For the details, see Fig. D.5.2.

The total construction costs are estimated as follows :

Stage I	:	US$	17.6	million
Stage II	:	US$	9.6	million
Total	:	US$	27.2	million

The Stage I and Stage II are scheduled to be commissioned at the end of 1992 and at end of 1997 respectively.

5.3 Taman Hutan Raya (Great Forest Park) Project

The Benoa Bay (1,392 ha) is one area in Bali where a mangrove forest has been preserved. The government of Indonesia has been eager to protect the forest by stipulating the General Governor's Decree (No. 28 Sub B.6.2, May 29, 1927) and Decision Letter of Agriculture Minister (No. 821/Kpt.5/Um/II/1982).

One of the government policies to protect and preserve the natural resources is the Forest Park Development. It is a management system for natural preservation area to optimize the function of the area. There should be established a well considered balance between preservation management of natural resources and environment, and regional tourism development program.

Based on the fact that Benoa Bay consists of a lot of natural resources like mangroves and Bali is very potential for tourist resort, the Mangrove Forest Park (TAHURA) in Benoa Bay (1,392 ha) needed a careful approach to development and is decided to have three (3) functions as follows.

- 838.2 ha protected forest
- 418.3 ha production forest
- 135.5 ha natural park.

The Development of Suwung Mangrove National Park are expected to have the following five (5) purposes :

1. Germ preservation
2. Environmental protection
3. Research of mangrove trees
4. Education and practice
5. Natural resources for tourists.

The Tahura started in 1989 and consists of a long standing strategy of development in harmony of environmental protection.

According to the plan each area in the Benoa Bay has been designated as :

- Recreation and sport area
- Research and training area
- Plant collection area
- Camping area
- Visitor center area
- Fishing area
- Coastal recreation area
- Turtle farming area
- Water skiing area.

For details, see Fig. D.5.3.

Table D.1.1(1) Kelurahan-wise Domestic Sanitation Service Level in Study Area-1991

Code Number	Name of Kelurahan/Desa & Kecamatan	TOILET WITH TREATMENT (%)	TOILET WITHOUT TREATMENT (%)	PUBLIC TOILET (%)	NO TOILET (%)
101	Dauh Puri	100.0	0.0	0.0	0.0
102	Dauh Puri Kaja	100.0	0.0	0.0	0.0
103	Dauh Puri Kauh	100.0	0.0	0.0	0.0
104	Dauh Puri Kangin	100.0	0.0	0.0	0.0
105	Dauh Puri Kelod	100.0	0.0	0.0	0.0
106	Pemecutan	100.0	0.0	0.0	0.0
107	Pemecutan Kaja	93.3	0.0	0.0	6.7
108	Pemecutan Kelod	100.0	0.0	0.0	0.0
109	Peguyangan	80.0	6.7	0.0	13.3
110	Peguyangan Kaja	26.7	0.0	0.0	73.3
111	Peguyangan Kangin	93.3	0.0	0.0	6.7
112	Padang Sambian	100.0	0.0	0.0	0.0
113	Padang Sambian Kaja	93.3	0.0	0.0	6.7
114	Padang Sambian Kelod	80.0	0.0	0.0	20.0
115	Ubung	100.0	0.0	0.0	0.0
116	Ubung Kaja	93.3	6.7	0.0	0.0
117	Tegal Kerta	95.0	0.0	0.0	5.0
118	Tegal Harum	100.0	0.0	0.0	0.0
100	**DENPASAR BARAT**	95.6	0.5	0.0	3.9
201	Dangin Puri	100.0	0.0	0.0	0.0
202	Dangin Puri Kauh	100.0	0.0	0.0	0.0
203	Dangin Puri Kaja	100.0	0.0	0.0	0.0
204	Dangin Puri Kangin	100.0	0.0	0.0	0.0
205	Dangin Puri Kelod	100.0	0.0	0.0	0.0
206	Sumerta	100.0	0.0	0.0	0.0
207	Sumerta Kauh	100.0	0.0	0.0	0.0
208	Sumerta Kaja	100.0	0.0	0.0	0.0
209	Sumerta Kelod	100.0	0.0	0.0	0.0
210	Kesiman	100.0	0.0	0.0	0.0
211	Kesiman Petilan	100.0	0.0	0.0	0.0
212	Kesiman Kertalangu	100.0	0.0	0.0	0.0
213	Tonja	100.0	0.0	0.0	0.0
214	Penatih	73.3	0.0	0.0	26.7
215	Penatih Dangin Puri	46.6	0.0	0.0	53.4
200	**DENPASAR TIMUR**	97.8	0.0	0.0	2.2

Table D.1.1(2) Kelurahan-wise Domestic Sanitation Service Level in Study Area-1991

Code Number	Name of Kelurahan/Desa & Kecamatan	TOILET WITH TREATMENT %	TOILET WITHOUT TREATMENT (%)	PUBLIC TOILET (%)	NO TOILET (%)
301	Sanur Kaja	100.0	0.0	0.0	0.0
302	Sanur	100.0	0.0	0.0	0.0
303	Sanur Kauh	100.0	0.0	0.0	0.0
304	Renon	100.0	0.0	0.0	0.0
305	Panjer	100.0	0.0	0.0	0.0
306	Sesetan	100.0	0.0	0.0	0.0
307	Sidakarya	100.0	0.0	0.0	0.0
308	Pedungan	80.0	0.0	0.0	20.0
309	Pemogan	93.3	6.7	0.0	0.0
310	Serangan	100.0	0.0	0.0	50.0
300	**DENPASAR SELATAN**	97.1	0.6	0.0	3.6
401	Dalung	93.3	6.7	0.0	0.0
402	Canggu	93.3	6.7	0.0	0.0
403	Kerobokan	100.0	0.0	0.0	0.0
404	Kuta	93.3	6.7	0.0	0.0
405	Tuban	100.0	0.0	0.0	0.0
406	Jimbaran	40.0	0.0	0.0	60.0
407	Benoa	93.3	0.0	0.0	6.7
400	**KUTA**	88.3	2.4	0.0	9.3
Total		95.1	0.8	0.0	4.4

Note : The number of samples per Kelurahan/Desa were 15

Source : JICA

Table D.1.2 (1) Kelurahan-wise Domestic Sanitation Service Level in Study Area - 1988

Code Number	Name of Kelurahan/Desa & Kecamatan	Total Sample	PRIVATE TOILET						NEIGHBOUR TOILET		COMMUNITY TOILET		PUBLIC TOILET (MCK)		OPEN SPACE		DRAIN/RIVER	
			WITH TREATMENT		WITHOUT TREATMENT		TOTAL											
		No.	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
101	Dauh Puri	62	57	92	4	6	61	98	0	0	0	0	0	0	0	0	1	2
102	Dauh Puri Kaja	16	16	100	0	0	16	100	0	0	0	0	0	0	0	0	0	0
103	Dauh Puri Kauh	18	17	94	1	6	18	100	0	0	0	0	0	0	0	0	0	0
104	Dauh Puri Kangin	23	19	83	4	17	23	100	0	0	0	0	0	0	0	0	0	0
105	Dauh Puri Kelod	52	51	98	0	0	51	98	0	0	0	0	0	0	1	0	0	0
* 106	Pemecutan	20	20	100	0	0	20	100	0	0	0	0	0	0	0	0	0	0
107	Pemecutan Kaja	30	30	100	0	0	30	100	0	0	0	0	0	0	0	0	0	0
108	Pemecutan Kelod	15	14	93	0	0	14	93	0	0	0	0	0	0	0	0	1	7
109	Peguyangan	42	41	98	1	2	42	100	0	0	0	0	0	0	0	0	0	0
• 110	Peguyangan Kaja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
• 111	Peguyangan Kangin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
112	Padang Sambian	45	36	80	0	0	36	80	0	0	0	0	0	0	3	7	6	13
• 113	Padang Sambian Kaja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
• 114	Padang Sambian Kelod	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
115	Ubung	7	6	86	0	0	6	86	0	0	0	0	0	0	0	0	1	14
• 116	Ubung Kaja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
* 117	Tegal Kerta																	
* 118	Tegal Harum																	
100	DENPASAR BARAT	330	307	93	10	3	317	96	0	0	0	0	0	0	4	1	9	3
201	Dangin Puri	26	25	96	1	4	26	100	0	0	0	0	0	0	0	0	0	0
202	Dangin Puri Kauh	22	19	86	3	14	22	100	0	0	0	0	0	0	0	0	0	0
203	Dangin Puri Kaja	45	45	100	0	0	45	100	0	0	0	0	0	0	0	0	0	0
204	Dangin Puri Kangin	53	53	100	0	0	53	100	0	0	0	0	0	0	0	0	0	0
205	Dangin Puri Kelod	55	52	95	3	5	55	100	0	0	0	0	0	0	0	0	0	0
206	Sumerta	38	38	100	0	0	38	100	0	0	0	0	0	0	0	0	0	0
207	Sumerta Kauh	30	29	97	1	3	30	100	0	0	0	0	0	0	0	0	0	0
208	Sumerta Kaja	25	25	100	0	0	25	100	0	0	0	0	0	0	0	0	0	0
209	Sumerta Kelod	21	20	95	0	0	20	95	0	0	0	0	0	0	1	5	0	0
210	Kesiman	20	20	100	0	0	20	100	0	0	0	0	0	0	0	0	0	0
• 211	Kesiman Petilan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
• 212	Kesiman Kertalangu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
213	Tonja	27	26	96	1	4	27	100	0	0	0	0	0	0	0	0	0	0
214	Penatih	12	8	67	0	0	8	67	0	0	0	0	0	0	1	8	3	25
215	Penatih Dangin Puri	8	4	50	0	0	4	50	0	0	0	0	0	0	1	13	3	38
200	DENPASAR TIMUR	382	364	95	9	2	373	97	0	0	0	0	0	0	3	1	6	2

Table D.1.2 (2) Kelurahan-wise Domestic Sanitation Service Level in Study Area – 1988

Code Number	Name of Kelurahan/Desa & Kecamatan	Total Sample	PRIVATE TOILET WITH TREATMENT		PRIVATE TOILET WITHOUT TREATMENT		PRIVATE TOILET TOTAL		NEIGHBOUR TOILET		COMMUNITY TOILET		PUBLIC TOILET (MCK)		OPEN SPACE		DRAIN/RIVER	
		No.	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
301	Sanur Kaja	28	28	100	0	0	28	100	0	0	0	0	0	0	0	0	0	0
302	Sanur	19	19	100	0	0	19	100	0	0	0	0	0	0	0	0	0	0
303	Sanur Kauh	26	22	85	0	0	22	85	0	0	0	0	0	0	1	4	3	12
304	Renon	18	18	100	0	0	18	100	0	0	0	0	0	0	0	0	0	0
305	Panjer	40	40	100	0	0	40	100	0	0	0	0	0	0	0	0	0	0
306	Sesetan	56	55	98	0	0	55	98	1	2	0	0	0	0	0	0	0	0
307	Sidakarya	39	39	100	0	0	39	100	0	0	0	0	0	0	0	0	0	0
308	Pedungan	20	19	95	1	5	20	100	0	0	0	0	0	0	0	0	0	0
309	Pemogan	13	11	85	0	0	11	85	0	0	0	0	0	0	2	15	0	0
• 310	Serangan	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
300	DENPASAR SELATAN	259	251	97	1	0	252	97	1	0	0	0	0	0	3	2	3	1
• 401	Dalung	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
• 402	Canggu	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
• 403	Kerobokan	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
404	Kuta	40	40	100	0	0	40	100	0	0	0	0	0	0	0	0	0	0
405	Tuban	48	43	90	0	0	43	90	1	2	0	0	0	0	4	8	0	0
406	Jimbaran	19	19	100	0	0	19	100	0	0	0	0	0	0	0	0	0	0
407	Benoa	51	41	80	1	2	42	82	0	0	0	0	0	0	9	18	0	0
400	KUTA	158	143	90	1	1	144	91	1	1	0	0	0	0	13	8	0	0
Total		1,129	1,065	94	21	2	1,086	96	2	0	0	0	0	0	23	2	18	2

Note * During the time of survey these three (3) Kelurahan/Desa were single one as Pemecutan
• Kelurahan/Desa not covered by the survey

Source : IUIDP Sampling Survey, 1988 — 1989

Table D.1.3 Existing Service Ratio of Commerce and Institution by Type of Sanitation Facility

Classification		Type of Sanitation Facility (%)			
		(i)	(ii)	(iii)	(iv)
Hotel	Large	0.0	57.1	28.6	14.3
	Ordinary	0.0	100.0	0.0	0.0
Restaurant	Large	0.0	100.0	0.0	0.0
	Ordinary	0.0	100.0	0.0	0.0
Shop	Large	0.0	100.0	0.0	0.0
	Ordinary	0.0	100.0	0.0	0.0
Factory	(1)	0.0	100.0	0.0	0.0
	(2)	0.0	100.0	0.0	0.0
	(3)	0.0	100.0	0.0	0.0
	(4)	0.0	100.0	0.0	0.0
	(5)	0.0	92.3	7.7	0.0
Office	Private	0.0	95.5	4.5	0.0
	Public	0.0	100.0	0.0	0.0

Meaning of code numbers

1. Type of sanitation facility
   - (i) No toilet facility
   - (ii) Toilet with leaching pit/septic tank treatment system
   - (iii) Toilet with septic tank and/or aerator treatment system
   - (iv) Toilet with sewerage

2. Classification of factories
   - (1) Food, beverage and tobacco manufacturing
   - (2) Manufacture of textile, wearing apparel and leather
   - (3) Manufacture of wood and wood products including furniture and fixtures
   - (4) Manufacture of paper, paper products, printing and publishing
   - (5) Manufacture of non-metallic mineral products

Note : No. of samples for each of the five classification were 30

Source : JICA

Table D.2.1 Survey Results of Flood Area

Flood Area No.	Location	Area (ha)	Depth of Flood (m)	Remarks
1.	Jl. Kenyiri/Jl. G. Subroto	1.4	0.1 - 0.2	Shortage of drainage capacity
2.	Jl. Suli	1.0	0.2	Interconnection of irrigation channel and surface drain due to broken gate
3.	Jl. Kenyiri /Jl. WR. Supratman	0.3	0.1 - 0.2	Garbage accumulation at culvert
4.	Jl. Plawa /Jl. Hayam Wuruk	1.9	0.1	Decreased drainage capacity due to silted drain
5.	Jl. Melati /Jl. Hayam Wuruk	2.3	0.1 - 0.2	Garbage accumulation inside culvert caused by interference of crossing pipelines through culvert
6.	Jl. Kepundung /Jl. Hayam Wuruk	0.4	0.1	Garbage accumulation in drain
7.	Jl. Letda Reta	0.6	0.1 - 0.2	Excessive irrigation water flow during high river stage due to improper operation intake gate during high river stage
8.	Jl. Raya Puputan	0.6	0.1	Garbage accumulation at gate
9.	Jl. Raya Puputan	0.6	0.1	Garbage accumulation in drain
10.	Jl. D.I. Panjaitan /Jl. Raya Puputan	4.1	0.1 - 0.2	Decreased drainage capacity of irrigation and drainage channel due to irrigation intake weir during rain
11.	Jl. Prof. Yamin /Jl. Raya Puputan	2.1	0.1	Garbage accumulation at culvert
12.	Jl. TK. Banyusari	0.3	0.1	Garbage accumulation at drain
13.	Jl. Hang Tuah /Jl. Bypass Sanur	0.3	0.1	Decreased drainage capacity due to silted drain

Source: Urban Drainage Project & JICA, 1992

Table D.3.1 Operation Results of STP in Nusa Dua

Sampling Date	October 11 '89					October 15 '89					March 13 '90		August 10 '90	
Sampling Point	Pond 1A	Pond 1B	Pond 3	Pond 4	Pump Station	Pond 1A	Pond 1B	Pond 2	Pond 3	Pond 4	Pond 1	Pond 4	Pond 1	Pond 4
BOD (mg/l)	23.3	17.6	2.3	8.8	54.8	45.6	40.0	5.6	4.0	16.0	41.2	9.4	0.0*	9.4
COD (mg/l)	43.1	92.0	26.3	45.1	45.1	51.7	58.0	66.0	33.0	39.0	64.4	27.1	26.5	40.4

Note : * seems to be a mistake.

Table D.4.1 Population and Wastewater in Kel. Kuta

Year	1985	1990	1995	2000	2005
Population	13,408	15,076	16,541	17,904	19,379
- PDAM	6,569	6,633	9,098	10,384	11,627
- Public tap	100	1,357	3,804	3,581	3,876
- Others	6,739	7,086	3,639	3,939	3,876
Water (m3/d)	983	1,249	1,669	1,990	2,325
- PDAM	778	995	1,446	1,765	2,093
- Public tap	3	41	114	107	116
- Others	202	213	109	118	116
Domestic Wastewater (m3/d)	953	999	1,343	1,593	1,860
Non Domestic Wastewater (m3/d)	191	200	269	319	372
Total Wastewater (m3/d)	1,144	1,199	1,612	1,912	2,232

Source : Final Report " Rencana Teknis Prasarana Dan Sarana Air Limbah Domestic di Kota Denpasar " (5/1990)

Note : Area of Kel. Kuta = 1,293 ha

Table D.4.2 Water Use and Wastewater Disposal in Service Area

(Unit : l/day)

Bloc	Household		Star Hotel		Hotel TB, Cottage		Home Stay & Inn		Restaurant		Total (l/day)		Daily Average	Daily Maximum
	Water	Wastewater	Water	Wastewater	Water	Wastewater	Water	Wastewater	Water	Wastewater	Water	Wastewater	Wastewater (l/sec.)	Wastewater 2 x average (l/sec.)
I	159,750	127,800	144,000	115,200	112,000	89,600	342,000	273,600	135,000	108,000	892,750	714,200	8.2	16.4
II	46,050	36,840	72,000	57,600	8,000	6,400	-	-	48,000	38,400	174,050	139,240	1.6	3.2
III	23,850	19,080	72,000	57,600	32,000	25,600	102,000	81,600	42,000	33,600	271,850	217,480	2.5	5.0
IV	18,300	14,640	72,000	57,600	48,000	38,400	96,000	76,800	30,000	24,000	264,300	211,440	2.4	4.8
V	14,250	11,400	144,000	115,200	92,000	73,600	78,000	62,400	63,000	50,400	391,250	313,000	3.6	7.2
VI	85,200	68,160	72,000	57,000	4,000	3,200	54,000	43,200	48,000	38,400	263,200	209,960	2.4	4.8
VII	43,800	35,040	216,000	172,800	40,000	32,000	102,000	81,600	9,000	7,200	410,800	328,640	3.8	7.6
Total	391,200	312,960	792,000	633,000	336,000	268,800	774,000	619,200	375,000	300,000	2,668,200	2,133,960	24.5	4.9

Source : Final Report "Rencana Teknis Prasarana dan Sarana Air Limbah Domestik di Kota Denpasar" (5/1990)

Table D.4.3 Diameter Calculation of Pipes

No. Pipe	No. Knot	Pipe Length (m)	Average Discharge (l/sec.)	Infiltration Discharge (l/sec.)	Maximum Discharge (l/sec.)	Pipe Diameter (m/m)	Pipe Slope	Flow Velocity (m/sec.)	Elevation Different (m)
1	1 - 2	808	1,9	1,19	4,99	150	0,0015	0,35	1,212
2	2 - 3	921	3,8	2,49	10,09	200	0,0015	0,42	1,382
3	4 - 3	706	2,4	1,19	5,99	150	0,0030	0,35	2,118
4	3 - 5	445	6,2	3,68	16,08	100	–	2	–
5	5 - 6	442	6,2	4,12	16,52	250	0,0015	0,48	0,663
6	6 - 7	564	6,2	4,68	17,08	250	0,0015	0,49	0,846
7	8 - 7	638	4,1	1,46	9,66	200	0,002	0,42	1,276
8	7 - 9	573	12,2	7,09	31,49	300	0,0015	0,56	0,860
9	10 - 11	486	4,1	1,31	9,51	200	0,0015	0,42	0,729
10	11 - 12	464	8,2	2,56	18,99	250	0,0015	0,49	0,069
11	12 - 13	337	9,8	3,25	22,85	300	0,0015	0,52	0,506
12	13 - 9	498	12,3	4,25	28,85	300	0,0015	0,55	0,747
13	9 - 14	542	24,5	11,88	60,88	400	0,0015	0,66	0,813
14	14 - 15	629	24,5	12,51	61,51	400	0,0015	0,66	0,944
15	15 - TPA	3,370	24,5	12,75	61,75	200	–	1,95	–
Total		11,423							

Remark:- Determined concrete pipe n = 0,014 (Criteria 0,012 - 0,015)

- Maximum discharge, = 2 x average discharge + pipe infiltration

  Pipe infiltration includes and is calculated :

  - 20% of average discharge in house connection boxes
  - 1 l per 1000 m length of pipes

- The pipe slope is determined 1,5% (permill) in average, except some pipe.
- The pipes need to be periodically cleaned-up.

Table D.4.4 Depth Calculation of Burried Pipes

No Pipe	No Knot	Pipe Start Depth (m)	Ground Elevation		Basic Elevation		Pipe Finish Depth (m)	Equipment
			Start (+m)	Finish (+m)	Start (+m)	Finish (+m)		
1	1 - 2	0.800	3.380	2.918	2.580	1.368	1.550	
2	2 - 3	1.550	2.918	2.952	1.368	0.013	2.966	Pump
3	4 - 3	0.900	3.945	2.952	3.045	0.927	2.025	Drop Manhole
4	3 - 5	1.000	2.952	3.360	1.952	2.360	1.000	Flow with pressure
5	5 - 6	1.000	3.360	3.283	2.360	1.697	1.586	
6	6 - 7	1.586	3.283	3.319	1.697	0.851	2.468	
7	8 - 7	1.100	4.218	3.319	3.118	1.842	1.477	Drop Manhole
8	7 - 9	2.522	3.319	4.098	0.797	0.062	4.161	Pump
9	10 - 11	0.800	4.074	5.303	3.274	2.545	2.758	
10	11 - 12	2.758	5.303	5.188	2.545	1.849	3.339	
11	12 - 13	3.339	5.188	5.047	1.849	1.343	3.704	
12	13 - 9	3.704	5.047	4.098	1.343	0.596	3.502	Drop Manhole
13	9 - 14	1.200	4.098	5.035	2.898	2.085	2.950	
14	14 - 15	2.950	5.035	5.000	2.085	1.142	3.859	Pump
15	15 - STP	1.000	5.000	2.850	4.000			Flow with pressure

Pipe Requirements

Kinds	Diameter (m)	Length (m)
Concrete	150	1,514
	200	2,045
	250	1,470
	300	1,408
	400	1,171
PVC	100	445
	200	3,370
Total		11,423

Table D.4.5 Estimated Cost of Kuta Sewerage Project

No.	Work	Unit	Volume	Unit Price x Rp. 1,000	Cost x Rp. 1,000
I.	Material and Construction				
1	Land Acquisition	m2	17,500	Government	
2	Pipe				
	- dia. 200 concrete	m	2,408	28	67,424
	- dia. 250	m	1,618	36	58,248
	- dia. 300	m	1,845	47	86,715
	- dia. 350	m	442	54	23,868
	- dia. 150 PVC	m	2,995	25	74,875
	- dia. 200 PVC pressure pipe	m	3,900	61	237,900
3	Connection				
	- House	Unit	617	300	185,100
	- Commercial	Unit	224	500	112,000
4	Pipe Laying				
	Concrete Pipe :				
	- dia. 200	m	2,048	66	135,168
	- dia. 250	m	1,618	84	135,912
	- dia. 300	m	1,845	96	177,120
	- dia. 350	m	442	108	47,736
	- dia. 150 PVC	m	2,995	49	146,755
	- dia. 200 PVC	m	3,900	60	234,000
5	Manhole	Unit	80	600	48,000
6	House & Pump Unit				
	- Q = 15 l/sec, H = 12 m	Unit	3	12,500	37,500
	- Q = 25 l/sec, H = 30 m	Unit	3	15,000	45,000
7	Treatment Plant :				
	- Grit Chamber & Screen	Unit	1	25,000	25,000
	- Aerated Basin	Unit	1	125,000	125,000
	- Facultative Basin	Unit	2	100,000	200,000
	- Masturation Basin	Unit	2	110,000	220,000
	- Aerator, 5,5 KW	Unit	15	35,000	525,000
	SUB-TOTAL I				2,948,321
II.	Others				
1	Detailed Eng. & Financial Analysis				200,000
	Institutional Development				75,000
	Construction Supervision				160,000
	Training				95,000
	Operation & Maintenance 5 Years				600,000
	Maintenance Equipment ls.				300,000
	Environmental Assesment				150,000
	SUB-TOTAL II				1,580,000
	SUB-TOTAL I + II				4,528,321
	Physical Contingencies 10 x Sub Total I				294,832
	Price Contingencies 10 x Sub Total II				158,000
	Total Estimated Cost				4,981,153

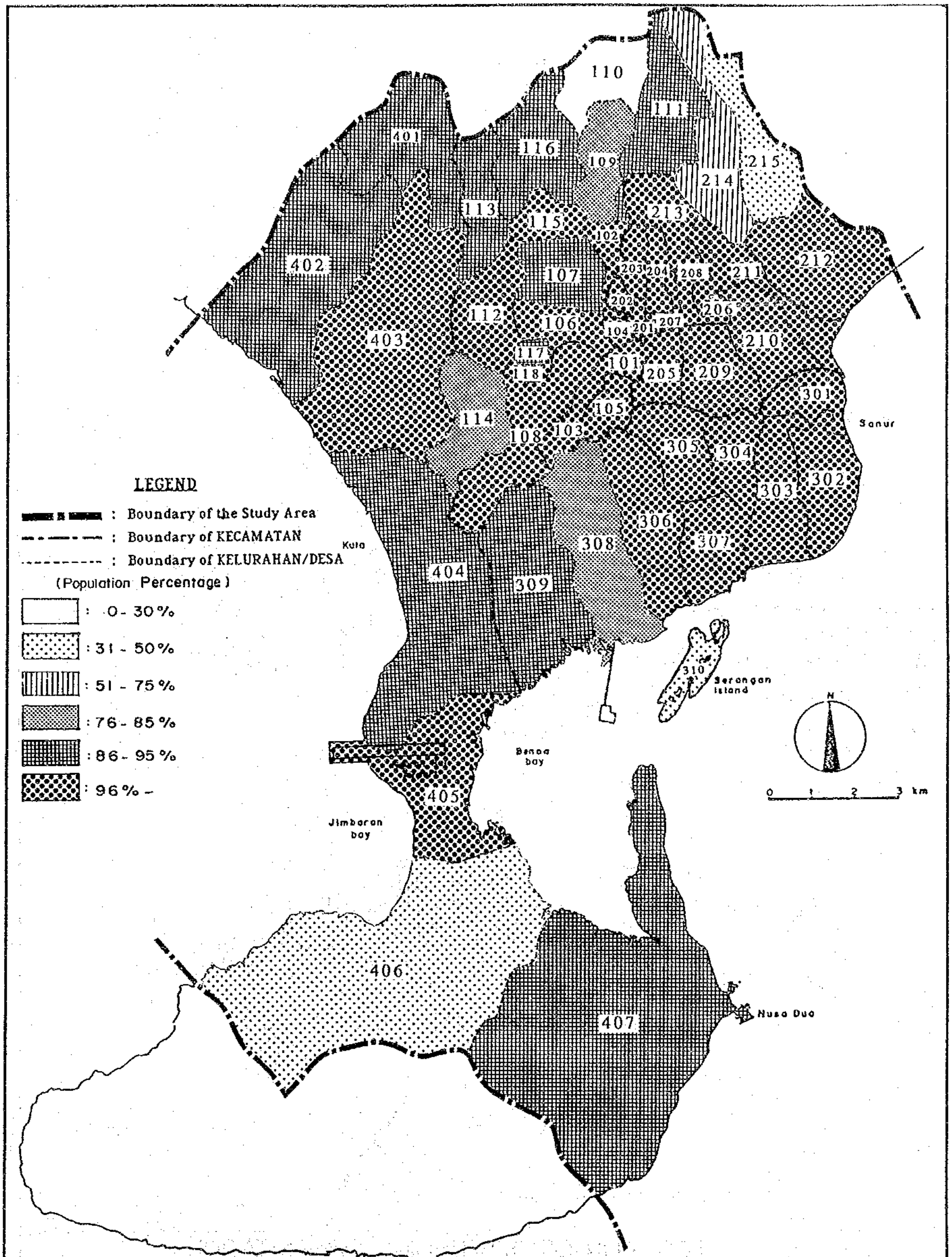

FIG. D.1.1 RATIO OF POPULATION HAVING TOILET WITH TREATMENT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

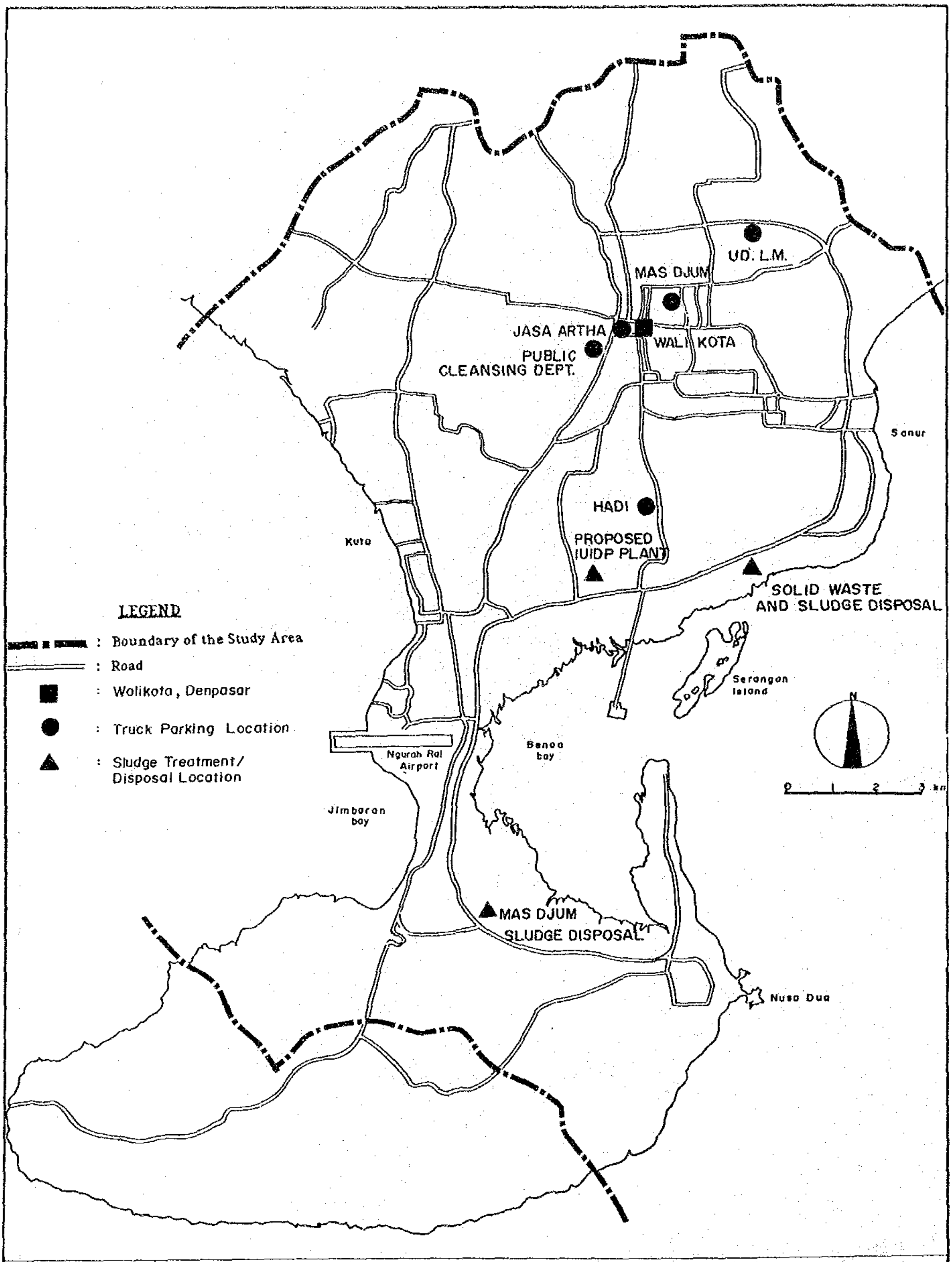

FIG. D.1.2	LOCATION OF DESLUDGING ORGANIZATION AND SLUDGE DISPOSAL

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

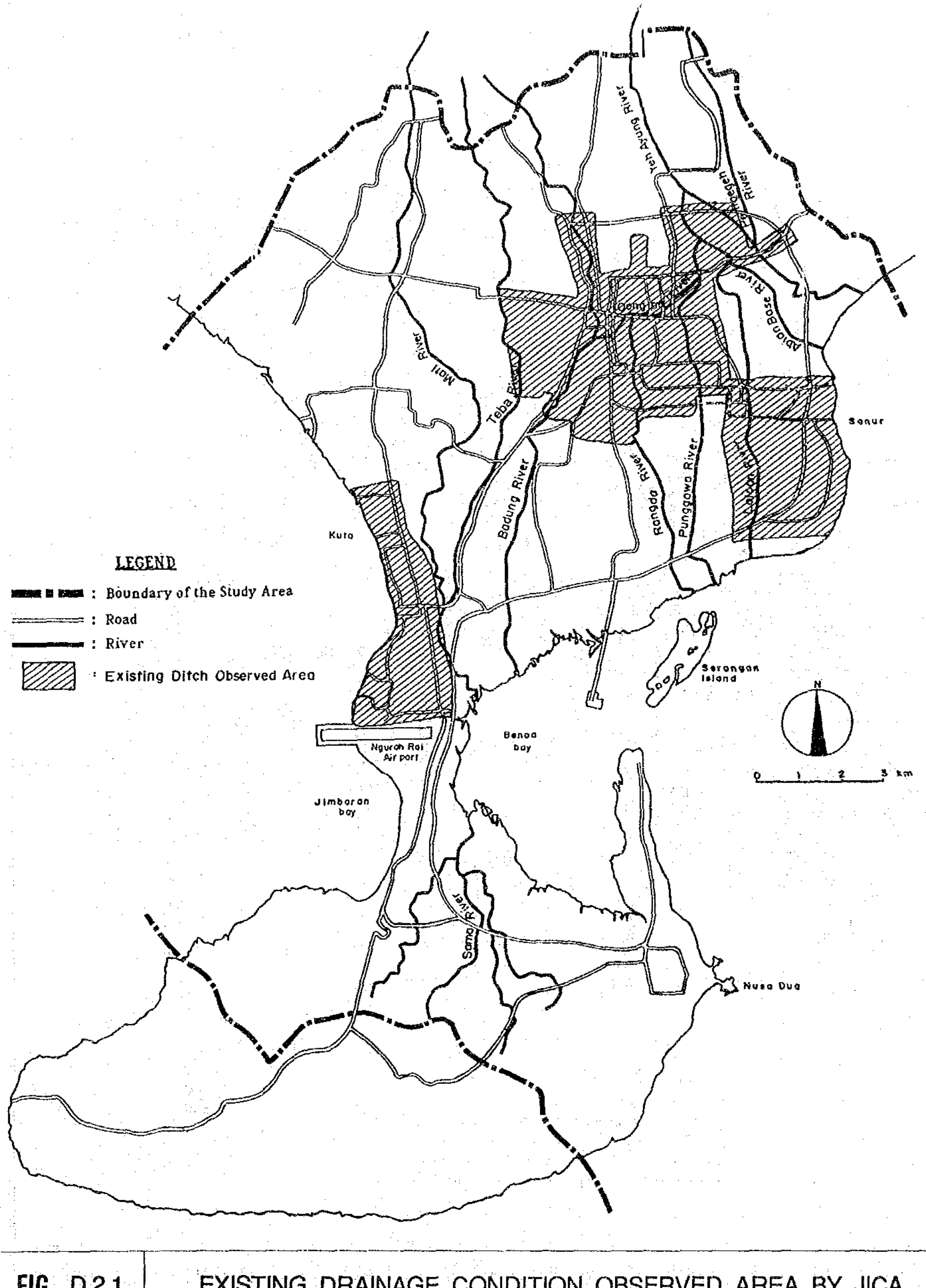

FIG. D.2.1 EXISTING DRAINAGE CONDITION OBSERVED AREA BY JICA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

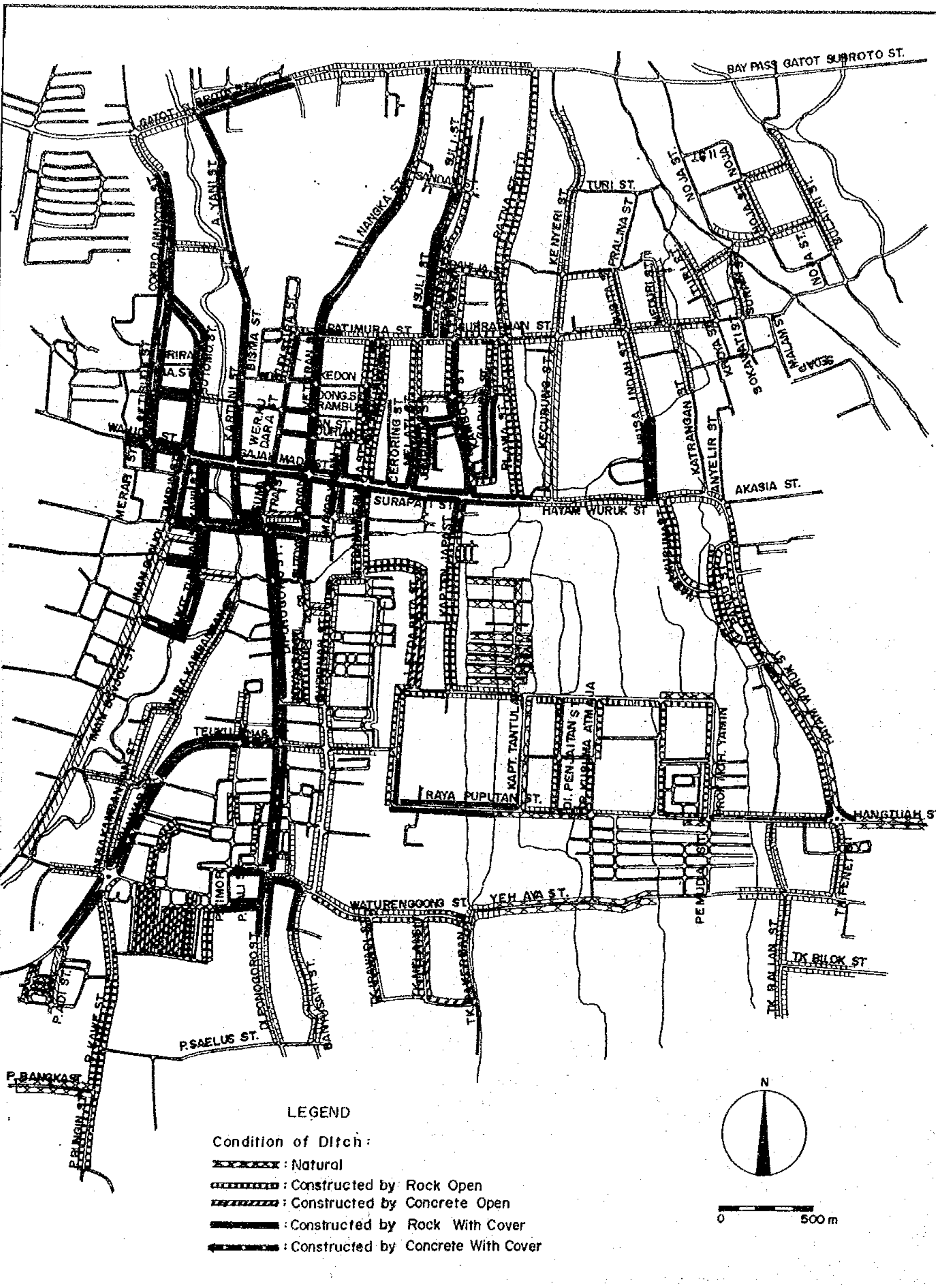

FIG.D.2.2(1) CLASSIFICATION OF EXISTING ROAD SIDE DITCH (DENPASAR)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

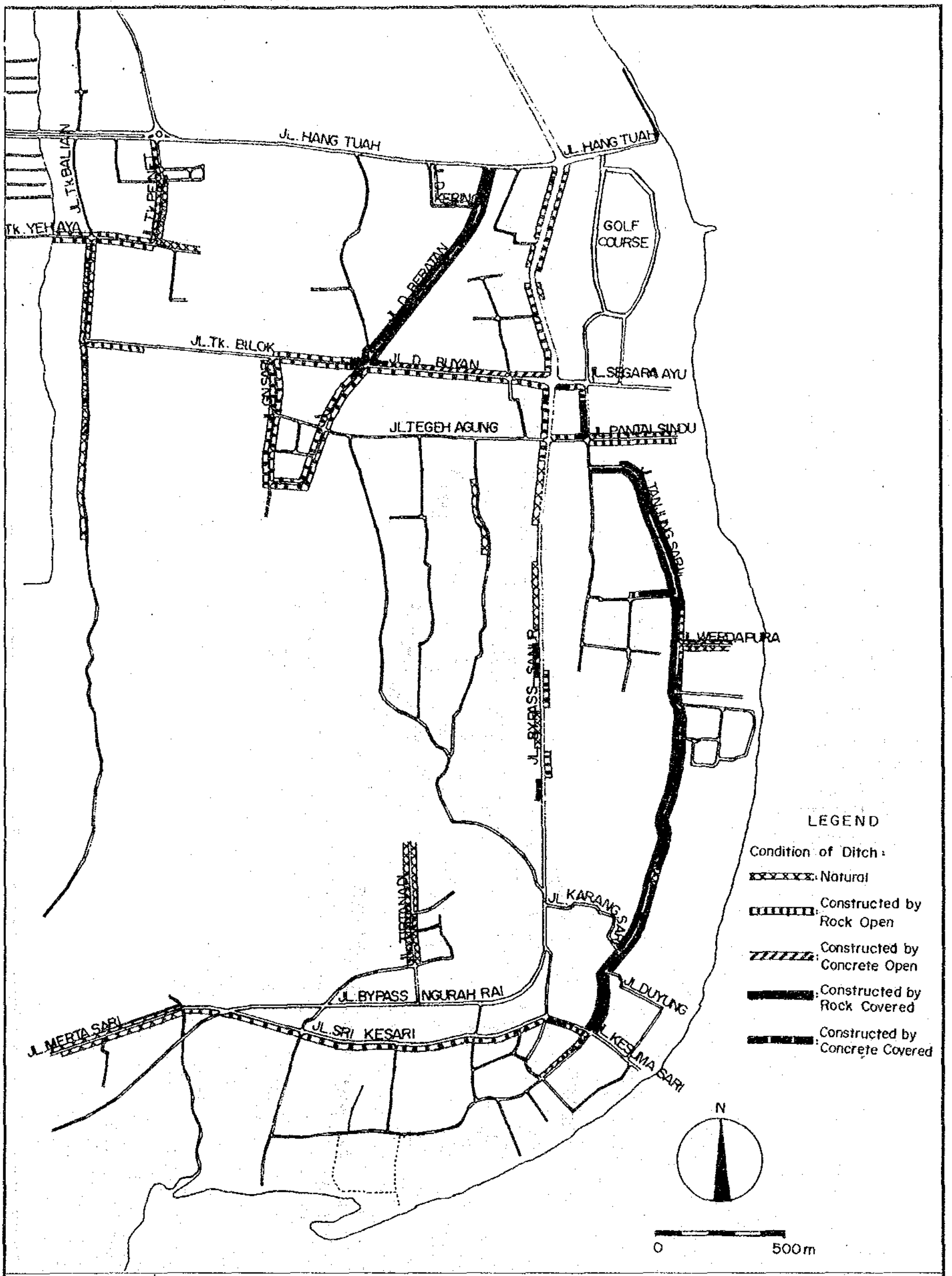

FIG. D.2.2(2) CLASSIFICATION OF EXISTING ROAD SIDE DITCH (SANUR)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

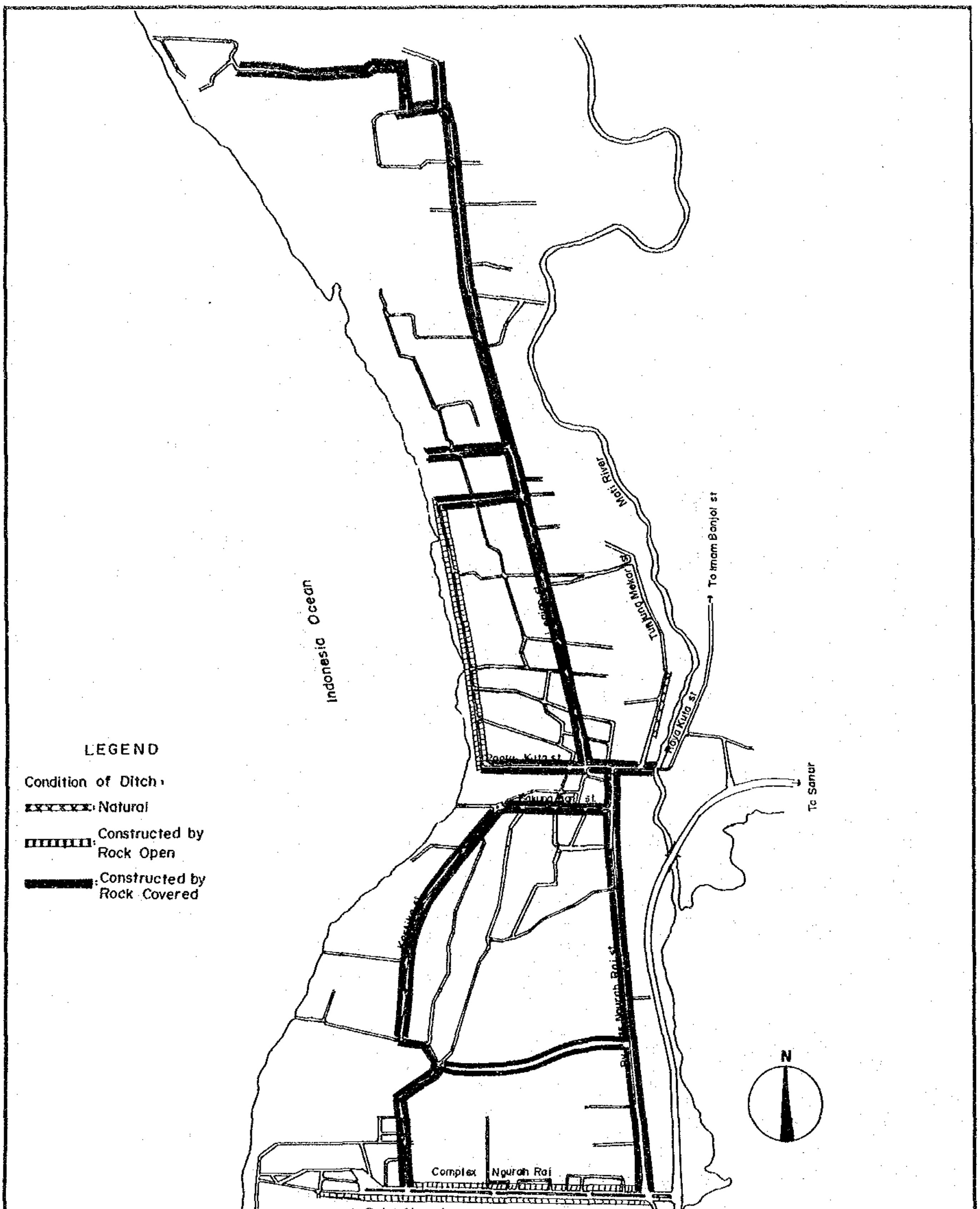

FIG.D.2.2(3) CLASSIFICATION OF EXISTING ROAD SIDE DITCH (KUTA)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

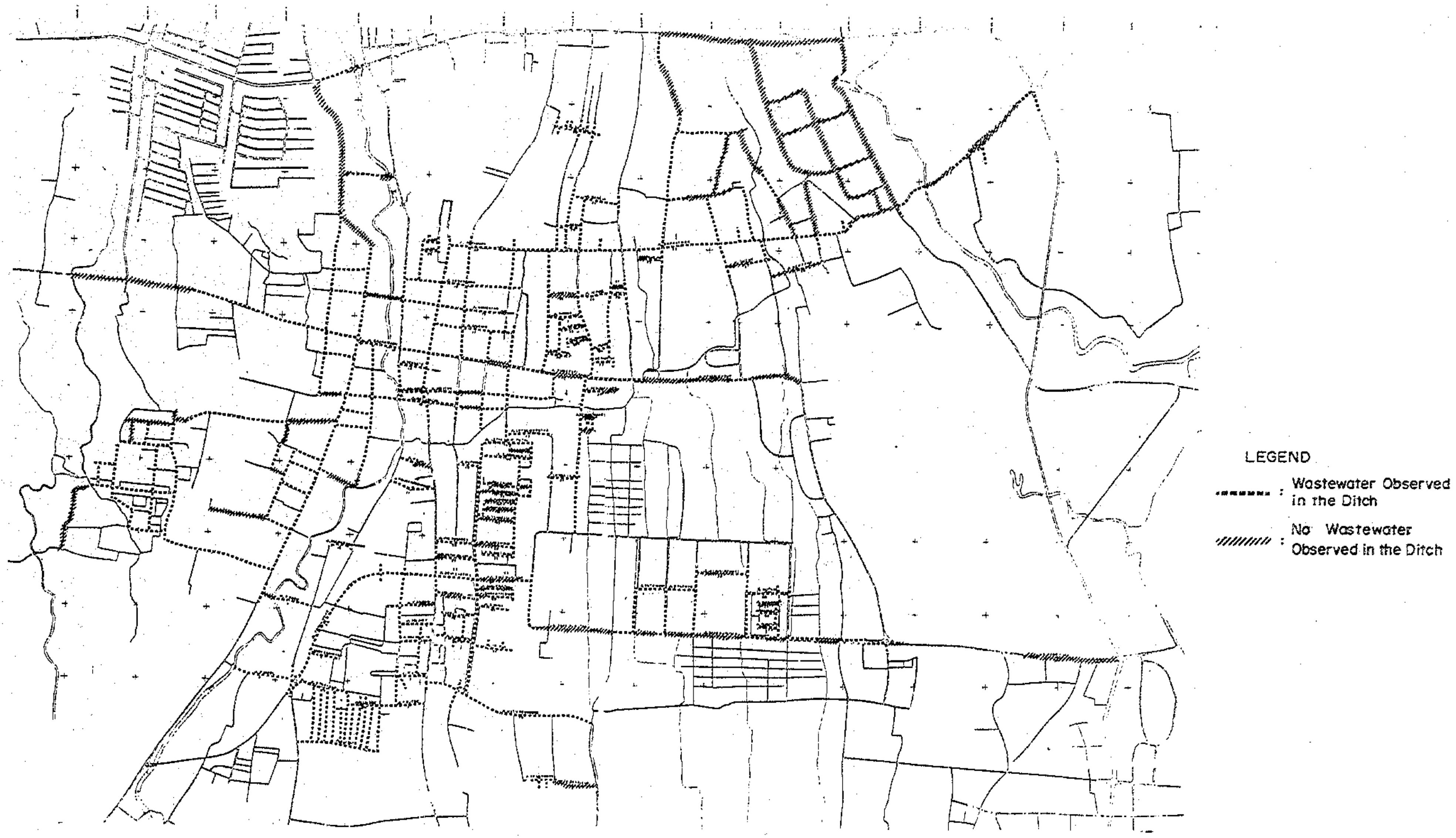

FIG. D.2.3(1) WASTEWATER OBSERVED DITCH (1)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

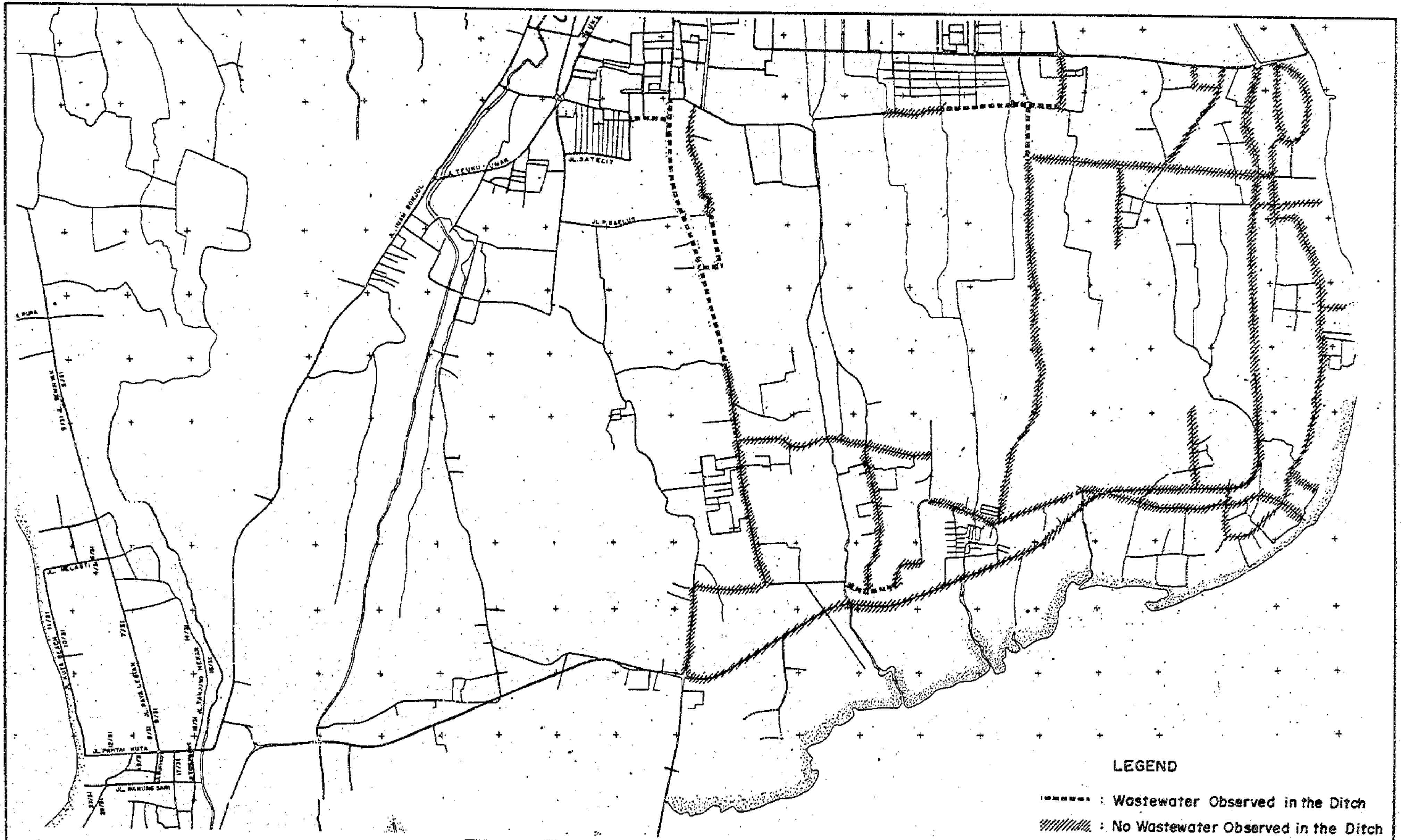

FIG. D.2.3(2)	WASTEWATER OBSERVED DITCH (2)
THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR	

JICA A.D 1993

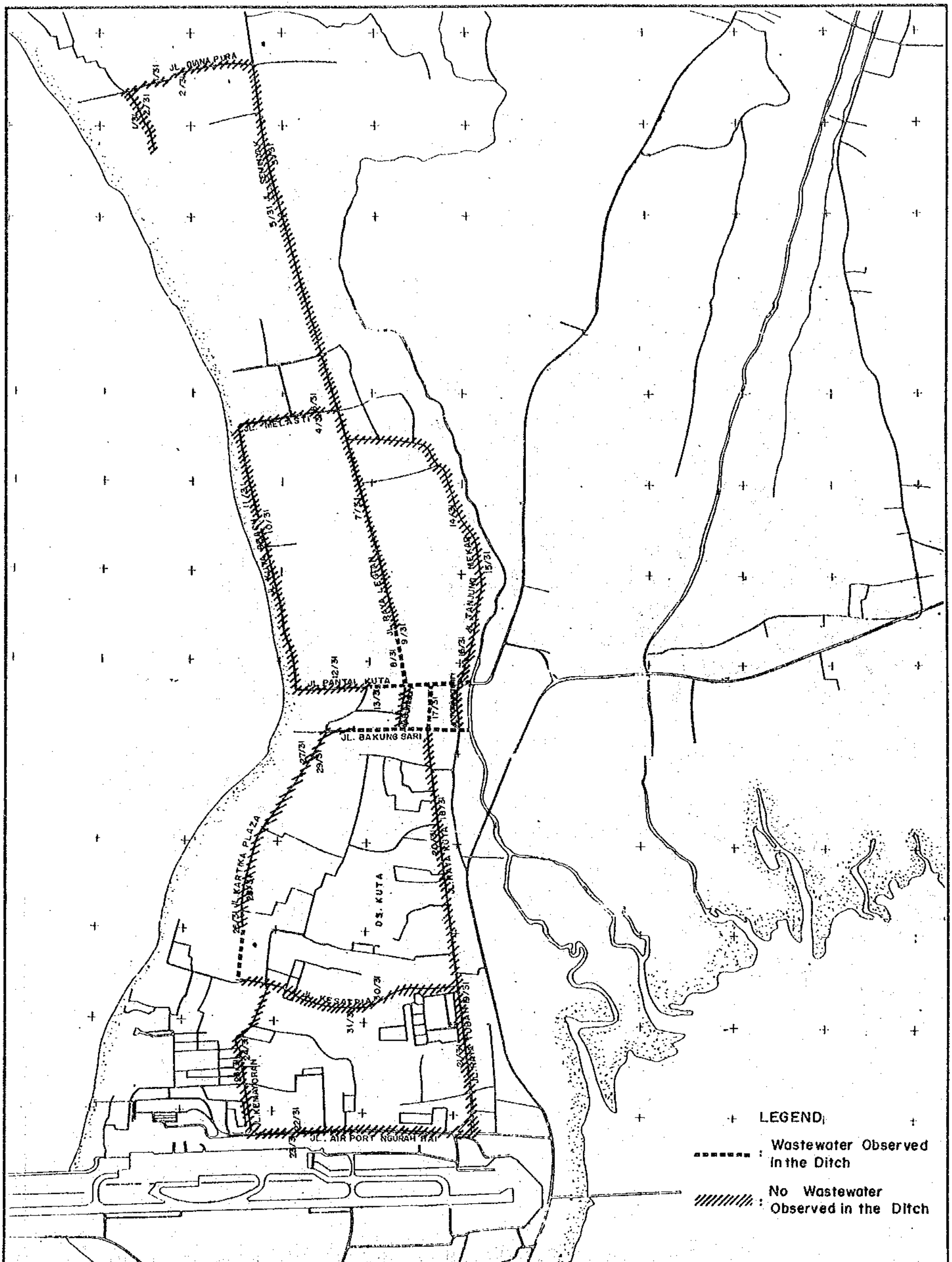

FIG. D.2.3(3) WASTEWATER OBSERVED DITCH (3)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

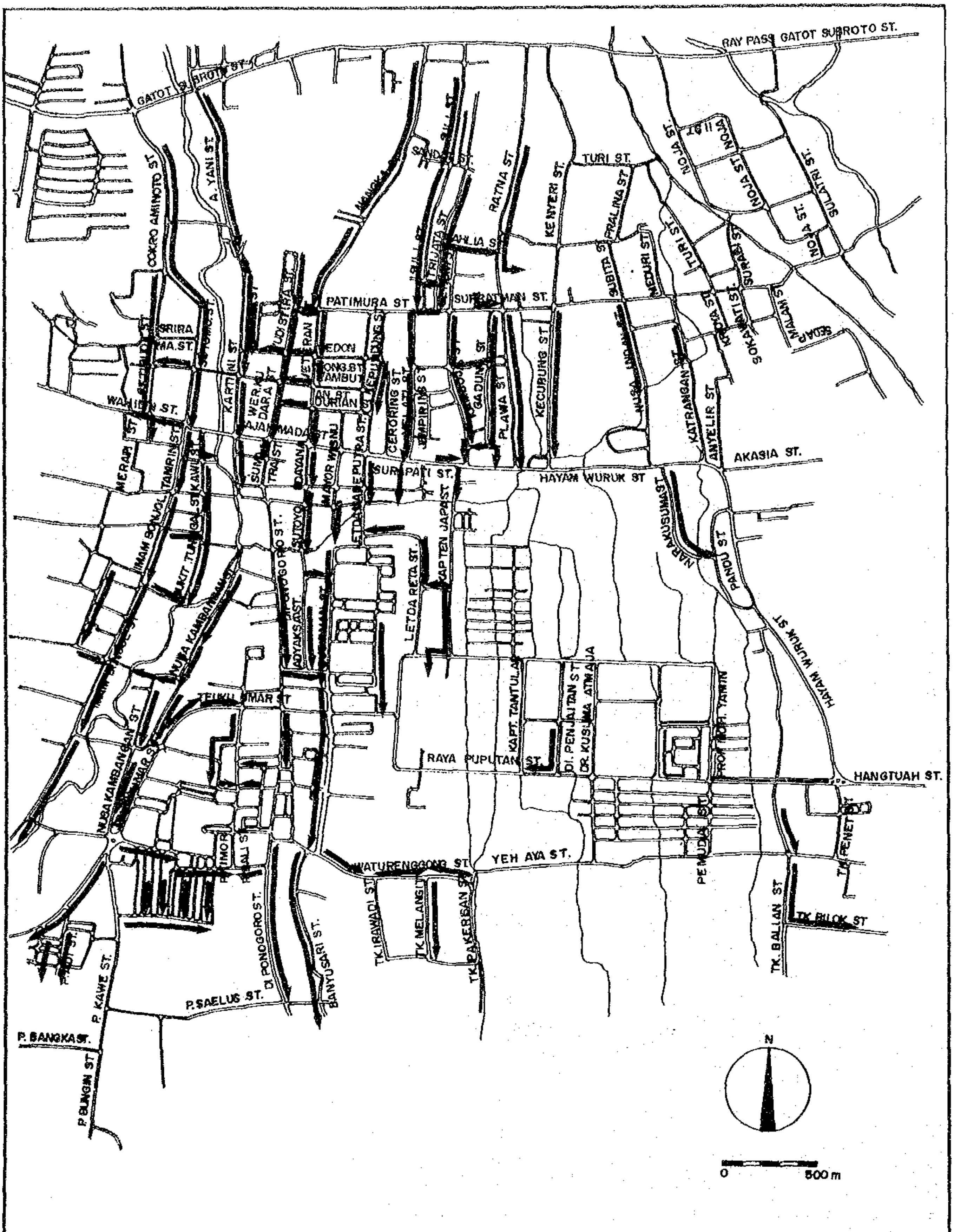

FIG.D.2.4(1) OBSERVED WASTEWATER FLOW DIRECTION IN DITCHES (DENPASAR)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

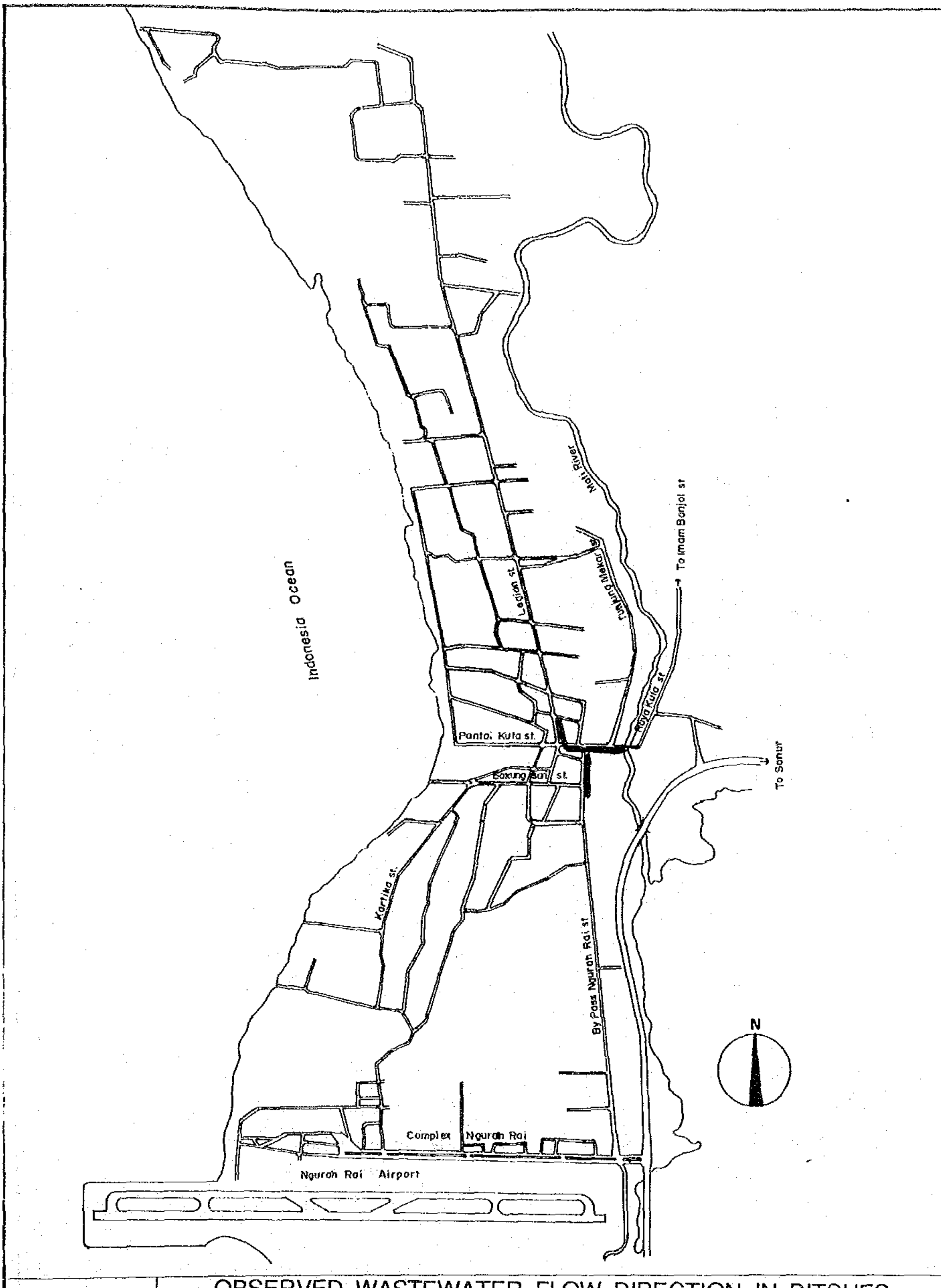

FIG. D.2.4(2) OBSERVED WASTEWATER FLOW DIRECTION IN DITCHES (KUTA)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

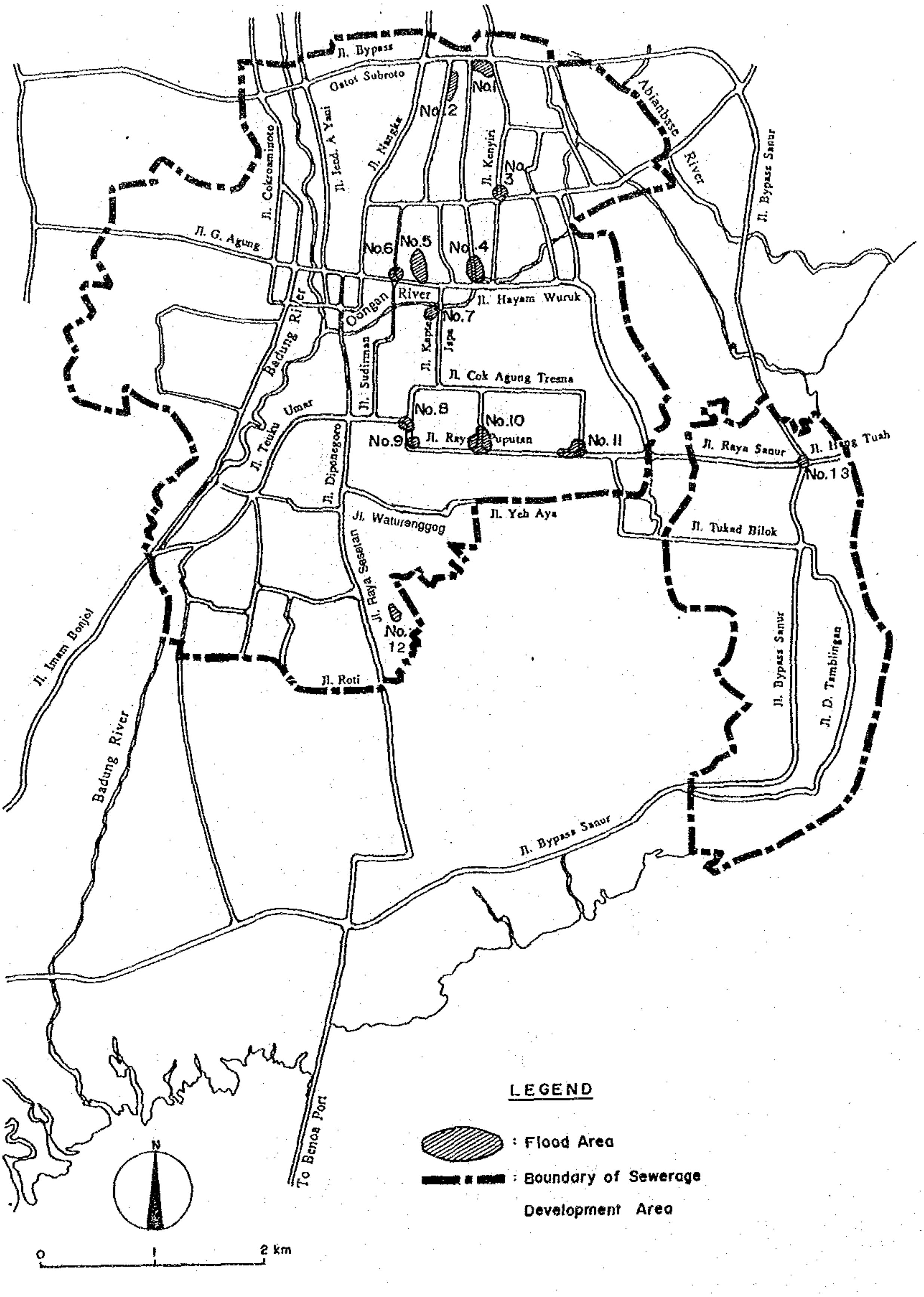

FIG. D.2.5 DISTRIBUTION OF FLOOD AREA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

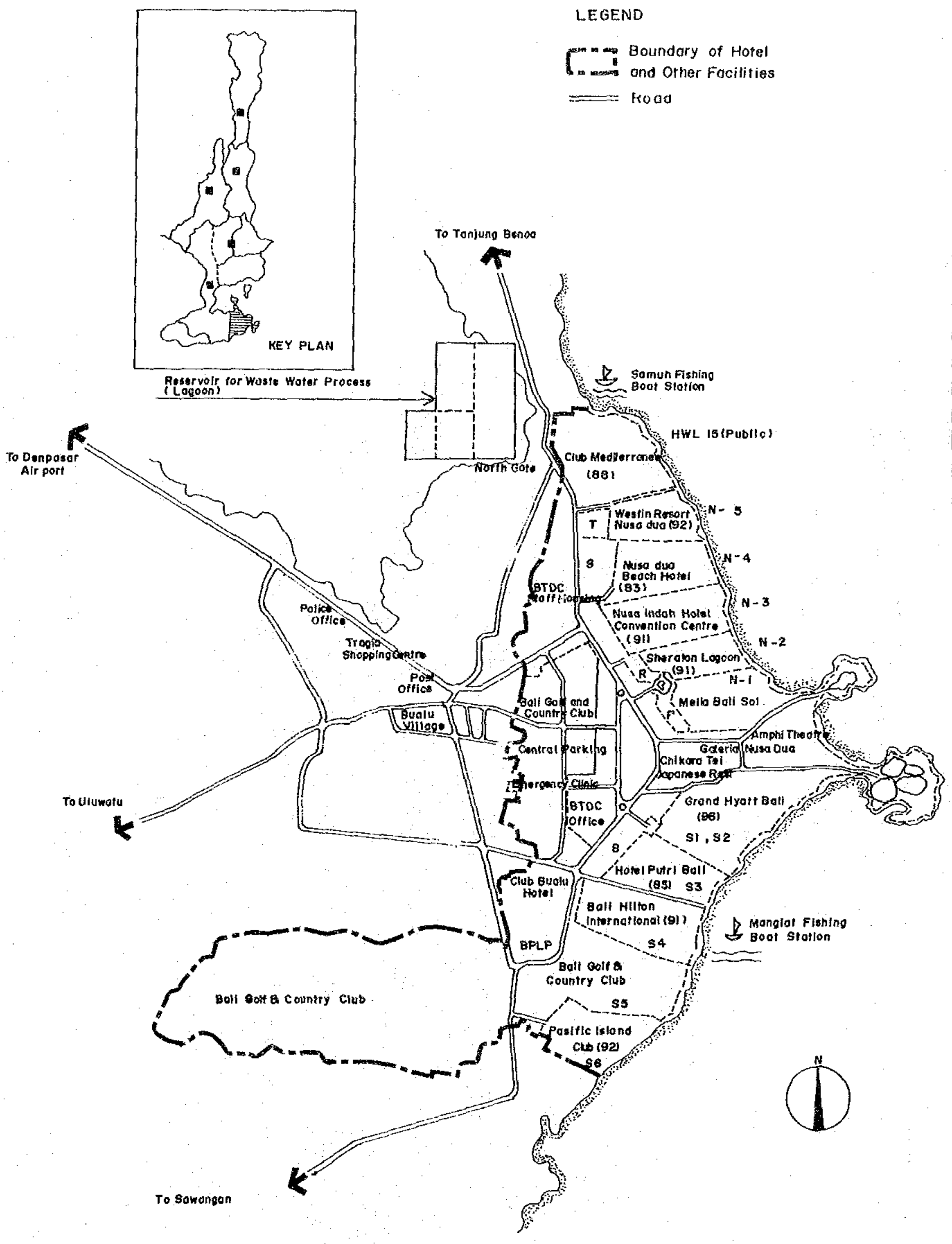

FIG. D.3.1 NUSA DUA TOURIST RESORT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

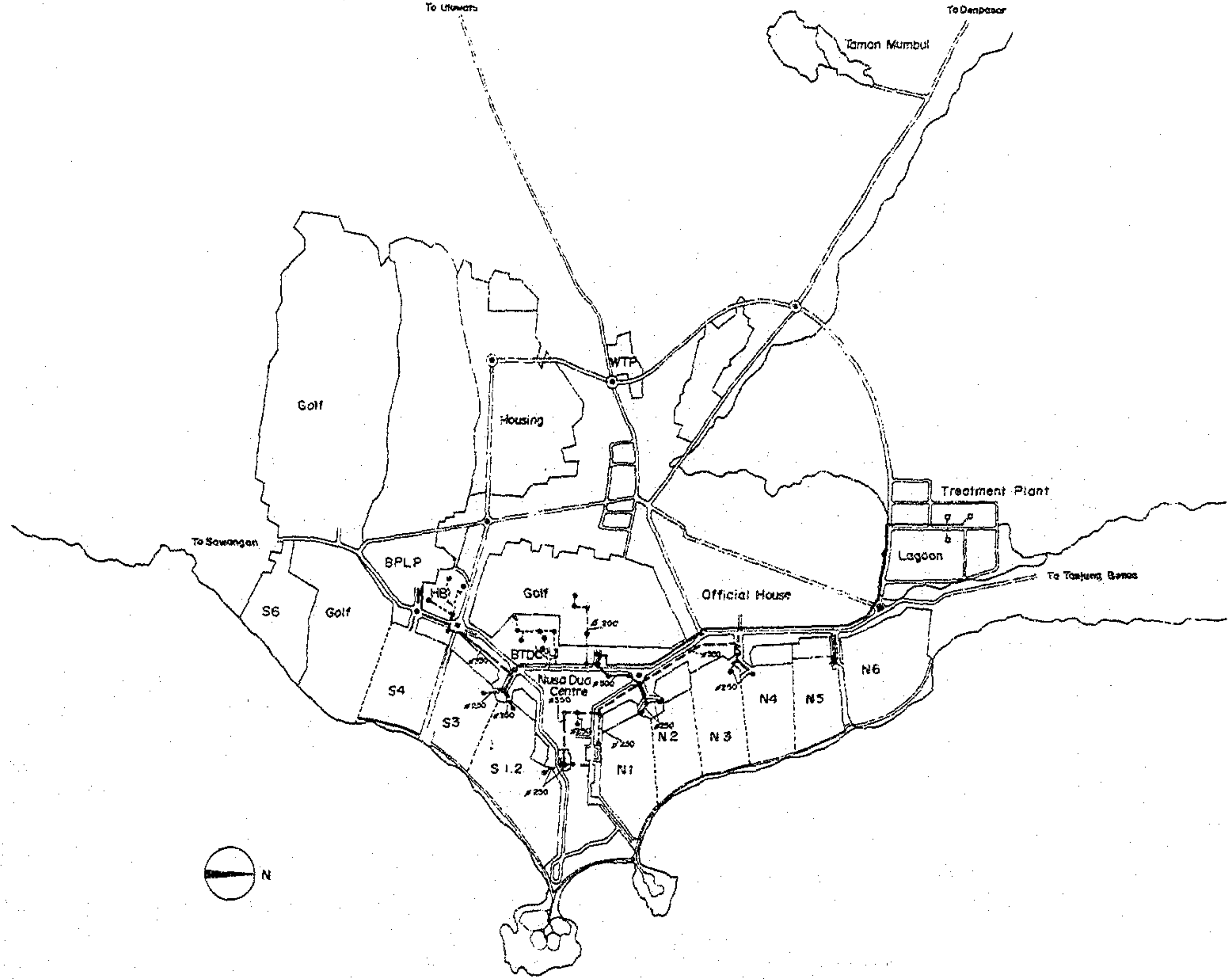

FIG. D.3.2	SEWERAGE SYSTEM OF BTDC IN NUSA DUA
THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR	

JICA A.D 1993

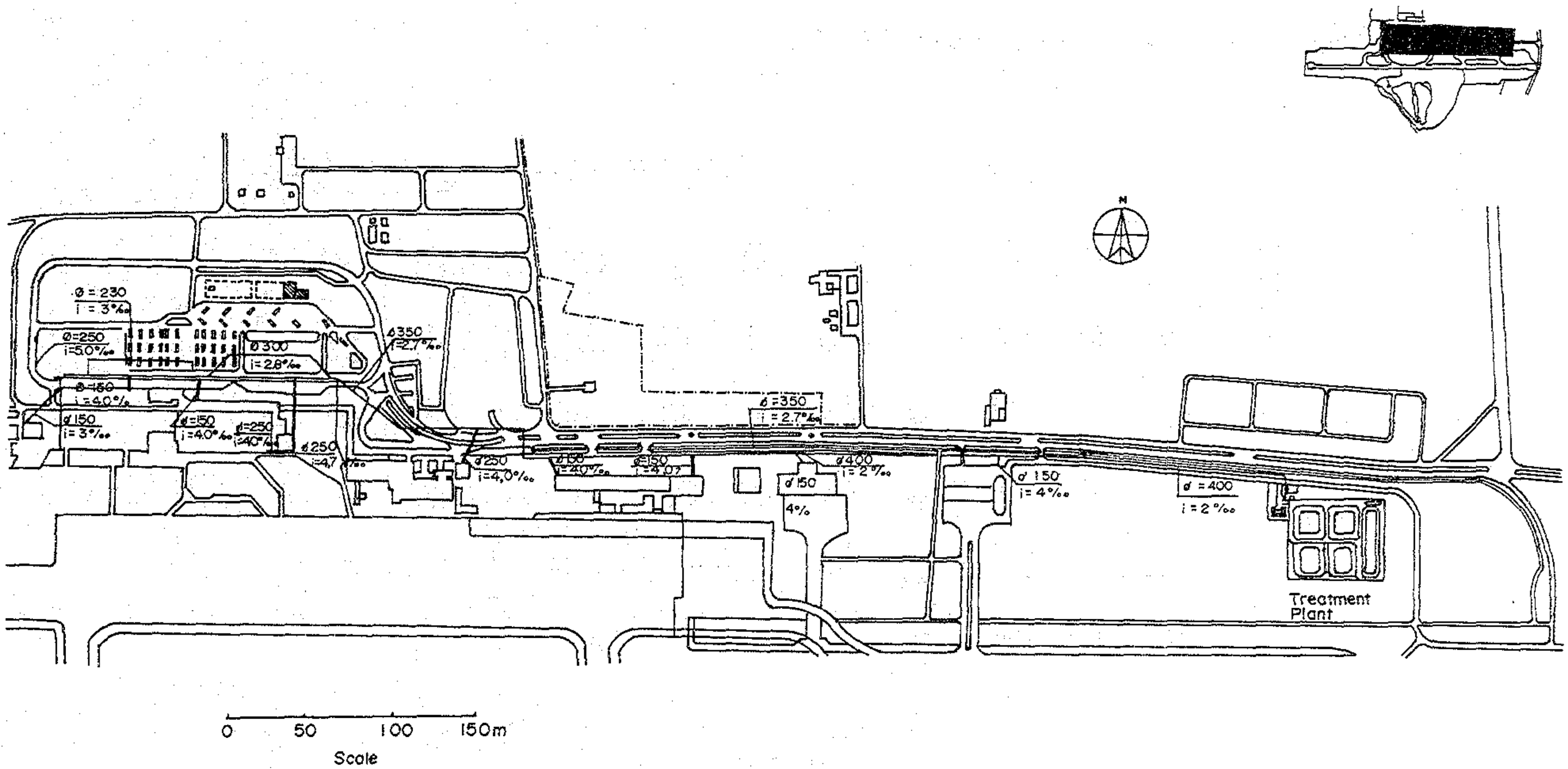

FIG. D.3.3	BALI AIRPORT SEWERAGE SYSTEM
THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR	

JICA A.D 1993

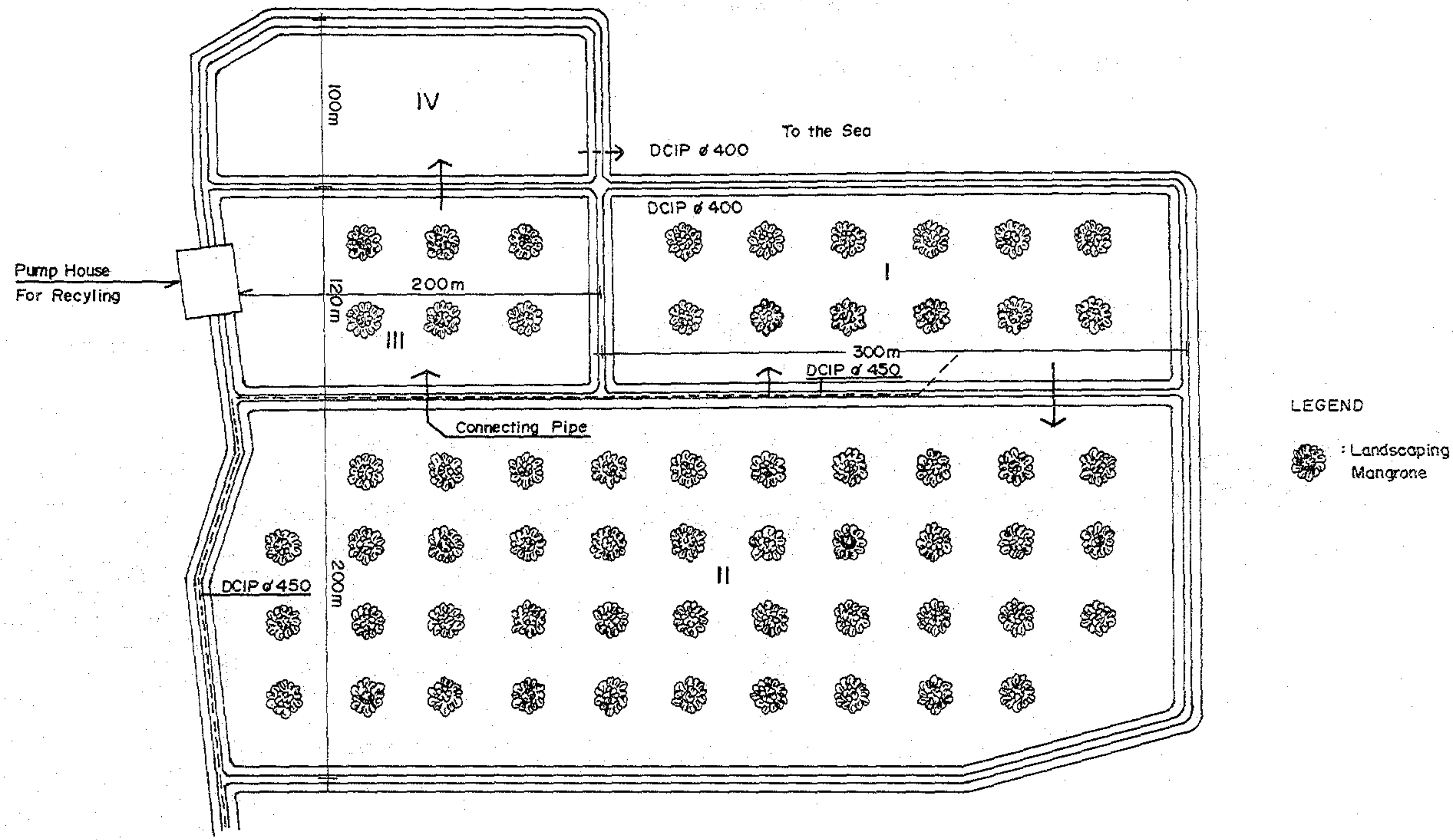

FIG. D.3.4	BTDC SEWAGE TREATMENT PLANT (LAGOON)
THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR	

JICA A.D 1993

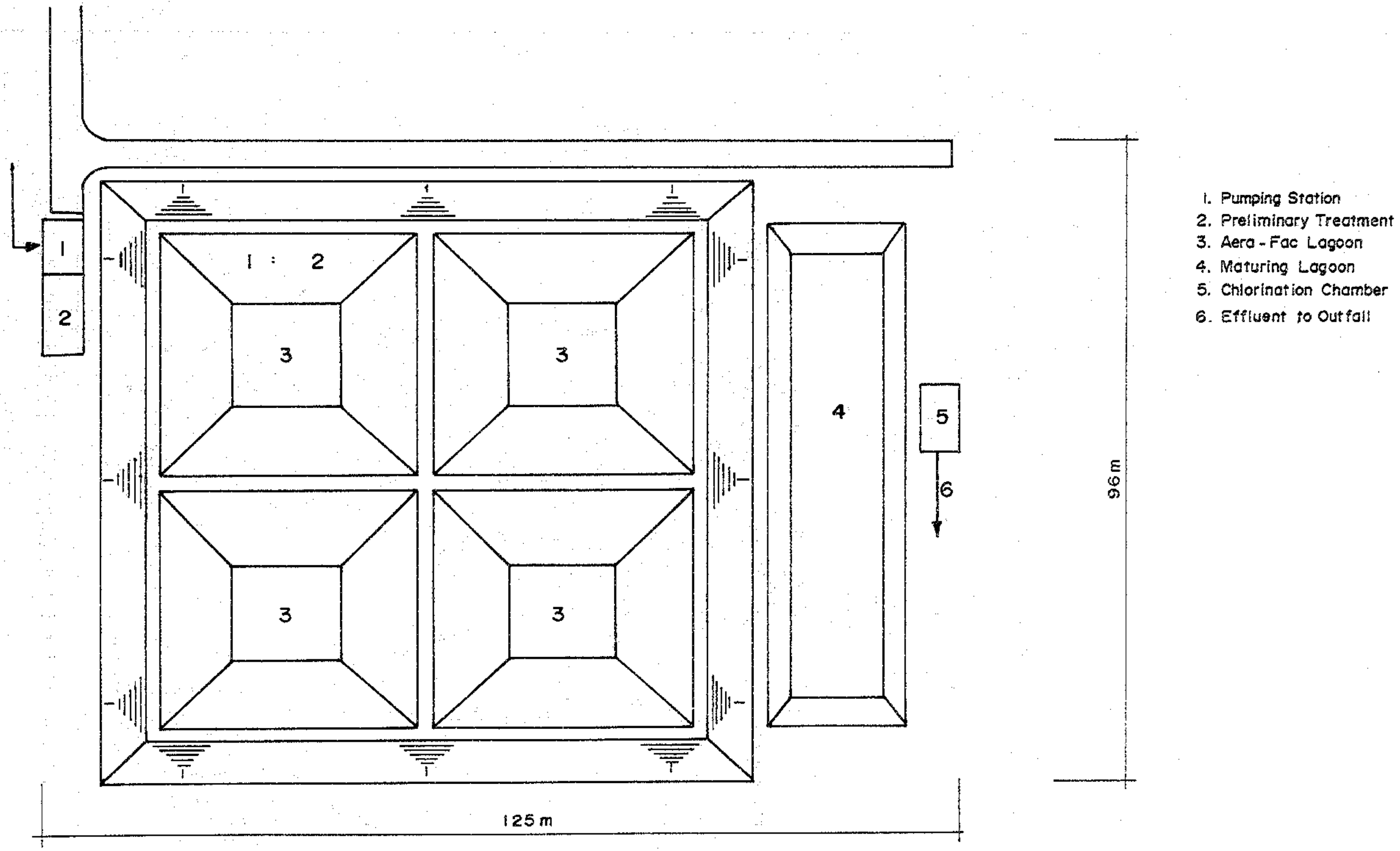

FIG. D.3.5 FACULTATIVE AERATED LAGOON (BALI AIRPORT)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

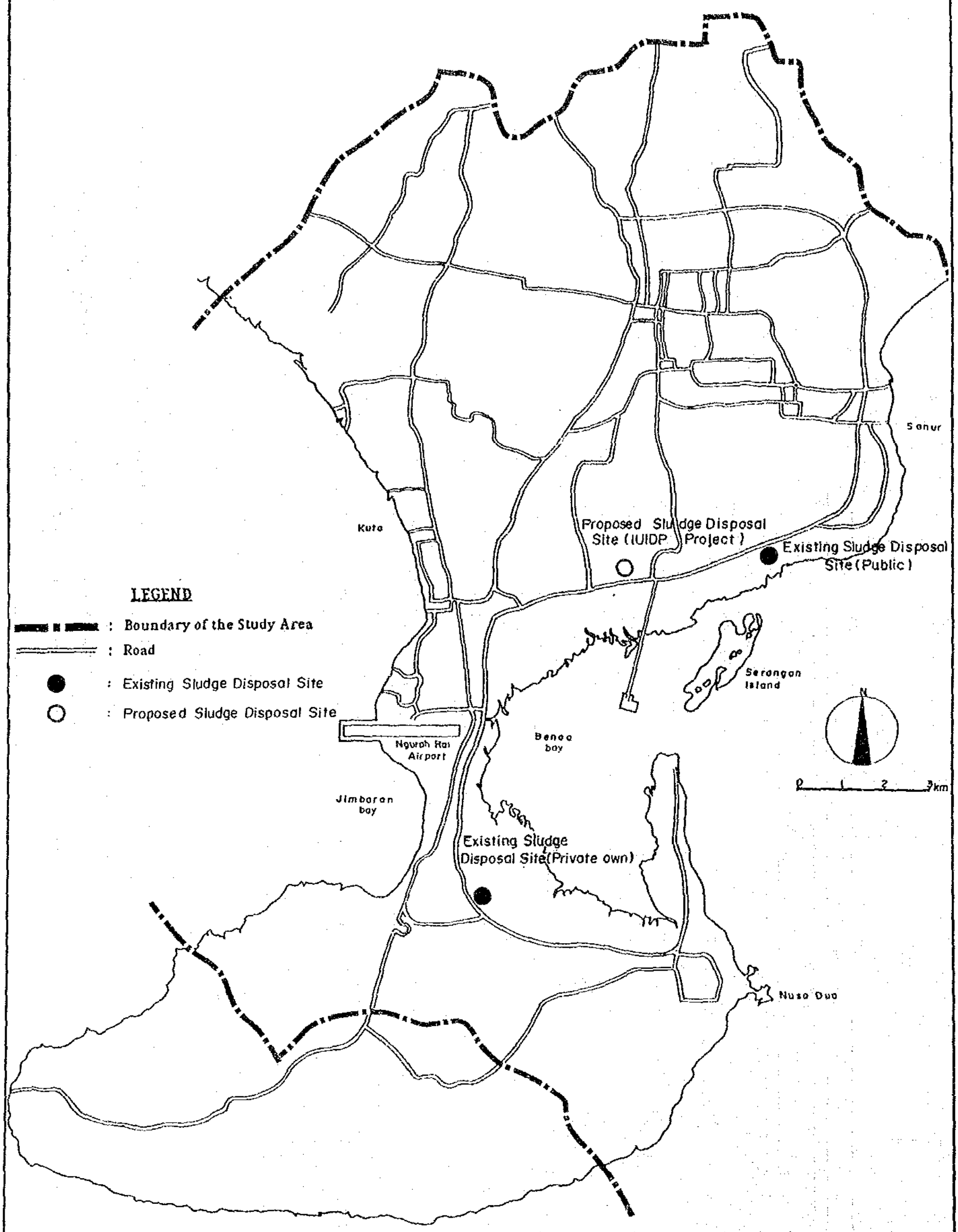

FIG. D.4.1 LOCATION OF HUMAN WASTE DISPOSAL SITE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

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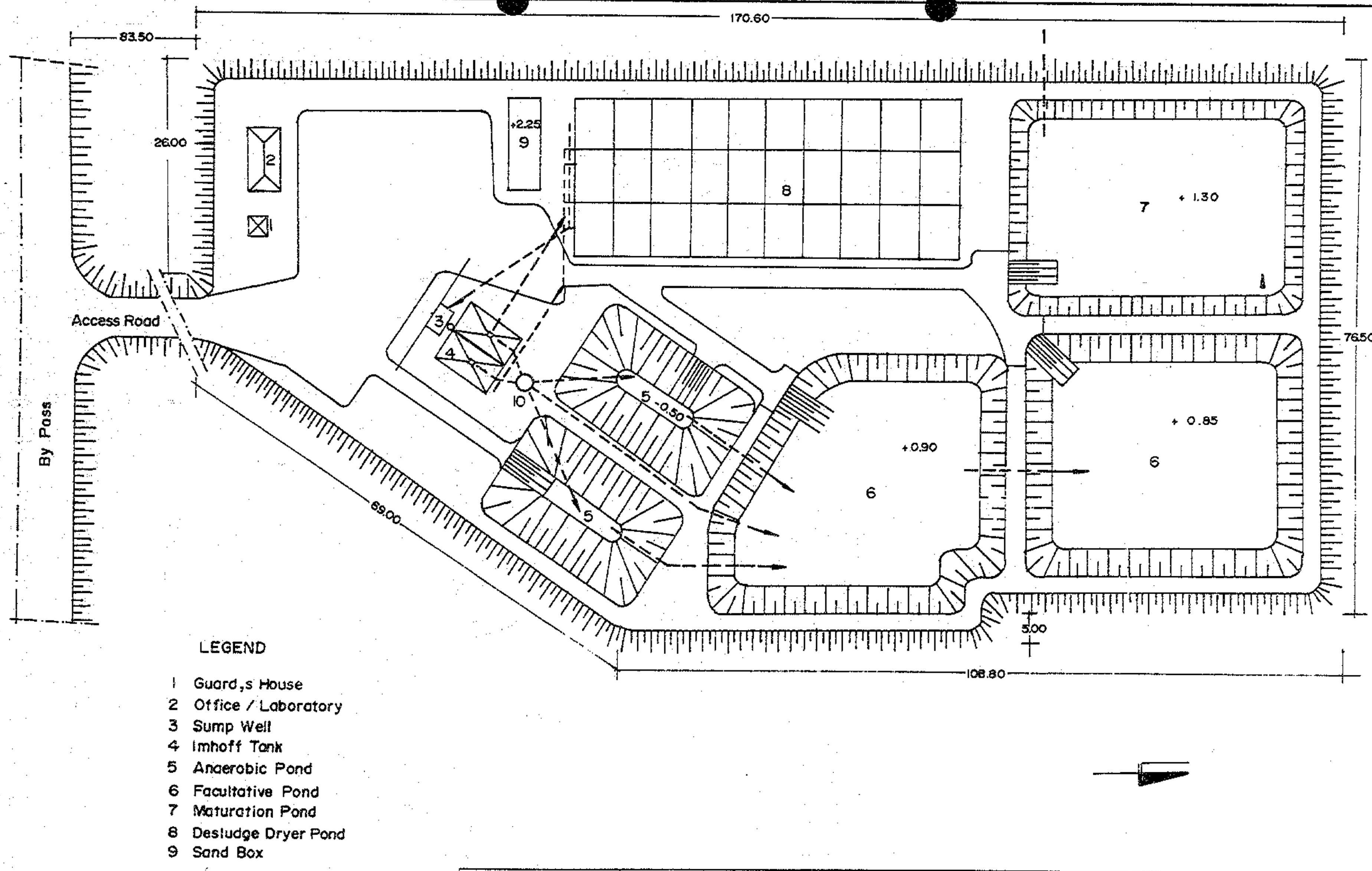

FIG. D.4.2 HUMAN WASTE DISPOSAL PLANT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

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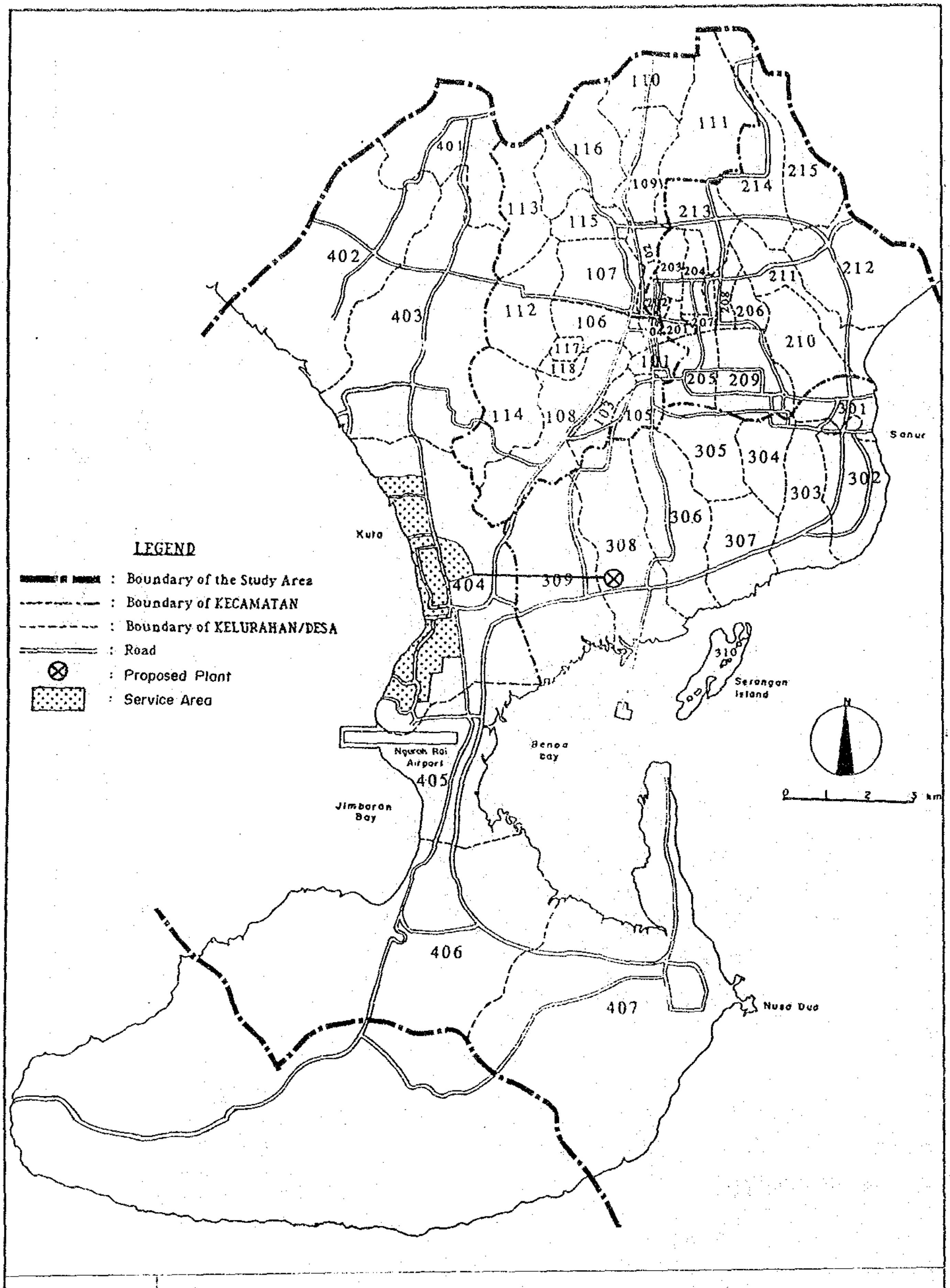


FIG. D.4.3 LOCATION OF KUTA SEWERAGE PROJECT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

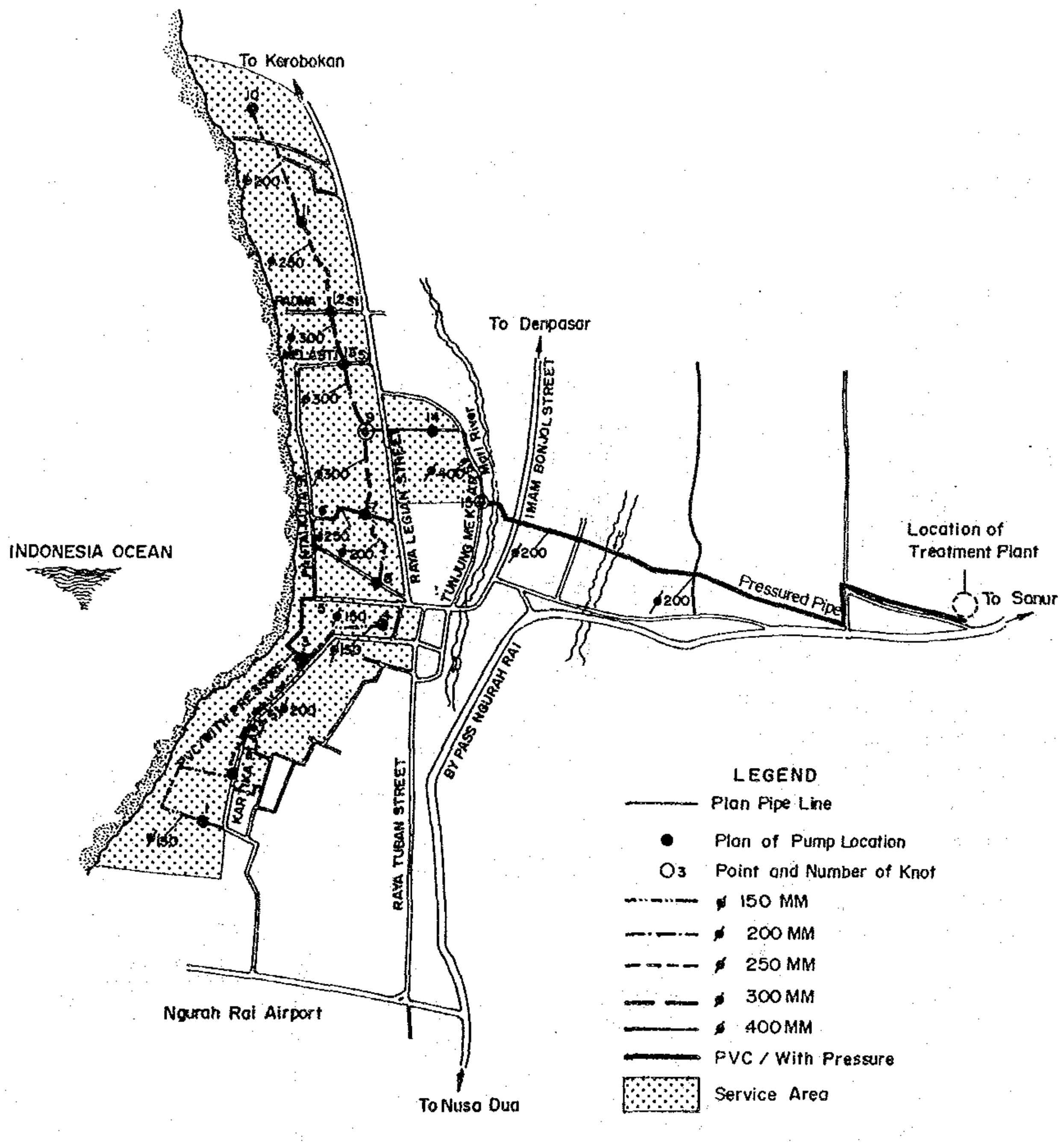


FIG. D.4.4 PLAN OF TRUNK SEWERS IN KUTA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

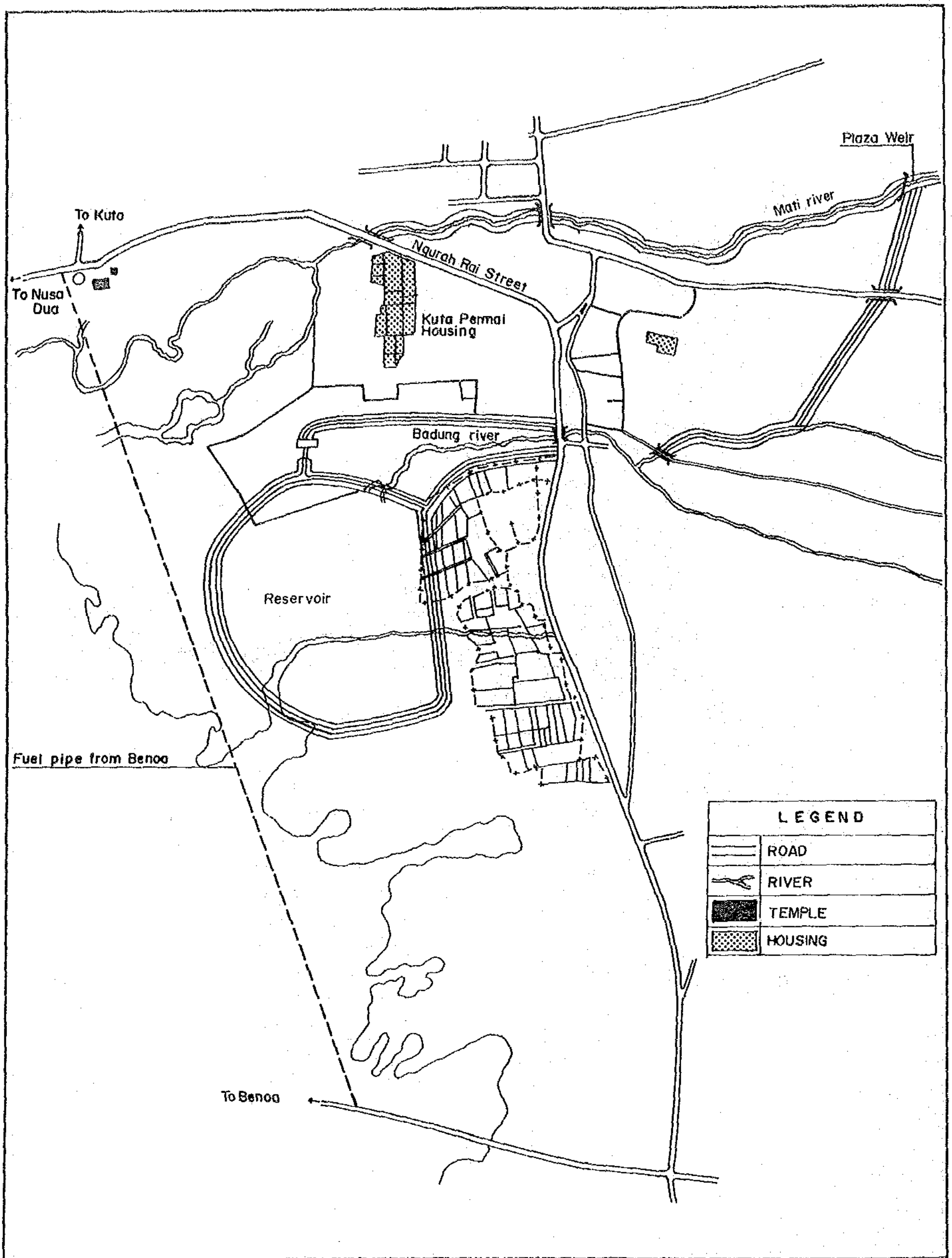


FIG. D.5.1 LOCATION OF ESTUARY RESERVOIR

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

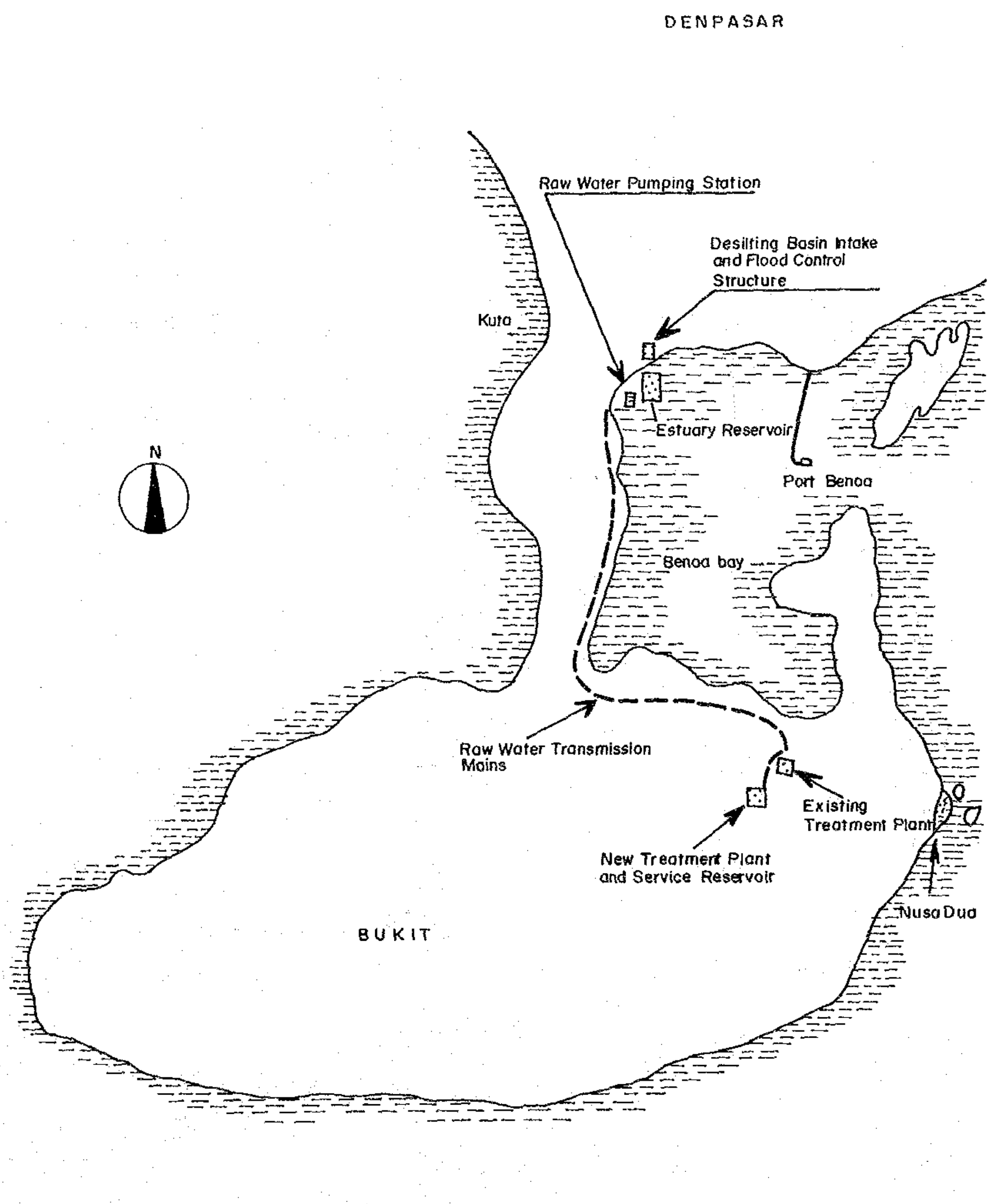


FIG. D.5.2 LAYOUT OF PROPOSED ESTUARY RESERVOIR PROJECT

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

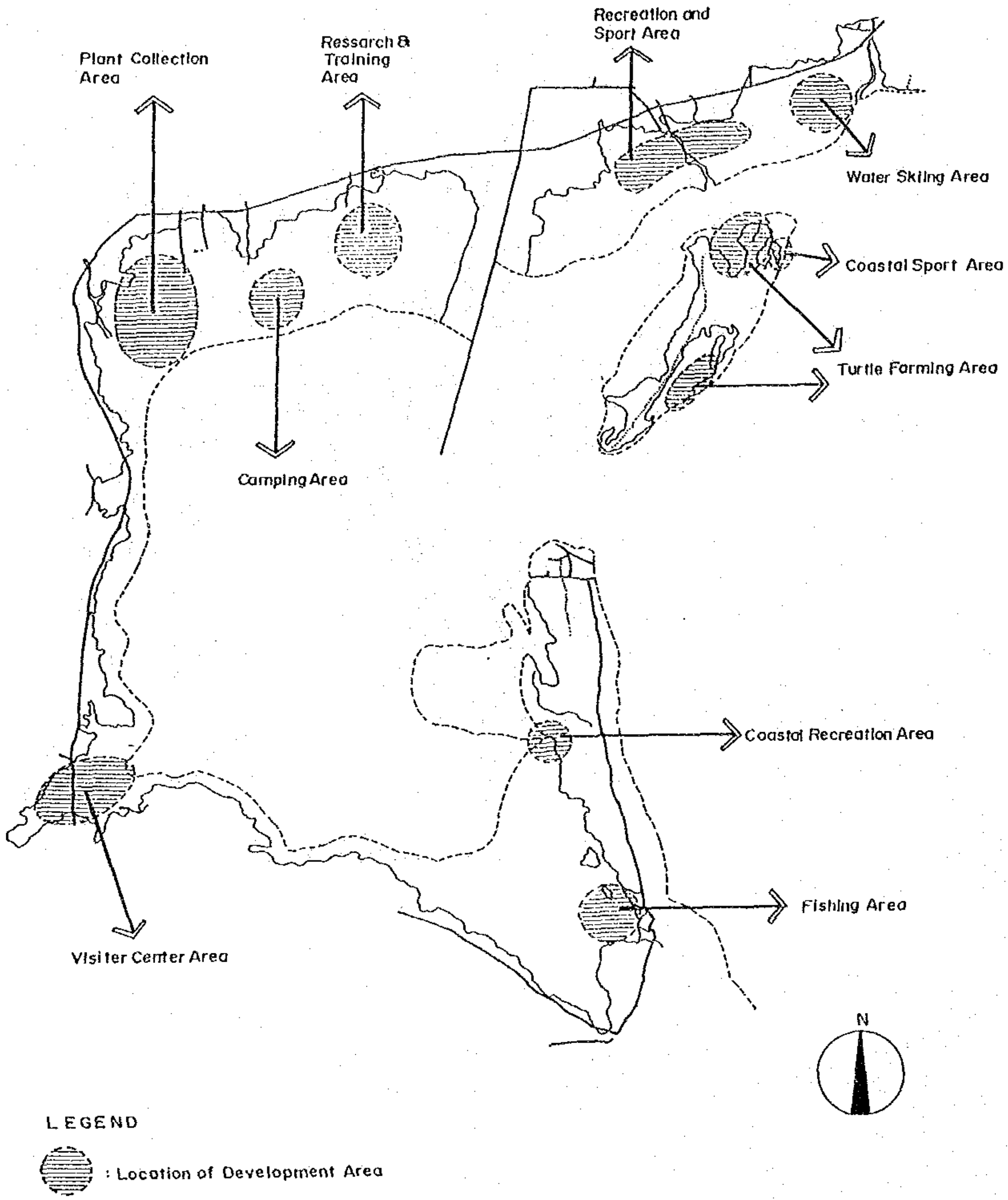


FIG. D.5.3 MANGROVE FOREST PARK PROJECT (TAHURA)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

APPENDIX E

WASTEWATER DISPOSAL DEVELOPMENT

APPENDIX E WASTEWATER DISPOSAL DEVELOPMENT

1. Simulation of River and Sea Water Quality

1.1 Simulation of River Water Quality

1.1.1 Construction of Simulation Model

(1) Division of River Basin

The objective area consists of four (4) river basins :

- Mati-Tega
- Badung
- Yeh Ayung
- Sama

The four (4) river basins cover an area of 14,494 ha or 61.3% of the Study Area. The area of 14,494 ha covers only the upstream catchments of the lower-most out-put stations of simulation. The downstream catchments are dealt with as the residual basins which are directly discharged to the sea. These river basins are further divided into 16 sub-basins as shown in Fig. E.1.1. Their catchment areas along with its existing and future population are shown in Table E.1.1.

The model of river systems has been established for simulation and is shown in Fig. E.1.2. In this figure, the affixed numbers and marks express the following stations and sub-basins.

(1) ~ (16) : Out-put station of water quality (21 stations)

▽1 ~ ▽16 : Sub-basin of wastewater and pollution load discharge

(A) ~ (D) : In-put station of water flow and pollution load (4 stations)

▽A ~ ▽D : River basin outside of the Study Area

(2) Pollution Load Generation of River Basin

Existing and future pollution load generation of sub-basins are estimated by multiplying the specific generated pollution load of Kelurahan/Desa estimated in Appendix C by the area of Kelurahan/Desa in its sub-basin. In this estimation only graywater is considered as an origin of the domestic pollution load, because all toilet wastes are assumed to completely infiltrate into underground after they are treated by the on-site sanitation facilities as septic tank/leaching system.

The estimated wastewater and pollution load generation of each sub-basin by origin of pollution load generation are shown in Tables E.1.2 and E.1.3.

1.1.2 Calibration of Simulation Model

(1) Existing River Water Quality and Flow

The existing river water quality as BOD_5 in both dry and rainy seasons were established at 25 stations of the Study Area in Appendix B. These stations cover the above mentioned 21 out-put stations and 4 in-put stations.

Water quality of the above 25 stations in both dry and rainy seasons are shown in Table E.1.4.

The existing river flow at 25 stations in both dry and rainy seasons were observed by the JICA Study Team and are shown in Appendix B.

(2) Pollution Load Run-off Coefficient

Pollution load run-off coefficient varies according to the urbanized ratio of basin.

Pollution load run-off coefficient of the Study Area is assumed as follows :

Urbanized Ratio	Pollution Load Run-off
Less than 30%	30%
30 ~ 50%	50%
50 ~ 70%	70%
More than 70%	90%

(3) Calibration of Simulation Model

Existing observed river discharge and river water quality are simulated by the following equations :

River discharge

$$Q_2 = Q_1 + qw \pm \Delta q$$

River water quality

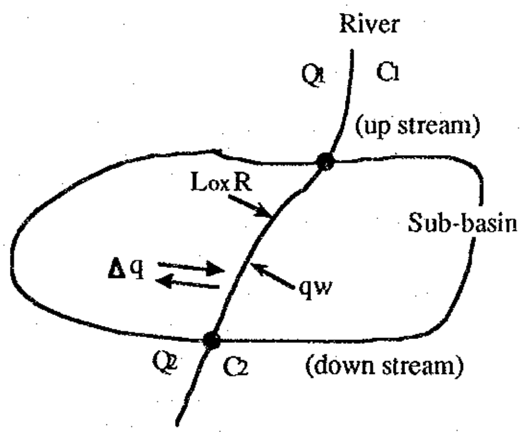
$$C_2 = [(C_1 \times Q_1) + (C_1 \times \Delta q) + (L_0 \times R)] \times 10^{-Krt}/Q_2$$

Where Q1,Q2 : River discharge (m^3/d) (Suffixes 1 and 2 indicate the upstream and downstream sections of the river respectively)

C1,C2 : River water quality (BOD_5,mg/ℓ) (Suffixes 1 and 2 indicate the upstream and downstream sections of the river respectively)

qw : Wastewater generation from the sub-basin (m^3/d)

Δq	:	Natural water inflow from the sub-basin (+) or irrigation water withdrawal (-)
Lo	:	Pollution load generation in the sub-basin (BOD_5 kg/d)
R	:	Pollution load run-off coefficient
Kr	:	Purification coefficient of the river (here 0.3 1/d is adopted)
t	:	Elapsed time of river flow from location 1 to location 2 (day)



In general, the water quality of irrigation water withdrawal is assumed to be the same as the upstream river water quality. And the water quality of natural water inflow is assumed to be the same as that of groundwater. However, in this Study both the river water qualities of inflow and withdrawal are assumed to be the same as upstream river water quality.

The observed and simulated river water quality at the respective 21 output stations are compared as shown in Table E.1.4.

As evident from Table E.1.4, the simulated river water quality is well in agreement with the observed one.

1.1.3 Forecasted Future River Water Quality

The future wastewater and pollution load generation in 2010 by sub-basin are estimated in the same manner as the existing ones. The estimated results are shown in Table E.1.2.(2) and Table E.1.3.(2).

The future river water quality in 2010 without wastewater disposal project at 21 out-put stations are also simulated in the same manner as the simulation of the existing water quality. In this simulation, the river discharge and water quality from the outside areas, and self purification coefficient of river are assumed to be the same as those in the existing conditions. The pollution load run-off coefficient of each sub-basin is re-estimated based on the urbanized ratio in 2010.

In order to compare the existing and future water quality of the rivers the following 10 stations were selected, which are located in the central and southern parts of Denpasar :

(BOD : mg/ℓ)

Station No.	Dry Season		Rainy Season	
	Existing	Future	Existing	Future
5	26.7	50.2	28.7	47.6
6	27.6	53.6	27.4	46.6
9-2	20.0	29.9	11.1	13.4
10-2	16.1	31.2	15.0	30.9
11	18.2	27.0	15 0	30.9
12-1	29.5	59.2	24.1	39.0
12-2	35.4	71.2	40.3	131.8
12-3	51.7	103.9	52.4	85.3
13	25.4	53.0	20.4	35.6
14	26.9	60.2	31.3	99.9
Average	27.8	53.9	26.6	56.1
Future/Existing Ratio	1.94		2.11	

In dry season the existing average water quality of the 10 stations is estimated at 27.8 mg/ℓ as stream BOD and is expected to worsen to 53.9 mg/ℓ in 2010. The ratio of existing and future average water quality of above 10 stations is 1.94.

In rainy season the existing average water quality of the 10 stations was observed at 26.6 mg/ℓ as stream BOD and is expected to worsen to 56.1 mg/ℓ in 2010. The ratio of existing and future average water quality is 2.11.

The worst river water pollution to a level of more than 100 mg/ℓ as stream BOD will occur at the downstream of Oongan River (st. No.12-3) in dry season and in the whole Rangda River (st. No.12-2, 14) in rainy season respectively.

The simulated river water quality in both dry and rainy season without project in 2010 at the 21 stations are compared those of under existing conditions as shown in Table E.1.4 and Fig. E.1.3.

In 2010, pollution load to the sea (most of them are discharged through the rivers and the remaining are directly) will increase to 16,970 kg/d as BOD in dry season and 26,811 kg/d as BOD in rainy season. These are more than twice of the existing ones of 8,290 Kg.BOD/d in dry season and 13,235 Kg.BOD/d in rainy season respectively.

1.2 Simulation of Sea Water Quality

1.2.1 Conditions of Simulation

The pollutions are generated in households, industries, institutions and others. They are discharged into sewerage system or receiving water body. The pollutions discharged into the sea are spread by diffusion and are convected due to currents caused by tides, waves and winds. The diffusion consist of mainly physical and biochemical ones.

The JICA Study Team observed the currents and found that the tidal currents in the sea of the Study Area are dominant, compared with waves and winds. Hence the study assumes that only the tidal currents should be used in this simulation.

In order to forecast the sea water quality in the future it is necessary to simulate the tidal currents and the diffusion phenomena. Generally these phenomena are governed by the mass conservation equations, which are described with the time-dependent partial differential equations.
To solve those equations on complicated boundary conditions given as pollution loads and topography, it is common to use the approximation techniques which can be solved by a computer. One of the approximation techniques is Finite Different Method (FDM). This method is based on small grids which the sea area to be calculated is divided into. The other one is Finite Element Method (FEM).

It has been found that the FEM is a more powerful tool as numerical method, compared with the FDM, because the FEM enables a better approximation of topography by discretization of the sea area. Therefore, the FEM is applied to the simulation of sea water quality in the Study. The sea area to be calculated is divided with triangle elements of arbitrary size, as shown in Fig. E.1.4.

Here are represented the concepts of using two (2) simulation models; tidal current model and diffusion model. They are used to simulate the transportation of pollutions in the sea. The simulation flow is shown in Fig. E.1.5.

Tidal Current Model

The basic equations of tidal currents consist of momentum equation and continuity equation. These equations are called as Shallow Water Equation. They are often applied to analysis of flow and wave in the coastal area where the wave length is much larger than depth.

These equations are derived by modifying the Navies-Stokes equation over the depth, and can be summarized as;

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\frac{\partial h}{\partial x} + Fx + Lx = 0 \quad \text{------------(E.1)}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\frac{\partial h}{\partial y} + Fy + Ly = 0 \quad \text{------------(E.2)}$$

$$\frac{\partial h}{\partial t} + \frac{\partial}{\partial x}\{u\ (h + h)\} + \frac{\partial}{\partial y}\{v\ (h + h)\} = 0 \quad \text{(E.3)}$$

$$Fx = \frac{g \cdot n^2}{(h+h)^{4/3}} \sqrt{u^2 + v^2} \cdot u \quad \text{------------(E.4)}$$

$$Fy = \frac{g \cdot n^2}{(h+h)^{4/3}} \sqrt{u^2 + v^2} \cdot v \quad \text{------------(E.5)}$$

$$Lx = A_l \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) \quad \text{------------(E.6)}$$

$$Ly = A_l \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) \quad \text{------------(E.7)}$$

Where,

u, v	:	x, y components of velocity integrated over depth
h	:	Sea surface elevation from mean sea level
h	:	depth
g	:	gravitational acceleration
n	:	Manning's roughness
A_l	:	coefficient of lateral eddy viscosity

Diffusion Model

The basic equation of diffusion model is based on mass conservation. This equation is often applied to many kinds of physical fields such as thermal transfer field or pollution diffusion field.

By integrating the equation the 3-dimensional mass transportation equation over the depth is given as follows;

$$\frac{\partial(ch)}{\partial t} + u\frac{\partial(ch)}{\partial x} + v\frac{\partial(ch)}{\partial y} - Kh\left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2}\right) + K_1 hc = 0 \text{------------} (E.8)$$

Where,

- u, v : x, y components of mean velocity over depth
- c : concentration (for instance, COD)
- h : depth
- K : diffusion coefficient
- c_a : pollution load
- K_1 : self-purification coefficient (1/day)

The coordinate system and the boundary conditions are shown in Fig. E.1.6. S_1 boundaries denote the pollution loads, while S_2 boundaries represent the land and the open sea.

(1) Topography and Discritized Model

The sea and topography for simulation is shown in Fig. E.1.7. The discritized model is shown in Fig. E.1.8. The contours of depth in the Study Area are shown in Fig. E.1.9.

(2) Boundary Conditions

The boundary conditions are shown below.

Boundary Conditions

Model	Boundary	Conditions
Tidal Current	Off-shore	A-B : $n = a_0 \mathrm{Sin}(2p\ t/T)$, a_0=1.04 m, T=12h25min B-C : $U_n = 0.0$ m/s C-D : $q = q_0 \mathrm{Sin}(2p\ t/T - d)$, q_0= 300,000 m^3/S, $d = p/4$
	Land	$U_n = 0.0$ m/S
Diffusion	Off-shore	$K(\partial c/\partial n) = 0$
	Land	$K(\partial c/\partial n) = 0$

The boundary A - B (see Fig. E.1.7) is the boundary to the sea . In the tidal simulation the water level was intentionally vibrated with an amplitude of 1.04 m and a cycle of 12 hrs 25 min. The vibration amplitude is almost the Mean High Water of the Study sea area to be studied. The cycle was applied with M2 (12 hrs 25 min), which is dominant in the sea area. Based on the field observation of the currents, it is assumed that the currents flow along with the Boundary B - C, and there is no crossing current through the boundary.

At the boundary C - D the flow flux is intentionally set with a lag of 1/4 behind the tides at the B - C boundary, so as to ensure constant currents.

In the diffusion simulation it is assumed that there is no gradient of concentration to the outside and land boundaries, as usually set for simulation.

(3) Initial Conditions

In the current simulation the calculation was started from the condition, when there are no changes for flow and water level. In the diffusion simulation the calculation was started with the initial condition when the concentration is 0 in the whole simulation area.

(4) Physical Parameters

The simulation models need some physical parameters such as bottom friction coefficient, diffusion coefficient. These parameters are settled as shown below.

Physical Parameters

Model	Parameters	Conditions
Tidal Current	Bottom Friction	Manning's Roughness n = 0.03
Diffusion	Diffusion Coeff.	K = 300 m^2/s
	Self-purification Coefficient	K_1 = 0.3 /day

Bottom Friction

As for the friction coefficient of sea bottom there are two kinds of roughness : Cezy's and Manning's. In the simulation the Manning's roughness was used as n = 0.03, which is commonly applicable for the natural geographical conditions.

Diffusion Coefficient

The diffusion coefficient is assumed to be K = 300 m^2/s, which was an average figure obtained from the auto-correlogram analysis of velocity data. The figure may be considered to be changeable depending upon locations and times. However in the simulation it was assumed to be constant, judging from the accuracy of the simulation.

Self-purification Coefficient

According to Streeter & Phelps the coefficient of self - purification is given as follows :

$K_1 = 0.092 \times (1.047)^T$ (1/day)

Where, T : Water temperature (° C)

On the assumption that the average temperature of the survey sea is 25°C, $K_1 = 0.29$ is given. In the simulation therefore the self-purification coefficient was assumed to be 0.3/day.

(5) Time Interval

The current and diffusion simulations are both unsteady, depending on time. It is needed that the time intervals should be set for calculation. In the current simulation, Dt = 2.0 sec was set.

The diffusion simulation is based on the Krank-Nickolson method as the time integration scheme, which is completely stable for time interval. Therefore it is assumed that 1/8 of the cycle of about 12 hours was set to 5,400 sec.

(6) Condition of Pollution Loads

Because the flow volumes were so small as less than $1m^3/s$, it was assumed that the flow volume should be neglected and the pollution load concentrations are given to the nodes.

1.2.2 Simulated Tidal current

Fig. E.1.10 and Fig. E.1.11 show the tide velocities in flood and ebb tides respectively.

Fig. E.1.12 compares the existing tidal ellipses and that calculated from the simulation. It is found that the flow directions are almost same in real and calculated ones at all five stations.

<u>Station A</u>

The calculated velocity is found to be larger than the observed one. This is because the flow meter was installed on the sea bottom and the velocity measurements were made about 70 cm above the sea bottom. Therefore the observed velocity was low. The calculated velocity is obtained by assuming the average flow.

Station B

Like St. A it was found the calculated velocity was larger than the observed one. This is because of the same reason as St. A. Due to navigation safety, the velocity meters were installed on the sea bottom.

Station C

A good agreement between the calculated and observed velocities was found.

Station D

The calculated velocity conform well with the observed one, though the amplitude of calculated velocity is slightly smaller than the observed one.

Station E

The same findings as St. D can be obtained for this station. The steady flow was found to be northern in both simulation and observation. The calculated steady flow at St E was 0.19 m/s in comparison with the observed one of 0.14 m/s.

An example of the changes of tidal elevations at one station (C) is shown in Fig. E.1.13. The observations at all stations indicate that a good agreement between the simulated and observed ones was found after two tides. It is concluded that the simulated results in the second tide should be used for the diffusion simulation.

1.2.3 Simulated Sea Water Quality

1) Existing Sea Water Quality

The existing pollution load concentration of COD is given in Fig. E.1.14. The JICA Study Team summarized the pollution loads in dry and rainy seasons. The pollution patterns move slightly forward and backward from sea shore due to tidal movements twice a day : high tide and low tide.

According to the simulation results the pollution patterns are almost the same for high and low tides. The high tide is on the safe side and is used for summary. In the field works the samples of sea water were taken in both high and low tides. However more samples were taken in high tides, because the water level in low tide was too shallow for sampling.

Fig. E.1.15 and Fig. E.1.16 show the COD distributions in dry and rainy seasons respectively.

The following findings can be drawn :

(a) Most of the Benoa Bay is already polluted with COD of 5 mg/ℓ or more both in dry and rainy seasons .

(b) The northern sea from Turtle Island is also polluted with COD of 5 mg/ℓ or more both in dry and rainy seasons. This pollution is caused by Loloan, Pungawa and Rangda Rivers.

(c) The northern part of Sanur is polluted in rainy season by Yeh and Abian Base Rivers.

(d) The polluted sea areas with COD of more than 5 mg/ℓ are summarized as follows :

Polluted Sea Area
(Existing)

(Km²)

Area	Dry Season	Rainy Season	Average
North Sanur	1.7	1.3	
South Sanur + Benoa	27.3	26.2	
Total	29.0	27.5	28.3

(e) Difference of the polluted areas in dry and rainy seasons is very small.

2) Future Sea Water Quality without Project

If no wastewater disposal system is implemented for the Project Area, the pollution in the sea will continue to expand, as the population, tourism and industry increase.

Fig. E.1.17 shows COD pollution loads in the future without Project, which was used for pollution simulation by a computer.

According to the computer simulation, the pollution will cover a quite large areas with higher concentrations. Fig. E.1.18 and Fig. E.1.19 show the COD pollution in dry and rainy seasons respectively. From these figures the following findings can be drawn :

(a) The pollution of COD 5 mg/ℓ or more occupies almost the whole Benoa Bay.

(b) Turtle Island is surrounded with pollution.

(c) Two polluted areas (South Sanur and Benoa) in existing conditions will combine into one large polluted area.

(d) The pollution in North Sanur will expand, because increased pollution loads by Yeh and Abian Base Rivers with COD of more than 5 mg/ℓ.

(e) The polluted sea areas, summarized for future without project, are shown below. It forcasts that 36.5 Km^2 in the Study Sea Area will be polluted with COD 5 mg/ℓ or more in 2010 if no sewerage system is implemented.

Polluted Sea Area (Future)
- without Project -

(Km^2)

Area	Dry Season	Rainy Season	Average
North Sanur	3.1	2.7	
South Sanur + Benoa	33.8	33.3	
Total	36.9	36.0	36.5

(f) Difference of the polluted areas in dry and rainy seasons is very small.

2. Zoning of Wastewater Disposal System

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.

The existing water quality of the rivers in the Study Area is classified into five (5) classes in terms of stream BOD_5 as shown below (refer to Appendix B, Figs. B.2.7, B.2.8).

Class	BOD_5(mg/ℓ)	Water Quality Condition	Applicable Water Use
I	0 ~ 5	Pristine	Drinking Water Source
II	6 ~ 10	Clean	Drinking Water Source
III	11 ~ 20	Slightly Polluted	Irrigation and Fishery
IV	21 ~ 30	Polluted	Conservation of Aquatic Biota
V	31 ~	Heavily Polluted	None

Applicable water uses are also classified according to the Standards of DKI Jakarta as shown in the above table.

The river water is mainly used for the irrigation of paddy field. Washing and bathing uses are also identified in many river sections.

The existing major water uses by river section is shown in Appendix B, Fig. B.2.16.

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 BOD in the river sections where people use water for washing and bathing.

(2) Sea water pollution control

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

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 Appendix B, Fig. B.3.4). This water quality is considered to be in a critical level for swimming and other water recreations in comparison with international standards.

No distinct relationship is established between sea water quality measured in organic parameter and coral life status. However, according to the field survey of the Study Team, sea water quality of the locations where coral life is healthy is clean and less than 5 mg/ℓ as COD_{cr}.

The coastal zones of the Study Area excluding the Benoa Bay and part of Jimbaran area are intensively used for water recreation. While, Benoa Harbor, part of Jimbaran and Tanjung Benoa are used as the bases of fishery. This coastal water recreation is one of the major inducements of Bali for international tourism.

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

The sea water quality standards of KEP-02/MENKLH/I/1988 is not applicable for determination of the target coastal sea water quality of the Study Area because the proposed water quality standard of 20 mg/ℓ as COD_{cr} for swimming and recreation is too lenient in comparison to the international coastal sea water quality standards (see, Appendix B, Table B.8.4). For example, the Japanese Standards stipulate 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.

From the above discussions, the sea water quality of the international resort beaches in the Study Area shall be maintained below 5 mg/ℓ as CODcr 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. E.2.1).

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

- entirely cut or discharged into road side drains/rivers/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

Almost all toilet waste of the Study Area are disposed into underground. Even gray water is discharged into underground in some areas with a high soil permeability. Such wastewater disposal is considered to be the cause of 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 Appendix B, Fig. B.5.5 ~ Fig. B.5.7).

Future increase of such wastewater disposal into underground will further progress the groundwater contamination in the Study Area. Hence, wastewater disposal into underground shall be carefully managed 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.

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

A large portion of the generated pollution loads in the Study Area are discharged to the Benoa Bay through the Oongan, Loloan, Punggawa, Rangda, Badung, Tega and Mati rivers.

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 seawater quality.

(2) Resort area

In the resort areas of Sanur, Kuta and Nusa Dua, groundwater contamination and communal sanitation problems are more acute in comparison to wastewater discharging problems to the rivers and sea. 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 required 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.

2.3 Wastewater Disposal System for Central and Southern Denpasar

(1) General

Wastewater disposal system of these areas are principally determined from the view points of river and sea water pollution control, and further checked from the aspects of sanitary improvement of communities and groundwater pollution control.

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

(i) Sewerage system only
(ii) Combination of sewerage and on-site systems

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

(2) Sewerage system only

Three (3) sewerage development plans covering the central Denpasar are compared in terms of the control effects of pollution load run-off to the sea and river water quality.

Case (1) : Small scale development covering seven (7) Kelurahan/Desa with a population density of more than 150 person/ha. The development area encompasses an area of 496 ha with a total population of 87,700 in 2010.

Case (2) : Medium scale development including 16 Kelurahan/Desa with a population density of more than 100 person/ha. The total covered area and population are 1,560 ha and 232,400 people in 2010.

Case (3) : Large scale development encompassing 23 Kelurahan/Desa with a population density of more than 50 person/ha. The development area covers an area of 3,759 ha including a total population of 368,600 in 2010.

Three (3) sewerage development areas are shown in Fig. E.2.2.

The above three (3) systems are all of conventional type which collects both toilet waste and gray water. The collected sewage is conveyed to the treatment plant located at the on-shore land along the Benoa Bay for treatment and final disposal. The treatment site is approximately 8.0 km distant from the center of the sewerage development areas toward south. The proposed treatment plant of aerated lagoon treats the collected wastewater to 20 mg/ℓ as BOD and discharge it to the Benoa Bay.

Total pollution load run-off of BOD to the sea of the three (3) cases in dry and rainy seasons are estimated by using the simulation model constructed in Section 1.1.

The simulation results are summarized below in comparison with the cases for existing (1990) and future without project (2010).

(Unit : BOD : kg/day)

	Dry Season	Rainy Season
Existing (1990)	8,294	13,238
Future without project (2010)	16,992	26,833
Case (1) in 2010	12,851	19,729
Case (2) in 2010	10,116	13,977
Case (3) in 2010	7,852	10,407

The river water quality at 25 locations of the Study Area in dry and rainy seasons are also simulated for the above three (3) sewerage development cases. The simulated river water quality are shown in Fig. E.2.3 through Fig. E.2.5, compared with the existing (1990) and future without project (2010).

As evident from the above simulations, only case (3) of large scale development can attain the targets of the river and sea water quality.

(3) Combination of sewerage and on-site system

As sewerage system, the above conventional type is applied. As on-site system, septic tank with up-flow filter is applied. This on-site system is capable of reducing the BOD load of a mixture of toilet waste and gray water by 70% under anaerobic conditions with a retention time of three (3) days. Layout of the system is shown in Fig. E.2.6.

This on-site system may be applicable for medium or low population density areas.

The proposed development areas of sewerage and on-site systems are as follows.

(i) Sewerage system covers 16 Kelurahan/Desa with a population density of more than 100 person/ha. The covered total area and population in 2010 are 1,560 ha and 232,400 respectively. This is the same as Case (2) in the above Section.

(ii) On-site sanitation system is applied for six (6) Kelurahan/Desa with a population density of 50-100 person/ha in the central Denpasar and for seven (7) Kelurahan/Desa in the southern Denpasar with a 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 total area and total population in 2010 covered by the above combined system are 7,247 ha and 456,200 respectively. The included number of Kelurahan/Desa are 29.

The covered area by the above combined system of sewerage and on-site sanitation is shown in Fig. E.2.7.

Pollution load run-off to the sea and river at 25 locations in dry and rainy seasons are simulated for this wastewater disposal development in the same way as in the above Section.

In this simulation, it is assumed that :

- Function of the sewerage system is the same as that in the above Section.
- The on-site system of septic tank with up-flow filter treats both toilet waste and gray water upto 60 mg/ℓ as BOD and discharges them to the neighboring road side drains/canals.

The estimated total pollution load run-off to the sea are shown below, compared with the existing (1990) and future without project (2010) cases.

(Unit : BOD kg/day)

	Dry Season	Rainy Season
Existing (1990)	8,294	13,238
Future without Project (2010)	16,992	26,833
Combined System (2010)	8,424	12,299

The estimated river water quality are also shown in Fig. E.2.8, compared with the existing (1990) and future without project (2010). This system can attain the targets of river and sea water pollution control.

(4) Comparison of alternatives

Cost of the above two (2) alternatives are compared as follows.

The construction cost of sewage system covers costs of wastewater collection system and treatment plant of aerated lagoon. No land acquisition cost is required because the land of the treatment plant is owned by the government.

The construction cost of on-site systems includes costs of septic tank with up-flow filter. The cost of sludge treatment plant is negligibly small.

The construction and O&M costs of the two (2) alternatives are shown in Table E.2.1.

As evident from Table E.2.1, the combination system of sewerage and on-site sanitation is more economical than the system of sewerage only.

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 depth is shallow, ranging from 0.6 m to 2.7 m with an average of 1.4 m below ground surface. The land is covered by silty soil/clay with a low permeability of less than 10^{-4} cm/sec and in some part, of 10^{-6} cm/sec.

Wastewater disposal into underground is considered inappropriate for this area, based on the above soil and groundwater conditions. Hence, septic tank with up flow filter is most appropriate.

The combined system of sewerage and on-site sanitation, while meeting the above technical requirement, is more economical than the sewerage only option.

(5) Conclusion

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

The proposed sewerage system covers 16 Kelurahan/Desa with a total area of 1,560 ha and a total population of 232,400 in 2010. The included Kelurahan/Desa are;

- Dauh Puri, Dauh Puri Kaja, Dauh Puri Kauh, Dauh Puri Kangin, Dauh Puri Kelod, Pemecutan, Tegal Kerta and Tegal Harum in Kec. Denpasar Barat.

- Dangin Puri, Dangin Puri Kauh, Dangin Puri Kaja, Dangin Puri Kangin,. Dangin Puri Kelod, Sumerta, Sumerta Kauh and Sumerta Kaja in Kec. Denpasar Timur.

The proposed on-site sanitation system includes 13 Kelurahan/Desa with a total area of 5,687 ha and a total population of 223,800 in 2010. The covered Kelurahan/Desa are;

- Pemecutan Kaja, Pemecutan Kelod, Padang Sambian and Ubung in Kec. Denpasar Barat.

- Sumerta Kelod and Tonja in Kec. Denpasar Timur.

- Sanur Kauh, Renon, Panjer, Sesetan, Sidakarya, Pedungan and Pemogan in Kec. Denpasar Selatan.

(6) Simulated future sea water quality with project

The sea water quality with project in the year 2010 is estimated for the case of the above combination of sewerage and on-site system.

Fig. E.2.9 shows COD_{cr} concentration input into the sea. Fig. E.2.10 and E.2.11 show the simulated COD_{cr} concentration in dry and rainy seasons respectively. The polluted sea areas with COD_{cr} of more than 5 mg/ℓ are summarized below.

Polluted Sea Area (Future)
- with Project -

(km^2)

Area	Dry Season	Rainy Season	
North Sanur	1.7	1.9	
South Sanur + Benoa	27.1	26.5	Average
Total	28.8	28.4	28.6

From the simulation results the following findings can be drawn in comparison with the case without Project (compare with Fig. E.1.18 & E.1.19) :

(a) The polluted area in Benoa Bay will remain unchanged, but the average pollution concentration will be clearly improved.

(b) The pollution in the area between Turtle Island and the opposite sea shore will be reduced, because the pollution loads from three rivers of Loloan, Pungawa and Rangda will be reduced by the proposed sewerage system.

(c) The pollution beyond Turtle Island will be almost the same as the existing conditions.

(d) The polluted area in North Sanur will be reduced by about 28%, because some pollution loads will be reduced by the sewerage system.

(e) The total polluted area will be almost the same as in the existing conditions. This means that the sewerage system proposed by Master Plan will be able to maintain the existing conditions.

The polluted sea area with COD_{cr} of more than 5 mg/ℓ of three (3) cases are summarized below.

Sea Pollution Summary

	Polluted Area (Km^2)	Ratio (%)
Existing	28.3	100
Future without Project	36.5	129.0
Future with Project	28.6	101.1

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/100 mℓ 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 (m³/d/ha) 1990	Wastewater (m³/d/ha) 2010	Pollution Load(Kg/d/ha) 1990	Pollution Load(Kg/d/ha) 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 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

According to the joint field survey of the Study Team and Indonesian Counterparts, the wastewater infiltration efficiency of septic tanks and leaching pits generally decreases 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 car 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

The sewerage systems of Sanur, Kuta and Tanjung Benoa are independent of each other. The sewerage systems are all of conventional type.

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. The treatment site is approximately 4.0 km distant from the center of the sewerage development area. The treatment plant of aerated lagoon treats the wastewater up to 20 mg/ℓ as BOD and discharge it to the Benoa Bay. The land of the treatment plant is owned by the government.

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. The treatment site is approximately 5.0 km distant from the center of the sewerage development area. The treatment plant is of aerated lagoon type. The treated wastewater of 20 mg/ℓ in BOD is discharged to the Benoa Bay. The land owner of the treatment site is the government.

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 of oxidation pond type. The wastewater will be treated to 20 mg/ℓ in BOD. The distance between the treatment plant and the center of the project area is approximately 3.0 km.

(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.

Layout of the system is shown in Fig. E.2.12.
This household package treatment plant is applied for the same population as the sewerage system. The covered population are :

Sanur area	:	28,000
Kuta area	:	22,000

Tanjung Benoa area : 2,000

(5) Cost comparison of alternative system

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

The construction cost of sewerage system covers costs of sewage collection system and treatment plant of aerated lagoon. No land acquisition cost is required for all the sewerage treatment plants. The lands of Sanur and Kuta treatment plants are owned by the government and the existing treatment plant of BTDC is available for the sewerage development of Tanjung Benoa area.

The construction cost of on-site system covers costs of household package treatment plant and sludge treatment plant.

The construction and O&M costs of sewerage and on-site system 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

The details is shown in Table E.2.2.

(6) Conclusion

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 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. E2.13). The covered total area and population in 2010 are 1,570 ha and 52,000 respectively.

2.5 Wastewater Disposal in Other Areas

The other areas cover 14,836 ha with a total population of 199,600 in 2010. The included 19 Kelurahan/Desa are :

- Peguyangan, Peguyangan Kaja, Peguyangan Kangin, Padang Sambian Kaja, Padang Sambian Kelod and Ubung Kaja in Kec. Denpasar Barat.

- Kesiman, Kesiman Petilan, Kesiman Kertalangu, Penatih and Penatih Dangin Puri in Kec. Denpasar Timur.

- Serangan in Kec. Denpasar Selatan

- Dalung, Canggu, Kerobokan, part of Kuta, Tuban, Jimbaran and part of Benoa.

These Kelurahan/Desa are expected to be sparsely populated even in 2010 with a low specific pollution load generation. The average population density and specific pollution load generation in BOD of the areas are shown below, in comparison with the existing ones.

	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 Appendix B. Fig. B.5.7). 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 to maintain the sanitary conditions of communities at satisfactory level.

Septic tank with leaching system is recommended for these areas.

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. E.2.14.

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 existing land use of the Benoa Bay area is shown in Fig. E.3.1. Zoning of the future land use of this area was prepared by Ministry of Forestry as shown in Fig. E.3.2.

The existing fish pond areas, which is categorized in the limited development area by the future land use zoning of Ministry of Forestry, 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 pond areas located in the Suwung Swamp Area shown in Fig. E.3.3.

4. Alternative Studies of Sewerage Development System

4.1 General

The objective sewerage development area for the year 2010 covers 3,130 ha located in central Denpasar, Kuta, Sanur and Tanjung Benoa as determined in the previous Section E.2.

The total population and wastewater generation of the objective area in 2010 are estimated at 284,400 people and 115,800 m^3/day respectively.

These four (4) sewerage development areas exist separately especially Tanjung Benoa Area. Hence, sewerage collection system should be developed by area. From its location of Tanjung Benoa Area, it is distinct that the wastewater treatment at existing oxidation pond of BTDC is the most economical system for this area.

The following three (3) alternative treatment system are considered for the evaluation of sewerage development for three (3) areas of Denpasar, Kuta and Sanur.

(1) Individual Treatment System

The wastewater of Denpasar, Kuta and Sanur areas will be collected and treated independent of each zone (ref. Fig. E.4.1).

(2) Partially Integrated Treatment System

The above individual treatment system is partially integrated. Wastewater of Denpasar and Kuta will be combined and treated at the one (1) treatment plant in Kel. Pedungan. Wastewater of Sanur will be collected and treated independently (ref. Fig. E.4.2).

(3) Fully Integrated Treatment System

Wastewater of three (3) areas of Denpasar, Kuta and Sanur will be combined and treated at one (1) treatment plant in Kel. Pedungan (ref. Fig. E.4.3).

4.2 Design Wastewater Discharge

The design wastewater discharge of each sewerage development area is as follows.

Sewerage Area		Design Wastewater Discharge
Denpasar	:	71,100 m^3/day
Kuta	:	20,200 m^3/day
Sanur	:	19,800 m^3/day

The figures are on daily average basis and include groundwater infiltration (10%).

4.3 Sewage Collection System

The proposed sewer line networks consisting of tertiary, secondary, main and trunk sewers classified by pipe diameter of each sewerage area are as follows.

Sewer Type	Diameter (mm)	Sewerage Zone		
		Denpasar	Kuta	Sanur
Secondary & Tertiary	150 ~ 300	157,600 m	65,700 m	79,200 m
Main	350 ~ 800	27,800 m	12,500 m	11,300 m
Trunk	900 ~	7,800 m	1,200 m	1,100 m
Total		193,200 m	79,400 m	91,600 m

The expected house connections of each sewerage zone in 2010 is shown below.

Sewerage Zone	No. of House Connection
Denpasar	33,200
Kuta	3,420
Sanur	4,150

4.4 Force Main

Required force main of three (3) alternatives by each sewerage area are summarized as follows.

Alternative Plan	Sewerage Development Area		
(1) Individual Treatment System	(Denpasar)	(Kuta)	(Sanur)
Force main pipe	-	Ø 600 L = 3,500 m	-
Booster pump	-	H = 35 m Q = 34 m^3/min	-
(2) Partially Integrated System	(Denpasar)	(Kuta)	(Sanur)
Force main pipe	-	Ø 600 L = 5,200 m	-
Booster pump	-	H = 45 m Q = 34 m^3/min	-
(3) Fully Integrated System	(Denpasar)	(Kuta)	(Sanur)
Force main pipe	-	Ø 600 L = 5,200 m	Ø 600 L = 4,000 m
Booster pump	-	H = 45 m Q = 34 m^3/min	H = 38 m Q = 34 m^3/min

4.5 Sewage Treatment Plant

Aerated lagoon is assumed as the most suitable treatment system in this alternative study based on a preliminary comparative study. For the detailed comparative study of sewage treatment system, refer to Section 5.6.

Design capacity of the treatment plants is determined to meet the daily average wastewater discharge including groundwater infiltration (10%) in 2010: 71,100 m^3/day for Denpasar, 20,200 m^3/day for Kuta and 19,800 m^3/day for Sanur.

The main features of treatment plant of three (3) alternatives by each sewerage area are shown below.

Alternative Plan	Sewerage Development Area		
(1) Individual Treatment System	(Denpasar)	(Kuta)	(Sanur)
Treatment Capacity (m^3/day)	71,100	20,200	19,800
Area (ha)	13.4	3.8	3.7
Inflow Pump (m^3/min)	102.7	35.5	34.8
Aerator (KW)	1,420	400	400
(2) Partially Integrated System	(Denpasar & Kuta)		(Sanur)
Treatment Capacity (m^3/day)	91,300		19,800
Area (ha)	17.2		3.7
Inflow Pump (m^3/min)	126.8		34.8
Aerator (KW)	1,830		400
(3) Integrated Treatment System	(Denpasar, Kuta & Sanur)		
Treatment Capacity (m^3/day)	111,100		
Area (ha)	20.9		
Inflow Pump (m^3/min)	145.5		
Aerator (KW)	2,220		

4.6 Estimated Cost

4.6.1 Individual Treatment System

(1) Construction Cost

Total construction cost for three (3) sewerage areas is estimated to be Rp. 193.07 billion at February 1992 prices, the break-down of which is shown below.

(Unit : Rp. billion)

House Connection	:	14.68
Collection sewer	:	142.71
Conveyance sewer	:	6.61
Treatment plant	:	29.07
Total		193.07

Construction cost by each sewerage area is shown in Table E.4.1.

(2) Operation and Maintenance Cost

Operation and maintenance cost of the collection sewer lines includes costs for cleaning and repairing. Annual operation and maintenance cost is assumed to be Rp. 300 per meter.

O&M cost of the pump station consists of electricity charge, repairing cost and personnel expenditure. Annual O&M cost is estimated by unit cost basis.

Electricity charge	:	130 Rp./KWH
Repairing cost	:	1% of mechanical and electrical equipment cost
Personnel expenditure	:	2.4 million Rp./person/annum

O&M cost of the treatment plant covers costs for electricity charge, chemicals, materials, repairing, personnel expenditure and others. The annual O&M cost is estimated by unit cost basis.

Electricity charge:	:	130 Rp./KWH
Chemical cost	:	3.2 Rp./m^3
Repairing cost	:	1% of mechanical and electrical equipment cost
Personnel expenditure	:	2.4 million Rp./person/annum

Total annual O/M cost of three (3) sewerage areas is estimated to be Rp. 3.39 billion at February 1992 price, the break-down of which is shown as below.

(Unit : Rp. million/year)

Collection sewer	:	109.3
Force main system	:	140.0
Treatment plant	:	3,140.2
Total		3,389.5

4.6.2 Partially Integrated Treatment System

(1) Construction cost

Total construction cost of this alternative plan is estimated at Rp. 190.61 billion at February 1992 price, the break-down of which is shown below.

(Unit : Rp. billion)

House connection		14.68
Collection sewer	:	142.71
Force main system	:	8.83
Treatment plant	:	24.39
Total		190.61

Construction cost by each sewerage area is shown in Table E.4.1.

(2) Operation and Maintenance Cost

Total annual O/M cost of this alternative plan is estimated at Rp. 3.42 billion, the break-down of which is shown below.

(Unit : Rp. million year)

Collection sewer	:	109.3
Force main system	:	172.2
Treatment plant	:	3,139.1
Total		3,420.6

O&M cost by each sewerage area is shown in Table E.4.2.

4.6.3 Integrated Treatment System

(1) Construction Cost

Total construction cost of this alternative plan is estimated to be Rp. 194.58 billion at February 1992 price, the break-down of which is shown below.

(Unit : Rp. billion)

House connection		14.68
Collection sewer	:	142.71
Force main system	:	15.99
Treatment plant	:	21.20
Total		194.58

Construction cost by each sewerage area is shown in Table E.4.1.

(2) Operation and Maintenance Cost

Total annual O/M cost is estimated to be Rp. 3.57 billion, the break-down of which is shown as below.

(Unit : Rp. million/year)

Collection sewer	:	109.3
Force main system	:	322.0
Treatment plant	:	3,138.1
Total		3,569.4

4.7 Comparative Evaluation

The construction and annual O&M cost of the three (3) alternative systems are compared as follows.

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

Based on the above table, no significant advantage of construction, and operation and maintenance cost among the three (3) alternatives is found.

JICA Study Team proposes the "Integrated Sewerage Treatment System" as an optimum system for this project based on the following reasons.

- As for operation and maintenance of treatment plant, the integrated system is more convenient than the separated one.

- The site of the proposed treatment plant of integrated sewerage system is located in the limited developed zone of proposed land use plan by Ministry of Forestry and far away from the tourist area of Sanur.

- Treatment plant could be constructed in stages at a single location.

5. Proposed Sewerage Development Plan

5.1 Wastewater Collection System

5.1.1 Definition of Wastewater Generation

Under the existing condition, average toilet waste of 16 lcd is infiltrated into the ground in the most part of the Study Area. However, complete sewerage system will collect the whole wastewater of those areas including toilet waste. In this Study, wastewater generation is defined as total wastewater volume generated at the origin of pollution source.

5.1.2 Type of Collection System

There are two (2) types of wastewater collection system. One is separate system and another is combined system. Separate system collects only sewage excluding storm water. While, combined system collects storm water along with sewage.

In this Study Area, storm water is drained mainly by open drainage networks consisting of ditches, irrigation canals and rivers. No drainage pipes are installed except at road crossings. The on-going drainage project aims at improvement of the open drainage system. The road side ditch improvement project had started in 1977 and still ongoing in the Study Area. Based on the existing road side ditch and small canal survey conducted by the Study Team, the drainage capacity of improved road side ditches are sufficient to drain the storm water in those respective areas.

Therefore, separate wastewater collection system is applied for this Study.

5.1.3 Design Criteria

(1) Peak Flow Factor

The following formula is adopted to estimate peak flow factor to daily average wastewater discharge.

$$F = 4.02\ (0.0864Q)^{-0.154}$$

where,

F : Peak flow factor to daily average wastewater discharge excluding groundwater infiltration

Q : Daily average wastewater discharge in l/s

The peak flow factors proposed by the previous relevant five (5) studies are shown below.

Study	Peak Flow Factor
- 1977 Master Plan of Jakarta Sewerage & Sanitation Project	$4.02\ Q^{-0.154}$ Q : daily average discharge in 1000 m^3/d
- Bandung Urban Development Project (BUDP)	1.5 ~ 4 Depending on population density
- Medan Urban Development Project (MUDP)	2 ~ 5 - ditto -
- On going Jakarta Sewerage & Sanitation Project (JSSP)	$4.02(0.0864Q)^{-0.154}$ Q : daily average discharge in l/s
- Urban Drainage and Wastewater Disposal Project in the City of Jakarta in 1991 by JICA	$4.02(0.0864Q)^{-0.154}$

The proposed formula is the same as those of 1977 Master Plan, JSSP and wastewater disposal project by JICA 1991.

This formula gives F=5 for a small service area with 1,500 population discharging wastewater of 225 m^3/d. While, it gives F=2 for a large service area discharging 60,000 m^3/d from its population of 400,000. From the above discussions, the proposed design criteria of peak flow factor is considered similar to the other two (2) proposals.

(2) Groundwater Infiltration

Groundwater infiltration including unexpected surface water intrusion is assumed to be 10% of daily average wastewater discharge.

Groundwater infiltration and unexpected surface water intrusion shall be considered for designing the capacity of sewage collection system.

The design criteria of groundwater infiltration including unexpected surface water intrusion proposed by the previous four (4) relevant studies are as follows.

Study	Groundwater Infiltration
1977 Master Plan	5 $m^3/d/ha$
BUDP and JICA 1991	10 % of daily average discharge
MUDP	10 $m^3/d/ha$
JSSP	5.2 $m^3/d/ha$

The proposed criteria of this Study considers a groundwater infiltration of 10% of daily average wastewater discharge into sewer system.

The proposed criteria is similar to those of the other five (5) projects.

(3) Flow Velocity

In calculation of flow velocity, the Manning's Formula is applied for gravity flow and Hazen-Williams' Formula for pressure flow. The minimum velocity is 0.6 m/s and maximum velocity is 3.0 m/s.

The Manning's Formula is shown below.

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

where,

V : Mean velocity

n : Roughness coefficient

R : Hydraulic radius

I : Hydraulic gradient

Roughness coefficient (n) is assumed as follows:

Pipe Material	n
RC Pipe	0.013
Vitrified Clay Pipe	0.013
PVC Pipe	0.010
GRP	0.010

The Hazen-Williams' Formula is assumed as follows.

$$V = 0.84935\ C\ R^{0.63}\ I^{0.54}$$

where,

V : Mean velocity (m/s)
C : Coefficient (C=110)
R : Hydraulic radius
I : Hydraulic gradient

The minimum velocity of 0.6 m/s is determined to prevent sediment deposition and to minimize sulfide formulation. The maximum velocity of 3.0 m/s is adopted to prevent erosion of the pipe material. The above five (5) relevant studies propose 0.6 m/s to 0.8 m/s as the minimum velocity and 3 m/s to 5 m/s as the maximum one.

(4) Allowance of Sewer Pipe Capacity

Allowance of sewer pipe capacity to design peak discharge is determined as follows.

Sewer Diameter (mm)	Allowance (%)
ø 150 -300	100
ø 350 - 800	50
Larger than ø 900	30