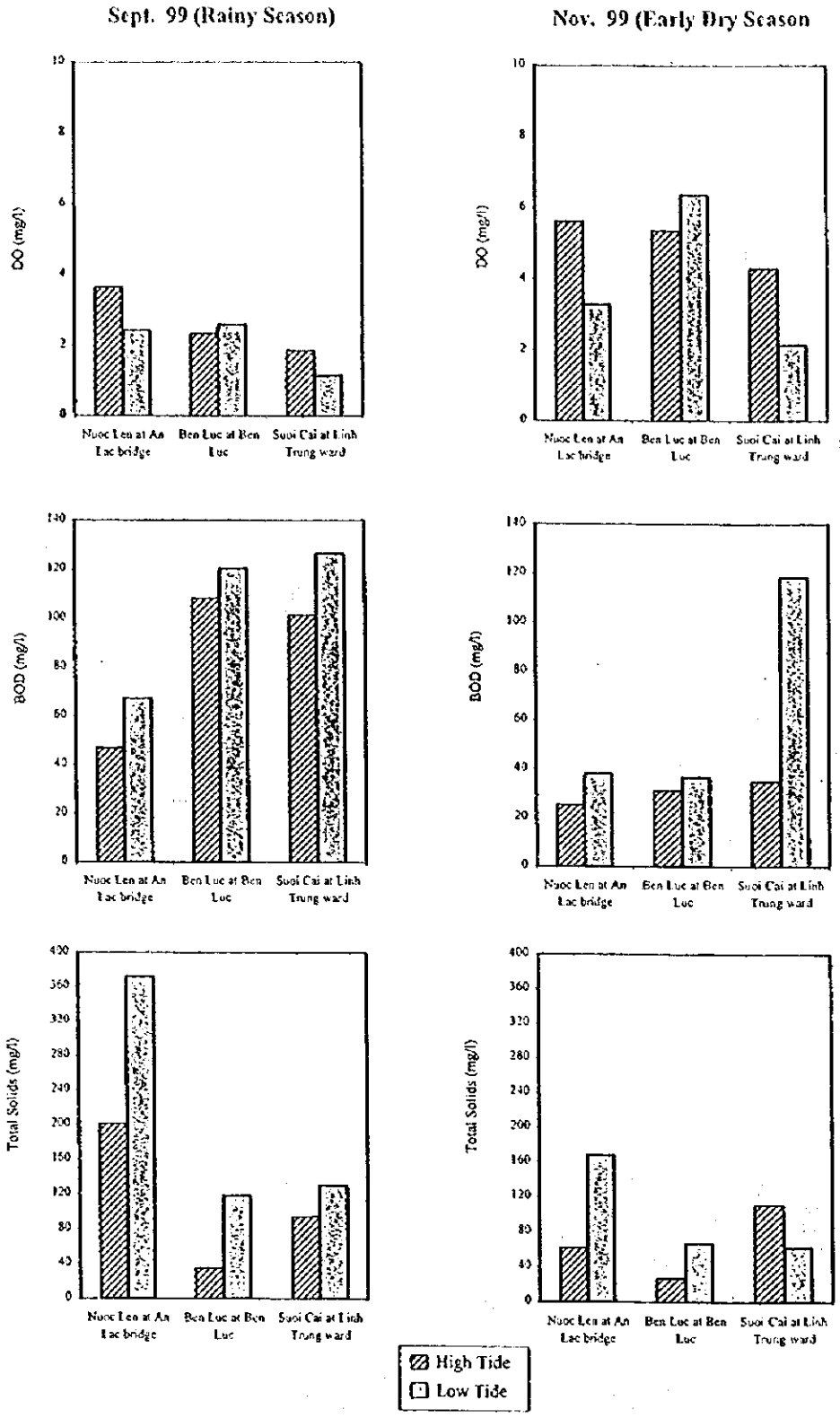


Fig. D.3.13 (1) Organic Pollution in Nuoc Len, Ben Luc and Suoi Cai Canal

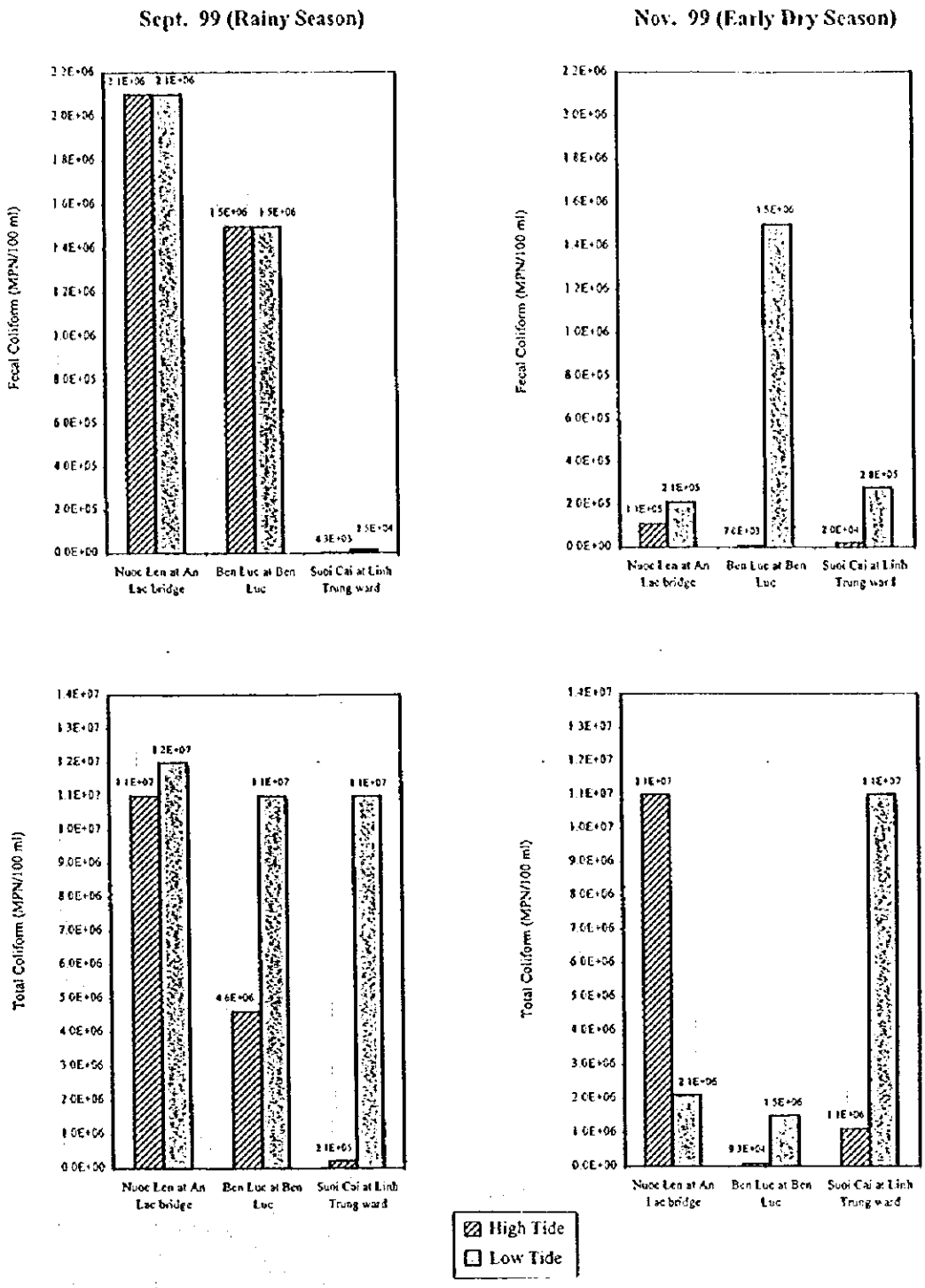


Fig. D.3.13 (2) Fecal Contamination in Nuoc Len, Ben Luc and Suoi Cai Canal

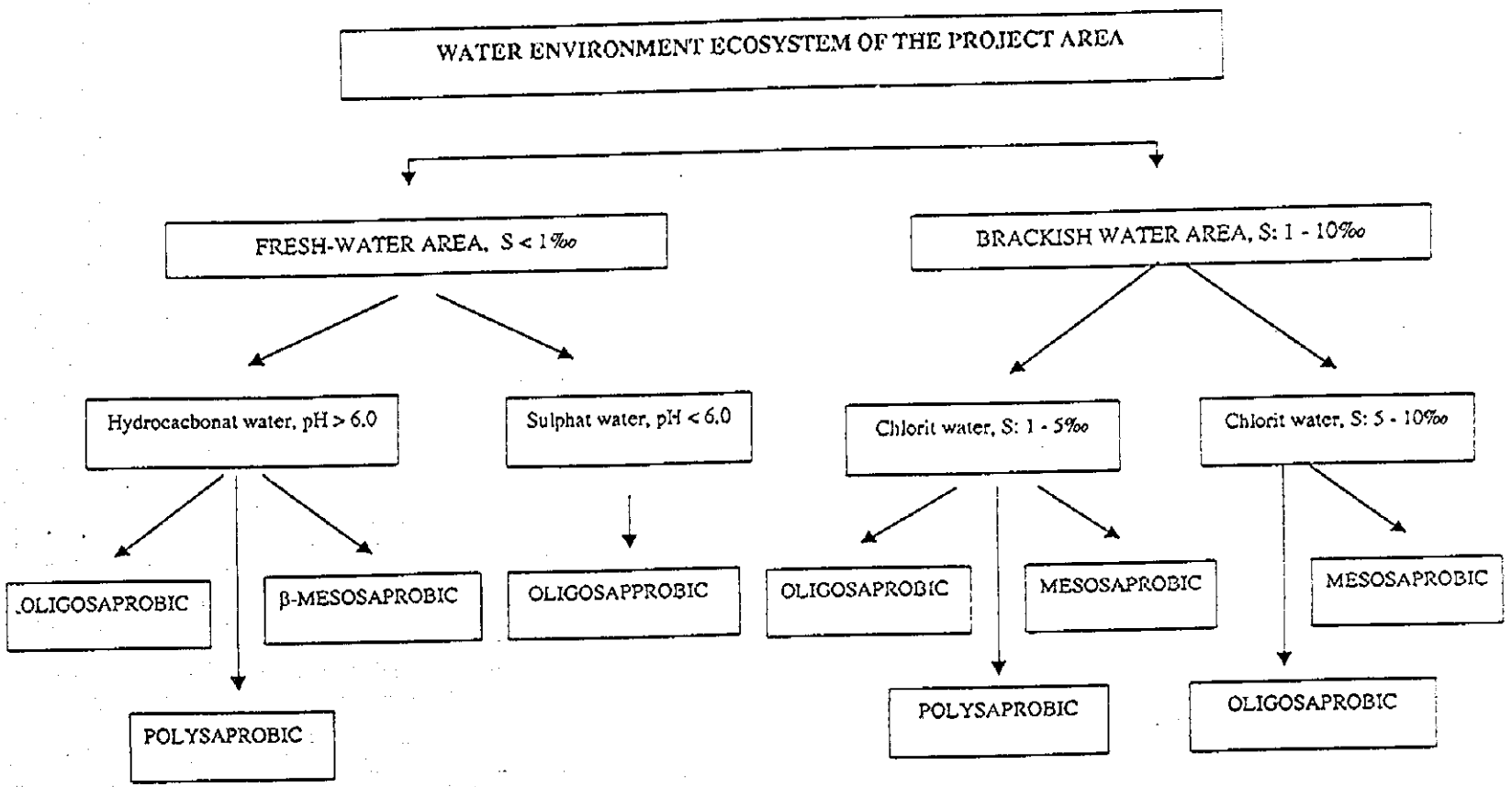


Fig. D.7.1 Classification of River and Canal System in the Study Area in Terms Of Salinity and pH Level

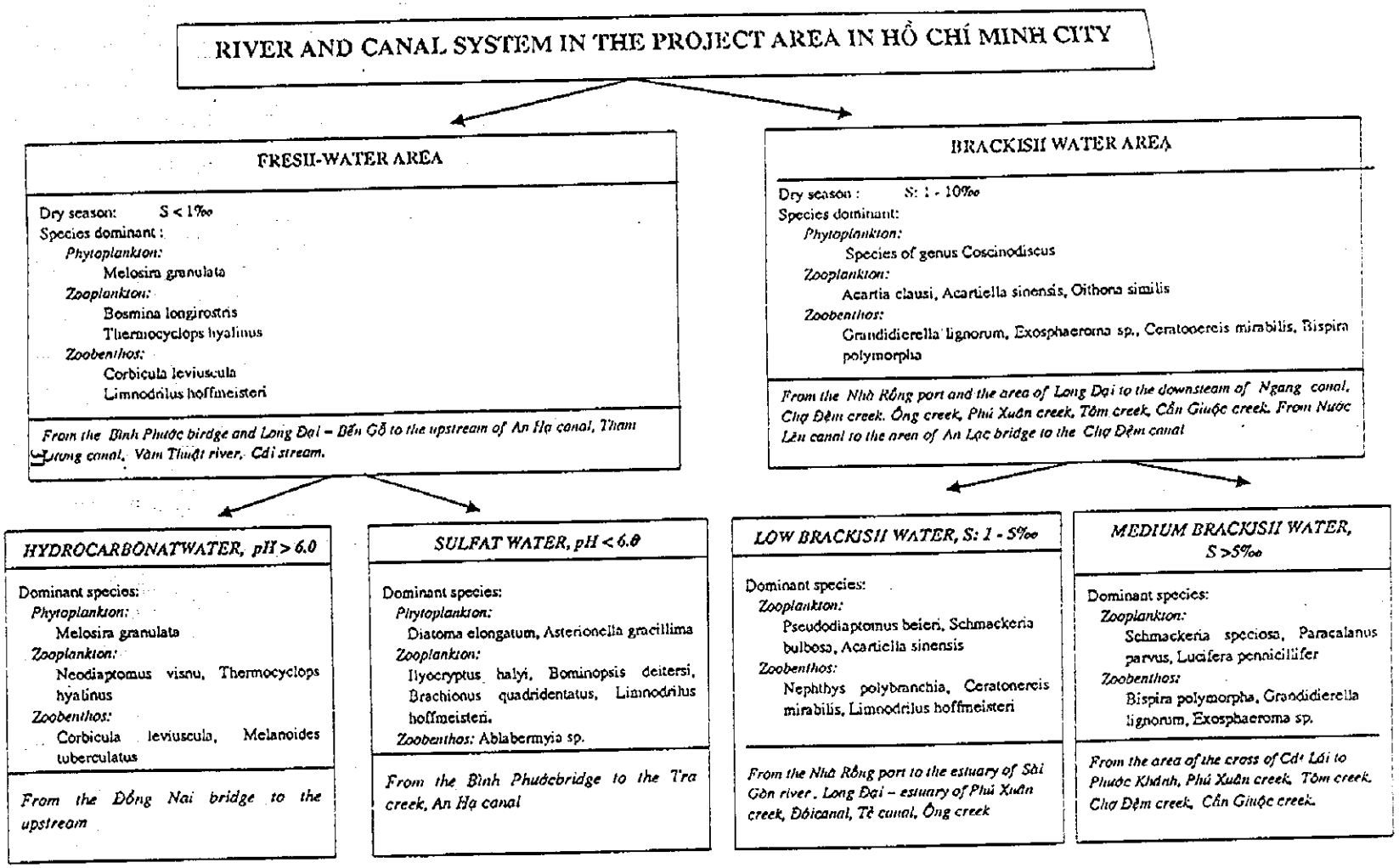


Fig. D.7.2(1/3) Dominant Plankton Species in Different Water Environment in the Study Area

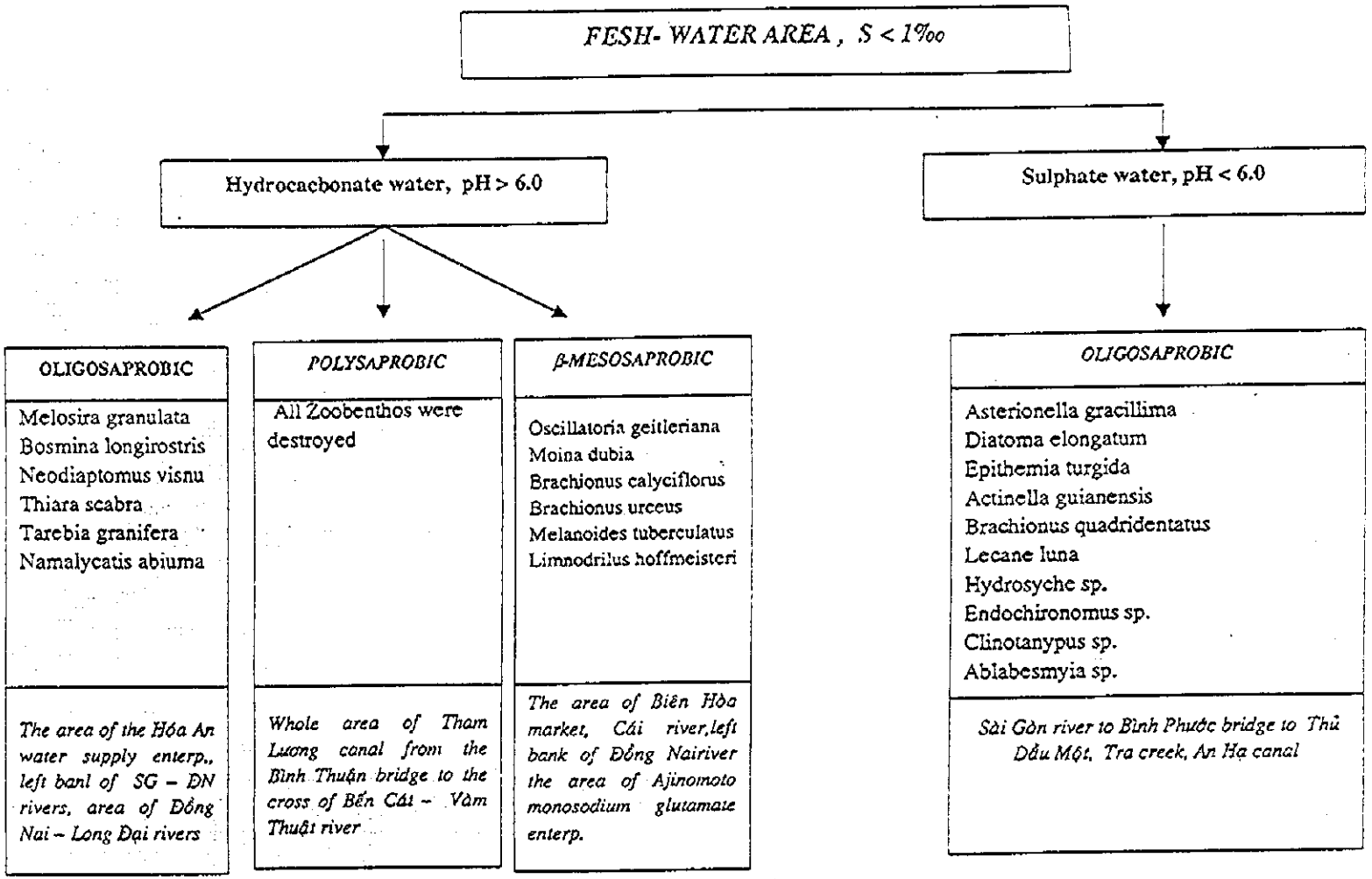


Fig. D.7.2(2/3) Dominant Plankton Species in Different Water Environment in the Study Area

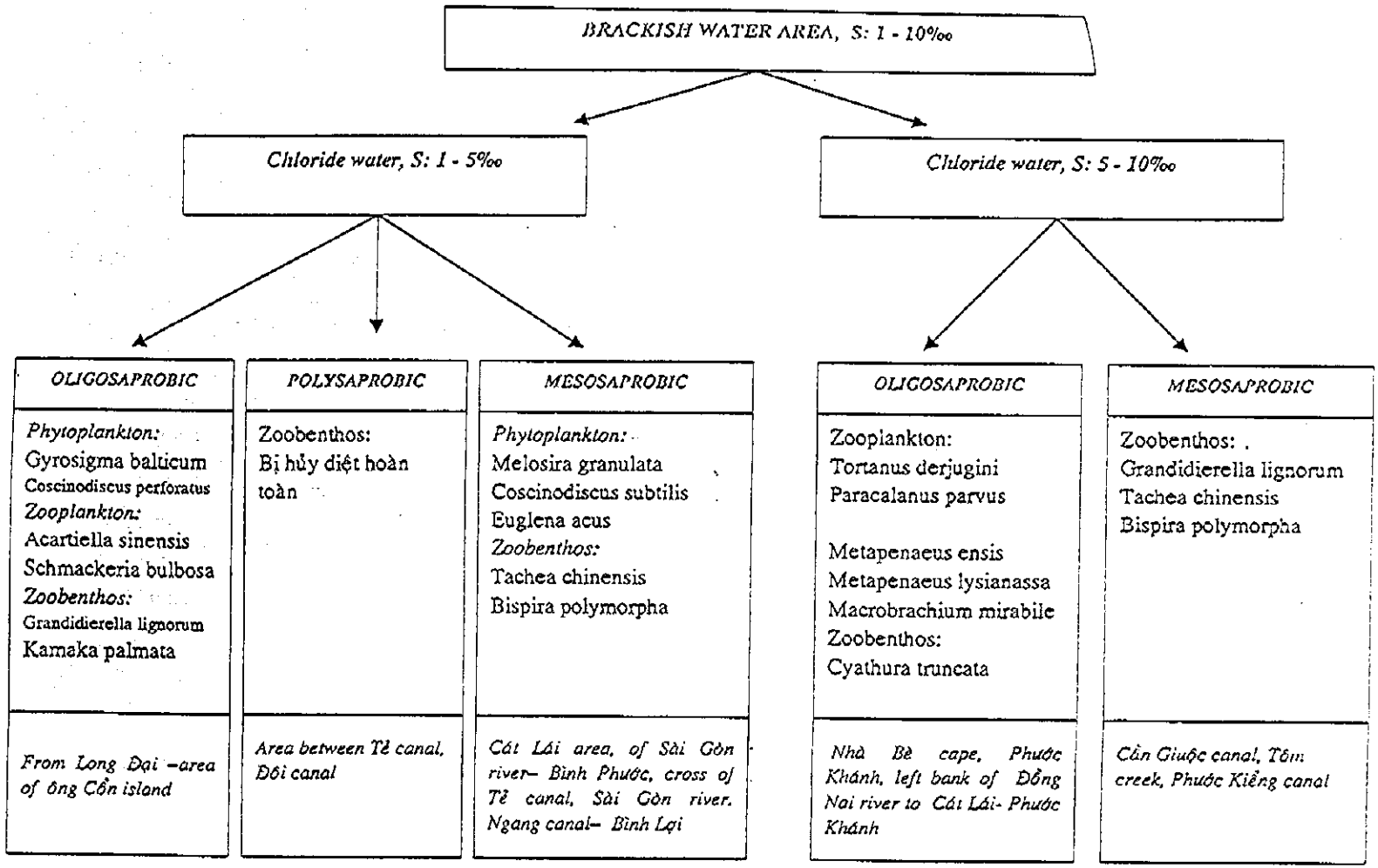


Fig. D.7.2(3/3) Dominant Plankton Species in Different Water Environment in the Study Area

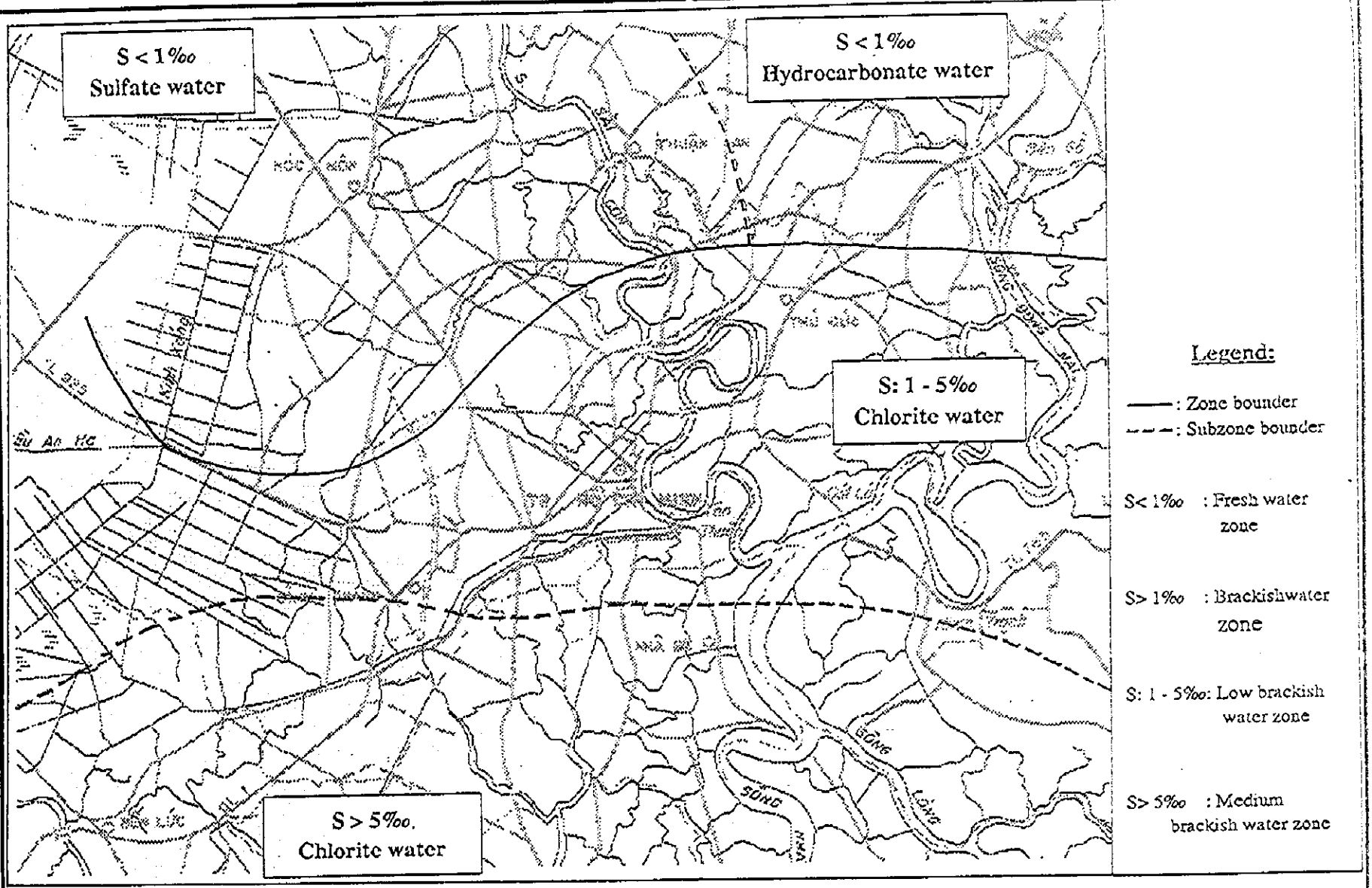


Fig. D.7.3 Zoning of Water Environment in the Study Area

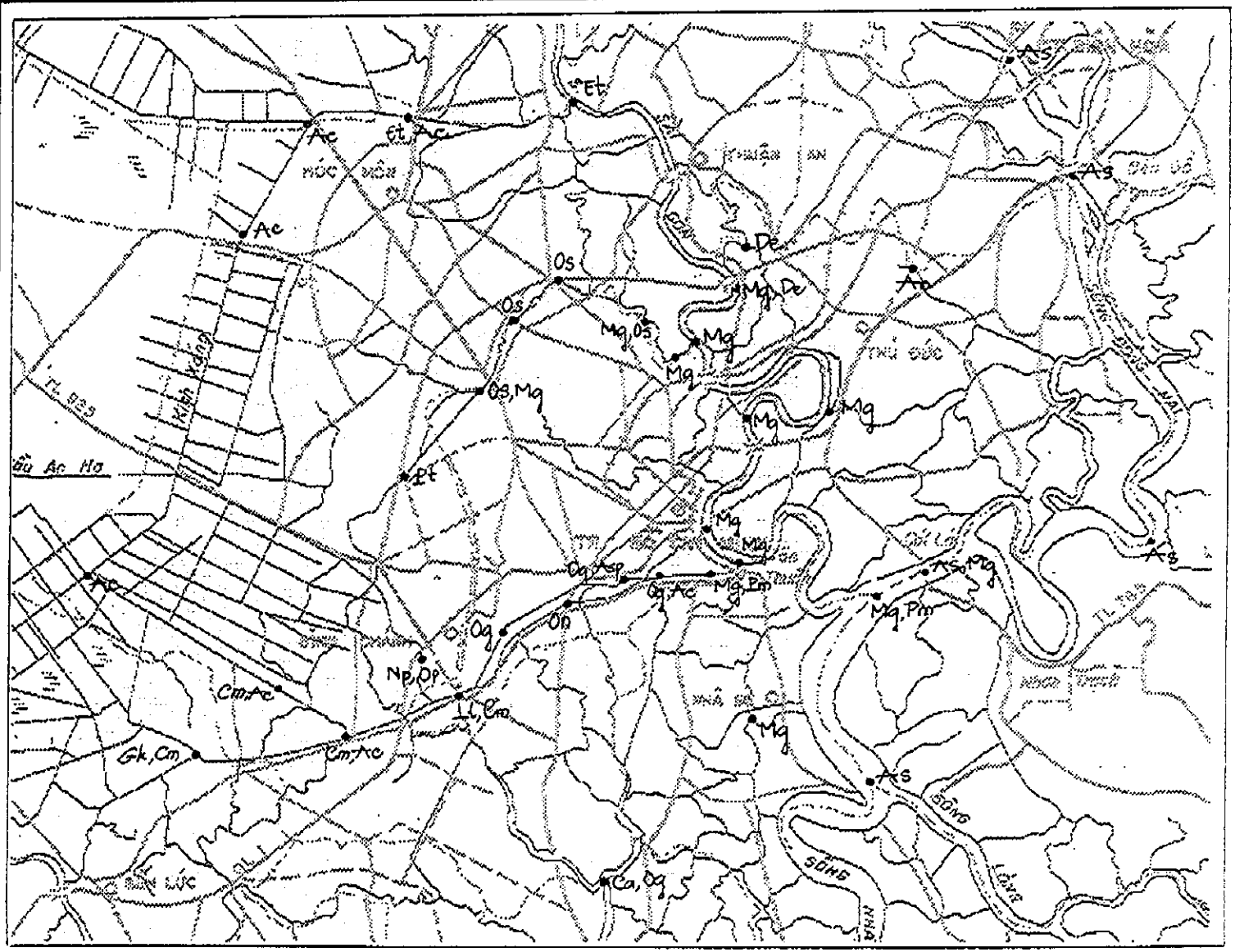


Fig. D.7.4 The Distribution of Dominant Species of Phytoplankton in the Study Area.

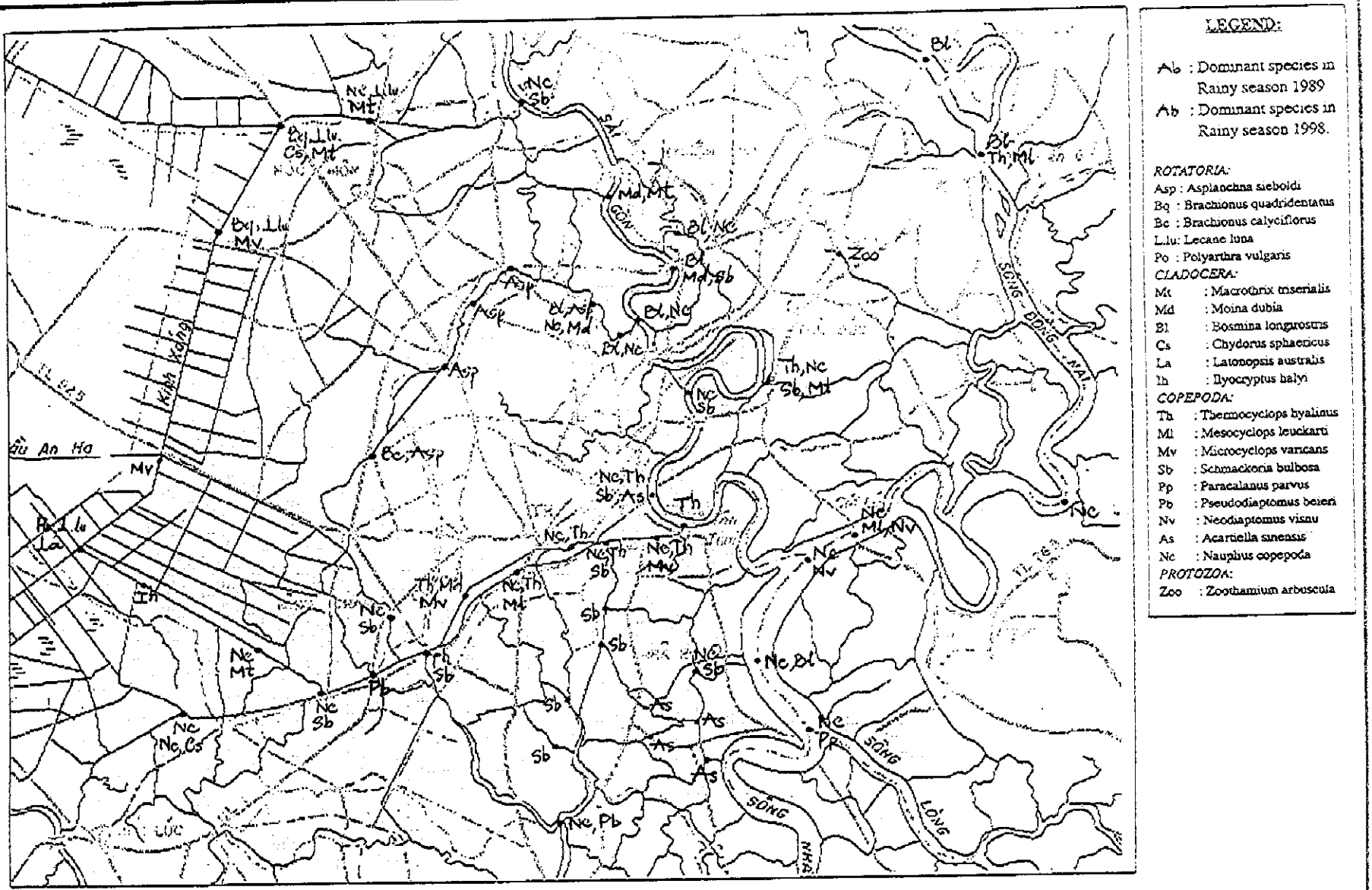
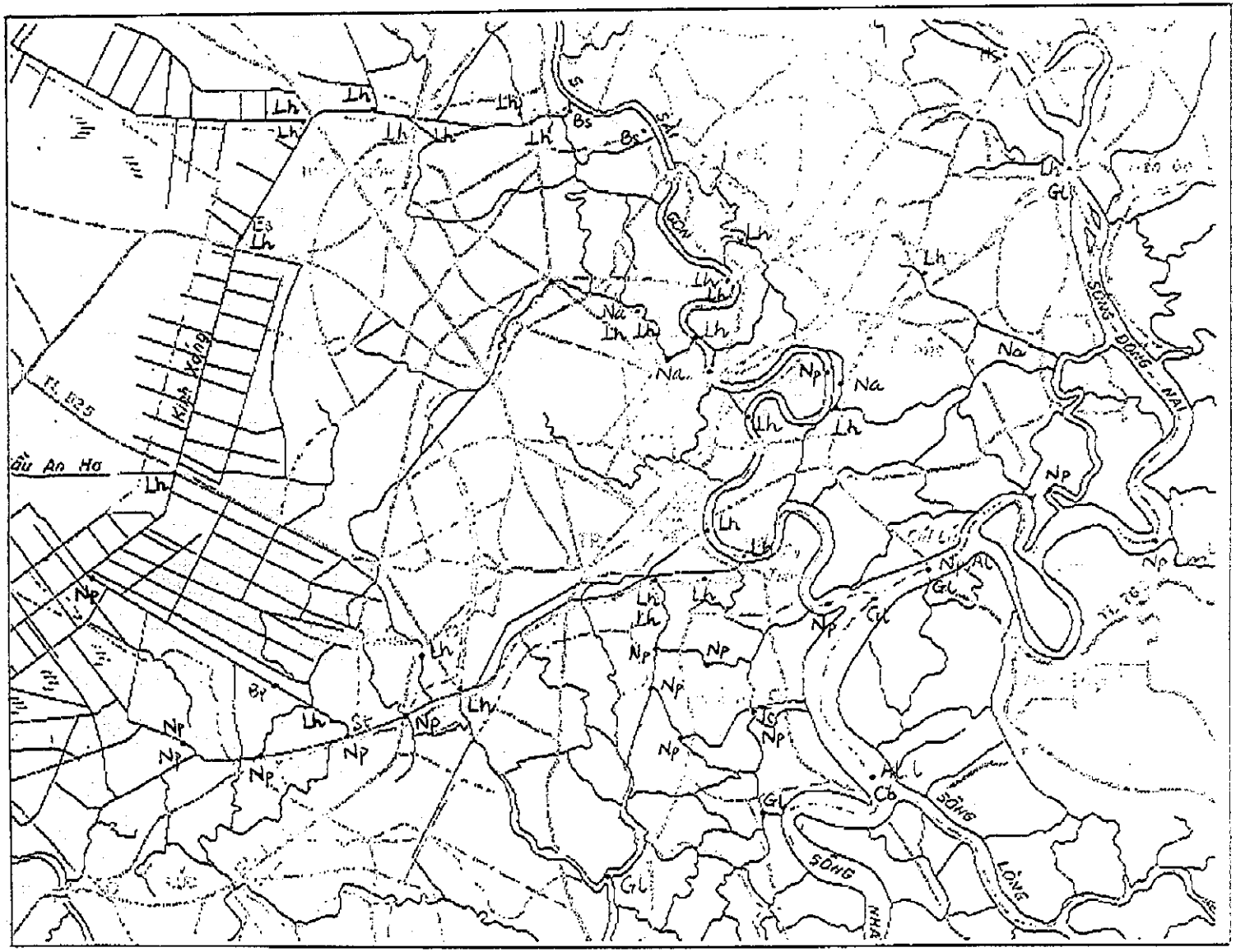


Fig. D.7.5 The Distribution of Dominant Species of Zooplankton in the Study Area



LEGEND:

Lh : Dominant species in Rainy season 1989

lh : Dominant species in Rainy season 1998.

POLYCHAETA:
Np : Nephthys polybranchia
Na : Namalycastis abiuma
Cm : Ceratonereis mirabilis
Al : Ammotrypane longicaudata
Bp : Bispira polymorpha

OLIGOCHAETA:
Lh : Limnodrilus hoffmeisteri
Bs : Branchiura sowerbyi

CRUSTACEA:
Tc : Tachea chinensis
Gl : Grandidierella lignorum
Al.l : Alpheus lottini

MOLLUSCA:
St : Sermyla tornatella

INSECTA LARVA:
Hs : Hydropsyche sp.
Es : Endochironomus sp.

Fig. D.7.6 The Distribution of Dominant Species of Zooplankton in the Study Area.

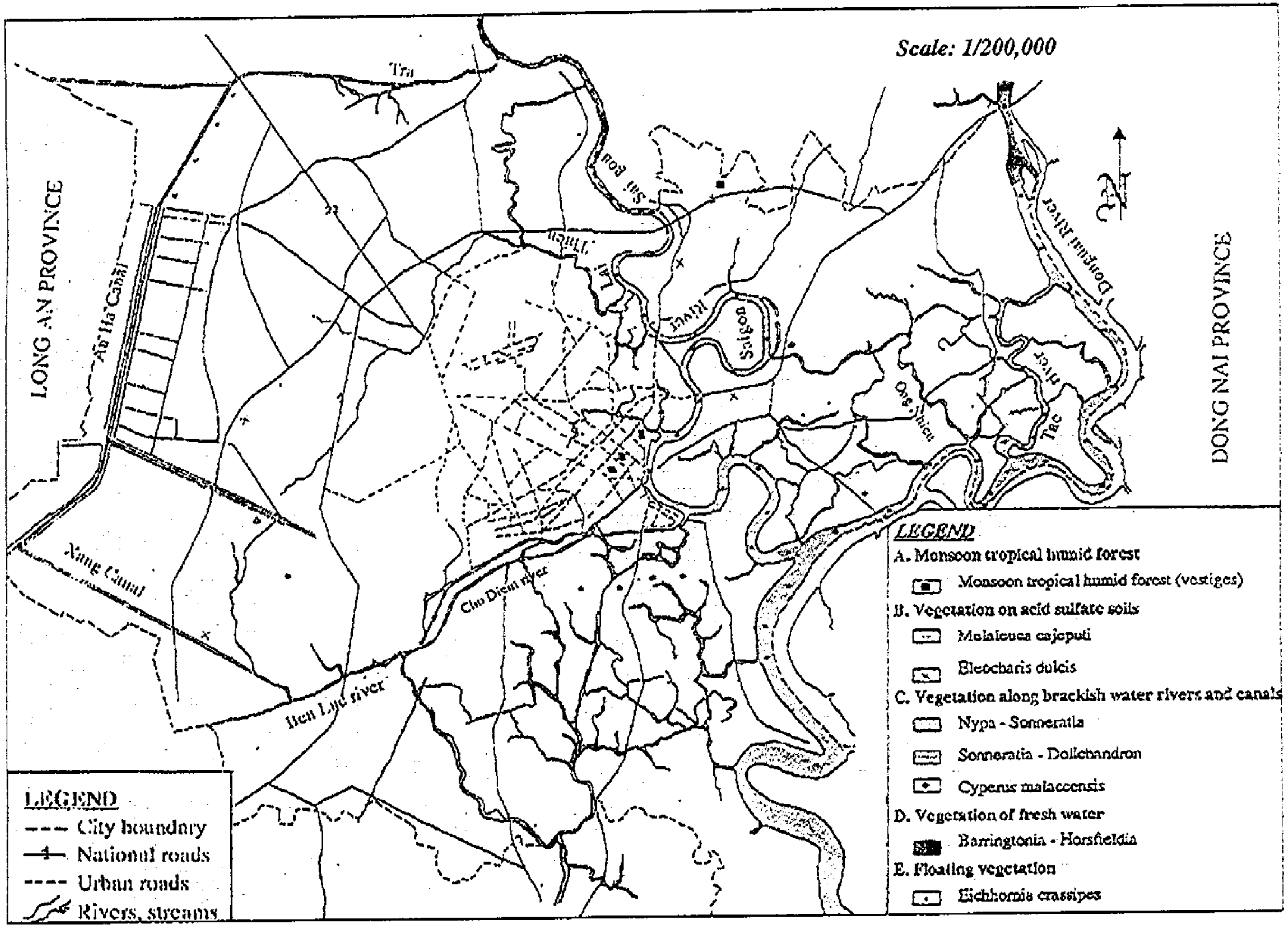


Fig. D.7.7 The Distribution of Representative Vegetation Types in the Study Area

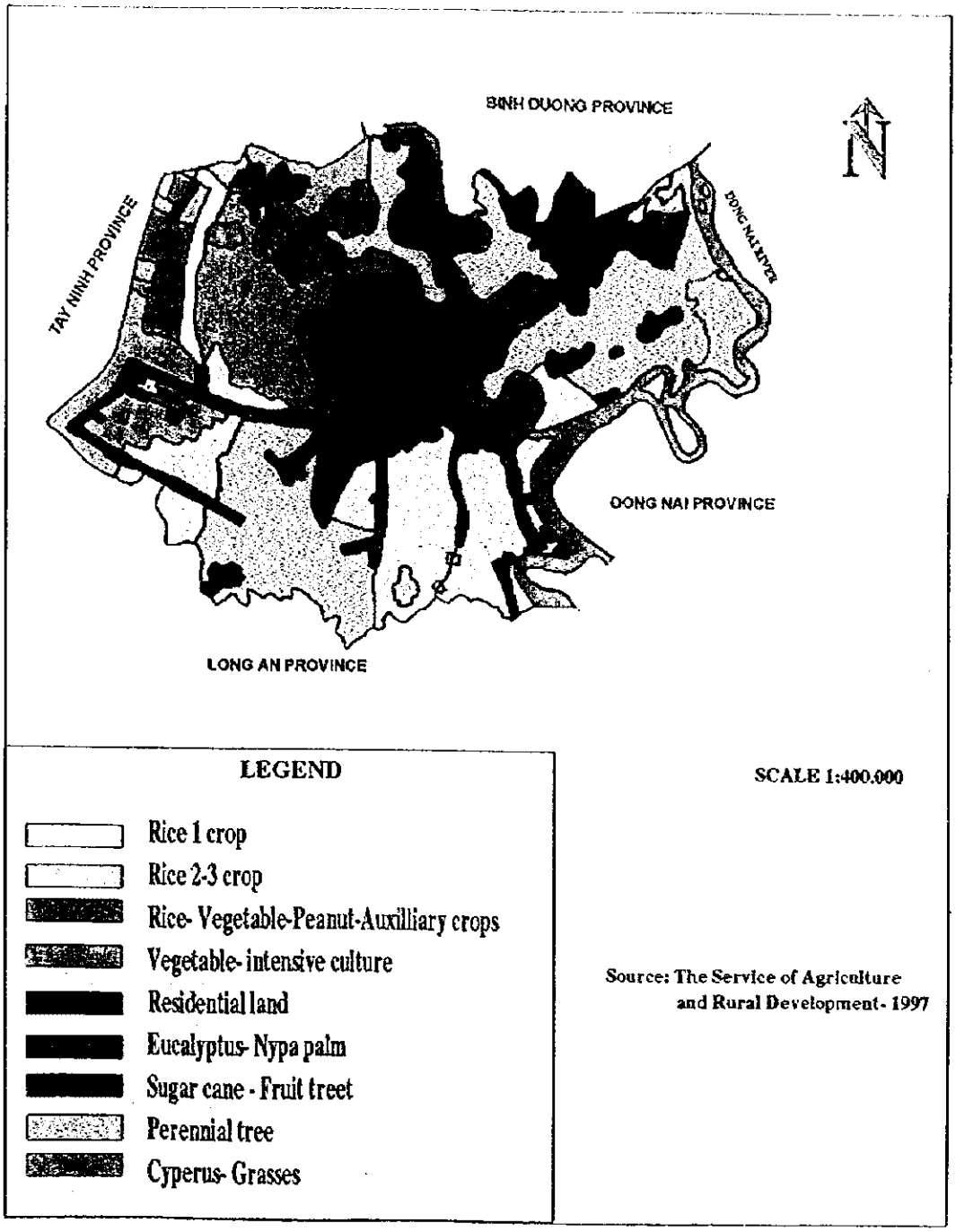


Fig. D.7.8 The Land Use and Vegetation Map of the Study Area

APPENDIX E URBAN DRAINAGE IMPROVEMENT

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1. INTRODUCTION

The Study area, which covers approximately 650 km^2 including the existing urbanized area of about 140 km^2 and surrounding areas of about 510 km^2 as shown in Fig. E.1.1 is located in the northeastern edge of the Mekong Delta. Due to the geographical condition, high rainfall intensity, high water level of the surrounding rivers affected by high tide of the South China Sea and insufficient drainage facilities, a great number of places in the Study area have suffered from habitual inundation during a rainy season.

According to the flood survey conducted by the Study Team in 1988, it is founded that total built-up area of approximately 3,000 ha equivalent to about 5 % of the Study area is affected every year. Considering the rapid urbanization of the Study area, flood area of built-up area, such as residential, commercial, institutional and industrial areas will be expanded in the future, if no countermeasures are implemented

To find out the effective, satisfactory and sustainable solution for the above flood problem, urban drainage improvement study has been planed to undertake in the following three (3) study stages:

(a) First Stage: From mid. of July to end of December 1998, Study on Present Condition of Study Area and Review of Relevant Study and Project

(b) Second Stage: From beginning of January to end of July 1999, Formulation of Master Plan and Identification of Priority Project

(c) Third Stage: From middle of May to end of December 1999, Execution of Feasibility Study on Priority Project

The study procedures are shown in Fig. E.1.2.

This is a Interim Report, which contains the whole study results on urban drainage improvement in First and Second Stage.

2. COLLECTED AVAILABLE DATA AND INFORMATION

Collected data and information related to the urban drainage study, of which lists are attached in Appendix, have been compiled into the following five (5) categories:

Category A: Topography
Category B: Population and Land Use]
Category C: Meteorology and Hydrology
Category C: Flood and Flood Damage
Category D: Existing Drainage System and Facilities
Category E: Relevant Studies and On-going Projects

Collected topographic maps with scale of 1:50,000 (10 sheets), 1:25,000 (12 sheets) and 1:10,000 (44 sheets) have been made at rather old time and lacked the topographical information of new developments, such as road, residential and industrial areas, and tourism facilities. So, supplementary topographic survey has been conducted to up-date the existing topographic map with scale of 1:10,000 in the study area. These information has been digitized to improve the original GIS base map prepared by Urban Planning Institute (UPI), which is the most suitable base map for formulation of urban drainage Master Plan. Details are mentioned in Appendix A

For the population and land use of the study area, the present (1997) and future (2020) projected data and information were compiled based on the study results of the Adjustment Master Plan prepared in 1997 by UPI. Details are referred to Appendix B.

Several meteorological and hydrological data and information have collected from the Southern Region Hydro Meteorological Center (SRHMC). Rainfall series of seven (7) stations, such as monthly rainfall, annual maximum daily rainfall, annual maximum short and long duration rainfall, etc. were collected. Water level data series of five (5) stations located Nha Be, Saigon, Dong Nai and Ben Luc rivers were also collected for annual maximum and minimum water level and hourly water level series. These details are referred to Appendix C.

Recent flood and flood damage data and information have also been collected from the agencies concerned. These are, however, rather insufficient because almost all data are for only inner city area. Supplementary interview survey has been conducted for the whole study area in order to enhance the data reliability for the economic and social evaluation of the proposed project. Details are mentioned in Section 5 in this report.

Many profile and cross sectional data and information of the main canals and rivers in the Study area has been collected from Urban Drainage Company (UDC). It is, however, found out that some of these data are rather old and not available because of unreliable elevation data. Profile and cross sectional survey has been conducted for the rivers and trunk drainage canals of more than 60 km to supplement the existing data. Cross

sectional survey of the Saigon River has been carried out at the confluence with some trunk canals. Data and information on the related structures along the rivers and canals, such as dike, retaining wall, bank protection, bridge and culvert were also collected from the several departments, companies and agencies concerned. These were used for the evaluation study of the existing river and canal system and related structures. Details are mentioned in Section 3 in this report.

Information on the existing drainage network system in the Study area has been collected from the UDC, UPI and the district offices concerned. This data contain the drainage network horizontal plan and shape and dimensions of drainage except drainage profile. A feasibility study entitled "Saigon Sewerage Feasibility Study" prepared by Ministry of Public Works in 1996 is also available. The study covered the whole area of District 1 and a part of District 3, 5, 6, 10 and 11. Simultaneously, a detailed survey of drainage network was conducted to prepare for a horizontal plan of the drainage network and an inventory including shape and dimensions of drainage and drainage profile. The drainage surveyed is still used without any major reconstruction, therefore the survey data is considered to be useful for the modeling to evaluate the capacity of the existing drainage network. Profile survey has been conducted for drainage of about 140 km to supplement the existing data. At present the results of survey has being examined. Details are mentioned in Section 3 in this report.

Several reports, documents and drawings concerning the previous and on-going relevant studies, plans and projects have been collected from the companies and agencies concerned. These have reviewed to acquire each planning concept, design criteria and recommendation, and to avoid the repetition of each project. Details are described in Section 4 in this report.

3. PRESENT CONDITION OF DRAINAGE AREA AND SYSTEM

3.1 Drainage Area

3.1.1 Topography

The Study Area with an area of about 650 km^2 is located from 106°35'to 106°55' east longitude and from 10°40' to 10°55' north latitude in the northeastern part of the Mekong Delta. The ground elevation ranges from about 0.5 to 30 m above MSL. The general ground slope of the area is from the north-northeast to the west-southwest. The regional topographic conditions are summarized as follows:

(a) West Bank of the Saigon and Nha Be rivers

The west bank of the Saigon and Nha Be rivers is classified into four (4) regions having the different topographic characteristics. The western region is mostly low-lying area with its ground elevation from EL.0.7 to 1.0 m in Binh Chanh district. This region is mainly used as a paddy field. The central region is high land area including a hilly area of Hoc Mon (EL.8 - 10 m), Go Vap (EL.10 m) and the existing urban area (EL.2 - 8 m). This region is fully urbanized because of the geographical and topographical advantage. The east region along the Saigon River is low land area with an elevation of EL.0.6 - 0.8 m, where has been mostly developed as a paddy field. The southern region along the Nha Be River is mainly low-lying paddy field with an elevation of EL.0.6 - 1.2 m.

(b) East Bank of the Saigon River

This area consists of two regions; the north and south. The northern region is the high hilly land belonging to Thu Dud district with its ground elevation from 2 to 30 m above MSL. Recently, this region has being rapidly urbanized, according to the convenience of transport and the advantage of topography. The southern region is mostly low-lying area in District 2 and 9. The ground elevation of the area ranges from 0.6 to 1.5 m above MSL. This region has been developed mostly a paddy field protected by the dike from the flood of the Saigon and Don Nai rivers.

Figs. E.3.1, E.3.2 (1/2) and (2/2) show the topography of the Study Area.

3.1.2 Population and Land Use

The Study area of 650 km^2 including 20 administrative districts consists of the inner city area of approximately 140 km^2 and the surrounding area of about 510 km^2. Population of the Study area of about 4.4 million (88% of a total population of HCNC) in 1997 is projected at about 7.6 million (76% of a total population of HCMC) in 2020, according to the Adjustment Master Plan (AMP) of HCMC prepared by UPI. Under the

rapid future population growth, the present built-up area of 190 km^2 (29% of the area) will be expanded mainly toward the north and northeast areas of the city up to approximately 380 km^2 (58% of the area). Details refer to Appendix B.

Table E.3.1 shows the present (1997) and future (2020) population and built-up area in the *Urban Drainage Study area (hereinafter referred to as "the Study area" in this Appendix). Fig. E.3.3 (1/2) and (2/2) illustrate the land use of the Study area in 1997 and the target year 2020 respectively.

Note: * : The boundary of the study area for urban drainage master plan was inclusively redefined based on the topographic condition and the existing canal system in the Study area of 650 km^2 defined in the Scope of Work signed between JICA and PCHCMC on 19th January 1998.

3.1.3 Division of Drainage Area

The Study area of 581.51 km^2 is divided into six (6) drainage zones based on the topographic condition, the existing urban drainage system, and the present and future urbanization. Since the Study area may be settled based on the district boundary, the total drainage area to be studied for urban drainage improvement is finally redefined at 581.51 km^2. The urban drainage study area and each drainage zone are illustrated in Fig. E.3.4 and described below:

(1) Central City Drainage Zone (C-zone)

This zone covers the entire central part of the city adjoining the right bank of the Saigon River. This zone administratively consists of District 1, 3, 4, 5, 6, 7, 8, 10, 11, Phu Nhuan, Go Vap, Binh Chanh, Binh Thanh and Tan Binh districts. The high land areas from 2 to 10 m above MSL are fully urbanized except the low-lying area of Tanda in Binh Thanh district, the western part from Rach Lo Gom in District 6 and the southern part from Doi canal in District 8, of which areas are rapidly urbanizing. The total area is 106.41 km^2, of which 75.38 km^2 (71 % of the area) is already built-up in 1997. The built-up area will be expanded at 87.56 km^2 (82 % of the area), according to the AMP. The population of 3.19 million in 1997 is projected at 3.42 million in the target year 2020 as shown in Table E.3.1.

The combined sewer network system has been developed in this zone from 1870s by the French Government, which consists of trunk sewer of about 93 km and secondary drain of more than 930 km at present. These sewers drain the collected rainwater and sewage directly into the Saigon River and main canals, such as Nhieu Loc - Thi Nghe, Tan Hoa - Lo Gom, Tau Hu - Ben Nghe and Doi - Te canals through over 93 outlets. Some projects have being undertaken to improve the environmental conditions in this zone including urban drainage and sewerage by the financial assistance of some donor countries and international organizations.

(2) Northern City Drainage Zone (N-zone)

This zone covers the north suburban area (136.19 km^2) from Tan Son Nhat airport, which includes administratively a part of District 12 and Go Vap, Binh Tanh, Tan Binh, Binh Chan and Hoc Mon districts. PCHCMC has developed the sewer pipe system for a part of Go Vap district located the right bank of Tham Lun - Ben Cat canal, however, the other areas have no sewer network yet. According to the AMP, the present built-up areas of 46.59 km^2 (34 % of the area) situated on relatively high land are estimated at 80.34 km^2 (59 % of the area) in 2020. Newly developed areas include low-lying flood plain along the Saigon River and Tham Lun upstream basin. The population of 422,000 in 1997 is projected at 1,127,000 in the target year 2020 as shown in Table E.3.1. Consequently, it is fared that environmental deterioration including inundation and water pollution will accelerate in near future.

The storm water collected by few sewer pipes, ditches and channels drain directly into the main canals, such as Tham Lun - Ben Cat canal, Rach Dai Han, Rach Ben Da - Ba Hong, etc., which are connected with the Saigon River. PCHCMC is in the planning stage of the improvement of Tham Lun - Ben Cat canal integrated with drainage, water purification by dilution method and waterway transport improvements.

(3) Western City Drainage Zone (W-zone)

W-zone covers the low-lying areas of 72.91 km^2 along the Rach Chua - Rach Nhuoc Len canal in District 6,8, Tan Binh and Binh Chanh, which is located the western part from C-zone. The area has been mainly used as a paddy field below 1.5 m above MSL, however the eastern parts of the area adjoining with Tan Hoa - Lo Gom basin have being developed by filling up as residential and industrial areas after the construction of national road No.1. The present built up area of 14.39 km^2 (20 % of the area) is estimated to be 33.62 km^2 (46 % of the area) in 2020 as shown in Table E.3.1. The population in 1997 and 2020 are estimated at 176,000 and 629,000 respectively. The future development of low-lying areas having a rainwater storage potential will be increase the peak discharge and accelerate the deterioration of the inundation condition.

Binh Chanh district has been constructed some sewer pipes for newly urbanized areas, however it is not enough. The storm waters collected to the main canal of Rach Chua - Rach Nhuoc Len through the ditches and channels are drained into the Ben Luc River and discharged toward the Nha Be River through the Can Guioc River.

(4) Southern City Drainage Zone (S-zone)

This zone covers the southern areas of 81.74 km^2 from District 8 and Te canal, which belong to District 7, Binh Chanh and Nha Be districts. This zone was naturally low-lying area below 1.5 m above MSL with dense canal networks and has been

developed as an agricultural land. In recent years, however, the northern part of the area along the Doi - Te canal has had several economic developments by the foreign investor. Especially, after the completion of Tan Thuan Export Processing Zone and the Saigon South Parkway, Tan Hung, Tan Qui and Tan Thuan Tay areas situated between Te canal and the Saigon South Parkway have rapidly being developed. The southern low-lying areas from the Saigon South Parkway are still used as a paddy field protected by dike system from the overflow of the surrounding rivers. According to the AMP, the present built up area of 11.37 km^2 (14 % of the area) is projected to be 39.46 km^2 (48 % of the area) in 2020 as shown in Table E.3.1. The population in 1997 and 2020 are estimated to be 127,000 and 475,000 respectively. Inundation problems in Saigon South project area will be deteriorate if no flood protection measures are undertaken.

Rainwater collected by natural small canals are drained directly into the trunk canals, such as Rach Ba Lao, Rach Xom Cui, Rach Ong Lon, Kinh Cay Kho, Rach Dia, Muong Chuoi River, etc. and finally discharged to the Nha Be River.

(5) North-Eastern City Drainage Zone (NE-zone)

This zone with an area of 64.91 km^2 includes a whole area of Thu Duc district and a part of District 9. The area is topographically hilly land from 5 to 30 m above MSL except a flood plain from EL.0.5 to 1.2 m along the left bank of Saigon River. This flood plain has mainly been used an agricultural land, which has been sometimes flooded due to the backwater from the Saigon River at the high tide and the insufficient dike system along the river. The hilly land along the national road No.1 has recently been developed as a residential area, industrial estate and tourist resort. Considering the convenience and advantage of the national road No.1 and hilly land, this zone is expected to develop rapidly and continuously in near future, according to the AMP. The present built-up area of 12.38 km^2 (19.1 % of the area) is estimated to expand at 44.57 km^2 (68.7 % of the area). The population in 2020 is projected at 537,000 from 174,000 in 1997 as shown in Table E.3.1. Development of the hilly land located at the upstream basin will give a hydraulic impact (increasing peak run-off) for the low-lying areas.

This area has no sewer line except a part of section along the national road No.1. Storm waters collected into the western and eastern canals, such as R. Go Dua, R. Nhum - R. Cau - R. Go Gong, under the topographical condition are directly discharged into the Saigon and Dong Nai rivers respectively.

(6) South-Eastern City Drainage Zone (SE-zone)

This zone covers the low-lying areas with an area of 119.37 km^2 situated between the Saigon and Dong Nai rivers, which belongs to District 2, 9 and a part of Thu Duc district. Ground elevation of the area ranges from 0.5 to 1.5 m above MSL. This zone has basically been developed as an agricultural land, which has been protected by the dike systems from the flood of the above rivers. However, the areas along the left bank

of the Saigon River in District 2 have recently been developed as a residential area due to the advantage of its location being very near from the central part of the city. According to the AMP, this zone is expected to develop as the residential area and ecological green space in future. The population of 160,000 in 1997 is estimated to increase at 844,000 in 2020. The present built-up area of 13.52 km^2 (11.3 % of the area) is projected at 54.25 km^2 (45.4 % of the area) as shown in Table E.3.1.

This zone has no sewer pipes, but very dense canal network system. Rain waters collected by the ditches and channels are drained directly into the trunk canals, such as R. Chiec, R. Ong Hong, R, Kieu, R. Ong Nhieu, R. Trau Trau, Tac River, etc. Rainwater in east and southeast parts of the area is discharged to the Saigon and Dong Nai rivers respectively through the dense canal network.

3.2 River System

3.2.1 Saigon River

The Saigon River with a catchment area of about 5,400 km^2 is one of large tributaries of Dong Nai River system. Total length of the river from its headwaters to its confluence with the Nha Be River is about 200 km. The river section from Binh Lio bridge to its junction with the Don Nai River is about 30 km in length, 225-370 m in width and 12-20 m in depth in average. The Saigon River is indirectly affected by tidal influence of the South China Sea through the Nha Be River.

Discharge capacity of the Saigon River at Thu Dau Mot located at almost 40 km upstream from the city of Saigon is estimated at 2,200 m3/sec equivalent to 100-year frequency run-off. The Saigon River downstream of the Rach Tra canal has enough capacity to prevent from the flood run-off except during the high tide. Due to the storage function of Dau Tieng reservoir located upstream of the Saigon River, safety level of the flood control for the Saigon River downstream basin has been raised up more.

3.2.2 Dong Nai and Nha Be River

The Nha Be River is named the river sections of almost 40 km long downstream from the confluence of the Saigon and Dong Nai rivers, almost 10 km southeast of the central part of HCMC. The Nha Be River is always directly affected by the tidal influence of the South China Sea. At the vicinity of the confluence of the Saigon and Dong Nai rivers, the Nha Be River is about 1.4 km width with depth of about 9-10 m.

The Dong Nai River with a catchment area of about 23,000 km^2 has its rise among the mountainous region, about 270 km northeast far from the center of HCMC. The river section from Dong Nai bridge to the confluence with the Saigon River is about 37.5 km in length, 300-1,200 m in width, and 15-25 m in depth in average.

Discharge capacity of the Dong Nai River is estimated at 6,200 m^3/sec at the confluence with the Saigon River equivalent to 72% of 20-year frequency run-off, which is almost same as 5-year frequency run-off. At present, Tri An and Thac Mo reservoirs constructed 1980s are under operation for flood control of the Dong Nai and Be rivers basin respectively. Considering Ham Thuan Dam being newly constructed in the La Nga River, safety level of flood control for the Dong Nai River basin including HCMC is increasing more.

As mentioned the above, even if the discharge capacity of the lower Saigon and Dong Nai rivers is partly lower the 20-year frequency flood, it can be said that there is little possibility of occurring the big flood by both rivers.

3.3 Canal System

3.3.1 Division of Drainage Zone

Six (6) drainage zones were divided into several catchment areas, based on the existing topographic condition and the canal system in each zone as shown in Fig. E.3.5. Total number of catchment area divided by zone is 27 basins having the canal system and 16 basins having the independent small canal or channel. Details by zone are shown in Table E.3.2 and the table below.

NUMBER OF CATCHMENT AREA DIVIDED BY ZONE

Drainage Zone	Number of Catchment Area		
	Main Canal	Small Canal	Total
Central (C)	4	3	7
Northern (N)	2	1	3
Western (W)	1	0	1
Southern (S)	5	3	8
North-Eastern (NE)	5	3	8
South-Eastern (SE)	10	6	16
Total	27	16	43

3.3.2 General Description of Drainage Catchment

(1) Central City Drainage Zone (C – zone): refer to Table E.3.3 and Fig. E.3.6 (1/5)

(a) C.1 Catchment:
This basin with an area of 31.67 km^2 (29.8% of the basin) is located at the eastern part of C-zone, where is fully urbanized on relatively high land. The main canal is Nhieu Loc – Thi Nghe of about 9.4 km in length. Although the combined sewer system has been developed since 1870s, several areas have flooded frequently due to mainly luck of discharge capacity of sewers and main canal. DTPW has being undertaken the storm water drainage and sewerage improvement project in this

basin by assistance of World Bank.

(b) C.2 Catchment:
This basin with an area of 5.14 km^2 is located at the northeastern edge of C-zone, where is mostly urbanized (74% of the basin) on the fringe area between high land and low-lying areas. The main canal is Rach Cau Son – Rach Tau Vam Tat with a length of 2.26 km, of which discharge capacity is mostly sufficient for storm run-off. However, several low-lying areas have suffered 3 times a year in average from the backwater of the Saigon River affected by the high tide of the South China Sea.

(c) C.3 Catchment:
This basin covers the western part of C-zone with an area of 20.22 km^2. The main channel for urban drainage is Tan Hoa – Lo Gom canal of 7.77 km long connected with Tau Hu canal. The existing built-up area of 12.4 km^2 (61% of the basin) is projected at 16.67 km^2 (82% of the basin). A number of places in the basin have flooded frequently during the rainy and high tide seasons due to the insufficient capacity of the existing sewers and canals. The Government of Belgium and ADB has assisted PCHCMC to upgrade the environmental condition of the basin including drainage and sewerage.

(d) C.4 Catchment:
This catchment area of 61.73 km^2 is located at the center of C-zone composed of commercial, residential and institutional areas, of which the northern parts from Doi - Te canal are wholly urbanized and the southern parts from these canals have being developed as residential and industrial area. Future built up area is projected at 32.45 km^2 (78% of the basin). The main canals are Tau Hu - Ben Nghe (l = 12.43 km) and Doi - Te (13.55 km) which run in parallel to direction from east to west. Some parts on the high land have been inundated habitually due to lack of flow capacity of sewer pipes. Some low-lying areas along Tau Hu and Doi canals have been flooded sometimes during the high tide season from October to December. Pre-feasibility study on Tau Hu - Doi - Te canal improvement has undertaken by DTPW, however it has not been implemented yet.

(e) C.a, C.b and C.c Catchment:
These basins are very small independent areas situated along the right bank of the Saigon River. These areas have no main canals. Rainwater drains directly into the Saigon River through the channels in C.b and a part of C.a basins and the sewers in a part of C.a and C.c basins. Tanda at the western part of C.a basin has seriously flooded during the high water level of the Saigon River.

(2) Northern City Drainage Zone (N – zone): refer to Table E.3.3 and Fig. E.3.6 (2/5)

(a) N.1 Catchment:

This basin (19.87 km^2) is located at northern edge of the Study area, where has been developed as an agricultural land. The main canal is Rach Ben Da - Rach Ba Hong with a length of 9.99 km. This basin is basically projected to preserved as an agricultural land except its upstream basin in AMP prepared by UPI.

(b) N.2 Catchment:
This basin is very vast one with an area of 107.57 km^2 equivalent to 79% of the basin. Main canal of the basin is Rach Dai Han - Tham Luong - Ben Cat canal with a length of 14.98 km, which is situated at almost center of the basin, flowing toward from west to east direction and drains finally into the Saigon River. The existing built up area of 41.54 km^2 (39% of the basin) is projected at 68.81 km^2 (64% of the basin). It is anticipated that peak run-off will be gradually increased and inundation condition will be deteriorated furthermore. DTPW are formulating the integrated canal improvement including Tham Luong - Ben Cat canal and Rach Chua - Nuloc Len canal as the inner ring canal connected with the Saigon and Ben Luc rivers,

(c) N.a catchment
This basin (8.75 km^2) is located at the right bank along the Saigon River and has been used as an agricultural land. This area has been suffered from the high water level of the Saigon River because of low-lying area (0.5 to 1.0 m above MSL) and the insufficient embankment along the river. Almost 50% of the basin are expected to build up in future as a medium residential area.

(3) Western City Drainage Zone (W – zone): refer to Table E.3.3 and Fig. E.3.6 (3/5)

This zone is only one basin (W.1) with total area of 72.91 km^2. The main canals of this catchment are Rach Chua – Rach Nhoc Len (l=13.54 km), Ben Luc River (l=3.66 km) and Can Giuoc River (l=4.19 km). Rainwater collected to these main canals flow toward south and southeast direction and drain finally into the Nha Be River through the Can Guioc River. The canal improvement has being formulated by DTPW as inner ring canal together with Tham Luong - Ben Cat canal. The existing land use of the basin is mainly agricultural and residential areas, of which area is estimated at 14.39 km^2 (20 % of the basin), however is projected at 33.62 km^2 (46 % of the basin). This basin is expected to develop as residential and industrial areas in future. The inundation condition will be grown more serious due to rapid urbanization.

(4) Southern City Drainage Zone (S – zone): refer to Table E.3.3 and Fig. E.3.6 (4/5)

(a) S.1 and S.2 Catchment:
These basins of 29.98 km^2 in total located at the western part of S-zone between the provincial roads No.50 and 34, where is low-lying area (EL.0.5 to 1.2 m) being used as an agricultural field. Main canals are R. Ba Lao (l=6.85 km), R. Xom Cui (l=7.35 km) and R. Ong Ion-Kinh Cay Kho (l=8.39 km). Storm water collected by

these canals drain into the Can Giuoc River connected the Nha Be River. These basins have been protected from overflow of the surrounding rivers by small scale dyke system, unfortunately it has not been successful at present due to several eroded and damaged embankment. Inundation condition is, however, not serious. These basins are projected to preserve as agricultural lands. Development rates of S.1 and S.2 in 2020 are 26% and 33% respectively.

(b) S.3 Catchment:
This catchment area of 34.51 km^2 is located at the center of the S-zone between the provincial roads No. 34 and 15, where is low-lying area (EL.0.5 to 1.0 m) being also developed as agricultural field. Main canal composed of R. Tan, R. Ca Cam, R. Roi, R. Tom, and Muon Chuoi canals with total length of 11.92 km flows toward the direction from north to south at the center of the basin and drains into the Nha Be River. Flood condition of the basin is almost the same as S.1 and S.2. The existing built-up area of 3.54 km^2 (10% of the basin) is projected at 20.96 km^2 (61% of the basin) as a medium residential area. Execution of protection measures from the high water of surrounding rivers will be required in future.

(c) S.4, S.5, S.a, S.b and S.c Catchment
These small basins are located at the right bank along the Saigon and Nha Be rivers. A rate of existing built up area of each basin is about 10 to 20 % except S.a basin, however is projected at 50 to 60 % in 2020 as an industrial estate. S.4 and S.5 basins were selected as a typical one in this area.

(5) North-Eastern City Drainage Zone (NE-zone): refer to Table E.3.3 and Fig. E.3.6 (5/5)

(a) NE.1 and NE.2 Catchment:
Two (2) basins with total area of 12.85 km^2 are located at low-lying agricultural land (EL.0.5 to 1.0 m) at the left bank along the Saigon River. Main canals are Rach Ong Dua ((l=3.86 km) and Rach Go Dua (l=3.55 km). Although these basins are flood prone from the flood of Saigon River, these are expected to develop as medium residential area according to the AMP.

(b) NE.3 and NE.4 Catchment:
These basins (A=4.45 km^2) cover the main city of Thu Duc on high land lying between the national railway and the road No.1. Flood is not serious at present. It is, however, fearful that the flood problem in downstream low-lying area will occur due to the development in upstream hilly basin because of the high development rates from about 40% in 1997 to 90% in 2020.

(c) NE.5 Catchment:
This catchment covers the hilly and low lands in Thu Duc and District 9 with an area of 34.38 km^2. The main canal (Rach Nhum - Rach Cau - Rach Go Gone: l=12.58 km) lying the eroded small valley collects the rainwater and drain into the

Tac River. Only the downstream basin has been inundated by the high tide of the Dong Nai River. The built-up area in 2020 is projected 21.46 km^2 (62% of the basin) from 5.13 km^2 (15% of the basin). Since the peak discharge will be rapidly increased, canal improvement will be required in future to prevent from the overflow of the storm run-off.

(d) NE.a, NE.b and SE.c Catchment:
These small basins of 7.88 km^2 are situated at the left bank of the Saigon River. The land use of NE.a and NE.b are agricultural land and NE.c is industrial area. Out of three (3) basins, NE.a has inundated by the high water level of the Saigon River, however it is not serious.

(6) South-Eastern City Drainage Zone (SE-zone): refer to Table E.3.3 and Fig. E.3.6 (5/5)

(a) SE.1, SE.2, SE.3 and SE.4 Catchment:
These catchment areas of 14.3 km^2 in total are situated at the low-lying left bank of the Saigon River. Main canals are Rach Binh Khanh (l=2.46 km), Rach Ca Tre Nho (l=2.20 km), Rach Da Do (l=3.67 km) and Rach Giong Ong To (l=5.61 km) respectively. Flood conditions of these basins are not serious except few small areas of SE.3. SE.1 and SE.4, which are used as an agricultural field at present, are projected to preserve as a green open space in future. SE.2 and SE.3 are projected to develop from agricultural land to residential area.

(b) SE.5 and SE.6 Catchment:
These two (2) catchment areas of 8.93 km^2 in total located at the left bank of the Saigon River have been used as agricultural land. These basins have sometimes overflowed of river water of the Saigon River due to the damaged embankment along the river. These are expected to develop as the residential area for SE.5 and industrial estate for SE.6.

(c) SE.7, SE.8, SE.9 and SE.10 Catchment:
These catchment areas with an area of 71.90 km^2 in total are located at the center of SE-zone, where are mostly low-lying areas and have been developed as an agricultural field. The main canals (Rach R. Ong Hong-R. Chuic: l= 6.75 km, R. Ong Cay-R. Ba Cua-R. Ong Kieu: l= 6.99 km, R. Tan-R. Ong Nhieu: 6.95 km, Tac River: l=13.85 km) are connected each other and drain into the Saigon and Dong Nai rivers. Most of all the basins have been attempt to protect from the floods of the above rivers by the inner linked dyke system. Unfortunately, it has not been successful completely, because of not continuous embankment to close the basins. However, inundation condition is not serious at present. Almost 50% of the areas in SE.7, 8 and 9 are projected to developed as an medium residential area. Remaining areas are expected to preserve an green open space.

(d) SE.a, SE.b and SE.c Catchment:

These catchment areas of 10.65 km^2 are situated at the low-lying left bank along the Saigon River. SE.a and a part of SE.b have being developed as residential area. According to the AMP, SE.a, and SE.b are expected to develop as an residential and institutional area respectively. SE.c is projected to preserve the green open space.

(e) SE.d, SE.e and SE.f Catchment:
These basins of 13.52 km^2 are located at the low-lying right bank along the Dong Nai River. SE.d has being developed as the Cat Lai industrial estate, which is protected by itself from the flood of the Dong Nai River. Industrialization of this area will be expanded more. SE.e and SE.f have used as agricultural fields and are projected to preserve as a green open space in future.

3.3.3 Characteristics of the Canals

Hydraulic characteristics of 63 canals in the Study area, which include canal length, canal bed and bank elevations, width, depth, maximum flow area, wetted perimeter and average hydraulic gradient were studied based on the collected longitudinal and cross sectional data, field reconnaissance and supplementary surveys by the Study Team. These are summarized in Tables E.3.4 (1/3) to (3/3). Hydraulic characteristics of some trunk canals in each drainage zone are illustrated in Figs. E.3.7 (1/6) to (6/6) as reference. Details are compiled in Data Book on Hydraulic Features of Rivers and Canals.

Most of the canals in the inner city area including Nieu Loc - Thi Nghe, Tan Hoa - Lo Gom, Tau Hu - Ben Nghe, Tham Lung - Ben Cat canals, etc. have been narrowed, due to the encroachment of illegal house and building. These canal beds have also been shallowed by garbage, waste disposal and soil deposit disposed from houses along the canal. These problems are one of a primary factor of inundation.

On the other hand, the existing canal conditions in surrounding areas are relatively better, particularly in the paddy field in S and SE zones.

3.3.4 Existing Discharge Capacity of the Canals

Existing discharge capacity of the above 63 canals was also estimated based on the collected longitudinal and cross sectional data, in addition to the supplementary survey data by the Study Team. Even if the discharge capacity of the canal is obviously affected by the water level of the river at the outlet of the canal, it could be estimated average discharge capacity of each canal by the following Manning's Formula:

$$Q = 1/n * R^{2/3} * i^{1/2} * A \qquad R = A/p$$

Where, Q : Discharge (m^3/s)

n : *Coefficient of roughness*
R : *Hydraulic Radius (m)*
p : *Wetted perimeter (m)*
i : *Hydraulic gradient*
A : *Flow area (m^2)*

These results are shown in Tables E.3.4 (1/3) to (3/3) and Figs. E.3.7 (1/6) to (6/6).

The first step evaluation for the existing discharge capacity of the 27 canal systems has been carried out for the design discharge from 5 to 10 year return period under the condition of existing land use. Design discharge was estimated by Rational formula mentioned in Section 6.1.6. According to the calculation results shown in Table E.3.5, some canal systems, which are located in C, N W, NE zones, will be required to increase their discharge capacities by widening and deepening works.

3.4 Related Structures

The existing status of related structures along the canals and rivers, such as the port facility, dike, bank protection, bridge and culvert have been studied based on the data and information collected from the agencies concerned and supplementary field reconnaissance. These are as follows:

(1) Port

Three (3) river ports with total length of 7.9 km are provided along the Saigon River as shown in Table E.3.6 and Fig. E.3.8 (1/2). The port facilities fulfill their function as the dike to protect the landside land from flood of the Saigon River. Tan Cang port belongs to Ministry of National Defense. The other two ports; Saigon and Ben Nghe ports are operated and maintained sufficiently under the DTPW.

(2) Dyke System

The Service of Water Resources (SWR), of which organization is now incorporated into Department of Agriculture and Rural Development (DARD), has constructed several dyke systems consist of embankment, earth dam and water gate along the rivers and canals in and around the Study area since 1976. These dike systems are shown in Fig. E.3.8 (1/2). The construction of the dyke system has undertaken in the following two phases under the different purposes.

(a) From 1976 to 1982

A large link dyke system, which composed of embankment, earth dam and gate, has been constructed along the Saigon, Dong Nai, Nha Be and some other rivers, in order to prevent the flood and salinity intrusion from the rivers. However, these

systems are not functioning sufficiently. Because the embankments has not constructed continuously, in addition, these facilities are now damaged, eroded and collapsed due to the insufficient operation and maintenance work based on the budgetary constrain.

(b) From 1983 to 1998

Small-scale inland dyke systems, which composed of embankment and water gate, have been constructed in the southern region of Hoc Mon district, the northern region of Binh Chanh and Nha Be districts to prevent flood and salinity intrusion from the surrounding rivers. The systems in Hoc Mon and the western part of Binh Chanh districts are functioning thoroughly under the sufficient operation and maintenance. However, in Nha Be and the southern region of Binh Chanh districts, some parts of the embankments have been damaged and eroded. So, floodwaters intrude sometimes into the low-lying paddy fields during the high tide season.

The existing condition and structural features of each facility are mentioned below:

(a) Embankment

Embankments with total length of 246.5 km have been constructed between 1976 and 1997 as shown in Table E.3.7. Top elevation of the embankment was designed at 2.0 m above MSL. The width of top of slope ranges from 1 to 3 m for small embankment and from 3 to 5 m for big one. As mentioned the above, since some parts of the embankments along the Saigon, Dong Nai rivers and some canals in Nha Be and Binh Chanh districts have been damaged, eroded and collapsed, these are not functioning sufficiently.

(b) Dam

Eight (8) dams have been constructed at the mouse of canal together with a gate between 1976 and 1980, out of which six (6) dams are in District 2 and 9 and two (2) dams are in District 7. Structural features and location of the earth dams are shown in Table E.3.8 and Fig. E.3.8 (1/2) respectively. The dam was designed the earth dam with the width of 5-6 m at the top of slope and top elevation of 2 m above MSL. Six (6) dams are operational under the good condition except two (2) constructed at Rach Bang and Rach Dia.

(c) Gate

From 1976 to 1980, eight (8) main gates shown in Table E.3.9 have been constructed in District 2 and 9. Many small gates have been built in Binh Chanh, Nha Be and District 7 between 1982 and 1998 as shown in Fig. E.3.8 (1/2). Currently, two (2) major gates; An Ha and Kenh C have been constructed in Binh

Chanh district during 1994-1996. These two (2) gates work well because of satisfactory quality control and sufficient operation and maintenance. Most of other gates are not operational because of insufficient operation and maintenance.

(3) Bank Protection

Some part of the river and canals, such as the Saigon River, Doi, Te, and Ben Nghe canals, has been provided the bank protection facilities by DTPW since 1950s. Total length of the bank protection is approximately 17.2 km, of which the existing condition are evaluated to be mostly good except few sections of 900 m in each of Tau Hu and Thi Nghe canals. These facilities are made of stone masonry, concrete block and reinforced concrete. These are shown in Table E.3.10 and Fig.E.3.8 (1/2).

(4) Bridges

Structural data and information of 92 road bridges along the canals including two (2) railway bridges have been collected from the agency concerned, DTPW, Road Bridge Company (RBC) and OWM. The Study Team has carried out the bridge survey to supplement the collected data and information. The number of bridges by type of superstructure and the drainage zone is summarized the table below:

NUMBER OF BRIDGES IN THE STUDY AREA

Drainage Zone	Number of Bridge by Type of Superstructure				
	Total	RC	PC	Steel	RC&Steel
Central Zone	37	9	17	5	6
Northern Zone	11	2	7	1	1
Western Zone	11	2	4	2	3
Southern Zone	13	0	11	2	0
Northeastern Zone	8	3	2	1	2
Southeastern Zone	12	4	2	3	3
Total	92	20	43	14	15

Note: RC: reinforced concrete, PC: pre-stressed concrete,

Tables E.3.11 (1/4) to (4/4) and Fig. E.3.8 (2/2) show the structural features of the bridges and these locations respectively.

(5) Culvert

There exist some pipe and box culverts at the crossing with road and canals. Structural features and locations of these culverts are listed in Table E.3.12 and presented in Fig. E.3.8 (2/2). Since the existing discharge capacities of these culverts may not enough for the design requirements, it will be required that these facilities are to be improved.

3.5 Waterway Transport (Navigation)

3.5.1 Present Condition and Necessity of Waterway Transport

Waterway transport in HCMC has been taken up as one of the main transport means on the background of developed navigation system consisting of over 1,200 km navigable rivers, canals and channels. Among these waterways, about 200 km sections are being able to convey 5,000 - 25,000 ton sea ships, about 250 km sections are for passing of 200 - 500 ton tugboats, about 250 km sections are for circulating of 50 - 100 ton ships and/or boats, and remaining sections are serving for traveling of 2 - 50 ton boats.

At present, over millions of tons of import and export goods are annually transported through the big rivers. The national waterways connected with HCMC and Mekong delta provinces are serving to transport the domestic products and agricultural goods of 4 to 5 million tons. The domestic products including construction materials (sand, stone, brick, timber, etc.) of about dozens million tons are also transported by canals and channels. It is forecasted that the needs of the waterway transport in HCMC will not be decreased considering its advantage on the dense and developed river and canal system in the city.

3.5.2 Navigable Canal in the Study Area

The Department of Transport and Public Works (DTPW), HCMC is responsible for the administration of traffic and waterway transport within the city. HCMC has managed almost 970 km rivers, canals and channels, in which about 736 km sections shown in table below are managed as the navigable waterways by Office of Waterway Management (OWM) and the remaining 234 km sections are managed by Urban Drainage Company (UDC) as the urban drainage facilities.

LIST OF WATERWAY IN HCMC ADMITTED BY WMC

Area	Number of Course	Canal Length (km)	Technical Grade					
			I	II	III	IV	V	VI
Cu Chi	14	109.0	-	-	-	37.8	-	71.2
Hoc Mon	08	74.8	-	-	-	49.1	-	25.7
Thu Duc	17	82.9	-	-	-	34.7	-	48.2
Binh Chanh	16	100.4	-	-	25.3	24.7	12.6	37.8
Inner City	14	71.8	-	-	1.3	31.2	11.4	27.9
Nha Be	19	74.6	-	-	-	29.5	11.7	33.4
Can Gio	25	223.0	100.1	5.2	44.0	46.5	12	15.2
Total	113	736.5	100.1	5.2	70.6	253.5	47.7	259.4

Note: The waterways are classified into six-(6) grade on the requirements of navigation.

In the study area, there are 66 navigable rivers and canals with total length of 309.1 km equivalent to almost half of them in HCMC as shown in the table below:

LIST OF WATERWAY IN THE STUDY AREA ADMITTED BY OWM

Drainage Zone	Number of Course	Length (m)	Technical Grade					
			I	II	III	IV	V	VI
C-Zone	15	68.1	-	-	14.5	10.1	11.6	31.9
N-Zone	5	35.2	-	-	-	9.5	8.0	17.7
W-Zone	9	47.5	-	-	10.4	2.0	13.8	21.3
S-Zone	19	75.4	-	-	8.3	33.6	9.7	23.8
NE-Zone	4	18.2	-	-	-	-	-	18.2
SE-Zone	14	64.7	-	-	-	32.7	-	32.0
Total	66	309.1	-	-	33.2	87.9	43.1	144.9

Tables E.3.13 (1/2) and (2/2) show the list of navigable rivers and canals admitted by OWM by each drainage zone in the study area. These locations are illustrated in Fig. E.3.9.

3.5.3 Navigation Problems along Canals

Recent rapid urbanization, motorization and lack of sufficient management for watercourse in HCMC have made the following problems for navigation:

(a) Some of the rivers and canals such as Bao Ngan canal, U Cay channel, etc. have been filled up and replaced to the covered sewer lines.

(b) The width of the rivers and canals have been reduced due to the encroachment of the illegal buildings, houses and other structures along the both banks. According to the current survey result, the number of encroaching structures were counted as almost 25,000 structures along the rivers and canals of about 70 km within the inner city.

(c) Due to poor garbage collection system, people's habitual action and lack of social morality, some rivers and canals have been dumped garbage, refuse and waste disposal which cause to block for navigation and to pollute the river water.

(d) Since the dimensions of watercrafts have recently been become much larger due to the cargo requirements, most of the bridges constructed in old time have not enough clearance for boat and barge passing.

3.5.4 Canal Dredging Project

(a) Periodical Dredging Project

OWM is undertaking the periodical dredging projects for several canals in the city to maintain the required canal cross section for city drainage and inland navigation of ships and boats. The recent dredging projects are listed as below:

- Nhieu Loc - Thin Nghe canal: 250,000 m^3
- Ngang No.2 and Ngang No.3 canal: 60,000 m^3
- Lo Gom canal: 170,000 m^3

(b) New Canal Dredging Project

In 1997, OWM has planned the waterway development project in HCMC integrated with the improvements of urban drainage and ecological environment functions. The project includes the canal improvement and river port development. As a part of this project, the following canal dredging works are projected from 1999 to 2,000.

- Ben Nghe (Grade 5), Tah Hu (Grade 4) and Lo Gom (Grade 6) canal: 800,000 m^3
- Te canal (Grade 3): 100,000 m^3
- Vanh Dai Trong (Grade 4) canal: 1,000,000 m^3
- Trao Trao and Chiec (Grade 4) canals: 600,000 m^3
- Giong Ong To (Grade 4) canal: 600,000 m^3

3.5.5 Design Criteria of Navigation Canal

Navigable rivers and canals are classified into six (6) grade based on their navigation requirements. The above canal improvements are to be carried out based on the design criteria provides in the National Inland Waterway Standard. Table E.3.14 shows the design criteria for navigation. According to this, the cross sectional requirements of navigable rivers and canals are mostly sufficient for the urban drainage requirements.

3.6 Drainage Pipe System Facilities

3.6.1 Drainage Pipe System

(1) History of Construction

Construction of drainage pipe dates from the 1870s and most of drainage pipe was mostly installed in the following different periods.

The drainage pipe system was originally designed by French engineers, with construction beginning in the 1870s. Construction continued in stages since that time to generally follow the city's expansion and centered on the old French city area, in District 1and 3.

According to the field investigation for the study entitled " Saigon Sewerage Feasibility Study " prepared by USAID and Ministry of Public Works, Vietnam in 1971, at the time about 113 km length of main drainage pipe had already been installed. The investigation also confirmed that these pipes were installed in the 1870s.

In the late 1960s, the Americans had expanded the drainage pipe network to District 10.

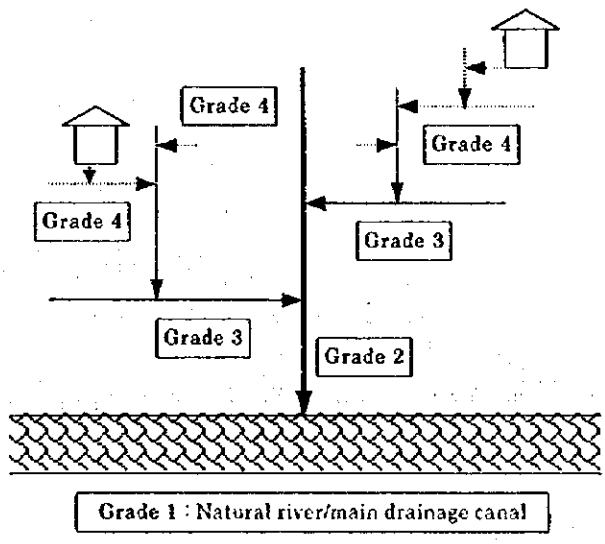
After the unification of the nation, the construction of drainage pipe network have continued since the early 1980s.

(2) Classification of Pipes

The existing drainage systems are classified into "3" **Grades** by UDC. The classification of "3" **Grades** was established to give priority in the drainage improvement and management plan.

Definition of "3" **Grades** is described in the table and the schematic below. The definition is based on a hierarchy of branches of drainage pipe network but not the dimensions.

Classification		Definition
Grade 2	:	Main pipe receiving storm/wastewater from ***Grade 3*** pipe and discharging directly into natural and main drainage channels ***(Grade 1)***.
Grade 3	:	Secondary pipe receiving storm/wastewater from ***Grade 4*** pipe and discharging into ***Grade 2*** pipe.
Grade 4	:	Tertiary pipe receiving storm water/wastewater from houses and discharging into ***Grade 3*** pipe.



The drainage pipes of **Grade 2** and **Grade 3** have been constructed by UDC and those of **Grade 4** have been constructed by district offices.

(3) Cross-section of Pipes

In general, cross-sections of drainage pipes are classified into 3 types, which are horse-shoe, circular and quadrilateral shaped ones. Furthermore, according to the typical cross-section, these are broken down into 12 types as presented in Table E.3.15 and Fig. E.3.10.

At the present time, the cross-sections of Type-D and Type-F are employed for the drainage pipes by UDC and district offices.

(4) Coverage Area and Length

a) Coverage Area

Among the 20 districts comprising the study area, 17 districts are covered by drainage system partially or entirely.

The total coverage area is approximately 62 km^2, which is about 12 % of the entire study area, as presented in Fig. E.3.11.

The coverage ratio of District 1, 3 and 5, which are urban district, is estimated at 100 %. However, Binh Chanh district belonging to rural district is estimated at only 0.3 %.

The coverage area and ratio by district is presented as the table below. The table shows that districts belonging to urban district have higher coverage ratio than districts belonging to new urban and rural districts.

District Name	Entire District Area (km^2)	Coverage Area (km^2)	
Urban District			
(1) 1	6.91 *1	6.91	100.0%
(2) 3	4.82 *1	4.82	100.0%
(3) 4	4.15	3.40	81.9%
(4) 5	3.97 *1	3.97	100.0%
(5) 6	7.01	4.82	68.8%
(6) 8	19.21	3.62	18.8%
(7) 10	5.69	5.49	96.5%
(8) 11	5.15	4.67	90.7%
(9) Go Vap	19.62	3.87	23.3%
(10) Tan Binh	38.27	10.44	27.3%
(11) Binh Thanh	20.81	4.02	19.3%
(12) Phu Nhuan	5.25	3.08	47.8%
Sub-total	140.86	59.11	42.0%

New Urban District			
(13) 2	49.90	0.19	0.4%
(14) 7	34.71	1.17	3.4%
(15) 9	114.18	0.71	0.6%
(16) Thu Duc	47.95	0.48	1.0%
Sub-total	246.74	2.55	1.0%
Rural District			
(17) Binh Chanh	142.88	0.40	0.3%
Total in Study Area	530.48	62.06	11.7%

Note : *1 excludes a area of river/channel.

b) Length

The total length of existing drainage pipe of **Grade 2** and **Grade 3** in the study area is estimated at approximately 533 km and its breakdown by **Grade** is presented in the table below. Furthermore, the length of existing drainage pipes by district and type is presented in Table E.3.16 and the location of the main drainage pipes is shown in Fig. E.3.12.

District / Classification	Length (m)					
	1	3	4	5	6	8
Grade 2	29,133	13,768	18,403	12,596	20,732	11,541
Grade 3	48,956	41,163	17,557	17,958	21,639	11,419
Sub-total	78,091	54,931	35,960	30,554	42,371	22,960
Grade 4	33,505	58,264	56,331	33,339	68,400	56,753
Total (m)	111,596	113,195	92,291	63,893	110,771	79,713
District / Classification	10	11	Go Vap	Tan Binh	Binh Thanh	Phu Nhuan
Grade 2	7,493	12,989	4,961	19,284	26,007	16,725
Grade 3	35,882	49,345	18,847	38,611	9,866	9,480
Sub-total	43,375	62,334	23,808	57,895	35,873	26,205
Grade 4	54,488	4,907	10,428	84,420	40,674	68,735
Total (m)	97,863	67,241	34,236	142,315	76,547	94,940
District / Classification	2	7	9	Thu Duc	Binh Chanh	Total in Study Area
Grade 2	2,000	4,823	2,150	3,650	3,400	209,657
Grade 3	300	1,777	-	250	-	323,050
Sub-total	2,300	6,600	2,150	3,900	3,400	532,707
Grade 4	-	-	-	-	-	570,244
Total (m)	2,300	6,600	2,150	3,900	3,400	1,102,951

Note : Information on Grade 2 & 3 is provided by UPI
Information on Grade 4 is provided by UDC

(5) Condition of Outlets

These drainage pipe systems are finally discharging into near-by river/main canals (for

example, the Saigon River, the Tau Hu-Ben Nghe, the Doi-Te and the Nhieu Loc-Thi Nghe canals).

The total number of outlet along the river/main canals counts 228 places and are listed as below.

The majority of outlets are located along the Tau Hu-Ben Nghe canal. Those outlets are discharging wastewater collected from District 1, 3 and 10.

Rivers/Canals	Nos. of Outlet
Saigon R.	20
Tau Hu-Ben Nghe C.	80
Doi-Te C.	34
Nhieu Loc-Thi Nghe C.	47
Hang Bang C.	17
Tan Hoa-Lo Gom C.	27
Tham Luong-Ben Cat C.	3
Total	228

3.6.2 Evaluation of Existing Drainage Pipe System

Existing discharge capacity of the existing main drainage pipe was estimated based on the collected longitudinal and cross sectional data of the drainage pipe, in addition to the supplementary survey data by the Study Team.

The existing drainage pipe systems are large and complex networks. Furthermore the outlets of the drainage pipe system are affected by the tidal time varying water levels.

Thus, for consideration of the drainage pipe network and the hydraulic condition at the outlet, MOUSE can be applied to modeling. More detailed explanation of modeling by using MOUSE is stated in Chapter C.

The evaluation for the discharge capacity of the existing main drainage pipe system has been carried out for the design rainfall of 3 year return period and the design flood water level of 2 year return period under the condition of existing land use. Design discharge was estimated by Rational formula mentioned in Section 6.1.6. According to the calculation results, some main drainage system systems, which are shown in Table E.3.17 and Fig. 3.13, will be required to increase their discharge capacities by installation of additional pipes.

4. REVIEW OF RELEVANT STUDIES AND ON-GOING PROJECTS

4.1 Pre-feasibility Study on Environmental Improvement Project of Ho Chi Mhin City

Department of Transportation and Public Works (DTPW), PCHCM has executed the pre-feasibility studies on environmental improvement project for some main canals in inner city area. These are as follows:

4.1.1 Improvement and Construction of Nhieu Loc - Thi Nghe Canal

(1) Summary of the project

The project has been carried out by the Urban Drainage Company (UDC) in 1996. The objectives of the project to conduct the pre-feasibility study on drainage (storm water and sewerage) system improvement of Nhieu Loc - Thi Nghe catchment area including construction of suitable street (right of way) along the canal to improve the environmental conditions and land acquisition & house relocation. Location of the project is shown in Fig. E.4.1.

(2) Findings

Findings concerning with the urban drainage are as follows:

(a) Considering the overage and poor capacity of the existing secondary sewers and the necessity of expansion of tertiary sewers for newly developed areas, the existing drainage networks with a combined system were proposed to improve and rehabilitate widely except the newly constructed facilities. The proposed improvements of drainage pipe are as follows:

- Total length of secondary sewer improvement: 75,405 m
- Total length of tertiary sewer improvement: 183,800 m
- Total cost of sewer system improvement: 458.3 billion VND
  This cost excludes the land acquisition and house relocation.

The sewer pipe installation is proposed to execute in parallel with the street improvement works and to complete up to 2005.

(b) For the canal improvement of 9,035 m long, normalization of the meandering was proposed result in shortening the canal improvement length of 725 m. Alternative study for the bank protection (4 options) was conducted and the following two (2) kinds of the canal shape and bank protection were proposed.

PROPOSED BANK PROTECTION

Shape of Canal	Bank Protection	Section
Rectangular	Concrete Pile Wall	From Dang Ding Dang St. to Kieu bridge (4,622m)
Trapezoid	Grass with Soil Basket	From Kieu bridge to Saigon River (4,622 m)

Note: Concrete pile wall was evaluated to be more economical than concrete wall in comparative study.

(c) Construction costs of canal improvements were estimated as follows:

- Dredging and canal normalization: 40.23 billion VND
- Bank protection & bank filling: 7.63 billion VND
- Embankment: 80.94 billion VND
- Contingency: 12.88 billion VND
- Total: 141.68 billion VND

4.1.2 Implementation, Construction and Rehabilitation of Tan Hoa-Ong Buong-Lo Gom Canal

(1) Summary of the Project

This project has been conducted by the Consulting Construction of Transportation and Public Works Monument Company in 1997. The main objectives of the project are to conduct the pre-feasibility study on storm water and sewerage system of Tan Hoa - Ong Buong - Lo Gom catchment area of 14.84 km^2. The project also includes the recover of the waterway transport for the canal, improvement of the road and street along these canals and land acquisition /relocation. Fig. E.4.1 shows the location of the project.

(2) Findings

Findings regarding to the urban drainage are as follows:

(a) Existing drainage system consists of the main canal of 7.8 km, five (5) tributaries: Dam Sen, Bau Trau, Ba Lai, Thui and Hang Bang canals, and the secondary and tertiary sewer pipes with a total length of about 127.6 km, which are distributed complicatedly and unevenly in the catchment area.

(b) The canal has being narrowed and shallowed due to the encroachment of illegal houses and buildings, and a lot of garbage and waste disposal including construction refuse. Hydraulic features of the canal are mentioned in Chapter 3.

(c) The canal is affected by the semi-tide mechanism of Saigon River. So, in the high tide season from October to December, the low land areas along the canal have flooded sometimes times a year.

(d) Summary of the proposed sewer pipe improvement is as follows:

- Total length of secondary sewers: 54,770 m
- Total length of tertiary sewers: 100,300 m
- Total construction cost excluding relocation cost: 270.8 billion VND

(e) The canal improvement is proposed for the following two (2) sections

- Part 1: 10.4 km from the uppermost point to Phu Lam bridge
- Part 2: 2.8 km from Phu Lam bridge to Tha Hu canal

The proposed cross sections of the canal of Part 1 and 2 were estimated based on the hydraulic requirement for design flood run-off of 5-year return period and for the waterway transport respectively.

(f) As a result of the alternative study for Part 1 canal improvement, the construction of box culvert (2,850 m) from the uppermost point to Ong Ich Khiem and trapezoidal shape canal (slope 1:1) with sod bank protection from Ong Ich Khiem to Ong Buong bridge (1,950 m) were proposed. Total construction cost was estimated at 32.09 billion VND including 5% of the total construction cost.

(g) For Part 2 canal improvement, the following two sections were proposed.

PROPOSED CROSS SECTION OF LO GOM CANAL

Section	Bottom Elevation (m)	Bottom Width (m)	Passage Depth (m)	Bank Slope (m)
Part 1	-3.8	>24.6	1.9	3
Part 2	-2.9	>10.5	1.0	3

Note: Part 1: 1.0 km from Km 0 to Km 1
Part 2: 1.8 km from Km 1 to Phu Lam Bridge

(h) Dumpsite of the dredged materials is selected at Do Hoa in Can Gio district, 25 km far from the project site. Total dredging cost was estimated at 10.1 billion VND (45,900 VND/m^3)

(i) Hydraulic design criteria for urban drainage plan were mainly used Viet Nam standard, as usual.

4.1.3 Tau Hu - Doi - Te Canal Improvement

(1) Summary of the project

This project has been conducted by Construction Consulting Company (CCC), DTPW,

HCMC from 1997 to 1998. The main objectives of the project are to conduct the pre-feasibility study on drainage (storm water and sewerage) system and environmental improvements of Tha Hu - Doi - Te catchment area of 28.51 km^2. The project also includes the recover of the waterway transport for Tha Hu canal, improvement of the road and street along these canals and land acquisition /relocation. Location of the project is shown in Fig. E.4.1.

(2) Findings

Findings regarding to the storm water drainage are as follows:

(a) For the drainage pipe improvement works, the following two Options were studied.

Option 1: Using the combined system for the whole area
Option 2: Using the separate system for newly developed area

The proposed scope of work and construction cost for the above Options are mentioned the table below:

COST COMPARISON OF OPTIONS FOR DRAINAGE SYSTEM

Item	Option 1	Option 2
Total length of secondary drainage pipe improvement (m)	92,506	92,506
Total length of tertiary drainage pipe improvement (m)	134,589	134,589
Total length of sewerage pipe construction(m)	-	100,929
Total construction cost (billion VND)	598.49	847.67

Option 2 was selected result from the preliminary comparison study on construction cost, easiness of operation & maintenance and construction.

(b) The canal improvement plan was studied for only Tha Hu canal from a viewpoint of the waterway transport. Because Doi - Te canal is being prepared the rehabilitation project for waterway by Ministry of Transportation (MOT).

(c) Design water level of Tha Hu canal is employed to be -1.2 m, which is 90% frequency for the satisfactory navigation. For two parts of Tha Hu canal, the following cross-sections were proposed.

PROPOSED CROSS SECTION OF THA HU CANAL

Section	Bottom Elevation (m)	Bottom Width (m)	Depth (m)	Bank Slope (m)
Part 1	-3.3	21.0	2.1	3
Part 2	-4.3	22.0	3.1	3

Note: Part 1: 4.3 km from Chu Y bridge to Ngan canal No.1
Part 2: 4.7 km Ngan canal No.1 to Phu Dinh crossing

(d) Dumpsite of the dredged materials is selected at Do Hoa in Can Gio district, 25 km far from the project site. Dredging cost is estimated at 31,860 VND/m

4.2 Hang Bang Canal Area Rehabilitation

4.2.1 Summary of the Project

This is one project component of the HCMC Environmental Improvement Project assisted by the Asian Development Bank (ADB). This project is a feasibility study on the rehabilitation of the sewers and drains in the Hang Bang canal catchment area, where was selected by HCMC as a high priority area of its citywide flood relief program. The project area of 3.8 km^2 covers District 5,6 and 11, which is one of the most densely populated areas of HCMC. The project has started at the beginning of February 1998 and will be completed up to the end of December 1998. The implementation agency of HCMC is Department of Science, Technology and Environment (DOSTE). Fig. E.4.1 shows the location of the project.

4.2.2 Findings

According to the Interim Report (IT/R) submitted DOSTE in June 1998, findings of the project are as follows:

(a) Three (3) options developed by UDC as alternative proposal have being studied for the drainage improvement. The difference of each option relates mainly to the method of rehabilitating the Hang Bang canal. The project cost of each option consisting of construction and relocation costs are reported in the table below:

COST ESTIMATE Unit: VND: billion, US$:million

Option	Construction		Relocation		Total	
	VND	US$	VND	US$	VND	US$
1	154	11.9	73	5.6	227	17.5
2	129	9.9	157	12.1	286	22.0
3	185	14.3	56	4.3	241	18.6

The optimum plan will be identified in the Final Report as a result of the integrated project evaluation consists of technical, economical, financial, social and environmental evaluation.

(b) Design criteria adopted are as follows:

Run-off Formula:	Rational's Formula
Run-off coefficient:	0.8
Time of concentration:	the same with UDC (VN standard)

Design Mean High Water Level: +1.00 m at Tha Hu canal

4.3 Canal Tan Hoa - Lo Gom Sanitation & Urban Upgrading Project - HCMC

4.3.1 Summary of the Project

This project has started on April 1998 to contribute a better quality of life in the Tan Hoa - Lo Gom basin and to strengthen the capacity of the communities and institutions involved to deal with problems related to urban development, water pollution and environmental deterioration. The project is scheduled for a period of 36 months and its budget is planned at 220 million Belgian Francs (BEF), of which 175 million BEF is a grant by the Belgium Government. Location of the project is shown in Fig. E.4.1.

4.3.2 Findings

Findings related to the urban drainage looked out through the collected Project Document are as follows:

(a) This is a global environmental improvement project in Tan Hoa - Lo Gom basin, which consists of seven (7) specific strategy for improvement of deteriorating living and sanitation environment concerning with solid waste disposal, wastewater treatment, canal inspection/maintenance, strengthening of institution, peoples awareness/participation, relocation and socio-economic support.

(b) Activities related urban drainage include the following:

- Assess on-going canal maintenance and especially identify bottlenecks of the canal,
- Strengthening of canal inspection and, maintenance service,
- Design and implement of canal cleaning and re-shaping pilot project for approximately 5.0 km long. However, detail of pilot project has not prepared yet.

4.4 Feasibility Study and Preliminary Design on Ho Chi Minh City Sewerage Project, Nhieu Loc-Thi Nghe Basin

4.4.1 Summary of the Project

In response to the request of Viet Nam Government for the World Bank, this project has started on mid. August 1998. The main purpose of the study is to carry out the comprehensive feasibility study and preliminary design of the project components, which consists of rehabilitation of the drainage system and environmental improvements in the Nhieu Loc - Thi Nghe basin, in order to consider financing, the International Development Agency (IDA). The project area is shown in Fig. E.4.1.

According to the Draft Inception Report (DIC/R) submitted on October 1998, it is reported that the feasibility study will be finished on mid. June 1999 and the project including the preliminary design will be completed on mid. August 1999.

4.4.2 Findings

Findings concerning with the urban drainage improvement looked through the DIC/R are as follows:

(1) The urban drainage improvement works will be included in the proposed project component are as follows:

(a) Renovation and replacement of existing drainage network and its extension to unserviced areas

(b) Canal improvements including canal alignment, dredging, and bank protection

(c) Resettlement for canal improvements

(2) The MIKE-SWMM software package, which is a Windows-based user- friendly software package developed initially by the Danish Hydraulics Institute (DHI) will be applied for the modeling of the drainage system. As the work progress, other models including the Rational Method may be used as appropriate for design of storm water drainage improvements.

(3) It is required that adjustment between the project area (Nhieu Loc - Thi Nghe Basin) illustrated in DIC/R and our proposed drainage basin of Nhieu Loc - Thi Nghe canal is to be carried out.

5. FLOOD AND FLOOD DAMAGE

5.1 General

Floods in a large number of HCMC have occurred several times during a rainy season between June and November and high tide season from October to January in every year. Floods are classified roughly into three (3) types. First is the external flood type that occurs in low-lying areas and results from the high water levels of surrounding canals and rivers. Second is the internal flood type occurred in relatively high land area and caused by the heavy rainstorm. Third is mix type flood occurred in the intermediate land and caused by combination of the above two (2) reasons.

In order to clarify the actual flood conditions including inundation area, depth, duration and frequency of habitual flood and to collect the flood damages data for estimation of direct and indirect damage costs, the following stepwise studies have been undertaken.

(a) 1st step: Review of the current data and information collected
(b) 2nd step: Hearing for 19 districts in the Study area
(c) 3rd step: Supplementary flood and flood damage survey

Each stepwise study is mentioned below.

5.2 Review of Current Flood and Flood Damage Data and Information

5.2.1 Survey in ADB Project

In July 1995, flood and flood damage survey in HCMC has been conducted in the Environmental Improvement Planning Project for HCMC with a financial support of Asian Development Bank (ADB). The objectives of the survey are to identify flooding and water logging caused by rainstorm and/or high water level due to tidal influence and to determine flood damage curve associated with rainstorm probability curve. The survey was carried out by a direct interview on 28 July 1994 flood (referred to as 1994 flood) for 150 families in severe inundation areas of District 4, 6 and 10. The survey results are as follows:

(1) Inundation survey results

Most of the families under the survey (85% in average) were situated in areas having a combined pipe sewer system. Functioning of the system was evaluated as good, moderate and poor service in order of 15%, 47% and 25% respectively.

It was found that inundation in the inner city area has been mainly caused by high intensity rainstorm (91%). Only 1% of total interviewed family reported affecting from tidal effect and 8% by combination of rain and tide.

The important reasons causing inundation reported by those families are drainage pipe damaged (47%), channels and canals covered by rubbish (17%), low ground elevation (15%) and no drainage system (14%).

Average inundation depth in 1994 was 25 cm in the survey areas with total submerged floor areas of 6,943 m^2. Flood conditions of each district are described below.

FLOOD CONDITIONS OF 1994 FLOOD IN DISTRICT 4, 6 AND 10

Items	District 4	District 6	District 10
Max flooding depth in 1994 (cm)	14	30	30
Flooding times in 1994 (hour)	5	8	8
Max flooding depth (cm)	16	37	30
Average flooding depth (cm)	7	31	19

The inundation area of 1994 flood was estimated to be 128.73 ha occupying 0.9% of the inner city area of about 140 km^2 and 1.75% of urban area in 1994. The affected area by inundation damage was considered to be 102.99 ha equivalent to 80% of the estimated inundated area. Flood prone areas in 1994 flood within inner city area of HCMC is shown in Fig. E.5.1.

(2) Flood damage survey results

Almost 45,000 residents affected by 1994 flood equivalent to 6,430 households was estimated from affected area by districts and population density in 1994. Average flood losses was estimated as VND 34.102 million per ha affected by inundation based on the collected flood lose data of VND 23.677 million for 150 households with submerged floor area of 6,943 m^2.

Flood losses in 1994 for the inner city, which are functions of damage unit rate (the above average damage loss), population density coefficients and affected submerged area, was estimated as VND 3,370 million. In addition, considering the loss of the governmental companies due to late for work as VND 450 million and maintenance cost of HCMC increased by 1994 flood of VND 2,000 million, total flood damage cost was estimated as VND 5.82 billion equivalent to US$ 0.53 million.

The relationship between flood damage and return period is reported as follows:

FLOOD DAMAGE COST BY FREQUENCY

Return Period (years)	P (%)	Flood Damage (billion VND)
2	50	0
5	20	5.82
10	10	7.50
20	5	10.0

5.2.2 Available Data and Information from Steering Committee of Flood and Storm Prevention (SCFSP) and Department of Agriculture and Rural Development (DARD)

On 19 December 1998, SCFSP has made a final report on 1996 flood and storm prevention in HCMC. Summary of the report is as follows:

(1) Flood Condition

The flood in 1996 caused by the flood water from the Mekong Delta was a serious one in HCMC. Main reason of the flood is combination of the highest water level of the Vam Co, Saigon, Dong Nai rivers within current 40 years and relatively heavy rainfalls in surrounding areas. It has lasted about one month from 10 October to 11 November 1996.

The flood water from the Vam Co River overflowed into HCMC has caused a large inundated area of 15,000 ha with a depth of 1.0 m in the West and South West of the city including Cu Chi, Hoc Mon district and the greater part of Binh Chanh district. In the downstream area of the Saigon and Dong Nai rivers, only an area of 1,500 ha in Thu Duc and a part of Cu Chi has inundated at the depth of 0.3m. The high tide on October 25,26 and 27, 1996 has caused serious inundation damage in many areas including Nha Be, Can Gio districts in the South of the city.

Many areas in inner city have also seriously inundated in 1996 rainy season. The inundation depth was about 0.3 - 0.5 m and its duration was 2 - 3 hours. It was reported that the main reason of the inundation was poor capacity of the sewer pipes and lack of sufficient maintenance work for drainage facilities; sewer pipes clogged by garbage and channels/canals blocked by rubbish and waste disposal. Flood condition of some districts are described below:

(a) District 6: There were 11 seriously inundated sites with a depth of 20 - 60 cm and its duration of more than 2 hours
(b) District 5:There were 71 inundated points including 36 points with 2 - 3 hours inundation and 19 points with more than 50 cm inundation depth.
(c) Tan Binh district: There were 5 serious inundation areas with inundation depth of 30 - 100 cm.
(d) Binh Thanh district: There were 9 seriously inundated areas with depth of 20 - 50 cm, especially an area of 50,000 m^2 of ward 13 has flooded with inundation depth of 20 - 120 cm and ward 21 with 100 cm in depth.

(2) Flood Damages

According to the flood report from the districts, floods in 1996 have affected mainly suburban areas. Average flood damages on agricultural production was estimated as the flood loss of 4,965 ha of paddy field, 3,684 ha of sugar cane fields, 365 ha of fruit gardens, 253 ha of fish breeding ponds. 1,015 households in Ch Chi district and 3,940 households in Binh Chanh district were affected.

Damages on infrastructure and irrigation works were estimated at 37 billion VND including 4.72 billion VND for canal damaged, 20.53 billion VND for dikes and rural road eroded, 11.33 billion VND for 65 culverts and weirs collapsed, and 190 million VND for power and fuel used for pumping.

In the inner areas of the city, flood has caused in many direct and indirect damages for peoples, such as general and public property loss, income and sales loss, transportation loss, etc.

5.3 Hearing for 19 Districts

Actual and specific information of the current flood and flood damage have been collected from 19 district offices through the direct hearing and questionnaires prepared by the Study Team. Ten (10) district offices gave the answer with inundation map and 2 districts sent back only inundation map without the answer. Table E.5.1 shows the flood and flood damage condition by district. Fig. E.5.2 illustrates the habitual flood areas in 12 districts.

Summary of the collected data and information are mentioned below:

Inundation occurs frequently in a large number of areas in each district, during the rainy season and high tide in six (6) months between August and December. Depth and duration of inundation range in district by district. The average inundation depth is reported at 20-60 cm. However, in some low-lying areas of Phu Nhuan, Tan Binh and Binh Chanh districts, it is reported to rise up to 80-120 cm. The duration of inundation is estimated at 1-3 hours in average, however, it has sometimes lasted from 5 hours to half a day in District 2, Tan Binh and Binh Chanh districts. Inundation in the city is mainly caused by the following reasons:

(a) The drainage system has not been completed yet, while some of the existing sewers are overage and damaged. Some of the manholes, channels and canals are blocked by garbage, rubbish and dumped soil. These lead to poor drainage capacity of sewers and canals and inundation will occur whenever it has heavy rainstorm.

(b) Some areas in District 2,7,12, Binh Chanh and Go Vap districts, where have been rapidly urbanized with high population density, has inundated due to the construction of illegal house, filling up of the existing drain and no consideration of the sufficient drainage system.

(c) High tide also causes inundation for low-lying areas in District 8,10, Nha Be and Phu Nhuan districts. Nha Be, Go Vap, Binh Thanh, Binh Chanh, Thu Duc districts have been protected from flood of Saigon, Dong Nai, Nha Be and other inner rivers by dike system, however, these areas are actually inundated during the high tide, because some parts of the embankments are eroded and damaged. In

addition, simultaneous occurrence of both rainfall and high tide causes more serious inundation for these areas.

Concerning with the flood damages, it is reported that the number of population and houses affected are estimated from about 22,000 to 71,200 peoples and from 4,500 to 14,000 houses respectively. Only Binh Chanh district, however, reported that the total damage of 1996 flood was estimated 15.4 billion VND including mainly agricultural product damage of paddy crops, sugar-canes and fish-breeding pond.

5.4 Flood and Flood Damage Survey

5.4.1 General

(1) Purpose of the Survey

In the course of the Study, the JICA Team has carried out the flood and flood damage survey by the interview for the residents in serious flood areas in cooperation with Project Management Unit (PMU). The purpose of the survey is to supplement the existing data, to clarify the more detail flood condition, and to collect the actual flood damage data in case of annual flood and the maximum flood in the past.

(2) Summary of the Survey Procedure and Method

The survey procedure and method are summarized as follows:

(a)	Survey period:	2 to 11 November 1998 (10 days)
(b)	The number of samples:	1,000 samples in total
(c)	Interviewers:	20 persons
(d)	Survey area:	19 districts in the Study area
(e)	Interview sheet:	refer to Appendix
(f)	Survey method:	Interviewers, who are informed in advance the purpose, scope and method of the survey, have visited the inundation area indicated by the Study Team and had direct interview for the residents by using the interview sheets.

5.4.2 Flooding Conditions

(1) Cause of Flood

Main cause of flood in the Study area is concluded as follows:

(a) Topographically low land located in the northeastern edge of Mekong Delta
(b) Rainfall with high intensity in short duration
(c) High water level of the surrounding rivers affected by high tide of South China Sea

(d) Insufficient of flood protection and drainage systems and facilities

(2) Flood Area, Depth, Duration and Frequency

Flood area was estimated at 34.61 km^2 in built-up area and 230.3 km^2 in agricultural land as shown Fig. E.5.3. Flood depths of frequent and the biggest floods range from 20 to 60 cm and 20 to 100 cm respectively. Flood duration of both floods range from 1.0 to 24 hours. Flood conditions (area, depth, duration) for the frequent and biggest flood by each district are summarized in the table below:

FLOOD CONDITION BY DISTRICT

District	Flood Area (ha)		Frequent Flood		Biggest Flood	
	Built-up Area	Agricultural land	Depth (cm)	Duration (hr)	Depth (cm)	Duration (hr)
1	34.3	0	28 (20-40)	2.2 (2-3)	42 (30-50)	4.2 (4-5)
2	140.6	2,341.4	23 (20-30)	3.8 (1-12)	34 (20-50)	4.8 (1-12)
3	65.5	0	27 (20-50)	3.4 (2-5)	47 (30-100)	5.0 (4-6)
4	30.1	0	20 (20)	1.0 (1.0)	40 (40)	24.0 (24)
5	147.3	0	22 (20-50)	1.1 (1-2)	65 (40-70)	20.0 (1-24)
6	348.5	0	25 (20-50)	10.9 (1-24)	41 (30-100)	12.6 (2-24)
7	180.6	1,364.6	21 (20-30)	2.7 (2-3)	37 (30-50)	5.7 (4-6)
8	203.8	514.3	31 (20-40)	3.1 (2-4)	44 (30-50)	4.9 (3-6)
9	0	6,280.0	-	-	-	-
10	63.3	0	30 (20-40)	2.8 (2-4)	69 (50-100)	3.8 (3-5)
11	100.5	0	31 (20-40)	2.5 (1-4)	78 (30-100)	8.8 (2-24)
12	253.9	2,266.2	-	-	-	-
Phu Nhuan	52.2	0	29 (20-50)	13.5 (1-24)	39 (20-100)	14.2 (2-24)
Binh Tang	657.3	124.4	46 (20-60)	2.5 (2-24)	63 (30-80)	5.4 (3-24)
Go Vap	337.6	377.0	25 (20-40)	6.3 (1-24)	27 (20-40)	6.3 (1-24)
Tan Binh	820.9	135.0	29 (20-60)	6.3 (1-24)	30 (20-60)	6.8 (1-24)
BinhChanh	25.4	5,133.6	26 (20-30)	18 (1-24)	34 (30-40)	18 (2-24)
Nha Be	0	3,145.3	-	-	-	-
Thu Duc	0	1,349.0	-	-	-	-

Table E.5.2 shows the flood condition by zone and catchment area for the habitual flood.

5.4.3 Flood Vulnerable Population

Almost 1,179 thousand peoples (27.7 %) in the Study area are affected from the flood at present. These vulnerable population will be increased about 2,475 thousand peoples (35.2 %). Present and future vulnerable population by catchment area is shown in Table E.5.3.

5.4.4 Flood Damage

Flood damage will be considered the following items in order to estimate the cost of project benefit.

(a) Building loss: residential, commercial, industrial and institutional buildings
(b) Indoor movable loss: furniture, stored good and materials in the above buildings
(c) Public facilities loss: infrastructures
(d) Agriculture production loss
(e) Business suspension loss for commercial activity
(f) Medical cost and others

Based on the flood damage survey results, these flood losses are estimated as follows:

Summary of Annual Average Direct Damages by Zone

(billion VND)

Zone	Amount of damages	
	In present situation	In future situation
C-Zone	366.5	439.9
N-Zone	218.1	273.4
W-Zone	40.9	117.5
S-Zone	39.1	117.9
NE-Zone	3.7	64.7
SE-Zone	39.4	127.5
Total	707.7	1,140.9

Summary of Indirect Damages by Zone

Zone	Indirect benefit (billion VND)	
	Base year	2020
C-Zone	107.7	120.0
N-Zone	8.2	22.1
W-Zone	6.7	14.6
S-Zone	4.0	13.6
NE-Zone	3.7	12.5
SE-Zone	6.7	34.7
Total	137.0	217.5

(Note) Base year : 1998.

Details are mentioned in Appendix L: Economy and Finance.