4. URBAN PLANNING

SUPPORTING REPORT
ON
URBAN PLANNING

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1. General

1.1 Purpose of Urban Planning Survey

The purpose of urban planning survey in this project is to establish the land use pattern and estimate the rate of permeable area in the basin expressed by the building-to-land ratio from the past to the future which will serve as basic data for calculating the runoff discharge in the drainage area and for estimating the benefit derived from the implementation of the project. On this context, the present and future urban development conditions are analyzed by studying the trend of population growth and changes in land use conditions and urban structure. From the results, the land use pattern and building-to-land use ratio on each basin is calculated.

1.2 Study Condition

The future population and land use patterns in Asuncion City and the neighboring area have been predicted by two studies. One is for the Urban Transport Study in Asuncion Metropolitan Area and the other is for the Asuncion Sewerage and Sewage Treatment Master Plan. These studies differ from each other in their target year and study area in accordance with their study objectives, as follows: the target year of the former is 2000 and that of the latter is 2010, and the study area of the former is 71,000 ha and that of the latter is 27,800 ha.

In this study, the former study's data about population prediction and future land use have been adopted in view of the following two main reasons: (1) the study area of the former study almost covers that of the storm water drainage project, and (2) the former study had already completed studies on items including future land use, etc., which this present study require. (Refer to Fig. 4-1.)

2. Population

2.1 Population Growth

Population census in the Republic of Paraguay were taken four times: in 1950, 1962, 1972 and 1982 (see Table 4-1). The table shows that the population of the whole country has increased by about 1.7 times, growing from about 1,820,000 to some 3,040,000 in the twenty years between 1962 and 1982. In this period, the average annual growth rate was 2.7% in the first ten years and decreasing a little to 2.55% in the latter ten years. In the same period, the population of the Asuncion Metropolitan Area (Asuncion City and other outskirt municipalities) had increased by about twice, growing from about 410,000 to some 800,000. In this area, the population is increasing relatively faster than that of the whole country. As a result, the share of the metropolitan population in the country had climbed from 22.5% in 1962 to 26.3% in 1982. This means that the concentration of population toward the metropolitan area is now in progress.

On the other hand, while the population of Asuncion City has increased by about 1.6 times, growing from about 290,000 to some 460,000 in these twenty years, the share of Asuncion's population in the metropolitan area had largely declined from 70.5% to 57.3% (refer to Figs. 4-2 and 4-3).

It should be noted that while the average annual growth rate in Asuncion City had largely declined to 1.6% in those ten years between 1972 and 1982, the outskirt municipalities such as Fernando de la Mora, Lambare, Mariano Roque Alonso, San Lorenzo, Villa Elisa, and so on, had rapidly increased their population with the average annual growth rate of more than 6% in the same period. This means that in contrast with the slow down of growth rate of population within the Asuncion city proper, high growth of population and urbanization are continuing in the outskirt municipalities which still have abundant unutilized land (refer to Figs. 4-4 and 4-5).

The population density in 1982 were 0.074 persons/ha for the whole country, 11 persons/ha for the Metropolitan Area, and 39 persons/ha for Asuncion City.

The component of the population by sex and age groups are shown in Table 4-2. From this table, it is seen that the sex ratio (number of males for every 100 females), which was 98.3 in 1972, had reversed itself to 100.3 in 1982.

On the other hand, in the Metropolitan Area the sex ratio which was 90.5 in 1972 had slightly climbed to 91.3 in 1982, although there is still a high proportion of females in this area.

By age group, the percentage of productive age (15-64) of the whole country had increase sharply from 51.2% in 1972 to 54.7% in 1982, and that of Metropolitan Area has also increased from 59.6% to 62.9% in the same period. (Refer to Table 4-2.)

2.2 Present and Future Population Distribution in Each Basin

In the Urban Transport Study, population growth by the year 2000 has been studied in combination of natural and social population increases (influx from outside cities in three dimensions), out of which the median value of 1,452,000 people is used as the population framework for the Asuncion Metropolitan Area (Asuncion City and the ten surrounding cities). Of this figure, the population of Asuncion itself is calculated to be 635,000 in consideration of past population growth trends and future population accommodation capacity. By extending the trend of these figures further to the future, the population of the year 2005 will be 1,647,000 in the metropolitan area and 678,000 in Asuncion City alone. In the Urban Transport Study, the entire metropolitan area is divided into 40 zones, and the future population in each zone was estimated based on the past trends in population growth and increment ratio of the housing lots in vacant lands and farmlands (refer to Fig. 4-2).

Population distribution in each river basin for the year 2005 is a vital material in obtaining a total grasp of the urban development conditions for the purpose of this study.

In this Storm Water Control Study, the study area related to it is divided into 31 basins (60 zones if subdivisions are included) and the population distribution in each basin in 1992 and 2000 is calculated by using a land area ratio on the data of the Urban Transport Study's population distribution. The population in each basin for the year 2005 was sought by extending the trends of the population in the above-zoned basins between the years 1992 and 2000. With the results, the total population of the area related to this study for 1984 is estimated at 822,000, and for 2005 at 1,579,000 (Table 4-3). Figs. 4-6 and 4-7 show the present and future population density distribution, and Table 4-3 shows the growth rates of the increasing population in each basin.

According to the figures of population density distribution for each basin, population density in about one-third of the area of Asuncion City exceeded 60 persons/ha in 1984. Such high density area is predicted to expand to about three-quarters of Asuncion City and major parts of Lambare and Fernando de la Mora by 2005. The population growth rate is expected to be below 1.5 times within Asuncion City and be more than 2 times in the surrounding cities during the period from 1984 to 2005. It shows that the rapid urbanization is predicted to increase in these areas. (Refer to Table 4-4.)

3. Present City Conditions

3.1 Urban Structure

Asuncion City has its urban core on the riverside where the government administrative organization and commercial and business establishments are concentrated. Outward to the east, there spread the residential area, including the shopping zone and the industrial zone along the trunk roads.

As urban infrastructures supporting the city development, six trunk roads extend radially from the center and play the very important role as urban arteries of transportation. A grid pattern road system also exists.

Fig. 4-8 shows that in these forty years, the city gradually expanded to the surrounding area. Specifically, the city developed in the southeast direction from Centro down along Eusebio Ayala Avenue and Mariscal Lopez Avenue, and also along Madame Lynch Avenue which links these trunk roads.

Along the seven trunk roads, the area has its own special features in terms of land use such as residential area (high class, middle class, low class), commercial area, warehouse and industrial area, and so on. These trunk roads link Asuncion City and the outskirt municipalities and also connect the national roads which lead to the important suburban cities.

3.2 Present Land Use

Administrative, commercial, business and financial functions are concentrated in the central area that corresponds to the heart of Asuncion City. The western half of the city bordering on Kubitscheck Avenue that runs from north to south across the city including a part of the central area is mainly made up of residential areas but with some commercial and other facilities as well, has a medium degree of population density; while, the eastern half, excluding the triangular belt between Eusebio Ayala Avenue and Fernando de la Mora Avenue, make up the low density residential area (refer to Fig. 4-9).

The area along each trunk road in Asuncion City is characterized by the following land use features:

- Artigas Avenue : Warehouses and small and medium scale factories.
- Espana Avenue : High class residential area with sports and cultural facilities, hospitals, clubs, etc.
- Mariscal Lopez Avenue: The most exclusive residential area with embassies and other government offices.
- Eusebio Ayala Avenue : Route-type commercial district constituting a commercial axis leads to

		Fernando de la Mora Avenue, with automobile dealerships, hardware shops, repair factories, miscellaneous shops, etc.
Fernando de la Mora Avenue	:	Coexistence of commercial establishments and middle class residences, forming a commercial axis leads to Ayala Avenue.
Madame Lynch Avenue	:	Complex land use area scattered with food mart, factories, public facilities, small type houses and unused land.

As mentioned before, Asuncion Metropolitan Area consists of Asuncion City and the ten outskirt municipalities with the total area of 71,000 ha. Out of this area, 24,800 ha has now urbanized and 35,000 ha are used as agricultural and as livestock grazing land. The remaining area located in low-lying land is frequently submerged with the floodwaters of the Paraguay River.

The urbanized area consists of most part of Asuncion City, Lambare, Fernando de la Mora, Luque, Villa Elisa and San Lorenzo. The present land use of this area is as follows: Residential Area, 41.0%; Commercial Area, 3.1%; Industrial Area, 1.9%; Recreational Area, 2.7%; Public Facilities, 15.5%; Roads, 22.4%; Unused Area, 13.4%

The present land use in Asuncion City with an area of 11,700 ha is as follows: Residential Area, 45.9%; Commercial Area, 3.6%; Industrial Area, 0.7%; Recreational Area, 3.6%; Public Facilities, 10.8%; Farmland, 0%, Unused Area (including the lower area along the Paraguay River), 17.9%; Roads, 17.5%. (Refer to Table 4-6.)

3.3 Present Traffic Conditions

According to the Urban Transport Study in Asuncion Metropolitan Area, bus travel accounts for 60% of the total mode of transportation. It means that bus travel is particularly frequent in the

Asuncion Metropolitan Area at present. The second place is automobile trip, 22% of the total, followed by cargo vehicles, 13%, which are used not only for works and business but also for shopping and social recreation. Motorcycle is relatively few and is 3%, and taxi is only 0.5%. City electric tram and train travel are used quite sparingly, because of relatively inconvenient location of their routes and infrequent departures.

With regard to the hourly transportation volume, there are three daily peak hours: 6:00 to 7:00, 11:00 to 12:00 and 17:00 to 18:00. The greatest peak of transportation volume occurs from 6:00 to 7:00 o'clock.

In Asuncion City, the total length of paved roads is approxi-mately 880 km consisting of three types of pavement: asphalt, 24.2%; concrete blocks, 1.2%; and cobblestone, 74.6%. The other roads remain in the unpaved condition.

The present traffic volumes of trunk roads are shown in Fig. 4-10. Mariscal Lopez, Eusebio Ayala and Espana avenues have the large traffic volume of from 15,000 to 80,000 vehicles per 24 hours.

4. Past Land Use

It is difficult to establish the past land use pattern in Asuncion City and its neighboring area because the available data is only the aerial photograph taken in 1965. In this study, therefore, the land use pattern presumed from the said aerial photograph is applied to the land use area in each basin, as shown in Table 4-5.

The situation in the study area obtainable from the 1965 aerial photograph is described as follows:

Centro which is the core of the city and the neighboring districts of Sajonia and Barrio Obrero which are situated along the Paraguay River (Basin Nos. B-1 to B-8) had almost the same road patterns as that at present, and urbanization has also spread as much as today. On the contrary, the Lambare district along the General Santos Avenue had vast farmland and pasture, where at present residential development is expanding (Basin No. B-19-3, B-19-4, B-19-6).

A part of Fernando de la Mora had been urbanized along the Madame Lynch Avenue but almost all of the other parts still remain as farmland. About twenty years ago, when the highway linking Espana Avenue and the airport has not been constructed yet, there were plenty of farmland and pasture along Espana Avenue where at present the Banco Central del Paraguay stands and a high class residential area is expanding (Basin No. 18-6, B-15-1). The other districts in Asuncion City had been generally equipped with the grid pattern roads and forming the urbanized area in that time.

5. Future Urban Development

5.1 Outline of Urban Transportation Study

On the basis of the study results on future population up to the year 2000, future urban development were studied considering the development regulation in this area. The outline of the future urban development up to the year 2000 of the Urban Transportation Study is summarized hereinafter.

Development Regulations

The municipal ordinance of Asuncion City which regulates future land use is principally as follows:

- In the case of land development for residential area, the construction of streets and drainage ditches is carried out by the owner at his own expense and these are turned over to the municipality without financial compensation.

- In the case of development of land subdivisions exceeding 3.0 ha, the owner is obligated to provide to the municipality, at no charge, 5% of the total land area for a public plaza and park and 2% as land for school, etc.

- Large industries are prohibited from establishing new factories within a 20 km radius of the center of Asuncion City, except expansion or modernization of existing factories.

- The minimum width of residential lots is 12 m and the minimum area is 360 m2.

- Maximum building-to-land ratio is 75%.

- Minimum street width is 16 m for streets and 32 m for avenues.

An ordinance similar to the above has not been enacted yet for the Metropolitan Asuncion Area which is still in the process of formulating a guideline for its urban development. The concept of the development of the Asuncion Metropolitan Area is as follows: one-third, or 24,800 ha, of the entire 71,000 ha of the metropolitan area is set aside as land for the first stages of urbanization; one-fourth, or 18,000 ha, as land for the second stage, an urbanization expansion area; and the remaining 28,200 ha where there are restrictions for urban development, as agricultural land. (Refer to Fig. 4-12.)

Urban Development Project

At present, high-degree urban functions are concentrated in the central district of Asuncion City. To ease the concentration of such functions in the city, large-scale public service facilities are now planned and developed at the rim of the fan made up by the trunk roads in Asuncion City such as the following:

- Banco Central del Paraguay has completed a huge building along Espana Avenue.

- A new municipal building is under construction along Mariscal Lopez Avenue.

- A food mart has been completed along Madame Lynch Avenue.

- The long distance bus terminal has been completed along Eusebio Ayala Avenue.

As the result of strong measures to realize these public service facilities, the urban structure is gradually shifting from an urban structure concentrated on a single core to one concentrated on several cores (refer to Figs. 4-13 and 4-14).

Future Land Use

Noteworthy about the future land use in the Asuncion Metropolitan Area is that: whereas only about half of Asuncion's residential areas are of medium density at the moment, almost all residential areas will be medium density by the year 2000; and medium density residential areas will also spread to neighboring cities such as Lambare and Fernando de la Mora. Furthermore, two distinct commercial areas will be formed along Eusebio Ayala Avenue and Fernando de la Mora Avenue and will extend to the neighboring cities of Fernando de la Mora, San Lorenzo and Nemby.

In addition to the above two areas, another commercial area will be set up along Madame Lynch Avenue, a major circumferential road linking the radial trunk roads in the outskirts of Asuncion City. This commercial area will play a vital role in the future suburban core. (Refer to Fig. 4-14.)

The low density residential areas in San Lorenzo, Nemby, Luque, and Mariano R. Alonso expand to the surrounding farmland as shown in Fig. 4-15. Large public parks, military facilities, airports, and other public facilities are located in the region between Asuncion and Luque, and the Asuncion National University and the National Agricultural and Livestock Experimental Research Station are scheduled to be constructed in the area west of San Lorenzo.

Future Traffic Condition

The Urban Transport Study has estimated the future traffic volume at the year 2000 taking into account the present transportation and population prediction, socio-economic trend and future land use, etc. The study shows that the six trunk roads have a good amount of traffic volume of 25,000 to 45,000 vehicles per day. This is due to the rapidly growing population in the outskirt cities and the great need for radial roads to connect these cities to the center of Asuncion City. Especially, Mariscal Lopez Avenue and Aviadores del Chaco Avenue (connecting with Espana Avenue) have the big traffic volume of more than 35,000 vehicles between Madame

Lynch Avenue and San Lorenzo, and between Madame Lynch Avenue and Luque. (Refer to Fig. 4-11.)

5.2 Land Use Area in the Year 2005

Since only the land use maps in the years 1984 and 2000 were provided in the Urban Transport Study, the land use area of each basin in these years was estimated on the basis of the said maps, classifying the area into eight (8) categories: commercial area, residential area (high, medium, low density), industrial area, public places (schools, hospitals, military, and other government agencies), parks, farmland, unused land, and road.

The estimation of the land use area of each basin in the year 2005 was made by extending the trend of each categorized land use area from 1984 to 2000 basinwisely assuming that the extension of commercial area, residential area, etc., would be made up through the conversion of non-used land and agricultural land. Table 4-7 shows the area of the future basinwise land use for each of the above categories.

As far as land use maps in 2005 are concerned, those of Mburicao and Itay river basins which are included in the target area of the First Stage Project were prepared to confirm the availability of public places and parks as detention facilities, as shown in Fig. 4-16.

Based on the land use patterns in 2005, the total area of the public places is estimated at 267 ha and 182 ha in Mburicao and Itay river basins, respectively, as tabulated in Table 4-8 and shown in Fig. 4-17.

6. Estimation of Building-to-Land Ratio

To estimate building-to-land ratio, several 500 m^2 areas each of four types of typical land use area (commercial and three types of residential) were selected, and average values were calculated. (Refer to Fig. 4-18 and Table 4-9.)

According to these calculations, the average building-to-land ratio in each land use area is estimated at about 73% for commercial, about 47% for high density residential, about 27% for medium density residential, and about 14% for low density residential.

There are clear differences in the building-to-land ratio in each of the four types of typical land use area and the figures indicate a staged difference in the building density. (Refer to Fig. 4-19.)

Since land use for public compounds and industrial areas is different from that of residential areas, the building-to-land ratio for public compounds and industrial areas were estimated by selecting several representative facilities for each category. The calculations gave a building-to-land ratio of about 20% for industrial area, about 12% for hospitals, about 17% for schools, and about 9% for military facilities.

As for open spaces by land category, they were divided into unpaved permeable areas and paved impermeable areas. The ratios of the typical areas are as follows: in commercial area, 3:7; in high density residential area, 4:6; in medium density residential area, 6:4; and in low density residential area, 9:1.

The building-to-land ratios given above are based on present conditions, but the densities are not expected to change by the year 2005. Basically, the highly developed commercial area has already reached the limit of development so that expansion is likely expected. As future development progresses in other areas, there will likely be an overall upgrading in density scale, i.e., the high density residential area will become commercial area, the medium density residential area will become high density residential area, the low density residential area will become medium density residential area, and so on and so forth.

TABLES

Table 4-1. POPULATION GROWTHS IN ASUNCION METROPOLITAN AREA AND THE COUNTRY

Location	1950		1962		1972		1982		Average Annual Growth Rate (%)		
	Population (Persons)	Rate (%)	Population (Persons)	Rate (%)	Population (Persons)	Rate (%)	Population (Persons)	Rate (%)	1950-62	1962-72	1972-82
1. Asuncion	206,634	76.0	288,882	70.6	388,958	67.2	457,210	57.2	2.83	3.10	1.63
2. F. de la Mora	5,253	2.0	14,519	3.5	36,892	6.4	66,450	8.3	8.84	10.04	6.06
3. Lambare	-	-	20,778	5.1	31,732	5.5	67,180	8.4	-	4.44	7.79
4. Limpio	8,473	3.1	10,126	2.5	12,767	2.2	16,650	2.1	1.50	2.41	2.69
5. Luque	22,361	8.2	30,834	7.5	40,677	7.0	63,210	7.9	2.71	2.88	4.51
6. M. R. Alonso	4,043	1.5	5,686	1.4	7,388	1.3	14,520	1.8	2.88	2.72	6.99
7. Nemby	4,974	1.8	5,984	1.5	6,899	1.2	12,310	1.5	1.55	1.47	5.96
8. San Antonio	4,698	1.7	5,965	1.5	7,321	1.3	8,110	1.0	2.01	2.12	1.03
9. San Lorenzo	13,100	4.8	18,573	4.5	36,811	6.3	74,240	9.3	2.95	7.27	7.27
10. Villa Elisa	2,365	0.9	3,214	0.8	4,774	0.8	11,600	1.5	2.59	4.14	9.28
11. Villa Hayes	-	-	4,712	1.1	4,795	0.8	7,660	1.0	-	0.18	4.80
Metropolitan Area (Total)	271,901	100.0	409,273	100.0	579,014	100.0	799,140	100.0	3.47	3.62	3.27
Paraguay	1,328,452		1,819,103		2,357,955		3,035,360		2.65	2.70	2.56

Source: Censo Nacional de Poblacion y Viviendas 1982

Table 4-2. POPULATION RATE BY SEX AND AGE GROUP

Age Group	1972 Both Sexes (%)	1972 Male (%)	1972 Female (%)	1982 Both Sexes (%)	1982 Male (%)	1982 Female (%)
PARAGUAY						
0 - 14	44.8	22.9	21.9	41.0	21.0	20.0
15 - 64	51.2	25.0	26.2	54.7	27.2	27.5
65 Above	4.0	1.7	2.3	4.3	1.9	2.4
Total	100.0	49.6	50.4	100.0	50.1	49.9
Index Number of Males		98.3			100.3	
ASUNCION METROPOLITAN AREA						
0 - 14	36.1	18.0	18.1	32.1	16.0	16.1
15 - 64	59.6	27.8	31.8	62.9	29.7	33.2
65 Above	4.3	1.7	2.6	5.0	2.0	3.0
Total	100.0	47.5	52.5	100.0	47.7	52.3
Index Number of Males		90.5			91.3	

Source: Censo Nacional de Poblacion y Viviendas, 1972 y 1982

Table 4-3 (1/2). POPULATION OF EACH BASIN

Basin Number	Area (ha)	Population (persons)		Population Density (persons/ha)		Population Growth Rate
		1984	2005	1984	2005	2005/1984
B-1	325	31,943	32,714	98.3	100.7	1.02
B-2	6	5,783	6,187	96.4	103.1	1.07
B-3	4	53,995	73,998	74.6	102.2	1.37
B-4	247	21,285	23,315	86.2	94.4	1.10
B-5	170	9,060	9,190	53.3	54.1	1.01
B-6	143	13,611	14,122	95.2	98.7	1.04
B-7-1	71	6,909	7,236	97.3	101.9	1.05
B-7-2	47	4,946	5,140	105.2	109.4	1.04
B-7(Total)	161	14,127	14,738	87.7	91.5	1.04
B-8-1	289	19,148	21,093	66.3	73.0	1.10
B-8-2	111	6,273	7,801	56.5	70.3	1.24
B-8(Total)	400	25,421	28,894	63.5	72.2	1.14
B-9	240	8,892	17,727	37.1	73.9	1.99
B-10	212	15,110	13,320	71.3	62.8	0.88
B-11	66	4,260	4,398	64.5	66.6	1.03
B-12	75	5,581	6,003	74.4	80.0	1.08
B-13	103	7,457	8,236	72.4	80.0	1.10
B-14-1	422	18,902	24,857	44.8	58.9	1.32
B-14-2	182	5,645	6,452	31.0	35.5	1.14
B-14-3	363	17,538	25,480	48.3	70.2	1.45
B-14-4	230	13,541	15,845	58.9	68.9	1.17
B-14-5	172	4,723	8,196	27.5	47.7	1.74
B-14-6	276	13,546	17,129	49.1	62.1	1.26
B-14(Total)	1,645	73,895	97,959	44.9	59.5	1.33
B-15-1	190	4,002	7,562	21.1	39.8	1.89
B-15-2	211	3,811	6,677	18.1	31.6	1.75
B-15(Total)	401	7,813	14,239	19.5	35.5	1.82
B-16	313	8,938	18,519	28.6	59.2	2.07
B-17	680	17,476	34,180	25.7	50.3	1.96
B-18-1	1,371	51,387	100,545	37.5	73.3	1.96
B-18-2	363	9,201	18,614	25.3	51.3	2.02
B-18-3	638	14,526	41,388	22.8	64.9	2.85
B-18-4	401	12,861	36,067	32.1	89.9	2.80
B-18-5	97	1,370	3,914	14.1	40.4	2.86
B-18-6	1,277	28,068	62,867	22.0	49.2	2.24
B-18-7	1,308	6,697	15,605	5.1	11.9	2.33
B-18-8	1,844	13,006	27,668	7.1	15.0	2.13
B-19-9	2,674	13,227	30,548	4.9	11.4	2.31
B-18-10	3,640	10,337	21,968	2.8	6.0	2.13
B-18(Total)	13,613	160,680	359,184	11.8	26.4	2.24
B-19-1	369	18,875	35,843	51.2	97.1	1.90
B-19-2	251	13,221	25,928	52.7	103.3	1.96

Table 4-3 (2/2). POPULATION OF EACH BASIN

Basin Number	Area (ha)	Population (persons) 1984	Population (persons) 2005	Population Density (persons/ha) 1984	Population Density (persons/ha) 2005	Population Growth Rate 2005/1984
B-19-3	710	19,402	50,260	27.3	70.8	2.59
B-19-4	478	19,346	49,062	40.5	102.6	2.54
B-19-5	484	29,992	40,202	62.0	83.1	1.34
B-19-6	236	11,819	22,157	50.1	93.9	1.87
B-19-7	38	1,698	3,870	44.7	101.8	2.28
B-19(Total)	2,566	100,008	181,375	39.0	70.7	1.81
B-20	1,063	26,072	76,367	24.5	71.8	2.93
B-21-1	288	4,253	12,061	14.8	41.9	2.84
B-21-2	198	1,974	5,718	10.0	28.9	2.90
B-21-3	667	9,700	31,678	14.5	47.5	3.27
B-21(Total)	1,153	15,927	49,457	13.8	42.9	3.11
B-22-1	558	13,183	28,988	23.6	51.9	2.20
B-22-2	728	4,571	14,127	6.3	19.4	3.09
B-22-3	1,433	10,210	35,226	7.1	24.6	3.45
B-22-4	945	5,611	18,047	5.9	19.1	3.22
B-22-5	753	3,388	8,687	4.5	11.5	2.56
B-22(Total)	4,417	36,963	105,075	8.4	23.8	2.84
B-23-1	1,544	37,929	87,673	24.6	56.8	2.31
B-23-2	1,825	23,459	54,150	12.9	29.7	2.31
B-23(Total)	3,369	61,388	141,823	18.2	42.1	2.31
B-24-1	1,450	24,246	72,249	16.7	49.8	2.98
B-24-2	548	8,869	21,729	16.2	39.7	2.45
B-24-3	1,015	18,688	47,742	18.4	47.0	2.55
B-24(Total)	3,013	51,821	141,720	17.2	47.0	2.73
B-25-1	675	3,314	7,722	4.9	11.4	2.33
B-25-2	582	2,969	6,919	5.1	11.9	2.34
B-25(Total)	1,257	6,283	14,641	5.0	11.6	2.33
B-26	213	4,618	7,892	21.7	37.1	1.71
B-27	549	8,425	15,073	15.3	27.5	1.79
B-28	1,565	6,897	17,185	4.4	11.0	2.49
B-29	895	8,242	23,089	9.2	25.8	2.80
B-30	523	3,572	11,432	6.8	21.9	3.20
B-31	1,335	6,668	16,614	5.0	12.4	2,49
Total	41,496	822,211	1,578,666	19.8	38.0	1.92

Table 4-4. LIST OF PROJECTS IN ASUNCION CITY

Item		Particulars	Stage	Undertaken By	Financial Source
Road Network	(1)	Improvement of Eusebio Ayala Ave., including Parking Lot (PRODEMA)	Planning Stage	Municipal Government	Not decided
	(2)	Improvement of Fernando de la Mora Ave.	-ditto-	-ditto-	-ditto-
	(3)	Widening of Road and Improvement of Drainage Along Avenue Madame Lynch Avenue	Under construction	-ditto-	Municipal Budget (for 1985)
	(4)	Improvement of Santa Teresa Avenue and Aviadores del Chaco Ave.	-ditto-	-ditto-	Municipal Government
Land Use	(1)	Urban Waste Disposal Facility (PRODEMA)	Planning Stage	-ditto-	-ditto-
	(2)	Construction of New Municipal Building	Under construction	-ditto-	-ditto-
	(3)	Improvement of Recreation Area (Plaza Palacio de Justicia)	Under construction	Private enterprise	
	(4)	Road Improvement for Pedestrians' Exclusive Use of Palma Street and Estrella Street (PRODEMA)	Planning Stage	Municipal Government	Municipal Government
	(5)	Rehabilitation of Slum Area Along Paraguay River	-ditto-	-ditto-	Not decided
	(6)	Construction of New Cemetery	-ditto-	-ditto-	-ditto-
	(7)	Expansion of Green Space Near Palacio de Govierno	-ditto-	-ditto-	-ditto-

Table 4-5 (1/3). LAND USE IN YEAR 1965

(Unit: ha)

Basin Number	Name of Basin	Commercial	Residential High	Residential Medium	Residential Low	Residential Total	Industrial	Public	Recreational	Farmland	Unused Land	Roads	Grand Total
B-1	Varadero	3	16	114	55	185	7	29	13	-	16	72	325
B-2	Jardin	-	30	5	-	35	-	7	2	-	2	14	60
B-3	Centro	109	94	109	101	304	7	80	29	-	29	166	724
B-4	Jaen	-	-	123	40	163	2	5	7	-	10	60	247
B-5	Tacumbu	-	-	43	20	63	2	54	3	-	7	41	170
B-6	Salamanca	-	-	45	26	71	-	8	17	-	6	41	143
B-7-1	Zanja Moroti	-	-	41	-	41	-	1	-	-	3	26	71
B-7-2		-	-	-	27	27	-	1	1	-	2	16	47
B-7 Total		-	-	41	58	99	-	3	1	-	6	52	161
B-8-1	Ferreira	-	-	175	23	198	-	9	3	-	17	62	289
B-8-2		-	-	-	82	82	-	1	1	-	4	23	111
B-8 Total		-	-	175	105	280	-	10	4	-	21	85	400
B-9	Villa Universitaria	-	-	-	24	24	-	29	2	144	24	17	240
B-10	Las Mercedes	4	-	42	95	137	2	15	11	-	11	32	212
B-11	Mariscal Lopez	-	-	30	17	47	1	1	-	-	3	14	66
B-12	Bella Vista	-	-	22	23	45	1	2	-	-	11	16	75
B-13	Tablada	-	-	8	63	71	4	1	1	-	10	16	103
B-14-1	Mburicao	21	-	97	127	224	4	34	21	-	42	76	422
B-14-2		-	-	-	109	109	-	11	13	-	27	22	182
B-14-3		-	-	-	199	199	-	11	7	-	73	73	363
B-14-4		-	-	-	83	83	-	16	5	-	91	35	230
B-14-5		-	-	-	26	26	-	64	2	-	29	51	172
B-14-6		-	-	-	109	109	3	66	3	28	39	28	276
B-14 Total		21	-	97	653	750	7	202	51	28	301	285	1645
B-15-1	Ycua Carrillo	-	-	-	19	19	-	2	11	114	38	6	190
B-15-2		-	-	-	119	119	2	4	2	21	42	21	211
B-15 Total		-	-	-	138	138	2	6	13	135	80	27	401
B-16	Santa Rosa	-	-	-	94	94	3	6	75	63	47	25	313
B-17	Tres Puentes Cue	-	-	-	103	103	7	129	231	88	68	54	680

Table 4-5 (2/3). LAND USE IN YEAR 1965

(Unit: ha)

Basin Number	Name of Basin	Commer-cial	Residential				Indus-trial	Public	Recrea-tional	Farmland	Unused Land	Roads	Grand Total
			High	Medium	Low	Total							
B-18-1	Itay	14	-	27	480	507	14	27	14	315	206	274	1371
B-18-2		-	-	-	72	72	4	4	4	196	54	29	363
B-18-3		-	-	-	32	32	-	-	-	574	-	32	638
B-18-4		-	-	-	60	60	4	4	-	241	60	32	401
B-18-5		-	-	-	5	5	-	-	-	77	10	5	97
B-18-6		-	-	-	255	255	-	345	77	383	89	128	1277
B-18-7		-	-	-	65	65	13	157	26	917	65	65	1308
B-18-8		-	-	-	37	37	-	313	-	1365	37	92	1844
B-18-9		27	-	-	160	160	-	27	-	2220	80	160	2674
B-18-10		-	-	-	182	182	-	36	-	3168	36	218	3640
B-18 Total		41	-	27	1348	1375	35	913	121	9456	637	1035	13613
B-19-1	Lambare	-	-	-	37	37	-	4	-	276	22	30	369
B-19-2		-	-	13	62	75	-	10	13	75	40	38	251
B-19-3		-	-	-	36	36	-	-	-	602	36	36	710
B-19-4		-	-	-	24	24	-	-	-	382	48	24	478
B-19-5		10	-	145	155	300	-	5	-	-	73	96	484
B-19-6		-	-	-	24	24	2	7	2	130	47	24	236
B-19-7		-	-	-	2	2	1	-	12	19	2	2	38
B-19 Total		10	-	158	340	498	3	26	27	1484	268	250	2566
B-20	Valle Apua	-	-	-	32	32	11	-	85	776	106	53	1063
B-21-1	Villa Elisa	-	-	-	6	6	3	-	-	251	14	14	288
B-21-2		-	-	-	2	2	-	-	-	192	-	4	198
B-21-3		-	-	-	7	7	13	-	-	634	-	13	667
B-21 Total		-	-	-	15	15	16	-	-	1077	14	31	1153
B-22-1	Nemby	-	-	-	6	6	-	-	-	524	-	28	558
B-22-2		-	-	-	-	-	-	-	-	713	-	15	728
B-22-3		-	-	-	-	-	14	-	-	1376	-	43	1433
B-22-4		-	-	-	-	-	-	-	-	926	-	19	945
B-22-5		-	-	-	-	-	8	-	-	730	-	15	753
B-22 Total		-	-	-	6	6	22	-	-	4269	-	120	4417

Table 4-5 (3/3). LAND USE IN YEAR 1965

(Unit: ha)

Basin Number	Name of Basin	Commer-cial	Residential				Indus-trial	Public	Recrea-tional	Farmland	Unused Land	Roads	Grand Total
			High	Medium	Low	Total							
B-23-1	San Lorenzo	15	-	-	232	232	15	201	15	835	77	154	1544
B-23-2		-	-	-	55	55	-	-	-	1642	37	91	1825
B-23 Total		15	-	-	287	287	15	201	15	2477	114	245	3369
B-24-1	Tayazuape	-	-	-	15	15	-	-	-	1391	-	44	1450
B-24-2		-	-	-	-	-	-	-	-	532	-	16	548
B-24-3		-	-	-	10	10	-	-	-	975	-	30	1015
B-24 Total		-	-	-	25	25	-	-	-	2898	-	90	3013
B-25-1	Ycua Dure	-	-	-	20	20	-	-	-	621	-	34	675
B-25-2		-	-	-	-	-	-	-	-	565	-	17	582
B-25 Total		-	-	-	20	20	-	-	-	1186	-	51	1257
B-26	Zeballos Cue	-	-	-	32	32	2	79	15	57	11	17	213
B-27	Paso Caí	-	-	-	55	55	-	33	-	401	27	33	549
B-28	Mariano Alonso	-	-	-	16	16	-	-	-	1486	-	63	1565
B-29	Villa Hayes	9	-	-	27	27	-	18	-	805	9	27	895
B-30	Petropar	-	-	-	-	-	10	-	-	503	-	10	523
B-31	Achucarro	-	-	-	67	67	27	13	-	1094	67	67	1335

Table 4-6 (1/3). LAND USE IN YEAR 1984

(Unit: ha)

Basin Number	Name of Basin	Commercial	Residential High	Residential Medium	Residential Low	Residential Total	Industrial	Public	Recreational	Farmland	Unused Land	Roads	Grand Total
B-1	Varadero	7.3	75.2	110.5	-	185.7	6.0	35.3	14.4	-	2.7	73.6	325
B-2	Jardin	-	36.5	-	-	36.5	-	7.5	1.8	-	0.3	13.9	60
B-3	Centro	157.0	121.4	48.0	104.5	273.9	2.0	85.3	31.5	-	3.6	170.7	724
B-4	Jaen	-	48.5	122.2	-	170.7	1.4	4.9	7.6	-	1.4	61.0	247
B-5	Tacumbu	-	-	69.1	-	69.1	1.0	54.5	3.3	-	0.6	41.5	170
B-6	Salamanca	1.7	-	71.0	-	71.0	-	9.2	18.5	-	0.7	41.9	143
B-7-1	Zanja Moroti	-	-	43.4	-	43.4	-	1.4	-	-	0.5	25.7	71
B-7-2		-	-	28.2	-	28.2	-	1.3	0.8	-	-	16.7	47
B-7 Total		-	-	103.6	-	103.6	-	3.3	0.8	-	0.9	50.0	161
B-8-1	Ferreira	3.5	-	203.0	-	203.0	-	9.2	2.8	-	9.7	60.8	289
B-8-2		-	-	78.0	5.6	83.6	-	1.4	1.1	-	1.6	23.3	111
B-8 Total		3.5	-	281.0	5.6	286.6	-	10.6	3.9	-	11.3	84.1	400
B-9	Villa Universitaria	-	-	28.9	81.8	110.7	-	28.7	2.9	-	44.4	53.3	240
B-10	Las Mercedes	10.7	-	125.9	9.3	135.2	1.0	15.8	11.5	-	3.9	33.4	212
B-11	Mariscal Lopez	-	-	49.2	-	49.2	1.1	0.6	-	-	1.0	14.1	66
B-12	Bella Vista	-	-	55.1	-	55.1	0.5	1.4	-	-	2.0	16.0	75
B-13	Tablada	-	-	76.0	-	76.0	4.3	0.5	1.5	-	2.7	18.0	103
B-14-1	Mburicao	65.8	-	112.1	94.1	206.2	2.0	37.0	23.8	-	10.6	76.6	422
B-14-2		-	-	83.6	41.5	125.1	-	11.6	13.8	-	6.3	25.2	182
B-14-3		1.0	-	7.2	246.5	253.7	-	12.2	7.2	-	11.2	77.7	363
B-14-4		2.9	-	114.5	40.2	154.7	-	17.5	4.2	-	11.2	39.5	230
B-14-5		2.0	-	-	70.6	70.6	-	65.2	1.7	-	8.1	24.4	172
B-14-6		2.9	-	107.2	53.6	160.8	2.3	66.4	1.3	5.0	5.7	31.6	276
B-14 Total		74.6	-	424.6	546.5	971.1	4.3	209.9	52.0	5.0	53.1	275.0	1645
B-15-1	Ycua Carrillo	3.5	-	-	120.4	120.4	-	0.8	12.8	-	27.4	25.1	190
B-15-2		11.2	-	-	156.0	156.0	-	4.9	1.4	10.2	4.0	23.3	211
B-15 Total		14.7	-	-	276.4	276.4	-	5.7	14.2	10.2	31.4	48.4	401
B-16	Santa Rosa	1.8	-	64.2	77.9	142.1	1.4	6.8	76.1	8.0	38.5	38.3	313
B-17	Tres Puentes Cue	3.0	-	76.6	79.9	156.3	1.4	133.0	232.0	36.0	43.8	74.5	680

Table 4-6 (2/3). LAND USE IN YEAR 1984

(Unit: ha)

Basin Number	Name of Basin	Commer-cial	Residential				Indus-trial	Public	Recrea-tional	Farmland	Unused Land	Roads	Grand Total
			High	Medium	Low	Total							
B-18-1	Itay	72.0	-	54.0	680.8	734.8	10.1	27.9	14.2	84.5	102.6	324.9	1371
B-18-2		-	-	-	231.9	231.9	4.3	12.5	6.3	25.2	25.8	57.0	363
B-18-3		-	-	-	264.8	264.8	0.6	2.0	1.0	194.3	77.0	98.3	638
B-18-4		-	-	-	185.5	185.5	3.7	2.5	1.2	44.9	97.0	66.2	401
B-18-5		-	-	-	36.0	36.0	-	-	-	42.4	4.2	14.4	97
B-18-6		-	-	235.8	384.6	620.4	-	351.2	82.3	51.5	6.9	164.7	1277
B-18-7		-	-	-	407.4	407.4	8.7	162.5	28.8	524.7	45.0	130.9	1308
B-18-8		1.2	-	-	45.4	45.4	2.6	325.9	1.8	1287.1	62.3	117.7	1844
B-18-9		26.8	-	-	272.2	272.2	3.1	4.3	1.1	2067.4	91.1	208.0	2674
B-18-10		13.8	-	-	293.6	293.6	5.6	4.4	4.5	3025.4	38.0	254.7	3640
B-18 Total		113.8	-	289.8	2802.2	3092.0	38.7	893.2	141.2	7347.4	549.9	1436.8	13613
B-19-1	Lambare	15.8	-	140.3	125.0	265.3	-	4.2	-	-	8.4	75.3	369
B-19-2		-	-	167.2		167.2	-	9.3	12.0	-	12.8	49.7	251
B-19-3		24.3	-	63.3	362.0	425.3	-	1.9	2.9	46.4	52.0	157.2	710
B-19-4		4.9	-	-	282.5	282.5	-	4.4	3.1	83.1	8.2	91.8	478
B-19-5		31.3	-	233.1	81.1	314.2	-	6.5	1.8	-	16.9	113.3	484
B-19-6		-	-	17.6	148.6	166.2	3.2	6.8	1.4	-	12.6	45.8	236
B-19-7		-	-	-	14.4	14.4	0.8	-	12.3	-	5.9	4.6	38
B-19 Total		76.3	-	621.5	1013.6	1635.1	4.0	33.1	33.5	129.5	116.8	537.7	2566
B-20	Valle Apua	5.0	-	-	345.0	395.0	5.0	4.0	92.0	230.0	142.0	190.0	1063
B-21-1	Villa Elisa	-	-	-	190.0	190.0	4.0	1.0	1.0	-	32.0	60.0	288
B-21-2		-	-	-	127.0	127.0	-	1.0	-	-	30.0	40.0	198
B-21-3		-	-	-	230.0	230.0	14.0	1.0	1.0	246.0	90.0	85.0	667
B-21 Total		-	-	-	547.0	547.0	18.0	3.0	2.0	246.0	152.0	185.0	1153
B-22-1	Nemby	-	-	-	155.0	155.0	3.0	1.0	1.0	228.0	90.0	80.0	558
B-22-2		-	-	-	130.0	130.0	3.0	3.0	1.0	491.0	30.0	70.0	728
B-22-3		10.0	-	-	163.0	163.0	4.0	11.0	4.0	998.0	113.0	130.0	1433
B-22-4		-	-	-	16.0	16.0	-	-	1.0	819.0	49.0	60.0	945
B-22-5		-	-	-	65.0	65.0	5.0	1.0	4.0	608.0	18.0	52.0	753
B-22 Total		10.0	-	-	529.0	529.0	15.0	16.0	11.0	3144	300	392	4417

Table 4-6 (3/3). LAND USE IN YEAR 1984

(Unit: ha)

Basin Number	Name of Basin	Commercial	Residential				Industrial	Public	Recreational	Farmland	Unused Land	Roads	Grand Total
			High	Medium	Low	Total							
B-23-1	San Lorenzo	47.0	-	-	660.0	660.0	10.0	215.0	9.0	143.0	210.0	250.0	1544
B-23-2		-	-	-	250.0	250.0	2.0	6.0	4.0	1223.0	160.0	180.0	1825
B-23 Total		47.0	-	-	910.0	910.0	12.0	221.0	13.0	1366.0	370	430	3369
B-24-1	Tayazuape	-	-	-	180.0	180.0	-	3.0	3.0	974.0	150.0	140.0	1450
B-24-2		-	-	-	-	-	-	-	-	518.0	-	30.0	548
B-24-3		-	-	-	75.0	75.0	-	4.0	1.0	830.0	30.0	75.0	1015
B-24 Total		-	-	-	256.0	256.0	-	7.0	4.0	2322.0	180.0	245	3013
B-25-1	Ycua Dure	3.0	-	-	125.0	125.0	2.0	2.0	2.0	438.0	23.0	80.0	675
B-25-2		2.0	-	-	90.0	90.0	-	2.0	1.0	417.0	20.0	50.0	582
B-25 Total		5.0	-	-	215.0	215.0	2.0	4.0	3.0	855.0	43.0	130	1257
B-26	Zeballos Cue	-	-	-	65.0	65.0	1.0	80.0	15.0	20.0	10.0	22.0	213
B-27	Paso Cai	1.0	-	-	110.0	110.0	-	36.0	2.0	324.0	26.0	50.0	549
B-28	Mariano Alonso	2.0	-	-	140.0	-	4.0	5.0	2.0	1276.0	26.0	110.0	1565
B-29	Villa Hayes	20.0	-	-	86.0	-	80.0	30.0	8.0	547.0	57.0	67.0	895
B-30	Petropar	-	-	-	68.0	68.0	8.0	-	1.0	375.0	25.0	46.0	523
B-31	Achucarro	11.0	-	-	202.0	202.0	25.0	4.0	4.0	920.0	43.0	126.0	1335

Table 4-7 (1/3). LAND USE IN YEAR 2005

(Unit: ha)

Basin Number	Name of Basin	Commercial	Residential				Industrial	Public	Recreational	Farmland	Unused Land	Roads	Grand Total
			High	Medium	Low	Total							
B-1	Varadero	14.0	144	40.0	-	184.0	3.0	35.0	14.0	-	-	75.0	325
B-2	Jardin	-	37.0	-	-	37.0	-	7.0	2.0	-	-	14.0	60
B-3	Centro	268.0	76.0	68.0	-	144.0	-	108.0	32.0	-	-	172.0	724
B-4	Jaen	36.0	19.0	118.0	-	137.0	-	5.0	7.0	-	-	62.0	247
B-5	Tacumbu	-	-	70.0	-	70.0	-	55.0	3.0	-	-	42.0	170
B-6	Salamanca	6.0	-	67.0	-	67.0	-	10.0	18.0	-	-	42.0	143
B-7-1	Zanja Moroti	4.0	-	40.0	-	40.0	-	1.0	-	-	-	26.0	71
B-7-2		-	-	28.0	-	28.0	-	1.0	1.0	-	-	17.0	47
B-7 Total		4.0	-	100.0	-	100.0	-	3.0	1.0	-	-	53.0	161
B-8-1	Ferreira	42.0	-	172.0	-	172.0	-	9.0	3.0	-	-	63.0	289
B-8-2		-	-	85.0	-	85.0	-	1.0	1.0	-	-	24.0	111
B-8 Total		42.0	-	257.0	-	257.0	-	10.0	4.0	-	-	87.0	400
B-9	Villa Universitaria	2.0	-	138.0	-	138.0	6.0	28.0	3.0	-	-	63.0	100
B-10	Las Mercedes	15.0	-	135.0	-	135.0	-	16.0	11.0	-	-	35.0	212
B-11	Mariscal Lopez	2.0	-	43.0	-	43.0	5.0	1.0	-	-	-	15.0	66
B-12	Bella Vista	4.0	-	49.0	-	49.0	4.0	1.0	-	-	-	17.0	75
B-13	Tablada	5.0	-	70.0	-	70.0	6.0	1.0	2.0	-	-	19.0	103
B-14-1	Mburicao	80.0	21.0	126.0	54.0	201.0	1.0	37.0	24.0	-	-	74.0	422
B-14-2		-	-	44.0	82.0	126.0	2.0	12.0	14.0	-	-	28.0	182
B-14-3		9.0	-	196.0	59.0	255.0	-	12.0	7.0	-	-	80.0	363
B-14-4		9.0	-	125.0	33.0	158.0	-	17.0	4.0	-	-	42.0	230
B-14-5		15.0	-	927.0	-	63.0	-	65.0	2.0	-	-	27.0	172
B-14-6		24.0	-	124.0	-	124.0	21.0	66.0	1.0	5.0	-	35.0	276
B-14 Total		137.0	21.0	678.0	228.0	927.0	24.0	209.0	52.0	5.0	-	291.0	1645
B-15-1	Ycua Carrillo	4.0	-	132.0	-	132.0	-	6.0	13.0	-	-	35.0	190
B-15-2		12.0	-	144.0	-	144.0	12.0	5.0	2.0	-	-	36.0	211
B-15-Total		16.0	-	276.0	-	276.0	12.0	11.0	15.0	-	-	71.0	401
B-16	Santa Rosa	4.0	77.0	94.0	-	94.0	1.0	7.0	76.0	8.0	-	46.0	313
B-17	Tres Puentes Cue	39.0	90.0	12.0	-	102.0	-	188.0	230.0	36.0	-	85.0	680

Table 4-7 (2/3). LAND USE IN YEAR 2005

(Unit: ha)

Basin Number	Name of Basin	Commercial	Residential				Industrial	Public	Recreational	Farmland	Unused Land	Roads	Grand Total
			High	Medium	Low	Total							
B-18-1	Itay	116.0	46.0	626.0	182.0	854.0	11.0	28.0	17.0	-	-	345.0	1371
B-18-2		45.0	-	32.0	192.0	224.0	2.0	13.0	6.0	10.0	-	63.0	363
B-18-3		-	-	-	396.0	396.0	1.0	2.0	1.0	123.0	-	115.0	638
B-18-4		17.0	-	204.0	68.0	272.0	4.0	15.0	2.0	5.0	-	86.0	401
B-18-5		-	-	-	40.0	40.0	-	-	-	42.0	-	15.0	97
B-18-6		23.0	235.0	138.0	230.0	603.0	-	351.0	82.0	51.0	-	167.0	1277
b-18-7		-	-	-	431.0	431.0	27.0	163.0	29.0	515.0	-	143.0	1308
B-18-8		22.0	-	76.0	41.0	117.0	-	340.0	6.0	1226.0	-	133.0	1844
B-18-9		81.0	-	-	317.0	317.0	5.0	4.0	2.0	2036.0	-	229.0	2674
B-18-10		122.0	-	-	407.0	407.0	6.0	6.0	5.0	2800.0	-	294.0	3640
B-18 Total		42.6	281.0	1076.0	2304.0	3661.0	56.0	922.0	150.0	6808.0	-	1590.0	13613
B-19-1	Lambare	36.0	134.0	115.0	-	249.0	2.0	4.0	-	-	-	78.0	369
B-19-2		3.0	129.0	44.0	-	173.0	-	10.0	12.0	-	-	53.0	251
B-19-3		90.0	100.0	344.0	-	444.0	3.0	2.0	3.0	-	-	168.0	710
B-19-4		35.0	-	329.0	-	329.0	-	7.0	6.0	-	-	101.0	478
B-19-5		74.0	35.0	236.0	-	271.0	13.0	7.0	2.0	-	-	117.0	484
B-19-6		5.0	-	164.0	-	164.0	9.0	7.0	2.0	-	-	49.0	236
B-19-7		-	-	17.0	-	17.0	2.0	-	12.0	-	-	7.0	38
B-19 Total		243.0	398.0	1249.0	-	1647.0	29.0	37.0	37.0	-	-	573.0	2566
B-20	Valle Apua	13.0	-	250.0	478.0	728.0	6.0	4.0	95.0	-	-	217.0	1063
B-21-1	Villa Elisa	18.0	-	82.0	116.0	198.0	5.0	1.0	1.0	-	-	65.0	288
B-21-2		9.0	-	24.0	119.0	143.0	1.0	-	-	-	-	45.0	198
B-21-3		-	-	97.0	409.0	506.0	14.0	1.0	1.0	-	-	145.0	667
B-21 Total		27.0	-	203.0	644.0	847.0	19.0	3.0	2.0	-	-	255.0	1153
B-22-1	Nemby	21.0	-	60.0	188.0	248.0	5.0	1.0	23.0	155.0	-	105.0	558
B-22-2		13.0	-	46.0	91.0	137.0	4.0	3.0	1.0	480.0	-	90.0	728
B-22-3		24.0	-	38.0	203.0	241.0	5.0	11.0	4.0	998.0	-	150.0	1433
B-22-4		13.0	-	-	140.0	140.0	-	-	1.0	706.0	-	85.0	945
B-22-5		6.0	-	5.0	164.0	169.0	5.0	2.0	4.0	487.0	-	80.0	753
B-22 Total		77.0	-	149.0	786.0	935.0	19.0	17.0	33.0	2826.0	-	510.0	4417

Table 4-7 (3/3). LAND USE IN YEAR 2005

(Unit: ha)

Basin Number	Name of Basin	Commer-cial	Residential				Indus-trial	Public	Recrea-tional	Farmland	Unused Land	Roads	Grand Total
			High	Medium	Low	Total							
B-23-1	San Lorenzo	96.0	-	56.0	687.0	743.0	10.0	250.0	115.0	45.0	-	285.0	1544
B-23-2		12.2	-	42.0	419.0	461.0	2.0	6.0	4.0	1100.0	-	240.0	1825
B-23 Total		108.0	-	98.0	1106.0	1204.0	12.0	256.0	119.0	1145.0	-	525.0	3369
B-24-1	Tayazuape	18.0	-	5.0	345.0	350.0	-	3.0	4.0	900.0	-	175.0	1450
B-24-2		-	-	-	-	-	-	-	-	508.0	-	40.0	548
B-24-3		39.0	-	3.0	118.0	121.0	-	4.0	1.0	760.0	-	90.0	1015
B-24 Total		57.0	-	8.0	463.0	471.0	-	7.0	5.0	2168.0	-	305.0	3013
B-25-1	Ycua Dure	4.0	-	-	225.0	225.0	2.0	2.0	2.0	340.0	-	100.0	675
B-25-2		8.0	-	-	111.0	111.0	-	2.0	1.0	400.0	-	60.0	582
B-25 Total		12.0	-	-	336.0	336.0	2.0	4.0	3.0	740.0	-	160.0	1257
B-26	Zeballos Cue	10.0	-	-	77.0	77.0	1.0	80.0	15.0	-	-	30.0	213
B-27	Paso Cai	27.0	-	212.0	47.0	259.0	-	36.0	2.0	130.0	-	95.0	549
B-28	Mariano Alonso	21.0	-	-	247.0	247.0	4.0	5.0	2.0	1146.0	-	140.0	1565
B-29	Villa Hayes	38.0	-	-	215.0	215.0	80.0	30.0	10.0	427.0	-	95.0	895
B-30	Petropar	-	-	11.0	130.0	141.0	8.0	-	2.0	312.0	-	60.0	523
B-31	Achucarro	15.0	-	-	422.0	422.0	31.0	4.0	5.0	698.0	-	160.0	1335

Table 4-8. PUBLIC PLACES IN THE STUDY AREA

River Basin	Utilization	Number of Facilities	Area of Site (ha)
Mburicao	School	15	49.4
	Hospital	6	105.3
	Public Office	9	43.6
	Military	4	13.6
	Church	7	5.6
	Park	6	23.5
	Sports	11	26.2
	Total Area		267.2
Itay	School	32	63.0
	Hospital	1	2.0
	Public Office	8	31.0
	Military	3	2.3
	Church	6	15.2
	Park	3	34.5
	Sports	11	33.7
	Total Area		181.7

Table 4-9 (1/4). BUILDING-TO-LAND RATIO

Classification	Number of Model Area/1	Unit	Roof	Interspace Hard/2	Interspace Soft/3	Roads	Total	Building-to-Land Ratio
Commercial	1	ha	14.0	2.0	0.9	8.1	25.0	
		%	56.0	8.0	3.6	32.4	100.0	82.8
	2	ha	13.8	2.3	1.0	7.9	25.0	
		%	55.2	9.2	4.0	31.6	100.0	80.7
	3	ha	14.3	3.2	1.3	6.2	25.0	
		%	57.2	12.8	5.2	24.8	100.0	76.1
	4	ha	11.7	2.9	3.0	7.4	25.0	
		%	46.8	11.6	12.0	29.6	100.0	66.5
	5	ha	14.8	3.6	1.0	5.6	25.0	
		%	59.2	14.4	4.0	22.4	100.0	76.4
	6	ha	10.5	4.3	3.6	6.6	25.0	
		%	42.0	17.2	14.4	26.4	100.0	57.1
Average		ha	13.2	2.9	1.9	7.0	25.0	
		%	52.7	11.6	7.6	27.9	100.0	73.3
High Density Residential	7	ha	7.8	6.2	4.2	6.8	25.0	
		%	31.2	25.0	16.8	27.2	100.0	42.8
	8	ha	9.6	5.0	3.4	7.0	25.0	
		%	38.4	20.0	13.6	28.0	100.0	58.3
	9	ha	9.5	5.0	4.0	6.5	25.0	
		%	38.0	20.0	16.0	26.0	100.0	51.3
	10	ha	8.3	6.0	4.6	6.1	25.0	
		%	33.2	24.0	18.4	24.4	100.0	43.8
	11	ha	9.4	4.8	3.8	7.0	25.0	
		%	37.6	19.2	15.2	28.0	100.0	52.3
	12	ha	7.5	7.0	4.6	5.9	25.0	
		%	30.0	28.0	18.4	23.6	100.0	35.3
Average		ha	8.7	5.7	4.0	6.6	25.0	
		%	34.7	22.7	16.0	26.2	100.0	47.1

/1 Locations are shown in Fig. 3-16.
2/ Impermeable area due to pavement.
/3 Permeable area where rainfall may infiltrate to some degree.

Table 4-9 (2/4). BUILDING-TO-LAND RATIO

Classification	Number of Model Area/1	Unit	Roof	Interspace Hard/2	Interspace Soft/3	Roads	Total	Building-to-Land Ratio
Medium Density Residential	13	ha	6.5	5.7	6.0	6.8	25.0	
		%	26.0	22.8	24.0	27.2	100.0	38.7
	14	ha	5.5	5.8	6.2	7.5	25.0	
		%	22.0	23.2	24.8	30.0	100.0	31.4
	15	ha	4.4	6.9	7.7	6.0	25.0	
		%	17.6	27.6	30.8	24.0	100.0	23.1
	16	ha	5.2	6.5	7.3	6.0	25.0	
		%	20.8	26.0	29.2	24.0	100.0	27.4
	17	ha	4.7	6.8	7.6	5.9	25.0	
		%	18.8	27.2	30.4	23.6	100.0	24.7
	18	ha	4.0	3.0	11.3	6.7	25.0	
		%	16.0	12.0	45.2	26.8	100.0	20.8
Average		ha	5.0	5.8	7.7	6.5	25.0	
		%	20.4	23.1	30.8	26.0	100.0	27.3
Low Density Residential	19	ha	4.0	3.3	11.2	6.5	25.0	
		%	16.0	13.2	44.8	26.0	100.0	21.6
	20	ha	3.6	1.5	13.7	6.2	25.0	
		%	14.4	6.0	54.8	24.8	100.0	19.1
	21	ha	2.7	1.6	15.0	5.7	25.0	
		%	10.8	6.4	60.0	22.8	100.0	14.0
	22	ha	2.1	1.7	15.9	5.3	25.0	
		%	8.4	6.8	63.6	21.2	100.0	10.9
	23	ha	1.9	1.5	17.0	4.6	25.0	
		%	7.6	6.0	68.0	18.4	100.0	9.3
	24	ha	1.7	1.9	17.2	4.2	25.0	
		%	6.8	7.6	68.8	16.8	100.0	8.2
Average		ha	2.7	1.9	15.0	5.4	25.0	
		%	10.6	7.7	60.0	21.7	100.0	13.8

/1 Locations are shown in Fig. 3-16.
2/ Impermeable area due to pavement.
/3 Permeable area where rainfall may infiltrate to some degree.

Table 4-9 (3/4). BUILDING-TO-LAND RATIO

Classification	Number of Model Area/1	Unit	Roof	Interspace Hard/2	Interspace Soft/3	Roads	Total	Building-to-Land Ratio
Industrial	25	ha	1.5	0.5	1.2	0.8	4.0	
		%	37.5	12.5	30.0	20.0	100.0	46.8
	26	ha	4.0	3.5	13.8	3.7	25.0	
		%	16.0	14.0	55.2	14.8	100.0	18.9
	27	ha	5.8	5.5	22.2	6.2	39.7	
		%	14.6	13.9	55.9	15.6	100.0	17.3
	28	ha	1.2	0.5	2.7	1.0	5.4	
		%	22.2	9.3	50.0	18.5	100.0	27.3
Average		ha	3.1	2.5	10.0	2.9	18.5	
		%	16.8	13.5	54.0	15.7	100.0	19.9
Public (Hospital)	29	ha	0.5	0.1	12.0	-	12.6	
		%	4.0	0.8	95.2	-	100.0	4.0
	30	ha	3.0	1.9	36.7	-	41.6	
		%	7.2	4.6	88.2	-	100.0	7.2
	31	ha	2.9	2.1	40.7	-	45.7	
		%	6.4	4.6	89.0	-	100.0	6.4
	32	ha	0.7	0.3	3.0	-	4.0	
		%	17.5	7.5	75.0	-	100.0	17.5
	33	ha	0.4	0.1	1.0	-	1.5	
		%	26.7	6.7	66.6	-	100.0	26.7
Average		ha	2.5	0.9	19.7	-	21.1	
		%	7.1	4.3	88.6	-	100.0	11.8

/1 Locations are shown in Fig. 3-16.
2/ Impermeable area due to pavement.
/3 Permeable area where rainfall may infiltrate to some degree.

Table 4-9 (4/4). BUILDING-TO-LAND RATIO

Classification	Number of Model Area/1	Unit	Roof	Interspace Hard/2	Interspace Soft/3	Roads	Total	Building-to-Land Ratio
Public (School)	34	ha	0.5	0.2	4.1	-	4.8	
		%	10.4	4.2	85.4	-	100.0	10.4
	35	ha	0.1	0.1	0.6	-	0.8	
		%	12.5	12.5	75.0	-	100.0	12.5
	36	ha	0.2	0.1	1.0	-	1.3	
		%	15.4	7.7	76.9	-	100.0	15.4
	37	ha	0.8	0.3	3.0	-	4.1	
		%	19.5	7.3	73.2	-	100.0	19.5
	38	ha	0.6	0.3	1.3	-	2.2	
		%	27.3	13.6	59.1	-	100.0	27.3
	39	ha	0.5	0.1	3.2	-	3.8	
		%	13.2	2.6	84.2	-	100.0	13.2
Average		ha	0.5	0.2	2.2	-	2.9	
		%	16.1	6.4	77.5	-	100.0	17.2
Public (Military)	40	ha	1.2	0.5	2.5	-	4.2	
		%	28.5	11.9	59.5	-	100.0	28.5
	41	ha	0.5	0.5	4.3	-	5.3	
		%	9.4	9.4	81.2	-	100.0	9.4
	42	ha	2.8	2.3	44.5	-	49.6	
		%	5.7	4.6	89.7	-	100.0	5.7
	43	ha	0.3	0.1	1.1	-	1.5	
		%	20.0	6.7	73.3	-	100.0	20.0
	44	ha	0.6	0.2	1.6	-	2.4	
		%	25.0	8.3	66.7	-	100.0	25.0
Average		ha	1.1	0.7	10.8	-	12.6	
		%	8.6	5.7	85.7	-	100.0	8.7

/1 Locations are shown in Fig. 3-16.
2/ Impermeable area due to pavement.
/3 Permeable area where rainfall may infiltrate to some degree.

FIGURES

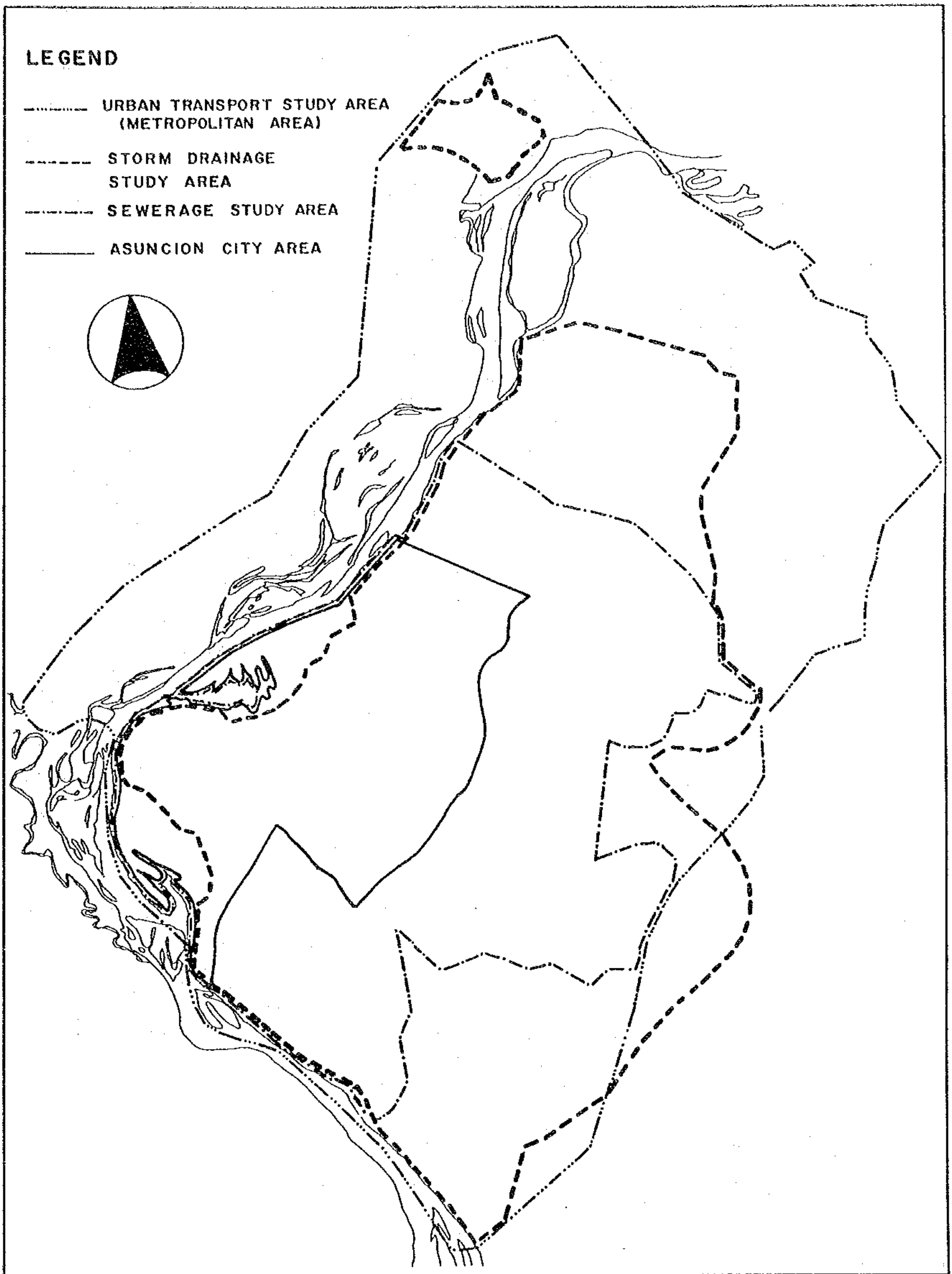


Fig. 4-1 STUDY AREAS OF ONGOING PROJECTS

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

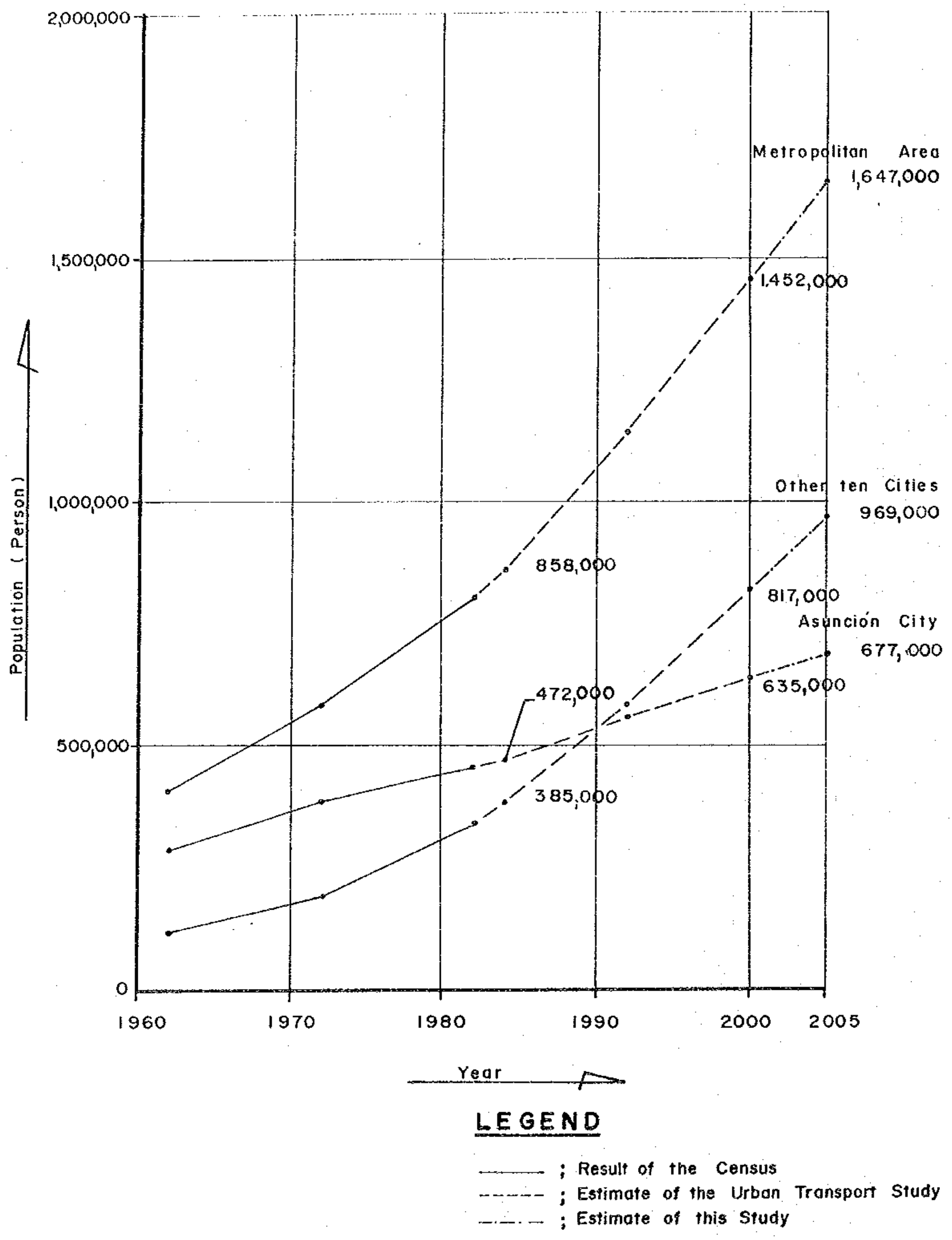


Fig. 4-2 POPULATION GROWTH

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT
IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

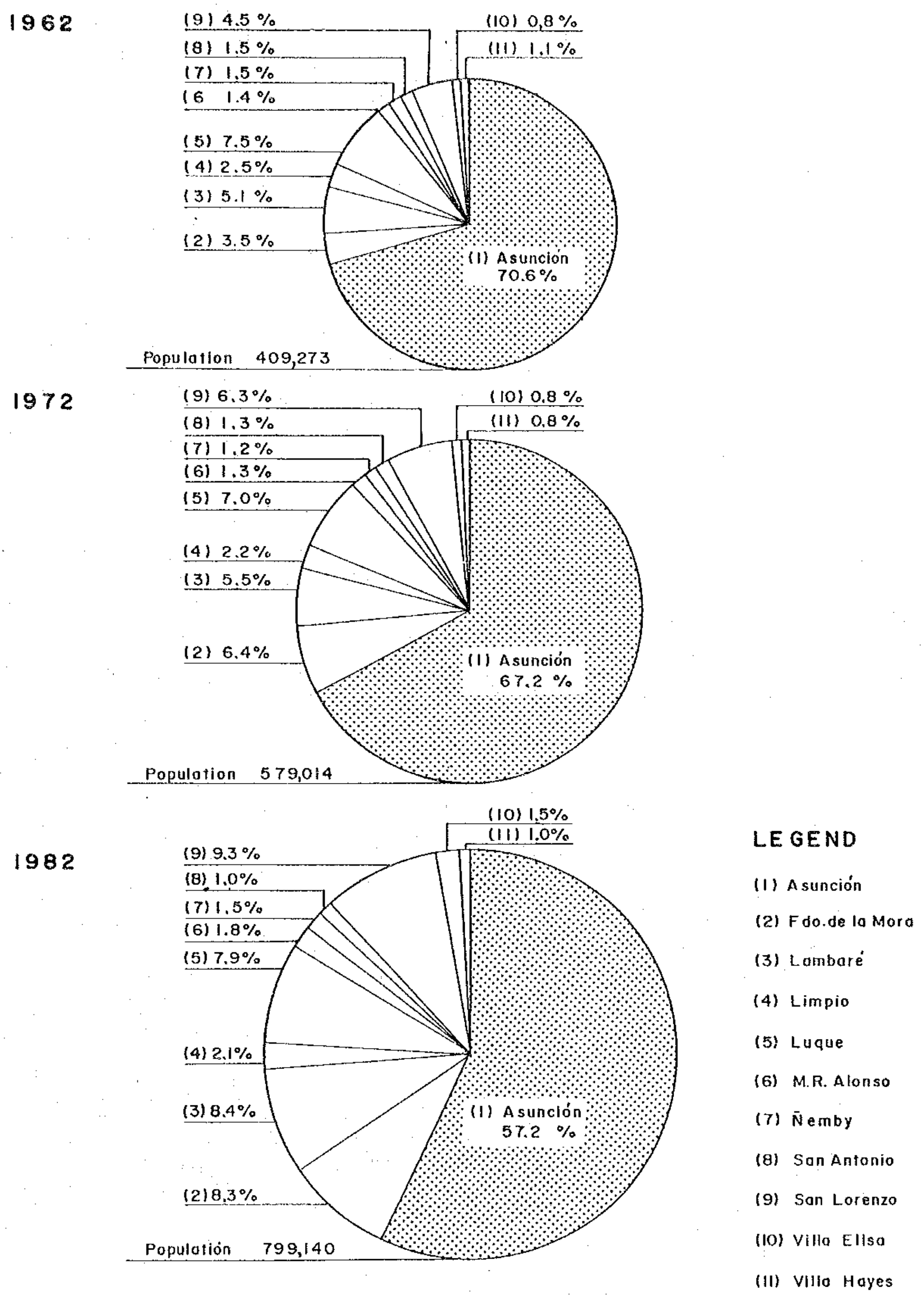


Fig. 4-3 SHARE OF POPULATION IN METROPOLITAN AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

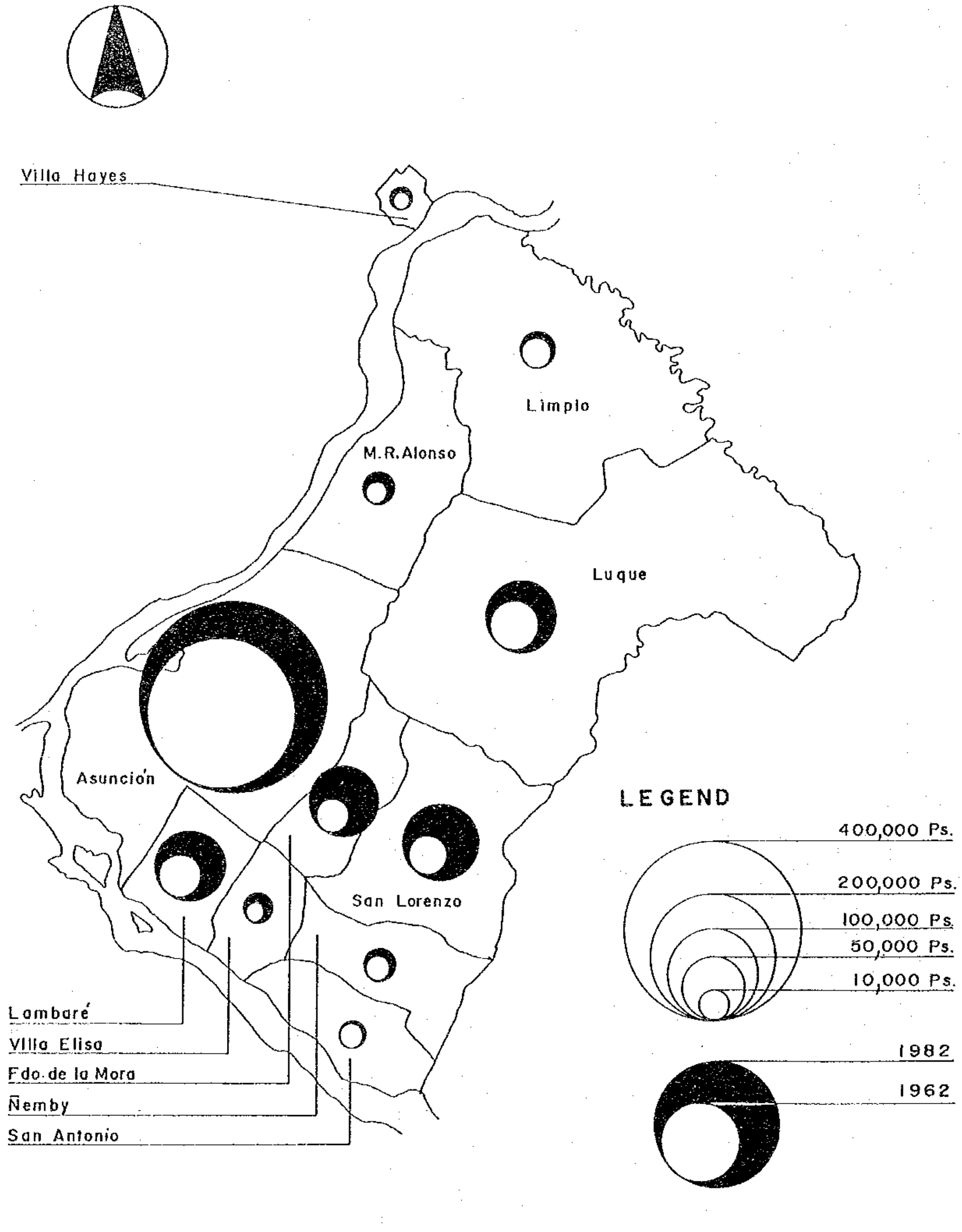


Fig. 4-4 GROWTH OF POPULATION IN METROPOLITAN AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

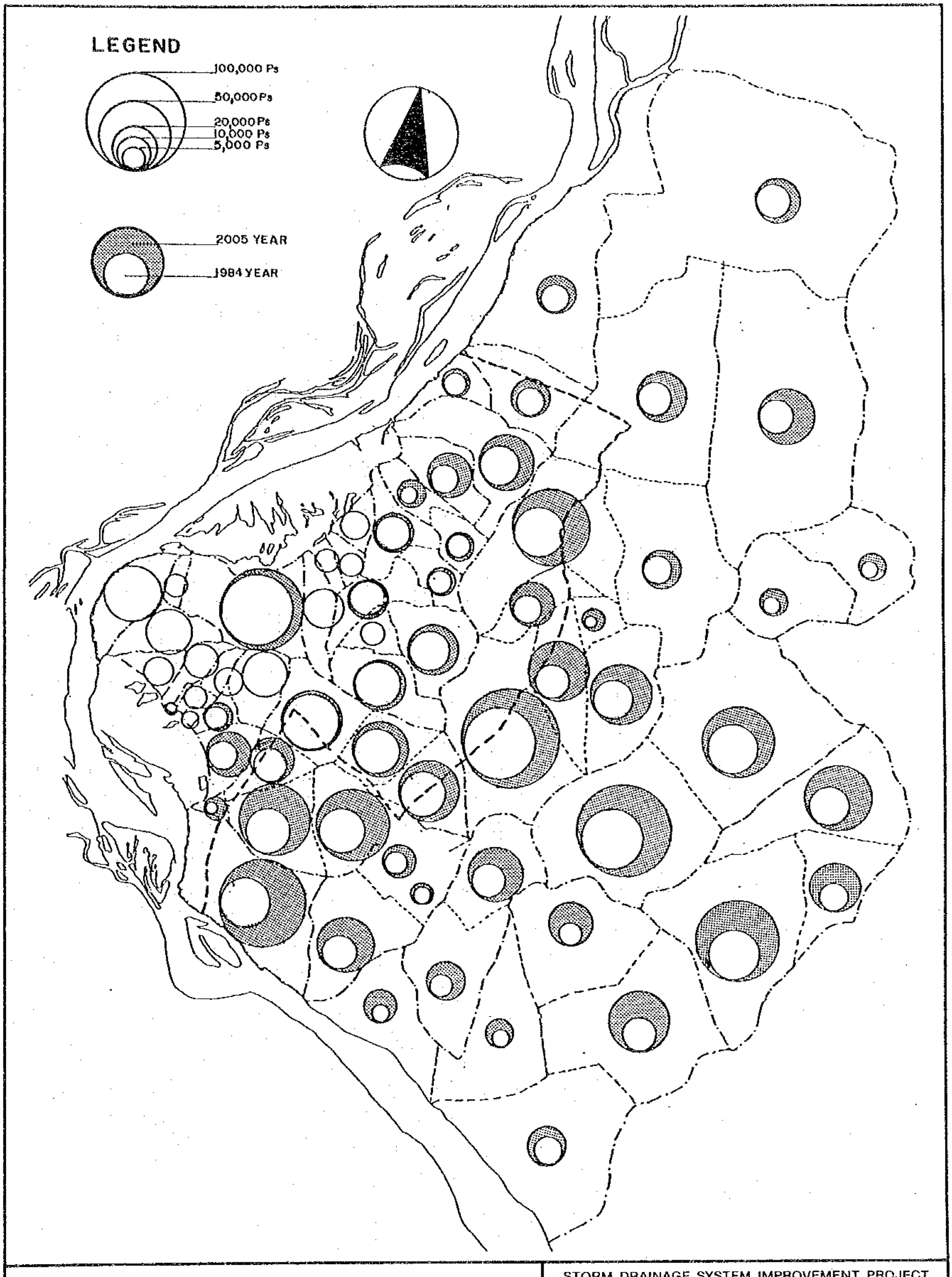


Fig. 4-5 GROWTH OF POPULATION

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

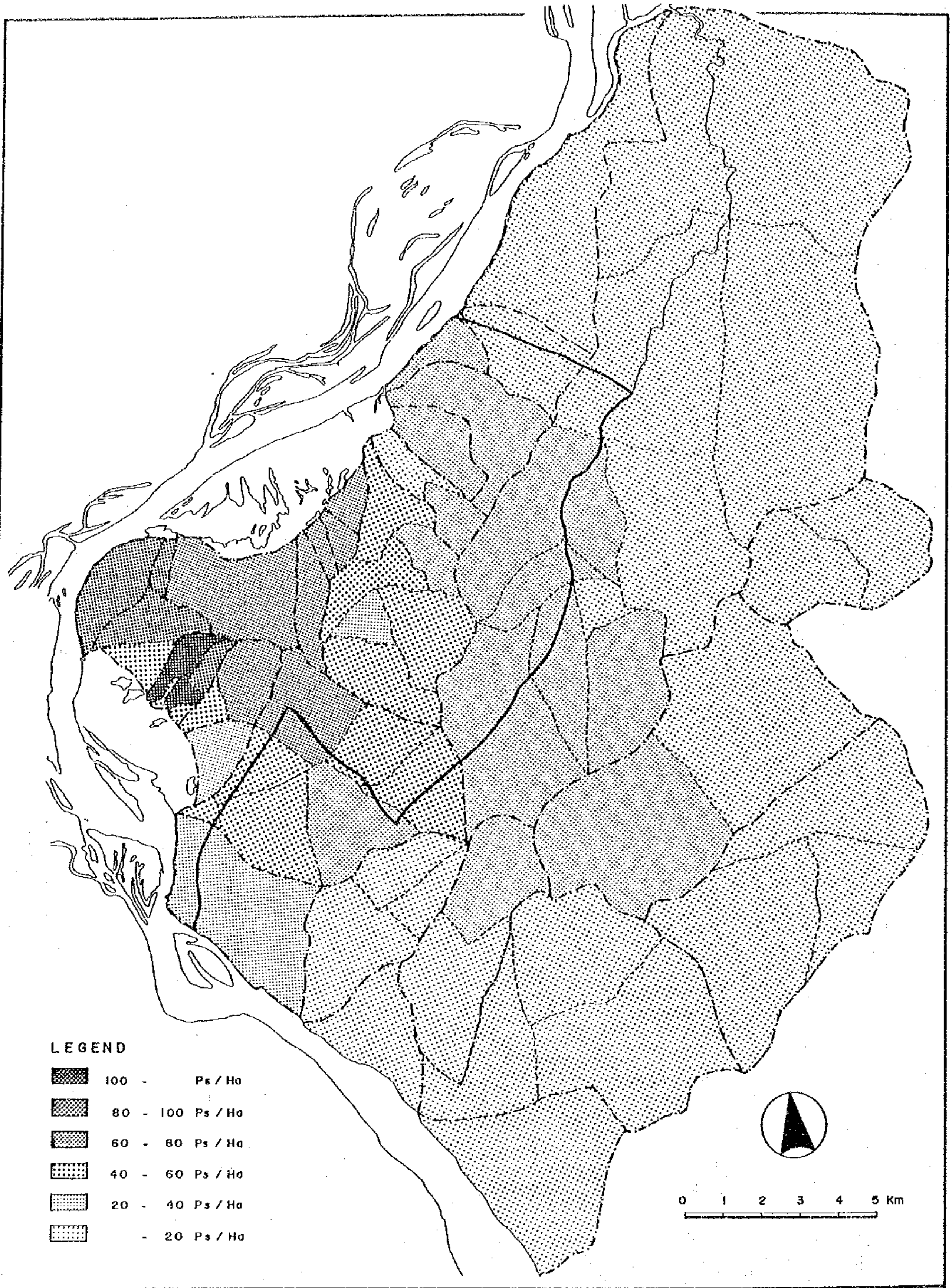


Fig. 4-6 PRESENT POPULATION DENSITY

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

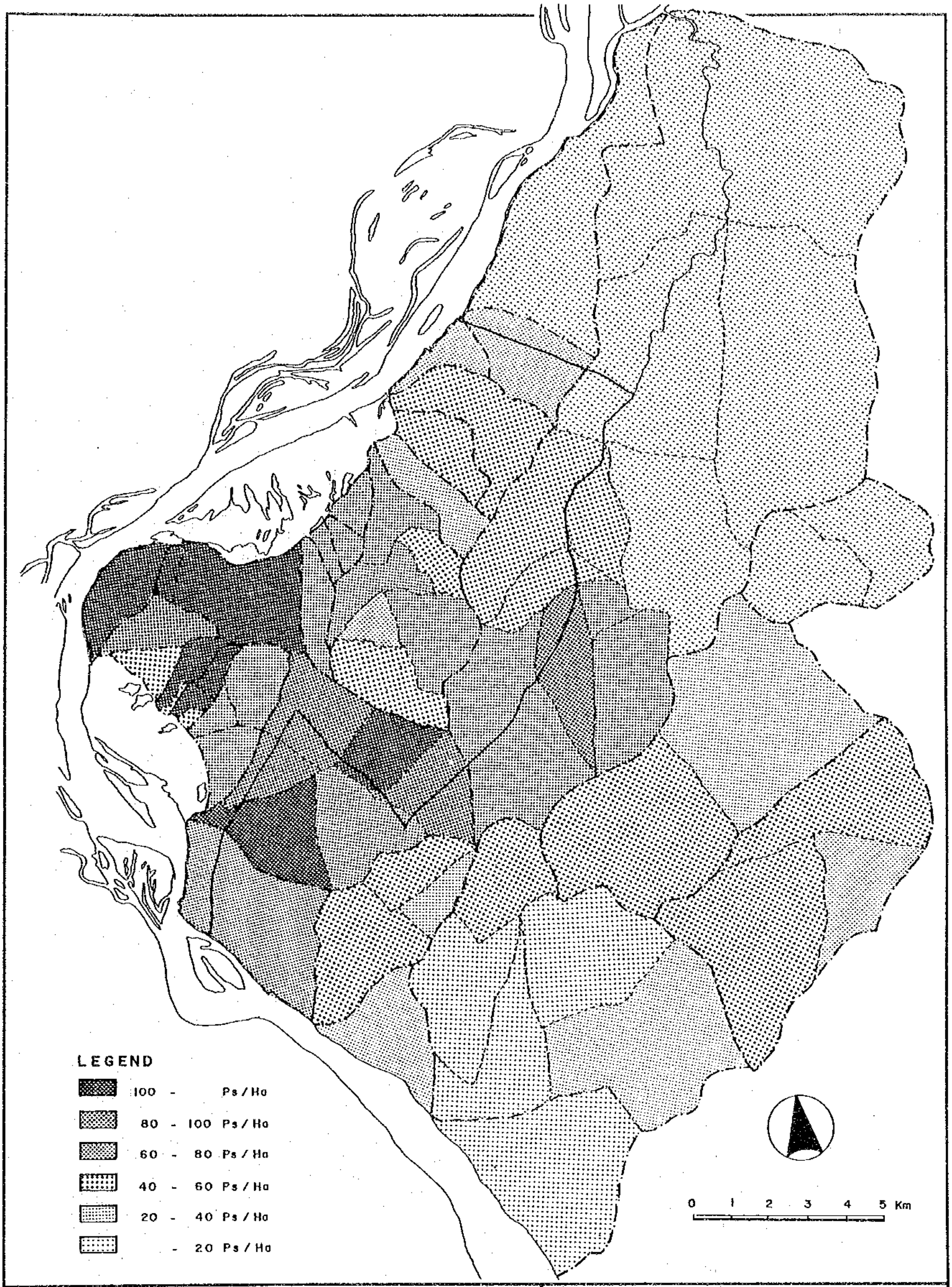


Fig. 4-7 FUTURE POPULATION DENSITY

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

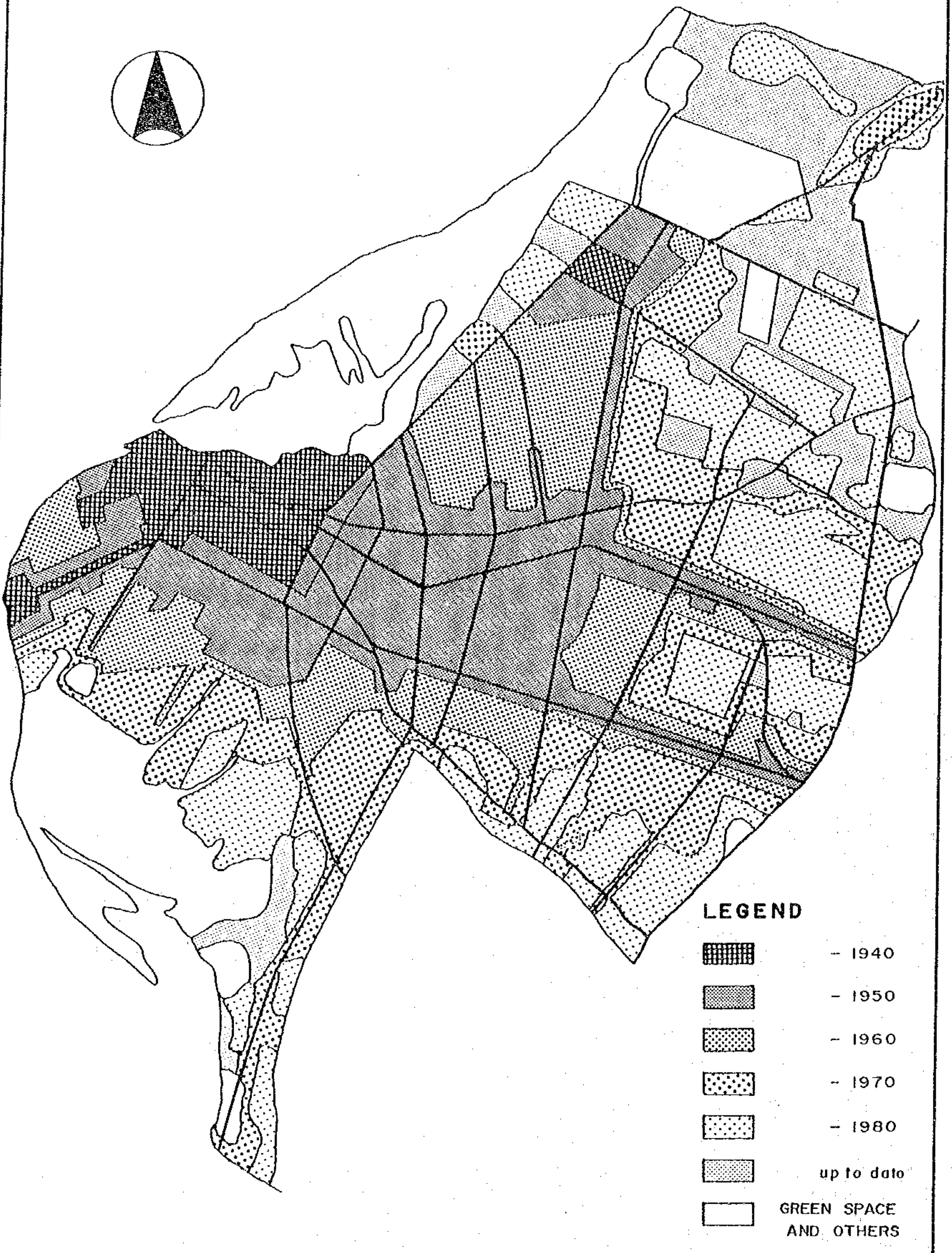


Fig. 4-8 EXPANSION OF URBAN AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

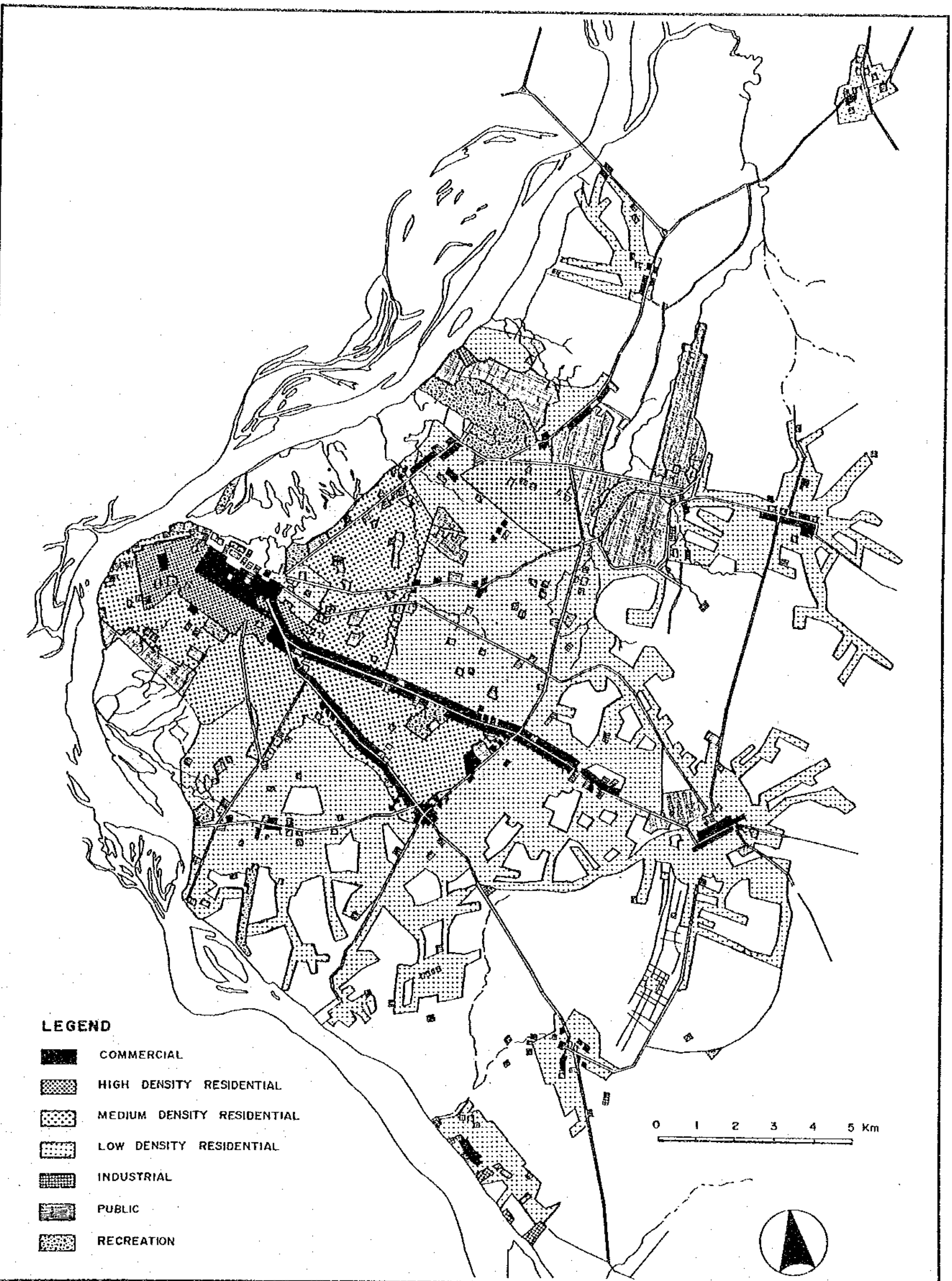
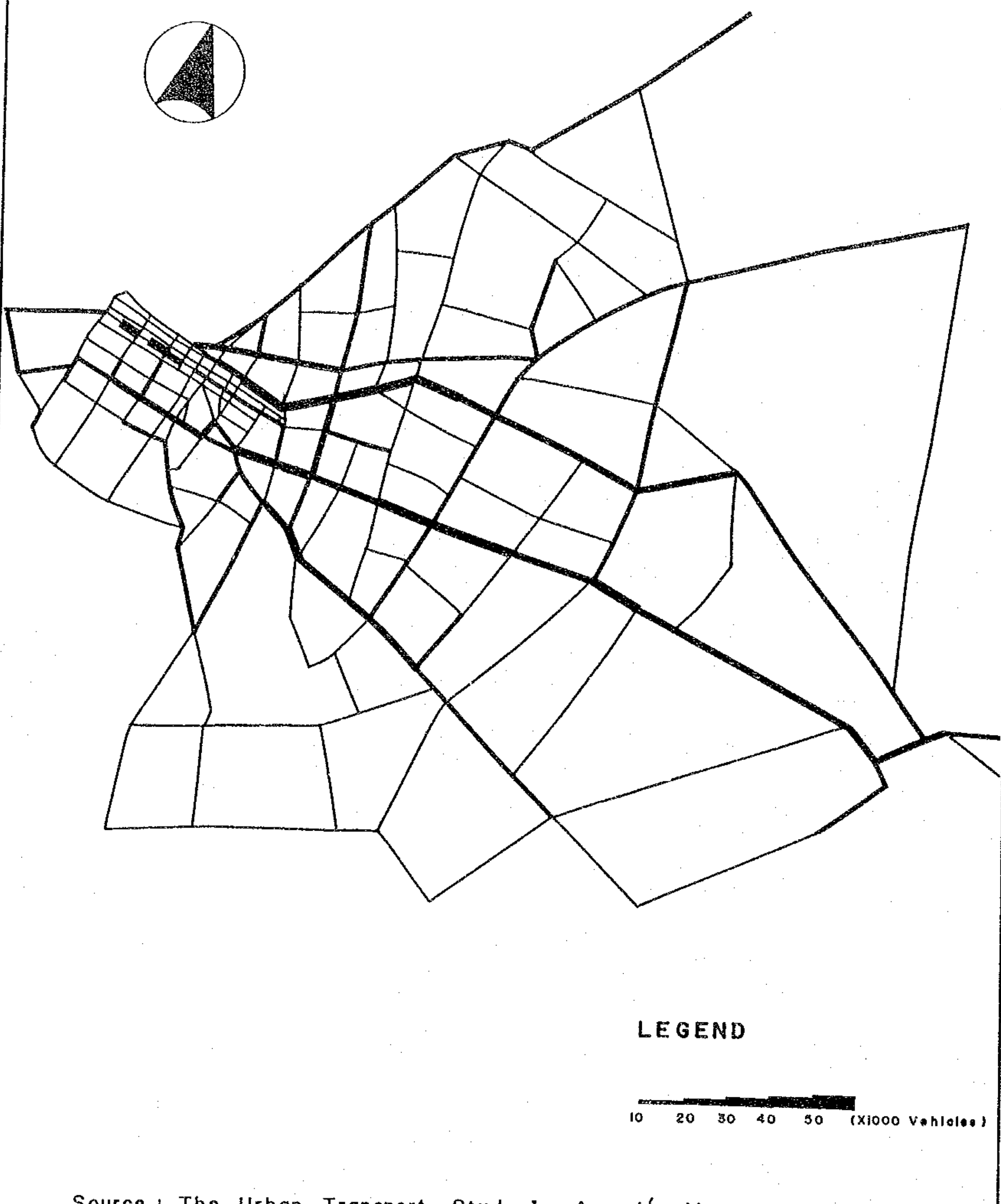


Fig. 4-9 PRESENT LAND USE

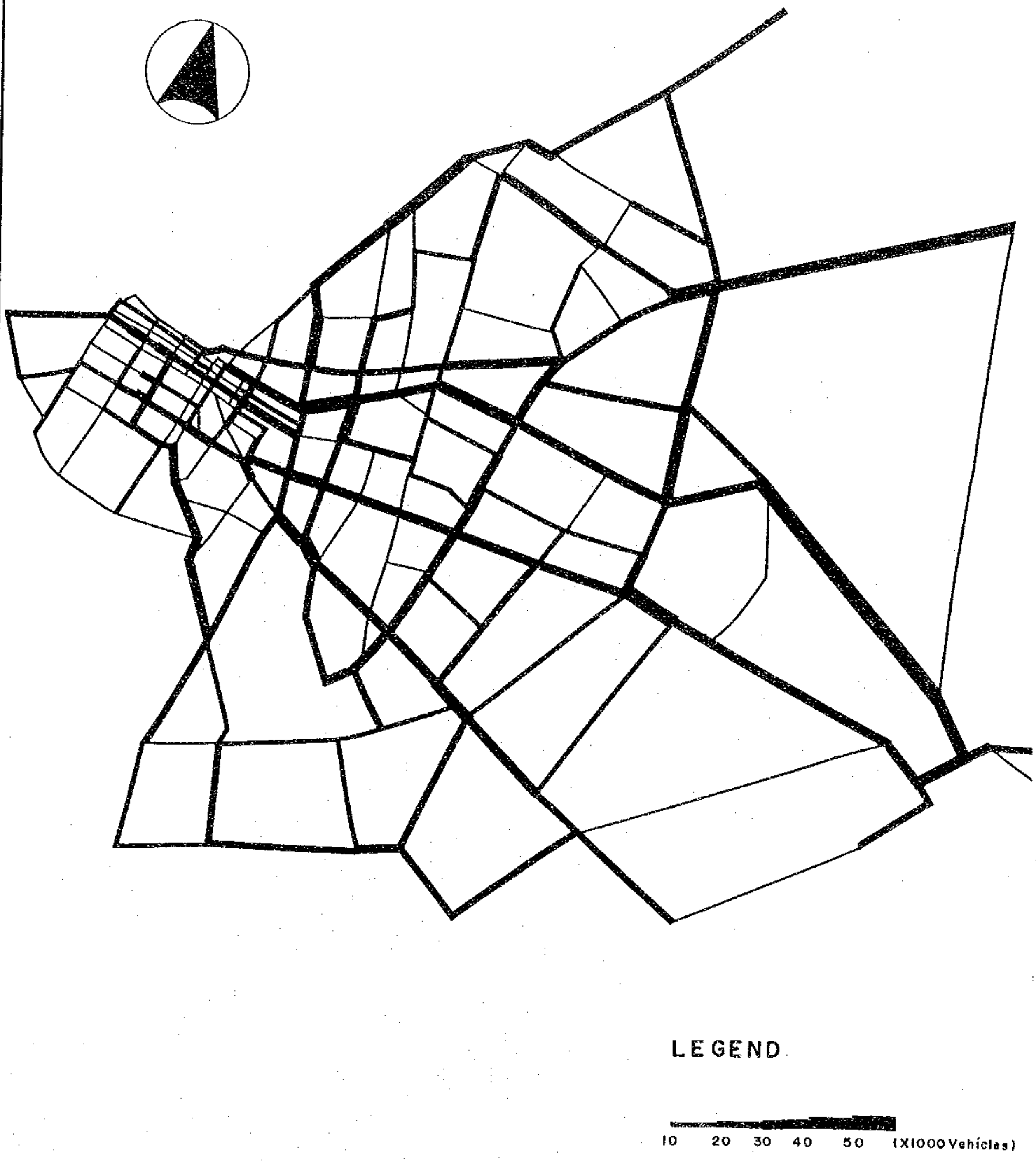
STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY



Source : The Urban Transport Study In Asunción Metropolitan Area

Fig. 4-10 TRAFFIC VOLUME (1984)	STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY
	JAPAN INTERNATIONAL COOPERATION AGENCY



Source: The Urban Transport Study In Asunción Metropolitan Area

Fig. 4-11 TRAFFIC VOLUME (2000)	STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY JAPAN INTERNATIONAL COOPERATION AGENCY

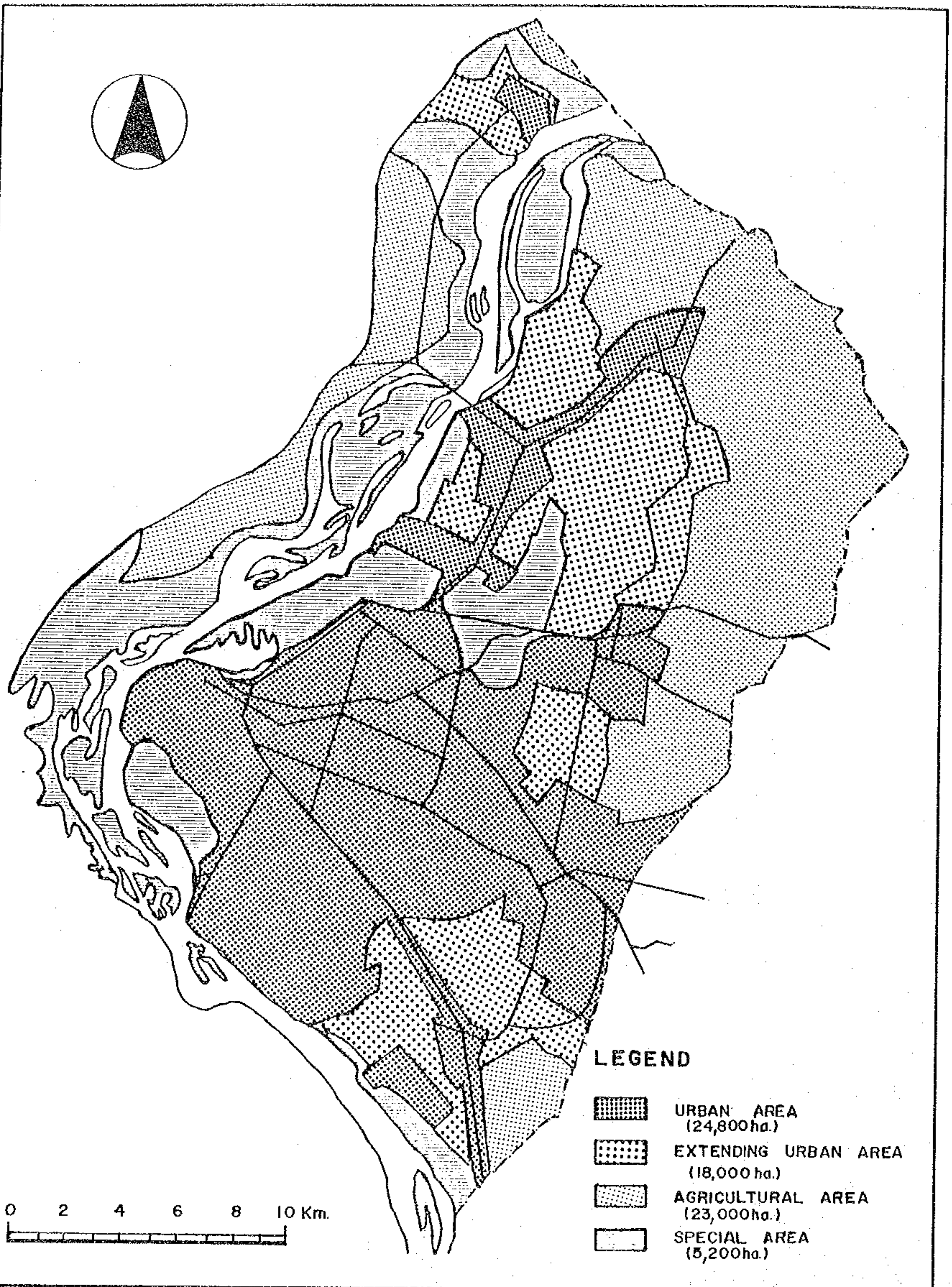
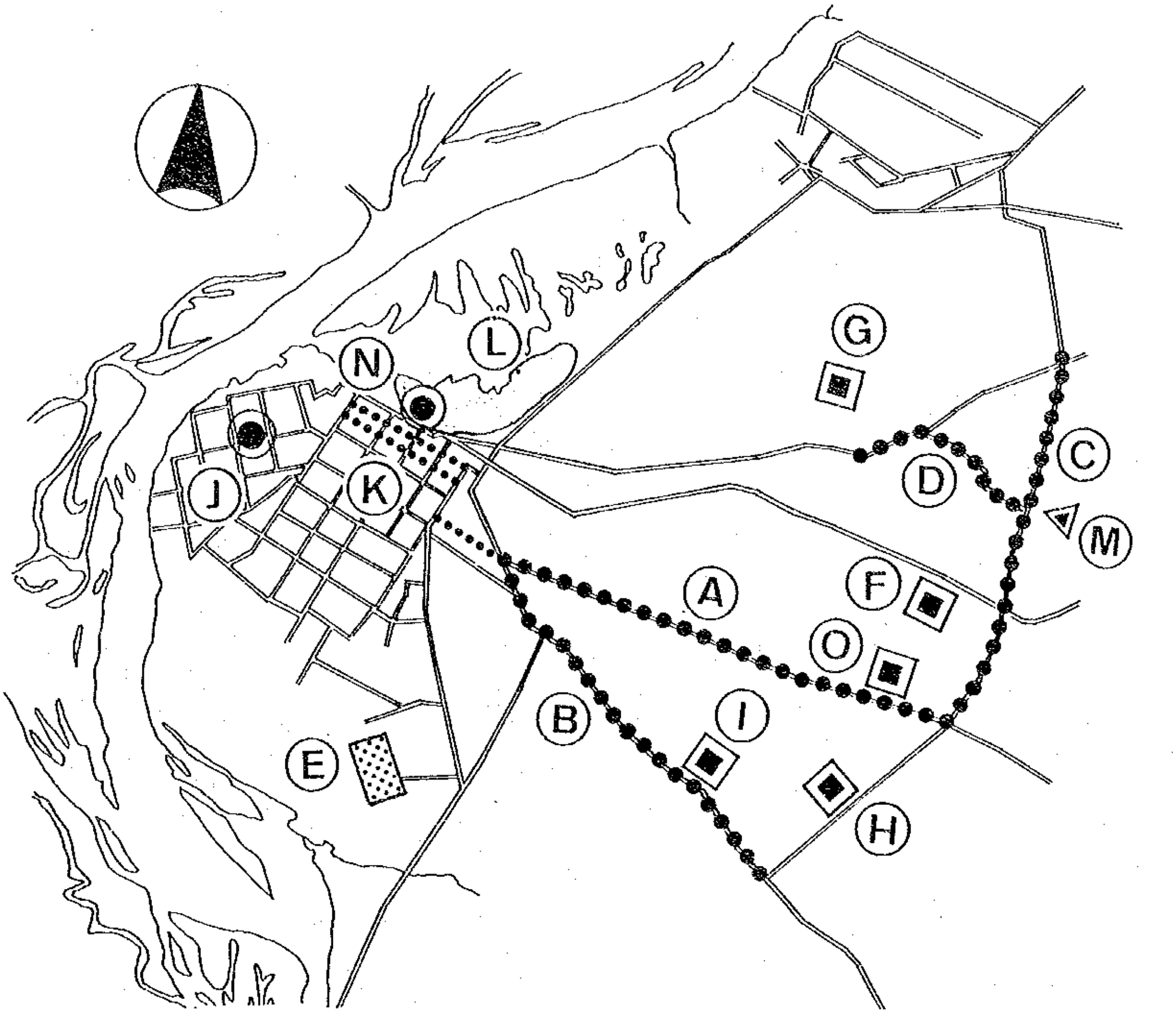


Fig. 4-12 METROPOLITAN URBAN AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT
IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY



LEGEND

●●●	(A)	EUSEBIO AYALA AVENUE
●●●	(B)	FERNANDO DE LA MORA AVENUE
●●●	(C)	MADAME LYNCH AVENUE
●●●	(D)	SANTA TERESA AVIADORES DEL CHACO
(dotted box)	(E)	DISPOSAL FACILITY
■	(F)	NEW MUNICIPAL BUILDING
■	(G)	BANCO CENTRAL DEL PARAGUAY
■	(H)	FOOD MART
■	(I)	BUS TERMINAL
●	(J)	IMPROVEMENT OF RECREA-TIONAL
......	(K)	PEDESTRIANS - PALMA - ESTRELLA STREET
□	(L)	REHABILITATION
▲	(M)	NEW CEMETERY
●	(N)	GREEN SPACE
■	(O)	LAND USE OF OLD AIRPORT SITE

Fig. 4-13 PROJECT IN ASUNSION CITY

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

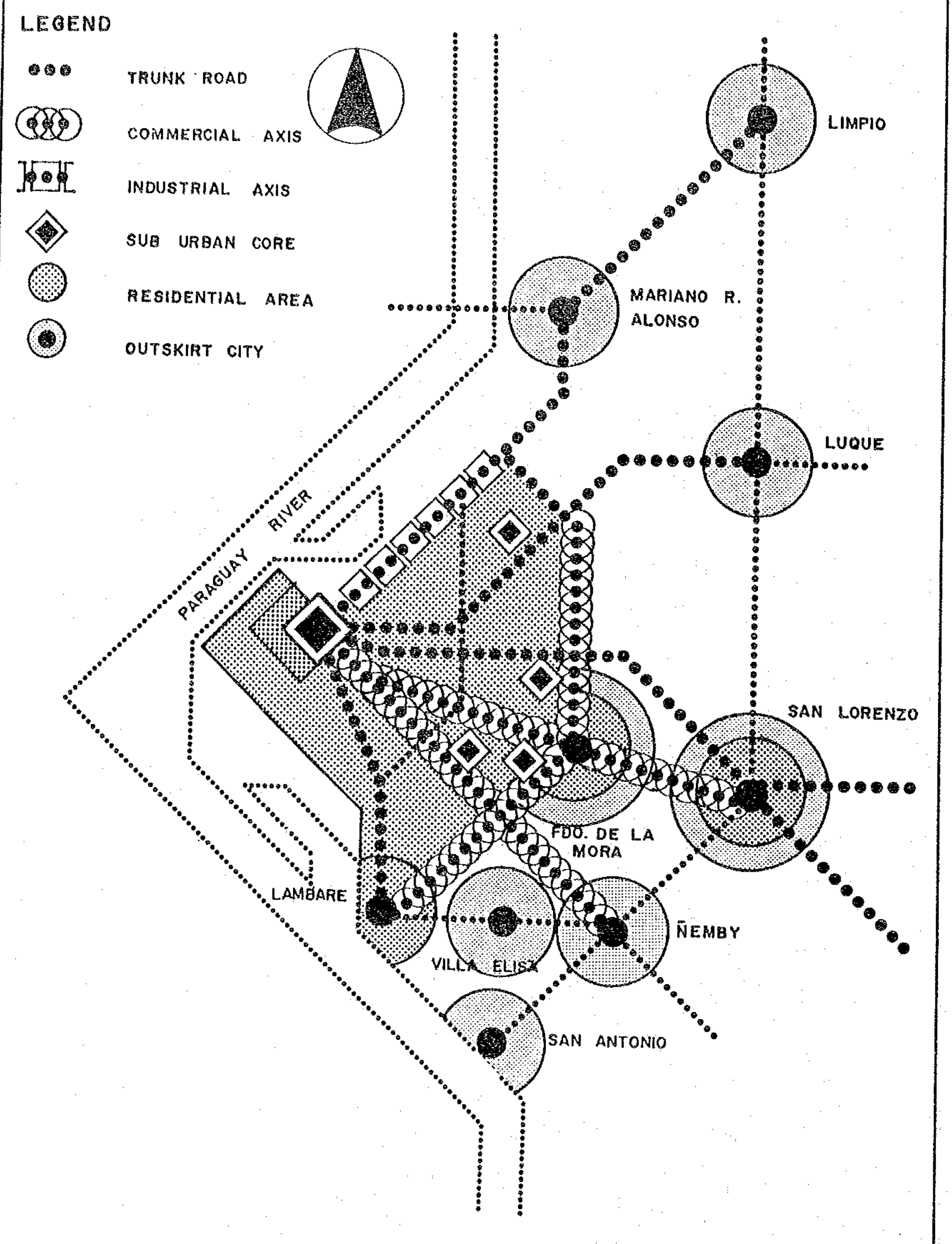


Fig. 4-14 THE URBAN STRUCTURE

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

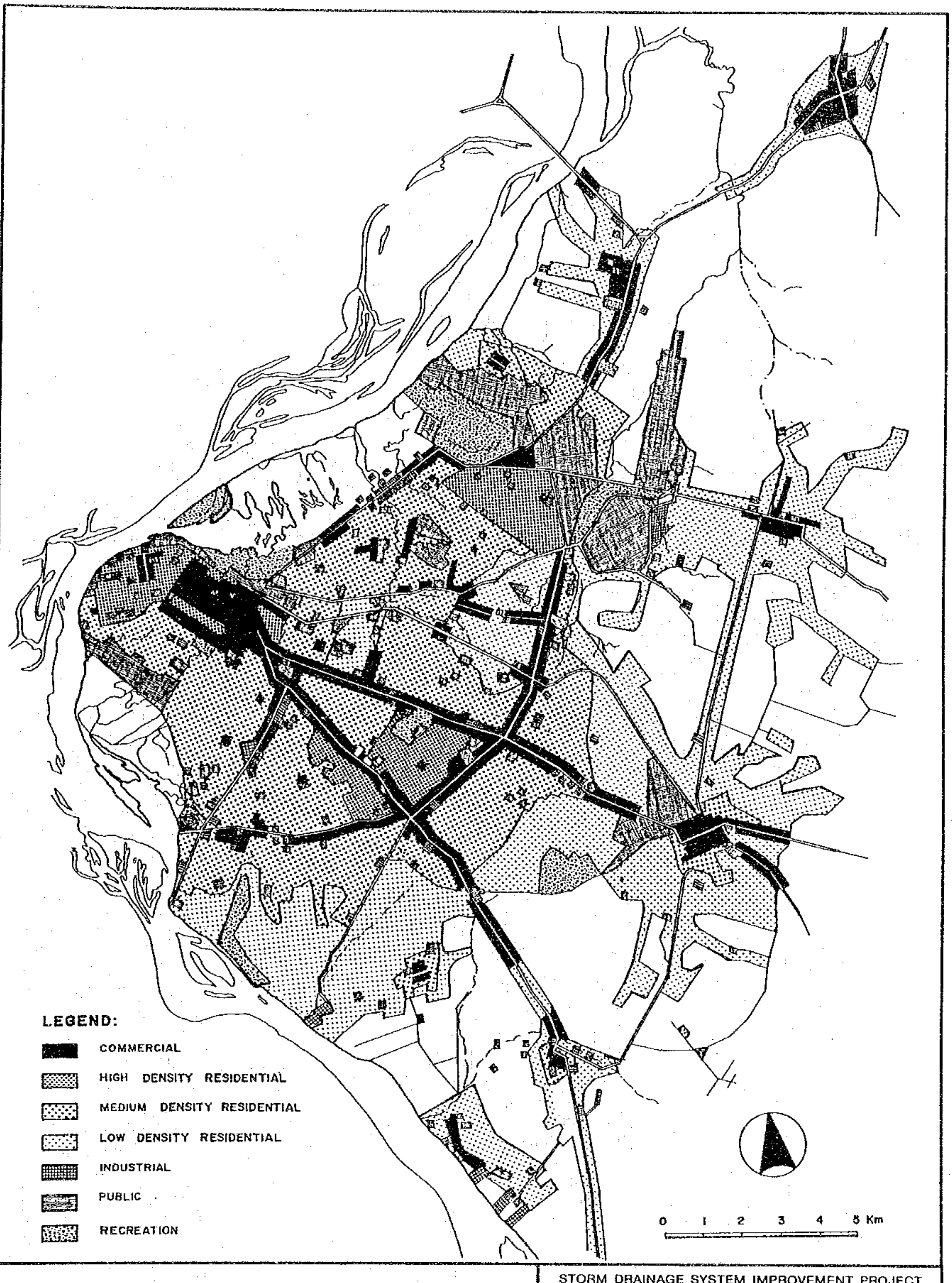


Fig. 4-15 FUTURE LAND USE OF YEAR 2000

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

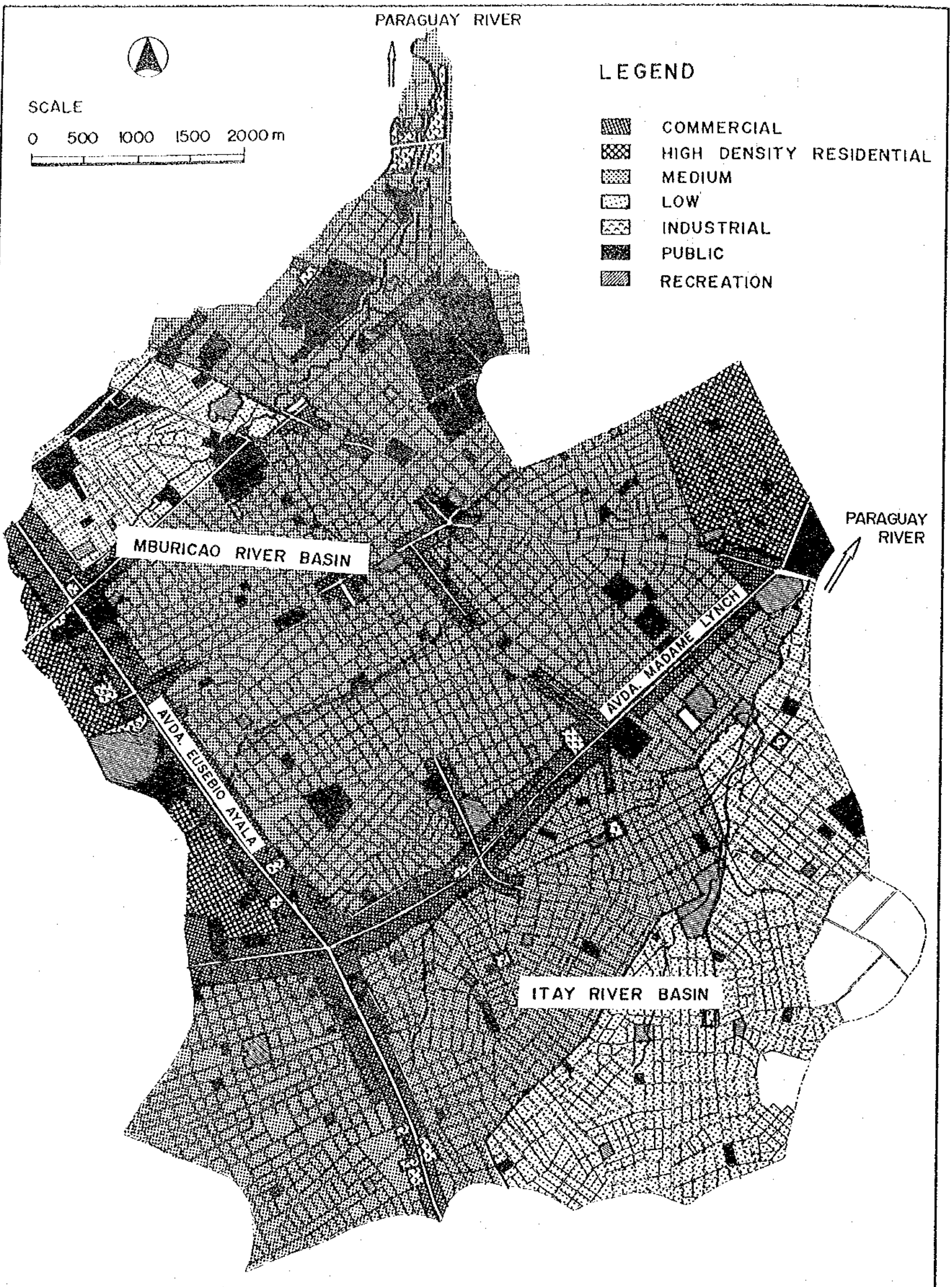


Fig. 4-16 FUTURE LAND USE IN MBURICAO AND ITAY RIVER BASIN	STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY JAPAN INTERNATIONAL COOPERATION AGENCY

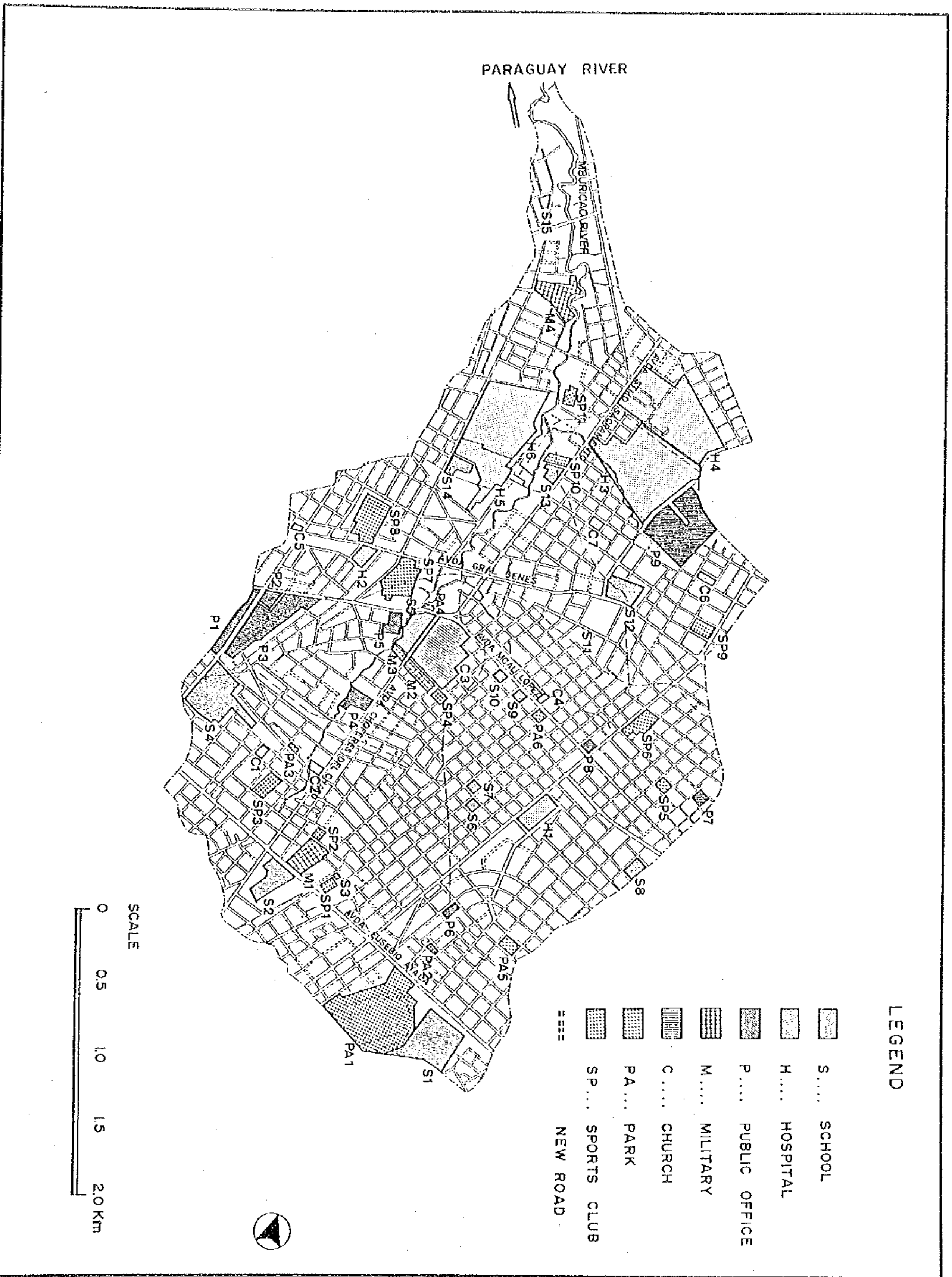


Fig. 4-17(1/2) PUBLIC PLACES IN THE STUDY AREA (MBURICAO RIVER BASIN)	STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY JAPAN INTERNATIONAL COOPERATION AGENCY

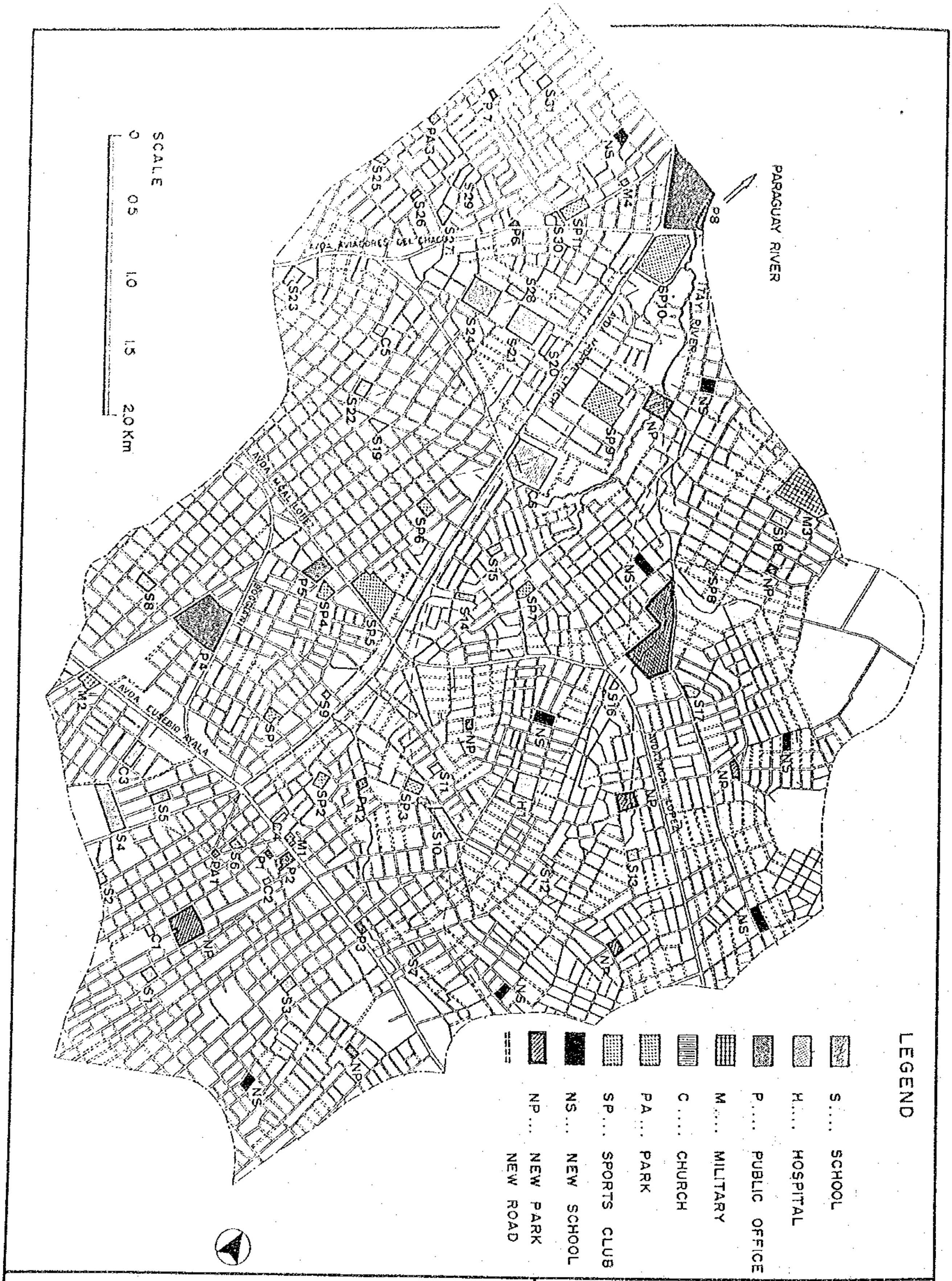


Fig. 4-17(2/2) PUBLIC PLACES IN THE STUDY AREA (ITAY RIVER BASIN)

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

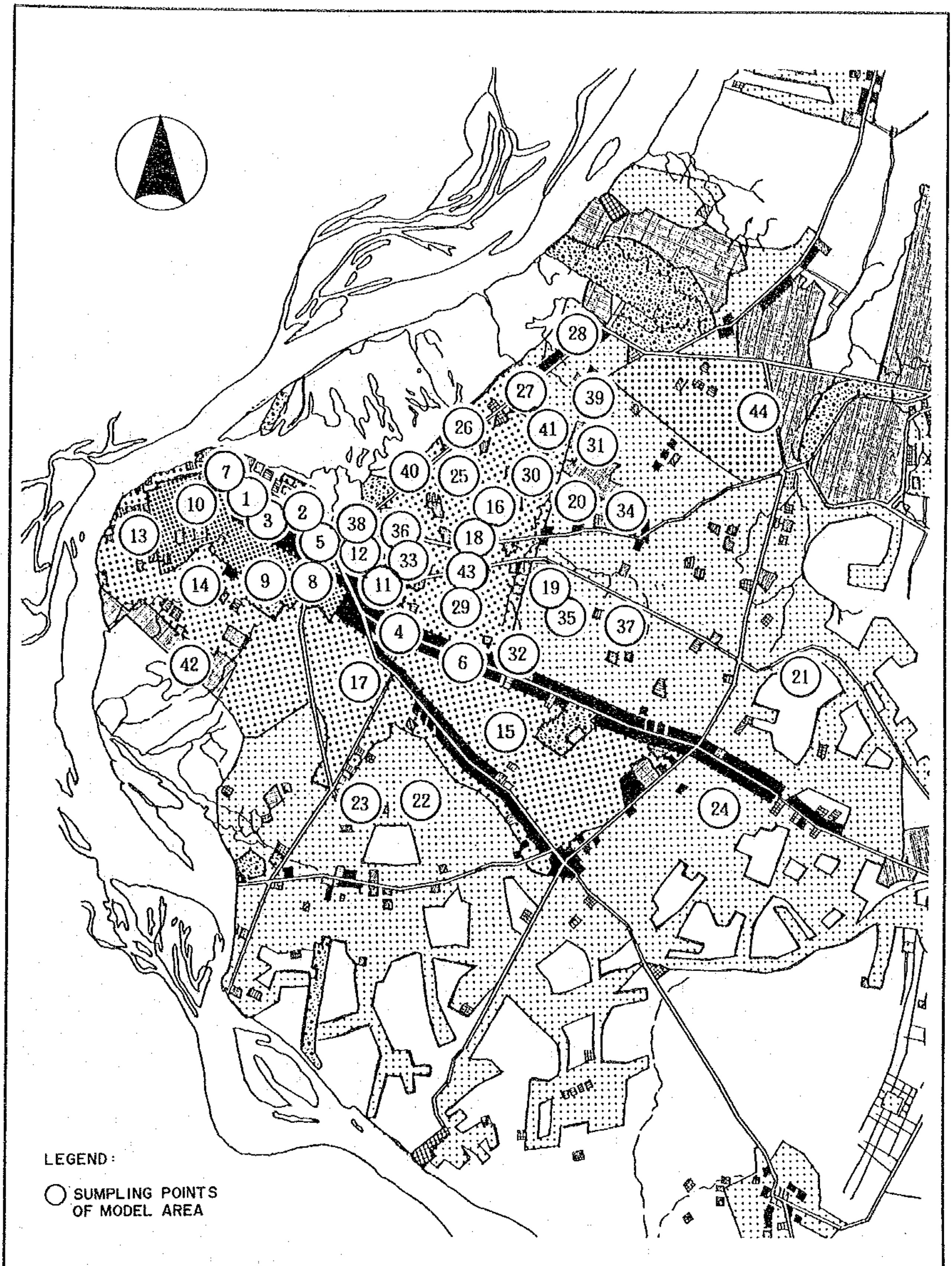
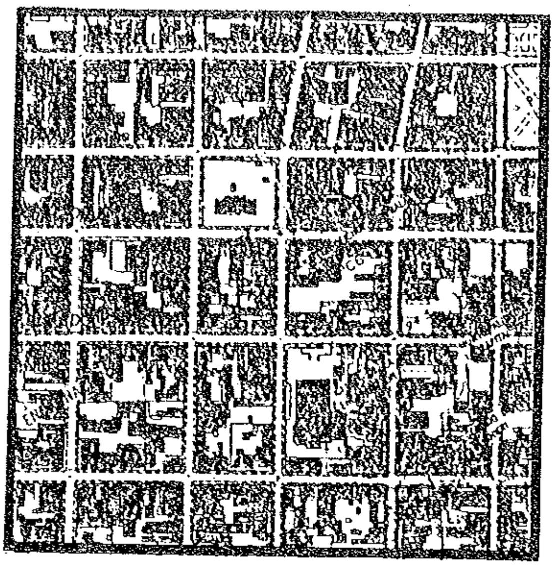


Fig. 4-18 LOCATION OF MODEL AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY



Commercial area

③ 76%

High density residential area

⑨ 51%

Medium density residential area

⑯ 27%

Low density residential area

㉑ 14%

LEGEND:

○ SUMPLING POINTS OF MODEL AREA (REFER TO Fig. 4-18)

Fig. 4-19 BUILDING-TO-LAND RATIO OF MODEL AREA

STORM DRAINAGE SYSTEM IMPROVEMENT PROJECT IN ASUNCION CITY, PARAGUAY

JAPAN INTERNATIONAL COOPERATION AGENCY

5. RIVER AND DRAINAGE PLANNING

SUPPORTING REPORT
ON
RIVER AND DRAINAGE PLANNING

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SUPPORTING REPORT
ON
RIVER AND DRAINAGE PLANNING

1. General

The river and drainage planning studies for the Basic Plan, the Master Plan and the First Stage Project aimed to plan a storm water control system consisting of river channel, drainage facilities and detention facilities, and to decide on the types and dimensions of these proposed facilities. Alternative case studies were made to clarify the existing condition of storm water control systems in the study area and thus establish the planning criteria.

2. Existing Conditions of Storm Water Control System

The area related to this study was divided into 31 basins according to drainage purpose (refer to Fig. 5-1). Twenty (20) of these basins have their own rivers and storm water can be drained through their respective rivers into Paraguay River. The other basins such as Varadero, Tacumbu, etc., have no rivers and storm water in these basins is drained into Paraguay River through roads and small ditches.

The flow capacity of each river was estimated through the cross section survey results and the roughness coefficients tabulated in Table 5-2, which are one of the most important factors for the calculation of flow capacity, were determined through the field reconnaissance. The features of the rivers and the calculation results are shown in Table 5-1.

To describe the present condition of the storm water control system in the study area, the 31 basins were divided into two (2) major groups. One group comprises basins with rivers and the other, without rivers.

2.1 Storm Water Control System in Basins with Rivers

Jardin River Basin

(1) River

Jardin River, which has a catchment area of 0.60 km^2 and a river length of 0.78 km, originates from the ridge and flows northward down to Asuncion Bay. The average longitudinal gradient of the river channel is about 1/46 and the width of the channel is about 3 to 6 m. It has a depth of from 3 to 4.5 m all through the river course. On the riverbed, base sand rock is exposed throughout the river course, except at the lowermost reaches.

The river basin is located to the west of the center of Asuncion City, and it is densely populated. The houses built closely to the river course are protected by rubble revetments that were privately constructed to prevent erosion of the banks. These revetments decrease the river width.

Five (5) permanent concrete and brick bridges span the river, but their abutments do not decrease the width of the river.

(2) Drainage Facilities

There are no drainage facilities in Jardin River Basin and storm water flows down to Jardin River through roads.

Jaen River Basin

(1) River

Jaen River, which has a catchment area of 2.47 km^2 and a river length of 1.90 km, originates near the center of its river basin and flows southwest down to the confluence with Paraguay River. The river basin is located south of Asuncion City and it is covered with high to medium density residential areas with single or two-storey houses.

The average longitudinal gradient of the river channel is about 1/79, and the river width at the upper reaches is about 3 to 7 m, widening to about 6 to 10 m at the middle and lower reaches. As for the depth of the river, it is 3 to 6 m in the upper and lower reaches though it is 6 to 10 m deep in the middle reaches. However, the lowermost reaches are only 1.0 m deep.

Sand base rock is exposed on the riverbed at places and sand or debris is deposited at other places in the channel. The river channel remains unimproved all through its course. The banks of the river are protected at portions with rubble revetments that have been privately constructed to avoid collapse of the banks. These privately constructed revetments help reduce the river width.

Four (4) permanent concrete bridges and one (1) temporary wooden bridge are built across the river; the abutments of the permanent bridges project into the river course, consequently reducing its width.

(2) Drainage Facilities

There are no drainage facilities except small privately constructed ones and storm water flows into Jaen River only through roads.

The catchment area at the starting point of the river is relatively large, so the streets near this point such as Centurion, J. E. O'Leary and Montevideo play the role of drainage canals when it rains.

Salamanca River Basin

(1) River

Salamanca River, which has a catchment area of 1.43 km^2 and a river length of 1.83 km, originates from a middle class residential area located to the south of the ridge. It flows in parallel with Zanja Moroti River to the southwest down to the confluence with Paraguay River. The river basin mainly consists of a medium density residential area and the military zone. The longitudinal gradient of the river is 1/46 on an average.

Since the river channel has been used as a dumping yard of the municipality along its entire length, the river which must have originally been a wider and deeper valley now turns to be a small stream with about 3 m in width and 0.5 to 1.0 m in depth all through its course. Slums are scattered on the river banks and the channel is full of wastes and garbage.

There exist three (3) permanent bridges across the river. Two of them are located on Ita Ybate Avenue and their bridge length of 32 m is long enough to assure the river flow capacity. However, the third bridge reduces the river channel width and forms an obstacle to the smooth flow of river water.

(2) Drainage Facilities

There are no drainage facilities on this basin and storm water is carried down to Salamanca River into Paraguay River through roads.

Zanja Moroti River Basin

(1) River

Zanja Moroti River, which has a catchment area of 1.61 km^2 and a river length of 2.35 km, originates from the residential area located south of the ridge and flows southwest almost in parallel to both Ferreira River and Salamanca River. The whole river basin is covered with medium density residential areas.

The river course may be divided into three portions by its longitudinal gradient which is gentle in the upper reaches as well as in the lower reaches but rather steep in the middle reaches, with an average gradient of 1/43.

In the middle reaches, it forms a deep valley of about 7 to 10 m deep and 10 to 13 m wide, but in its lower reaches, it develops into small sections of about 4.0 m wide and only 0.2 to 0.4 m deep.

A groundsill with head of about 3.0 m is located at the bridge of Ita Ybate Avenue to protect the bridge from erosion. Three permanent concrete bridges and one temporary wooden bridge are located at the upper reaches and they are reduce the river channel width at the bridge sites. Rubble revetments that have been privately constructed at some portions in the upper reaches also help to reduce the river width.

(2) Drainage Facilities

There are no drainage facilities, so that storm water is carried down either to Zanja Moroti River or directly flows into Paraguay River through roads.

Ferreira River Basin

(1) River

Ferreira River, which has a catchment area of 4.00 km^2 and a river length of 3.34 km, originates from a middle class residential area near the top of the ridge and flows southwest down to the confluence with Paraguay River. The river basin is almost entirely covered with a medium density residential area with single-storey houses.

Since the river has a steep longitudinal gradient of about 1/68, it forms a deep valley of about 5 m to 15 m along the river course. The width of the river which is about 3 to 5 m in its upper reaches is increased to 15 m to 30 m in the lower stream.

The base sand rock of Asuncion City is exposed on the riverbed along almost the entire river course except at the lower reaches. Therefore, riverbed fluctuation cannot be observed although the channel has a steep gradient.

Bank erosion is observed at the convex sides of the curves of the river course and the banks remain unimproved throughout the entire course.

There are four permanent bridges and some wooden bridges that have been privately constructed across the river. The abutments of some of these bridges project into the river and thus making the flow capacity smaller, aggravated by the garbage, wastes and debris that are dumped into the river by the residents nearby.

In the middle and upper reaches of this river, rubble revetments have been privately constructed at some portions to protect the river banks from erosion. Several groundsills have also been constructed with head of about 0.5 m to 1.0 m to stabilize the riverbed.

(2) Drainage Facilities

There are no drainage facilities, except for some privately constructed small channels.

Pozo Favorito Street which runs along the bottom of the valley in this basin assumes a topographical feature that collects storm water rather easily and thus plays the role of drainage canal when it rains.

Las Mercedes River Basin

(1) River

Las Mercedes River is a tentative name given by the project from the name of the district through which the river is flowing. With a catchment area of 2.12 km^2 and a river length of 1.35 km, it originates at the point of the outfall of the storm drainage pipe installed by CORPOSANA and flows to the north down along Uruguay Avenue to Asuncion Bay. In the middle reaches, the river runs through a privately-owned land where the channel has been changed into a culvert. The rest of the river channel is left unimproved.

The channel section measures about 3 m wide and 2 m deep at the uppermost stream, and its width gradually widens as the river flows down until it reaches about 8.5 m at the lowermost stream, although its depth remains almost the same throughout the river course. However, the section at the aforesaid culvert measures 4.5 m in width and 1.3 m in depth. The river has a steep gradient of 1/45 on an average.

The river is protected for one-third of its entire length by rubble or brick revetments and several groundsills with head of 0.3 to 1.5 m for stabilization of the riverbed. Where road and railroad cross the river, two permanent concrete bridges, one brick bridge and three box culverts are constructed.

The river basin is located near the center of Asuncion City where CORPOSANA installed the storm drainage system through the financial assistance of IDB. It is partially covered with a medium density residential area. (Refer to Fig. 5-2.)

(2) Drainage Facilities

There are two (2) drainage facilities in this basin. One is the storm drainage pipe joining with Las Mercedes River mentioned above and the other is the drainage culvert installed along Artigas Avenue. The former which was constructed by CORPOSANA under the IDB loan starts from the crossing of General Bernardino Caballero Avenue and Azara Street, and has a length of 1,700 m and a diameter of from 0.80 m to 1.80 m. The latter which mainly drains the storm water along Artigas Avenue has 300 m in length and about 1.0 m in width by 0.7 m in depth in its section.

Bella Vista River Basin

(1) River

Bella Vista River is also a tentative name given by the project from the name of the district where the river flows. It originates from the residential area located east of the center of Asuncion City and has a catchment area of 0.75 km^2 and a river length of 0.86 km. Its middle and upper reaches are covered by medium density residential areas, but mainly by slums, factories and warehouses in its lower reaches.

The river flows towards the north down to Asuncion Bay at a very steep gradient of 1/34 on an average. The river channel section varies from about 5 m by 2 m in width to 2 m by 2.7 m. Throughout its course, the riverbed is covered by sand deposits and the river remains unimproved along almost all its entire length.

The river channel is protected at portions by rubble revetments to prevent bank erosion, and several groundsills with head of about 0.5 m are installed for stabilization of the riverbed.

Two permanent concrete bridges and one brick bridge are built across the river, and their abutments project into the river and reduce the river width.

(2) Drainage Facilities

There are no drainage facilities and the storm water flows down to Bella Vista River on the roads. Atilio Machain Street has the topographic feature to easily gather the storm water running along Brasilia Avenue, and it serves as a main drainage channel to the river when it rains.

Mburicao River Basin

(1) River

Mburicao River, which has a catchment area of 16.45 km^2 and a river length of 11.04 km including tributaries, originates from the ridge east of the central part of Asuncion City. It flows toward the north down to the confluence with Paraguay River, meandering from the middle reaches downstream.

The river basin is made up of a highly developed area comprising high class residential areas with medium to low density side by side with commercial areas including public buildings such as hospitals, diplomatic missions, schools, etc. It is scarcely with any unutilized land.

The average longitudinal gradient of the river channel is

1/100, and its width which is about 3 m to 5 m in the upper reaches and widens to 30 m in the lowermost reaches. The depth of the river channel is about 2 to 4 m along the entire course, except in the terrace of Paraguay River where its depth increases to about 10 m.

Sand rock which is the base rock of Asuncion City is exposed on the riverbed along the entire river length, except in the lowermost reaches. No riverbed fluctuation was observed.

The river banks remain unimproved along almost all its stretch, except at portions where revetments were constructed by CORPOSANA or by landowners to protect their lands from bank erosion. The banks left unimproved are covered with shrubs and weeds.

At some portions, the river course has been privately converted into culverts for use of lands that came to be developed through construction works. In the middle reaches of this river, a house stands just above the river channel and supported by pillars that have been driven into the channel itself.

Eighteen permanent concrete bridges and four temporary wooden bridges are built across the river. Some of their abutments project into the river to make the span of the bridges shorter and thus narrowing the river channel. Culverts, shrubs and weeds on the banks and the meandering of the river course also help make the flow capacity less.

There are several groundsills with head of 0.3 m to 2.0 m in the upper and middle reaches for stabilization of the riverbed.

(2) Drainage Facilities

There are storm water drainage pipes constructed by CORPOSANA under the IDB loan in the second stage from 1979 to 1985 to solve problems at several critical points. The pipes are 1.50 to 2.00 m in diameter and 2,200 m in total length (refer to

Fig. 5-2). In addition, there are some other drainage facilities to partially drain stagnant storm water, but most of the storm water is usually carried into Mburicao River through roads.

Ycua Carrillo River Basin

(1) River

Ycua Carrillo River with 4.01 km^2 catchment area and 3.00 km river length originates from the area that has been newly developed as a residential area, and flows down to the north. The river basin is located in the eastern part of Asuncion City, consisting of low density residential and industrial areas. There still remains a lot of unutilized land in this basin, especially in the upper reaches.

The river channel is small all through the river course, i.e., about 4 m wide by 1 m deep in the upper reaches and about 7 m wide by 2 m deep in the lower reaches. The river has a relatively steep gradient of 1/78. On the upper stream side of Artigas Avenue, there exists a culvert of about 40 m in length and its top is utilized for private use.

The river remains unimproved and the sand rock is exposed on the riverbed throughout the river course, except in the lowermost reaches. Five permanent concrete bridges and ten or more temporary wooden bridges are constructed across the river and since the abutments of some of the permanent bridges project into the river, the width of the river is reduced at such places.

(2) Drainage Facilities

There are no drainage facilities and storm water is carried down directly to Ycua Carrillo River through roads. Molas Lopez Avenue which runs along the bottom of the valley seems to have been a river and, therefore, storm water is easily gathered along the avenue which plays the role as a main drainage channel to the river when it rains.

Santa Rosa River Basin

(1) River

Santa Rosa River is named after the district where it flows. With a catchment area of 3.13 km^2 and a river length of 2.40 km, the river originates at the center of the river basin and flows northeastward to Asuncion Bay after crossing Artigas and Sacramento avenues.

The river basin is covered by low density residential areas and partly by the Jardin Botanico (botanical garden) which is the largest park in Asuncion City.

The river channel has a relatively steep longitudinal gradient of 1/87 on an average, with a small cross section of about 1.5 m by 0.5 m in the upper reaches and about 6 to 8 m by 1 to 2.5 m in the middle and lower reaches. The riverbed is covered by sand deposited all through the river course, except in the middle reaches where sand rock is being exposed.

At several points in the upper reaches, the river channel has been changed into culverts by landowners who built their houses on them. At such culvert sections, the flow capacity seems to be very much restricted.

Six permanent concrete bridges and ten or more temporary wooden bridges are built across the river, and since the abutment of some of the permanent bridges projected into the river, the width of the river is reduced at such places.

(2) Drainage Facilities

There are no drainage facilities and storm water is carried into Santa Rosa River directly or through roads, as is the case in most of the other basins.

Tres Puentes Cue River Basin

(1) River

Tres Puentes Cue River, which has a catchment area of 6.80 km^2 and a river length of 5.99 km, originates in Jardin Botanico, the biggest park in Asuncion City composed of a botanical garden, a zoo, a golf course and others. The river runs northwestward while flowing through Jardin Botanico, and then turns southwestward until it joins Paraguay River. About 50% of the river basin is occupied by Jardin Botanico and the rest is covered with a low density residential area.

The river channel is about 1 to 2 m wide by 0.5 m deep all through its course, and its longitudinal gradient is relatively gentle at 1/171. Six permanent concrete bridges cross the river, but their abutments do not affect the flow capacity so much.

(2) Drainage Facilities

There remain several ditches and natural waterways running through unutilized land as well as in Jardin Botanico. Storm water is carried down to Tres Puentes Cue River through such ditches and waterways or on the roads. Their flow capacities seem to be very poor compared to the size of their catchment area.

Itay River Basin

(1) River

Itay River has the widest catchment area and the longest course among all the rivers in the basins in the study area. With a catchment area of 136.13 km^2 and a length of 25.50 km, it originates from Fernando de la Mora City and flows northward down to Paraguay River. It has 7 main tributaries and shows the most gentle longitudinal gradient of 1/318 on an average.

The river basin is located at the eastern boundary of the study area and is mainly covered with unutilized land and stock farms in its reaches lower than Aviadores del Chaco Avenue. President Stroessner International Airport and the military zone neighboring to the airport are in this lower area.

In the upper reaches beyond Aviadores del Chaco Avenue, the river basin is covered with unutilized land mixed with a low density residential area, factory and commercial zone. The unutilized land in this area is presently being developed as residential area.

The river channel remains unimproved throughout the river course and its cross section seems to be small taking the catchment area into consideration. Its sections are about 2 to 4 m wide by 0.5 to 1 m deep in the upper reaches and about 7 to 10 m wide by 2 to 3 m deep in the lower reaches.

The riverbed material mainly consists of sand, but sand rock and soft clay rock are exposed on the riverbed at several points.

Among the seven main tributaries, the one which flows along Madame Lynch Avenue for the length of 5.34 km has an important role to play as drainage channel for the westside area of the avenue. It has sections of about 3 to 4 m wide by 1.5 m deep in the upper reaches and about 7 to 10 m wide by 1 to 2.5 m deep in the middle and lower reaches. Since the river channel has not been improved or properly maintained except the lowest portion of 300 m of Madame Lynch River, one of the main tributaries of Itay River, the river banks are covered by weeds and shrubs.

The construction of a channel with revetments of wet masonry and invert has been planned. The municipality plans to improve 680 m of the channel out of the total target of 4 km to begin in 1985. Many temporary bridges were privately constructed across the channel and their abutments which project into the channel are obstacles to river flow because the bridges have their piers inside the channel and their slabs are set lower than the bank shoulder. Several rubble groundsills with head of 1 to 2 m exist in the channel along Madame Lynch Avenue to stabilize the riverbed.

As for the other main tributaries, their existing conditions are almost the same as the main stream in terms of river channel condition, gentle gradient and riverbed materials. Where Madame Lynch River crosses the avenue, a concrete box culvert of about 8.5 m wide by about 1.5 m high is used.

There are more than thirty permanent and temporary bridges across the river.

(2) Drainage Facilities

Storm water is mainly drained into the river directly through natural waterways in the unutilized land and stock farms in the lower reaches. Storm water in the urbanized area is carried into the river mainly through roads and natural waterways and, partially, through some artificial drainage channels. Most of the artificial drainage channels located in the upper reaches of the river belong to Asuncion City and Fernando de la Mora City. The flow capacity of these drainage channels seems to be very poor compared to their catchment area.

Lambare River Basin

(1) River

Lambare River, which has a catchment area of 25.66 km^2 and a river length of 7.03 km, originates from the residential area of Tembetary District. It flows southwestward in the upper to the middle reaches and then turns in the middle to lower reaches down to the confluence with Paraguay River.

The river basin is located south of Asuncion City and its upper reaches have been developed as residential area. There still remains some unutilized land in the middle to lower reaches which are also being developed as residential areas.

As for the river channel, the longitudinal gradient of Lambare River is 1/107 on an average. The cross section of this river is very small in the upper reaches beyond Fernando de la Mora Avenue, but the river channel gradually increases in width to about 5 m in the middle reaches and to about 20 m in the lower reaches.

On the other hand, Lambare River forms a relatively deep valley with about 3 to 6 m in depth all throughout its course. Lambare River has a big tributary, Sosa River, which has a catchment area of 7.20 km^2, river length of 3.75 km, and longitudinal gradient of 1/67. The cross section of Sosa River is about 10 to 14 m wide by 3 to 5.5 m deep through its entire course.

Along both rivers, sand rock is exposed on the river banks with no revetment. Bank erosion is taking place everywhere all through the river course.

Sosa River was filled up intentionally for road construction in its upper stream from the uppermost reaches. Apparently, this is the cause for the rainwater flowing in the streets in this area.

River water is being utilized by a paper mill located in the lower reaches of Lambare River, which is the only example of industrial use of river water in the study area.

There is a rubble groundsill with head of about 5 m at the confluence of the Lambare and Sosa rivers. One permanent concrete bridge and nine temporary wooden bridges are crossing Sosa River, and four permanent concrete bridges and eight temporary wooden bridges are crossing Lambare River. The abutments of some of the permanent bridges are projecting into the rivers thereby reducing their widths.

(2) Drainage Facilities

There are some drainage pipes and natural waterways in Lambare River Basin, but they are playing a little role as drainage facilities because of their small flow capacity and the lack of a systemized network.

Most of the storm water is carried into Lambare River through the roads. Some of these roads seem to have been waterways and, due to their topographical features to favorably gather storm water, play the role of drainage channel. The upper reaches of the river have been filled up and paved with rubble to be utilized as road.

Villa Elisa River Basin

(1) River

Villa Elisa River which has 11.53 km^2 catchment area and 5.20 km river length originates from Villa Elisa City and flows southwestward down to the confluence with Paraguay River.

The river basin is located at about 10 km southeast of the center of Asuncion City. It is almost entirely covered with a flat plain, some thin forests and livestock farms.

The river has a relatively steep longitudinal gradient of 1/68 on an average. The riverbed material is sand in the upper to middle reaches, though rock is exposed on the riverbed in the lower reaches. Both banks of the river are covered with trees and weeds, and since the river channel has been neither improved nor properly maintained, river bank erosion is taking place at several points.

The river channel is about 15 m wide by 3 m deep in the upper reaches, but assumes the shape of a deep valley with 15 m in width and 10 m in depth in its middle and lower reaches.

Several bridges cross the river, and because the abutments of some of them are projecting into the river channel, the width of the river is thereby narrowed.

(2) Drainage Facilities

There are no drainage facilities except natural waterways, and storm water is thus carried down to Villa Elisa River through roads in the urbanized area and through the natural waterways or directly into the river in the forest, stock farms and other areas.

Nemby River Basin

(1) River

Nemby River which has 44.17 km^2 catchment area and 7.55 km river length originates from the east of Nemby City and flows westward by passing through the northern part of San Antonio City just before it joins Paraguay River. It has two main tributaries; namely, Mbocayaty River and Painu River.

The river basin is located southwest of San Lorenzo City and 15 km southeast of the center of Asuncion City. Although it includes the cities of Nemby and San Antonio, most of the basin consists of forest, stock farms, and others.

The longitudinal gradient of the river is 1/101 on an average. The river channel is about 10 m wide by 2 m deep in the lower reaches and about 5 m wide by 2 m deep in the middle reaches. In the middle reaches, much sand is deposited on the riverbed so that it is being used as borrow pit of sand as construction material for Asuncion and other cities.

No structure other than a few bridges are found throughout the river course.

(2) Drainage Facilities

There are no drainage facilities except natural waterways, and storm water is carried down to Nemby River through roads in the urbanized area and through the natural waterways or directly into the river in the forest, stock farms and other areas.

San Lorenzo River Basin

(1) River

San Lorenzo River which has 33.69 km^2 catchment area and 9.60 km river length originates from southwest of San Lorenzo City. It flows northeastward by passing through the northwestern part of San Lorenzo City, then after joining with Yukyry River, finally pours into Ypacarai Lake which is located 30 km east of the center of Asuncion City.

The river basin is located east of the reaches of Itay River Basin. It is almost entirely covered with forests, stock farms, etc., except the city area of San Lorenzo.

The longitudinal gradient of the river is 1/142 on an average. The river channel is about 10 to 15 m wide by 2 to 3 m deep in the middle reaches, although it narrows down to about 5 to 7 m wide by 2 m deep in the lower reaches. At some portions, rock is exposed on the riverbed and sand deposits are observed at other portions.

At some portions in the San Lorenzo City area, the river banks are protected from erosion by rubble revetments. Five permanent concrete bridges are crossing the river, but their abutments do not affect the flow capacity.

(2) Drainage Facilities

There are no drainage facilities except natural waterways, and storm water is carried down to San Lorenzo River through roads in the urbanized area and through the natural waterways or directly into the river in forestland, stock farms, and other areas.

Tayazuape River Basin

(1) River

Tayazuape River which has 30.13 km^2 catchment area and 8.80 km river length originates from the northern part of San Lorenzo City. It flows down toward the northeast and finally pours into Ypacarai Lake after joining with San Lorenzo River and Yukyry River.

The river basin lies east of San Lorenzo River Basin. While several houses are scattered on the eastern side of the basin as part of the suburbs of San Lorenzo City, plains including stock farms mainly cover the western side.

The river channel is about 4 to 6 m wide by 1 to 1.5 m deep throughout the river course. Since the riverbed material is made up of sand, some sand borrow pits are seen on the river course.

The river course has a relatively gentle longitudinal gradient of 1/163 on an average. Five permanent concrete bridges are crossing the river, and some of their abutments are narrowing down the river width.

(2) Drainage Facilities

There are no drainage facilities except natural waterways, and storm water is carried down to Tayazuape River through roads in the urbanized area and through natural waterways or directly into the river in forestland, stock farms and other areas.

Ycua Dure River Basin

(1) River

Ycua Dure River which has 12.57 km^2 catchment area and 4.50 km river length originates at the southern part of Luque City. It runs to the east joining with Yukyry River below its confluence with San Lorenzo River.

The river basin is neighboring to the center of Luque City and includes a part of its suburbs which occupies one third of the upper reaches. Except the suburban area of Luque City, the basin is almost entirely covered with forestland and stock farms.

The river channel is small with about 2 to 4 m wide by 1 m deep, and its longitudinal gradient is relatively gentle at 1/113 on an average. Two permanent concrete bridges span the river and their abutments adversely affect the flow capacity.

(2) Drainage Facilities

There are no drainage facilities except natural waterways, and storm water is carried down to Ycua Dure River through roads in the urbanized area and through the natural waterways or directly into the river in forestland, stock farms and other areas.

Zeballos Cue River Basin

(1) River

The river is so small that it has not been given any name. For convenience, it will be tentatively called Zeballos Cue River from the name of the surrounding locality.

Zeballos Cue River with 2.13 km^2 catchment area and 1.23 km river length and 1/68 of the longitudinal gradient merely serves as a natural drainage channel of the local sewerage. It flows westward almost steadily until it pours into Paraguay River. Its channel is very small, measuring about 1 to 1.5 m in width and 0.5 m in depth. The river basin is located between Jardin Botanico (Tres Puentes Cue River Basin) and Paso Cai River Basin, and covers a part of Zeballos Cue town. There is no particular structure along the river course.

(2) Drainage Facilities

In this basin, natural waterways and roads have the main role of drainage facilities as in most of the other basins. Storm water is carried through these facilities into the river or directly into Paraguay River.

Paso Cai River Basin

(1) River

Paso Cai River which has 5.49 km^2 catchment area and 4.00 km river length originates at the sandy plain, flowing westward down to the confluence with Paraguay River. The river basin is neighboring to the middle reaches of Itay River Basin along its western part. The town area of Zeballos Cue is almost entirely included in this basin and stock farms cover the rest. Since the soil of the basin consists of sand or silty sand, bank erosion is observed along the mainstream as well as its tributaries in their upper and middle reaches.

The longitudinal gradient of the river is 1/129 on an average, and its riverbed is made up of sand throughout the river course. The river usually remains dry in its upper reaches except at the time of rain when water appears on the riverbed from the middle reaches downward.

The river channel is about 5 m wide and 1 m deep in almost the entire length. No particular structure is found along the river.

(2) Drainage facilities

There are no drainage facilities except natural waterways, and storm water is carried down to Paso Cai River through roads in the urbanized area and through the natural waterways or directly into the river in forestland, stock farms and other areas.

2.2 Storm Water Control System in Basins Without Rivers

Varadero Basin

Varadero Basin which is located in the western end of Asuncion City occupies an area of 3.25 km^2 mainly covered with high to medium density residential areas and an industrial zone scattering along Paraguay River.

There are no drainage facilities except two short natural waterways, and storm water is directly carried down into Paraguay River through roads, especially Bartolome Coronel and Isabel la Catolica streets. These streets run along the bottom of the valley and play the role of main drainage canals when it rains.

Centro Basin

Centro Basin lies in the central part of Asuncion, the most important area of the capital city, extending over 7.24 km^2 comprising commercial and high density residential areas. This is the only basin which has an almost complete storm water drainage system that was constructed by CORPOSANA under the IDB loan.

The construction period of the drainage system was divided into 2 stages, the first stage extending from 1973 to 1976 based on the project scale of 10-year return period at an area of 200 ha and the second stage extending from 1979 to 1984 based on the project scale of 5-year return period on the remaining 510 ha. In the first stage, the system of pipes of about 9,100 m in length and 0.60 m to 2.70 m in diameter was installed. In the second stage, a system of pipes of 14,100 m in length and 0.60 m to 2.50 m in diameter was set up. (Refer to Fig. 5-2.)

Tacumbu Basin

Tacumbu Basin covers an area of 1.70 km^2 which is made up of medium density residential area in the northern part of General Patricio Colon M. Street and the military zone in the southern part. Though there are some natural waterways in the military zone, there are no drainage facilities in the residential area and storm water is carried down through roads and then directly flow into Paraguay River.

Villa Universitaria Basin

Villa Universitaria Basin which is located in the southern part of Asuncion City has an area of 2.40 km^2 mainly consisting of a low density residential area. In this area, there is neither river nor drainage facilities. Storm water, therefore, flows down to Paraguay River either directly or through roads.

Drainage pipes were installed by MOPC across Jose Felix Bogado Avenue to drain stagnant storm water from the upper part to the lower part of the avenue. Nevertheless, they are not effectively contributing to solve the present problem caused by storm water all over the basin.

Mariscal Lopez Basin

Mariscal Lopez Basin, the second smallest basin in the study area, has an area of 0.66 km^2 which is mainly covered with a low density residential area and an industrial area along Artigas Avenue. There are no drainage facilities in the area south of Artigas Avenue and storm water is carried down through roads. Private drainage pipes with 0.5 m to 0.8 m in diameter were installed along the northern side of the avenue to drain storm water in the area into Asuncion Bay.

Tablada Basin

Tablada Basin has an area extending over 1.03 km^2 which is mainly covered with a medium density residential area and an industrial area along Artigas Avenue. A horseshoe-shaped culvert with a section of 1.20 m in width and 1.80 m in depth has been installed by a private firm to drain storm water across the railway.

Valle Apua Basin

Valle Apua Basin is located in the southern part of Lambare City and has an area of 10.63 km^2 which consists of the low density residential area of Lambare City and forestland, stock farms, and others. Storm water is carried into Paraguay River either directly or through roads and natural waterways.

Mariano Alonso Basin

Mariano Alonso Basin is located in the northern part of the study area. It has an area of 15.65 km^2 which is made up of a part of Mariano Alonso City and forestland. In this basin, there are no drainage facilities and storm water is carried down to Paraguay River through roads and natural waterways.

Villa Hayes Basin

Villa Hayes Basin is located 25 km north of the center of Asuncion City and is situated on the right bank of Paraguay River. It has an area of 8.95 km^2 which is covered with a low density residential area and stock farms. There are no drainage facilities in this basin and storm water is carried down into Paraguay River through roads and natural waterways.

Petropar Basin

Petropar Basin lies between the Villa Elisa River Basin and the Nemby River Basin. It has an area of 5.23 km^2 which consists mainly of farmland and low density residential area in small scale. There are no drainage facilities except for a natural waterway, and most of the storm water flow down to Paraguay River through this waterway.

Achucarro Basin

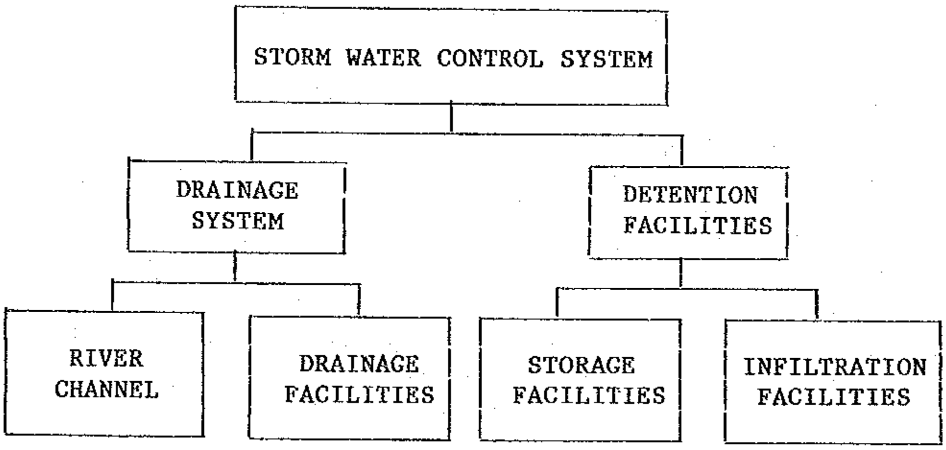
Achucarro Basin has an area of 13.35 km^2 and is located in the southernmost part of the study area. It consists of a low density residential area of San Antonio City, farmland and forest. Roads in the urbanized area play the role of main drainage system during heavy rainfall and storm water is carried through the roads or the natural waterways to Paraguay River directly.

3. Storm Water Control Measures

3.1 Outline of the Control System

3.1.1 Component of Storm Water Control System

The storm water control system for this study area can be schematically presented as follows:



Drainage System

The concept of the drainage system is to discharge storm water safely and quickly from the proposed area. The drainage system consists of the river channel and the drainage facilities.

Detention Facilities

The concept of the detention facilities is to reduce discharge into rivers by controlling storm water runoff and thus reducing the discharge load of the rivers.

3.1.2 Conceivable Measures for Drainage System

River Channel

Generally, there are four (4) measures to be studied for river improvement in city areas, as follows:

- Improvement of River Channel
- Construction of Floodway
- Construction of Retarding Basin
- Installation of Pumping Station

(1) Improvement of River Channel

River improvement is generally the most effective measure against flooding. The primary purpose of river improvement works is to augment the flow capacity of a river channel so that more volume of runoff discharge can flow down safely without overbanking.

In cases where the river concerned flows through a densely populated area, river improvement works sometimes encounter social and financial restrictions, especially when a vast tract of land has to be acquired and an enormous number of house evacuation is needed for the widening of the river channel. In such a case, river improvement works have to be foregone or employed in combination with other measures.

(2) Construction of Floodway

Flood diversion facilities include channels and tunnels as bypass to drain storm water directly into a river or the sea. This measure may be adopted in case that it is very difficult to execute river improvement works in view of the restrictions mentioned above. (Refer to Fig. 5-3.)

(3) Construction of Retarding Basin

Retarding basins have the function of regulating the peak discharge of flood by storing floodwaters in the middle reaches of a river. This measure is effective for river basins with very short flood concentration time, and the availability of a suitable site is a deciding factor for its application. (Refer to Fig. 5-4.)

(4) Installation of Pumping Stations

Contrary to the river improvement works and the floodway which depend on gravity drainage, the drainage by pumping is one of the mechanical measures employed to drain storm water. When the topographic conditions do not allow storm water to drain itself by gravitational means, drainage by pumping by the installation of pumping stations has to be considered.

Drainage Facilities

Drainage facilities drain storm water from the drainage area into rivers. Underground conduits and open channels are the facilities to be studied for the improvement of drainage facilities.

(1) Underground Conduit

Underground conduits consisting of pipes and box culverts are buried under roads, so that they can be applied even in well urbanized basins where land acquisition is considered difficult.

(2) Open Channel

Open channels are usually constructed as extension of existing drainage open channels; therefore, it is difficult to construct them in urbanized areas, because there will be no sufficient open space for their construction.

3.1.3 Conceivable Measures for Detention Facilities

Detention facility works that control runoff discharge include the installation of storage and infiltration facilities and the detour of drainage pipe systems that are usually employed in urbanized areas where there is difficulty in acquiring enough sites for river improvement works, floodways, etc. These facilities have the function of temporarily storing runoff discharge on the way to the rivers and thus regulating the peak discharge, but their control capacity is small if adopted independently, so that they should be provided liberally and in combination with each other.

The features of the above facilities are briefly discussed as follows:

Storage Facilities

(1) Storage Facilities in Open Space

School playgrounds, parks, parking lots and other wide public places may be utilized as retarding ponds. These places need to be excavated to a certain depth to assure an adequate regulation capacity for storm water and not to mar their original functions. (Refer to Fig. 5-5.)

(2) Storage Facilities in House Lots

Water storage tanks are installed under or on the ground to catch storm water from the roofs of houses or buildings. The basements of such houses or buildings are sometimes used as storage tanks. (Refer to Fig. 5-5.)

It is necessary to spread this kind of storage facilities in wide areas involving a number of privately-owned houses because a single unit of facility has a very small capacity.

(3) Detour of Drainage Pipes

In general, the longer it takes for storm runoff to arrive at its outlet or at the river, the smaller is the peak runoff discharge at the river. Peak runoff discharge is regulated by detouring drainage pipes because of increase in storage capacity by pipes and longer concentration time. This measure is effective, especially in a basin with a gentle gradient.

Infiltration Facilities

Infiltration facilities to be taken into consideration consist of infiltration trench with inlet, infiltration well, permeable pavement, etc., (refer to Fig. 5-6). The infiltration capacity of these devices highly depends on the permeability of the site.

(1) Infiltration Trench with Inlet

Infiltration trench is composed of perforated pipe, gravel, sand and porous sheet installed under the ground to enable seeping in of storm water. Storm water from rooftops is generally led into the infiltration trench through drain pipe and inlet, because storm water from areas such as roads, gardens, playground, etc., may deteriorate the function of the facilities.

(2) Infiltration Well

Infiltration well is employed in an area where there is no permeable layer near the ground surface. Storm water is led into the infiltration well which is dug down to the permeable layer.

(3) Permeable Pavement

Permeable pavement generally consists of layers of porous pavement material, gravel and sand. Storm water running on roads directly goes into the ground through these layers, but this measure is difficult to manage and maintain its function.

3.2 Applicable Measures to Each Basin

The storm water control facilities as mentioned in 3.1 are studied to know which facilities will be applied to each basin.

3.2.1 Drainage System

River Channel

Since the improvement of river channel is the most effective measure for the improvement of a storm water control system, its application on all the rivers will be studied. The construction of floodway and retarding basin can be applied only to Itay river basin from the topographical viewpoint.

As for the installation of pumping station, this measure will not be applied since all of the basins in the planning area have enough gradient and suitable topographic conditions for the gravity drainage method.

Drainage Facilities

Both underground conduit and open channel are applicable as drainage facilities in this study. Underground conduit can be employed in any case; while, the use of open channel which is less costly and more easily maintained than the underground conduit is subject to the land use pattern in the area concerned. In this respect, open channel is applied to the area where sufficient open space for its construction is available.

3.2.2 Detention Facilities

The detention facilities mentioned in Table 5-3 are fully capable of fulfilling their functions satisfactorily, and can be used in the planning area. Among them, the parking lots storage facilities, the between-houses storage facilities and the infiltration well facilities will not be employed in this study for the following reasons:

(1) Parking lots storage facilities are less efficient and less economical due to their smaller effective depth that are designed not to mar their original functions when compared with other storage facilities.

(2) Between-houses storage facilities may not be practical to consider at present since there is no large-scale housing compound in the planning area and furthermore, the future possibility is still obscure.

(3) For infiltration wells, geological data covering the planning area are insufficient for evaluation of the effect of these facilities.

Accordingly, this study will include storage facilities consisting of storage facilities in public compounds, storage facilities in parks, and storage facilities in house lots. Infiltration facilities consisting of the infiltration trench and inlet are also applicable in this study.

As for the storage facilities in parks and the storage facilities in public facility compounds, their functions and structures are almost the same, so that they will be treated as storage facilities in public compounds hereinafter.

Storage facilities in house lots require the citizens' voluntary cooperation for their maintenance and operation. These facilities are, therefore, applicable when proper laws and regulations for the participation of citizens are enacted.

As for the detour of drainage pipes, this measure will not be applied in view of the topographic characteristics of the planning area. Permeable pavement is not considered in this study in view of maintenance and management.

4. Planning Criteria

4.1 Drainage System

4.1.1 River Channel

In general, planning of river improvement works involves alignment planning, longitudinal profile planning and cross sectional planning. The planning criteria are as follows:

River Section to be Improved

Improvement works are considered for river channels when the flow capacity of the existing channel is smaller than the design discharge of the river channel.

Alignment Planning

Alignment planning is executed in principle along the existing river course except in the following cases:

(1) When the river extremely meander, the alignment will be made milder.

(2) When it is considered economical to transfer a confluence to the upper stream, the confluence will be transfered.

Longitudinal Profile Planning

From the technical and economical viewpoints, the longitudinal profile of a proposed river channel is planned on the basis of the existing riverbed gradient which is adopted in most cases. Since the existing longitudinal profile of most rivers in the planning area have steep slopes and they cannot be maintained when the existing riverbed gradients are employed for the planned longitudinal profile because of scouring, the riverbed gradients are made gentle to keep the flow velocity within the allowable limits by providing groundsills in the river course to compensate for the difference in riverbed elevations between the existing and the planned profiles. However, the existing riverbed gradients will be applied to the longitudinal plans whenever the flow velocity under the existing gradient can be maintained within the specified limit.

Cross Sectional Planning

In general, the single cross section is adopted in planning the cross section of rivers with small design discharge, and the double cross section is adopted for rivers with large design discharge in view of the following reasons:

- At the time of flood, the main stream which has a higher velocity can be confined in the low water channel by means of adopting the double cross section, while streams having lower velocity can flow on the high water channel. Thus, revetments or banks are protected from erosion caused by high velocity streams.

- For rivers with a big difference in discharge between high and low water levels, it is necessary to maintain a certain velocity during low water level by means of low water channel to avoid sedimentation in the channel.

On the other hand, the reasons for adopting the single cross section to rivers with steep longitudinal gradients are as follows:

- Even if the double cross section is adopted to rivers with steep longitudinal gradient, main streams cannot be confined in the low water channel and the mainstream sometimes flow on the high water channel causing erosion on the banks or revetments. Accordingly, the adoption of double cross section is not effective for bank protection of rivers with steep gradient.

- The low water channels in steep gradient rivers are difficult to maintain because the staggering course of the main stream of floods causes deposit of eroded materials or scours the low water channel itself according to the staggering condition of the main stream.

To prevent erosion in the channel and at the bank, it is considered effective to distribute the energy of flood to the total cross sectional area by applying single cross sections with shallower depth but wider width, because the low water channel is not required to avoid sedimentation at the time of low water as the flow velocity is high even if the river flow is divided into streams.

In view of the foregoing reasons and since all the rivers in the planning area have steep gradients, the single cross section is applied.

Bank Protection

As for the study on the Basic and the Master plans, the principles mentioned below are applied to select the appropriate type of the bank protection work of the river channel.

The excavated river channels can be classified into channels with revetment and channels without revetment. The former is applied to the rivers in the urbanized area where land acquisition for the improvement works is difficult and the latter is applied to the rivers in areas that are not yet urbanized and land acquisition is considered not difficult.

If land acquisition is more difficult in an advanced urbanized area, river channel with revetment and invert will be applied to the rivers in such area because this can discharge more flow than the channels with revetment and without invert. Moreover, in case that the river channels are constructed under the roads or if the route of the river channels are expected to be used for roads in the future, box culvert will be employed on these closed conduit channels.

As to the First Stage Project, the appropriate type of the bank protection will be justified through the study on the economic advantage and less social problem which may take place during the project implementation.

Other Standards

For the formulation of river improvement, standards such as allowable maximum flow velocity, roughness coefficient for river channel and others are given in Table 5-4.

Maintenance Road

Maintenance roads along the rivers will be planned according to the conditions along the rivers and the type of the river channels. (Refer to Fig. 5-7.)

(1) Unurbanized Area

Within the basins where urbanization has not progressed, the arrangement of roads for public use are not well planned, so that two roads are planned at both sides of river channels for river maintenance purposes. One road has the width of 3.0 m to enable passage of light vehicles for maintenance and the other is 1.0 m wide for the passage of maintenance crew only.

(2) Urbanized Area

In the basins where urbanization has progressed, there are many public roads crossing river channels and they can be used by maintenance vehicles going to these channels. Therefore, roads on both banks of only 1.0 m in width are provided for the passage of maintenance crew.

(3) Channel along Public Road

When rivers flow along existing public roads, the public roads can be used by maintenance vehicles, so that the maintenance road of 1.0 m wide is provided on only the opposite side of public roads.

(4) Channel with Embankment

The crowns of embankments having the width of 3.0 m at either side of channels are used for the maintenance roads.

(5) Underground Conduit

Underground conduits will be located under areas planned or already procured for public roads and maintenance road is not required.

Formula for Flow Capacity

The flow capacity of the river channels will be calculated by the following Manning's Formula:

$$Q = A \times v$$

$$v = \frac{1}{n} \times I^{1/2} \times R^{2/3}$$

$$R = A/P$$

where,

Q : Flow quantity (m^3/s)
v : Flow velocity (m/s)
n : Roughness coefficient
I : Gradient
R : Hydraulic mean depth (m)
A : Cross sectional area (m^2)
P : Wetted perimeter (m)

4.1.2 Drainage Facilities

Planning of drainage facilities will be made in accordance with the conditions described hereinafter.

Runoff Coefficient and Area for Drainage Facilities

Runoff coefficients and catchment areas for the rivers are mentioned in the sector on Hydrology; while, the area for drainage facilities in this study is limited to the urbanized area. Farmlands and public lots such as large parks, airport and military facilities are excluded.

The drainage areas and runoff coefficients calculated for the newly planned drainage area are mentioned in Table 5-5. Values will be used only for the drainage planning. The same method of calculation for the runoff coefficient as in the sector on Hydrology is used for the newly planned drainage areas.

Runoff Discharge for Drainage Facilities

(1) Calculation Formula

The runoff discharge for the drainage facilities is calculated through the following rational formula:

$$Q = C \times I \times A / 360$$

where,

- Q : Peak discharge (m^3/s)
- C : Runoff coefficient
- I : Average rainfall intensity within concentration time (mm/hr)
- A : Drainage area (ha)

(2) Equation for Rainfall Intensity

The equation obtained under the sector on Hydrology is applied for the rainfall intensity.

(3) Concentration Time

Concentration time (T_c) consists of the initial concentration time (T_{ci}) which is the time required for the storm water to travel from the farthest portion of the drainage area to the drainage channel after falling from roofs and flowing on yards, roads, etc., and the running time (T_{cr}) which is the time necessary for the storm water to flow from the uppermost point of a drainage pipe to a designated point of the conduit.

$$T_c = T_{ci} + T_{cr}$$

where,

T_c : Concentration time
T_{ci}: Time of initial concentration
T_{cr}: Time of running

The time of initial concentration can be obtained by means of Kerby's Formula which is generally used for assuming time of initial concentration where data for its estimation is insufficient.

$$T_{ci} = \left(2.19 \times \frac{d \times n}{\sqrt{S}}\right)^{0.467}$$

where,

T_{ci}: Time of initial concentration (minutes).

d : Distance between the farthest point in drainage area and point of flowing into a terminal inlet of drainage pipe (m).

S : Average gradient for distance "d".

n : Retarding coefficient (n = 0.05 is applied in this Study).

The time of running is assumed by the following formula:

$$T_{cr} = \frac{D}{v \times 60}$$

where,

T_{cr}: Time of running (minute)

D : Distance of running (m)

v : Average velocity (m/sec)

Dimensional Calculation of Drainage Facilities

(1) Calculation Formula

The Manning's Formula is applied to the calculation of flow capacity of drainage facilities as well as the river. The roughness coefficient for the Manning's Formula of $n = 0.013$ is applied for proposed concrete pipes or concrete culverts and the roughness coefficient shown in Table 5-4 is applied for proposed open channel.

(2) Drainage Conduit

The minimum and maximum diameters of 500 mm and 2,500 mm, respectively, are applied for pipes based on past experiences. When drainage pipes bigger than 2,500 mm are required, box culverts are employed. Open channel is also employed where sufficient open space is available.

(3) Velocity

The faster is the flow velocity in pipe conduits, the smaller is the required diameter of pipe conduits to discharge the same quantity of flow and thus more economical. However, too fast flow accelerates wearing of pipes and manholes and often causes overflow from manholes at the downstream.

Accordingly, the minimum allowable velocity in pipe conduits is fixed in this study at 0.8 m/s and the maximum at 3.0 m/s and allowable maximum velocity shown in Table 5-4 is applied to box culvert and open channel.

(4) Manhole

Manholes are provided at junction points of drainage pipes and at every 100 m to 200 m of drainage pipes in straight lines for maintenance purposes.

Design Catchment Area

Drainage facilities are to be provided within the planning area lest flood damage will be inflicted on the transportation network and the assets therein. Based on the average gradient and width of roads, and in case of 3-year return probability for example, storm water in an area of 5.0 ha will be collected with a resultant runoff discharge of about 1.5 m^3/s which will inundate the streets to a depth of about 0.15 m and hamper economic activities by disrupting the smooth flow of traffic on the street.

In this connection, it is reasonable that the maximum design catchment area of drainage pipes is 5.0 ha, and correspondingly, drainage pipes are designed to cope with the storm water on an area of 5.0 ha at the maximum. This design catchment area will be applied to the planning of drainage facilities covering the entire drainage area.

4.2 Detention Facilities

Type of Detention Facilities

As described in the previous section, detention facilities such as storage in public compounds, infiltration trench (including infiltration inlet), and storage in house lots are considered in this study as applicable facilities.

The following combination of facilities are prepared in consideration of their operation and management.

- Combination of the storage in public compounds and the infiltration trench maintained by government authorities.

- Combination of the storage in public compounds and the storage in house lots maintained by government authorities in cooperation with the residents.

The share of the combination of facilities in the capacity of detention is studied based on the premise that rainfall on roofs of houses are controlled by the storage in house lots or the infiltration trenches, and the rainfall on other impermeable areas are controlled by the storage in public compounds. The shares of the above-said two combinations of facilities are set at 50% to 50% based on the fact that the ratio between the total rooftop and impermeable areas in the residential areas is 1:1 approximately. (Refer to Table 5-6)

Calculation of Detention Effect

The effect of detention is calculated by the following formula by using the runoff discharge estimated in the sector on Hydrology, for both cases of with and without detention facilities.

$$d = \frac{D}{(Q_o - Q_1)} = \frac{D}{q}$$

where,

d : Quantity of detention facilities required for detention of 1.0 m^3/s of runoff discharge.

For storage in public compounds ($ha/m^3/s$).
For infiltration trench ($m/m^3/s$)
For storage in house lots ($m^3/m^3/s$)

D : Quantity of detention facilities used for the said runoff calculation.

For storage in public compounds (ha)
For infiltration trench (m)
For storage in house lots (m^3)

Q_o: Runoff discharge when detention facilities are not provided (m^3/s)

Q_1: Runoff discharge when detention facilities are provided (m^3/s)

q : Effect of detention facilities (m^3/s)

The value of "d" depends on the conditions of the catchment area, the probable rainfall, the quantity of detention facilities, etc. The average of "d" is used in representing the value for each basin.

Table 5-7 shows the capacity of individual detention facilities of each basin for both cases of with and without drainage facilities.

5. Study on Basic Plan

5.1 Premises

The formulation of the Basic Plan is based on the following premises:

- The proposed storm water control system shall be worked out on a long-term point of view taking into account the importance of Asuncion City in Paraguay.

- The project scale is set on a 10-year probability in view of social, financial, economical and technical consideration.

- The planning area for Basic Plan is selected as shown in Table 5-8 and in Fig. 5-8 in considereation of the city development and expected flood damage.

- Storm water control facilities proposed in the Basic Plan shall be an appropriate combination of the storm water drainage system and the detention facilities.

- The coverage of the above-said facilities extends to all the urban areas in the planning area.

- Land use pattern on which the storm water drainage system will be framed shall correspond to that presumed in 2005, and runoff discharge in each basin shall be what has been estimated as arising from the land use practices in 2005.

5.2 Alternative Study

5.2.1 Study Cases

In case acquisition of right-of-way for the construction works is possible, storm water control works are generally performed through improvement by the combination of river channel and drainage facilities in view of lower costs and higher reliability.

It may be difficult in urbanized areas such as Asuncion City, Fernando de la Mora, etc., to acquire enough land for the drainage system improvement including river improvement works because a large number of houses has to be considered for evacuation. Therefore, detention facilities are proposed for storm water control.

Detention facilities may be divided in two groups from the viewpoint of maintenance and administration, i.e., one that is controlled by government authorities and one that is controlled by government authorities with the cooperation of citizens. Each group has its own advantages in matters of construction cost, etc., as well as management.

Taking the above viewpoints into consideration, three cases with two divisions in cases II and Case III are taken up for consideration as alternatives to obtain a suitable combination of river channel/drainage facilities and detention facilities, as given in the following table:

Study Case	Flood Control Facilities To Be Planned	Regulation Ratio of Detention Facilities	Operation and Management
Case I	River and Drainage Facilities	0%	Government Authorities
Case II-1	River, Drainage Facilities and Detention Facilities	About 5%	- do -
II-2	- do -	About 15%	- do -
Case III-1	- do -	About 5%	Government Authorities in Cooperation with citizens
III-2	- do -	About 15%	

5.2.2 Study Method

River Channel

In the study of the alternative plans, the plan which presents various advantageous factors such as economy, efficiency and social factors is selected as the optimum. An estimation of construction cost for evaluation of economic advantage, and number of houses under forced evacuation resulting from the proposed improvement works for evaluation of advantage in social problems are required to be carried out.

However, there are considerably large numbers of alternative cases in the Basic Plan and also in the Master Plan in the succeeding chapter, so that the estimation of the construction costs and of the number of houses to be evacuated by the respective cases reaches to an enormous work volume. To reduce the above-mentioned work volume, relations between the construction cost and discharge and between the number of houses to be evacuated and discharge were obtained on the respective river sections. This is because design discharge indicates the scale of the alternative cases.

From the two relations in the foregoing, the construction cost and number of houses to be evacuated to cope with the discharge shared by the rivers as elaborated in the respective alternative cases in 5.2.3, Distribution of Design Discharge, were obtained.

Drainage Facilities

The Basic Plan aims to make the restoration of the drainage function in the whole planning area in the year 2005. Drainage facilities planning for the Basic Plan is carried out through the study in model basins on the ground that there is no detailed map and data covering the entire planning area.

For the selection of the model basins, the following conditions were taken into account, and accordingly, Ferreira and Mburicao river basins were selected as model basins:

- The basins are covered with detailed maps.

- The basins have sufficient data required for the study.

- The basins have different features in aspects of catchment area, river condition, flood condition, etc. to represent all the basins.

- The basins are already highly urbanized and have little possibility of further urbanization, because drainage facilities planning is carried out in the model basins on the assumption that the basins at present have the road network as of 2005.

Alternatives are proposed on condition that about 5 and 15% of the design discharge are controlled by detention facilities. Therefore, the discharge differs in every basin in the planning area. It is required for comparative study of alternatives to estimate the construction cost of drainage facilities for each basin under various runoff coefficients proportional to the discharge.

The relationship between runoff coefficient and construction cost of drainage facilities are found through the study in model basins, and construction cost of drainage facilities for the Basic Plan was estimated through the procedure outlined hereunder:

- Planning of drainage facilities in the model basins for some different runoff coefficients.

- Cost estimation of drainage facilities for the above runoff coefficients in the model basins.

- Calculation of construction cost per 1.0 ha for the above cases in the model basins.

- Finding of relationship between runoff coefficient and construction cost per 1.0 ha.

- Estimation of runoff coefficient in each alternative on the assumption that ratio of variation between runoff coefficient and discharge is equal.

- Applying the said relationship to each basin in the planning area.

Detention Facilities

The subject sites of detention facilities is as extensive as 2,300 ha, and there is no detailed map covering the entire planning area. Therefore, the layout of detention facilities cannot be carried out in this study.

To make a comparison among the alternatives, it is required to estimate the construction cost of detention facilities just like in the case of river channel and drainage facilities. Hereinafter is the method of estimation of the required construction cost.

The quantity of detention facilities required to control 1.0 m^3/sec of discharge was estimated as mentioned in "Planning Criteria." On the other hand, the discharge to be controlled by detention facilities are given in the alternatives. The quantity of required detention facilities was determined by means of the said quantity multiplied by the discharge to be controlled. Construction cost of detention facilities was obtained based on the unit construction cost and the quantity of required detention facilities. By using the construction cost thus obtained, comparative study for alternatives was carried out.

5.2.3 Distribution of Design Discharge

Among the study cases tabulated in 5.2.1, design discharge is shared by the river channels together with drainage facilities and detention facilities in cases II and III. The distribution of the design discharges of Case II and Case III together with Case I are shown in Table 5-9.

5.2.4 System Planning and Construction Cost

River Channel

In accordance with the planning criteria as described in 4.1.1, the types and dimensions of the river channels of every basin against the arbitrarily selected four types of discharge were fixed. As the findings of the study above, dimensions of river channels are shown in Table 5-10, together with the corresponding arbitrarily selected discharges.

In accordance with the dimensions shown in Table 5-10, the work volume of items such as earthwork (excavation, backfill, spoil), revetments (masonry works), inverts, groundsills, bridge improvement, required area of land and number of houses to be evacuated were estimated. Based on the work quantity, the construction cost of the respective discharges established was calculated as prescribed in Sector 6, Implementation Schedule and Cost Estimate, and the cost-discharge curve was obtained. The results are shown in Fig. 6-8.

Drainage Facilities

Route planning of drainage facilities for the model basins was made, as shown in Fig. 5-9, based on the planning criteria mentioned in 4.1.2, and its dimensional design has been carried out under the following conditions:

- Runoff coefficients are 40%, 60% and 80%.

- The initial concentration time is 10 minutes which was calculated by applying the average distance and the average gradient of the design catchment area in the model basins to the Kerby's Formula.

In accordance with the above conditions, three (3) cases of runoff calculation based on different runoff coefficients were made for the model basins. Table 5-11 gives the quantity of drainage facilities in the model basins.

Construction cost of drainage facilities will be estimated for each case and the relationship between runoff coefficient and construction cost per 1.0 ha will be made in Sector 6, Implementation Schedule and Cost Estimate, as shown in Fig. 6-9. By using this figure, construction costs of drainage facilities for each basin were calculated according to the discharge distribution mentioned in 5.2.1, Study Cases.

Detention Facilites

Under the condition that about 5 and 15% of design discharge is controlled by detention facilities, the alternatives are proposed. The discharge to be controlled by detention facilities and the required quantity of detention facilities for each alternative are shown in Table 5-12. The construction cost of detention facilities was estimated in acordance with the procedures described in 5.2.2, Study Method.

As the results, the construction costs of river channel, drainage facilities and detention facilites for each alternative case are shown in Table 5-13.

5.2.5 Number of House Evacuation and Area of Land Acquisition

River Channel

By the same procedures used in the estimation of the construction costs, the relation curve between number of houses to be evacuated and discharge was formulated, especially on the nine basins where a large number of evacuation of houses is expected in places such as Jaen, Zanja Moroti, Ferreira, Las Mercedes, Mburicao, Ycua Carrillo, Santa Rosa, Itay and Lambare Rivers. The results are shown in Fig. 5-10, and the area of land to be acquired for the alternative cases are tabulated in Table 5-14.

Drainage Facilities

Since drainage conduits are proposed to be embedded below public roads in the Basic Plan, no house evacuation and land acquisition are required in planning the drainage facilities.

Detention Facilities

Detention facilities are planned to fulfill the function of detention of storm water without damaging the proper functions of the existing public facilities or private house lots. Therefore, house evacuation is not required, but it will be necessary to get permission to use the public facilities or private house lots from agencies concerned or houseowners.

5.2.6 Countermeasure for Area below Aviadores del Chaco Avenue

In the area below Aviadores del Chaco Avenue in Itay river basin (Subbasin No.6 and 7), flood discharge increment by improvement of drainage system in the upper reaches will take place. Accordingly, increment of flood discharge in this area has to be controlled by improvement of the river in the lower reaches (Subbasin No.8 and 10) or by construction of a retarding basin in this area.

The economical advantage of the two measures mentioned above was studied and the results are shown in the table shown hereinafter. As a result, it becomes clear that the construction of retarding basin has much advantage in construction cost.

On the other hand, the flood water level rise in the river channels in Subbasins No. 8 and 10 by the increment of the discharge caused by the river improvement in Subbasin No. 7 is negligible and since Subbasins No. 8 and 10 are almost covered with unutilized land, flood damage will not take place in these subbasins.

The concept of providing the retarding basin is based on the assumption of regulating the incremental discharge from the upper reaches of Aviadores del Chaco Avenue under the urbanized state of the basin in 2005, so that the discharge in Subbasins No. 8 and

No. 10 may be nearly equal to the discharge under the existing condition, as far as the retarding basin is able to compete in terms of cost with the river channel improvement works that are provided in Subbasin No. 8 and No. 10 to drain the discharge at the year 2005.

The conditions for the comparative study of both cases mentioned above are tabulated in the following table. In this table, the design volume of retarding basin is estimated as the volume to regulate the incremental discharge from the existing condition up to the year 2005, and the design discharges from Subbasins No. 8 and No. 10 are estimated by the hydrological study.

Particulars	Retarding Basin in Subbasin No.6	River Channel Improvement in Subbasin No.8 and No. 10
Project Scale	10-Year Return Period	10-Year Return Period
Study Case	Case I	Case I
Design Volume	550,000 m^3	-
Design Discharge	-	Subbasin No. 8: 900 m^3/s Subbasin No. 10 1,260 m^3/s

The construction costs of the retarding basin in Subbasin No. 6 and the river improvement in Subbasin No. 8 and No. 10 are as follows:

Particulars	Retarding Basin in Subbasin No.6	River Channel Improvement in Subbasin No.8 and No. 10
Construction Cost	¢1,700 Million	¢5,200 Million

From the above table, it becomes clear that the application of the retarding basin is more economical than the river channel improvement.

5.3 Optimum Plan

5.3.1 Selection of Optimum Plan

The optimum combination of storm water control facilities varies from basin to basin. From the viewpoint of construction cost, storm water control by means of river channel and drainage facilities (Case I) is superior to other cases in every basin. However, house evacuation in nine (9) basins such as Ferreira, Mburicao, Itay and Lambare, as shown in Fig. 5-10, will come up to a considerable extent and may bring about social problems. Thus, it becomes necessary to apply the combination of river channel/ drainage improvement works and detention facilities (Case II and Case III) to these basins, but Case III costs less than Case II in all the basins concerned. In conclusion, storm water should be controlled by river channel and drainage facilities in some basins and in combination with detention facilities in others, as follows:

Optimum Combination	River Basins	Design Discharge (m3/s)		
River Channel and Drainage Facilities (Case I)	Jardin	20		
	Salamanca	35		
	Bella Vista	25		
	Tres Puentes Cue	105		
	Villa Elisa	220		
	Nemby	90		
	San Lorenzo	410		
	Tayazuape	300		
	Zeballos Cue	17		
	Paso Cai	115		
	Varadero	Only drainage facilitiles are provided because of no river channel		
	Centro			
	Tacumbu			
	Villa-Universitaria			
	Mariscal Lopez			
	Tablada			
	Valle Apua			
		Entire Basin	Drainage System	Detention Facilities
River Channel and Drainage Facilities in combination with Detention Facilities (Case III)	Jaen	70	62(89)/1	8(11)/1
	Zanja Moroti	36	30(83)	6(17)
	Ferreira	115	100(87)	15(13)
	Las Mercedes	56	48(86)	8(14)
	Mburicao	320	270(84)	50(16)
	Ycua Carrillo	110	85(77)	25(23)
	Santa Rosa	75	64(85)	11(15)
	Itay	770	650(84)	120(16)
	Lambare	590	470(80)	120(20)

/1 Figures in parentheses show percentage of sharing ratio between drainage system and detention facilities.

The design discharge for the Basic Plan is presented in Table 5-15.

5.3.2 Features of the Optimum Plan

River

(1) River Channel

Regarding the respective rivers, river channel improvement plan is worked out in accordance with the requirements of design discharge and 4.1.1, Planning Criteria. Features of the respective rivers are shown in Table 5-16.

In the Basic Plan, the river width required for the river improvement was fixed depending on the conclusion of the proposed river improvement plan, and the result is as shown in Fig. 5-11 and Table 5-17. The structural types of river channel for each river basin are tabulated in Table 5-18, and land acquisition and house evacuation are presented in Table 5-19.

The longitudinal profile of Mburicao, Itay, Madame Lynch and Lambare Rivers are shown in Figs. 5-12 to 5-15 and the cross sections of these rivers are shown in Figs. 5-16 to 5-18. The location of the cross sections is presented in Fig. 5-19.

(2) Retarding Basin

The appropriate area for the retarding basin in Itay river basin is found at the area in Subbasin No. 6 where is developping as a national park. The location of the retarding basin is also shown in Fig. 5-11. The required volume for the proposed retarding basin is 550,000 m^3.

(3) Related Structures

The facilities mentioned hereunder are also planned together with the planning of river channel improvement.

- Revetment

Revetments to protect river banks from scouring are planned by wet masonry with rubble which is locally available as generally practiced in Paraguay. The standard structure of revetment is shown in Fig. 5-20.

- Embankment

The embankment consists of well compacted soil and revetment which covers all of the embankment surface to protect it from erosion considered to be caused by flow of both Paraguay River and the proposed river channel. (Refer to Fig. 5-7)

- Box Culvert

The box culvert is made of reinforced concrete and have a freeboard of 0.6 m at the top of the inside. The standard cross section is shown in Fig. 5-7.

- Groundsill with Head

The groundsills with head are made of wet masoury placed crosswise in riverbeds with both ends well embedded in the river banks to avoid damage by scouring. Aprons are provided to secure the stability of the groundsills against damage caused by seapage or scouring (refer to Fig. 5-20).

- Bridge

All bridges in the portion of river improvement will be rebuilt in accordance with the widening of river channels by the river improvement plan, and reinforced concrete simple beam bridge type will be employed to the plan from the viewpoint of easier construction and lower cost.

The bridge girders will be constructed above high water level with a clearance of 0.6 m or 0.3 m depending on the design discharge. The width of the proposed bridges will follow the widths of the existing bridges. (Refer to Fig. 5-20)

Drainage Facilities

(1) Drainage Conduit

Drainage conduits consist of drain pipes and box culverts. These are proposed to be installed on the urbanized area of 17,200 ha in the planning area. Features of drainage facilities by respective basins are shown in Table 5-16.

(2) Related Structures

Storm water running on roads is collected by inlets with gutters, and flows into Paraguay River or its tributaries through pipes or box culverts.

Gutters are made of reinforced concrete and inlets are made of concrete and brick. Manholes that are classified into several types according to the pipe diameter or the dimensions of box culverts connected to them are made of reinforced concrete and brick provided at intervals for the inspection of underground conduits. Reinforced concrete box culverts are used for underground conduits where flow quantities require more than 2,500 mm diameter reinforced concrete pipes.

Detention Facilities

(1) Storage in Public Compounds

The storage facilities of 394 ha in public compound for storm water regulation is proposed as an optimum plan. The features of the facilities for the respective basins are shown in Table 5-16.

The facilities for storage in public compounds is constructed by excavating the existing ground surface. The auxiliary devices to the storage facilities are drain pipes, gutters and catchbasins to drain ordinary rainwater.

(2) Storage in House Lots

Storage of 172,000 m^3 of storm water in house lots through the participation and cooperation of citizens is proposed as an optimum plan. Features of storage in house lots by respective basins are shown in Table 5-16.

The storage in house lots is set under the roof edge to catch storm water from the roof. It consists of concrete storage tanks and drain pipes.

5.3.3 Standard Drawing of Typical Structures

The standard drawings of the facilities under the Plan are as below:

(1) River Structures

Standard drawings of the revetment, groundsill and the bridge are shown in Fig. 5-20.

(2) Drainage Facilities

Drainage facilities consist of gutters, inlets, manholes, and drain pipes or box culverts, and their standard structural drawings are shown in Fig. 5-21.

(3) Detention Facilities

Detention facilities under the optimum plan consist of storage in public compounds and storage in house lots. Their standard structural drawings are shown in Fig. 5-22.

6. Study on Master Plan

6.1 Premises

The concepts and premises for the formulation of the Master Plan are presented as follows:

(1) The target year of the Master Plan for storm water control system shall be the year 2005. The Plan will be, therefore, formulated on the basis of the urbanized conditions which are presumably existing in 2005.

- Land use pattern on which the storm water drainage system will be framed shall correspond to that presumed in 2005.

- Runoff discharge in each basin shall be what has been estimated as arising from the land use practices in 2005.

(2) The scale of the entire project is set on a 3-year probability taking technical, social and financial aspects in consideration to enable its implementation within the given period of time until the year 2005.

(3) The planning area for the Master Plan covers the same area as the Basic Plan.

(4) Storm water control facilities to be proposed in the Plan shall be an appropriate combination of the storm water drainage system and the detention facilities, in the same manner as of the Basic Plan.

6.2 Alternative Study

6.2.1 Study Cases

To ensure the implementation of the project by the year 2005, the plan will have to be properly adjusted to meet the prevailing financial situations. In this connection, three (3) cases are taken up as alternatives in view of the improvement objectives; i.e., (1) overall restoration of drainage system, (2) improvement of the trouble spots, and (3) improvement of drainage system along the trunk roads. The three cases are further divided into three divisions each according to the facilities to be applied, as shown in the following table.

The scale of the Master Plan is defined as a 3-year probability, however, the studies on the scale of 2 and 5-year probability are also carried out for reference.

Study Case	Improvement Objectives	Facilities To Be Applied	Administration Method	Remarks
Case I-1	Overall Restoration	A	Government Authorities	Complete provision of facilities along river channels and drainage ditches, including detention facilities. (Ref. to Fig. 5-23)
Case I-2	-ditto-	B	-ditto-	
Case I-3	-ditto-	C	Government Authorities in cooperation with citizens.	
Case II-1	Trouble Spots Improvement	A	Government Authorities	Improvement works at trouble spots habitually affected by flood damage and/or places presumed to suffer from flood damage through future urbanization. (Ref. Fig. 5-24)
Case II-2	-ditto-	B	-ditto-	
Case II-3	-ditto-	C	Government Authorities in cooperation with citizens.	
Case III-1	Improvement Along Trunk Roads	A	Government Authorities	Improvement works at damaged spots on the trunk roads such as Artigas, Espana, M.A.C. Lopez, Ayala, Fernando de la Mora and General Maximo Santos, and Madame Lynch. River improvement works may be provided as the case demands. (Ref. Fig. 5-24)
Case III-2	-ditto-	B	-ditto-	
Case III-3	-ditto-	C	Government Authorities in cooperation with citizens.	

Note:

1. In facilities to be planned, "A" is a combination of river channel and drainage facilities, "B" is a combination of river channel and drainage facilities plus detention facilities (including infiltration trench), and "C" is a combination of river and drainage facilities plus detention facilities (including storage in house lots).

2. Cooperation of residents in controlling storm water will be necessary only in the case of installation of storage facilities in house lots.

3. As to Case III with detention facilities, the detention facilities are not effective for mitigation of flood damage on only the trunk roads because of their functions. Case III-2 and Case III-3 are studied only for reference.

4. In each study case to be provided with detention facilities, the storm water discharge in the land use condition as of 1984 will be confined in the drainage system, and incremental runoff discharge due to further urbanization up to 2005 will be controlled through the provision of detention facilites.

5. In study case II-2 (3-year probability), 5 cases of different share ratio of design discharge between river channel/drainage facilities and detention facilities will be studied to find out the most economical combination.

6.2.2 Study Method

River Channel

Alternative study in Master Plan is executed in the same manner as in the Basic Plan.

Drainage Facilities

In Case I where drainage facilities are provided for the whole planning area, the results of the study in the model basins of Ferreira and Mburicao will be applied to the whole planning area in the same manner as described in the Basic Plan.

In Case II and Case III, drainage facilities are provided for only trouble spots that are habitually suffering from flood damage at present and/or presumed to suffer from flood damage in the future. Construction cost of drainage facilites is estimated based on the above conditions.

Detention Facilities

Alternative study in the Master Plan is executed in the same manner as in the Basic Plan.

6.2.3 Design Discharge

The design discharge for the Master Plan is presented in Table 5-20.

6.2.4 System Planning and Construction Cost

River Channel

- Planning of River Channel

The alignment planning, longitudinal planning and cross sectional planning were executed in the same manner as those of the Basic Plan for Case I, II and III.

- Countermeasure for Area below Aviadores del Chaco Avenue

In accordance with the study results in the Basic Plan, a retarding basin with a regulation capacity of 350,000 m^3 as estimated by hydrological study will be provided at Subbasin No. 6 of Itay river basin to regulate the increase in flow discharge from the upper reaches after completion of improvement works. The river channel will not be improved below Subbasin No. 8 of the same basin.

- Planning of Other Riparian Structures

The type, scale and dimension of the structures will be planned in the same manner as the Basic Plan.

Construction cost of the river channels was estimated in the same manner as in the Basic Plan.

Drainage Facilities

(1) Case I

Study of drainage facilities for Case I is executed for three probabilities, 2-year, 3-year and 5-year return period, in the same manner as in the Basic Plan. Table 5-11 gives the quantity of drainage facilities for each probability in model basins. By using the relationship between runoff coefficient and construction cost per 1.0 ha shown in Fig. 6-9, construction costs of drainage facilities for each basin were calculated according to the discharge distribution mentioned in 6.2.1, Study Cases.

As for Centro basin, the drainage system under the IDB loan has been partly installed in Centro basin. Since it is considered that the drainage system covers about 70% of the entire basin, the drainage facilities in this study is planned for the remaining 30%.

(2) Case II

Trouble spots to be improved are selected in consideration of the field survey results mentioned in the sector on Inundation and Flood Damage, topographic conditions and the progress of urban development in the planning area. Selected trouble spots are distributed in 18 basins and drainage conduits of 60 routes, about 35 km in total, are proposed to solve the inundation damage in these spots. (Refer to Fig. 5-24.)

In this case, catchment area and initial concentration time were estimated and calculations of runoff discharge for drainage facilities were carried out for individual trouble spots based on the planning criteria mentioned in 4.1.2.

Table 5-21 shows the structural dimensions of drainage conduits designed for each study case. Construction cost of drainage facilities for each trouble spot has been estimated in this case.

(3) Case III

In this case, drainage improvement works are proposed only for trouble spots on the trunk roads such as Artigas, España, M.A.C. Lopez, Ayala, Fernando de la Mora, General Maximo Santos and Madame Lynch. Drainage conduits for 19 routes in a total length of about 14 km were selected out of the abovementioned 60 conduit routes, and they are distributed in only the five basins of Las Mercedes, Mburicao, Santa Rosa, Itay and Lambare.

Table 5-21 shows the structural dimensions of drainage conduits designed for each study case. In this case, construction cost of drainage facilities has been estimated for each trouble spots on trunk roads.

Detention Facilities

The quantity and the construction cost of detention facilities required for each study case will be determined in the same method mentioned in the Basic Plan study. Runoff discharge to be controlled by detention facilities, i.e., incremental runoff discharge from 1984 to 2005 due to further urbanization in the basin, are shown for each study case in Table 5-22.

The construction costs of alternatives for the Master Plan are in Tables 5-23 and 5-24.

6.2.5 Findings of Alternative Study

Construction costs of each study case are summarized as follows:

(Unit: ¢ Million)

Study Case	Return Period		
	2-year	3-year	5 year
Case I-1	140,430	166,720	188,000
I-2	173,320	204,740	238,190
I-3	161,320	190,140	220,790
Case II-1	46,070	55,090	64,980
II-2	70,020	84,160	101,300
II-3	63,850	76,740	92,260
Case III-1	18,410	22,260	26,950
III-2	32,090	38,810	47,460
III-3	28,760	34,820	42,520

The study results show that the cases without detention facilities are most economical in all river basins. Area of land to be acquired and number of houses to be evacuated were roughly estimated and are tabulated in Table 5-25.

6.3 Optimum Plan

6.3.1 Selection of Optimum Plan

Improvement Objectives

In selecting the Optimum Plan, financial constraints may first have to be taken into account. Further investigation is also necessary for its social, technical and economical aspects. In view of the following considerations, it is concluded that Case II is the optimum one for the improvement objectives.

- Financial Consideration

The financial considerations for project implementation are quite strict. The maximum realizable financial allocation for this purpose, even upon the assumption of the assistance from other government authorities concerned, including increased taxation for purposes of storm water control, will not go beyond the amount between 5,000 million Guaranies and 6,000 million Guaranies a year.

On the other hand, the required construction costs per annum for the execution of this project ranges from approximately 2,000 million Guaranies to 20,000 million Guaranies. Assuming that all the project cost is assured by a loan at an interest rate of 4% per annum and repayment period of 30 years including 10-year grace period, the total expenditure will still reach a considerable amount depending on the study case ranging from 1,500 million Guaranies to 14,000 million Guaranies.

In this context, Case I may present some problems in project execution.

- Social Consideration

It is desirable that infrastructure projects such as improvement works of storm water control facilities are executed over areas as wide as practically possible. Therefore, Case I or Case II are deemed practical to meet the above condition.

- Technical Consideration

In Case I and Case II, there is no problem as far as technical aspects are concerned. With regard to Case III, improvement works is locally executed and there is a strong possibility that an adverse influence will appear in the downstream basin. In this context, Case III, though advantageous in terms of cost, should be proposed as the second alternative.

- Economic Consideration

The present study includes 26 basins for which the reliability of available data is not quite even; thus, precluding the possibility of economic evaluation of the effect of project implementation at an even pace.

The evaluation of the project from the economic point of view is, therefore, conducted on two selected basins having sufficient data but with contrasting features, i.e., Mburicao and Ferreira river basins. Internal rates of return (IRRs) of the combination of storm water control facilities in both basins, which can be representative for the purpose of merely comparing the combinations, are summarized hereunder:

Study Case	Internal Rate of Return (%)	
	Mburicao	Ferreira
Case I	1.2	3.7
Case II	9.1	11.4
Case III	11.0	-

Note: Since no important trunk road exists in Ferreira River Basin, IRR of Case III was not calculated.

Case III has the highest internal rate of return (IRR), followed by Case II. There is not much difference in the IRRs of Case III and Case II, and they are both viable from the viewpoint of economics. In the case of Case I, IRR is very low because of the substantially high construction cost; hence, uneconomical.

Optimum Combination of Proposed Facilities

All sub-projects in each basin cannot be implemented at the same time, but it is difficult to decide at this moment the detailed timing of project implementation in each basin. Therefore, it may be reasonable to divide the whole scheme into two groups, and priorities are placed on some of the basins suffering from serious flood damage, as described below.

- River Basins with High Priority

  In the river basins on which priorities of implementation are placed, projects are supposed to be put into implementation in the early stage. These are the three (3) basins of Itay (upper stream area of Aviadores del Chaco Avenue), Mburicao and Lambare.

- Remaining River Basins

  There are twenty-three (23) basins, except the above three, and the projects will be implemented in the second half.

With regard to the optimum combination for Itay, Mburicao and Lambare which are given high priority considerations, the storm discharge of the basin condition in the early stage will be confined in the river channels to be improved, and incremental runoff discharge due to further urbanization in the second half will be dealt with through the provision of detention facilities in view of completing the work urgently within a reasonable range of investment.

As to execution and administration aspects for the detention facilities, no statutory measure to encourage residents' participation in the project has been worked out. Therefore, it is not preferable to expect participation of the residents in the storm water control operation and maintenance for the time being (Case II-2).

In connection with the remaining river basins, the projects will be formulated by means of least cost method, based on the proper combination of river channel improvement works, drainage facilities and detention facilities, as a result of which, the combination of river channel improvement works and drainage facilities (Case II-1) is justified as the optimum one. (Even if the design discharge is controlled by only river channel and drainage improvement works, no large number of forced house evacuation and no extensive land acquisition may be required, as shown in Table 5-25; hence, there will be no social problem to be solved.)

6.3.2 Features of the Optimum Plan

The features of the drainage system and the detention facilities are shown in Table 5-26.

River Channel

The outline of the improvement works of the river channels proposed as the Optimum Plan is presented in Fig. 5-25 and Table 5-27. The longitudinal profiles and cross sections planned as the optimum plan for the rivers of Mburicao, Itay and Lambare are presented in Figs. 5-26 to 5-32, respectively.

The optimum plan is to improve the drainage system in the basins where flood damage is at present very big and where damage is anticipated in the future by the progress of urbanization. The three river channels of Mburicao, Itay and Lambare will be improved to cope with the floods at the year 1995, while the increase in runoff up to 2005 owing to urbanization will be controlled by detention facilities.

The required land acquisition and number of house evacuation for the Optimum Plan are shown in Table 5-28.

Drainage Facilities

Optimum drainage facilites for Master Plan are summarized as follows:

Pipe	18.7 km long and 1.0 m to 2.5 m in diameter

Box Culvert	10.6 km long and 2.0 m wide x 2.0 m high to 3.5 m wide x 2.0 m high
Open Channel	5.3 km long and 3.0 m wide x 2.0 high to 3.5 m wide x 2.0 m high

Dimensional data of drainage conduits are shown in Table 5-29, and their layout are given as Case II in Fig. 5-24.

Detention Facilities

Detention facilities under the Optimum Plan consist of storage in public compounds of 148 ha and infiltration trench of 561 km for the storm water regulation in the three river basins mentioned above.

6.4 Standard Drawing of Typical Structures

The standard drawings of the facilities for the river structures, drainage facilities and detention facilities are same as those facilities of the Basic Plan, except the infiltration trench of the detention facilities. The standard drawing of the infiltration trench is shown in Fig. 5-33.

7. Study on First Stage Project

7.1 Premises

The First Stage Project which is extracted from the Master Plan is formulated based on the following premises:

- A 3-year return period flood, which was estimated by the runoff analysis under the land use patterns in 1995, is adopted as the planning scale.

- Mburicao and Itay river basins were selected as target areas for the First Stage Project in view of the seriousness of flood damage (refer to Fig. 5-34).

- Storm drainage system improvement works will be proposed for the trouble spots that suffer from frequent flooding at present and in the future.

- The drainage system proposed in this study consists of river channels and drainage facilities.

7.2 Flow Capacity of Existing Drainage System

7.2.1 River channels

The existing flow capacities of Mburicao and Itay rivers were calculated at the interval of 100 m along the river course by means of the Manning's Formula on the basis of the cross sectional and longitudinal survey results which have been conducted in this study. The calculation results on the flow capacity of the existing river channels are shown in Figs. 5-35 and 5-36 and in Table 5-30.

In Mburicao River, the portions downstream of Artigas Avenue (1.5 km from the river mouth) and at the upstream point 2.9 km from the river mouth have flow capacities of from 100 m3/s to 250 m3/s, except in some portions, which are sufficient to confine the design discharge. The flow capacities of the other portions are less than the design discharge. As to the rivers in Itay river basin, river channels have no sufficient flow capacities in all sections for the design discharge.

7.2.2 Drainage Facilities

There exists only a few major drainage facilities in Mburicao river basin. Drainage pipes installed under the IDB loan are located in the upper reaches of Mburical River and its tributary, San Martin River, and their flow capacity is relatively large. Besides the above mentioned drainage pipes, some drainage facilities are provided to drain the storm water in limited places which have difficulties in draining because of flatness or depression of the ground, and their flow capacities are small.

As for Itay river basin, there are four (4) drainage channels in the basin. These channels are relatively long and reach the rivers. The cross sectional areas of these drainage channels seem to be very small for their catchment areas, and some portions of the channels do not fulfill their function due to the deposition of debris and trash damped into them.

The flow capacity of the existing drainage facilities are calculated by means of the Manning's Formula. The results are shown in Fig. 5-37 with the location of the drainage facilities.

7.3 River Section and Drainage Area to be Improved

The river sections that do not have enough flow capacity compared with the design discharge and the trouble spots that are habitually inundated shall be improved. In this context, the sections to be improved in Mburicao and Itay river basins are 5.6 km and 15.6 km in total lengths, respectively, and the trouble spots where drainage facilities shall be newly installed are 14 areas with 910 ha in Mbricao river basin and 10 areas with 1,570 ha in Itay river basin. Fig 5-38 shows the river sections to be improved and trouble spots in both river basins.

7.4 Reference Points

To identify the design discharge which varies section by section, reference points and sub-reference points were set up, as shown in Fig. 5-39. Reference points were set up at the lowest elevation of every sub-basin; namely, at the immediate upstream of the confluence points in case of the main river channels, and at the confluence points in case of the tributaries. Sub-reference points were set up at the points where the design discharge needs to be calculated for the alternative study, and at the middle point of two reference points adjacent to each other which have a considerable difference in design discharge.

7.5 Alternative Study

7.5.1 Condition for Selection of Study Case

In the selection of cases for the alternative study, the following points were considered:

(1) River Facilities

River channel improvement works are in general advantageous in terms of cost to drain safely the storm water. However, as many alternative plans as possible should be considered at river stretches where it is possible to replace river channel improvement works by other methods such as short-cut, retarding basins, etc., from the viewpoints of existing conditions of the river channel, topography and conditions of land utilization along the subject rivers as described below.

- The flow capacity of the river section to be improved is extremely smaller than the design discharge;
- River channel improvement works involve difficulties in evacuating houses and acquiring site to widen a river channel;
- The topographic conditions allow the drainage channel or conduit to join the river channel in the downstream of the improvement section; and
- It is possible from the topographic viewpoint to provide retarding basins and short-cut channels which may be less costly than the river improvement works.

(2) Drainage Facilities

The best route for drainage facilities can be determined by the topographic features in consideration of public utilities installed underground. There is thus no alternative plan for the drainage facilities except the case where their outlets are installed at the position lower than the existing one to decrease the design discharge in the river section where flow capacity is far from sufficient.

7.5.2 Study Cases

As given in the following table, alternative study cases are proposed for four (4) river sections of Mburicao River and two (2) of Itay River in due consideration of the aforementioned conditions (refer to Figs. 5-39 and 5-40). Alternative methods include river channel improvement works, short-cut or diversion channel, retarding basin, and detouring of drainage route to decrease the design discharge for the river channel.

The optimum plan may be determined in a form of combination of these alternative cases, i.e., by sharing the design discharge between the river channel and other works. As for the other river sections, the design discharge will be controlled by only river channel improvement works.

River Basin	Section	Study Case	Applicable Method
Mburicao	Mburicao 7.78K to 8.07K	Case A-1	River improvement works.
		Case A-2	Detouring of drainage route 1.
	Mburicao 5.18K to 7.24K	Case B-1	River improvement works.
		Case B-2	Detouring of drainage route 1.
		Case B-3	Detouring of drainage route 2.
		Case B-4	Detouring of drainage route 3.
	San Martin 0.83K to 1.61K	Case C-1	River improvement works.
		Case C-2	Detouring of drainage route.
	Mburicao 1.96K to 2.53K	Case D-1	River improvement works.
		Case D-2	Short-cut channel.
Itay	Madame Lynch 0.00K to 2.61K	Case E-1	River improvement works.
		Case E-2	Diversion channel to San Pablo River
		Case E-3	Diversion channel to Santa Teresa River.
	Itay 0.00K to 3.23K	Case F-1	River improvement works.
		Case F-2	Retarding basin 1.
	Itay 0.00K to Santa Teresa 1.34K	Case F-3	Retarding basin 2.

Note: San Martin River is a tributary of Mburicao River; Madame Lynch and Santa Teresa are of Itay River.

The explanations of each alternative case are as follows:

Mburicao River Basin

(a) Section 7.78 Km to 8.07 Km (Zone A)

This section has a trouble spot in the vicinity of the uppermost end of Mburicao River. The minimum flow capacity of this section is 6 m^3/s at 7.97 Km, which is smaller than the design discharge of 15 m^3/s.

Two (2) alternatives, A-1 and A-2, are proposed in this section, as follows:

A-1 : River improvement works from 7.78 Km to 8.07 Km.

A-2 : Detouring of drainage route to drain the storm water not only from the trouble spot but also from the right side of the route into the river channel at 7.78 Km.

(b) Section 5.18 Km to 7.24 Km (Zone B)

Trouble spots are located on both sides of the river in this section. The flow capacity of the existing river channel is estimated at 38 m^3/s and 30 m^3/s at 6.42 Km and 5.64 Km, both of which are smaller than the design discharge of 75 m^3/s to 80 m^3/s, respectively. River improvement works (B-1) and three (3) route alternatives (B-2, B-3 and B-4) will be studied in combination with each other.

The features of these alternatives are summarized as follows:

B-1 : River improvement works from 5.18 Km to 7.24 Km.

B-2 : Detouring of drainage route to drain the storm water from the right side of the river course into San Martin River at 0.09 Km.

B-3 : Detouring of drainage route to drain the storm water from the left side of the river course (above Mariscal Lopez Avenue) into Mburicao River main channel at 5.18 Km.

B-4 : Detouring of drainage route with a drainage area above Espana Avenue on the same side as B-3, which is connected to Mburicao River at 5.18 Km.

(c) Section 0.83 Km to 1.61 Km of San Martin River (Zone C)

There exists a trouble spot in the upper reaches of San Martin River. The river channel in this section has a flow capacity of 14 m^3/s, while the design discharge is estimated at 35 m^3/s.

In addition to river improvement works (C-1), one route alternative of drainage (C-2) is proposed, as described below:

C-1 : River improvement works from 0.83 Km to 1.61 Km.

C-2 : Detouring of drainage route to drain the storm water from the trouble spot and from the area to the left of Mariscal Lopez Avenue into San Martin River at 0.83 Km.

(d) Section 1.96 Km to 2.53 Km (Zone D)

In this section, inundation takes place only due to the lack of flow capacity of 56 m^3/s of the existing river channel portion which heavily meanders. As an alternative to the river improvement plan (D-1), a short-cut river channel (D-2) with a design discharge of 155 m^3/s which is the same as that of the existing channel improvement is proposed.

The features of the alternatives are summarized below.

D-1 : River improvement works from 1.96 km to 2.53 Km.

D-2 : Short-cut channel with a length of 180 m.

Itay River Basin

(a) Section 0.0 Km to 2.61 Km of Madame Lynch River (Zone E)

Two (2) diversion channels (E-2 and E-3) to divert the discharge from the middle stream of Madame Lynch River to Santa Teresa River and San Pablo River are proposed in addition to the river improvement works (E-1) from the viewpoints of topographic conditions and land use patterns thereat. These alternatives are summarized as follows:

E-1 : River improvement works from 0.0 Km to 2.61 Km.

E-2 : Diversion channel from 2.61 Km of Madame Lynch River to 0.67 Km (B.P.) of San Pablo River.

E-3 : Diversion channel from 1.67 Km of Madame Lynch River to 0.77 Km of Santa Teresa River.

(b) Section 0.0 Km to 3.23 Km of Itay River and to 1.34 Km of Santa Teresa River (Zone F)

In this section, two (2) retarding basins (F-2 and F-3) are proposed as alternatives in addition to river improvement works (F-1), as briefly described hereunder:

F-1 : River improvement works from 0.0 Km to 3.23 Km of Itay River and from 0.0 Km to 1.34 Km of Santa Teresa River.

F-2 : Retarding basin at the left side of the confluence of Santa Teresa and San Pablo Rivers.

F-3 : Retarding basin at the left side of the confluence of Itay and Orilla Rivers.

The study cases and the features of the alternative plans are shown in Table 5-31.

7.5.3 Distribution of Design Discharge

The design discharge is shared by the control of the river channel and drainage facilities in the section in which the alternative case was set up.

The design discharge of each river section (between reference points) are summarized in Table 5-32 and shown in Fig. 5-41, together with the discharge shared by the drainage facilities.

7.5.4 Study on the System of Alternatives and Optimum Structural Type

River Channel

For the entire river course including the sections which are studied by the alternative cases, the planning of the river channel is executed in accordance with the river channel planning criteria described in Section 4.1.1. In the determination of the river channel cross-sections, it is required to simultaneously examine the structural type of the river channel, since it has close relation to the river channel cross-section.

In river channel planning, maps with the scale of 1:1,000 blown up from the existing maps with the scale of 1:5,000 were used for alignment planning. The results of the topographic survey executed for the First Stage Project were used for the longitudinal and cross sectional planning.

The structural type differences exert an influence on important factors in making selections of the Optimum Plan such as construction costs and number of houses to be evacuated. Therefore, it was necessary to carry out a study for the selection of optimum structural type of river channel for all study cases mentioned in 7.5.2 by river sections.

The river channel planning was carried out in accordance with the foregoing planning criteria and premises. Regarding the structural type of the river channel, the 3 types mentioned below were considered.

- Without any protection works
- With revetments on both sides
- With revetments on both sides and invert on the riverbed

Based on the results of the river improvement plan, estimation of the construction cost, the land acquisition area, and the number of houses to be evacuated were carried out for the respective types by river sections. The study results for the alternative cases and for the entire river section are shown in Tables 5-33 and 5-34, respectively.

The optimum structural types for the alternative cases and for the entire river section were selected by the least cost and the selected types are tabulated in Table 5-35 and 5-36, respectively, together with area of land acquisition and number of house evacuation.

There are several sections in which the number of house evacuation is smaller than the case of the least cost type, but there is not much difference in number of house evacuation when compared with the case of the least cost type. As an example, the biggest difference in the number of house evacuation can be noticed in Section 5 to 2-2 where the difference in number of houses is only 4.

In compliance with the above consideration, the least cost structural type is selected as the optimum type.

<u>Drainage Facilities</u>

As described in the premises, the proposed drainage facilities plan was formed to cope with the runoff discharge of 3-year probability based on the urbanized condition in the year 1995. The dimensional design of drainage conduits was made under the planning criteria mentioned in Subsection 4.1.2, and the following conditions:

- Equation for rainfall intensity of 3-year probability as shown below is used in this study.

$$R = \frac{6300}{T + 36.4}$$

where, R : Rainfall intensity (mm/hr)

T : Concentration time (min)

- Runoff coefficients of the subject two (2) river basins based on land utilization as of 1995 are fixed as below:

Sub-Basin No.	Mburicao River Basin	Itay River Basin
1	0.59	0.55
2	0.53	0.46
3	0.52	0.44
4	0.58	0.51
5	0.46	0.45
6	0.53	0.57

The structural types of drainage facilities include open channel and underground conduit. In general, the former is less costly and maintained more easily than the latter, but the latter will be adopted in the following cases:

(a) There is no sufficient open space to provide an open channel, and an enough road width cannot be obtained when an open channel is constructed.

(b) Provision of an open channel may involve difficulties because of underground utilities such as water supply pipes, electricity cables, and sewage pipes.

The structural types of drainage facilities were determined on the basis of the findings on the possibility of land acquisition for the construction of open channel and the possible existence of underground utilities along the respective drainage routes. The structural types of drainage facilities, together with the reasons for adoption, are shown in Table 5-37.

7.5.5 Findings of Alternatives

On the basis of the design discharge shown in Table 5-32 and in Fig. 5-41, and the study results on the structural type, the construction costs, the required area of land acquisition and the number of houses to be evacuated were roughly estimated section by section on each alternative plan. The study results are shown in Table 5-38.

7.6 Optimum Plan

7.6.1 Principles of Planning

The other principles of planning aside from the design discharge are the same as those of the Basic Plan and the Master Plan formulation. The design discharges of both Mburicao and Itay Rivers which were computed under the conditions of land utilization in the year 1995 are shown in Table 5-39 and in Fig. 5-42.

7.6.2 Selection of the Optimum Plan

As a result of the comparison among the various study cases from the economical and social viewpoints as mentioned hereinafter, it is concluded that the river channel improvement is the optimum alternative in the sections in question along the channels of the main course and the tributaries.

(1) Consideration on Economic Viewpoint

As shown in the Table 5-38, the river improvement is more economical than the other cases as in Cases A-1, B-1, C-1 and D-1 on Mburicao river basin, and E-1 and F-1 on Itay river basin.

(2) Consideration on Social Viewpoint

Since the estimated cost of land acquisition and evacuation of Cases A-1, B-1, C-1, D-1, E-1 and F-1 is only slightly higher than that of the other cases, the advantage over social problems caused by land acquisition and house evacuation seems to be about the same (refer to Table 5-38). Based on the above study, storm water control works will be carried out by means of river channel improvement and the installation of drainage facilities for the whole stretches of both Mburicao and Itay rivers and their tributaries, except the retarding basin.

A retarding basin will be constructed at the downstream end of the improved section of Itay River to cope with the anticipated increase of discharge due to the proposed improvement works in the upper reaches of Aviadores del Chaco Avenue in accordance with the concept of the Master Plan.

7.6.3 Features of the Optimum Plan

River Channel

With the results of the alternative study, the course alignment, longitudinal profile planning and cross sectional planning for the optimum plan were executed. The river sections to be improved and proposed structural type of river channel are presented in Fig. 5-43 and in Table 5-40. The typical cross sections of the rivers in both Mburicao and Itay river basins are shown in Fig. 5-44. The course alignments of the rivers, the longitudinal profiles and the cross sections at intervals of 100 m are presented in the Drawings attached. The location of the cross sections is shown in Fig. 5-45.

The findings of the study on the optimum plan of river channel improvement are summarized below.

Particulars	Mburicao River Basin	Itay River Basin	Total
Existing Channel Length (including Tributaries)	11.0 km	15.6 km	26.6 km
Channel Improvement Length	5.6 km	15.6 km	21.2 km
Channel without any Protection	0 km	2.7 km	2.7 km

Channel with Revetment	4.0 km	10.4 km	14.4 km
Channel with Revetment and Invert	1.6 km	0 km	1.6 km
Culvert	0.2 km	2.5 km*	2.7 km
Retarding Basin	0	1 place ($350,000 m^3$)	1 place ($350,000 m^3$)
Land Acquisition	$26,800\ m^2$	$127,100\ m^2$	$153,900\ m^2$
House Evacuation (Number of Household)	17	60	77

* In the upstream section of Madame Lynch River, the installation of box culverts is presently ongoing under the jurisdiction of the municipal office, therefore, the same improvement method is taken up in this section.

There are the revetments, the groundsills with head and the bridges as appurtenant facilities of the rivers. Their respective locations are shown in Fig. 5-46. The purpose of constructing the revetments is to protect the river banks from erosion and to reduce the number of house evacuation and the area of land acquisition, as it needs less width than channels without revetments.

Generally speaking, the existing gradient of the subject rivers are very steep, resulting in bank erosion due to high flow velocity in the channel. To reduce flow velocity, groundsills are proposed in both Mburicao and Itay Rivers to make the longitudinal gradient milder.

At present, a number of road bridges and a railroad bridge span across the subject rivers. All the bridges at the site where the river improvement works are applied will be reconstructed in this project. The width and elevation of bridges is principally the same as those of the respective existing bridges.

The findings of the study on the appurtenant facilities are as shown in the following table:

Particulars	Mburicao River Basin	Itay River Basin	Total
Revetment	38,900 m^2	58,100 m^2	97,000 m^2
Invert	7,800 m^2	0 m^2	7,800 m^2
Groundsill with Head	12 units	27 units	39 units
Bridge	16 units*	32 units	48 units

* Including one railroad bridge.

Drainage Facilities

The drainage facilities under the optimum plan consist of pipe, box culvert, open channel and appurtenant facilities, and their structural dimensions were determined in accordance with the planning conditions mentioned in 7.5.4. The following four (4) trouble spots are, however, under a conspicuous condition and the planning for these spots are executed as mentioned hereinafter.

- Location 14-1

The subject spot is located at the uppermost stream of Mburicao River, and the trouble is caused by insufficient amounts of existing inlets. Therefore, only installation of inlets is proposed for improvement works in this study.

- Location 14-2

At the end of this trouble spot, a drainage pipeline constructed by IDB loan is found. As this pipeline does not have enough flow capacity to drain storm water from the area of the trouble spot, the proposed drainage conduit cannot be connected to the above mentioned pipeline. For this reason, proposed drainage conduit route is plotted on the road running on the south of the said pipeline route.

- Location 14-6

  At the end of this trouble spot with 102 ha of catchment area, there exists a drainage pipeline constructed by IDB loan. This pipeline has enough flow capacity to drain storm water from 80.1 ha out of 102 ha of the catchment area, therefore, the proposed drainage conduit can be connected to the said pipeline, and storm water from the residual area out of 102 ha is discharged through the proposed drainage conduit.

- Location 18-1

  To solve the trouble on this spot, drainage conduit from the intersection of Eusebio Ayala Avenue and Madame Lynch Avenue to the uppermost stream of Madame Lynch River is proposed. The improvement works of the upper stream of Madame Lynch River are now being implemented by the municipality of Asuncion City, therefore, the cross section of the proposed drainage conduit is to be decided within the limitation of the improved cross section of the river.

Drainage routes in the Mburicao river basin consist of 14 routes with a total length of 9.3 km and the service area of 910 ha. The location and dimensional data of the cross sections of the drainage conduits are shown in Fig. 5-47 and in Table 5-41. Since the subject basin is one of the advanced urbanized ones, there is almost no chance for the construction of open channel under the conditions prescribed in Subsection 7.5.4; hence, most of the routes are planned to use conduits embedded under the roads.

The drainage routes in Itay river basin consist of 10 routes with a total length of 9.6 km and their service area of 1,570 ha. The location and dimensional data of its cross sections are shown in Fig. 5-47 and in Table 5-41. Since the subject basin is at present not fully urbanized and hence, plenty of open spaces, there are a number of routes which allow the planning of open channels.

The findings of the study on the facilities located in the two river basins are tabulated as follows:

Particulars	Mburicao River Basin	Itay River Basin	Total
Pipe	5.54 km	0.44 km	5.98 km
Box Culvert	3.59 km	2.64 km	6.23 km
Open Channel	0.18 km	6.56 km	6.74 km
Total	9.31 km	9.64 km	18.95 km
Land Acquisition	800 m^2	9,100 m^2	9,900 m^2

Appurtenant facilities of the drainage facilities consist of manholes, inlets and outlets, and their layout plans are made based on the conditions prescribed below.

Manholes are installed at locations where they are structurally required as enumerated below, and also where it is required for the maintenance and administration of the drainage facilities.

- Initial point of conduit, points where changes in direction, gradient and/or diameter, and points of abrupt drop and of junctions.

- Along straight sections, a manhole is installed at an interval of less than 200 m.

Inlets are required to gather storm water running on roads into drainage facilities. For the optimum plan, two (2) types of inlet are considered, one is an independent type and the other is a continuous type. Independent type inlets are used where the collecting area is small, and for a large collecting area continuous inlets are used. Practical collecting areas of the respective types of inlets are as below:

Independent Type	:	0.75 ha per unit
Continuous Type	:	0.50 ha per meter

Outlets are provided at the end of drainage facilities, i.e., at the point to discharge gathered storm water into rivers. To protect river banks and riverbed in the neighborhood areas of outlets, revetments and riverbed protection works in the length of 10 m are planned up and downstream of the location of outlets.

The findings of the study on the appurtenant facilities of drainage facilities are as shown below:

Particulars	Mburicao River Basin	Itay River Basin	Total
Manhole	92 pc.	32 pc.	124 pc.
Independent Type Inlet	224 pc.	54 pc.	278 pc.
Continuous Type Inlet	1,310 m	2,240 m	3,550 m
Outlet	14 pc.	10 pc.	24 pc.

7.7 Preliminary Design of Required Facilities

The structures specified in the First Stage Project, which consist of revetment, groundsill with head, box culvert, pipe, bridge, etc., as shown in Fig. 5-20 and 5-21, are as described hereinafter.

Revetment

In view of economical reasons and abundance of materials in the project site, wet masonry which is widely accepted in Paraguay is adopted. The revetment crown is 0.4 to 0.5 m wide, and the front slope is 1:0.2. The height of the revetment is 1.5 to 4.0 m. To protect the revetment from scouring of the riverbed, its foundation is embedded to a depth varying between 0.4 m and 1.0 m depending on the design discharge.

Groundsill with Head

For the same reasons as the foregoing, wet masonry is also adopted. The crown width is 0.5 m and the front face is perpendicular. The height of the groundsill with head is between 0.2 m and 3.7 m. Embedment of the foundation varies between 0.4 m and 1.0 m in depth. An apron of wet masonry is constructed at the downstream of the groundsill, and at the downstream of the apron, a gabion mattress is installed. The length of the apron is between 2 m and 11 m and the thickness is 0.4 m to 1.0 m.

Box Culvert

For construction of box culvert, reinforced concrete is adopted taking easier workability, longer durability and easier procurement of materials into consideration. The cross section of the smallest culvert is one box of 2.0 m wide and 2.0 m high, and the largest is 3-box culverts of 4.1 m wide and 3.6 m high each. Their minimum wall thickness is 0.3 m. The foundation of the box culvert is directly placed on the ground because of sound and solid geological conditions.

Pipe

For pipes, centrifugal reinforced concrete pipe is adopted, taking the large cross section and the heavy earth covering load. Pipes planned in this study are between 1.0 and 2.2 m in diameter, and the anticipated earth covering load is 4.5 m in the maximum. The sand foundation is adopted because the ground conditions are sound and solid.

Bridge

For the same reason as the foregoing, bridges are all reinforced concrete structures. The width of the bridges varies between 4.5 and 24.0 m depending on the width of the respective existing bridges. The span length is between 4.5 and 22 m. The types of bridges are either floor slab (span length is less than 10 m) or T-Girder (span length is over 10 m). Either spread or pile foundation will be taken depending on the geological conditions of the site.

Manhole

The upper portion of manhole is made up of composite of reinforced concrete cylinder and hollow conical brick sections with wrought iron lid and the lower portion is of reinforced concrete box that links to the conduits.

Inlet

Two types of inlet, independent type and continuous type, are proposed, both of which are composite of reinforced concrete and bricks with precast concrete slabs and/or steel gratings.

Outlet

Outlets of conduit are made of wet masonry to protect erosion and scouring to full river width and in length ranging up and downstream by 10 m each.