URBAN TRANSPORT STUDY

IN

GREATER METROPOLITAN AREAS

OF

GEORGETOWN, BUTTERWORTH AND BUKIT MERTAJAM

MALAYSIA

HIGHWAY STUDY

OUTER RING ROAD PROJECT (PHASE II)

TECHNICAL REPORT-04

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1.1 Comparison of Design Standards

1.1.1 General

The design standard in Malaysia is only applicable to rural areas but not applicable to urban areas. The Outer Ring Road will be passing through the urban area so that the Design Standard to be used will be compared with the Malaysian Design Standard, American Design Standards and Japanese Design Standards before deciding on the desirable Design Standard.

The Malaysian Design Standard will be adopted from "Recommended Minimum Geometric Design Criteria for New Roads in Rural Areas", the American Design Standard will be adopted from "A Policy on Design of Urban Highway and Arterial Streets 1973" (hereafter referred as AASHTO) and the Japanese Design Standards will be adopted from "Explanation and Usage of Road Design Code in Japan".

1.1.2 1. Comparison of design standards

Design Vehicles

1) In the case of Malaysia
   No description.
2) In the case of AASHTO.

   The physical characteristics of vehicles and the proportions of various size vehicles using the highways are positive controls in geometric design. Therefore, it is necessary to examine all vehicle types, select general class groupings, and establish representative size vehicles within each class for design use. A "design vehicle" is a selected motor vehicle the weight, dimensions, and operating characteristics of which are used to establish highway design controls to accommodate vehicles of a designated type. For purposes of geometric design, the design vehicle has physical dimensions and a minimum turning radius larger than those of almost all vehicles in its class. Freeways nearly always are designed to accommodate the largest of the several design vehicles.

However, on other urban highways, which may include intersections with small turning radii and narrower pavements with curbs, a careful determination should be made as to which design vehicle or vehicles control the design.

Table 1.1
DESIGN VEHICLE DIMENSIONS

Design vehicle	Symbol	Wheel base	Front Overhang	Rear Overhang	Overall length	Overall width	Height
		Dimension in Meter					
Passenger car	P	3.3	0.9	1.5	5.7	2.1	-
Single unit truck	SU	6.0	1.2	1.8	9.0	2.6	4.05
Single unit bus	BUS	9.5	2.1	2.4	12.0	2.6	4.05
Semitrailer combination intermediate	WB-10	12.0	1.2	1.8	15.0	2.6	4.05
Semitrailer combination large	WB-50	15.0	0.9	0.6	16.5	2.6	4.05
Semitrailer-full trailer	WB-60	18.0	0.6	0.9	19.5	2.6	4.05

Source: A policy on design of urban highways and arterial street.

3) In the case of Japan.

The Primary Distributor of intra-urban areas and inter-urban areas takes into account the passing through of all kinds of vehicles, such as passenger cars, single unit trucks and semitrailer combination and others.

On the roads mentioned below the Primary Distributor, the passing through of the Semitrailer Combination is not taken into account.

Table 1.2

DESIGN VEHICLE DIMENSIONS

Design Vehicle Type	Dimension in Meters						
	Wheel base	Front Overhang	Rear Overhang	Overall length	Overall width	Height	Min. turning Radius
Passenger car	4.7	0.8	2.7	1.2	1.7	2.0	6.0
Single unit Truck	12.0	1.5	6.5	4.0	2.5	3.8	12.0
Semitrailer Combination	16.5	1.3	-	2.2	2.5	3.8	12.0

2. Design speed

1) In the case of Malaysia

One of the controlling factors for geometric features is the design speed, which is assumed to be the maximum safe speed that can be sustained over a specified section of roadway. It determines the values assigned to the geometric features, and its selection is principally influenced by the class of highway, character of terrain, traffic volume and economic considerations. The values of the geometric features corresponding to the design speed chosen, must ensure that this speed can be maintained comfortably and without-hazard throughout the roadway section it is applied to. Features such as vertical and horizontal alignments, sight distances and superelevation vary appreciably with design speed. Other features such as width of pavement and shoulders, side clearances etc., are generally not directly related to design speed but to road capacity.

Table 1.3

DESIGN SPEED

Group	Terrain	Design Speed (Km.p.h.)	Remarks
01	F R M	50 50 30	
02	F R M	65 50 40	
03	F R M	80 65 50	
04	F R M	80 65 50	
05	F R M	95 80 65	
06	F R M	110 95 80	

Note: F : Flat Terrain
R : Rolling Terrain
M : Mountain Terrain

2) In the case of AASHTO

Design speeds should be commensurate with anticipated running speeds. It is sometimes necessary to use a design speed of a somewhat lower order than would otherwise be desirable for reasons such as to avoid disruption of neighbourhoods,to preserve major buildings and to keep right of way cost within reasonable limits. Highways designed with high design speeds are usually safer than those designed for low speeds. Emphasis should be given to use of as high a design speed as is economicallly feasible for the urban conditions.

General working ranges for design speeds for various classes of highways are shown in Table 1.4. Downtown areas would comprise the central business district and other sections with extremely heavy development. Suburban areas cover intermediate and outlying districts of the urban areas.

Table 1.4

DESIGN SPEED

Type of Facility	Design Speed	
	Downtown Areas	Suburban Areas
Arterial Streets	50-80 km.p.h.	65-95 km.p.h.
Freeways	80-110 km.p.h.	95-110 km.p.h.

3) In the case of Japan

Table 1.5 <u>DESIGN SPEED</u>

	Terrain	Class	Speed (km.p.h)	Access control	Traffic Volume (V/day)					
					above 30,000	20,000 ~ 30,000	10,000 ~ 20,000	below 10,000		
Freeway	Rural	1	120	F	▨					
		2	100	F.P	▨	▨	▨			
		3	80	F.P	▨	▨	▨	▨		
		4	60	F.P			▨	▨		
	Urban	1	80	F	▨	▨	▨	▨		
		2	60	F	▨	▨	▨	▨		
					Traffic Volume (V/day)					
					above 20,000	10,000 ~ 20,000	4,000 ~ 10,000	1,500 ~ 4,000	500 ~ 1,500	below 500
Road	Rural	1	80	P.N	▨					
		2	60	N	▨	▨	▨			
		3	40-60	N		▨	▨	▨	▨	▨
		4	30-50	N				▨	▨	▨
		5	20-40	N						▨
	Urban	1	60	P.N	▨	▨	▨			
		2	40-60	N			▨	▨	▨	▨
		3	30-50	N				▨	▨	▨
		4	20-40	N						▨

3. Sight Distance

Sight distance is the length of highway ahead visible to the driver. The minimum sight distance available on a highway should be sufficiently long to enable a vehicle travelling at or near the likely top speed to stop before reaching an object in its path. While greater length is desirable, sight distance at every point along the highway should be at least that required for a below average operator or vehicle to stop.

Minimum stopping sight distance is the sum of two distances; one, the distance traversed by a vehicle from the instant the brakes are applied; and the other, the distance required to stop the vehicle after the brake application begins.

Table 1.6 COMPARISON OF SIGHT DISTANCE

		Design speed (km.p.h.)					
		50	65	80	95	100	110
Min: Stopping Distance (M)	M	60	83	105	143	-	180
	AASHTO	60	83	105	143	165	180
	J	55	75	110	-	160	-
Desirable Stopping Distance (M)	M	-	-	-	-	-	-
	AASHTO	60	90	135	195	225	255
	J	-	-	-	-	-	-
Min: Passing Distance (M)	M	330	450	550	630	-	-
	AASHTO	330	450	550	630	690	750
	J	250	350	550	-	-	-

M : Malaysia
J : Japan
AASHTO : U.S.A.

4. Minimum Radius

For balance in highway design all geometric elements should, as far as economically feasible, be determined to provide safe, continuous operation at a likely speed under the general conditions for that highway. For the most part, this is done through use of design speed as the overall control. In the design of highway curves it is necessary to establish the proper relation between design speed and curvature and also their joint relations with superelevation. While these relations stem from laws of mechanics, the actual values for use in design depend upon practical limits and factors determined more or less empirically over the range of variables involved.

Table 1.7 COMPARISON OF MINIMUM RADIUS

Design Speed (KM.P.H)	Min. Radius (M)			Remarks
	M	AASHTO	J	
50	70	70	80	
65	130	130	120	
80	210	210	230	
95	320	320	-	
100	-	-	380	
110	450	370	-	

e: Malaysia e = 0.10
AASHTO e = 0.10
Japan e = 0.10

5. Maximum Grades

Highways should be designed to encourage uniform operation throughout. Use of a selected design speed as previously discussed is a means toward this end by correlation of various geometric features of the highway. Design values have been determined and agreed upon for many highway features but few conclusions have been reached on roadway gradients in relation to design speed. Vehicle operating characteristics on gradients are discussed under this heading and relations of gradients and their lengths to design speed are developed.

Table 1.8 COMPARISON OF MAXIMUM GRADES

Terrain		Design speed (km.p.h.)					
		50	65	80	95	100	110
Flat	M	7	6	4	3	-	3
	AASHTO	8	7	6	5	-	-
	J	6	5	4	-	3	3
Rolling	M	9	6	5	4	-	-
	AASHTO	9	8	7	6	-	-
	J	6	5	4	-	3	-
Mountain	M	9	8	7	-	-	-
	AASHTO	11	10	9	8	-	-
	J	-	-	-	-	-	-

6. Vertical Curves

Vertical curves should be simple in application, pleasing in appearance, and adequate for drainage. The major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed. Minimim stopping sight distance of greater value should be provided in all cases. In any design, the the sight distances should be as long as possible and above the minimum for the design speed where economically feasible.

Considerations of comfort require that vehicular rate of change of gradients be kept within tolerable limits. This is most important is sag vertical curves where gravitational and vertical centrifugal forces act in the same direction. Appearance also should be considered. A long curve has a more pleasing appearance than a short one which may given the appearance of a sudden "break" in the profile due to the effect of foreshortening.

Table 1.9 COMPARISON OF VERTICAL CURVES

	Class	K. Value		Remarks
		Crest	Sugg.	
50	M	840	1050	
	AASHTO	840	1050	
	J	800	700	
65	M	1650	1650	
	AASHTO	1650	1650	
	J	1400	1000	
80	M	2550	2250	
	AASHTO	2550	2250	
	J	3000	2000	
95	M	4800	3150	
	AASHTO	4800	3150	
	J	-	-	
110	M	6450	3900	
	AASHTO	6450	3900	
	J	6500	3000	

Note:

$L = I \times K$

L = Vertical Curve Length (m)

$I = |i_1 + i_2|$; Total Gradient

K = Value

1.1.3 Results of comparison of Design Standards

1) Design Vehicles

The criteria of design vehicle is not described in the Malaysian design standard. The dimensions of different vehicles throughout the world are almost the same so the AASHTO criteria of design vehicle will be adopted.

2) Design Speed

The comparison of design speed is very difficult because in deciding design speed many factors must be taken into account i.e, landuse along the road, design speed of existing road and road being planned, environmental aspects, traffic volume and others, so that the Malaysian Standard will be adopted as the criteria for design speed.

3) Elements of Design Standards

The Malaysian design standards will be adopted in the rural area and AASHTO and the Japanese design standards will be adopted in the urban area.

The result of the comparison of the elements of design standards show that these values are almost the same, so that the Malaysian design standard as described in the MINIMUM GEOMETRIC DESIGN CRITERIA FOR NEW ROADS IN RURAL AREAS will be adopted as the design standard in all aspects for this study except in the case of shoulder width.

1.2 Adopted Geometric Design Standards

The Geometric Design Standards for this study are adopted from the "Minimum Geometric Design Criteria for New Roads in Rural Areas" by the J.K.R.

1.2.1 Design Vehicles

The decision of the type of vehicle for a particular road design is a very important one. The relation between different types of vehicles to the geometric design of the road is as follows:

1. Carriage width
2. Climbing lane
3. Longitudinal Gradient
4. Design of intersection and
5. Others.

On the basis of vehicle characteristics, four types of design vehicles can be classified and this classification should be used in the geometric design for roads. Minimum turning radius of design vehicles are listed in Table 1.10.

Table 1.10 MINIMUM TURNING RADIUS OF DESIGN VEHICLES (Meter)

Design vehicle type	Passenger car	Single Unit truck	Single Unit bus	Semi-trailer Intermediate	combination: Large	Semitrailer full trailer combination
Symbol	P	SU	BUS	WB-40	WB-50	WB-60
Figure	G-1	G-2	G-3	G-4	G-5	G-6
Min. turning radius	7.2	12.6	12.6	12.0	13.5	13.5
Min. inside radius	4.6	8.5	7.0	6.0	6.0	6.8

Source: A policy on design of urban highways and arterial street.

The design vehicles adopted in the study are all those types mentioned above.

The reasons are as follows:

The outer ring road in the study is a primary distributor and is mainly connected to the Penang Bridge, North Coastal Road, Ayer Itam Road, Green Lane, and the Tanjong Tokong Road. These roads are main roads in Penang Islang and various types of vehicles as mentioned above use these roads. Therefore, the Outer Ring Road in the study is designed for the above mentioned vehicles.

Massive development projects will be undertaken in the future and construction machines, increasing in efficiency and size, will be used in the transportion of construction material and equipment. Therefore, this point is given consideration when the earlier mentioned design vehicles is adopted in the study.

1.2.2 Design Speed

1) General

"Design Speed" is a speed determined for design and correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern. The assumed design speed should be a logical one with respect to the character of terrain and the type of highway. Every effort should be made to use as high a design speed as practicable to attain a desired degree of safety, mobility and efficiency. Once selected, all of the pertinent features of the highway should be related to it to obtain a balanced design. Above minimum design values, however, should be utilized where feasible. Some features, such as curvature, superelevation, and sight distance are directly related to and vary appreciably with design speed. Other features such as widths of pavements and shoulders and clearances to walls and rails are not directly related to design speed, but they affect vehicle speed and higher standards should be accorded these features for the higher design speeds. Thus, nearly all design elements of the highway are subject to increase or decrease with a change in design speed.[1]

2) Urban highway

A) Design speeds should be commensurate with anticipated running speeds. It is sometimes necessary to use a design speed of somewhat lower order than would otherwise be desirable for reasons such as to avoid disruption of neighbourhoods, to preserve major buildings and to keep right of way cost within reasonable limits. Highways designed with high design speeds are usually safer than those designed for low speeds. Emphasis should be given to use of as high a design speed as is economically feasible for the urban situations.

General working ranges for design speeds for various classes of highways are shown in Table 1.11. Downtown areas would comprise the central business district and other sections with extremely heavy development. Suburban areas cover intermediate and outlying districts of the urban areas.

Table 1.11 DESIGN SPEEDS FOR URBAN HIGHWAYS

Type of Facility	Design Speed	
	Downtown Areas	Suburban Areas
Arterial Streets	50-80 km.p.h.	65-95 km.p.h.
Freeways	80-110 km.p.h.	95-110 km.p.h.

Source: A Policy on Design of Urban Highway and Arterial Streets, 1973.

B) The Design Speed of Urban Highway has been recommended by the "Ministry of Transport, Scottish Development Department".

Note:

1) "A Policy on Geometric Design of Rural Highway, 1965".

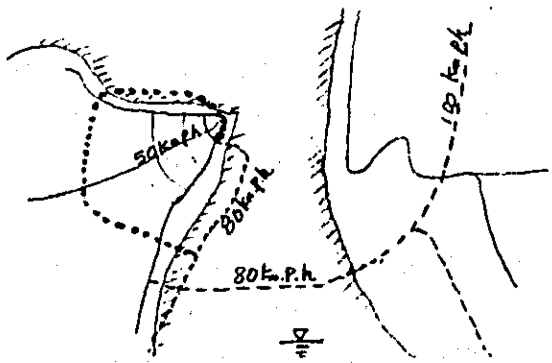
Recommended design speeds for urban roads are as follows:
Primary distributor; urban motorway -------- (50 mph) 80 km.p.h.
Primary distributor; all purpose ----------- (40 mph) 65 km.p.h.
District distributor- local distributor ---- (30 mph) 50 km.p.h.

These recommendations are intended only as a guide; it may sometimes be practicable to raise or necessary to lower the design speed for certain types of road or for part of a road though 50 km.p.h. should be regarded as the minimum value for all distributors.

3) Design speed on other roads including existing roads or planned roads.

1. Regulation speed of main existing road is 50 km.p.h. (two lines highway).
2. Design speed of the North Coastal Road is 80 km.p.h. (Dual carriageway)
3. Design speed of Penang Bridge is 80 km.p.h.
4. Design speed of New Federal Route 1 is 100 km.p.h.

Fig. 1.1 DESIGN SPEED OF EACH ROAD



4) Design speed in the study

Basically, the design speed of the study is 80 km per hour, but construction cost, construction method, existing landuse, environmental impacts and others must be taken into account. The reasons are as follows:

A) The Outer Ring Road is a primary distributor and thus, it requires a higher running speed.

B) The running speed on main roads in George Town is 50 km per hour; these roads are classified as local distributors. Thus, there will occur a change in the running speed between the Primary distributor and the Local distributor.

C) From the viewpoint of road network, the Outer Ring Road will be directly connected to the North Coastal Road and then connected to the Penang Bridge. The design speed on these roads is 80 km. per hour.

Since the Outer Ring Road and the North Coastal Road has the same characteristics, their design speed will also be the same.

1.2.3 Sight Distance

1) Stopping Sight Distance

Minimum stopping sight distance is the distance required by the driver of a vehicle travelling at a given speed to stop after an object on the road becomes visible. It is measured from the driver's eyes which are assumed to be 1.10 meter above the pavement surface to an object 0.15 meter high on the road.

The sight distance criterion must be applied in the design of highways, interchanges, at-grade intersections and major entrances of the interchanges.

Minimum values to be adopted are as follows:

Table 1.12

MINIMUM STOPPING SIGHT DISTANCE

Design speed (km.p.h.)	Min. sight Distance (m)
30	60
50	60
65	85
80	105
95	145
110	180

2) Passing Sight Distance

Passing sight distance is the minimum visible distance that must be available to enable a driver of one vehicle to pass another vehicle safely and comfortably without interfering with the speed of an oncoming vehicle travelling at the design speed should it come into view after the overtaking manoeuvre is started. The sight distance available for passing at any place is the longest distance at which a driver whose eyes are 1.10 meter above the pavement surface can see the top of an object 1.35 meter high on the road.

Minimum passing sight distances for level or nearly level grades should be as follows:

Table 1.13 MINIMUM PASSING DISTANCES

Design speed (km.p.h.)	Minimum Passing distance (m)
30	330
50	450
65	550
80	630
95	690
110	750

1.2.4 Horizontal Alignment

1) Minimum Radius

The maximum degree of curvature or the minimum radius is governed by the design speed, the maximum rate of superelevation and the maximum coefficient of lateral friction between the tyres and the road surface. The use of sharper curvature for a particular design speed would call for superelevation beyond the limit considered practical or for operation with tyre friction beyond safe limits, or both. While higher values of curve radii are always desirable, situation such as terrain conditions may develop where the designer is forced to adopt lower standards in a particular case, but this should be the exception to the rule and based only on sound economic reasoning.

The following table gives the minimum radius of curve for various design speeds.

Table 1.14 MINIMUM RADIUS

Design Speed (km.p.h.)	Min. Radius (m)	Max. Degree of Curve (approx.)
30	30	58.0
40	45	36.5
50	70	25.0
65	130	13.5
80	210	8.5
95	320	5.5
100	370	4.5
110	450	4.0

On occasions it will not be possible to adhere to the above table but under no circumstances should sight distance or other safety considerations be sacrificed.

1.2.5 Gradient

1) Maximum Gradient

The effects of grades on truck speeds is more pronounced than on speeds of passenger cars. On upgrades the maximum speed that can be maintained by a commercial vehicle is dependent primarily on the length and steepness or the grade and upon the weight-power ratio.

A range of 3% to 9% maximum was chosen for medium to heavy traffic, depending upon speed and terrain. As grades may be steeper for highways in the light traffic group, gradients ranging from 6% to 10% maximum were chosen for groups 01 and 02. Group 03 on the other hand was planned to remain consistent with group 04 for its potential upgrading.

The following is a list of points to be considered when setting grade lines:

a. Preliminary grade should roughly balance throughout the length (i.e. borrow equals cut + 15% compaction).
b. Generally preliminary grades line "rades" 2½ ft. above the ground line. The final grade is dependent on the amount of top soil stripping.
c. Clearance over swamp: If the depth of soft material is up to 3.0 meter the grade line is set at a minimum of 1.5 meter above the swamp.
d. Cross road grade should be designed based on sight distance, safety and comfortable driving.

2) Critical Grade Length

Except in level country it is generally not economically feasible to design a profile grade which will allow a uniform operating speed for all classes of vehicles. Sometimes a long sustained grade is unavoidable.

From a truck operation stand-point, a profile with sections of maximum grade broken by lengths of flatter grades is preferable to long sustained grades. The critical length of these sustained upgrades are assumed to be those which will cause a 25 km.p.h. reduction in speed of trucks below the average running speed on the approach to the grade. Critical length depends upon.

a. Size and power of a representative lorry.
b. Grade ability data for this vehicle.
c. Speed at entrance to critical length of grade.
d. Maximum speed on the grade which is considered unreasonable to following vehicles.

Maximum gradient and critical grades where trucks are concerned are shown for various percent of grades below.

Table 1.15 CRITICAL GRADE LENGTH

Design speed (km.p.h.)	Terrain	Maximum gradient (%)	Critical Length (m)
30	F	-	-
	R	-	-
	M	-	-
40	F	-	-
	R	-	-
	M	10	-
50	F	7	-
	R	8	-
	M	9	120
65	F	6	-
	R	6	180
	M	8	120
80	F	4	330
	R	5	240
	M	7	210
95	F	3	510
	R	4	330
	M	-	-
110	F	3	510
	R	-	
	M	-	

1.2.6 Transition Curves

Transition curves are introduced into the horizontal alignment to provide a gradual change between straight sections of a road and circular curves; or between two circular curves of substantially different radii. This transition path has to be longer with higher speeds and sharper curves. To design a highway with built-in safety, the alignment should be such that a driver travelling at the design speed will not only find it possible to confine his vehicle to his own lane but will be encouraged to do so.

The minimum length of transition curves are as follows.

Table 1.16 TRANSITION CURVES

Design speed (km.p.h.)	Maximum length (m)
30	-
40	54
50	54
65	63
80	72
95	81
110	90

1.2.7 Vertical Curves

Vertical curves effect gradual change between tangent grades. The major control for safe operation on crest vertical curves is ample sight distance. The minimum stopping sight distances should be provided in all cases, and the designer should strive to provide greater sight distances by making the vertical curves as long as possible where economically feasible. Controls for executing the gradual change between grades, within the sight distance restrictions, are expressed in terms of the constant K. (the horizontal distance in feet required to effect a one percent change in gradient. The K value is determined by the reciprocal L/A, where L = length of vertical curve and A is the algebraic difference between intersecting tangent grades. The constant K need only be multiplied by the algebraic difference between grades to arrive at a safe minimum length of vertical curve. The K values for the design of crest vertical curves was derived using the minimum stopping sight distance for each design speed of road. The lengths of curve computed from K are deemed sufficient for night time driving where running speeds are generally lower. On extremely long crest curves, special attention should be given near the apex of the curve to provide for proper pavement drainage. The K values for the design of sag vertical curves was derived by using headlight sight distance. The light beam distance used is nearly the same as the stopping sight distance.

Another important factor is driver comfort, but the values of distance derived by using the headlight sight distance are also satisfactory for driver comfort. On sag vertical curves, the designer should pay particular attention to drainage, as extremely long curves could result in flat spots near the apex of the curve.

Minimum K values of Vertical Curves are as follows.

Table 1.17 VERTICAL CURVES

Design speed (m.p.h)	Min. K values	
	Crest	Sag
50	840	1050
65	1650	1650
80	2550	2250
95	4800	3150
110	6450	3900

Note : ═══ Adopted figures for our Study

1.2.8 Typical cross-section

There are two different types of terrain along the Outer Ring Road; flat terrain and mountain terrain. Basically the design speed on the outer ring road is 80 km/hr. The design speed is the same in flat terrain and in mountain terrain. This is because the Outer Ring Road through mountain terrain measures only a short distance.

Therefore, a minimum geometric design criteria 04 - 06 of the "Minimum Geometric Design Criteria" of J.K.R will be adopted.

1) Carriageway width

Driver convenience, ease of operation and safety are directly influenced by the width of carriageway. On low volume roads where available funds are usually limited, narrow carriageways are justified and are sufficient for its needs on most occassions.

For high volume roads, wide lane widths are absolutely essential to provide for safe smooth flow of traffic and should have high preference in design. The width of carriageway to be adopted by J.K.R standards are as follows.

a. For Light Traffic Roads widths shall be 4.2 meter, 4.8 meter and 6.0 meter for group 01, 02 and 03 respectively.
b. For Medium Traffic Roads widths shall be 6.6 meter and 7.2 meter for group 04 and 05 respectively.
c. For Heavy Traffic Roads it shall be a divided highway with each lane 3.3 meter wide.

The J.K.R standard 0.4-0.6 will be adopted for the design criteria of the Outer Ring Road. Therefore, each lane of the carriageway will be 3.5 meters wide.

2) Width of shoulder

Usable width of shoulder should be considered as the actual width that can accommodate a vehicle for emergency or parking stops. In addition to this primary function its other main functions are to keep pedestrians and cyclists off the carriageway, to provide lateral support to the pavement, to improve sight distance in cut sections thus reducing road hazards, to provide space to avoid potential accidents or reduce their severity and a host of others.

The J.K.R standard to be adopted for the width of shoulder is as follows:

a. Group 01 and 02: 1.2 meter wide for flat and rolling terrain and 0.9 meter for mountainous terrain.
b. Group 03: 1.8 meter wide for flat and rolling terrain and 0.9 meter for mountainous terrain.
c. Group 04: 2.4 meter wide for flat and rolling terrain and 1.2 meter for mountainous terrain.
d. Group 05: 3.0 meter wide for flat and rolling terrain and 1.2 meter for mountainous terrain.
e. Group 06: 3.0 meter wide for flat and rolling terrain and 1.5 meter for mountainous terrain. The interior shoulder adjacent to the median shall be 0.9 meter wide.

According to the J.K.R standards, the shoulder width of flat terrain and mountain terrain is 3.0 meters and 1.5 meters respectively, so that a shoulder width of 1.5 meters will be adopted for mountain terrain and a shoulder width of 2.0 meters will be adopted for flat terrain.

The reasons are as follows:

The land acquisition of flat terrain in commercial and residential areas is very costly and difficult.

Cars will be prohibited from passing through road shoulders while motor-cycles and bicycles will be permitted. It would be unneccessary therefore to have the shoulder width at 3.0 meters through which cars can be pass and thus the shoulder width must be decreased.

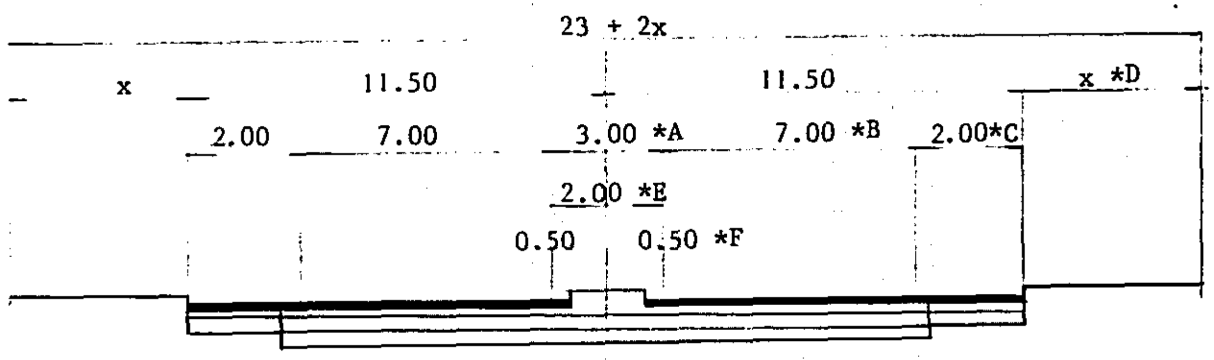
3) Central Reservation or Median

Central reservation or Median strips, as generally known, is the zone in the roadway formation that separates opposing streams of traffic; thus with a guard fence the glare of the opposing headlight can be avoided.

Also they can be planted in median strips as a form of maintaining the environment along the road. In the above consideration, it is necessary that the width of the central reservation be more than 3.0 meters. The central reservation consists of median strips and inside shoulders.

Fig. 1.2 <u>TYPICAL CROSS-SECTION</u>

Scale 1 : 200



*A : Central Reservation

*B : Carriageway

*C : Shoulder

*D : Side walk or Buffer zone

*E : Median strip

*F : Inside shoulder

Table 1.18

SUMMARY OF GEOMETRIC DESIGN STANDARD

Items	Unit	Description
Adopted Group	-	04 - 06
Design Vehicles	-	all type of vehicles
Design Speed	Km.p.h.	80
Carriageway width	m	3.5 each lane
Central Reservation	m	3.0
Median Strip width	m	2.0
Flat Terrain (F)	%	4
Rolling Terrain (R)	%	5
Mountain Terrain (M)	%	7
Critical Grade Length	m	F = 330 R = 240 M = 150
Stopping Sight Distance	m	105
Passing Sight Distance	m	540
Maximum Radius	m	210
Transition Curves Length	m	72
Vertical Curves (crest)	-	85
Vertical Curves (sag)	-	75

2. ROUTE LOCATION

2.1 Basic Guideline in Route Location

1) Route Location Site

As mentioned in the Inception Report, the area where the route is located is as follows:

(1) From the intersection of existing Weld Quay and North Coastal road to the intersection of Pesara King Edward.

(2) From the intersection of Pesara King Edward to Tanjong Tokong.

(3) From Tanjong Tokong to Waterfall Road.

(4) From Waterfall Road to Jalan Ayer Itam.

(5) From Jalan Ayer Itam through Gelugor to the North Coastal Road.

2) Route Location Policy

The important function of the road alignment is to ensure smooth and safe traffic flow. For this purpose, the following should be considered important and should be carried out.

(1) Conform to the existing ground level.

(2) Conform to the existing and future land use pattern.

(3) Preserve the existing environment

(4) Harmonize with the horizontal alignment, vertical alignment and the cross-section.

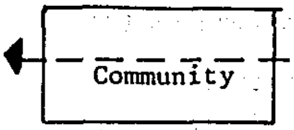
(5) Examine the safety of traffic operations and its economics.

(6) Conform to the decided geometric design standards.

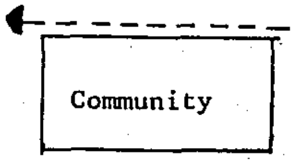
(7) Decrease construction cost.

3) Guideline to Route Location

(1) To preserve the environment of residential areas. Should the route cross through residential area, it will result in splitting up of the community that has existed as a single community into two divisions. This community may have been created over a long period of time and a separation of the community may destroy it functional significance. Therefore, the location of the route should deviate from such communities. As such, all residential communities in the area of the route should be considered carefully and necessary changes should be made in the route location plan.



Undesirable route location



Desirable route location

(2) To preserve cemeteries

There are many cemeteries that occupy a large space which are situated on flat and rolling terrain. Some difficulties may be encountered in the removal of cemeteries, such as to select and to choose alternative available land for the cemeteries and to negotiate for the removal of the cemeteries. Therefore, the route location should be planned to avoid passing through these cemeteries.

(3) To preserve environment

There are many trees lining both sides of the existing roads, and which provide a good environment to George Town. Therefore, they should not be cut down in the improvement of the existing road. There are also public open spaces with parks, golf coures, race courses and others in the study area. These facilities are for public use and therefore the route should avoid passing through these facilities.

(4) To decrease construction cost

Construction of a road in mountainous area is always very costly because it will be necessary to build bridges, concrete walls and other structures. To decrease construction cost the building of the above mentioned structures should be minimised in number as far as possible. Therefore, as far as possible the route location should be on flat terrain and areas with good soil conditions.

(5) To conform to the future development plans

There are future development plans in the study area especially, around Ayer Itam, Glugor and Tanjong Bungah. The location of the route should be in accordance with the above mentioned development plans.

(6) To preserve historical structures and sites

The route location should avoid historical structures and sites because they are of historical significance to the country.

(7) Avoid permanent concrete buildings

It is desirable to take due consideration on the location of permenant concrete buildings in order to reduce the difficulties of implementation in terms of time and cost.

2.2 Possible Route Location and Evaluation

1) General

It is possible to classify eight areas of different characteristics in the study area by sections which are illustrated in Fig. 1.2. The possible location of the route will be described according to each area. The purpose of this section is to consider and evaluate each alternative route location.

2) Description of Sections

(1) A-B Section

i) Related Site Conditions

Some site conditions along this section of the route location that should be given consideration are:

* North Coastal Road
* Future development plan
* Cemetery
* Residential area

a) North Coastal Road

The plan of the North Coastal Road, the interchange of the North Coastal Road, the Penang Bridge and the improvement of Glugor intersection have already been approved by the Malaysian Government and the feasibility study already carried out. The above mentioned plans are premises in our study.

b) Future development plan

The site of the future development plan is located between residential areas and there are six-storey buildings for residence which are under construction at present.

c) Cemetery

The cemetery is not very big and is located along Calthrop Road.

d) Residential area and others

The Penang Bridge will be connected to the North Coastal Road in front of U.S.M (Universiti Sains Malaysia) and the interchange is planned at that point. If the route is to pass through the existing residential area (B) and U.S.M it will be difficult to connect it to the North Coastal Road because it is too near the interchange of the Penang Bridge.

ii) Alternative Routes

The route location takes into account the above mentioned conditions. In this section, two alternative routes are proposed as illustrated in Fig. 2.1.

a) Route A

The location of Route A is based on the following considerations:

* To avoid housing, cemetery land, school and future development area as far as possible.
* To select a good geographical condition for the geometric design standards.

Advantages:

* Only a few houses need be demolished.
* Disruption of the community can be avoided.

Disadvantages:

* The North Coastal Road is a Primary Distributor in the inter-urban area so the route should be built up to avoid many interchanges on this road. However, one additional interchange is necessary to be established on the North Coastal Road.

b) Route B

The location of Route B is based on the following considerations:

* The disadvantages mentioned in Route A are taken care of in Route B.

Advantages:

* It is not necessary to add a new intercharge on the North Coastal Road.

Disadvantages:

* There are many houses that have to be demolished.
* The width of the right of way of the route will have to be decreased in order to minimise conflict with the residential area.

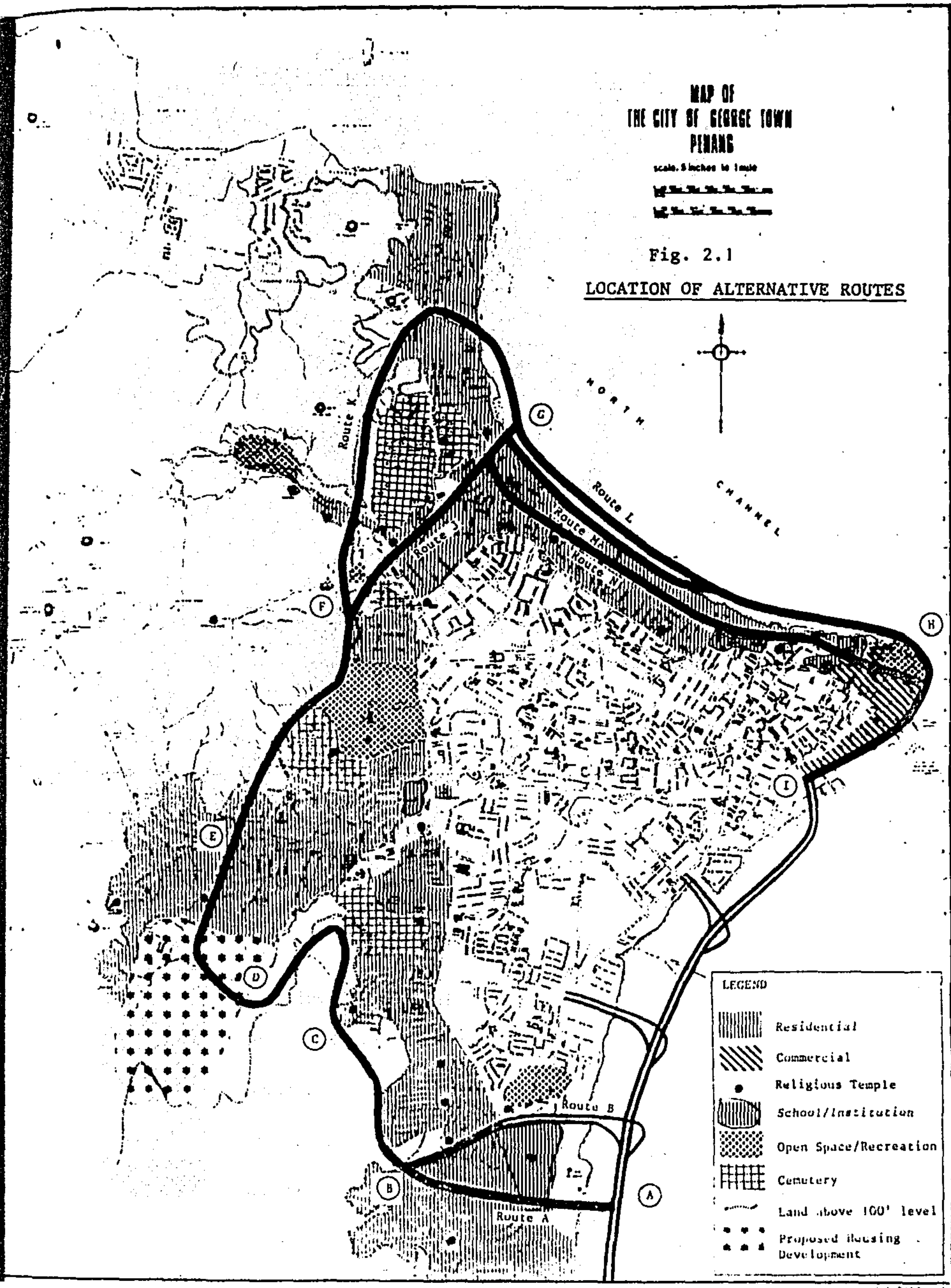
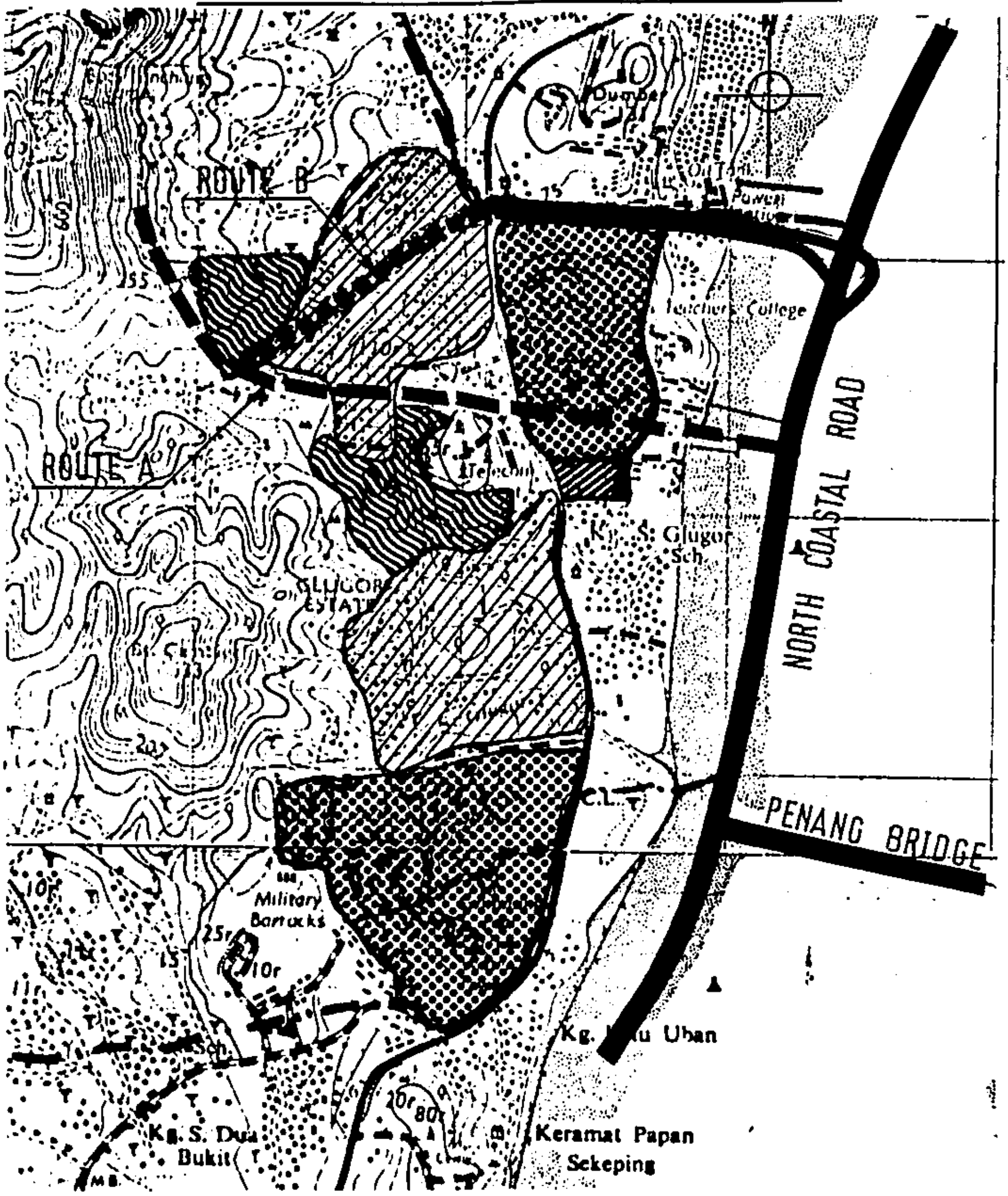


Fig. 2.1

LOCATION OF ALTERNATIVE ROUTES

Fig. 2.2
ALTERNATIVE ROUTE LOCATION IN A-B SECTION



LEGEND

▨	Existing Residential Area
▨	Future Development Area
▨	Cemetery
◌	Open Space
▩	School

(2) B-C-D section

i) Related Site Condition

Some site conditions along this section of the route location that should be given consideration are:

* Existing Residential area
* Cemetery
* Existing ground and geographical conditions.

a) Existing Residential Area

The existing residential area stretches from Green Lane to the foot of the mountains. The highest point in the residential area is about 20-25 meter above sea-level and this area is already fully built up with many houses.

b) Cemetery

A very large portion of the northern area is occupied by cemetery from the foot to the top of a mountain or hill.

c) Existing Ground Condition

The existing ground condition varies suddenly from residential to mountainous area. This mountainous area is very steep and there are many rocky parts in some places.

ii) Alternative Route

The policy for the route location is as follows:

* To avoid the cemetery as far as possible.
* To avoid passing through the residential area.

The reason for this will be described hereafter in E-F section. Taking into account the above-mentioned matter, the route can be located only in the mountainous area, 60 meter to 90 meter above sea-level. The location of route is illustrated in Fig. 2.3.

(3) D-E Sections

i) Related Site Conditions

Some site conditions of this section to be given consideration are:

* Future development plan.
* Existing residential area.

a) Future development plan

The future development plans by the Planning Department of the MPPP has been approved.

According to the future plan, road with a right of way of about 44 meters (40' + 66' + 40' = 146') is located in the center of this residential area.

b) Existing residential area

The existing residential area is a high density new housing area.

ii) Alternative Routes

The route location takes into account the above-mentioned matters. In this section, two alternative routes are proposed (see Fig. 2.4).

Fig. 2.3

ALTERNATIVE ROUTE LOCATION IN B-C-D SECTION

LEGEND

Existing Residential Area

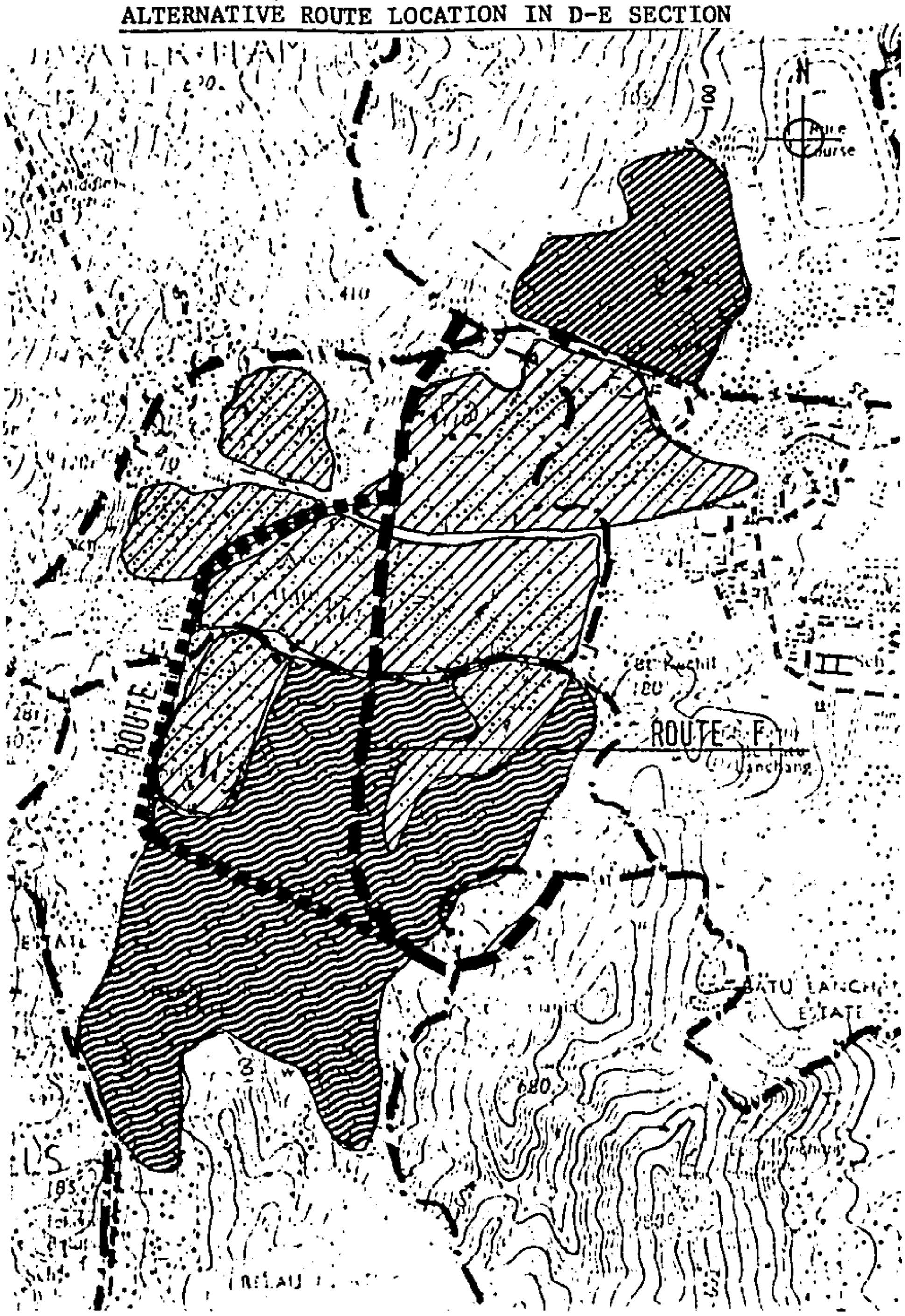
Future Development Area

Cemetery

Open Space

School

Fig. 2.4
ALTERNATIVE ROUTE LOCATION IN D-E SECTION



LEGEND

- Existing Residential Area
- Future Development Area
- Cemetery
- Open Space
- School

a) Route E

The location of Route E is based on the following considerations:

* As far as possible the route should follow the location of the existing road.

Advantages:

* The Outer Ring Road will be of use to the inhabitants of the center of Ayer Itam town.

Disadvantages:

* This route passes through the old Ayer Itam town and may cause disruption of the community.
* The length of this route is longer than Route F.
* Expansion of the existing road in Ayer Itam is very difficult.
* Since the route will pass through the center of Ayer Itam town, the function of Ayer Itam town may be disrupted by the road.

b) Route F

The location of Route F is based on the following considerations:

* As far as possible the location of the route should be in line with the future development plan of the Planning Department of MPPP.
* To avoid passing through any permanent building made of concrete.

Advantages:

* The route conforms with the future development plan.
* The route can avoid the disruption of Ayer Itam town.

Disadvantages:

* The minimum geometric design standard is adopted for the horizontal alignment.

As indicated above, alternative Route E is obviously undesirable. Therefore, alternative Route F is adopted for this this section.

(4) E-F Section

i) Related Site Conditions

Some site conditions along this section of the route location that should be given consideration are:

* Topography
* Cemetery
* Residential area

a) Topography

This section is a mountainous area. It is very steep and the area is rocky over 90 meter (300 ft.) above sea-level.

b) Cemetery

This cemetery area is located from 20 meters to 45 meters above sea-level and is very large.

c) Residential Area

This area is located from 20 meters to 45 meters (150 ft.) above sea-level and immediately behind this area is a mountainous area so that there is insufficient space to construct the road in the flat terrain.

ii) Alternative Routes

The policy for the route location is as follows:

* To avoid passing through the cemetery and existing residential area as far as possible.
* Consideration must be given to decrease the construction costs.
* The environmental aspects must be considered.

The location of these three routes are shown in Fig. 2.5.

Route G: Located over 120 meter (400 ft.) above sea-level.

Route H: Located between 60 meter (200 ft.) and 90 meter (300 ft.) above sea-level.

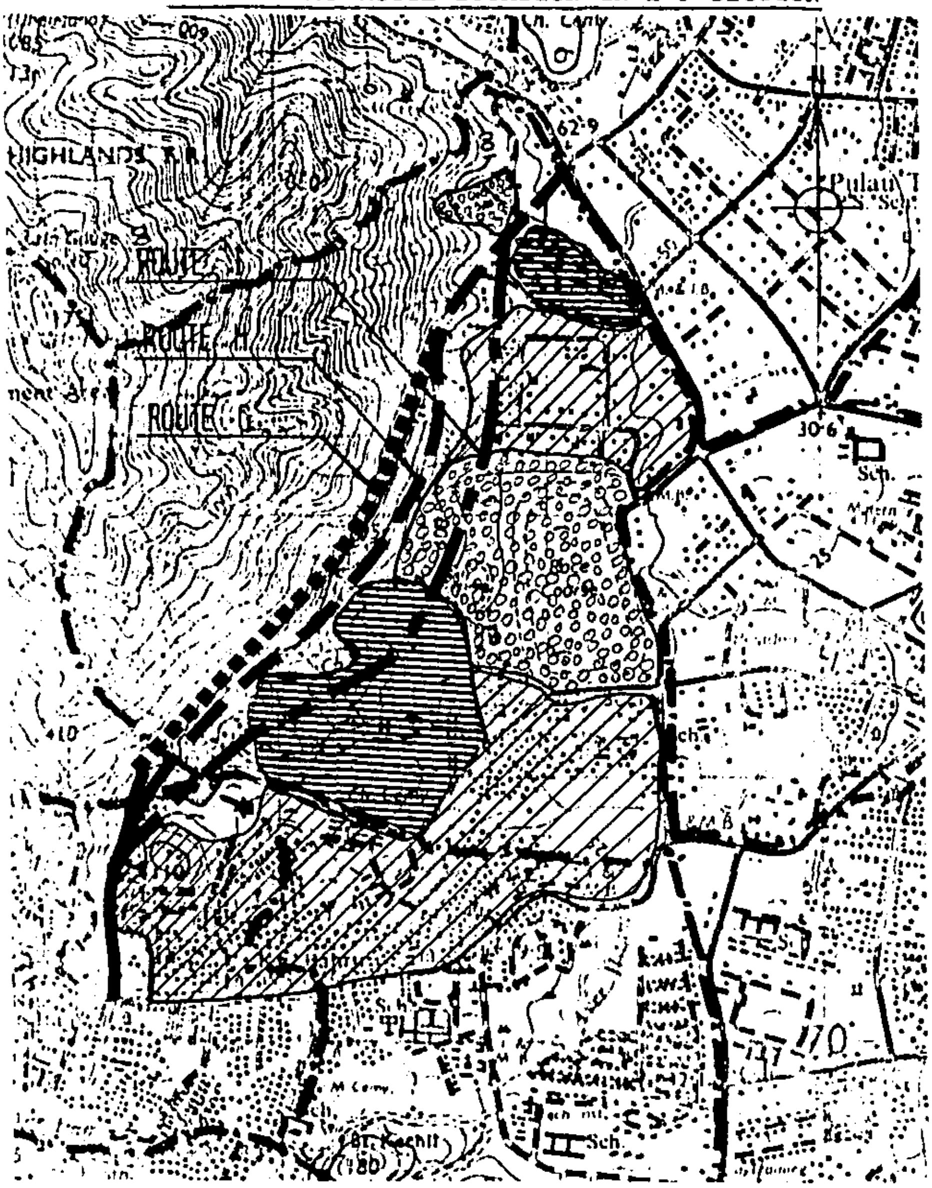
Route I: Located about 30 meter (100 ft.) above sea-level.

The route for the feasibility study is Route H and the reasons for this selection are as follows:

* The available route location area should be between 60 meter (200 ft.) and 90 meter (300 ft.) above sea-level. This is because the topographic conditions of the area over 90 meter above sea-level is partially rocky and that over 120 meter above sea-level is rocky. To construct a road in such areas involves very high cost. Therefore, Route G cannot be selected. Also, the area in Route I that is below 60 meters which in any case is occupied by the cemetery and residential area cannot be selected. (See Fig. 2.5).

Fig. 2.5

ALTERNATIVE ROUTE LOCATION IN E-F SECTION



LEGEND

- Existing Residential Area
- Development Area
- Cemetery
- Open Space
- School

Besides the above-mentioned, the following reasons justify the selection of Route H. There are two control points that must connect the Outer Ring Road to the existing road. The distance between each road is about 2.5 kilometers. When the maximum gradient to be used is 6.0 per cent, the route should not be over 120 meter above sea-level. If maximum gradient to be used is 8.0 per cent, the route can climb 120 meter above sea-level, but it must slope downwards again after a short distance. If 10.0 per cent is to be used, the route can pass through flat areas but 10.0 per cent of the maximum gradient is too steep for the primary distributor in urban areas. (see Fig. 2.6 and Fig. 2.7).

(5) F-G Section

i) Related Site Conditions

Some site conditions to be given consideration are:

* The cemetery
* Existing residential area
* Existing road
* The development plan.

FIG. 2.6 EXISTING SITUATION

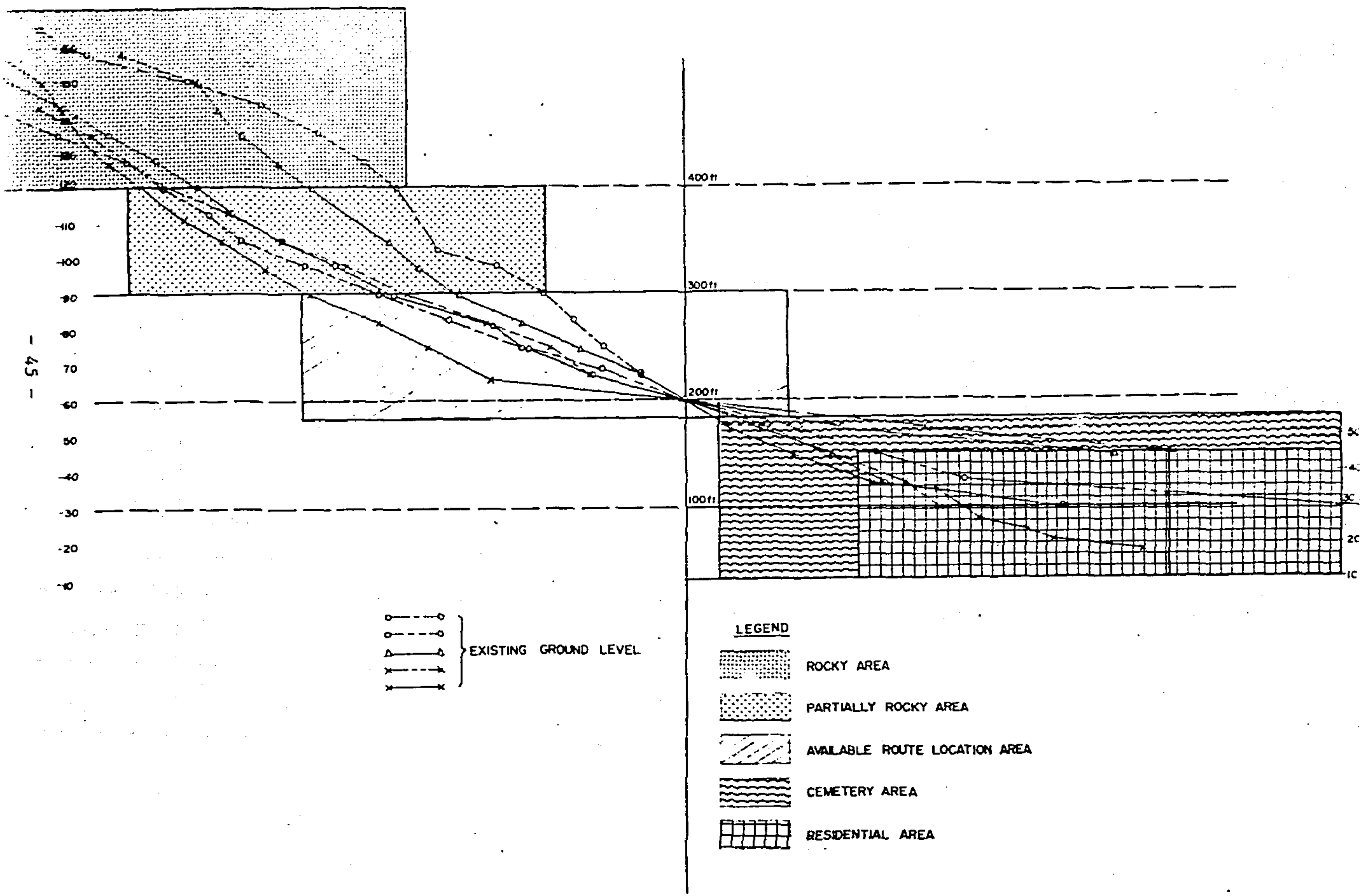
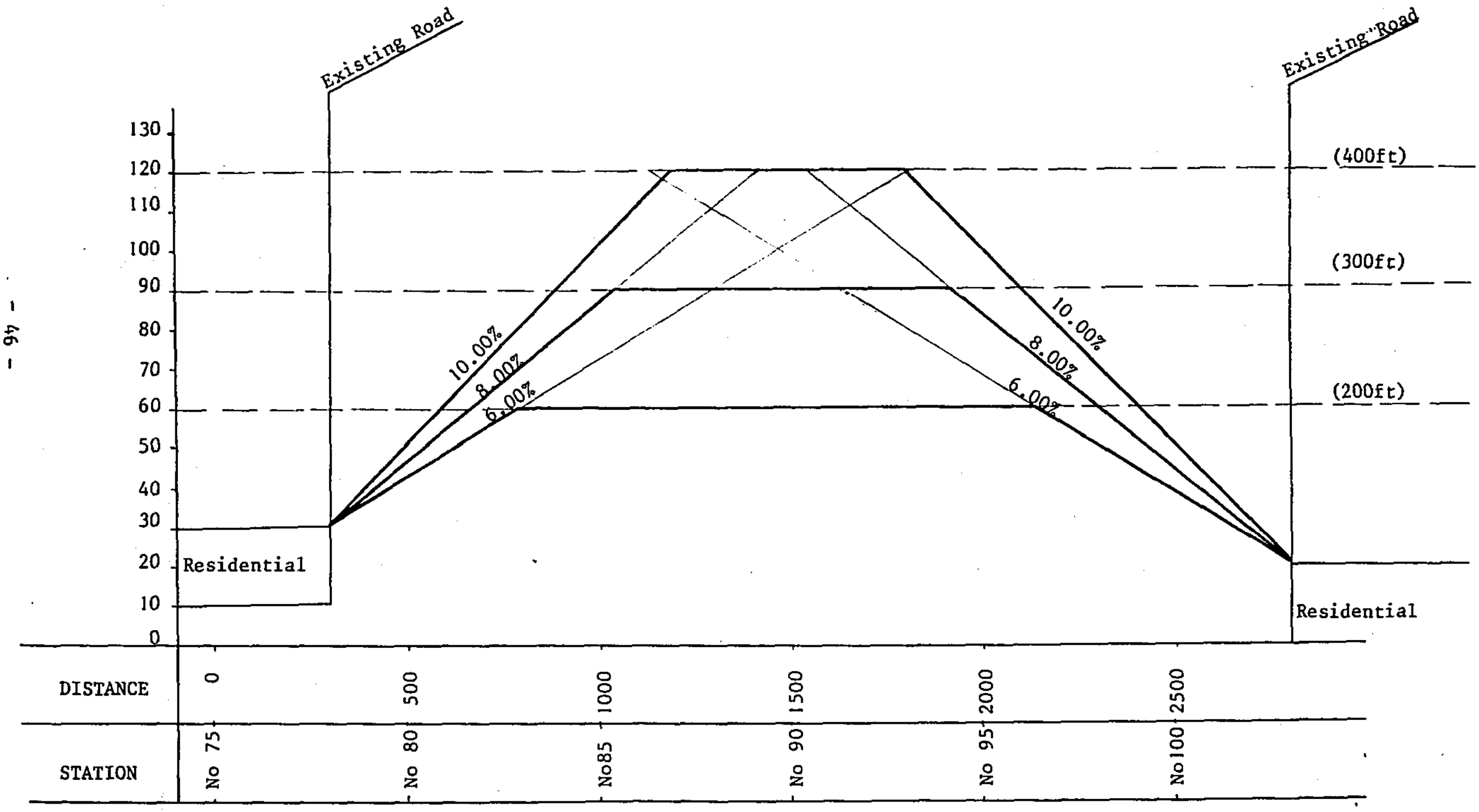


Fig. 2.7 RELATIONSHIP BETWEEN GRADIENT AND MOUNTAIN HEIGHT



a) The cemetery

The cemetery is located along Jalan Tanjong Tokong and occupies a large portion of the hill area.

b) Existing road and conditions along the road.

The existing road is a two-way carriageway and there are roadside trees along the road. One side of the road is occupied by a school and the other is occupied by a residential area consisting of old and large houses.

c) Development plan

There are two development plans in this section. One passes through the mountainous area and is connected to Batu Ferringhi. This is planned by the JKR Penang. The other passes through the sea-shore line of Tanjong Tokong and is connected to the existing Jalan Tanjong Tokong.

ii) Alternative Routes

The route location takes into account the above-mentioned matters. In this section, two alternative routes will be located as shown in Fig. 2.8.

a) Route K

The location of Route K is based on the following considerations:

* Maintain the environment.
* Conform to the proposed development plans.

Advantages:

* It avoids the residential area.
* It conforms easily with the development plan.

Disadvantages:

* The distance between F point and G point is very long i.e about two times of Route J.
* It is difficult to connect to Waterfall Road.

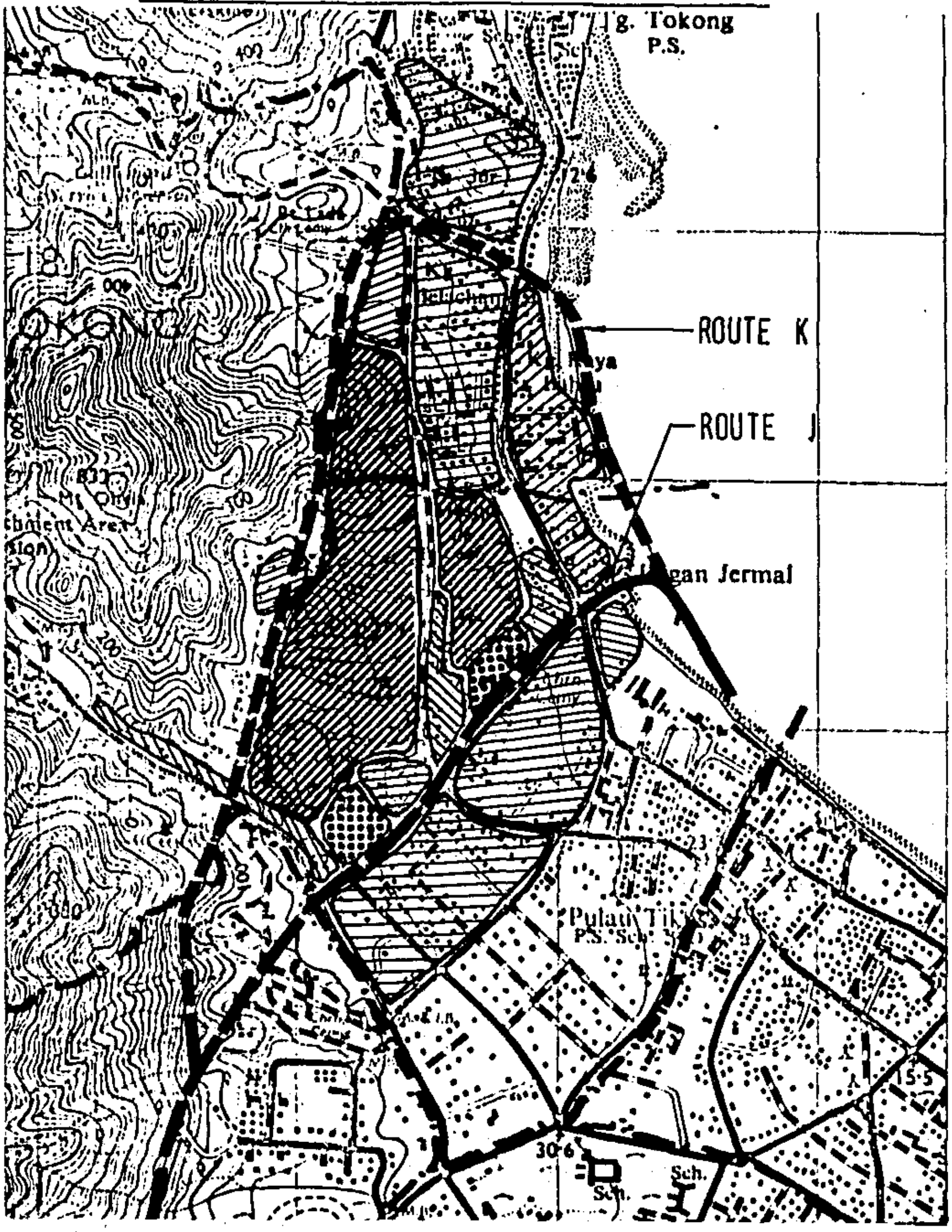
b) Route J

The location of Route J is based on the following considerations:

* Conformity with the existing road network.
* To connect F point and G point with a straight line to decrease the distance.

Fig. 2.8

ALTERNATIVE ROUTE LOCATION IN F-G SECTION



LEGEND

Existing Residential Area

Future Development Area

Cemetery

Open Space

School

Advantages:

* This is a shorter route than Route K.
* Conforms with the existing road network.

Disadvantages:

* It is necessary to mitigate adverse impacts to the existing environment.
* Land acquistion is difficult.

(6) G-I Section

i) Related Site Conditions

Some site conditions along this section of the route that should be taken into consideration are:

* Environmental aspects.
* Existing road.
* Existing residential area.

a) Environmental aspects

Gurney Drive provides a good environment for walking, viewing the sea, playing on the seashore and others.

b) Existing road

In this section, there are two major roads, that is Gurney Drive and Jalan Northam. Gurney Drive is two-way carriageway with parking space allocated on one side of the road. Jalan Northam is also two-way roadside trees along the road.

c) Existing residential area

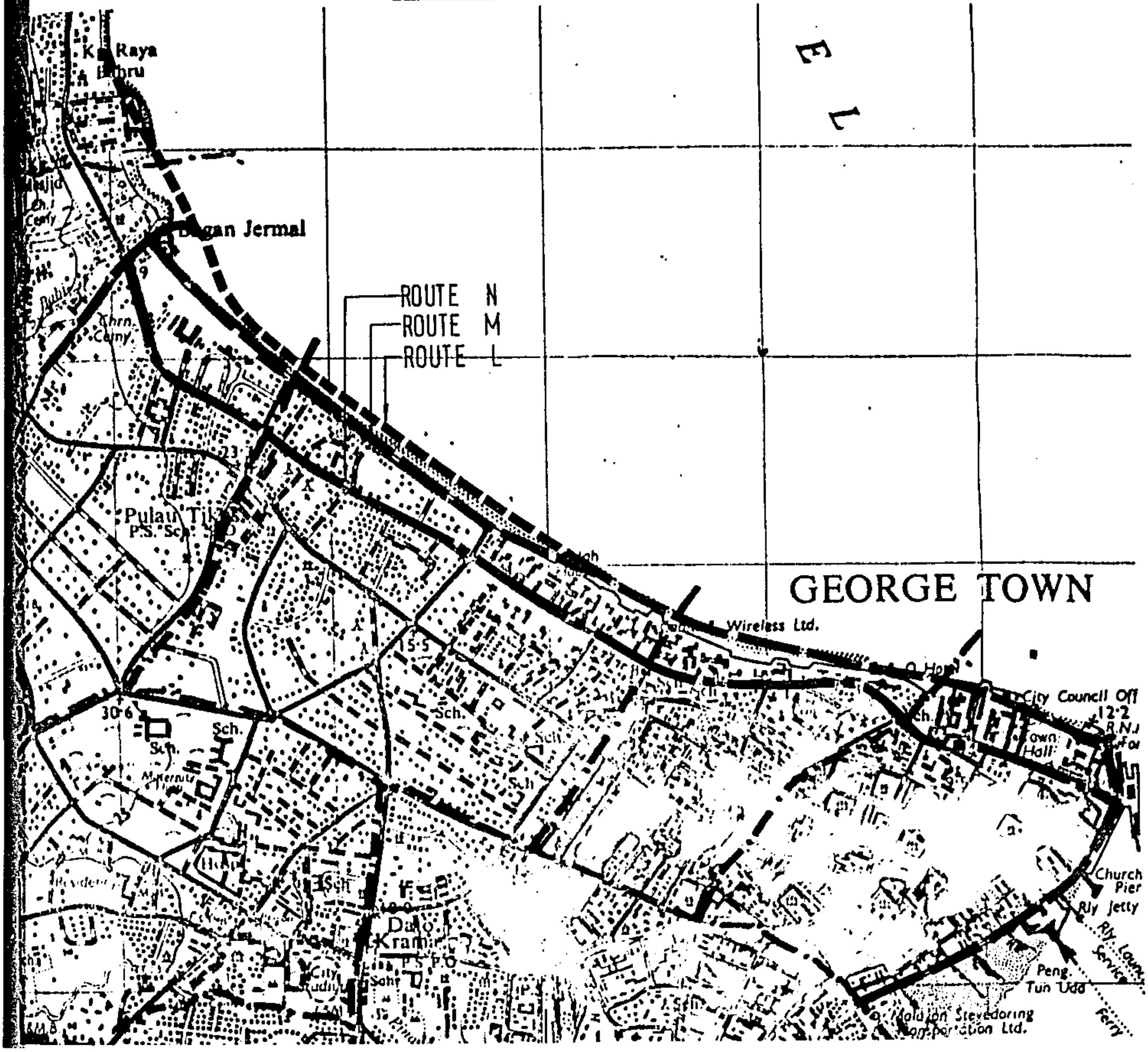
A residential area is located between Gurney Drive and Jalan Northam. Each individual house lot is very large which provides a very good environment around the house.

ii) Alternative Routes

The route location takes into account the above-mentioned matter. In this section, three alternative routes are proposed. (see Fig. 2.9).

Fig. 2.9

ALTERNATIVE ROUTE LOCATION IN G-I SECTION



LEGEND

Existing Residential Area

Future Development Area

Cemetery

Open Space

School

a) Route L

The location of Route L is based on the following considerations:

* To preserve the environment
* To avoid residential areas.

Advantages:

* It maintains the good environment of residential areas.
* It provides a good open space for taking walks, etc.
* The traffic volume passing through the town will be decreased.

Disadvantages:

* Construction cost is very expensive.
* The view of the sea from the residential area will require adequate mitigation measures.

b) Route M

The location of Route M is based on the following considerations:

* The same as the basic matters of Route L.
* Construction cost decreases.
* Route M will conform to the existing Gurney Drive.

Advantages:

* The same as Route L.
* Construction cost is cheaper than Route L.

Disadvantages:

* Some problems will be encountered in the improvement of the intersection at Tanjong Tokong.

c) Route N

The location of Route N is based on the following considerations:

* Improvement of existing road.
* The construction cost will be lower.

Advantages:

* It will be difficult to prepare the land for the expansion of the road.

(7) H-I Section

i) Related Site Conditions

Some site conditions along this section of the route location that should be taken into consideration are:

a) The existing road and conditions along the road.

Weld Quay consists of a dual carriageway and a single carriageway.

In the case of the single carriageway the width of the road varies. The minimum width is 18.00 meter and the common section is over 20.00 meters. Along the existing road there are many old buildings, the removal of which may cause problems.

There are roads behind Weld Quay. The width of these roads is narrower than Weld Quay and conditions along these roads are the same as along Weld Quay.

ii) Alternative Routes

In order to join with the North Coastal Road, it is necessary to improve Weld Quay.

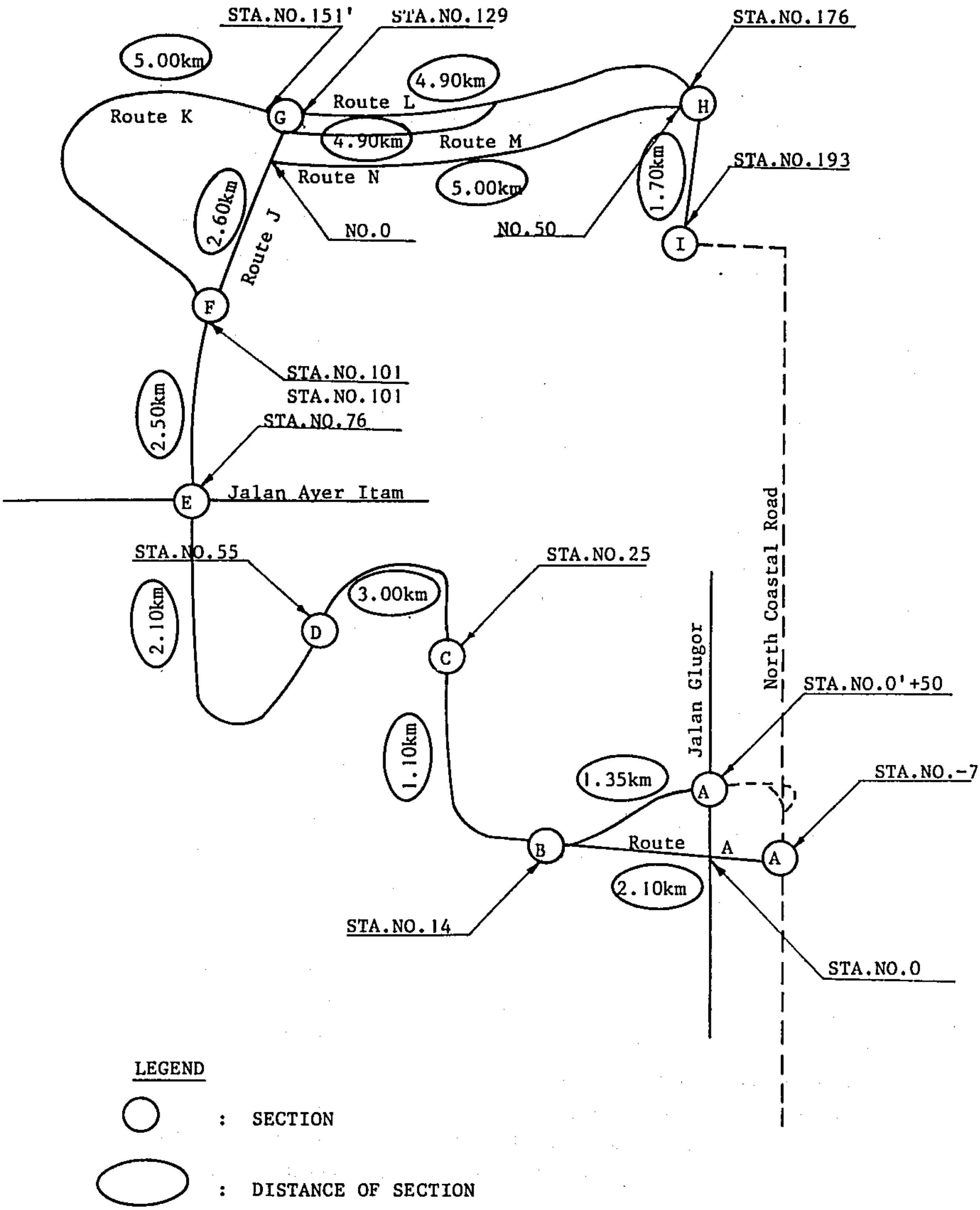
2.3 Preliminary Comparison of the Alternatives

Some alternative routes have been proposed in the previous section. Even though these alternatives will be evaluated in greater detail in relation to environmental aspects, traffic assignment, construction costs, etc, a preliminary comparison is done here. Table 2.1 and Fig. 2.10 summarises these comparisons.

Table 2.1 COMPARISON OF ALTERNATIVE ROUTES

Item	Route	A - B Section		F - G Section		G - H Section		
		Route A	Route B	Route J	Route K	Route L	Route M	Route N
Outline	Length	2.10 Km	1.35 Km	2.60 Km	5.00 Km	4.90 Km	4.90 Km	5.00 Km
	Plan	New Construction & Improvement of existing Valley Road	New Construction	Improvement of existing Jalan Gottlieb and Jalan Bagan Jermal	New Construction	New Construction	Improvement of existing Gurney Drive & New Construction	Improvement of existing Jalan Kelawei and Jalan Northam
	Land use	Existing housing area & Future housing area	Existing housing area	Existing housing area	Mountainous area	Seashore	Existing housing area & seashore	Existing housing area & commer-cial area
Driving Comfort	Max. Grade	Below 3.00%	Below 3.00%	Below 3.00%	6.00%	Below 3.00%	Below 3.00%	Below 3.00%
	Min. Radius	Over 600 m	Over 500 m	Over 300 m	Over 300 m	Over 300 m	Over 300 m	Over 100 m
	Alignment	Smooth Almost flat	There are up and down slopes	Almost flat	There are up and down slopes	Very smooth Almost flat	Very smooth Almost flat	There are many curves. Almost flat
Cons-truction	Construction condition	Easy	Many problems	Some problems	Easy	Easy	Easy	Some problems
	Land acquisition	Easy	Many problems	Many problems	Easy	Easy	Easy	Many problems
Safety		More safe than Route B	Moderate	Moderate	More safe than Route J	More safe than Route N	More safe than Route N	Moderate
Economical		The length of the road is longer than Route B. Land acquisition cost is cheaper than Route B.	The length of road is shorter than Route A. Land acquisition cost is very high	Land acquisition cost is very high	The length of road is longer than Route J. Land acquisition cost is very cheap.	There are many structures.	Cheaper than Route L.	Land acquisition cost is very high.
Environment	Community	Route passes through the border of the community	Route passess through the community	Route passes through the border of the community	Separate from the community	Separate from the community	Separate from the community	Passes through the border of the community
	Greenery	Can maintain existing good environment	Some problems in creating good environment	Some problems in creating good environment	Can maintain existing good environment	Can maintain existing good environment	Can maintain existing good environment	Some problems in creating good environment
	Decreasing noise level	Some problems	Many problems	Some problems	No problem	No problem	No problem	Many problems
	View from road	-	-	-	Beautiful	Beautiful	Beautiful	-
	View of road	-	-	-	Mitigation measure required	Mitigation measure required	Mitigation measure required	-

Fig. 2.10 LENGTH OF EACH SECTION



3. CROSS-SECTION

3.1 General

The typical cross-section of the Outer Ring Road was originally proposed as a dual carriageway in the Phase One Study, however, in the Phase Two study, it is necessary to design it in detail bearing in mind the various site conditions and to evaluate it.

For this purposes, typical cross-sections are provided according to the site conditions.

The nature of the environment along the Outer Ring Road which decides the types of cross-section can be classified into commercial area, seashore area, residential area and mountain area. Major considerations for each type of area are as follows.

1) Residential area

The most important factor that must be taken into account with regard to residential areas is the environmental aspect and accessibility. The Outer Ring Road is a primary distributor so that access from minor roads should be controlled.

Details on environmental aspects are studied hereafter, but it seems desirable to provide the buffer zone width, for a better environment.

2) Seashore area

Since this area provide a good environment and opportunities for recreational activities, it is quite desirable to design the Outer Ring Road so as to contribute these aspects. Therefore, the space for landscaping is necessary to be taken into account.

3) Mountain area

Any construction to be undertaken in the mountain area is very costly because of many earth work and structures. Therefore, the decrease of shoulder width could be considered, since the shoulder width is used for emergency parking, protection of pavement and others usually. It also makes it less possible of having to change the present environment.

3.2 Cross-section Planning Policy

1) Basic standard to be used

The width of each cross-section will be based on the J.K.R standard.

2) Width of carriageway

According to the J.K.R standard, the width of carriageway for group 04, 05 and 06 is 3.2 meters, 3.6 meters and 3.6 meters respectively and their terrain is flat, rolling and mountainous on which design speed is 80 kilometer per hour. The terrain along the Outer Ring Road varies between flat terrain, rolling terrain and mountain terrain. The distance between each terrain is not very long and therefore, changing the width of the carriageway on each terrain should be avoided. Thus the J.K.R standard is adopted for the width of carriageway in the study whereby each lane will be 3.5 meters.

3) Width of central reservation

The width of the central reservation of group 04, 05 is not described in the J.K.R standard, but for group 06 it is described as a minimum of 3.0 meters.

Guard fences, lighting and other structures will be established on the central reservation. Therefore, the width of the central reservation needs to be at least 3.0 meter.

4) Width of shoulder

The shoulder width of group 04, 05 and 06 are 2.4 meter, 3.0 meter and 3.0 meter respectively by the J.K.R standard. A shoulder width of 2.0 meters will be adopted in the study. The reasons are as follows:

The land acquisition of flat terrain in commercial and residential areas is very costly and difficult. A width of 2.0 meters provides a lane for motor-cycles and bicycles. so that they can avoid cars which may otherwise run on the shoulder.

5) Service road

Basically, a service road should be prepared in residential areas. The service road should have a width of 4.5 meters and will be a one-way street. After a reconnaissance survey in the actual site, the service road will be planned.

6) Buffer zone

It is desirable that there should be a buffer zone in residential areas. After a detailed environmental study is done, the width and situation of the buffer zone will be decided upon.

7) Right of way

Basically the width of right of way should be 30 meters (100') or 40 meters (132') in flat terrain according to the J.K.R standard. However, it should be more than 40 meters in mountainous areas.

3.3 Cross-Section

The characteristic of the land condition along the Outer Ring Road can be classified as follows:

Type 1

This is re-developed area and in this area Type 1 cross-section is adopted. The width of the existing road in this area is very narrow about 6.0 - 10.0 meters.

Type 2

Type 2 is mountainous area and Type 2 cross-section is adopted for this area.

Type 3

Type 3 is developing area and in this area Type 3 cross-section is referred to. The Right of Way is 23.00 meter and a reservation area of 12.00 meters wide on both sides is prepared. Sidewalks and a buffer zone should be constructed in the reservation area by a private developer.

Type 4

Type 4 is also re-developed area. So in this section there is an improvement from the existing 2-lane road to a 4-lane dual carriageway. In this section Type 4 cross-section is adopted.

Type 5

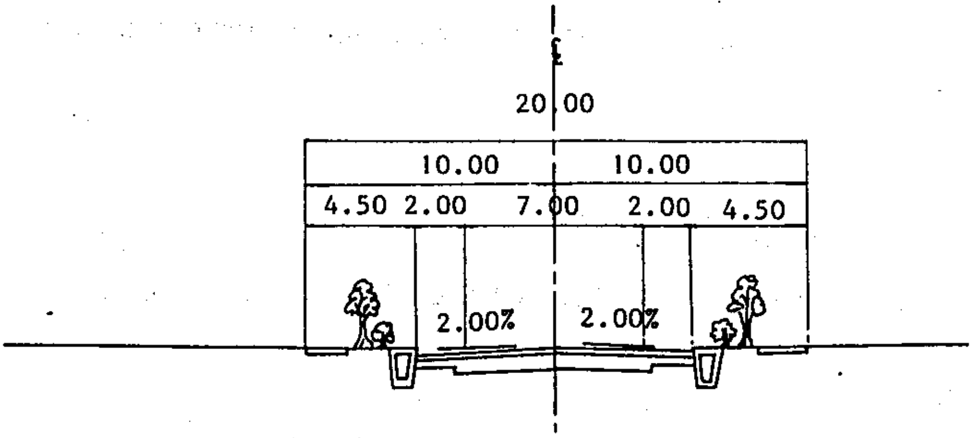
Type 5 is seashore area. The cross-section in this area should consider the environmental aspects, and Type 5 cross-section should be adopted.

Type 6

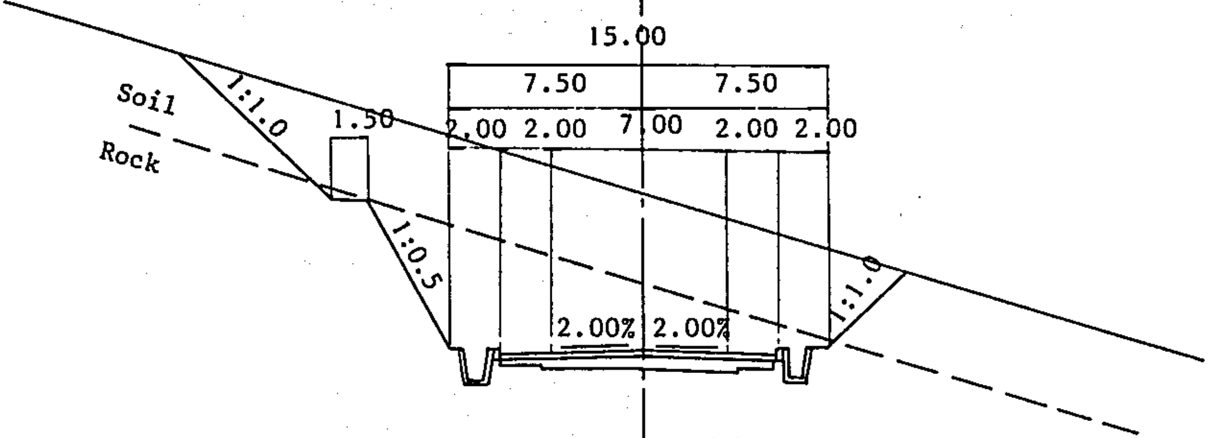
Type 6 is commercial area. Along the existing road, there are many buildings and the width of existing road is about 20.0 meter. The dual carriageway can be provided in the existing road width. So, in this section there will not be a need to expand the existing road and only the establishment of the central reservation lane-marking will be prepared. Type 6 cross-section will be prepared. The above-mentioned cross-section is shown in Fig. 3.1 and 3.2.

Fig. 3.1 EACH TYPE OF CROSS-SECTION (2-LANE)

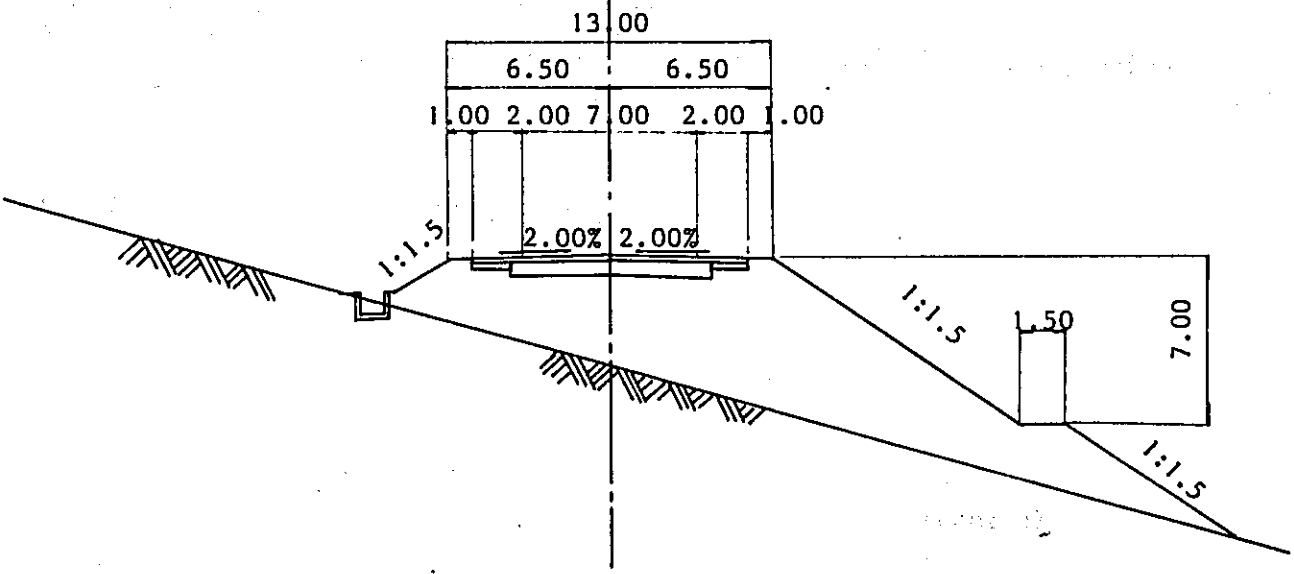
1) TYPE 1 RESIDENTIAL AREA WITHOUT SERVICE ROAD



2) TYPE 2 CUTTING SECTION



2) TYPE 2 EMBANKMENT SECTION



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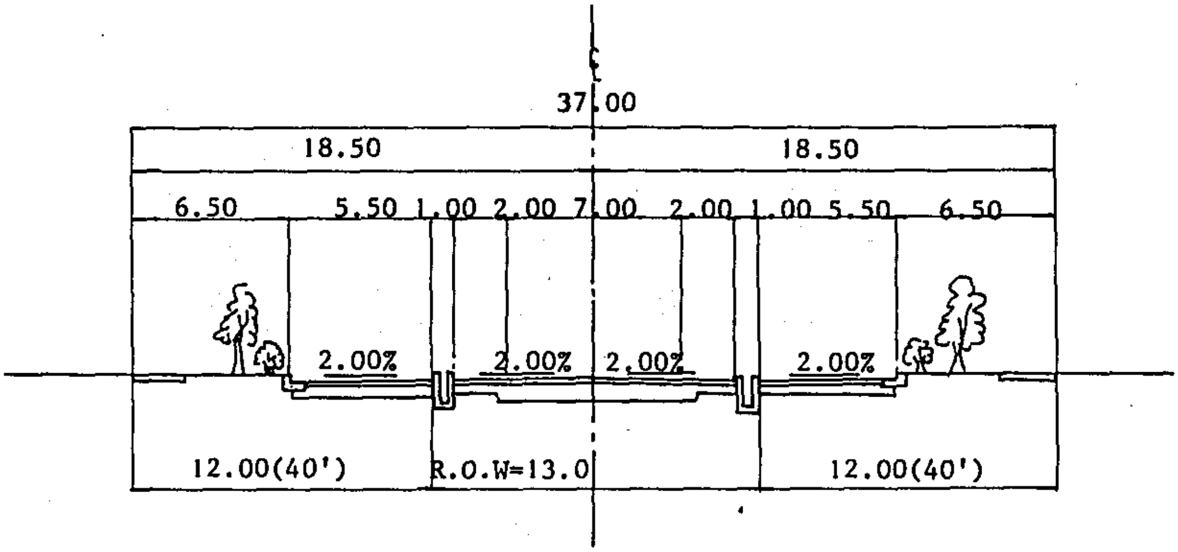
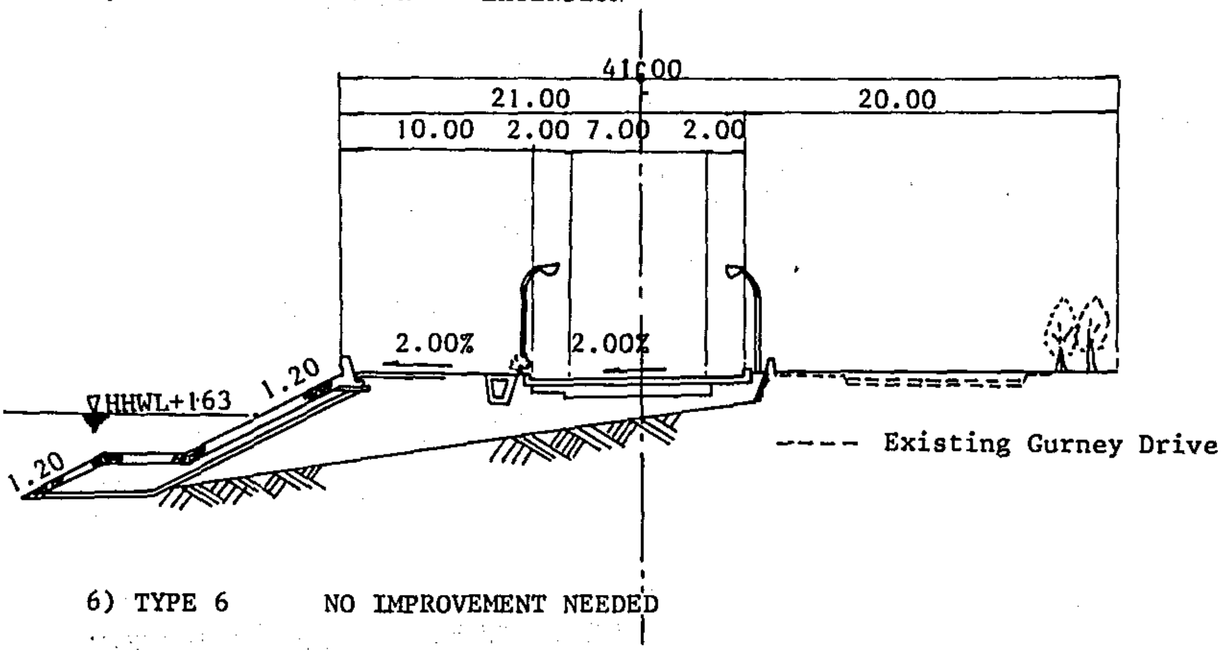
3) TYPE 3 RESIDENTIAL AREA WITH SERVICE ROAD



4) TYPE 4 NO IMPROVEMENT NEEDED

5) TYPE 5 GURNEY DRIVE EXTENSION



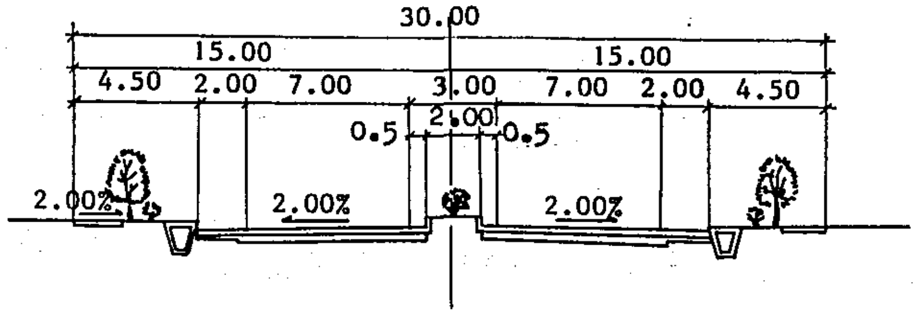
6) TYPE 6 NO IMPROVEMENT NEEDED

(cont'd)

Fig. 3.2 EACH TYPE OF CROSS-SECTION (4-LANE)

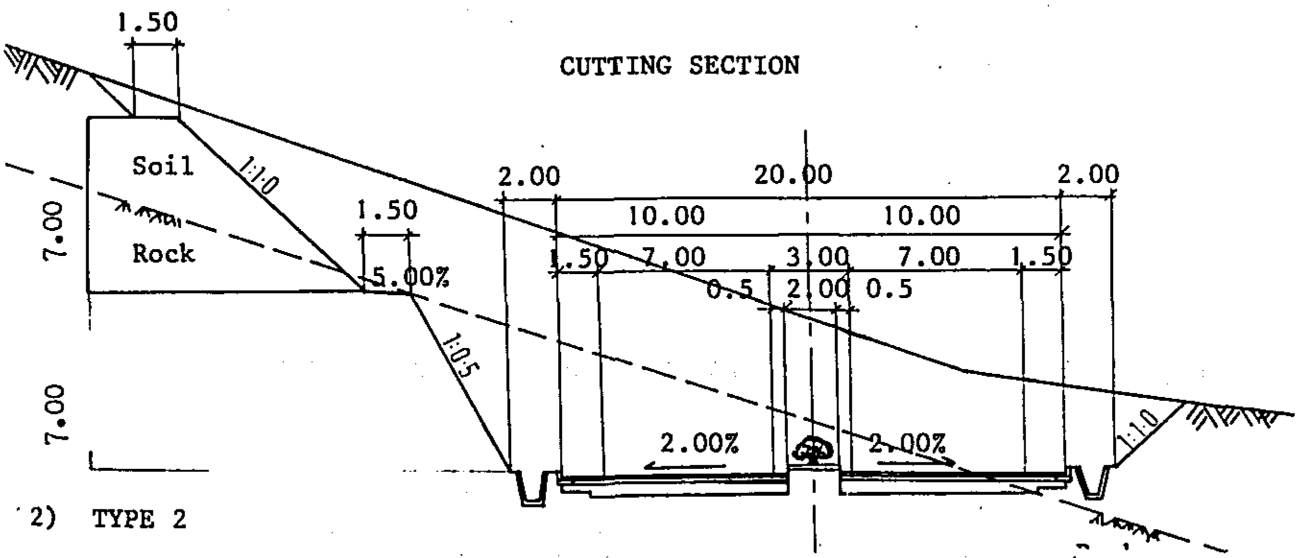
1) TYPE 1

RESIDENTIAL AREA WITHOUT SERVICE ROAD



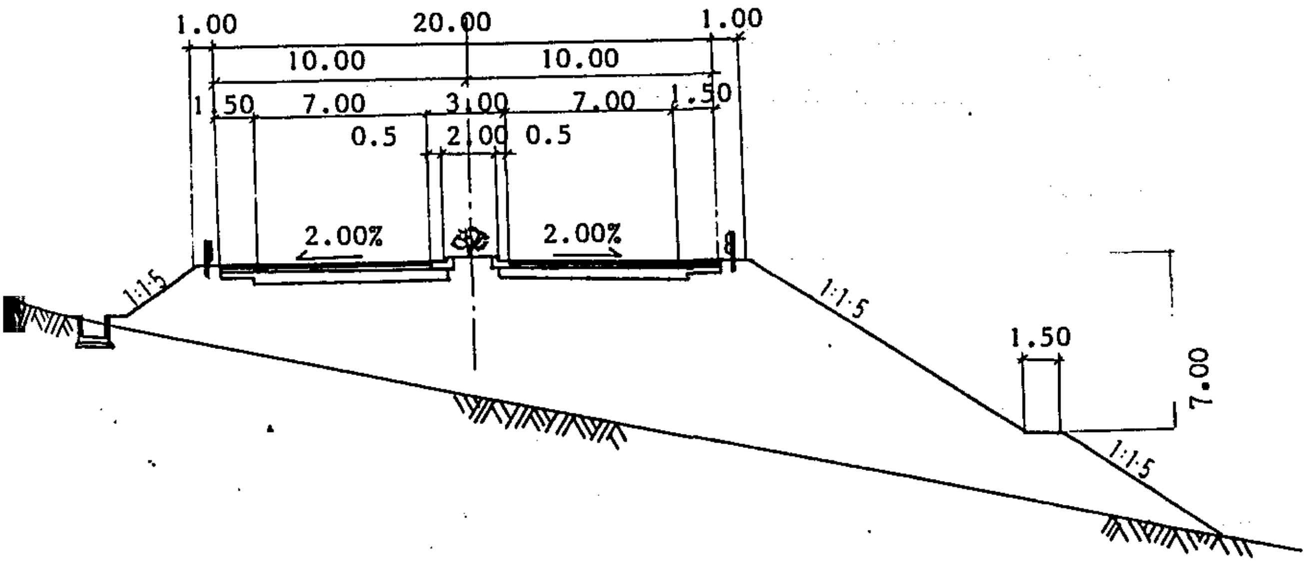
2) TYPE 2

CUTTING SECTION



2) TYPE 2

EMBANKMENT SECTION



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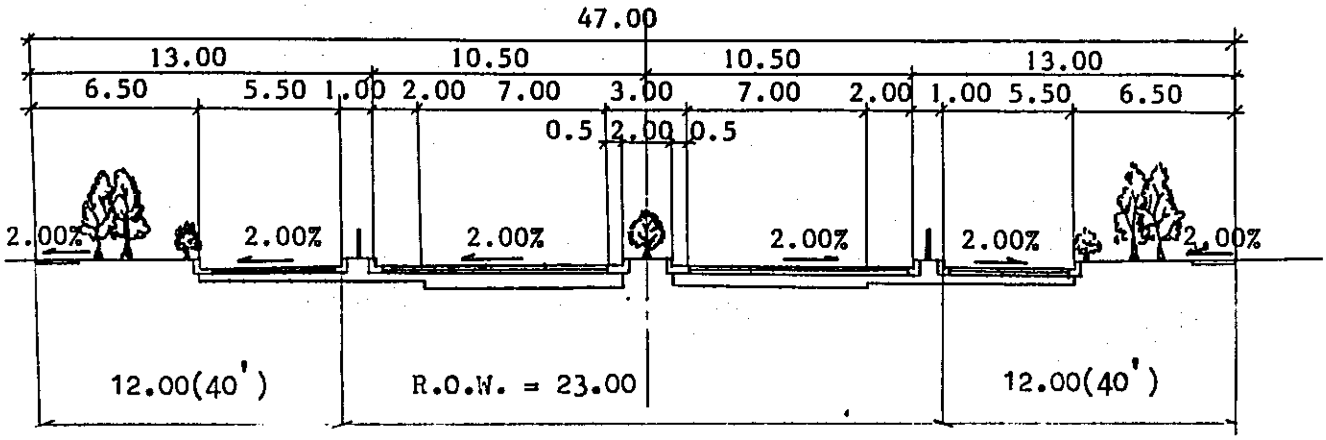
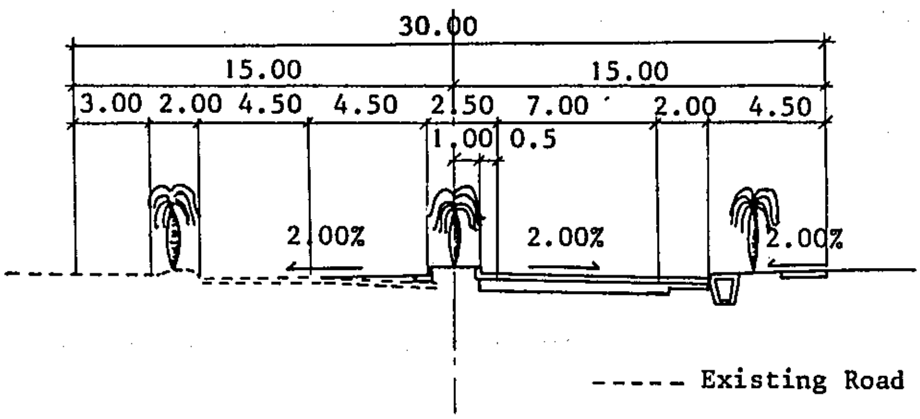
3) TYPE 3

RESIDENTIAL AREA WITH SERVICE ROAD



4) TYPE 4

IMPROVEMENT OF EXISTING JALAN GOTTLIEB & JALAN BAGAN JERMAL



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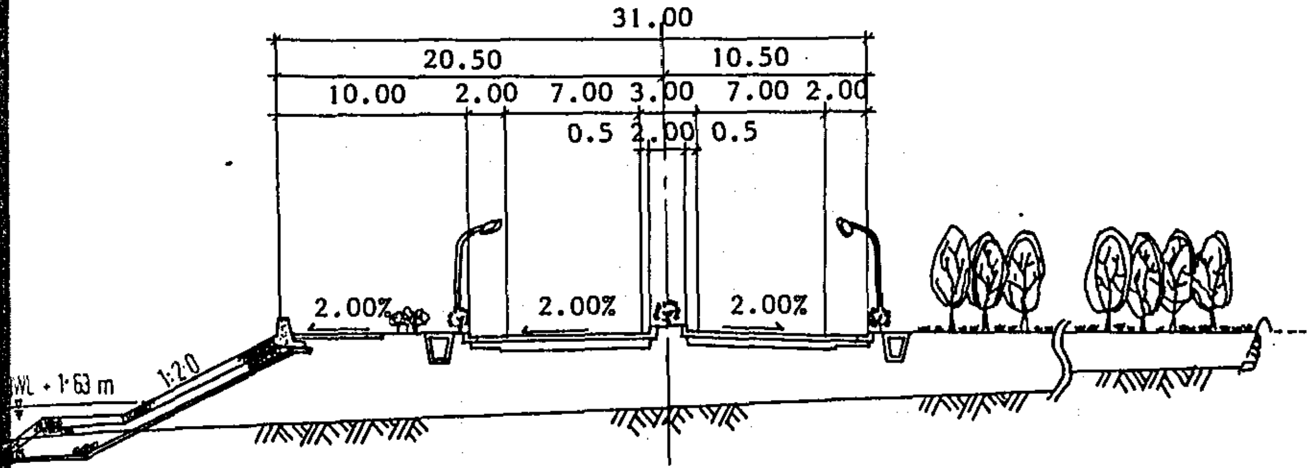
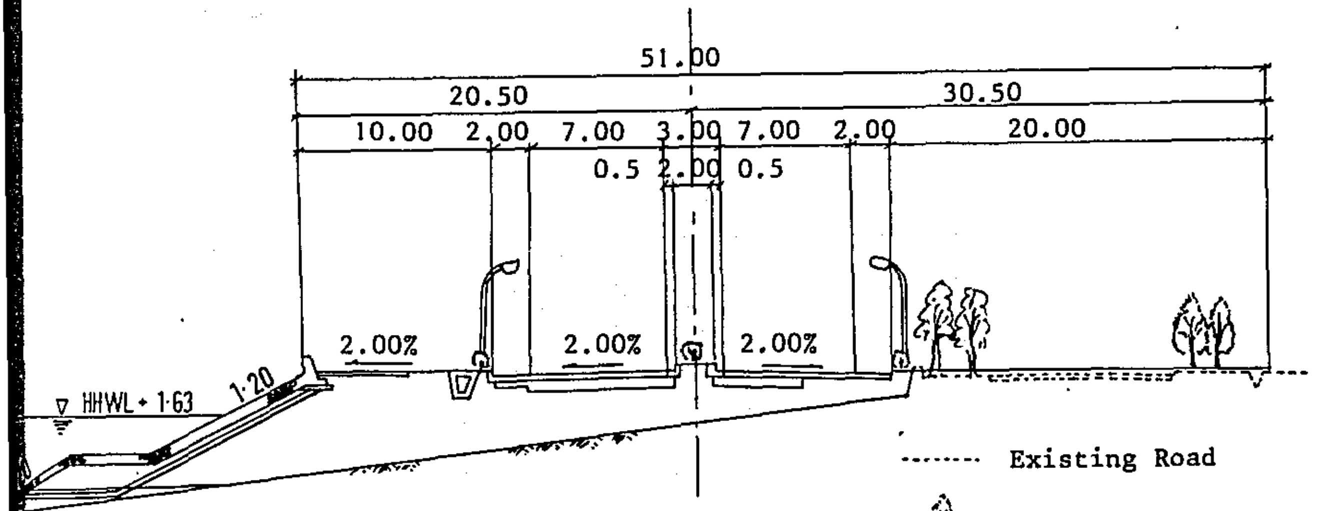
5) TYPE 5

GURNEY DRIVE EXTENSION





--------- Existing Road

Existing Tree

6) TYPE 6

IMPROVEMENT OF EXISTING WELD QUAY

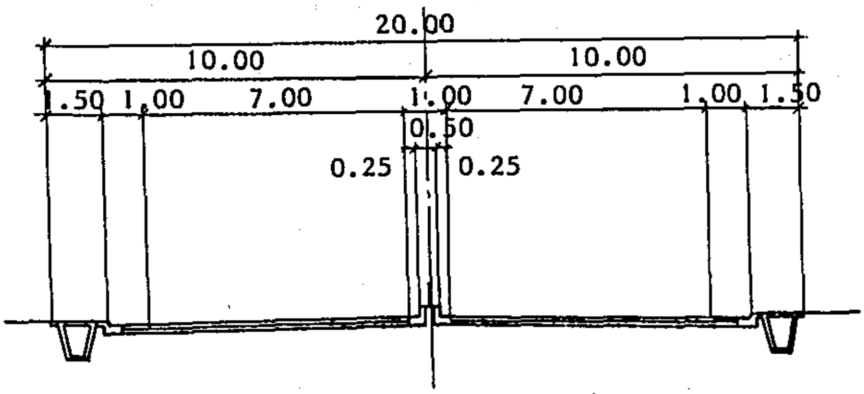
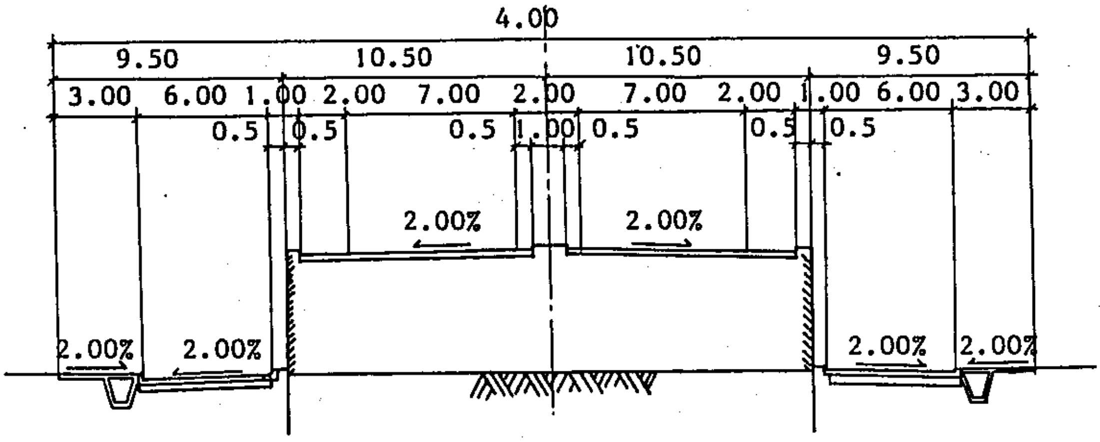


Fig. 3.3 BRIDGE CROSS-SECTION

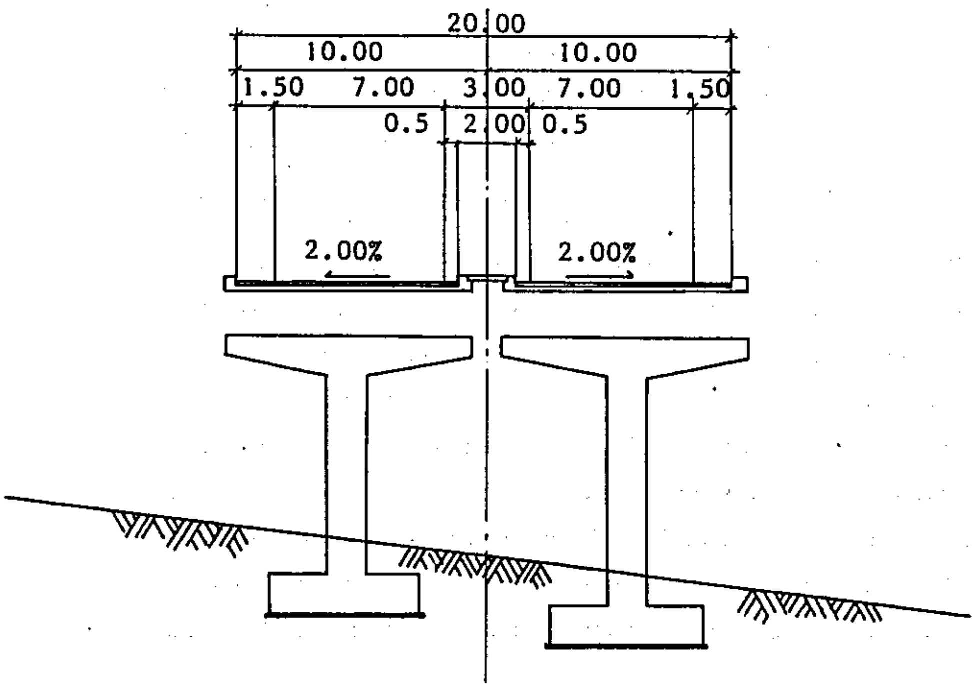
1) TYPE A

GRADE SEPARATION SECTION



2) TYPE B

BRIDGE SECTION



4. Drainage

4.1 General

The drainage of a road is a very important factor to be viewed as a basic problem of road construction. In some instances cutting and embarkment slopes of the road are washed off due to a poor drainage system and a poor drainage system in flat terrain sometimes causes water from heavy rains to flow onto the road. This results not only in a disuse of the road by traffic but also poses a problem to the inhabitants along the road.

The items to be examined in planning drainage systems are as follows:

*) To calculate run-off of each zone

*) To decide size of roadside drainage

*) To decide size of pipe-culvert, box culvert and bridge

*) To examine size of existing drainage that relates to the Outer Ring Road.

4.2 To calculate run-off

1) Basic data

The Malaysian Drainage standards referred from the URBAN DRAINAGE DESIGN STANDARDS AND PROCEDURES FOR PENINSULAR MALAYSIA is adopted as basic data.

2) Initial Drainage System

The initial drainage system is that part of the drainage system which caters for the maximum rate of run-off from the initial storm and includes: street gutters, roadside drainage channels and ditches, culverts, stormwater pipes, open channels, and any other feature designed to handle run-off from the initial storm. The initial storm may have a design return period of 2 or 5 years depending on the adjacent land use. All elements of the drainage system should be designed for at least the initial storm to ensure a minimum of future drainage complaints.

3) The Formula

The formula to be used to obtain the peak run-off estimation is as follow:

$$Q = \frac{1}{3.6} \times A \times C \times I$$

Where

Q is the peak discharge (m^3/sec)

A is the catchment area (Km^2)

C is the run-off coefficient

I is the storage coefficient (m/h)

4) Run-off Coefficient (C)

The run-off coefficient,C, is the variable of the Rational Method least susceptible to precise determination and understanding on the part of the engineer. The values adopted in design are to be based on the ultimate expected development of the land. Table 4.1 presents recommended values of run-off coefficients.

Table 4.1 RATIONAL METHOD RUN-OFF COEFFICIENTS FOR URBAN CENTRES

Land Use	Run-off Coefficient
Business:-	
City Areas Fully built-up and shophouses	0.90
Industrial:-	
Fully built-up	0.80
Residential:-	
4 houses/acre	0.55
4-8 houses/acre	0.65
8-12 houses/acre	0.75
12 houses/acre	0.85
Pavement	0.95
Parks (normally flat in urban areas)	0.30
Rubber	0.45
Jungle (normally steet in urban areas)	0.35
Mining Land	0.10
Bare Earth	0.75

5) Rainfall

For a given storm recurrence interval the rainfall intensity, I, is the average rate in inches per hour from a storm having a duration equal to the time of concentration, t_c. The appropriate value of i for the following towns can be determined from fig. 4.1.

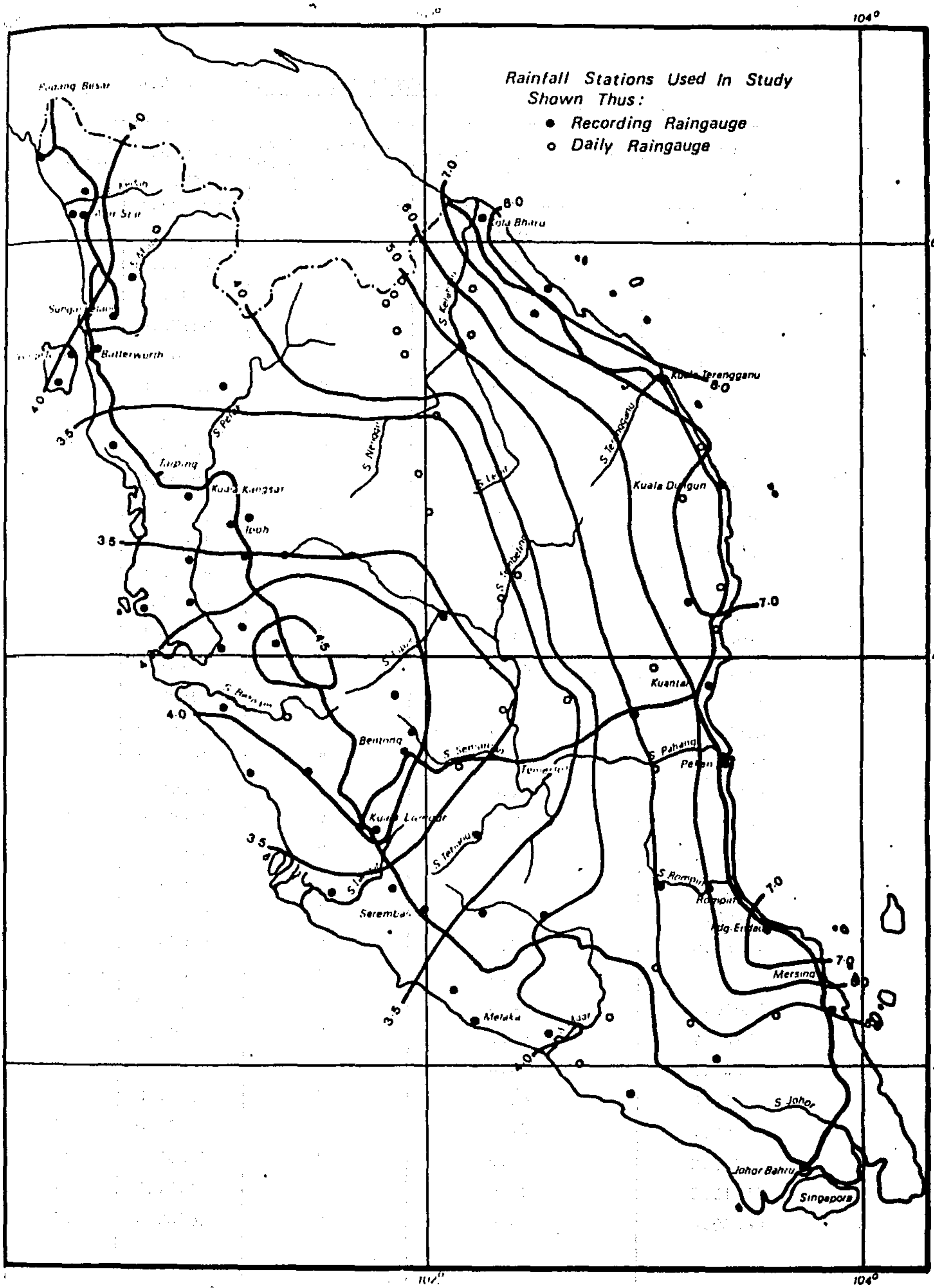


Fig. 4.1 ISOPLETHS OF 24 HOUR STORM RAINFALL FOR RETURN OF 2 YEARS - x(2.24)

Table 4.2 RESULT OF CALCULATION

Zone No.	Areas (A) (Km^2)	Coefficient of Run-off (C) (mm/h)	Storage coefficient (Z)	(Q) $Q = \frac{C.I.A}{3.6}$ (m^3/sec)
1	0.18722	100	0.85	4.42047
2	0.21707	"	0.75	4.52231
3	0.27880	"	0.75	5.80833
4	0.22188	"	0.75	4.6225
5	0.16065	"	0.75	3.34689
6	0.19101	"	0.45	2.38736
7	0.26438	"	0.45	3.30475
8	0.08424	"	0.75	1.755
9	0.14699	"	0.45	1.83739
10	0.42124	"	0.55	6.43561
11	0.27551	"	0.45	3.44389
12	0.26919	"	0.45	3.36489
13	0.22643	"	0.75	4.71730
14	0.09841	"	0.45	1.23013
15	0.12144	"	0.75	2.53
16	0.26767	"	0.45	3.34589
17	0.34458	"	0.75	7.17875
18	0.17355	"	0.75	3.61563
19	0.20366	"	0.75	4.24292
20	0.09917	"	0.75	2.06583
21	0.36432	"	0.35	3.542
22	0.27652	"	0.35	2.689
23	0.34914	"	0.35	3.39442
24	0.09082	"	0.35	0.88297
25	0.14623	"	0.35	1.422
26	0.16723	"	0.45	2.01039
27	0.20391	"	0.45	2.54989
28	0.29955	"	0.45	3.7444
29	0.14421	"	0.75	3.0043
30	0.3504	"	0.45	4.38
31	0.20467	"	0.45	2.558
32	0.1771	"	0.45	2.21375
33	0.24035	"	0.45	3.00439

(cont'd)

Zone No.	Areas (A) (Km^2)	Coefficient of Run-off (C) (mm/h)	Storage coefficient (Z)	(Q) $Q = \frac{C.I.A}{3.6}$ (m^3/sec)
34	0.07058	100	0.75	1.47042
35	0.05186	"	0.75	1.08042
36	0.09614	"	0.45	1.20175
37	0.14977	"	0.75	3.12022
38	0.19455	"	0.45	2.43188
39	0.49613	"	0.45	6.20164
40	0.32687	"	0.75	6.80981
41	0.39746	"	0.85	9.38447
42	0.46046	"	0.85	10.87197
43	0.07084	"	0.75	1.47583
44	0.20999	"	0.75	4.37481
45	0.42251	"	0.75	8.80231
46	0.19278	"	0.75	4.01625
47	0.23250	"	0.75	4.84375
48	0.15534	"	0.75	3.23625
49	0.53560	"	0.75	11.15833
50	0.13737	"	0.75	2.86188
51	0.0885	"	0.75	1.84375
52	0.11157	"	0.45	1.39463
53	0.07210	"	0.45	0.90125
54	0.06679	"	0.45	0.83489
55	0.19202	"	0.45	2.40025
56	0.12194	"	0.45	1.52425
57	0.18646	"	0.45	2.33075
58	0.36912	"	0.45	4.614
59	0.14876	"	0.75	3.09916
60	0.14927	"	0.45	1.86588
61	0.17254	"	0.75	3.59458
62	0.11916	"	0.45	1.4895
63	0.35673	"	0.55	5.4500
64	0.33648	"	0.45	4.206
65	0.19202	"	0.45	2.40025
66	0.11434	"	0.45	1.42925
67	0.16698	"	0.45	2.08725

(cont'd)

Zone No.	Areas (A) (Km^2)	Coefficient of Run-off(C) (mm/h)	Storage coefficient (Z)	(Q) $Q = \frac{C.I.A}{3.6}$ (m^3/sec)
68	0.132	100	0.45	1.65
69	0.24464	"	0.45	3.058
70	0.21226	"	0.45	2.65325
71	0.22516	"	0.45	2.8145
72	0.16266	"	0.45	2.03325
73	0.18418	"	0.45	2.30225
74	0.3514	"	0.75	7.32083
75	0.1265	"	0.75	2.63542
76	0.27324	"	0.75	5.6925
77	0.174	"	0.75	3.624
78	0.2058	"	0.75	4.2875
79	0.1662	"	0.75	3.4625
80	0.0942	"	0.75	1.9625
81	0.2340	"	0.75	4.875
82	0.1036	"	0.75	2.1583
83	0.173	"	0.75	3.60416
84	0.1548	"	0.75	3.225
85	0.2736	"	0.75	5.7
86	0.1826	"	0.75	3.80416

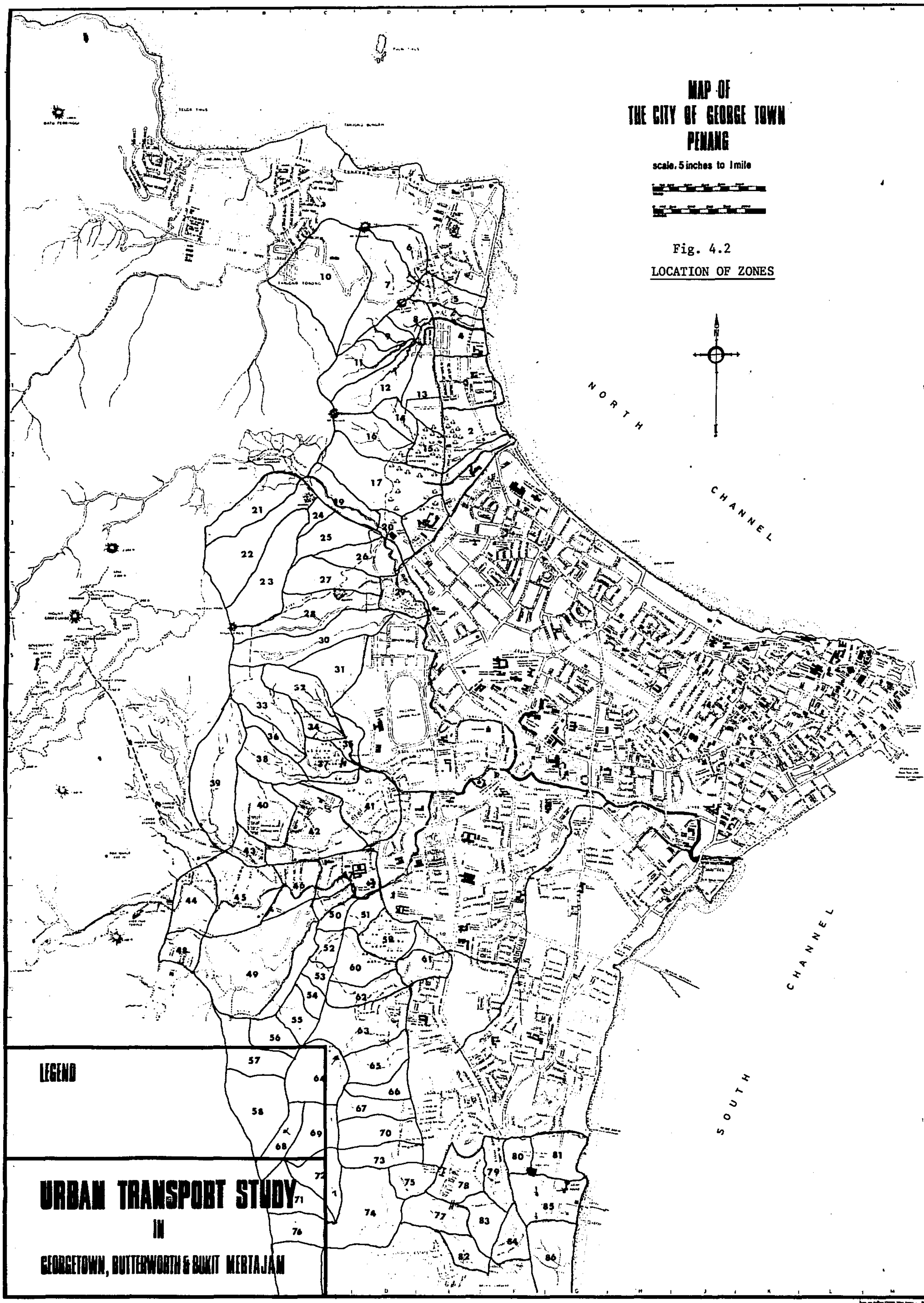


Fig. 4.2
LOCATION OF ZONES

4.3 Calculation of Run-off of Roadside Drain

1) The results of calculation

Along the Outer Ring Road, the comparison between run-off volume and capacity run-off volume along the Outer Ring Road has been carried out. The result is shown in Table 4.3 below.

Table 4.3 RESULTS OF CALCULATIONS

Station		Section	% Gradient	Discharge Volume (m3/sec)	Capacity of Discharge Volume (m3/sec)
No 8 + 0	STA No 0 + 0	0.5 x 1.0	4.1	1.43	2.1
No 0 + 0	No 6 + 0	0.5 x 1.0	2.5	1.07	1.7
No 6 + 0	No 9 + 0	0.5 x 1.0	2.0	1.07	1.6
No 9 + 0	No 16	1.0 x 1.0	6.0	7.79	8.0
No 16 + 0	No 28	1.0 x 1.0	3.0	1.9	1.9
No 28	No 37	1.0 x 1.0	4.0	0.9	2.0
No 37	No 42	1.0 x 1.0	5.0	1.15	2.5
No 42	No 50	1.0 x 1.0	1.34	0.81	1.4
No 50	No 80	0.5 x 1.0	-	-	-
No 80	No 88	0.5 x 1.0	6.00	2.44	2.8
No 96	No 104	1.0 x 1.0	6.00	2.5	2.8
No 106'	No 112'	1.0 x 1.0	6.00	2.25	2.8
No 116'	No 128'	1.0 x 1.0	1.09	1.19	1.2
No 128'	No 140'	1.0 x 1.0	2.14	1.12	1.6

2) Method of calculation

The capacity volume of run-off is calculated from fig. 4.3. This figure is drawn by using the following formula.

$$Qa = \frac{1}{m} \times R^{\frac{2}{3}} \times I^{\frac{1}{2}} \times A$$

Qa : The capacity volume of run-off (m^3/sec)

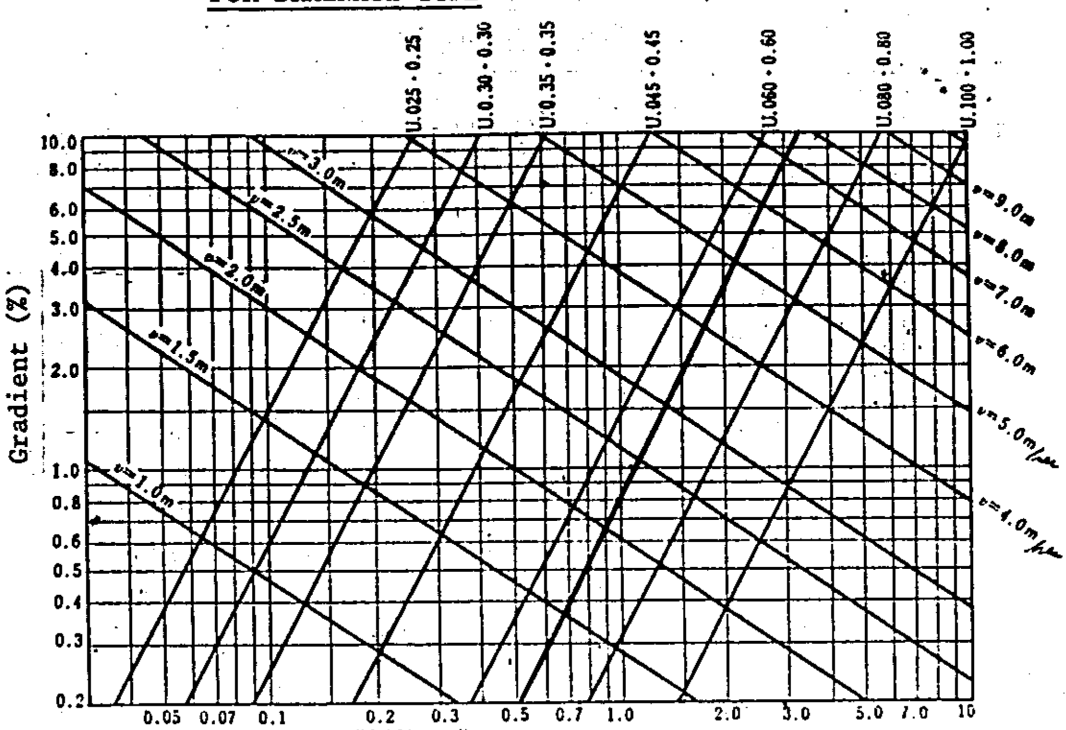
m : Coefficient of roughness

R : Hydraulic mean depth (m)

I : Gradient of drainage

A : Area (m^2)

Fig. 4.3 RELATIONSHIP BETWEEN GRADIENT AND RUN-OFF VOLUME FOR DRAINAGE TYPE



Run-off volume (m^3/sec) (m = 0.015)

4.4 Calculation of Run-off of Culvert Box

The capacity volume of the culvert box is also calculated by using the previous formula.

The premises of calculation.

1) m : Coefficient of roughness is 0.015

2) I : Gradient of culvert is 0.30%

The capacity volume of culvert box with cross-section 2.0 x 2.0 and 3.0 x 3.0 are 11.3m^3/sec and 32.9m^3/sec respectively. On the basis of the discharge volume, it is possible to use culvert boxes of cross-section 2.0 x 2.0, but when considering the soil, sand, branches and gravel that will face into the culvert boxes, it is more suitable to use culvert boxes with Cross-Section of 3.0 x 3.0.

Table 4.4 - COMPARISON OF DISCHARGE VOLUME AND CAPACITY DISCHARGE VOLUME

Station	Section (m3/sec)	Discharge Volume (m3/sec)	Capacity discharge Volume (m3/sec)
No 6 + 40.00	3.00 x 3.00	4.29	30.00
No 35 + 0.00	"	0.93	"
No 39 + 0.00	"	1.39	"
No 42 + 0.00	"	0.90	"
No 33 + 50.00	"	1.52	"
No 123' + 10.00	"	1.79	"
No 123' + 70.00	"	1.79	"
No 126' + 20.00	"	3.36	"
No 131' + 70.00	"	3.44	"
No 132' + 60.00	"	3.44	"
No 133' + 40.00	"	1.84	"
No 134' + 80.00	"	1.76	"

5. PAVEMENT DESIGN

5.1. Type of Pavement

There are basically two different types of pavement, asphalt concrete pavement and cement concrete pavement. The asphalt concrete pavement is adopted in the Outer Ring Road project. The reasons are as follows:

1) Lower construction cost

In Penang Island, there is a limited source of sand for use in cement concrete pavement. Moreover, the sand is expensive, so construction cost of cement concrete pavement will be higher than that of asphalt concrete pavement. For example, the construction cost of asphalt concrete pavement and cement concrete pavement are $28.8 per square meter and $33.4 per square meter respectively.

Table 5.1 COMPARISON OF CONSTRUCTION COST BETWEEN CEMENT CONCRETE PAVEMENT AND ASPHALT CONCRETE PAVEMENT

(per m^2)

	Cement Concrete Pavement			Asphalt Concrete Pavement		
	Quantity	Unit Cost	Cost	Quantity	Unit Cost	Cost
Surface Course	$0.2m^3$	141.3	28.3	$0.10m^3$	196.0	19.6
Base Course	$0.15m^3$	28.0	4.2	$0.25m^3$	20.0	5.0
Sub-Base Course	$0.20m^3$	4.7	0.9	$0.20m^3$	20.8	4.2
			33.4			28.8

2) Easy availability of material needed

The materials for base course and sub-base course of the asphalt concrete pavement can be obtained from the site of the Outer Ring Road, but fine aggregate such as sand for structure is not as easily available. The quantity of fine aggregate required for cement concrete pavement is more than that for asphalt concrete pavement. Therefore, the materials required for asphalt concrete pavement is more easily available.

Reinforced concrete is required for cement concrete pavement and there does not exist a large volume of such materials in Malaysia. Therefore, construction of the asphalt concrete pavement is easier than cement concrete pavement for the reasons mentioned.

3) Technical know-how

The asphalt concrete pavement type has been in use in Malaysia for a long time and therefore, the technical know-how required in its construction is easily obtainable.

4) Easy maintenance

In the urban area, it will be necessary to re-construct road services like water supply, drainage and other road facilities. When this is considered, asphalt concrete pavement stands superior to cement concrete pavement because such facilities are easier to construct on asphalt concrete pavement.

5.2. Design Criteria

1) Design standards

Design standards of asphalt concrete pavement is based on the "Manual For Design and Construction of Asphalt Pavement, 1980, (Japan Road Association)". "Asphalt Institute of U.S.A" and "Shell Pavement Design Manual" are also referred to.

5.3. Design Method

1) Classification of roads by traffic Volume

The one-way daily traffic volume of heavy vehicles in 5 years is first estimated to determine the pavement standard from among the five grades shown in Table 5.2."Heavy vehicles" refers to cargo trucks, buses and special vehicles such as truck cranes.

For roads with 3 or more traffic lanes, the design traffic load may be taken at about 80% of the estimated traffic volume when designing its pavement.

Table 5.2 ROAD CLASSIFICATION BY TRAFFIC VOLUME

Classification	One Way Daily Traffic of Heavy Vehicles
L	Less than 100
A	100 to 250
B	250 to 1,000
C	1,000 to 3,000
D	More than 3,000

Source: Manual for Design and Construction of Asphalt Pavement. (Japan)

2) Design of pavement thickness

Pavement thickness is designed based on the design CBR and the road classification given in Table 5.3 such that each individual course does not fall below the target value of T_A shown in Table 5.3 and that the total pavement thickness does not become smaller than the target total thickness in Table 5.3 by 1/5 or more.

Where the design CBR of the subgrade soil is 2 to 3, a filter course of 15 to 30 cm in thickness should be laid as part of the subgrade. Pavement thickness in this case is determined based on the design CBR of the subgrade soil, without taking the CBR of the filter course into account. Where soil varies in the subgrade depending on the depth, construction of a filter course is not required even if the design CBR falls below 3, provided that the CBR of the uppermost layer, 30cm or greater in thickness, is 3 or more.

Table 5.3 TARGET VALUES FOR T_A AND FOR THE TOTAL PAVEMENT THICKNESS, H, cm

Design CBR	Road Classification									
	L		A		B		C		D	
	T_A	H	T_A	H	T_A	H	T_A	H	T_A	H
2	17	52	21	61	29	74	39	90	51	105
3	15	41	19	48	26	58	35	70	45	83
4	14	35	18	41	24	49	32	59	41	70
6	12	27	16	32	21	38	28	47	37	55
8	11	23	14	27	19	32	26	39	34	46
12	-	-	13	21	17	26	23	31	30	36
20 or more	-	-	-	-	-	-	20	23	26	27

Source: Manual for Design and Construction of Asphalt Pavement (Japan)

T_A represents the pavement thickness which would be required if the entire depth of the pavement were to be constructed of hot asphalt mixused for binder and surface courses.

3) Pavement Structure

In determining the pavement structure, a tentative design is first made using a combined thickness of the binder and surface courses as taken from Table 5.4. obtained values of T_A and the total pavement thickness are then compared with the target values given in Table 5.3.When the value of T_A falls below the target, or when the total pavement thickness is found to fall below the target by 1/5 or more, the above process is repeated with an alternative design, until a final design which meets the targets is obtained. For the calculation of T_A, the following formula is applied.

$T_A = a_1T_1 + a_2T_2 + \dots\dots\dots + a_n T_n$

where a_1, a_2,........., a_n : Coefficients of relative strength given in Table 5.5

T_1, T_2,........., T_n : Thickness of individual layers of pavement, cm.

Cofficients of relative strength in Table 5.5 indicate in cm the thickness of hot asphalt mix used in constructing binder and surface courses, having a strength equivalent to 1 layer of pavement of 1 cm thickness of other materials and methods of construction.

For example, the coefficient being 0.35 for a mechanically stabilized material indicates that the strength of a 1 cm layer of such material is equivalent to that of a 0.35 cm layer of hot asphalt mixused in binder and surface courses. It therefore follows that a 20 cm layer of such mechanically stabilized material is equivalent to a 7 cm layer of hot-mixed concrete used in construction of binder and surface courses.

The minimum desirable thickness of cement stabilized soil for the base course is 15 cm for roads of L,A and B traffic, and 20 cm for roads of D traffic. For roads of L,A and B traffic, values of unconfined compressive strength and the coefficient smaller than those given in Table 5.5 are sometimes adopted based on engineering experience.

Table 5.4 MINIMUM COMBINED THICKNESS OF BINDER AND SURFACE COURSES

Road Classification	Minimum Combined Thickness of Binder and Surface Courses
L,A	5
B	10 (5)
C	15 (10)
D	20 (15)

Note: Figures in ( ) indicate the minimum thickness applicable to pavements with bitumen stabilized bases.

Source : Manual for Design and Construction of Asphalt Pavement (Japan)

Table 5.5 COEFFICIENTS OF RELATIVE STRENGTH FOR CALCULATING T_A

Pavement Course	Method and Construction Materials used	Conditions	Coefficient
Binder and Surface Courses	Hot asphalt mix for binder and surface courses		1.00
Base	Bituminous Stabilization	- Hot-mixed, Marshall stability: 350kg or more	0.80
		- Cold-mixed, Marshall stability: 250kg or more	0.55
	Cement Stabilization	- Unconfined compressive strength (7days): $30kg/m^2$	0.55
	Lime Stabilization	- Unconfined compressive strength (10days): $10kg/cm^2$	0.45
	Mechanically Stabilized Gravel and Slag	- Modified CBR:80 or more	0.35
	Hydraulic Mechanically Stabilized Slag	- Modified CBR:80 or more	0.55
	Penetration Macadam	- Unconfined compressive strength:(14 days): $12kg/cm^2$	0.55
Sub-base	Crusher-run, Slag,	- Modified CBR:30 or more,	0.25
	Sand, etc.	- Modified CBR:20 or more, less than 30	0.20
	Cement Stabilization	- Unconfined compressive Strength, (7days): $10kg/cm^2$	0.25
	Lime Stabilization	- Unconfined compressive Strength (10 days): $7kg/cm^2$	0.25

Note: Layer coefficient for any construction method or material other than those listed in Table 5.5 should only be adopted when based on established engineering experience.

Source: Manual of Design and Construction of Asphalt Pavement (Japan)

5.4. Design of Pavement

1) Premises for design .

a. On the basis of soil investigation, the C.B.R value of sub-grade is about 5% - 6%.

b. On the basis of traffic counting survey, the percentage of trucks and buses is less than 5.0%.

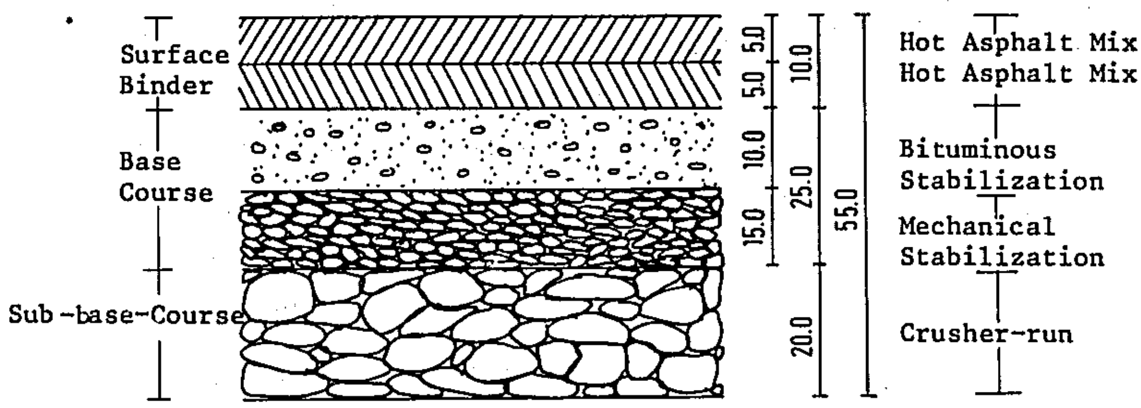
c. The average daily traffic volume is adopted to be 53,000/day; this volume is expected to pass between Jalan Ayer Itam and Waterfall Road in the year 2000. .

d. The lifetime adopted for asphalt concrete pavement is 20 years.

2) Calculation of thickness of individual courses

a. Material of individual course

Fig. 5.1 CROSS-SECTION OF PAVEMENT



3) Examination of thickness

a. The thickness of each course is shown in Fig. 5.2

Fig. 5.2 THE THICKNESS OF EACH COURSE

Surface	(1.0)	5.0	55.0
Binder	(1.0)	5.0	
Bitumen Stabilized Course	(0.8)	10.0	
Mechanically Stabilized Course	(0.35)	15.0	
Crusher run	(0.25)	20.0	

Note: ( ) is coefficients of relative strength for calculation. Refer to Table 5.5

b. Road classification by volume of traffic

The average daily traffic volume is adopted to be 53,300/day. The percentage of heavy traffic is adopted to be 5 %. So, one way daily volume of heavy traffic is 1325V/D (53,000 x 0.5 x 0.05) therefore, from Table 5.3, "Classification C" is relevant.

c. Thickness of T_A and H

The C.B.R of sub-grade is 60%. Therefore, from Table 5.3, the thickness of T_A and H have to be 28cm and 47cm respectively. So, from Fig. 5.2.

$$T_A = 5.0 \times 1.0 + 5.0 \times 1.0 + 10.0 \times 0.8 + 15.0 \times 0.35 + 20.0 \times 0.25 = 28.25\text{cm} \quad \text{\_\_\_\_\_\_\_\_(1)}$$

$$H = 55.0 \text{ cm} \quad \text{\_\_\_\_\_\_\_\_(2)}$$

The figures in (1) and (2) above is higher than the figures in Table 5.3. Therefore, the Cross-Section mentioned above maintains enough thickness for through traffic on the road.

6. DESIGN OF SLOPES

6.1 Soil Condition

6.1.1 Subsurface Ground Conditions along the Outer Ring Road

a. From Station -5 to Station 6

Subsurface ground in the area may consist mainly of a clayey layer derived from weathered granite.

b. From Station 6 to Station 12

Subsurface ground in the area consists of a sandy layer (mainly Clayey Sand) and a clayey layer (Sandy Clay). N value-blow counts by Standard Penetration Test for sandy layer varies from 6 to 23 and N value for clayey layer is in the range of 16 to 20 (very stiff).

c. From Station 12 to Station 31

Subsurface ground in the area may consist of intact granite and residual sandy soil of granite with a thickness of 0.3m to 15m. The weathered depth may be thicker around Station 24 to Station 27 than in the other areas; the depth may reach a maximum of 15m from ground level.

Debris consists mainly of boulders with a diameter of 1m to 5m at Station 20 to Station 22. Boulders with a diameter of 5m to 10m can be seen in the debris at Station 27 to Station 30.

Diameters of boulders along the area are generally 2m to 20m and approximately 150 of these boulders may be required to be removed or blasted to make them stable at construction time. The average size of the boulders are 4m in diameter. Joints of granite in the area do not have the same direction of strikes, however, the main strikes are north-south with main dips of 80° to 83° SE.

d. From Station 31 to Station 52

Ground in this area may consist mainly of intact granite and residual clayey soil of granite. At BH-7, residual soil is encountered from ground level to 10m below ground surface and the N-value of the soil varies from 3 to 17. Two boulders were found at the depths of 11m and 17m and their vertical thickness were 1.55m and 1.20m respectively. Intact granite was found at a depth of approximately 20m and the rock core length obtained by diamond bid was 15mm to 40mm which is short. The joints of granite around Station 34 strikes N 35° E and dips 50° SE. The number of boulders that have to be treated to make them stable at construction time is approximately 100 in the area, and the average size of the boulders is approximately 3m.

e. From Station 52 to Station 72

The ground may be composed of sandy and clayey layers and residual clayey layer of granite. Generally, the ground will be well consolidated. No significant problems of earthwork for embankment is expected.

f. From Station 72 to Station 102

The ground may consist mainly of intact granite and residual sandy layer. The thickness of residual sandy layer may be 5m to 10m at Station 72 to Station 78. The thickness of residual sandy layer at Station 78 to Station 88 will be 3m to 7m and the thickness at Station 88 to Station 96 may be 0.5m to 3.0m which is comparatively thinner.

N-value (SPT) of the sandy layer varies from 14 to more than 50.

The rock cores obtained by diamond bid at BH-5 and BH-6 are generally 200mm to 1000mm long and the rocks are in firm contact with each other. The rock at a depth of around 15.3m at BH-5 has many joints and the core length was 20mm to 50mm which is short. However, no clay was observed at the joints at any depth at the bore-holes of BH-5 and BH-6.

The joints of intact rock in the area have irregular strikes and dips. Boulders of size 2m to 20m can be observed and the number of boulders to be removed or blasted to avoid them falling at construction time are in the range of 100 to 120 and the average size is 5m in diameter in the area. Outcrops of intact granite were seen at previous quarry sites along the alignment at Station 88 to Station 95, and the outcrops are cut with the vertical height of 10m to 25m. The interval of joints of outcrops are generally 0.3m to 1.5m and the rocks are in firm contact with each other at the joints.

6.1.2 Depth of Subsurface Soil in each Station

Depth of subsurface soil in each station is shown in Table 6.2 and granite is found below the subsurface soil.

6.1.3 Rock Condition

The rock that is directly located below the subsurface is granite. Granite bodies are extensively distributed throughout the country and commonly form topographic heights. The basic formation of Penang Island is a single mass of granite isolated from the Peninsular. The granite of Penang Island seems to be intruded during the Jurrassic period, radiometrically between 165 million to 208 million years ago. The granite mass has been highly weathered by the tropical climate in this region, the surface portion of which has changed into residual soil. The depth of weathered granite is great and a thickness in excess of 10m is not uncommon. In areas of massive granite, weathering has produced rounded core boulders of granite which are "floating" in a thick layer of residual soil derived from heavily weathered granite. In drilling at field investigation, such core boulders pose a further difficulty in ascertaining whether drilling has reached the bedrock or has only reached the core boulder.

6.1.4 Embankment Materials

In the project site of the Outer Ring Road the material for embankment is easily obtainable. Therefore this material will be used for the embankment fill. This material is a mixture of clayey layer, sandy layer, residual clayey layer and of the above-mentioned rock material.

Table 6.1 SUMMARY OF SUBSURFACE GROUND CONDITIONS

Area	Layer	Standard Penetration Test SPT	Specific Gravity Gs	Natural Water Content wn	Atterberg Limits: Liquid Limit	Atterberg Limits: Plastic Limit	Atterberg Limits: Plasticity Index	Grading Analysis: Gravel G	Grading Analysis: Sand S	Grading Analysis: Silt M	Grading Analysis: Clay C	Unit Weight γ_t	Cohesion & Angle of Internal Friction* c	ϕ	Consolidation Properties: Cc	Consolidation Properties: Cv	Consolidation Properties: mv	Consolidation Properties: k
Hilly Area	Clayey Layer	16-20	2.616 - 2.620	19-25 %	60%	37%	23	7-21 %	31-47 %	7-26 %	25-26 %	$1.82 t/m^3$	$5.25 t/m^2$	-	0.30	$2 \times 10^{-1} cm^2/min$	$5 \times 10^{-2} cm^2/kg$	$2.3 \times 10^{-5} cm/min$
	Sandy Layer	6-23	2.588 - 2.605	19-20%	41-87	20-24	22-(58)	1-9	45-69	5-15	20-31	2.00	4.85 2.2	85°	0.21	3×10^{-1}	2.4×10^{-2}	7.1×10^{-6}
	Residual Clayey Layer	3-17	2.588 - 2.032	14-27	58-64	22-36	28-37	3-30	28-49	3-22	22-41	2.00	4.25 3.6	10	0.14	4.2×10^{-1}	1.6×10^{-2}	6.4×10^{-6}
	Residual Sandy Layer	14->50	2.579	23	63	31	32	8	43	12	37	2.00	-	-	-	-	-	-
Offshore and Gurney Drive Area	Upper Clayey Layer, Cu	4-8	2.568 - 2.671	76-110	89-129	31-52	58-88	0-1	1-4	3-31	68-92	1.57	(0.27) 1 1.9 2.9	0	0.81 - 1.75	$1.25 \times 10^{-2} - 2 \times 10^{-1}$	$2.1 \times 10^{-2} - 1.7 \times 10^{-1}$	$(2-6) \times 10^{-6}$
	Middle Clayey Layer, Cm	9-28	2.584 - 2.664	22-78	42-130	23-51	20-88	0-9	2-42 -(53)	6-39	28-92	1.56	3.2 1 4.5	0	1.29 -1.35	$1.6 \times 10^{-2} - 1.1 \times 10^{0}$	$(1.1-7.3) \times 10^{-2}$	$1.2 \times 10^{-6} - 1.2 \times 10^{-5}$
	Lower Clayey Layer, Cl	30-38	2.642	48	74	23	51	0	12	30	58	1.60	-	-	-	-	-	-
	Upper Sandy Layer, Su	5-20	2.567 - 2.641	10-41 -(64)	33-51 -(83)	14-24 -(30)	19-30 -(57)	3-35	23-84	2-31	21-60	1.94	1.0 1 1.8 1.5	24	0.08 -0.16 -(0.41)	$8.3 \times 10^{-2} - 1.9 \times 10^{-1}$	$(2.6-3.0) \times 10^{-2}$	$(2.7-5) \times 10^{-6}$
	Lower Sandy Layer, Sl	13->50	2.593 - 2.614	15-20	-	-	-	3-16	29-80	8-10 -(36)	19-36	2.00	-	-	-	-	-	-
	Residual Clayey Layer	31->50	2.622	30	55	34	21	2	40	31	27	2.00	-	-	-	-	-	-

(Notes) Cc : Compression Index Mv : Coef. of Volume Compressibility ( ) : Abnormal Value * : Triaxial Comp. Test (U-U)

Cv : Coef. of Consolidation k : Coef. of Permeability —— : Assumed Value

Cv, mv and k are given at a pressure of $10 t/m^2$

Table 6.2 DEPTH OF SUBSURFACE SOIL

Station	Type of soil	Depth of soil (m)	Remarks
No 0 - No 11	R.C.L	10.00	
11 - 18	R.S.L	5.00	
18 - 24	D.E	3.00	
24 - 28	R.S.L	10.00	
28 - 31	D.E	3.00	
31 - 32	R.C.L	3.00	
32 - 33	-	-	
33 - 55	R.C.L	7.50	
55 - 80	-	-	
80 - 92	R.S.L	5.00	
92 - 100	R.S.L	1.50	
100 - 105	R.S.L	1.00	
-			
No100' - No 110'	R.S.L	2.00	
110' - 115'	R.S.L	8.00	
115' - 120'	S.L	6.00	
120' - 122'	R.S.L	6.00	
122' - 126'	R.S.L	20.00	
126' - 136'	R.S.L	10.00	

R.C.L : Residual Clayey Layer

R.S.L : Residual Sandy Layer

D.E : Talus

S.L : Sandy Layer

6.2 Cutting Slope

6.2.1 General

In the case of determining location of cutting slopes, the following items will be taken into account.

(1) Direction of soil or rock strata, joints and cracks and their frequency and range.

(2) Presence of ground water, level of water-table and degree of seepage.

(3) Direction and range of faults, fractured zones, boundary of rock or soil strata and range of talus corns.

The standard safe slopes for various types of subsoil or rock is shown in Table 6.3. The values in this table are the results from the long experience of road work in Japan.

6.2.2 Gradient of Cutting Slope

1) Part of Soil Material

The soil condition was described earlier in the section. It can be classified into sandy soil and dense sandy soil and is shown in Table 6.1. According to this table, the gradient of cutting slope is described as 1:0.8 to 1:1.0 (Horizontal distance per vertical distance). Taking safety into account, 1:1.0 is adopted as the gradient of cutting slope.

2) Part of Rock Material

The type of rock found in the construction site is granite. This rock is very solid therefore it will be possible to cut a slope of gradient 90^{o} after consideration is given to running comfort, environmental aspect, construction method and so on.

Taking the above into account, 1:0.5 is adopted as the gradient of slope.

3) Berms

1. Height of Berms

Generally, berms are established with long cutting slopes. This is because, long cutting slopes keep them safe from destruction caused by erosion through rainfall, ground water, etc.

The height of berms is decided by the soil condition and gradient of cutting slope. In the previous section, the gradient of cutting slope was decided to be 1:1.0. According to table 6.4, the depth of cutting ranges from 5 meter to 10 meter. Therefore 7.0 meter is adopted as the height of berm. Usually no destruction of slope takes place in areas of rock so berms need not be established here.

2. Width of Berm

The main purpose of the berm is to keep the cutting slope safe from destruction. The berm will be able to reduce the force of the water on the slope. Ordinarily, the width of the berm is 1.5 meter. Therefore in the Outer Ring Road project 1.5 meter is adopted as the width of the berm and the cutting slope is of two different types, i.e, soil and rock. So berms should be established between soil and rock.

6.3 Embankment Slope

6.3.1 General

Strictly speaking, when the gradient of the embankment slope is decided, the circular slip calculation should be carried out but in this case the gradient of slope has been taken from a guideline of the gradient of embankment slope which had been formed through a long experience of road work in Japan. In this study the above-mentioned guideline is adopted and shown in table 6.3.

6.3.2 Gradient of Embankment Slope

The gradient of embankment slope should take into account material of embankment, condition of existing ground and soil, and so on. The material of embankment will be obtained from the cutting site along the Outer Ring Road and these materials consist of sandy layer, gravel and crushed stone.

These materials can be classified into sandy soils, hard cohesive soil or hard clay in Table 6.1. According to this table, 1:1.5 is adopted as the gradient of embankment slope (Vertical distance per horizontal distance).

Table 6.3 STANDARD SAFE SLOPE FOR EMBANKMENT SLOPES

Fill material	Allowable height of embankment (m)	Recommended gradient of fill slopes
Good-grade sand or Gravel or gravelly sand	0 - 6	1 : 1.5 - 1 : 1.8
	6 - 15	1 : 1.8 - 1 : 2.0
Poor-grade sand	0 - 10	1 : 1.8 - 1 : 2.0
Rocks or cobbles	0 - 10	1 : 1.5 - 1 : 1.8
	10 - 20	1 : 1.8 - 1 : 2.0
Sandy soil, hard cohesive soil,, or hard clay	0 - 6	1 : 1.5 - 1 : 1.8
	6 - 10	1 : 1.8 - 1 : 2.0
Soft cohesive soil	0 - 6	1 : 1.8 - 1 : 2.0

6.3.3 Berm of Embankment Slope

In the berm of a high embankment slope, greater safety can be achieved by having a slope with a footpath.

1. Height of Berm.

The height of berm in embankment slope differs from the embankment material. According to the above-mentioned Table 6.3, the height of berm was described as about 6.0 meter, but taking into account the embankment material, the height should be increased by one more meter. So the height of berm will be 7.00 meter.

6.3.4 Width of Berm

The width of berm should consider the space for maintenance of the slope. From the viewpoint of the above-mentioned, 1.5 is also adopted as the width of berm.

6.4 Slope Protection

6.4.1 General

The slope is covered by vegetation or by some structure to protect it from erosion or weathering of the soil and rock and it ensures the safety of the slope.

Generally speaking, there are two types of slope protection; the slope protection with vegetation and the slope protection with artificial material. To make protection of slopes stable and durable it is essential to select appropriate types of slope protection suitable to the conditions of individual slopes such as type of surface soil, hardness of soil, weather condition at the site, condition of water seepage and so on.

Especially when and plenty of water seepage is found on the slope surface, a sufficient drainage system should be provided even on the slope surface.

Where slopes consist of weathered rocks with the frequent cracks, it is recommended to spray a mixture of seeds and soils over the layer of soil-and-fertilizer mixture which is sprayed in advance.

Where the surface soils of slope are stiff clayey soils, ditches or holes are excavated on the surface and filled with soil and fertilizer in advance of spraying the mixture over the surface to help roots of grass penetrate deeply. The ditches are excavated horizontal-wise at intervals of about 50cm, and their depth and width are about 15cm. and 20cm., respectively. Depth and diameter of holes are about 15cm. and 10cm., respectively, and about 18 holes are drilled in 1 sq.m.

(2) Turfing:

There are also two ways of turfing. They are, all-over turfing and strip turfing.

The former is to cover the whole slope surface with patches of grass. Since effects of slope protection are expected immediately after the turfing, this method is applicable to slopes that are easily eroded although this is a labour-intensive method.

Rectangular patches of grass are laid horizontally on their longer sides and their vertical sides (joints) are staggered at adjacent rows. Each patch of grass should be fixed to the ground with two bamboo sticks with a hook on its head or with pieces of U-shaped wire of about 30 cm. in length.

The slope surface should be shaped smooth and should preferably be fertilized before turfing. Spreading topsoil over the turf where the slope is flat will effectively prevent the grass from drying up.

The latter method is usually used to fill slopes. A row of grass-patches is put beside a stretch of soil-covered slope which is about 30cm, wide. This method is especially useful where covering soils are necessary because the fill materials are very coarse. Fertilization is required if the covering soil is sterile.

If the slope is sometimes submerged under water, precast concrete-block or stone pitching are preferable.

The same types as above are applied to the fill slopes under bridges or viaducts where sunlight and rain are blocked out. Where it is necessary to adopt steeper slopes than usual for an embankment in order to preserve the width of right of way, stone or precast concrete-block pitching are applied on the slopes less steep than 1:1.0. For slopes steeper than 1:1.0, it is necessary to design retaining walls or other like structures.

(2) When surfaces of cut slopes are of non-cohesive soils or talus corn (in such cases the surfaces are easily eroded), block or stone masonry walls are applied with sufficient number of drain pipes. If, however, any amount of water seepage is found on the cut slopes, it is desirable to apply cast-in-place or precast concrete frames.

(3) When cut slopes consist of weathered rocks or rocks likely to be weathered quickly after cutting, mortar or concrete spraying is applied if there is no possibility of water seepage on the slopes. If water seepage is anticipated, it is preferable to apply stone or precast concrete-block pitching, cast-in-place concrete slabs, or precast concrete frames.

(4) Although it is not always impossible to cover cut slopes of stiff clay or hardpan with vegetation, stone or precast concrete-block pitchings are usually applied to such slopes.

(5) Cut slopes with water seepage should be covered with permeable protection besides setting up a sufficient slope drainage system. Usually, precast concrete-block frames are used where water seepage is anticipated and the inside of each frame is filled with cobbles. Sometimes, heavier cast-in-place concrete frames should be tightly fixed to the slope with anchors where falling rocks are anticipated.

(6) Cut slopes of gravelly soils or of weathered rocks are sometimes covered with nets made from synthetic fiber or steel wire together with seed-sprayed protection to prevent gravels or small rocks on the slope surface from falling down. When it is anticipated that large rocks will fall from cut slopes or when deep joints develope over a wide area, the surface should be covered with concrete slabs.

2. Type of Artificial Protection

This type of slope protection is applicable to slopes where protection with vegetation is neither applicable nor suitable to maintain the stability of the slopes.

Such slopes are as follows:

(a) Fill slopes under bridges or viaducts.
(b) Slopes of gravelly or sandy soils.
(c) Slopes of weathered rocks or rocks likely to be quickly weathered.
(d) Slopes of rocks with many fissures.
(e) Slopes of very stiff clays or hardpans.

To prevent erosion, weathering, and collapse of these slopes as well as to intercept falling rocks from these slopes, slopes are protected with stones, cement mortar, concrete, bamboo, metal, plastics or a combination of these materials.

Types of slope protection methods are as follows:

1) Stone or precast concrete block pitching
2) Concrete slab
3) Precast concrete-block frame
4) Cast-in-place concrete frame
5) Mortar or concrete spraying
6) Bamboo fencing
7) Rock netting
8) Rock fence
9) Stone or precast concrete-block masonry.

Many types of protection have been developed to meet the great variety of characteristics of slope surfaces. In general, types of protection are selected by considering the slope and site conditions described as follows:

(1) Where shallow surface slips are anticipated to occur on such fill slopes as around the toe of a high embankment filled with non-cohesive soils, it is preferable to apply precast concrete-block frames or bamboo fences besides vegetation.

6.4.2 Necessity of Slope Protection

Part of the Outer Ring Road is located in mountain area and part of it is in urban area. The road in urban area is planned to be an at-grade road where the proposed height of the road is the same level with the existing ground. Therefore the slope protection should not be considered in the residential area.

The road has many cutting and embankment slopes and has been maintaining the greenery. The Outer Ring Road can be viewed from existing urban area. It is required to ensure the good environmental condition of the good road. Therefore, the slope protection of the road in the mountain area will be required from the environmental as well as the safety aspect.

6.4.3 Type of Slope Protection

1. Type of Vegetation

There are two methods of planting. They are, to plant patches of grass(sods) on slope surfaces and to plant grass seeds over slope surfaces. The former is usually called "turfing" and the latter "seeding". Although the seeding method is seldom applied in this country, some of them are time-saving and an efficient method to cover a wide area of slope surfaces, especially of cut slopes.

(1) Seed-spraying method

There are two methods in this category. The first one is to spray a mixture of seeds, fertilizer, soils and water on to the slope surface with a spray gun which is connected to an air compressor. After spraying the mixture, asphalt emulsion is sprayed over this layer of the mixture to protect it from being washed away by water. This method is effectively applied to long cut slopes of sandy or cohesive soils, or even of weathered sandstones and mudstones.

Another method is to spray a mixture of seeds, fertilizer, and fibers which are dispersed together in water with a pump. This method can be applied to rather flat and low slopes.

6.4.4 Type of Slope Protection Adopted

1. Slope with Soil Material

In the protection of slope with soil material the seed spraying type and turfing type such as mentioned in the previous section will be considered. The turfing type is recommended in this project.

The reasons for this recommendation are as follows:

1) In this country, turfing has been carried out in many places. Therefore it will be easy to use this method.

2) The materials for seed spraying have to be imported from other countries, whereas the materials of turfing are easily obtained locally.

2. Slope with Rock Material

Many types of slope protection for slopes with rock material have been developed such as described in the previous section.

The mortar or concrete spraying type is recommended. The reasons for this recommendation are as follows:

1) The rock material of the slope is granite such as mentioned above. Usually, such material may not need protection, but weathering of the rock should be taken into account. The mortar or concrete spraying method is better than any other method.

2) The environmental aspect of the road must be considered before deciding on whether rock netting or rock fence is better for the road. The mortar or concrete spraying method is described below. This type of protection is applied to cut slopes of weathered soil on loose rocks or rocks likely to weathered after cutting, but where no water seepage is anticipated.

The thickness of mortar cover is 5 to 10cm. and that of concrete cover is 10 to 20cm. Mortar or concrete together with compressed air is sprayed over the slope surface with a spray gun. Steel-wire nets are laid and fixed over the slope surface with steel-bar anchors before the spraying. The proportion by weight is 1:3 to 1:4 for mortar spraying, and 1:3:1 to 1:5:2 for concrete spraying. Water-cement ratio is 45 to 50% for mortar spraying and 40 to 45% for concrete spraying.

Table 6.4 STANDARD SAFE SLOPE FOR CUT SLOPES

Type of subsoil or rock strata	Allowable depth of cutting	Recommended gradient of cut slope
Hard rocks		1 : 0.3 - 1 : 0.8
Weathered rocks		1 : 0.5 - 1 : 1.2
Sand		Less steep than 1 : 1.5
Sandy soil, Dense sandy soil	5 - 10 m	1 : 0.8 - 1 : 1.0 1 : 1.0 - 1 : 1.2
Loose sandy soil	5 - 10 m	1 : 1.0 - 1 : 1.2 1 : 1.2 - 1 : 1.5
Gravelly sandy soil Dense or well-graded	10 - 15 m	1 : 0.8 - 1 : 1.0 1 : 1.0 - 1 : 1.2
Loose or poorly-graded	10 - 15 m	1 : 1.0 - 1 : 1.2 1 : 1.2 - 1 : 1.2
Clay or cohesive soil	0 - 10 m	1 : 0.8 - 1 : 1.2
Cohesive soil with gravels or cobbles	5 - 10 m	1 : 1.0 - 1 : 1.2 1 : 1.2 - 1 : 1.5

7. INTERSECTIONS

7.1 Intersection Design

7.1.1 Type of Intersection

The Outer Ring Road is a primary distributor in an inter-urban area so the operating speed should be higher than that of the existing road and has to be able to provide an uninterrupted traffic flow. Generally, the type of intersection which is most suitable between the Outer Ring Road in relation to the other roads is shown in Table.

Table 7.1 TYPE OF INTERSECTION

Intersection of Outer Ring Road	At-grade intersection		grade separation	Remarks
	non-signalled	signalled		
to Primary Distributor inter-urban	X	X	0	
to Primary Distributor intra-urban	X	X	0	
to District Distributor	X	0	X	
to Local and Access Road	X	X	X	access control
to Approach Road	X	0	X	

Note: 0 - suitable type of intersection.
X - not suitable type of intersection.

The above mentioned table describes the type of intersections generally but these are subject to change after conditions of the actual site and stage construction are considered.

7.2 Design Standards

(1) At-grade intersection

The design standards for at-grade intersection is adopted from "A Policy on Design of Highways and Arterial Streets" (AASHTO).

(2) Interchange

The design standards for interchange is adopted from "A Policy on Geometric Design of Rural Highways." The design speed of ramp is adopted to be 40km/hr.

7.3 Intersection Design

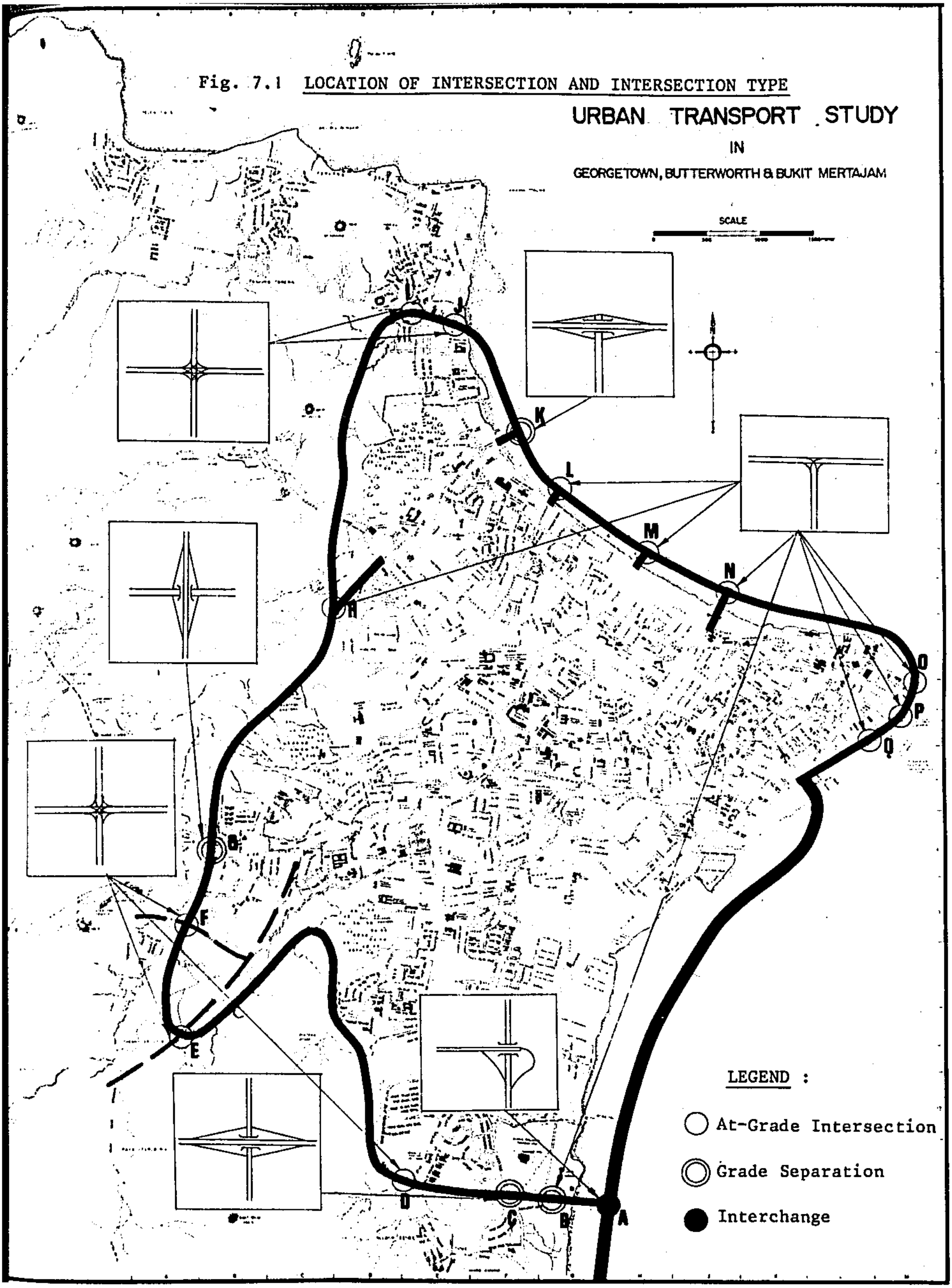
On the basis of Table 7.1, the type of intersection is decided upon. The location and type of intersection is shown in Fig. 7.1.

(1) A-intersection

A-intersection is situated between a primary distributor inter-urban road (North Coastal Road) and primary distributor intra-urban road (Outer Ring Road).

The above two roads are classified to be primary distributors, therefore the intersection required is the grade separated intersection type. The interchange of this type can either be a partial interchange or a full interchange. After discussion with the Malaysia Government, it is decided that the interchange will be the partial interchange.

Fig. 7.1 LOCATION OF INTERSECTION AND INTERSECTION TYPE



(2) B-intersection

B-intersection is situated between two primary distributor intra-urban roads (the Outer Ring Road and the Weld Quay Extension Road).

This intersection is projected to have heavy traffic volume. The result of the traffic capacity analysis show that the flow will exceed the capacity traffic volume after the year 2000 and therefore the grade separated intersection is required. However, the distance from this intersection to A and B-intersection is very close and therefore there will be some problems in constructing the grade separated intersection, e.g. shortage of weaving length and others. So, the intersection will be the at-grade intersection type.

(3) C, G and K intersection

These intersections are situated between two primary distributor intra-urban roads in George Town (the Outer Ring Road and Jalan Glugor/Jalan Ayer Itam). According to Table 7.1, these intersections should be grade separated intersections.

(4) Other intersections

Other intersections are situated between the Outer Ring Road and District Distributor and Local Roads. The traffic volume on district distributor and local roads is not very heavy, so the at-grade intersection with signals is suitable.

Table 7.2 CALCULATION OF CAPACITY VOLUME

Phase		Possible Capacity	Capacity	Time
1	1	2,000 x 0.96 x 0.9 = 1,728	1,728 x 50 ÷ 116 = 745	50 + 2
	2	2 x 2,000 x 0.96 x 0.9 = 3,456	3,456 x 50 ÷ 116 = 1,490	
	3	2 x 2,000 x 0.96 x 0.9 = 3,456	3,456 x 50 ÷ 116 = 1,490	
2	1	2,000 x 0.96 x 0.9 = 1,728	1,728 x 30 ÷ 116 = 447	30 + 2
	4	2,000 x 0.96 x 0.9 = 1,728	1,728 x 30 ÷ 116 = 447	
	3	1,200 x 0.96 x 0.9 = 1,037	1,037 x 30 ÷ 116 = 268	
	5	2,000 x 0.96 x 2 x 0.9 = 3,456	3,456 x 30 ÷ 116 = 894	
3	1	2,000 x 0.96 x 0.9 = 1,728	1,728 x 30 ÷ 116 = 447	30 + 2
	3	2,000 x 0.96 x 2 x 0.9 = 3,456	3,456 x 30 ÷ 116 = 894	
	5	2,000 x 0.96 x 2 x 0.9 = 3,456	3,456 x 30 ÷ 116 = 894	
	6	2,000 x 0.96 x 2 x 0.9 = 3,456	3,456 x 30 ÷ 116 = 894	

Table 7.3 CALCULATION OF DEGREE OF CONGESTION

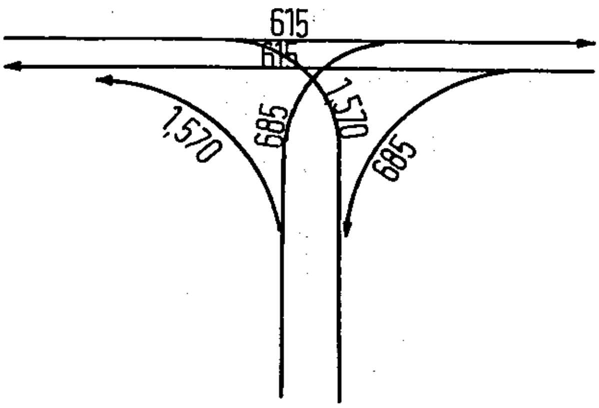
(P.C.U./hour)

	Capacity	Volume	Degree of Congestion
1	1,639	512	0.31
2	1,490	1,822	1.2228
3	2,652	2,107	0.7945
4	447	489	1.0940
5	1,788	1,290	0.7215
6	894	1,199	1.3412

7.4 Intersection between Outer Ring Road and Gurney Drive

1) Traffic volume

The traffic volume is as follows:

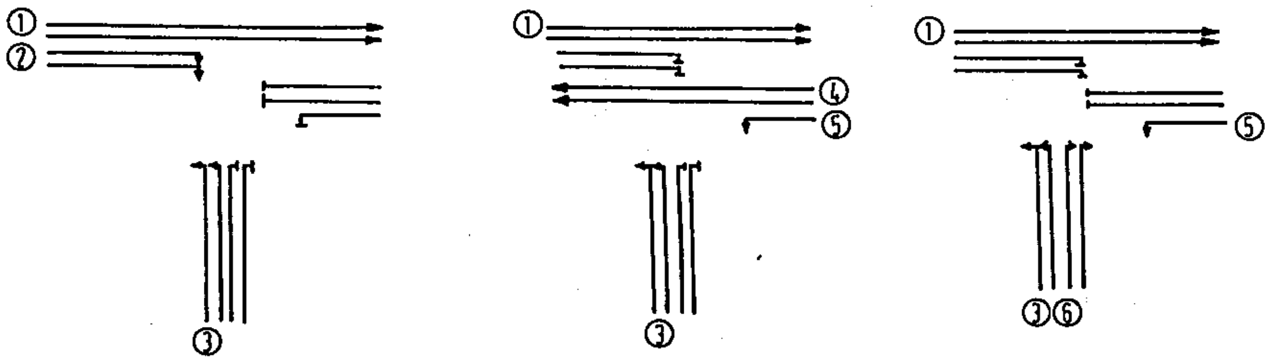


(year 2000 P.C.U. per hour)

2) Phase

The Phases are as follows:

Phase 1 | Phase 2 | Phase 3

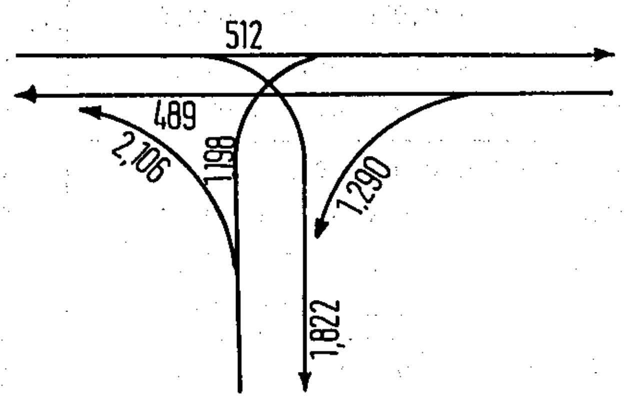


(30 sec) | (20 sec) | (30 sec)

7.4.1 Intersection between Outer Ring Road and Weld Quay Extension Road

1) Traffic volume

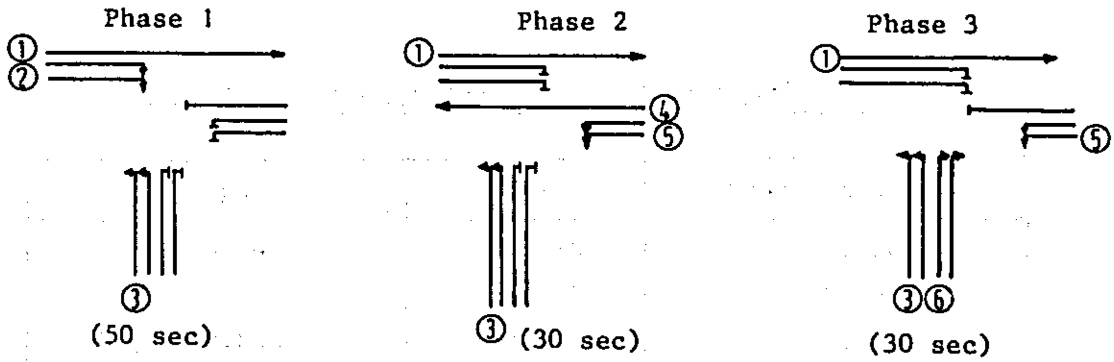
The traffic volume is as follows:



(year 2000 P.C.U. per hour)

2) Phase

The phases are as follows:



3) Traffic capacity

* Basic traffic capacity is adopted to be 2000 P.C.U/hr.
* Percentage of truck and bus is adopted to be less than 5.0 percent.

Table 7.4 CALCULATION OF CAPACITY VOLUME

Phase		Possible Capacity	Capacity	Time
1	1	2,000 x 0.96 x 0.9 x 2 = 3,456	3,456 x 50 ÷ 106 = 1,630	50 + 2
	2	2,000 x 0.96 x 0.9 x 2 = 3,456	3,456 x 50 ÷ 106 = 1,630	
	3	2,000 x 0.96 x 0.9 x 2 = 3,456	3,456 x 50 ÷ 106 = 1,630	
2	1	2,000 x 0.96 x 0.9 x 2 = 3,456	3,456 x 20 ÷ 106 = 652	20 + 2
	3	1,200 x 0.96 x 0.9 x 1 = 1,036	1,036 x 20 ÷ 106 = 195	
	4	2,000 x 0.96 x 0.9 x 2 = 3,456	3,456 x 20 ÷ 106 = 652	
	5	1,200 x 0.96 x 0.9 x 1 = 1,036	1,036 x 20 ÷ 106 = 195	
3	1	2,000 x 0.96 x 0.9 x 2 = 3,456	3,456 x 30 ÷ 106 = 978	30 + 2
	3	2,000 x 0.96 x 0.9 x 2 = 3,456	3,456 x 30 ÷ 106 = 978	
	5	2,000 x 0.96 x 0.9 x 1 = 1,728	1,728 x 30 ÷ 106 = 489	
	6	2,000 x 0.96 x 0.9 x 2 = 3,456	3,456 x 30 ÷ 106 = 978	

Table 7.5 CALCULATION OF DEGREE OF CONGESTION

	Capacity	Volume	Congestion degree
1	3,260	615	0.1887
2	1,630	1,570	0.9632
3	2,803	1,570	0.5601
4	652	615	0.9433
5	684	685	1.0015
6	978	685	0.7004

8. **BRIDGE DESIGN**

8.1 Design Criteria

1. Loadings

The design loading of the bridge is adopted according to the British Ministry of Transport Memorandum No. 791 to carry Type HA loading of B.S 153 and also 45 units of HB loading guided along the centre of each of the two-lane carriageway.

2. Specification of material

The specification of material for reinforced concrete and prestressed concrete is adopted according to the British Ministry of Transport Memorandum No. 785, BE 2/73 and the British Standard code of Practice 110.

3. Vertical clearance

The minimim vertical clearance used in Malaysia is 4.35 meter (14'6") in Malaysia. But the re-surfacing of the existing road and others should be considered. Therefore the minimum vertical clearance adopted in this study is 5.0 meter which measures from the lowest point of thedeck structure to the highest road level over rivers.

4. The geometric design standard

The Geometric Design Standard which comprise right distance, minimum radius, vertical length, etc. is adopted by J.K.R. design standard such as that described in the previous section.

5. Cross-section of the bridge

The cross-section of the grade separation intersection bridge is as follows:

1) Width of carriageway is 3.5 meter on each lane.
2) Width of shoulder is 2.00 meter on both sides.
3) Width of central reservation is 2.00 meter.

Typical cross-section is shown in Fig. 8.1 for grade separation section (type A) and the cross-section of the mountainous area bridge is as follows:

1) Width of carriageway is 3.50 meter on each lane.
2) Width of shoulder is 1.5 meter (inc. both sides of road).
3) Width of central reservation is 3.00 meter.

The typical cross-section for the bridge section (type B) is shown in Fig. 8.1.

8.2 Criteria for Selection of Bridge Site

The alignment of the Outer Ring Road is located between mountain area and flat terrain and the existing ground condition of the mountain area is very steep. Certain conditions along the Outer Ring Road will necessitate the construction of bridges.

The criteria for bridge location site is as follows:

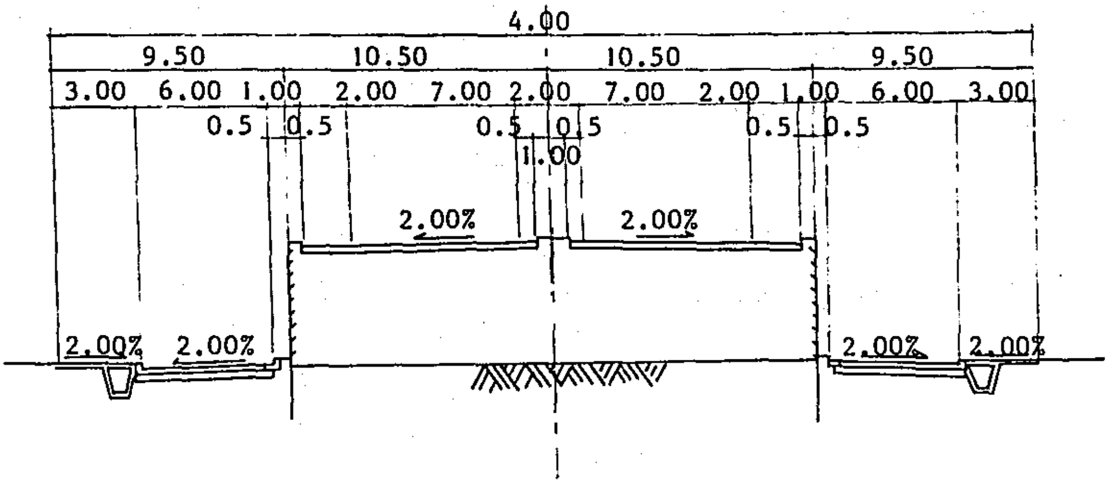
1) Undulating land where it is impossible to establish embankment fill.
2) Along a river where the width is over 10.0 meter.
3) Places where grade intersection is planned.
4) High embankments where it is impossible to establish embankment fill.

Taking into account the above-mentioned, the bridge is located such as shown in Table 8.1 and the location of the main bridges is shown in Fig. 8.2.

Fig. 8.1 TYPICAL CROSS-SECTION

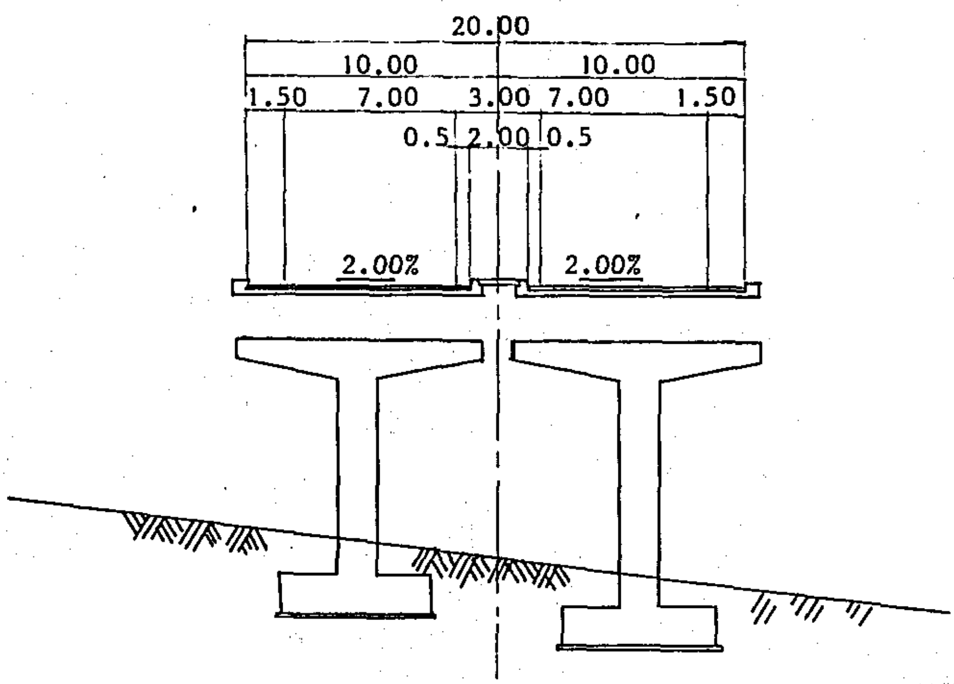
1) TYPE A

GRADE SEPARATION SECTION



2) TYPE B

BRIDGE SECTION



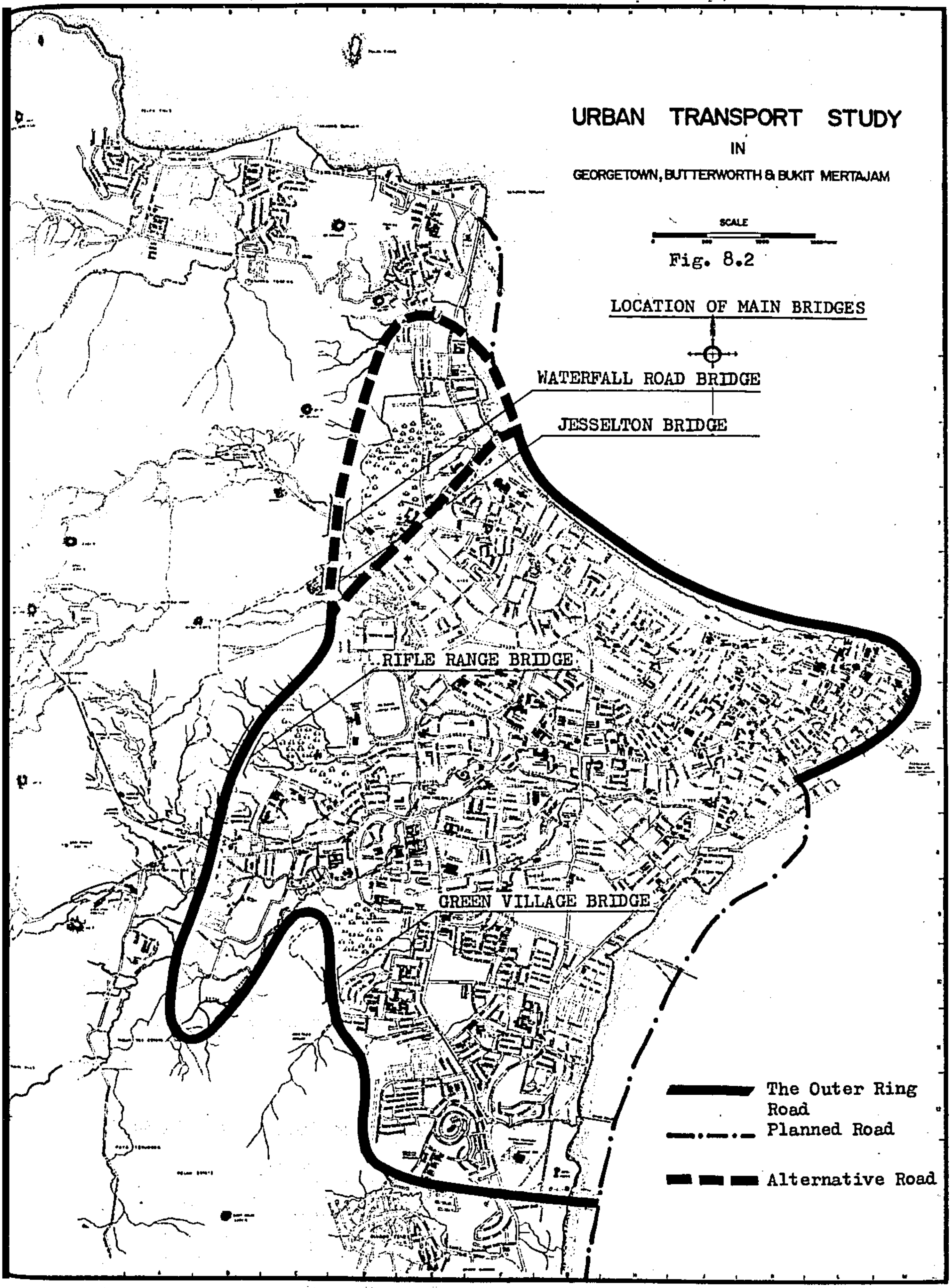
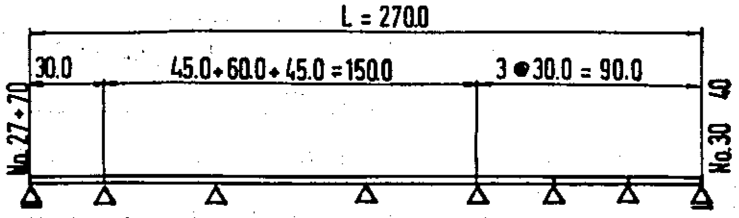
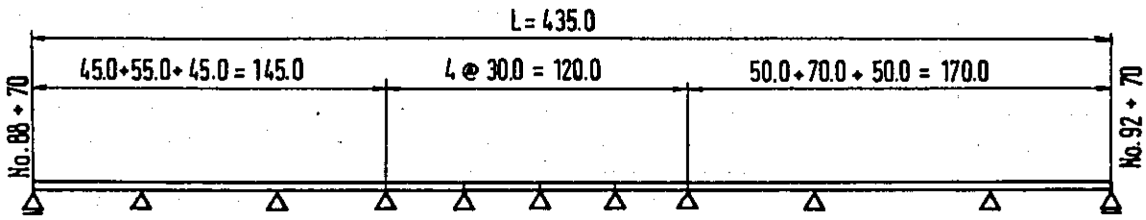

URBAN TRANSPORT STUDY
IN
GEORGETOWN, BUTTERWORTH & BUKIT MERTAJAM
SCALE
Fig. 8.2
LOCATION OF MAIN BRIDGES
WATERFALL ROAD BRIDGE
JESSELTON BRIDGE
RIFLE RANGE BRIDGE
GREEN VILLAGE BRIDGE
The Outer Ring Road
Planned Road
Alternative Road

Fig. 8.3 SPAN ARRANGEMENT

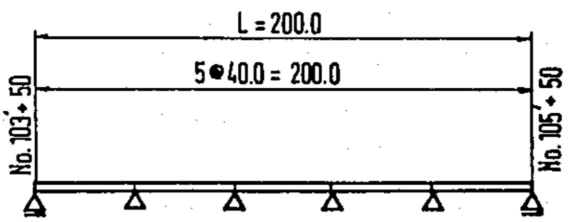
1. GREEN VILLAGE BRIDGE



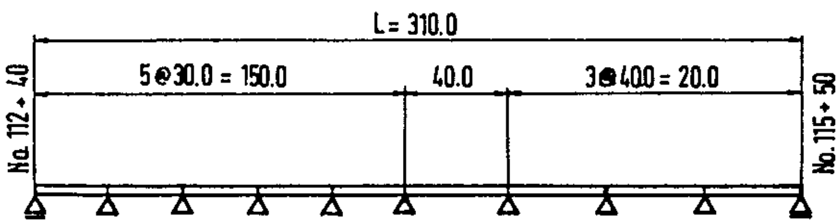
2. RIFLE RANGE BRIDGE



3. JESSELTON BRIDGE



4. WATERFALL ROAD BRIDGE



5. GRADE SEPARATION INTERSECTION BRIDGE

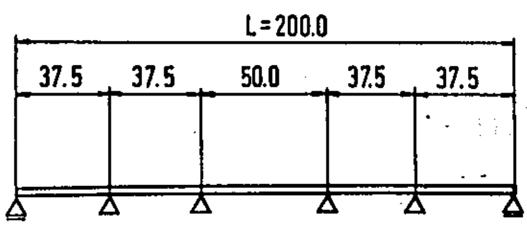


Table 8.1 LOCATION OF BRIDGE

Station \ Item	Length (m)	Width (m)	Arrangement of Section	Remarks
-No4' + 0.0 - No1' + 50.0	550	9.0 x 2	0	Grade Separation
-No1 + 0.0 - No1 + 0.0	200	9.0 x 2	1 & 2	Grade Separation
No27 + 70 - No30 + 40	270	9.0 x 2	3	
No45 + 80 - No46 + 30	50	9.0 x 2	3	
No67 + 0 - No67 + 20	20	9.5 x 2	3	
No73 + 90 - No74 + 15	25	9.5 x 2	3	
No77 + 50 - No79 + 50	200	9.0 x 2	3 & 4	Grade Separation
No88 + 35 - No92 + 70	435	9.0 x 2	4	
No95 + 80 - No96 + 10	30	9.0 x 2	4	
No111 + 15 - No111 + 40	25	9.0 x 2	7	
No111 + 50 - No113 + 50	200	9.0 x 2	7 & 8	Grade Separation
No103' + 50 - No105' + 50	200	9.0 x 2	5	
No112' + 40 - No115' + 50	210	9.0 x 2	5	
No143'	200	9.0 x 2	6	Grade Separation
No129	200	9.0 x 2	8 & 9	Grade Separation

2) Abutment

The position of abutment should take into consideration the existing ground level, construction method, existing landuse, river, existing road, and construction cost.

Regarding the grade separation bridge, they are planned in the urban area, when the site of abutment is decided. The environment aspects with a scene of nature and wind should be considered.

From the viewpoint of establishing open space under the bridge, the location of the abutment will be at a site where the distance between the girder to the existing ground level is 2.0 meter.

3) Piers

The position of piers should also take into consideration the same factors as the abutment. The undulating area of the location site of the mountain area is very deep, so the height of the pier should also be established likewise. A high pier is very costly therefore a long span bridge is recommended from the economic point of view.

In the bridge at the grade separation intersection, the distance between the piers should take into account the traffic flow under the bridge.

4) Foundation

From the rsults of the preliminary soil investigation in mountainous area it appears that the rock depths are about 5.0 meter to 10 meter below the existing round level in individual sites. Therefore the foundation for mountainous area will be established by mass foundation. But the grade separation intersection bridge is located in flat terrain. The soil condition of this area is not good soil, therefore, in this area some form of pile foundation is required. But the actual soil condition at each individual site should be investigated during the detailed design stage and then the most suitable type of foundation should be determined.

8.3 Bridge Features

1) Superstructure

There are many types of superstructure such as steel type, reinforced concrete type, prestressed concrete type, post-tension concrete type and so on. Strictly speaking, when the type of bridge is to be selected, a comparative examination of bridge design should be done taking into account soil condition, existing ground condition, construction method, material investigation, environmental aspect, construction cost and so on.

A concrete bridge which includes reinforced concrete bridge and prestressed concrete bridge will be more in conformity than steel bridge in this country. This is because from a technical viewpoint of bridge condtruction, a concrete bridge is higher than a steel bridge and the material for concrete bridge is more easily available than for steel bridge.

The maximum length of reinforced concrete bridge and prestressed concrete bridge (taking into account economic considerations) is about 30 meter to 40 meter and 15 meter to 20 meter respectively. In the mountain area, the construction method, a pilot road for construction and construction cost should be considered and the selection of the type of bridge will be based on the most economical plan.

Taking into account the above-mentioned, the post-tension bridge is adopted for the Outer Ring Road as the lowest point of the undulating land is very deep.

9. ESTIMATION OF THE PROJECT COST

9.1 General

Cost estimates were carried out based on 1980 prices. Direct construction cost include cost of labour, equipment, material and other necessary items.

The total construction cost was estimated based on direct construction cost and in addition includes overhead cost, profits of contractor, contractor's tax, contingency and engineering and supervisory fees. The cost was broken down into foreign and local components. These are shown in Table 9.1.

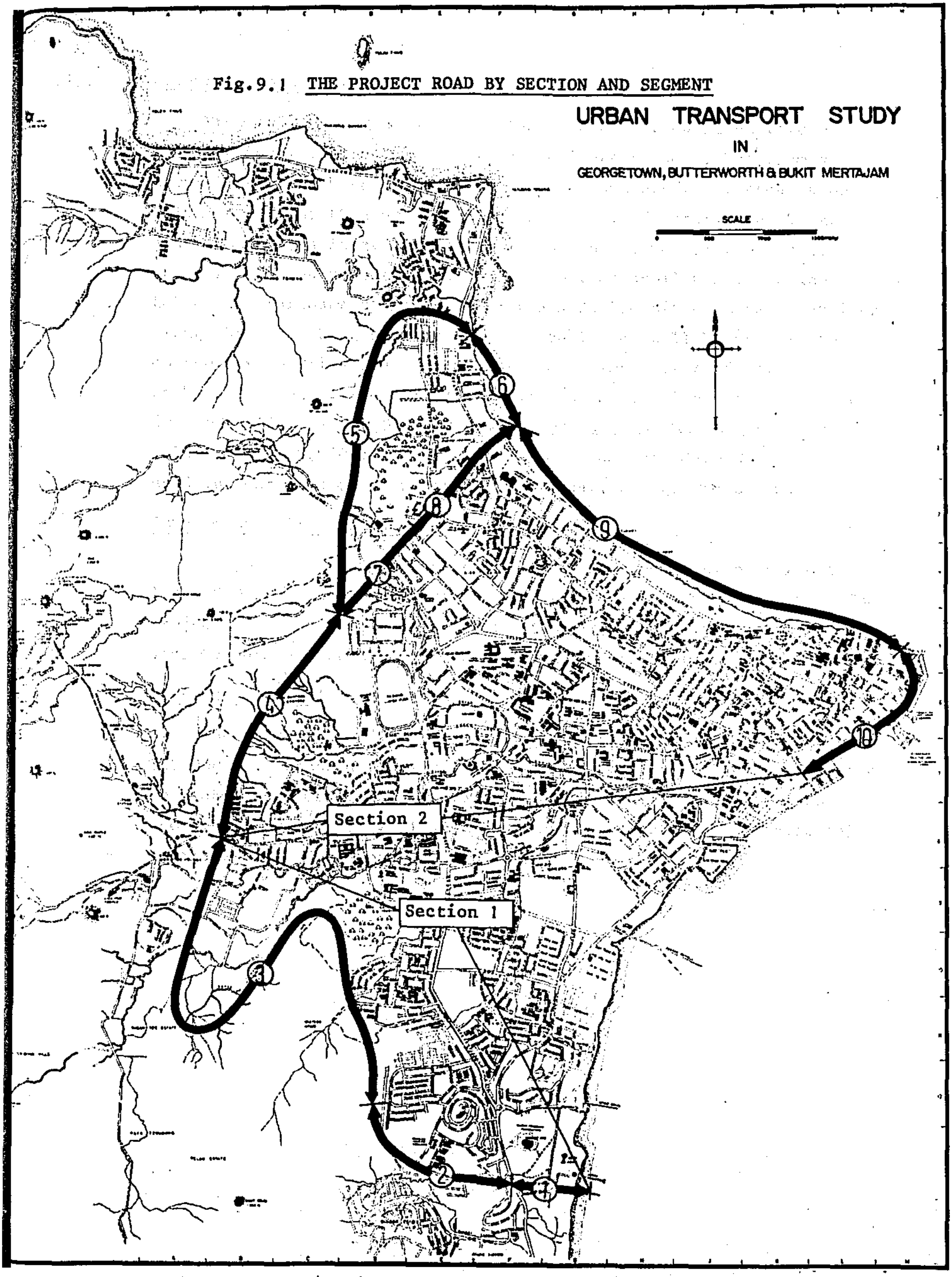
Table 9.1 PERCENTAGE OF EACH ITEM

Items		Component (%)	
	Foreign	Local	Tax
Overhead (10%)	0	95	5
Profit (10%)	0	95	5
Contractor's Tax (3%)	0	0	100
Engineering and Supervisory Fees (10%)	50	45	5
Contingency (5%)	50	45	5
Total (45.0%)			

9.2 Construction Quantities Estimate

On the basis of preliminary highway design on a map of scale 1 to 3,000, the construction quantities were estimated. These segments are shown in Fig. 9.1 and construction quantities are shown in Tables 9.2 to 9.5.

Fig.9.1 THE PROJECT ROAD BY SECTION AND SEGMENT



9.2.1 Excavation and Filling Volume

From the viewpoint of the balance between excavation volume and embankment fill volume, it is approximately equal, but from a comparison of each section, in the mountainous area, the excavation volume is larger than embankment fill volume. Generally speaking, since there is a large excavation volume in the mountainous area, there is no need to establish a hollow pit or spoil bank, but when taking into account stage construction a hollow pit will be established along the Outer Ring Road area and a spoil bank will be established on the Gurney Drive area. The soil conversion factor of soil and rock is 0.9 and 1.5 respectively. So the total volume of excavation is 2,685,000m^3 (1,400,000 x 0.9 + 950,000 x 1.5) and embankment volume is 2,500,000 m^3. Therefore, the volume of 185,000m^3 will be used in construction of revetment, pavement, bridge and so on.

9.2.2 Embankment Fill Material for Reclamation

The volume of the embankment fill in the reclamation is about 1,760,000 m^3. These materials can be obtained from the Outer Ring Road project site and the material of revetment for protection of lane can also be obtained from the Outer Ring Road project site.

9.2.3 Pavement Material

The total area of pavement in the Outer Ring Road is about 330,000 m^2. Crushed stone will be used as the material of base-course and sub-base course. The volume of crushed stone is calculated to be about 130,000 m^3. It will also be possible to obtain these material from the Outer Ring Road project site.

Table 9.2 QUANTITY LIST (2-LANE)

Item	Sub-Item	Class	Unit	Quantity Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6	Segment 7	Segment 8	Segment 9	Segment 10
Site Clearing	Residential		m^2	17,430	40,920	0	0	0	0	0		0	
	Field		m^2	0	0	0	0	0	0	0		0	
	Mountain		m^2	0	0	190,690	55,660	118,125	0	35,170		0	
Excavation	Soil		m^3	10,600	204,900	433,240	136,650	178,700	0	64,350		0	
	Rock		"	0	258,800	183,000	140,100	272,050	0	13,200		0	
Embankment	Soil		"	8,550	27,200	238,600	15,600	102,160	273,250	6,900		1,009,960	
Slope	Grass		m^2	1,160	11,930	45,450	20,370	30,170	0	9,720		0	
	Concrete		"	0	24,560	26,700	16,720	23,050	0	16,470		0	
Turfing	Sidewalk		"	1,160	755	0	0	0	1,150	0		0	
	Open Space		"	0	0	16,450	0	0	0	0		146,720	
Drainage	Roadside	0.5 x 1.0	m	1,160	4,000	4,500	0	1,600	1,150	0		9,000	
		1.0 x 1.0	"	0	1,100	3,600	2,150	7,000	0	1,120		0	
	Pipe Culvert	ø = 600	"	60	80	351	114	229	92	89		0	
	Box Culvert	3.0 x 3.0	"	0	30	155	0	205	325	0		90	
		5.0 x 5.0	"	0	0	0	0	0	0	0		0	
	Demolishing	0.5 x 1.0	"	0	0	0	0	0	0	0		0	
Wall	Concrete	H = 1.0	m	0	0	0	0	0	0	0		0	
	Concrete	H = 5.0	"	0	0	0	300	0	0	0		0	
	Masonry	H = 5.0	"	0	0	0	0	0	0	0		0	
	Revetment	Stone	"	0	0	0	0	0	1,150	0		2,700	
	Demolishing	Concrete	"	0	0	0	0	0	0	0		0	
Pavement	Carriage-Way	Asphalt	m^2	6,400	16,000	52,440	13,250	25,120	9,200	9,700		46,400	
	Shoulder	"	"	2,400	6,000	19,665	5,070	9,420	1,725	3,645		8,700	
	Service Road	"	"	0	0	0	0	0	0	0		0	
	Sidewalk	Concrete	"	6,400	3,000	3,480	5,200	6,400	11,500	0		45,000	
	Overlay	Asphalt	"	0	0	0	0	0	0	0		0	
	Removing	"	"	0	0	0	0	0	0	0		0	
Additional Facility	Kerb	L = 50	m	1,600	4,000	0	4,300	8,600	2,300	2,240		0	
	Central Reservation		"	0	0	0	0	0	0	0		0	
	Guard-Rail		"	0	1,000	4,500	2,150	4,300	2,300	0		0	
	Lighting		"	0	0	0	0	0	1,150	0		0	
Inter-section	Lane-Marks		"	800	2,000	5,850	2,150	4,300	1,150	0		0	
	At-grade		Vol.	2	0	3	0	4	1	1		4	
	Grade Separation		Vol.	0	0	0	0	0	0	0		0	
Bridge	Interchange		Vol.	0	0	0	0	0	0	0		0	
	L= < 50		m^2	0	0	405	270	0	0	0		0	
	L= > 50		m^2	0	0	1,350	4,050	4,050	0	0		0	

9.3 Unit Cost Analysis

9.3.1 General

The unit cost analysis of the main items involved in the construction of the Outer Ring Road is carried out based on 1980 prices.

"The Penang Island Dispersal Study Report," "East West Highway Project Report," "Penang Bridge Project Report" and "Federal Route 1 (Alor Star - Butterworth Section) Report" are referred to.

The Unit Cost itself consists of two parts, namely, Foreign Cost and Local Cost. Foreign Cost is the portion of the Unit Cost which involves the purchasing of plants and parts that are not produced locally but imported from foreign countries. Local Cost is the cost which involves local materials and manpower.

9.3.2 Construction Equipment

The various plants on which unit cost analysis are made are currently available in this country. The size and the capacity range of the plants adopted are considered suitable for the construction of the proposed Outer Ring Road.

The premises are as follows:

(i) Service life of plant - 8 years.
(ii) Working hours per annum - 2160.
(iii) Interest per capital outlayed - 8%.
(iv) Spare parts cost per annum - 5% of initial cost of plant.
(v) Maintenance and repairs - 5% of initial cost of plant.
(vi) Average plant efficiency - 70% .

Table 9.3 QUANTITY LIST (4-LANE)

Item	Sub-Item	Class	Unit	Quantity Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6	Segment 7	Segment 8	Segment 9	Segment 10
Site Clearing	Residential		m^2	25,400	75,260	0	0	0	0	0	15,000	0	0
	Field		m^2	0	0	0	0	0	0	0	0	0	0
	Mountain		m^2	0	0	297,030	80,190	163,130	0	45,670	0	0	0
Excavation	Soil		m^3	18,000	263,800	597,500	168,600	353,000	0	88,000	11,250	0	0
	Rock		"	0	328,800	234,100	162,050	223,500	0	169,400	0	0	0
Embankment	Soil		"	12,600	47,650	503,750	30,650	164,200	273,250	13,550	0	1,490,660	0
Slope	Grass		m^2	1,160	12,690	44,520	17,790	29,850	0	9,400	0	0	0
	Concrete		"	0	23,260	23,970	14,480	21,590	0	14,470	0	0	0
Turfing	Sidewalk		"	1,160	755	0	0	0	1,150	0	1,700	44,500	0
	Open Space		"	0	0	16,450	0	0	0	0	0	157,400	0
Drainage	Roadside	0.5 x 1.0	m	1,600	4,000	4,500	0	1,600	1,150	0	1,900	8,900	4,000
		1.0 x 1.0	"	0	1,100	3,600	2,150	7,000	0	1,120	0	0	0
	Pipe Culvert	ø = 600	"	60	120	468	172	344	92	89	90	360	0
	Box Culvert	3.0 x 3.0	"	0	40	185	0	265	325	0	200	180	0
		5.0 x 5.0	"	0	0	0	0	0	0	0	0	0	0
	Demolishing	0.5 x 1.0	"	0	0	0	0	0	0	0	1,900	0	4,000
Wall	Concrete	H = 1.0	m	0	0	0	200	0	0	0	0	0	0
	Concrete	H = 5.0	"	0	200	200	300	0	200	200	0	0	0
	Masonry	H = 5.0	"	0	0	0	0	0	0	0	0	0	0
	Revetment	Stone	"	0	0	0	0	0	1,150	0	0	4,500	0
	Demolishing	Concrete	"	0	0	0	0	0	0	0	200	0	0
Pavement	Carriage-way	Asphalt	m^2	14,200	33,400	90,280	28,440	50,240	18,400	18,400	12,000	71,200	0
	Shoulder	"	"	2,400	5,400	13,015	4,230	7,080	3,450	2,400	2,250	13,350	0
	Service Road	"	"	0	0	0	1,800	0	0	0	0	0	0
	Sidewalk	Concrete	"	7,400	7,600	3,480	7,480	6,400	11,500	0	6,000	44,500	3,000
	Overlay	Asphalt	"	0	0	0	0	0	0	0	17,000	0	28,000
	Removing	"	"	0	0	0	0	0	0	0	0	0	0
Additional Facility	Kerb	L = 50	m	1,600	4,000	11,700	4,300	8,600	2,300	2,240	3,400	8,900	4,000
	Central Reservation		"	800	2,000	5,850	2,150	4,300	1,150	1,120	1,700	4,450	2,000
	Guard-Rail		"	800	1,000	4,500	2,150	4,300	2,300	0	3,200	8,900	4,000
	Lighting		"	0	0	0	0	0	1,150	0	0	4,450	0
	Lane-Marks		"	800	2,000	5,850	2,150	4,300	1,150	0	1,700	4,450	0
Inter-Section	At-grade		Vol.	1	1	2	0	3	0	0	4	3	3
	Grade Separation		Vol.	1	1	1	0	1	1	1	1	1	0
	Interchange		Vol.	1	0	0	0	0	0	0	0	0	0
Bridge	L=<50		m^2	0	0	1,755	540	0	0	450	0	0	0
	L=>50		m^2	1,800	1,800	6,660	9,630	7,380	3,600	1,800	3,600	1,800	0
				0	0	0	0	0	0	0	0	300	0

9.3.3 Labour Cost

The labour cost is shown in Table 9.4.

Table 9.4 LABOUR COST (Day Work Rates)

	Items	Unit Cost per hour day (M$)	Remarks
1	General Labourer	14.00	
2	Concrete Labourer	20.00	
3	Mason	20.00	
4	Mason's Labourer	16.00	
5	Carpenter	22.00	
6	Carpenter's Labourer	18.00	
7	Steel Bender and Fixer	20.00	
8	Pneumatic Tool Operator	22.00	
9	Fitter	28.00	
10	Welder	28.00	
11	Painter	22.00	
12	Truck Driver	24.00	
13	Earth Moving Equipment Operator	32.00	

9.3.4 Unit Cost

The unit cost of the main items are shown in Table 9.5.

9.4 Land Acquisition Cost and Compensation

9.4.1 Land Acquisition Cost

1. Introduction

As mentioned in the section on compensation cost, the route of the Outer Ring Road was studied carefully. This report looks into the subject of land acquisition cost, that is, the land that is affected by the Outer Ring Road which needs to be acquired by the relevant authorities to carry on their project. This involves a payment to be made to the land-owners and hence the value of the land in question is estimated in terms of its selling value.

Landuse varies considerably from area to area and in the affected areas in our project they range from residential areas and commercial areas to hill land. The values used in our study were decided upon after discussion with the authorities from the Land Valuation Office and confirmation from the Technical Committee. It must be noted that not only does the land value differ by the type of landuse but also by the location and function of any road in relation to the land. For example, land behind a wide road will have a higher value than land behind a small road. In this report the cost is also estimated by area and different lots of varying values are grouped together and therefore the acquisition cost may not reflect the value of any one type of landuse.

2. Procedure

In order to obtain the value of the land along the route of the Outer Ring Road, a survey was done to place a value on the land affected. They range from residential areas and commercial areas to hill land.

The length of the right of way of the road was used as a measure to estimate the land to be acquired. A cross-section was made of every 100 meters along the Outer Ring Road.

The right of way area was calculated by the following method.

$$\frac{L1 + L2}{2} \times \text{Distance between Cross-Sections} = \text{Area of right of way}$$

L1 = Length of Right of Way of Cross-Section of first 100m .

L2 = Length of Right of Way of Cross-Section of second 100m.

9.4.2 Compensation Cost

1. Introduction

The route of the Outer Ring Road passes through a wide expanse of area that differs widely in terms of landuse. It is highly imperative in our study to study the landuse and the nature and type of buildings that stand in the way of the Outer Ring Road in order that compensation can be given to those buildings affected adversely whereby they have to be demolished. This report looks into the subject of compensation cost which is taken to mean the suitable payment which is given to make up for the loss of house, land and all the non-tangible benefits that was enjoyed in terms of convenience, attachments formed, etc.

2. Procedure

1) Survey of affected buildings

In order to obtain the value of residences affected along the Outer Ring Road, a survey was done to count the number of houses and to categorise them according to type. All houses that are located along a distance of two lots from the existing road were denoted as affected buildings. These were identified on a map of scale 1:3000 and the data documented according to location, type of building, distance of building to new road, landuse, building use, number of storeys and condition of building.

2) Categorisation of area

Being aware of the fact that the value of houses vary greatly according to location, not only was the categorisation made according to terrace, semi-detached and detached houses but also by area, that is, within the city limits and out of the city limits. After assessment of the whole route of the Outer Ring Road, most of the affected buildings fell into the following areas:

a) Ayer Itam
b) Jalan Bagan Jermal/Gottlieb Road
c) Jalan Kelawai/Jalan Northam
d) Gurney Drive
e) Waterfall Road
f) Jalan Tanjong Tokong/Fettes Road

The first four areas are within the city limits where the value of detached houses is very high. The last two areas are areas out of the city limits and the value of detached houses here are of low and medium value respectively.

3) Value of affected residential units

In order to obtain the value of the affected residential units, the average area was first estimated and then multiplied by the average cost per sq. ft. These also differed in terms of whether the location was in the city limit or outside it. The following table shows the method by which the average cost of houses (excluding land cost) was estimated.

It must be brought to attention that there is no difference indicated between the area size of houses within the city limit and those outside of it. Also, only detached houses have been classified in terms of size and cost per unit. This is due to the vast difference that exists between detached houses that should not be overlooked.

4) Results

As shown in Table 9.7, the average cost of each type of house is obtained and multiplied by the number of houses counted in a particular area. The result is seen in Table 9.8. The figure indicates each area affected and the total cost of houses incurred as part of compensation cost.

When the area of the right of way of all the cross-sections was obtained, their summation multiplied by the unit cost of the land resulted in the Land Acquisition Cost..

3. <u>The Unit Cost Used</u>

The cost of the land per sq.meter varies according to the type and condition of the land. For the purpose of calculating the land acquisition cost, the average unit cost for the different type of landuse was estimated.

The mountain area was divided into two sections and their unit cost varied. The mountain area behind Island Glades was estimated at $22 per sq.m. the area behind the Batu Gantong Chinese cemetery was valued at $11 per sq.m.and the area behind the Mt. Erskine cemetery was valued at between $16 to $22 per sq.m.

In the case of residential areas, the unit cost fluctuates according to the function of each area, i.e from $110 to $594 per sq.m.

A summary of the land acquisition cost by area is shown in Table 9.6 with reference to Fig 9.1..

Table 9.5 UNIT COST

Item	Sub-Item	Class	Unit	Unit Cost			
				F.C	L.C	Tax	Total
Site Clearing	Residential		m^2	1.80	1.20	0.15	3.15
	Field		"	0.25	0.16	0.02	0.43
	Mountain		"	0.35	0.20	0.03	0.58
Excavation	Soil		m^3	1.18	0.85	0.1	2.13
	Rock		"	5.51	10.68	0.81	17.0
Embankment	Soil		"	1.4	0.9	0.11	2.41
Slope	Grass		m^2	0	5.0	0.3	5.3
	Concrete		"	4.8	3.8	0.7	9.3
Turfing	Sidewalk	Grass & Tree	"	1.2	4.7	0.3	6.2
	Open Space	Grass	"	0	5.0	0.3	5.3
Drainage	Roadside	0.5 x 1.0	m	48.5	101.3	6.1	155.9
		1.0 x 1.0	"	54.0	99.1	6.6	159.7
	Pipe Culvert	Ø = 600	"	59.3	91.4	6.8	157.5
	Box Culvert	3.0 x 3.0	"	609.5	702.15	77.4	1389.05
		5.0 x 5.0	"	1374.3	1563.9	162.7	3100.9
	Demolishing	0.5 x 1.0	"	6.8	3.1	0.9	10.8
Wall	Concrete	H = 1.0	"				
	Concrete	H = 5.0	"	459.6	557.9	58.3	1075.8
	Masonry	H = 5.0	"	76.0	116.8	9.7	202.5
	Revetment	Stone	"	671.1	1110.5	123.6	1905.2
	Demolishing		"				
Pavement	Carriage-way	Asphalt	m^2	15.9	11.6	1.3	28.8
	Shoulder	Asphalt	"	12.4	8.3	1.0	21.7
	Service Road	Asphalt	"	12.4	8.3	1.0	21.7
	Sidewalk	Concrete Block	"	6.1	8.4	0.8	15.3
	Overlay	Asphalt	"	2.5	10.3	1.4	14.2
	Removing	Asphalt	"				
Additional Facility	Kerb	Concrete	m	5.7	12.6	0.9	19.2
	Central Reservation	Concrete	"	10.4	25.2	1.8	37.4
	Guard-Rail	Steel	"	34.5	10.3	4.4	49.2
	Lighting	Steel	"	11.0	9.0	1.0	21.0
	Lane-Marks	Paint	"	0.3	0.6	0.05	0.95
Inter-Section	At-grade		No.	30,534.8	59,728.4	2,706.2	92969.4
	Grade Separation						
	Interchange		Vol.	705,314.0	775,542.6	74928.8	1555785.4
Bridge	L = 50	Concrete	m^3				
	L = 50	Concrete	m^2	380	570	50	1,000
Approach Road			m	428.2	461.3	45.1	934.6

9.5 Construction Cost

9.5.1 Road Construction Cost

Road construction cost includes earthwork, pavement, drainage, concrete wall and culvert pipes and culvert box. Construction cost of segment 2 and 7 is higher by about four (4) million dollars per kilometer. This is because many rocks have to be excavated. Excavation of rocks is very costly. The construction of other segments is about 2.0-2.5 million dollars per kilometer.

In order to decrease construction cost in the mountainous area, the cutting volume should be decreases as far as possible. When the cutting volume decreases the bridge length should be considered.

9.5.2 Construction Cost of Structures

Construction cost of structures is only for the bridge. The construction material for the bridge was estimated according to the types of bridges to be built, viz, simple girder bridge with span lengths of 30 meters and 40 meters, three span continous girder type and others. The bridge construction cost was estimated according to each construction quantity. The construction cost is estimated at about $630 to $810 per square meter.

9.5.3 Reclamation Construction Cost

Reclamation construction cost is the embankment fill of reclamation and revetment of seaside. It is possible to obtain all the material for reclamation from the other sections.

Table 9.6 SUMMARY OF LAND ACQUISITION COST BY SECTION

Segment	Land Acquisition Cost	
	4-lane	2-lane
0	8,033,980	5,834,994
1	2,330,790	1,711,710
2	3,675,970	2,374,380
3	13,804,620	11,553,390
4	6,789,960	3,916,020
5	5,442,220	3,892,800
6	-	-
7	475,970	386,870
8	11,947,500	-
9	-	-
10	-	-

Table 9.7 AVERAGE COST OF HOUSE BY TYPE (exc. land value)

Location	Type of House	Unit Cost Per Sq.Ft. (M$)	Average Area of House (sq. ft)	Average Cost of House (M$)
Within City Limits	1. Terrace	29	Single-Storey - 800	23,200
			Double-Storey - 1,600	46,400
	2. Semi-detached	36.5	Single-Storey - 1,500	54,750
			Double-Storey - 3,000	109,500
	3. Detached	42.5	Single-Storey Low - 1,000	Low - 42,500
			Single-Storey Medium - 1,500	Medium - 63,750
			Single-Storey High - 2,400	High - 102,000
			Double-Storey Low - 1,500	Low - 63,750
			Double-Storey Medium - 2,250	Medium - 95,625
			Double-Storey High - 3,600	High - 153,000
Out of City Limits	1. Terrace	26	Single-Storey - 800	20,800
			Double-Storey - 1,600	41,600
	2. Semi-detached	32.5	Single-Storey - 1,500	48,750
			Double-Storey - 3,000	97,500
	3. Detached	38	Single-Storey Low - 1,000	Low - 38,000
			Single-Storey Medium - 1,500	Medium - 57,000
			Single-Storey High - 2,400	High - 91,200
			Double-Storey Low - 1,500	Low - 57,000
			Double-Storey Medium - 2,250	Medium - 85,500
			Double-Storey High - 3,600	High - 136,800

Table 9.8 SUMMARY OF COMPENSATION COST

Segment	Compensation Cost	
	4-lane	2-lane
0	4,025,000	2,656,500
1	0	0
2	1,987,000	1,311,400
3	2,628,000	1,734,500
4	2,967,000	1,958,200
5	3,614,000	2,385,200
6	-	-
7	-	-
8	4,957,000	-
9	-	-
10	-	-

Table 9.9 SUMMARY OF CONSTRUCTION COST (2-lane)

(M$'000)

Items / Segment	Length (m)	Construction Cost: Road F. C	Road L. C	Road Tax	Road Total	Structure F. C	Structure L. C	Structure Tax	Structure Total	Reclamation F. C	Reclamation L. C	Reclamation Tax	Reclamation Total	Land Acquisition & Compensation Cost L. C	Total Cost (F. C + L. C)	Total Cost F. C	Total Cost L. C	Total Cost Tax	Total Cost Total
0	2,500	1,984	2,435	214	4,633	1,778	1,185	156	3,119	0	0	0	0	8,491	15,873	3,762	12,111	370	16,243
1	800	358	460	36	853	323	216	29	568	0	0	0	0	1,712	3,069	681	2,388	65	3,134
2	2,000	2,529	4,033	332	6,944	323	216	29	568	0	0	0	0	3,685	10,786	2,852	7,934	361	11,147
3	5,900	3,923	4,969	445	9,339	1,692	1,612	149	3,453	0	0	0	0	13,288	25,484	5,615	19,869	594	26,078
4	2,100	1,724	2,514	221	4,459	2,300	1,434	208	3,942	0	0	0	0	5,874	13,846	4,024	9,822	429	14,275
5	4,300	3,475	5,249	437	9,161	1,682	1,191	145	3,018	0	0	0	0	6,278	17,875	5,157	12,718	582	18,457
6	1,050	635	700	72	1,407	399	266	35	700	1,154	1,523	172	2,849	0	4,677	2,188	2,489	279	4,956
7	1,120	558	670	62	1,290	403	269	36	708	0	0	0	0	387	2,287	961	1,326	98	2,385
8	1,600	0	0	0	0	723	482	64	1,269	0	0	0	0	0	1,205	723	482	64	1,269
9	4,400	1,453	2,682	194	4,329	399	266	35	700	6,093	7,302	798	14,193	0	18,195	7,945	10,250	1,027	19,222
10	2,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 9.10 SUMMARY OF CONSTRUCTION COST (4-lane)

(M$'000)

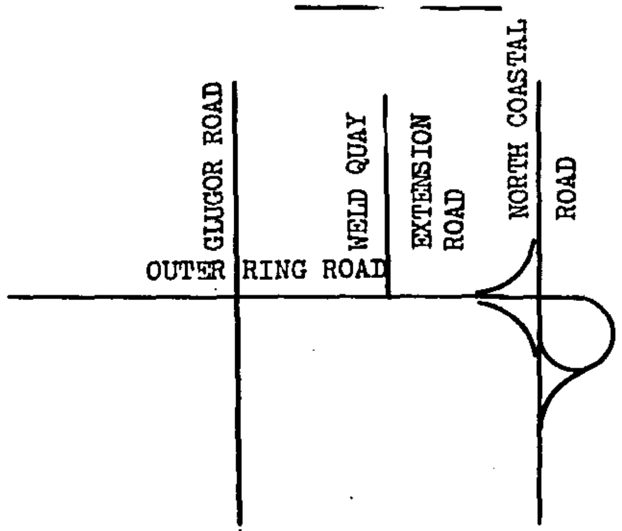
Items / Segment	Length (m)	Construction Cost												Land Acquisition & Compensation Cost	Total Cost				
		Road				Structure				Reclamation									
		F. C	L. C	Tax	Total	F. C	L. C	Tax	Total	F. C	L. C	Tax	Total	L. C	F. C + L. C	F. C	L. C	Tax	Total
0	2,500	4,633	6,909	579	12,121	3,555	2,370	312	6,239	0	0	0	0	12,059	29,526	8,188	21,338	891	30,417
1	800	1,229	1,323	126	2,678	646	431	57	1,124	0	0	0	0	2,331	5,960	1,875	4,085	183	6,143
2	2,000	3,568	5,357	446	9,371	646	431	57	1,124	0	0	0	0	5,662	15,664	4,214	11,450	503	16,167
3	5,900	5,507	6,560	659	12,726	3,385	3,224	298	6,907	0	0	0	0	16,433	35,109	8,892	26,217	957	36,066
4	2,100	2,144	2,998	265	5,407	4,600	2,869	415	7,884	0	0	0	0	9,757	22,368	6,744	15,624	680	23,048
5	4,300	3,937	5,310	462	9,709	3,363	2,381	290	6,034	0	0	0	0	9,056	24,047	7,300	16,747	752	24,799
6	1,050	876	901	97	1,874	798	532	70	1,400	1,154	1,523	172	2,849	0	5,784	2,828	2,956	339	6,123
7	1,120	1,646	2,528	212	4,386	807	538	71	1,416	0	0	0	0	476	5,995	2,453	3,542	283	6,278
8	1,600	843	1,125	111	2,079	1,445	963	127	2,535	0	0	0	0	16,905	21,281	2,288	18,993	238	21,519
9	4,400	2,860	4,044	621	7,525	798	532	70	1,400	6,712	7,773	848	15,333	0	22,719	10,370	12,349	1,539	24,258
10	2,000	583	1,052	103	1,738	0	0	0	0	0	0	0	0	0	1,635	583	1,052	103	1,738

Table 9.11 CONSTRUCTION COST OF SEGMENT: 1

(M$'000)

Items / Type	Length (m)	Construction Cost												Land Acquisition & Compensation Cost	Total Cost				
		Road				Structure				Reclamation					Total			Tax	Total
		F.C	L.C	Tax	Total	F.C	L.C	Tax	Total	F.C	L.C	Tax	Total	L.C	Total	F.C	L.C		
4-lane																			
A	800	1,229	1,323	126	2,678	646	431	57	1,134	0	0	0	0	2,331	5,960	1,875	4,085	183	6,143
B	800	953	1,100	101	2,154	646	431	57	1,134	0	0	0	0	2,331	5,461	1,599	3,862	158	5,619
C	400	289	321	28	638	646	431	57	1,134	0	0	0	0	1,565	3,252	935	2,317	85	3,337
2-lane																			
A	800	358	460	36	854	323	216	29	568	0	0	0	0	1,712	3,069	681	2,388	65	3,134
B	800	358	460	36	854	323	216	29	568	0	0	0	0	1,712	3,069	681	2,388	65	3,134
C	400	234	303	22	559	0	0	0	0	0	0	0	0	1,005	1,542	234	303	22	1,564

TYPE A



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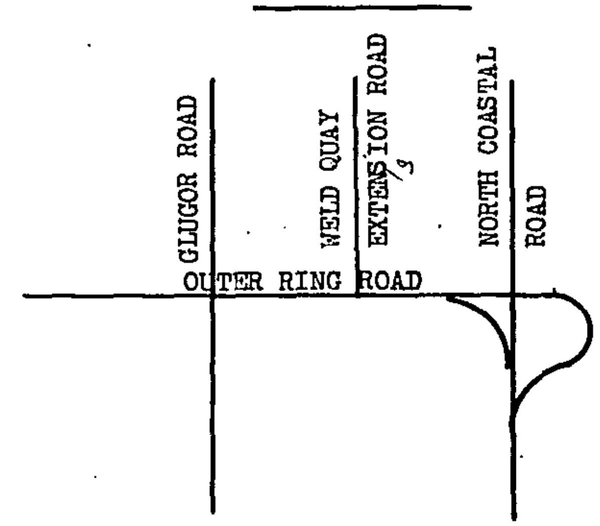

TYPE C

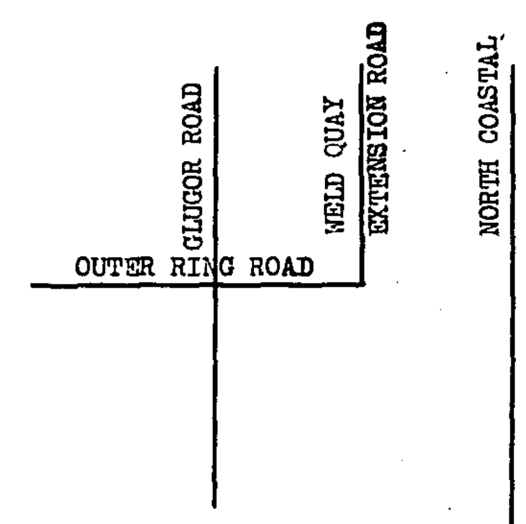

Table 9.12 <u>CONSTRUCTION COST OF BRIDGE</u>

Item / Station	Length (m)	Width (m)	Area (m^2)	Unit Cost L.C	Unit Cost F.C	Unit Cost Tax	Cost L.C	Cost F.C	Cost Tax	Total
N04'+0.0 – N01'+50.0	550	9.0 x 2 = 18.0	9,900	239.4	359.1	31.5	2,370,060	3,555,090	311,850	6,237,000
N01+0.0 – N01+0.0	200	9.0 x 2 = 18.0	3,600	239.4	359.1	31.5	861,840	1,292,760	113,400	2,268,000
N027+70 – N030+40	270	9.0 x 2 = 18.0	4,860	272.1	418.5	36.9	1,322,693	2,033,927	179,412	3,536,032
N045+80 – N046+30	50	9.0 x 2 = 18.0	900	295.6	443.4	38.9	266,040	399,060	35,010	700,110
N067+0 – N067+20	20	9.5 x 2 = 19.0	380	238.6	358.0	31.4	90,668	136,040	11,932	238,640
N073+90 – N074+15	25	9.5 x 2 = 19.0	475	238.6	358.0	31.4	113,335	170,050	14,915	298,300
N077+50 – N079+50	200	9.0 x 2 = 18.0	3,600	239.4	359.1	31.5	861,840	1,292,760	113,400	2,268,000
N088+35 – N092+70	435	9.0 x 2 = 18.0	7,830	294.9	480.3	43.5	2,309,430	3,760,420	340,808	6,410,658
N095+80 – N096+10	30	9.0 x 2 = 18.0	540	238.6	358.0	31.4	128,844	193,320	16,956	339,120
N0111+15 – N0111+40	25	9.0 x 2 = 18.0	450	238.6	358.0	31.4	107,370	161,100	14,130	282,600
N0111+50 – N0113+50	200	9.0 x 2 = 18.0	3,600	239.4	359.1	31.5	861,840	1,292,760	113,400	2,268,000
N0103'+50– N0105'+50	200	9.0 x 2 = 18.0	3,600	295.6	443.4	38.9	1,064,160	1,596,240	140,040	2,800,440
N0112'+40– N0115'+50	310	9.0 x 2 = 18.0	5,580	236.0	316.7	26.8	1,316,820	1,767,171	149,581	3,233,572
N0143'	200	9.0 x 2 = 18.0	3,600	295.6	443.5	38.9	1,064,160	1,596,600	140,040	2,800,800
N0129	200	9.0 x 2 = 18.0	3,600	295.6	443.5	38.9	1,064,160	1,596,600	140,040	2,800,800

Table 9.13 MAINTENANCE COST (2-lane)

(Unit : per km)

	Unit	Unit Cost ($)	Quantity	Cost		
				Economic	Tax (5%)	Total
Resurfacing of road	m^2	5	950	4,750	237	4,987
Roadside trees	km	1,000	1	1,000	50	1,050
Drainage	m	50	100	5,000	250	5,250
Kerb	m	15	100	1,500	75	1,575
Marking and Light	km	1,000	1	1,000	50	1,050
Traffic Signals	km	1,250	1	1,250	63	1,313
Slope Protection	km	0.05	20,000	1,000	50	1,050
Central Reservation	km	0.05	0	0	0	0
Guard-Rail	km	50	50	2,500	125	2,625
Pipe and Kerb Outlet	km	800	1	800	40	840
Bridges and other Structures	km	1,000	1	1,000	50	1,050
Sub-Total				19,800	990	20,790
15% Administrative and Technical Staff				2,970	148	3,118
Total				22,770	1,138	23,908

Table 9.14 MAINTENANCE COST (4-lane)

(Unit : per km)

	Unit	Unit Cost ($)	Quantity	Cost		
				Economic	Tax (5%)	Total
Resurfacing of road	m^2	5	1,900	9,500	475	9,975
Roadside trees	km	1,000	1	1,000	50	1,050
Drainage	m	50	100	5,000	250	5,250
Kerb	m	15	100	1,500	75	1,575
Marking and Light	km	1,000	1	1,000	50	1,050
Traffic Signals	km	1,250	1	1,250	63	1,313
Slope Protection	km^2	0.05	20,000	1,000	50	1,050
Central Reservation	km	0.05	100	50	3	53
Guard-Rail	km	50	50	2,500	125	2,625
Pipe and Kerb Outlet	km	800	1	800	40	840
Bridges and other Structures	km	1,000	1	1,000	50	1,050
Sub-Total				24,600	1,231	25,831
15% Administrative and Technical Staff				3,690	185	3,875
Total				28,290	1,416	29,706

Table 9.15 MAINTENANCE COST OF EACH SEGMENT

Segment	Length (Km)	4-lane			2-lane		
		Economic	Tax	Total	Economic	Tax	Total
Segment 0	2,500	70,725	3,540	74,265	56,925	2,845	59,770
Segment 1	0,800	22,632	1,133	23,765	18,216	0,910	19,126
Segment 2	2,000	56,580	2,832	59,412	45,540	2,276	47,816
Segment 3	5,900	116,911	8,354	177,265	134,343	6,714	141,057
Segment 4	2,100	59,409	2,974	62,383	47,817	2,390	50,207
Segment 5	4,300	121,647	6,089	127,736	97,911	4,893	102,804
Segment 6	1,050	29,705	1,487	31,192	23,909	1,195	25,104
Segment 7	1,120	31,685	1,586	33,201	25,502	1,274	26,776
Segment 8	1,600	45,264	2,266	47,530	36,432	1,821	38,253
Segment 9	4,400	124,476	6,230	130,706	100,188	5,007	105,195
Segment 10	2,000	56,580	2,832	59,412	45,540	2,276	47,816

9.6 Annual Maintenance Cost

Data from "The Malaysia Highway Maintenance Study", "Memorandum for A Case for the Revision for grant-in-aid for maintenance to municipalities in West Malaysia" and other related references were used in the estimation of the annual maintenance cost of the Outer Ring Road in this study. The cross-section of the Outer Ring Road is somewhat different from roads mentioned in the above references and so a change in the items of maintenance cost must be considered.

The following items must be taken into account in the estimation of the annual maintenance cost.

1) Resurfacing of roads

The resurfacing of roads including the carriageway and shoulder is to be carried out once every 10 years. The unit cost of resurfacing per square meter of carriageway and shoulder with 4 cm thick Premixed Asphalt Macadam is estimated at five dollars.

2) Roadside trees

The maintenance of roadside trees consist of the trimming of branches, ensuring water supply, protection of the trees and others. The unit cost is estimated at one thousand dollars per kilometer.

3) Drainage

The lifespan of the drainage system is assumed to be 20 years and 5% of it has to be renewed or repaired every year. The unit cost of maintaining drainage is estimated at fifty dollars per kilometer.

4) Kerbs

The lifespan of kerbs is assumed to be 20 years and 5% of kerbs have to be renewed or repaired every year. The unit cost of changing kerbs is estimated at fifteen dollars per kilometer.

5) Road marking and traffic lights

The maintenance of the above includes road-line painting, kerb repainting, repainting of traffic signs and others. The unit cost is estimated at one thousand dollars per kilometer.

6) Traffic signals

The maintenance of traffic signals includes repairing the signals and renewing them if necessary. The lifespan of signals is 20 years, The unit cost is estimated to be $1,250.

7) Slope protection

It is necessary to upkeep and protect slopes and to cut and plant grass, on cutting slopes and embankment slopes. The width of the slope is 20 meters (total of both sides) and one cutting per month is $0.05 per square meter.

8) Central reservation

The maintenance of the central reservation involves the cutting of grass and pruning of trees. The width of the central reservation is 20 meter and one cutting a month is $0.05 per square meter.

9) Guard-rails

In the maintenance of guard-rails, it is necessary to change and repair the guard-rails and 5% of guard-rails have to be renewed or repaired every year. The cost of changing is estimated to be fifty dollars per kilometer.

10) Scupper pipes and kerb outlet channels

Scupper pipes and kerb outlet have to be cleared regularly. The unit cost is estimated to be eight hundred dollars per kilometer.

11) Bridges and other structures

The condition of bridges and other structures have to be investigated regularly and repaired if found faulty. The unit cost is estimated at one thousand dollars per kilometer.

The maintenance cost is shown in Table 9.13 to 9.15.