(3) Sediment Transport Capacity

Sediment transport capacity of the Apure river were estimated for various discharges using the sediment transport formula modified by the sediment observation records by PROA as follows:

1) Relationship between channel discharge and sediment load observed by PROA is shown in Fig. 4.4.5.
2) Sediment discharge was calculated as a sum of bed load and suspended load. These loads were calculated for various segment sizes of bed materials.
3) Sato-Kikkawa-Ashida's formula was adopted for estimation of the bed load, and Brown's formula for the suspended load. The Brown's formula was modified based on the observed data.

Results of calculations are shown in Fig. 4.4.6 for various discharges.

(4) Annual Sediment Transport

Multiplying the sediment transport capacity by the duration of flow, annual sediment transport capacity was estimated, as an average for each river stretch. The result is presented below in brief.

Stretches	Annual iment loadsed (mil. m^3/yr)	Stretch length (km)	Approx. channel width (m)
River mouth to S.Fernando	14.7	167.3	340
S.Fernando to El Samán	15.2	180.8	342
El Samán to Bruzual	14.5	94.1	522
Bruzual to Suripa R.	13.0	81.4	501
Suripa R. to Remolino Br.	14.3	139.8	265

V. STUDY ON CHANNEL STABILIZATION PLAN

5.1 General

Study on channel stabilization aims to formulate a channel improvement plan for navigation purposes.

The Study started from the review of previous studies and works based on the data and information collected. Then the characteristics of the existing channel were studied from the geometric and hydraulic aspects. Channel improvement measures for navigation and principles for facility design were discussed on the basis of the review and the channel studies. Finally the channel stabilization plan was formulated.

Project size and its implementation program of the channel improvement for navigation should be discussed in line with the navigation master plan in consideration of economic viability. Study on the navigation master plan is scheduled to be conducted separately and is still waiting for its commencement.

The channel improvement plan for navigation was discussed therefore mainly from technical aspect. Through the study it was intended to provide technical data for channel stabilization activities both under the navigation master plan and under the current channel improvement works being implemented by PROA and other authorities concerned.

5.2 Previous Studies and Works

5.2.1 Water Resources Development Projects

Channel flow is an important factor of the fluvial navigation and its changes due to water resources development are also of important concern to the study. In view of this, water resources development projects, among others, dam projects in the study area were reviewed.

(1) Existing and Proposed Dams

Existing and proposed dams in the study area were inventoried together with their major features. Locations of these dams are shown in Fig. 5.2.1. There are 22 dams in the study area including proposed dams as follows:

Project	Existing	Under construction	Proposed
1) Uribante-Caparo project	1	2	1
2) Guanare-Masparro project	3	-	1
3) Other dams in Apure river basin	1	-	-
4) Other dams in Portuguesariver basin	5	2	6
Total	(10)	(4)	(8)

(2) Uribante-Caparo Project

The project aims mainly to develop hydro-power of 1,274 MW in total, constructing dams in the Uribante river (1,000 m MSL), Doradas river (700 m MSL). Camburito river (200 m MSL) and Caparo river (200 m MSL) having a basin area of about 4,580 km^2 in total.

Component project works and their construction status are as follows:

1) Uribante river
   a) La Honda dam: Existing
   b) Uribante-Doradas tunnel: Existing
   c) San Agaton power station: Existing
      Installed capacity: 300 MW
   d) Linda-Doradas diversion tunnel: Proposed

2) Doradas river
   a) Las Cuevas dam: Proposed
   b) Doradas-Camburito tunnel: Proposed
   c) La Colorada power station: Proposed
      Installed capacity: 460 MW

3) Camburito river
   a) Borde Seco dam: Under construction

4) Caparo river
   a) La Vueltosa dam: Under construction
   b) La Vueltosa power station: Proposed
      Installed capacity: 514 MW
   c) Caparo-Uribante Viejo derivation channel for navigation: Proposed

(3) Guanare-Masparro Project

Guanare-Masparro project is an integrated area development project including various components of infrastructure works such as water resources development, road and education facilities, conservation and recovery of natural resources, covering an area of about 950,000 ha which consists of 500,000 ha for development and 450,000 ha for conservation and recovery of natural resources.

As to the water resources development, four (4) dams with three (3) reservoirs play an important role:

1) Masparro dam: Existing
   a) Irrigation: 67,500 ha
   b) Hydro-power: Masparro hydro-electric station has a capacity to generate 25 MW during dry season

2) Bocono-Tucupido dams: Existing
   a) Irrigation: Two dams jointly have capacity to irrigate 300,000 ha of agricultural lands. The existing Bocono-Tucupido irrigation system covers an area of 9,200 ha of which 7,200 ha are subject to irrigation.
   b) Hydro-power: Peña Larga hydro-electric station located at the foot of Bocono dam will have a capacity to generate 80 MW (40 MW x 2 units). The electric plant work is ongoing by CADAFE.

3) Guanare dam: Proposed.
   a) Three (3) possible sites are being evaluated and the most promising site is Mesa de Cavaca.
   b) The dam will have irrigation and flood control functions. The Guanare irrigation system covers an area of about 7,690 ha.

5.2.2 Navigation Plan

Master plan study for the fluvial navigation of the Orinoco-Apure system is scheduled to be conducted separately. The master plan study is not started yet. Although the master plan for fluvial navigation is not prepared yet, navigation plan has been discussed among PROA and other authorities concerned because of the daily needs of navigation, and some works are being implemented in the field.

Based on the information obtained so far from PROA, the existing navigation plan was outlined hereunder. The existing plan has a nature of short term navigation improvement plan.

(1) Principle of Navigation Improvement

1) Sequence of project implementation:
   1st : Orinoco river to San Fernando port (Stretch-A1)
   2nd : San Fernando port to El Baul port (Stretches-A2, P1 and P2)
   3rd : San Fernando port to Nutrias port/Bruzual (Stretch-A3)
   4th : Nutrias to Santos Luzardo port/Guasdualito (Stretch-A4)

2) Level of improvement: To equip necessary facilities to attain eight (8) months navigation by effective use of the existing river channel.

(2) Construction of Fluvial Ports

Construction of four (4) ports have been planned and the works are ongoing.

1) San Fernando port : constructed
2) El Baul port : under construction
3) Nutrias port/Bruzual : constructed
4) Santos Luzardo port : constructed

(3) Criteria for Carrier and Standard Canal Section

Barges and boats are used for transportation of goods, and the size of barge with tugboat would be critical for the navigation canal section. The following sizes of barge and tugboat are adopted as size criteria for channel improvement study:

Item	Apure R.	Portuguesa R.
1) Barge		
Width (Ws)	13 m	10 m
Length (Ls)	60 m	40 m
2) Tugboat		
Length (Lt)	20 m	20 m
3) Channel (Assuming no navigational aid)		
Depth (Dc)	≥ 2.00 m	≥ 1.70 m
Width (Wc)	≥ 3xWs (*)	≥ 30 m
Radius of curvature (Rc)	≥ 4x(Ls+20) (*)	≥ 240 m

(*) Ws and Ls for the Apure river may change by composition of barge(s).

5.2.3 Previous Studies and Works

River improvement of the Apure initiated in 1960s as well as water resources development for such as hydro-power generation, irrigation and municipal water supply and flood control.

Channel improvement works implemented so far are mostly for protection of towns, public facilities and agricultural lands from flood water and bank erosion. Recently, studies and works of the Apure river as navigation channel are started paying attention to its unique situation in the country.

Major previous studies and works are shown in Fig. 5.2.2.

5.3 Characteristics of Channel

For the conveniences of description, river channel was divided into several stretches according to the location of fluvial ports and features of the river as follows:

<u>Apure River</u>

1) Stretch-A1(or St-A1): From river mouth (confluence of the Orinoco river) to San Fernando port

2) Stretch-A2(or St-A2): From San Fernando port to confluence of the Portuguesa river

3) Stretch-A3(or St-A3): From confluence of the Portuguesa river to Nutrias port at Bruzual
   a) Stretch-A3.1: From confluence of the Portuguesa river to Apurito
   b) Stretch-A3.2: From Apurito to Nutrias port

4) Stretch-A4(or St-A4): From Nutrias port to Santos Luzardo port
   a) Stretch-A4.1: From Nutrias port to confluence of the Suripa river
   b) Stretch-A4.2: From confluence of the Suripa river to Santos Luzardo port

Portuguesa River

5) Stretch-P1(or St-P1): From river mouth (confluence of the Apure river) to confluence of the Cojedes river

6) Stretch-P2(or St-P2): From confluence of the Cojedes river to El Baul port at Paso La Portuguesa

5.3.1 General Channel Features

Longitudinal profile and river width of the existing Apure river were studied using the topographic maps of scale 1/10,000. Results of study are shown in Fig. 5.3.1 for longitudinal river bank profile, and in Fig. 5.3.2 for river width and channel system. Principal features of the Apure river are presented for respective stretches as follows:

1) Stretch-A1: Ground slope is 1/8,500. Large scale anabranches develop in this stretch. River is not braided. In the downstream reaches from Arichuna, ground elevation fluctuates much probably due to the effect of the Orinoco river. Average river width is 257 m ranging from 120 m to 600 m for the main Apure and 340 m ranging from 135 m to 600 m including anabranches.

2) Stretches-A2 and A3.1: Ground slope is 1/7,200. Large scale anabranches develop in this stretch. River is not braided. Average river width is 251 m ranging from 100 m to 560 m for the main Apure and 342 m ranging from 250 m to 560 m including anabranches.

3) Stretch-A3.2: Ground slope is 1/5,000. River is braided and average river width is 522 m fluctuating much from 200 m to 880 m.

4) Stretch-A4.1: Ground slope is 1/4,200. There are several confluence of tributaries with much sediment. River is braided and average river width is 501 m fluctuating much from 220 m to 800 m.

5) Stretch-A4.2: Ground slope of 1/2,500. There is no confluence of major tributaries and channel is not braided. Average river width is 265 m ranging from 100 m to 370 m.

5.3.2 Historical Variation

(1) River Course and Banks

In comparison with the topographic maps of the year 1988 (scale 1/10,000) and those of year 1960 to 1966 (scale 1/25,000), variations of left and right banks were studied. The results are shown in Fig. 5.3.3.

From the figure, the following characteristics of river bank shifting are seen for the existing Apure river:

1) Stretches-A1,A2 and A3.1: Activities of bank erosion and sedimentation in these stretches are relatively low as a whole. Large river bank changes near the town of San Fernando are due to artificial channel works.

2) Stretches-A3.2 and A4.1: Bank erosion is most active in the stretch-A4.1, while the activity is medium or low in the stretch-A3.2. The active channel movement in stretch-A4.1 would be brought about by the runoff and sediment inflow from the left tributaries.

3) Stretch-A4.2: Erosion prevails on the left bank and sedimentation prevails on the right bank, which indicates the river course is shifting toward left bank side as a whole. Activities of bank erosion are moderate comparing to the other stretches.

Shifting of river courses are shown in Fig. 5.3.4 selecting typical sites in Guasdualito, Bruzual and San Fernando.

(2) River Section

PROA has been conducting cross sectional survey at the selected stations of the main Apure and Portuguesa rivers since 1988 as well as hydrological observations.
Using the PROA survey sections, characteristics of river sections and their changes were studied. Surveyed cross sections were first superposed for each site and verify the sectional data. Representative river sections are shown in Fig. 5.3.5. Longitudinal river depth and changes of river depth of representative sections were also studied.

From the above data, the following are seen:

1) River depth increase toward downstream in general. Around San Fernando bridge and Bruzual bridge, channels are deeper.

2) Annual change of river bed is not clear on these data. Seasonal change of river depth, i.e., the difference of mean river depth in dry season and rainy season, is not clear, too.

3) As an index of channel stability, variation index: (max-min)/mean was calculated for the sections with at least five (5) years of survey data. The variation index ranges from 0.12 to 0.58. Sections of lower and higher values of the coefficient are as follows:

Section	Location	(Max-Min)/Mean
(Lower three: relatively stable)		
1. San Fernando	180.47 km	0.12
2. El Chinal	397.07 km	0.18
3. El Saman	348.12 km	0.21
(Higher three: changeable)		
1. Totumito	633.36 km	0.58
2. Santos Luzardo	663.38 km	0.57
3. San Vicente	465.41 km	0.51

5.3.3 Variation through Flood Season

Variation of channel through flood season was studied based on the river survey results of June/July in 1992 and January/February in 1993 conducted by JICA survey party at the following three sites:

1) Guasdualito site from Remolino bridge to Santos Luzardo port of the Apure river
2) Bruzual site from San Vicente to Bruzual of the Apure river
3) Camaguán site from Camaguan town to 10 km upstream of the Portuguesa river.

(1) Variation of Channel Characteristics

Channel characteristics of June/July in 1992 and January/February in 1993 were compared. The results are shown in Figs.5.3.6 through 5.3.8 for respective sites.

Changes in river section during a flood season are outlined as follows:

1) River channels in Camaguan site are deep and narrow, while those of Guasdualito and Bruzual sites are relatively flat. Width-depth ratio in these sites

are as follows:

Site	Width (B:m)	Mean depth (hm:m)	(B/hm)
a) Guasdualito	258	3.58	72
b) Bruzual	415	5.07	82
c) Camaguán	139	7.49	19

2) It is clearly known that the channels in Camaguán site are stable comparing with those of other two sites.

3) Regarding the maximum or deepest channel depth, changes in Guasdualito and Bruzual are remarkable. The maximum change of channel depth through a flood was 2.3 m (or 37 % of average maximum depth) in Guasdualito site and 3.3 m (or 41 %) in Bruzual site, while it was 1.4 m (or 13 %) in Camaguán site.

4) Regarding lateral changes, the maximum changes of channel width and left and right banks through a flood were around 70 % of river width in Guasdualito site, and around 55 % in Bruzual. In Camaguán site, river width varied around 35 % at maximum and river banks around 20 % of river width.

(2) Depth Ratio of Channel Section

Relationship between depth ratio (hmax/hm) and eccentricity (Ec) was examined and shown in Fig. 5.3.9. The eccentricity (Ec) is defined as |E-B/2|/B, where E is a horizontal distance from left bank to the point of maximum depth in a section.

Item	Guasdualito 1992	Guasdualito 1993	Bruzual 1992	Bruzual 1993	Camaguán 1992	Camaguán 1993
Depth ratio (hmax/hm)						
Maximum	3.32	3.47	2.58	3.05	1.95	2.13
Minimum1	.231	.171	.101	.171	.181	.16
Average	1.77	1.85	1.52	1.77	1.46	1.45
(Max-Min)/Ave.	1.18	1.24	0.97	1.06	0.53	0.67
Eccentricity (Ec)						
Maximum	0.48	0.48	0.49	0.48	0.44	0.39
Average	0.35	0.37	0.33	0.32	0.25	0.25

From the above, the following are considered:

1) The maximum values of the depth ratios (hmax/hm) are around 3.5, 3.0 and 2.0 at Guasdualito, Bruzual and Camaguan sites, respectively. The channel bed can be said flatter in Camaguán site as a whole.

2) Distributions of plots of Guasdualito site is similar to those of Bruzual site, having increasing tendency of depth ratio for increasing eccentricity.

3) Distribution for Camaguán site is quite different from other sites, having no significant tendency for the eccentricity.

4) Significant changes of depth ratios in 1992 and 1993 sections are not observed for the Guasdualito and Camaguán sites. For Bruzual site, the upper limit of depth ratio in 1992 is almost half of that of 1993. This might be caused by filling-up due to low flows.

5.4 Evaluation of Channel Capacity for Navigation

5.4.1 Criteria

Existing channel capacity for navigation was evaluated for the following six (6) major channel stretches based on the criteria of channel size and channel flow.

Apure River

1) St-A1 : From river mouth (Orinoco river) to San Fernando port
2) St-A2 : From San Fernando port to confluence of Portuguesa river
3) St-A3 : From confluence of Portuguesa river to Nutrias port (Bruzual)
4) St-A4 : From Nutrias port to Santos Luzardo port (Guasdualito)

Portuguesa River

5) St-P1 : From river mouth (Apure river) to confluence of Cojedes river
6) St-P2 : From confluence of Cojedes river to El Baul port

Navigability was examined for water depth, radius of curvature and width of navigation channel. The critical sections due to shortage of water depth and channel width were examined in comparison with water level calculated for various channel flow conditions and the actual river section. The critical radius of curvature was studied on the topographic maps of scale 1/10,000 for most of the Apure river, and those of scale 1/25,000 for a part of the Apure river near Apulito and the whole Portuguesa river.

(1) Channel Size Criteria

Items	Apure River	Portuguesa River
Water depth	≥ 2.00 m	≥ 1.70 m
Radius of curvature	≥ 560 m	≥ 240 m
Channel width	≥ 80 m	≥ 30 m

(2) Channel Flow Criteria

For the evaluation of navigability, the following ordinal daily discharge was adopted as criteria for navigable period. The ordinal daily discharges are based on the average flow duration at respective stream gauging stations along the main Apure and Portuguesa rivers:

Apure River

Ordinal daily discharge (Qnd)	Navigation months (mon.)	Ordinal daily discharge (m^3/s)			
		P. Remolino Sta.	Bruzual Sta.	El Samán Sta.	S.Fernando Sta.
Q1d	12	83	148	217	289
Q30d	11	104	203	270	391
Q60d	10	137	276	346	511
Q90d	9	208	380	449	669
Q120d	8	319	586	629	961
Q150d	7	424	890	961	1,469
Q180d	6	514	1,490	1,376	2,164
Q210d	5	599	1,849	1,886	2,839

Portuguesa River

Ordinal daily discharge (Qnd)	Navigation months (mon)	Ordinal daily discharge (m^3/s)		
		El Baul Sta.	Jobalito Sta.	Camaguán Sta.
Q1d	12	9	31	57
Q30d	11	12	37	72
Q60d	10	15	43	89
Q90d	9	20	57	120
Q120d	8	26	82	179
Q150d	7	35	119	275
Q180d	6	57	190	438
Q210d	5	80	254	613

Note: El Baul sta. is located in El Baul town along the Cojedes river.

5.4.2 Evaluation of Apure River

(1) Channel Flow Calculation

River sections surveyed in March 1992 by PROA were used for channel flow calculation supplementing some additional sections with INC sounding results. Forty nine (49) sections were incorporated with the channel flow model for the entire stretch of 681 km from river mouth (Orinoco river) to Remolino bridge.

Making use of the channel flow model, channel water levels were calculated under various different flow conditions, i.e., 1, 30, 60, 90, 120, 150, 180 and 210 day discharges. For each case the discharge distribution was determined and channel roughness was estimated by trial and error procedures.

(2) Critical Depth ($Dc < 2.00$ m)

Sounding maps prepared by the INC are available at the intervals of about 150 m for the Apure river except for the lowest 95.74km stretch. The sounding maps were used for the comparison with the calculated water level. Navigation route was drawn on the sounding map of the Apure river prepared by the INC, mostly connecting the deepest point of the river, and longitudinal profile was prepared.

River bed elevations of the sounding map are not known. The river bed elevation of each section in MSL-datum was estimated based on several sections of which elevations were known, assuming linear water surface in-between.

On the other hand, required water depth for navigation is 2.00 m considering the draft of barge and some allowance. Therefore, the critical river bed which enables the navigation of barge is assumed to be 2.00 m below the calculated water level for the Apure river.

Result of evaluation is summarized below.

Navigation months (mon.)	No. of critical sections			
	St-A1 (Sect) (%)	St-A2 (Sect) (%)	St-A3 (Sect) (%)	St-A4 (Sect) (%)
12	43 (9.4)	24 (15.2)	367 (23.2)	423 (29.1)
11	25 (5.5)	18 (11.4)	331 (20.9)	359 (24.7)
10	21 (4.6)	7 (10.8)	272 (17.2)	289 (19.9)
9	11 (2.4)	13 (8.2)	214 (13.5)	192 (13.2)
8	3 (0.7)	6 (3.8)	148 (9.4)	95 (6.5)
7	1 (0.2)	3 (1.9)	38 (2.4)	45 (3.1)
6	0 (0)	1 (0.6)	6 (0.4)	26 (1.8)
5	0 (0)	0 (0)	0 (0)	18 (1.2)
Total	(458)	(158)	(1,581)	(1,455)

Note: Sections in the lowest stretch of 95.74 km of St-A1 is not included because of no section data

(3) Critical Width (Wc < 80 m)

River width at the elevation of critical river bed (2.00 m below calculated water level) was examined for sections incorporated in the channel flow model of the Apure river. The critical sections with channel width less than 80 m are shown below for respective navigation month or flow conditions.

Navigation months (mon.)	No. of critical sections			
	St-A1 (Sect) (%)	St-A2 (Sect) (%)	St-A3 (Sect) (%)	St-A4 (Sect) (%)
12	6 (55)	0 (0)	9 (56)	12 (71)
11	4 (36)	0 (0)	9 (56)	9 (53)
10	1 (9)	0 (0)	7 (44)	5 (29)
9	1 (9)	0 (0)	4 (25)	2 (12)
8	0 (0)	0 (0)	1 (6)	0 (0)
7	0 (0)	0 (0)	1 (6)	0 (0)
6	0 (0)	0 (0)	1 (6)	0 (0)
Total	(11)	(3)	(16)	(17)

(4) Critical Radius of Curvature (Rc < 560 m)

Radius	No. of critical curvatures			
	St-A1 (km/sect)	St-A2 (km/sect)	St-A3 (km/sect)	St-A4 (km/sect)
Rc < 560 m (sect)	12 (14)	0 (-)	16 (16)	12 (18)
Rc < 320 m (sect)	6	0	5	5
Chan. length (km)	167.3	24.9	250.0	221.2

(5) Summary

1) Result of evaluation is shown in Fig. 5.4.1 schematically.

2) Shortage of water depth is the principal problem of the Apure river. For the navigation longer than nine (9) months, channel width also become critical.

3) Judging from the critical water depth, navigable months of the Apure river were evaluated as follows, assuming that existing critical sections less than 1.0 % were navigable with minor improvement:

Stretch :	St-A1	St-A2	St-A3	St-A4
Navigable month :	8	6	6	4

5.4.3 Evaluation of Portuguesa River

(1) Channel Flow Calculation

Thirty nine (39) sections are available in total over the stretch of about 249 km from river mouth to El Baul port. All of these sections are surveyed from water surface and are not related to the MSL-datum.

Channel flow model was constructed using the channel sections assuming water surface slope and channel roughness, and the critical sections were studied on these sections principally in the similar manner as the Apure river.

(2) Critical Depth (Dc < 1.70 m)

The critical river bed elevation is set at 1.70 m below calculated water level. The critical sections for channel depth were estimated by the channel flow model. The results are summarized below.

Navigation months	No. of critical sections	
	St-P1 (Sect) (%)	St-P2 (Sect) (%)
12	3 (10)	0 (0)
11	1 (3)	0 (0)
10	1 (3)	0 (0)
9	1 (3)	0 (0)
8	0 (0)	0 (0)
Total	(31)	(8)

(3) Critical Width (Wc < 30 m)

Channel width at 1.70 m below water surface was examined. Numbers of critical sections of which channel width are less than 30 m are shown below for respective navigation months.

Navigation months	No. of critical sections	
	St-P1 (Sect) (%)	St-P2 (Sect) (%)
12	15 (48)	8 (100)
11	9 (29)	8 (100)
10	7 (23)	5 (63)
9	3 (10)	3 (38)
8	0 (0)	1 (13)
Total	(31)	(8)

(4) Critical Radius of Curvature (Rc < 240 m)

Radius	No. of critical curvatures	
	St-P1(km/sect)	St-P2(km/sect)
Rc < 240 m (sect)	27 (8)	5 (7)
Rc < 150 m (sect)	5	2
Chan. length (km)	214.8	33.7

(5) Summary

1) Result of evaluation is shown in Fig. 5.4.2.

2) Shortage of channel width and radius of curvature is the principal problems of the Portuguesa river.

3) The critical channel sections increase abruptly for the navigation longer than nine (9) months. The situation is more serious in Stretch-P2 (upstream from confluence of the Cojedes river).

4) Judging from the critical channel width, navigable months of the existing Portuguesa river were evaluated to be eight (8) months for St-P1 and St-P2, assuming that existing critical sections less than 1.0 % or only one section for calculation were navigable with minor improvement.

5.5 Channel Stabilization Measures for Navigation

5.5.1 Principles of Channel Stabilization

In order to improve channel capacity for navigation, two (2) principal measures were considered, i.e., (1) flow improvement to increase channel discharge and (2) channel improvement to provide enough channel section.

Various schemes for the flow and channel improvement were considered and schematically shown in Fig. 5.5.1. Efforts were made to incorporate ideas and schemes studied by PROA and other authorities concerned of MARNR in discussing the measures.

(1) Flow Improvement

There are several existing dams in the upstream reaches of the main Apure and Portuguesa rivers. Released water from reservoir for hydro-power generation would contribute to increase channel discharge in the dry season.

Some reservoir space which is not used effectively now also could be used to increase channel discharge. However, this measure may not be economically feasible and will realize only when the released water is used for multipurpose.

In order to utilize the river water effectively for navigation, derivation channel would be effective, leading the water to the upstream of critical sections. It would be more effective if the released water from hydro-power plant is combined with the derivation channel scheme.

(2) Channel Improvement

Various measures are conceivable for channel improvement:

1) Treatment of anabranches: By closing or controlling diversion of discharge into anabranch, discharge in the main channel could be increased and stabilized.

2) Normalization of alignment: In order to attain smooth navigation in the river, the critical bends would be normalized by realignment works or cut-off channels.

3) Improvement of channel section: In the stretches where channel depth and/or width are critical, channel improvement works to provide enough section for navigation would be required.

(3) Facilities and Works

Channel stabilization for fluvial navigation would include the following types of works:

1) Flow Improvement
   a) Dams: Use of released water from hydro-power plant
   b) Derivation channel works

2) Treatment of Anabranches
   a) Submerged dike works
   b) Closing dike works

3) Normalization of Alignment
   a) Realignment works of severe bend
   b) Cut-off channel works

4) Improvement of Channel Section
   a) Island treatment works
   b) Channel dredging works
   c) River training works
   d) Temporary canalization works

5) Bank protection

In this section, principles for plan and design of aforementioned works are discussed. The natural forces to shift the river course and to reform the channel section would be by far large comparing with the works to be implemented, and the available budget for the works are limited. It is essential to plan and design the works so as to harmonize with the behavior of the natural river as much as possible.

In order to harmonize with the natural river, characteristics and behavior of river should be first studied and investigated, and function of the facilities should be examined by hydraulic model tests and prototype tests in field.

Principles and preliminary ideas for facility design were presented in subsequent sub-sections. The facilities and works presented here are not definitive. They should be improved and developed based on the further studies, investigation, hydraulic model tests, and experience through actual works in field.

Details of the design principles of these facilities are presented in the Supporting Report; Part E.

5.5.2 Flow Improvement

(1) Component Schemes for Flow Improvement

<u>Dams</u>

New dams for navigation purpose were not considered because they clearly do not pay, but those constructed or proposed for other purposes were studied for navigation use of their released water.

Dams for the flow improvement study were selected from the dams constructed and under construction, considering the status of construction, size and location of dams as follows:

1) Dams for Uribante-Caparo project (Uribante-Caparo dams):
   a) La Honda dam : Existing
   b) Borde Seco dam : Under construction
   c) La Vueltosa dam : Under construction

2) Dams for Guanare-Masparro project (Guanare-Masparro dams):
   a) Bocono dam : Existing
   b) Masparro dam : Dam is existing but the power plant is not constructed yet

3) Dams of Cojedes river (Cojedes dams):
   a) Las Majaguas dam : Existing
   b) Las Palmas dam : Under construction

Derivation Channels

After reviewing the ideas and schemes prepared by PROA, the following three (3) derivation channels were taken up for the study:

1) Caparo-Uribante Viejo derivation channel: To lead water of the Caparo river to the Apure river at just downstream of Santos Luzardo port through the Uribante Viejo river.

2) Bocono-Masparro derivation channel: To lead water of the Bocono river to the Apure river at upstream of Nutrias port (Bruzual) through the Masparro river.

3) Cojedes-El Frasco derivation channel: To lead water of the Cojedes river to the main Portuguesa river at upstream of El Baul port

A trans-basin channel scheme to take Arauca water into the Apure river near Guasdualito is conceivable. However, this scheme was not considered, because the Arauca river is an international river and the realization of trans-basin may take long time and is difficult to take it into schedule.

Component Schemes

For the flow improvement, the following component schemes in combination with dams and derivation channels were considered for further study:

1) Upper Apure flow improvement scheme: A scheme consisting of Uribante Caparo dams and Caparo-Uribante Viejo derivation channel

2) Middle Apure flow improvement scheme: A scheme consisting of Guanare-Masparro dams and Bocono-Masparro derivation channel

3) Upper Portuguesa flow improvement scheme: A scheme consisting of Cojedes dams and Cojedes-El Frasco derivation channel

For respective flow improvement schemes, two stages, i.e., initial and final stages, were considered depending on the development stage of power generation and related projects. Major dimensions of dams for respective development stages are shown in Table 5.5.1. General location maps of derivation channels for study are shown in Figs. 5.5.2 through 5.5.4.

(2) Evaluation of Effects

The hydraulic effects for respective flow improvement measures are calculated and shown in Fig. 5.5.5 as examples for 7 and 12-month navigation.

The critical sections for channel depth were examined by flow calculations under various flow conditions. The results are shown in Fig. 5.5.6. In the figure, the critical sections were expressed by critical channel length assuming one critical section is equivalent to 150 m of critical channel length.

(3) Upper Apure Flow Improvement Scheme

The upper Apure flow improvement scheme principally depends on the released water from San Agaton power station of La Honda reservoir and La Vueltosa power station of Borde Seco/La Vueltosa reservoir, and Caparo Uribante Viejo derivation channel. The effect of existing San Agaton power station was considered to have already been incorporated in the flow records accordingly in the average flow duration.

Taking an example for 7-month navigation, the scheme contributes to reduce the critical length by 41.2 % in total at the initial stage and by 26.7 % at the final stage.

The effect is more effective in the stretch between the Suripa river confluence and the Uribante Viejo river confluence. This stretch includes one of the most critical stretches for navigation. This scheme will contribute to the improvement of navigation by one to two months for the upstream reaches of the Suripa river confluence, while for the downstream reaches by one month or less.

Similar effects could be expected under the final stage conditions, too.

(4) Middle Apure Flow Improvement Scheme

The middle Apure flow improvement scheme principally depends on the released water from Peña Larga hydro-electric station of Bocono-Tucupido reservoir and Masparro hydro-electric station. The effect of Peña Larga station was considered to have already been incorporated in the flow records.

The effects of this scheme are not much, reducing the critical channel length by 13.0 % in total, for example, for 7-month navigation at the initial stage. The effects will be very small for the final stage reducing the critical length only by 1.5 %. This comes from the increase of irrigation water to be taken from the released water for power generation. This situation indicates that the effect of flow improvement facilities such as Bocono-Masparro derivation channel would not be expected for flow improvement in future.

However, Bocono-Masparro derivation channel constructed for other purposes such as irrigation for effective use of Bocono-Tucupido reservoir could contribute to the flow improvement at the initial stage.

(5) Upper Portuguesa Flow Improvement Scheme

The Portuguesa has channel capacity for almost eight (8) month navigation. If it is intended to increase the navigation period more than nine (9) months, the river is critical over the whole stretch for width and radius of curvature. The situation is more serious in the upper Portuguesa river for about 34 km long from confluence of the Cojedes river to El Baul port.

In order to improve the navigation capacity of the Portuguesa river, the following measures could be considered solely or in combination:

1) Right dike of the upper Portuguesa river to prevent the spilling water into the Igües river

2) Cojedes-El Frasco derivation channel to lead water of the Cojedes river to the Portuguesa river at the upstream of El Baul port to increase low flow discharge

3) Channel improvement

The right dike scheme and the derivation channel scheme are for flow improvement and the channel improvement scheme will be adopted complementarily.

Right Dike of Upper Portuguesa River

The upper Portuguesa river has been silted up at the downstream of the confluence of the Acarigua river (Canal Piloto). Because of the channel siltation the flow of the upper Portuguesa river spills over and drained into the Igües river. The flow at El Baul port located downstream is decreasing.

Channel improvement works of the Acarigua river including the silted-up Portuguesa river are being studied and designed by PROA. Right dike of the upper Portuguesa river will prevent the Portuguesa river water from spilling and would function to maintain water and sediment flow properly.

Cojedes-El Frasco Derivation Channel

Cojedes-El Frasco derivation channel aims to lead a part of the Cojedes river water to the main Portuguesa river upstream of El Baul port. The existing drainage channel L-5 (Longitudinal 5) in Turen III South Project area could be used as the derivation channel. Construction of hydraulic control structure at the head of the derivation channel and connection channel with the Portuguesa river at the lower portion of the derivation channel would be necessary.

According to the preliminary study on Las Majaguas dam (existing) and Las Palmas dam (under construction), these dams have little effects for flow improvement for navigation in the Portuguesa river.

PROA is studying the Cojedes-El Frasco derivation channel.

5.5.3 Treatment of Anabranches

(1) Approach to Anabranch Treatment

Two (2) sites of large scale anabranches exist along the Apure river in the downstream and upstream reaches of San Fernando as follows:

1) Chirel/Apurito site: The site is located at the downstream of San Fernando, extending to about 90 km from San Fernando to La Maciera.

2) Bravo/Garzas site: The site is located at the upstream of San Fernando, extending to about 90 km from Apurito town to confluence of the Guanaparo river.

Channel discharge in the main Apure river could be stabilized and increased, by closing these anabranches or regulating diversion discharge into these anabranches. In order to close or regulate the anabranches, closing dike and submerged dike works are conceivable:

Influence of anabranch treatment will extend over a hundred kilometer along the river and the impacts to social and natural environment would be extensive. The existing anabranches have been formed as an integrated effects of water and sediment movements for long years. Treatment of anabranches therefore should be planned based on careful investigation and studies.

In planning the anabranch works, mechanism of water and sediment flow should be grasped through hydraulic and geomorphological investigation. Otherwise the proposed works may lose their function in a short period or may cause instability of river channels.

In the anabranch site, river channels are relatively stable, since the energy of river flow is divided into plural channels. When the river flow is gathered to the main Apure river, the behavior of river channel might be activated.

(2) Evaluation of Effects

Treatment of Chirel Site

According to preliminary studies, the following principles were set for the study of Chirel site:

1) Chirel river will be closed partially by submerged dike, if the diversion discharge into the Chirel river is increasing.
2) Boquerones river will be left as it is, since the channel seems to be stable.
3) Upper Apurito river will be left as it is, since it has been closed naturally.

Effects of partial closure of the Chirel river were evaluated and results are shown in Figs. 5.5.7 and 5.5.8.

In view of the above, flow improvement effects of the Chirel submerged dike is not much. However, it is said that the discharge of the main Apure is decreasing due to increase of diversion discharge into the Chirel river. If so, the Chirel submerged dike could function as consolidation works to stabilize the diversion of flow. The actual situation of discharge diversion and its historical changes are needed to be confirmed.

Treatment of Bravo/Garzas Site

According to preliminary studies, the following principles were set for the study of Bravo/Garzas site:

1) Bravo river will be closed partially by submerged dike.
2) Ca_afistolito and Rompida rivers will be closed completely by closing dikes.

3) Yeguas and Upper Garzas rivers will be left as they are, since they are closed naturally during dry season.
4) Apure Viejo river will be left as it is, since it has been closed by right dike.

Effect of partial closure of the Bravo river were studied and results are shown in Figs. 5.5.9 and 5.5.10.

In view of the above, flow improvement effects of the Bravo submerged dike could be expected. However, careful study and investigation are needed before the final decision.

(3) Submerged Dike Works

The submerged dike aims to stabilize and regulate the diversion flow into major anabranch during the low flow period. The dike should be designed satisfying the following conditions to maintain the existing functions of the anabranch:

1) The submerged dike should not affect much to the flood flow conditions in the main channel and the anabranch, so as not to cause radical changes of river channel and environmental conditions thereabout.

2) The submerged dike should be the fixed type weir which would not need any artificial operation.

3) The submerged dike should allow passage of rural boats between main channel and anabranch as much as possible even during the low flow period.

The submerged dike works shall consist of low fixed weir and navigation way provided with river bed consolidation works and revetment works.

(4) Closing Dike Works

The closing dike aims to close minor anabranch completely throughout the year. The closing dike principally consists of earth dike with slope protection works.

5.5.4 Normalization of Channel Alignment

Following works are planned at the critical sections to normalize the alignment, so as to alleviate severe bends and/or to shorten navigation length in meandering reaches:

1) Realignment works
2) Cut-off channel works

(1) Realignment Works

Realignment works aim to alleviate the curvature at the severe channel bends for smooth navigation operation.

The realignment works are planned at the severe bends in the main channel for navigation. For the selection of sites for realignment works, the following criteria are introduced:

1) The bends of which radius of curvature (Rc) are less than four (4) times of ship length (Ls) shall be subjected to the works. Applying this to the Apure and Portuguesa rivers, the sites which need realignment works are selected at the following severe bends:
   Rc < 560 m; for the Apure river
   Rc < 240 m; for the Portuguesa river

2) For immediate implementation as an urgent improvement:
   Rc < 320 m; for the Apure river
   Rc < 150 m; for the Portuguesa river

The realignment works generally include channel dredging/excavation works to enlarge the channel curvature and groyne works to guide the river flow to new channel.

(2) Cut-off Channel Works

The cut-off channel works aim to construct a new channel to shorten the navigation length and to avoid channel improvement works due to critical curvature, depth and width. Some cut-off channels aim to normalize the channel alignment.

The cut-off channel works generally include dredging/excavation works of new channel, closing dike works for the channel to be abandoned and earth dike works along the new channel. Groyne works and revetment works may also be needed to guide the river flow to new channel smoothly and safely.

5.5.5 Improvement of Channel Section

Following works are planned at the critical sections in order to secure the depth and width required for fluvial navigation:

1) Island treatment works
2) Channel dredging works
3) River training works
4) Temporary channel improvement works

(1) Island Treatment Works

Island treatment works are planned at the critical channel section where river channel is divided by the permanent island(s).

The island treatment works aim to increase and maintain the main channel depth for navigation closing the channel behind the island by closing dike or pile works.

The island treatment works include closing dike works for relatively small channels behind the island and pile works for larger channels. Groyne works may also be necessary to guide the river flow to the main channel.

(2) Channel Dredging Works

Channel dredging works aim to secure the channel section required for the navigation by mechanical measures. The effect of the works are very sure, but sometimes it may require repeated maintenance dredging works after every flood seasons. The channel dredging works are planned in the following critical sites:

1) Important navigation channel which requires urgent improvement
2) The site where other improvement measures are not applicable due to geological, technical and social reasons.
3) Local sites which require maintenance dredging works

The channel dredging works include dredging and spoil bank yard works. Groyne works may also be needed to guide the flow to the dredged channel.

(3) River Training Works

River training works are planned at the critical channel sections where river channel is braided with sand bars.

The river training works aim to train and stabilize the river course, and increase and maintain the channel depth for navigation by guiding the water flow and narrowing the low water channel by series of groynes. Generally staged approach would be necessary for the implementation monitoring the effect and would take time to realize the final results.

Series of groyne works should be considered for river training of the Apure and Portuguesa rivers. In order to develop effective training measures for the Apure and Portuguesa rivers, the trial and error approaches may be necessary to accumulate the experience by prototype and laboratory tests.

(4) Temporary Canalization Works

Temporary canalization works aim to improve sporadic and local critical sections as remedial measures. The works may be needed recurrently at the beginning of every dry seasons. For the channel with less navigation transport, the temporary canalization works may play more important role than the permanent works for economical reason.

Various measures have been proposed as the temporary canalization works. The major temporary canalization works are as follows:

1) Bandalls
2) Floating panels (surface panels)
3) Bottom panels

The effects of these works are not always definite. In order to Develop effective measures applicable to the Apure and Portuguesa rivers, the approach of trial and error may be necessary by laboratory and prototype tests.

5.5.6 Bank Protection

Due to lateral movement of river courses and local scour, towns and villages, farm lands, public roads, bridges and other river facilities such as dikes and groynes are suffering from damages.

In planning the measures to protect river bank from scouring due to flow, countermeasures should be discussed on the following principal measures and an appropriate measure should be selected in consideration of technical and economic viability:

1) Revetment works: To protect bank slope directly from scouring due to flow by covering the slope

2) Groyne works: To guide main river flow keeping away from the scouring river bank by a series of groynes.

3) Realignment works of river course: To realign river course away from the river bank to be protected, improving the existing channel alignment by realignment works or cut-off channel works which were presented in the foregoing section.

4) Relocation of facilities: To relocate facilities such as road and river facilities evacuating from the site suffering from scouring.

In this section, design principles of revetment works and groyne works were taken up for further discussion. These works are also expected to stabilize the river courses preventing lateral movement of river course. In addition to the above, vane array works to regulate lateral sediment movement are also introduced here.

(1) Revetment Works

Revetment works aim to protect the bank slope directly from scouring. The revetment works are planned for the river banks scoured due to attacking water flows, and river banks at the structure site such as weir and gate.

The revetment works generally consist of slope protection, sure-footing (foundation), and foot protection works.

Slope Protection Works

Slope protection works are the principal part of the revetment works, which prevent the bank slope from scouring due to water flow and damage due to floating materials such as logs.

There are various types of slope protection works as follows:

1) Stone and concrete block masonry (dry and wet types): For steeper bank slope of medium and small size rivers
2) Stone and concrete block pavement (dry and wet types)
3) Concrete flame pavement
4) Interconnected concrete block pavement: Commonly as temporary works
5) Gabion pavement: Commonly as temporary works

The types of slope protection shall be selected depending on the size of river, channel conditions, gradient of bank slope, kinds of soil, etc.

Back-fill gravel should be placed behind the surface covering as drain and filter to prevent the soil from washing away.

Sure-Footing (Foundation) Works

Sure-footing works are the foundation to support and stabilize the slope protection works. Type of sure-footing works is selected depending on the kind of foundation soil, working condition, and river conditions.

In case the foundation soil is firm and stable, the foundation would be placed directly on the river bed. If the foundation soil is poor, pile or sheet pile works would be adopted.

Foot Protection Works

Foot protection works should be provided for the revetment works in case the scouring may occur at the foot of revetment due to direct flow attack and other causes.

The foot protection works aims to stabilize the sure-footing works and accordingly the slope protection works by reducing flow velocity and preventing scouring at the foot of revetment. Failure of revetment works often occurs due to the failure of foundation. The roles of the foot protection works are very important.

The foot protection works shall be resistible to tractive force of flow, durable, and adjustable to the fluctuation of river bed. Therefore the foot protection works should provide with appropriate flexibility, roughness and weight.

Typical foot protection works are shown below. The works shall be selected depending on the characteristics and conditions of the river:

1) Pitching stone
2) Timber mattress
3) Stone basket
4) Concrete block
5) Deformed concrete block
6) Groynes

(2) Groyne Works

Groyne works are planned for bank protection and river training. The groyne works for the mild slope channel as the Apure and the Portuguesa rivers are discussed below.

The groyne works principally function as follows:

1) To decrease flow velocity near the bank increasing the friction against flow
2) To change flow direction and protect the site forming the wake zone of the groynes.

Type of the groyne shall be selected depending on the purpose in due consideration of alignment and cross-sectional features of river channel, discharge, water level, bed materials, river bed fluctuation, etc.

The groynes are classified into permeable and impermeable type, and overflow and non-overflow types. Effect of the impermeable type and non-overflow type groynes is large, but the force of flow acting on the groyne is also large. The acting force may cause bigger local scouring and damage the groyne structure itself.

In the mild slope rivers, permeable type groynes such as pile groyne and low impermeable type groyne are commonly adopted.

(3) Vane Array Works

The vane array works aims to alleviate local scouring at the meandering bends and shift the thalweg toward river center keeping some distance from the river bank.

The vane array works fall under the same category as bottom panel which had been put into practice since the end of 19th century. In 1980s Odgaard et al made studies based on the secondary flow theory in meandering section and used the term "vane".

Recently Fukuoka et al proposed design method of vane array works based on laboratory tests and prototype tests in actual river in Japan. The method could be applicable to the developed meandering bends of the Apure river, although the works implemented so far in field are still limited.

The vane array works consist of arrays of vanes installed on river bed. The vane is composed of cylindrical pile and vane of trapezoidal shape.

The height of vane shall be 1/4 to 1/3 of average channel depth, and the depth of vane to be penetrated into ground shall be determined based on the scouring around the vane and its stability under ordinary and flood flow conditions.

The vane array shall be located keeping distance by 1/5 to 1/4 of river width from outer river bank.

5.6 Formulation of Channel Stabilization Plan

5.6.1 Principles

Based on the discussions made in the foregoing subsection, the following principles for the formulation of channel stabilization plan were derived:

1) Upper Apure flow improvement: Caparo-Uribante Viejo derivation channel will be taken up. Works related to dams will not be included, since new dams are not proposed but the released water from the power generation will be used.

2) Middle Apure flow improvement: Bocono-Masparro derivation channel scheme will be discarded, since its hydraulic effects are low in the initial stage, and moreover, it will get lower in future due to the increase of irrigation water demand.

3) Upper Portuguesa flow improvement: Right dike of the upper Portuguesa river will be taken up within a framework of flood management plan. The Cojedes-El Frasco derivation channel will not be considered for the present study, but might be incorporated in future for enhancement of navigation capacity based on the navigation master plan after examining the economic viability. Therefore, channel improvement works will be the principal measures for the Portuguesa river for the time being.

4) Treatment of anabranches at Chirel site and Bravo/Garzas site will be taken up for the plan, since the treatment of Chirel site would be effective for stabilization of the bifurcation, and the treatment of Bravo/Garzas site would also be effective for flow improvement of the main Apure river. These measures, however, needs further studies and investigation on channels, facilities and environment.

5) Normalization of channel alignment: Realignment and cut-off channel will be the principal measures for the section of critical radius of curvature in the meandering reaches.

6) Improvement of channel section: The island treatment and channel dredging would be the principal measures. The other improvement works of channel section such as river training and temporary works are expected to be adopted gradually depending on the progress of development of measures, accumulating the technology and experience through hydraulic model tests in laboratory and prototype tests in the Apure river.

5.6.2 Project Works

Three (3) stages of plans were considered for the channel stabilization plan, i.e., short-term plan, mid-term plan and long-term plan.

The short-term plan aims to accomplish the following physical target:

1) Apure river: To attain eight (8) month navigation from river mouth to San Fernando port (St-A1) and seven (7) month navigation from San Fernando port to Santos Luzardo port (St-A2, A3 and A4).

2) Portuguesa river: To attain eight (8) month navigation from San Fernando port to El Baul port (St-A2, P1 and P2).

The short-term plan includes the following works:

1) Derivation channel works: Caparo-Uribante Viejo derivation channel with water release of La Vueltosa power station at the initial development stage.
2) Anabranch treatment works: Chirel site and Bravo/Garzas site
3) Alignment normalization works: For critical bends with Rc<320 m for the Apure river and Rc<150 m for the Portuguesa river
4) Channel section improvement works: For 8 month navigation for St-A1, A2, P1 and P2, and 7 month navigation for St-A3 and A4.

The mid-term plan aims to accomplish the following physical target:

1) Apure river: To attain nine (9) month navigation from river mouth to San Fernando port (St-A1) and eight (8) month navigation from San Fernando port to Santos Luzardo port (St-A2, A3 and A4).
2) Portuguesa river: To attain nine (9) month navigation from San Fernando port to El Baul port (St-A2, P1 and P2).

The mid-term plan includes the following works:

1) Flow improvement by Caparo-Uribante Viejo derivation channel with water release of La Vueltosa power station at the final development stage.
2) Alignment normalization works: For critical bends with Rc<560 m for the Apure river and Rc<240 m for the Portuguesa river.
3) Channel section improvement works: For 9 month navigation for St-A1, A2, P1 and P2, and 8 month navigation for St-A3 and A4.

Physical target of the long-term plan shall be discussed in line with the navigation master plan to be prepared. The channel works to realize the physical target of the long-term plan would be principally the channel section improvement works.

The above physical targets of staged plans were set in consideration of the existing navigable months and the limit of channel improvement works at the present stage. The limit of channel improvement works was assumed to be 10 % of the total channel length, and is considered to be the physical target of the mid-term plan. The physical target of the short-term plan was set in-between as an immediate works.

Critical sections and countermeasures of respective staged plans were summarized and shown in Fig. 5.6.1 for the Apure river and in Fig. 5.6.2 for the Portuguesa river.

5.6.3 Cost Estimate

Project cost was estimated at the price level of February 1993. Currency of the project cost was expressed in US$ by using the prevailing exchange rate in February, 1993 as follows:

US$1 = Bs.82 = ¥119.72; Bs.1 = ¥1.46

Project cost estimated for the short-term and mid-term plans are shown below in brief. Detail of the cost estimate is described in the Supporting Report; Part-G.

Work Item	Short-term Plan (US$1,000)	Mid-term Plan (US$1,000)	STP+MTP (US$1,000)
1) Construction cost	40,013	55,576	95,589
a) Preparatory works	3,737	5,053	8,690
b) Derivation channel	3,020	0	3,020
c) Anabranch treatment	1,029	0	1,029
d) Alignment normalization	20,941	27,813	48,754
e) Channel section improvement	10,326	21,239	31,565
f) Miscellaneous works	1,060	1,471	2,531
2) Land acquisition	5	2	7
3) Administration cost	2,001	2,780	4,781
4) Engineering services cost	6,803	9,448	16,251
5) Physical contingency	4,883	6,781	11,664
6) Total	53,705	74,587	128,293

5.6.4 Economic Consideration

The fluvial navigation has the advantages of the low-cost and massive load transportation. The benefit of fluvial navigation is to be estimated mainly for the transportation cost reduction, in comparison with the land transportation, for the extended navigation period by the channel stabilization works.

The effect of channel stabilization plan shall be evaluated in accordance with the navigation master plan, because the channel stabilization plan would be a part program of the master plan.

In this section some preliminary economic considerations on the channel stabilization plan were made based on cargo and transportation cost data prepared provisionally by PROA. Detailed discussions on the economic aspects are presented in the Supporting Report; Part H.

According to the preliminary evaluation, economic viability of the short-term plan and mid-term plan are as follows:

Plan	EIRR (%)	B/C	B-C (US$1,000)
Short-term Plan	17.7	1.72	38,677
Mid-term Plan (STP+MTP)	13.7	1.46	46,666

Remarks : B/C and B-C were estimated under the discount rate of 8%/yr.

5.6.5 Environmental Considerations

The study area for the channel stabilization plan cover the stretch of the main Apure river from confluence with the Orinoco river to Santos Luzardo port, and the Portuguesa river from confluence with the Apure river to El Baul port.

The channel stabilization for navigation would be attained by channel improvement and flow improvement. The channel improvement includes works of anabranch treatment, alignment normalization, channel section improvement, and bank protection.

The following changes in river and surrounding areas would be more or less brought about from the implementation of the channel stabilization works.

Changes in river flow due to derivation channel and anabranch treatment works:

1) Flow will cease in the channel abandoned by the closing dike.
2) Flow will be controlled to be low in the source river downstream of the derivation channel and the anabranch downstream of the submerged dike.
3) Flow will increase in the main Apure river downstream of confluence of the derivation channel and bifurcation of anabranch.

Changes in river bank due to river training and bank protection works:

4) River bank during dry season may shift toward river center because of sedimentation in the wake zones of groynes.
5) River bank will be covered by the slope protection works.

Changes in river bed and river bank conditions due to channel dredging and disposal:

6) River bed will be lowered and agitated by river dredging works.
7) Lowlying lands in the river bank will be filled up by dredged materials.

Among the above changes due to the channel stabilization works, items 1), 2) and 7) are more important. Other items would give minor impact to the environment, since the works are of small scale and sporadic.

Regarding items 1), 2) and 7), further intensive study and investigation would be necessary at the design stage on the following aspects, but not limited to:

1) Existing water use
2) Existing ecological condition
3) Identification of objects to be conserved

Based on the study and investigation, the plan and design should be revised, if necessary, to conserve the ecological system and/or to compensate the right of resident people.

VI. STUDY ON FLOOD MANAGEMENT PLAN

6.1 General

According to the Scope of Work stipulated in the agreement between JICA and MARNR, the area subject to the present flood management study is 22,200 km^2 bounded by the Apure river in south, Portuguesa river in north and east and Masparro river in west as shown in Fig. 6.1.1.

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 mostly 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.

Detail of the study on flood management is described in the Supporting Report: Part-F.

6.2 Present Conditions of the Study Area

6.2.1 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, but not at river level. Among the studies, the study on excess water in western llanos (flat land) provides precise data for the present flood management study.

According to the study reports published so far, the hydraulic characteristics of the study area will be outlined by the following data.

1) Habitual inundation area
2) Behavior of surface water
3) Flow characteristics of rivers in and around the study area
4) Possibility of solution of drainage problems
5) Present discharge capacities of rivers in and around the study area

The habitual inundation area is shown in Fig. 6.2.1 and it is classified into three categories depending on the cause. The total inundation area comes to 11,200 km^2 which corresponds to 53 % of the study area. The inundation caused by flooding of rivers is distributed along the Portuguesa, Guanare and Apure rivers which are major rivers in the study area.

Fig. 6.2.2 shows flow directions of the surface water in the study area. They are largely divided into three groups of northwest to southeast, west to east and northwest to southwest by direction. Major overflow points are observed in the river reaches between Guanarito and Arismendi on the Guanare river and a little downstream from Bruzual in the Apure river.

Fig. 6.2.3 shows the flow characteristics of the rivers in the Portuguesa and Guanare river basins including the study area. Both rivers are hydrologically influenced by runoff from upstream of mountain areas up to their middle reaches. On the other hand, their downstream reaches are hydraulically influenced by confluence of tributaries.

Fig. 6.2.4 shows classification of possibility of solution of drainage problems in the study area. The possibilities are classified into three categories of possibility, low possibility and almost no possibility. The areas of low and almost no possibilities occupy a half of the study area. The areas with possibility are distributed in upper and middle basins and partly on the left bank area of the Apure river, while most of the lower basins have almost no possibility of solution of drainage problems.

Fig. 6.2.5 shows present discharge capacities of the rivers in the study area and adjacent basins. They are estimated based on the observed discharge measurement data. The 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 other rivers, but it is still small for its catchment area.

6.2.2 Existing Flood Management/Control Plans and Facilities

No overall flood management/control plan for the study area has been prepared yet. Existing and proposed flood control facilities are as follows.

(1) River Dikes

1) Existing river dikes

By the present, seven (7) river dikes shown in Fig. 6.2.6 have been constructed in parallel with the river courses.

2) Proposed river dike

A railway project to pass on the right bank of Portuguesa river is planned as shown in Fig. 6.2.6. In order to protect the railway from flooding of Portuguesa river, a dike is planned on the river side along the railway.

(2) Dams

1) Existing dams

In the upstream of the study area, seven (7) dams have been constructed so far. Their locations and principal features are shown in Fig. 6.2.7 and Table 6.2.1, respectively.

2) Proposed dams

Other than the existing dams mentioned above, several dams are under study in the Portuguesa river basin. Among them, two (2) dams shown in Fig. 6.2.7 and Table 6.2.1 are proposed for implementation.

(3) Floodway and Diversion Channel

1) Existing floodway

A floodway from the Portuguesa river to the Apurito river exists at Hato Gorrin 6 km north from San Fernando as shown in Fig. 6.2.8 crossing Camaguan-San Fernando 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.

2) Proposed diversion channel

A diversion channel is proposed at Sombrerito about 3 km north from the existing diversion channel as shown in Fig. 6.2.8. This channel has a width of 400 m and low water channel of 60 m wide, but it is narrowed by bridge of 85 m long. The length is 18 km and design discharge is 440 m^3/s for 50-year probable flood.

6.2.3 Existing and Proposed Projects

(1) Existing Project

The land use in the study area is limited at present due to inundation and drainage problems. Only Guanare-Masparro agricultural development project is on-going in the area. The project site is naturally situated in the higher part of the area as shown in Fig. 6.2.9.

(2) Proposed Project

There are two proposed projects. One is extension of the Guanare-Masparro Project under consideration and the other is a railway project mentioned before, which is scheduled to be implemented near future. They are shown in Figs. 6.2.9 and 6.2.6, respectively.

6.2.4 Existing Land Use Plan

As existing land use plan, zoning plans of Barinas, Portuguesa and Cojedes states prepared by MARNR shown in Fig. 6.2.9 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 of high, medium and low priorities.

On the other hand, flood plain occupies 27 % of the study area (about 5,700 km^2) and the areas without any assignment of land use 29 % of the study area (about 6,000 km^2).

6.3 Basic Concept for Flood Management Planning

6.3.1 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.

6.3.2 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 managemant plan

6.3.3 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.

Consequently, the following four (4) areas shown in Fig. 6.3.1 were selected as protection area.

1) Area "A" : Area extending on the right bank side of Caño Igüés
2) Area "B" : Area extending on the right bank side of Guanare river
3) Area "C" : Area extending on the left bank side of Apure river
4) Area "D" : San Fernando city and its surrounding area

Area "D" is selected for the reason that the flood management works for Areas "A", "B" and "C" in the upstream may influence to the area and therefore increase of safety degree against flood will be necessary to protect San Fernando city from flood.

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

6.3.4 Design Scale of the Plan

As mentioned before, most of the study area are suffering from inundation and drainage problems. According to the zoning plan 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 large size flood control facilities and the project proposed will be costly.

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.

6.3.5 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 section.

6.4 Formulation of Flood Management Plan

6.4.1 Preliminary Study for Planning

(1) Probable Discharge Distribution

The probable 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. 6.4.1 to 6.4.3 for the following three conditions.

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

(2) Water Balance in Apure River Basin

The water balance in Apure river basin is roughly estimated as shown in Fig. 6.4.4 referring to runoff in 1976 and 1981.

The inflow to the study area from the upper Portuguesa river basin is about $20x10^9$ m^3 and rainfall amount in the pond area is $51x10^9$ m^3 in 1981. In the pond model area, 70 % of the inflow including rainfall is discharged from Apure river through San Fernando funnel and remaining 30 % is loosed as evapotranspiration, etc. in the area.

(3) 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. 6.4.5. The peak runoff 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.

(4) Effect of Dams

As shown in the probable peak discharge distributions shown in Figs. 6.4.1 to 6.4.2, 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. 6.2.2.

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 x 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 $165x10^6$ 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 $279x10^6$ 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.

(5) 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. 6.4.6. Maximum water depth is 1.4 m. Interval of transversal dike is 8 km. The ground slope is calculated at 1/3,000 to 1/4,000.

Table 6.4.1 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. 6.4.7. This limitation in ground slope makes the Apure type module not applicable in some areas.

(6) Possibility of 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.

6.4.2 Formulation of Alternative Plans

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.

(1) Protection Area "A"

Basic consideration is made as follows:

1) Possible measures to protect Area "A" (see Fig. 6.3.1) 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.

Based on the basic consideration, the following three (3) alternative plans shown in Fig. 6.4.9 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)

(2) Protection Area "B"

Basic consideration is made as follows:

1) Possible measures to protect Area "B" (see Fig. 6.3.1) 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.

Based on the basic consideration, the following three (3) alternative plans shown in Fig. 6.4.10 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)

(3) Protection Area "C"

Basic consideration is made as follows:

1) Possible measures to protect Area "C" (see Fig. 6.3.1) 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) The area has much less human intervention than Areas "A" and "B" and therefore environmental considerations such as conservation of wetlands, etc. is also important.

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

5) 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.

6) These alternative plans should be evaluated after more detailed hydraulic, geomorphologic and environmental studies to confirm feasibility of the dike on the left bank of the Apure river were completed. If the dike is not feasible, then the Apure type module should be applied.

Based on the basic consideration, the following three (3) alternative plans shown in Fig. 6.4.11 are formulated.

1) Plan C1: Dike on the left bank of Apure river from Puerto Nutrias to Samanal (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 areas other than wetlands subject to environmental conservation

(4) Protection Area "D"

Basic consideration is made as follows:

1) The purpose of the flood management for Area "D" (see Fig. 6.3.1) is to increase safety degree against flood to cope with flood management for Areas "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.

Based on the basic consideration, the following two (2) alternative plans shown in Fig. 6.4.12 are formulated.

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

This plan is divided into the following three (3) 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. 6.4.7)
- Natural retarding basin : Remaining present flood plain

(5) Whole Area

The proposed flood management plan is subject to the whole study area and it will be of integration of the component 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.

6.4.3 Study on Alternative Plans

(1) Hydraulic Study

Effects and influences of respective alternative plans are hydraulically studied by the pond model method. The alternative plans to be studied are listed in Table. 6.4.2.

Table 6.4.3 presents the maximum inundation depth by block and difference from present conditions. Major changes of inundations by plans are summarized in Table 6.4.4.

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

Plan A1 rises the inundation depth on the left bank area for about 40 ~ 50 cm.

Plan B1, B2A and B2B have almost same results. Effects of dike and improvement of existing channel are 5 cm and 2 ~ 5 cm, respectively.

Plan C1 and C2 have almost same results. They increase inundation depth in the area around confluence of Caño Guaritico at about 60 cm.

Plan D1A and D1B have small effect of 10 ~ 20 cm for lowering water level of the Apure river at San Fernando. Plan D2 decreases the inundation depth in the Apure depression area at about 10 cm.

(2) Plans Proposed for Respective Protection 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) Area "A"

Among the alternative plans, Plan A1 was selected by the reasons mentioned below.

- Plans A2 and A3 have smaller increase of inundation depth on the left bank of the Portuguesa river than Plan A1, but they reversely much decrease the protectable area (about 30%), that is, the benefit.

- 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. 6.2.1) 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. 6.4.13.

2) 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 2 cm against Plan B1 and Plan B2B by 5 cm. On the other hand, costs of Plans B2A and B2B are about 2 to 3 times of Plan B1.

- 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. 6.2.1 there are existing roads of about 130 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. 6.4.13.

3) 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. 6.4.19, 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 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 300 m^3/s at maximum for 50-yr return period).

- Plan C1 can cover the whole area by a dike length of 155 km, but Plan C2 covers 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. 6.4.14.

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 Area "C" by the Apure type module.

4) 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. 6.4.20). 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.

6.4.4. Environmental Consideration

The plan for each protection area is proposed in the previous section 6.4.3 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 vegitation 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 Guatirico Wildife Refuge ia 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.

6.4.5 Proposed Flood Management 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. 6.4.21.

Plan A1 for Area "A" (Dike for Portuguesa river)
Plan B1 for Area "B" (Dike for Guanare river)
Plan C1 or Plan 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 6.4.3 and Figs. 6.4.22 and 6.4.23.

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.

6.4.6 Preliminary Facility Design

(1) Cross Section of Dike

Typical cross section of the river dike is shown in Fig. 6.4.24, 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.

(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. 6.4.25.

(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. 6.4.25.

(4) Borrow Pit of Enbankment 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 shown in Fig. 6.4.25 is proposed on the river side for fish and animals as well as the borrow pit said above.

6.4.7 Cost Estimate

The project cost of the proposed flood management plan is estimated by using the prevailing exchange rate in February, 1993 as follows:

US$1 = Bs.82 = ¥119.72; Bs.1 = ¥1.46

The project cost estimated is presented below.

Work Item	Plan A1 (US$1,000)	Plan B1 (US$1,000)	Plan C1 (US$1,000)	Overall (US$1,000)
1) Construction cost	25,312	18,916	25,284	69,512
a) Preparatory works	2,240	1,674	2,238	6,152
b) Foundation excavation	960	740	790	2,490
c) Dike embankment	19,400	14,500	19,925	53,825
d) Vegetation cover	1,240	900	1,060	3,200
e) Sluiceway	800	600	600	2,000
f) Miscellaneous works	672	502	671	1,845
2) Land acquisition	187	145	155	487
3) Administration cost	1,275	953	1,272	3,500
4) Engineering services cost	4,303	3,216	4,298	11,817
5) Physical contingency	3,108	2,323	3,101	8,532
6) Total	34,185	25,553	34,110	93,848

Also, the costs of other alternative plans are roughly estimated as presented in Table 6.4.5. The cost of Plan C3 was not estimated because the locations subject to protection have not been decided yet.

6.4.8 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 A1.

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

VII. FORMULATION OF MASTER PLAN

7.1 Arrangement of Plans

The Study on Comprehensive Improvement of the Apure River Basin includes two component plans, i.e., channel stabilization and flood management plans. These two component plans had better to be treated independently by the following reasons:

1) Different objectives: The channel stabilization plan aims at improvement of fluvial navigation in river channel, and the flood management plan aims at management of flood water in some part of the basin. Project area and type of works are also different, and implementing agency of the works would be different.

2) Different problems: Problem of the channel stabilization for navigation is mainly the shortage of channel sections in dry season, while problem of the flood management is mainly the flood water in rainy season. Problems take place in different seasons.

3) Different basis of planning: The channel stabilization plan was discussed under the conditions without navigation master plan, which made difficult the study on appropriate project size, implementation schedule and project evaluation. On the other hand, the flood management plan was discussed based on the zoning plan, etc. in which areas to be protected from flooding and areas to be preserved were identified. Due to the difference of the basis and circumstances, contents of these two plans are not always at the same level.

Although channel stabilization plan and flood management plan are treated independently, adjustment should be made, if required, between the two.

The influence of the channel stabilization to the flood management plan is not substantial. Derivation channel and anabranch treatment works are designed principally so as not to give radical changes to the flood flows.

The influence of the flood management to the channel stabilization plan is also not substantial. The flood management will not intend to make substantial drainage of inundation water and widening of river channel. Therefore the works would not affect the runoff in dry season.

7.2 Channel Stabilization Plan

7.2.1 General

Implementation program for the channel stabilization plan was discussed here. However, since the navigation master plan is not prepared yet, discussions on appropriate project size, implementation schedule and project evaluation are difficult to made. Therefore the programs discussed here are preliminary level and should be reviewed and revised so as to comply with the navigation master plan after its preparation.

The channel stabilization plan is composed of three (3) staged plans, i.e., short-term plan, mid-term plan, and long-term plan.

The proposed plans are in line with the principles and policies of the Ministry, since component schemes of the plan are mostly based on the ideas and schemes prepared by PROA and other authorities concerned.

7.2.2 Short-Term Plan

(1) Physical Target

Physical target of the short-term plan is to accomplish the following navigable months for immediate implementation:

1) Apure river: To attain eight (8) month navigation from river mouth to San Fernando port (St-A1) and seven (7) month navigation from San Fernando port to Santos Luzardo port (St-A2, A3 and A4).

2) Portuguesa river: To attain eight (8) month navigation from San Fernando to El Baul port (St-A2, P1 and P2).

(2) Improvement Works

1) Derivation Channel Works: Caparo-Uribante Viejo derivation channel with water release of La Vueltosa power station at the initial development stage.

2) Anabranch Treatment Works:
   a) Chirel site: Submerged dike across the Chirel river
   b) Bravo/Garzas site: Submerged dike across the Bravo river and closing dikes across the Rompida and Ca_afistolito rivers.

3) Alignment Normalization Works:
   a) Apure river: For the critical bends with radius of curvature (Rc)<320 m
   b) Portuguesa river: For the critical bends with Rc<150 m

4) Channel Section Improvement Works:
   a) St-A1 : For 8 month navigation
   b) St-A2 : For 8 month navigation
   c) St-A3 : For 7 month navigation
   d) St-A4 : For 7 month navigation
   e) St-P1 : For 8 month navigation
   f) St-P2 : For 8 month navigation

7.2.3 Mid-Term Plan

(1) Physical Target

Physical target of the mid-term plan is to accomplish the following navigable months by full employment of existing schemes and measures:

1) To attain nine (9) month navigation from river mouth to San Fernando port (St-A1) and eight (8) month navigation for the Apure river from San Fernando port to Santos Luzardo port (St-A2, A3 and A4).

2) To attain nine (9) month navigation from San Fernando to El Baul port (St-A2, P1 and P2).

(2) Improvement Works

1) Derivation Channel Works: No work was considered, but Caparo-Uribante Viejo derivation channel with water release of La Vueltosa power station at the final development stage.

2) Alignment Normalization Works:
   a) Apure river: For the critical bands with radius of curvature (Rc)<560 m
   b) Portuguesa river: for the critical bends with Rc<240 m

3) Channel Section Improvement Works:
   a) St-A1 : For 9 month navigation
   b) St-A2 : For 9 month navigation
   c) St-A3 : For 8 month navigation
   d) St-A4 : For 8 month navigation
   e) St-P1 : For 9 month navigation
   f) St-P2 : For 9 month navigation

7.2.4 Long-Term Plan

Physical target of the long-term plan shall be discussed in line with navigation master plan. Improvement works for the long-term plan will be mostly the channel section improvement works.

7.3 Flood Management Plan

7.3.1 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. Futher, order of implementation of each component plans is determined taking into account socio-economic, environmental and engineering aspects.

7.3.2 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 module (some specific locations)

According to the information, railway project mentioned before is scheduled to be implemented in the 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 modules

7.3.3 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). 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.

7.4 Implementation Schedule

The implementation schedule for the channel stabilization plan and flood management plan is shown in Fig. 7.4.1. Some descriptions are given below on the implementation of the plans.

(1) Channel Stabilization plan

The short-term plan shall be implemented first and then the mid-term plan depending on the increase of the cargo to be transported and the economic viability. The implementation schedule shown in Fig. 7.4.1 is tentatively proposed and shall be revised in line with the navigation master plan. The sequence of project works would be as follows:

1) Project Preparation: 1st to 5th year

a) Navigation master plan study
b) Feasibility study
c) Financing

2) Short-Term Plan: 1st to 7th year

a) Preparation: 1st to 2nd year
b) Detailed design: 1st to 2nd year
c) Construction works: 3rd to 7th year
- Urgent channel works : St-A4 for 6 month navigation
- Channel works : St-A1
- Channel works : St-A2, P1 and P2
- Anabranch treatment work: Chirel site and Bravo/Garzas site
- Channel works : St-A3
- Channel works : St-A4
- Caparo-Uribante Viejo derivation channel

3) Mid-Term Plan: 6th to 17th year

a) Preparation: 6th to 7th year
b) Detailed design: 6th to 7th year
c) Construction works: 8th to 17th year
- Channel works : St-A1
- Channel works : St-A2, P1 and P2
- Channel works : St-A3
- Channel works : St-A4

4) Long-Term Plan: Not scheduled (After 18th year)

(2) Flood Management Plan

The short-term plan shall be implemented first and then the long-term plan. The implementation schedule shown in Fig. 7.4.1 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 modules (some specific locations): 17th to 20th year

VIII. CONCLUSION AND RECOMMENDATION

8.1 Channel Stabilization Plan

8.1.1 Conclusion

1) Considering the expected quantity of cargo, radical channel improvement over the entire stretch would not be practical from the economic standpoint. Channel improvement for navigation for the Apure and Portuguesa rivers should be planned and designed considering the characteristics of the existing river to the maximum extent.

2) Shortage of water depth is the principal problem for the fluvial navigation of the Apure river. Navigable months of the Apure river were evaluated to be 8 months for downstream reaches of San Fernando and 6 months for the upstream reaches. As for the Portuguesa river, the shortage of channel width and curvature are the principal problems. Navigable months of the existing Portuguesa river were evaluated to be eight (8) months for downstream reaches of the Cojedes river junction and seven (7) months for the upstream reaches.

3) Three (3) stages of plans were considered for the channel stabilization plan for the fluvial navigation, i.e., short-term plan, mid-term plan and long-term plan. Physical targets of staged plans were set as follows:

   a) Short-term plan: Eight (8) months navigation for the stretches from Orinoco river via San Fernando port upto El Baul port and seven (7) months navigation for the stretches from San Fernando port via Nutrias port upto Santos Luzardo port.

   b) Mid-term plan: Navigable months will be enhanced by one (1) month from the short-term plan for respective stretches. The plan requires the channel improvement of about 10% of the total length.

   c) Long-term plan were not discussed in detail.

4) The plan was evaluated economically to be viable according to the preliminary study.

8.1.2 Recommendation

For further studies on the prepared channel stabilization plan, the followings are recommended:

1) To implement study on navigation master plan as soon as possible. The master plan will be the basis of all the activities related to the fluvial navigation including channel stabilization. The review of economic viability and implementation program should be included in the study on the navigation master plan.

2) To conduct further geomorphologic and hydraulic studies on the channel stabilization measures, especially for the derivation channel works and anabranch treatment works.

3) To develop channel improvement measures applicable to the Apure and Portuguesa rivers by means of hydraulic model tests in laboratory and prototype tests in field.

8.2 Flood Management Plan

8.2.1 Conclusion

The proposed flood management plan consists of dike on the right bank of Portuguesa river for Area "A", dike on the right bank of Guanare river for Area "B" and dike on the left bank of Apure river or Apure type module (some specific locations) for Area "C". According to the economic evaluation except the Apure type module, economic viabilities of dike plans for Areas "A" and "B" are sufficient, while that of dike plan for Area "C" is relatively low.

Therefore, it is concluded that the dike constructions for Portuguesa river and Guanare river may proceed to further study paying much attention to the environmental aspect. However, as the flood control and management are closely related to lives of peoples living there, implementation of the flood control and management works cannot be decided from the economic viewpoint only. The flood management in Area "C" should be planned based on more detailed environmental investigation and impact study, so that dike construction on the left bank should be evaluated from the environmental aspect before its construction.

8.2.2 Recommendation

For the further study on the proposed flood management plan, the followings are recommended.

1) To systematically accumulate basic data and information such as those on the hydrology, hydraulics, topography, geology, geomorphology, etc.

2) To establish more concrete regional development plan of the subject area and basin plan of the subject basin taking into account environmental aspect.

3) To conform the flood management and control plans to the said regional development and basin plan.

TABLES

Table 1.4.1 LIST OF PERSONNEL FOR STUDY (1/3)

I. STUDY TEAM MEMBERS

1.	Yoichi Takeuchi	Team Leader
2.	Noboru Jitsuhiro	River Engineer (Channel Stabilization)
3.	Hirofumi Sadamura	River Engineer (Flood Management)
4.	Yasuhiko Kato	Hydraulic Engineer
5.	Kazumi Yonemori	Hydrologist
6.	Atutoshi Sakata	Geomorphologist
7.	Luis Rosado	Agronomist/Land Use Specialist
8.	Carlos Rivero	Environmentalist
9.	Noritoshi Maehara	Institution/Socio-economist
10.	Eiichiro Seki	Construction Planner/Cost Estimater
11.	Akira Nakanishi	Chief Geodetic Engineer
12.	Kenji Torimae	Senior Geodetic Engineer
13.	Mituo Saito	Geodetic Engineer
14.	Masashi Suzuki	Geodetic Engineer
15.	Yukiyoshi Fujita	Geodetic Engineer
16.	Muneaki Wakita	Civil Engineer

II. COUNTERPART PERSONNEL

A. Coodination

1.	Arq. Carmen M. Delgado Z.	Director General of Program Orinoco-Apure (PROA)
2.	Ing. Juan J. Garcia	Director of National Hydraulic Laboratory (LNH)
3.	Ing. Jesus Silva	PROA
4.	Ing. Oscar Mirabal	Technical Coordinator, PROA

B. Group of River Channel Stabilization Study

1.	Ing. Jesus Silva	PROA
2.	Ing. Rafael Montilla	PROA
3.	Ing. Francisco Milazzo	LNH
4.	Ing. Luis Garcia	PROA
5.	Ing. Roberto Pascal	DEP

Table 1.4.1 LIST OF PERSONNEL FOR STUDY (2/3)

C. Group of Flood Management Study

1.	Ing. Haydee Canas	POA
2.	Ing. Noel Javier	DPC
3.	Ing. Esther Molina	POA
4.	Ing. Silvia Rojas	DEP
5.	Ing. Edgardo Ruiz	PROA
6.	Ing. Aurelio Trujillo	DPC
7.	Lic. Marcos Campos	PROFAUNA

D. Group of Hydrological Study

1.	Ing. Luis Velasquez	PROA
2.	Ing. William Andrade	PROA
3.	Ing. Carlos Corrales	LNH
4.	Ing. Manuel Fuentes	LNH
5.	Ing. David Perez Hernandez	DHM

E. Group of Survey and Investigation

1.	Ing. William Andrade	PROA
2.	Ing. Luis Velasquez	PROA
3.	Ing. Manuel Fuentes	LNH
4.	Ing. Carlos Corrales	LNH
5.	Ing. Edgardo Ruiz	PROA
6.	Ing. Caoilda Raminez	PROA

III. ADVISORY COMMITTEE MEMBERS OF JICA

1.	Motoo FUJIYOSHI	Chairman Senior Officer for Integrated River Information, River Bureau, Ministry of Construction

Table 1.4.1 LIST OF PERSONNEL FOR STUDY (3/3)

2. Yoshikuni KAWASE	Flood Management Planning
	Deputy Director, Flood Control Division, River Bureau, Ministry of Construction
3. Koh-ichi FUJITA	RiverChannel Planning
	Senior Researcher, River Hydraulics Division, River Department, Public Works Research Institute, Ministry of Construction

Table 3.2.1 LIST OF MATERIAL INVESTIGATION SITES

Site		River Bed Materials	Bore Hole Drilling	Test Pit
1)	Apure River :			
a)	Puente Remolino	M-1	P-1	TP-1
b)	Totumito	M-2	P-2	TP-2
c)	Palmarito	M-3	P-3	TP-3
d)	Suripa	M-4	P-4	TP-4
e)	San Vicente	M-5	P-5	TP-5
f)	Bruzual	M-6	P-6	TP-6
g)	El Saman	M-7	P-7	TP-7
h)	Apurito	M-8	P-8	TP-8
i)	San Fernando	M-9	P-9	TP-9
j)	Arichuna	M-10	P-10	TP-10
	(Sub-total)	(10)	(10)	(10)
2)	Portuguesa River :			
a)	Paso la Portuguesa	M-11	-	-
b)	El Baul (Cojedes river)	M-12	P-11	TP-11
c)	Guadarrama	M-13	-	-
d)	El Socorro	-	P-12	TP-12
e)	La Union	M-14	-	-
f)	Camaguan	M-15	P-13	TP-13
g)	Arismendi (Guanare river)	M-16	-	-
	(Sub-total)	(6)	(3)	(3)
3)	Tributaries at Crossing of Main Road Route-13 and Route-5:			
a)	Verde River	M-17	-	-
b)	Pao River	M-18	-	-
c)	Tinaco River	M-19	-	-
d)	San Carlos River	M-20	-	-
e)	Cojedes River	M-21	-	-
f)	Acarigua river	M-22	-	-
g)	Portuguesa river	M-23	-	-
h)	Guanare river	M-24	-	-
i)	Tucupido river	M-25	-	-
j)	Bocono river	M-26	-	-
k)	Masparo river	M-27	-	-
l)	Santo Domingo river	M-28	-	-
m)	Santo Domingo river (El Real)	M-28A		
n)	Santo Domingo river (El Real)	M-28B		
o)	Paguey River	M-29	-	-
p)	Canagua River	M-30	-	-
q)	Acequia River	M-31	-	-
r)	Bumbum River	M-32	-	-
s)	Socopo River	M-33	-	-
t)	Caparo river	M-34	-	-
u)	Uribante river (Chorrosquero)	M-35	-	-
	(Sub-total)	(21)	(0)	(0)
4)	Orinoco River			
a)	Puerto Ordaz (1)	M-36	-	-
b)	Puerto Ordaz (2)	M-37	-	-
	(Sub-total)	(2)	(0)	(0)
Total nos. of sites		(39)	(13)	(13)

Table 3.2.2 RESULT OF LABOLATORY TEST

Item	Mean Specific Gravity	Mean Moisture Content (%)	Mean Liquid Limit (%)	Mean Plastic Limit (%)
(1) River Bed Material				
1) Rivers in Piedmont	2.65	11.9	36.0	17.0
2) Apure River	2.66	14.8	27.4	19.5
3) Portuguesa River	2.68	19.4	45.0	23.0
(2) River Bank Material				
1) First Clay (AC1)*1	2.70	21	22	99
2) Second Clay (AC2)*1	2.70	26	17	33
3) Third Clay (AC3)*1	2.74	36	22	40
4) First Sand (AS1)*1	2.65	18	-	-
5) First Clay (DC1)*2	2.71	17	17	42
6) Second Clay (DC2)*2	2.73	31	19	37
7) First Sand (DS1)*2	2.74	18	-	-
8) Second Sand (DS2)*2	2.67	18	-	-
(3) Embankment Material				
1) Maximum	2.80	28	39	17 (22*3)
2) Minimum	2.57	7	22	7 (15*3)
3) Mean	2.71	15	31	11 (20*3)

Note : *1 Geological formation in Holocene.
*2 Geological formation in Pleistocene.
*3 Plasticity index (%)

Table 3.4.1 PRESENT AGRICULTURAL PRODUCTION AND FUTURE TARGETS

(Unit: ton)

Crops	Production in 1982	Production in 1991	Production Target for the Year 2010	Required Increase Over 1991 Level
Corn	546,000	1,024,589	1,980,000	1.93
Rice	617,000	610,508	3,209,700	5.26
Sorghum	314,000	615,088	1,521,000	2.47
Plantain	431,000	558,022	1,512,000	2.71
Banana	900,000	1,214,847	2,160,000	1.8
Frijol	10,000	14,726	183,000	12.4
Beans	22,000	36,723	122,000	3.32
Soybean	---	9,107	856,800	94.08
Sesame	53,000	45,072	180,000	3.99
Cotton	39,000	71,876	320,000	4.45
Peanut	14,000	4,778	120,000	25.1
Palm Oil	---	5,885	50,000	8.50
Sugar Cane	4,820,000	7,066,033	11,249,900	1.59

Source: MAC, 1991, UNELLEZ, 1983

Table 3.4.2 TARGETS FOR AGRICULTURAL LAND AREA OF MAIN CROPS IN THE STATES OF THE STUDY AREA

(Unit: ha)

State / Year	1995	2000	2005	2010
PORTUGUESA				
Rice	353,017	436,597	520,178	603,758
Corn	167,314	199,607	231,901	264,196
Sorghum	135,276	166,444	195,612	225,779
Cotton	22,722	28,931	35,140	41,348
Sesame	228,470	265,089	301,711	338,330
Black beans	5,492	6,894	8,294	9,695
Sugarcane	13,576	15,298	17,021	18,744
Total	925,867	1,118,860	1,309,857	1,501,850
BARINAS				
Rice	41,461	54,388	67,316	80,243
Corn	34,773	41,852	48,932	56,011
Sorghum	101,504	131,798	157,093	182,388
Cotton	41,076	49,312	57,547	65,782
Black beans	3,591	4,516	5,441	6,365
Banana	13,238	16,201	19,164	22,127
Total	235,643	298,067	355,493	412,916
COJEDES				
Rice	52,931	61,281	69,632	77,982
Corn	31,096	37,337	43,658	49,944
Sorghum	26,615	31,135	35,654	40,174
Cotton	2,778	3,470	4,161	4,854
Total	113,420	133,223	153,105	172,954
Grand total	1,274,930	1,550,150	1,818,455	2,087,722

Source: UNELLEZ, 1983

Table 3.4.3 POTENTIAL LAND USE FOR AGRICULTURE AND LIVESTOCK PRODUCTION

Item	Nation (ha)	% of Nation	Portuguesa (ha)	% of Portuguesa	Barinas (ha)	% of Barinas	Cojedes (ha)	% of Cojedes
Agriculture	7,905,195	14.36	974,546	64	994,069	28.2	262,195	17.8%
Agriculture and/or livestock	9,280,617	16.85					69,349	4.7
Livestock	18,420,569	33.46	448,006	30	1,351,912	38.4	550,565	37.35
Forest	19,457,160	35.33	90,667	6	1,317,580	37.4	591,850	40.15

Source: MARNR, 1983

Table 3.4.4 LAND CLASSIFICATION OF THE STUDY AREA

Land Class	Present Condition		With Project		Constraints for Intensive Use
	Area (ha)	% of total	Area (ha)	% of total	
I and II	604,800	28.8	636,300	30.3	Flood and Irrigation
III s_2d	214,200	10.2	266,700	12.7	Flood, Drainage and Irrigation
IVs_2d	65,100	3.1	151,200	7.2	Flood, Drainage and Irrigation Clayey soil texture
V and VI s_2d	1,003,800	47.8	835,800	39.8	Flood, Drainage and Irrigation Clayey soil texture
Others	210,000	10.0	210,000	10.0	Flood and Drainage
Total	2,097,900		2,100,000	100.0	

Source: MARNR, 1979

Table 3.4.5 FARM LAND BY DISTRICT WITHIN THE STUDY AREA

(Unit: ha)

District	Corn	Cotton	Sesame	Sun-flower	Sorghum	Sugar-cane	Rice	Beans
Guanare	10,460	935	1,215	6,115	3,680	17,533	1,905	730
Guanarito	12,100	500	2,086	10,708	4,750		4,366	390
Alb. Torre alba	4,595	1,016	622	733	248		845	456
Rojas	6,703	1,476	505	2,590	385			60
Sosa	3,885	3,259	218	772	95			65
Arismendi								55
Total	37,743	7,186	4,646	20,918	9,158	17,533	7,329	1,756

Source: MAC, 1991

Table 3.5.1 POPULATION BY SEX, URBAN/RURAL RESIDENT AND LABOR FORCE IN VENEZUELA

	Item	Number of Persons			Percentage Distribution (%)			Average Annual Growth Rate (%)		
		1971	1981	1990	1971	1981	1990	'71-81	'81-90	'71-90
1.	Population	10,721,522	14,516,735	18,105,265	100.0	100.0	100.0	3.08	2.48	2.80
2.	Male	5,349,711	7,259,812	9,004,717	49.9	50.0	49.7	3.10	2.42	2.78
3.	Female	5,371,811	7,256,923	9,100,548	50.1	50.0	50.3	3.05	2.55	2.81
4.	Urban	7,808,650	11,655,332	15,227,740	72.8	80.3	84.1	4.09	3.02	3.58
5.	Rural	2,912,872	2,861,403	2,877,525	27.2	19.7	15.9	-0.18	0.06	-0.06
6.	15 year or over	5,897,240	8,719,466	11,361,414	55.0	60.1	62.8	3.99	2.98	3.51
	Male	2,912,066	4,322,715	5,591,072	27.2	29.8	30.9	4.03	2.90	3.49
	Female	2,985,174	4,396,751	5,770,342	27.8	30.3	31.9	3.95	3.07	3.53
7.	Lobor force	3,014,674	4,634,500	6,155,513	28.1	31.9	34.0	4.39	3.20	3.83
	(No declaration)	-	-	244,054	-	-	-	-	-	-
8.	Labor Participation Rate/1	51.1%	53.2%	55.4%	-	-	-	-	-	-
9.	Gainful Worker	2,828,696	4,177,718	5,292,024	26.4	28.8	29.2	3.98	2.66	3.35
10.	Employment Rate	93.8%	90.1%	86.0%	-	-	-	-	-	-
11.	Unemployment	185,978	456,782	863,489	1.7	3.1	4.8	9.40	7.33	8.42
12.	Unemployment Rate	6.2%	9.9%	14.0%	-	-	-	-	-	-

Remarks: Source ; Oficina Central de Estadistica e Informatica
/1 ; calculated based on number of labor force and population of 15 years or over excluding number of no declaration.

Table 3.5.2 POPULATION BY PROVINCES IN VENEZUELA

Provinces	Number of Persons			Percentage Distribution (%)			Average Annual Growth Rate (%)		
	1971	1981	1990	1971	1981	1990	'71-81	'81-90	'71-90
Total	10,721,522	14,516,735	18,105,265	100.0	100.0	100.0	3.08	2.48	2.80
Distrito Federal	1,860,637	2,070,742	2,103,661	17.4	14.3	11.6	1.08	0.18	0.65
Anzoategui	506,297	683,717	859,758	4.7	4.7	4.7	3.05	2.58	2.83
Apure	164,705	188,187	285,412	1.5	1.3	1.6	1.34	4.74	2.94
Aragua	543,170	891,623	1,120,132	5.1	6.1	6.2	5.08	2.57	3.88
Barinas	231,046	326,166	424,491	2.2	2.2	2.3	3.51	2.97	3.25
Bolivar	391,665	668,340	900,310	3.7	4.6	5.0	5.49	3.37	4.48
Carabobo	659,339	1,062,268	1,453,232	6.1	7.3	8.0	4.88	3.54	4.25
Cojedes	94,351	133,991	182,066	0.9	0.9	1.0	3.57	3.47	3.52
Delta Amacuro	48,139	56,720	84,564	0.4	0.4	0.5	1.65	4.54	3.01
Falcon	407,957	503,896	599,185	3.8	3.5	3.3	2.13	1.94	2.04
Guarico	318,905	393,467	488,623	3.0	2.7	2.7	2.12	2.44	2.27
Lara	671,410	945,064	1,193,161	6.3	6.5	6.6	3.48	2.62	3.07
Merida	347,095	459,361	570,215	3.2	3.2	3.1	2.84	2.43	2.65
Miranda	856,272	1,421,442	1,871,093	8.0	9.8	10.3	5.20	3.10	4.20
Monagas	298,239	388,536	470,157	2.8	2.7	2.6	2.68	2.14	2.42
Nueve Esparta	118,830	197,198	263,748	1.1	1.4	1.5	5.20	3.28	4.29
Portuguesa	297,047	424,984	576,435	2.8	2.9	3.2	3.65	3.44	3.55
Sucre	469,004	585,698	679,595	4.4	4.0	3.8	2.25	1.67	1.97
Tachira	511,346	660,234	807,712	4.8	4.5	4.5	2.59	2.27	2.44
Trujillo	381,334	433,735	493,912	3.6	3.0	2.7	1.30	1.45	1.37
Yaracuy	223,545	300,597	384,536	2.1	2.1	2.1	3.01	2.77	2.90
Zulia	1,299,030	1,674,252	2,235,305	12.1	11.5	12.3	2.57	3.26	2.90
T.F. Amazonas	21,696	45,667	55,717	0.2	0.3	0.3	7.73	2.23	5.09
Dependecias Federales	463	850	2,245	0.0	0.0	0.0	6.26	11.40	8.66

Remark: Populations mentioned here are based on Population Censuses 1971, 1981 and 1990 made by Oficina Central de Estadistica e Informatica (OCEI)

Table 3.5.3 GROSS DOMESTIC PRODUCT

Year	At Current Price				At 1984 Constant Price			
	GDP		GDP Per Capita/1		GDP		GDP Per Capita/1	
	Amount (Bs.million)	Growth Rate(%)	Amount (Bs.)	Growth Rate(%)	Amount (Bs.million)	Growth Rate(%)	Amount (Bs.)	Growth Rate(%)
1981	285,208	-	19,647	-	-	-	-	-
1982	291,268	2.1	18,500	-5.8	439,811	-	27,935	-
1983	290,492	-0.3	17,949	-3.0	415,107	-5.6	25,649	-8.2
1984	409,487	41.0	24,624	37.2	409,487	-1.4	24,624	-4.0
1985	464,620	13.5	27,208	10.5	414,750	1.3	24,288	-1.4
1986	493,765	6.3	28,173	3.5	443,093	6.8	25,282	4.1
1987	696,421	41.0	38,747	37.5	464,341	4.8	25,834	2.2
1988	873,283	25.4	47,404	22.3	491,372	5.8	26,673	3.2
1989	1,510,361	73.0	80,032	68.8	449,262	-8.6	23,806	-10.7
1990	2,279,261	50.9	117,942	47.4	478,320	6.5	24,751	4.0
1991	3,036,275	33.2	153,452	30.1	527,927	10.4	26,681	7.8

Remark Source: Banco Central de Venezuela
Note : Population used for calculation of GDP Per Capita is based on population projection made by Oficina Central de Estadistica e Informatica.

Table 3.5.4 GROSS DOMESTIC PRODUCT BY INDUSTRIAL ORIGIN AT 1984 CONSTANT PRICE

Industrial Group	Gross Domestic Product (in Bs.million)							Annual Growth Rate (%)					
	1985	1986	1987	1988	1989	1990	1991	'85 -'86	'86 -'87	'87 -'88	'88 -'89	'89 -'90	'90 -'91
Total	414,750	443,093	464,341	491,372	449,262	478,320	527,927	6.83	4.80	5.82	-8.57	6.47	10.37
1. Agriculture, Hunting, Forestry and Fishery	23,299	25,224	26,126	27,338	25,937	25,483	26,303	8.26	3.58	4.64	-5.12	-1.75	3.22
2. Crude Petroleum and Natural Gas	62,553	67,110	67,459	70,216	70,224	82,766	90,514	7.29	0.52	4.09	0.01	17.86	9.36
3. Mining	2,096	2,485	3,116	3,939	3,771	3,971	3,830	18.56	25.39	26.41	-4.27	5.30	-3.55
4. Industry	82,219	87,969	103,645	110,755	97,654	103,614	115,476	6.99	17.82	6.86	-11.83	6.10	11.45
- Manufacturing	59,986	65,577	84,159	87,047	74,317	79,816	88,449	9.32	28.34	3.43	-14.62	7.40	10.82
- Refinery of Petroleum	22,233	22,392	19,486	23,708	23,337	23,798	27,027	0.72	-12.98	21.67	-1.56	1.98	13.57
5. Electricity and Water Supply	6,596	6,860	7,086	7,612	7,726	8,123	8,854	4.00	3.29	7.42	1.50	5.14	9.00
6. Construction	18,532	20,346	27,822	30,019	21,884	23,576	30,826	9.79	36.74	7.90	-27.10	7.73	30.75
7. Commerce, Restaurant and Hotel	58,771	64,051	71,644	75,525	63,581	66,013	70,931	8.98	11.85	5.42	-15.81	3.83	7.45
8. Transportation, Warehouse and Communication	26,558	29,046	24,980	27,015	25,297	25,233	27,215	9.37	-14.00	8.15	-6.36	-0.25	7.85
9. Bank, Insurance, Real Estate and Other Services for Firms	58,101	61,229	64,912	69,203	64,854	66,020	69,283	5.38	6.02	6.61	-6.28	1.80	4.94
10. Community, Social and Personal Services	30,247	33,302	21,135	22,681	22,551	24,025	26,048	10.10	-36.54	7.31	-0.57	6.54	8.42
11. Products and Services for Public Office	35,450	35,301	37,365	39,095	40,682	43,781	47,313	-0.42	5.85	4.63	4.06	7.62	8.07
12. Products and Services for Individual without Benefit	4,891	5,071	6,094	6,306	6,227	7,024	7,591	3.68	20.17	3.48	-1.25	12.80	8.07
13. Banking Service (Minus)	-10,785	-12,478	-8,577	-9,023	-6,559	-6,675	-7,484	15.70	-31.26	5.20	-27.31	1.77	12.12
Sub-total	398,528	425,516	452,807	480,681	443,829	472,954	516,700	6.77	6.41	6.16	-7.67	6.56	9.25
14. Import Right and Adjustment due to Variation of Foreign Exchange	16,222	17,577	11,534	10,691	5,433	5,366	11,227	8.35	-34.38	-7.31	-49.18	-1.23	109.22

Source: Banco Central de Venezuela

Table 3.5.5 PRICE INDEX: 1981 - 1991

Year	Consumer Price	Wholesale Price			
	Metropolitan of Caracas	General	Agriculture	Manufacturing	Construction
1981	76.5	-	-	-	67.5
1982	83.9	-	-	-	78.6
1983	89.2	-	-	-	84.0
1984	100.0	100.0	100.0	100.0	100.0
1985	111.4	115.2	117.0	115.0	111.4
1986	124.3	134.7	149.5	133.6	122.2
1987	159.2	196.2	223.3	194.1	156.6
1988	206.1	234.0	276.7	230.8	188.8
1989	380.2	462.2	390.2	467.7	393.4
1990	534.8	588.0	613.7	586.2	472.7
1991	717.7	718.9	828.4	710.7	579.6
Inflation Rate:					
1981-1991 (10 years)	25.1%	-	-	-	24.0%
1988-1991 (3 years)	51.6%	45.4%	44.1%	45.5%	45.3%

Remarks: Source; Anuario de Estadisticas, Precios y Mercado Laboral, Banco Central de Venezuela
Note ; 1984 Price = 100

Table 3.5.6 FOREIGN EXCHANGE RATE

Year	Average Price	Year/Month	Average Price
1981	4.30	1993	
1982	4.30	January	80.34
1983	8.62	February	81.97
1984	12.51		
1985	13.73		
1986	19.85		
1987	27.85		
1988	33.61		
1989	38.91		
1990	47.13		
1991	56.89		
1992	68.40		

Remarks: Source; Estadisticas Sobre El Tipo de Cambio Promedio Diario del Bolivar Frente Al Dolar Banco Central de Venezuela
Unit ; Bs./US$1.00

Table 4.3.1 YEARLY 8-MONTH BASIN MEAN RAINFALL

(Unit : mm)

Year	Apure River Basin	Portuguesa River Basin	Whole Basin
1967	1,857	1,238	1,556
1968	1,776	1,204	1,497
1969	1,688	1,645	1,667
1970	1,658	1,405	1,535
1971	1,521	1,191	1,360
1972	1,751	1,335	1,549
1973	1,508	1,242	1,378
1974	1,333	1,099	1,219
1975	1,487	1,279	1,386
1976	1,715	1,437	1,580
1977	1,683	1,245	1,470
1978	1,862	1,479	1,675
1979	1,878	1,438	1,664
1980	1,771	1,506	1,642
1981	2,004	1,623	1,818
1982	1,878	1,376	1,634
1983	1,821	1,532	1,680
1984	1,459	1,236	1,350
1985	1,600	1,193	1,402
1986	1,822	1,378	1,606
1987	1,578	1,301	1,443
1988	1,678	1,228	1,459
1989	1,540	1,028	1,291
1990	1,687	1,384	1,539
Average	1,690	1,334	1,517

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

Table 4.3.2 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 4.3.3 ANNUAL MAXIMUM DAILY MEAN DISCHARGE

(Unit: m3/s)

Year	Base Point			
	Bruzual (Apure River)	El Saman (Apure River)	Camaguan (Portuguesa River)	San Fernando (Apure River)
1975	2,529	3,012	882	3,606
1976	3,662	4,824	1,090	6,416
1977	3,592	4,196	996	5,428
1978	3,676	4,308	1,046	5,626
1979	3,592	4,523	1,074	6,522
1980	3,592	4,421	1,224	7,132
1981	3,933	4,744	1,238	8,645
1982	3,918	4,601	-	6,840
1983	3,962	4,283	1,217	-
1984	2,952	4,283	985	-
1985	3,270	3,740	940	-
1986	3,861	-	1,062	-
1987	2,895	4,358	1,002	5,005
1988	3,079	3,751	-	4,757
1989	2,835	3,377	629	3,569
1990	2,855	3,567	1,087	4,439

Table 4.3.4 PROBABLE DAILY MEAN DISCHARGES

(Unit: m^3/s)

Return Period	Base Point			
	Bruzual (Apure R.)	El Saman (Apure R.)	Camaguan (Portuguesa R.)	San Fernando (Apure R.)
2-Year	3,322	4,060	1,012	5,464 (4,360)
5-Year	3,821	4,625	1,182	7,133 (5,980)
10-Year	4,151	4,999	1,295	8,238 (6,880)
20-Year	4,467	5,358	1,402	9,298 (7,820)
30-Year	4,649	5,564	1,465	9,908 (8,300)
50-Year	4,876	5,822	1,542	10,670 (8,920)
80-Year	5,085	6,059	1,613	11,368 (9,460)
100-Year	5,183	6,170	1,647	11,699 (9,760)

Note : Figures in parethes are those estimated from water levels.
Data used for calculation are as follows:
(1) Bruzual 1975 - 1990
(2) El Saman 1975 - 1990
(3) Camaguan 1975 - 1990
(4) San Fernando 1975 - 1990 (Discharge), 1945 - 1992 (Water Level)

Table 4.4.1 AVERAGE FLOW DURATION

Ordinal Days	Apure River			Portuguesa River			
	P.Remolino (M3/S)	Bruzual (M3/S)	El Saman (M3/S)	S.Fernando (M3/S)	El Baul (M3/S)	Jobalito (M3/S)	Camaguan (M3/S)
1	83	148	217	289	9	31	57
5	88	158	225	302	10	32	59
10	92	167	239	322	11	33	63
20	97	188	251	362	11	35	67
30	104	203	270	391	12	37	72
40	113	224	292	422	13	39	77
50	122	248	319	466	14	41	82
60	137	276	346	511	15	43	89
70	154	308	380	554	16	47	98
80	176	341	410	606	18	51	106
90	208	380	449	669	20	57	120
100	246	445	506	749	22	62	135
110	287	523	561	856	24	73	154
120	319	586	629	961	26	82	179
130	350	673	705	1,103	29	91	210
140	385	762	812	1,273	31	105	239
150	424	890	961	1,469	35	119	275
160	449	1,059	1,095	1,698	39	139	339
170	482	1,289	1,255	1,940	47	167	386
180	514	1,490	1,376	2,164	57	190	438
190	537	1,621	1,536	2,357	65	212	497
200	563	1,759	1,715	2,582	73	233	560
210	599	1,849	1,886	2,839	80	254	613
220	623	1,948	2,041	3,083	87	273	663
230	656	2,033	2,198	3,258	94	289	705
240	677	2,163	2,345	3,454	103	308	747
250	707	2,263	2,448	3,609	111	324	786
260	743	2,375	2,576	3,742	118	343	833
270	775	2,479	2,714	3,904	128	367	872
280	802	2,580	2,847	4,066	142	388	907
290	838	2,667	2,978	4,256	151	401	934
300	874	2,783	3,134	4,427	162	412	954
310	905	2,911	3,280	4,691	172	421	964
320	922	3,014	3,452	4,925	183	428	979
330	938	3,105	3,570	5,147	193	436	990
340	963	3,183	3,646	5,357	202	443	1,000
350	1,003	3,296	3,768	5,581	211	449	1,016
360	1,037	3,422	3,903	5,701	223	456	1,029
365	1,060	3,442	3,954	5,744	229	458	1,034

Table 5.5.1 DIMENSION OF DAMS FOR CHANNEL STABILIZATION STUDY

Dam		Catchment Area	Effective Reservoir Capacity	Stage	Power Generation				Intake for Irrigation	Effective Discharge for Navigation	Remarks
Name	Purpose	(km2)	(mill.m3)		Installed Capacities (MW)	Released Discharge (m3/s) A	Load Factor B	Average Discharge (m3/s) C (A x B)	(m3/s) D	(m3/s) C - D	
La Honda	HP	1340	126.5	Initial	150 x 2	100	0.364	37	0	37	
CADAFE(C)				Final	150 x 2	100	0.364	37	0	**37	
Las Cuevas	HP	390	345	Initial	-	-	-	-	-	-	
CADAFE(S)				Final	120 x 3	(127)	0.470	60	0	#60	**37+23=#60
Borde Seco/La Vueltosa	HP	3090	2097	Initial	208 x 2	(445)	0.327	145	0	::145	
CADAFE(U)				Final	208 x 3	(627)	0.327	205	0	@205	#60+::145=@205
Masparro	HP,IR	500	837	Initial	25 x 1	50	0.500	25	1	24	Final Stage
MARNR(C)	FC,LI			Final	25 x 1	50	0.500	25	17	8	(AD 2020)
Bocono-Tucupido	HP,IR	2020	2595	Initial	40 x 2	130	0.500	65	4	61	Final Stage
MARNR(C)	FC			Final	40 x 2	130	0.500	65	41	24	(AD 2020)
Las Majaguas	IR,FC	-	303.5	Initial	-	-	-	-	-	-	
MARNR(C)				Final	-	-	-	-	-	-	
Las Palmas	HP,IR	4325	1750	Initial	25 x 1	55	0.290	16	0	16	
MARNR(U)	WS,FC			Final	25 x 1	55	0.290	16	10	6	

Remarks :

1 (C) : Constructed, (U) : Under Const., (S) : Scheduled
2 HP : Hydro-Power, IR : Irrigation, WS : Water Supply, FC : Flood Control
3 Released discharge in ( ) : Estimated from Load Factor
4 Source of intake for navigation at Bocono-Masparro : "Estudio Preliminar del Trasvase Bocono-Masparro para Mejorar las Condiciones de Navegacion del Eje Fluvial Orinoco-Apure" (PROA Jan. '91)
5 Ratio of intake for irrigation at Bocono and Masparro : Estimated by ratio of effective resovoir capacity

Table 6.2.1 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 6.4.1 **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 6.4.2 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 6.4.3 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 6.4.3 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

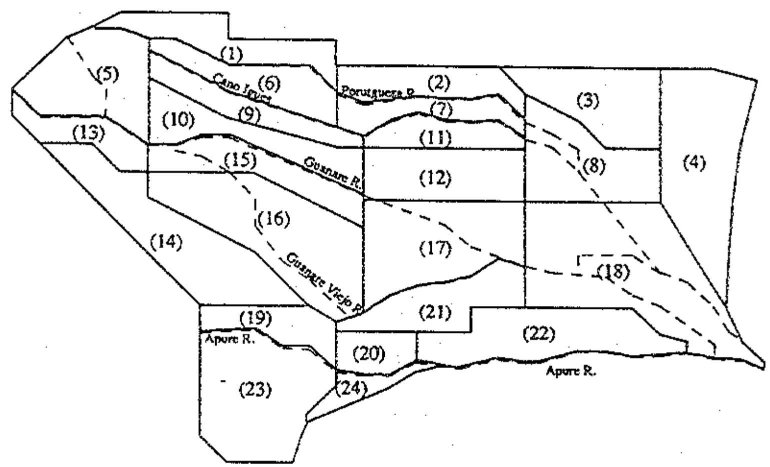


Table 6.4.4 MAJOR CHANGE OF INUNDATION (1/2)

Area	Plan	Block	Location	Inundation Depth (m)		Remarks
				Present Condition	With Project	
A	A1	2 7 11 8	Downstream section, river side Downstream section, land side Adjacent to block 7 Downstream of dike	0.35 0.24 0.37 0.29	0.77(+) 0.10(-) 0.17(-) 0.41(+)	(Dike for Portuguesa River) No change in upstream section, land side and river side
B	B1	10 16	Downstream section, river side Downstream areas	0.17 0.30	0.24(+) 0.25(-)	(Dike for Guanare River) No change in upstream section, land side
	B2A	10 16	Downstream section, river side Downstream areas	0.17 0.30	0.24(+) 0.23(-)	(Dike for Guanare River) No change in upstream section, land side
	B2B	10 16	Downstream section, river side Downstream areas	0.17 0.30	0.24(+) 0.20(-)	(Dike for Guanare River) No change in upstream section, land side
C	C1	24 20 21 -	Opposit bank area Left bank, land side Adjacent to block 20 San Fernando	1.28 0.41 0.50 El.45.44	1.90(+) 0.13(-) 0.36(-) El.45.44	(Dike for Apure River) Almost no change in upstream section, land side
	C2	24 20 21 -	Opposit bank area Left bank, land side Adjacent to block 20 San Fernando	1.28 0.41 0.50 El.45.44	1.90(+) 0.13(-) 0.36(-) El.45.44	(Dike for Apure River - shortened) Almost no change in upstream section land side
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 6.4.4 MAJOR CHANGE 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	Left bank of Portuguesa Right bank of Portuguesa	0.35 0.24	0.56(+) 0.62(+)	(Retarding Basin by Apure Module)
		8	Around confluence of Portuguesa and Igues	0.29	0.40(+)	
		11 17 22	Right bank of Igues Center of study area Left bank of Apure	0.37 1.77 0.07	0.51(+) 1.67(-) 0.43(+)	

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

Table 6.4.5 PROJECT COSTS OF ALTERNATIVE FLOOD MANAGEMENT PLANS

Plan	Main Facility	Feature	Main Work Quantity (million m3)	Project Cost (million US$)	Remarks
A1	Dike	190 km	7.8	34.2	
B1	Dike	145 km	5.8	25.6	
B2A	Dike Channel	145 km 95 km	5.8	55.0	
B2B	Dike Channel	145 km 95 km	5.8	72.3	
C1	Dike	155 km	8.0	34.1	
C2	Dike	105 km	5.6	22.6	
D1A	Diversion Bridge	10 km 400 m	2.4 3,200 m2	14.6	1 no. Excavation
D1B	Diversion Bridge	28 km 400 m	5.6 3,200 m2	25.6	2 nos. Excavation and Embankment
D2	Module dike	5,200 km2	104.0	157.7	Apure type module

FIGURES

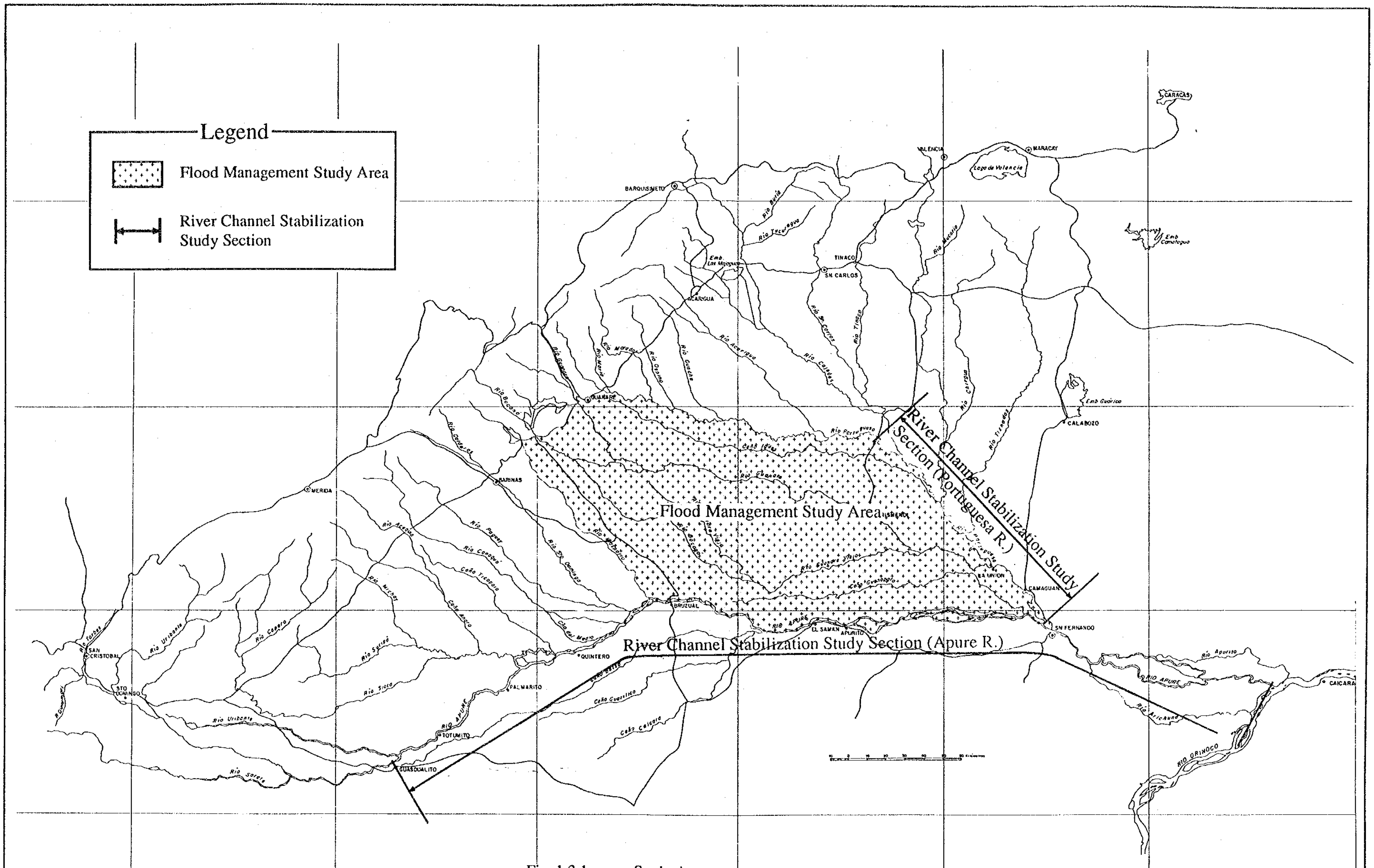


Fig. 1.3.1 Study Area

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

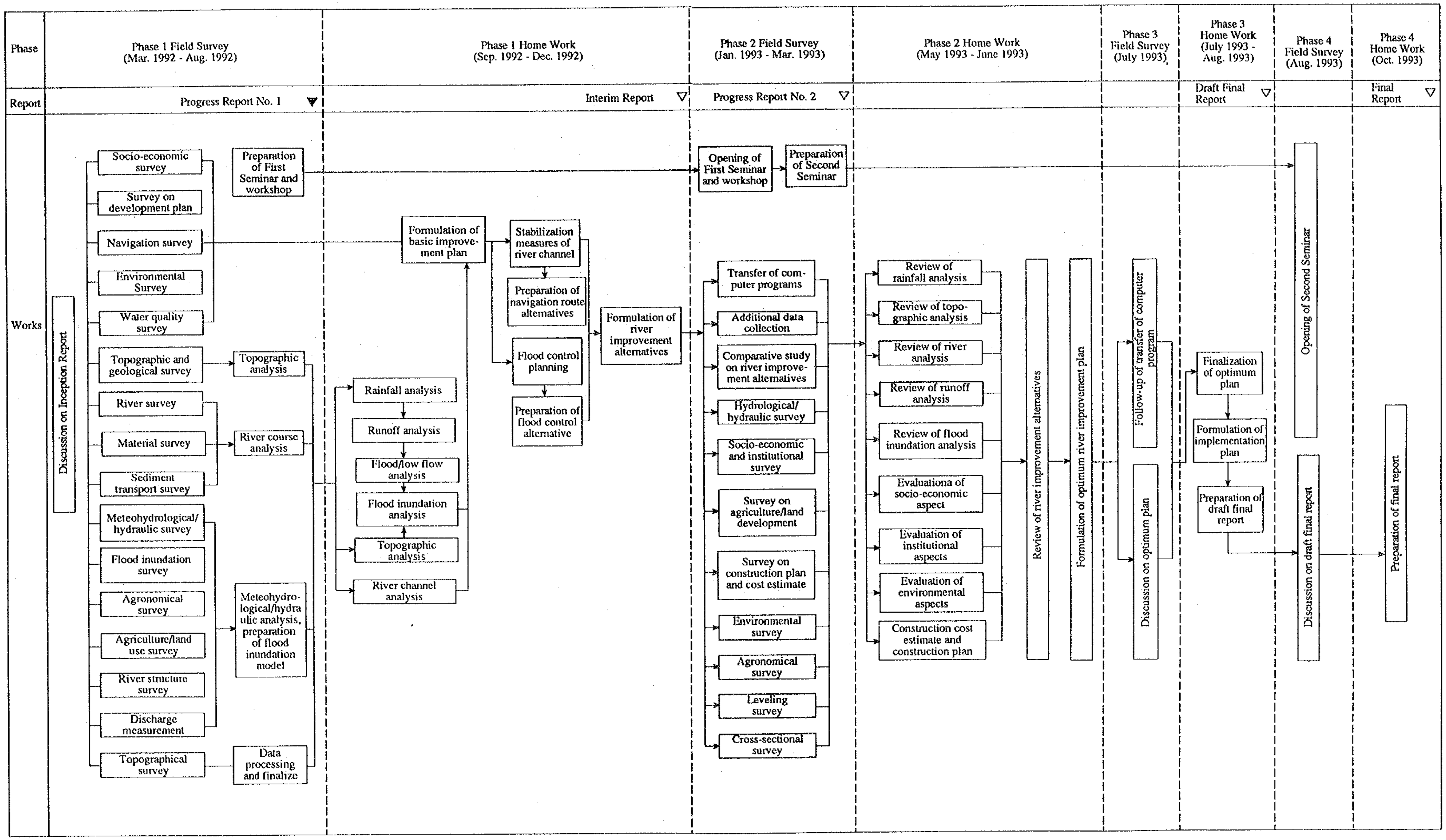
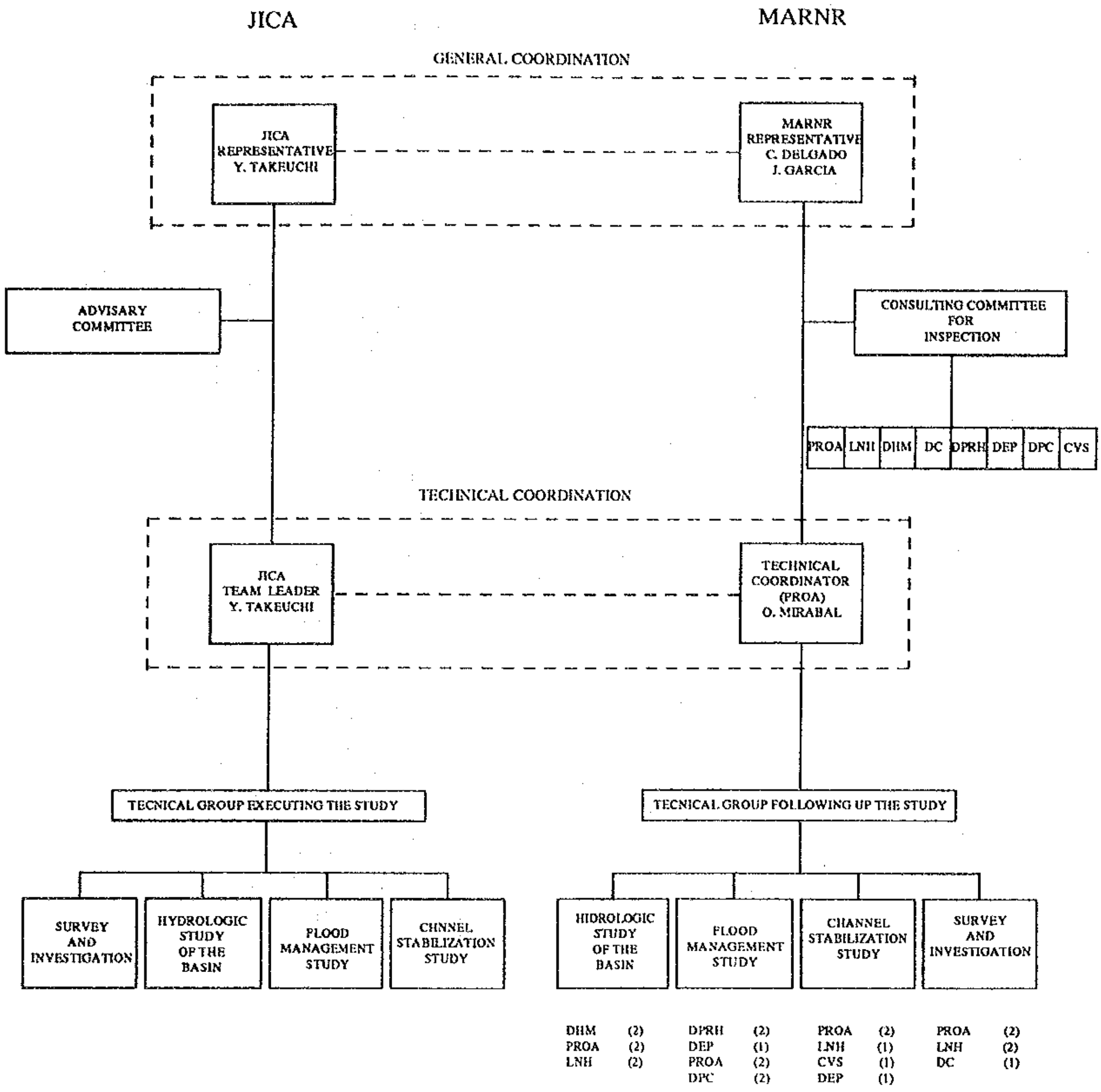


Fig. 1.4.1 Overall Work Flow of Study

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY



PROA: ORINOCO-APURE PROGRAM D.C: DIRECTION OF CARTOGRAPHY LNH: HYDRAULIC NATIONAL LABORATORY
DPRH: DIRECTION OF PLANNING OF THE HYDRAULIC RESOURCES, SOIL, VEGETATION AND FAUNA
DPC: DIRECTION OF CONSERVATIONIST PLANS CVS: SOUTHWEST VENEZUELAN CORPORATION
DHM: DIRECTION OF HYDROLOGY AND METEOROLOGY DEP: DIRECTION OF STUDY AND PROJECTS.

Fig. 1.4.2 Organization of MARNR and JICA for The Study

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

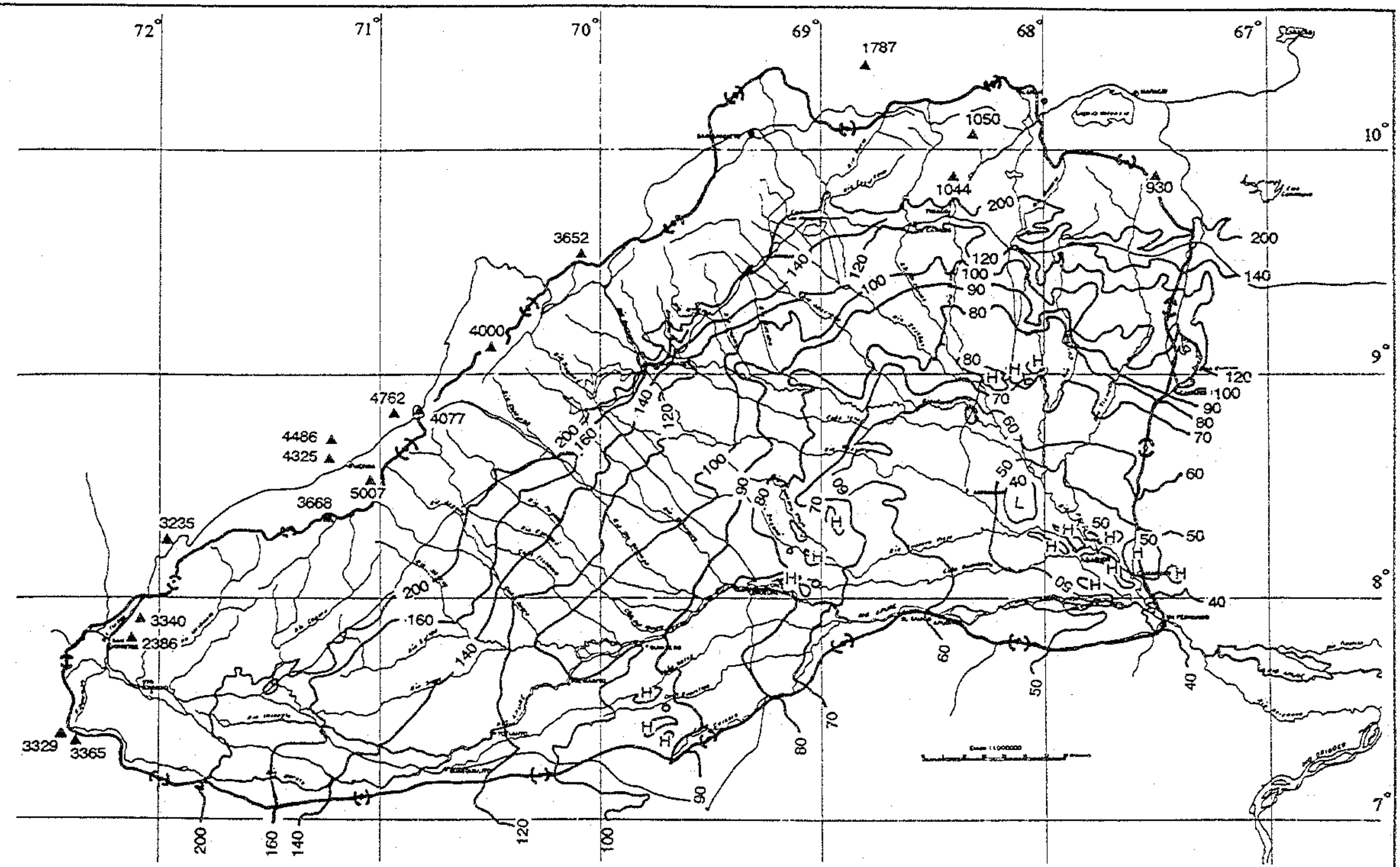


Fig. 2.1.1 Topography of Study Area

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

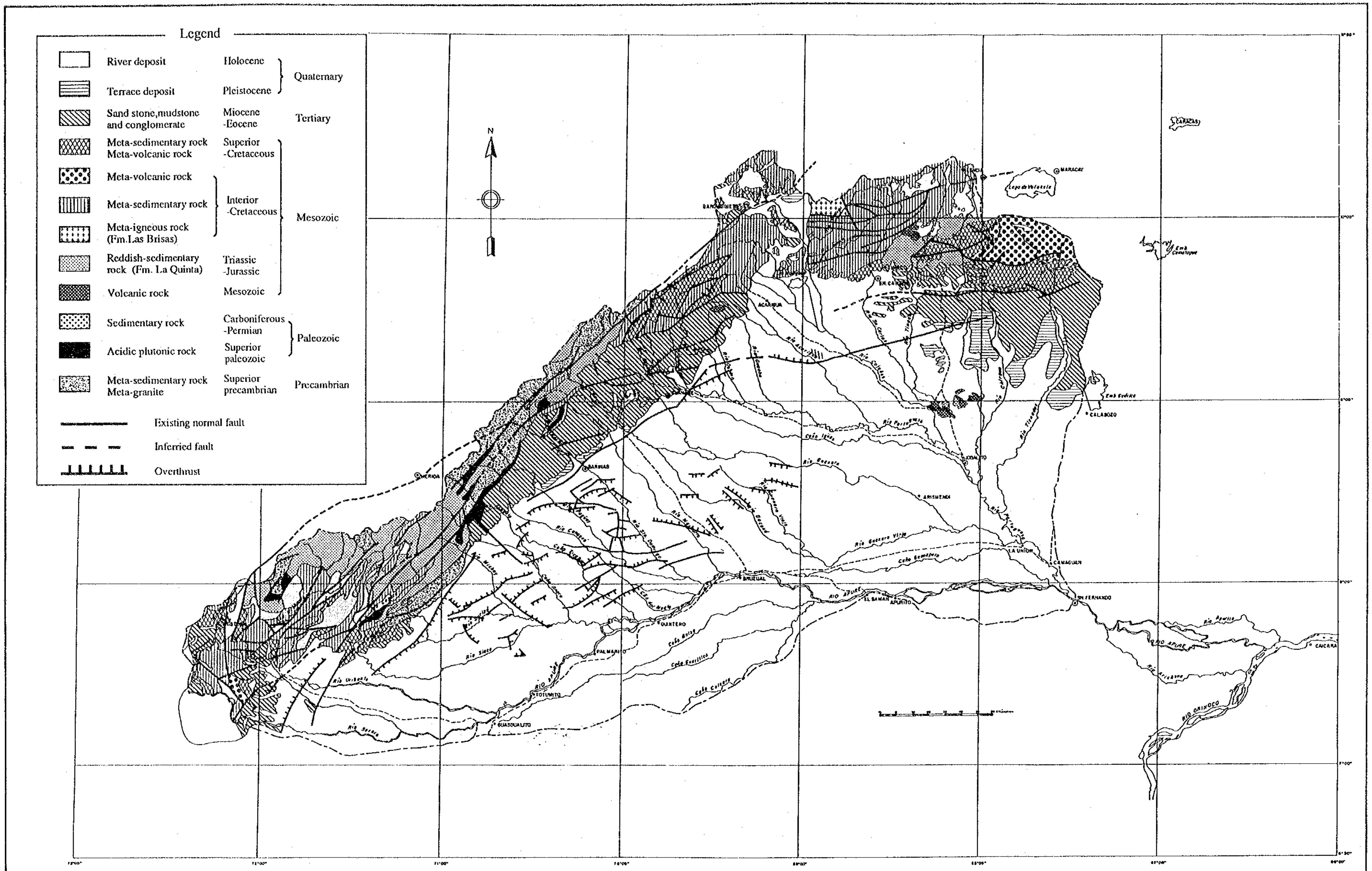


Fig. 2.2.1 Geological Map of Apure River Basin

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