9.3 Flood Mitigation Measures

9.3.1 Basic Concept

In the hurricane Fifi, most of the urban areas and agricultural lands in the study area were submerged by the flood water from the Rio Chamelecon and the pilot river basins. The hurricane Fifi gave severe damage not only to the people in the study area, but also to the major infrastructures such as transportation and communication systems. After the hurricane Fifi, some flood mitigation measures such as embanked channels and embankments have been provided, but the study area is extremely vulnerable to floods as ever.

The study area is a part of the Sula Valley which is one of the most important productive areas of the country. Currently, the importance of the area is increasing, with several industrial parks being developed in both San Pedro Sula and Choloma areas.

The basic concept for planning of flood mitigation measures is to protect the people, their assets and social properties from the floods of the pilot rivers by structural measures and non-structural measures, based on the results of the assessment on the floods caused by the hurricane Fifi.

9.3.2 Structural Measures

1) Rio Choloma

a) Design Discharge

The design discharges at the major stations are as follows:

- The confluence with the Canal San Roque (11.25 km) : 790 cu. m/s
- The national road bridge (19.08 km) : 620 cu. m/s

b) Design longitudinal profile

The design longitudinal profile is determined to be I = 1/360 and 1/330 and assessed to be stable according to the Sedimentology study (Chapter 8). The design longitudinal profile is shown in *Fig.* 9.6.

c) Cross section

A compound cross-section is planned by considering easy operation and maintenance. The low water channel section is designed to have a flow capacity of once in 2 to 3-year flood frequency. The river width is determined based on the regime theory (B = C*Q^0.5. Where, B: flow width, C: constant and Q: design discharge). The design cross section is decided as follows:

- Width of low water river channel (B1) : 60 m
- Height of the low water river channel (h) : 2 m
- River width (B2) : 140 m

d) Design high water level

The design high water levels at major points are as follows:

- The confluence of the Canal San Roque : 12.00 m above mean sea level
- The national road bridge : 32.26 m above mean sea level

The design high water is shown in *Fig*. 9.6.

e) Flood mitigation facilities

The proposed facilities are summarized as follows and shown in *Fig*. 9.7.

- Embankment : 15.6 km in total (237,700 m^3)
- Revetment : 4 Places, 4.8 km in total (42,600 m^2)
- Low water channel works : 7.8 km (1,102,000 m^3)
- Rehabilitation of bridges : 2 places

2) Rio Blanco

When the Rio Blanco was improved in 1979, the river course downstream of the national road bridge was diverted to flow to the Lake Carmen, instead of following its original river course. Accordingly the flood water flows into the Rio Chamelecon through the drainage canals i.e., the Canal San Roque, the Canal San Roque Cuabanos and the Canal Copen-Higuero Cuabanos.

It is reported that the flooding from the Canal San Roque become more frequent and worser than before the improvement of the Rio Blanco and the Laguna Carmen might become shallow by sedimentation.

For flood mitigation purposes, the following alternatives are planned (refer to *Fig.* 9.8):

- Alternative-1 to improve both the Rio Blanco and the Canal San Roque against the design flood discharge,

- Alternative-2 to divert the Rio Blanco from the station at 22.4 km to the station at 12.60 km of the Rio El Sauce, that is revert to the original channel of the Rio Blanco.

  to carry out the flood mitigation works required for the Rio Blanco and the Rio El Sauce.

a) Design discharge

The design discharges of the Rio Blanco are summarized as follows:

Station	Alternative 1 (cu. m.)	Alternative 2 (cu. m.)
– Canal San Roque (station 0.0 km)	1,110	840
- Station 20.5 km (upper reach of the Laguna Carmen)	660	-
- Station 21.9 km (proposed diversion point)	420	420
- Station 25.5 km (junction with the Rio de Armenta)	420	420

b) Design longitudinal profile

The design river bed slopes are shown in *Figs.* 9.9 and 9.10 (2).

c) Cross section

A compound section is planned by considering easy operation and maintenance. On the other hand, a single cross section is applied for the Quebrada San Agustin which flows through in the hilly area between the Laguna Carmen and the Canal San Roque. The water channel of the compound section is designed to have a flow capacity of once in 2 to 3 -year flood frequency. The river width is determined as follows:

(Alternative 1)

	Location	B1(m)	h(m)	B2(m)
-	Canal San Roque (0.0~6.4 km)	60	3	146
-	Qda. San Agustin (6.4~9.8 km)	60	2	134
-	Rio Blanco	use the existing channel		

(Alternative 2)

The plan is to follow the existing channel of the Rio Blanco and to construct a diversion channel of 2.6 km from the Rio Blanco to the Rio El Sauce. A compound section is also planned for the diversion channel as follows:

	Location	B1(m)	h(m)	B2(m)
-	Diversion channel:	40	1.5	126

d) Design high water level

The design high water levels of the major points are listed as follows:

(Alternative 1)

	Location	Design High Water(EL)
-	Canal San Roque (0.0 km)	12.00 m
-	Canal San Roque (6.4 km)	15.70 m
-	Rio Blanco (20.5 km)	56.10 m
-	Rio Blanco (21.9 km) (proposed diversion)	62.00 m

- Rio Blanco(23.9 km) 69.50 m

(national road bridge)

(Alternative 2)

Location	Design High Water(EL)
Rio Blanco(20.5 km)	60.51 m
Rio Blanco (23.9 km)	67.06 m

e) Flood mitigation facilities

The improvement works of the Rio Blanco are shown in *Table* 9.3 and *Figs* 9.11 and 9.12. They are summarized as follows:

(Alternative 1)

(1) Canal San Roque (0 ~ 6.4 km)

- Embankment : 12.80 km (1,488,300 m^3)
- Channel improvement : 6.40 km (998,400 m^3)
- Rehabilitation of Bridge : 2 places (146 m x 5 m x 2 no)
- Sodding : 12.80 km (429,100 m^2)

(2) Qda. San Agustin (6.4 km ~ 14.0 km)

- Embankment : 2.20 km (147,400 m^3)
- Channel Improvement : 4.40 km (533,400 m^3)
- Sodding : 2.20 km (55,700 m^2)
- Bridge rehabilitation : one place (150 m x 5 m x 1 no)
- Ground sill: : 3 places (70 m x 4 m x 3 no)
- Revetment (gabion) : 3 places (3,600 m^2)

(3) Laguna El Carmen (14.07 ~ 20.50 km)

- Embankment : 1.85 km (536,000 m^3)

- Revetment (gabion) : 1.85 km (78,800 m^2)
- Sodding : 1.85 km (69,600 m^2)
- Culvert : 4 places (2 m x 2 m x 15 m x 15 no)
- Outlet : 1 place (10 m x 8 m x 36 m)

(4) Rio Blanco (20.5 ~ 23.9 km)

- Embankment : 1.5 km (85,500 m^3)
- Sodding : 1.5 km (28,500 m^2)

(Alternative 2)

(1) Rio Blanco (21.4 km ~ 23.9 km)

- Embankment : 1.50 km (85,500 m^3)
- Diversion Channel : 2.60 km

Embankment	:	5.20 km (296,400 m^3)
Excavation	:	2.60 km (431,600 m^3)
Sodding	:	5.20 km (98,700 m^2)
Bed protection	:	70 m x 50 m
Diversion weir and bridge(B=10 m)	:	1 place(L=70 m, H=3 m)

In the Alternative 2, also flood mitigation works are required.

3) Rio El Sauce

When the Rio El Sauce was improved, the river channel was shifted to flow to the former channel of the Rio Blanco. The river course at upstream of the station 9.75 km has enough conveyance capacity for the design discharge. Also the river course between 12.60 km and 9.75 km has an enough conveyance capacity for both the Rio El Sauce and the Rio Blanco. The lower reaches from 9.75 km to the Rio Chamelecon, need improvements.

a) Design Discharge

The design discharges at major points are as follows:

Station	Rio El Sauce	With Rio Blanco
- 0.00 km (junction to the Rio Chamelecon)	1.310 m^3/s	1,660 m^3/s
- 1.60 km (junction of the Rio Chotepe)	790 m^3/s	1,170 m^3/s
- 12.6 km (Junction with the Rio Blanco)	610 m^3/s	1.050 m^3/s
- 14.60 km (Junction of the Rio Bermejo)	610 m^3/s	610 m^3/s

b) Design Longitudinal Profile

The design river bed slopes and longitudinal sections are shown in *Fig.* 9.10 (1).

c) Cross section

A compound section is planned by considering easy maintenance. The proposed sections for the reach (0.00 km ~ 9.75 km) under with and without the Rio Blanco are as follows:

Alternative	B1(m)	h(m)	B2(m)
Without Rio Blanco	40	2	144
With Rio Blanco	60	2	184

The reach from Sta. 9.75 km to Sta. 14.60 km is planned to use the existing section.

d) Design High Water Level

The design high water levels are planned as follows:

Station	Without Rio Blanco(EL)	With Rio Blanco(EL)
0.00 km	25.00 m	25.00 m
1.60 km	25.53 m	25.49 m

12.60 km	52.67 m	53.49 m
14.60 km	58.67 m	58.52 m

e) Flood Mitigation Facilities

The proposed improvement works are shown in *Table* 9.3, *Fig*. 9.11 and *Fig*. 9.12. The major works are summarized as follows:

- Embankment (left bank) : 5.50 km (296,300 m^3)
- Heightening of the existing Em. : 7.50 km (300,000 m^3)
- Channel improvement : 7.50 km (810,000 m^3)
- Sodding : 11.00 km (563,500 m^2)
- Revetment : 2.00 km (41,100 m^2)
- Bridge (Sta. 12. 60 km) : one place (150 m x 10 m)

TABLES

TABLE 9.1 (1) EXISTING FLOOD CONTROL FACILITIES

A. Drainage Canal/

River/Canal	Location	Length(m)	Dimension(DM)				Construction(CO)		Remarks
(RV)	(LO)	(LN)	B1(m)	B2(m)	H1(m)	S	Agency(A)	Date(D)	(RM)
Canal Montanuela Cuabanos	C1	5.000	5,00	14,00	3,00	1,50	C.V.S	1992	
Canal Copen-Higuero Cuabanos	C2	11.390	21,00	28,50	2,50	1,50	C.V.S	1992	
		5.000	10,00	18,25	2,75	1,50	SECOPT	1990	
Canal San Roque Cuabanos	C3	690	21,00	28,50	2,50	1,50	C.V.S	1992	
		3.810					SECOPT	N.A	
Canal San Roque	C4	6.500	15,00	20,00	2,50	1,00	SECOPT	1992	
Canal Cotepe	C5	4.000	22,00	28,00	2,00	1,50	SECOPT	1990	

B.Embankment/

River/Canal /etc.	Location	Length(m)	Dimension(DM)				Construction(CO)		Remarks
(RV)	(LO)	(LN)	B1(m)	H(m)	S1	S2	Agency(A)	Date(D)	(RM)
Rio Chamelecon	E1	1.800	2,5	3,0/3,5	2	1,5	TELA R.C	*1930	
	E2	37.800	2,5	3,0/3,5	2	1,5	TELA R.C	*1930	
	E3	6.200	2,5	3,0/3,5	2	1,5	TELA R.C	1988	
	E4	5.500	2,5	3,0/3,5	2	1,5	TELA R.C	1988	
	E5	2.760	4	5,1	2	2	SECOPT	1991	
Rio Choloma	Ec1	3.000	3,0/4,0	3,0/4,0	2	2	SECOPT	1991	
	Ec2	1.000	3,5	2,5	3	2	SECOPT	1975	
	Ec3	1.000	4,5/6,0	2,5	3	3	SECOPT	1975	
Rio Blanco-Canal San Roqe	Eb1	1.000	2,5	3,5	1,5	1,5	SECOPT	1969	
	Eb2	1.000	2	2	1,5	1,5	Private	1970	
	Eb3	3.940	10	3,8	5	3	MUNICIP.	1978	
	Eb4	4.365	10	4	5	3	MUNICIP.	1978	
		3.425	10	4	3	3	SECOPT	1978	
	Eb5	2.400	5	2	3	3	MUNICIP.	1978	
	Eb6	3.400	5	2	3	3	MUNICIP.	1978	
Rio El Sauce	Es1	1.800	2	1,5	2	2	MUNICIP.	1978	
	Es2	5.000	10	4	2	2	SECOPT	1992	
		13.500	10	2,0/4,0	3	3	MUNICIP.	1977	
	Es3	11.890	10	3,0/4,0	3	3	MUNICIP.	1977	
	Es4	5.590	10	3,0/4,0	3	3	MUNICIP.	1977	
	Es5	6.300	10	2,0/4,0	3	3	MUNICIP.	1977	
Rio El Sauce(viejo)-Chotepe	Ev1	7.000	3,5/4,0	3,0/4,0	2	2	SECOPT	1979/1992	
	Ev2	2.800	3	3	2	2	SECOPT	1979	
	Ev3	2.200	10	1,8/4,3	5	5	MUNICIP.	1977	
	Ev4	700	10	4,0/4,2	5	5	MUNICIP.	1977	
Lima Airport	Ea	11.500	4	4	2	2	SECOPT	1981/1990	

Note/Nota:

1.(RV):River/Canal
2.(LO):Location/
3.(LN):Length/
4.(DM): Dimension/
5.(CO):Construction/
(A):Agency/
(D):Date/ :* Approximately
C.V.S:Commission Sula Valley
MUNICIP.:Municipality of SanPedro Sula
TELA R.C:TELA Railway Company
6.(RM):Remarks/

TABLE 9.1 (2) EXISTING FLOOD AND DEBRIS CONTROL FACILITIES

C. Sabo Dam

River/Canal (RV)	Location (LO)	Elevation (EL)	Dimension(DM) L(m)	Dimension(DM) H(m)	Construction(CO) Agency(A)	Construction(CO) Date(D)	Remarks (RM)
Rio La Jutosa	SD1	274	84	11	SECOPT	1984	

D. Water Intake

River/Canal (RV)	Location (LO)	Elevation (EL)	Dimension(DM) L(m)	Dimension(DM) H(m)	Construction(CO) Agency(A)	Construction(CO) Date(D)	Remarks (RM)
Rio Santa Ana	W1	N.A	15	3,5	MUNICIP.	N.A	
Rio Piedras	W2	N.A	21,6	3,5	MUNICIP.	N.A	

E. River Crossing Roads (Concrete)/DISPERSION WORK

River/Canal (RV)	Location (LO)	Elevation (EL)	Dimension(DM) L(m)	Dimension(DM) B(m)	Dimension(DM) H(m)	Construction(CO) Agency(A)	Construction(CO) Date(D)	Remarks (RM)
Rio Choloma	Rc1	N.A	9,1	5,5	0,6	Patronato	1990	
Rio Blanco	Dp1	N.A	56	1,6	1,2	MUNICIP.	1978	
Rio Zapotal	Rz1	N.A	46	8,4	0,8	MUNICIP.	1978	
Rio El Sause	Rs1	N.A	38,6	8,1	1,8	MUNICIP.	1977	
Rio Santa Ana	Ra1	N.A	50	4	0,6	MUNICIP.	1977	
	Ra2	N.A	20	9	0,6	MUNICIP.	1977	
	Ra3	N.A	24	4.2	0.65	MUNICIP.	1977	
Rio Piedras	Rp1	N.A	38	8	0,6	MUNICIP.	1992	
	Rp2	N.A	34,5	9,3	0,8	MUNICIP.	1977	

Note/Nota:
1.(RV):River/Canal
2.(LO):Location/
3.(LN):Length/
4.(DM): Dimension/
5.(CO):Construction/
(A):Agency/
(D):Date/
C.V.S:Commission Sula Valley
MUNICIP.:Municipality of SanPedro Sula
TELA R.C:TELA Railway Company
6.(RM):Remarks/
7.N.A:Data is not Available
8.Choloma .M:Choloma Municipality

TABLE 9.2 (1) WATER LEVEL CALCULATION FOR PROBABLE DISCHARGE

1)Rio Choloma (UNIT:EL.M)

STA.km	Distance(m)	100-YEAR	50-YEAR	30-YEAR	10-YEAR	5-YEAR	2-YEAR
*11.48	0	12.00	12.00	12.00	12.00	12.00	12.00
12.23	750	13.55	13.30	13.14	12.74	12.47	12.11
13.08	850	15.61	15.45	15.33	15.00	14.71	14.15
14.28	1200	19.52	19.37	19.25	18.90	18.57	17.84
15.28	1000	21.90	21.73	21.60	21.23	20.90	20.28
16.28	1000	25.52	25.37	25.25	24.91	24.61	23.64
17.08	800	28.66	28.49	28.36	28.01	27.69	27.02
18.28	1200	32.05	31.89	31.77	31.44	31.15	30.78
*19.08	800	36.10	35.78	35.55	34.84	34.17	32.73
19.58	500	39.43	39.07	38.80	38.07	37.45	36.40
20.08	500	42.34	42.10	41.89	41.39	40.92	40.11
20.58	500	45.17	44.89	44.65	44.01	43.37	42.04
21.08	500	48.59	48.26	47.97	47.24	46.55	45.23
21.78	700	54.24	53.94	53.68	53.04	52.44	51.30
22.08	500	57.52	57.25	57.01	56.42	55.86	54.84
22.58	500	61.42	61.24	61.09	60.70	60.34	59.64
*22.98	400	65.96	65.81	65.66	65.31	64.97	64.33

Note: *

1) Sta 11.48 :Junction of Canal San Roqe

2) Sta 19.08 :Road Bridge (Sabo Control Point)

3) Sta 22.98 :Junction of Tributaries (Sub -Control Point)

(UNIT:M3/S)

STA.	100-YEAR	50-YEAR	30-YEAR	10-YEAR	5-YEAR	2-YEAR
11.48-19.08	890	790	720	530	380	150
19.08-22.98	690	620	560	420	300	120

TABLE 9.2 (2) WATER LEVEL CALCULATION FOR PROBABLE DISCHARGE

2) CANAL SAN ROQUE - RIO BLANCO (UNIT:EL.M)

STA.	Distance	100-YEAR	50-YEAR	30-YEAR	10-YEAR	5-YEAR	2-YEAR
CANAL SAN ROQUE							
*0	0	12.00	12.00	12.00	12.00	12.00	12.00
1.00	1000	13.00	12.80	12.66	12.36	12.19	12.03
2.10	1100	13.46	13.22	13.04	12.63	12.35	12.06
3.20	1100	13.96	13.70	13.49	12.97	12.58	12.11
4.10	900	14.33	14.04	13.82	13.25	12.79	12.17
5.00	900	14.71	14.41	14.17	13.54	13.02	12.24
5.70	700	15.01	14.71	14.46	13.83	13.29	12.41
6.40	700	15.43	15.13	14.88	14.22	13.66	12.63
Qda San Agustin : No Data available Sta.6.4~9.8 (Assumed Cross Section B=60m)							
6.40	0	15.43	15.13	14.88	14.22	13.66	12.63
8.00	1600	16.05	15.75	15.50	14.88	14.33	13.30
9.00	1000	18.50	18.28	18.10	17.66	17.24	16.49
9.80	800	22.66	22.47	22.30	21.86	21.44	20.53
9.80	0	22.66	22.47	22.30	21.86	21.44	20.53
10.30	500	24.77	24.53	24.32	23.79	23.24	21.99
10.80	500	26.38	26.14	25.93	25.41	24.89	23.78
11.30	500	29.04	28.74	28.48	27.83	27.20	25.87
11.80	500	31.44	30.96	30.57	29.62	28.77	27.11
12.30	500	32.96	32.64	32.38	31.75	31.19	30.00
12.80	500	37.05	36.65	36.32	35.48	34.61	32.94
13.07	270	37.64	37.24	36.90	36.09	35.33	33.83
13.57	500	44.20	43.78	43.42	42.59	41.76	40.15
*14.07	500	48.53	48.16	47.87	47.19	46.67	45.74
(LAGUNA EL CARMEN)							
18.90	0	48.00	48.00	48.00	48.00	48.00	48.00
19.70	800	51.46	51.35	51.26	51.05	50.87	50.43
20.50	800	56.16	56.04	55.93	55.64	55.36	54.77
21.40	900	59.51	59.37	59.24	58.94	58.67	58.08
22.40	1000	62.95	62.77	62.61	62.21	61.80	60.64
*23.45	1050	65.30	65.15	65.03	64.77	64.51	63.80
24.45	1000	69.62	69.48	69.37	69.11	68.85	68.18
25.45	1000	75.33	75.19	75.03	74.70	74.38	73.60

PROBABLE DISCHARGE DISTRIBUTION

(UNIT:M3/S)

STA.	100-YEAR	50-YEAR	30-YEAR	10-YEAR	5-YEAR	2-YEAR
0.00-6.40	1250	1110	1000	730	520	200
6.40-9.80	1000	890	800	590	420	160
9.80-14.07	880	780	700	520	370	140
18.90-21.40	740	660	590	440	320	120
21.40-25.45	680	600	540	410	300	110

Note: *

1) Sta 0.00 :Junction of Rio Choloma
2) Sta 14.07 :Outlet of Lake El Carmen
3) Sta 23.45 :Near the Road Bridge (Subo Control Point)

TABLE 9.2 (3) WATER LEVEL CALCULATION FOR PROBABLE DISCHARGE

3) Rio El Sauce (UNIT:EL.M)

STA.	Distance(m)	100-YEAR	50-YEAR	30-YEAR	10-YEAR	5-YEAR	2-YEAR
*0	0	26.00	26.00	26.00	26.00	26.00	26.00
1.60	1200	27.11	26.78	26.64	26.36	26.19	26.03
2.80	1200	27.60	27.18	27.00	26.61	26.34	26.05
3.90	1100	28.37	27.93	27.74	27.30	26.92	26.29
4.90	1000	29.66	29.28	29.11	28.70	28.33	27.58
5.90	1000	31.39	31.12	31.00	30.71	30.45	29.87
6.90	1000	33.01	32.79	32.68	32.40	32.12	31.56
7.90	1000	35.61	35.47	35.41	35.26	35.12	34.73
8.50	600	39.04	38.87	38.80	38.60	38.40	37.88
9.00	500	41.49	41.19	41.01	40.59	40.18	39.37
9.75	750	43.55	43.28	43.15	42.83	42.54	41.88
10.75	1000	47.63	47.35	47.21	46.84	46.52	45.73
11.55	800	49.26	48.96	48.81	48.43	48.09	47.25
*12.6	1050	52.90	52.66	52.52	52.19	51.88	51.12
13.55	950	56.00	55.71	55.56	55.18	54.83	54.07
*14.6	1050	58.90	58.54	58.38	57.98	57.62	56.78

PROBABLE DISCHARGE DISTRIBUTION

(UNIT:M3/S)

STA.	100-YEAR	50-YEAR	30-YEAR	10-YEAR	5-YEAR	2-YEAR
0.00	1480	1310	1180	860	610	230
1.60-12.60	890	790	710	530	380	140
12.60-14.60	690	610	530	410	300	110

Note: *
1) Sta 0.00 :Junction of Rio Chamelecon
2) Sta 12.60 :Road crossing
3) Sta 14.6 :Junction of Tributaries

TABLE 9.3 PROPOSED FACILITIES OF ALTERNATIVES

Area/River of Alternatives	River Improvement Facilities/Works	Alternative 1	Alternative 2	Major Works
1.Rio.Blanco-Canal San Roqe and Rio Sauce (Alternative 1)				
1.1 Canal San Roqe(0-6.4km)	1).Embankment	H=5.3m,L=12.8km	Out of Basin	Banking Works Sodding Works
	2). Channel Improvement	B1=60m,L=6.4km		Excavation Works
	3).Bridge Improvement	1pls		Miscellaneous
	4).Land Acquision	149.76 ha		1)-2)
1.2 Rio Blanco(Lower)			Out of Basin	
1) .6.4km-9.6km	1).Embankment	H=4m,L=2.2km		Banking Works Sodding Works
	2). Channel Improvement	B1=60m,L=3.4km		Excavation Works
	3).Culvert Improvement	1pls		Miscellaneous
	4).Land Acquision	53.72 ha		1)-2)
2). 9.6km-14.0km	1). Channel Improvement	L=0.5km		Excavation Works
	2).Ground.Sill	3		Concrete Works Gabion Works
1.3 Lake Carmen (14.0-20.5km)	1).Embankment (Closing Dike)	H=5.7-6.4m,1.85 km	Out of Basin	Banking Works Sodding Works
	2).Revetment	1.85 km		Gabion Works
	3).Outlet	1pls		Concrete Works Gate Works
	4).Culvert	4 pls		
	5).Land Acquision	5.15 ha		1)-3)
1.4/2.1 Rio Blanco(Upper) (Alternative 1 &2)	1).Embankment *Left Bank Only	H=3.0m,L=1.5km	H=3.0m,L=1.5km	Banking Works Sodding Works
	2).Revetment	0	0	Revetment Works
	3). Channel Improvement	1.5km	1.5km	Excavation Works Gabion Works
	4).Land Acquision	4.2 ha	4.2 ha	1)-3)
2.2 Diversion Canal (2.6 km) Rio Blanco-El.Sauce (Alternative 2)				
	1).Embankment	0	H=3.0m,L=5.2km	Banking Works Sodding Works
	2). Channel Improvement	0	B1=60m,L=2.6km	Excavation Works
	3).Diversion Weir	0	1 Pls	Concrete Works Gabion Works Bridge Works
	4).Land Acquision	0	56.68 ha	1)-2)
2.3 El.Sauce (Alternative 1 & 2)				
1).Left Bank	1).Embankment	H=3.6m,L=5.5km	H=3.6m,L=5.5km	Banking Works Sodding Works
2).Right Bank	1).Embankment	H=4.5m,L=7.5km Exit.H=3.5m	H=4.5m,L=7.5km Exit.H=3.5m	Banking Works Sodding Works
	2). Channel Improvement	B1=40m,L=2.6km	B1=60m,L=7.5km	Excavation Works
	3).Revetment	2.0 km	2.0 km	Revetment Works
	4).Bridge	1	1	Concrete Works Gabion Works Bridge Works
	5).Land Acquision	95.25 ha	117.75 ha	1)-2)

Note:
1).H :Height of Embankment
2).L : Length
3).B1:Width of Low Water Channel

FIGURES

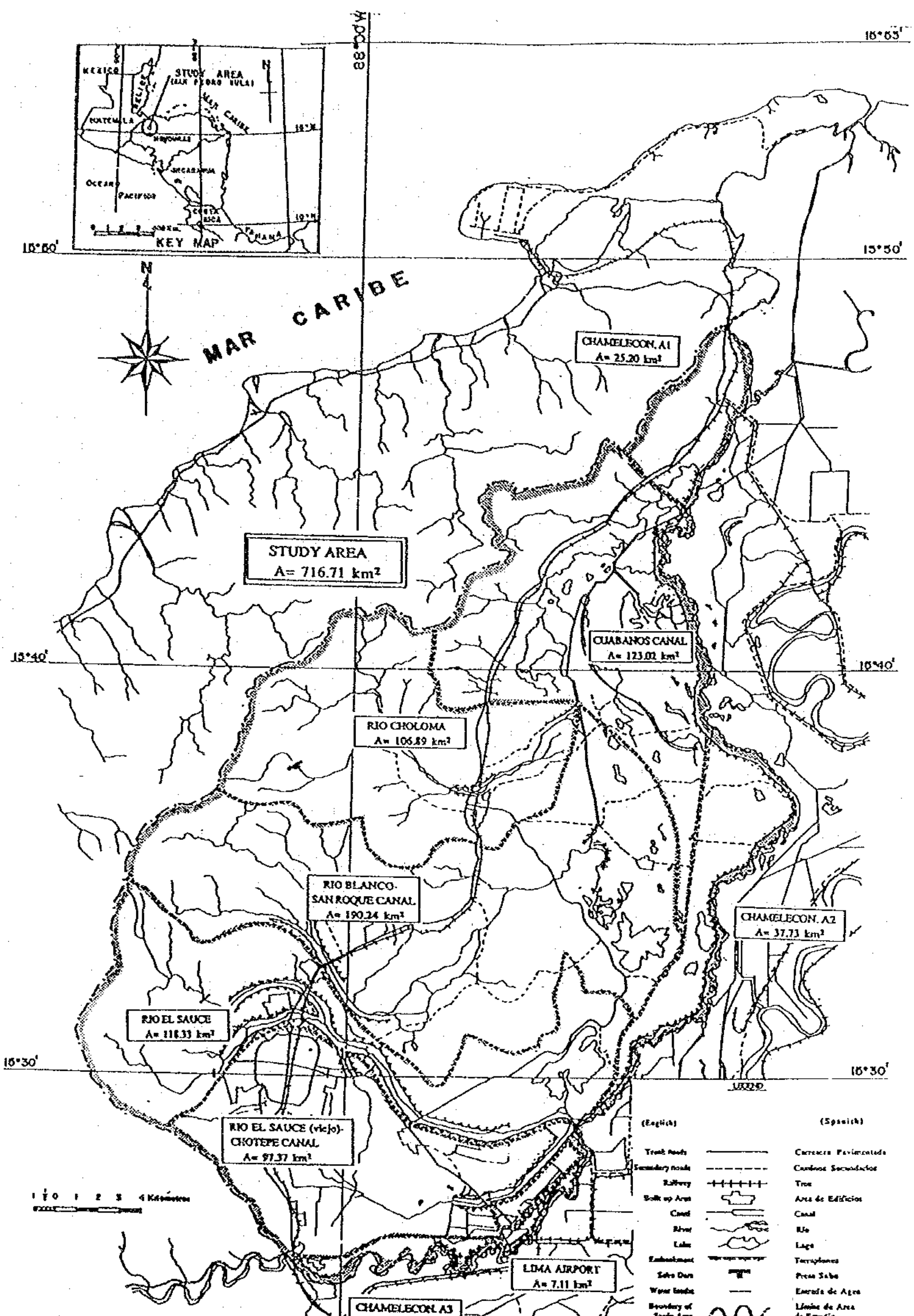


FIG. 9.1 RIVER SYSTEM OF THE STUDY AREA

JICA

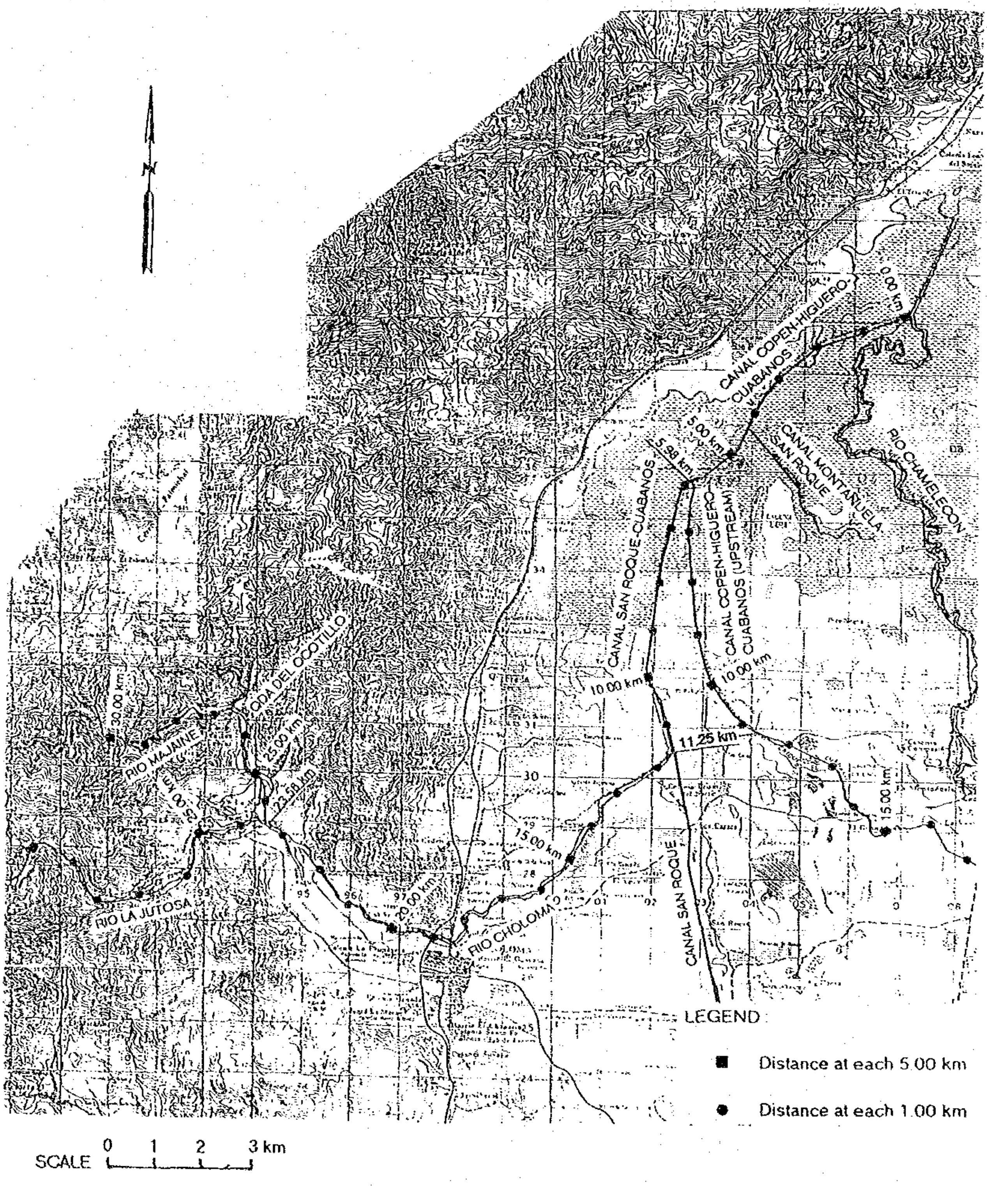


FIG. 9.2 (1) RIVER SYSTEM OF THE RIO CHOLOMA AND THE DOWNSTREAM CANALS

JICA

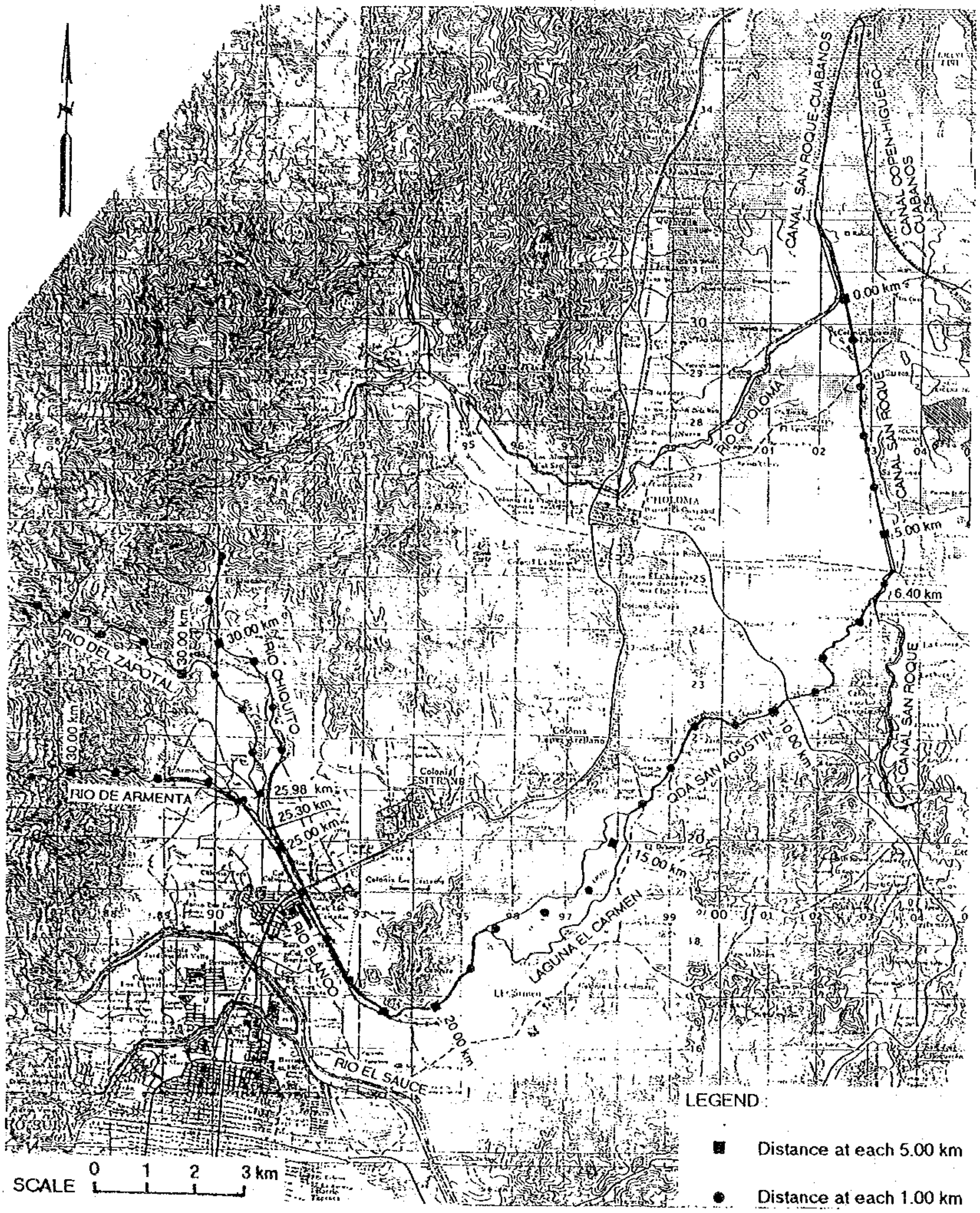


FIG. 9.2 (2) RIVER SYSTEM OF THE RIO BLANCO AND THE CANAL SAN ROQUE

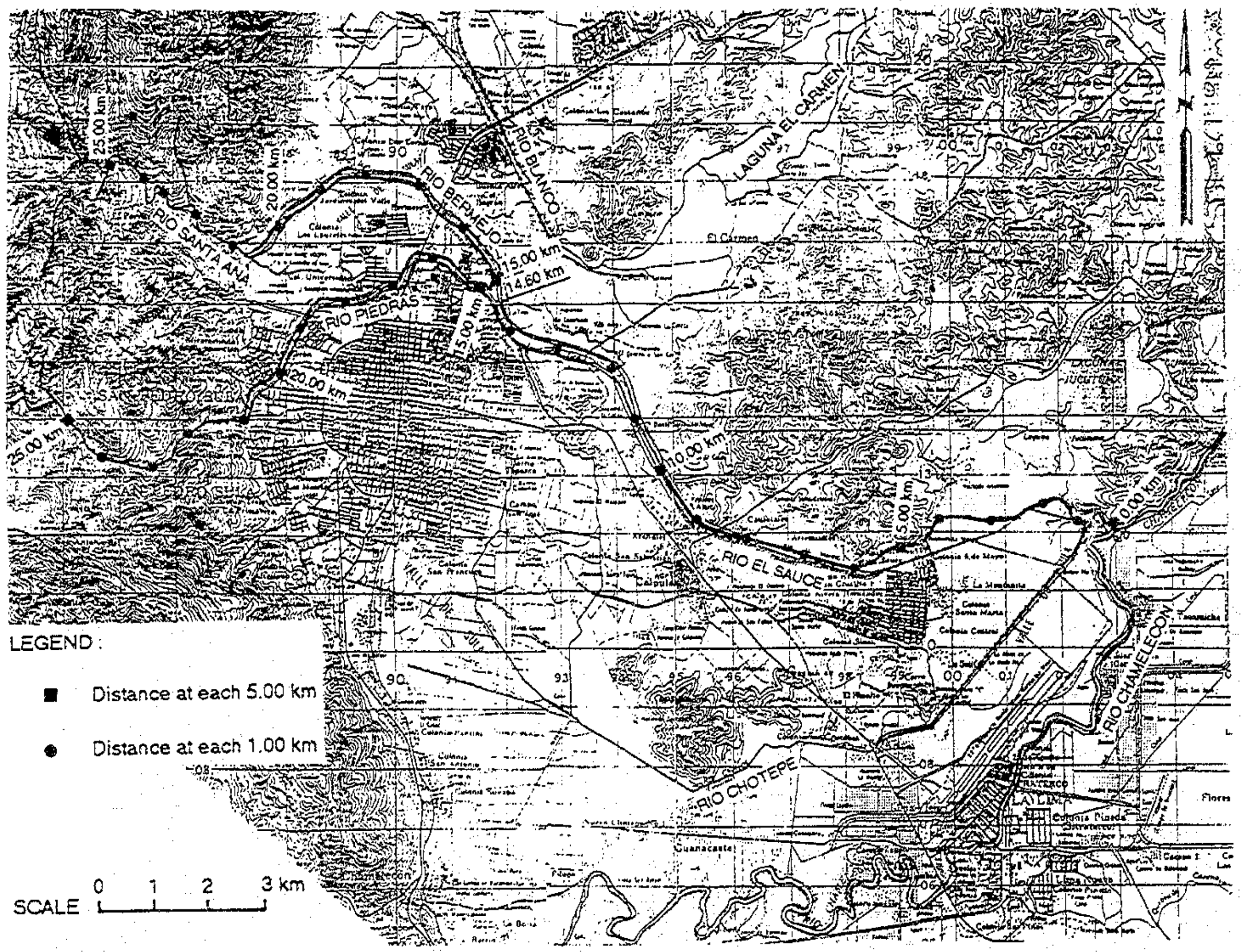


FIG. 9.2 (3) RIVER SYSTEM OF THE RIO EL SAUCE

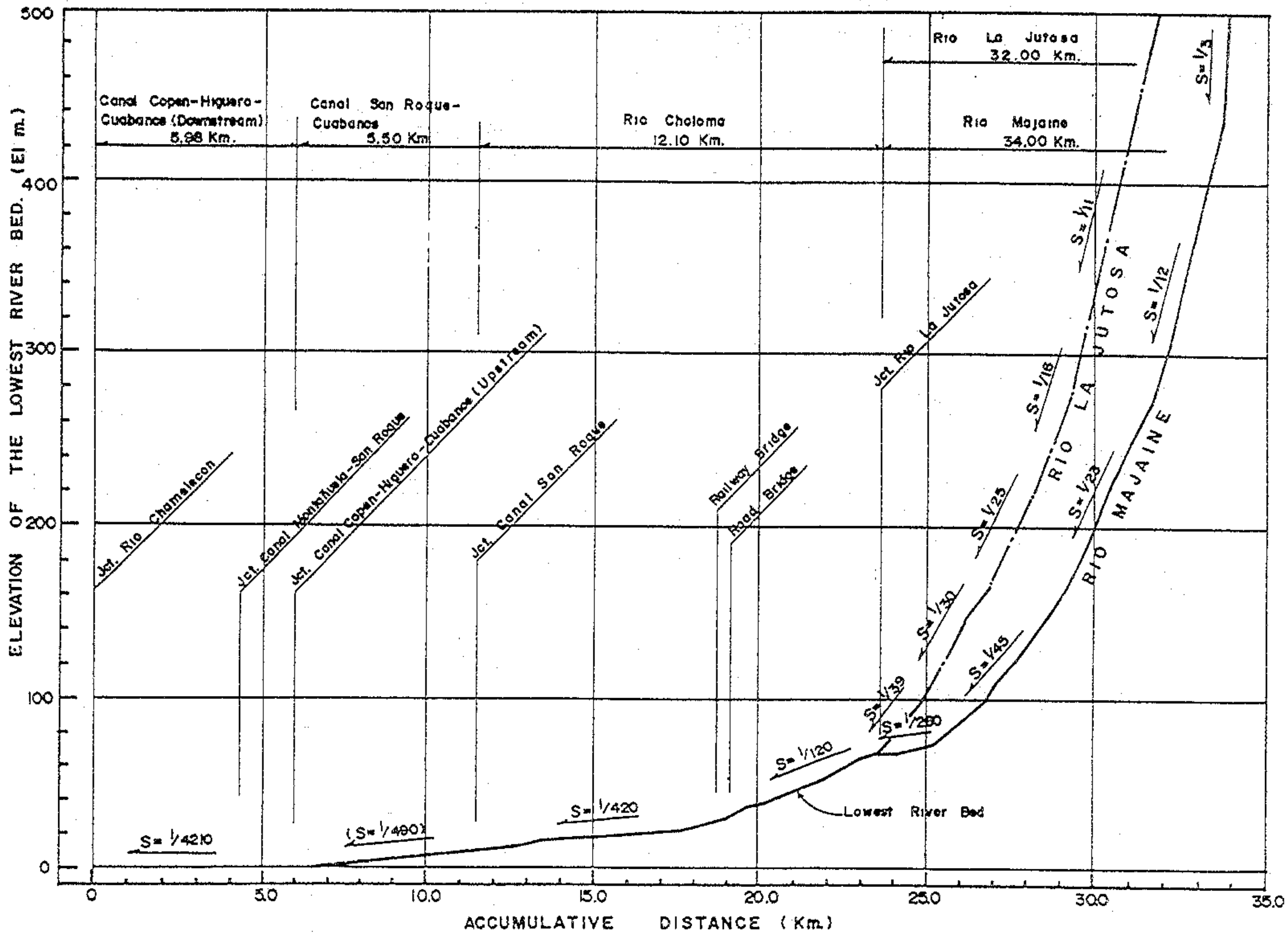


FIG. 9.3 (1) LONGITUDINAL PROFILE OF THE RIO CHOLOMA AND THE DOWNSTREAM CANALS

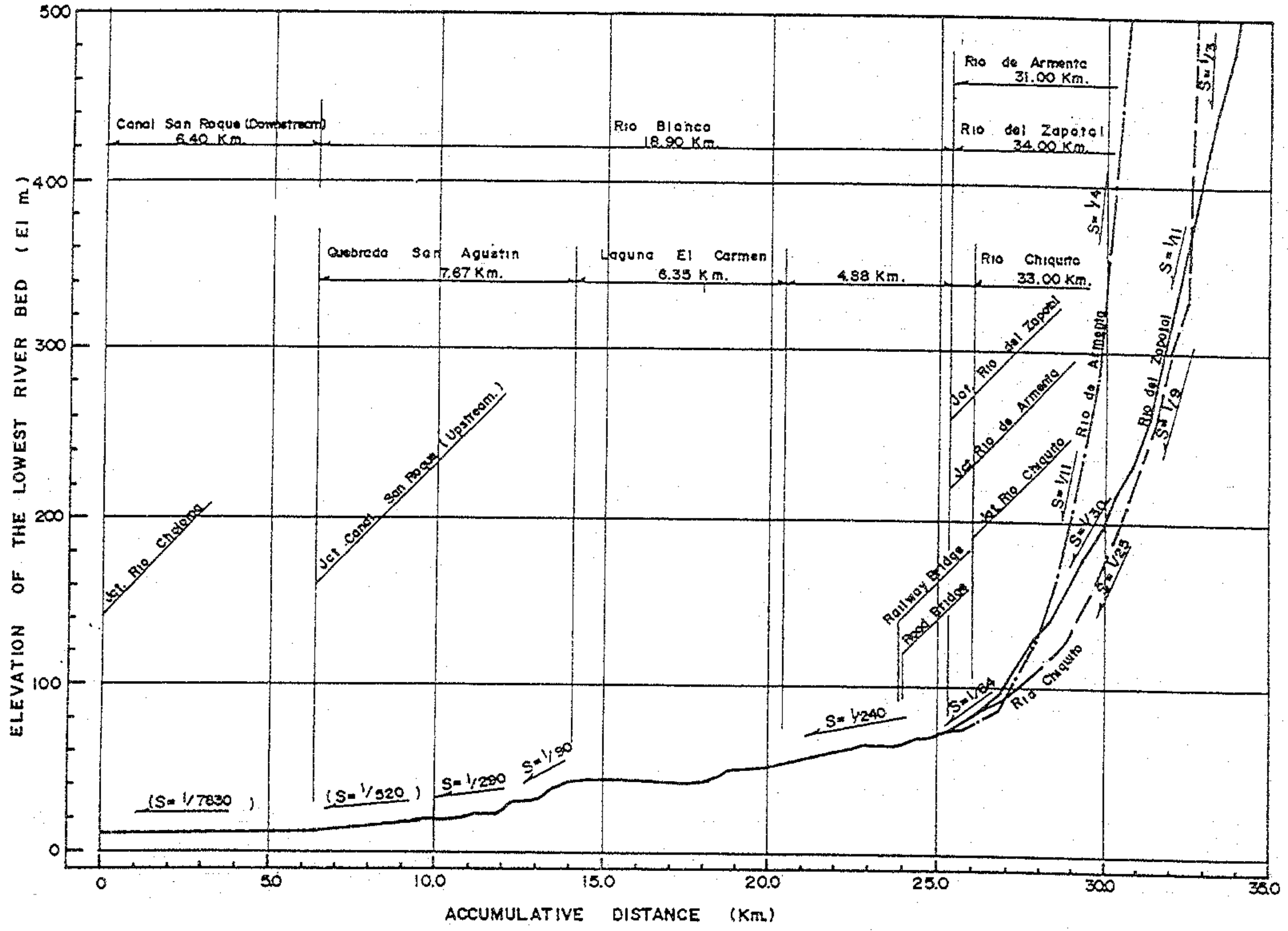


FIG. 9.3 (2) LONGITUDINAL PROFILE OF THE RIO BLANCO AND THE CANAL SAN ROQUE

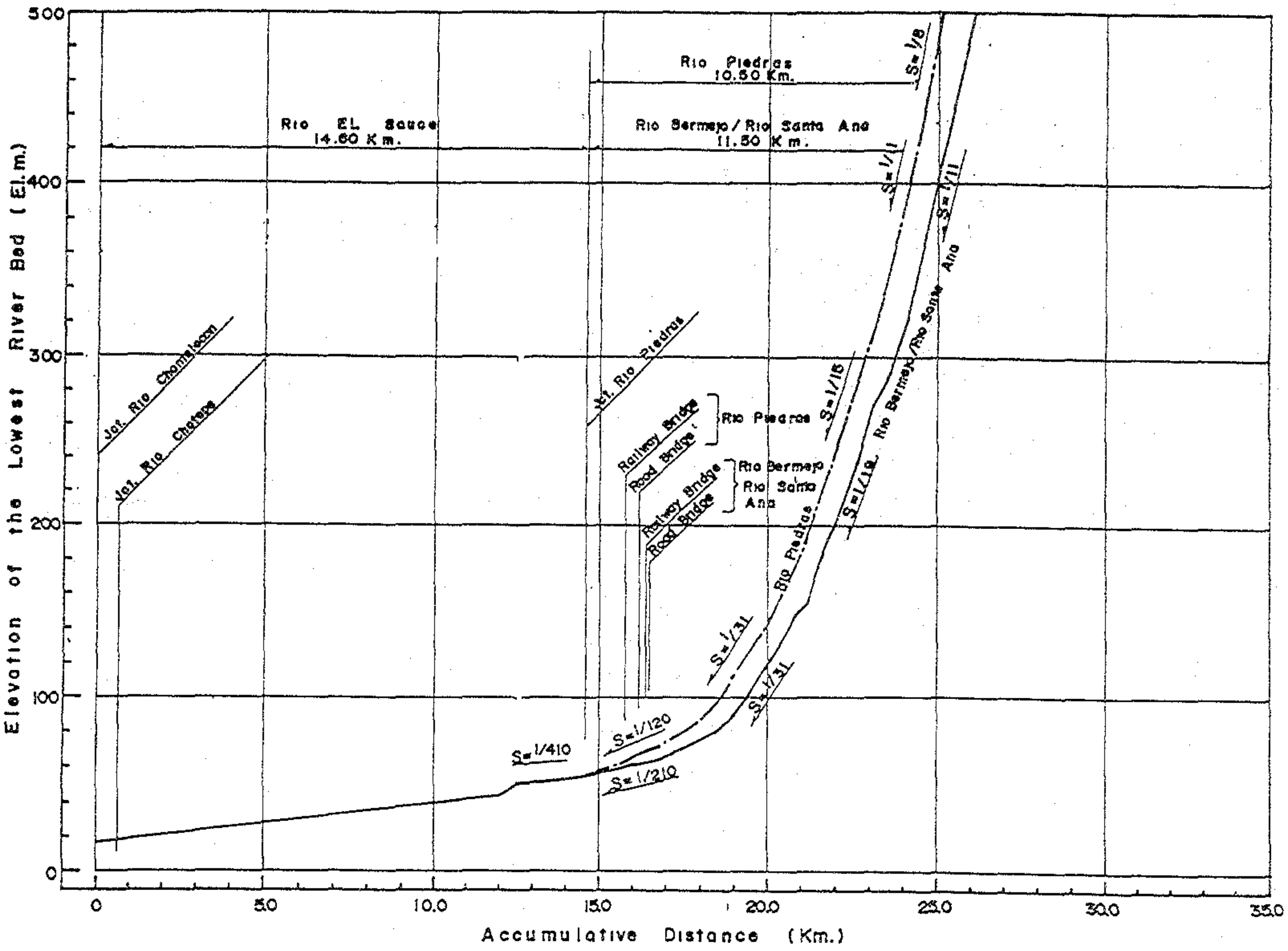


FIG. 9.3 (3) LONGITUDINAL PROFILE OF THE RIO EL SAUCE

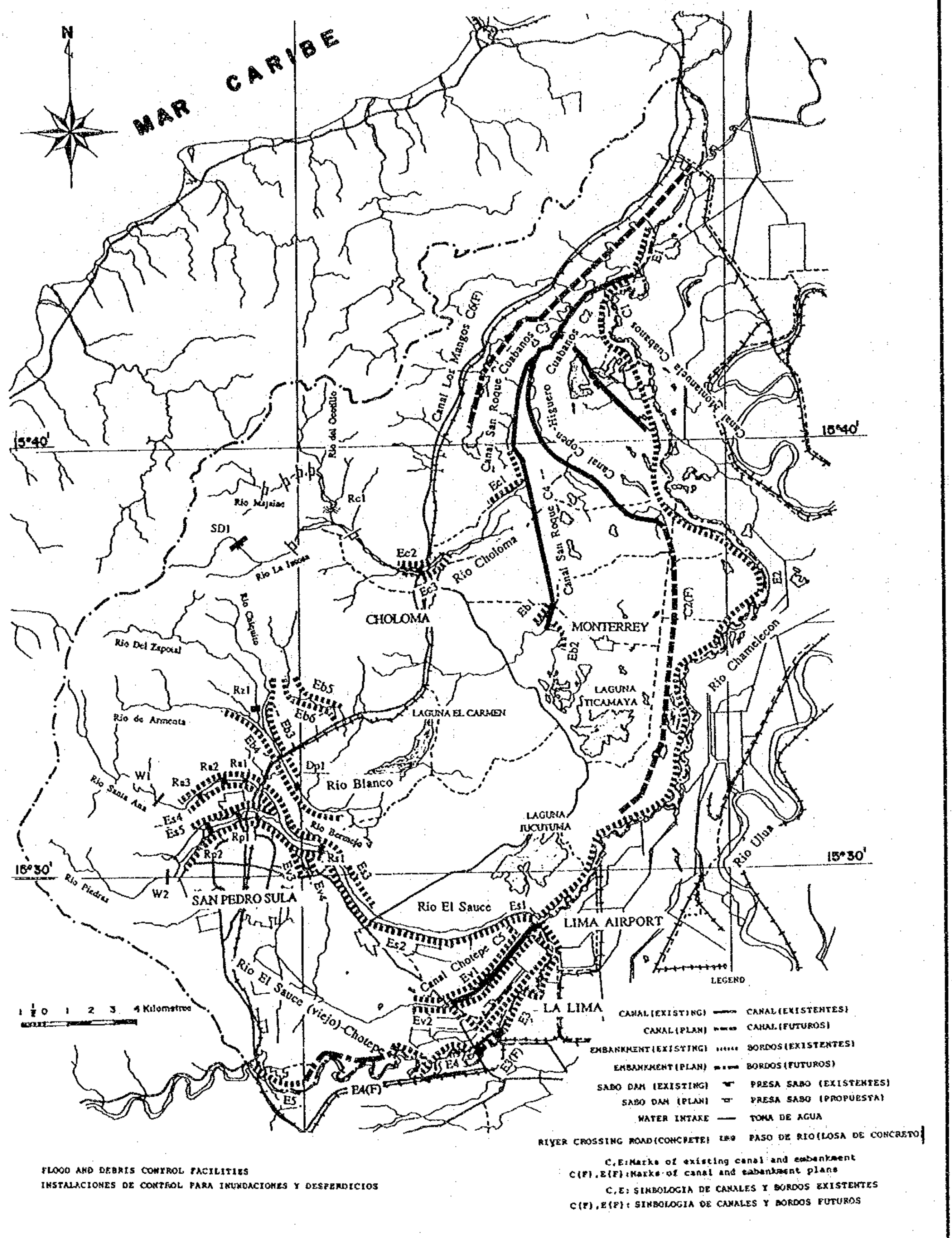


FIG. 9.4 EXISTING FLOOD CONTROL FACILITIES AND FACILITIES PLANS

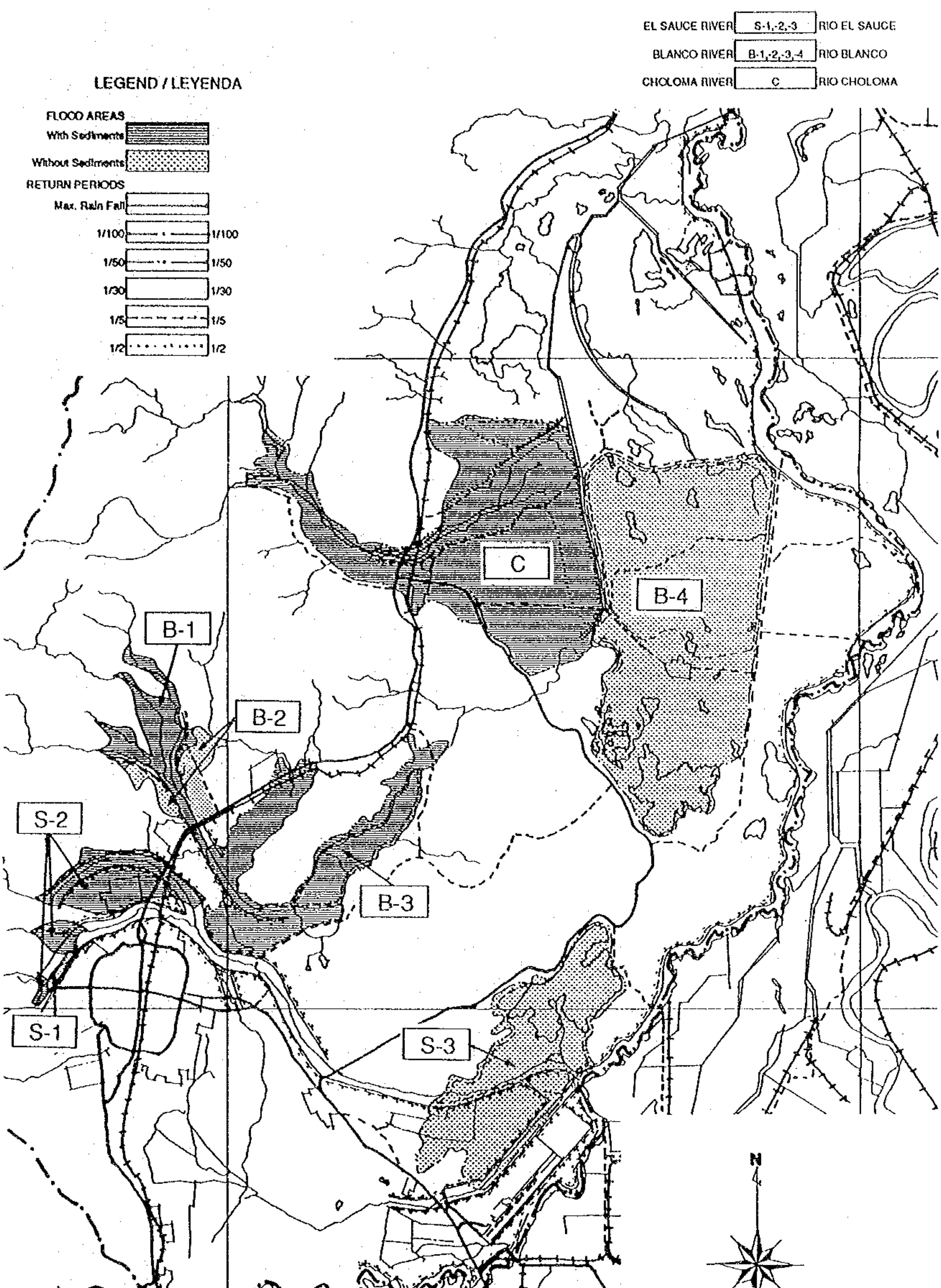
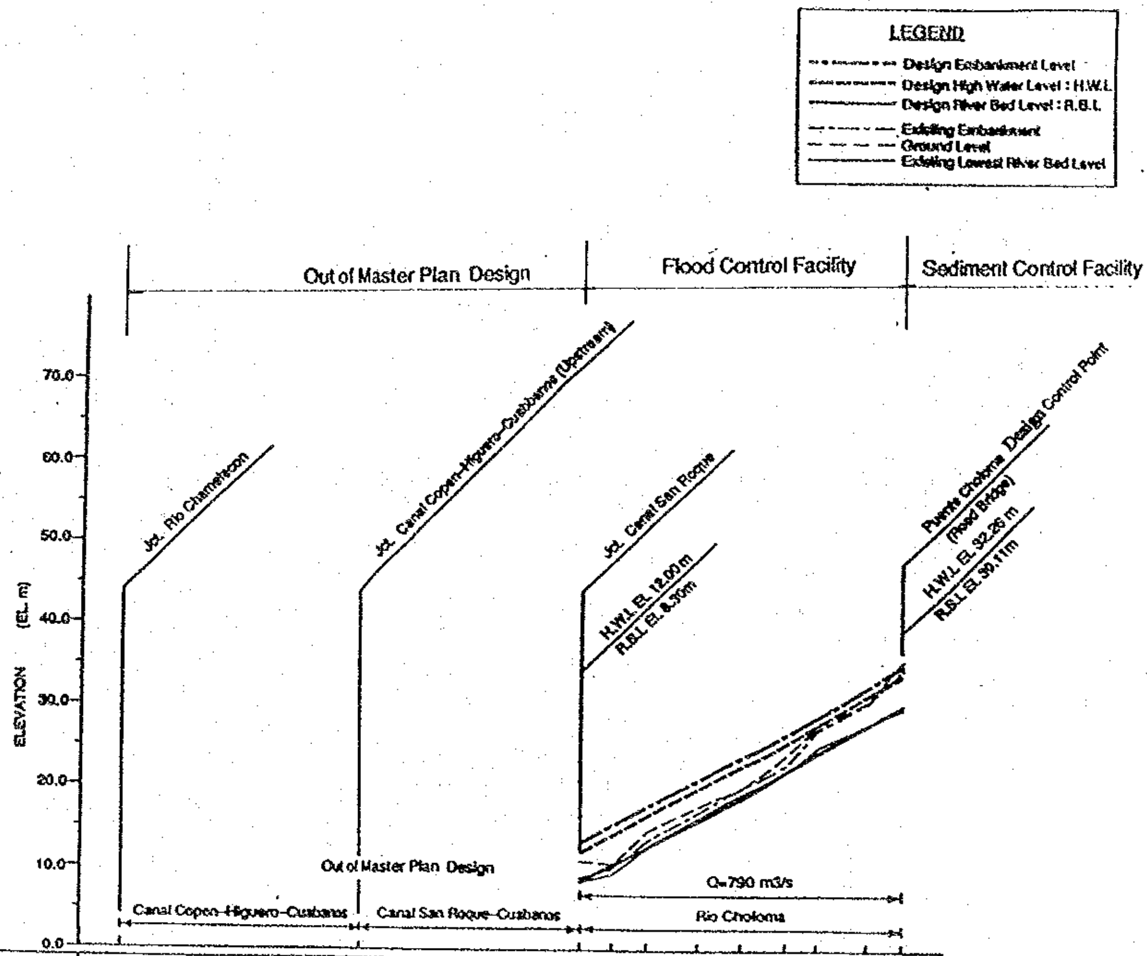


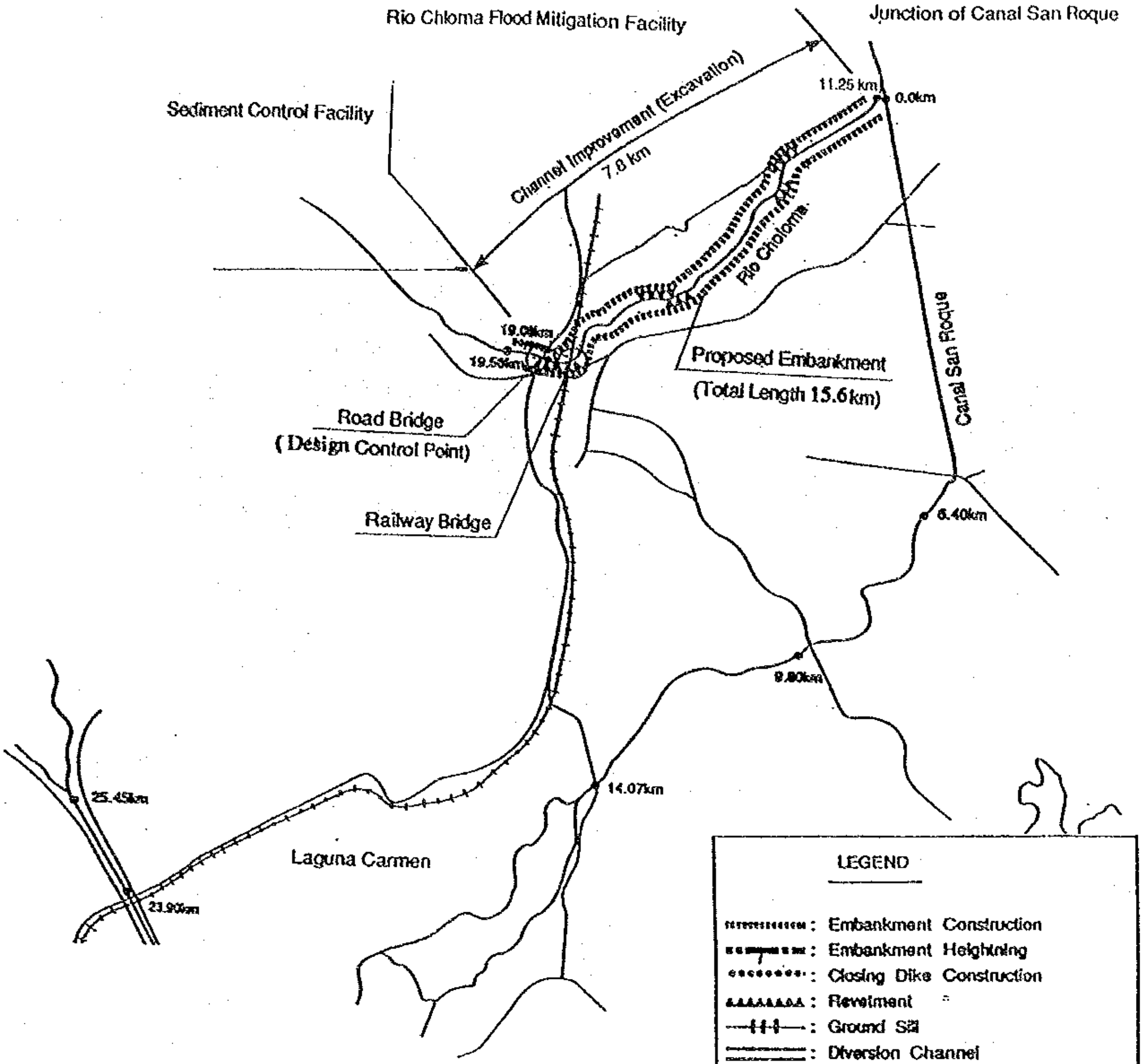
FIG. 9.5 ESTIMATED FLOOD AREA BY FLOOD SCALES



RIGHT EMBANKMENT (EL. m)	(0.4 ~ 9.5 m)		8.70	10.00	13.70	16.60	19.60	23.70	27.50	30.30	34.40
LEFT EMBANKMENT (EL. m)	(1.3 ~ 10.8 m)		10.90	10.30	14.60	17.50	19.50	22.90	27.20	30.30	35.30
LOWEST RIVER BED (EL. m)	-1.30	0.12	8.30	9.20	12.60	15.70	18.50	21.70	24.80	27.70	29.40
SECTION DISTANCE (km)	0.00	5.98	4.27	0.98	0.85	1.20	1.00	1.00	0.80	1.20	0.80
STATION	0.00	6.98	11.25	12.23	13.08	14.28	15.28	16.28	17.08	18.28	19.08

Design River Bed Slope |—— 1/350 ——|—— 1/330 ——|

FIG. 9.6 DESIGN LONGITUDINAL SECTION OF THE RIO CHOLOMA



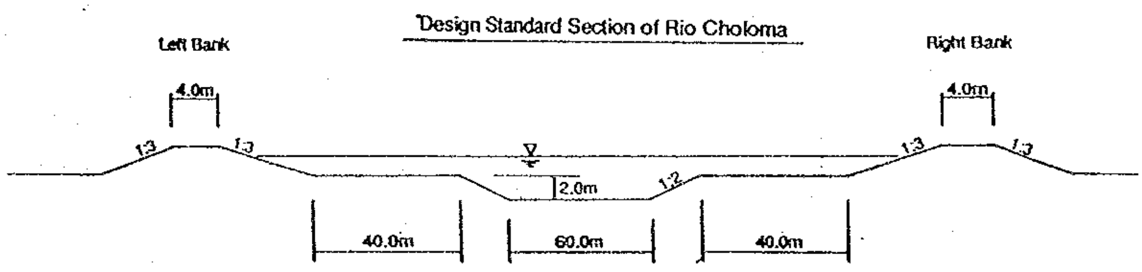


FIG. 9.7 PROPOSED FLOOD MITIGATION FACILITIES AND DESIGN CROSS SECTION OF THE RIO CHOLOMA

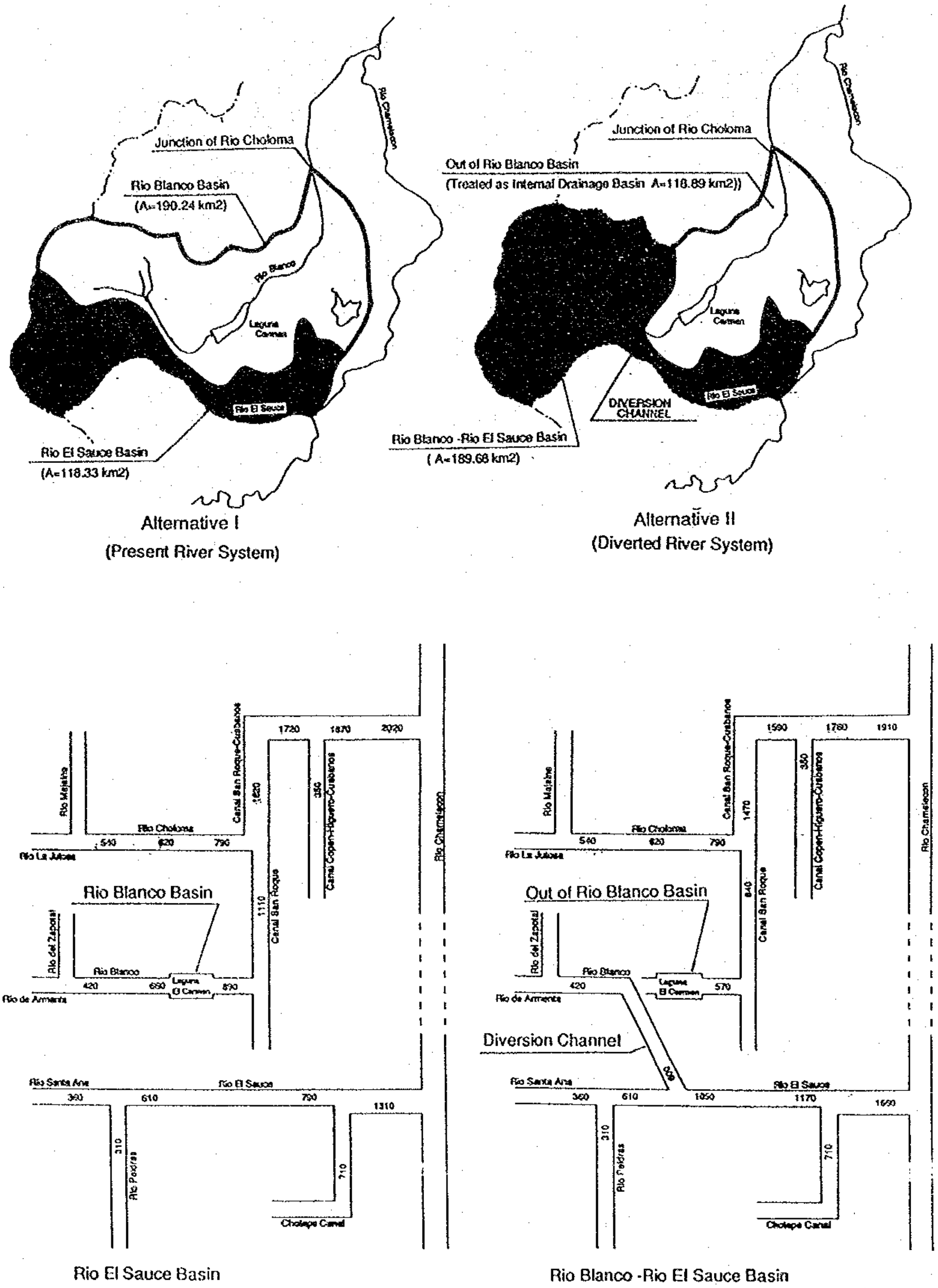
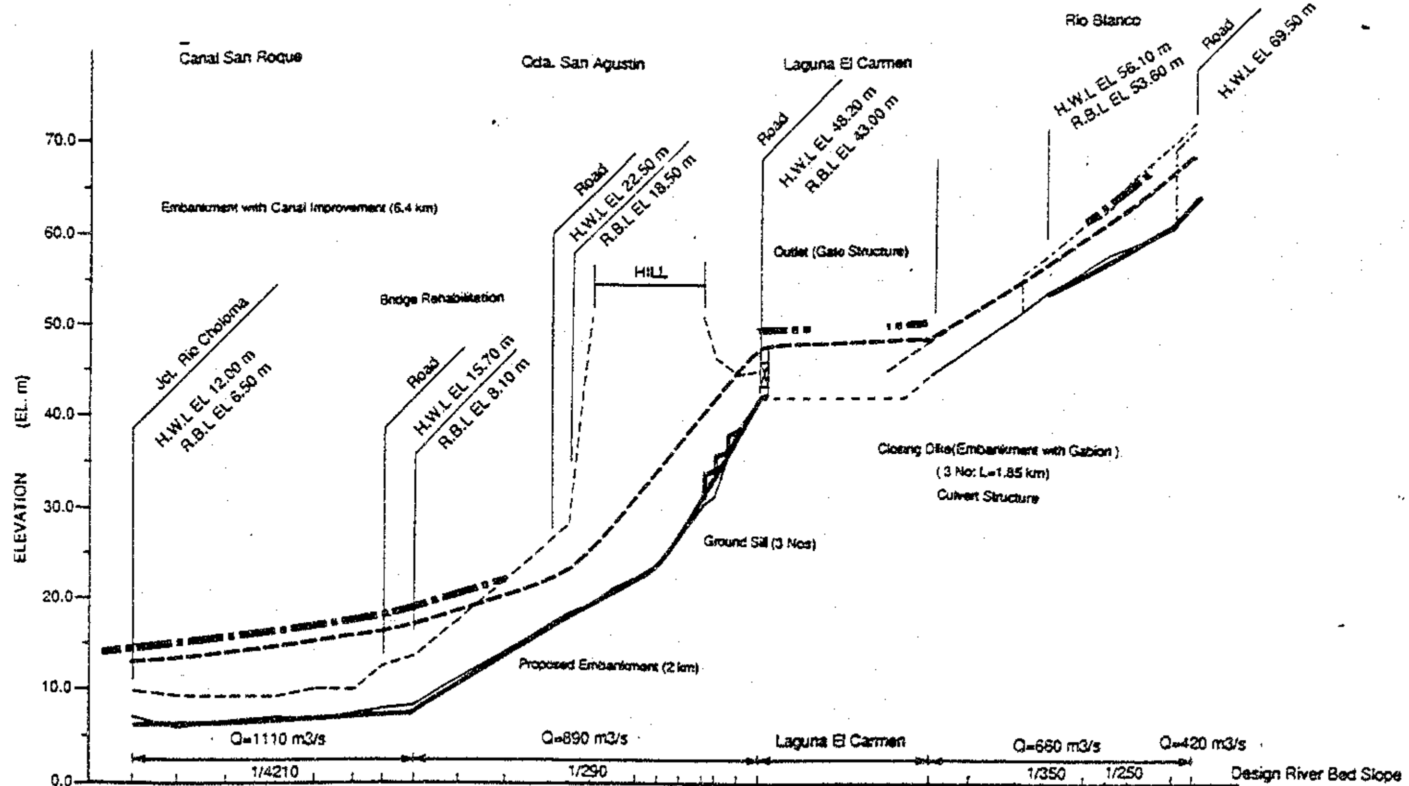
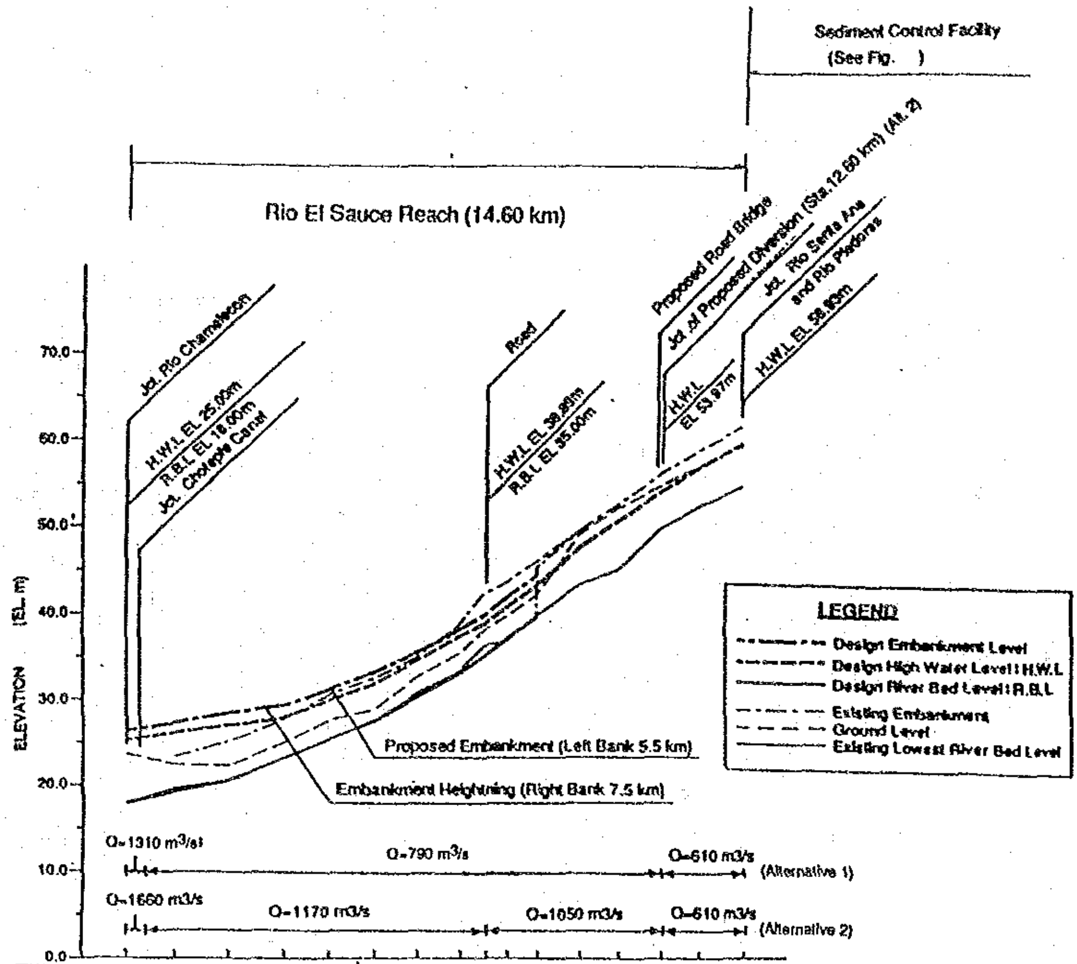


FIG. 9.8 MAIN FEATURE OF RIVER SYSTEM OF ALTERNATIVES



RIGHT EMBANKMENT (EL. m)																								57.60	61.40	(63.00)	66.04	70.73	72.50
LEFT EMBANKMENT (EL. m)																												69.50	71.80
LOWEST RIVER BED (EL. m)	7.00	6.00	6.60	7.00	6.80	7.50	8.00	8.30	11.30	14.30	17.30	18.50	19.50	21.40	22.50	24.00	27.00	30.50	31.50	38.60	42.00				53.60	58.30	(58.00)	59.00	62.00	64.20
SECTION DISTANCE (km)	0.00	1.00	1.10	1.10	0.90	0.90	0.70	0.70	1.00	1.00	1.00	0.40	0.50	0.50	0.50	0.50	0.50	0.50	0.27	0.50	0.50			1.00	0.60	0.90		1.00	1.05	0.45
STATION	0.00	1.00	2.10	3.20	4.10	5.00	5.70	6.40	7.40	8.40	9.40	9.80	10.30	10.80	11.30	11.80	12.30	12.80	13.07	13.57	14.07	18.00	18.90	19.90	20.50	21.40	(21.90)	22.40	23.45	23.90

FIG. 9.9 DESIGN LONGITUDINAL SECTION OF THE RIO BLANCO (ALTERNATIVE 1)

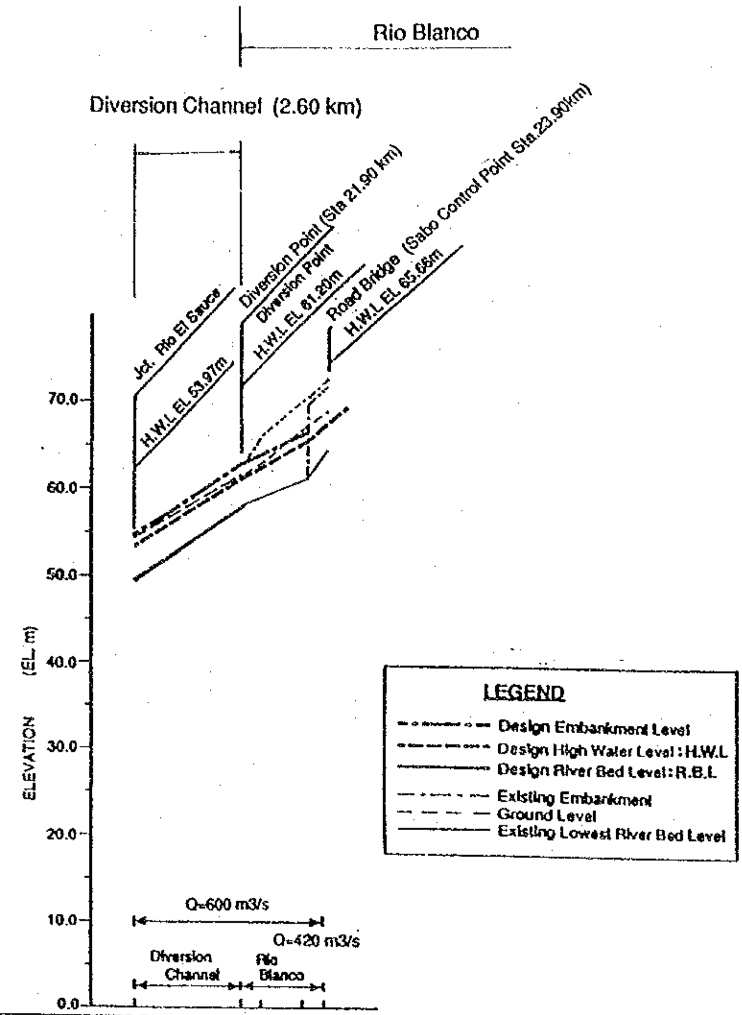


RIGHT EMBANKMENT (EL. m)		23.20	25.00	27.30	30.03	32.01	34.61	38.40	42.00	43.20		Hill		55.60	58.35	61.00
LEFT EMBANKMENT (EL. m)	No Embankment Reachs													55.50	58.50	60.40
LOWEST RIVER BED (EL. m)	18.00	19.50	20.40	23.00	25.20	27.20	30.50	33.00	36.00	38.50	39.50	43.00	44.90	49.40	52.00	54.20
SECTION DISTANCE (km)	0.00	1.20	1.20	1.10	1.00	1.00	1.00	1.00	0.60	0.50	0.75	1.00	0.80	1.05	0.95	1.05
STATION	0.00	1.60	2.80	3.90	4.90	5.90	6.90	7.90	8.50	9.00	9.75	10.75	11.55	12.60	13.55	14.60

Design River Bed Slope |— 1/1000 —|—— 1/450 ——|— 1/350 —|— 1/360 —|

FIG. 9.10 (1) DESIGN LONGITUDINAL SECTION OF THE RIO BLANCO AND THE RIO EL SAUCE (ALTERNATIVE 1 AND ALTERNATIVE 2)

JICA



RIGHT EMBANKMENT (EL. m)	55.60	(63.00)	66.04	70.73	72.50
LEFT EMBANKMENT (EL. m)	55.50			69.50	71.80
LOWEST RIVER BED (EL. m)	49.40	(58.00)	59.00	62.00	64.20
SECTION DISTANCE (km)	0.00	2.60	0.50	1.05	0.45
STATION	12.60	(21.90)	22.40	23.45	23.90

Design River Bed Slope: 1/300

FIG. 9.10 (2) DESIGN LONGITUDINAL SECTION OF DIVERSION CHANNEL

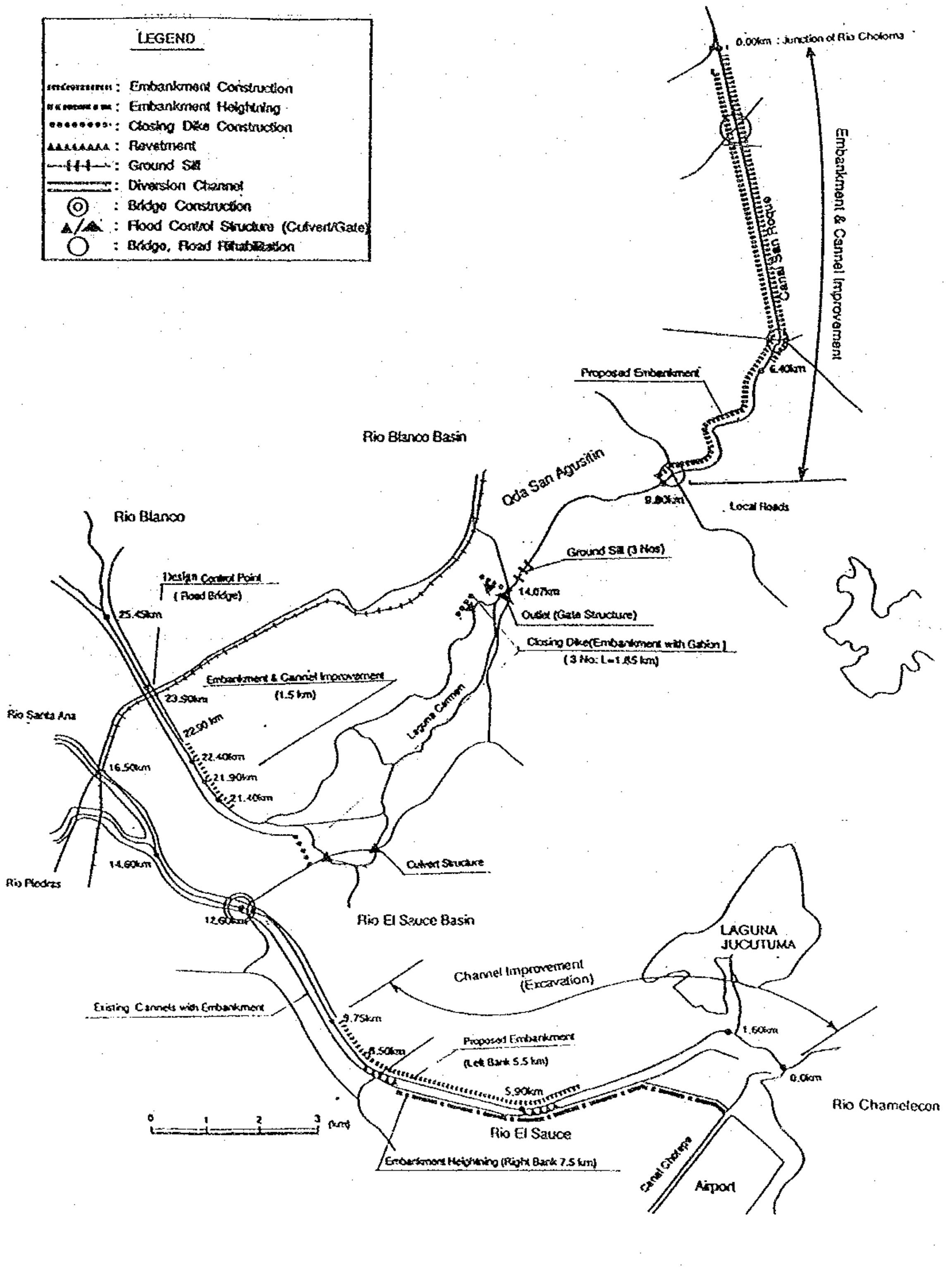


FIG. 9.11 PROPOSED FLOOD MITIGATION FACILITIES OF THE RIO BLANCO AND EL SAUCE (ALTERNATIVE 1)

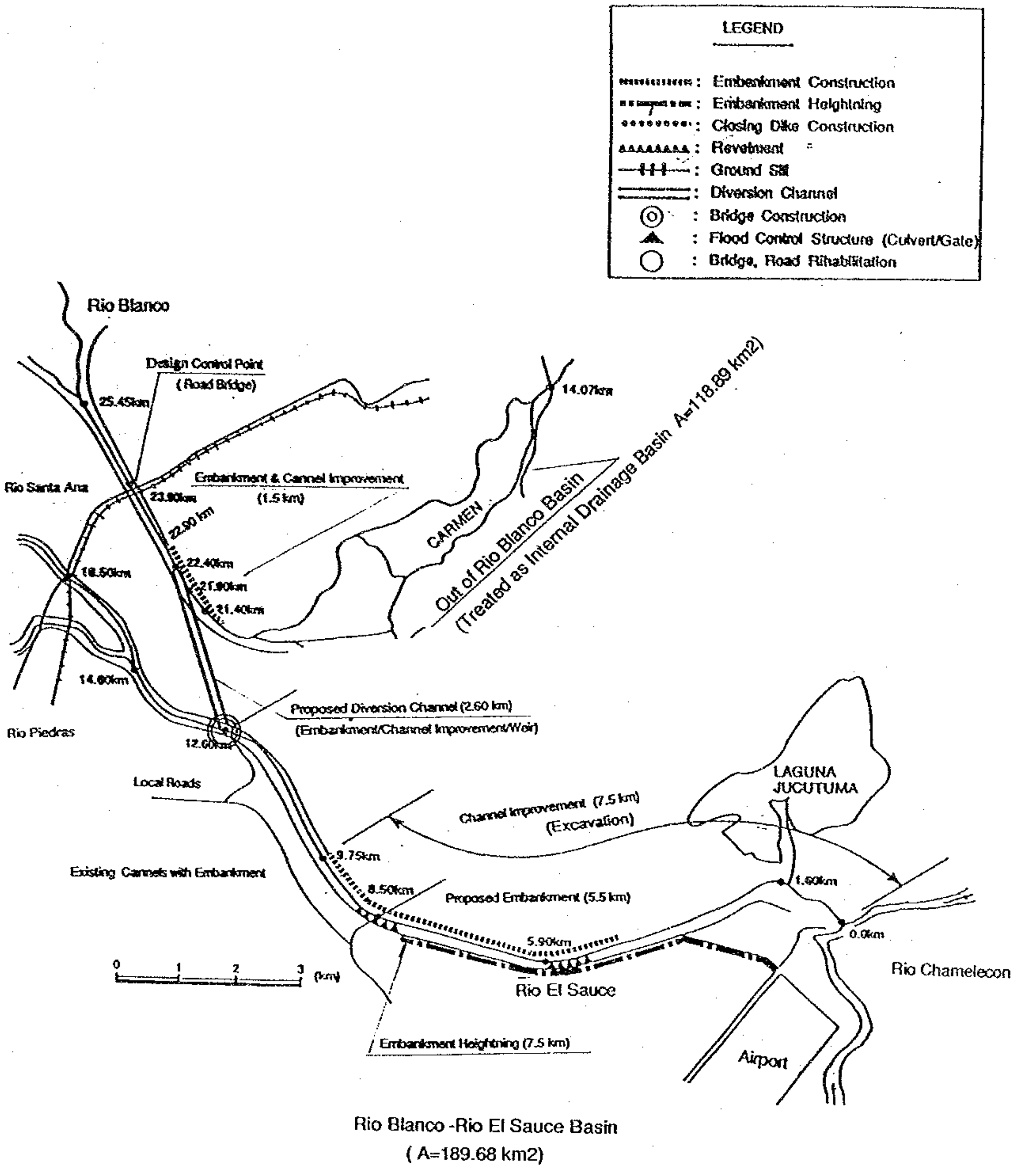


FIG. 9.12 PROPOSED FLOOD MITIGATION FACILITIES OF THE RIO BLANCO AND EL SAUCE (ALTERNATIVE 2)

DEFORESTED SLOPING TERRAINS IN RIO CHOLOMA BASIN (1993)

EL GALLITO PLANT NURSERY FOR REFORESTATION - DIMA (1993)

CHAPTER 10
HILLSIDE WORK

CHAPTER 10 HILLSIDE WORK

10.1 General

In 1974 the hurricane Fifi caused numerous hillslope collapses in the Merendon mountain range and severe debris flows occurred in both the Rio Choloma and the Rio Blanco basins, but no debris flows occurred in the other pilot basins. During the hurricane Fifi, about 10 percent of the mountain slopes were collapsed in the Rio Choloma basin according to the sediment yield study (Chapter 6).

During the Phase 1, the existing conditions of the pilot river basins were assessed. And thousands of hillside collapses were identified in the aerial photographs taken soon after the hurricane Fifi, but most of them were likely self-rehabilitated within a few years, because they were not identified in the aerial photograph taken later.

The current aerial photographs taken in 1989, shows 646 numbers of hillslope collapses in the study area. The most of them would get a quick self-rehabilitation, but some of the collapses in the Rio Choloma basin will require countermeasures. In the Master Plan the Rio Choloma basin was selected as the priority basin for the Feasibility Study.

The Rio Choloma basin is recognized to be the most deteriorated area and requires optimum watershed management from erosion and sediment control aspects. The execution of an optimum watershed management will be one of the major tasks for mitigation of erosion and sediment problems in the basin.

In the Phase 2, a pilot plan for hillside works has been studied in the Rio Choloma basin as a part of the watershed management.

There are several public institutions such as COHDEFOR, INA, DIMA, JRD, relating to the watershed management in the study area.

In the Rio Choloma basin the Spanish International Cooperation Agency through the institute of Iberoamerican Cooperation has commenced three years agroforest development project related with the watershed management since October 1992. The objectives of the project are summarized as follows;

- To promote the protection and conservation of the forest ,
- To contribute to the restoration of the forest in the watershed, integrating the peasants who live in the area to the tasks of management, conservation and

exploitation, also including the rehabilitation of roads with the purpose to have a complete access to the areas where the project will be implemented

10.2 Land Use and Gradient Range

The land use map has been prepared based on the orthophotographs of 1977, aerial photographs of 1989 and field visits during the study. The land use of the study area is summarized and shown in *Table* 10.1 and *Fig*. 10.1.

The forest and the agricultural land (or pasture) cover 31 percent and 43 percent of the mountain area (304.5 sq. km) respectively. About 80 percent of the forest area is located in San Pedro Sula. The mountain area of 65 percent from Choloma towards the north is used for agricultural purposes.

The municipality of San Pedro Sula purchased the mountain areas both of the Rio Santa Ana and the Rio Piedras in 1917 and has managed the mountain as a forest reserve zone. While the mountain area of the municipality of Choloma, has been used as agricultural purposes such as pastures and denuded by production of firewood, forest fire and shifting cultivation.

The slope over 30 degrees has a trend for hillslope collapses, especially at where the geological formation is unstable. The gradient distribution of the mountain area is shown in *Table* 10.2 and *Fig*. 10.2.

In the Rio El Sauce basin, the slope over 30 degrees covers it's 81 percent and the slope is covered mostly by forest. While in the Rio Choloma basin, the steep slope over 30 degrees covers 31 percent and might be used for agricultural purposes.

10.3 Hillside Works

10.3.1 Pilot Area for Hillside Works

Most of the Rio Choloma basin is left without forest cover. In order to identify a pilot area for hillside works, five sites are studied in the Rio Choloma basin and Cerro Los Olingos was selected. It is located at the village of El Portillo which has about 500 inhabitants, located near Takemoto dam, in the Rio La Jutosa.

The area seems to have a typical topographic and land use condition. The pilot area is located in the slopes between the left bank (EL: 240 m) of the Rio La Jutosa and the hill top (EL: 516 m) of Cerro Los Olingos and divided into 8 blocks, naturally limited by small streams. The location and the topographic conditions are shown in *Figs*. 10.3 and 10.4.

The pilot area was covered by forest in the past, but currently denuded. The existing land use conditions are shown in *Fig.* 10.5. The details of the pilot area are summarized as follows:

-	Area	:	62.4 ha
-	Average gradient	:	35 degrees
-	Land use		
	Pasture	:	67 percent
	Brushwood	:	17 percent
	Forest	:	15 percent
	Sugar cane, banana & others	:	1 percent

The steep slopes of the area produce and discharge sediment during rainfall. The natural pasture area is the most eroded zone because of the lack of permanent vegetation and require some countermeasures against erosion and sediment yield. With the application of the hillside works, the sediment yields and discharge from the area would be decreased.

10.3.2 Proposed Hillside Works

1) General

Hill gradients are one of the key factors to restrict the types vegetation and hillside works. The pasture area is classified and shown in *Table* 10.3.

The proposed hillside works were studied based on the aerial photographs and site investigation. The types of hillside work and the tentative land use were proposed as follows:

Gradient(%) Land Use	Symbol	Type of Hillside Work and Land Use
0~20 % Pasture	T	Terraces, living barrier, Cultivation of basic grain
21~30 % Pasture	A	Contour trench, living barriers Cultivation of citric
31~40 % Pasture	B	Contour trench, living barriers Cultivation of citric
41~50 % Pasture	C	Contour trench, living barriers Cultivation of citric
51 % or more Pasture	Pr	Reforestation
Brushwood	Rfw	Reforestation

The general locations of terraces and contour trenches and the proposed hillside works are shown in *Figs.* 10.6 and 10.7 respectively.

2) Terraces (Hillside Ditches)

Hillside ditches are narrow terraces of approximately 2 meters. The slope is protected with common grass (paspalum notatum) or plain fodder (axonopus compresus). The distances between ditches are approximately 12 meters. The main function is to cut the surface flow on the slopes. For avoiding sheet erosion between ditches, it is desirable to apply auxiliary soil conservation measures, such as mulch and contour line cultivation.

In order to facilitate the drainage of the terrace, usually an inverse gradient of 10 percent is adopted along the width of the terrace. The longitudinal gradients are usually among 0.5 to 1.0 percent in humid regions. The gradient of the terrace embankment is 0.75 : 1 for hand works and 1 : 1 for machine works.

3) Contour Trench

The contour trench work aims temporally to retain the rainfall water and slow down the velocity of the flow on the hillslope, regulating the discharge during heavy rainfalls. The rainfall water stored in the trenches may improve the soil moisture along them and also be better for the plants around. It may help to prevent erosion and sediment yield. This method is applied for a half of the pilot area where the hillslope gradient is 20~50 percent.

The depth of the trench is to be 20~40 cm from the ground surface. The partitions, which are 10 to 20 cm lower than the trench, are required at every 10 to 15 meters interval in order to slow down the flow velocity.

4) Living Barriers

The living barriers would be aligned along the contour trenches and terraces. The living barriers are narrow strips of dense growth perennial plants, placed at a horizontal spacing along contour lines, and used at edges of terraces or ditches for their protection. The plants used as living barriers should have strong stem. Some of the recommended species are:

- Yerba Guinea (panicum maximum)
- Yerba Paez (panicum purpureum)
- Yerba Elefante (pannisetum purpureum)
- Limoncillo de Te (cymbopogar citratus)
- Pachuli (vativeria zizaniodes)
- Sorgo Forrajero (sorghum vulgare)

TABLES

TABLE 10.1 UPPER BASIN LAND USE

(Unit : sq.km)

SUB-BASIN	FOREST (Q)	BRUSHWOOD (M)	AGRICULTURE+PASTURE (G)	POPULATED (U)	RIVERS (R)	TOTAL
Queb.La Cumbre, Between Queb.La Cumbre and Queb. La Puerta	9.07	2.04	2.32	12.93		26.36
%	34%	8%	9%	49%		100%
Rio de Piedras, Between Rio de Piedras and Queb.Santa Ana Queb.Santa Ana Miramelinda	23.49	1.02		5.99		30.50
%	77%	3%		20%		100%
Rio Santa Ana Between Rio Santa Ana and Queb. Armenta and Rio Zapotal	24.03	1.67	5.71	4.46		35.87
%	67%	5%	16%	12%		100%
Rio Zapotal, Rio Chiquito	23.52	12.54	37.17	8.32	0.33	81.88
%	29%	15%	45%	10%	0%	100%
Rio Choloma	6.13	8.13	47.17	5.11	5.1	71.64
%	9%	11%	66%	7%	7%	100%
North-eastern	7.06	5.17	38.59	7.47		58.29
%	12%	9%	66%	13%		100%
TOTAL (KM2)	93.30	30.57	130.96	44.28	5.43	304.54
%	31%	10%	43%	15%	2%	100%

TABLE 10.2 GRADIENT DISTRIBUTION IN THE MOUNTAIN SIDE OF THE STUDY AREA

	TOTAL		0-20		21-30		31-40		41-50		Over 50	
Basin	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1. Cerro Azul	425	100	25	6	25	6	56	13	138	32	181	43
2. Quebrada La Cumbre	93	100	0	0	12	13	50	54	31	33	0	0
3. Between La Cumbre and La Puerta	88	100	0	0	13	15	25	28	50	57	0	0
4. Quebrada La Puerta	244	100	0	0	25	10	75	31	94	39	50	20
5. Between La Puerta and Las Mesetas	144	100	0	0	19	13	63	44	56	39	6	4
6. Quebrada Las Mesetas/ Primavera	412	100	0	0	6	1	106	26	131	32	169	41
7. Between Las Mesetas and Rio Piedras	94	100	0	0	6	6	25	27	38	40	25	27
8. Rio Piedras	1993	100	0	0	31	1	200	10	331	17	1431	72
9. Between Rio Piedras and Quebrada Santa Ana	239	100	0	0	12	5	31	13	75	31	121	51
10. Quebrada Santa Ana/ Miramelinda	381	100	0	0	0	0	12	3	81	21	288	76
11. Rio Santa Ana	2225	100	0	0	19	1	100	4	312	14	1794	81
12. Between Rio Santa Ana and Armenta	556	100	0	0	31	6	50	9	119	21	356	64
13. Quebrada Armenta	918	100	0	0	6	1	19	2	87	9	806	88
14. Between Quebrada Armenta and Rio Zapotal	267	100	0	0	6	2	68	25	50	19	143	54
15. Rio Zapotal	1793	100	6	0	37	2	106	2	138	8	1506	84
16. Rio Chiquito	806	100	100	13	181	22	169	21	137	17	219	27
17. Rio Choloma	7164	100	900	12	795	11	1447	20	1831	26	2192	31
18. North-Eastern	5646	100	556	10	719	13	1232	22	1482	26	1657	29
19. Plain	6966	100	6966	100								

Source: Plan de Manejo Sierra de Omoa, Jan Bauer, 1980

TABLE 10.3 GRADIENTS CLASSIFICATION IN PASTURE AREA (m^2)

BLOCK	0-20% (T)	21-30% (A)	31-40% (B)	41-50% (C)	>50% (R)	TOTAL	%
A	8,214	36,554	13,267	8,029	--	66,064	16
B	--	7,783	4,727	20,651	22,198	55,359	13
C	12,159	--	24,899	--	26,704	63,762	15
D	2,545	4,210	1,200	7,385	1,590	16,930	4
E	27,109	3,555	34,837	19,849	18,041	103,391	25
F	--	7,532	--	8,232	20,023	35,787	9
G	--	4,875	--	--	30,608	35,483	9
H	--	--	--	--	39,757	39,757	10
TOTAL	50,027	64,509	78,930	64,146	158,921	416,533	100
%	12	15	19	15	38	100	
Chol. Basin %	12	11	20	26	31	100	

FIGURES

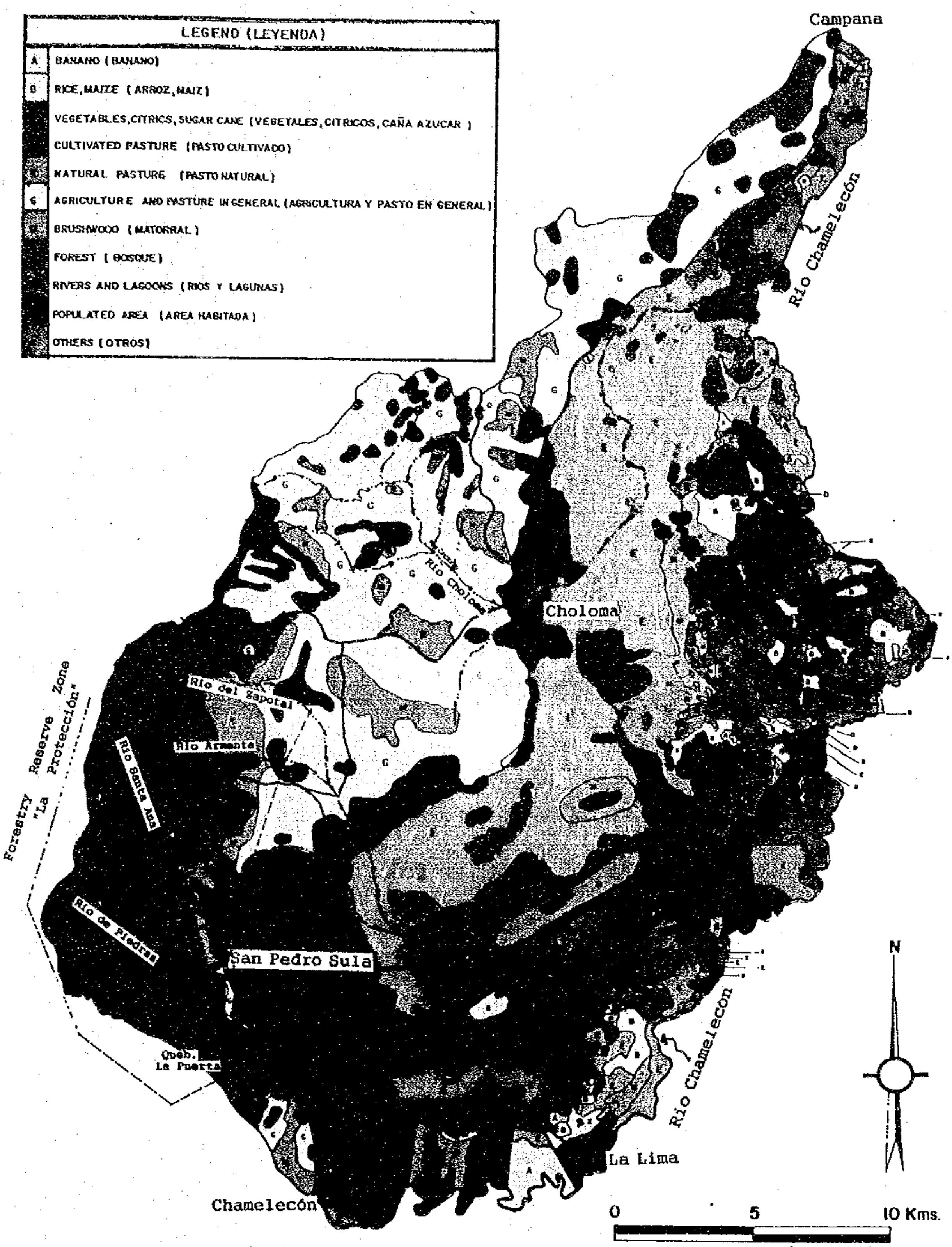


FIG.10.1 LAND USE MAP

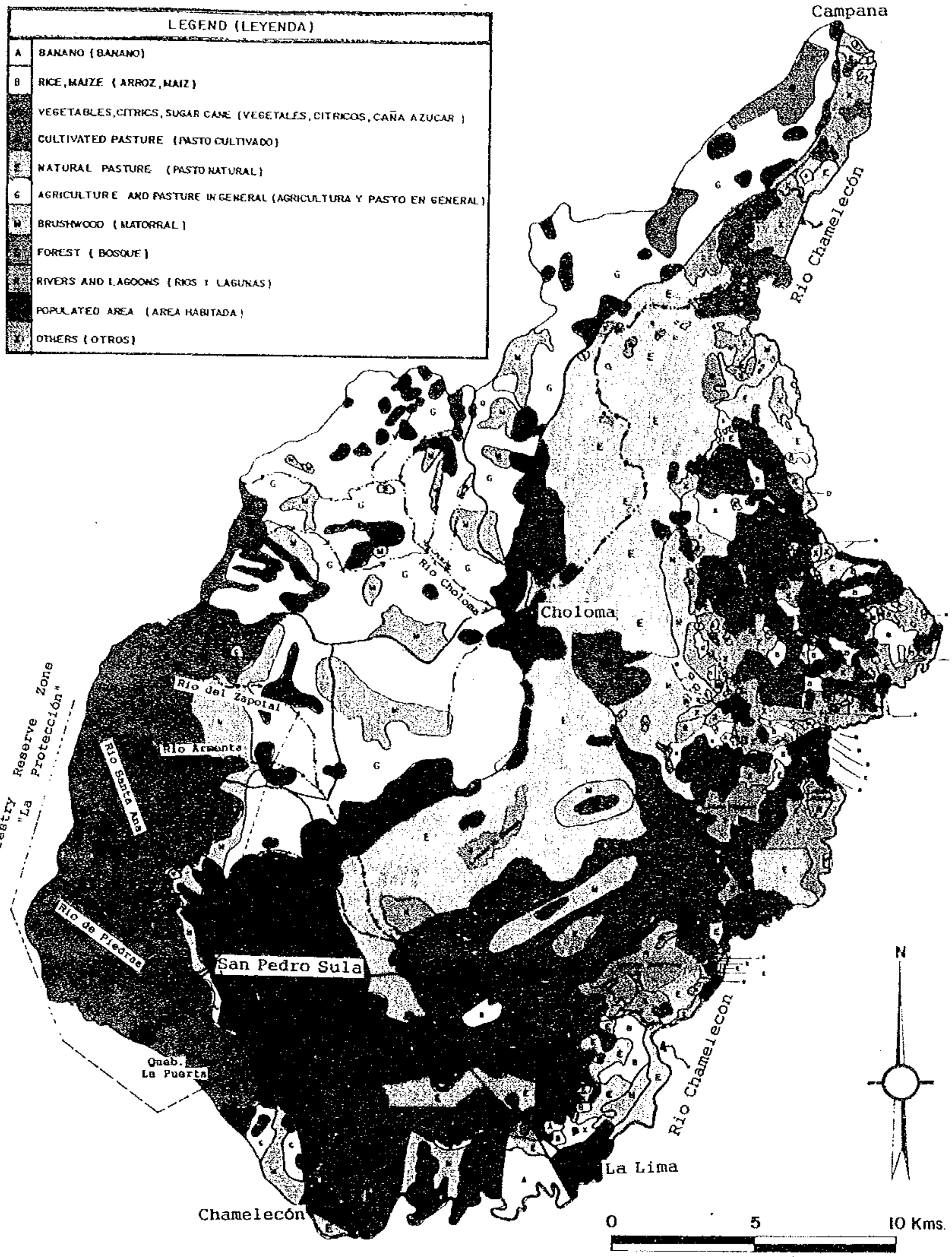


FIG.10.1 LAND USE MAP

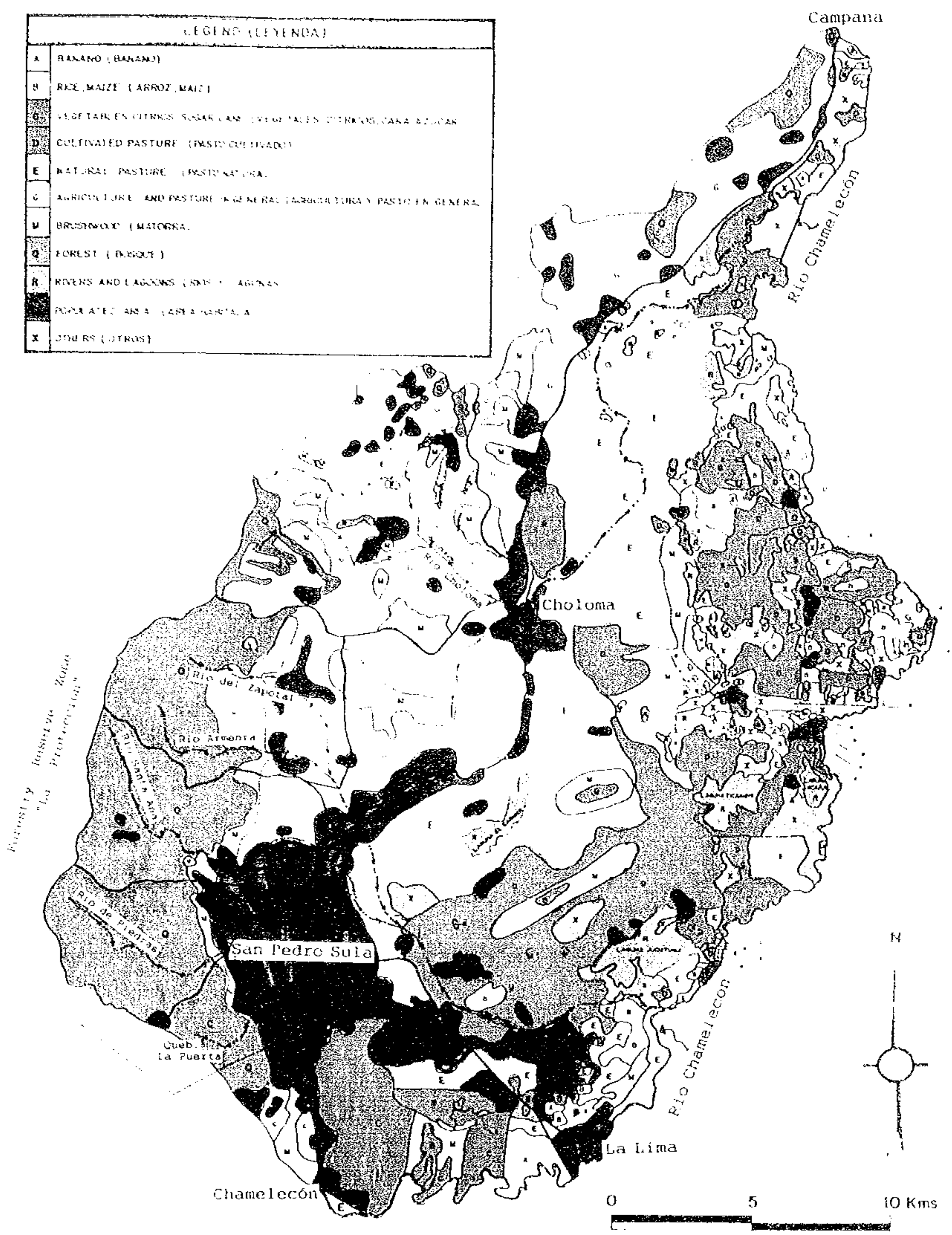


FIG.10.1 LAND USE MAP

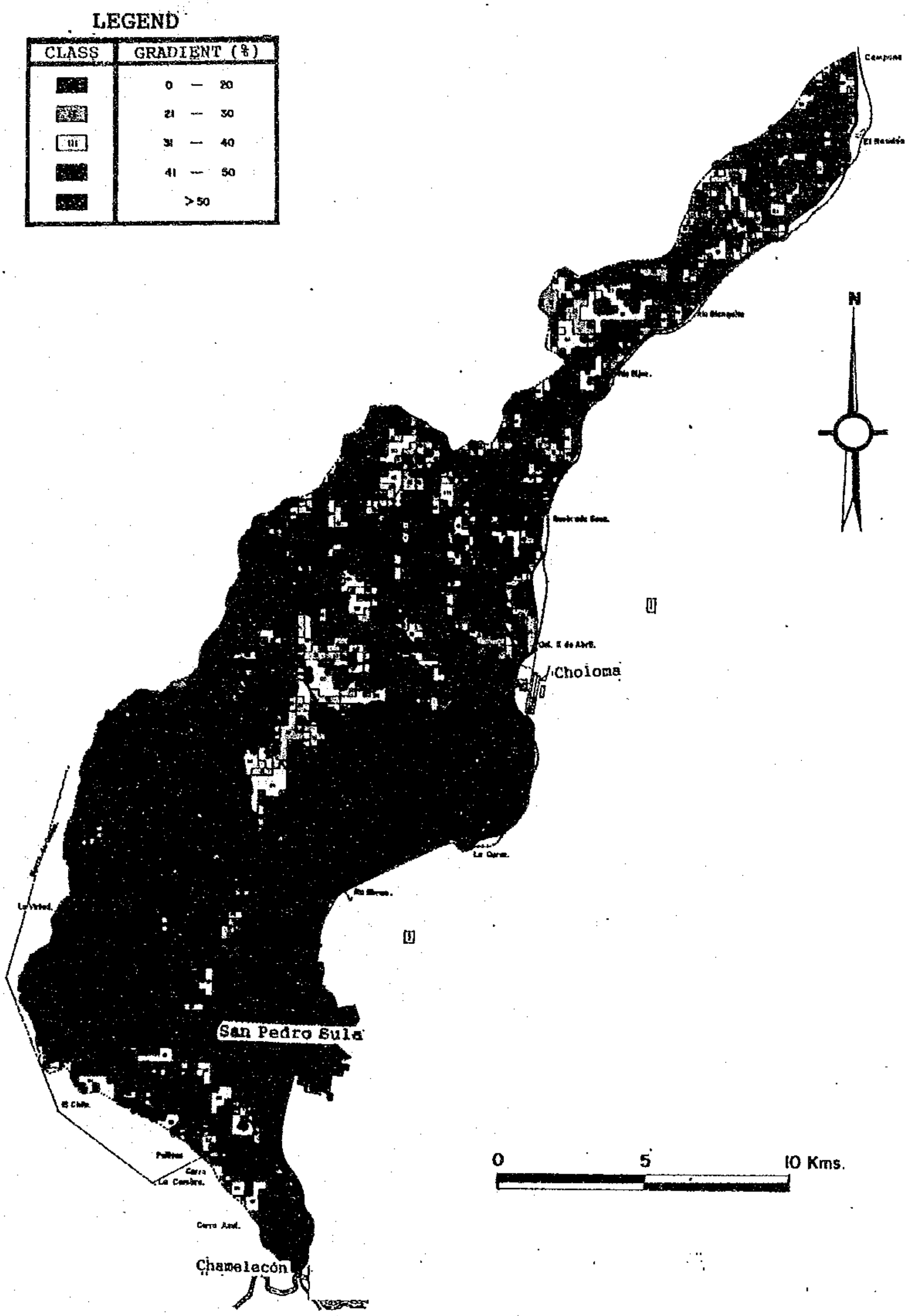


FIG.10.2 GRADIENTS MAP (UPPER BASIN)

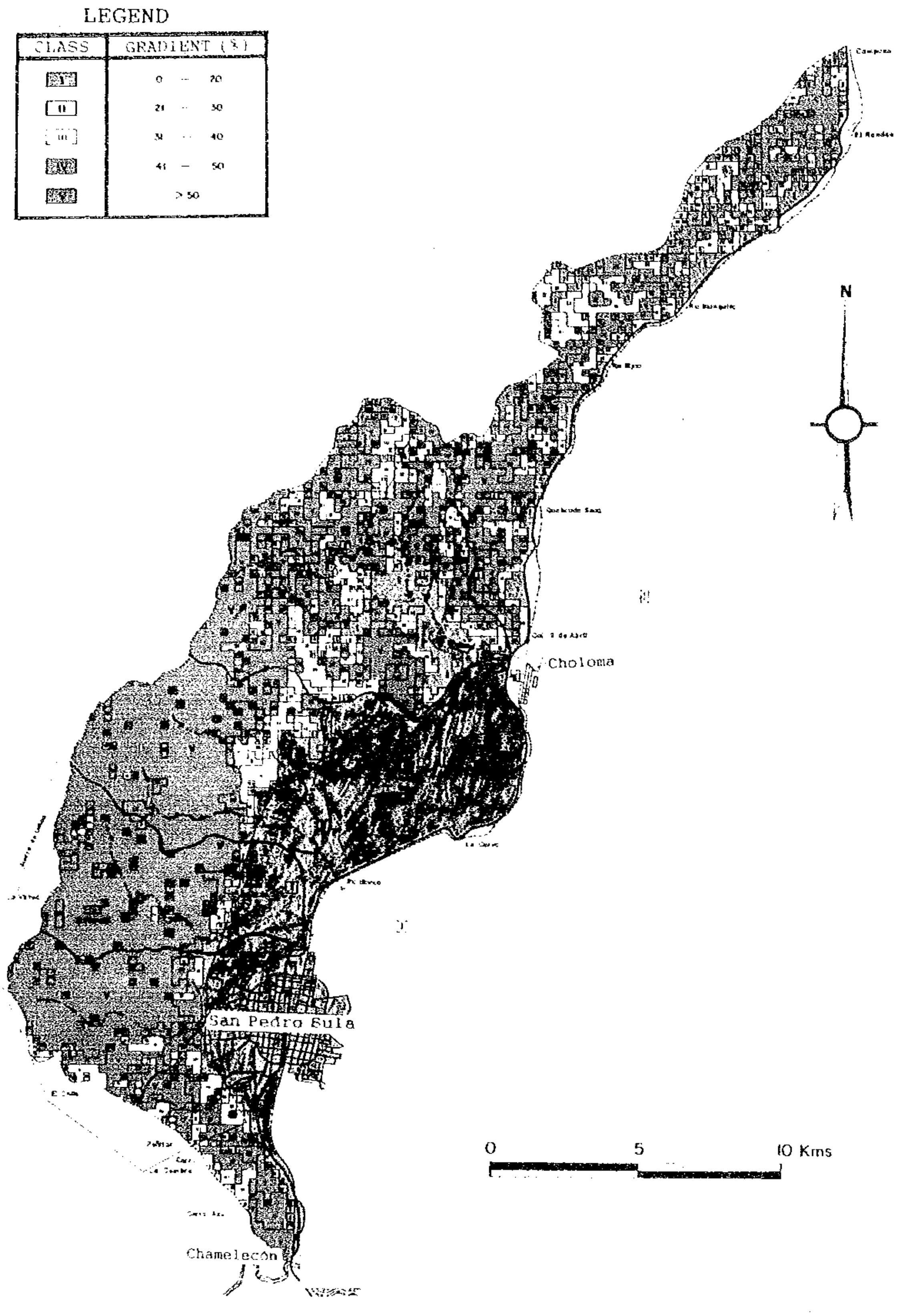


FIG.10.2 GRADIENTS MAP (UPPER BASIN)

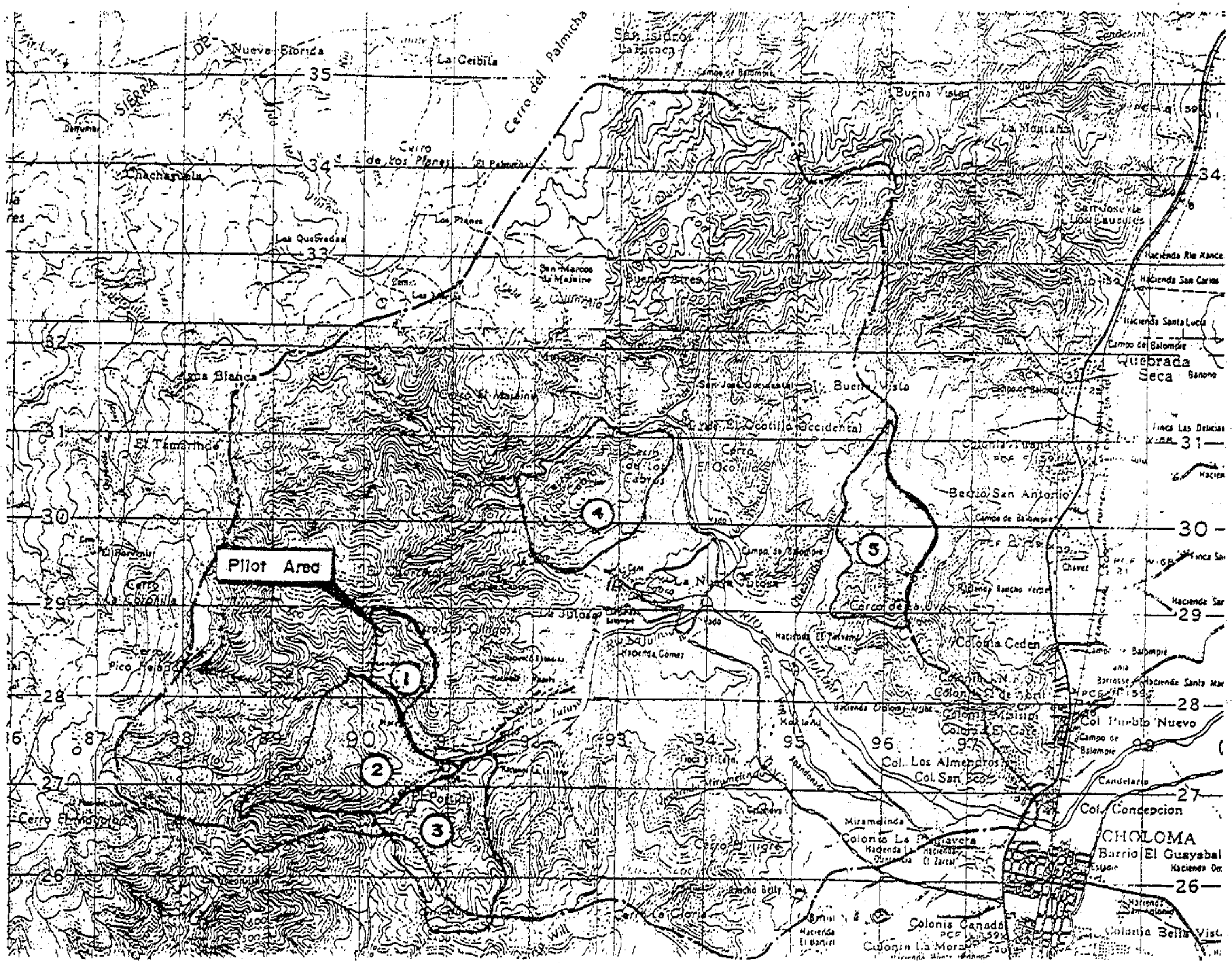


FIG.10.3 LOCATION MAP OF HILLSIDE WORK AREA

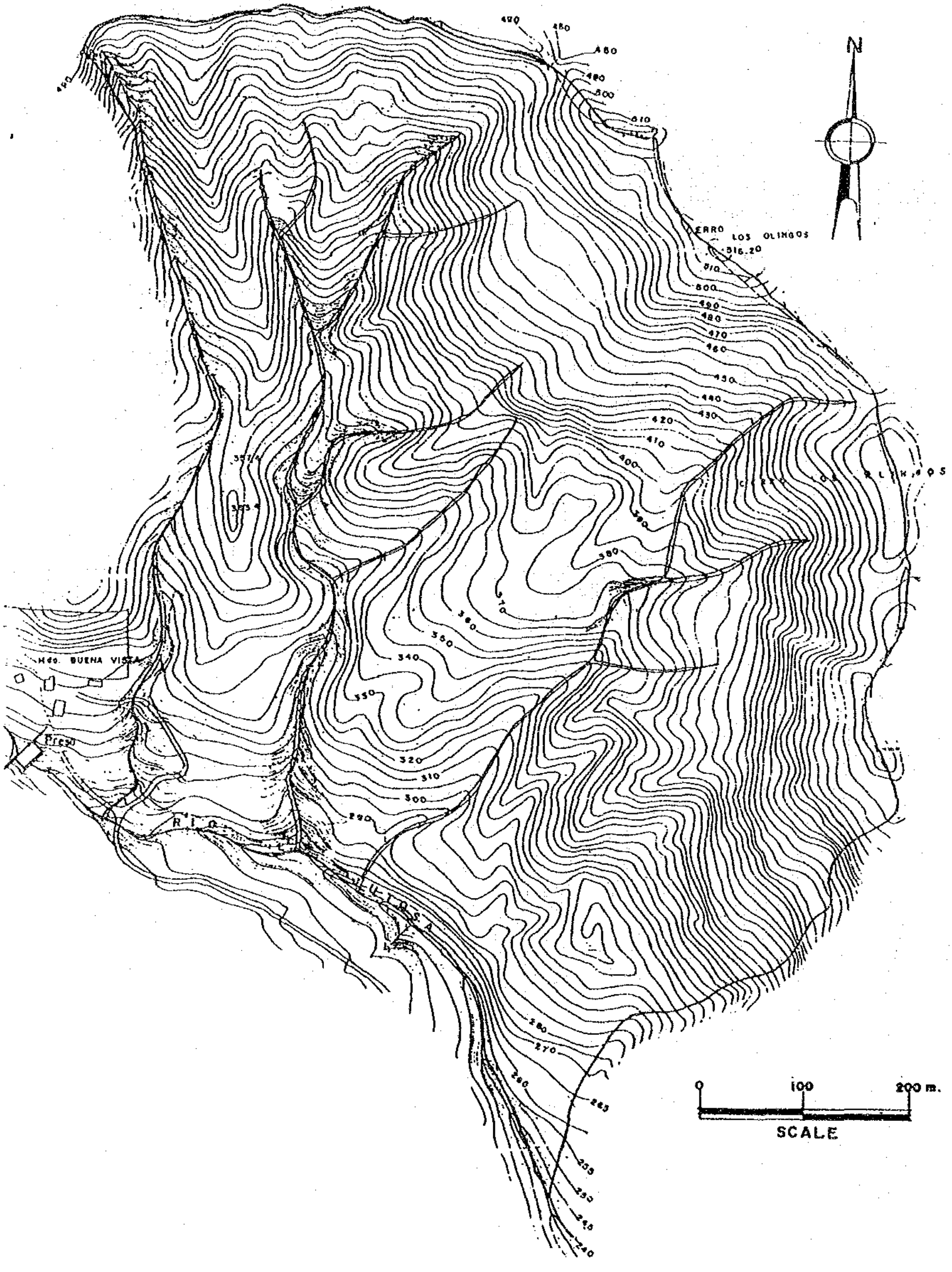


FIG.10.4 TOPOGRAPHICAL CONDITION OF PILOT HILLSIDE WORKS AREA

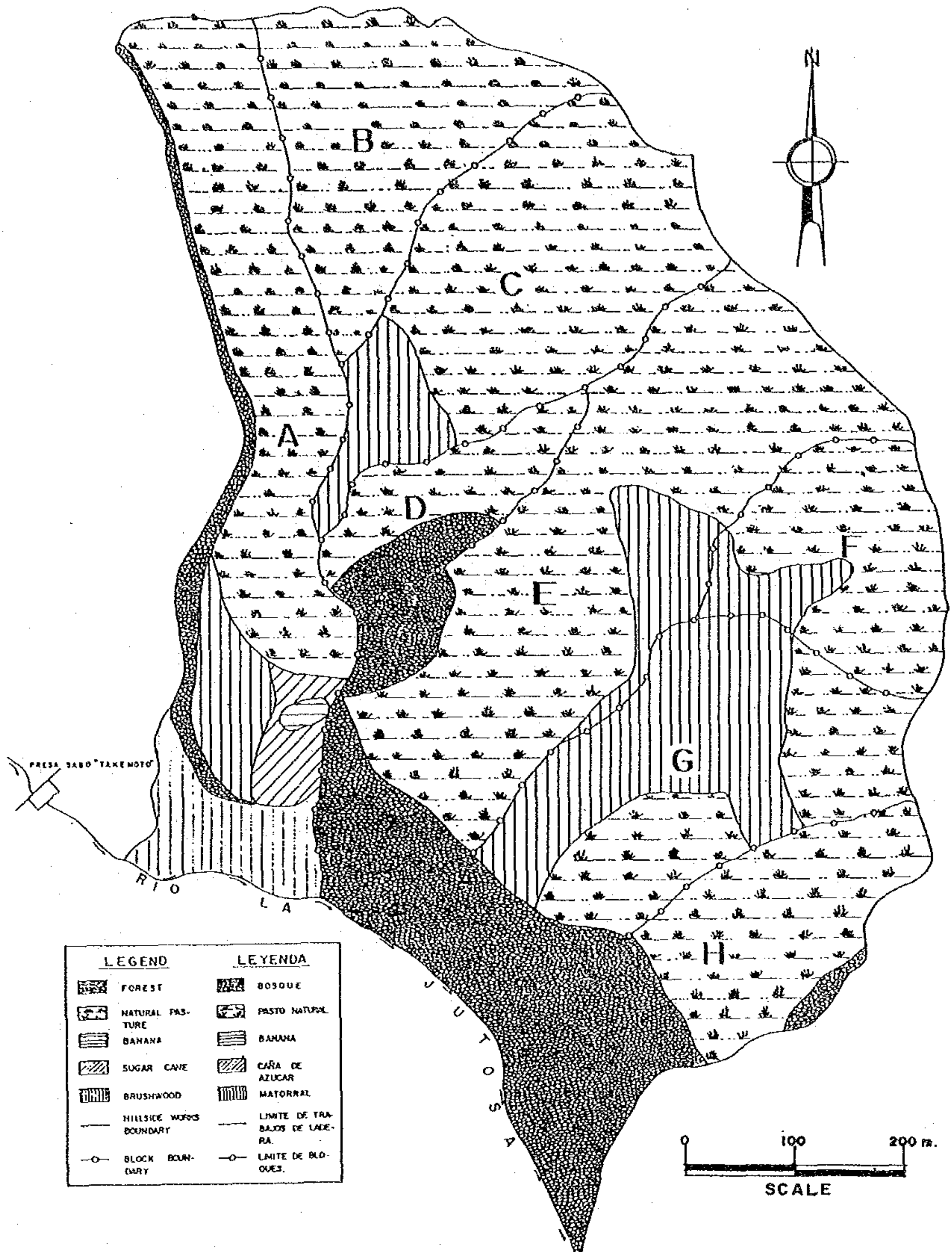


FIG.10.5 LAND USE CONDITION IN PILOT HILLSIDE WORKS AREA

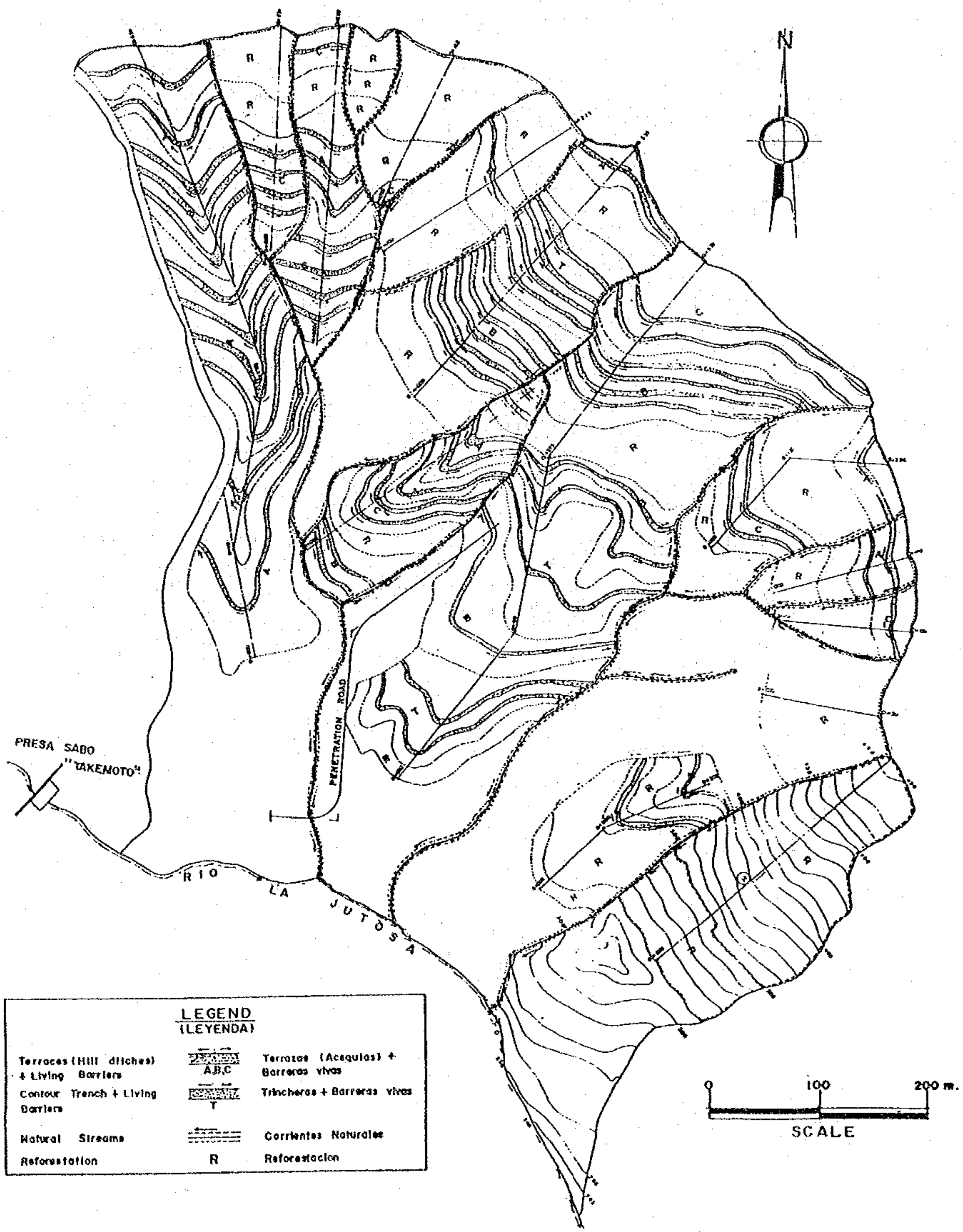


FIG.10.6 GENERAL PLAN OF HILLSIDE DITCHES AND CONTOUR TRENCHES

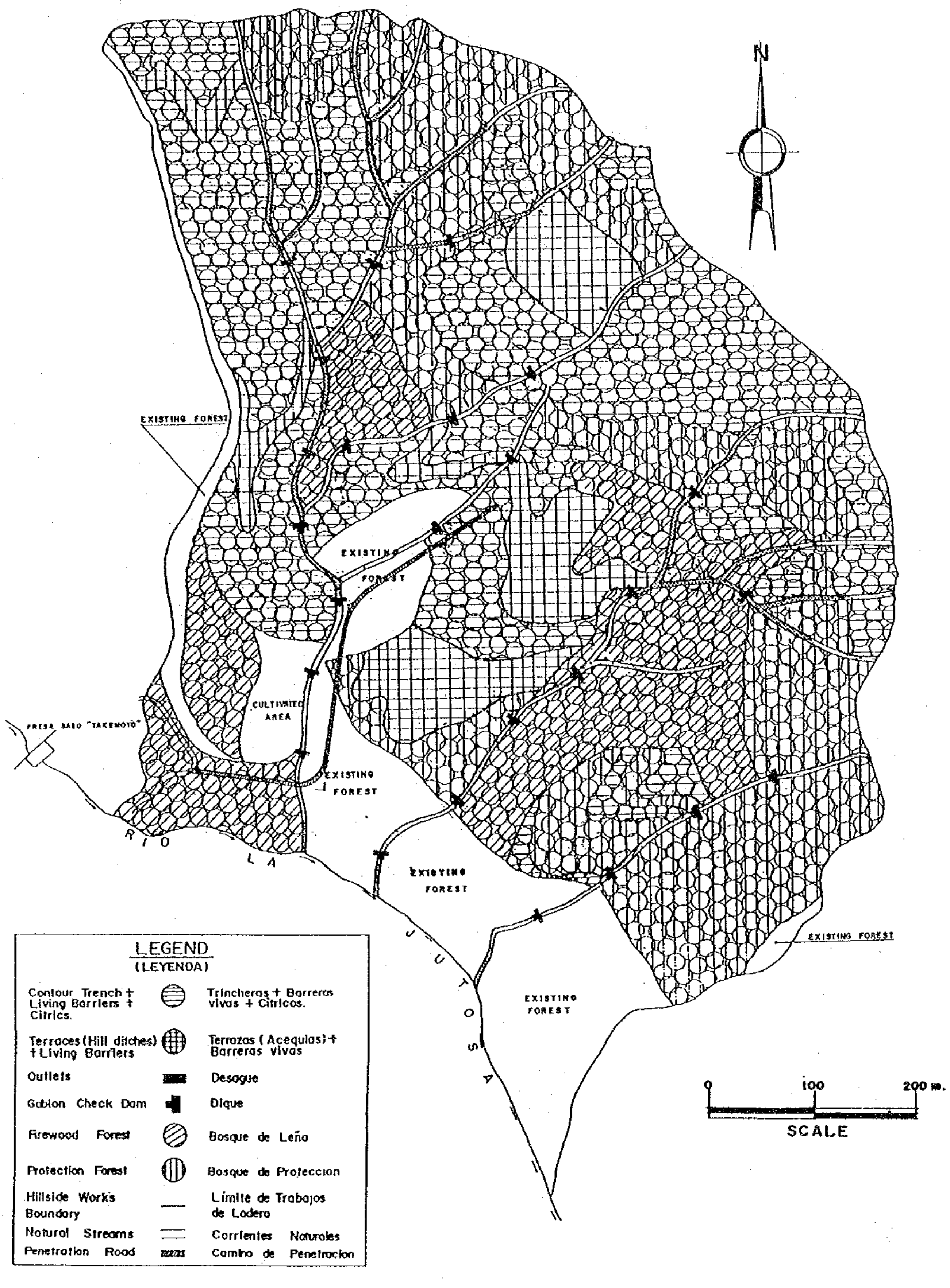
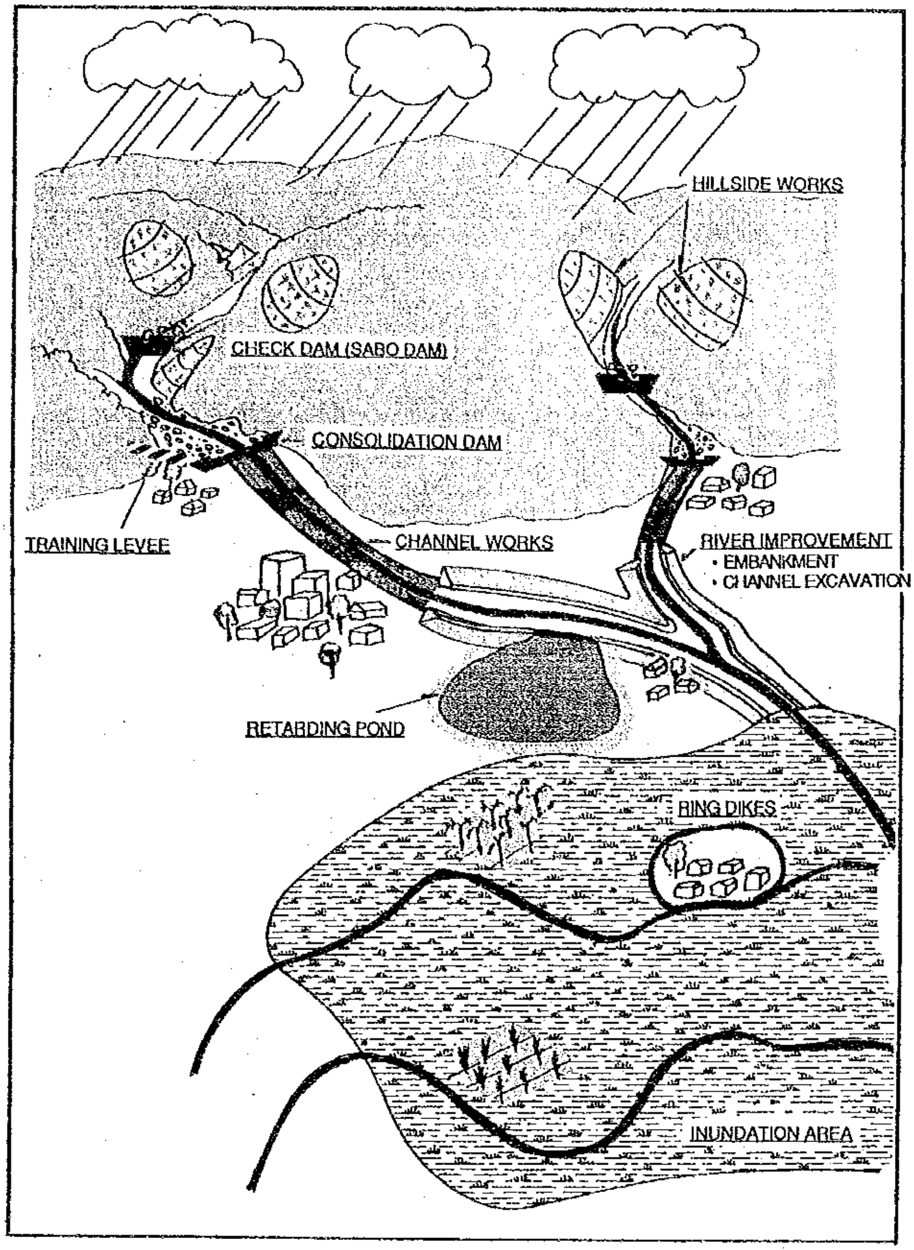


FIG.10.7 GENERAL PLAN FOR HILLSIDE WORKS



GENERAL CONCEPT OF SEDIMENT AND FLOOD CONTROL

CHAPTER 11
MASTER PLAN

CHAPTER 11 MASTER PLAN

11.1 General

The study area has suffered from a heavy sediment disasters and frequent flooding. In 1974 the study area experienced a catastrophic sediment and flood damage, caused by the hurricane Fifi. It caused numerous hill slope collapses and severe debris flows in the Merendon mountains, especially in the Rio Choloma and the Rio Blanco basins. Most of the valley floor and urban areas were affected by the floods from the Rio Chamelecon and its tributaries.

During the phase-1, the past major floods were studied and assessed. A master plan for sediment and flood control has been formulated based on the field surveys and studies. The basic concept of the proposed master plan is summarized as follows:

(1) To eliminate erosion and sedimentation problems from the pilot river basins, erosion and sediment control facilities such as check dam, consolidation dam, sand retarding area and training levee, are planned to protect the study area from the same scale of a flood caused by the hurricane Fifi of 1974.

(2) To eliminate flood problems from the pilot river basins, flood protection works such as low-flow channel improvement, embanked channel improvement and local protection works, are planned to protect the study area from the floods of a 50-year flood return period, that is approximately the same scale of the flood caused by the hurricane Fifi.

(3) To protect the people outside the pilot basins from debris flows and floods, the basic concept of a warning system is recommended as a non-structural measure for the sediment and flood damage mitigation.

The basic data and the facility plans for erosion and sediment control measures are given in Chapter 7 and those for flood mitigation measures in Chapter 9 respectively.

The proposed master plan consists of structural measures and non-structural measures. The proposed structural measures are summarized and shown in *Fig.* 11.1. The outline of the proposed master plan is given as follows.

11.2 Structural Measures

11.2.1 Erosion and Sediment Control Measures

1) Rio Choloma Basin

The proposed facilities are composed of ten (10) check dams, three (3) series of consolidation dams, sediment retarding area and training levee. They are explained as follows:

- The reach between the design control point and the confluence with the Rio La Jutosa has a riverbed gradient ranging from 1/100 to 1/140. Most part of the reach is planned as a sediment retarding area and seven consolidation dams are planned to stabilize the unstable sediment deposits.

  One training levee is planned at the right side of the sediment retarding area to protect Choloma urban area from floods and sediment flows.

- A series of consolidation dams is planned for the reaches of Rio Majaine (in between its confluence with the Rio Ocotillo and Rio Choloma) and the Rio La Jutosa, because the river courses have considerable amount of unsound fine materials and likely produce a major part of the sediment discharge to the Rio Choloma reach at downstream.

- Ten(10) check dams are planned for the Rio Choloma basin. they are as follows:

Rio Majaine:	Four (4) check dams
Rio del Ocotillo:	Three (3) check dams
Rio La Jutosa:	Three (3) check dams and a series of consolidation dams

2) Rio Blanco basin

The proposed facilities are composed of consolidation dams, training levees and check dams. They are explained as follows:

- At the design control point one consolidation dam is planned to control the sediment yield and discharge from the alluvial fan area,

- At the alluvial fan area downstream of the sub-control points, training levees are planned. The alluvial fan area is planned as a sediment retarding area,

- At the head of alluvial fan a series of consolidation dams is planned for the Rio Zapotal in order to retain the existing unsound materials along the river course and guide the direction of debris flows,

- At the upper reaches of the sub-control points, five (5) check dams are planned for the Rio Zapotal and four (4) check dams for the Rio de Armenta.

3) Rio El Sauce basin

a) Rio Santa Ana

- Channel improvement works including consolidation dams are planned at the river course (river bed slope: 1/20~1/100) between the design control point and the sub-control point,

- Seven (7) check dams are planned at the upper reach of the sub-control point.

b) Rio Piedras

- Channel improvement works including consolidation dams are planned at the reach (river bed gradient : 1/30~1/100) between the design control point and the sub-control point,

- Five (5) check dams are planned at the upper reach of the sub-control point and two(2) check dams are planned for the tributary area against debris flows.

11.2.2 Flood Mitigation Facilities

1) Facility Location Plan

a) Rio Choloma

For mitigation of flood damages from the area, it is necessary to increase the conveyance capacity of the river channel to the design flood of 50-year frequency. The reach to be improved for the erosion and sediment control plan is about 7.5 km from the design control point to the confluence with the Canal San Roque.

The proposed flood mitigation works and their locations are shown in *Table* 11.1.

b) Rio Blanco

The Rio Blanco had flowed through the present river course of the Rio El Sauce until the floods of the hurricane Fifi in 1974. By the improvement in 1979, the river course of the Rio Blanco was shifted to the Laguna El Carmen.

By the improvement the embanked channel was constructed. The embanked channel mostly has enough capacity for carrying 50 year floods. However the river channel was shifted from the original river course to the El Carmen. Accordingly the floodwater from the Rio Blanco flows to the drainage canals downstream of the Rio Choloma through the Canal San Roque, causing floods at the Laguna El Carmen and the Canal San Roque.

For the elimination of flood damages, the following two alternatives are studied, and the Alternative-2 that is to shift the downstream of the Rio Blanco to the Rio El Sauce, is proposed for the flood mitigation plan of the Rio Blanco. The two alternatives are as follows:

(1) Alternative-1:

It is to follow the existing river course that flows through the Laguna El Carmen, the Qda. San Agustin, the Canal San Roque, the Canal San Roque-Cuabanos and the Canal Coped-Higuero-Cuabanos. The river improvements of the Alternative-1 are to include those of the Rio Blanco and those of the drainage canals downstream until the Rio Chamelecon.

The river improvement of the Rio Blanco is required partly in the downstream reaches with embankment. As for the Canal San Roque and other canals, improvements with embankment as well as enlargement are required.

As for the sediment balance of the Rio Blanco, the river channel will have good sediment balance except the inlet portion of the Laguna El Carmen. Sediment deposition will be estimated to occur around the most downstream reach of the Rio Blanco and the Laguna El Carmen.

(2) Alternative-2:

It is to divert the Rio Blanco to the Rio El Sauce that was improved after the hurricane Fifi to follow the original river course of the Rio Blanco. The river improvements of the Rio Blanco are to include a diversion channel from the upstream of the Laguna El Carmen (Sta. 21.90 km) to the Rio El Sauce (Sta. 12.60 km) and those of the Rio El Sauce. In this case , the Canal San Roque is to drain its own drainage basin.

3) Rio El Sauce

The existing embanked channel that was constructed after the hurricane Fifi, has enough conveyance capacity to carry the design discharge of a 50 year flood return period. The river channel was improved to follow the original river course in the upper reach, but in the mid/lower reach, the river channel was improved to follow the river course of the former Rio Blanco.

For the flood mitigation plan of the Rio El Sauce, also two alternatives are studied conforming the flood mitigation plan of the Rio Blanco, and the Alternative 2 with the Rio Blanco is proposed for the Master Plan. The two alternatives are explained as follows.

(1) Alternative -1

The existing upper channel from Sta. 9.75 km has enough conveyance capacity for the design flood discharge of a 50 year flood return period, but the river channel at downstream (0.0 km ~ 9.75 km) requires increase in the conveyance capacity up to the design flood discharge. River improvement works such as excavation of a low water channel and embankment or heightening of the existing embankment of the channel, are necessary for preventing the inundation in the downstream reach.

As for the sediment balance of the Rio El Sauce, some unbalance in the sediment discharge capacity of the channel will be anticipated in the reaches. Hence periodical maintenance of the river bed will be necessary.

(2) Alternative-2

The Rio Blanco is to flow into the Rio El Sauce at Sta. 12.60 km by a diversion channel from Sta. 21.90 km of the Rio Blanco. Accordingly the river channel of the Rio El Sauce is to be improved from sta. 0.00 km to sta. 9.75 km as same as the Alternative-1. Though the design discharge of the Alternative-2 increases from 610 m^3 to 1,050 m^3 at Sta. 12.60 km, the low water channel and the river course of the Alternative-2 are 20 meters and 40 meters wider than those of the Alternative-1.

11.3 Non-structural Measures

1) Warning System

The study area has been affected by floods and heavy sedimentation yearly. In order to protect the human lives and assets of the study area from sedimentation and flood disasters, optimum countermeasures are indispensable. However the structural measures will take a long time and require a huge amount of investment before completion of the proposed facilities. As a part of the necessary countermeasures, an optimum warning system is studied for the study area. If the area is equipped with an optimum warning system and provided a reliable, real time flood warnings, a lot of people would be safe from debris flows and floods.

The study area has no flood warning system. In order to establish an optimum warning system in the study area, several basic conditions are necessary to be solved before implementation. The basic conditions to be solved are to be as follows:

(1) Hazard map, showing the areas affected by possible debris flows and floods, should be issued,

(2) An optimum hydrological observation network with a telemetric system, consisting of one base station, river stages and rainfall gauges, should be established in the Sula Valley,

(3) Some delivery system and an emergency response plan should be studied for each hazard area,

(4) A warning will be decided at the base station and informed the local people in the hazard area through the delivering system,

(5) Evacuation systems in the potential hazard areas should be studied and prepared.

Some reference materials on warning systems executed in the other countries, including Japan are attached in the data book.

11.4 Cost Estimation

11.4.1 Basic Conditions

1) Component of the Project Cost

The project cost is composed of direct cost, indirect cost and contingency as follows:

a) Direct Cost

-Construction cost.

b) Indirect Cost

-Land acquisition and compensation cost,
-Administration cost,
-Engineering service cost.

c) Contingency
-Physical contingency.

2) Price Level

The unit price and cost are estimated based on prevailing market price in and around the Sula Valley in June 1993 in Honduras Lempiras. The cost of land required and compensations for project constructions are based on prevailing market prices. Traded goods are valued on the basis of their international (border) prices evaluated in 1993/1994, CIF for imports and FOB for exports.

3) Mode of Contract

The construction works will be contracted to general contractors through international tender.

4) Currency Portion

The costs are divided into foreign and local currency portions as follows:

a) Foreign currency portion (FC)

- Imported goods,
- Overhead of contractors,
- Expense of expatriate personnel.

b) Local currency Portion (L.C.)

- Equipment and materials available in the local market,
- Land acquisition and compensation cost,
- Expense of local personnel,
- Overhead for local firms,
- Tax and tariff.

The components of the unit cost are summarized as follows:

	Particular	**F/C (%)**	**L/C (%)**
(1)	Labor cost	0	100
(2)	Equipment cost	100	0
(3)	Material cost		
	Fuel	100	0
	Cement	25	75
	Ready mixed concrete	15	85
	Binding wire	100	0
	Re-bar	50	50

Structure steel	100	0
Iron plate	50	50
pine plywood	10	90
Others	0	100

5) Exchange Rate

The exchange rates of foreign currencies applied are;

Lps. 6.20 = US$ 1.0 = Yen 110.0.

6) Indirect Cost

The land acquisition and compensation costs are based on prevailing market price, and other costs will be estimated based on the following assumption:

- Administration cost: 5.0 % of the base construction cost,

- Engineering service cost: 10 % of the base construction cost plus physical contingency.

7) Contingency

Physical contingency will be estimated to be 20 % of the base construction cost.

8) Unit Price

The unit prices of labor, material and equipment are estimated based on prevailing market price referring the data collected from SECOPT and other agencies concerned. The unit costs of the construction works are divided into foreign currency portion and local currency portion based on the current dada applied to similar projects. They are shown in *Tables* 11.2~11.5.

9) Operation and Maintenance Cost

The cost will be estimated to be 1.0 % of the base construction cost. The costs should include costs of technical staff, departmental overheads, labor and materials, operation and maintenance of equipment.

11.4.2 Project Cost

The total project cost is estimated at Lps. 1,057.81 million (F/C: Lps. 652.30 million, L/C: Lps. 405.51 million). The proposed cost for each project is shown below:

1) Rio Choloma

(Unit: million Lps)

	Item	F/C	L/C	Total
A	Direct Cost			
	1) River Improvement	46.06	12.87	58.93
	2) Sediment Control	181.62	111.42	293.04
	3) Sub Total	227.68	124.29	351.97
B	Indirect Cost			
	1) Land Acquisition	0.00	1.07	1.07
	2) Administration	0.00	17.60	17.60
	3) Engineering Service	27.32	14.92	42.24
	4) Sub Total	27.32	33.59	60.91
C	Physical Contingency	45.54	24.86	70.40
D	Total	300.54	182.74	483.28

2) Rio El Sauce with Rio Blanco

(Unit: million Lps.)

	Item	F/C	L/C	Total
A	Direct Cost			
	1) River Improvement	64.61	30.52	95.13
	2) Sediment Control	201.87	121.58	323.45
	3) Sub Total	266.48	152.10	418.58
B	Indirect Cost			
	1) Land Acquisition	0.00	1.07	1.07
	2) Administration	0.00	20.93	20.93
	3) Engineering Services	31.98	18.25	50.23
	4) Sub Total	31.98	40.25	72.23
	C Physical Contingency	53.30	30.42	83.72
	D Total	351.76	222.77	574.53

The detail data of the construction costs are explained in Supporting Report G and summarized in *Tables* 11.6~11.9.

11.5 Implementation Program

11.5.1 General

The implementation of the project is scheduled to be commenced in 1996 and completed in 2005.

11.5.2 Proposed Component

For mitigation of erosion ,sediment and flood problems from the study area, the Master Plan proposes structural measures for the pilot river basins. The master plan encompassed the following river basins.

(1) Rio Choloma

(2) Rio El Sauce with Rio Blanco

11.6 Project Evaluation

11.6.1 Conditions of Evaluation

The project evaluation is mainly based on the economic evaluation. In the Master Plan study, the economic evaluation is made with aim of finding out an economic optimum plan out of several alternative plans for the erosion and sediment control projects of three rivers; Rio Choloma, Rio Blanco and Rio El Sauce.

In order to select the optimum economic plan of the project, the procedures of two steps are taken: study at the first step is a comparison among the said three rivers in regard to economic effect of the flood protection project with the 50-year probable flood.

At the second step, the comparison is carried out about the economic effects of protection works for several probable floods of the river that will produce the highest economic effect among the three rivers, in accordance with the result of study in the first step.

The economic effects of the project are examined by making a comparison between both present values of the economic cost and benefit, by means of the Economic Internal Rate of Return (EIRR).

The economic cost and benefit of the project would be given by a shadow prices, after deducting transfer payments from cost and benefit at the market prices, in accordance with conditions and assumptions shown in Chapter 1 of the Supporting Report J.

The project life is economically taken as 50 years after commencement of the construction works. The benefits together with the OM cost are assumed to accrue throughout the period of project life after completion of the construction works. The partial benefit and OM-cost under the construction period are regarded as proportion to the direct costs which have been already invested for the construction of facilities.

11.6.2 Economic Cost

The economic construction costs of the flood protection project with 50-year return period for the said three rivers including a combined project of Rio Blanco and Rio El Sauce are summarized in *Table* 11.10 compared to the respective financial costs (except price contingency). Annual flows of them are provided in *Tables* J.2.3, J.2.4, J.2.5 and J.2.6 (4) of the Supporting Report J.

The economic construction costs of the Choloma project with the return periods of 2-, 5-, 30- and 100-year are summarized in *Table* 11.11, and these annual flows are given in *Tables* J.2.6 (1), (2), (3) and (5) of Supporting Report J.

For all alternative projects, the OM cost is approximately regarded as 1 % of the direct construction cost including its physical contingency. Annual disbursements of the OM cost are provided by projects concerned in *Tables* J.2.3 through J.2.6 of Supporting Report J.

11.6.3 Economic Benefit

The tangible direct economic benefit produced by executing the project is generally given as an effect of reduction in flood damage. The average annual economic benefits of the project are quoted from the average annual flood damage, and annual flows of the economic benefits, together with the annual disbursements of economic costs concerned, are provided in *Tables* J.2.3 through J.2.6 of Supporting Report J.

Average Annual Economic Benefit

(In 1,000 Lps.)

Return Period (years)	Choloma Basin	Blanco Basin	El Sauce Basin	Blanco & El Sauce Basins
2	5,882	-	-	-
5	19,161	7,144	17,862	25,006
30	49,392	21,490	29,938	51,428
50	55,855	23,716	31,353	55,069
100	62,747	25,656	32,696	58,352

11.6.4 Economic Evaluation of Alternative Projects

1) EIRR of the Project with 50-year Return Period for Rio Choloma, Rio Blanco and Rio El Sauce

The EIRRs of the project with 50-year return period for the said three rivers including the combined project of Rio Blanco and Rio El Sauce are estimated as follows:

Estimates of EIRR for Flood Protection Project with 50-year Return Period

	Choloma	Blanco	El Sauce	Blanco & El Sauce
EIRR (%)	15.3	4.3	14.5	13.0

The result above suggests the following matters:

(a) Regarding the Rio Choloma and Rio El Sauce projects, the EIRRs of the projects with the 50-year return period indicate 15.3 % and 14.5 % respectively which is a comparatively high rate as flood protection project, i.e. these projects are regarded as viable economically.

(b) The Rio Blanco project with 50-year return period shows an EIRR of 4.3 % which has little viability economically, due to a low potential of assets inundated.

(c) However, the EIRR of the flood protection project combining both rivers of Rio Blanco and El Sauce would come to 13.0 %. It shows that the combined project is economically feasible, considering that the opportunity cost of capital in Honduras would be between 10 % and 12 %.

(d) In the Master Plan Study, it is concluded that the said three projects, except an independent project of Rio Blanco, would be economically feasible with the return period of 50-year, and that the first priority would be economically given to the Rio Choloma project.

2) EIRR of Rio Choloma Project with Return Periods of 2-, 5-, 30-, 50- and 100-year

On the basis of the conclusion shown in previous section 1), the EIRRs are estimated on the Choloma project with return periods of 2-, 5-, 30-, 50 and 100-year. The results, together with the EIRR of 50-year return period, are summarized as follows:

Estimates of EIRR of Rio Choloma Project

	Return Period (year)				
	2	5	30	50	100
EIRR (%)	5.8	13.8	15.3	15.3	15.3

The values above indicate that the Rio Choloma project is economically feasible for the return period of 5-, 30, 50- and 100-year. However, there is no significant difference economically among projects with the return periods of 30-, 50- and 100-year. It suggests that the optimum plan among them should be selected from technical, political, social and environmental view-points, other than economic aspect.

11.6.5 Intangible Socio-Economic Impacts

It is expected that the project also would have, besides the foregoing tangible direct benefits, several intangible effects of reducing the socio-economic damage as follows:

1) Loss and injury of lives

The heavy flood in the past caused loss and injury of many lives.

2) Spread of Infectious Diseases

The flood may frequently cause a spread of infectious diseases due to insufficiency of water supply and drainage facilities.

3) Shortage of Goods

The flood would cause shortage of goods in and around the flooded area due to damage to agricultural products and manufacturing factories, standstills of distribution system of commodities and road and railway traffic, and increase in demand of equipment and materials caused by damage to buildings, household effects and public facilities.

There is the possibility that such a shortage of goods expands in the whole country, because San Pedro Sula, Choloma and their surrounding areas are the greatest industrial zone in the country, the rural area inundated is among the largest production area of agricultural products including cattle-farming in Honduras, and further the significant transportation facility, Route CA-5, is included in the flooded area.

4) Steep Rise in Prices

The shortage of goods and the standstills of traffic and distribution system of commodities would cause a steep rise in prices in and around the flooded area. Further there is the possibility that such a steep rise in prices expands in the whole country on the grounds that is described in 3) above.

5) Lowering of Administrative and Educational Activities

Administrative and educational activities in the flooded area would drop due to the flood damage to public offices and schools.

6) Decline in Communication

Communications between the flooded area and other areas would decline due to damage to telecommunication facilities and standstill of traffic.

7) Decline in the Standard of Living

Inhabitants in the inundated area would experience inevitably a decline in the standard of their living due to damage to their assets and public facilities, shortage of goods, steep rise in prices, lowering of administrative and educational activities, etc.

8) Time Lag of Social and Economic Development

Various negative factors mentioned above would cause a time lag for social and economic developments in and around the flooded area. Further there is the possibility that this time lag expands in the country as a whole, on grounds that the flood damage is caused in the highest potential area, socio-economically, in the country.

9) Promotion of External Trade Deficits

In the country, the Department of Cortes is among the largest production area of bananas and sugar cane that are the most important goods for the export of Honduras, especially bananas have a share of about 40 % of the total exports of Honduras. The Study Area is situated in the central part of the Department of Cortes on these productions. Therefore, the damage to these products would cause a reduction in exports of Honduras.

On the other hand, urban areas of San Pedro Sula and Choloma are the greatest industrial zone which manufactured various commodities including export and import-substitution goods. Accordingly, the damage to manufacturing factories would bring not only a reduction in exports, but also increase in imports.

Honduras is under a situation of unfavorable external trade every year. The damage mentioned above, as a result, would aggravate more the external trade deficits of Honduras.

It is expected that the above-mentioned damages would be reduced by executing the flood protection project, and such a reduction in damage would be evaluated as the significant intangible effects of the project. A socio-economic background, which would bring the intangible impacts, is provided in Section 2.4 of the Supporting Report J.

In addition to these effects, construction works of the project would produce the intangible benefit such as increase in employment opportunity and stimulate the regional development.

11.6.6 Environmental Impact

The anticipated environmental impacts by the project are both direct and indirect. However , the adverse effects directly by the project are anticipated to be insignificant in comparison to the beneficial effects. The indirect effects by the project will be caused by the subsequent change in land use with the implementation of the project, principally in the low land Sula Valley area.

The effect by the project will be mostly beneficial as the project is aimed at disaster mitigation of erosion and sediment control. The mitigation of flooding will enhance the land use potential of the area to a variety of beneficial uses like urban, industrial and agricultural development. Moreover, enhanced protection to such existing land utilization will be obtained.

No significant direct adverse effects by the project, either to the high land Meredon mountain range or to the low land areas of the Sula valley, including the wetland and lagoon areas, are anticipated.

Nevertheless, resettlement of population, through anticipated to be not significant, would be necessary due to river improvement and diversion works.