CHAPTER 6
LAND REQUIREMENTS FOR SEWERAGE FACILITIES

6.1 General

Most of sewers are laid on the public roads, therefore no land acquisition is required. However, quite a huge land is needed for construction of treatment plant and pumping station, and these lands are usually private property so that land acquisition cost is required.

In this chapter, the relationship between required site area and capacity of pumping station and treatment plant is discussed.

6.2 Treatment Plants

On the basis of the plant layouts of 5 different capacities, 5,000 cum/day, 10,000 cum/day, 50,000 cum/day, 100,000 cum/day, and 200,000 cum/day, required site areas for different treatment process were obtained as shown in Table D-18 and Figure D-19.

TABLE D-18 Required Site Area of Treatment Plant by Method

unti: hectare

Capacity / Treatment method	5,000 cum/day	10,000	50,000	100,000	200,000
Stabilization pond	11.5	20.9	91.1	175.7	342.7
Aerated lagoon	5.8	10.1	41.0	77.9	150.0
Oxidation ditch	1.9	3.3	13.7	26.7	53.1

From these table and figure, equations were developed as follows:

(a) Stabilization pond process
$S = 0.00443\ Q^{0.920}$

(b) Aerated lagoon process
$S = 0.00307\ Q^{0.881}$

(c) Oxidation ditch process
$S = 0.00081\ Q^{0.904}$

where S : Required land area, ha
Q : Daily average flow, cu m/day

Total site area for treatment plant is obtained by adding the site area for pumping station which is calculated based on the peak flow instead of daily average flow.

6.3 Pumping Stations

In developing required land equation, 7 stations, different capacities of 0.05 cum/sec, 0.2 cum/sec, 0.5 cum/sec, 0.87 cum/sec, 1.73 cum/sec, 3.0 cum/sec, and 5.0 cum/sec, were considered. From the layouts of 7 stations, site areas as shown in Table D-19 were obtained.

TABLE D-19 Required Site Area for Pumping Station

Peak flow, cum/sec	0.05	0.2	0.5	0.87	1.73	3.0	5.0
Area, sq m	50	120	155	1,600	1,700	1,800	2,400

The relationship between peak flow and site area is illustrated in Figure D-13. The equation may be expressed as:

APPENDIX E

WASTEWATER CHARACTERISTICS

APPENDIX E

WASTEWATER CHARACTERISTICS

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CHAPTER 1

STUDIES ON DOMESTIC WASTEWATER

1.1 Survey on Domestic Sewage in the Project Area

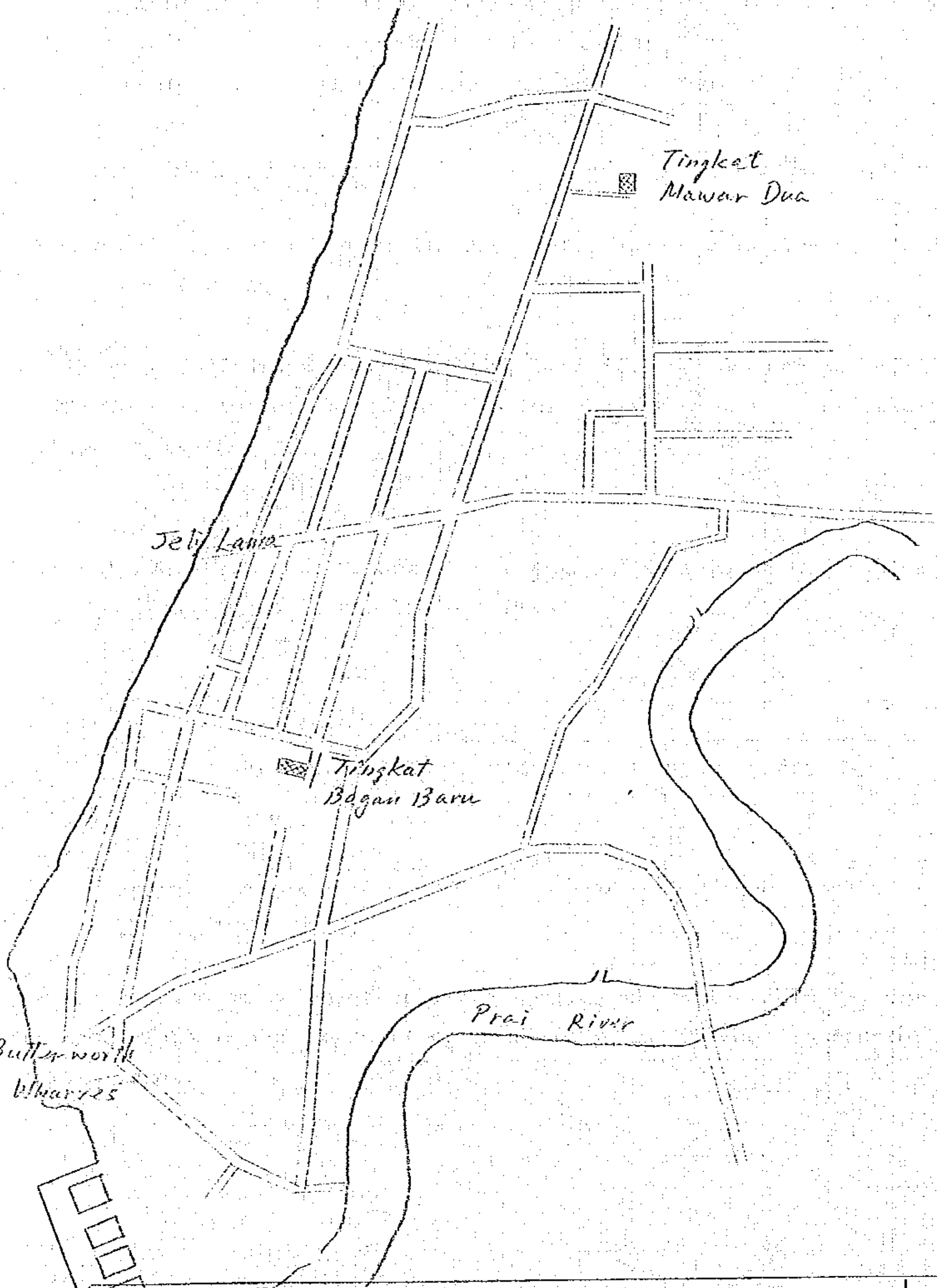
1.1.1 Description of Survey

As one of the basic information for per capital waste loads and sewage flow rate projection for domestic wastewater, quality and quantity surveys of open ditches amang the residencial areas selected were performed by us in November and December, 1976.

Two typ-ical housing blocts out of other necessary for the study were selected whereby open concrete ditches sorrounded and the domestic wastewater discharged into these ditches directly at the sites of each houses by gravity. These blocks selected are average level typical residence in the Project Area, where no night soil is discharged into open ditch. Therefore, the waste load by night soil is not estimated in this survey. The location of selected housing blocks are indicated in Fig. E-1.

At the corner of the ditch, V-notch was installed to measure flow rate, and the sampling and measurements were carried out. These performances were done during 6:00 am to 12:00 pm of the day for every 1 to 2 hours for sampling and every 15 to 30 minutes for measurements. Water temperature, pH, dissolved oxygen (DO), and electric conductivity were measured at the site by a potable "water quality checker", which are consisted of thermister, pH-electrode, DO-electrode, and electric conductivity meter.

The samples collected were analyzed on biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), and chloride ions in the laboratories of Department of Chemistry and Indus Laboratories Co., Ltd.



The Location of Domestic Sewage Survey Areas	FIGURE E-1

Analytical methods used are follows :

BOD	:	glass bottle method, 5 days at 20 C
COD	:	potassium permanganate method, 100 C 30 minutes
SS	:	glass fiber filter method
Chloride	:	silver nitrate titration method

1.1.2 Results and Discussion

The findings of the domestic wastewater survey are shown in ANNEX E-1 of the present Report.

Using the findings of the survey, quantity and BOD and SS contents of sullage from typical residences in the Project Area were calculated as shown in Table E-1.

TABLE E-1 Quantity and BOD and SS Contents of Sullage from the Typical Residences in the Project Area

Block	Quantity	BOD			
	l/day.cap.	ppm	g/day.cap	ppm	g/day.cap
R-1	93	241	22.4	31	3
R-2	95	224	21.3	42	4

The results on calculation of SS content shown in Table E-1 are very low. This is due to settling SS material in ditches in case of too low slopes.

In computing the estimated quantity of domestic sewage and BOD contents for the design basis of the sewerage system, appropriate allowances are considered necessary for settling in drains and removal of flushing water for septic tank system, to give a realistic estimates of the residential components of domestic sewage.

As night soil is independently treated by septic tank systems at the surveyed blocks, flashing water use for water closet should be given allowances of approximately 60 l/day. cap, concerning sewage production.

Further, it is considered daily variation of water consumption may be approximately 20 %, and according to PWA data, the field surveys were made in the lowest season of water consumption, so that approximately 30 l/day. cap of allowances is estimated for variation component.

Therefore, total quantity of domestic sewage is estimated at approximately 190 l/day. cap on the typical pure residential area, as following way:

(1) 95 l/day.cap for pure sullage
(2) 60 l/day.cap for flashing water
(3) 30 l/day. cap for variation allowances.

The BOD of the wastewater samples from the drains was found to range from minimum of 110 mg/l to a maximum of 370 mg/l, varying with the time of the day. The average daily per capital BOD of sullage is estimated at 21.9 g/day.cap on typical residential area as shown in Table E-1.

Because of extremely low concentration of SS in the collected samples as shown in Table E-1, it is reasonable to expect that BOD matter is lost through settling in the collection system due to low velocities. This is often seen in the Project Area because the slope of the drains are very flat in common housing areas, and also in surveyed blocks. Assuming 10 to 20 % reduction through settling in a drain during collection of samples, 2 to 4 g/day.cap of BOD should be allowed for BOD production shown in Table E-1.

Nightsoil BOD has been estimated at 13 to 20 g/day.cap in Japan and other Asian country. In this planning, 13 g/day.cap of nightsoil BOD is applied on the basis of experience in Japan.

Therefore, total unit BOD production is estimated at approximately 37 g/day.cap on the present living condition in the Project Area, as following way :

(1) 22 g/day.cap for actual measurement on pure sullage
(2 2 g/day.cap for allowance components on settling
(3) 13 g/day.cap for nightsoild BOD

The estimated unit flow rate and strength of domestic sewage in the present condition are shown in Table E-2.

TABLE E-2 The Estimated Unit Flow Rate and Strength of Domestic Sewage Produced in the Project Area in Present Condition

Concentration*		Volume**	Unit Production***	
BOD	SS		BOD	SS
185	180	200++	37	20

* Unit : mg/l
** Unit : l/day.cap
*** Unit : g/day.cap
++ Estimted by the results of home visiting

1.2 ESTIMATION OF FUTURE DOMESTIC WASTEWATER PRODUCTION

1.2.1 Sewage Flow

The results of the domestic wastewater survey, described in Section 1.1 of this Chapter, state that the volume of domestic wastewater is estimated at 200 l/day.cap. However, volume and characteristics of wastewater will increase in company with future economic growth, improvement of social services including water supply, toilet facilities and other factors.

Therefore, it is assumed that volume of wastewater production would increase, by the year 2000, within 15% of the present value, namely, 200 l/day.cap, based on the increasing rate of the water supply plan of PWA. The design value of the sewage flow is therefore estimated at 230 l/day.cap for planning purpose.

1.2.2 Quality

The present per capita waste production is estimated at 37 g/day.cap as mentioned in Section 1.1 of this Chapter.

Future improvement of living conditions will raise the waste load as a result of the increase of its substance. Assuming that per capita waste production in the Project Area reaches the level similar to 1970 Japanese level of 44 g/day.cap by the year 2000, it is estimated taht the BOD load would increase, with a few allowance, to 46 g/day.cap by the year 2000.

Using this value with a flow contribution of 230 l/day.cap, 200 mg/l of BOD is considered reasonable as average concentration of domestic wastewater.

1.2.3 Comparison with Data from Other Countries

Table E-3 shows comparison of characteristics of wastewater in various cities.

TABLE E-3 Comparison of Characteristics of Wastewater in Various Cities*

		BOD mg/l	SS mg/l	BOD g/d.c	SS g/d.c	Flow l/d.c	
Butterworth	2000	200	200	46	46	230	Design values recommended
Ipon	1968	370	276	–	–	205	Average
"	2020	200	250	45	54	227	Design values
Kuara Limpur	1985	250	–	55	–	220	Design values
"	2002	222	–	60	–	270	Design values
San Juan	1967	204	264	45	59	318	
Tema Ghana	1965	280	219	45	36	168	
Seoul	1985	312	374	59	73	232	Design values
Japan	1953	114	165	23	32	241	7 cities average
"	1970	–	–	44	40	–	Design standard
Keelung	1963	200	250	41	50	241	Design values

* Modified and rearanged form follows:

(1) Manila Sewerage Report (1969)

(2) Municipality of Ipoh Sewerage Feasibility Study (1974)

(3) Kuala Lumpur Master Plan for Sewerage and Sewage Disposal (1975)

(4) Japanese Design Standard for SEwerage System (1972)

The value of unit BOD production of the recommended plan is similar to the value of Ipoh (2020), San Juan, Tema Ghana, and Japanese standard (1975). While, although the values of Kuala Lumpur and Seoul are slightly higher than the other cities, this may be due to highly developed commercial areas in the cities because of the metropolis of the countries.

Therefore, the recommended value, 46 g/day.cap of BOD, is considered to be reasonable.

As the ratio of SS/BOD fluctuates in every cities, it is difficult to predict the future SS value accurately. Assuming the ratio is 1, the recommended unit SS production is estimated at 46 g/day.cap.

The value of sewage flow in the Project Area is predicted at 230 l/day.cap and similar to the value of Ipoh (2020), Kuala Lumpur (1985), and Seoul (1985). As the sewage flow reflects the living pattern of the area, and as it is considered that the living pattern of higher than the middle income class in the Project Area would not drastically change by the year 2000, the above predicted 230 l/day.cap value is considered to be reasonable.

1.1.3 Daily Variation of Domestic Wastewater Flow Rate

The Flow rate of domestic wastewater was measured every 15 to 30 minutes at the selected residential blocks. The results is shown in ANNEX E-2. 2 different patterns, 2 peaks and 3 peaks, were obtained. These patterns reflect each living activities, cooking, bathing, washing, etc., although each peaks cannot exactly correspond to each activities.

CHAPTER 2

QUANTITY AND QUALITY OF INDUSTRIAL WASTEWATER

In this chapter, the present and future conditions of industry in the project area are described and studied on quantity and quality of industrial wastewater. All data and information used herein are offered by courtesy of Ministry of Environment, LPKT-SP, Department of Chemistry of Penang, PDC, PWA, together with field survey conducted by us throuth field visits and questionnaires directed to each establishments.

2.1 GENERAL

There are 8 industrial areas in Penang State because of the high priority given to the industrial development in the State. 5 of such areas are located in the Butterworth-Bukit Mertajam Metropolitan Area (see Figure E-2).

Most of large and midiam scale factories are concentrated in the industrial areas of Mak Mandin Industrial Estate, Prai Industrial Complex*, and Seberang Jaya Complex. Rest of the smaller scale factories are distributed in the Bukit Mertajam District, and a few in the other area.

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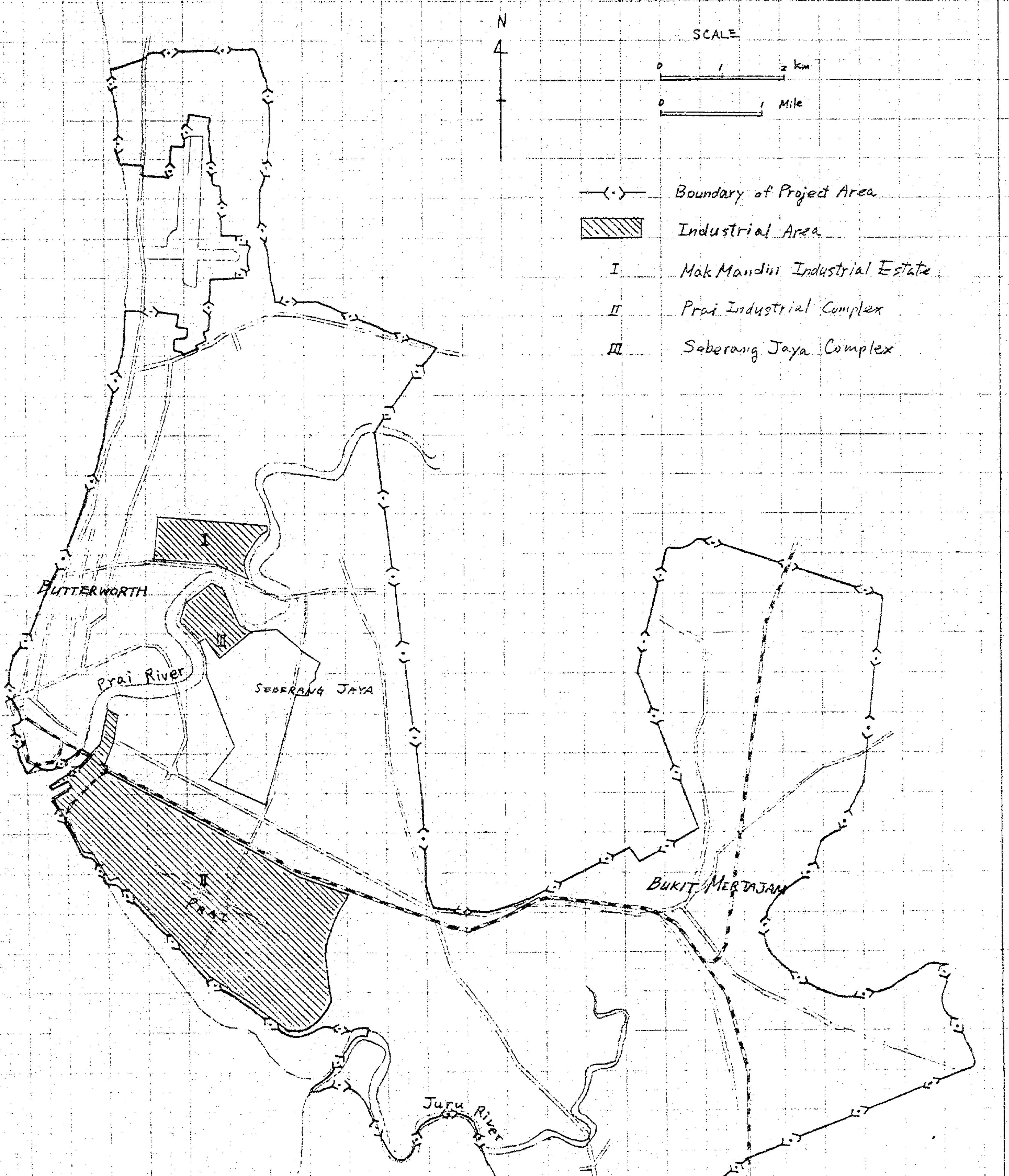
* Prai Industrial Comples is, in this report, defined as the whole area including Prai Industrial Estate, Prai Free Trade Zone, Prai Wharves Free Trade Zone, and other industrialized Prai area (see Figure 2-1).



Location of Industrial Area

FIGURE E - 2

MAK MANDIN INDUSTRIAL ESTATE covers an area of about 120 ha within the Butterworth town area, mainly food staff manufacturing with the rest of textile, light metalling, plastic processing and others. As of 1976, there are 32 detached-type factories in operation in the Estate, and another 13 allocated sites for future construction. In addition to the detached-type factories mentioned above, there are 48 middle scale factories, which are classified as terraced-typed and/or semi-detached-type ones, in operation in MIEL units* constructed in the Estate. The Estate has already reached full utilization.

PRAI INDUSTRIAL COMPLEX covers about 1,000 ha located at the south-east part of the Project Area and the biggest of its kind in the country with food staff manufacturing dominated, followed by textile, light metal and prastic processing and others. As of 1974, at least 27 factories employing about 6,000 workers were already in operation in the area. According to PDC's information, as at the end of 1976, there are 77 factories including MIEL units* in operation, and 23 factories are additionally allocated in the area. This indicates that industrial development of this area is well in progress.

SEBERANG JAYA COMPLEX includes an industrial area covering about 46 ha. This complex is under construction for development so that only 2 factories are in operation for production.

Number of factorories in each industrial areas are shown in Table E-4.

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* MIEL units are built by private industrial developers who put up ready-built, fully served standard factory buildings for industrialists who are unable to put up their own factories.

TABLE E-4 The Number of Factories by Industrial Classification and their Location (1976)

Class No.	Mak Mandin Industrial Estate		Prai Industrial Complex		Seberang Jaya
	Existing	Approved	Existing	Application	Existing
1	11	1	13	4	1
2	4	1	11	1	1
3	2	-	6	3	-
4	4	-	9	4	-
5	-	1	4	1	-
6	5	3	10	5	-
7	-	2	2	-	-
8	1	1	4	4	-
9	5	4	18	1	-
Total	32*	13	77**	23	2

* excluding MIEL units (48 factories)

** including MIEL units

*** Class No. : 1 Food
2 Textile
3 Chemicals
4 Rubber & Plastics
5 Stone & Clay Products
6 Metals
7 Electrics
8 Machinary & Equipments
9 Others

In the area out of the three industrial areas, about 60 middle scale factories and about 700 small scale factories are scattered. Most of them are distributed among residential and/or commercial areas.

2.2 INDUSTRIAL WASTEWATER SURVEY

2.2.1 Industrial Wastewater Surveys

The Sub-Committee on Pollution Control of Penang conducted an industrial wastewater survey in the Prai Industrial Complex in 1976 to study on the pollution of Kuara Juru with the assistance of LPKT-SP and Department of Chemistry. Questionnaires were sent to 73 factories in Prai Industrial Estate to get information on the volume of water consumed and discharged. Answers to the questionnaires received from 41 factories, and further, effluent samples from 22 factories suspected to be the worst pollutants were taken and analized.

In addition to the survey, Ministry of Environment conducting the Anti-Pollution Committee in Malaysia surveyed on the industrial wastewater quality of some factories in the Prai Industrial Comples and the Bukit Mertajam District. These surveys were too simple to estimate the total amount of wastes from the industrial area at present and/or in the future.

For the purpose of estimating present and future industrial wastewater production and its quality in the Project Area, NSC conducted its own industrial wastewater survey in November, 1976. The factories were classified into 9 industries with 29 groups as shown Table E-5 by using the list of factories made by PDC. The questionnaires including the questions on (1) water consumption, (2) waste production and disposal, (3) treatment facilities, (4) effluent quality, (5) factory scale and expansion planning, (6) working hours, and (7) main process related to waste production, were sent to 47 factories altogether selected from all those classified and grouped

TABLE E-5 List of Industries Classified

Code No. Class	Group	Name of Industry Classified	Remarks
1		Foods	
	11	Sea Products	Frozen Foods, Tinned Foods
	12	Oil Products	Palm Oils, Refined Oils
	13	Other Foods	including Feeds
2		Textile	
	21	Spinning	Yarn, Thread
	22	Weaving	Fabrics
	23	Dyeing	
	24	Apparel	
3		Chemicals	
	31	Fertiliser	
	32	Synthetic Chemistry	
	33	Other Chemicals	
4		Rubber& Plastics	
	41	Rubber	Later
	42	Rubber & Plastics Processing	
5		Stone & Clay Projects	
	51	Glass	
	52	Concrete	
	53	Others	Pottery
6		Metals	
	61	Iron & Steel	
	62	Non-Ferous Metals	
	63	Fabricated Metals	
	64	Other Metal Works	
7		Electrics	
	71	Electronics	
	72	Other Electric Goods	
8		Machinary & Equipments	
	81	Machinary	
	82	Assembling	
	83	Others	Parts/Tools Making
9		Others	
	91	Battery	
	92	Plating	
	93	Woodworking	
	94	Other Processing	
	95	Others	

accordingly. The staff members followed up with field visits after the questionnaires, and discussed with the persons in charge. 85% of the questionnaires sent were returned.

Further, 7 effluent samples suspected of bad quality were collected during the visits of the factories, which were analized by Department of Chemistry and Indus Laboratories. The Results are shown in ANNEX of the present report.

2.2.2. Findings of Wastewater Surveys

Concerning with water consumption and discharge, effluent quality, number of employees, and factory site area, the findings of the industrial wastewater surveys carried out independently by Ministry of Environment, LPKT-SP, and this Project Team mentioned above were summarized in Table E-6 with their factory code numbers. All of the data summarized in Table E-6 are based on year 1976 except some of water consumption data which is that of 1975 from PWA.

Malaysia Science University and LPKT-SP carried out a survey of small scale industry in Butterworth Town through the field visits in 1976. Table E-7 shows numbers of small scale factories in Butterworth, which are mainly Metal-processing, woodworking, motor-work-shop, and food factories. As most of these factories are as small as home size, it is expected that they would not cause any serious problems in terms of pollution. The similar situation prevails in the other Districts regarding the small scale factories.

TABLE E-6 The Summary of the Industrial Wastewater Surveys

	Quantity		Quality***		Employee	Site	Factory
	Q_c*	Q_d**	BOD	SS	No.	Area	Code No.
1	8,182.8	8,182.8	130.0	61.7	875	28.4	2-23-15
2	3,182.2	2,273.0	-	79.0	739	21.6	3-32-02
3	2,500.0	2,200.0	-	102.5	310	7.1	1-13-11
4	718.3	-	-	-	3,036	4.7	2-22-04
5	609.2	591.0	2.0	70.0	104	2.0	3-33-07
6	609.1	436.4	20.0	30.0	587	4.8	2-21-02
7	371.9	-	-	-	453	2.1	2-22-05
8	318.2	181.8	55.0	30.0	267	2.4	2-21-03
9	308.9	234.1	26.0	49.0	90	4.1	3-32-04
10	297.0	53.5	-	-	440	2.8	6-64-06
11	245.5	122.8	78.6	900.0	50	-	3-33-08
12	218.2	8.1	122.0	42.0	137	6.1	1-12-05
13	216.5	214.9	85.0	171.0	900	8.1	4-42-04
14	136.4	113.7	-	-	-	-	1-11-03
15	131.8	-	-	-	434	16.2	2-21-01
16	113.7	-	410.0	100.0	137	1.6	1-11-02
17	107.7	-	265.0	170.0	147	1.3	1-11-01
18	104.9	104.9	-	-	-	-	2-22-13
19	90.9	27.3	325.0	78.0	47	2.0	3-32-03
20	90.9	78.2	3.0	10.0	108	4.2	6-63-01
21	79.7	76.6	-	-	238	1.0	2-22-07
22	75.8	63.2	-	-	417	2.6	4-42-05
23	73.3	-	15.0	110.0	-	-	1-11-08
24	69.2	41.6	-	-	239	2.4	1-13-09
25	68.2	63.6	2,680.0	12,460.0	96	2.0	1-12-04
26	63.6	-	575.0	10.0	-	-	4-41-01
27	59.1	59.1	120.0	1,260.0	60	2.0	1-13-13
28	58.7	-	5.0	30.0	-	-	9-92-03
29	53.8	53.8	-	-	165	2.8	5-51-01
30	45.5	-	25.5	10.0	79	0.4	9-92-02
31	45.6	-	140.0	230.0	-	-	2-22-16
32	44.6		-	-	160	4.1	6-64-05
33	40.2	9.8	25.0	20.0	186	2.0	1-12-06
34	39.1	-	-	-	140	0.4	2-22-08
35	36.8	36.8	-	-	36	0.6	1-11-16
36	36.4	1.8	-	-	27	1.8	3-33-09
37	35.2	16.5	55.0	110.0	-	-	2-22-10
38	29.9	-	25.0	30.0	-	-	9-94-09
39	28.6	28.4	138.0	118.0	216	1.2	9-94-07
40	27.3	-	-	-	118	3.2	2-22-06

TABLE E-6 The Summary of the Industrial Wastewater Surveys (Continued)

	Quantity		Quality***		Employee	Site	Factory
	Q_c *	Q_d**	BOD	SS	No.	Area ****	Code No.
41	26.4	6.6	–	–	–	–	2-22-12
42	25.6	–	–	2,430.0	110	–	1-13-10
43	25.6	–	3.0	20.0	16	5.1	3-31-01
44	25.0	18.2	–	–	82	1.3	8-82-01
45	24.1	–	–	–	150	4.1	6-64-02
46	22.7	–	–	–	215	0.6	3-33-06
47	20.5		–	–	131	4.0	9-93-05
48	20.0	20.0	–	–	210	1.7	9-93-06
49	19.4		10.0	40.0	52	3.9	3-33-05
50	19.2	13.6	30.0	65.0	–	–	6-64-08
51	18.4	–	3.0	80.0	–	–	6-64-07
52	18.0	–	615.0	3,455.0	–	–	1-12-07
53	17.3	13.6	–	–	137	6.1	6-64-03
54	16.7	–	–	–	105	1.7	1-13-12
55	15.9	3.2	–	–	–	–	9-95-13
56	14.1	14.1	–	–	–	–	9-94-12
57	13.6	3.0	–	–	–	–	4-42-06
58	13.3	–	–	–	535	2.2	7-71-01
59	12.9	10.3	25.0	20.0	72	0.4	2-22-09
60	11.5	–	–	–	98	0.8	9-93-04
61	11.5	–	20.0	80.0	–	–	1-13-14
62	11.4	–	320.0	130.0	–	–	4-41-02
63	11.4	–	85.0	475.0	–	–	4-41-03
64	10.8	–	740.0	40.0	–	–	2-22-09
65	10.2	10.2	4.0	15.0	64	0.4	8-83-02
66	9.1	9.1	–	–	20	1.2	9-95-10
67	8.0	–	13.0	10.0	–	–	9-91-01
68	7.2	7.2	–	–	157	0.4	6-64-09
69	3.2	3.2	20.0	460.0	–	–	9-94-08
70	1.9	1.0	43.0	113.0	34	0.4	9-94-08
71	0.7	0.7	–	–	–	–	6-64-04
72	0.5	0.5	–	–	–	–	2-22-11
73	0.2	0.2	–	–	–	–	1-11-15

* Q_c : Water Consumption (cu m/day)

** Q_d : Water Discharge (cu m/day)

*** unit : mg/l

**** unit : ha

TABLE E-7 Number of Small Scale Factories in Butterworth

Class* No.	Types of Factories	No. of Factories	Remarks
1	Food	79	
2	Textile (Apparel)	22	
3	Chemicals	15	
4	Rubber & Plastics	31	Manufacturing
5	Stone & Clay Products	15	
6	Metals	121	Manufacturing
7	Precision Equipment	-	
8	Transport Equipment	83	Motor Work Shop
9	Others		
	Woodworking	94	
	Paper	19	Processing
	Printing	8	
	Others	67	
	General Service	15	
	Junk Yard	37	
	Store	28	

after Malaysia Science University and LPKT, SP, "Survey of Small Scale Industries in Butterworth Town" (1976)

* Industrial Classification Number (see Table E-5)

2.3 QUANTITY OF INDUSTRIAL WASTEWATER

2.3.1 Industrial Water Consumption

Review of the limited information through questionnaires carried out by LPKT-SP and NSC together with those by PWA-data enables to undertake assumption on the existing industrial water consumption in the Area.

Table E-9 and E-10 shows industrial water consumption per capita-employee and per factory-site-area by industrial classification. Although the number of samples are not enouth to estimate water consumption by each industrial classification, the figures of water consumption per employee and/or per site area indicates the characteristics of each industries. Both of the Tables E-9 and E-10 indicate that food-, textile-, and chemicals industries are water-demand type industries.

Average industrial water consumption per site area of major factories in the Project Area is shown in Table E-9. And total existing factory site area estimated in the Area is shown in Table E-8. Therefore, total industrial water consumption is estimated as:

$$105.6 \text{ (cu m/day.ha)} \times 386 \text{ (ha)} = 40{,}761.6 \text{ (cu m/day)}.$$

TABLE E-8 Existing Factory Site Area Estimated in the Project Area

(unit: ha)

Mak Mandin I.E.	Prai I.C.	Seberang J.C.	Others	Total
59	288	19	20	386

TABLE E-9 Water Consumption VS Factory Site Area

Class No.	Water Consumption (cu m/day)	Site Area (ha)	Per Unit Area Water Consumption (cu m/day.ha)	Samples No.
1	3,229.8	26.8	120.6	10
2	10,400.2	62.8	165.7	10
3	4,295.3	40.1	104.6	8
4	292.3	10.7	27.3	2
5	53.8	2.8	19.0	1
6	481.1	21.6	22.3	6
7	13.3	2.2	5.9	1
8	35.2	1.7	20.6	2
9	137.1	9.7	14.2	7
	18,938.4	179.4	105.6	47

TABLE E-10 Industrial Water Consumption per Capita Employee

Class No.	Water Consumption (cu m/day)	Number of Employees	Per Capita Water Consumption (cu m/day.cap)	Samples No.
1	3,255.7	1,564	2.08	11
2	10,400.2	6,220	1.67	10
3	4,540.8	1,340	3.39	9
4	292.3	1,317	0.22	2
5	53.8	165	0.33	1
6	481.1	1,152	0.42	6
7	13.3	535	0.02	1
8	35.2	146	0.24	2
9	137.9	788	0.17	7
	19,209.5	13,227	1.45	49

2.3.2 Industrial Wastewater Discharge

A part of industrial water used is lost by evapolation (boiler, etc.) and leakage, and the rest is discharged with and without pollutants. In this report, only polluted industrial wastewater is considered.

Industrial wastewater discharge is estimated on the following process to calculation.

(1) to calculate the water consumption per site area by using all data obtained (see Table E-9),

(2) to calculate the ratio of water discharge/water consumption by using all of the couple data obtained (see Table E-11),,

and then

(3) water discharge was calculated by (1) x (2),

that is, 105.6 (cu m/day. ha) x 0.861 = 90.9 (cu m/day. ha). So, total industrial wastewater discharged by existing factories in the Project Area is estimated at:

90.9 (cu m/day. ha) x 386 (ha) = 35,087.4 (cu m/day).

TABLE E-11 The Ratio of Water Discharge/Water Consumption by Industrial Classification

	Food	Textile	Chemical	Others	Total
Water Consumption (C)	3,081.5	9,373.9	4,472.6	919.4	17,847.4
Water Discharge (D)	2,496.1	9,019.1	3,250.0	608.4	15,373.4
Ratio (C/C) %	81.7	96.2	72.7	66.2	86.1
No. of Samples	8	9	6	18	41

2.4 Quality of Industrial Wastewater

As shown in Table E-6, industrial wastewater quality varies between 2.0 to 2,680 mg/l of BOD and between 10 to 12,460 mg/l of SS, depending upon the difference of industry type and wastewater qualities of each factories. Average wastewater qualities of each industry types are shown in Table E-12.

TABLE E-12 Average Wastewater Quality of Each Industry Types

		Food	Textile	Chemical	Others
Average Concentration (mg/l)	BOD	200	122	73	67
	SS	399	58	106	127
Waste Water	(cu m)	2,341	8,828	3,248	336
	(%)	16	60	22	2
Amount of Waste (kg/day)	BOD	468	1,077	237	26
	SS	934	516	345	43
No. of Sample		5	5	5	6

The estimated quality of industrial wastewater is 122 mg/l of BOD and 125 mg/l of SS as shown in Table E-13. Thus, unit wastewater production, which is defined as the amount of wastes produced per site area, was estimated at :

BOD : 122 (g/cu m) x 90.9 (cu m/day. ha) = 11,089.8 (g/day.ha)
say 11 kg/day. ha

SS : 125 (g/cu m) x 90.9 (cu m/day. ha) = 11,362.5 (g/day. ha)
say 11 kg/day. ha

So, total amount of BOD and SS produced by existing factories in the Project Area were estimated at :

11 (kg/day. ha) x 386 (ha) = 4,246 (kg/day) of BOD and SS respectively.

TABLE E-13 Unit Wastewater Production

Concentration*		Volume**	Unit Production***	
BOD	SS		BOD	SS
122	125	90.9	11	11

* mg/l
** cu m/day per site area
*** kg/day per site area

2.5 ESTIMATION OF FUTURE INDUSTRIAL WASTEWATER PRODUCTION

Major industrial development in the Project Area is concentrated in three areas. After completion of development, the total of the industrial areas will be 1,242 ha, of which approximately 40% has already been occupied by existing factories under operation.

Although detailed planning for the whole industrial areas has not been completed, it is possible to estimate the future condition by studying existing industrial areas on the basis of assumption that the constituent of industrial classification will be kept identical even in the future.

The results of questionnaire survey including visits of major factories representing each industry types shows that most of major factories are almost fully working in their capacity, and that the factories under operation and/or construction are equiped with fully advanced installations, which warrant that the unit wastewater production in the future would remain to be constant in the foreseeable future in spite of the accelated industrialization programme.

On the basis of the above assumption, followings are considered reasonable prediction of the future unit industrial wastewater production:

(1) Increase of industrial wastewater volume would be within 10% in unit area production,

(2) BOD produced by some food factories would be reduced by improvement of their processing, but total BOD produced by entire factories would increase about 30% in unit area production as area-productivity is increased.

(3) The ratio of BOD/SS is nearly equal to 1 in the present whole industrial condition in the Project Area, and this is similar to the value of highly industrialized countries. Therefore the ratio in considered to be kept the same in the future.

(4) Total factory site area is considered to occupy 80% of whole industrial area in the future.

The future industrial wastewater production by unit industrial area is estimated as shown in Table E-14.

TABLE E-14 Future Unit Wastewater Production

Concentration*		Volume**	Unit Production***	
BOD	SS		BOD	SS
150	150	80	12	12

* mg/1

** cu m/day. ha

*** Kg/day. ha

CHAPTER 3

EXTRANEOUS WATER

In spite of the fact that a sewerage system is designed sewage only, because of many thousands of pipe joints, manholes and inspection covers, etc., a certain amount of extraneous water will find its way into the sewers.

In view of these conditions, for the separate sewers, an infiltration allowance is considered in determining sewer capacities. The inflitration allowance, 18 cu m/km/day, is considered to be a fair estimate of the extraneous flows to sewers, including ground water and surface water infiltration frim public sewers and house connections through broken manholes, etc. This should be adequate since the sewer joints specified for the project are of rubber ring type for concrete pipes and of the factory applied resident type for clay pipes, both types affording an almost bottle-tight system.

The infiltration allowance, 18 cu m/km/day, was based on analysis of infiltration from George Town Sewerage Study*. George Town Sewerage Study used figure of 0.002 cubic feet per second per acre for infiltration. This is equivalent to 12 cu m/ha/day. In consideration of these conditions, we recommend that an allowance of 18 cu m/km/day be allowed in addition to peak sanitary sewer flow, and an infiltration allowance by land use was calculated as follows:

Infiltration Allowance by Land Use

Land Use	Total Sewer Lenght	Infiltration Allowance	
Residential			
High density	600 m/ha	18 cu m/km/day	12 cu m/ha/day
Low density	450 "	"	8 "
Industrial	250 "	"	5 "

* George Town Sewerage Study: A Colombo Plan Project for the Government of Canada and the Government of Malaysia, Nov. 1968

TABLE E-15 The Findings of Survey for Domestic Wastewater Quantity and Quality (Residential Area - 1)

Time	Q	WT	pH	DO	BOD	COD	SS	Cl^-
	cum/d	C		ppm	ppm	ppm	ppm	ppm
7:40	-	-	-	-	365	195	30	16
8:30	6.2	23.8	6.5	2.0	360	455	47	41
9:30	24.8	23.8	6.9	2.4	285	195	39	31
10:30	16.9	27.9	7.8	1.1	300	325	49	29
11:30	19.3	26.4	7.1	1.5	130	195	24	25
13:30	26.2	28.1	5.5	2.3	180	195	24	44
15:30	12.9	27.6	5.3	2.0	315	115	34	37
17:30	18.1	27.0	6.3	0.7	225	155	38	26
18:30	19.3	26.8	6.5	1.2	215	80	23	29
19:30	20.6	26.5	6.8	0.9	240	80	18	37
21:30	7.5	25.9	7.2	0.7	370	115	16	35
23:30	4.4	24.9	6.8	0.3	195	155	34	43

Q	Quantity of Water Flow
WT	Water Temperature
DO	Dissolved Oxygen
BOD	Biochemical Oxygen Deamnd
COD	Chemical Oxygen Demand
SS	Suspended Solids
-	not measured

Note Date : 7 Dec. 1976

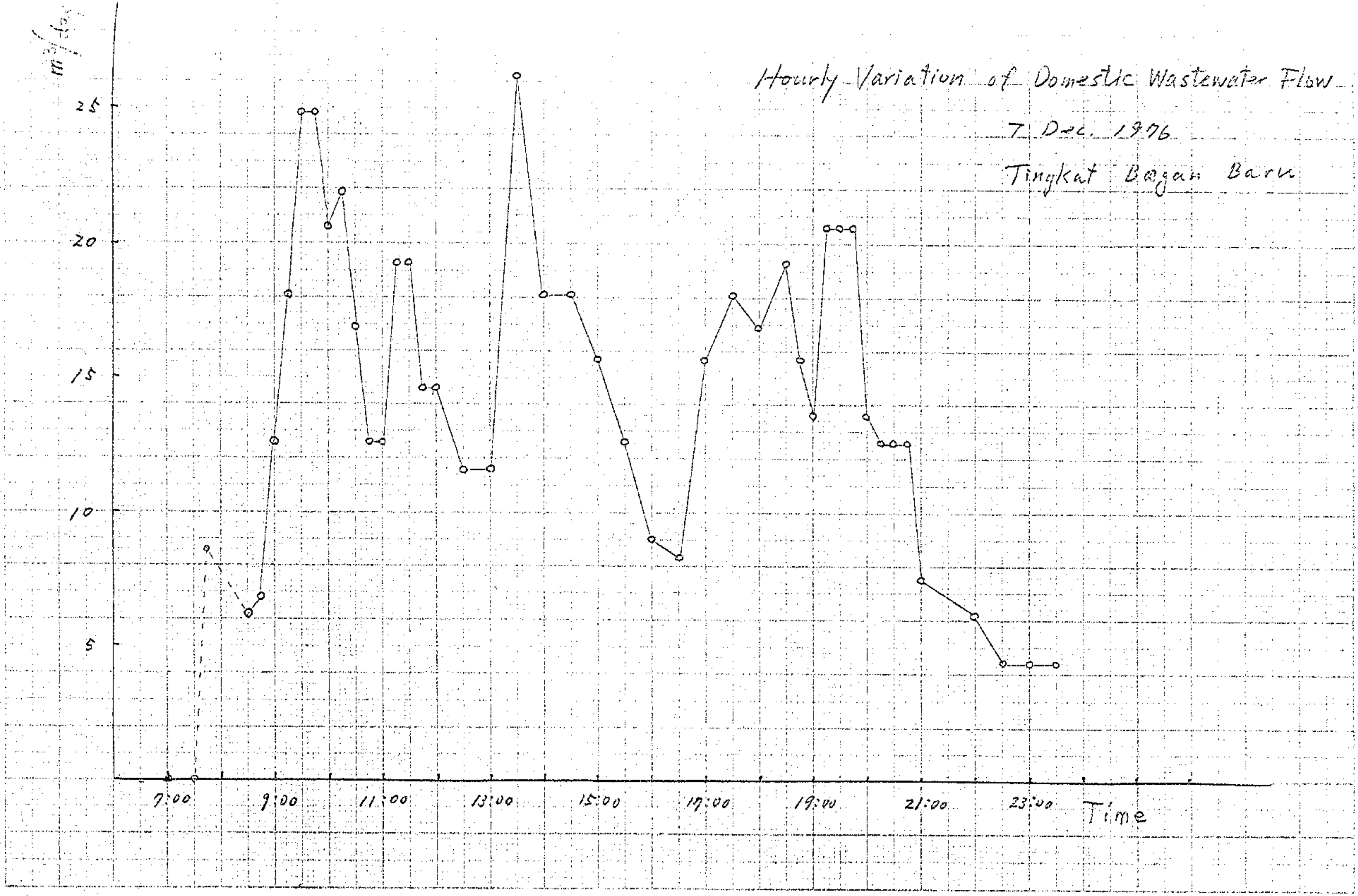
Location : Tingkat Bagan Baru Sepuloh, Butterworth

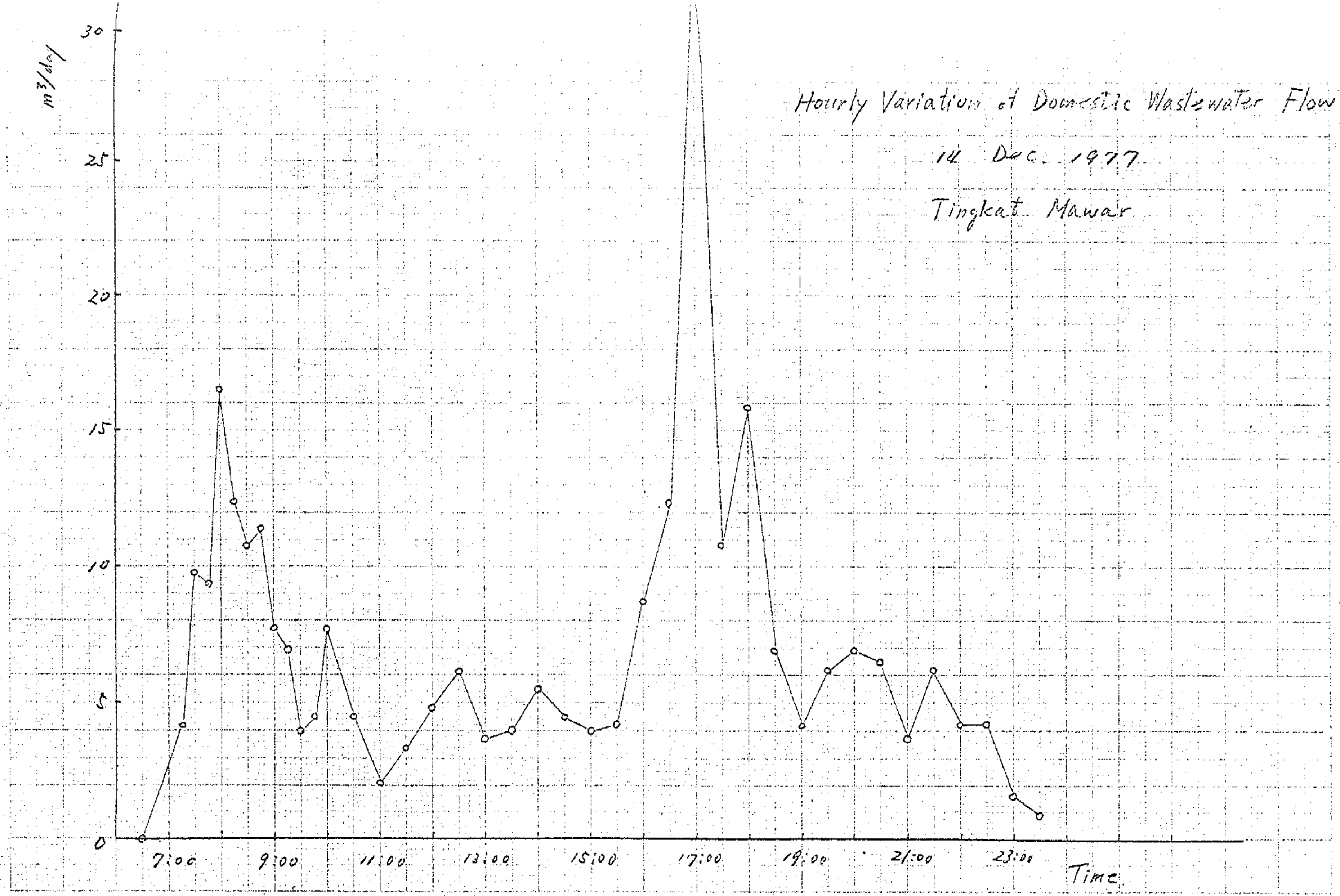
TABLE E-16 The Findings of Survey for Domestic Wastewater Quantity and Quality (Residential Area - 2)

Time	Q cu m/d	WT C	pH	DO ppm	BOD ppm	COD ppm	SS ppm	Cl^- ppm
7:30	9.8	26.8	7.2	4.5	105	135	25	34
8:30	10.8	27.0	6.8	4.3	275	145	14	51
9:30	4.0	27.1	6.7	3.9	110	190	35	27
11:30	3.4	28.9	6.2	3.5	125	135	42	70
13:30	4.0	30.6	6.2	4.1	195	180	21	37
15:30	4.2	29.6	7.0	1.5	320	495	86	61
17:30	10.8	28.6	6.7	4.8	255	145	26	43
19:30	6.2	28.4	-	-	320	360	94	64
21:30	6.2	-	-	-	265	450	85	102
23:30	0.9	-	-	-	140	180	31	60

Q Quantity of Water Flowing
WT Water Temperature
DO Dissolved Oxygen
BOD Biochemical Oxygen Deamnd
COD Chemical Oxyten Demand
SS Suspended Solids
\- not measured

NOTES Date : 14 December 1976
Location : Tingkat Mawar Dua, Butterworth


Hourly Variation of Domestic Wastewater Flow
7 Dec. 1976
Tingkat Bagan Baru
25
20
15
10
5
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
Time



Hourly Variation of Domestic Wastewater Flow
14 Dec. 1977
Tingkat Mawar
m³/day
30
25
20
15
10
5
0
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
Time

Date on Domestic Sewage by Home Visiting

For the purpose of the survey on domestic water consumption rate, questionnaires were prepared and directed to the selected household in the Project Area. The information obtained is usefully employed in determining per capita sewage flow rate projection.

Table C shows domestic water consumption rates together with average income level according to the differnt types of house accomodation.

TABEL C Per Capita Water Consumption Rates

Water Consumption		Number of Households			
1/day.cap		Lower	Midium	Higher	Total
less than	100	1	4	0	5
101 -	150	5	12	1	18
151 -	200	5	11	1	17
201 -	250	3	5	2	10
251 -	300	3	6	1	10
301 -	350	0	2	2	4
351 -	400	0	2	0	2
more than	401	1	6	1	8
Total house No.		18	48	8	74
Average Water Consumption		181	190	269	196

APPENDIX F

WATER POLLUTION STUDIES

APPENDIX F

Water Pollution Studies

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Annex F-1 - F-41

1. SUMMARY

Existing conditions of aquatic environment focused upon the water qualities of the rivers and water-ways consisting of "monsoon" drains and road-side ditches in the Project Area, and the Penang Channel receiving the run-off waters of the rivers and drains in the area are described in this APPENDIX

There are two rivers, the Prai and the Juru, receiving the waters discharged from the towns and villeges, industries, wet rice fields, rubber and palm-plantation forests, and from natural forests where pig-farms and poultry-farms are existing. Both of the rivers are strongly affected by tidal movements of sea water level, so that all the part of the Prai included in the Project Area and the part of the Juru upto the tidal gate are raided by sea water of the flood tide.

As the tidal water wash out pollutants from the rivers, the water qualities fo the river monthes are not noticeably polluted except during the short period of the end of ebb tide, the BOD values remaining between 1 to 7 mg/l, with the average of less than 4 mg/l. as of 1976. During the short period of the end of ebb tide, slightly polluted waters flow into the sea, but they flow on thin layers, with scraps of plants and other similar matters.

Most of drains together with "monsoon" drains and road-side ditches are polluted by domestic sewage in the town areas and by industrial wastewater near factories. Especially, the drains of the Butterworth-Whalves, the Butterworth-No.3, the Mak Mandin, the Derahaka, and the Prai Industries, together with the tidal gate area of the Juru are extremely polluted, so that very little dissolved oxygen makes the water colour blackish, the smell of hydrogen sulfide abundant, and the black sludge sedimented on the bottom.

As the drains of town areas are receiving the effluents of septic tanks, most of them are polluted by colliform bacteria. This indicates that the current use of these drain system for communical sanitary facility is not satisfactory, although they are serving for protection of the living condition from flooding water.

The sea water of the Penang Channel is not heavily polluted by organic pollutants, according to our survey, although it is turbid by silty materials from rivers, and floating matters from George Town and Butterworth, such as woods, plastics, etc., are found. Only the river mouth areas and the outfall point of George Town sewerage system are polluted by coliform bacteria.

The tidal currents are very strong in the Penang Channel, southwards at flood tide and northwards at ebb tide. The verocity is roughly estimated at approximately 80 to 100 cm/sec.

On the overall aspects of aquatic environment in the Project Area, non-concentrated desposal of sewage was successful for reducing environmental desruption in the Butterworth area, while, in the Bukit Mertajam area, most of wastewater including domestic and industrial, wastes, together will devise from the pig farms are concentrated into the Juru river, which are causing pollution in the Juru river. Currently the tidal currents are serving to flush out pollutants from the Penang Channel, but the future, as the urbanization and industrialization of the Project Area increase, the waste loads will proportionalety the become quater to make aquatic environmental condition of the level of serious concern for health and welfare of the population, for which careful preventive plan has to be worked out and implemented at the earliest possible date.

2. DISCRIPTION OF AQUATIC ENVIRONMENT

2-1 General

The Project Area extends over the alluvial plain of the Prai River and the hill of Bukit Mertajam. A half of the area is located in the flat area of the former, and the rest is included in the Juru River basin which originates from the latter. (see Figure F-1).

Both of the rivers are affected by tidal movements of sea water level, and have wide swamps which are also included in tidal area, and are being reclamed for the purpose of developing the Project Area. The rivers receive waters of their tributaries and drains for discharging rain water, irrigation water, sewage, effluent of septic tank, and industrial wastewater.

Rain fall in the area is approximately 2700 mm annual*, and its seasonal variation between rainy and dry seasons is small.

Air temperature is very stable throughout the year in this State, average 26.8 C*, and annual difference is within 9C.

The Malacca Strait has strong tidal steams ranging from 26 to 100 cm/sec in daily maximum. **The tidal stream of the Penang Channel itself is also strong, and its maximum verocity is roughly estimated approximately as 80 to 100 cm/sec.

The mean tidal range is approximately 1.5 m at Penang Port**.

The depth of the channel is very shallow, write maximum of 23 m deep.

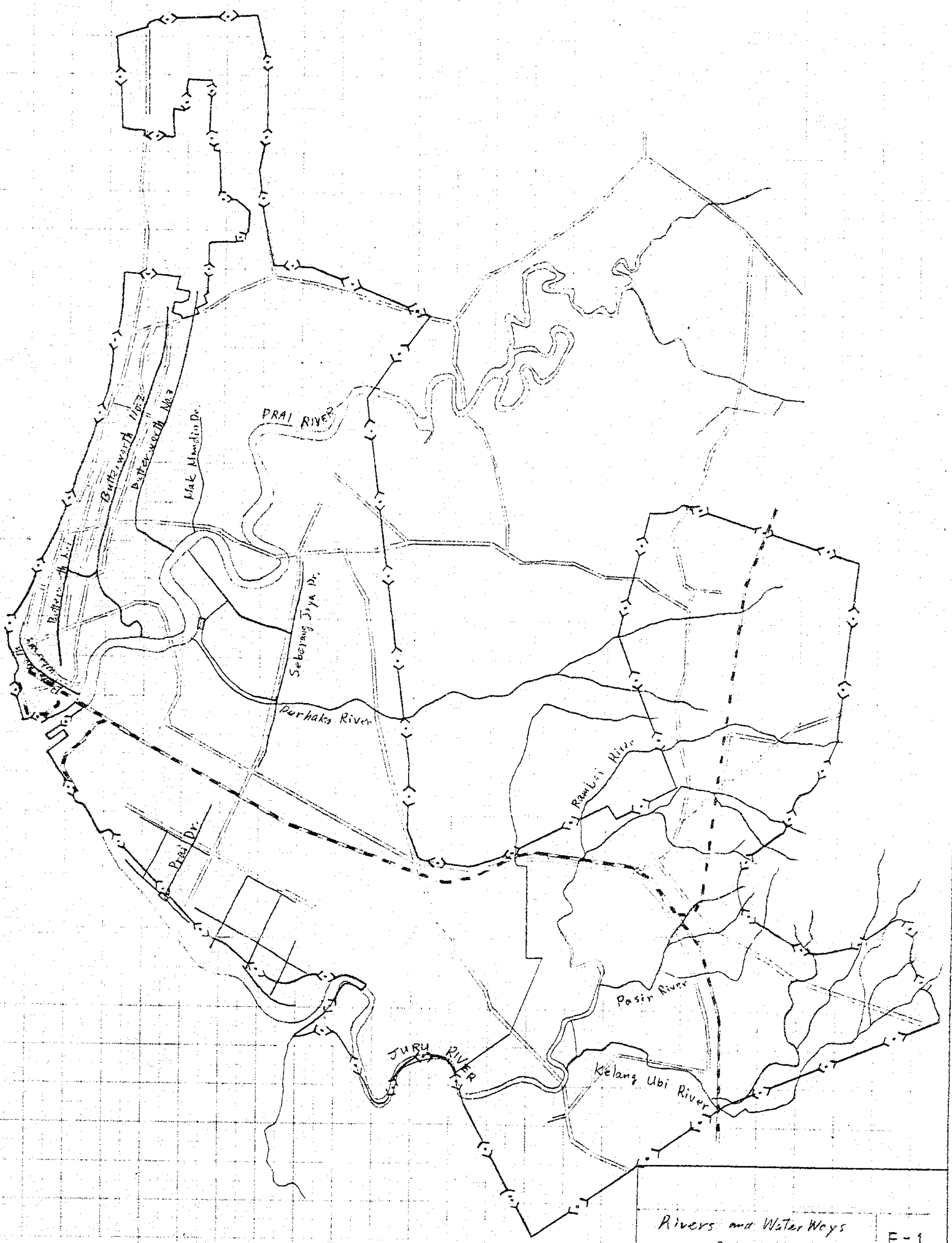
---

* "Feasibility Report on Drainage and Reclamation of Sg. Prai Basin in Malaysia", JICA (1968)

** Tide Table", Habour Master. (1976)

As the whole area of the Penang Channel is designated as a port area, fishing activity is negligible in the Channel. The Penang Port is one of the most important trading port in Malaysia in spite of its whallowness, and it is under expansion and improvement of its facilities at George Town and Butterworth Whalves Area.

Although there is no particular recreational area along the Butterworth-Prai beach, the Butterworth beach is often used for bathing and fishing by the people living along the beach on holidays, and the zones along Juru river-mouth and the air port are used for fishing by fixed nets. (see Figure F-1).



Rivers and Water Ways in the Project Area

F-1

2-2 SURVEY ON RIVERS AND WATERWAYS WATER QUALITY

2.2.1 Sampling and Analysis

Water quality of rivers and waterways in the Project Area were surveyed by the project team on December, 1976.

Sampling points are shown in Figure F-2.

Most of the samples were collected at surface, and water temperature, pH, dissolved oxygen, and electric conductivity were measured at the site by potable "water quality checker". The samples collected from the Prai were analyzed on suspended solids, chemical oxygen demand, coliforms and chlorides in laboratory.

The analytical methods used were as follows:

COD	:	potassium permanganate method, 27°C 4 hours
SS	:	glass fiber filter method
Coliforms	:	desoxycholate method
Chlorides	:	silver nitrate titration method
Hidrogen Sulfide	:	filter colorimetry by zink acetate

The Juru River and its tributaries were surveyed by the Ministry of Environment, the findings of which are refered in this chapter.

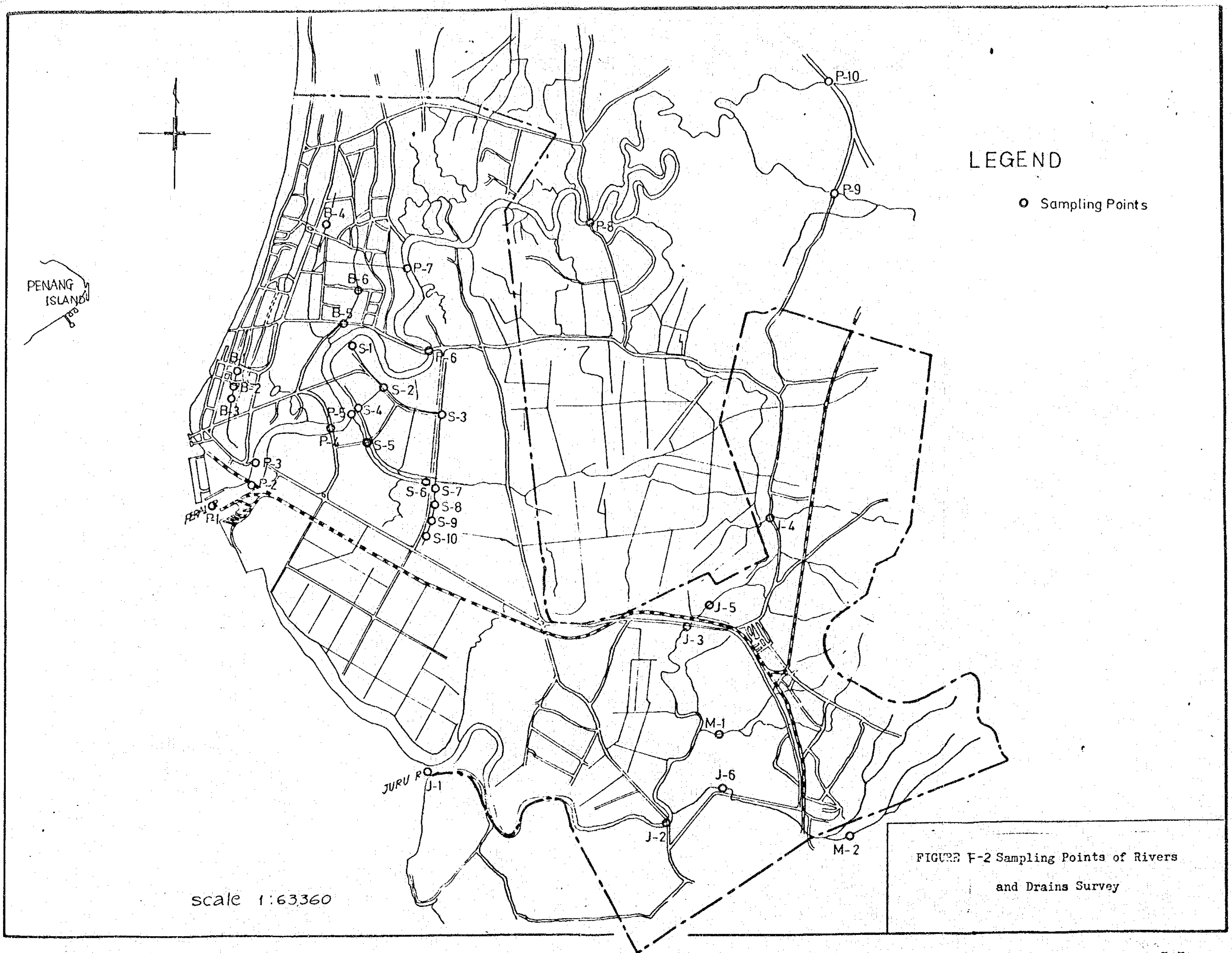


FIGURE F-2 Sampling Points of Rivers and Drains Survey

2.2.2 Findings of the Survey

The results of water quality analyses are shown in Table 2-1.

(1) Water Temperature

As shown in Table 2.1, water temperature of rivers and drains vary according to their flowing condition, higher in slack waters, lower in rapid streams. The highest temperature, 34.4 C, was recorded at the Butterworth Drain-No.1, according to our Master Paln, during the survey on December. As the hottest season of the State is between February to May, the annual highest temperature of drains may be more than 37 C. The average water temperature of the Prai River was 28.4 C.

In general, water temperature of natural waters in the Project Area is, in all seasons, suitable for bacterial activity to decompose organic load.

(2) Electric Conductivity

Electric conductivity, which is a indicator of tidal water penetration to the streams, indicates that, at flood tide, tidal water comes up to the point No. P-7 which is located at about 10 km of upstream from the river mouth. Further, tidal variation of water level is observed at the point No. P-10 which is located at more than 20 km of upstream from the river mouth.

In case of the Juru River, as the tidal gate has been constructed at the Tuan Abdul Rahaman Bridge, the sampling point No. J-2, tide water is stopped at the gate, so that electric conductivity of the up stream water from the point No. J-2 are low. (Table F-1).

(3) DO

The levels of dissolved oxygen is shown in Figure F-3. Zero (less than 1 mg/l.) DO concentrations we are recorded for the drains of the Butterworth-Shalves, -No.1, -No.2, the Mak Mandin, the Derahaka, and the Prai Industries, and the tidal gate area of the Juru. This sudden decrease of DO is due to organic loads included in domestic, industrial, and pig farm wastewaters. The colour of the lower stream of the drains is changed to blackish, and black ooze is accumulated in the area referred above. This is the results of successional reactions, namely, organic loads, oxygen consumption, sulfate reduction, sulfide formation, and then ferous sulfide (black) accumulation. Further formation of sulfide leads to bad smell, releasing hydrogen sulfide.

After discharged into the rivers, the conditions are rapidly recovered by the flashing-out effects of tidal movements. However, tidal gate of the Juru is interfering the flashing-out of the upper streams, so that accumulation of the upper stream pollution is accelerated.

The water temperature of the Seberang Jaya drains averaged about 30 ℃ during the survey gives a DO saturation value of 7.5 mg/l. The DO content of the waters at the sampling points, No.1, 2, 3 and 11 was more than the saturation value (Table F-1). This is due to photosynthesis of aquatic plants in the slack waters of the drains, and due to scarce organic loads. If organic loads discharged into the slack waters, the DO content may be greatly decreased as in case of the points No.7 to 9. This is a shortcoming of slack water in the drains.

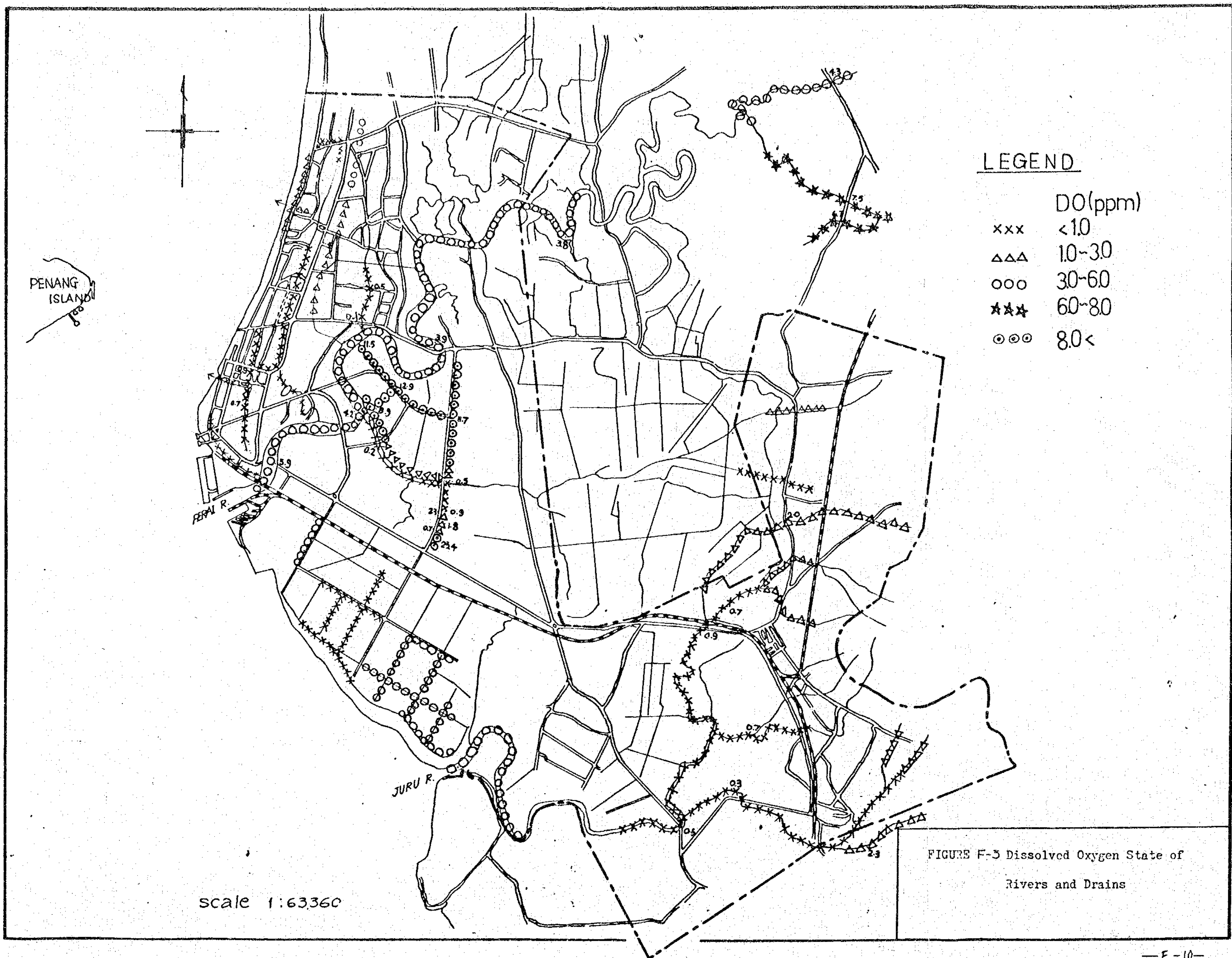


FIGURE F-3 Dissolved Oxygen State of Rivers and Drains

4) BOD & COD

According to the findings of the Juru River Pollution Survey, in spite of discharging heavily polluted waters at the upper tributaries from the tidal gate, the BOD and COD values are comparatively low. This may be explained by tidal flashing. The same effect can be expected at the Prai River because of comparatively low COD contents although the data are very limited (Table F-1).

TABLE F-1 Water Quality of Rivers and Drains in the Project Area

No. of Station	Date/Time	WT	pH	EC	DO	COD	SS	Cl⁻	Coli-forms
		C			ppm	ppm	ppm	ppm	N/ml
P-1*	16 Dec.13:00	28.6	7.3	32.5	5.2	3.4	15	9500	-
P-1**	17 Dec. 7:45	27.1	7.0	41.9	6.0	1.8	8	14700	-
P-2**	9 Dec.16:20	28.9	8.3	47.2	8.4	-	-	-	-
P-3*	3 Dec.14:20	32.2	6.0	41.3	5.3	8	303	12190	138
P-4**	9 Dec.15:55	29.3	8.2	45.1	8.7	-	-	-	-
P-5**	4 Dec. 9:57	27.7	6.9	28.2	4.2	-	-	-	-
P-6**	4 Dec.10:10	27.7	6.7	22.6	3.9	3	15	7160	561
P-6**	9 Dec.14:00	28.4	7.6	32.2	4.4	-	-	-	-
P-7**	9 Dec.15:00	29.2	7.7	27.1	5.2	-	-	-	-
P-8**	4 Dec.11:00	27.2	6.8	0.1	3.8	2	20	222	25
P-9**	4 Dec.11:40	25.8	7.2	0.4	7.5	1	21	9	110
P-10**	4 Dec.11:45	28.2	6.7	0.4	4.3	1	11	8	43
J-1*	5 Dec. 9:20	27.4	6.6	37.2	3.6	-	-	-	-
J-1**	17 Dec. 8:44	26.7	7.8	43.6	6.9	3.3	62	15600	15
J-2*	5 Dec. 8:50	27.9	6.2	3.8	0.5	-	-	-	-
J-3**	5 Dec.12:30	28.4	6.5	0.1	0.9	-	-	-	-
J-4**	5 Dec.12:55	26.6	6.6	0.2	2.0	-	-	-	-
J-5**	5 Dec.11:35	30.1	5.8	0.5	0.3	-	-	-	-
J-6**	5 Dec.12:40	27.7	6.5	0.2	0.7	-	-	-	-

To be continued

* low tide

** high tide

TABLE F-1 Water Quality of Rivers and Drains in the Project Area (Continue)

No. of Station	Date/Time	WT	pH	EC	DO	COD	SS	Cl$^-$	Coli-forms
		C			ppm	ppm	ppm	ppm	N/ml
B-1	7 Dec.14:30	33.4	5.8	0.6	0.9	-	-	-	-
B-2	7 Dec.14:45	34.4	6.6	0.6	0.7	-	-	-	-
B-3	7 Dec.15:00	33.4	6.7	0.6	0.7	-	-	-	-
B-4	14 Dec.18:30	28.8	7.0	0.5	1.1	-	-	-	-
B-5	3 Dec.15:00	31.3	6.2	4.8	0.1	-	-	-	-
B-6	3 Dec.15:10	33.7	6.2	0.5	0.5	-	-	-	-
S-1	3 Dec.15:50	30.7	6.4	8.1	11.5	-	-	-	-
S-2	3 Dec.15:45	30.7	6.4	2.6	12.9	-	-	-	-
S-3	3 Dec.14:40	31.8	6.6	0.2	11.7	-	-	-	-
S-4	3 Dec.15:58	28.5	6.6	0.2	0.2	-	-	-	-
S-5	3 Dec.16:10	28.2	6.2	0.7	0.5	-	-	-	-
S-6	3 Dec.16:15	31.4	6.1	0.1	0.5	-	-	-	-
S-7	3 Dec.16:40	30.5	7.8	0.6	0.9	-	-	-	-
S-8	3 Dec.16:35	27.7	7.8	0.1	2.3	-	-	-	-
S-9	3 Dec.16:30	32.0	7.9	0.4	0.7	-	-	-	-
S-10	3 Dec.16:32	32.3	7.9	0.3	1.8	-	-	-	-
S-11	3 Dec.16:25	33.5	8.5	0.6	21.9	-	-	-	-
M-1	5 Dec.11:40	28.4	6.5	0.3	0.7	-	-	-	-
M-2	5 Dec.10:00	24.7	7.3	0.3	2.3	-	-	-	-

2-3 SURVEY ON SEA WATER QUALITY

2-3-1 Sampling and Analysis

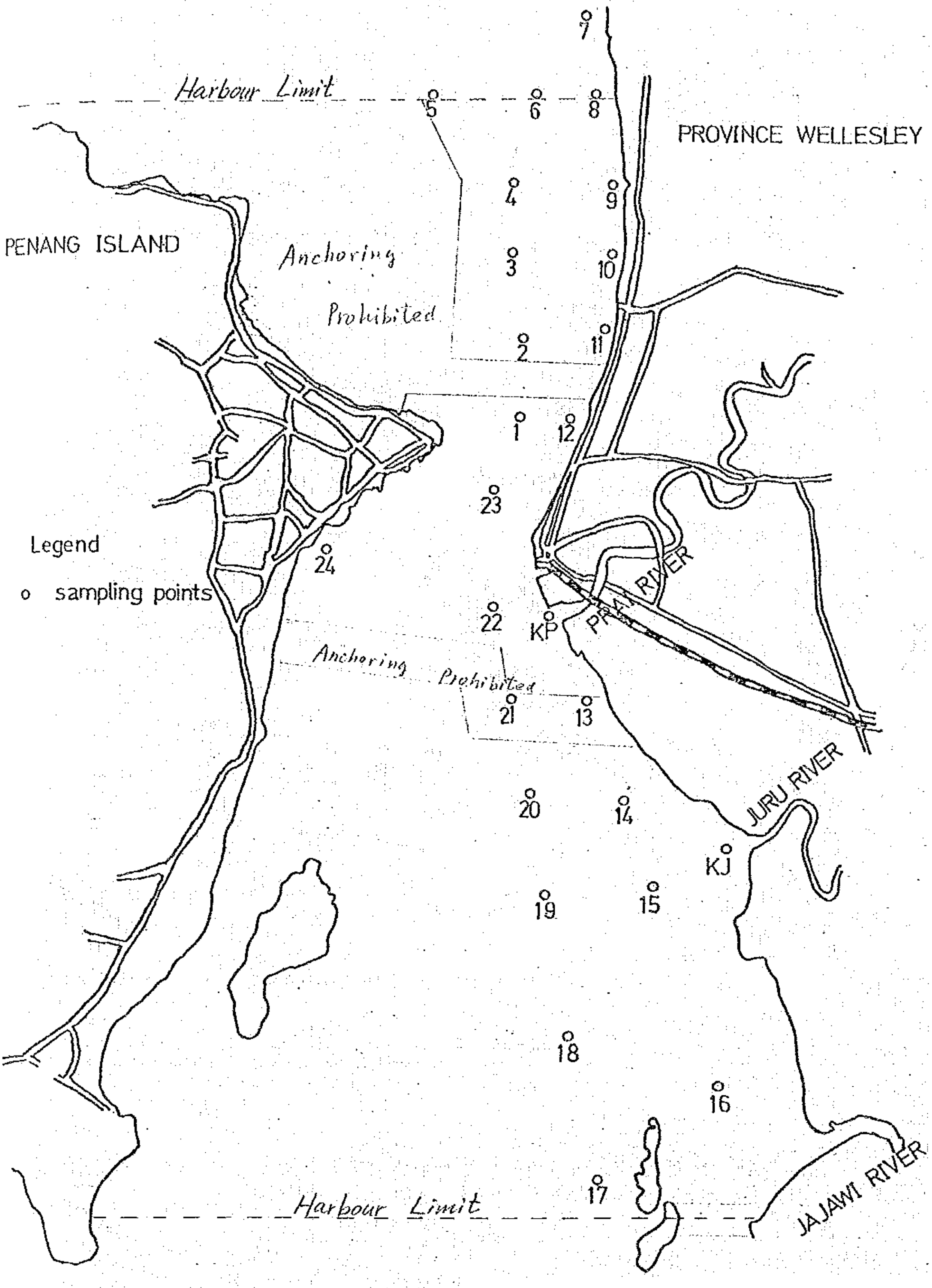
Sea survey was carried out on December, 1976, along the east coast of the Penang Channel extending from the river mouth of the Prai to about 13 km south and north respectively (see Figure F-4). The sea water samples were taken at the surface at 26 points as shown in Figure , and analyzed for ;

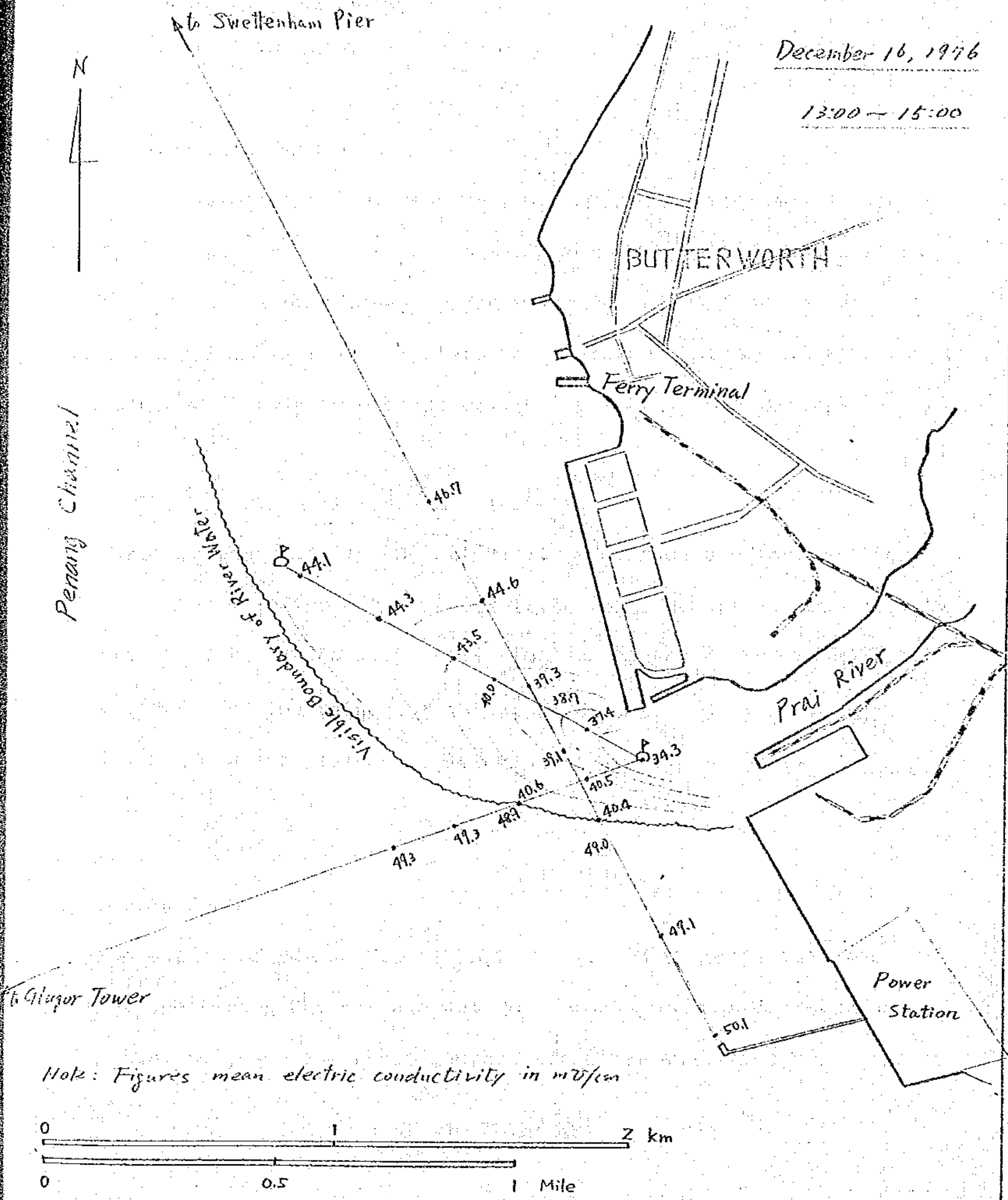
1. Water Temperature (WT)
2. pH
3. Electric Conductivity (EC)
4. Dissolved Oxygen (DO)
5. Chemical Oxygen Demand (COD)
6. Chlorinity
7. Suspended Solids (SS)
8. Choliform bacteria (Choliforms)

WT, pH, EC, and DO were immediately tested after sampling by potable "water quality checker". The other components were analyzed at the laboratory facility as soon as possible after they were brought back in the town.

Analytical methods used were the same ones as mentioned in Section 2-2.

FIGURE F-4 Sampling Points of Sea Survey





SEWERAGE AND DRAINAGE SYSTEM PROJECT,
BUTTERWORTH/BUKIT MERTAJAM METROPOLITAN AREA,
MALAYSIA

Freshwater Runoff from Prai River at Ebb Tide.	FIGURE F-5

2-3-2 Findings of the Survey

The results of water quality analyses are shown in Table 2-2 .

(1) Water Temperature

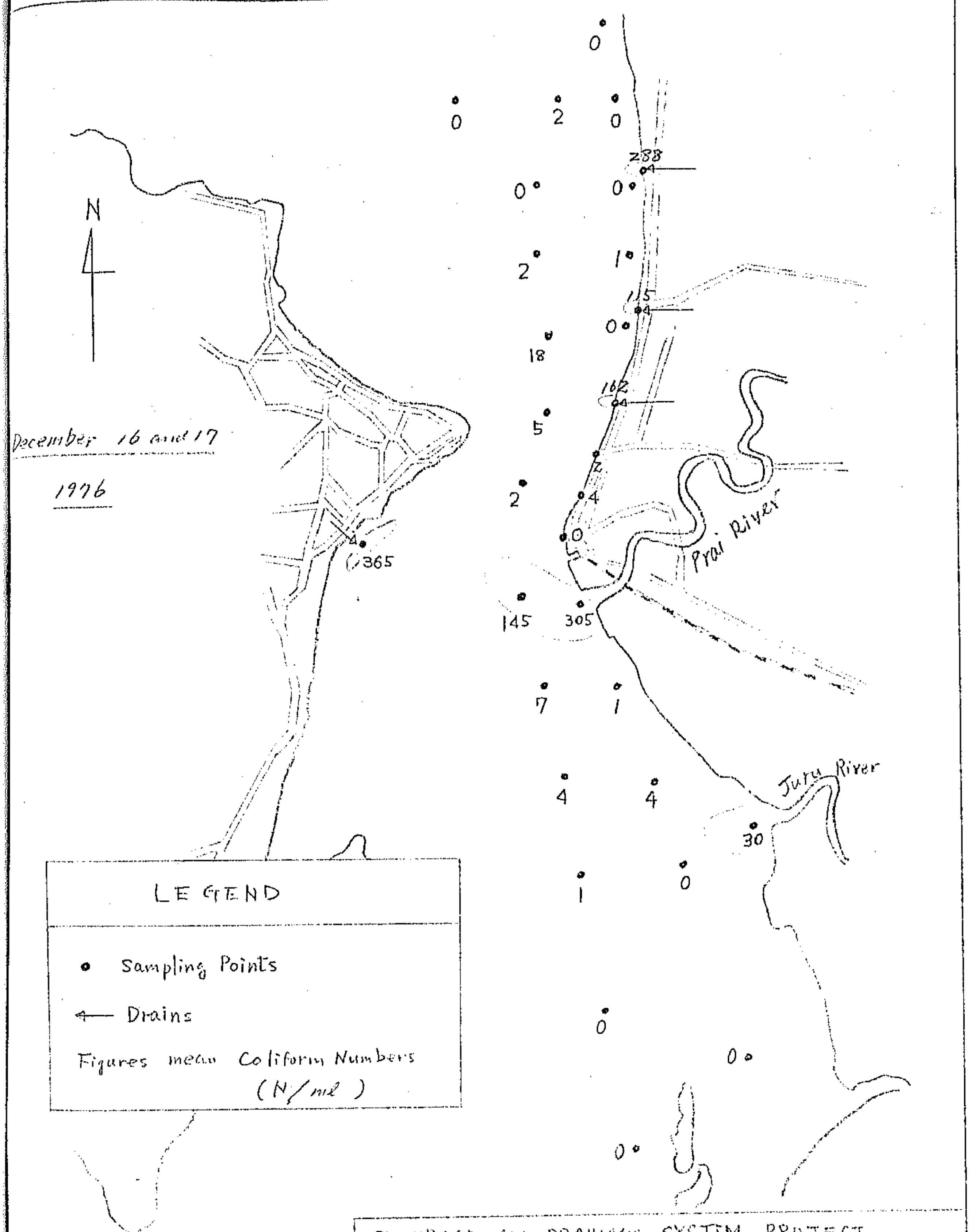
The surface water temperatures obtained during the survey were 26.5 to 28.6 C, and rose in the morning in company with the sun rising. The diurnal variation of the surface water temperature may be more than 2.5 C. This diurnal tempeture variation and strong tidal currents mentioned above would accelerate vertical mixing of sea water.

(2) Electric Conductivity and Chlorinity

Electric conductivity and chlorinity are indeces of penetration of fresh water into the sea. The distribution of electric conductivity (Figure F-5) shows the fresh water feather of the Priver run-off at ebb tide. The low values of the sampling points 8, 13, 15, 16, 22, KP, and KJ are explained by dilution of sea water by river waters.

(3) DO and COD

The values of DO and COD as shown Table F-2 indicate that the water of the Penang Channel has not yet been heavily polluted by organic pollutants, but,near the river mouths, the water qualities are slightly worse, FIGURE



SEWERAGE AND DRAINAGE SYSTEM PROJECT, BUTTERWORTH/BUKIT MERTAJAM METROPOLITAN AREA.	
Distribution of Coliforms in Penang Channel	FIGURE F-6

(4) SS and Floating Matter

The results of analysis shows that the concentration of SS is lower off shore than near shore. This may be due to vertical mixing of shallow bottom material by strong tidal currents and waves. The sub-surface waters at both of the river mouths, the Prai and the Juru, keep higher SS concentration than the surface waters. This may be also due to turbulence of tidal movements.

As the whole sea area surveyed included in the Penang Port Area, many floating matters were found which included plastics, wood fragments, and other floatables desposed of from the ships, or flowed out of rivers and drains from George Town, Butterworth, and other towns. These floatables are found up to the sampling points 5, 18 and further on current lines.

(5) Coliforms

In spite of discharged wastewaters from George Town, Butterworth, and other town area, the concetration of coliforms was comparatively low in the sea water except near the river mouth of the Prai and at the outfall point of the sewage from George Town. The results of coastal water survey on coliforms also shows that coliform contamination appears only in the water near sewer discharge as shown in Figure F-6.

For the purpose of referrence, a few notable standard of the world are described herewith;

The WHO criteria are based on fecal coliforms, and suggest a limit of 0.5 coliforms/ml. for a satisfactory marine bathing water, and consider that fecal coliform concentrations between 0.5 to 2 cells/ml. indicate slight pollution, between 10 to 20 cells/ml. distinct pollution, and more than 20 cells/ml. heavy pollution.

A review of available information indicates that the California standard (10 to 100 total coliforms/ml), while effective, is quite conservative, and that the Brazil standard of 100 total coliforms/ml. may prove to be resonable for use in developing nations with limited financial resources*.

(6) Miscellaneous

a) Plankton

Planktonic blooming often appears along the shore in the Penang Channel. Redish motile type plankton is dominant in the bloom, and gathers in the surface thin layer. The patch of the bloom are comparatively small, approximately 1 to 2 km long, 0.5 to 1 km wide, and the chlorophyll a content, which is a good index of the standing crop of phytoplankton, of the water was not so high, 0.4 mg/cu m on December, 1976.

b) Bottom Condition

The bottom conditions of the Penang Channel were observed at the same time when water quality survey was carried out on December, 1976. The bottom condition in front of the Prai Industrial Complex is silty mud, which might have been accumulated by tidal currents for a long time. This silty mud is grayish, and does not include black organic ooze and/or coalblack mud, but slightly smells of hydrogen sulfide. The sediments of the river mouths of the Prai and the Juru are also grayish silty

* "Criteria for Marine Waste Disposal in Southeast Asia"
"H.F. Ludwig (1973)

clay, and not highly polluted in spite of receiving coalblack waters and muds from their tributaries. This may be ude to the effects of tidal washing out. The most part of the Butterworth beach is sandy.

TABLE F-2 The Results of Seawater Analyses (The Penang Channel)

No. of Station	WT	pH	EC	Chlori- nity	DO	COD	SS	Coli- forms
	°C		ms	‰	ppm	ppm	ppm	N/ml
1	27.1	7.7	47.7	18.4	6.8	1.6	3	5
2	27.3	7.9	46.7	18.4	6.8	1.3	14	18
3	27.6	8.0	47.9	17.0	6.8	1.2	9	2
4	27.5	8.0	47.8	17.3	6.8	1.1	5	0
5	27.4	8.0	48.0	17.2	7.0	1.4	12	0
6	27.6	8.0	47.8	17.3	7.5	1.3	3	2
7	27.7	7.9	48.3	17.2	7.3	2.0	20	0
8	27.9	7.8	43.9	14.6	6.9	2.7	21	0
9	28.3	8.0	49.2	17.3	6.9	1.4	14	0
10	28.6	8.0	49.1	17.2	7.1	1.8	27	1
11	28.6	8.0	49.0	17.2	7.3	1.8	55	0
12	28.2	7.9	48.8	-	6.3	-	-	-
13	26.5	7.9	46.8	17.3	6.8	1.5	14	1
14	26.7	8.0	47.7	17.3	7.3	1.5	11	4
15	27.1	7.5	46.3	17.1	7.5	1.5	24	0
16	26.4	8.1	46.1	17.1	7.2	1.6	12	0
17	27.0	8.0	48.0	17.3	7.5	1.0	5	0
18	27.3	8.0	47.7	17.3	7.7	1.3	16	0
19	27.3	7.9	47.7	17.2	7.2	1.3	3	1
20	27.5	7.9	47.7	17.4	6.8	1.0	8	4
21	27.6	7.9	47.5	17.2	7.9	1.1	5	7
22	28.6	8.3	47.7	17.8	7.3	0.8	6	0

To be continued

TABLE F-2 The Results of Seawater Analyses (The Penang Channel) (Continue)

No. of Station	WT	pH	EC	Chlorinity	DO	COD	SS	Coliforms
	°C		mʊ	‰	ppm	ppm	ppm	N/ml
23	28.2	8.3	47.8	17.4	7.5	1.2	3	2
24	28.2	8.3	48.2	17.3	7.3	1.4	12	365
KP	28.6	7.3	32.5	9.5	5.2	3.4	15	125
22	28.4	7.7	38.2	12.5	5.5	3.2	8	145
KP	27.1	7.0	41.9	14.7	6.0	1.8	8	20
KP*	26.2	7.5	43.1	17.0	6.8	2.4	114	305
KJ	26.7	7.8	43.6	15.6	6.9	3.3	19	15
KJ**	25.7	7.8	41.2	16.5	6.1	2.3	62	30

* 2.7 m deep

** 5.0 m deep

The Surveys were carried out on 16th and 17th December, 1976.

All samples were collected at the surface except marked ones.

WT Water Temperature

EC Electric Conductivity

DO Dissolved Oxygen

COD Chemical Oxygen Demand

SS Suspended Solids

3. ASPECTS ON WASTE DISPOSAL AND WATER POLLUTION CONTROL

3-1 General

At the terminus of any sewerage system, there is a resultant discharge of wastewater into a river, the sea, or other place for final disposal. Taking account of the locality for final disposal, treatment-level/disposal method should be considered to safeguard the beneficial values of the receiving area.

There are ideally 6 alternatives for wastewater disposal as follows ;

(1) Nontreatment - Discharge into a drain

(2) Nontreatment - Short outfall into a river or shallow waters near the beach

(3) Nontreatment - Ocean outfall

(4) Secondary treatment - Discharge into a drain

(5) Secondary treatment - Short outfall into a river or shallow waters near the beach

(6) Secondary treatment - Ocean outfall.

For the purpose of decision of the final discharge of sanitary sewage,at least 6 alternatives shown above should be considered on the view point of water pollution control and beneficial uses of the receiving waters.

3-2 Consideration of Treatment and Disposal of Sanitary Sewage

In order to design the future treatment-disposal system of the sewerage system in the Project Area, the 6 alternatives are considered on the view point of the relationships of existing disposal systems of wastewater and present environmental water quality.

(1) Nontreatment - Discharge into a Drain

This way is the most common in the Project Area except human excreta disposal. Most of domestic and industrial wastewaters are discharged into drains or road-side ditches. As the result, many drains in town area, as shown in Figure F-3, are in wrong condition, that is, dissolved oxygen is less than 1 mg/l, and hydrogen sulfide is occuring from the bottom sediments of the drain. And some "monsoon drains" have changed colour of water and sediment to coalblack, for example, the drains of the Butterworth-Whalves, the Butterworth-No.3, the Mak Mandin, the Derahaka, and the Prai Industries, and the tidal gate area of the Juru River. On the basis of the facts, this way is unsuitable for the future disposal system of domestic and industrial wastewaters.

(2) Nontreatment - Dischage into a River or Shallow Waters near the Beach

Along the Butterworth beach, there are many sewer outfalls including domestic wastewater and septic tank effluents. As mentioned in Section 2-3, The areas near sewer outfall points are polluted by coliforms.

This is supported by the results of the pollution control study by the Ministry of Health*.

The waters of the rivers of the Prai and the Juru are also polluted by coliforms. This may be due to fecal pollution of human after discharging the effluents of septic tanks which may be mulfunctual for elimination of coliform bacteria.

Although, as mentioned above, coliform contamination is found in riverwaters and coastal waters, the organic contamination is not so highly significant on coastal and river pollution. This indicates that direct discharge of domestic wastewaters except human excreta into a river or coastal water may be undestructive for the water quality conservation on the present conditions. However, the present "minimum" success on direct discharge of domestic wastewater may be based on dividual and unconcentrated discharging. If plenty of wastewaters were concentrated to a limited receiving water such as the Juru River, direct discharge would bring upon remarkable environmental desruption.

(3) Nontreatment - Ocean Outfall

Nontreatment - Ocean Outfall system is very economic if following problems can be soluted ;

a) to obtain suitable outfall points

b) to make safeguard measures for other beneficial uses of the receiving water

c) construction and maintainance of long piping systems for sewage collection.

* "Pollution Control Study of the Batu Fringgi/Telok Bahang Coastal Areas" Ministry of Health (1972)

a) Outfall Points

For outfall points, the open ocean with strong oceanic currents is the best to protect from environmental pollution. If ocean outfall is accepted for this sewerage system, however, the Penang Channel will be selected for the receiving area on an economical view point because the Project Area is facing to the channel.

The Penang Channel is narrow, minimum about 2 km wide, but with strong tidal currents, roughly estimated at 26 to 100 cm/sec in daily maximum. So, capacity of flashing out effects by the tidal currents may be enough to receive the organic pollutants (BOD or COD) from the Project Area.

b) Safeguard Measures

The port of Penang is one of the most important ports in Malaysia, and the port area extends over the whole Penang Channel as shown Figure F-4. The area in front of the Project area is the most important for anchoring, therefore, submarine constructs should be avoided for safety of navigation,and safeguard of the constructs would be difficult.

Water pollution control is also necessary because the sand beaches along or neighbouring the channel are used for bathing or water contact sports. The outfall points should be designed taking enough distance between the outfalls and beaches to avoid carring back sewage pollutants (floating matter and coliforms). But this is very difficult because of narrowness of the channel and high velosity of the tidal currents.

For experience on George Town Sewage disposal, it should be concluded that coliform contamination could not be avoided by nontreatment - ocean outfall.

c) Long Piping Systems

It is necessary to construct and maintain long piping systems for conbinning individual sewage producers and outfall points. As the Project area is flat except Bukit Mertajam District, the long piping systems would require deep piping or many pumping stations to keep minimum velocity for preventing sedimentation and sulfides control. Therefore, long piping systems would require high construction and maintainance costs. Further, the larger system requires the higher primary investment.

(4) Secondary Treatment - Discharge into a Drain

Organic pollutants(BOD and COD), and SS including floating matter can be reduced more than 75 % by secondary treatment. And, accepting secondary treatment with long detention time, coliforms could be also reduced markedly.

Therefore, after secondary treatment, the effluents can be discharged into a drain.

(5) Secondary Treatment - Short Outfall into a River or Shallow Waters near the Beach

As mentioned above, the effluents of secondary treatment can be discharged into a river or shallow waters near the beach, if the treatment plant is near a river or coastal area.

(6) Secondary Treatment - Ocean Outfall

This is the most complete disposal for water pollution control. This way, however, requires high construction and maintainance costs, and submarine constructs should not be constructed if possible.

3-3 Conclusion

Some drains in the Project Area are under desruption on their water quality, and most of existing waterways in town area have been saturated for waste disposal, especially, direct discharging of domestic wastewater. So, new waste disposal systems are required for water pollution control in the Project Area under urbanization.

As a result of consideration mentioned above, construction of sewerage systems with secondary treatment are recommended. After establishing the systems, the waters including drains, rivers, and/or coastal waters could , without any environmental desruption, receive all the wastewaters produced in the future up to year 2000.

However, about the Juru River pollution, further consideration is required.

4. COMMENTS ON JURU RIVER POLLUTION

The tributaries of the Juru originating from Bukit Mertajam Hill expand in areas of towns, forests, and farms, and receive domestic waste water, septic tank effluents, effluents from factories which widely seattered in the watershed, and farm effluents. When surveyed in 1976, the Juru River had already been heavily polluted at the Tun Abdul Razak's bridge where a tidal gate was constructed. Criticism was noted that the gate construction was one of the causes of the pollution. The river water near there was low dissolved oxygen, high COD, black, and bad smelling, and recently fishing extremely decreased in the river mouth area of the Juru.

Ministry of Environment carried out a comprehensive survey on the Juru River Pollution in 1976 to establish the sources and causes of the pollution.

Following are such sources according to the survey:

(1) Pig farms discharging their wastewater into the stream without treatment.

(2) Factories discharging their effluents into the streams without adequate treatment.

(3) Domestic wastewater discharged from houses in the basin.

(4) Septic tank effluents from all major housing schemes.

(5) People living along the streams used the stream as the dumping ground for refuse.

(6) Over hanging latrines were found in the tributaries.

It was assumed that the main sources of pollution would be among 1 to 4 of above.

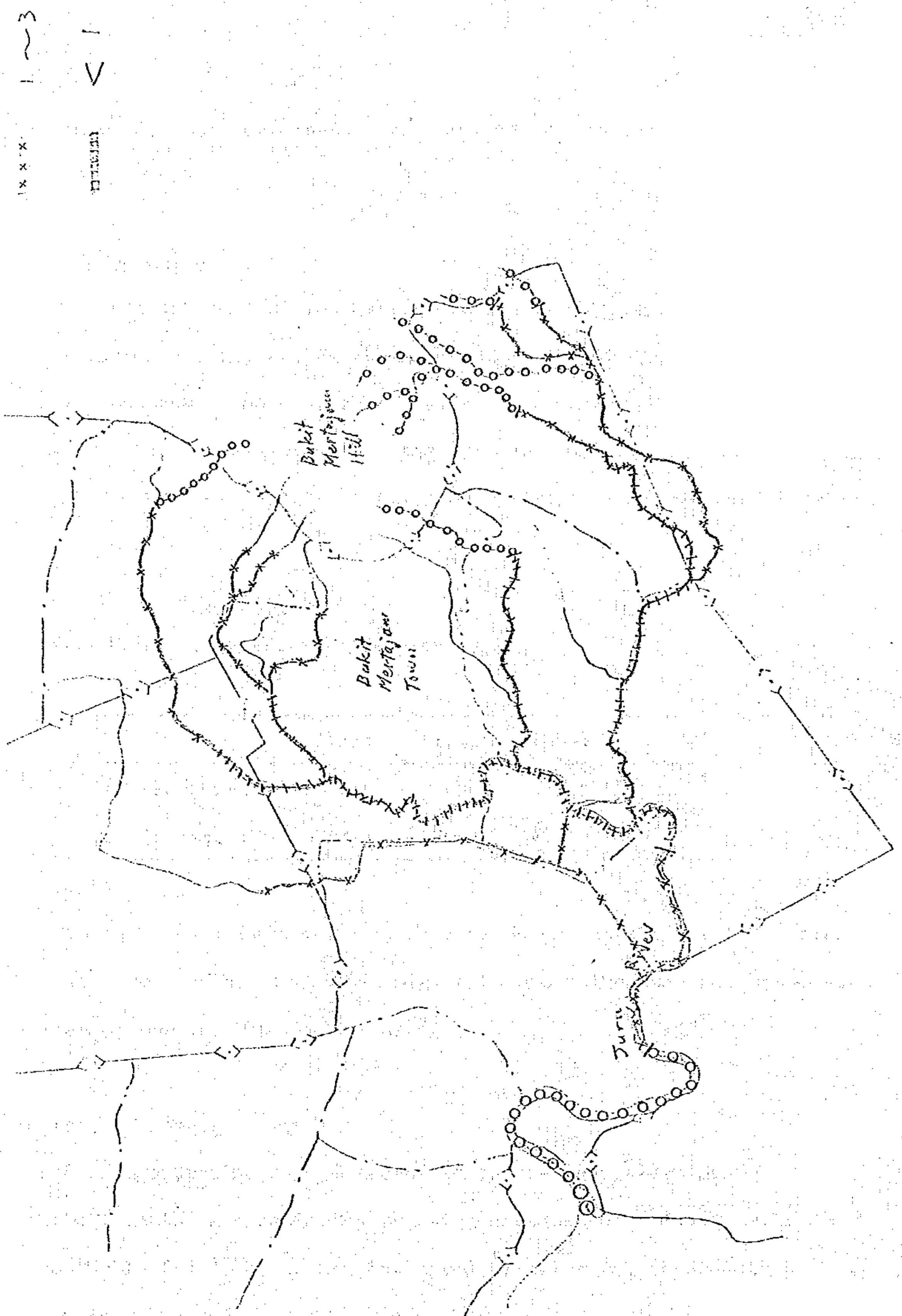


FIGURE F-7

Based on the data obtained, waste productions in the Juru River Basin were estimated ;

Pig Farm Wastes

The amount and composition of pig excreta were estimated by Ministry of Agriculture and Forestry, Japan, are shown in ANNEX F-1 of this chapter. Using this data but as both of them are varied by individual weight of pig and/or kind of feeds, assuming that the average weight of pig was 60 kg and that the feeds were average of leftover and garbags, and is shown in Table F-3.

TABLE F-3. Unit Waste Production by Pig

	Feces	Urine	Total
BOD (kg/animal)	185.1	6.38	191.5 (200)
SS (kg/animal)	470.6	9.57	480.2 (500)

According to data from Ministry of Environment, there are 18700 pigs in the Juru River Basin. So, total pig waste production was estimated at 3740 kg/day of BOD and 9350 kg/day of SS

Factory Effluents

There are approximately 40 factories in the Juru River Basin. The total effluents are estimated by using unit waste productions by factories (Table F-4), which are estimated by using the informations summerized in Table E-6 of APPENDIX E.

The results are shown in Table F-4 .

TABLE F-4. Unit Waste Productions by Factories

	Food	Dyeing	Soap	Rubber	Others
BOD (ppm)	200	740	320	500	100
COD (ppm)	400	40	610	100	120
Quantity(cu m/d)	15	10.8	245.5	30	15

Domestic Wastewater & Human Excreta

Per capita waste production was estimated and shown in Table E-2 of APPENDIX E. And the total population in the Juru River Basin was estimated at apploximately 90000 persons.

So, the total human waste production which includes kitchin and bathing wastes and human excreta, was estimated at 3120 kg/day of BOD and 1733 kg/day of SS as Shown in Table F-5 .

TABLE F-5. Total Waste Production in the Juru River Basin

	BOD		SS	
	kg/d	%	kg/d	%
Human Wastes	3240	45	1800	15
Factory	225	3	293	3
Pig Farm	3740	52	9350	82
Total	7205	100	11443	100

For human excreta disposal, approximately 30% of population in Bukit Mertajam are surved by septik tank system, of which treatment efficiency is about 40% on BOD, and most of the rest of population surved by bucket system and/or pit privy, so that approximately 30% of total BOD produced would be removed by excreta disposal system. Further, it is assumed that approximately 60% of domestic BOD would be removed by accumulation and/or decomposition in sewer system. Therefore, it is estimated that approximately 30% of total BOD produced would run off into the river.

There are approximately 300 pig farms in the Juru River Basin, ranging from very small to large scale farms. Some large scale farms are discharging their wastes into streams without adequate treatment, while small farms are discharging wastes to surrounding land, normally palm forest, so that they are infiltrated into the ground and decomposed, resulting in the natural treatment. Therefore, for pig farm waste disposal, it is assumed that approximately 40% of total BOD produced would be run off into the river.

Assuming 100% run-off-ratio for industrial wastewater, total BOD loading to the Juru River are estimated as shown in Table F-6

TABLE F-6 Total BOD Loading to the Juru River

	Human Wastes	Factory	Pig Farm	Total
Kg/day	1039	225	1496	2750
%	38	8	54	100

Table F-6 indicates that pig farm effluents and human wastes are main sources of Juru River pollution, on the basis of assumptions stated earlier.

It is evident this construction of the tidal gate at the Tuan Abdul Razak's bridge and reclamation of swamp area along the river have interfered natural water flow and/or decreased the volume of water exchange which affectes washing out effects. This would have caused accumulation of pollutants in the river basin and brought about water pollution.

Therefore, it is necessary to make further survey for determining each waste production mechanism (course), their run off ratios, water pollution mechanism, and measures on pollution control.

5. WATER QUALITY SURVEILLANCE

5-1 Administration of Surveillance Programme

It would be highly desirable, as a part of the Master Plan implementation, to establish a centralized organization for water quality surveillance, and to implement a surveillance programme.

A suggested organization is shown in Figure F-8.

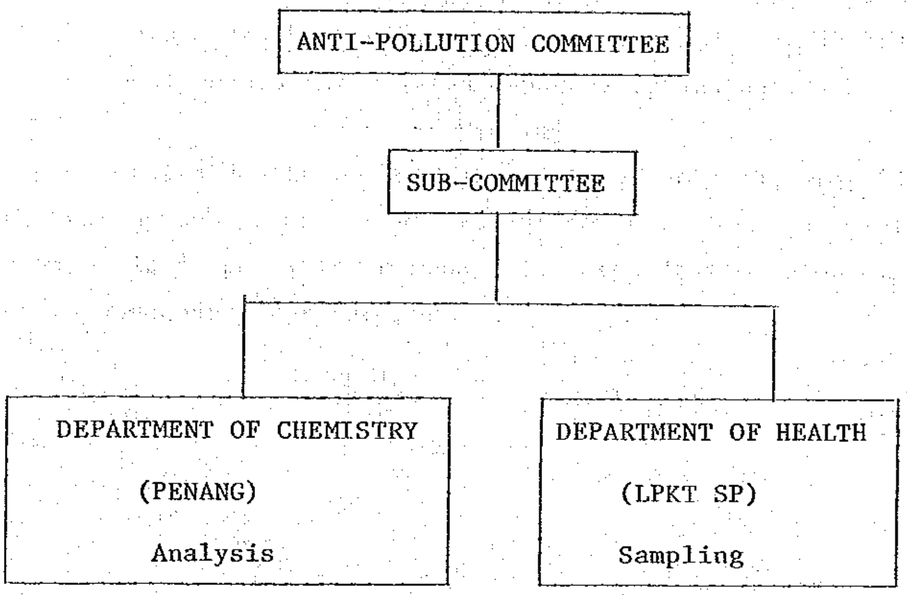


Figure F-8. Organization of Water Quality Surveillance

Anti-pollution Committee be established on a Federal order which may be initiated by the Ministry of Environment.

Sub-Committee is a standing committee established on a State order.

The Sub-Committee be organized by the members of the Department of Health, Department of Chemistry, and other departments or agencies related to water use or city planning. The Committee conducts completion and implementation of the water quality surveillance programme.

The Department of Health of LPKT SP takes samples regularly at the fixed monitoring points which are located at or in treatment plants, waterways, and other receiving waters. The Department of Health acts a data center of water pollution.

The Department of Chemistry of Penang analyzes the samples brought in the laboratory by the Department of Health, and distributes the results of analyses to the related departments and agencies.

The organization shown in Figure F-5 was actually established for the survey on the Juru River Pollution in 1976. According to the experience, it is possible to manage the organization smoothly, and to get a consequence for the purpose.

5-2 Proposed Surveillance Programme

5-2-1 Effluent Monitoring of Treatment Plants

All wastewater treatment plants should be operated with effluent monitoring for assessing the efficiency of plant performance.

The suggested parameters and frequency of monitoring are shown in Table F-7 . The parameters of DO, BOD, COD, SS including floatables, and coliforms are very important to assess the functional efficiency of the plants. Data on the quality of influent water and the amount of bottom sediments, if additionally estimated, would give very useful informations for plant maintainance and future improvement of the treatment facilities.

5-2-2 Receiving Waters

Table F-7 presents the suggested monitoring programme for the receiving waters. And sampling points shown in Figure F-9 are fixed on purposing to assess the effect of waste inputs to the water. It is understood this is a preliminary listing, to be refined and improved on the basis of actual experience.

The measurements of bottom materials listed in Table F-9 are intended to assess the present levels of pollution accumulated in the bottom materials, to assess the environmental improvement to be attained through water pollution control.

FIGURE


SCALE
KILOMETRES
0 1 2
MILE
0 1/4 2/4 3/4 1
Kutim River
Derhaka River
Rambai River
Pasir River
Juru River
Kelang Uli River
Boundary of Project Area
Sampling Points
SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA
Monitoring Points
FIGURE
F-9

TABLE F-7. Suggested Monitoring Programme for the Treatment Plants and Receiving Waters

Parameters	Frequency of Sampling		Remarks
	Monthly	Annually	
A) Water Quality			
1) Temperature	*		
2) pH	*		
3) Transparency	*		
4) DO	*		
5) BOD	*		
6) COD	*		
7) SS	*		
8) Cl^-	*		
9) Coliforms	*		Total & Fecal
10) Nutrients(N, P)	*		Total & Inorganic
11) Detergents		*	
12) Heavy Metals		*	Total & Selected
13) Oil & Grease		*	
(B) Bottom Sediments		*	
1) Volatile Matter		*	
2) Benthic Animals		*	
3) Oil & Grease		*	
4) Heavy Metals		*	Total & Selected

NOTES : (1) Flow rate of waterways to be measured or estimated at the time of sampling

(2) Locations of monitoring points are shown in Figure 5-2 .

(3) Methods of Sampling and Analyses are submitted to the British Standards

TABLE F-8 Amount of Pig Excreta

unit ; Kg/animal·day

Weight	Full Feeding			Controled Feeding		
	Feces	Urine	Total	Feces	Urine	Total
20	1.1	1.3	2.4	0.5	–	–
30	1.8	1.9	3.7	0.7	–	–
40	2.1	2.5	4.6	0.9	–	–
50	2.5	2.8	5.3	1.2	4.0	5.2
60	2.6	2.9	5.5	1.6	4.0	5.6
70	3.3	3.1	6.4	2.0	3.9	5.9
80	3.5	3.2	6.7	2.3	3.7	6.0
90	4.6	3.4	8.0	2.6	3.5	6.1

(Data Source ; Ministry of Agriculture and Forestry, Japan)

TABLE F-9 Composition of Pig Excreta

	Combination Feeds		Leftover		Garbage	
	Feces	Urine	Feces	Urine	Feces	Urine
BOD x 1000 ppm	62.8	5.1	89.3	1.2	53.1	3.1
COD x 1000 ppm	53.0	9.3	50.1	1.4	38.2	2.6
SS x 1000 ppm	223	4.5	188	3.0	173	3.5
Total Solids %	29.5	4.5	24.2	0.5	21.8	1.3
Ignition Loss %	24.2	3.3	22.5	0.2	17.5	1.1

(Data Source ; Ministry of Agriculture and Forestry, Japan)

APPENDIX G

STORMWATER QUANTITY

TABLE OF CONTENTS

1. Rainfall Formula ....

2. Runoff Coefficient G-1

3. Time of Concentration G-7

2. Runoff Coefficient

It has been generally recognized that the values assigned to the runoff coefficient depend mainly upon the surface characteristics including the imperviousness and the slope.

On the basis of numerous experiences in the past, the surface characteristics in terms of the impervious factor of the different types of surface such as roof, road, yard and others, can be estimated.

Using these impervious factors of individual type of surface, the composite runoff coefficients, expressed by the following equation, have been developed for this project.

$$C = \sum_{i=i}^{m} CiAi \Big/ \sum_{i=1}^{m} Ai$$

where

C = composite runoff coefficient

Ci= impervious factor by the type of surface

Ai= area by surface type, in ha

m = number of the surface type

2-1 Selected Representative Area

Four districts representing typical patterns of the land use were selected and their coefficients in the future were estimated as follows:

Type of land use		Representative area (refer to Figure - G-1)
1. Residential-A (residential with semi-detached houses)	-------	planned housing development area along Juru river
2. Residential-B (residential with detached houses)	-------	out skirt of Bukit Mertajam
3. Commercial area	-------	central part of Bukit Mertajam
4. Industrial area	-------	Macmandin area in Butterworth

2-2 Runoff Coefficient by Surface Type

Coefficients with respect to surface type currently in use are shown below.

Table G-1 Runoff Coefficient with respect to Surface Type

Type of Surface	Runoff Coefficient	
	Range	Used
Roofs	0.85 ~ 0.95	0.90
Roads	0.80 ~ 0.90	0.85
Other pavement	0.75 ~ 0.80	0.80
Vacant lots	0.10 ~ 0.30	0.20
Lawns	0.05 ~ 0.20	0.10

Sauce: WPCF Manual of Practice No. 9 (USA) (1970)

Manual of Sewerage Facility Design, 1972, Sewerage

2-3 <u>Estimation of Coefficients in the Selected Areas</u>

The various types of surfaces were calculated, in percentage of total surface, for each of the selected four representative districts. After that the runoff coefficients of representative district were calculated and shown in Table G·2

Table G·2 Percentage of Individual Surface Type and Runoff Coefficient

(in year 2000)

Type of Surface	Runoff Coefficient of Individual Type of Surface	Residential area (semi-detached)	Residential area (detached)	Commercial area	Industrial area
Roofs	0.90	0.30/0.27	0.25/0.23	0.28/0.25	0.18/0.16
Paved road	0.85	0.35/0.30	0.35/0.30	0.26/0.22	0.30/0.25
Other pavement	0.80	0.05/0.04	0.05/0.04	0.46/0.37	0.05/0.04
Vacant lot	0.20	0.05/0.01	0.05/0.01	- / -	- / -
Lawn	0.10	0.25/0.03	0.29/0.03	- / -	0.47/0.05
Total	-	1.00/0.65	1.00/0.61	1.00/0.84	1.00/0.50

Note: percentage of individual type of surface/runoff coefficient

Sparsely inhabited residential area, with population density of 53 persons/ha, is projected in the future land use plan.*
The runoff coefficient in such areas are determined on the basis of an assumption in which an inhibitation would take place in association with the housing development project with population density around 120 persons/ha in some parts of the areas. The percentage of areas with 120 persons/ha is $\frac{53}{120} = 0.44$ and remaining part (1 - 0.44 = 0.56) would be areas uninhabited with runoff coefficient of 0.1. The composite coefficient in the sparsely inhabited area, therefore, can be estimated as follows:

$$\frac{53}{120} \times 0.65 + \frac{(120-53)}{120} \times 0.10 \doteqdot 0.35$$

In this project the runoff coefficient of 0.35 is used for sparsely inhabited residential area.

* The residential area is defined as the residential-C in the discussion of runoff coefficients.

2-4 Runoff Coefficient at Present

Existing land use types in the Project Area are the residential are are the residential area with detached house, commercial area and industrial area. The runoff coefficient of individual land use mentioned above was claculated in the same manner as that used in the case of future coefficients estimation.
In Table G.3 , is shown the present runoff coefficient.

Table G.3 Present Runoff Coefficient

Type	Runoff co-efficient of Individual Surface	Residential area	Commercial area	Industrial area
Roofs	0.90	0.10/0.09	0.35/0.31	0.11/0.10
Roads paved	0.85	0.10/0.09	0.35/0.30	0.18/0.15
Other pavement	0.80	- / -	- / -	0.05/0.04
Vacant lot	0.20	0.30/0.06	0.30/0.06	- / -
Lawn	0.10	0.45/0.05	- / -	0.66/0.07
Palm tree coverage	0.10	0.05/0.01	- / -	- / -
Total		1.00/0.30	1.00/0.67	1.00/0.36

Note: percentage of individual type of surface/runoff coefficient

Remaining parts of the Project Area are mountenous areas and agricultural areas. The runoff coefficient of those areas are 0.5 and 0.1 respectively.

2-5 Comparison with Others Areas

The calculated coefficients were also compared with those used for other cities.

Table G-4 Coefficients Adopted in Other Areas

Type of Land Use	Proposed Co-efficient in the Project	Malaysian Standard	Practice in U.S.A.	Standard in Japan
Residential	0.65	0.75	0.60 ~ 0.75	0.65
Commercial	0.85	0.90	0.70 ~ 0.95	0.80
Industrial	0.50	0.80	0.50 ~ 0.80	0.65

As indicated in the above table, the coefficients for the Project Area are in good agreement with those in other areas.

2-6 Recommended Runoff Coefficients

Taking the facts and assumptions mentioned above into account, the following runoff coefficient are recommended for drainage system planning.

Table G-5 Recommended Runoff Coefficients

Land Use		in 1976	in 2000
Residential area	Residential-A	0.65	0.65
	Residential-B	0.30	0.65
	Residential-C	-	0.35
Commercial area		0.70	0.85
Industrial area		0.35	0.50
Agricultural area		0.10	0.10
Mountinous area		0.50	0.50