MASTER PLAN AND FEASIBILITY STUDY FOR SEWERAGE AND DRAINAGE SYSTEM PROJECT IN ALOR SETAR AND ITS URBAN ENVIRONS MALAYSIA

VOLUME III

DRAINAGE MASTER PLAN FOR KUALA KEDAH

MARCH 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

MASTER PLAN AND FEASIBILITY STUDY
FOR
SEWERAGE AND DRAINAGE SYSTEM PROJECT
IN
ALOR SETAR AND ITS URBAN ENVIRONS
MALAYSIA

VOLUME III

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DRAINAGE MASTER PLAN REPORT

ON

MASTER PLAN AND FEASIBILITY STUDY

FOR

SEWERAGE AND DRAINAGE SYSTEM PROJECT

IN

ALOR SETAR AND ITS URBAN ENVIRONS

MALAYSIA

Guide to the Reports

The Reports consist of the following,

VOLUME I	:	SUMMARY
VOLUME II	:	SEWERAGE MASTER PLAN REPORT
VOLUME III	:	DRAINAGE MASTER PLAN REPORT
VOLUME IV	:	SEWERAGE FEASIBILITY STUDY REPORT
VOLUME V	:	DRAINAGE FEASIBILITY STUDY REPORT
VOLUME VI	:	INSTITUTIONAL STUDY REPORT
VOLUME VII	:	APPENDICES (FOR VOLUME II)
VOLUME VIII	:	DRAWINGS (FOR VOLUME II, IV & V)

VOLUME III - DRAINAGE MASTER PLAN FOR KUALA KEDAH

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LIST OF ABBREVIATIONS

ACP	- Asbestos cement pipe
ASTM	- American Society for Testing Materials
BOD	- Biochemical oxygen demand (3-day, 30 degrees C)
CRCP	- Centrifugally cast reinforced concrete pipe
DE	- Department of Environment, Ministry of Science, Technology and Environment
DID	- Drainage and Irrigation Department, Ministry of Agriculture and Fisheries
DO	- Dissolved oxygen
DWF	- Dry weather flow
EHEU	- Environmental Health and Engineering Unit, Ministry of Health
EPU	- Economic Planning Unit, Prime Minister's Office
ft	- feet
FTCP	- Federal Town and Country Planning
g/cap	- grammes per capita
g/day	- grammes per day
gal	- Imperial gallons
gal/cap	- gallons per capita
gal/day	- gallons per day
GDP	- Gross Domestic Product
GSD	- Federal Geological Survey Department
ha	- hectares
hr	- hours
IBRD	- International Bank for Reconstruction and Development
IMF	- International Monetary Fund
kg	- kilogrammes
km	- kilometres
l/day	- litres per day
l/day/cap	- litres per day per capita
l/sec	- litres per second
m	- metres
m^2	- square metres
m^3	- cubic metres

LIST OF ABBREVIATIONS (Continued)

MADA	- Muda Agricultural Development Authority
mg/l	- milligrames per litre
mil	- miles
MLG	- Ministry of Local Government
mm	- millimetres
MPKS	- Majlis Perbandaran Kota Setar (Municipal Council Kota Setar)
MPN	- Most probable number
MS	- Meterological Station
MSWL	- Mean Sea Water Level
NEB (LLN)	- National Electricity Board (Lembaga Letrik Negara)
p/ha	- persons per hectare
pH	- Hydrogen iron potential
ppm	- parts per million
PVCP	- poly Vinyl chloride pipe
PWD (JKR)	- Public Works Department, Ministry of Works and Utilities (Jabatan Kerja Raya)
RCP	- Reinforced concrete pipe
SDID	- State Drainage and Irrigation Department
SEDC	- State Economic Development Corporation
SEPU	- State Economic Planning Unit
SLO	- State Land Office
SMHD	- State Medical and Health Services Department
SS	- Suspended solids
STCP	- State Town and Country Planning
VCP	- Vitrified clay pipe
WHO	- World Health Organization
yr	- years

CONVERSION FACTORS

Multiply imperial unit by figures in multiplier column to obtain metric (Sl) equivalent; multiply metric (Sl) unit by reciprocal to obtain imperial equivalent.

Imperial Unit	Multiplier	Metric unit	Reciprocal
acre	0.4047	hectare (ha)	2.471
ft	0.3048	m	3.281
ft/s	0.3048	m/s	3.281
ft^2	0.0929	m^2	10.76
ft^3	0.02832	m^3	35.31
ft^3/s (cusec)	0.02832	m^3/s (cumec)	35.31
gal	4.546	litre	0.220
gal	0.004546	m^3	220
hp	0.7457	kW	1.341
in	25.40	mm	0.03937
lb	0.4536	kg	2.205
lb/ft^2	4.881	kg/m^2	0.2049
lb/ft^3	16.03	kg/m^3	0.06243
mile	1.609	km	0.6214
$mile^2$	2.589	km^2	0.3862
ton	1.016	tonne	0.9842
yd	0.9144	m	1.094
yd^2	0.8361	m^2	1.196
yd^3	0.7646	m^3	1.308

CHAPTER 1
SUMMARY

1. The purpose of this study is to develop the drainage master plan for Kuala Kedah town in order to meet both immediate and future requirements of the drainage to alleviate and/or protect the flood problems. The study carried out is basically in accordance with the Terms of Reference prepared by the Government and results of the discussion made with the government officials, with due consideration of the present and future development of the area. For supplementally information, flow chart indicating the process of the study for preparation of master plan is presented as shown in Figure 1.1.

2. The Study Area covers the total area of 125 ha (313 acres) which is identical to the area that of the Sewerage Study for Kuala Kedah as presented in the separated report. In addition, the area outside the Study Area, from which stormwater discharges into the Study Area, is also considered as a contributing area in calculating stormwater runoffs for the drainage system planning. This contributing area is estimated to be approximately 104 ha (261 acres). Hence, the total area concerned to this study is 229 ha (574 acres).

3. For the drainage study, all available information and data have been collected from the various agencies concerned and actual field survey, including topographic and street maps, records of tide levels, expected land use in target year of 2000, nuisance flood prone area, condition of existing drainage system. The results of the survey and investigation, and their evaluation of the existing conditions are concluded as follows;

- The Study Area is situated in low-lying and flat coastal plains with ground elevation ranging from less than 1 m (3.3 ft) at the lowest, to 2.6 m (8.6 ft) at the highest. In consequence of low-lying and flat situation, major parts of the Study Area, especially regions in fringe of the Sg. Kedah and shore line, are subject to be effected by

tidal influence, and are flooded frequently by tidal inundation. This is main causes of local flooding in the Study Area.

- In the Study Area, there are still numerous swamps and paddy field now functioning as reservoirs which cut the peak flow rate and alleviate floods downstream. It is, however, noted that these areas will be reclaimed gradually by urban development. Thus, significant increase of the peak discharge of stormwater runoff is expected to be effected to the urban drainage of the area in the future.

- The existing drainage system consist of open channels, either lined or unlined, and tidal gates. Those channels are one major drain and many of road side drains, and the tidal gate exists at the down stream of major drain. Most of the road side drains are in the existing urbanized area. Although these road side drains can normally cope with the storm discharge on the present land use condition, no proper cleaning for these drains are, however, provided presently. If appropriate maintenance measures are taken, the condition will be significantly improved. The major drain is basically natural stream with earth channel and can generally accommodate the surface runoff for the storm of 2-year frequency on the present land use condition. However, due mainly to the progress of urbanization of the area, stormwater runoff will increase gradually in the future. Thus this major existing drain is required to be enlarged and lined to increase its capacity to cope with the increased runoff.

- In view of the overall existing drainage system, the Study Area can be identified into four independent drainage basins. The basin mainly occupying the existing urbanized area is situated at the center of Kuala Kedah covering an area of 136 ha (340 acres), and remainings are situated along the Sg. Kedah and coastal line in very low-lying areas. Out of these remainings, one which lines at the northeastern part of the Study Area is situated at the industrial estate. All of those basins are under the development area.

4. On the basis of the findings on evaluation of the existing condition, and taking into consideration of the development plan prepared by the Government, the most desirable layout of the drainage system is made for solution of the flood problems in the following:

- The design work of the drainage facilities proposed is basically in accordance with those recommended in DID's "Planning and Design Procedure No. 1, Urban Drainage Design Standards and Procedure for Peninsular Malaysia", and is carried out by applying the Design Mast Plan (DMP) in accordance with the Terms of Reference.

- The proposed drainage basins are basically identical to those of the existing drainage basins to be divided into four independent basins consisting of one major basin and three minor basins. Out of these proposed basins, trunk drain is considered only in the major basin area covering the area of 155 ha (388 acres), while the minor basins have no provision of the trunk drains, since those basins cover the area of less than 40 ha (100 acres) which is not necessary to provide the trunk drains. These minor catchments shall be provided with the secondary drain facilities to be considered in the future study.

  Basically, stormwater discharge from the major basin is first collected by many of smaller drains, and flows into the proposed trunk drain. This trunk drain connects finally to the Sg. Kedah. In the minor basisn, collected stormwater by smaller drains flow out directly into either sea or the Sg. Kedah.

  Since the master plan is to develop the trunk drainage system, the proposed drainage system covering the whole Study Area consists of one trunk drain only, which is provided in one major basin, while, for estimation of the total project cost, smaller drain net works are also considered and then designed on the basis of the provisional road net works supplied by the development plan.

The proposed route of the trunk drain is basically same as that of the existing natural stream. The type of this drain is of rubble wall with mortar lining on wire nets by way of improving existing natural water courses, taking into account the advantages on hydraulic economic and esthetic points.

- In the actual design of the trunk drainage system, it is found that no provision of the pumping and storage facilities is necessary for the proposed drainage system, since the existing low-lying areas are expected to be reclaimed in the future by development programme.

5. On the basis of the preliminary engineering design, the total construction cost and maintenance cost per year of proposed trunk drain and smaller drains are estimated to be M$4,453,000 and M$50,900 per year respectively.

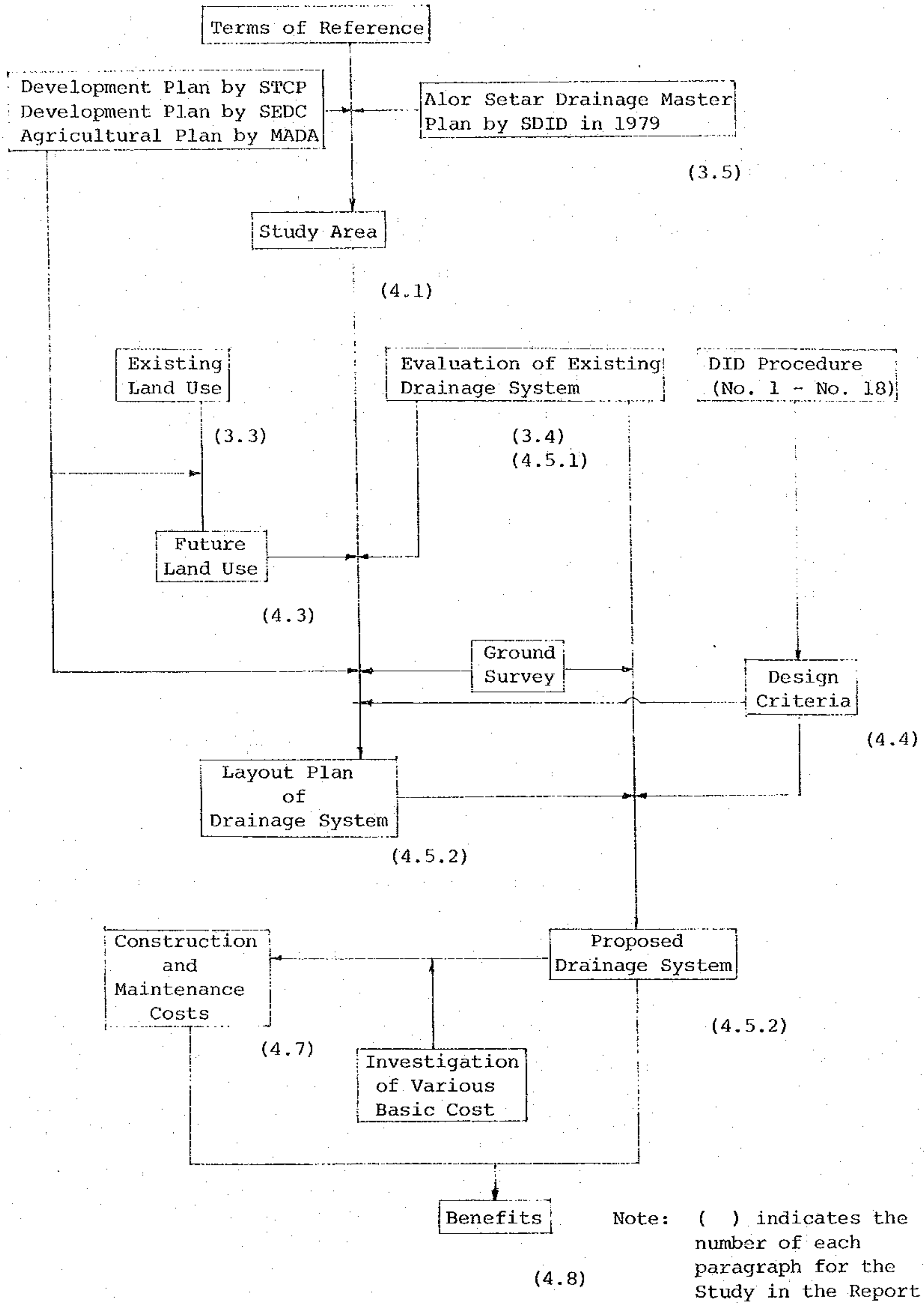
The estimated construction cost is divided into two sources of contribution, namely Government and private. The private contribution is based on the assumption that all smaller drains in undeveloped areas would be provided by private developers. The Government will contribute the costs of proposed trunk drain which can be accommodated in the catchment area exceeding 40 ha (100 acres), together with smaller drains required for further improvement in existing built up areas.

No implementation schedule for the proposed drainage system for the Study Area has been provided in this study, because the provision of the drainage facilities should be determined in accordance with priorities to be established based on urgency and available magnitude of the investment for whole of the municipal boundary, and the Study Area is only a part of Kota Setar municipality.

6. However, various types of benefit will be derived from the implementation of the proposed drainage facilities.

The anticipated benefits include the prevention of the occurrence of flood damage, improvement of public health and convenience of community, and increase of land value. Although most of the benefits are not fully quantifiable, it is evident that there will be high social benefits together with the environmental improvement of the areas.

Figure 1.1 Working Flow Sheet for Drainage Master Plan



CHAPTER 2
INTRODUCTION

Alor Setar and Kuala Kedah towns have been currently experienced of the flood problems, since no adequate drainage system exists except the limited areas with smaller drainage facilities in the city as a whole. Generally, the existing drainage system consists of natural and piecemeal improved water course with meandering alignment with varied widths and depths. Most of these drains are heavily silted and in many cases inadequate to accommodate the runoff from heavy rain storm, thus causing frequent flooding in many places throughout the city. Further, due to the rapid development, numerous swamps and paddy field now functioning as reservoirs for controlling considerable flooding are demolishing. Significant increase of the peak discharge of stormwater runoff shall be consequently expected in the future, and flooding will be more significant in the area, if there is no provision of the adequate drainage system. Accordingly it is emphasized that a comprehensive planning of drainage system is necessary to establish immediately for alleviation of the flooding problems by way of provision of an adequate facilities to meet the present and future requirement with due consideration on the development programme for the town.

The State Government of Kedah has long been cognizant of the actual situation mentioned above, and, in 1979, developed the comprehensive drainage master plan covering for the area of Alor Setar town and its urban environs, in order to determine the necessary works for alleviation of floods and future requirements, while the area of Kuala Kedah town has been excluded. The provision of an adequate drainage system for Kuala Kedah town is also an urgent requirement for the area to alleviate the flood problems which has currently been experienced, and to meet the future development.

Based on the above background, the study of this report under this Project is to provide in developing a programme to establish the master plan of drainage system for Kuala Kedah town, in accordance with the Terms of Reference prepared by the Government of Malaysia and the discussion held with the Government officials concerned.

Due to the fact that Kuala Kedah town has been incorporated within the municipality same as that of Alor Setar town, the determination of the priority for drainage implementation and reasonable magnitude of the investment should be made in view of the overall works required in entire area of the city including Alor Setar and Kuala Kedah towns. Therefore, this report shall be read in line with the "Drainage Master Plan for Alor Setar" prepared by the State Government of Kedah.

CHAPTER 3
BACKGROUND INFORMATION FOR THE STUDY

1. LOCATION AND HISTORICAL BACKGROUND OF THE STUDY AREA

The town of Kuala Kedah, the Study Area for Drainage Master Plan, is situated at the western tip of Kota Setar District in the State of Kedah which is divided into 11 districts, and to the west about 8 km (5 miles) from the center of Alor Setar town, as shown in Figure 3.1. It is lying along the estuary of the Sg. Kedah on the north, and the Straits of Malacca on the west. Further, the region to the south and to the northerneast of the town is overspread with the paddy field toward the Alor Setar town.

Basically, the town has been developed as a fishing village in the past, due to the fact that there exist beneficial fishing grounds along the coast.

At present, both the large scale hausing development schemes and development of industrial estates are underway by the Government at the southern part of Jl. Kuala Kedah and northern part of the town along the estuary of the Sg. Kedah respectively. Effort on improvement and future requirements of the drainage system for these areas is, hence, necessary taking into consideration of the overall town planning, to ensure the provision of necessary infrastructural facilities.

2. PHYSICAL CHARACTERISTICS

2.1 Geology and Topography

The town of Kuala Kedah lies in the very flat region in general, with high land areas of maximum of about 2.6 m (8.6 ft) elevation above the mean sea water level.

Although sufficient data are not available to indicate the soil conditions in the town area, it is characterized generally by an alluvial clay with fine sand and very high ground-water table.

In consequence of low-lying and flat situation, considerable parts of the town are swampy and flooded during the monsoon season. Furthermore, major streams are basically influenced by tidal flows, thus causing tidal inundation, due to flat gradient of streams and heavy sedimentation of the garbage in the streams.

2.2 Climate

The climate is tropical, the north-east monsoon of a dry season from October to February, and the south-west monsoon of a wet season from April to September. Further, inter monsoon also occurs between the north-east and south-west monsoons.

The south-west monsoon brings heavy and long duration of rain storms having two peaks on May and September, while the north-east monsoon characterizes comparatively less precipitation due to interruption by the islands of Sumatra. For the inter monsoon, there are two seasons of about eight weeks duration. No prevailing winds blow at these times, but there is abundant daily occasional rain.

Temperature is relatively constant throughout the year and the average monthly temperatures vary only by about 2°C with a low of about 26°C and a high of about 28°C. However, the daily temperatures range from a mean day time maximum of 36°C to a mean maximum of 27°C at night. The mean annual precipitation in the last 27 years (1951 to 1977) is about 2,180 mm, of which more than 90% is occurred during the months from March to November, but the maximum 24 hr rainfall occurred in 1970 amounting to 154.7 mm (39.3 in.), according to the Meteorological Department data obtained at the observation station, Alor Setar. Winds are generally gentle, and humidity is relatively high.

3. LAND USE AND POPULATION

3.1 Present Land Use

On the basis of the findings of survey and data obtained from the Government Officials concerned to the Project, the entire town area is divided appropriately into the five categories of land use pattern, namely (1) residential, (2) commercial, (3) industrial, (4) schools, and (5) agricultural areas as shown in Figure 3.2.

The estimated acreage of present land use according to the five categories is presented in table 3.1.

Table 3.1 Present Land Use in 1979

Land Use	Area (ha)	Prorated Ratio (%)
Residential Area	56.4	45.1
Commercial Area	14.0	11.2
Industrial Area	1.6	1.3
Schools	2.6	2.1
Agricultural Area	50.4	40.3
Total	125.0	100

Presently, residential and agricultural areas occupy predominatingly in the town area, while the development of industrial estate which locates at the northern region of the town along the Sg. Kedah is now underway by the Government. Hence, present land use pattern will be modified significantly in the near future.

3.2 Present Population

Statistics of population available in the town together with entire Kedah State including Alor Setar town are only for the year 1970, which shows the total population of 7,665 for the town, with enumerated population by blocks.

As discussed in the separated report on Sewerage Study, for determination of the present population in 1979, an attempt was made in terms of overall population distribution covering the entire area of Alor Setar and Kuala Kedah towns, on the basis of (1) assumption on the natural average annual growth rate to be 2.7 percent in the year from 1970 to 1979, using the rate estimated in the Kedah-Perlis Development Study Report, 1978, and (2) consideration on migration in relation to social factors due to the industrial and agricultural development.

From the above referred study, the total present population in 1979 for the town is estimated to be approximately 9,100, which indicates average population density of about of 73 persons/ha.

4. RIVER, DRAINAGE AND IRRIGATION SYSTEMS

4.1 River and Drainage Systems

The town area is situated at the coastal region along the mouth of the Sg. Kedah.

The Sg. Kedah flows from east to west toward the Straites of Malacca through Alor Setar town, and is very flat "tidal river" which is influenced by the ocean tides, with meandering condition of varied widths and depths. Since bunds of the Sg. Kedah were constructed on the way from the town to the tidal barrage which exists at about 12 km upstream from the river mouth, significant tidal inundation in the coastal region around the town has been avoided. However, in consequence of low-lying and flat situations ranging from about 0.9 m (3 ft) to 2.6 m (8.6 ft) above the mean sea water level, considerable parts of the town are subject to back up of the sea water inflows which necessitates to provide the tidal gate for the existing outlet drains, and are liable to occurrence of the flooding or inundation, especially in undeveloped areas.

The existing drainage facilities in the town are mostly of open channels, either lined or unlined, consisting of trunk, secondary and road side drains. Most of major drains are basically natural watercourses with piecemeal improved drains. Many of those are heavily silted and the capacity is reduced accordingly. These inadequate drains are the main cause of flooding. Details are described in the succeeding Chapter of this Report, Section 5, Chapter 4.

In general, although rehabilitation and construction as well as maintenance of the trunk drains serving the area of above 40 ha (100 acres), are undertaken by the State Drainage and Irrigation Department (SDID), the trunk drain within the town area are still under the responsibility of Muda Agricultural Development Authority (MADA). The secondary and other smaller drains (or infrastructural drains, generally road side drains) are under the responsibility of both Municipality (MPKS) and JKR.

4.2 Irrigation System

As discussed in details in the Sewerage Study Report, Vol. II the Muda Agricultural Development Authority (MADA), a quasi-government established in 1970 is undertaking further development of the irrigation scheme within the gazetted MUDA area, in the state of Kedah and Perlis. The scheme covers the total area of 950 km^2 (237,000 acres) including the surrounding area of the town, in the coastal alluvial plain of two States. The irrigation system consists of irrigation channels, drains and auxiliary facilities, which is provided for the paddy field.

Although the major drain within the town area still exists under the responsibility of MADA, it is recommended that those drains are to be transferred to SDID, and converted into urban drainage system, in accordance with the agreement made between SDID and MADA, and no discharge is expected to flow into urban drains from the paddy field, according to the information obtained from MADA and SDID during the

course of the study. It is, therefore, considered that the used water for irrigation do not affect to the urban drainage function when agricultural area within the town area would completely urganized in the future.

5. PREVIOUS STUDIES

Relevant or referential report and studies to this Project are discussed herewith.

5.1 Preliminary Report on Alor Setar Town Drainage

In 1971, the Report on Alor Setar Town Drainage was prepared by Messrs. Ganendra, Ahmad & Associates of Kuala Lumpur for Alor Setar town which was administered by the then Majlis Bandaran Alor Setar who was later included in the Majlis Perbandaran Kota Setar (MPKS) since 1977, with it new organization set up.

Preliminary objective of this study was to establish the drainage system including the improvement of the existing internal drainage system within the town council area of Alor Setar, for solving the flood problems.

The report contained the analyses of river flooding in the Sg. Kedah and Sg. Anak Bukit and preliminary design of the proposed drainage system in Alor Setar town, and pointed out that some storage capacity with the provision of pumping facilities would be necessary in the main drains within the town area, according to the flood analyses based on maximum intensities of storm level. It also included the implementation programme for improvement of the existing main drains on the basis of the engineering works recommended.

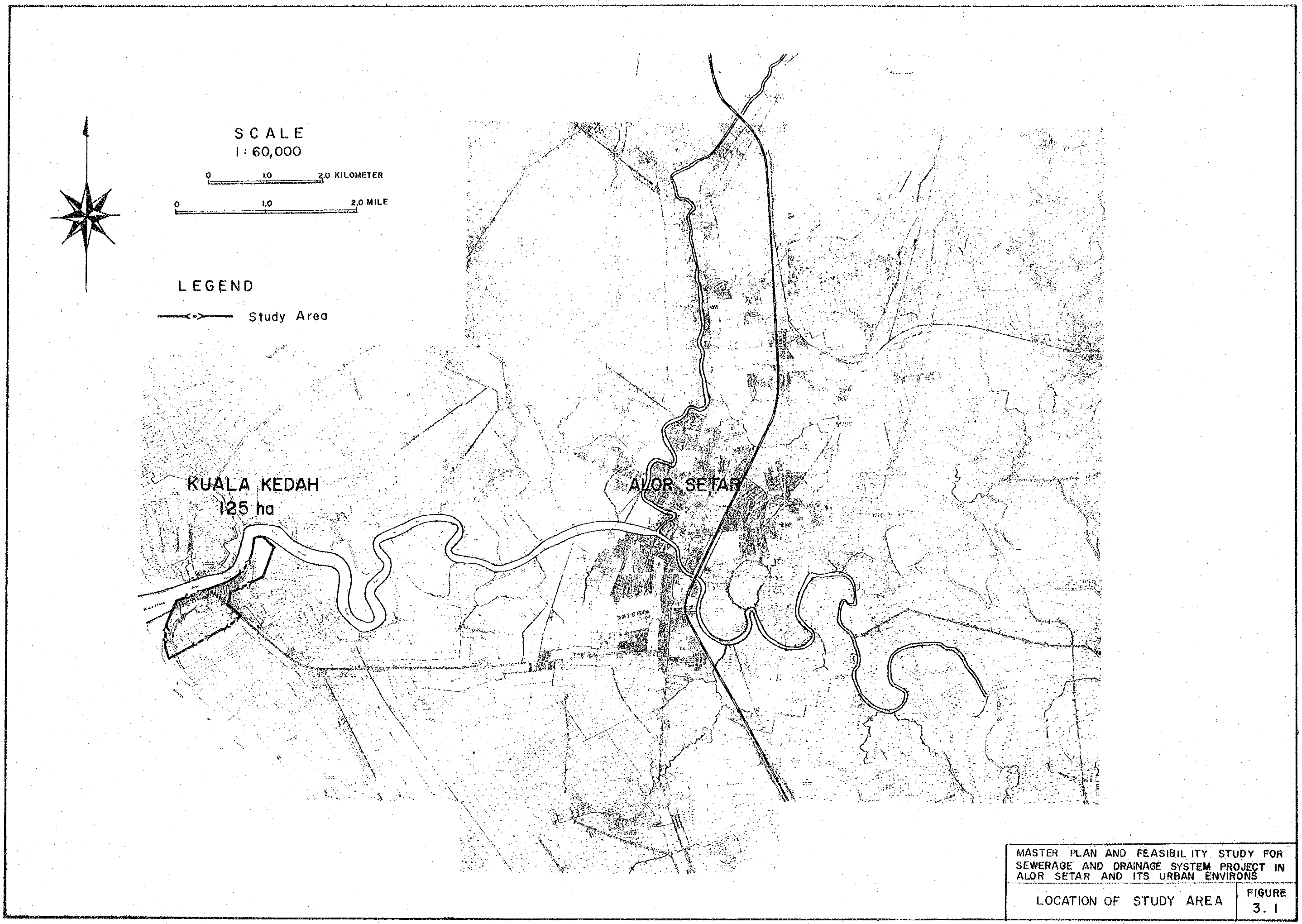
In addition to the above referred report, Supplementary Report on Alor Setar Town Drainage was also prepared in 1972. The purpose of this supplement was to clarify certain aspects of the previous report which arose in the discussion with the government officials.

5.2 Alor Setar Master Drainage Plan

To establish a comprehensive planning of drainage system for Alor Setar town, a study has been undertaken by SDID since 1978, on the basis of the Preliminary Report on Alor Setar Town Drainage as mentioned previously, and the Draft Report on Alor Setar Master Drainage Plan was prepared in March 1979, in which certain revision has been made on the previous reports.

The study covered the total area of 3,584 ha (14 sq. miles) of Alor Setar Conurbation, in developing the adequate drainage system and the flood mitigation measures. For the flood mitigation measures, it recommended that major portion of both the Sg. Kedah and Sg. Anak Bukit are necessary to be provided with the river bunds to protect the town from the high water levels in the rivers especially when coincidence of high spring tide level and high flood flows in the upstream of trunk drains within the town area during the monsoon period occurs.

As mentioned above and in the previous paragraph, both of the reports by SDID and MPKS have covered only for the area of Alor Setar town and/or Alor Setar Conurbation excluding the Kuala Kedah town. So far, no attempt has been made to prepare a comprehensive planning of drainage system for Kuala Kedah town, although it is also included in the same city organization as that of Alor Setar town, and problems of flooding have occurred frequently within the town.

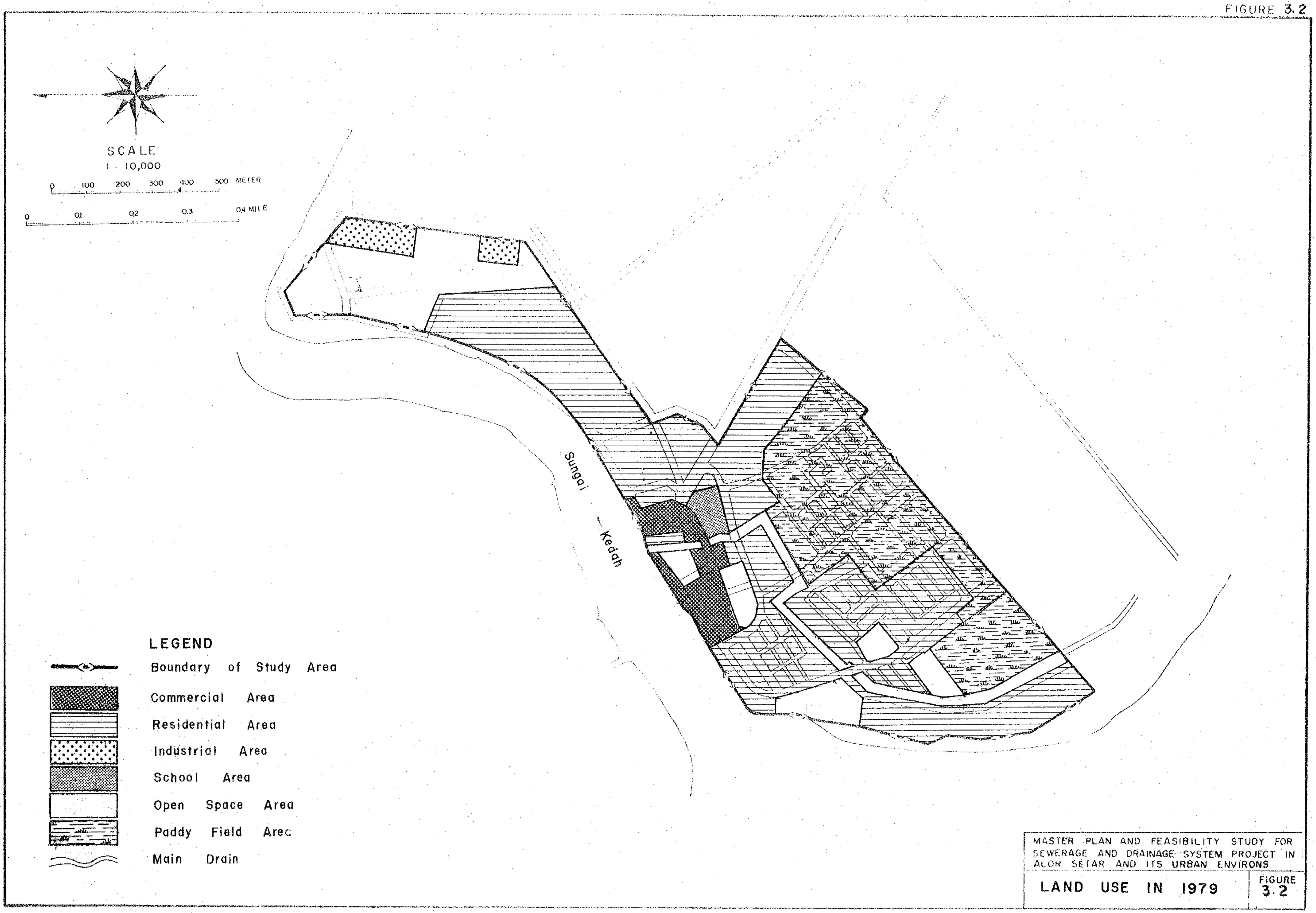


MASTER PLAN AND FEASIBILITY STUDY FOR SEWERAGE AND DRAINAGE SYSTEM PROJECT IN ALOR SETAR AND ITS URBAN ENVIRONS

LOCATION OF STUDY AREA

FIGURE 3.1

FIGURE 3.2



MASTER PLAN AND FEASIBILITY STUDY FOR SEWERAGE AND DRAINAGE SYSTEM PROJECT IN ALOR SETAR AND ITS URBAN ENVIRONS

LAND USE IN 1979

FIGURE 3.2

CHAPTER 4
DRAINAGE STUDY

1. STUDY AREA

As discussed in previous Chapters, and in accordance with the Terms of Reference of Master Drainage Plan for Alor Setar Conurbation prepared by the Government of Malaysia for this Project, the area for drainage work to be covered by this study for preparation of the master plan is limited to Kuala Kedah town.

For delineation of the Study Area, comprehensive discussions have been made with Government Officials such as MADA, STCP and SDID during the course of the study. Through the discussions, it is considered appropriate that the Study Area considered for provision of the drainage system under this Project is to be 125 ha (313 acres) approximately, which is identical to the area for sewerage study for Kuala Kedah, as shown in Figure 4.1. Moreover, for planning of the drainage capacities, approximately 104 ha (261 acres) of tributary outside the Study Area is considered because such tributary contributes its storm runoff to the urban drainage within the Study Area.

Hence, the total area concerned for the drainage study under this Project is 229 ha (574 acres) approximately, but no facilities will be planned for tributary areas mentioned above, in this master plan.

2. TERMS OF THE STUDY

In accordance with the Terms of Reference of Master Drainage Plan for Alor Setar Conurbation prepared by the Government of Malaysia for this Project, and discussions held with Government Officials, the following terms are presented for preparation of the drainage master plan.

2.1 Trunk Drainage System

The master plan is to establish the trunk drainage system for Kuala Kedah town in order to meet both immediate and future requirement for solving the flood problems.

A trunk drain shall generally serve an area of more than approximately 40 ha (100 acres). An area serving less than the above is covered by the secondary drainage system which will be provided by the further study (Feasibility Study).

Generally, a secondary drain shall serve an area of approximately 4 ha (10 acres) according to the DID definition.

2.2 Design Master Plan and Preventive Master Plan

(a) Design Master Plan (DMP)

This plan shall be made for the built-up areas. Its objective is to prepare comprehensive long-range plan for the solution of existing drainage problems in the built-up areas.

(b) Preventive Master Plan (PMP)

The objective of this plan is to prepare drainage strategies for the undeveloped areas to prevent drainage problems from occurrence of future urban development of the land.

3. FUTURE LAND USE AND POPULATION PROJECTION

3.1 Future Land Use

The characteristics of the storm water runoff is significantly affected by the land use pattern of the area.

At present, numerous agricultural areas still exist within the Study Area, which conveniently serve to prevent the storm water inflows into the urban drainage.

However, due mainly to the development of the town in the future, it is expected that most of those areas will be coverted by other land use categories such as residential, commercial and industrial areas, thus stormwater runoff increasing into the urban drainage.

For design of the drainage system, the land use pattern for the year 2,000 has been taken into consideration, and is developed with due consideration on the development plan as mentioned above.

On the basis of the existing land use and in consultation with TCP, future land use plan is developed as shown in Table 4.1 and Figure 4.2. The land use pattern applied for this study is that whole of the Study Area will essentially be urbanized and no agricultural area will remain by the target year of 2,000. It is planned to be classified into three categories, such as residential, commercial and industrial areas in the target year, converting the present agricultural areas owing to the development programme within the Study Area as mentioned above.

Table 4.1 Future Land Use in 2000

(ha)

Land Use	Area	Prorated Ratio (%)
Residential Area	89.0	71.0
Commercial Area	18.0	14.5
Industrial Area	18.0	14.5
Total	125.0	100

3.2 Population Projection

As discussed in previous Chapter, the estimated total population of the Study Area for the year 1970 and 1979 is 7,665 and 9,100 respectively. On the basis of the above population estimates, and in accordance with the land use pattern developed for the year 2000, population in 2000 for the Study Area is estimated to be 12,900. This is based on the con-

sideration of overall view of population projection covering Alor Setar and Kuala Kedah towns as discussed in details in the separated report on Sewerage Study.

4. DESIGN BASIS

Design criteria presented herein are basically in accordance with those recommended in DID's "Planning and Design Procedure No. 1, Urban Drainage Design Standards and Procedures for Peninsular Malaysia".

Followings are brief description on the design basis adopted for the study.

4.1 Sea Water Level Used for Design

The reference data used in this study are those established in the Malaysian Survey Ordinance Datum, of which the zero point is mean sea water level (1912 determination).

The ground elevations used for this study are expressed in a reduced level (RL) which is identical to the zero level of the Survey Ordinance Datum. All levels are referred to the Malaysian Survey Ordinance Datum.

For design basis of the drainage study, following sea water levels are used as referred in the Terms of Reference prepared by the Government of Malaysia.

HHWL (highest recorded level, high water spring tide)	SOD + 2.23 m (+7.3 ft)
HWL (high water level)	" + 1.68 m (+5.5 ft)
MHWL (mean high water level, spring tide)	" + 1.53 m (+5.0 ft)
LWL (low water level)	" - 0.46 m (-1.5 ft)

SOD: Survey Ordinance Datum is the height above mean sea level at Port Swettenham in 1912

It is expressed as,

mean sea level (1912) .... SOD + 0.00

Further, the selected levels in order to carry out the actual design for determination of the drainage requirements are described below:

(a) For checking the trunk drainage system for the Major Storm, the tailwater is determined by adopting "Mean High Water Level (+1.53 m or + 5.0 ft) tide conditions.

(b) For designing the trunk drainage system for the Initial Storm, the tailwater is determined by adopting "High Water Level (+1.68 m or +5.5 ft) tide conditions.

(c) For design storage systems subject to tidal influence, the following is assumed;

- Tide is diurnal in approximately 12 hours duration
- Rise and fall of tide is sinusoidal
- High water level is +1.68 m (+5.5 ft) and low level is -0.46 m (-1.5 ft)

(d) For land filling, ground elevation to be raised is determined by adopting "Highest Recorded Tide Level (R.L. + 2.23 m or + 7.3 ft)"

4.2 Stormwater Quantities

As the basis of the engineering design of drainage facilities, stormwater quantities have to be estimated as accurate as possible, for which many formulas and methods have been developed. Following is to describe the various factors required for estimation of the stormwater quantities.

4.2.1 Runoff Formula

The "Rational Formula" is widely used as current practice for computing quantities of stormwater runoff. Although it is normal to apply to the "Rational Method" in which no storage effects inside ditches are weighted, the Malaysian Standards recommended the use of the "Rational Method" with a storage coefficient as described follow:

$$Q = \frac{1}{360} Cs.C.I.A.$$

where Q: peak discharge of return period T-year (m^3/sec)

I: average intensity of rainfall for duration equal to the time of concentration t_c and a return period T-year (mm/hr)

A: catchment area (ha)

C: a runoff coefficient

Cs: storage coefficient which is expressed as

$$Cs = \frac{2t_c}{2t_c + t_d}$$

t_c: time of concentration, (min.)

t_d: time of flow in the drain, (min.)

The application of a runoff formula modified by a storage coefficient is preferable in the Study Area which is totally flat and low-lying.

The relationship between Cs, t_c and t_d in Malaysian Standard is derived on the basis of the theory acceptable internationally, and the result of its practical application on four drainage basins in Kuala Lumpur coincide with those obtained by the more elaborate routing procedure by way of computer calculation. The derivation of Cs as a function of t_c and t_d is explained in "Flood Estimation for Urban Areas in Peninsular Malaysia", Hydrological Procedure No. 16, published by Ministry of Agriculture and Rural Development Malaysia. With the background above "Rational Method" with storage coefficient Cs, i.e., Q = 1/360 Cs.C.I.A. is adopted for this study.

4.2.2 Rainfall Frequency for Design

Basically, storm drains could be designed to carry the runoff from the maximum stormwater expected for a given location. However, it should be noted that actual design of the drainage facilities shall be made on the basis of the average frequencies of rainfall occurrence with due consideration on the reasonable investment for the implementation. Hence, frequencies of rainfall are necessary to determine for the design purpose.

The standards as for rainfall frequencies as a basis for the design of urban drainage systems are 2-year for residential areas and 5-year return period for commercial and industrial areas. These figures are acceptable for the size of municipalities like those in the study area and also for the sake of design practices. For this Project, therefore, the same rainfall frequencies as that of the national standards is applied and summarized below:

Residential Area	2-year
Commercial & Industrial Areas	5-year

In addition, for checking the trunk drainage system, 100-year rainfall frequency is also considered in this study. The basic consideration of the design for the drainage system is that no inconvenience flooding from the initial storm (2 or 5-year return period) and no major damage from the major storm (100-year return period) are expected.

4.2.3 Rainfall Intensity - Duration - Frequency Formula

For expression of the rainfall intensity - duration - frequency curves following equations have been developed on the basis of the figure indicated on "Rainfall Intensity - Duration - Frequency Relationship", DID's "Planning and Design Procedure No. 1 Urban Drainage Design Standards and Procedures for Peninsular Malaysia", and are applied for this study.

2 - year frequency $I_2 = \frac{6,350}{t + 32}$ (mm/hr)

5 - year frequency $I_5 = \frac{9,145}{t + 49}$ (mm/hr)

100 - year frequency $I_{100} = \frac{16,500}{t + 66}$ (mm/hr)

4.2.4 Runoff Coefficient

Runoff coefficients to be used for the design are determined taking into account the various type of surface of the study area. The recommended coefficients for the area by type of future land use are shown in Table 4.2 (Details refer to Annex A, Stormwater Quantity)

Table 4.2 Runoff Coefficients by Type of Land Use

Land Use	Runoff Coefficient
Residential area	0.65
Commercial area	0.85
Industrial area	0.65

4.2.5 Time of Concentration

The concept of the time of concentration is used for the estimation of peak discharge rate derived from rainfall duration relationship curve for the given frequency.

The time of concentration consists of the inlet time of runoff flow over the ground surface to the nearest drain plus the time of flow in the drain from the most remote inlet to the point under consideration, as expressed in the following equation.

$$t_c = t_o + t_d$$

where t_c: time of concentration, (min.)

t_o: inlet time, (min.)

t_d: time of flow in the drain, (min.)

The time of flow in drains is estimated depending upon the hydraulic properties of the individual conduit. Inlet time shall be estimated on the basis of situation in the area considered. In Annex A "Stormwater Quantity", the estimation of inlet time is described in details.

4.3 Drainage Facilities

A discussion necessary for the drainage facilities required for design basis of the drainage study, are made as follows:

4.3.1 Storm Drain

(a) Open channel vs. Closed Conduit

Existing drains in the Study Area are mostly open channels. This have considerable advantage over closed conduits, including cost effectiveness, easiness of maintenance, elimination of hazardous problems relating to manholes and shallow excavation required. In addition, the shallow construction requirement would minimize the crossings with sewer pipes in case of the separate system which is recommended for this Project, as referred in the Sewerage Study Report.

The major disadvantage, on the other hand, is that residents have easy access to the disposal of refuse into drains resulting in blockages in many places, and are exposed to danger. This disadvantage should be however dealt, although it would take time, by an educational campaign.

On the basis of the above mentioned reasons, basically open channel will be used for proposed drains.

(b) Flow Friction Formula

For the hydraulic design of open channels, the Manning's Formula is applied and expressed as follows;

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

where V: velocity, (m/sec.)
n: roughness coefficient
R: hydraulic radius, (m)
I: gradient

The value of "n" is depending upon the type of drains as defined below:

Concrete drain

Cast-in place	=	0.015
Pre-cast	=	0.013
Wet masonry drain	=	0.025
Earth drain	=	0.030

The selection of the type of drain will be made in the actual design works taking into account the local situations, and most economical and feasible means will be proposed. Evidently, the earth channel is the cheapest. However, this should be specified with trapezoidal cross section which result in requirements for land space larger than the case of rectangular type. Therefore, in case of sufficient surface spaces are not available for drains, stone masonry channels or rectangular concrete channels would be proposed. In case of smaller road-side drains, pre-cast "U" shape channels are to be used taking advantage of the shorter construction time required and easiness of construction.

(a) Velocity of Flow

To prevent deposition of grit and sand in storm drains, the velocity of flow shall not be lower than 0.6 metre per second (2 ft/sec.) in any type of drain.

Care should also be given to maximum velocity of flow to prevent erosion of drains. The recommended minimum and maximum velocities for various types of drain are summarized below:

Type of Drain	Design Velocity (m/sec)	
	Minimum	Maximum
Concrete Drain	0.6	3.0
Stome Drain	0.6	2.5
Gross Lined Drain	0.6	2.2 (1)
Earth Drain	0.6	1.0 (2)

Data source (1) DID's Procedure
(2) Portier & Sioby

4.3.2 Reservoir

Although a storage of stormwater requires generally considerable land space, it is one of the most effective means to reduce the peak stormwater runoff. This facility would be, therefore, considered in the actual design works for the areas presently undeveloped where enough land space is still available. Even when development is applied in such undeveloped areas in the future, the concept of storing stormwater should be adopted to limit the discharge to downstream and eliminate the major flood damages. Consequently, storage of stormwaters would be able to reduce the cost for improvement of drainage system. For computing the required capacity of the reservoir, the following processes are taken:

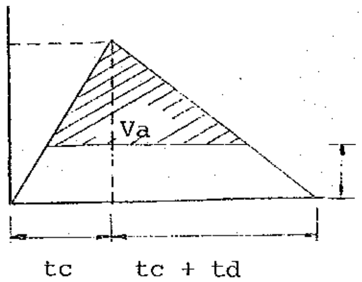
° Develop inflow hydrograph

° Set allowable discharge rate, and

° Calculate required storage capacity of the reservoir

In general, two types of inflow hydrograph are considered; one is for the case of tc≧te and the other for tc<te. The required capacity is then determined by comparing these two cases in the manner as illustrated in the following;

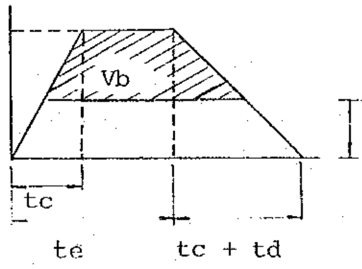
(a) tc ≥ te



allowable discharge rate

where Va: required storage volume
tc: time of concentration
te: rainfall duration time
td: time of flow in channel

(b) tc < te



allowable discharge rate

where Vb: required storage volume
tc: time of concentration
te: rainfall duration time
td: time of flow in channel

Between Va and Vb, the larger one should be adopted as the required storage volume.

4.3.3 Pumping Station

Cutting off back water from rivers or the sea by providing levees or gates, and lifting stormwater runoff discharged within the closed areas by pumps are the effective countermeasures to alleviate the flooding.

Generally, it is, however, noted that the pumping station is not necessary to be operated so often, because its operation is depending upon the intensity and frequency of rainfall within the area. Thus, provision of the pumping station may not be economically feasible.

Further, construction of pumping station may require considerable amount of initial investment including procurement of equipment and their spare parts, and careful operation and maintenance services would be required for maintaining proper function of the station.

Taking into account the above mentioned disadvantages, the provision of the pumping station is considered carefully in the actual design works.

5. DRAINAGE SYSTEM LAYOUT PLANNING

To provide the most desirable layout of the drainage system for the Study Area, a review and evaluation on the present conditions of the existing drainage system are necessary steps of the planning consideration. The field reconnaissance and surveys have been therefore undertaken during the course of the field works, in order to ascertain the drainage requirements. The requirements for the drainage improvement are then identified on the basis of the evaluation of existing drainage system.

Following paragraphs deal with the analyses of existing condition of the drainage system and recommendation of the proposed drainage system in the Study Area in order to meet both immediate and future requirements for alleviating the flood problems.

5.1 Review and Evaluation of Existing Drainage System

As discussed in the preceding Chapter, the Study Area is generally flat and low-lying, in a tributary of the Sg. Kedah and at the coastal region.

In consequence of low-lying and flat situations, major parts of the Study Area, especially areas in fringe of the Sg. Kedah and shore line, are subject to be effected by tidal influence, and are flooded by tidal inundation. Moreover, when the flood flows occurred during the high intensity storms coincide with the high spring tide, flooding areas are spreading within the Study Area.

The causes of flooding in the area are due to low ground elevations as mentioned above and inadequate drains, together with poor maintenance, particularly, the lack of sufficient smaller drains. The location of the present flood prone areas is shown in Figure 4.3.

The existing trunk and smaller drains have generally been working comparatively well so far under the present land use condition whereby agricultural area prevails. However, the rapid urbanization would result in the increase of surface water runoff which cannot be handled by the existing system unless necessary improvement measures are taken. It is also clear that the development in the upstream of the area in which the existing agricultural area has contribute significantly to alleviate the burden of flooding, would contribute to the flood in this area in the future. Therefore, it is apparent that if no countermeasures are taken, the situation will be further deteriorated. In view of the above overall findings for the present drainage conditions in the Study Area, further evaluation is made dividing into individual present drainage basins.

The present drainage system can be identified into four independent drainage basins namely Basisn A, B1, B2 and B3, as shown in Figure 4.3. The results of evaluation for these individual drainage basins are described in the following:

(1) Basin A

This basin has an area of 136 ha (340 acres) which includes the major parts of the urbanized area within the Study Area. Out of this area, an area of 68.6 ha (172 acres) lies within the Study Area, and the area outside the Study Area is, at present, paddy cultivation. This area is under responsibility of MADA.

At present, an approximately 40 percent within the Study Area in this basin has been already urbanized mainly by residential area. Basically, the area is proposed to be developed for residential and commercial according to the development plan prepared by STCP, but the area under the paddy field outside the Study Area is also to be developed by the Government in the future for urbanization to be extended, according to the preliminary information obtained from the government officials concerned to this Project.

The ground elevation in the urbanized area, especially newly developed area in recent years is generally flat with an average of 2 m (6.5 ft) above mean sea water level, so that, no significant flooding has occurred in this area. However, the kampung area which is situated at the northeast of this basin and nearby the coastal, has experienced the nuisance flooding due to the fact that the area lies at very low ground elevation with about 1 m (3.3 ft). Particularly, when the high intensity storm is coupled with the high tide, flooding has even spread out within the area.

The existing drainage system in this basin consists of only one trunk drain and many of secondary drains. The trunk drain runs from paddy field on the southwest to the Sg. Kedah on the north throughout the urbanized area. This drain is, at present, utilized for both agriculture and urban drainage, since MADA is responsible for this drain. Although this drain is basically natural stream with an earth channel with varied widths and depths, it can generally accommodate the flow capacity from about 5 m^3/sec (177 cfs) to 6 m^3/sec (212 cfs), which is sufficient to

flow the surface runoff for the storm of 2-year frequency, under the present ground condition. Presently, the water level of this drain in upstream is kept at 1.3 m (4.3 ft) for agricultural purpose. This is controlled by the existing tidal gate which exists at downstream of the drain. The existing tidal gate is useful in protecting backing up of the high tide, when appropriately operated. In the development plan prepared by STCP, the trunk drain to be proposed in due course is to be routed the same as that of the existing trunk drain. The plan also includes the trunk drain reserve width from 20 m (1 chain) to 30 m (1.5 chain). This drain reserve width will be useful for the final design of proposed trunk drain. Generally, the smaller drains in the urbanized area in this basin do exist. However, some of these have inadequate capacity to cater for the runoff from the area, and are not functioning properly due mainly to inadequate maintenance. In the area covered by such drains, significant floods have occurred occasionally.

(2) Basin B1

This basin covers an area of 17.8 ha (45 acres), which is situated at the western part of the Study Area bounded by the shore line and the catchment of Basin A.

The northern part in the region along the Sg. Kedah has been already developed for residential and small scale commercial purposes, while some of southern parts of this basin are still under the swampy area. Basically, whole the area of this basin will be developed for residential and commercial purposes, according to the development plan by STCP.

In the developed area, the ground elevation is more than 2 m (6.5 ft), so that no significant flood problems have been experienced. However, since the southern part of about 9 ha (23 acres) where many of the wooden houses are scattered in the area is low-lying with ground elevation of less than 1 m (3.3 ft), it have been inundated by the high tide.

The existing drainage system in this basin consists of many small drains with either concrete or earth channel. Most of them are drained out directly into the sea. The capacity of these drains has sufficient to cater for the stormwater discharge on the present land use condition, if the better maintenance such as desiltings are carried out.

(3) Basin B2

This basin is bordered by Jl. Kuala Kedah on the west and boundary of the industrial estate where Basin B3 lies on the northeastern part of the Study Area. The north and south together with the southeastern fringes of this basin are delineated along the Sg. Kedah and at the paddy field respectively. The total area of this basin is 67.4 ha (169 acres) comprising Kampung areas in low-lying part and large scale paddy field. Out of the total area of this basin, an area of 20.6 ha (52 acres) lies within the Study Area covering both for residential and commercial, and rest are outside the Study Area, which are currently under paddy field.

According to the preliminary information obtained from the government officials, the area outside the Study Area is also expected to be developed and included in the proposed urbanization area for future development, together with the area outside the Study Area in Basin A, as mentioned in preceding paragraph.

Out of the area of 20.6 ha (52 acres) which lies within the Study Area in this basin, an area of 13.2 ha (33 acres) is situated along the Sg. Kedah in very low-lying with ground elevation of less than 1 m (3.3 ft). This area occurs frequently the flooding and inundation by high tide. The rest of the area have relatively high ground elevations at about 1.8 m (5.9 ft), which do not cause the significant flooding. However, when the high intensity storms coincide with the high tide, those areas are also subject to flooding. The existing drainage

conditions in this basin are rather poor. Most of drains consist of natural streams which should be improved to meet the flow capacity from either present and future surface conditions.

(4) Basin B3

This basin has an area of 18 ha (45 acres), which is situated at the northeastern part of the Study Area along the Sg. Kedah. Whole area of this basin is proposed to be developed for the industrial estate, according to the development plan prepared by SEDC.

Presently, whole area of this basin is surrounded by the road with the high ground elevation at more than 2 m (6.5 ft) which is utilized as a river bund, and have an effect on protecting the river flooding. The most of the area surrounded by the road are still vacant low-lying area at about 1 m (3.3 ft) ground elevation except the reclaimed land for existing four factories. The ground elevation in this reclaimed land is same as the road height of 2 m (6.5 ft). This ground elevation is appropriate to contribute the protection of river flooding.

Since this basin is still mostly undeveloped, the existing drains in this basin consist of only road side drains which in developed areas where a few factories are already located as mentioned above. The storm runoff through those drains are well discharged by gravity flow into the Sg. Kedah directly. The other areas under undevelopment low-lying areas have no facilities so far.

5.2 Recommended Layout Planning for Drainage System

On the basis of the findings on evaluation of the existing drainage conditions as mentioned in previous section, the most desirable layout of the drainage system is made for solution of the flood problems. The basic approach and major items considered in the study may include:

(a) Improvment of existing drains and/or provision of new drains for collection and conveyance systems of stormwaters.

(b) Storage of stormwaters in assigned area for alleviating flood in downstream areas.

(c) Shutting out the back water by gates or levees. and where necessary, draining off the stormwater runoff to the river by means of pumps during the period of high water levels in the river.

(d) Raising of ground elevations by land filling.

In view of the above basic considerations, the best suited drainage system for the Study Area is selected and recommended thereafter.

5.2.1. Proposed Individual Drainage Basin

Delineation of the drainage basins proposed is basically identical to that of the existing drainage basins divided by an overall review of the actual present drainage conditions. The parts of Basin B2 are, however, shifted to incorporate into Basin A, in accordance with the development plan prepared by STCP on which the development of those areas would be performed and should include necessary provision for drainage requirements. The areas shifted into Basin A from Basin B2 are those under the commercial area which is situated in the region along Jl. Kuala Kedah, together with the contributing area where some number of houses are scattered along Jl. Kuala Kedah.

Hence, those individual drainage basins proposed are shown in Table 4.3 and Figure 4.4. The proposed drainage facilities consist of one major basin and three minor basins. The major basin is given to undertake the provision of trunk drainage system together with adequate secondary drains, while the minor basins would be by the secondary drainage system to be considered in the further study (Feasibility Study). Brief descriptions of each proposed drainage basin are as follows:

Table 4.3 Proposed Drainage Basin

Name of Drainage Basin	Area Served Within the Study Area for Provision of the Drainage System	Area Served Outside of the Study Area (Contributing Area)	Total
A	76.0 ha (190 acres)	79.0 ha (198 acres)	155 ha (388 acres)
B1	17.8 ha (45 acres)	-	17.8 ha (45 acres)
B2	13.2 ha (33 acres)	25.2 ha (63 acres)	38.4 ha (96 acres)
B3	18.0 ha (45 acres)	-	18.0 ha (45 acres)
Total	125.0 ha (313 acres)	104.2 ha (261 acres)	229.2 ha (574 acres)

(1) Basin A

This basin is proposed as a major basin covering the area of 155 ha (388 acres), which is necessary to provide the trunk drainage system. Out of the area covered by this basin, the provision of drainage facilities including trunk and smaller drains shall be that of the area of 76 ha (190 acres) which lies within the Study Area, since the rest of the area is considered to be contributing area. For calculation of the stormwaters, it is, however, noted that the storm runoff from the contributing area is estimated to have identical burden of discharge originated in the Study Area, because the contributing area delineated is also expected to be developed by the Government for extension of the urbanization, as discussed previously.

In view of the present situation in this basin, it is found that the ground elevation in built up areas is generally high at more than 2 m (6.5 ft), and the rest under the undevelopment at present is also expected to be raised its ground level by land filling, in accordance with the development plan.

Hence, whole area of this basin is expected to be sufficient to discharge the surface runoff for the storm of 5-year frequency of the future land use condition, coinciding with Mean High Water Level (MHWL) at 1.5 m (5.0 ft), if the adequate drains would be provided. Thus no provision of the pumping and storage facilities is necessary to consider for this basin. For development area, it is however recommended that the land filling should be at 2.4 m (8 ft) ground level for protection of the maximum tide recorded at 2.2 m (7.3 ft).

(2) Basin B1

This basin covers an area of approximately 18 ha (45 acres). It is apparent that the provision of the drainage system in this basin shall be by the adequate smaller drains.

The discharge of the storm runoff from this basin is proposed to be directly into sea through the smaller drains, thus each smaller drains should have adequate individual outlets to be provided. As discussed in the preceding section, whole area of this basin will be basically developed with the land reclamation. The land level in those areas are recommended to be raised at 2.4 m (8 ft) for protection of the maximum tide.

(3) Basin B2

This basin is the one modifying the existing drainage catchment area as mentioned in previous paragraph. The area covered by this basin is to be approximately 38 ha (96 acres) including the contributing area.

Presently, major part of the area delineated within the Study Area in this basin, where there exist the Kampung area, is situated in low-lying along the Sg. Kedah. Those areas are not able to protect the flood problems unless the river bund together with pumping facilities is provided. However, since whole area of this basin is under development

plan which will be undertaken by the Government, as discussed previously, they are expected to be redeveloped and reclaimed the land at reasonable ground elevations in the future. Thus no pumping facilities are necessary to provide for the drainage system in this basin. The land filling level is recommended to be 2.4 m (8 ft).

(4) Basin B3

This basin occupies the entire area of industrial estate covering the area of 18 ha (45 acres).

The drainage system in this basin will consist of many smaller drains. The net work of those smaller drains will be made in accordance with the development plan for industrial estate prepared by SEDC. At present, most of areas in this basin are still under undevelopment area. Those areas should be reclaimed at 2.4 m (8 ft), and an adequate smaller drains are then provided.

5.2.2 Proposed Drainage Facilities

In view of the overall analyses of the drainage study, only one trunk drain which is routed in the Basin A, is proposed in the entire Study Area. Further, it is considered that since whole the Study Area is placed under the development area in which the ground elevation shall be raised by land filling, no provision of pumping and storage facilities is necessary in order to alleviate the flood problems due mainly to high tide and high intensity storms. Recommendation and proposals are described below:

(a) Trunk Drain

For design of the trunk drain, it is noted that the study is undertaken by applying the Design Master Plan (DMP) in accordance with the Terms of Reference prepared by the Government.

Recommended layout together with the proposed individual drainage basins and profile of the trunk drain are shown in Figure 4.4 and Figure B.1 presented in Annex B respectively.

The proposed route of the trunk drain is basically same as the existing natural water course which is, at present, undertaken by MADA, from the fringe of southwestern part of the Study Area through the urbanized area to the Sg. Kedah on the north. The width of reserves for the proposed trunk drain is determined upon final development of land, taking into account of the development plan.

For selection of the type of drain, three types of drain, (1) trapezoidal section of rubble wall, (2) rectangular section of reinforced concrete, and (3) earthern channel, have first been considered as alternatives, and economic analysis was made among those types of drains in terms of the construction cost estimated by cost function curves developed as presented in Figure B.3 of Annex B. Due to the flat gradient, a large cross sectional area is basically required. Thus, the selected type of the proposed trunk drain is of rubble wall with mortar lining using wire nets taking into consideration of the advantages on hydraulic, economic and esthetic points. The proposed cross section of the trunk drain is shown in Figure B.2 presented in Annex. B.

(b) Smaller Drain (Secondary Drain)

Since the purpose of the Master Plan is to develop the trunk drainage system as mentioned in preceding section, no smaller drains are proposed in this study. However, for estimation of the total project cost in order to provide an adequate drainage system in the Study Area, the typical network of smaller drains is considered on the basis of the development plan and then designed in order to find out the required facilities.

Basically, pre-cast "U" shape drains and for larger sizes, rubble wall channels will be used for smaller drains, because of advantages in which the land space will be conserved and maximum development will be permitted, and economic view points. The network of smaller drains considered as discussed in succeeding section will be illustrative for provision of the smaller drainage system.

6. NOTE ON IMPLEMENTATION OF THE PROPOSED TRUNK DRAIN

Because the time schedule for future urban development programme is not definite, the implementation of the proposed trunk drain should be determined carefully. Basically, the implementation of the proposed trunk drain shall be required pursuant to progress of the urban development programme.

Presently, the existing trunk drain, which should be improved as the proposed trunk drain, has sufficient capacity to flow the surface runoff on the present land use condition. Thus no high priority is necessary for immediate implementation of the proposed trunk drain unless the urban development programme is taken up urgently.

In the existing trunk drainage system, there exists the tidal gates which utilize for controlling the water levels in the upstream of the drain, and protecting the backing up of the high tide. The water levels kept at reasonable height are due to agricultural purpose.

When urban development programme is practicable, the need for controlling the water level and protecting the backing up of the high tide disappears, because no agricultural area is remaining and land elevations in low-lying areas are expected to be raised by land reclamation to meet the high tide. Therefore, no tidal gate has been proposed in the actual design for the proposed trunk drainage system. However, as long as the agricultural area exist at the upstream of the proposed trunk drain, which has been considered as a contributing area

for calculating the stormwater runoff into the urban drainage, the tidal gate would be still in use for agricultural purpose.

The above should be kept in mind for implementation of the proposed trunk drain. The priority required for the drainage implementation in the Study Area shall be basically given in developing the smaller drainage system together with the land reclamation in accordance with the development programme. The proposed trunk drain shall be then required to meet the progress of the urbanization.

7. CONSTRUCTION AND MAINTENANCE COSTS

7.1 Construction Cost

Construction costs for the Project may be defined as the sum of all expenditures required to bring the Project to completion. These expenditures are divided into direct items and indirect items, including civil works, installation of the equipment, contractor's profits and overhead, and all related construction works. The estimated construction costs are described below:

7.1.1 Unit Cost

For estimating the construction costs of the proposed drainage facilities, the information and data on materials and labour costs in the Study Area have been collected from various sources during the course of the field works. The sources of the information and data are:

- MPKS
- JKR (Kedah)
- ED, MPPP (Penang)
- Various local contractors and manufactures

All basic costs collected from the above sources are expressed in 1979 price levels in Malaysia. Using the basic costs obtained, unit costs for construction including both labour and materials are estimated with due consideration on the methods of construction and suitable construction materials including ability of local contractors and availability of local materials. These estimated unit costs together with the basic prices of materials are summarized in Table 4.4.

In addition, for estimation of the construction cost of smaller drains, the typical networks of smaller drains have first been considered on the basis of the road networks planned in the development area, and preliminary design has been then made.

The networks made for smaller drains are of three typical areas, namely residential, commercial and industrial as shown in Figures B.4, B.5 and B.6 presented in Annex B. The recommended smaller drains in those areas are of "U" shape pre-cast concrete and rubble wall open channels, taking into account the economic point and easiness of the construction. Construction cost of those smaller drains are then estimated by use of the cost function curves developed as shown in Figure B.3 presented in Annex B. The costs reflected by the curves include excavation, dewatering, backfilling, disposal of surplus soil, material and labour for structures, and contractor's profit and overhead.

From the above study, the estimated construction costs of smaller drains in each typical areas, in terms of the per hectare are as below:

Residential Area	18,000 M$/ha
Commercial Area	24,000 M$/ha
Industrial Area	24,000 M$/ha

7.1.2 Construction Cost of Proposed Drainage Facilities

Construction cost of the proposed trunk drain is estimated in multiplying the quantities required in proposed structure by the unit

construction cost, while construction costs of smaller drains are derived from the unit construction cost on per hectare as discussed in previous section.

Since the proposed trunk drainage system include box culvert facility, this construction cost is also estimated by use of the cost function curve developed as presented in Annex. B.

The costs comprise materials and labour, contingency allowance, engineering fee, and land acquisition. As the engineering fee, 15 percent of the estimated actual construction costs is added, and 20 percent of the total cost is assumed for contingencies. Out of the engineering fee, 10 percent is considered for engineering design and the remaining for supervision services for construction.

The estimated total construction cost including proposed trunk drain and smaller drains is to be approximately M$4,453,000 at 1979 price levels as shown in Table 4.5. As indicated in this Table, the construction costs by private contribution is to be estimated on the assumption that all smaller drains in undeveloped areas would be provided by private developers. The government will contribute the costs of proposed trunk drain which can accommodate the catchment area exceeding 40 ha (100 acres), and smaller drains in built up areas. For estimating the cost for smaller drains in built up areas, it is assumed that an approximately 30 percent out of the total networks of smaller drains is necessary to improve or newly provide the smaller drains.

Table 4.4 Schedule of Unit Construction Costs

(1) Basic Price of Material

Nominal Size	Price per 0.61 m (2') including transporting
U shape	
300 mm (12")	3.50 M$
380 mm (15")	4.80
460 mm (18")	6.20
610 mm (24")	8.50
Box Culvert	Price per 1.22 m (4') including transporting
610 x 455 (24" x 18")	183.80 M$
760 x 610 (30" x 24")	217.00
915 x 760 (36" x 30")	251.50
1,220 x 760 (48" x 30")	324.60
1,220 x 915 (48" x 36")	342.70
1,830 x 1,220 (72" x 48")	665.80
1,830 x 1,525 (72" x 60")	742.30
1,830 x 1,830 (72" x 72")	802.00

(2) Unit Construction Cost

Item	Description	Unit	Cost (M$)
Concrete	1 : 2 : 4	m^3	156.90
	1 : 3 : 6	"	124.20
Reinforced Concrete	1 : 2 : 4	"	313.70
Mortar	1 : 2	"	186.50
	1 : 3	"	182.10
Trench Excavation (by hand)	depth		
	0 - 1.5 m	"	4.70
	1.5 - 3.0	"	8.60
	3.0 - 4.5	"	11.50
	4.5 - 6.0	"	15.10
	6.0 - 7.5	"	18.90
	7.5 -	"	22.50
Excavation (by machine)	Irrespective of depth	"	2.30
Backfilling and Compaction		"	3.00
Form Works		"	8.20
Masonry Works		"	71.00
Dewatering		hr	3.00

Table 4.5 Construction Costs for Proposed Drainage Facilities (1,000 M$)

	Description	Basin				Total
		A	B1	B2	B3	
Main Drain (Government Constructio)	(A) Main Drain	1,190	-	-	-	1,190
	(B) Engineering Fee					
	Design	119	-	-	-	119
	Supervision	60	-	-	-	60
	(C) Contingency	274	-	-	-	274
	(D) Land Acquisition	134	-	-	-	134
	Sub-Total	1,777	-	-	-	1,777
Smaller Drain in Built-up Area (Government Construction)	(A) Network of Smaller Drain	178	68	0	0	246
	(B) Engineering Fee					
	Design	18	7	0	0	25
	Supervision	9	4	0	0	13
	(C) Contingency	41	16	0	0	57
	Sub-Total	246	95	0	0	341
Smaller Drain in Future Development Area (Private Construction)	(A) Network of Smaller Drain	872	16	371	432	1,691
	(B) Engineering Fee					
	Design	87	2	37	43	169
	Supervision	44	1	19	22	86
	(C) Contingency	201	4	85	99	389
	Sub-Total	1,204	23	512	596	2,335
	TOTAL	3,227	118	512	596	4,453

Note : (B) = (A) x 0.15

(C) = [(A)+(B)] x 0.20

7.2 Maintenance Cost

Currently the maintenance of existing drainage system in the Study Area has been performed by MADA, SDID and JKR. MADA is responsible for the maintenance of the major drain which exists within Basin A as discussed previously, and road side drains are under JKR responsibility. Tidal gates which exist at outlets of the drains are controlled or operated by MADA. For maintenance of the drainage system in the future, consideration should be given to place under the responsibility of MPKS for both trunk and small drains. In some cases, JKR will be concerned with road side drains.

Generally, maintenance works for drains consist mainly of removing deposit from drains and carrying those wastes from the site to assigned dumping places. Repairing of broken parts of channels are also included in the maintenance work. For these works, estimated maintenance cost for proposed drainage facilities are described below.

7.2.1 Unit Cost

For the purpose of estimating maintenance cost, it is assumed that the cost for removing deposits from drains is the same as that of cost for excavation estimated in unit construction cost. For trunk drain, machine excavation will be applied and for smaller drain, hand excavation will be applied. For the cost of carrying removed materials from the site to the designated dumping places, the cost of disposing of excess soil is applied. On the basis of assumption of the above, the unit cost of removal of deposit including disposing materials for trunk drain is estimated at 3.2 M$/$m^3$, while 5.6 M$/m^3 is of smaller drains. The average volume of deposits in drains is estimated roughly on the assumption that the part of accumulation of silt to be removed in terms of annual basis would be 10 percent of the cross sectional area. The average cross sectional area of proposed trunk drain is 12 m^2. The deposit volume, therefore, is $12 \times 0.1 = 1.2$ m^3 per one meter of trunk drain. For smaller

drains, the average volume of drain is estimated at 110 m^3 with expression of per hectare. Therefore, the average deposit volume is 110 x 0.1 = 11 m^3 per hectare.

The annual repairing cost for each drains is assumed to be one percent of constrution cost.

In addition, for dredging or cleaning of the drains, a clamshell grabbing crane, hand rodding machine and dump truck will be required, and these equipment may have to be purchased for performing the required maintenance works. However, the purchase of these equipment should be recommended with due consideration on the overall maintenance works required in the entire drainage system covering the whole administrative areas including Alor Setar and Kuala Kedah towns. Thus, these costs have not been included in the estimation of costs.

7.2.2 Maintenance Cost of Proposed Drainage Facilities.

Prior to estimate the maintenance cost, the total amount of maintenance works is estimated in the following:

Amount of Maintenance Works

Length of proposed trunk drain	1,711 m
Area served by smaller drains	125 ha

On the basis of the unit cost estimated as described in previous paragraph, and amount of maintenance works required, the total maintenance cost for proposed drainage facilities is estimated as summarized in Table 4.6, while costs for payroll and administration are not included in the above total maintenance costs.

Table 4.6 Maintenance Cost for Proposed Drainage Facilities (M$/year)

Item	Maintenance cost of trunk drain	Maintenance cost of smaller drains	Total
Removal Deposit	6,600	7,700	14,300
Repairing	11,900	24,700	36,600
Total	18,500	32,400	50,900

8. BENEFITS

8.1 Anticipated Benefits

Proper construction and operation of drainage systems are expected to result in certain types of benefits towards inhabitants of the areas concerned. These benefits include either quantifiable or non-quantifiable benefits as follows:

(a) Reduction of flood damage.

(b) Improvement of Public Health and Convenience of Community

(c) Increase of Land Value

The items above are discussed in the following sections.

8.2 Recognition and Measurement of Benefits

8.2.1 Reduction of Flood Damage

On urban area, local flooding can and does cause considerable nuisance and hardship to those affected, which can be alleviated by proper remedial work on the drainage system. The implementation of such works will result in considerable benefit to the community at large, in terms

of public road and private properties becoming flood free, and also, in a more significant benefit, on the living condition of people whose houses and business premises are previously flood prone.

The quantifiable benefit expected by preventing flooding is equivalent to the amount of damages due to the flood. In the absence of data concerning flood damages the quantity of benefit is not figured. However, it should be kept in mind that the expenditure to recover flood damage is the recurrent cost upon residents or the municipality and will increase unless flood relief measures are undertaken, whereas initial investment with comparatively small amount of fund for operative and maintenance will be sufficient for prevention of the floodings.

8.2.2 Improvement of Public Health and Convenience of Community

Benefits under this item can be understood easily when situations in which certain area is flooded and all kinds of waste water including sullage, human excreta and discharge from industry, are mixed each other spreading coliforms, disease germs and toxic materials.

It is generally recognized through abundant experiences in the past that after flooding the cases of waterborne disease increase. Together with that of the sewerage system, contribution of the drainage systems to public health improvement can be expected to be very significant, especially in areas where people depend on bucket systems and pit privies for disposal of excreta.

8.2.3 Increase of Land Value

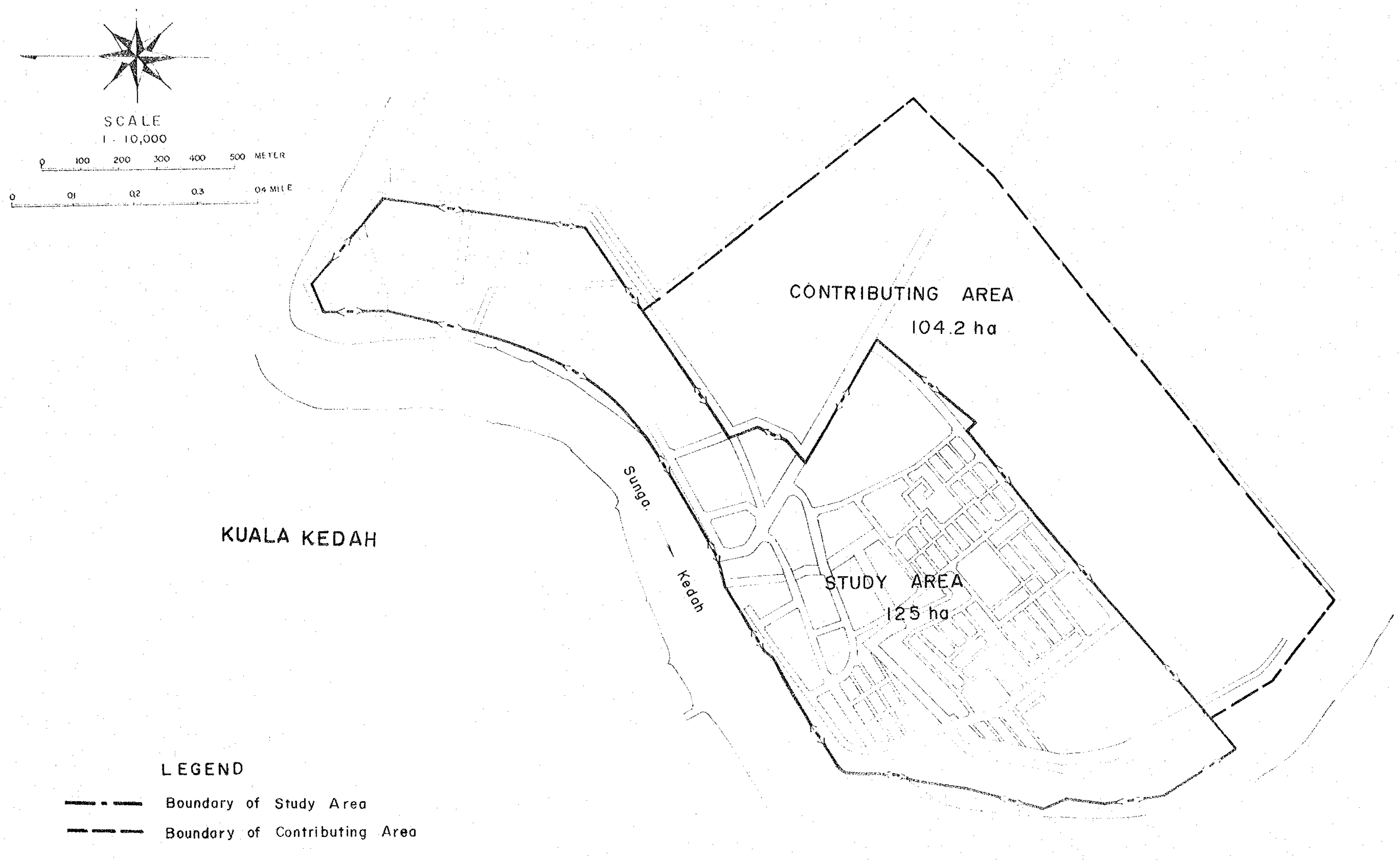
With the provision of infrastructure including drainage system, development programme, for both public and private sectors, will be greatly stimulated and land values increased. The value added to the land tends to equal or exceed the pro rata share of the total investment involved.

The added land value will be major economic benefit which will stimulate larger scale of financial transaction, and will cause additional source of taxation for the revenue in favour of the government agencies concerned. (Ref. Vol. II "Sewerage Master Plan")

8.3 Benefits Justification

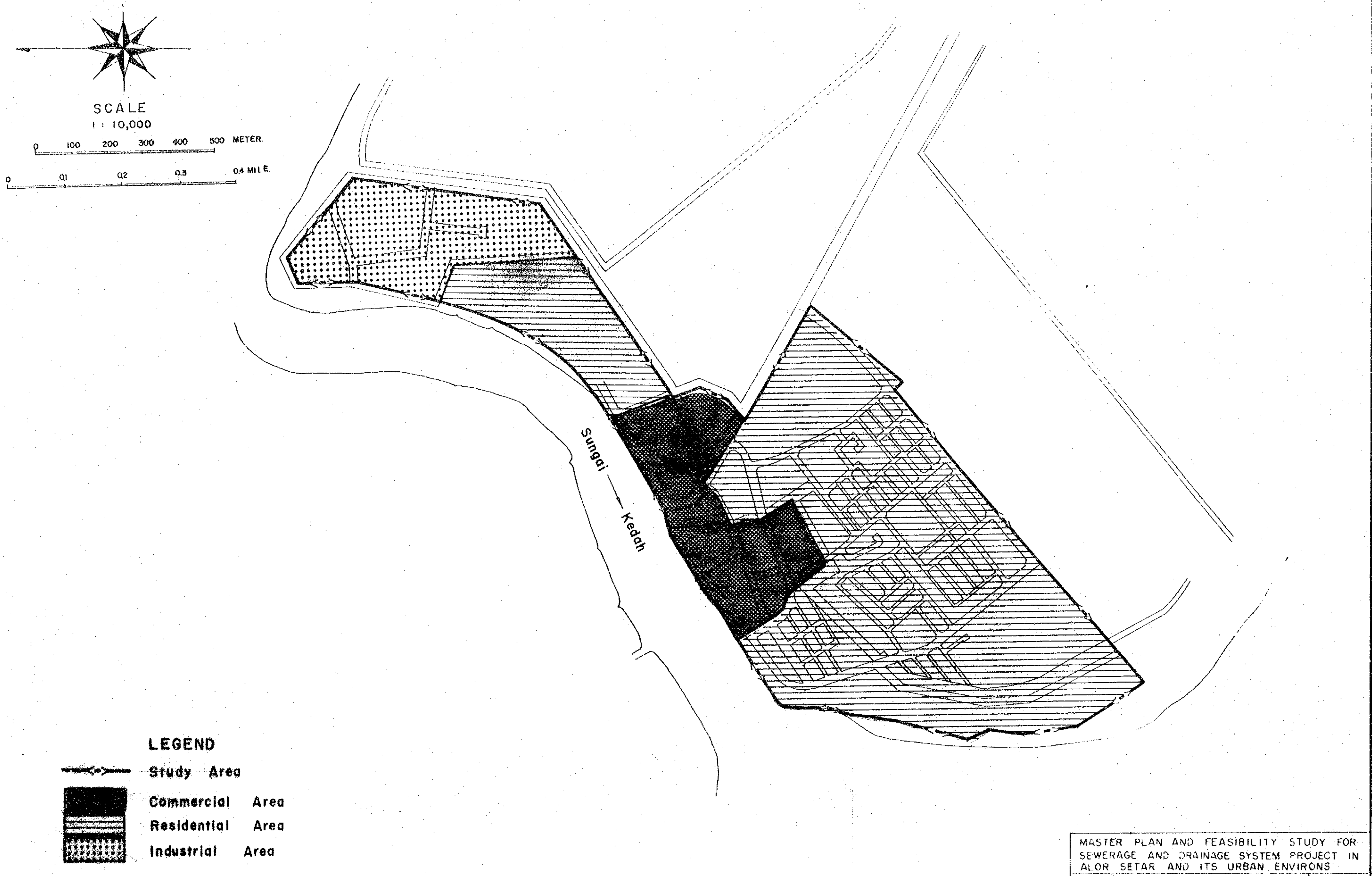
As has already been described in the previous paragraph, major portion of the benefits by the drainage improvement is hardly quantifiable in monetary terms.

Nevertheless, there will no doubt be high social benefits if the project is completed because the system will make significant flood-free land for further development, upgrade the existing living environment, and also contribute to improving the inconvenience of the community life.



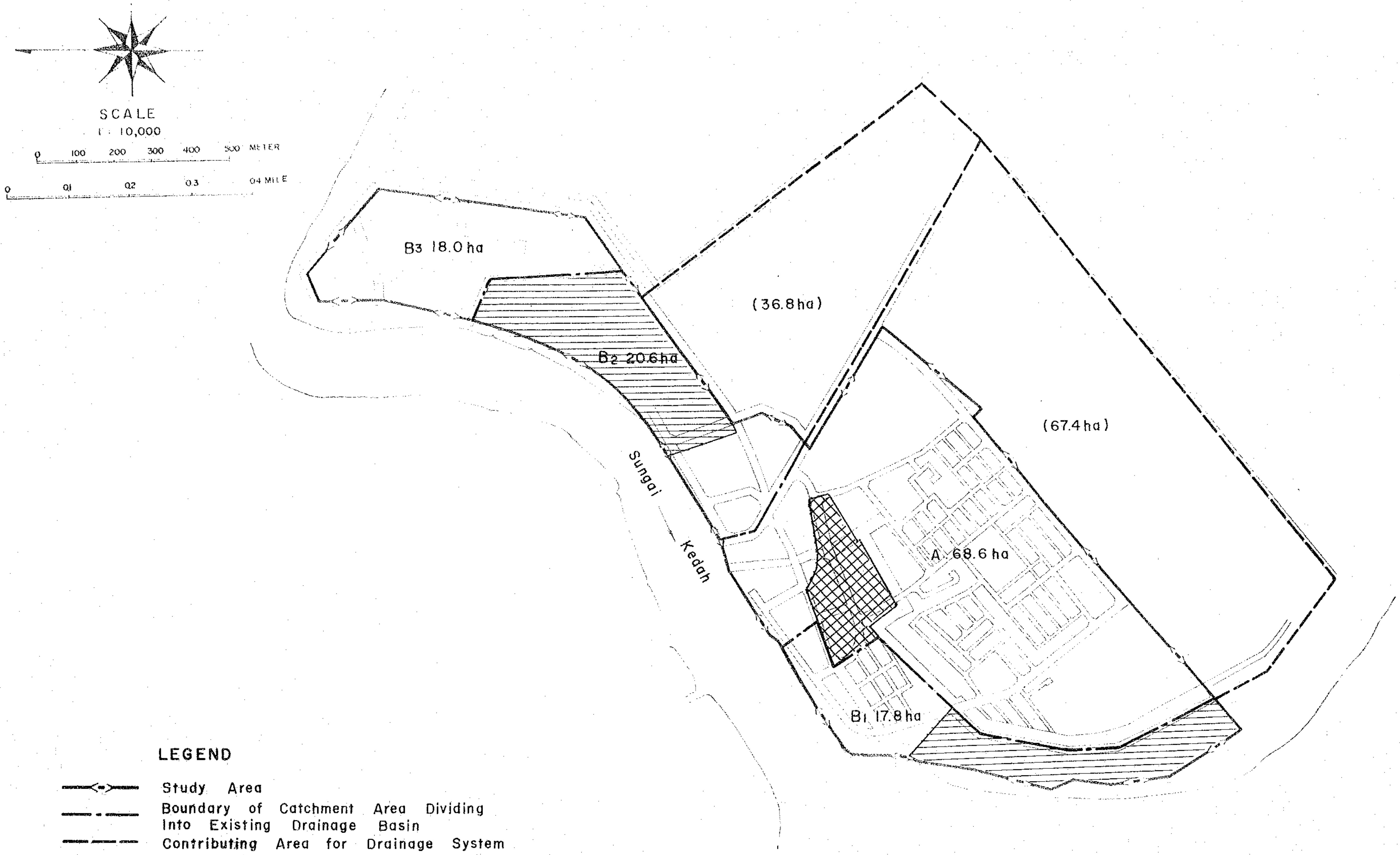
MASTER PLAN AND FEASIBILITY STUDY FOR SEWERAGE AND DRAINAGE SYSTEM PROJECT IN ALOR SETAR AND ITS URBAN ENVIRONS

STUDY AREA	FIGURE 4.1



MASTER PLAN AND FEASIBILITY STUDY FOR SEWERAGE AND DRAINAGE SYSTEM PROJECT IN ALOR SETAR AND ITS URBAN ENVIRONS

LAND USE IN 2000	FIGURE 4.2



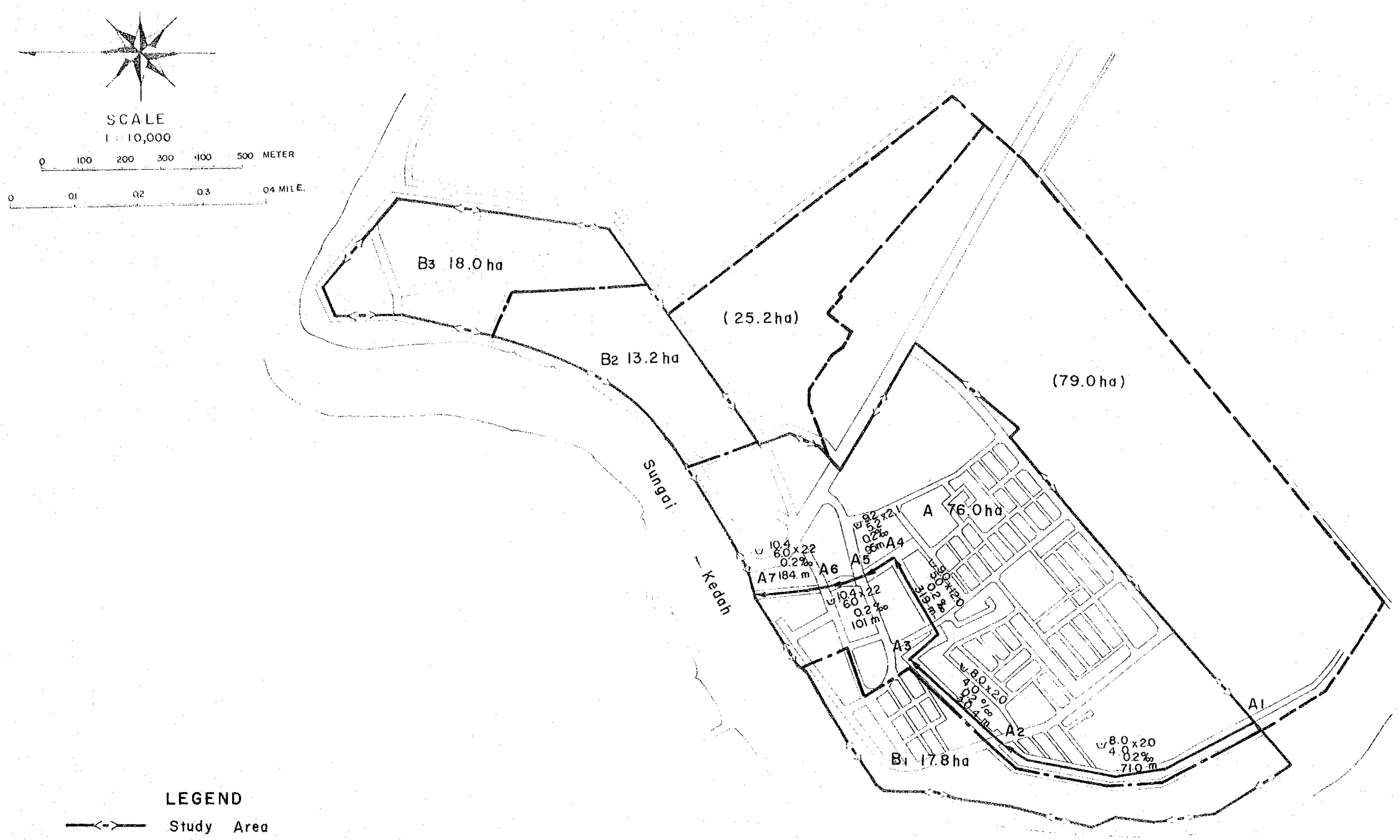
LEGEND

- Study Area
- Boundary of Catchment Area Dividing Into Existing Drainage Basin
- Contributing Area for Drainage System
- Existing Flooding Area by High Tide
- Existing Flooding Area by Rain Fall

MASTER PLAN AND FEASIBILITY STUDY FOR SEWERAGE AND DRAINAGE SYSTEM PROJECT IN ALOR SETAR AND ITS URBAN ENVIRONS

PRESENT DRAINAGE BASINS AND FLOOD PRONE AREA

FIGURE 4.3



LEGEND

- Study Area
- Boundary of Catchment Area
- Contributing Area for Drainage Sysem
- A · 76.0ha Catchment Area
- Proposed Drain
- A1 Point of Drain

MASTER PLAN AND FEASIBILITY STUDY FOR SEWERAGE AND DRAINAGE SYSTEM PROJECT IN ALOR SETAR AND ITS URBAN ENVIRONS

RECOMMENDED LAYOUT PLANNING FOR DRAINAGE SYSTEM	FIGURE 4·4

ANNEXES

ANNEX A. STORMWATER QUANTITY

ANNEX B. SUPPLEMENTAL FIGURES AND TABLES FOR DRAINAGE SYSTEM PLANNING

ANNEX C. LIST OF REFERNCES

ANNEX A
STORMWATER QUANTITY

1. 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.

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

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

1.1 Selected Representative Area

For commercial and residential areas, four districts representating typical patterns of the land use were selected in the Study Area, while, for industrial area, no completion pattern of the land use exist so far in the Study Area. It was, therefore, assumed reasonable based on the present land use pattern of the existing industrial area in Alor Setar, taking into account the development plan for the industrial estate prepared by the Government.

Their coefficient in the future were estimated as follows:

Type of land use

1) Residential - A .... planned housing development area with isolated terrace houses in Kuala Kedah.
2) Residential - B .... planned housing development area with attached houses in Kuala Kedah.
3) Commercial - A .... planned development area in Kuala Kedah.
4) Commercial - B .... existing urbanized area in Kuala Kedah.
5) Industrial .... planned development area in Alor Setar.

1.2 Runoff Coefficient by Surface Type

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

Table A.1 Runoff Coefficient with Respect to Surface Type

Type of Surface	Runoff Coefficient	
	Range	Used
Roofs	0.85 - 0.95	0.90
Paved Roads	0.80 - 0.90	0.85
Other Pavement	0.75 - 0.80	0.80
Vacant Lots	0.10 - 0.30	0.20
Lawns	0.50 - 0.20	0.10

Source: MPCF Manual of Practice No.9 (USA) (1970)
Manual of Sewerage Facilities Design, 1972, Japan

1.3 Estimation of Coefficients in the Selected Area

The various type of surface were calculated, in percentage of total surface, for each of the selected five representative districts. After that the runoff coefficients of representative districts were calculated and shown below in Table A.2.

Table A.2 Percentage of Individual Surface Type and Runoff Coefficient (in 2000)

Type of surface	Runoff coefficient of individual type of surface	Residential A	Residential B	Commercial A	Commercial B	Industrial
		*1 *2				
Roofs	0.90	0.11/0.099	0.19/0.171	0.21/0.189	0.54/0.486	0.26/0.234
Paved roads	0.85	0.30/0.255	0.33/0.281	0.52/0.442	0.24/0.204	0.20/0.170
Other pavement	0.80	0.28/0.224	0.16/0.128	0.20/0.160	0.16/0.128	0.17/0.136
Vacant lots	0.20	0.31/0.062	0.32/0.064	0.07/0.014	0.06/0.012	0.37/0.074
TOTAL	-	1.00/0.640	1.00/0.644	1.00/0.805	1.00/0.830	1.00/0.614

Note: 1) *1 Area of individual type of surface.
*2 Runoff coefficient distributed to individual type of surface.

2) For industrial area, the ratio of paved roads is determined on the basis of the road net work planned in development plan for industrial estate of Alor Setar, and the ratio of roots is calculated based on the data obtained by the survey on questionnaire of "Industrial wastewater" as presented in separated report, Volume II "Sewerage Master Plan", concerning the area served by each factory and its floor space. The ratio of other pavement is assumed to be 30 percent of the remainder area from the results of survey referred above.

1.4 Runoff Coefficient at Present

Existing land use type in the Study Area are basically under the residential area with isolated house, and commercial area. The runoff coefficient of individual land use mentioned above is calculated in the same manner as that used in the case of future coefficient estimation.

The present runoff coefficient is shown in Table A.3.

Table A.3 Present Runoff Coefficient (in 1979)

Type	Runoff coefficient of indivi-dual surface	Residential A	Residential B	Commercial A	Commercial B
Roofs	0.90	0.28/0.252	0.20/0.180	0.56/0.504	0.41/0.369
Paved roads	0.85	- / -	- / -	- / -	0.07/0.060
Other pavement	0.80	- / -	- / -	- / -	0.14/0.112
Vacant lots & earth roads	0.20	0.72/0.144	0.80/0.160	0.44/0.088	0.38/0.076
TOTAL	-	1.00/0.396	1.00/0.340	1.00/0.592	1.00/0.617

Note: Percentage of individual type of surface/runoff coefficient.

Remaining parts of the Study Area are agricultural area. The discharge from this agricultural area is calculated by use of the method given in DID's Hydrological Procedure No.18 "Hydrological Design of Agricultural Drainage Systems".

1.5 Comparison with Other Area

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

Table A.4 Coefficients Adopted in Other Area

Type of Land Use	Coefficient Proposed for this Project	Standard in Malaysia	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	0.65	0.80	0.50-0.80	0.65

As indicated in the above table, the coefficient for the Study Area coincide substantially with those in other places.

1.6 Recommended Runoff Coefficients

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

Table A.5 Recommended Runoff Coefficient

Land Use	in 1979	in 2000
Residential area	0.40	0.65
Commercial area	0.65	0.85
Industrial area	-	0.65

2. TIME OF CONCENTRATION

An estimation of the time for the flow to concentrate at the point under consideration must be made for the purpose of application of the Rational method. For urban storm drains, the time of concentration (tc) consists of the time required for runoff to flow over the ground surface to the nearest drain (inlet time) (to) plus the time of flow in the drain from the most remote inlet to the point under consideration (td).

$$tc = to + td$$

The time of flow in the drain (td) shall be estimated from the hydraulic properties of the drain when it is designed. However, the inlet time (to) is in similar range in areas in which surface slope, nature of surface cover, and length of path of surface flow are of the same charactor. Therefore it is a general practice to use the fixed inlet time (to) in areas with similar characteristics.

In this Study the inlet time (to) has been estimated by Kerby formula method as described below:

2.1 Inlet Time (to)

2.1.1 Inlet Time of Individual Land Use

An equation which represents the inlet time for urban sewer design was originally proposed by Horton (*1) and later modified and formulated by Kerby (*2) in the form:

$$Ti = [\ \frac{2}{3} \times 3.28 \times L \times (\frac{n}{\sqrt{S}})\ ]^{0.467}$$

where Ti : inlet time (minutes)

L : distance from the most remote point to the point of inlet, (m).

n : coefficient of roughness, similar to runoff coefficient, as given in table below.

S : average land slope.

Table A.6 Coefficient of Roughness in Kerby's Equation

Character of Surface	Coefficient of Roughness
Smooth pavement	0.02
Bore, packed soil, free of stone	0.10
Poor grass cover	0.20
Moderately rough bare surface	0.20
Average grass cover	0.40
Forest (deciduous tree)	0.60
Dense grass cover	0.80
Forest (deciduous tree, with deep dead leaves)	0.80
Forest (needle-leaved tree)	0.80

The surface slope in the Study Area is around 0.4/1,000 and length of path of surface flow was decided for individual type of land use. The inlet time of individual land use is estimated as described below.

(*1) R.E. Horton, The Role of Infiltration in the Hydrologic Cycle. Trans. AGU, Vol. 14, 1933

(*2) W.S. Kerby, Civil Engineering 29,174 (1959).

(A) Residential Area

From the layout plan of a new housing development area the distance from the remote point of the premise is estimated as shown in the figure below.

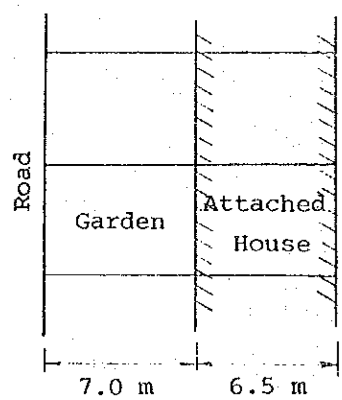
The inlet time can be calculated as:

$L = 7.0$ m

$n = 0.2$

$$T = [\frac{2}{3} \times 3.28 \times 7 \times \frac{0.2}{\sqrt{0.0004}}]^{0.467}$$

$= 10.5$ minutes



(B) Commercial Area

The commercial area in Kuala Kedah is served with roads which run in parallel approximately in every 60 meters or more. The distance from the centre of an area between two roads is calculated to be 30 meters.

The inlet time of 7.0 minutes is calculated when the distance of surface flow is 30 meters and 'n' = 0.02.

(C) Industrial Area

In case of industrial area, the distance of surface flow is 35 meters and 'n' = 0.1. The inlet time is then calculated at 16.1 minutes.

By applying Kerby formula, the inlet time discussed above are summarized as follows:

Residential area	10.5 minutes
Commercial area	7.0 minutes
Industrial area	16.1 minutes

2.1.2 Comparison with Practice in Other Areas

The inlet time in this Study is compared with practices in Japan and U.S.A. as shown in Table A.7.

Table A.7 Comparison of Inlet Time (minute)

	The value by Kerby method	Standard in Japan	Standard in ASCE
Residential area	10.5	-	-
Commercial area	7	-	-
Industrial area	16.1	-	-
Densely populated area with paved roads and drainage systems	(7-10)	5	5
Sparsely populated area	(10-16)	10	10 - 15

2.1.3 Recommended Inlet Time

The recommended inlet time is 7 minutes with due consideration on the safety side as shown above.