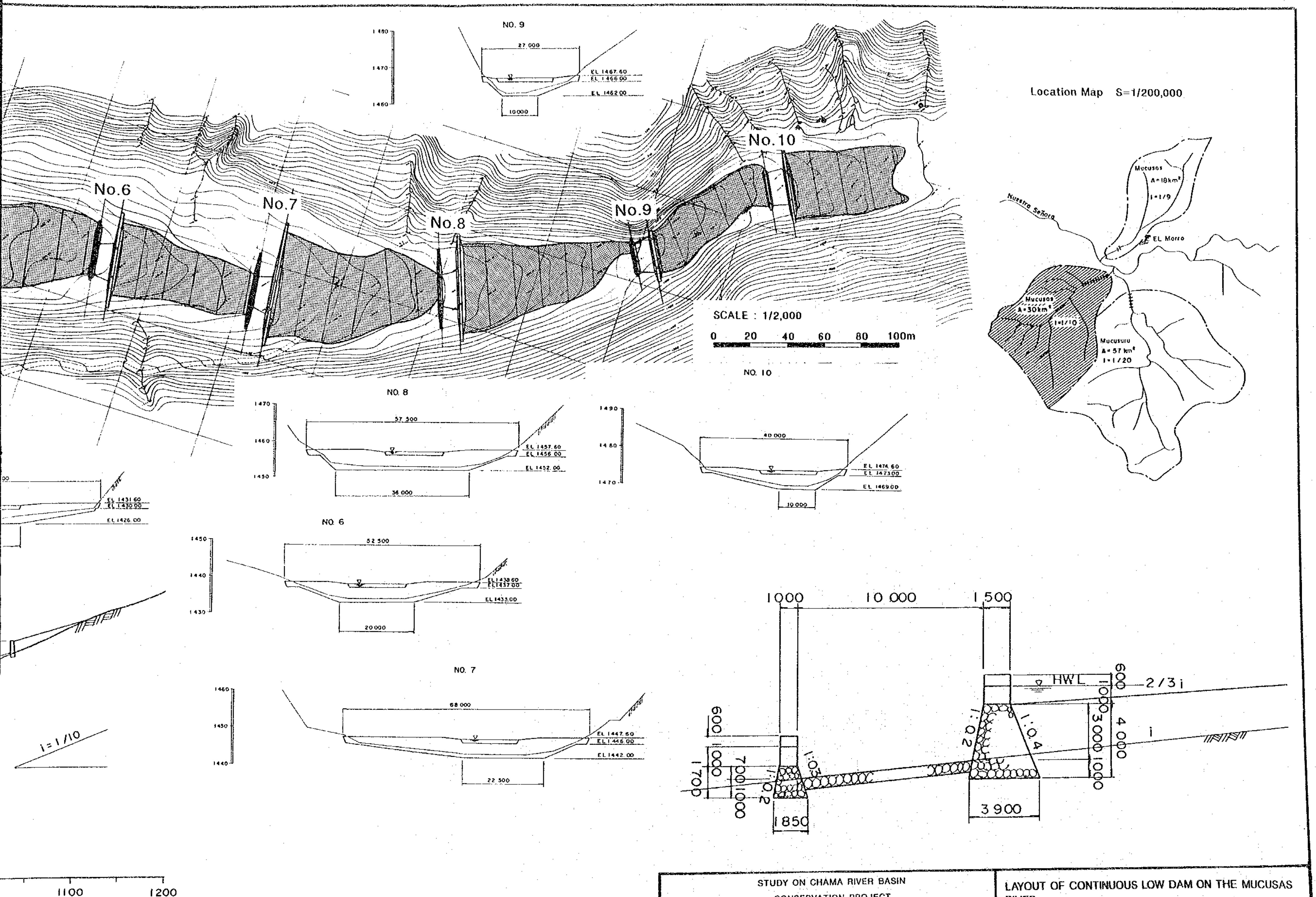
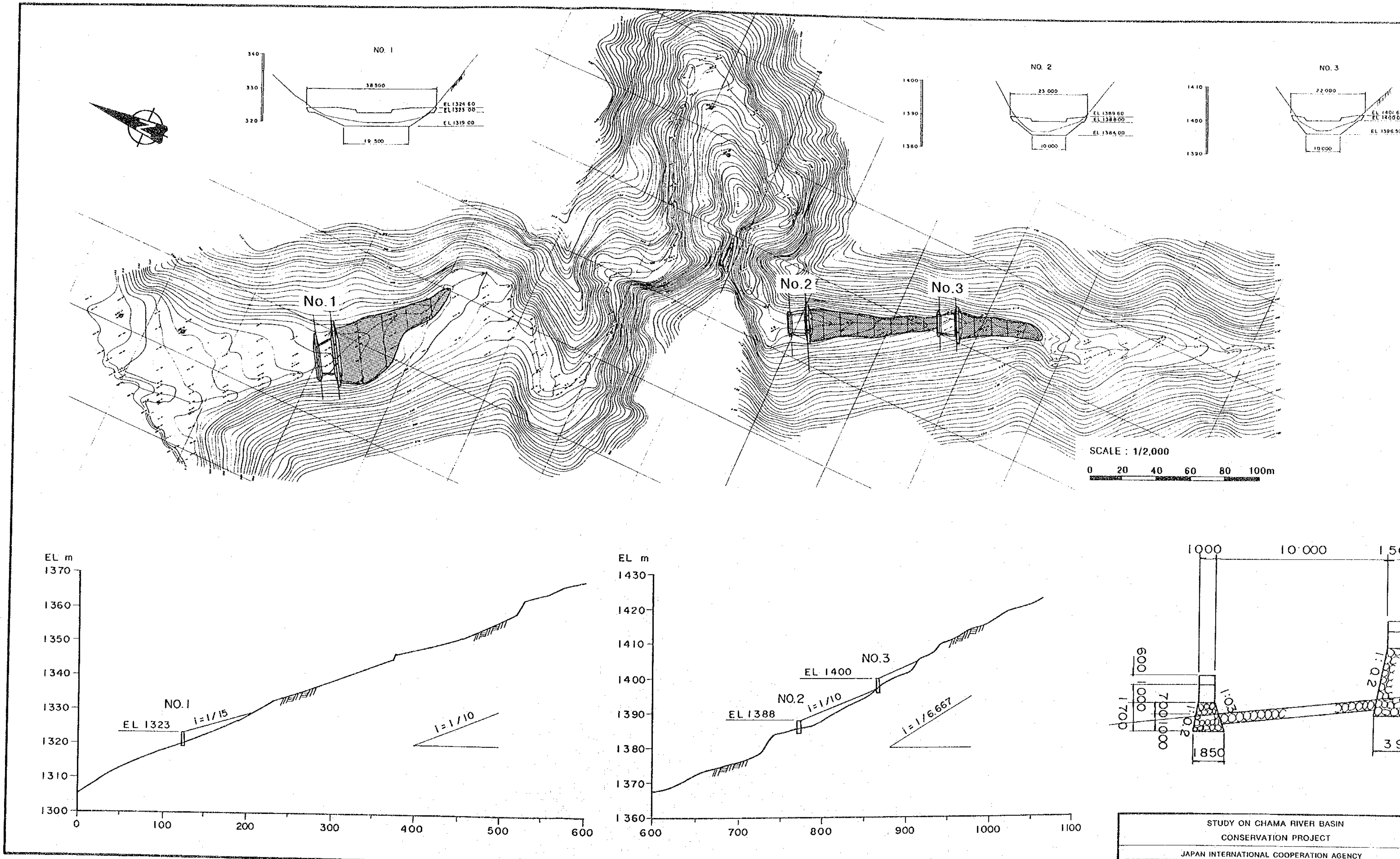


STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

LAYOUT OF CONTINUOUS LOW DAM ON THE MUCUSAS RIVER

Fig. VI-40


NO. 1
NO. 2
NO. 3
No.1
No.2
No.3
SCALE : 1/2,000
0 20 40 60 80 100m
EL m
EL 1323
NO.1
i=1/15
i=1/10
EL 1388
NO.2
i=1/10
EL 1400
NO.3
i=1/6.667
1000
10·000
600
1700
1850
STUDY ON CHAMA RIVER BASIN
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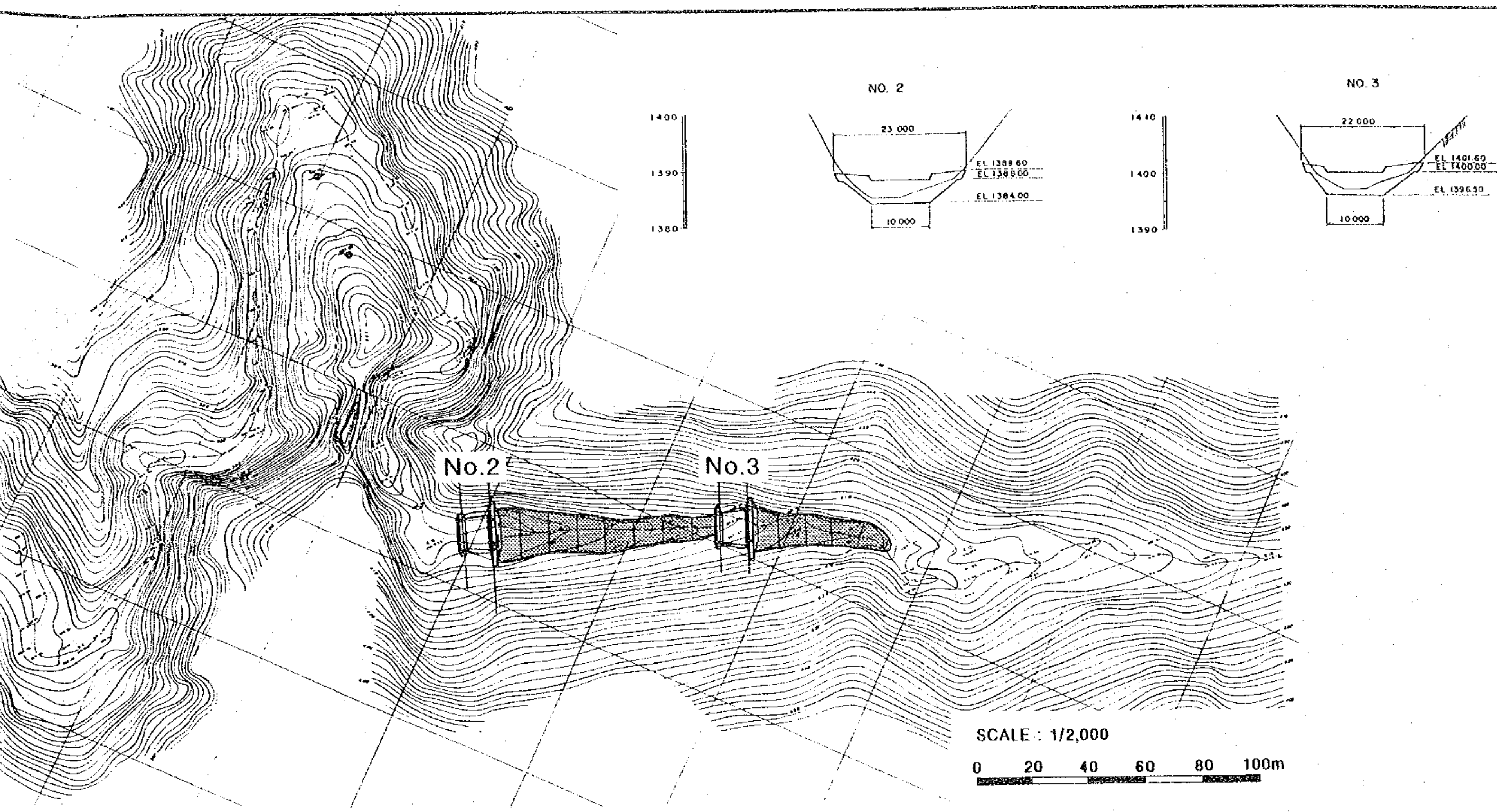
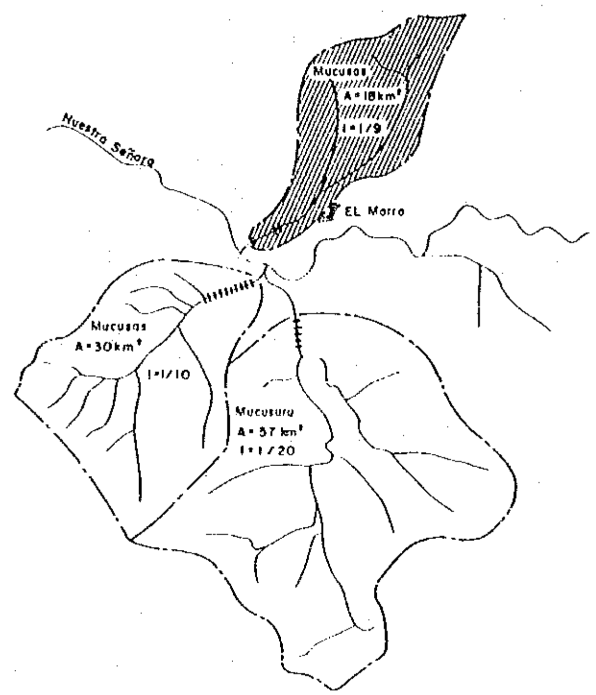
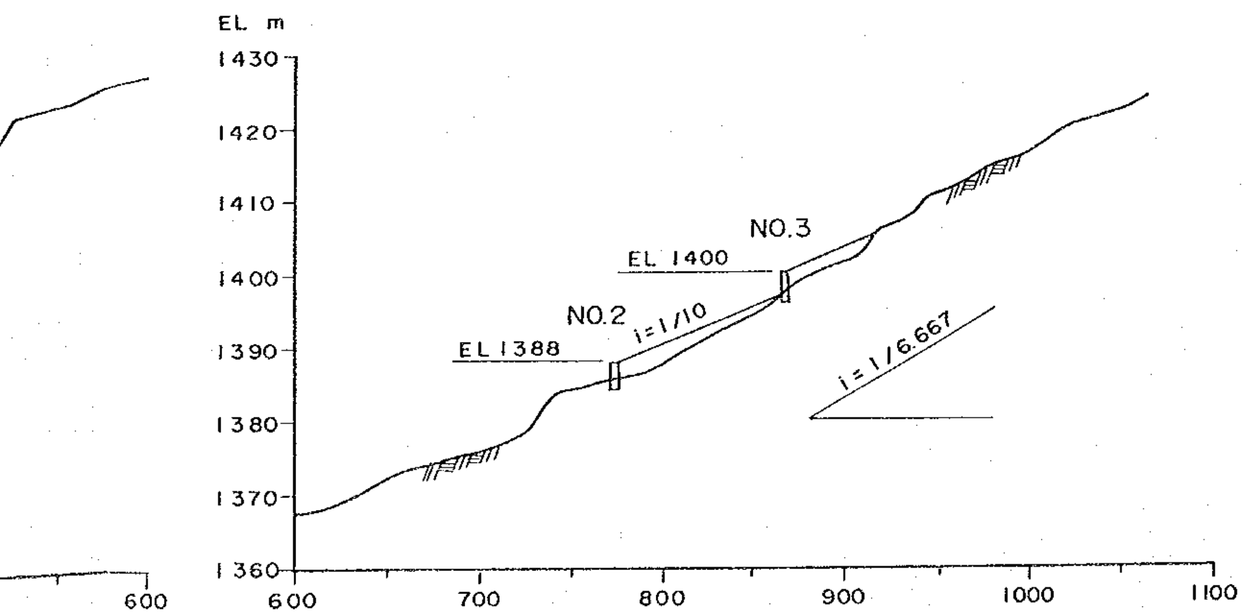
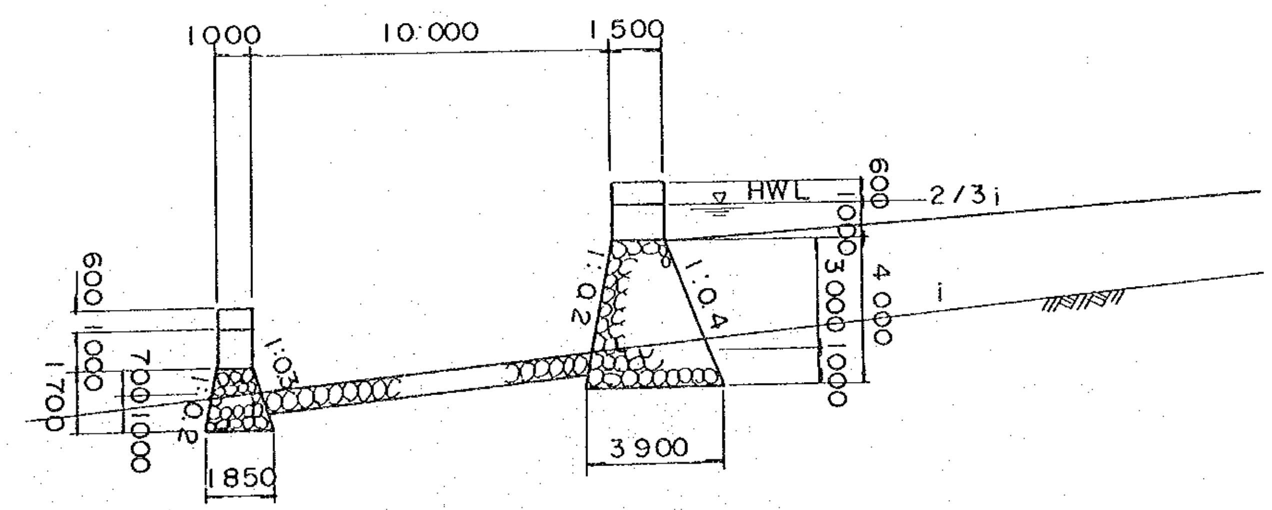


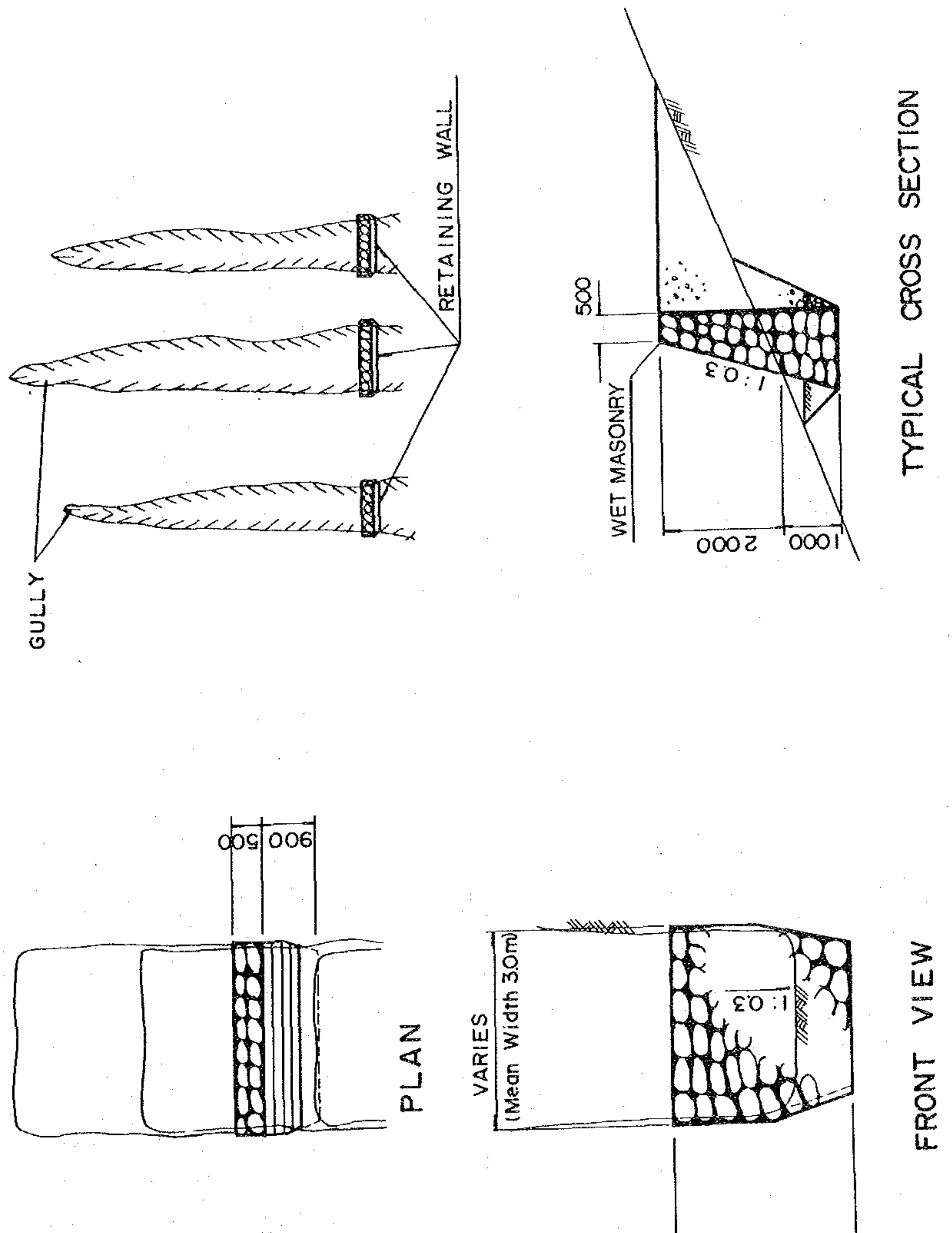
Location Map S=1/200,000



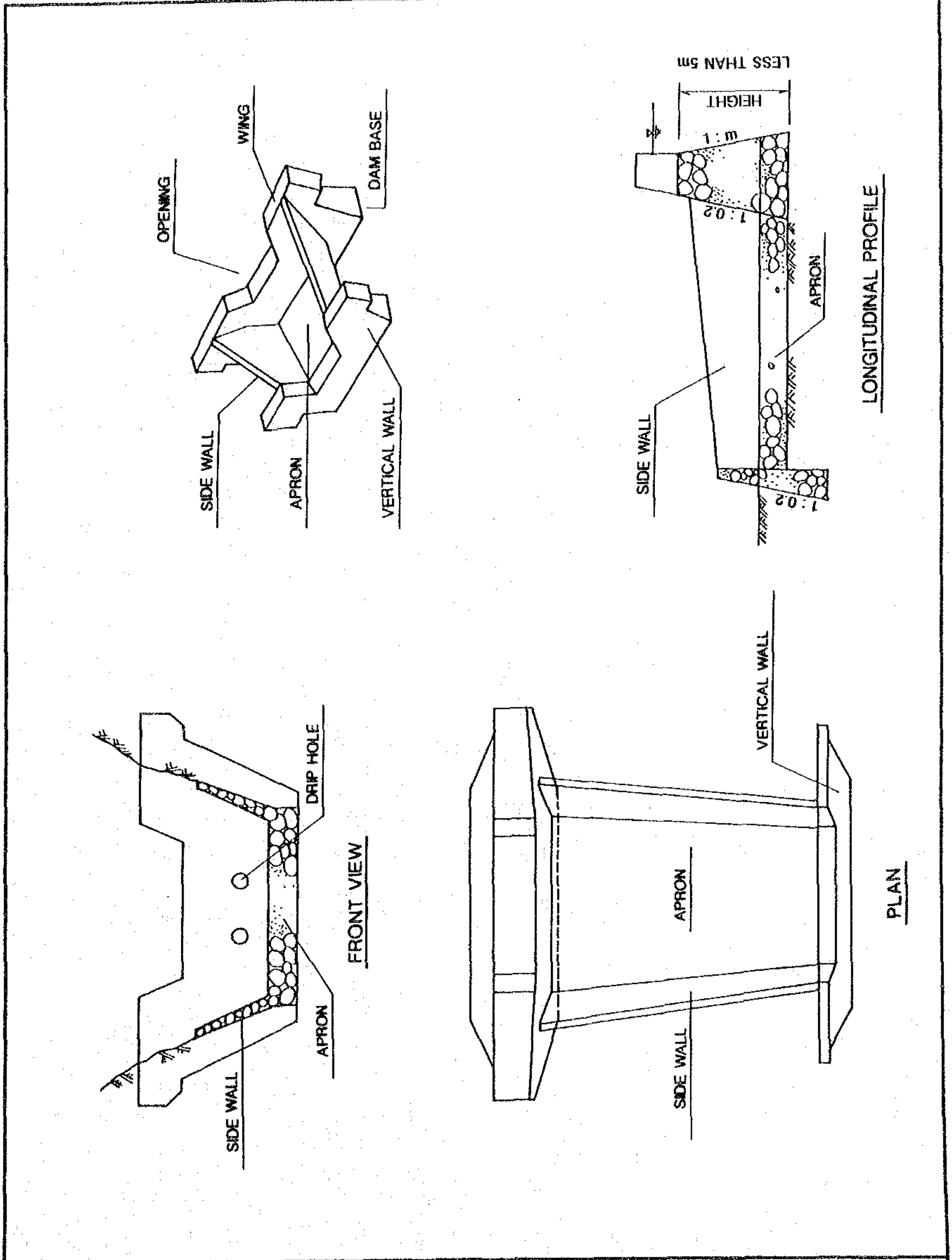




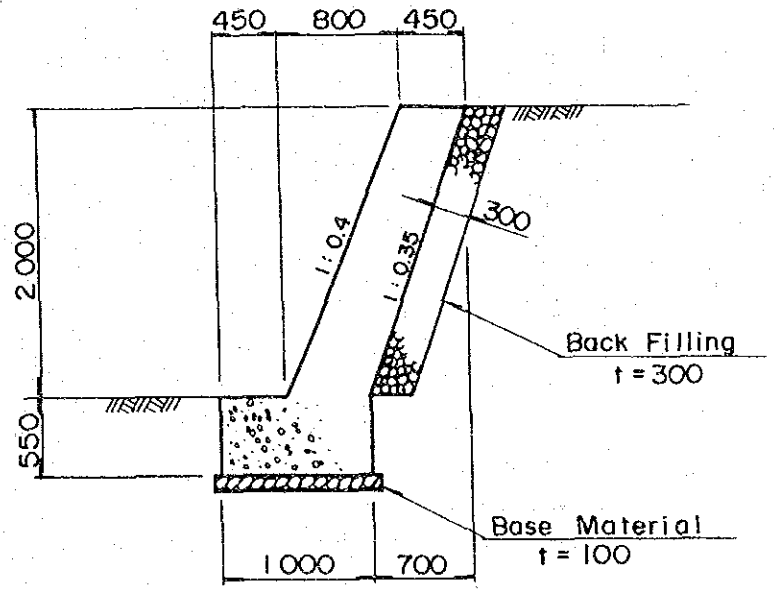
STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT	LAYOUT OF CONTINUOUS LOW DAM ON THE MUCUSOS RIVER
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. VI-41



FEATURES OF RETAINING WALL FOR GULLY PROTECTION Fig. VI-42	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY



TYPICAL STRUCTURE OF CHECK DAM	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT
Fig. VI-43	JAPAN INTERNATIONAL COOPERATION AGENCY



TYPICAL STRUCTURE OF RETAINING WALL FOR ROAD PROTECTION

Fig. VI-44

STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

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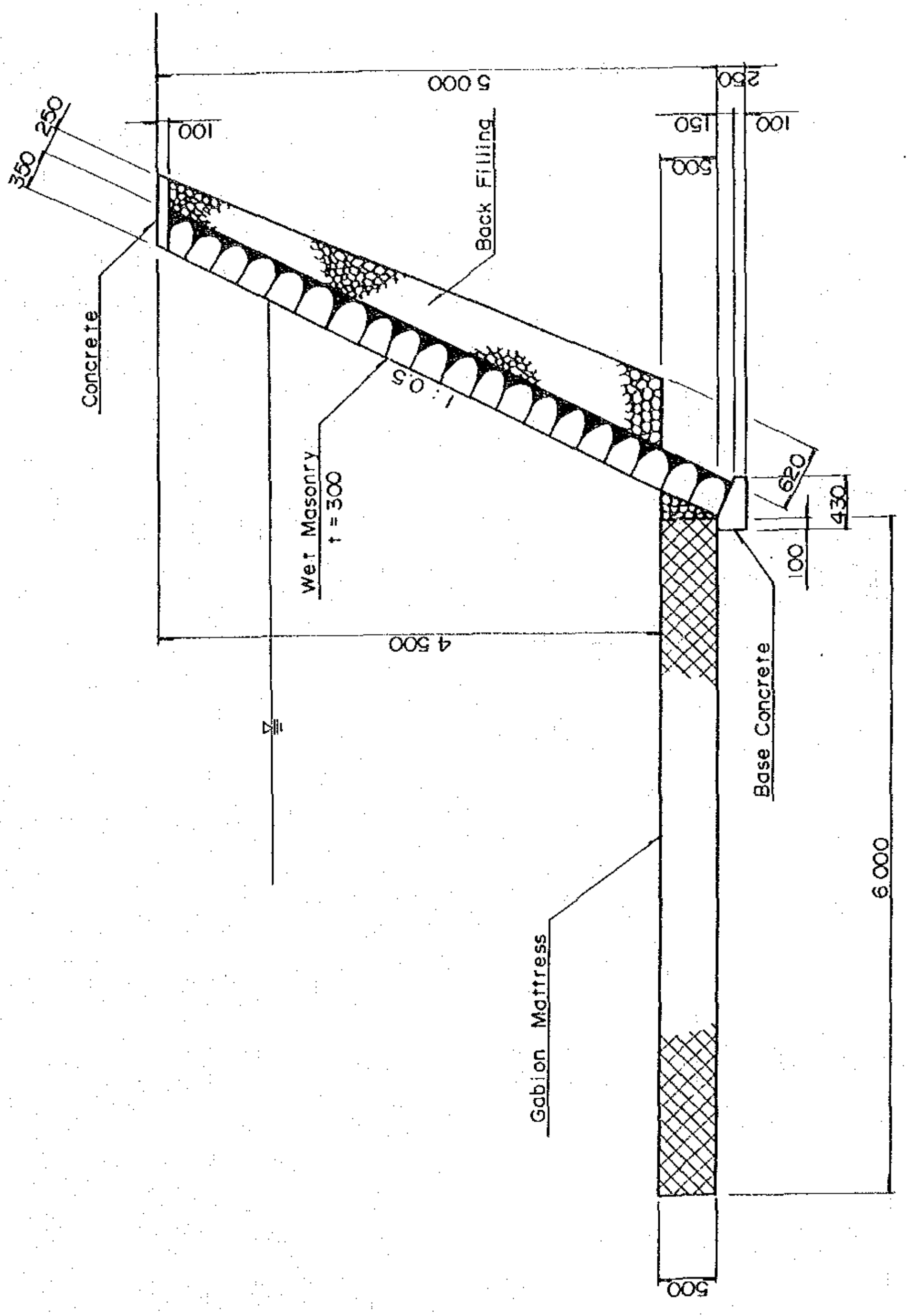
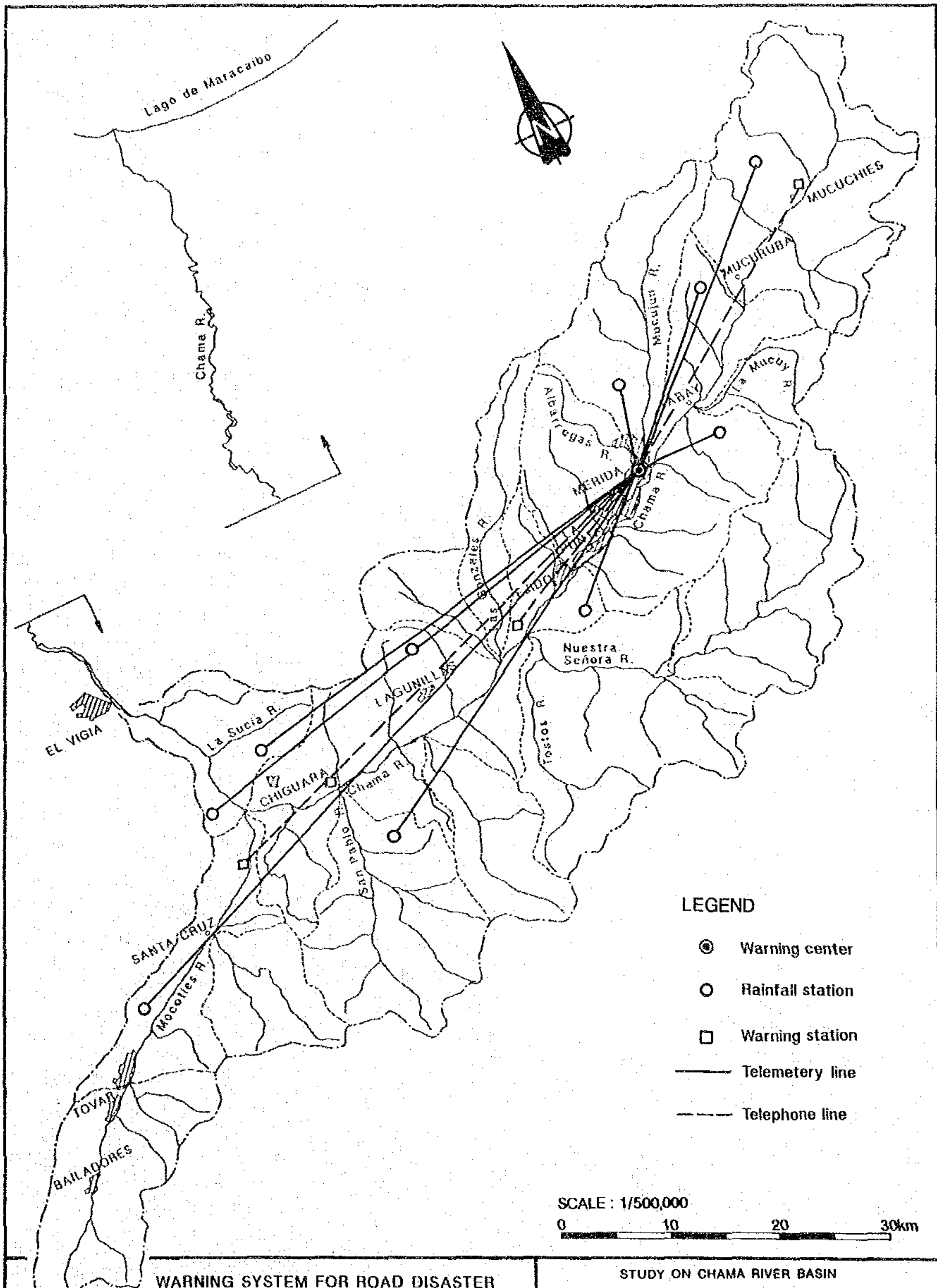


TYPICAL STRUCTURE OF REVETMENT	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT
Fig. VI-45	JAPAN INTERNATIONAL COOPERATION AGENCY



WARNING SYSTEM FOR ROAD DISASTER PREVENTION

Fig. VI-46

STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

VII. FLOOD CONTROL

SUPPORTING REPORT

VII. FLOOD CONTROL

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1. PRESENT CONDITION

1.1 Transition Condition of the River Course

Upper and Middle Reaches

In the upper reaches from Tabay, the Chama river course and its longitudinal profile are stable as confirmed by the outcrops of bedrock on the riverbed. The river channel running down the steep and narrow valley has a sufficient flow capacity, except at points where bridges cross the channel or where the elevation of the road running along the river is relatively low.

In the middle reaches from Tabay to Estánquez, the Chama River is wide at about 200-300 m. The river course and its longitudinal profile are unstable due to the supply of sediment from the tributaries such as the Nuestra Señora and La Vizcaína rivers. Bank erosion can be seen at several points, especially on the right bank. The Mocotíes River is stable with favorable vegetation condition at the basin.

Lower Reaches

The Chama River which flows down with a steep gradient in the upper middle reaches comes to a flat plain in the lower reaches, and a typical alluvial fan area has been developing through the supply of tremendous sediment from the upper reaches. In the lower reaches the following features were deduced from the previous studies, collected data, and interview-survey results.

- The Chama River was once included in the Escalante River system in the 1870s and had sometimes shifted its course developing the alluvial fan area.

- In the past 20 years, the river had steadily maintained its course with minor changes in the shape of meandering.

- Although the shape of meandering had changed, the features of the meandering such as amplitude and length remain within a certain range of the previous ones and the maximum amplitude is within 600 m.

- The change of meandering can be seen at more than 15 points among about 50 points in 4 years from 1973 to 1977 corresponding to 4 points of the change per year on an average. (Refer to Fig. VII-1.)

- Aggradation of the riverbed still continues, which is proven by the fact that the excavated channel in 1985 returned to its previous condition full of sediment before long. The riverbed at the Puerto Chama Bridge has also aggradated, as shown in Fig. VII-2.

As for the development of the alluvial fan, the contour line map based on the topographic map in 1968 is shown in Fig. VII-3. Fig. VII-4 shows the longitudinal profile along the course connecting El Vigía to the river mouth of the Chama River, the river mouth of the Mucujepe River and Sta. Barbara. From these figures, it is deduced that the alluvial fan has been developing downwards from El Vigía, drawing a concentric circle by the counter line.

1.2 River Use Condition

In the Chama River Basin, river water is mainly used for irrigation of agricultural land, domestic water supply and also, the trout culture industry.

The irrigation system in the upper and middle reaches can be seen in the hilly land for the cultivation of carrot, maize, casava and so on. (Refer to Table VII-1.)

The domestic water supply system which has been developed mainly in Mérida and Ejido cities in the middle reaches using the river water from tributaries such as Mucujún and Albarregas rivers is shown in Fig. VII-5.

Besides, small scale intake facilities with distribution system for irrigation and domestic water supply are seen in the middle reaches occupied by the Mocotíes River Basin.

As for water utilization in the lower reaches, river water is not used for irrigation and municipal water. Domestic water is taken from deepwells or the other river system such as the Mucujepe River.

Trout culture is maintained in the tributaries in the middle reaches such as El Robo River, the Mucunután River and the Mocono River, and production amounted to 110 tons in 1988. (Refer to Table VII-2).

Riverbed materials have been taken for construction purposes from several places in the Chama River Basin, especially in the middle reaches of La Mucuy River. The volume of riverbed materials taken from the lower reaches near El Vigía amounted to 97,500 m^3 in 1985, 100,000 m^3 in 1987 and 200,000 m^3 in 1988.

1.3 Related Projects

Among the completed and ongoing projects in and around the Chama River Basin, the following are specifically related to the project under study.

(1) Project at the South of Maracaibo Lake

In 1963, the MARNR, then MOP, started implementing an agricultural development project which includes flood control, road improvement and drainage system improvement for the area of 630,000 ha located at the south of the Maracaibo Lake. The project consists of river improvement of 486 km, construction of the Onia Dam, drainage system improvement of 323 km and road construction of 247.4 km.

As a part of the flood control component, the MARNR has been promoting the river improvement of main rivers in the area such as the Zulia River, Catatumbo River, Escalante River and Chama River on the project scale ranging from 50 to 100-year return period.

Out of the projected 486 km, the river improvement stretch completed as of 1988 amounts to 327 km. The total construction cost for this basin development project was estimated at 1,100 million bolívares as of 1979 which was almost equivalent to the then total annual budget of the MARNR.

As for the Chama River, the river improvement works were suspended due to the problem on sedimentation from the middle and upper reachs. Fig. VII-6 shows the outline of the proposed river improvement stretch.

(2) Diversion Channel Project from Chama River to Mucujepe River

As a part of the flood control plan of the aforementioned project, the river improvement project along the Chama River course was firstly formulated to mitigate the flood damage in the lower reaches. Then, the diversion channel project connecting the Chama River has taken over in 1972 because of the technical and economical advantages over the improvement project.

In this diversion channel project, it was proposed that all the flood discharge flowing down the Chama River be diverted to the Mucujepe River at 12 km downstream of El Vigía. The plan of the proposed diversion channel is shown in Fig. VII-7 and the history of study on the diversion project is summarized in Table VII-3.

The design discharge of 1,500 m^3/s with a 100-year return period was adopted for the diversion channel stretch of approximately 40 km, and the total construction cost was estimated at 215 million bolivares as of 1980. Although channel excavation works on the Mucujepe River was executed for 10 km from the river mouth, the project was suspended due to the problems on sedimentation.

(3) Milla River Improvement Project

The Milla River flowing through Mérida City is causing the inundation problem on roads and houses along the river course. To find a solution to this problem, Zone Office No. 16 of the MARNR had conducted the study on river improvement in 1985, and construction has commenced on the project with a design discharge of 50-year return period.

(4) Dikes Along Chama River

Small scale dikes have been provided by MARNR and inhabitants along some sections of the Chama River to prevent flood inundation.

2. STUDY ON FLOOD INUNDATION

The purpose of flood inundation analysis in the lower reaches from El Vigía is to know the inundation conditions such as duration, area, depth, etc., which will be utilized as the basic data to formulate the flood control plan and to estimate the benefit derived from the execution of the river basin conservation project.

2.1 Features of Flood Inundation

This section presents the study on the possible inundation area using the past inundation records and topographic maps. The inundation area of floods in 1972, 1982 and 1988 are shown in Fig. V-1 to V-3 of the supporting report on Sediment and Flood Disaster.

Inundation in 1972, 1982 and 1988

To understand the inundation condition in 1972, 1982 and 1988, the lower reaches was divided into five stretches, i.e., (1) stretch of 12 km downstream from El Vigía with embankment on the left bank; (2) stretch of 16 km in the further lower reaches; (3) stretch between 45 km and 32 km from the river mouth; (4) stretch of 16 km downstream from Puerto Chama Bridge; and (5) stretch of 16 km of the upper reaches from the river mouth.

According to the past inundation record, the area of inundation is large in stretches (1), (2), (4) and (5), while inundation in stretch (3) was reported to be not so large. Inundation water flowing down along the river course in stretch (1) and stretch (2) is presumed to return to the river course on its way to stretch (3).

Topographic Features of Inundation Area

Generally, the inundation areas are in the alluvial fan that had developed downwards from El Vigía (refer to Fig. VII-3). Since the behavior of inundation water is influenced by the minor undulations in the area, a study on the minor undulations is essential.

Cross sections of the alluvial fan area where inundation water is assumed to flow down were obtained from the topographic map with the scale of 1/25,000 (refer to Fig. VII-8). These cross sections indicate that natural levees with channel widths ranging from 200 to 1,500 m have been formed along the Chama river course and undulations with widths ranging from 4,000 to 5,500 m are noted. In case of a small-scale flood, inundation water will be confined within the natural levees which may have the flow capacity of about 500 m^3/s. The excess water in case of a big flood will flow down the undulations which may have the flow capacity of about 2,000 m^3/s. In the lower reaches, 15 km from the river mouth, natural levees are not found and floodwaters tend to spread over a wide area. The probable inundation areas are indicated in Fig. VII-9.

2.2 Flow Capacity of River Channel

Calculation Condition

Before the formulation of the flood inundation model, the flow capacity of the Chama river channel in the lower reaches from El Vigía was examined under the following conditions, using the results of the survey made during this period of the Study.

- Non-uniform calculation method is applied;
- Manning's roughness coefficient of 0.035 is adopted, judging from the river conditions; and
- Three cases of discharge, 50, 100 and 150 m^3/s, are firstly examined for the whole stretch and the other three cases of 1,000, 2,000 and 3,000 m^3/s are applied for the stretch of 12 km with embankment, because this portion has a bigger flow capacity compared with the other stretch without embankment.

Non-Uniform Calculation Method

(1) Basic Equation

The following equation is used for the flood flow analysis:

$$[H_2 + \frac{1}{2g} (\frac{Q_2}{A_2})^2] - [H1 + \frac{1}{2g} (\frac{Q_1}{A_1})^2] = h_e \qquad \ldots (1)$$

$$he = \frac{1}{2} [\frac{N_1^2 Q_1^2}{A_1^2 R_1^{4/3}} + \frac{N_2^2 Q_2^2}{A_2^2 R_2^{4/3}}] \Delta X \qquad \ldots (2)$$

where, subscripts 1 and 2 indicate the dimensions of the upstream and downstream sections, respectively.

H = water level

g = gravity acceleration

Q = discharge

A = cross sectional area

R = hydraulic radius

ΔX = distance between two adjacent cross sections

n = roughness coefficient

(2) Calculation Procedure

(a) Determination of Cross Section Characteristics

Tables of water level H and the corresponding values A and R are prepared by using the cross sections.

(b) Determination of Water Level at Downstream End

Water level at the downstream end is determined taking into consideration the discharge to be used and the conditions at the downstream end such as tide level and main river stage.

(c) Non-Uniform Flow Calculation

Based on the foregoing conditions and by Eqs. (1) and (2), the successive calculation of non-uniform flow is started from the downstream cross section and successively up to the upstream ones to calculate the inundation water level and areas.

Calculation Results

The calculation results are shown in Figs. VII-10 and VII-11. It is presumed from these figures that the bankful flow capacity of the Chama River which is obtainable in comparison between bank height and calculation water stage is about 100 m^3/s in the stretch without embankment and about 1,000 m^3/s in the stretch with embankment.

The flow capacity in the stretch with embankment, however, reduces to about 300 m^3/s when the embankment is broken, as noted from the fact that the flood in 1988 with the discharge of about 700 m^3/s had inundation in this stretch when the dike was broken.

2.3 Flood Inundation Analysis

The procedure of flood inundation analysis is as follows:

- Selection of methodology for flood inundation analysis;
- Formulation of flood inundation simulation model;
- Determination of the constant parameter of the model; and
- Calculation of the flood inundation discharge and water level.

Selection of Method for Flood Inundation Analysis

The inundation area in the lower reaches is on the relatively steep slope with the gradient of more than 1/1,000. Inundation water flows down the slope along the river course up to the Maracaibo Lake.

Among the flood inundation types which are broadly classified into the storage type and the diffusion type, inundation condition in this area may belong to the storage type judging from the aforementioned topographic condition in the inundation area.

In consideration of the flood inundation type and the topography of the flood prone area, the storage function model was selected over the other inundation model such as Muskingum Model, the Simplified Unsteady Flow Model, the Two-Dimensional Unsteady Flow, etc., for consistency with the method of runoff analysis.

Formulation of Flood Inundation Simulation Model

On the basis of the recorded inundation area in 1972, 1982 and 1988, as well as the topographic map, the probable inundation area which can be subdivided into five stretches was presumed (refer to Fig. VII-9). To reflect these flood inundation conditions, the simulation model was featured with the subdivided stretches of the lower reaches as shown in Fig. VII-12.

Determination of the Constant Parameter of the Model

In the storage function model, the following exponential equation was used to express the relation between flood discharge (Q) and storage volume (S) of the inundation area including the river channel.

$$S = KQ^{p}$$

where,

S : storage volume (m^3/s)
Q : discharge (m^3/s)
K, p: constant parameters

The relation between Q and S largely changes when flood discharge is over the flow capacity of the river channel, because of the storage volume for flood discharge below the flow capacity is counted only for that of the river channel, while the storage volume above the flow capacity includes that of the inundation area and that of the river channel.

Thus, the relation between Q and S is generally assumed with a two-step exponential function, as shown in Fig. VII-12. The constant parameters "k" and "p" of the storage function model were determined on the basis of the hydrological relation between flood discharge and its corresponding storage volume of the river channel and the inundation area. (Refer to Table VII-4.)

Calculation of Flood Inundation Discharge and Water Level

Calculation of flood inundation discharge was made on the basis of the following conditions. The calculation results are shown in Table VII-5(1/2).

- Six study cases with the probability of 2, 5, 10, 30, 50 and 100-year return period were employed.

- One week was applied as the calculation duration to evaluate the flood damage on agricultural products, since the magnitude of the damage depends on not only inundation water depth but also inundation duration.

- Calculated flood discharge was converted into water level by rating curve based on the non-uniform calculation.

Since partial improvement is proposed in the action plan mentioned in Chapter 5, it is necessary to know the influence of partial river improvement to the inundation condition.

In this connection, the calculation was made assuming that the inundation area in the stretch where the partial embankment is provided vanishes after completion of the action plan.

The constants K, p of the storage function is obtained in the same manner as aforementioned.

The calculation results are shown in Table VII-5 (2/2). As a result, the peak flood discharge is about 10% bigger compared with that under the present condition.

3. PRINCIPLES OF FORMULATION FOR FLOOD CONTROL PROJECT

3.1 Target Asssets to be Protected in Flood Control Project

Through the study on damage condition in the Chama River Basin, the following assets were identified as those to be protected in this project: (1) arterial roads of route 2 and route 7, (2) urban areas of Mérida and Ejido, and (3) agricultural area including residential area in the lower reaches of the Chama River Basin. Among these assets, the latter two are to be protected in this flood control project.

3.2 Manner of Flood Control Project Formulation

The flood control project in this river basin conservation project was formulated in the manner of a master plan and an action plan in accordance with the scope of work, with the target year at 2020 and 2000, respectively. According to the target assets as aforementioned, the planning area for the flood control project are as follows.

(1) Urban Areas of Mérida and Ejido

The urban areas in the cities of Mérida and Ejido belong to the small river basin of Albarregas including its tributary, the Milla River, and Portuguesa. Therefore, the planning area is limited to the small area of the basin.

(2) Agricultural and Residential Areas in Lower Reaches

Flood disasters are caused by the flood discharge coming from the whole basin and, therefore, the planning area shall cover the whole Chama River Basin.

Since there is much difference in the scale of planning area between (1) and (2), it is desirable to formulate the flood control project individually for each planning area. Consequently, the flood control project is divided into two sub-projects as follows. The master and action plans for the sub-projects will be formulated individually, however, the project evaluation for both sub-projects was made as a whole for both plans.

Sub-Project	Target Asset	Planning Area
1. Basin-wide Project	Agriculture and Houses	Whole River Basin
2. Local Project	Urban area of Mérida and Ejido cities	Albarregas and Portuguesu River Basins

3.3 Concept of Project Formulation

3.3.1 Basin-wide Project

Objective

The basin-wide project is formulated to mitigate flood inundation damage in the lower reaches attributed to sediment deposition in the riverbed resulting in the reduction of river flow capacity and the flood discharge in the lower reaches. The project then aims to control the flood discharge in the lower reaches during flood time. Sediment control is described in the sediment control sector of this supporting report.

Project Scale

The master plan of the project is formulated by considering the technical, social, economical and financial aspects. It is, however, desirable that this kind of infrastructure project be formulated with more emphasis on the social aspect and the technical aspect. The project scale for flood control is then decided in accordance with the social requirements of the basin.

Although the appropriate project scale to fulfill the social requirements is hardly identified, the project scales employed on similar projects could serve as one of the reference materials. In this study, the project scale based on the similar projects will be examined first to confirm the adequacy of the project.

The project scale of the action plan for the urgent project will be decided within the framework of the Master Plan, considering the technical, economical and financial aspects.

Alternative Study Cases

Countermeasures for flood disasters can be classified into two groups; namely, structural and non-structural measures. The major structural measures were primarily selected in consideration of the basin characteristics such as topographic and geological conditions, meteorological and hydrological conditions and so on.

Alternative cases of structural measures for the Master Plan, applied either individually or in combination with each other, will be studied to identify the most effective measure for the protection of target assets. Alternative cases for the Action Plan will be studied in the context of the Master Plan.

As for the non-structural measures that can be introduced to supplement the structural ones with less fund, optimum measures were examined in conjunction with the formulation of the action plan for the urgent project.

Selection of Optimum Plan

Among the alternative study cases the optimum combination of structural measures will be selected from the technical and economical aspects. The adequacy of the aforementioned project scale will be confirmed in consideration of economic viability and financial aforability.

3.3.2 Local Project

Objective

The local disaster prevention project aims at the protection of the urban areas of Mérida and Ejido cities from flood inundation.

Project Scale

As in the formulation of the basin-wide project, the project scale of the local project was decided on the basis of the social requirements.

Applicable Method

The structural measures for the local project will be proposed in consideration of those commonly used in Venezuela and in other countries, as well as from the topographic, geologic and hydrologic conditions, and other aspects.

Optimum Method

The optimum method of protection is to be selected through a conceptual study on the applicable methods, because a detailed comparative study on alternative structural measures can hardly be carried out due to the limited information for these areas.

4. FORMULATION OF FLOOD CONTROL PROJECT FOR MASTER PLAN

4.1 Basin-Wide Project

4.1.1 Project Scale

The scale for this flood control project was decided in consideration of those employed on similar projects as mentioned before. Examples of these projects are the Zulia River Improvement, the Catatumbo River Improvement and the Escalante Diversion Channel which are all located south of the Maracaibo Lake and which were executed with the probability of between 50 and 100-year return period.

Since land use and living conditions in the lower reaches of the Chama River Basin are quite similar to those in the project area of the aforementioned projects, the social requirements in the Chama River Basin are supposed to be at the same level as these project areas. Therefore, the probable discharge of 100-year return period was primarily examined in relation to the adequacy of the Chama River Basin Conservation Project. Other cases of probable discharge were studied for reference.

4.1.2 Applicable Method

For a basin-wide project, several methods are proposed as applicable ones; namely, (1) river channel improvement, (2) diversion channel, (3) retarding basin, and (4) dam and reservoir. Among these applicable methods, the following views are pointed out:

- Retarding basin is generally proposed in the area where wide flat land with gentle slope gradient are situated, so that the large storage volume to regulate the flood discharge can be easily ensured through the provision of a small scale dike. In view of the topographic condition in the Chama River Basin, the retarding basin is not applicable.

- Dam and reservoir does not have any economical advantage over the other alternatives such as river channel improvement and diversion channel, which has been clarified in the previous study. Furthermore, at the suitable dam site proposed in the previous study, the Pan-American Highway Project is going on and it is not realistic to apply the same site in this study for dam construction which may require the relocation of the Pan-American Highway. The other damsite will have less economical and technical advantage over the previous one.

- In the comparative study between a diversion channel and river channel improvement, the diversion channel was identified to have an economical advantage over the river channel improvement, although there is not much difference in the costs. However, the economical advantage may be reduced due to the recent land development.

In view of the above, the diversion channel and the channel improvement of Chama River will be studied to determine the optimum method of flood control.

4.1.3 Alternative Study Cases

Possible Study Cases

River improvement and diversion channel plans were determined as the applicable methods for flood control. To select the optimum method, the following items were studied: (a) design of alignment, (b) design of longitudinal profile, and (c) design of cross section.

(1) Case of Chama River Improvement

The present channel of the Chama River has the following features:

- As mentioned before, the river course has not drastically changed in the past 20 years except for a minor change in meandering points.

- The flow capacity of around 100 m^3/s is very poor compared with the expected design discharge of 2,300 m^3/s of 100-year return period, and it is presumed that the flood discharge flows down along the center line of the meandering course of the river channel (refer to Fig. VII-13).

- The riverbed gradient is still steep even in the lowland as shown in Fig. VII-14; the flow velocity of the design discharge is very swift.

Under the above features, the river channel will be designed on the following principles:

- New alignment will be designed along the center line of meandering of the present river course, since the river course has been stable for the past 20-years. As a result, the river length from the river mouth to El Vigía measures up to 53 km, though the river length measured along the present river course is 73 km because of the meandering.

- Longitudinal profile is designed on the basis of the new alignment.

- For selection of the appropriate cross section based on economical and tehcnical aspects, the following cases were examined:

Case 1: For easier maintenance, single cross section with sufficient river width is proposed, so that the channel meandering can be developed without erosion on embankment.

Case 2: To save on land aquisition cost, single cross section with a narrower river width than Case 1 is proposed, so that groins and revetment may have to be provided to the embankment portion that is subject to water collision.

Case 3: To assure the stability of the river channel and safety of the embankment, a complex cross section with a much narrowed river width is proposed, which can also save on land acquisition cost.

(2) Case of Diversion Channel

The diversion channel is designed under the same principles as river channel improvement in consideration of the previous study results on diversion channel, as follows:

- Design alignment is adopted from the previous study results.
- Longitudinal profile is designed by taking into account the ground height along the design alignment.
- For the selection of the appropriate cross section, the same alternative cases are examined.

In accordance with the above principles, the following study cases were examined:

Alternative Plan	Alignment	Longitudinal Profile	Cross-Section	Total
Chama River Channel Improvement	1 case	1 case	3 cases	3 cases
Diversion Channel	1 case	1 case	3 cases	3 cases

In these study cases, the optimum cross section of the diversion channel well coincides with the Chama River channel improvement because of the similarity of channel characteristics such as river gradient, meandering, soil condition, land use condition, etc. For convenience, the optimum cross section of the Chama river improvement was firstly selected and a comparative study between river improvement and diversion channel were examined using the optimum cross section among the three cases.

Outline of the Design Features of Study Cases

The design features for the study cases on Chama river improvement are in Table VII-6. In this table, river width and the necessary structures are designed under the following considerations.

(1) Case 1

Since the amplitude of meandering of the present river channel is within about 600 m as shown in Fig. VII-15, the river width of 1,400 m including some allowance for meandering is adopted (refer to Fig. VII-16). Groins are provided in the stretch where water velocity is over 2 m/s to protect the dike from erosion. Groundsill is provided at the section of the Chama Bridge to prevent degradation of the riverbed.

(2) Case 2

Floodmarks in an aerial photograph of the El Vigía area show that the width of the Chama River had extended to about 600 m, and a natural levee had been formed. Therefore, 600 m is adopted as the design width because it is possible to confine the flood discharge within this river width by means of embankment, and the velocity of flood discharge can be kept at around 2 m/s (refer to Fig. VII-17). Revetment is provided to prevent erosion of levee at the water colliding front of the meandering section of the river course. Groins and a groundsill are provided in the same manner as Case 1.

(3) Case 3

In this complex cross section, the low water channel is designed with a flow capacity corresponding to a discharge of 2 to 3-year return period. The high water channel is designed not to exceed the velocity of 2 m/s and thus a river width of 150 to 290 m is applied to the design. Revetment is provided to the low water channel to assure its stability. Groins and a groundsill are provided in the same manner as Case 1. (Refer to Fig. VII-18).

4.1.4 Selection of Optimum Method

Selection of Optimum Cross Section of Chama River Improvement

For the selection of optimum cross section, the construction cost of each case was roughly estimated as shown in Table VII-7. Judging from the table, the following features are pointed out:

- Among the three study cases, Case 3 with a complex cross section is too costly compared with the other cases due to a large excavation volume.

- There is not much cost difference between Case 1 and Case 2; however, a wide tract of cultivated land of approx. 3,000 ha which is equivalent to 60% of the annual average inundation area of about 5,000 ha will be lost for the river area in Case 1. Therefore, Case 1 is not desirable since the purpose of this project is to mitigate the flood damage on the flood prone area to secure agricultural production.

Case 2 is then selected as the optimum cross setion of the Chama river improvement.

Selection of Optimum Flood Control Plan

In accordance with the results of the optimum cross section of the Chama river improvement, the diversion channel plan is designed in the same manner as the Chama river improvement (refer to Fig. VII-19).

Table VII-8 shows the cost comparison between Chama river improvement and the diversion channel. Judging from this table, the following features are pointed out:

- The diversion channel plan has an advantage in land acquisition cost compared with the river channel improvement plan due to the difference of land use conditions, plantain plantations and pasture. However, the difference is not so large, since the land acquired for diversion channel is larger than that for river channel improvement because the present river area is excluded from the land acquisition in case of river channel improvement, while the whole land in case of diversion channel is acquired.

- As for the low water channel, it is necessary to excavate only a small portion for river channel improvement. On the other hand, a new low water channel has to be excavated in the case of diversion and thus the excavation cost is higher.

As a conclusion, the diversion channel plan has no advantage over the river channel improvement in economical aspects.

Consideration on the Other Aspects

The following differences are pointed out in the other aspects:

- In connection with the stability of the river channel, the Chama River has changed its course only in minor portions, therefore, it may not be difficult to confine the flood discharge within the proposed channel along the present river course. On the other hand, it is difficult to predict how the new diversion channel will meander, therefore, it may require more maintenance work to confine the flood discharge safely.

- At present, the Chama River contributes to the supply of ground water in the alluvial fan area of the lower reaches from El Vigía which is utilized for agricultural production and domestic water. The diversion channel project may adversely affect agricultural production and the living conditions of the people along the Chama River course due to the lowering of ground water level.

- From the environmental aspect, a diversion channel will hamper the smooth communication between the inhabitants on both sides of the channel.

- From the economic efficiency of investment, the Chama river channel improvement has an advantage since project benefit is expected at once in proportion to investment cost, while the diversion project expects the project benefit only after completion of the diversion channel. In case the economic efficiency is evaluated in the manner of ratio of benefit (B) and cost (c), the ratio of the river channel improvement amounts to ten times of that of the diversion channel.

From the above consideration, it is desirable to select the Chama river channel improvement plan as the optimum case.

The proposed alignment, design longitudinal profile and typical cross section of the Chama River channel improvement plan are shown in Figs. VII-20, VII-21 and VII-22. Tables VII-9 to VII-10 show the design features of the cross section and the construction cost for other probable discharges.

Confirmation of Appropriate River Width

Through the comparative study of the three cases of river widths, 1,400 m, 600 m and 290 m, the river width of 600 m was finally selected as the optimum. To confirm the adequacy of 600 m of the river width, the following considerations were made:

- In case a river width of more than 600 m, such as 700 m and 800 m, etc., is adopted, the abundant agricultural area will be lost for the use as river area and the construction cost will slightly increase because of land acquisition and extension of the Puerto Chama Bridge.
- On the other hand, narrowing down the river width to less than 600 m, such as 500 m and 400 m, etc., will bring about increment of the shortcut sections for meandering and necessary sections of groin and revetment, which will cause an increase of construction and maintenance costs.

4.2 Local Project

4.2.1 Applicable Method

According to the interview-survey results, flood inundation damage occurred along the Albarregas River and one of its tributaries, the Milla River, as well as the Portuguesu River. The former inflicts damage on the urban area of Mérida City and the latter brings about damage to Ejido City.

Among several applicable methods such as diversion channel, retarding basin, dam and reservoir, and river channel improvement, river improvement is considered as the applicable one judging from the topographic and flood damage conditions in the area.

4.2.2 Application of River Improvement

(1) River Improvement Section

Judging from the inundation condition in the cities of Mérida and Ejido, the section of rivers to be improved are as follows:

- Albarregas River : Section between 11.9 km and 12.9 km from the confluence with the Chama River.
- Milla River : Section between 0.0 km and 3.04 km from the confluence with Albarregas River.
- Portuguesu River : Section between 2.0 km and 3.4 km from the confluence with the Chama River.

(2) Flow Capacity of the Rivers

The average flow capacities of sections of the Albarregas and Portuguesu rivers which were calculated by uniform calculation method are 150 m3/s and 70 m3/s, respectively.

As for the Milla river, the flow capacity is estimated at the range between 30 and 60 m^3/s according to the previous study results in 1986.

(3) Design Condition for River Improvement

As the project scale, the probable discharge with a 100-year return period for Albarregas and Portuguesu rivers is adopted in accordance with the social requirement, in the same manner as the basin-wide flood control project. On the other hand, the design discharge for the Milla River is based on the previous study results which applied the 50-year return period.

The river channel improvement plan for these sections is proposed with the following features (refer to Figs. VII-23 and VII-24).

(a) Albarregas River

- Design Discharge : 180 m^3/s (100-year return period)
- Improvement Stretch : 1,000 m
- Standard Cross Section: Width of 6 m and depth of 3.5 m
- Manner of Improvement : Embankment

(b) Milla River

- Design Discharge : 60 m^3/s (50-year return period)
- Improvement Stretch : 3,040 m
- Manner of Improvement : Excavation

(c) Portuguesu River

- Design Discharge : 130 m^3/s (100-year return period)
- Improvement Stretch : 1,400 m
- Standard Cross Section: Width of 5 m and depth of 2.5 m
- Manner of Improvement : Widening of river channel and excavation

4.3 Prioritization of Flood Control Project

4.3.1 Basin-wide Project

For the formulation of the construction schedule, the flood control project conducted in the manner of river channel improvement has to be subdivided into several components which can be expressed by subdividing the whole river channel improvement stretch in accordance with the land use condition of the area to be protected. Since the Chama River improvement is basically proposed to protect the plantain area from flood damage, the whole improvement stretch was subdivided according to the following three classifications of land use for the plantain area (refer to Fig. VII-25).

- Class I : The area that is mostly used for plantain.
- Class II : The area that is partly used for plantain.
- Class III : The area where plantain sparsely exists.

In consideration of the land use classification of the plantain area, as well as the technical and economical aspects, the priority of river channel improvement was given as follows.

- Since flood damage on plantain is emphasized, high priority is given to the area where plantain plantation is dominant in land use.

- High priority is also given to the plantain area where the residential area is widely involved in the probable inundation area such as El Vigía and La Fortuna.

- In the other areas, priority is given in the order of the stretch from the upper part to the lower part, as generally promoted in the embankment works, since it is difficult to confine the floodwaters in the river channel by only embankment in the lower part. However, the embankment of the uppermost area should be carefully provided, since the sediment from the upper reaches will adversely affect the maintenance of the design riverbed, unless the sediment control structures are completed in the lower reaches.

In accordance with the prioritization, the order of construction is summarized as follows:

- Reinforcememt of the existing dike (10.4 km) and one-side embankment of 24.7 km for Class I plantain plantation area.

- One-side embankment of 31 km for Class II plantain plantation area and extention of the Puerto Chama Bridge.

- Embankment for Class III plantain plantation area including the uppermost open area.

Although the flood control plan for the master plan is formulated with the project scale of 100-year return period, the action plan corresponding to the first 10-year work volume is proposed to apply the 10-year return period as mentioned in Section 5. In this connection, the enhancement work of the dike from 10-year return period to 100-year return period will be executed in the last phase.

4.3.2 Local Project

The local project was subdivided into three components depending on the river basin and the features of the project. These components will involve the Albarregas River, the Milla river, and the Porutugesu river.

The priority among these three components will be given according to the magnitude of expected damage. Judging from the damage condition, the priority order of construction will be given in the order of Albarregas River, Milla River, and Portuguesu River.

5. FORMULATION OF URGENT FLOOD CONTROL PROJECT

5.1 Basin-wide Project

5.1.1 Selection of the Location

The urgent project was formulated within the framework of the master plan by narrowing down the project components included in the first 10-year construction schedule of the master plan which could be realized by the target year 2000 and within the financial capability of the government. The selected locations of urgent project under the action plan are as follows.

- The right bank of 6.0 km river stretch between 3.0 km and 9.0 km from the river mouth for embankment.
- The left bank of 6.3 km river stretch between 10.4 km and 16.7 km from the river mouth for embankment.
- The right bank of 4.4 km river stretch between 17.9 km and 22.3 km from the river mouth for embankment.
- The left bank of 8.0 km river stretch between 35.0 km and 43.0 km from the river mouth for embankment.
- The left bank of 10.4 km river stretch between 43.0 km and 53.4 km from the river mouth for reinforcement of the existing dike.
- The Chama Bridge for construction of groundsill.

The location of river improvement plan is shown in Fig. VII-26.

5.1.2 Selection of Project Scale

Since the project in the master plan is to protect the whole stretch in the lower reaches, a project scale of 100-year return period was adopted for the project formulation mainly based on the social and technical aspects.

However, in the case of the action plan for the urgent project where river embankment will be partially provided to protect the high priority area in the least laps of time, it is more desirable to protect a longer river stretch with a lesser financial burden. In this connection, a project scale lower than a 100-year return period is considered to be employed for the formulation of the action plan.

Although the appropriate return period for the action plan is hardly identified, the project scale should be decided under the following considerations.

- Generally, the project scale of between 5 and 10 years return period is applied to action plans for flood control to facilitate project realization.
- In this basin, economic efficiency tends to increase in proportion to probability of design flood until 30-year return period, as identified in the project evaluation sector of this supporting report, and thus a higher economic efficiency is expected with a larger project scale.
- Since only partial embankment will be provided in the urgent project, flood inundation will still occur in the stretch where a dike is not provided and, therefore, the flood peak discharge of 2,300 m^3/s of a 100-year return period is expected to be reduced due to the retarding effect of the inundation area to less than 1,500 m^3/s corresponding to a 10-year return period.

Judging from the above consideration, it is recommended that a project scale of a 10-year return period is applied to the action plan for the urgent project.

5.1.3 Design Features

In accordance with the project scale, the design features of the action plan is summarized as follows.

- Design Discharge : 1,450 m^3/s
- Design Water Depth : Between 1.1 m and 2.0 m (Refer to Table VII-11.)

- Design Dike Height : Between 1.9 and 3.0 m

Groin is provided at the portion where the flow velocity is over 2 m/s and revetment is provided at the water colliding front of meandering sections. (Refer to Fig. VII-26.)

Longitudinal profile and typical cross section are shown in Figs. VII-27 and VII-28.

5.1.4 Basic Design Conditions

In the master plan study, several alternative cases were examined as to methodology to select the optimum method. The action plan for the urgent project was then formulated in the context of the master plan study.

The alternative study for the action plan was basically made with emphasis on the materials to be employed, considering the capability of local contractors and the locally obtainable materials. The study cases are as shown in Table VII-12.

The main structures applied for flood control include (1) dike, (2) revetment, (3) groin, and (4) groundsill. For the selection of optimum structure type and suitable materials, alternative studies were made in the following condition.

- As for the construction of a dike, earth material is the only one to be applied from the technical and economical point of view, and therefore, the study is made only to confirm the applicability of earth materials obtainable at the construction sites.

- For the protection of the dike from erosion, there are two kinds of structure applicable; revetment and groin, which are applied depending on the features of the section of dike to be protected: (1) the section with water collision front, and (2) the section with high current velocity. In this flood control plan, the revetment is applied to the former section and groin is to the latter section and then a study was made to select the most suitable material. (Refer to ANNEX of this sector.)

- As for the groundsill, a study was made for selection of optimum structures among two kinds of structures: (1) gravity type, and (2) concrete block type, and then suitable materials are selected for the applied structure type.

5.1.5 Selection of Optimum Case

(1) Dike

As aforementioned, the availability of earth material which is obtainable at the construction site was confirmed, putting emphasis on the following aspects:

- having durability against variation of weather conditions.
- not containing organic matter.
- being easily compacted.

The Chama River downstream of El Vigía can be broadly divided into two stretches separated by the alluvial fan. The riverbed of the upper stretch is composed of sand and gravel, while that of the lower stretch is mainly silty clay. Both materials can be used for embankment by themselves or adding a small amount of sand or clay.

(2) Revetment

Among the five cases of applicable materials for revetment, comparison was made from the technical and economical aspects as shown in Table VII-13.

Judging from this table, wet masonry which has high reliability for the protection of the dike and economical advantages, was selected the most suitable material.

(3) Groin

The comparison to select suitable materials for groin was also made among the three materials as shown in Table VII-14.

Eventually, gabion was selected because of the advantage from the economical aspect, since there is no big difference in the function of groin according to material.

(4) Groundsill

As for the groundsill, there are two kinds of structure type applicable: (1) gravity type, and (2) concrete block type. Among these types, gravity type is commonly used because of the economical advantage, while the latter is used at the sites where flexibility is required against the transformation as mentioned in the preceding section.

Since no geographical condition requiring a sustainable type for transformation was identified at the construction sites, gravity type was selected as the optimum type.

As for the materials to apply to the gravity type of groundsill, rubble concrete was selected by its economical advantage as shown below.

Material	Cost (x 10^6 Bs.)
Rubble concrete	22.1
Concrete	25.4
Concrete block	25.4
Saco concrete	23.5

5.2 Local Project

For the formulation of the flood control of local projects, the following consideration is made:

- As noted from the construction cost and work volume for the Master Plan, those of flood control for the local project is less than 1% of those of the basin-wide project. Thus, all the flood control works of the local project formulated for the master plan may be possible to put into execution in the action plan stage and they will not affect the feasibility of the Chama River Basin Conservation Project.

- Although the project scale of flood control for basin-wide project is lowered to 10-year return period to facilitate the project execution, the project cost in case of local projects will not affect the total cost and thus, it is recommendable to apply the same project scale as the master plan to the action plan to secure the safety against this flood disaster and to avoid double investment through lowering the project scale.

- Since the data available for project formulation has been used for the study on the master plan, the further modification of the contents of the plan is not necessary even in the action plan study when the same project scale and river improvement stretch are applied.

In this connection, the flood control plan of the local project under the master plan is directly applied to the action plan. In accordance with the contents of the master plan, the project features are summarized as follows.

(a) Albarregas River

Design Discharge	:	180 m^3/s (100-year return period
Improvement Stretch	:	1,000 m
Standard Cross-Section	:	6 m wide x 3.5 m deep
Improvement Type	:	Embankment

(b) Milla River

Design Discharge	:	60 m^3/s (50-year return period)
Improvement Stretch	:	3,040 m
Improvement Type	:	Excavation

(c) Portuguesa River

Design Discharge	:	130 m^3 (100-year return period)
Improvement Stretch	:	1,400 m
Standard Cross-Section	:	5 m wide x 2.5 m deep
Improvement Type	:	Channel widening and excavation

5.3 Prioritization for Action Plan

5.3.1 Basin-wide Project

According to the economic evaluation, the project benefit expected from river embankment at the project scale of 10-year return period with the construction of sediment control structures is as follows.

Embankment Stretch	Benefit (1) (x 10^9 Bs.)	Cost (2) (x 10^9 Bs.)	(1)/(2)
3.0 km to 9.0 km	51.0	80.5	0.63
10.4 km to 16.7 km	16.2	80.3	0.20
17.9 km to 22.3 km	12.4	56.7	0.22
35.0 km to 43.0 km	4.4	103.8	0.04
43.0 km to 53.4 km	4.9	48.3	0.10

The above table shows a tendency that the economic efficiency expressed by the ratio between the direct cost and benefit becomes higher from the lower reaches to the upper reaches except the stretch between 43.0 km and 53.4 km where the existing dike will be reinforced. The priority of river improvement will then be placed according to economic efficiency.

As for the groundsill, high priority will be given to the construction of groundsill near the Chama Bridge which is proposed to protect the foundation from erosion of the riverbed, because erosion may be brought about by the construction of sediment control structures in the middle/upper reaches.

Although the economic efficiency of the reinforcement of existing dike is not high compared with river improvement in the lower reaches, the high priority should be given to assure the safety of the existing dike so that the urban area of El Vigía City can be released from the menance of flood disaster.

As a conclusion, the constructon of flood control structures will be in the following order.

- Embankment for the stretch between 3.0 km and 9.0 km and construction of groundsill.
- Embankment for the stretch between 10.4 km and 16.7 km and reinforcement of the existing dike between 43.0 km and 53.4 km.
- Embankment for the stretch between 18.2 km and 22.3 km.
- Embankment for the stretch between 35.0 km and 43.0 km.

5.3.2 Local Project

As described in 4.3, Prioritization of Flood Control Project, the project whose contents is not different from the master plan will follow the prioritization of the master plan; namely, river improvement of the Milla River, the Albarregas River and the Portuguesa River.

5.4 Organization for Project Execution

In this section, the necessary organization for the realization of the Action Plan is studied. Although there exist several agencies concerned in this Chama River Basin Conservation Project, it may be difficult to realize the project with the existing agencies due to staff and other limitations, since this project requires many staff familiar to this field and coordination is also required among the agencies concerned. Therefore, it may be desirable to establish a project office which will exclusively implement the realization of this project, including operation and maintenance.

For the establishment of a project office, the following points are considered:

- Like other project offices, the office shall have the functions and responsibilities on planning and design, construction, equipment and materials, and operation and maintenance.

- Since this river basin conservation project is divided into two sub-projects with different features, i.e., the basin-wide project and the local project, the project office must have the expertise to handle all the engineering fields involve in both of the sub-projects; namely, sediment control and flood control for the basin-wide project and sediment control for the protection of roads and flood control for the protection of urban areas for the local project.

- Since the project involves several agencies such as the MARNR, the MTC, the MAC and so on, a committee has to be organized for the acquisition of funds and coordination to solve any problem that may arise among the agencies concerned.

Under the above considerations, two kinds of organizations are proposed. Case 1 will put emphasis on the function such as planning, design, construction, etc., and Case 2 is on the engineering field such as flood control and sediment control, as shown in Fig. VII-29 and VII-30.

Among these two kinds of organizations, the former may be more recommendable, since staff engage in the same engineering field can be shared to perform one function, although this setup may present some difficulties in the coordination of the same engineering field such as road protection for the local project and sediment control for the basin-wide project.

6. PRELIMINARY DESIGN

6.1 Dike

6.1.1 Embankment and Excavation

(1) Cross Section

The standard cross section of the dike is shown in Fig. VII-31. The height of the dike was obtained by adding the required freeboard to the design flood water level. The required freeboard 1.2 m corresponding to the 100 year flood discharge 2,300 m^3/s is employed for the master plan to prepare for temporary rises of the water level caused by wind and waves on the occasion of a flood, swell and hydraulic jump.

The slope of the dike is 1:2.0 from the viewpoint of stability of soil. However, it is necessary to sod the slopes of the dike to prevent erosion by rainfall or river water.

The dike has the crest width of 5.0 m, and a 3 m gravel-paved road is constructed on the top of the dike to permit movement of maintenance equipment.

(2) Excavation of Riverbed

Riverbed excavation is proposed to improve the hydraulic capacity of the channel by means of shortcut of the remarkable meanders and to obtain the construction materials for the dike.

6.1.2 Groin and Revetment

(1) Groin

The purpose of groin is to prevent erosion at the foot of the side slope by fixing the low water channel, decreasing velocity and acceralating sediment deposit. Gabion cylinder semipermiable groin is employed for this purpose.

The groin can be arranged upward, downward or right angle to the flow direction. The right angled groin is recommendable for arresting sediments and accelerating their deposit.

The height, length and intervals of groyne are calculated by the empirical formulation which are accepted in Japan,

Hg/H = 1.0 (applied for rapids)
D/Hg = 10 - 30 (10 is most effective for roughness)
D/L = 1.7 - 2.3

where; Hg: Water depth (1.33 - 1.9 m)
H: Height of groin
D: Intervals of groin
L: Length of groin

The structual details are shown in Fig. VII-32 and the parameters are as follows.

Stretch	IV	V	VI	VII	Range
Hg	1.87	1.57	1.43	1.33	
Hg/H	1.19	1.00	0.91	0.85	Hg/H = 1.0
D/Hg	10.7	12.7	14.0	15.0	10<D/Hg<30
D/L	2.0	2.0	2.0	2.0	1.7<D/L<2.3

(2) Revetment

Wet masonry is employed for revetment at the water colliding front using cobbles which are easily obtained at the project site. The revetment structure consists of a revetment and a foot protection. The height of revetment is as high as the design flood level. The foot protection of gabion is provided at the base of the revetment to prevent riverbed erosion. The structual details are shown in Fig. VII-33, and the layout of groins and revetments are in Fig. VII-20.

6.2 Groundsill

The crest elevation of the groundsill is equal to the design riverbed elevation and its is embedded 3 m from the riverbed. Concrete revetments are provided at both sides of the groundsill to prevent scouring.

Aprons of gabion mattress are constructed upstream of the groundsill at a length of 7 m and downstream at a length of 20 m for protection against scouring. Gabion mattress is also placed around the pier of bridge to prevent local scouring.

The groundsill is installed at 10 m downstream of the Chama Bridge to prevent scouring of the riverbed in the vicinity of its foundation. It is placed over the full width of the river. The structural profile is shown in Fig. VII-34.

6.3 Extension of Puerto Chama Bridge

The existing Puerto Chama Bridge 10.9 m wide and 137 m long consists of 1 steel span and 2 concrete spans. In consonance with the construction of dike along both sides of the river, it is necessary to extend the existing bridge by 480 m. The extended portion is of 16 concrete spans, each of which is 30 m long. The profile of the proposed bridge extension is shown in Fig. VII-35.

6.4 Action Plan

Among the river improvement structures in the action plan, the groundsill and the dike whose height corresponds to a 10-year flood water level are to protect the most important area along the Chama River, and anti-erosion works, groin and revetment are provided.

Dike

In the action plan, the standard cross-section of the dike is the same as the master plan but the height corresponds to a 10-year return period, so that the bottom width is also made narrower at 2.5 m. The dike in the action plan will be placed along the foot of the front slope of the dike in the master plan to avoid double investment for revetment and groin when the dike is widened to the design height and width of the master plan. (Refer to Fig. VII-36.)

Other Structures

Groundsills, groins and revetments are constructed at the same scale as the master plan so as to avoid double investment in case the dike is enhanced to the scale of the master plan.

7. NON-STRUCTURAL MEASURES

The structural measures to be applied in the river basin conservation project were studied in the preceding section. Since it may take a long time to complete the structural measures, while the river basin suffers continuously from disasters, it is necessary to provide certain measures to mitigate the disaster until the time when the structural measures are completed.

In this sence, study is made on non-structural measures to cope with this situation and also, to be used as supplementary measures for disaster prevention even after completion of the proposed structural measures.

7.1 Basin-wide Project

7.1.1 Necessary Measures

Among several non-structural measures which include flood forecasting and warning, flood fighting, relocation of assets, flood proofing, land use regulation, public investment policy, etc., the following measures were basically considered as the applicable measures judging from the disaster conditions in the lower reaches:

- Land use regulation;
- Flood forecasting and warning; and
- Consolidation of river structure management and flood fighting.

7.1.2 Application of Non-Structural Measures

In this basin, the non-structural measures will be applied in the following manner:

<u>Land Use Regulation</u>

The flood prone area in the lower reaches is classified into three categories: (1) river area, (2) presumed inundation area, and (3) other areas. Among them, land use in the river area and the presumed inundation area should be regulated as follows:

(1) River Area

In this master plan, the river area was proposed as discussed in the preceding section, and this proposed river area should be acquired and delineated from private use.

(2) Presumed Inundation Area

The recorded flood inundation area has been clarified in this study and this area is currently used for plantain plantation, pastures, etc. Among them, the plantain plantation covering more than 50% of the land use in the flood inundation area is not so durable against flood inundation damage. Therefore, it is desirable to control the land use for plantain plantation and to promote the diversification of crops to the more sturdy ones like tree crops.

In case of urbanization and construction of public facilities, they should be provided on the ground above the presumed inundation water level which may require land reclamation.

Flood Forecasting and Warning

Flood forecasting and warning is performed to obtain the information necessary for flood fighting works of protecting the dike against flood discharge. Although flood forecasting and warning works were never executed, the water level obserbed at the Ejido gauging station during flood time is informed by telephone to Zone Office No. 5, and flood fighting works are experimentally taken based on such information.

Since the information on hydrological condition in the Mocoties River Basin is not obtainable, no emergency action can be taken against the flood discharge of the Mocoties River. Furthermore, since there is no information on runoff discharge between El Vigía and the Mocoties River Basin, the lower reaches suddenly falls under the menace flooding. Under this condition, it is desirable to execute the following works:

- Preparation of appropriate hydrological flood forecasting model to predict water level or runoff discharge at El Vigía.

- Provision of hydrological observation system and data collection system.

- Provision of data management system for the operation of the flood forecasting system.

To establish an updated overall flood forecasting and warning system, it is desirable to provide a number of hydrological observation stations together with a telemetering system. However, an enormous fund is required to install new facilities and to carry out a precise study which will require an abundance of hydrological data, and such an updated system may not be realistic in this basin.

A convenient system that can be realized with a lesser investment with the use of existing facilities is recommendable. In this connection, the following principles will be considered for its formulation:

- The water stage in the lower reaches is predicted on the basis of correlation of water stage with that of the upper reaches.

- As the hydrological observation network, a new water stage gauging station with an observer at the confluence point of the Chama River with the Mocoties River and another station at the Mocoties River Basin are required. (Refer to Fig. VII-37.)

- Water stage in the upper reaches is informed to Zone Office No. 5 by telephone.

- Zone Office No. 5 after data processing for prediction of water stage based on the observed data disseminates the information to the Civil Defence Department by telephone, if necessary.

Consolidation of River Management and Flood Fighting

(1) River Management

The following purposes are generally pointed out for river management:

- To prevent disasters caused by river water through the operation and maintenance of river structures and river channels;

- To promote the appropriate water utilization of agricultural, industrial, hydropower generation, etc.; and

- To assure the favorable environmental circumstances of the river by maintaining both the quality and the quantity of river water.

Among these purposes, as far as this study is concerned, the main purpose of river management is to maintain the structures and river channel under normal condition, so that they can fulfill their function of disaster prevention when needed.

The maintenance works will involve the following items: (1) restoration of dike, (2) dredging of river channel, (3) regulation on construction of structures, and (4) land use regulation in the river area.

Although Zone Office No. 5 is trying its best to cover all these works, its capability is maybe insufficient as noted from the fact that the bank failure in September 1988 has been left for a long time without restoration due to lack of financing, and the river area is illegally used for planting crops resulting in the reduction of flow capacity and increment of flood damage. It is then necessary to consolidate the maintenance works through the allocation of sufficient funds and putting additional personnel.

(2) Flood Fighting

Flood fighting during flood time mainly covers the following works: (1) tentative reinforcement of flood control structures, (2) prevention of the spread of inundation water, and (3) evacuation of inhabitants from the inundation area.

In the Chama River Basin, flood fighting is mainly carried out through the tentative reinforcement of the existing dike by gabbions, sand bags, gravels, etc. From the interview-survey with the inhavithants, it was noted that they need information on inundation water so as to mitigate flood disasters, although the share of the present flood damage on houses and household effects is not so much among the whole damage amount. The inhabitants expect public agencies to take some action in preventing the spread of flooding to the urban area, which have never been carried out up to the present. It is then desirable to consolidate flood fighting works through the MARNR in coopertation with the Civil Defence Department.

7.1.3 Organization for Operations

Land Use Regulation

The agencies concerned in land use management in this country are as follows:

- River Area : MARNR
- Flood Prone Areas
  - Agricultural Area : MAC, IAN, MARNR
  - Urban Area : MINDUR
- Public Facilities : MARNR, MTC, State Governments

Regarding the management of flood prone areas, exchange of information is made but not periodically through the activities of the agencies concerned, and the coordinating committee does not convene periodically for the regulation of land use in the flood prone area. In this connection, it is recommended that a coordinating committee consisting of representatives of these agencies be established to monitor any disorder in land development and to give instructions on appropriate land use.

Flood Forecasting and Warning

Although flood forecasting and warning were never executed in the Chama River Basin, hydrological information has been collected by the MARNR, and the Civil Defence Department of the Ministry of Interior has the responsibility of flood fighting and rescue works. In this connection, it is possible to cope with the flood forecasting and warning works by these existing agencies through the consolidation of organization and flood warning efforts.

Flood Fighting

As in flood forecasting and warning works, flood fighting is tasked with the MARNR and the Civil Defence Department, and it is necessary to consolidate the present organization for flood fighting.

7.2 Local Project

7.2.1 Applicable Measures and their Application

The measures applicable for flood disasters in the cities of Mérida and Ejido are (1) land use regulation, (2) flood warning system, and (3) evacuation of inhabitants. These measures are proposed to be employed as follows.

Land Use Regulation

A land use map for the year 2000 covering Mérida and Ejido cities has been prepared by the MINDUR and the municipilities. The areas to be protected from urbanization such as forests, potential landslide areas and river areas have been delineated. Even these areas, however, are urbanized resulting in the increment of flood disasters. In this connection, the consolidation of inspection by the agencies concerned is necessary.

Flood Warning System

In addition to the warning system for sediment disaster along national road routes 2 and 7, a flood warning system should be installed to mitigate damage on household effects and prevent loss of human life. The warning system consisting of rainfall observation system, data transmission system, dissemination system and warning system is featured as follows:

- Three rainfall stations equipped with transmission devices are proposed to be installed as the rainfall observation system in the upper reaches of the Albarregas, Milla and Portuguesu river basins.

- Data is transmitted by simplex telemetering through the existing telephone line to Zone Office No. 16 of the MARNR.

- Data is disseminated to the Civil Defence Department of the Ministry of Interior as the warning center.

- Flood warning is issued by the warning center to the inhabitants by siren based on the magnitude of rainfall.

Evacuation of Inhabitants

Since the flood damage area is not so large, it may be possible to avoid flood damage on household effects and loss of human life through evacuation to higher places adjoining the possible flood damage area. In this connection, it is recommended that the evacuation system in the flood damage area be established by setting up the rules, route and place of evacuation.

7.2.2 Organization for Operations

The agencies concerned in the above tasks are as follows:

- Land Use Regulation : MINDUR and municipality

- Flood Warning System : MARNR and Civil Defence Department

- Evacuation of Inhabitants : Civil Defence Department

To accomplish the tasks, a new organization is not necessary, but augmentation of the staff of the existing organization is needed.

Table VII-1 IRRIGATION SYSTEM FOR AGTICULTURAL AREA

Municipality		Benificialy Families	Area (ha)
Rivas Davila	Rincon de Las Playitas	26	43
	Marmolejo	15	30
	Rincon de Los Alovarez	33	22
	Bardo Seco	40	16
	Rincon Las Rosas	35	34
	San Vicente El Molono	10	18
	La Periquera El Volcan	150	150
Libertador	San Jajinto	150	
Foraneo Mucuruba	Cacutico La Granja	32	40
Santos Marquina	Pedregal	21	24
Rivas Devila	Capellania Neito	39	51
	Rincon de La Laguna	6	10
Mucuruba	Mesa de Mococon	12	16
Foraneo Estanquez	Hato Bajo Estanquez	38	70
Sucre	Unidad El Molono	58	74
	Sabana La Trampa	47	234
	Mucumbu	95	96
Foraneo El Morro	Hoto Las Perez	26	92
Santos Marquina	San Geronimo	22	26
Sucre	La Carela	127	114

Source : Corpoandes "ORIENTA EL POTENCIAL REGIONAL"

Table VII-2 PRODUCTION OF TROUT

(Unit : ton)

Year	Location		
	El Robo River	Mucunutan River	Mocono River
1984	27.9	26.0	19.2
1985	7.4	35.5	22.3
1986	9.8	61.0	29.1
1987	17.2	53.6	32.3
1988	4.8	75.9	31.4

Source : M.A.C., "Desarrollo Pesquero"

Table VII-3 HISTORY OF STUDY ON CHAMA RIVER IMPROVEMENT

Year	Outline of Study	Agency or Engineer
1967	Study of Chama River Improvement in the stretch of 40km downstreem from El Vigia with the design river width of between 700 and 1000 m.	Ing. N.J.Yonis
1972	Study on Mucujepe Diversion Channel Project with the design river width of 1400 m and design discharge of 1500 m3/s. The cost was estimated at 89 million Bs as of 1972.	Ing. Eits
1979	Economic evaluation of Mucujepe Diversion Channel Project. *1)	CIDIAT
1984	Study on Mucujepe Diversion Channel Project. (Memoria Technica)	Ing. Eits
1988	Proposal for Promotion of Mucujepe Diversion Channel Project.	Ing. Verasco

Note *1): In this study, the following alternative cases were examined

Study Cases	Cost
(1) Flood control dam	: 506 million Bs
(2) Chama River Improvement	: 170 million Bs
(3) Mucujepe diversion Channel	: 158 million Bs
(4) Combination of (2) and (3)	: 158 million Bs
(5) Combination of (1) and (3)	: 259 million Bs
(6) Combination of (1) and (2)	: 264 million Bs

Table VII-4(1/2) CONSTANTS OF STORAGE FUNCTION MODEL FOR LOWER REACHES (PRESENT CONDITION)

Number of Model	Flow Capacity (m3/s)	Less than Flow Capacity		More than Flow Capacity	
		K	P	K	P
I	300	28.3	0.6	0.47	1.32
II	100	16.5	0.6	4.71	0.87
III	100	24.4	0.6	9.71	0.80
IV	100	15.9	0.6	1.98	1.05
V	100	20.8	0.6	1.89	1.12

Table VII-4(2/2) CONSTANTS OF STORAGE FUNCTION MODEL FOR LOWER REACHES (AFTER COMPLETION OF ACTION PLAN)

Number of Model	Flow Capacity (m3/s)	Less than Flow Capacity		More than Flow Capacity	
		K	P	K	P
I	1,000	28.3	0.6	2.34	0.96
II	100	16.5	0.6	9.12	0.73
III	100	24.4	0.6	15.49	0.70
IV	100	15.9	0.6	5.50	0.83
V	100	20.8	0.6	6.31	0.86

Table VII-5(1/2) CALCULATION RESULTS OF FLOOD INUNDATION

DAY	STRETCH 1			STRETCH 2			STRETCH 3			STRETCH 4			STRETCH 5		
	Q. (m3/s)	I.D. (cm)	F.D. (hr)	Q. (m3/s)	I.D. (cm)	F.D. (hr)	Q. (m3/s)	I.D. (cm)	F.D. (hr)	Q. (m3/s)	I.D. (cm)	F.D. (hr)	Q. (m3/s)	I.D. (cm)	F.D. (hr)
(2-yr. return peirod)															
1st	---	0	0	---	0	0	---	0	0	210	8	1	149	5	16
2nd	---	0	0	---	0	0	---	0	0	210	10	5	152	5	24
3rd	682	20	5	394	7	18	370	11	19	359	14	20	330	23	24
4th	723	23	6	412	8	19	395	12	22	379	14	24	354	25	24
5th	682	20	5	395	7	18	372	11	19	364	14	20	333	24	24
6th	---	0	0	---	0	0	---	0	0	215	10	5	160	6	24
7th	---	0	0	---	0	0	---	0	0	211	8	1	151	5	20
(5-yr. return peirod)															
1st	310	2	1	230	4	1	220	5	2	215	8	2	202	10	16
2nd	311	2	3	231	5	6	222	8	10	217	10	10	209	11	24
3rd	851	32	7	470	10	19	450	15	18	424	16	16	388	29	24
4th	1,170	47	8	622	12	20	583	16	22	552	20	24	504	40	24
5th	851	32	7	470	10	19	451	15	20	430	16	24	406	31	24
6th	311	2	3	231	5	6	222	8	11	210	11	20	222	12	24
7th	310	2	1	230	4	1	220	5	2	210	8	2	209	11	24
(10-yr. return peirod)															
1st	445	5	2	292	8	2	281	8	3	270	10	3	249	15	16
2nd	448	7	7	295	10	10	282	11	14	273	12	17	260	16	24
3rd	969	40	8	524	12	19	495	14	21	470	16	23	430	33	24
4th	1,443	74	9	762	15	20	704	20	22	660	25	24	598	43	24
5th	969	40	8	524	12	19	495	16	22	476	20	24	449	35	24
6th	448	7	7	295	10	10	290	13	17	366	16	24	271	17	24
7th	445	5	2	292	8	2	288	8	3	362	10	3	261	16	24
(30-yr. return peirod)															
1st	668	15	3	387	8	3	330	10	5	311	11	4	302	22	16
2nd	668	20	13	387	10	19	361	13	22	358	16	24	337	24	24
3rd	1,182	55	14	629	15	20	580	18	22	556	20	24	504	40	24
4th	1,845	80	17	980	20	24	893	26	24	831	32	24	742	46	24
5th	1,182	55	14	629	15	20	580	18	22	561	20	24	526	41	24
6th	668	20	13	390	10	19	360	13	22	350	16	24	346	25	24
7th	667	15	3	387	8	3	328	10	5	305	11	4	296	25	24
(50-yr. return peirod)															
1st	780	8	3	415	8	4	350	10	8	340	14	15	333	24	16
2nd	781	10	13	418	10	19	401	13	22	385	16	24	358	26	24
3rd	1,288	59	14	678	16	20	632	19	22	595	22	24	540	41	24
4th	2,012	101	17	1,061	25	24	970	31	24	901	36	24	802	48	24
5th	1,288	59	16	678	16	23	630	19	24	601	22	24	563	42	24
6th	781	10	14	441	10	20	410	15	22	388	20	24	386	29	24
7th	781	8	3	438	8	4	350	10	8	342	18	24	331	28	24
(100-yr. return peirod)															
1st	969	20	4	524	10	5	480	13	10	465	16	15	417	32	16
2nd	969	27	13	524	12	19	490	15	22	474	17	24	440	34	24
3rd	1,423	72	14	749	18	20	705	21	23	651	24	24	590	42	24
4th	2,239	110	16	1,173	34	23	1,072	37	24	995	40	24	883	50	24
5th	1,423	72	14	749	18	24	705	22	23	658	25	24	613	43	24
6th	969	27	14	524	12	20	490	15	22	476	17	24	448	35	24
7th	969	20	4	524	10	5	480	13	10	474	17	24	440	34	24

NOTE: Q.= discharge D.= depth P.= period (flood duration)
"---" in the column of Q. means no overtopping river water.

Table VII-5(2/2) CALCULATION RESULTS OF FLOOD INUNDATION (AFTER COMPLETION OF ACTION PLAN)

Return Period (Year)	STRETCH 1	STRETCH 2	STRETCH 3	STRETCH 4	STRETCH 5
	Q. (m3/s)	Q. (m3/s)	Q. (m3/s)	Q. (m3/s)	Q. (m3/s)
100	2,239	1,393	1,220	1,096	1,057
50	2,012	1,260	1,094	984	953
30	1,845	1,161	1,000	903	876
10	1,443	922	788	713	692
5	1,170	759	648	590	574
2	723	490	436	398	391

Table VII-6 DESIGN FEATURES OF CROSS SECTION BY ALTERNATIVE CASE

(Unit: m)

Stretch	Riverbed Gradient	Case 1		Case 2		Case 3		
		Width	Depth	Width	Depth	Width (High Water Channel)	Width (Low Water Channel)	Depth
I 0.0k-12.6k	1/1,400	1,400	1.6	600	2.7	290	210	4.7
II 12.6k-28.0k	1/880	1,400	1.4	600	2.3	240	160	4.6
III 28.0k-35.2k	1/625	1,400	1.3	600	2.1	230	150	4.5
IV 35.2k-45.6k	1/450	1,100	1.3	600	1.9	210	130	4.3
V 45.6k-48.0k	1/250	1,100	1.1	600	1.6	180	100	4.1
VI 48.0k-50.0k	1/185	1,100	1.0	600	1.5	170	90	4.0
VII 50.0k-53.4k	1/145	1,100	0.9	600	1.3	150	70	3.9

Note: Stretch is measured along the design alignment

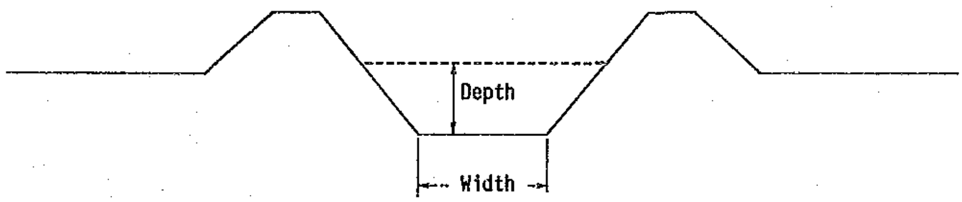


Table VII-7 COST COMPARISON FOR ALTERNATIVE CASES

Item	Unit of Quantity	Case 1		Case 2		Case 3	
		Quantity	Cost (Bs.million)	Quantity	Cost (Bs.million)	Quantity	Cost (Bs.million)
Land Acquisition	million m2	64.6	442	24.2	166	11.5	79
Embankment	million m3	2.55	741	4.17	871	4.63	901
Excavation	million m3	-	-	(1.08)	-	11.91 (16.83)	1,942
Revetment	1000 m3	13	19	213	305	150	215
Groin	1000 m3	70	69	164	162	65	64
Bridge	no.	1	494	1	183	1	90
Total			1,765		1,687		3,291

Table VII-8 COST COMPARISON BETWEEN RIVER CHANNEL IMPROVEMENT PLAN AND DIVERSION CHANNEL PLAN

Item	Unit of Quantity	Channel Improvement Plan		Diversion Channel Plan	
		Quantity	Cost (million Bs.)	Quantity	Cost (million Bs.)
Land Acquisition	million m2	24.2	166	30.4	146
Embankment	million m3	4.17	871	4.17	871
Excavation	million m3	(1.08)*		1.58 ** (5.75)*	264
Rivetment	1000 m3	213	305	213	305
Groin	1000 m3	164	162	164	162
Bridge	no.	1	183	1	183
Total			1,687		1,931

NOTE * : To be used for embankment.
**: Volume for spoil. (= Excavation Volume - Embankment Volume)

Table VII-9 DESIGN FEATURES OF CROSS SECTION BY PROBABLE DISCHARGE

Stretch	Riverbed Gradient	100-Year Q=2,300 m3/s			50-Year Q=2,100 m3/s			30-Year Q=1,850 m3/s			10-Year Q=1,450 m3/s			5-Year Q=1,200 m3/s			2-Year Q=700 m3/s		
		W (m)	D (m)	V (m/s)	W (m)	D (m)	V (m/s)	W (m)	D (m)	V (m/s)	W (m)	D (m)	V (m/s)	W (m)	D (m)	V (m/s)	W (m)	D (m)	V (m/s)
I 0.0k-12.6k	1/1,400	600	2.7	1.5	600	2.5	1.4	600	2.4	1.3	600	2.0	1.2	500	2.0	1.2	300	2.0	1.2
II 12.6k-28.0k	1/880	600	2.3	1.7	600	2.2	1.6	600	2.0	1.6	600	1.7	1.4	500	1.7	1.4	300	1.7	1.4
III 28.0k-35.2k	1/625	600	2.1	1.8	600	2.0	1.8	600	1.9	1.7	600	1.6	1.5	500	1.6	1.5	300	1.6	1.5
IV 35.2k-45.6k	1/450	600	1.9	2.0	600	1.8	2.0	600	1.7	1.9	600	1.5	1.7	500	1.5	1.7	300	1.4	1.7
V 45.6k-48.0k	1/250	600	1.6	2.5	600	1.5	2.4	600	1.4	2.3	600	1.2	2.1	500	1.2	2.0	300	1.2	2.0
VI 48.0k-50.0k	1/185	600	1.5	2.7	600	1.4	2.6	600	1.3	2.4	600	1.1	2.2	500	1.1	2.2	300	1.1	2.2
VII 50.0k-53.4k	1/145	600	1.3	3.2	600	1.2	3.0	600	1.1	2.9	600	1.0	2.6	500	1.0	2.6	300	1.0	2.6

Note: Stretch is measured from the river mouth along the design alignment

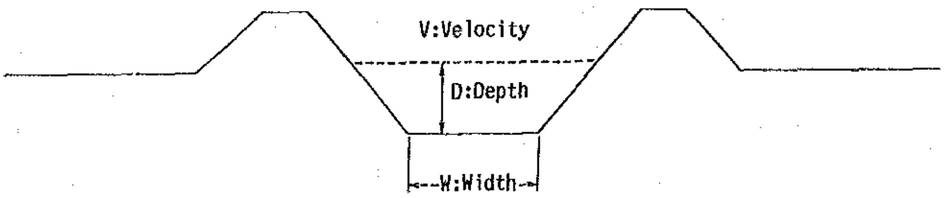


Table VII-10 CONSTRUCTION COST BY PROBABLE DISCHARGE

Unit for cost : million Bs

Item	Unit for Q'ty.	100-Year Q=2,300 m3/s Quantity	Cost	50-Year Q=2,100 m3/s Quantity	Cost	30-Year Q=1,850 m3/s Quantity	Cost	10-Year Q=1,450 m3/s Quantity	Cost	5-Year Q=1,200 m3/s Quantity	Cost	2-Year Q=700 m3/s Quantity	Cost
Land Acquisition	km2	24.2	166	24.1	165	24.0	164	23.8	163	18.5	127	8.0	55
Embankment	million m3	4.17	871	3.69	787	3.21	704	2.60	613	2.69	593	2.69	552
Excavation	million m3	(1.08)	-	(1.08)	-	(1.08)	-	(1.08)	-	(1.08)	-	(1.08)	-
Revetment	million m3	213	305	2.00	279	187	252	160	215	160	215	16	215
Groyn	million m3	164	162	133	132	60	60	52	51	52	51	52	51
Bridge	no.	1	183	1	183	1	183	1	183	1	153	1	93
Total			1,687		1,546		1,363		1,225		1,139		966

Table VII-11 DESIGN FEATURES OF RIVER IMPROVEMENT

Stretch	Riverbed Gradient	Design Water Depth		Height of Dike (m)		Proposed length of dike in M/P
		1/100 (M/P)	1/10 (A/P)	1/100 (M/P)	1/10 (A/P)	
I 0.0k-12.6k	1/1,400	2.7	2.0	3.9	3.0	8.1km (3.0-9.0; 10.4-12.5)
II 12.6k-28.0k	1/880	2.3	1.8	3.5	2.8	8.6km (12.5-16.7; 17.9-22.3)
III 28.0k-35.2k	1/625	2.1	1.6	3.3	2.6	-
IV 35.2k-45.6k	1/450	1.9	1.5	3.1	2.5	8.0km (35.0-43.0)
V 45.6k-48.0k	1/250	1.6	1.2	2.8	2.2	-
VI 48.0k-50.0k	1/185	1.5	1.1	2.7	2.1	-
VII 50.0k-53.4k	1/145	1.4	1.1	2.6	2.1	-
Total						24.7km

Note: The height of dike were obtained by adding the freeboard of 1.2m and 1.0m respectively for the master plan and action plan to the design water depth.

Table VII-12 ALTERNATIVE STUDY CASES FOR FLOOD CONTROL STRUCTURE

Structure	Materials
Revetment	Sodding
	Gabion
	Wet masonry (concrete)
	Wet masonry (asphalt)
	Concrete
	Asphalt
	Textile form concrete
Groyne	Gabion
	Concrete block
	Cobble stone concrete
	Textile form concrete
Groundsill	Concrete
	Rubble concrete
	Concrete block
	Textile form concrete

NOTE: Applicable anti-erosion work will be changed according to the current velocity and direction.

Table VII-13 SELECTION OF OPTIMUM CASE FOR REVETMENT

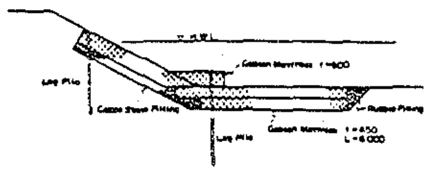
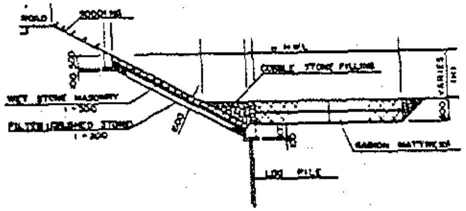
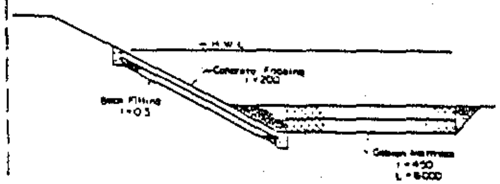
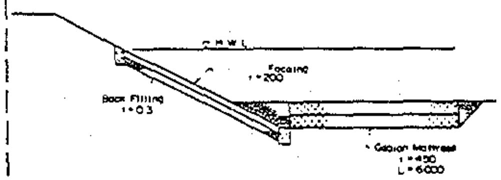
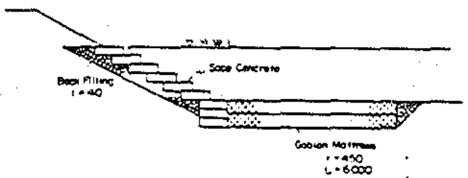
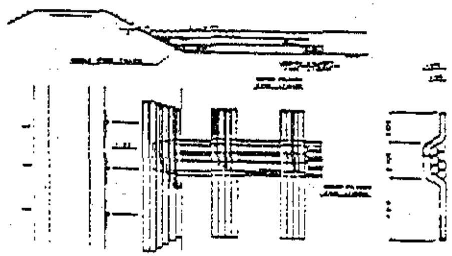
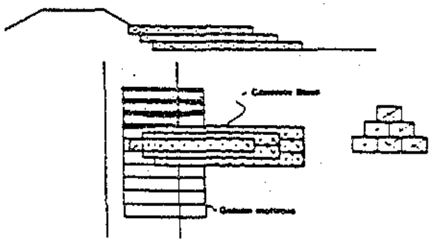
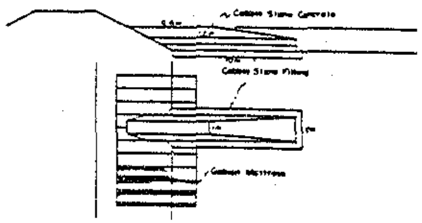
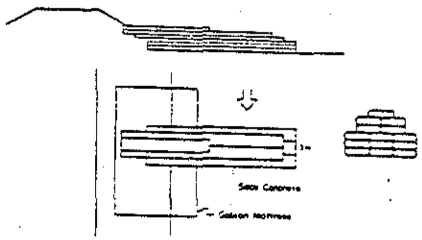
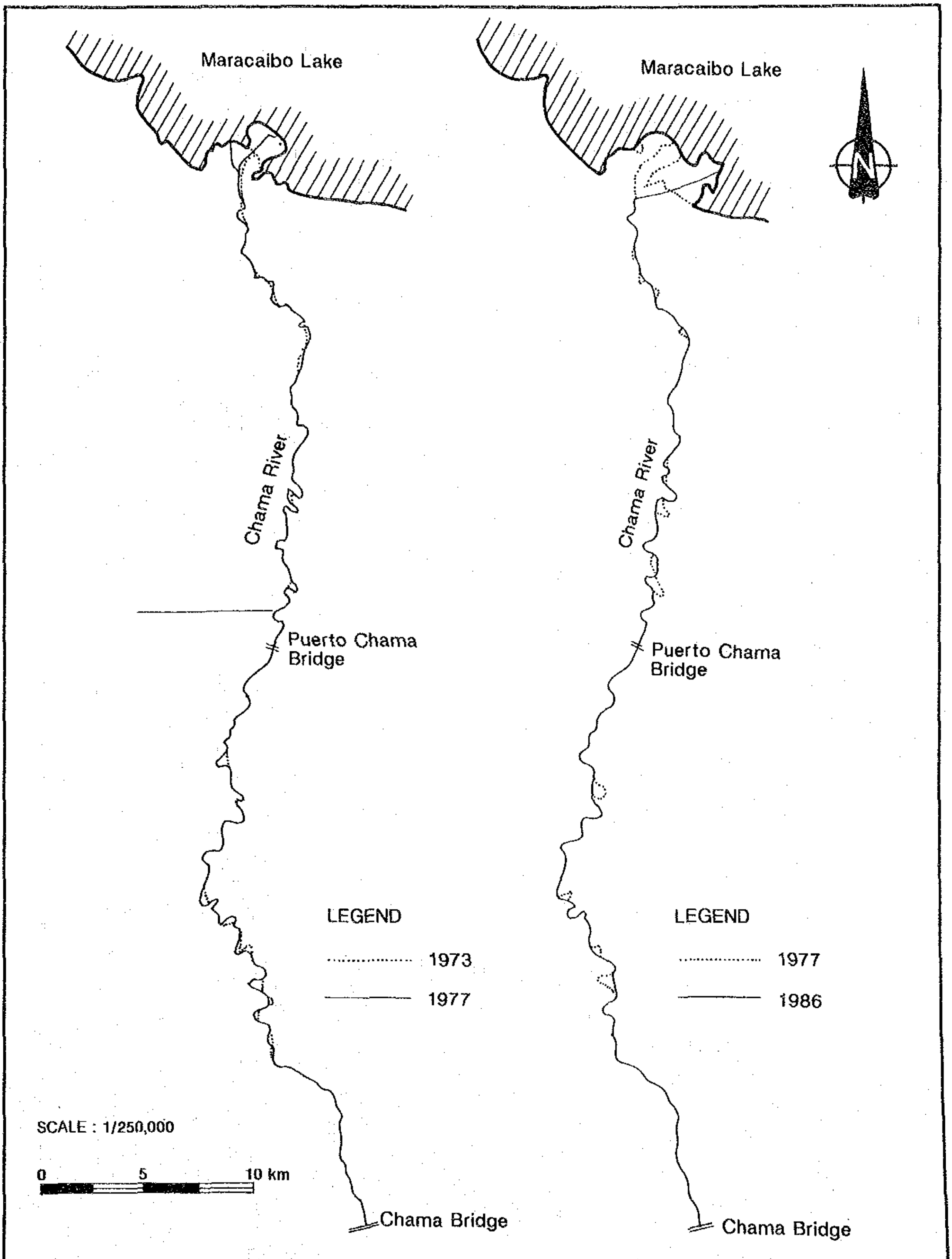
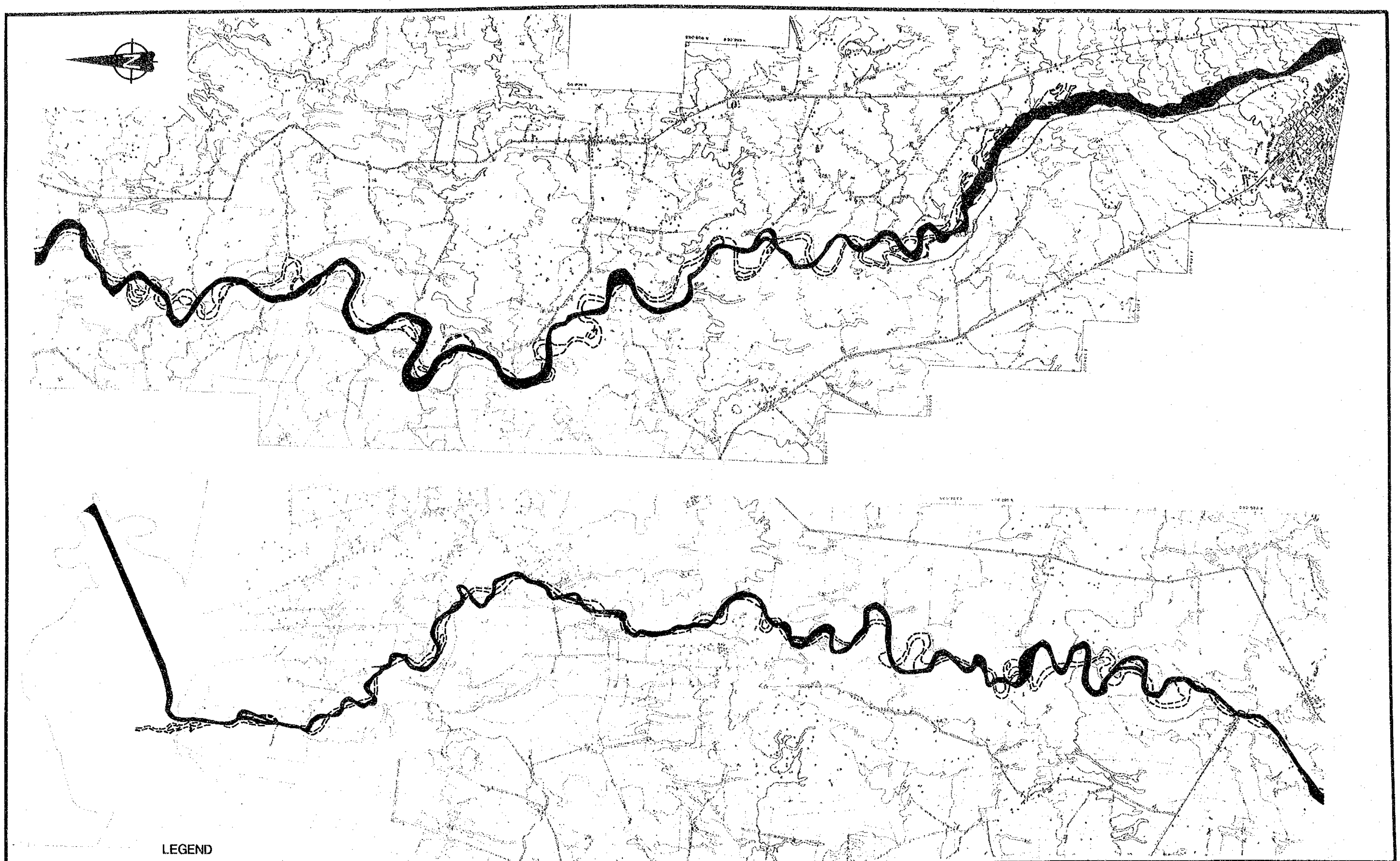
Works	Typical Cross Section	Materials	Notes	Cost(Bs/m)
Gabion		Gabion Iron Wire Cobble Stone	Flexible against embankment deformation. Not difficult to construct. Necessary to maintain the iron wire every 20 years.	17,100
Wet Masonry		Concrete Block Special Form Concrete	Inflexible against embankment deformation. Not difficult to construct. Maintenance free.	15,200
Concrete		Concrete	Inflexible against embankment deformation. Not difficult to construct. Maintenance free. Applied for the heavy stream portion and the place rubbles are not available.	17,300
Asphalt		Asphalt	Flexible against embankment deformation. Difficult to construct, especially for compaction on the slope. Maintenance free. Applied for the place where rubbles are not available.	19,900
Textile Concrete		Textile Concrete Concrete Concrete Bag	Flexible against embankment deformation. Not difficult to construct. Maintenance free.	15,800

Table VII-14 SELECTION OF OPTIMUM CASE FOR GROIN

Works	Typical Cross Section	Materials	Notes	Cost(Bs/no.)
Gabion		Gabion Iron Wire Cobble Stone	Flexible against riverbed fluctuation. Not difficult to construct. Necessary to maintain the iron wire every 20 years. The least expensive type of groin.	45,700 (2,285 Bs/m)
Concrete Block		Concrete Block Special Form Concrete	Flexible against riverbed fluctuation. Not difficult to construct. Necessary to use a special form. Maintenance free. The most expensive type of groin.	127,300 (6,365 Bs/m)
Concrete		Concrete	Inflexible against riverbed fluctuation. Necessary to divert river water. Maintenance free.	111,700 (5,585 Bs/m)
Textile Concrete		Textile Concrete Concrete Concrete Bag	Inflexible against riverbed fluctuation. Not difficult to construct. Maintenance free.	78,700 (3,935 Bs/m)



HISTORICAL CHANGE OF CHAMA RIVER COURCE	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT
Fig. VII-1(1/2)	JAPAN INTERNATIONAL COOPERATION AGENCY



LEGEND

: River Channel Course in 1989

: River Channel Course in 1968

SCALE : 1/70,000

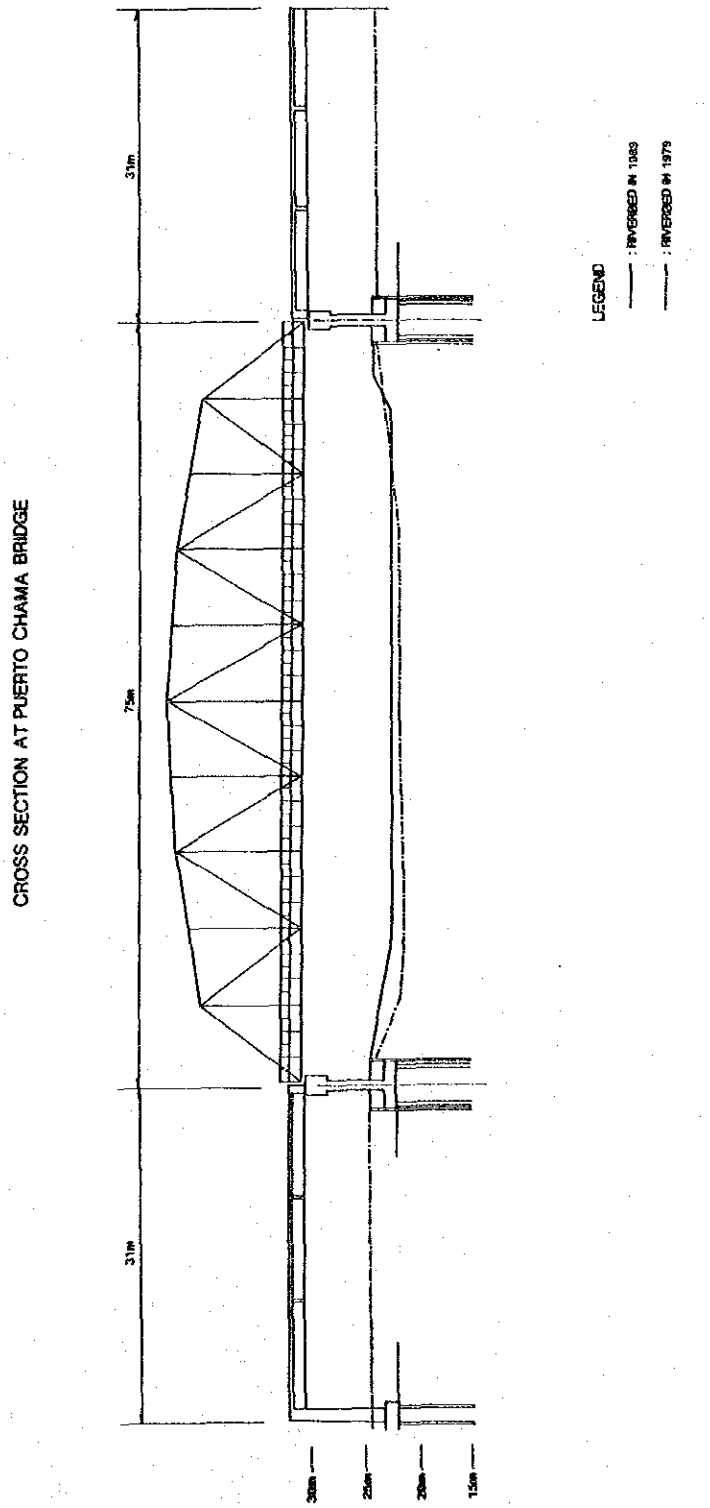
0 1 2 3 4 5km

STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

HISTORICAL CHANGE OF CHAMA RIVER COURCE

Fig. VII-1(2/2)

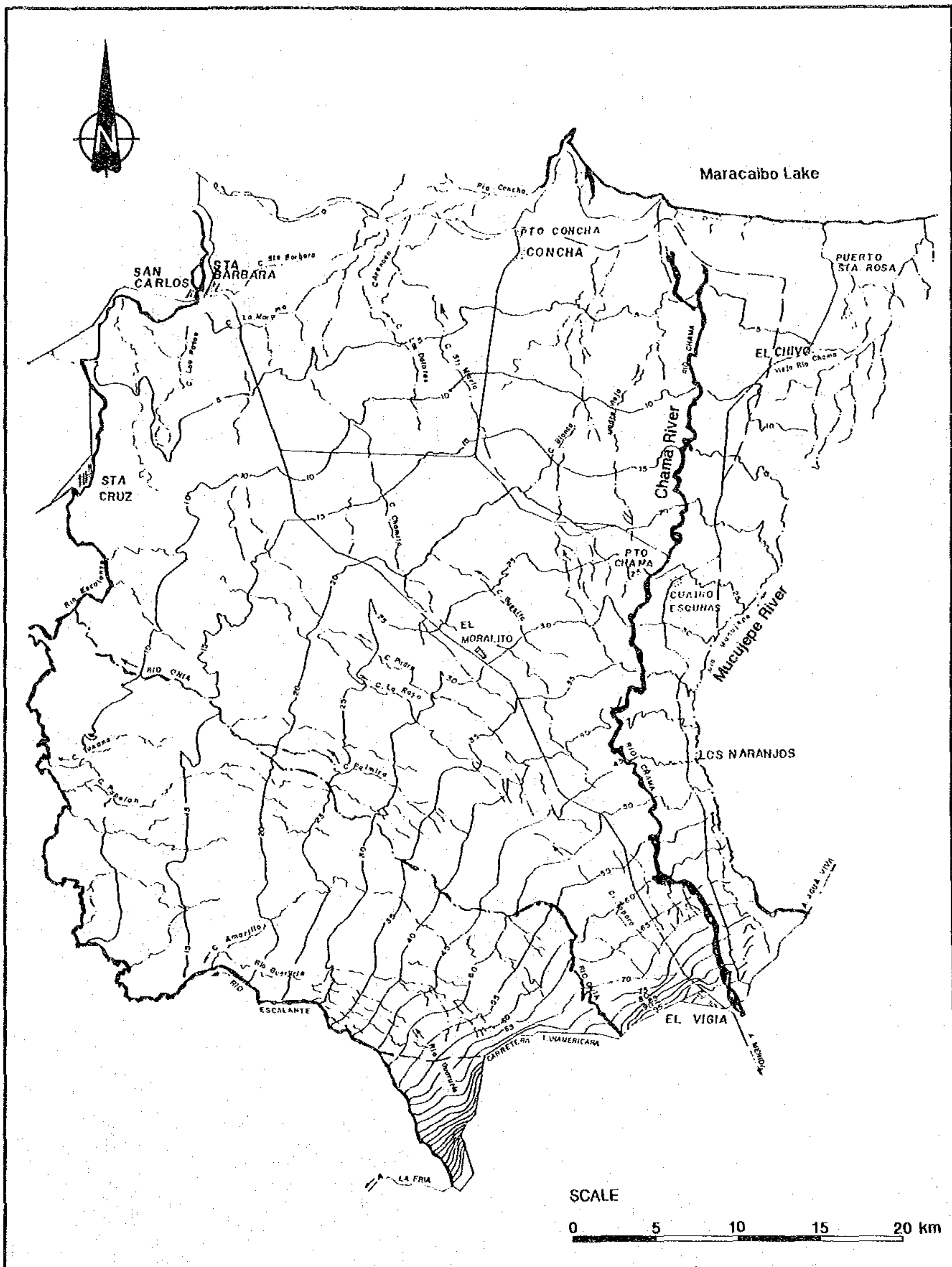


HYSTORICAL CHANGE IN CROSS SECTION AT PUERTO CHAMA BRIDGE

Fig. VII-2

STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

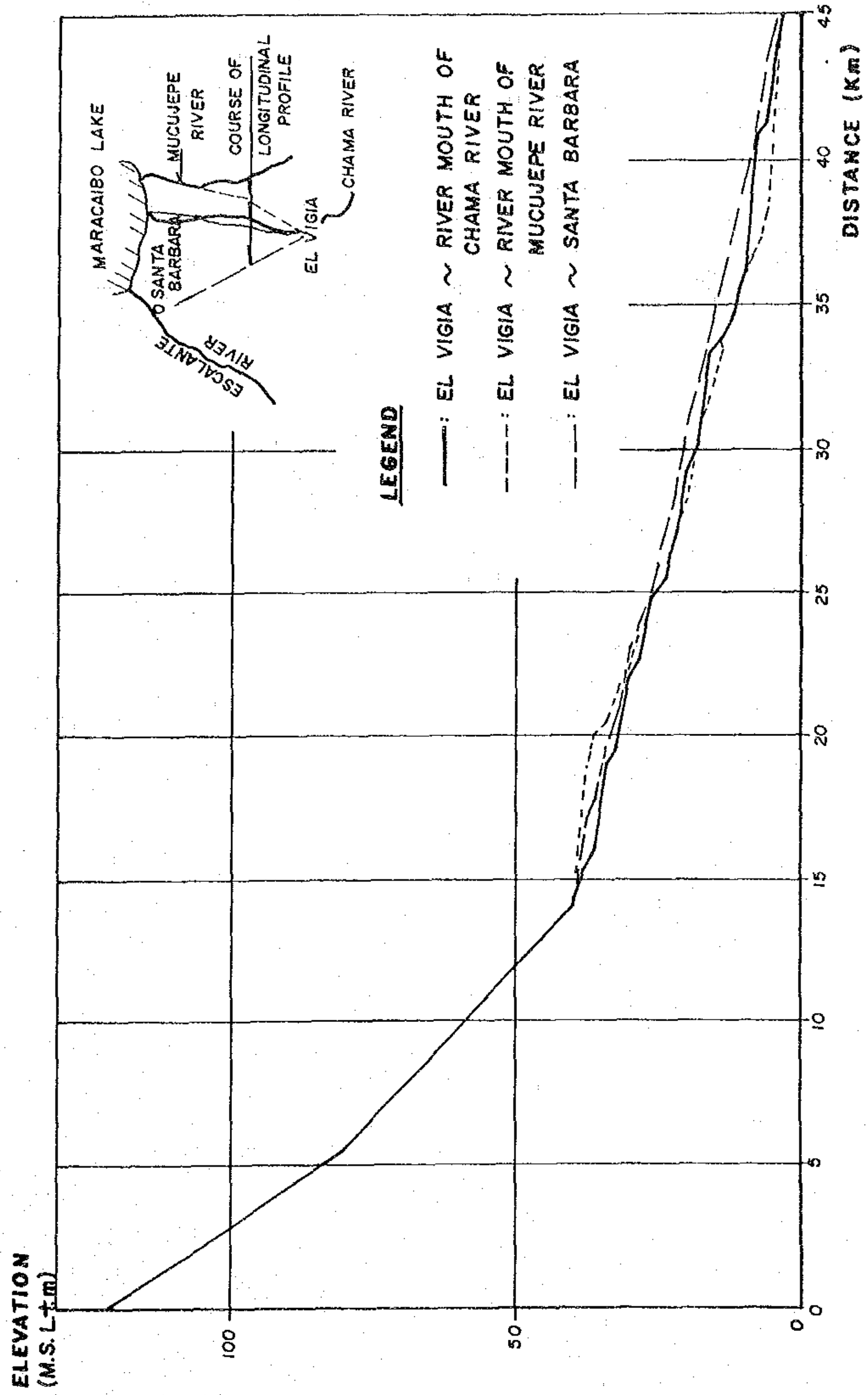


CONTOUR MAP OF THE LOWER REACHES

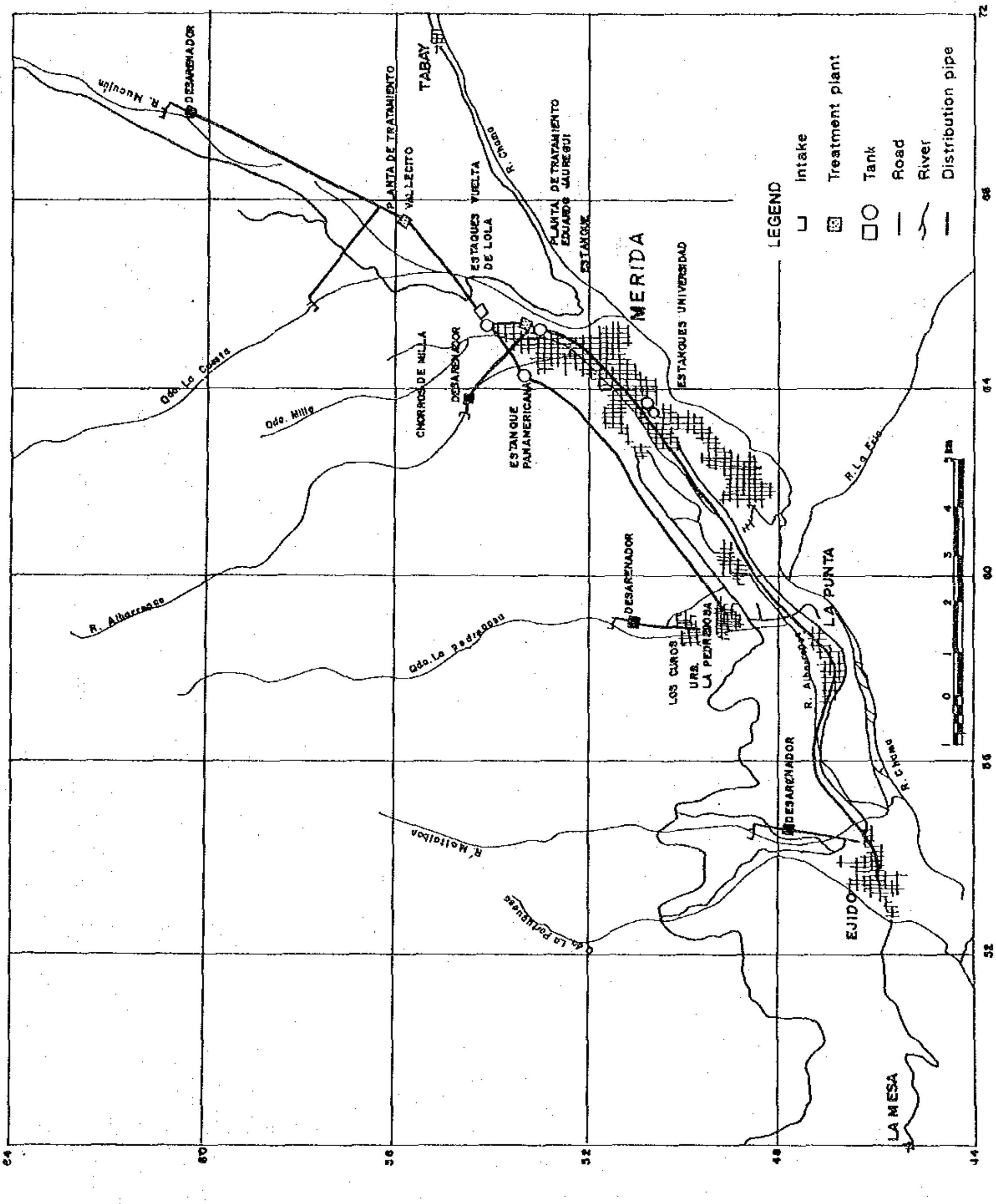
Fig. VII-3

STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

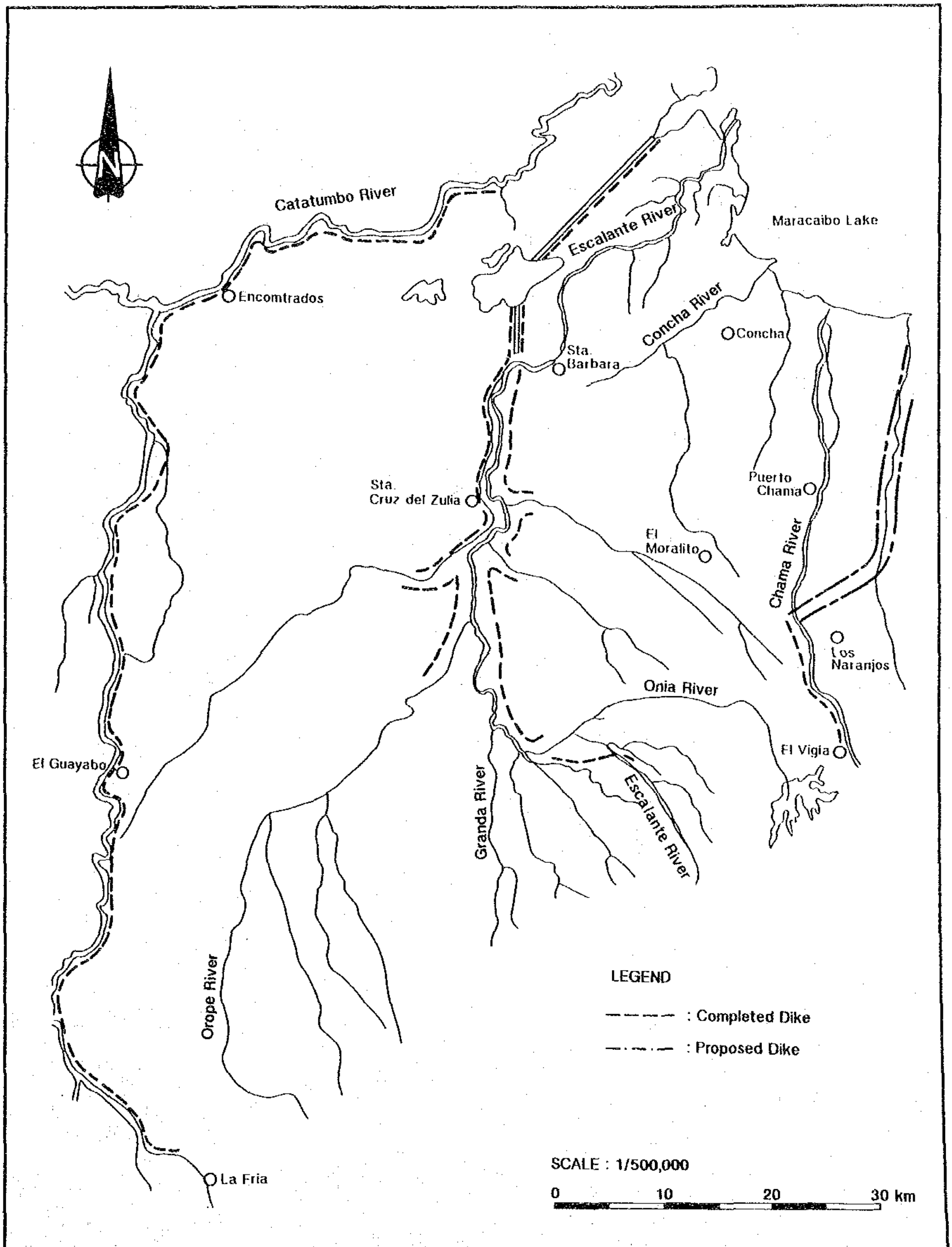
JAPAN INTERNATIONAL COOPERATION AGENCY



LONGITUDINAL PROFILE OF LOWER REACHES	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT
Fig. VII-4	JAPAN INTERNATIONAL COOPERATION AGENCY



MUNICIPAL WATER SUPPLY SYSTEM OF MÉRIDA CITY	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT
Fig. VII-5	JAPAN INTERNATIONAL COOPERATION AGENCY

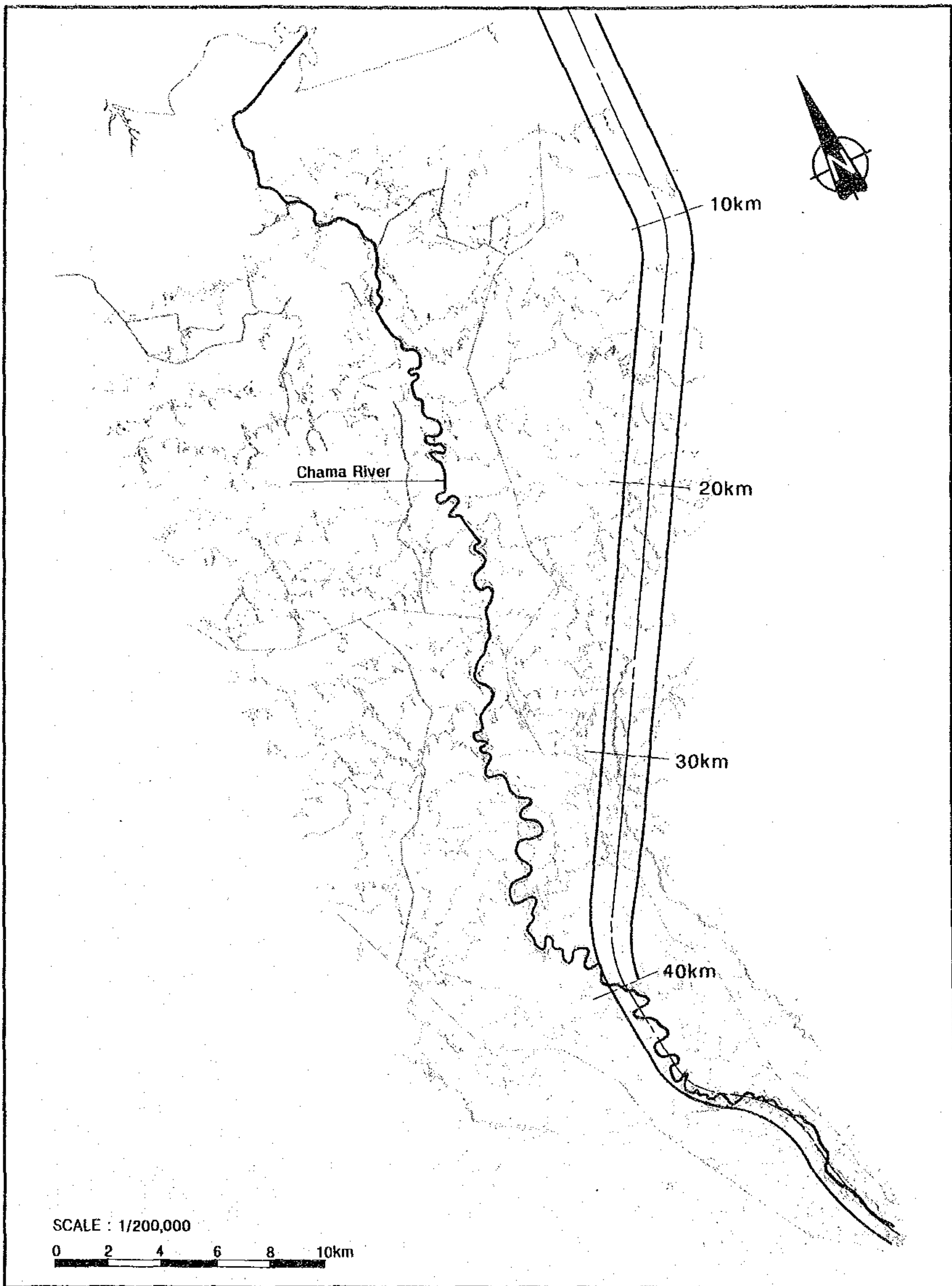


RIVER IMPROVEMENT STRETCHES IN THE SOUTHERN MARACAIBO AREA

Fig. VII-6

STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

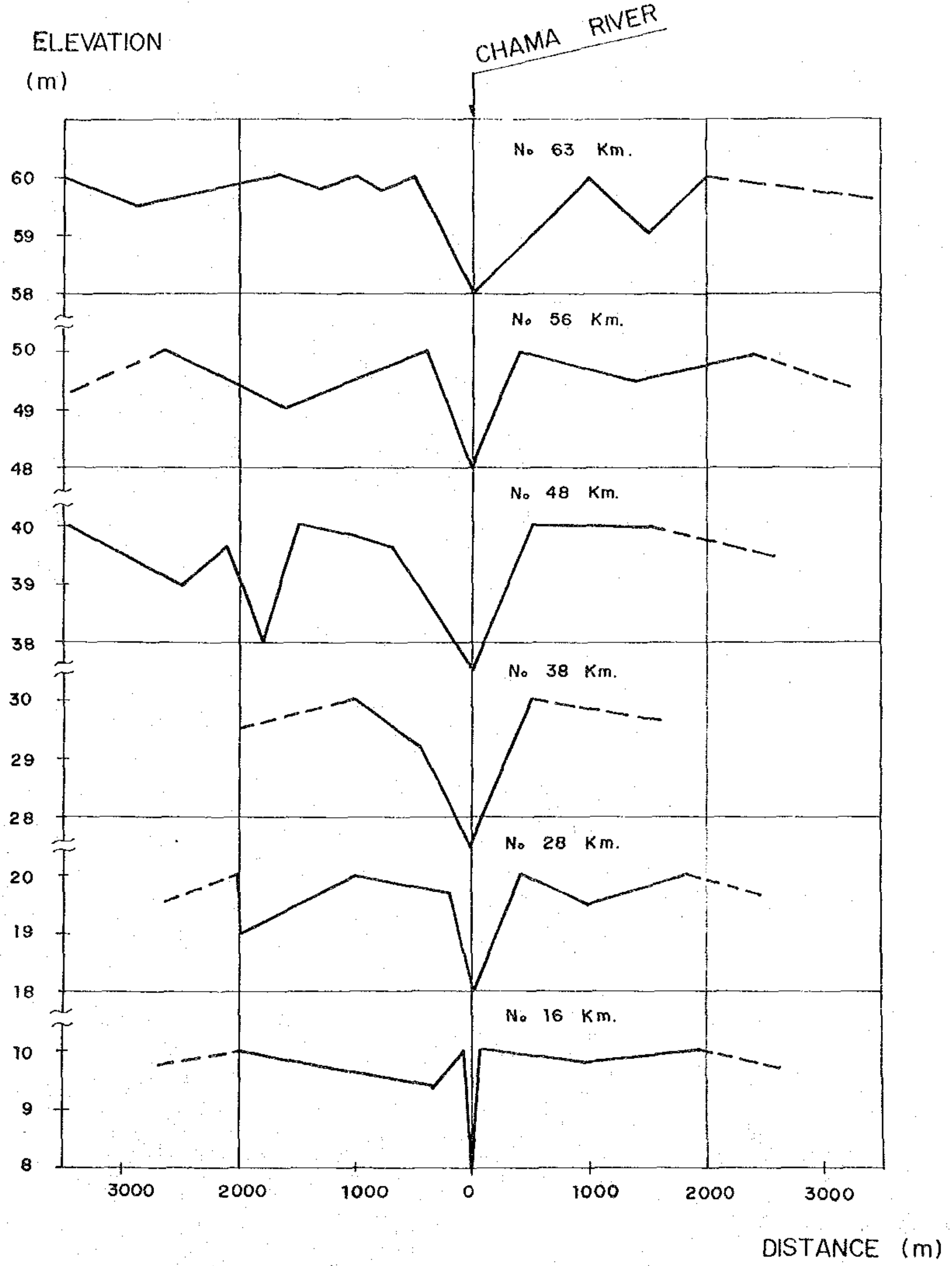


PLAN OF MUCUJEPE DIVERSION CHANNEL

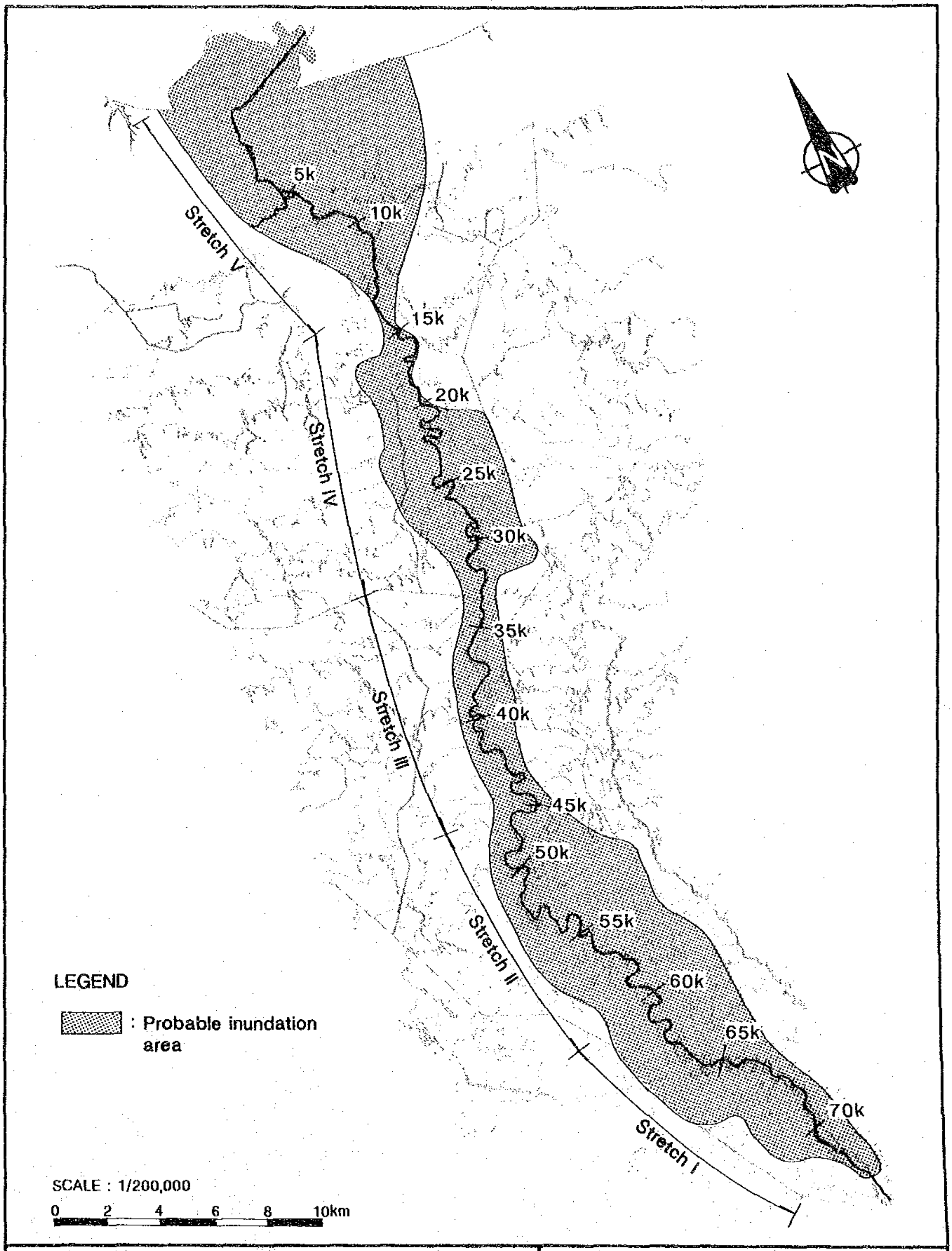
Fig. VII-7

STUDY ON CHAMA RIVER BASIN
CONSERVATION PROJECT

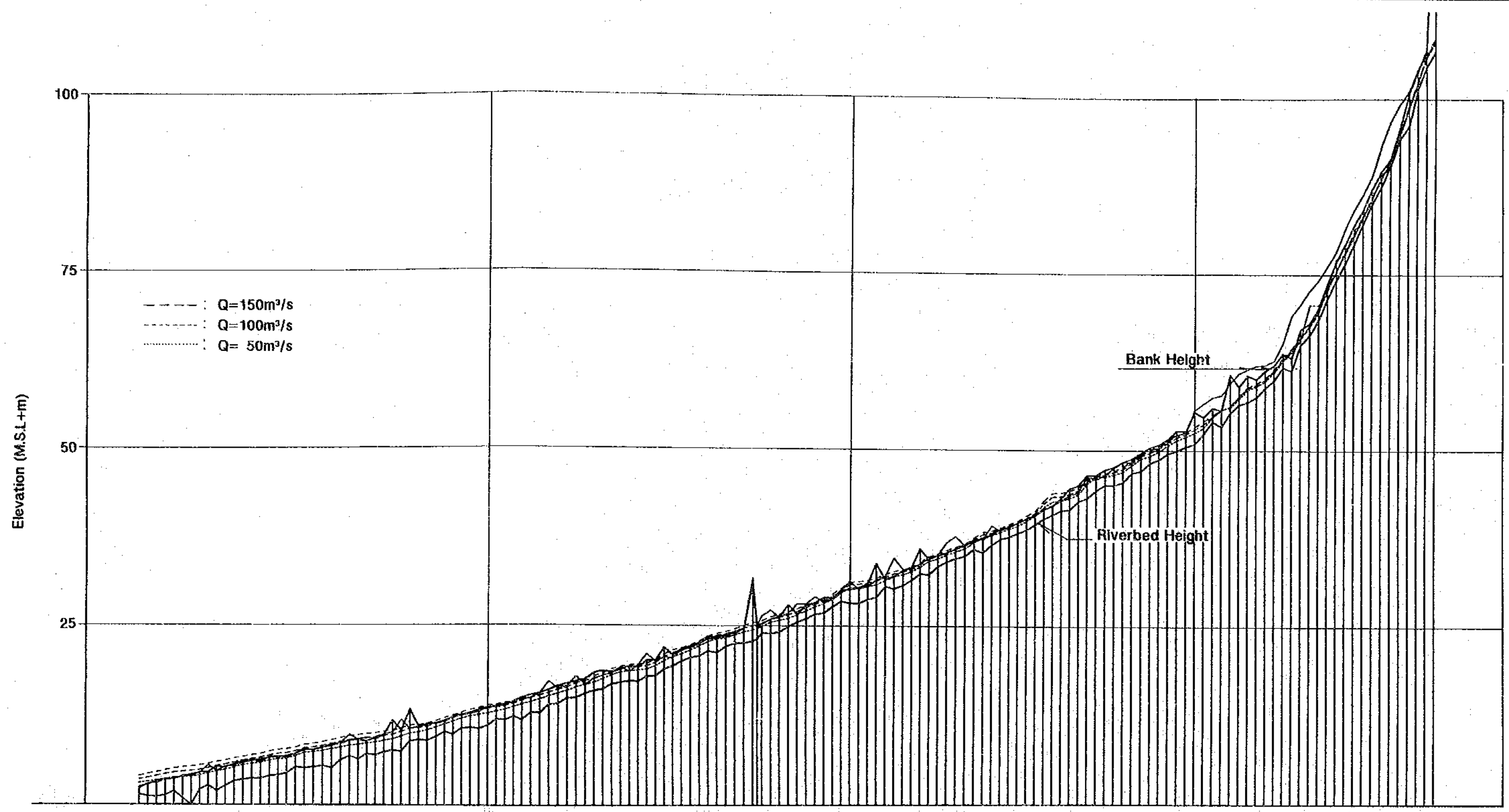
JAPAN INTERNATIONAL COOPERATION AGENCY



CROSS SECTION OF ALLVIAL FAN AREA	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT
Fig. VII-8	JAPAN INTERNATIONAL COOPERATION AGENCY



PROBABLE INUNDATION AREA Fig. VII-9	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY



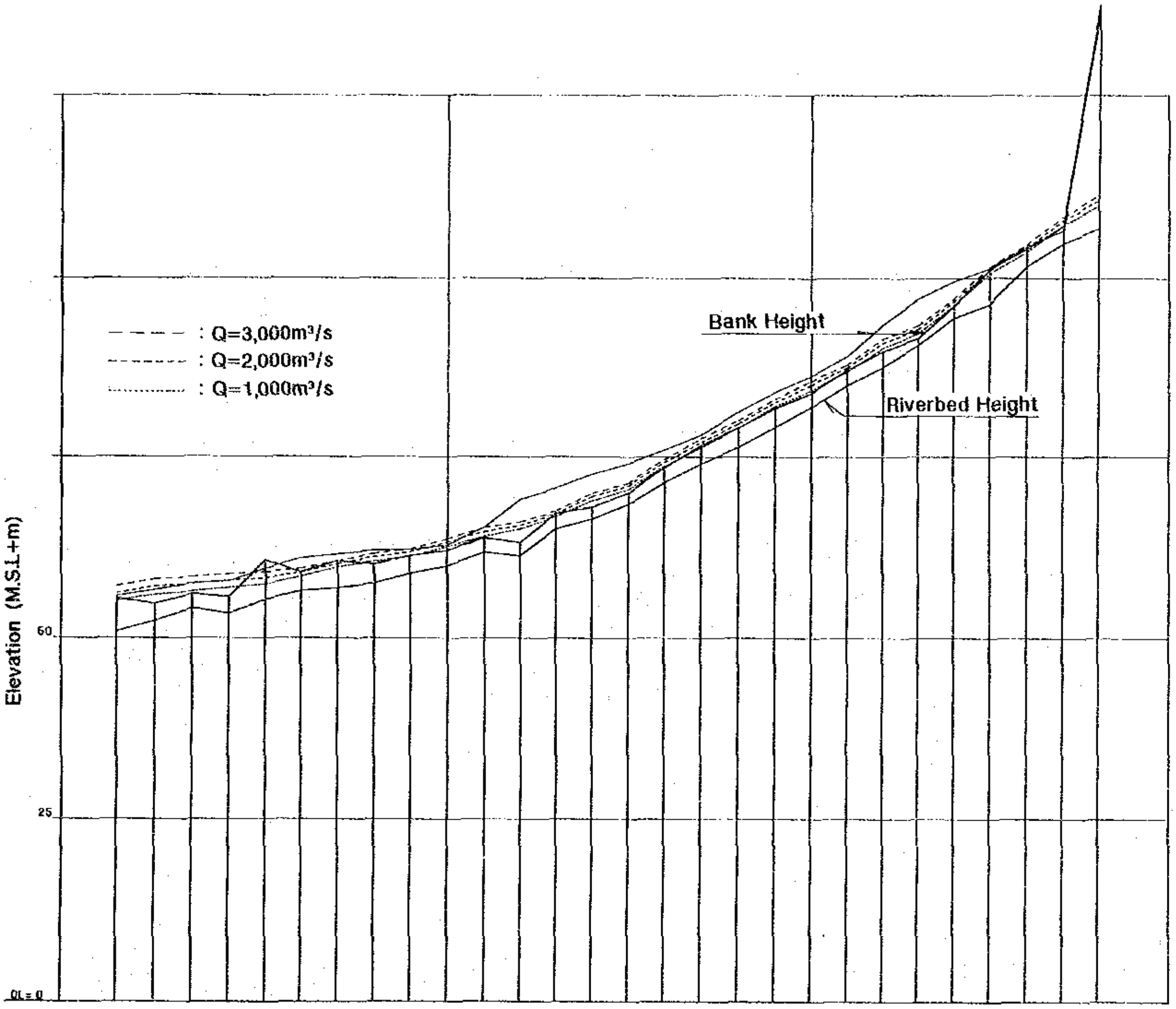
STATION NUMBER	UNIT DISTANCE (m)	ACCUMULATIVE DISTANCE (m)	PRESENT ELEVATION (m) LOWEST RIVER BED	LEFT BANK	RIGHT BANK
0.000	0.0	0.0	1.40	2.20	2.40
0.500	500.0	500.0	1.15	2.90	2.80
1.000	500.0	1000.0	1.09	3.00	3.22
1.500	500.0	1500.0	1.30	3.40	3.50
2.000	500.0	2000.0	1.67	3.60	3.80
2.500	500.0	2500.0	0.92	4.00	3.90
3.000	500.0	3000.0	-0.04	4.20	4.00
3.500	500.0	3500.0	2.10	4.40	4.50
4.000	500.0	4000.0	2.68	5.50	4.50
4.500	500.0	4500.0	1.90	4.70	6.30
5.000	500.0	5000.0	2.61	5.30	5.20
5.500	500.0	5500.0	3.28	5.40	5.60
6.000	500.0	6000.0	3.50	5.80	6.10
6.500	500.0	6500.0	3.65	6.10	6.20
7.000	500.0	7000.0	3.57	5.90	6.00
7.500	500.0	7500.0	3.99	5.50	5.70
8.000	500.0	8000.0	4.11	5.50	6.70
8.500	500.0	8500.0	4.36	5.80	6.70
9.000	500.0	9000.0	5.25	7.10	7.10
9.500	500.0	9500.0	5.10	7.50	7.80
10.000	500.0	10000.0	5.26	7.70	7.60
10.500	500.0	10500.0	5.44	8.00	8.00
11.000	500.0	11000.0	5.11	8.20	8.40
11.500	500.0	11500.0	6.24	8.60	8.60
12.000	500.0	12000.0	6.78	9.80	9.00
12.500	500.0	12500.0	6.38	9.10	9.10
13.000	500.0	13000.0	7.11	9.40	8.60
13.500	500.0	13500.0	6.95	9.10	9.40
14.000	500.0	14000.0	7.98	9.80	9.60
14.500	500.0	14500.0	7.63	10.10	11.60
15.000	500.0	15000.0	7.46	11.90	10.40
15.500	500.0	15500.0	8.90	10.60	13.30
16.000	500.0	16000.0	9.06	10.80	11.00
16.500	500.0	16500.0	9.99	11.10	11.30
17.000	500.0	17000.0	9.53	11.40	11.40
17.500	500.0	17500.0	10.18	11.80	11.60
18.000	500.0	18000.0	9.86	12.20	12.30
18.500	500.0	18500.0	10.68	12.50	12.60
19.000	500.0	19000.0	10.82	12.70	12.60
19.500	500.0	19500.0	10.85	13.00	13.30
20.000	500.0	20000.0	11.10	13.60	13.50
20.500	500.0	20500.0	11.95	13.60	13.70
21.000	500.0	21000.0	11.86	14.10	14.00
21.500	500.0	21500.0	12.35	14.40	14.40
22.000	500.0	22000.0	11.80	15.00	14.80
22.500	500.0	22500.0	12.92	15.30	14.90
23.000	500.0	23000.0	12.85	15.60	15.60
23.500	500.0	23500.0	14.01	17.20	16.00
24.000	500.0	24000.0	14.10	15.10	16.60
24.500	500.0	24500.0	14.67	16.80	16.90
25.000	500.0	25000.0	14.81	17.90	17.20
25.500	500.0	25500.0	15.60	15.70	17.60
26.000	500.0	26000.0	16.80	17.50	18.40
26.500	500.0	26500.0	16.11	18.00	18.70
27.000	500.0	27000.0	16.81	18.90	18.60
27.500	500.0	27500.0	17.03	19.20	18.80
28.000	500.0	28000.0	17.25	18.50	19.90
28.500	500.0	28500.0	17.18	19.50	19.10
29.000	500.0	29000.0	17.86	21.00	20.10
29.500	500.0	29500.0	17.95	20.00	20.10
30.000	500.0	30000.0	18.88	20.50	21.90
30.500	500.0	30500.0	19.30	20.40	20.90
31.000	500.0	31000.0	19.95	21.60	21.70
31.500	500.0	31500.0	20.48	21.80	22.10
32.000	500.0	32000.0	20.68	22.40	22.60
32.500	500.0	32500.0	21.40	23.10	23.50
33.000	500.0	33000.0	21.19	23.20	23.30
33.500	500.0	33500.0	22.02	23.50	23.70
34.000	500.0	34000.0	22.46	23.80	24.10
34.500	500.0	34500.0	22.64	24.60	24.50
[illegible]	[illegible]	[illegible]	[illegible]	31.78	31.98
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36.000	500.0	36000.0	23.86	27.10	25.60
36.500	500.0	36500.0	24.05	26.10	28.20
37.000	500.0	37000.0	24.82	26.70	27.80
37.500	500.0	37500.0	25.45	28.00	25.80
38.000	500.0	38000.0	25.92	28.00	27.80
38.500	500.0	38500.0	26.57	28.90	28.10
39.000	500.0	39000.0	26.79	28.70	28.90
39.500	500.0	39500.0	27.61	29.80	28.60
40.000	500.0	40000.0	28.34	31.20	29.90
40.500	500.0	40500.0	28.12	30.10	30.00
41.000	500.0	41000.0	28.10	30.60	30.30
41.500	500.0	41500.0	28.84	31.30	30.60
42.000	500.0	42000.0	28.95	31.80	33.70
42.500	500.0	42500.0	30.45	34.60	31.50
43.000	500.0	43000.0	30.15	32.90	31.90
43.500	500.0	43500.0	30.69	33.10	32.70
44.000	500.0	44000.0	31.38	33.70	33.20
44.500	500.0	44500.0	32.25	34.50	35.60
45.000	500.0	45000.0	32.19	34.90	34.30
45.500	500.0	45500.0	33.20	36.70	34.90
46.000	500.0	46000.0	33.95	37.60	35.20
46.500	500.0	46500.0	34.42	36.30	35.80
47.000	500.0	47000.0	34.76	36.90	36.40
47.500	500.0	47500.0	35.74	37.20	37.10
48.000	500.0	48000.0	35.28	39.10	37.20
48.500	500.0	48500.0	35.35	38.40	37.90
49.000	500.0	49000.0	37.19	39.10	38.60
49.500	500.0	49500.0	37.51	39.50	38.90
50.000	500.0	50000.0	38.03	40.20	39.50
50.500	500.0	50500.0	38.52	40.60	40.10
51.000	500.0	51000.0	39.28	41.40	40.70
51.500	500.0	51500.0	40.10	42.00	41.50
52.000	500.0	52000.0	40.65	42.70	41.90
52.500	500.0	52500.0	41.29	43.40	43.00
53.000	500.0	53000.0	42.42	43.00	44.40
53.500	500.0	53500.0	42.58	46.10	44.90
54.000	500.0	54000.0	43.02	45.70	45.90
54.500	500.0	54500.0	44.06	46.40	46.30
55.000	500.0	55000.0	44.93	47.30	47.10
55.500	500.0	55500.0	44.86	48.20	47.50
56.000	500.0	56000.0	45.90	48.10	48.20
56.500	500.0	56500.0	45.84	49.50	48.70
57.000	500.0	57000.0	45.95	50.30	49.50
57.500	500.0	57500.0	48.04	50.10	50.30
58.000	500.0	58000.0	48.55	51.50	50.70
58.500	500.0	58500.0	49.40	52.10	51.50
59.000	500.0	59000.0	49.82	52.40	52.70
59.500	500.0	59500.0	50.44	[illegible]	52.60
60.000	500.0	60000.0	50.81	55.80	55.30
60.500	500.0	60500.0	52.25	56.50	54.60
61.000	500.0	61000.0	53.97	57.40	55.90
61.500	500.0	61500.0	53.24	57.70	56.50
62.000	500.0	62000.0	55.15	59.40	58.60
62.500	500.0	62500.0	56.35	60.80	58.90
63.000	500.0	63000.0	56.78	61.40	60.60
63.500	500.0	63500.0	57.44	61.90	60.00
64.000	500.0	64000.0	58.78	62.00	61.20
64.500	500.0	64500.0	59.80	62.80	61.90
65.000	500.0	65000.0	61.87	65.10	63.60
65.500	500.0	65500.0	61.20	69.00	63.00
66.000	500.0	65991.0	64.84	70.60	67.00
66.500	500.0	66491.0	65.26	72.50	67.90
67.000	500.0	66991.0	68.38	74.00	70.00
67.500	500.0	67491.0	71.39	75.60	73.40
68.000	500.0	67991.0	74.01	78.00	76.60
68.500	500.0	68491.0	76.32	81.20	79.00
69.000	500.0	68991.0	79.09	83.90	81.70
69.500	500.0	69491.0	81.90	85.10	83.60
70.000	500.0	69991.0	84.80	88.80	86.90
70.500	500.0	70491.0	87.39	93.20	89.50
71.000	500.0	70991.0	90.95	96.70	91.30
71.500	500.0	71491.0	94.08	99.10	95.70
72.000	500.0	71991.0	95.01	100.90	100.70
72.500	500.0	72491.0	101.18	103.90	103.60
73.000	500.0	72991.0	104.30	106.10	106.70
73.500	500.0	73491.0	108.42	136.30	137.20

STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

NON-UNIFORM CALCULATION RESULT FROM RIVER MOUTH TO EL VIGÍA

Fig. VII-10



Station Number	Unit Distance (m)	Accumulative Distance (m)	Present Elevation (m): Lowest River Bed	Present Elevation (m): Left Bank	Present Elevation (m): Right Bank
60.000	500.0	500.0	50.51	56.50	55.50
60.500	500.0	1000.0	52.85	56.50	54.60
61.000	500.0	1500.0	53.67	57.40	55.90
61.500	500.0	2000.0	53.24	57.70	55.80
62.000	500.0	2500.0	55.16	59.40	60.80
62.500	500.0	3000.0	56.36	60.80	58.90
63.000	500.0	3500.0	56.78	61.40	60.50
63.500	500.0	4000.0	57.44	61.80	60.00
64.000	500.0	4500.0	58.78	62.00	61.20
64.500	500.0	5000.0	59.50	62.50	61.90
65.000	500.0	5500.0	61.67	65.10	63.60
65.500	500.0	6000.0	61.20	68.00	63.00
66.000	500.0	6500.0	64.84	70.80	67.00
66.500	500.0	7000.0	66.25	72.50	67.90
67.000	500.0	7500.0	68.39	74.00	70.00
67.500	500.0	8000.0	71.39	75.80	73.40
68.000	500.0	8500.0	74.01	78.00	76.50
68.500	500.0	9000.0	75.52	81.20	78.00
69.000	500.0	9500.0	78.00	83.90	81.70
69.500	500.0	10000.0	81.90	85.10	83.00
70.000	500.0	10500.0	84.80	85.80	86.80
70.500	500.0	11000.0	87.53	89.20	88.60
71.000	500.0	11500.0	90.36	90.70	91.50
71.500	500.0	12000.0	94.08	96.10	95.70
72.000	500.0	12500.0	98.01	100.90	100.70
72.500	500.0	13000.0	101.18	105.00	103.80
73.000	500.0	13500.0	104.30	108.10	106.70
73.500	500.0	14000.0	108.42	136.90	157.20

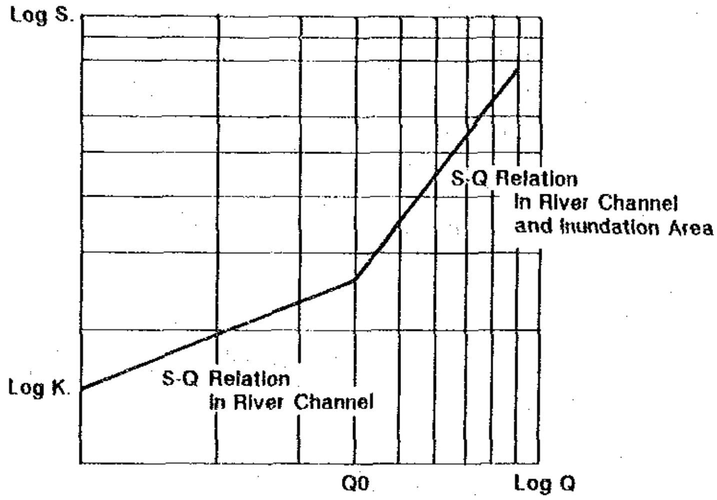
NON-UNIFORM CALCULATION RESULT IN THE STRETCH OF EXISTING DIKE NEAR EL VIGÍA

Fig. VII-11

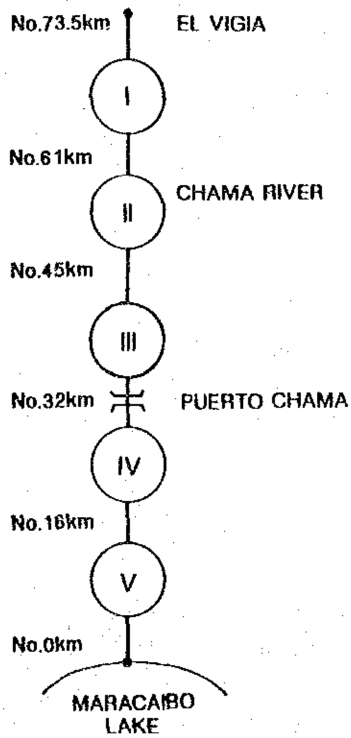
STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

RELATION BETWEEN STRAGEVOLUME AND DISCHARGE



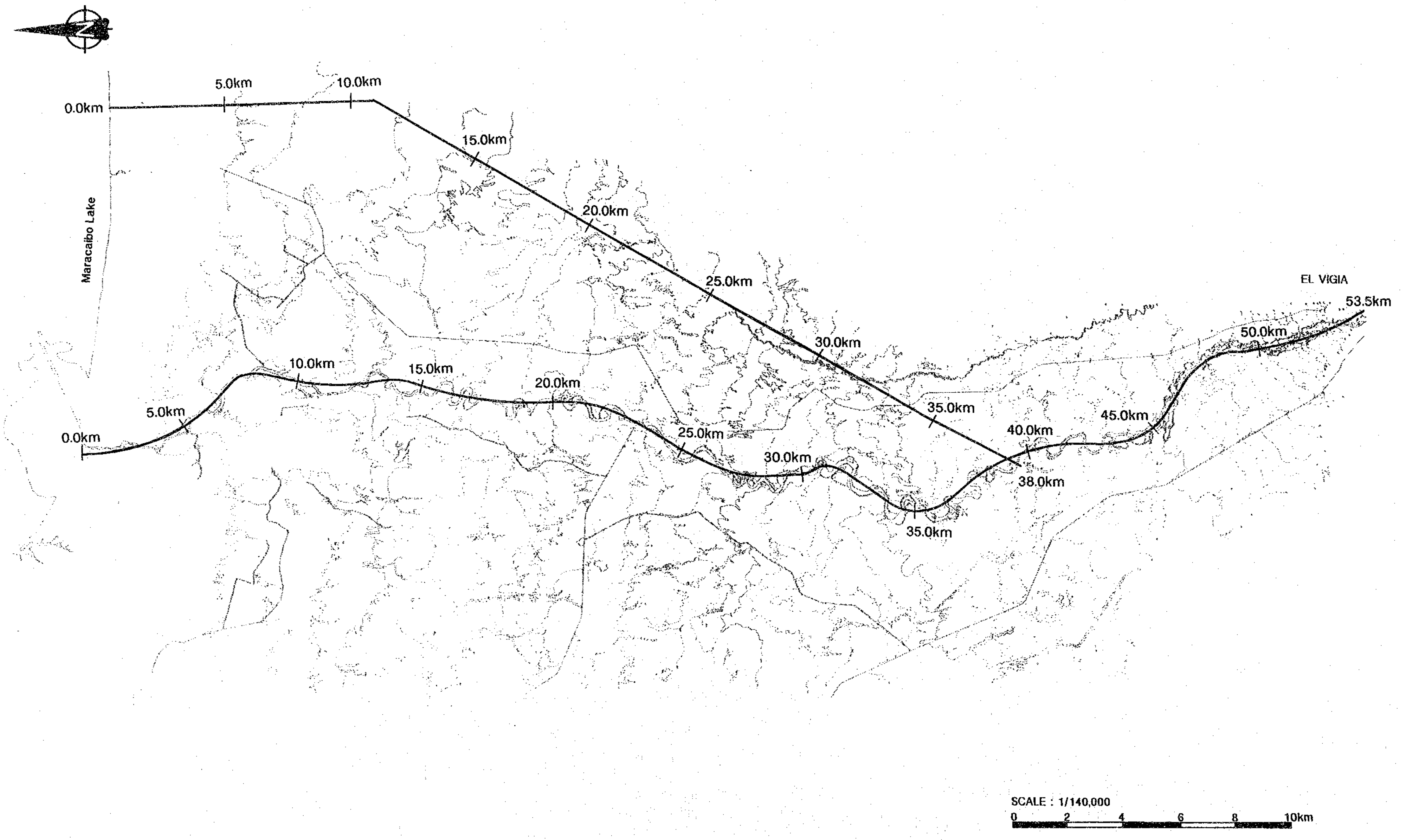
Note: Q0: Flow Capacity



LEGEND

○ : CALCULATION MODEL FOR INUNDATION AREA

FLOOD INUNDATION SIMULATION MODEL FOR LOWER REACHES	STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT
Fig. VII-12	JAPAN INTERNATIONAL COOPERATION AGENCY



STUDY ON CHAMA RIVER BASIN CONSERVATION PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

CENTERLINE OF MEANDERING OF THE CHAMA RIVER AND PROPOSED ALIGNMENT OF THE MUCUJEPE DIVERSION CHANNEL

Fig. VII-13