INTERIM REPORT

ON

MASTER PLAN

FOR

SEWERAGE AND DRAINAGE SYSTEM PROJECT

BUTTERWORTH/BUKIT MERTAJAM METROPOLITAN AREA

MALAYSIA

VOLUME II
APPENDICES

APRIL 1977

JAPAN INTERNATIONAL COOPERATION AGENCY

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APPENDIX A

POPULATION & LAND USE DISTRIBUTION

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CHAPTER 1

THE POPULATION

1.1 Demographic Data Obtained

The basic source of information on population used in this study is the demographic data of the following four reports including those referred in them on National Census and other statistical data by the different government agencies:

i) Penang State Water Supply Project Report, 1965 - 2000 by Binnre & Partners Consultants Co., Ltd. for Public Works Dept. Penang, 1967.

ii) Penang Master Plan, 1969 - 1985 by Robert Nathan Associates Inc. for the Penang Master Plan Committee, 1970.

iii) WHO assignment Report, 1975 - 1995 by WHO, 1973.

iv) Population Projection for the State of Peninsular Malaysia, 1970 - 1980 by Dept. of Statistics, 1976.

(1) Penang State Water Supply Project, 1967

The data used in population projection in this study were obtained from 1957 Census and population projections for the period of 1957 - 1982 given by the Statistic Department. For the purpose of the study, the population of the Penang Island and the Province Wellesley were estimated separately for the period from 1965 to 2000. Among the previous data referred above, this was the only one that estimated the population up to the year 2000, with the projection by the year 1970 to be between 839,200 (lower growth rate) and 889,600 (upper growth rate). However, according to the 1970 Census the population of Penang State is 776,124, which indicates that the population projection in this study should be considered as over estimates.

(2) Penang Master Plan, 1970

Source of the data for the population projection in this report was the 1957 Census and the population projection by the Statistic Department. In this report, the population of the Project Area, according to our analysis, was projected as 166,000, 250,000 and 385,000 for the years 1970, 1975 and 1985 respectively, with average growth rate of 5.5%. The demographic data in the report is very useful as it has separate estimates for Island Penang and Province Wellesley on different periods, which gives us sound basis for detailed projection of population growth and its distribution.

(3) WHO Assignment Report, 1973

Study area of this Report is Butterworth and Bukit Mertajam Metro-Politan Area, and estimated population in the year 1985 is that of Penang Master Plan. Namely, 385,000 based on which the population in 1995 is projected as 545,000 with annual growth rate of 3.5%.

(4) Population Projection for the State of Peninsular Malaysia, 1976

In this projection the Statistic Department used the fertility and mortality of each five-year groups for future population estimation. The fertility and mortality used in this projection are medium scale in the Department's assumption scales. This population projection also includes the internal immigration between States in Peninsular Malaysia. However, since the projection was made at the State level, no detailed breakdown of the areas in the State is obtainable from this projection, which does not serve well for the purpose of our study.

1.2 The Population Estimates for the Project Area, 1970 & 1976

As the data referred above do not specifically indicate the population and its distribution according to the land use, either in terms of the Project Area or for the year 1976, the time of the present study, the undertaking was done to estimate these two factors. The 1970 Census which has the breakdown of all the mukims in the State, was used as the basis of the estimate, out of which total of 27 mukims are involved with the Project Area. The total population of these mukims are 209,380 for the area of 28,891 ha., but some of the mukims are only partially included in the Project Area. These were therefore identified accordingly in order to determine the total population of the Area, and its distribution in 1970, and is shown in Table A-1, which shows total population of 172,230 in the total Project Area of 11,600 ha.

Thus defining the population of the Project Area in 1970 to be 172,230 for the area of 11,600 ha, the projection for the year 1976 was then undertaken. As the average annual growth rate of 5.5% employed in case of Penang Master Plan during the period 1970 - 1985 is considered adequate and reasonable, this same rate was applied to the population of each of the 27 mukims involved with the Project Area in order to obtain 1976 estimate, which is also indicated in Table A-1 at its last column, showing the total population as 238,000.

1.3 The Population Projection up to 2000

As the population for the years 1970 and 1976 was established for the Project Area as described in the preceding chapters, the population projection in the years 1980, 1985, 1990, 1995 and 2000 were undertaken. As stated earlier the average annual growth rate of 5.5% employed in the Penang Master Plan up to the year 1985 was considered reasonable, and therefore the same rate was applied for annual growth for the period of 1976 - 1985. From 1985 - 2000, 3.5% annual growth rate employed by WHO report up to the year 1995 was considered appropriate and was used. Table A-2 below shows the result of the projection stated above.

TABLE A-2 Future Projection of the Project Area

Year	Population	Annual Growth Rate
1970	172,230	
		5.5%
1976	238,000	
		5.5%
1980	294,400	
		5.5%
1985	385,000	
		3.5%
1990	458,000	
		3.5%
1995	545,000	
		3.5%
2000	648,000	

TABLE A-1 Population & Distribution by Mukims in 1970, with 1976 Projection

No. of Mukim Involved	Mukim Total (by 1970 Census)			Project Area (by NSC)			Population
	Population (1970)	Area (ha)	Population Density	Area (ha)	Population (1970)	Population Density	(1976)
N 7	8,485	1,152	7.4	389	3,751	9.6	5,183
N 9	6,917	650	10.6	281	2,691	9.6	3,719
N10	3,286	1,059	3.1	47	146	3.1	202
N14	39,502	885	44.6	885	39,502	44.6	54,587
N15	30,035	645	46.6	645	30,035	46.6	41,505
N16	3,441	668	5.2	523	2,720	5.2	3,759
C 1	10,875	2,174	5.0	2,174	10,875	5.0	15,028
C 2	3,952	848	4.7	420	3,162	7.5	4,369
C 3	3,381	457	7.4	88	2,029	23.1	2,804
C 4	5,934	781	7.6	354	5,341	15.1	7,381
C 5	2,861	625	4.5	187	2,253	12.0	3,113
C 6	4,096	1,035	4.0	762	4,096	5.4	5,660
C 7	1,665	1,176	1.4	54	1,665	30.8	2,301
C 8	10,116	406	24.9	193	10,116	52.4	13,979
C 9	9,131	270	33.8	270	9,131	33.8	12,617
C10	19,641	445	44.1	445	19,641	44.1	27,141
C11	5,116	1,060	4.8	1,060	5,116	4.8	7,070
C12	2,740	1,480	1.9	60	114	1.9	158
C13	2,776	1,328	2.1	366	2,776	7.6	3,836
C14	6,645	1,813	3.7	618	3,323	5.4	4,592
C15	9,706	1,535	6.3	681	8,735	12.8	12,071
C16	5,567	1,688	3.3	5	17	3.3	23
C17	1,100	2,195	0.5	309	155	0.5	214
C18	1,405	1,055	1.3	215	280	1.3	387
C19	2,137	1,551	1.4	5	7	1.4	10
C20	6,477	1,008	6.4	557	4,534	8.1	6,265
C21	2,438	902	2.7	7	19	2.7	26
Total	209,380	28,891		11,600	172,230		238,000

CHAPTER 2

LAND USE DISTRIBUTION

2.1 The Population Distribution according to Land Use, 1976

After the total population in the Project Area is properly estimated for the present and assumed up to the year 2000, it was necessary to identify the state of distribution according to the condition of land use. The categories of land use employed for such purpose is defined as follows:

(1) Industrial Area

The areas where factories are established or to be established under control of the State Government for industrial activity.

(2) Social and Commercial Area

The areas occupied mainly by social and public administrative buildings and stores and shops. Isolated public premises such as schools are not included in this category, but small industries and workshops, such as motor vehicles repairing workshops, are included.

(3) Residential Area

The housing areas which have relatively high population density. The difference between residential area and rural area is the difference in their population density. New housing schemes are included in this category.

(4) Rural Area

The areas where scattered houses are situated. The rural villages or "kampong" are included in this category.

(5) Agricultural Area

The areas consist of rice fields (padly) coconut plantations and rubber plantations.

(6) Others

Non-habitable open spaces, such as rivers, swamps, mountains, cemeteries, and etc. are included in this category.

TableA-3 Population and Land Use by Mukims in 1976 shows the state of distribution of total population of 238,000 according to the land use, on the basis of field surveys and technical assumption using the following criteria as basis of assumption.

Areas		
(1) Social & commercial area	0, 120 or 160	persons/ha
(2) Residential area (Builtup area).	160	persons/ha
(3) " " (New housing area). . . .	120	persons/ha
(4) " " (Low density area). . . .	52	persons/ha
(5) Industrial area	0	
(6) Others	0	

2.2 <u>The Population Distribution according to Land Use, 2000</u>

On the basis of TableA-3 as stated in the preceding chapter, further assumption was mode for the year 2000 with the assumed total population of 648,000, which is shown in TableA-4 Population and Land Use by Mukim in 2000. Assumption is made in this table that rural and agricultural areas would be converted to the other categories of land use, mostly residential and industrial, by the year 2000, and therefore mukims of residential areas are given higher increase of population distribution.

TABLE A-3 Population and Land Use by Mukim in 1976

No. of Mukim	Area (ha)							Population Density			Population			Total
	Social Commercial	Residential	Industrial	Rural	Agricultural	Others	Total	Social Commercial	Residential	Rural	Social Commercial	Residential	Rural	
N 7		18		141	230*		389		120	21.4		2,160	3,023	5,183
N 9				175	106*		281			21.3			3,719	3,719
N10				30	17*		47			6.7			202	202
N14	2	197	95*	530		61*	885	120	120	57.9	240	23,640	30,707	54,587
N15	16*	133						0	108.6		0	3,585		
	47	190	79*			280*	645	160	160		7,520	30,400		41,505
N16				201	58*	246*	523			18.7			3,759	3,759
C 1		157	670*	108	593*	646*	2,174		80	22.9		12,560	2,468	15,028
C 2				138	115*	167*	420			31.7			4,369	4,369
C 3				67	21*		88			41.9			2,804	2,804
C 4				137	208*	9*	354			53.9			7,381	7,381
C 5				61	126*		187			51.0			3,113	3,113
C 6				304	382*	76*	762			18.6			5,660	5,660
C 7				49	5*		54			47.0			2,301	2,301
C 8	1	86		72	34*		193	120	120	49.2	120	10,320	3,539	13,979
C 9		57		148	65*		270		120	39.0		6,480	5,777	12,617
C10	19	108		221	28*	69*	445	120	120	53.9	2,280	12,960	11,901	27,141
C11		16		292	450*	302*	1,060		80	19.8		1,280	5,790	7,070
C12				4		56*	60			39.5			158	158
C13		38		24	288*	16*	366		80	33.2		3,040	796	3,836
C14				216	359*	43*	618			21.2			4,592	4,592
C15		13		344	324*		681		80	32.1		1,040	11,031	12,071
C16				3	2*		5			7.7			23	23
C17				11	154*	144*	309			19.5			214	214
C18				10	185*	20*	215			38.7			387	387
C19				2	3*		5			5.0			10	10
C20				189	296*	72*	557			33.1			6,265	6,265
C21				7			7			3.7			26	26
Total	16* 69	913	844	3,484	4,049	2,225	11,600	0 147.2	118.1		10,160	107,825	120,015	238,000

Note: * is not inhabited area, e.g. government office etc.

TABLE A-4 Population and Land Use by Mukim in 2000

No. of Mukim	Area						Population Density				Population			
	Total	Social Commercial	Residential (High)	Residential (Low)	Industrial	Others	Total	Social Commercial	Residential (High)	Residential	Total	Social Commercial	Residential (High)	Residential (Low)
N 7	389		36	353			58.3		120	52.0	22,692		4,320	18,372
N 9	281			281			52.0			52.0	14,626			14,626
N10	47			47			52.0			52.0	2,446			2,446
N14	885	2	462	305	95	21	80.9	120	120	52.0	71,554	240	55,440	15,874
N15	645	16 47	207 237		79	59	109.0	0 160	120 160		70,280	0 7,520	24,840 37,920	
N16	523		74	430		19	59.8		120	52.0	31,259		8,880	22,379
C 1	2,174	46 35	508	297	1,024	264	37.1	0 120	120	52.0	80,617	0 4,200	60,960	15,457
C 2	420			368		52	45.6			52.0	19,152			19,152
C 3	88			88			52.0			52.0	4,580			4,580
C 4	354	2		352			51.8	0		52.0	18,320	0		18,320
C 5	187			187			52.0			52.0	9,732			9,732
C 6	762			659	91	12	45.0			52.0	34,298			34,298
C 7	54			54			52.0			52.0	2,810			2,810
C 8	193	1	86	106			82.7	120	120	52.0	15,957	120	10,320	5,517
C 9	270		57	213			66.4		120	52.0	17,926		6,840	11,086
C10	445	19	108	315		3	71.1	120	120	52.0	31,634	2,280	12,960	16,394
C11	1,060		162	850		48	60.1		120	52.0	63,679		19,440	44,239
C12	60			46		14	39.9			52.0	2,394			2,394
C13	366		38	318		10	57.7		120	52.0	21,110		4,560	16,550
C14	618			610		8	51.4			52.0	31,747			31,747
C15	681		13	668			53.3		120	52.0	36,325		1,560	34,765
C16	5			5			52.0			52.0	260			260
C17	309			165		144	27.8			52.0	8,587			8,587
C18	215			195		20	47.2			52.0	10,149			10,149
C19	5			5			52.0			52.0	260			260
C20	557			485		72	45.3			52.0	25,242			25,242
C 21	7			7			52.0			52.0	364			364
Total	11,600	64 104	1,988	7,409	1,289	746		0 130.1	124.8	52.0	648,000	14,360	248,040	385,600

2.3 The Population Distribution for Sewerage Districts & Zones

For the purpose of developing sewerage Master Plan, sewerage distincts and zones are considered on the basis of geological, topographical, demographical and other factors, which are enumerated in details in Appendix B. Sewerage System Consideration. Attempt was therefore made to identify the areas involved and to specify population concerned and its distribution in terms of land use. These are shown in Table A-5. Correlation between Mukims and Sewerage Districts, Table A-6. Land Use and Population by Zones in 1976, and Table A-7. Land Use and Population by Zone in 2000. These will be referred again in the study reports and in the Master Plan perticularly in case of staging consideration of construction programme.

TABLE A-5 Correlation between Mukims and Sewerage District (area: ha)

	Butterworth						Seberang Jaya					Prai		Bukit Mertajam							Total
	1	2	3	4	5	6	1	2	3	4	5	1	2	1	2	3	4	5	6	7	
N 7						389															389
N 9						281															281
N10					47																47
N14			435	450																	885
N15	390	200	55																		645
N16					523																523
C 1							480	360	119	76		1,139									2,174
C 2											420										420
C 3																				88	88
C 4										354											354
C 5																			55	132	187
C 6									391			91	280								762
C 7														10		44					54
C 8																153			40		193
C 9																53			217		270
C10																445					445
C11														870		190					1,060
C12														60							60
C13															366						366
C14															364		235	19			618
C15																32	235	414			681
C16																		5			5
C17																63		52	194		309
C18																			32	183	215
C19																				5	5
C20																			122	435	557
C21																				7	7
Total	390	200	490	450	570	670	480	360	510	430	420	1,230	280	940	730	980	470	490	660	850	11,600
	2,770						2,200					1,510		5,120							

TABLE A-6 Land Use and Population by Zone in 1976 (area: ha)

District	Zone No.	Area: Total	Area: Social Commer-cial	Area: Residen-tial	Area: Indust-rial	Area: Rural	Area: Agri-cul-tural	Area: Others	Population Density: Total	Population Density: Social Commer-cial	Population Density: Residen-tial	Population Density: Residen-tial	Population: Total	Population: Social Commer-cial	Population: Residen-tial	Population: Rural
Butterworth	1	390	16* 47	190	67			70	97.2	0 160	160		37,920	0 7,520	30,400	
	2	200		33				167	17.9		108.6		3,585		3,585	
	3	490	2	176	107	119		86	57.7	120	120	57.9	28,255	240	21,120	6,895
	4	450		21		411		18	58.5		120	57.9	26,332		2,520	23,812
	5	570				231	75	264	6.9			17.1	3,961			3,961
	6	670		18		316	336		13.3		120	21.3	8,902		2,160	6,742
Seberang Jaya	1	480		157	2	48	159	114	28.5		80	22.9	13,657		12,560	1,097
	2	360			29	3	229	99	0.2			23.0	69			69
	3	510				155	300	55	5.9			19.3	2,991			2,991
	4	430				143	264	23	17.5			52.6	7,518			7,518
	5	420				138	115	167	10.4			31.7	4,369			4,369
Prai	1	1,230			639	94	93	404	1.5			19.8	1,860			1,860
	2	280				106	138	36	7.1			18.6	1,974			1,974
Bukit Meltajam	1	940		16		299	450	175	8.0		80	21.0	7,559		1,280	6,279
	2	730		38		144	509	39	8.7		80	23.2	6,387		3,040	3,347
	3	980	20	209		376	87	288	46.5	120	119.2	48.5	45,540	2,400	24,920	18,220
	4	470		9		193	248	20	12.9		80	27.8	6,0-7		720	5,357
	5	490				235	224	31	14.8			30.9	7,257			7,257
	6	660		46		208	319	87	21.0		120	40.0	13,840		5,520	8,320
	7	850				265	503	82	11.7			37.5	9,947			9,947
Total		11,600	16* 69	913	844	3,484	4,049	2,225		0 147.2	118.1	34.4	238,000	10,160	107,325	120,015

Note: * is not inhabited area, e.g. government office.

TABLE A-7 Land Use and Population by Zone in 2000 (area: ha)

District	Zone No.	Total	Social Commer-cial	Residen-tial (high)	Residen-tial (low)	Indus-trial	Others	Total	Social Commer-cial	Residen-tial (high)	Residen-tial (low)	Total	Social Commer-cial	Residen-tial (high)	Residen-tial (low)
Betterworth	1	390	16* 47	237		67	23	116.5	0 160	160		45,440	0 7,520	37,920	
	2	200		182			18	109.2		120		21,840		21,840	
	3	490	2	275	73	107	33	75.6	120	120	52.0	37,039	240	33,000	3,799
	4	450		212	232		6	83.4		120	52.0	37,514		25,440	12,074
	5	570		74	477		19	59.1		120	52.0	33,705		8,880	24,825
	6	670		36	634			55.7		120	52.0	37,316		4,320	32,996
Seberang Jaya	1	480		354	82	2	42	97.4		120	52.0	46,748		42,480	4,268
	2	360	18* 35	154	48	50	55	69.9	0 120	120	52.0	25,178	4,200	18,480	2,498
	3	510			510			52.0			52.0	26,543			26,543
	4	430	30*		400			0 48.4			52.0	20,818			20,818
	5	420			368		52	45.6			52.0	19,152			19,152
Prai	1	1,230				1,063	167	0							
	2	280			268		12	49.8			52.0	13,948			13,948
Bukit	1	940		16	876		48	50.5		120	52.0	39,794		4,560	35,234
	3	980	20	355	552		53	75.2	120	120	52.0	73,729	2,400	42,600	28,729
	4	470		9	458		3	53.0		120	52.0	24,917		1,080	23,837
	5	490			459		31	48.8			52.0	23,889			23,889
	6	660		46	527		87	49.9		120	52.0	32,948		5,520	27,428
	7	850			768		82	47.0			52.0	39,970			39,970
Total		11,600	64* 104	1,988	7,409	1,289	746		0 138.1	124.8	52.0	648,000	14,360	248,040	385,600

Note: * is not inhabited area, e.g. government office etc.

APPENDIX B

SEWERAGE SYSTEM CONSIDERATION

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CHAPTER 1

BASIC CONSIDERATION

1.1 GENERAL

To examine all reasonable alternatives and to select the most cost-effective system therefrom, network models were developed, and sewage treatment methods of sewerage system considered for application to the Project Area. Using these models, all feasible alternative combinations of sewerage systems were developed and each of the alternatives was studied with respect to its capital, operation, and maintenance costs as well as effects on flexibility and speed of implementation to identify the most economical system achieving the desired results. The economic analysis considered sewage flow rates and costs incurred over 20 year period to the year 2000.

Result of these studies indicates that the alternative, essentially independent treatment plant constructed in each zone, is the most economical sewerage system.

1.2 Sewerage Districts and Zones

Generally, two alternative sewerage systems, whole Project Area is covered by one intensive sewerage system and more than one sewerage systems in the Project Area, are considered. Which is the most desirable system or how to divide or not the Project Area is depend upon the characteristics of the study area.

If intensive sewerage system is planed in a huge area, to convey sewage from individual house to the treatment plant windingly, big sized deep trunk sewers (especially where ground surface is flat) are required, and it cause high preceding investment. Consequently, immediate functionning of comprehensive sewerage system will be delayed by lack of funds for small sewers such as laterals, branchs, and house connexions.

The physical characteristics of the Project Area are (1) populated urban areas are limited, (2) huge rural areas still remain at present to be developed in the future, and (3) mostly flat ground surface.

Under the circumstance, it is considered practical, as WHO Assignment Report recommends, that the Project Area be properly deliviated into districts and zones to be dealt with separately, rather than planning area-wide system to cover whole Project Area. The advantage considered would be:

(1) It is possible to design sewer facilities according to the characteristics of each of such areas.

(2) Implementation of construction plan will be flexible to adjust according to the degree of requirement and availability of financial resources.

(3) Long conveyance can be avoided, which will enable better controll of sulfide build-up.

(4) Rural areas, in which no urbanized plan is done, will remain flexible.

The Project Area has, as indicated earlier, total of 11,600 ha altogether, but, excluding watercourses, swamp and other non-habitable areas, total area for sewerage planning purpose is 10,854 ha. For the convenience of planning, an attempt is made to divide the total area available into 4 districts, namely, Batterworth, Seberang Jaya, Prai and Bukit Mertajam in accordance with the geographical conditions. They are further divided into zones with due consideration of the followings.

(1) Population density by area.

(2) Existence of rivers, railways, and roads.

(3) Land use situation.

(4) Administrative boundaries (Mukim).

(5) Condition of built-up areas.

(6) Topography.

Several alternative deliniations are considered, but with due note of the advantages for smaller deliniation is stated earlier, the following is considered to serve the purpose.

	Name of District	Name of Zone	Area (ha)	Covered by Sewerage (ha)
1.	Butterworth	Zone - 1	390	367
2.	"	" - 2	200	182
3.	"	" - 3	490	457
4.	"	" - 4	450	444
5.	"	" - 5	570	551
6.	"	" - 6	670	670
7.	Seberang Jaya	Zone - 1	480	438
8.	"	" - 2	360	305
9.	"	" - 3	510	510
10.	"	" - 4	430	430
11.	"	" - 5	420	368
12.	Prai	Zone - 1	1,230	1,063
13.	"	" - 2	280	268
14.	Bukit Mertajam	Zone - 1	940	892
15.	"	" - 2	730	715
16.	"	" - 3	980	927
17.	"	" - 4	470	467
18.	"	" - 5	490	459
19.	"	" - 6	660	573
20.	"	" - 7	850	768
	Total		11,600	10,854

NOTE: The area covered by sewerage of 10,854 ha is derived from excluding nonhabitable areas such as mountains, rivers, and cemeteries from the entire Project Area of 11,600 ha.

The detailed descriptions of present condition of each sewerage zone are as follows:

(1) Butterworth Sewerage District

This district is the northern part of the Butterworth/Bukit Mertajam Metropolitan Area and the sourthern end is limited by the Prai river. It covers an area of 2,671 ha. (excluding the airforce base), with a present population of approximately 109,000. The twon area of Butterworth is included within this district. For more detailed planning consideration, the district is deemed appropriate to divide into 6 zones, on the basis of roads, administrative subdistrict boundaries, and town area boundaries.

Zone	Area (ha)	Population	Population density (persons/ha)
Zone-1	367	37,920	103
-2	182	3,585	20
-3	457	28,225	62
-4	444	26,332	59
-5	551	3,961	7
-6	670	8,902	13
Total	2671	108,955	

Small stormwater drains into which kitchen wastes are discharged directly at present, are provided in the twon area. Ground elevations in this district are low, ranging between 1.8 to 3.5 meters above mean sea level (RL).

In most of housing areas in the town area and new housing development areas, flush toilet systems with septic tanks are commonly used, while in the rural area bucket toilet systems are commonly used. Wastewater produced within this district finally flow into the Prai river through its branchs and drains.

Comments on some of the zones are as follows:

(a) Zone-1 covers the center of this district, in which there are both commercial and residential areas. The available land for treatment plant is an area of approximately 12 ha.

(b) Zone - 2 and 3 are covered by residential, industrial, and partly rural areas, and is within town area.
Because zone-2 comprises built-up urban area in the near furutre, enough land necessary for treatment plant is not available within this zone. The available land for treatment plant in zone-3 is an area of approximately 60 ha.

(c) A part of zone-4 is town area, however this zone is still rural at present.

(d) Zone - 5 and 6 are rural areas at present, and are partly under housing development programes.

(2) Seberang Jaya Sewerage District

This district lies between the Prai river and the railway, and covers an area of approximately 2051 ha with a present population of 28600. Most areas of this district are under the industrial and housing development plans. The district is proposed to be divided into 5 zones in accordance with new planning roads.

The area, population, and population density by zone at present are as follows:

Zone	Area (ha)	Population	Population density (persons/ha)
Zone-1	438	13657	31
-2	305	69	0.2
-3	510	2991	6
-4	430	7518	17
-5	368	4369	12
	2051	28604	

There are drainage system including wide and flat grade open channels and pumping station which has not been operated yet. Ground elevations in this district are also low, ranging between 1.5 to 2.5 meters above mean sea level (RL).

In new housing devlopment area of this district, flush toilet systems followed by the stabilization pond are installed, while in the rural area bucket toilet systems are commonly used. Wastewater produced within this district is finally discharged into the Perai river through drains.

Comments on these zones are as follows:

(a) New industrial and housing complexes are under construction in zone - 1 and 2. he available land for treatment plant in zone-1 is an area of approximately 30 ha.

In zone-2, the available land for treatment plant is impossible to obtain.

(b) Zone - 3, 4 and 5 are covered by rubber firms, rural housing areas, and wilds at present.

(3) Prai Sewerage District

This district is the south-west part of the Metropolitan Area limited by the railway, and covers an area of approximately 1331 ha with a present population of 3800. Most of the district is covered by the industrial development plan, and under construction.

The district is proposed to be divided into 2 zones by new planning boundaries of industrial area.

The area, population and population density by zone at present are as follows:

Zone	Area (ha)	Population	Population density (persons/ha)
Zone - 1	1063	1860	2
- 2	268	1974	7
	1331	3834	

Ground elevations in this district are low, ranging between 1.1 to 1.8 meters above mean sea level (RL). Wide and flat grade open drains and pumping stations (one is functionning and the other one is under planning) are installed. Wastewater produced within this area is discharged into the ocean through drains and pumping station.

(a) Zone - 1 is covered by the Prai industrial complex and the industrial development area.

(b) Zone - 2 is rural housing area and is wild at present.

(4) Bukit Mertajam Sewerage District

This district is the eastern half of the Metropolitan Area and covers an area of 4801 ha, with a present population of approximately 96600. The town area of Bukit Metajam is included within this district. The district is proposed to be divided into 7 zones on the basis of roads, administrative sub-district (Mukim) boundaries, town area boundaries, and topographical conditions.

The area, population, and population desity by zone are as follows:

	Area (ha)	Population	Population density (Persons/ha)
Zone - 1	892	7559	8
Zone - 2	715	6387	9
Zone - 3	927	45540	49
Zone - 4	467	6077	13
Zone - 5	459	7257	16
Zone - 6	573	13840	24
Zone - 7	768	8947	13
TOTAL	4801	96607	

Small stormwater drains consisting mainly of side ditches have been provided in the town areas. In other areas natural drainage systems are functionning well because of adequate slope of ground surface at present. Ground elevations in this district are ranging between 1.8 to 16 meters above mean sea level (RL).

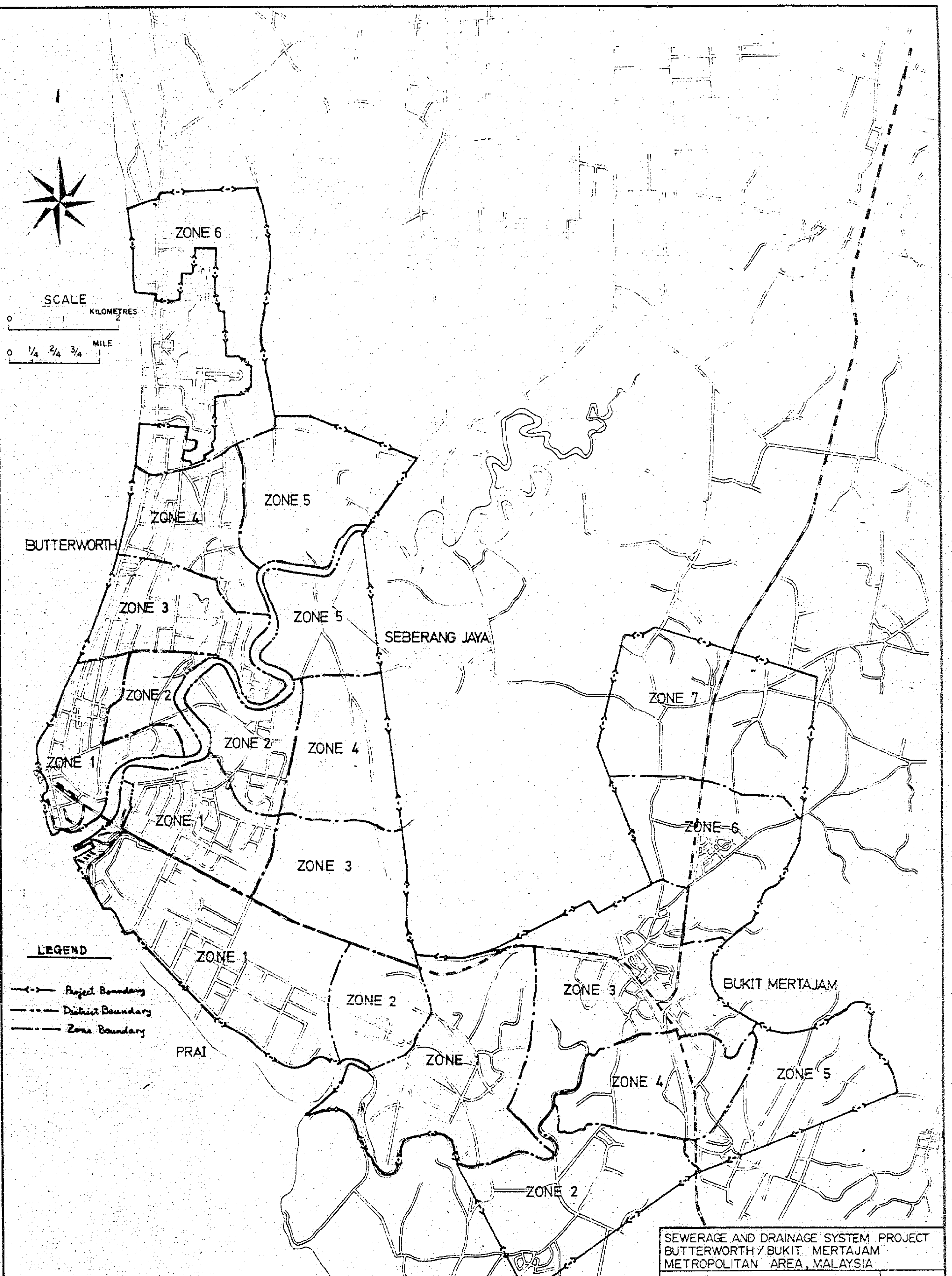
In most of housing areas in the town are and new housing development areas, flush toilet systems with septic tanks are commonly installed, while in the rural and mountanous areas bucket or pit latrine toilet systems are commonly used. Wastewater produced within this district is discharged finally into the Jurn river through its branches and drains.

Comments on some of the zones are as follows:

(a) Town area which is built-up populated area, and new housing development area along the upper-stream of the Juru river are in zone-3.

(b) Remainders, Zones - 1, 2, 4, 5, 6 and 7 are rural or mountainous areas.

FIGURE



SEWERAGE AND DRAINAGE SYSTEM PROJECT
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METROPOLITAN AREA, MALAYSIA

SEWERAGE DISTRICTS & ZONES

FIGURE B - 1

CHAPTER 2

SYSTEM ANALYSIS

2.1 GENERAL

Considering the sewerage master plan objectives, many special investigations were carried out during our studies, and evaluation of the results have led to the formulation of general design criteria for desirable optimum system. On the basis of these, alternative systems were designed and cost estimates made for comparative analysis.

It is apparent that a sewerage system serving the Project Area will involve conveyance and treatment of raw sewage flows and disposal of treated sewage effluents through the combination of most appropriate several locations. To examine all reasonable alternatives and to select the most cost-effective system therefrom, a network model was developed to facilitate the analysis. Using this model, all feasible alternative combinations of sewerage systems were defined and each of the alternative was studied with respect to its capital, maintenance and operation costs as well as the effect on flexibility and speed of implementation in order to determine the best solution.

2.2 ALTERNATIVE SEWERAGE SYSTEM CONSIDERED

2.2.1 Conveyance Network

The entire Project Area is Butterworth/Bukit Mertajam Metropolitan Area, for the area to be included in the Master Plan's programme of sewerage to be achieved by the year 2000. The network model covers the master plan area of approximately 10,854 ha, consisting of 20 sewerage zones. These are illustrated in Figure B-1 and described in Table B-1.

In adopting the network model to conditions, cost functions were developed for each component facility such as sewage treatment plants, pumping stations and sewers. Development of these cost functions are described in Appendix D.

A large number of cases of conveyance networks were studied on a preliminary basis, considering topographical and economic aspects both for present and future conditions.

From these preliminaly studies, two cases were identified for detailed comparative analysis. These two cases were selected from a number of possible combinations, all but two of which were eliminated by preliminary screening processes. These screening processes included availability of land suitable for treatment plant facilities, rough cost estimates of capital and operation and maintenance, inpact on waterways, priority of sewerage provision, the Government's development programmes and policies, etc. These two cases are illustrated in Figures B-2 and B-3 with the following comments.

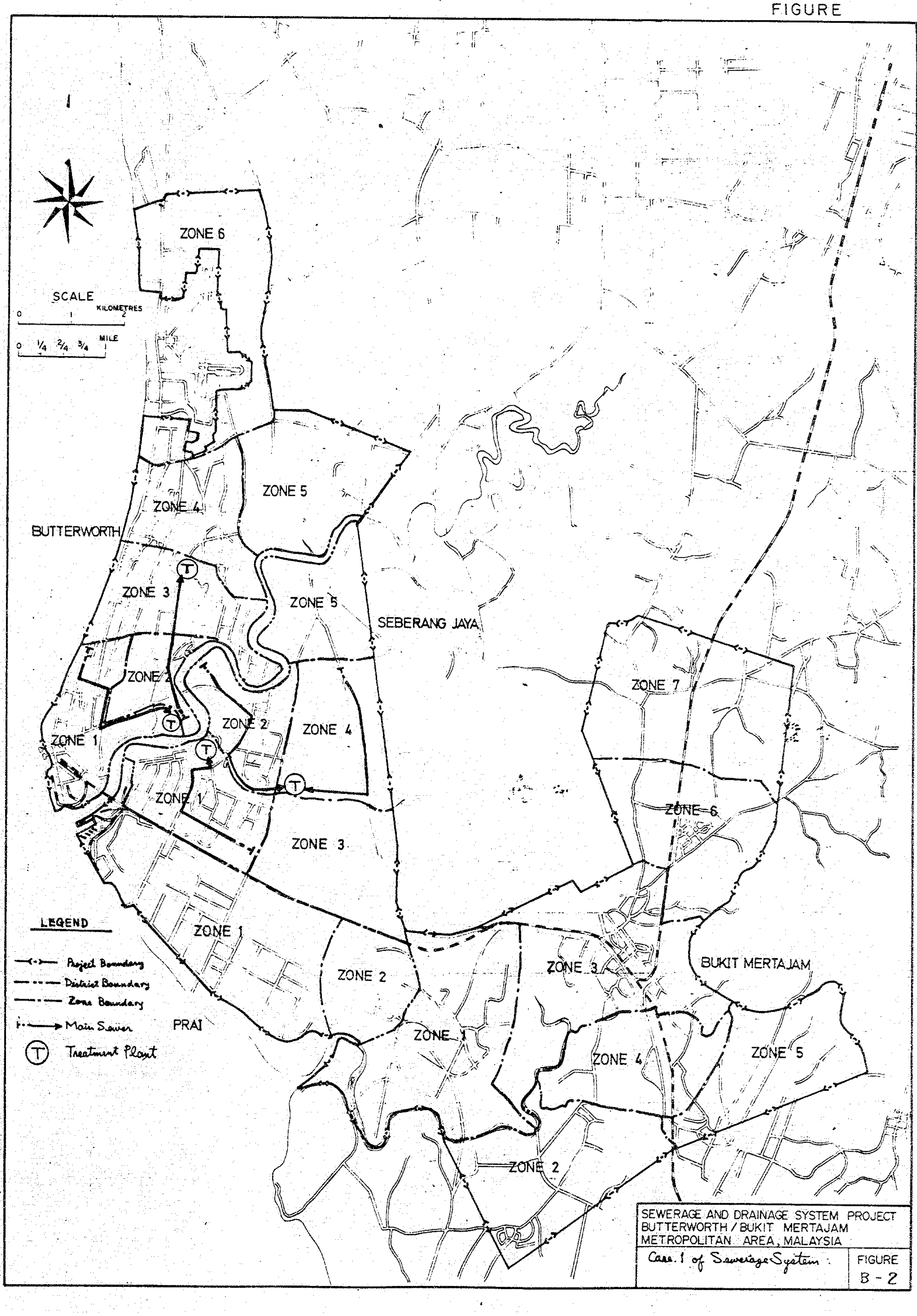
(a) Case 1.

In this case, the sewage flow of the Butterworth zone 2 is conveyed to the Butterworth zone 3 through a connecting sewer, and the collected sewage is treated by treatment process at the Butterworth zone 3, discharging effluent into the Prai river through drain, as shown in Figure B-2.

(b) Case 2.

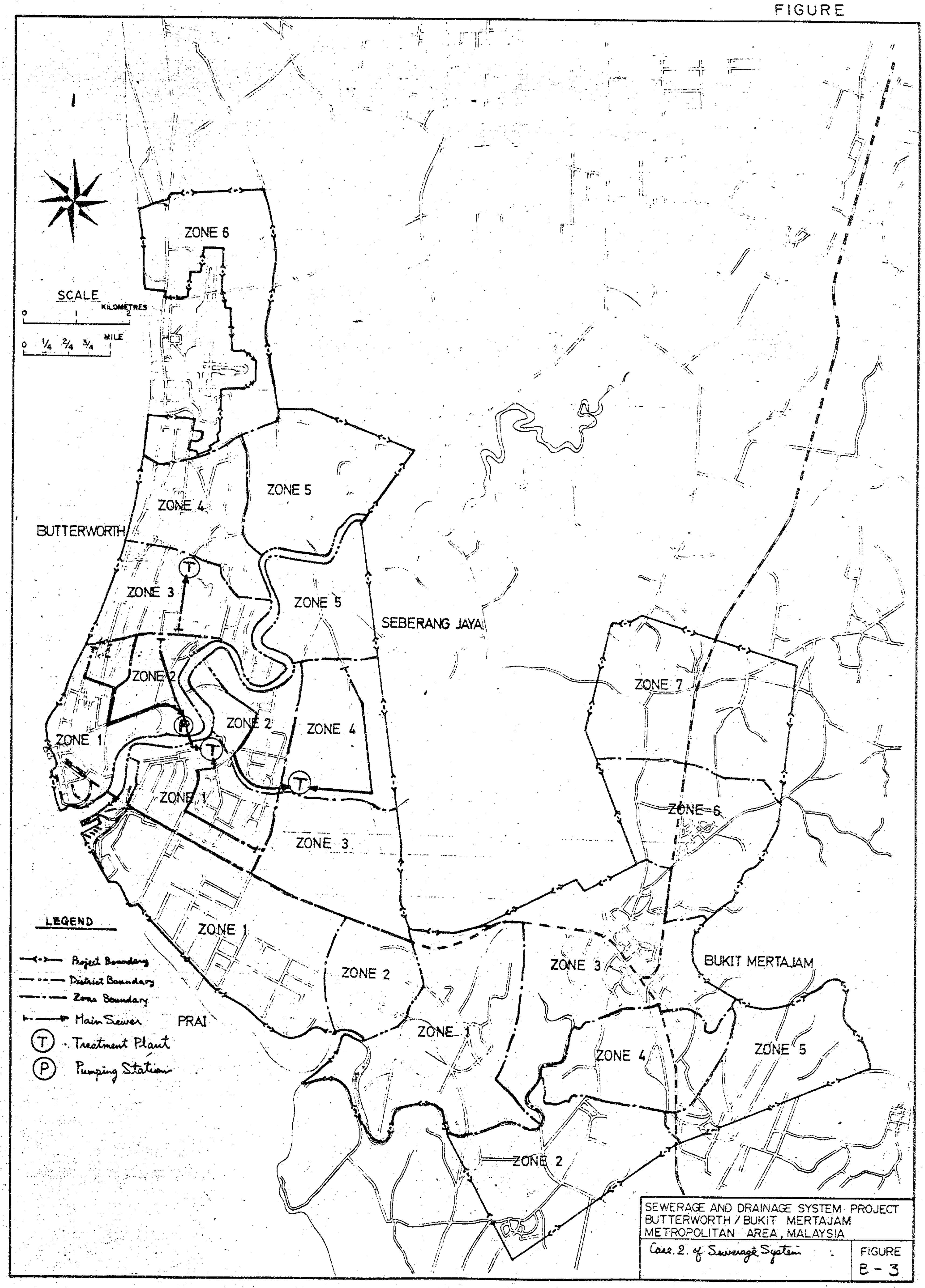
In this case, the collected sewage of the Butterworth zone 1 and 2, and the Seberang Jaya zone 1 will be treated by treatment plant at the Seberang Jaya zone 1 discharging effluent into the Prai river, as shown in Figure B-3.

FIGURE



ZONE 6
SCALE
KILOMETRES
0 1 2
MILE
0 1/4 2/4 3/4 1
ZONE 5
ZONE 4
BUTTERWORTH
ZONE 3
ZONE 5
SEBERANG JAYA
ZONE 2
ZONE 2
ZONE 4
ZONE 7
ZONE 1
ZONE 1
ZONE 6
ZONE 3
LEGEND
Project Boundary
District Boundary
Zone Boundary
Main Sewer
Treatment Plant
ZONE 1
ZONE 2
ZONE 3
BUKIT MERTAJAM
PRAI
ZONE 1
ZONE 4
ZONE 5
ZONE 2
SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA
Case. 1 of Sewerage System.
FIGURE
B - 2

FIGURE



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METROPOLITAN AREA, MALAYSIA

Case. 2. of Sewerage System

FIGURE
B - 3

2.2.2 Sewage Treatment and Disposal System

(1) Introduction

Sewage treatment plant is the facility to convert a raw waste water into an acceptable final effluent, and to dispose of the solid removed in the process. It is fundamental, therefore, first to determine the characteristics of the raw waste water and the required degree of the effluent or the required treatment, before proceeding with the design of treatment plant.

In the design of treatment plants of study area, it is necessary to determine the most desirable treatment system from the various methods, to meet the degree of the required effluent, and economical analysis.

This section deals with the briefly alternative methods of treatment system such as stabilization pond, Aerated Lagoon and Oxidation Ditch, and to recommend the desirable treatment method from both the technical and economical view point.

(2) Alternative methods of treatment

1) Stabilization Pond

Stabilization pond has been successfully used in many countries, which is sometimes referred as "oxidation pond" or "lagoon."

They are recognized means of sewage treatment and have considerable advantages particulary as regards the costs and maintenance requirements and the removal of faecal bacteria.

They are without doubt the most important method of sewage treatment in hot climates where sufficient land is available and where the temperature is most favourable for their operation.

Major types of pond, namely, facultative, maturation and anaerobic ponds, while the type of pond considered for the stabilization pond in this study are facultative and maturation pond as described follow.

a) Facultative Pond

Facultative pond is the system in which the upper layers of the pond are aerobic and the bottom layers are either devoid of dissolved oxygen or are anaerobic. At present most of the existing waste stabilization pond installations are of the facultative type.

The facultative pond is oxygenated principally by the photosynthetic activity of algae under the influence of solar radiation, although in the larger ponds surface aeration by the wind action contributes significantly to the total oxygen budget.

The dissolved oxygen concentration is greater during daylight periods than at night. The measurement of oxidation-reduction potential shows the tendency towards true aerobic or anaerobic conditions.

The reducing environment will be found near the bottom, indicating true anaerobic conditions. For the facultative pond, temperature is of great importance because it affects the rate of biochemical degradation. The average temperature, daily fluctuations, and yearly variations all influence the biological, physical and chemical processes in the pond.

The practical design of a facultative pond depends on a great variety of local conditions, but a number of useful and rational design procedures are available. They are based on

(i) load per unit area procedure
(ii) the empirical procedure
(iii) South African Procedure

In the experience of design of facultative pond, used load per unit area procedure has obtained that certain generalizations can be made concerning the acceptable organic load of a facultative pond, mainly in India where climatic conditions favour the working of pond with the value of 170 - 340 kg/ha/day, and in some cases even 400 - 500 kg/ha/day, who adopted. For the pond in the Project Area, great care must be taken in using values of organic loading as the design basis because of different climatic condition. The information on design criteria of organic loading in pond with respect to considerable value for this study has been assessed from various countries experienced.

The empirical procedure by the results of many small laboratory ponds, larger pilot plant and some operating ponds, have developed formulation that can be used to relate pond volume to temperature, BOD, influent volume and toxicity.

The devloped equation by the empirical procedure is as follows.

$$V = (3.5 \times 10^{-5}) \, NqLa \, \theta^{(35-Tm)}$$

where

V = pond volume, cum
N = number of people contributing waste
q = per capita waste contribution, l/day
θ = temperature reaction coefficient = 1.085
Tm = average water temperature of coldest month, °C

Thus, as the required volume of pond is estimated by the above equation, if the depth is selected, and desirable factors for the pond can be designed.

South African procedure is taken on the basis of first order kinetics and the assumption of complete mixing. If it is assumed that all the influent BOD is stabilized by facultative organisms, the the effluent and influent BOD concentrations may be given by following equation.

$$\frac{Le}{Li} = \frac{1}{1 + K_1 t}$$

where

Le = pond and effluent BOD_5, m5/l

Li = influent BOD_5, mg/l

K_1 = first order rate constant for BOD removal at temperature T

t = detention time at temperature T, days

The selection of a suitable value of K_1 is the most difficult element in using design procedures on first order kinetics.

An according to the experience in India, analysis of performance of pond showed that in the temperature range of 26 to 35°C for a first cell of a multicelled unit and for single-celled ponds receiving raw municipal waste water, the rate constant K_1 was 0.23 per day for detention times up to about 3 days, for the second and third cells in this multicelled pond again having 3 days detention in each cell, the K_1 value was approximately taken as 0.1 and 0.06 per day respectively for the same temperature range. In sourthern Africa also, the value of K_1 was found to be 0.23 per day for the first order kinetics. Howeyer, mentioned above value of K_1 which were obtained from waste water analysed both in India and South Africa, should differ by the types of waste, and at temperatures of operation.

Mara [(1)] suggested that the value of K_1 of different temperatures can be calculated from the equation following.

$$K_T = K_{20}(1.05)^{T-20}$$

where

K_T = value of K_1 at T°C

K_{20} = value of K_1 at 20°C

Mara also suggested that reference temperature is 20°C and the design value of K_{20} is conserratively taken as of $0.3d^{-1}$.

Then, area required of pond for the design based on completely mixed reactors in which BOD_5 removal follows first order kinetics is assumed following equation.

$$A = \frac{Q}{DK}\left(\frac{Li}{Le} - 1\right)$$

where A = surface area in pond, sqm

Q = flow, cu m/day

D = pond depth, m

In the design of one of factor, the operational depth of facultative ponds should not be less than 0.9m. Depths lower than 0.9m are conductive to emergent regetation and consequent mosquite breeding. Depths greater than 1.5m promote anaerobic conditions in the pond.

In general, it would be advisable to design of ponds on rational design procedure which has been described at once. The actual design procedure applied of facultative pond in this study is to be considered on the basis of first order kinetics of BOD removal in pond, and then considered factors are assumed that frequently organic load per unit area is as of 100 - 200 kg/ha/day, first order rate of BOD removal at 20°C is as of $0.3d^{-1}$, Minimum detention time is as of 10 days, and depth of pond is as of 1.5m. In addition, temperature in project area is assumed as of 27°C from the meteorological data obtained under the present project.

b) Maturation Ponds

The main purpose of maturation ponds is to provide a high-quality effluent which are used as a second stage to facultative ponds. The principal factor for the design of the maturation pond is detention time, but for efficient reduction of the faecal bacteria it is essential that the pond be arranged in series with the preceding pond. The detention time in the maturation pond, as well as the number of ponds, is determined primarily by the degree of bacterial purification required. Normally the detention time in ponds is taken as of 7 - 10 days, and the depth of pond is taken as the same as that of the associated facultative pond as of 1 - 1.5m.
In design of maturation pond the reduction of faecal coliform in a pond has been found to follow first order kinetics. The appropriate equation is as follows.

$$Ne = \frac{Ni}{1 + K_b t}$$

where

Ne = number of Coliforms/100 ml of effluent
Ni = number of Coliforms/100 ml of influent
K_b = first order rate constant for FC removal, 1/d
t = detention time in the pond, days

In this study, maturation pond is also designed to be considered with the second-stage pond in the aerated lagoon process. The design values of depth and detention time are taken as of 1.5m and 7 days respectively.

2) Aerated Lagoons

Aerated lagoon is activated sludge units operated without sludge return. This is historically developed from stabilization pond.

Low cost mechanical aeration is a most important matter to be useful engineering alternative when waste loads increase, when land is limited, and when high-quality effluents are required. Commonly, floating aerators for surface aeration are used to supply the necessary oxygen and mixing power for bio-oxidation and for mixing lagoon contents.

In common with all activated sludge systems, aerated lagoons are not particulary effective in removing faecal Coliforms, FC reductions are only 90 - 95 percent and further treatment may therefore be necessary, hence it is considered that maturation pond needs for required effluent. For the design of aerated lagoon in the study the first order rate for BOD_5 removal is assumed as of 1.5, then its value at other temperatures can be estimated from the following equation.

$$K_{(T)} = 1.5\ (1.035)^{T-20}$$

Then the quantity of oxygen required for bio-oxidation and oxygen supplied by mechnical aeration are determined as following equation.

$$Bo_2 = 1.5\ (Li - Le)Q$$

where

Bo_2 = oxygen required, kg/hr
Li = BOD_5 of the influent, mg/l
Le = BOD_5 of the effluent, mg/l
Q = volumetric flow rate, cu m/day

$$N = No\ [\ \alpha\ ]\ [(1.024)^{T-20}]\ [\frac{\beta Cs_{(T.A)} - C_2}{Cs_{(20.0)}}]$$

where

- $\dot{N}$ = oxygen supplied by mechanical aeration, kg oxygen/hph
- No= manufacturer's rating of aerator, usually 2.0 kgO_2/kwh
- α= ratio of the oxygen transfer rate in the waste to that in tap water at the same temperature (=0.7)
- Cs= O_2 saturation level of distilled water at T°C
- C_L= level of dissolved oxygen in pond (= 1 mg/l)
- β = ratio of O_2 saturation level in the waste to that in distilled water (= 0.9)

In addition to the design the adopted detention time is to be 4 days and depth of 4 m in pond.

3) Oxidation Ditch

The oxidation ditch is usually used in activated aludge process it can be also used for pretreatment in units followed by stabilization pond. The oxidation ditch is a long continuous channel usually oval in plan and 1.0 - 1.5 m deep. The ditch liquor is aerated by one or more cage rotors placed across the channel.

At present, there are few oxidation ditches in the hot climates due to the fact that stabilization ponds are usually more favourable both in terms of cost and the removal of faecal coliform, althrough where there is a reliable electricity supply with insufficient land for pond, they are being increasingly used.

A design of oxidation ditch are purely empivical at the present the depth is in the range 1 - 2 m and the volume is dependent on the retention time which in turn is based on the sludge loading factor. This is the weight of BOD_5 applied to the ditch liquor suspended solids per day.

Therefore the sludge loading factor is given following equation.

$$Y = \frac{Li}{St}$$

where

r = sludge loading factor, 1/d

Li= influent BOD_5 mg/l

S = ditch liquor suspended solids, mg/l

t = detention time, days

Then, ditch volume is estimated as follow.

$$V = \frac{LiQ}{Sr}$$

where

V = ditch volume, cu m

Q = flow, cu m/day

Design values of this study are, $r = 0.1^{d-1}$, S = 4000 mg/l, t = 0.5 day, and depth of pond as of 1.5 m.

(3) Comparison of Alternative Treatment and Disposal Systems

For the purpose of cost comparison of alternative treatment and disposal systems for the stabilization pond, aerated lagoon and oxidation ditch, firstly each type of treatment facilities were designed to flow rate of waste water from 5,000 to 200,000 cu m daily average flow with associated facilities such as primary, secondary treatment and sludge disposal facility in order to required effluent quality.

The waste water quality of each treatment was estimated with the influent BOD_5 as of 200 mg/l and the effluents that ultimate BOD_5 is of 90 percent removal of influent BOD on the basis of design values, while the effluent quality also was estimated with actual BOD_5 for the stabilization pond and aerated lagoon process as discussed in ANNEX.

Then each type of treatment was analysed and/or made of all costs accruing to alternative considered. Considered each type of methods of treatment and disposal systems for alternative study are described as follow and illustrated as Figure B-4.

1) A method of stabilization pond process which treats for the purpose of mainly BOD and FC removal, consists of primary treatment, stabilization pond to be designed with faculative pond, digestion tank for the purpose of reduction of the complex organic matter present in raw sludge removed and the drying bed which is commonly used for means of dewatering sludge to draw the sludge from digestion tank.

2) A method of aerated lagoon process consists of, as well as above mentioned sedimentation tank, aerated lagoon, stabilization pond that is to be designed with maturation pond depending upon required degree of treatment, digestion tank and the drying bed.

3) A method of oxidation ditch process consists of two sedimentation tanks for the purpose of primary and secondary treatment, oxidation ditch, digestion tank and the drying bed.

The capital costs of the each selected alternative of sewage treatmenr on the flow rate from 5,000 to 200,000 cu m daily average flow were estimated with included the facility of pond, tank and associated equipment in plants on the basis of cost functions developed for the purpose of Master Plan as discussed in Appendix D and, annual operation and maintenance costs for these facilities also estimated.

Table shows the estimation of construction, operation and maintenance sosts of the treatment and disposal systems and required land acquisition for the system. All costs are at 1976 levels in the penang site, but no consideration is given to cost escalation for purposes of economic comparison between alternatives.

Because the availability of funds for this project is still to be decided, and no exact staged investment programme is final yet, in this study, the evaluation of the alternative costs is made on the basis of the constant annual cost method.

For comparison purpose, all costs are then expressed on an annual basis, using the following weighted average lives of facilities,

(a)	pond, tank	30 years
(b)	pump, aerator	7 years

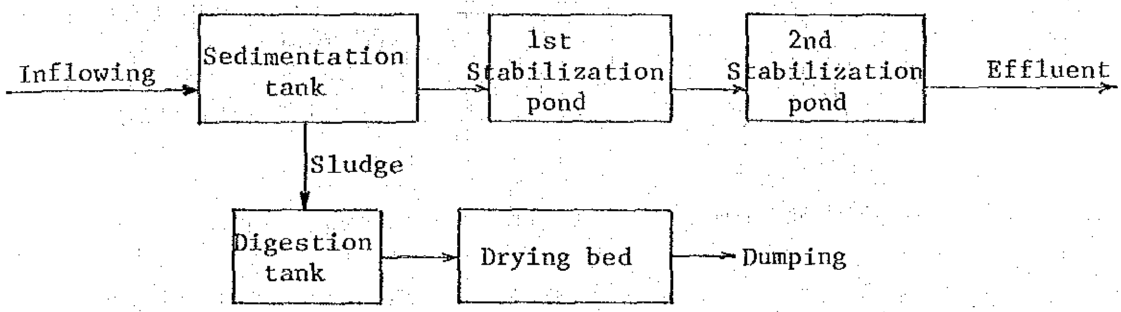
These overall useful lives were estimated on the basis of the useful lives of component facilities, 30 years for civil works and 7 years for machinery of equipment. It is assumed that the fund is available at 10 percent interest and that annual depreciation payments into the sinking fund would grow the some rate.

Depreciated capital costs of the alternative systems are summarized in Table B-2, and total annual costs for the alternatives are shown in Table B-3.

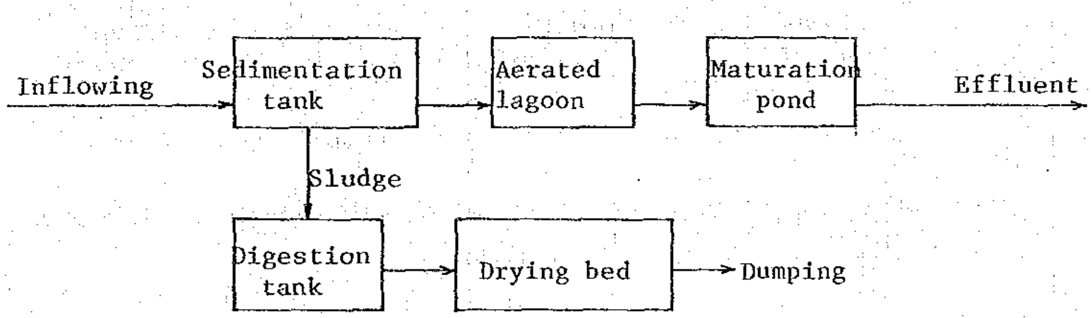
The results of cost analysis indicate that alternative (I) (method of stabilization pond process) including sedimentation tank, stabilization pond, digestion tank, and drying bed, would be most economical method for treatment and disposal system in terms of total annual cost, although the costs of required land of treatment plant were included for the cost comparison on the barsts of available land values from M$2.0 to 30 obtained under the present project.

FIGURE B-4 Flow Chart

(1) Stabilization pond process



(2) Aerated lagoon process



(3) Oxidation ditch process

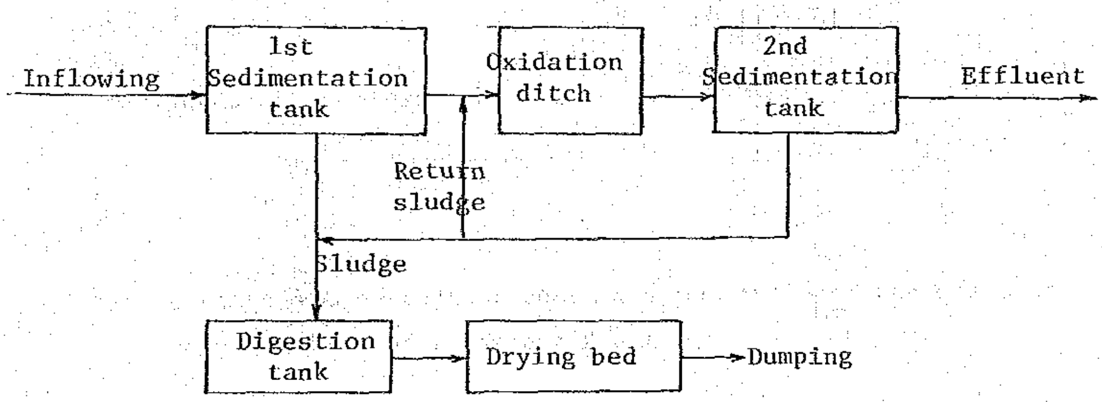


TABLE B-1: Comparison on Alternative Treatment/Disposal Systems

Alternative	Flow Rate (cum/day)				
	5,000	10,000	50,000	100,000	200,000
1) Construction Costs (1000 M$)					
Alt. I Stabilization Pond Process	1,538	2,586	10,087	19,045	37,470
Alt. II Aerated Lagoon Process	4,371	7,195	24,866	45,355	85,311
Alt. III Oxidation Ditch Process	4,882	8,934	40,228	79,869	158,817
2) Operation & Maintenance Costs (1000 M$/year)					
Alt. I Stabilization Pond Process	14.40	15.04	16.84	20.56	27.94
Alt. II Aerated Lagoon Process	39.62	65.50	269.12	525.13	1,037.09
Alt. III Oxidation Ditch Process	218.12	422.47	2,042.56	4,071.96	8,130.76
3) Land Acquisition (ha)					
Alt. I Stabilization Pond Process	11.5	20.9	91.1	175.7	342.7
Alt. II Aerated Lagoon Process	5.8	10.1	41.0	77.9	150.0
Alt. III Oxidation Ditch Process	1.9	3.3	13.7	26.7	53.1

Note: Estimated construction costs are not included the costs of required land of treatment Plant.

TABLE B-2: Depreciation Costs for Alternative Treatment/Disposal Systems

(Unit 1000M$)

Alternative	Flow Rate (cum/day)				
	5,000	10,000	50,000	100,000	200,000
Alt. I Stabilization Pond Process	11.46	19.27	75.15	141.89	279.15
Alt. II Aerated Lagoon Process	29.42	48.42	167.35	305.24	574.14
Alt. III Oxidation Ditch Process	135.82	248.54	1,119.14	2,221.96	4,418.29

TABLE B-3: Total Annual Cost of Alternative Treatment/Disposal Systems

Alternative	Flow Rate (cum/day)				
	5,000	10,000	50,000	100,000	200,000
Alt. I Stabilization pond Process	179.7	292.9	1,100.7	2,067.0	4,054.1
Alt. II Aerated Lagoon Process	506.1	833.4	2,923.1	5,369.9	10,142.3
Alt. III Oxidation Ditch Process	842.1	1,564.4	7,184.5	14,280.8	28,430.8

ANNEX Study of Actual BOD_5 estimated of the Effluents of a Stabilization Pond

From the experienced operation of stabilization pond, the BOD_5 of effluents may be expected to be more than 20 to 50 mg/l after enough detention time, and in spite of no short-circuit of influents. This BOD consists of soluble BOD and suspended BOD. The former is due to remaining BOD of the influents, and the latter results from respiration of algae grown up during retaining in the pond. This respiratory BOD of algae is significant only if the effluent is discharged into waters where algal photosynthesis may be obstracted by unsuitable conditions on light, nutrients, temperature, etc.

Although the respiratory requirement of algae is different by kind of algae, that is to say motile algae such as Euglena or Chlamidomonas are higher than nonmotile types such as Chlorella or Scenedesmus, the algal respiration is estimated at 10 to 20% of gross production per day under suitable condition. Inasmuch this, the respiratory BOD of algae in effluents can be roughly estimated from gross production in the pond.

According to Oswald and Gotaas (1947), daily yield of oxygen by algal photosynthesis in a stabilization pond is given by following function;

Yield of Oxygen O_2 = 0.25FS in lb of oxygen per acre per day
(say 0.028FS in g O_2 per sq m per day

in which

F is a functional factor of light energy flux, detention time, diurnal illumination, applied BOD, and temperature.
S is average visible solar energy (cal per sq cm per day).

As F and S are given from latitude, weather conditions, influent BOD, and detention time of the stabilization pond, Daily yield of oxygen would be estimated for the recommended ponds in Penang.

The estimated F and S are 2,76 and 2.4 respectively. Then, daily yield of oxygen would be estimated at approximately 17 g/sq m/day.

This daily yield of oxygen corresponds to daily gross production. So that, assuming algal respiration is 20% of gross production, and the depth of the recommended ponds is 1.5 m deep, the algal respiratory BOD of the effluents would be estimated as follow;

$$\text{Respiratory } BOD_5 = 17 \times 0.2 \times 1/1.5 \times 5$$
$$= 11.33$$

Therefore, actual BOD_5 of the effluents after 90% treatment of influent BOD would be estimated as follow;

$$\text{Actual } BOD_5 = \text{influent } BOD_5 \times 0.9 + 11$$

CHAPTER 3

ECONOMIC ANALYSIS OF SYSTEMS

3.1 GENERAL

Economic analysis were made of the alternatives sewerage systems, which were indicated to be competitive solutions for provisions of regional sewerage in the sewerage implementation area up to the year 2000. Descriptions of the physical features and comparative analysis of these alternatives are presented in this chapter, and conclusions are drawn as to the most effective sewerage system. In the analysis, sewage flows and costs incurred were studied over 20-year period to the year 2000.

3.2 Design Bases of Facilities

Design bases used in this study were prepared in chapter 5. part III of this report. The possible routes of conveyance facilities and locations of sewage treatment sites for the sewerage system are shown in Figure Ground elevations and sewer service areas for each of these sewer lines were estimated on the basis of the available topographic maps in the scale of 1:7500 to 1:25000, and sewage flow rates in this sewer lines were computed to determine the size of the facilities. The design criteria used are summarized in Table B-4.

For the cost estimates, sewage quantities for the conveyance facilities were estimated from the projected populations and sewage flow rates for the year 2000 as presented in Table B-6, B-7 and rough profiles of major sewers were prepared.

TABLE B-4 Estimated Wastewater Flow Rates (2000)

Type of Wastewater	Estimated Flow Rates
1. Per Capita Sewage Flow	230 litre/day
2. Industrial Wastewater in Zone	80 cu m/day/ha
3. Infiltration	
° Residential of High density	12 cu m/day/ha
° " of Low density	8 cu m/day/ha
° Industrial	5 cu m/day/ha

TABLE B-5 Population Density (2000)

Land Use	Presidential		Commercial		Industrial
	High density	Low density	Residential	Social	
Population Density (persons/ha)	160-120	52	160-120	0	0

TABLE B-6: Population by Sewerage Zone (2000)

District	Zone	Area(ha)	Population
Butterworth	1	367	45440
	2	182	21840
	3	457	37039
	4	444	37514
	5	551	33705
	6	670	37316
Seberang Jaya	1	438	46748
	2	305	25178
	3	510	26543
	4	430	20818
	5	368	19152
Pari	1	1063	0
	2	268	13948
Bukit Mertajan	1	892	47512
	2	715	39794
	3	927	73729
	4	467	24917
	5	459	23889
	6	573	32948
	7	768	39970
	TOTAL	10854	648000

TABLE B-7: Design Sewerage Flow Rate by Sewerage Zone

Sewerage Zone		Area (ha)	Wastewater Domestic (cum/day)	Wastewater Industrial (cum/day)	Extraneous (cum/day)	Total (cum/day)
Butterworth	1	367	10450	1600	3700	15750
	2	182	5020	-	2190	7210
	3	457	8520	8560	4440	21520
	4	444	8630	-	4400	13030
	5	551	7750	-	4700	12450
	6	670	8580	-	5510	14090
Seberang Jaya						
	1	438	10750	160	4920	15830
	2	305	5790	4000	3120	12910
	3	510	6110	-	4080	10190
	4	430	4790	-	3560	8350
	5	368	4400	-	2950	7350
Prai	1	1063	-	85040	5320	90360
	2	268	3210	-	2150	5360
Bukit Mertajam						
	1	892	10930	-	7200	18130
	2	715	9150	-	5870	15020
	3	927	16960	-	8920	25880
	4	467	5730	-	3770	9500
	5	459	5500	-	3670	9170
	6	573	7580	-	4770	12350
	7	768	9190	-	6110	15300
Total		10854	149040	99360	91350	339750

(a) Conveyance Facilities

Indetermining the required capacities of conveyancee facilities. the following factors were considered.

i) Peak flow rates of domestic sewage
ii) Peak flow rates of industrial wastewater.
iii) Groundwater infiltration
iv) Depth of excavation
v) Location of treatment facilities
vi) Pumping requirement
vii) Design Velocities and other design criteria.

(b) Pumping Stations

Lift pumping stations were designed to raise sewage from deep sewers, generally those with more than 7 meters of earth covering, to higher elevation sewers in order to permit continuing flow by gravity. These intermediate pumping stations are provided with suitable structures, grit and/or debris facilities, and pumping equipment to lift the peak sewage flow rates.

(c) Sewage Treatment Facilities

For cimparison purposes, sewage treatment plants were considered at the terminal of each zones. In determining locations and process of treatment for treatment plants for each zone, an evaluation was made of the effects of the waste discharges on the receiving water environment.

For practical purposes for cost comparisons, the cost were determined using the cost functions for treatment facilities for all treatment plants discharging to rivers and waterways. The design capacities of these plants were determined on the basis of the daily average flow.

3.3 Cost Estimates of the Systems

On the basis of the designed sewerage systems, costs of sewage conveyance, pumping stations, and treatment facilities are estimated for cost comparison. As discussed in preceding chapter, two cases of conveyance networks are considered for the areas where no sufficient land area for stabilization pond process, which is recognized as most economical process in preceding paragraph, is available.

Costs for each of two cases is estimated with respect to capital, operation and maintenance, land acquisition, and is compared on the assumed present value.

The cost estimating procedures are on the basis of cost functions developed in Appendix D based on recent costs for constructing major projects in the State of Penang, and from up-to-date materials cost quotations from manufactures in Malaysia.

3.4 Cost Comparison

For cost comparison of two cases, all of cost including capital, operation and maintenance, and land acquisition costs, are expressed as total present value for the 24 years up to the year 2000, at 10 percent of discounted rate.

Detailed cost estimating procedures for two cases are as follows:

(a) Cost Estimates of Sewers

	Construction Cost	O&M Cost
Case 1	75,600 (1000 M$)	990 (1000 M$/year)
Case 2	76,940 (1000 M$)	990 (1000 M$/year)

(b) Cost Estimates of Treatment Plants

	Land Cost	Construction Cost	O&M Cost
Case 1	11,260(1000M$)	37,950(1000M$)	1,010(1000M$/year)
Case 2	10,330(1000M$)	36,300(1000M$)	440(1000M$/year)

The selected treatment process is:

Case 1 ... Butterworth Zone 1
Treatment Plant: Oxidation Ditch Process
(Required land area is 5.2 ha)

Butterworth Zone 3
Treatment Plant: Stabilization Pond Process
(Required land area is 56.1 ha.)

Seberang Jaya Zone 1
Treatment Plant: Stabilization Pond Process
(Required land area is 32.3 ha.)

Case 2 ... Butterworth Zone 3
Treatment Plant: Stabilization Pond Process
(Required land area is 42.5 ha.)

Seberang Jaya Zone 1
Treatment Plant: Aerated Lagoon Process
(Required land area is 35.0 ha.)

(c) Cost Estimates of Pumping Stations

	Land Cost	Construction Cost	O&M Cost
Case 1	-	-	-
Case 2	20(1000M$)	4,600(1000M$)	110(1000M$/year)

(d) Present Value of Alternative Systems

Estimated Total Present Value of Alternative Systems

	Land Cost	Construction Cost	O&M Cost	Total Present Value (Interest 10%)
Case 1	11,260 (1000M$)	113,550 (1000M$)	2,000 (1000M$/year)	68,630 (1000M$)
Case 2	10,350 (1000M$)	117,840 (1000M$)	1,540 (1000M$/year)	69,010 (1000M$)

* The construction program is:

	1981	1982	1983	1984	1985
Land	o	–	–	–	–
Sewers	–	o	o	o	o
Treatment Plants	–	o	o	o	o

(e) Conclusion

From the economic analyses described above, it can be concluded that Case 1 is more economical than Case 2.

3.5 Comparison of Intangible Consideration

Nonquantifiable factors are also important as cost comparison on the selection of sewerage system.

The nonquantifiable considerations deemed of major importance in evaluating alternatives are (1) flexibility and (2) speed of project implementation.

(1) Flexibility

Case 2 would require higher initial investment than Case 1, because of the construction trunk sewer across the Prai river and pumping stations. Therefore, Case 1 is superior than Case 2 for flexibility.

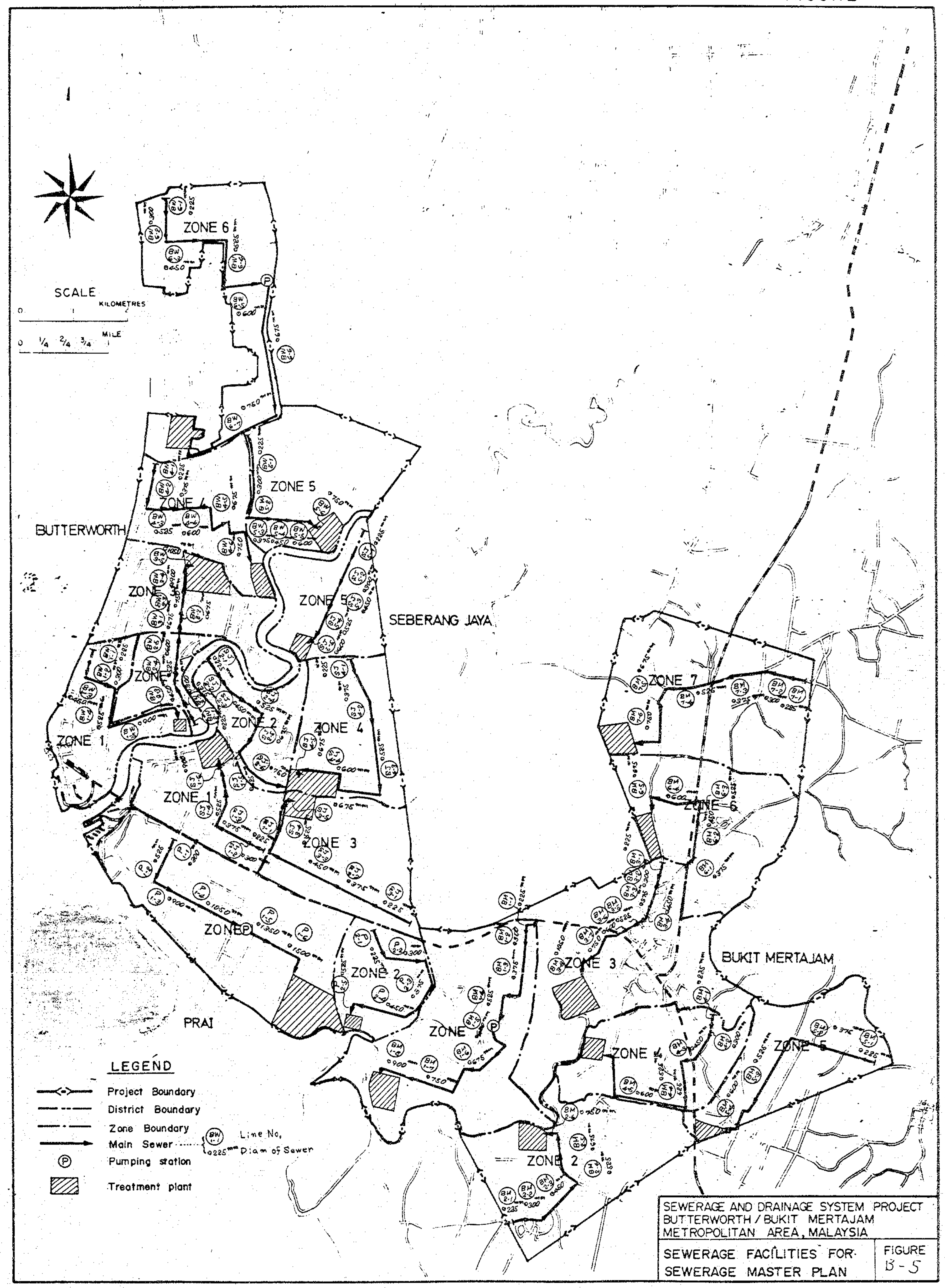
(2) Speed of Implementation

Alternative 1 has three separate sewage treatment plants.
Alternative 2 has two separate sewage treatment plants.
From the viewpoint of ease of rapid implementation, Case 1 is superior than Case 2.

3.6 Conclusion

From the foregoing analyses, it is concluded that Case 1 represented satisfactory alternative, because of its superior potential for cost comparison and flexibility, and speed of implementation. Consequently, it is recommended that Case 1 be adopted for the sewerage system for the project area.

Thus, sewerage system for entire Project Area is proposed as illustrated in Figure B-5. And proposed sewerage facilities by zone, construction cost at 1976 price of proposed sewerage system, and operation and maintenance cost at 1976 price of proposed sewerage system is tabulated in Tables B-8, B-9, and B-10 respectively.


SCALE
KILOMETRES
0 1 2
MILE
0 1/4 2/4 3/4 1
BUTTERWORTH
SEBERANG JAYA
BUKIT MERTAJAM
PRAI
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
LEGEND
Project Boundary
District Boundary
Zone Boundary
Main Sewer
Line No,
Diam of Sewer
Pumping station
Treatment plant
SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA
SEWERAGE FACILITIES FOR
SEWERAGE MASTER PLAN
FIGURE
B-5

- B-40 -

TABLE B-8: Proposed Sewerage Facilities by Zone

Name of Sewerage Zone		Sewer (public) Diam (mm)	Sewer (public) Length (m)	Sewer (house connexion) Diam (mm)	Sewer (house connexion) Length (m)	Pumping station Peak flow (cum/s)	Pumping station Req'd land area(m^2)	Treatment plant Process	Treatment plant Daily average flow(cum/d)	Treatment plant Req'd land & area(ha)	Receiving Water
Butterworth,	Zone-1	225-900	92200	150	110800			OD	15,800	5.2	Prai river
	-2	" -600	54600	"	65500						
	-3	" -1050	116800	"	125700			) SP	28,700	56.1	Drain
	-4	" -750	133200	"	111100			SP	13,000	27.0	Prai river
	-5	" -750	165300	"	98200			"	12,500	26.0	"
	-6	" -750	201000	"	108000	0.18	100	"	14,100	29.1	Drain
Seberang Jaya,	Zone-1	" -900	131000	"	140000			"	15,800	32.3	Prai river
	-2	" -750	82000	"	88700			"			
	-3	" -675	153000	"	76500				10,200	21.6	Drain
	-4	" -675	129000	"	70800			"	21,300	42.7	"
	-5	" -600	110400	"	55200			"	7,400	16.1	Prai river
Prai	Zone-1	" -1500	116900	"	148800	0.89	1540	"	90,400	160.9	Juru river
	-2	" -525	80400	"	40200			"	5,400	12.0	"
Bukit Mertajam,	Zone-1	" -900	267600	"	137200	0.14	90	"	18,100	36.8	"
	-2	" -750	214500	"	115200			"	15,000	30.8	"
	-3	" -1050	278100	"	217800			"	25,900	51.1	"
	-4	" -600	140100	"	71900		"	"	9,500	20.2	"
	-5	" -600	137700	"	68900			"	9,200	19.6	Drain
	-6	" -675	171900	"	95600			"	12,400	25.8	"
	-7	" -750	230400	"	115200			"	15,300	31.4	"

Note: SP --- Stabilization pond process
OD --- Oxidation ditch process

TABLE B-9: Construction Cost of Proposed Sewerage System at 1976 Price

(1000 M$)

Name of Sewerage Zone		Sewer		Pumping Station		Treatment Plant			Total	Remarks
		Public Sewer	House Connex'n	Land Cost	Const'n Cost	Treatment Process	Land Cost	Const'n Cost		
Butterworth	Zone-1	15190	3320	-	-	Oxidation ditch	670	18280	37,460	
	-2	8230	1970	-	-	-	-	-	10,200	
	-3	18950	3770	-	-	Stabilization pond	3650	11440	37,810	
	-4	20740	3330	-	-	"	1760	3760	29,590	
	-5	23910	2950	-	-	"	100	3640	30,600	
	-6	33270	3240	0.3	230	"	6260	4020	47,020	
Seberang Jaya	Zone-1	19970	4200	-	-	"	6940	8230	39,340	
	-2	12730	2660	-	-	"	-	-	15,390	
	-3	22820	2300	-	-	"	4640	3080	32,840	
	-4	19380	2120	-	-	"	9180	9630	40,310	
	-5	16510	1660	-	-	"	3460	2370	24,000	
Prai	Zone-1	19910	4460	41.4	4750	"	34590	25240	88,991	
	-2	11460	1210	-	-	"	360	1850	19,880	
Bukit-Mestajam	Zone-1	39520	4110	0.3	200	"	180	8820	52,830	
	-2	30420	3460	-	-	"	920	4240	39,040	
	-3	39380	6530	-	-	"	1530	10760	58,200	
	-4	20030	2160	-	-	"	610	2900	25,700	
	-5	19610	2070	-	-	"	590	2830	25,100	
	-6	24340	2870	-	-	"	770	3620	31,600	
	-7	32750	3460	-	-	"	470	8100	44,780	

TABLE B-10 Operation and Maintenance Cost of Proposed Sewerage System at 1976 Price

(1000 M$/year)

Name of Sewerage Zone	Sewer		Pumping Station	Treatment Plant	Total
	Public Sewer	House Conect'n			
Butterworth Zone-1	160	80	-	760	1000
-2	90	50	-	-	140
-3	200	90	-	130	420
-4	230	80	-	60	370
-5	280	70	-	60	410
-6	340	80	30	60	510
Seberang Jaya Zone-1	220	100	-	120	440
-2	140	60	-	-	200
-3	260	50	-	50	360
-4	220	50	-	120	390
-5	190	40	-	50	280
Prai Zone-1	200	100	110	170	580
-2	140	30	-	40	210
Bukit-Mertajam Zone-1	450	100	20	120	690
-2	360	80	-	70	510
-3	470	150	-	120	740
-4	240	50	-	50	340
-5	230	50	-	50	330
-6	290	70	-	60	420
-7	390	80	-	120	590