JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
NIPPON KOEI CO., LTD.
NIHON SUIDO CONSULTANTS CO., LTD.
SANTA CRUZ REGIONAL DEVELOPMENT CORPORATION
REPUBLIC OF BOLIVIA

THE MASTER PLAN STUDY
ON
FLOOD CONTROL IN THE NORTHERN
RURAL REGION OF SANTA CRUZ
IN
THE REPUBLIC OF BOLIVIA

FINAL REPORT

SUMMARY

PACIFIC CONSULTANTS INTERNATIONAL
IN ASSOCIATION WITH
CENTRAL CONSULTANTS INC., TOKYO

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF SUSTAINABLE DEVELOPMENT AND ENVIRONMENT
MINISTRY OF ECONOMIC DEVELOPMENT
SANTA CRUZ REGIONAL DEVELOPMENT CORPORATION
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The cost estimate was made based on prevailing market price in October 1995 and expresses in Bolivianos according to the following exchange rate.

US $ 1.00 = Bs. 4.86 = Yen 100.00

(As of October, 1995)

PREFACE

In response to a request from the Government of the Republic of Bolivia, the Government of Japan decided to conduct a master plan study on Flood Control in the Northern Rural Region of Santa Cruz in the Republic of Bolivia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bolivia a study team headed by Mr. Hajime Tanaka of Pacific Consultants International and composed of members from Pacific Consultants International and Central Consultants INC., three times between March 1995 and June 1996.

The team held discussions with officials concerned of the Government of Bolivia and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

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

June 1996

Kimio Fujita
President
Japan International Cooperation Agency

THE MASTER PLAN STUDY
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FLOOD CONTROL IN THE NORTHERN RURAL REGION OF SANTA CRUZ
IN
THE REPUBLIC OF BOLIVIA

June, 1996

Mr. Kimio FUJITA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit the final report entitled the " The Master Plan Study on Flood Control in the Northern Rural Region of Santa Cruz in the Republic of Bolivia." This report has been prepared by the Study Team in accordance with the contract signed on March 20, 1995, January 22, 1996 and May 20, 1996 between the Japan International Cooperation Agency and Pacific Consultants International in associate with Central Consultant Inc.

In the study, the Study Team based on the analysis of the existing flood and drainage problems in the northern rural region of Santa Cruz, presents a master plan of flood mitigation and drainage improvement measures and priority projects for Feasibility Study were identified. The report consists of the Summary, Main Report, Supporting Report and Data Book.

All members of the Study Team wish to express sincere appreciation to the personnel of your Agency, Advisory Committee, and Embassy of Japan in Bolivia, and also to the officials and individuals of the Government of the Republic of Bolivia for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the flood mitigation and drainage improvement and the socio-economic development in the northern rural region of Santa Cruz.

Yours Faithfully

Hajime TANAKA
Team Leader of the Study Team

THE MASTER PLAN STUDY ON FLOOD CONTROL IN THE NORTHERN RURAL REGION OF SANTA CRUZ IN THE REPUBLIC OF BOLIVIA

OUTLINE OF THE STUDY

1. The study area (approximately 7,000 km^2) is situated in the northern rural area of Santa Cruz that is the capital city of the Department of Santa Cruz, located in the eastern part of the Republic of Bolivia. The population of the Department was 1,364,389 in 1992 that accounted for 21 % of the population of the country. The GDP of the Department accounted for about 30 % of the Bolivian GDP in 1992.

   The study area was mostly cleared of forest for cultivation or grazing ground by the first half of 1980s and has become an important agricultural center, producing soybeans, sugarcane, rice and livestock. Also the agro-based industries in the Department are mostly located in the study area and play an important role in the regional socio-economy.

   However, the study area has been suffering from floods yearly from the rivers, including the major rivers such as the Rio Grande, Rio Pirai and Rio Yapacani. The most severe damages in record were caused by the 1992 floods. The flood hazard areas by the annual floods and by the 1992 floods are estimated to be 2,444 km^2 and 4,857 km^2 respectively. The dominant colonies such as Okinawa, Aroma, Puest Fernandez, San Juan and Antofgasta, are mostly located in the flood hazard area.

   The study area is extremely vulnerable to flood and drainage problems due to the flat topography and difficult meteo-hydrological conditions. These problems are serious constrains for stabilization and further development.

   The situation of flood damages and flood hazard area have been studied and optimum flood mitigation and drainage improvement measures have been studied for the study area.

2. Master Plan for Flood Mitigation and Drainage Improvement

2.1 Basic Concept

The flood hazard areas and poor drainage areas have been assessed based on the flood conditions such as flood depth, duration, damage and land use, and divided into the following areas:

-1 The area for structural measures with non-structural measures:

The area was selected based on the following criteria:

- Intensive land use areas such as urban and intensive farming areas affected by annual floods,
- Intensive land use areas severely affected by the 1992 floods i.e., flood depth more than 50 cm and duration more than 2 days,

-2 The area for non-structural area:

The area was selected based on the following criteria:

- Not intensive land use areas such as pasture and forest areas both in the annual flood hazard area and in the 1992 floods hazard area,
- Intensive land use areas in the 1992 flood hazard area with less than 50 cm deep and 2 days long.

However, the area influenced directly by the Rio Pirai is not included, because the main reach of the Rio Pirai has already had a master plan for the management and training of the main river reach.

The structural measure area was divided by river or drainage basin into the following seven basins:

a. Chane - Pailon Area

-1 Rio Chane,
-2 Rio Pailon,
-3 Chane - Chacras,
-4 Queb. Chane,
-5 Okinawa drainage.

b. San Juan - Antofagasta

-1 San Juan,
-2 Antofagasta.

The design scales were decided as follows:

-1 Flood mitigation facilities: 10-year frequency flood with an allowable inundation depth of 30 cm,

-2 Drainage improvement facilities: 5-year frequency storm runoff with an allowable inundation depth of 30 cm

-3 Important or fundamental public facilities such as national road bridges, the design scale of a 50-year frequency flood should be considered according to the scale of 1992 floods.

The target year of the Master Plan was decided to be the year of 2010 considering the target years of the national development plan and the regional development plan.

Socio-economic frames of the target year of 2010 were estimated as follows:

- The mean annual growth rate of population in the study area was estimated to be 2.3 % for the period. The population of the study area was estimated to be 300,000 in 2010 from 198,000 in 1992, according to CORDECRUZ.

The population will increase in the urban areas, but not increase in the rural area.

- According to the Land Use Plan of the Department, the study area is located in the intensive agricultural area, including intensive cattle raising area. The land uses in 2010 was estimated to be the same as those in 1995, because the study area was mostly cleared for cultivation or grazing ground by the first half of 1980s and the land use has been kept same sine the 1980s.

- The national economic growth for the next decade was targeted by the national economic development plan at a rate of 5 % per annum in GDP.

2.2 Flood Mitigation Measures

The proposed measures for flood mitigation and drainage improvement are consisting of structural measures and non-structural measures as follows:

(1) Structural Measures

The structural measures are composed of river improvement works that increase conveyance capacities of channels by widening, deepening and improving channels, and embankment (including road-cum embankment) that confine the flow within a channel, and drainage improvement works.

The road-cum-embankment is planned between the Arroyo Yapacanicito Basin and Arroyo Jochi Basin. The purpose of the road-cum-embankment is to separate the flood water of these two basins as well as to reinforce the evacuation and transportation route during floods.

The flood mitigation and drainage improvement works are summarized in the following table:

Structural Measures

Project	River Improvement	Main Drainage	Secondary Drainage	Road cum Embankment
1. Chane-Pailon				
-1 Rio Chane	27.0 km	0	0	0
-2 Rio Pailon	32.0 km	6.5 km	50.0 km^2	0
-3 Okinawa Drainage	-	21.5 km	147.0 km^2	0
-4 Quebrada Chane	34.0 km	8.0 km	0	0
-5 Chane-Chacras	36.5 km	21.0 km	284.0 km^2	0
2. San Juan-Antofagasta				
-1 San Juan	14.1 km	41.3 km	115.0 km^2	0
-2 Antofagasta	20.3 km	10.0 km	97.0 km^2	9.0 km
Total	163.9 km	108.3 km	693.0 km^2	9.0 km

For Chane-Pailon area, considering the situation of the Rio Chane that is strongly affected by the flood of the Rio Pirai, two alternative plans were planned as follows:

- Alternative-I is consisting of the Rio Chane and all the other sub projects,
- Alternative-II is consisting of all the sub projects except the Rio Chane.

For San Juan-Antofagasta area, considering the flow capacities of approximately 2 year frequency of the existing drainage mains, two alternatives were planned as follows

- Alternative-I is consisting of San Juan and Antofagasta sub projects. In alternative-1 the flow capacities of the existing drainage mains of San Juan area are planned to be maximized by rehabilitation and the surplus storm runoffs are planned to be drained by supplementary drainage facilities to the Arroyo Yapacanicito.
- Alternative-II is also consisting of San Juan and Antofagasta sub projects. In alternative-II the drainage mains of San Juan area are planned to be enlarged to discharge the design storm runoffs by improvement.

(2) Non-structural Measures

Non-structural measures are planned to be applied for the entire flood hazard area. The structural measures will generally need a long time before completion and the flood and drainage problems shoul.: be mitigated by non-structrual measures as much as possible. The proposed non-structural measures are composed of the followings:

a. Non-structural measures for flood mitigation

-1 Flood warning and evacuation systems for reducing casualties and flood damages,

-2 Flood proofing and flood plain management for reducing flood damages caused by inappropriate land use in the flood hazard area,

-3 Land use control for retarding basins and others for utilization and maintenance of retarding or regulation effects of natural swampy areas,

-4 Preservation of protected forest along river channels for preservation of the natural environmental resources,

-5 Land use management for farm lands and forest areas for reducing flood damages by appropriate management of farm lands and forest areas.

b. Non-structural measures for drainage improvement

-1 Introduction of appropriate water tolerant crops or varieties for reducing damages caused by drainage problems,

-2 Introduction of proper farm land management for reducing the damages caused by drainage problems by proper farm land management.

2.3 Project Cost

The construction costs are composed of direct cost and indirect cost. The indirect construction costs are estimated to be 30 % of the direct construction cost.

The project costs are composed of direct cost, indirect cost and contingency. The indirect costs of administration, engineering service and physical contingency are estimated to be 5 %, 10 % and 15 % of the direct construction cost.

The project costs were estimated and summarized as follows:

1) Alternative-I

(Unit: 1,000 Bs.)

Sub-Project	L/C	F/C	Total
1. CHANE-PAILON	449,234	453,041	902,275
(1) Rio Chane	82,582	93,166	175,748
(2) Rio Pailon	144,415	145,967	290,382
(3) Chane Chacras	110,375	107,675	218,050
(4) Queb. Chane	66,771	59,508	126,279
(5) Okinawa Drainage	45,091	46,725	91,816
2. SAN JUAN-ANTOFAGASTA	92,613	94,727	187,340
(6) San Juan	42,042	44,796	86,838
(7) Antofagasta	50,571	49,931	100,502
Total	541,847	547,768	1,089,615

Note: 1.0 US$ = Bs. 4.86 = Yen 100.0

2) Project costs of Alternative-II

(Unit: 1,000 Bs.)

Project	L/C	F/C	Total
1. CHANE-PAILON	366,652	359,875	726,527
(1) Rio Chane	-	-	-
(2) Rio Pailon	144,415	145,967	290,382
(3) Chane Chacras	110,375	107,675	218,050
(4) Queb. Chane	66,771	59,508	126,279
(5) Okinawa Drainage	45,091	46,725	91,816
2. SAN JUAN-ANTOFAGASTA	98,204	100,663	198,867
(6) San Juan	47,633	50,732	98,365
(7) Antofagasta	50,571	49,931	100,502
Total	464,856	460,538	925,394

Note: 1.0 US$ = Bs. 4.86 = Yen 100.0

For economic evaluation, OM cost of 1 % of the direct construction cost, the price contingency is estimated assuming the inflation rate to be 4 % per annum for foreign currency and 7 % per annum for the local currency portion.

2.4 The implementation period is planned to be complete by 2010, including a preparation period.

2.5 The economic benefit was assessed by comparing the flood damages in the "with and without project" situation. The flood damages are classified into the following categories:

- Direct damage to building and household effects,
- Direct damage to agricultural crops and livestock,
- Damage to public facilities, including transportation and agricultural facilities,
- Income /profit losses in business activities.

The EIRR values of the projects are estimated as follows:

	Sub Projects	EIRR (%)	
		Alternative-1	Alternative-2
1	Chane-Pailon	11.04	14.00
	-Rio Chane	Negative	Excluded
	-Rio Pailon	14.33	14.33
	-Queb. Chane	12.52	12.52
	-Chane Chacras	15.38	15.38
	-Okinawa Drainage	12.21	12.21
2	San Juan-Antofagasta	13.41	12.51
	-San Juan	9.97	8.48
	-Antofagasta	16.24	16.24

2.6 Environmental Impact

The improvement of river channels will increase their flow capacities and might give impacts not only to the fauna and flora along the river channels, but also to the ground water table in the flood mitigation areas. However, the adverse environmental impacts will not be significant. From Initial Environmental Evaluation (IEE), Environmental Impact Assessment (EIA) will be required for the further study stage.

2.7 Project Evaluation

The structural measures in the Master Plan were evaluated from technical, economical, social and environmental terms. The technical efficiency is evaluated by reduction effect in flood area, depth and duration. The economic efficiency is evaluated mainly by EIRR of which the values of higher than 10 % is considered to be feasible due to the opportunity cost of capital, estimated to be between 10 % and 12 %. The social and environmental terms are evaluated by reduction of flood hazard area.

1) Chane-Pailon Area

The structural measures for the area are feasible as a whole in technical, economical, social and environmental.

The conditions of inundation at the sub projects, i.e., Rio Pailon, Quebrada Chane, Chane-Chacras and Okinawa Drainage, will be very much improved by both of Alternative-I and Alternative-II. However, the amount of the increasing of flood water level of Rio Chane of Alternative II will be 0.5 m to 0.9 m for 10 year floods.

The EIRR values of 11.04 % for alternative-I and 14.00 % for alternative-II (without improvement of the Rio Chane). The EIRR values of all sub-projects except the Rio Chane show higher values than 12.21 %.

The social impacts will be significant both of Alternative-I and Alternative-II due to the protected area of 470 km^2,

As positive social impacts, the mitigation of flood damages, the generation of employment opportunity and enhancement of land use potential of flood protected land will be expected.

Environmental adverse effects by the projects will be not significant, except the Rio Chane in Alternative-II.

From technical, economic, social and environmental aspects, the alternative-I is recommended in order to avoid any adverse social and environmental effects, because the estimated flood conditions will become worse than the existing condition. The priority orders of the sub projects are:

1st Priority:

- Rio Chane
- Rio Pailon
- Okinawa drainage

2nd Priority:

- Chane-Chacras

3rd Priority:

- Quebrada Chane

2) Sun Juan-Antofagasta Area

The structural measures for the area are feasible as a whole in technical, economical, social and environmental. The conditions of inundation will be very much improved by both of Alternative-I and Alternative-II.

The structural measures for the area are feasible as a whole with the EIRR values of 13.41 % for Alternative-I (with rehabilitation of the drainage mains) and 12.51 % for Alternative-II (with improvement of the drainage mains). Although the structural measures for San Juan was evaluated marginal with EIRR value of 9.97 %.

The social impacts will be significant at both of Alternative-I and Alternative-II due to the protected area of 210 km^2. The positive social impacts like the Chane-Pailon area will be expected. It is considered to be viable from the socioeconomic aspects because the area is one of the most developed agricultural area. Environmental adverse effects by the projects will be not significant.

From technical, economic, social and environmental aspects, the alternative-I is recommended. The priority orders of the sub projects are:

1st Priority:

- Antofagasta

2nd Priority:

- San Juan

2.8 Priority Projects for F/S

According to the project evaluation urgent measures that have high technical, economic efficiencies and social importance were selected for the priority projects as follows:

-1 Alternative-1 of Chane Pailon area

-Rio Chane,

-Rio Pailon,

-Okinawa Drainage.

-2 Alternative-1 of San Juan-Antofagasta area

-Antofagasta.

A draft of terms of reference of the F/S is attached to Appendix-C of the main report.

2.9 The existing organizations related to flood mitigation are MDS, SENAMHI, SEARPI, CDF, CORDECRUZ, MDN and Municipalities. For implementation of the Master Plan,

the overall coordination shall be provided by the Ministry of Sustainable Development and Environment and CORDECRUZ.

2.10 The implementation of the proposed measures is planned to be carried out from 1996 to 2010 as follows:

Stage-1: Preparatory period from 1996 to 2000

-1 Institutional Arrangement

-2 Execution of F/S and D/D on the priority projects,

-3 Preparation of execution of non-structural measures,

-4 Implementation of measures for early implementation,

-5 Improvement of the hydrological observation network,

-6 Preparation of complementary studies on the Rio Grande, Rio Pirai and Rio Yapacani, and improvement works of secondary roads.

Stage-2: Implementation of proposed measures from 2001 to 2010.

-1 Institutional arrangement for execution of the Master Plan,

-2 Implementation of the priority measures identified in the F/S,

-3 Execution of non-structural measures,

-4 Implementation of complementary works and studies.

2.11 A proper operation and maintenance (OM) is indispensable to realize the benefits expected by the project, and shall be carried out by the implementation organization for the master plan and the related municipalities. The regular OM activities required are as follows:

- Inspection of hydrological observation network of flood warning system,
- Management and control of land use according to the regulations, including the prohibition of any harmful activities from flood mitigation aspects,
- Inspection and periodical maintenance works of river and drainage channels, including related facilities like bridges and culverts.

3. Conclusion and Recommendation

(1) It is concluded that the proposed flood mitigation and drainage improvement plans will be feasible in technical, economic, social and environmental terms. The study area needs immediate action for implementation of the proposed plans.

The proposed plans will enable the study area to mitigate flood and drainage problems and to stabilize the agricultural sector. The stabilization will enable the study area to achieve a growth rate of 5 % per annum that is the target of the national economic development plan by enhancement of high land use efficiency, expansion of planted area, increase of yield, decrease of post harvest damage and introduction of high productive crops. Also high positive social impacts such as the generation of employment opportunities will be expected.

In order to attain the expected project benefit, prompt actions will be required for the following actions.

(2) It is necessary for the study area to take an immediate action for execution of F/S for the urgent measures.

(3) Preparatory works for regulation or preliminary design of non-structural measures should be started immediately in order to facilitate the non-structural measures for flood mitigation.

(4) An implementation organization should be established for smooth execution of the Master Plan, in order to carry out structural and non-structural measures smoothly, and also to control & manage the land use effectively. The following ideas should be taken into consideration for establishing the organization:

-1 The organization should be a strong implementation and coordination organization at Prefecto level.

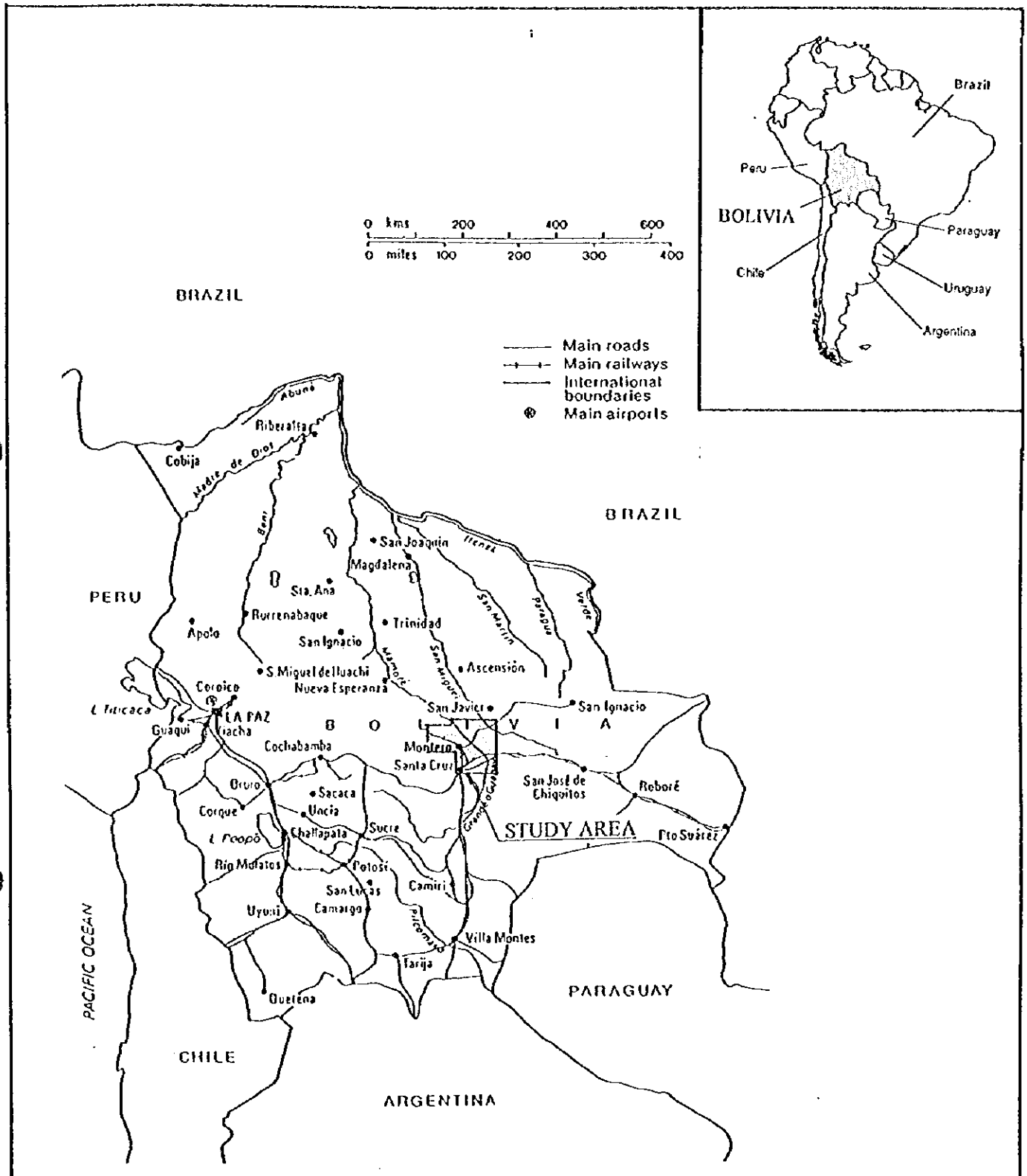
-2 Some of the counterpart of the Master Plan Study should be assigned for the organization because of their basic knowledge of the Master Plan.

-3 Also some of the members should be selected from CORDECRUZ, SEARPI and SENAMHI.

-4 The Organization is responsible to establish new organization for execution of the proposed measures and OM after implementation of urgent flood mitigation and drainage improvement measures.

(5) Improvement of the existing hydrological observation network should be carried out immediately in connection with warning systems and complementary development studies.

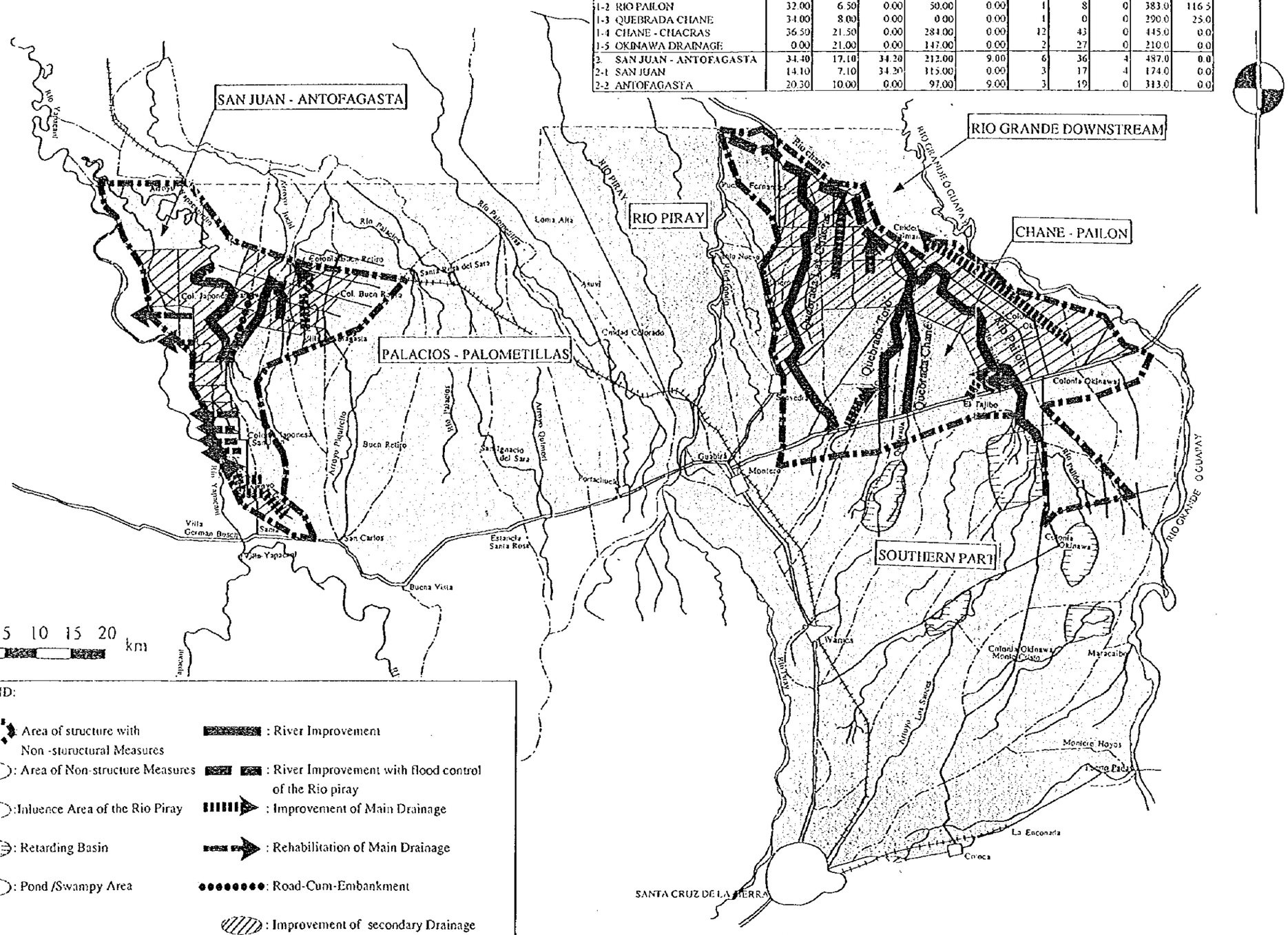
(6) Complementary development studies and works mentioned in the Master Plan should be carried out to support the regional development.



LOCATION MAP

WORK VOLUME OF STRUCTURAL MEASURES

Project/Sub-project	River Improv. (km)	Main Drainage Improve. (km)	Main Drainage Rehabili (km)	Secondary Drainage (km2)	Road-Cum Embank (km)	Bridge (Nos.)	Culvert (Nos.)	Divers. Weir (Nos.)	Land Acquisi (ha.)	Retard. Basin (km2)
1. CHANE - PAILON	137.50	57.00	0.00	481.00	0.00	21	78	0	1550.0	141.5
1-1 RIO CHANE	35.00	0.00	0.00	0.00	0.00	5	0	0	222.0	0.0
1-2 RIO PAILON	32.00	6.50	0.00	50.00	0.00	1	8	0	383.0	116.5
1-3 QUEBRADA CHANE	34.00	8.00	0.00	0.00	0.00	1	0	0	290.0	25.0
1-4 CHANE - CHACRAS	36.50	21.50	0.00	284.00	0.00	12	43	0	445.0	0.0
1-5 OKINAWA DRAINAGE	0.00	21.00	0.00	147.00	0.00	2	27	0	210.0	0.0
2. SAN JUAN - ANTOFAGASTA	34.40	17.10	34.20	212.00	9.00	6	36	4	487.0	0.0
2-1 SAN JUAN	14.10	7.10	34.20	115.00	0.00	3	17	4	174.0	0.0
2-2 ANTOFAGASTA	20.30	10.00	0.00	97.00	9.00	3	19	0	313.0	0.0



LEGEND:

- Area of structure with Non -stuructural Measures
- : Area of Non-structure Measures
- :Inluence Area of the Rio Piray
- : Retarding Basin
- : Pond /Swampy Area
- : River Improvement
- : River Improvement with flood control of the Rio piray
- : Improvement of Main Drainage
- : Rehabilitation of Main Drainage
- : Road-Cum-Embankment
- : Improvement of secondary Drainage

MASTER PLAN

SUMMARY OF THE MASTER PLAN

PROJECT/SUBPROJECT	FLOOD MITIGATION AND DRAINAGE IMPROVEMENT MEASURES				PROJECT EVALUATION											
	STRUCTURAL MEASURES		PROJECT COST (1,000 Bs)	NON-STRUCTURAL MEASURES	ASSESSMENT										PROJECT VIABILITY	
					Technical Evaluation		Economic Evaluation (EIRR: %)			Social Impact (Protected Area: km2)			Environmental Impact			
1.CHANE - PAILON			902,275		Highly effective	A	Feasible	11.04	A	High Impact	470.1	A	Negligibly small	B	High viability	A
1-1 Rio Chane	Improvement of Rio Chane	27.0 km	175,748		As the main stream area, indispensable for avoiding any adverse effect. More effective with flood control of the Rio Piray.	A	Not feasible	negative	C	Same as present	0.0	B	Same as present	B	High viability for avoiding any adverse effect. More effective with flood control of the Rio Piray.	A
1-2 Rio Pailon	Improvement of Rio Pailon Main Drainage Secondary Drainage	32.0 km 6.5 km 50.0 sq km	290,382	- Flood warning and evacuation system, - Preservation of protection forest along river channels, - Land use management for farm lands in the flood hazard area,	Indispensable as the main stream area	A	Highly feasible	14.33	A	High impact	117.8	A	Negligibly small	B	High viability as the stream area	A
1-3 Okinawa Drainage	Main Drainage Secondary Drainage	21.5 km 147.0 sq km	91,816	- Land use management in the poor drainage area, - Planting habit management in the poor drainage area.	High necessity as the major drainage area	A	Feasible	12.21	A	High impact as the intensive landuse area	71.9	A	Negligibly small	B	High viability as the major drainage area	A
1-4 Quebrada Chane	Improvement of Qda. Chane Main Drainage	34.0 km 8.0 km	126,279		Effect to only limited area of the tributary area	C	Feasible	12.52	A	Medium impact as the extensive landuse area	54.0	B	Negligibly small	B	Low viability as the tributary area	C
1-5 Chane -Chacras	Improvement of Qda. Chacras Main Drainage Secondary Drainage	36.5 km 21.0 km 284.0 sq km	218,050		High necessity as the tributary area	B	Highly feasible	15.38	A	High impact as wide effective area	226.4	A	Negligibly small	B	Medium viability as the tributary area	B
2.SAN JUAN - ANTOFAGASTA			187,340		Highly effective	A	Feasible	13.41	A	High Impact	210.3	A	Negligibly small	B	High viability	A
2-1 San Juan	Improvement of A. Yapacanicito Main Drainage Secondary Drainage	14.1 km 41.3 km 115.0 sq km	86,838	- Flood warning and evacuation system, - Preservation of protection forest along river channels,	Necessary	B	Marginal	9.97	B	High impact as the intensive landuse area	81.4	A	Negligibly small	B	High viability	A
2-2 Antofagasta	Improvement of A. Jochi, A. Tacuaral Main Drainage Secondary Drainage Road Cum Embankment	20.3 km 10.0 km 97.0 sq km 9.0 km	100,502	- Land use management for farm lands in the flood hazard area, - Land use management in the poor drainage area, - Planting habit management in the poor drainage area.	Indispensable	A	Highly feasible	16.24	A	High impact as the local colony	128.9	A	Negligibly small	B	High viability	A
3.RIO GRANDE DOWNSTREAM	None			- Flood warning and evacuation system, - Flood proofing for settlement in the flood hazard area, - Preservation of protection forest along river channels, - Land use management for farm lands in the flood hazard area, - Land use management in the poor drainage area,	Highly effective		-			High Impact			-		High viability	
4.SOUTHERN PART	None			- Planting habit management in the poor drainage area. - Flood warning and evacuation system, - Flood proofing for settlement in the flood hazard area, - Land use control for retarding basins, - Preservation of protection forest along river channels, - Land use management for farm lands in the flood hazard area, - Land use management in the poor drainage area,	Highly effective		-			High Impact			-		High viability	
5.PALACIOS - PALOMETILLAS	None			- Planting habit management in the poor drainage area. - Flood warning and evacuation system, - Preservation of protection forest along river channels, - Land use management for farm lands in the flood hazard area, - Land use management in the poor drainage area, - Planting habit management in the poor drainage area.	Effective		-			Medium Impact			-		Medium viability	
6.RIO PIRAY	MASTER PLAN OF RIO PIRAY															

REMARKS Ranking of viability for priority projects: A: High B: Marginal C: Low

IMPLEMENTATION PLAN OF THE MASTER PLAN

ITEMS	STAGE	STAGE-1 PREPARATION PERIOD					STAGE-2 IMPREMENTATIONOF URGENT WORKS									
	YEAR	1 1996	2 1997	3 1998	4 1999	5 2000	1 2001	2 2002	3 2003	4 2004	5 2005	6 2006	7 2007	8 2008	9 2009	10 2010
1. Institutional Arrangement																
1-1 Establishing an organization to carry out the preparation works for implemenattion of the Master Plan			———	———	———	———										
1-2 Establishing a new implementation organization to i,plement the Master Plan							———	———	———	———	———	———	———	———	———	———
1-3 Establishing a new organization for O/M activities												———	———	———	———	———
2. Execution of F/S and D/D on the Priority Projects																
- Chane - Pailon Area				F/S	- - -	D/D										
- San Juan - Antofagasta Area				F/S	- - -	D/D										
3. Preparation of Regulation or Preliminary Design Related to the Non-structural Measures			———	———	———	———										
4. Improvement of the Hydrological Obserbation Networks																
- Installation of rain guages			———	———												
- Installation of water level guages			———	———												
5. Complementary Works and Studies			———	———	———	———	———	———	———	———	———	———	———	———	———	———
- Complementary development study			———	———	———	———	———	———	———	———	———	———	———	———	———	———
- Improvement of the secondary roads			———	———	———	———	———	———	———	———	———	———	———	———	———	———
6. Implementation of the Structural Measures Identified in the F/S																
6-1 Chane - Pailon Area																
(1) Rio Chane Basin							———	———	———	———	———					
(2) Rio Pailon Baisn												———	———	———	———	———
(3) Chane Chacras Basin									———	———	———	———	———	———	———	———
(4) Quebrada Chane												———	———	———	———	———
(5) Okinawa Drainage							———	———	———	———	———					
6-2 San Juan - Antofagasta Area																
(1) San Juan Baisn							———	———	———	———						
(2) Antofagasta Baisn							———	———	———	———	———					
7. Execution of Non-structural Measures					- - -	- - -	———	———	———	———	———	———	———	———	———	———
- Flood warning and evacuation system					- - -	- - -	———	———	———	———	———	———	———	———	———	———
- Flood proofing of settlements in the flood hazard area					- - -	- - -	———	———	———	———	———	———	———	———	———	———
- Land use control of the proposed retarding basins					- - -	- - -	———	———	———	———	———	———	———	———	———	———
- Preservation of protection forests along river channels					- - -	- - -	———	———	———	———	———	———	———	———	———	———
- Land use management for farmlands in the flood hazard area					- - -	- - -	———	———	———	———	———	———	———	———	———	———
- Lamd use management in the poor drainage area					- - -	- - -	———	———	———	———	———	———	———	———	———	———
- Planning habit management in the poor drainage area					- - -	- - -	———	———	———	———	———	———	———	———	———	———

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ABBREVIATIONS

AASANA:	Administración Autónoma de Servicios la Navegación Aérea
ADEPLE:	Asociación de Productores de Leche
CAICO:	Cooperativa Agropecuaria Integral Colonias Okinawa Ltda.
CAISY:	Cooperativa Agropecuaria Integral San Juan de Yapacaní Ltda.
CAO:	Cámara Agropecuaria del Oriente
CDF:	Center of Forest Development
CETABOL - JICA:	Centro Tecnológico Agropecuario en Bolivia - JICA
CIF:	Cost, Insurance and Freight
CNPV:	Encuesta Demográfica Nacional de Población y Vivienda
COD:	Chemical Oxygen Demand
CORDECRUZ:	Corporación Regional de Desarrollo de Santa Cruz (Santa Cruz Regional Development Corporation)
DHI:	International Hydrological Decade
EDEN:	Encuesta Demográfica Nacional
EEC:	European Economic Community
EIA:	Environmental Impact Assessment
ENDSA:	Encuesta Nacional de Demografía y Salud
ENPV:	Encuesta Nacional de Población y Vivienda
FEGASACRUZ:	Federación de Ganaderos de Santa Cruz
FOB:	Free on Board
GDP:	Gross Domestic Product
GOB:	The Government of Bolivia
GOJ:	The Government of Japan
JICA:	Japan International Cooperation Agency (Agencia de Cooperación Internacional del Japón)
MDN:	Ministerio de Defensa Nacional (Ministry of National Defense)
MDSMA:	Ministerio de Desarrollo Sostenible y Medio Ambiente (Ministry of Sustainable Development and Environment)
OMM:	World Meteorological Organization
OTAI:	Organización de Técnicos de la Agro-Industria
SEARPI:	Servicio Encauzamiento de Aguas y Regularización del Río Piraí
SEDAMA:	Secretarías Departamentales del Medio Ambiente
SENAMHI:	Servicio Nacional de Meteorología e Hidrología
SENMA:	Secretaría Nacional de Medio Ambiente
SNA:	Servicio Nacional de Aerofotogrametría
SNC:	Servicio Nacional de Caminos

SUMMARY

1. General

This is a summary of the Final Report for the Master Plan Study on Flood Control in the Northern Rural Region of Santa Cruz in the Republic of Bolivia.

The study area is to cover approximately 7,000 km^2 of the rural region between the Rio Grande and the Rio Yapacani in the northern part of the city of Santa Cruz of the Department of Santa Cruz. The study area is shown in *Fig. 1.*

The objectives of the study are to formulate a comprehensive Master Plan on flood mitigation and drainage improvement measures for the study area, except the main reach of Rio Pirai that has already a master plan for the management and training of the main river reach, and to pursue technical transfer to the counterpart personnel through on the job training in the course of the Study.

This Final Report presents the outline of the study from April 1995 to June 1996. The study results are summarized below:

2. Study Area

2.1 The Study Area is located in the integrated development area that is the most developed area in the Department, and administratively related to five provinces, i.e., Andres Ibanez, Warnes, Ichilo, Sara and Obispo Santistevan, as shown in *Fig. 2.*

2.2 The topography of the study area is inclined 1/400 - 1/1000 to the northward. There are a lot of depressed lands and low-lying areas that are mostly vulnerable to flood and drainage problems.

The river systems are consisting of three major rivers and their tributaries. The three major rivers are the Rio Grande (106,000 sq. km), the Rio Pirai (10,660 sq. km), the Rio Yapacani (9,969 sq. km) as shown in *Fig. 3.*

2.3 The climate is consisting of dry season (from April to October), wet season (from October to March) and transition seasons (March to April and September to October).

The rainfall amount varies locally and seasonally. The mean annual rainfalls in the western part and in the eastern part are 1,898 mm and 1,274 mm respectively. Rainfall amount in the wet season is about 60 to 70 % of the annual rainfall amount.

3. Socioeconomic Conditions

3.1 The Department has the highest population increase rate in the country. The population of the Department was 1,364,389 in 1992 that accounted for 21 % of the population of the country. The mean annual growth rate of population in the Department is 4.16 % for the period (1976-1992), consisting of 6.21 % for urban area and 0.8 % for the rural area.

The population projection of the Department that was estimated by the average growth rates of the population projection based on the census population 1,364 389 in 1992. The population projection is shown as follows:

Year	Population	Ratio to National Pop.	Annual Growth rate
1992	1,364,000	21.2	-
1995	1,525,000	20.5	3.79 (1992-1995)
2000	1,821,000	21.9	3.61(1995-2000)
2005	2,163,000	23.3	3.50 (2000-2005)
2010	2,552,000	24.9	3.36 (2005-2010)

3.2 The Department has the largest share of the national product. In 1992 the GDP of the Department accounted for about 30 % of the Bolivian GDP. The Bolivia's per capita GDP grew at an annual rate of 2.37 % (US$ base) from 1988 to 1992 and reached US$ 804 in 1992. During the same period the Department achieved the average annual rate of 4.29 % and the per capita GDP of US$ 1,177 in 1992.

3.3 The annual growth rate of Bolivian GDP indicated 3.85 % on average for the period 1988-1992. Of all sector GDP, the rapidest growth was the agroindustrial sector with the annual rate of 14.39 % on average during the same period and in contrast the agricultural sector was the slowest growth rate of 0.83 %.

The total GDP of agricultural sector and its related sectors (agro-industry, stock raising, hunting, forestry and fishing) accounted for 17.7 % of the Bolivian GDP in 1992.

Following these sector, manufacturing industrial sector had a share of 15.4 % in the same year.

3.4 Of all sector GDP of the Department of Santa Cruz, the agro-industrial sector also indicated the rapidest growth, an average annual rate of 16.27 % during same period. The departmental GDP of the agricultural sector achieved a comparatively rapid growth at an annual rate of 10.32 % during the same period. Following the agricultural sector, the manufacturing industrial and trade sectors indicated the high shares of 19.2 % and 12.5 %, respectively.

4. Flood and Drainage Problems

4.1 The recorded major floods in the study area are as follows:

-Eastern area: 1968, 1972, 1983, 1987 and 1992,
-Western area: 1963, 1966, 1982, 1983, 1991 and 1992.

The 1992 floods caused the severest damages to the study area.

Flood hazard areas and flood damages were surveyed to study on the conditions of 1992 floods and annual floods. The flood hazard areas by the 1992 floods and by the annual floods were estimated to be 4,857 km^2 and 2,444 km^2 respectively and shown in *Figs. 4 and 5.*

4.2 The inundation area was divided by causes of floods into four (4) areas as shown in *Fig. 6.* The areas are explained as follows:

-1 Inundation by the Rio Grande, Rio Pirai and Rio Yapacani,
-2 Inundation by its own basin runoff,
-3 Inundation mostly by its own basin with backwater effect of the Rio Pirai,
-4 Inundation not only by its own basin runoff, but also by the Rio Pirai, Rio Grande or Rio Yapacani.

4.3 The drainage problems were identified mostly to be caused by unfavorable topographic, soil, hydrological conditions, however, there are some drainage problems caused by the development activities such as farm development and road construction. The poor drainage areas identified are shown in *Fig. 7.*

4.4 There is no significant flood mitigation facility in the study area, except the flood embankment constructed along the Rio Pirai to protect the city of Santa Cruz and the bridge protection works at the Rio Grande, Rio Pirai and Rio Yapacani.

4.5 As for the existing drainage facilities, there are only small scale drainage canals and farm drains locally made by land owners. The major existing drainage systems are observed in Colonia Okinawa and Colonia San Juan de Yapacani. Colonia Okinawa has one drainage main with the capacity less than 2-year return period. Colonia San Juan de Yapacani has seven (7) drainage mains with the capacity lass than 2-year return period.

5 Hydrology

5.1 There are 33 rainfall stations in the study area, including two general meteorological stations, i.e., Santa Cruz - Trompillo and Viru Viru Airport. The rainfall stations are distributed much in the central part of the Rio Pirai Basin, but less in the eastern part and in the western part.

Among them only ten stations have daily rainfall data before 1975 or 1976, of which the four (4) stations have relatively long period of data. The four station are selected as the principal stations for the study. They are listed as follows:

Station	Observation record
-1 5806 Santa Cruz-Trompillo:	52 years
-2 61NP Saavedra:	44 years
-3 Colonia San Juan de Yapacani:	35 years
-4 OkinawaII:	26 years

Available hourly rainfall data relating to the principal stations are listed below:

- 25NP Santa Cruz-Office 1973 - 1994 (21 years record)
- 61NP Saavedra 1951 - 1994 (44 years record)
- Okinawa II 1986 - 1994 (8 years record)

5.2 The river gauging stations are only four (4), i.e. two at the Rio Pirai, one at the Rio Yapacani and one at the Rio Palometillas. Along the Rio Grande, once there were two stations, one at Puerto Pailas and the other at Abapo about 150 km upstream from Puerto Pailas.

5.3 The annual rainfall of 1992 was about 2 to 2.5 times of the mean annual rainfall. The monthly rainfall of January, February and December were about 2 to 3 times of those mean monthly rainfalls. Those of April and May were also about 2 to 4 times of those mean monthly rainfalls.

5.4 As for the daily rainfall of the 1992 floods, the heavy rainfall was lasting for 4 to 6 days in the whole study area. The amounts of the continuous rainfall and the daily maximum rainfalls were shown as follows:

Station	Continuous rainfall	Daily maximum rainfall
Saavedra	453.6 mm	220.4 mm (January 14)
Okinawa II	374.0 mm	194.0 mm (January 15)
Colonia San Juan de Yapacani	293.3 mm	196.5 mm (January 15)
Santa Cruz - Trompillo	168.1 mm	168.1 mm (January 13)

5.5 The return period of the storm rainfall of the 1992 floods were assessed as follows:

Station	Return period
- Santa Cruz-Trompillo:	2 to 5-year
- Saavedra:	over 100-year
- Okinawa II:	50 to 100-year
- Colonia San Juan de Yapacani	5 to 10-year

5.6 Design rainfalls of the four principal stations were studied. The design rainfall is three day continuous rainfall with peak behind.

Rainfall intensity curves of Santa Cruz and Saavedra were used for making their own design rainfalls. The rainfall pattern of Saavedra was also applied for making the design hydrograph of Okinawa II and Colonia San Juan de Yapacani. This is because the correlation of annual maximum daily rainfall of these two stations with Saavedra are bigger than those of these two stations with Santa Cruz.

5.7 Rainfall runoff analysis was conducted by the Unit Hydrograph Method by U.S. Soil Conservation Service (SCS Unit Hydrograph Method) for the Rio Chane basin and the Rio Yapacanicito-Jochi-Tacuaral-Tejeria basins.

(1) Rio Chane Basin

1) Design rainfall

Design rainfalls with return periods of 2, 5, 10, 20, 30, 50 and 100 year of Santa Cruz, Okinawa II and Saavedra were used for the runoff analysis.

2) Runoff Discharge

The probable peak runoff discharges at the major runoff points are as follows:

Probable Peak Runoff Discharge (m^3/s)

	Return Period (Year)		
	10-year	20-year	50-year
Rio Chane (downstream)	1270	1510	1820
Rio Chane (upstream)	1200	1420	1700
Rio Pailon (at Road 9)	1340	1580	1890
Qda. Chane (at Road 9)	390	460	540

Specific discharges of the most downstream of Rio Chane were calculated and shown in *Fig. 8*. The values are about 0.2 to 0.8 $m^3/s/km^2$. These specific discharges coincide with the tendency of specific discharges of the Rio Pirai which was calculated by SEARPI.

(2) Arroyo Yapacanicito-Jochi-Tacuaral-Tejeria Basin

1) Design Rainfall

Design rainfall with return periods 2, 5, 10, 20, 30, 50 and 100 year of Colonia San Juan de Yapacani were used for the runoff analysis.

2) Runoff Discharge

The calculated probable runoff discharges at the major runoff points are as follows:

Probable Runoff Discharge (m^3/s)

	Return Period (Year)		
	10-Year	20-Year	50-Year
A. Yapacanicito (downstream)	540	630	740
A. Yapacanicito (upstream)	220	250	290
A. Jochi (mid-stream)	270	310	360
A. Tacuaral (mid-stream)	330	380	440
A. Tejeria (downstream)	210	240	280

The specific discharges calculated are shown in *Fig. 8.* The tendency of specific discharges of this basin is almost the same as that of the Rio Chane basin.

5.8 Hydraulic models were made for the Rio Chane basin and the Arroyo Yapacanicito-Jochi-Tacuaral basins. Model structures are composed of river and drainage systems with subcatchments, including inundation areas and retarding basins. They are shown in *Figs. 9 and 10.*

Rainfall runoff of each sub-catchments is calculated by SCS method and enter into river systems as lateral inflow. Hydraulic calculation was by unsteady flow method. The hydraulic models were calibrated by comparing the simulated flood conditions with actual flood conditions of the 1992 floods.

5.9 Simulation of probable floods of 2, 5, 10, 20 and 50 year floods for with and without flood mitigation and drainage improvement measures were conducted.

(1) Rio Chane Basin

Simulation of the Rio Chane basin for with and without project situations were conducted. The inundation areas with depth for 10 year floods for with-project and without-project situations are shown in *Figs. 11 and 12.* The simulated peak discharges of the Alternative-1 are shown in *Fig. 13.*

Inundation conditions of the Rio Pailon, Qda. Chane, Chane-Chacras and Okinawa drainage area will be improved very much by both of Alternative-I and Alternative-II. However, flood levels of the Rio Chane will be increased by both Alternative-I and -II.

This is because of the increment of flood discharge from the upstream basins due to the river and drainage improvement as well as the backwater effect of the Rio Pirai.

(2) Arroyo Yapacanicito-Jochi-Tacuaral Basin

Simulation of two alternatives for with and without project situations were conducted. The inundation areas with depth of 10 year floods for with and without the project are shown in *Figs. 14 and 15* respectively. The simulated peak discharges for Alternative-1 are shown in *Fig. 16*.

Inundation conditions of San Juan and Antofagasta will be improved very much by the plan for the reaches in which river and drainage improvement will be done.

5.10 According to drought analysis, there are three (3) years of drought between 1984 and 1994. They are 1988, 1993 and 1994. 1995 is also drought year. Drought scales of four month rainfall for the principal four stations are shown below:

Drought Scale (4 Month Rainfall)

Station	1st	2nd	3rd
SC-Trompillo	1994	1988	1995
	(49.4)	(34.4)	(18.9)
Saavedra	1988	1995	1993
	(Over 200)	(31.9)	(3.5)
Okinawa II	1995	1988	1993
	(16.5)	(12.8)	(5.7)
Col. San Juan de Yapacani	1988	1995	1993
	(Over 200)	(145.6)	(28.6)

Remarks: values in parenthesis are return periods of drought.

6. Development Trend

6.1 The study area was rapidly developed since the 1950s and mostly developed by the first half of 1980s. Currently the development activities have been extended toward outside of the study area, i.e., the east side of the Rio Grande, the west side of the Rio Yapacani and the north side of the Rio Chane. The locations of currently developed colonies are shown in *Fig. 17*.

6.2 There are five (5) dominant colonies, i.e., Okinawa, Aroma, Puesto Fernandez, San Juan and Antofagasta, in the study area. They are covering 1,334 km^2, and play an important role for production of agricultural crops such as soybean, rice, sugarcane and livestock. However, they are mostly located in the flood hazard area (*Fig. 18*).

6.3 The road network of the study area is consisting of fundamental roads and secondary roads. The fundamental roads consist of national road No. 4, No. 7 and No. 9. The most part of the fundamental roads have been paved except the road from Guabira to the Rio Grande that is planned to be paved in two years. However, the most of the secondary roads are gravel or earth made. The surface conditions surveyed are as follows:

-1.	Asphalt road:	187 km (8 %)
-2.	Gravel road:	808 km (34 %)
-3.	Earth road:	1,354 km (58 %)
	Total length	2,349 km

6.4 The road that is accessible through year, is only 40 % in length and the other roads are not accessible for one month to five months yearly because of weak road bed, poor drainage and poor maintenance. The poor accessibility of the road is affecting the transportation of agricultural crops, at their harvest times. The roads that are accessible through year or not accessible through year are shown in *Figs. 19 and 20* respectably.

6.5 The regional development plan of the Department of Santa Cruz, prepared by CORDECRUZ, depends on the General Plan for Social and Economic Development (PGDES) that is formulated by the Ministry of Sustainable Development and Environment, and aims to realize a new policy for the national development with a slogan of sustainable development.

6.6 The mean annual growth rate of population in the study area was estimated to be 2.3 % for the period. The population of the study area was estimated to be about 300,000 in 2010 from about 200,000 in 1992 , according to CORDECRUZ. The population will increase in the urban areas, but not increase in the rural area.

6.7 The national economic growth for the next decade was targeted by the national economic development plan at a rate of 5 % per annum.

7. Agriculture and Land Use

7.1 The main crops in the Department of Santa Cruz are soybean, sugarcane, rice and maize that are account for about 75 % of the total crop planted area. The dominant crop in the Department was rice until 1988, but soybean after 1988. From 1990 to 1994, the production of crops increased explosively due to the expansion of planted area of soybean, except the summer soybean.

7.2 The study area is the agricultural center in the Department. The crop planted area accounts for 44 % of the whole crop planted area in the Department. The main crops in the study area are soybean, sugarcane and rice. The share of the crop production to that of the Department, is very high, i.e., soybean: 37 %, sugarcane: 89 % and rice: 72 %.

The livestock and chicken production also have grown steadily. The main livestock in the study area is cattle. The study area raised 400,000 heads of cattle in 1994 that accounted for 30 % of the livestock in the Department. The egg production and swine production are growing rapidly and become the main sectors.

7.3 The agro-based industries in the Department are mostly located in the study area, and play an important role not only in economy and employment ,but also supporting farming and poultry development. The processing facilities of the main crops such as edible oil, soybean cake, rice and sugar, can afford to treat more materials. Especially expansion of fruits' production has a high potential.

7.4 The natural forest area in the study area was diminished to 20 % in 1984 due to the agricultural development. The forest is generally distributed along rivers and the unarable lands. Currently the secondary forest are increasing and covers 7.4 % in the study area. The secondary forest areas are likely corresponding to the idle land in 1984. It is suggesting that the current secondary forest areas were developed once for agriculture, but abandoned later.

7.5 The agricultural lands, including pasture, in the study area was initially developed by 1984. After 1984 the area of agricultural lands has been the same as before, but the ratio between the farming lands and the pasture has been changed. The cropping land has been increased, but the grazing land decreased.

The efficiency of land utilization, annual cropping area per farm land, is still low. The farmers of small scale are cultivating their land less than 110 %, almost once a year.

7.6 The yields of main crops are fluctuate in the past decade, though the consumption of improved seed, especially soybean and wheat, has been increased rapidly at the same period. However, the agricultural productivity is not increasing, but likely decreasing, in the study area.

7.7 The farmland in the flood hazard area seems to be more fertile and more intensively used. However, the ratio between the harvest area and the seeding area of maize, soybean, sorghum and cotton that are intolerant species to flooding, are lower in the flood hazard area. The floods have affected the crop productivity.

7.8 The farm income per farm family is much different due to the farm size. The smaller farmers yield lower, because the small farmers select the same crops as those of the large farmers. They are less organized and accordingly receiving less supporting services.

7.9 Agricultural diversification will be necessary to avoid the risk of price fluctuation in the international market. Okinawa and San Juan areas are accelerating diversification for income stabilization and conservation of soil fertility through the introduction of fruits and livestock. However, most of the farmers still want to continue the same crop cultivation such as soybean, rice, maize and sugarcane and the farmers who want to diversify their agriculture are only 10 %.

7.10 The agricultural area was classified into nine (9) zones as shown in *Fig. 21* and possible countermeasures were tentatively planned and shown in *Table 1*.

8. Master Plan for Flood Mitigation and Drainage Improvement

8.1 Basic Concept

(1) Basic Policy

The optimum measures should enable the study area to get stabilized or to be safe by mitigation of flood and drainage problems and support to promote the sustainable development of the study area.

The flood hazard areas and poor drainage areas have been assessed on the flood damage conditions such as flood depth, flood duration, flood damage and land use.

(2) Target Area

The study area was divided into the followings based on the conditions such as flood depth, duration, damage and land use as shown in *Figs. 22* and *23*:

-1 The areas for structural measures with non-structural measures:

The area was selected based on the following criteria:

- Intensive land use areas such as urban and intensive farming areas affected by annual floods,

  Intensive land use areas severely affected by the 1992 floods i.e., flood depth more than 50 cm and duration more than 2 days,

-2 The areas for non-structural area :

The area was selected based on the following criteria:

- Not intensive land use areas such as pasture and forest areas both in the annual flood hazard area and in the 1992 floods hazard area,
- Intensive land use areas in the 1992 flood hazard area with less than 50 cm deep and 2 days long.

The poor drainage area was also divided into the areas for structural measures and non-structural measures as shown in *Fig. 23*.

The structural measure areas were divided by river or drainage basin into the following seven (7) areas as shown in *Figs. 24 and 25*:

a. Chane - Pailon Area

-1. Rio Chane,
-2. Rio Pailon,
-3. Chane Chacras,
-4. Quebrada Chane,
-5. Okinawa drainage.

b. San Juan - Antofagasta Area

-1. San Juan,
-2. Antofagasta.

(3) Design Scale

The design scales for flood mitigation and drainage improvement measures were decided considering the efficiency of flood mitigation by the facilities as follows:

-1 The design scale of flood mitigation facilities is decided to be 10-year frequency flood with an allowable inundation depth of 30 cm,
-2 The design scale of drainage improvement facilities is decided to be 5-year frequency storm runoff with an allowable inundation depth of 30 cm.

The important or fundamental public facilities such as national road bridges, the design scale of a 50-year frequency flood should be considered according to the scale of 1992 floods.

The design discharges of 10 year floods for the rivers are shown in *Figs. 26 and 27.*

(4) Target Year

The target year of the Master Plan was decided to be the year of 2010 considering the target years of the national development plan 2010 and the regional development plan by CORDECRUZ(every five years).

The major works in the Master Plan were planned to be complete by 2010, considering the period required, five years for preparation and ten years for execution of the proposed measures.

(5) Socio-economic Frams of the Master Plan

Considering the existing national and regional development plans, socio-economic frames of the target year of 2010 were estimated as follows:

- The total population of the study area is estimated to be about 300,000 in 2010 from about 200,000 in 1992. The population will increase in the urban areas, but not increase in the rural area.

- Annual growth rate of the regional product in 2010 is targeted at a rate of 5 % by the expanding agricultural production with stabilization in the flood area.

- The land use in 2010 is to be almost the same as those in 1995, because the study area was mostly cleared for cultivation .

8.2 Components of the Mater Plan

(1) Structural Measures

The proposed structural measures are composed of river improvement works that increase conveyance capacities of channels by widening, deepening and improving channels, and embankment (including road-cum-embankment) that confine the flow within a channel, and drainage improvement works. The road-cum-embankment was planned between the Arroyo Yapacanicito Basin and Arroyo Jochi Basin. The purpose of the road-cum-embankment is to separate the flood water of these two basins as well as to reinforce the evacuation and transportation route during floods.

The structural measures for flood mitigation and drainage improvement are shown in *Figs. 28 and 29*. The major works are summarized as follows:

Structural Measures

Project	River Improvement	Main Drainage	Secondary Drainage	Road cum Embankment
1. Chane-Pailon				
-1 Rio Chane	27.0 km	0	0	0
-2 Rio Pailon	32.0 km	6.5 km	50.0 km^2	0
-3 Okinawa Drainage	-	21.5 km	147.0 km^2	0
-4 Quebrada Chane	34.0 km	8.0 km	0	0
-5 Chane-Chacras	36.5 km	21.0 km	284.0 km^2	0
2. San Juan-Antofagasta				
-1 San Juan	14.1 km	41.3 km	115.0 km^2	0
-2 Antofagasta	20.3 km	10.0 km	97.0 km^2	9.0 km
Total	163.9 km	108.3 km	693.0 km^2	9.0 km

For Chane-Pailon area, considering the situation of the Rio Chane that is strongly affected by the flood of the Rio Pirai, two alternative plans were planned as follows:

- Alternative-I is consisting of the Rio Chane and all the other sub projects,
- Alternative-II is consisting of all the sub projects except the Rio Chane.

For San Juan-Antofagasta area, considering the flow capacities of approximately 2 year frequency of the existing drainage mains, two alternatives were planned as follows

- Alternative-I is consisting of San Juan and Antofagasta sub-projects. The flow capacities of the existing drainage mains of San Juan area are planned to be maximized by rehabilitation. The surplus storm runoffs of the San Juan area are drained through the Arroyo Yapacanicito which is planned to be improved with design scale of 10 year return period of flood.
- Alternative-II is also consisting of San Juan and Antofagasta sub-projects. The existing drainage mains of San Juan area are planned to be improved with the design scale of 5 year storm runoff and planned to be separated from the Arroyo Yapacanicito. The Arroyo Yapacanicito are also planned to be improved with design scale of 10 year return period of flood.

(2) Non-structural Measures

Non-structural measures are planned to be applied for the entire flood hazard area. The structural measures will generally need a long time before completion and the flood and drainage problems should be mitigated by non-structural measures as much as possible. The proposed non-structural measures are composed of the followings:

a. Non-structural measures for flood mitigation

-1 Flood warning and evacuation systems for reducing casualties and flood damages,

-2 Flood proofing and flood plain management for reducing flood damages caused by inappropriate land use in the flood hazard area,

-3 Land use control for retarding basins and others for utilization and maintenance of retarding or regulation effects of natural swampy areas,

-4 Preservation of protected forest along river channels for preservation of the natural environmental resources,

-5 Land use management of farm lands and forest areas for reducing flood damages by appropriate management of farm lands and forest areas.

b. Non-structural measures for drainage improvement

-1 Introduction of appropriate water tolerant crops or varieties for reducing damages caused by drainage problems,

-2 Introduction of proper farm land management for reducing the damages caused by drainage problems by proper farm land management.

8.3 Cost Estimation

(1) Construction Cost

The unit price and cost were estimated based on prevailing market price in October 1995.

The construction cost is composed of direct construction cost and indirect construction cost. The indirect construction costs were estimated to be thirty percent (5 % of unforeseen, 10 % of overhead, 15 % of profit) of the direct construction cost.

(2) Project Cost

The project costs are composed of direct cost, indirect cost and contingency. The indirect cost of administration and engineering are estimated to be 5 % and 10 % of the direct construction cost respectively. Physical contingency is estimated to be 15 % of the direct construction cost.

The project costs in 1995 price were estimated and summarized as follows:

1) Alternative-I

(Unit: 1,000 Bs.)

Sub-Project	L/C	F/C	Total
1. CHANE-PAILON	449,234	453,041	902,275
(1) Rio Chane	82,582	93,166	175,748
(2) Rio Pailon	144,415	145,967	290,382
(3) Chane Chacras	110,375	107,675	218,050
(4) Queb. Chane	66,771	59,508	126,279
(5) Okinawa Drainage	45,091	46,725	91,816
2. SAN JUAN-ANTOFAGASTA	92,613	94,727	187,340
(6) San Juan	42,042	44,796	86,838
(7) Antofagasta	50,571	49,931	100,502
Total	541,847	547,768	1,089,615

Note: 1.0 US$ = Bs. 4.86 = Yen 100.0

2) Project costs of Alternative-II

(Unit: 1,000 Bs.)

Project	L/C	F/C	Total
1. CHANE-PAILON	366,652	359,875	726,527
(1) Rio Chane	-	-	-
(2) Rio Pailon	144,415	145,967	290,382
(3) Chane Chacras	110,375	107,675	218,050
(4) Queb. Chane	66,771	59,508	126,279
(5) Okinawa Drainage	45,091	46,725	91,816
2. SAN JUAN-ANTOFAGASTA	98,204	100,663	198,867
(6) San Juan	47,633	50,732	98,365
(7) Antofagasta	50,571	49,931	100,502
Total	464,856	460,538	925,394

Note: 1.0 US$ = Bs. 4.86 = Yen 100.0

8.4 Construction Schedule

The proposed major construction works are planned to be complete within ten (10) years from the year of 2001 to the target year of 2010. The construction schedule of the major structural measures are shown in *Tables 2 to 5*.

8.5 Environmental Impact

Environmental impacts anticipated to result from the project are both direct and indirect, and short term and long term.

The improvement of river channels will increase their flow capacities and might give impacts not only to the fauna and flora along the river channels, but also to the ground water table in the flood mitigation areas. However, the adverse environmental impacts will not be significant.

From Initial Environmental Evaluation (IEE), Environmental Impact Assessment (EIA) will be required for the further study stage.

8.6 Project Evaluation

The economic benefit of a flood control project could be presented by an expected reduction effect in flood damage by implementing the flood mitigation project, that is a difference between with and without project situations. The flood damages are classified into the following categories:

- Direct damage to building and household effects,
- Direct damage to agricultural crops and livestock,
- Damage to public facilities including transportation and agricultural facilities,
- Income profit losses in business activities.

The structural measures in the Master Plan were evaluated from technical, economical, social and environmental terms. The technical efficiency is evaluated by reduction effect in flood area, depth and duration. The economic efficiency is evaluated mainly by EIRR of which the values of higher than 10 % is considered to be feasible due to the opportunity cost of capital, estimated to be between 10 % and 12 %. The social and environmental terms are evaluated by reduction of flood hazard area.

1) Chane-Pailon Area

The structural measures for the area are feasible as a whole in technical, economical, social and environmental.

The conditions of inundation at the sub-projects, i.e., Rio Pailon, Quebrada Chane, Chane-Chacras and Okinawa Drainage, will be very much improved by both of Alternative-I and Alternative-II. However, the amount of the increasing of flood water level of Rio Chane of Alternative II will be 0.5 m to 0.9 m for 10 year floods.

The EIRR values of 11.04 % for alternative-I and 14.00 % for alternative-II (without improvement of the Rio Chane). The EIRR values of all sub-projects except the Rio Chane show higher values than 12.21 %.

The social impacts will be significant both of Alternative-I and Alternative-II due to the protected area of 470 km^2, and environmental adverse effects by the projects will be not significant, except the Rio Chane in Alternative-II.

From technical, economic, social and environmental aspects, the alternative-I is recommended in order to avoid any adverse social and environmental effects, because the estimated flood conditions will become worse than the existing condition. The priority orders of the sub-projects are:

1st Priority:

- Rio Chane
- Rio Pailon
- Okinawa drainage

2nd Priority:

- Chane-Chacras

3rd Priority:

- Quebrada Chane

2) San Juan-Antofagasta Area

The structural measures for the area are feasible as a whole in technical, economical, social and environmental. The conditions of inundation will be very much improved by both of Alternative-I and Alternative-II.

The structural measures for the area are feasible as a whole with the EIRR values of 13.41 % for Alternative-I (with rehabilitation of the drainage mains) and

12.51 % for Alternative-II (with improvement of the drainage mains). Although the structural measures for San Juan was evaluated marginal with EIRR value of 9.97 %.

The social impacts will be significant at both of Alternative-I and Alternative-II due to the protected area of 210 km^2, it is considered to be viable from the socio-economic aspects because the area is one of the most developed agricultural area. Environmental adverse effects by the projects will be not significant.

From technical, economic, social and environmental aspects, the alternative-I is recommended. The priority orders of the sub-projects are:

1st Priority:

- Antofagasta

2nd Priority:

- San Juan

8.7 Implementation Organization

The existing organizations related to flood mitigation are MDS, SENAMHI, SEARPI, CDF, CORDECRUZ, MDN and Municipalities.

The reformation of administrative structure of the local government is still on going and the new framework of the local government is not clear. The required implementation organization for implementation of the Master Plan should have administrative functions of planning, managing and executing the proposed measures.

8.8 Implementation Plan

The implementation of the proposed measures is planned to be divided into two stages as follows:

Stage-1: Preparatory period from 1996 to 2000

The major items are as follows:

-1 Institutional Arrangement
-2 Execution of F/S and D/D on the priority projects,

-3 Preparation of execution of non-structural measures,
-4 Implementation of measures for early implementation,
-5 Improvement of the hydrological observation network,
-6 Preparation of complementary works and studies.

Stage-2: Implementation of proposed measures from 2001 to 2010.

-1 Institutional arrangement for execution of the Master Plan,
-2 Implementation of the priority measures identified in the F/S,
-3 Execution of non-structural measures,
-4 Implementation of complementary works and studies.

8.9 Operation and Maintenance (OM)

A proper operation and maintenance (OM) is indispensable to realize the benefits expected by the project, and shall be carried out by the implementation organization for the master plan and the related municipalities. The regular OM activities required are as follows:

- Inspection of hydrological observation network of flood warning system,
- Management and control of land use according to the regulations, including the prohibition of any harmful activities from flood mitigation aspects,
- Inspection and periodical maintenance works of river and drainage channels, including related facilities like bridges and culverts.

9 Priority Projects for F/S

Priority projects are selected as a result of integrated evaluation of technical, economical, environmental and social aspects, and alleviation effect of flood damage.

According to the project evaluation urgent measures of the alternative-I for the Chane-Pailon area and the alternative-I for the San Juan-Antofagasta area are proposed for the Feasibility Study as follows:

-1 Alternative-I of Chane-Pailon area

-Rio Chane,
-Rio Pailon,
-Okinawa Drainage.

-2 Alternative-I of San Juan-Antofagasta area

-Antofagasta.

A draft of terms of reference of the Feasibility Study is attached to Appendix-c of main report.

10 Conclusion and Recommendation

(1) It is concluded that the proposed flood mitigation and drainage improvement plans will be feasible in technical, economic, social and environmental terms. The study area needs immediate action for implementation of the proposed plans.

The proposed plans will enable the study area to mitigate flood and drainage problems and to stabilize the agricultural sector. The stabilization will enable the study area to achieve a growth rate of 5 % per annum that is the target of the national economic development plan by enhancement of high land use efficiency, expansion of planted area, increase of yield, decrease of post harvest damage and introduction of high productive crops. Also high positive social impacts such as the generation of employment opportunities will be expected.

In order to attain the expected project benefit, prompt action will be required for the following actions.

(2) It is necessary for the study area to take an immediate action for execution of F/S for the urgent measures.

(3) Preparatory works for regulation or preliminary design of non-structural measures should be started immediately in order to facilitate the non-structural measures for flood mitigation.

(4) An implementation organization should be established for smooth execution of the Master Plan, in order to carry out structural and non-structural measures smoothly, and also to control & manage the land use effectively. The following ideas should be taken into consideration for establishing the organization:

-1 The organization should be a strong implementation and coordination organization at Prefecto level.

-2 Some of the counterpart of the Master Plan Study should be assigned for the organization because of their basic knowledge of the Master Plan.

-3 Also some of the members should be selected from CORDECRUZ, SEARPI and SENAMHI.

-4 The Organization is responsible to establish new organization for execution of the proposed measures and OM after implementation of urgent flood mitigation and drainage improvement measures.

(5) Improvement of the existing hydrological observation network should be carried out immediately in connection with warning systems and complementary development studies.

(6) Complementary development studies and improvement works of secondary roads on the Rio Grande, Rio Pirai and Rio Yapacani mentioned in the Master Plan should be carried out to support the regional development.

TABLES

TABLE 1 SUMMARY OF LAND USE PLAN

Zone	Name	Main production	Natural conditions	Type of inundation	Problem of agriculture	Countermeasure for inundation	Alleviationeffect for inundation**	Countermeasure for agriculture	Target of agriculture development
1	Low precipitation area (Cotoca)	cattle ,cotton, sugar cane, Soybean	soil consisting of sand and silt,Low precipitation (1,300mm)	Uncommon (D)	- Disparity of farm income by size, - Drought	-	-	Introduction of high productive crop for small scale farmer	High productive area
2	Intensive upland crop area (Okinawa)	soybean , rice, maize, wheat, cattle	Fertile alluvial soil, Low precipitation(1,300mm)	Flood and drainage (B,C)	- Degradation of soil fertility	-Protection of overflow -Drainage improvement	A,B	Introduction of appropriate crop rotation and diversification	Diversified crop production area
3	Sugar cane production area (Montero)	sugar cane, cattle	Fertile alluvial soil, Medium precipitation(1,300-1,800mm)	Flood and drainage (B,C)	-Decreasing productivity by continuous cropping	-River improvement -Drainage improvement	A,B	Introduction of appropriate crop rotation, diversification	Diversified crop production area
4	Local colony -1 (Minero)	Sugar cane, rice	Fertile alluvial soil, Medium precipitation(1,300-1,800mm)	Flood (A)	- Severe flood damage	-River improvement	C	Introduction of water tolerant variety or crop	Stable production area
5	New developed upland crop area (Chane)	soybean, sugar cane, rice	Fertile alluvial soil, Medium precipitation(1,300-1,800mm)	Flood (A)	- Severe flood damage	-Protection of overflow	C,D	Introduction of water tolerant variety or crop	Stable and high productivity area
6	Intensive diversified agricultural area (San Juan)	rice ,egg soybean , cattle, fruits	Poor drainagesoil, High precipitation(more than 1,800mm)	Drainage (B)	- Poor drainage of soil	-Drainage improvement	A	Expansion of perennial crop	Intensive mixed farming area
7	Local colony-2 (Anto Fagasta)	soybean,rice, cattle	Poor drainage, High precipitation (more than 1,800mm)	Drainage (B)	- Poor drainage - Damage of rat	-Drainage improvement	B	Introduction of high productive crop	Stable production area
8	Grazing area (Chane)	cattle ,soybean	Low fertile soil, Medium precipitation (1,300-1,800mm)	Uncommon (D)	- Low fertility	-	-	Introduction of high productive pasture	Intensive cattle raising area
9	Forest area (Sara)	timber,cattle	Low fertile soil, High precipitation (more than 1,800mm)	Partially flood (B,C,D)	- Decreasing of useful timber	-Local drainage improvement	D	Reforestation of useful tree	High productive forest area

* :Severity of inundation=A>B>C>D

**:Alleviationeffects for inundation=A>B>C>D

TABLE 2 CONSTRUCTION SCHEDULE OF CHANE-PAILON

ALTERNATIVE I

Sub-Project	Const. Volume	Year 0	1	2	3	4	5	6	7	8	9	10
1.RIO CHANE BASIN												
Rio Chane	27.0km											
2. RIO PAILON BASIN												
Rio Pailon	32.0km											
Main Drainage	6.5km											
Secondary Drainage	50.0km2											
3. CHANE CHACRAS BASIN												
Queb. Las Chacras	36.5 km											
Main Drainage	21.5 km											
Secondary Drainage	284.0km2											
4. QUEBRADA CHANE BASIN												
Queb. Chane	18.0km											
Queb. El Toro	16.0km											
Main Drainage	8.0km											
5. OKINAWA DRAINAGE BASIN												
Main Drainage	21.0km											
Secondary Drainage	147.0km2											

TABLE 3 CONSTRUCTION SCHEDULE OF SAN JUAN-ANTOFAGASTA

ALTERNATIVE I

Sub-Project	Const. Volume	Year										
		0	1	2	3	4	5	6	7	8	9	10
1.SAN JUAN BASIN												
Arroyo Yapacanicito	14.1km											
Main Drainage	41.3km											
Secondary Drainage	115.0km2											
2. ANTOFAGASTA BASIN												
Arroyo Tacuaral	7.7km											
Arroyo Jochi	12.6km											
Road -	9.0km											
Main Drainage	10.0km											
Secondary Drainage	121.0km											

TABLE 4 CONSTRUCTION SCHEDULE OF CHANE-PAILON

ALTERNATIVE II

Sub-Project	Const. Volume	Year 0	1	2	3	4	5	6	7	8	9	10
2. RIO PAILON BASIN												
Rio Pailon	32.0km											
Main Drainage	6.5km											
Secondary Drainage	50.0km2											
3. CHANE CHACRAS BASIN												
Queb. Las Chacras	36.5 km											
Main Drainage	21.5 km											
Secondary Drainage	284.0km2											
4. QUEBRADA CHANE BASIN												
Queb. Chane	18.0km											
Queb. El Toro	16.0km											
Main Drainage	8.0km											
5. OKINAWA DRAINAGE BASIN												
Main Drainage	21.0km											
Secondary Drainage	147.0km2											

TABLE 5 CONSTRUCTION SCHEDULE OF SAN JUAN-ANTOFAGASTA

ALTERNATIVE II

Sub-Project	Const. Volume	Year 0	1	2	3	4	5	6	7	8	9	10
1.SAN JUAN BASIN												
Arroyo Yapacanicito	14.1km											
Main Drainage	41.3km											
Secondary Drainage	115.0km2											
2. ANTOFAGASTA BASIN												
Arroyo Tacuaral	7.7km											
Arroyo Jochi	12.6km											
Road	9.0km											
Main Drainage	10.0km											
Secondary Drainage	121.0km											

TABLE 6 RESULTS OF PROJECT EVALUATION FOR FLOOD MITIGATION AND DRAINAGE IMPROVEMENT - ALTERNATIVE I

Ranking of Viability for Priority Projects : A: High B: Marginal C: Low

Project/Sub-project	Measures	Assessment								Project Viability	
		Technical Evaluation		Economic Evaluation		Social Impact		Environmental Impact			
				Feasibility	EIRR (%)	Impact	Protected Area (km2)				
A. EASTERN AREA											
A-1 CHANE - PAILON	**Structural with non-structural measures**	**Highly Effective**	A	**Feasible**	**11.04** A	**High Impact**	**470.1** A	**Negligibly small**	B	**High viability**	A
1) Rio Chane	- ditto -	As the main stream area, indispensable for avoiding any adverse effect. More effective with flood control of the Rio Piray.	A	Not feasible	negative C	Same as present	0.0 B	Same as present	B	High viability for avoiding any adverse effect. More effective with flood control of the Rio Piray.	A
2) Rio Pailon	- ditto -	Indispensable as the main stream area	A	Highly feasible	14.33 A	High impact	117.8 A	Negligibly small	B	High viability as the main stream area	A
3) Quebrada Chane	- ditto -	Effect to only limited area of the tributary area	C	Feasible	12.52 A	Medium impact as the extensive landuse area	54.0 B	Negligibly small	B	Low viability as the tributary area	C
4) Chane - Chacras	- ditto -	High necessity as the tributary area	B	Highly feasible	15.38 A	High impact as wide effective area	226.4 A	Negligibly small	B	Medium viability as the tributary area	B
5) Okinawa Drainage	- ditto -	High necessity as the major drainage area	A	Feasible	12.21 A	High impact as the intensive landuse area	71.9 A	Negligibly small	B	High viability as the major drainage area	A
A-2 SOUTHERN PART	**Non-structural Measures**	**Highly Effective**		-		**High impact**		-		**High viability**	
A-3 RIO GRANDE DOWNSTREAM	**Non-structural Measures**	**Highly effective**		-		**High impact**		-		**High viability**	
B. WESTERN AREA											
B-1 SAN JUAN - ANTOFAGASTA	**Structural with non-structural measures**	**Highly effective**	A	**Feasible**	**13.41** A	**High impact**	**210.3** A	**Negligibly small**	B	**High viability**	A
1) San Juan	- ditto -	Necessary	B	Marginal	9.97 B	High impact as the intensive landuse area	81.4 A	Negligibly small	B	High viability	A
2) Antofagasta	- ditto -	Indispensable	A	Highly feasible	16.24 A	High impact as the local colony	128.9 A	Negligibly small	B	High viability	A
B-2 PALACIOS - PALOMETILLAS	**Non-structural Measures**	**Effective**		-		**Medium impact**		-		**Medium viability**	
C. RIO PIRAY	-	**Flood control measures necessary**		-		-		-		-	

Note: 1) Protected area is the mitigated area by flood control and drainage improvement for the 10-year floods.

TABLE 7 RESULTS OF PROJECT EVALUATION FOR FLOOD MITIGATION AND DRAINAGE IMPROVEMENT - ALTERNATIVE II

Ranking of Viability for Priority Projects : A: High B: Marginal C: Low

	Project/Sub-project	Measures	Assessment								Project Viability	
			Technical Evaluation		Economic Evaluation			Social Impact			Environmental Impact			
					Feasibility	EIRR (%)		Impact	Protected Area (km2)					
A.	**EASTERN AREA**													
A-1	**CHANE - PAILON**	**Structural with non-structural measures**	**Highly Effective**	A	**Feasible**	**14.00**	A	**High Impact**	**470.1**	A	**Negligibly small**	B	**High viability**	A
1)	Rio Chane	Non-structural measures	Highly effective		-	-		High impact	-		-		High viability	
2)	Rio Pailon	Structural with non-structural measures	Indispensable as the main stream area	A	Highly feasible	14.33	A	High impact	117.8	A	Negligibly small	B	High viability as the main stream area	A
3)	Quebrada Chane	- ditto -	Effect to only limited area of the tributary area	C	Feasible	12.52	A	Medium impact as the extensive landuse area	54.0	B	Negligibly small	B	Low viability as the tributary area	C
4)	Chane - Chacras	- ditto -	High necessity as the tributary area	B	Highly feasible	15.38	A	High impact as wide effective area	226.4	A	Negligibly small	B	Medium viability as the tributary area	B
5)	Okinawa Drainage	- ditto -	High necessity as the major drainage area	A	Feasible	12.21	A	High impact as the intensive landuse area	71.9	A	Negligibly small	B	High viability as the major drainage area	A
A-2	**SOUTHERN PART**	**Non-structural Measures**	**Highly Effective**		-			**High impact**			-		**High viability**	
A-3	**RIO GRANDE DOWNSTREAM**	**Non-structural Measures**	**Highly effective**		-			**High impact**			-		**High viability**	
B.	**WESTERN AREA**													
B-1	**SAN JUAN - ANTOFAGASTA**	**Structural with non-structural measures**	**Highly effective**	A	**Feasible**	**12.51**	A	**High impact**	**206.1**	A	**Negligibly small**	B	**High viability**	A
1)	San Juan	- ditto -	Necessary	B	Marginal	8.48	B	High impact as the intensive landuse area	77.2	A	Negligibly small	B	High viability	A
2)	Antofagasta	- ditto -	Indispensable	A	Highly feasible	16.24	A	High impact as the local colony	128.9	A	Negligibly small	B	High viability	A
B-2	**PALACIOS - PALOMETILLAS**	**Non-structural Measures**	**Effective**		-			**Medium impact**			-		**Medium viability**	
C.	**RIO PIRAY**	-	**Flood control measures necessary**		-			-			-		-	

Note: 1) Protected area is the mitigated area by flood control and drainage improvement for the 10-year floods.