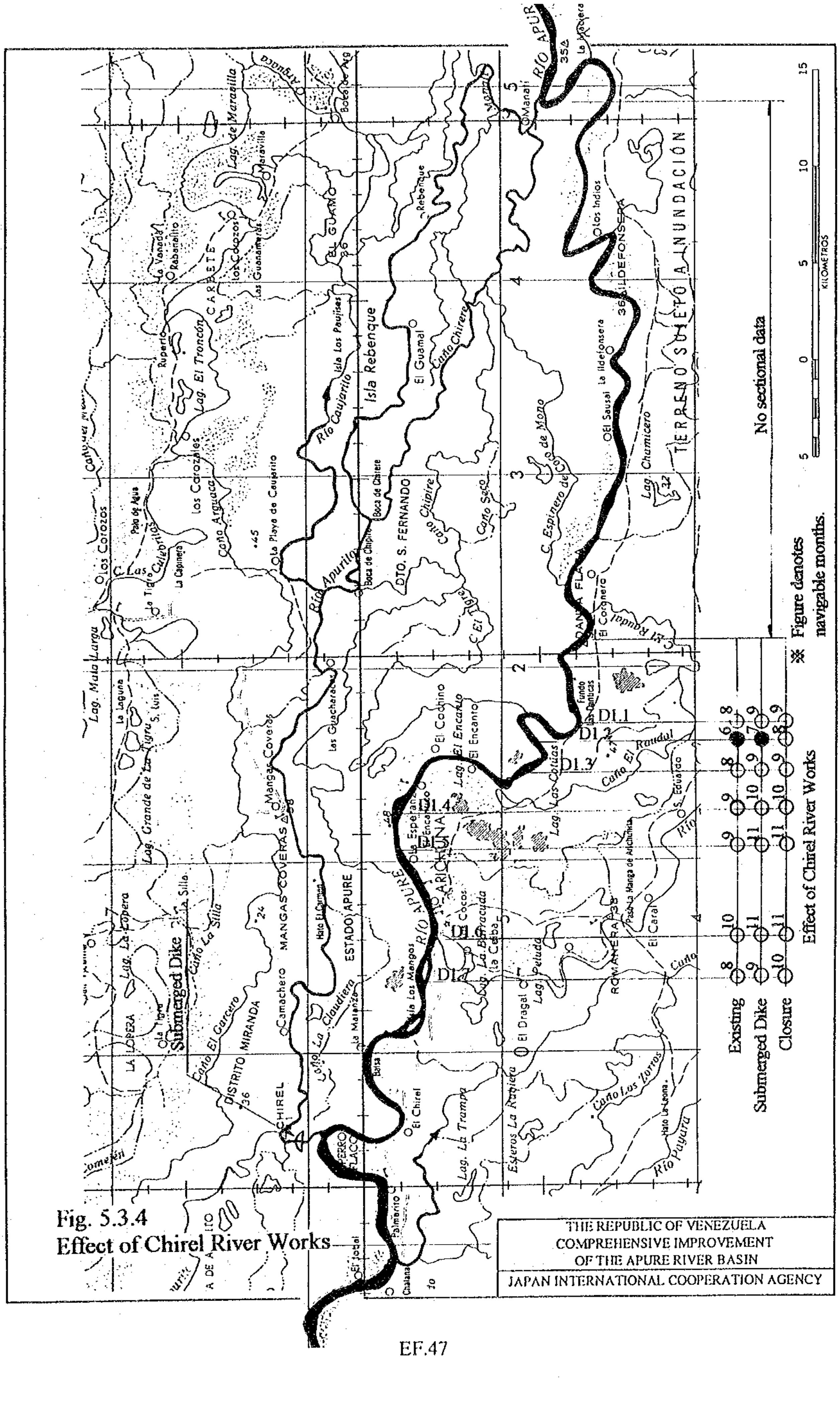
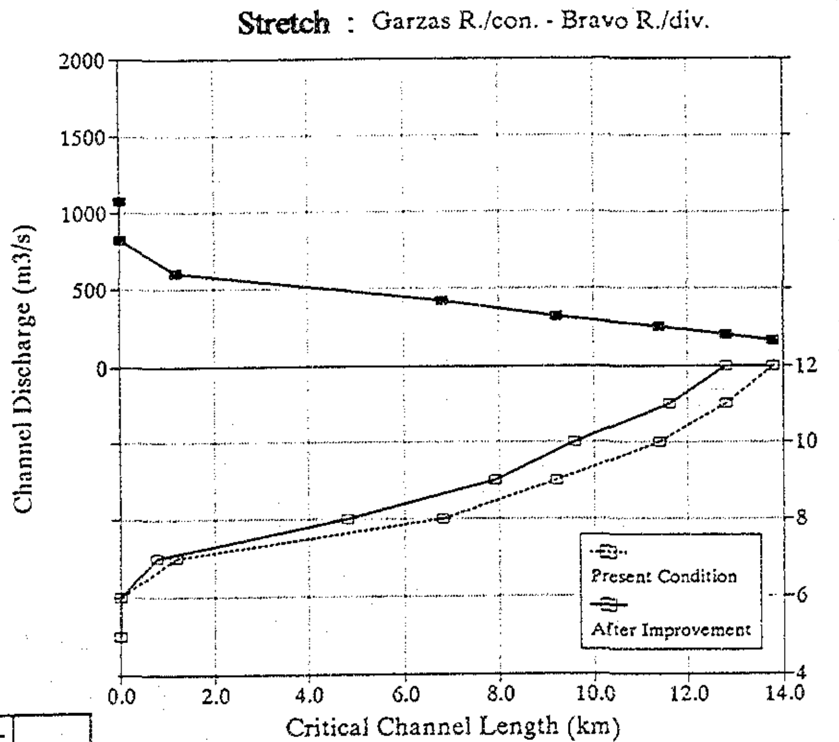
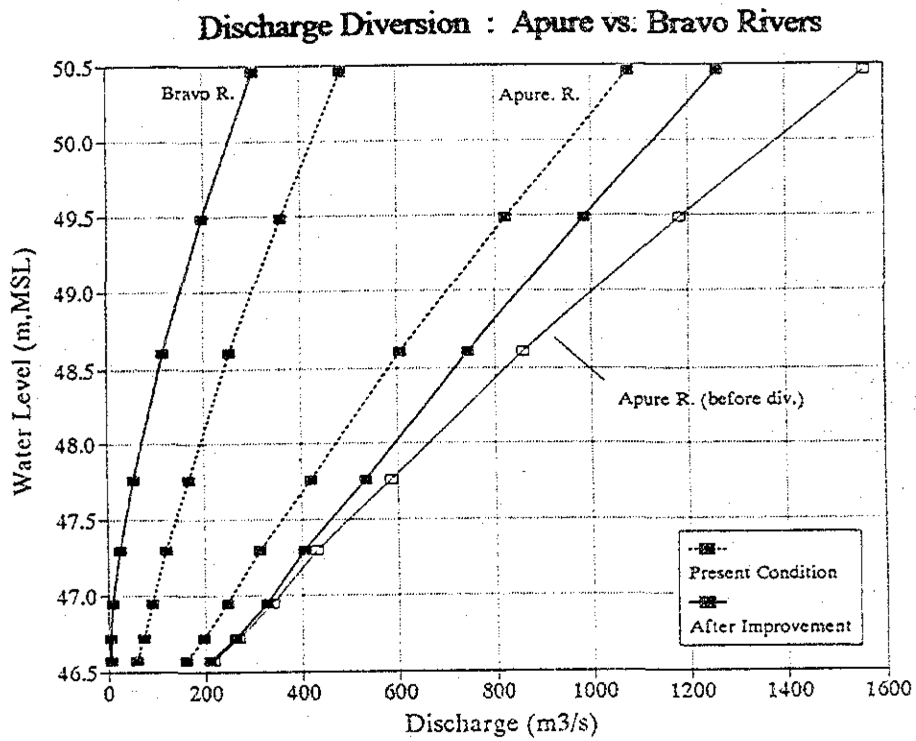


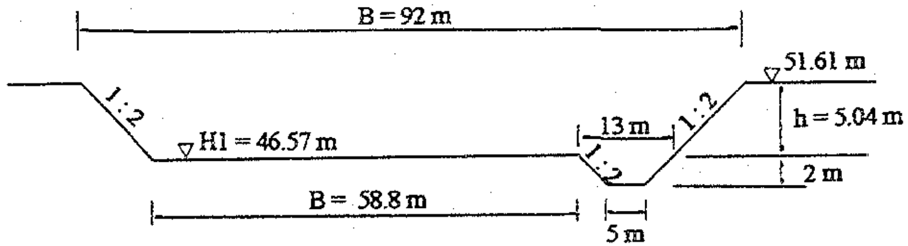
Fig. 5.3.4
Effect of Chirel River Works

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY







- Cross Section of Submerged Dike at Brvo River -

Fig. 5.3.5 Effect of Submerged Dike of Bravo River

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

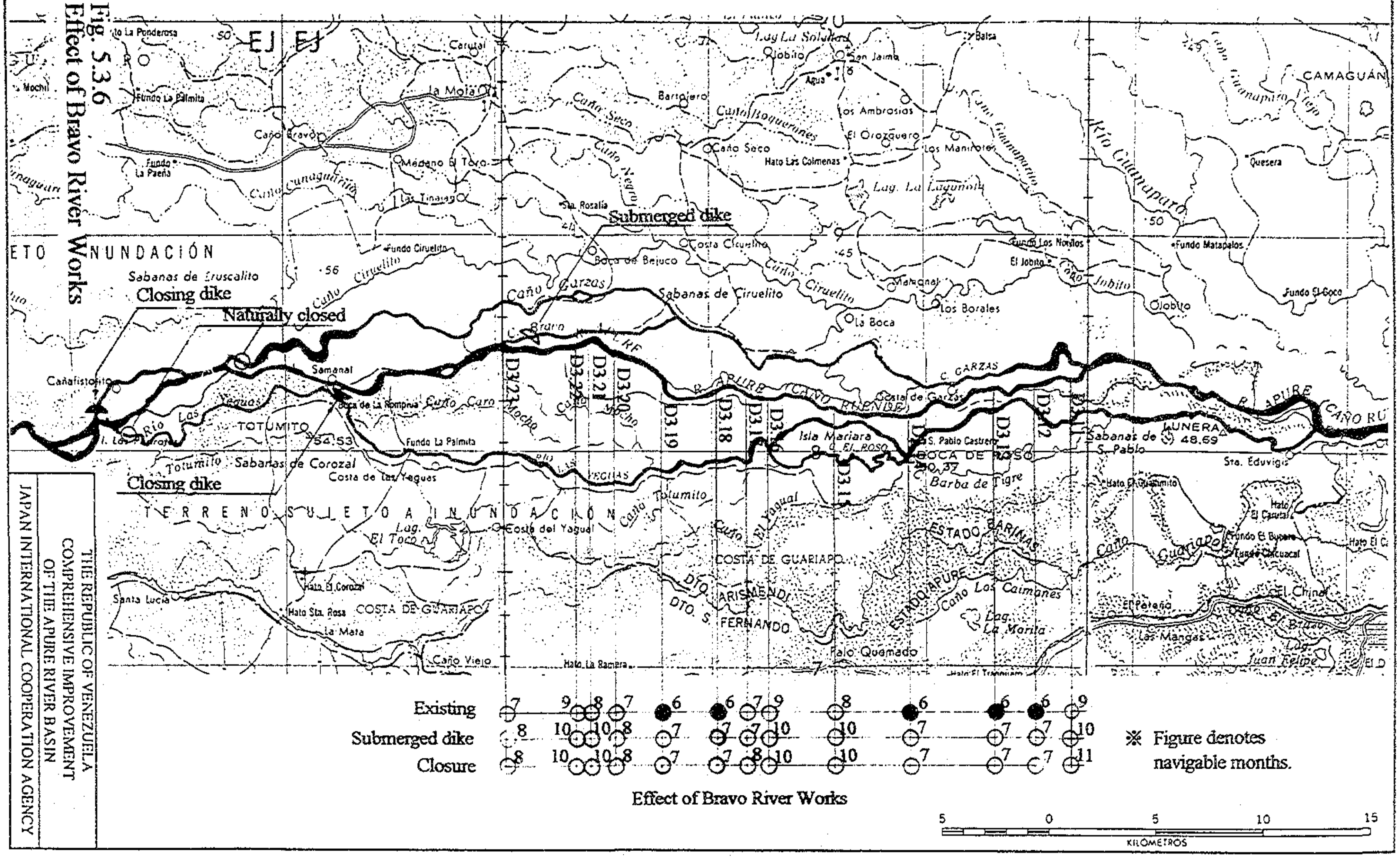


Fig. 5.3.6
Effect of Bravo River Works

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

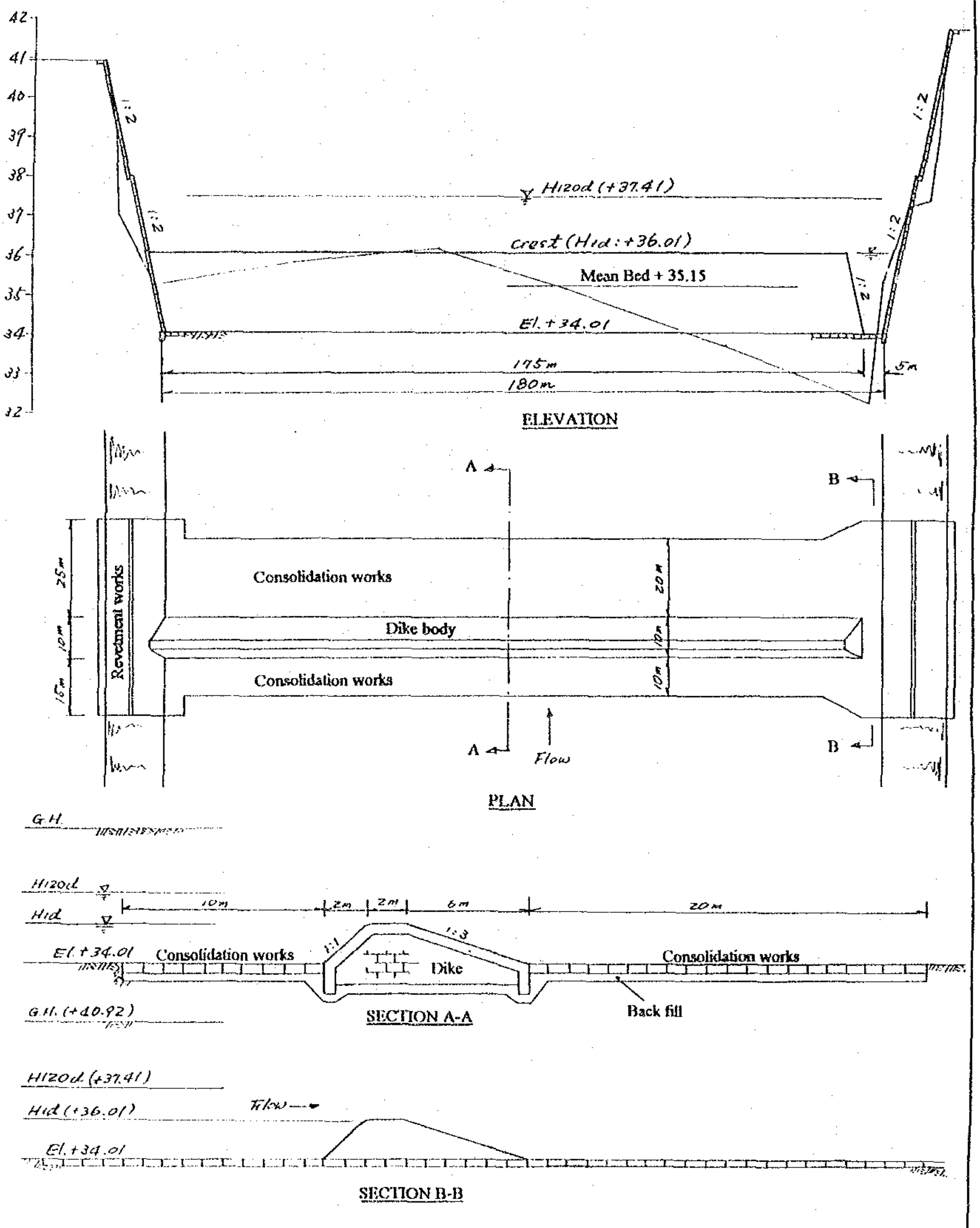


Fig.5.7.1 Sample Drawing : Submerged Dike Works

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

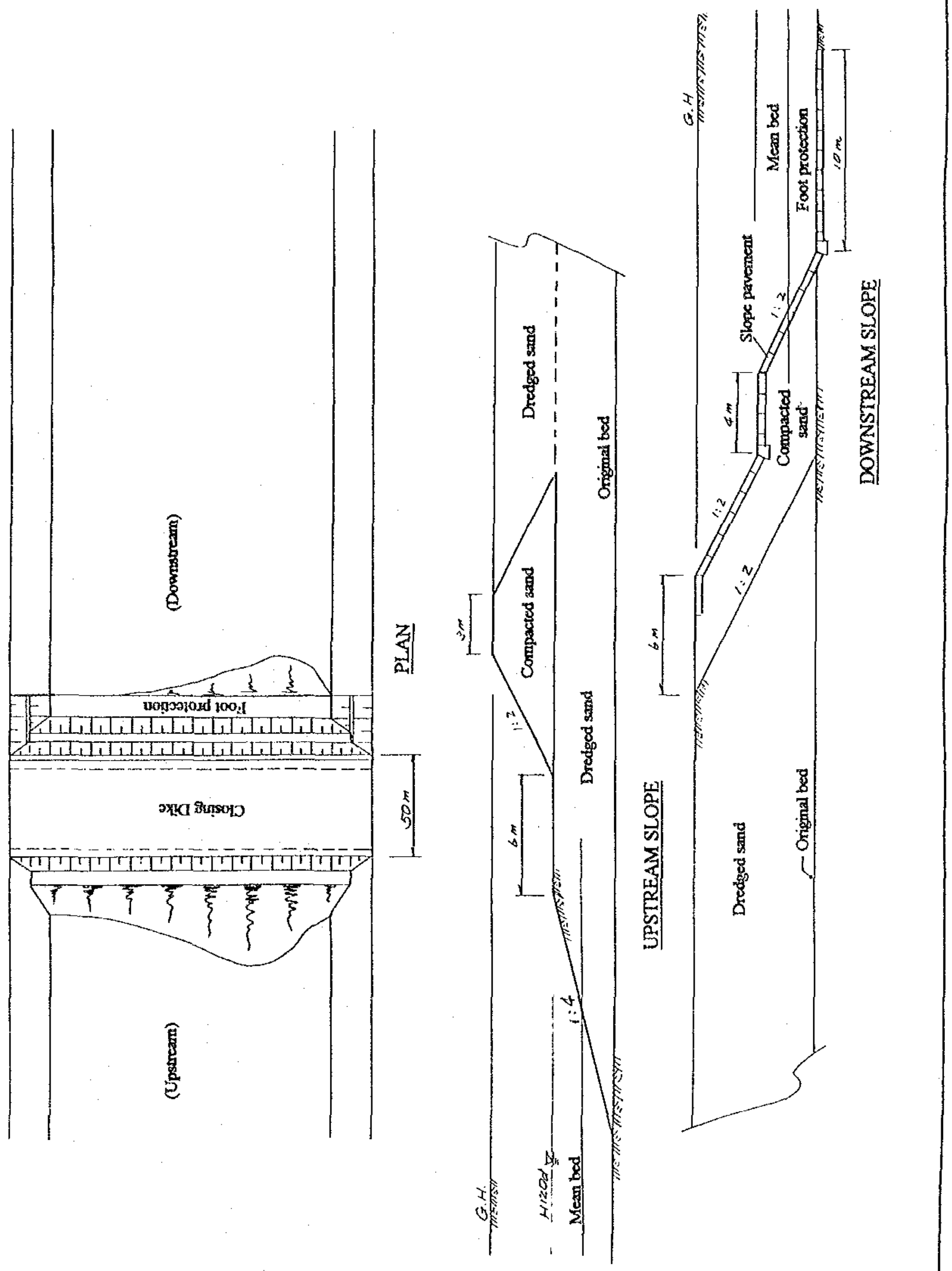
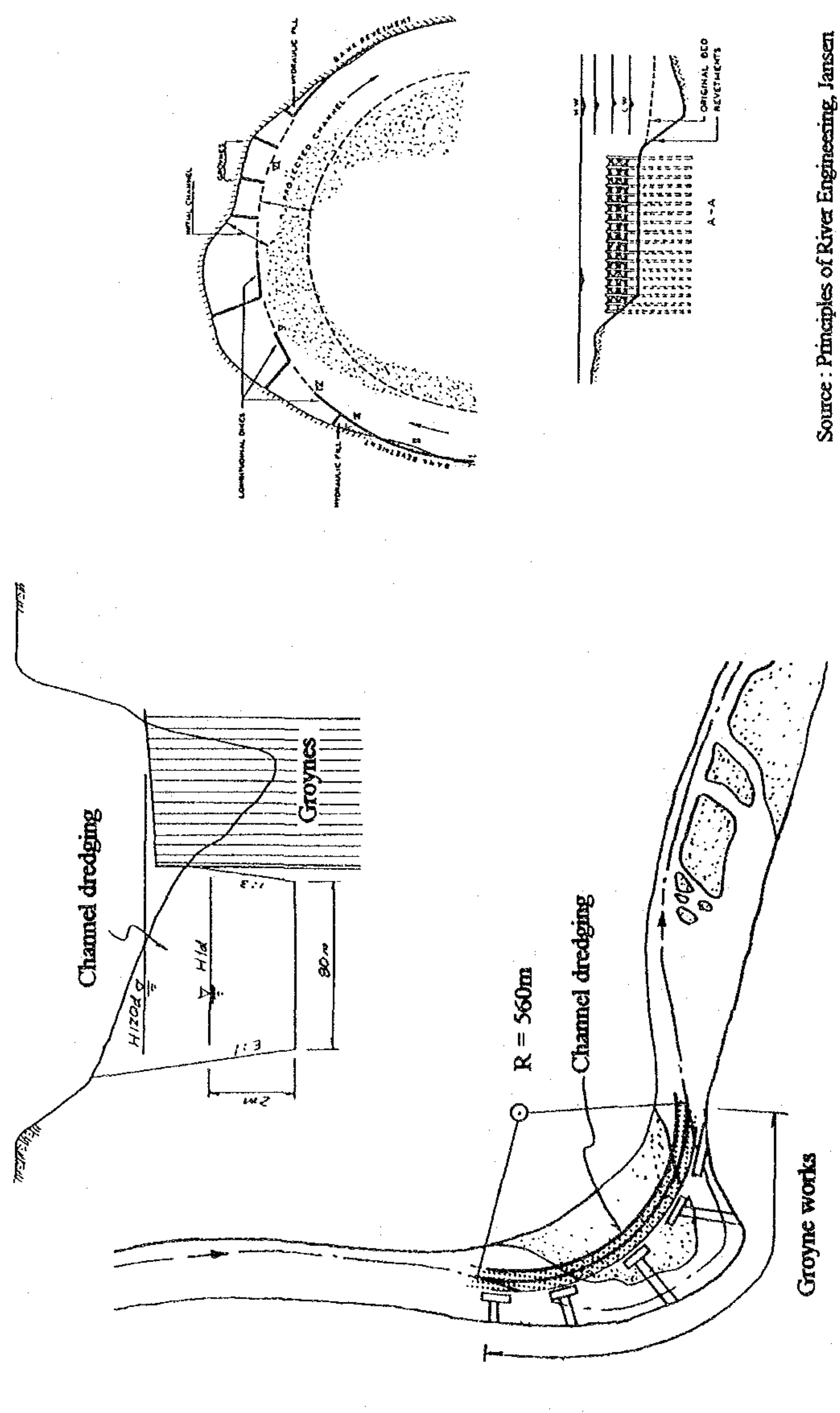


Fig.5.7.2 Sample Drawing : Closing Dike

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY



Source : Principles of River Engineering, Jansen

Fig.5.7.3
Sample Drawing : Realignment Works

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

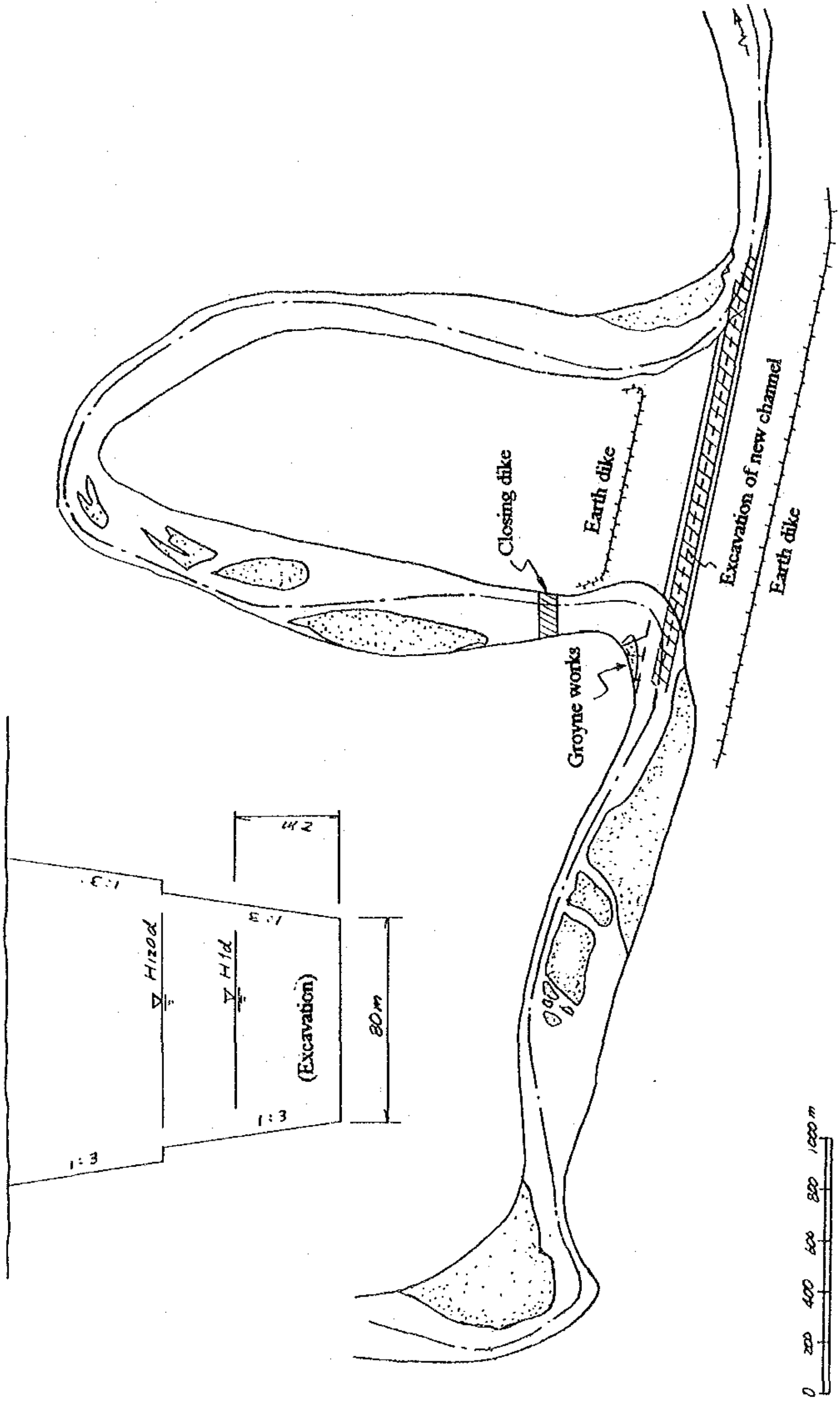


Fig.5.7.4 Sample Drawing : Cut-Off Channel Works

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

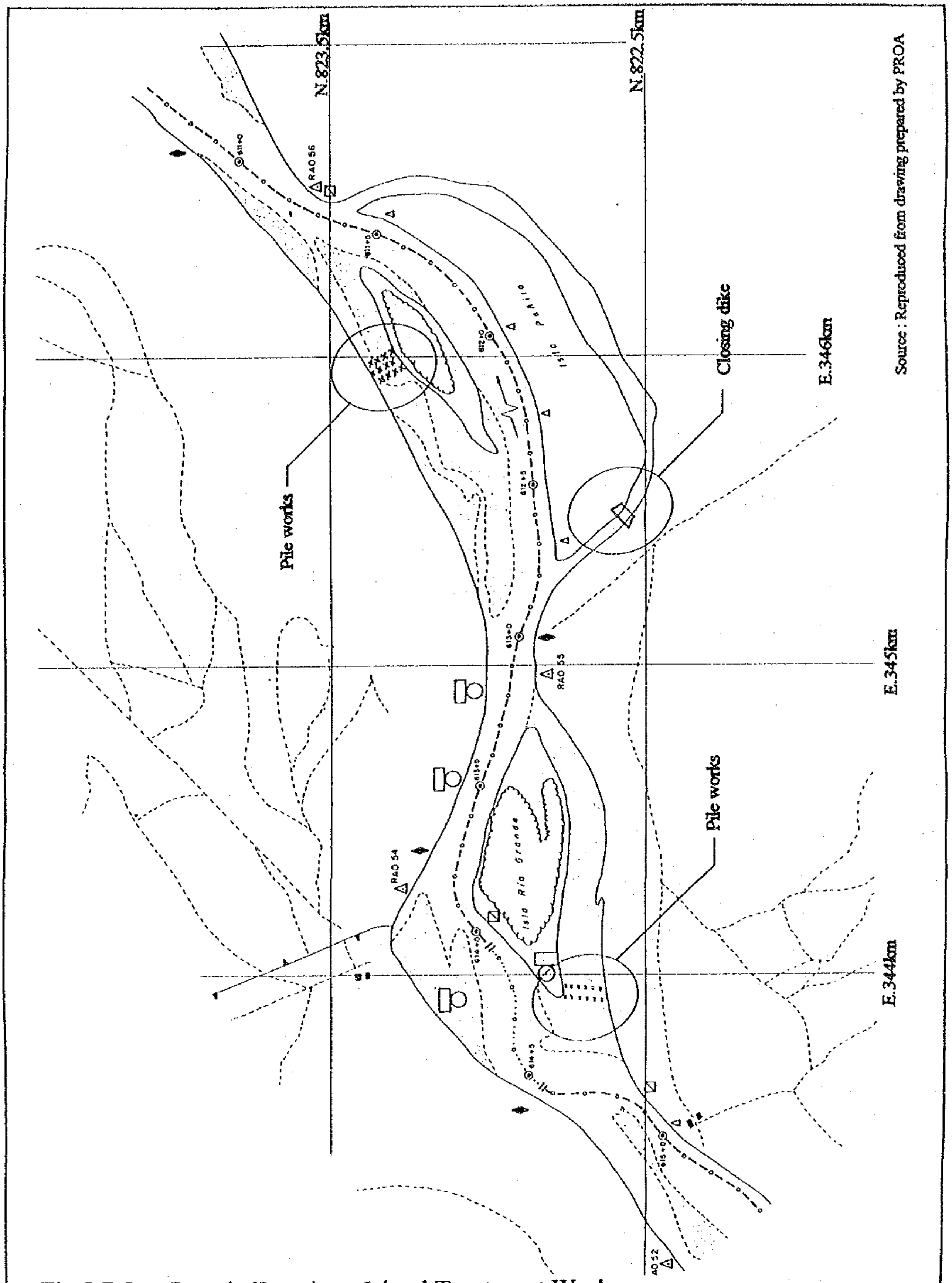
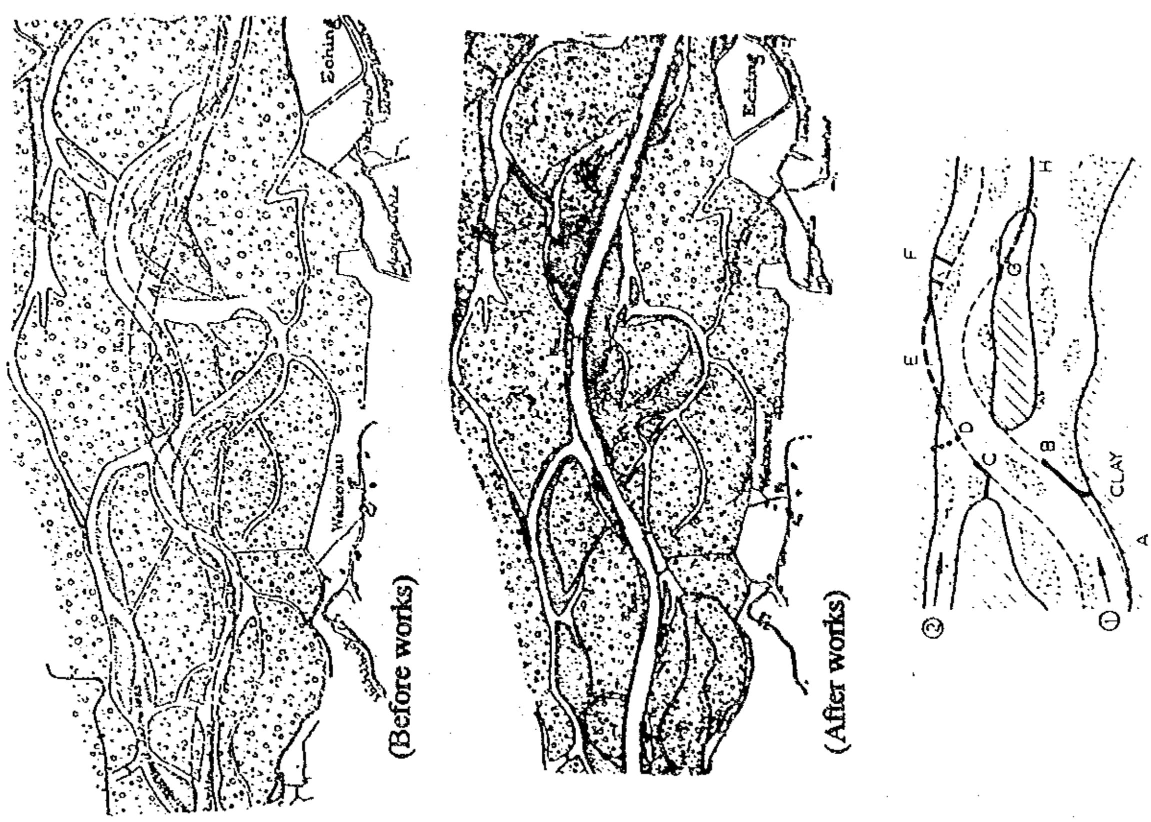
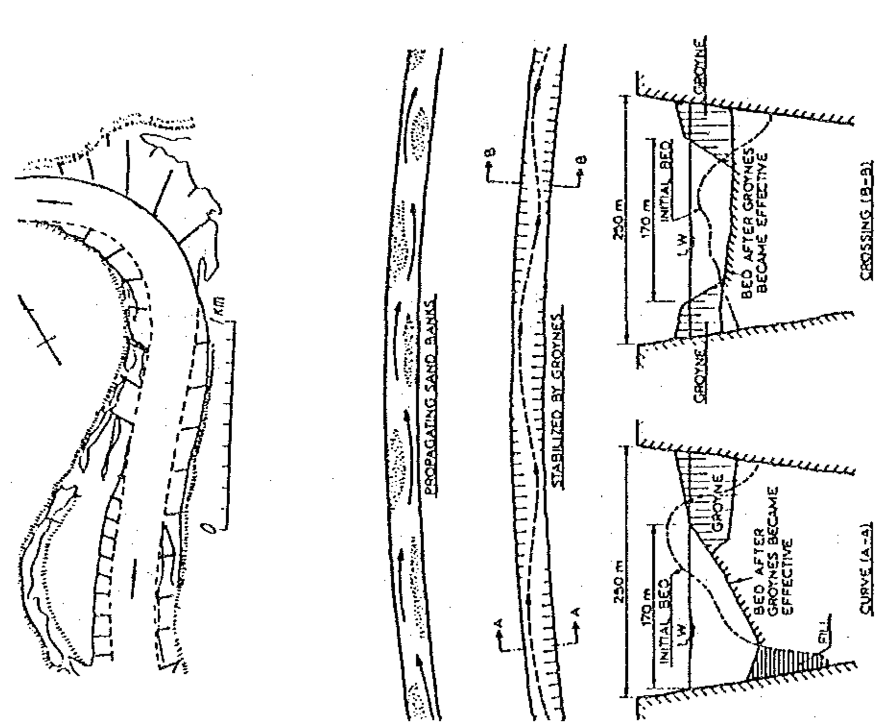


Fig.5.7.5 Sample Drawing : Island Treatment Works

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY



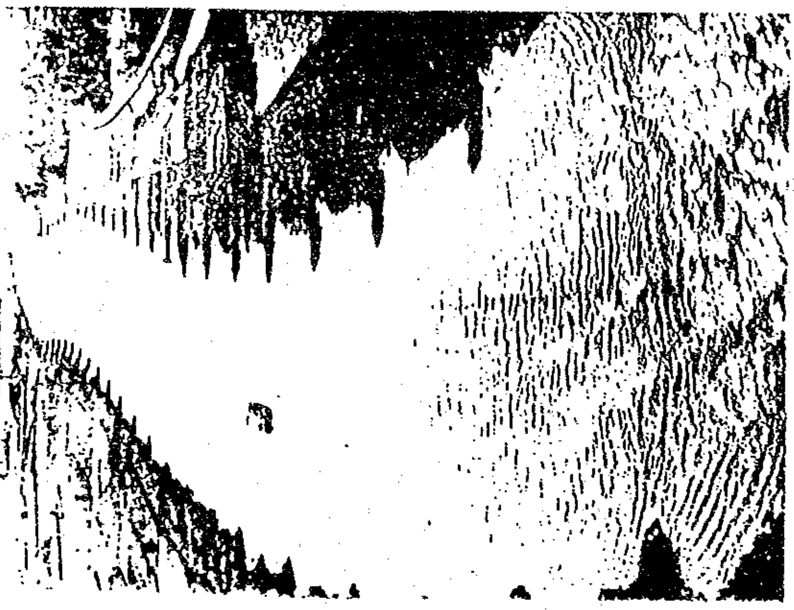


Source : Principles of River Engineering, Jansen

Fig.5.7.6
Sample Drawing :
River Training Works by Groynes (1/2)

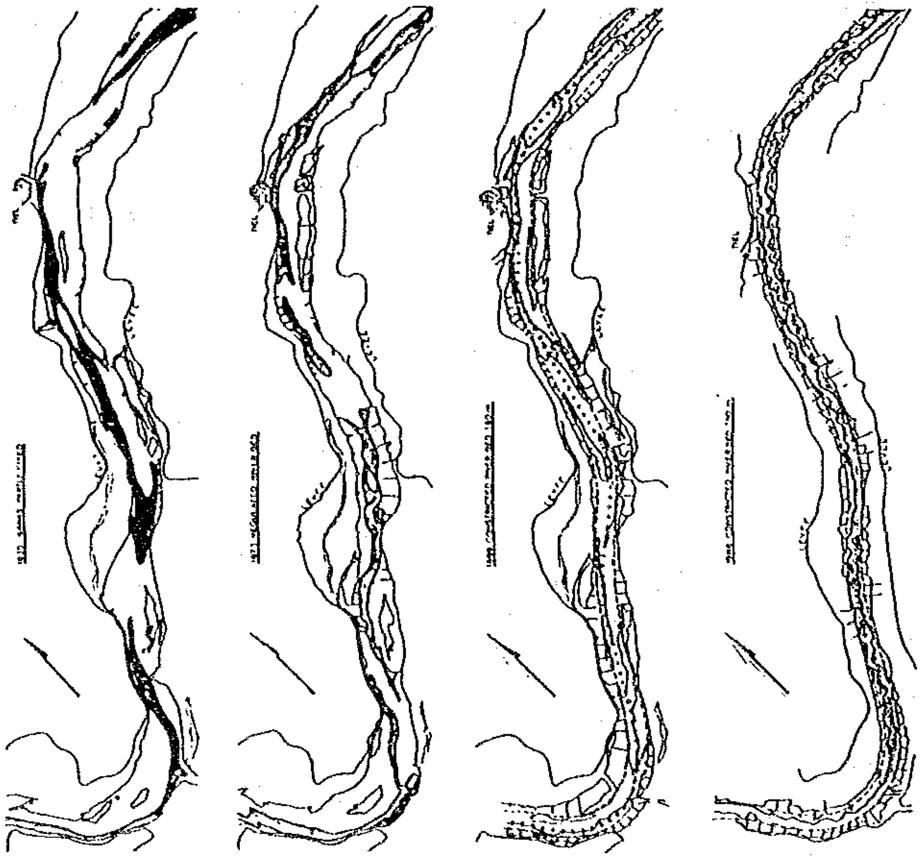
THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY



Nederrijn below Arnhem

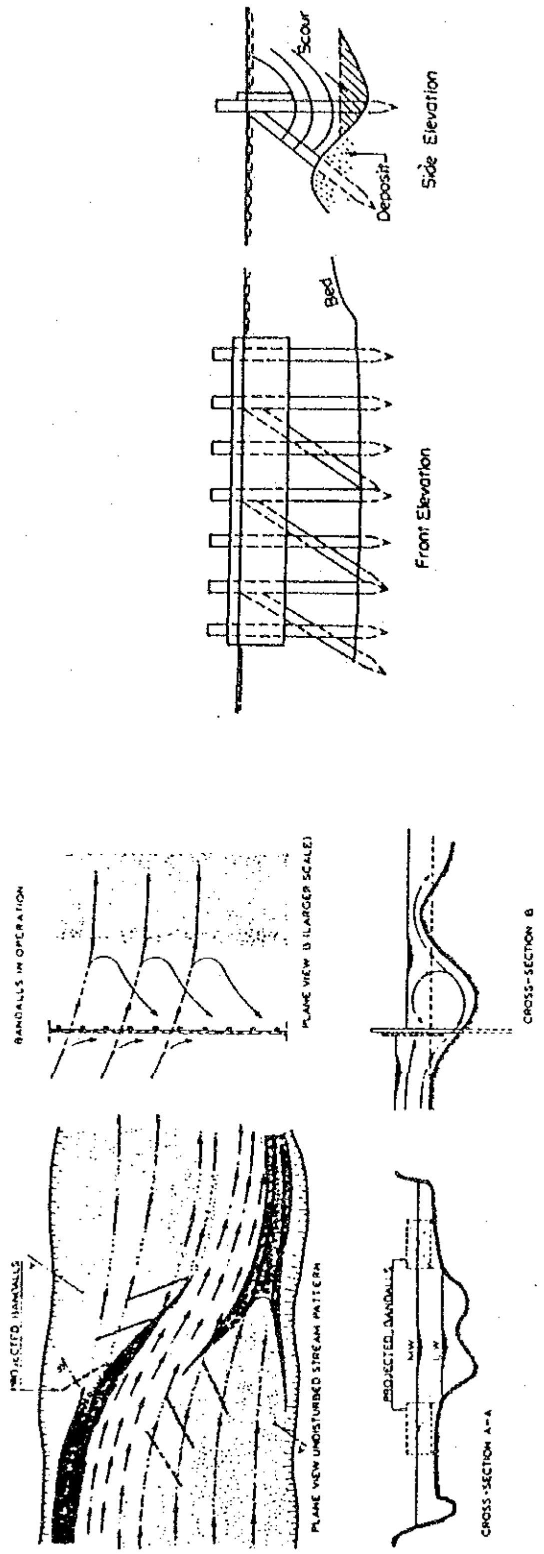
Source : Principles of River Engineering, Jansen



History of River Improvement : Woal River

Fig.5.7.6
Sample Drawing :
River Training Works by Groynes (2/2)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY



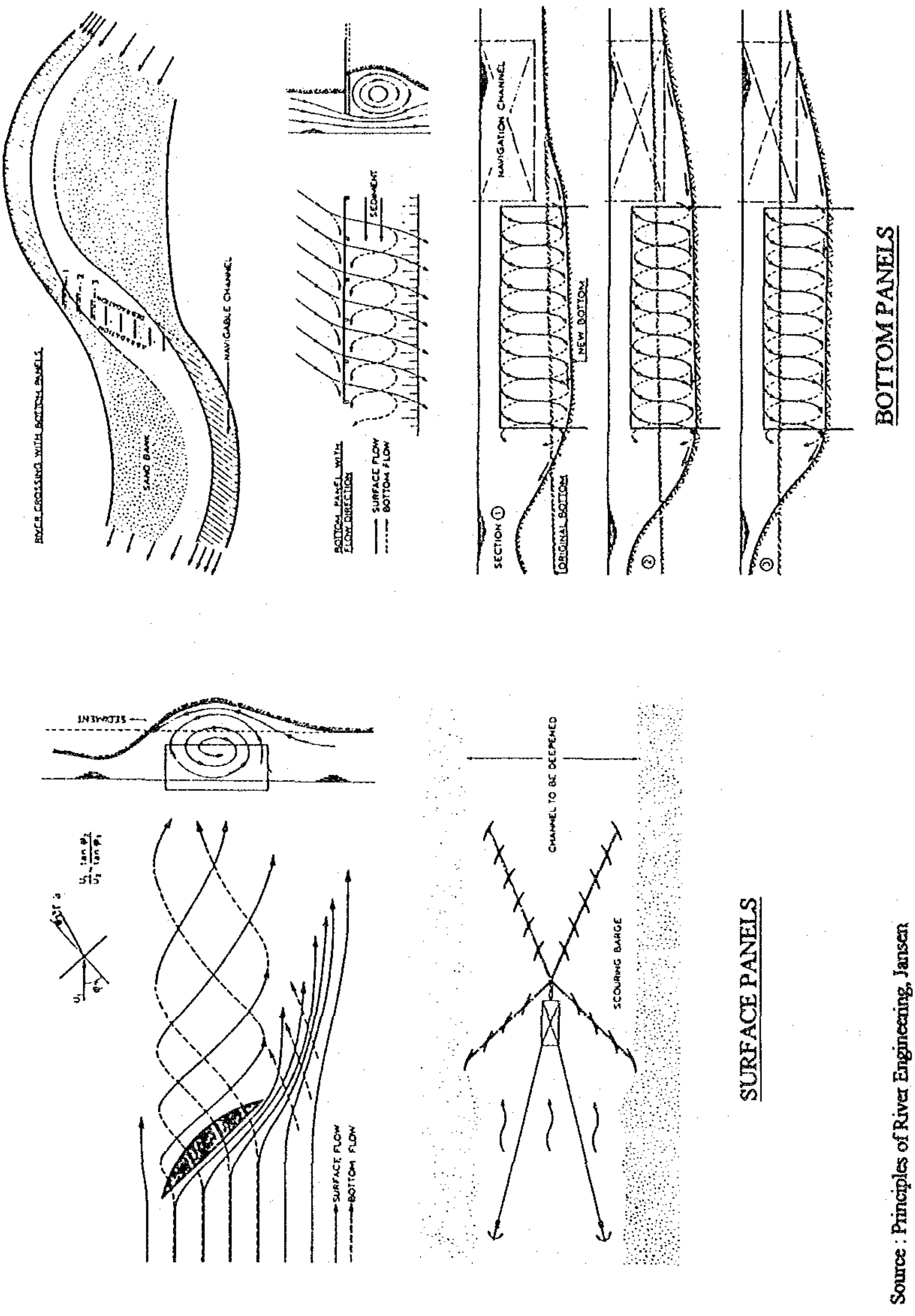
BANDALS

Source : Principles of River Engineering, Jansen

Fig.5.7.7
Sample Drawing :
Temporary Canalization Works (1/2)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

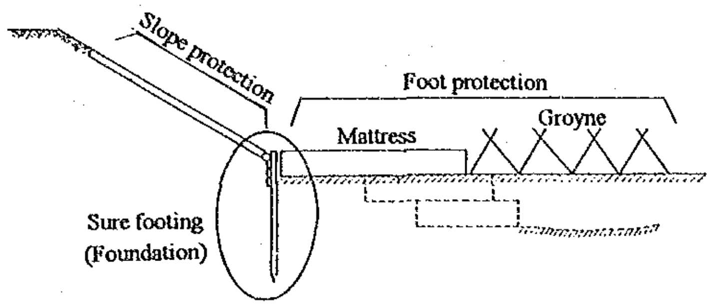
JAPAN INTERNATIONAL COOPERATION AGENCY



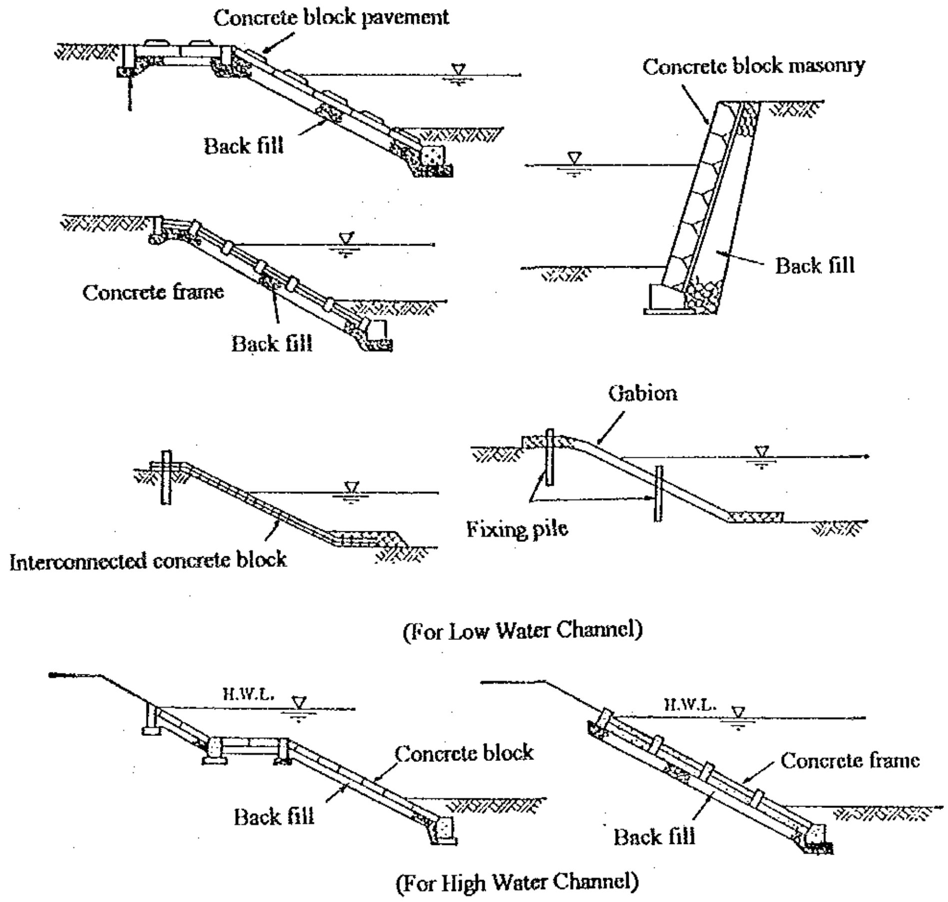
Source : Principles of River Engineering, Jansen

Fig.5.7.7
Sample Drawing :
Temporary Canalization Works (2/2)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY



COMPOSITION OF REVETMENT WORKS

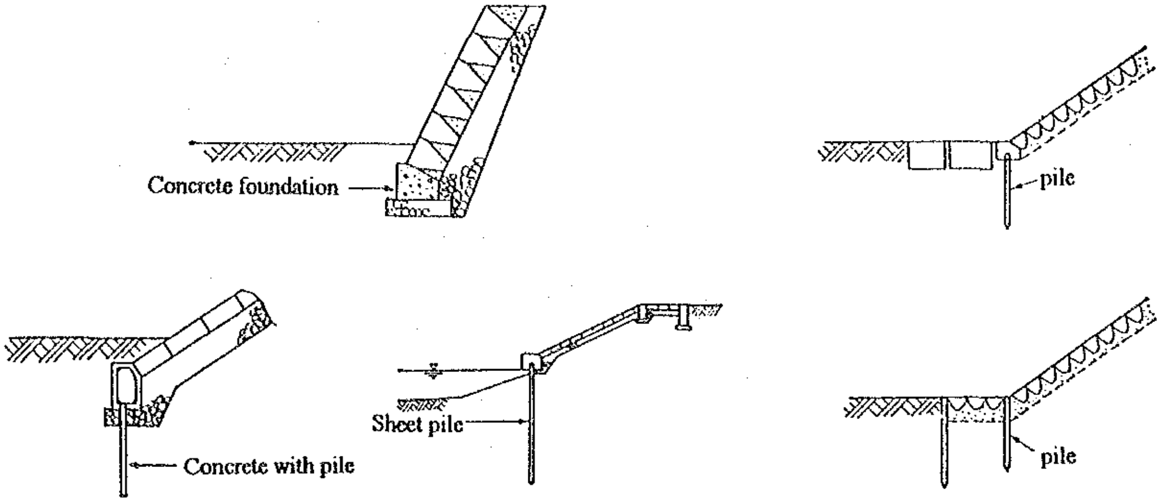


TYPES OF SLOPE PROTECTION WORKS

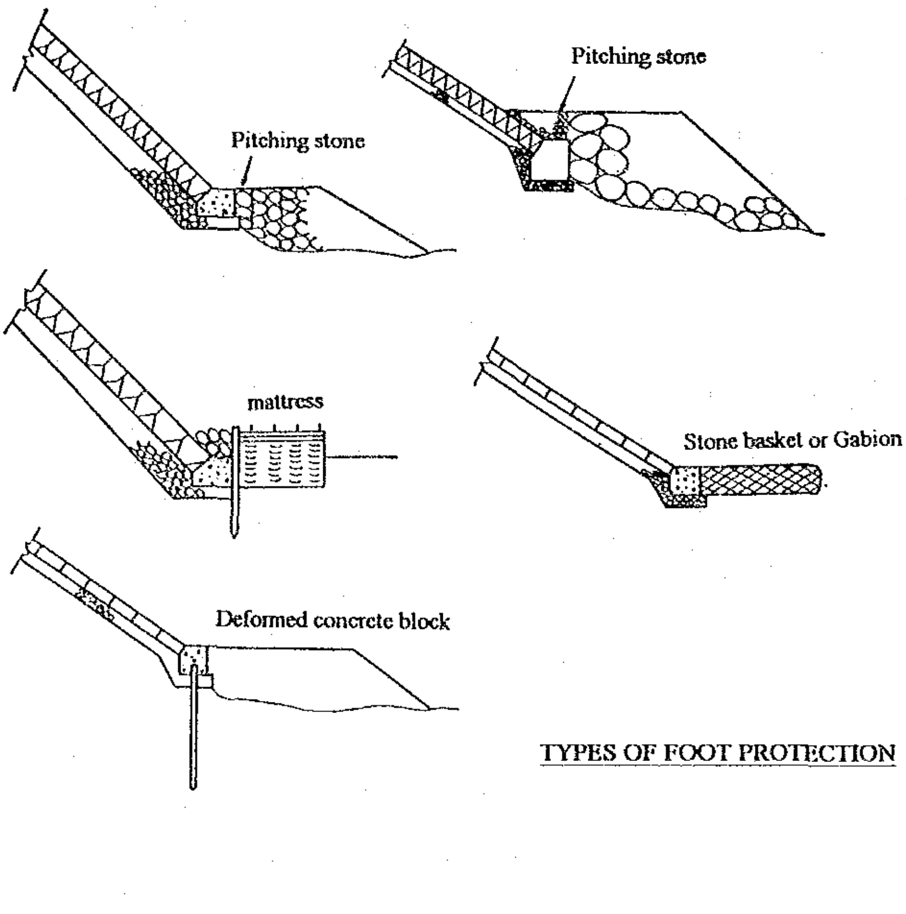
Fig. 5.7.8
Sample Drawing : Revetment Works (1/2)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY



TYPES OF SURE FOOTING



TYPES OF FOOT PROTECTION

Fig. 5.7.8

Sample Drawing : Revetment Works (2/2)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

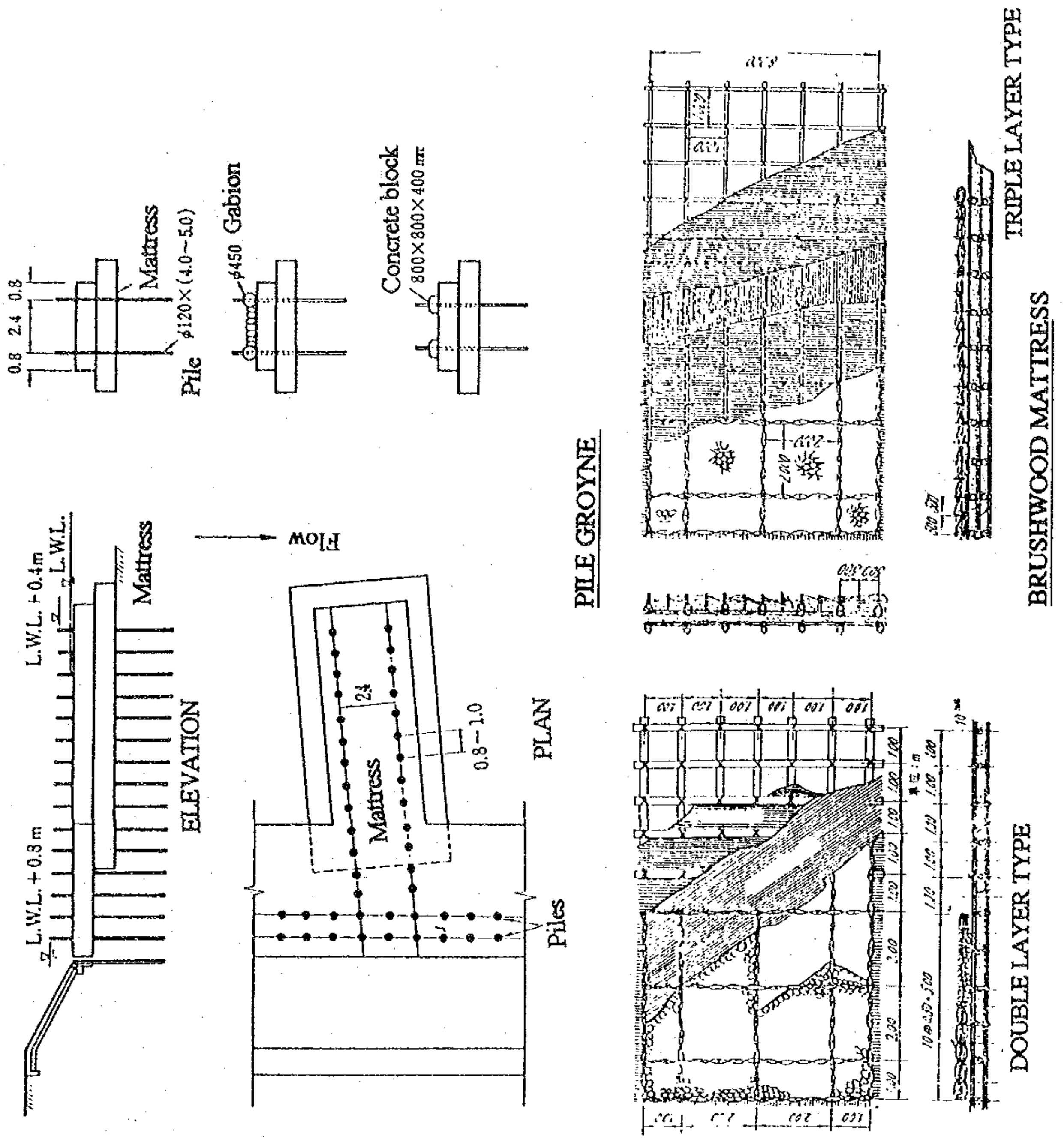
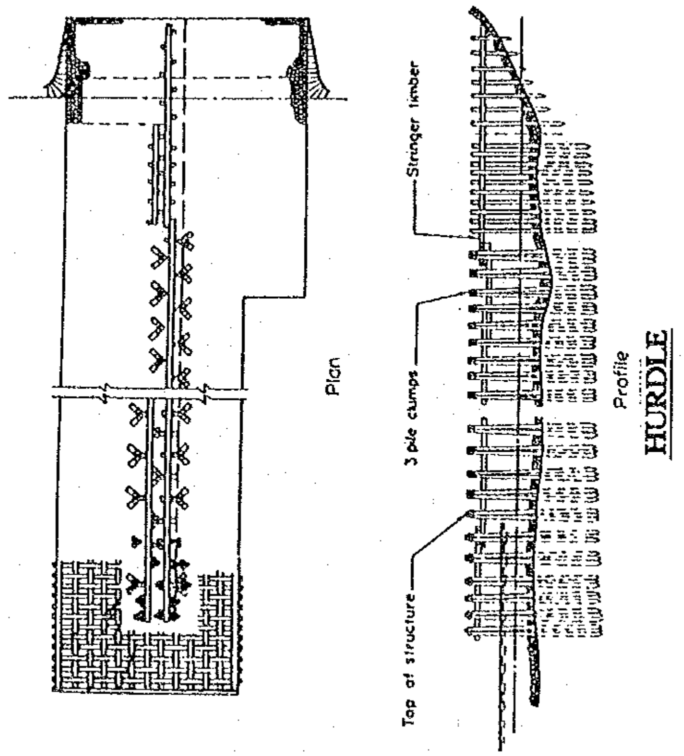
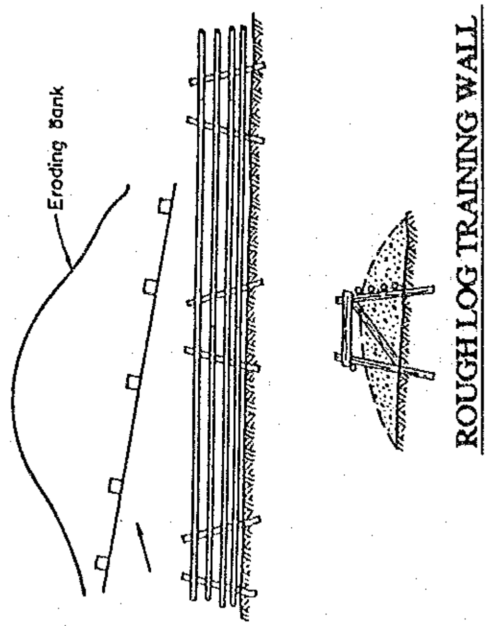


Fig.5.7.9 Sample Drawing : Groyne Works (Pile Type) (1/2)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY





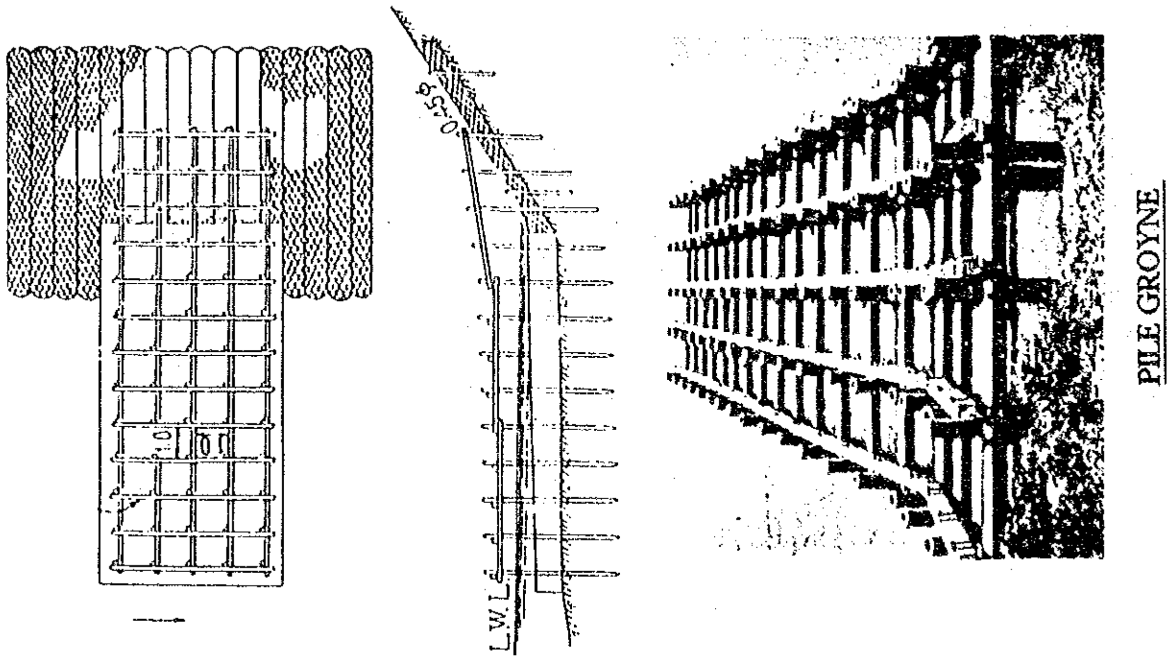


Fig.5.7.9 Sample Drawing : Groyne Works (Pile Type) (2/2)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

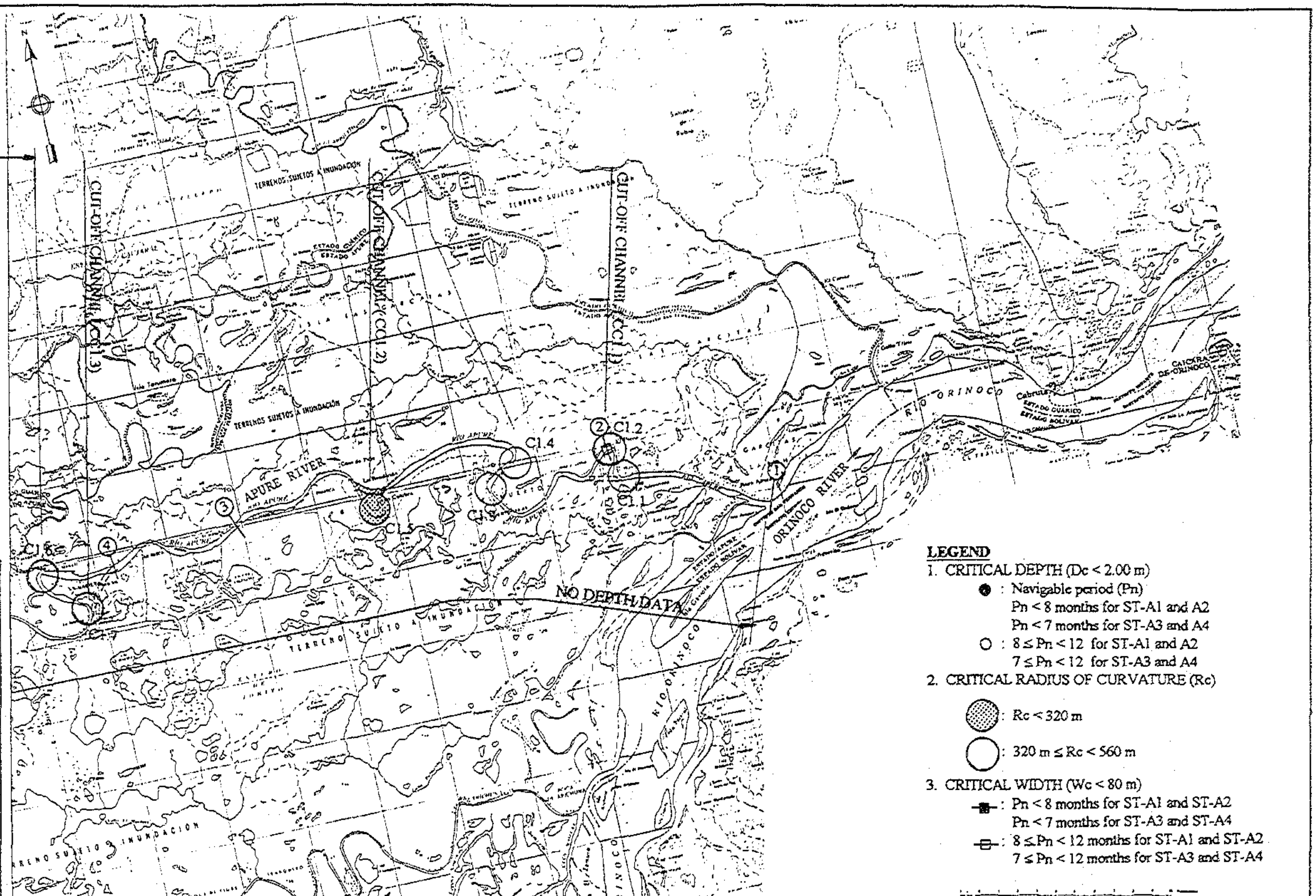


Fig. 6.2.1 Location of Critical Sections : Apure River (1/8)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

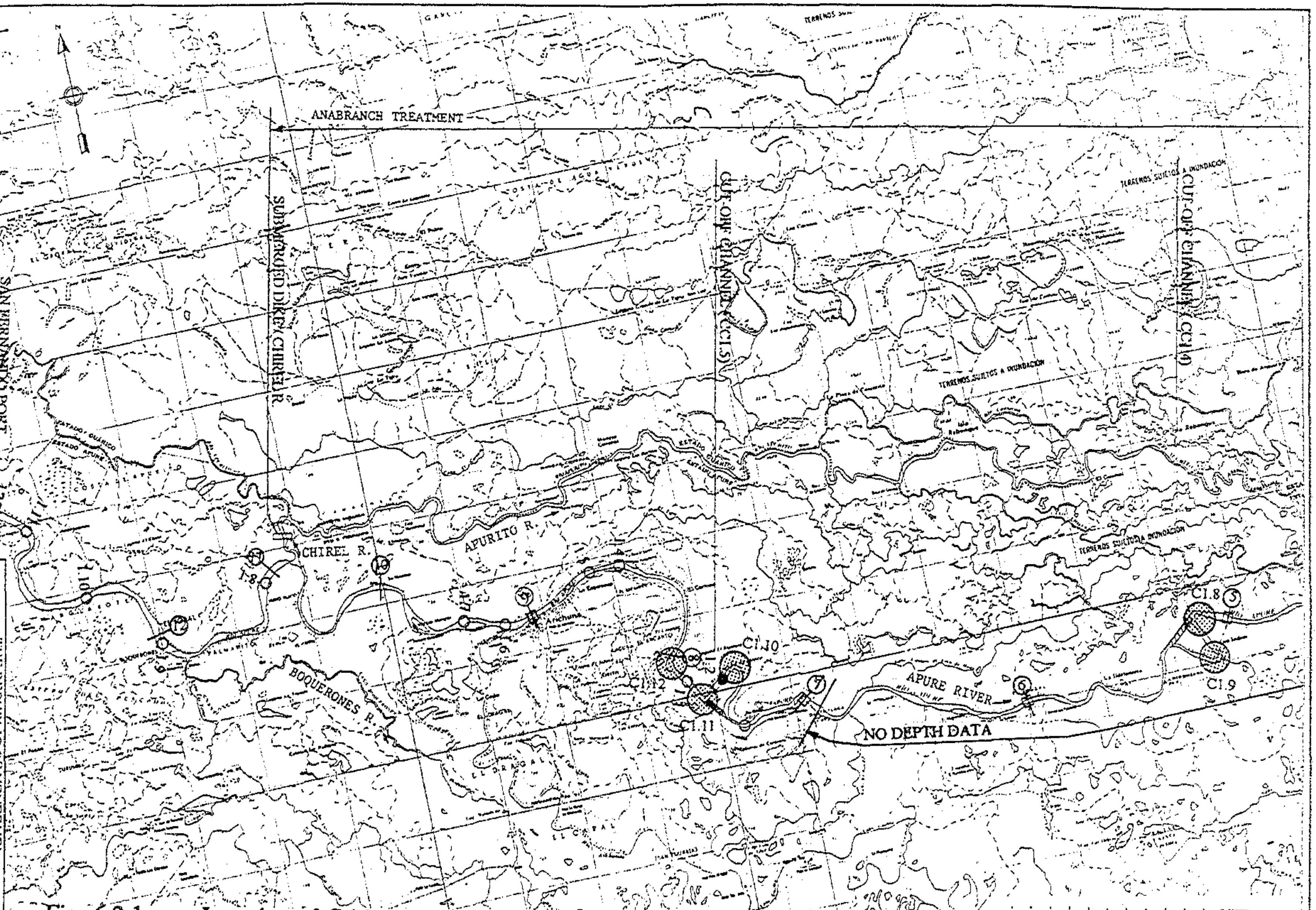


Fig. 6.2.1 Location of Critical Sections : Apure River (2/8)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

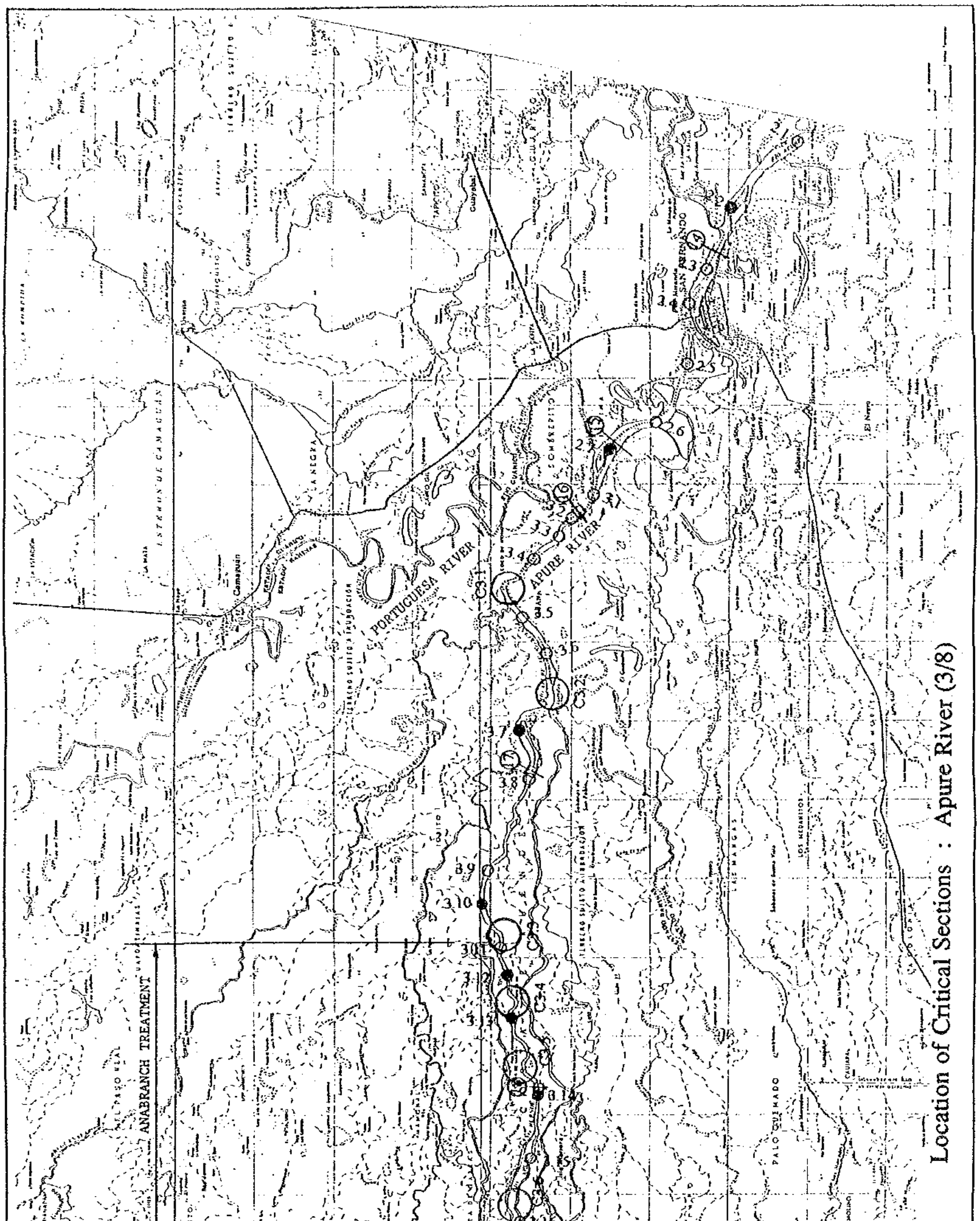


Fig. 6.2.1 Location of Critical Sections : Apure River (3/8)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

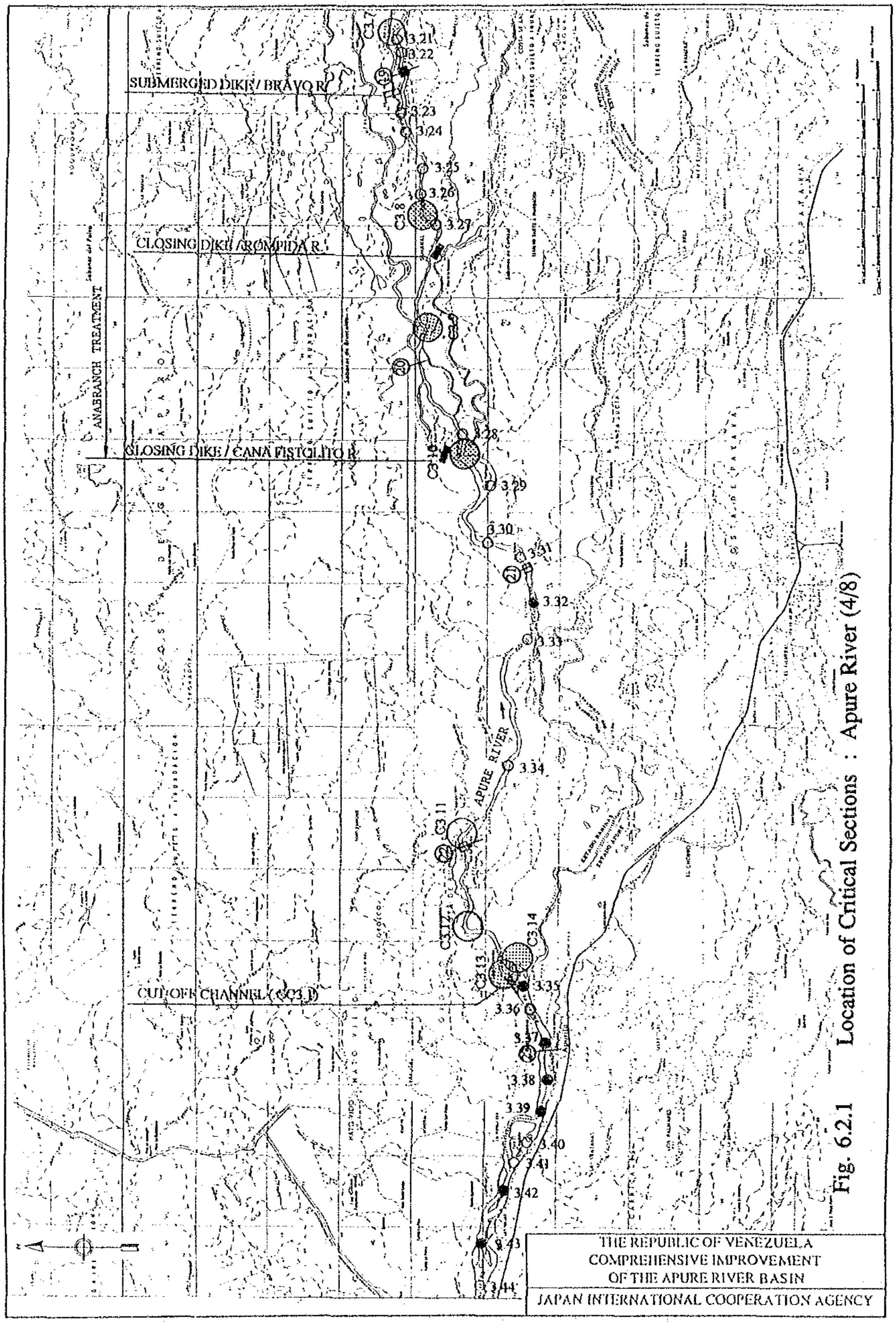
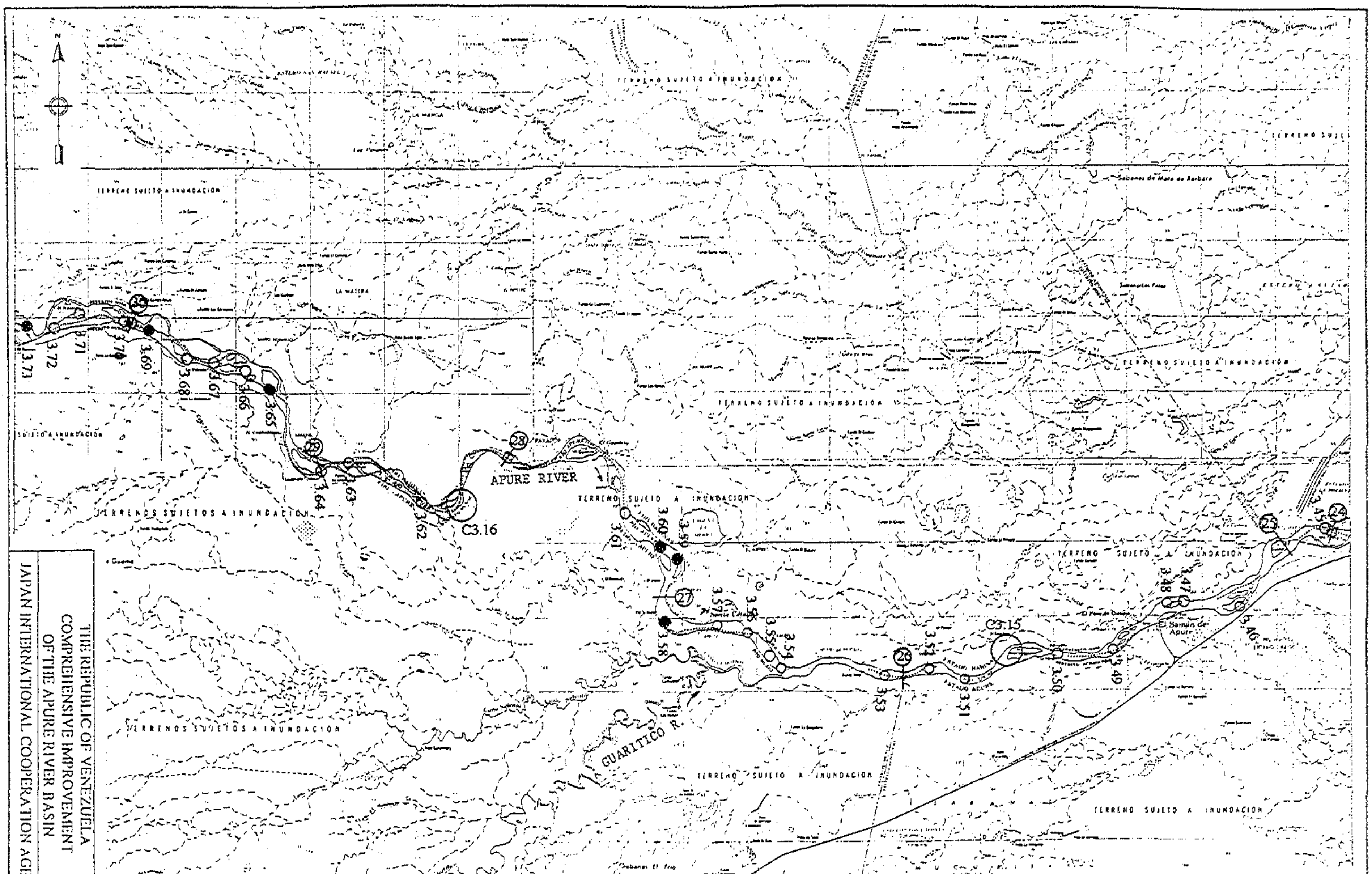


Fig. 6.2.1 Location of Critical Sections : Apure River (4/8)



THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 6.2.1 Location of Critical Sections : Apure River (5/8)

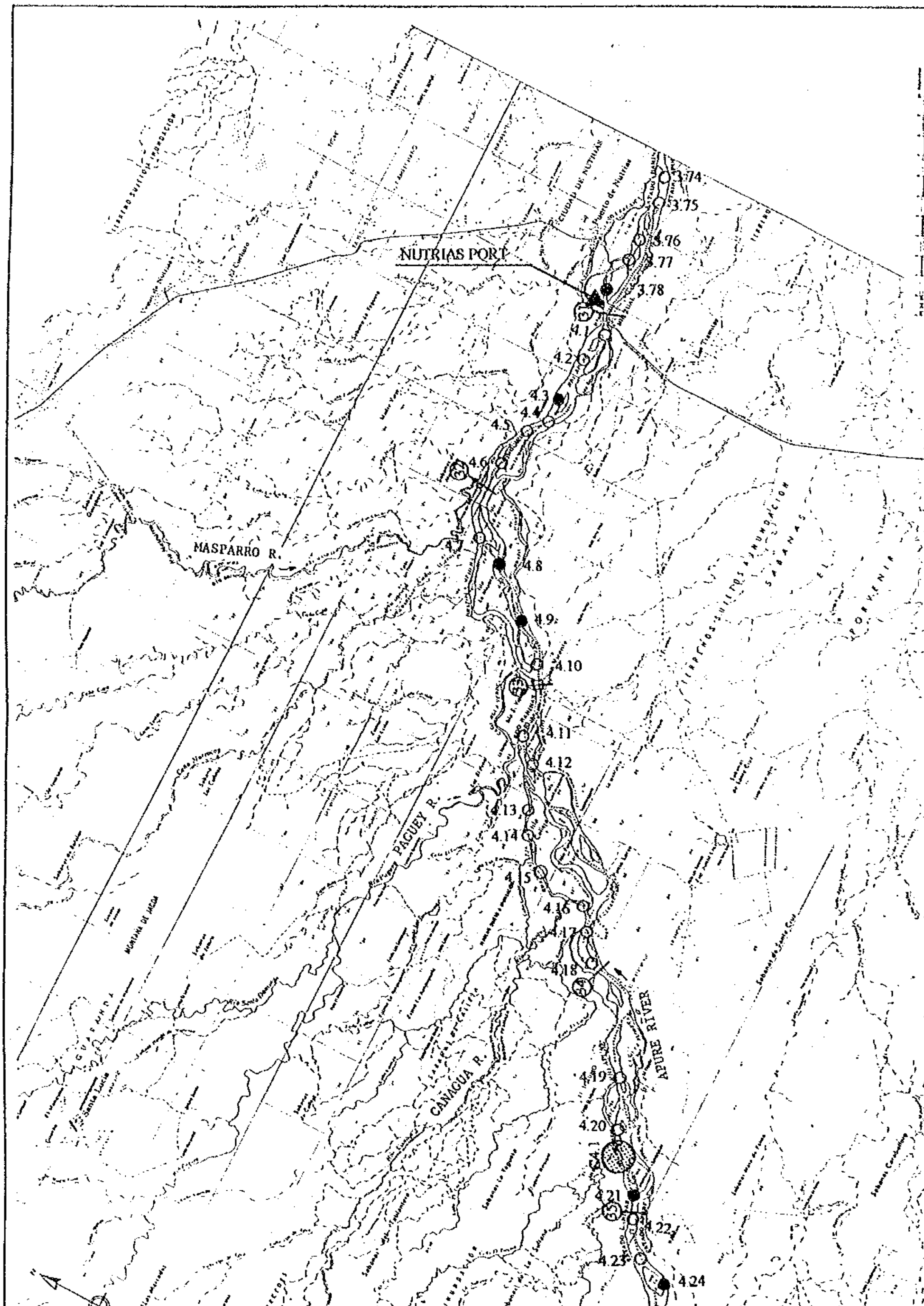


Fig. 6.2.1 Location of Critical Sections : Apure River (6/8)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

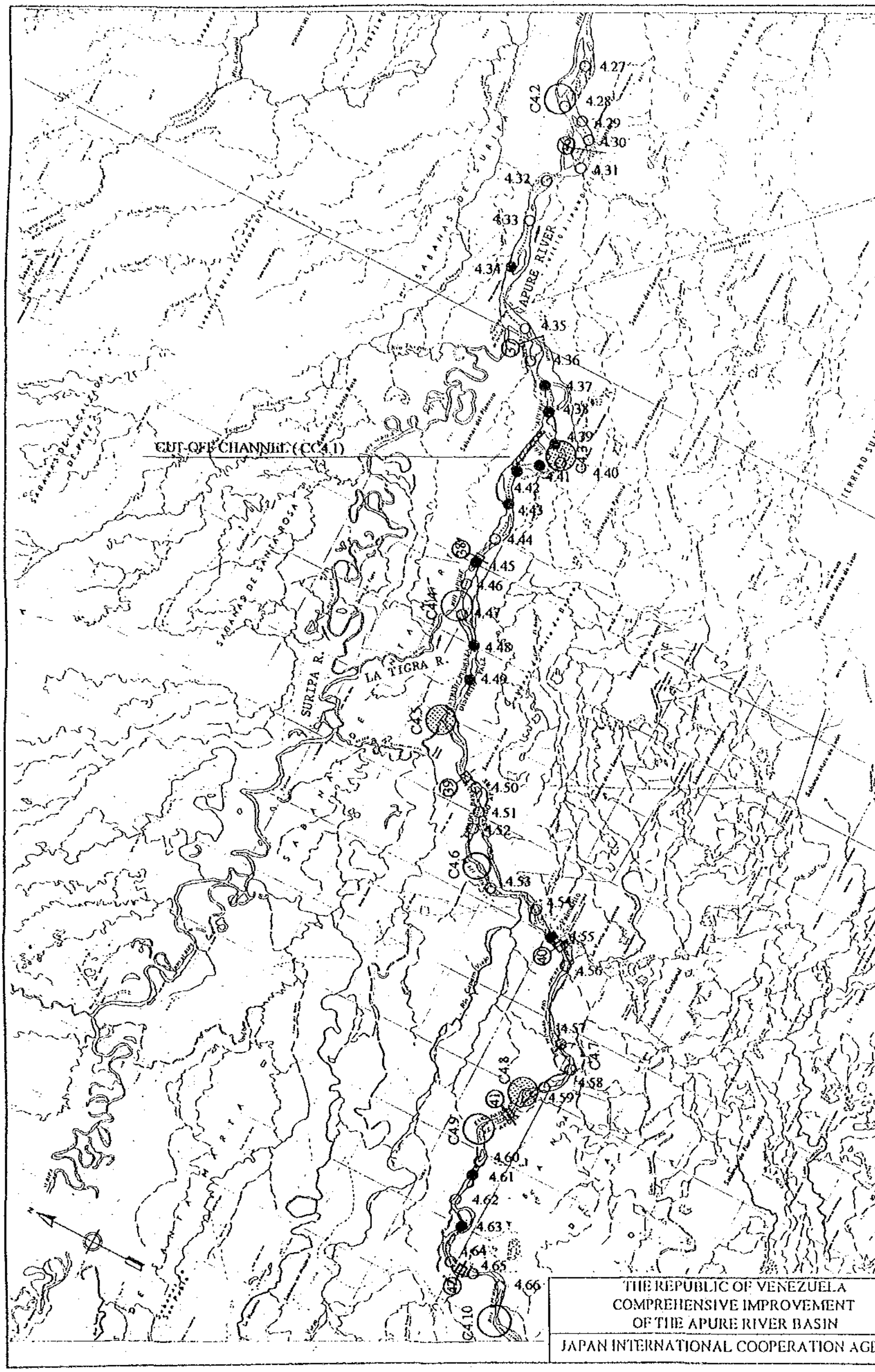


Fig. 6.2.1 Location of Critical Sections : Apure River (7/8)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

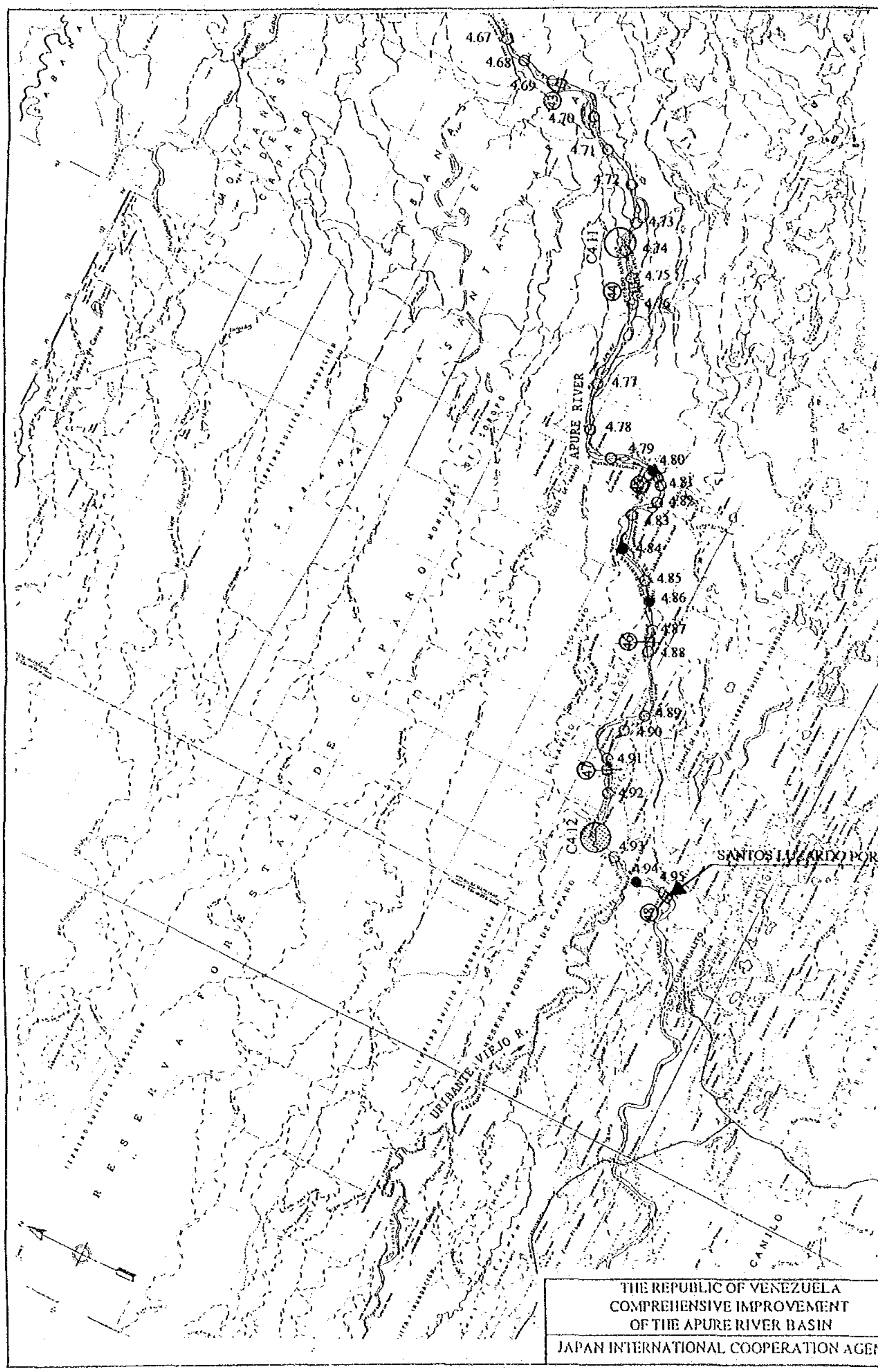


Fig. 6.2.1 Location of Critical Sections : Apure River (8/8)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

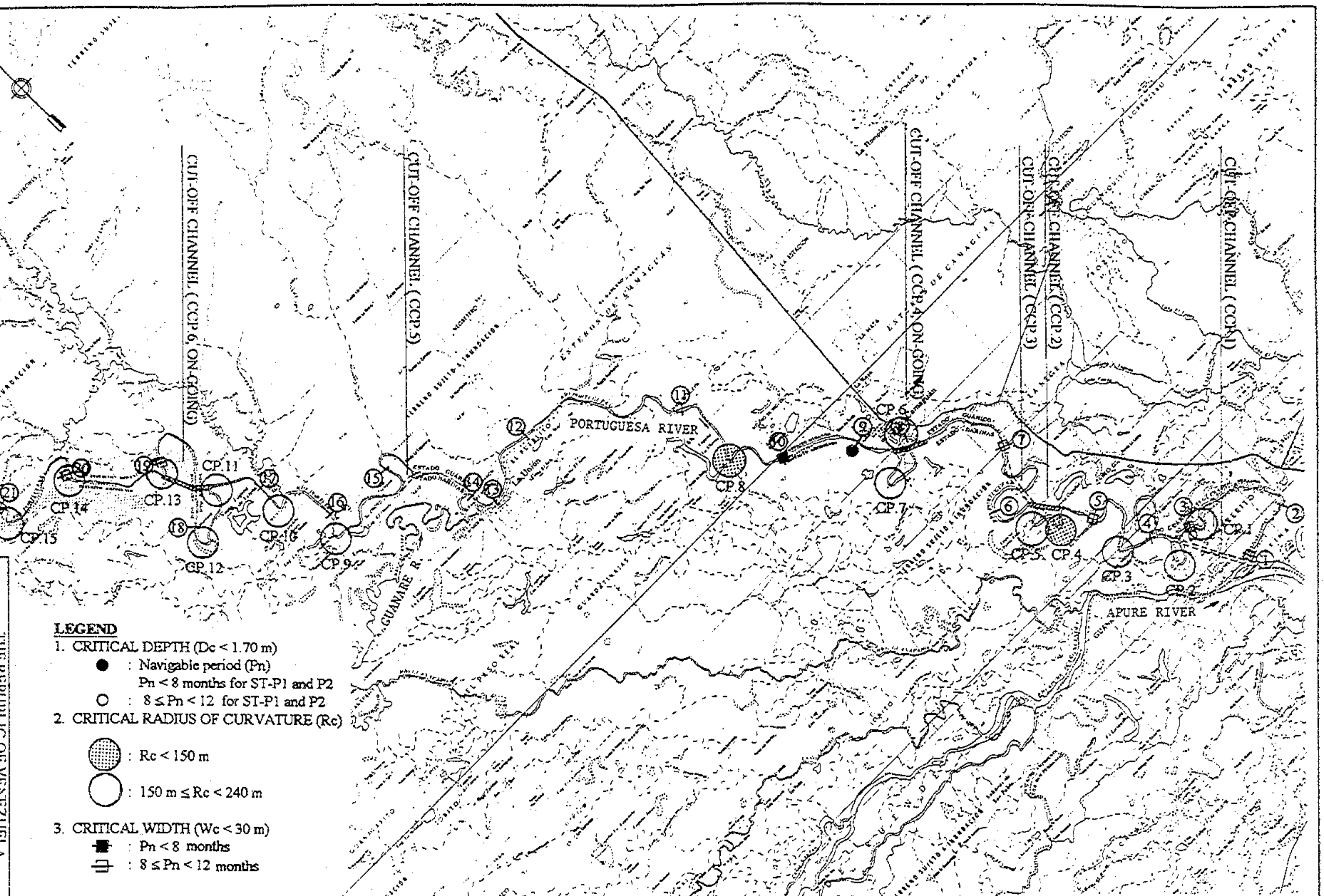


Fig. 6.2.2 Location of Critical Sections : Portuguesa River (1/2)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

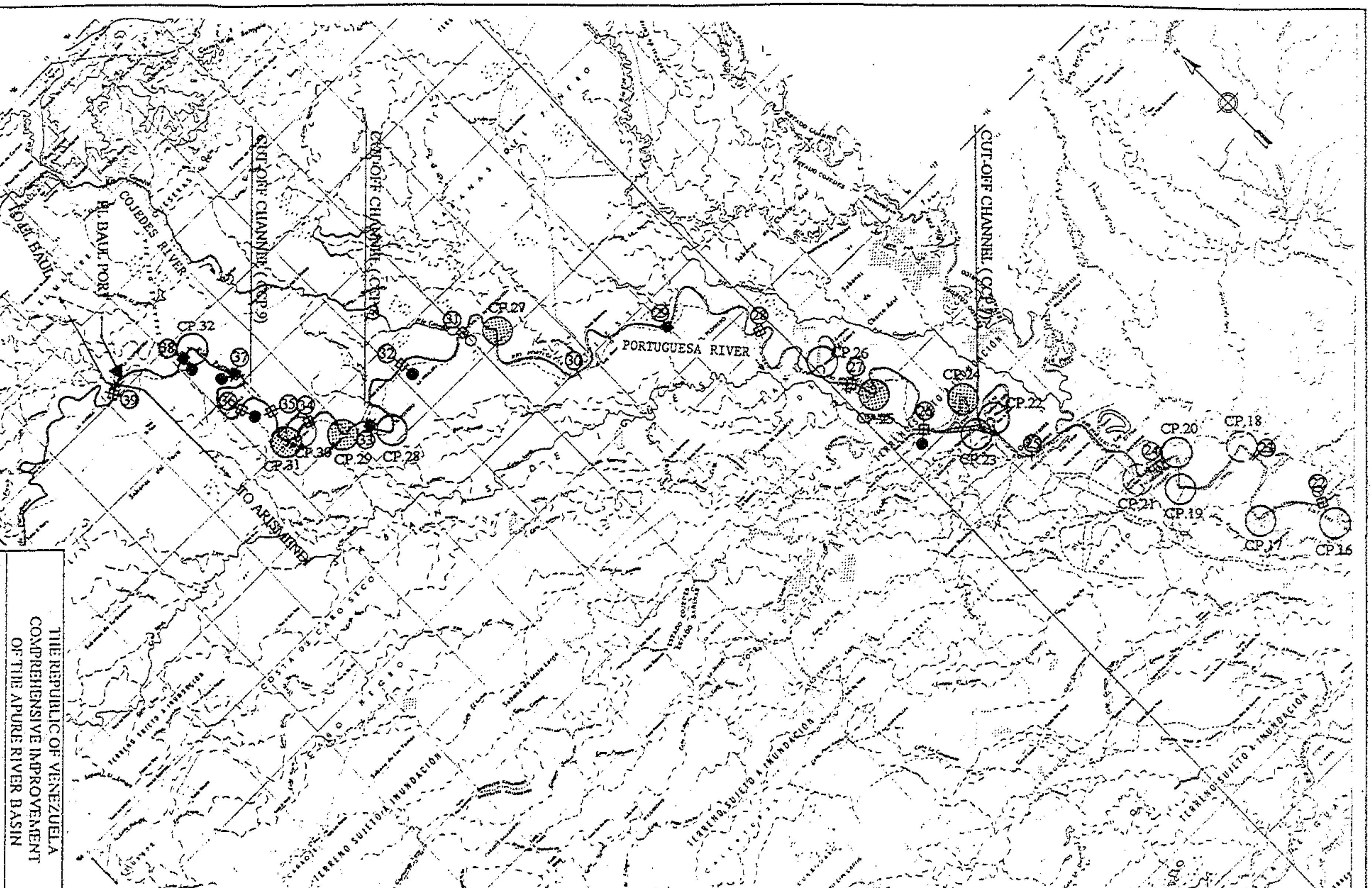


Fig. 6.2.2 Location of Critical Sections : Portuguesa River (2/2)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

Work items	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
1. Project Preparation																				
a) Navigation master plan study	***	***																		
b) Feasibility study	***	***	***	***	***															
c) Financing	***	***	***	***	***															
2. Short-Term Plan																				
a) Preparation	***	***																		
b) Detailed design	***	***																		
c) Construction works			***	***	***	***	***													
- Urgent channel work:St-A4			===	===																
- Channel works: St-A1			===	===																
- Channel works: St-A2,P1,P2				===	===															
- Anabranch treatment works				===	===															
- Channel works: St-A3					===	===	===													
- Channel works: St-A4					===	===	===													
- Derivation channel works							===													
3. Mid-Term Plan																				
a) Prepartation						***	***													
b) Detailed design						***	***													
c) Construction works								***	***	***	***	***	***	***	***	***	***			
- Channel works: St-A1								===	===											
- Channel works: St-A2,P1,P2										===	===									
- Channel works: St-A3												===	===	===						
- Channel works: St-A4															===	===	===			
4. Long-Term Plan																		***	***	>>

Fig. 7.5.1 Implementation Schedule of Channel Stabilization Plan

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

PART-F

STUDY ON FLOOD MANAGEMENT

STUDY ON COMPREHENSIVE IMPROVEMENT
OF
THE APURE RIVER BASIN

FINAL REPORT

VOLUME III : SUPPORTING REPORT
PART-F : STUDY ON FLOOD MANAGEMENT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

1.1 Objectives of the Study

According to the Scope of Work stipulated in the agreement between JICA and MARNR, the area subject to the present flood management study is bounded by the Apure river in south, Portuguesa river in north and east and Masparro river in west as shown in Fig. 1.1.1.

The study aims to formulate a flood management plan to mitigate the flood damage in the study area and facilitate land use there.

The study area is vast and presently almost in natural condition, so that it will take very long time until the flood management work in the area reaches a satisfactory level. During long lasting flood management, social, economic and environmental conditions in the area will be changed, but it is difficult to foresee them. Especially, change of environmental aspect should be carefully considered. A drastic change of hydraulic conditions of the area resulting from implementation of the flood management works will give strong impact to the environment of the area.

Therefore, the present study dose not intend to propose a large scale flood management plan which may give a strong impact to the environment of the area. The flood management plan to be proposed in the present study will be a plan as first step toward the long-run flood management works in the area with development of the area.

1.2 Study Area

The area has an extension of 22,200 km^2. However, the Masparro river basin is hydraulically separated from the rest area by local road route 2 connecting Bruzual and Veguita and has no serious flood problem, so that it is excluded from the study area. In this case, the study area is 21,000 km^2.

Major rivers in the study area are the Apure river and Portuguesa river mentioned above and also the Guanare river which runs through the center part of the study area. Besides that, a lot of small streams called "Caño" run in the study area. Among them, Caño Igues, Caño La Aguada, Caño Chorroco, Caño Salsipuedes, etc. are major.

The study area administratively belongs to three states, that is, Barinas, Portuguesa and Cojedes. The Barinas state in the study area is further divided into two districts of Arismendi and Sosa and the Portuguesa state into four districts of Guanarito, Papelon, Guanare and San Genaro de Boconoito. While, in the Cojedes state, a part of Girardot district belongs to the study area.

In the study area, the Arismendi district is known as a center of Apure depression which is the lowest zone of western llanos (flatland). The ground slopes of surrounding areas converge from south, west and north in a radial manner. The actual depression center is situated in the east of Arismendi town as seen in Fig. 1.1.1.

II. PRESENT CONDITIONS OF THE STUDY AREA

2.1 Hydraulic Characteristics

Hydraulic characteristics in the study area such as dynamics of drainage, evolutionary process of inundation, etc. have been studied several times so far by MARNR though those studies were made at district level and not at river level.

Among the studies, the study on excess water in western llanos provides precise data for the present flood control study such as inundation area, behaviors of surface water and rivers, possibility of solution of drainage problem, etc.

Referring to the study reports published so far, the hydraulic characteristics of the study area are explained as mentioned hereinafter.

2.1.1 General Characteristics

(1) Flood Characteristics Upstream from San Fernando

The rivers which run in the low flat plains of Barinas state pour into the Apure river which subsequently flows into the Orinoco river. During high water period from June to October, the water surface slope of the Orinoco river becomes very gentle and it results in very slow flow. Because of this, the flow of the Apure river in the lower reaches is influenced.

The same phenomena is observed in the Apure river and the Portuguesa river. They repress runoff from their tributaries and cause overflowing of the tributaries . Also, the large areas of the flat plain are flooded by overflowing of the caños which do not have enough capacities for large discharge due to very gentle slope or shallow depth. The flooding in the low flat plain lasts for 3 to 4 months in a year.

The annual variation of water level of the Apure river at San Fernando is about 7 m in average, which corresponds to the variation of monthly mean discharge from 200 to 4,500 m^3/s. The descent or rise of water level is 1 m or more per week.

The water stored upstream from San Fernando at the end of August is estimated at approximately 40 x 10^9 m^3, while that in the area between Arismendi and San Fernando (12,230 km^2), lower part of the study area, is estimated at 6 x 10^9 m^3. (Refer to

Simulacion Hidrological de la Cuenca del Rio Apure hasta San Fernando, GONZALEZ C. CILINO Y GONZALEZ ANGELA, Octubre 1992)

(2) Evolutionary Process of Inundation in Arismendi Districts

With beginning of rain, first saturation of soils in the savanna and stagnation of water appear in the lower lands (esteros). At the same time, the water in the channels starts to increase. Then, runoff water from the upper and middle basins overflow in the savanna until inundation called "water mirror" is formed.

During overflowing, the savanna behaves as a very wide channel and the water flows from west to east looking for an outlet toward the Orinoco river with varying speed being faster in the natural river courses and very slow in the savanna. The water surface has a gentle slope like slope of the land.

The retention period of the inundation in the Apure river basin depends on the water level of the Apure river. The water levels of tributaries decrease with decrease of water level of the Apure river. Finally, the water levels of the caños in the savanna become low leaving some stagnated water in the low lands. The bigger water stagnation forms a lagoon, while the smaller one finally disappears because of infiltration and evaporation.

During the rainy months, most of natural drainage in the area are suspended since the lower Portuguesa river cannot collect the water anymore due to high water level or overflow of the Apure river.

Regarding hydraulic characteristics of the canõs (channels) in the area, all of them have the same configuration such as rectangular cross sections and very wide channels with small ratio of depth and width of the channels. The channels consist of fine material. The flow velocity does not exceed 2 m/s.

Some of the river reaches are covered with so-called "gallery forest", which gives a certain stability to the channels. The roughness coefficient is approximately 0.020 in the channel and 0.15 in the margins, while that in the savanna ranges from 0.030 to 0.045 depending of the density and type of vegetation. (Refer to Diagnostico Preliminar de la Problematica de Inundaciones en el Distrito Arismendi del Estado Barinas, MARNR, Julio 1984)

(3) Drainage Conditions in Interbasin between Portuguesa River and Caño Igüés

The problem of interbasin between the Portuguesa river and the Caño Igüés is centered on overflowing. The natural channel of the Portuguesa river causes a series of inundation almost every year. In the section between the main road route 5 and the Canal Piloto (diversion channel of Acarigua river) in Turen, the Portuguesa river receives several tributaries on its left bank and those tributaries transport large volumes of discharges and sediments.

Practically, from the crossing of the Acarigua-Guanare road, the Portuguesa river causes overflowing due to shortage of the channel capacity on its right bank. Among the most evident causes to loose capacity of the channel, the uprising of the channel bed by sediment deposition is typical, but most of the sediment deposited are carried away by the overflow together with trees which obstruct the normal water flow. The river presents a series of low lands which serve in a natural way as a major inundation channel.

The Caño Igüés has less activity because of the overflow, but it is becoming a natural receiver of the excess water from the Portuguesa river. As the Caño Igüés is a channel with small capacity, it cannot discharge the inflow from the Portuguesa river and the runoff from the adjacent areas.

In the present, a tendency to increase the drainage problems is observed in the interbasin due to insufficient capacity of the channels to drain the concentrated runoff. It is also very probable that the excess water due to rainfall or overflow prolongs the period of their affectation to the lower areas. There is no possibility of decreasing the overflow of the Portuguesa river in a short term. On the contrary, the overflow has been increasing in the recent years.

Any work to improve this situation of water excess should be subject to the conservation of the upper basins of all the tributaries of the Portuguesa river. It is also important to improve the river channel downstream from the Canal Piloto so that the middle and upper basin can accelerate its drainage.

It is well known that the problem of the poor functioning of the Portuguesa river is complicated because it concerns a series of rivers and caños which have very active flow dynamics. Most of these rivers and caños join the Portuguesa river on its left bank and the greater agricultural development areas in the basin are located there. This situation complicates the solution of drainage. (Refer to Analisis Geomorphologico y del Drenaje Superficial Interfluvio : Rio Portuguesa-Caño Igüés, MARNR, Diciembre 1991)

2.1.2 Inundation Area

According to the results of study on excess water in western llanos made by MARNR, inundation in the western llanos which includes the study area is largely classified into the following four categories by type of inundation and they are further divided into fourteen classes in total by cause of inundation.

Category I	:	Non or little inundation sectors (Class 1 to 3)
Category II	:	Partial inundation sectors (Short term inundation) (Class 4 to 7)
Category III	:	Total inundation sectors (Long term inundation) (Class 8 to 11)
Category IV	:	Total inundation sectors (Short-repetitive inundation) (Class 12 to 14)

Among them, the Category III will be related to the present study. It is further divided into the following four classes.

Class 8	:	Sectors totally inundated by overflowed water
Class 9	:	Sectors totally inundated by runoff water repressed
Class 10	:	Sectors totally inundated by rainfall water
Class 11	:	Sectors totally inundated by local runoff water repressed by overflowing of rivers

Fig. 2.1.1 shows the inundation distribution of the classes 8, 9 and 11 as habitual inundation area. The inundation of the class 10 is not shown as it is limited in small area and distributed in almost all the study area.

The total inundation area shown in the figure comes to 11,200 km^2 which corresponds to 53 % of the study area. As seen in the figure, the inundation caused by flooding of rivers is distributed along the Portuguesa, Guanare and Apure rivers which are major rivers in the study area. (Refer to Los Excesos de Aguas Superficiales en los Ilanos Occidentales, MARNR, Septiembre 1979)

Besides that, Figs. 4.1.3 and 4.1.4 in Part B of this report show the inundation areas in the dry and wet seasons obtained from satellite images and some results of the previous studies.

2.1.3 Behavior of Surface Water

Fig. 2.1.2 shows flow direction of drainage of the surface water in the study area. The surface water finally reaches to San Fernando funnel. The flows are largely divided into three groups by direction of drainage.

First group along the Guanare Viejo river, Caño Chorroco etc. directs from northwest to southeast, second group in the left bank area of the Apure river from west to east and third group in the area between Portuguesa river and Guanare river from northwest to southwest. The flows of third group are toward the lowest part in the study area called "Apure Depression" located in east of Arismendi.

Also, major overflow points are observed on the Guanare river between Guanarito and Arismendi and also on the Apure river a little downstream from Bruzual. A point to be noted is that the direction of drainage does not always match that of ground slope, especially in the basins of the Guanare Viejo river, Caño Chorroco and Caño La Aguada. (Refer to Diagnostico Preliminar de la Problematica de Inundaciones en el Distrito Arismendi del Estado Barinas, MARNR, Julio 1984)

2.1.4 Flow Characteristics of Rivers

Fig. 2.1.3 shows the flow characteristics of the rivers in the Portuguesa and Guanare river basins including the study area. The Portuguesa and Guanare rivers are hydrologically influenced by runoff from upstream of mountain areas up to their middle reaches. On the other hand, the water levels of the downstream reaches of the Portuguesa and Guanare rivers are raised by high water level of the Apure river.

The behaviors of other rivers in the area depend on rainfall of the subject local basin. The Guanare river is flooded near confluence with the Bocono river and in the upstream of Arismendi. (Refer to Los Excesos de Aguas Superficiales en los Llanos Occidentales, MARNR, Septiembre 1979)

2.1.5 Possibility of Solution of Drainage Problem

Fig. 2.1.4 shows classification of possibility of solution of drainage problem in the study area. The possibilities are classified into the following three categories.

Category I	:	Area with possibility of solution	(9,900 km^2 - 47%)
Category II	:	Area with low possibility	(5,200 km^2 - 25%)
Category III	:	Area with almost no possibility	(5,900 km^2 - 28%)

The areas of Category II and Category III occupy a half of the study area. As seen in the figure, the areas with some possibilities are distributed in upper and middle basins of the study area and partly on left bank area of the Apure river, while most of the lower basins are evaluated as the area with almost no possibility of solution of drainage problems. (Refer to Los Excesos de Aguas Superficiales en los Llanos Occidentales, MARNR, Septiembre 1979)

2.1.6 Present Discharge Capacities of River Channels

Fig. 2.1.5 shows present discharge capacities of the rivers in the study area and adjacent basins which are estimated based on the observed discharge measurement data.

The discharge capacities of the Apure, Portuguesa and Guanare rivers at their major points are as follows:

River	Station	Bankful Discharge (m^3/s)	Channel Width (m)	Channel Depth (m)
Apure	Bruzual	3,800	320	15
Apure	El Chinal	2,500	220	12
Apure	El Saman	3,800	350	9
Apure	San Fernando	6,900	580	15
Portuguesa	Pte Portuguesa	300	50	-
Portuguesa	Nueva Florida	590	100	11
Portuguesa	Jobalito	600	100	14
Portuguesa	Camaguan	1,200	120	14
Guanare	Arismendi	200	60	4
Guanare	Los Caballos	140	50	7

As shown above, discharge capacity of the Guanare river which runs in the center of the study area is as small as about 200 m^3/s and the Portuguesa river also has small capacity for its large catchment area. The capacity of the Apure river is much lager than the other rivers, but it is still small for its catchment area.

2.2 Existing Flood Management/Control Plans and Facilities.

No overall flood management/control plan for the study area has been prepared yet. Only an additional diversion channel from the Portuguese river to the Apurite river is planned so far. While, several kinds of flood defense works have been carried out in and around the study area as mentioned hereinafter.

2.2.1 River Dikes

(1) Existing River Dikes

By the present, the following seven (7) river dikes have been constructed in parallel with the river courses at the locations shown in Fig. 2.2.1.

1) Camaguan-Puerto Miranda dike constructed by MOP in 1955 to protect the east side area from flood.

2) San Fernando-Achaguas-Apurito road dike completed in 1967. In spite of provision of aqua duct, overflow of the river to south were reduced.

3) Promollano dike constructed in 1971 on the right bank of the Apure Viejo river to protect the area situated between this river and San Fernando-Achaguas road.

4) San Fernando-Apurito dike, 120 km long, constructed by Apure State in 1981 to improve 120,000 ha.

5) Palmarito-San Vicente-El Setenta dike, constructed to protect Apure module in 1982 and 1983.

6) Dike near San Antonio on the left bank of Apure river, about 10 km long, constructed by private sector to protect the properties.

7) Dike near Ciudad de Nutrias on the left bank of the Apure river, about 20 km long, constructed by MARNR in 1982 and 1983 to protect overflow of the Apure river toward Caño La Aguada.

The Camaguan-Puerto Miranda road dike largely eliminated flood of the area located in the east of the dike and consequently promoted agricultural / livestock development in the area. On the other hand, this dike contributed to aggravate the flood damage in the depression area situated on the upstream side (west) of the dike because it partially impedes drainage of the said area which had previously been made through a corridor of 80 km wide in the direction of the Guariquto river.

The San Fernando-Apurito and Palmarito-San Vicente-El Setenta dikes are to recuperate agricultural land with good quality of 180,000 ha and to protect infrastructure of "Apure Module" from damages caused by overflowing of the Apure river. However, it is said that they consequently have aggravated the conditions of the inundation area in the depression on the left bank of the Apure river.

The problem rested is that no consideration was made on the technical and economical aspects and also the negative effects which could be produced at the time of their constructions .

(2) Proposed River Dike

A railway project to pass the right bank of the Portuguesa river is planned as shown in Fig. 2.2.1. In order to protect the proposed railway from flooding of the Portuguesa river, a dike is planned on the river side along the railway.

2.2.2 Dams

(1) Existing Dams

In the upstream of the study area, seven (7) dams listed below have been constructed so far. Their locations are shown in Fig. 2.2.2. and principle features are presented in Table 2.2.1.

Dam	Status	Flood Control Capacity (10^6 m^3)
1. Bocono–Tucupido	Constructed	249
2. Guaremal	Constructed	0 (*1)
3. Las Majaguas	Constructed	41
4. Cabuy	Constructed	4
5. Cachinche	Constructed	67 (*2)
6. La Balsa	Constructed	56
7. Tinados	Constructed	229

Note : *1 already filled up with sediment
*2 estimated from reservoir water levels

(2) Proposed Dams

Other than the existing dams mentioned above, several dams are under study in the Portuguesa river basin. Among them, the following two (2) dams are proposed for implementation.

Dam	Status	Flood Control Capacity ($10^6 m^3$)
1. Yacambu	Under Construction	26
2. Las Palmas	Under Bidding	125

Note : As of March 1993

Their locations and principal features are shown in Fig. 2.2.2 and Table 2.2.1, respectively.

2.2.3 Floodway and Diversion Channel

(1) Existing Floodway

In order to reduce the inundation upstream from Maria Nieves bridge on the Apure river at San Fernando, a floodway from the Portuguesa river to the Apurito river was constructed at Hato Gorrin 6 km north from San Fernando as shown in Fig. 2.2.3 crossing Camaguan-San Fernando road dike in 1982 at the time of reconstruction of the said road dike. This floodway has a width of 400 m , but it is narrowed by bridge of 120 m long and does not have low water channel. The length is 10 km and design discharge is 190 m^3/s for 50-year probable flood.

This floodway is to drain a part of flood confined by the road dike, but it is not sufficient as explained by the fact that the water level of the Apure river at San Fernando is almost same for the different rainfall magnitudes as it was El. 45.55 m in 1981 and El. 45.32 m in 1983.

(2) Proposed Diversion Channel

A diversion channel is proposed at Sombrerito about 3 km north from the existing diversion channel as shown in Fig. 2.2.3. This channel has a width of 400 m and low water channel of 60 m wide, but it will be narrowed by bridge of 85 m long. The length 18 km and design discharge is 440 m^3/s for 50-year flood.

2.3 Existing and Proposed Projects

(1) Existing Project

The study area is classified into an interior deltaic zone. The lower part of the area belongs to a habitual inundation zone as shown in Fig. 2.1.1 due to drainage problem of the Apure river.

Therefore, the land use in the study area is limited at present. Only Guanare-Masparro agricultural development projects are on-going in the area. The project site is naturally situated on the higher part of the area as shown in Fig. 2.3.1.

(2) Proposed Project

There are two (2) projects as proposed ones. One is extension of the Guanare-Masparro Project under consideration and the other is the railway project which will pass on the right bank of the Portuguesa river mentioned before. The railway project is scheduled to be implemented near future.

2.4 Existing Land Use Plan

As existing land use plan, zoning plans of Barinas, Portuguesa and Cojedes states prepared by MARNR shown in Fig. 2.4.1 are available, which aim to picture the future development of the respective states till the year 2010, the proposed land use in the study area is mostly for agriculture use (cattle breeding).

The areas to be preserved for agricultural use are classified into three categories by priority in use as shown in Fig. 2.3.1. The areas of Category I with high priority (16 % of the study area of 21,000 km^2) have been fixed, while those of Categories II (12 %) and III (16 %) with medium and low priorities respectively are changeable depending on the conditions. The areas selected for agricultural use mostly coincide with the areas free from long-term inundation.

Besides that, middle and downstream area of the Portuguesa river and downstream area of the Guanare river are assigned as flood plain because of difficulty of solution of drainage problems. The flood plain occupies (27 % of the study area about 5,700 km^2).

In the upstream part of the study area, Guanare-Masparro agricultural development project is on-going as mentioned before and most of the upper area are included in the project.

The area without any assignment of land use occupies 29 % of the study area (about 6,000 km^2).

2.5 Environmental Protected Area

There are two wildlife refuge areas in and around the study area as envirinmental protected area (see Fig. 2.2.1).

1) Chiliguare wildlife refuge (center of the study area)
2) Caño Guaritico wildlife refuge (right tributary of the Apure river)

III. BASIC CONCEPT FOR FLOOD MANAGEMENT PLANNING

3.1 Basic Consideration

The inundation in the study area is characterized by extensive and long term inundation. In order to mitigate the inundation, increase of discharge capacities of the rivers in the area will be primary consideration. However, it will incur concentration of flood flow to San Fernando funnel as sole exit and will put San Fernando, the most important city in the region, in dangerous situation because it is difficult to increase the discharge capacity of the Apure river at San Fernando under the present circumstances.

Therefore, improvement method which incur flood concentration to San Fernando such as confining of flood water with dikes or widening of the present river channels will not be appropriate for the present study.

On the other hand, the flood inundation contributes to the life of inhabitants in the area as water resources though it causes damages. For this, smooth drainage of flood water to the downstream or outside the study area is not always proper. Also, consideration from environmental aspect is important as the study area is presently mostly in the natural conditions.

Therefore, the flood management plan to be proposed in this study will be of change of inundation condition and runoff regulation by retarding.

3.2 Procedure of Planning

The proposed flood management plan will be formulated by the following procedure.

1) Selection of protection area
2) Selection of design scale of the plan
3) Selection of possible measures
4) Formulation of alternative plans
5) Study on alternative plans
6) Environmental consideration
7) Determination of proposed flood management plan

3.3 Protection Area

No area or site is specially designated as protection area in the present flood management study. The area to be protected by the proposed flood management plan should be selected taking into account the present conditions of the study area explained in the previous section.

In the study, the selection was made applying the criteria that protection area should have possibility of solution of drainage problems and land use assignment in the future.

The possibility of solution of drainage problem is referred to Fig. 2.1.4 and the land use assignment to Fig. 2.3.1. The areas with land use assignment almost coincide with those which do not have influence of long-term inundation and roughly with the areas having possibility of solution of drainage problem . However, the habitual inundation areas also have potential of agricultural use according to the land classification.

Consequently, the following four (4) areas shown in Fig. 3.3.1 were selected as protection area.

1) Area extending on the right bank side of caño Igues

   This area (Area "A" in the figure) extends between Caño Igues and Guanare river. It is influenced by flooding of the Caño Igues and indirectly the Portuguesa river.

2) Area extending on the right bank side of Guanare river

   This area (Area "B" in the figure) extends between Guanare river and national road No. 5. It is situated in the higher part of the study area, but influenced by the flooding of the Guanare river around confluence with Bocono river. Also, inundation by local rainfall is significant.

3) Area extending on the left bank side of Apure river

   This area (Area "C" in the figure) is surrounded by the Apure, Guanare and Guanare Viejo rivers and influenced mostly by flooding of the Apure river and partly by the Guanare river. The area is situated in the lower part of the study area.

4) San Fernando city and its surrounding area

The runoff from the Portuguesa and Guanare river basins topographically concentrate to the Apure river at San Fernando and raises the water level of the Apure river. Therefore, the area (Area "D" in the figure) may be influenced by the proposed flood management plan in the upstream. Increase of safety degree against flood will be necessary to protect San Fernando city and its surrounding area.

They are target areas for flood management planning and therefore their boundaries are approximate and subject to change depending on locations and effects of the plans.

3.4 Design Scale of The Plan

The design scale of the flood management plan is usually determined depending on degree of importance of the subject river and overall consideration is made for the actual state of flood damage and economic effectiveness of the project.

As mentioned before, most of the study area are suffering from inundation and drainage problems. According to the zoning plans at state level prepared by MARNR targeting the year 2010, almost half of the study area will remain unused and a part of the area is designated as a flood plain to retard flood.

For such area, a large scale design flood may not be proper for planning because it requires a large size flood control facilities and the project proposed will be costly. Also, effect of the flood control by medium and small size facilities will not be clear for the large scale design flood.

The return period of 10 years was therefore employed as design scale of the plan, which is commonly applied to the rural area in Venezuela. The design rainfall with 10-year return period corresponds to 96% of rainfall in 1981 which is the largest recorded in the study area.

3.5 Possible Measures

The possible measures for the present flood management planning will be as follows:

1) Dike
2) Diversion channel
3) Retarding basin (natural and artificial)
4) Dam
5) Widening and deepening of present river channel

Applicability of the above measures will be preliminarily studied in the subsequent Chapter IV.

IV. FORMULATION OF FLOOD MANAGEMENT PLAN

4.1 Preliminary Study for Planning

4.1.1 Hydrological Aspect

(1) Design Rainfall

The probable basin average rainfall amounts at base points of San Fernando and Camaguan are presented in Table 4.1.1.

The rainfall pattern employed is that in 1981 and duration of rainfall is eight (8) months (Apr. - Nov.) for runoff calculation and four (4) months (June - Sept.) for flood inundation calculation.

(2) Probable Discharge Distribution

The probable flood peak discharge distributions of rivers in the Portuguesa river basin with 10-year return period excluding the area subject to inundation calculation are shown in Figs. 4.1.1 to 4.1.3 for the following three conditions.

1) Without dams
2) With existing dams (present condition)
3) With existing and proposed dams

(3) Water Balance in Apure River Basin

The water balance in Apure river basin is roughly estimated as shown in Fig. 4.1.4 referring to runoff in 1976 and 1981.

The inflow to the study area from the upper Portuguesa river basin is about 20×10^9 m^3 and rainfall amount in the pond area is 51×10^9 m^3 in 1981. In the pond model area, 70% of the inflow including rainfall is discharged from the Apure river through San Fernando funnel and remaining 30% is loosed as evapotranspiration, etc. in the area.

4.1.2 Possible Measures

(1) Possibility of Dikes on Both River Banks

It is a general approach to confine the flood runoff water in the river channel by construction of dikes on both banks of the river. However, in case of the study area it may not be proper because of much inundation outside the river channels.

In order to know the influence by confining the flood runoff water in the river channel, flood runoff calculation was carried out under the following conditions.

- No inundation
- No improvement of present river channel
- Water depth of high water channel of about 2 m

The calculation result for the flood in 1981 is shown in Fig. 4.1.5. The peak discharge at Camaguan on the Portuguesa river is 6,800 m^3/s for the channel width of 10 km in the downstream reaches.

Considering the present discharge capacity of the Apure river (bankful - 6,900 m^3/s) at San Fernando and also difficulty of increase of the capacity, the flood management plan to confine the runoff water in the river channel is not appropriate.

Therefore, it may be better to apply one side dike so as to softly regulate the flood flow. Fortunately, the study area has a gentle slope from north to south and also from west to east. It is convenient topography to apply one side dike.

(2) Effect of Dams

As shown in the probable peak discharge distributions shown in Figs. 4.1.1 to 4.1.3, existing six (6) dams except Bocono-Tucupido dam and proposed (2) dams have almost no effect to the study area because of their locations as shown in Fig. 2.2.2.

This fact is understood by the following data.

1)	Catchment area of Portuguesa river	: 54,400 km^2
2)	Total dam basin	: 10,960 km^2
3)	Total runoff (10-year return period)	: 71 x 10^9 m^3
4)	Total effective storage capacity	: 6,325 x 10^6 m^3 (9% of total runoff)

5) Total flood control capacity : $797 \times 10^6\ m^3$
(1% of total runoff)

Besides that, effect of two (2) dams planned on the Portuguesa and Guanare rivers are evaluated as they are located a little upstream from the protection areas "A" and "B", respectively.

1) Vega Honda Dam
- Located on the Portuguesa river, a little upstream of Protection Area "A"
- Catchment area 730 km^2
- Flood control capacity $165 \times 10^6\ m^3$
- Peak discharge cut from 300 m^3/s to 90 m^3/s (10-year return period)

2) Mesa de Cavaca Dam
- Located on the Guanare river, upstream of Protection Area "B"
- Catchment area 1,319 km^2
- Flood control capacity $279 \times 10^6\ m^3$
- Peak discharge cut from 1,500 m^3/s to 250 m^3/s (10-year return period)

Both dams are fairly effective for flood peak reduction as they are near protection area. However, Vega Honda dam is evaluated to be not feasible at this moment and Mesa de Cavaca dam is under consideration and has no schedule for implementation.

(3) Applicability of Apure Type Module

As mentioned before, water resources conservation in the study area is another important aspect as well as flood management. Apure type module is one of the possible measures for the said purpose.

According to MARNR's study, the optimum size of the Apure module is as shown in Fig. 4.1.6. Maximum water depth is 1.4 m. Interval of transversal dike is 8 km. The ground slope is calculated as 1/3,000 to 1/4,000.

Table 4.1.2 gives relation between ground slope, storage capacity and cost. The unit cost of module is naturally cheaper for gentler ground slope. The storage capacity is a little short to store the design rainfall amount with 10-year return period though the module stores almost 90% of the 10-year probable rainfall in the subject module area.

After a diagnosis on behavior of the existing Apure modules, several problems were revealed regarding constructive and operational aspects which, nevertheless, can be improved.

The Apure type module has an advantage of storage of water for dry season and produce benefit by more intensive cattle breeding, so that it should be introduced for development purpose. The area suitable for Apure type module having ground slope of 1/3,000 - 1/4,000 is shown in Fig. 4.1.7. This limitation in ground slope makes the Apure type module not applicable in some areas.

(4) Widening and Deepening of Present River Channel

To decrease the inundation in the study area, increase of discharge capacities of rivers in the study area such as Portuguesa and Guanare rivers will be primary consideration.

The widening and deepening of the present river channels are common method to increase capacity of river channel, but they are not employed for the present study by reasons below.

- Flood concentration to the downstream, finally to San Fernando is caused, but it is difficult to increase capacity of the Apure river at San Fernando.
- Widening will break stability of the channel resulting from loss of river bank forests in some reaches. Also, widening will result in decrease of water depth in the Portuguesa river will much influence the navigation there.
- Deepening by river bed excavation or dredging will not be proper because the existing channel width is narrow and widening is inevitable. Also, river bed slope is very gentle in the downstream reaches, so that effect of deepening may be small.

4.2 Plan Formulation

The alternative plans for flood management are formulated in the manner mentioned hereinafter based on the preliminary study results. Firstly alternative plans for respective protection areas are formulated and the respective best plans will be integrated as proposed flood management plan.

4.2.1 Protection Area "A"

(1) Basic Consideration

1) Possible measures to protect Area "A" (see Fig. 3.3.1) are:

   a) Dike against flooding and
   b) Dam for flood peak cut.

   However, there exist no proposed and feasible dams effective for protection of the Area "A". Therefore, dam plan is discarded.

2) Protection area and adjacent area between Portuguesa river and Caño Igues are roughly divided into two parts by ground slope. Long term inundation occurs in the downstream area from Nueva Florida due to very gentle slope of about 1/10,000 (along river course).

3) The Caño Igues is an inner basin river and its runoff volume is much smaller than that of Portuguesa river. Therefore, large part of the inundation water comes from the Portuguesa river

4) The first idea for flood management is construction of dike on the right bank of the Portuguesa river in order to directly prevent flooding of the Portuguesa river though the inundation on the left bank will be increased due to reduction of inundation area. While, the dike on the right bank of Caño Igues to keep existing inundation area and the dikes on the right bank of the Portuguesa river in the upstream section and on the left bank of the Caño Igues in the downstream section will be alternatives.

5) The proposed railway is planned to pass on the right bank of the Portuguesa river and dike will be constructed to protect the railway from flooding of the Portuguesa river. This plan partly competes with the above-mentioned dike plan.

6) Furthermore, it is possible to completely protect the area by construction of dike on the left bank of Guanare river. In this case, the reaches where the protection area "A" is adjacent to the protection area "B" have dikes on the both banks and the runoff from the upstream basin is confined. The confined water may affect to the Chiriguare wildlife refuge located just downstream from the said reaches.

7) Existing road of 50 km long is located between Maceo and Nueva Florida. This can be used as dike with some reinforcement assuming that the elevation is higher than the proposed dike.

8) Regarding water resources, Bocono-Tucupido reservoir can meet the water requirement in the protected area, if necessary, and river water is also available.

(2) Alternative Plans

Based on the basic consideration, the following three (3) alternative plans shown in Fig. 4.2.1 are formulated.

1) Plan A1: Dike on the right bank of the Portuguesa river (187 km long)
2) Plan A2: Dike on the right bank of Caño Igues (190 km long)
3) Plan A3: Dike on the right bank of the Portuguesa river and left bank of Caño Igues (185 km long)

4.2.2 Protection Area "B"

(1) Basic Consideration

1) Possible measures to protect Area "B" (see Fig. 3.3.1) are:

   a) Dike against flooding,
   b) Dam for flood peak cut and
   c) Improvement of existing river channels.

   There exist no proposed and feasible dams effective for protection of the Area "B" other than existing Bocano-Tucupido dam. Therefore, dam plan is discarded.

2) The area has a ground slope of 1/1,000 to 1/2,000 and its northern boundary is the Guanare river. The flooding of Guanare river occurs in the reaches just downstream from the confluence with Bocono river and the flooded water easily intrudes the area.

3) Dike on the right bank of Bocono and Guanare rivers is considered to prevent the flooding of Guanare river. The dike extends from Veguitas to southeast of La Hoyada. In the downstream section, the dike is deviated from the river course to minimize the effect to the Chiriguare wildlife refuge located just downstream.

4) In this area, inundation by local rainfall is also serious. Improvement of major existing river channels is considered to decrease the said inundation. The major river channels in the area are Guanare Viejo river, Caño Chorroco and Caño La Aguada.

5) The Guanare Viejo river runs through the eastern part of the area and Caño La Aguada partly the western part. On the other hand, most of the area along Caño Chorroco is excluded from the land use area due to difficulty of drainage.

6) The area along Caño Chorroco is presently functioning as retarding basin for the runoff from Area "B" and has no land use assignment, so that it should remain as it is. While, Caño La Aguada covers the western lower half of the area and therefore effect of improvement will be small.

7) On the other hand, improvement of Guanare Viejo river may have some effect on mitigation of inundation in the eastern part of the area. The proposed improvement reaches will be from uppermost point to the downstream turning point.

8) For the better drainage improvement, several channels should be improve. However, the improvement of channels in the area will cause increase of flood and inundation in the downstream area unless the river channel in the downstream is also improved. As the entire drainage improvement in the study area is impossible at present, influence to the downstream by improvement should be minimized.

9) The area is included in the Guanare-Masparro agricultural development project area and the required water is supplied from Bocono-Tucupido reservoir. No problem on water resources may be caused by construction of the dike.

(2) Alternative Plans

Based on the basic consideration, the following three (3) alternative plans shown in Fig. 4.2.2 are formulated.

1) Plan B1: Dike on the right bank of Guanare river (145 km long)
2) Plan B2: Dike on the right bank of Guanare river (145 km long) and improvement of Guanare Viejo river (95 km long)

By the capacity of Guanare Viejo river, this plan is divided into the following two cases.

Plan B2A: Proposed width and depth of Guanare Viejo river are 25 m and 3 m, respectively. (about 100 m^3/s in capacity)

Plan B2B: Proposed width and depth of Guanare Viejo river are 50 m and 3 m, respectively. (about 200 m^3/s in capacity)

4.2.3 Protection Area "C"

(1) Basic Consideration

1) Possible measures to protect Area "C" (see Fig. 3.3.1) are:

   a) Dike against flooding and
   b) Apure type module to protect some specific locations.

2) The area is mostly located on the micro relief in the Apure depression and has very gentle ground slope of 1/4,000 to 1/10,000. Discharge capacity of Apure river becomes smaller in the reaches around El Chinal and overflow occurs there. The upstream part of the area is influenced by the overflowed water.

3) Dike on the left bank of the Apure river is proposed to prevent the flooding of the Apure river. The dike extends from Puerto Nutrias to the downstream end of the area (Samanal).

4) As an alternative plan, it is considered to limit the dike within the overflow section from Puerto Nutrias to Apurito in order to reduce the cost though the influence of dike may remain in the downstream part of the area.

5) Furthermore, it is considered to construct the dike on the northern boundary of the area to completely protect the area. However, major caños which are drainage canals transverse the downstream part of the area and also flood plain is laying along the northern boundary. Because of this, the dike may not be needed.

6) Regarding the water resources, the area depending on the overflowing of Apure river may be affected by construction of dike, but degree of the effect will be small. If it is necessary to secure the water, employment of Apure type module will be proper.

(2) Alternative Plans

Based on the basic consideration, the following three (3) alternative plans shown in Fig. 4.2.3 are formulated.

1) Plan C1: Dike on the left bank of Apure river from Puerto Nutrias to Samanal , downstream of Apurito (155 km long)
2) Plan C2: Dike on the left bank of Apure river from Puerto Nutrias to Apurito (105 km long)
3) Plan C3: Apure type modules in the areas other than wetland subject to environmental conservation

4.2.4 Protection Area "D"

(1) Basic Consideration

1) The purpose of the flood management for Area "D" (see Fig. 3.3.1) is to increase safety degree against flood to cope with flood management for Area "A", "B" and "C". Possible measures are:

   a) Widening of the present Apure river channel,
   b) Diversion channel to alleviate burden of Apure river,
   c) Retarding basin to regulate flood concentration to San Fernando funnel,
   d) Heightening of existing dike surrounding San Fernando and
   e) Lowering of water level of downstream stretch from San Fernando.

   Widening of the present Apure river channel is difficult under the present site conditions. Heightening of existing dike should be employed when other measures are not effective because it does not mean improvement of the hydraulic condition.

   Lowering of the water level of Apure river downstream from San Fernando is difficult in the rainy season because inundation totally occurs there. Short cut of meandering stretch is effective to lower the water level, but it will not be applicable because the reaches downstream from San Fernando is almost straight for about 20 km.

2) The flood management plan for Areas "A" and "B" may not affect so much to the area "D" because a large natural retarding area exists between the Areas "A", "B" and "D". While, the dike on the left bank of Apure river to protect Area

"C" may have a possibility to influence to San Fernando as the water level in the river channel will increase.

3) Diversion channel from Portuguesa to Apurito is proper to increase discharge capacity of San Fernando funnel as planned by MARNR considering difficulty of increase of discharge capacity.

4) Retarding basin is essential to regulate the runoff to avoid flood concentration to the San Fernando funnel. The flood plains in the zoning plans should be kept as natural retarding basin. Besides that, the Apure type module may contribute to more effective retarding as artificial retarding basin since it stores most of the rainfall in the module area.

(2) Alternative Plans

Based on the basic consideration, the following three (3) alternative plans shown in Fig. 4.2.4 are formulated.

1) Plan D1: Diversion channel from Portuguesa to Apurito rivers

Typical cross sections of the existing floodway and diversion channel proposed by MARNR are shown in Fig. 2.2.3. They have a width of 400 m, but they are narrowed to about one fourth in width by bridge at road crossing point. The existing floodway does not have a low water channel, but the proposed diversion channel has.

Therefore, the plan is divided into the following two (2) cases.

Plan D1A : Improvement of existing floodway
- Bridge span is the same as channel width of 400 m.
- Low water channel is provided with bottom width of 60 m.

Plan D1B : Improvement of existing floodway and proposed diversion channel
- Same dimension as Plan D1A.

2) Plan D2: Retarding basin by Apure type module

- Artificial retarding basin : Area suitable for Apure type module (see Fig. 4.1.7)
- Natural retarding basin : Remaining present flood plain

4.2.5 Whole Area

The proposed flood management plan is subject to the whole study area and it may be of integration of the plans proposed for respective protection areas as follows:

Area "A"	Plan A1
Area "B"	Selection among Plans B1, B2A and B2B
Area "C"	Selection among Plans C1, C2 and C3
Area "D"	Selection among Plans D1A, D1B and D2 or combination of them.

4.3 Study on Alternative Plans

4.3.1 Hydraulic Study

Effects and influences of respective alternative plans are hydraulically studied by the pond model method mentioned in hydrological study. The alternative plans to be studied are listed in Table. 4.3.1.

Figs. 4.3.1 to 4.3.10 show maximum inundation condition of each plan. Table 4.3.2 present the maximum inundation depth by block and difference from present conditions. Major changes of inundations by plans are summarized in Table 4.3.3.

The points to be remarked for respective plans are as follows :

1) Plan A1

In the river side of dike, inundation depth of block -2 (downstream section) increases from 0.35 m for present condition to 0.77 m. While, no change is recognized in block-1 (upstream section).

In the side protected with dike, inundation depth of block-7 (downstream section) decreases from 0.24 m for present condition to 0.10 m. Also, inundation depths of blocks-11 and 12 (adjacent to block 7) decrease from 0.37 m to 0.17 m and from 0.52 m to 0.40 m, respectively.

In the downstream from dike, inundation depth of block-8 increases from 0.29 m to 0.41 m.

2) Plan B1

Change of inundation is generally small. It is less than 0.1 m in decrease of inundation depth in both river and protected sides. However, the proposed dike prevents overflowing of the Guanare river, about 100 m^3/s at maximum for 10-yr return period and about 300 m^3/s for 50-yr return period.

3) Plan B2A

Effect of improvement of existing channel is small. It is only 0.02 m in decrease of inundation depth against Plan B1.

4) Plan B2B

Effect of improvement of existing channel is small. It is only 0.05 m in decrease of inundation depth against Plan B1. On the other hand, inundation depth in the downstream block-21 increase by 0.07 m against Plan B1.

5) Plan C1

On the right bank side, inundation depth of block-24 increases from 1.28 m for present condition to 1.90 m. On the other hand, inundation of block-20 in the protected side decreases from 0.41 m to 0.13 m.

Increase of water level of the Apure river by dike construction is about 1 m for the present condition. No influence to San Fernando is recognized. Water level of the Apure river is shown in Fig. 4.3.11.

6) Plan C2

Result is almost same as Plan C1. Only small increase of inundation of block-22 is recognized because of overflow in the reaches downstream from Apurito, about 100 m^3/s at maximum for 10-yr return period and about 300 m^3/s for 50-yr return period. No influence to San Fernando is recognized. Water level of the Apure river is shown in Fig. 4.3.11.

7) Plan D1A

Lowering of water level at San Fernando is only 0.11 m. Hydrographs of outflows from Diversion channel and the Apure river are shown in Fig. 4.3.12.

8) Plan D1B

Lowering of water level at San Fernando is 0.18 m. Hydrographs of outflows from Diversion channels and the Apure river are shown in Fig. 4.3.12.

9) Plan D2

Effect of runoff retarding by Apure type module is recognized in block-18, but it is small. Decrease of inundation depth is only 0.10 m. On the other hand, increase of inundation depth is recognized in block-2 (0.22 m) and block-24 (0.62 m) other than module area.

4.3.2 Plans Proposed for Respective Areas

Based on the hydraulic study, consideration on environmental, land use and socio-economic aspects and preliminary economic evaluation, the proposed plans for the respective areas are selected as follows.

(1) Proposed Plan for Area "A"

Plan A1 is actually sole candidate plan, but it is proposed to be taken by the reasons mentioned below.

- Inundation depth on the left bank of the Portuguesa river increases at about 40 ~ 50 cm at maximum for the present condition. However, inundation area may not extend due to topographic condition. Also, no serious environmental impact is expected according to the preliminary investigation.
- Land between Portuguesa river and Caño Igues becomes usable because of decrease of inundation.

Besides the above, Plan A1 has the following aspects.

- Economic effect is expectable by using the dike as road connecting national road route 5 and route 8.
- There is existing road of 50 km long between Maceo Village - La Aduana - Nueva Florida as mentioned before. (see Fig. 2.2.1) It can be used as dike with some improvement assuming that crest elevation is higher than the proposed dike elevation. Also, private road of 18 km long connected to national road route 8 exists on the route of the proposed dike. (No data on those roads is available.)

- A part of this dike has been incorporated in the railway project mentioned before to protect the railway from flooding of the Portuguesa river. It will be constructed near future.

Profile along the dike is shown in Fig. 4.3.13.

(2) Proposed Plan for Area "B"

Among the alternatives, Plan B1 is selected for the reasons mentioned below.

- Effect of improvement of the Guanare Viejo river is small. Plan B2A decreases the inundation depth in the subject area by only 0.03 m against Plan B1 and Plan B2B by 0.06 m.

- Plan B1 is also not so effective for reduction of inundation. This may be due to steeper ground slope. However, the proposed dike prevents overflowing of the Guanare river (about 100 m^3/s at maximum for 10-yr return period and about 300 m^3/s for 50-yr return period) and also it can function as access road to the center part of the study area and economic effect is expectable.

- The construction of more substantial drainage network may be necessary to get satisfactory effect, but it should be considered as a part of development project as it is costly.

Besides the above, Plan B1 has the following aspects.

- By using the dike as road, the dike will function as access road to the center part of the study area and economic effect is expectable.

- The area belong to the Guanare-Masparro project area and has high potential in agriculture development though the development has not been progressed yet due to lack of road network and drainage system. Considering reversely, the proposed dike with function of road will contribute to the development of the area.

- As seen in Fig. 2.2.1 there are existing roads of about 120 km long in total along the Bocono and Guanare rivers with interruption. Assuming that those roads are usable for dike with some reinforcement, the provisional flood management work can be completed with much less cost since the new dike length is reduced from 145 km to 25 km.

Profile along the dike is shown in Fig. 4.3.13.

(3) Proposed Plan for Area "C"

Assuming that the dike on the left bank of the Apure river is feasible, Plan C1 is better than Plan C2 for the reasons mentioned below.

- As seen in Fig. 4.3.11, influence to San Fernando by the dike on the left bank of Apure river is almost none in both plans due to existence of retarding area on the right bank side of Apure river upstream from El Saman and also between downstream end of the dike San Fernando.
- Both of Plans C1 and C2 increase the water level of the Apure river by about 1 m for the present condition. In case of Plan C2, this influence remains in the reaches downstream from Apurito and overflow to the area occurs. (about 100 m^3/s at maximum for 10-yr return period and about 300 m^3/s for 50-yr return period)
- Plan C1 can cover the whole area by a dike length of 155 km, but Plan C2 cover the half by 105 km. Plan C1 will be more economical.

Besides the above, Plan C1 has the following aspects.

- By using the dike as road, the dike will function as access road to the left bank area of Apure river and economic effect is expectable.
- Economic viability by flood mitigation may be not so high because the proposed land use in the protection area is cattle breeding by applying Apure type module and it will remain unchanged even after construction of dike.
- Existing dikes are located at Puerto Nutrias (20 km long) and at Apurito (10 km long). They can be used as a part of the proposed dike assuming that their crest elevations are higher than that of the proposed dike.

Profile along the dike is shown in Fig. 4.3.14.

However, if Plans C1 and C2 are not feasible according to the results of more detailed hydraulic, geomorphological and environmental studies, Plan C3 should be adopted to protect some specific locations in the Area "C" by the Apure type module.

(4) Proposed Plan for Area "D"

According to the result of hydraulic analysis, no plan has significant effect for increase of safety degree against flood and also no harmful influence by the flood management plan in the upstream area is recognized as mentioned hereinafter. Therefore, no plan is proposed for Area "D".

- Decrease of peak water level of Apure river at San Fernando by diversion channel is as small as 10 ~ 20 cm. It is because of too gentle ground slope of around 1/15,000 (see Fig. 4.3.15). As far as the Portuguese river is used for navigation through San Fernando, this plan is not effective. If whole the water of the Portuguesa river can be diverted to the Apure river, the diversion channel may become effective.

- Considering degree of effect of diversion channel, heightening of existing dikes surrounding the area will be better and more economical.

- Also, effect of retarding basin by the Apure type module is not effective to lower the peak water level at San Fernando. However, the retarding basin will be indispensable even in the future considering present circumstances at San Fernando point. On the other hand, natural retarding basin is less productive than other areas. Positive use of the retarding basin should be considered. Apure type module meets the purpose as artificial retarding basin. It should be introduced from the viewpoint of development as it has positive effect to store the rainfall.

4.4 Environmental Consideration

The plan for each protection area is proposed in the previous section 3.3 based on the hydraulic study. However, environmental aspect is also important because the study area is mostly in natural condition at present.

In the present study, a preliminary environmental survey and study were carried out and its result is described in the Supporting Report : Part I. According to the study result, no significant environmental impact is expected though the further detailed environmental impact analysis mentioned in Supporting Report : Part-I has to be made for final conclusion.

Among the areas protected by the respective dikes, the following difference is recognized in the general environmental condition.

In the area protected by the dike on the right banks of Portuguesa and Guanare rivers (Areas "A" and "B", respectively), human intervention has caused physical impact on nature and therefore the proposed dikes will not cause major ecological impact, but instead will promote consolidation of existing incipient farming development by protecting them from flooding of rivers.

On the other hand, the protection area "C" protected by the dike on the left bank of the Apure river has much less human intervention than Areas "A" and "B". Therefore, the environmental impact by the dike should be analyzed before dike construction.

If the dike construction is not allowed from the environmental viewpoint, plan to protect the specific areas by such as module should be considered as alternative for the continuous river dike.

With regard to the influence to specific areas by dike construction, the following consideration is made.

(1) Dike for the Portuguesa river

The inundation in the area on the left bank of the river between Nueva Florida and national load route 8 will be increased by this dike. This change will probably cause a local change in spatial distribution of vegetation cover and also in the proportion of the space used by vegetation. However, since inundations are a rather common phenomena in the area, its effect will not be extraneous to plants and animals in the area. Most of them will re-arrange their local distribution pattern in order to go with the changes.

With regard to the Orinoco crocodiles living here, no influence is expected since the flood management plan is effective during the rainy season.

(2) Dike for the Guanare river

The most important concern is influence to the Chirigüare Wildlife Refuge. According to the hydraulic study, almost no change of inundation is caused by this dike, so that no influence is expected.

(3) Dike for the Apure river

Proximity of the Caño Guaritico Wildlife Refuge is an area for reproduction of the Orinoco Crocodile. The sandy beaches should be guaranteed during the dry season. Since the flood management plan is effective during the rainy season, no problem will be caused by water level increase by this dike.

4.5 Proposed Flood Management Plan

4.5.1 Proposed Plan

As mentioned before, the proposed flood management plan is integration of the following component plans proposed for respective protection areas as shown in Fig. 4.5.1.

Plan A1 for Area "A" (Dike for Portuguesa river)
Plan B1 for Area "B" (Dike for Guanare river)
Plan C1 or C3 for Area "C" (Dike for Apure river or Apure type module)

Regarding the Area "C", if the dike plan is not allowed from environmental viewpoint, Plan C3 should be considered in the further study as mentioned before.

In order to know the mutual interference by integration of the proposed three component plans, inundation simulation by the pond model method was made for the proposed flood management plan. The simulation result is presented in Table 4.3.2 and Figs. 4.5.2 and 4.5.3.

As seen in the results, no significant change occurs in inundation by integration of the respective component plans comparing with the result of hydraulic study for each plans.

4.5.2 Preliminary Facility Design

(1) Cross Section of Dike

Typical cross section of the river dike is shown in Fig. 4.5.4, which was taken from MARNR's design applied for San Vicente-Palmarito dike. The dike is designed as road-dike and therefore it has a crest width of 10 m and is paved with asphalt. Height is more than 2 m. Typical cross section of the dike for railway is also shown in the same figure. Its crest width is 4 m, but 10 m is employed in this study to use the dike as road. Required height of dikes are presented in Tables 4.5.1 and 4.5.2.

(2) Sluiceway

In order to secure the existing waterway for water supply and drainage, sluiceways are to be arranged at the points where the existing streams cross the dike as shown in Fig. 4.5.5.

(3) Alignment of Dike

The dike is to be positioned keeping enough distance from the river bank to avoid influence of river course changing and also taking into account future improvement.

According to the preliminary study for channel stabilization, the Apure river is stable in the reaches of dike and river bank shifting is about 200 m at most for about 20 years. On the other hand, the water level increase by construction of left bank dike is calculated at about 1 m, wider high water channel is not always effective. Therefore, the dike for the Apure river is to be positioned more than 500 m apart from the river bank taking some allowance.

Dikes for Portuguesa and Guanare rivers are of the one-sided type and both rivers have heavy meandering of which width is about 1 to 2 km. Therefore, the position of dike is to be considered for the future improvement. According to the hydrological calculation result mentioned before, the peak discharges of the Portuguesa river and Guanare river are 2,000 ~ 4,000 m^3/s and 2,000 ~ 3,000 m^3/s, respectively under the flow condition softly confined by dikes. Assuming that about 30 % of the peak discharge is borne by the low water channel and the rest by high water channel in the future, the dikes are to be arranged more than 1 km apart from the meandering zone as shown in Fig. 4.5.5.

(4) Borrow Pit of Embankment Material

Material of dike is to be borrowed beside the proposed dike on the land side. The borrow pit is to be used as drainage channel after excavation. Besides that, from the environmental view point, round-shaped borrow pit with gentle bank slope shown in Fig. 4.5.5 is proposed on the river side for fish and animals as well as the borrow pit said above.

4.6 Cost Estimate

The project cost of the proposed flood management plan is estimated as presented in Table 4.6.1, applying.the following prevailing exchange rate in February, 1993.

US$1 = Bs.82 = ¥119.72; Bs.1 = ¥1.46

It consists of costs of construction, land acquisition, administration, engineering services and physical contingency. The project cost estimated is US$ 93.9 million and it is broken down by component plan as follows:

1. Plan A1 (Dike for Portuguesa river)	US$ 34.2 million
2. Plan B1 (Dike for Guanare river)	US$ 25.6 million
3. Plan C1 (Dike for Apure river)	US$ 34.1 million
Total	US$ 93.9 million

Also, the project costs of the other alternative plans are roughly estimated as presented in Table 4.6.2. Cost of Plan C3 was not estimated because locations of the Apure type modules have not been determined yet.

In the cost estimate, cost of asphalt pavement of dike crest for road use is not counted because it is cost to be counted in the development project.

4.7 Economic Consideration

Preliminary economic evaluation for the proposed flood management plan was made as described in the Supporting Report: Part-H.

The costs estimated in the previous section are converted to economic costs for evaluation. Benefits counted in the evaluation are flood reduction benefit and land enhancement benefit. Discount rate is 8% and project life is 50 years.

According to the result of evaluation, economic internal rate of return (EIRR) and benefit-cost ratio (B/C) are calculated as follows:

Plan	Annual Benefit (US$ 1,000)	EIRR (%)	B/C	B-C (US$ 1,000)
A1	4,482	11.0	1.39	9,124
B1	3,473	11.0	1.45	7,295
C1	4,042	6.6	0.82	-5,212
Overall	11,286	9.2	1.15	7,614

Among the component plans, Plan A1 has the highest economic viability, while Plan C1 is the lowest, of which B/C is a little lower 1.0. Plan B1 has almost same economic viability as Plan B1.

The B/C of the overall plan is over 1.0, so that the proposed flood management plan is economically sound.

V. IMPLEMENTATION PROGRAM

5.1 General

The proposed flood management plan requires construction of dikes of about 500 km long in total and construction cost is estimated at about US$ 94 million in total.

Considering scale of the works, stage-wised implementation is proposed. For this, a long-term plan and short-term plan are introduced. The long-term plan aims to accomplish the entire flood management plan proposed, while the short-term plan aims at earlier implementation of a part of the long-term plan. Further, order of implementation of each component plans is determined taking into account socio-economic, environmental and engineering aspects.

5.2 Long-Term Plan

The target of the long-term plan is to accomplish the entire flood management plan proposed. The long-term plan largely consists of the following works.

1) Construction of dike on the right bank of Portuguesa river (187 km long)
2) Construction of dike on the right bank of Guanare river (145 km long)
3) Construction of dike on the left bank of Apure river (155 km long) or Apure type modules (some specific locations)

According to the information, railway project mentioned before is scheduled to be implemented near future. In relation with this, construction of dike for Portuguesa river will have high priority.

On the other hand, construction of dike for Apure river will have low priority from the environmental viewpoint as mentioned in the previous section 4.4.

In the economic evaluation, high priority is given to the dike for Portuguesa river and low priority to the dike for Apure river.

Based on the above, order of implementation in the long-term plan will be as follows :

Order of Implementation	Works
1st	Construction of dike for Portuguesa river
2nd	Construction of dike for Guanare river
3rd	Construction of dike for Apure river or Apure type module

5.3 Short-Term Plan

The short-term plan aims at implementation of the priority works and effective works in the long term plan. The following works are subject to the short-term plan.

- Works with immediate effect
- Works with high priority
- Works with small scale (in return period)

In the proposed flood management plan, the following two works are taken up as the short-term plan.

1) Partial dike for Portuguesa river (103 km long)

   As mentioned before, railway project is scheduled to be implemented near future, so that dike for Portuguesa river from national road route 8 to Nueva Florida has high priority.

2) Partial dike for Guanare river (25 km long)

   Along the Guanare river, existing roads are extending from Sabaneta to El Caldaro (about 80 km) and from Banco de Morrones to Sabanas Flor Amarilla (about 50 km). The section of about 120 km long of these roads can be used as dike with some reinforcement, so that new dike is to be constructed so as to connect those roads for the time being. This idea reduces the cost and expect immediate effect.

Among the above two (2) dikes, the dike for the Portuguesa river is assumed to be implemented first from the viewpoint of necessity though it depends on the schedule of the railway project.

5.4 Implementation Schedule

The short-term plan shall be implemented first and then the long-term plan. The implementation schedule shown in Fig. 5.4.1 is tentatively proposed. The sequence of project works would be as follows:

1) Preparatory Period: 1st to 5th year

   a) Feasibility study
   b) Financing

2) Short-Term Plan: 2nd to 10th year

   a) Preparation : 2nd to 3rd year
   b) Detailed design : 4th to 5th year
   c) Partial dike for the Portuguesa river for railway project (103 km long) : 6th to 8th year
   d) Partial dike for the Guanare river (25 km long) : 9th to 10th year

3) Long-Term Plan: 8th to 20th year

   a) Preparation : 9th to 10th year
   b) Detailed design : 9th to 10th year
   c) Dike for the Portuguesa river (Remaining 84 km long) : 11th to 12th year
   d) Dike for the Guanare river (Remaining 120 km long) : 13th to 16th year
   e) Dike for the Apure river (155 km long) or Apure type module (some specific locations) : 17th to 20th year

TABLES

Table 2.2.1 PRINCIPAL FEATURES OF DAMS IN THE PORTUGUESA RIVER BASIN

Dam	Status	Owner	Function	Catchment Area (km2)	Gross Storage (mil m3)	Effective Capacity (mil m3)	Flood Control Capacity (mil m3)	Spillway Capacity (m3/s)
1. Bocono-Tucupido	Constructed	CADAFE/MARNR	P, I, W, F	2,020	3,485	2,595	249	687
2. Guaremal	Constructed	-	F	-	4	(Filled up with sediment)		
3. Las Majaguas	Constructed	MARNR	I, F	100	304	303	41	60
4. Cabuy	Constructed	MARNR	I	44	11	10	4	80
5. Pao Cachinche	Constructed	INOS	I,W	940	170	165	67	760
6. Pao La Balsa	Constructed	INOS	I,W	2,700	394	369	56	60
7. Tisnados	Constructed	MARNR	I,F	1,480	870	820	229	486
8. Yacambu	Under Construction	MARNR	I,W,F	335	435	313	26	480
9. Las Palmas	Under Bidding	MARNR	P,I,W,F	4,325	1,920	1,750	125	170

Note : - Data are not available.

P - Power generation
I - Irrigation
W - Water supply
F - Flood control

As of March 1993

Table 4.1.1 PROBABLE 8-MONTH BASIN MEAN RAINFALL

(unit : mm)

Return Period	Apure River Basin	Portuguesa River Basin	Whole Basin
2-Year	1,666	1,311	1,495
5-Year	1,832	1,471	1,644
10-Year	1,942	1,576	1,742
20-Year	2,047	1,677	1,836
30-Year	2,108	1,735	1,890
50-Year	2,184	1,808	1,958
80-Year	2,253	1,875	2,020
100-Year	2,286	1,906	2,049

Note : 8-month indicates the period from April to November.

Table 4.1.2 RELATION BETWEEN GROUND SLOPE, STORAGE CAPACITY AND COST OF APURE TYPE MODULE

Ground Slope	Transversal Dike Intervals (km)	Transversal Dike Length (km)	Maximum Water Depth (m)	Dike Height (m)	Storage Capacity (mil m3)	10-Year Rainfall Amount (mil m3)	Dike Volume per Module (1,000 m3)	Cost of Module per ha (US$)
1/1,000	2.10	5.00	1.40	1.90	0.98	1.12	191	95
1/2,000	4.20	5.00	1.40	1.90	1.96	2.24	247	124
1/3,000	6.30	5.00	1.40	1.90	2.94	3.36	304	152
1/4,000	8.40	5.00	1.40	1.90	3.92	4.48	360	180
1/5,000	10.50	5.00	1.40	1.90	4.90	5.60	417	208
1/1,000	2.40	5.00	1.60	2.10	1.12	1.28	228	114
1/2,000	4.80	5.00	1.60	2.10	2.40	2.56	302	151
1/3,000	7.20	5.00	1.60	2.10	3.36	3.84	375	188
1/4,000	9.60	5.00	1.60	2.10	4.48	5.11	449	225
1/5,000	12.00	5.00	1.60	2.10	5.60	6.39	523	262
1/1,000	2.70	5.00	1.80	2.30	1.26	1.44	269	134
1/2,000	5.40	5.00	1.80	2.30	2.52	2.88	363	181
1/3,000	8.10	5.00	1.80	2.30	3.78	4.32	457	229
1/4,000	10.80	5.00	1.80	2.30	5.04	5.75	551	276
1/5,000	13.50	5.00	1.80	2.30	6.30	7.19	645	323
1/1,000	3.00	5.00	2.00	2.50	1.40	1.60	314	157
1/2,000	6.00	5.00	2.00	2.50	2.80	3.20	432	216
1/3,000	9.00	5.00	2.00	2.50	4.20	4.79	550	275
1/4,000	12.00	5.00	2.00	2.50	5.60	6.39	667	334
1/5,000	15.00	5.00	2.00	2.50	7.00	7.99	785	393

Note : Unit cost of dike US$2.0/m3

Table 4.3.1 ALTERNATIVE PLANS FOR FLOOD MANAGEMENT STUDY

Possible Measures	Plan	Area "A"			Area "B"			Area "C"			Area "D"			Whole	Remarks
		Alt. 1			Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6		Alt. 7	Alt. 8	Alt. 9	Alt. 10	
I. Flood Defence Measures															
(1) Protection Area "A"															
1) Dike on the right bank of Portuguesa river	A1	X	-	-	-	-	-	-	-	-	-	-	-	X	Selected
2) Dike on the right bank of Guanare river	A2	-	-	-	-	-	-	-	-	-	-	-	-	-	Excluded
3) Dike on the right bank of Portuguesa river on the left bank of Cano Igues	A3	-	-	-	-	-	-	-	-	-	-	-	-	-	Excluded
(2) Protection Area "B"															
1) Dike on the right bank of Guanare river	B1	-	-	-	X	-	-	-	X	-	-	X	-	X	Selected
2) Dike on the right bank of Guanare river and improvement of Guanare Viejo river	B2A	-	-	-	-	X	-	-	-	-	-	-	-	-	
3) Dike on the right bank of Guanare river and improvement of Guanare Viejo river	B2B	-	-	-	-	-	X	-	-	-	-	-	-	-	
(3) Protection Area "C"															
1) Dike on the left bank of Apure river	C1	-	-	-	-	-	-	X	-	-	-	-	-	X	Selected
2) Dike on the left bank of Apure river (shorter	C2	-	-	-	-	-	-	-	X	-	-	-	-	-	
3) Apure type module	C3	-	-	-	-	-	-	-	-	-	-	-	-	-	Selected
(4) Protection Area "D"															
1) Diversion channel from Portuguesa river to Apurito river (1 no.)	D1A	-	-	-	-	-	-	-	-	-	X	-	-	-	
2) Diversion channel from Portuguesa river to Apurito river (2 no.)	D1B	-	-	-	-	-	-	-	-	-	-	X	-	-	
3) Retarding basin by Apure type module	D2	-	-	-	-	-	-	-	-	-	-	-	X	-	
II. Water Resources Measures															
(1) Protection Area "A"															
1) Existing Bocono-Tucupido dam		*	-	-	-	-	-	-	-	-	-	-	-	*	
2) Module of Apure type (Partial)		*	-	-	-	-	-	-	-	-	-	-	-	*	
(2) Protection Area "B"															
1) Existing Bocono-Tucupido dam		-	-	-	*	*	*	-	-	-	-	-	-	*	
(3) Protection Area "C"															
1) Module of Apure type		-	-	-	-	-	-	*	*	*	-	-	-	*	
(4) Protection Area "D"															
Not required			-	-	-	-	-	-	-	-	-	-	-	-	

Note : X Plans to be studied

Table 4.3.2 MAXIMUM INUNDATION DEPTH BY BLOCK (10-YEAR RETURN PERIOD) (1/2)

Block	Present	A1		B1		B2A		B2B		C1		C2	
No.	Condition	Depth	Difference	Depth	Difference	Depth	Difference	Depth	Difference	Depth	Difference	Depth	Difference
1	0.25	0.25		0.25		0.25		0.25		0.25		0.25	
2	0.35	0.77	0.42	0.35		0.35		0.35		0.35		0.35	
3	0.10	0.10		0.10		0.10		0.10		0.10		0.10	
4	0.13	0.13		0.13		0.13		0.13		0.13		0.13	
5	0.05	0.05		0.06	0.01	0.06	0.01	0.06	0.01	0.05		0.05	
6	0.12	0.12		0.12		0.12		0.12		0.12		0.12	
7	0.24	0.10	-0.14	0.24		0.24		0.24		0.24		0.24	
8	0.29	0.41	0.12	0.30	0.01	0.29		0.29		0.29		0.29	
9	0.18	0.18		0.20	0.02	0.19	0.01	0.19	0.01	0.18		0.18	
10	0.17	0.17		0.24	0.07	0.24	0.07	0.24	0.07	0.17		0.17	
11	0.37	0.17	-0.20	0.37		0.37		0.37		0.37		0.37	
12	0.52	0.40	-0.12	0.53	0.01	0.53	0.01	0.53	0.01	0.52		0.52	
13	0.07	0.07		0.06	-0.01	0.06	-0.01	0.06	-0.01	0.07		0.07	
14	0.08	0.08		0.08		0.08		0.08		0.08		0.08	
15	0.14	0.14		0.14		0.12	-0.02	0.12	-0.02	0.14		0.14	
16	0.30	0.30		0.25	-0.05	0.23	-0.07	0.20	-0.10	0.30		0.30	
17	0.49	0.45	-0.04	0.49		0.48	-0.01	0.48	-0.01	0.49		0.49	
18	1.77	1.74	-0.03	1.78	0.01	1.78	0.01	1.78	0.01	1.77		1.77	
19	0.13	0.13		0.13		0.13		0.13		0.13		0.13	
20	0.41	0.41		0.41		0.41		0.42	0.01	0.13	-0.28	0.13	-0.28
21	0.50	0.50		0.47	-0.03	0.52	0.02	0.54	0.04	0.36	-0.14	0.36	-0.14
22	0.07	0.07		0.07		0.07		0.07		0.07		0.09	0.02
23	0.31	0.31		0.31		0.31		0.31		0.31		0.31	
24	1.28	1.28		1.28		1.28		1.28		1.90	0.62	1.90	0.62

Note :
A1 Dike for Portuguesa river (right bank)
B1 Dike for Guanare river (right bank)
B2A Dike for Guanare river (right bank)+improvement of Guanare Viejo river
B2B Dike for Guanare river (right bank)+improvement of Guanare Viejo river
C1 Dike for Apure river (left bank)
C2 Dike for Apure river (left bank-shortened)
D1A Diversion channel by improvement of existing floodway
D1B D1A + new diversion channel
D2 Retarding basin applying Apure type module
Overall Plan A1+Plan B1+Plan C1

Table 4.3.2 MAXIMUM INUNDATION DEPTH BY BLOCK (10-YEAR RETURN PERIOD) (2/2)

Block	D1A		D1B		D2		Overall	
No.	Depth	Difference	Depth	Difference	Depth	Difference	Depth	Difference
1	0.25		0.25		0.25		0.25	
2	0.35		0.35		0.56	0.21	0.77	0.42
3	0.10		0.10		0.10		0.10	
4	0.13		0.13		0.13		0.13	
5	0.05		0.05		0.05		0.06	0.01
6	0.12		0.12		0.11	-0.01	0.11	-0.01
7	0.24		0.24		0.62	0.38	0.10	-0.14
8	0.29		0.29		0.40	0.11	0.41	0.12
9	0.18		0.18		0.18		0.18	
10	0.17		0.17		0.17		0.24	0.07
11	0.37		0.37		0.51	0.14	0.17	-0.20
12	0.52		0.52		0.56	0.04	0.41	-0.11
13	0.07		0.07		0.07		0.06	-0.01
14	0.08		0.08		0.08		0.08	
15	0.14		0.14		0.14		0.14	
16	0.30		0.30		0.30		0.25	-0.05
17	0.49		0.49		0.40	-0.09	0.41	-0.08
18	1.77		1.77		1.67	-0.10	1.74	-0.03
19	0.13		0.13		0.17	0.04	0.13	
20	0.41		0.41		0.41		0.13	-0.28
21	0.50		0.50		0.43	-0.07	0.31	-0.19
22	0.07		0.07		0.43	0.36	0.07	
23	0.31		0.31		0.30	-0.01	0.31	
24	1.28		1.28		1.90	0.62	1.90	0.62

Note :

A1	Dike for Portuguesa river (right bank)
B1	Dike for Guanare river (right bank)
B2A	Dike for Guanare river (right bank)+improvement of Guanare Viejo river
B2B	Dike for Guanare river (right bank)+improvement of Guanare Viejo river
C1	Dike for Apure river (left bank)
C2	Dike for Apure river (left bank-shortened)
D1A	Diversion channel by improvement of existing floodway
D1B	D1A + new diversion channel
D2	Retarding basin applying Apure type module
Overall	Plan A1+Plan B1+Plan C1

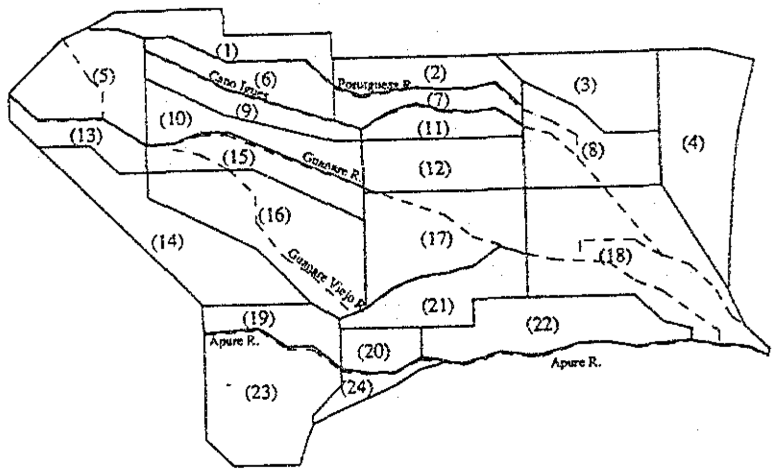


Table 4.3.3 MAJOR CHANGES OF INUNDATION (1/2)

Area	Plan	Block	Location	Inundation Depth (m)		Remarks
				Present Condition	With Project	
A	A1	2	Downstream section, river side	0.35	0.77(+)	(Dike for Portuguesa River)
		7	Downstream section, land side	0.24	0.10(-)	
		11	Adjacent to block 7	0.37	0.17(-)	No change in upstream section, land side and
		8	Downstream of dike	0.29	0.41(+)	river side
B	B1	10	Downstream section, river side	0.17	0.24(+)	(Dike for Guanare River)
		16	Downstream areas	0.30	0.25(-)	No change in upstream section, land side
	B2A	10	Downstream section, river side	0.17	0.24(+)	(Dike for Guanare River)
		16	Downstream areas	0.30	0.23(-)	No change in upstream section, land side
	B2B	10	Downstream section, river side	0.17	0.24(+)	(Dike for Guanare River)
		16	Downstream areas	0.30	0.20(-)	No change in upstream section, land side
C	C1	24	Opposit bank area	1.28	1.90(+)	(Dike for Apure River)
		20	Left bank, land side	0.41	0.13(-)	Almost no change in upstream section, land side
		21	Adjacent to block 20	0.50	0.36(-)	
		-	San Fernando	El.45.44	El.45.44	
	C2	24	Opposit bank area	1.28	1.90(+)	(Dike for Apure River - shortened)
		20	Left bank, land side	0.41	0.13(-)	Almost no change in upstream section land side
		21	Adjacent to block 20	0.50	0.36(-)	
		-	San Fernando	El.45.44	El.45.44	
D	D1A	-	San Fernando	El. 45.44	El. 45.33	(Diversion Channel - 1 no.) No change in inundation area Discharge 760 m^3/s

Table 4.3.3 MAJOR CHANGES OF INUNDATION (2/2)

	D1B	-	San Fernando	El. 45.44	El. 45.26	(Diversion Channel - 2 nos.) No change in inundation area Discharge 1,240 m^3/s
	D2	2 7 8 11 17 22	Left bank of Portuguesa Right bank of Portuguesa Around confluence of Portuguesa and Igues Right bank of Igues Center of study area Left bank of Apure	0.35 0.24 0.29 0.37 1.77 0.07	0.56(+) 0.62(+) 0.40(+) 0.51(+) 1.67(-) 0.43(+)	(Retarding Basin by Apure Module)

Note: (+) Increase of inundation depth, (-) dcrease of inundation depth

Table 4.5.1 REQUIRED HEIGHTS OF DIKES FOR PORTUGUESA AND GUANARE RIVERS

Pond No.	Ground Elevation (El.m)	Present Condition Water Depth (m)	Present Condition Water Level (El.m)	Present Condition Over Flow (m)	Plan A1 Water Level (El.m)	Plan A1 Over Flow (m)	Plan A1 Difference (m)	Plan A1 Required Dike H. (m)
61	46.00	14.10	49.60	3.60	49.59	3.59	-0.01	
73	46.00	12.64	49.64	3.64	49.64	3.64	0.00	
72	51.00	11.52	51.02	0.02	51.40	0.40	0.38	
84	56.00	13.82	55.82	-0.18	56.13	0.13	0.31	
84	56.00	12.65	56.65	0.65	56.79	0.79	0.14	
98	57.00	11.25	57.25	0.25	57.61	0.61	0.36	
111 *	58.00	10.23	58.23	0.23	58.93	0.93	0.70	2.00
123 *	60.00	8.54	59.54	-0.46	60.66	0.66	1.12	2.00
135 *	60.00	8.19	60.19	0.19	61.18	1.18	0.99	2.18
148 *	60.00	7.81	60.81	0.81	61.90	1.90	1.09	2.90
162 *	61.00	7.78	61.78	0.78	62.36	1.36	0.58	2.36
176 *	64.00	7.43	64.43	0.43	64.71	0.71	0.28	2.00
193 *	68.00	7.39	68.39	0.39	68.50	0.50	0.11	2.00
211 *	76.00	8.00	75.00	-1.00	75.00	-1.00	0.00	2.00
231 *	79.00	8.00	78.00	-1.00	78.00	-1.00	0.00	2.00
252 *	81.00	6.47	80.47	-0.53	80.54	-0.46	0.07	2.00
273 *	87.00	6.00	86.00	-1.00	86.00	-1.00	0.00	2.00
295 *	92.00	6.00	91.00	-1.00	91.00	-1.00	0.00	2.00
316 *	98.00	6.00	97.00	-1.00	97.00	-1.00	0.00	2.00
330 *	109.00	6.00	108.00	-1.00	108.00	-1.00	0.00	2.00
341 *	120.00	6.00	119.00	-1.00	119.00	-1.00	0.00	2.00
352 *	130.00	6.00	129.00	-1.00	129.00	-1.00	0.00	2.00

Pond No.	Ground Elevation (El.m)	Present Condition Water Depth (m)	Present Condition Water Level (El.m)	Present Condition Over Flow (m)	Plan B1 Water Level (El.m)	Plan B1 Over Flow (m)	Plan B1 Difference (m)	Plan B1 Required Dike H. (m)
129	54.00	6.80	54.78	0.78	54.79	0.79	0.01	
141	56.00	5.92	55.91	-0.09	55.90	-0.10	-0.01	
154	57.00	6.06	57.56	0.56	57.54	0.54	-0.02	
167	61.00	4.98	58.01	-2.99	58.01	-2.99	0.00	
182	62.00	4.63	60.14	-1.86	60.13	-1.87	-0.01	
198 *	64.00	4.43	64.45	0.45	64.46	0.46	0.01	2.00
216 *	70.00	4.12	70.13	0.13	70.29	0.29	0.16	2.00
237 *	76.00	5.00	75.00	-1.00	75.00	-1.00	0.00	2.00
257 *	78.00	4.46	78.49	0.49	79.41	1.41	0.92	2.00
277 *	84.00	4.22	84.27	0.27	84.42	0.42	0.15	2.00
300 *	92.00	3.78	91.99	-0.01	92.03	0.03	0.04	2.00
321 *	101.00	3.52	100.65	-0.35	100.78	-0.22	0.13	2.00
335 *	107.00	4.13	107.15	0.15	107.33	0.33	0.18	2.00
346 *	114.00	4.00	114.12	0.12	114.32	0.32	0.20	2.00
356 *	117.00	4.00	116.37	-0.63	117.58	0.58	1.21	2.00
367 *	126.00	4.00	125.00	-1.00	125.00	-1.00	0.00	2.00
374 *	138.00	4.00	137.00	-1.00	137.00	-1.00	0.00	2.00
378 *	174.00	4.00	173.00	-1.00	173.00	-1.00	0.00	2.00

Note : * Dike section
Freeboad is taken as 1.0 m.
Minimum height of dike is 2.0 m.

Table 4.5.2 REQUIRED HEIGHT OF DIKE FOR APURE RIVER

Pond No.	Ground Elevation (El.m)	Present Condition Water Depth (m)	Present Condition Water Level (El.m)	Present Condition Over Flow (m)	Plan C1 Water Level (El.m)	Plan C1 Over Flow (m)	Plan C1 Difference (m)	Plan C1 Required Dike H. (m)	Plan C2 Water Level (El.m)	Plan C2 Over Flow (m)	Plan C2 Difference (m)	Plan C2 Required Dike H. (m)
1	45.00	14.44	45.44	0.44	45.44	0.44	0.00		45.44	0.44	0.00	
13	46.00	13.68	45.79	-0.21	45.79	-0.21	0.00		45.79	-0.21	0.00	
26	47.00	12.69	46.29	-0.71	46.34	-0.66	0.05		46.14	-0.86	-0.15	
39	51.00	13.25	48.25	-2.75	49.04	-1.96	0.79		48.77	-2.23	0.52	
53	51.00	14.71	50.37	-0.63	51.22	0.22	0.85		50.93	-0.07	0.56	
66	53.00	14.16	51.66	-1.34	52.58	-0.42	0.92		52.22	-0.78	0.56	
80 *	54.00	14.15	52.95	-1.05	53.88	-0.12	0.93	2.00	53.52	-0.48	0.57	
94 *	54.50	14.14	54.24	-0.26	55.18	0.68	0.94	2.00	54.81	0.31	0.57	
108 *	56.00	14.13	55.63	-0.37	56.57	0.57	0.94	2.00	56.32	0.32	0.69	
121 *	57.50	14.12	56.92	-0.58	57.87	0.37	0.95	2.00	57.76	0.26	0.84	
133 *	59.00	14.11	58.21	-0.79	59.17	0.17	0.96	2.00	59.15	0.15	0.94	
146 *	62.00	14.09	59.49	-2.51	60.47	-1.53	0.98	2.00	60.47	-1.53	0.98	
159 *	67.00	14.08	60.78	-6.22	61.76	-5.24	0.98	2.00	61.76	-5.24	0.98	2.00
173 *	65.00	17.78	65.88	0.88	67.05	2.05	1.17	3.05	67.05	2.05	1.17	3.05
190 *	66.00	17.20	66.60	0.60	67.54	1.54	0.94	2.54	67.54	1.54	0.94	2.54
206 *	67.00	16.80	67.50	0.50	68.11	1.11	0.61	2.11	68.11	1.11	0.61	2.11
225 *	70.00	16.57	69.67	-0.33	69.64	-0.36	-0.03	2.00	69.64	-0.36	-0.03	2.00
245 *	73.00	16.53	72.33	-0.67	72.30	-0.70	-0.03	2.00	72.30	-0.70	-0.03	2.00
265 *	79.00	17.83	78.23	-0.77	78.18	-0.82	-0.05	2.00	78.18	-0.82	-0.05	2.00
286 *	80.00	17.79	79.49	-0.51	79.46	-0.54	-0.03	2.00	79.46	-0.54	-0.03	2.00
308 *	81.00	17.83	80.83	-0.17	80.84	-0.16	0.01	2.00	80.84	-0.16	0.01	2.00

Note : * Dike section
Freeboad is taken as 1.0 m.
Minimum height of dike is 2.0 m.

Table 4.6.1 PROJECT COST OF FLOOD MANAGEMENT PROJECT

Cost Item	Unit	Unit price (US$)	Plan A1		Plan B1		Plan C1		Overall	
			Qty	Amount (US$)	Qty	Amount (US$)	Qty	Amount (US$)	Qty	Amount (US$)
I. CONSTRUCTION COST (DIKE CONSTRUCTION)										
(1) Preparatory works	L.S	10%	1	2,240,000	1	1,674,000	1	2,237,500	1	6,151,500
(2) Foundation excavation	cu.m	1.0	960,000	960,000	740,000	740,000	790,000	790,000	2,490,000	2,490,000
(3) Dike embankment	cu.m	2.5	7,760,000	19,400,000	5,800,000	14,500,000	7,970,000	19,925,000	21,530,000	53,825,000
(4) Vegitation Cover	cu.m	1.0	1,240,000	1,240,000	900,000	900,000	1,060,000	1,060,000	3,200,000	3,200,000
(5) Sluiceway	nos.	20,000	40	800,000	30	600,000	30	600,000	100	2,000,000
(6) Miscellaneous works	L.S	3%	1	672,000	1	502,200	1	671,250	1	1,845,450
Sub-total of I				25,312,000		18,916,200		25,283,750		69,511,950
II. LAND ACQUISITION COST	ha	100.0	1,870	187,000	1,450	145,000	1,550	155,000	4,870	487,000
III. ADMINISTRATION COST (5% of I + II)	L.S			1,274,950		953,060		1,271,938		3,499,948
IV. ENGINEERING SERVICE COST	L.S			4,303,040		3,215,754		4,298,238		11,817,032
Detailed Design (7% of I)				1,771,840		1,324,134		1,769,863		4,865,837
Construction Supervision (10 % of I)				2,531,200		1,891,620		2,528,375		6,951,195
V. PHYSICAL CONTINGENCY (10 % of I + II + III + IV)	L.S			3,107,699		2,323,001		3,100,893		8,531,593
GRAND TOTAL				34,184,689		25,553,015		34,109,818		93,847,522

Note: (1) Currency exchange rate : 1 US $ = 82: BS = 119.72 ¥
(2) Sluiceway isarranged at intervals of 5 km.
(3) Length of dike Plan A1 = 187 km, Plan B1 = 145 km, Plan C1 = 155 km