社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF PUBLIC WORKS
THE GOVERNMENT OF THE REPUBLIC OF INDONESIA

# THE DEVELOPMENT STUDY
# ON
# WASTEWATER DISPOSAL FOR DENPASAR

# MAIN REPORT



JANUARY 1993

PACIFIC CONSULTANTS INTERNATIONAL

# PREFACE

In response to a request from the Government of the Republic of Indonesia, the Government of Japan decided to conduct the development study on Wastewater Disposal for Denpasar and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Indonesia a study team headed by Mr. Naohito Murata, Pacific Consultants International, three times between October 1991 and November 1992.

The team held discussions with the officials concerned of the Government of Indonesia, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Indonesia for their close cooperation extended to the team.

January, 1993

Kensuke Yanagiya
President
Japan International Cooperation Agency

# THE DEVELOPMENT STUDY
# ON
# WASTEWATER DISPOSAL FOR DENPASAR

Mr. Kensuke YANAGIYA

President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR". This report has been prepared by the Study Team in accordance with the contract signed on 27 September 1991 and 3 June 1992 between the Japan International Cooperation Agency and Pacific Consultants International.

The report examines the existing conditions of wastewater disposal in Denpasar, presents a master plan of sanitation and sewerage development and the results of a feasibility study on sewerage development for the priority areas selected by the master plan.

The report consists of the Executive Summary, Main Report, and Supporting Study Report. The Summary Summarizes the results of all studies. The Main Report contains background conditions, overall sanitation and sewerage development plan, urgent sewerage development project, conclusions and recommendations. The Supporting Study Report includes data and technical details. In addition, a Data Book has been prepared and is submitted herewith.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs. Ministry of Construction, and Embassy of Japan in Indonesia, and also to officials and individuals of the Government of Indonesia for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the socio-economic development and the improvement of health and hygiene in Denpasar.

Yours faithfully,

村田直人

Naohito MURATA
Team Leader

# SUMMARY

# SUMMARY

## 1. Background

Denpasar and its vicinity, the political, economical and tourism centers of Bali, is undergoing rapid urban and tourism developments in recent years. The population has increased from 0.256 million in 1975 to 0.477 million in 1990, and is expected to grow further to 0.709 million in 2010. The number of tourists visiting there has doubled in the recent 10 years from 1.24 million in 1980 to 2.55 million in 1990.

However, the area virtually lacks an environmentally and sanitarily acceptable means of wastewater disposal in commensuration with its urbanization and tourism development.

Hence, the formulation of a comprehensive sewerage and sanitation development plan has become necessary to improve sanitary environments and to protect tourism resources of the area.

The objectives of the Study are as follows:

- Formulate a master plan of sewerage and sanitation development encompassing the whole Study Area for the target year of 2010.
- Conduct a feasibility study for sewerage development for the areas selected by the master plan.

The Study Area of the master plan, shown in Fig. 1, encompasses Denpasar and its vicinity with an area of 237 $km^2$.

Following the master plan study, the feasibility study was conducted for central Denpasar and Sanur districts with a total area of 3,423 ha shown in Fig. 1.

## 2. Wastewater Disposal Master Plan

### 2.1 Water Environments

The wastewater generation in the Study Area is expected to double in 2010 due to the rapid urbanization and tourism development. It will cause a serious deterioration in the water environments of the Study Area if no appropriate countermeasures are taken.

(1) The average river water quality of central and southern Denpasar areas will worsen from 27.2 mg/ℓ in 1990 to 55.0 mg/ℓ in 2010 as stream BOD. In some areas, it is forecast to reach approximately 100 mg/ℓ.

(2) The existing sea water quality of Sanur, Kuta and Nusa Dua beaches is 5 mg/ℓ in terms of $COD_{Cr}$ on an average, however, it exceeds 8 mg/ℓ in some areas. This water quality is considered to be in a critical level for swimming and other water recreations in comparison with international standards.

The future increase of wastewater generation in the Study Area will also have a severe effect on the sea water quality.

(3) More than 90% of the toilet waste in the Study Area is disposed into underground by leaching system. However, 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.

(4) Heavy groundwater contaminations are recognized in central and southern Denpasar areas due to the human waste disposals into underground. It is critical even in the resort areas of Sanur, Kuta and Nusa Dua.

(5) As the consequence, the Study Area is afflicted with waterborne diseases at a high contraction rate of 57.1 cases per 1,000 population per year.

## 2.2 Zoning of Wastewater Disposal

The conditions for the environmental and sanitary improvements of the Study Area are different by region. Hence, the most appropriate wastewater disposal system shall be planned by region.

Zoning of the wastewater disposal system was established based on the following policies.

(1) The river water quality shall be maintained below 20 mg/ℓ in stream BOD.

(2) The sea water quality of the resort beaches shall be maintained below 5 mg/ℓ in $COD_{cr}$ or at least, below the existing level.

(3) Sanitary environments of the resort areas shall be maintained in a satisfactory level as international resort.

(4) Wastewater disposal system with a high treatment level shall be applied for high population density areas, however, system with a moderate treatment level can be proposed for medium population density areas.

(5) Wastewater disposal into underground shall carefully be managed to control groundwater contamination.

The proposed zoning of wastewater disposal system is as follows.

(1) Conventional sewerage system capable of treating both toilet waste and gray water up to 20 mg/ℓ in BOD is applied for central Denpasar, and Sanur, Kuta and Nusa Dua resort areas.

(2) Septic tank with up-flow filter system is proposed for southern Denpasar area. This system will treat both toilet waste and gray water up to 60 mg/ℓ in BOD.

(3) Septic tank with leaching pit system is recommended for the other areas.

The service area and served population in 2010 by each system are summarized below.

| | Service Area (ha) | | Served Population in 2010 | |
|---|---|---|---|---|
| Conventional Sewerage | 4,207 | (18%) | 335,020 | (47%) |
| Septic Tank with Up-flow Filter | 3,614 | (15%) | 107,700 | (15%) |
| Septic Tank with Leaching Pit | 15,832 | (67%) | 266,580 | (38%) |
| Total | 23,653 | (100%) | 709,300 | (100%) |

Location of each zone is shown in Fig. 2.

## 2.3 Sewerage Development Plan

Three (3) new sewage collection systems of conventional separate type are proposed for 2,683 ha of Denpasar area, 648 ha of Kuta area and 740 ha of Sanur area. Moreover, the existing sewage collection system of Bali Tourism Development Corporation (BTDC) of conventional separate type is developed to cover the whole Tanjung Benoa area of 136 ha including Nusa Dua beach.

Wastewater of Denpasar, Kuta and Sanur areas are almost all treated by one (1) common treatment plant of aerated lagoon type proposed in the Suwung Swamp Area along Benoa Bay. A portion of the wastewater of Kuta area is treated by the treatment plant of the on-going East Jawa and Bali Urban Infrastructure Development Project. However, wastewater of Tanjung Benoa area is treated by remodelling the existing treatment plant of oxidation pond type to aerated lagoon type.

The main features of the proposed sewerage master plan are shown in Table 1. Location of the sewerage systems are shown in Fig. 2.

The total project cost of sewerage development is estimated at Rp.253.6 billion at 1992 price. The total operation and maintenance (O&M) cost of the sewerage system is estimated to be Rp.2,670 million per annum under the full operation in 2010 at 1992 price.

Break-down of the project cost and O&M cost of the proposed sewerage master plan are shown in Table 2.

## 2.4 Project Evaluation

### (1) Water Pollution Abatement

The proposed wastewater disposal project will control the future river water quality of the Study Area below the target one of 20 mg/ℓ in BOD. The existing and future river water quality of central and southern Denpasar areas are compared below.

(Unit : $BOD_5$ mg/ℓ)

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

The proposed project will also reduce the pollution loads to the sea from the Study Area. The pollution loads under the existing, future without project and future with project conditions are shown below.

| | Pollution Load to Sea ($BOD_5$, ton/day) |
|---|---|
| Existing (1990) | 10.8 |
| Future (2010) without Project | 21.9 |
| Future (2010) with Project | 10.2 |

The proposed project will maintain the future sea water quality of the Study Area around the existing level. The existing and future polluted sea areas exceeding the target water quality of 5 mg/ℓ in $COD_{Cr}$ are compared below.

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

(2) Reduction of Water-borne Disease

Contraction of the water-borne diseases causes two (2) major economic costs: medical cost and opportunity cost of time spent by a hospitalized patient.

The total annual economic cost across the Study Area is calculated to be Rp.3,809 million under the existing conditions. A considerable portion of this economic cost will be reduced by the proposed project.

(3) Increase of Tourism Income

The tourism income of the Study Area is estimated to increase from Rp.183 billion in 1990 to Rp.717 billion in 2010 if wastewater disposal and the other all related infrastructures are well developed in future. However, it is expected that the future tourism income will much decrease from the above estimated one if the sea and river environments get worse in future than present.

The proposed project will much contribute to the increase of tourism income.

(4) Financial Aspects

The total amount of willingness to pay of the households and establishments in the proposed sewerage service area in 2010 is estimated to be Rp.4,460 million/year. It is more than the required O&M cost of Rp.2,670 million/year in 2010.

The development budget for infrastructures of the Study Area over the 17 years of the project implementation period from 1994 to 2010 is estimated at Rp.3,246 billion at 1992 price. This amount is adequate to carry out the proposed sewerage development project with the initial cost of Rp.254 billion at 1992 price.

## 3. Feasibility Study of Sewerage Development

The feasibility study area covers 2,683 ha in central Denpasar and 740 ha in Sanur, adding up 3,423 ha.

### 3.1 Sewerage Development Plan

#### (1) Sewer Network Plan

##### (i) Overall Plan

The detailed sewer network plans of Denpasar and Sanur areas, targeting the year of 2010 were prepared based on the policies and frames established by the master plan study.

The proposed overall plan of Denpasar covers the net sewerage service area of 2,663 ha with a total served population of 284,100 in 2010. The entire service area is covered by conventional separate sewer system.

The overall plan proposed for Sanur covers the net sewerage service area of 726 ha and serves the population of 27,800 in 2010. The entire service area is covered by conventional separate sewer system.

The collected wastewater of Denpasar and Sanur areas are transferred to the common treatment plant by a conveyance sewer of 4.4 km and a force main with booster pump of 5.2 km respectively.

The main features of the proposed overall sewerage plans for Denpasar and Sanur areas are shown in Table 3. The proposed overall main sewer networks for Denpasar and Sanur areas are shown in Fig. 3.

##### (ii) Urgent Plan

The urgent sewer networks of Denpasar and Sanur areas, targeting the year 2000 were selected from the respective overall sewer networks.

The urgent plan of Denpasar covers the most developed central area of Denpasar with a high population density where the highest cost-effectiveness of sewerage development is expected. The planned service area and served population in 2000 are 1,030.8 ha and 117,864 respectively. The proposed urgent plan, however, covers the service area combined with the conventional separate sewer system covering 714.6 ha and interceptor collection system covering 316.2 ha to minimize the project cost and to facilitate the project implementation.

The urgent plan of Sanur covers the Sanur beach area of 331.8 ha in view of the importance of ensuring its continued tourism potential. The planned served population is 11,513 in 2000. The entire urgent service area is covered by conventional separate sewer system.

The collected wastewater of the urgent plan are transferred to the treatment plant in the same way as the overall plan.

The main features of the proposed sewerage urgent plans for Denpasar and Sanur areas are shown in Table 3. The proposed urgent main sewer networks of Denpasar and Sanur areas are shown in Fig. 3.

(2) Treatment Plant

The proposed treatment plant of aerated lagoon system is located at Suwung Swamp Area along Benoa Bay.

The treatment plant is planned to treat only the wastewater of Denpasar and Sanur areas until 2000, thereafter it is expected to treat the wastewater of Kuta area as well. Required capacity of the treatment plant in the year 2000 and 2010 are 44,000 $m^3$/day and 117,000 $m^3$/day respectively.

The urgent plan of the treatment plant targeting the year 2000 consists of inflow pump station of capacity of 70 $m^3$/min., aerated lagoon with 450 kW of aerator, facultative aerated lagoon with 132 kW

of aerator, polishing pond, sludge drying bed and other facilities. The required land space of the urgent plan is 9.2 ha.

(3) Estimated Cost and Implementation Programme

Project cost of the urgent sewerage development is estimated to be Rp.82,400 million at 1992 price. Annual O&M cost of the urgent project is estimated at Rp.1,194 million/year at 1992 price. Break-down of the project cost and O&M cost of the proposed sewerage urgent plan are shown in Table 4.

3.2 Economic Social and Environmental Evaluation

(1) Water Pollution Abatement

The proposed urgent project will control the future river water pollution of the most developed central and southern Denpasar areas to a large extent. The control effects are shown below.

(Unit : $BOD_5$ mg/ℓ)

| | Range | Average |
|---|---|---|
| Existing (1990) | 22.9 - 51.8 | 32.2 |
| Future without Project (2000) | 35.1 - 80.3 | 52.7 |
| Future with Project (2000) | 15.3 - 30.8 | 23.0 |

The urgent project will reduce the pollution load to the sea from the Study Area under the existing, future without project in 2000 and future with urgent project are shown below.

| | Pollution Load ($BOD_5$, ton/day) |
|---|---|
| Existing (1990) | 10.8 |
| Future (2000) without Project | 17.2 |
| Future (2000) with Urgent Project | 11.6 |

As the consequence, the sea water quality of the Project Area in 2000 will be maintained around the existing level. The existing and future polluted areas exceeding 5 mg/ℓ in $COD_{Cr}$ are compared as follows.

| | Polluted Sea Area ($km^2$) |
|---|---|
| Existing (1990) | 28.3 |
| Future without Project (2000) | 35.3 |
| Future with Project (2000) | 31.1 |

(2) Reduction of Water-borne Disease

The annual number of water-borne disease contraction and the related economic costs in the urgent project area are estimated to be 7,387 cases and Rp.1,032 million respectively in 2000.

The urgent project will greatly contribute to the reduction of these water-borne diseases and related economic costs.

(3) Increase of Tourism Income

The tourism income of the sewerage development areas of Denpasar and Sanur is expected to increase from Rp.40,388 million in 1990 to Rp.94,986 million in 2000 and Rp.161,250 million in 2010 if wastewater disposal and the other all related infrastructures are well developed in future.

However, it is forecast that the future tourism incomes will much decrease from the above estimated ones, if the sea and river environments get worse in future than present.

Tourism benefits to be produced by the sewerage development project of Denpasar and Sanur areas are estimated to be Rp.10,788 million in 2000 and Rp.36,628 million in 2010.

(4) Economic Evaluation

Economic efficiency of the sewerage development project of Denpasar and Sanur areas is evaluated as follows.

| | | |
|---|---|---|
| Net Present Value (NPV) | : | Rp.42,321 million |
| Benefit Cost Ratio (B/C) | : | 1.40 |
| Economic Internal Rate of Return (EIRR) | : | 14.1% |

(5) Environmental Assessment

The anticipated environmental impacts due to the project activities are mostly beneficial as the Project in itself is an environmental improvement project. No significant long term adverse environmental effects by the Project are identified since the treatment plant is located far from residential areas and expected to be surrounded by mangrove forestation in future.

3.3 Financial and Institutional Aspects

(1) People's Willingness to Pay

The total amount of annual willingness to pay in the urgent sewerage service area is estimated to be Rp.1,314 million in 2000 at 1992 price. In 2010, the sewerage services are expected to cover the entire sewerage development area of Denpasar and Sanur. As a result, the total annual willingness to pay will reach Rp.3,582 million in 2010.

These annual willingness to pay are more than the required annual O&M costs of Rp.1,194 million in 2000 and Rp.2,670 million in 2010 respectively.

(2) Affordability and Contribution of Tourism Industry

The Project is primarily economically motivated, although it has an important social role by improving public health. Therefore, the major part of project costs will be borne by beneficiaries themselves. And the balance will be borne by the government.

Hotels are the prime beneficiary of the clean, clear and beautiful sea which will be kept that way by the Project. Accordingly, hotels in the sewerage service area will bear the initial investment cost that are to be duly expected of them. The construction costs of household package treatment plant are considered as the upper limit that hotels can bear.

The sewerage development project in Denpasar and Sanur areas will have beneficial effects on tourism industry more or less over the entire master plan study area. Therefore, a substantial part of the

remaining initial investment costs will be borne by the tourism industry there, represented by hotels and restaurants.

(3) Proposed Sewerage Charge

(i) Sewerage Service Charge

Sewerage service charge is levied on all the beneficiaries having direct connection to the sewers. The proposed monthly charge is summarized below.

| | | |
|---|---|---|
| Households | : | Rp.22/$m^2$ |
| Hotels | : | Rp.125/$m^2$ for classified hotels<br>Rp.50/$m^2$ for other hotels |
| Restaurants | : | Rp.50/$m^2$ |
| Shops | : | Rp.70/$m^2$ for large shops<br>Rp.30/$m^2$ for other shops |
| Offices | : | Rp.30/$m^2$ - Rp.50/$m^2$ |

A household will pay 0.935% of average monthly income.

The present value of the cumulative sewerage service charge accounts for 140.5% of that of the cumulative O&M costs.

(ii) Capital Works Charge

Capital works charge will be applied to all the existing and future hotels located within the sewerage service areas. The proposed capital works charge is Rp.1.97 million/room for classified hotels and Rp.1.41 million/room for non-classified hotels/other accommodations.

The contribution of the capital works charge to the initial investment costs of the Project is estimated at 5.8%.

(iii) Tourism Tax

Hotels and restaurants in the master plan study area are subjected to the tourism tax of 2% at present. Out of 2%, 0.7% will be appropriated for the recovery of the initial investment costs of

the sewerage development project along with the above capital works charge.

This tourism tax will be collected by the government and later will be transferred to the sewerage organization as subsidy.

The contribution of the tourism tax to the initial investment costs of the Project is estimated to be 55.4%.

(4) Financial Analysis

It is proposed that :

(i) The central/local governments will grant 35% of the initial investment costs and further the central government will extend a loan for the remaining 65% of the initial investment costs.

(ii) The entire replacement cost will be self-financed by the sewerage organization.

(iii) The entire O&M cost will be recovered by sewerage service charge.

(iv) The initial investment costs borrowed from the central government will be recovered by capital works charge and tourism tax.

For the above financial conditions, the financial internal rate of return (FIRR) of the Project is estimated at 5.5% which is considered as sufficient and reasonable.

(5) Sewerage Organization

It is recommended to set up a new department for wastewater management in the existing PDAM rather than establishing an independent organization.

## 3.4 Recommendations

(1) An immediate implementation of the Project is necessary for both development of the tourism industry and improvement of the overall sanitary environments of the Project Area.
Hence, it is recommended to commence the necessary financial procurement at the earliest.

(2) Monitoring system of the water quality of rivers, coastal sea and groundwater shall be developed for better environmental management of the Project Area.
For this purpose, a laboratory with sufficient experimental equipment shall be immediately established.

Table 1 Main Features of Sewerage Master Plan

| Item | Denpasar | Kuta | Sanur | Tanjung Benoa | Total |
|---|---|---|---|---|---|
| Service Area (ha) | 2,683 | 648 | 740 | 136 | 4,207 |
| Served Population in 2010 | 284,100 | 21,580 | 27,800 | 1,540 | 335,020 |
| Wastewater Generation ($m^3$/day) | 75,300 | 18,400 | 16,800 | 4,220 | 114,720 |
| Secondary & Tertiary (km) | 418.4 | 65.7 | 97.2 | 3.1 | 584.4 |
| Main (km) | 50.9 | 12.5 | 10.9 | 3.4 | 77.7 |
| Conveyance Sewer (km) | 4.4 | 1.2 | - | - | 5.6 |
| Force Main (km) | - | 5.2 | 5.2 | - | 10.4 |
| Sub-total | 473.7 | 84.6 | 113.3 | 6.5 | 678.1 |
| Lift/Booster Pump (place) | 2 | 4 | 4 | 1 | 11 |
| Treatment Plant | 1 | | | 1 | 2 |

Table 2 Project Cost and O&M Cost of Sewerage Master Plan

| | Denpasar | Kuta | Sanur | Tanjung Benoa | Total |
|---|---|---|---|---|---|
| Project Cost (million Rp.) | | | | | |
| Direct Const. Cost | 129,335 | 41,640 | 33,199 | 7,135 | 211,309 |
| Collection Sewer | 113,794 | 33,673 | 23,078 | 3,957 | 174,502 |
| Force Main | - | 4,965 | 6,644 | - | 11,609 |
| Treatment Plant | 15,541 | 3,002 | 3,477 | 3,178 | 25,198 |
| Administration Cost | 2,869 | 554 | 642 | 161 | 4,226 |
| Engineering Cost | 11,477 | 2,218 | 2,567 | 643 | 16,905 |
| Physical Contingency | 14,366 | 2,776 | 3,214 | 804 | 21,160 |
| Total | 158,047 | 47,188 | 39,622 | 8,743 | 253,600 |
| O&M Cost (million Rp./yr.) | 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.

Table 3 Main Features of Sewerage Overall and Urgent Plans

| Item | Denpasar | | Sanur | | Total | |
|---|---|---|---|---|---|---|
| | Overall | Urgent | Overall | Urgent | Overall | Urgent |
| Service Area (ha) | 2,663 | 1,030.8 | 726 | 331.8 | 3,389 | 1,362.6 |
| Served Population | 284,100 | 117,864 | 27,800 | 11,513 | 311,900 | 129,377 |
| Secondary & Tertiary Sewer (km) | 418.4 | 126.02 | 97.22 | 32.72 | 515.62 | 158.74 |
| Main Sewer (km) | 48.75 | 15.14 | 10.94 | 4.31 | 59.69 | 19.45 |
| Conveyance Sewer (km) | 4.39 | 4.39 | - | - | 4.39 | 4.39 |
| Force Main (km) | 1.07 | - | 5.16 | 5.16 | 6.23 | 5.16 |
| Total (km) | 472.61 | 145.55 | 113.32 | 42.19 | 585.93 | 187.74 |
| Lift/Booster Pump (place) | 2 | - | 4 | 3 | 6 | 3 |
| ($m^3$/min.) | 54.0 | - | 43.28 | 23.17 | 97.28 | 23.17 |
| Treatment Plant ($m^3$/day) | - | - | - | - | 117,000* | 44,000 |

Note: * including wastewater of Kuta area

Table 4 Project Cost and O&M Cost of Sewerage Urgent Plan

(1992 price)

| | Denpasar | Sanur | Total |
|---|---|---|---|
| Project Cost (million Rp.) | | | |
| Direct Const. Cost | | | 66,000 |
| Collection System | 42,634 | 11,166 | 53,800 |
| Secondary & Tertiary Sewer | 16,933 | 3,657 | 20,590 |
| Main Sewer | 14,143 | 4,222 | 18,365 |
| Conveyance Sewer | 11,558 | - | 11,558 |
| Force Main | - | 1,992 | 1,992 |
| Lift/Booster Pump | - | 1,295 | 1,295 |
| Treatment Plant | | | 12,200 |
| Land Acquisition | | | 500 |
| Administration Cost | | | 1,320 |
| Engineering Cost | | | 7,920 |
| Physical Contingency | | | 6,660 |
| Total | | | 82,400 |
| O&M Cost (million Rp./year) | | | |
| Collection System | | | 160 |
| Treatment Plant | | | 849 |
| Overhead | | | 185 |
| Total | | | 1,194 |

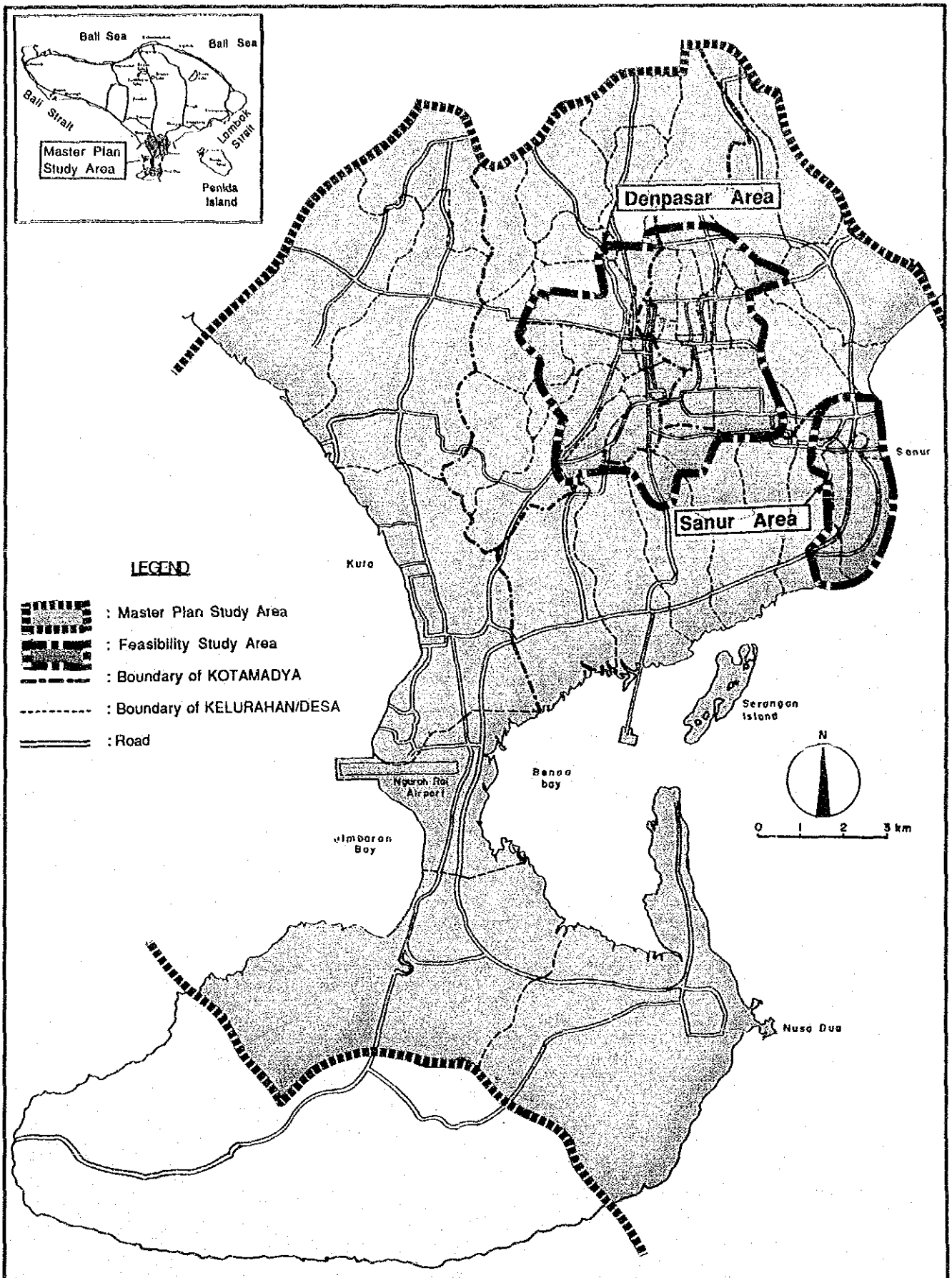



FIG. 1 MASTER PLAN AND FEASIBILITY STUDY AREAS

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

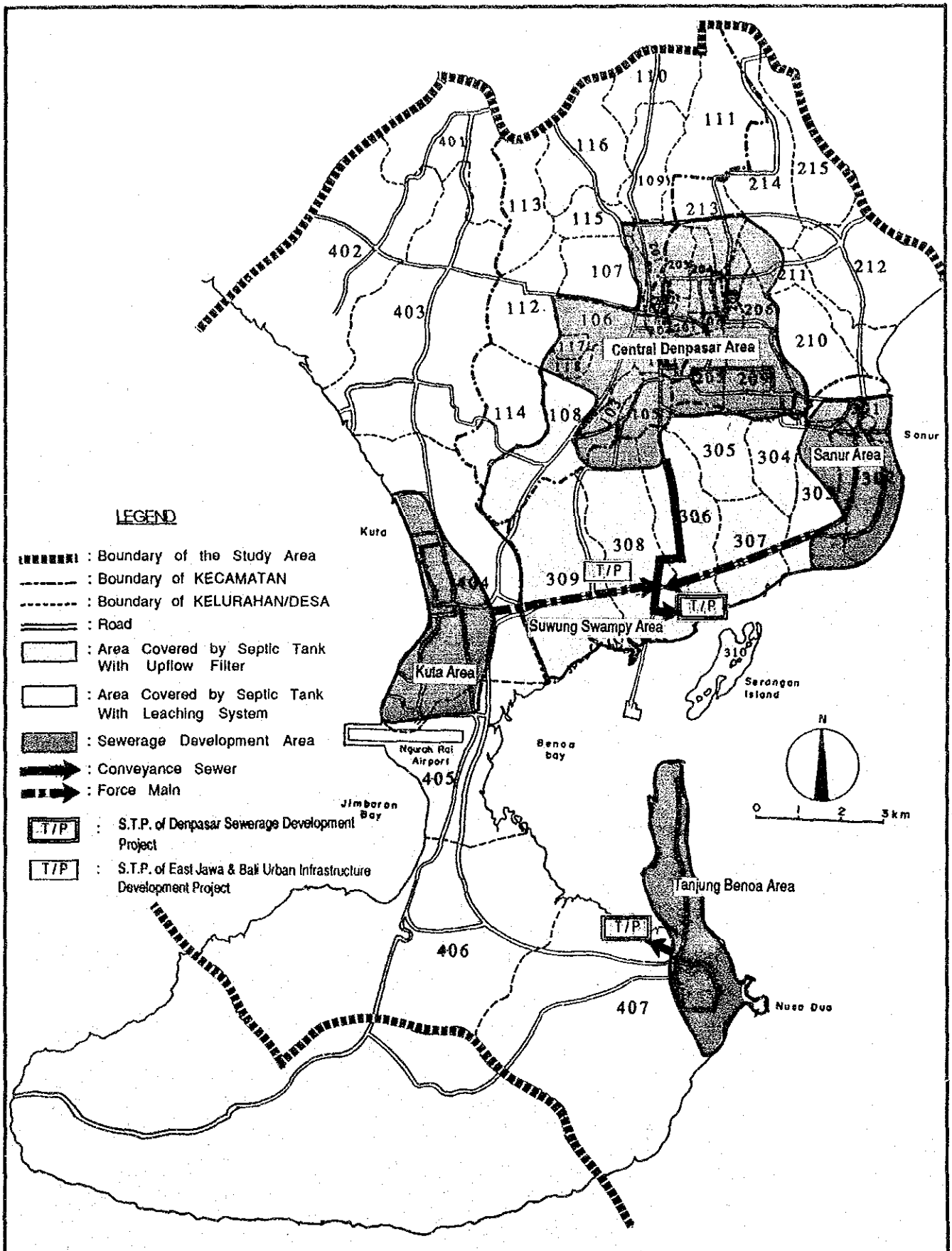
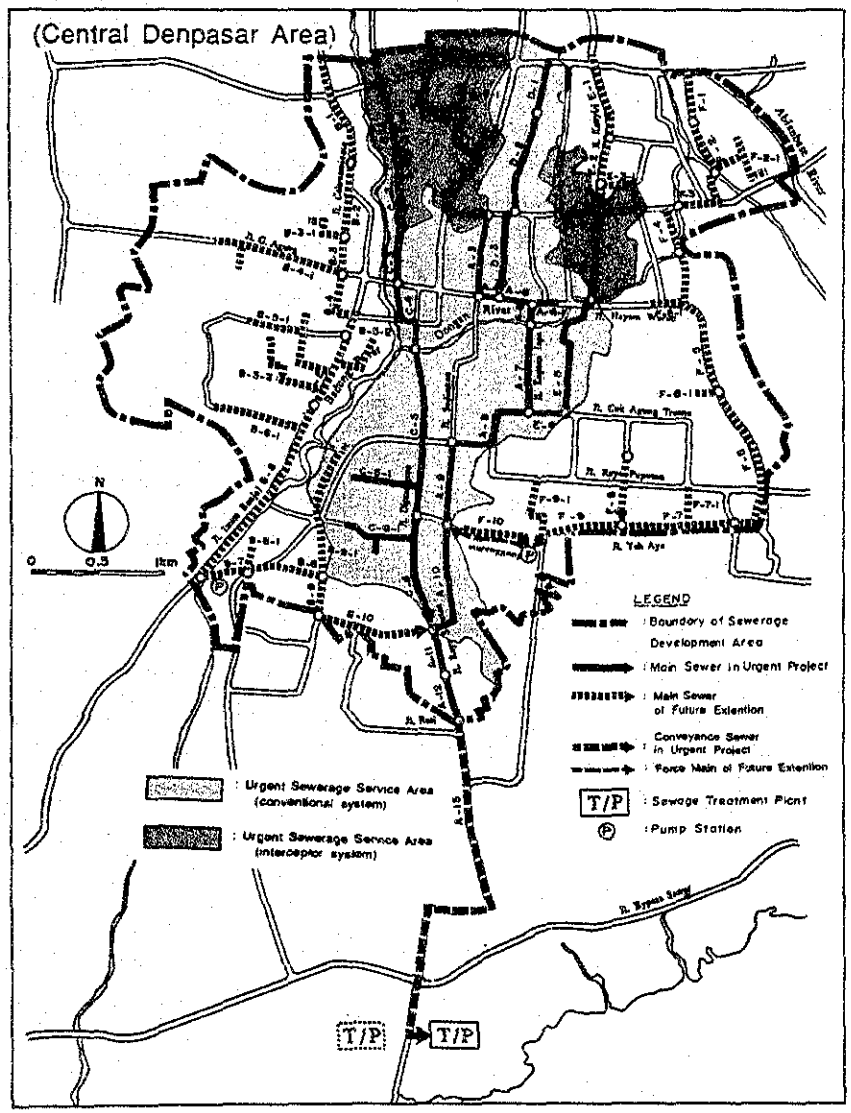



FIG. 2 WASTEWATER DISPOSAL ZONING AND SEWERAGE DEVELOPMENT SYSTEM

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR



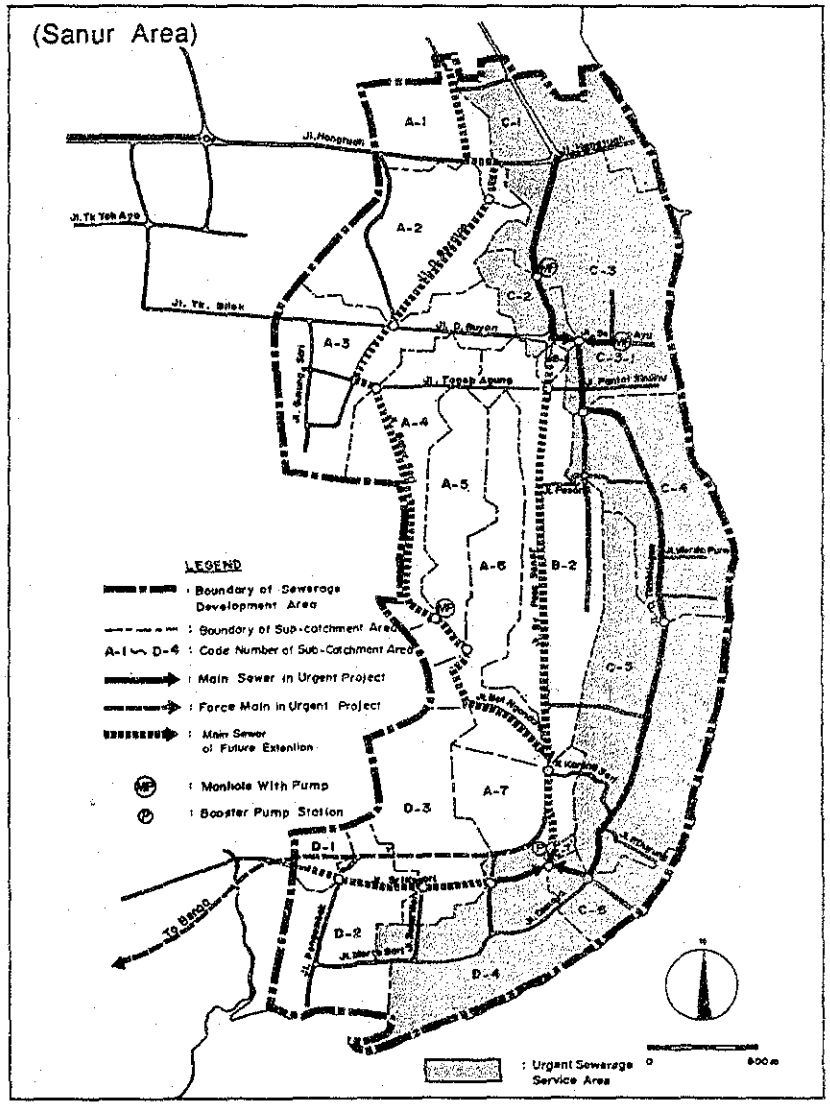




FIG. 3 OVERALL AND URGENT MAIN SEWER NETWORKS

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

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## III. FEASIBILITY STUDY

## ABBREVIATION

| | |
|---|---|
| AIT | Asian Institute of Technology |
| AMDAL | Environmental Impact Assessment |
| B/C | Benefit Cost Ratio |
| BAPPEDA | Regional Planning and Development Board, DKI Jakarta |
| BAPPENAS | National Planning and Development Board |
| BOD | Biological Oxygen Demand |
| BTDC | Bali Tourism Development Corporation |
| CIPTA KARYA | Directorate General of Human Settlements |
| COD | Chemical Oxygen Demand |
| COR | Coast Ocean Research Co.,Ltd |
| DKI | Jakarta Metropolitan Government |
| DO | Dissolved Oxygen |
| EIRR | Economic Internal Rate of Return |
| ENSIC | Environmental Sanitation and Information Center of AIT |
| Fig. | Figure |
| FIRR | Financial Internal Rate of Return |
| gcd | Gram per Capita per Day |
| GOI | Government of Indonesia |
| GRDP | Gross Regional Domestic Product |
| HWL | High Water Level |
| INA | INA Corporation |
| IUIDP | Integrated Urban Infrastructure Development Project |
| JICA | Japan International Cooperation Agency |
| JSSP | Jakarta Sewerage and Sanitation Project |
| Kec. | Kecamatan |
| Kel. | Kelurahan |
| lcd | Liter per Capita per Day |
| MCK | Communal Toilet |
| MENKLH | State Minister of Population and Environment |
| MSL | Mean Sea Level |
| NPV | Net Present Value |
| OCC | Opportunity Cost of Capital |
| PASCO | PASCO International Inc. |
| PCI | Pacific Consultants International |

| | |
|---|---|
| PDAM | Water Supply Company |
| PEI | Project Economy Institute Inc. |
| PIL | Initial Environmental Examination |
| RBC | Rotating Biological Contactor |
| RKL | Environmental Management Plan |
| Rp | Indonesian Rupiah |
| RPL | Environmental Monitoring Plan |
| SCF | Standard Conversion Factor |
| SS | Suspended Solids |
| UNCHS | United Nation Center of Human Settlements |
| UNDP | United Nation Development Program |

## PRICE AND EXCHANGE RATE

Project cost is estimated at June 1992 and at an exchange rate of 1US$ = Yen 127.0 = Rp. 2020.0.

# I. INTRODUCTION

# I. Introduction

## 1. Background of the Study

Bali Island, a volcanic island with an area of 5,632.86 $km^2$ surrounded by white sand beach and blue ocean, is the most important international resort of Indonesia. The Study Area, as shown in Fig. I.1, covers the most developed southern region of the Island with an area of 237 $km^2$ including the political, economical and tourism centers of Bali ; Denpasar, Sanur, Kuta and Nusa Dua.

The Study Area has been undergoing rapid urbanization and tourism development in recent years. The population has increased from 0.256 million in 1975 to 0.477 million in 1990, and is expected to grow further to 0.709 million in the year 2010. The number of tourists visiting Bali has doubled in the recent 10 years from 1.24 million in 1980 to 2.55 million in 1990.

However, the Study Area virtually lacks an environmentally and sanitarily acceptable means of wastewater disposal in commensuration with its urbanization and tourism development. Only a sewerage system covering the limited resort area of Nusa Dua has been in operation since 1979.

Bulk of the gray water generated from domestic, commercial and tourism uses is discharged to nearby ditches, drains and rivers with no treatment. Moreover, toilet waste is disposed into underground with an unsatisfactory treatment. As the consequence, the waterways, rivers, sea and groundwater in the Study Area are much polluted. The rivers in the central part of Denpasar are black in color and emanate offensive odour with their stream BOD levels reaching even a 50 mg/l. The sea water quality in some part of Sanur, Kuta and Nusa Dua resort areas is already in excess of the permissible limit for the international resort beach. The groundwater is also much contaminated all over the urban and tourism areas.

Hence, a comprehensive sewerage and sanitation development is essentially necessary to improve sanitary environments of the communities and to protect tourism resources of Bali.

## 2. Objectives of the Study

The objectives of the Study are as follows.

- Formulate a master plan of sewerage and sanitation development encompassing the whole Study Area for the target year of 2010.
- Conduct a feasibility study for sewerage development for the areas selected by the master plan.

## 3. Implementation of the Study

Directorate General of Human Settlements (Cipta Karya), Ministry of Public Works was assigned as the counterpart executing agency of the Government of Indonesia, while the Japan International Cooperation Agency (JICA) was assigned as the official agency responsible for the implementation of the technical cooperation program of the Government of Japan.

The Study was carried out by the Japanese consultant team retained by JICA and Indonesian counterpart staff.

The whole study, consisting of master plan and feasibility studies, was conducted from October, 1991 to December, 1992. The members involved in the studies are listed below.

(1) JICA Study Team

Team Leader

| | |
|---|---|
| Mr. Naohito Murata | (PCI) |

Members

| | |
|---|---|
| Mr. Masami Kondo | (PCI) |
| Dr. Norihiro Noda | (PCI) |
| Mr. Takaaki Katsuki | (PCI) |
| Dr. Somasundaram Jayamohan | (PCI) |
| Mr. Shinji Okada | (COR) |
| Mr. Kazuo Unoki | (INA) |

| | |
|---|---|
| Mr. Etsuro Yamamura | (PCI) |
| Mr. Naomichi Ishibashi | (PEI) |
| Mr. Kuniaki Takamatsu | (PASCO) |

(2) JICA Advisory Committee

Chairman

| | |
|---|---|
| Mr. Tokuji Annaka | Ministry of Construction |

Members

| | |
|---|---|
| Mr. Masakazu Nakao | Japan Sewage Works Agency |
| Mr. Akihiko Ozaki | Kobe Municipality |

(3) Steering Committee of Indonesia

Chairman

| | |
|---|---|
| Ir. Rachmadi B.S. | Director General of Cipta Karya |

Vice Chairman/Member

| | |
|---|---|
| Drs. Wayan Rendha | Head of BAPPEDA of Bali Province |

Secretaries

| | |
|---|---|
| Ir. Darmawan Saleh | Director of Environmental Sanitation of Directorate General of Cipta Karya |
| Ir. Asrap Hadiroso MSc | Head of Public Works Office of Bali Province |

Members

| | |
|---|---|
| Drs. Saad A. Basaib MSc | Head of Social Welfare and Public Housing - BAPPENAS |
| Yusuf Anwar SH, MA | Director of Foreign Fund, Ministry of Finance |
| Dr. Amanda Niode Katili | Director of System Research - BPPT (Research and Application of Technology Agency) |
| Drs. Gembong Priyono MSc | Head of Foreign Collaboration Bureau, Ministry of Public Works |
| Ir. Hartono Pramudo Dipl. HE. | Director of River - Directorate General of Water Resources, Ministry of Public Works |

| | |
|---|---|
| Ir. P. Sidabutar | Director of Planning Program of Directorate General of Cipta Karya |
| Ir. A.R. Tambing | Director of Water Supply of Directorate General of Cipta Karya |
| Ir. Tubagus Haedar Ali | Director of City and Regional System of Directorate General of Cipta Karya |
| I Gusti Bagus Alit Putra | Head of Badung Regency |
| Drs. Nengah Netra | Chairman of Local Development Planning Agency of Badung Regency |
| Drs. I Made Suwendha | Mayor of Denpasar |
| Drs. I Gusti Made Suanda | Chairman of Local Development Planning Agency of Denpasar |

(4) Technical Committee of Indonesia

Chairman

| | |
|---|---|
| Ir. Darmawan Salch | Director of Environmental Sanitation of Directorate General of Cipta Karya |

Vice Chairman

| | |
|---|---|
| Ir. I Wayan Subagiarta | Head of Regional Public Works of Bali Province |

Secretaries

| | |
|---|---|
| Ir. Jacob Ruzuar | Head of Sub Directorate of Waste Water, Directorate of Environmental Sanitation, Dit. Gen. of Cipta Karya |
| Ir. Putu Darta | Deputy Head of Sub Office of Cipta Karya, Public Works Bali Office |

Members

| | |
|---|---|
| Ir. I Made Gede Tegug Dipl. HE. | Head of Technical Section, Public Works Office Bali Province |
| Ir. I Ketut Kaler M. Eng. | Head of Sub Office of Water Resource, Public Works Office Bali Province |
| Ir. Putu Sujana Cahyanta | Head of Physical Infrastructure I, Local Development Planning Agency of Bali Province |
| Ir. Nyoman Sudiana | Head of Public Works Office, Badung Regency |

| | |
|---|---|
| Ir. Witrawan | Head of Public Works Branch Office, Badung Regency |
| Ir. Uki Ashardiatmo | Director of Water Supply Region Company, (PDAM) Badung Regency |
| Ir. F.W. Adam | Staff of Social Welfare and Public Housing Bureau, National Development Planning Agency |
| Ir. Siswoko, Dipl. HE. | Head of Sub Directorate of Technical Planning, Directorate of River, Directorate General of Water Resources |
| Drs. Herwanto Ali, K. | Head of Administration Section of Bilateral Cooperation, Foreign Collaboration Bureau, Ministry of Public Works |
| Ir. Andria S. MA. | Head of Sub Directorate Preparation of Project Evaluation, Directorate of Planning Program, Dit. Gen. of Cipta Karya |
| Drs. Suwarso | Head of Sub Directorate of Foreign Aid Administration, Directorate of Planning Program, Dit. Gen. of Cipta Karya |
| Ir. Mustaram Kowara | Head of Sub Directorate of City Planning System I, Directorate of City and Regional System, Dit. Gen. of Cipta Karya |
| Ir. Widia Alfisa | Head of Sub Directorate of Drainage, Directorate of Environment Sanitation, Dit. Gen. of Cipta Karya |
| Ir. Risyana Sukarna Dipl. HE. | Head of Sub Directorate of Technical Planning, Directorate of Water Supply, Dit. Gen. of Cipta Karya |
| Ir. IGP Suara | Head of Public Works Office Denpasar Region |

(5) Counterparts

Chairman

| | |
|---|---|
| Ir. Putu Darta | Deputy Head of Sub Office of Cipta Karya, Public Works Office Bali Province |

| | |
|---|---|
| Vice Chairman | |
| Ir. KS. Irawan | Project Manager of Environment Sanitation, Bali Province |
| Members | |
| Ir. IGM Haryawan Dipl. SE. | Staff of Bali Environment Sanitation Project, Bali Province |
| I Made Sudira BE | Staff of Public Works Office, Badung Regency |
| Ir. Rai Semadi | Section Head of Cipta Karya, Public Works Branch Office, Badung Regency |
| Ir. Ketut Suwandi | Head of Pre-Physical Section, Local Development Planning Agency, Badung Regency |
| Ir. Susmono | Head of Technical Planning, Wastewater Div., Dit. Gen. of Cipta Karya |
| Harry Simanjuntak BSc. | Staff of Sub Directorate of Wastewater, Directorate of Environment Sanitation, Dit. Gen. of Cipta Karya |
| Luki Rais D.D. BE | Staff of Environment Sanitation Project, Bali Province |
| Herning Widayati M. Eng. | Staff of Public Works Region Office, Bali Province |
| Ir. Eko Sunyoto | Head of Technical Sanitation of Sub Office Cipta Karya, Public Works Office, Bali Province |
| Ir. Handy B.L. MSES | Staff of Sub Directorate of Wastewater, Directorate of Environment Sanitation, Dit. Gen. of Cipta Karya |
| Gusti Ayu Sri Wardani | Staff of Local Development Planning Agency, Denpasar Region |
| I Made Sunetra BE | Staff of Public Works Office, Denpasar Region |

## 4. Composition of Report

This report consists of six (6) volumes: Summary Report, Main Report, Supporting Report I and II, Drawing and Data Book.

The Main Report presents the summarized results of both master plan study on development of wastewater disposal and feasibility study on sewerage development. While Supporting Report I deals with in details, the master plan study and Supporting Report II deals with the feasibility study respectively.

These reports are listed below.

(1) Main Report
    Part I : Master Plan Study
    Part II : Feasibility Study
(2) Supporting Report I
    Master Plan Study
(3) Supporting Report II
    Feasibility Study
(4) Drawing
(5) Data Book
(6) Executive Summary

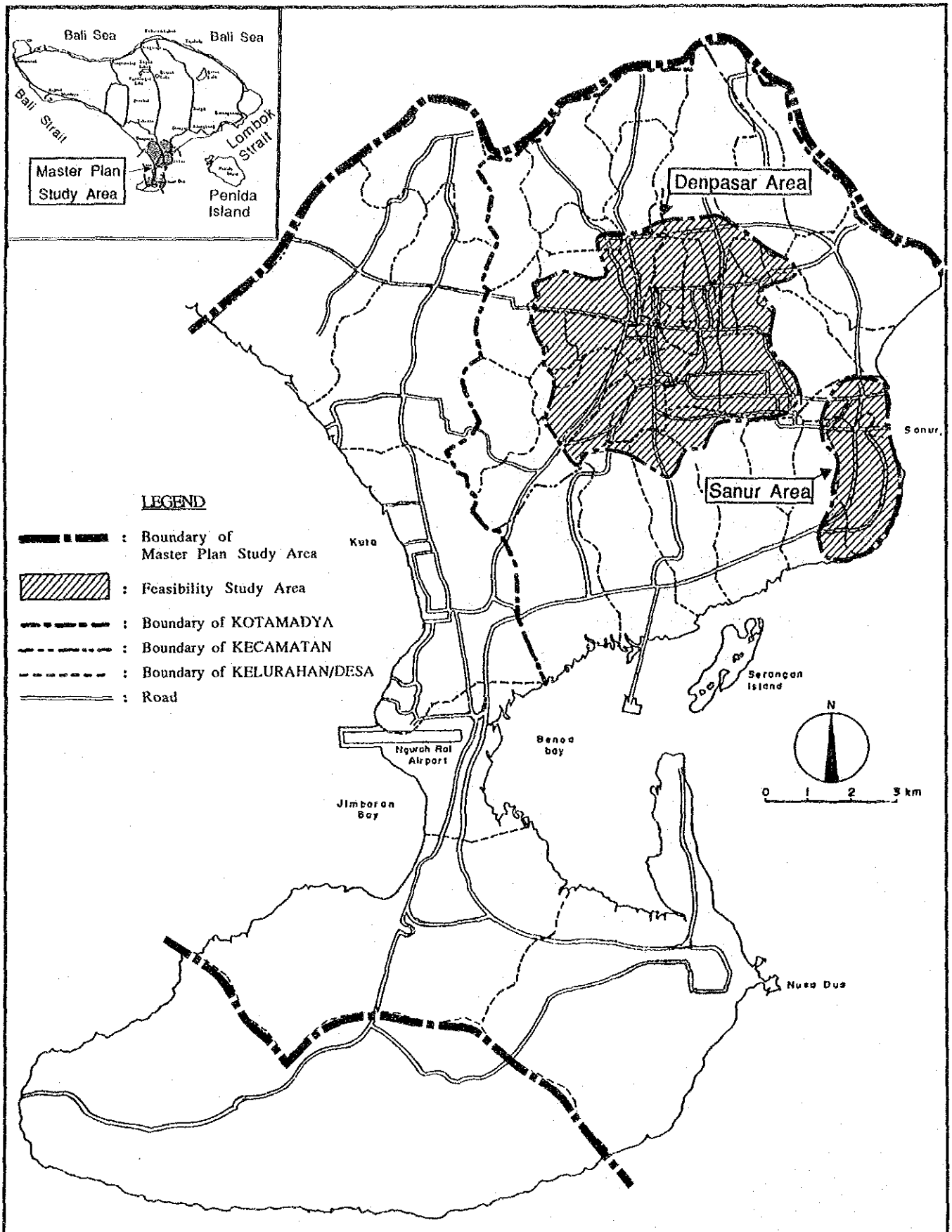



FIG. I.1 MASTER PLAN AND FEASIBILITY STUDY AREA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

# II. MASTER PLAN STUDY

# II. MASTER PLAN STUDY

## CHAPTER 1 STUDY AREA

### 1.1 Population and Land Use

The Study Area covering approximately 237 $km^2$ consists of three (3) districts (Kecamatan) of Kotamadya Denpasar; West Denpasar (Denpasar Barat), East Denpasar (Denpasar Timur) and South Denpasar (Denpasar Selatan), and a part of Kuta district of Kabupaten Badung. The Study Area is further divided into 50 sub-districts (Kelurahan/Desa).

The administrative boundaries of the Kecamatan and Kelurahan/Desa of the Study Area are shown in Fig. 1.1.

The Study Area has been undergoing a rapid population increase in the recent years. It has increased from 256,363 in 1975 to 477,437 in 1990 with an average annual growth rate of 4.2%. The future population in 2010 is projected to be 709,300 at an average annual growth rate of 2.0%.

The regional distribution of the population density in 1990 and 2010 by Kelurahan/Desa is shown in Fig. 1.2 and Fig. 1.3.

The existing and future land use patterns of the Study Area are estimated as follows.

| Land Use | 1989 Area(ha) | 1989 Ratio(%) | 2010 Area(ha) | 2010 Ratio(%) |
|---|---|---|---|---|
| Residential | 2,881.8 | (12.2) | 5,063.2 | (21.4) |
| Commercial and Institutional | 946.0 | (4.0) | 1,604.4 | (6.8) |
| Tourism | 429.9 | (1.8) | 1,737.7 | (7.3) |
| Industrial | 70.7 | (0.3) | 72.6 | (0.3) |
| Others | 19,324.6 | (81.7) | 15,175.1 | (64.2) |
| Total | 23,653.0 | (100.0) | 23.653.0 | (100.0) |

## 1.2 Economy and Tourism

The existing (1990) and future (2010) gross regional domestic product (GRDP) and per Capita GRDP of the Study Area are estimated at 1990 prices as shown below.

| | 1990 | 2010 | Average Annual Growth Rate (%) |
|---|---|---|---|
| GRDP (Rp.billion) | 815 | 3,463 | 7.5% |
| per Capita GRDP (US$) | 916 | 2,619 | 5.4% |

The largest economic sectors are Trade, Hotels and Restaurants, and Transport and Communications which share 46.2% in 1990 and 54.6% in 2010, in total.

The people's income level of the Study Area was estimated by income class based on sampling questionnaire survey. The estimated average per capita per month income and population composition in 1991 and 2010 are summarized below.

| Income Class | Per Capita Per Month Income (Rp.) | | Population Composition (%) | |
|---|---|---|---|---|
| | 1991 | 2010 | 1991 | 2010 |
| High | 165,600 | 335,600 | 3.2 | 18.8 |
| Middle | 55,200 | 104,100 | 51.0 | 53.7 |
| Low | 39,600 | 74,900 | 45.8 | 27.5 |
| Average | 51,500 | 139,800 | 100.0 | 100.0 |

The existing per capita per month income distribution by Kelurahan/Desa is shown in Fig. 1.4.

The existing (1990) and future (2010) number of tourists to Bali and their expenditures in the Study Area are estimated as follows.

| | 1990 | 2010 | Average Annual Growth Rate (%) |
|---|---|---|---|
| Total Number of Tourists to Bali (million) | 2.55 | 8.02 | 5.9 |
| Foreigner (million) | 0.87 (34%) | 3.80 (47%) | |
| Indonesian (million) | 1.68 (66%) | 4.22 (53%) | |
| Total Expenditure in Study Area (Rp. billion) | 610 | 2,391 | |

## 1.3 Natural Conditions

Average Annual rainfall of the Study Area is estimated to be 1,890 mm of which more than 50% concentrates in the three (3) rainy months of December to February. While in the driest months of August, September and October, the Study Area is blessed with a rain fall of less than even 50 mm.

The land of the Denpasar area gently declines toward south to the Benoa Bay, from an elevation of 75 m to 0 m. The ground level of the central Denpasar is 20 m.

Topographic map with contour lines of the Study Area is shown in Fig. 1.5.

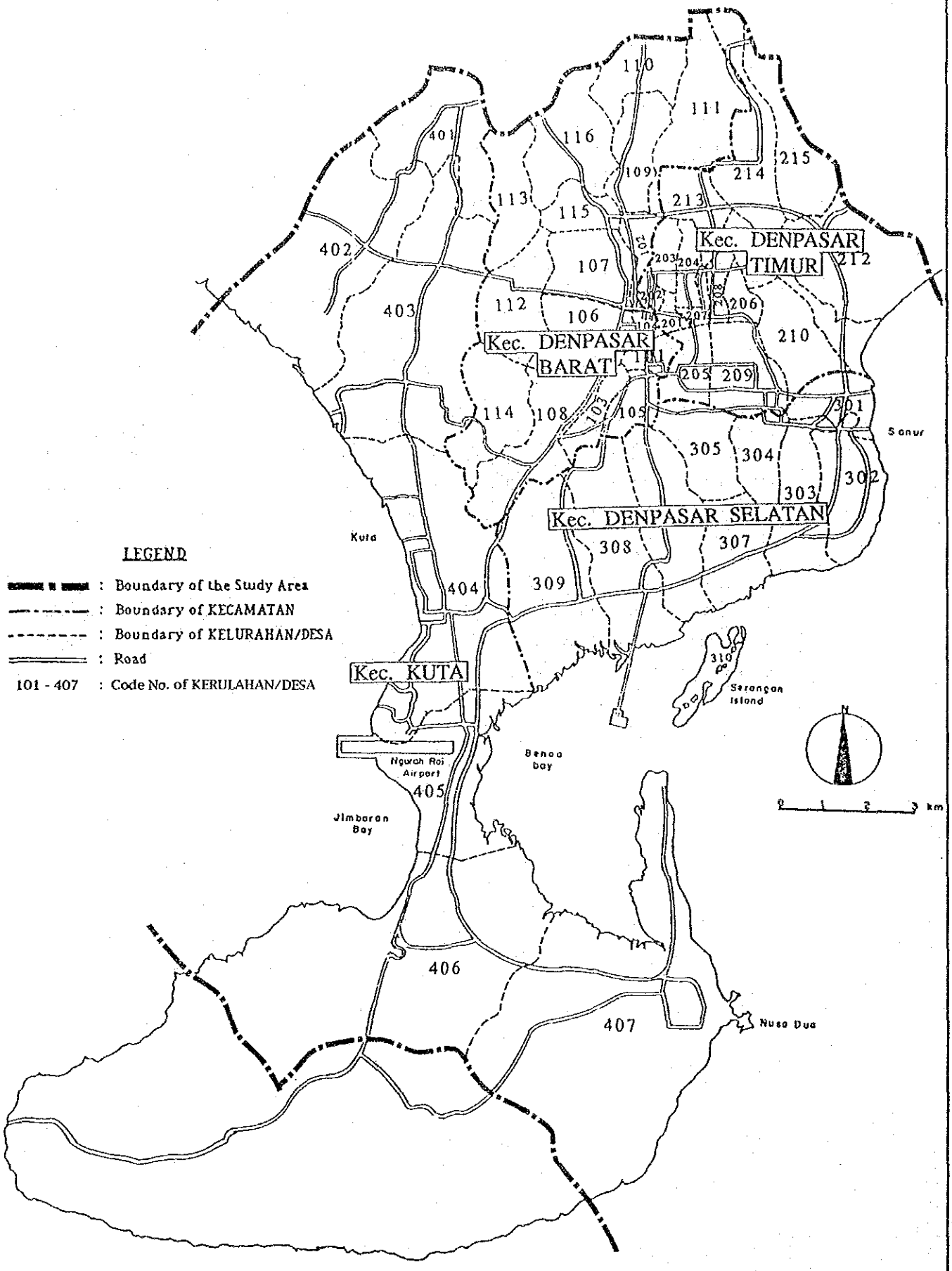



FIG. 1.1 ADMINISTRATIVE BOUNDARY

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

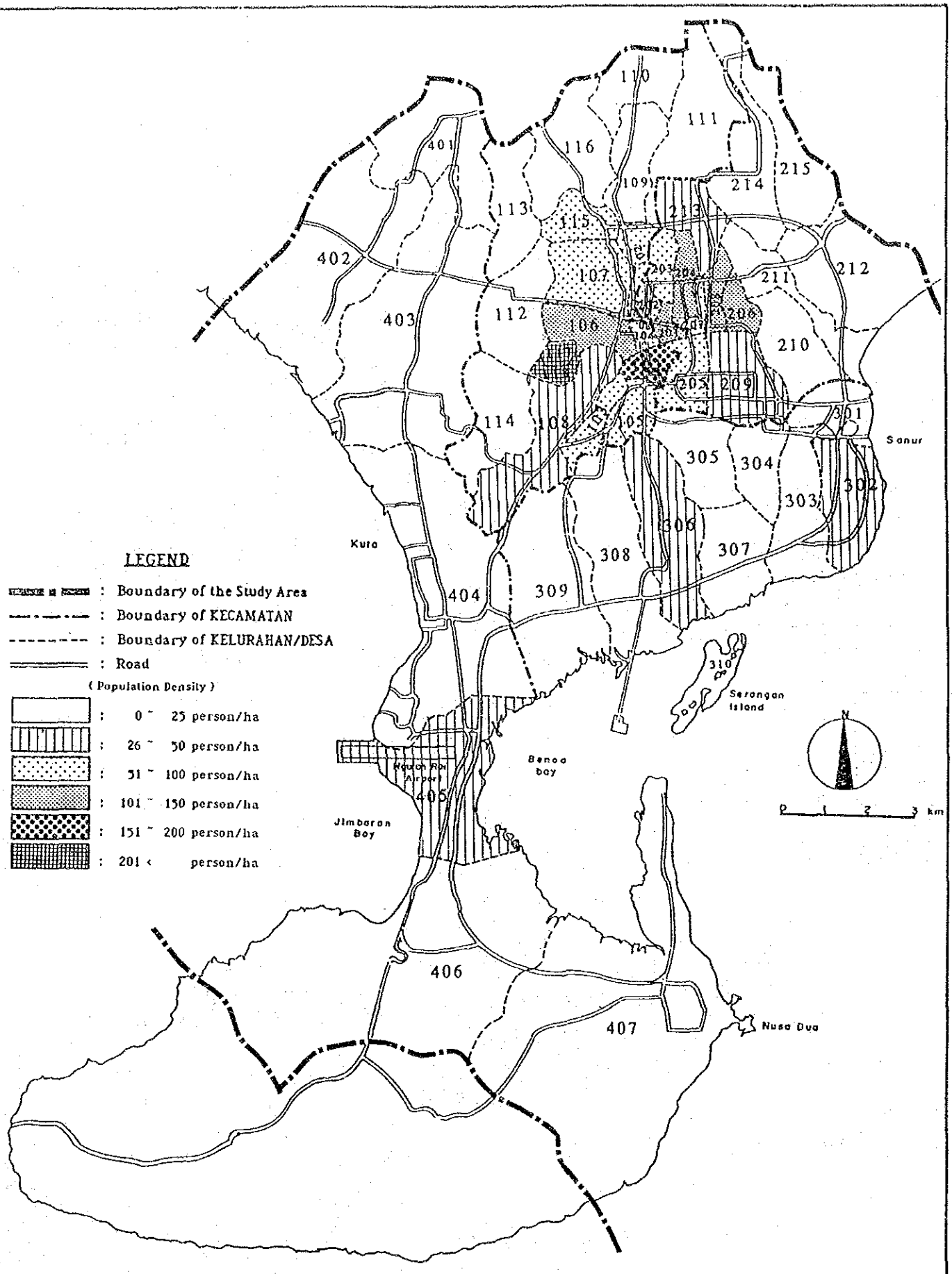



**FIG. 1.2** EXISTING POPULATION DENSITY BY KELURAHAN/DESA (1990)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

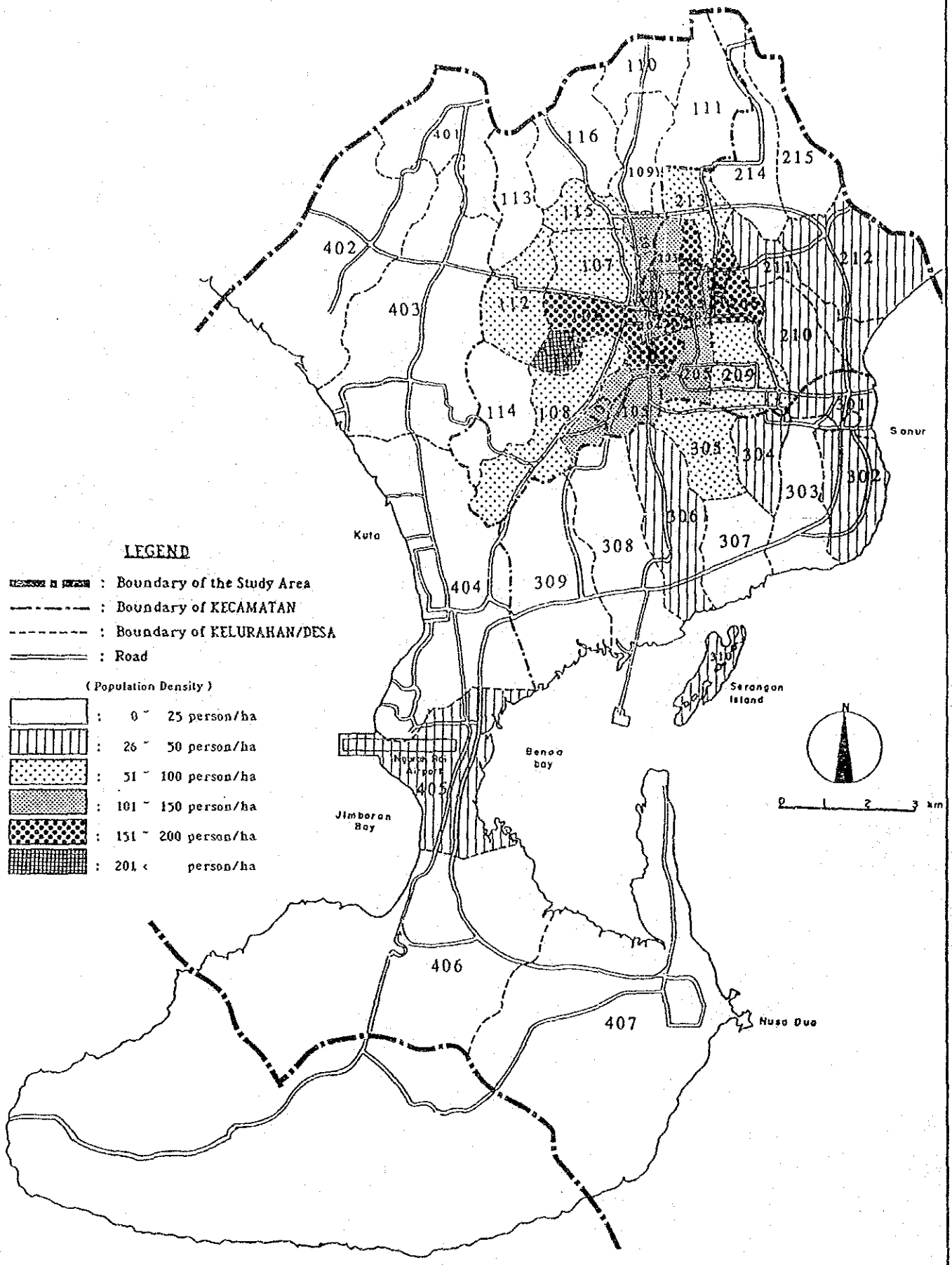



**FIG. 1.3** FUTURE POPULATION DENSITY BY KELURAHAN/DESA (2010)

**THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR**

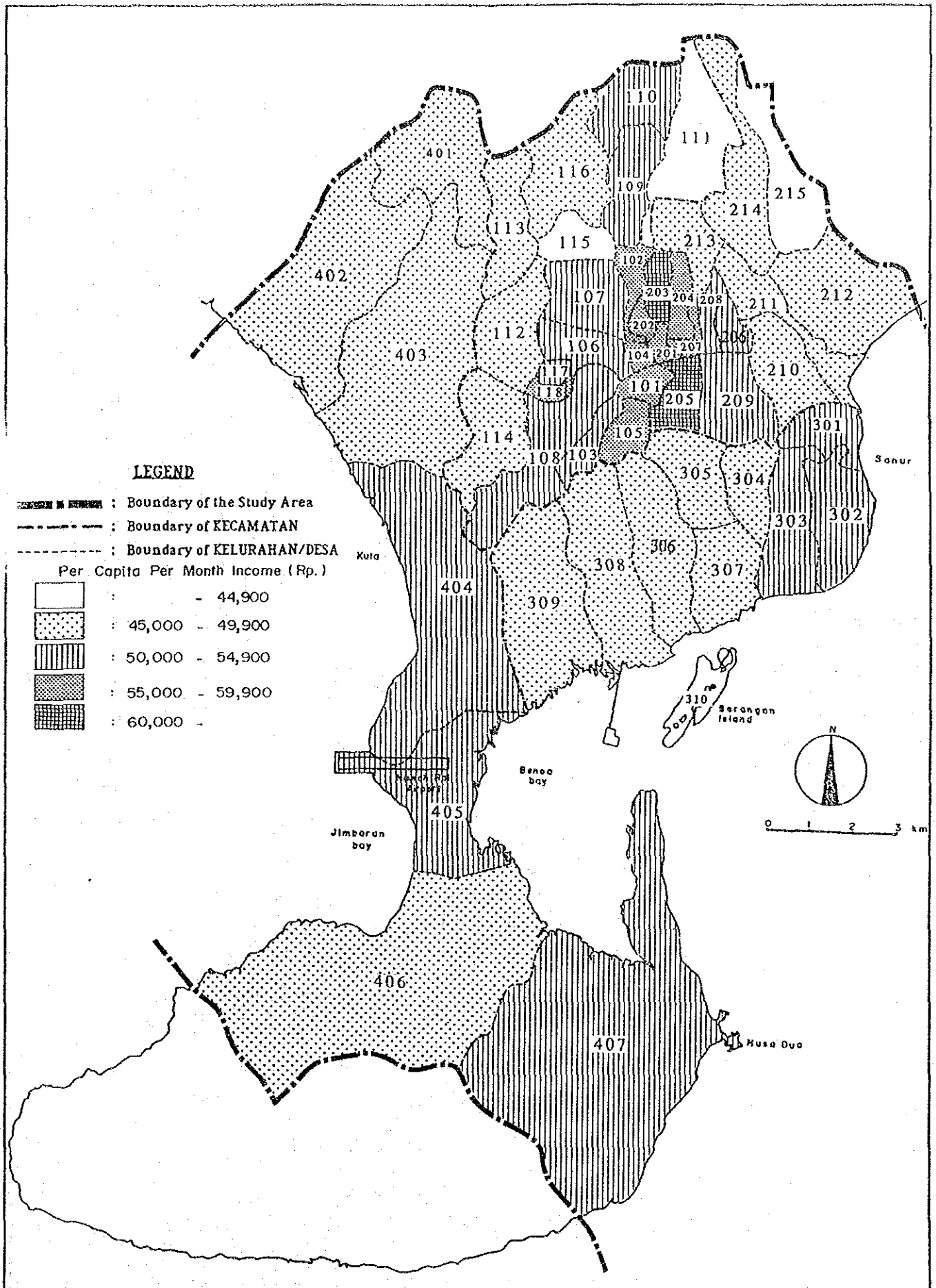



**FIG. 1.4** PER CAPITA PER MONTH HOUSEHOLD INCOME BY KELURAHAN/DESA IN 1991

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

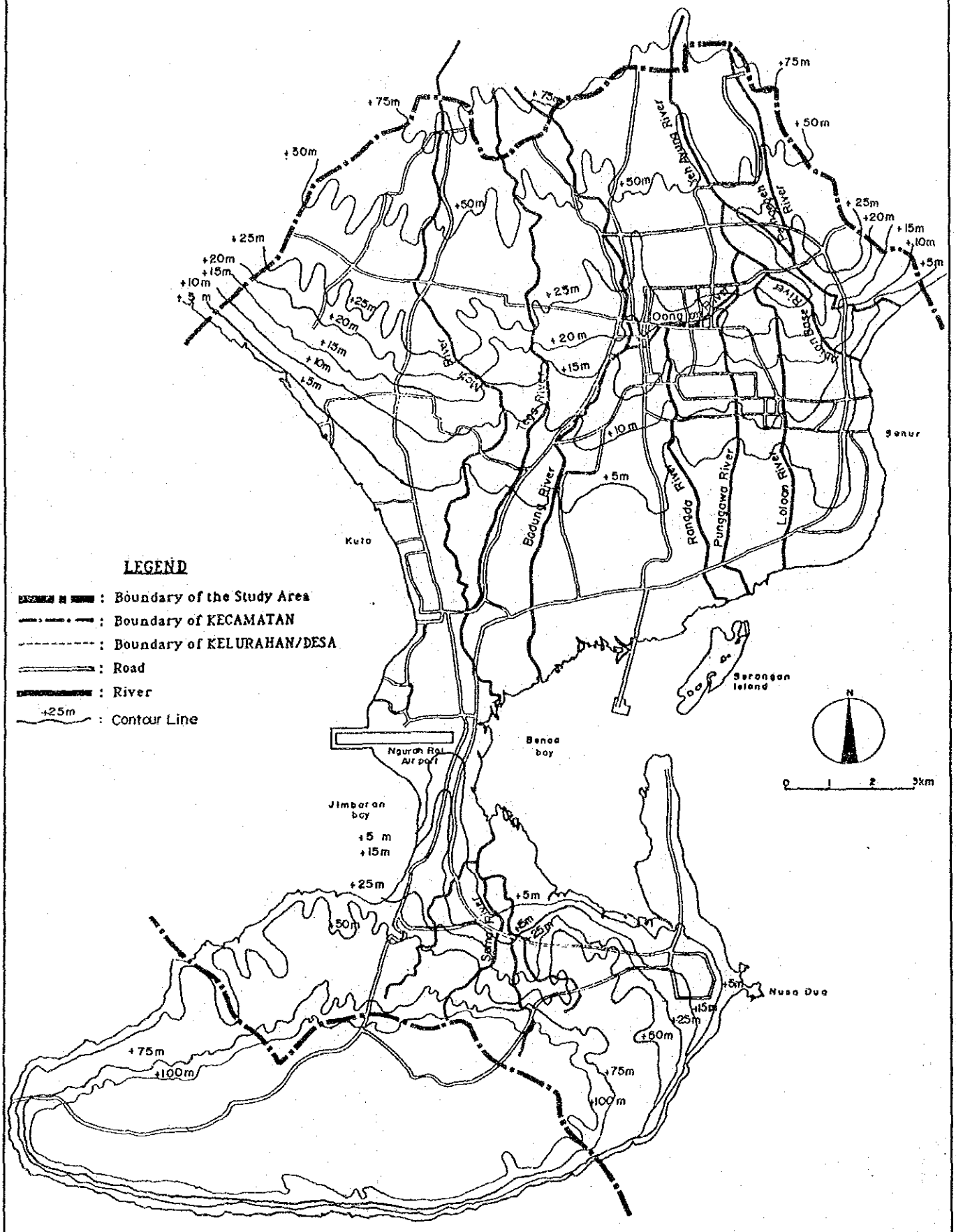



FIG. 1.5 TOPOGRAPHIC MAP OF STUDY AREA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

# CHAPTER 2 WATER ENVIRONMENTS

## 2.1 River Water Quality and Use

### (1) River Networks

A major portion of the Study Area (161.9 $km^2$ or 68% of the Study Area) is drained by the 11 rivers : Pengegeh, Yeh Ayung, Abian Base, Loloan, Punggawa, Oongan, Rangda, Badung, Teba, Mati and Sama. While, the remaining area of 74.6 $km^2$ is directly discharged to the sea.

Total length of the 11 rivers within the Study Area is measured to be 63.0 km.

The networks of the above rivers are shown in Fig. 2.1.

### (2) River Water Quality

The Study Team observed river water quality at 25 locations of the Study Area in dry season of 1991 and wet season of 1992. The observed river water quality as BOD are shown in Fig. 2.2.

High BOD is observed in the river reaches extending from upstream to downstream of Oongan, middle and lower reaches of Loloan and Badung, and mid-stream of Punggawa, Teba and Rangda.

The above rivers except Teba River are affected mainly by domestic and commercial wastewater, while flowing through the urbanized area of Denpasar. However, the major pollution source of the Tega River is industrial wastes of the batik factories.

The other rivers of Pengegeh, Yeh Ayung, Abian Base and Mati running through rural areas are still less polluted with BOD concentration of less than 10 mg/l.

The existing river water quality of the Study Area is classified into five (5) classes in terms of BOD as shown below.

| Class | BOD (mg/l) | Water Quality Condition |
|---|---|---|
| I | BOD ≤ 5 | Pristine |
| II | 5 < BOD ≤ 10 | Clean |
| III | 10 < BOD ≤ 20 | Slightly polluted |
| IV | 20 < BOD ≤ 30 | Significantly polluted |
| V | 30 < BOD | Heavily polluted |

The river sections of the Study Area are classified based on the river water quality in dry season as shown in Fig. 2.3. Similarly, the river classification for wet season is shown in Fig. 2.4.

(3) River Water Use

Irrigation is the largest river water use in the Study Area. Irrigation water is withdrawn from five (5) intakes in the Yeh Ayung and Badung rivers to irrigate the paddy field of 9,602 ha.

Location of the intakes and their commanding irrigation areas are shown in Fig. 2.5.

Washing and bathing uses are observed in many river sections, especially in the upstream reaches where good water quality is maintained. Fishery and recreational uses are small. Drinking water use is not recognized.

The existing major positive uses of river water by river section are summarized as shown in Fig. 2.6.

2.2 Sea Water Quality and Use

(1) Sea Water Quality

The Study Team observed sea water quality at 52 points of the Study Area in dry season of 1991 and wet season of 1992. The results are shown in Fig. 2.7.

The regional variation of $COD_{cr}$ in the coastal sea of the Study Area ranges from 0.4 mg/l to 25.3 mg/l. The maximum value is observed along the approach route of navigation to Benoa Port located between the Serangan Island and Cape Benoa. While, the minimum is at the off-shore of Nusa Dua.

High $COD_{cr}$ of more than 5 mg/l is observed along the coastal line of Sanur, Nusa Dua and part of Kuta, around the Serangan Island and inside of Benoa Bay.

Distribution of the sea water pollution as $COD_{cr}$ in the Study Area is shown in Fig. 2.8.

(2) Sea Water Use

Water recreations at Sanur, Kuta and Nusa Dua are the largest sea water use, followed by fishery use. The water recreations cover swimming, sun-bathing, fishing, surfing, boating, parasailing, diving, etc.

Apart from off-shore fisheries, brackish water fishery of shrimp cultivation is the most predominant one. Shrimp cultivation is conducted in Suwung area along the Benoa Bay. The total production amount and value in 1989 were respectively 1,750 ton and Rp. 14,978 million.

(3) Coral Life

The existing coral life of the Study Area is classified into four (4) classes based on the field survey as shown in Fig. 2.9.

## 2.3 Groundwater Quality and Use

The Study Team conducted sampling observations of groundwater table depth, groundwater quality and groundwater use at 75 wells of the Study Area.

Groundwater table depth is deeper than 3.0 m in most part of the Study Area. However, the low-lying southern Denpasar areas are prone to shallow groundwater table. Contourline of the groundwater table depth in the Study Area is shown in Fig. 2.10.

Significant organic pollution is recognized in the shallow groundwater wells in the central and southern Denpasar areas. The Study Team made an integrated evaluation for the organic pollution of groundwater as shown in Fig. 2.10.

Most of the wells in the Study Area is used for domestic purpose. Even in PDAM service area, well water is still a major source of domestic water.

## 2.4 Soil Permeability

The soil condition in the Study Area is classified into three (3) groups in terms of its infiltration capacity, based on the sampling survey as shown in Fig. 2.11.

## 2.5 Water Borne Disease

The average contraction rate of water borne disease across the Study Area in 1990 is estimated based on the questionnaire survey as shown below.

(Unit : No. of cases per 1,000 population)

| | | | | | |
|---|---|---|---|---|---|
| Malaria | 4.0 | D.H.F | 0.9 | Measles | 1.3 |
| Diarrhea | 41.5 | Typhoid | 1.3 | Hepatitis A | 0.1 |
| Cholera | 0.6 | Dysentery | 4.4 | Hepatitis B | 0.3 |
| Tuberculosis | 1.4 | Diphtheria | 1.3 | | |
| | | | | Total | 57.1 |

## 2.6 Water Quality Standards

The Bali Provincial Government has not yet completed the river and sea water quality standards. Hence, the river water quality standards of DKI Jakarta are used in planning the river water pollution control. The sea water quality standards in foreign countries are referred in planning the sea water pollution control.

The applied water quality standards are as follows.

River Water

| | | |
|---|---|---|
| For drinking water source | : | BOD < 10 mg/l |
| For agricultural use | : | BOD < 20 mg/l |
| For fishery use | : | BOD < 20 mg/l |
| For conservation of acquatic biota | : | BOD < 30 mg/l |

Sea Water

| | | |
|---|---|---|
| For water recreation | : | $COD_{cr}$ < 5 mg/l |

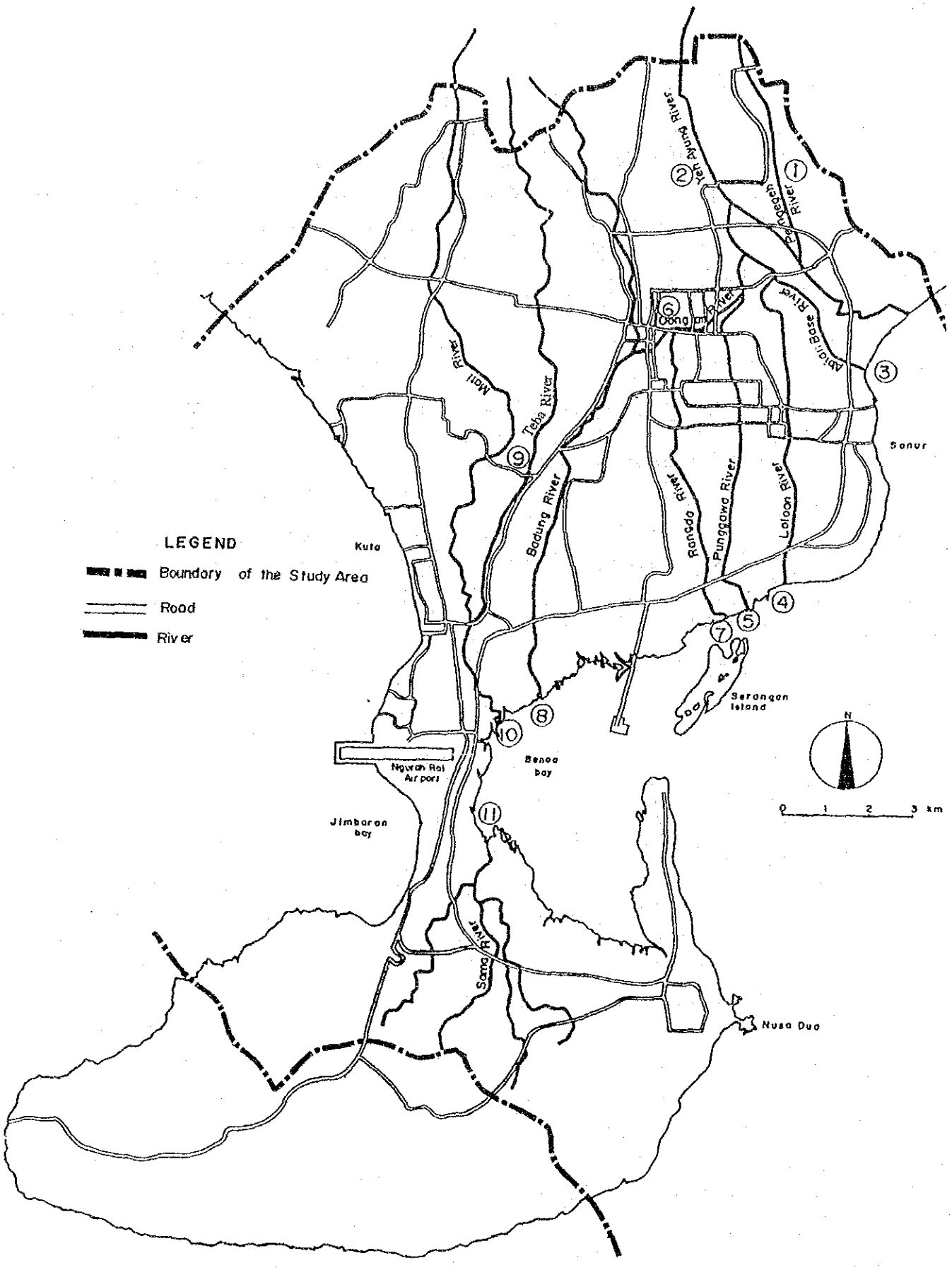



**FIG. 2.1** RIVER NETWORKS IN THE STUDY AREA

**THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR**

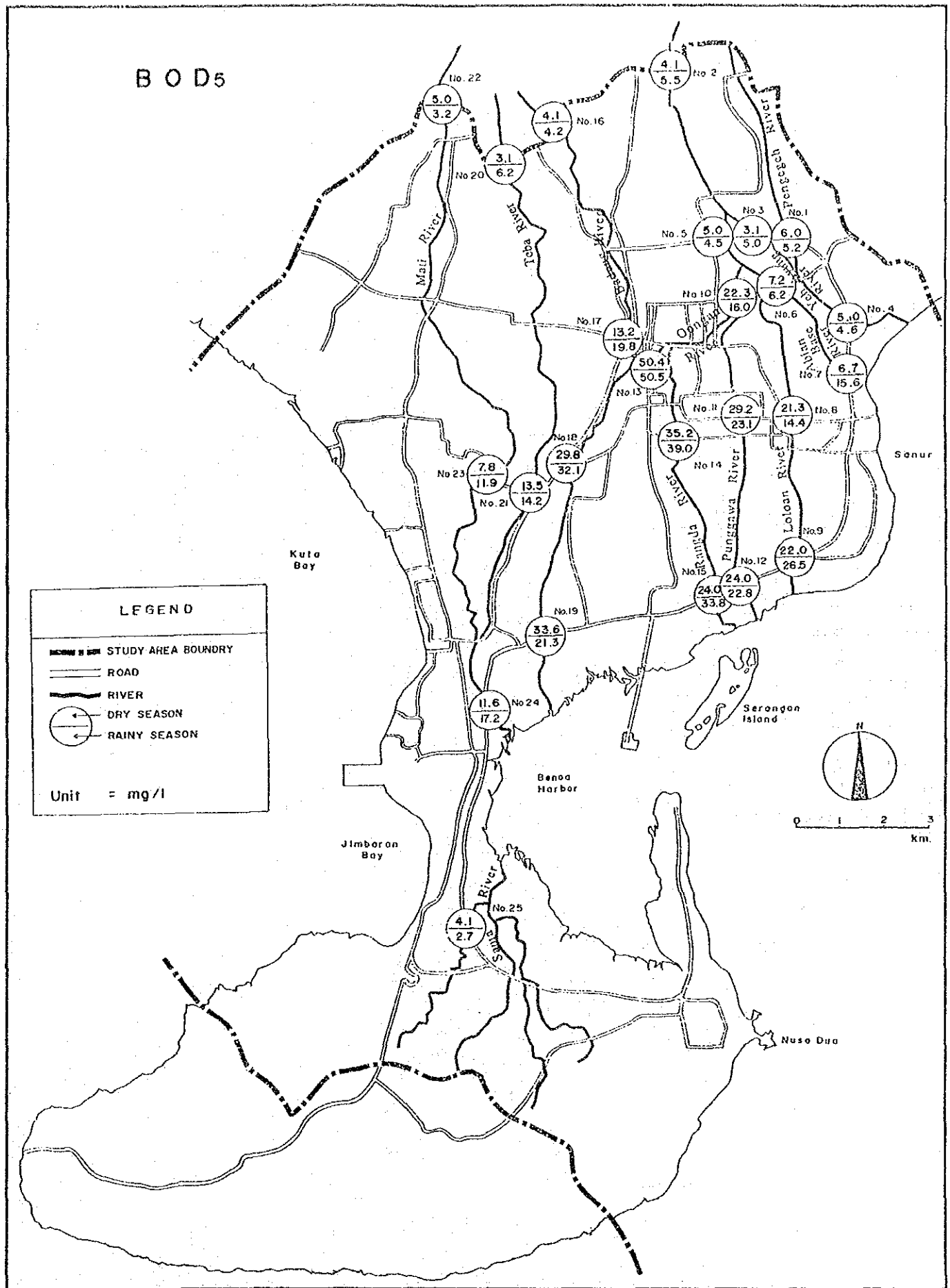
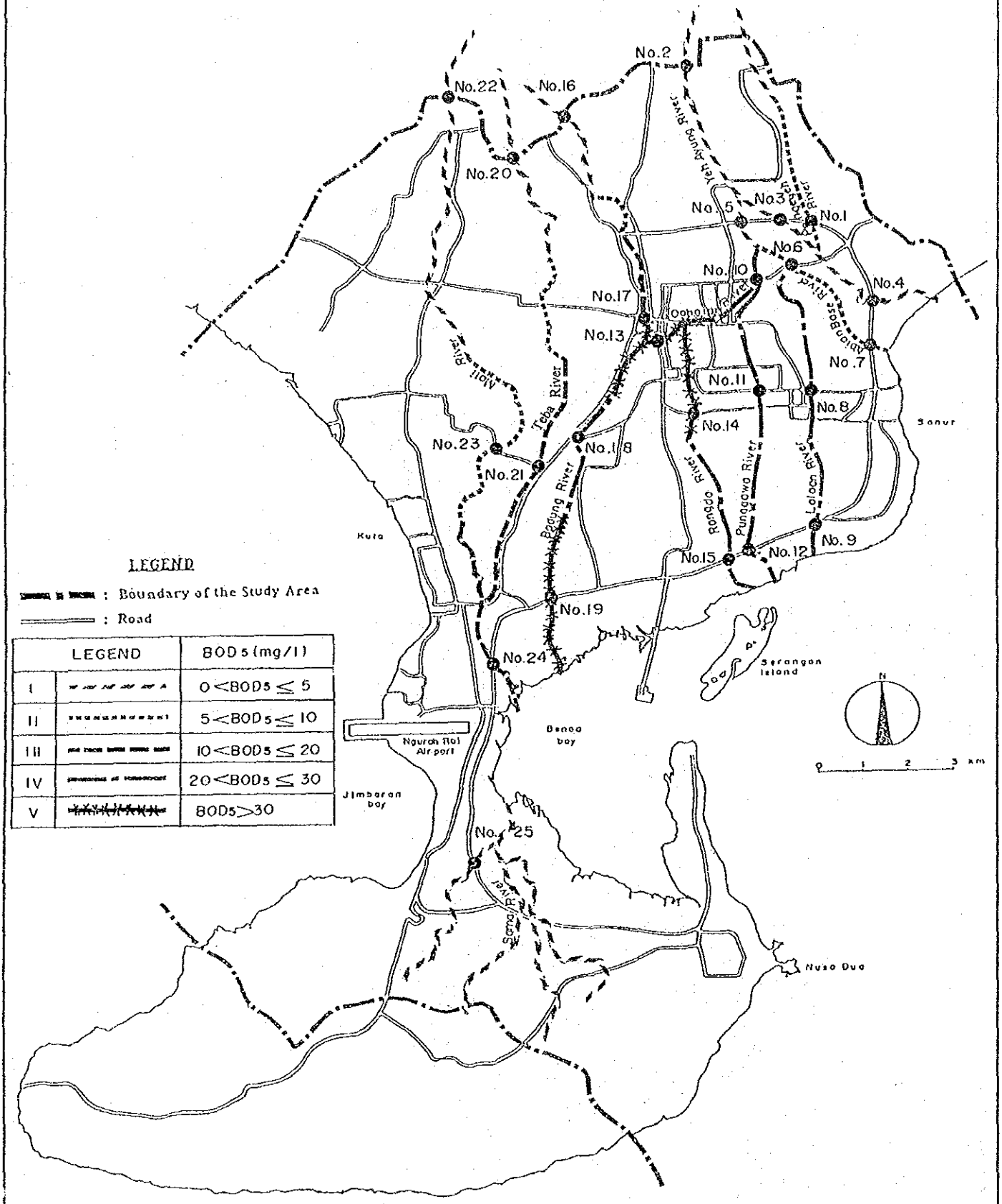



**FIG. 2.2** OBSERVED RIVER WATER QUALITY BY JICA

**THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR**




LEGEND

: Boundary of the Study Area

: Road

| LEGEND | | BOD5 (mg/l) |
|---|---|---|
| I | | 0 < BOD5 ≤ 5 |
| II | | 5 < BOD5 ≤ 10 |
| III | | 10 < BOD5 ≤ 20 |
| IV | | 20 < BOD5 ≤ 30 |
| V | | BOD5 > 30 |

FIG. 2.3 CLASSIFICATION OF RIVER STRETCHES BY WATER QUALITY (DRY SEASON)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

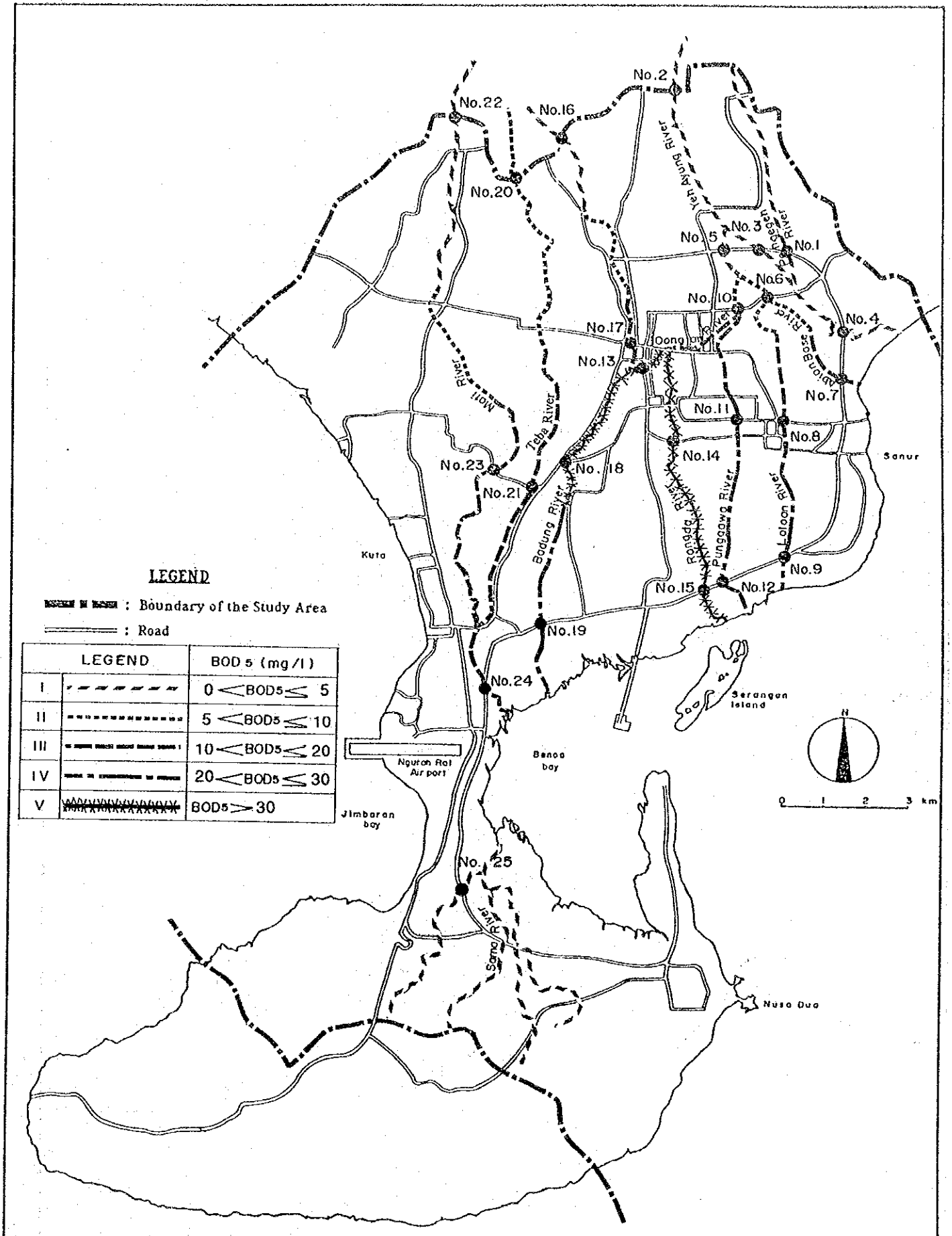



FIG. 2.4 CLASSIFICATION OF RIVER STRETCHES BY WATER QUALITY (RAINY SEASON)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

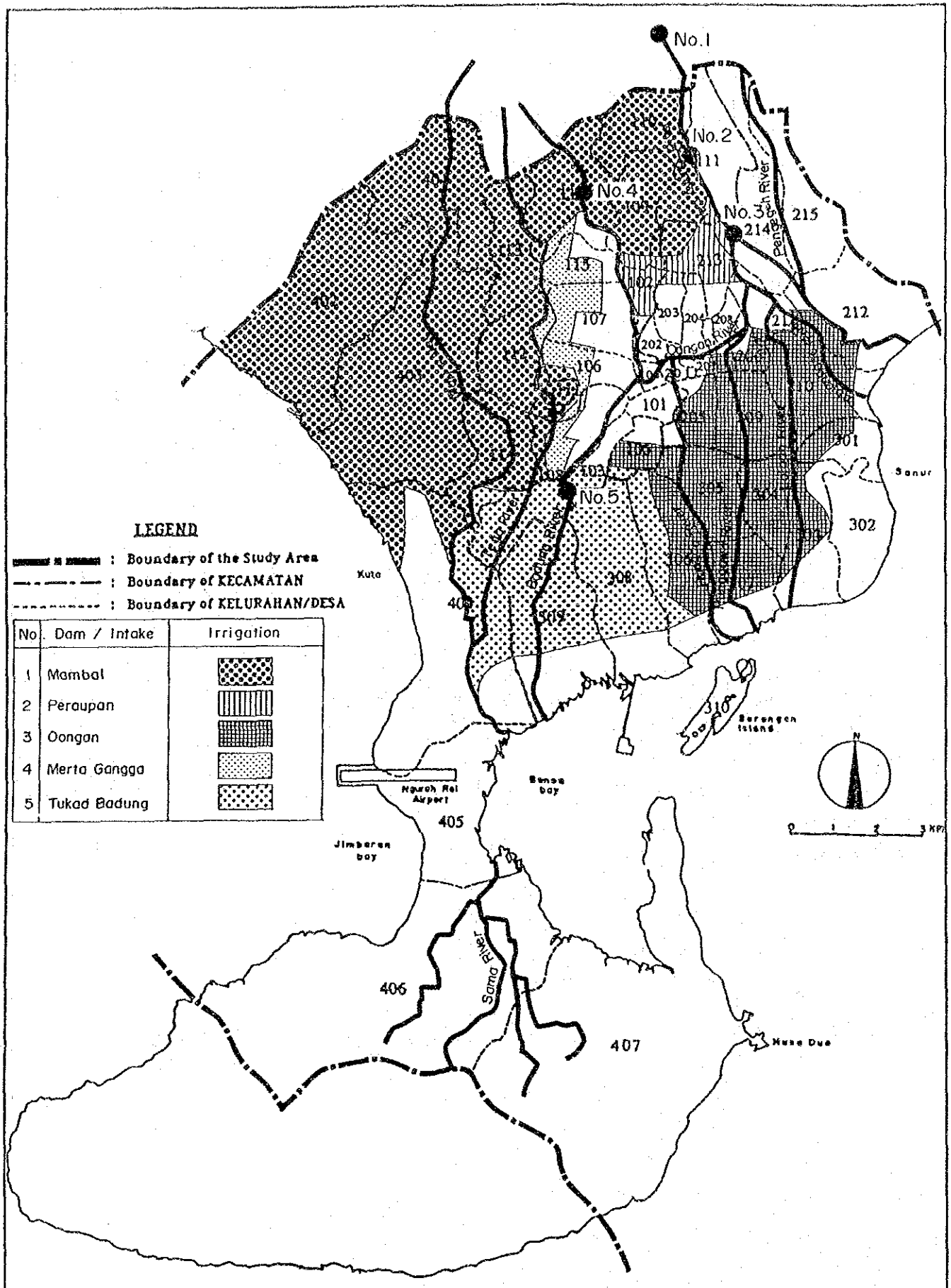



FIG. 2.5 IRRIGATION INTAKE SITE AND COMMANDING AREA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

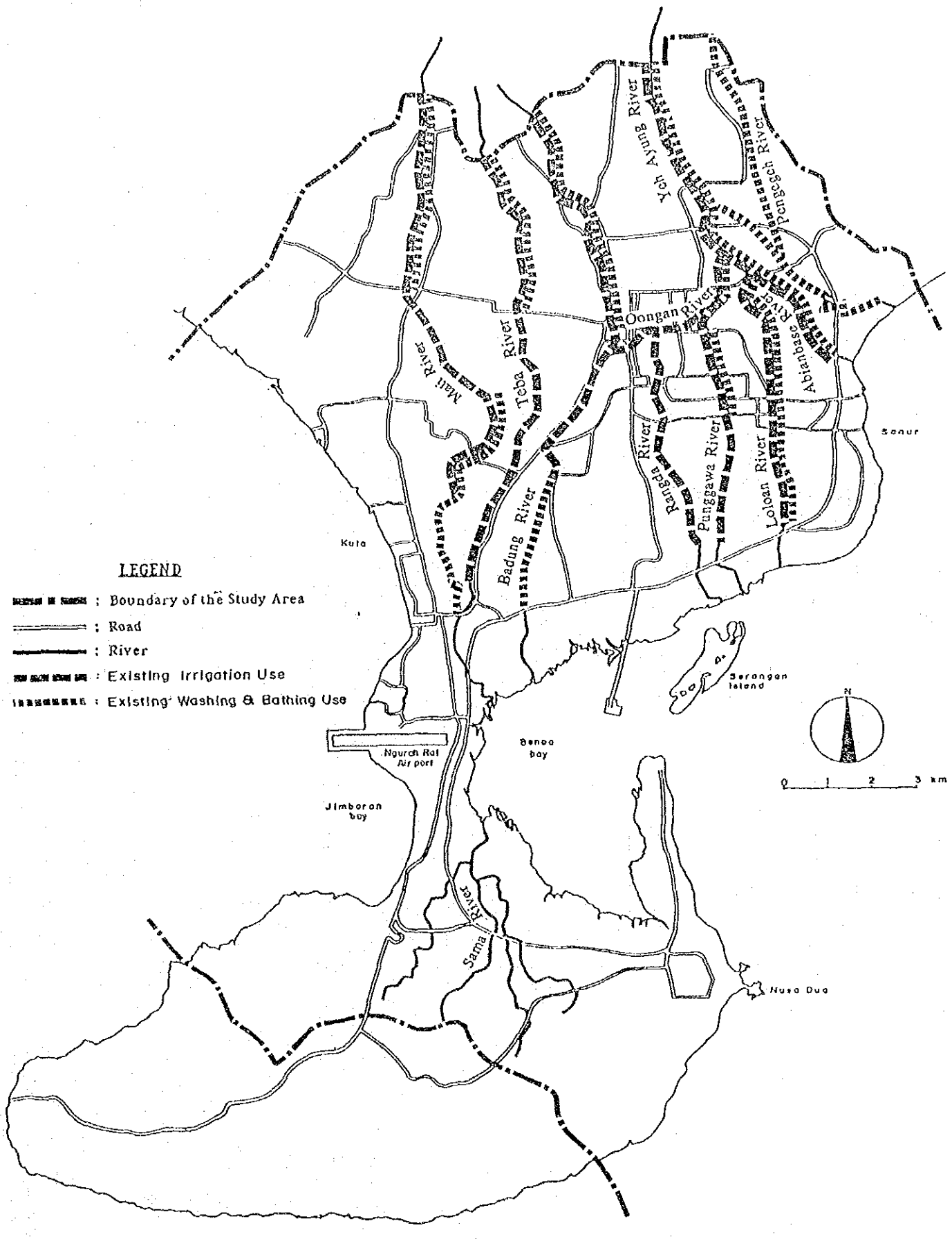



FIG. 2.6 EXISTING MAJOR WATER USE BY RIVER SECTION

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

COD cr

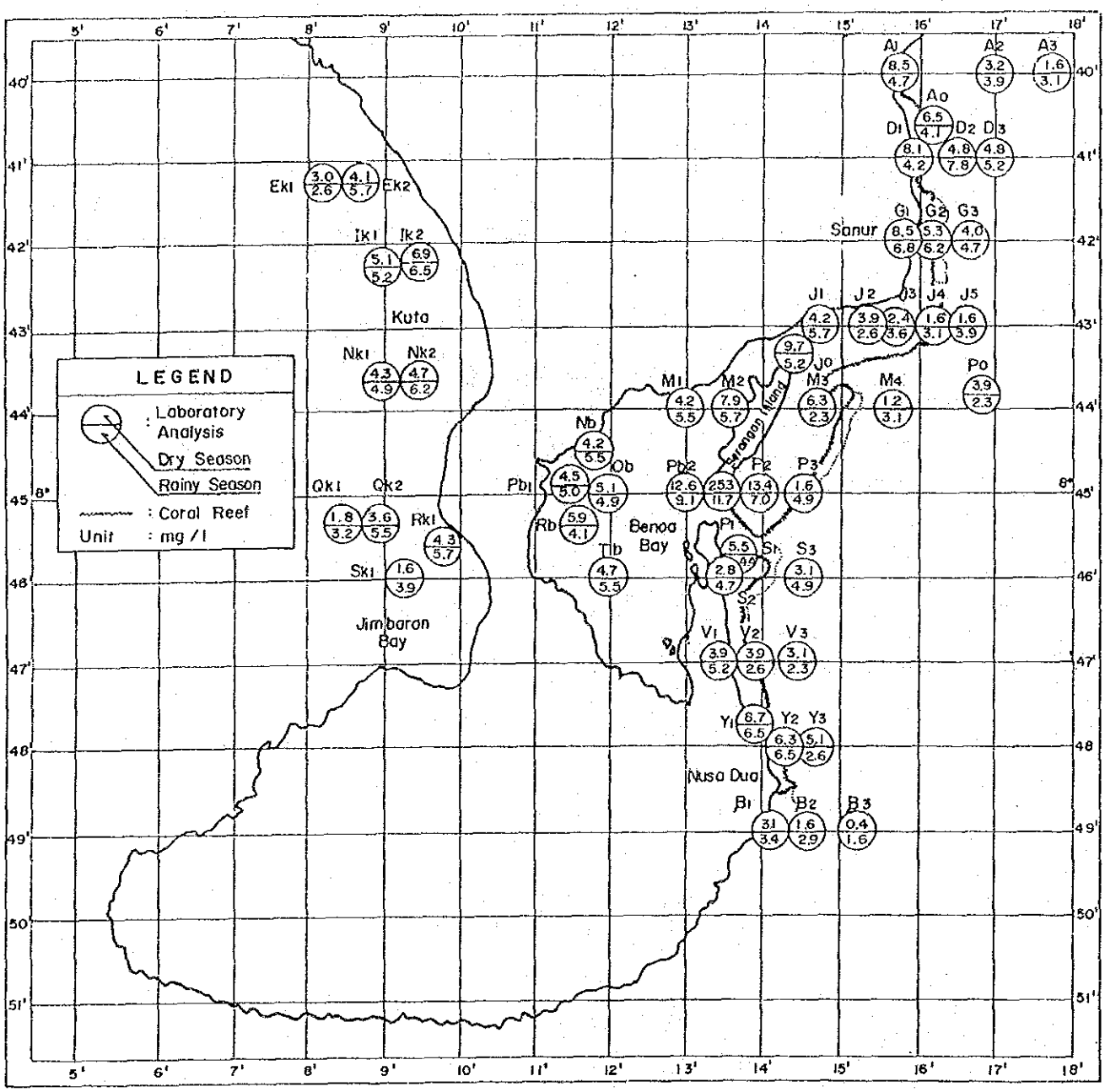



**FIG. 2.7** OBSERVED SEA WATER QUALITY BY JICA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

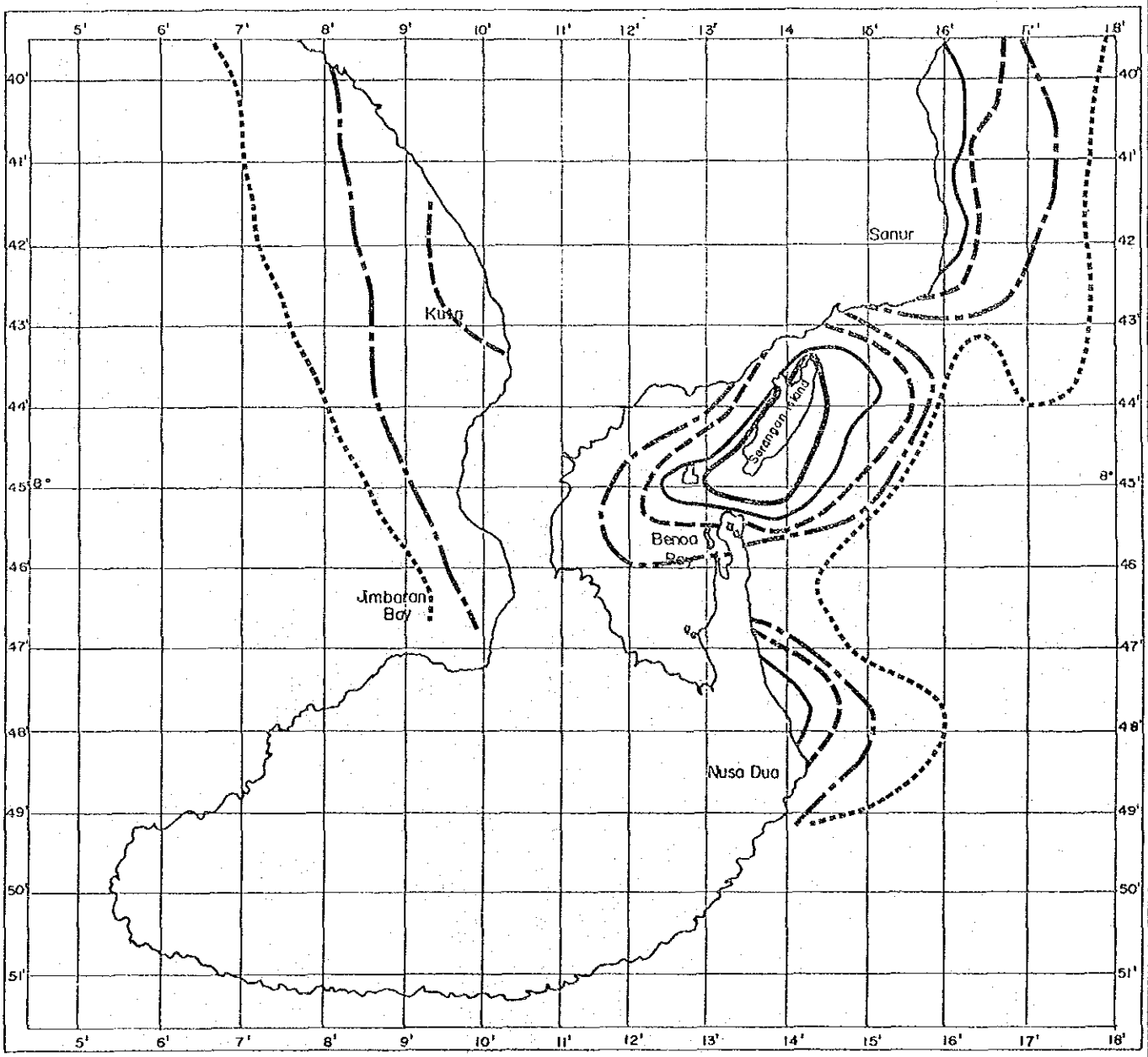
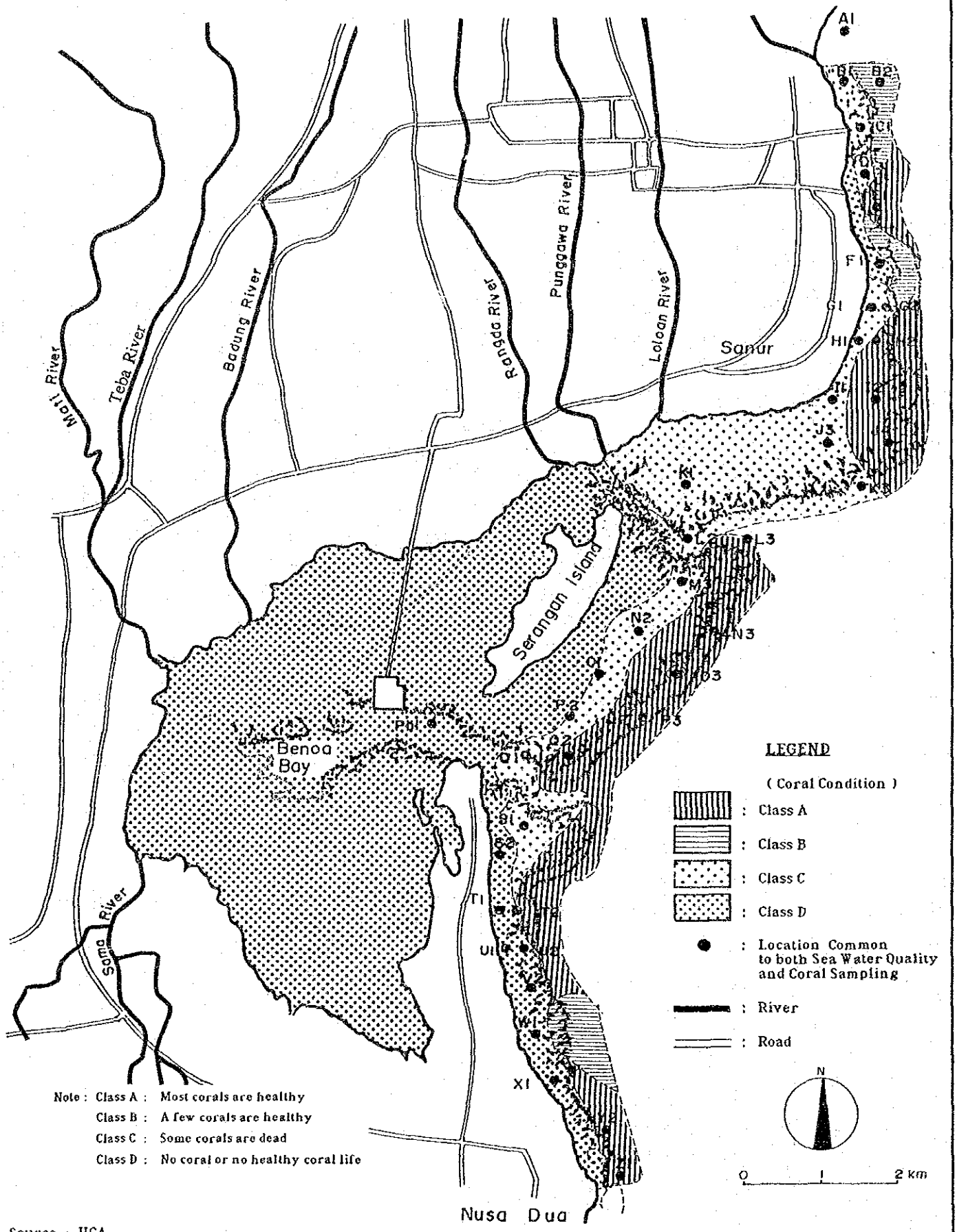



FIG. 2.8 COD POLLUTION DISTRIBUTION IN DRY SEASON BY JICA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR




Source : JICA

**FIG. 2.9** DISTRIBUTION OF CORAL LIFE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

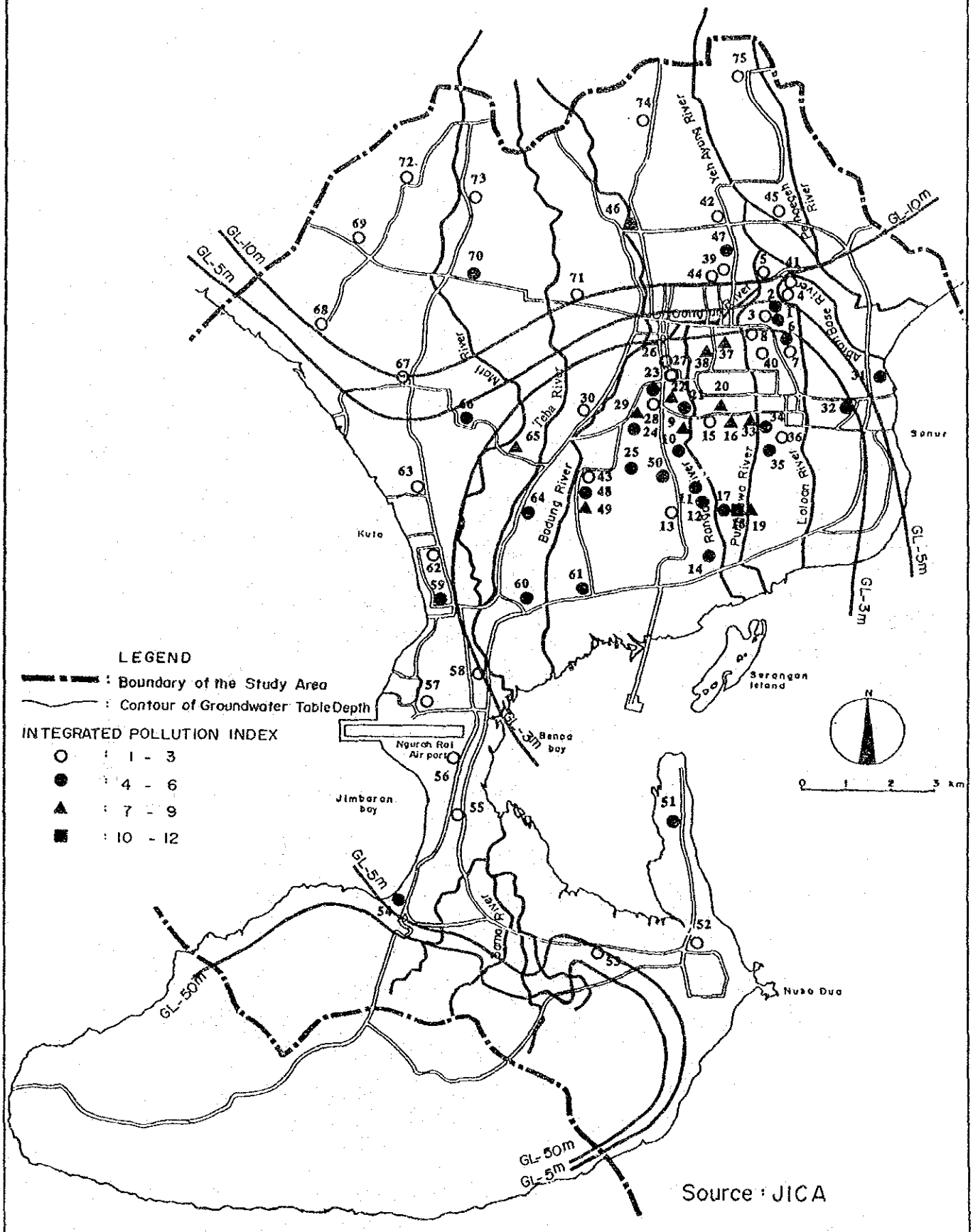



FIG. 2.10 EXISTING SITUATION OF GROUNDWATER CONTAMINATION (INTEGRATED POLLUTION INDEX)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

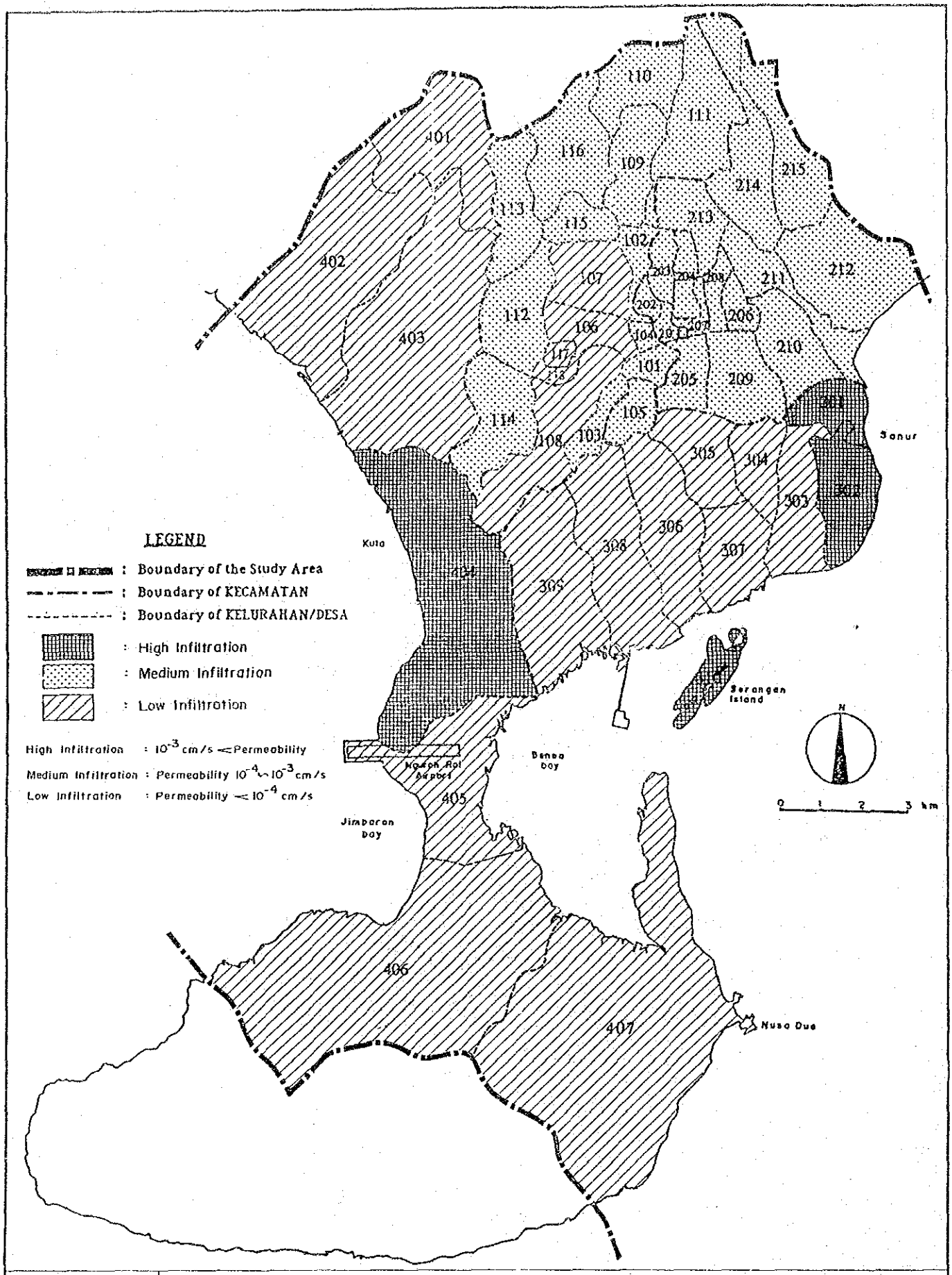



FIG. 2.11 SOIL INFILTRATION CAPACITY BY KELURAHAN/DESA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

# CHAPTER 3 POLLUTION LOAD GENERATION

## 3.1 Water Consumption

### (1) Domestic

The existing piped water service is small. Major portion of the water demand in the Study Area is met by individual groundwater wells. The existing service ratio of piped water for the whole Study Area is estimated to be 33%. The service area is shown in Fig. 3.1.

The existing and future unit water consumption for each income class are determined as follows based on the sampling survey.

| | | |
|---|---|---|
| High class | : | 330 lcd |
| Middle class | : | 210 lcd |
| Low class | : | 160 lcd |

The average existing and future unit water consumption of the Study Area is estimated to be 191 lcd and 219 lcd respectively.

### (2) Commercial and Institutional

Commercial and institutional water consumption of an area can be estimated by multiplying its domestic water consumption by a certain ratio. This ratio varies mainly, depending on land use pattern of the area.

Existing Commercial & Institutional Water Consumption Ratio :

$Y(\%) = 1.143 \cdot X(\%) - 3.556$

$X(\%)$ = Existing Commercial & Institutional Land Area / Existing Residential Land Area x 100

The future commercial and institutional water consumption ratio is assumed to be the same as the existing one.

(3) Tourism

The existing and future unit water consumption are determined as follows, based on the sampling survey.

| | | |
|---|---|---|
| High class hotel | : | 2.1 $m^3$/room/day |
| Middle and low class hotel | : | 1.5 $m^3$/room/day |
| Restaurant | : | 22 l/seat/day |

(4) Industrial

The existing and future unit water consumption 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 0.002 $m^3$/day/million Rp./yr. and 0.027 $m^3$/day/million Rp./yr.

3.2 Unit Pollution Load

(1) Domestic

Domestic wastewater consists of toilet waste and gray water. Quantity of toilet waste varies depending on type of toilet. Some portion of domestic water is lost due to gardening, car washing and other similar water uses.

Hence, the existing and future unit wastewater and pollution load generation for each income class are determined based on the sampling survey as shown below.

| | Unit Wastewater (lcd) | | | Unit Pollution Load ($BOD_5$ gcd) | | |
|---|---|---|---|---|---|---|
| | Gray Water | Toilet Waste | Total | Gray Water | Toilet Waste | Total |
| - High Class | 268 | 30 | 298 | 32.7 | 11.2 | 43.9 |
| - Middle Class | 169 | 16 | 185 | 20.5 | 11.2 | 31.7 |
| - Low Class | 133 | 16 | 149 | 15.6 | 11.2 | 26.8 |