The average unit wastewater and pollution load generation across the whole Study Area are estimated as follows.

	Existing	Future
Unit Wastewater Generation (lcd)	172	196
Unit Pollution Load Generation (BOD gcd)	29.8	32.6

(2) Commercial and Institutional

The existing and future wastewater quality of commerce and institution are determined to be 216 mg/l as BOD, based on the sampling survey.

(3) Tourism

The existing and future unit pollution load generation of hotel covering both toilet waste and gray water, and restaurant are determined as follows, based on the sampling survey.

High class hotel	:	98.3 g/room/day (BOD)
Middle and low class hotel	:	80.2 g/room/day (BOD)
Restaurant	:	5.6 g/seat/day (BOD)

(4) Industrial

The existing and future unit pollution load generation by industrial classification are assumed to be the same as those in Jakarta based on the check survey in the Study Area. They are in the range of 0.38 g/day/million Rp./yr. and 18.00 g/day/million Rp./yr.

3.3 Pollution Load Generation

The total existing and future wastewater and pollution load generation by waste origin of the Study Area are estimated as follows.

	Wastewater (10^3 m^3/d) Existing (1990)	Future (2010)	Pollution Load (t/d) Existing (1990)	Future (2010)
Domestic	82.2	139.3	14.2	23.2
Commercial & Institutional	16.9	28.0	3.66	6.04
Tourism	16.8	54.8	0.91	2.84
Industrial	0.8	5.1	0.92	5.99
Total	116.8	227.2	19.7	38.0

The average daily wastewater and pollution load generation of unit area in the Study Area are given below.

	Existing (1990)	Future (2010)
Specific Wastewater (m^3/d/ha)	4.94	9.61
Specific Pollution Load (BOD kg/d/ha)	0.83	1.61

Regional distribution of the existing and future specific wastewater and pollution load generation by Kelurahan/Desa are shown in Fig. 3.2 through Fig. 3.5.

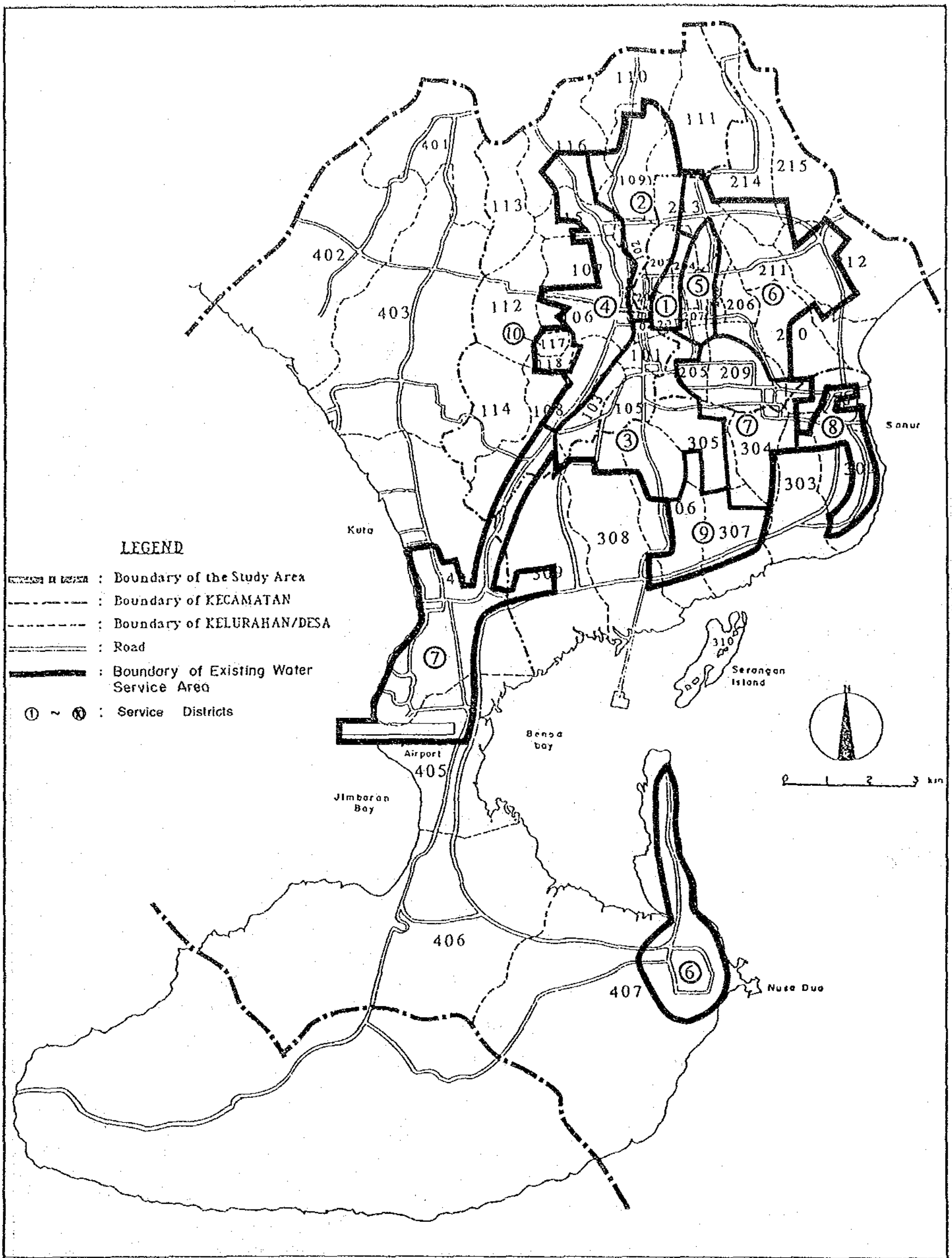


FIG. 3.1

WATER SERVICE AREA OF PDAM

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

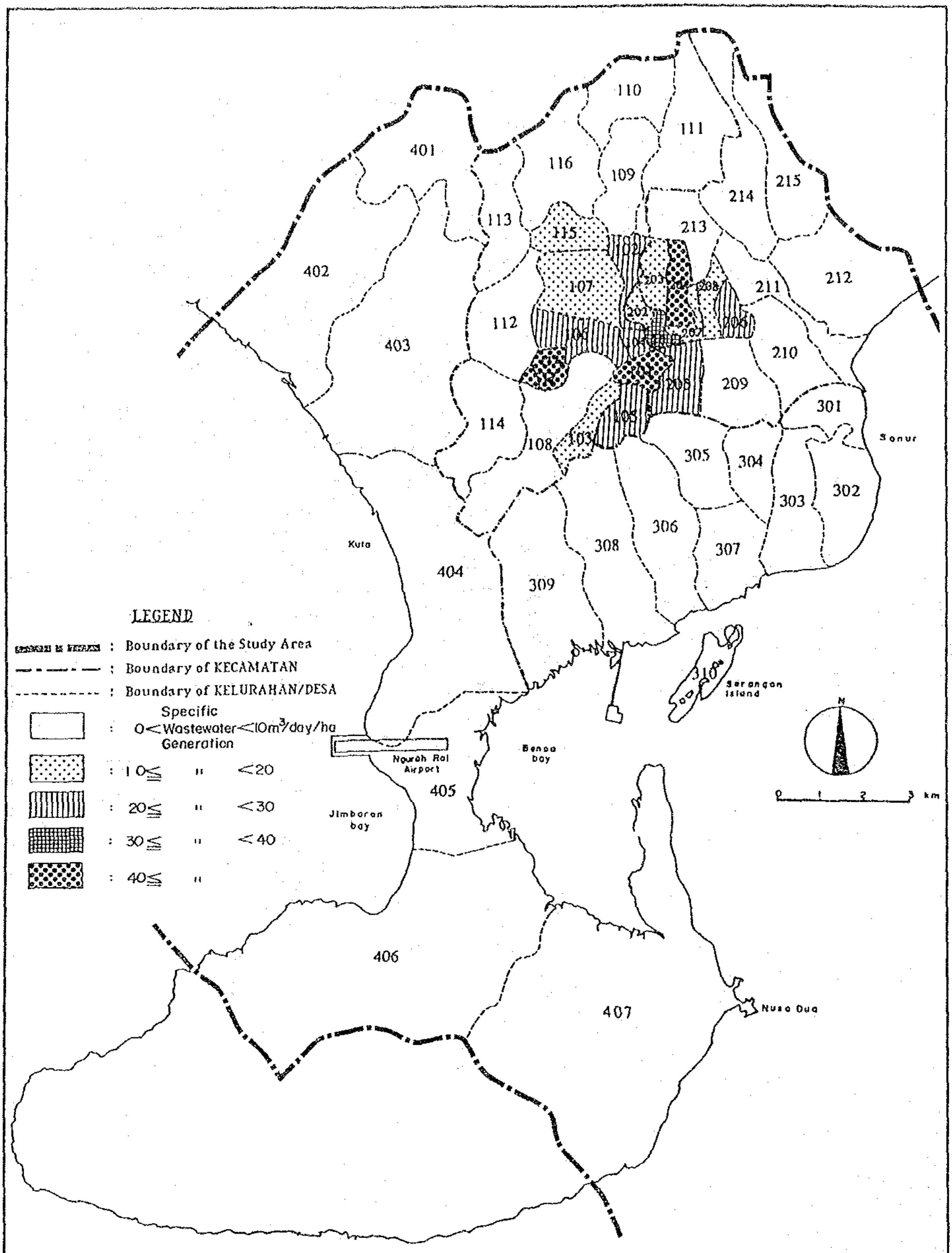


FIG. 3.2 EXISTING SPECIFIC WASTEWATER GENERATION (1990)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

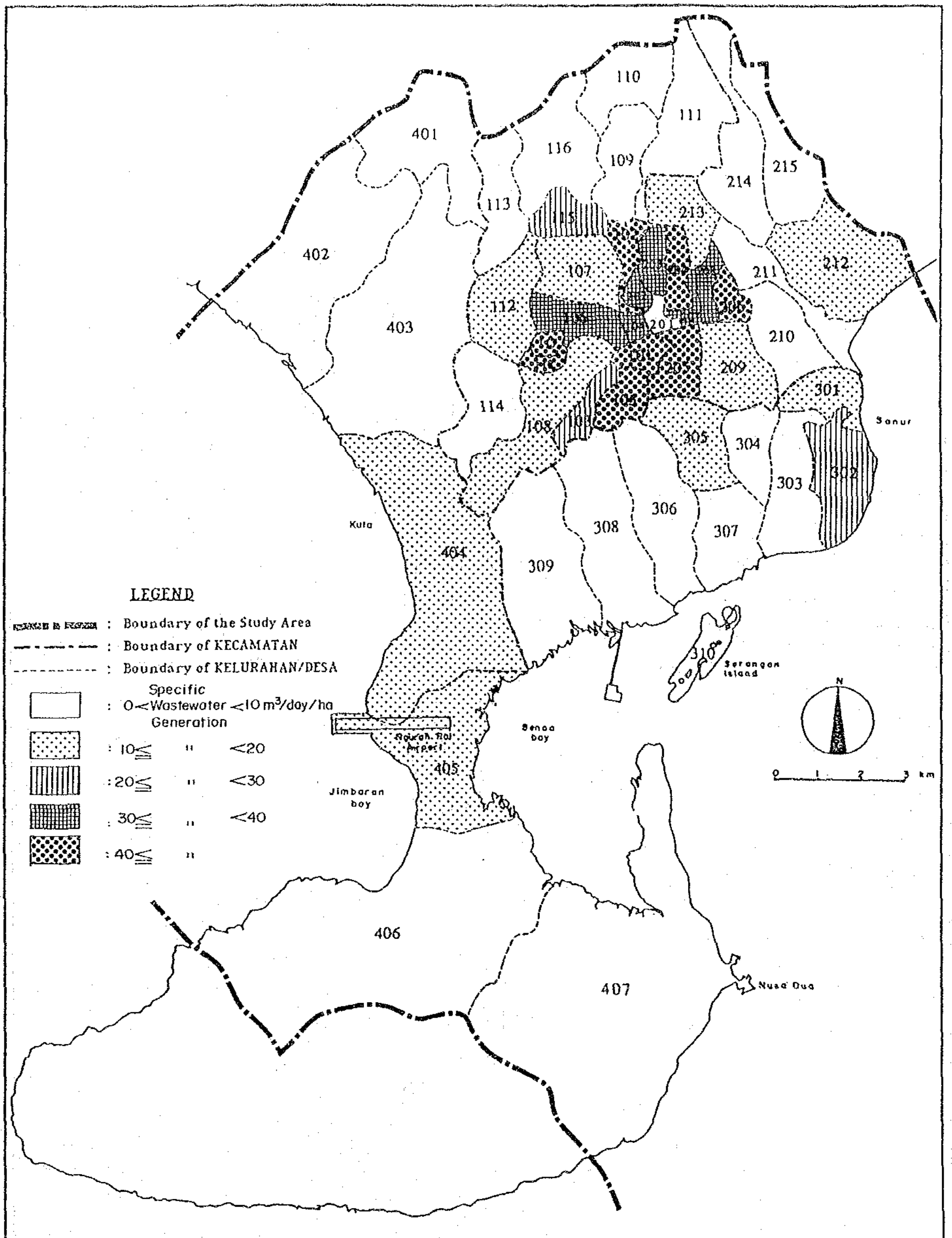


FIG. 3.3 FUTURE SPECIFIC WASTEWATER GENERATION (2010)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

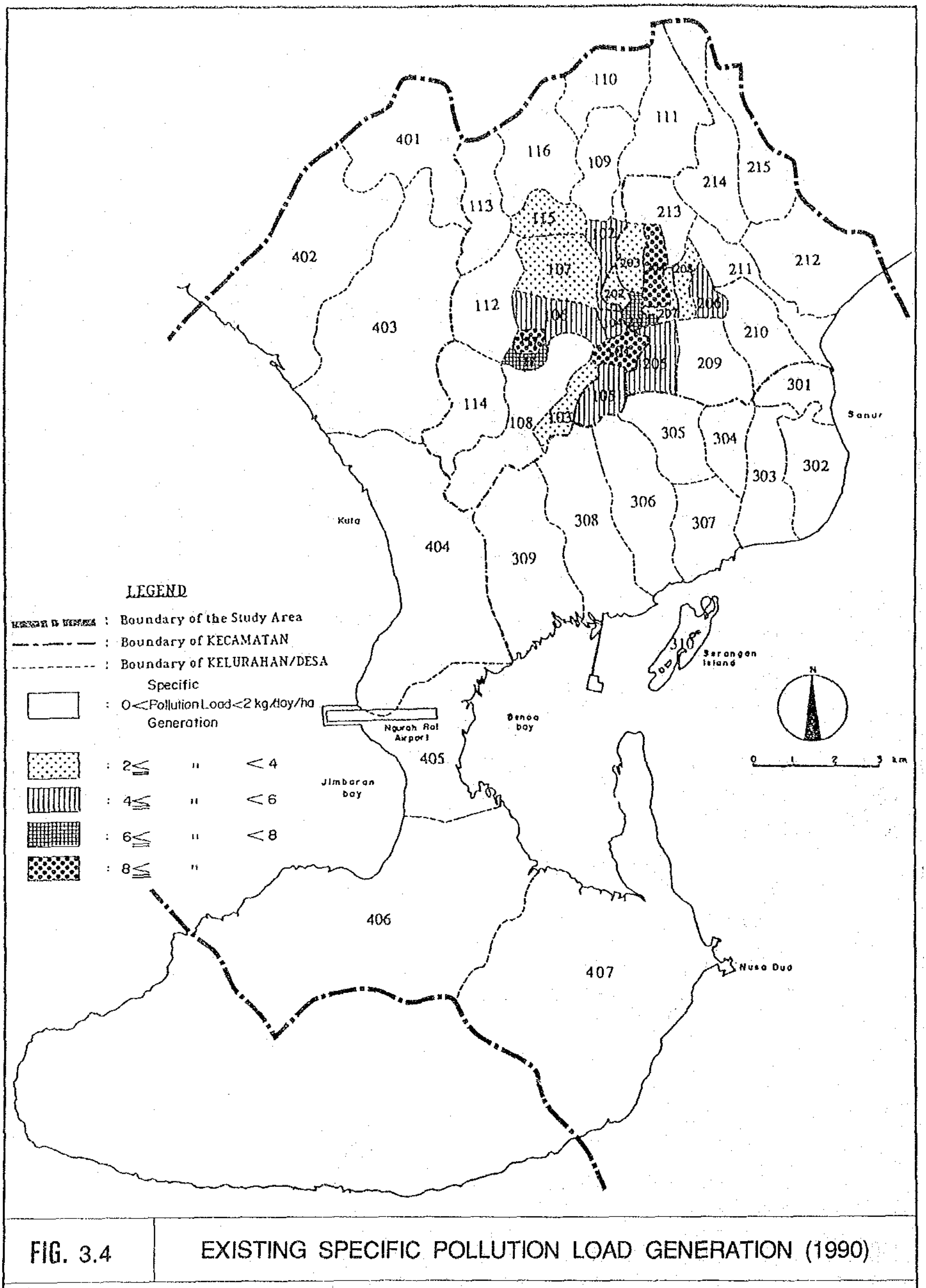


FIG. 3.4 EXISTING SPECIFIC POLLUTION LOAD GENERATION (1990)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

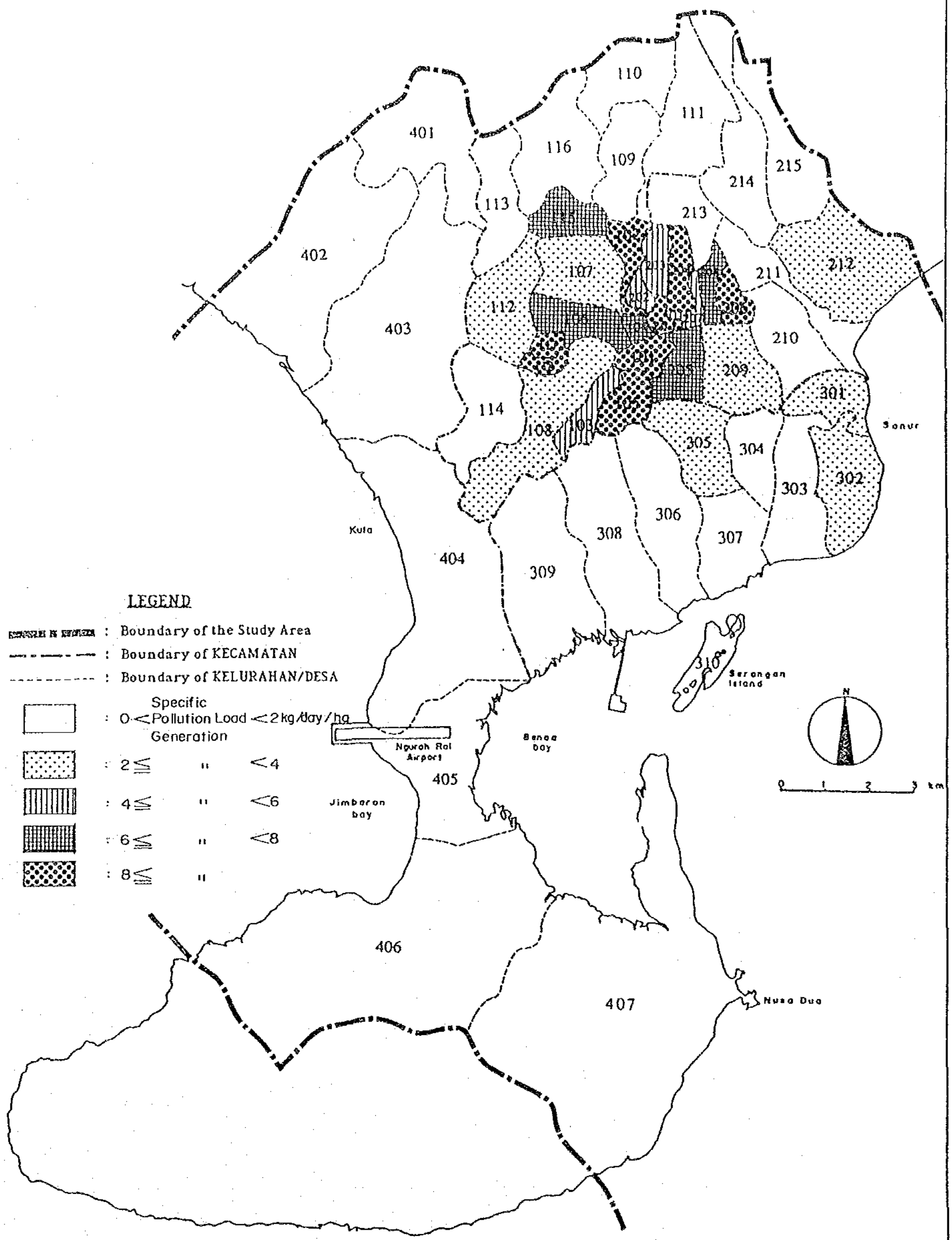


FIG. 3.5 FUTURE SPECIFIC POLLUTION LOAD GENERATION (2010)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

CHAPTER 4 EXISTING SANITATION AND SEWERAGE PROJECTS AND FACILITIES

4.1 Existing On-site Sanitation Facilities

(1) Domestic

The existing domestic on-site systems in the Study Area are utilized to treat toilet waste only, while the gray water originating from wash, bath, cooking and laundry is either disposed/discharged to lawns/drains with no treatment or infiltrated into underground using separate soak pit or soakaway.

The existing ratio of population having toilet with treatment by leaching pit/septic tank is estimated based on the sampling questionnaire survey as follows.

Denpasar Barat	:	95.6%
Denpasar Timur	:	97.8%
Denpasar Selatan	:	95.8%
Kuta	:	88.3%
Study Area	:	95.1%

(2) Commercial & Institutional and Industrial

Leaching pit/septic tank is the sole treatment system almost universally used. While some hotels, factories and offices utilize elaborate treatment facility like extended aeration system.

(3) Desludging and Treatment

Both the Public Cleansing Department of Walikota Denpasar and four (4) private companies provide desludging and its subsequent transportation and disposal of leaching pit/septic tank sludge utilizing vacuum trucks. However, there is no organized sludge treatment system.

Based on the IUIDP sampling survey of 1988 concerning the operation and maintenance of domestic on-site sanitation systems of septic tank and leaching pit, it became evident that about 60% of the systems were never desludged. However, the remaining 40% of the systems had an average desludging frequency of once in three (3) years.

The existing desludging activities in the Study Area are summarized below.

Organization	Vacuum Truck			Household Served (No./ Annum)	Desludging Quantity (m^3/ Annum)	Financial Aspect	
	No.	Capacity (m^3)	Cycle/ Day			Typical Tariff (Rp./Trip)	Gross Income (M. Rp./ Annum)
Public Sector	1	6	1.5	400	2,400	13,000	7.0
Private Sector	6	4	2.0	1,800	10,100	35,000	123.6
Total	7	–	–	2,200	12,500	–	130.6

4.2 Existing Sewerage System

(1) Nusa Dua

The existing Nusa Dua sewerage system of BTDC covers nine (9) high-class hotels. Further, two (2) hotels are scheduled to be connected in 1992.

The sewerage system consists of :

- Sewer pipe : 5.1 km
- Oxidation pond treatment system : 16 ha
- Design wastewater treatment : 7,200 m^3/d
- Existing wastewater treatment : 2,500 m^3/d of which 50% is recycled for gardening, etc.

The operation started in 1979.

Location of the sewerage system is shown in Fig. 4.1

(2) Airport

The sewerage system serves the Ngurah Rai Airport only, covering approximately 300 ha. The sewerage system consists of :

- Sewer pipe : 1.8 km
- Aerated-facultative lagoon with maturation pond
- Design wastewater treatment : 2,300 m^3/day

The system became operational only recently in fall of 1991.

4.3 On-going Sanitation and Sewerage Project

(1) Human Waste Disposal of Kabupaten Badung and Kotamadya Denpasar

The project consists of :

- On-site sanitation facilities
- Desludging truck
- Sludge treatment plant (1.1 ha)

Design sludge volume : 110 m^3/day.

(2) Kuta Sewerage Project

The sewerage system covers an area of 355 ha in Kel. Kuta with the following connections.

- 492 households
- 224 hotel, home stay and losmen
- 125 restaurants

The design wastewater discharge is 4,200 m^3/day. The collected wastewater is conveyed to the sewage treatment plant, where human wastes of Kotamadya Denpasar and Kabupaten Badung are also treated.

Total sewer pipe length is 11.4 km. The required land area for the sewage treatment plant is 2.9 ha.

Location of the Kuta Sewerage Project is shown in Fig. 4.2.

(3) Estuary Reservoir

Development of the estuary reservoir is planned at the estuary of the Badung River for domestic water supply. The water resources of the Mati River are exploited by this project along with that of the Badung River. The area and effective storage capacity of the reservoir are 140 ha and 1.4 million m^3 respectively.

Location of the estuary reservoir is shown in Fig. 4.3.

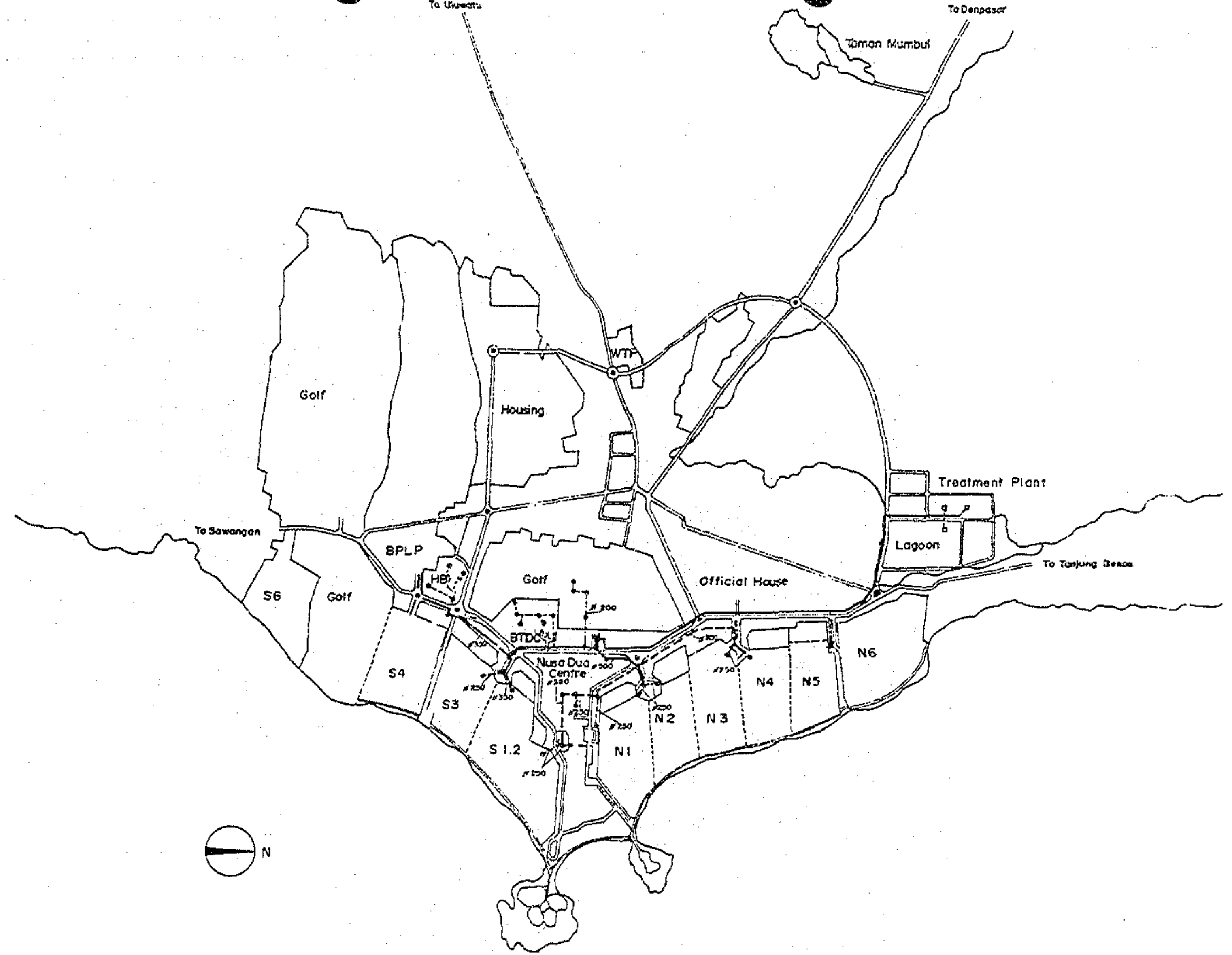


FIG. 4.1	SEWERAGE SYSTEM OF BTDC IN NUSA DUA
THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR	

JICA A.D 1993

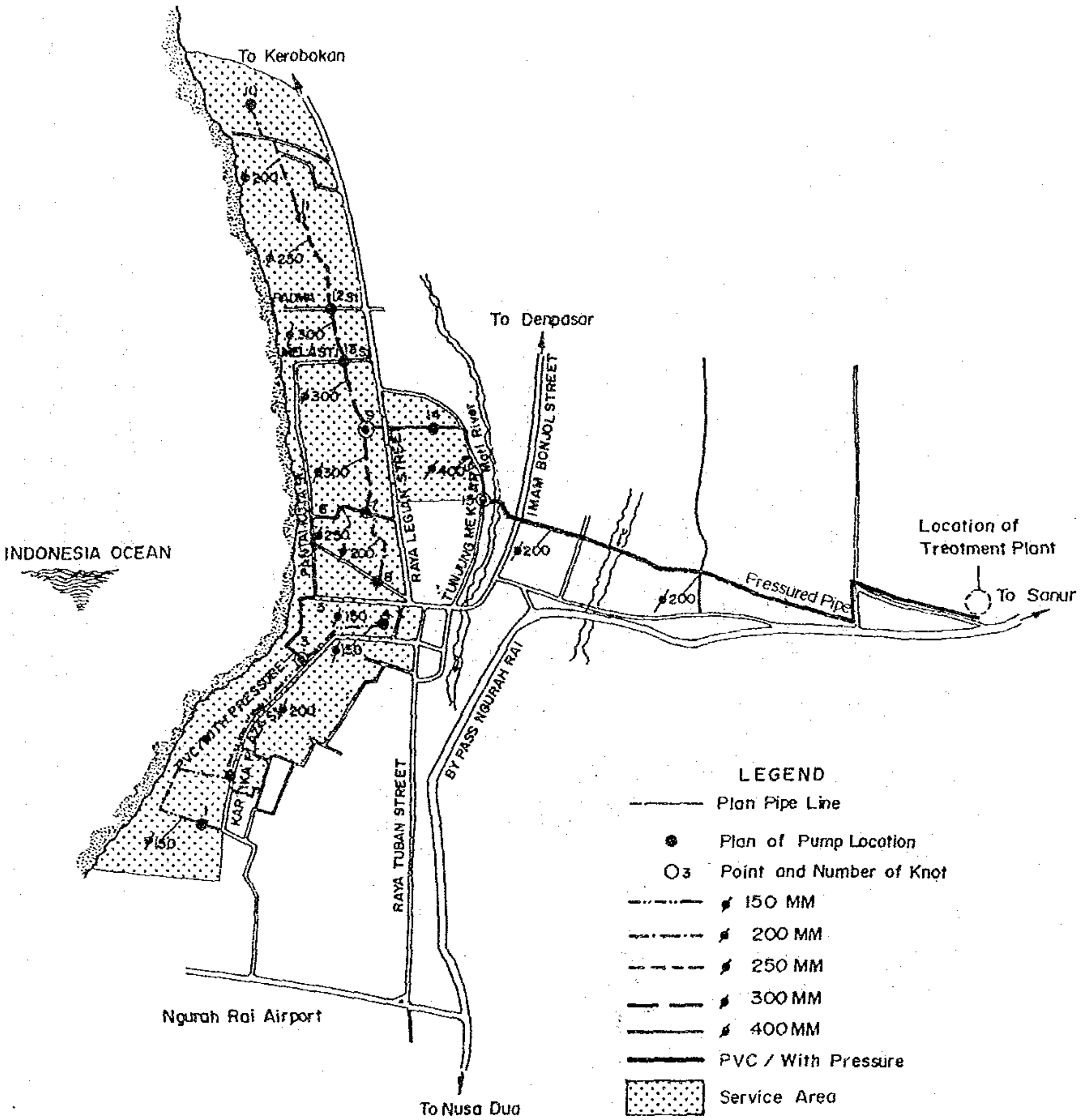


FIG. 4.2 PLAN OF TRUNK SEWERS IN KUTA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

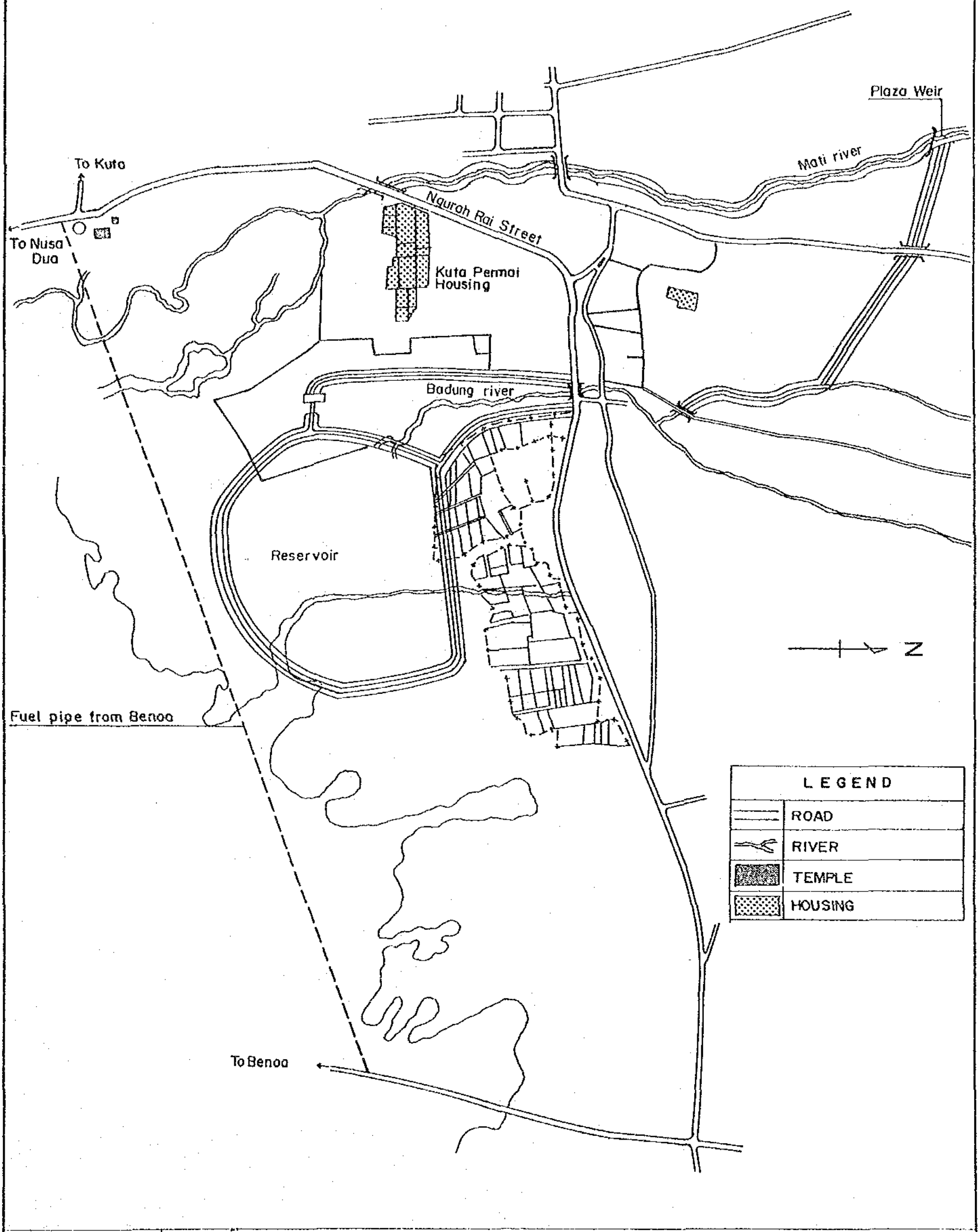


FIG. 4.3 ESTUARY RESERVOIR PROJECT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

CHAPTER 5 WASTEWATER DISPOSAL DEVELOPMENT

5.1 Simulation of River and Sea Water Quality

5.1.1 Simulation of River Water Quality

The objective area consists of four (4) river basins of Mati-Teba, Badung, Yeh Ayung and Sama. These river basins cover a total area of 14,494 ha or 61.3% of the Study Area at the lower-most out-put stations of simulation. The four (4) river basins are further divided into 16 sub-basins (see Fig. 5.1). The model of river systems are established for simulation as shown in Fig. 5.2.

The simulation model was calibrated by comparing the observed and simulated river water quality at 21 out-put stations. The simulated river water quality is well in agreement with the observed one as shown below.

(Unit : BOD mg/l)

	Dry Season	Rainy Season
Average observed water quality	17.9	18.4
Average simulated water quality	16.8	17.3

For details, see Appendix E, Table E.1.4.

The river water quality of the Study Area in 2010 will worsen to two (2) times of the existing one in terms of stream BOD. The average existing and future river water quality of the central and southern Denpasar areas are compared as follows.

	1990	2010
Dry Season (BOD, mg/l)	27.8	53.9
Rainy Season (BOD, mg/l)	26.6	56.1

The future pollution load to the sea from the Study Area will double in BOD as shown below.

(Unit : BOD kg/d)

	Dry Season	Rainy Season
Existing (1990)	8,294	13,238
Future (2010)	16,992	26,833

5.1.2 Simulation of Sea Water Quality

The pollution loads discharged into the sea are spread by diffusion and are convected due to currents caused by tides, waves and winds. However in the sea of the Study Area, the tidal currents are dominant, and the currents by waves and winds are considered negligibly small.

Hence, the sea water quality of the Study Area is simulated by using the diffusion and tidal current models. For the constructed models, see Appendix E.1.2.1. The objective area of the simulation is shown in Fig. 5.3.

The sea water quality as COD was simulated for the four (4) conditions; dry and rainy seasons in the years of 1990 and 2010. Differences of the simulation results between dry and rainy seasons are quite small. The existing and future simulated sea water quality in dry season are shown in Fig. 5.4 and Fig. 5.5 respectively.

The simulated sea water quality is in good agreement with the observed one (compare with Fig. 2.8). The existing polluted areas with COD of more than 5 mg/l in the year 1990 is estimated to be 28.3 km^2. It is projected to expand to 36.5 km^2 in the year 2010, if no wastewater disposal project is implemented.

5.2 Zoning of Wastewater Disposal System

5.2.1 Target of Wastewater Disposal Development

The principal objectives of wastewater disposal development for the Study Area are (1) river water pollution control, (2) sea water pollution control, (3) sanitary improvement of communities and (4) groundwater pollution control.

The targets to achieve the above objectives are proposed as follows.

(1) River water pollution control

The target river water quality of the Study Area is determined based on the existing river water quality, existing river water use, and environmental river water quality standards.

River water quality shall be maintained, as a proposal, below 20 mg/l as stream BOD in the river sections where there are irrigation off-takes and preferably below 10 mg/l as BOD in the river sections where people use water for washing and bathing.

For the existing river water quality and river water use, see Fig. 2.3, Fig. 2.4 and Fig. 2.6.

(2) Sea water pollution control

The existing sea water quality of Sanur, Kuta and Nusa Dua beaches is 5 mg/l in terms of COD_{cr} on an average, while it exceeds 8 mg/l in some areas (see Fig. 2.7 and Fig. 2.8). This water quality is considered to be in a critical level for swimming and other water recreations in comparison with international standards. For example, the Japanese Standards stipulates a coastal sea water quality of 2 mg/l as COD_{Mn} (roughly equivalent to 4 mg/l as COD_{cr}) for swimming and conservation of natural life.

Further progress of the sea water pollution will cause vital damage on the tourism industry of Bali.

The sea water quality of the resort beaches in the Study Area shall be maintained below 5 mg/l in COD_{cr} or at least, below the existing level. Hence, the future pollution load run-off to the sea shall be controlled not to exceed the existing level at least.

(3) Sanitary improvement of communities

More than 90% of the toilet waste in the Study Area is disposed into underground by leaching system. A large portion of gray water are directly discharged to the road side drains or rivers/canals, resulting in creation of unsanitary environments in the communities. Such unsanitary environments concentrate in the densely populated areas of the central Denpasar (see Fig. 5.6).

To protect the sanitary environments of communities, wastewater shall be :

- entirely cut or discharged into road side drains/canals after a high level treatment of 20 mg/l as BOD for the areas with a high population density and the resort areas.

- discharged into road side drains/rivers/canals after a moderate level treatment of 60 mg/l as BOD for the areas with a medium population density.

(4) Groundwater pollution control

Wastewater disposal is considered to be the cause of the existing groundwater pollution. Heavy groundwater contaminations are recognized in the central and southern Denpasar areas. Even groundwater quality in the resort beach areas is in a critical level (see Fig. 2.10).

Hence, wastewater disposal into underground shall be managed carefully to control groundwater contamination, taking into consideration the facts that many people are using groundwater for their alternative or supplementary water supply and as a result, the existing population service ratio of piped water of the Study Area is only 33% in average.

5.2.2 General Zoning Principle of Wastewater Disposal System

The Study Area is divided into the following three (3) wastewater disposal areas from the aspects of river water pollution control, sea water pollution control, sanitary improvement of communities and groundwater pollution control.

(1) Central and southern Denpasar

The river and sea water pollution of the Study Area are mainly due to the wastewater discharged from the central and southern Denpasar. Hence, the wastewater disposal of these areas shall be dealt with integrally in order to protect the river and coastal sea water quality.

(2) Resort area

The environments and sanitation of the areas shall meet not only local requirements but also international ones, for ensuring their continued tourism potential. Hence, the wastewater disposal system of these areas are dealt with separately from the central and southern Denpasar, and other areas.

(3) Other areas

The population density of the other areas in the Study Area is not high. The river and groundwater quality are comparatively good. The required wastewater disposal system of the areas will be determined independently, based on their local situations.

5.2.3 Wastewater Disposal System for Central and Southern Denpasar

(1) General

To achieve the targets of river and coastal sea water quality, the following two (2) alternative systems are considered practical.

(i) Sewerage system only (conventional type capable of treating both toilet waste and gray water up to 20 mg/l as BOD)

(ii) Combination of sewerage and on-site systems (septic tank with up-flow filter capable of treating both toilet waste and gray water up to 60 mg/l as BOD)

The two (2) alternative systems are compared as follows.

(2) Sewerage system only

This system covers 23 Kelurahan/Desa in the central Denpasar with a future population density of more than 50 person/ha. The covered total area and population in 2010 are 3,759 ha and 368,600 respectively (see Fig. 5.7).

(3) Combination of sewerage and on-site sanitation system

Sewerage system covers 16 Kelurahan/Desa with a future population density of more than 100 person/ha. The covered total area and population in 2010 are 1,560 ha and 232,400 respectively.

On-site sanitation system is applied for six (6) Kelurahan/Desa with a future population density of 50-100 person/ha in the central Denpasar and for seven (7) Kelurahan/Desa in the southern Denpasar with a future population density of 20-60 person/ha. The on-site system covers a total area of 5,687 ha and a total population of 223,800 in 2010.

The covered area by the above combination system of sewerage and on-site sanitation is shown in Fig. 5.8.

(4) Comparison and conclusion

The simulated pollution load to the sea and river water quality in dry and rainy seasons for the above two (2) systems are shown in Fig. 5.9(1)-5.9(2) and Fig. 5.10(1)-5.10(2). Both alternatives can attain the targets of river and sea water pollution control. Their control effects of river and sea water pollution are almost equivalent.

The combination system of sewerage and on-site sanitation is more economical than the system of sewerage only as shown below.

	Construction Cost (billion Rp.)	O&M Cost (million Rp./yr.)
Sewerage Only	227.1	3,131
Combination of Sewerage and On-site	178.7	2,361

The system of sewerage only excludes six (6) Kelurahan/Desa of Kecamatan Denpasar Selatan from the covered area of the combination system of sewerage and on-site sanitation. The excluded area and population in 2010 are respectively 3,488 ha and 87,600.

The excluded areas are affected by a severe groundwater contamination. The groundwater table is shallow and the land is covered by soils with a low permeability. Wastewater disposal into underground is considered inappropriate for these areas. Hence, septic tank with up-flow filter is most appropriate.

As evident from the above discussions, the combination of sewerage and on-site system is more recommendable.

(5) Simulated future sea water quality with project

The sea water quality as COD with the above proposed project in the year 2010 is simulated as shown in Fig. 5.11.

The polluted sea areas with COD of more than 5 mg/l are shown below, compared with those under the existing and future conditions without project.

	Polluted Area (km^2)
Existing	28.3
Future without Project	36.5
Future with Project	28.6

The proposed project will be able to attain the target of future sea water quality.

5.2.4 Wastewater Disposal System of Resort Area

(1) Existing wastewater disposal conditions

In the resort areas of Sanur, Kuta and Nusa Dua (excluding BTDC area), a major portion of the wastewater are disposed into underground through septic tank/leaching pit with no special treatment. It is due to the high infiltration capacity of the soils.

However, some wastewater is directly discharged to the road side drains here and there. The discharged wastewater are infiltrated into underground from the drain beds to some extent while it flows down. The remaining wastewater of limited quantity is finally discharged to the neighbouring rivers and seas. Such wastewater discharge to the road side drains are striking along the main streets of Kuta where shops and restaurants are densely located.

(2) Groundwater contamination problems

Groundwater contamination of the areas is very significant and considered to be in a critical level at present. The existing average groundwater quality of the areas is 6.5 mg/l of COD_{cr}, 0.1 mg/l of NH_4-N and 72 N/100ml of Fecal Coliform. This water quality is inappropriate for domestic use without treatment.

The existing (1990) and future (2010) wastewater and pollution load generation per unit area of each resort area are estimated as shown below.

	Area(ha)	Wastewater (m^3/d/ha)		Pollution Load(Kg/d/ha)	
		1990	2010	1990	2010
Sanur	671 <1	9.50	23.87	1.25	2.94
Kuta	1,293	9.54	17.03	1.01	1.88
Nusa Dua	140 <2	8.15	23.49	0.97	2.07
Central Denpasar	1,560 <3	24.47	41.42	4.45	7.00
Study Area	23,653	4.94	9.61	0.83	1.61

Note :

<1 : covers Kel. Sanur Kaja and Kel. Sanur

<2 : covers Benoa peninsula area only and excludes BTDC area

<3 : covers 16 Kel./Desa where sewerage system is proposed in Section 5.2.3

The wastewater and pollution load generation per unit area in 2010 will increase to more than two (2) times of the existing ones. This future increase of pollution load will further progress groundwater contamination and as a result, may cause serious public hazards if no control measures of wastewater disposal are taken. This is because many people, even large hotels, are still using the groundwater for drinking, cooking, bathing, washing, etc.

(3) Communal sanitation problems

The wastewater infiltration efficiency of the existing septic tanks and leaching pits generally is decreasing with the elapse of time due to clogging of the leaching system. Especially, septic tanks/leaching pits of restaurants and hotel restaurants require frequent desludging of sludge due to clogging by oily materials. Frequency of the desludging increases as time goes by, and finally, replacement become necessary.

The desludging by vacuum truck is not always easy because of lack of access roads to inner places.

Hence, people are inclined to directly discharge wastewater into the road side drains or small ditches/open spaces in the neighbourhood, resulting in creation of unsanitary environments of communities.

The above sanitary problems of communities will become further serious in future with the increase of wastewater generation.

(4) Alternative wastewater disposal systems

A wastewater disposal system of high treatment level shall be applied for these areas to maintain the groundwater quality and communal sanitation of the areas in a satisfactory level as international resorts. The following two (2) alternatives are proposable.

- Sewerage system (sewerage system of conventional type)

- On-site system with a treatment level of 20~30 mg/l as BOD (household package treatment plant with aeration system)

(i) Sewerage system

(Sanur Sewerage Development)
The sewerage system of Sanur covers three (3) Kelurahan/Desa of Sanur Kaja, Sanur and Sanur Kauh. The covered area and population in 2010 are 780 ha and 28,000 respectively. The collected wastewater is conveyed to the treatment plant located at the on-shore land in the southern edge of Sanur area.

(Kuta Sewerage Development)
The sewerage system of Kuta covers only the beach area to be developed by 2010 with an area of 650 ha. The remaining undeveloped area of Kelurahan Kuta covering 643 ha will be provided with on-site system. The covered population in 2010 by sewerage system is 22,000. The collected wastewater is conveyed to the treatment plant located at the on-shore land along the Benoa Bay.

(Tanjung Benoa Sewerage Development)

The sewerage system of Tanjung Benoa covers only the Benoa peninsula area. The covered area and population in 2010 are 140 ha and 2,000 respectively. The collected wastewater is conveyed to the existing treatment plant of BTDC.

(ii) On-site system

Household package treatment plant is considered as the on-site system to treat the wastewater to the same level as the sewerage system. This system is composed of sedimentation, contact aeration and disinfection systems to treat a mixture of toilet waste and gray water under both anaerobic and aerobic conditions.

(5) Cost comparison and conclusion

Cost of the above two (2) alternatives are compared for three (3) resort areas of Sanur, Kuta and Tanjung Benoa.

The construction and O&M costs of sewerage and on-site systems for three (3) areas are summarized below.

	Sanur	Kuta	Tanjung Benoa
Construction Cost (billion Rp.)			
Sewerage	44.4	49.5	7.0
On-site	46.9	50.7	11.8
O&M Cost (million Rp./yr.)			
Sewerage	588	735	513
On-site	1,412	1,531	358

As evident from the above table sewerage system is more economical than on-site system for all areas. Sewerage system of conventional type is recommended for the wastewater disposal of Sanur, Kuta and Nusa Dua (Tanjung Benoa) resort areas.

The proposed sewerage system covers five (5) Kelurahan/Desa of Sanur Kaja, Sanur, part of Sanur Kauh, part of Kuta and part of Benoa (see Fig. 5.12). The covered total area and population in 2010 are 1,570 ha and 52,000 respectively.

5.2.5 Wastewater Disposal in Other Areas

The other areas cover 14,836 ha with a total population of 199,600 in 2010. Number of the included Kelurahan/Desa are 19. These Kelurahan/Desa are expected to be sparsely populated even in 2010 with a low specific pollution load generation as shown below.

	1990	2010
Area(ha)	14,836	14,836
Population	137,860	199,600
Population Density (person/ha)	9	13
Specific Pollution Load Generation (kg/day/ha)	0.35	0.68

The river water quality of these areas are comparatively good. The existing river water quality is 3-10 mg/l with an average of 5.1 mg/l as stream BOD. The future river water quality (after completion of the sewerage and on-site sanitation systems of Denpasar and resort areas) in 2010 is estimated to be still 3~15 mg/l, averaging 6.5 mg/l as stream BOD.

The groundwater quality of the areas are also generally good (see Fig. 2.10). However, the future increase of pollution loads may deteriorate the groundwater quality down to a critical level in some areas.

Based on the above facts and discussions, it is concluded that :

- No large scale or high level wastewater disposal system will be required until 2010.

- The existing on-site sanitation system, most of which are leaching pits only, shall be improved to a certain level to preserve the groundwater quality and maintain the sanitary conditions of communities at satisfactory level.

Septic tank with leaching system is recommended for these areas.

5.2.6 Total Wastewater Disposal System

Total wastewater disposal system of the Study Area is summarized below.

System	Area(ha)	Population in 2010	Region
Sewerage	3,130(13.2%)	285,900(40.3%)	Central Denpasar & Resort Area
On-site I	5,687(24.0%)	223,800(31.6%)	Surrounding of Central Denpasar& Southern Denpasar
On-site II	14,836(62.8%)	199,600(28.1%)	Other Areas
Total	23,653(100%)	709,300(100%)	

Note : On-site I : Septic tank with up-flow filter
On-site II : Septic tank with leaching system

Zoning of the total wastewater disposal system is shown in Fig. 5.13.

5.3 Potential Sites for Sewage Treatment Plant

The proposed sewerage master plan of the Study Area consists of the sewerage developments of Denpasar, Sanur, Kuta and Tanjung Benoa areas.

Wastewater of the Tanjung Benoa area can be optimally treated by improving the existing treatment plant of BTDC. On the other hand, identified potential sites of the treatment plant for the other three (3) areas are as follows.

The surrounding lands of the Denpasar, Sanur and Kuta sewerage development areas are already highly developed. Only the Benoa Bay area is available for construction of the treatment plant.

The on-shore land along the Benoa Bay is mainly covered by mangrove forests and fish ponds (see, Appendix E, Fig. E.3.2). According to the future land use zoning prepared by Ministry of Forestry, the existing mangrove forest and fish pond areas are categorized into protection zone and limited development zone respectively (see, Appendix E, Fig. E.3.3). Accordingly, the existing fish ponds are considered as the most feasible area for the treatment plant of this Project.

The fish pond areas are originally government own although being used for shrimp cultivation by private sector. They will be returned to the government by the end of 1992.

Sites for the treatment plant of this Project can be selected from the existing fish ponds located in the Suwung Swamp Area shown in Fig. 5.14.

5.4 Alternative Studies of Sewerage Development System

5.4.1 Alternative Systems

The sewerage development plan proposed in Section 5.2 covers four (4) sewerage areas of Denpasar, Kuta, Sanur and Tanjung Benoa. The sewerage area of Tanjung Benoa is independent from the other three (3) areas. On the other hand, the areas of Denpasar, Kuta and Sanur are closely related in use of the potential treatment sites.

The following three (3) alternatives are considered for the optimum development of treatment system.

(1) Individual treatment system

Wastewater of Denpasar, Kuta and Sanur areas are collected and treated independent of each other (see, Fig. 5.15).

(2) Partially integrated treatment system

Wastewater of Denpasar and Kuta are collected independently but treated at one (1) treatment plant. On the contrary, that of Sanur is collected and treated independently (see, Fig. 5.16).

(3) Fully integrated treatment system

Wastewater of Denpasar, Kuta and Sanur are collected independently but all treated at one (1) treatment plant (see, Fig. 5.17).

The design wastewater including groundwater infiltration (10%) of three (3) sewerage areas are as follows.

Denpasar	:	71,100 m^3/day
Kuta	:	20,200 m^3/day
Sanur	:	19,800 m^3/day

Aerated lagoon system is assumed for treatment of the above wastewater.

5.4.2 Sewerage Facilities

Salient features of the proposed sewerage facilities for three (3) alternatives are summarized below.

<table>
<tr><th></th><th>Denpasar</th><th>Kuta</th><th>Sanur</th></tr>
<tr><td>Individual</td><td></td><td></td><td></td></tr>
<tr><td>Collection Sewer (km)</td><td>193.2</td><td>79.4</td><td>91.6</td></tr>
<tr><td>Force Main (km)</td><td>-</td><td>3.5</td><td>-</td></tr>
<tr><td>Treatment Plant</td><td></td><td></td><td></td></tr>
<tr><td>Capacity (m^3/day)</td><td>71,100</td><td>20,200</td><td>19,800</td></tr>
<tr><td>Area (ha)</td><td>13.4</td><td>3.8</td><td>3.7</td></tr>
<tr><td>Partially Integrated</td><td></td><td></td><td></td></tr>
<tr><td>Collection Sewer (km)</td><td>193.2</td><td>79.4</td><td>91.6</td></tr>
<tr><td>Force Main (km)</td><td>-</td><td>5.2</td><td>-</td></tr>
<tr><td>Treatment Plant</td><td></td><td></td><td></td></tr>
<tr><td>Capacity (m^3/day)</td><td colspan="2">91,300</td><td>19,800</td></tr>
<tr><td>Area (ha)</td><td colspan="2">17.2</td><td>3.7</td></tr>
<tr><td>Fully Integrated</td><td></td><td></td><td></td></tr>
<tr><td>Collection Sewer (km)</td><td>193.2</td><td>79.4</td><td>91.6</td></tr>
<tr><td>Force Main (km)</td><td>-</td><td>5.2</td><td>0.4</td></tr>
<tr><td>Treatment Plant</td><td></td><td></td><td></td></tr>
<tr><td>Capacity (m^3/day)</td><td colspan="3">111,100</td></tr>
<tr><td>Area (ha)</td><td colspan="3">20.9</td></tr>
</table>

5.4.3 Cost Comparison and Conclusion

Construction cost and O&M cost are estimated for three (3) alternatives as shown below.

Alternative System	Construction (billion Rp.)	O&M (billion Rp./year)
Individual	193.07	3.39
Partially Integrated	190.61	3.42
Fully Integrated	194.58	3.57

There is no significant cost difference among the three (3) alternatives.

The Study Team recommends "Fully Integrated Treatment System" from the aspects of :

- Easiness of operation and maintenance
- Minimization of environmental adverse impacts

5.5 Proposed Sewerage Development Plan

5.5.1 Wastewater Collection System

The proposed sewerage system is of conventional type which collects both toilet and gray water.

In the Study Area, storm water is mainly drained by open drainage networks consisting of road side ditches, irrigation canals and rivers. No drainage pipes are installed except at the crossings of roads. The on-going drainage projects aim at improvement of the open drainage system.

Hence, separate wastewater collection system is applied.

5.5.2 Denpasar Sewerage Development

(1) Sewerage development area

The sewerage development area proposed in Section 5.2 covers 16 Kelurahan/Desa with a future population density of more than 100 person/ha. The total covered area and population in 2010 are 1,560 ha and 232,400 respectively.

The above sewerage development area is adjusted to prepare a practical sewerage development plan well suited to the topographic, road network and administrative conditions. The adjustments are made based on the following considerations.

(i) Large roads, rivers and Kelurahan/Desa boundaries are considered as the boundaries of the sewerage development areas.

(ii) Kelurahan Sumerta Kelod is expected to develop as the institutional center. It is fully incorporated into the sewerage development area although its future population density is less than 100 person/ha.

(iii) When sewer pipes are planned under the boundary roads, some outside areas of the roads are included to collect the wastewater of the areas.

The adjusted sewerage development area and included total population are shown below (see, Fig. 5.18).

	1990	2010
Area (ha)	2,683.0	2,683.0
Population	194,209	284,100
Population Density (person/ha)	72.4	105.9
Nos. of Concerned Kel./Desa	26	26

The existing and future land uses in the sewerage development area are summarized below.

	1990 (ha)	2010 (ha)
Residential area	832.1 (31.0%)	1,261.0 (47.0%)
Commercial & Institutional area	201.4 (7.5%)	232.3 (8.7%)
Tourism area	12.3 (0.5%)	19.7 (0.7%)
Industrial area	9.4 (0.4%)	10.3 (0.4%)
Other area	1,627.8 (60.6%)	1,159.7 (43.2%)
Total	2,683.0 (100.0%)	2,683.0 (100.0%)

(2) Design wastewater generation

The design wastewater generation is summarized in Table 5.1.

(3) Collection system

The proposed collection system is summarized in Table 5.2.

5.5.3 Kuta Sewerage Development

(1) Sewerage development area

The proposed sewerage development covers the developed Kuta Beach areas of 648 ha (see Fig. 5.18). The existing and future population covered by the project are as follows.

	1990	2010
Area (ha)	648	648
Population	14,600	21,580
Population Density (person/ha)	22.5	33.3

The existing and future land uses of the project area are summarized below.

	Existing (1990)	Future (2010)
Residential area	156.2 (24.1%)	199.7 (30.8%)
Commercial & Institutional area	62.7 (9.7%)	80.6 (12.4%)
Tourism area	122.7 (18.9%)	157.7 (24.3%)
Industrial area	12.8 (2.0%)	12.8 (2.0%)
Other area	293.6 (45.3%)	197.2 (30.5%)
Total	648 (100.0%)	648 (100.0%)

(2) Design wastewater generation

The design wastewater generation is summarized in Table 5.1.

(3) Collection system

The proposed collection system is summarized in Table 5.2.

5.5.4 Sanur Sewerage Development

The proposed sewerage development covers Desa Sanur Kaja, Kelurahan Sanur and part of Desa Sanur Kauh with a total area of 740 ha (see Fig. 5.18). The existing and future population of the sewerage development area are as follows.

	1990	2010
Area (ha)	740	740
Population	17,864	27,800
Population Density (person/ha)	24.1	37.6

The existing and future land uses of the project area are as follows.

	Existing (1990)	Future (2010)
Residential area	106.4 (14.4%)	192.2 (26.0%)
Commercial & Institutional area	18.8 (2.5%)	18.8 (2.5%)
Tourism area	86.5 (11.7%)	164.3 (22.2%)
Industrial area	5.1 (0.7%)	5.1 (0.7%)
Other area	523.2 (70.7%)	359.6 (48.6%)
Total	740 (100.0%)	740 (100.0%)

(2) Design wastewater generation

The design wastewater generation is summarized in Table 5.1.

(3) Collection system

The proposed collection system is summarized in Table 5.2.

5.5.5 Tanjung Benoa Sewerage Development

The proposed sewerage development covers the whole Benoa peninsula of 136 ha (see Fig. 5.18). The existing and future population of the sewerage development area are as follows.

	1990	2010
Area (ha)	136	136
Population	1,040	1,540
Population Density (person/ha)	7.6	11.5

The existing and future land uses of the project area are as follows.

	Existing (1990)	Future (2010)
Residential area	30.0 (22.1%)	30.0 (22.1%)
Commercial & Institutional area	1.9 (1.4%)	1.9 (1.4%)
Tourism area	12.8 (9.4%)	100.6 (74.0%)
Industrial area	-	-
Other area	91.3 (67.1%)	3.5 (2.5%)
Total	136 (100.0%)	136 (100.0%)

(2) Design wastewater generation

The design wastewater generation is summarized in Table 5.1.

(3) Collection system

The proposed collection system is summarized in Table 5.2.

5.5.6 Treatment Plant

(1) Selection of Treatment System

Wastewater of the Tanjung Benoa area can be optimally treated by improving the existing treatment plant of BTDC of oxidation pond type. However, various types of sewage treatment system can be considered for the other three (3) areas.

The wastewater generation in the three (3) areas are estimated to be 82,800 m^3/day for Denpasar, 18,500 m^3/day for Sanur and 19,700 m^3/day for Kuta in 2010. However, 4,000 m^3/day in Kuta area is planned to be treated by IUIDP project. Accordingly, 117,000 m^3/day shall be treated by this Project in total. The expected treated water quality is less than 20 mg/l as BOD.

Four (4) treatment systems of aerated lagoon, conventional activated sludge, oxidation ditch and ocean outfall are applicable to meet the above requirements. The above four (4) systems are compared under the following design conditions.

- Design wastewater discharge : 117,000 m^3/day
- Design wastewater quality (influent) : BOD : 190 mg/l
  (effluent) : BOD < 20 mg/l

(i) Aerated lagoon

The proposed system consists of inflow pump, aerated lagoon, aerated facultative lagoon and polishing pond. The included major mechanical/electrical equipment are inflow pumps with a total capacity of 153 m^3/min. x 7.4 m and aerators with total capacity of 1,455 kW.

The site of the treatment plant is assumed in the existing fish pond along Benoa Bay.

(ii) Conventional activated sludge

The system consisting of inflow pump station, primary settling tank, aeration tank, secondary settling tank and sludge disposal facilities is proposed in the same location as the aerated lagoon. The included major mechanical/electrical equipment are inflow pumps (153 m^3/min. x 7.4 m) and air diffusers (860 kW).

(iii) Oxidation ditch

The system consisting of inflow pump station, oxidation ditch, final settling tank and sludge disposal facilities is proposed in the same location as the aerated lagoon. The included major mechanical/electrical equipment are inflow pumps (153 m^3/min. x 7.4 m) and rotors (2,068 kW).

(iv) Ocean outfall

The wastewater is discharged 7 km off-shore through a conduit from the southern edge of Sanur Beach after primary treatment.

The system consists of primary settling tank, booster pump station, conduit and sludge disposal facilities. The included major mechanical/electrical equipment are only booster pumps (153 m^3/min. x 16 m).

The above four (4) systems are compared in terms of required construction and O&M costs, required land space and easiness of O&M as shown below.

Evaluation Item	Aerated Lagoon	Conventional Activated Sludge	Oxidation Ditch	Ocean Outfall
(1) Const. Cost (million Rp.)	22,500	71,200	57,000	87,600
(2) O&M Cost (million Rp./year)	1,691	1,132	2,508	370
(3) Required Land Space (ha)	22.0	6.8	16.1	3.2
(4) Easiness of O&M				
- Adaptability to Overload	A	C	B	A
- Required Technology Level	A	C	B	A
- Sludge Disposal	A	C	C	C

Note: 1) Const Cost: direct construction cost excluding land acquisition, engineering and administration costs
2) O&M Cost : electric charge
3) Adaptability to Overload : A: high, B: middle, C: low
4) Required Technology Level : A: low, B: middle, C: high
5) Sludge Disposal : A: easy, B: medium, C: hard

As evident from the above table, aerated lagoon system is the most recommendable one.

(2) Treatment plant for Denpasar, Kuta and Sanur

The wastewater of Denpasar, Kuta and Sanur areas are treated by the treatment plant of aerated lagoon which is located at the on-shore land in Kelurahan Pedungan. The treatment plant consisting of aerated lagoon, facultative aerated lagoon and maturation pond requires a land of 22.0 ha to treat the design wastewater of 117,000 m^3/day.

Salient features of the treatment plant are:

Inflow pump	:	152.5 m^3/min
Aerated lagoon	:	234,000 m^3, 67,000 m^2
Facultative aerated lagoon	:	234,000 m^3, 67,000 m^2
Aerator	:	1,455 kW

(3) Treatment plant for Tanjung Benoa

The capacity of the existing treatment plant of oxidation pond is 7,200 m^3/day. This treatment plant is remodeled to an aerated lagoon system to meet the future wastewater of 18,800 m^3/day generated in BTDC and Tanjung Benoa areas.

5.6 Proposed On-site Sanitation Development

Septic tank with up-flow filter and septic tank with leaching system are proposed as on-site sanitation systems for this master plan, which could also be considered respectively as high level and simple on-site sanitation systems.

(1) Septic Tank with Up-flow Filter

A total area of 3,614 ha in southern Denpasar is covered by septic tank with up-flow filter (see, Fig. 5.19). The ground water table of this area is shallow and the soil permeability is low. Hence, the leaching system is not applicable. Both toilet waste and gray water generated in this area are treated by septic tank with up-flow filter, then discharged to rivers/ditches nearby.

The existing and future population of this area are 73,300 and 107,700 respectively. The entire future population of 107,700 in 2010 is planned for the provision of septic tank with up-flow filter, as there is no such units under existing conditions.

(2) Septic Tank with Leaching Pit

Septic tank with leaching system covers an area of 15,832 ha in the northern and southern fringes of the Study Area (see Fig. 5.19). The total population of this area in the year 1990 and 2010 are 176,420 and 266,580 respectively.

In principle, both toilet waste and gray water are treated by septic tank with leaching system. No wastewater is discharged directly to the public water ways.

The population planned for this simple system in future includes both the future population increase and those having no toilet with treatment under the existing conditions. Accordingly, the total population requiring the provision of new septic tank with leaching system until 2010 is estimated to be about 90,160.

(3) Desludging and Treatment

The total quantity of desludging of the on-site sanitation system in the year 1990 and 2010 is estimated to be 6,700 m^3/year and 14,914 m^3/year respectively.

A sludge treatment plant with a capacity of 110 m^3/day is already planned by IUIDP. This plant is sufficient to meet the estimated future average desludging quantity of 41 m^3/day. Hence, no additional sludge treatment plants are required.

Total number of the existing vacuum trucks of both public and private sectors are nine (9). These vacuum trucks are sufficient to meet the future desludging and hauling of sludge. Hence, no additional vacuum trucks are required.

5.7 Estimated Cost

The project cost for the sewerage development is estimated at Rp. 253.6 billion at 1992 prices (Rp. 274.4 billion including house connection cost). Cost for land acquisition of the treatment site is not considered since the land is owned by the government.

Breakdown of the project cost by cost item is shown below.

Project Cost	(Unit : Million Rp.)
(A) Direct Construction Cost	211,309
(1) Collection Sewer	174,502
(2) Force Main	11,609
(3) Treatment Plant	25,198
(B) Administration Cost	4,226
(C) Engineering Cost	16,905
(D) Physical Contingency	21,160
Total	253,600
(E) House Connection Cost	20,751
Grand Total	274,351

The O&M cost of the sewerage system is estimated to be Rp. 2,670 million per annum under the full operation in 2010.

Break-down of the project cost and O&M cost by sewerage development area are shown in Table 5.3.

Table 5.1 Design Wastewater Generation

(Unit : 10^3 m^3/day)

	Denpasar	Kuta	Sanur	Tanjung Benoa
Domestic	57.5 (76.4%)	4.3 (23.4%)	5.4 (32.1%)	0.3 (7.1%)
Comm. & Inst.	14.7 (19.5%)	2.0 (10.9%)	1.0 (6.0%)	0.02 (5.0%)
Tourism	1.9 (2.5%)	11.9 (64.7%)	10.1 (60.1%)	3.9 (92.4%)
Industrial	1.2 (1.6%)	0.2 (1.0%)	0.3 (1.8%)	-
Total	75.3 (100%)	18.4 (100%)	16.8 (100%)	4.22 (100%)

Table 5.2 Proposed Collection System

	Denpasar	Kuta	Sanur	Tanjung Benoa
Secondary & Tertiary (ø150-300 mm)	418.4 km	65.7 km	97.2 km	3.1 km
Main (ø350~1,500 mm)	50.9 km	12.5 km	10.9 km	3.4 km
Conveyance Sewer (ø1,500~1,800mm)	4.4 km	1.2 km	- km	-
Force Main	-	5.2 km	5.2 km x 2	-
Sub Total	473.7 km	84.6 km	118.5 km	6.5 km
Lift Pump (Place)	1	3	3	1
Booster Pump (Place)	1	1	1	-

Table 5.3 Break-down of Project Cost and O&M Cost by Sewerage Development Area

	Denpasar	Kuta	Sanur	Tanjung Benoa	Total
Project Cost (million Rp.)					
(A) Direct Const. Cost	129,335	41,640	33,199	7,135	211,309
(1) Collection Sewer	113,794	33,673	23,078	3,957	174,502
(2) Force Main	-	4,965	6,644	-	11,609
(3) Treatment Plant	15,541	3,002	3,477	3,178	25,198
(B) Administration Cost	2,869	554	642	161	4,226
(C) Engineering Cost	11,477	2,218	2,567	643	16,905
(D) Physical Contingency	14,366	2,776	3,214	804	21,160
Total	158,047	47,188	39,622	8,743	253,600
(E) House Connection Cost	17,656	1,231	1,749	115	20,751
Grand Total	175,703	48,419	41,371	8,858	274,351
O&M Cost (million Rp./yr.)					
(A) Collection Sewer	215	24	36	2	277
(B) Force Main	-	136	195	-	331
(C) Treatment Plant	1,366	264	306	126	2,062
Total	1,581	424	537	128	2,670

Note : The construction cost and O&M cost of the integrated treatment plant are allocated for Denpasar, Kuta and Sanur in proportion to the wastewater generation of each area.

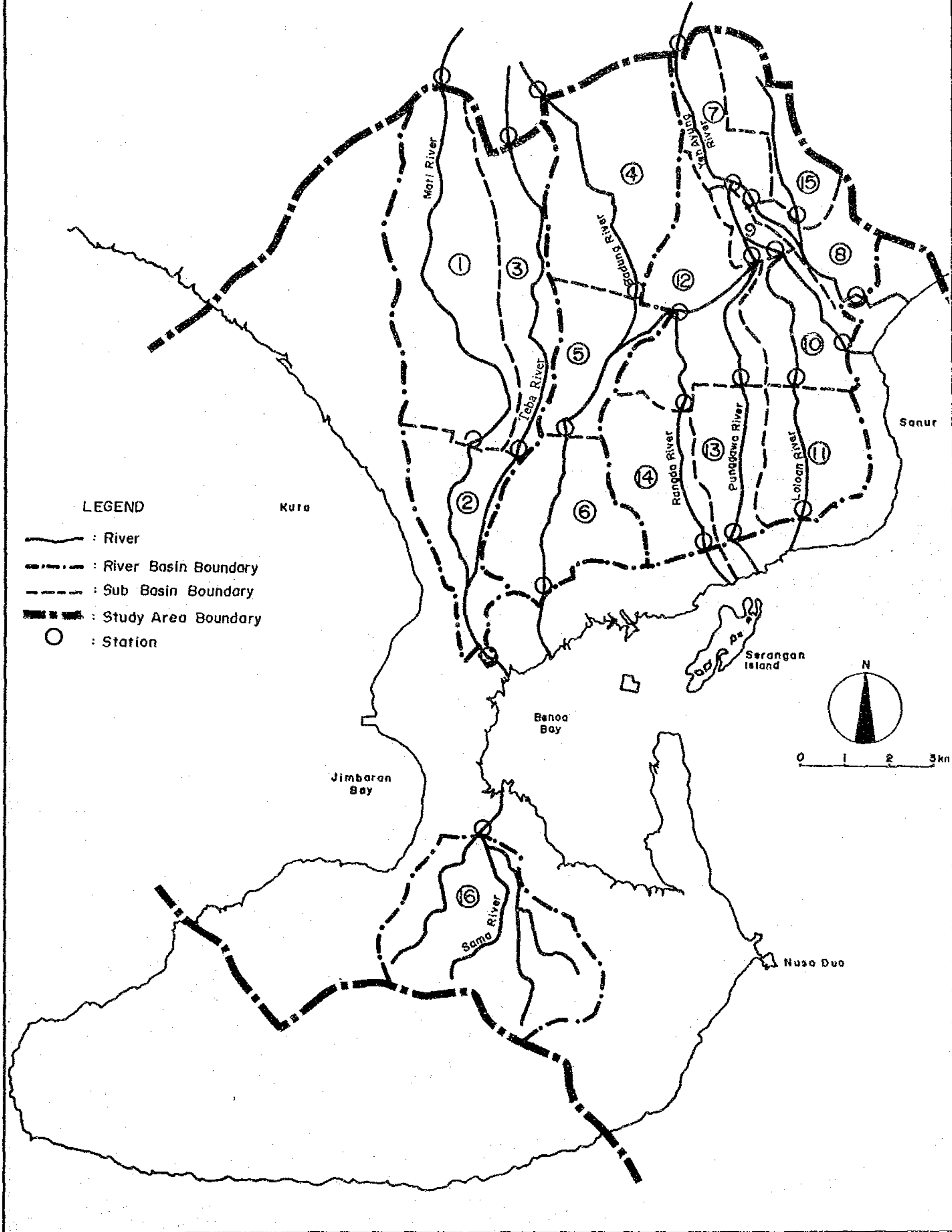


FIG. 5.1 DIVISION OF OBJECTIVE RIVER BASIN

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

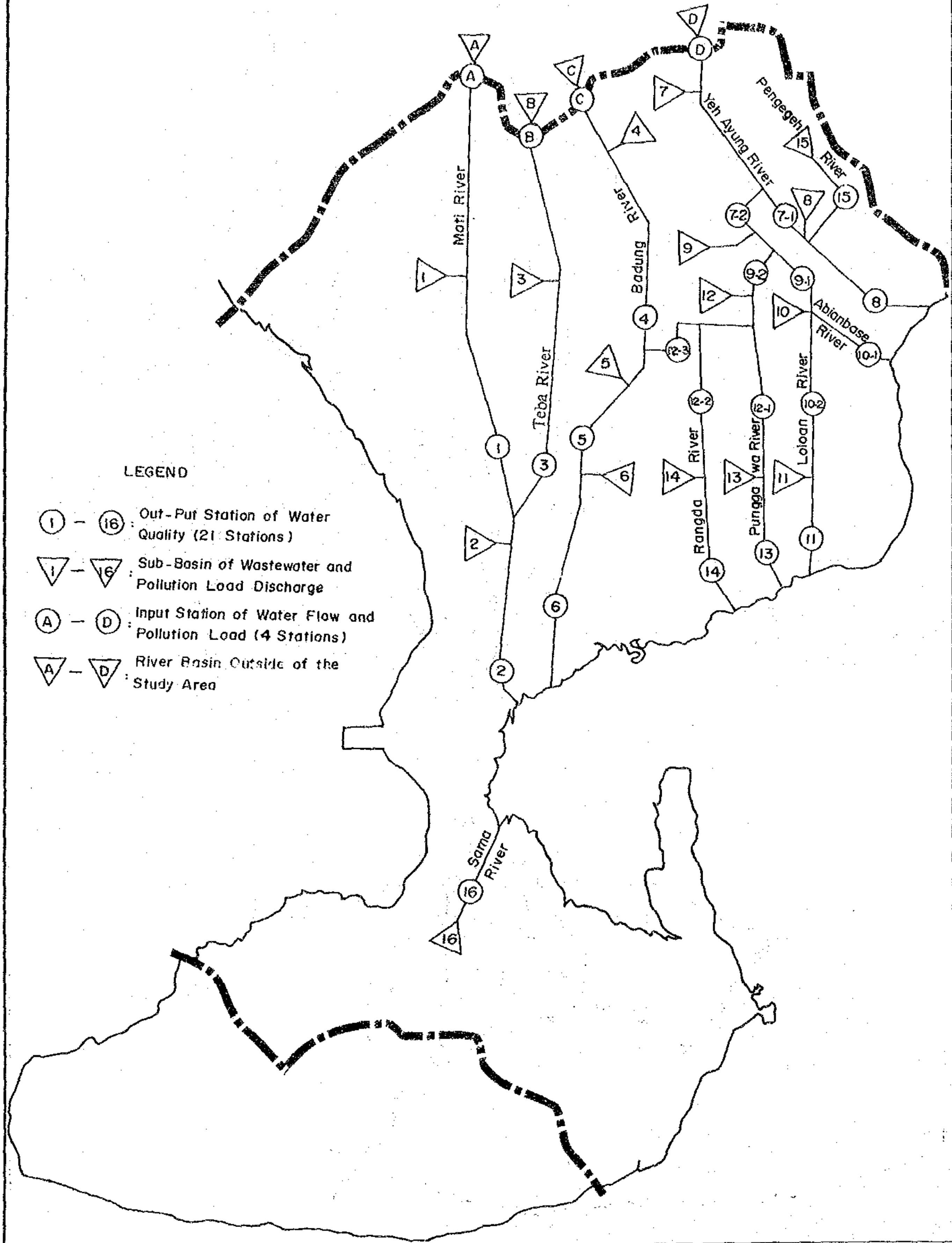
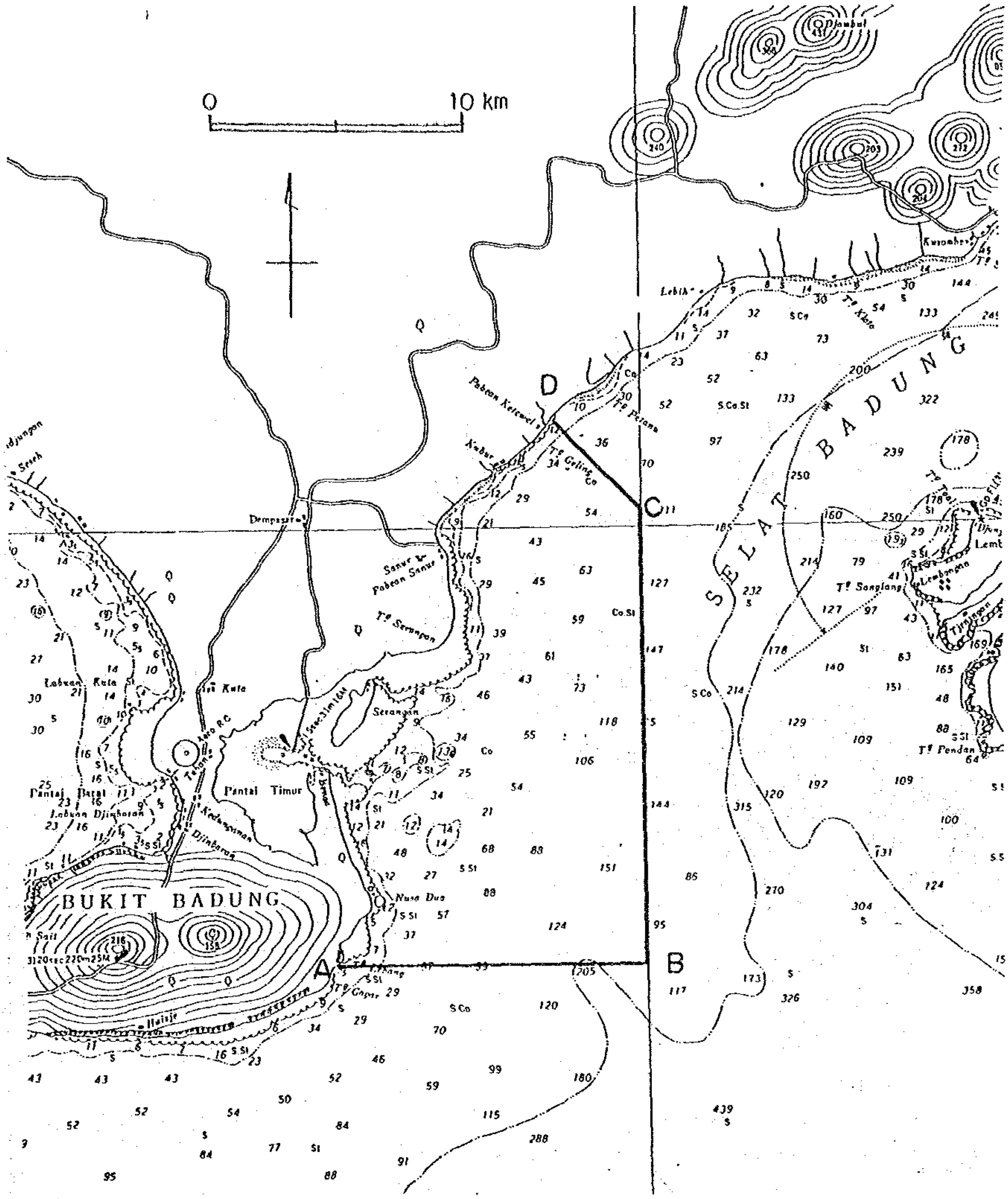


FIG. 5.2 MODEL OF RIVER SYSTEM

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR



Figures in the sea : water depth (m)

FIG. 5.3 SIMULATION AREA FOR SEA WATER QUALITY

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

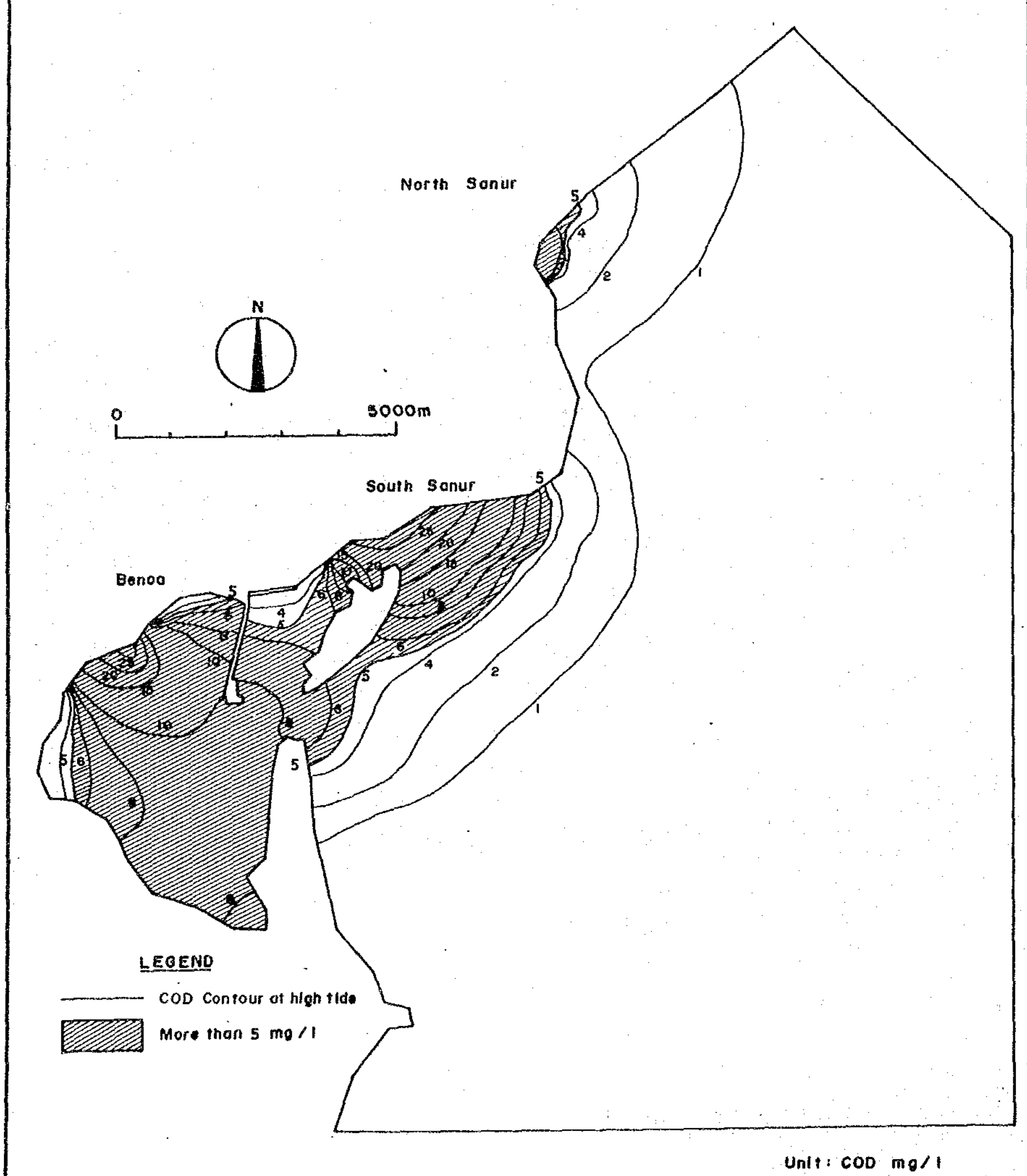


FIG. 5.4 COD DISTRIBUTION IN DRY SEASON (EXISTING)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

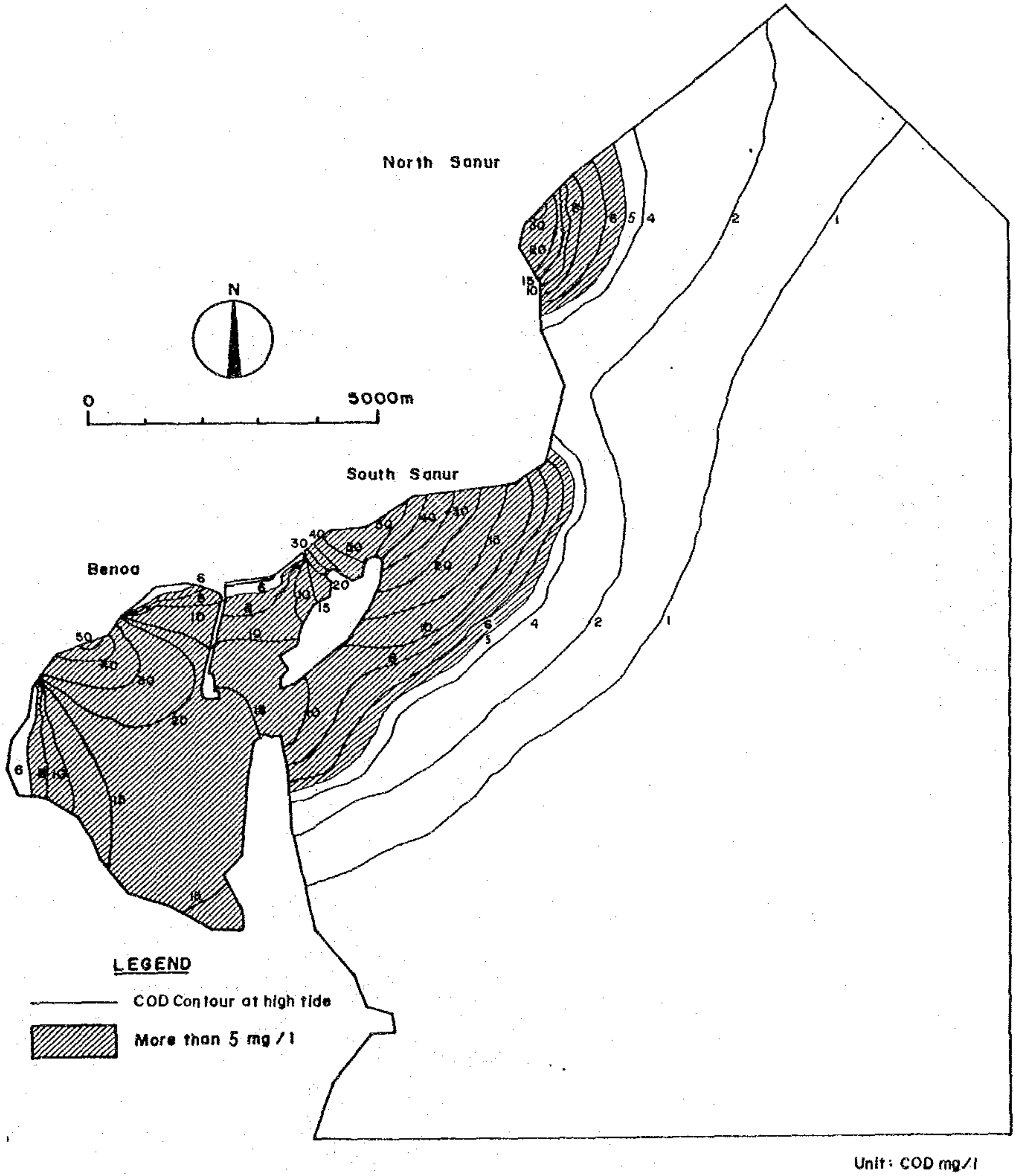


FIG. 5.5 COD DISTRIBUTION IN DRY SEASON (FUTURE) - WITHOUT PROJECT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

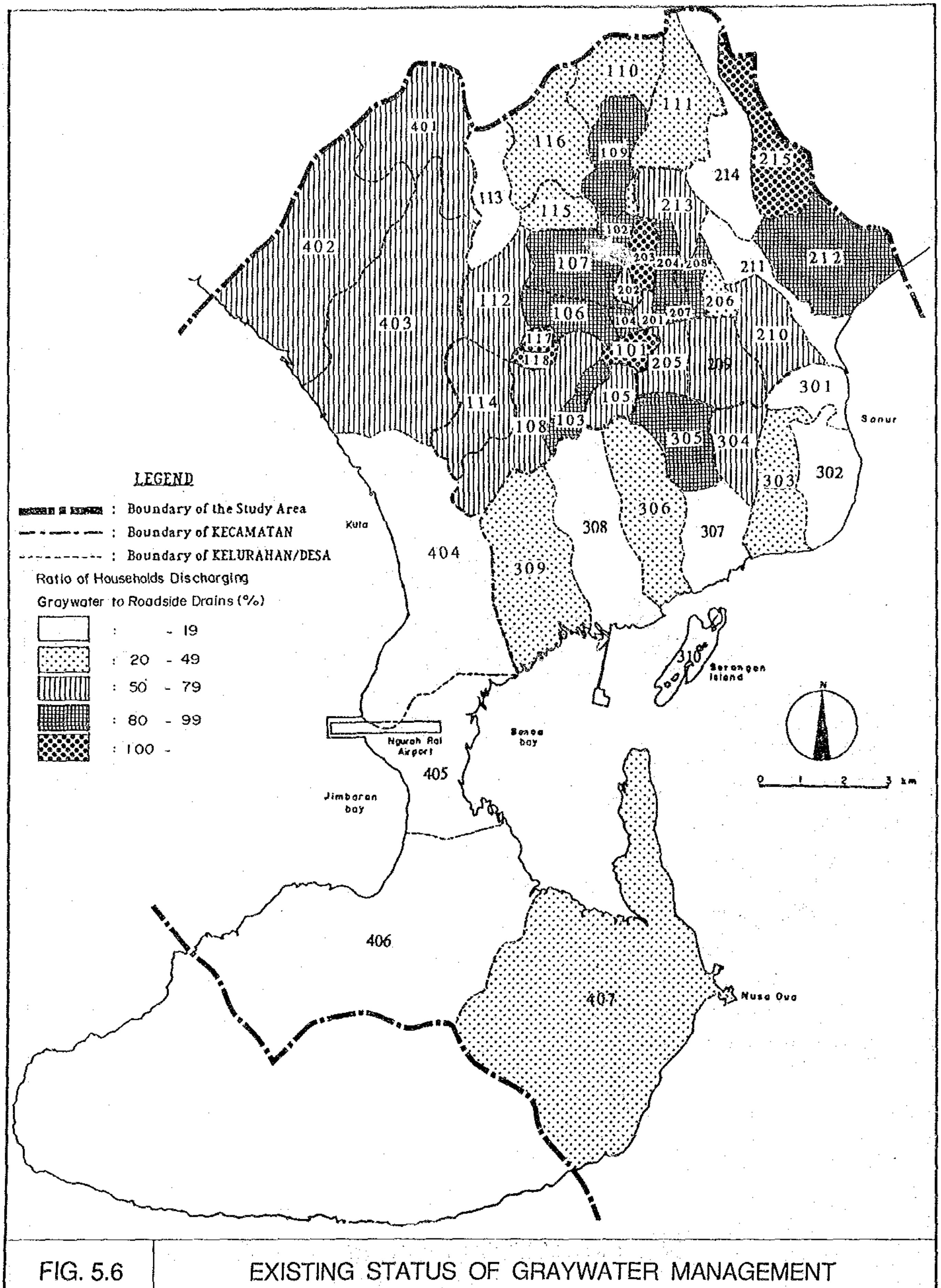


FIG. 5.6 EXISTING STATUS OF GRAYWATER MANAGEMENT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

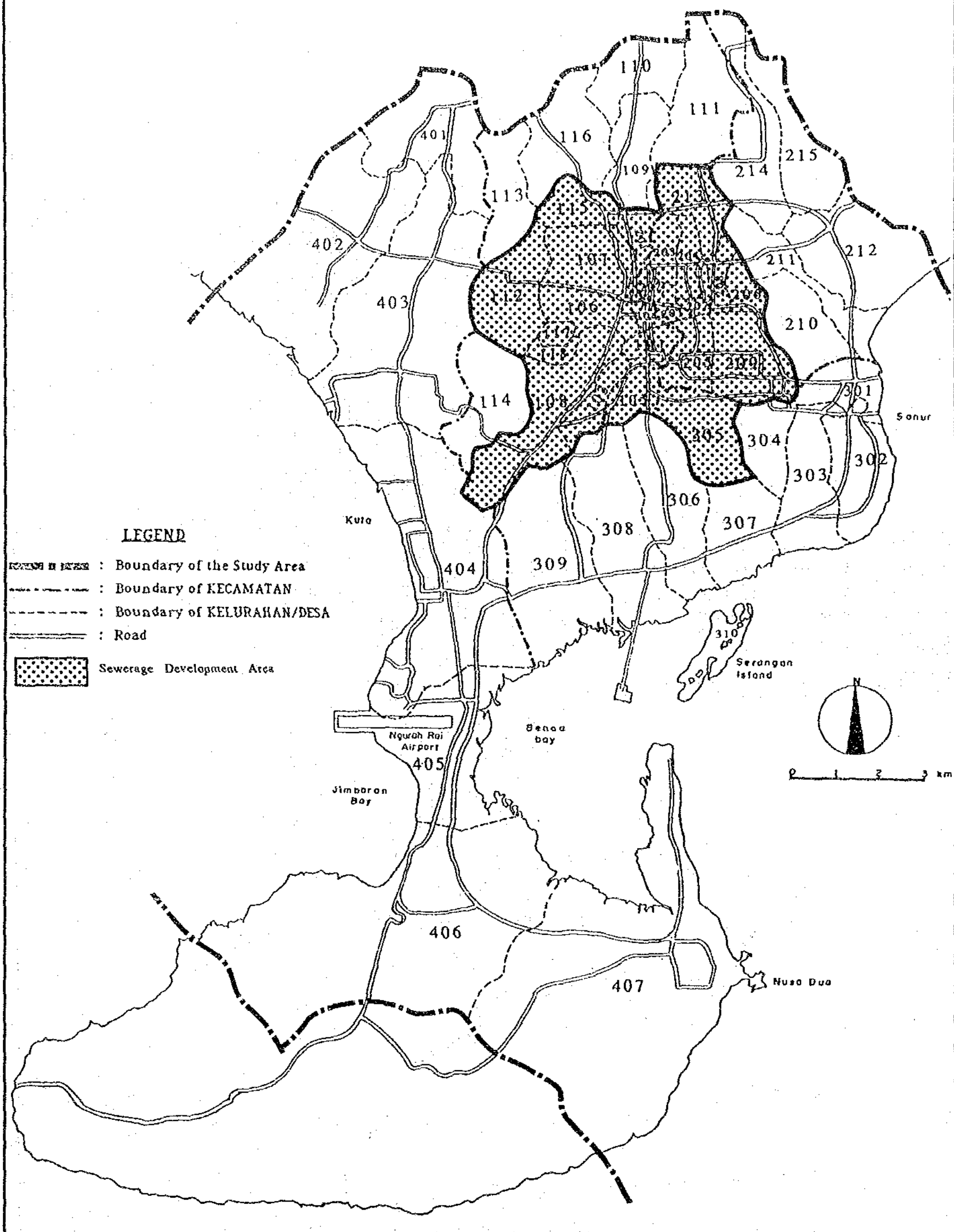


FIG. 5.7 SEWERAGE SYSTEM ONLY

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

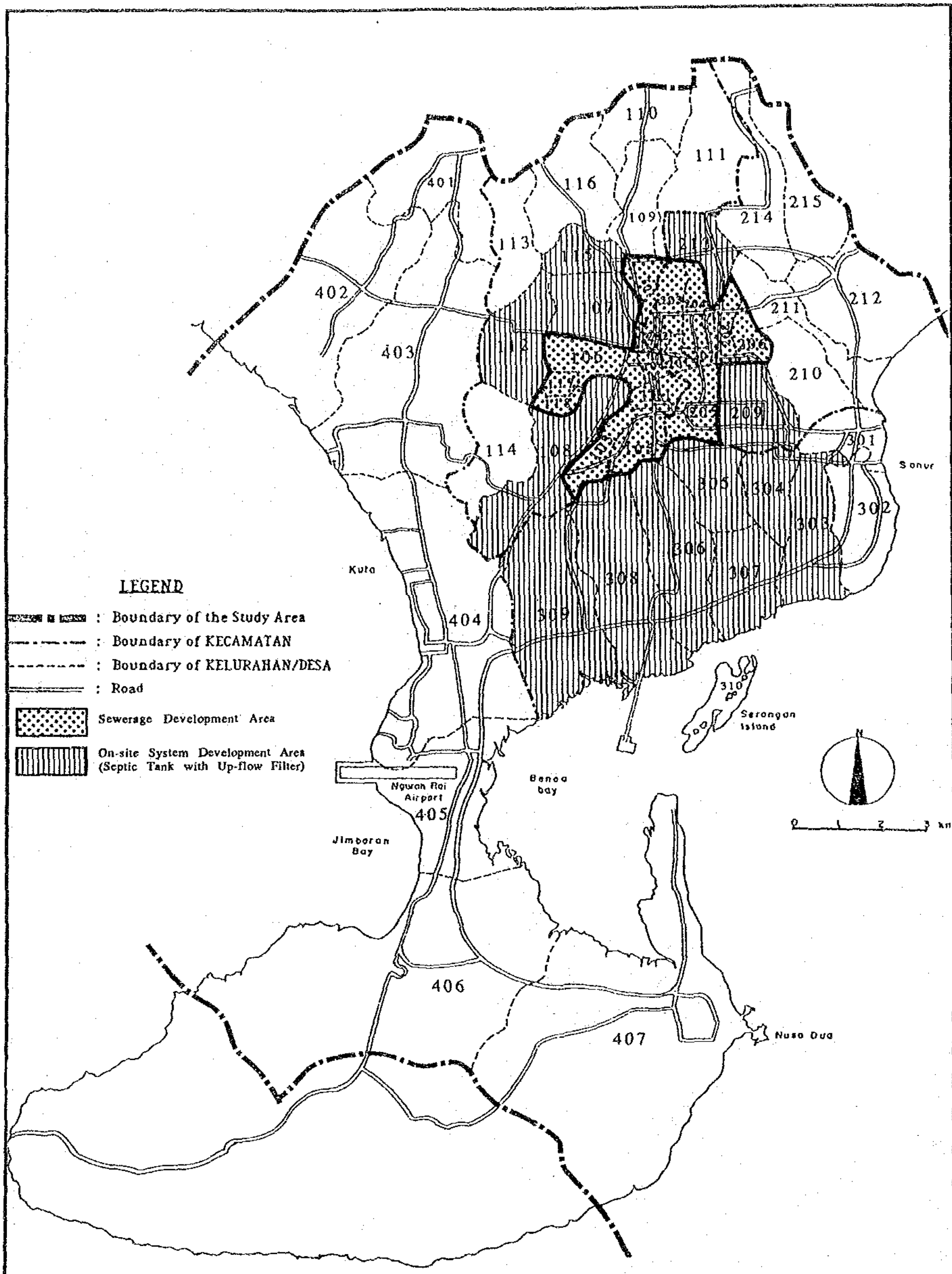


FIG. 5.8 COMBINATION OF SEWERAGE AND ON-SITE SYSTEM

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

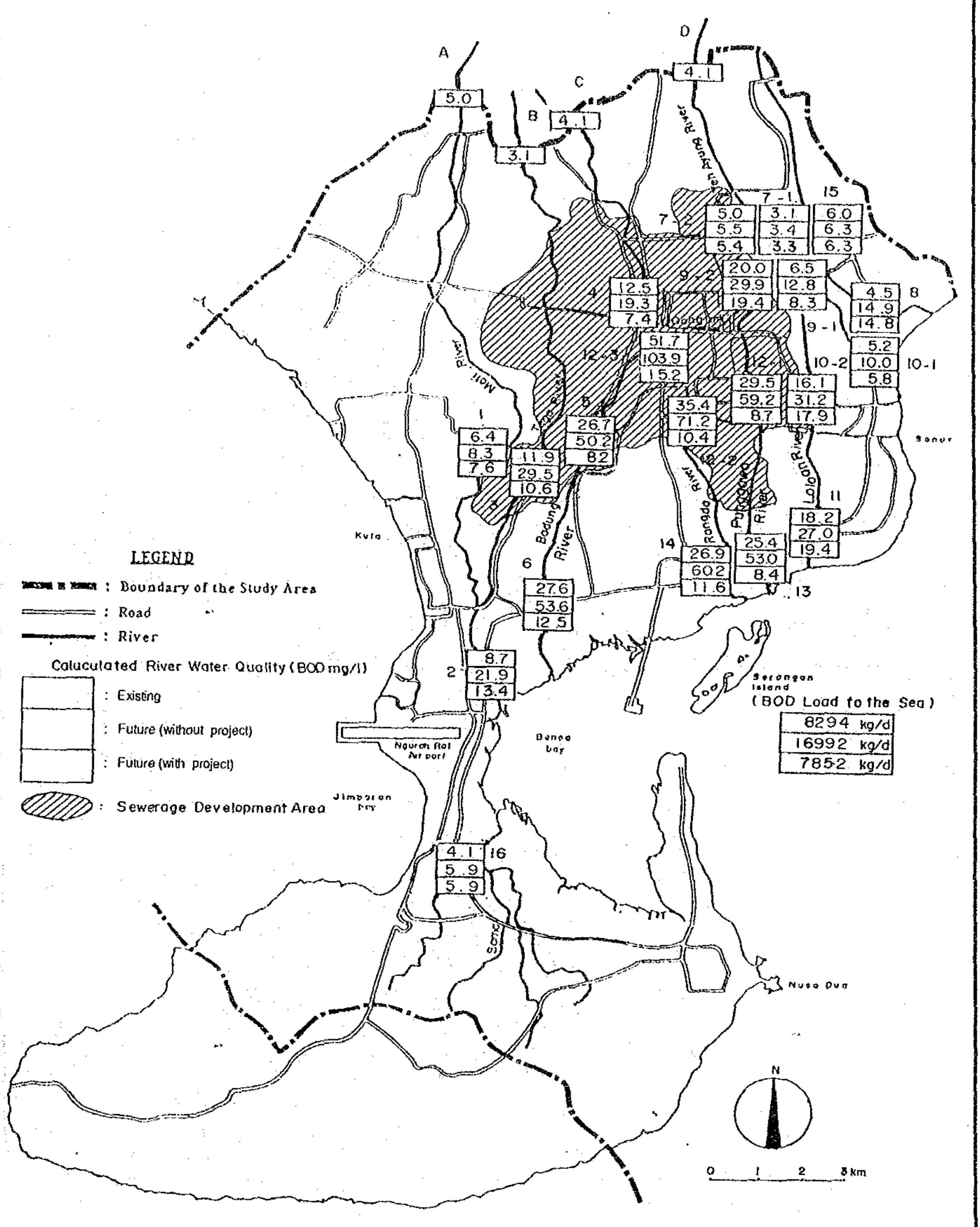


FIG. 5.9(1)	POLLUTION CONTROL EFFECTS BY SEWERAGE SYSTEM ONLY (DRY SEASON)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

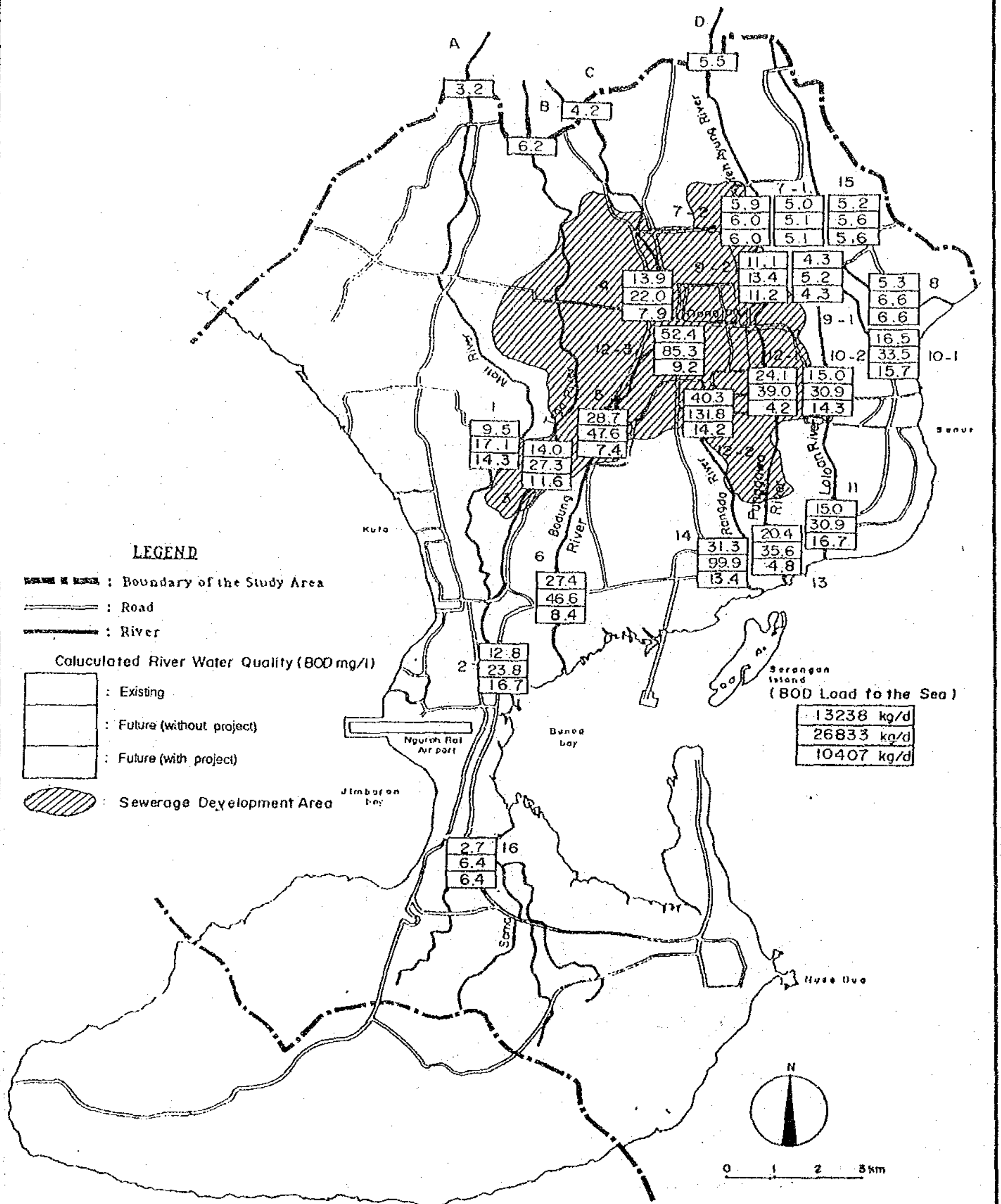


FIG. 5.9(2) POLLUTION CONTROL EFFECTS BY SEWERAGE SYSTEM ONLY (RAINY SEASON)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

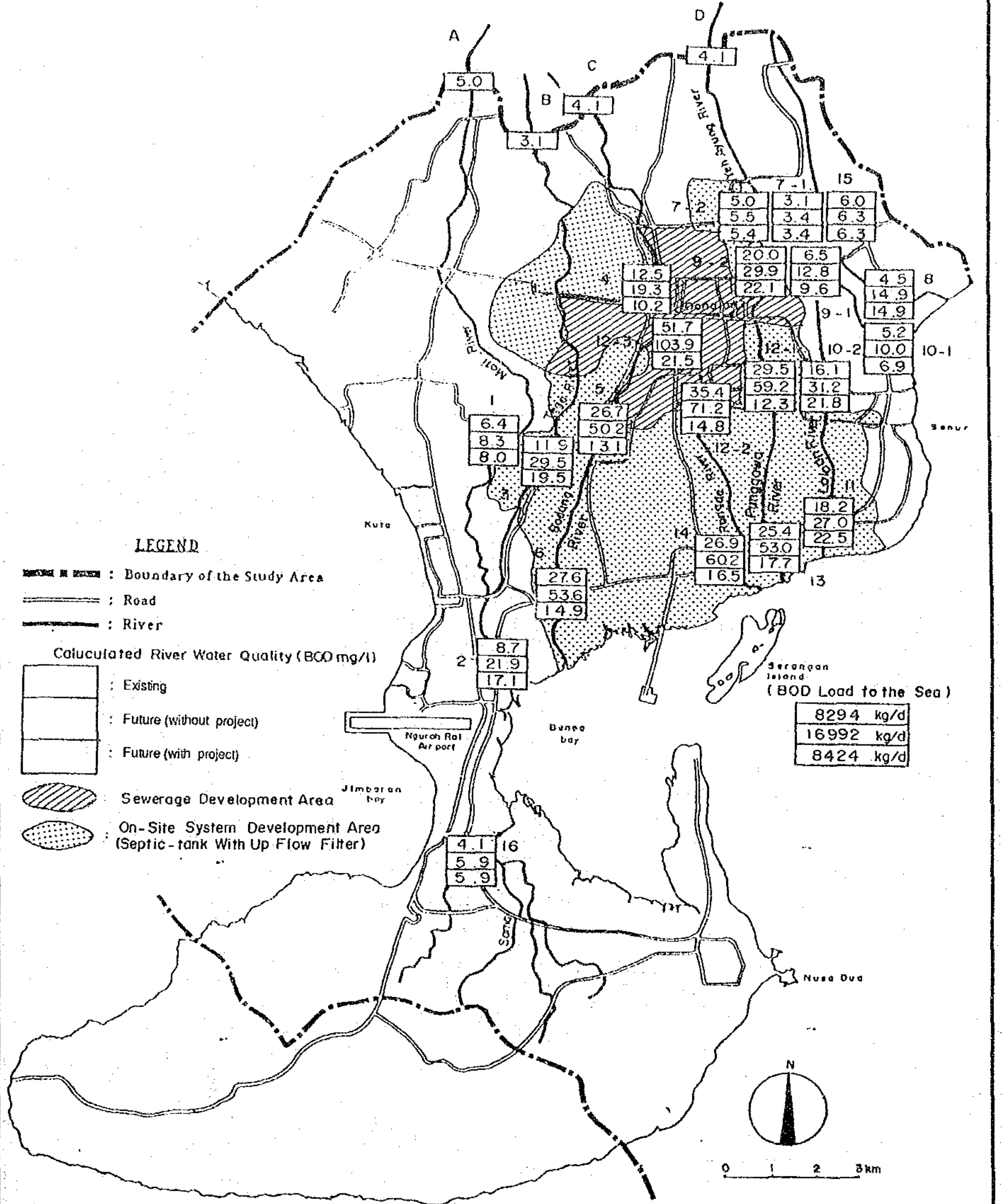


FIG. 5.10(1) POLLUTION CONTROL EFFECTS BY COMBINATION OF SEWERAGE AND ON-SITE SYSTEM (DRY SEASON)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

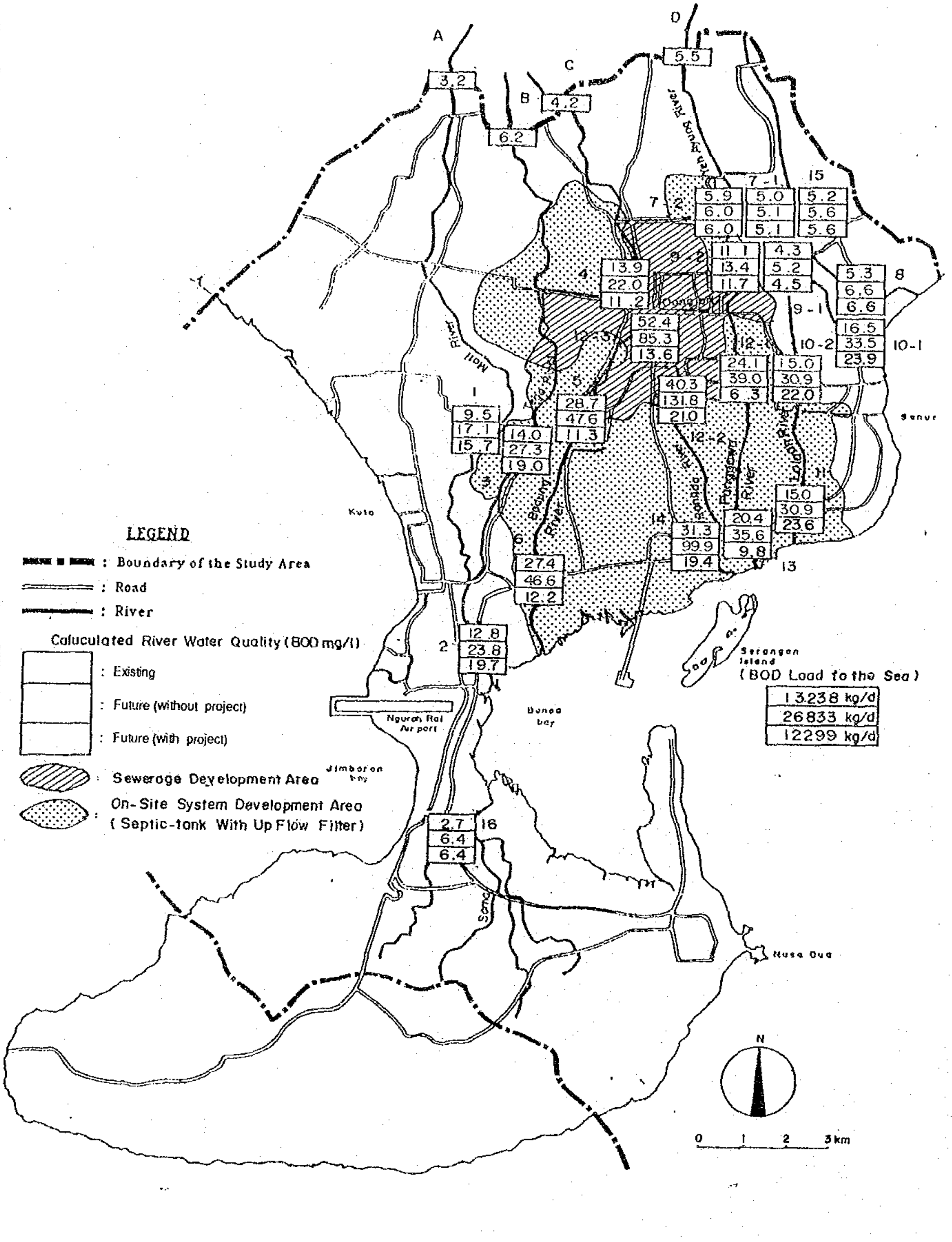


FIG. 5.10(2) POLLUTION CONTROL EFFECTS BY COMBINATION OF SEWERAGE AND ON-SITE SYSTEM (RAINY SEASON)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

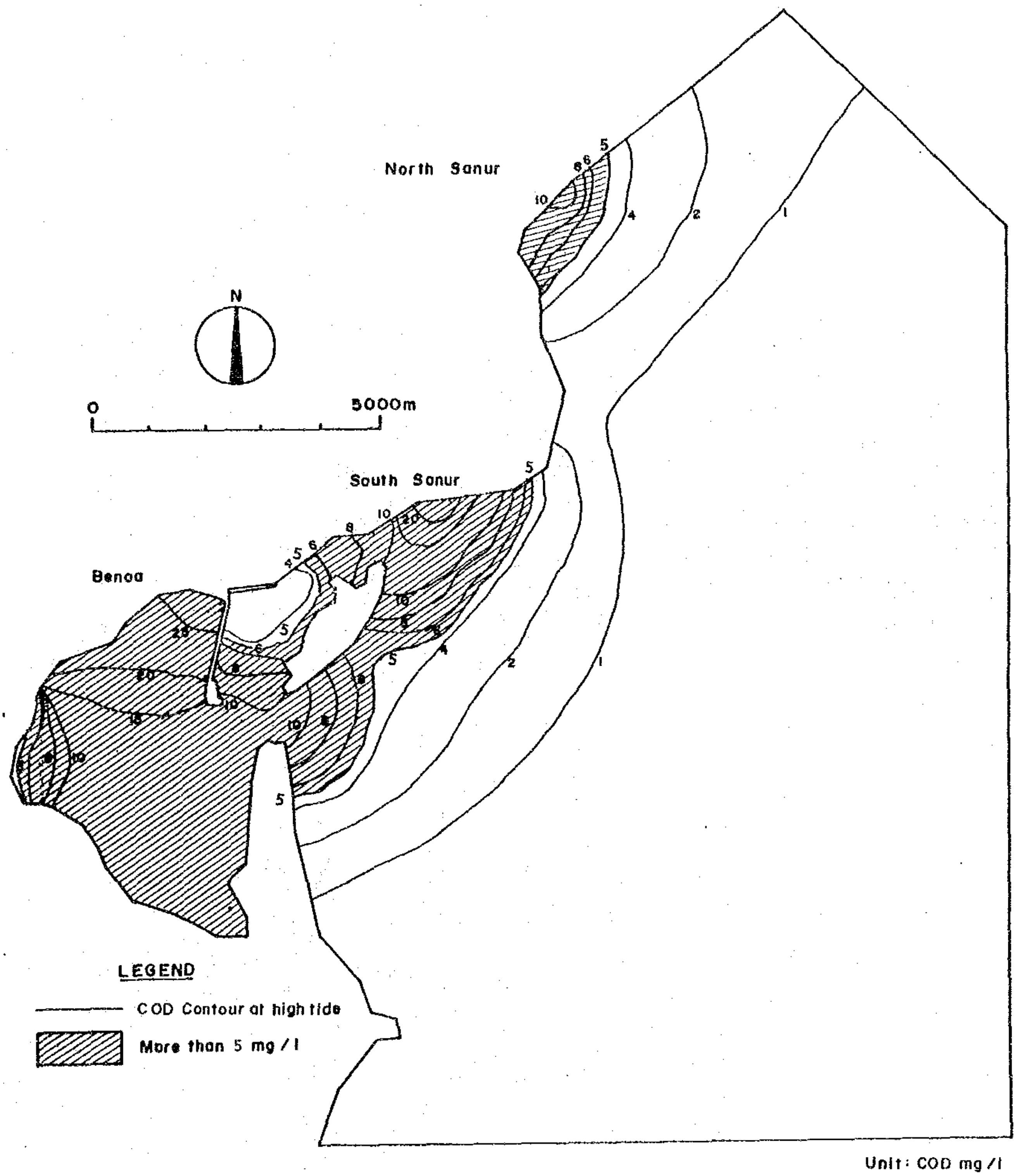


FIG. 5.11 COD DISTRIBUTION IN DRY SEASON (FUTURE) - WITH PROJECT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

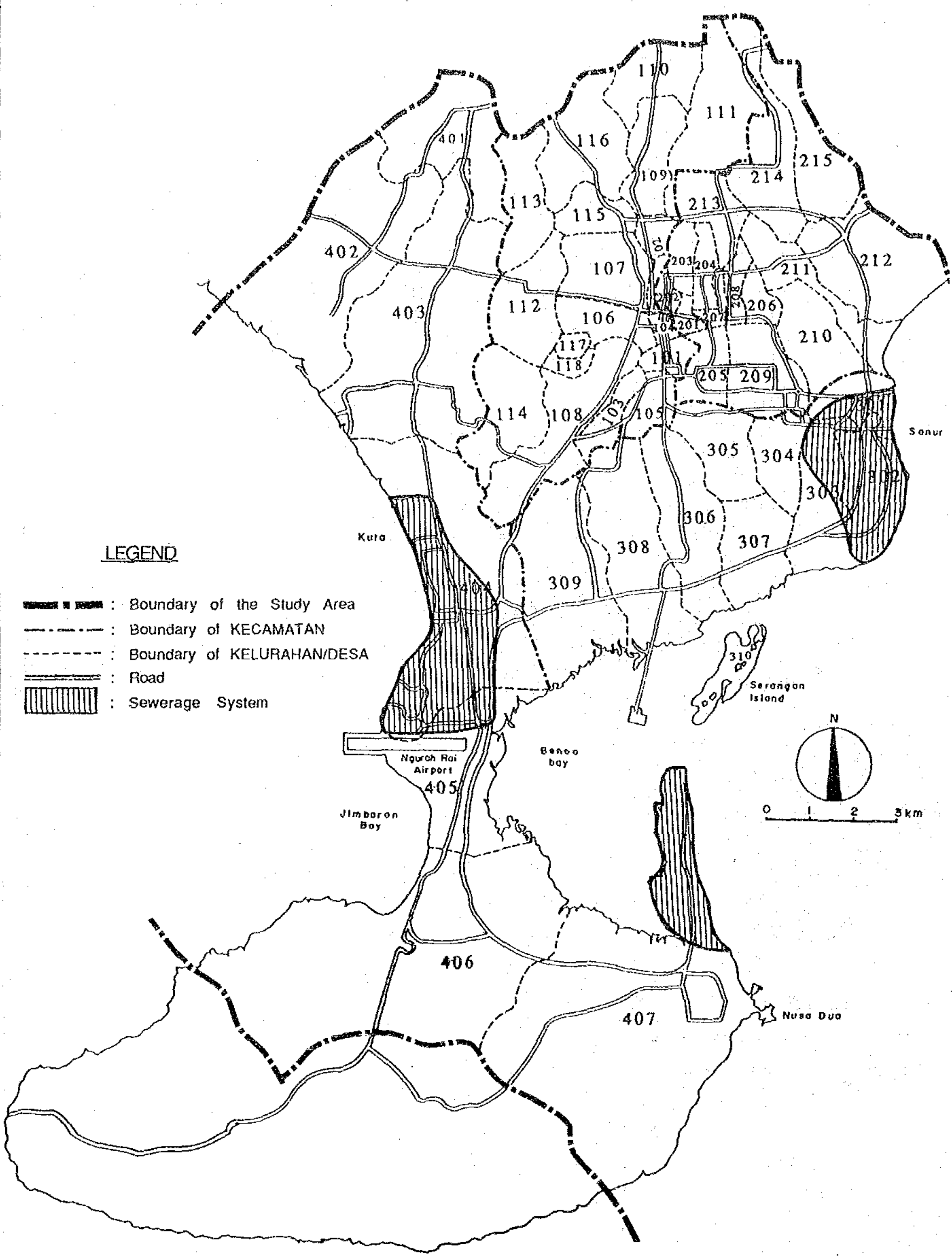


FIG. 5. 12	SEWERAGE SYSTEM DEVELOPMENT AREA (RESORT AREA)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

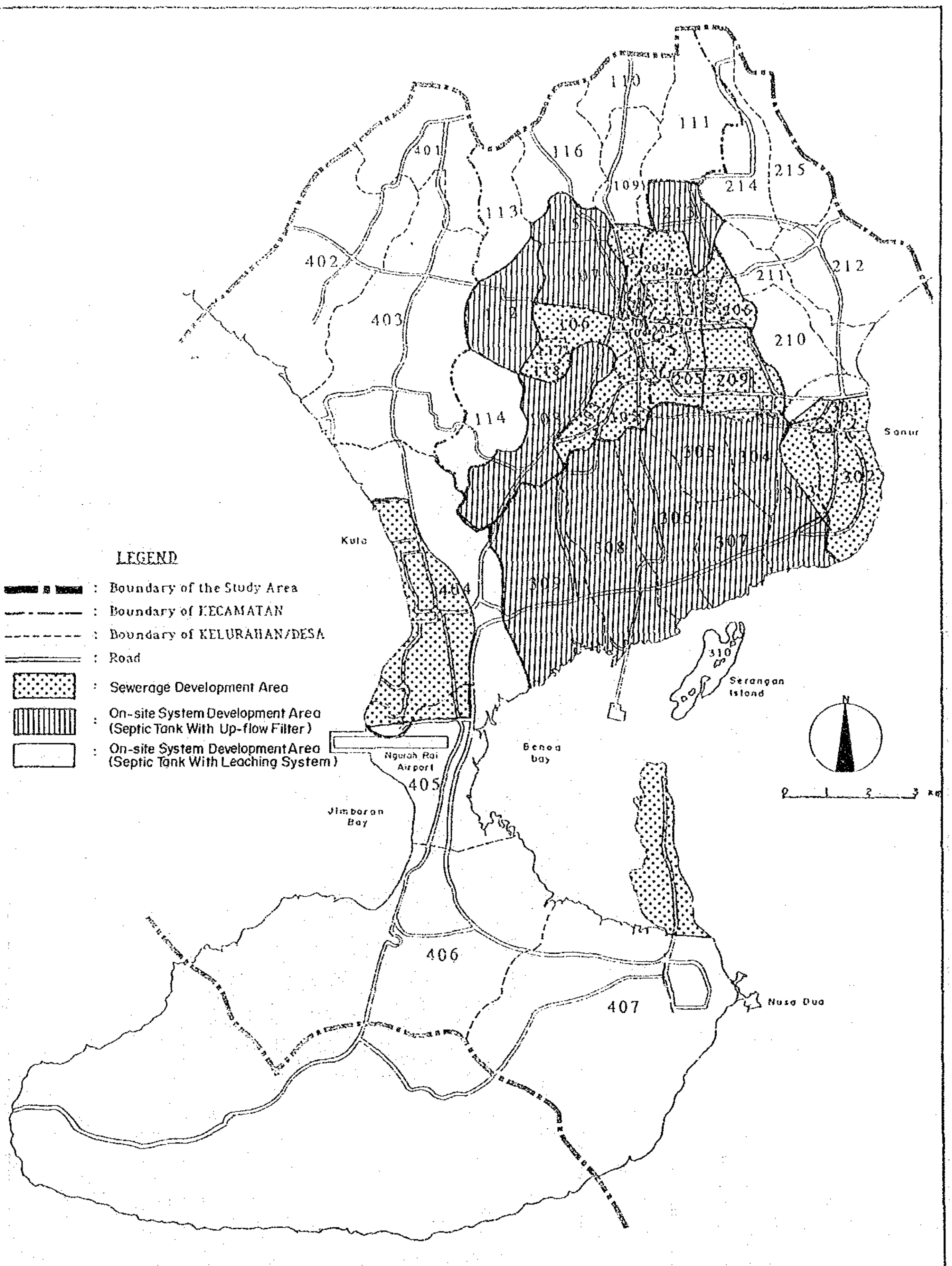


FIG. 5.13 ZONING OF WASTEWATER DISPOSAL SYSTEM DEVELOPMENT

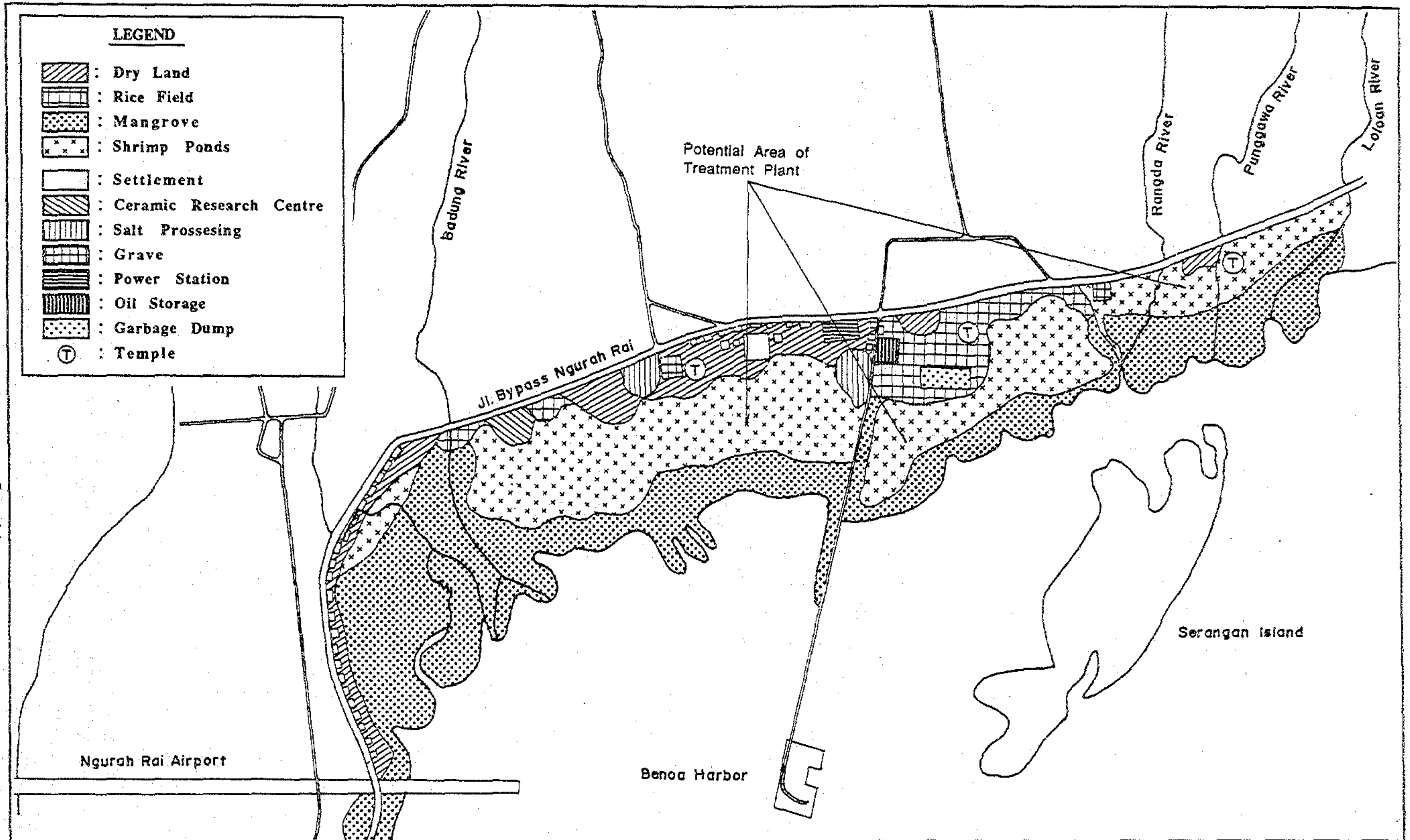


FIG. 5.14	POTENTIAL AREA OF TREATMENT PLANT
	THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

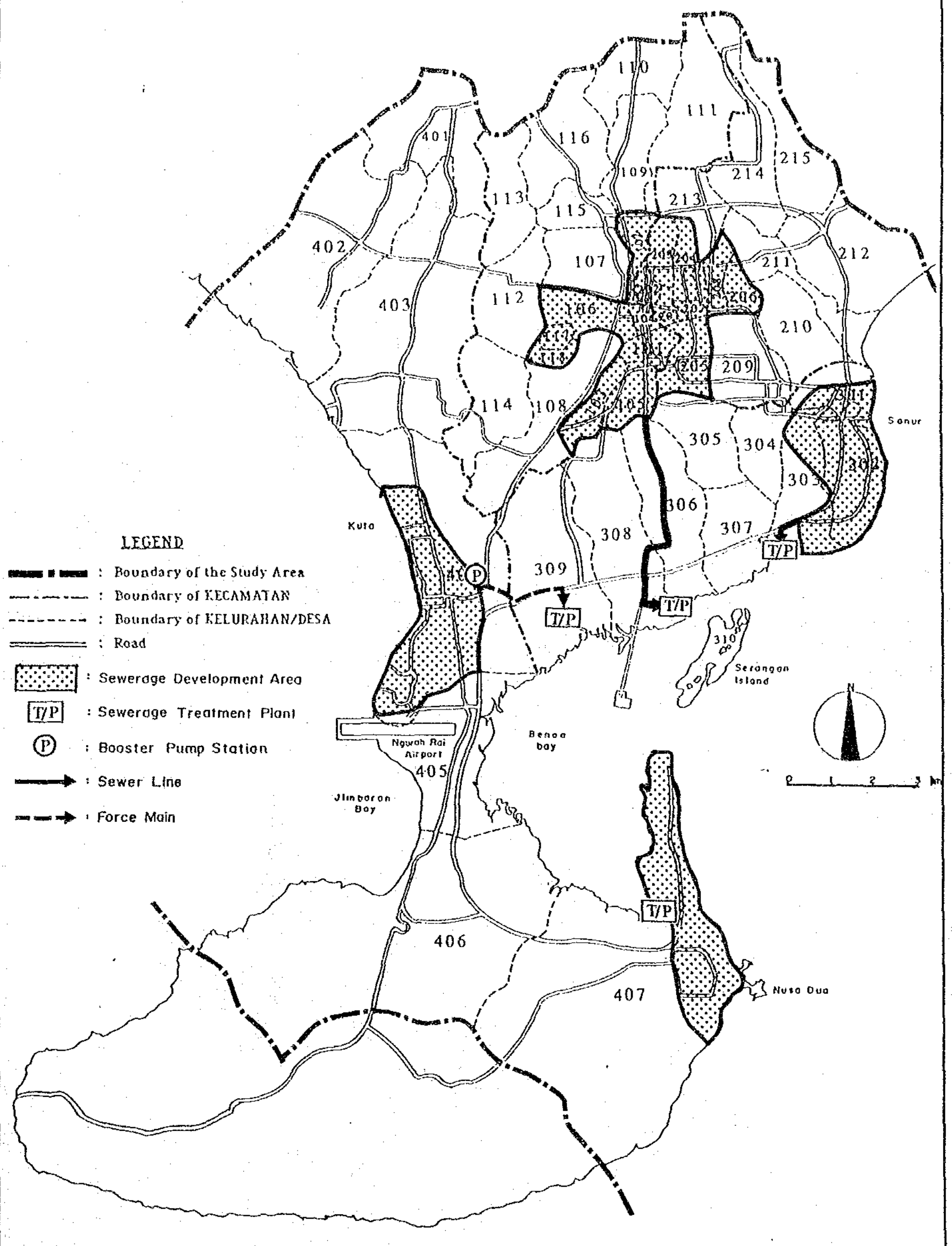


FIG. 5.15 INDIVIDUAL TREATMENT SYSTEM

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

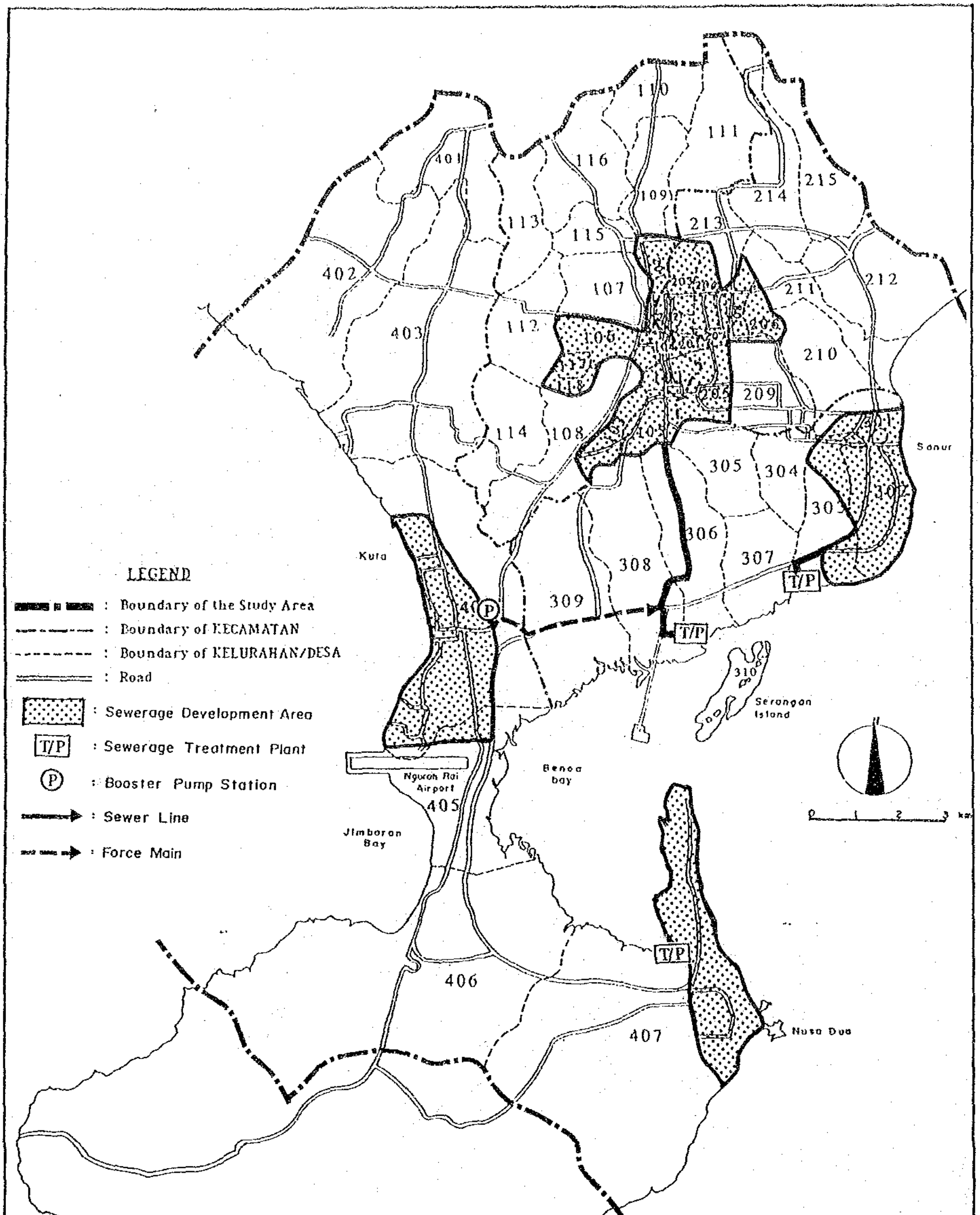


FIG. 5.16 PARTIALLY INTEGRATED TREATMENT SYSTEM

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

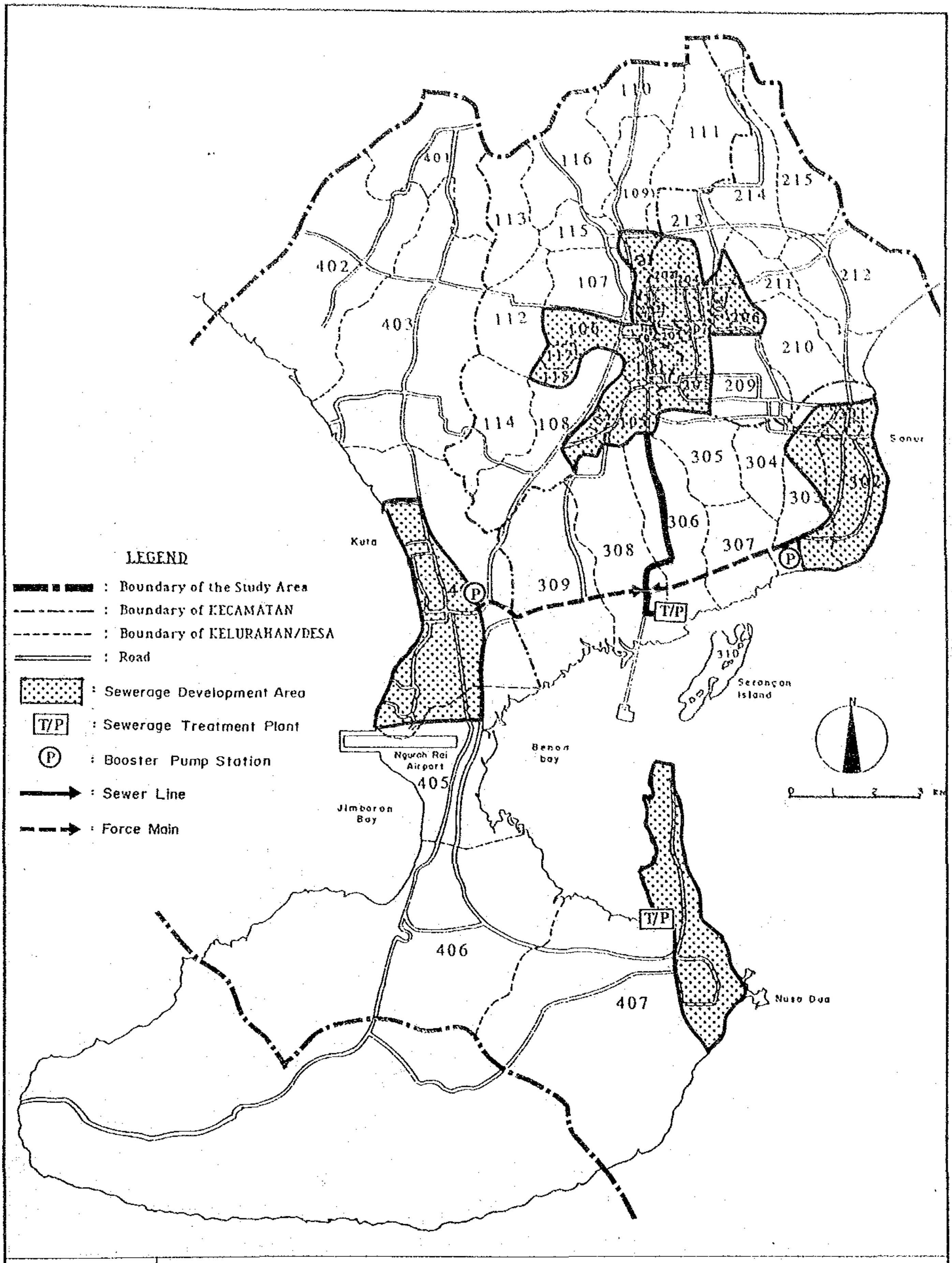


FIG. 5.17	INTEGRATED TREATMENT SYSTEM

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

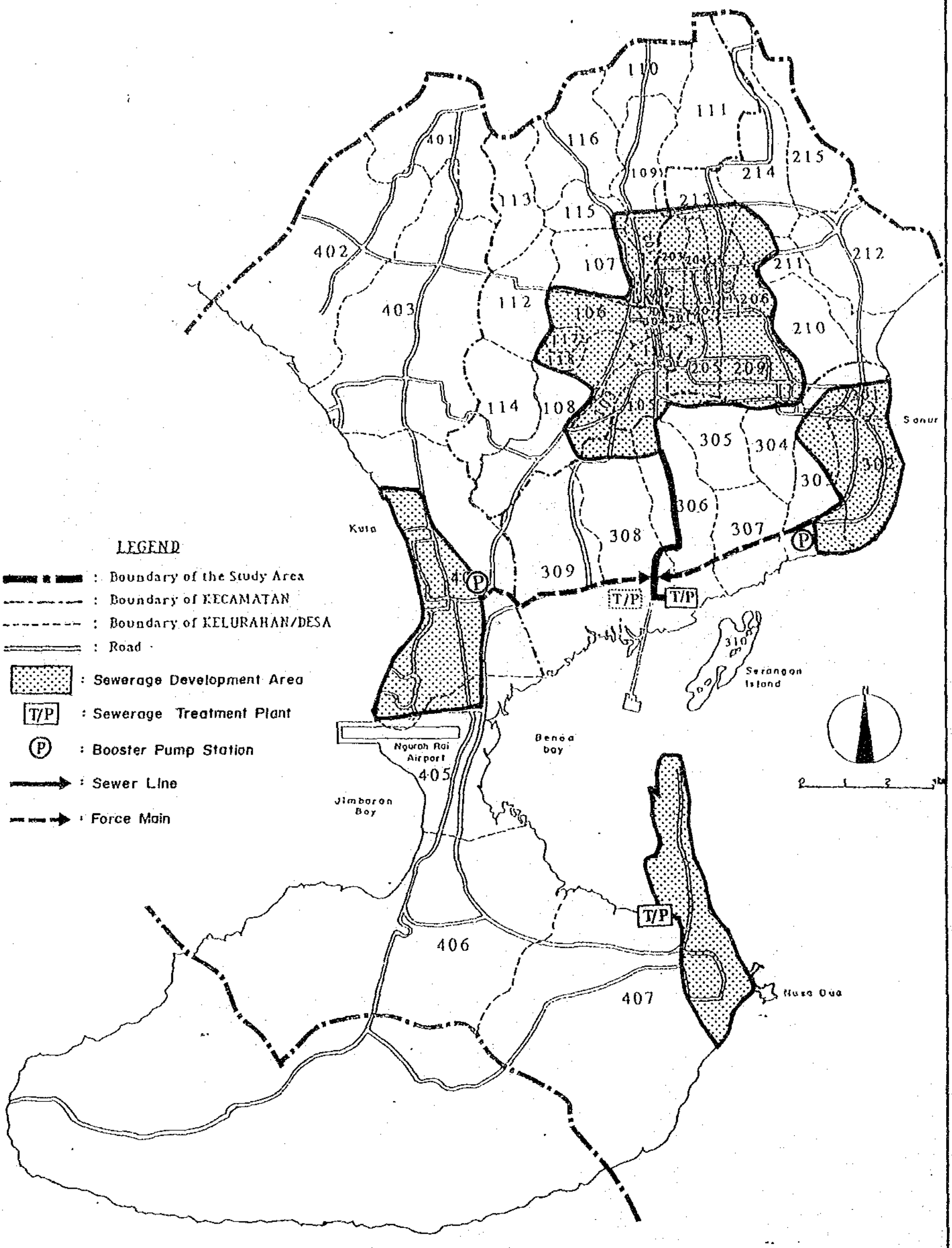


FIG. 5.18 PROPOSED SEWERAGE DEVELOPMENT PLAN

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

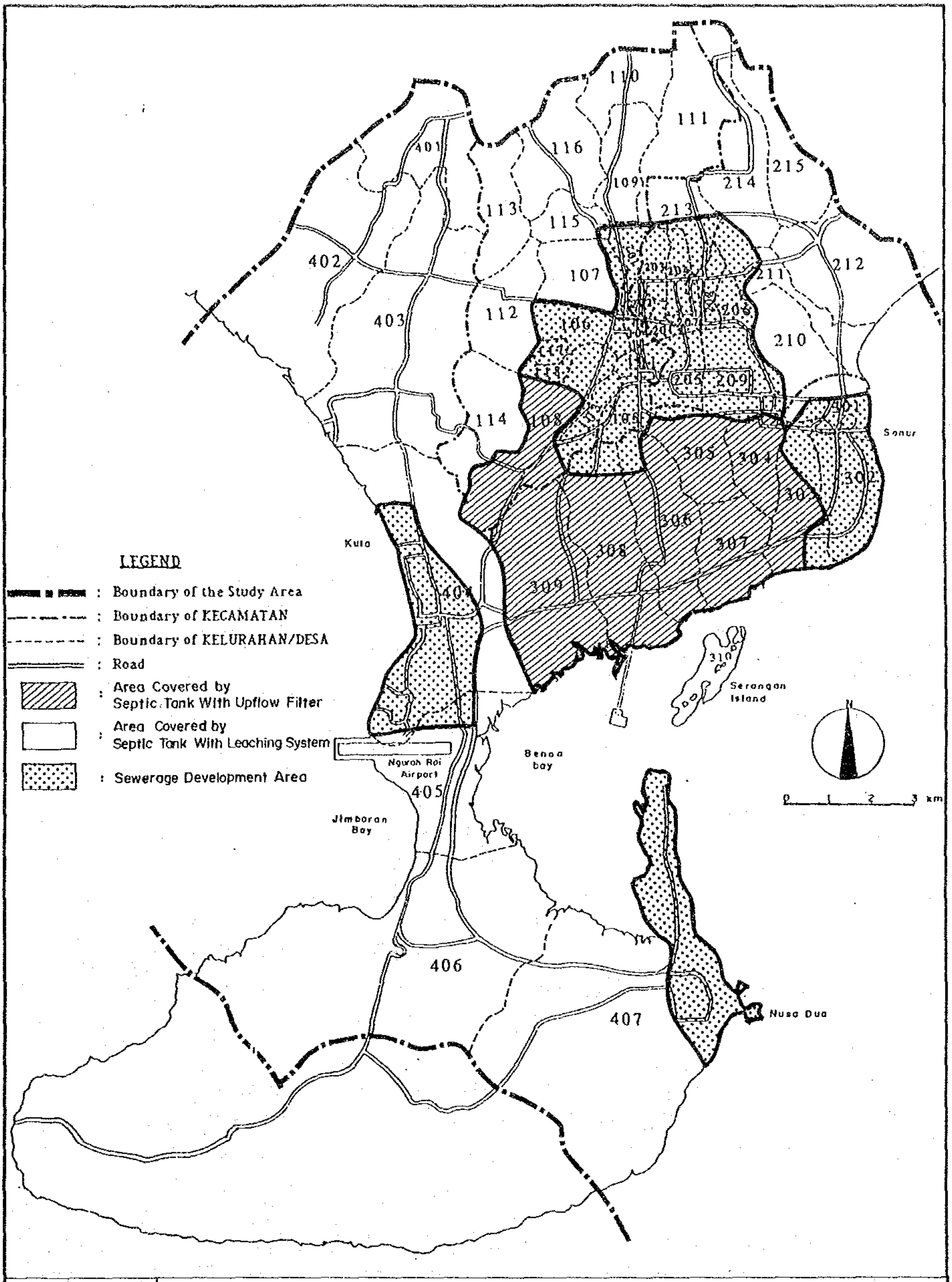


FIG. 5.19 PROPOSED ON-SITE DEVELOPMENT AREA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

CHAPTER 6 PROJECT EVALUATION

6.1 Economic, Social and Environmental Evaluation

6.1.1 Water Pollution Abatement

The river water quality of the Study Area under the existing, future without project and future with project conditions are summarized below (see Fig. 5.10(1) and Fig. 5.10(2)).

(Unit : BOD mg/l)

	Range	Average
Existing (1990)	3.4 - 52.1	17.1
Future (2010) without Project	4.3 - 101.5	33.3
Future (2010) with Project	4.3 - 23.1	13.3

The river water quality of the central and southern Denpasar areas under the same conditions are shown below.

(Unit : BOD mg/l)

	Range	Average
Existing (1990)	15.6 - 52.1	27.2
Future (2010) without Project	21.7 - 101.5	55.0
Future (2010) with Project	9.3 - 23.1	16.4

The proposed wastewater disposal project will control the river water quality of the Study Area in 2010 below 20 mg/l in BOD. The control effects are especially large for the river sections in the central and southern Denpasar.

The pollution loads to the sea from the Study Area under the existing, future without project and future with project conditions are shown below (see Fig. 5.10(1) and Fig. 5.10(2).

	Pollution Load to Sea (BOD, ton/day)
Existing (1990)	10.8
Future (2010) without Project	21.9
Future (2010) with Project	10.2

The polluted sea areas with COD of more than 5 mg/l under the existing, future without project and with project conditions are summarized below.

	Polluted Sea Area (km^2)
Existing (1990)	28.3
Future (2010) without Project	36.5
Future (2010) with Project	28.6

The proposed wastewater disposal project will control the sea water quality in 2010 around the existing one.

6.1.2 Reduction of Water-Borne Disease

The major water-borne diseases in the Study Area are Malaria, Cholera, Tuberculosis, DHF, Typhoid, Dysentery, Diphtheria, Measles, Hepatitis A, Hepatitis B and Diarrhea.

People of the Study Area are afflicted with water-borne disease at the rate of 57.1 cases per 1,000 persons per year on an average. The number of water-borne disease contractions in 1990 was 27,263 cases.

Contraction of the water-borne diseases causes two (2) kinds of economic costs. One is the medical cost. Another is the opportunity cost of time spent by a hospitalized patient.

The average medical cost per case and average opportunity cost of time spent per case are estimated to be Rp. 129,839 and Rp. 9,873 respectively at 1991 price. These two (2) costs add up to Rp. 139,712. Then, the total annual economic cost across the Study Area is calculated to be Rp. 3,809 million under the existing conditions.

The proposed wastewater disposal project will much contribute to the reduction of water-borne diseases and related economic costs.

6.1.3 Increase of Tourism Income

(1) Results of questionnaire survey

The results of the sampling questionnaire survey towards the tourists by the Study Team are summarized below.

(i) This was the 1st visit for 45.1% of them, the 2nd visit for 29.5% and the 3rd or more for the remaining 25.4%.

(ii) They consider the attraction of clean, clear and beautiful seas and rivers accounts for 70.6% of the entire attractions of Bali.

(iii) 43.9% of the tourists consider the conditions of the seas are clean, clear and in good conditions, however, 44.5% of them consider the conditions of the seas not so clean and clear in some locations.

(iv) 44.5% of the tourists consider the conditions of the rivers not so clean and clear in some locations. Only 8.7% of them consider the rivers clean, clear and in good conditions.

(v) 67.6% of the tourists do not want to visit Bali again as tourists, if the conditions of the seas and rivers get worse than present in the coming years.

(2) Tourism Income

The existing (1990) and future (2010) tourists' expenditures in the Study Area are estimated as shown below (refer to Appendix A, Chapter 5, Master Plan Study).

(Unit : billion Rp./year)

	1990	2010	Average Annual Growth Rate (%)
(i) Tourists' Expenditures	610	2,391	7.1 %
(ii) Contribution to Economy	183	717	
(iii) GRDP	815	3,463	7.5 %
(iv) (ii/iii) (%)	22.5	20.7	

The direct contributions of tourism to the economy of the Study Area in 1990 and 2010 are estimated as shown in the above table by assuming that the gross profit ratio of the commercial businesses catering for tourists is 30% on average.

(3) Benefits of project

The above-mentioned tourism income or direct contribution of tourism to the economy of the Study Area will be realized only if the conditions of the seas and the rivers in the area do not deteriorate more in the future. In other words, it will be realized in the "with" situation.

In the "without" situation, according to the results of the sampling questionnaire survey for the tourists, the number of tourists visiting Bali is expected to drastically decline in the coming years. It is assumed based on the results of the survey that in the target year of 2010 tourism income in the "without" situation will be 32.4% of tourism income expected under the "with" situation.

Tourism benefits are defined as the difference in tourism income between the "without" and "with" situations. The results are shown in Table 6.1.

As the table shows tourism benefits will be Rp. 143,316 million in 2000, climb sharply every year and reach Rp. 484,793 million in 2010.

It is to be noted that the above tourism benefits will not accrue from the wastewater disposal project alone, but will be realized only by the combined support of all the related fields such as road, water supply, drainage, telecommunications, electricity and garbage disposal projects.

6.2 Financial Evaluation

6.2.1 People's Willingness to Pay

(1) Existing People's Willingness to Pay

The amount of willingness to pay of households and establishments for sewerage services in 1991 are estimated based on the sampling questionnaire survey. Ratio of willingness to pay to monthly household income/corporate sales goes up in parallel with the increase of income/sales. The results are summarized as follows.

Item	Monthly Income/Sales (Million Rp.)	Ratio (%)
Households	1.04 - 0.21	0.98 - 0.40
Hotel	982.8 - 13.0	0.49 - 0.25
Restaurant	11.0 - 2.7	0.37 - 0.11
Shop	215.1 - 1.7	0.15 - 0.07
Bank	18.9	0.16
Factory	16.0 - 2.5	0.13 - 0.05

For details, see Appendix F, Table F.2.2, Master Plan Study.

The total amount of willingness to pay in the proposed sewerage service areas in 1990 is estimated to be Rp. 1,914 million/year. Out of it, households and hotels account for 39.1% and 28.4% respectively, adding up to 67.5%. Shops, banks, restaurants and factories account for 8.5%, 5.0%, 1.4% and 0.9% respectively. Others account for 16.7%.

(2) Future People's Willingness to Pay

The future amount of willingness to pay will increase according to growth of the number of households and establishments. The total amount of willingness to pay in the proposed sewerage service area in 2010 is estimated to be Rp. 4,460 million/year. Out of it, households and hotels account for 46.0% and 20.3% respectively, adding up to 66.3%. Shops, banks, factories and restaurants account for 8.1%, 6.9%, 1.1% and 0.9% respectively. Others account for 16.7%.

The amount of Rp. 4,460 million is much greater than the estimated operation and maintenance cost of Rp. 2,670 million.

6.2.2 Estimated Allocable Budget of Government

(1) Development Budget in 1991/1992

The total development budget for Kabupaten Badung including Denpasar area in 1991/1992 adds up to Rp. 154,005 million. It is equivalent to 12.6% of GRDP of the Regency in 1991/1992.

Out of Rp. 154,005 million, Rp. 110,412 million or 71.7% is allocated for the development/improvement of infrastructures such as irrigation, road, bridge, water supply, drainage, transport and housing, and related fields. The above budget for infrastructures is from the regencial government by 6.1%, from the provincial government by 10.3% and from the central government by 83.6%.

The budget for infrastructures of the Study Area in 1991/1992 is estimated to be Rp. 79,497 million by allocating the budget of Kabupaten Badung in proportion to the population.

(2) Estimated Allocable Budget in Future

The budget for infrastructures of the Study Area will increase from Rp. 73,670 million in 1990 to Rp. 312,871 million in 2010 at the average annual rate of 7.5%. Supposing the Project starts in 1994, the cumulative allocable budget will reach Rp. 3,245,607 million during the 17 years from 1994 to 2010.

On the other hand, the construction cost of the Project during the same period is estimated at Rp. 253,600 million. This amount occupies 7.81% of the allocable budget.

Table 6.1 Estimation of Tourism Benefits

(Unit: Rp. million)

Year	Tourism Income			Tourism Benefits
	Theoretical "With" Case	"With" Case	"Without" Case	
	A1	A2	B	C = A2 - B
1990	183,096	183,096	183,096	0
1991	203,658	196,774	196,774	0
1992	225,878	210,608	210,608	0
1993	248,697	223,479	223,479	0
1994	272,198	235,311	235,311	0
1995	296,067	246,032	246,032	0
1996	320,591	255,575	255,575	0
1997	345,657	263,875	263,875	0
1998	371,256	304,331	270,868	33,463
1999	397,377	359,083	276,495	82,588
2000	424,012	424,012	280,696	143,316
2001	451,153	451,153	283,414	167,739
2002	478,792	478,792	284,594	194,198
2003	506,923	506,923	284,181	222,742
2004	535,541	535,541	282,123	253,418
2005	564,636	564,636	278,366	286,270
2006	594,209	594,209	272,861	321,348
2007	624,250	624,250	265,556	358,694
2008	654,757	654,757	256,403	398,354
2009	685,725	685,725	245,352	440,373
2010	717,150	717,150	232,357	484,793

Source: JICA

III. FEASIBILITY STUDY

III. FEASIBILITY STUDY

The feasibility study is conducted for the sewerage development of central Denpasar and Sanur areas with a total area of 3,423 ha. For the location of the feasibility study area, see Fig. I.1.

CHAPTER 1 SEWER NETWORK PLAN

1.1 Sewer Networks of Denpasar Area

1.1.1 Overall Plan

The overall plan targets the year of 2010.

(1) Sewerage Service Area

The Project Area covers an area of 2,683 ha in the central Denpasar of which the net sewerage service area excluding green area is 2,663 ha (see, Fig. 1.1).

Land of the Project Area declines toward south. The gradient in north-south direction is 5‰ to 10‰ in the northern area of Oongan River and 1‰ to 4‰ in the southern area of Oongan River. The gradient in east-west direction is gentle but undulated.

Population of the service area in 1990 and 2010 are estimated to be 194,209 and 284,100 respectively. The average population density is 72.9 person/ha in 1990 and 106.7 person/ha in 2010.

(2) Alternative Study of Sewer Networks

The following four (4) typical sewer networks are proposed as alternatives.

Alternative A: Centralized collection system by gravity only

This system consists of seven (7) main sewers which join at three (3) locations along the central line of the sewerage service area.

Wastewater collected by the main sewers is further conveyed by a conveyance sewer from the southern edge of the service area to the treatment plant located at central Suwung Swamp Area. All wastewater of the service area is collected and conveyed by gravity only.

The sewer networks are shown in Fig. 1.2.

Alternative B: Multiple collection system by gravity only

This system consists of six (6) main sewers laid in north-south direction in parallel. Most of the wastewater is collected by independent main sewers to the southern edge of the service area. The collected wastewater is further conveyed by a conveyance sewer to the same treatment plant as Alternative A. All wastewater of the service area is collected and conveyed by gravity only.

The sewer networks are shown in Fig. 1.3.

Alternative C: Centralized collection system with lift/booster pump station

This is a modification of Alternative A. Alternative A requires a deep sewer laying exceeding 8.0 m depth for a long distance of 8,560 m of the main and conveyance sewers. Hence, Alternative C is provided with lift/booster pump station to minimize the earth covering depth of sewers at the expense of O&M cost. One (1) lift pump station is installed at the eastern bank of Badung River and further, one (1) booster pump station with a force main is constructed in the central southern location of the service area.

The sewer alignments are the same as Alternative A except the section of the force main. The sewer networks with lift and booster pump stations are shown in Fig. 1.2.

Alternative D: Multiple collection system with lift/booster pump station

This is a modification of Alternative B. Alternative B requires a deep sewer laying for a long distance of the main and conveyance sewers as well. Accordingly, Alternative D is also provided with lift/booster pump station at the same locations as Alternative C to minimize the earth covering depth of sewers.

The sewer alignments are the same as Alternative B except the section of the force main. The sewer networks with lift and booster pump stations are shown in Fig. 1.3.

The total direct construction cost of the above four (4) Alternatives are compared as follows.

(Unit: billion Rp. 1992 price)

Works	Construction Cost A	B	C	D
Secondary & Tertiary Sewer	56.5	56.5	56.5	56.5
Main Sewer*	74.2	67.7	47.7	41.2
Conveyance Sewer	40.2	40.5	7.8	11.6
Lift & Booster P.S.	—	—	4.4	4.6
Total	170.9	164.7	116.4	113.9

*: including cost of force main

As evident from the table, Alternative D is the most economical even if it requires a certain amount of additional O&M cost for the lift and booster pump stations. Moreover, its multiple collection system has much advantage on stagewise implementation.

Hence, Alternative D is recommended.

(3) Proposed Sewer Networks

The net sewerage service area covers 2,663 ha with a total served population of 284,100 in 2010. The service area is divided into six (6) catchment zones covered by the proposed six (6) main sewers. Each catchment zone is further divided into several sub-catchment areas covered by secondary and tertiary sewers. See, Fig. 1.4.

The proposed sewer networks consist of secondary and tertiary sewers, main sewer including siphon, conveyance sewer, force main, and lift and booster pump stations. Their salient features are shown below.

Secondary & Tertiary Sewer (ø150-300 mm)	:	418,400 m
Main Sewer	:	48,750 m
Normal Main (ø350-1,500 mm)	:	48,400 m
Siphon (ø150-450 mm)	:	350 m
Conveyance Sewer (ø1,500-1,800 mm)	:	4,390 m
Force Main (ø350 mm x 2 units)	:	1,070 m
Total	:	472,610 m
Lift Pump Station	:	31.44 m^3/min., 1 place
Booster Pump Station	:	22.56 m^3/min., 1 place

1.1.2 Urgent Plan

The urgent plan targets the year of 2000. However, the sewer networks of the urgent plan shall be designed to meet the design wastewater discharge in 2010. Because it is difficult to enlarge sewer pipes in stage.

(1) Selection of Sewerage Service Area

The urgent sewerage service area is selected taking into consideration the existing and future (2000) population density and economical efficiency of the project.

The six (6) catchment zones of the overall plan is classified into three (3) groups as follows in terms of required construction cost per served population.

Low cost area (0.21-0.4 million Rp./Pop.): catchment zone A, C, D & E
Middle cost area (0.41-0.6 million Rp./Pop.): catchment zone B
High cost area (0.61 - million Rp./Pop.): catchment zone F

Such areas that meet the following conditions are selected as urgent service area.

(i) Located within the catchment zones of A, C, D and E.
(ii) Population density in 2000 is more than 100 person/ha in principle.

(iii) Land is already developed.

The selected urgent service area is shown in Fig. 1.5. The service area and served population in 2000 are 1,030.8 ha and 117,864 respectively.

(2) Delineation of Conventional and Interceptor Areas

The proposed urgent service area is covered by two (2) sewage collection systems: conventional system and interceptor system.

Conventional system collects both toilet waste and gray water through a complete sewer pipe networks separately from storm water.

However, for an area where such storm water drainage system of open type as road-side ditches and channels is already developed, interceptor system is applied to minimize the construction cost of sewer networks and to facilitate the implementation of project. Interceptor system collects gray water only through existing road-side ditches and intercepts it to main sewer. This interceptor system is a stage construction of the conventional system.

Interceptor system is applied for the areas to meet the following conditions.

(i) Existing road-side ditch has a sufficient slope to avoid sedimentation in the bed (more than 5‰).
(ii) Existing road-side ditch is not used for irrigation.
(iii) Bottom of existing road-side ditch is paved by concrete or cement mortar.
(iv) No inundations occur.
(v) Gray water flow is observed in the existing road-side ditch.
(vi) Toilet waste is treated by on-site sanitation system.

The conventional and interceptor areas are delineated as shown in Fig. 1.6.