SUPPORTING REPORT F

FLOOD MITIGATION

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1. General

Flood mitigation plan for the study area was studied. The basic information for formulating flood mitigation plan includes conditions of flood damage, landuse, hydrology, river characteristics and related plans and facilities with flood mitigation. The latter two items are described in the first.

Flood mitigation plan that is composed of structural measures and non-structural measures was formulated. Finally, necessary items to be studied in the future are described.

2. River Characteristics

2.1 River System

The study area is bounded by the Río Grande in the east, Río Piray in the center and Río Yapacani in the west. Río Chané Basin, Río Palometillas Basin and Río Palacios Basin are existing between the above three rivers. Catchment areas of the Río Chané, Río Palometillas and Río Palacios basins are 2,271 km^2, 878 km^2 and 1,827 km^2 respectively. Those of the Río Grande, Río Piray and Río Yapacani basins in the study area are 1,248 km^2, 1,165 km^2 and 536 km^2 respectively.

The major rivers of Río Chané Basin are the Río Chané, Río Pailón, Quebrada Chané, Quebrada Las Chacras. Those of Río Palometillas Basin are the Río Palometillas, Arroyo Quimori. The major rivers of Río Palacios Basin are the Río Palacios, Arroyo Tacuaral, Arroyo Jochi. Arroyo Yapacanicito and Tejeria are belonging to the Río Yapacani Basin. Location and catchment areas of the river basins of the study area are shown in the Supporting Report A.

2.2 River Topography

Fig. F.2.1 shows the topography of the river basins as well as river bed slopes of the major rivers in the study area. *Fig. F.2.2* shows typical sizes of river cross sections of the major rivers.

(1) Eastern Part

In the eastern part of the study area, ground elevation is higher in the south-western direction and lower in the north-eastern direction.

In the Río Chané Basin, the Arroyo Los Sauces-Río Pailón-Río Chané flow around the lowest portion of the topography. They have the longest distance about 140 km between the junction of the Río Piray with the Río Chané and Santa Cruz de La Sierra. They form the main stream of Río Chané Basin. Quebrada Chané, Quebrada El Toro and Quebrada Las Chacras are the major tributaries of the main stream. Up-stream and mid-stream reaches of the Quebrada Las Chacras locate in the higher portion than the Quebrada Chané and Quebrada El Toro. In the upstream basins from the National Road No.9, there are several swampy areas.

Due to the heavy sediment discharge and deposition, natural levees are formed along the Río Grande. River bed elevation of the Río Grande is slightly higher than that of the Río Pailón as well as the Río Chané in the downstream reaches from Okinawa II. The drainage basin of Okinawa I belongs to the Río Grande Basin.

As shown in *Fig. F.2.1*, river bed slopes in the downstream reaches from the National Road No.9 are relatively small. The sizes of the river cross sections are rather small compared to the sizes of the river basins (refer to *Fig. F.2.2*).

(2) Central Part

In the central part, the Río Piray main stream is existing. In the downstream reaches from the National Road No.7, the Río Piray has changed its river course to the Río Honda since 1983 Floods. The river course of these downstream reaches of the Río Piray is still unstable due to the heavy sediment discharge and deposition as well as frequent floods.

(3) Western Part

Contour line of the ground elevation of the western part is parallel. Elevation is higher in the southern portion and lower in the northern portion. At the northern boundary of the study area around Santa Rosa del Sara, a mountainous area is existing.

The Río Palometillas flows to north-west direction. Around the junction of the Río Palometillas with Arroyo Quimori, a low-lying area is existing.

The Río Palacios goes around to north-western direction. Around the junction of the Río Palacios with Arroyo Tacuaral as well as Arroyo Jochi, a big swampy area is existing. At the junction of the Arroyo Tacuaral with the Arroyo Jochi, a swampy area is also formed.

As the Arroyo Jochi is flowing near the mid-stream of Arroyo Yapacanicito, Arroyo Yapacanicito is affected by the flood water of the Arroyo Jochi. Along the Río Yapacani, meandering is progressing in the downstream reaches from the National Road No.7.

River bed slopes of the major rivers are almost same as ground slope except the most downstream reaches. The slopes are about 1/700 to 1/1000 as shown in *Fig. F.2.1.* Typical sizes of the river cross sections are also small compared to the sizes of the river basins as shown in *Fig. F.2.2.*

2.3 Flow Capacity

As described in the Supporting Report C, floods are observed annually in the study area. Flow capacities of the rivers in the study area are rather smaller than the annual flood discharges. Flow capacities of the major rivers in the study area were checked by using uniform flow calculation. Considering the present river conditions, the adopted Manning's roughness coefficients of the existing rivers are 0.035 for the rivers in the Río Chané Basin, Río Grande and Río Yapacani and 0.040 for the Arroyo Yapacanicito, Jochi, Tacuaral and Tejeria. *Fig. F.2.3* shows the calculated flow capacities of these rivers.

2.4 Sediment Transport

The study area is located in the alluvial plains formed by the Río Grande, Río Piray, Río Yapacani and other rivers. These three rivers are active in sediment production, transportation and deposition.

The study report on "The Master Plan for Management and Training of the Río Piray Basin in 1991" discussed the sediment deposition and morphology. According to the report, the stretch from the confluence of the Río Grande to the railway bridge has strong deposition of sediment. The situation of sedimentation along the main stream from La Angostura to the confluence with the Río Chané, with a river stretch of 170 km, was reported as follows;

River Stretch	Sedimentation
A. La Angostura to La Guardia:	Morphological equilibrium
B. La Guardia to Río Guenda Confl.:	Low deposition, 2.6 mm/year
C. Río Guenda Confl. to the railway bridge:	Strong deposition, 35 mm/year
D. The railway bridge to Río Chané Confl.:	Medium deposition, 7 mm/year

3. Related Plans and Facilities

3.1 Related Plans and Projects

There are three projects that are related to this project. They are the "Flood Protection Project for the Río Piray", "Improvement of the National Road No.9" and the "Bridge Construction Project for the National Road No.9".

(1) Flood Protection Project for the Río Piray

SEARPI prepared to start the detailed design of the priority project by assistance of EC. The design work will undertake Section-A and part of Section-B around Montero that are among three sections recommended in the feasibility study. The major works are as follows:

Work Item	Section-A	Section-B
1. Dike construction	58.0 km	31.9 km
2. Bank Protection		
Type-A	29.5 km	
Type-B	7.8 km	
Soil cement	2.7 km	0.2 km
3. Excavation	3.2 M m^3	0.7 M m^3

(2) Improvement of the National Road No.9

SNC is implementing the "Road Improvement Project Second Phase (1992 - 1995)" under the financial assistance of the International Development Association (IDA).

This project includes the improvements of major roads with total length of 1,546.8 km composed of paved road of 781.4 km and un-paved road of 765.4 km. Improvement of bridges is included in this project but new construction of bridges is not included. Road improvement between Guabira and Okinawa is one of the component of this project. Its major works are as follows;

1. Guabira - Km 24 (length 24 km)
    1) Raising of road: 30 cm height
    2) Pavement: 2.5 cm thickness
    3) Cross drainage: corrugated steel pipe at 28 places

2. Km 24 - Okinawa I (length 23 km)
    1) Raising of road: 45 cm height
    2) Pavement: 2.5 cm thickness
    3) Cross drainage: corrugated steel pipe at 25 places

(3) Bridge Construction Project for the National Road No.9

The project is ongoing by JICA grant aid. The construction works started in October 1995. The project is consisting of seven bridges that are planned at the river crossings between Guabira and Okinawa of the National Road No.9. They are as follows;

Name of Bridge	Location	Length
1. Las Chacras:	Tributary of Río Chané	25.80 m
2. Las Maras:	Tributary of Río Chané	51.55 m
3. El Toro:	Tributary of Río Chané	77.30 m
4. El Empalme II:	Tributary of Río Pailón	25.80 m
5. Chaco:	Tributary of Río Pailón	51.55 m
6. Rancho Chico:	Tributary of Río Pailón	25.80 m
7. Pailón:	Río Pailón	92.30 m

3.2 Existing Facilities

Existing facilities related to the flood control and drainage improvements in the study area are described below.

(1) Facilities for Flood Control and Drainage Improvement

Along the Río Piray, there are flood embankments with length of 15 km that was designed in 1987 and constructed in 1993 to protect the city of Santa Cruz. There are main drainage channels in Okinawa I (total length 20.0 km), Okinawa II (total length 5.0 km) and Colonia San Juan de Yapacani (total length 32.0 km).

(2) Bridges and Culverts

Major bridges and culverts in the study area were shown in *Table F.3.1* and *Fig. F.3.1*.

4. Flood Mitigation and Drainage Improvement Measures

Flood mitigation and drainage improvement measures are composed of structural measures and non-structural measures. Structural measures will be applied for the area that has severe flood damages. Non-structural measures will be applied for the area that has not significant flood problems. Areas for structural and non-structural measures were described in the first. Structural measures are described in the second. Non-structural measures are described in the third.

4.1 Flood Mitigation and Drainage Improvement Area

4.1.1 Structural Areas and Non-structural Areas

Fig. F.4.1 shows the structural and non-structural areas for flood mitigation and drainage improvements in the study area. According to the flood damage survey, the flood hazard ar as in the study area were divided into four categories by the causes of floods. They are,

1) Inundation by the Río Piray, Río Grande or Río Yapacani
2) Inundation by its own basin runoff with backwater effect of the Río Piray
3) Inundation by its own basin runoff with inflow water from the Río Piray, Río Grande or Río Yapacani
4) Inundation by its own basin runoff

Areas for structural measures and non-structural measures were selected considering the above categories of floods as well as landuse condition.

(1) Northen Area of the Eastern Part (Chané - Pailón)

In the eastern part of the study area, downstream areas from the National Road No.9 are belonging to the category 2) and 3). These areas have severe flood damage. These areas are the intensive agricultural lands for cultivation of soybean and sugar cane. Structural measures with non-structural measures for flood mitigation and drainage improvement will be necessary in this area.

(2) Southern Area of the Eastern Part

Upstream areas from the National Road No.9 of the eastern part are belonging to the category 3) and 4). These areas are also intensive agricultural lands for soybeans and sugar cane. Flood damages of these areas are not so severe compared to the northern area because the depth and duration of floods are smaller than those of northern area. Non-structural measures will be applied for these areas.

(3) Central Part

Central part of the study area is belonging to the category 1). Flood conditions of this part are necessary to be improved by the future flood mitigation plan of the Río Piray.

(4) San Juan and Antofagasta of Western Part (San Juan - Antofagasta)

These areas are belonging to the category 3) and 4). Colonia San Juan de Yapacani is an intensive diversified agricultural area of rice, egg and soybean. Antofagasta has agricultural potential and this area is important as local colony. As these areas have severe flood damage, structural measures with non-structural measures will be necessary.

(5) Eastern Area of the Western Part (Palacios - Palometillas)

Eastern area of the western part is belonging to the category 4). As the land is not used intensively and flood damage is not so severe, non-structural measures will be applied for this area.

4.1.2 Division of Structural Areas

The target areas of structural measures are divided by river or drainage basin into seven areas as shown in *Fig. F.4.2* and *Fig. F.4.3*. They are named as follows;

1) Río Chané - Pailón Area

a) Río Chané
b) Río Pailón
c) Chané - Chacras
d) Quebrada Chané
e) Okinawa Drainage

2) San Juan - Antofagasta Area

a) San Juan
b) Antofagasta

4.2 Structural Measures

Possible structural measure for flood mitigation and drainage improvement for the study area includes river improvement, retarding basins and road-cum-embankments. Their effects are as follows;

- River improvement works are to increase conveyance capacities of channels by widening, deepening and improving channels,

- Retarding basins are to reduce peak flow of floods,

- Road-cum-embankments are to have the effects both of flood embankments and roads

As the flood hazard area is mainly composed of agricultural lands, absolute mitigation of flood and drainage problems is unlikely feasible either physically and economically. In order to reduce the required size of the facilities of flood mitigation and drainage improvements, natural retarding effects of the swampy areas etc. are necessary to be utilized as much as possible.

4.2.1 Design Criteria

(1) Design Scale

The design scale of the flood mitigation and drainage improvement measures were decided based on the results of evaluation in technical, economic and social terms.

Relations between the design scale and (annual average protected area/required excavation volume of river improvement) were studied for the Chané - Pailón Area and San Juan - Antofagasta Area (see *Fig. F.4.4*). The river improvement works were supposed to be done to pass all of the probable runoff discharges of corresponding design scales without overflow (*Table F.4.1*). Annual average protected area is the statistical average of the areas within the design scale that will be protected by the river improvement. Annual average protected area corresponds to the benefit of flood mitigation and drainage improvement (*Table F.4.2*). Required excavation volume corresponds to the required energy or cost for the flood mitigation and drainage improvement (see *Table F.4.3*).

The results of the analysis are as follows;

1) The result of the analysis on Chané - Pailón Area shows that the most effective design scale for flood mitigation measures is between 5-year and 10-year flood frequencies.

2) The result of the analysis on San Juan - Antofagasta Area shows that the effective design scale is about 10-year flood frequency.

The design scale for flood mitigation and drainage improvement measures are planned as follows;

1) The design scale of flood mitigation facilities is decided to be 10-year frequency flood.

2) The design scale of drainage improvement facilities is decided to be 5-year storm runoff.

(2) Allowable Inundation Depth

For designing flood mitigation and drainage improvement facilities, an allowable inundation depth of 30 cm is considered based on the study of the flood damage for crops.

(3) Design River Cross Section

In order to utilize the natural retarding effect of the flood plain within the allowable inundation depth, the improved river cross sections were set as single excavation channels. Compound cross section that is composed of low water channel and high water channel with flood embankments was not applied for the river improvement.

4.2.2 Facility Planning of Chané - Pailón

(1) Alternative Plans

Fig. F.4.5 and *Fig. F.4.6* shows the concepts of Alternative I and Alternative II of facility plans for Chané - Pailón respectively.

1) Alternative I

Flood mitigation and drainage improvement measures are planned for the target area, including the Río Chané Area that is under the backwater effect of the Río Piray. The target area will be protected from floods by doing the river improvements and drainage improvement. Five swampy areas in the upstream basins from the National Road No.9 are proposed as the natural retarding basins.

The most downstream reaches of the Río Chané between the junction with the Río Piray and the most downstream road bridge near Puesto Fernandez (length 8.0 km) are belonging to the flood hazard area of the Río Piray main stream. River improvements of these most downstream reaches are necessary to be done in combination with the flood mitigation of the Río Piray. Necessary improvements of these reaches are shown in this study, but the construction cost and benefit of these reaches are excluded in the economic evaluation.

2) Alternative II

Flood mitigation and drainage improvement measures are planned for the target area, but without the structural measures for the backwater effect area by the Río Piray.

(2) River Improvement Plan

1) Alternative I

River improvement are planned for the following rivers (refer to *Fig. F.4.7* and *Table F.4.4*);

	River Improvement Reach	Length
a)	Río Chané (Jct. Río Piray to Jct. Río Pailón):	35.00 km
	- Jct. Río Piray to Downstream Road Bridge:	8.00 km
	- Downstream Road Bridge to Jct. Río Pailón:	27.00 km
b)	Río Pailón (Jct. Río Chané to Jct. A. Los Sauces):	32.00 km
c)	Quebrada Chané (Jct. Río Chané to Road No.9):	18.00 km
d)	Quebrada El Toro (Jct. Qda. Chané to Road No.9):	16.00 km
e)	Quebrada Las Chacras (Jct. Río Chané to Road No.9):	36.50 km

Fig. F.4.8 shows the design discharge of 10 year floods. *Table F.4.5* shows the required size of improved river cross sections. *Fig. F.4.9* shows the longitudinal profile of the river improvement.

2) Alternative II

River improvement are planned for the following rivers (see *Table F.4.4*);

	River Improvement Reach	Length
a)	Río Pailón (Jct. Río Chané to Jct. A. Los Sauces):	32.00 km
b)	Quebrada Chané (Jct. Río Chané to Road No.9):	18.00 km
c)	Quebrada El Toro (Jct. Qda. Chané to Road No.9):	16.00 km
d)	Quebrada Las Chacras (Jct. Río Chané to Road No.9):	36.50 km

Río Chané will not be improved by the Alternative II. River improvements of the other four rivers are same as the Alternative I. The design discharge distribution of the Alternative II is same as that of the Alternative I (see *Fig. F.4.10*).

(3) Drainage Improvement

Drainage improvement is composed of the improvement and newly construction of main drainage and secondary drainage (see *Fig. F.4.7* and *Table F.4.4*). Construction works of Alternative I and Alternative II are same.

	Drainage Improvement	Length/Area
a)	Drainage Main:	36.00 km
b)	Okinawa Drainage Main:	21.00 km
c)	Secondary Drainage:	481.00 km^2

Details are described in the Supporting Report G.

4.2.3 Facility Planning of San Juan - Antofagasta

(1) Alternative Plans

Fig. F.4.11 and *Fig. F.4.12* shows the concepts of Alternative I and Alternative II of facility plans for San Juan - Antofagasta respectively.

1) Alternative I

Flood mitigation and drainage improvements are planned in the target area. The existing drainage facilities in Colonia San Juan de Yapacani are to be rehabilitated.

2) Alternative II

Flood mitigation and drainage improvement measures are planned for the target area, including improvement works of the existing drainage facilities.

(2) River Improvement Plan

1) Alternative I

River improvement are planned for the following rivers (refer to *Fig. F.4.13* and *Table F.4.4*);

	River Improvement Reach	Length
a)	Arroyo Yapacanicito (Downstream bridge to existing drainage):	14.10 km
b)	Arroyo Jochi (Downstream Swamp to Mid-stream):	12.60 km
c)	Arroyo Tacuaral (Downstream Swamp to Mid-stream):	7.70 km

Fig. F.4.14 shows the design discharge of 10 year floods. *Table F.4.5* shows the required size of improved river cross sections. *Fig. F.4.15* shows the longitudinal profile of the river improvement.

2) Alternative II

The reaches of the river improvement are same as those of the Alternative I. *Fig. F.4.16* shows the design discharge of Alternative II.

(3) Drainage Improvement

Drainage improvement is composed of the improvement and newly construction of main drainage and secondary drainage. Details are described in the Supporting Report G.

1) Alternative I

Drainage improvements of Alternative I are as follows (see *Fig. F.4.13* and *Table F.4.4*);

	Drainage Improvement	Length/Area
a)	Main Drainage:	51.30 km
	- Rehabilitation of San Juan Drainage Main:	34.20 km
	- Improvement of Arroyo Tejeria:	7.10 km
	- Main Drainage of Antofagasta:	10.00 km
b)	Secondary Drainage:	212.00 km^2

2) Alternative II

Drainage improvements of Alternative II are as follows;

	Drainage Improvement	Length/Area
a)	Main Drainage:	51.30 km
	- Improvement of San Juan Drainage Main:	34.20 km
	- Improvement of Arroyo Tejeria:	7.10 km
	- Main Drainage of Antofagasta:	10.00 km
b)	Secondary Drainage:	212.00 km^2

(3) Road-cum-embankment

Road-cum-embankment is planned between the Arroyo Yapacanicito Basin and Arroyo Jochi Basin both for the Alternative I and Alternative II. 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 length of the road-cum-embankment is 9.0 km.

4.3 Non-structural Measures

Non-structural measures are consisting of such measures as flood proofing of building, reduction of flood runoff by landuse management, evacuation by flood warnings and flood plain management. Followings are the non-structural measures for flood mitigation as well as for drainage improvement proposed for the study area.

a. Non-structural Measures for Flood Mitigation

-1 Flood warning and evacuation system
-2 Flood proofing of settlement in flood hazard area
-3 Landuse control of retarding basins
-4 Preservation of protected forest along river channels
-5 Landuse management of farm lands in the flood hazard area

b. Drainage Improvement Measures

-1 Landuse management in the poor drainage area
-2 Introduction of water tolerant crop varieties in the poor drainage area

(1) Eastern Part

1) Southern Area

Southern area of the eastern part is mainly composed of the upper reaches of the Río Pailón, Quebrada Chané, Arroyo Los Sauces. Five retarding basins are proposed as a component of the structural measures.

The required non-structural measures for this area are as follows;

a) Conservation of the proposed retarding basins

In order to utilize and maintain retarding effect of natural swampy areas, conservation of the proposed five retarding basins is necessary. Among the five retarding basins, two of them locate in Arroyo Los Sauce basin and others locate in upstream basin of the Quebrada Chané, upstream basin of the Río Pailón and Quebrada Meco basin. Total area of the retarding basins is 141.5 km^2.

Appropriate regulations in legal basis are required to be prepared and applied for prohibiting any land reclamation which may reduce the retarding effect of the above five swampy areas. If any development activities is necessary, maintaining the existing retarding capacity by considering multipurpose use of the retarding basins will be required.

b) Landuse management to reduce flood runoff

In general, land development such as cutting of woods and plants as well as filling of natural undulation of land is necessary for human activity such as urban development and agricultural development. However, from the flood control point of view, excess land development will make faster and bigger the rainfall runoff and flood discharge. In order to control the rainfall runoff and flood discharge by natural retarding effect, areas with woods and plants as well as undulation are desirable to be kept as much as possible.

In order to control rainfall runoff, landuse management is necessary for maintaining the areas with natural woods and plants. Furthermore, the necessary guideline is to be prepared to preserve the existing agricultural area against excessive enlargement and development of urbanized area such as Santa Cruz City in future.

c) Flood plain management including improvement of farming system by introducing water tolerant variety crop in the flood haz d area

Especially for the areas that encounter annual inundation, flood plain management is necessary for reducing flood damage caused by inappropriate landuse and farming system. Flood plain management includes activities such as delineation and declaration of potential flood hazard area, guidance on landuse pattern and improvement of farming system such as introducing water tolerant variety of crop.

d) Flood warning and evacuation system

Strengthening of meteo-hydrological observation system such as rainfall and water level measurement of rivers is necessary not only for the southern area but also for the whole study area. Flood warning and evacuation system is to be formulated and applied. Flood warning and evacuation system includes followings;

- Meteo-hydrological observation including rainfall and water level measurements
- Broadcasting flood warnings
- Designation of evacuation shelters and guiding people evacuated from floods

2) Northern Area (Chané - Pailón)

In the Chané - Pailón Area, flood condition of the Río Chané area will not be improved even by the planned structural measures. Non-structural measures are required for the area including the Río Chané Area. The necessary non-structural measures for Chané - Pailón are as follows;

a) Flood plain management including improvement of farming system in the flood hazard area especially for the Río Chané and the areas along the rivers where inundation would continue to occur.

Even with the implementation of the flood mitigation and drainage improvement measures, there would remain some areas, especially those located along the rivers, where inundation would continue to occur. Furthermore, inundation condition in the Río Chané area will not be improved very much without the river improvement of the Río Piray.

Flood plain management is necessary for the above areas. Flood plain management includes delineation and declaration of potential flood hazard area, landuse guidance and improvement of farming system such as introducing water tolerant crop variety.

b) Flood warning and evacuation system

As the design scale of flood mitigation measures is 10 year return period of floods, wide inundation would occur due to floods larger than 10 year return period. Furthermore, inundation would continue to occur in some areas along the rivers as well as the Río Chané area even by the 10 year floods.

Flood warning and evacuation system is necessary to be formulated and applied. Evacuation roads are also to be included in the system.

c) Flood proofing especially for the Río Chané Area

Even in the area like Río Chané area where habitual inundation occurs, there exists residential houses. In order to mitigate damage to building from floods, guidance on flood proofing such as raising of foundation of houses and roads is necessary to be introduced. Furthermore, relocation of houses is also to be considered.

(2) Western Part

1) Western Area (San Juan - Antofagasta)

The required non-structural measures for this area are as follows;

a) Conservation of the swampy area at the junction of the Arroyo Jochi and Arroyo Tacuaral

At the junction of the Arroyo Jochi and Arroyo Tacuaral, there is a natural swampy area. Flood waters from these rivers, once enter into the swampy area, exit the downstream reaches. The swampy area acts as one of the hydraulic boundary between the upstream to middle stream and downstream reaches. Furthermore, it acts as a regulating pond for the downstream reaches.

In order to preserve the above functions of the swampy area, appropriate regulation and management with the necessary legal basis are to be under taken. If any development is necessary in future, maintaining the present retarding capacity and multipurpose use of the area will be required.

b) Landuse management to reduce the flood runoff from upper reaches

In order to control rainfall runoff by using natural retarding effect of the areas with woods and plants, landuse management is necessary to be applied.

c) Flood plain management including improvement of farming system in the flood hazard area especially for the downstream area of the Arroyo Yapacanicito and the areas along the rivers where inundation would continue to occur.

Even if the flood mitigation measures are implemented, some inundation would continue to occur in the upper and downstream reaches of the Arroyo Yapacanicito, Jochi and Tacuaral.

Flood plain management is necessary for the areas where inundation would continue to occur. Flood plain management includes declaration of potential flood hazard area and improvement of farming system such as introducing water tolerant variety.

d) Flood warning and evacuation system

Even with implementation of the flood mitigation measures some inundation would continue to occur including inundation of a wide area under larger floods.

Therefore, flood warning and evacuation system is necessary. Evacuation road is also to be included in the system.

2) Eastern Area (Palacios - Palometillas)

The required non-structural measures for the Palacios - Palometillas area are as follows;

a) Flood plain management in the potential flood hazard area

There are some habitual inundation area along the upstream and downstream reaches of the Río Palacios and the downstream reaches of the Río Palometillas. Even though landuse of the eastern part is not so intensive, flood plain management including improvement of farming system is necessary to be introduced.

b) Landuse management

As this area is forest at present, rainfall is retarded naturally. In order to retain this natural retarding effect, landuse management including guidance for conservation of forest cover is necessary. This is also in accordance with the proposed future landuse of this area as forest cover.

c) Flood warning and evacuation system

Flood warning and evacuation system is necessary to be introduced for the potential flood hazard areas.

5. Study Items for the Future

A master plan of flood mitigation and drainage improvement for the study area was formulated as described in the above chapters. In order to improve the quality of the Master Plan as much as possible, following items are necessary to be studied in the future as well as the feasibility studies for the two priority areas of Chané - Pailón and San Juan - Antofagasta.

1) Flood control studies of the Río Grande, Río Piray (downstream reaches) and Río Yapacani

2) Detail strategy of flood plain management

3) Detail strategy of landuse management including conservation of retarding basins

4) Detail strategy of flood warning and evacuation system

5) Detail strategy of flood proofing

TABLES

TABLE F.3.1 EXISTING MAJOR BRIDGES AND CULVERTS ALONG RIVERS

No.	River System / River	Structural Type	Bridge Dimension L(m)	Bridge Dimension W(m)	Bridge Dimension H(m)	Culvert Dimension	Remarks
	Rio Grande						
Gr-1	Rio Grande	Steel Truss Bridge	1,200.0	7.4	6.0		.@Span=68m
2	Qda. Cotoca	Wooden Bridge	8.5	4.5	2.6		1-span
3	Qda. Cotoca	Wooden Bridge	10.5	4.5	1.8		1-span
4	Qda. Churia	RC-Bridge	9.5	5.7	4.5		1-span
5	Qda. Ajal	RC-Pipe Culvert	(15.0)	(4.0)	(1.4)	D-1.0 m x 2 pipes	
6	Qda. Ajal	RC-Box Culvert	(8.0)	(6.0)	(1.8)	W-2.7 m x H-1.8 m x 3 boxes	
7	Qda. Alal	RC-Box Culvert	(6.2)	(4.0)	(1.9)	W-3.1 m x H-1.9 m x 2 boxes	
8	Qda. Alal	RC-Box Culvert	(6.2)	(2.0)	(2.3)	W-1.0 m x H-1.0 m x 1 box	
9	Qda. S/Nombre	RC-Pipe Culvert	(8.0)	(2.0)	(1.5)	D-1.0 m x 1 pipe	
10	Qda. S/Nombre	RC-Box Culvert	(6.2)	(1.0)	(1.5)	W-0.5 m x H-0.5 m x 1 box	
11	Qda.Okinawa	RC-Box Culvert	(17.0)	(6.3)	(2.8)	W-2.1 m x H-2.8 m x 2 boxes	
12	Qda.Okinawa	RC-Box Culvert	(6.0)	(5.5)	(3.0)	W-1.95 m x H-3.0 m x 2 boxes	
	Rio Chane						
Ch-1	Rio Pailon	RC-Bridge	28.0	6.0	7.0		3-spans
2	Rio Pailon	RC-Bridge	24.5	5.5	6.0		3-spans
3	Qda. S/Nombre	Wooden Bridge	6.0	3.2	1.7		1-span
4	Qda. Honda	RC-Pipe Culvert	(9.0)	(5.0)	(3.2)	D-1.5 m x 1 pipe	
5	Qda.Asafran	Wooden Bridge	5.5	4.2	2.6		1-span
6	Qda.Asafran	RC-Pipe Culvert	(6.5)	(3.5)		D-1.0 m x 2 pipes	
7	Qda.Asafran	Wooden Bridge	12.0	5.0	4.0		2-spans
8	Qda.Asafran	Wooden Bridge	6.4	3.9	2.8		3-spans
9	Qda.Asafran	Wooden Bridge	20.0	3.5	1.9		4-spans
10	Qda.Asafran	Wooden Bridge	20.0	3.6	5.2		1-span
11	Rio Pailon	RC-Bridge	28.0	8.0	7.0		1-span
12	Rio Pailon	Wooden Bridge	26.0	4.0	4.5		4-spans
13	Qda.Chane	RC-Pipe Culvert	(7.0)	(4.5)	(1.6)	D-1.3 m x 2 pipes	
14	Qda. S/Nombre	RC-Bridge	10.7	3.7	3.9		1-span
15	Qda.Chane	RC-Box Culvert	(5.3)	(13.8)	(2.6)	W-5.3 m x H-2.3 m x 1 box	
16	Qda.Chane	RC-Bridge	23.0	8.0	4.5		1-span
17	Qda. El Toro	RC-Bridge	22.5	8.0	5.5		1-span
18	Rio Chane	Wooden Bridge(Truss)	22.0	4.0	9.0		1-span
19	Rio Chane	Wooden Bridge	8.2	4.0	3.5		1-span
20	Rio Chane	RC-Box Culvert	(2.5)	(9.0)	(2.0)	W-2.5 m x H-2.0 m x 1 box	
21	Qda. S/Nombre	Wooden Bridge	5.0	4.5	2.0		1-span
22	Rio Chane	RC-Bridge	12.0	3.5	4.2		1-span
23	Rio Chane	RC-Bridge	68.5	8.5	40.0		3-spans
24	Rio Linares	RC-Bridge	24.0	5.0	3.0		3-spans
25	Rio Linares	RC-Bridge	15.2	3.5	4.2		1-span
	Rio Pilai						
Pi-1	Rio Pirai	Steel Truss Bridge	300.0	7.0	9.7		.@Span=60m
2	Rio La Madre	RC-Bridge	38.3	7.6	7.9		1-span
3	Rio Pirai	RC-Bridge	92.5	8.4	11.5		2-spans
4	Rio Honda	RC-Pipe Culvert	(12.5)	(5.0)	(2.7)	D-2.1 m x 2 pipes	
5	Rio Vibosi	RC-Pipe Culvert	(9.5)	(11.0)	(1.6)	D-1.0 m x 2 pipes	
6	Rio Honda	Wooden Bridge	5.6	2.8	1.5		1-span
7	Rio Honda	RC-Pipe Culvert	(5.0)	(4.0)	(2.7)	D-1.2 m x 2 pipes	
	Rio Palometillas						
Pm-1	Rio Asuuicito	RC-Box Culvert	(9.5)	(8.0)	(2.3)	W-2.5 m x H-1.8 m x 3 boxes	
2	Rio Asuuicito	RC-Bridge	19.7	5.0	3.5		1-span
3	Rio Palometilla	Wooden Bridge	19.6	4.6	4.9		4-spans
4	Arry. Quimori	RC-Bridge	46.0	8.2	10.0		1-span
5	Arry. Quimori	Wooden Bridge	20.0	5.0	4.8		4-spans
6	Rio Palacios-Taca	RC-Pipe Culvert	(11.8)	(4.1)	(5.3)	D-2.0 m x 2 pipes	
7	Rio Palacios-Taca	Wooden Bridge	20.0	5.0	4.3		4-spans
	Rio Palacios						
Pc-1	Qda.Palometilla	RC-Bridge	26.0	8.2	8.0		1-span
2	Qda.Palometilla	RC-Bridge	9.9	4.0	3.2		1-span
3	Qda.Palometilla	RC-Bridge	35.0	7.4	5.0		3-spans
4	Rio Palacios	Steel Truss Bridge	52.0	5.0	11.0		1-span
5	Arry.Piquiricito	Wooden Bridge	7.4	5.5	2.5		1-span
	Rio Yapacani						
Ya-1	Rio Yapacani	RC-Bridge	700.0	7.5	11.0		.@Span=40m
2	Arry.Tejeria	RC-Bridge	7.0	8.0	4.6		1-span
3	Arry.Yapacanicito	RC-Bridge	5.0	4.5	5.6		1-span

TABLE F.4.1

DESIGN CROSS SECTIONS OF PROBABLE FLOODS FOR THE DETERMINATION OF DESIGN SCALE

River	Length	2 - Year			5 - Year			10 - Year			20 - Year			50 - Year		
	(km)	Q	W	D	Q	W	D	Q	W	D	Q	W	D	Q	W	D
A. CHANE-PAILON																
1) Rio Chane	12.50	950	97.0	6.0	1213	119.0	6.0	1500	142.0	6.0	1777	164.0	6.0	2143	193.0	6.0
	22.50	791	73.0	6.0	978	85.0	6.0	1212	101.0	6.0	1431	116.0	6.0	1718	135.0	6.0
2) Rio Pailon	24.00	591	70.0	5.0	738	84.0	5.0	908	99.0	5.0	1073	114.0	5.0	1278	132.0	5.0
	8.00	663	64.0	5.0	809	75.0	5.0	995	88.0	5.0	1173	101.0	5.0	1404	117.0	5.0
3) Qda. Chane	3.80	407	44.0	4.5	483	49.0	4.5	584	57.0	4.5	681	64.0	4.5	807	72.0	4.5
	14.20	226	36.0	3.5	293	44.0	3.5	353	50.0	3.5	410	56.0	3.5	485	64.0	3.5
4) Qda. El Toro	16.00	328	53.0	4.0	420	64.0	4.0	503	74.0	4.0	583	84.0	4.0	688	96.0	4.0
5) Qda. Las Chacras	20.50	262	44.0	3.0	365	57.0	3.0	440	67.0	3.0	513	76.0	3.0	607	68.0	3.0
	16.00	199	36.0	3.0	270	45.0	3.0	326	52.0	3.0	379	59.0	3.0	449	68.0	3.0
B. SAN JUAN - ANTOFAGASTA																
1) Arroyo Yapacanicito	2.80	141	35.0	3.0	181	42.0	3.0	213	47.0	3.0	244	53.0	3.0	284	59.0	3.0
	11.30	111	29.0	3.0	140	35.0	3.0	165	39.0	3.0	189	43.0	3.0	220	48.0	3.0
2) Arroyo Jochi	8.40	162	30.0	0.5	163	30.0	3.5	194	34.0	3.5	225	37.0	3.5	263	42.0	3.5
	4.20	112	22.0	3.5	148	25.0	3.5	174	28.0	3.5	200	30.0	3.5	232	33.0	3.5
3) Arroyo Tacuaral	7.70	169	26.0	4.0	164	26.0	4.0	194	28.0	4.0	223	30.0	4.0	260	33.0	4.0

NOTE: Q: Design discharge (m3/s)
W: Surface width of channel (m)
D: Depth of channel (m)

TABLE F.4.2 ANNUAL AVERAGE PROTECTED AREA OF PROBABLE FLOODS FOR THE DETERMINATION OF DESIGN SCALE

1. CHANE-PAILON (Unit: km2)

Area	Design Scale (Year)				
	2	5	10	20	50
1) Rio Chane	93.3	106.0	107.4	107.4	107.4
2) Rio Pailon	107.4	182.6	190.0	197.7	209.3
3) Qda. Chane	56.9	81.1	100.7	112.4	123.2
4) Chane-Chacras	233.1	296.8	318.9	318.9	318.9
Total Protected Area	490.7	666.5	717.0	736.4	758.8
Annual Average Protected Area	245.3	378.7	450.4	487.2	502.3

2. SAN JUAN-ANTOFAGASTA (Unit: km2)

Area	Design Scale (Year)				
	2	5	10	20	50
1) San Juan	60.6	99.4	118.5	132.5	150.8
2) Antofagasta	128.0	160.1	180.8	197.4	217.6
Total Protected Area	188.6	259.5	299.3	329.9	368.4
Annual Average Protected Area	94.3	146.2	176.1	192.6	200.0

TABLE F.4.3 EXCAVATION VOLUME OF RIVER IMPROVEMENT OF PROBABLE FLOODS FOR THE DETERMINAION OF DESIGN SCALES

River	Length	Excavation Volume (1000m3)				
	(km)	2 - Year	5 - Year	10 - Year	20 - Year	50 - Year
A. CHANE-PAILON						
1)Rio Chane	12.50	6,375	8,025	9,750	11,400	13,575
	22.50	8,235	9,855	12,015	13,354	16,605
2) Rio Pailon	24.00	7,200	8,880	10,681	12,480	14,640
	8.00	2,160	2,601	3,120	3,641	4,281
3) Qda. Chane	3.80	599	684	821	941	1,078
	14.20	1,442	1,839	2,137	2,436	2,833
4) Qda. El Toro	16.00	2,880	3,584	4,224	4,864	5,633
5) Qda. Las Chacras	20.50	2,337	3,137	3,752	4,305	5,043
	16.00	1,440	1,873	2,208	2,545	2,976
Total A	137.50	32,667	40,478	48,708	55,965	66,663
B. SAN JUAN-ANTOFAGASTA						
1) Arroyo Yapacanicito	2.80	244	302	344	395	445
	11.30	780	983	1,119	1,254	1,424
2) Arroyo Jochi	8.40	676	676	794	882	1,029
	4.20	221	264	309	338	382
3) Arroyo Tacuaral	7.70	554	554	616	678	770
Total B	34.40	2,475	2,779	3,182	3,547	4,050

TABLE F.4.4 FLOOD MITIGATION AND DRAINAGE IMPROVEMENT WORKS (1/2)
- ALTERNATIVE I

Project/Sub-project	River Improvement		Main Drainage		Secondary	Bridge	Culvert	Diversion	Land	Retarding
	River	Length (km)	Improve. (km)	Rehabili. (km)	Drainage (km2)	(Nos.)	(Nos.)	Weir (Nos.)	Acquisition (ha.)	Basin (km2)
1. CHANE - PAILON		**137.50**	**57.00**	**0.00**	**481.00**	**21**	**78**	**0**	**1550.0**	**141.5**
1-1 RIO CHANE	Rio Chane	35.00	0.00	0.00	0.00	5	0	0	222.0	0.0
	Acc.0.00 - 8.00 km	8.00								
	Acc.8.00 - 35.00 km	27.00								
1-2 RIO PAILON		32.00	6.50	0.00	50.00	1	8	0	383.0	116.5
	Rio Pailon	32.00								
1-3 QUEBRADA CHANE		34.00	8.00	0.00	0.00	1	0	0	290.0	25.0
	Qda. Chane	18.00								
	Qda. Toro	16.00								
1-4 CHANE - CHACRAS		36.50	21.50	0.00	284.00	12	43	0	445.0	0.0
	Qda. Chacras	36.50								
1-5 OKINAWA DRAINAGE		0.00	21.00	0.00	147.00	2	27	0	210.0	0.0
2. SAN JUAN - ANTOFAGASTA		**34.40**	**17.10**	**34.20**	**212.00**	**6**	**36**	**4**	**487.0**	**0.0**
2-1 SAN JUAN		14.10	7.10	34.20	115.00	3	17	4	174.0	0.0
	Arroyo Yapacanicito	14.10								
2-2 ANTOFAGASTA		20.30	10.00	0.00	97.00	3	19	0	313.0	0.0
	Arroyo Jochi	12.60								
	Arroyo Tacuaral	7.70								

TABLE F.4.4 FLOOD MITIGATION AND DRAINAGE IMPROVEMENT WORKS (2/2)
- ALTERNATIVE II

Project/Sub-project	River Improvement		Main Drainage		Secondary Drainage	Bridge	Culvert	Diversion Weir	Land Acquisition	Retarding Basin
	River	Length (km)	Improve. (km)	Rehabili. (km)	(km2)	(Nos.)	(Nos.)	(Nos.)	(ha.)	(km2)
1. CHANE - PAILON		**102.50**	**57.00**	**0.00**	**481.00**	**16**	**78**	**0**	**1328.0**	**141.5**
1-1 RIO CHANE		0.00	0.00	0.00	0.00	0	0	0	0.0	0.0
1-2 RIO PAILON		32.00	6.50	0.00	50.00	1	8	0	383.0	116.5
	Rio Pailon	32.00								
1-3 QUEBRADA CHANE		34.00	8.00	0.00	0.00	1	0	0	290.0	25.0
	Qda. Chane	18.00								
	Qda. Toro	16.00								
1-4 CHANE - CHACRAS		36.50	21.50	0.00	284.00	12	43	0	445.0	0.0
	Qda. Chacras	36.50								
1-5 OKINAWA DRAINAGE		0.00	21.00	0.00	147.00	2	27	0	210.0	0.0
2. SAN JUAN - ANTOFAGASTA		**34.40**	**51.30**	**0.00**	**212.00**	**8**	**41**	**0**	**487.0**	**0.0**
2-1 SAN JUAN		14.10	41.30	0.00	115.00	5	22	0	174.0	0.0
	Arroyo Yapacanicito	14.10								
2-2 ANTOFAGASTA		20.30	10.00	0.00	97.00	3	19	0	313.0	0.0
	Arroyo Jochi	12.60								
	Arroyo Tacuaral	7.70								

TABLE F.4.5 DESIGN CROSS SECTIONS OF RIVER IMPROVEMENT FOR ALTERNATIVE I

River	Length (km)	Water Depth (m)	Width (W.S.) (m)	Bank Slope	Flow Area (m2)	Design Discharge (m3/s)
CHANE-PAILON						
1) Rio Chane	35.00					
Jct. Rio Piray - Jct. Qda. Chacras	12.50	6.0	100.0	1:2	528.0	1500
Jct. Qda. Chacras - Jct. Rio Pailon	22.50	6.0	75.0	1:2	378.0	1212
2) Rio Pailon	32.00					
Jct. Rio Chane - Road 9	24.00	5.0	70.0	1:2	300.0	908
Road 9 - Jct. Arroyo Los Sauces	8.00	5.0	65.0	1:2	275.0	995
3) Qda. Chane	18.00					
Jct. Rio Chane - Jct. Qda. Toro	3.80	4.5	45.0	1:2	162.0	584
Jct. Qda. Toro - Road 9	14.20	3.5	37.0	1:2	105.0	353
4) Qda. El Toro	16.00					
Jct. Qda. Chane - Road 9	16.00	4.0	55.0	1:2	188.0	503
5) Qda. Las Chacras	36.50					
Jct. Rio Chane - Mid-stream	20.50	3.0	45.0	1:2	117.0	440
Mid-stream - Road 9	16.00	3.0	37.0	1:2	93.0	326
SAN JUAN-ANTOFAGASTA						
1) Arroyo Yapacanicito	14.10					
Downstream - Mid-stream	2.80	3.0	35.0	1:2	87.0	213
Mid-stream - Upstream	11.30	3.0	30.0	1:2	72.0	165
2) Arroyo Jochi	12.60					
Down. Swamp - Mid-stream	8.40	3.5	30.0	1:2	80.5	194
Mid-stream - Upstream	4.20	3.5	22.0	1:2	52.5	174
3) Arroyo Tacuaral	7.70					
Down. Swamp - Mid-stream	7.70	4.0	26.0	1:2	72.0	194

Note: 1) Design cress sections are single trapezoidal shapes without flood embankments.

FIGURES

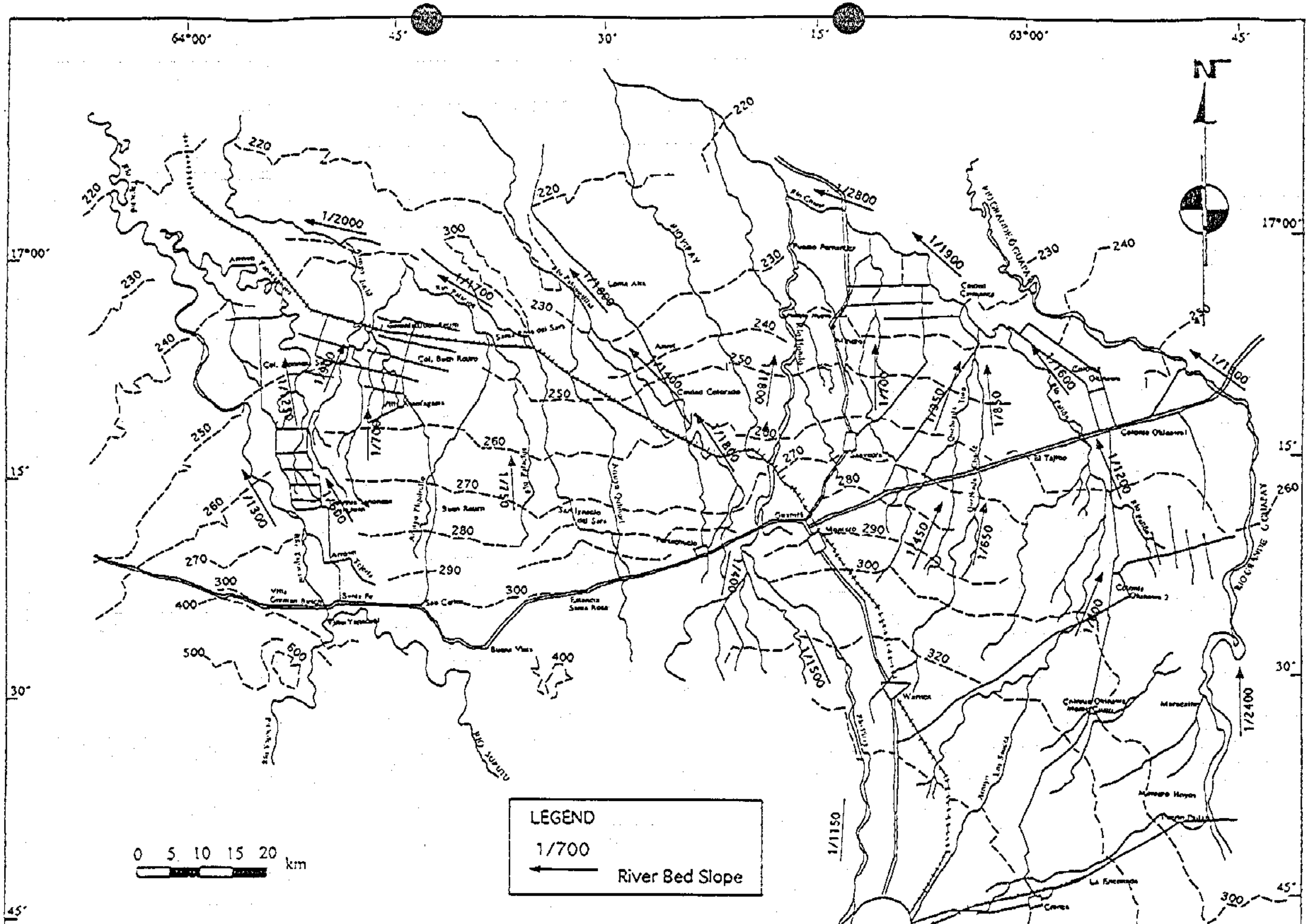


FIG. F.2.1 TOPOGRAPHY AND RIVER BED SCOPES OF THE STUDY AREA

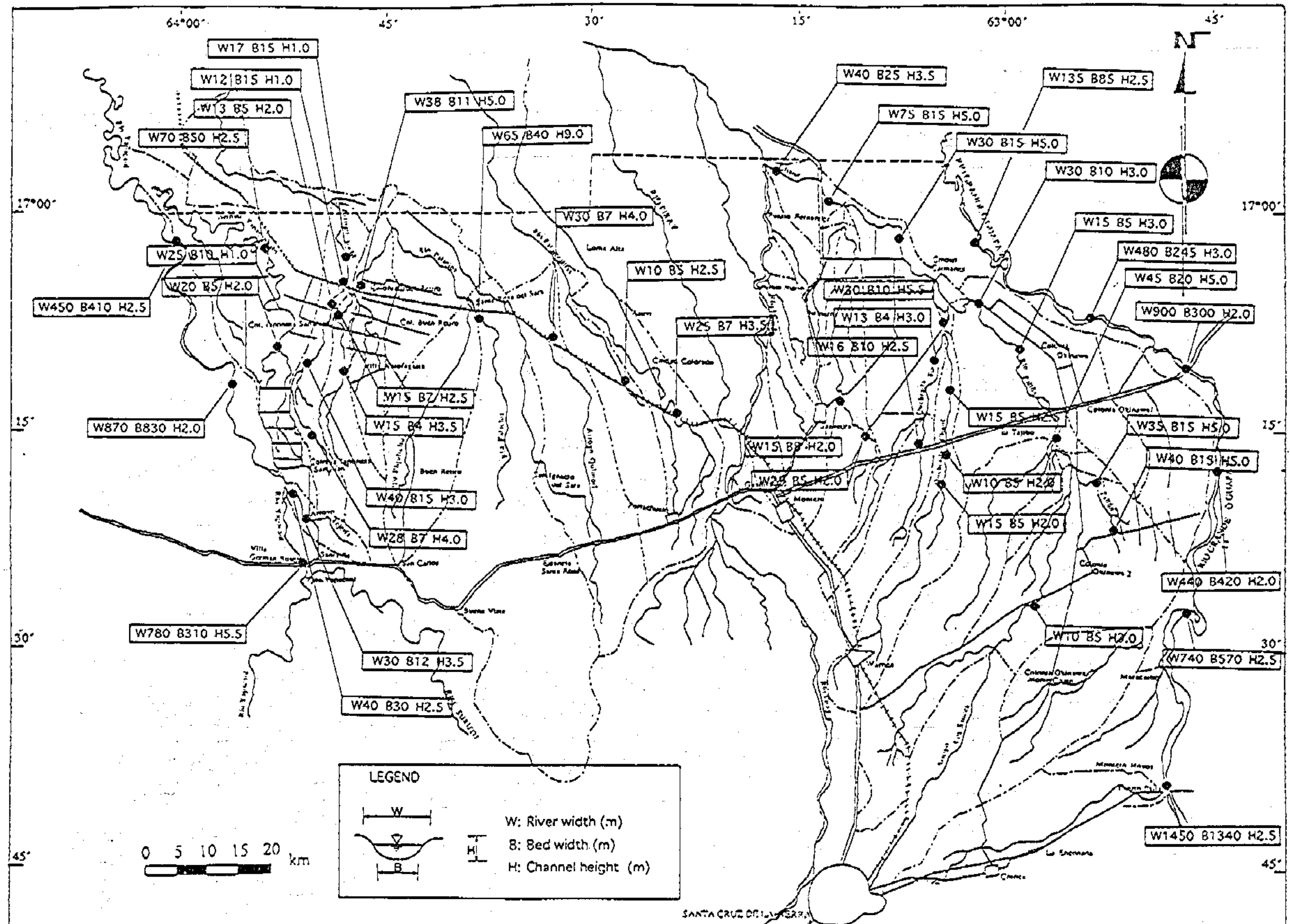


FIG. F.2.2 TYPICAL SIZES OF RIVER CROSS SECTIONS

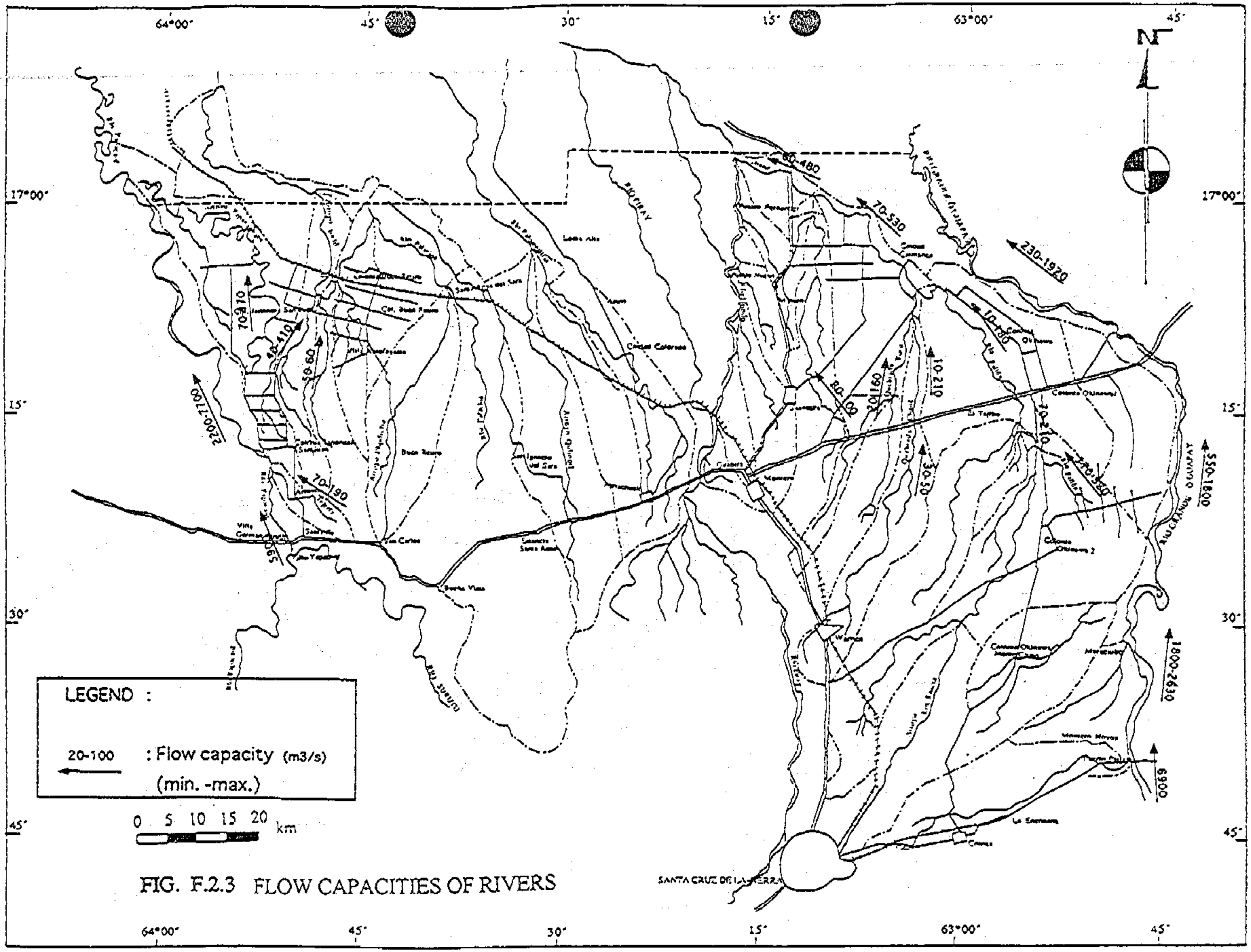


FIG. F.2.3 FLOW CAPACITIES OF RIVERS

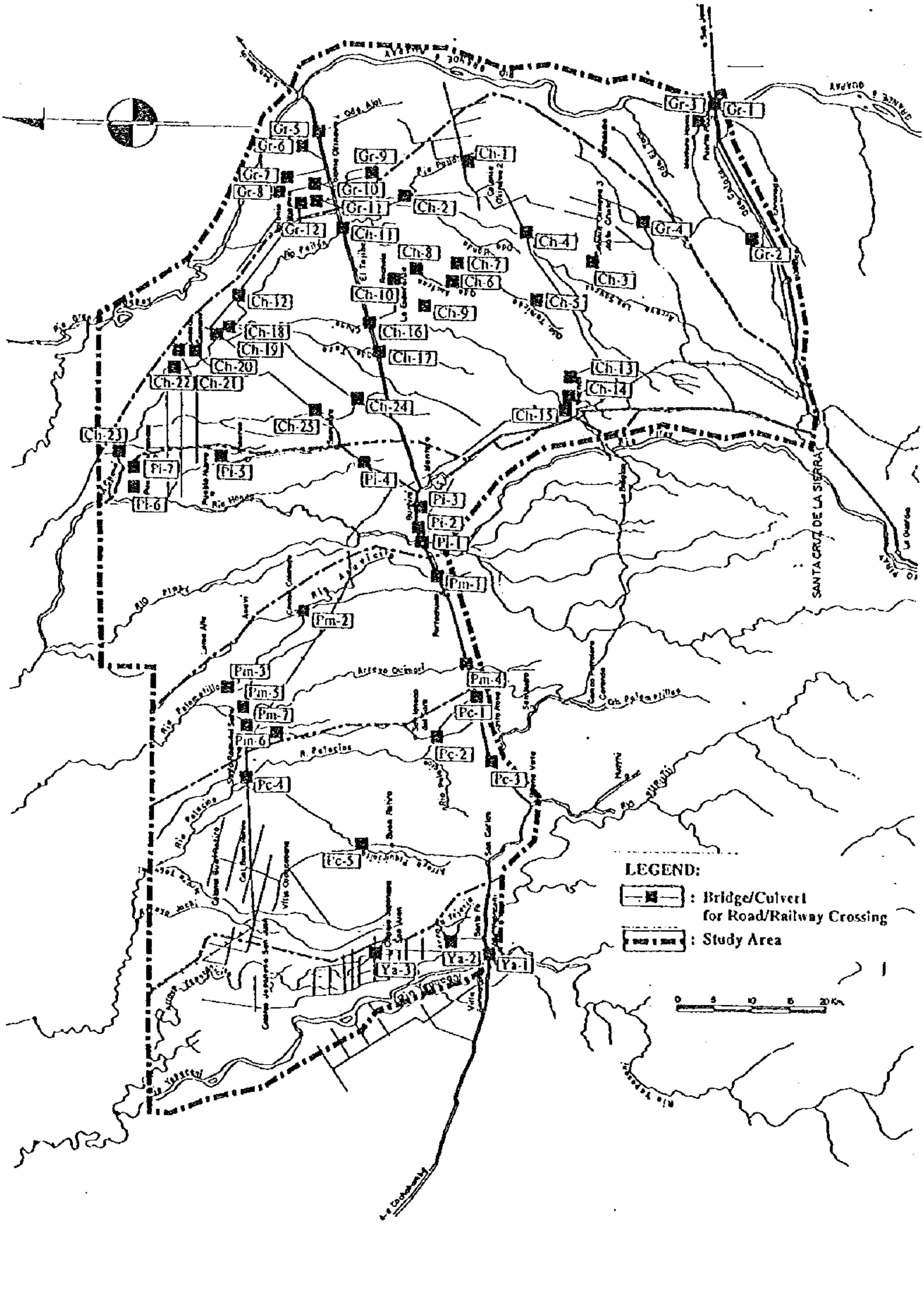


FIG. F.3.1 EXISTING BRIDGES AND CULVERTS ALONG RIVERS

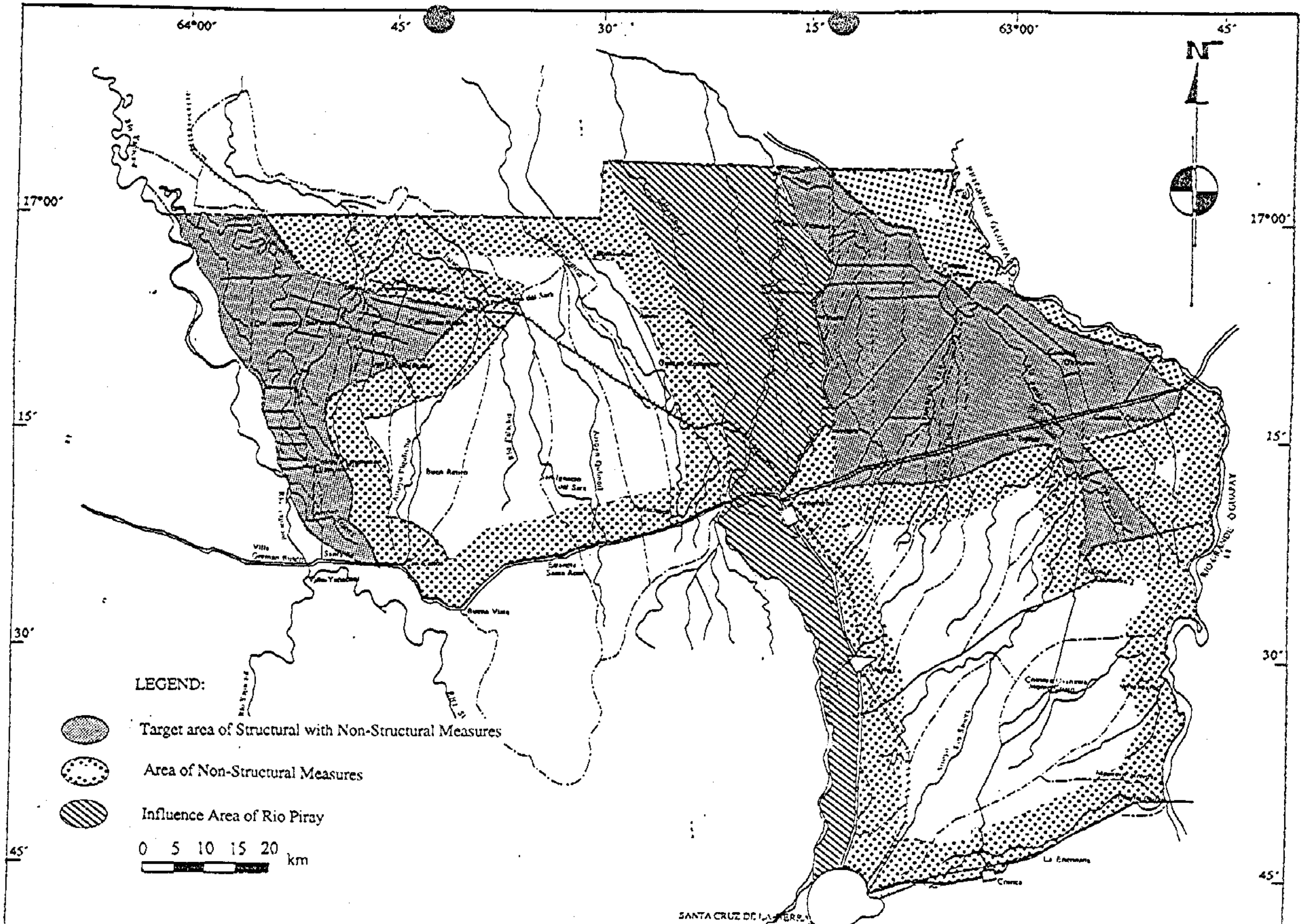


FIG. F.4.1 DIVISION OF THE STUDY AREA FOR FLOOD CONTROL MEASURES

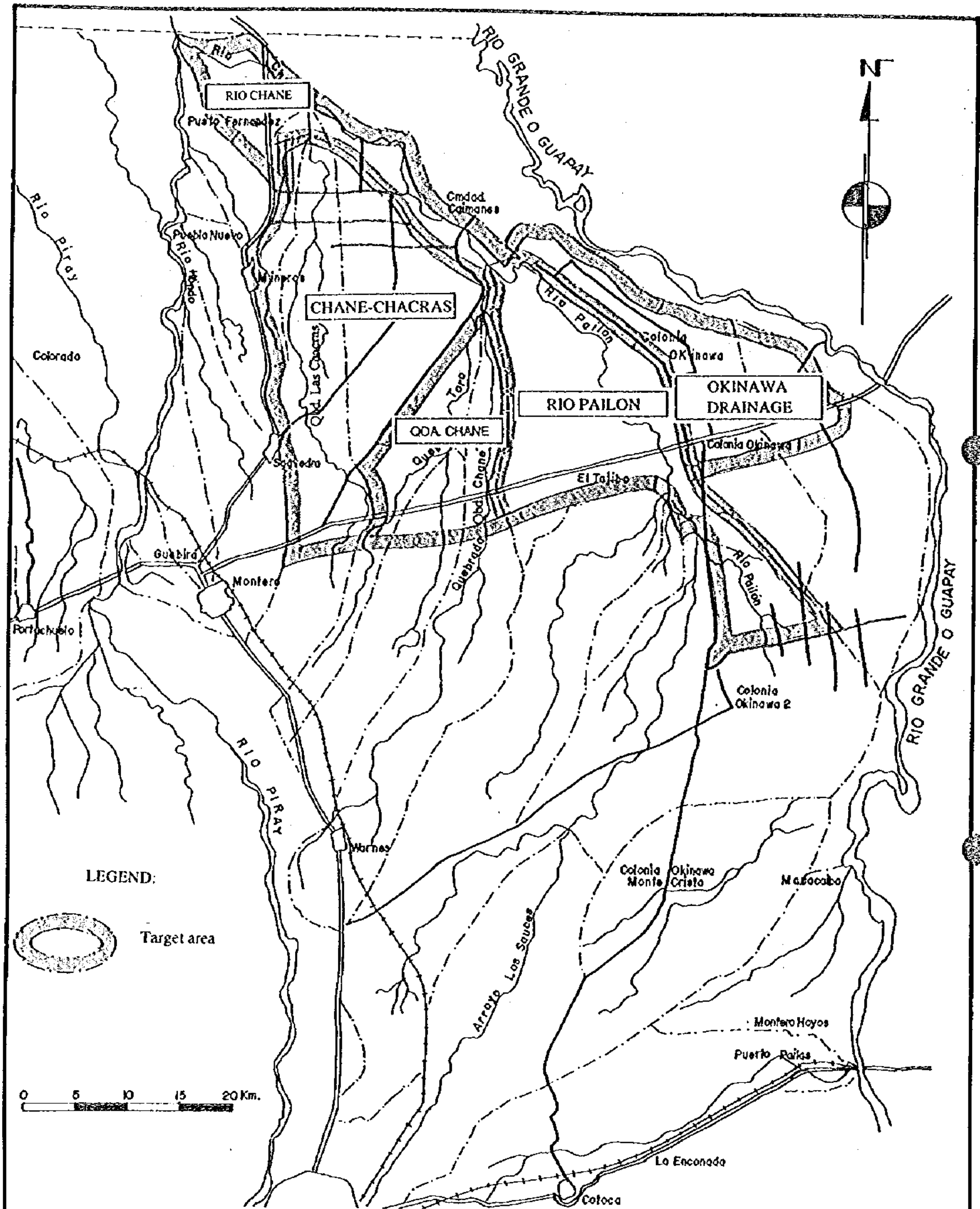


FIG. F.4.2 TARGET AREA OF FLOOD MITIGATION AND DRAINAGE IMPROVEMENT MEASURES - CHANE - PAILON AREA

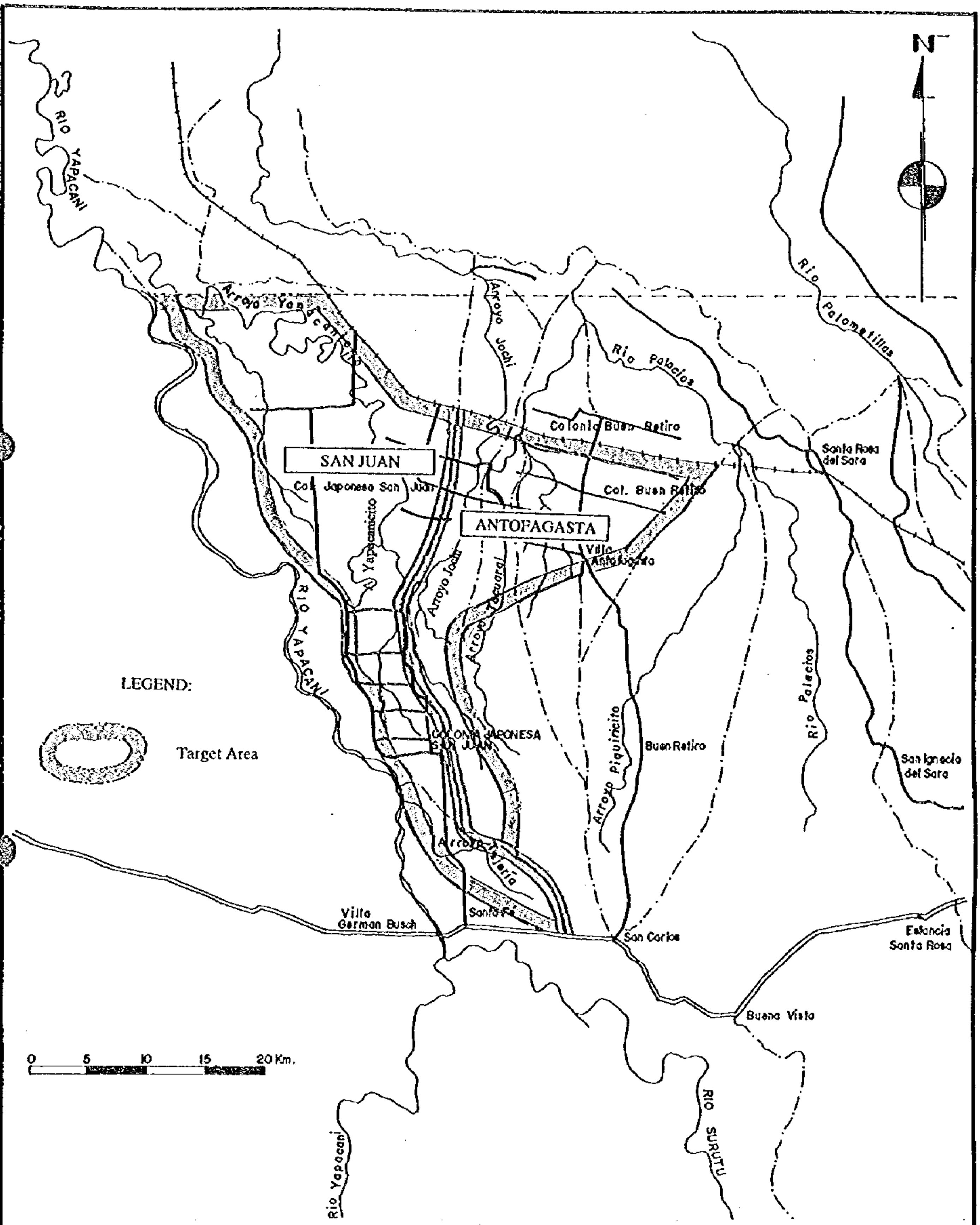
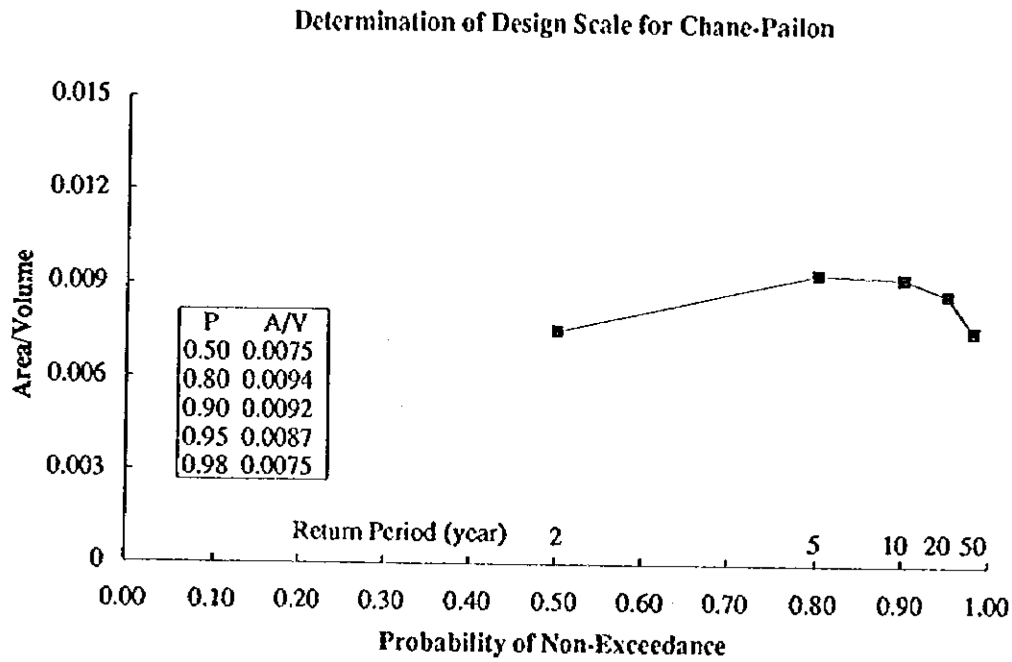
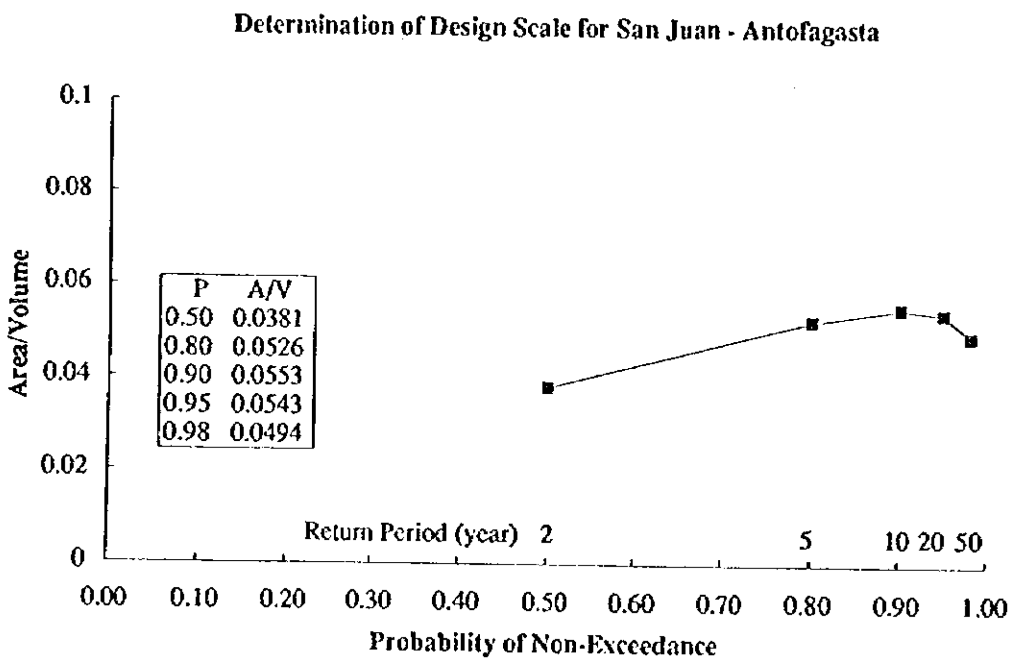


FIG. F.4.3 TARGET AREA OF FLOOD MITIGATION AND DRAINAGE IMPROVEMENT MEASURES - SAN JUAN - ANTOFAGASTA AREA





Note: Area - Annual Average Protected Area
Volume - Excavation Volume

FIG. F.4.4 DETERMINATION OF DESIGN SCALE

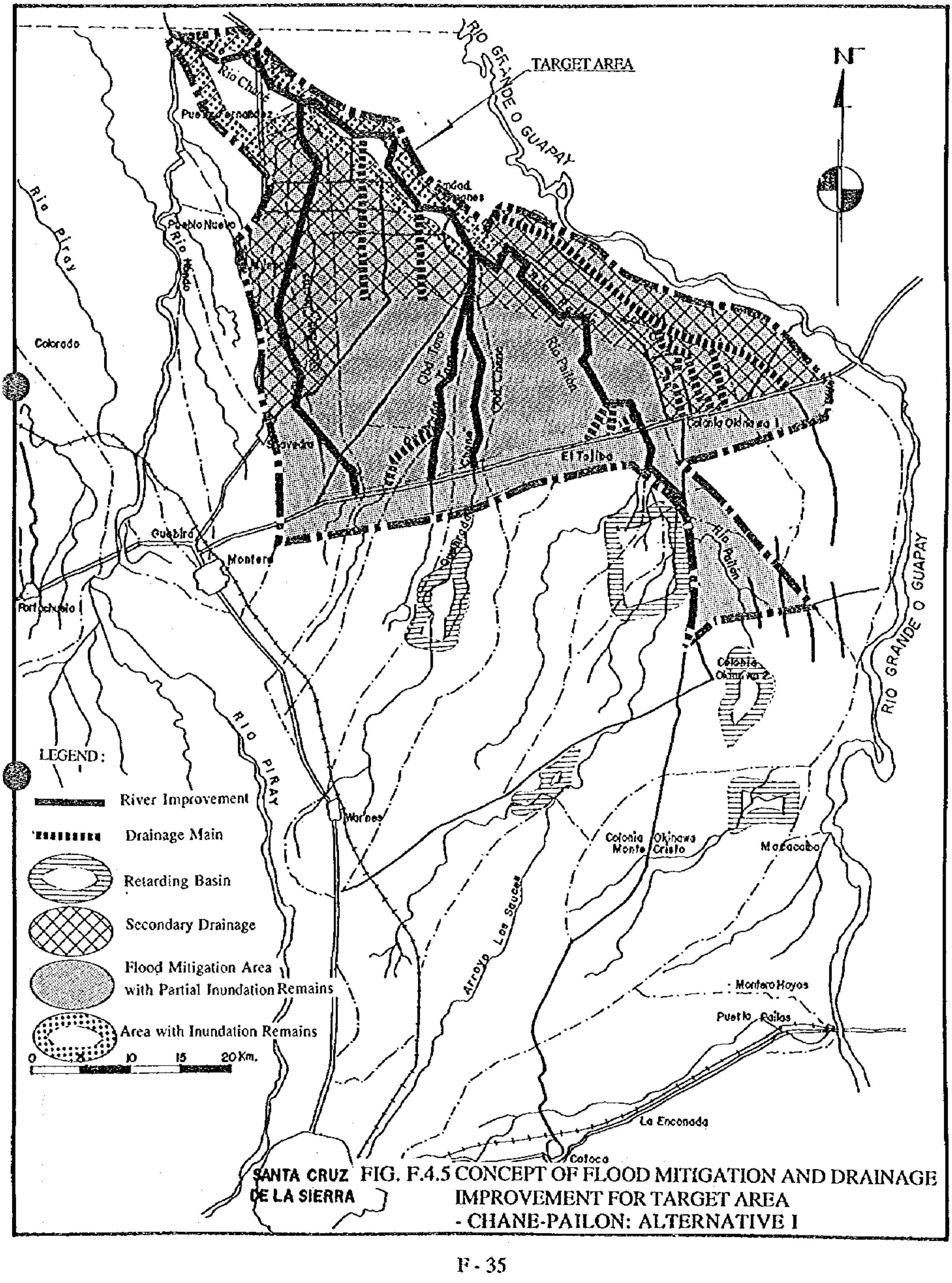


FIG. F.4.5 CONCEPT OF FLOOD MITIGATION AND DRAINAGE IMPROVEMENT FOR TARGET AREA - CHANE-PAILON: ALTERNATIVE I

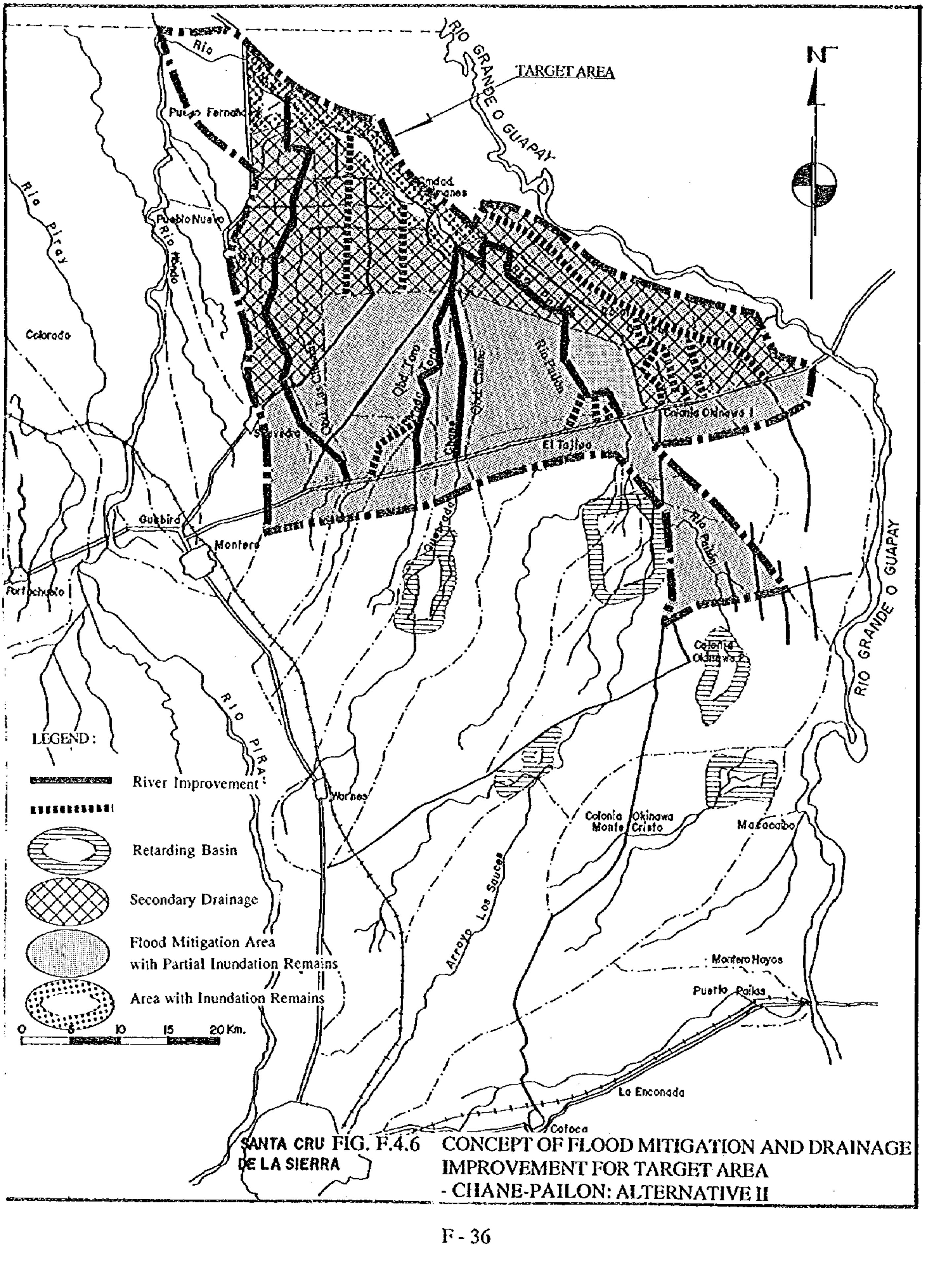
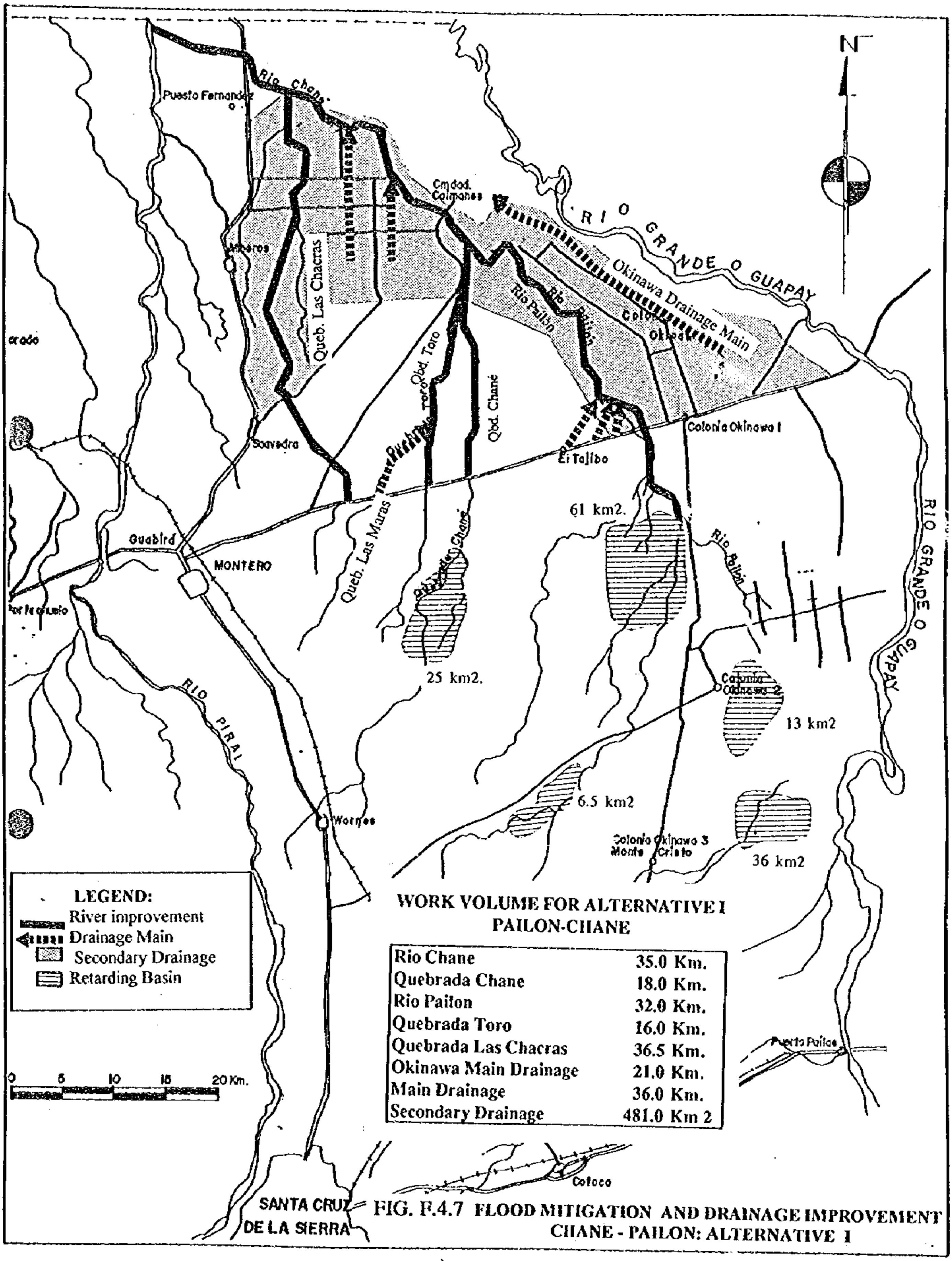


FIG. F.4.6 CONCEPT OF FLOOD MITIGATION AND DRAINAGE IMPROVEMENT FOR TARGET AREA - CHANE-PAILON: ALTERNATIVE II



WORK VOLUME FOR ALTERNATIVE I
PAILON-CHANE

Rio Chane	35.0 Km.
Quebrada Chane	18.0 Km.
Rio Pailon	32.0 Km.
Quebrada Toro	16.0 Km.
Quebrada Las Chacras	36.5 Km.
Okinawa Main Drainage	21.0 Km.
Main Drainage	36.0 Km.
Secondary Drainage	481.0 Km 2

FIG. F.4.7 FLOOD MITIGATION AND DRAINAGE IMPROVEMENT CHANE - PAILON: ALTERNATIVE I

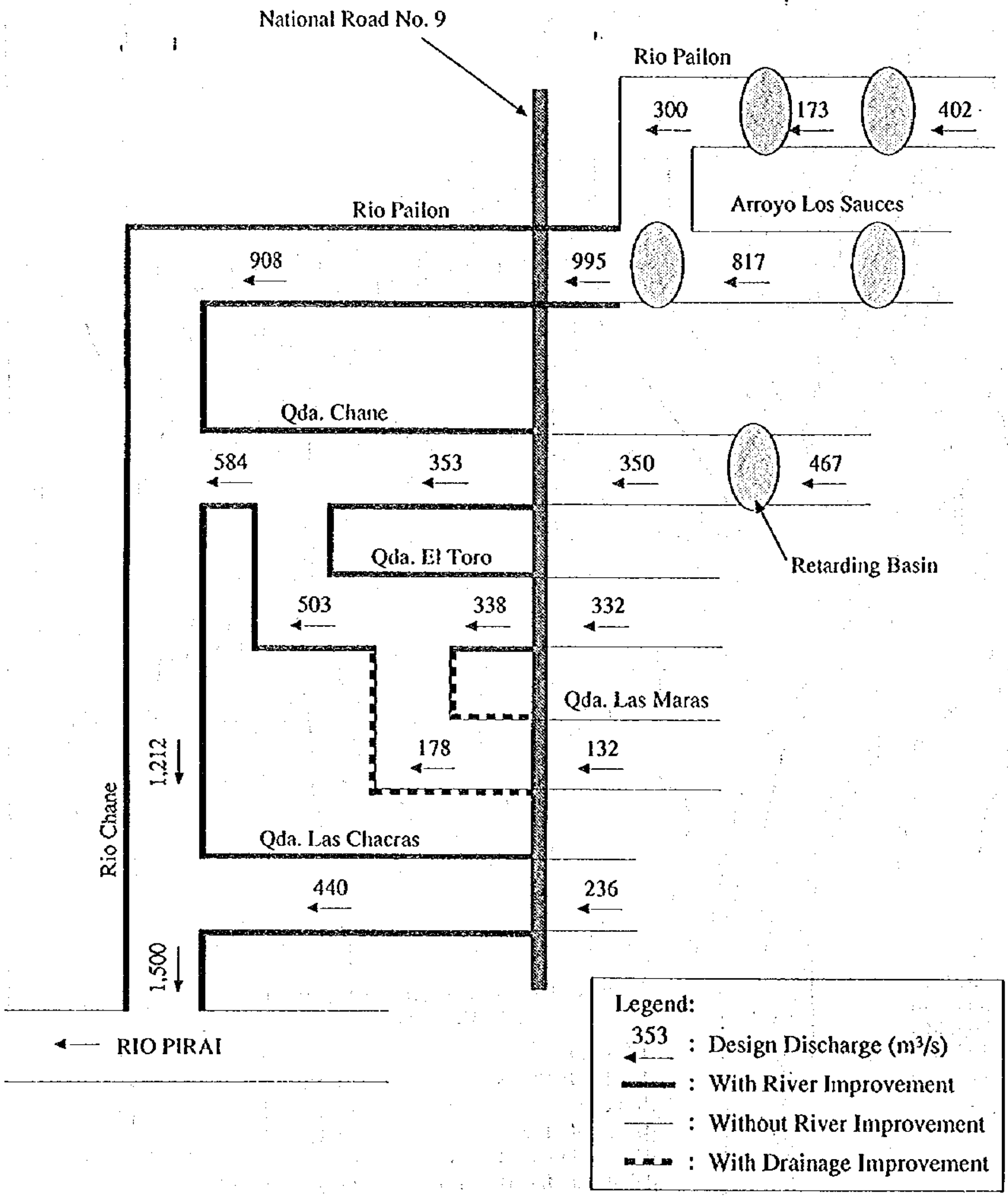
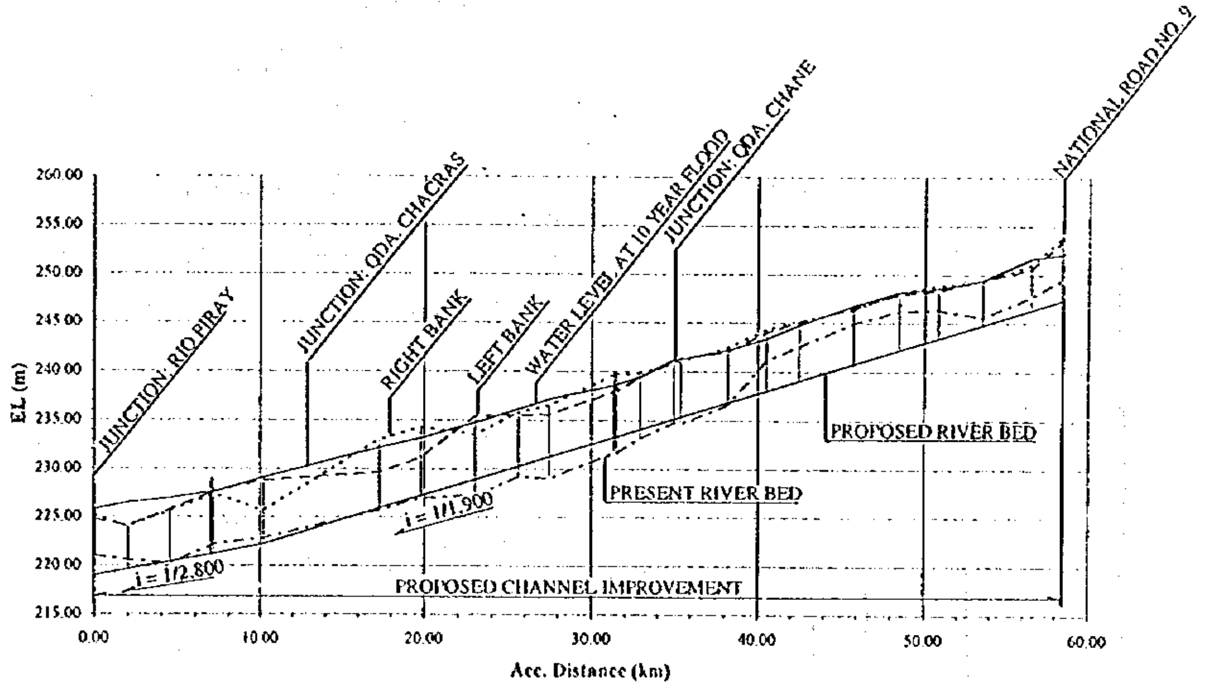


FIG. F.4.8 DESIGN DISCHARGE DISTRIBUTION OF 10-YEAR FLOODS CHANE-PAILON: ALTERNATIVE I

RIO CHANE - RIO PAILON



QDA. CHANE

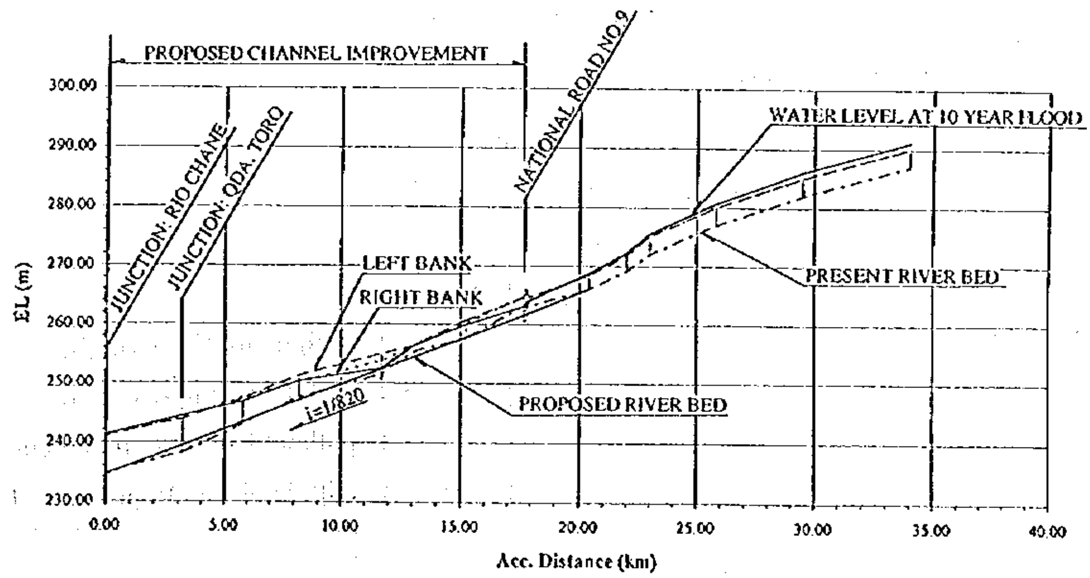


FIG. F.4.9 DESIGN LONGITUDINAL PROFILE OF THE RIVER IMPROVEMENT CHANE-PAILON: ALTERNATIVE I

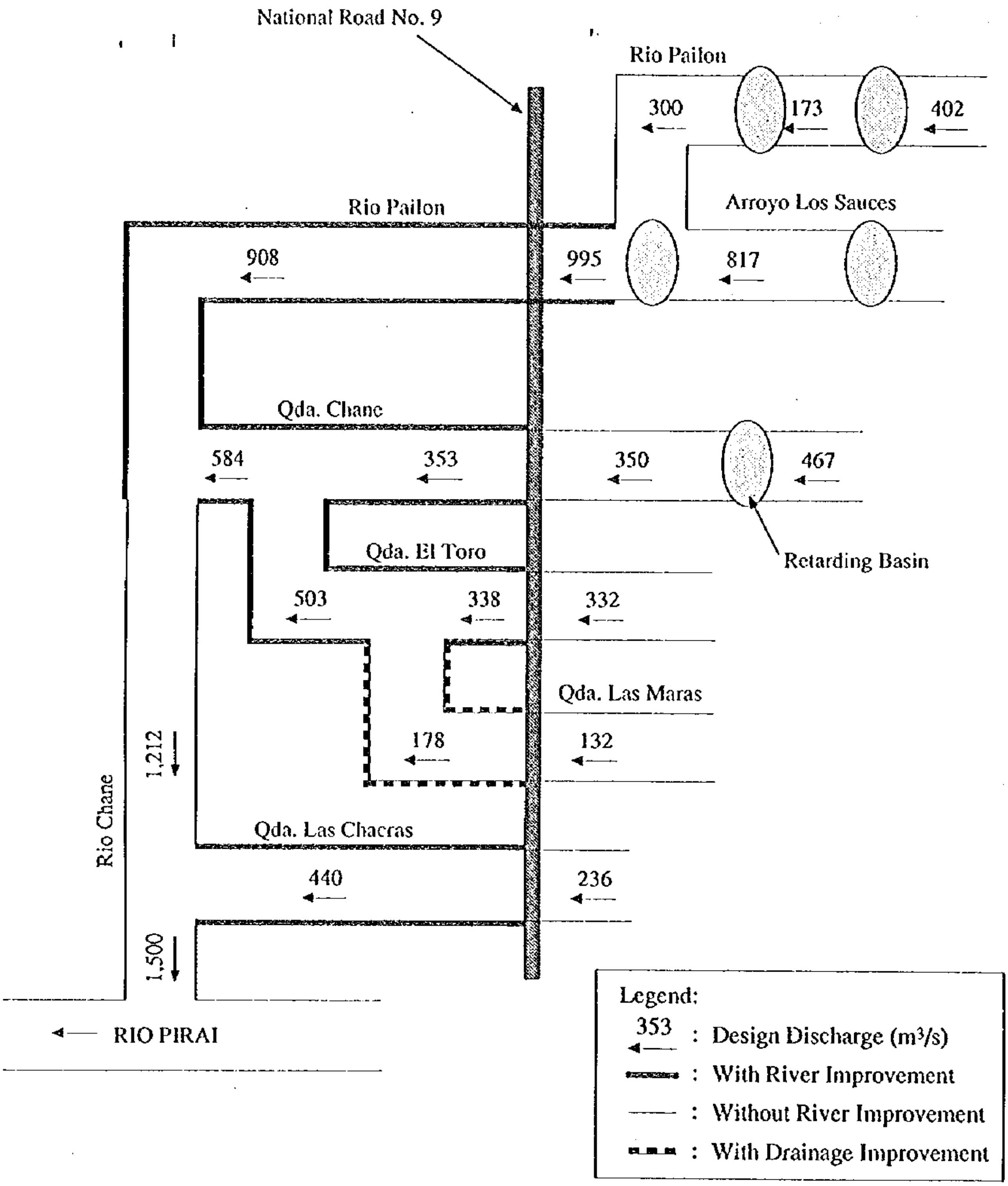


FIG. F.4.10 DESIGN DISCHARGE DISTRIBUTION OF 10-YEAR FLOODS CHANE-PAILON: ALTERNATIVE II

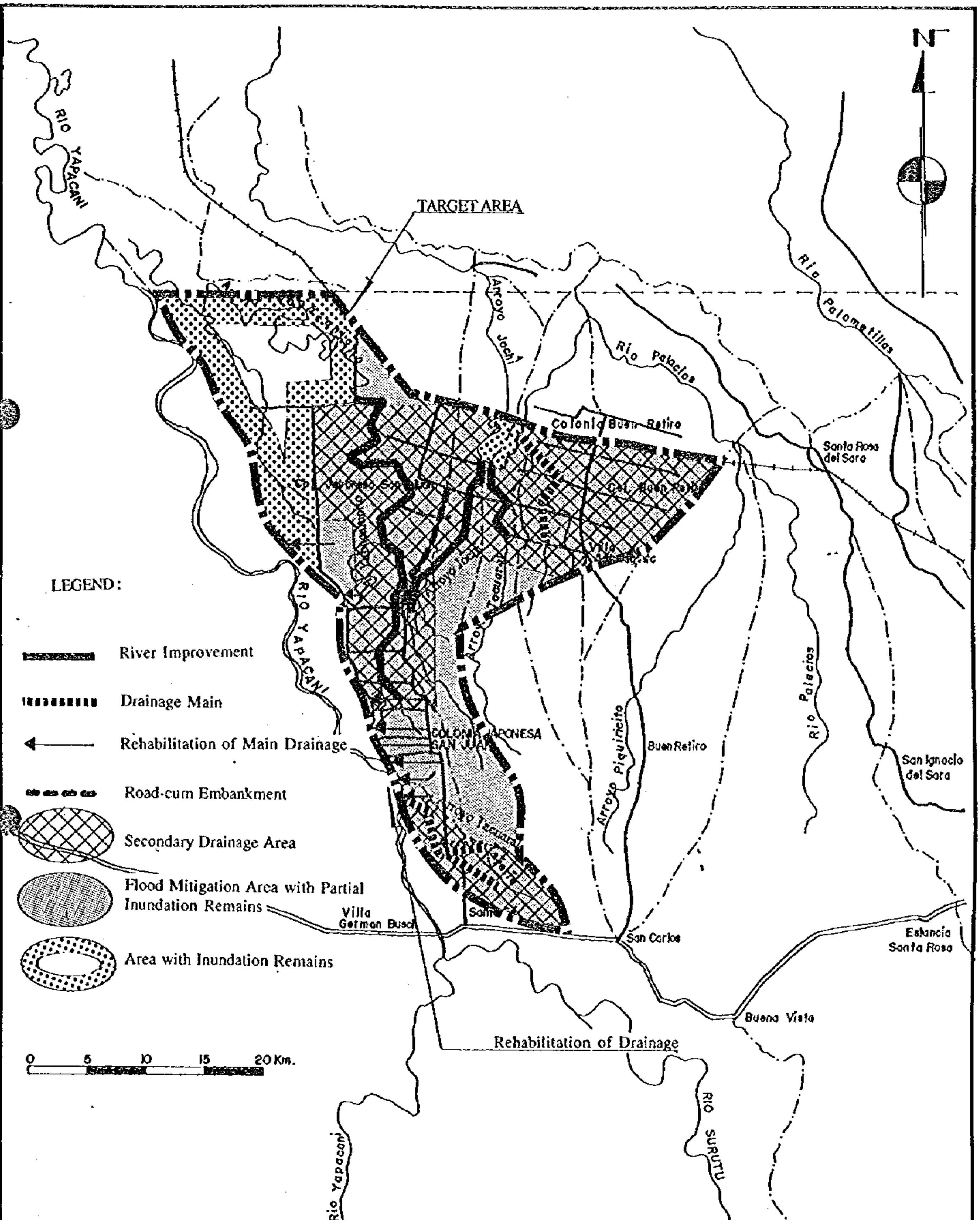


FIG. F.4.11 CONCEPT OF FLOOD MITIGATION AND DRAINAGE IMPROVEMENT FOR TARGET AREA - SAN JUAN-ANTOFAGASTA: ALTERNATIVE I

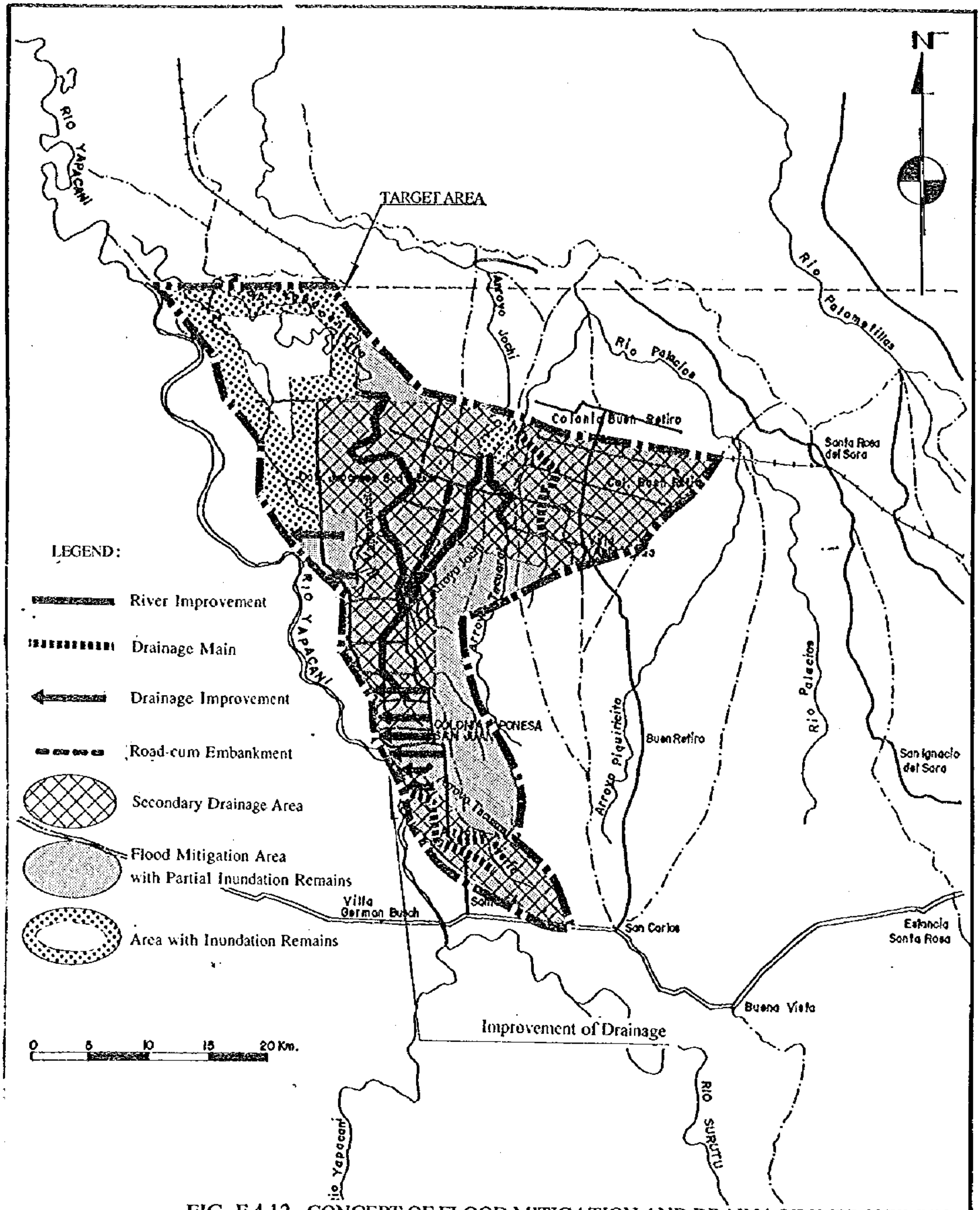


FIG. F.4.12 CONCEPT OF FLOOD MITIGATION AND DRAINAGE IMPROVEMENT FOR TARGET AREA
- SAN JUAN-ANTOFAGASTA: ALTERNATIVE II

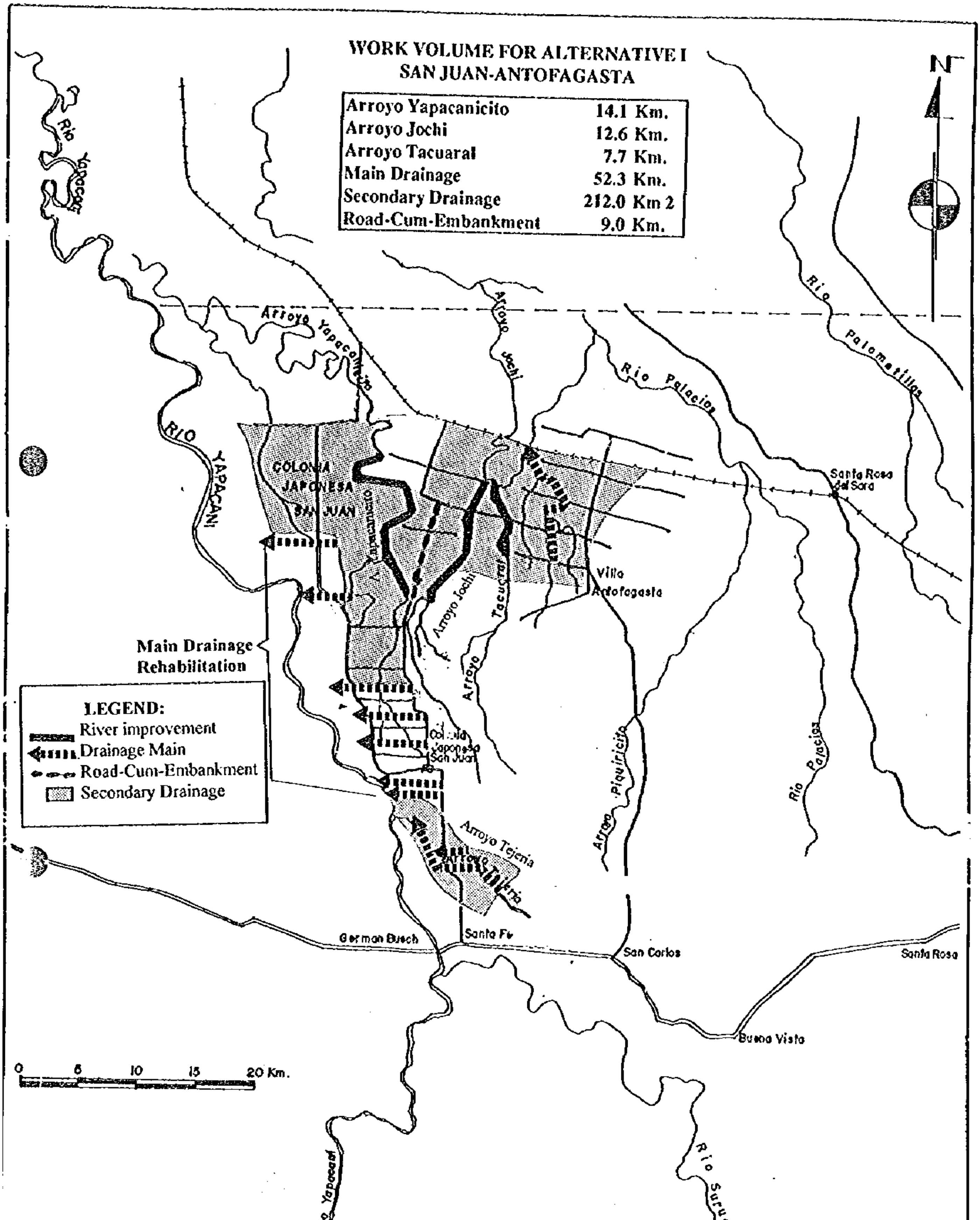


FIG. F.4.13 FLOOD MITIGATION AND DRAINAGE IMPROVEMENT
SAN JUAN - ANTOFAGASTA: ALTERNATIVE I

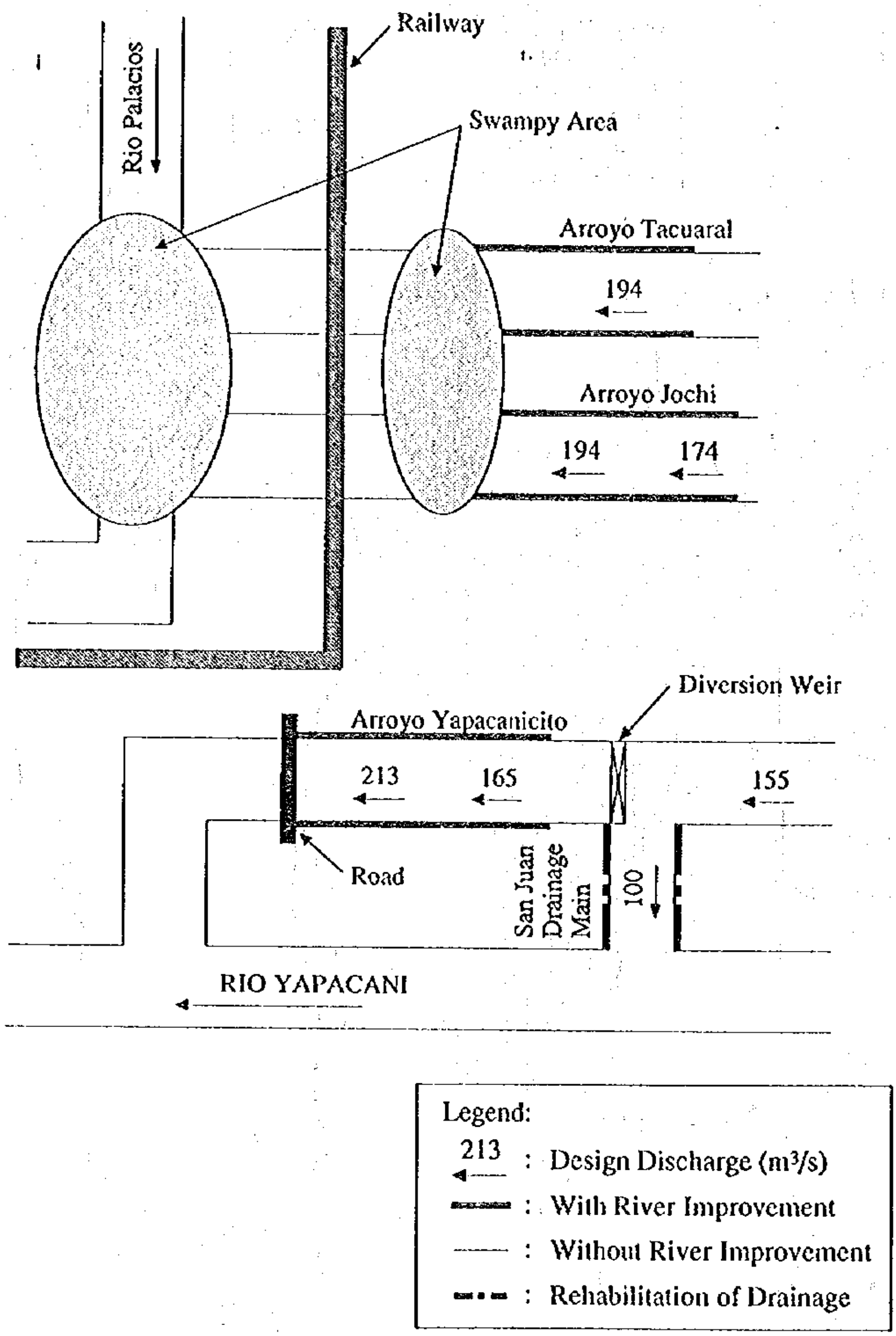
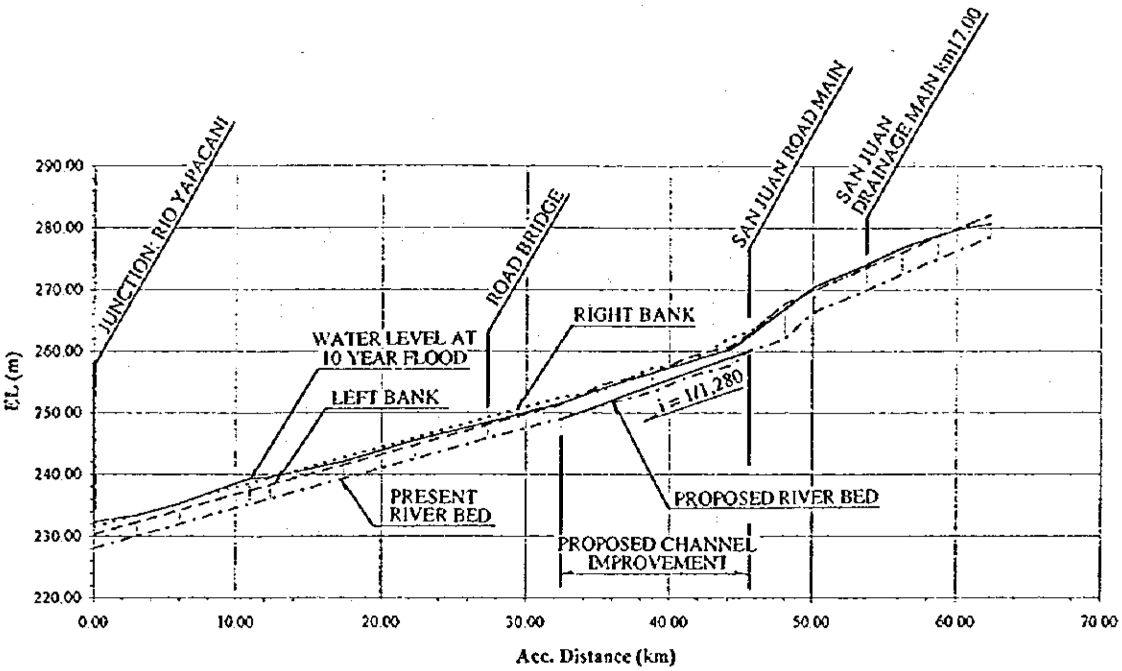


FIG. F.4.14 DESIGN DISCHARGE DISTRIBUTION OF 10-YEAR FLOODS SAN JUAN-ANTOFAGASTA: ALTERNATIVE I

ARROYO YAPACANICITO



ARROYO JOCHI

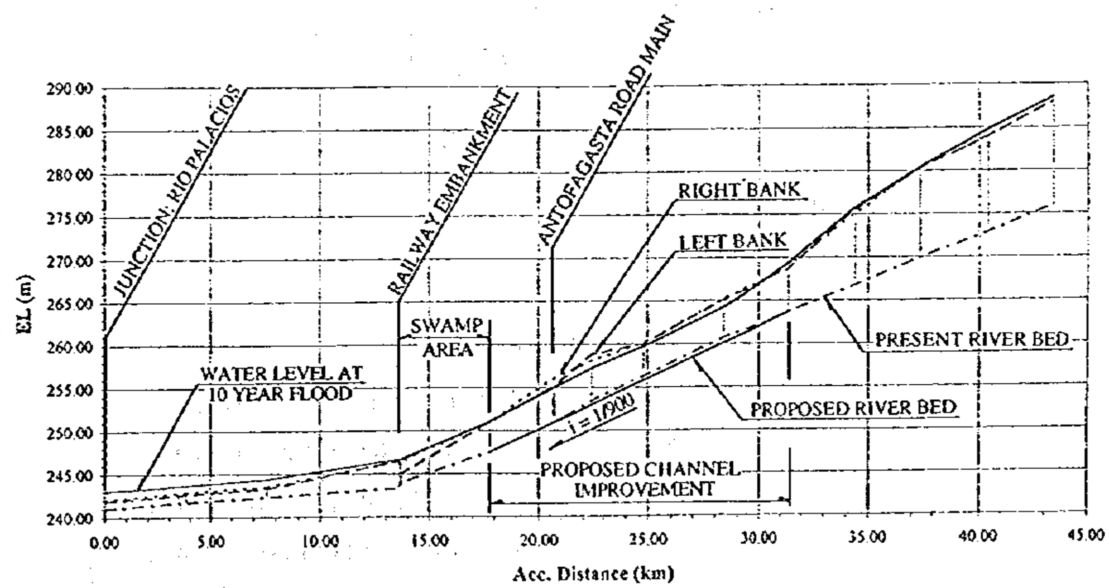


FIG. F.4.15 DESIGN LONGITUDINAL PROFILE OF THE RIVER IMPROVEMENT SAN JUAN-ANTOFAGASTA: ALTERNATIVE I

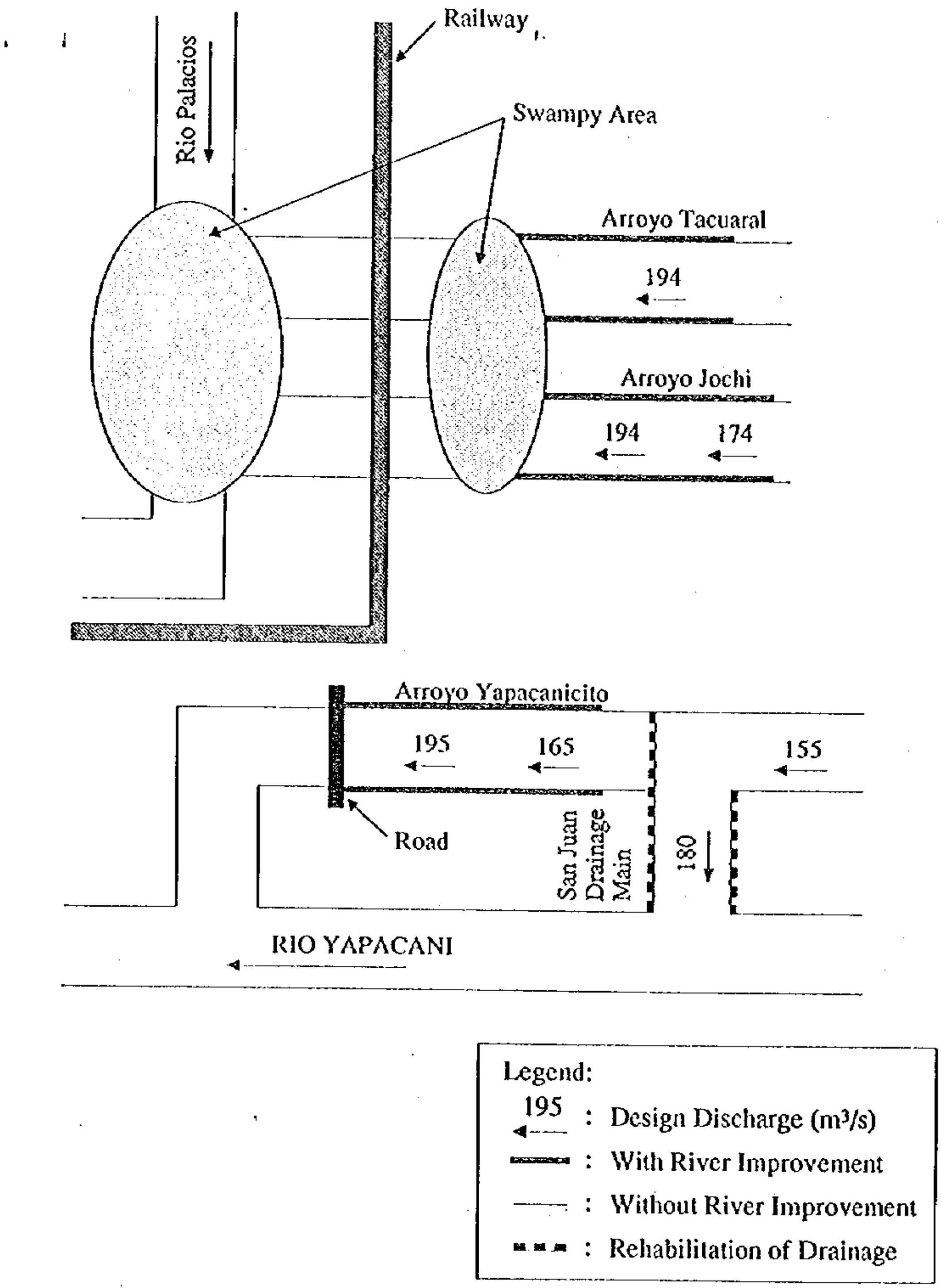


FIG. F.4.16 DESIGN DISCHARGE DISTRIBUTION OF 10-YEAR FLOODS SAN JUAN-ANTOFAGASTA: ALTERNATIVE II

SUPPORTING REPORT G

DRAINAGE IMPROVEMENT

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SUPPORTING REPORT G DRAINAGE IMPROVEMENT

1. Present Drainage Condition

1.1 Existing Facilities of Drainage Systems

The drainage systems in the study area are generally not developed compared with the rainfall. Only on-farm drains and drains for road facilities, i.e. cross drains, are observed, and drainage facilities are not developed systematically in the area.

The existing drainage facilities observed are shown in *Table G.1.1*.

(1) San Juan de Yapacani Area

In the San Juan de Yapacani area, drainage facilities have been excavated by the colony. The main drainage canals were planned to discharge to Rio Yapacani.

These drainage canals are effective for the inner basin to drain an ordinary rainfall or small scale run-off, however, their discharge capacities are decreased by thickly grown weeds and trees on the canal slopes, or by local slope collapses and by sedimentation.

The outlet of each drainage main is bottlenecked by the box culvert or culvert pipe that is crossing the road along Rio Yapacani. The standard size of culvert is 3 m wide x 2 m high or 3 m in diameter and the discharge capacity is smaller than that of the connecting drainage canal.

(2) Central Part of the Study Area

The area belongs to Rio Chane and its tributary basins. There are many small natural streams distributed over this area. Drainage facilities observed in this area are only small canals and small cross drains under roads, that were likely prepared only to drain the area nearby. There is no systematic drainage network.

(3) Okinawa Area

In this area, there is one drainage network that consists of natural streams and drainage canals constructed by the colony.

This drainage network aims to drain the rain water of the area and to drain the runoff from the upper basin into the lower reach of Rio Grande.

In Rio Pailon basin, there is a concrete lined canal of 1.5 km long and unlined canal of 3.5 km long. The canal discharges to Rio Pailon. However, the discharge capacity is affected by the water level of Rio Pailon and drainage problem occurs when Rio Pailon become full.

There are several small streams that drain to Rio Grande.

1.2 Present Condition of Drainage Problem

Present condition of drainage problem are indicated by the inundation status which occur frequently.

The characteristics of drainage problem in the area are classified into three (3) classes by the status of inundation, which are shown in *Table G.1.2*.

(1) West Part of the Study Area

1) San Juan area

In the Arroyo Tejeria basin, the depth of water varies between 10 cm and 30 cm for less than 3 days. The inundation of this area is usually light with a short duration.

In the Arroyo Yapacanicito basin, the depth of water is higher than that of the Arroyo Tejeria basins, the duration is less than 2 days.

The runoff from the upper basin of Arroyo Jochi flows into the middle and lower parts of this area and the inundation has likely become more severe due to the farm land development at the upper basin.

The upper part of this area is originally belonged to the upper reach of Arroyo Yapacanicito, but the area is drained to a 2-year probable runoff scale into Rio Yapacani through the drainage canals constructed by the colony.

Arroyo Yapacanicito has no sufficient flow capacity, and to make matters worse, storm water flows in from the neighboring river basin, Arroyo Jochi basin.

The lower reach of Arroyo Yapacanicito is affected by flooding from Arroyo Yapacanicito and also likely influenced by the back water from Rio Yapacani.

2) Antofagasta area

Antofagasta area is divided into 2 areas by the cause of inundation. The east area is not influenced by floods from rivers and has a light inundation with a depth between 10 cm and 60 cm for less than 3 days. The rain water on the east Antofagasta runs parallel to the secondary roads and flows into Arroyo Tacuaral.

On the other hand, the west part is suffered by floods from rivers and has a rather heavy inundation with the depth between 30 cm and 100 cm for 5 to 10 days. The drainage depends mainly on Arroyo Yapacanicito.

The problems of this area are caused not only by the insufficient discharge capacity of Arroyo Yapacanicito, but also by the concentration of runoff from the upper basin. The run-off from the upper basin, flows into Arroyo Jochi, but overflows both at the west Antofagasta and at the lower San Juan de Yapacani.

3) Upper Palacios and Palometillas Area

The upper basin of Rio Palacios are inundated locally, but the depth and duration are likely light with less than 30 cm in depth for less than 2 days in duration.

The inundation in this area is presumed due to the undulation of ground. The land is mostly used for cattle raising, so that the effect of inundation gives unlikely significant effects to the agricultural activity.

The lower Palometilla basin is mostly inundated deep. The depth and duration of inundation vary widely.

(2) Central Part of the Study Area

The situation is different between the northern side and the southern side of the Route 9.

1) Northern Side

The northern side is a heavy inundation area. Most part of the area is affected by inundation frequently. The depth and duration of inundation are medium or heavy.

The natural streams do not have enough flow capacities to cope with runoffs from their drainage areas. The right bank of Rio Chane, defined as "Chane North", suffers from inundation of around 50 cm deep for a long duration. The area suffers frequently from floods from the rivers, i.e., Rio Chane and her tributaries. The long duration of inundation is resulted from both the topographical condition of low-lying and the rivers' low flow capacities.

The Chane-Pirai area includes Colonia Cuatro Ojitos, Colonia Nuevo Munde and Colonia San Juan de Amarillos. The lower part of this area, Colonia Cuatro Ojitos, is inundated frequently by floods from Rio Chane.

The inundation of this area is between 20 cm and 60 cm deep for less than 5 days.

The middle part, Colonia San Juan de Amarillos, is not influenced by the floods, but the drainage condition is poor because of insufficient natural streams and drainage canals.

The upper part, Colonia Aroma, is almost free from serious floods or inundation. The embankment of the national road No.9 has been regulating the discharge from the upstream basin. After the completion of the seven bridges, the discharge from the upper basin may increase.

The flood and drainage problems of the upstream area will be improved by the bridge construction project at the national road No.9, but the downstream area will be influenced by some increment of runoff. In order to improve the situation, the improvement of river channels downstream of the seven bridges are required.

2) Southern Side

In the southern side of the national road, the small inundation areas are scattered with a shallow depth and a short duration. In particular, the inundation area of less than 2 or 3 days in the Upper Chane and Warnes area, means that the inundation is caused by the undulation of ground and the insufficient drainage channels connected to river channels.

(3) East Part of the Study Area

1) Okinawa-1 Area

The lower part of Okinawa-1 suffers mainly from floods. The area suffers partly from a heavy inundation of around 50 cm for 5 to 15 days.

2) Okinawa-2 Area

The area is divided into 2 basins, i.e., the Rio Grande basin and the Rio Pailon basin. The Rio Grande basin suffers from a heavy inundation for 5 to 15 days. This area dose not have enough discharge capacity. Furthermore, a natural levee along Rio Grande obstructs to discharge into Rio Grande. That causes water stagnation for a long time.

Rio Pailon basin is frequently inundated by floods from the confluence of Rio Pailon with Arroyo Honda and Quebrada Tomichá, at where these river streams form a habitual inundation area.

3) Okinawa-3 Area

The area, including the colony of Mennonite that are located in the upstream of Okinawa-3, has frequent inundation areas of less than 30 cm deep for 3 to 5 days. It is classified "medium" and lighter than that of the other Okinawa areas.

This area is located in the most upper reach of Rio Pailon, and it dose not have any inflow from the other basin. Nonetheless, the topographic slope is almost 1 / 800 and is gentler than the others around. Simultaneously, many small low-lying lands are scattered in the area.

4) El Tajibo Area

The area is affected by the embankment of the national road No.9. The area along the national road is frequently inundated 30 ~ 50 cm deep for 3 ~ 7 days, which are classified "middle".

2. Hydrological Study for Drainage Improvement

2.1 Rainfall Intensity Formula for Drainage Improvement

Drainage systems have small scale subcatchment compared with the river system, and the lag time of the catchment is plenty short while the river system has 1 or 2 days of the lag time.

The study area is divided into 4 meteorological sub areas based on the selected representative observation stations, and four rainfall intensity formulas within 24 hours are composed to each sub areas for the study of the drainage improvement. The divided sub areas for the rainfall intensity are shown in *Fig. G.2.1*.

The short term rainfall data is available at Santa Cruz and Saavedora, and rainfall intensity formulas for remained sub areas are estimated based on the proportion of daily rainfall. The daily rainfall and estimation of the formulas are shown in *Table. G.2.1* and *2.2*.

2.2 Runoff Analysis for Drainage Improvement

The rational formula method is applied to the runoff analysis of drainage improvement taking account of the characteristic of drainage basin, that is small scale catchment area and short term lag time.

The rational formula is defined as follows;

$$Q = \frac{1}{3.6} \times f \times I \times A$$

Q : Peak Discharge (m^3/s)
f : Runoff Coefficient
I : Rainfall Intensity within Lag Time (mm/hr)
A : Catchment Area (km^2)

Runoff coefficient of 0.50 is adopted to the analysis taking account of the land use and geological condition, that is a plain agricultural area. This coefficient is evaluated to be a reasonable value, compared with the result of 0.38 ~ 0.51 back calculated in the model case area of 5 ~ 20 km^2 by SCS-UHM method, that is applied to the river analysis. The results of the case study are shown in *Table G.2.3 ~ G.2.5*.

Following conditions are adopted to SCS-UHM study.

Design Rainfall 1 day rainfall
Initial Antecedent Moisture Content Class 2 (medium), that is estimated based on the average 5 days rainfall in January of 30 ~ 51 mm, besides 36 ~ 53 mm of 5 days rainfall is classified to Class 2 by SCS.
SCS Curve Number 82, the characteristic of subcatchments are shown in *Table G.2.6*.

For the Okinawa drainage basin, the SCS-UHM method and hydrodynamic model, that is applied to the river analysis, are adopted as an exception in the drainage improvement, because this basin has a large catchment area of 380 km^2 and a flood plain storage is predominant in the existing hydraulic condition.

3. Hydraulic Study for Drainage Improvement

3.1 Evaluation of Existing Drainage Systems

The condition of the existing drainage systems is evaluated by discharge capacity of typical section, that is estimated by the uniform flow method.

The unit area discharge and the result of evaluation of the major drainage are shown in *Fig. G.3.1* and *G.3.2*.

In general, the discharge capacities of the drainage main are less than 2-year runoff.

3.2 San Juan Drainage Main

Two alternatives were studied for San Juan drainage basin.

Alternative 1 is planned to use fully the existing drainage canals with rehabilitation and to discharge the excess water to the downstream through a hydraulic structure.

Alternative 2 is planned to drain the runoff from own catchment by the drainage mains with canal improvement.

The flow condition of the canal is evaluated by the sectional discharge capacity.

Tables G.3.1 ~ G.3.4 show the calculated flow condition of the existing and planned drainage canals.

There is from 34 cm to 100 cm more of 5 year frequent inundation in the existing condition, that is expected to be improved with less than 30 cm by the alternatives.

3.3 Arroyo Tejeria

The arroyo Tejeria is planned to be improved as a drainage canal because the catchment area is small and short.

The flow condition of the channel is evaluated by the sectional discharge capacity, that is 20 ~ 52 cm of 5 year frequent inundation in the existing condition and be improved to be less than 30 cm of overflow.

The flow conditions are shown in *Table G.3.5 ~ G.3.7.*

3.4 Okinawa Drainage Main

The flow conditions of the Okinawa drainage basin are studied with SCS-UHM runoff analysis and hydrodynamic model.

The drainage improvement measures consist of construction of drainage canals and a new drainage main, which connect the existing drainage to the swamp and the former Rio Grande river course.

The inundation of 71 cm by 5 year frequency in the existing condition, is expected to be improved to less than 30 cm by the drainage improvement measures.

The results of hydraulic study are shown in *Table G.3.8 ~ G.3.9* and *Fig. G.3.6.*

3.5 Other Drainage Mains and Drainage Channels for Crossing the National Road No.9

Antofagasta drainage main and Chane drainage mains, which function together with river improvement works, are planned.

In addition, the drainage channels for crossing the national road No.9 are also planned. They are El Empalme II, Las Maras, Chaco and Rancho Chico.

These channels are planned to discharge a 5 year frequency flood with inundation less than 30 cm in depth. The flow conditions of these canals are calculated and shown in *Table G.3.10* and *G.3.11.*

3.6 Secondary Drainage

The secondary drainage is defined as the canal to correct water in the subcatchment and to discharge it to the drainage main or river.

The dimension of the secondary canal is designed to drain a 5 year frequency flood with inundation less than 30 cm deep. The flow conditions of canals are studied by the cross sectional discharge capacities.

The density of the secondary drainage canal is planned to satisfy that each secondary canal is 2 ~ 3 km long from the drainage main or the river with around 5 km^2 of subcatchment.

The secondary drainage has two types of canal dimension fit into the rainfall intensity, which flow conditions are shown in *Table G.3.12*.

4. Facility Plan

Based on the hydraulic study, the drainage facilities planned are shown in *Table G.4.1 ~ G.4.2*.

Drainage mains at Tejeria and Antofagasta basin are planned to be improved by widening the existing channels, and that of Okinawa is to be improved by combination of widening of the existing channels and constructing new canals.

For San Juan drainage Main, rehabilitation of the existing canals is planned for Alternative 1 and channel widening is planned for Alternative 2.

TABLES

TABLE G.1.1 EXISTING DRAINAGE FACILITIES

San Juan Area

Drainage Facility	Items	Condition
Drainage Main	Number of Canals	8 lines
	Total Length	32 km
	Canal Type	Unlined Trapezoid canal
	Width of Canal	3.0 ~ 5.5 m at canal bed
	Slope of Cross Section	1 : 1.0
	Longitude Gradient	0.02 % ~ 0.17 %
Drainage Canal along Roads	Total Length	23 km
Bridge and Cross Drain	Density of Facilities	1.49 pcs / km of road length

Central North Area

Zone	Distance of Road	Quebrada / Canãda**	Bridge / Culvert
Col. aroma / S.J. de Amarillos	182.5 km	0.46 pcs / km road	0.72 pcs / km road
Col. Cuatro Ojitos	96.7 km	0.55 pcs / km road	0.97 pcs / km road
Average		0.49 pcs / km road	0.72 pcs / km road

Okinawa Area

Items	Canal Length	Canal Width	Type of Canal
Okinawa-1 Drainage Network	8.0 km	8 ~ 10 m	Unlined Canal
	4.0 km	4 ~ 5 m	Unlined Canal
	5.0 km	3 m	Unlined Canal
	3.0 km	3 m	Unlined Canal
Natural Course			
Natural Lagoon	2 pcs		
Total Length			
Okinawa-2 Drainage Canal	1.5 km	3m at canal bed	Concrete Lined Canal
	3.5 km	3m at canal bed	Unlined Canal
Total Length	5.0 km		

TABLE G.1.2 SUMMARY OF FREQUENTLY INUNDATING CONDITION

Area	Groupe	Depth		Duration		Classification
		(cm)	Class	(days)	Class	
West Part	San Juan Tejeria	30~60	middle	less than 2	clement	clement
	San Juan Yapacanicito	less than 30	clement	less than 3	clement	clement
	Antofagasta West	30~100	heavy	5~10	heavy	heavy
	Antofagasta East	10~60	clement	less than 3	clement	clement
	Upper Palacios	20~40	clement	less than 2	clement	clement
	Lower Palometilla	10~100	heavy	less than 5	middle	middle
Central North Part	Chané North	20~50	middle	more than 5	heavy	heavy
	Chané Piray	20~60	middle	less than 5	middle	middle
	Montero North	10~60	middle	less than 5	middle	middle
Central South Part	El Tajibo	30~50	middle	3~7	middle	middle
	Upper Chané	10~50	clement	less than 2	clement	clement
	Maracaibo	les than 30	clement	less than 3	clement	clement
East Part	Okinawa 1	around 50	middle	5~15	heavy	heavy
	Okinawa 2	30~100	heavy	5~15	heavy	heavy
	Okinawa 3	less than 30	clement	3~5	middle	middle

TABLE G.2.1 1-DAY RAINFALL INTENSITY

Station		2-year 1day Rainfall (mm)	5-year 1day Rainfall (mm)	10-year 1day Rainfall (mm)	Adopted Proportion for Rainfall Intensity Formuala
Santa Curz Officina		100.9	145.0	174.2	
	(Proportion)	(1.00)	(1.41)	(1.73)	
Saavedra		102.4	137.9	161.4	
	(Proportion)	(1.00)	(1.35)	(1.58)	
Snata Cruz Trompio		100.5	144.8	174.2	Snata Cruz Officina
	(Proportion)	(1.00)	(1.44)	(1.73)	
Okinawa 2		102.8	140.4	165.3	Saavedra
	(Proportion)	(1.00)	(1.37)	(1.61)	
C.S. de Yapacani		139.3	188.3	220.8	Saavedra
	(Proportion)	(1.00)	(1.35)	(1.59)	

TABLE G.2.2 RAINFALL INTENSITY FORMULA WITHIN 24 HOURS

2-yearReturn Period

Station	1day Rainfall (mm)	Proportion		2-yearReturn Period 0<T≤4 a	b	4<T≤24 a	b	R60 (mm)
Santa Curz Officina	100.9	1.00	(－)	9,463	142.63	5,812	-5.00	46.70
Saavedra	102.4	1.00	(－)	6,292	89.00	6,842	117.73	42.23
Snata Cruz Trompio	100.5	1.00	(SC Officina)	9,463	142.63	5,812	-5.00	46.70
Okinawa 2	102.8	1.00	(Saavedra)	6,292	89.00	6,842	117.73	42.23
C.S. de Yapacani	139.3	1.36	(Saavedra)	8,557	89.00	9,305	117.73	57.43

5-yearReturn Period

Station	1day Rainfall (mm)	Proportion		5-yearReturn Period 0<T≤4 a	b	4<T≤24 a	b	R60 (mm)
Santa Curz Officina	145.0	1.00	(－)	12,240	137.66	9,574	55.38	61.92
Saavedra	137.9	1.00	(－)	7,778	72.63	10,271	172.82	58.64
Snata Cruz Trompio	144.8	1.00	(SC Officina)	12,240	137.66	9,574	55.38	61.92
Okinawa 2	140.3	1.02	(Saavedra)	7,934	72.63	10,476	172.82	59.82
C.S. de Yapacani	188.3	1.37	(Saavedra)	10,656	72.63	14,071	172.82	80.34

10-yearReturn Period

Station	1day Rainfall (mm)	Proportion		10-yearReturn Period 0<T≤4 a	b	4<T≤24 a	b	R60 (mm)
Santa Curz Officina	174.2	1.00	(－)	14,079	135.44	11,666	71.09	72.04
Saavedra	161.4	1.00	(－)	8,791	66.56	12,263	187.66	69.46
Snata Cruz Trompio	174.2	1.00	(SC Officina)	14,079	135.44	11,666	71.09	72.04
Okinawa 2	165.3	1.02	(Saavedra)	8,967	66.56	12,508	187.66	70.85
C.S. de Yapacani	220.8	1.37	(Saavedra)	12,044	66.56	16,800	187.66	95.16

20-yearReturn Period

Station	1day Rainfall (mm)	Proportion		20-yearReturn Period 0<T≤4 a	b	4<T≤24 a	b	R60 (mm)
Santa Curz Officina	202.2	1.00	(－)	15,822	133.68	14,966	113.47	81.69
Saavedra	184.0	1.00	(－)	9,778	62.48	14,422	206.14	79.83
Snata Cruz Trompio	202.2	1.00	(SC Officina)	15,822	133.68	14,966	113.47	81.69
Okinawa 2	189.2	1.03	(Saavedra)	10,071	62.48	14,855	206.14	82.23
C.S. de Yapacani	251.9	1.37	(Saavedra)	13,396	62.48	19,758	206.14	109.37

50-yearReturn Period

Station	1day Rainfall (mm)	Proportion		50-yearReturn Period 0<T≤4 a	b	4<T≤24 a	b	R60 (mm)
Santa Curz Officina	238.5	1.00	(－)	18,094	131.97	17,899	127.98	94.25
Saavedra	213.2	1.00	(－)	11,062	58.67	17,243	225.57	93.22
Snata Cruz Trompio	238.5	1.00	(SC Officina)	18,094	131.97	17,899	127.98	94.25
Okinawa 2	220.1	1.03	(Saavedra)	11,394	58.67	17,760	225.57	96.01
C.S. de Yapacani	292.2	1.37	(Saavedra)	15,155	58.67	23,623	225.57	127.71

NOTE : Rainfall Intensity Formula is discribed as $I = \frac{a}{T+b}$ (mm / hr)

whereby T:(minutes)

TABLE G.2.3 PEAK DISCHARGE CALCULATED BY SCS-UHM METHOD

1 Day Design Rainfall with Initial AMC=2,CN=82

Location		Santa Cruz			Okinawa 2			Saavedra			S.C.Yapacani		
Return Period		2-year	5-year	10-year	2-year	5-year	10-year	2-year	5-year	10-year	2-year	5-year	10-year
Area (km^2)	Geological Slope	Discharge (m^3/s)			Discharge (m^3/s)			Discharge (m^3/s)			Discharge (m^3/s)		
5.0	1/2,000	18.59	29.81	37.32	16.14	25.11	31.15	16.01	24.46	30.17	25.31	37.32	45.22
10.0	1/2,000	31.43	50.12	62.88	27.12	42.52	52.93	26.90	41.40	51.26	42.82	63.54	76.99
15.0	1/2,000	42.01	67.45	84.86	36.66	57.35	71.37	36.35	55.82	69.11	57.81	85.73	103.87
20.0	1/2,000	51.28	83.25	104.97	45.41	70.88	88.10	45.02	69.00	85.32	71.55	105.85	128.22

TABLE G.2.4 RUNOFF COEFFICIENT FOR RATIONAL FORMULA BACKCALCULATED BY SCS-UHM MODEL

Location		Santa Cruz			Okinawa 2			Saavedra			S.C.Yapacani		
Return Period		2-year	5-year	10-year	2-year	5-year	10-year	2-year	5-year	10-year	2-year	5-year	10-year
Area (km^2)	Geological Slope	Runoff Coefficient (f)			Runoff Coefficient (f)			Runoff Coefficient (f)			Runoff Coefficient (f)		
5.0	1/2,000	0.38	0.46	0.49	0.39	0.45	0.48	0.39	0.44	0.47	0.45	0.49	0.51
10.0	1/2,000	0.36	0.44	0.48	0.39	0.45	0.48	0.39	0.45	0.48	0.45	0.50	0.52
15.0	1/2,000	0.35	0.43	0.47	0.39	0.45	0.49	0.38	0.45	0.48	0.45	0.50	0.53
20.0	1/2,000	0.34	0.43	0.46	0.39	0.46	0.49	0.39	0.45	0.48	0.45	0.51	0.53
Average for Station		0.42			0.44			0.44			0.49		
Grand Average		0.45											

TABLE G.2.5 (1) ESTIMATED PEAK DISCHARGE WITH RATIONAL FORMULA METHOD (1)

Saavedra			CASE1	CASE2	CASE3	CASE4
Area (km2)			5.00	10.00	15.00	20.00
Georogical Slope			1/2,000	1/2,000	1/2,000	1/2,000
HL (km)			2.24	3.16	3.87	4.47
LagTime(hrs) by USBR			2.30	3.00	3.51	3.92
Rainfall Intensity	a	b	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)
2-year period	6292.25	89.00	27.72	23.39	21.00	19.41
5-year period	7778.06	72.63	36.93	30.79	27.46	25.27
10-year period	8790.79	66.56	42.97	35.65	31.72	29.13
Unit Areal Discharge	f		($m^3/s/km^2$)	(m3/s/km2)	(m3/s/km2)	(m3/s/km2)
2-year period	0.50		3.85	3.25	2.92	2.70
5-year period	0.50		5.13	4.28	3.81	3.51
10-year period	0.50		5.97	4.95	4.41	4.05
Peak Discharge			(m3/s)	(m3/s)	(m3/s)	(m3/s)
2-year period			19.25	32.50	43.80	54.00
5-year period			25.65	42.80	57.15	70.20
10-year period			29.85	49.50	66.15	81.00

Santa Cruz			CASE1	CASE2	CASE3	CASE4
Area (km2)			5.00	10.00	15.00	20.00
Georogical Slope			1/2,000	1/2,000	1/2,000	1/2,000
HL (km)			2.24	3.16	3.87	4.47
LagTime(hrs) by USBR			2.30	3.00	3.51	3.92
Rainfall Intensity	a	b	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)
2-year period (mm/hr)	9463.00	142.63	33.72	29.33	26.79	25.05
5-year period (mm/hr)	12240.00	137.66	44.40	38.53	35.15	32.83
10-year period (mm/hr)	14079.00	135.44	51.49	44.63	40.69	37.99
Unit Areal Discharge	f		($m^3/s/km^2$)	(m3/s/km2)	(m3/s/km2)	(m3/s/km2)
2-year period (m3/s/km2)	0.50		4.68	4.07	3.72	3.48
5-year period (m3/s/km2)	0.50		6.17	5.35	4.88	4.56
10-year period (m3/s/km2)	0.50		7.15	6.20	5.65	5.28
Peak Discharge			(m3/s)	(m3/s)	(m3/s)	(m3/s)
2-year period (m3/s)			23.40	40.70	55.80	69.60
5-year period (m3/s)			30.85	53.50	73.20	91.20
10-year period (m3/s)			35.75	62.00	84.75	105.60

Lag Time : $T_L = \left(11.9 \times \frac{H_L^3}{h}\right)^{0.385}$

Unit Area Discharge : $q_P = \frac{1}{3.6} \times f_C \times I$

Rainfall Intensity : $I = \frac{a}{T_L \times 60 + b}$

Peak Discharge : $Q_P = \frac{1}{3.6} \times f_C \times I \times A$

TABLE G.2.5 (2) ESTIMATED PEAK DISCHARGE WITH RATIONAL FORMULA METHOD (2)

Okinawa 2			CASE1	CASE2	CASE3	CASE4
Area (km2)			5.00	10.00	15.00	20.00
Georogical Slope			1/2,000	1/2,000	1/2,000	1/2,000
HL (km)			2.24	3.16	3.87	4.47
LagTime(hrs) by USBR			2.30	3.00	3.51	3.92
Rainfall Intensity	a	b	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)
2-year period (mm/hr)	6292.00	89.00	27.72	23.39	21.00	19.41
5-year period (mm/hr)	7934.00	72.63	37.67	31.41	28.01	25.77
10-year period (mm/hr)	8967.00	66.56	43.84	36.37	32.35	29.72
Unit Areal Discharge	f		($m^3/s/km^2$)	(m3/s/km2)	(m3/s/km2)	(m3/s/km2)
2-year period (m3/s/km2)	0.50		3.85	3.25	2.92	2.70
5-year period (m3/s/km2)	0.50		5.23	4.36	3.89	3.58
10-year period (m3/s/km2)	0.50		6.09	5.05	4.49	4.13
Peak Discharge			(m3/s)	(m3/s)	(m3/s)	(m3/s)
2-year period (m3/s)			19.25	32.50	43.80	54.00
5-year period (m3/s)			26.15	43.60	58.35	71.60
10-year period (m3/s)			30.45	50.50	67.35	82.60

Yapacani			CASE1	CASE2	CASE3	CASE4
Area (km2)			5.00	10.00	15.00	20.00
Georogical Slope			1/2,000	1/2,000	1/2,000	1/2,000
HL (km)			2.24	3.16	3.87	4.47
LagTime(hrs) by USBR			2.30	3.00	3.51	3.92
Rainfall Intensity	a	b	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)
2-year period (mm/hr)	8557.00	89.00	37.70	31.81	28.56	26.39
5-year period (mm/hr)	10656.00	72.63	50.59	42.18	37.62	34.62
10-year period (mm/hr)	12044.00	66.56	58.88	48.85	43.46	39.91
Unit Areal Discharge	f		($m^3/s/km^2$)	(m3/s/km2)	(m3/s/km2)	(m3/s/km2)
2-year period (m3/s/km2)	0.50		5.24	4.42	3.97	3.67
5-year period (m3/s/km2)	0.50		7.03	5.86	5.23	4.81
10-year period (m3/s/km2)	0.50		8.18	6.78	6.04	5.54
Peak Discharge			(m3/s)	(m3/s)	(m3/s)	(m3/s)
2-year period (m3/s)			26.20	44.20	59.55	73.40
5-year period (m3/s)			35.15	58.60	78.45	96.20
10-year period (m3/s)			40.90	67.80	90.60	110.80

Lag Time : $T_L = \left(11.9 \times \frac{H_L^3}{h}\right)^{0.385}$

Unit Area Discharge : $q_P = \frac{1}{3.6} \times f_C \times I$

Rainfall Intensity : $I = \frac{a}{T_L \times 60 + b}$

Peak Discharge : $Q_P = \frac{1}{3.6} \times f_C \times I \times A$

TABLE G.2.6 (1) CHARACTERISTICS OF CATCHMENT AREA AND SCS CURVE NUMBER (1) : SAN JUAN AREA

River	Area Code	Acreage	Course Length	Geographical Slope	Ground Condition (Acreage %) Hydraulic Soil Groupe C Cultivated	Hydraulic Soil Groupe C Pasture	Hydraulic Soil Groupe C Forest	Hydraulic Soil Groupe D Cultivated	Hydraulic Soil Groupe D Pasture	Hydraulic Soil Groupe D Forest	SCS Curve Number(CN)	USRD method Lag Time	USRD method Velocity	SCS metod Lag Time	SCS metod Velocity
		(km^2)	(km)	(%)	83.0	80.0	73.5	86.0	84.5	80.0		(hr)	(m/sec)	(hr)	(m/sec)
Yapacanicito	R_Y1_1	66.8	10.3	0.050	12.5	12.5	25.0	12.5	12.5	25.0	80	7.5	0.38	23.70	0.121
	R_Y1_2	98.4	19.6	0.050	12.5	12.5	25.0	12.5	12.5	25.0	80	12.2	0.44	39.65	0.137
	R_Y1_3_1	32.8	3.5	0.050	30.0	10.0	10.0	30.0	10.0	10.0	83	3.2	0.30	9.24	0.105
	R_Y1_3_2	21.1	2.4	0.125	30.0	10.0	10.0	30.0	10.0	10.0	83	1.7	0.39	4.32	0.154
	R_Y1_3_3	42.0	13.8	0.125	30.0	10.0	10.0	30.0	10.0	10.0	83	6.6	0.58	17.52	0.219
Subtotal	R_Y1_3	95.9	19.7	0.112							83	9.0	0.61	24.64	0.222
	R_Y1_4_1	8.3	2.5	0.200	30.0	10.0	10.0	30.0	10.0	10.0	83	1.5	0.47	3.53	0.197
	R_Y1_4_2	10.0	2.5	0.200	30.0	10.0	10.0	30.0	10.0	10.0	83	1.5	0.47	3.53	0.197
	R_Y1_4_3	8.9	2.1	0.200	30.0	10.0	10.0	30.0	10.0	10.0	83	1.3	0.45	3.07	0.190
	R_Y1_4_4	4.3	1.5	0.200	30.0	10.0	10.0	30.0	10.0	10.0	83	1.0	0.42	2.35	0.178
	R_Y1_4_5	3.4	3.2	0.200	30.0	10.0	10.0	30.0	10.0	10.0	83	1.8	0.50	4.30	0.207
Subtotal	R_Y1_4	34.9	11.8	0.200							83	4.9	0.67	12.22	0.268
	R_Y2_1	62.8	19.4	0.050	20.0	10.0	20.0	20.0	10.0	20.0	81	12.1	0.44	38.24	0.141
	R_Y2_2_1	10.5	4.2	0.083	30.0	10.0	10.0	30.0	10.0	10.0	83	3.1	0.38	8.30	0.141
	R_Y2_2_2	1.4	2.3	0.083	30.0	10.0	10.0	30.0	10.0	10.0	83	1.9	0.33	5.13	0.125
Subtotal	R_Y2_2	11.9	6.5	0.083							82	4.3	0.42	12.12	0.149
Subtotal	Yapacanicito	370.7													
Jochi	R_J_1	41.6	13.6	0.070	7.5	7.5	35.0	7.5	7.5	35.0	79	8.1	0.47	26.06	0.145
	R_J_2	11.8	2.1	0.070	15.0	10.0	25.0	15.0	10.0	25.0	80	1.9	0.30	5.59	0.104
	R_J_3_1	5.3	2.6	0.070	20.0	10.0	20.0	20.0	10.0	20.0	81	2.3	0.32	6.47	0.112
	R_J_3_2	6.3	2.5	0.070	20.0	10.0	20.0	20.0	10.0	20.0	81	2.2	0.32	6.27	0.111
	R_J_3_3	64.7	21.0	0.115	25.0	10.0	15.0	25.0	10.0	15.0	82	9.4	0.62	26.21	0.223
Subtotal	R_J_3	76.3	26.1	0.106							82	11.4	0.63	32.57	0.223
	R_J_4	18.3	5.0	0.120	25.0	10.0	15.0	25.0	10.0	15.0	82	3.1	0.46	8.14	0.171
Subtotal	Jochi	148.0													
Tacuaral	R_T_1	38.2	10.2	0.050	7.5	7.5	35.0	7.5	7.5	35.0	79	7.4	0.38	24.50	0.116
	R_T_2	88.2	26.0	0.100	15.0	10.0	25.0	15.0	10.0	25.0	80	11.7	0.62	35.03	0.206
	R_T_3_1	10.0	4.7	0.110	15.0	10.0	25.0	15.0	10.0	25.0	80	3.0	0.43	8.50	0.154
	R_T_3_2	67.0	19.8	0.110	15.0	20.0	15.0	15.0	20.0	15.0	81	9.1	0.60	25.94	0.212
Subtotal	R_T_3	77.0	24.5	0.110							80	10.7	0.63	31.75	0.214
	R_T_4	49.4	13.2	0.200	10.0	20.0	20.0	10.0	20.0	20.0	81	5.3	0.69	14.25	0.257
Subtotal	Tacuaral	252.8													
Tejeria	R_TJ	43.6	17.0	0.180	25.0	10.0	15.0	25.0	10.0	15.0	82	6.7	0.70	17.69	0.267

TABLE G.2.6 (2) CHARACTERISTICS OF CATCHMENT AREA AND SCS CURVE NUMBER (2) : CHANE-PAILON-OKINAWA AREA

Sub-catchment	Area	Main Stream			Average	Ground Condition (Acreage %)						SCS Curve	USRD method		SCS method	
		Hydraulic Length	ownstream Point	Upstream Point	Catchment Slope	Hydraulic Soil Groupe C			Hydraulic Soil Groupe D			Number(CN)	Lag Time	Velocity	Lag Time	Velocity
						Cultivated	Pasture	Forest	Cultivated	Pasture	Forest					
	(km2)	(m)	(El. m)	(El. m)	(%)	83.0	80.0	73.5	86.0	84.5	80.0		(hr)	(m/sec)	(hr)	(m/sec)
A - 1	63.35	12500	223	233	0.080	5.0	5.0	20.0	45.0	5.0	20.0	82	7.2	0.48	20.7	0.168
A - 2	198.68	22000	233	239	0.027	25.0	10.0	15.0	25.0	10.0	15.0	82	16.9	0.36	55.9	0.109
A - 3	164.7	23000	239	255	0.070	30.0	5.0	15.0	30.0	5.0	15.0	82	12.2	0.52	36.0	0.178
A - 4	60.08	4200	255	258	0.071	25.0	10.0	15.0	25.0	10.0	15.0	82	3.3	0.36	9.2	0.127
A - 5	15.8	4000	258	260	0.050	30.0	5.0	15.0	30.0	5.0	15.0	82	3.6	0.31	10.5	0.106
A - 6	211.87	22000	260	293	0.150	25.0	5.0	15.0	35.0	5.0	15.0	82	8.8	0.70	23.5	0.260
A - 7	112.68	28000	260	313	0.189	20.0	10.0	15.0	30.0	10.0	15.0	82	9.6	0.81	25.6	0.304
A - 8	270.08	39000	313	400	0.223	17.5	17.5	10.0	27.5	17.5	10.0	82	11.7	0.93	30.3	0.358
A - 9	141.89	32000	313	385	0.225	17.5	17.5	10.0	27.5	17.5	10.0	82	10.0	0.89	25.7	0.345
A-10	66.14	28000	258	318	0.214	17.5	17.5	10.0	27.5	17.5	10.0	82	9.2	0.85	23.7	0.328
A-11	275.46	42000	258	355	0.231	17.5	17.5	10.0	27.5	17.5	10.0	82	12.2	0.96	31.6	0.369
B - 1	6.72	2500	233	235	0.080	12.5	12.5	20.0	22.5	12.5	20.0	81	2.1	0.33	5.9	0.118
B - 2	153.49	32000	235	276	0.128	20.0	15.0	15.0	20.0	15.0	15.0	82	12.4	0.72	35.0	0.254
B - 3	64.04	16000	276	310	0.213	20.0	20.0	10.0	20.0	20.0	10.0	82	6.0	0.74	15.3	0.290
C - 1	3.18	4000	239	245	0.150	10.0	10.0	20.0	30.0	10.0	20.0	81	2.4	0.47	6.2	0.180
C - 2	35.03	14500	245	265	0.138	20.0	20.0	10.0	20.0	20.0	10.0	82	6.6	0.61	17.6	0.229
C - 3	197.4	40000	265	355	0.225	20.0	20.0	10.0	20.0	20.0	10.0	82	11.9	0.94	31.0	0.358
C - 4	38.77	11500	245	261	0.139	20.0	20.0	10.0	20.0	20.0	10.0	82	5.5	0.58	14.6	0.219
C - 5	11.36	4500	261	267	0.133	20.0	20.0	10.0	20.0	20.0	10.0	82	2.7	0.46	7.0	0.178
C - 6	121.16	28000	267	335	0.243	20.0	20.0	10.0	20.0	20.0	10.0	82	8.8	0.89	22.5	0.346
C - 7	23.93	7000	261	274	0.186	20.0	20.0	10.0	20.0	20.0	10.0	82	3.3	0.58	8.5	0.229
C - 8	38.43	21000	274	320	0.219	20.0	20.0	10.0	20.0	20.0	10.0	82	7.3	0.80	18.8	0.310
D - 1	244.82	33000	293	355	0.188	20.0	10.0	10.0	40.0	10.0	10.0	83	11.0	0.83	28.4	0.323
E - 1	105.9	24300	232	251	0.078	35.0	7.5	7.5	35.0	7.5	7.5	83	12.2	0.56	34.5	0.197
E - 2	69.70	13700	251	270	0.139	35.0	7.5	7.5	35.0	7.5	7.5	83	6.3	0.61	16.3	0.234

TABLE G.3.1 DESIGN DISCHARGE OF SAN JUAN DRAINAGE MAIN

2-Year Return Period

	km9.00	km11.00	km13.00	km15.00	km17.00	km24.00	km28.00
$T_L = \left(11.9 \times \frac{H_L^3}{h}\right)^{0.385}$ (hrs H_L : miles h : feet)							
H_L : (km)	3.00	3.00	4.00	4.20	4.50	1.50	5.00
h : (m)	2.00	2.00	2.67	2.80	3.00	1.00	3.30
T_L : (hrs)	2.50	2.50	3.00	3.50	3.50	1.50	4.00
$I = \frac{a}{T_L + b}$ (mm/hr T_L : minutes)							
a :	8,557	8,557	8,557	8,557	8,557	8,557	8,557
b :	89.00	89.00	89.00	89.00	89.00	89.00	89.00
I : (mm/hr)	35.80	35.80	31.81	28.62	28.62	47.80	26.01
$Q_P = \frac{1}{3.6} \times f_C \times I \times A$ (m^3/s I : mm/hr A : km^2)							
f_C :	0.50	0.50	0.50	0.50	0.50	0.50	0.50
A : (km^2)	3.00	5.00	9.50	9.50	8.00	2.00	13.50
Q_P : (m^3/s)	14.92	24.86	41.97	37.76	31.80	13.28	48.77

5-Year Return Period

	km9.00	km11.00	km13.00	km15.00	km17.00	km24.00	km28.00
$T_L = \left(11.9 \times \frac{H_L^3}{h}\right)^{0.385}$ (hrs H_L : miles h : feet)							
H_L : (km)	3.00	3.00	4.00	4.20	4.50	1.50	5.00
h : (m)	2.00	2.00	2.67	2.80	3.00	1.00	3.30
T_L : (hrs)	2.50	2.50	3.00	3.50	3.50	1.50	4.00
$I = \frac{a}{T_L + b}$ (mm/hr T_L : minutes)							
a :	10,656	10,656	10,656	10,656	10,656	10,656	10,656
b :	72.63	72.63	72.63	72.63	72.63	72.63	72.63
I : (mm/hr)	47.86	47.86	42.18	37.70	37.70	65.52	34.09
$Q_P = \frac{1}{3.6} \times f_C \times I \times A$ (m^3/s I : mm/hr A : km^2)							
f_C :	0.50	0.50	0.50	0.50	0.50	0.50	0.50
A : (km^2)	3.00	5.00	9.50	9.50	8.00	2.00	13.50
Q_P : (m^3/s)	19.94	33.24	55.65	49.74	41.89	18.20	63.92

10-Year Return Period

	km9.00	km11.00	km13.00	km15.00	km17.00	km24.00	km28.00
$T_L = \left(11.9 \times \frac{H_L^3}{h}\right)^{0.385}$ (hrs H_L : miles h : feet)							
H_L : (km)	3.00	3.00	4.00	4.20	4.50	1.50	5.00
h : (m)	2.00	2.00	2.67	2.80	3.00	1.00	3.33
T_L : (hrs)	2.50	2.50	3.00	3.50	3.50	1.50	4.00
$I = \frac{a}{T_L + b}$ (mm/hr T_L : minutes)							
a :	12,044	12,044	12,044	12,044	12,044	12,044	12,044
b :	66.56	66.56	66.56	66.56	66.56	66.56	66.56
I : (mm/hr)	55.62	55.62	48.85	43.55	43.55	76.93	39.29
$Q_P = \frac{1}{3.6} \times f_C \times I \times A$ (m^3/s I : mm/hr A : km^2)							
f_C :	0.50	0.50	0.50	0.50	0.50	0.50	0.50
A : (km^2)	3.00	5.00	9.50	9.50	8.00	2.00	13.50
Q_P : (m^3/s)	23.18	38.63	64.45	57.46	48.39	21.37	73.67

TABLE G.3.1 DESIGN DISCHARGE OF SAN JUAN DRAINAGE MAIN

20-Year Return Period

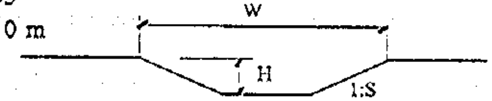
	km9.00	km11.00	km13.00	km15.00	km17.00	km24.00	km28.00
$T_L = \left(11.9 \times \frac{H_L^3}{h}\right)^{0.385}$ (hrs H_L : miles h : feet)							
H_L : (km)	3.00	3.00	4.00	4.20	4.50	1.50	5.00
h : (m)	2.00	2.00	2.67	2.80	3.00	1.00	3.33
T_L : (hrs)	2.50	2.50	3.00	3.50	3.50	1.50	4.00
$I = \frac{a}{T_L + b}$ (mm/hr T_L : minutes)							
a :	13,396	13,396	13,396	13,396	13,396	13,396	13,396
b :	62.48	62.48	62.48	62.48	62.48	62.48	62.48
I : (mm/hr)	63.05	63.05	55.25	49.16	49.16	87.85	44.29
$Q_P = \frac{1}{3.6} \times f_C \times I \times A$ (m^3/s I : mm/hr A : km^2)							
f_C :	0.50	0.50	0.50	0.50	0.50	0.50	0.50
A : (km^2)	3.00	5.00	9.50	9.50	8.00	2.00	13.50
Q_P : (m^3/s)	26.27	43.78	72.90	64.86	54.62	24.40	83.04

50-Year Return Period

	km9.00	km11.00	km13.00	km15.00	km17.00	km24.00	km28.00
$T_L = \left(11.9 \times \frac{H_L^3}{h}\right)^{0.385}$ (hrs H_L : miles h : feet)							
H_L : (km)	3.00	3.00	4.00	4.20	4.50	1.50	5.00
h : (m)	2.00	2.00	2.67	2.80	3.00	1.00	3.33
T_L : (hrs)	2.50	2.50	3.00	3.50	3.50	1.50	4.00
$I = \frac{a}{T_L + b}$ (mm/hr T_L : minutes)							
a :	15,155	15,155	15,155	15,155	15,155	15,155	15,155
b :	58.67	58.67	58.67	58.67	58.67	58.67	58.67
I : (mm/hr)	72.63	72.63	63.50	56.41	56.41	101.94	50.74
$Q_P = \frac{1}{3.6} \times f_C \times I \times A$ (m^3/s I : mm/hr A : km^2)							
f_C :	0.50	0.50	0.50	0.50	0.50	0.50	0.50
A : (km^2)	3.00	5.00	9.50	9.50	8.00	2.00	13.50
Q_P : (m^3/s)	30.26	50.41	83.78	74.43	62.68	28.32	95.14

TABLE G.3.2 HYDRAULIC CONDITION OF EXISTING CANAL OF SAN JUAN DRAINAGE MAINS

n 0.035
Fb 0 m



Case	Slope	Cross Section Data				2-Year Flood			5-Year Flood			10-Year Flood		
Section		W (m)	S	H (m)	$Q_{capacity}$* (m^3/s)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top*** (m)	Q_{PEAK} (m_3/s)	Depth (m)	Over Top (m)	Q_{PEAK} (m_3/s)	Depth (m)	Over Top (m)
km09.00	1/1,500	11.00	1/1.0	3.00	26.00	14.92	2.31	none	19.94	2.65	none	23.18	2.83	none
km11.00	1/1,500	11.00	1/1.0	3.00	26.00	24.86	2.94	none	33.24	3.34	0.34	38.63	3.56	0.56
km13.00	1/1,500	11.00	1/1.0	3.00	26.00	41.97	3.73	0.73	55.65	4.14	1.14	64.45	4.40	1.40
km15.00	1/1,500	11.00	1/1.0	3.00	26.00	37.76	3.56	0.56	49.74	3.96	0.96	57.46	4.20	1.20
km17.00	1/1,500	11.00	1/1.0	3.00	26.00	31.80	3.29	0.29	41.89	3.68	0.68	48.39	3.91	0.91
km24.00	1/1,500	11.00	1/1.0	3.00	26.00	13.28	2.19	none	18.20	2.54	none	21.37	2.73	none
km28.00	1/1,500	11.00	1/1.0	3.00	26.00	48.77	3.99	0.99	63.92	4.39	1.39	73.67	4.65	1.65

Case	Slope	Cross Section Data				20-Year Flood			50-Year Flood		
Section		W (m)	S	H (m)	$Q_{capacity}$* (m^3/s)	Q_{PEAK} (m_3/s)	Depth (m)	Over Top (m)	Q_{PEAK} (m_3/s)	Depth (m)	Over Top (m)
km09.00	1/1,500	11.00	1/1.0	3.00	26.00	26.27	2.99	none	30.26	3.18	0.18
km11.00	1/1,500	11.00	1/1.0	3.00	26.00	43.78	3.75	0.75	50.44	3.98	0.98
km13.00	1/1,500	11.00	1/1.0	3.00	26.00	72.90	4.63	1.63	83.78	4.89	1.89
km15.00	1/1,500	11.00	1/1.0	3.00	26.00	64.86	4.41	1.41	74.43	4.67	1.67
km17.00	1/1,500	11.00	1/1.0	3.00	26.00	54.62	4.11	1.11	62.68	4.35	1.35
km24.00	1/1,500	11.00	1/1.0	3.00	26.00	24.40	2.89	none	28.32	3.09	0.09
km28.00	1/1,500	11.00	1/1.0	3.00	26.00	83.04	4.88	1.88	95.14	5.15	2.15

TABLE G.3.3 HYDRAULIC CONDITION OF PROPOSED IMPROVEMENT ALTERNATIVE 1 OF SAN JUAN DRAINAGE MAINS

n= 0.03
c= 1.60

Canal	Return Period	$Q_{discharge}$ (m^3/s)	i	Water Depth: Depth (m)	Water Depth: Over Top (m)	Cross Section Dimension: W (m)	Cross Section Dimension: B (m)	Cross Section Dimension: D (m)	Cross Section Dimension: S	Discharge of Canal: L (m)	Discharge of Canal: A (m^2)	Discharge of Canal: R (m)	Discharge of Canal: Q_{canal} (m^3/s)	Discharge of Wier: B (m)	Discharge of Wier: Z (m)	Discharge of Wier: Q_{weir} (m^3/s)
km 13.00	2 - year	41.97	1/1,500	2.97	none	11.00	5.00	3.00	1/1.0	13.40	23.66	1.77	29.76	8.00	2.00	12.21
	5 - year	55.65	1/1,500	3.27	0.27	11.00	5.00	3.00	1/1.0	13.49	27.15	2.01	37.26	8.00	2.00	18.39
	10 - year	64.45	1/1,500	3.44	0.44	11.00	5.00	3.00	1/1.0	13.49	29.28	2.17	42.24	8.00	2.00	22.21
	20 - year	72.90	1/1,500	3.60	0.60	11.00	5.00	3.00	1/1.0	13.49	31.26	2.32	47.11	8.00	2.00	25.79
	50 - year	83.78	1/1,500	3.78	0.78	11.00	5.00	3.00	1/1.0	13.49	33.73	2.50	53.50	8.00	2.00	30.28
km 15.00	2 - year	37.76	1/1,500	2.95	none	11.00	5.00	3.00	1/1.0	13.33	23.42	1.76	29.34	14.00	2.00	20.64
	5 - year	49.74	1/1,500	3.25	0.25	11.00	5.00	3.00	1/1.0	13.49	26.91	2.00	36.71	14.00	2.00	31.42
	10 - year	57.46	1/1,500	3.42	0.42	11.00	5.00	3.00	1/1.0	13.49	29.02	2.15	41.62	14.00	2.00	38.04
	20 - year	64.86	1/1,500	3.57	0.57	11.00	5.00	3.00	1/1.0	13.49	30.97	2.30	46.41	14.00	2.00	44.24
	50 - year	74.43	1/1,500	3.75	0.75	11.00	5.00	3.00	1/1.0	13.49	33.43	2.48	52.69	14.00	2.00	52.02
km 17.00	2 - year	31.80	1/1,500	2.97	none	11.00	5.00	3.00	1/1.0	13.39	23.62	1.76	29.68	15.00	2.00	22.76
	5 - year	41.89	1/1,500	3.30	0.30	11.00	5.00	3.00	1/1.0	13.49	27.43	2.03	37.90	15.00	2.00	35.41
	10 - year	48.39	1/1,500	3.48	0.48	11.00	5.00	3.00	1/1.0	13.49	29.72	2.20	43.31	15.00	2.00	43.13
	20 - year	54.62	1/1,500	3.64	0.64	11.00	5.00	3.00	1/1.0	13.49	31.83	2.36	48.56	15.00	2.00	50.30
	50 - year	62.68	1/1,500	3.83	0.83	11.00	5.00	3.00	1/1.0	13.49	34.46	2.56	55.44	15.00	2.00	59.26
km 28.00	2 - year	48.77	1/1,500	2.98	none	11.00	5.00	3.00	1/1.0	13.44	23.82	1.77	30.03	12.00	2.00	18.74
	5 - year	63.92	1/1,500	3.26	0.26	11.00	5.00	3.00	1/1.0	13.49	26.97	2.00	36.84	12.00	2.00	27.08
	10 - year	73.67	1/1,500	3.41	0.41	11.00	5.00	3.00	1/1.0	13.49	28.91	2.14	41.36	12.00	2.00	32.31
	20 - year	83.04	1/1,500	3.56	0.56	11.00	5.00	3.00	1/1.0	13.49	30.73	2.28	45.79	12.00	2.00	37.25
	50 - year	95.14	1/1,500	3.72	0.72	11.00	5.00	3.00	1/1.0	13.49	33.03	2.45	51.64	12.00	2.00	43.50

* : Discharge capacity of canal is estimated by Manning Formula where assumed flow area is applied to the area above ground elevation.

$$Q_{canal} = \frac{1}{n} \times i^{\frac{1}{2}} \times R^{\frac{2}{3}} \times A$$

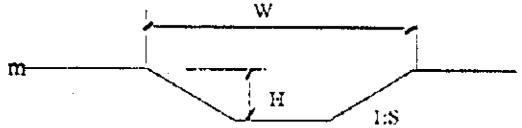
** : Discharge capacity of diversion wier is estimated by Wier Formula shown below.

$$Q_{wier} = C \times B \times H^{\frac{1}{2}}$$

*** : Diversion balance of canal and wier is estimated as to be $Q_{discharge} = Q_{canal} + Q_{wier}$ where same water level is applied.

TABLE G.3.4 HYDRAULIC CONDITION OF PROPOSED IMPROVEMENT ALTERNATIVE 2 OF SAN JUAN DRAINAGE MAINS

n 0.03
Fb 0 m



* : Roughness coefficient of 0.030 is applied.

** : Q_{PEAK} for each flood is estimated in Hydro Dynamic Model.

***: Assumed flow area is applied for the area above ground level.

Canal	Slope	Cross Section Data				2-Year Flood			5-Year Flood			10-Year Flood		
		W (m)	S	H (m)	$Q_{capacity}$* (m^3/s)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top*** (m)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top (m)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top (m)
km09.00	1/1,500	14.00	1/1.5	3.00	36.32	14.92	2.04	none	19.94	2.32	none	23.18	2.47	none
km11.00	1/1,500	14.00	1/1.5	3.00	36.32	24.86	2.55	none	33.24	2.89	none	38.63	3.07	0.07
km13.00	1/1,500	16.00	1/1.5	3.00	46.13	41.97	2.88	none	55.65	3.25	0.25	64.45	3.46	0.46
km15.00	1/1,500	15.00	1/1.5	3.00	41.20	37.76	2.89	none	49.74	3.25	0.25	57.46	3.44	0.44
km17.00	1/1,500	14.00	1/1.5	3.00	36.32	31.80	2.84	none	41.89	3.18	0.18	48.39	3.37	0.37
km24.00	1/1,500	14.00	1/1.5	3.00	36.32	13.28	1.94	none	18.20	2.23	none	21.37	2.39	none
km28.00	1/1,500	18.00	1/1.5	3.00	56.14	48.77	2.81	none	63.92	3.18	0.18	73.67	3.39	0.39

Canal	Slope	Cross Section Data				20-Year Flood			50-Year Flood		
		W (m)	S	H (m)	$Q_{capacity}$* (m^3/s)	Q_{PEAK} (m_3/s)	Depth (m)	Over Top (m)	Q_{PEAK} (m_3/s)	Depth (m)	Over Top (m)
km09.00	1/1,500	14.00	1/1.5	3.00	36.32	26.27	2.61	none	30.26	2.76	none
km11.00	1/1,500	14.00	1/1.5	3.00	36.32	43.78	3.23	0.23	50.44	3.42	0.42
km13.00	1/1,500	16.00	1/1.5	3.00	46.13	72.90	3.64	0.64	83.78	3.86	0.86
km15.00	1/1,500	15.00	1/1.5	3.00	41.20	64.86	3.62	0.62	74.43	3.83	0.83
km17.00	1/1,500	14.00	1/1.5	3.00	36.32	54.62	3.53	0.53	62.68	3.73	0.73
km24.00	1/1,500	14.00	1/1.5	3.00	36.32	24.40	2.52	none	28.32	2.69	none
km28.00	1/1,500	18.00	1/1.5	3.00	56.14	83.04	3.57	0.57	95.14	3.79	0.79

TABLE G.3.5 DESIGN DISCHARGE OF ARROYO TEJERIA

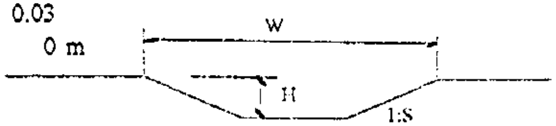
Section	Catchment Area	δh	H_L	Lag Time	$I_{1/2}$	$Q_{peak\ 1/2}$	$I_{1/5}$	$Q_{peak\ 1/5}$	$I_{1/10}$	$Q_{peak\ 1/10}$	$I_{1/20}$	$Q_{peak\ 1/20}$	$I_{1/50}$	$Q_{peak\ 1/50}$
	(km^2)	(m)	(km)	(hrs)	(mm/hr)	(m^3/s)	(mm/hr)	(m^3/s)	(mm/hr)	(m^3/s)	(mm/hr)	(m^3/s)	(mm/hr)	(m^3/s)
A101	43.60	25.00	18.00	7.50	16.39	99.25	22.59	136.80	26.35	159.56	30.11	182.33	34.97	211.76
A103	35.30	18.00	12.50	6.00	19.48	95.51	26.41	129.48	30.68	150.42	34.90	171.11	40.34	197.78
Branch A														
A104'	18.60	13.00	8.50	4.00	26.01	67.19	34.09	88.07	39.29	101.50	44.29	114.42	50.74	131.08
Control Structure														
A105'	16.60	12.00	7.50	3.50	28.62	65.99	37.70	86.92	43.55	100.41	49.16	113.34	56.41	130.06
Branch B														
A104	11.00	8.00	7.00	4.00	26.01	39.74	34.09	52.08	39.29	60.03	44.29	67.67	50.74	77.52
Control Structure														
A105	6.50	6.00	5.50	3.50	28.62	25.84	37.70	34.03	43.55	39.32	49.16	44.38	56.41	50.93

TABLE G.3.6 HYDRAULIC CONDITION OF EXISTING CHANNEL OF ARROYO TEJERIA

Section	Water Level (1/2) (EL m)	Depth (1/2) (m)	Over Top (1/2) (m)	Water Level (1/5) (EL m)	Depth (1/5) (m)	Over Top (1/5) (m)	Water Level (1/10) (EL m)	Depth (1/10) (m)	Over Top (1/10) (m)	Water Level (1/20) (EL m)	Depth (1/20) (m)	Over Top (1/20) (m)	Water Level (1/50) (EL m)	Depth (1/50) (m)	Over Top (1/50) (m)
A101	282.78	2.44	none	283.20	2.86	0.20	283.35	3.01	0.35	283.54	3.20	0.54	283.69	3.35	0.69
A103	289.10	4.00	0.20	289.42	4.32	0.52	289.59	4.49	0.69	289.75	4.65	0.85	289.95	4.84	1.05
Branch A															
A104'	292.70	3.93	0.13	292.90	4.13	0.33	293.01	4.24	0.44	293.10	4.34	0.53	293.24	4.47	0.67
Control Structure															
A105'	294.56	2.22	0.27	294.75	2.41	0.46	294.86	2.52	0.57	294.89	2.62	0.60	295.09	2.75	0.80
Branch B															
A104	294.84	3.27	none	294.99	3.42	none	295.08	3.51	none	295.14	3.58	none	295.23	3.66	none
Control Structure															
A105	294.84		2.04	294.99		2.19	295.08		2.28	295.14		2.34	295.23		2.43

TABLE G.3.7 HYDRAULIC CONDITION OF PROPOSED IMPROVEMENT OF ARROYO TEJERIA

n 0.03
Fb 0 m



* : Roughness coefficient of 0.030 is applied.
** : Q_{PEAK} for each flood is estimated in Hydro Dynamic Model.
***: Assumed flow area is applied for the area above ground level.

Case Section	Slope	Cross Section Data				2-Year Flood			5-Year Flood			10-Year Flood		
		W (m)	S	H (m)	$Q_{capacity}$* (m^3/s)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top*** (m)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top (m)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top (m)
km4.20	1/900	22.00	1/2.0	4.00	109.80	95.51	3.79	none	129.48	4.26	0.26	150.42	4.51	0.51
Branch A														
km7.50'	1/900	20.00	1/2.0	4.00	90.02	67.19	3.59	none	88.07	3.97	none	101.50	4.18	0.18
km9.50'	1/900	20.00	1/2.0	3.00	73.12	65.99	2.87	none	86.92	3.22	0.22	100.41	3.42	0.42
Branch B														
km6.00	1/400	16.00	1/2.0	3.00	71.85	39.74	2.38	none	52.08	2.65	none	60.03	2.80	none
km7.00	1/2,000	16.00	1/2.0	3.00	32.13	25.84	2.76	none	34.03	3.07	0.07	39.32	3.23	0.23

Case Section	Slope	Cross Section Data				20-Year Flood			50-Year Flood		
		W (m)	S	H (m)	$Q_{capacity}$* (m^3/s)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top (m)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top (m)
km4.20	1/900	22.00	1/2.0	4.00	109.80	171.11	4.73	0.73	197.78	4.99	0.99
Branch A											
km7.50'	1/900	20.00	1/2.0	4.00	90.02	114.42	4.36	0.36	131.08	4.57	0.57
km9.50'	1/900	20.00	1/2.0	3.00	73.12	113.34	3.60	0.60	130.06	3.80	0.80
Branch B											
km6.00	1/400	16.00	1/2.0	3.00	71.85	67.67	2.93	none	77.52	3.08	0.08
km7.00	1/2,000	16.00	1/2.0	3.00	32.13	44.38	3.38	0.38	50.93	3.56	0.56

TABLE G.3.8 HYDRAULIC CONDITION OF PRESENT CANAL OF OKINAWA DRAINAGE MAIN BY HD MODEL ANALYSIS

River Name	Chanage (km)	Left Bank (EL m)	Right Bank (EL m)	Bank Height (EL m)	Peak Water Level (m)	Duration (hrs)	Duration (days)	Inundaton Depth(m)	
2-year Flood									
Okinawa DM	0.00	250.00	250.00	250.00	250.97	286.0	11.9 more	0.97	
	7.00	247.60	247.60	247.60	248.11	127.7	5.3	0.51	
	16.00	240.80	240.80	240.80	241.57	266.8	11.1 more	0.77	**Average 7.00 - 25.00**
	25.00	234.00	234.00	234.00	234.32	104.3	4.3	0.32	0.53m 6.9days
5-year Flood									
Okinawa DM	0.00	250.00	250.00	250.00	251.30	286.0	11.9 more	1.30	
	7.00	247.60	247.60	247.60	248.26	205.8	8.6	0.66	
	16.00	240.80	240.80	240.80	241.83	269.8	11.2 more	1.03	**Average 7.00 - 25.00**
	25.00	234.00	234.00	234.00	234.45	160.8	6.7	0.45	0.71m 8.8days
10-year Flood									
Okinawa DM	0.00	250.00	250.00	250.00	251.50	286.0	11.9 more	1.50	
	7.00	247.60	247.60	247.60	248.35	227.3	9.5 more	0.75	
	16.00	240.80	240.80	240.80	242.00	270.7	11.3 more	1.20	**Average 7.00 - 25.00**
	25.00	234.00	234.00	234.00	234.52	196.0	8.2	0.52	0.82m 9.6days
20-year Flood									
Okinawa DM	0.00	250.00	250.00	250.00	251.68	286.0	11.9 more	1.68	
	7.00	247.60	247.60	247.60	248.43	246.5	10.3 more	0.83	
	16.00	240.80	240.80	240.80	242.14	271.2	11.3 more	1.34	**Average 7.00 - 25.00**
	25.00	234.00	234.00	234.00	234.54	195.7	8.2	0.54	0.90m 9.9days
50-year Flood									
Okinawa DM	0.00	250.00	250.00	250.00	251.90	286.0	11.9 more	1.90	
	7.00	247.60	247.60	247.60	248.53	263.8	11.0 more	0.93	
	16.00	240.80	240.80	240.80	242.34	271.8	11.3 more	1.54	**Average 7.00 - 25.00**
	25.00	234.00	234.00	234.00	234.66	227.7	9.5 more	0.66	1.04m 10.6days
1992 Flood									
Okinawa DM	0.00	250.00	250.00	250.00	252.20	318.0	13.3 more	2.20	
	7.00	247.60	247.60	247.60	248.61	297.8	12.4 more	1.01	
	16.00	240.80	240.80	240.80	242.45	300.5	12.5 more	1.65	**Average 7.00 - 25.00**
	25.00	234.00	234.00	234.00	234.73	294.7	12.3 more	0.73	1.13m 12.4days

TABLE G.3.9 HYDRAULIC CONDITION OF PROPOSED IMPROVEMENT OF OKINAWA DRAINAGE MAIN BY HD MODEL ANALYSIS

River Name	Chanage (km)	Left Bank (EL m)	Right Bank (EL m)	Bank Height (EL m)	Peak Water Level (m)	Duration (hrs)	Duration (days)	Inundaton Depth(m)		
2-year Flood										
Okinawa DM	0.00	250.00	250.00	250.00	250.60	80.5	3.4	0.60		
	7.00	247.60	247.60	247.60	247.71	7.2	0.3	0.11		
	16.00	240.80	240.80	240.80	240.69	0.0	0.0	none	**Average 7.00 - 25.00**	
	25.00	234.00	234.00	234.00	233.75	0.0	0.0	none	0.04m	0.1days
5-year Flood										
Okinawa DM	0.00	250.00	250.00	250.00	250.94	107.5	4.5	0.94		
	7.00	247.60	247.60	247.60	247.92	15.3	0.6	0.32		
	16.00	240.80	240.80	240.80	241.18	14.5	0.6	0.38	**Average 7.00 - 25.00**	
	25.00	234.00	234.00	234.00	234.00	1.0	0.0	none	0.23m	0.4days
10-year Flood										
Okinawa DM	0.00	250.00	250.00	250.00	251.13	122.8	5.1	1.13		
	7.00	247.60	247.60	247.60	248.00	19.5	0.8	0.40		
	16.00	240.80	240.80	240.80	241.36	19.8	0.8	0.56	**Average 7.00 - 25.00**	
	25.00	234.00	234.00	234.00	234.13	13.3	0.6	0.13	0.36m	0.7days
20-year Flood										
Okinawa DM	0.00	250.00	250.00	250.00	251.31	135.5	5.6	1.31		
	7.00	247.60	247.60	247.60	248.05	23.3	1.0	0.45		
	16.00	240.80	240.80	240.80	241.49	24.7	1.0	0.69	**Average 7.00 - 25.00**	
	25.00	234.00	234.00	234.00	234.24	19.0	0.8	0.24	0.46m	0.9days
50-year Flood										
Okinawa DM	0.00	250.00	250.00	250.00	251.53	150.5	6.3	1.53		
	7.00	247.60	247.60	247.60	248.12	28.8	1.2	0.52		
	16.00	240.80	240.80	240.80	241.64	30.5	1.3	0.84	**Average 7.00 - 25.00**	
	25.00	234.00	234.00	234.00	234.33	25.0	1.0	0.33	0.56m	1.2days

TABLE G.3.10 DESIGN DISCHARGE OF ANTOFAGASTA DRAINAGE MAIN, CHANE DRAINAGE MAINS AND DRAINAGE CHANNELS FOR CROSSING THE NATIONAL ROAD No.9

Section	Catchment Area (km^2)	δh (m)	H_L (km)	Lag Time (hrs)	$I_{1/2}$ (mm/hr)	$Q_{peak\ 1/2}$ (m^3/s)	$q_{1/2}$ ($m^3/s/km^2$)	$I_{1/5}$ (mm/hr)	$Q_{peak\ 1/5}$ (m^3/s)	$q_{1/5}$ ($m^3/s/km^2$)
Antofagasta Drainage Main										
km 0.00	88.20	26.00	26.00	11.50	11.52	141.12	1.60	16.31	199.80	2.27
km 8.00	60.20	18.00	18.00	9.00	14.15	118.31	1.97	19.74	165.05	2.74
Chane Drainage Main 1										
km 0.00	90.00	36.00	25.00	10.00	9.53	119.13	1.32	13.29	166.13	1.85
km 8.00	58.00	31.00	17.00	6.50	13.48	108.59	1.87	18.25	147.01	2.53
Chane Drainage Main 2										
km 0.00	90.00	23.00	13.50	5.50	15.28	191.00	2.12	20.43	255.38	2.84
km 4.00	46.00	17.00	8.50	4.00	19.12	122.16	2.66	24.88	158.96	3.46
Connecting Channels for JICA/SNC Bridge Project										
El Empalme II	8.90	3.00	3.00	2.00	30.11	37.22	4.18	41.19	50.92	5.72
Chaco	35.30	3.00	4.20	3.50	21.04	103.15	2.92	28.07	137.62	3.90
Rancho Chico						74.20			109.00	
Las Maras	62.40	59.00	29.00	9.50	9.95	86.23	1.38	13.83	119.86	1.92

* : Rainfall intensity of S. C. Yapacani is applied for Antofagasta Drainage Main, of Saavedor for Chane Drainage Mains and Las Maras and of Okinawa II for El Empalme II, Chaco and Rancho Chico.

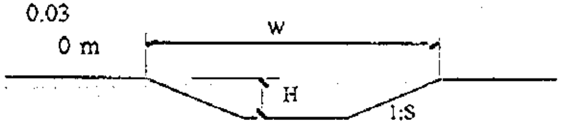
TABLE G.3.11 HYDRAULIC CONDITION OF ANTOFAGASTA DRAINAGE MAIN, CHANE DRAINAGE MAINS AND DRAINAGE CHANNELS FOR CROSSING THE NATIONAL ROAD No.9

n 0.03
Fb 0 m

Canal	Slope	Cross Section Data				2-Year Flood			5-Year Flood		
		W (m)	S	H (m)	$Q_{capacity}$* (m^3/s)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top*** (m)	Q_{PEAK} (m_3/s)	Depth (m)	Over Top (m)
Antofagasta Drainage Main											
km 0.00	1/900	28.00	1/2.0	4.00	171.36	141.12	3.67	none	199.80	4.27	0.27
km 8.00	1/900	25.00	1/2.0	4.00	140.25	118.31	3.73	none	165.05	4.27	0.27
Chane Drainage Main 1											
km 0.00	1/1,600	35.00	1/2.0	3.50	157.32	122.16	3.05	none	158.96	3.59	0.09
km 8.00	1/550	25.00	1/2.0	3.00	135.28	0.00	2.71	none	0.00	3.12	0.12
Chane Drainage Main 2											
km 0.00	1/700	35.00	1/2.0	3.50	237.85	0.00	3.14	none	0.00	3.62	0.12
km 4.00	1/600	25.00	1/2.0	3.00	129.52	0.00	2.92	none	0.00	3.29	0.29
Connecting Channels for JICA/SNC Bridge Project											
El Empalme II	1/1,900	18.00	1/2.0	3.00	41.55	0.00	2.87	none	0.00	3.25	0.25
Chaco	1/1,900	30.00	1/2.0	3.50	114.70	0.00	3.33	none	0.00	3.80	0.30
Rancho Chico	1/1,900	30.00	1/2.0	3.00	95.71	0.00	2.65	none	0.00	3.19	0.19
Las Maras	1/800	25.00	1/2.0	3.00	112.17	0.00	2.65	none	0.00	3.09	0.09

TABLE G.3.12 HYDRAULIC CONDITION OF SECONDARY DRAINAGE

n 0.03
Fb 0 m



Canal	Slope	Cross Section Data				2-Year Flood			5-Year Flood		
		W (m)	S	H (m)	$Q_{capacity}$ (m^3/s)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top (m)	Q_{PEAK} (m_3/s)	Depth (m)	Over Top (m)
OKINAWA/SAAVEDORA											
Section 1	1/2,000	12.00	1/1.5	3.00	23.21	19.25	2.79	none	26.15	3.14	0.14
Section 2	1/2,000	10.00	1/1.5	2.50	14.28	12.83	2.40	none	17.43	2.69	0.19
Section 3	1/2,000	8.00	1/1.5	2.00	7.87	6.42	1.85	none	8.72	2.08	0.08
YAPACANI											
Section 1	1/2,000	14.00	1/1.5	3.00	31.46	26.20	2.78	none	35.13	3.14	0.14
Section 2	1/2,000	12.00	1/1.5	2.50	20.38	17.47	2.34	none	23.43	2.65	0.15
Section 3	1/2,000	9.00	1/1.5	2.00	9.96	8.73	1.89	none	11.72	2.13	0.13

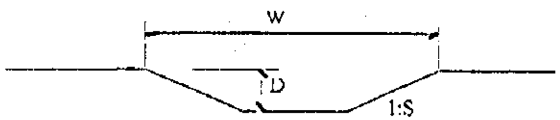
TABLE G.4.1 DIMENSION AND DESIGN DISCHARGE OF DRAINAGE MAINS

Drainage Main	Length (km)	Slope	Proposed Cross Section *			2-Year Flood			5-Year Flood		
			W (m)	S	D (m)	Design Discharge (m^3/s)	Depth (m)	Over Top (m)	Design Discharge (m^3/s)	Depth (m)	Over Top (m)
Arroyo Tejeria											
Lower Reach	2.30	1/900	22.00	1/2.0	4.00	95.5	3.79	none	129.5	4.26	0.26
Branch A	2.00	1/900	20.00	1/2.0	4.00	67.2	3.59	none	88.1	3.97	none
Branch B	1.00	1/400	16.00	1/2.0	3.00	39.7	2.38	none	52.1	2.65	none
TOTAL	**5.30**										
San Juan Drainage Main - Alternative 1											
km13.00	4.00	1/1,500	11.00	1/1.0	5.00	29.8	2.97	none	37.3	3.27	0.27
Diversion			8.00		1.00	12.2	2.97	none	18.4	3.27	0.27
km15.00	4.20	1/1,500	11.00	1/1.0	5.00	29.3	2.95	none	36.7	3.25	0.25
Diversion			14.00		1.00	20.6	2.95	none	31.4	3.25	0.25
km17.00	4.50	1/1,500	11.00	1/1.0	5.00	29.7	2.97	none	37.9	3.30	0.30
Diversion			15.00		1.00	22.8	2.97	none	35.4	3.30	0.30
km28.00	13.50	1/1,500	11.00	1/1.0	5.00	30.0	2.98	none	36.8	3.26	0.26
Diversion			12.00		1.00	18.7	2.98	none	27.1	3.26	0.26
TOTAL	**26.20**										
San Juan Drainage Main - Alternative 2											
km09.00	3.00	1/1,500	14.00	1/1.5	3.00	14.9	2.04	none	19.9	2.32	none
km11.00	3.00	1/1,500	14.00	1/1.5	3.00	24.9	2.55	none	33.2	2.89	none
km13.00	4.00	1/1,500	16.00	1/1.5	3.00	42.0	2.88	none	55.7	3.25	0.25
km15.00	4.20	1/1,500	15.00	1/1.5	3.00	37.8	2.89	none	49.7	3.25	0.25
km17.00	4.50	1/1,500	14.00	1/1.5	3.00	31.8	2.84	none	41.9	3.18	0.18
km24.00	2.00	1/1,500	14.00	1/1.5	3.00	13.3	1.94	none	18.2	2.23	none
km28.00	13.50	1/1,500	18.00	1/1.5	3.00	48.8	2.81	none	63.9	3.18	0.18
TOTAL	**34.20**										
Antofagasta Drainage Main											
km 0.00	8.00	1/900	28.00	1/2.0	4.00	141.1	3.67	none	199.8	4.27	0.27
km 8.00	2.00	1/900	25.00	1/2.0	4.00	118.3	3.73	none	165.0	4.27	0.27
TOTAL	**10.00**										

TABLE G.4.1 DIMENSION AND DESIGN DISCHARGE OF DRAINAGE MAINS

Drainage Main	Length (km)	Slope	Proposed Cross Section * W (m)	S	D (m)	2-Year Flood Design Discharge (m^3/s)	Depth (m)	Over Top (m)	5-Year Flood Design Discharge (m^3/s)	Depth (m)	Over Top (m)
Chane Drainage Main 1											
km 0.00	8.00	1/1,600	35.00	1/2.0	3.50	119.1	3.05	none	166.1	3.59	0.09
km 8.00	5.50	1/550	25.00	1/2.0	3.00	108.6	2.71	none	147.0	3.12	0.12
TOTAL	**13.50**										
Chane Drainage Main 2											
km 0.00	4.00	1/700	35.00	1/2.0	3.50	191.0	3.14	none	255.4	3.62	0.12
km 4.00	4.00	1/600	25.00	1/2.0	3.00	122.2	2.92	none	159.0	3.29	0.29
TOTAL	**8.00**										
Okinawa Drainage Main											
km 3.00	13.50	1/1,100	35.00	1/2.0	4.00	197.4	3.78	none	249.4	4.22	0.22
km 16.50	4.50	1/1,400	27.00	1/2.0	3.00	85.5	2.85	none	115.7	3.28	0.28
km 21.00	3.00	1/1,400	16.00	1/1.5	3.00	42.8	2.86	none	57.9	3.26	0.26
TOTAL	**21.00**							0.60			0.94

* : Dimension of Canal



Dimension of Diversion Weir

TABLE G.4.2 DIMENSION AND DESIGN DISCHARGE OF CONNECTING CHANNELS FOR JICA/SNC BRIDGE PROJECT

Canal	Length (km)	Slope	Proposed Cross Section *			2-Year Flood			5-Year Flood		
			W (m)	S	D (m)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top*** (m)	Q_{PEAK} (m^3/s)	Depth (m)	Over Top (m)
Las Maras	8.00	1/800	25.00	1/2.0	3.00	86.23	2.65	none	119.86	3.09	0.09
Rancho Chico	1.00	1/1,900	30.00	1/2.0	3.00	74.20	2.65	none	109.00	3.19	0.19
Chaco	2.00	1/1,900	30.00	1/2.0	3.50	103.15	3.33	none	137.62	3.80	0.30
El Empalme II	3.50	1/1,900	18.00	1/2.0	3.00	37.22	2.87	none	50.92	3.25	0.25

* : Dimension

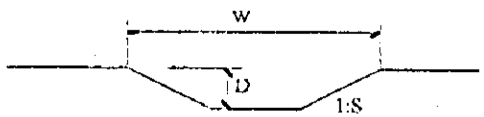


TABLE G.4.3 DIMENSION AND DESIGN DISCHARGE OF SECONDARY DRAINAGE

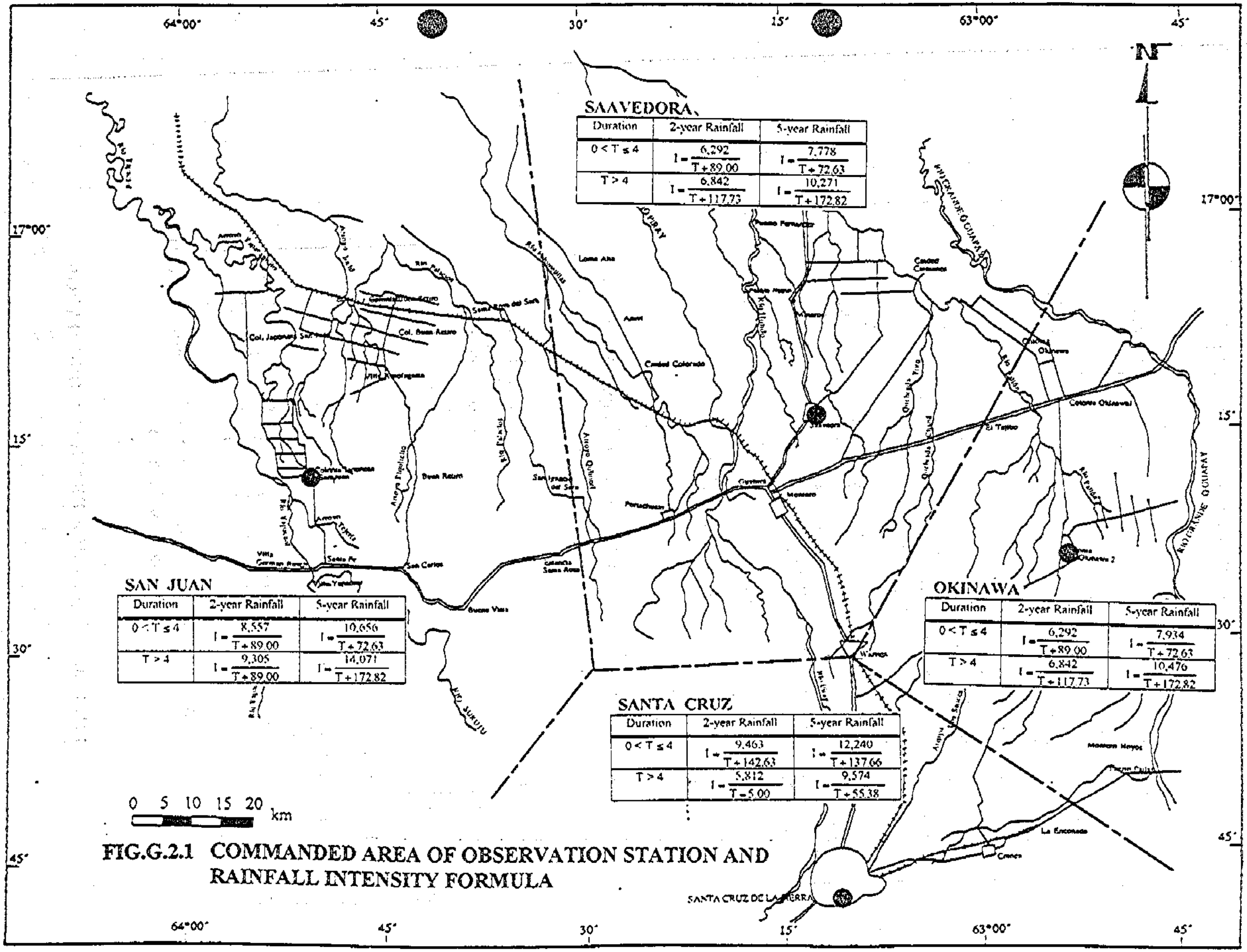
Block	Area	Standard Cross Section*				Number of Canal**	Average Length	Total Length	Related Structure	
		Type	W	D	S					
	(km²)		(m)	(m)		(canal)	(km)	(km)		
East Part (Chane Pailon)										
Okinawa Drainage Main	147.00	A	12.00	3.00	1/1.5	23	2.00	46.00	BC(A) 3.5x3.0x2***	23
Rio Pailon	50.00	A	12.00	3.00	1/1.5	8	2.00	16.00	BC(A) 3.5x3.0x2	8
Chane Drainage Main	144.00	A	12.00	3.00	1/1.5	22	[illegible]	44.00	BC(A) 3.5x3.0x2	22
Quebrada Chacras	140.00	A	12.00	3.00	1/1.5	21	2.00	42.00	BC(A) 3.5x3.0x2	21
West Part (San Juan Antofagasta)										
Arroyo Tejeria	24.00	B	14.00	3.00	1/1.5	4	2.00	7.00	BC(B) 3.0x3.0x3	4
San Juan - Yapacanicito	91.00	B	14.00	3.00	1/1.5	14	2.00	27.00	BC(B) 3.0x3.0x3	14
Antofagasta	97.00	B	14.00	3.00	1/1.5	15	2.00	30.00	BC(B) 3.0x3.0x3	15
Summary										
Canal Type A								148.00		
Canal Type B								64.00		
Box Culvert Type A									3.5m x 3.0m x2	74
Box Culvert Type B									3.0m x 3.0m x3	33

* : Canal Dimension :

** : Canal Numbr = Area Total x 75% / Unit Area (5.0km²)

*** : Box Culvert Dimension : w(m) x h(m) x n(pcs)

FIGURES



SAAVEDORA

Duration	2-year Rainfall	5-year Rainfall
$0 < T \leq 4$	$I = \frac{6,292}{T+89.00}$	$I = \frac{7,778}{T+72.63}$
$T > 4$	$I = \frac{6,842}{T+117.73}$	$I = \frac{10,271}{T+172.82}$

SAN JUAN

Duration	2-year Rainfall	5-year Rainfall
$0 < T \leq 4$	$I = \frac{8,557}{T+89.00}$	$I = \frac{10,656}{T+72.63}$
$T > 4$	$I = \frac{9,305}{T+89.00}$	$I = \frac{14,071}{T+172.82}$

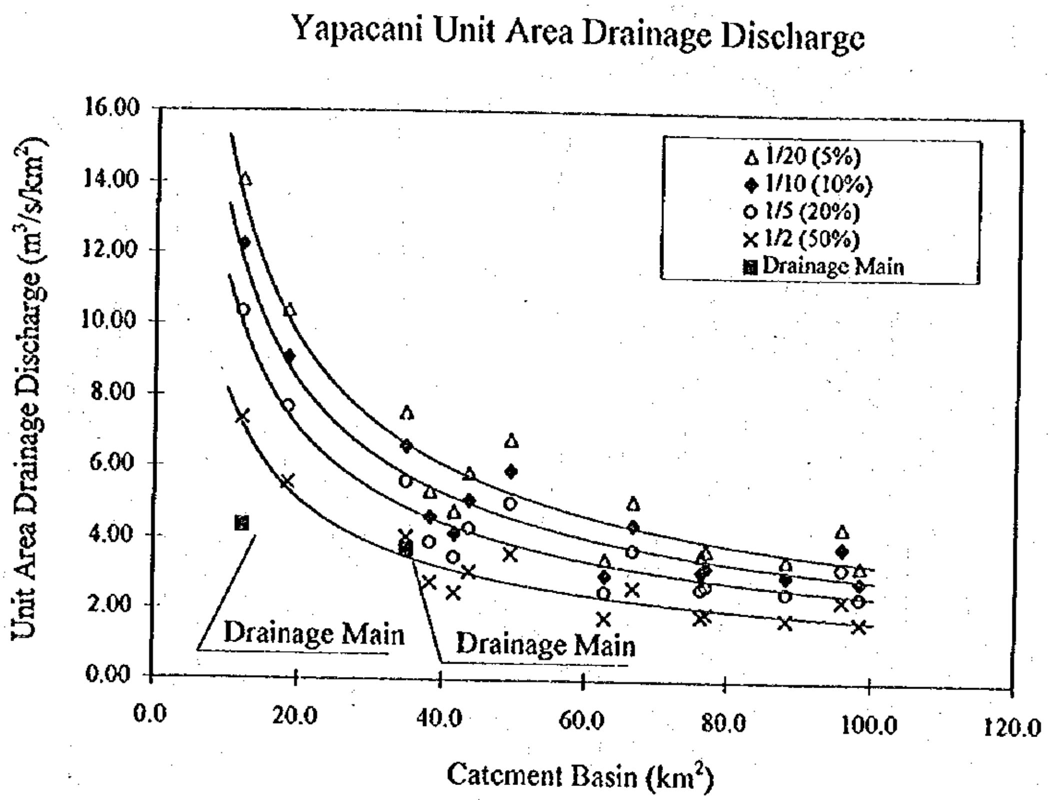
SANTA CRUZ

Duration	2-year Rainfall	5-year Rainfall
$0 < T \leq 4$	$I = \frac{9,463}{T+142.63}$	$I = \frac{12,240}{T+137.66}$
$T > 4$	$I = \frac{5,812}{T-5.00}$	$I = \frac{9,574}{T+55.38}$

OKINAWA

Duration	2-year Rainfall	5-year Rainfall
$0 < T \leq 4$	$I = \frac{6,292}{T+89.00}$	$I = \frac{7,934}{T+72.63}$
$T > 4$	$I = \frac{6,842}{T+117.73}$	$I = \frac{10,476}{T+172.82}$

FIG.G.2.1 COMMANDED AREA OF OBSERVATION STATION AND RAINFALL INTENSITY FORMULA



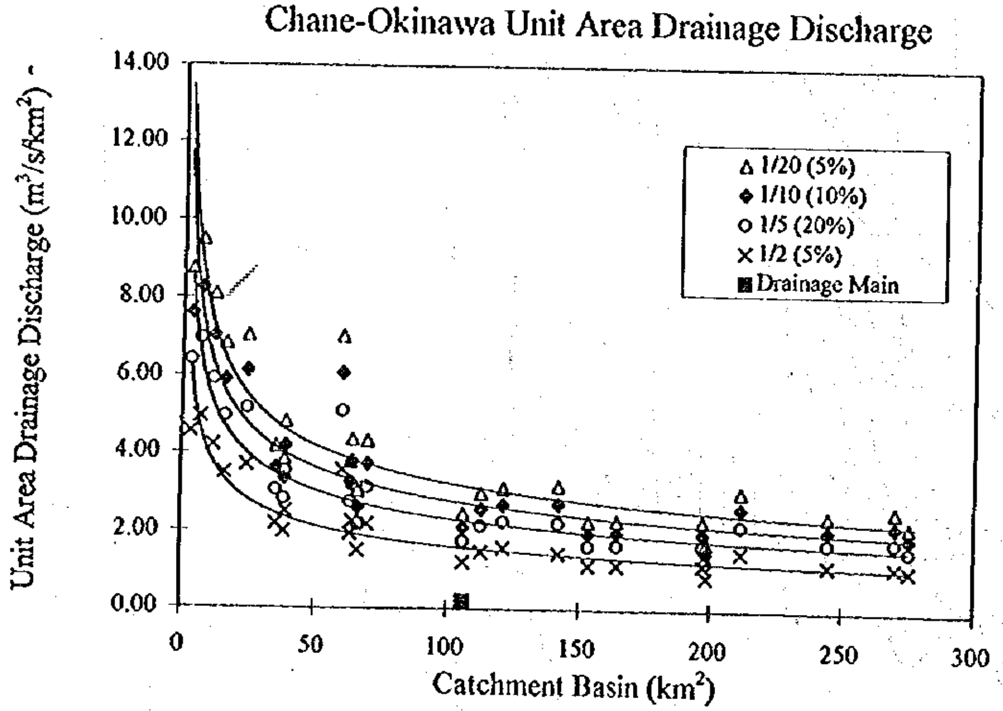
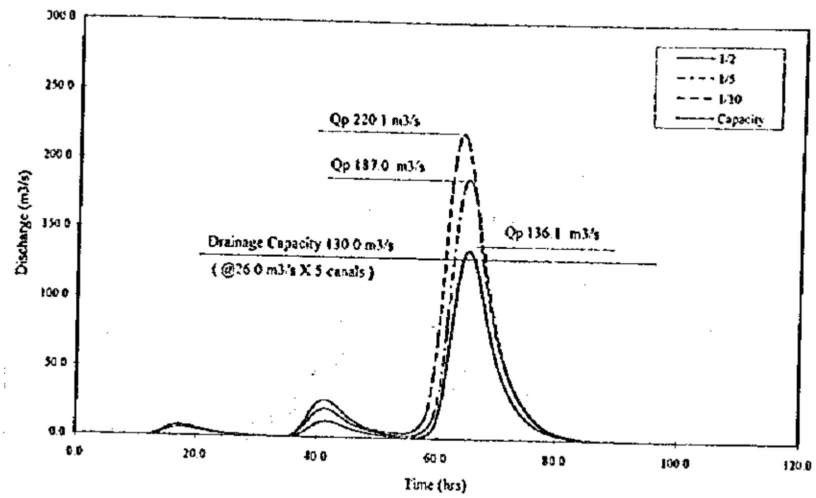
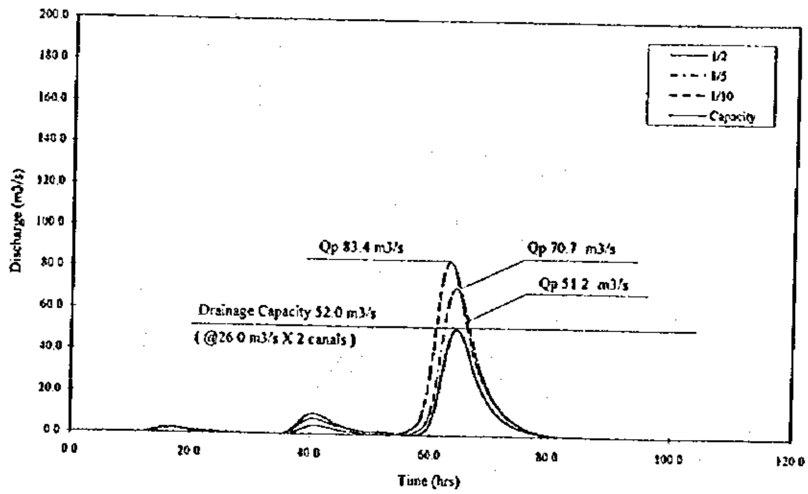


FIG.G.3.1 UNIT AREA DRAINAGE DISCHARGE

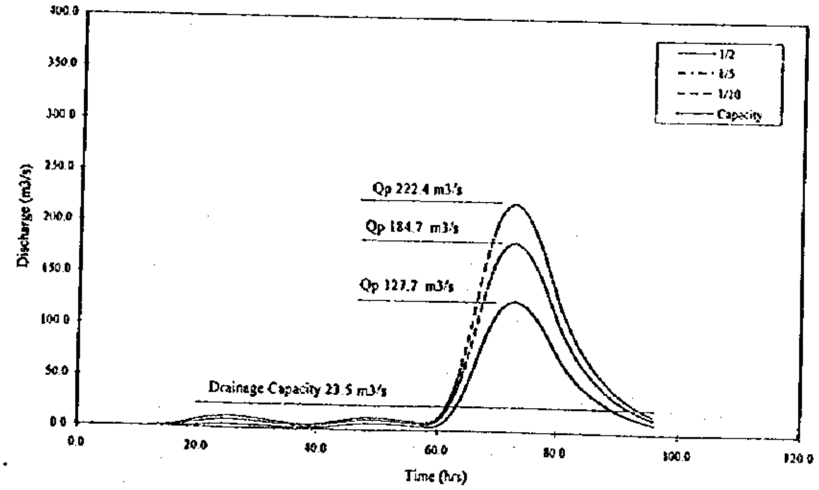
San Juan Drainage Main 1



San Juan Drainage Main 2



Okinawa 1 Drainage Main



FIG,G.3.2 (1) RUNOFF AND DISCHARGE CAPACITY

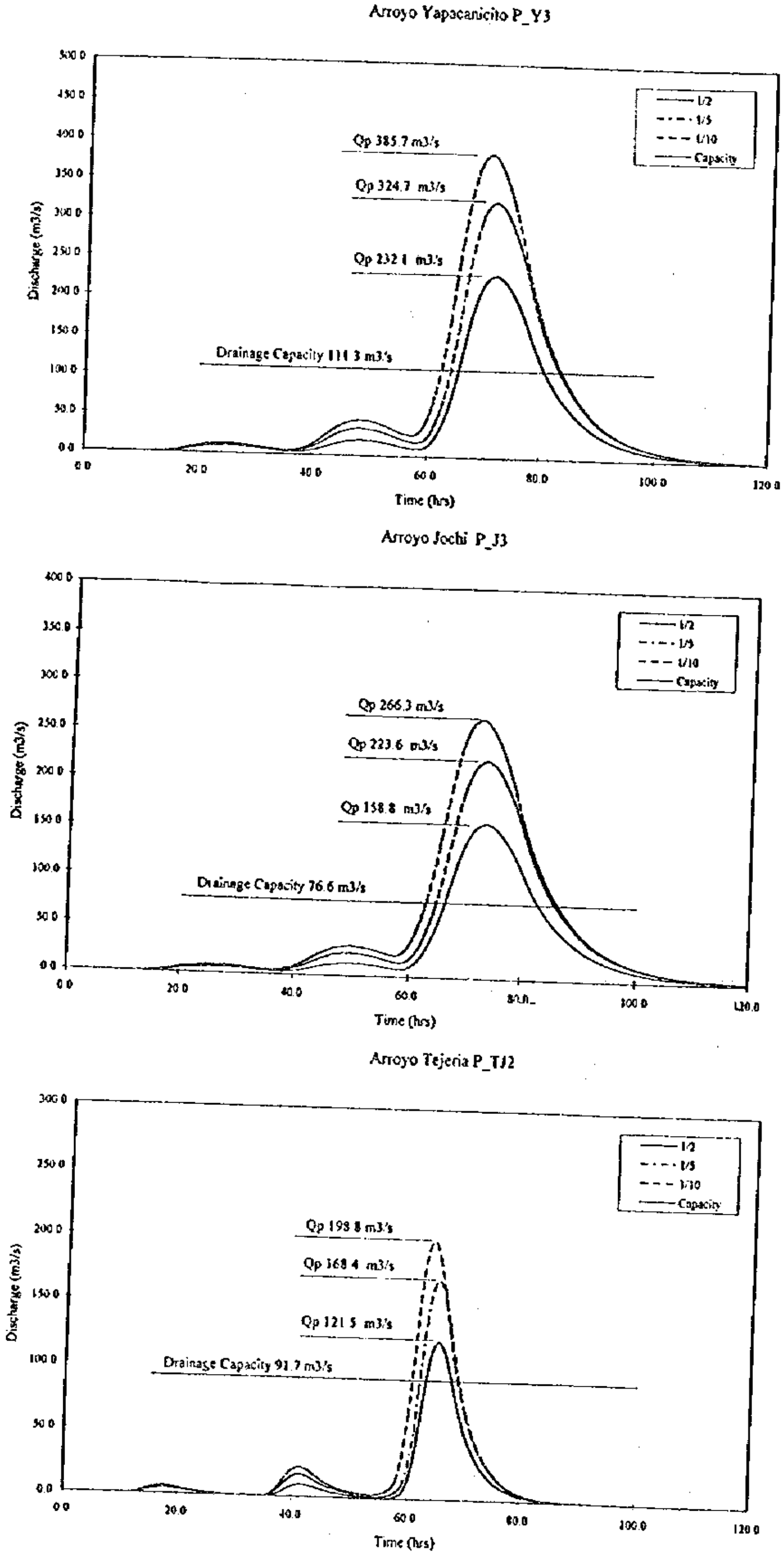


FIG.G.3.2 (2) RUNOFF AND DISCHARGE CAPACITY

SUPPORTING REPORT H

ENVIRONMENT

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SUPPORTING REPORT H

SUPPORTING REPORT II ENVIRONMENT

1. General

Every flood damage mitigation measures has some effects on the environment. Environmental law and regulations are briefly summarized and natural environmental conditions in the study area are investigated. Environmental impacts are assessed as the initial environmental examination (IEE). Water quality was also analyzed to get information about the degree of water contamination at the selected points along the rivers in the study area.

2. Law and Regulations Related to Environment

2.1 Natural Environmental Law

The Natural Environmental Law (Modified by Law of Ministries of the Executive Power) No. 1333 dated April 27, 1992 was the starting point to deal with environmental issues in a global and systematic manner. The object of the law is the protection and conservation of the natural environment and natural resources. It regulates the action of the man related to the nature and promotes the sustainable development in order to raise the quality of life. The sustainable development means the process by which the necessities of the present generation are satisfied without risking the satisfaction of necessities for future generations. The sustainable development is a global and permanent task. The natural environment and the natural resources are the nation's patrimony, their protection and utilization are ruled by law. The law is public order, of social, economic and cultural interest.

The Natural Environmental Law establishes the principals for protection, conservation, and restoration of wild fauna and flora aquatic of living on land.

- It is a patrimony of the State, particularly the endemic species of restrict distribution, threatened or in danger of extinction.
- Encouragement to programs of research and evaluation of wild fauna and flora in order to know its value in every sense.
- Sustainable management of wild fauna and flora of the authorized species for its utilization.
- Protection to the bio-diversity and the integrity of genetic patrimony of wild fauna and

flora and domestication.

The authorizations for hunting, collection, extraction, trading of species and products and the time when hunting and fishing is forbidden shall be processed. The authorizations for hunting, recollection, extraction, trading of species through correspondent authorities.

At the present the Law of Wild Life, National Parks, Hunting and Fishing is partially in effect, establishing regulations about everything related to wild fauna. The Executive Power is in charge of this law through CDF. It establishes the cases of prohibitions, the zones, and declarations of time when fishing and hunting is prohibited, methods and systems of hunting.

2.2 Environmental Impact Assessment

Environmental impact assessment (EIA) is applied as a set of management procedures to determine the effects of certain actions in the natural environment. It establishes the management process that should follow the tasks or activities in order to comply with the EIA. All projects or activities must be classified into following levels:

1. Require integrated EIA
2. Require specific EIA
3. Require no EIA but advisable conceptual EIA
4. Require no EIA

SENMA (Secretaria Nacional del Medio Ambiente) and SEDAMA (Secretarias Departmentls del Medio Ambiente) are in charge of controlling the compliance of EIA. specific regulations and are established to govern the administrative and legal aspects of EIA.

In May, 1994 the Ministry of Sustainable Development approved a provisional rule of EIA which set up the environmental card (FA) as an instrument of categorization of EIA. At the present other plans are being prepared such as the rule of prevention and control of the environmental quality, which states the procedure for EIA, as well as control mechanisms for the activities, works and projects.

3. Natural Environment in the Study Area

3.1 General

The flood mitigation project is planed in the northern part of the Santa Cruz city and spread over five provinces; Andres Ibanez, Warnes, Ichilio, Sara and Obispo Santistevan. It has an area of about 7,000 km^2 and the 220,000 population in 1992 composed of the urban population of 120,000 and the rural population of 100,000. Number of households is 46,800 and an average family size is 4.7 person per household. Community in the study area reaches about 370 in number.

The north part of Santa Cruz belongs geologically to the Brazilian Shield and it is mostly covered with tertiary and quaternary sediments. The area has low hills in some parts with mountain areas and plains of partially steep slope. The central part in the study area is made of quaternary plains with old and new alluvial ones with clay and loam soils with poor drainage and sandy loam soils. These alluvial plains in the North with no slope and poor drainage are frequently flooded areas during rainy seasons. The northeast part that descends from a sudden southern change receives most of the rains in the department.

The weather is subtropical and humid with rainfalls between 900 to 2,000 mm and in the northern area the annual rainfall is over 3,000 mm. The region is hit by strong winds from the north and south, the latter is called "surazos" coming from the Patagonia, Argentina. These can lower the temperature down to 10 to 15 °C and cause chilly condition in some extreme situations. The mean temperature in the area is 24 °C at the altitude of 300 m and increases 0.5 °C with the increase of every 100 m in height.

The classification of the soil in the study area, according to the soil and agriculture use capacity map, is considered to be suitable for livestock and agriculture with some restrictions and fit for cattle raising and permanent cultivation with erosion and fertility restrictions. The good and average fertility of the soil is causing migrations to urban areas and intensive agriculture.

Winds with combinations of non-suitable agriculture techniques are causes for soil degradation, due to a severe wind erosion and loss of soil fertility, endangering the agricultural sustainable development of the area.

All drainage network belongs to the Amazon basin, therefor, there are plenty of water resources in all the region with distributed water channels.

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3.2 Ecological Areas

In the study area there are five ecological zones:

- Tropical humid zone
- Tropical highly humid zone to subtropical transition
- Sub-tropical humid zone
- Very humid subtropical zone
- Mid humid zone

(1) Tropical humid zone

It covers river banks of Yapacani, Grande and Pirai rivers towards the northwest. It is below 400 m with a temperature between 22 and 24 degrees, and an annual rainfall which varies from 1800 to 2900 mm. The area shows good scenery and old wavy terraces, plain savannas and swamps. Along the well-drained lands there are forest almost ever green and original trees higher than 40 m and whose diameters may exceed 100 cm.

(2) Tropical highly humid zone to subtropical transition

It is located in the western region, the average annual temperature 22 degrees, the rainfall varies from 2000 to 3000 mm annually and is at an altitude of about 600 m. Physiologically there are two different scenery; those that correspond to the mountain spurs of the Andes, formed by mountain chains and alluvial plains characterized by sub-raised terraces, natural dikes, basins and discharges of some rivers.

This is an ever green forest with five layers and herbaceous vegetation, showing also species such as moss and fern, even orchids, cactaceum and bromeliaceum. The emerging trees are over 50 m high and 2 m wide. Other common element is the various species of palm trees.

(3) Sub-tropical humid zone

This covers the north part of Santa Rosa del Sara and northwestern area of Yapacani and Pirai rivers, its altitude varies from 800 to 300 m with a temperature from 18 to 24 degrees and rainfall levels from 100 to 200 mm. The plains area has two different vegetal layers: the "pampas" or savannas and forests, from which 50 % of its species are caducifolious type and a few ephyfites species.

(4) Very humid subtropical zone

It covers plains at the north and west part, the temperature is between 21 and 24 degrees and rainfall from 2000 to 3000 mm. In this life zone, there is a forest with optimum characteristics which is of about 40 m high, thick logs and spread branches. Forests are associated, due to high humidity, with various ephyfites and the "sotobosque" contains a high percentage of palm trees.

(5) Mid humid zone

It covers the basin of Pirai and Grande river with an altitude of 300 to 400 m, temperature from 21 to 24 degrees and annual rainfall between 1850 to 2150 mm. Geographically this is an alluvial plain region characterized by dikes and meanders. The vegetal association in its original state is a latifoliated mixed forest with 50 % of caducifokious species, Nowadays only a minimum extension is covered with forest, the rest has been replaced with cultivation, pastures and secondary forests.

3.3 Vegetation and Wild Fauna

In the northern part of the study area, different types of forests, medium, high and very high forest still prevail along with many rivers and riverside forests. In the central and southern area secondary forests, savannas with low trees and pastures prevail, in these areas man's impact is evident. In all urban areas, man's impact is evident due to over pasture, forest decrease, deforestation and soil degradation.

The micro-region shows areas with high and very high ecological value. The ecological value assessment is the result of applied criteria, based on natural state similitude before men actions. Also the rare flora and fauna and the species variety are very important, as well as some characteristic biotops valuable for their conservation.

Applying the above criteria, there are regions with a very high ecological value:

- Flora and fauna protected area of Serranía Santa Rosa
- Flora and fauna protected area of Bañdos Rio Grande, Piraí, and Laguna Bella
- River protection of Rio Piraí, Rio Grande, Rio Surutú, and Yapacaní

(1) Vegetation

The surface of the region is covered with different forest type vegetation, which has anthropomorphic modifications, caused mainly by intensive land stripping for farmland and lumber exploitation.

The study area shows seven vegetation types:

- Medium and high forest

This is one of the most deteriorated formation mainly due to the selective forest exploitation(Swietenis-Cedrela-Amburan). Settlements, following the lumbering taking advantage of newly made roads, has widen the agricultural frontier damaging natural life. The degradation effects are more evident near Santa Cruz city.

The biological diversity of this region may be the highest in the whole country, the rain forest is dense and polystratified, reaches an average of 25 to 30m high with some parts of 40m high there are many tubular root species and great number of palm trees.

There are many epiphyte species with great number of vascular species (*Pireraceous, Bromeliaceous, Araceous, Orquidaceous).* Among the most important tree species we can mention: *Spondias mombin, Ceiba pentrandra, Dipteryx alata Terminalia amazonica, Sloanea fragana, Hura creptians, Clarisia racemosa, Virola calophylla, Cedrela odorata, Guarea spp. and Cedrelinga catenaeformis.*

The palm trees concentrations are very important in the mid layer, the most important are *Atales spp., Schelea princeps. Astrocaryum spp., Iriartea deltoidea and Jessenia batana.* In large areas the "sotobosque" (smaller forest that grows under taller forest) has mostly low palm trees.

- Low forest

Among the topographic gradient towards the more severe flooding areas, there are mainly flood forest and swampy forest, these are characterized by its short size and poor diversity of species.

The humid season forest of the Beni plains is poorer in species that the piedmont formations, among the most important species we can mention *Ceiba pentandra, Amazon teminalia, Teminakia oblonga, Hura crepitans, ficus spp.* Among the most influent species in the Closed Chao, we can mention *chorista insignis, Tabebula senatifokis, Vitex cimosa.* The palm trees are very important in the intermediate layer, specially the following two species: *Scheelea princeps and Astrocaryum macrocalyx.*

- Riverside forest

It is distributed along the borders of most rivers with a intense erosion dynamism and lateral deposition such as: Rio Grande, Pirai and Yapacani. They are placed like long strips that can reach 5 km wide.

Because in these areas the primary succession of forest is produced dynamically, the vegetation communities are mainly formed by pioneering or succeeding early species. Strips of the following prevail: *Tessaria Integrifolia, Gynerium sagittatum, Salix humboldtiana,* the tree successions are very rich in *Cecropia spp., Erythrina poeppigiana, Sapium marmieri and Ochroma pyramidalis.*

- Palmar (Palm tree concentration)

This ecological region shows xeromorphous palm trees, there are no important researches in this area, it is supposed to have different palm trees than the northern area such as: *Euterpe spp., Copemicia alba, Acrocomia totaí.*

- Savanna

This area has taken those places where former semi-humid transition and "chaqueño" forests used to exist. The agro-industrial activities such as sugar cane, soy bean and rice which was intensified some decade ago, replace the original forest with secondary formations which later on were transformed into pasture areas and bush-woods. Nowadays there is an open scenery rich in palm trees such as *Acromia totai and Copemicia aloba.*

- Pasture

Very complex in structure and composition, the higher areas are mainly formed by "hard" species, not very desirable for cattle, such as *Andropogon bicomis,* regarding the lower areas in where there are effective flooding periods, they show pastures such as: *Hymenachbe spp., Paspalum acuminatum* and *Peruvian Luziola.* There are areas with abundant *cyperaceous* and *helophytus.*

- Secondary vegetation

It is mainly formed by species which represent a deterioration parameter of vegetal communities, this is due to human activity impact carries out by the agricultural frontier enlargement and replacement of original woods by cultivation areas.

(2) Wild Life

There is a wide diversity in the local fauna, therefore its forests are considered as the richest in fauna e.i. mammals, reptiles, amphibious and entomofauna.

Among the endangered species, there are felines like pumas, jaguars (*Felis concolor, Feris onca, Fellis wiedii, Felis yagoaroundi*), otters, londras, water dogs(*Tapirus terrestris, Tayassu pecari, Tayassu tajacu)* and armadillos (*Dasypus spp.).* The river is rich in fish.

In the agricultural area, the fauna has almost disappeared or is scattered due to its habitat destruction and commercial man hunting, which caused its migration. Among the most hunted species are: londras, water dogs (*Canidae*), felines in general (*Felidae, Canidae*), saurian (*Crocodikidae, Tekidae*), deer (*Cervidae*), wild pigs and "tatus" or armadillo (*Tayassuidae, Dasipodidae, Dasypodidae*). On the other hand, it is evident the agriculture plagues as well as some bird species spreading.

Likewise, some rivers are infested with pirañas (*Serrasalmus spp.)* due to the extermination of their natural predators. The extinction of different monkeys and bat species, causes severe spreading of some vegetal species which are used as food by those animals.

(3) Endangered Species

The "National Workshop : Red Book of Vertebrates of Bolivia", organized by the "Centro de Datos para la Consevación" and sponsored by the Secretaria PL-48 and LIDELA, was of great importance. The Environmental and Sustainable Development Ministry, through its National Office of Bio-diversity Conservation, recognized such document as a reference to make decisions regarding wild fauna conservation field.