SUPPORTING REPORT F

FLOOD DAMAGE MITIGATION PLAN

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SUPPORTING-F
FLOOD DAMAGE MITIGATION PLAN

1. INTRODUCTION

This is the Supporting Report F of flood damage mitigation plan for the project entitled "The Study on Flood Control and Landslide Prevention in Tegucigalpa Metropolitan Area in the Republic of Honduras".

The Study Area covers the following river basins:

Choluteca River basin in Tegucigalpa,
Grande River basin,
San Jose River basin,
Guacerique River basin and
Chiquito River basin.

These drainage basins are shown in *Figure F.1.1*. The main trunk of the Choluteca River is shown in *Figure F.1.2*.

The Target Area is 10 km x 10 km in Tegucigalpa Metropolitan Area. River course of 20km along the Choluteca River is the main concern for flood damage mitigation plan.

In the flood damage mitigation plan, following items are emphasized in the Study.

- Flood control facilities plan (structural measures)
- Preparation and publication of a hazard map (non-structural measures)
- Preparation for forecasting/warning and evacuation (non-structural measures)

Among the Flood Damage Mitigation Plan components, Priority Project(s) are selected for Feasibility Study.

Major study contents and methodology area presented as follows;

- River and river structure survey
  River courses and river structures such as revetment, dams, weirs and bridges are surveyed.
- River bed material survey
  River bed material survey is conducted in the Choluteca River and the Chiquito River to study the river regime.
- Sediment Investigation
  Sediment volume during flood caused by Hurricane Mitch is surveyed.
- River bed variation and sediment transport analysis
  River bed variation analysis is carried out to identify the mechanism of river bed rising by Hurricane Mitch. Using the result of river bed material test and the hydraulic analysis, sediment transport analysis is conducted.
- Meteorological observation facilities survey
  Present status of meteorological observation facilities is checked to grasp the function of the existing forecasting/warning system.

- Flood damage mitigation measures study

  Flood damage mitigation measures are studied for both structural and non-structural aspects. As for structural measures, river-training facilities are studied. For non-structural measures, preparation of hazard map and flood warning system are studied.

2. FEATURES OF THE CHOLUTECA RIVER

2.1 CHOLUTECA RIVER BASIN

The Choluteca River has a basin area of 7,465 km^2 and the river length of 320km. It originates from 3 main tributaries, namely are the Grande, the San Jose and the Guacerique Rivers, in the southern part of the Tegucigalpa City. The Choluteca River flows toward north and turns to south in the middle and lower reaches and flows into the Gulf of Fonseca in the Pacific Ocean. Its slope is 1/35 at most upper reaches, 1/200 in Tegucigalpa City reach, 1/450 in middle reach and 1/850 in lower reach. Annual rainfall is 1,000 mm/year in upper reach and 1,450 mm in lower reach. (Refer to *Figure F.1.2*)

2.2 RIVERS IN THE STUDY AREA

The Study Area is about 820 km^2 and divided into the sub-basins of the Choluteca River, *i.e.* the Guacerique River basin, the Grande River basin, the San Jose River basin and the Chiquito River basin.

The total drainage area is about 820 km^2 as shown in *Figure F.1.1*, with the sub-basin areas as follows:

Table F.2.1 Drainage Basins of Choluteca River

River/Basin	Basin Area (km^2)	
	Sub-basin	Total
Grande	258.18	258.18
San Jose	168.50	426.68
Guacerique	244.16	670.84
Chiquito	90.42	761.26
Sapo	2.97	764.23
Choluteca in Tegucigalpa	55.42	819.65

Longitudinal profiles of major rivers are shown in *Figure F.2.1*.

The Target Area for Disaster Prevention is Tegucigalpa urban area, as shown in *Figure F.1.1*, the total area of which is 105 km^2. The elevation of the urban area is between 900 m and 1,400 m.

(1) Choluteca River

The upper reach of the Choluteca River in the Study Area flows down from south to north in Tegucigalpa City. The main trunk of the Choluteca River is called Grande in its upper reach and is joined by its tributaries such as the San Jose, Guacerique, Chiquito, Sapo and Cacao Rivers. Bank condition and hinterland along the Choluteca River are shown in *Table F.2.2*. After Hurricane Mitch, a large amount of sediment still remains and its volume is estimated as 1,100,000m^3.

(2) Grande River

It is the main trunk of the upper reach of the Choluteca River. Its catchment area is about 258 km^2 and its slope is 1/30-1/60. Conception Dam operated by SANNA exists on the river. The dam is equipped with a free flow spillway with the capacity of 950m^3/s. During Hurricane Mitch, a flood with its peak value of about 850m^3/s was discharged through the spillway. On its tributary, so called Qu La Lagura stream, there is a lake named Pescado Lake, which was created by landslide long time ago.

(3) San Jose River

It flows down from southeast into the Choluteca River. The catchment area of the San Jose River is about 169 km^2. Its slope is 1/10-1/50. There is no dam on this river, but a plan of Sabacuante Dam by SANAA exists.

(4) Guacerique River

It flows down from west mountains into the Choluteca River in the Tegucigalpa urban area. Its catchment area is about 244 km^2 and its slope is 1/30. Los Laureles dam of SANAA is located on the river. The spillway of the dam is equipped with a rubber gate 3 m high and 68 m long. During Hurricane Mitch, the rubber dam had not been shrunk and the flood flow overtopped the rubber dam as well as the side dam causing the peak discharge of about 1,200m^3/s.

(5) Chiquito River

It flows down from east hillside in Tegucigalpa City. The catchment area of the Chiquito River is about 90 km^2 and its slope is 1/10-1/50. River bed material is coarse, mean diameter 40 mm.

(6) Sapo River

It is located at western hilly area in Tegucigalpa City. The river slope is very steep, which is about 1/15. Its catchment area is about 3 km^2. Its waterway is an artificial concrete channel of 5m wide and 3m deep. Its outlet is located at C51 of the Choluteca River section (The number is referred to the river survey). The channel is connected by a pipe culvert with the diameter about 3m, 600m long with the slope 1/80. During Hurricane Mitch, the outlet was filled up by sediment of the Choluteca River and flood occurred near the inlet of the pipe culvert.

(7) Cacao River

It is located at down stream of Chile Bridge at C39, in western hilly area of Tegucigalpa City. Its slope is about 1/8 and the catchment area is about 3 km^2. The waterway is mostly composed of artificial concrete walls with natural gravel and cobblestone bed. The width of the channel is about 8m and the depth is 2m. The channel changes its course to the north perpendicularly near the Choluteca River. Its channel alignment caused sudden decrease of flow velocity and sediment deposited in the area.

(8) Bambu River

It is located on the Chiquito River 2km upstream from the confluence with the Choluteca River. Its catchment area is about 0.3 km^2. It connects to the Chiquito River by a culvert with the diameter of about 1m. The length of the culvert is 400m.

(9) Pescado Lake

It is a small lake of about 150,000 m^2 located along Qu La Lagura stream (one of the tributaries of the Grande River) about 1.3 km upstream from the confluence with the Grande River. The Pescado Lake was formed by landslide that stopped the flow of the river. A natural dam height had been about 4.5m. During Hurricane Mitch, water level of the lake rose 3.5m more. The maximum lake water level at that time was about 8 m higher than the present level. The natural dam was broken by the flood. The break of the dam and subsequent violent flow caused flood damage downstream.

The area of the lake decreased from 0.15km² to 0.07km² after Hurricane Mitch, shrinking to approximately half of its former size. Water volume of more than 1.5 million m³ flowed down in one hour. Maximum discharge is estimated as 1,000 m³/s.

2.3 RIVER SURVEY

(1) River Survey

Following river survey was carried out in order to understand existing river features.

The work quantities executed along the objective rivers are as below:

- Horizontal and vertical control survey: 590 points
- Cross-section survey: 295 sections
- Drawings of cross-sections: 295 sections
- Drawings of longitudinal profiles: 30.962 km

The work quantities of cross-section survey executed along the objective rivers are as below:

Table F.2.3 Work Quantities of River Survey

Objective rivers	Nos. of sections	Length of profiles	Interval of section
1) Choluteca river	202	20.875 km	Approx. 100 m
2) Guacerique river	11	1.061 km	Approx. 100 m
3) Chiquite river	51	5.924 km	Approx. 100 m
4) Sapo river	31	3.102 km	Approx. 100 m
Total:	295	30.962 km	

The Point numbers of cross-section survey in the Choluteca River are shown in *Figure F.2.2.*

(2) Present Capacity of the Choluteca River in the Study Area

1) River Capacity

Figure F.2.3 shows the width of the present river obtained through the river survey mentioned above. It shows that at 4.8 km and 4.9 km from point A, the river width is very small compared to the other portion of the river. These two points correspond to the river course near Berrinche landslide where the landslide mass is intruding into the river course and squeezing the width.

Figure F.2.4 shows the profile of the present river. It shows that the original river has a rather uniform profile with the slope of 1/190 to 1/250.

Figure F.2.5 shows the discharge capacity of each section of the river calculated by a non-uniform flow model. River capacity is comparatively small between 3 to 10 km from point A. The discharge capacity of 0-2km is about 2000m^3/s. The capacity of 2-5km is 500-1500 m^3/s. But it is 200-300 m^3/s at Berrinche site. The capacity of 5-10km is about 500-700 m^3/s, while that of 10-20km is 400 m^3/s.

If this is compared with *Figure F.2.3*, it is clearly revealed that the capacity of the river is small because of the narrow width of the channel and because of the sediment of the river except at Berrinche. Therefore, two main causes of shortage of channel capacity are narrow channel at Berrinche (at C47-C50) and sediment between C27 and C93.

2.4 SEDIMENT RUNOFF AND SEDIMENT TRANSPORT IN THE STUDY AREA

(1) River Bed Material Survey

A river bed material survey was carried out at about 1km interval in the Choluteca River and the Chiquito River, 12 sites of the Choluteca River and 3 sites of the Chiquito River. Detail of river bed material survey is described in Supporting Report D. According to the survey result, the Choluteca and the Chiquito Rivers bed materials are coarse, d_{60} being 30 mm and 40 mm in the Choluteca River and the Chiquito River respectively. Therefore, the Choluteca and the Chiquito Rivers have capacity of flushing out fine sediment less than 30-40 mm.

(2) Erosion in the Basin

1) Sediment Yield

According to the site reconnaissance and interpretation of topographic maps and aerial photographs, large scale collapses of mountain slope are not found in the upper basin of the Choluteca River. According to sedimentation data of Los Laureles dam of SANNA, during 26years, 3,000,000m^3 sediment is deposited in the dam. Catchment area of Los Laureles dam is 195km^2. Based on those data, sediment yield of the Guaserique River is about 0.6mm/year. The soil characteristics, slope features, rainfall intensity and erosion features of each basin were studied in Supporting Report I. Sediment yields of other catchment area were estimated. According to the study, sediment yield in the whole Study Area is about 0.4mm/year. Therefore, sediment runoff is comparatively small in the Study Area.

2) Erosion Control Plan

According to the field observation and the study on aerial photo, a large scale housing development is on going especially in the watershed of the Chiquito River, where there is no plan of water resources development and it is not designated as water resources conservation watershed.

For erosion control in the watershed, reforestation program and micro scale erosion control structures are planned in Supporting Report I. Dry masonry dams for sediment retention and formation of natural terrace with living barrier are planned.

(3) Sediment Transport in the River Course

1) Sediment Investigation

A river cross section survey at 100m interval along 20km long was carried out in the Study (Supporting Report A). As the river topography before the Hurricane Mitch, topographic map was created with a scale of 1/5,000 by aerial photos in 1996. Based on this topographic map, river cross sections in 1996 were estimated. Comparing theses cross sections in 1996 and 2001, sediment volume in the river was estimated. That estimated volume is about 1,100,000m^3. Most of sediment volume is deposited at downstream reach (C0-C21) and at Berrinche (C40-C50).

2) River Bed Variation Analysis

During Hurricane Mitch, Berrinche landslide stopped the flow of the Choluteca River. Upper reach of Berrinche became a reservoir. Therefore, silt, sand and gravel were deposited in the river. In the 20km reach, total deposition volume is about 1,100,000m^3. At 0-2km from point A; 660,000m^3, at 2-4km; 45,000 m^3, at 4-6km; 100,000m^3, at 6-8km; 140,000m^3, at 8-10km; 50,000m^3, at 10-12km; 5,000m^3, at 12-14km; 60,000m^3, at 14-16km; 17,000m^3, at 16-18km; 23,000m^3 were deposited. At 0-10km 1,000,000m^3 which is 90% of total and at 10-20km 100,000m^3 which is 10% of total were deposited respectively. River bed rose 4-5m at lower reach (C0-C21) and 2-3m at Berrinche (C40-C50).

3) Sediment Transport Analysis

Before Hurricane Mitch, diameter of mean river bed material was about 30mm and river bed seemed to be stable. Annual maximum flood of the Choluteca River's is about 1,000m^3/s. About 10,000m^3 is estimated as annual sediment discharge by sediment transport analysis.

4) Sediment Control Plan

Sediment load from upper reaches in the Grande, San Jose, Guacerique and Chiquito Rivers is comparatively small. Flood of more than 1,000m^3/s will occure less than once a year. As the sedimentation of 1,100,000m^3 is deposited in the Target Area of the Choluteca River, 100 years will be needed to carry over deposition materials. Existing river condition is very dangerous against floods. Therefore, river bed excavation is needed as soon as possible.

The sediment transport capacity was calculated along the river taking the present and planned configuration of the river. The capacity was evaluated by the sediment transport capacity of the annual maximum discharge, 1,000 m^3/s and the sediment model with diameter of d_{60}=30 mm.

The calculation result is shown in *Figure F.2.6*. It shows that in the present river, the sediment transport capacity is low in the upstream of Berrinche area. On the other hand, in the planned river profile, the sediment transport capacity is uniform along the river. Therefore, improvement of the river capacity improves the sediment transport capacity of the river also.

River bed variation was studied by using the sediment model. The annual maximum discharge was used for 100 years against the planned river. The result is shown in *Figure F.2.7.* It shows that the rising or falling of riverbed by sediment transport is within the range of 1 to 2 meters in 100 years. It means that the planned river profile is maintained without periodical artificial excavation.

3. RIVER FLOOD DURING HURRICANE MITCH

3.1 HIGH WATER MARK SURVEY

High water marks during Hurricane Mitch were surveyed. The survey was carried out at points of cross sections survey along the river. The interval of survey is 100 m and the high water marks was surveyed also at every crossing road of the area in Comayaguela where a large area was inundated.

The survey was conducted through hearing from the residents who experienced Hurricane Mitch. The elevations of high water's mark were calculated from the known points through river survey.

The result of the high water mark survey is shown in *Table F.3.1* and *Figure F.3.1*.

3.2 FLOOD PHENOMENON

The USGS conducted a preliminary flood condition and damage survey after the Hurricane Mitch in 1998. The sequence of flood damage surveyed by them was as follows:

Table F.3.1 Flood Condition and Damage during the Hurricane Mitch

Date	Time	Condition and Damage
October 30	22:45	Spillway of Los Laureles dam overflowed
October 30	23:00	Pescado Lake collapsed
October 30	22:00 – 24:00	Severe erosion and landslide occurred at El Country bridge
October 30 - 31	23:00 – 6:00	Outflow was at peak at Concepcion dam
October 30	24:00	Chiquito river was at peak
October 30 - 31	24:00 – 1:00	Landslide occurred in many locations
October 31	1:00	Flow at Chile Bridge was at peak
October 31	Morning	Landslide at Berinche occurred

Source : Survey Response to Hurricane in Honduras in 1998" by USGS

It was reported that the natural dam at the Pescado Lake collapsed during the Hurricane Mitch on October 30, 1998 at 22:00-23:00.

The hydrograph in the upstream had 2 peaks during October, 30 – 31, 1998, the higher peak was at 23:00 on October 30, while that in the downstream had the only one peak at 2:00 on October 31. This can be interpreted that the impact of the dam-break was only in the upstream before the confluence with the San Jose River basin.

3.3 FREQUENCY ANALYSIS

Detail frequency analysis of flood is described in Supporting Report C. According to the study, relationship of the runoff at Point A and its return period is shown in the following table.

Table F.3.2 Runoff in the Choluteca River Basin (At Point A)

Return Period (Year)	Runoff (m^3/s)
5	1,508
10	1,867
25	2,328
50	2,673
Mitch (500)	3,954

4. FLOOD DAMAGE MITIGATION (STRUCTURAL MEASURES)

4.1 GENERAL

In order to understand the river features, an extensive river survey was carried out along the river. The width, the profile and the present capacity of each section of the river was studied for the length of 30km including the Choluteca, Guacerique, Chiquito and Sapo Rivers.

According to Supporting Report C, by analysis of configuration of the river and hydraulic model simulation, the flood mechanism in Tegucigalpa City has become clear.

After understanding the flood mechanism, alternative study was made to select an appropriate choice of design flood. Design flood was selected taking into account the constraints of land acquisition and resettlement caused by river improvement works. River improvement works were planned to accommodate the design flood in the river course safely.

In the Supporting Report C, runoff in the sub-basins was calculated and the result is shown in the following table.

Table F.4.1 Maximum Discharge in the Sub-basins

Basin	Drainage Area (km^2)		Maximum Discharge (m^3/s)				
	Each	Accumulated	5 year	10 year	25 year	50 year	Mitch
Grande	258.18	258.18	475.03	588.08	733.27	842.00	1,245.46
San Jose	168.50	426.68	310.03	383.81	478.57	549.53	812.85
Guacerique	244.16	670.84	449.24	556.15	693.45	796.27	1,177.83
Chiquito	90.42	761.26	166.37	205.97	256.82	294.90	436.20
Sapo	2.97	764.23	5.47	6.77	8.45	9.70	14.35
Remaining	55.42	819.65	101.97	126.23	157.40	180.74	267.34
Choluteca (Tegucigalpa)		819.65	1,508.11	1,867.02	2,327.96	2,673.14	3,954.04

4.2 ALTERNATIVE STUDY OF FLOOD CONTROL FACILITIES

(1) Flood Control Facilities Considered

For flood control purpose, not only the improvement of the river course but also flood water storage structure was taken into account.

1) Retarding Pond

According to the river survey result and the inundation survey result during Hurricane Mitch, there is no appropriate open space along the river for flood storage utilized as a retarding pond. Therefore, the idea of a retarding pond was abandoned as an alternative.

2) Dam

As for a flood storage in upper reach, Sabacuante Dam was studied. In the study on Water Supply System in Tegucigalpa Urban Area by JICA in 2001, the dam was studied as a single purpose dam for water supply. It was not adopted in the water supply master plan but in the course of the study, the idea of making it a multi-purpose project was raised. Therefore, in this Study, the preliminary study was made to make Sabacuante a multi-purpose dam. (Refer to *Figure F.4.1*)

The planned Sabacuante dam is as follows;

Catchment area;	80 km^2
Gross Storage Capacity;	36,700,000 m^3
Effective Storage Capacity;	24,000,000 m^3
Storage Capacity for Flood Control;	12,00,000 m^3
Storage Capacity for Water Supply;	12,000,000 m^3
Reduction of Flood Peak Discharge;	411m^3/s to 75m^3/s (return period 15 years)

Construction Cost;	US$34,500,000
Cost Allocated for Flood Control;	US$17,250,000

The effect of the dam is to reduce the peak discharge by the amount of 336 m^3/s. The cost of the dam for flood control is much larger than the cost increment by increasing the river capacity through excavation operation. The total cost reduction by the reduction of peak discharge by 336 m^3/s is estimated as US$500,000.

3) Pescado Lake Outlet Improvement

According to the hydraulic simulation, the effect of the natural dam break at the outlet of the Pescado Lake is significant in the upper reach. As treatment of the outlet was studied and it was found out the civil work is not so difficult to prevent repetition of the dam break incident. Therefore, it was planned to stabilize the outlet of the lake so that the flood caused by the natural dam break is eliminated.

(2) Conclusion

Based on above study, river improvement and stabilizing of outlet of the Pescado Lake were selected concerning flood control facilities.

4.3 ALTERNATIVE STUDY OF DESIGN FLOOD

(1) Alternative Design Flood Discharges

Alternative study of flood control plan was made. Five alternative design floods with different peak values were generated and relevant river improvement plans to accommodate the peak discharge were planned.

The river improvement plans were made considering the methods as excavation of the river, enlargement of the channel width, construction of parapets and construction of revetments. Required land acquisition was also studied and compared for each alternative.

The peak discharge of the flood during the Hurricane Mitch at Point A (the downstream end of the Study Area) is 4,000 m^3/s according to the run-off simulation. And it is known that the return period of two-day rainfall during Hurricane Mitch is approximately 500 years.

On the other hand, the bank-full capacity of the Choluteca River at point A is 2,000 - 3,000 m^3/s. Considering the built-up area along the Choluteca River in Centro and Comayaguela area, it is difficult to enlarge the river width at the portion.

Thus as peak flood discharge, five alternatives, namely 1000, 1500, 2000, 2500 and 3000 m^3/s were selected for study.

The design flood distributions were prepared for each alternative based on the proportion of run-off simulation. *Figures F.4.2* shows each design flood distribution.

(2) Design Profile of Choluteca River

The longitudinal profile of Choluteca River was designed based on the existing river profile. The planned river bed slopes are 1/200, 1/250, 1/190 at 2.7-5.1km, 5.1-11.4km, 11.4-15.5km respectively. The design profile is shown in *Figure F.4.3*.

(3) Design Cross Sections of Choluteca River

The design cross sections were planned to accommodate each design peak flood (1,000 - 3,000

m^3/s) taking into account the design profile set above and the design cross sections for each design peak flood discharge. The width of the channels for each case is as follows. (Refer to *Figure F.4.4*)

Table F.4.2 Width of Channels

Reach	C27-C51	C51-C56	C56-C67	C67-C93
Discharge(m^3/s)	Channel Width (m)			
1,000	35	36	32	24
1,500	48	49	45	32
2,000	61	63	56	39
2,500	73	76	68	47
3,000	86	89	80	54

(4) Planned Alignment of Choluteca River

The design alignment of the Choluteca River followed the existing alignment of the river, except the river course adjacent to Berrinche landslide, where the river width is very narrow and the capacity of the channel is small. The river course was planned to shift to the right hand side by fixing the left periphery of the river in order not to disturb the large landslide mass of Berrinche. (Refer to *Figure F.4.5* and *Figure F.4.6*)

(5) Selection of Design Flood Discharge

Five alternatives were compared in terms of return period, amount of civil work and land acquisition. *Table F.4.3* shows the comparison of each alternative.

Considering the importance of Tegucigalpa City as the capital of Honduras, 1-year return period or 5-year return period is too small. 15-year return period is also comparatively small. 35-year or 80-year return period is adequate.

The amount of river bed excavation is proportional to the amount of peak discharge and the project cost is also proportional to the peak discharge.

As the narrow river at Berrinche is the control section of the river flow, it is necessary to enlarge that particular portion in order to accommodate the peak discharge safely. The widening of the river course is limited by the position of the landslide mass of Berrinche. The river must be widened in the direction of east side. However, there exists a built-up area along the east side of the river, it is necessary to acquire a new land for new river course. Hurricane Mitch and Berrinche landslide caused a severe damage to the area. After the Hurricane Mitch, the Planning Department of Tegucigalpa City prepared a regulation stating that the damaged portion of the land is to be acquired as river area. Therefore, it is rather easy to utilize that area for new river course, while additional land acquisition is rather difficult considering the existing structures such as a church, a school and a police station.

This problem was discussed with AMDC, which is in charge of the urban planning, and it was concluded that the alternative 4 and 5, which are with the peak discharge 2,500 m^3/s and 3,000 m^3/s respectively, are quite difficult in terms of land acquisition. Thus the alternative 3 with the peak discharge 2,000 m^3/s was selected as the flood control master plan. The corresponding return period is 15 years.

Table F.4.3 Comparison of Alternative Design Flood Discharge

No	Q (m3/s)	Return period (year)	Excavation (m^3)	Land Acquisition	Overall Evaluation
1	1,000	1	320,000	Ready	No good
2	1,500	5	520,000	Ready	No good
3	2,000	15	750,000	Ready	Good
4	2,500	35	920,000	Difficult	Fair
5	3,000	80	1,420,000	Difficult	Fair

(6) Planned River Facilities by Other Donor

Planned facilities in the river course by other donor are as follows.

1) Plan of New Bridge between Mallol Bridge and Juan Ramón Morina Bridge

A plan for new bridge construction between Mallol Bridge and Juan Ramón Morina Bridge has been made by the fund of Swedish Government. The planned bridge is 5 span bridge, with the length of 150 m and slope of 5.5 %. The bridge links between the urban area of Commayagüela, which is three blocks upstream of the Mallol Bridge, and Calle Coheles. The bottom PC beams of the bridge are higher enough than design high water level. Foundations of abutment and piers are lower than the planned river bed elevation. Therefore, this project has no adverse effects against the river improvement plan of the Study. (Refer to *Figure F.4.7*)

2) Plan of New Bus Terminal

AMDC has a plan to construct a new bus terminal. Bus terminal is planned in the left side of the existing river course of the Cholteca River between Mallol Bridge and Carias Bridge. Elevation of bus terminal is 918 m, which is lower than the design water level at this point of 920 m. Width of bus terminal is 40 m.

The bus terminal interferes the proposed river alignment and causes the higher water level of 0.3 m at Mallol Bridge during the event of design discharge of 2,000 m^3/s. (Refer to *Figure F.4.7*)

3) "Choluteca River Rehabilitation, Express Way and Urban Axis Project"

The study for the project of "Choluteca River Rehabilitation, Express Way and Urban Axis Project" has been done by the fund of the Canadian Government. However, there is no plan and fund for implementation at present.

4.4 MASTER PLAN PROJECTS

(1) General

Major river improvement plan for the Choluteca River is composed of the following item;

River bed excavation	L= 7 km, V=800,000 m^3	(C27 - C93)
River widening	L= 200m	(C48 - C50)
Revetment construction	L= 8km	(C32 - C78, C93 - C99, C150)
Dike construction	L= 4km	(C57 - C78, C93 - C99)
Bridge reconstruction	1 bridge	(Mallol Bridge)

(Refer to *Figure F.4.8*)

(2) River Bed Excavation

Excavation was planned to obtain the required river cross section and required river profile. However, the lower reach of the river between the cross section number C0 and number C27 (approximately 3 km) was eliminated from this operation, because there is no house or agricultural land to be protected in the area.

Thus the river bed excavation is planned between cross section number C27 and number C93. The total length of the river for the operation is approximately 7 km and the total excavation volume is 750,000 m^3, among which 40,000 m^3 is rock excavation.

The excavated material was planned to be hauled to downstream of the river and to be filled up along the Choluteca River. At that location, the river has a wide valley and the pile of soil does not give any adverse effect on the flood in upstream. (Refer to *Figure F.4.9*)

(3) River Widening at Berrinche

The only place where river widening is required is the neighborhood of Berrinche landslide. The required width to accommodate the design flood is 60 meter. Existing channel width is only 20m. Therefore, additional 40 meters of widening is necessary.

It is necessary to protect the left side of the river against the landslide of Berrinche. In this Master Pan Project, structures were planned to prevent the destabilization of the left bank of the Choluteca River during the channel excavation operation. Planned cross section at Berrinche is shown in *Figure F.4.10*.

The right side of the river is planned to be protected by a vertical wall with earth retention by tieback anchor in order to minimize the area of land acquisition.

According to Supporting Report G, there are small scale landslides along the left bank of the Choluteca River. Since such landslide may repeatedly occur, it is necessary to take measures on the bank in order to stabilize the river bed and to prevent erosion of the hilly areas of Berrinche. The measures are described in 4.5 of this Supporting F.

(4) Revetment

Revetment along the river is needed to stabilize the bank against erosion and sliding where built-up area is just next to the river. Revetment structure is planned as stone-masonry as it is a common practice in Tegucigalpa. The height of the structure is about 8m. Total length of the structure along the river is 8 km. The locations of revetment are shown in *Figure*s *F.4.9*.

(5) Dike

According to the hydraulic simulation, there are some area along the river where the inland elevation is low and it is necessary to protect that area by dike construction. The proposed dike structure is concrete parapet walls (1-2m hight) along the river by the length of 4 km. The locations of dike are shown in *Figure*s *F.4.9*.

(6) Alternative Study of Mallol Bridge and Comayaguela Area

There are Chile, Carias, Soberania, Mallol, Molina, Padilla, Jose, Brisas, San Jose, Satelite, Loarque and Germania bridges in the Study Area of the Choluteca River.

In these bridges, area of flow at Mallol Bridge is not enough against 15-years flood (planned discharge 2,000 m^3/sec). The Mallol Bridge hampers the flood flow because of its bulky structure. Reconstruction of Mallol Bridge was planned to make flood flow smoothly. As for other bridges, the discharge capacities are enough.

Following three alternative studies were carried out.

- Reconstruction of the bridge
- Construction of dike
- Forecasting/warning/evacuation(non-structural measures)

In three alternatives, effect against flood, landscape and economy were considered.

Table F.4.4 Alternative Study of Mallol Bridge

Alternative	Against flood	Landscape	Economy	Evaluation
Reconstruction of Mallol Bridge	O	O	X	O
Construction of Dike	O	X	X	X
Forecasting/warning/evacuation	X	O	O	X

O : adequate
X : inadequate

Planned new bridge is an arch type and has 4 piers, like Carias Bridge. While the existing flow area of Mallol Bridge is only about $300m^2$, the planned flow area is $480\ m^2$.

If the reconstruction of this bridge is not realized, a dike of 2m high and 1km long is needed along the upper river instead. (Refer to *Figure F.4.11*)

This idea was discussed in the counter part meeting as well as in the steering committee and in three alternatives, reconstruction of Mallol Bridge was selected for Master Plan. As there are various opinions on the type of the new bridge, further study and discussion should be made in the F/S stage of the structure in future.

It was concluded that further alternative study is made taking into account the opinion of the Honduran Institute of Anthropology and History.

Existing bridge and the proposed new bridge are shown in *Figure F.4.12*.

(7) Bus Terminal

Bus Terminal is planned in the left side of the Choluteca River between Mallol and Carlias bridges by AMDC. The impact of this terminal was investigated in supporting report C.

The dimension of the bus terminal is as follows:

Top elevation of terminal	=	EL 918 m
Width of terminal from the left bank	=	40 m

The bus terminal make the water level increase slightly in the upstream. The maximum increase of water level is about 0.3 – 0.4 m. (Refer to *Figure F.4.13*)

(8) Remove of Water Supply and Sewage Pipes

Water supply pipes cross the river, which are shown in *Figure F.4.14*. Elevation of those pipes is higher than planned river bed elevation. Therefore, those pipes (total 1,200m) are needed to remove under planned river bed. Sewage pipes run along the Choluteca River. There are sewage pipes in excavation area of Master Plan. But some pipes are not used.

Elevation of those pipes is not sure. Therefore, sewage pipes removing of about 1,100m (20 % of total length of sewage pipes in the reach of C27-C93) are planned in Master Plan Project.

(9) Condition of Right Bank of C60-C65

Condition of right bank of C60-C65 is steep slope and geological condition is bearable against floods. There is rock layer at planned excavation part. Therefore, revetment at right bank between C60-C65 is not needed.

(10) Foundation Depth of Bridges

There are Chile, Carias, Soberania, Mallol, Molina, Padilla, Jose and Brisas bridges in the river improvement reach. In these bridges, the new Chile and the new Molina Bridges foundation depths are deeper than planned river bed. Carias, Soberania and Mallol Bridges foundation depths were surveyed by SOPTRAVI. Those bridges foundation stand on the rock and are deeper than planned river bed. Other bridge foundation depths, which are not included in the Priority Projects but included in the Master Plan, are not sure at present.

(11) Spoil Bank

River excavation volume is about 700,000m^3. Planned spoil bank is located at along C0-C15. That area is about 200,000m^2. Gabion wall of 3m high surrounds the bank. Spoil bank capacity is about 1,000,000m^3. There are many chicken farms along the river. Those chicken farms are at high land. But against flood with the scale of Hurricane Mitch, some chicken farms are inundated. Therefore, parapet (300m long) around chicken farms is needed. Revetment (400m long) around chicken farms is needed also. Access road is made in the river. (Refer to *Figure F.4.15*)

(12) Loarque Bridge

Area of flow at Loarque Bridge is enough against 15-years flood (planned discharge 630m3/s). Lowest elevation of bridge beam is higher than planned high water level. But, flow condition is not good. Therefore, 20m training wall is needed to smooth flow at upstream of bridge. (Refer to Figure *F.4.16*)

(13) River Improvement Plan for Tributaries

1) Sapo River

The Sapo River is a small tributary, which flows into the Choluteca River at left bank of C50. The catchment area is about 3 km^2. The discharge capacity of the culvert portion is 15m^3/s, the return period of which is around 50 years and its capacity is enough to discharge the design flood.

Therefore, excavation of the Choluteca River and exposing the outlet completely will recover the flow capacity of the Sapo River and solve the inundation problem along the river. However, it is necessary to prevent the clogging of the inlet of the culvert by garbage and it is necessary to educate the people and create the awareness of the people along the river to preserve the river course.

2) Cacao River

Improvement of river alignment was proposed to mitigate the flood and debris flow damage of the Cacao River. As debris source along the river is large landslide mass and it is not practical to stop those landslides. Therefore, the non-structural measure (resettlement) was proposed.

3) Pescado Lake

The geology around the outlet of the lake consists of lava of ignimbritas and tuff. Although the rock on the right bank appears to be basic rock formation, it is a large piece of rock that slipped down from the up-hill gradually in a very long period of several tens of thousand years. Probably, the large rock piece seems to be stable for a short period of time. However, a large amount of talus material depositing around the rock piece suggests its deterioration in a long time span.

On the left bank, the lava of ignimbritas is distributed along the ridge and talus material deposits on the downstream side. The talus material seems to include the material from the right bank in addition to the talus material from the left bank. This observation suggests that the outlet have been subjected to frequent blocking by the collapse of the right bank.

It is planned to improve the outlet of the Pescado Lake so that further landslide is prevented in order to avoid filling up of the outlet and natural dam break. The outlet improvement is shown in *Figure F.4.17*. Periodical investigation of slope deformation of right bank is needed.

4) Bambu River

It is located in the Chiquito River basin. Its catchment area is about 0.3 km^2. It connects to the Chiquito River by a culvert with the diameter of about 1m. The length of the culvert is 400m. The discharge capacity of the culvert portion is $1.5m^3/s$, which is around 50 years-flood.

Therefore, excavation of the Chiquito River and exposing the outlet completely recover the flow capacity of the Bambu River. However, it is necessary to prevent the clogging of the inlet of the culvert by garbage and it is necessary to educate the people and create the awareness of the people along the river to preserve the river course.

4.5 PRIORITY PROJECTS

(1) General

The selection of the Priority Projects was made based on the pre-set criteria (significance, urgency, immediate consequence and economy) and the discussion among the counterpart team members as well as the steering committee of the Honduran side.

As a result, a part of the flood control structural measures and a part of the non-structural measures were selected as the Priority Projects. *Figure F.4.18* shows the location map of proposed Priority Projects (structural measures).

(2) Flood Control Structural Measures

In terms of flood damage prevention, the main causes of the problem is the bottleneck of the main channel at the location of Berrinche and the large amount of sediment caused by the bottleneck. Therefore, the widening of the Choluteca River adjacent to Berrinche landslide is the most significant project. The next significant project is the removal of the large amount of sediment, which deposited during Hurricane Mitch with the combination of revetment and dike construction. Reconstruction of Mallol Bridge is less significant in terms of the effect to the river discharge. Improvement of the Pescado Lake is also significant considering its large impact to the flood in the downstream.

Area along the Choluteca River, which is inundated by flood of Hurricane Mitch scale, was studied in case of with and without river improvement project. *Figure F.4.19* shows the area to be inundated by the flood. It is judged that the river improvement project between C27 and C93 saves the wide built up area where houses are densely populated. Therefore the Choluteca River improvement, including riverbed excavation between C27 and C93 and revetment and dike construction between C40 and C60, is chosen as a Priority Project. Gabion mattress is placed temporarily against bank erosion at part of revetment construction in Master Plan excluding part of between C40 and C60.

Removal of sediment in the Choluteca River affects the capacity of the Sapo River which causes inundation in the area almost every rainy season.

Mallol Bridge reconstruction is excluded from the Priority Projects as they are less significant and it is anticipated a long time to clear the environmental issues.

Therefore, the following projects are selected as Priority Project for Feasibility Study;

<u>Choluteca River Improvement</u>

River widening at Berrinche	L=200 m	
A part of riverbed excavation	V=C27 – C93	800,000 m^3
A part of revetment construction	L=C40 - C60	
A part of dike construction	L=C40 - C60	

<u>Other Projects</u>

Pescado Lake Outlet Improvement

The location map of the Choluteca River improvement plan is shown in *Figure*s *F.4.20*.

(3) Non-Structural Measures

The non-structural measures are composed of watershed management, land use regulation, structural code application, warning/evacuation, education of people and establishment of disaster management system. (Supporting Report P and Q)

That non-structural measures which give an immediate consequence are forecasting, warning and evacuation. The land use regulation, structural code application and watershed management do not give prompt solution to the inundation problems. They should be regarded as long term solutions. The warning/ evacuation is the most significant projects, which deal with the largest number of household in danger. It is also a project, which gives prompt solution to the problems.

Land use regulation, structural code application and watershed management is long term solution of the problem, although they are significant component of the solutions.

Education is an urgent part of the solution to be initiated as soon as possible. The disaster management system is essential to start and maintain the whole plan of disaster prevention.

Therefore, following projects were selected as Priority Projects in non-structural measures.

Forecasting/warning/evacuation

Education of people

Establishment of disaster management system

(4) Alternative Study of River Widening near Berrinche Landslide

According to Supporting Report G, there is small scale landslide along the left bank of Choluteca River. Since such landslide may repeatedly occur, it is necessary to take measures on the bank in order to stabilize the river bed and to prevent erosion of the hilly areas of Berrinche.

Berrinche landslide site is at left side of C45-C50 in river improvement course. This site is toe of large scale landslide, therefore, common revetment (stone masonry type) can not bear against land sliding force at toe of landslide area. Special structures are needed against land sliding force. This reach is divided into three reaches based on the geology of landslide area. Three reaches are C45-C47, C47-C49 and C49-C50. Alternative structures against landslide in the three reaches are as follows.

Table F.4.5 Alternative Structures in Berrinche Landslide Site

Reach	Geology	Type of Structures			
		RC-shaft	Steel Piles	Counterweight fill	Earth Retention by Tieback Anchor
C45-C47 (150m)	River bed deposit, Chiquito layor and sliding soil	X	X	O	X
C47-C49 (250m)	Sliding soil and debris	O	X	X	X
C49-C50 (100m)	Sliding soil and gravel	O	X	X	X

O : adequate
X : inadequate

(Refer to *Figure F.4.21*)

Steel piles (φ500mm, 18m length/piece)have to be driven 8m into rock layer. Those works are very difficult and expensive. Counterweight fill is the most economical solution but not used at C47-C50, because of shortage of bearing capacity of retaining wall's foundation for counterweight fill at that site. Earth retention by tieback anchor method is not possible, because anchoring interval of 1.5m can not be secured at Berrinche landslide site. Sliding plane of landslide and sliding depth are determined to study countermeasures against landslide based on the data of geological survey by JICA. (Refer to Supporting Report G). Sliding depth of small scall landslide is about 25m at C45-C47. Safety factor of sliding is 1.0 in case of without counterweight fill and more than 1.2 in case of with counterweight fill.

Planned structures against landslide in the three reaches are as follows.

Table F.4.6 Planned Structures in Berrinche Landslide Site

Reach	Type of work and Specification	Quantity	Location
C45-C47 (150m)	Counterweight fill with surface drainage dich	40,000 back-fill	0-80m hillside from planned revetment
C47-C49 (250m)	RC-Shaft φ4.0 m (16 m length/piece) (6m into rock) φ32mm x 225 pieces of rc-bar Drainage pipe for groundwater drawdown φ100mm (50m length/piece/every 7.5m)	36 pieces 36 pieces	20-30m hillside from planned revetment
C49-C50 (100m)	RC-Shaft φ4.0 m (16 m length/piece) (6m into rock) φ32mm x 225 pieces of rc-bar Drainage pipe for groundwater drawdown φ100mm (50m length/piece/every 7.5m)	16 pieces 15 pieces	20-30m hillside from planned revetment

RC-Shaft of 4.0m diameter is selected among those of five diameters of 2.5m, 3.0m, 3.5m, 4.0m and 4.5m, because 4.0m diameter shaft is common, economical and easy to construct than other diameters shafts. RC-Shaft length is determined in assuming that the shaft is cantilever type. The length of 16m length is needed, of which 6m length should be driven into rock layer. (Refer to *Table F.4.7*)

Table F.4.7 Alternative Diameter of RC-shaft

Diameter (m)	Cost	Construction	Evaluation
2.5	×	△	×
3.0	△	○	△
3.5	○	◎	○
4.0	◎	◎	◎
4.5	○	◎	○

◎: very good, ○: good, △: fair, ×: no good

The common revetment is planned to prevent the erosion of the left bank of the Choluteca River and to stabilize the river bed. The revetment is stone masonry type, height is 8m, base width is 5m and crown width is 0.5m.

There is river-width-widening site along the right side bank, which length is 120m. That bank elevation is 13m higher than planned riverbed elevation. The school, church and police station are adjacent to the planned bank. Stone masonry and cantilever concrete wall types destroy the foundation of those public buildings under construction. Only concrete wall with earth retention by tieback anchor is possible. Periodical monitoring of deformation of this wall is needed because of special structure.

(5) Outlet of Pescado Lake

Following counter measures are planned in order to prevent reduce outlet width of the Pescado Lake.

Placing of gabion mattress, which is 15m wide, 60m long and 0.5m thick, at outlet.

Placing of gabion wall, which is 2m wide, 3m high and 60m long, at left and right slope sides.

Cut of slope, which is in danger of collapse at right slope side.

(6) Reinforcement of Revetment at No. 52-56

Bus terminal is planned at left side between Carias Bridge and Mallol Bridge in the course of the Choluteca River. That plan causes the Choluteca River's course shift to right side. Depth of existing revetment's foundation at right side is 3m shorter than planned river bed elevation. Therefore, reinforcement structure of revetment is needed. Reinforcement structure is planned at 5m in front of existing revetment. That structure is reinforcement concrete wall. The wall hight is 3m, bottom width of body is 4.2m and crown width is 1.2m. (Refer to *Figure F.4.22*)

(7) Pier's depth of Carias, Soberania and Mallol Bridges

Pier's depth of Carias, Soberania and Mallol Bridges were surveyed by SOPTRAVI using boring machine. Result is that Carias, Soberania and Mallol Bridges piers stand on the rock, which elevation is 912.3m, 907.1m and 910.9m respectively. Rock layer is under planned river bed elevation. Therefore, reinforcements of piers do not need. Some surface treatment of existing piers is needed.

(8) Remove of Water Supply and Sewage Pipes

Water supply pipes cross the river, which are shown in *Figure F.4.14*. In the Priority Project, total 500m of water supply pipes is needed to remove. Concern of sewage pipes, about 500m (20 % of total length of sewage pipes in the reach of C40-C65) are planned to remove in the Priority Project.

(9) River Bed Variation

Priority Project shall cause river bed variation. Therefore, river bed variation was studied by using the model. The annual maximum discharge 1,000m^3/s was used against the planned river. The result is shown in *Figure F.4.23*. It shows that the rising of river bed by sediment transport is within the range of 1 meter and falling is within the range of 3 to 4 meters in 100 years. It means that the planned river profile is maintained without periodical artificial excavation.

5. FLOOD DAMAGE MITIGATION PLAN (NON-STRUCTURAL MEASURES)

5.1 LAND USE REGULATION AND STRUCTURAL CODE

(1) Land Use Regulation

The Planning Department of Tegucigalpa City is planning to make a preservation zone along the Choluteca River where a large area were devastated by Hurricane Mitch and still the place is deserted. The Study Team incorporates with their plan and proposes a land use regulation along the river as one of the non-structural measures for flood damage mitigation. (Supporting Report J)

(2) Structural Code

COPECO is working for revision of the structural code taking into account of the damage by Hurricane Mitch. The Study Team incorporates with their discussion by providing anticipated inundation area and inundation depth along the river. (Supporting Report J)

5.2 FLOOD HAZARD MAP

According to Supporting Report C, peak flow at each sub-basin can be summarized in *Table F.5.1*.

Table F.5.1 Peak Flow in the Sub-basins

Sub-basin/Location	Peak Flow in the Sub-basins (m^3/s)				
	5-Year	10-Year	25-Year	50-year	Mitch
Choluteca Upstream (Grande)	473.90	584.70	727.39	834.30	1,459.83
After confluence with San Jose	825.71	1,010.73	1,249.55	1,428.75	2,092.00
After confluence with Guacerique	1,318.27	1,603.87	1,971.80	2,261.69	3,337.57
Choluteca Downstream	1,505.80	1,823.82	2,231.51	2,601.52	3,878.28

Hazard map in the Choluteca River is shown in *Figure F.5.1*. These hazard maps are in case of 5-year flood, 10-year flood, 25-year flood and 50-year flood in without-project case.

This hazard map shows the without-project situation. This map should be utilized to educate and enlighten the people for them to be aware of the danger of flood.

For the publication method of the hazard map, the following are proposed;

- To make a simple brochure carrying a simplified version of the hazard map and distributed to all the communities in the city.

- To make a full scale (1/10,000) hazard map and distribute to the community leaders in the dangerous areas.
- To make a full scale hazard map and leave it in the municipality offices for anybody who is interested in it can observe.
- To make a digital version of the hazard map and publish it on an official website of the Honduran government. The website of COPECO will be an appropriate candidate site.

5.3 FLOOD FORECASTING AND WARNING

(1) Present Warning System

There are four basins of approximately the same area in the Choluteca River. Those river slopes are steep and those rivers flow into Tegucigalpa City approximately at the same time. The flood reaches in short time after the rainfall. Therefore, as for the flood warning system in Tegucigalpa City, if not making information communication prompt, the flood warning doesn't function well.

The organizations, which concern the present flood warning, include COPECO, CODEM, SERNA and SMN (the Meteorological Agency).

SERNA possesses three stations of automatic rainfall and water level observatories (the upstream of the Conception dam, Los Laureles dam and north of Tegucigalpa City) in the Target Area of the Study. Information of three stations are transmitted to SMN at the airport direct and by satellite through USGS water resources of the Caribbean in Puerto Rico at almost real time and are communicated to COPECO and SERNA from there. It is communicated to CODEM from COPECO by telephone and fax.

COPECO is the organization, which should correspond to the nationwide protection against disasters and gets information from SERNA and SMN, and so on. It operates a 24-hour system but the facilities and the staff are insufficient and is not in the condition of being well equipped against the flood warning. Also, there is not a particular plan of the flood warning in Tegucigalpa City.

On the other hand, CODEM is an organization for the protection against disasters in Tegucigalpa City and is carrying forward services to the disaster warning (such as the flood and the landslide). There are few budgets and few warning facilities at present. Also, because the information comes through COPECO, there is time loss and there is a problem of communication in emergency.

(2) Problems and Constraints of Rainfall and Water Gauging Stations

According to Supporting Report C, there are some problems and constraints of rainfall stations and water gauging stations in using those data for flood forecasting and warning.

At present, there are only 3 telemetric stations at Mateo in the Guacerique River, Concepcion in the Grande River and north of Tegucigalpa City. Rainfall and water level data are recorded continuously and transmitted automatically to SERNA. But they were established in 1999, the recorded data range is still short,

It seems that the telemetric station at Concepcion has a problem of sediment clogging at its sensor and needs frequent cleaning,

Many organizations including SERNA, SANAA and SMN are in charge in the stations. This may cause some confusion in the data management now.

(3) Recommendations

1) Observation Stations

The existing telemetric stations at Mateo, Concepcion and Sagastume are in the Guacerique River basin, the Grande River basin and north of Tegucigalpa respectively. Only three stations are not enough to cover whole basin for establishment of flood warning system in the Target Area.

It is proposed that:

A new telemetric station shall be established at Chimbo in the Chiquito River basin.

A new telemetric station shall be established at Aldea El Tablon site in the San Jose River basin.

A new telemetric station shall be established at Berrinche in the Choluteca River basin.

(Refer to Figure F.5.2)

2) Flood Warning Level

It is proposed that:

Flood warning system shall be established in the basin using three existing and three new telemetric stations.

All data transmit to CODEM and COPECO for the analysis and determination of flood alert.

Flood warning shall be set up for at 2 levels as follows:

Table F.5.2 Planned Flood Warning Level

Warning Level	Data to be used for Warning	Condition and Preparation
1	Rain and water level	The preparation of flood countermeasure is done such as the annoucement to public,etc.
2	Rain and water level	A full scale flood countermeasures is done such as evacuation, emergency rescue, etc.

Due to the shortage of information on rainfall and water level in the Choluteca River, relationship of rainfall and water level during the Hurricane Mitch was used to determine the warning level as a reference. COPECO is establishing more accurate methodology in warning threshold values.

Warning Level 1

The rainfall for the warning level 1 is 80 mm in cumulative rainfall.

(The discharge at this rainfall corresponds to 1,200 m^3/s during the Hurricane Mitch.)

Warning Level 2

The rainfall for the warning level 2 is 120 mm in cumulative rainfall.

(The discharge becomes almost 2,000 m^3/s after the accumulated rainfall reaches 120 mm during the Hurricane Mitch.)

(The available time before the discharge reaches the river capacity is about 2-3 hours.)

3) Flood Warning System

Following flood warning system is proposed;

- Three automatic water level gage and automatic rain gage stations are set up at the San

Jose River, Chiquito River and Choluteca River. Existing three and new three stations data are sent to CODEM and COPECO.

- CODEM judges the warning.
- CODEM sends the warning of pay attention or evacuation order to Despues De La Cortins, Colonia El Loarque, Colonia El Prado, Guacerique, Colonia Comayaguel, Colonia Los Laureles, Colonia Primavera.

(Refer to *Figure F.5.3*)

4) Organization

CODEM is an organization that is in charge of the protection against disasters in Tegucigalpa City and is carrying forward services to the disaster warning (such as the flood and the landslide). Therefore it is proposed that CODEM should get information of rainfall and flood water level of existing stations at the same time as SERNA or COPECO and dispatch warning to the people.

5) Evacuation Place

Evacuation places are proposed in *Table F.5.3*.

Table F.5.3 Inundated Area and Evacuation Places(in case of Hurricane Mitch scale storm)

Inundated Area	Evacuation Place
Barrio El Chile	Colonia El Porvenir's high land
Barrio Abajo	Barrio Abajo, Barrio Los Dolores's high land, Barrio Buenos Aires
Barrio El Centavo	Barrio El Centavo's high land
Barrio La Bolsa	Barrio La Bolsa's high land
Colonia El Prado	Colonia Humuya
Colonia Maradiaga	Barrio La Granja
Campo de Balompie	Colonia Las Brisas's high land
Colonia San Jose De La Vega	Colonia San Jose De La Vega's high land
Colonia Jardines De Loarque	Colonia Jardines De Loarque's high land
Colonia Satelite	Colonia Stelite's high land

Table F.2.2 Bank and Hinterland Condition along Choluteca River (1/3)

Section No.	Left Side			Right Side		
	Revetment	Bank Erosion	Hinterland	Revetment	Bank Erosion	Hinterland
0	no revetment		flood area	no revetment		factory
1	no revetment		flood area	no revetment		factory
2	no revetment		flood area	no revetment		factory
3	no revetment		flood area	no revetment		factory
4	no revetment		flood area	no revetment		factory
5	no revetment		flood area	no revetment		factory
6	no revetment		flood area	no revetment		factory
7	no revetment		flood area	no revetment		factory
8	no revetment		flood area	no revetment		factory
9	no revetment		flood area	no revetment		slope land
10	no revetment		flood area	no revetment		flood area
11	no revetment		flood area	no revetment		flood area
12	no revetment		slope land	no revetment		flood area
13	no revetment		slope land	no revetment		flood area
14	no revetment		slope land	no revetment		flood area
15	no revetment		cliff	no revetment		flood area
16	no revetment		cliff	no revetment		flood area
17	no revetment		cliff	no revetment		flood area
18	no revetment		cliff	no revetment		flood area
19	no revetment		cliff	no revetment		flood area
20	no revetment		cliff	no revetment		flood area
21	no revetment		cliff	no revetment		flood area
22	no revetment		cliff	no revetment		slope land
23	no revetment		cliff	no revetment		slope land
24	no revetment		cliff	no revetment		slope land
25	no revetment		slope land	no revetment		cliff
26	no revetment		slope land	no revetment		cliff
27	no revetment		slope land	no revetment		cliff
28	no revetment		flood area	no revetment		cliff
29	no revetment		flood area	no revetment		cliff
30	no revetment		flood area	no revetment		cliff
31	no revetment		cliff	no revetment		cliff
32	no revetment		slope land	no revetment		cliff
33	no revetment		slope land	no revetment		slope land
34	no revetment		cliff	no revetment		slope land
35	no revetment		cliff	no revetment		slope land
36	no revetment		cliff	no revetment		slope land
37	no revetment		slope land	no revetment		slope land
38	no revetment		slope land	no revetment		slope land
39	no revetment		flood area	no revetment		cliff
40	no revetment		flood area	no revetment		cliff
41	no revetment		flood area	no revetment	erosion	slope land
42	no revetment		flood area	no revetment	erosion	slope land
43	no revetment		flood area	no revetment	erosion	flood area
44	no revetment		flood area	no revetment	erosion	flood area
45	revetment		cliff	revetment		slope land
46	revetment		cliff	revetment		slope land
47	no revetment		cliff	revetment		slope land
48	no revetment		cliff	revetment		slope land
49	no revetment		cliff	revetment		slope land
50	no revetment		cliff	revetment		slope land
51	no revetment		commercial area	revetment		commercial area
52	revetment		commercial area	revetment		commercial area
53	revetment		commercial area	revetment		commercial area
54	revetment		commercial area	revetment		commercial area
55	revetment		commercial area	revetment		commercial area
56	revetment		commercial area	revetment		commercial area
57	revetment		commercial area	revetment		commercial area
58	no revetment		commercial area	revetment		playground
59	no revetment		commercial area	revetment		playground
60	no revetment		commercial area	no revetment		cliff
61	no revetment		commercial area	no revetment		cliff
62	no revetment		commercial area	no revetment		cliff
63	no revetment		commercial area	no revetment		cliff
64	no revetment		commercial area	no revetment		cliff
65	revetment		commercial area	revetment		cliff
66	no revetment		commercial area	no revetment		cliff
67	no revetment		commercial area	no revetment		cliff
68	no revetment		commercial area	no revetment		cliff
69	no revetment		commercial area	no revetment		cliff
70	no revetment		commercial area	no revetment		cliff
71	no revetment		commercial area	no revetment		cliff
72	revetment		commercial area	revetment		residential area
73	no revetment		commercial area	revetment		residential area

Table F.2.2 Bank and Hinterland Condition along Choluteca River (2/3)

Section	Left Side			Right Side		
No.	Revetment	Bank Erosion	Hinterland	Revetment	Bank Erosion	Hinterland
74	no revetment		commercial area	revetment		residential area
75	no revetment		commercial area	revetment		residential area
76	no revetment		commercial area	revetment		residential area
77	no revetment		commercial area	revetment		residential area
78	no revetment		commercial area	revetment		residential area
79	no revetment		commercial area	revetment		residential area
80	no revetment		open space	revetment		residential area
81	no revetment		open space	revetment		residential area
82	no revetment		open space	no revetment		road
83	no revetment		open space	no revetment		road
84	no revetment		open space	no revetment		road
85	no revetment		open space	no revetment		road
86	no revetment		open space	no revetment		road
87	no revetment		cliff	no revetment		road
88	no revetment		slope land	no revetment		road
89	no revetment		slope land	no revetment		cliff
90	no revetment		slope land	no revetment		cliff
91	no revetment		slope land	no revetment		cliff
92	no revetment		slope land	no revetment		cliff
93	no revetment		slope land	no revetment		cliff
94	no revetment		slope land	no revetment		cliff
95	no revetment		open space	no revetment		cliff
96	no revetment		open space	no revetment		residential area
97	no revetment		cliff	no revetment		residential area
98	no revetment		cliff	no revetment		residential area
99	no revetment		cliff	no revetment		residential area
100	no revetment		cliff	no revetment		residential area
101	no revetment		cliff	no revetment		residential area
102	no revetment		cliff	no revetment		road
103	no revetment		cliff	no revetment		residential area
104	no revetment		road	no revetment		residential area
105	no revetment		cliff, residential area	no revetment		residential area
106	no revetment		cliff, residential area	no revetment		residential area
107	no revetment		cliff, residential area	no revetment		cliff
108	no revetment		cliff, residential area	no revetment		slope land
109	no revetment		cliff, residential area	no revetment		slope land
110	no revetment		cliff, residential area	no revetment		slope land
111	no revetment		slope land	no revetment		cliff
112	no revetment		commercial area	no revetment		cliff
113	no revetment		commercial area	no revetment		cliff
114	no revetment		commercial area	no revetment		open space
115	no revetment		open space	no revetment		open space
116	no revetment		open space	no revetment		cliff
117	no revetment		factory	no revetment		residential area
118	no revetment		factory	no revetment		residential area
119	no revetment		factory	no revetment		residential area
120	no revetment		road	no revetment		road
121	no revetment		slope land	no revetment		residential area
122	no revetment		slope land	no revetment		residential area
123	no revetment		slope land	no revetment		residential area
124	no revetment		slope land	no revetment		residential area
125	no revetment		residential area	no revetment		residential area
126	no revetment		cliff	no revetment		cliff
127	no revetment		cliff	no revetment		cliff
128	no revetment		cliff	no revetment		slope land
129	no revetment		road	no revetment		road
130	no revetment		road	no revetment		road
131	no revetment		road	no revetment		road
132	no revetment		road	no revetment		road
133	no revetment		road	no revetment		road
134	no revetment		road	no revetment		road
135	no revetment		road	no revetment		road
136	no revetment		road	no revetment		road
137	no revetment		cliff	no revetment		road
138	no revetment		cliff	no revetment		cliff
139	no revetment		cliff	no revetment		cliff
140	no revetment		cliff	no revetment		slope land
141	no revetment		residential area	no revetment		slope land
142	no revetment		residential area	no revetment		cliff
143	revetment		residential area	no revetment		cliff
144	revetment		residential area	no revetment		cliff
145	revetment		residential area	no revetment		cliff
146	revetment		residential area	no revetment		cliff
147	revetment		residential area	no revetment		cliff

Table F.2.2 Bank and Hinterland Condition along Choluteca River (3/3)

Section No.	Left Side			Right Side		
	Revetment	Bank Erosion	Hinterland	Revetment	Bank Erosion	Hinterland
148	revetment		residential area	no revetment		residential area
149	no revetment		residential area	no revetment		residential area
150	no revetment	erosion	residential area	no revetment	erosion	residential area
151	no revetment		residential area	no revetment		residential area
152	no revetment		residential area	no revetment		residential area
153	no revetment		residential area	no revetment		residential area
154	no revetment		residential area	no revetment		residential area
155	no revetment		residential area	no revetment		residential area
156	no revetment		residential area	no revetment		residential area
157	no revetment		residential area	no revetment		residential area
158	no revetment		cliff	no revetment		residential area
159	no revetment		cliff	no revetment		residential area
160	no revetment		cliff	no revetment		residential area
161	no revetment		cliff	no revetment		residential area
162	no revetment		factory	no revetment		residential area
163	no revetment		factory	no revetment		residential area
164	no revetment		factory	no revetment		slope land
165	no revetment		road	no revetment		slope land
166	no revetment		road	no revetment		slope land
167	no revetment		road	no revetment		slope land
168	no revetment		road	no revetment		slope land
169	no revetment		slope land	no revetment		cliff
170	no revetment		slope land	no revetment		cliff
171	no revetment		slope land	no revetment		slope land
172	no revetment		cliff	no revetment		slope land
173	no revetment		cliff	no revetment		slope land
174	no revetment		cliff	no revetment		slope land
175	no revetment		cliff	no revetment		slope land
176	no revetment		slope land	no revetment		slope land
177	no revetment		slope land	no revetment		slope land
178	no revetment		slope land	no revetment		slope land
179	no revetment		slope land	no revetment		slope land
180	no revetment		slope land	no revetment		road
181	no revetment		slope land	no revetment		road
182	no revetment		cliff	no revetment		residential area
183	no revetment		cliff	no revetment		residential area
184	no revetment		cliff	no revetment		residential area
185	no revetment		cliff	no revetment		slope land
186	no revetment		cliff	no revetment		slope land
187	no revetment		slope land	no revetment		cliff
188	no revetment		slope land	no revetment		road
189	no revetment		cliff	no revetment		road
190	no revetment		cliff	no revetment		road
191	no revetment		road	no revetment		road
192	no revetment		slope land	no revetment		road
193	no revetment		slope land	no revetment		road
194	no revetment		flood area	no revetment		cliff
195	no revetment		flood area	no revetment		cliff
196	no revetment		flood area	no revetment		cliff
197	no revetment		flood area	no revetment		cliff
198	no revetment		flood area	no revetment		cliff
199	no revetment		flood area	no revetment		cliff
200	no revetment		flood area	no revetment		slope land

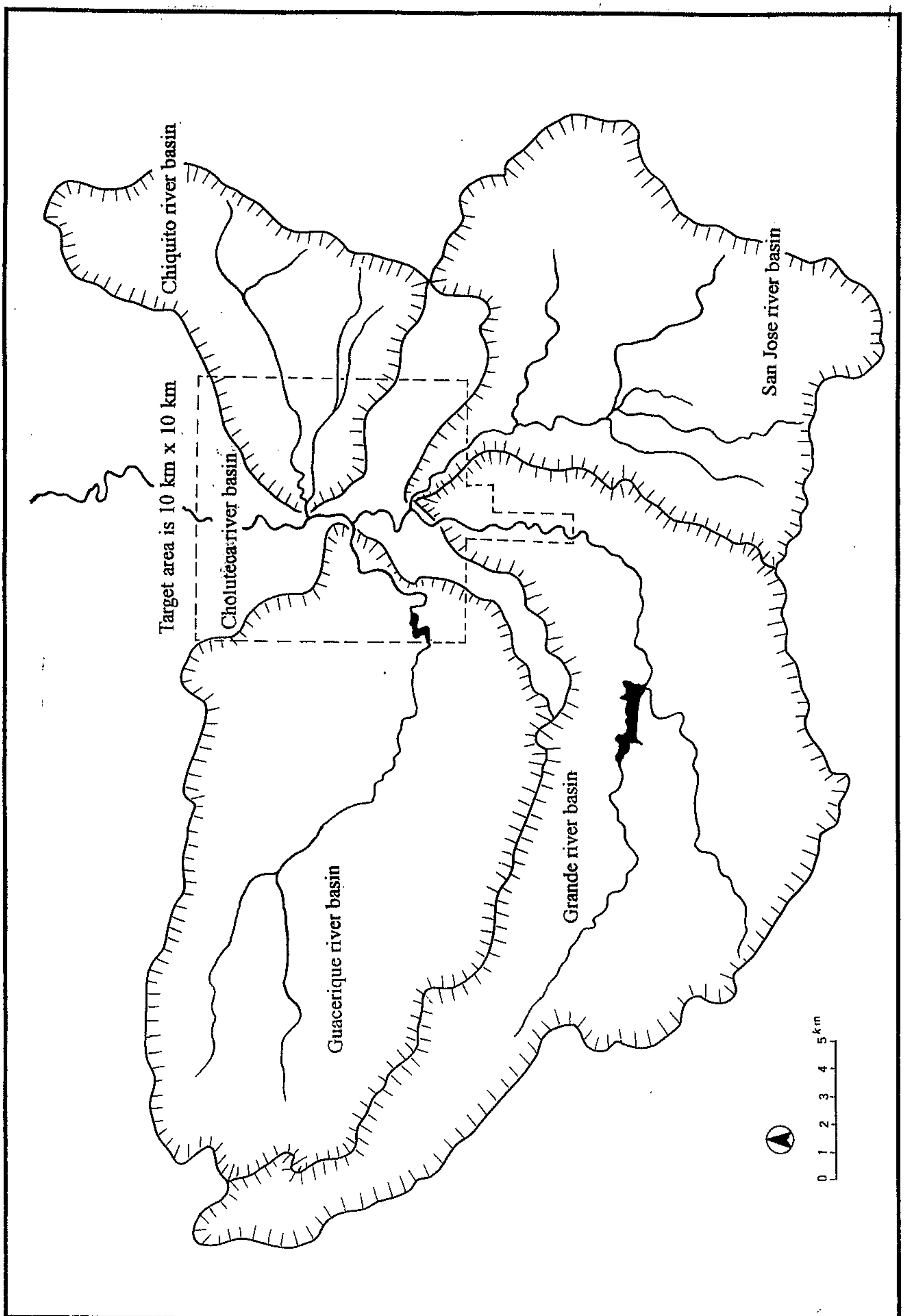


Figure F.1.1	Choluteca River Basin (Study Area)

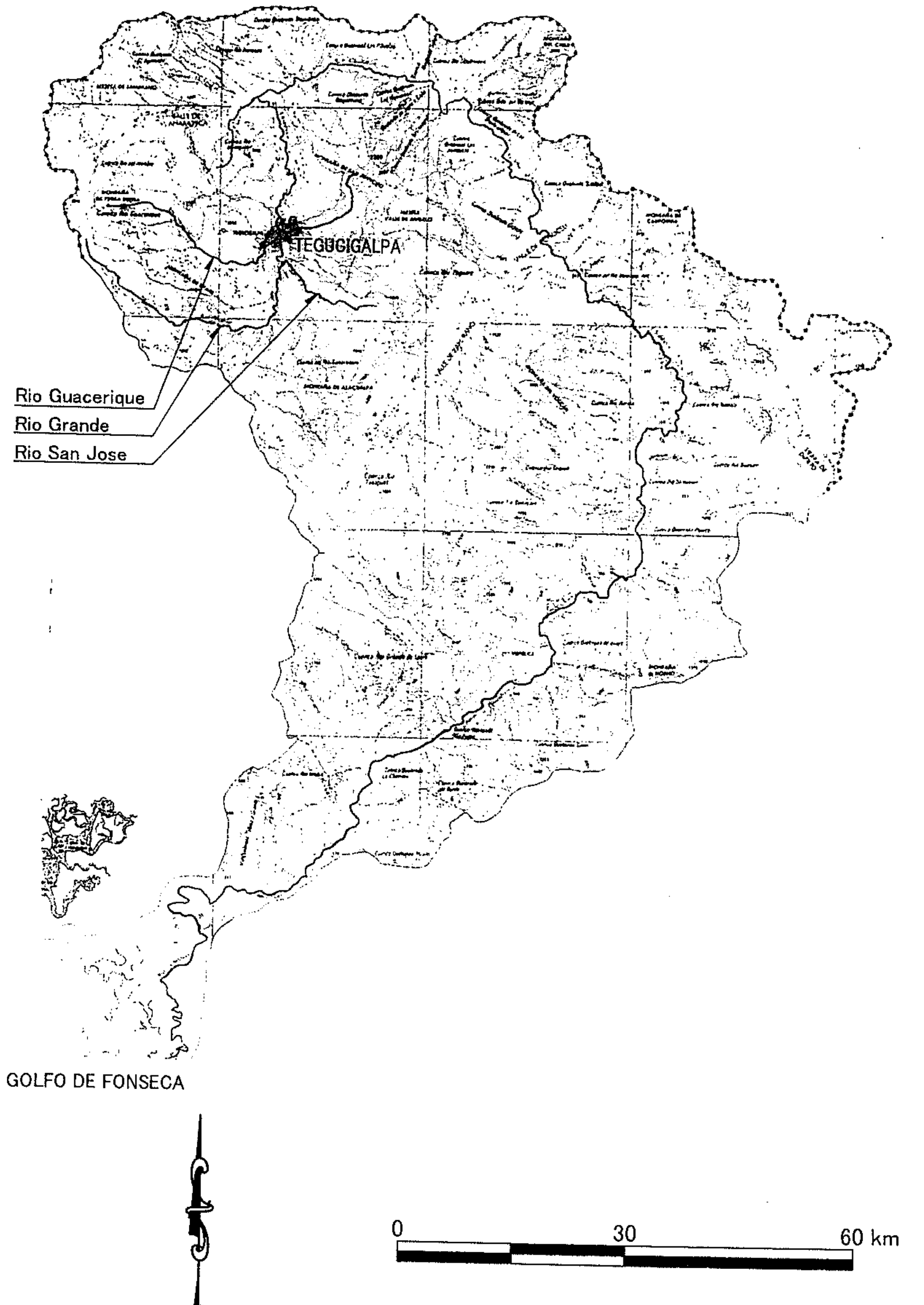


Figure F.1.2	Choluteca River Basin

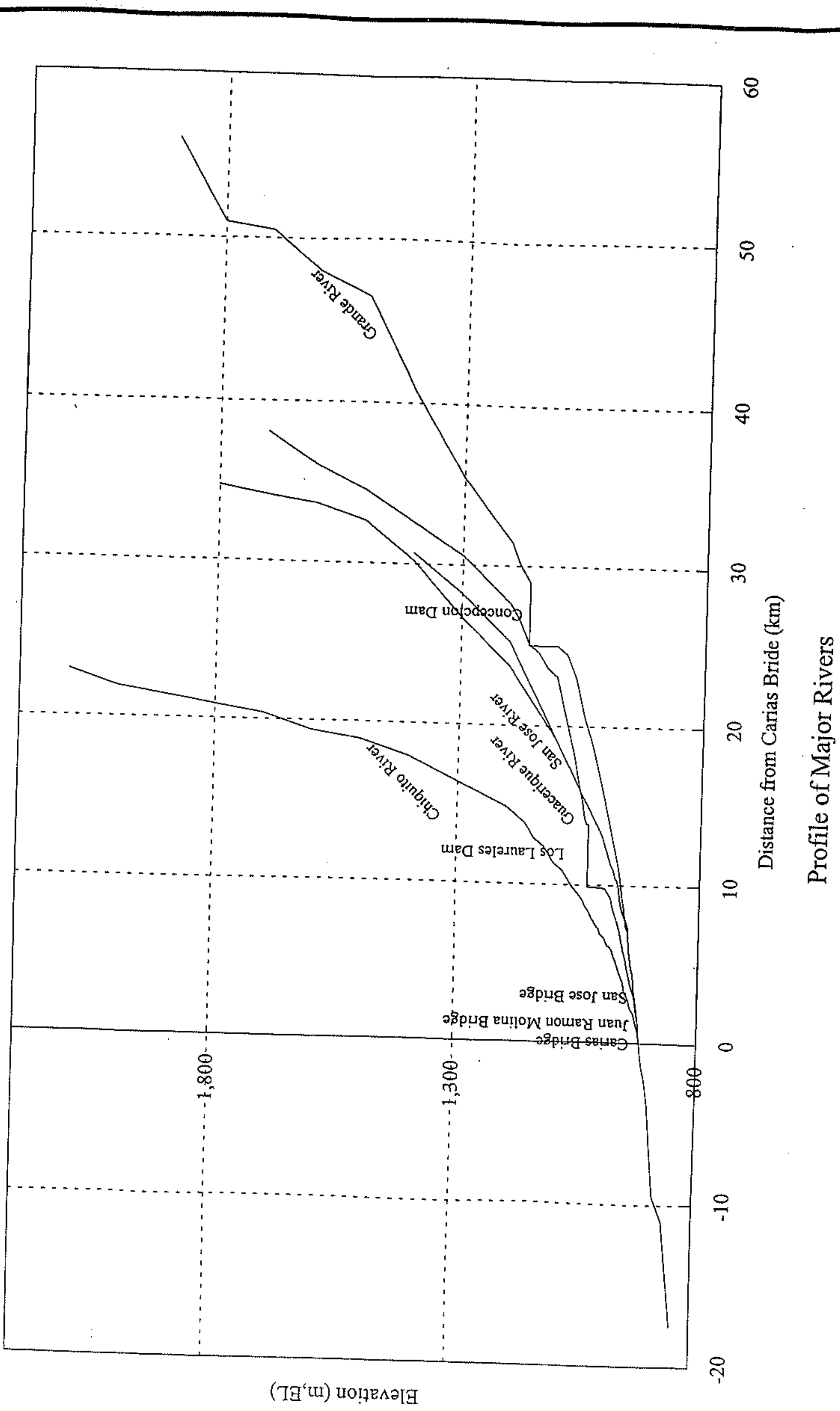


Figure F.2.1	Profile of Major Rivers

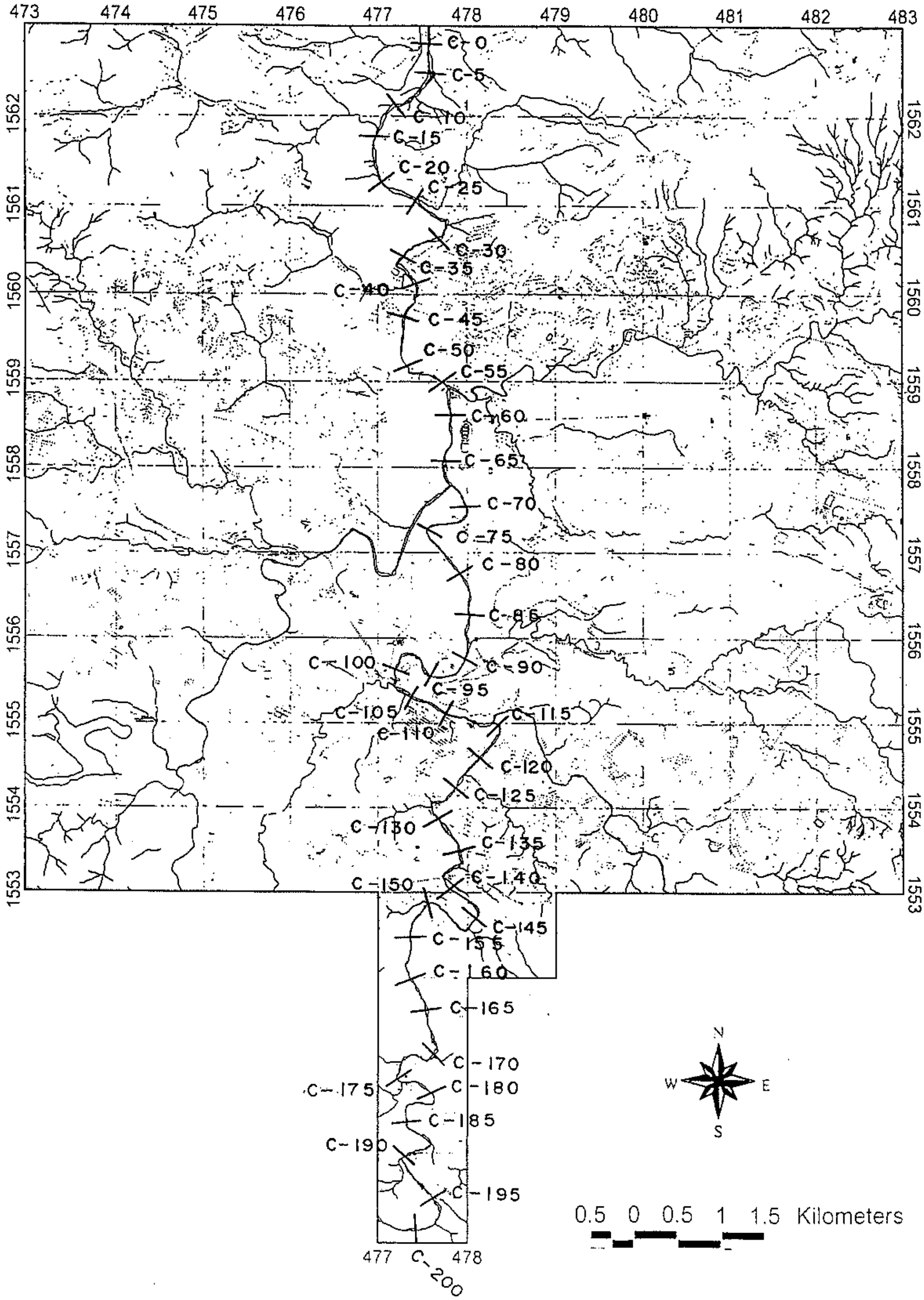


Figure F.2.2	Cross Section Survey Points

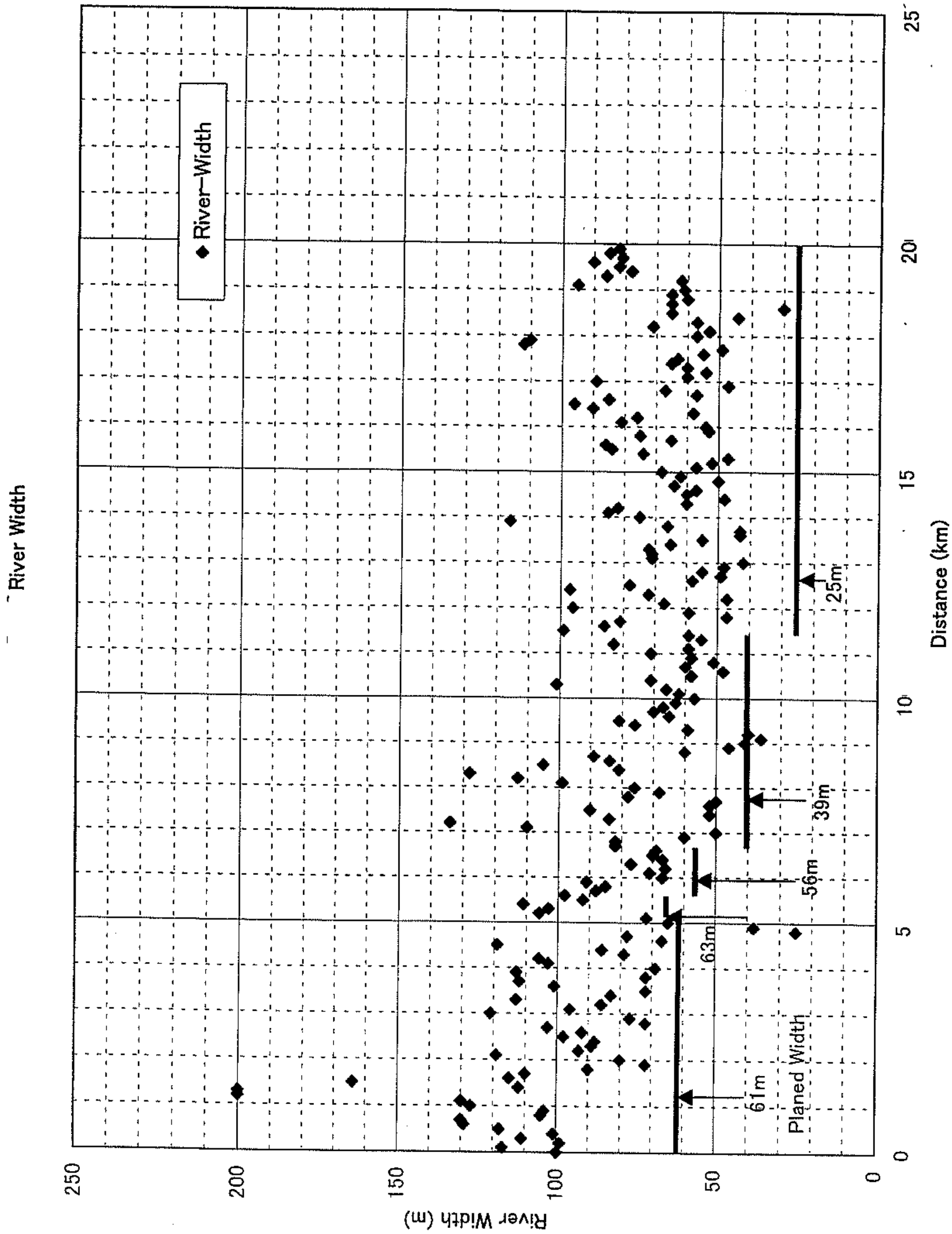


Figure F.2.3	Width of Present River

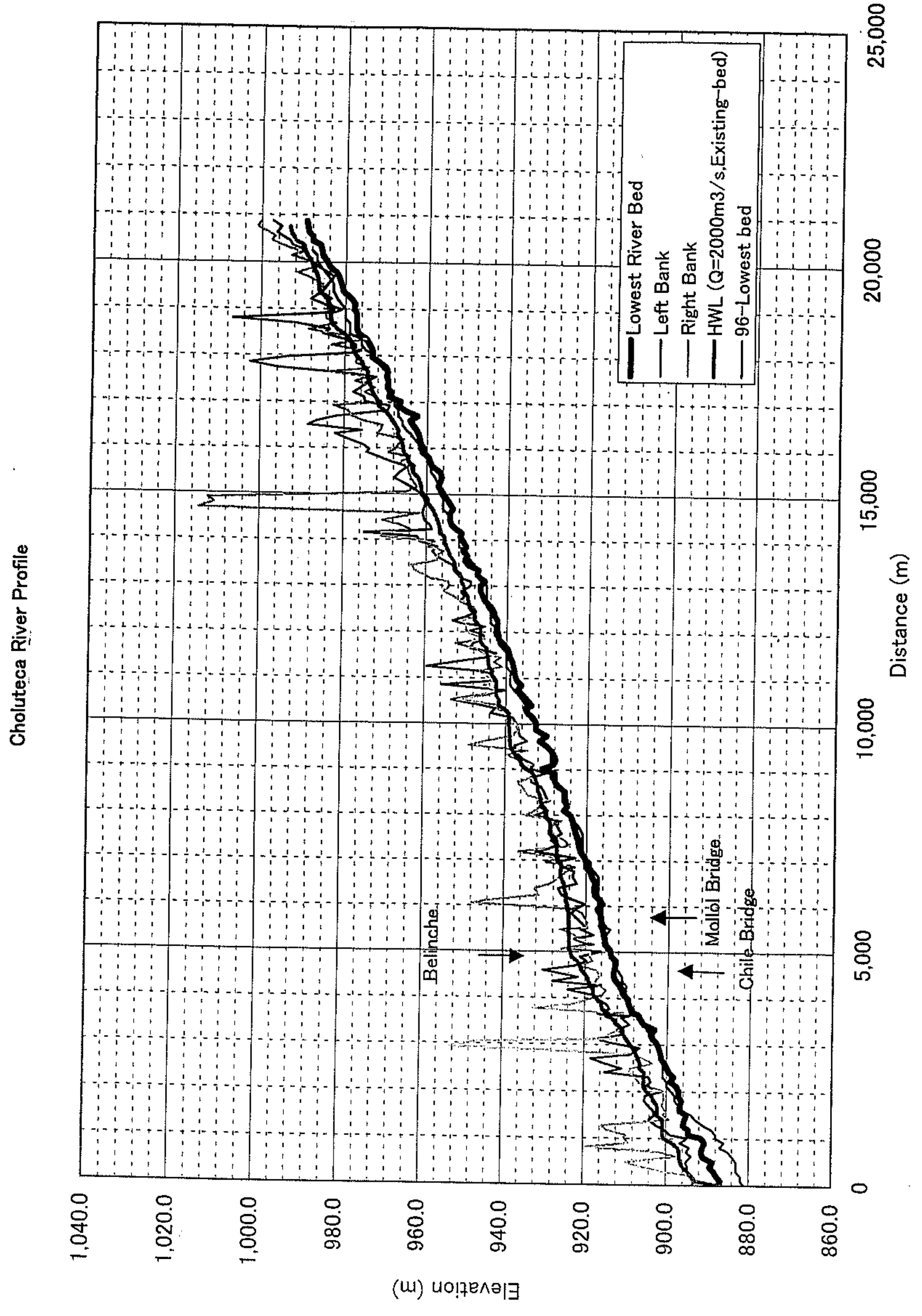


Figure F.2.4	Profile of the Present River (1/2)

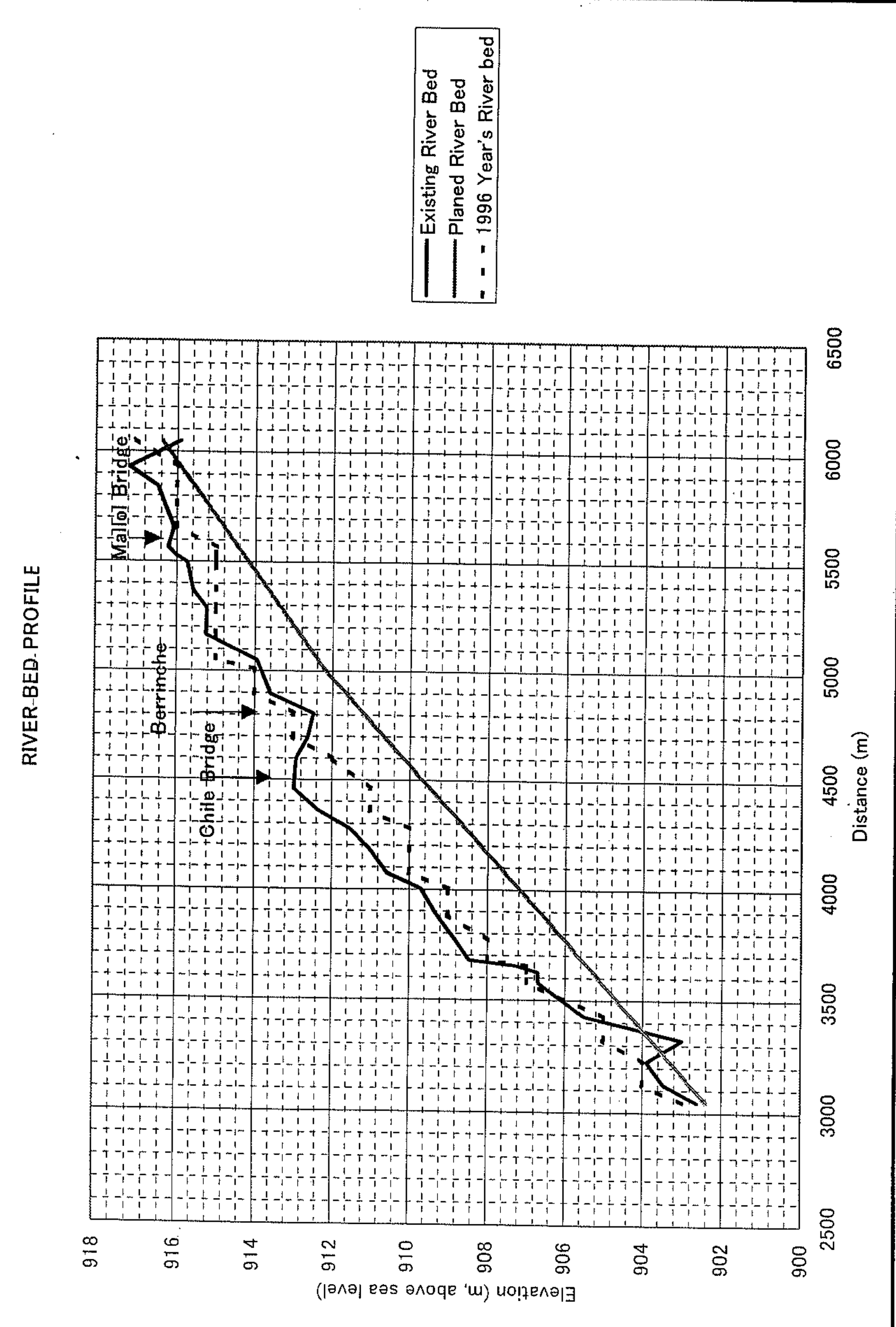


Figure F.2.4	Profile of the Present River (2/2)

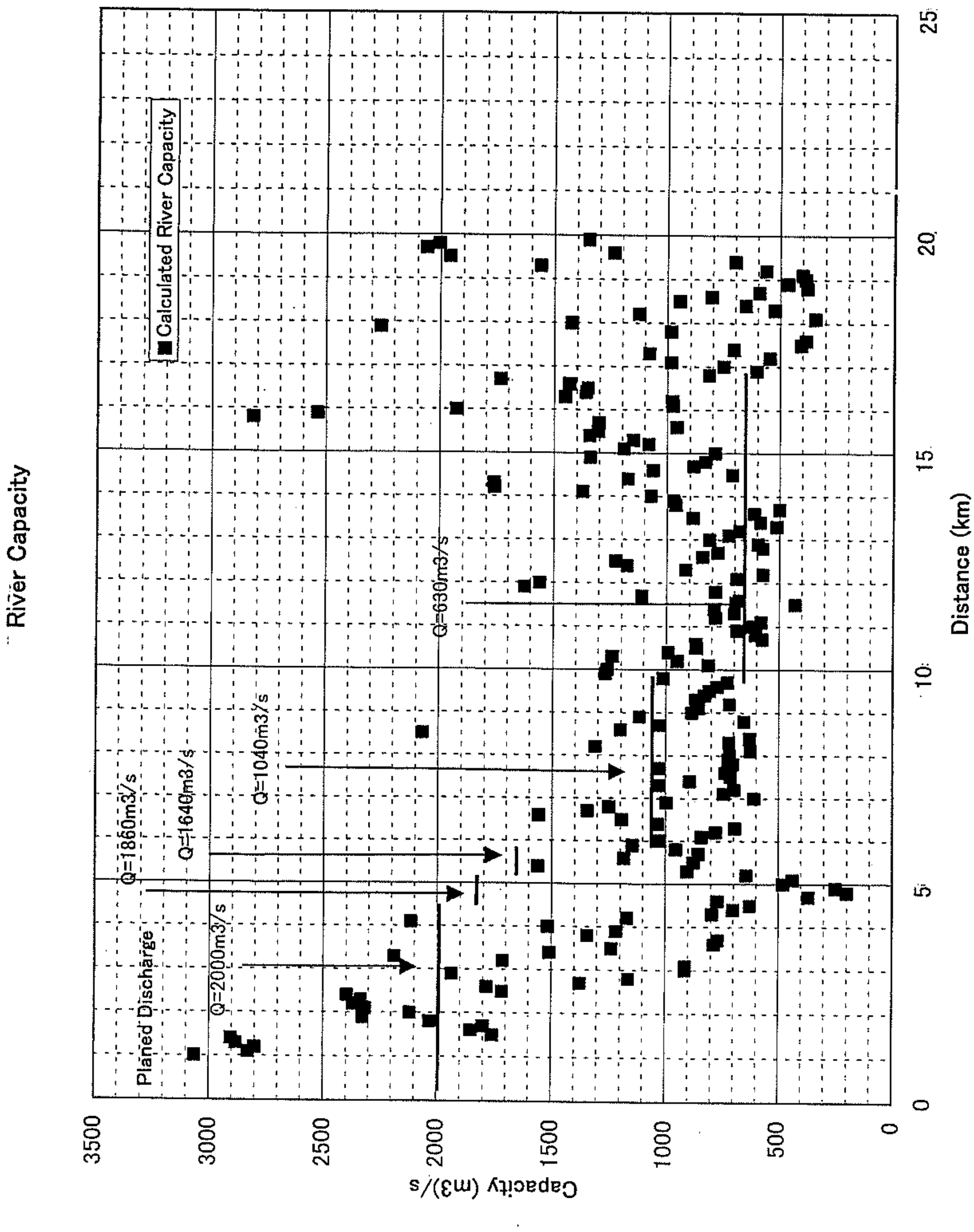


Figure F.2.5	Discharge Capacity of Each Section of the Present River

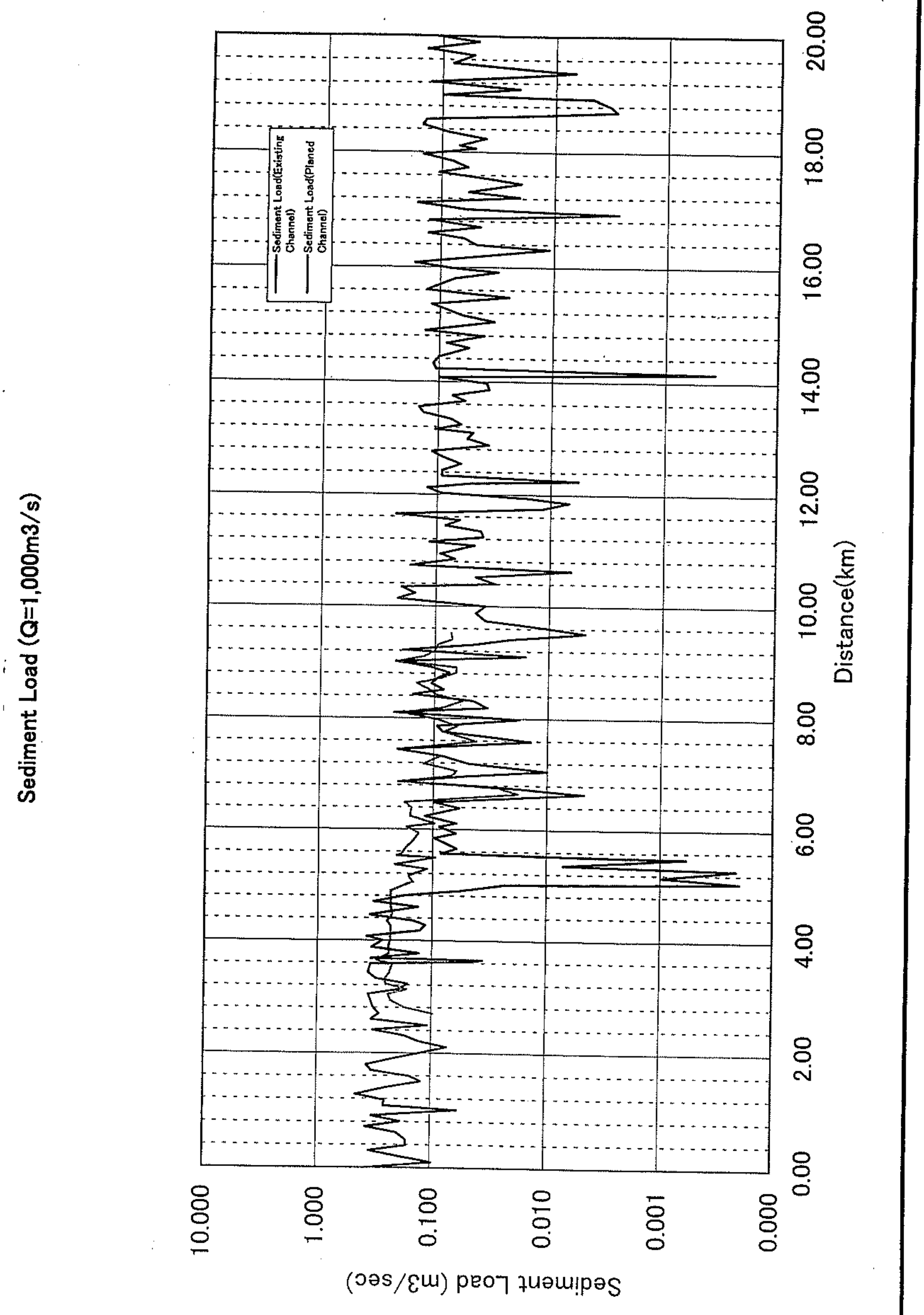


Figure F.2.6	Sediment Load

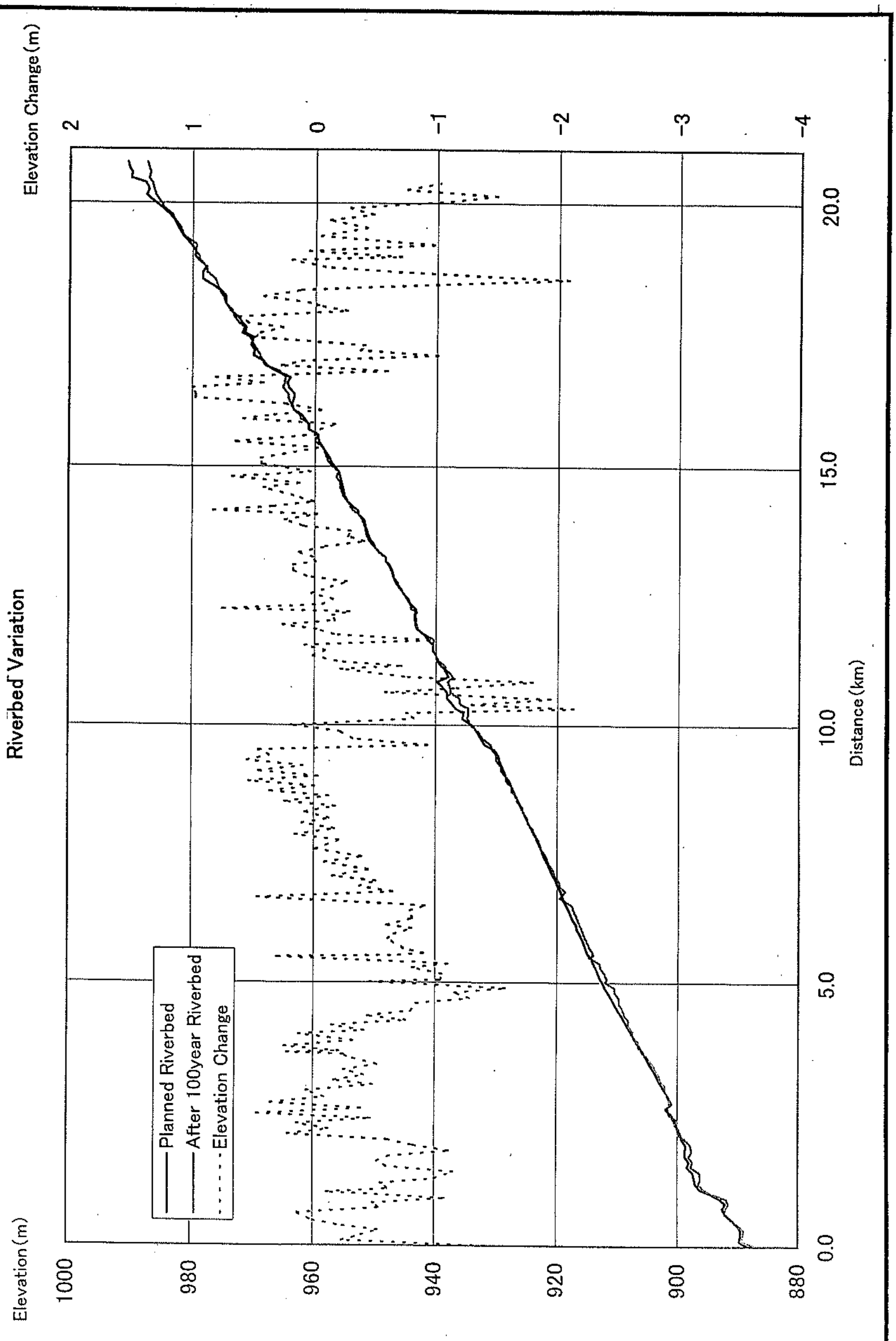


Figure F.2.7	Riverbed Variation

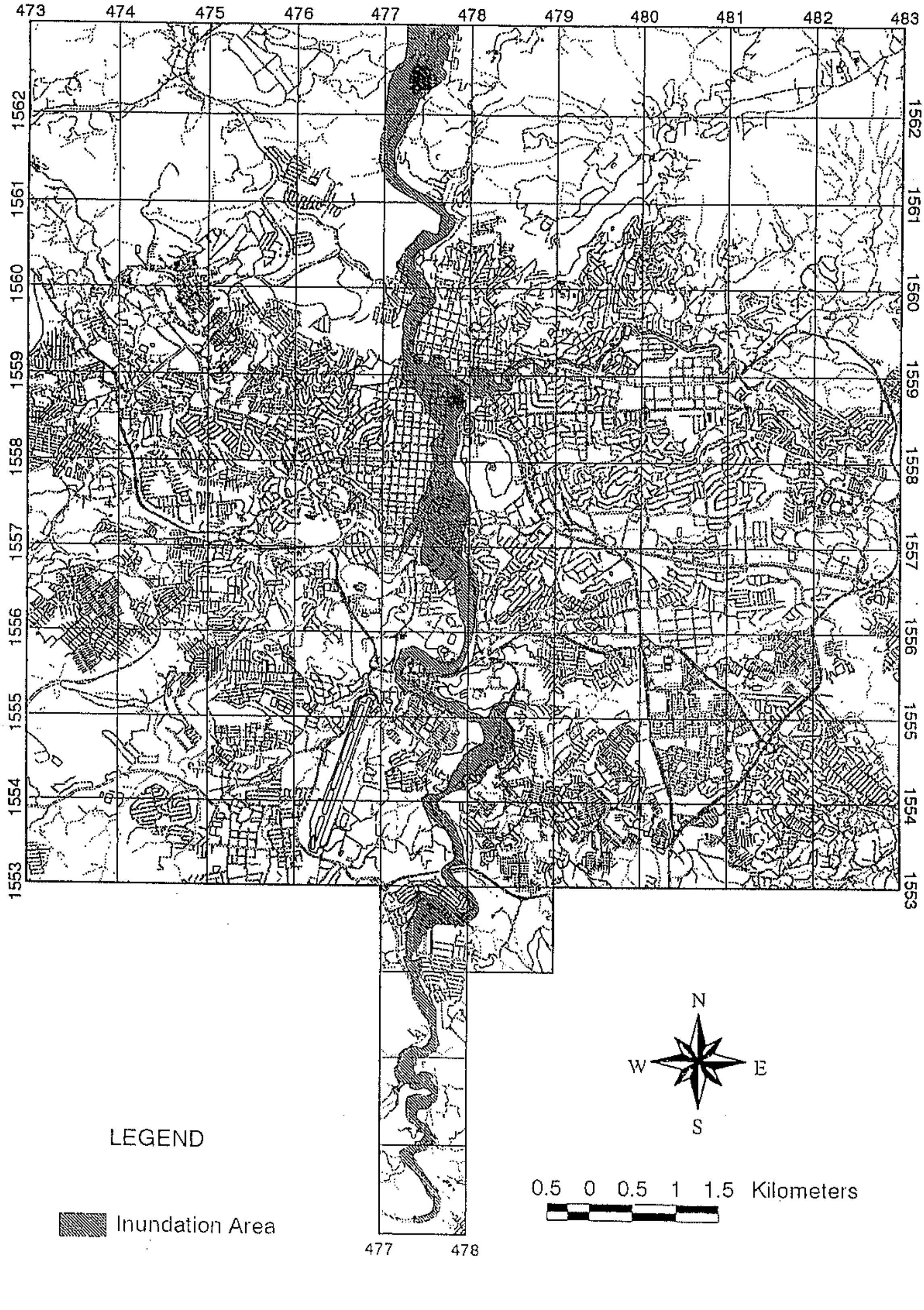


Figure F.3.1	Result of The High Water Mark Survey

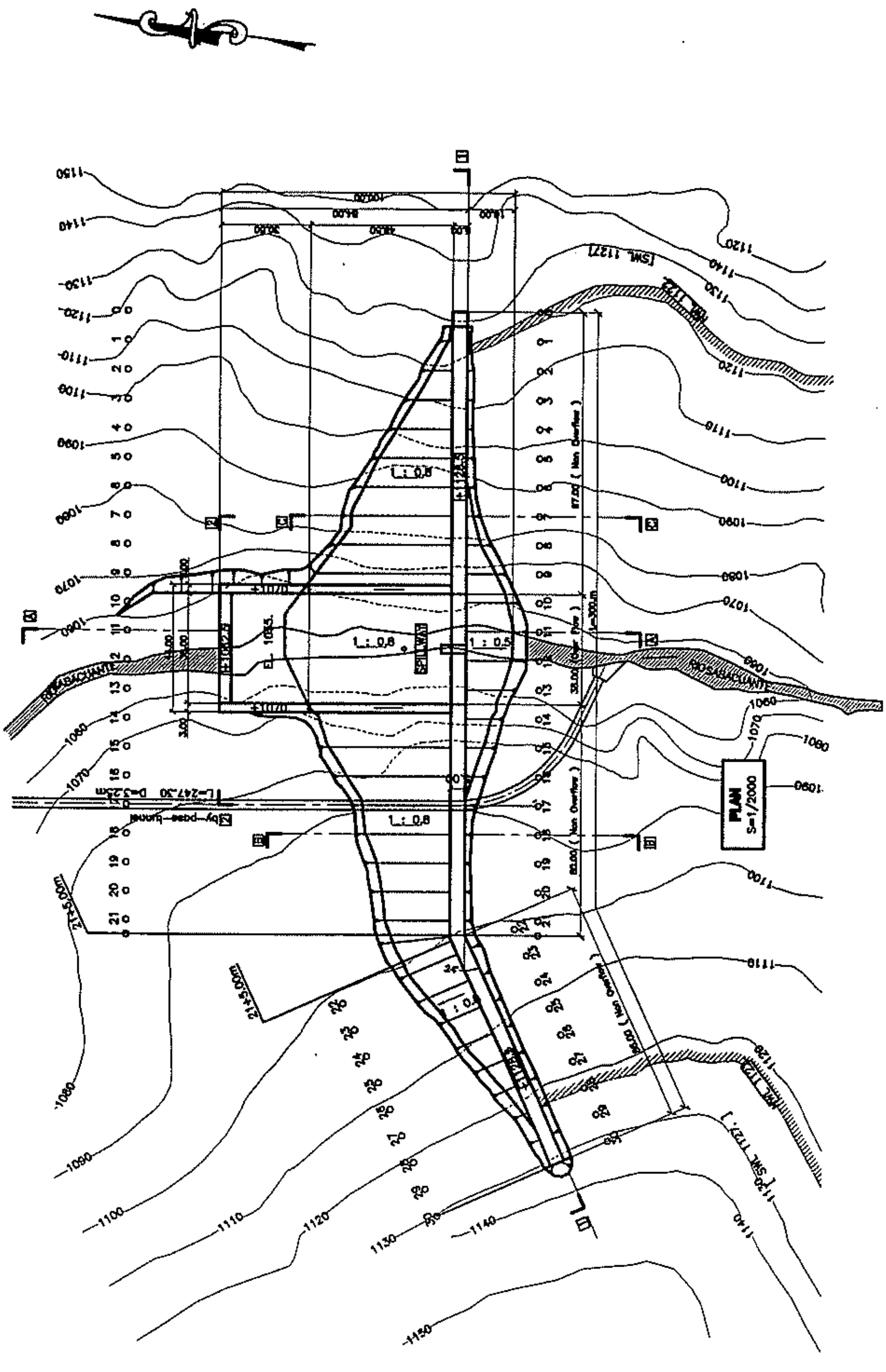
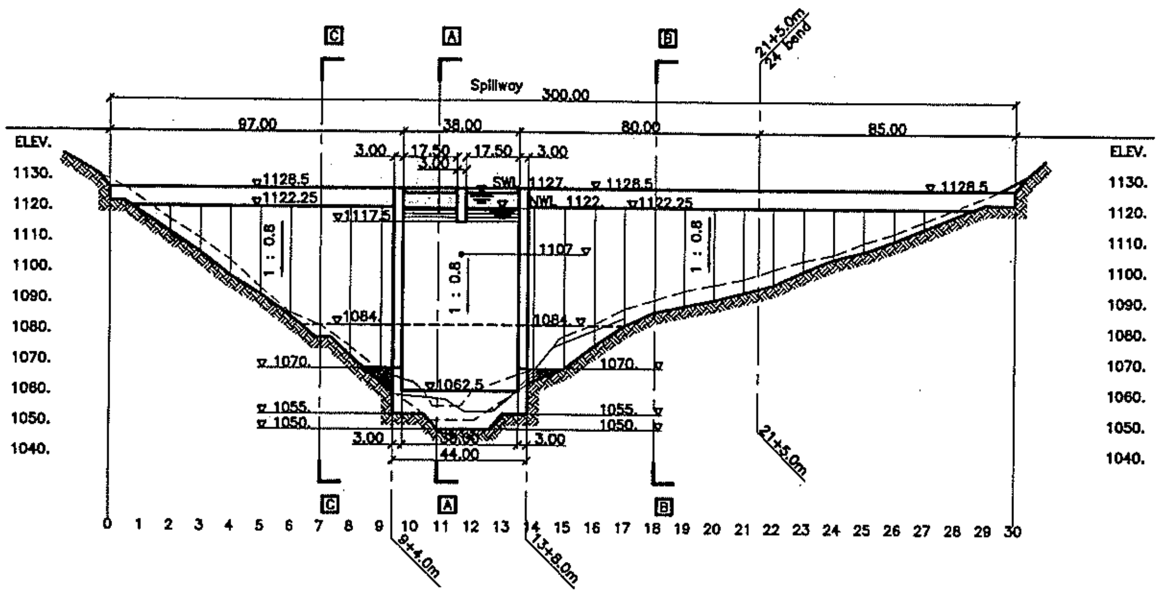
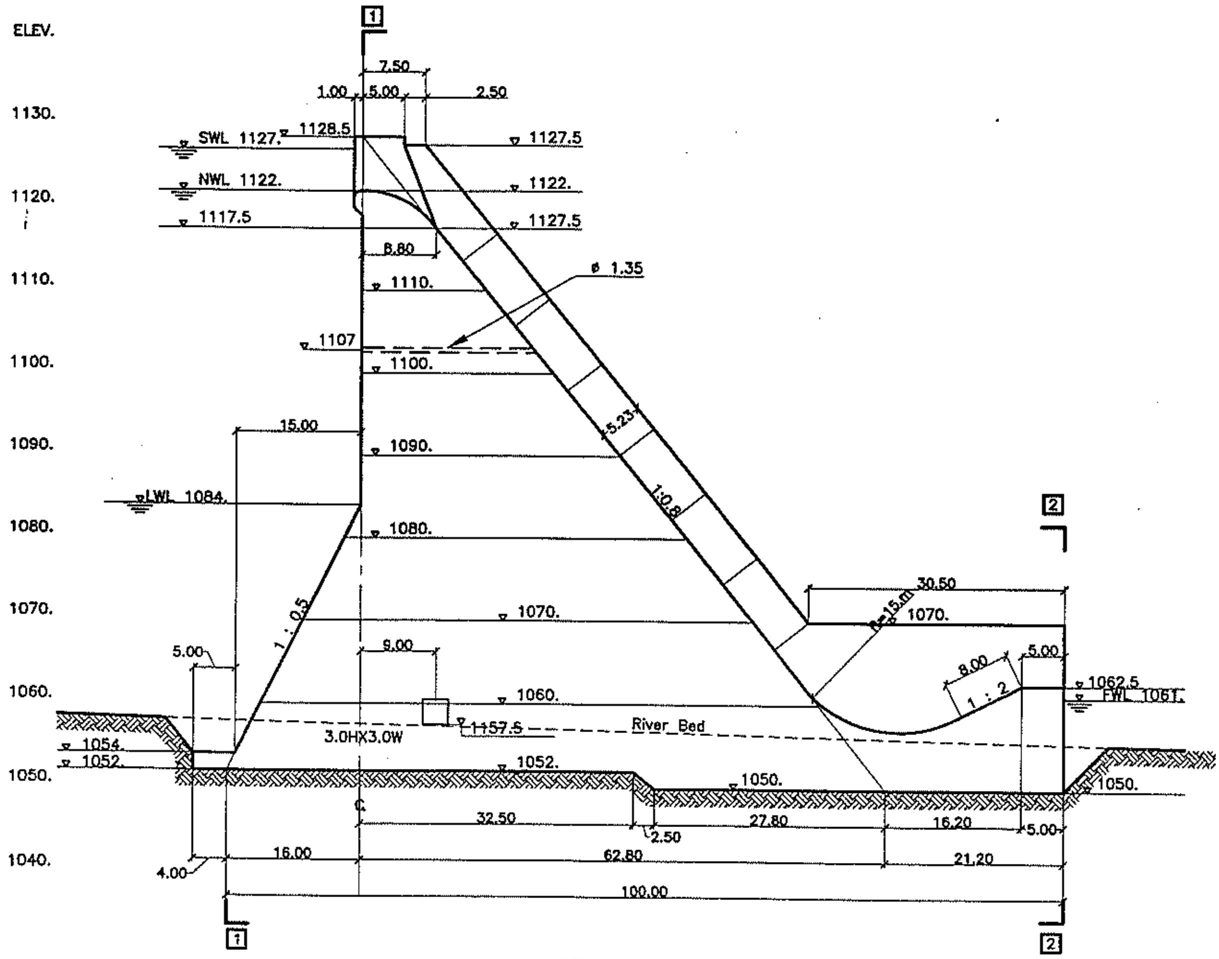


Figure F.4.1	Sabacuante Dam (1/2)



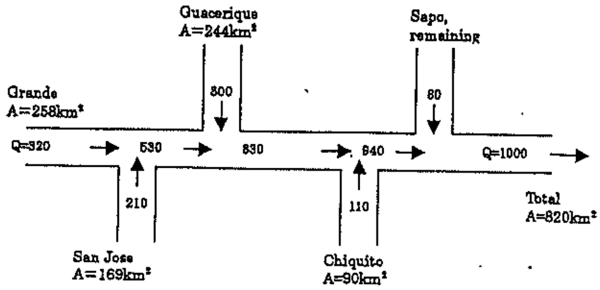
PROFILE
S=1/2,500



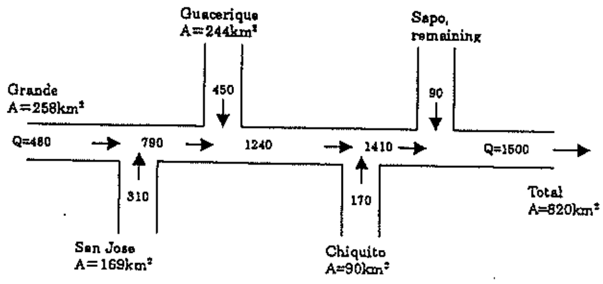
SECTION
S=1/900

Figure F.4.1	Sabacuante Dam (2/2)

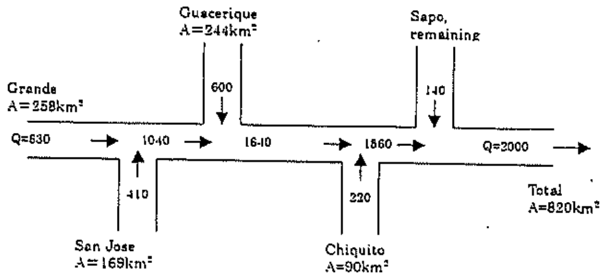
(1,000 m³/sec flood) (Unit : m³/sec)



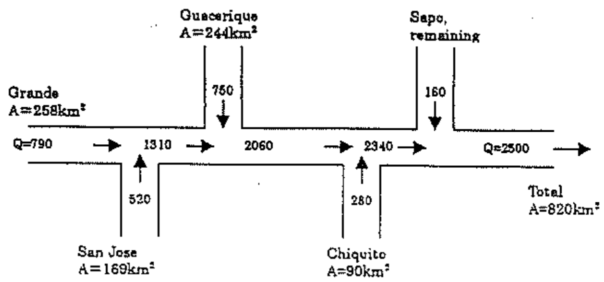
(1,500 m³/sec flood)



(2,000 m³/sec flood)



(2,500 m³/sec flood)



(3,000 m³/sec flood)

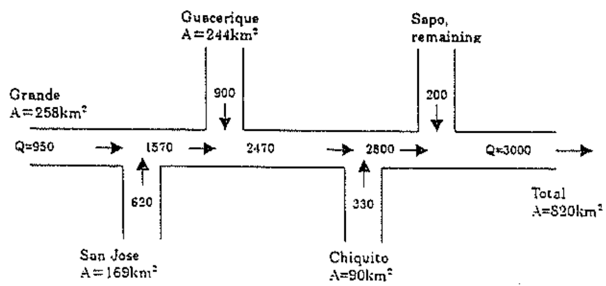


Figure F.4.2	Design Flood Distribution

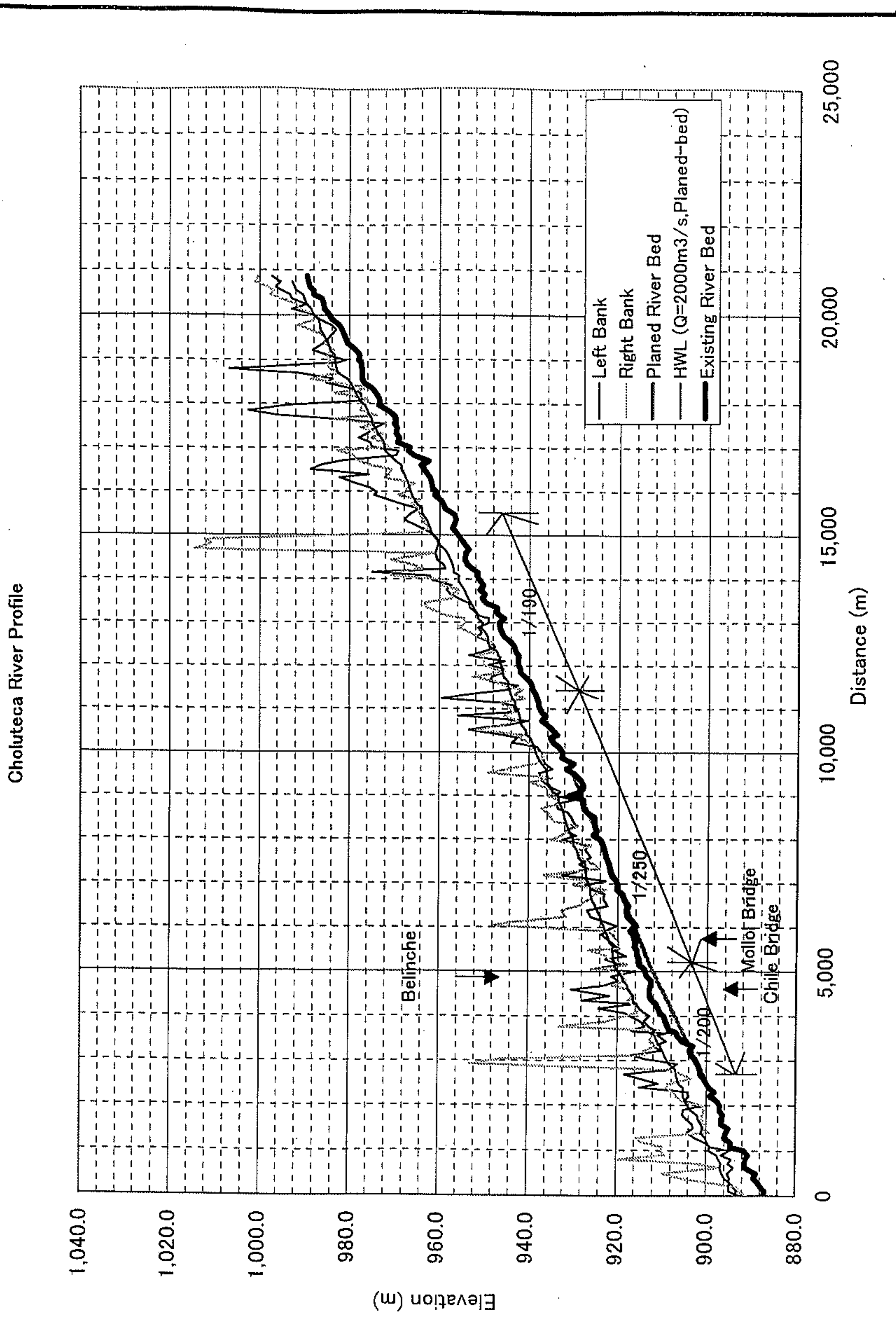


Figure F.4.3	Profile of Planned River

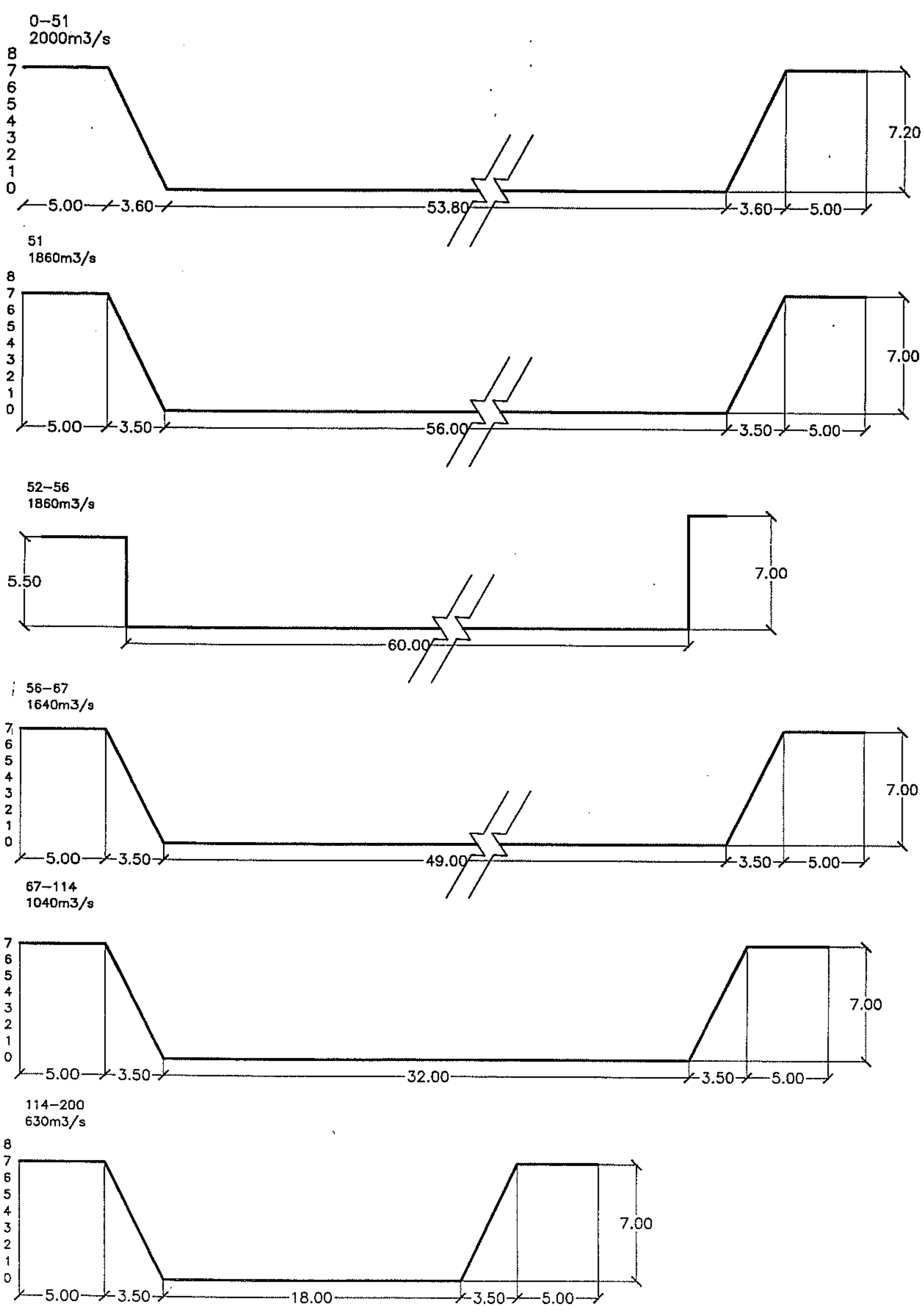


Figure F.4.4	Planned Channel Section

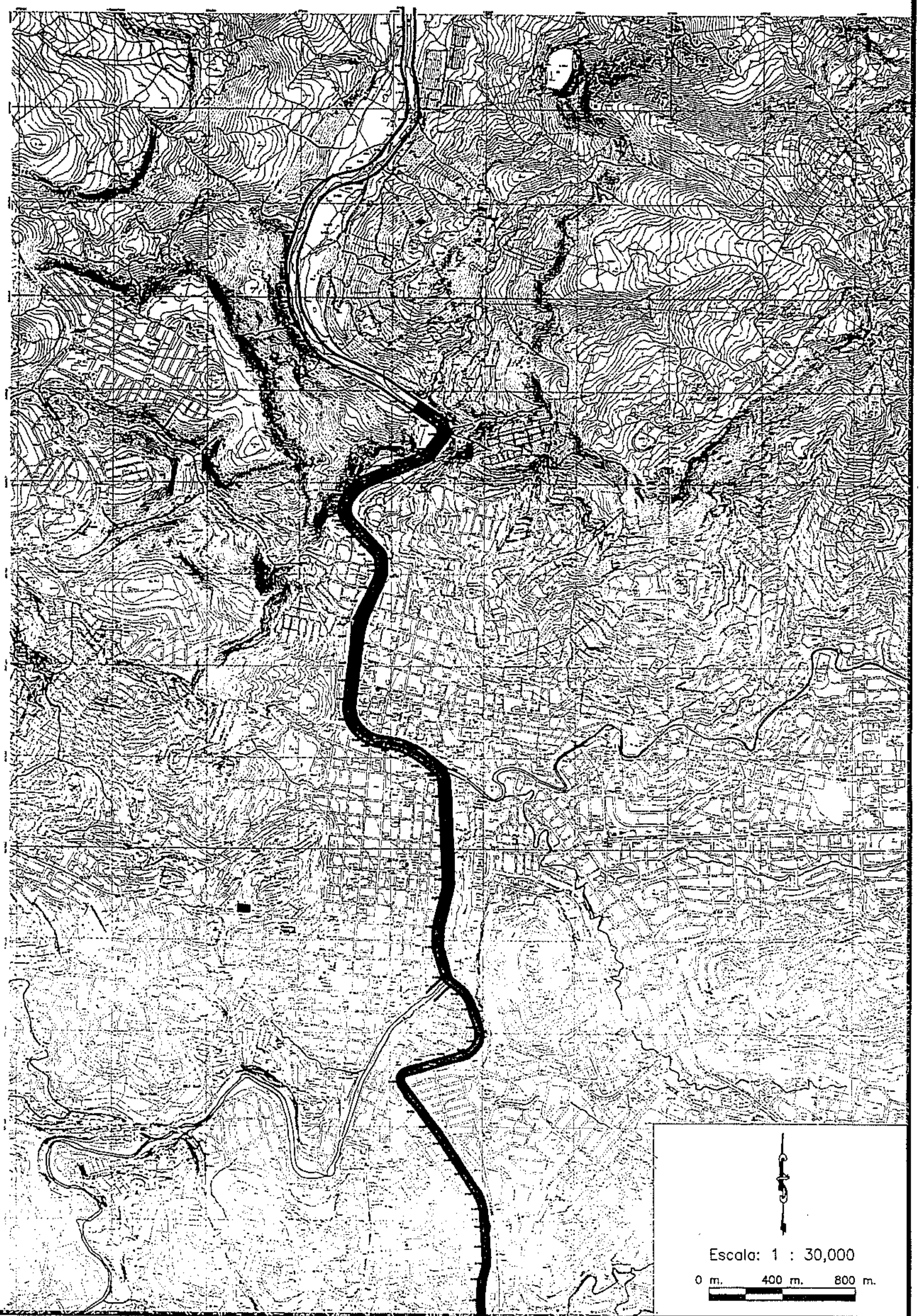


Figure F.4.5	Planned Choluteca River Alignment (1/2)

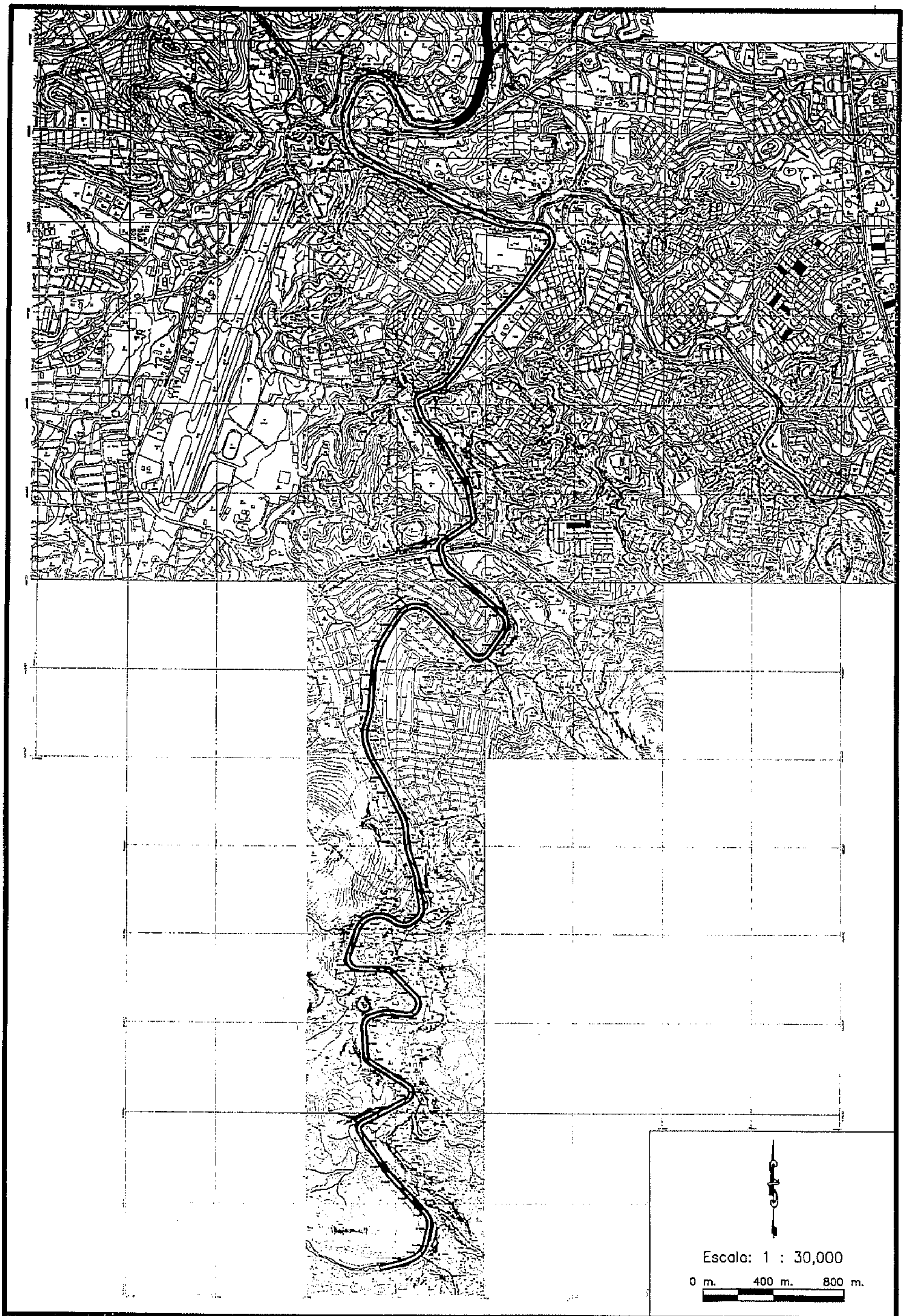


Figure F.4.5	Planned Choluteca River Alignment (2/2)