1.5	1,364.2
		11-20	0.0	8.6	56.4	175.5	62.4	19.4	0.2	2.4	3.4	17.0	4.1	3.6	
		21-end	75.8	0.0	94.9	248.7	10.7	91.7	0.3	22.1	2.4	3.4	2.1	0.0	
		Month	76.1	38.1	151.3	496.5	305.2	218.4	5.2	24.5	9.1	26.5	8.4	5.0	
2	1994/95	1-10	36.9	0.0	36.7	12.7	173.9	3.8	28.3	31.7	9.6	0.0	0.3	0.5	1,301.2
		11-20	118.2	0.0	89.1	312.2	70.0	64.2	26.0	0.0	1.6	3.6	2.2	0.3	
		21-end	38.8	4.0	0.3	204.1	6.2	21.5	0.6	1.5	0.1	1.1	0.9	0.1	
		Month	193.9	4.0	126.2	529.0	250.1	89.5	54.9	33.2	11.4	4.7	3.4	0.9	
3	1995/96	1-10	2.1	0.7	179.9	157.6	106.6	89.7	3.1	3.7	0.5	1.8	1.4	0.3	1,596.4
		11-20	0.5	0.0	99.2	205.2	7.6	22.4	1.5	0.6	0.6	0.8	0.6	0.2	
		21-end	2.3	3.0	305.9	194.9	33.6	148.1	16.6	0.0	2.2	2.5	0.6	0.3	
		Month	4.8	3.7	585.0	557.7	147.7	260.2	21.2	4.2	3.2	5.2	2.5	0.9	
4	1996/97	1-10	0.1	0.0	118.6	151.6	125.5	6.4	47.1	3.6	0.0	7.5	6.1	4.5	1,431.2
		11-20	0.1	0.0	270.4	53.6	78.1	14.0	0.5	0.2	1.5	1.0	0.0	0.6	
		21-end	0.0	4.9	80.1	346.1	87.8	0.9	0.0	1.0	1.0	2.4	1.1	14.9	
		Month	0.2	4.9	469.0	551.3	291.4	21.3	47.6	4.8	2.5	10.9	7.2	20.0	
5	1997/98	1-10	0.9	0.5	136.2	80.4	43.5	19.2	0.5	13.5	0.9	0.9	3.8	40.6	1,248.0
		11-20	8.7	73.3	0.6	19.6	143.6	0.0	3.1	0.0	4.2	0.6	3.1	0.5	
		21-end	17.4	24.0	34.1	237.4	331.7	0.2	0.0	0.0	0.7	1.8	1.8	0.7	
		Month	27.1	97.7	170.8	337.5	518.8	19.4	3.6	13.5	5.9	3.3	8.7	41.8	
6	1998/99	1-10	0.0	0.0	65.3	228.3	8.3	21.9	6.2	43.1	8.0	14.6	3.0	0.0	756.3
		11-20	0.0	0.0	73.9	14.0	12.6	95.3	6.8	0.0	0.1	0.0	2.0	1.3	
		21-end	0.0	0.7	102.8	17.0	19.7	1.3	0.9	2.1	2.5	2.4	1.7	0.7	
		Month	0.0	0.7	241.9	259.2	40.6	118.5	13.9	45.2	10.7	17.0	6.7	2.0	
7	1999/00	1-10	0.3	3.8	22.1	52.4	37.5	213.6	15.3	2.9	5.4	9.8	5.4	0.1	739.3
		11-20	0.0	3.0	91.0	59.1	112.8	2.3	0.0	0.3	5.9	2.9	0.7	1.7	
		21-end	0.9	0.9	0.0	14.7	62.2	0.1	0.0	0.0	1.0	5.9	2.3	3.2	
		Month	1.3	7.7	113.1	126.2	212.4	216.0	15.3	3.2	12.3	18.5	8.4	5.0	
8	2000/01	1-10	0.0	0.0	52.3	8.9	118.0	12.3	31.1	0.0	2.5	1.1	9.6	0.0	1,221.3
		11-20	0.2	20.0	18.7	282.4	3.6	4.1	2.1	2.5	0.2	0.2	0.7	1.5	
		21-end	1.0	1.8	153.7	472.9	0.0	11.5	0.0	0.8	5.2	0.3	1.8	0.0	
		Month	1.3	21.8	224.7	764.3	121.6	27.9	33.2	3.3	7.9	1.7	12.2	1.5	
9	2001/02	1-10	0.2	0.1	34.3	65.3	220.8	26.5	0.7	98.7	0.8	0.0	0.3	0.0	1,174.7
		11-20	0.0	0.0	45.1	41.8	228.3	3.9	5.0	33.6	6.5	0.1	1.1	9.9	
		21-end	18.0	0.0	159.9	10.7	103.5	36.9	10.4	4.9	0.0	6.9	0.5	0.0	
		Month	18.2	0.1	239.3	117.7	552.6	67.3	16.2	137.2	7.3	7.0	2.0	9.9	
10	2002/03	1-10	0.0	15.9	29.9	63.7	14.9	47.3	3.6	8.1	0.0	0.0	1.0	2.5	1,604.6
		11-20	0.2	3.2	248.8	263.0	224.6	106.8	0.0	1.3	0.6	4.5	0.0	2.4	
		21-end	0.8	33.0	168.2	230.7	117.5	1.5	0.0	0.5	4.4	0.6	0.9	4.2	
		Month	1.0	52.2	446.9	557.4	357.0	155.5	3.6	9.9	4.9	5.0	2.0	9.2	
	Average	1-10	4.1	5.0	67.5	89.3	108.1	54.8	14.0	20.5	3.1	4.2	3.3	5.0	1,243.7
		11-20	12.8	10.8	99.3	142.6	94.3	33.2	4.5	4.1	2.5	3.1	1.4	2.2	
		21-end	15.5	7.2	110.0	197.7	77.3	31.4	2.9	3.3	2.0	2.7	1.4	2.4	
		Month	32.4	23.1	276.8	429.7	279.7	119.4	21.5	27.9	7.5	10.0	6.1	9.6	
	5-year drought	1-10	3.4	4.2	56.7	75.0	90.8	46.0	11.8	17.2	2.6	3.5	2.8	4.2	1,044.7
		11-20	10.7	9.1	83.4	119.8	79.3	27.9	3.8	3.4	2.1	2.6	1.2	1.8	
		21-end	13.0	6.1	92.4	166.1	64.9	26.3	2.4	2.8	1.6	2.3	1.2	2.0	
		Month	27.2	19.4	232.5	360.9	235.0	100.3	18.0	23.4	6.3	8.4	5.2	8.1	
	5-year wet	1-10	4.9	6.1	81.0	107.2	129.7	65.8	16.8	24.6	3.7	5.0	4.0	6.0	1,492.5
		11-20	15.3	13.0	119.2	171.2	113.2	39.9	5.4	4.9	3.0	3.7	1.7	2.6	
		21-end	18.6	8.7	132.0	237.3	92.7	37.6	3.5	4.0	2.3	3.3	1.7	2.9	
		Month	38.9	27.7	332.2	515.6	335.7	143.3	25.7	33.5	9.0	12.0	7.4	11.5	

Source: JICA study team

Table 4.8 10-day rainfall at National Road Bridge (Asahamena river)

River System
Catchment Area: 119 km2
Basin Elevation: 1061 (El.m) Adjustment Factor: 1.385 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.3	35.6	0.0	87.3	280.4	129.7	5.5	0.0	3.9	7.3	2.6	1.8	1,647.5
		11-20	0.0	10.4	68.2	211.9	75.4	23.4	0.3	2.9	4.2	20.5	5.0	4.3	
		21-end	91.6	0.0	114.6	300.3	12.9	110.7	0.4	26.7	2.9	4.2	2.5	0.0	
		Month	91.8	46.0	182.7	599.5	368.6	263.8	6.2	29.6	10.9	32.0	10.1	6.1	
2	1994/95	1-10	44.6	0.0	44.3	15.4	210.0	4.6	34.2	38.2	11.6	0.0	0.4	0.6	1,571.3
		11-20	142.7	0.0	107.6	377.1	84.5	77.6	31.4	0.0	1.9	4.3	2.6	0.4	
		21-end	46.8	4.8	0.4	246.4	7.5	25.9	0.7	1.8	0.1	1.4	1.1	0.1	
		Month	234.1	4.8	152.4	638.9	302.0	108.0	66.4	40.0	13.7	5.7	4.2	1.1	
3	1995/96	1-10	2.5	0.8	217.2	190.3	128.7	108.3	3.7	4.4	0.6	2.2	1.7	0.4	1,927.9
		11-20	0.6	0.0	119.8	247.8	9.1	27.0	1.8	0.7	0.7	1.0	0.7	0.3	
		21-end	2.8	3.6	369.4	235.4	40.6	178.8	20.1	0.0	2.6	3.0	0.7	0.4	
		Month	5.8	4.4	706.5	673.5	178.4	314.2	25.6	5.1	3.9	6.2	3.0	1.1	
4	1996/97	1-10	0.1	0.0	143.2	183.1	151.5	7.8	56.9	4.3	0.0	9.0	7.3	5.4	1,728.4
		11-20	0.1	0.0	326.5	64.7	94.3	16.9	0.6	0.3	1.8	1.2	0.0	0.7	
		21-end	0.0	6.0	96.7	417.9	106.0	1.1	0.0	1.2	1.2	2.9	1.4	18.0	
		Month	0.3	6.0	566.4	665.8	351.9	25.8	57.5	5.8	3.0	13.2	8.7	24.1	
5	1997/98	1-10	1.1	0.6	164.4	97.1	52.5	23.1	0.6	16.3	1.1	1.1	4.6	49.0	1,507.2
		11-20	10.5	88.5	0.7	23.7	173.4	0.0	3.7	0.0	5.1	0.7	3.7	0.6	
		21-end	21.1	29.0	41.1	286.7	400.6	0.3	0.0	0.0	0.8	2.2	2.2	0.8	
		Month	32.7	118.0	206.3	407.5	626.5	23.4	4.3	16.3	7.1	4.0	10.5	50.4	
6	1998/99	1-10	0.0	0.0	78.8	275.7	10.0	26.5	7.5	52.1	9.7	17.6	3.6	0.0	913.3
		11-20	0.0	0.0	89.2	16.9	15.2	115.1	8.2	0.0	0.1	0.0	2.4	1.5	
		21-end	0.0	0.8	124.1	20.5	23.8	1.5	1.1	2.5	3.0	2.9	2.1	0.8	
		Month	0.0	0.8	292.1	313.1	49.0	143.1	16.8	54.6	12.9	20.5	8.0	2.4	
7	1999/00	1-10	0.4	4.6	26.7	63.3	45.3	257.9	18.4	3.5	6.5	11.8	6.5	0.1	892.8
		11-20	0.0	3.6	109.9	71.3	136.2	2.8	0.0	0.4	7.1	3.5	0.8	2.1	
		21-end	1.1	1.1	0.0	17.7	75.1	0.1	0.0	0.0	1.2	7.1	2.8	3.9	
		Month	1.5	9.3	136.6	152.4	256.5	260.8	18.4	3.9	14.8	22.3	10.1	6.1	
8	2000/01	1-10	0.0	0.0	63.2	10.8	142.5	14.8	37.5	0.0	3.0	1.4	11.6	0.0	1,474.9
		11-20	0.3	24.1	22.6	341.0	4.3	5.0	2.5	3.0	0.3	0.3	0.8	1.8	
		21-end	1.2	2.2	185.6	571.1	0.0	13.9	0.0	1.0	6.2	0.4	2.2	0.0	
		Month	1.5	26.3	271.4	923.0	146.8	33.7	40.0	4.0	9.6	2.1	14.7	1.8	
9	2001/02	1-10	0.3	0.1	41.4	78.8	266.7	32.0	0.8	119.1	1.0	0.0	0.4	0.0	1,418.6
		11-20	0.0	0.0	54.4	50.4	275.7	4.7	6.1	40.6	7.9	0.1	1.4	11.9	
		21-end	21.7	0.0	193.1	12.9	124.9	44.6	12.6	6.0	0.0	8.3	0.6	0.0	
		Month	22.0	0.1	289.0	142.1	667.3	81.3	19.5	165.7	8.9	8.5	2.4	11.9	
10	2002/03	1-10	0.0	19.3	36.2	76.9	18.0	57.1	4.3	9.8	0.0	0.0	1.2	3.0	1,937.7
		11-20	0.3	3.9	300.5	317.6	271.2	129.0	0.0	1.5	0.7	5.4	0.0	2.9	
		21-end	1.0	39.9	203.1	278.6	141.8	1.8	0.0	0.6	5.3	0.7	1.1	5.1	
		Month	1.2	63.0	539.7	673.1	431.1	187.8	4.3	11.9	6.0	6.1	2.4	11.1	
	Average	1-10	4.9	6.1	81.5	107.9	130.6	66.2	17.0	24.8	3.7	5.0	4.0	6.0	1,501.9
		11-20	15.4	13.0	119.9	172.3	113.9	40.1	5.5	4.9	3.0	3.7	1.7	2.6	
		21-end	18.7	8.7	132.8	238.8	93.3	37.9	3.5	4.0	2.4	3.3	1.7	2.9	
		Month	39.1	27.9	334.3	518.9	337.8	144.2	25.9	33.7	9.1	12.1	7.4	11.6	
	5-year drought	1-10	4.1	5.1	68.5	90.6	109.7	55.6	14.2	20.8	3.1	4.2	3.4	5.1	1,261.6
		11-20	13.0	11.0	100.7	144.7	95.7	33.7	4.6	4.2	2.5	3.1	1.5	2.2	
		21-end	15.7	7.3	111.6	200.6	78.4	31.8	2.9	3.3	2.0	2.8	1.4	2.5	
		Month	32.8	23.4	280.8	435.9	283.8	121.1	21.8	28.3	7.6	10.1	6.2	9.8	
	5-year wet	1-10	5.9	7.3	97.9	129.4	156.7	79.4	20.3	29.7	4.5	6.1	4.8	7.2	1,802.3
		11-20	18.5	15.7	143.9	206.7	136.7	48.2	6.5	5.9	3.6	4.4	2.1	3.2	
		21-end	22.5	10.5	159.4	286.5	112.0	45.4	4.2	4.8	2.8	4.0	2.0	3.5	
		Month	46.9	33.5	401.2	622.7	405.4	173.0	31.1	40.4	10.9	14.5	8.9	13.9	

Source: JICA study team

Table 4.9 10-day rainfall at National Road Bridge (Behengitra river)

River System
Catchment Area: 27 km2
Basin Elevation: 918 (El.m) Adjustment Factor: 1.185 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.2	30.5	0.0	74.6	239.8	110.9	4.7	0.0	3.3	6.3	2.3	1.5	1,409.2
		11-20	0.0	8.9	58.3	181.3	64.5	20.0	0.2	2.5	3.6	17.5	4.3	3.7	
		21-end	78.3	0.0	98.0	256.9	11.0	94.7	0.4	22.9	2.5	3.6	2.1	0.0	
		Month	78.6	39.3	156.3	512.8	315.3	225.6	5.3	25.4	9.4	27.4	8.6	5.2	
2	1994/95	1-10	38.2	0.0	37.9	13.2	179.6	3.9	29.3	32.7	10.0	0.0	0.4	0.5	1,344.1
		11-20	122.0	0.0	92.1	322.5	72.3	66.4	26.9	0.0	1.7	3.7	2.3	0.4	
		21-end	40.1	4.1	0.4	210.8	6.4	22.2	0.6	1.5	0.1	1.2	0.9	0.1	
		Month	200.3	4.1	130.3	546.5	258.3	92.4	56.8	34.2	11.7	4.9	3.6	0.9	
3	1995/96	1-10	2.1	0.7	185.8	162.8	110.1	92.7	3.2	3.8	0.5	1.9	1.4	0.4	1,649.1
		11-20	0.5	0.0	102.5	212.0	7.8	23.1	1.5	0.6	0.6	0.8	0.6	0.2	
		21-end	2.4	3.1	316.0	201.3	34.7	153.0	17.2	0.0	2.3	2.6	0.6	0.4	
		Month	5.0	3.8	604.3	576.1	152.6	268.7	21.9	4.4	3.3	5.3	2.6	0.9	
4	1996/97	1-10	0.1	0.0	122.5	156.6	129.6	6.6	48.7	3.7	0.0	7.7	6.3	4.6	1,478.4
		11-20	0.1	0.0	279.3	55.3	80.7	14.5	0.5	0.2	1.5	1.1	0.0	0.6	
		21-end	0.0	5.1	82.7	357.5	90.6	0.9	0.0	1.1	1.1	2.5	1.2	15.4	
		Month	0.2	5.1	484.5	569.5	301.0	22.0	49.2	5.0	2.6	11.3	7.5	20.6	
5	1997/98	1-10	0.9	0.5	140.7	83.1	44.9	19.8	0.5	14.0	0.9	0.9	3.9	41.9	1,289.2
		11-20	9.0	75.7	0.6	20.3	148.4	0.0	3.2	0.0	4.4	0.6	3.2	0.5	
		21-end	18.0	24.8	35.2	245.3	342.7	0.2	0.0	0.0	0.7	1.9	1.9	0.7	
		Month	28.0	101.0	176.4	348.6	535.9	20.0	3.7	14.0	6.0	3.4	9.0	43.1	
6	1998/99	1-10	0.0	0.0	67.4	235.8	8.5	22.6	6.4	44.6	8.3	15.0	3.1	0.0	781.2
		11-20	0.0	0.0	76.3	14.5	13.0	98.5	7.0	0.0	0.1	0.0	2.0	1.3	
		21-end	0.0	0.7	106.2	17.5	20.4	1.3	0.9	2.1	2.6	2.5	1.8	0.7	
		Month	0.0	0.7	249.9	267.8	41.9	122.4	14.3	46.7	11.0	17.5	6.9	2.0	
7	1999/00	1-10	0.4	3.9	22.9	54.2	38.7	220.6	15.8	3.0	5.6	10.1	5.6	0.1	763.7
		11-20	0.0	3.1	94.0	61.0	116.5	2.4	0.0	0.4	6.0	3.0	0.7	1.8	
		21-end	0.9	0.9	0.0	15.2	64.2	0.1	0.0	0.0	1.1	6.0	2.4	3.3	
		Month	1.3	7.9	116.8	130.3	219.4	223.1	15.8	3.3	12.7	19.1	8.6	5.2	
8	2000/01	1-10	0.0	0.0	54.0	9.2	121.9	12.7	32.1	0.0	2.6	1.2	10.0	0.0	1,261.6
		11-20	0.2	20.6	19.3	291.7	3.7	4.3	2.1	2.6	0.2	0.2	0.7	1.5	
		21-end	1.1	1.9	158.8	488.5	0.0	11.8	0.0	0.8	5.3	0.4	1.9	0.0	
		Month	1.3	22.5	232.1	789.5	125.6	28.8	34.2	3.4	8.2	1.8	12.6	1.5	
9	2001/02	1-10	0.2	0.1	35.4	67.4	228.1	27.4	0.7	101.9	0.8	0.0	0.4	0.0	1,213.5
		11-20	0.0	0.0	46.6	43.1	235.8	4.0	5.2	34.7	6.8	0.1	1.2	10.2	
		21-end	18.6	0.0	165.2	11.0	106.9	38.2	10.8	5.1	0.0	7.1	0.5	0.0	
		Month	18.8	0.1	247.2	121.6	570.8	69.6	16.7	141.7	7.6	7.2	2.0	10.2	
10	2002/03	1-10	0.0	16.5	30.9	65.8	15.4	48.8	3.7	8.4	0.0	0.0	1.1	2.6	1,657.5
		11-20	0.2	3.3	257.0	271.7	232.0	110.3	0.0	1.3	0.6	4.6	0.0	Source:,	
		21-end	0.8	34.1	173.7	238.3	121.3	1.5	0.0	0.5	4.5	0.6	0.9	4.4	
		Month	1.1	53.9	461.6	575.8	368.7	160.7	3.7	10.2	5.1	5.2	2.0	9.5	
	Average	1-10	4.2	5.2	69.8	92.3	111.7	56.6	14.5	21.2	3.2	4.3	3.4	5.2	1,284.7
		11-20	13.2	11.2	102.6	147.3	97.5	34.3	4.7	4.2	2.5	3.2	1.5	2.2	
		21-end	16.0	7.5	113.6	204.2	79.8	32.4	3.0	3.4	2.0	2.8	1.4	2.5	
		Month	33.5	23.9	286.0	443.8	289.0	123.3	22.2	28.8	7.8	10.3	6.3	9.9	
	5-year drought	1-10	3.5	4.4	58.6	77.5	93.8	47.5	12.2	17.8	2.7	3.6	2.9	4.3	1,079.2
		11-20	11.1	9.4	86.2	123.8	81.9	28.8	3.9	3.6	2.1	2.7	1.3	1.9	
		21-end	13.5	6.3	95.4	171.6	67.1	27.2	2.5	2.9	1.7	2.4	1.2	2.1	
		Month	28.1	20.0	240.2	372.8	242.7	103.6	18.6	24.2	6.5	8.7	5.3	8.3	
	5-year wet	1-10	5.1	6.3	83.7	110.7	134.0	67.9	17.4	25.4	3.8	5.2	4.1	6.2	1,541.7
		11-20	15.9	13.4	123.1	176.8	117.0	41.2	5.6	5.1	3.1	3.8	1.8	2.7	
		21-end	19.2	9.0	136.3	245.1	95.8	38.9	3.6	4.1	2.4	3.4	1.7	3.0	
		Month	40.1	28.6	343.1	532.6	346.8	148.0	26.6	34.6	9.3	12.4	7.6	11.9	

Source: JICA study team

Table 4.10 10-day rainfall at National Road Bridge (Bemarenina river)

River System
Catchment Area: 45 km2
Basin Elevation: 914 (El.m) Adjustment Factor: 1.179 Unit :mm

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (mm)
1	1993/94	1-10	0.2	30.3	0.0	74.3	238.7	110.4	4.7	0.0	3.3	6.3	2.2	1.5	1,375.3
		11-20	0.0	8.8	58.0	180.4	64.2	19.9	0.2	2.5	3.5	17.5	4.2	3.7	
		21-end	78.0	0.0	97.5	255.7	11.0	94.2	0.4	22.8	2.5	3.5	2.1	0.0	
		Month	78.2	39.2	155.6	510.4	313.8	224.5	5.3	25.2	9.3	Source:	8.6	5.2	
2	1994/95	1-10	38.0	0.0	37.7	13.1	178.8	3.9	29.1	32.5	9.9	0.0	0.4	0.5	1,337.7
		11-20	121.5	0.0	91.6	321.0	71.9	66.0	26.8	0.0	1.7	3.7	2.2	0.4	
		21-end	39.9	4.1	0.4	209.8	6.4	22.1	0.6	1.5	0.1	1.2	0.9	0.1	
		Month	199.3	4.1	129.7	543.9	257.1	92.0	56.5	34.1	11.7	4.8	3.5	0.9	
3	1995/96	1-10	2.1	0.7	184.9	162.0	109.6	92.2	3.2	3.8	0.5	1.9	1.4	0.4	1,641.3
		11-20	0.5	0.0	102.0	211.0	7.8	23.0	1.5	0.6	0.6	0.8	0.6	0.2	
		21-end	2.4	3.1	314.5	200.4	34.6	152.2	17.1	0.0	2.2	2.6	0.6	0.4	
		Month	5.0	3.8	601.5	573.4	151.9	267.5	21.8	4.4	3.3	5.3	2.6	0.9	
4	1996/97	1-10	0.1	0.0	121.9	155.9	129.0	6.6	48.5	3.7	0.0	7.7	6.3	4.6	1,471.4
		11-20	0.1	0.0	278.0	55.1	80.3	14.4	0.5	0.2	1.5	1.1	0.0	0.6	
		21-end	0.0	5.1	82.3	355.8	90.2	0.9	0.0	1.1	1.1	2.5	1.2	15.3	
		Month	0.2	5.1	482.2	566.8	299.5	21.9	48.9	5.0	2.6	11.2	7.4	20.5	
5	1997/98	1-10	0.9	0.5	140.0	82.7	44.7	19.7	0.5	13.9	0.9	0.9	3.9	41.7	1,283.1
		11-20	9.0	75.4	0.6	20.2	147.7	0.0	3.2	0.0	4.4	0.6	3.2	0.5	
		21-end	17.9	24.6	35.0	244.1	341.1	0.2	0.0	0.0	0.7	1.9	1.9	0.7	
		Month	27.8	100.5	175.6	347.0	533.4	19.9	3.7	13.9	6.0	3.4	9.0	42.9	
6	1998/99	1-10	0.0	0.0	67.1	234.7	8.5	22.5	6.4	44.3	8.3	15.0	3.1	0.0	777.5
		11-20	0.0	0.0	75.9	14.4	13.0	98.0	7.0	0.0	0.1	0.0	2.0	1.3	
		21-end	0.0	0.7	105.7	17.5	20.3	1.3	0.9	2.1	2.6	2.5	1.8	0.7	
		Month	0.0	0.7	248.7	266.5	41.7	121.8	14.3	46.5	11.0	17.5	6.8	2.0	
7	1999/00	1-10	0.4	3.9	22.8	53.9	38.6	219.6	15.7	2.9	5.5	10.0	5.5	0.1	760.1
		11-20	0.0	3.1	93.5	60.7	115.9	2.4	0.0	0.4	6.0	2.9	0.7	1.8	
		21-end	0.9	0.9	0.0	15.1	63.9	0.1	0.0	0.0	1.1	6.0	2.4	3.3	
		Month	1.3	7.9	116.3	129.7	218.4	222.1	15.7	3.3	12.6	19.0	8.6	5.2	
8	2000/01	1-10	0.0	0.0	53.8	9.2	121.4	12.6	32.0	0.0	2.6	1.2	9.9	0.0	1,255.6
		11-20	0.2	20.5	19.2	290.3	3.7	4.2	2.1	2.6	0.2	0.2	0.7	1.5	
		21-end	1.1	1.9	158.0	486.2	0.0	11.8	0.0	0.8	5.3	0.4	1.9	0.0	
		Month	1.3	22.4	231.0	785.8	125.0	28.7	34.1	3.4	8.1	1.8	12.5	1.5	
9	2001/02	1-10	0.2	0.1	35.3	67.1	227.0	27.2	0.7	101.4	0.8	0.0	0.4	0.0	1,207.7
		11-20	0.0	0.0	46.3	42.9	234.7	4.0	5.2	34.6	6.7	0.1	1.2	10.1	
		21-end	18.5	0.0	164.4	11.0	106.4	38.0	10.7	5.1	0.0	7.1	0.5	0.0	
		Month	18.8	0.1	246.0	121.0	568.1	69.2	16.6	141.0	7.5	7.2	2.0	10.1	
10	2002/03	1-10	0.0	16.4	30.8	65.5	15.3	48.6	3.7	8.4	0.0	0.0	1.1	2.6	1,649.6
		11-20	0.2	3.3	255.8	270.4	230.9	109.8	0.0	1.3	0.6	4.6	0.0	2.5	
		21-end	0.8	34.0	172.9	237.2	120.8	1.5	0.0	0.5	4.5	0.6	0.9	4.4	
		Month	1.1	53.7	459.5	573.0	367.0	159.9	3.7	10.1	5.1	5.2	2.0	9.4	
	Average	1-10	4.2	5.2	69.4	91.8	111.2	56.3	14.4	21.1	3.2	4.3	3.4	5.1	1,276.8
		11-20	13.1	11.1	102.1	146.6	97.0	34.2	4.6	4.2	2.5	3.1	1.5	2.3	
		21-end	15.9	7.4	113.1	203.3	79.5	32.2	3.0	3.4	2.0	2.8	1.4	2.5	
		Month	33.3	23.7	284.6	441.7	287.6	122.8	22.1	28.7	7.7	8.4	6.3	9.9	
	5-year drought	1-10	3.5	4.4	58.3	77.1	93.4	47.3	12.1	17.7	2.7	3.6	2.9	4.3	1,072.5
		11-20	11.0	9.3	85.8	123.2	81.5	28.7	3.9	3.5	2.1	2.6	1.2	1.9	
		21-end	13.4	6.3	95.0	170.7	66.7	27.1	2.5	2.8	1.7	2.4	1.2	2.1	
		Month	28.0	19.9	239.1	371.1	241.6	103.1	18.5	24.1	6.5	7.0	5.3	8.3	
	5-year wet	1-10	5.0	6.2	83.3	110.2	133.4	67.6	17.3	25.3	3.8	5.2	4.1	6.2	1,532.1
		11-20	15.8	13.3	122.5	176.0	116.4	41.0	5.6	5.1	3.0	3.8	1.8	2.7	
		21-end	19.1	8.9	135.7	243.9	95.3	38.7	3.6	4.1	2.4	3.4	1.7	3.0	
		Month	40.0	28.5	341.5	530.1	345.1	147.3	26.5	34.4	9.3	10.0	7.6	11.9	

Source: JICA study team

Table 4.11 Simulated 10-day probable discharge atAmohimitsotra (Sahabe river)

River System
Catchment Area: 427 km2
Basin Elevation: 1031 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	1.93	4.54	1.78	7.66	47.05	11.61	15.56	5.29	2.86	2.22	2.23	2.13	7.82
		11-20	1.88	1.83	1.73	7.01	45.72	18.77	8.84	4.05	2.57	2.22	2.18	2.13	
		21-end	1.66	1.78	2.15	24.97	20.14	9.34	6.82	2.65	2.27	1.98	1.97	2.08	
		Month	1.82	2.72	1.89	13.21	37.64	13.24	10.41	4.00	2.57	2.14	2.13	2.11	
2	1994/95	1-10	2.08	3.17	1.93	1.93	34.85	10.62	7.01	4.30	2.62	2.23	2.13	2.08	7.08
		11-20	2.03	2.03	1.93	1.88	33.26	8.25	6.27	4.30	2.38	2.18	2.13	2.08	
		21-end	8.27	1.98	5.26	50.14	20.01	8.94	5.58	2.69	2.23	1.98	1.93	2.08	
		Month	4.13	2.39	3.04	17.98	29.37	9.27	6.29	3.76	2.41	2.13	2.06	2.08	
3	1995/96	1-10	1.98	1.93	1.88	60.10	41.90	13.00	28.86	7.32	3.51	2.72	2.66	2.57	10.91
		11-20	1.98	1.93	24.86	27.23	23.57	17.15	10.53	5.88	3.02	2.72	2.61	2.57	
		21-end	1.79	1.93	9.29	38.28	16.53	10.02	8.36	4.14	2.77	2.42	2.38	2.52	
		Month	1.92	1.93	12.01	41.87	27.33	13.39	15.92	5.78	3.10	2.62	2.55	2.55	
4	1996/97	1-10	2.52	2.42	2.33	11.82	72.70	20.65	8.64	5.23	2.96	2.91	2.81	2.72	9.93
		11-20	2.47	2.38	11.32	27.33	23.62	13.14	9.34	4.15	2.96	2.86	2.77	2.67	
		21-end	2.25	2.33	44.11	10.15	25.89	9.84	6.62	3.01	2.91	2.56	2.47	2.67	
		Month	2.41	2.38	19.25	16.43	40.74	14.54	8.20	4.13	2.94	2.78	2.68	2.69	
5	1997/98	1-10	2.62	2.52	2.67	2.91	40.87	69.29	8.15	3.70	2.67	2.57	2.47	2.42	7.81
		11-20	2.62	2.52	15.81	6.96	7.41	13.24	6.42	3.25	2.62	2.57	2.47	2.47	
		21-end	2.33	4.95	2.74	2.69	31.08	9.39	4.93	2.47	2.62	2.29	2.20	2.32	
		Month	2.52	3.33	7.07	4.19	26.45	30.64	6.50	3.14	2.64	2.48	2.38	2.40	
6	1998/99	1-10	2.32	2.27	2.18	10.68	5.89	2.82	2.77	2.13	2.03	1.98	1.93	1.83	4.11
		11-20	2.32	2.23	4.01	41.52	4.31	2.58	2.33	3.52	2.03	1.98	1.93	1.83	
		21-end	2.07	2.23	4.85	6.60	4.26	7.59	1.93	1.89	2.03	1.75	1.66	1.83	
		Month	2.24	2.24	3.68	19.60	4.82	4.33	2.34	2.51	2.03	1.90	1.84	1.83	
7	1999/00	1-10	1.78	1.73	1.73	1.73	2.22	5.78	4.35	1.63	1.58	1.53	1.48	1.43	3.34
		11-20	1.78	1.73	1.68	2.62	2.17	37.26	3.16	1.63	1.58	1.53	1.48	1.43	
		21-end	1.62	1.73	5.30	6.29	5.55	5.48	2.12	1.43	1.58	1.35	1.35	1.43	
		Month	1.73	1.73	2.90	3.55	3.31	16.17	3.21	1.56	1.58	1.47	1.44	1.43	
8	2000/01	1-10	1.43	1.38	1.33	19.12	97.21	11.36	5.53	2.56	1.88	1.78	1.73	1.68	7.88
		11-20	1.38	1.38	1.97	2.47	21.69	9.13	4.93	2.02	1.83	1.78	1.68	1.63	
		21-end	1.26	1.38	1.21	44.79	18.10	6.29	3.70	1.66	1.78	1.57	1.53	1.63	
		Month	1.36	1.38	1.50	22.13	45.67	8.93	4.72	2.08	1.83	1.71	1.65	1.65	
9	2001/02	1-10	1.63	1.58	1.48	20.85	2.96	17.10	7.32	3.36	3.96	1.98	1.78	1.73	6.56
		11-20	1.58	1.53	1.48	6.62	36.87	10.38	5.49	11.96	3.02	1.83	1.78	1.73	
		21-end	1.44	1.48	1.38	3.82	54.00	7.23	4.15	5.17	2.37	1.66	1.61	1.73	
		Month	1.55	1.53	1.45	10.43	31.28	11.57	5.65	6.83	3.12	1.82	1.72	1.73	
10	2002/03	1-10	1.68	1.63	1.58	25.95	46.16	24.41	12.35	6.08	2.96	2.42	2.37	2.33	10.69
		11-20	1.68	1.63	1.53	10.38	13.44	16.21	9.93	4.99	2.62	2.42	2.32	2.28	
		21-end	1.52	1.63	35.81	46.41	60.24	19.68	7.76	3.46	2.47	2.16	2.07	2.28	
		Month	1.63	1.63	12.97	27.58	39.95	20.10	10.01	4.84	2.68	2.33	2.25	2.30	
	Average	1-10	2.00	2.32	1.89	16.28	39.18	18.66	10.05	4.16	2.70	2.23	2.16	2.09	7.61
		11-20	1.97	1.92	6.63	13.40	21.21	14.61	6.72	4.58	2.46	2.21	2.14	2.08	
		21-end	2.42	2.14	11.21	23.41	25.58	9.38	5.20	2.86	2.30	1.97	1.92	2.06	
		Month	2.13	2.13	6.58	17.70	28.66	14.22	7.33	3.86	2.49	2.14	2.07	2.08	
	5-year drought	1-10	1.68	1.95	1.59	13.67	32.91	15.68	8.45	3.49	2.27	1.88	1.81	1.76	6.82
		11-20	1.66	1.61	5.57	11.26	17.81	12.27	5.65	3.84	2.07	1.86	1.79	1.75	
		21-end	2.03	1.80	9.42	19.67	21.49	7.88	4.37	2.40	1.93	1.66	1.61	1.73	
		Month	1.79	1.79	5.52	14.87	24.07	11.94	6.15	3.25	2.09	1.80	1.74	1.74	
	5-year wet	1-10	2.40	2.78	2.27	19.53	47.02	22.40	12.06	4.99	3.24	2.68	2.59	2.51	9.14
		11-20	2.37	2.30	7.96	16.08	25.45	17.53	8.07	5.49	2.96	2.65	2.56	2.50	
		21-end	2.91	2.57	13.45	28.10	30.70	11.26	6.24	3.43	2.76	2.37	2.30	2.47	
		Month	2.56	2.55	7.89	21.24	34.39	17.06	8.79	4.64	2.99	2.57	2.48	2.49	

Source: JICA study team

Table 4.12 Simulated 10-day probable discharge at Morarano (Andranomainty river)

(Under the Sahabe River System)

River System Sahabe River System
Catchment Area: 79 km2
Basin Elevation: 937 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	0.34	0.67	0.31	1.17	7.32	1.83	2.41	0.79	0.45	0.38	0.36	0.35	1.21
		11-20	0.33	0.32	0.31	1.03	7.08	2.77	1.35	0.58	0.39	0.37	0.36	0.35	
		21-end	0.30	0.31	0.30	3.70	3.15	1.45	1.03	0.40	0.38	0.34	0.32	0.35	
		Month	0.32	0.43	0.31	1.97	5.85	2.02	1.60	0.59	0.41	0.36	0.35	0.35	
2	1994/95	1-10	0.35	0.48	0.32	0.32	5.39	1.64	1.06	0.61	0.38	0.35	0.35	0.34	1.09
		11-20	0.34	0.34	0.32	0.32	5.11	1.27	0.94	0.59	0.36	0.35	0.35	0.34	
		21-end	1.18	0.34	0.78	7.77	3.16	1.32	0.82	0.40	0.36	0.32	0.31	0.34	
		Month	0.62	0.39	0.47	2.80	4.55	1.41	0.94	0.53	0.37	0.34	0.34	0.34	
3	1995/96	1-10	0.33	0.32	0.31	9.30	6.48	2.01	4.29	1.08	0.50	0.43	0.41	0.41	1.67
		11-20	0.32	0.31	3.69	4.09	3.62	2.62	1.61	0.85	0.44	0.43	0.41	0.40	
		21-end	0.29	0.31	1.42	5.90	2.58	1.53	1.27	0.56	0.44	0.38	0.37	0.39	
		Month	0.31	0.31	1.81	6.43	4.23	2.05	2.39	0.83	0.46	0.41	0.40	0.40	
4	1996/97	1-10	0.38	0.38	0.37	1.80	11.33	3.17	1.29	0.73	0.47	0.46	0.44	0.43	1.51
		11-20	0.38	0.38	1.50	4.03	3.58	2.03	1.33	0.58	0.46	0.45	0.43	0.42	
		21-end	0.34	0.37	6.83	1.53	4.01	1.49	0.95	0.44	0.46	0.40	0.39	0.41	
		Month	0.37	0.38	2.90	2.45	6.31	2.23	1.19	0.58	0.46	0.44	0.42	0.42	
5	1997/98	1-10	0.41	0.40	0.40	0.42	6.18	10.82	1.19	0.50	0.40	0.39	0.39	0.37	1.17
		11-20	0.41	0.40	2.18	0.95	1.07	2.03	0.91	0.45	0.39	0.39	0.37	0.37	
		21-end	0.37	0.71	0.41	0.39	4.53	1.42	0.67	0.37	0.39	0.35	0.33	0.36	
		Month	0.40	0.50	1.00	0.59	3.93	4.76	0.92	0.44	0.39	0.38	0.36	0.37	
6	1998/99	1-10	0.36	0.34	0.34	1.49	0.86	0.40	0.38	0.32	0.31	0.29	0.29	0.28	0.60
		11-20	0.35	0.34	0.56	6.31	0.60	0.34	0.33	0.48	0.31	0.29	0.28	0.28	
		21-end	0.31	0.34	0.67	0.98	0.56	1.03	0.29	0.28	0.31	0.26	0.26	0.27	
		Month	0.34	0.34	0.52	2.93	0.67	0.59	0.33	0.36	0.31	0.28	0.28	0.28	
7	1999/00	1-10	0.27	0.26	0.26	0.26	0.32	0.78	0.55	0.25	0.23	0.23	0.22	0.22	0.48
		11-20	0.27	0.26	0.26	0.34	0.31	5.61	0.43	0.25	0.23	0.23	0.22	0.22	
		21-end	0.25	0.26	0.74	0.88	0.72	0.74	0.29	0.21	0.23	0.20	0.20	0.21	
		Month	0.26	0.26	0.42	0.49	0.45	2.38	0.42	0.24	0.23	0.22	0.21	0.22	
8	2000/01	1-10	0.21	0.21	0.20	2.73	15.34	1.73	0.77	0.33	0.27	0.26	0.26	0.25	1.20
		11-20	0.21	0.20	0.22	0.35	3.35	1.36	0.68	0.28	0.27	0.26	0.25	0.24	
		21-end	0.19	0.20	0.18	6.87	2.80	0.90	0.47	0.25	0.26	0.23	0.22	0.24	
		Month	0.20	0.20	0.20	3.32	7.16	1.33	0.64	0.29	0.27	0.25	0.24	0.24	
9	2001/02	1-10	0.24	0.23	0.23	3.00	0.38	2.61	1.05	0.41	0.54	0.27	0.27	0.26	0.96
		11-20	0.24	0.23	0.23	0.97	5.56	1.58	0.77	1.60	0.38	0.27	0.27	0.26	
		21-end	0.21	0.23	0.19	0.55	8.33	1.07	0.54	0.71	0.32	0.24	0.23	0.25	
		Month	0.23	0.23	0.22	1.51	4.76	1.75	0.79	0.91	0.41	0.26	0.26	0.26	
10	2002/03	1-10	0.25	0.24	0.24	3.90	7.15	3.64	1.88	0.87	0.42	0.37	0.35	0.34	1.62
		11-20	0.25	0.24	0.23	1.57	2.08	2.48	1.51	0.70	0.37	0.36	0.35	0.34	
		21-end	0.23	0.24	5.43	7.11	9.28	2.90	1.15	0.46	0.38	0.33	0.32	0.33	
		Month	0.24	0.24	1.97	4.19	6.17	3.01	1.51	0.68	0.39	0.35	0.34	0.34	
	Average	1-10	0.31	0.35	0.30	2.44	6.08	2.86	1.49	0.59	0.40	0.34	0.33	0.33	1.15
		11-20	0.31	0.30	0.95	2.00	3.24	2.21	0.99	0.64	0.36	0.34	0.33	0.32	
		21-end	0.37	0.33	1.70	3.57	3.91	1.39	0.75	0.41	0.35	0.31	0.30	0.32	
		Month	0.33	0.33	0.98	2.67	4.41	2.15	1.07	0.54	0.37	0.33	0.32	0.32	
	5-year drought	1-10	0.26	0.30	0.25	2.05	5.10	2.40	1.25	0.49	0.33	0.29	0.28	0.27	1.03
		11-20	0.26	0.25	0.80	1.68	2.72	1.86	0.83	0.53	0.30	0.29	0.28	0.27	
		21-end	0.31	0.28	1.42	3.00	3.29	1.16	0.63	0.34	0.30	0.26	0.25	0.26	
		Month	0.28	0.28	0.82	2.24	3.70	1.81	0.90	0.46	0.31	0.28	0.27	0.27	
	5-year wet	1-10	0.38	0.42	0.36	2.93	7.29	3.44	1.78	0.71	0.48	0.41	0.40	0.39	1.38
		11-20	0.37	0.36	1.14	2.40	3.88	2.65	1.18	0.76	0.43	0.41	0.39	0.39	
		21-end	0.44	0.40	2.03	4.28	4.69	1.66	0.90	0.49	0.42	0.37	0.35	0.38	
		Month	0.40	0.39	1.18	3.20	5.29	2.58	1.29	0.65	0.44	0.40	0.38	0.38	

Source: JICA study team

Table 4.13 Simulated 10-day probable discharge at Ranofotsy (Ranomanty river)

(Under the Sahabe River System)

River System Sahabe River System
Catchment Area: 79 km2 (at Ranofotsy)
Basin Elevation: 1008 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	0.34	0.80	0.33	1.38	8.46	2.10	2.81	0.95	0.52	0.43	0.42	0.40	1.41
		11-20	0.33	0.33	0.33	1.25	8.18	3.33	1.59	0.71	0.46	0.42	0.42	0.40	
		21-end	0.31	0.33	0.37	4.41	3.62	1.67	1.23	0.48	0.43	0.39	0.38	0.40	
		Month	0.33	0.49	0.34	2.35	6.75	2.37	1.88	0.71	0.47	0.41	0.41	0.40	
2	1994/95	1-10	0.40	0.60	0.39	0.38	6.29	1.94	1.30	0.80	0.50	0.45	0.44	0.43	1.30
		11-20	0.39	0.39	0.38	0.38	5.97	1.51	1.16	0.78	0.47	0.45	0.44	0.43	
		21-end	1.44	0.39	0.97	9.01	3.64	1.63	1.04	0.51	0.45	0.40	0.39	0.43	
		Month	0.74	0.46	0.58	3.26	5.30	1.69	1.17	0.70	0.47	0.43	0.42	0.43	
3	1995/96	1-10	0.42	0.42	0.41	10.81	7.55	2.40	5.19	1.35	0.69	0.58	0.56	0.55	2.02
		11-20	0.42	0.41	4.48	4.91	4.26	3.14	1.95	1.11	0.62	0.57	0.56	0.55	
		21-end	0.38	0.41	1.70	6.91	3.03	1.86	1.57	0.78	0.58	0.51	0.50	0.54	
		Month	0.41	0.41	2.20	7.54	4.95	2.47	2.90	1.08	0.63	0.55	0.54	0.55	
4	1996/97	1-10	0.54	0.53	0.51	2.21	13.13	3.79	1.65	1.03	0.65	0.64	0.63	0.61	1.88
		11-20	0.53	0.52	2.05	4.95	4.32	2.47	1.74	0.84	0.65	0.64	0.62	0.61	
		21-end	0.48	0.52	8.00	1.92	4.77	1.85	1.26	0.63	0.65	0.58	0.57	0.60	
		Month	0.52	0.52	3.52	3.03	7.41	2.70	1.55	0.83	0.65	0.62	0.61	0.61	
5	1997/98	1-10	0.60	0.59	0.61	0.65	7.42	12.56	1.61	0.80	0.62	0.61	0.61	0.59	1.53
		11-20	0.60	0.59	2.88	1.36	1.44	2.51	1.26	0.72	0.62	0.61	0.60	0.61	
		21-end	0.54	1.01	0.62	0.61	5.68	1.80	1.01	0.58	0.61	0.55	0.54	0.58	
		Month	0.58	0.73	1.37	0.87	4.85	5.62	1.29	0.70	0.62	0.59	0.58	0.59	
6	1998/99	1-10	0.58	0.57	0.55	2.02	1.21	0.65	0.66	0.55	0.54	0.53	0.51	0.50	0.89
		11-20	0.57	0.56	0.88	7.59	0.92	0.61	0.58	0.78	0.53	0.52	0.50	0.50	
		21-end	0.52	0.56	0.99	1.33	0.96	1.47	0.51	0.49	0.53	0.48	0.46	0.50	
		Month	0.56	0.56	0.81	3.65	1.03	0.91	0.58	0.61	0.53	0.51	0.49	0.50	
7	1999/00	1-10	0.49	0.48	0.48	0.47	0.56	1.19	0.93	0.47	0.46	0.45	0.44	0.43	0.76
		11-20	0.49	0.48	0.47	0.62	0.55	6.80	0.73	0.46	0.45	0.44	0.44	0.43	
		21-end	0.44	0.48	1.08	1.27	1.13	1.12	0.54	0.42	0.45	0.40	0.39	0.42	
		Month	0.47	0.48	0.68	0.79	0.75	3.04	0.73	0.45	0.45	0.43	0.42	0.43	
8	2000/01	1-10	0.41	0.40	0.40	3.53	17.66	2.18	1.14	0.60	0.49	0.48	0.48	0.46	1.57
		11-20	0.41	0.40	0.48	0.62	4.05	1.79	1.03	0.51	0.48	0.48	0.46	0.45	
		21-end	0.37	0.40	0.36	8.15	3.45	1.25	0.79	0.45	0.48	0.43	0.41	0.45	
		Month	0.40	0.40	0.41	4.10	8.39	1.74	0.99	0.52	0.48	0.46	0.45	0.45	
9	2001/02	1-10	0.45	0.44	0.43	3.84	0.67	3.21	1.45	0.73	0.86	0.50	0.48	0.47	1.32
		11-20	0.44	0.44	0.43	1.35	6.74	2.01	1.13	2.23	0.67	0.48	0.47	0.47	
		21-end	0.40	0.43	0.38	0.82	9.84	1.42	0.87	1.05	0.57	0.44	0.43	0.47	
		Month	0.43	0.44	0.41	2.00	5.75	2.21	1.15	1.34	0.70	0.47	0.46	0.47	
10	2002/03	1-10	0.46	0.46	0.45	4.79	8.44	4.51	2.35	1.22	0.68	0.59	0.58	0.58	2.06
		11-20	0.46	0.45	0.44	2.03	2.56	3.05	1.92	1.04	0.61	0.59	0.58	0.57	
		21-end	0.41	0.45	6.54	8.43	10.97	3.60	1.53	0.73	0.60	0.53	0.52	0.57	
		Month	0.44	0.45	2.48	5.08	7.32	3.72	1.93	1.00	0.63	0.57	0.56	0.57	
	Average	1-10	0.47	0.53	0.46	3.01	7.14	3.45	1.91	0.85	0.60	0.53	0.52	0.50	1.47
		11-20	0.46	0.46	1.28	2.51	3.90	2.72	1.31	0.92	0.56	0.52	0.51	0.50	
		21-end	0.53	0.50	2.10	4.29	4.71	1.77	1.04	0.61	0.54	0.47	0.46	0.50	
		Month	0.49	0.49	1.28	3.27	5.25	2.65	1.42	0.79	0.56	0.51	0.49	0.50	
	5-year drought	1-10	0.39	0.44	0.38	2.53	6.00	2.90	1.60	0.71	0.50	0.44	0.43	0.42	1.31
		11-20	0.39	0.38	1.08	2.11	3.28	2.29	1.10	0.77	0.47	0.44	0.43	0.42	
		21-end	0.44	0.42	1.76	3.60	3.96	1.48	0.87	0.51	0.45	0.40	0.39	0.42	
		Month	0.41	0.42	1.07	2.74	4.41	2.22	1.19	0.67	0.47	0.42	0.42	0.42	
	5-year wet	1-10	0.56	0.63	0.55	3.61	8.57	4.14	2.29	1.02	0.72	0.63	0.62	0.60	1.77
		11-20	0.56	0.55	1.54	3.01	4.68	3.27	1.57	1.10	0.67	0.62	0.61	0.60	
		21-end	0.63	0.60	2.52	5.14	5.65	2.12	1.24	0.73	0.64	0.57	0.55	0.60	
		Month	0.58	0.59	1.54	3.92	6.30	3.18	1.70	0.95	0.68	0.61	0.59	0.60	

Source: JICA study team

Table 4.14 Simulated 10-day probable discharge at Sahanidingana (Mavalova-Ampandra river

(at Sahadingana, downstream of the Ampandra River Confluence)

River System Sahabe River System

Catchment Area: 129 km2 (at Sahadingana, d/s of the Ampandra River Confluence)

Basin Elevation: 947 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	0.58	1.16	0.53	1.98	12.63	3.12	4.11	1.36	0.75	0.63	0.61	0.59	2.08
		11-20	0.56	0.55	0.52	1.81	12.21	4.79	2.34	0.98	0.64	0.61	0.61	0.58	
		21-end	0.50	0.53	0.50	6.40	5.45	2.48	1.77	0.71	0.64	0.58	0.56	0.57	
		Month	0.55	0.75	0.52	3.40	10.10	3.46	2.74	1.02	0.68	0.61	0.59	0.58	
2	1994/95	1-10	0.57	0.79	0.55	0.52	9.26	2.85	1.81	1.05	0.62	0.60	0.57	0.55	1.86
		11-20	0.57	0.55	0.52	0.52	8.79	2.16	1.61	1.02	0.61	0.58	0.57	0.53	
		21-end	2.03	0.55	1.34	13.40	5.42	2.29	1.42	0.68	0.60	0.53	0.51	0.53	
		Month	1.06	0.63	0.80	4.81	7.82	2.43	1.61	0.92	0.61	0.57	0.55	0.54	
3	1995/96	1-10	0.52	0.52	0.49	16.04	11.14	3.43	7.42	1.84	0.86	0.70	0.69	0.67	2.85
		11-20	0.52	0.49	6.35	7.09	6.22	4.47	2.74	1.47	0.74	0.70	0.69	0.66	
		21-end	0.48	0.49	2.40	10.15	4.41	2.60	2.14	0.98	0.71	0.64	0.62	0.66	
		Month	0.51	0.50	3.08	11.09	7.26	3.50	4.10	1.43	0.77	0.68	0.67	0.66	
4	1996/97	1-10	0.64	0.61	0.59	3.10	19.49	5.44	2.19	1.24	0.76	0.74	0.71	0.70	2.58
		11-20	0.64	0.61	2.58	6.97	6.09	3.50	2.31	0.96	0.75	0.73	0.71	0.67	
		21-end	0.59	0.59	11.75	2.67	6.90	2.56	1.63	0.73	0.76	0.67	0.64	0.67	
		Month	0.62	0.60	4.97	4.25	10.83	3.83	2.04	0.98	0.76	0.71	0.69	0.68	
5	1997/98	1-10	0.66	0.64	0.63	0.67	10.64	18.59	2.06	0.84	0.66	0.64	0.61	0.59	1.98
		11-20	0.66	0.62	3.77	1.60	1.83	3.48	1.53	0.76	0.66	0.63	0.59	0.60	
		21-end	0.59	1.17	0.68	0.65	7.82	2.42	1.14	0.62	0.64	0.55	0.54	0.57	
		Month	0.64	0.81	1.69	0.97	6.76	8.16	1.58	0.74	0.65	0.61	0.58	0.59	
6	1998/99	1-10	0.57	0.55	0.53	2.55	1.42	0.62	0.61	0.51	0.49	0.47	0.45	0.45	1.00
		11-20	0.57	0.53	0.90	10.90	0.98	0.53	0.52	0.80	0.47	0.46	0.45	0.43	
		21-end	0.52	0.53	1.09	1.67	0.94	1.77	0.45	0.44	0.47	0.41	0.41	0.43	
		Month	0.55	0.54	0.84	5.04	1.11	0.97	0.53	0.58	0.48	0.45	0.44	0.44	
7	1999/00	1-10	0.43	0.42	0.40	0.39	0.51	1.30	0.92	0.37	0.36	0.34	0.34	0.33	0.79
		11-20	0.43	0.42	0.40	0.53	0.49	9.67	0.68	0.37	0.36	0.34	0.34	0.33	
		21-end	0.38	0.40	1.28	1.49	1.19	1.25	0.44	0.34	0.36	0.31	0.31	0.33	
		Month	0.41	0.41	0.69	0.80	0.73	4.07	0.68	0.36	0.36	0.33	0.33	0.33	
8	2000/01	1-10	0.33	0.31	0.31	4.75	26.35	2.97	1.33	0.55	0.43	0.41	0.40	0.38	2.03
		11-20	0.33	0.31	0.35	0.57	5.76	2.31	1.17	0.44	0.43	0.40	0.38	0.37	
		21-end	0.30	0.31	0.27	11.82	4.79	1.55	0.78	0.41	0.41	0.36	0.35	0.37	
		Month	0.32	0.31	0.31	5.71	12.30	2.28	1.09	0.47	0.42	0.39	0.38	0.37	
9	2001/02	1-10	0.37	0.35	0.35	5.18	0.64	4.46	1.78	0.70	0.90	0.43	0.42	0.40	1.63
		11-20	0.37	0.35	0.35	1.63	9.57	2.69	1.31	2.76	0.63	0.43	0.42	0.40	
		21-end	0.34	0.35	0.30	0.91	14.33	1.80	0.92	1.23	0.54	0.38	0.37	0.40	
		Month	0.36	0.35	0.33	2.57	8.18	2.98	1.34	1.56	0.69	0.41	0.40	0.40	
10	2002/03	1-10	0.39	0.39	0.37	6.70	12.27	6.26	3.23	1.50	0.68	0.60	0.58	0.56	2.76
		11-20	0.39	0.37	0.37	2.66	3.56	4.24	2.56	1.20	0.63	0.58	0.58	0.55	
		21-end	0.36	0.37	9.38	12.28	15.96	4.95	1.96	0.76	0.61	0.54	0.52	0.55	
		Month	0.38	0.38	3.37	7.21	10.60	5.15	2.58	1.15	0.64	0.57	0.56	0.55	
	Average	1-10	0.51	0.57	0.48	4.19	10.44	4.90	2.55	1.00	0.65	0.56	0.54	0.52	1.96
		11-20	0.50	0.48	1.61	3.43	5.55	3.78	1.68	1.08	0.59	0.55	0.53	0.51	
		21-end	0.61	0.53	2.90	6.14	6.72	2.37	1.27	0.69	0.57	0.50	0.48	0.51	
		Month	0.54	0.53	1.66	4.59	7.57	3.69	1.83	0.92	0.61	0.53	0.52	0.51	
	5-year drought	1-10	0.43	0.48	0.40	3.52	8.77	4.12	2.14	0.84	0.55	0.47	0.45	0.44	1.75
		11-20	0.42	0.40	1.35	2.88	4.66	3.18	1.41	0.90	0.50	0.46	0.45	0.43	
		21-end	0.51	0.44	2.44	5.16	5.65	1.99	1.06	0.58	0.48	0.42	0.41	0.43	
		Month	0.45	0.44	1.40	3.85	6.36	3.10	1.54	0.77	0.51	0.45	0.44	0.43	
	5-year wet	1-10	0.61	0.69	0.57	5.03	12.52	5.88	3.06	1.20	0.78	0.67	0.65	0.63	2.35
		11-20	0.60	0.58	1.93	4.11	6.66	4.54	2.01	1.29	0.71	0.66	0.64	0.61	
		21-end	0.73	0.63	3.48	7.37	8.07	2.84	1.52	0.83	0.69	0.60	0.58	0.61	
		Month	0.65	0.63	1.99	5.50	9.08	4.42	2.20	1.10	0.73	0.64	0.62	0.62	

Source: JICA study team

Table 4.15 Simulated 10-day discharge at Maheriana (Sahamilay river)

River System Sahamilay River System
Catchment Area: 152 km2
Basin Elevation: 1097 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	1.53	2.61	1.34	3.78	19.15	5.58	7.53	3.52	2.78	2.53	2.31	2.13	4.21
		11-20	1.50	1.45	1.32	3.54	18.77	8.77	4.78	3.10	2.69	2.45	2.26	2.08	
		21-end	1.33	1.37	1.52	10.64	9.11	4.73	4.08	2.59	2.60	2.16	1.98	2.01	
		Month	1.45	1.81	1.39	5.99	15.68	6.36	5.46	3.07	2.69	2.38	2.18	2.07	
2	1994/95	1-10	1.96	2.38	1.74	1.68	14.71	5.30	4.07	3.11	2.57	2.36	2.16	1.99	4.00
		11-20	1.91	1.89	1.71	1.62	14.20	4.45	3.84	3.19	2.50	2.29	2.11	1.94	
		21-end	4.63	1.80	3.03	20.43	9.28	4.75	3.61	2.50	2.43	2.03	1.86	1.88	
		Month	2.83	2.02	2.16	7.91	12.73	4.83	3.84	2.93	2.50	2.23	2.04	1.94	
3	1995/96	1-10	1.81	1.67	1.55	24.38	17.68	6.54	13.30	4.82	3.59	3.27	2.99	2.72	5.81
		11-20	1.76	1.62	10.79	11.80	10.80	8.39	5.96	4.31	3.48	3.16	2.88	2.64	
		21-end	1.56	1.58	4.45	16.07	8.01	5.45	5.22	3.50	3.38	2.79	2.54	2.57	
		Month	1.71	1.62	5.60	17.42	12.16	6.79	8.16	4.21	3.48	3.07	2.80	2.64	
4	1996/97	1-10	2.46	2.26	2.07	5.87	29.67	9.83	5.24	3.99	3.44	3.13	2.85	2.60	5.53
		11-20	2.39	2.19	5.92	12.20	10.98	6.89	5.63	3.72	3.34	3.04	2.76	2.53	
		21-end	2.11	2.12	18.30	5.22	12.10	5.49	4.54	3.23	3.23	2.67	2.45	2.46	
		Month	2.32	2.19	8.76	7.76	17.58	7.40	5.14	3.65	3.34	2.95	2.69	2.53	
5	1997/98	1-10	2.37	2.18	2.13	2.18	17.13	28.03	4.52	2.96	2.62	2.40	2.18	2.01	4.30
		11-20	2.32	2.11	7.58	3.85	3.96	6.42	3.83	2.82	2.54	2.33	2.13	2.06	
		21-end	2.05	3.15	2.06	2.05	13.83	4.84	3.29	2.45	2.47	2.05	1.87	1.90	
		Month	2.25	2.48	3.92	2.69	11.64	13.10	3.88	2.74	2.54	2.26	2.06	1.99	
6	1998/99	1-10	1.85	1.69	1.55	5.27	3.12	2.01	1.98	1.65	1.53	1.41	1.30	1.21	2.34
		11-20	1.78	1.64	2.36	16.98	2.52	1.88	1.78	2.22	1.49	1.37	1.26	1.16	
		21-end	1.57	1.58	2.65	3.33	2.72	3.80	1.30	1.44	1.44	1.22	1.12	1.12	
		Month	1.73	1.64	2.19	8.53	2.79	2.56	1.69	1.77	1.49	1.33	1.23	1.16	
7	1999/00	1-10	1.10	1.02	0.95	0.97	1.23	2.77	2.22	1.32	1.22	1.11	1.02	0.95	1.75
		11-20	1.07	1.00	0.93	1.41	1.22	15.14	1.80	1.29	1.16	1.07	1.00	0.92	
		21-end	0.96	0.96	2.42	2.87	2.72	2.61	1.45	1.14	1.13	0.94	0.88	0.90	
		Month	1.04	0.99	1.43	1.75	1.72	6.84	1.82	1.25	1.17	1.04	0.97	0.92	
8	2000/01	1-10	0.88	0.83	0.76	8.01	38.05	5.26	3.20	2.34	2.13	1.93	1.76	1.62	3.88
		11-20	0.86	0.79	1.09	1.29	9.13	4.47	3.07	2.25	2.06	1.88	1.71	1.56	
		21-end	0.77	0.77	0.66	17.85	8.01	3.33	2.58	1.99	1.99	1.65	1.52	1.53	
		Month	0.84	0.80	0.84	9.05	18.40	4.35	2.95	2.19	2.06	1.82	1.66	1.57	
9	2001/02	1-10	1.48	1.35	1.23	9.09	1.86	7.71	3.99	2.44	2.74	2.09	1.90	1.74	3.53
		11-20	1.44	1.32	1.19	3.29	15.28	5.01	3.23	6.11	2.39	2.02	1.84	1.69	
		21-end	1.27	1.28	1.08	2.18	22.06	3.71	2.72	3.10	2.23	1.79	1.63	1.63	
		Month	1.40	1.32	1.17	4.85	13.07	5.48	3.31	3.88	2.45	1.97	1.79	1.69	
10	2002/03	1-10	1.58	1.46	1.33	11.06	19.07	11.03	6.40	4.18	3.34	3.02	2.74	2.50	5.58
		11-20	1.54	1.40	1.30	4.94	6.34	7.76	5.55	3.78	3.22	2.94	2.66	2.41	
		21-end	1.36	1.37	14.82	18.98	25.09	9.33	4.80	3.17	3.13	2.58	2.34	2.34	
		Month	1.49	1.41	5.82	11.66	16.83	9.37	5.58	3.71	3.23	2.85	2.58	2.42	
	Average	1-10	1.70	1.75	1.47	7.23	16.17	8.41	5.25	3.03	2.60	2.33	2.12	1.95	4.09
		11-20	1.66	1.54	3.42	6.09	9.32	6.92	3.95	3.28	2.49	2.26	2.06	1.90	
		21-end	1.76	1.60	5.10	9.96	11.29	4.80	3.36	2.51	2.40	1.99	1.82	1.83	
		Month	1.71	1.63	3.33	7.76	12.26	6.71	4.18	2.94	2.50	2.19	2.00	1.89	
	5-year drought	1-10	1.43	1.47	1.23	6.07	13.58	7.06	4.41	2.55	2.18	1.95	1.78	1.64	3.60
		11-20	1.39	1.29	2.87	5.12	7.83	5.81	3.32	2.75	2.09	1.89	1.73	1.60	
		21-end	1.48	1.34	4.28	8.37	9.49	4.04	2.82	2.11	2.02	1.67	1.53	1.54	
		Month	1.43	1.37	2.80	6.52	10.30	5.64	3.51	2.47	2.10	1.84	1.68	1.59	
	5-year wet	1-10	2.04	2.09	1.76	8.67	19.40	10.09	6.29	3.64	3.12	2.79	2.55	2.34	4.91
		11-20	1.99	1.85	4.10	7.31	11.18	8.30	4.74	3.93	2.98	2.71	2.47	2.28	
		21-end	2.11	1.92	6.12	11.95	13.55	5.76	4.03	3.01	2.88	2.39	2.18	2.20	
		Month	2.05	1.95	3.99	9.31	14.71	8.05	5.02	3.53	2.99	2.63	2.40	2.27	

Source: JICA study team

Table 4.16 Stimulated 10-day probable discharge at National Road Bridge (Ampasimena river

River System Ampasimena River System
Catchment Area: 27 km2
Basin Elevation: 891 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	0.27	0.36	0.24	0.49	2.57	0.66	0.90	0.51	0.47	0.43	0.38	0.35	0.58
		11-20	0.26	0.25	0.23	0.45	2.47	0.98	0.57	0.49	0.45	0.42	0.37	0.34	
		21-end	0.24	0.25	0.21	1.30	1.13	0.55	0.52	0.44	0.44	0.37	0.34	0.33	
		Month	0.26	0.29	0.23	0.75	2.06	0.73	0.66	0.48	0.45	0.41	0.36	0.34	
2	1994/95	1-10	0.32	0.35	0.30	0.29	1.97	0.64	0.51	0.46	0.42	0.39	0.36	0.33	0.57
		11-20	0.32	0.31	0.29	0.28	1.84	0.54	0.49	0.45	0.41	0.38	0.35	0.32	
		21-end	0.58	0.31	0.42	2.76	1.21	0.54	0.47	0.39	0.40	0.33	0.30	0.31	
		Month	0.41	0.32	0.34	1.11	1.67	0.57	0.49	0.43	0.41	0.37	0.34	0.32	
3	1995/96	1-10	0.30	0.28	0.26	3.27	2.26	0.75	1.59	0.64	0.58	0.53	0.48	0.43	0.78
		11-20	0.30	0.27	1.37	1.49	1.31	0.99	0.72	0.62	0.56	0.51	0.46	0.42	
		21-end	0.26	0.26	0.60	2.05	0.93	0.64	0.66	0.54	0.55	0.45	0.41	0.41	
		Month	0.29	0.27	0.74	2.27	1.50	0.79	0.99	0.60	0.56	0.50	0.45	0.42	
4	1996/97	1-10	0.40	0.36	0.33	0.79	3.96	1.18	0.67	0.61	0.56	0.51	0.46	0.43	0.76
		11-20	0.39	0.35	0.70	1.48	1.34	0.80	0.69	0.60	0.54	0.50	0.45	0.41	
		21-end	0.35	0.34	2.47	0.64	1.51	0.65	0.64	0.53	0.53	0.44	0.41	0.40	
		Month	0.38	0.35	1.17	0.97	2.27	0.88	0.67	0.58	0.54	0.48	0.44	0.41	
5	1997/98	1-10	0.39	0.36	0.33	0.33	2.22	3.79	0.52	0.48	0.44	0.40	0.36	0.33	0.60
		11-20	0.38	0.35	0.88	0.49	0.51	0.79	0.50	0.46	0.42	0.39	0.35	0.33	
		21-end	0.33	0.43	0.30	0.29	1.66	0.54	0.49	0.40	0.41	0.34	0.31	0.32	
		Month	0.37	0.38	0.50	0.37	1.46	1.71	0.50	0.45	0.42	0.38	0.34	0.33	
6	1998/99	1-10	0.31	0.28	0.26	0.62	0.36	0.31	0.30	0.27	0.25	0.24	0.22	0.20	0.34
		11-20	0.30	0.28	0.32	2.21	0.33	0.30	0.29	0.31	0.25	0.23	0.21	0.20	
		21-end	0.26	0.27	0.34	0.41	0.40	0.50	0.22	0.24	0.24	0.20	0.18	0.19	
		Month	0.29	0.28	0.31	1.08	0.36	0.37	0.27	0.27	0.25	0.22	0.20	0.20	
7	1999/00	1-10	0.19	0.17	0.16	0.16	0.18	0.30	0.22	0.21	0.19	0.18	0.16	0.15	0.24
		11-20	0.18	0.17	0.16	0.17	0.17	1.92	0.22	0.20	0.18	0.17	0.16	0.15	
		21-end	0.16	0.17	0.31	0.34	0.29	0.27	0.21	0.18	0.18	0.16	0.14	0.14	
		Month	0.18	0.17	0.21	0.22	0.21	0.83	0.22	0.20	0.18	0.17	0.15	0.15	
8	2000/01	1-10	0.14	0.13	0.12	0.94	5.26	0.55	0.43	0.40	0.36	0.33	0.30	0.28	0.54
		11-20	0.14	0.13	0.13	0.17	1.15	0.47	0.42	0.38	0.35	0.32	0.29	0.27	
		21-end	0.13	0.13	0.11	2.34	0.91	0.41	0.41	0.34	0.34	0.28	0.25	0.26	
		Month	0.14	0.13	0.12	1.15	2.44	0.48	0.42	0.37	0.35	0.31	0.28	0.27	
9	2001/02	1-10	0.25	0.23	0.21	1.11	0.24	0.97	0.43	0.38	0.39	0.34	0.32	0.29	0.48
		11-20	0.24	0.23	0.21	0.44	1.94	0.58	0.40	0.74	0.37	0.33	0.31	0.28	
		21-end	0.21	0.22	0.18	0.27	2.93	0.40	0.39	0.40	0.36	0.29	0.26	0.27	
		Month	0.23	0.23	0.20	0.61	1.70	0.65	0.41	0.51	0.37	0.32	0.30	0.28	
10	2002/03	1-10	0.26	0.24	0.21	1.42	2.46	1.28	0.74	0.61	0.56	0.50	0.46	0.42	0.75
		11-20	0.26	0.22	0.21	0.62	0.75	0.91	0.66	0.59	0.54	0.49	0.44	0.40	
		21-end	0.22	0.22	1.93	2.45	3.17	1.06	0.63	0.52	0.52	0.42	0.39	0.39	
		Month	0.25	0.23	0.78	1.50	2.13	1.08	0.68	0.57	0.54	0.47	0.43	0.40	
	Average	1-10	0.28	0.28	0.24	0.94	2.15	1.04	0.63	0.46	0.42	0.39	0.35	0.32	0.57
		11-20	0.28	0.26	0.45	0.78	1.18	0.83	0.50	0.48	0.41	0.37	0.34	0.31	
		21-end	0.27	0.26	0.69	1.29	1.41	0.56	0.46	0.40	0.40	0.33	0.30	0.30	
		Month	0.28	0.26	0.46	1.00	1.58	0.81	0.53	0.45	0.41	0.36	0.33	0.31	
	5-year drought	1-10	0.24	0.23	0.20	0.79	1.80	0.88	0.53	0.38	0.35	0.32	0.29	0.27	0.49
		11-20	0.23	0.22	0.38	0.66	0.99	0.70	0.42	0.41	0.34	0.31	0.28	0.26	
		21-end	0.23	0.22	0.58	1.08	1.19	0.47	0.39	0.33	0.33	0.28	0.25	0.25	
		Month	0.23	0.22	0.39	0.84	1.33	0.68	0.45	0.37	0.34	0.30	0.28	0.26	
	5-year wet	1-10	0.34	0.33	0.29	1.13	2.58	1.25	0.76	0.55	0.51	0.46	0.42	0.39	0.68
		11-20	0.33	0.31	0.54	0.94	1.42	0.99	0.60	0.58	0.49	0.45	0.41	0.37	
		21-end	0.33	0.31	0.82	1.54	1.70	0.67	0.56	0.48	0.48	0.39	0.36	0.36	
		Month	0.33	0.32	0.55	1.20	1.90	0.97	0.64	0.54	0.49	0.43	0.40	0.37	

Source:JICA study team

Table 4.17 Simulated 10-day probable discharge at National Road Bridge (Asahamena river)

River System Asahamena River System
Catchment Area: 119 km2
Basin Elevation: 1061 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	1.20	1.97	1.05	2.78	14.37	4.21	5.55	2.64	2.11	1.90	1.75	1.61	3.16
		11-20	1.17	1.11	1.03	2.62	14.06	6.49	3.59	2.33	2.04	1.84	1.71	1.57	
		21-end	1.04	1.07	1.12	7.86	6.83	3.55	3.04	1.95	1.97	1.64	1.50	1.53	
		Month	1.14	1.38	1.07	4.42	11.75	4.75	4.06	2.31	2.04	1.79	1.65	1.57	
2	1994/95	1-10	1.49	1.76	1.32	1.26	10.98	3.97	3.04	2.28	1.92	1.76	1.62	1.47	2.98
		11-20	1.44	1.39	1.30	1.23	10.57	3.30	2.84	2.31	1.87	1.72	1.58	1.45	
		21-end	3.34	1.37	2.24	15.29	7.00	3.50	2.65	1.85	1.81	1.51	1.39	1.40	
		Month	2.09	1.51	1.62	5.93	9.52	3.59	2.84	2.15	1.87	1.66	1.53	1.44	
3	1995/96	1-10	1.36	1.25	1.16	18.22	13.17	4.89	9.83	3.56	2.69	2.44	2.23	2.03	4.33
		11-20	1.32	1.23	7.99	8.76	8.00	6.25	4.46	3.17	2.61	2.37	2.17	1.97	
		21-end	1.18	1.20	3.32	11.96	5.99	4.09	3.86	2.60	2.52	2.09	1.91	1.92	
		Month	1.29	1.23	4.16	12.98	9.05	5.08	6.05	3.11	2.61	2.30	2.10	1.97	
4	1996/97	1-10	1.86	1.70	1.56	4.39	22.23	7.30	3.90	2.97	2.58	2.36	2.15	1.96	4.13
		11-20	1.81	1.66	4.30	9.03	8.15	5.17	4.16	2.77	2.50	2.28	2.08	1.90	
		21-end	1.59	1.61	13.68	3.87	9.07	4.11	3.37	2.42	2.43	2.01	1.83	1.83	
		Month	1.75	1.66	6.51	5.76	13.15	5.53	3.81	2.72	2.50	2.22	2.02	1.90	
5	1997/98	1-10	1.77	1.62	1.57	1.60	12.72	21.00	3.34	2.19	1.94	1.76	1.61	1.47	3.18
		11-20	1.72	1.58	5.52	2.81	2.93	4.80	2.81	2.06	1.88	1.71	1.57	1.49	
		21-end	1.53	2.29	1.52	1.48	10.18	3.60	2.41	1.83	1.82	1.51	1.39	1.41	
		Month	1.67	1.83	2.87	1.96	8.61	9.80	2.85	2.03	1.88	1.66	1.52	1.46	
6	1998/99	1-10	1.36	1.25	1.16	3.78	2.27	1.46	1.45	1.22	1.13	1.03	0.95	0.88	1.72
		11-20	1.32	1.23	1.73	12.66	1.83	1.37	1.29	1.62	1.11	1.00	0.92	0.85	
		21-end	1.17	1.19	1.92	2.45	1.96	2.72	0.95	1.05	1.06	0.89	0.83	0.84	
		Month	1.28	1.22	1.60	6.30	2.02	1.85	1.23	1.30	1.10	0.97	0.90	0.86	
7	1999/00	1-10	0.81	0.75	0.69	0.69	0.87	1.99	1.60	0.95	0.88	0.81	0.75	0.69	1.27
		11-20	0.80	0.73	0.68	1.01	0.87	11.21	1.27	0.92	0.85	0.78	0.73	0.67	
		21-end	0.70	0.72	1.75	2.07	1.91	1.90	1.01	0.81	0.82	0.70	0.65	0.65	
		Month	0.77	0.73	1.04	1.26	1.22	5.03	1.29	0.89	0.85	0.76	0.71	0.67	
8	2000/01	1-10	0.63	0.59	0.55	5.84	28.60	3.89	2.36	1.73	1.57	1.44	1.31	1.20	2.88
		11-20	0.62	0.58	0.78	0.95	6.83	3.31	2.23	1.67	1.52	1.39	1.27	1.16	
		21-end	0.55	0.56	0.49	13.31	5.95	2.45	1.90	1.47	1.48	1.23	1.12	1.13	
		Month	0.60	0.58	0.61	6.70	13.79	3.22	2.16	1.62	1.52	1.35	1.23	1.16	
9	2001/02	1-10	1.09	1.01	0.93	6.67	1.35	5.69	2.93	1.80	2.01	1.55	1.42	1.30	2.61
		11-20	1.06	0.98	0.90	2.44	11.33	3.73	2.37	4.40	1.76	1.50	1.37	1.26	
		21-end	0.94	0.95	0.80	1.57	16.49	2.76	1.99	2.29	1.64	1.33	1.20	1.22	
		Month	1.03	0.98	0.88	3.56	9.72	4.06	2.43	2.83	1.80	1.46	1.33	1.26	
10	2002/03	1-10	1.17	1.06	0.98	8.22	14.25	8.19	4.78	3.13	2.48	2.25	2.04	1.86	4.15
		11-20	1.13	1.03	0.95	3.66	4.72	5.76	4.15	2.82	2.40	2.18	1.97	1.79	
		21-end	1.01	1.00	10.98	14.15	18.71	6.86	3.56	2.36	2.33	1.92	1.74	1.74	
		Month	1.10	1.03	4.30	8.68	12.56	6.94	4.16	2.77	2.40	2.12	1.92	1.80	
	Average	1-10	1.27	1.30	1.10	5.35	12.08	6.26	3.88	2.25	1.93	1.73	1.58	1.45	3.04
		11-20	1.24	1.15	2.52	4.52	6.93	5.14	2.92	2.41	1.85	1.68	1.54	1.41	
		21-end	1.31	1.20	3.78	7.40	8.41	3.55	2.47	1.86	1.79	1.48	1.36	1.37	
		Month	1.27	1.21	2.47	5.75	9.14	4.98	3.09	2.17	1.86	1.63	1.49	1.41	
	5-year drought	1-10	1.07	1.09	0.92	4.49	10.15	5.26	3.26	1.89	1.62	1.45	1.33	1.22	2.68
		11-20	1.04	0.97	2.12	3.79	5.82	4.32	2.45	2.02	1.56	1.41	1.29	1.19	
		21-end	1.10	1.00	3.18	6.22	7.06	2.99	2.08	1.56	1.50	1.25	1.14	1.15	
		Month	1.07	1.02	2.07	4.83	7.68	4.19	2.60	1.82	1.56	1.37	1.25	1.18	
	5-year wet	1-10	1.53	1.56	1.32	6.41	14.50	7.51	4.65	2.70	2.32	2.08	1.90	1.74	3.65
		11-20	1.49	1.38	3.02	5.42	8.31	6.17	3.50	2.89	2.22	2.01	1.84	1.69	
		21-end	1.57	1.44	4.54	8.88	10.09	4.26	2.97	2.24	2.15	1.78	1.63	1.64	
		Month	1.53	1.46	2.96	6.91	10.97	5.98	3.71	2.61	2.23	1.96	1.79	1.69	

Source: JICA study team

Table 4.18 Simulated 10-day probable discharge at National Road Bridge (Behengitra river)

River System Behengitra River System
Catchment Area: 27 km2
Basin Elevation: 918 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	0.27	0.37	0.24	0.52	2.67	0.74	0.96	0.50	0.46	0.42	0.38	0.35	0.60
		11-20	0.26	0.25	0.23	0.47	2.59	1.07	0.61	0.48	0.44	0.40	0.36	0.34	
		21-end	0.24	0.24	0.22	1.38	1.23	0.60	0.53	0.43	0.43	0.36	0.33	0.33	
		Month	0.26	0.29	0.23	0.79	2.16	0.80	0.70	0.47	0.44	0.39	0.36	0.34	
2	1994/95	1-10	0.32	0.34	0.29	0.28	2.04	0.72	0.52	0.45	0.41	0.38	0.35	0.32	0.57
		11-20	0.31	0.31	0.28	0.27	1.93	0.57	0.50	0.45	0.40	0.37	0.34	0.31	
		21-end	0.58	0.30	0.42	2.85	1.28	0.58	0.48	0.39	0.39	0.33	0.30	0.31	
		Month	0.40	0.32	0.33	1.13	1.75	0.62	0.50	0.43	0.40	0.36	0.33	0.31	
3	1995/96	1-10	0.30	0.28	0.26	3.39	2.39	0.84	1.68	0.63	0.56	0.51	0.47	0.43	0.81
		11-20	0.29	0.27	1.42	1.56	1.40	1.07	0.77	0.60	0.55	0.50	0.45	0.42	
		21-end	0.25	0.26	0.63	2.17	1.03	0.70	0.67	0.54	0.53	0.45	0.41	0.40	
		Month	0.28	0.27	0.77	2.37	1.61	0.87	1.04	0.59	0.55	0.49	0.44	0.42	
4	1996/97	1-10	0.39	0.36	0.33	0.83	4.14	1.29	0.67	0.60	0.55	0.50	0.45	0.41	0.78
		11-20	0.38	0.35	0.73	1.58	1.44	0.89	0.71	0.58	0.53	0.48	0.44	0.40	
		21-end	0.34	0.34	2.55	0.68	1.63	0.70	0.62	0.52	0.51	0.42	0.38	0.39	
		Month	0.37	0.35	1.20	1.03	2.40	0.96	0.67	0.57	0.53	0.47	0.42	0.40	
5	1997/98	1-10	0.38	0.35	0.32	0.32	2.31	3.93	0.54	0.45	0.41	0.38	0.35	0.32	0.60
		11-20	0.37	0.34	0.91	0.49	0.52	0.85	0.48	0.44	0.40	0.37	0.34	0.31	
		21-end	0.32	0.43	0.30	0.28	1.73	0.60	0.46	0.38	0.39	0.32	0.29	0.30	
		Month	0.36	0.37	0.51	0.36	1.52	1.79	0.49	0.42	0.40	0.36	0.33	0.31	
6	1998/99	1-10	0.29	0.26	0.24	0.64	0.37	0.29	0.29	0.26	0.24	0.22	0.20	0.19	0.33
		11-20	0.29	0.25	0.32	2.31	0.32	0.28	0.27	0.30	0.23	0.22	0.20	0.19	
		21-end	0.25	0.25	0.34	0.44	0.38	0.50	0.20	0.22	0.23	0.19	0.17	0.18	
		Month	0.28	0.25	0.30	1.13	0.36	0.36	0.25	0.26	0.23	0.21	0.19	0.19	
7	1999/00	1-10	0.18	0.16	0.15	0.15	0.16	0.31	0.24	0.19	0.18	0.17	0.15	0.14	0.24
		11-20	0.17	0.16	0.15	0.16	0.16	2.00	0.20	0.19	0.18	0.16	0.15	0.14	
		21-end	0.15	0.16	0.31	0.35	0.30	0.29	0.20	0.17	0.17	0.15	0.14	0.14	
		Month	0.17	0.16	0.20	0.22	0.21	0.87	0.21	0.18	0.18	0.16	0.15	0.14	
8	2000/01	1-10	0.13	0.13	0.12	0.99	5.44	0.64	0.41	0.37	0.34	0.31	0.28	0.26	0.54
		11-20	0.13	0.12	0.13	0.17	1.25	0.52	0.40	0.36	0.33	0.30	0.28	0.25	
		21-end	0.12	0.12	0.10	2.43	1.03	0.39	0.38	0.31	0.32	0.26	0.24	0.25	
		Month	0.13	0.12	0.12	1.20	2.57	0.52	0.40	0.35	0.33	0.29	0.27	0.25	
9	2001/02	1-10	0.24	0.22	0.20	1.14	0.24	1.01	0.45	0.35	0.37	0.32	0.29	0.26	0.48
		11-20	0.23	0.21	0.19	0.45	2.02	0.63	0.38	0.73	0.34	0.31	0.28	0.26	
		21-end	0.20	0.21	0.17	0.27	3.03	0.44	0.36	0.41	0.33	0.28	0.25	0.25	
		Month	0.22	0.21	0.19	0.62	1.76	0.69	0.40	0.50	0.35	0.30	0.27	0.26	
10	2002/03	1-10	0.24	0.22	0.20	1.47	2.61	1.39	0.81	0.58	0.52	0.49	0.44	0.40	0.77
		11-20	0.23	0.22	0.20	0.66	0.82	0.98	0.68	0.56	0.51	0.47	0.43	0.39	
		21-end	0.21	0.21	2.00	2.57	3.37	1.14	0.61	0.50	0.50	0.41	0.37	0.38	
		Month	0.23	0.22	0.80	1.57	2.27	1.17	0.70	0.55	0.51	0.46	0.41	0.39	
	Average	1-10	0.27	0.27	0.24	0.97	2.24	1.12	0.66	0.44	0.40	0.37	0.34	0.31	0.57
		11-20	0.27	0.25	0.46	0.81	1.25	0.89	0.50	0.47	0.39	0.36	0.33	0.30	
		21-end	0.27	0.25	0.70	1.34	1.50	0.59	0.45	0.39	0.38	0.32	0.29	0.29	
		Month	0.27	0.26	0.47	1.04	1.66	0.87	0.54	0.43	0.39	0.35	0.32	0.30	
	5-year drought	1-10	0.23	0.23	0.20	0.82	1.88	0.94	0.55	0.37	0.34	0.31	0.28	0.26	0.50
		11-20	0.22	0.21	0.38	0.68	1.05	0.74	0.42	0.39	0.33	0.30	0.27	0.25	
		21-end	0.22	0.21	0.59	1.13	1.26	0.50	0.38	0.33	0.32	0.27	0.24	0.25	
		Month	0.23	0.22	0.39	0.88	1.40	0.73	0.45	0.36	0.33	0.29	0.27	0.25	
	5-year wet	1-10	0.33	0.32	0.28	1.17	2.68	1.34	0.79	0.53	0.48	0.44	0.40	0.37	0.69
		11-20	0.32	0.30	0.55	0.97	1.49	1.06	0.60	0.56	0.47	0.43	0.39	0.36	
		21-end	0.32	0.30	0.84	1.61	1.80	0.71	0.54	0.46	0.46	0.38	0.35	0.35	
		Month	0.32	0.31	0.56	1.25	1.99	1.04	0.64	0.52	0.47	0.42	0.38	0.36	

Source: JICA study team

Table 4.19 Stimulated 10-day probable discharge at National Road Bridge (Bemarenina river)

River System Bemarenina River System
Catchment Area: 45 km2
Basin Elevation: 914 (El.m) Adjustment Factor: 1.000 Unit :m3/s

No.	Year	Month Days	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual (m3/s)
1	1993/94	1-10	0.46	0.61	0.38	0.82	4.40	1.30	1.65	0.73	0.60	0.54	0.49	0.44	0.94
		11-20	0.44	0.40	0.37	0.76	4.29	1.84	1.04	0.65	0.58	0.52	0.47	0.43	
		21-end	0.38	0.39	0.33	2.24	2.11	1.06	0.86	0.57	0.56	0.45	0.41	0.41	
		Month	0.43	0.47	0.36	1.27	3.60	1.40	1.18	0.65	0.58	0.50	0.46	0.43	
2	1994/95	1-10	0.40	0.45	0.36	0.33	3.26	1.15	0.83	0.60	0.51	0.46	0.42	0.38	0.83
		11-20	0.39	0.38	0.34	0.32	3.12	0.92	0.77	0.59	0.49	0.45	0.41	0.37	
		21-end	0.84	0.37	0.57	4.59	2.07	0.94	0.69	0.48	0.48	0.39	0.35	0.36	
		Month	0.54	0.40	0.42	1.75	2.82	1.00	0.76	0.56	0.49	0.43	0.39	0.37	
3	1995/96	1-10	0.35	0.33	0.29	5.49	3.93	1.44	2.77	0.96	0.73	0.65	0.58	0.52	1.22
		11-20	0.34	0.31	2.20	2.52	2.34	1.79	1.27	0.82	0.70	0.62	0.56	0.50	
		21-end	0.30	0.30	0.93	3.56	1.79	1.15	1.06	0.68	0.67	0.54	0.49	0.49	
		Month	0.33	0.31	1.14	3.86	2.69	1.46	1.70	0.82	0.70	0.60	0.54	0.50	
4	1996/97	1-10	0.47	0.43	0.39	1.23	6.74	2.13	1.05	0.78	0.68	0.61	0.55	0.50	1.14
		11-20	0.46	0.41	1.02	2.50	2.33	1.48	1.09	0.73	0.65	0.59	0.53	0.48	
		21-end	0.40	0.40	4.07	1.07	2.67	1.14	0.86	0.64	0.63	0.52	0.47	0.47	
		Month	0.44	0.41	1.83	1.60	3.91	1.58	1.00	0.72	0.65	0.57	0.52	0.48	
5	1997/98	1-10	0.45	0.41	0.38	0.39	3.66	6.42	0.88	0.56	0.50	0.46	0.42	0.38	0.86
		11-20	0.44	0.40	1.36	0.68	0.75	1.37	0.73	0.54	0.49	0.45	0.41	0.38	
		21-end	0.38	0.56	0.37	0.34	2.76	0.99	0.61	0.47	0.48	0.39	0.36	0.36	
		Month	0.42	0.46	0.70	0.47	2.39	2.93	0.74	0.52	0.49	0.43	0.40	0.37	
6	1998/99	1-10	0.35	0.32	0.30	0.97	0.60	0.37	0.37	0.32	0.30	0.28	0.26	0.25	0.46
		11-20	0.34	0.32	0.42	3.73	0.45	0.36	0.34	0.41	0.30	0.27	0.26	0.25	
		21-end	0.31	0.31	0.46	0.67	0.50	0.74	0.26	0.28	0.28	0.24	0.23	0.24	
		Month	0.33	0.32	0.39	1.79	0.52	0.49	0.32	0.34	0.29	0.26	0.25	0.25	
7	1999/00	1-10	0.23	0.22	0.21	0.21	0.25	0.49	0.39	0.27	0.25	0.24	0.22	0.21	0.36
		11-20	0.22	0.21	0.21	0.25	0.25	3.28	0.34	0.26	0.25	0.23	0.22	0.20	
		21-end	0.21	0.21	0.48	0.56	0.47	0.51	0.28	0.24	0.24	0.20	0.19	0.20	
		Month	0.22	0.21	0.30	0.34	0.32	1.43	0.34	0.26	0.25	0.22	0.21	0.20	
8	2000/01	1-10	0.19	0.18	0.18	1.61	8.98	1.19	0.64	0.50	0.45	0.41	0.36	0.33	0.86
		11-20	0.19	0.18	0.19	0.27	2.11	0.98	0.61	0.48	0.43	0.39	0.35	0.32	
		21-end	0.17	0.18	0.15	4.01	1.85	0.69	0.53	0.43	0.42	0.35	0.31	0.31	
		Month	0.18	0.18	0.17	1.96	4.31	0.95	0.59	0.47	0.43	0.38	0.34	0.32	
9	2001/02	1-10	0.31	0.28	0.26	1.83	0.35	1.67	0.79	0.47	0.51	0.41	0.37	0.34	0.73
		11-20	0.30	0.28	0.25	0.68	3.30	1.10	0.63	1.12	0.46	0.40	0.36	0.33	
		21-end	0.26	0.27	0.22	0.43	4.97	0.76	0.52	0.58	0.42	0.35	0.32	0.32	
		Month	0.29	0.28	0.24	0.98	2.87	1.18	0.65	0.72	0.46	0.39	0.35	0.33	
10	2002/03	1-10	0.31	0.28	0.26	2.38	4.31	2.34	1.41	0.84	0.68	0.60	0.55	0.49	1.19
		11-20	0.30	0.28	0.25	1.06	1.42	1.72	1.19	0.77	0.66	0.58	0.53	0.48	
		21-end	0.27	0.27	3.21	4.22	5.61	1.95	0.99	0.65	0.63	0.51	0.46	0.46	
		Month	0.29	0.28	1.24	2.55	3.78	2.00	1.20	0.75	0.66	0.56	0.51	0.48	
	Average	1-10	0.35	0.35	0.30	1.53	3.65	1.85	1.08	0.60	0.52	0.47	0.42	0.38	0.86
		11-20	0.34	0.32	0.66	1.28	2.04	1.48	0.80	0.64	0.50	0.45	0.41	0.37	
		21-end	0.35	0.33	1.08	2.17	2.48	0.99	0.67	0.50	0.48	0.39	0.36	0.36	
		Month	0.35	0.33	0.68	1.66	2.72	1.44	0.85	0.58	0.50	0.44	0.40	0.37	
	5-year drought	1-10	0.30	0.29	0.25	1.28	3.06	1.55	0.91	0.51	0.44	0.39	0.35	0.32	0.76
		11-20	0.29	0.27	0.56	1.07	1.71	1.25	0.67	0.54	0.42	0.38	0.34	0.31	
		21-end	0.30	0.27	0.91	1.82	2.08	0.83	0.56	0.42	0.40	0.33	0.30	0.30	
		Month	0.29	0.28	0.57	1.39	2.29	1.21	0.71	0.49	0.42	0.37	0.33	0.31	
	5-year wet	1-10	0.42	0.42	0.36	1.83	4.38	2.22	1.29	0.72	0.63	0.56	0.51	0.46	1.03
		11-20	0.41	0.38	0.79	1.53	2.44	1.78	0.96	0.76	0.60	0.54	0.49	0.45	
		21-end	0.42	0.39	1.29	2.60	2.98	1.19	0.80	0.60	0.58	0.47	0.43	0.43	
		Month	0.42	0.40	0.82	1.99	3.27	1.73	1.02	0.70	0.60	0.52	0.48	0.45	

Source: JICA study team

EXPLANATION NOTE 3-2

Evaluation of Water Management System

EVALUATION OF WATER MANAGEMENT SYSTEM

1 Present condition of water users' association

There are 6 water users' associations (AUE) in PC23 at present. According to the interview survey with these associations, two AUEs (Amparamanina and Vonona P1) are already registered as of Jan. 2004. General outline of the associations are summarized in the table below and covering area of each AUE is shown in Figure 1.1.

Table 1.1 Present condition of AUE

AUE	Planned irrigation area (ha)	Number of members	form	Status of registration
1. Amparamanina	1,790	701	Federation	done (July 2001)
2. Mahakary	3,460	509	Association	Not yet
3. Vohibora-Mandroso	2,790	684	Association	Not yet
4. Vonona P1	780	320	Association	done (April 2000)
5. Tsaratanibary	1,565	425	Federation	Not yet
6. Zoto P1	250	80	Association	Not yet

Source: JICA study team

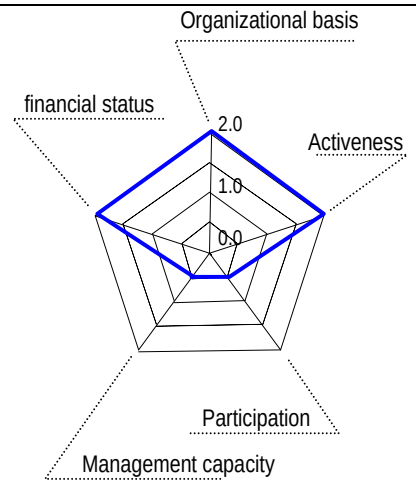
There are two types of AUE, "federation" and "association". Federation consists of several water users groups called FMR (Fikambanana Mampiasa Rano: Direct meaning of FMR is water users association), while association is a group formed by one water users' group (FMR). Among the 6 AUEs, Amparamanina and Tsaratanbary are federation and other 4 associations are FMR. Besides, co-federation is presently under establishment that covers whole PC23 with 6 above mentioned AUEs.

In PC 23, all the AUEs are not functioning well. Among 6 AUEs, however, Amparamanina and Vonona P1 are relatively active. On the other hand, almost no activities are observed in Mahakary, Vohibola-Mandroso and Zoto P1. Tsaratambary AUEs do some minor maintenance work of irrigation facilities, but not regularly.

2 Assessment of AUEs' function

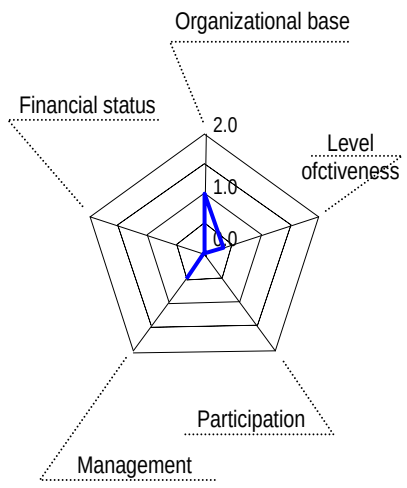
In order to evaluate these AUEs, an analysis was made from 5 aspects, organizational basis, level of activeness, level of participation, management ability, and present financial status. Level of AUE is scored for each aspect and overall score is calculated by summation of weighted score for each aspect. Overall score varies from 0.0 ~ 1.0 and higher value shows higher level of functioning. Details of calculation are shown in Table 2.1 and following are the summary of the analysis.

Figure 2.1 Functional assessment of AMPARAMANINA

Aspect	AMPARAMANINA	Overall score: 0.70
1.Organizational basis	• AUE was registered in July, 2001. • Regulations and member list of the association are already prepared. • The association has a bank account in Bank of Africa.	
2. Level of activeness	• General meeting is held more than twice a year. • Minor maintenance work is done by the association by employing labors. • The association is presently planning to construct a paddy storage	
3. Participation level	• Level of participation is relatively low. Only 12% of total member participates in the general meeting.	
4. Managemnet ability	• Cash are controlled by treasury using cash book and deposited to the bank account. • Rate of water charge collection is low as about 25% in 2002.	
5.Financial status	• About FMG 7 millions are deposited to the bank account as of Jan. 2004.	
Overall evaluation	• The association is relatively well established compare to the other associations. However, level of participation is quite low. Major reasons for low participation are considered as follows. 1) AUE member is skeptical for management of AUE, especially use of water fee collected. The member s do not rely activities of AUE through experement during the SOMALAC period in general. 2) Some irrigated area is not irrigated. The members in such area are apto to hesitate paticipation to AUE activities. On the other hand, only the members who receive irrigation water supply paticipate the AUE activities. 3) The members do not get enough information of AUE, so they do not understand significance for participating AUE.. • Although the basis of organization is well facilitated, the association itself is functioning to a part of members as it can be seen from the above chart that skew to upper side of the chart.	

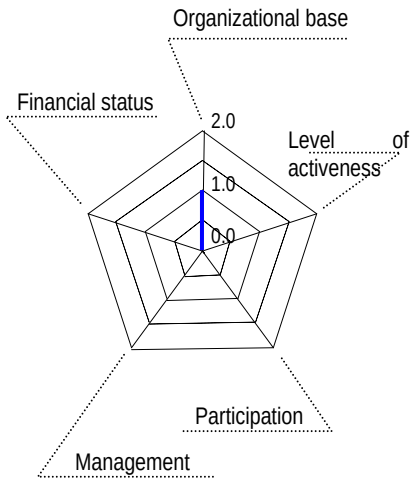
Source: JICA study team

Figure 2.2 Functional assessment of MAHAKARY

Aspect	MAHAKARY	Overall : 0.18
1.Organizational basis	• Although the application for registration is already made, it is still under examination. • The association dos not have any bank account..	
2. Level of activeness	• General meeting is held once a year. • AUE itself does not conduct any maintenance work. Instead, farmers do necessary repair work by themselves.	
3. Participation level	• Level of participation is almost nil since AUE has no activity.	
4. Managemnet ability	• Water charge is set as 5,000 FMG/ha/year. However, members do not pay because they can use water regardless its payment where water is available.	
5.Financial status	• There is no cash that AUE keeps due to no water fee collection	
Overall evaluation	• The association is not functioning. Since major part of the covering area of AUE is either rain-fed or malfunctioning irrigation, farmers do not feel any necessity of participating in AUE.	

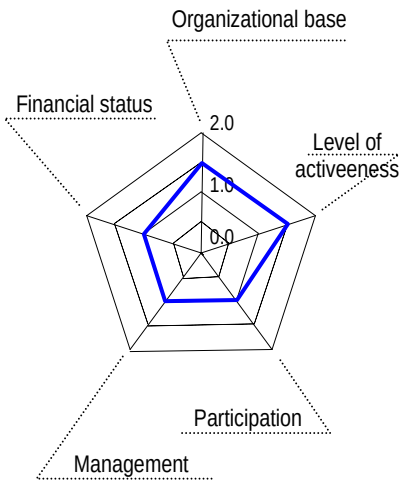
Source: JICA study team

Figure 2.3 Functional assessment of VOHIBOLA-MANDROSO

Aspect	VOHIBOLA-MANDROSO	Overall score: 0.10
1.Organizational base	• AUE does not have any activities at present. • The association dos not have any bank account.	
2. Level of activeness	• General meeting is not held at all. • AUE do not conduct any activities.	
3. Participation	• The criteria are not applicable since no activities are made for the AUE.	
4. Management ability	• Water charge is not collected.	
5.Financial status	• No deposit is made since water charge is not collected.	
Overall evaluation	• The association is not functioning at all. As in the Mahakary, most of the covering area of Vohibola-Mandroso is rain-fed, malfunctioning irrigation and suffering from inundation during rainy season. Due to this, farmers do not feel any necessity of participating in AUE.	

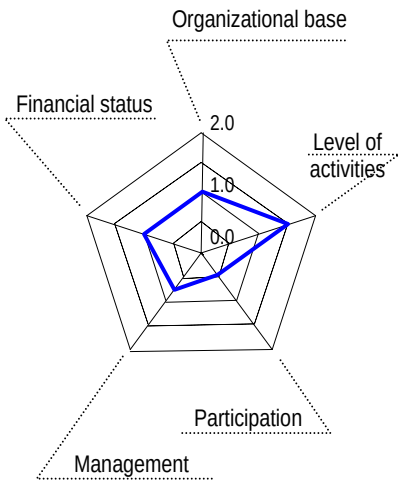
Source: JICA study team

Figure 2.4 Functional assessment of VONONA P1

Aspect	VONONA P1	Overall score: 0.6
1.Organizational base	• AUE was registered in April 2000. • Although the association does not have a bank account, it is planned to open an account near future. • Member list is well prepared and location of members is also recorded.	
2.Level of activeness	• General meeting is held once to twice a year. • AUE conducts minor maintenance work and management of water distribution.	
3. Participation	• Participation in the general meeting is about 35 – 50 %. Many of the members do not understand the meaning of AUE and therefore they are reluctant to participate.	
4. Management ability	• Water charge is collected only when repair work is necessary. Water charge collectors are assigned for each block and collect charge whenever it is necessary. However, they are reluctant to do it since no incentives are paid for them.	
5. Financial status	• AUE deposits about FMG 1 million at the bank account of SILAC.	
Overall evaluation	• The association is relatively functioning well. Major reason for this would be that the AUE locates near the National Route 3.a and irrigation water is relatively well distributed compare to the other AUEs. Besides, the small size of AUE (about 300 members) may also contribute to its easiness in management. • Water charge is not collected regularly at present. Although the AUE is considering to collect regularly, following problems makes its realization difficult. 1) AUE members reside in widely scattered area, for example Amparafaravola, Bejofo, Anbatondrazaka, and so on.. 2) Water charge collectors are reluctant to do their job since they are not paid. The AUE is considering payment of incentives to them based on collected amount. However, the AUE cannot afford those incentives with its unstable financial status.	

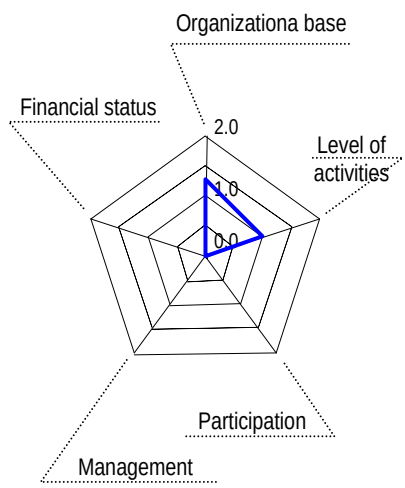
Source: JICA study team

Figure 2.5 Functional assessment of TSARATANIBARY

Aspect	TSARATANIBARY	Overall score: 0.48
1.Organizational base	• AUE is applying for registration and it is under procedure. • Although the association does not have a bank account, the AUE is planning to open an account near future. • Regulation of the association is already prepared and it is under finalization stage.	
2. Level of activities	• General meeting is held twice a year. • AUE conducts minor maintenance work. • Disputes on water use often occurred between CMS Anosiboribory.	
3. Participation	• Participation in the general meeting is less than 50 %. Many of the members are disappointed at the function of AUE since irrigation water is not available.	
4. Management ability	• Water charge is not collected regularly. Recently the charge was collected about FMG 5,000/ha for necessary repair work. However, the collection rate was about 35%. • It is difficult to collect water charge since irrigation system does not functioning well.	
5.Financila status	• About FMG200,000 are kept by the treasury of AUE. Treasury keeps cash at his house since bank account is not opened.	
Overall evaluation	• The association is moderately functioning but still it is at lower level. • Participation is still low due to malfunction of irrigation system. • Management of the AUE is difficult because residences of members are widely scattered. This also makes communication difficult among AUE member • About half of farm land within the covering area is rented. In this case, land owners usually become member of AUE, while water charge will be shouldered by land users (tenants). This fact makes water charge collection more difficult in addition to the location of residence.	

Source: JICA study team

Figure 2.6 Functional assessment of ZOTO P1

Aspect	ZOTO	Overall score: 0.23
1.Organizational base	• AUE is considering its registration, but no action has been made so far. • AUE has a bank account at Bank of Africa. This account was opened during SOMALAC period and about FMG 450,000 is deposited. However, AUE cannot access to the account because of ownership of the account is not clarified. • Although the list of member is prepared, regulation of AUE is not prepared yet.	
2. Level of activities	• General meeting is not held at all.. • AUE do not conduct any maintenance work. Instead, farmers who use neighboring paddy field get together and repair facilities when it is necessary.	
3. Participation	• Since no meeting and activity are made, it is considered that there is no participation in the AUE.	
4. Management ability	• Water charge is not collected and hence no cash control is made in the AUE.	
5.Financila status	• As it is mentioned, about FMG450,000 is deposited at bank account. However, the AUE does not have any access to this deposit. Hence, it is considered that the AUE doesn't have any financial basis for its activity.	
Overall evaluation	• The AUE is not functioning. Major reasons are considered as follows. 1) Farmers are skeptical about the function of the association due to the experience during the SOMALAC period. 2) Existence of large scale land owner makes other farmers reluctant to participate in association. 3) Location of residence is widely scattered and hence farmers do not have sufficient communication among themselves.	

Source: JICA study area

AUE can be summarized as in the table below.

Table 2.1 Function level and main causes of low function level

Name of AUE	Function level	Causes of low function level
1. Amparamanina	Medium (0.70)	• Location (residence) of members is widely scattered. • Poor communication among members • Members are doubtful about AUE management • Insufficient distribution of irrigation water.
2. Mahakary	Very low (0.18)	• Insufficient distribution of irrigation water and non-functioning irrigation facilities. • Existence of large part of non-irrigated area and inundated area. • Location (residence) of members is widely scattered. • Poor communication among members • Lack of organizational basis

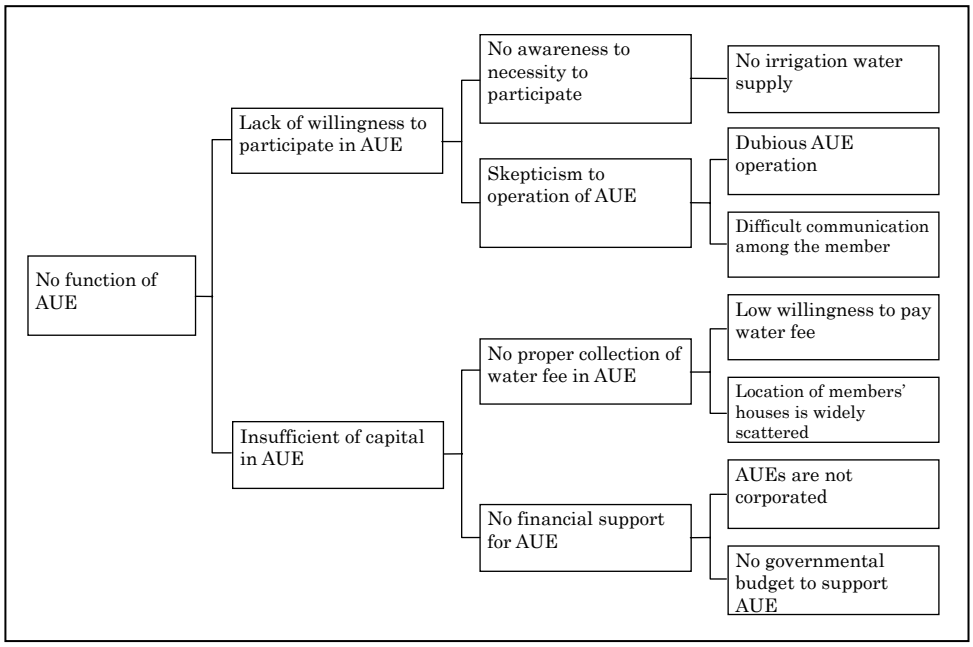
3. Vohibola-Mandroso	Very low (0.10)	• Insufficient distribution of irrigation water and non-functioning irrigation facilities. • Existence of large part of non-irrigated area and inundated area. • Location (residence) of members is widely scattered. • Poor communication among members • Lack of organizational basis
4. Vonona P1	Fair (0.60)	• Location (residence) of members is widely scattered. Poor communication among members
5. Tsaratanibary	Fair (0.48)	• Location (residence) of members is widely scattered. • Poor communication among members • Insufficient water distribution and conflict with CMS over irrigation water • Existence of non-irrigated area and inundation area
6. Zoto P1	Low (0.23)	• Location (residence) of members is widely scattered. • Poor communication among members • Insufficient water distribution • Lack of organizational basis

- Source: JICA study team

*: Criteria for function level are set as follows

Very high.....0.81~1.00
Medium.....0.61~0.80
Fair.....0.41~0.60
Low.....0.21~0.40
Very low.....0.00~0.20

Although e level of functioning is different from one AUE to another, factors for not functioning can be analyzed as in the problem tree shown below.



Among these problems, most serious and critical problems may considered to be three points, 1) lack of irrigation water, 2) skepticism about AUE function and 3) location of farmers.

a) Lack of irrigation water

The non-functioning AUEs, Mahakary and Vohibola-Mandroso have serious problem regarding irrigation water (see Figure 2.7.5.2). A large scale area of the AUE is rain-fed due to incomplete irrigation system. Besides, other area also suffers from malfunctioning irrigation system and inundation caused by poor drainage. Therefore, most of the farmers do not see any necessity to participate in AUE. Only a part of members who can receives irrigation water conducts maintenance and repair work for their own paddy field. This tendency can be observed not only in these two AUEs but also in other 4 AUEs and it is one of the most critical causes for not functioning.

b) Farmers' skepticism about AUE

AUEs are originally established as organizations responsible for operation and maintenance of irrigation system during SOMALAC period. However, management of the AUE had been unclear especially regarding financial and assets management. Besides, AUE has been incapable to manage irrigation system after dissolution of SOMALAC. Due to this, farmers think that AUE is controlled by a small part of farmers who are large scale land owner and use AUE for their own benefits. Farmers also think that insufficient distribution of irrigation water is partly because of mismanagement of AUE and do not trust their activities. This tendency hinders farmers from participating in AUE.

c) Location (residence) of the farmers

Farmers' residence are widely scattered in and out of PC23. Many of the farmers live outside of PC23 and they go to their paddy field in PC23 during cropping season only. In some cases, land owners live in far place such as Antananarivo, Antsirabe, etc. and lend their land to the farmers living in and nearby PC23. Accordingly, it is quite difficult for AUE to grasp actual land users.

According to the member list prepared by the AUE Vonona P1, about 58.0 % of members live in PC23. The rest of members are scattered in various places outside of PC23 except 5.7% of unidentified members. The distribution of members by location is shown in the figure below.

Due to this fact, farmers have very limited communication among them especially for meeting and decision making and it also makes water charge collection quite difficult.

d) Lack of organizational basis

In PC23, no AUE are legally registered except Amparamanina and Vonona P1. Legal registration makes AUE accessible to governmental and other donors' support and be allowed

to take legal action against those who violate AUE's regulations. Apart from legalization of AUE, most of the executive members and water charge collectors do their task on voluntary basis without receiving any incentives. They have to do many tasks for management of AUE without payment and, therefore, they have less motivation to work and it leads to inactiveness of AUE.

e) Farmers' Intention and Capability for Participating Water Management Activities

According to the result of the detailed village survey, about 34% farmers in Ambohidrony think that less water become available due to sedimentation, while 32% observe no change regarding the condition of irrigation water. On the other hand, in Mahakary, 52% of the respondents answered that less water is available due to sedimentation and 40% answered that irrigation water is not available because of non-functioning irrigation system.

Table 2.2 Observation on the present condition of irrigation water

Observation	Ambohidrony	Mahakary
1. Less water is available due to sedimentation.	34.0%	52.0%
2. Less water is available due to water stealing.	6.0%	0.0%
3. System doesn't function due to lack of maintenance.	6.0%	40.0%
4. System doesn't function due to sedimentation.	0.0%	2.0%
5. No change is observed.	32.0%	0.0%
6. Others	22.0%	6.0%

Source: JICA study team

In both villages, majority of farmers (86% in Ambohidorony and 100% in Mahakary) intend to take some action to improve availability of irrigation water, although they do not have any specific plan for this purpose. However, this indicates high demand of farmers for irrigation water. Similarly, farmers in both villages show their willingness to participate if any projects would be implemented for improvement of irrigation system.

Table 2.3 Intention to take action to improve water availability and Willingness to participate in projects

	Ambohidrony		Mahakary	
	Intension to to take action to improve water a ailability	Willing to participate	Intension to to take action to improve water a ailability	Willing to participate
Yes	86.0%	84.0%	100.0%	96.0%
No	14.0%	16.0%	0.0%	4.0%

Source: JICA study team

Based on the result of the detailed village survey, capacity to pay of farmers is also analyzed. Dividing samples into three type of farm size, small, medium and large scale, net return of paddy production is compared to the typical water charge adopted in PC23. Following table shows the comparison.

Table 2.4 Comparison of water charge and net return of paddy production

Scale of farm land		Average farm land (ha)	Net reserve*1 (FMG/an)	Water fee*2 (FMG/an)	Ratio of water fee/Net resurve (%)
Ambohidrony					
large	(> 5 ha)	12.2	13,773,800	124,000	0.9%
medium	(1~5 ha)	2.6	2,935,400	28,000	1.0%
small	(< 1 ha)	0.6	677,400	8,000	1.2%
Mahakary					
large	(> 5 ha)	15.6	17,612,400	158,000	0.9%
medium	(1~5 ha)	3.2	3,612,800	34,000	0.9%
small	(< 1 ha)	0.7	790,300	9,000	1.1%

Source: JICA study team

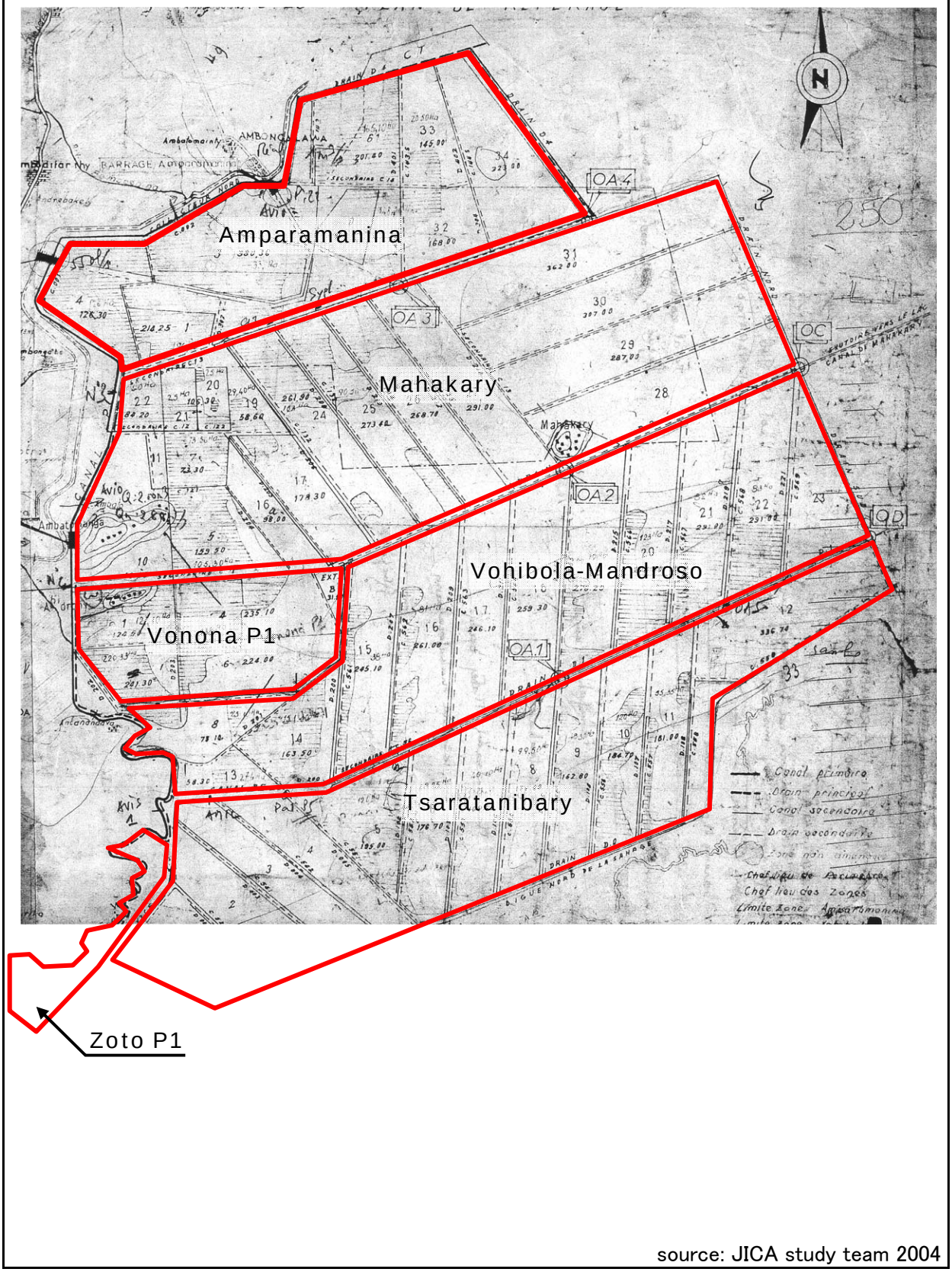
*1: Net return of paddy production is assumed to be FMG1,129,000/ha. The figure is calculated based on the average of 4 fokontany (Mahakary, Ambohidrony, Morarano Chrome and Manakambahinikely). The data were collected through the detailed village survey conducted by JICA Study Team during Dec.2003 ~ Jan. 2004.

*2: Water charge used at Amparamanina AUE is used for calculation. The AUE collects irrigation fee for operation and maintenance of the irrigation system and participation fee for administration. The fees are set as follows

Irrigation fee ..... 10,000 FMG/ha/year

Participation fee..... 2,000FMG/person/year

Based on the calculation, the burden of the water charge is around 1% of net return from paddy production and it can be said that farmers are capable to pay this level of charge without any serious problems.



source: JICA study team 2004

Figure 1.1 Area controlled by 6 AUEs

Table 2.1 Evaluation of Water Users' Association

					Amparamanina		Mahakary		Vohibola		Vonona P1		Tsaratanibary		Zoto P1	
Aspect	Evaluation Items	Criteria	Score	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted	Score	Weighted	Score	Weighted
1. Organizational Basis	a) Registration	Yes	1.0													
		No	0.0	0.5	1.0	0.5	0	0.0	0	0.0	1	0.5	0	0.0	0	0.0
	b) Preparation of Member List	Yes	1.0													
		No	0.0	1.0	1.0	1.0	1	1.0	1	1.0	1	1.0	1	1.0	1	1.0
	c) Bank Account	Yes	1.0													
		No	0.0	0.5	1.0	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0.5	0.3
						2.0		1.0		1.0		1.5		1.0		1.3
2. Level of Activeness	a) Frequency of meeting (general meeting)	2/yr or more	1.0													
		once a year	0.5													
		None	0.0	0.5	1.0	0.5	0.5	0.3	0	0.0	1	0.5	1	0.5	0	0.0
	b) Recent Activity	Yes	1.0													
		No	0.0	1.0	1.0	1.0	0	0.0	0	0.0	1	1.0	1	1.0	1	1.0
	c) Plan for future activity	Yes	1.0													
		No	0.0	0.5	1.0	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
						2.0		0.3		0.0		1.5		1.5		1.0
3. Participation Level	a) Participation in meeting	70%<	2.0													
		40%-70%	1.0													
		10-40%	0.5													
		0-10%	0.0	1.0	0.5	0.5	0	0.0	0	0.0	1	1.0	0.5	0.5	0	0.0
						0.5		0.0		0.0		1.0		0.5		0.0
4. Management Ability	a) Cash book	Yes	1.0													
		No	0.0	0.5	1.0	0.5	1	0.5	0	0.0	1	0.5	1	0.5	0	0.0
	b) Water charge collection	60%<	1.0													
		30%-60%	0.5													
		<30%	0.0	0.5	0.0	0.0	0	0.0	0	0.0	1	0.5	0.5	0.3	0	0.0
						0.5		0.5		0.0		1.0		0.8		0.0
5. Financial Status	a) Ammount of cash/deposit	5 million <	2.0													
		0<, < 4 million	1.0													
		0 or unknown	0.0	1.0	2.0	2.0	0	0.0	0	0.0	1	1.0	1	1.0	0	0.0
						2.0		0.0		0.0		1.0		1.0		0.0
Overall Evaluation						0.70		0.18		0.10		0.60		0.48		0.23

Source: JICA study team