# 3. INUNDATION AND FLOOD DAMAGE

SUPPORTING REPORT
ON
INUNDATION AND FLOOD DAMAGE

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# SUPPORTING REPORT
# ON
# INUNDATION AND FLOOD DAMAGE

## 1. General

In accordance with the Scope of Work, the study on inundation and flood damage was carried out to clarify the nature and contents of inundation and flooding in each basin in the study area for the Basic and Master plans, and for the First Stage Project.

The Basic and Master Plan studies carried out in Asuncion City and its neighboring area aimed to delineate the planning area, to obtain data for economic evaluation for the year 2005, and to estimate the increment of annual average flood damage. The study for the First Stage Project carried out in Mburicao and Itay river basins which were selected out of the results of the Basic and Master Plan studies aimed to obtain detailed information in connection with the present flooding condition and the presumed flood damage as of 1995.

## 2. Existing Flooding Condition and Damage

The existing flooding condition and damage in Asuncion City and its neighboring area were studied as follows:

### 2.1 Characteristics of Flood

The characteristics of flood were studied from the data compiled by CORPOSANA and the information published in newspapers that have information on flood such as area, cause, date, and others. The data such as inundation water depth, inundation duration, flood frequency and contents of flood damage were collected through the interview survey with residents to clarify the flooding conditions.

#### 2.1.1 Causes of Flood

Flood and flood damage in the study area has been arising from the following circumstances:

(1) Topography and Storm Water

Generally, storm rainfall with high intensity falls on hilly land which characterizes the study area. It concentrates on roads and flows into drainage channels. As mentioned in the sector of River and Drainage Planning, the river gradient varies from 1/34 to 1/318. Most of the gradients are steeper than 1/100 so that the concentration time is short and the peak discharge volume is big.

Floods in the area for the Basic and the Master Plan studies occur mainly along the river course, at the crossing point of rivers and roads, at the confluences of rivers and at the intersections of roads where storm water from various directions are collected as shown in Fig. 3-1 together with the topographic features at the time of the recorded maximum flood.

Therefore, it may be said that the topographic conditions determine the location of flooded areas and the number of inundated areas may not increase in the future, although expansion of the flooded area may occur due to further urbanization.

Fig. 3-2 shows the topographic features in detail and the flood damaged areas of Mburicao and Itay river basins as examples.

(2) Urbanization

The rapid urban development in the study area such as the construction of houses and roads causes the reduction of permeable area resulting in the shortening of storm water concentration time and the increment of runoff coefficient. These phenomena cause the increment of runoff discharge with high peak leading to the increment of inundated area and the duration of traffic interruption. Furthermore, the assets and traffic volume in the inundated area also increase in line with the population increment and economical development.

Under the above situation, flood damage is increased in the synergistic effect of the increment of inundation area and assets and of the increment of traffic volume and flood duration on the roads.

(3) Operation and Maintenance of Existing Drainage Facilities

Except the Centro Basin, most of the drainage channels and ditches serving to drain the runoff discharge in the study area have poor capacity due to negligence in maintenance and the inappropriate reclamation of drainage channels and ditches for the construction of houses and roads as observed in many places.

Drainage facilities were installed throughout the Centro basin area and some in the Las Mercedes and the Mburicao river basins. However, the drainage facilities are not always properly maintained even in the Centro Basin area, and garbage sometimes obstruct the smooth flow of water into the roadside inlet, so that flood damage in several spots and areas still exists.

### 2.1.2 Frequency of Flood

Inundation and flood damage have taken place several times a year at portions such as along the river courses, at the crossing point of rivers and roads, at confluences of rivers, and at the intersections of roads. Based on Fig. 3-3 which shows the frequency of floods by month and year obtained from the data on record, it was generally understood that the frequency of flood is gradually increasing with the urban development. The highest frequency of flood a year was observed in 1983.

## 2.2 Recorded Maximum Flood and Damage

The recorded maximum flood occurred in November 1982. From the map of 1:5,000 scale prepared in 1984 and the data obtained through the interview survey, the extent of damage under the present condition of the study area were estimated as follows:

| | | |
|---|---|---|
| Inundated Area | : | 391 ha |
| Inundated Houses | : | 1,800 houses |
| Number of Vehicles Interrupted on Trunk Roads | : | 64,000 vehicles |
| Number of Inundated Street Intersections | : | 450 intersections |

The recorded maximum flood corresponds to a 30-year return period, based on the daily rainfall record.

## 2.3 Flood Damage in the Basic and Master Plan Areas

Inundation areas and flooding spots spread over Asuncion City and the neighboring cities of Luque, San Lorenzo, Fernando de la Mora and Lambare where inundation and flood damage are much more severe than in other cities like Villa Hayes, Limpio, Mariano R. Alonso, Villa Elisa, Nemby and San Antonio where flood damage is slight and negligible because people live in flood-free places from the topographic point of view.

In the study area other than Metropolitan Asuncion, inundation and flood damage is negligible since it is sparsely populated and assets are few.

Among the cities suffering from inundation and flood damage, Asuncion City, Fernando de la Mora City and Lambare City have the largest inundation areas with many flooding spots.

### 2.3.1 Contents of Flood Damage

The damage caused directly by storm water are broadly classified into two types; namely, (1) traffic interruptions caused by floods flowing on the road surface and the flood from rivers, and (2) submergence of assets along river courses, confluences of rivers, and crossing points of rivers and roads.

Traffic interruptions cause augmentation of travel time and cost of vehicles affected by detours and speed down, as well as loss of productivity, and they vary from less than one hour to six hours.

The submergence of assets consisting mainly of private houses and household effects sometimes last for a maximum of twelve hours. Damage to agricultural crops and others are negligible.

### 2.3.2 Damage in Each Basin

Among the 31 basins into which the study area had been divided, 22 were identified as having flood damage and their present flood damage conditions are described hereinafter.

Varadero River Basin (B-1)

Floods occur frequently for a short time at several street intersections and are causing local traffic inconveniences.

Fig. 3-4(1/6) and Table 3-1 show the flooded area and flood damage at the time of the recorded maximum flood. There were thirteen (13) inundated street intersections and eight (8) inundated houses.

Jardin River Basin (B-2)

Since storm water concentrates on the streets and flows into the inlet at the uppermost reach of the river and to the intersection of the road at the upper stream, short time traffic interruption frequently occur in these spots.

Fig. 3-4(1/6) and Table 3-1 show the flooded areas and flood damage at the time of the recorded maximum flood. There were three (3) inundated houses.

Centro Basin (B-3)

There is no conspicuous flood damage in the area where the water drainage system financed under the Inter-American Development Bank (IDB) loan has been completed in 1983. On the streets not covered by the system and at the portions where maintenance of the system is not adequate, floods still occur frequently.

Fig. 3-4(2/6) and Table 3-1 show the flooded area and flood damage at the time of the biggest flood after the completion

of the above drainage system. There were one (1) inundated trunk road, twelve (12) inundated street intersections, and twelve (12) inundated houses.

Jaen River Basin (B-4)

Since the upper stream of the river was filled up for the construction of streets without storm water drainage facilities, the constructed streets are forced to play the role of drainage channel when it rains. Therefore, traffic interruption occurs whenever it rains, though the flood damage depends on the runoff discharge volume.

Fig. 3-4(1/6) and Table 3-1 show the flooded area and flood damage at the time of the recorded maximum flood. There were eight (8) inundated street intersections and eight (8) inundated houses.

Tacumbu Basin (B-5)

The floods occur on the streets in every storm rainfall because the streets were constructed without drainage facilities. However, no damage to houses was found.

Fig. 3-4(1/6) and Table 3-1 show the flooded area and flood damage at the time of the recorded maximum flood. There were seven (7) inundated street intersections.

Salamanca River Basin (B-6)

Traffic hindrance at the uppermost reach of the river and inundation of houses in its lower reaches occur at the time of rainfall with high intensity because the continuous dumping of rubbish into the river reduces the river's flow capacity.

Fig. 3-4(1/6) and Table 3-1 show the flooded area and flood damage at the time of the recorded maximum flood. There were one (1) inundated street intersection and thirty-one (31) inundated houses.

Zanja Moroti River Basin (B-7)

Although the trunk roads are not affected, storm water flowing down into several portions of the river disrupts traffic at the time of heavy rain. Floods cause inconveniences to people in the basin.

Fig. 3-4(1/6) and Table 3-1 show the flooded area and flood damage at the time of the recorded maximum flood. There were five (5) inundated street intersections and eleven (11) inundated houses.

Ferreira River Basin (B-8)

Together with the inundation damage from the river in the downstream, floods along the Pozo Favorito Street and the crossing point of Jose Felix Bogado Avenue and Ferreira River are giving serious damage to traffic. Especially, the traffic interruption occurring two or three times a year along Jose Felix Bogado Avenue causes much adverse influence on the economic activities since this avenue is one of the trunk roads connecting the center of Asuncion City with Lambare City.

Fig. 3-4(3/6) and Table 3-1 show the flooded area and flood damage at the time of the recorded maximum flood. There were one (1) inundated trunk road, seventeen (17) inundated street intersections, and eight (8) inundated houses.

Villa Universitaria Basin (B-9)

Floods of short duration occur on and near the Jose Felix Bogado Avenue but the frequency of occurrence is low, and flood in other areas of this basin cannot be found. Flood damage in this area can be described as relatively minor among the basins.

Fig. 3-4(3/6) and Table 3-1 show the flood area and flood damage at the time of the recorded maximum flood.

Las Mercedes River Basin (B-10)

Although the storm water drainage system financially assisted by the Inter-American Development Bank (IDB) has been completed, floods still occur on streets and trunk roads that are not covered by the system.

Fig. 3-4(4/6) and Table 3-1 show the flooded area and flood damage at the time of flood after the completion of the drainage system. There were one (1) inundated trunk roads and two (2) inundated street intersections.

Mariscal Lopez Basin (B-11)

The street along the Las Mercedes River becomes flooded at the time of heavy rain and storm water flows down into the river at its lower reaches.

Fig. 3-4(4/6) and Table 3-1 show the inundated area and flood damage at the time of the recorded maximum flood. There were five (5) inundated street intersections.

Bella Vista River Basin (B-12)

Storm water concentrating on the Brasilia Avenue flows down to the starting point of the Bella Vista River through the unpaved street. Flood damage in the basin is serious although the catchment area is small.

Fig. 3-4(4/6) and Table 3-1 show the inundated area and flood damage at the time of the recorded maximum flood. There were one (1) inundated trunk road, six (6) inundated street intersections, and fourteen (14) inundated houses.

Tablada River Basin (B-13)

The pattern of flood in this basin is similar to that in the Bella Vista River Basin bordering on the Tablada River Basin, i.e., flood damage occurs in the upstream and causes traffic

interruption at the Brasilia Avenue. Although partial revetment works were privately provided at the uppermost reach of the river, the flow capacity of the river is insufficient, especially at the tunnel constructed under the railway at its downstream.

Fig. 3-4(4/6) and Table 3-1 show the inundated area and flood damage at the time of the recorded maximum flood. There were one (1) inundated trunk road, five (5) inundated street intersections, and six (6) inundated houses.

Mburicao River Basin (B-14)

Inundation from the river and flooding on the roads causing the inundation of houses and traffic interruption along the trunk roads occur at many points with high frequency. Traffic interruption is serious especially at the crossing points of Mburicao River and Generalisimo Franco Avenue, as well as Mariscal Lopez Avenue, and along Eusebio Ayala Avenue with very high frequency. At the said crossing points, floods on the road are also caused by inundation from the river. The inundation and flood damage in this basin is one of the most serious among the basins.

Fig. 3-4(4/6) and Table 3-1 show the flooded area and flood damage at the time of the recorded maximum flood. There were eight (8) inundated trunk roads, sixty-seven (67) inundated street intersections, and one-hundred (100) inundated houses.

Ycua Carrillo River Basin (B-15)

Generally, the river has a sufficient flow capacity but at the confluences of the tributaries, inundation from the river occurs, especially at the crossing point of the river and the railway.

Fig. 3-4(5/6) and Table 3-1 show the inundated area and flood damage at the time of the recorded maximum flood. There were two (2) inundated street intersections and twenty-two (22) inundated houses.

Santa Rosa River Basin (B-16)

Inundation from the river at the crossing point of the river and Artigas Avenue as well as Santisimo Sacramento Avenue occur two or three times a year because the river width is narrow in the upper reaches above Artigas Avenue, and yet several small ditches join together at many points. However, the ponding of water in this area lessens the inundation damage in the downstream from the Artigas Avenue.

Fig. 3-4(5/6) and Table 3-1 show the flooded area and flood damage at the time of the recorded maximum flood. There were one (1) inundated trunk road, eight (8) inundated street intersections, and forty-four (44) inundated houses.

Tres Puentes Cue River Basin (B-17)

Damage caused by floods is not serious since flood frequency and population density is low and the traffic volume is small at present.

Fig. 3-4(5/6) and Table 3-1 show the inundated area and flood damage at the time of the recorded maximum flood. There were one (1) inundated trunk road, one (1) inundated street junction, and twenty-two (22) inundated houses.

Itay River Basin (Upstream from Aviadores del Chaco Avenue) (B-18)

Since the basin has the largest catchment area and the most gentle river gradient among all the basins within the study area, the characteristics of inundation and flood damage are different from those in other basins in point of duration and area of inundation.

At the junction of Boggiani Avenue and Eusebio Ayala Avenue, as well as along Madame Lynch Avenue, floods habitually take place and cause traffic interruption and house inundation. The frequency exceeds ten (10) times a year.

Fig. 3-4(6/6) shows the inundated area at the time of the recorded maximum flood. Inundation took place along all the

rivers and tributaries, including the ditch along Madame Lynch Avenue and the Aviadores del Chaco Avenue. In Grupo Habitacional Aeropuerto area, the maximum depth of inundation reached up to 1.5 m and ponding water lasted for more than 12 hours. As shown in Table 3-1 which indicates the flood damage at the time of the recorded maximum flood, the number of inundated trunk roads, street intersections and houses were six (6), two hundred forty-three (243), and one thousand three hundred twenty-five (1,325), respectively.

This basin, especially along the Madame Lynch Avenue and its upper stream including the intersection of Boggiani Avenue and Eusebio Ayala Avenue, is suffering from flood damage most seriously in the study area.

Lambare River Basin (B-19)

As shown in Fig. 3-4(3/6), the pattern of flood in this basin is similar to that in the Mburicao River Basin, i.e., the inundation damage on houses occurs at the confluence of the rivers, and the floodwaters on the roads at several points in all its subbasins flow towards the uppermost reach of the river.

One of the most seriously damaged areas are at the crossing point of the Lambare River and the Fernando de la Mora Avenue, and at the uppermost reaches of Sosa River, a tributary of Lambare River. At the uppermost reach of the Lambare River, flood frequency exceeds five (5) times a year. As shown in Table 3-1 which indicates the flood damage at the time of the recorded maximum flood, the number of inundated trunk roads, street intersections and houses were six (6), sixty-nine (69) and two hundred eleven (211), respectively.

San Lorenzo River Basin (B-23)

Inundation of houses and traffic interruption occur in the upstream of the San Lorenzo River, especially at the crossing point of the river and the trunk roads connected to the national roads (Route 1 and Route 2). However, the duration and frequency of the floods are short.

It is difficult to pinpoint the extent and place of the damage because there is no suitable map for the estimation in this basin.

Zeballos Cue River Basin (B-26)

Traffic interruption caused by flood occurs on the unpaved road along the Zeballos Cue River and the houses along the river are suffering from the inundations. However, population density in this basin is low so that the damage is not so serious.

It is difficult to pinpoint the extent and place of the damage because there is no suitable map for the estimation in this basin.

Paso Cai River Basin (B-27)

The pattern of flood and the situation of the basin is similar to that in the Zeballos Cue River Basin. Traffic interruption caused by flood occurs on the unpaved road along the Paso Cai River and houses built near the river are suffering from the inundations. However, the density of population is low in this basin so that flood damage is not so serious.

It is difficult to pinpoint the extent and place of the damage because there is no suitable map for the estimation in this basin.

The following basins have no conspicuous flood damage:

Itay River Basin (dowstream) (B-18)
Valle Apua River Basin (B-20)
Villa Elisa River Basin (B-21)
Nemby River Basin (B-22)
Tayazuape River Basin (B-24)
Ycua Dure River Basin (B-25)
Mariano Alonso River Basin (B-28)
Villa Hayes River Basin (B-29)
Petropar River Basin (B-30)
Achucarro River Basin (B-31)

### 2.3.3 Damage on Trunk Roads

In the study area, six (6) trunk roads radiate from the center of Asuncion City and they are connected with each other by lateral circumferential roads. During heavy rains, the smooth flow of traffic is interrupted on several spots on these roads.

Fig. 3-5 shows the present traffic volume on the trunk road network obtained from the study results of Urban Planning based on the Urban Transport Study in Asuncion Metropolitan Area. The frequency of traffic interruption and volume of traffic especially on the roads enumerated hereunder have a big influence to the socio-economic activities in the study area and to whole the country.

- Artigas Avenue
- Espana Avenue (Generalisimo Franco, General Genes, Aviadores del Chaco)
- Mariscal Lopez Avenue
- Eusebio Ayala Avenue
- Fernando de la Mora Avenue
- General Maximo Santos Avenue and Jose Felix Bogado Avenue
- Madame Lynch Avenue

Fig. 3-6 shows these trunk roads and the flooded portions, and Table 3-2 gives the total number of vehicles stranded which were counted individually at each flooded portion at the time of the recorded maximum flood. The present flood damage condition on the above roads are described hereunder.

Artigas Avenue

Artigas Avenue stretches in the northern part of Asuncion City and extends to Poso Colorado City through Mariano R. Alonso City after connecting with Route 9.

In the study area, the flooded spots of this road are found in the following basins:

- Tres Puentes Cue River Basin (1 spot)
- Santa Rosa River Basin (1 spot)
- Mburicao River Basin (1 spot)

Among the above traffic-interrupted spots, the interruption at the crossing point of Mburicao River is the most serious.

Espana Avenue

This avenue has one of the biggest traffic volumes in the study area and its extension, the Aviadores del Chaco Avenue, passes through Luque City and Aregua City. Espana Avenue is the route to the international airport.

In the study area, the flooded spots on this road are found in the following basins:

- Mburicao River Basin (1 spot)
- Itay River Basin (2 spots)

At the above three (3) spots, traffic interruption is very serious, and flood frequency on the road is extremely high; even weak and short duration rainfall causes traffic interruption.

Mariscal Lopez Avenue

This avenue is connected to Route 1 which reaches up to Encarnacion City and to Route 2 which stretches up to Stroessner City at San Lorenzo City. The flooded spots on this avenue are found in the following basins:

- Las Mercedes River Basin (1 spot)
- Mburicao River Basin (1 spot)
- Itay River Basin (3 spots)

Traffic interruption in the four (4) spots in the Mburicao and the Itay river basins are more serious than that at Las

Mercedes.

Eusebio Ayala Avenue

This avenue is connected to Route 1 and Route 2 at San Lorenzo City, as well as to Mariscal Lopez Avenue, and both sides of the road are commercial areas. The flooded spots on this avenue are found on the following basins:

- Mburicao River Basin (2 spots in the upstream)
- Itay River Basin (2 spots in the upstream)

Among the above-said four (4) spots, traffic interruption at the junction of Eusebio Ayala Avenue and Boggiani Avenue is one of the most serious in the study area from the viewpoint of flood duration, flood frequency, and traffic volume.

Fernando de la Mora Avenue

This avenue passes through Fernando de la Mora City through the biggest bus terminal in Metropolitan Asuncion. The flooded points on this road are two in the Lambare River Basin, which are situated at the crossing points of the Lambare River and the Sosa River which is an upstream tributary of Lambare River. Though flood duration is not long, flood frequency is very high and storm water in the aforesaid two spots is fast.

General Maximo Santos Avenue and Jose Felix Bogado Avenue

General Maximo Santos Avenue extends from the center of Asuncion City to Lambare City, while Jose Felix Bogado Avenue extends from the eastside of Asuncion City and joins General Maximo Santos Avenue on the way to Lambare City.

On General Maximo Santos Avenue and Jose Felix Bogado Avenue, there are one (1) and two (2) flooded spots, as follows:

- Gen. Maximo Santos Avenue (1 spot in Lambare River Basin)
- J.F. Bogado Avenue (1 spot in Ferreira River Basin and 1 spot in Villa Universitaria area)

Though the frequency of flood is relatively low, the influence of the flood damage is serious when both routes are simultaneously interrupted by storm water because the traffic volume on these roads is considerably big.

Madame Lynch Avenue

Madame Lynch Avenue stretches near the eastern boundary of Asuncion City and it is playing an important role in the socio-economic activities of the city because all the major trunk roads mentioned above are crossing this road. Flood on almost the entire portion of the avenue comes from the channel constructed along this avenue and the natural ditches that connect with the channel.

The frequency of flood on this avenue is extremely high and flood duration is relatively long compared to the other flooded spots mentioned before.

The total number of vehicles affected at the time of the recorded maximum flood is estimated at 14,000 cars and 3,000 buses.

## 2.4 Magnitude of Flood Damage

As shown in Fig. 3-7, 15 basins among the aforementioned 22 basins are suffering from flood damage more seriously than the others. The 15 basins with more serious flood damage are the following:

Varadero River Basin (B-1)
Jardin River Basin (B-2)
Jaen River Basin (B-4)
Salamanca River Basin (B-6)
Zanja Moroti River Basin (B-7)
Ferreira River Basin (B-8)

Las Mercedes River Basin (B-10)

Mariscal Lopez Basin (B-11)

Bella Vista River Basin (B-12)

Tablada River Basin (B-13)

Mburicao River Basin (B-14)

Ycua Carrillo River Basin (B-15)

Santa Rosa River Basin (B-16)

Itay River Basin (upstream from Aviadores del Chaco Avenue) (B-18)

Lambare River Basin (B-19)

The basins that suffer from flood damage but less serious than the above 15 basins are as follows:

Centro Basin (B-3)

Tacumbu Basin(B-5)

Villa Universitaria Basin (B-9)

Tres Puentes Cue River Basin (B-17)

San Lorenzo River Basin (B-23)

Zeballos Cue River Basin (B-26)

Paso Cai River Basin (B-27)

Tables 3-1 and 3-3 show the flood damage at the time of the recorded maximum flood and the evaluation considering the frequency of flood, respectively. Judging from these tables , the basins having the most serious inundation and flood damage are the Itay River Basin, the Mburicao River Basin and the Lambave River Basin in that order.

## 3. Presumed Flood Damage in Year 2005

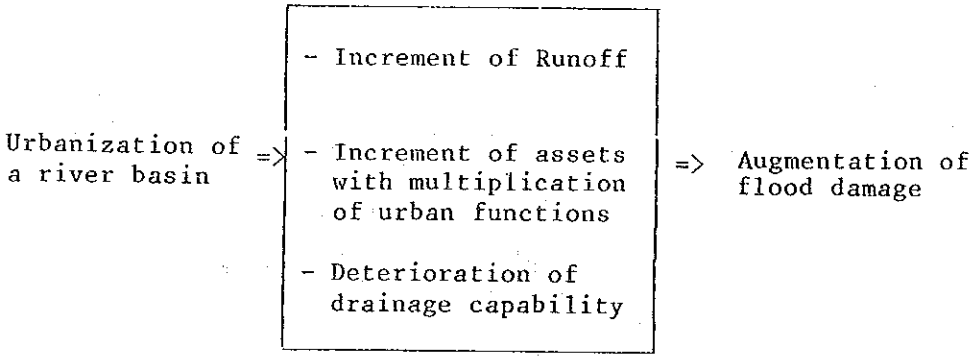
The presumed flood damage in the year 2005 was estimated with regard to the representative river basins on the basis of the following basic concept.

### 3.1 Basic Concept

As an area develops, runoff discharge therein will augment and the inundation area will expand because urban development results in the reduction of permeable area. Population increment also

increases flood damage to assets, therefore, flood damage to assets will increase by the synergistic effect of assets and runoff discharge increment. On the other hand, damage due to traffic interruption will also increase by the synergistic effect of traffic volume and inundation duration increment.

Augmentation of flood damage in areas being rapidly urbanized is attributed to insufficient drainage capacity in relation to the volume of storm water runoff as schematized below:




Flood damage, without any appropriate countermeasure for drainage of storm water, tends to augment in a river basin being urbanized. The flood damage condition in 2005 under the same drainage system condition at present are obtained as follows.

## 3.2 Presumed Flood Damage in Representative River Basins

For the estimation of annual average flood damage in monetary terms under the 2005 condition, the number of inundated houses and interrupted vehicles in each return period of flood (1.1, 2, 3, 5, 10, 30-year) were estimated for the representative river basins; namely, Ferreira and Mburicao.

### Inundated Houses

The data for the estimation of the number of inundated houses in the foregoing return periods of flood under the 2005 condition are (1) runoff discharge under present and 2005 conditions estimated in the sector of Hydrology, (2) cross sections of inundated area, (3) inundated area, inundated width and number of inundated houses

at the time of the recorded maximum flood obtained through the field survey, and (4) number of houses per unit area under 2005 condition estimated in the sector of Urban Planning.

Based on the data of (1) and (2), the flood water depth and its corresponding inundation width to each return period of flood under the 2005 condition were estimated by Manning's formula. The estimation method confirmed that the data of (3) well coincide with the estimation results of (1) and (2) in the present condition. The inundated areas in each return period of flood were obtained by multiplying the estimated inundation width and the inundated length, so that the number of inundated houses were also estimated by multiplying the obtained inundated area with the number of houses per unit area under the 2005 condition based on the data of (4).

The estimation results for Ferreira and Mburicao River Basins are shown in Table 3-4.

Traffic Interruption

Traffic interruptions caused by floods occur on the portions as schematically shown in Fig. 3-8. This figure also show the average traffic volume per hour under the estimated traffic volume condition in 2005 obtained by means of extrapolation of the Urban Planning study results on the traffic condition at present and in the year 2000. The volume of interrupted traffic under each return period of flood at trunk roads was estimated by multiplying the duration of traffic interruption obtained through the hydrological study with the average traffic volume per hour.

The volumes of traffic at the trouble spots, together with the inundation duration under each return period of flood, are shown in Table 3-5.

4. Increment of Flood Damage

For a better understanding of the flood damage characteristics, the factors causing the increment of flood damage are hereinafter described, and the flood damage in monetary terms are presumed for 1965, 1984 and 2005.

## 4.1 Increment of Flood Damage in the Planning Area

As mentioned in the Sector 1, Hydrology, of this Supporting Report, runoff coefficient had increased in accordance with the recent urbanization of the study area, as shown in Table 3-6 and in Figs. 3-9 and 3-10. The storm water runoff discharge in the study area has increased by approximately 20% to 50% from 1965 to 1984, with an additional 30% to 50% increase from 1984 to 2005, as the examples shown in Fig. 3-11.

By applying the method mentioned in 3.2, the average rate of increment of inundated area which corresponds to the increment of runoff discharge in 1965 is estimated at 0.7 times that of 1984 and the increment rate in 2005 is 1.3 times. Likewise, the number of inundated houses in 1965 are estimated at 0.5 times that of 1984 and 1.5 times in 2005. On the other hand, the average volume of traffic interruption in 1965 was estimated to be 0.5 times that of 1984 and 2 times in 2005.

Fig. 3-12 shows the increment of runoff discharge and the incremental assets in the habitually flooded portion at the upstream of Artigas Avenue in Mburicao River Basin as an example.

## 4.2 Increment of Flood Damage in Monetary Terms

The annual average flood damage of the planning area in monetary terms in 1965, 1984 and 2005 conditions were estimated in the following procedure based on the study results mentioned in 4.1

(1) The number of annual average flood damage consisting of the inundated houses and interrupted traffic were counted in each basin under the 1984 condition.

(2) The unit damage of vehicles and houses in monetary terms per year were obtained based on the study result of Project Evaluation.

(3) The annual average flood damage of planning area in monetary terms under 1984 condition were obtained by multiplying the above-said (1) by (2).

(4) The number of annual average flood damage under 1965 and 2005 conditions were estimated in consideration of (a) the increment of inundated area caused by the increment of runoff discharge, (b) the increment of assets in inundated area, and (c) the increment of number of vehicles on the trunk roads as mentioned in 4.1

(5) By multiplying the above-said (1) by the estimated results of (4), the increment of annual average flood damage of inundated houses and interrupted vehicle movements in monetary terms were estimated as shown in Fig. 3-13.

## 5. Presumed Flood Damage for the First Stage Project

As mentioned in Section 2.4, Magnitude of Flood Damage, the Mburicao and the Itay river basins are suffering most seriously from flood damage, so that the detailed survey in connection with the present flooding condition and the study on the presumed flood damage as of 1995 were carried out as described hereinafter.

### 5.1 Detailed Study on Existing Flood Damage

From the field reconnaissance and interview survey carried out to obtain detailed information on flooding conditions at the time of the recorded maximum flood and in other conspicuous floods, it was noted that the number of inundated areas at the time of the recorded maximum flood broadly coincides with those of the other conspicuous floods, though differences in water stage still exist depending on the volume of runoff discharge. Fig. 3-14 is an example.

The flooded area were classified into two according to the degree of flood damage. One is the portion that will receive serious flood damage at present and in the future, and the other is the portion which is not affected so much by flood damage at present and in the future. Figs. 3-15, 3-16 and 3-17 show the flooded areas in the Mburicao and the Itay river basins at the time of the recorded maximum flood, together with the detail of the flood flow direction on the roads.

A research on the traffic volume at trouble spots of the streets has been carried out to identify the number of vehicles affected by storm water inundation. The results are summarized by the 3-hour range in Table 3-7.

As for the trunk roads such as Eusebio Ayala, Madame Lynch and Mariscal Lopez, the data on traffic volume at trouble spots were obtained from the study results of the Urban Transport Survey in Metropolitan Asuncion Area by JICA.

5.1.1 Mburicao River Basin

Floods in Mburicao River Basin can be classified into two (2) types; namely, (a) flood flowing on the roads and (b) floods causing inundation along the river channels due to insufficient flow capacity.

Although the flood duration is relatively short, floods in the basin frequently take place on the roads even at the portions having a small catchment area. Floodwaters flow down toward the uppermost reach of the tributaries, or into the nearest river channel, as schematically shown in Fig. 3-18.

The inundated areas are mainly observed in the upper portions of the following points:

(1) The bridge at the crossing point of Mburicao River and Generalisimo Franco Avenue, the extention of Espana Avenue;

(2) The confluence of Mburicao River and its tributary near Cervantes Avenue;

(3) The confluence of Mburicao and Santo Domingo rivers;

(4) The confluence of Mburicao and Jose Lombardo rivers;

(5) The railway bridge crossing Mburicao River; and

(6) The bridge at the crossing point of Mburicao River and Artigas Avenue.

As for the inundated areas of (1) to (4) above, flood duration and

inundation depth at the time of the recorded maximum flood are estimated in the range of from 2 to 4 hours and 40 to 80 cm, while those in (5) and (6) are about 6 hours and 120 cm, respectively.

Damage on assets due to storm water submergence generally takes place in the six locations mentioned above, although some submerged houses are seen along the roads on which storm waters flow down. The total number of submerged houses at the time of the recorded maximum flood was counted at 100 houses.

Traffic damage in Mburicao River Basin is subject to the number of traffic volume, although the flood duration is rather short. Traffic interruption frequently takes place on the main roads of Artigas, Generalisimo Franco, Mariscal Lopez, Eusebio Ayala, Monsignor Bogarin, and Sacramento, and takes place also in several streets such as Cervantes and Azara, as shown in Fig. 3-19, which also shows the hourly average traffic volumes. Among the main roads, seriously damaged are Generalisimo Franco, Mariscal Lopez and Eusebio Ayala avenues, because of their bigger traffic volumes and the longer duration of floods.

The total number of vehicles affected at the time of the recorded maximum flood is estimated at 25,000 cars and 3,000 buses.

### 5.1.2 Itay River Basin

Floodwaters spread widely along most of the river courses and the existing drainage channels, because the river flow capacities are extremely small in relation to the runoff discharge and that the geographical gradient of this basin, especially in the immediate upper reaches of Aviadores del Chaco Avenue, is rather gentle. On the other hand, floodwaters that flow on the roads are observed at only a few spots, as schematically shown in Fig. 3-20. Even in the area where inundation spreads widely along the river courses, floods over the banks flow down at a certain velocity. Fig. 3-21 shows the water stage and the longitudinal profile of the river channel along the Madame Lynch Avenue as an example.

The areas where inundations frequently occur are summarized hereunder, together with the maximum inundation depth and flood duration at the time of the recorded maximum flood.

(1) Grupo Habitacional Aeropuerto Area; 150 cm and 12 hours.

(2) The vicinity of the intersection between Boggiani Avenue and Eusebio Ayala Avenue; 100 cm and 6 hours.

(3) The area along Madame Lynch Avenue; 100 cm and 12 hours.

Damage on assets due to storm water submergence has been frequently observed in the three (3) locations mentioned above, although some houses located along the tributaries and the drainage channels may be submerged in case of big floods. The total submerged houses at the time of the recorded maximum flood is estimated at 1,325 houses.

Although the number of traffic interruption in Itay River Basin is smaller than that in Mburicao River Basin, the damage due to traffic interruption likewise reaches to a considerable extent because of the long flood duration.

The traffic interruption takes place mainly on the roads of Madame Lynch, Aviadores del Chaco, Mariscal Lopez and Eusebio Ayala, and in some streets. Fig. 3-22 shows the sections where traffic interruptions occur, together with the average hourly traffic volumes. Among the main roads, seriously damaged are the intersections of Madame Lynch and Mariscal Lopez, and of Eusebio Ayala and Boggiani avenues.

## 5.2 Presumed Flood Damage

The presumed flood damage in Mburicao and Itay river basins as of 1995 was estimated by the same method as mentioned in 3.2, Presumed Flood Damage in Representative River Basins. For a more precise estimation of flood damage under each return period of flood, a total of 26 cross sections of the inundated areas and flooded roads were taken, as plotted in Fig. 3-23.

The estimation on the number of inundated houses are in Table 3-8, while those of the traffic interruptions are in Table 3-9, based on the estimated traffic conditions of 1995 as shown in Fig. 3-24.

Although the number of traffic interruption in Itay River Basin is smaller than that in Mburicao River Basin, the damage due to traffic interruption likewise reaches to a considerable extent because of the long flood duration.

The traffic interruption takes place mainly on the roads of Madame Lynch, Aviadores del Chaco, Mariscal Lopez and Eusebio Ayala, and in some streets. Fig. 3-22 shows the sections where traffic interruptions occur, together with the average hourly traffic volumes. Among the main roads, seriously damaged are the intersections of Madame Lynch and Mariscal Lopez, and of Eusebio Ayala and Boggiani avenues.

## 5.2 Presumed Flood Damage

The presumed flood damage in Mburicao and Itay river basins as of 1995 was estimated by the same method as mentioned in 3.2, Presumed Flood Damage in Representative River Basins. For a more precise estimation of flood damage under each return period of flood, a total of 26 cross sections of the inundated areas and flooded roads were taken, as plotted in Fig. 3-23.

The estimation on the number of inundated houses are in Table 3-8, while those of the traffic interruptions are in Table 3-9, based on the estimated traffic conditions of 1995 as shown in Fig. 3-24.

# TABLES

Table 3-1. FLOOD DAMAGE IN EACH BASIN DURING THE RECORDED MAXIMUM FLOOD IN 1982

| Name of Basin | Catchment Area (ha) | Inundated Area (ha) | Inundated Houses (No.) | Inundated Trunk Roads (Spot) | Inundated Street Inter-sections (Spot) | Affected Vehicles At Trunk Roads ($10^3$ Unit) |
|---|---|---|---|---|---|---|
| Varadero* | 325 | 2.1 | 8 | - | 13 | - |
| Jardin* | 60 | 0.2 | - | - | 3 | - |
| Centro | 724 | 1.6 | 12 | 1 | 12 | 0.8 |
| Jaen* | 247 | 1.4 | 8 | - | 8 | - |
| Tacumbu | 170 | 0.9 | - | - | 7 | - |
| Salamanca* | 143 | 2.7 | 31 | - | 1 | - |
| Zanja Moroti* | 161 | 1.3 | 11 | - | 5 | - |
| Ferreira* | 400 | 4.3 | 18 | 1 | 17 | 1.0 |
| Villa Universitaria | 240 | 1.0 | 1 | 1 | 1 | 0.5 |
| Las Mercedes* | 212 | 1.0 | - | 2(1) | 2 | 3.0 |
| Mariscal Lopez* | 66 | 0.7 | - | - | 5 | - |
| Bella Vista* | 75 | 2.0 | 14 | 1 | 6 | 1.3 |
| Tablada* | 103 | 1.0 | 6 | 1 | 5 | 1.0 |
| Mburicao* | 1,645 | 46.6 | 100 | 8(4) | 67 | 28.0 |
| Ycua Carrillo* | 401 | 1.6 | 22 | - | 2 | - |
| Santa Rosa* | 313 | 2.7 | 44 | 1(1) | 8 | 2.5 |
| Tres Puentes Cue | 680 | 1.6 | 12 | 1 | 2 | 1.0 |
| Ytay* | 5,455 /1 | 283.9 | 1,325 | 6(4) | 243 | 17.0 |
| Lambare* | 2,566 | 39.9 | 189 | 6(3) | 69 | 8.0 |
| San Lorenzo | 3,369 | - | - | - | - | - |
| Zeballos Cue | 213 | - | - | - | - | - |
| Paso Cai | 549 | - | - | - | - | - |

Note:
* Basins with habitual flood damage.
( ) Number of spots on habitually inundated trunk road.

/1 Excluding the downstream area of Aviadores del Chaco Avenue.

Table 3-2. FLOOD DAMAGE AT TRUNK ROADS DURING THE RECORDED MAXIMUM FLOOD IN 1982

| Name of Road | No. of Inundated Spots on Trunk Roads | Affected Vehicles At Trunk Roads ($10^3$ Unit) |
|---|---|---|
| Artigas Avenue | 3 | 5 |
| Espana Avenue | 3 | 10 |
| Mariscal Lopez Avenue | 5 | 22 |
| Eusebio Ayala Avenue | 4 | 28 |
| Fernando de la Mora Avenue | 2 | 5 |
| Feneral Maximo Santos Avenue | 3 | 2 |
| Madame Lynch Avenue | 6 | 17 |

Table 3-3. EVALUATION OF FLOOD DAMAGE

| Name of Basin | Inundated Area | Inundated Houses | Influence To Traffic | Flood Frequency and Duration | Evaluation |
|---|---|---|---|---|---|
| Varadero | * | * | * | * | * |
| Jardin | * | * | * | * | * |
| Centro | * | * | * | * | - |
| Mburicao (Jaen) | * | * | * | * | * |
| Tacumbu | * | - | * | * | - |
| Salamanca | * | ** | * | * | ** |
| Zanja Moroti | * | ** | * | * | * |
| Ferreira | * | ** | * | ** | ** |
| Villa Universitaria | * | * | * | * | - |
| Las Mercedes | * | - | * | ** | * |
| Mariscal Lopez | * | - | * | ** | * |
| Bella Vista | * | ** | * | * | * |
| Tablada | * | * | * | ** | ** |
| Mburicao | ** | *** | **** | **** | **** |
| Ycua Carrillo | * | ** | * | * | * |
| Santa Rosa | * | ** | * | ** | ** |
| Tres Puentes Cue | * | * | * | * | - |
| Ytay | **** | **** | **** | **** | **** |
| Lambare | ** | *** | *** | *** | *** |
| San Lorenxo | * | * | * | * | - |
| Zeballos Cue | * | * | * | * | - |
| Paso Cai | * | * | * | * | - |

Legend: * Less Serious ** Serious *** Very Serious **** Extremely Serious - Negligible

Table 3-4. INUNDATED AREAS AND HOUSES IN MBURICAO AND FERREIRA RIVER BASINS AS OF 2005

| Location | Return Period (Year) | Inundated Area (ha) | Inundated Houses (Number) | Inundated Depth (m) |
|---|---|---|---|---|
| Ferreira River Basin | | | | |
| Upstream of Ferreira River | 1.1 | 0.4 | 2 | 0.4 |
| | 2 | 0.9 | 5 | 1.1 |
| | 3 | 1.0 | 6 | 1.2 |
| | 5 | 1.2 | 7 | 1.4 |
| | 10 | 1.8 | 10 | 1.6 |
| | 30 | 4.2 | 24 | 1.8 |
| Downstream of Ferreira River | 1.1 | 0.4 | 2 | 0.4 |
| | 2 | 0.9 | 4 | 0.6 |
| | 3 | 1.3 | 6 | 0.7 |
| | 5 | 1.7 | 8 | 0.8 |
| | 10 | 2.6 | 12 | 0.9 |
| | 30 | 4.5 | 21 | 1.0 |
| T o t a l | 1.1 | 0.8 | 4 | - |
| | 2 | 1.8 | 9 | - |
| | 3 | 2.3 | 12 | - |
| | 5 | 2.9 | 15 | - |
| | 10 | 4.4 | 22 | - |
| | 30 | 8.7 | 45 | - |
| Mburicao River Basin | | | | |
| Upper Portion of Artigas Avenue | 1.1 | 5.2 | 3 | 0.3 |
| | 2 | 7.4 | 11 | 0.8 |
| | 3 | 8.6 | 14 | 1.2 |
| | 5 | 12.2 | 22 | 1.6 |
| | 10 | 16.1 | 55 | 1.9 |
| | 30 | 19.9 | 79 | 2.0 |
| Crossing Point of Mburicao River and Generalisimo Franco Avenue | 1.1 | - | - | - |
| | 2 | - | - | - |
| | 3 | 2.2 | 2 | 0.4 |
| | 5 | 5.0 | 7 | 0.8 |
| | 10 | 7.3 | 11 | 1.1 |
| | 30 | 9.1 | 17 | 1.3 |
| Other Inundated Road Sections (Total) | 1.1 | 6.8 | 6 | 0.3 |
| | 2 | 8.1 | 11 | 0.4 |
| | 3 | 9.8 | 13 | 0.5 |
| | 5 | 11.8 | 18 | 0.6 |
| | 10 | 15.0 | 40 | 0.8 |
| | 30 | 21.5 | 101 | 1.1 |
| T o t a l | 1.1 | 12.0 | 9 | - |
| | 2 | 15.5 | 22 | - |
| | 3 | 20.6 | 37 | - |
| | 5 | 29.0 | 47 | - |
| | 10 | 38.4 | 106 | - |
| | 30 | 50.5 | 197 | - |

Table 3-5. ESTIMATED TRAFFIC VOLUME AND INUNDATION DURATION AT TROUBLE SPOTS AS OF 2005

| Trouble Spot No. | No. of Vehicles (Per Hour) | | Inundation Duration (min) Return Period | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Car | Bus | 1.1-Yr | 2-Yr | 3-Yr | 5-Yr | 10-Yr | 30-Yr |
| Ferreira River Basin | | | | | | | | |
| FT-1 | 1,875 | 182 | 35 | 65 | 75 | 100 | 125 | 165 |
| FS-1 | 484 | 53 | 20 | 30 | 40 | 55 | 75 | 100 |
| FS-2 | 198 | - | 30 | 50 | 60 | 90 | 110 | 150 |
| FS-3 | 236 | 130 | 0 | 10 | 20 | 35 | 40 | 55 |
| FS-4 | 72 | 53 | 30 | 55 | 65 | 95 | 120 | 155 |
| Mburicao River Basin | | | | | | | | |
| MT-1 | 1,668 | 206 | 10 | 30 | 35 | 65 | 75 | 110 |
| MT-2 | 495 | 66 | 30 | 60 | 70 | 95 | 120 | 165 |
| MT-3 | 1,029 | 93 | 30 | 60 | 65 | 95 | 125 | 165 |
| MT-4 | 1,832 | 397 | 40 | 60 | 85 | 120 | 140 | 190 |
| MT-5 | 1,521 | 418 | 20 | 30 | 40 | 65 | 75 | 110 |
| MT-6 | 758 | 104 | 0 | 0 | 0 | 15 | 25 | 45 |
| MT-7 | 1,127 | 125 | 45 | 90 | 110 | 140 | 170 | 230 |
| MT-8 | 1,706 | 397 | 20 | 45 | 60 | 75 | 100 | 160 |
| MS-1 | 536 | 55 | 10 | 30 | 35 | 65 | 75 | 110 |
| MS-2 | 245 | 70 | 10 | 30 | 40 | 65 | 75 | 110 |
| MS-3 | 781 | - | 10 | 30 | 40 | 65 | 75 | 110 |
| MS-4 | 632 | 55 | 30 | 60 | 65 | 95 | 120 | 165 |
| MS-5 | 475 | 19 | 50 | 90 | 110 | 140 | 170 | 230 |
| MS-6 | 578 | - | 45 | 90 | 110 | 140 | 170 | 230 |
| MS-7 | 90 | - | 10 | 30 | 40 | 65 | 75 | 110 |

Note: Refer to Fig. 3-8 for the location of trouble spots.

Table 3-6. INCREMENT OF RUNOFF COEFFICIENT BY URBANIZATION

| River Basin | Name of Basin | Runoff Coefficient | | |
|---|---|---|---|---|
| | | 1965 | 1984 | 2005 |
| B-1 | Varadero | 0.54 | 0.62 | 0.66 |
| B-2 | Jardin | 0.65 | 0.68 | 0.68 |
| B-3 | Centro | 0.59 | 0.62 | 0.67 |
| B-4 | Jaen | 0.57 | 0.65 | 0.67 |
| B-5 | Tacumbu | 0.48 | 0.53 | 0.53 |
| B-6 | Salamanca | 0.52 | 0.57 | 0.58 |
| B-7 | Zanja Moroti | 0.63 | 0.64 | 0.65 |
| B-8 | Ferreira | 0.50 | 0.63 | 0.66 |
| B-9 | Villa Universitaria | 0.32 | 0.44 | 0.60 |
| B-10 | Las Mercedes | 0.48 | 0.59 | 0.62 |
| B-11 | Mariscal Lopez | 0.56 | 0.62 | 0.63 |
| B-12 | Bella Vista | 0.50 | 0.63 | 0.65 |
| B-13 | Tablada | 0.45 | 0.62 | 0.63 |
| B-14 | Mburicao | 0.42 | 0.50 | 0.57 |
| B-15 | Ycua Carrillo | 0.37 | 0.44 | 0.63 |
| B-16 | Santa Rosa | 0.33 | 0.41 | 0.56 |
| B-17 | Tres Puentes Cue | 0.30 | 0.35 | 0.41 |
| B-18 | Itay | 0.33 | 0.41 | 0.50 |
| B-19 | Lambare | 0.36 | 0.51 | 0.67 |
| B-20 | Valle Apua | 0.30 | 0.38 | 0.40 |
| B-21 | Villa Elisa | 0.31 | 0.40 | 0.51 |
| B-22 | Nemby | 0.30 | 0.36 | 0.44 |
| B-23 | San Lorenzo | 0.30 | 0.32 | 0.35 |
| B-24 | Tayazuape | 0.30 | 0.32 | 0.35 |
| B-26 | Zeballos Cue | 0.32 | 0.35 | 0.41 |
| B-27 | Paso Cai | 0.32 | 0.34 | 0.52 |

Table 3-7. TRAFFIC VOLUME ON STREETS

(Unit: Vehicle)

| Name of Street | | Traffic Hours 6:00-9:00 | 9:00-12:00 | 12:00-15:00 | 15:00-18:00 | Total |
|---|---|---|---|---|---|---|
| Mburicao River Basin | | | | | | |
| General Garay | (Car) | 930 | 923 | 1,112 | 1,065 | 4,032 |
| | (Bus) | 44 | 47 | 40 | 40 | 171 |
| Cervantes | (Car) | 685 | 771 | 856 | 752 | 3,074 |
| | (Bus) | 76 | 67 | 60 | 77 | 280 |
| Chaco Boreal | (Car) | 749 | 848 | 980 | 819 | 3,396 |
| | (Bus) | 82 | 73 | 70 | 84 | 309 |
| 25 de Mayo | (Car) | 2,228 | 2,417 | 2,740 | 2,588 | 9,974 |
| | (Bus) | - | - | - | - | - |
| Azara | (Car) | 1,508 | 1,748 | 1,966 | 1,942 | 7,164 |
| | (Bus) | - | - | - | - | - |
| Andres Campos | (Car) | 222 | 125 | 193 | 193 | 734 |
| Cervera | (Bus) | - | - | - | - | - |
| San Rafael | (Car) | 549 | 586 | 715 | 589 | 2,439 |
| | (Bus) | - | - | - | - | - |
| Itay River Basin | | | | | | |
| Santa Teresa | (Car) | 489 | 540 | 659 | 602 | 2,290 |
| | (Bus) | 165 | 183 | 193 | 175 | 716 |
| Zavalas Cue | (Car) | 106 | 149 | 132 | 164 | 551 |
| | (Bus) | 36 | 32 | 33 | 40 | 141 |
| Eusebio Lillo | (Car) | 800 | 837 | 840 | 958 | 3,436 |
| | (Bus) | 115 | 117 | 113 | 127 | 472 |

Table 3-8 (1/2). INUNDATED AREAS AND HOUSES IN THE TARGET AREA AS OF 1995

| Location | Return Period (Year) | Inundated Area (ha) | Inundated Houses (Number) | Inundated Depth (m) |
|---|---|---|---|---|
| Mburicao River Basin | | | | |
| Upper Portion of Artigas Avenue | 1.1 | 5.0 | 3 | 0.3 |
| | 2 | 7.1 | 11 | 0.8 |
| | 3 | 8.2 | 13 | 1.2 |
| | 5 | 11.7 | 21 | 1.6 |
| | 10 | 15.4 | 38 | 1.8 |
| | 30 | 19.1 | 61 | 1.9 |
| Crossing Point of Mburicao River and Generalisimo Franco Avenue | 1.1 | - | - | - |
| | 2 | - | - | - |
| | 3 | 2.1 | 2 | 0.4 |
| | 5 | 4.8 | 6 | 0.8 |
| | 10 | 7.0 | 9 | 1.0 |
| | 30 | 8.7 | 13 | 1.2 |
| Other Inundated Road Portions (Total) | 1.1 | 6.5 | 7 | 0.3 |
| | 2 | 7.8 | 11 | 0.4 |
| | 3 | 9.4 | 13 | 0.5 |
| | 5 | 11.3 | 17 | 0.6 |
| | 10 | 14.4 | 35 | 0.8 |
| | 30 | 20.6 | 78 | 1.0 |
| T o t a l | 1.1 | 11.5 | 10 | - |
| | 2 | 14.9 | 22 | - |
| | 3 | 19.7 | 28 | - |
| | 5 | 27.8 | 44 | - |
| | 10 | 36.8 | 82 | - |
| | 30 | 48.4 | 152 | - |

Table 3-8 (2/2). INUNDATED AREAS AND HOUSES IN THE TARGET AREA AS OF 1995

| Location | Return Period (Year) | Inundated Areas (ha) | Inundated Houses (Number) | Inundated Depth (m) |
|---|---|---|---|---|
| Itay River Basin | | | | |
| Along Aviadores del Chaco Avenue | 1.1 | 9.8 | 12 | 0.1 |
| | 2 | 15.5 | 25 | 0.2 |
| | 3 | 20.3 | 42 | 0.3 |
| | 5 | 35.0 | 62 | 0.4 |
| | 10 | 60.4 | 195 | 0.6 |
| | 30 | 68.0 | 350 | 0.7 |
| Along Madame Lynch River | 1.1 | 20.5 | 26 | 0.3 |
| | 2 | 32.1 | 61 | 0.6 |
| | 3 | 43.1 | 86 | 0.8 |
| | 5 | 68.3 | 173 | 1.0 |
| | 10 | 117.5 | 505 | 1.1 |
| | 30 | 171 | 1,229 | 1.2 |
| Along Itay River | 1.1 | 11.5 | 21 | 0.1 |
| | 2 | 17.8 | 45 | 0.3 |
| | 3 | 28.3 | 71 | 0.5 |
| | 5 | 43.2 | 92 | 0.7 |
| | 10 | 73.6 | 300 | 1.0 |
| | 30 | 91.0 | 612 | 1.2 |
| T o t a l | 1.1 | 41.8 | 59 | - |
| | 2 | 65.4 | 131 | - |
| | 3 | 91.7 | 199 | - |
| | 5 | 146.5 | 327 | - |
| | 10 | 251.5 | 1,000 | - |
| | 30 | 330.0 | 2,191 | - |

Table 3-9. ESTIMATED TRAFFIC VOLUME AND INUNDATION DURATION AT TROUBLE SPOTS AS OF 1995

| Trouble Spot No. | No. of Vehicles (Per Hour) | | Inundation Duration (min) Return Period | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Car | Bus | 1.1-Yr | 2-Yr | 3-Yr | 5-Yr | 10-Yr | 30-Yr |
| Mburicao River Basin | | | | | | | | |
| MT-1 | 1,467 | 196 | 10 | 30 | 35 | 60 | 70 | 100 |
| MT-2 | 436 | 63 | 30 | 55 | 65 | 90 | 110 | 155 |
| MT-3 | 876 | 89 | 30 | 55 | 60 | 90 | 115 | 155 |
| MT-4 | 1,770 | 378 | 35 | 55 | 80 | 110 | 130 | 175 |
| MT-5 | 1,386 | 398 | 20 | 30 | 35 | 60 | 70 | 100 |
| MT-6 | 749 | 99 | 0 | 0 | 0 | 15 | 25 | 40 |
| MT-7 | 992 | 119 | 45 | 85 | 100 | 130 | 160 | 215 |
| MT-8 | 1,676 | 393 | 20 | 40 | 55 | 70 | 95 | 150 |
| MS-1 | 323 | 53 | 10 | 30 | 35 | 60 | 70 | 100 |
| MS-2 | 238 | 50 | 10 | 30 | 35 | 60 | 70 | 100 |
| MS-3 | 768 | 0 | 10 | 30 | 35 | 60 | 70 | 100 |
| MS-4 | 631 | 61 | 30 | 55 | 60 | 90 | 110 | 155 |
| MS-5 | 395 | 17 | 45 | 85 | 100 | 130 | 160 | 215 |
| MS-6 | 560 | 0 | 45 | 85 | 100 | 130 | 160 | 215 |
| MS-7 | 75 | 0 | 10 | 30 | 35 | 60 | 70 | 100 |
| Itay River Basin | | | | | | | | |
| IT-1 | 1,291 | 175 | 40 | 70 | 80 | 110 | 135 | 180 |
| IT-2 | 2,013 | 420 | 80 | 170 | 190 | 210 | 230 | 270 |
| IT-3 | 854 | 408 | 90 | 170 | 200 | 220 | 250 | 290 |
| IS-1 | 230 | 63 | 40 | 70 | 80 | 110 | 135 | 180 |
| IS-2 | 171 | 33 | 70 | 160 | 180 | 190 | 210 | 290 |

Note: Refer to Fig. 3-24 for the location of trouble spots.

# FIGURES

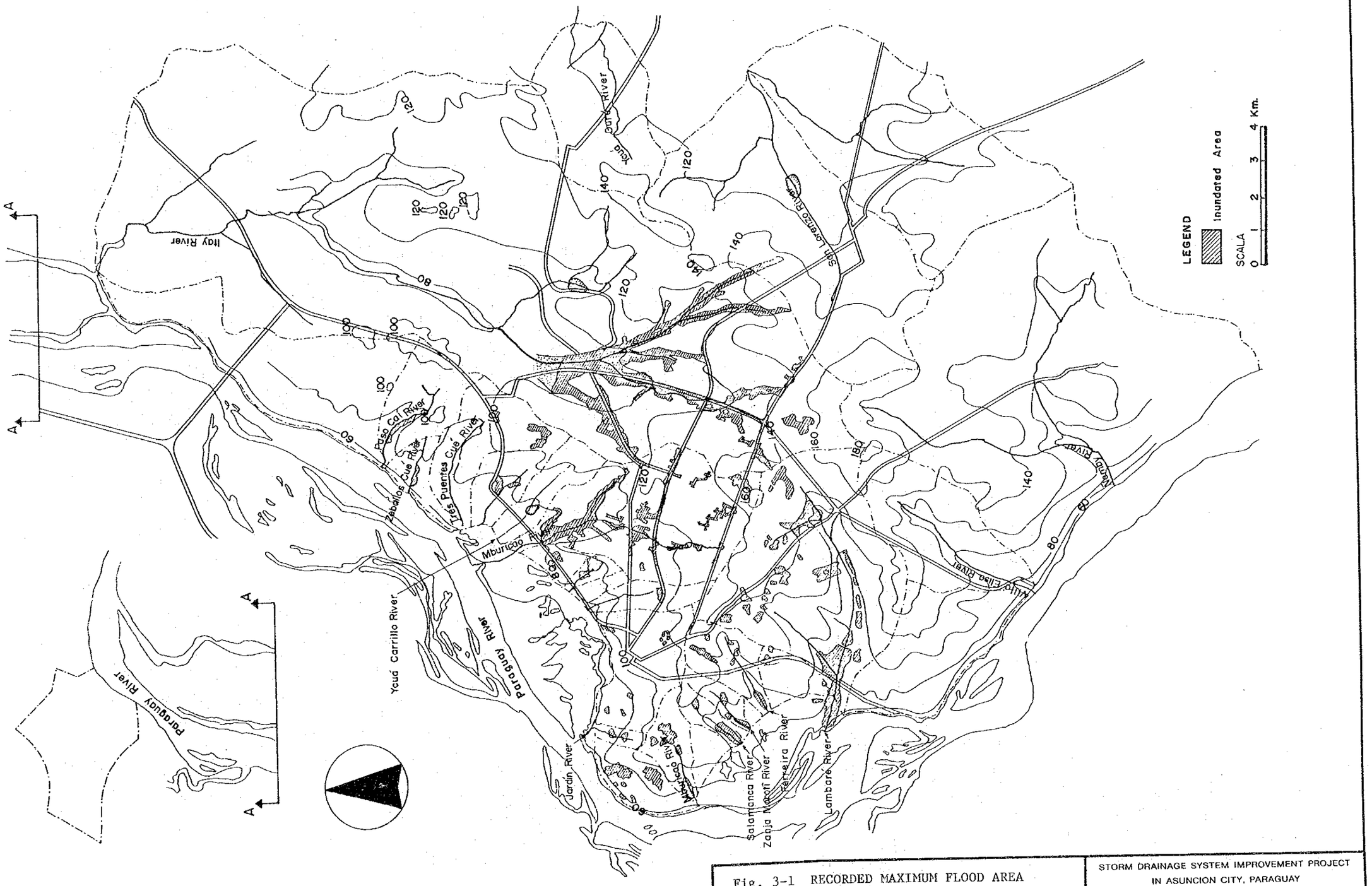



Fig. 3-1 RECORDED MAXIMUM FLOOD AREA IN THE STUDY AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

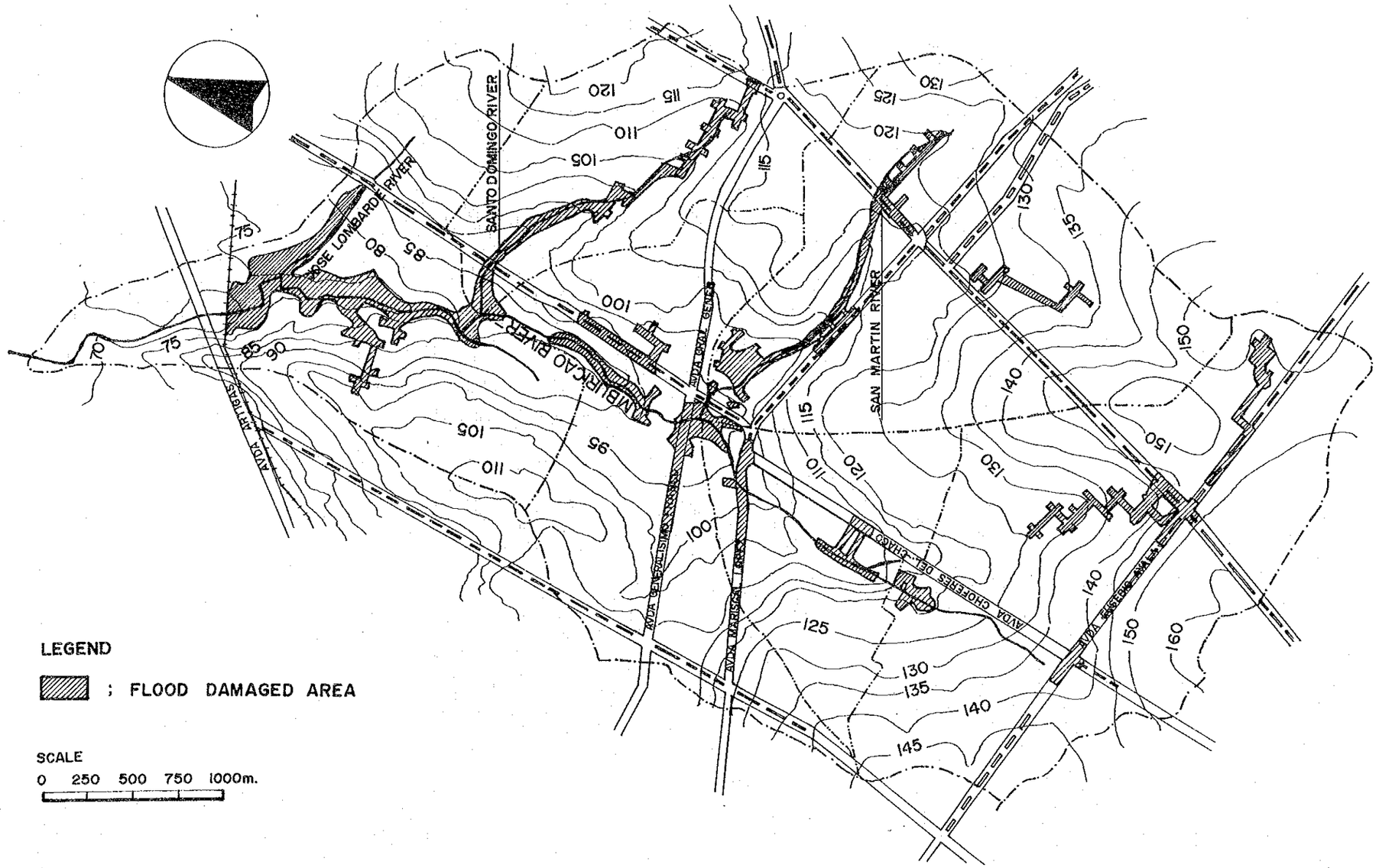



Fig. 3-2 (1/2) TOPOGRAPHIC FEATURES AND FLOODED AREA (MBURICAO RIVER BASIN)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

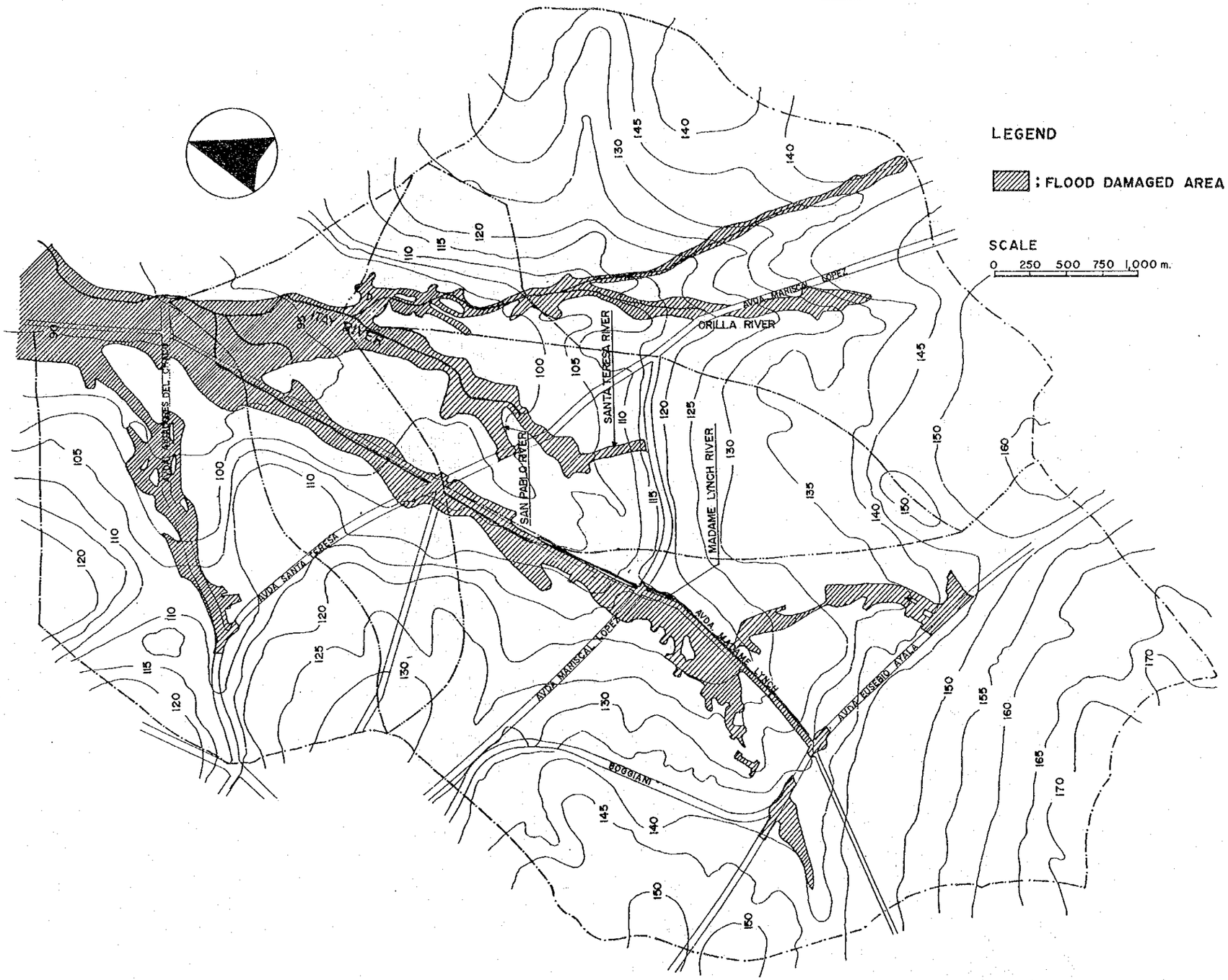



Fig. 3-2 (2/2) TOPOGRAPHIC FEATURES AND FLOODED AREA (ITAY RIVER BASIN)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

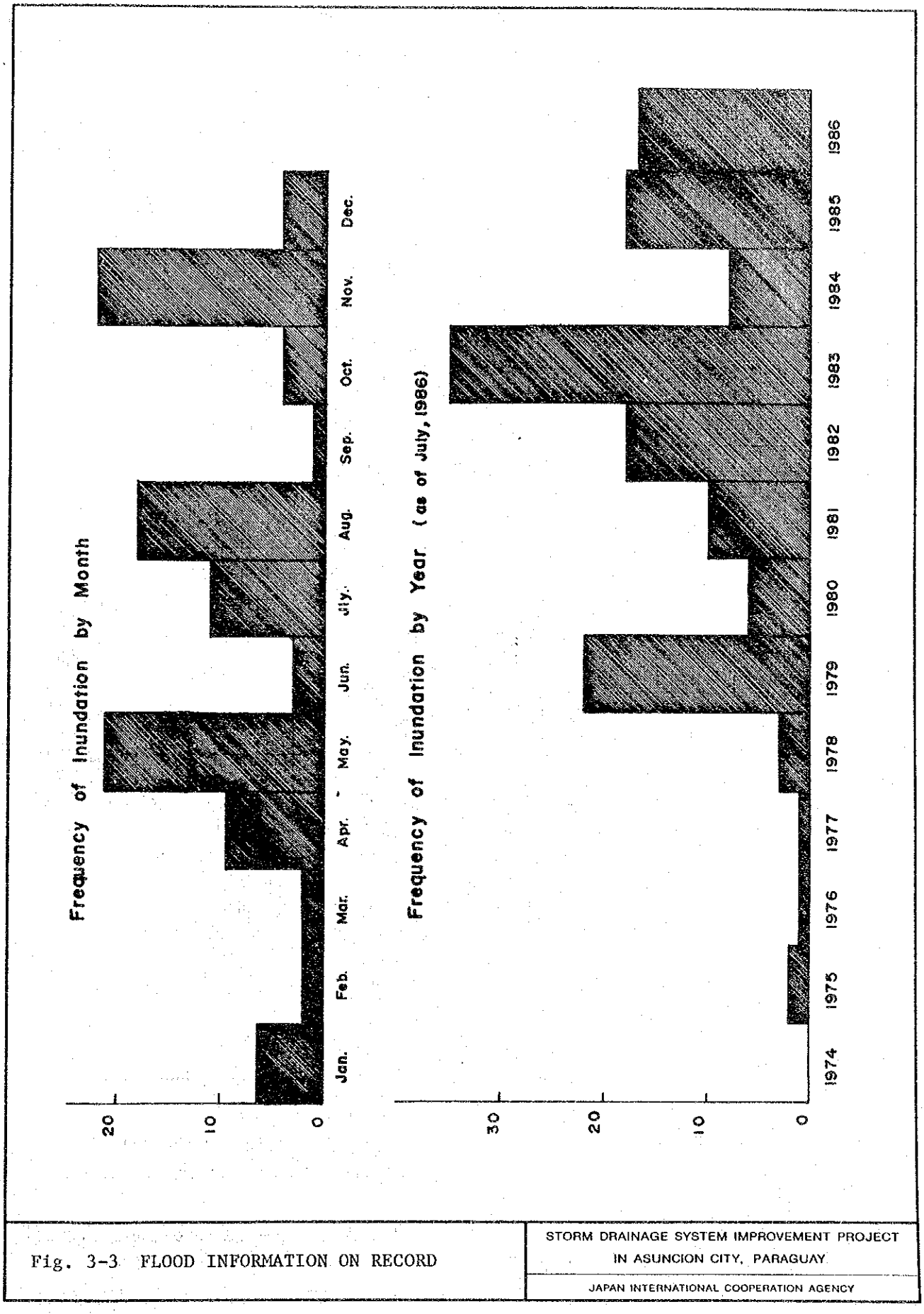



Fig. 3-3 FLOOD INFORMATION ON RECORD

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT
IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

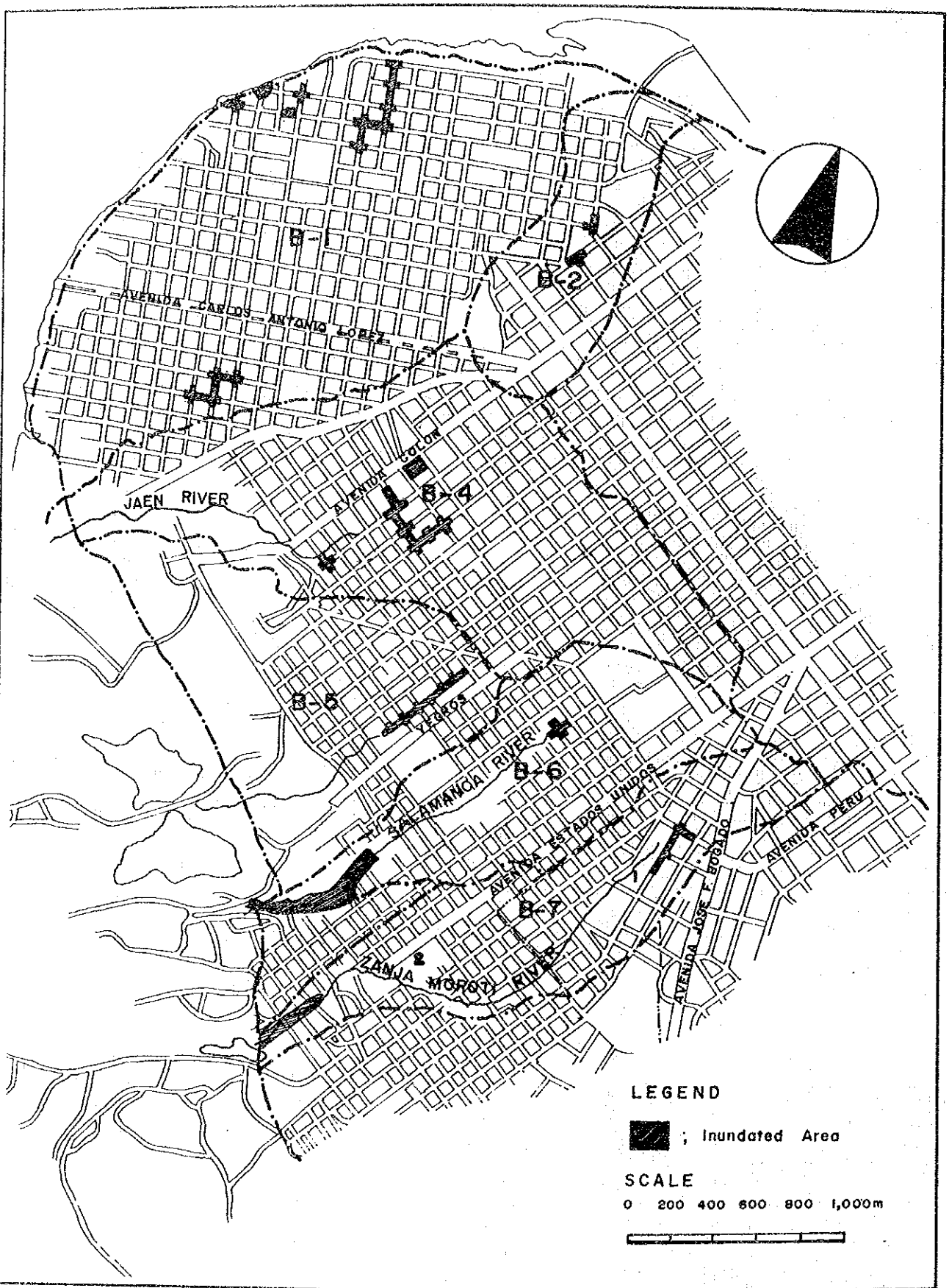



Fig. 3-4 (1/6) FLOODED AREA IN DIVIDED BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

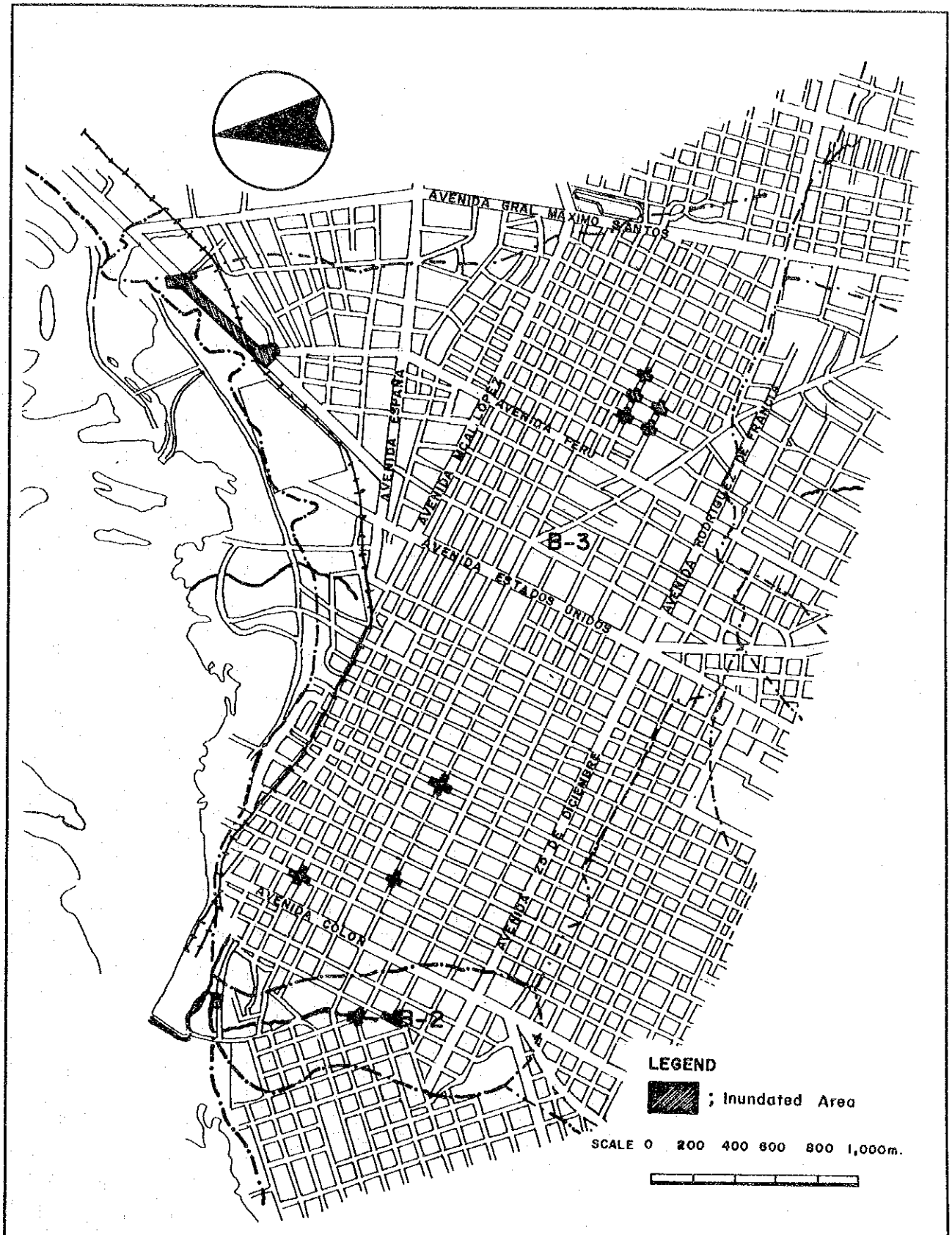



Fig. 3-4 (2/6) FLOODED AREA IN DIVIDED BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT
IN ASUNCION CITY, PARAGUAY
JAPAN INTERNATIONAL COOPERATION AGENCY

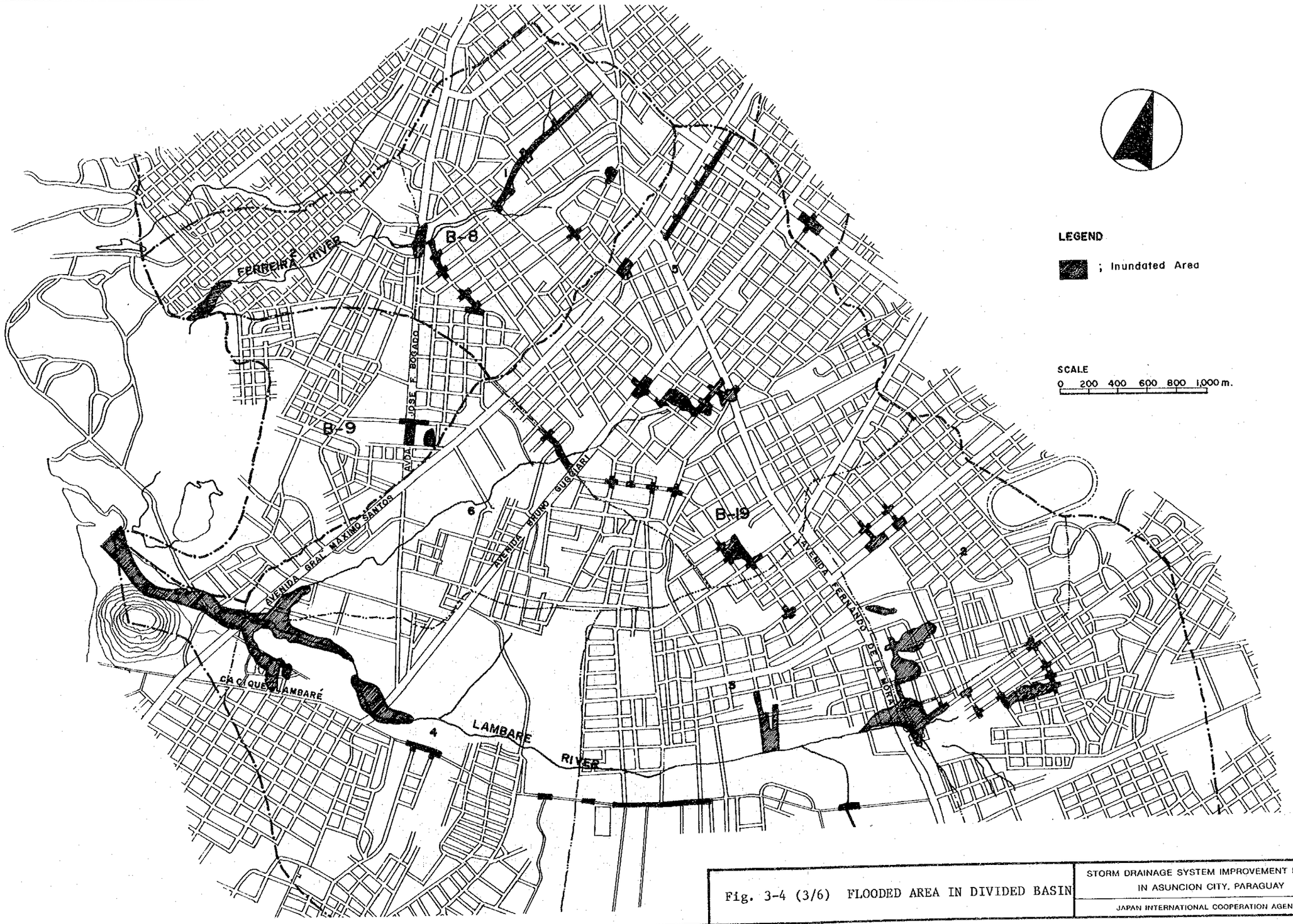



Fig. 3-4 (3/6) FLOODED AREA IN DIVIDED BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

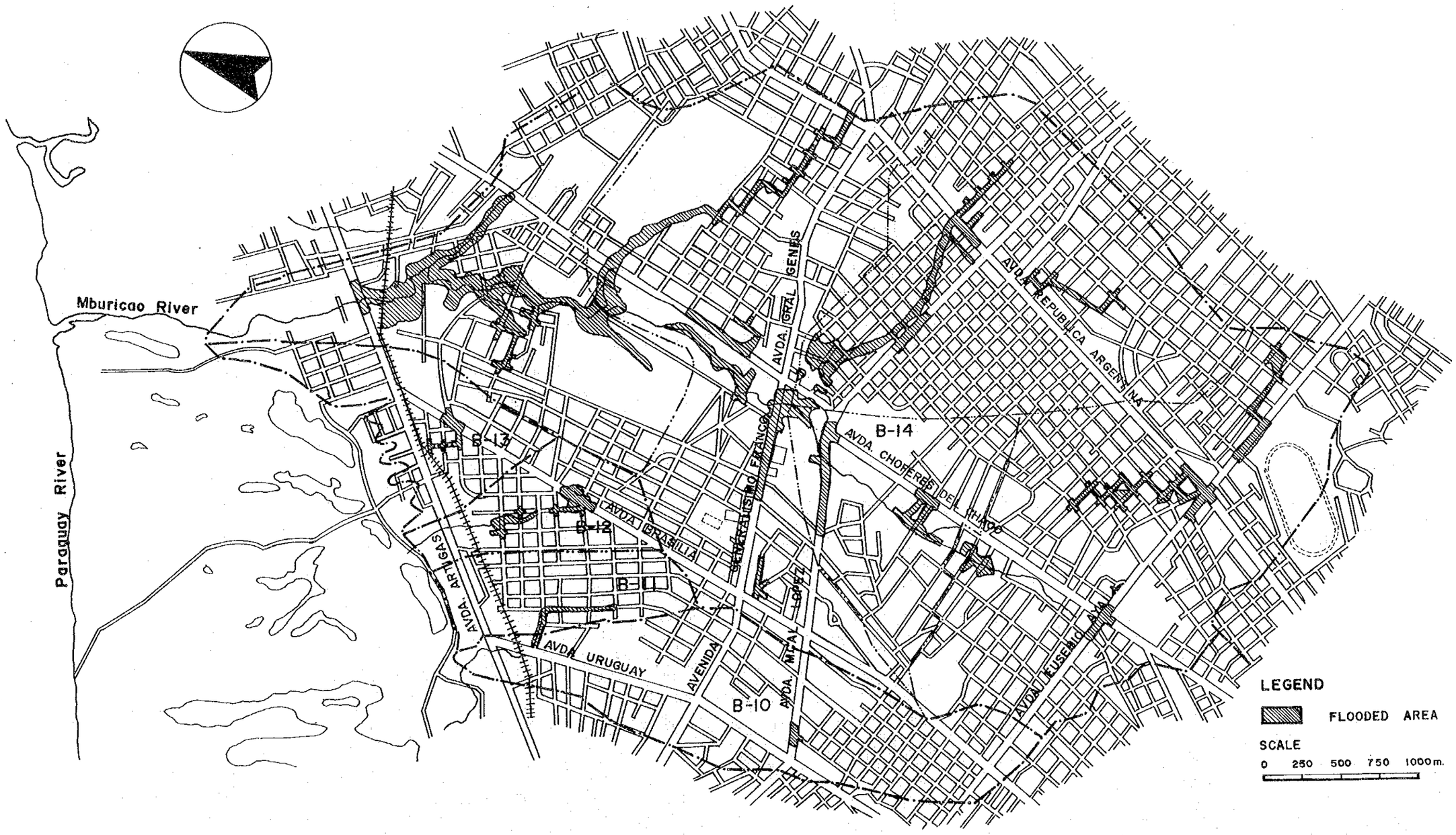



Fig. 3-4 (4/6) FLOODED AREA IN DIVIDED BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

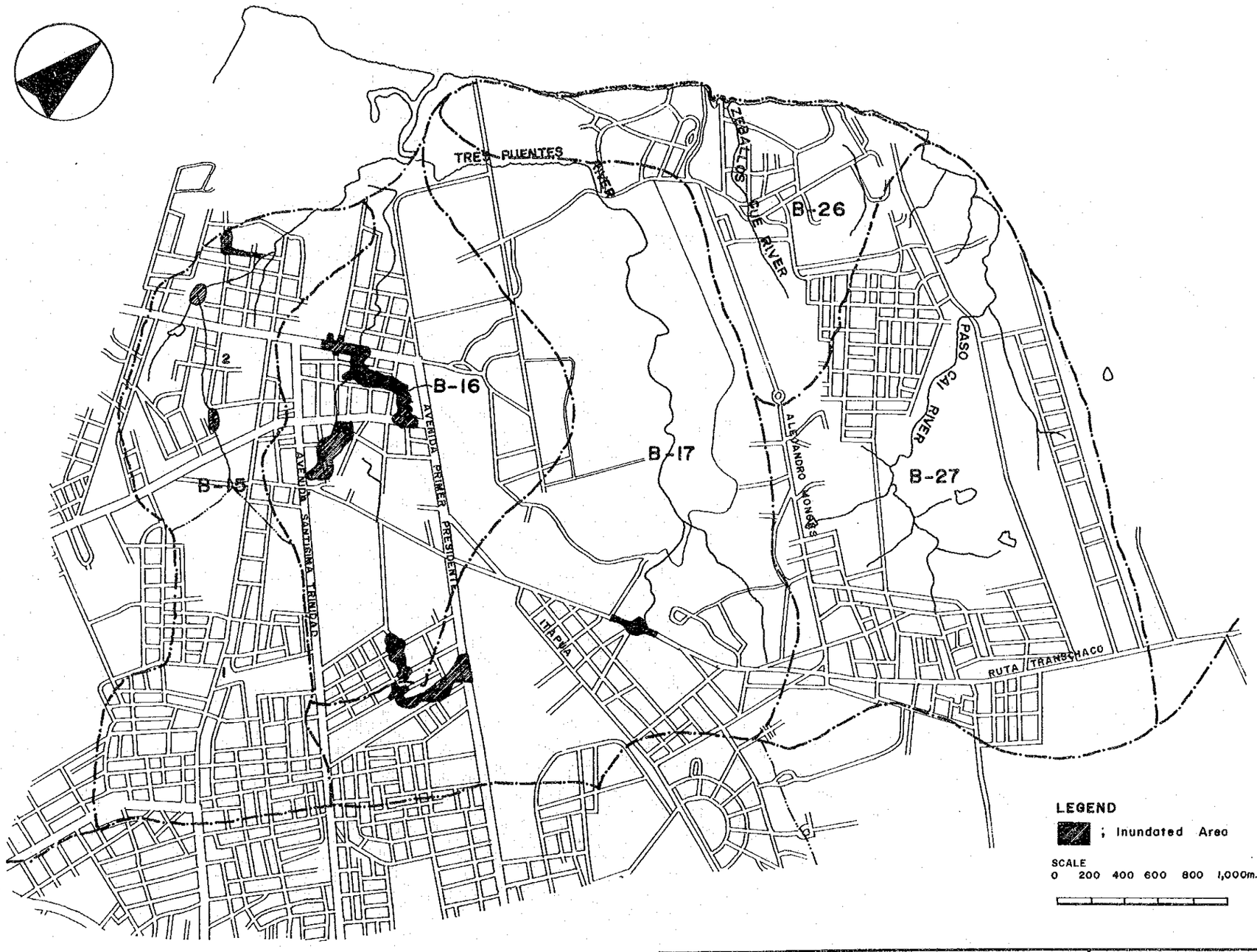
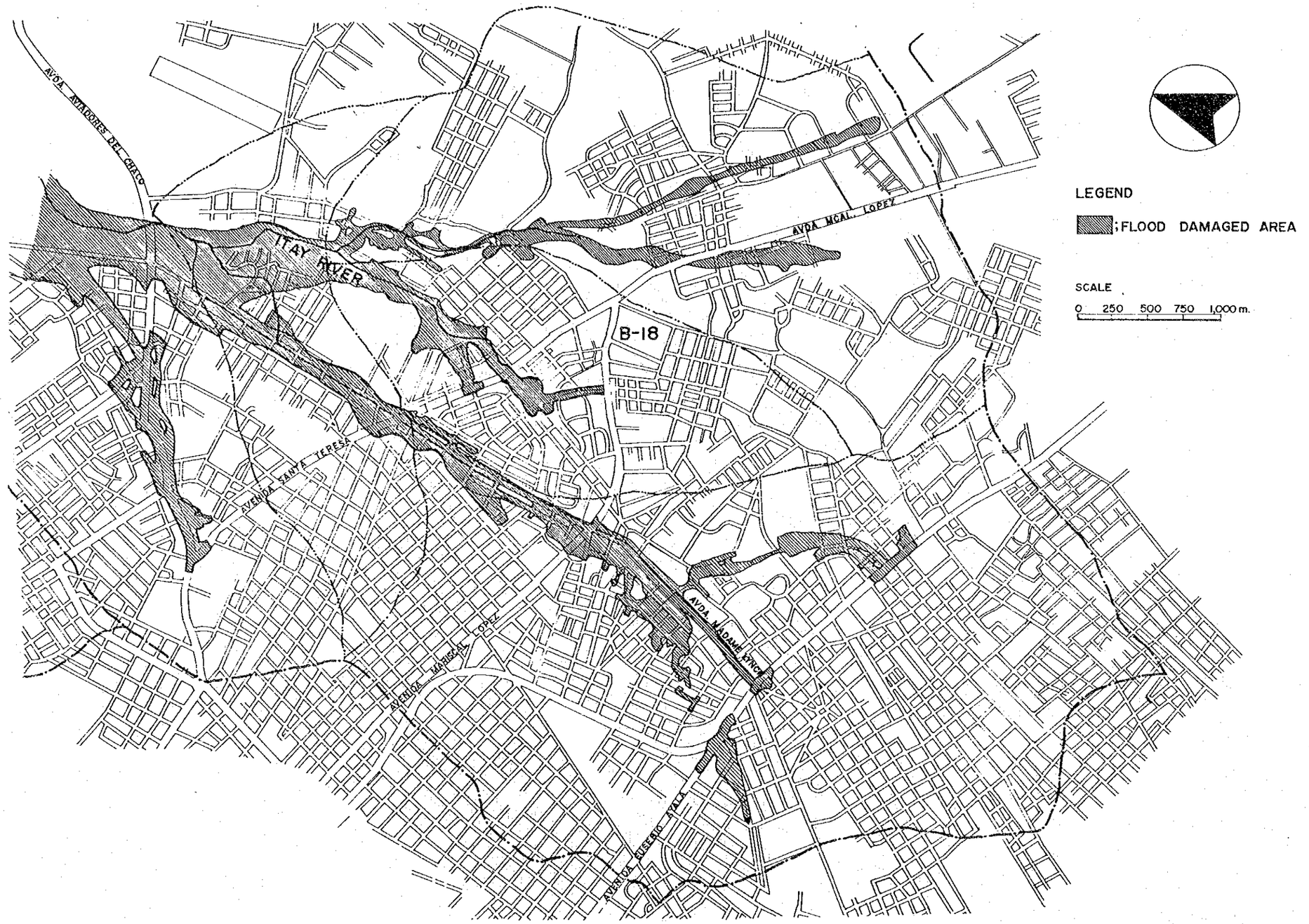



Fig. 3-4 (5/6) FLOODED AREA IN DIVIDED BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY




LEGEND

; FLOOD DAMAGED AREA

SCALE

0 250 500 750 1,000 m.

Fig. 3-4 (6/6) FLOODED AREA IN DIVIDED BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

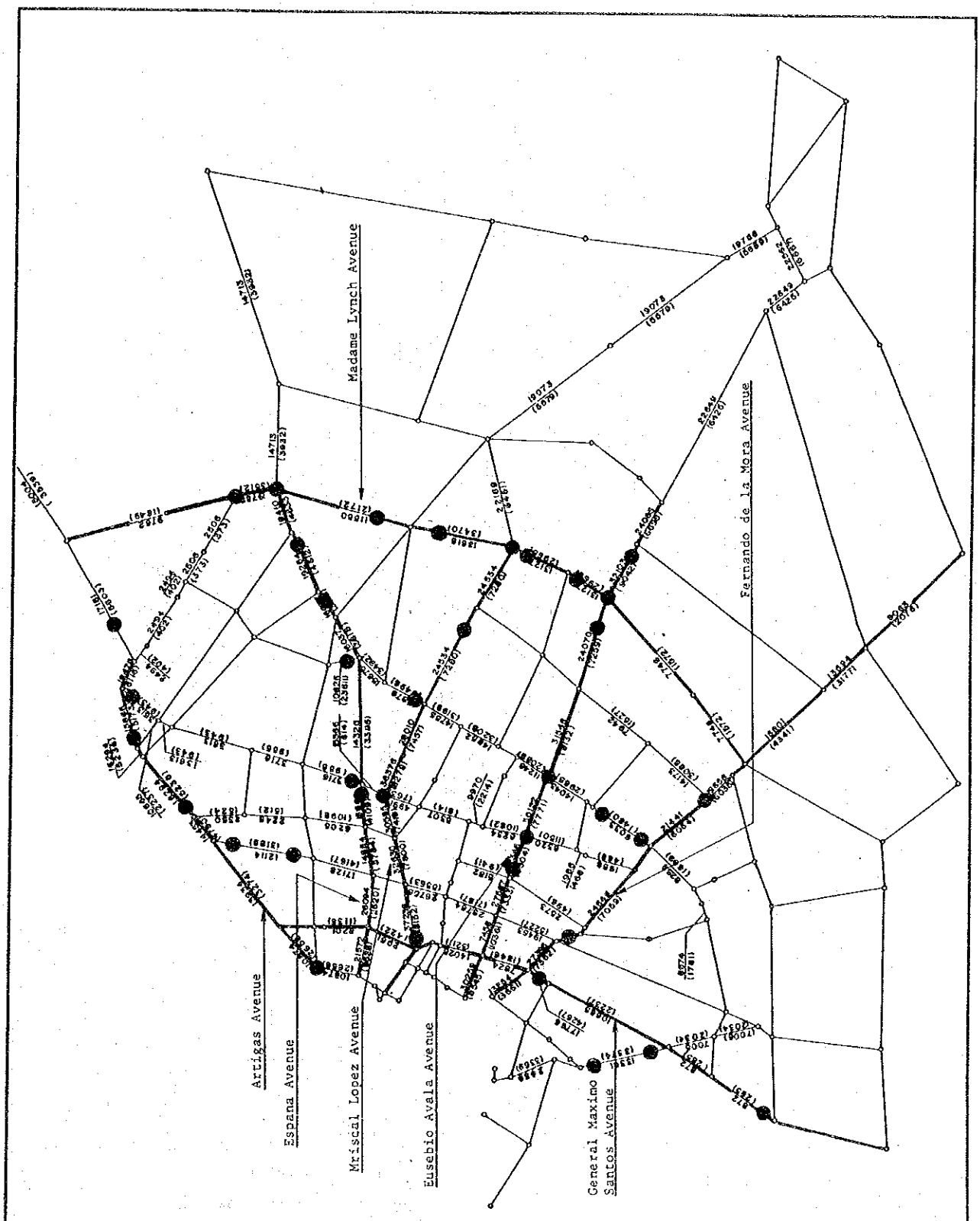



Fig. 3-5 PRESENT TRAFFIC VOLUME ON TRUNK ROAD

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

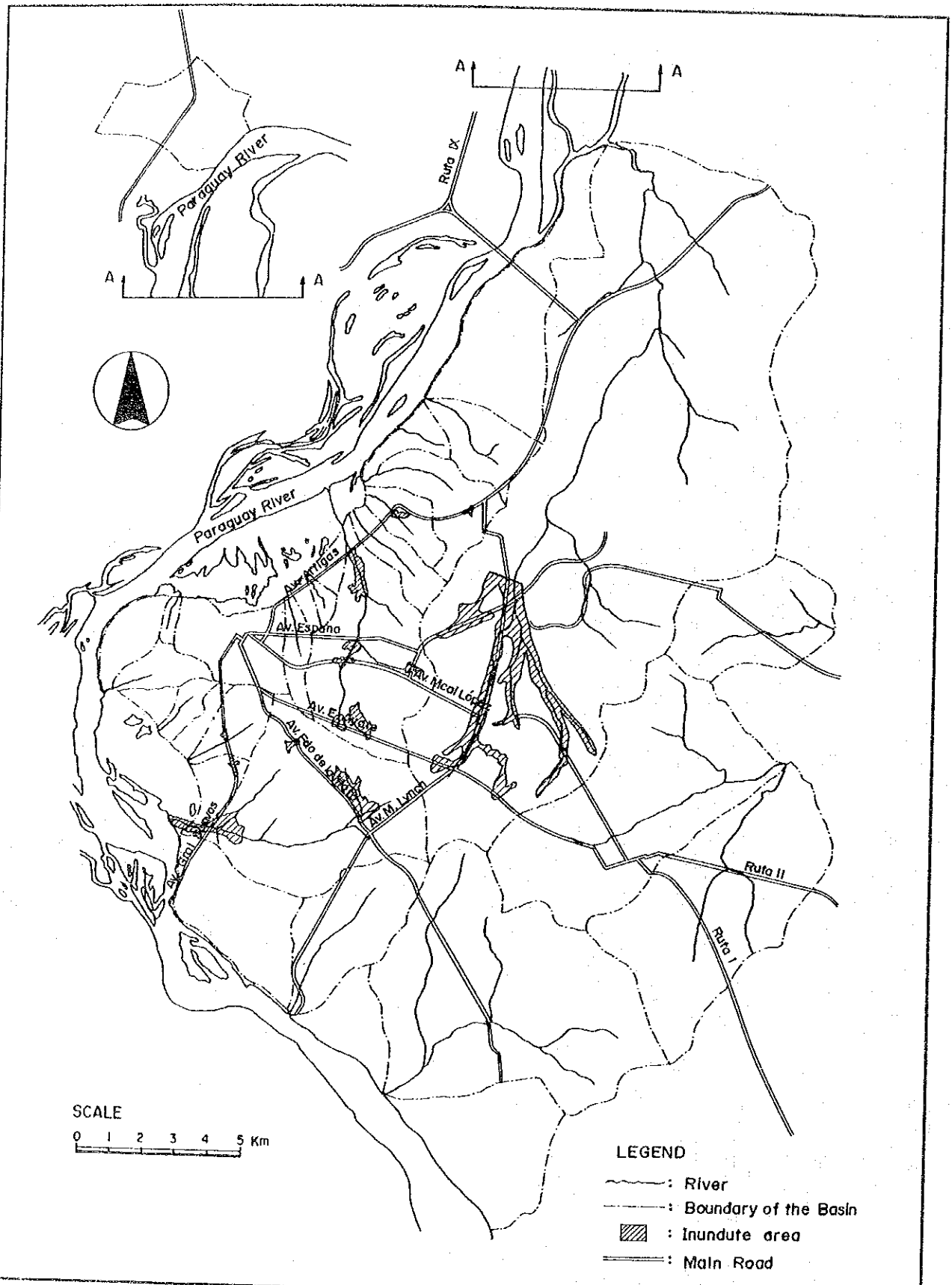



Fig. 3-6 FLOODED SPOTS ON TRUNK ROAD

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

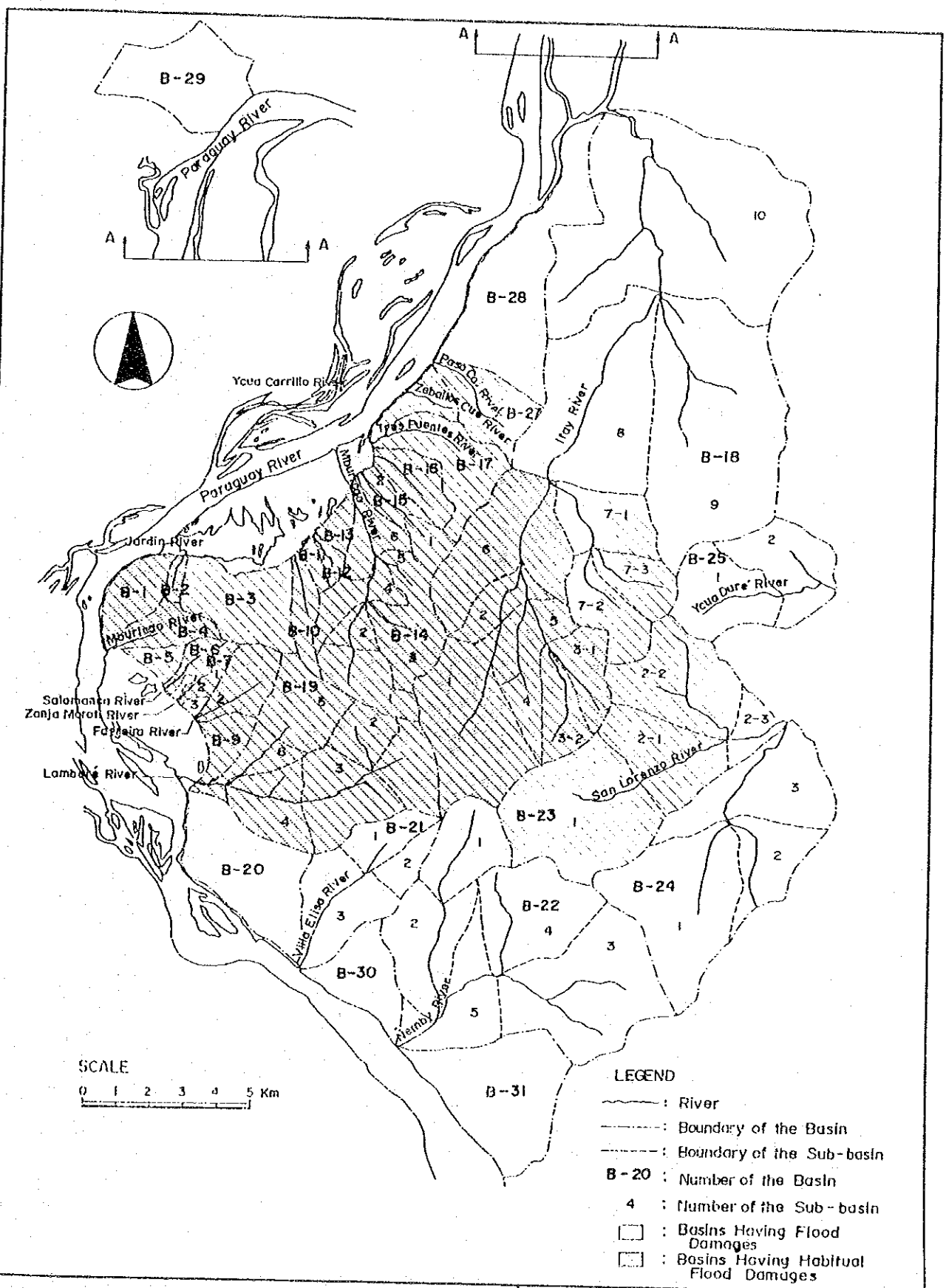



Fig. 3-7 DEGREE OF FLOOD DAMAGE PER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

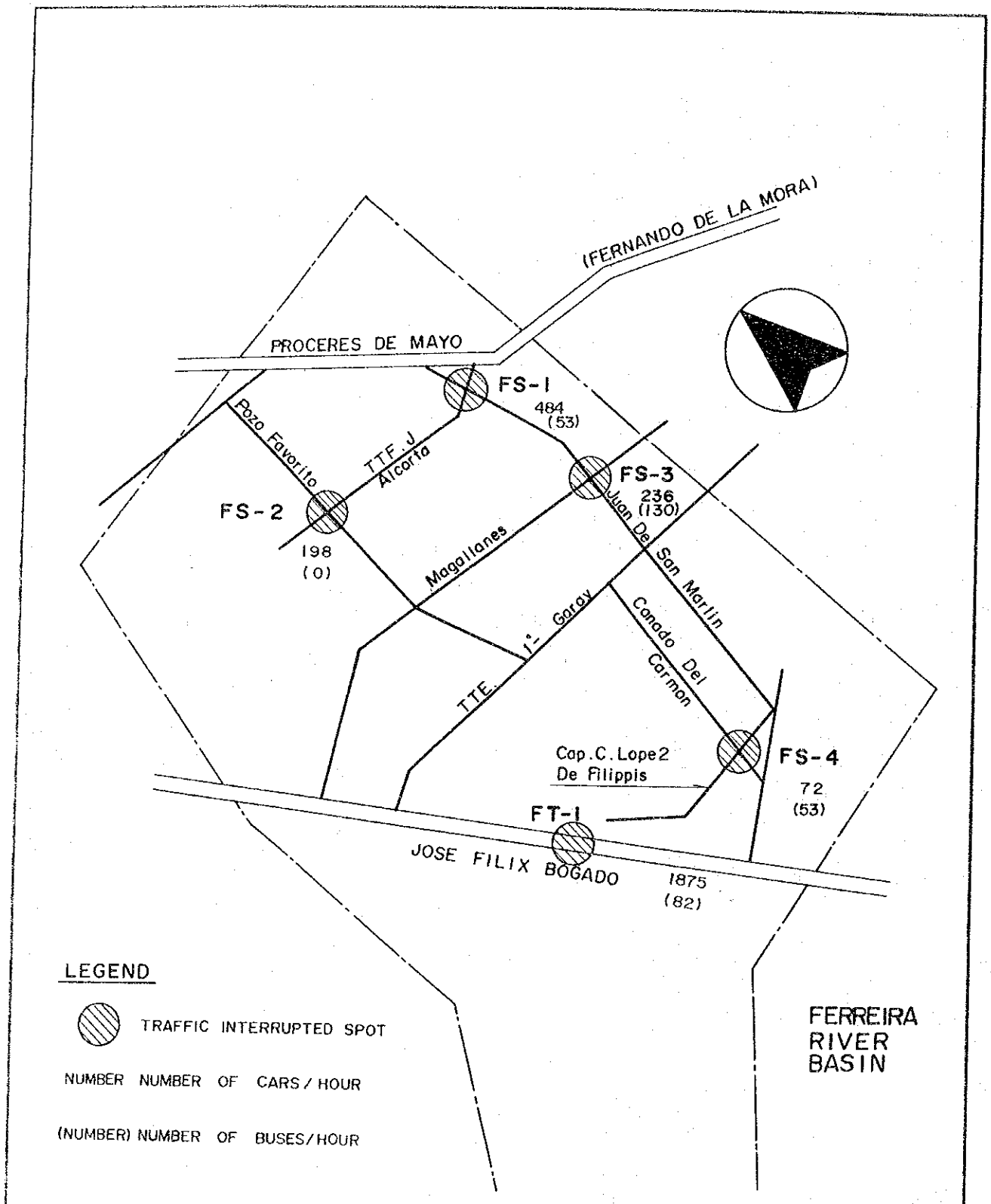



Fig. 3-8 (1/2) LOCATION OF TRAFFIC INTERRUPTION SPOTS AS OF 2005 (FERREIRA RIVER BASIN)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

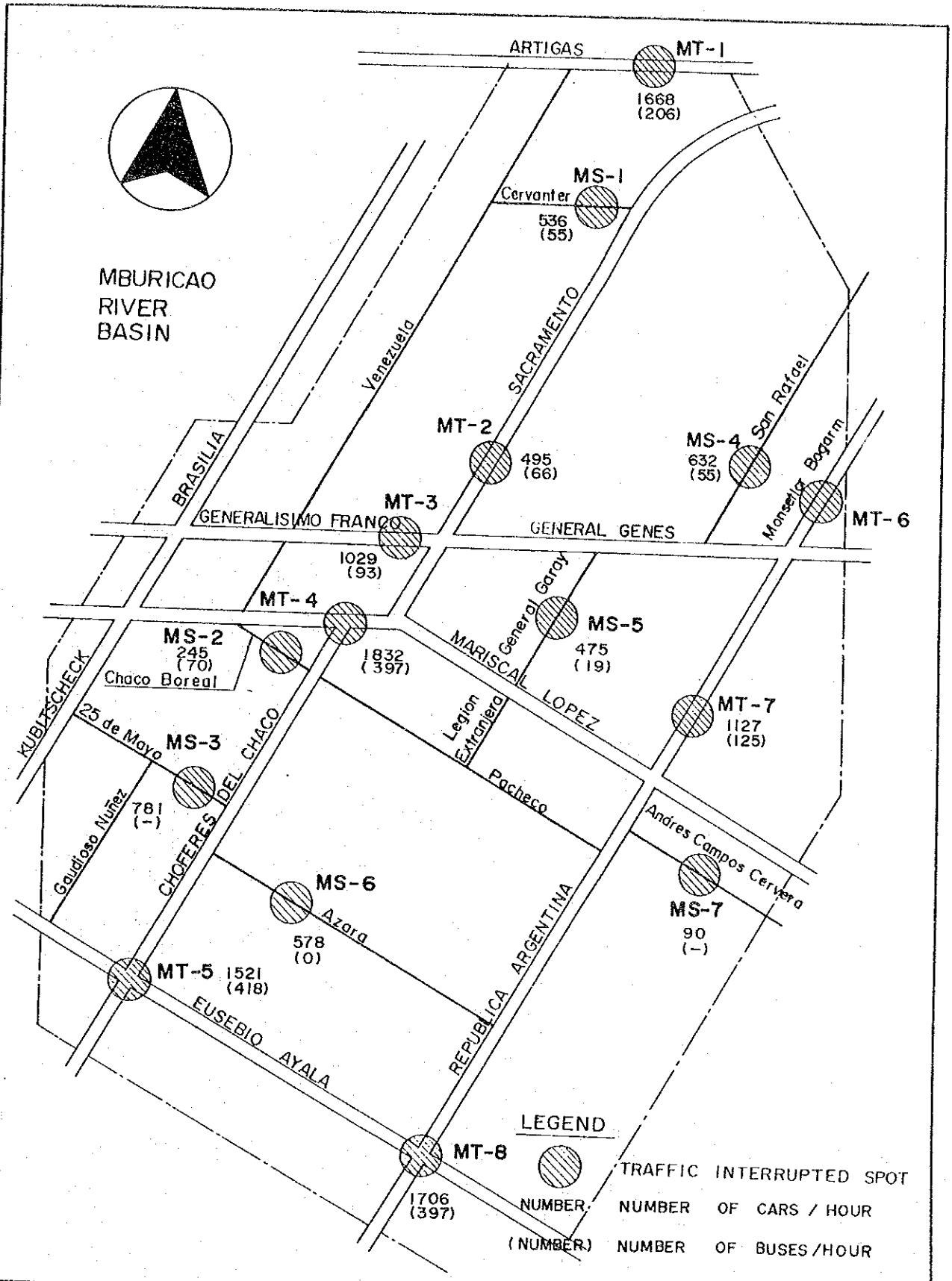



Fig. 3-8 (2/2) LOCATION OF TRAFFIC INTERRUPTION SPOTS AS OF 2005 (MBURICAO RIVER BASIN)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

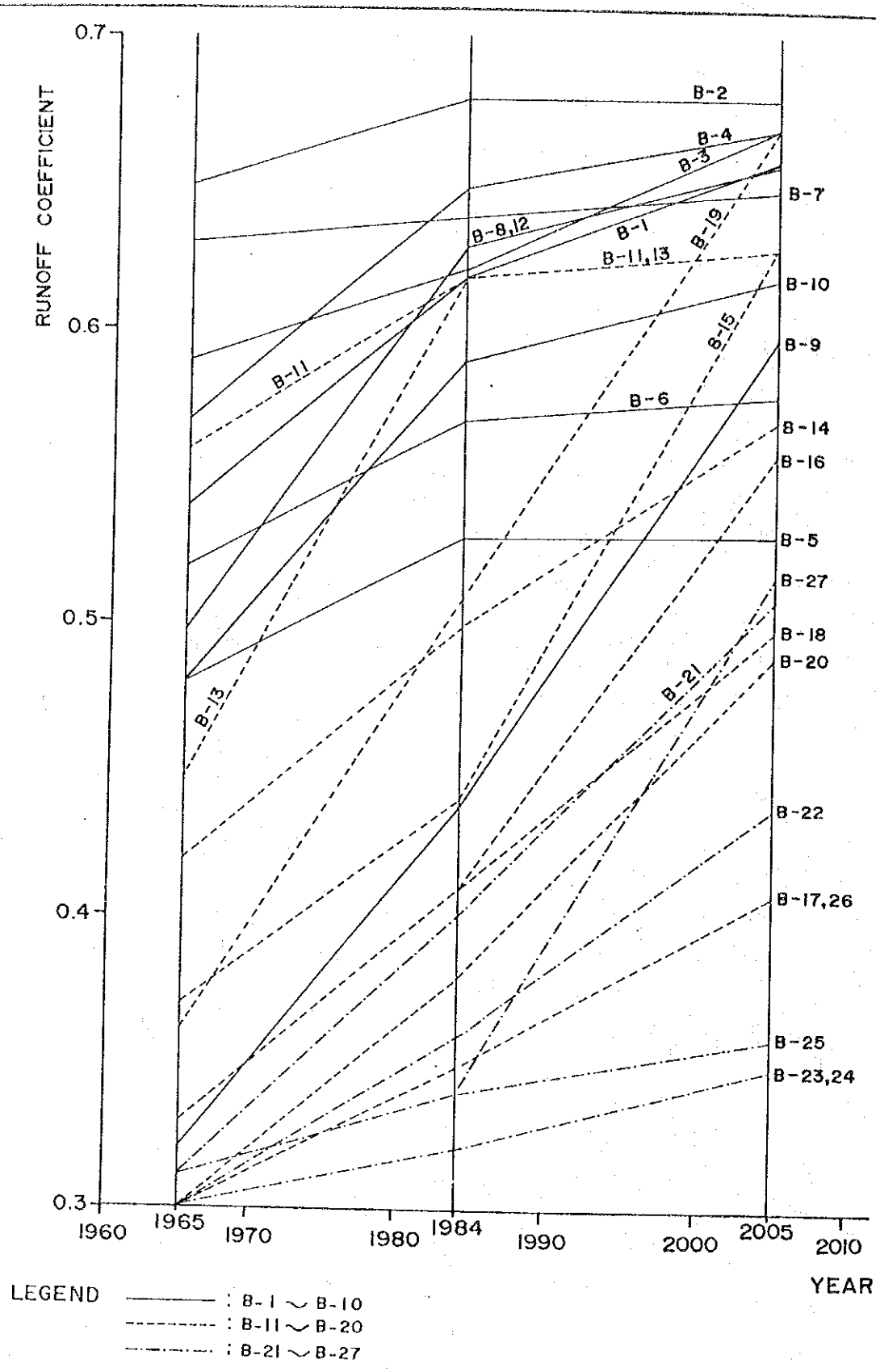



Fig. 3-9 INCREMENT OF RUNOFF COEFFICIENT BY URBANIZATION

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

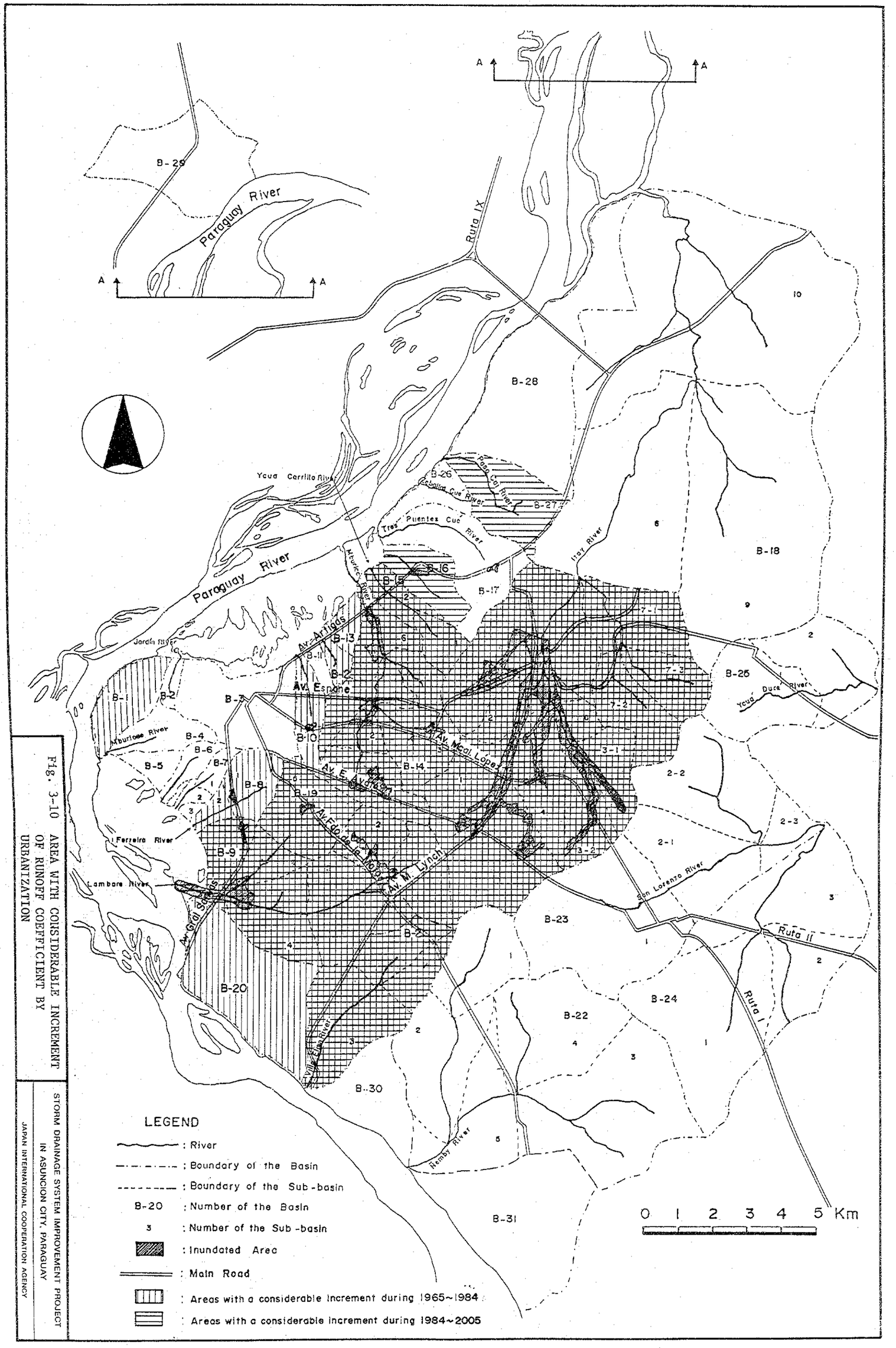



Fig. 3-10 AREA WITH CONSIDERABLE INCREMENT OF RUNOFF COEFFICIENT BY URBANIZATION

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

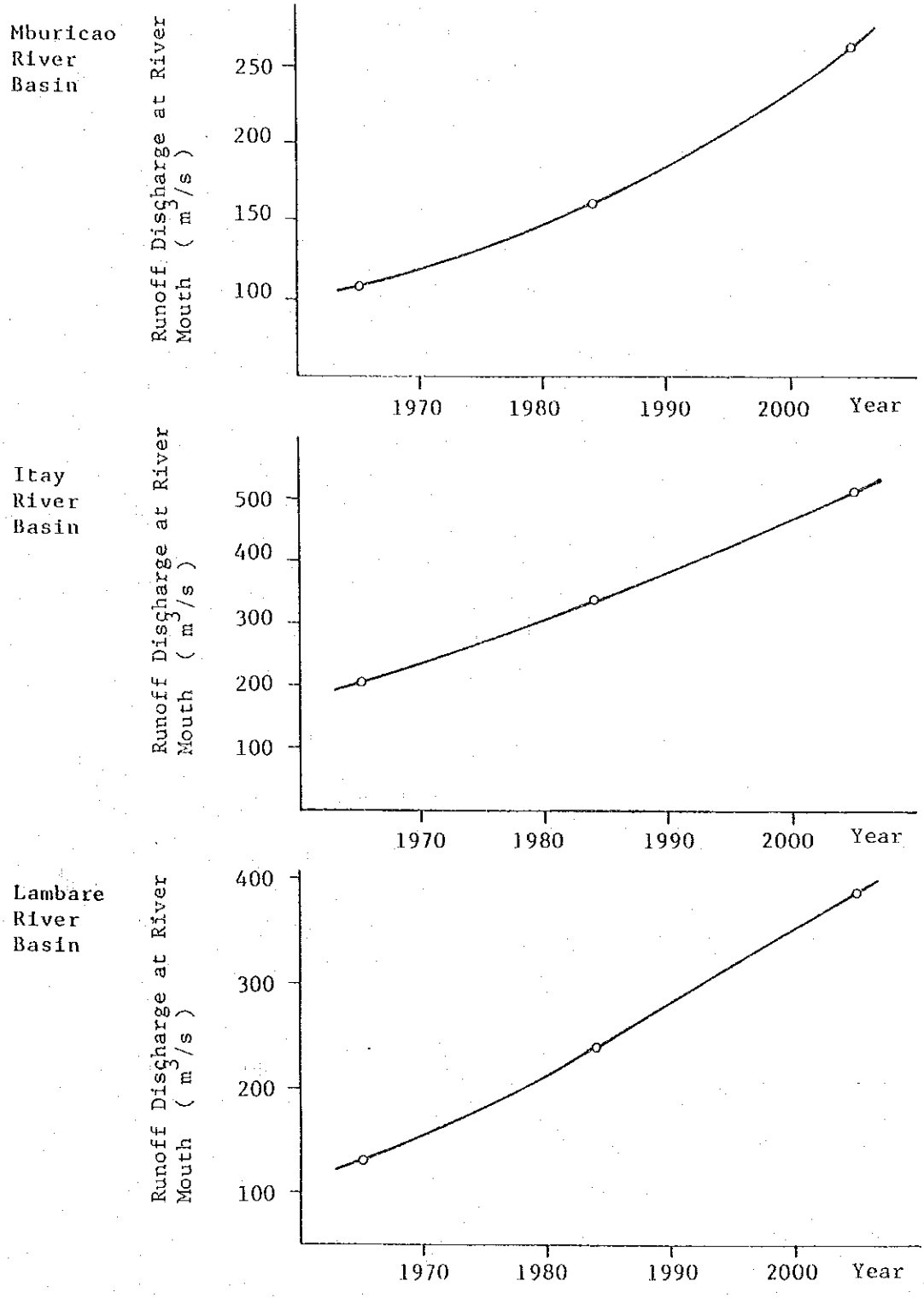
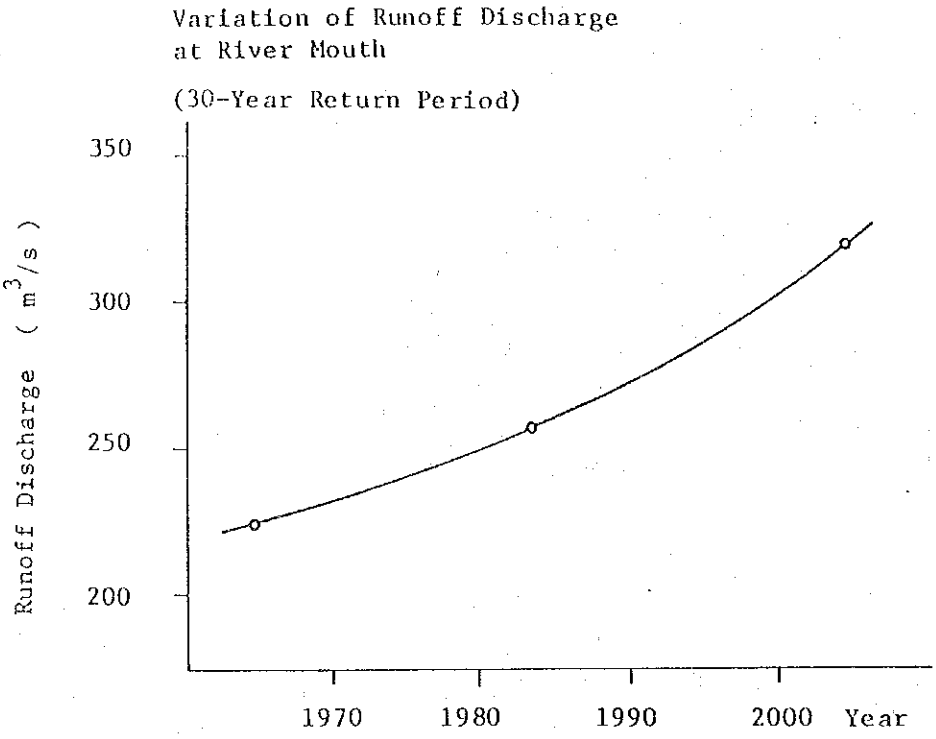



Fig. 3-11 INCREMENT OF RUNOFF DISCHARGE BY URBANIZATION (3-YEAR RETURN PERIOD)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY



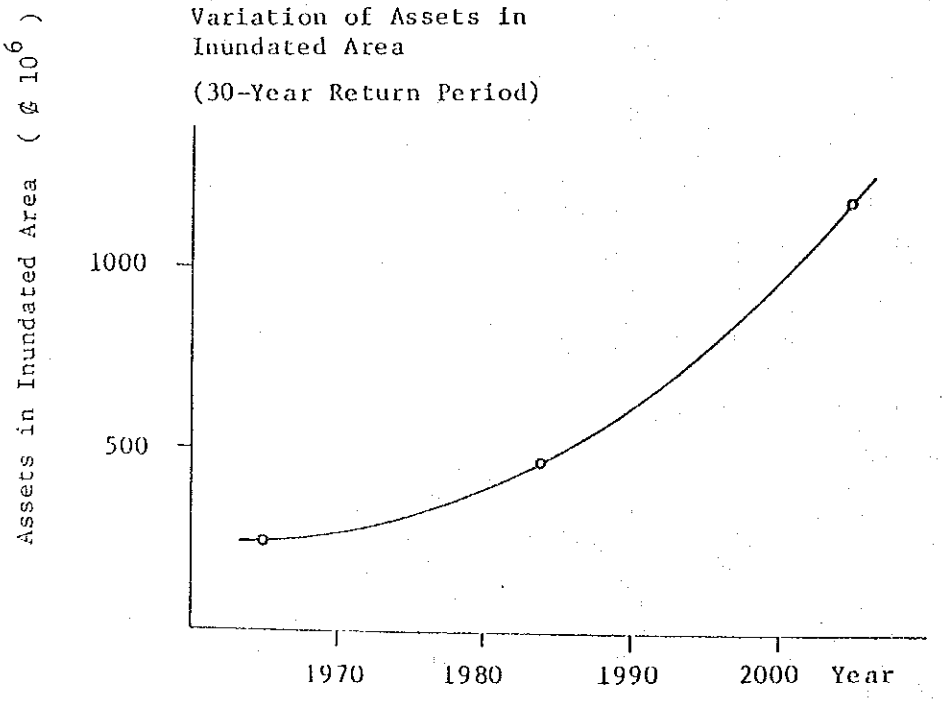




Fig. 3-12 INCREMENT OF RUNOFF DISCHARGE AND ASSETS (MBURICAO RIVER BASIN)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT
IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

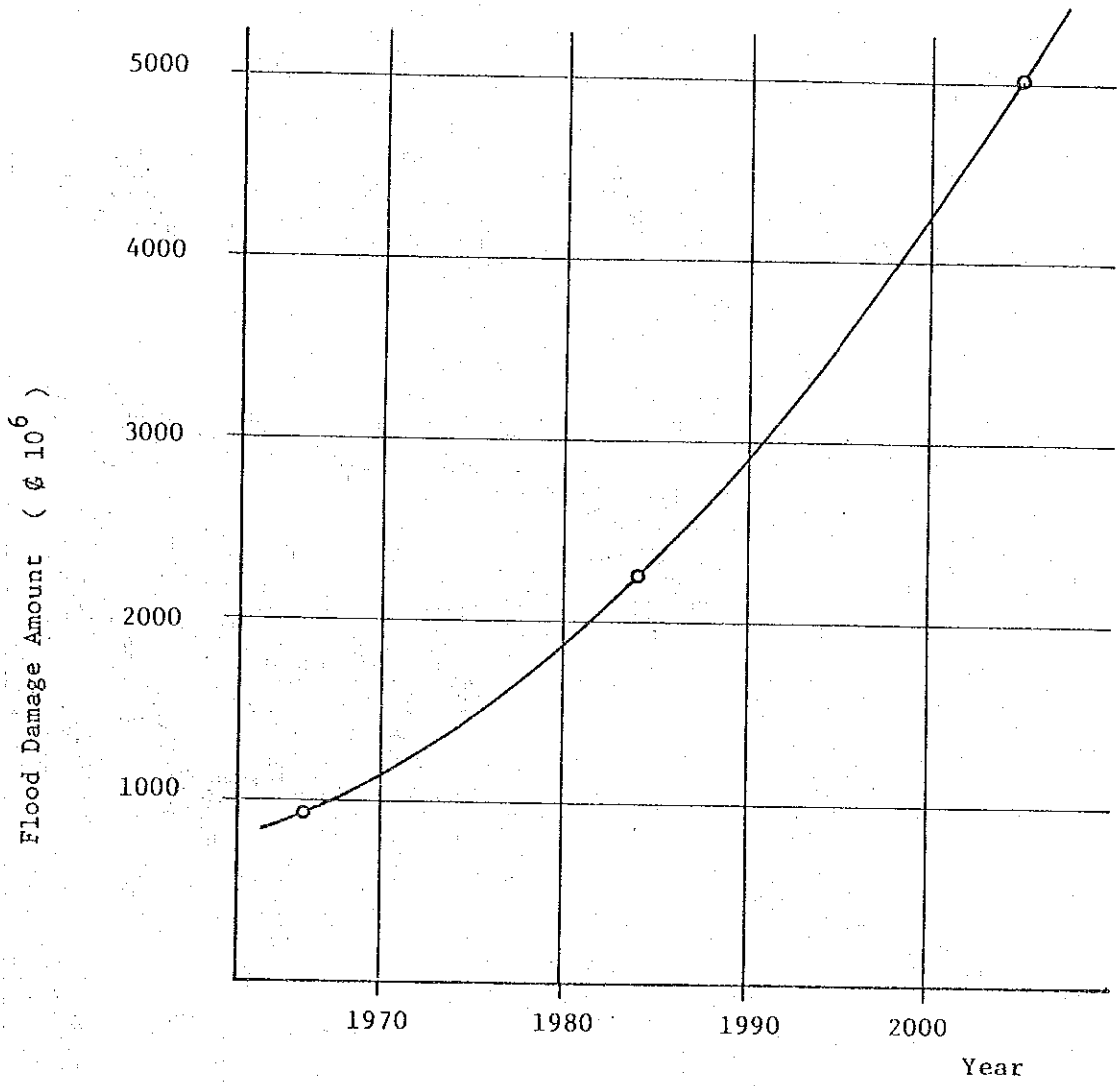



Fig. 3-13 TOTAL FLOOD DAMAGE AMOUNT IN PLANNING AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

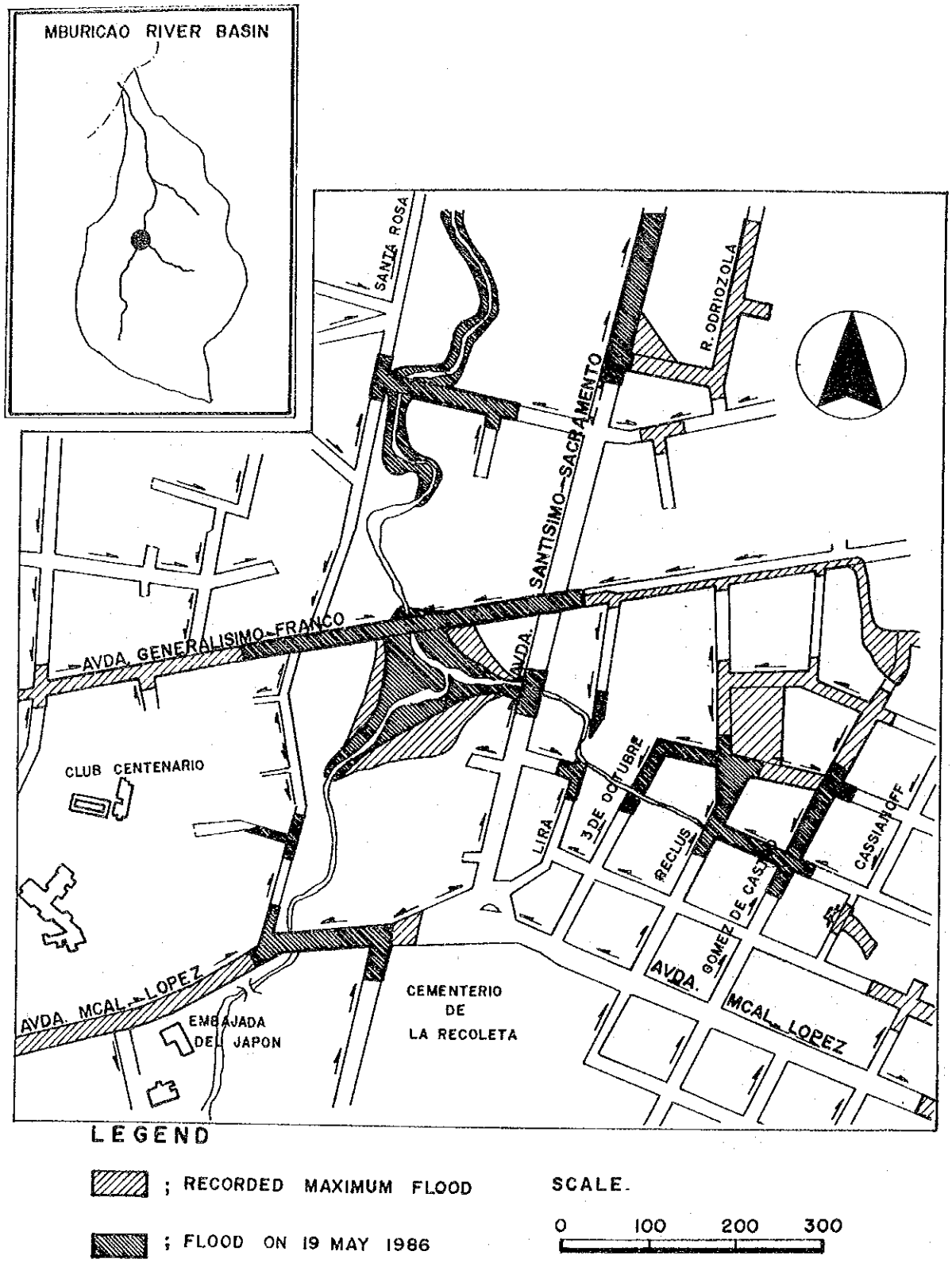



Fig. 3-14 INUNDATED PORTIONS OF DIFFERENT FLOODS

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

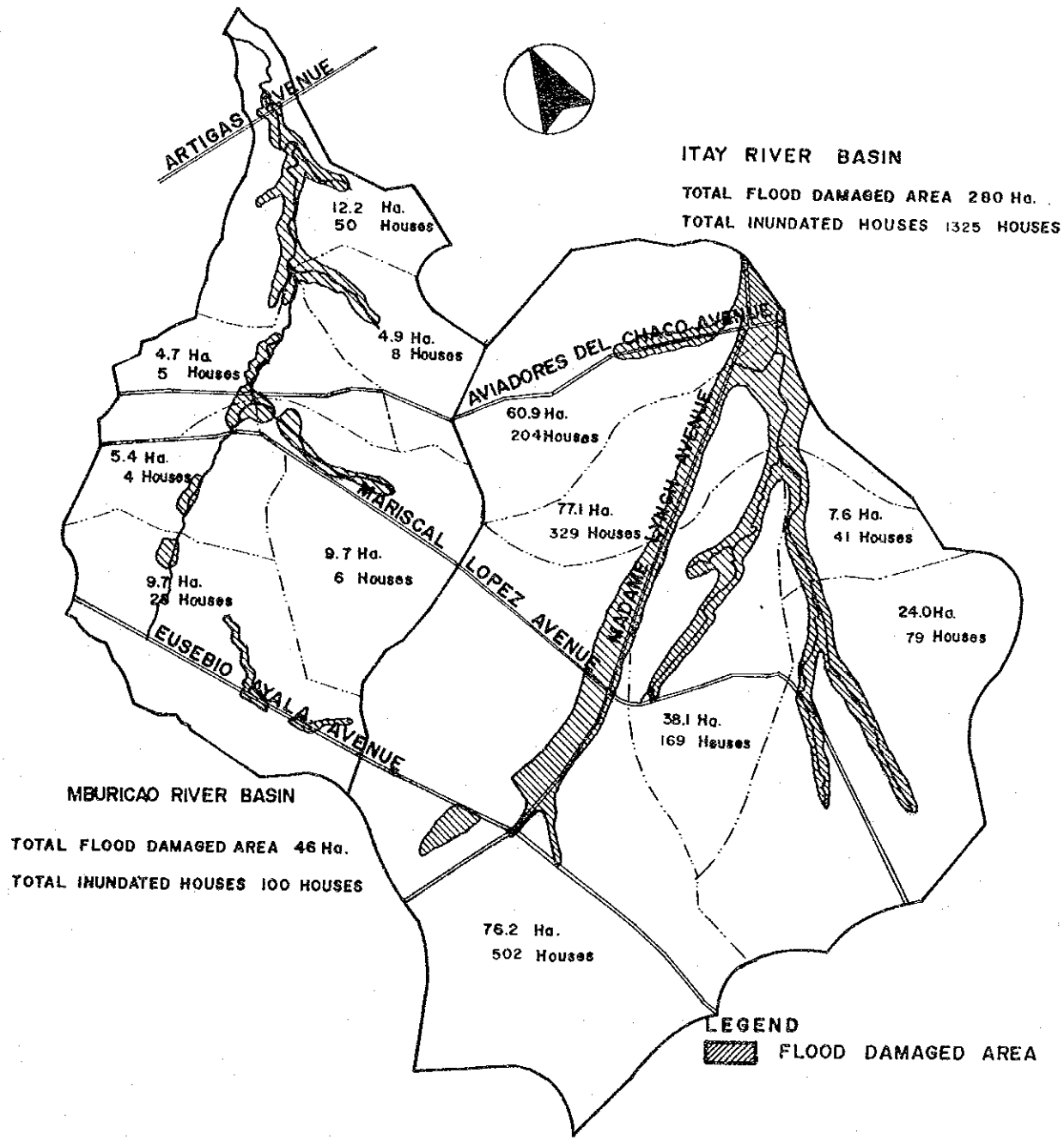



Fig. 3-15 FLOOD DAMAGED AREA IN TARGET AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT
IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

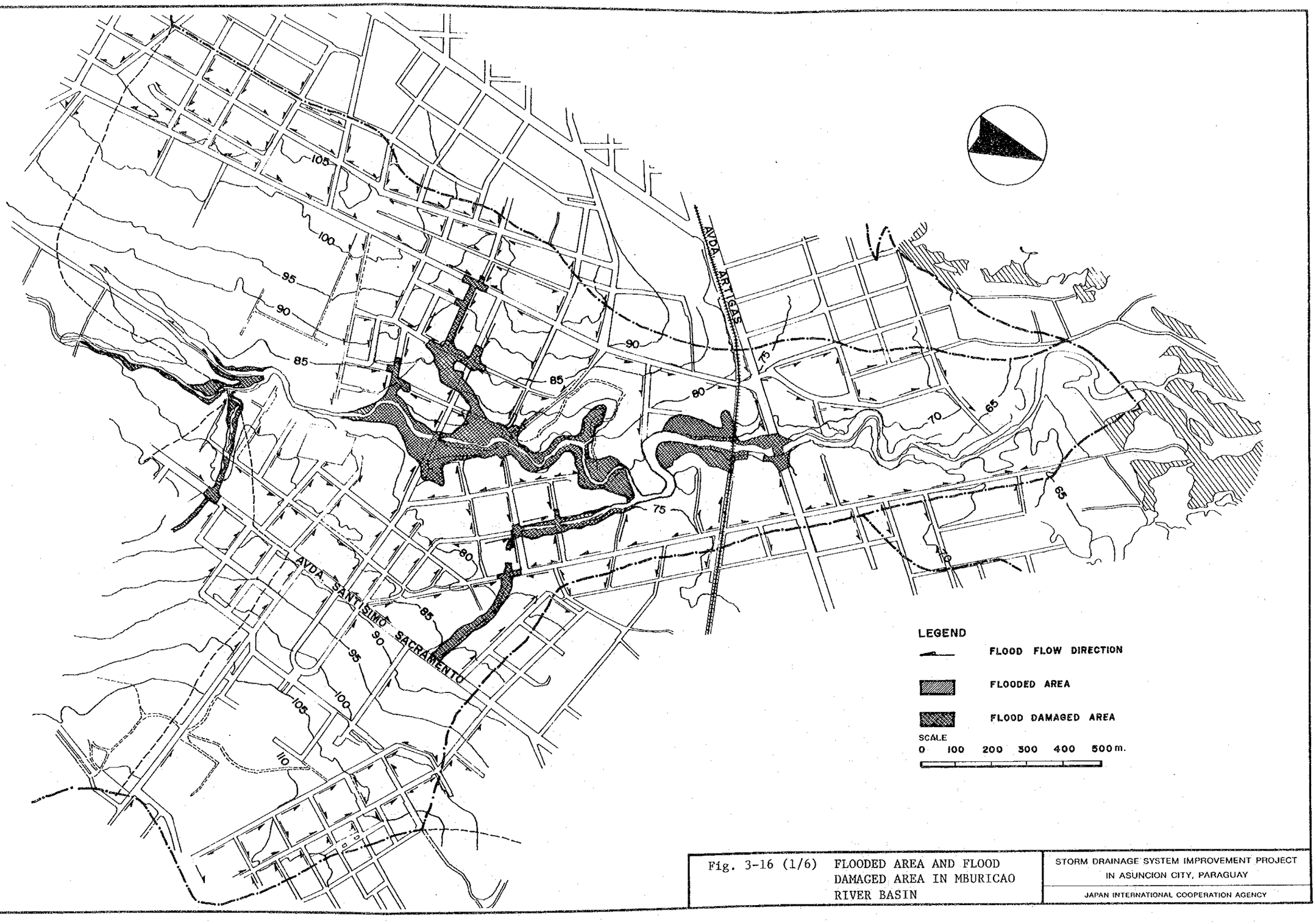



Fig. 3-16 (1/6) FLOODED AREA AND FLOOD DAMAGED AREA IN MBURICAO RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

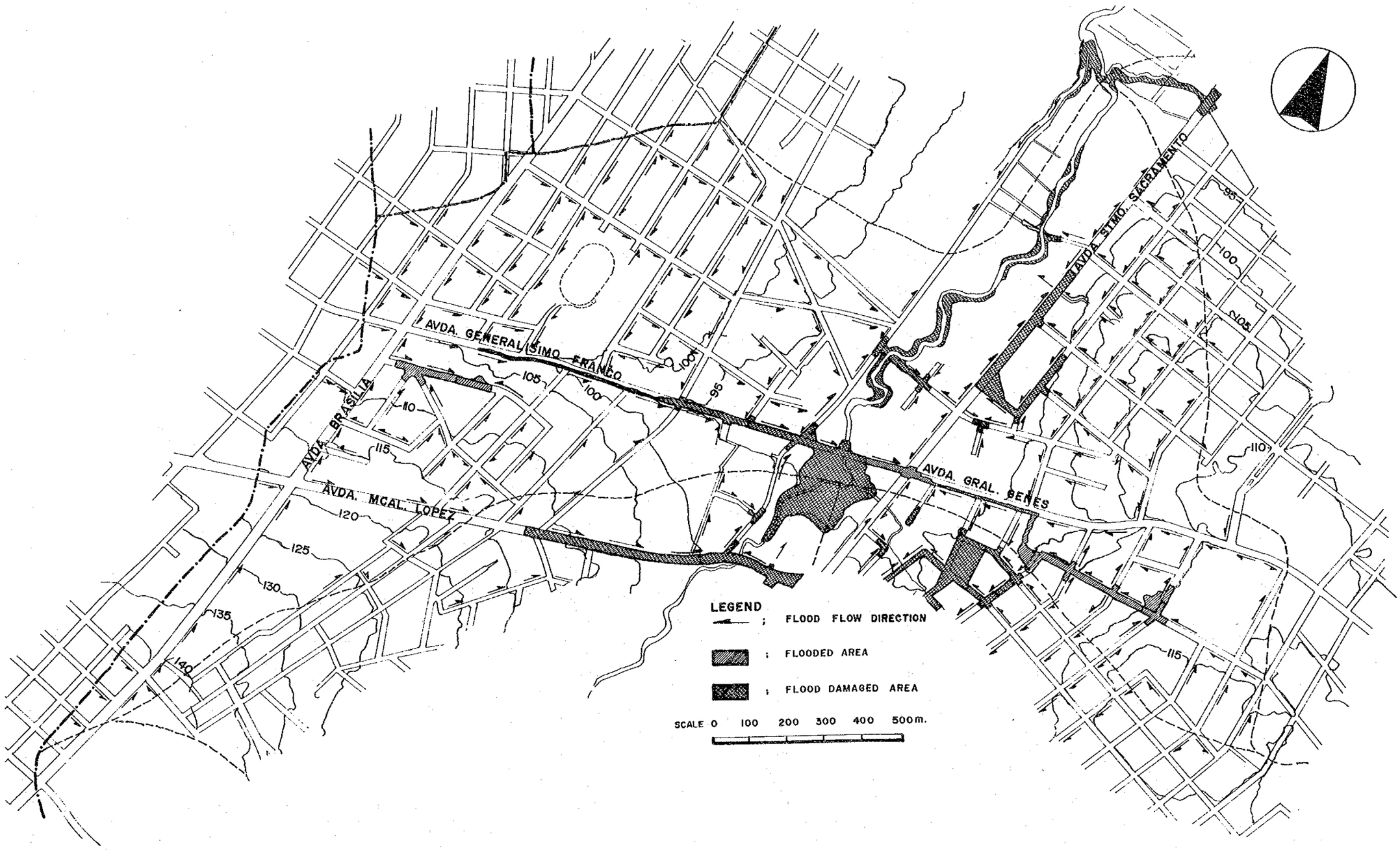



Fig. 3-16 (2/6) FLOODED AREA AND FLOOD DAMAGED AREA IN MBURICAO RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

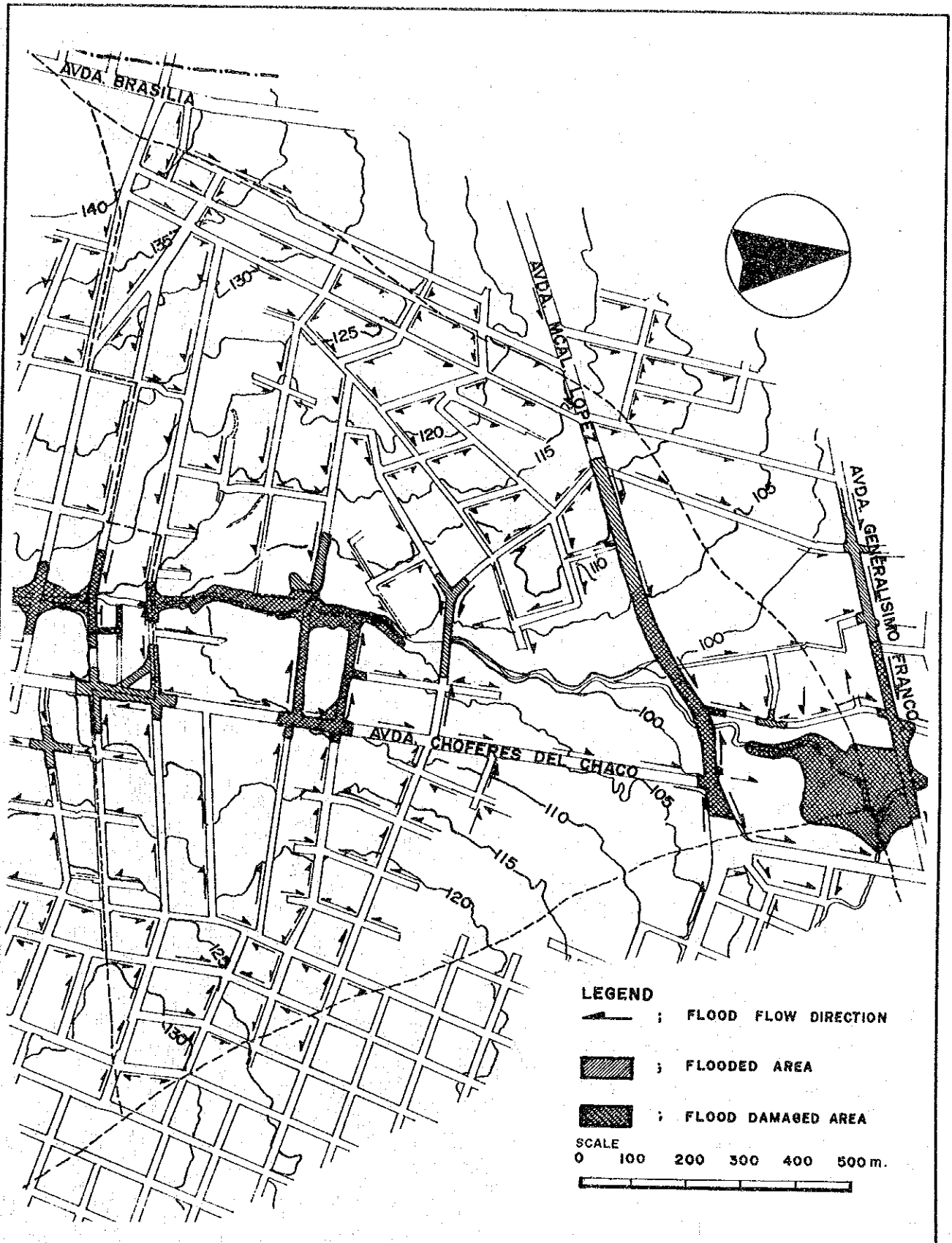



Fig. 3-16 (3/6) FLOODED AREA AND FLOOD DAMAGED AREA IN MBURICAO RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

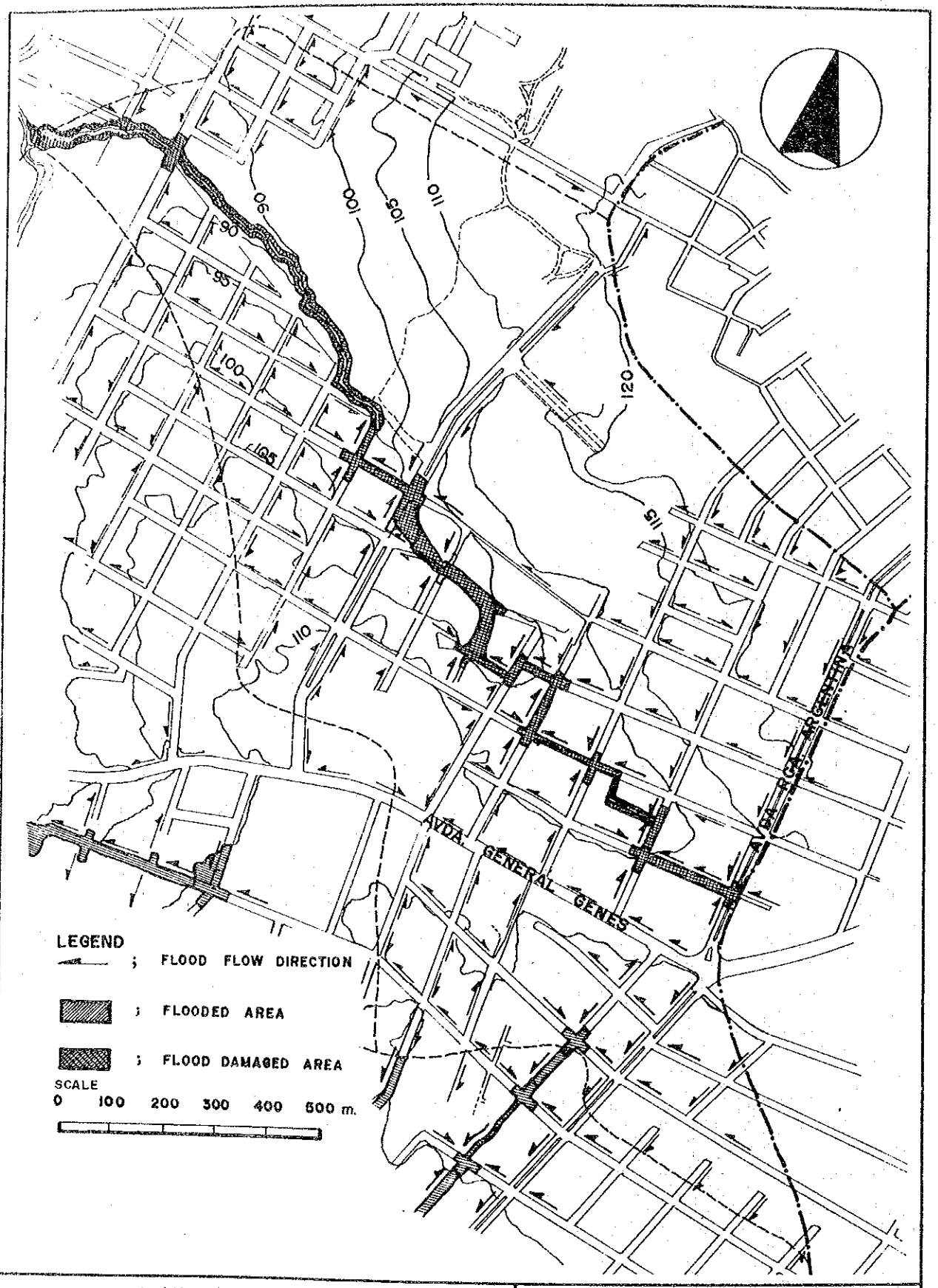



Fig. 3-16 (4/6) FLOODED AREA AND FLOOD DAMAGED AREA IN MBURICAO RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

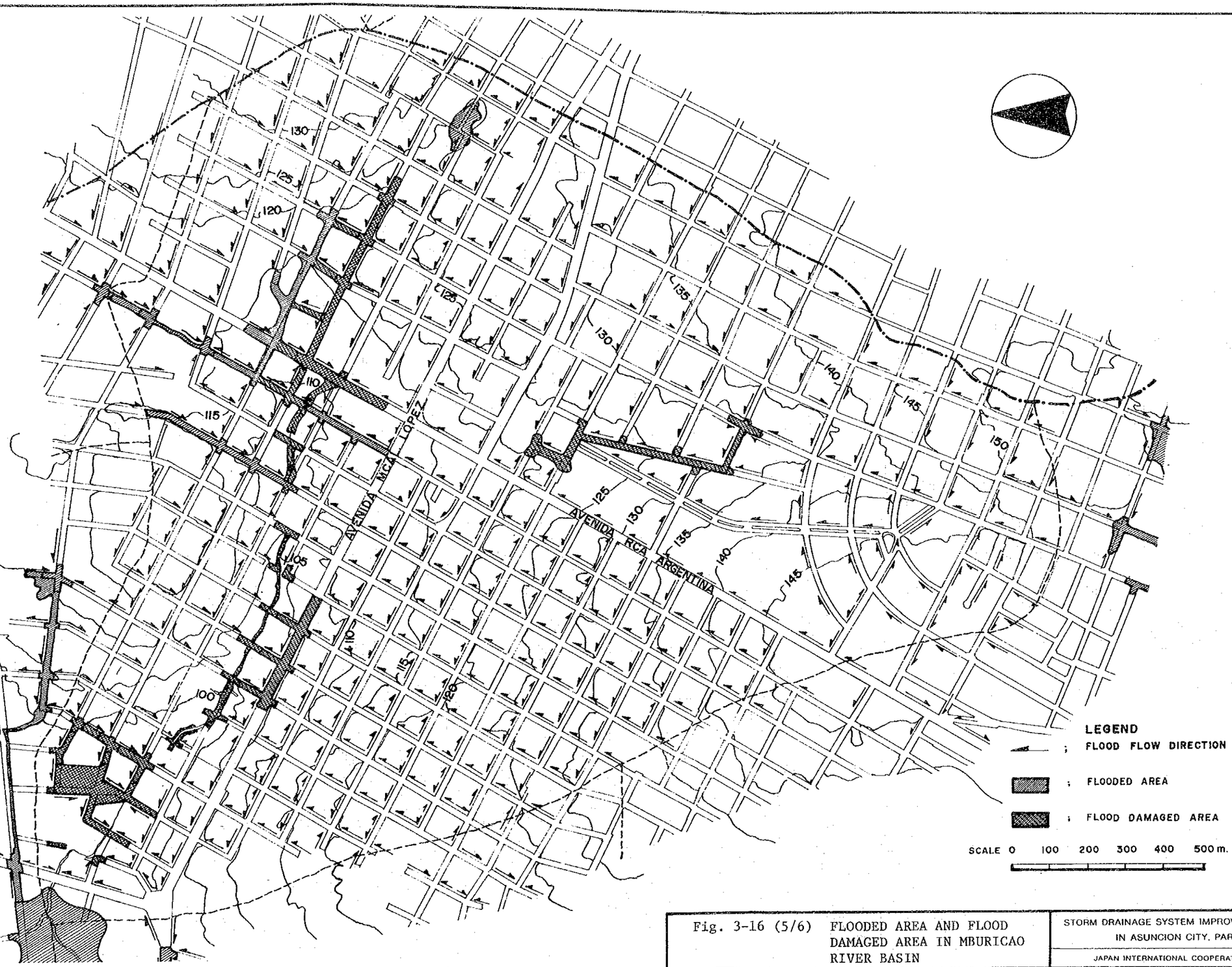



Fig. 3-16 (5/6) FLOODED AREA AND FLOOD DAMAGED AREA IN MBURICAO RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

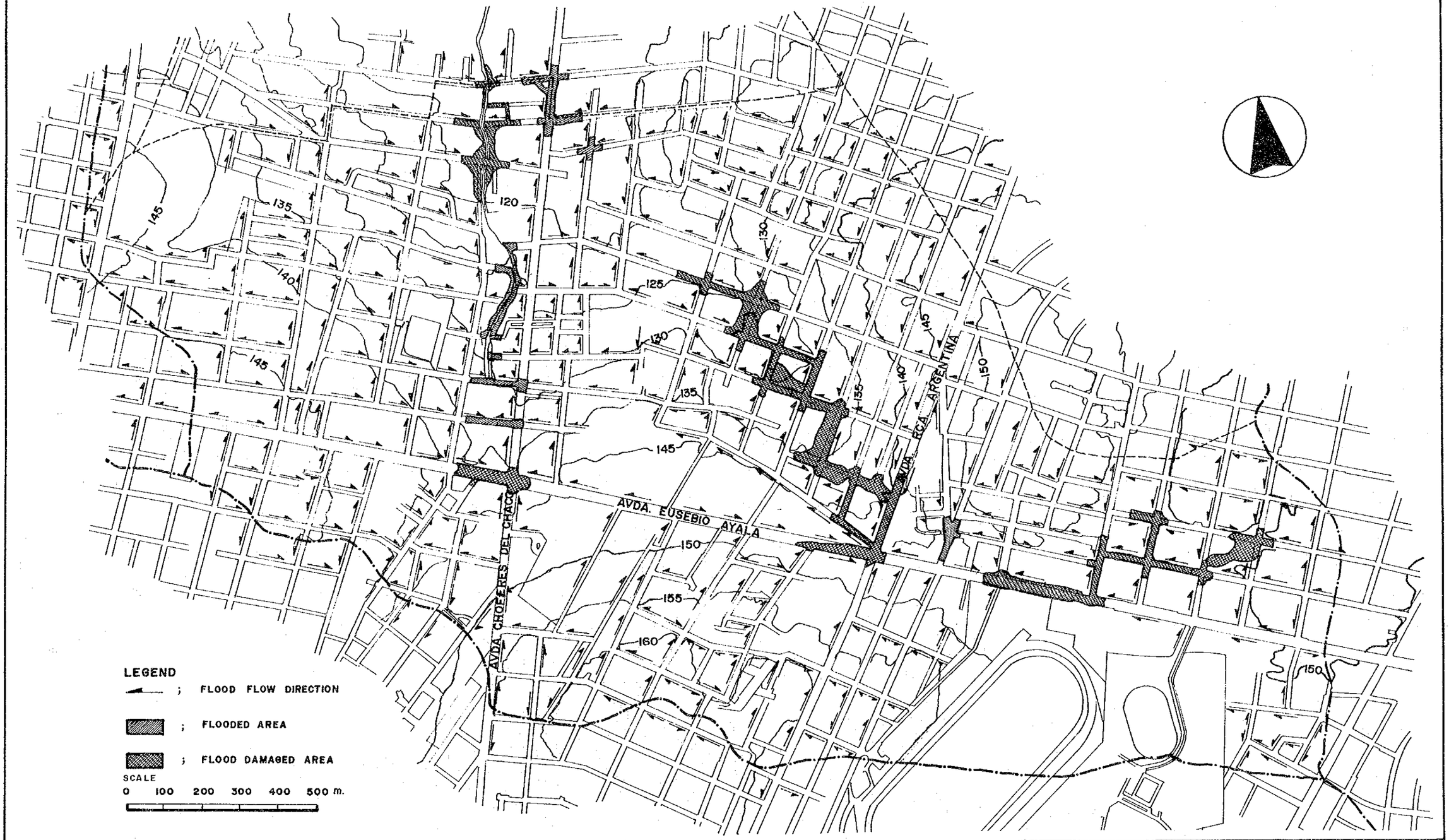



Fig. 3-16 (6/6) FLOODED AREA AND FLOOD DAMAGED AREA IN MBURICAO RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

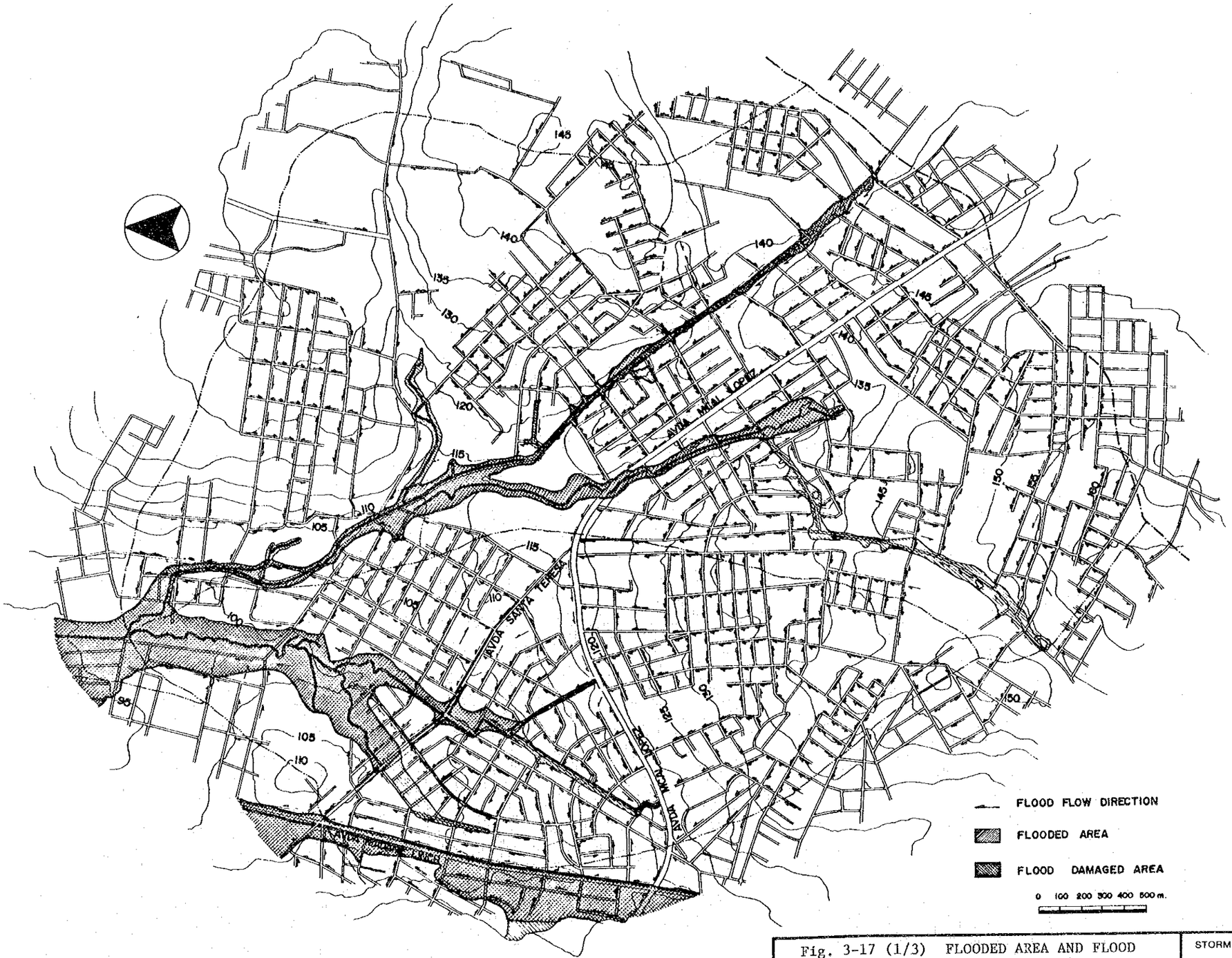



Fig. 3-17 (1/3) FLOODED AREA AND FLOOD DAMAGED AREA IN ITAY RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY


Fig. 3-17 (2/3) FLOODED AREA AND FLOOD DAMAGED AREA IN ITAY RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY


Fig. 3-17 (3/3) FLOODED AREA AND FLOOD DAMAGED AREA IN ITAY RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

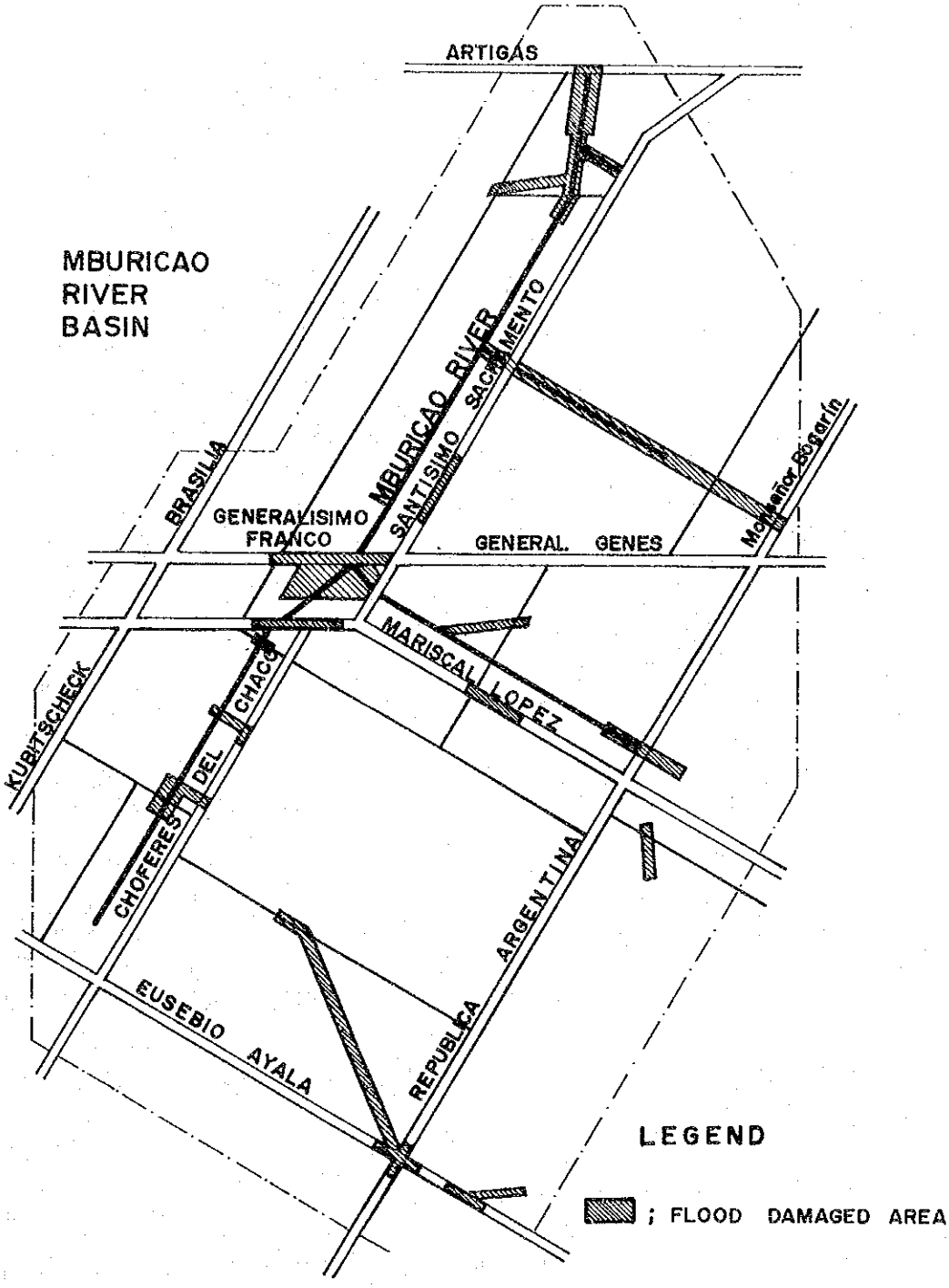



Fig. 3-18 LOCATION OF FLOOD DAMAGED AREA MBURICAO RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

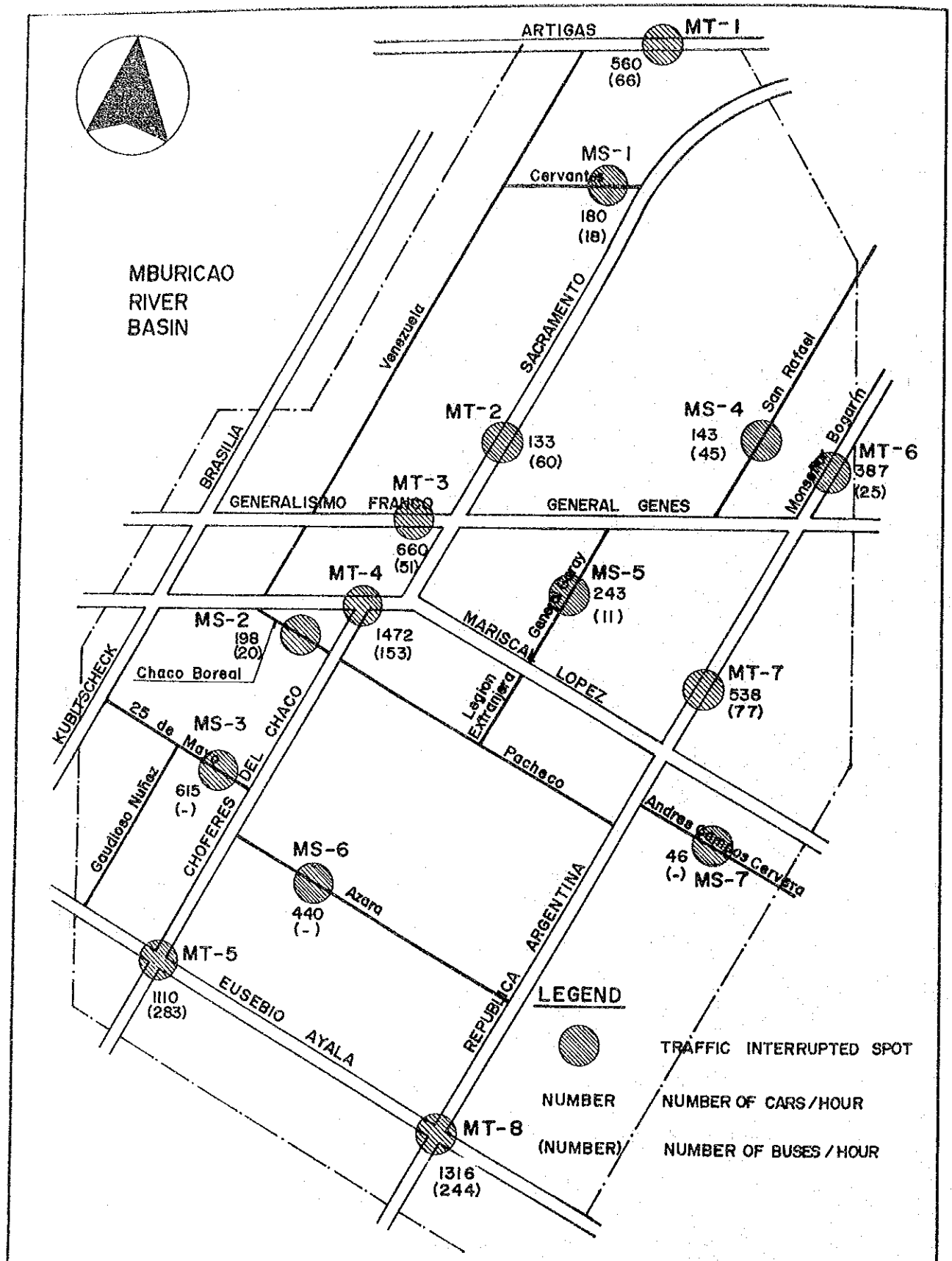



Fig. 3-19 LOCATION OF TRAFFIC INTERRUPTED SPOTS IN MBURICAO RIVER BASIN (AT PRESENT)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

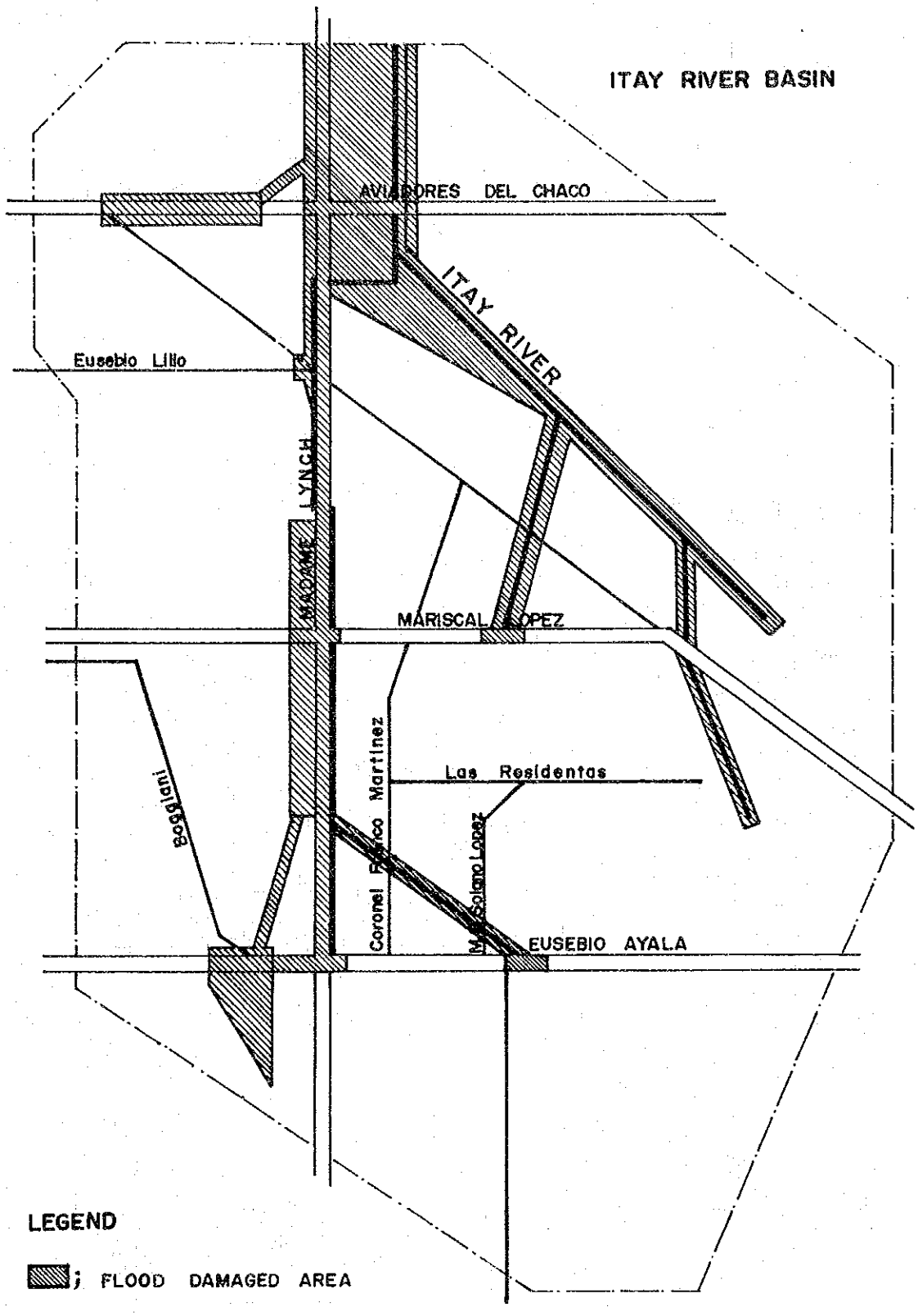



Fig. 3-20 LOCATION OF FLOOD DAMAGED AREA IN ITAY RIVER BASIN

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

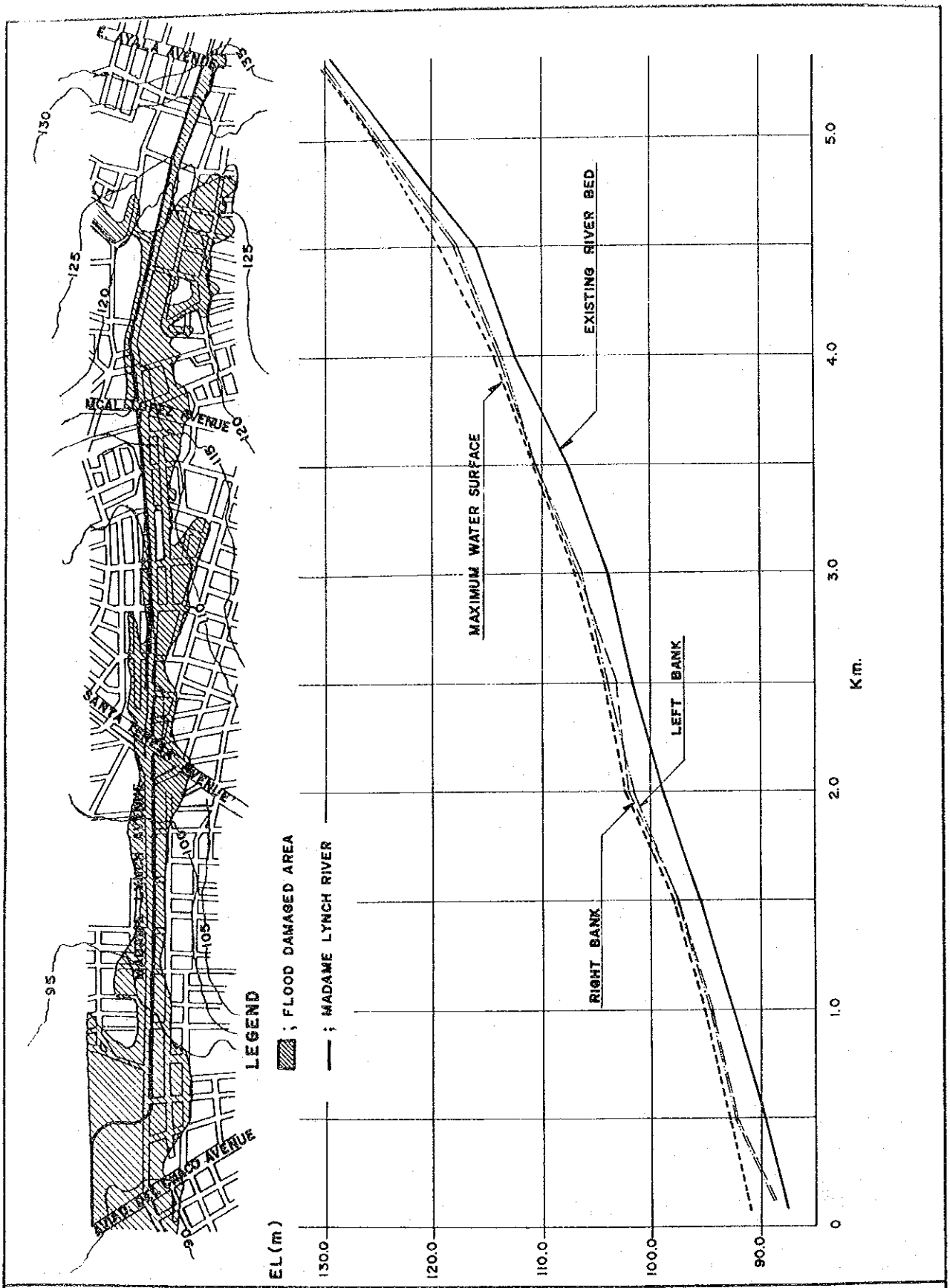



Fig. 3-21 LONGITUDINAL PROFILE OF FLOOD WATER STAGE ALONG MADAME LYNCH AVENUE

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

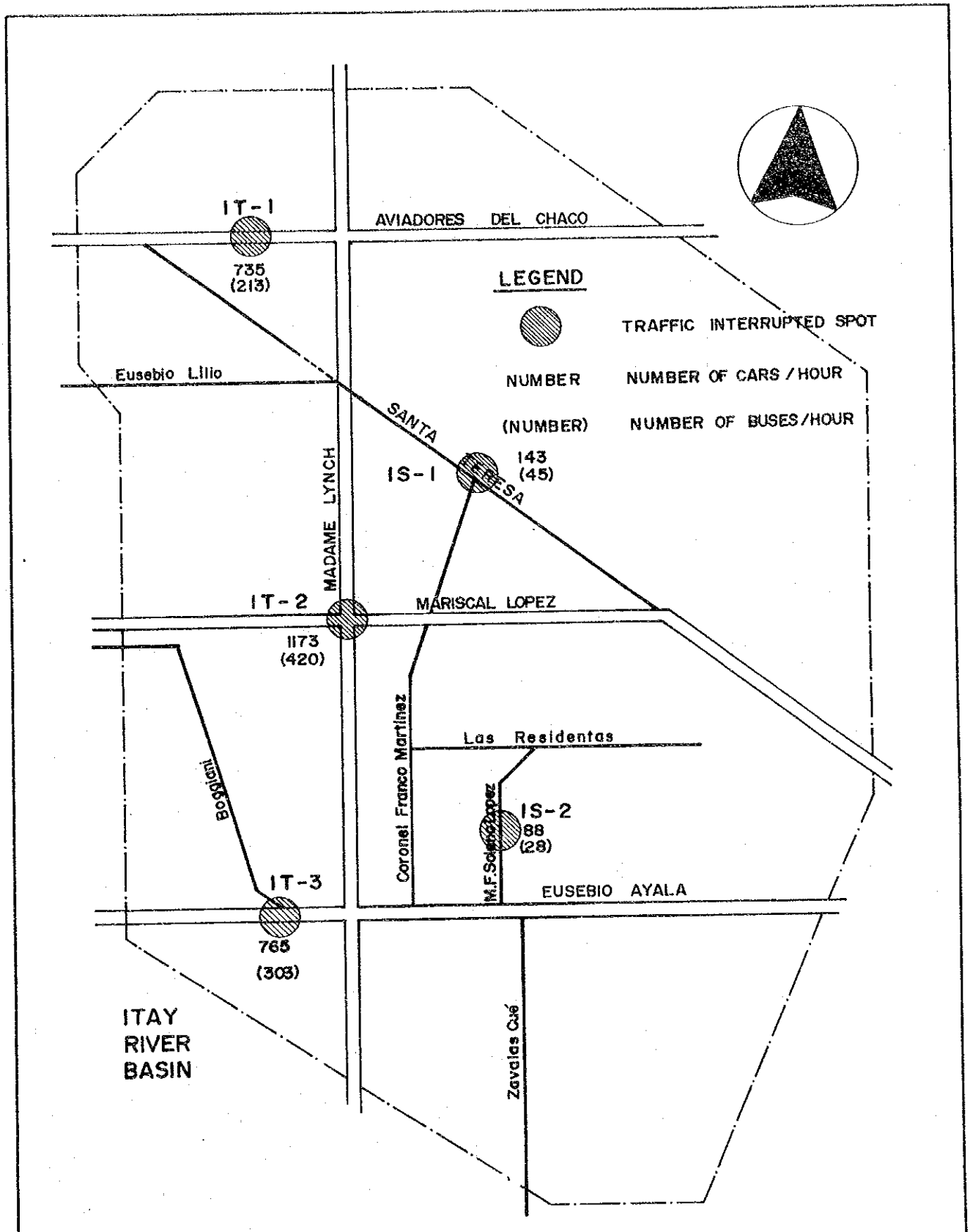



Fig. 3-22 LOCATION OF TRAFFIC INTERRUPTION SPOTS IN ITAY RIVER BASIN (AT PRESENT)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

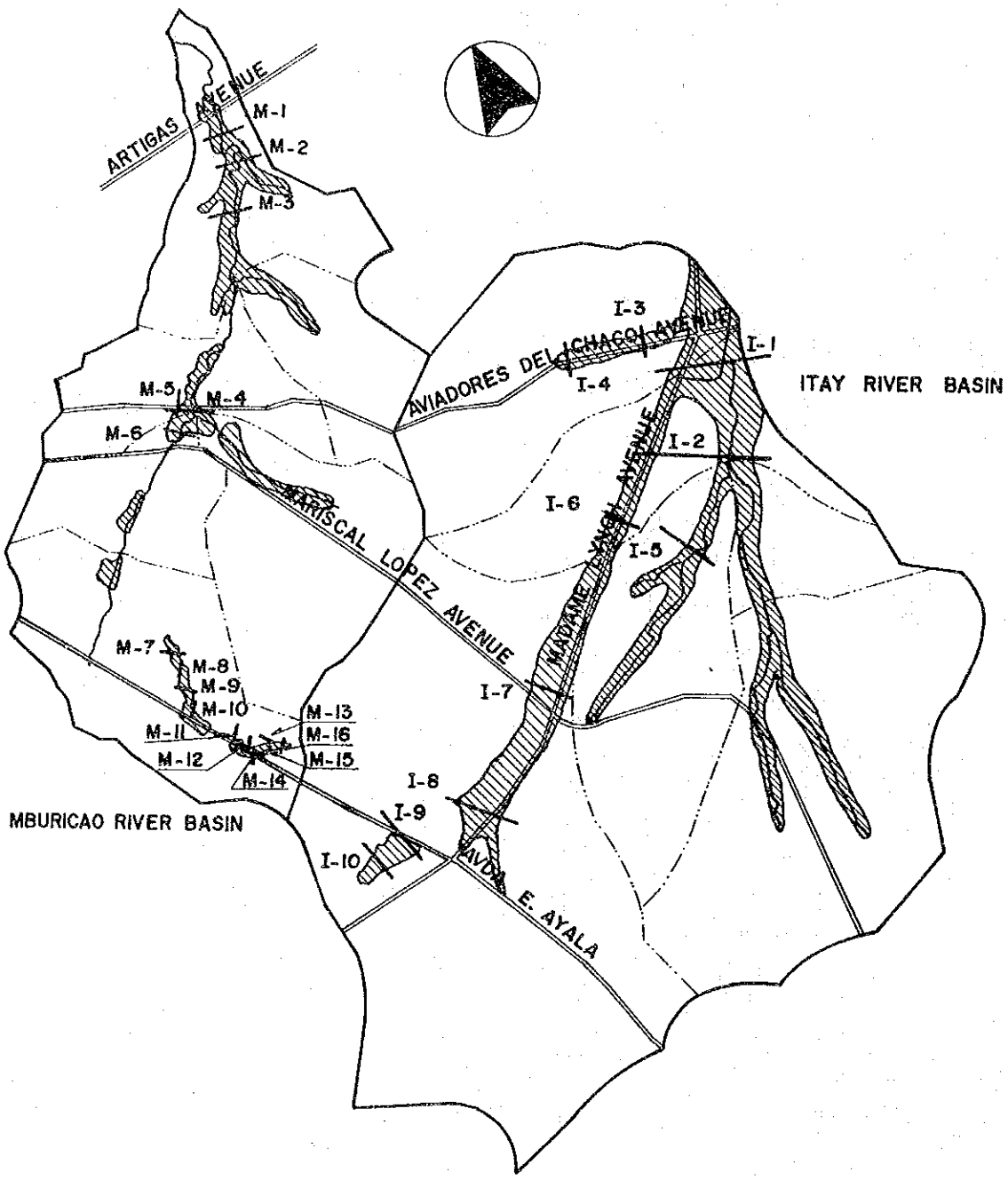



Fig. 3-23 LOCATION OF CROSS SECTIONAL SURVEY

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

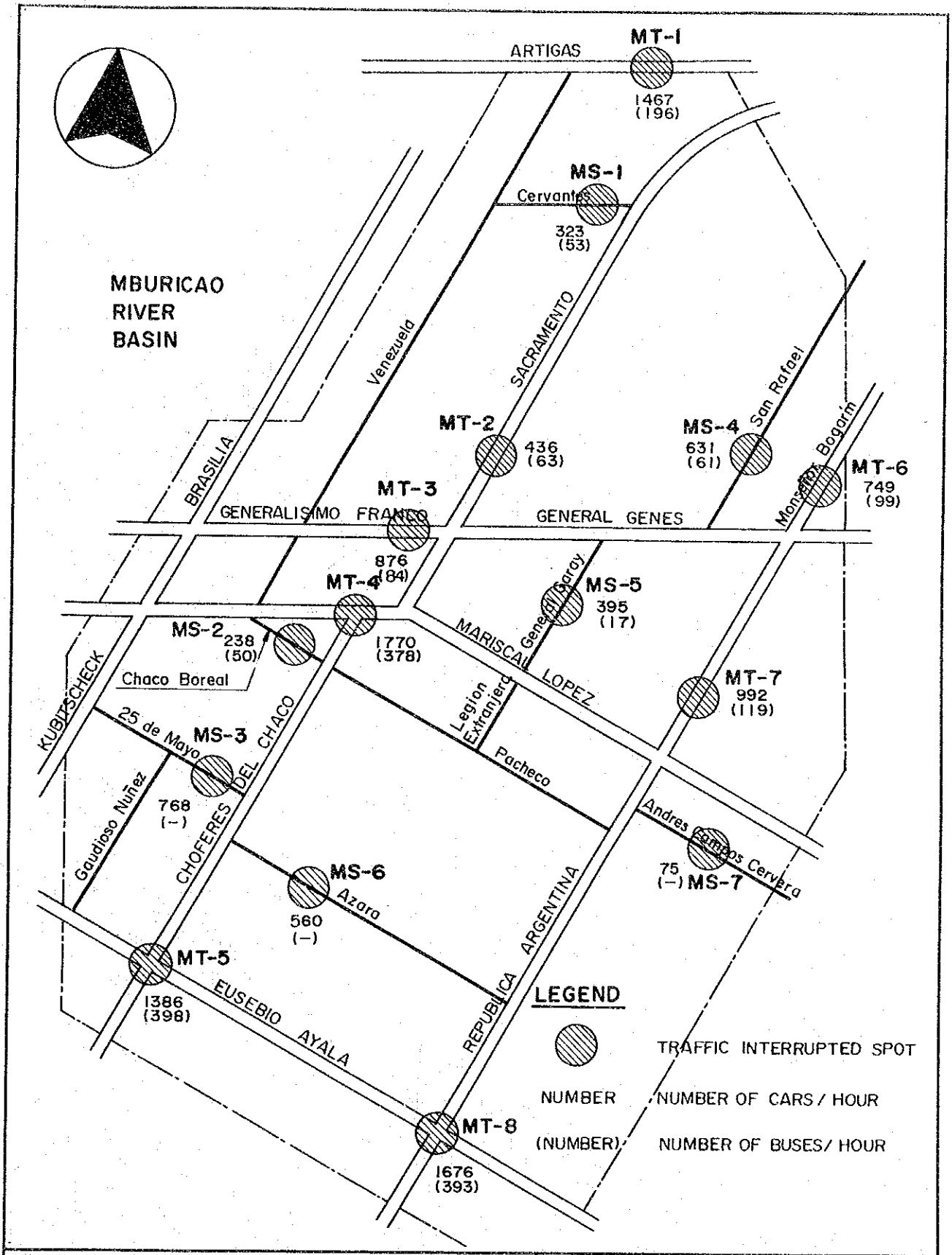



Fig. 3-24 (1/2) LOCATION OF TRAFFIC INTERRUPTION SPOTS IN TARGET AREA AS OF 1995

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

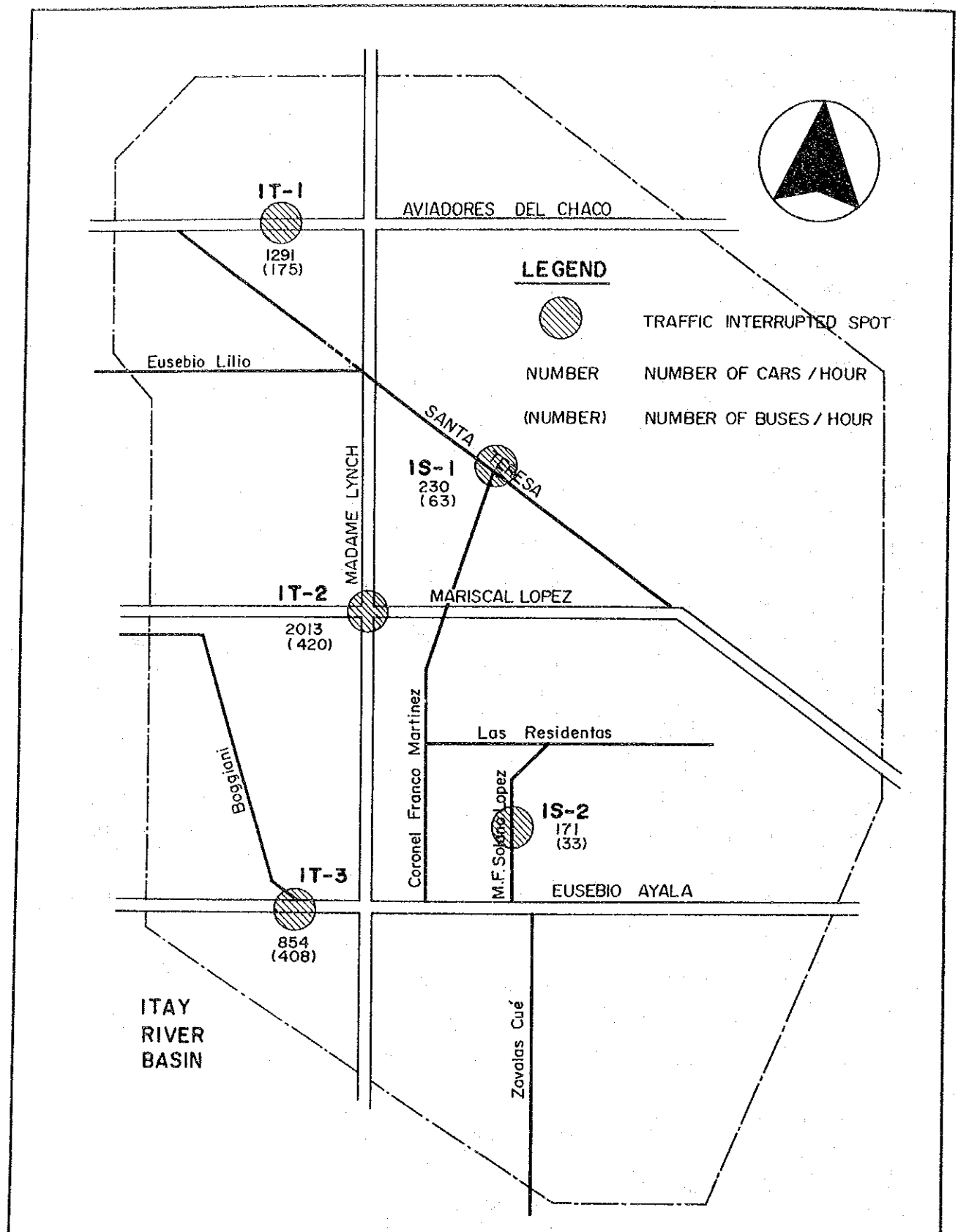



Fig. 3-24 (2/2) LOCATION OF TRAFFIC INTERRUPTION SPOTS IN TARGET AREA AS OF 1995

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY