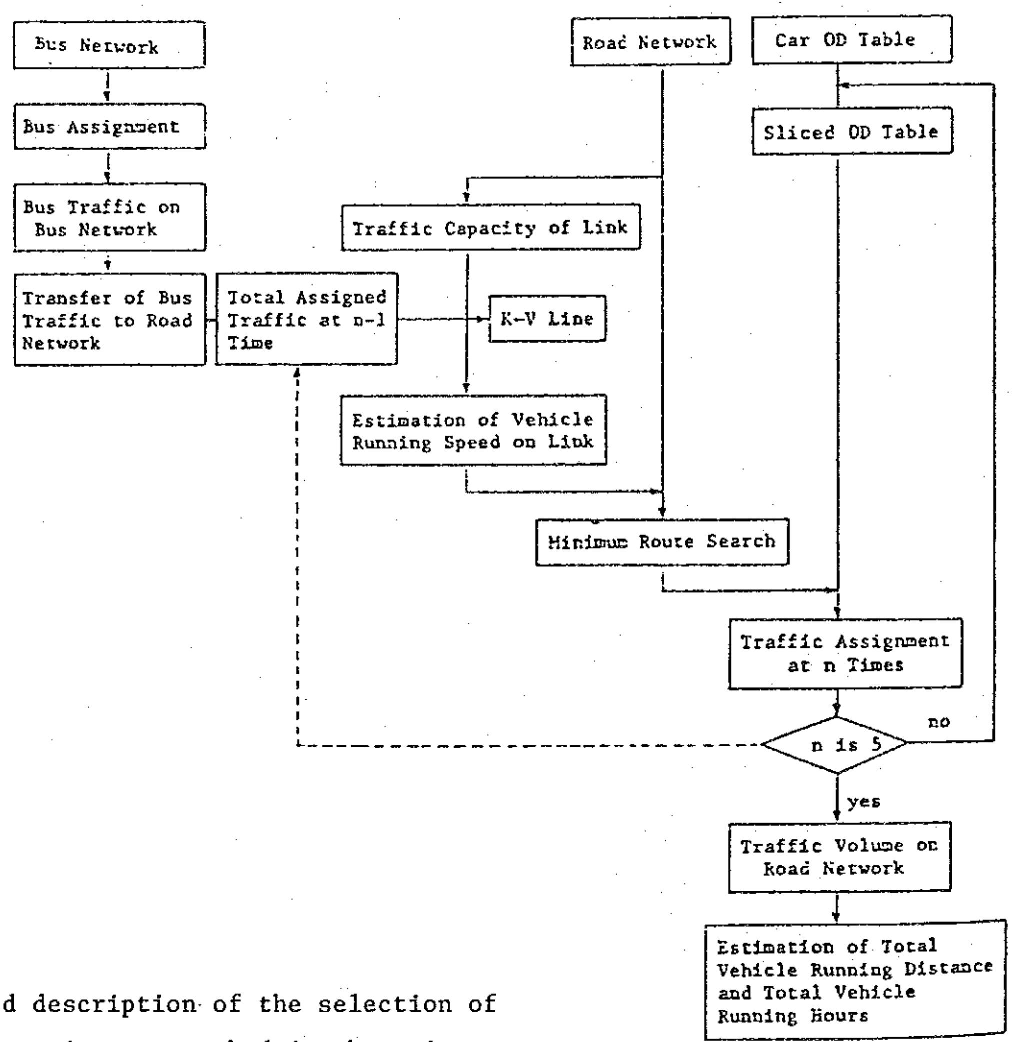
VI.4 Traffic Assignment

VI.4.1 Traffic assignment model

In order to know the traffic demand for each alternative networks, traffic assignment were carried out. The assignment method is practical assignment methoa, the process of which are as follows.

Fig. VI-4-1

Process of Traffic Assignment



Detailed description of the selection of traffic assignment method is shown in VI.6 Study of Traffic Assignment Methods.

VI.4.2 Three alternative routes were prepared for the bypass all of which start from the neighborhood of Wilson Aerodrome and take the same route as far as the eastern end of the Dagoretti Forest but from there until the bypass merge with the existing A104, each takes the shortest, the longest and the intermediate route respectively. The objects of traffic assignment here shall be the shortest route and the longest route only. (Functionally, the intermediate rounte is almost the same as the longest route). Furthermore, both four-lane and two-lane traffic were considered for each proposed plan, as a result of which the following cases were set up.

Alternative A-0	Without Bypass		Target year 2000
A-3-4	Longest bypass	(4-Lane)	"
A-3-2	Longest bypass	(2-Lane)	"
A-1-4	Shortest bypass	(4-Lane)	"
A-1-2	Shortest bypass	(2-Lane)	"
A-2-4	Intermediate bypass	(4-Lane)	"

Alternative A-0 consists of the present trunk roads mainly, the roads under construction and the anticipated planning roads.

(Refer to the Article V.6.2)

VI.4.3 Preparation of the Road Network

The road network is composed of the generating nodes, access links, and the travel links. The generating node is the point at which the traffic in each zone is generated and attracted and is placed at the location which is assumed to be the centre of gravity of the population in each zone. The accsss link is assumed in order to calculate the required time from the generating node.

Traffic capacity and K-V conditional formula were given to each travelling link in order to reflect the travelling condition on the road.

(1) Traffic capacity (Evaluation criterion: daily traffic volume).

Generally, the traffic capacity of a road (as shown in detail in the appendix V-4), means the maximum number of vehicles which can be expected to pass through a traffic lane or to pass a cross-section of a road in a designated amount of time, under actual specified road, traffic, and control conditions. Therefore, when the actual road, traffic, and control conditions have changed, the traffic capacity of the road will also change.

The traffic capacity of each road comprising the network were calculated according to the following formula.

$$C = \frac{C_D/2}{(K/100) \times (D/100)} \times y = C_D \times \frac{5000}{K \times D} \times y$$

(Dual carriage way)

$$C = \frac{C_D}{K/100} \times y = C_D \times \frac{100}{K} \times y$$

(Single carriage way)

Wherein:

- C: Daily traffic volume as the evaluation criterion (P.C.U./24 h)
- C_D: Design capacity (P.C.U./h)
- K: % ratio of the 30th highest hourly traffic volume to annual average 12 hr traffic volume
- D: Percentage of traffic in the direction for peak hours
- Y: Daily/daytime ratio (24 hr/12 hr traffic ratio)

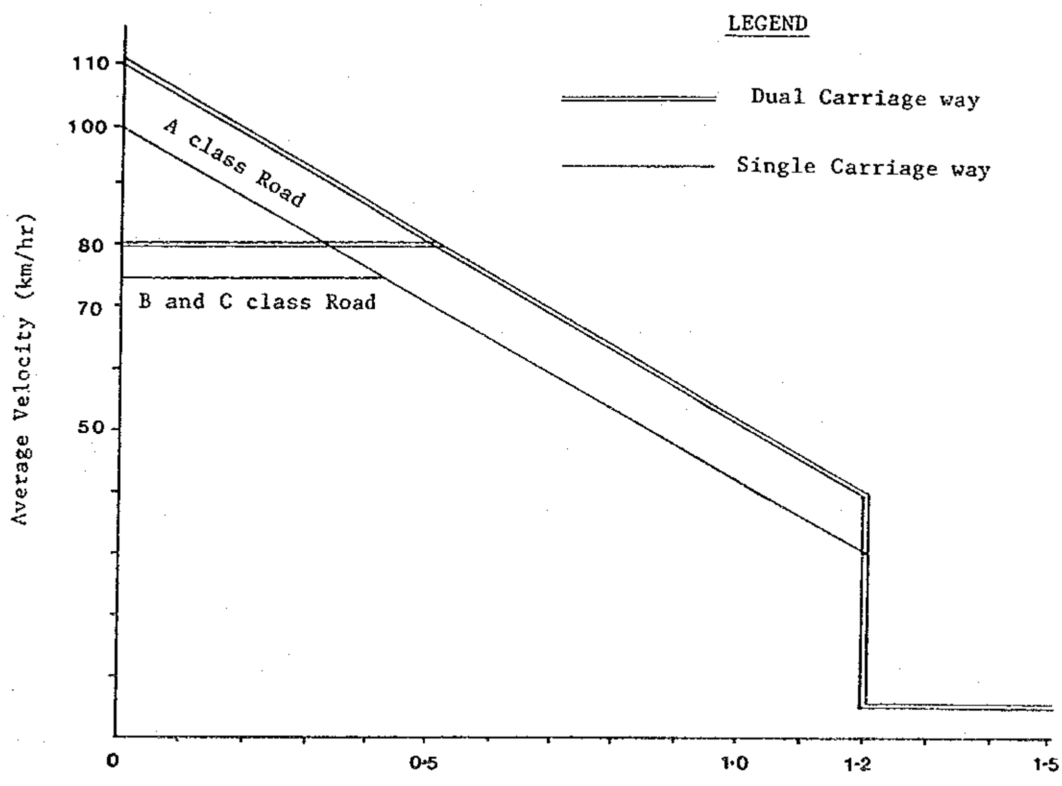
The traffic capacities of each link on each alternative network are shown in Appendix VI-3.

(2) K-V curve

The speed of a vehicle moving on the road is closely related to the traffic volume at the time. Generally, the speed gradually becomes slower as the traffic volume increases, and when the traffic volume has reached capacity, the speed not only becomes slower, but the traffic volume that can be handled also decreases. Such relationship can be represented as the Congestion Rate velocity cure (K-V curve).

Fig. VI-4-2

Relationship between Congestion Rate and Velocity



$$\text{Congestion Rate} = \frac{\text{Actual Traffic Volume (P.C.U)}}{\text{Traffic Capacity (P.C.U.)}}$$

Note: The velocity on the access link was uniformly assumed to be 15 km/hr.

In order to set up a K-V conditional formula that matches the actual state of major roads in the urban area of Nairobi City and the vehicles travelling on them, a travelling speed survey was conducted. Based on the survey results and using the legal speed enforced as a reference, a K-V curve formula as shown on Fig. VI-4-2 was derived.

VI.4.4 Traffic Assignment

The traffic assignment was carried out according to the practical assignment method. The traffic volume of each O-D pair was assigned to each link of the route so as to make the required travel time shortest. In the case of the practical assignment method, the traffic volume of all O-D pairs were partitioned into n parts and assigned n times iteratively. Since the travelling speed on each link of each assignment was determined by the aggregate volume of traffic assigned up to the previous time by referring to the K-V curve formula. The phenomenon of traffic jam or detouring of vehicles that take place with the traffic congestion were reproduced.

In the estimation procedure here, the number of times of partitioning was five times, and the method of partitioning into five equal parts was adopted.

(1) Assignment of K.B.S. Buses and Matatus

Regular route buses excluding sightseeing buses and hired used buses were assigned to the existing bus network (bus travelling links). Also, a new route shall be opened on the bypass in the portion related to the industrial estate, and the new route shall be assigned to this route.

(2) Assignment of motor vehicles

The actual number of units by type of vehicle (car,taxi, light, medium, heavy, bus and matatu) shall be converted into passenger car equivalent units (P.C.U.) respectively, and respective P.C.U.s shall be partitioned into five parts and respectively assigned.

Large-sized motor vehicles (medium, heavy, or buses) occupy a greater area of the road. The speed of large-sized motor vehicles in particular will decrease slope sections, and will cause a decrease in traffic capacity and service volume of traffic.

The amount of this effect is shown by the conversion value (passenger car equivalents) which indicates how many passenger cars are equivalent to a large-sized vehicle. This passenger car equivalent was considered to vary according to the rate of inclusion of large-sized vehicles, the number of lanes, the degree of slope and the length of slope sections.

Basically, in this study, the passenger car equivalent was determined in accordance with the "Japanese Road Struture Ordnances".

In general, the effects of large-sized vehicles on traffic flow, will vary according to the type of vehicle and the running performance of the vehicles. The running performance of vehicles, however, has been improving year by year, and the ratio of large-sized vehicles which have extremely poor hill-climbing ability, will be greatly reduced in future. Therefore the same passenger car equivalent was used for medium and heavy vehicles and for buses.

The "matatu" coefficient, of which there are no examples in Japan, was determined at a rate of 1.5 in consideration of the special properties of its form of operation.

VI.4.5 Assignment Results

A macroscopic comparison of the traffic assignment results of alternative 0, which is the base case, and the four other alternatives assumed is presented on Table VI-4-1 (for the target year of 2000)

Table VI-4-1

Principal Particulars of the Assignment Results (Part 1)

Alter-native	Contents of each alternative	Traffic on the bypass: Vehicle-km	Traffic on the bypass: Vehicle-hours (minutes)	Traffic on the Total Network: Vehicle-km *	Traffic on the Total Network: Vehicle hours **
A-0	Without bypass	-	-	11,156	11,352
A-3-4	Longest bypass plan (4-lane, 30.7km)	424,936	216,768	11,241	11,220
A-3-4	Longest bypass plan (2-lane, 30.7km)	284,504	217,923	11,200	11,334
A-1-4	Shortest bypass plan (4-lane, 28.6km)	544,436	376,400	11,379	11,211
A-1-2	Shortest bypass plan (4-lane, 28.6km)	299,062	242,066	11,213	11,361

* Units in 1,000 Vehicle-km

** Units in 1,000 Vehicle-minutes

Table VI-4-2

Principal Particulars of the Assignment Results (Part 2)

Alternatives	Traffic on the Bypass		Traffic on the Total network	
	Mean Travelling Speed	Mean Congestion Rate	Mean Travelling Speed	Mean Trip Length
	km/h		km/h	km
A-0	-	-	59.0	58.7
A-3-4	37	0.40	60.1	59.2
A-3-2	47	0.91	59.3	59.0
A-1-4	81	0.49	60.9	59.9
A-1-2	37	1.09	59.2	59.0

In order to evaluate the traffic assignment of each alternative, the traffic demand and supply must be balanced. For this purpose, the congestion rate of any link shall not exceed 1.0 as a rule. However, there are cases where due to assignment techniques the congestion rate will inevitably exceed 1.0 on the link which connects to the generating node or on the link which represents a plural number of roads. Also, in the eastern area of Nairobi City where the development of resident and industry of a large scale is planned, a plural number of new roads becomes necessary to respond to the development pattern.

The Traffic Assignment for each Alternative is outlined below.

(1) A-0

All east-west traffic related to the Nairobi area, such as in the City center, between Dagoretti corner and Kabete on C61 and on Langata Road, will be jammed. The mean driving speed is slower by 1 to 2 km/h than the other four plans which are prepared a bypass and the traffic jam will be contained in the city center and will extend over a wide area.

(See Appendix Fig. A-VI-4(1))

(2) A-3-4

Traffic jams in the city center will be somewhat mitigated, and the traffic on Langata Road will be allocated within its capacity, indicating the inducing effect of a bypass. Among the alternatives proposed, the mean travelling speed on the bypass is the fastest at 87 km/h, and the mean travelling speed of the total network is 60.1 km/h which is the second fastest following A-1-4, suggesting that it is a network with a high service level.

(See Appendix Fig. A-VI-4(2))

(3) A-3-2

When viewed from the aspect of time-benefit, the inducement of a two-lane bypass is seen to have some effect, but the average congestion rate of the bypass is high at 0.9, indicating that the plan is capable of meeting the short term targets but out of keeping with the long term target.

(See Appendix Fig. A-VI-4(3))

(4) A-1-4

The distance of the bypass is shorter than A-3-4 by 2.2 km and is somewhat advantageous in terms of cost. The mean travelling speed on the bypass is 81 km/h which is slower than A-3-4 by about 6 km/h, but the mean travelling speed of the total network is 60.9 km/h and is faster than A-3-4 and fastest among all the alternatives.

When attention is paid not only to the bypass alone but to the area of Nairobi as a whole, the network is of the highest service level among the alternatives. The average trip length is longer than the other four alternatives, and the phenomenon of detouring is prominent.

(See Appendix Fig. A-VI-4(4))

(5) A-1-2

The average congestion rate of the bypass exceeds 1.0 and the average vehicle speed is the slowest at 37 km/h. Even when reviewed for the urban area as a whole, the average vehicle speed is the slowest among the four with bypass plans, and almost unchanged from Alternative 0 (without bypass plan), indicating the low effect of inducing a bypass in general.

(See Appendix Fig. A-VI-4(5))

VI.4.6 Conclusion

With increased future trip generation/attraction, the number of bottleneck links over 1.00 congestion rate for the alternative A-0 was counted as 15 links on the representative roads (A104, C58/63, C60/61) and 30 links on all the network.

(See Table VI-4-3)

The effects of the Bypass for reducing the congestion are shown in the number of Bottleneck links, 40-47% reduction on the representative roads and 17-20% for all the network of A-1-4 and A-3-4 and 0-7% on the representative roads and 3% increasing to 0% reduction for all the network of A-1-2 and A-3-2.

This suggests that Alternative network A-1-4 is most effective. It would be most advisable, therefore, to establish a 4-lane bypass on the shortest route by 2,000 year.

Table VI-4-3

Number of Bottleneck Links by Alternative Plan

Alter-native	Future AADT in pcu on the Bypass	No. of Bottleneck Links Over 1.00 Congestion Rate					
		Representative Roads					All
		Bypass	A104	C58/63	C60/61	Subtotal	Network
A-0	-	-	5	4	6	15(100%)	30(100%)
A-1-4	18-26 x 10^3	-	3	1	4	8(53%)	24(80%)
A-3-4	11-24 x 10^3	-	4	1	4	9(60%)	25(83%)
A-1-2	11-12 x 10^3	3	5	3	4	15(100%)	31(103%)
A-3-2	8-11 x 10^3	1	5	3	5	14(93%)	30(100%)

Additionally, when the Bypass is completed as a dual carriageway, the following measures will be required for the future road network to reduce the traffic congestion in the city of Nairobi.

(1) Construction of the Eastern Bypass
(2) Improvement of radial road to the Eastern area of Nairobi; The Jogoo Road Widening and the Koma Rock Road Widening
(3) Intensification of the public transport
(4) Improvement of the Roundabout on the Uhuru Highway to increase traffic capacity
(5) Improvement of the parking facilities in the city centre of Nairobi.

Table VI-4-4 and Appendix Fig. A-VI-4(6) show the case where the Bypass is provided with a single carriageway for the traffic demand in 1986. The diverted traffic on the Bypass was assumed as 4,000 to 9,000 AADT by link for A-1-2 network.

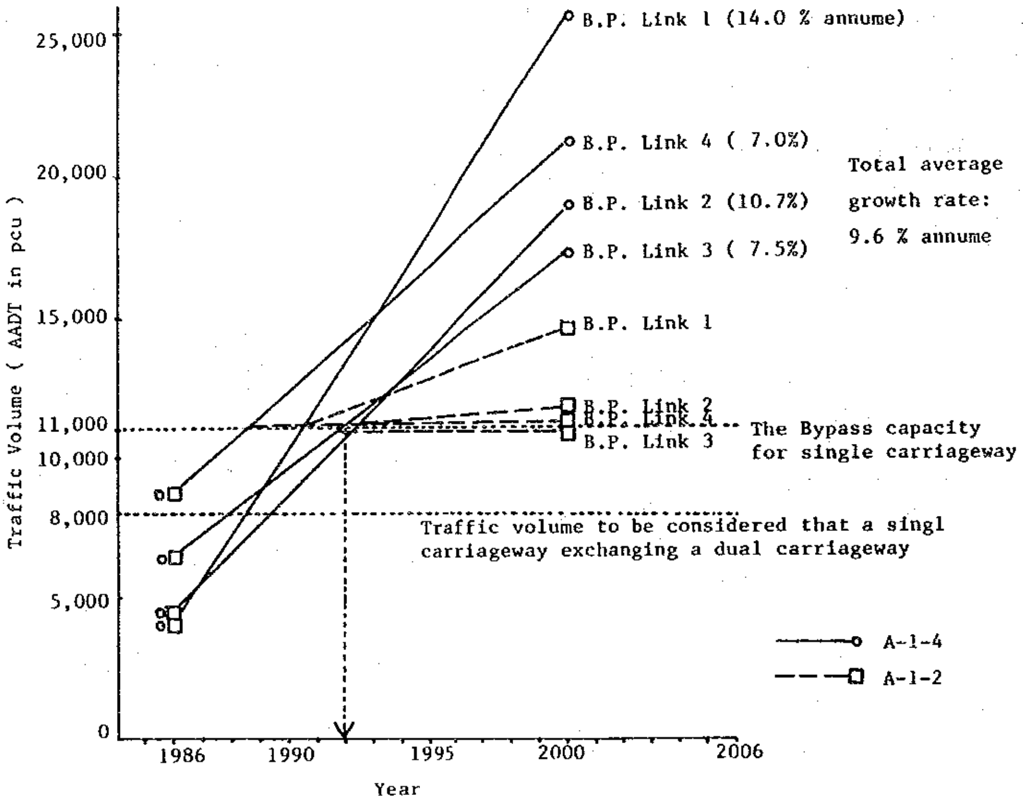
The stage construction of the Bypass should be referred to as to growth rate of the diverted traffic and the capacity of the single carriageway.

The Figure VI-4-3 and the Table VI-4-4 show the growth of Bypass traffic by link. According to the Road Design Manual of Kenya, the Figure VI-4-3 shows that where the traffic volume is over 8,000 in pcu, dual carriageway should be considered and the year to be exchanged for dual carriageway would be in 1992 at latest.

Accordingly, it would be said that a dual carriageway be recommendable in view of traffic planning in the opening year.

Fig. VI-4-3

Consideration of the stage construction



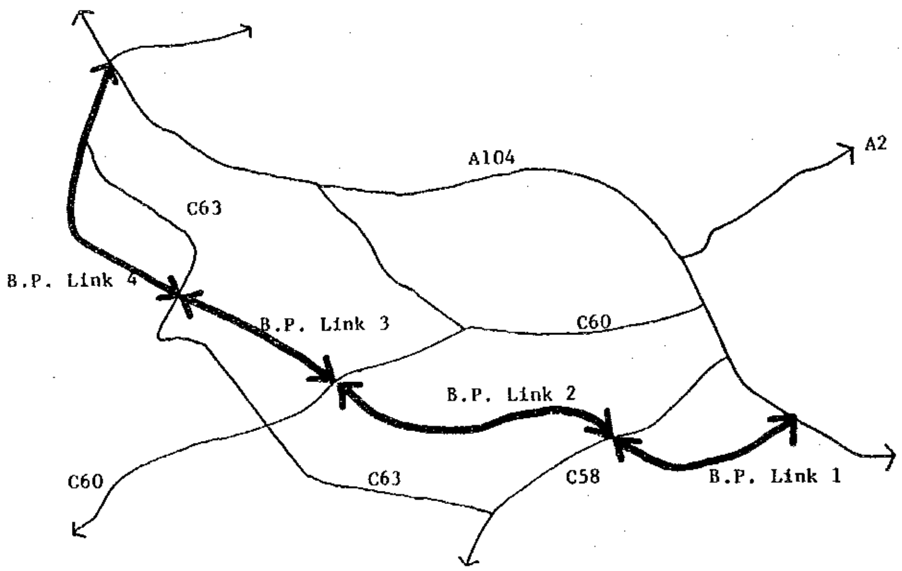


Table VI-4-4

FUTURE TRAFFIC GROWTH OF THE BYPASS BY LINK

		B.P. link-1 (131-132) Both direction			BP link-2(132-133) Both direction		BP link-3(133-134) Both direction		B.P. link-4 (134-22) from 22 to 134		B.P. link-4 (134-22) from 134 to 22			B.P. link-4 (134-22) Both direction	
		AADT	pcu rate	AADT in pcu	AADT	AADT in pcu	AADT	AADT in pcu	AADT	AADT in pcu	AADT	pcu rate	AADT in pcu	AADT	AADT in pcu
2 lane shortest Bypass in 1986	Car,taxi	898	1.0	898	1,208	1,208	3,468	3,468				1.0		3,812	3,812
	Light goods V.	414	1.0	414	934	934	1,675	1,675				1.0		1,846	1,846
	Medium goods V.	588	2.0	1,176	575	1,150	224	448				3.8		295	1,112
	Heavy goods V.	491	2.0	982	465	930	374	748				3.8		412	1,583
	Bus	313	2.0	626	172	344	104	208				3.8		112	429
	Matatu	-	1.5	-	-	-	-	-				1.5		-	-
	Total	2,704		4,096	3,354	4,566	5,845	6,547						6,477	8,782
		100.0		100.0	100.0	100.0	100.0	100.0						100.0	100.0
2 lane shortest Bypass in 2000	Car,taxi	5,790	1.0	5,790	4,517	4,517	5,274	5,274				1.0		3,853	3,853
	Light goods V.	4,200	1.0	4,200	3,534	3,534	3,620	3,620				1.0		2,628	2,628
	Medium goods V.	943	2.0	1,886	771	1,542	259	518				3.8		383	1,459
	Heavy goods V.	855	2.0	1,710	749	1,498	597	1,194				3.8		701	2,711
	Bus	449	2.0	898	287	574	121	242				3.8		148	571
	Matatu	-	1.5	-	-	-	-	-				1.5		-	-
	Total	12,237		14,484	9,858	11,665	9,871	10,848						7,713	11,222
		452.6		353.6	293.9	255.5	168.9	165.6						119.1	127.8
4 lane shortest Bypass in 2000	Car,taxi	12,750	1.0	12,750	8,780	8,780	9,371	9,371	4,973	4,973	5,498	1.0	5,498	10,921	10,921
	Light goods V.	8,272	1.0	8,272	6,547	6,547	5,220	5,220	3,549	3,549	3,039	1.0	3,039	6,588	6,588
	Medium goods V.	965	2.0	1,930	771	1,542	659	1,318	303	606	380	3.8	1,444	683	2,050
	Heavy goods V.	1,066	2.0	2,131	999	1,998	1,027	2,054	581	1,162	520	3.8	1,976	1,101	3,138
	Bus	255	2.0	510	37	74	41	82	27	54	21	3.8	80	48	134
	Matatu	-	1.5	-	-	-	-	-	-	-	-	1.5	-	-	-
	Total	23,308		25,594	17,134	18,941	16,318	18,045	9,433	10,344	9,908		12,037	19,341	22,831
		862.0		624.9	510.8	414.8	279.2	275.6						298.6	260.0
Annual average growth rate of 4-lane Bypass (from 1986 to 2000)		16.6%		14.0%	12.4%	10.7%	7.6%	7.5%						8.1%	7.0%

VI-4-7. Converted Traffic

(1) Objectives of analysis

When measuring the effects of improvement on ordinary urban roads, the shortening of driving time and vehicle running distance in the entire road network constitutes the benefits to be measured generally.

The construction of the bypass, however, has two major purposes, that is, converting the through traffic of Nairobi from A104 (international trunk road) and eliminating traffic congestion on the roads inside the city. It is necessary, therefore, to divide the bypass traffic according to the purposes of utilization, and then the benefits pertaining to each division constitute the effects of improvement to be measured.

In addition, the benefits arising from this project ought to be calculated conservatively, as a basic rule, regarding the items capable of being quantified. There is something numerically uncertain and negligible amount on the urban road network about the development traffic and induced traffic which arise incidentally after completion of the bypass. Because, most of development schems are including in the futuve Land-use plan and most of existing roads are already paved. Excluding these, therefore, the future traffic assigned to the bypass should include only the normal traffic converted from the existing roads.

(2) Results of analysis

Standpoints of analysis

There are three different standpoints of analysis, as described below, concerning the forecasted bypass traffic in A.D. 2000. The conditions of bypass utilization and the characteristics of bypass traffic will be analyzed from these standpoints.

- Trends of bypass utilization categorized by the type of traffic (internal, external, and through traffic).
- The rate of traffic conversion into the bypass (the traffic utilizing the bypass/the total traffic of OD pairs utilizing the bypass x 100).
- The traffic converted from A104 in the traffic utilizing the bypass throughout.

Results of analysis

Table VI-4-5 shows the distribution ratio and conversion rate of the traffic utilizing the bypass classified by Bypass link and itemized by traffic category. Using both of the table VI-4-5 and the converted OD trip table (given in the appendix), the trends of bypass utilization and the characteristics of bypass traffic were analyzed and the volume of traffic converted from A104 into the bypass was calculated.

The results of analysis are summarized as follows.

a) Regarding the bypass traffic volume itemized by traffic category, the internal plus external traffics represent more than 90% in every section, whereas the through traffic ranges approximately from about 1,200 to 1,300 vehicle/day, accounting for less than 10% of the total traffic. (see table VI-4-5)

b) The bypass conversion rate becomes higher as the direction of the desired line between zones becomes closer to that of the bypass route. (see appendix table)

c) The through traffic has its trip ends over the extensions of both beginning and ending points of the bypass. For reasons stated in b) above, the through traffic shows a very high conversion rate (over 95%). (see table VI-4-5)

d) The conversion rates of external and internal traffics are about 80% and 50% respectively. This is suggestive of a tendency that the bypass conversion rate becomes lower as the gap between the direction of the bypass route and that of the desired line becomes greater. Such a tendency seems to reflect the effect of the traffic assignment method that is capable of selecting the shortest time route. (see table VI-4-5)

e) The traffic converted from A104 and running throughout the bypass is considered to include both the through traffic and external traffic which has its origin around the beginning point of the bypass (in or around the airport, industrial area, and other districts) and its destination beyond the ending point of the bypass. The results of an analysis of converted O.D. trips on the Bypass show that the volume of converted-throughout traffic amounts to a total of 6,282 vehicle/day, consisting of 1,213 through and 5,069 external trips (see table VI-4-6). The bypass conversion rates of these cars are almost 100%.

f) The converted traffic from A104 throughout the bypass which is anticipated through traffic of Nairobi in 2,000 will reach about 1,210 VPD, as shown in Table VI-4-6. The traffic of passenger cars and light goods vehicles amounts to about 570 VPD.

Nairobi City Commission is planning to build a truck terminal near the starting point of the bypass and also planning the prohibitation of the truck parking in the city center. As a result of these public estabiishments, the traffic of freight vehicles will most certainly be converted to the bypass rather than passing through the city center.

Let us assume, nonetheless, that all passenger cars and light goods vehicles (570 VPD) or half of the whole traffic (600 VPD) may go by way of the city center instead of being converted to the bypass, although it is an unrealistic assumption. Even if this becomes realistic, only a drease of 600 VPD out of the calculated 6,282 VPD which is only 9.5% reduction of the traffic.

The decrease of 600 VPD which is mere 2.6 to 3.7% of the total bypass traffic (ranging from 16,318 to 23,308 VPD) is equivalent to a decrease by about 3% of the whole benefits. This is covered within the range of 20% benefit cutdown in the sensitivity analysis.

It is true that Nairobi is well situated for accommodation, shopping, and other purposes. Therefore it may be considered that some of the through traffic may not select the bypass. The numerical values given above have been estimated on the basis of a traffic assignment model which applied the practical assignment method in order to estimate the traffic figures. These figures are not precisely identical with the real values.

In this respect, it is probable that a few passenger car and light goods vehicle driving through Nairobi City may drop into the city center, not diverting their course to the bypass. It is difficult, however, to determine the exact percentage. In addition, the probability would produce very little, or rather negligible, effect on the future traffic of the bypass and the economic evaluation of the project. Therefore, we believe that the estimated values based on the traffic assignment model are applicable, without any modification, for the calculation of benefits.

g) Therefore, the traffic volume excluding 6,282 vehicle/day constitutes the volume of other converted traffic (see Table VI-4-6).

The volume of converted traffic other than from A104 to the bypass is expected to reach 10,040 to 17,030 VPD (depending on different bypass links) by 2,000 years. These trips most often originate in Nairobi City. In the case of closer direction of their OD pairs to that of the bypass route, the higher conversion rate to the bypass was assigned. In addition, there are OD pairs with high growth potential, linking the increasingly populous districts to urban centers and industrial areas such as South-west and South-east development area of Nairobi. The direction of these OD pairs is close to that of the bypass route and therefore the high conversion retes was assignd in these pairs.

Based of the results of the traffic assignment in the case of without bypass in 2,000, Future traffic volume on C61 was forecasted about 45,800 AADT in PCU and the congestion rate on C61 was estimated over 1.0 (see Appendix Feg. A-VI-3(2)). But in the case of with bypass in 2,000, Future traffic volume on C61 was forecasted as about 28,600 AADT in PCU and the congestion rate on C61 was decreased as under 1.0 by the results of reasonable amount of converted traffic from the roads other than A104 to the bypass. (see Appendix Fig. A-VI-3(5))

Due to the reasons decribed above, it was forecasted that much of the traffic from roads other than A104 was assigned to the bypass.

Concerning the forecasted bypass traffic in A.D. 2,000, the volume of bypass traffic in 1991 is also shown in Table VI-4-6 for the benefit calculation.

The traffic volume in 1991 has been determined on the basis of interpolation between the traffic volumes in 1986 and 2000.

Furthermore, the future traffic volume on A104 by type of car which will be used for the benefit calculation is shown in Table VI-4-7.

Table VI-4-5 Trends of Bypass Utilization in 2000 by the Bypass Link

Bypass Link / Traffic Category	Link 1			Link 2			Link 3			Link 4		
	Traffic Volume (100 VPD)	Distribution ratio (%)	Conversion rate (%)	Traffic Volume (100 VPD)	Distribution ratio (%)	Conversion rate (%)	Traffic Volume (100 VPD)	Distribution ratio (%)	Conversion rate (%)	Traffic Volume (100 VPD)	Distribution ratio (%)	Conversion rate (%)
Internal Traffic	138	60	64	80	47	49	61	38	47	75	39	51
External Traffic	82	35	84	79	46	80	90	55	78	105	54	74
Through Traffic	12	5	95	12	7	98	12	7	100	13	7	99
Total	232	100	71	171	100	62	163	100	63	193	100	64

Note:

Internal Traffic : Zone pairs having both trip ends inside Nairobi City

External Traffic : Zone pairs having their trip ends both inside and outside of Nairobi City

THrough Traffic : Zone pairs passing through Nairobi City

TABLE VI-4-6 TOTAL CONVERTED TRAFFIC TO THE BYPASS BY LINK

Unite: AADT

Bypass Link No.	Converted Traffic from		Year in 1991							Year in 2000						
			Car	L.G.V.	M.C.V.	H.G.V.	BUS	MA.	Total	Car	L.G.V.	M.G.V.	H.G.V.	BUS	MA.	Total
1	from A104	(1)	237	150	122	388	11	--	908	351	222	132	496	12	--	1,213
		(2)	1,009	1,336	415	424	18	--	3,202	1,778	2,309	460	502	20	--	5,069
		(1)+(2)	1,246	1,486	537	812	29	--	4,110	2,129	2,353	592	998	32	--	6,282
	from other roads		3,990	1,799	186	13	135	--	6,123	10,621	5,919	373	68	223	--	17,026
	Total		5,236	3,285	723	825	164	--	10,233	12,750	8,272	965	1,066	255	--	23,308
2	from A104	(1)	237	150	122	388	11	--	908	351	222	132	496	12	--	1,213
		(2)	1,009	1,336	415	424	18	--	3,202	1,778	2,309	460	502	20	--	5,069
		(1)+(2)	1,246	1,486	537	812	29	--	4,110	2,129	2,353	592	998	32	--	6,282
	from other roads		3,009	1,626	38	4	4	--	4,681	6,651	4,194	179	1	5	--	10,852
	Total		4,255	3,112	575	816	33	--	8,791	8,780	6,547	771	999	37	--	17,134
3	from A104	(1)	237	150	122	388	11	--	908	351	222	132	496	12	--	1,213
		(2)	1,009	1,336	415	425	18	--	3,202	1,778	2,309	460	502	20	--	5,069
		(1)+(2)	1,246	1,486	537	812	29	--	4,110	2,129	2,353	592	998	32	--	6,282
	from other roads		3,871	1,136	105	78	4	--	5,194	7,242	2,867	67	29	9	--	10,036
	Total		5,117	2,622	642	890	33	--	9,304	9,371	5,220	659	1,027	41	--	16,318
4	from A104	(1)	237	150	122	388	11	--	908	351	222	132	496	12	--	1,213
		(2)	1,009	1,336	415	425	18	--	3,202	1,778	2,309	460	502	20	--	5,069
		(1)+(2)	1,246	1,486	537	812	29	--	4,110	2,129	2,353	592	998	32	--	6,282
	from other roads		5,727	1,940	89	103	16	--	7,875	8,792	4,235	91	103	16	--	13,059
	Total		6,973	3,426	626	915	45	--	11,985	10,921	6,588	683	1,101	48	--	19,341

Note:
- L.G.V. : Light Goods Vehicle
- M.G.V. : Medium Goods Vehicle
- H.G.V. : Heavy Goods Vehicle
- MA. : Matatu

(1) : Through-Traffic of Nairobi converted from A104 to Bypass
(2) : Converted from A104 to Bypass of both or either O-D inside Nairobi (External Traffic)

Table VI-4-7 AADT on A104 in the case of Alternative A-1-4

(Vehicle/day)

Link No. of A104	Original Link No.	Year in 1991							Year in 2000						
		Car	L.G.V.	M.G.V.	H.G.V.	BUS	MA.	Total	Car	L.G.V.	M.G.V.	H.G.V.	BUS	MA.	Total
A104-1	1043	4,514	2,590	356	279	274	808	8,821	5,620	3,954	340	294	313	808	11,329
	1044	5,819	2,695	411	190	275	538	9,928	6,571	3,470	414	205	299	538	11,497
	Both Direction	10,333	5,285	767	469	549	1,346	18,749	12,191	7,424	754	499	612	1,346	22,826
A104-2	1001	9,549	4,755	373	162	174	638	15,651	9,328	5,517	387	173	181	638	16,224
	1002	9,585	4,283	302	79	205	638	15,092	8,714	4,648	316	80	222	638	14,618
	Both Direction	19,134	9,038	675	241	379	1,276	30,743	18,042	10,165	703	253	403	1,276	30,842
A104-3	1008	11,252	6,354	396	187	570	638	19,397	13,490	8,429	412	197	593	638	23,759
	1009	11,598	5,961	394	184	408	638	19,183	13,329	7,454	407	187	429	638	22,444
	Both Direction	22,850	12,315	790	371	978	1,276	38,580	26,819	15,883	819	384	1,022	1,276	46,203
A104-4	1010	9,620	5,061	194	139	552	638	16,204	11,838	6,880	202	142	553	638	20,253
	1011	9,811	4,703	209	143	519	638	16,023	11,274	5,833	221	147	524	638	18,637
	Both Direction	19,431	9,764	403	282	1,071	1,276	32,227	23,112	12,713	423	289	1,077	1,276	38,890
A104-5	1012	10,160	5,567	199	139	552	638	17,255	13,315	8,399	207	142	553	638	23,254
	1013	10,315	5,154	208	143	519	638	16,977	12,558	7,162	220	147	524	638	21,249
	Both Direction	20,475	10,721	407	282	1,071	1,276	34,232	25,873	15,561	427	289	1,077	1,276	44,503
A104-6	1014	5,636	3,157	79	11	339	1,128	10,350	8,791	5,989	87	14	340	1,128	16,349
	1056	5,791	2,744	88	15	345	1,128	10,111	8,034	4,752	100	19	345	1,128	14,378
	Both Direction	11,427	5,901	167	26	684	2,256	20,461	16,825	10,741	187	33	685	2,256	30,727
A104-7	1015	5,742	3,061	71	16	344	1,128	10,362	9,285	5,999	81	23	347	1,128	16,863
	1057	6,005	2,622	45	10	346	1,128	10,156	8,583	4,636	49	13	354	1,128	14,763
	Both Direction	11,747	5,683	116	26	690	2,256	20,518	17,868	10,635	130	36	701	2,256	31,626
A104-8	1016	3,404	2,248	57	17	358	1,074	7,158	6,512	4,751	68	23	372	1,074	12,800
	1017	3,926	2,170	73	16	347	1,182	7,714	6,190	4,114	94	21	372	1,182	11,973
	Both Direction	7,330	4,418	130	33	705	2,256	14,872	12,702	8,865	162	44	744	2,256	24,773
A104-9	1018	3,478	1,995	165	5	321	236	6,200	5,382	3,476	232	8	332	236	9,666
	1058	3,272	1,664	144	30	343	236	5,689	4,634	2,706	239	47	367	236	8,229
	Both Direction	6,750	3,659	309	35	664	472	11,889	10,016	6,182	471	55	699	472	17,895

Note L.G.V. : Light Goods Vehicle M.G.V. : Medium Goods Vehicle
H.G.V. : Heavy Goods Vehicle MA. : MATATU

VI.5 Junction Traffic

Future traffic by direction on each junction were estimated by Alternative plans and shown in Fig. VI-5-1, VI-5-2 and VI-5-3.

Classifications of junction were settled shown as in Table VI-5-1 considering with land use, geographical conditions and the volume of junction traffic by direction.

The Mombasa road and Uhuru monument junctions were each considered Grade separation due to manage the large amount of Future Traffic Volume. The Ngong road, Dagoretti forest and Kikuyu junctions were considered as Grade separation due to steep geographical conditions and the relation with the proposed grade separation of the Kabete-Limuru Road Project.

For the stage of the selection of the optimum route, at-grade junctions were not considered for a high-grade road service.

At-grade junction also were reviewed at the stage of the preliminary designing.

Fig. VI-5-1

FUTURE JUNCTION TRAFFIC FOR THE ALTERNATIVE PLAN (A-1-4) IN 2000

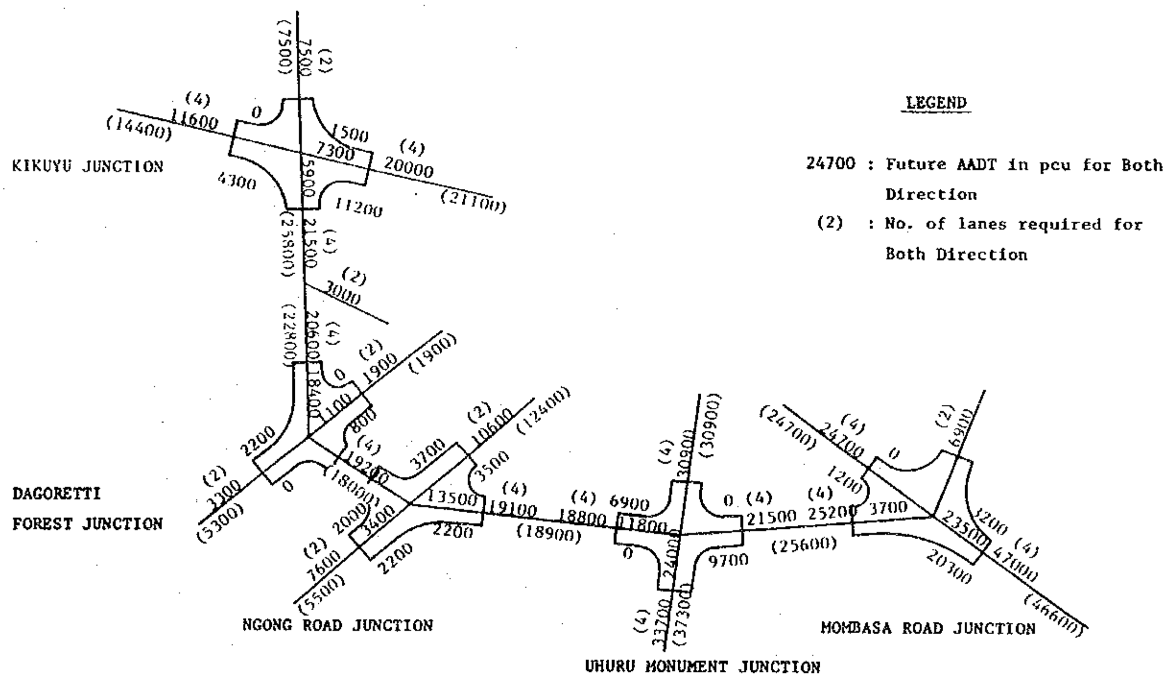


Fig. VI-5-2

FUTURE JUNCTION TRAFFIC FOR THE ALTERNATIVE PLAN (A-2-4) IN 2000

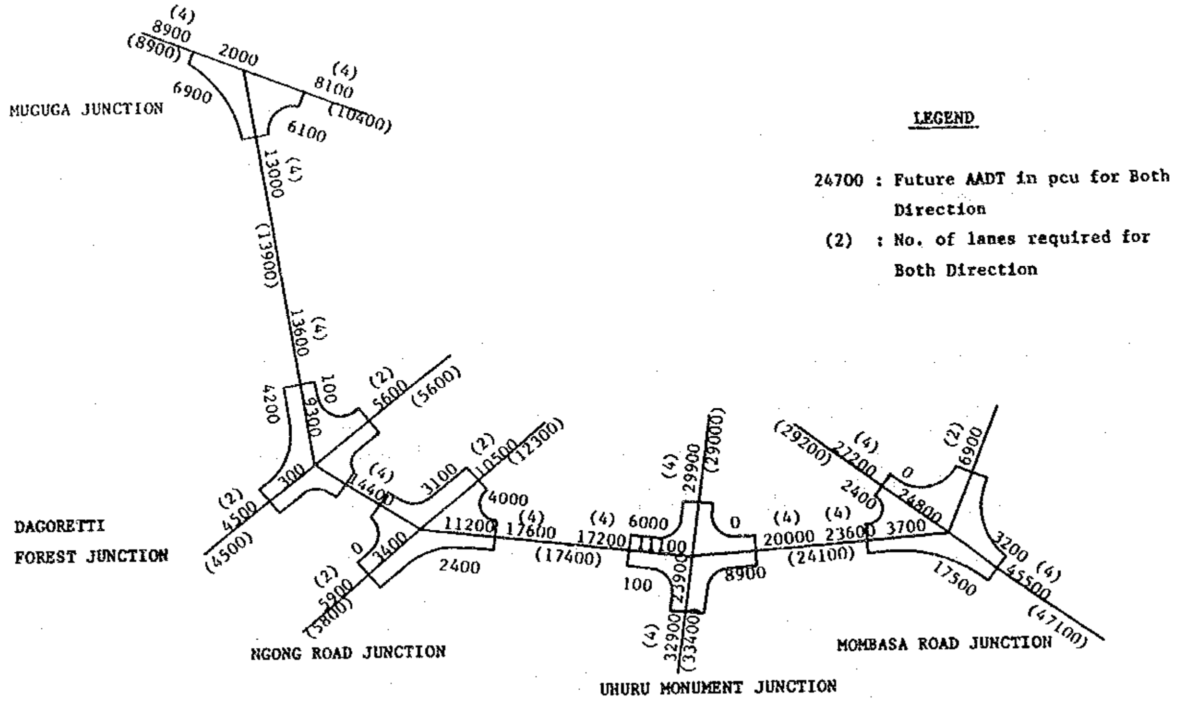


Fig. VI-5-3

FUTURE JUNCTION TRAFFIC FOR THE ALTERNATIVE PLAN (A-3-4) IN 2000

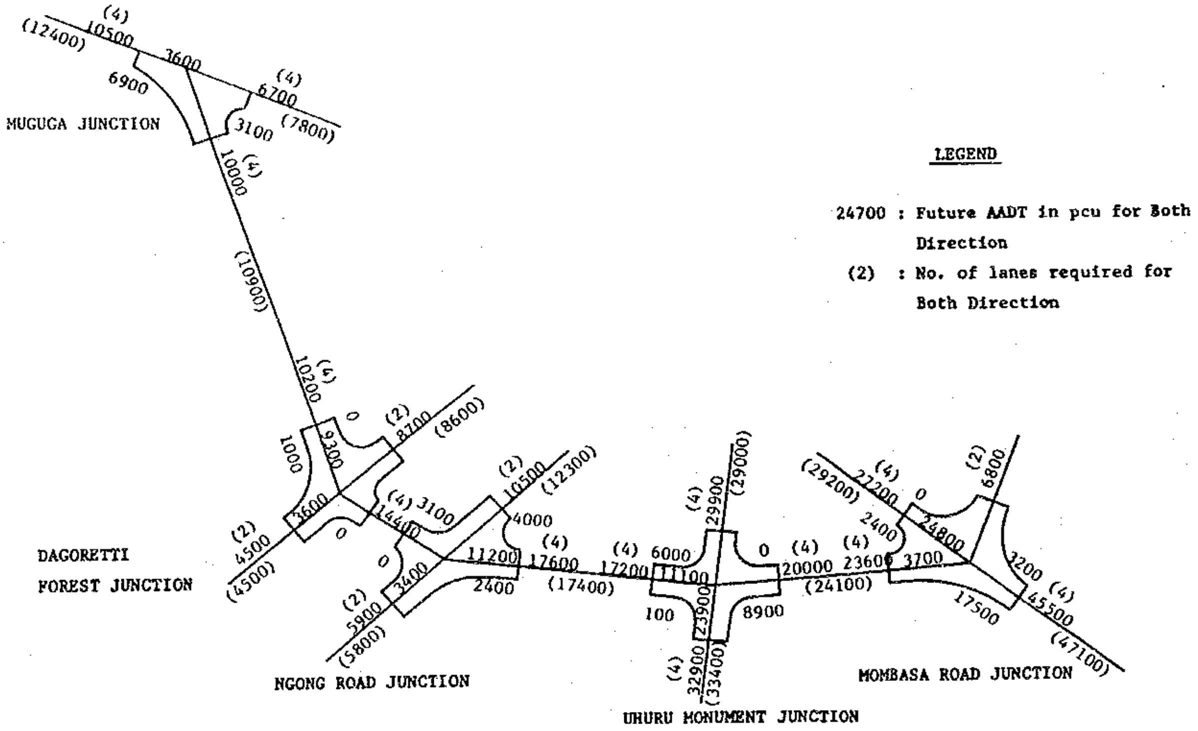


Table VI-5-1

Classifications of Junctions Considered

Junction Name	Cross Road No. Name of Lanes	Future Cutted Traffic	Alternative Plan A-1-4	A-2-4	A-3-4
Mombasa A104 Road Junction	4	23,500 -24,800	Grade Separation	-do-	-do-
Uhuru Mombasa C58	4	23,900 -24,000	Grade Separation	-do-	-do-
Junction with new Road between C58 and C60	-	16,600 -17,900	No Junction was considered, because of steep geographical future	-do-	-do-
Ngong Road Junction C60	2	3,400	Grade separation was considered for the geographical condition	-do-	-do
Dagoretti Forest Junction	2	300 -3,600	-do	-do	-do-
Kikuyu A104	4	7,300	Grade Separation was considered, because of the proposed grade separtion of the Kabete-Limuru Road Project	Nil	Nil
Muguga A104	4	2,000 -3,600	Nil	At grade and grade Separation	-do

VI.5.1 Study of Grade Separation

(a) Mombasa Road Junction

Full Cloverleaf Junctions were considered for each Alternative plans, but some of the ramps have no traffic and are useless. (See Fig. VI-5-4)
Therefore a Partial Cloverleaf Junction was recommended.

(b) Uhuru Monument Junction

Diamond Junctions and Partial Cloverleaf Junctions were considered for each Alternative plan, but there were some ramps with no traffic and two cutting sections making it impossible to manage the traffic on the Diamond Junctions. (See Fig. VI-5-5)
Therefore, Partial Cloverleaf Junctions were recommended.

(c) Ngong Road Junction

Diamond Junctions were considered due to topographical conditions. (See Fig. VI-5-6)

(d) Dagoretti Forest Junction

Diamond Junctions and Partial Cloverleaf Junctions were considered. (See Fig. VI-5-7). For reasons of reduction of Construction Cost and safety, Partial Cloverleaf Junctions were recommended.

(e) Kikuyu Junction

With respect to the proposed grade separation, Partial Cloverleaf Junction and Directional Junctions were considered and Directional Junction was recommendable taking into consideration the Design Speed required for the Bypass. (See Fig. VI-5-8)

(f) Muguga Junction

Y - junctions were recommended taking into consideration the future traffic volume and construction cost. (See Fig. VI-5-9)

Fig. VI-5-4

Mombasa Road Junction

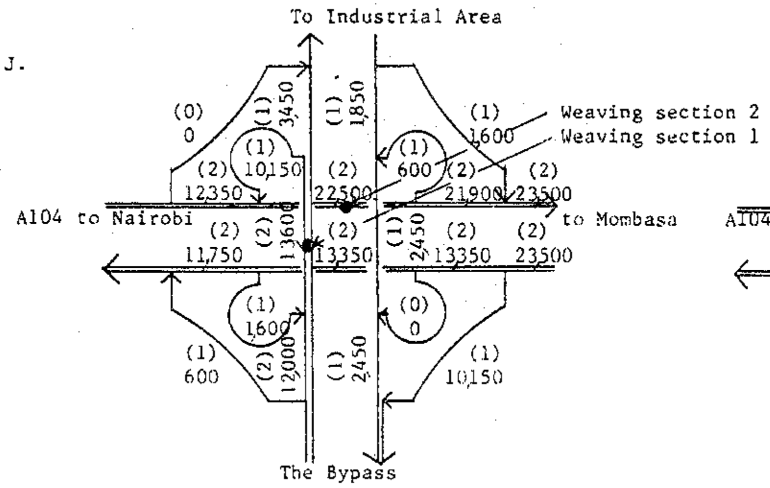
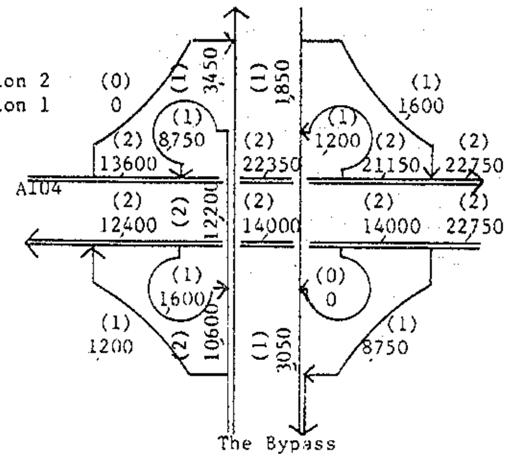
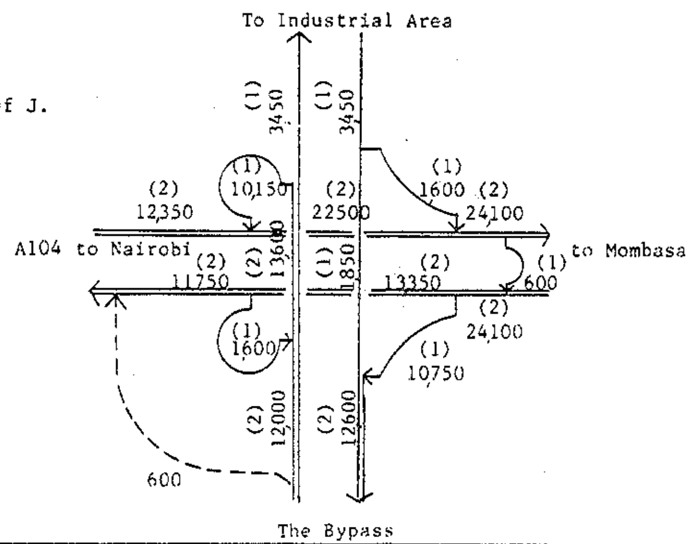
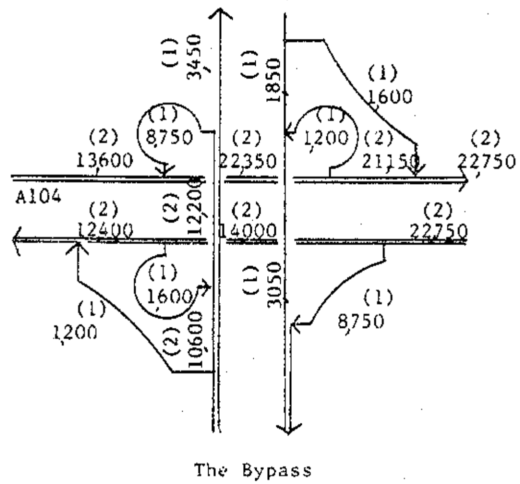
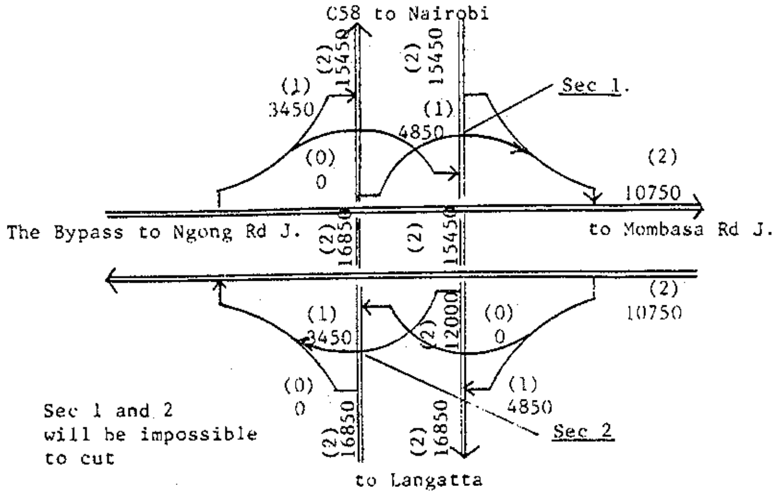
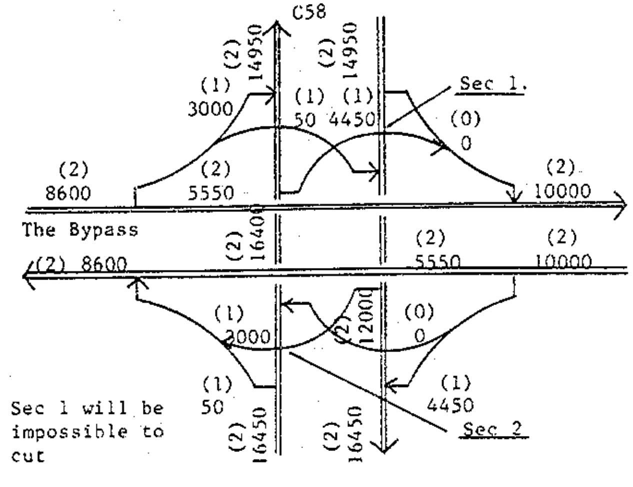
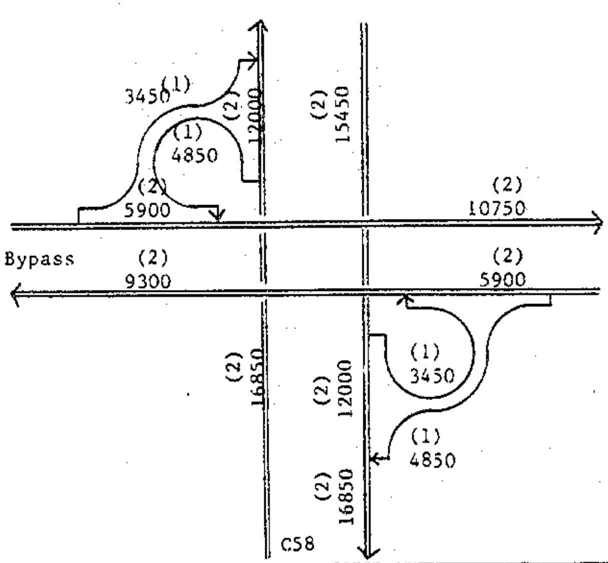
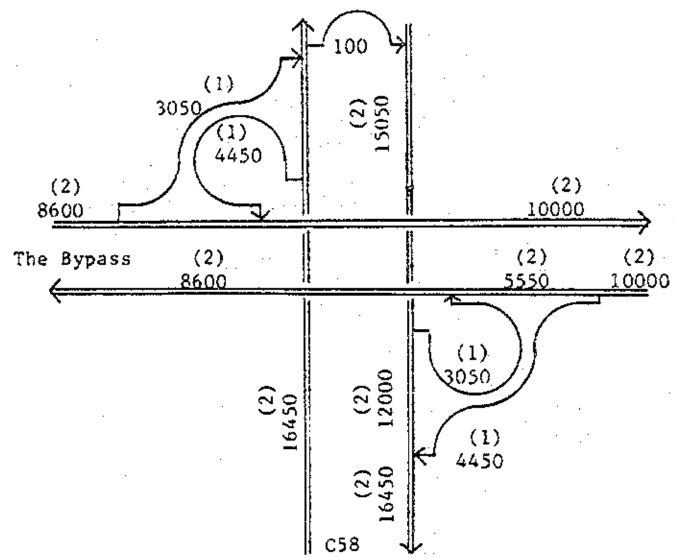
CASE	Future AADT and No. of lanes required by the Alternative plan: A - 1 - 4	Future AADT and No. of lanes required by the Alternative plan: A - 2 - 4 and A - 3 - 4	comments
Case 1 : Full Cloverleaf J.			Based on the Future Weaving Traffic on each weaving sections, the calculated weaving length required are; more than 10 m length on the weaving section 1 ; and more than 25m length on the weaving section 2.
Case 2 : Partial Cloverleaf J.			- do -

Fig. VI-5-5

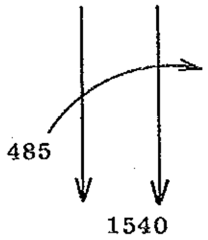
Uhuru Monument Junction

Case	Future AADT and No. of lanes required by the Alternative plan	
	A - 1 - 4	A - 2 - 4 and A - 3 - 4
Case 1 : Diamond J.		
Case 2 : Half Cloverleaf J.		

Capacity Calculation for Uhuru Monument Junction

A-1-4/Diamond J.   Refering to the Design Manual of Kenya

Section 1



Manoeuvre: Cutting

Q = 1540 PCU/hr (Peak hour Rate 10%)

Junction design speed = 15km/hr

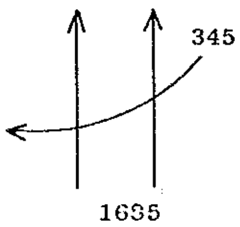
Capacity Curve: B(6 Secs.)

Capacity of minor road flows

= 380 PCU/hr < 485 PCU/hr.

Therefore Cutting will be impossible

Section 2



Manoeuvre: Cutting

Q = 1685 PCU/hr Peak hour Rate 10%

Junction design speed = 65 PCU/hr

Capacity Curve: B(6 secs.)

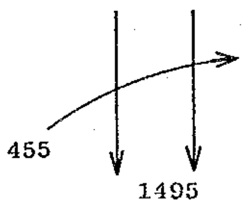
Capacity of minor road flows

= 320 PCU/hr < 345 PCU/hr.

Therefore Cutting will be impossible

A-2-4, A-3-4/Diamond J.

Section 1



Manoeuvre: Cutting

Q = 1495 PCU/hr

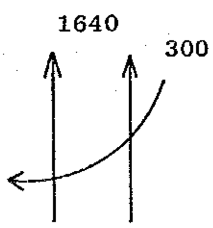
Junction design speed = 65/hr

Capacity Curve: B(6 secs.)

= 410 PCU/hr < 445 PCU/hr.

Therefore Cutting will be impossible

Section 2



Manoeuvre: Cutting

Q = 1640

J.D.S. = 65km/hr.

C.C. : B(6 secs.)

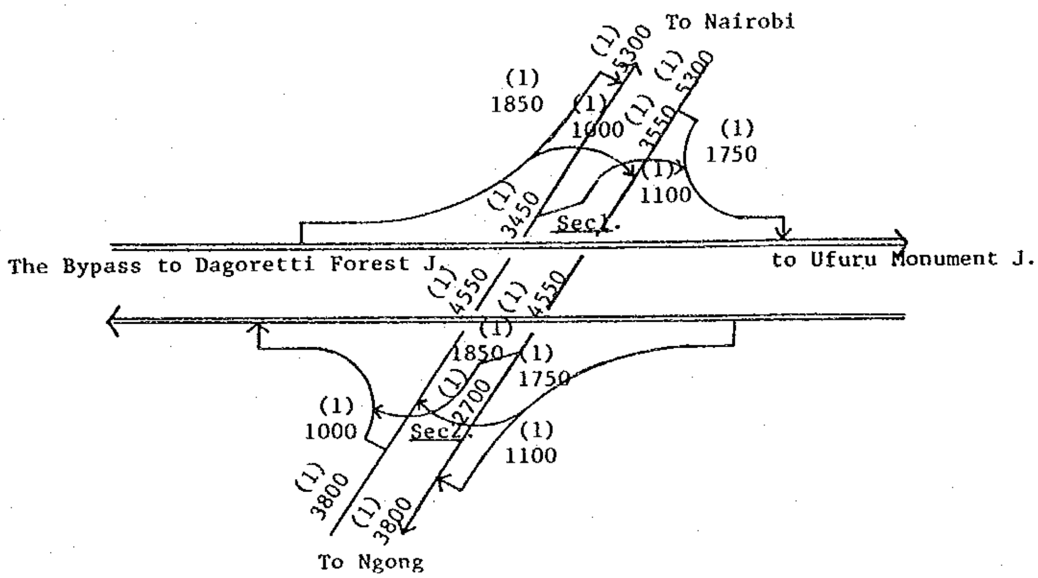
Cpacity of minor road flows

= 335 PCU/hr > 300 PCU/hr

Cutting will be possible

Fig. VI-5-6

Ngong Road Junction (A-1-4, A-2-4, A-3-4)



Section 1

- Manoeurve: Cutting and merging
- $Q = (355 + 345) + 1\frac{2}{3} \times 100 = 867$ PCU/h
- Junction design speed 65km/h
- Capacity Curve: D (8 secs.)
- Capacity of minor road flows = 570 PCU/h

  $> 110 + 100 = 210$ PCU/h

Therefore cutting and merging will be possible and No. of waiting vehicles at right turn lane = 210/3600/10 = 1

Section 2

- Manoeurve: Cutting and merging
- $Q = (280 + 270) + 1\frac{2}{3} \times 185 = 858$ PCU/h
- Junction Design Speed 65km/h
- Capacity Curve : D (8 secs.)
- Capacity of minor road flows = 570 PCU/h

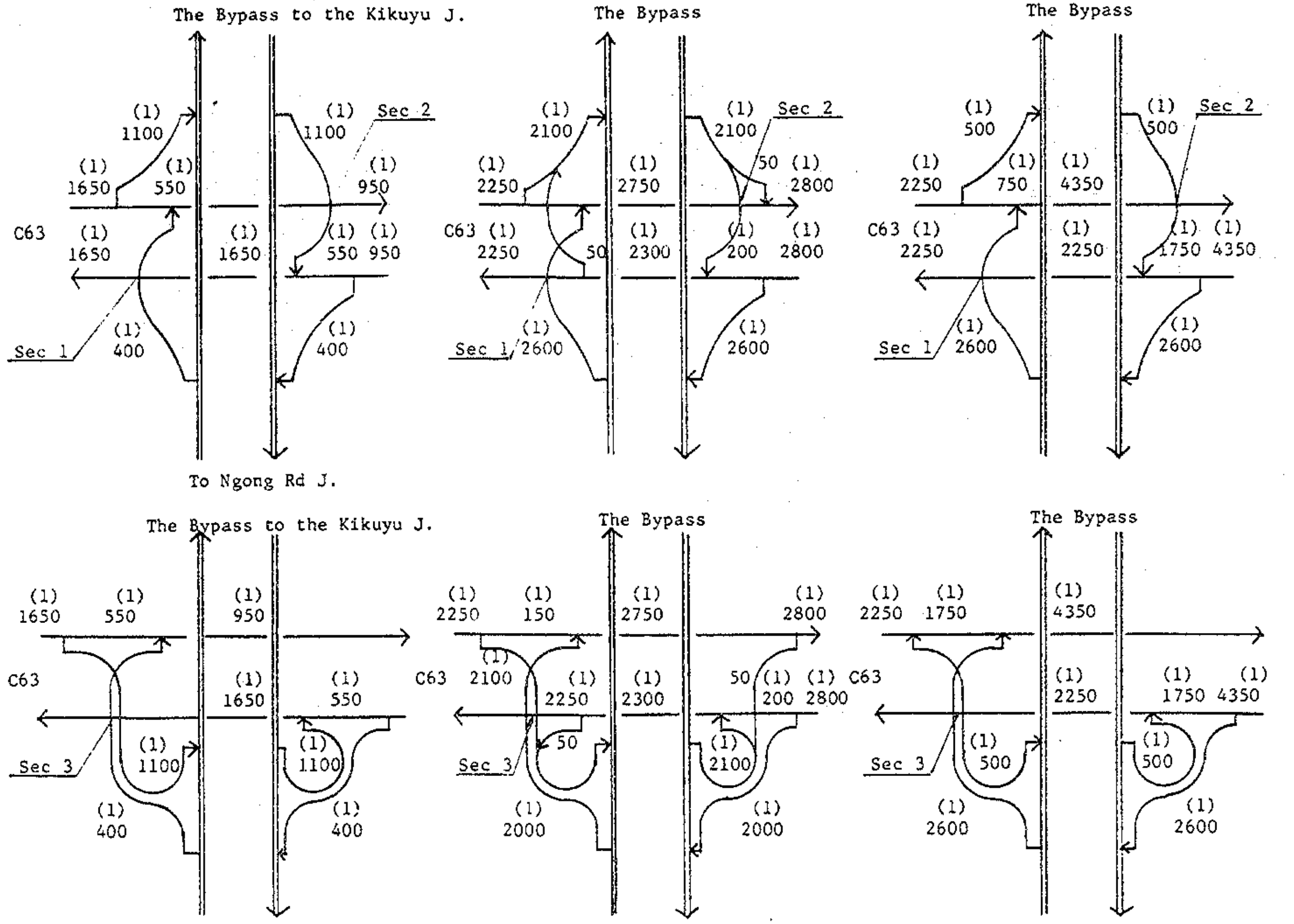
  $> 175 + 185 = 360$ PCU/h

Therefore cutting and merging will be possible and No. of waiting vehicles at right turn lane = 360/3600/10 = 1

Fig. VI-5-7

Dagoretti Forest Junction

Case	Future AADT and No. of lanes required by the Alternative plan		
	A - 1 - 4	A - 2 - 4	A - 3 - 4
Case 1 : Diamond J.			
Case 2 : Half Cloverleaf J.			

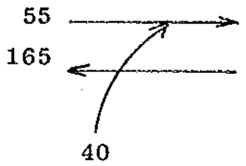


Capacity Calculation on Dagoretti Forest Junction

A-1-4

Case 1(Diamond J.)

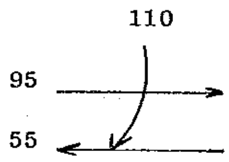
Section 1



- Manoeuvre: Cutting and merging
- Q = 55 + 165 = 220 PCU/hr
- Junction design speed = 65km/hr
- Capacity Curve: D(8 secs.)
- Capacity of minor road flows
  = 600 $>$ 40

Cutting and merging will be possible

Section 2

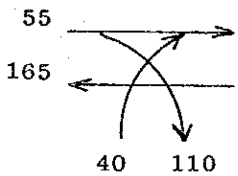


- Manoeuvre: Cutting and merging
- Q = 95 + 55 = 150
- Junction design speed = 65 PCU/hr
- Capacity Curve: D(8 secs.)
- Capacity of minor road flows
  = 600 $>$ 110

Cutting and merging will be possible

Case 2 (Partial Cloverleaf J.)

Section 3



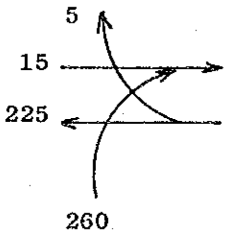
- Manoeuvre: Cutting and merging
- Q = 55 + 65 + $1\frac{2}{3}$ x 110 = 403
- Junction design speed = 65km/hr
- Capacity Curve: D(8 secs.)
- Capacity of minor road flows
  = 600 $>$ 150

Cutting and merging will be possible

A-2-4, A-3-4

Case 1 (Diamond J.)

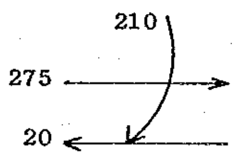
Section 1



- Manoeuvre: Cutting and merging
- $Q = 15+225+ 1\frac{2}{3} \times 5 = 248$
- Junction design speed (J.D.S.)
  = 65km/hr
- Capacity Curve (CC) : D (8 secs.)
- Capacity of minor road flows
  $= 600 > 265$

Cutting and merging will be possible

Section 2

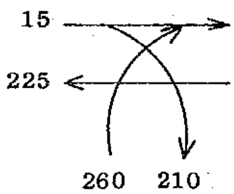


- Manoeuvre: Cutting and merging
- $Q = 275 + 20 = 295$
- JDS 65km/hr
- CC : D (8 secs.)
- Capacity of minor road flows
  $= 600 > 210$

Cutting and merging will be possible

Case 2 (Partial Cloverleaf J.)

Section 3



- Manoeuvre: Cutting and merging
- $Q = 15 + 225 + 1\frac{2}{3} \times 260 = 673$
- JDS 65km/hr
- CC: D (8 secs.)
- Capacity of minor road flows
  $= 600 > 210 + 260 = 470$

Cutting and merging will be possible

Fig. VI-5-8
Kikuyu Junction

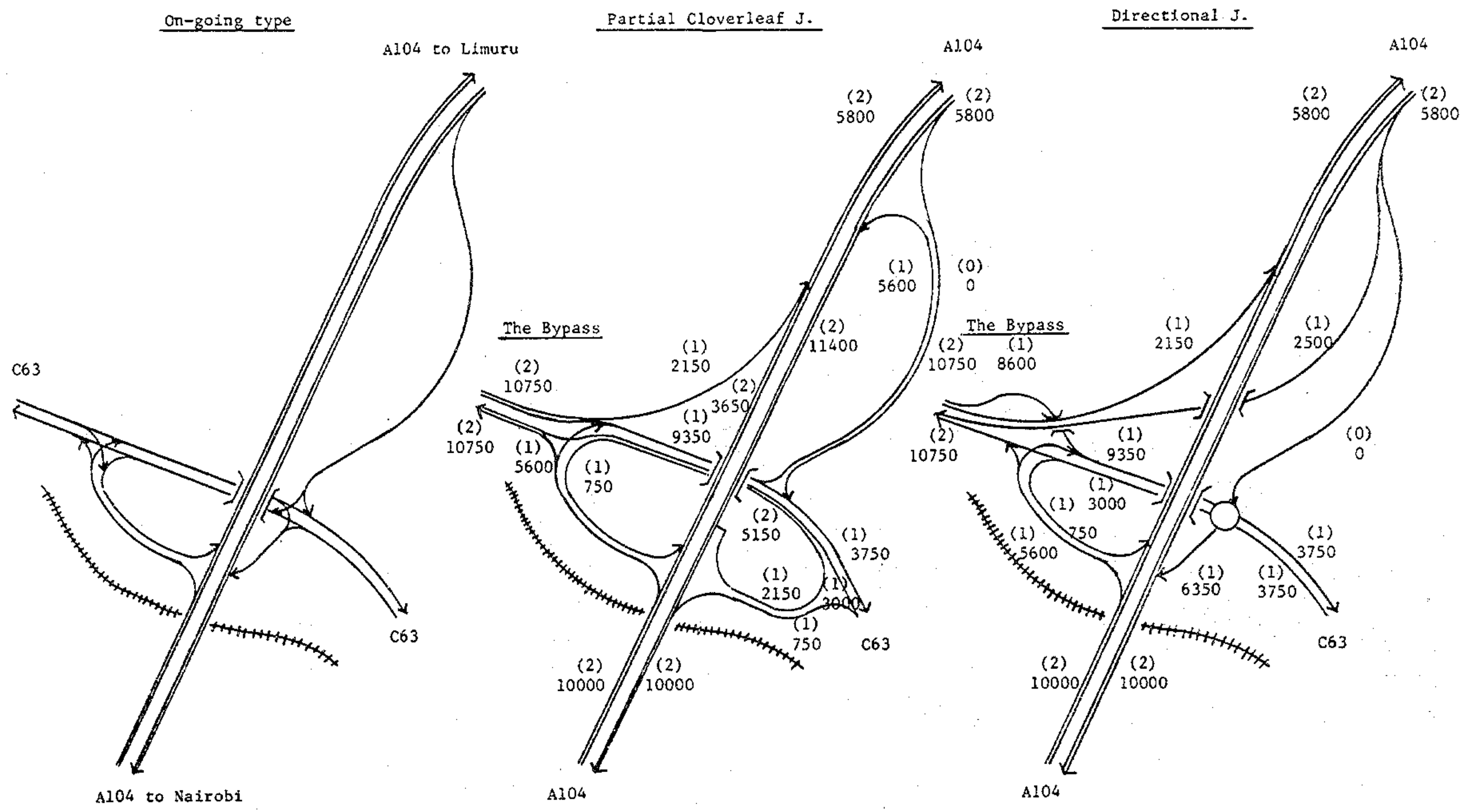
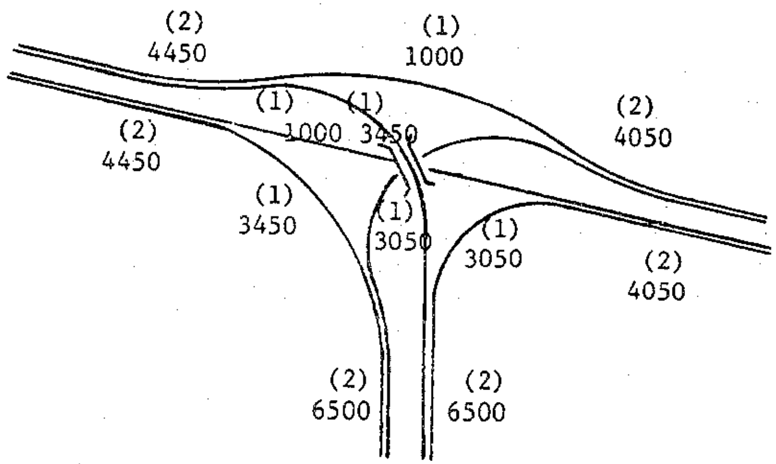
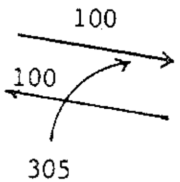


Fig. VI-5-9

Muguga Junction

A - 2 - 4





Design Speed 65 Km/h

Cutting and merging

Q = 100 + 100 = 200 pcu/h

Curve E

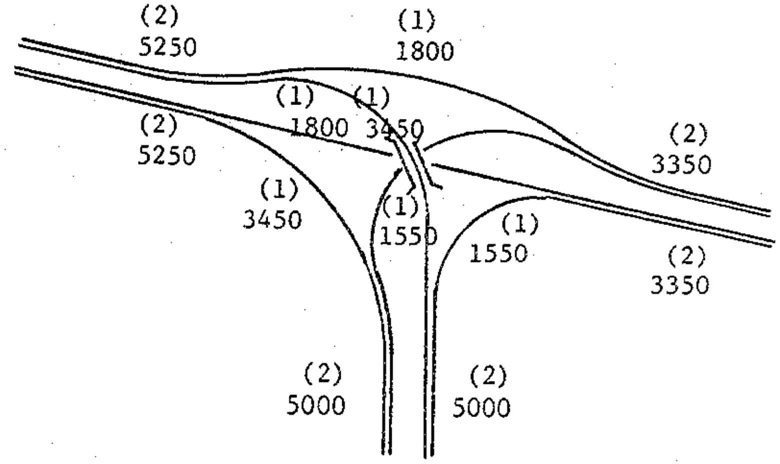
Capacity of minor road flows

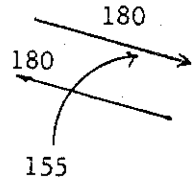
= 430 pcu/h > 305 pcu/h

Therefor Cutting and merging

will be possible.

A - 3 - 4





Design Speed 65 Km/h

Cutting and merging

Q = 180 + 180 = 360 pcu/h

Curve E

Capacity of monor road flows

= 430 pcu/h > 155 pcu/h

Therefor Cutting and merging

will be possible.

VI.6 Study of Traffic Assignment Methods

VI.6.1 Comparison of Traffic Assignment Methods

Typical methods of assigning future O-D traffic volumes to a transportation network include the minimum distance method (M.D.M.) and the minimum time method (M.T.M.).

M.D.M. assigns traffic volumes to a route with the shortest distance among those available between an origin and a destination; the method does not take into consideration the grade of road, road surface conditions, the number of lanes, design speeds in the route selection. This may lead to unrealistic results, such as assignment of traffic volumes in excess of capacity, and higher traffic volumes flowing into a lower grade road which is slightly shorter than a higher grade road running parallel to it.

On the other hand, M.T.M. assigns traffic volumes to a route requiring the shortest travel time between an origin and destination; it takes into account that travel time varies with traffic volumes in each link. In this method, congestion rate-velocity curves are used to determine travel time for each of alternate routes on the basis of running speeds corresponding to traffic volumes.

The Study used the practical assignment method (P.A.M.); distributed traffic volumes are at first divided into five equal portions, each of which is assigned one by one to a route with minimum travel time which is determined from travel speed in the link based on the distributed traffic volumes. At the initial stage of assignment (assignment of first portions), the shortest route is selected until traffic volumes reach the traffic capacity of the route. Then as more and more links reach their traffic capacity due to traffic assignment, diversion flow occurs to simulate realistic traffic flows.

Thus, while both P.A.M. and M.D.M. are likely to show similar results when distributed traffic volumes are relatively small, P.A.M. clearly has an advantage over M.D.M. when large traffic volumes in urban transport are assigned and simulation of diversion flow as required.

VI.6.2 Traffic Assignment for Alternative Cases

To compare assigned traffic volumes by M.D.M. and P.A.M., additional assignment was made for the network with and without the Bypass by using M.D.M..

These alternative cases are summarized as follows.

Case	Year	Assignment Method
1. Without Bypass	2000	M.D.M.
2. -do-	-do-	P.A.M.
3. With Bypass	-do-	M.D.M.
4. -do-	-do-	P.A.M.

Table VI-6-1 shows results of traffic assignment to major roads and links, as well as congestion rate.

The detailed assignment results for the case of No. 2 and 4 in the upper table are shown in Appendix Fig. A-VI-4(1) and Fig. A-VI-4(4).

Table VI-6-1

Future Assigned Traffic by Two Methods on Major Roads

Road Name	Link No.	With Bypass P.A.M. Q	With Bypass P.A.M. K	With Bypass M.D.M. Q	With Bypass M.D.M. K	Without Bypass P.A.M. Q	Without Bypass P.A.M. K	Without Bypass M.D.M. Q	Without Bypass M.D.M. K
A104	1043	123	0.68	170	0.95	224	1.24	190	1.05
	1044	124	0.68	175	0.97	235	1.30	181	1.00
	1001	173	1.44	300	2.50	213	1.77	307	2.56
	1002	156	1.30	296	2.46	198	1.65	302	2.52
	1008	253	2.10	243	2.02	287	2.39	248	2.07
	1009	238	1.98	312	1.78	263	2.19	217	1.81
	1010	215	0.98	166	0.76	248	1.13	170	0.77
	1011	214	0.97	175	0.79	239	1.09	178	0.81
	1012	245	1.11	181	0.82	246	1.12	185	0.84
	1013	241	1.09	188	0.85	240	1.09	191	0.87
	1014	178	0.89	111	0.56	180	0.90	118	0.59
	1056	161	0.80	106	0.53	161	0.80	112	0.56
	1015	183	0.92	105	0.52	175	0.88	112	0.56
	1057	164	0.82	96	0.48	154	0.77	102	0.51
	1016	138	0.86	37	0.23	120	0.75	42	0.26
	1017	139	0.87	49	0.30	119	0.75	53	0.33
	1018	112	0.56	72	0.36	100	0.50	80	0.40
	1058	101	0.50	71	0.36	69	0.35	71	0.35
C60	2001	176	0.98	190	1.06	188	1.04	194	1.08
	2040	136	0.76	179	0.99	159	0.88	183	1.02
	2002	234	1.30	248	1.38	246	1.36	252	1.40
	2041	194	1.08	237	1.32	217	1.21	241	1.34
	2042	236	1.31	234	1.30	241	1.34	238	1.32
	2043	195	1.08	221	1.23	211	1.17	225	1.25
	2003	175	0.97	248	1.38	185	1.03	262	1.46
	2044	166	0.92	244	1.36	184	1.02	249	1.39
	2006	124	1.04	80	0.67	98	0.81	75	0.63
	2045	55	0.46	59	0.49	75	0.62	53	0.44

Note: Q : Future Assigned AADT (100 pcu/day)

K : Future Congestion Rate

Continue

Road Name	Link No.	With Bypass P.A.M.		With Bypass M.D.M.		Without Bypass P.A.M.		Without Bypass M.D.M.	
		Q	K	Q	K	Q	K	Q	K
B.P.	1045	121	0.55	37	0.17	-	-	-	-
	1046	135	0.61	27	0.12	-	-	-	-
	1047	94	0.47	28	0.14	-	-	-	-
	1048	96	0.48	19	0.09	-	-	-	-
	1049	91	0.45	12	0.06	-	-	-	-
	1050	90	0.45	10	0.05	-	-	-	-
	1053	103	0.47	16	0.07	-	-	-	-
	1054	120	0.55	20	0.09	-	-	-	-
C58	2014	95	0.48	188	0.94	249	1.25	209	1.05
	2035	76	0.38	140	0.70	214	1.07	149	0.74
	2013	97	0.49	146	0.73	226	1.13	167	0.83
	2036	104	0.52	123	0.62	216	1.08	131	0.66
	2037	190	0.86	153	0.69	226	1.03	167	0.76
	2038	193	0.88	130	0.59	216	0.98	131	0.60
	2012	76	0.35	88	0.40	112	0.51	94	0.43
	2039	48	0.22	58	0.26	74	0.34	59	0.27
C61	2004	244	2.44	404	4.04	250	2.50	403	4.03
	2005	173	1.73	170	1.70	210	2.10	180	1.80

VI.6.3 Evaluation and Selection of Traffic Assignment Method

Table VI-6-2 shows the average traffic volume and congestion rate for major roads which are estimated from those by links in Table VI-6-1. Major findings from the table are as follows.

(1) "Without Bypass" Case

Both average traffic volumes and congestion rate for major roads show little difference between M.D.M. and P.A.M. This is because future working population distribution in Nairobi is expected to concentrate in a limited area, and as a result traffic demand basically takes a radial pattern; the road network in the "without Bypass" case mainly consists of radial roads to cause little difference in traffic assignment by M.D.M. and P.A.M.

If no Bypass is provided, Uhuru Highway (A104) will have to be expanded to 10 lanes or all intersections on the Uhuru Highway will have to be graded separately, while Ngong Road (C60) will have to be expanded to 6 lanes.

(2) "With Bypass" Case by M.D.M.

Traffic assignment by M.D.M. to the road network having a Bypass indicates that traffic volume on the Bypass will be 4,300 pcu/day while traffic volumes and congestion rates will be at similar levels to those without the Bypass.

Traffic volumes on Ngong Road (C60) and Langatta Road (C58), which will be over 25,000 pcu/day, or more than six times that on the Bypass. This is because, when a traffic assignment is made by M.D.M. to the radial road pattern with an added ring road, travel distance on the radial roads is shorter than the ring road for most of O-D pairs, resulting in an unrealistic estimate that the ring road (Bypass) is not likely to be used.

Similarly, although the Bypass is designed to divert through-traffic in the city centre and to reduce congestion on existing roads, traffic assignment by M.D.M. shows unrealistic results that through-traffic will continue to use A104 instead of the Bypass, and congestion on the existing roads will not be reduced because the Bypass is longer than A104.

Table VI-6-2

Results of Future Assigned Traffic by Two Method

Road	Future Average Traffic				Future Average Congestion Rate				Existing or Authorized No. of Lane	No. of lanes required			
	With Bypass		Without Bypass		With Bypass		Without Bypass			With Bypass		Without Bypass	
	P.A.M	M.D.M	P.A.M	M.D.M	P.A.M	M.D.M	P.A.M	M.D.M		P.A.M	M.D.M	P.A.M	M.D.M
Bypass	22,000	4,300	-	-	0.49	0.10	-	-	4	4	2	-	-
A104/Central Area	40,400	42,100	47,900	43,400	1.26	1.39	1.50	1.43	6	8 or Signal Intersection	10	10 or Grade Separated Junction	10
A104/Other Urban Area	30,000	12,800	27,200	13,900	0.78	0.49	0.72	0.45	4	4	4	4	4
C60 (Ngong Road)	20,900	28,700	23,000	29,200	1.02	1.25	1.13	1.16	4	4	6	6	6
C58 (Langatta Road)	22,100	25,700	38,600	27,800	0.52	0.71	0.92	0.67	4	4	4	4	4

With Bypass : Future Road Network with Bypass
Without Bypass: Future Road Network without Bypass
M.D.M. : Minimum Distance Assignment Method
P.A.M. : Practical Assignment Method

(3) "With Bypass" case by P.A.M.

On the other hand, when future traffic volumes are assigned by P.A.M. to the road network having a Bypass, an average traffic volume of 22,000 pcu/day will use the Bypass to greatly reduce congestion on most major roads except a part of the Uhuru Highway in the City centre. The reason for this is that, as discussed earlier, P.A.M. assigns an equally divided portion of O-D traffic to the road network resulting in minimum distance routes at the initial stage of assignment. Because traffic assignment is made by selecting a route with the shortest travel time in each link under free running conditions so that the radial road is selected for radial traffic demand pattern in consideration of the grade of road and running conditions.

Having assigned O-D traffic several times, traffic volumes on some radial roads reach their capacities and produce congestion. Then, the Bypass is selected as an alternate route on which a specific running speed can be maintained despite the longer distance. As a result, a realistic traffic demand forecast which takes into account the overall road network is attained.

(4) Conclusion

As is clearly shown above, in forecasting traffic demand for urban roads, P.A.M. allows route selection which takes into account the grade of road and congestion. At the same time it can select the shortest distance routes at the initial stage of assignment, resulting in realistic and reliable forecast. On the other hand. M.D.M. neglects the grade of road and congestion and causes an unrealistic assignment. It should be noted that K-V curves, a basic component of P.A.M., have been prepared on the basis of the road inventory survey and vehicle running speed survey conducted in Nairobi area, and they serve as a model showing the relationship between the actual degree of congestion and running speeds on major roads of class A, B and C.

Fig. VI-6-1

Future Assigned Traffic to the "With Bypass" network in 2000 by M.D.M.

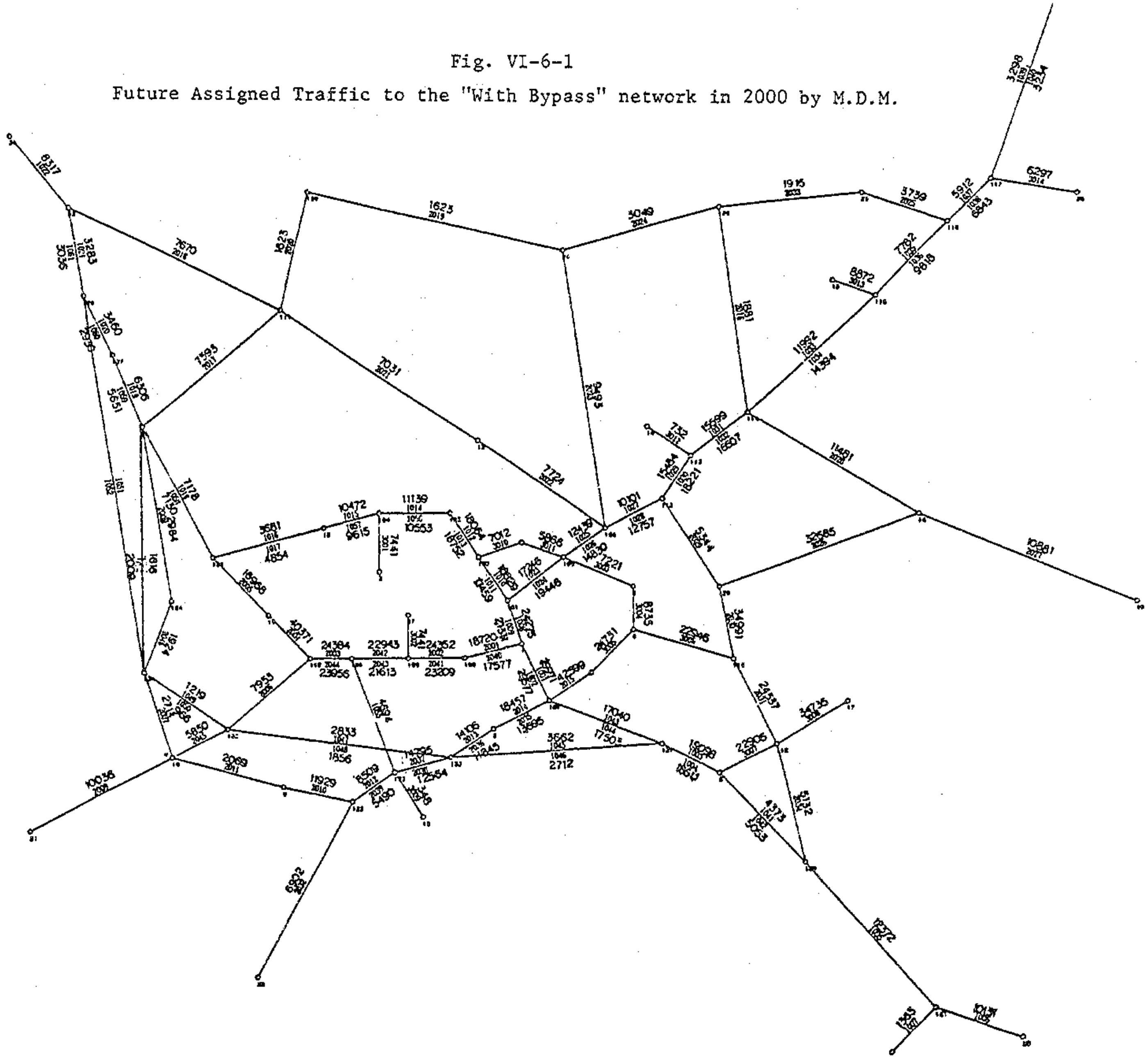
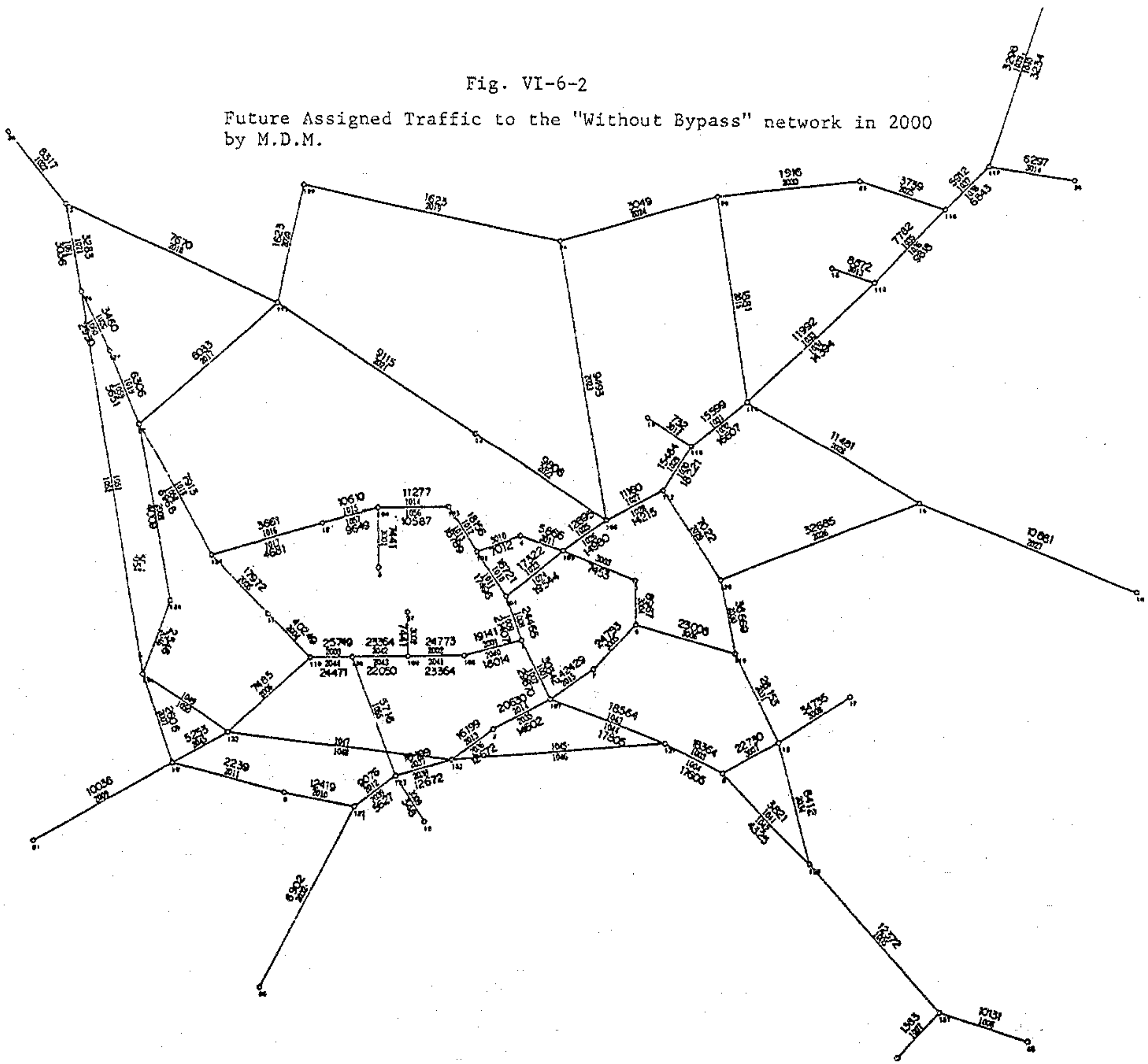


Fig. VI-6-2

Future Assigned Traffic to the "Without Bypass" network in 2000 by M.D.M.



VI.7 Consideration of the Stage Construction

To perform economical road construction, the road shall be constructed first to the scale so as to cope with traffic demand, and when traffic volume is in excess of it's capacity, an additional part will be constructed, which means the stage construction.

In general, this gives economical effects in terms of road investment including construction cost, maintenance cost and running cost. However, as stated in the preceding paragraph, Fig. VI-4-3 and Table VI-4-4 give the growth of traffic by link on the Bypass and show that in 1992 the traffic volume will pass over AADT 8,000 in PCU requiring a dual carriageway instead of a single one.

According to the road design manual of Kenya, where the traffic volume purpasses AADT 8,000 in PCU, a dual carriageway should be considered.

Therefore, in the implementation plan of the Bypass, it is not recommended that the stage construction be preferred to.

VII. Alternative Route Selections

VII. Alternative Route Selections

VII.1 General Conditions for the Selection of Alternative Routes

The factors considered in deciding the project road and various alternatives were based on the comparison of the following:

- Route Location
- Structures
- Control Points

The most important item is the route location.

VII.2 Route Location

VII.2.1 General condition for route location

General conditions for route location were as follows:

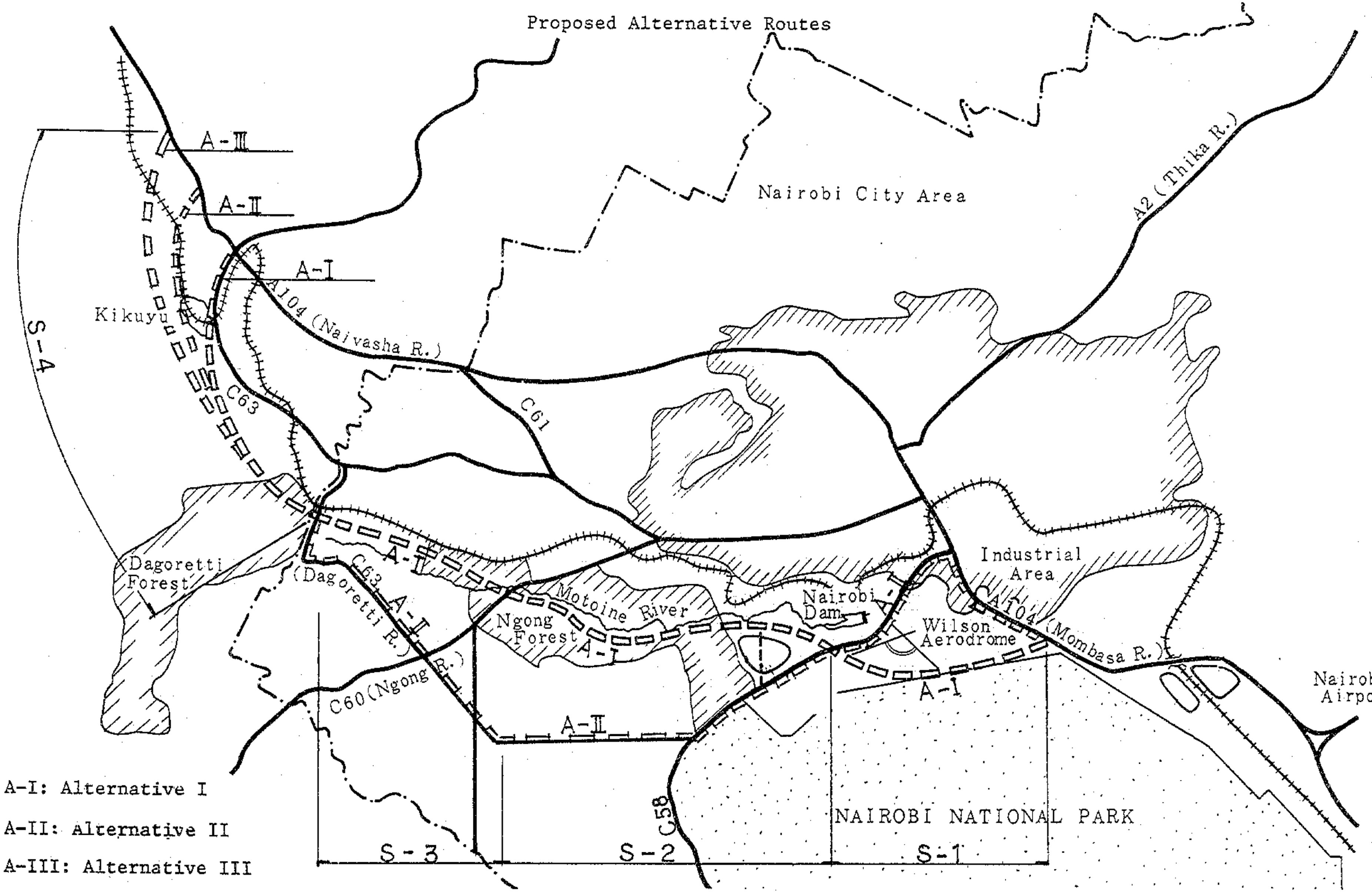
(1) Nairobi Southern Bypass (hereafter called Nairobi Bypass) is a part of the Trans African Highway.

(2) The right of way for the Trans African Highway had been proposed on the STRUCTURE PLAN (NAIROBI) by the Department of Physical Planning in the Ministry of Works Housing & Physical Planning. (Departmental Reference No. 42-28-85-9).

(3) Threfore, the route of the Nairobi Bypass should be located in the right of way for the Trans African Highway which was proposed in the STRUCTURAL PLAN up to the north edge of SOUTHLAND ESTATE after crossing the LANGATA ROAD.

Fig. VII-2-1

Proposed Alternative Routes



A-I: Alternative I

A-II: Alternative II

A-III: Alternative III

(4) To use public land as much as possible to reduce the project cost.

VII.2.2 Route Location

(1) In considering the previously mentioned condition, the route location was carried out on the maps of scale 1:5,000 and maps of scale 1:50,000 which was obtained from the Survey of kenya referring to the aerial photos by the Air Survey Section of M.O.T.C. after reconnaisance. Alternative routes consist of two big sections from Mombasa Road (A104) to Dagoretti Road (C63) and from Dagoretti Road (C63) to Naivasha Road (A104) as shown in Fig. VII-2-1. These two sections contain sub-sections and the sub-sections consist of alternative routes which were selected as follows:

Section		Alternative
S-1. Mombasa Road (A104) - Langata Road (C58)	I	Construction of a new road in the right of way for the Trans-African Highway.
	II	Improvement of existing road C58.
S-2. Langata Road (C58) - Ngong Road (C60)	I	Construction of a new road in the right of way for the Trans-African Highway and in the Ngong Road Forest.
	II	Improvement of existing road C58 and C63.

S-3. Ngong Road (C60) - Dagoretti Road (C63)	I	Construction of a new road in the Ngong Road Forest and on private land.
	II	Improvement of existing road C58 and C63.
S-4. Dagoretti Road (C63) - Naivasha Road (A104)	I	Construction of a new road in the Dagoretti Forest, on private land and widening C63.
	II	Construction of a new road in the Dagoreetti Forest and on private land (up to the junction of A104 and E422).
	III	Construction of a new road in the Dagoretti Forest and private land (up to Muguga).

(2) Identification of Control Points

Field reconnaisance, collection of data such as investigation of map, report from traffic studies and interviews with people were conducted to identify the control points. The following is the summary of major control points by section:-

a) Section S-1 (Mombasa Road)
- Leading to Industrial Area
- New resident quarters near Drive-In Cinema
- Nairobi National Park
- Wilson Aerodrome
- Independence Monument
- Plan of Ministry of Natural Resources and Housing

b) Section S-2 (C58 - Ngong Road)

- C58
- Nairobi Dam
- New Residence quarters along C58
- Langata Prison
- Army Quarters
- Moi Estate
- Langata Cemetry
- Karen Estate
- Ngong Road Forest

c) Section S-3 (Ngong Road - Dagoretti Road)

- Karen Estate
- Motoine Stream
- Mutuini Primary School
- Langata Road
- Houses along Mutuini Road
- Railway at the end of this segment

d) Section S-4 (Dagoretti Road - A104)

- Railway running near the alignment of the Bypass
- Dagoretti Forest
- D411 (feeder road)
- Alliance Girls High School
- Church and housing along the feeder road leading to C63
- Dagoretti Road (C63)
- Ondiri Swamp
- E422 (feeder road)
- Sigona Golf Course
- Railway Crossing
- Junction to A104 (trunk road)

(3) Explanation of Each Segment of the Bypass

Section S-1, Alternative I: A104 (Mombasa Road) - C58 (Uhuru Monument Junction), L = 6.67 km

The A104 Mombasa road junction will be located a little south of the Drive-In Chinema between Nairobi City and Jomo Kenyatta International Airport and covering an area wide enough for an interchange construction. From the junction, the Bypass will run westwards by the northern edge of Nairobi National Park and just to the south of Wilson Airport runway and Kenya's Independence Monument. The By-pass will proceed on to meet C58, covering a distance of about 6.67 km.
The junction of the Bypass with C58 will consist of grade separation since it is a junction of two major roads.

Section S-2, Alternative I: C58 (Uhuru Monument Junction) - Ngong Road Junction, L = 8.7 km

The Bypass will extend westwards along the south bank of Motoine Stream which is a water source for the Nairobi Dam reservoir. It extends along an open area with many control points, identified in the preceeding paragraph, which include residential quarters namely Ngei and Otiende Estates, the Army quarters and Langata Prison. Along the alignment lies 2 km length of escarpment and partly exposed rock.

For a greater part of the length, the road will pass through the Ngong Road forest, along the northern edge of Karen Estate, leading to the Ngong Road junction. The alignment of this segment will satisfy the geometric requirements of the road and the geological conditions are positive.

Section S-3, Alternative I: Ngong Road-Dagoretti Road, Length = 5.3 km

After passing Ngong Road junction, the Motoine stream will be passed with box culvert and the Bypass will extend westward mostly along the north side of the stream, its alignment will satisfy the geometrics of the road because of the gentle undulation of the terrain and assessing very houses in the R.O.W but partly some farm land for vegetable. At the end of the segment, there will be a large junction with Dagoretti road, a grade separation will be provided with the Bypass passing over due to the topography. This will be near the existing railway crossing of Dagoretti Road, which occupies the west border of Nairobi City. The intersection site covers a wide space for intersection structure and west of it lie rocky hills requiring some blasting works though this will be a stable foundation for the structures.

The design and layout of the intersection was selected on the basis of the results obtained from computer analysis of future traffic flows. This section covers an approximate distance of 5.3 km.

Section 4, Alternative III : Dagoretti Road Junction - A104 (Naivasha Road) Junction, L = 9.9 km

The Bypass will extend northwest to pass through the north edge of the Dagoretti forest, cross a local road D411. Beyond it, school buildings such as Musa Primary School, Kikuyu DHK High School and a famous church are established. Therefore, the road will extend eastwards around the area and will pass a local road, E422, beyond which the depressed area will be raised with an embankment nearly 100m long and

10m high to the east of the neighbouring hills. Then the Bypass will have an up-grade to the railway crossing at Muguga. The crossing with the railway shall be a grade separation as the frequency of passing trains is as high as 29 per day. The Bypass proceeds to A104 (Naivasha Road) junction.

Section 4, Alternative II : Dagoretti Road Junction - A104 (Naivasha Road) Junction, L = 9.1 km

Alternative II will branch off near a local road, D411, and extend northwest around the west of Alliance High School to the C63 (Dagoretti Road) and will again branch off from the C63 to extend along the existing earth road lying on hilly terrain to the Ondiri Swamp. The Bypass will run northwards parallel to the railway with a down slope on the other side. Though the available land is rather narrow, the road will pass over the railway to extend along the west of Sigona Golf Course, and cross the local road leading to Muguga Village from the A104 (Naivasha Road). The alignment of the road will satisfy the geometric criteria of the road. However, it was felt that the construction of the road will cost much more and the desired alignment will not be attained due to the narrow width of the existing road and the topography of the area.

Section 4, Alternative I : Dagoretti Road Junction - A104 (Naivasha Road) Junction, L = 7.3 km

Alternative I will extend northwestward to pass through the north edge of the Dagoretti forest, to cross a local road D411. Beyond it, school buildings such as Musa Primary School, Kikuyu DHK High School and a famous church and also Alliance High School, then the route extends northwestwards along the west of Alliance High School to the C63 (Dagoretti Road) passing the eastern of the Ondiri Swamp. Along C63 it will extend to A104 (Naivasha Road). The Kikuyu junction will be constructed under the project of Kabete-Limuru Project as a part of the improvement project of A104 (Naivasha Road). The junction of the Bypass with A104 shall be made in conjunction with the design of the Kabete-Limuru Project.

In the Kabete-Limuru Road improvement project, a dual carriageway plan with improvement on geometric of the existing road is being undertaken, and the Kikuyu junction between A104 and C63 would be improved and widened to accommodate the future traffic volume of both roads. The bottle-neck section on A104 for several kilometers on the west of Kikuyu junction would also be improved. Thus Alternative I would have preference over the other two routes in terms of distance.

(4) Route Comparison

The route comparison was made by a simplified method considering five major factors, namely, route length, engineering aspect, difficulty of implementation, social environment impact, costs including land acquisition, compensation and construction.

In order to select the optimum route, a rating method was employed for evaluation of an alternative route. (See Table VII-2-1 - VII-2-4). While for the alternative route in Section 4, tentative design was carried out assuming the same standard, which is class A (International Trunk Road) in accordance with Geometric Design of Rural Roads, Road Design Manual MOTC. Engineering terms construction quantities and their costs were assumed. In addition, traffic economy was referred to.

Table VII-2-1: Route Comparison
Section 1: A104 (Mombasa Road) - C58

Description	WT	Alternative I	WT	Alternative II	WT
Total Length	(15)	6.5 km	15	8.0 km	12
Road Network	(5)	Importance	4	Importance	4
Engineering Aspect	(20)				
- Accessibility problem	3	Fair	2	Bad	1
- Horizontal Alignment	3	Good	2	Bad	1
- Vertical Alignment	5	Good	4	Good	4
- No. of Intersections	5	Fair	3	Fair	2
- Bridge Structures	4	Fair	3	Fair	2
Difficulty of Implementation	(15)				
- Land area to be acquired	10	Ready	6	Bad	4
- No. of Permanent Structures to be demolished	5	Good	4	Bad	2
Social/Environment Impact	(10)				
- House/Other facilities within R.O.W	4	Good	3	Bad	2
- Road length following existing road R.O.W	3	No Good	2	Bad	1
- Road length in open area	3	All the length good	2	Bad	1
Cost	(35)				
- Land acquisition	10	Good	8	Bad	4
- Compensation	10	Good	8	Bad	4
- Construction	15	Good	12	Bad	12
	-----		--		--
	(100)		78		56

NOTE: R.O.W of the length has been reserved by M.O.T.C. The rating method is as follows:

Good or Importance - 80%; Fair or Ready - 60%; Bad - 40% or below

Table VII-2-2: Route Comparison
Section 2: C58 - Ngong Road

Description	WT	Alternative I	WT	Alternative II	WT
Total Length	(15)	8.7 km	15	10.0km	13
Road Network	(5)	Importance	4	Fair	3
Engineering Aspect	(20)				
- Accessibility problem	3	Good	2	Fair	2
- Horizontal Alignment	3	Good	2	Good	2
- Vertical Alignment	5	Good	4	Good	4
- No. of Intersections	5	Fair	3	Fair	2
- Bridge Structures	4	Fair	2	Fair	2
Difficulty of Implementation	(15)				
- Land area to be acquired	10	Goody	8	Bad	4
- No. of Permanent Structures to be demolished	5	Good	4	Fair	3
Social/Environment Impact	(10)				
- House/Other facilities within R.O.W	4	Good	3	Fair	2
- Road length following existing road R.O.W	3	Good	3	Fair	2
- Road length in open area	3	Good	3	Fair	2
Cost	(35)				
- Land acquisition	10	Fair	6	Fair	6
- Compensation	10	Fair	6	Fair	6
- Construction	15	Fair	9	Fair	6
	-----		--		--
	(100)		74		59

NOTE: R.O.W of the length has been reserved by M.O.T.C. The rating method is as follows:
Good or Importance - 80%; Fair or Ready - 60%; Bad - 40% or below

Table VII-2-3: Route Comparison
Section 3: Ngong Road - Dagoretti Road

Description	WT	Alternative I	WT	Alternative II	WT
Total Length	(15)	5.5 km	15	6.5 km	13
Road Network	(5)	Importance	4	Fair	3
Engineering Aspect	(20)				
- Accessibility problem	3	Good	2	Fair	2
- Horizontal Alignment	3	Good	2	Fair	2
- Vertical Alignment	5	Good	4	Good	4
- No. of Intersections	5	Fair	2	Good	4
- Bridge Structures	4	Fair	2	Good	3
Difficulty of Implementation	(15)				
- Land area to be acquired	10	Fair	6	Bad	4
- No. of Permanent Structures to be demolished	5	Good	4	Fair	3
Social/Environment Impact	(10)				
- House/Other facilities within R.O.W	4	Good	3	Fair	2
- Road length following existing road R.O.W	3	Good	3	Fair	2
- Road length in open area	3	Good	3		
Cost	(35)				
- Land acquisition	10	Fair	6		6
- Compensation	10	Fair	6		6
- Construction	15	Fair	9		9
	-----		--		--
	(100)		71		65

NOTE: R.O.W of the length has been reserved by M.O.T.C. The rating method is as follows:

Good or Importance - 80%; Fair or Ready - 60%; Bad - 40% or below

Table VII-2-4: Route Comparison
Section 4: Dagoretti Road - A104 (Naigasha Road)

Description	WT	Alternative I	WT	Alternative II	WT	Alternative III	WT
Total Length	(15)	7.8 km	15	9.1 km	12	9.9 km	12
Road Network	(5)	Fair	3	Fair	3	Fair	3
Engineering Aspect	(20)						
- Accessibility problem	3	Fair	2	Fair	2	Fair	2
- Horizontal Alignment	3	Fair	2	Fair	2	Good	2
- Vertical Alignment	5	Fair	3	Fair	3	Good	4
- No. of Intersections	5	Fair	3	Fair	3	Fair	3
- Bridge Structures	4	Fair	2	Bad	1	Fair	2
Difficulty of Implementation	(15)						
- Land area to be acquired	10	Fair	6	Fair	6	Fair	6
- No. of Permanent Structures to be demolished	5	Good	4	Fair	3	Good	4
Social/Environment Impact	(10)						
- House/Other facilities within R.O.W	4	Fair	2	Fair	2	Good	3
- Road length following existing road R.O.W	3	Fair	2	Fair	2	Fair	2
- Road length in open area	3	Fair	2	Fair	2	Fair	2
Cost	(35)						
- Land acquisition	10	Fair	6	Fair	6	Fair	6
- Compensation	10	Fair	6	Fair	6	Fair	6
- Construction	15	Fair	9	Far	9	Fair	9
	(100)		67		62		66

NOTE: R.O.W of the length has been reserved by M.O.T.C. The rating method is as follows:

Good or Importance - 80%; Fair or Ready - 60%; Bad - 40% or below

Table of comparison/construction costs by alternative plans is shown on Table VII-4-1.

VII.3 Establishment of Design Criteria and Standard

The Nairobi Bypass will rank as a Class A road linking centers of international importance and crossing international boundaries as a part of the most important trunk roads, A104 and A109, which cross Kenya from east to west linking Mombasa-Nairobi-Nakuru-Kisumu and is also part of an international trunk road (Trans-African Highway). The design criteria of the Bypass has to fulfill the same requirements.

In accordance with the Geometric Design of Rural Road, Road Design Manual, Ministry of Transport and Communications in Kenya, the Bypass adopted a design speed of 100 kms per hour for flat terrain and 70 kms per hour for hilly terrain. The geometric design was established based on the above indicated design speed and corrected and revised through discussion with Ministry of Transport and Communications' engineers concerned.

Table VII-3-1 : Geometric Design Standard

ITEM	UNIT	VALUES
Road Classification		A
Road Reserve (Right-of-Way)	m	60
Design Speed	Km/h	100 - 70
Lane Width	m	3.50
Shoulder Width Right	m	1.0
Left		1.50
Crossfall of Roadway	%	2.5
Maximum Gradient	%	Flat:3 Rolling:4 Mountainous:7
Acceleration Lane (including Tapers)		240
Deceleration Lane (including Tapers)	m	150
Clearance	m	Vertical: 5.25 Horizontal: +1.50 x 2
Maximum Stopping sight Distance	m	135(+3%), 145(-3%)
Min. Horizontal Curve Radii		Min. 600
Min. Vertical Curve Radii	m	6,500 (crest), 3,000 (sag.)
Min. Horizontal Curve Length	m	1,200 (IR = 7^{o})

Table VII-3-2: Geometric Design Standard for Intersection

ITEM	UNIT	INTERSECTION
Design Speed	Km/h	50 - 40
One Way Lane Width	m	4.00 & 6.00
Shoulder Width - Right	m	1.0
Left	m	1.5
Crossfall or Carriageway	%	2.5
Minimum Radius	m	50.0
Maximum Gradient	%	6.0
Max. Superelevation	%	6.0
Acceleration Lane	m	100 km/h ... 240
(including Tapers)	m	80 km/h 210
Deceleration Lane	m	100 km/h ... 150
(including Tapers)	m	80 km/h 130

VII.4 Tentative Design and Selection of Optimum Route

This is composed of the engineering studies related to the route location through the comparative studies for all route alternatives formulated in the prior section.

Route alternatives were selected first on the 1: 50,000 scale topographic map and field reconnaisance, inventory survey, socio-economic survey and through discussion with M.O.T.C.

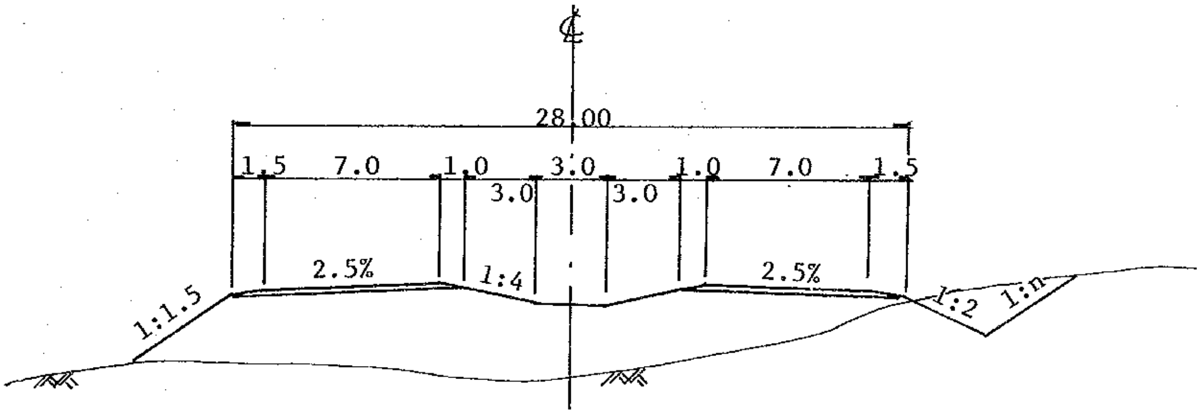
VII.4.1 Horizontal Alignment and Profile

Each route alternative was based on the 1:5,000 scale maps and information obtained through the field reconnaisance and inventory survey. The embankment height was determined in consideration of such factors as topographic features, flood conditions, drainage structures and approaches of intersections, bridges and culverts.

VII.4.2 Typical Cross-Section

Typical cross-section of the Nairobi Bypass has been prepared in accordance with Geometric Design Standard of Kenya (1979) as follows:

Typical Cross-Section (Tentative Design Stage)



VII.4.3 Construction Work Quantities

Construction work quantities together with area of required land acquisition were calculated based on the information obtained in the inventory survey and field reconnaisance, and the preliminary design.

By multiplying unit costs, which were derived from the analysis of the latest contracts for similar type of construction and interviews with contractors on work quantities, construction costs were estimated for each alternative route.

Calculations are made based on the following major work items:

1 General
2 Site Clearance and Top-soil Stripping
3 Earth Work

4 Structure Works
5 Culverts and Drainage Works
6 Natural Sub-base
7 Cement Treated Base
8 Crushed Stone Sub-base
9 Asphalt Concrete
10 Road Furniture

VII.4.4 Cost Estimate (Tentative)

These estimates were made for the purpose of selecting the optimum route from the alternatives, based on the prevalent 1986-1987 price used for similar construction projects in Kenya, referring to MOTC estimate procedures.

Cost estimates were made on the basis of the quantities derived from the road design (horizontal 1:5,000; vertical 1:500 which had been carried out on the map at the scale of 5,000 prepared by MOTC Survey Section).

In general, construction costs or unit prices have recently tended to fall down yearly, reflecting the sluggish economy. Thus the estimates were rather low.

Three cost estimates were derived on the basis of the quantities of the road design respectively, out of which two other routes were on the road design made on a map at a scale of 1:50,000 published by "Kenya Survey".

A comparison of tentative construction costs by alternative plans was given in the following.

VII.4.5 Selection of Optimum Route

The selection of optimum route has been carried out on the rational consideration, so as for the first step, establishment of Route Alternatives was aforementioned in VII-3 in this report to evaluate the route from geology, route alignment, road network with other trunk and feeder roads and many a ristricting control points of view.

In this paragraph, a comparison of construction cost, cost/length, construction efficiency, showing the construction cost required for the future one vehicle running one km was given by alternative plans in the Table VII-4-1.

AS seen on the Table VII-4-1, Alt.-1 (so called shortest Route) was the most applicable route for the bypass, because of the cheapest cost for the construction, cost/length and construction efficiency compering that of other route alternatives. Besides, A104 (Naivasha Road) in the vicinity of Kikuyu Junction, junction with the bypass, will be improved by MOTC to a dual carriageway road in near future, that would be the more encouragement to this route.

Table VII-4-1: Comparison of Tentative Construction Cost by Altanative Plans

Item No	Description	Alt.1	Alt.2	Alt.3
1	General	$9,465 \times 10^3$ xKshs (3)	$9,465 \times 10^3$ xKshs (3)	$9,465 \times 10^3$ xKshs (3)
4	Site Clearance and Topsoil Stipping	6,760 (2)	7,150 (2)	7,176 (2)
5	Earthwork	87,776	111,781 (33)	134,838 (37)
7.9.17	Structure Works	52,185 (17)	46,391 (17)	45,912 (15)
8	Culvert and Drainage Works	1,998 (1)	1,874	1,998
12	Natural Sub-base	38	38	38
13	Cement Treated Base	35,856 (12)	36,670 (10)	37,620 (10)
14	GIR Crushed Stone Sub-base	28,613 (9)	29,900 (9)	30,759 (8)
15	Asphalt Concrete	66,169 (22)	70,970 (20)	72,764 (20)
20	Road Furniture	12,983 (4)	14,017 (4)	16,022 (4)
	Sub - Total	301,843 (100)	328,256 (100)	356,592 (100)
	Add the sum of 7.5% for Contingencies	22,638	24,619	26,744
	Add 10% for price Esclation	30,184	32,825	35,659
	Add 5% for Contractor's Camps Office & other preparations	15,092	16,412	17,829
	TOTAL	369,757	402,112	436,824
	Land acquisition/Compensa-tion/Detail Engineering/ Supervision 1/	22,805	26,525	25,865
	10% of Sub-total	30,184	32,825	35,659
	GRAND TOTAL	422,746 (1)	461,462 (2)	498,348 (3)
	Length of By-pass			
	Through way	28,560 m	29,850 m	30,700 m
	Ramp way	13,480	12,430	12,420
	Total	42,040	42,280	48,120
		(35,300) 2/	(36,065) 2/	(36,910) 2/
	Construction Cost/Length	$11,975 \times 10^3$ Kshs/km (1)	12,795 (2)	13,501 (3)
	Future Traffic (Vehicle Km/ day in year 2000)	544.4×10^3 Vehicle Km/day	444.4×10^3	424.0×10^3
	Transport Efficiency (Construction Cost /Future Traffic)	776 KSh/Vehicle Km/day (1)	1,038 (2)	1,172 (3)

	Alt.1	Alt.2	Alt.3
1 Compensation:	No. $50 \times 150 \times 10^3 = 7500 \times 10^3$	No. $70 \times 150 \times 10^3 = 10500 \times 10^3$	No. $50 \times 150 \times 10^3 = 7,500 \times 10^3$
Land Aquisition:	15,305	16,025	8,365
TOTAL	22,805	26,525	25,865

2 Figure in ( ) : Length of the through way + ½ Ramp way

VII.5 Geological, Soil and Material Survey

VII.5.1 General

Along the proposed alignment, reconnaissance was carried out to define the soil investigation sites with good co-operation from MOTC and Ministry of Natural Resources before execution of soil investigation.

The sub-surface investigations (Boring Survey) for the design of bridge foundations and earth-works were performed. In addition, aggregate materials investigation was carried out in and around Nairobi region.

Test pit surveys were also carried out at proposed borrowing sites and along the proposed alignment at every 2 or 3 km.

After that, laboratory soil tests were carried out.

Details of the geological, soil and material survey are given as follows.

More detailed soil investigation should be carried out at the detailed design stage to support the project.

(1) Boring Survey

Eight mechanical boring surveys were carried out at the points of crossing existing roads and railway in order to identify geological structure and soil characteristics of the various strata.

Furthermore, two mechanical boring surveys at the place where an embankment is being planned and sub-soil is presumed to have poor characteristics and one mechanical boring survey at the place where a deep cut is being planned, were carried out with the object of obtaining basic data to judge the road structure.

The location of the boring place the depth of each boring and the data referring to sample collection, and the standard penetration test to be carried out are shown in Table VII-5-1, Fig. VII-5-1 and Fig. VII-5-2 (1)-(11).

Table VII-5-1

The List of the Mechanical Boring

Bore Hole	Station	Depth (m)	Standard Penetration Test	Undisturbed Sample Collection	Location
B/H No.					
1	At the vicinity of No. 0	7.10	2	1	Interesection with (A104) road to Mombasa
2		6.80	2	-	"
3	No. 63 + 56m	5.25	1	-	Intersection with C58 road
4	At the vicinity of No. 152	6.50	-	-	Intersection with C60 road
5	No. 206 + 25m	14.20	10	9	Intersection with C63 road
6	No. 208 + 40m	20.17	2	1	Deep cut of Dagoretti Forest
7	No. 228 + 10m	10.35	7	6	Intersection with local road to Thogoto
8	No. 267 + 10m	10.95	10	10	Intersection with Railway at the vicinity of Kikuyu
9	No. 204 + 20m	8.80	3	2	Embankment of Kibiriraini
10	No. 260 + 50m	6.65	3	2	Embankment of Nyongara River
11	No. 283 + 95m	9.95	4	3	Intersection with (104) road to Naivasha
Total		106.72	44	34	

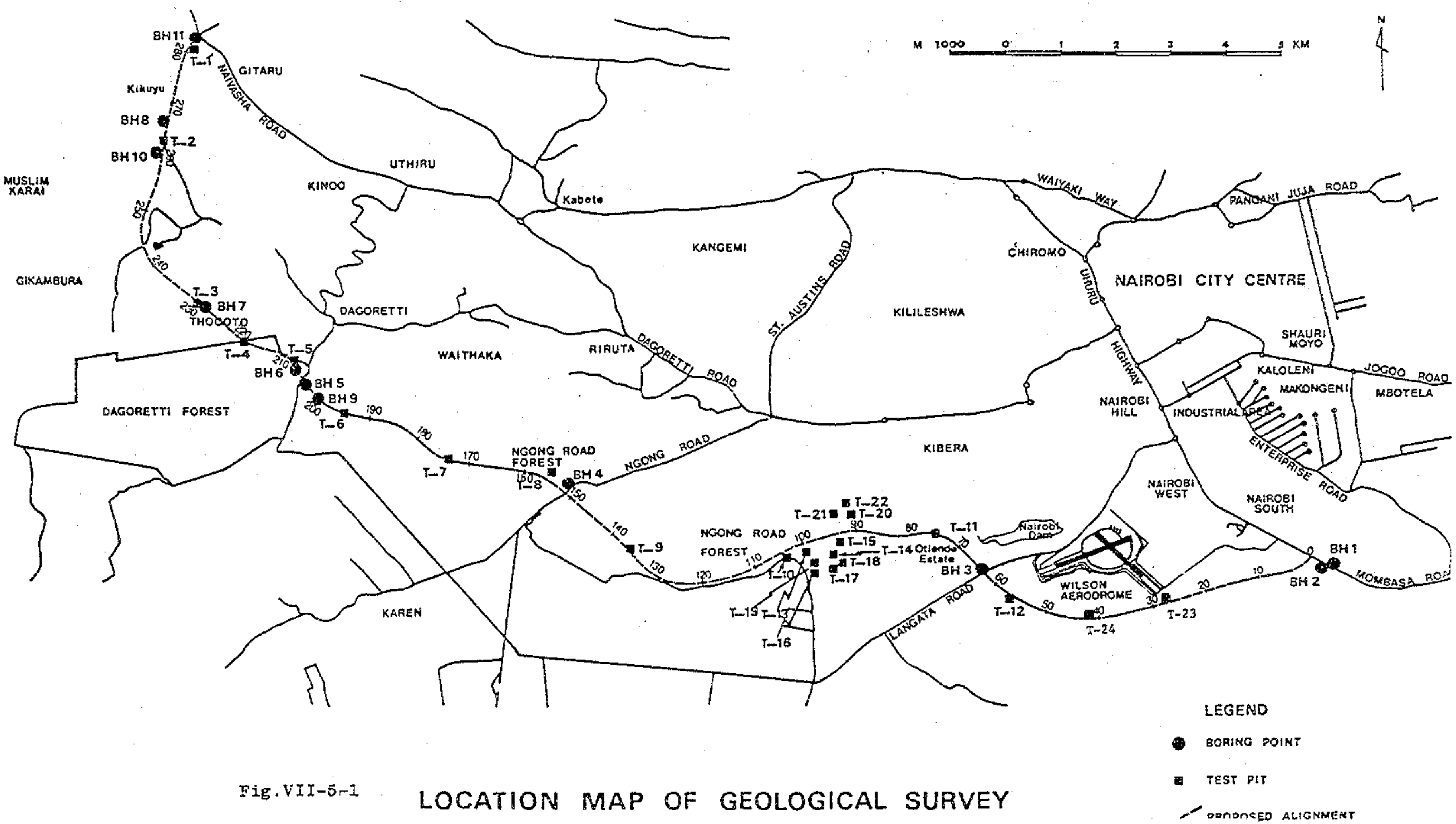


Fig.VII-5-1 LOCATION MAP OF GEOLOGICAL SURVEY a). Geological Record of Boring

DEFINITIONS USED IN DESCRIPTION OF ROCK CORES

WEATHERING GRADE

1A	Fresh	-	No visible sign of weathering
1B	Faint	-	Discolouration on major discontinuity surfaces
II	Slightly	-	Penetrative weathering on open discontinuities but only slight weathering of rock mass
III	Moderately	-	Weathering extends throughout but rock mass not friable
IV	Highly	-	Weathering extends throughout and rock mass is friable.
V	Completely	-	Rock is wholly decomposed and friable but structure and texture are still maintained
VI	Residual Soil	-	Rock completely converted to soil and structure etc. destroyed. Material not significantly transported.

DISCONTINUITY SPACING

Term	Spacing
Very wide	> 2m
Wide	600 mm - 2m
Moderately wide	200 mm - 600 mm
Close	60 mm - 200 mm
Very close	20 mm - 60 mm
Extremely close	< 20 mm

GRAIN SIZE

Term	Particle size	Equivalent soil term
Very coarse	> 60mm	Boulders & Cobbles
Coarse	2 - 60mm	Gravel
Medium	60 micron - 2mm	Sand
Fine	2 - 60 micron	Silt
Very fine	< 2 micron	Clay

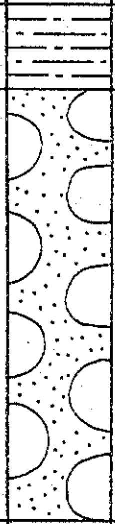
Fig.VII-5-2 (1)

GEOLOGICAL RECORD OF BORING

HOLE No. 1

PROJECT	The Nairobi Bypass Construction Project		LOCATION	A104 road to Monbasa	
GROUND ELEVATION	1,662.2m	DEPTH OF HOLE	7.10m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	150~146mm	MACHINE	Pace Maker	DATE OF DRILLING	26-27/1/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY S.WAMBUA		LOGGED BY J.ODERA	

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY %	CORE RECOVERY cm
1661.0	1.20	1.20		Clay	Dark Grey	with occasional angular lava fragments upto 5cm;with root fibres			
1655.1	7.10	3.90		Phonolitic Agglomerate	Grey with brown patches	Moderately weathered with medium spaced, occasionally closely spaced fractures, grey with brown patches phonolitic AGGLONERATE of angular compact, occasionally vesicular lava fragments upto 15cm in fine grained matrix partially replaced with brown clay. Fractures 0-40° rough clay lined/with upto 3mm clay filling.	II		80, 70, 140, 100, 100, 80



STANDARD PENETRATION TEST

DEPTH (m)	(N)
0.65	24
0.95	
1.25	50/5
1.40	
2.20	
2.90	
4.30	
5.30	
6.30	
7.10	

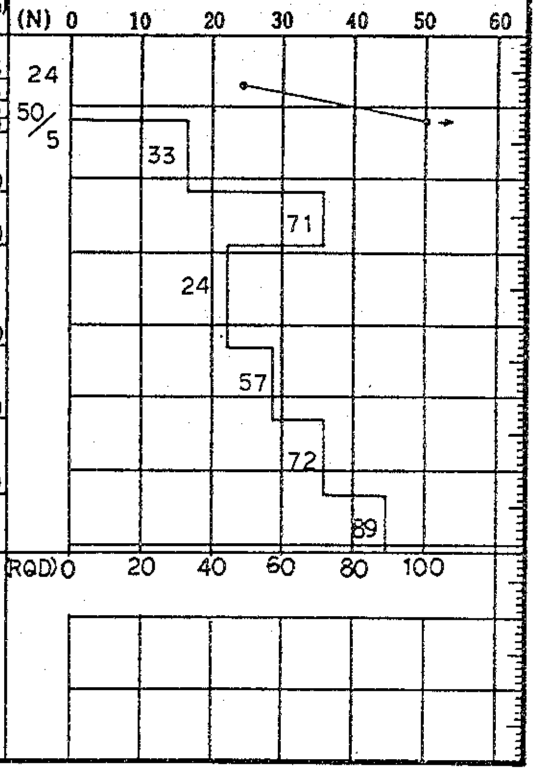


Fig.VII-5-2 (2) **GEOLOGICAL RECORD OF BORING** HOLE No. 2

PROJECT	The Nairobi Bypass Construction Project		LOCATION	A104 road to Monbasa	
GROUND ELEVATION	1,660.9m	DEPTH OF HOLE	6.80	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	150~146mm	MACHINE	B-34	DATE OF DRILLING	26-28/1/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY M.MAKURIBI		LOGGED BY J.ODERA	

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION: COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY %	CORE RECOVERY cm	SPT DEPTH (m)	NUMBER OF BLOWS N
1660.1	0.80	0.80		Clay	Dark Grey	with rare occasional lava fragments upto 5cm; becoming slightly sandy and with weathered fragments at bottom.				0.55 0.80	63/25
					Grey with brown patches	Moderately weathered with closely spaced fractures with subanguiar compact lava fragments upto 12cm in fine grained matrix. Fractures subhorizontal rough with upto 2cm. clay filling.	III		80	1.20 2.60	39
						Slightly weathered with close and medium spaced fractures with subangular phonolite fragments upto 10cm in fine grained matrix (as above).	II		210	4.10	59
						Fractures subhorizontal rough with clay veneer/filling upto 2cm; iron oxide stained.			140	5.50	84
1654.1	6.80	6.00		Phonolitic Agglomerate	Grey with green tint				130	6.80	55

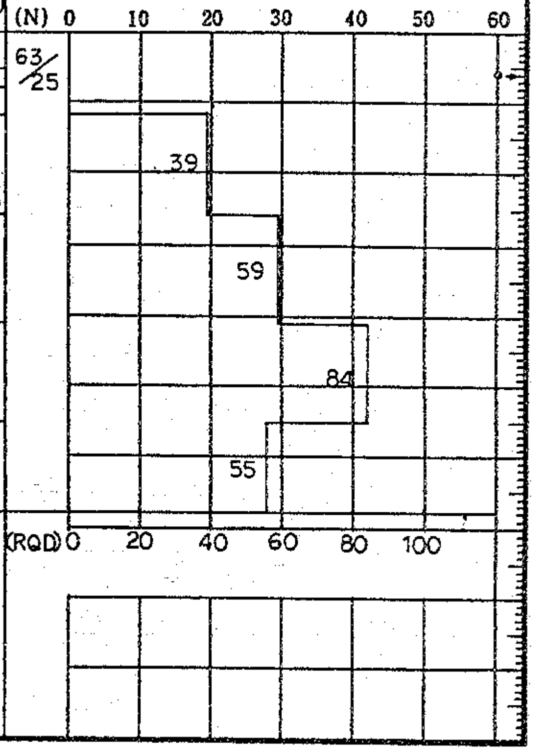


Fig.VII-5-2 (3) **GEOLOGICAL RECORD OF BORING** HOLE No. 3

PROJECT	The Nairobi Bypass Construction Project		LOCATION	C58 road	
GROUND ELEVATION	1732.4m	DEPTH OF HOLE	5.25m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	86mm	MACHINE	Δ750	DATE OF DRILLING	27/1/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	E.SABWA	LOGGED BY	J.ODERA

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION: COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY cm	SPT DEPTH (m)	(N)
			V V V			Faintly weathered with close and medium spaced fractures fine grained TRACHYTE. With faint flow structure of 45° dip. Fractures subhorizontal to medium steep rough tight/planar limonite coated.	IB	55	0.05 0.60	50/5
								55	1.15	29
								55	1.70	85
								145	3.15	62
								150	4.65	45
1727.15	5.25	5.25		Trachyte	Grey			60	5.25	79

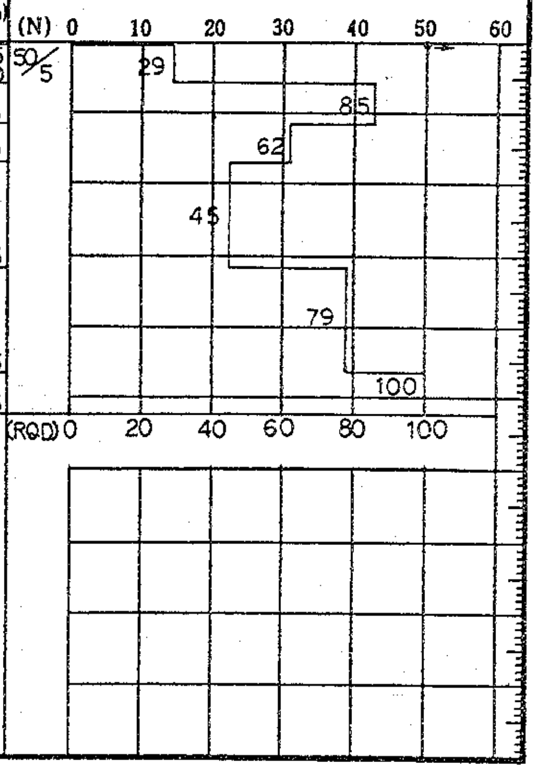


Fig. VII-5-2 (4) GEOLOGICAL RECORD OF BORING

HOLE No. 4

PROJECT	The Nairobi Bypass Construction Project		LOCATION	C60 road	
GROUND ELEVATION	1826.5m	DEPTH OF HOLE	6.50	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	86mm	MACHINE	Δ750	DATE OF DRILLING	30-31/1/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	E.SABWA	LOGGED BY	J.ODERA

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY cm	SPT DEPTH (m)	NUMBER OF BLOWS N
					Brownish grey	0~1.05m, 5.00~6.50m moderately weathered with medium spaced fractures	III	50	0.20–0.85	
						1.05~5.00m slightly weathered with widely spaced fractures	II	140	2.25	66
								125	3.50	94
					light grey			150	5.00	93
1820.0	6.50	6.50		Agglomeratic Tuff	Brown		III	150	6.50	34

STANDARD PENETRATION TEST: NUMBER OF BLOWS N — (N) 0 10 20 30 40 50 60; (RQD) 0 20 40 60 80 100

Fig. VII-5-2 (5) **GEOLOGICAL RECORD OF BORING** HOLE No. 5

PROJECT	The Nairobi Bypass Construction Project	LOCATION	C63 road		
GROUND ELEVATION	1896.0m	DEPTH OF HOLE	14.20m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	150~86mm	MACHINE	Pace Maker	DATE OF DRILLING	28-31/1/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	S.WAMBUA	LOGGED BY	J.ODERA

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY (cm)
1894.80	1.20	1.20	Silty Clay	Reddish Brown			
1894.35	1.65	.45	Silty Sand	Brownish grey	fine~medium sand		
1892.00	4.00	2.35	Silty Clay	Brownish grey	slightly sandy		
1888.00	8.00	4.00	Clay	Brown			
1887.00	9.00	1.00	Clayey Silt	Brown	slightly sandy		
1886.28	9.72	0.72	Clay	Brown			
1885.60	10.40	0.68	Boulder	light grey	trachyte boulder		
1883.45	12.55	2.15	Clay	Grey stained [illegible]	[illegible] trace [illegible]		
1881.80	14.20	1.66	Tuff	Pinkish grey	moderately weathrned with widely spaced fractures with occasional lava inclusions upto 5mm	III	70 / 70

STANDARD PENETRATION TEST

DEPTH (m)	NUMBER OF BLOWS (N)
1.35–1.65	42
2.40–2.70	26
3.65–3.95	16
4.65–4.95	17
5.65–5.95	30
6.65–6.95	24
7.65–7.95	32
8.65–8.95	30
9.50–9.725	70/12.5
	35

DEPTH (m)	RQD
13.50	13
14.20	71

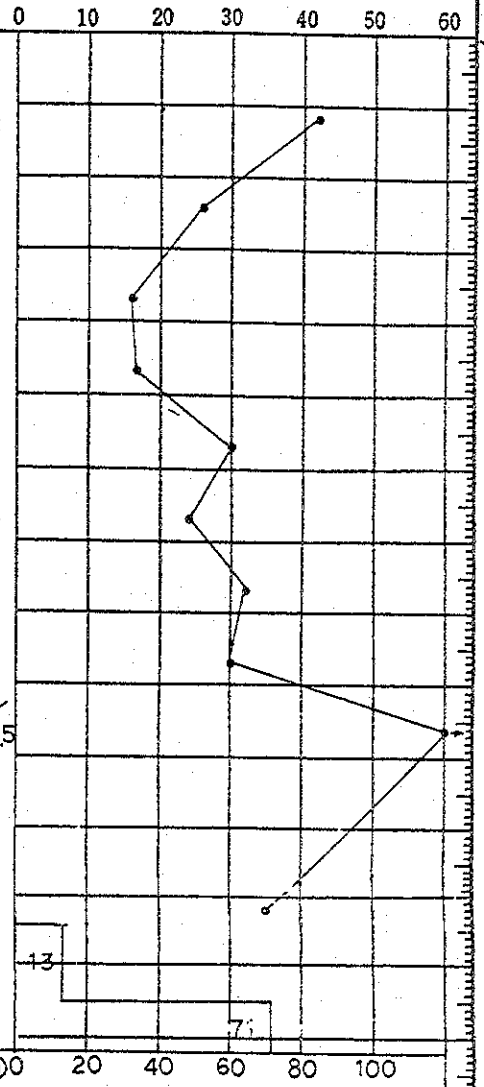
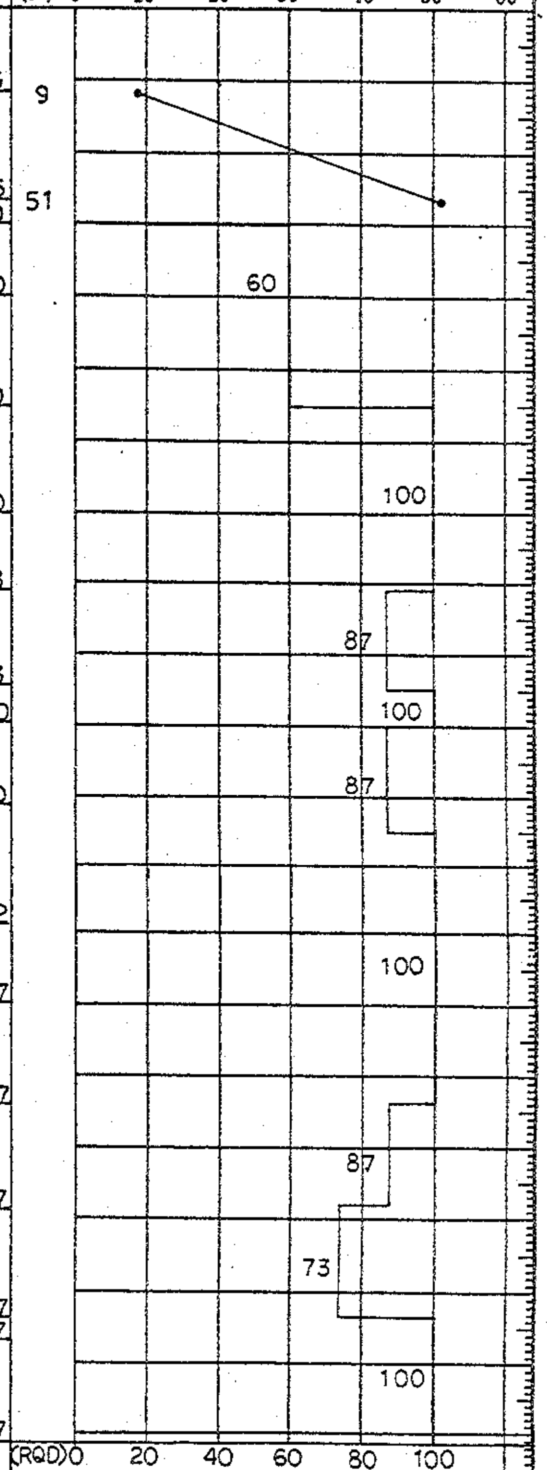


Fig. VII-5-2 (6) **GEOLOGICAL RECORD OF BORING** HOLE No. 6

PROJECT	The Nairobi Bypass Construction Project		LOCATION	Pagoretti Forest	
GROUND ELEVATION	1933.5m	DEPTH OF HOLE	20.17m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	150~86mm	MACHINE	B－34	DATE OF DRILLING	29-31/1/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	M.MAKURIBI	LOGGED BY J.ODERA	

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE
1931.00	2.50	2.50	x x	Silty Clay	Reddish brown / Greyish brown	0~2.00m with occasional black ferruginous spots upto 5mm in lower zone. 2.00 ~2.50m completely weathered trachyte	
1930.50	3.00	0.50	v v v	Highly Weathered Trachyte	Light grey	fragmented	
1913.33	20.17	17.17	v v v	Porphyritic Trachyte	Light grey / Grey	3.00~4.05m slightly weathered with widely spaced fractures vesicular 4.05~20.17m faintly weathered with widely spaced fractures with vesicular bands a few cm upto 35cm thick in zone 4.05~9.10m. Fractures horizontal and steep rough iron oxide encrusted	II / IB

CORE RECOVERY / STANDARD PENETRATION TEST



DEPTH (m)	Core recovery (cm)	N	RQD
1.15		9	
2.65		51	
3.00			
4.00	100		60
5.50	150		
7.00	150		100
8.08	108		
9.43	135		87
10.00	57		100
11.50	150		87
12.92	142		
13.97	107		100
15.37	140		
16.87	150		87
18.37	150		73
18.67	30		
20.17	150		100

Fig. VII-5-2 (7) **GEOLOGICAL RECORD OF BORING** HOLE No. 7

PROJECT	The Nairobi Bypass Construction Project		LOCATION	Thogoto	
GROUND ELEVATION	1944.1m	DEPTH OF HOLE	10.35m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	150~146mm	MACHINE	Pace Maker	DATE OF DRILLING	31/1-1/2/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	S.WAMBUA	LOGGED BY	J.ODERA

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE
1987.30	6.80	6.80	Silty Clay	Reddish brown	with trace and occasional black ferruginous spots upto 5mm below 1.15m depth.	
1983.75	10.35	3.55	Porphyritic Trachyte	Light grey	6.80~8.02m highly weathered 8.02 ~8.40m reddish brown silty clay patches 8.40~9.15m moderately weathered 9.15~10.35m slightly weathered	IV NA III I

STANDARD PENETRATION TEST

DEPTH (m)	NUMBER OF BLOWS (N)
1.35–1.65	44
2.30–2.60	53
3.45–3.75	60
4.25–4.55	53
5.35–5.65	47
6.30–6.60	50
7.00–7.23	121/23

RQD: 60 (to 7.82), 30 (to 9.00), 65 (to 10.35)

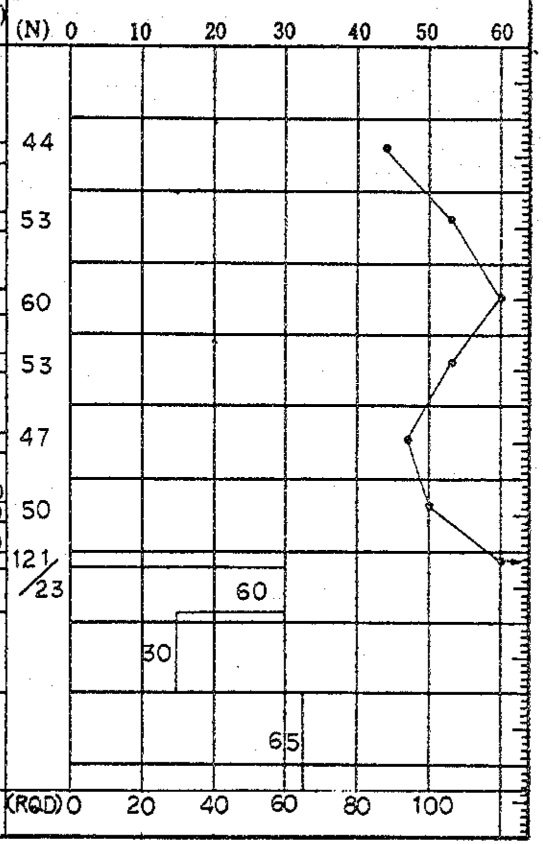


Fig.VII-5-2 (8) **GEOLOGICAL RECORD OF BORING** HOLE No. 8

PROJECT	The Nairobi Bypass Construction Project		LOCATION	Railway at the vicinity Kikuya	
GROUND ELEVATION	2039.5m	DEPTH OF HOLE	10.95m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	200mm	MACHINE	△750	DATE OF DRILLING	1-4/2/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	E. SABWA	LOGGED BY	J.ODERA

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY %	CORE RECOVERY cm
2028.55	10.95	10.95		Silty Clay	Reddish brown	with occasional black ferruginous spots upto 5mm.			

STANDARD PENETRATION TEST

DEPTH (m)	NUMBER OF BLOWS (N)
1.65	17
2.65	31
3.65	35
4.65	41
5.65	48
6.65	56
7.65	65
8.65	29
9.65	27
10.65	32
10.95	

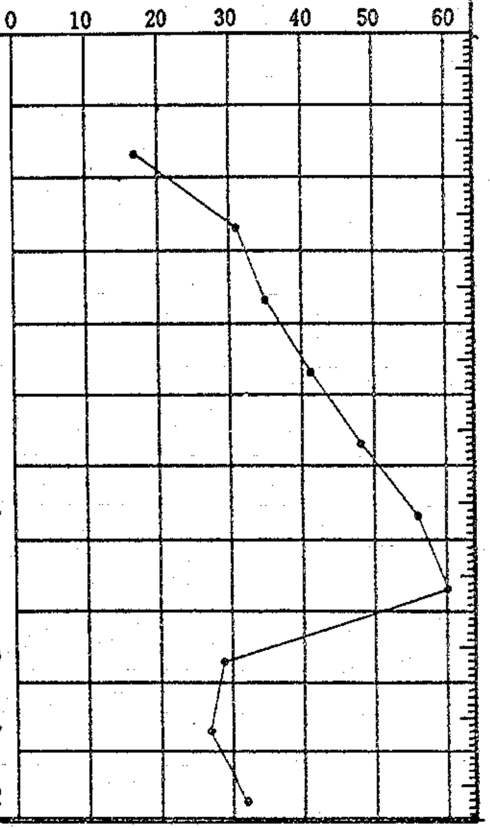


Fig. VII-5-2 (9) **GEOLOGICAL RECORD OF BORING** HOLE No. 9

PROJECT	The Nairobi Bypass Construction Project	LOCATION	Kibiriraini		
GROUND ELEVATION	1892.7m	DEPTH OF HOLE	8.80m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	150~146mm	MACHINE	B-34	DATE OF DRILLING	3~4/2/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	M. MAKURIBI	LOGGED BY	J.ODERA

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY cm
188925	3.45	3.45	Clay	Grey / Brown	occasionaly with some fine and medium gravel		
188760	5.10	1.65	Clayey silt	Orange brown	sandy and with some fine gravel in lower zone		
188390	8.80	3.70	Agglomeratic Tuff	Brown ~ Grey	5.10~7.75m, 8.25~8.80m moderately weathered subangular pumice and lava fragments upto 4cm in fine and medium grained matrix. 7.75 ~8.25m light brownish grey clay	III / VI / III	70 / 150 / 150

STANDARD PENETRATION TEST

DEPTH (m)	(N)
1.65	9
3.65	22
5.00	52/10

DEPTH (m)	(RQD)
5.00~5.80	86
5.80~7.30	56
7.30~8.80	8

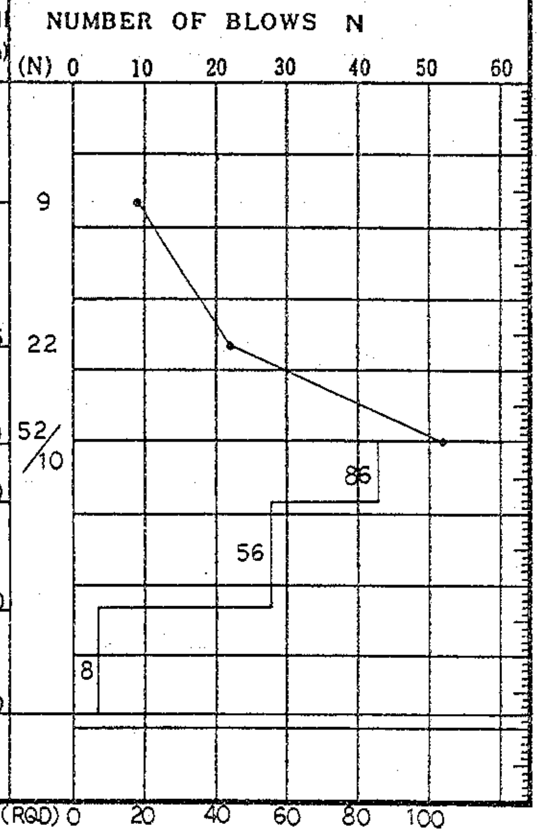


Fig. VII-5-2 (10) GEOLOGICAL RECORD OF BORING — HOLE No. 10

PROJECT	The Nairobi Bypass Construction Project	LOCATION	Nyongara River		
GROUND ELEVATION	1999.9 m	DEPTH OF HOLE	6.65m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	150~86mm	MACHINE	△750	DATE OF DRILLING	7/2/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	E. SABWA	LOGGED BY	J.ODERA

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY (cm)	SPT DEPTH (m)	(N)
1998.40	1.50	1.50	Peat	Dark brown	decomposing swamp vegetation with sandy clayey silt layer at bottom			0.50	0
1997.75	2.15	0.65	Completely Weathered Agglomerate	Light grey	trachytic			1.65	35
								2.10	50/5
1994.60	5.30	3.15	Trachytic Agglomerate	Grey	2.15~2.70m slightly weathered 2.70~5.30m moderately weathered	II III	150 150	3.65 5.15	
1993.25	6.65	1.35	Trachyte	Grey	faintly weathered with widely spaced fractures	IB	150	6.65	

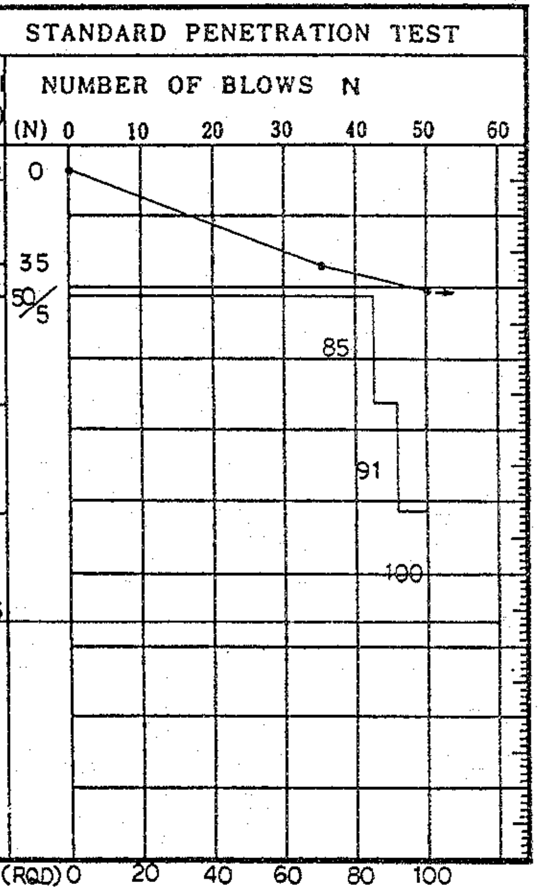


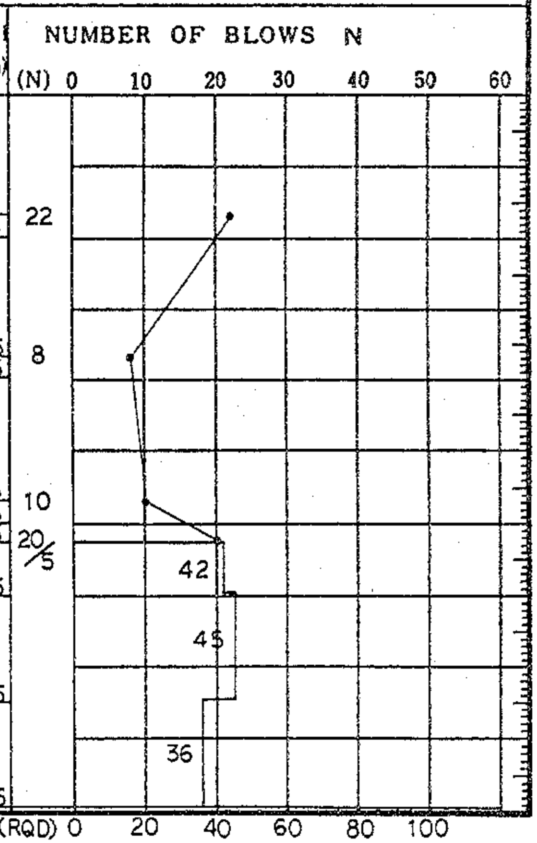
Fig.VII-5-2 (11) **GEOLOGICAL RECORD OF BORING** HOLE No. 11

PROJECT	The Nairobi Bypass Construction Project		LOCATION	A104 road to Naivasha	
GROUND ELEVATION	2040.5 m	DEPTH OF HOLE	9.95m	ANGLE FROM VERTICAL	0°
DIAMETER OF HOLE	150~86mm	MACHINE	B-34	DATE OF DRILLING	5-6/2/87
CORE RECOVERY		DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	M. MAKURIBI	LOGGED BY	J.ODERA

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	GRADE	CORE RECOVERY (cm)
2037.00	3.50	3.50	Silty Clay	Reddish brown	completely weathered trachyte		
2034.30	6.20	2.70	Sandy Silt	Grey			
2030.55	9.95	3.75	Porphyritic Trachyte	Light grey	moderately weathered with close and medium spaced fractures	III	70 / 129 / 129

STANDARD PENETRATION TEST

DEPTH (m)	N
1.65–1.95	22
3.65–3.95	8
5.65–5.95	10
5.95–6.25	20/5
6.95	42
8.45	45
9.95	36



(2) Soil Test

Laboratory tests were carried out in order to obtain basic soil data along the proposed alignment. 36 samples from mechanical boring and 12 samples (T-1-12) from test pits at the presumed cutting places were collected.

Furthermore, 10 test pit samples (T-13-22) from proposed borrowing sites were collected and laboratory tests for subgrade material were also carried out to confirm deposits of good material.

These tests were conducted based on the British Standards (B.S.). The list of the tests is shown in Table VII-5-2, Table VII-5-3, and Table VII-5-4.

Table VII-5-2

The List of Laboratory Tests for Soils

		PHYSICAL TESTS				MECHANICAL TESTS					
		Grain Size	Specific Gravity	Water Cont-ent.	Plasticity Index	Unit Wei-ght.	Unco-fined Comp-ress-ion.	Tria-xial Test	Con-soli-dati-on Test	Com-patio-n Test	Sub-gra earth CBR
SAMPLES COLLECTED BY MECHANICAL BORING	H-1	2	2	2	2	1	-	-	-	-	-
	2	1	1	1	1	-	-	-	-	-	-
	3	10	10	10	10	9	5	-	-	-	-
	4	1	1	1	1	-	-	-	-	-	-
	5	2	2	2	2	2	1	-	-	-	-
	6	10	10	10	10	10	12	-	-	-	-
	7	4	4	3	4	2	-	1	1	-	-
	8	2	2	2	2	2	-	2	2	-	-
	9	3	3	3	3	3	1	-	-	-	-
ROAD CUTTIN 12 PLACES	T-1	1	1	1	1	-	-	-	-	1	1
	2	1	1	1	1		-	-	-	-	-
	3	1	1	1	1		-	-	-	-	-
	4	1	1	1	1		-	-	-	-	-
	5	1	1	1	1		-	-	-	1	1
	6	1	1	1	1		-	-	-	1	1
	7	1	1	1	1		-	-	-	-	-
	8	1	1	1	1		-	-	-	1	1
	9	1	1	1	1		-	-	-	-	-
	10	1	1	1	1		-	-	-	-	-
	11	1	1	1	1		-	-	-	1	1
	12	1	1	1	1		-	-	-	-	-
PROPOSED BORROWING 10 PLACES	13	1	1	1	1		-	-	-	-	-
	14	1	1	1	1		-	-	-	1	1
	15	1	1	1	1		-	-	-	1	1
	16	1	1	1	1		-	-	-	-	-
	17	1	1	1	1		-	-	-	1	1
	18	1	1	1	1		-	-	-	-	-
	19	1	1	1	1		-	-	-	-	-
	20	1	1	1	1		-	-	-	-	-
	21	1	1	1	1		-	-	-	1	1
	22	1	1	1	1		-	-	-	-	-
Total		57	57	56	57	29	9	3	3	8	8

Table VII-5-3 Soil Test Results, Summary (Bore Holes)

B/H No.	Depth (m)	Particle size distribution (%)					Atterberg Limits		SG	MC (%)	UW g/cm³	Classification of Soils			Consolidation Test			U.C.S.	Triaxial Test		Remarks
		>5mm	5-2mm	2mm-75μm	75-2μm	2μm>	LL	PI				Class.	group index	AASHOT	e_o	C_c	C_v cm²/d	q_u kg/cm²	c kg/cm²	φ	
1	0.00~1.00	9	3	5	25	58	89	45	2.33	*24.8	—	MH	20	A-7-5	—	—	—	—	—	—	
1	1.00~1.20	0	0	40	35	25	42	18	2.65	20.1	1.967	CL	8	A-7-6	—	—	—	—	—	—	B/H-9, 1.00-1.45m :Sample noted to be swelling during the conalidation test without the applied pressure(461.4KN/m²=4.6kg/cm²).
2	0.00~0.70	13	1	3	20	63	93	44	2.61	*27.7	—	MH	20	A-7-5	—	—	—	—	—	—	
5	0.00~1.00	6	5	22	35	32	45	20	2.47	*13.6	—	CL	11	A-7-6	—	—	—	—	—	—	
5	1.00~1.15	21	3	8	28	40	49	20	2.40	15.4	1.970	ML	12	A-7-6	—	—	—	11.50	—	—	
5	2.00~2.20									15.5	1.762				—	—	—	—	—	—	SG: Specific Gravity
5	3.00~3.45	0	0	34	53	13	45	18	2.45	18.0	2.035	ML	10	A-7-6	—	—	—	10.19	—	—	MC: Natural Moisture Content
5	4.00~4.45	0	0	22	42	36	58	29	2.52	29.8	1.919	CH	19	A-7-6	—	—	—	3.64	—	—	
5	5.00~5.45	0	0	23	32	45	74	42	2.53	31.0	1.878	CH	20	A-7-5	—	—	—	—	—	—	UW: UnitWeight
5	6.00~6.45	0	0	32	30	38	54	22	2.51	37.7	1.808	MH	14	A-7-5	—	—	—	2.61	—	—	Class: TheUnified Soil Classification System
5	7.00~7.45	0	0	24	33	43	64	29	2.48	30.3	1.791	MH	20	A-7-5	—	—	—	—	—	—	
5	8.00~8.45	0	0	37	37	26	41	16	2.49	47.1	1.917	CL	8	A-7-6	—	—	—	1.41	—	—	
5	9.00~9.45	0	0	29	39	32	47	23	2.68	31.0	1.897	CL	14	A-7-6	—	—	—	—	—	—	e_o : Initial Void Ratio
5	11.00~12.00	0	0	19	47	34	54	22	2.37	—	—	MH	14	A-7-5	—	—	—	—	—	—	C_c : Compression Index
6	1.45~1.90	0	0	7	16	77	58	20	2.64	38.9	—	MH	16	A-7-5	—	—	—	—	—	—	
7	1.00~1.15	0	0	4	20	76	62	24	2.65	27.6	1.636	MH	18	A-7-5	—	—	—	—	—	—	C_v : Coeficient of Consolidation
7	3.00~3.25	0	0	5	17	78	66	24	2.71	28.1	1.580	MH	18	A-7-5	—	—	—	3.79	—	—	
8	1.00~1.45	0	0	5	32	63	67	30	2.58	34.4	1.684	MH	20	A-7-5	—	—	—	—	—	—	q_u : Unconfind Conpression Strength
8	2.00~2.45	0	10	19	41	30	60	23	2.59	26.2	1.810	MH	16	A-7-5	—	—	—	9.49	—	—	
8	3.00~3.45	0	0	4	9	87	76	37	2.66	31.6	1.879	MH	20	A-7-5	—	—	—	—	—	—	C : Cohesion
8	4.00~4.45	0	0	4	8	88	74	35	2.63	32.8	1.878	MH	20	A-7-5	—	—	—	—	—	—	φ : internal friction
8	5.00~5.45	0	0	2	9	89	67	24	2.68	36.6	1.805	MH	18	A-7-5	—	—	—	—	—	—	* : Dry Condition
8	6.00~6.45	0	0	3	12	85	69	29	2.67	25.2	1.905	MH	20	A-7-5	—	—	—	2.37	—	—	
8	7.00~7.45	0	0	2	7	91	71	29	2.56	33.8	1.789	MH	20	A-7-5	—	—	—	—	—	—	
8	8.00~8.45	0	0	1	8	91	71	27	2.48	35.6	1.814	MH	19	A-7-5	—	—	—	—	—	—	
8	9.00~9.45	0	0	1	14	85	77	35	2.59	36.9	1.817	MH	20	A-7-5	—	—	—	—	—	—	
8	10.00~10.45	0	0	2	13	85	73	28	2.65	38.4	1.732	MH	19	A-7-5	—	—	—	—	—	—	
9	0.00~1.00	0	0	4	22	74	90	47	2.36	*27.7	—	MH	20	A-7-5	—	—	—	—	—	—	
9	1.00~1.45	0	1	3	14	82	96	50	2.39	30.6	1.818	MH	20	A-7-5	0.803	0.332	15.6-11.2	—	3.58	15	
9	3.00~3.45	1	4	26	33	36	66	28	2.62	31.7	1.810	MH	17	A-7-5	—	—	—	—	—	—	
9	4.00~5.00	1	3	45	47	12	41	9	2.53	—	—	ML	3	A-5	—	—	—	—	—	—	
10	0.50~0.95	1	12	51	21	15	NP		2.28	332.1	1.125	PT			1.233	0.800	72.6-6.61	—	0	0	
10	1.00~1.45	0	3	36	52	9	NP		1.81	210.8	1.175	PT			0.286	0.152	136.7-83.6	—	0	0	
11	1.00~1.45	0	0	2	7	91	77	33	2.55	31.2	1.741	MH	20	A-7-5	—	—	—	—	—	—	
11	3.00~3.45	0	0	17	63	20	55	23	2.61	51.7	1.645	MH	16	A-7-5	—	—	—	1.29	—	—	
11	5.00~5.45	0	0	21	71	8	33	7	2.51	38.0	1.718	ML	11	A-4	—	—	—	—	—	—	

Table VII-5-4 Soil Test Resulys, Summary (Test Pits)

T/P No.	Particle size distribution (%)					Atterberg Limits		SG	MC (%)	Classification of Soils			Compaction		C. B. R.		Remarks
	>5mm	5-2mm	2mm-75μm	75-2μm	2μm>	L L	P I			Class.	group Index	AASHOT	M.D.D. (g/cm³)	O.M.C. (%)	%	Swell (%)	
1	0	0	1	10	89	76	29	2.68	35.7	MH	20	A-7-5	1.316	35	12	2.7	SG: Specific Gravity MS: Moisture Content Class: TheUnified Soil Classification System M.D.D.: Maximum DryDencity O.M.C.: Optimum Moisture Content C.B.R.: California Bearing Ratio: 4days soak
2	3	0	2	10	85	67	22	2.67	29.7	MH	17	A-7-5	—	—	—	—	
3	0	0	4	24	72	65	25	2.68	30.0	MH	18	A-7-5	—	—	—	—	
4	0	0	8	59	33	60	23	2.65	25.8	MH	17	A-7-5	—	—	—	—	
5	1	1	15	45	38	56	17	2.64	23.2	MH	14	A-7-5	1.460	28	30	0.2	
6	0	0	3	25	72	63	21	2.69	31.8	MH	16	A-7-5	1.388	31	12	1.3	
7	0	0	6	55	39	53	17	2.74	24.8	MH	13	A-7-5	—	—	—	—	
8	1	13	4	37	45	61	19	2.67	31.8	MH	16	A-7-5	1.388	32	16	1.2	
9	0	0	3	56	41	58	18	2.72	25.6	MH	15	A-7-5	—	—	—	—	
10	0	0	8	39	53	58	24	2.67	25.7	MH	17	A-7-5	—	—	—	—	
11	20	22	19	22	17	55	19	2.67	31.8	SM	3	A-7-5	1.476	29	33	0.1	
12	2	5	11	46	36	49	16	2.52	23.1	ML	12	A-7-5	—	—	—	—	
13	0	0	7	63	30	59	16	2.70	25.4	MH	14	A-7-5	—	—	—	—	
14	0	1	5	20	74	55	18	2.67	23.8	MH	15	A-7-5	—	—	—	—	
15	0	0	6	25	69	60	19	2.65	25.7	MH	16	A-7-5	1.380	32	18	0.3	
16	43	12	15	26	4	49	15	2.64	27.3	SM	1	A-2-7	—	—	—	—	
17	5	30	10	24	31	60	19	2.72	22.7	MH	10	A-7-5	1.552	26	24	0.1	
18	0	0	4	22	74	54	14	2.60	23.7	MH	12	A-7-5	—	—	—	—	
19	13	19	9	31	28	53	16	2.58	20.6	SM	9	A-7-5	—	—	—	—	
20	14	10	14	23	39	61	18	2.60	31.2	MH	11	A-7-5	—	—	—	—	
21	0	0	8	57	35	58	19	2.61	24.5	MH	15	A-7-5	1.375	32	19	0.1	
22	1	1	4	48	46	58	19	2.63	32.1	MH	15	A-7-5	—	—	—	—	

(3) Material Survey

Materials were classified into 3 kinds as follows: -

Coarse aggregates for sub-base and shoulders

Coarse aggregate for base and surfacing

Fine aggregate

Materials for sub-base and shoulder were studied by means of a field survey along the proposed alignment. Six samples were collected from proposed quarries along or near the alignment and taken for laboratory tests.

Materials for base and surfacing were studied by means of field survey and data collected from Materials Branch (M.O.T.C.). Three samples of fine aggregate were collected for testing.

Table VII-5-5 shows the list of Laboratory tests.

Table VII-5-5

The List of Laboratory Tests for Materials

	Particle Distribution (to 75 Micron)	Specific Gravity	Water Absorption	Plasticity Index	Los Angeles Abrasion Test
Fine Aggregate 3 Samples					
1. Rhwaje River	1	1	1	1	-
2. Ikiwe River	1	1	1	1	-
3. Talala River	1	1	1	1	-
Coarse Aggregate 6 Samples					
1. Kirari		1	1	1	1
2. Alliance School	-	1	1	1	1
3. Dagoretti Forest (Porous)	-	1	1	1	1
4. Dagoretti Forest (Non-porous)	-	1	1	1	1
5. Langata Prison (Upper)	-	1	1	1	1
6. Langata Prison (Lower)	1	1	1	1	1
Total	3	9	9	9	6

VII.5.2 Outlines of Physiography and Geology

(1) Topography

Kenya consists of four major regions namely Coastal region, Rift Valley, its associated highlands, and the Lake Victoria Basin.

Nairobi and its environs are located on the eastside highland of the Rift Valley. Nairobi's western and northern parts are hilly land which is about 2,000m above sea level. The southern and eastern parts of Nairobi are spreaded on the Athi and Kapiti Plains 1,899m above sea-level. From west to east, the topography inclines gently.
Rocky mountains lie in Machakos District about 50 - 60km east of Nairobi. Highland regions to the west and north of Nairobi are mainly used as farm land and except for town streets, unused land is covered with trees. The surface of the Athi plain is covered with black cotton soil which is very cohesive.

This area belongs to the Athi River Drainage System and is crossed by many rivers (Motoine River, Mokoyoti River, Nairobi River etc.) which flow from the eastern highlands of the Rift valley towards the east forming alluvial deposits in places

(2) Geology

Bedrock in East Africa including Kenya is formed by crystalline Precambrian rocks belonging to the Mozambique Belt. The geological structure is typified by the Great Rift Valley stretching South and North.

Bedrock in this area has been cut by many faults along the Rift Valley, and the Rift Valley and environs have been covered with thick volcanic rock produced by aggressive igneous action after the tertiary period.

Accordingly, phonolite, trachyte, Tuff etc. which were spouted sometimes from tertiary to pleistocene are distributed on the east highlands of the Rift Valley including Nairobi.

Distribution of Precambrian crystalline rocks is only the east side of the rock mountains in Machakos 50 - 60 km east of Nairobi.

Surface soil on the northwest highland region of Nairobi is composed with soil from volcanic ash, weathered volcanic rocks etc. Black cotton soil, however, which is cohesive and hygroscopic is distributed in the Athi Plain on the southeast side of Nairobi.

The field survey area is crossed by a lot of rivers belonging to the Athi River Drainage System and there is some intermittent distribution of alluvial deposits. Some of these alluvial deposits show locally in swamps during the rainy season. Geological conditions of Nairobi and environs are shown in Fig. VII-5-3.

VII.5.3 Results of Geological Survey Along the Proposed Alignment

(1) Geology

The proposed road starts on the Mombasa Road (A104) near the northeast edge of Nairobi National Park and reaches Kikuyu junction on Naivasha Road (A104) passing through Ngong Forest located to the south and Dagoretti Forest to the west of Nairobi City.

Geological stratigraphy along the proposed alignment is shown in Table VII-5-6.

Table VII-5-6 Geological Stratigraphy

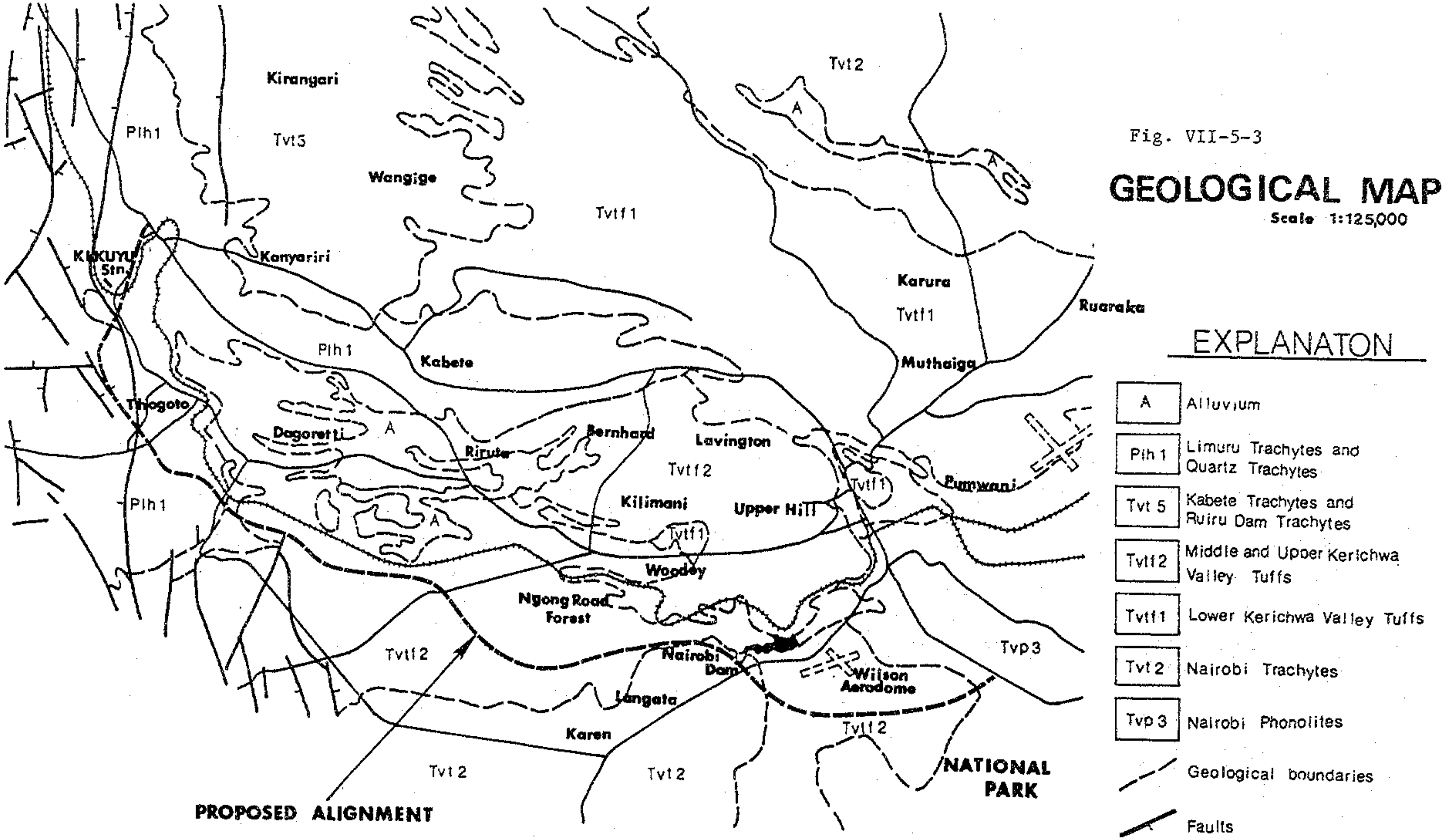
Geological Age	Stratum		Lithologic Character
Alluvium	Alluvium	A	Clay, peat, Sand, Gravel etc.
	Black Cotton Soil	B	Clay
	Soil and high weathering rock	S	
Pleistocene	Limuru Trachytes	Plh_1	Trachyte Lava
	Middle and Upper Karichwa Valley tuffs	$Tvtf_2$	Pyroclastic tuff
	Lower Karichwa Valley tuffs	$Tvtf_1$	Welded Tuff
	Nairobi Trachy-tes	$Tvtf_2$	Trachyte
	Nairobi Phono-lites	Tvp_3	Phonolitic Agglome-rate and Phonolite

Topographical feature and geological conditions along the proposed route are as follows.

Fig. VII-5-3

GEOLOGICAL MAP

Scale 1:125,000



STA No. 0 - No. 52

Proposed alignment stretches along the boundary of the Nairobi National Park. Topography is generally flat and about 1,700m above sea level (Athi plain).

Surface of land is covered overall with black cotton soil which on the average is less than 0.5m thick (maximum about 1.0m thick).

Up to STA No. 15, bedrock is phonolitic agglomerate which belongs to the horizon of Nairobi phonotiles (TVP3) and Pyroclastic tuff (TVtf2) distributes between STA No. 15 and No. 52.

STA No. 52 - No. 72

This section lies on a gentle slop between Athi plain and Highland. It crosses Langata Road (C58) and slightly the edge of the Army camp.

Trachyte of Nairobi Trachytes Horizon (TVt_2) is distributed in this section, and surface soil is very thin.

STA No. 75 - No. 151

This section stretches on a gentle slope on the right bank of Motoine River.

There are some rolling topography at crossing valleys of branches of Motoine River.

Geology of this section is mainly composed of pyroclastic tuff of TVtfz horizon, but in the section, between STA No. 75 - No. 1.0 outcrops of welded tuff ($TVtf_2$) and Trachyte (TVt_2), were observed at low land along the valley.

Surface soil is mainly composed of red brown silty clay more than 3.0m thick maximum covering it. However, it is thin on the slope along the river and lateratic soil is observed in places.

STA No. 151 - No. 206

Proposed alignment crosses Ngong Road and Motoine River near STA No. 151. After that it passes through the gentle slope at the left bank of Motoine River and alluvial low land in the section STA No. 198 - No. 206 which is the river head of Motoine River.

Pyroclustic Tuff is overall distributed as bedrock and the surface is covered with redbrown silty soil 5.0m thick maximum.

STA No. 206 - Kikuyu Junction

This section stretches on a plateau lying between 1,900 to 2,000m above sea-level in which Limuru Trachytes of Pleistone is distributed. The plateau was formed with Lava.

Topography of this section is rolling contrary to the above mentioned gentle land in which Tertiary is distributed.

Deposit in this section is mainly formed with Trachyte lava. The surface is covered with redbrown silty clay, and its depth is more than 10m. Surface soil, however, at the steep slope at the boundary of Dagoretti Forest near STA No. 207 is very thin and an outcrop of bedrock is found. There is a dissected valley near STA No. 260 where Nyongara River flows alluvial (peat) deposit of 1.5m thick is distributed at the bottom of the valley.

The above-mentioned geological condition is shown on the geological section as follows.

The result of the Test pit is shown in the Appendix.

FIGURE VII-5-4

GEOLOGICAL SECTION (A)

Scale H 1 : 40,000
V 1 : 1,000

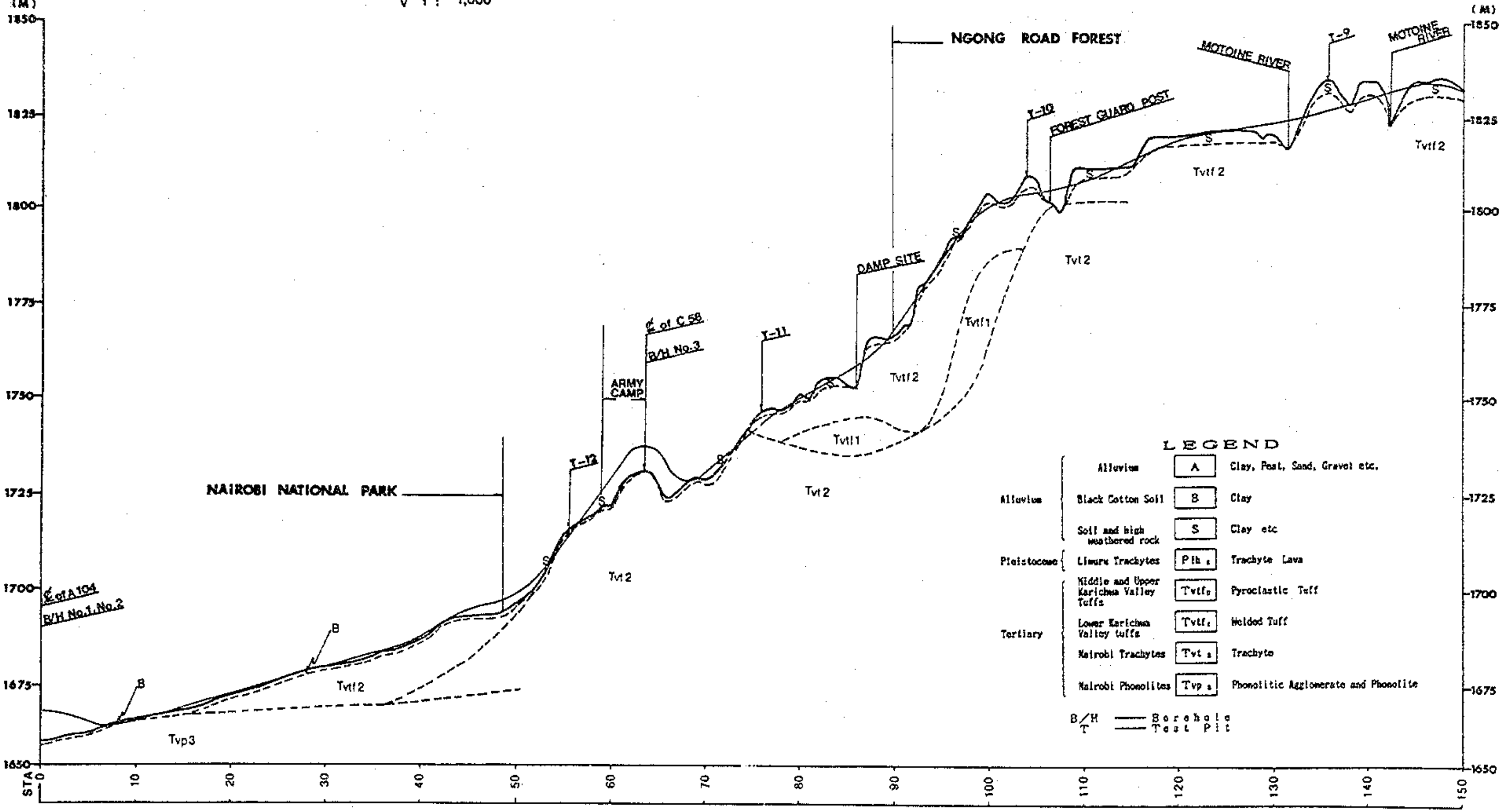
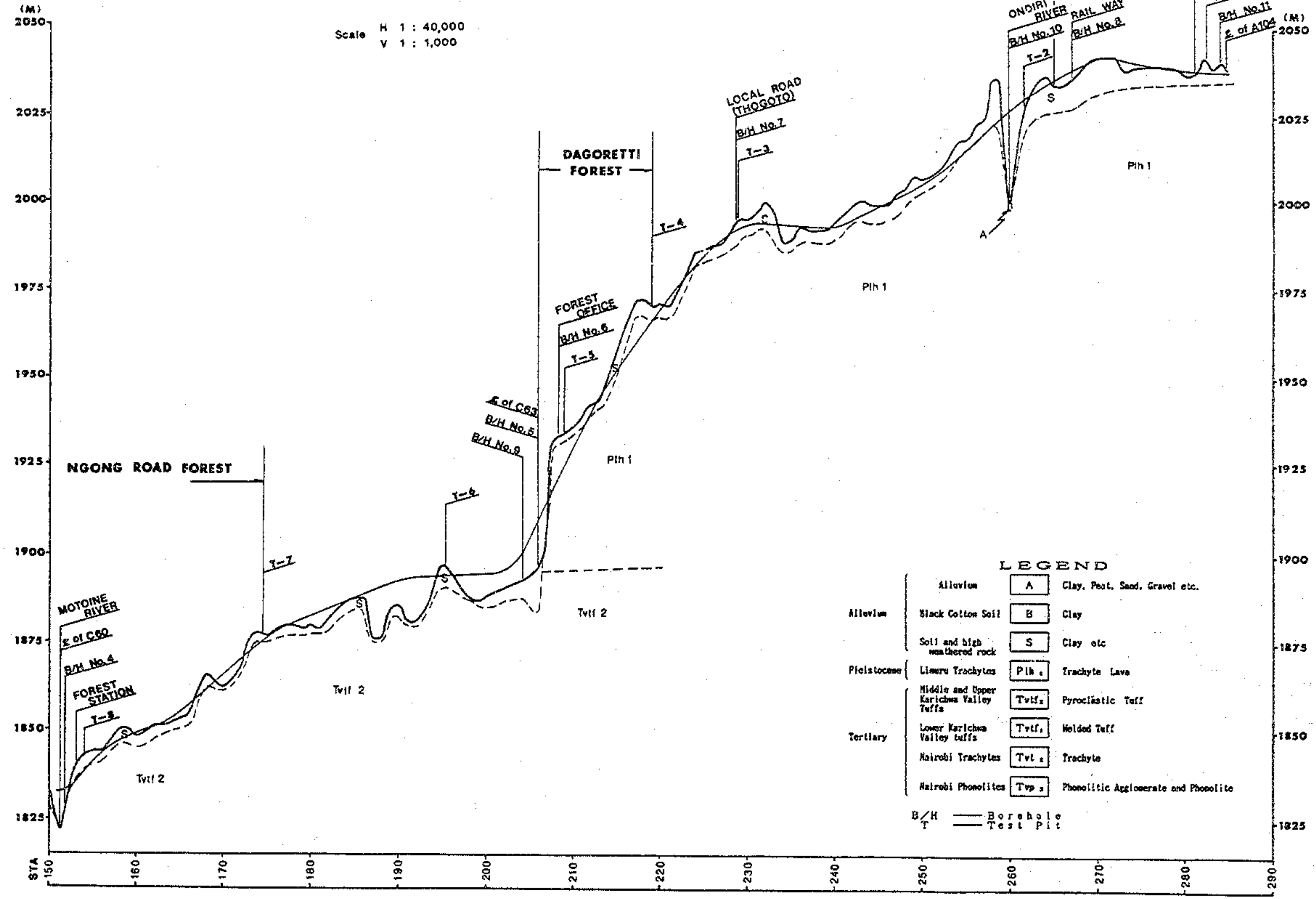


FIGURE . VII-5-5

GEOLOGICAL SECTION (B)



(2) Foundation of Bridge

Drilling surveys were carried out at the sites where bridges, culverts and other structures would be constructed. Results of the drilling surveys are shown on Table VII-5-7 and in the geological record (Fig. VII-5-2).

Weathering grade III or IB class rock are distributed at places of proposed junctions, i.e. Mombasa Road junction, Uhuru Monument junction and Ngong Road junction; therefore the general conditions for foundation of structure are good.

At Mombasa Road junction, there is distributed black cotton soil to be cut off, and it is found that thickness is about 1.0m.

At Ngong Road junction, there is found outcrop of Tuff ($TVtf_2$) in the riverbed of the Motoine River. Its nature is almost the same as the nature of rock that was got by drilling at the tentative proposed drilling site.

There is the Dagoretti junction on an alluvial plain which is the headwater of the Motoine River. The thickness of the alluvial deposit is 12.55m by the drilling survey, and the stratum consists mainly of fine-grained soil namely clay, sandy clay, silt etc.

To understand the dynamic nature of this alluvial deposit, standard penetration test and unconfined compression test were carried out and their results are arranged in Fig. VII-5-6.

Uniconfined Compression Strength (qu) kgf.cm^2

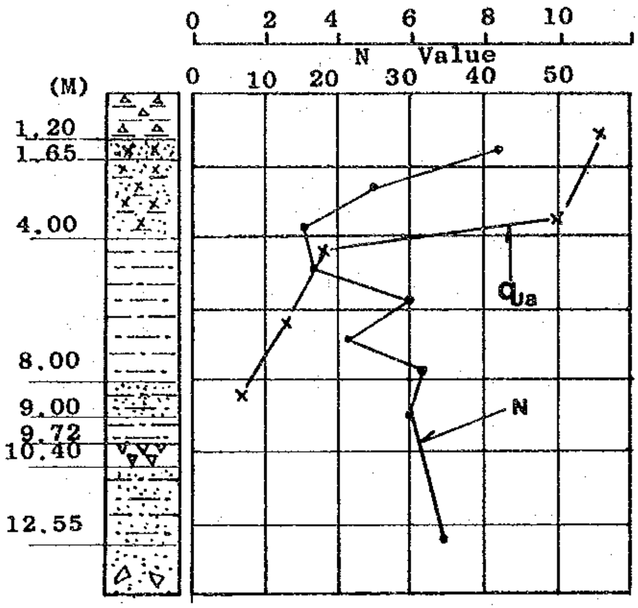


Fig. VII-5-6

Result of Standard Penetration Test and Unconfined Compression Strength at B/H No. 5

Generally, there is clear correlativity between the two above-mentioned test results, but in this case value reduces its strength in accordance with depth and not relative to N value. This seems that test pieces were disturbed due to some problem in the sampling method. (Sampling by using hammer to push cutter in the earth).

Anyway, consistency of this alluvial cohesive ranges from very hard to hard and it is considered that this deposit is no problem as foundation for a Box Culvert.

Table VII-5-7

List of Geological Conditions for Bridge and Box Culvert Foundations

Site	Bore Hole No.	Geological Condition ( ) : Weathering Grade	Standard Penetration Test	Unconfined Compression Strength (qu)	Remarks
Intersection with A104 road to Mombasa	B/H No.1	0-1.20^m stiff clay 1.20-9.10^m phonolitic Agglomerate (III)	N=24 -	- -	
	B/H No.2	0-0.80^m Hard clay 0.80-6.8^m phonolitic Agglomerate (II-I)	N=63/25 -	- -	(Bridge)
Intersection with C58 Road	B/H No.3	0-5.25^m Trachyte (IB)	0 - 0.05^m N=50/5	-	(Bridge)
Intersection with C60 Road	B/H No.4	0-6.50^m Agglomeratic Tuff (III-II)	-	-	(Bridge)
Intersection with C63 Road	B/H No.5	0-12.55^m stiff and hard clay - Sandy clayeg silt 12.55 - 14.20^m Tuff (III)	mainly N=16 - 35	1.00 1.05^m qu=11.3kgf/cm^2 8.00 8.45^m qu= 1.4kgf/cm^2	(Box-Culvert)
Intersection with Local Road of Thogoto	B/H No.7	0-6.80^m Hard silty clay 6.80 - 1035^m Trachyte (IV - II)	N=44 - 60 -	3.00 - 3.25^m qu = 3.7kgf/cm^2	(Bridge)
Intersection with Railway at the vicinity of Kikuyu	B/H No.8	0-10.95^m stiff becoming hard silty clay	1.65-1.95^m N=17 2.65-10.95^m N=27 - 65	2.00 - 2.45^m qu = 9.3kgf/cm^2 6.00 - 6.45^m qu = 2.3kgf/cm^2	(Bridge)
Inersection with A104 Road to Naivasha	H/B No.11	0-3.50^m stiff silty clay 3.50 - 6.20^m completely westhered Trachyte (slightly Sandy Silt) 6.20 & 9.95^m Trachyte (III)	N=22 N=8-10 -	3.00 - 3.45^m qu = 1.3kgf/cm^2 -	(Box-Culvert)

There is not any deformation of culvert and an embankment 7.0m in height for a railway near this point.

There is distributed Trachyte of Plh horizon where the proposed route intersects Thogoto Road (Bore Hole No. 7), Railway (Bore Hole No. 8) Naivasha Road (Bore Hole No. 11) and deep silty clay covers the trachyte.

Weathered Grade IV to II rock were found 6.80m below Bore Hole No. 7 and 6.20m below Bore Hole No. 11.

Results of Standard penetration test for the surface soil show that each surface soil of Bore Holes No. 7, No. 8 and No. 11 is hard, very stiff to hard and very stiff, respectively, and at 3.50 to 6.20m there is completely weathered trachyte (stiff).

(3) Foundation of Embankment

The drilling survey and soil test were carried out at the following three proposed embankment sections where attention must be paid to filling.

a) Black cotton soil distributed area at the beginning point which is located in Athi Plain.
b) Alluvial deposit plain at Motoine River head water.
c) Swamp area of Nangara River (Ondri Swamp).

a) Black cotton soil is distributed over this section to an average depth of 50cm. It has comparatively high strength (N=23 - 50) in the dry season, but it swells and becomes soft absorbing water in rainy season. Therefore, this soil has much problem for earthwork. MOTC has defined the CBR value (4 days) of black cotton soil ranges from 2 to 5, from their experience in the Road Design Manual.

As embankment height of the proposed road is very low, existing ground level would be subgrade. This soil should be removed to replace with good material in view of ease of construction and construction cost.

b) High embankment of 5 to 10m height is proposed at the alluvial deposit at the head water area of Motoine River, according to a drilling test (Bore Hole No. 9). At the center of this plain, depth of alluvial deposit is 5.1m. Consolidation test of this undisturbed sample was carried out.

An undisturbed soft sample was obtained from near the surface and the consolidation test was carried out. It was found that the compression load was under $4.9kg/cm^2$. It is shown that this alluvial deposit would not settle by consolidation under the condition that the embankment height is 10m and unit weight of filling material is $1.8t/m^3$.

On the other hand, cohesion of the sample was extremely high value ($3.58kg/cm^2$) by a triaxial compression test, and it is expected to provide enough stability against a high embankment of 10m.

c) A 28M high embankment crosses River Ondiri at the end of a swamp which extends upward from the river. There is found pete of 1.5m depth on trachyte (PlhI) by a drilling test at this point.

The pete has high water content and is highly compressible, and it has a lower shearing strength than expected.

Therefore, it is supposed that compression settlement would occur with high embankment. However, this peat deposit is in a narrow area of 10m in width upward of the proposed route, so it is desirable to cut off at the time of construction of a culvert.

(4) Earthwork

a) Cuttings

There is distributed comparatively good soil for cutting except in a section from Dagoretti Forest to Thogoto.

As observed from a drilling test at Bore Hole No. 8 in the Dagoretti Forest office compound, trachyte is distributed (class IB) 4m below ground level. This trachyte is classified as weathered rock by rock classification in the Road Design manual of MOTC and the stability of the cutting slope is assumed to be 2:1 to 4:1.

On the other hand, the cutting slope of the railway near Kikuyu and the road near Limuru were observed as 2:1 to 3:1. Therefore, the cutting slope of the project road would be desired to follow these gradients.

However, it has been boserved that the following debris from the surface of the cutting slope which had been weathered at the border of the upper surface layer and trachyte, at the cutting slope, will not be stable. Therefore, at this point, the slope should be as gentle as the slope at S layer, or it is desired to set a protection for falling debris.

Surface soil in the Dagoretti Forest and other cutting sections is generally cohesion soil, and the gradient of the cutting slope is 1:1 and stable. But it is necessary to make slope protection and to make a ditch or other counter-measure for erosion.

b) Embankment

Embankment material to be obtained from the project section is mainly cohesion soil as reddish brown silty clay except the rock from Dagoretti Forest, so the amount of coarse material is very little.

Therefore, most fitting material is class A-7 by classification of AASHTO.

However, natural moisture content of these solids were very near to optimum moisture content, and it is supposed that high density compaction would be expected under the condition of natural moisture content.

This soil is characterised by becoming soft upon absorbing water and efficiency of compaction could not be expected, therefore, earthwork during the rainy season would not be carried out.

It is expected that embankment slope would be stabilized with a grade of 1:1.5, but observing the existing slope gully, erosion is found on the surface of the slope.

As the surface of the slope easily suffers full erosion because of rain, it is necessary to provide counter measures such as planting and ditches on berms for slope protection.

(5) Borrow Sites

Borrow sites are required where the alignment design has not achieved a balance of cut and fill material. This is the case between station No. 0 and 90. Ten test pits were selected in this area to decide potential borrow pits.
The eastern side of the area shown in the map was not considered as it was already in use as a borrow-pit.

Four areas were identified on the basis of road accessibility. Block A(T-13, 14, 15), B(T-16, 17, 19) and C(T-18) are all within Ngong Road Forest to the south of the proposed alignment between stations No. 95 and 102. Block D, half of which is in Ngong Road Forest, is situated to the north of the alignment between stations No. 91 and 95.

On the assumption that the depth of the borrow pits will be 3 meters, the estimated volume of each block is as follows:-

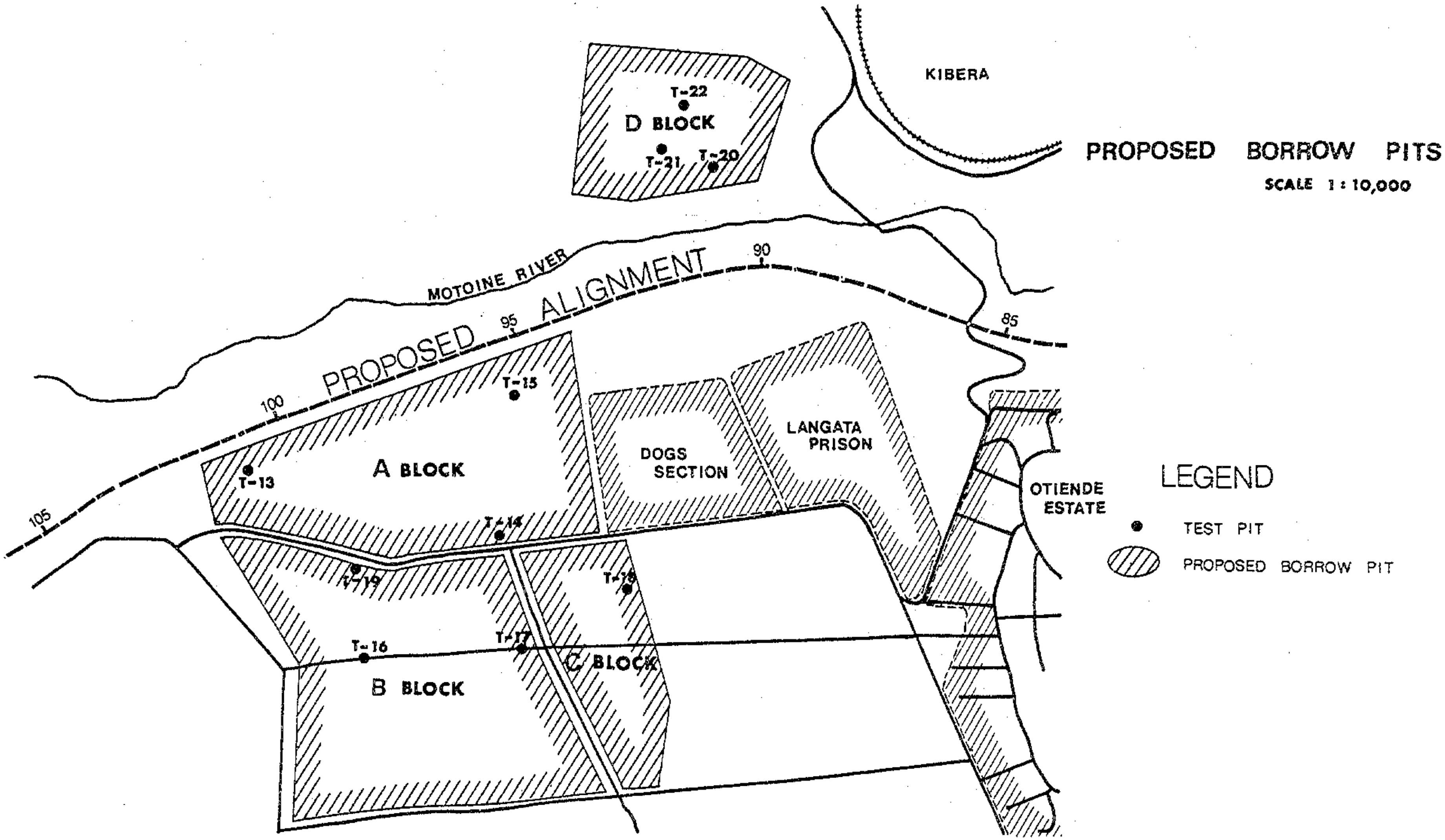
Block	A	650,000m^3
Block	B	900,000m^3
Block	C	200,000m^3
Block	D	200,000m^3

The geological and soil conditions within each block were studied. Soil in blocks A and D is mainly silty clay and the base consists of tuff ($TVtf_2$).

The embankment materials have a similar nature to material T1-T2, and all of them belong to class A - 7 of AASHTO soil classification.

Soil in block B and C is silty clay or lateritic soil and the base is mainly trachyte (TVt_2) with some tuff ($TVtf_2$). The materials of this block are generally lateratic soil and largery contain sand of more than 75mm diameter. It is better as embankment material than the material in blocks A and D.

Fig. VII-5-7


PROPOSED BORROW PITS
SCALE 1 : 10,000
KIBERA
D BLOCK
T-22
T-21
T-20
MOTOINE RIVER
PROPOSED ALIGNMENT
85
90
95
100
105
A BLOCK
T-13
T-14
T-15
B BLOCK
T-16
T-17
T-19
C BLOCK
DOGS SECTION
LANGATA PRISON
OTIENDE ESTATE
LEGEND
TEST PIT
PROPOSED BORROW PIT

(6) CBR of Subgrade

Subgrade soil were classified by the Road Design Manual of MOTC as follows:

Table VII-5-8 Bearing Strength Classes of Subgrade

Soil Class	CBR Range
S1	2 - 5
S2	5 - 7
S3	7 - 13
S4	10 - 18
S5	15 - 30
S6	30

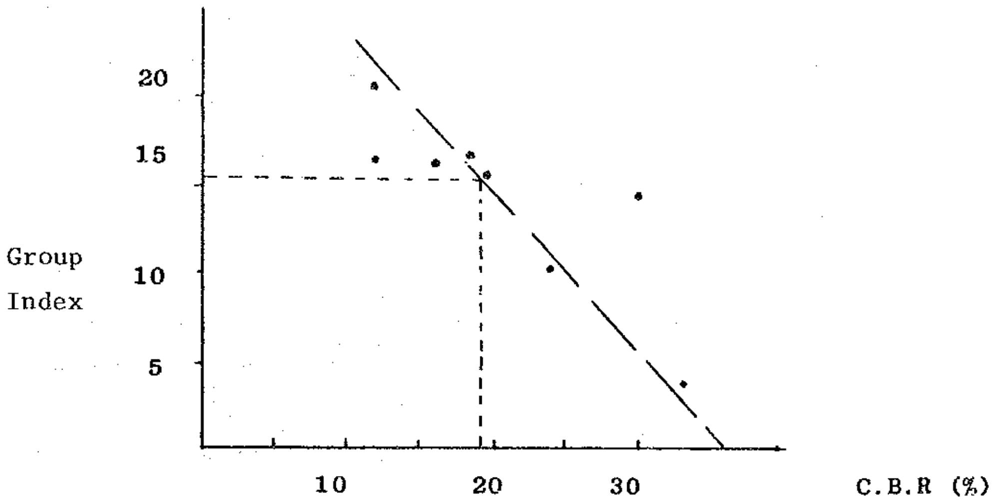
On the other hand, earthwork material along the route and in borrow pits is generally silt or clay, and almost all of it belongs to A-7 of AASHTO soil classification or MH of unified soil classification.

According to the results of CBR test, they have a wide range of value from 12 to 33.

Therefore, in accordance with the correlation of CBR and Group Index of AASHTO and CBR, subgrade material was classified as follows:

Fig. VII-5-8

Correlation of CBR and Group Index of AASHTO



It is provided by Fig. VII-5-8 that CBR would be more than 19, and in case of Group Index is less than 15.

Based on this group index, soil along the route was classified as follows:

Table VII-5-9

Classification of Soil Class for Sub-Grade

Soil Class	Station and Borrow Site
S 4	STA No. 90 - 285 without No. 210 - 220 Borrow Site Block A, D
S 5	STA No. 55 - 90 Borrow Site Block B, C.
S 6	STA No. 200 - 220

(7) Material Survey

a) Sub-base coarse Material

The survey area included the whole of the proposed alignment i.e. from the A104 (Mombasa Road) intersection to Limuru. 14 sites, including existing quarries, were studied. 4 promising sites were selected (See Table VII-5-10 from which 6 samples were obtained for laboratory testing).

For four sites are as follows:

(1)	Karai	1 Sample (4km West of Kikuyu Station)
(2)	Ondiri River Side	1 Sample (Basede alignement)
(3)	Degoretti Forest	2 Sample (Along alignment)
(4)	Langata Prison	2 Sample (600m North of Langara Prison)

The geological condition of sites (1), (2) and (3) is trachyte (PlHl) while site (4) has 2 conditions, an upper layer of pyroclastic tuff ($TVtf_2$), and a lower layer of welded tuff ($TVtf_1$). The surface of site (4) is to be used as a borrow site (Block D).

Estimated volumes of material from the quarries are as follows:

(1)	Karai	$500,000m^3$
(2)	Ondiri River side	$30,000 - 50,000m^3$
(3)	Dagoretti Forest	- available during road construction
(4)	Langata - Upper layer -	$1,000,000m^3$
	Lower layer -	$150,000m^3$

Table VII-5-10

The Test Results of Course Aggregates for Sub-Base

Name of Site		Los-Angeles Specific Abrasion Gravity (%)	Water Absorption Coefficienty (%)	Plasticity Index	Material
Karai	53	2.43(+5) 2.38(-5)	5.5(+5) 9.I(-5)	NP	Trachyte (Plhl)
Ondiri River Side	68	2.44(+5) 2.30(-5)	6.5(+5) I2.7(-5)	NP	"
Dagoretti Forest	Upper 57	2.42(+5)	5.1(+5)	NP	"
	(porous)	2.43(-5)	8.9(-5)	NP	"
	Lower 36	2.53(+5) 2.51(-5)	3.1(+5) 5.7(-5)	NP	"
Langata	Upper 28	2.23(+5) 2.25(-5)	II.5(+5) I4.7(-5)	NP	Phroctastic Tuff(TVtf$_2$)
Prison	Lower 27	I.67(+5) I.85(-5)	24.4(+5) 26.8(-5)	NP	Welded Tuff (TVtf$_I$)

( ) Sample Grain (mm)

Road Design Manual (MOTC) prescribed that in case of Traffic class TI, LAA of graded crushed stone for sub-base should be less than 40%. Tuff and trachyte (Plhl) from borrow pits along the proposed route are out of this condition.
Water absorption coefficient of Tuff is high (11.5 - 26.8%) and specific gravity is low (1.67 - 2.25), so this materials is very porous. In case of using this material, a large amount of soil covering the surface should be taken out. (Borrow Pit Block D)

b) Fine Aggregate

Sand, the material referred to as fine aggregate, cannot be found within Nairobi and its suburbs. It occurs naturally as river sand in the shallow river beds of Machakos District. The main quarry sites are as follows:-

Thwake River
Ikiwe River
Talala River

Geologically, the basement of Machakos District consists of Precambrian metamorphic rocks. The supply of river sand is normally replenished during the rainy season when large amounts are washed down from the mountains.

Three samples were collected from the above-mentioned quarries and taken for laboratory tests. (See location Map Fig. VII-5-9) Test results are shown in Table VII-5-11.

Table VII-5-11

The Test Results of Fine Aggreagates

Name of Sample	Grading Percentage by weight passing (sieve size) (in mm)									Specifici Gravity	Water Absorption Coefficient (%)	Plastici Index
	37.5	25	14	10	6.3	5	2.36	0.425	0.075			
Thwake River						100	98	54	1	2.62	1.0	N.P
Ikiwe River			100	99	98	97	90	50	1	2.55	3.8	N.P
Talala River	100	96	95	92	87	84	67	7	0	2.63	0.9	N.P.

Even though sand from the same river, it has a variety of graduations and it is possible to select fine material for various objectives.

The County Council of Masaku exercises overall control over the collection of all sand from the district.
However, the Municipal Council of Machakos controls those quarries within the Municipality like Ikiwe River.

Sand collected from Thwake and Talala Rivers during the dry season amounts to about 100 lorries per month.
During the rainy season, access is difficult and the figure is about 50 lorries per month.

From Ikiwe River an average of 10 lorries per month is collected. An 8 tonne lorry makes an average of 3 trips per day to and from Nairobi.

c) Coarse aggregate (Crushed hard rock)

Several hard stone quarries exist along Ngong River on the eastern side of Nairobi and 4 - 8 km northeast of the start of the proposed bypass. About 7 quarry companies are situated at various points along the river side. The geological name of the rock is phonolite (TVP_3) although it is locally known as black-trap.

The biggest 3 companies together have a total yield of about 2,000 tons/day. It is estimated that all the quarries in the area can yield more than 3,000 tons/day. The quarries can supply the client with material of any grain size depending on his specification, and more used for base material and surface dressing material.
Laboratory test results were obtained from Materials Branch of M.O.T.C. and are shown in Table VII-5-12.

Table VII-5-12

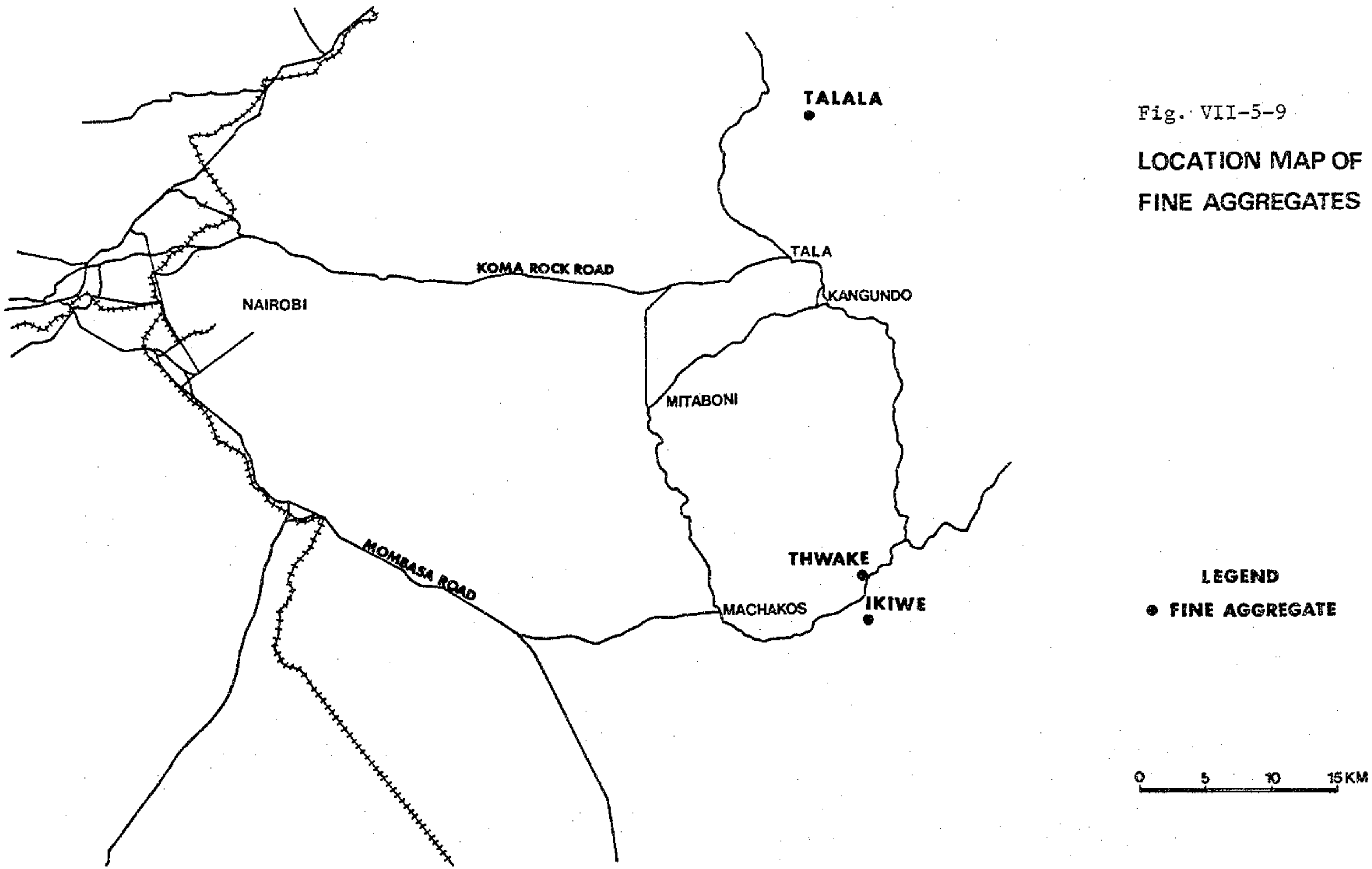
The Test Results Of Course Aggregates (Crushed Hard Rock)

Sample No.	Nominal Size (mm)	Chippings From Commercial Sources: Grading Percentage By Weight Passing (Sieve Size in mm) 28	20	14	10	6.3	5	2	0.4	0.095	Flake-ness Index	A.L.D (mm)	A.C.V	L.A.A	S.S.S	Bituness Affinity	Specific Grarity	Water Absorption Coefficient	Plastcity Index	Material
Sample																				
1	20	100	91	13	1	0					2.6	11.5								Phnolite (T.V.P3)
2	20	100	74	17	0						17	125								"
3	20	100	66	13	2	0					21	13								"
4	20	100	88	6	0.5	0.2	0				24	11.5								"
Present Kenya (Specification)	20	100	85 ~ 100	0 ~ 35	0 ~ 5			0 ~ 2			20									
Sample																				
5	14		100	98	69	19	6	2.4	1.3	0.6	35	6								Phnolite (T.V.P3)
6	14		100	77	62	5	2	0			27	6								"
7	14		100	98	70	31	20	10	3.4	1.4	35	5								"
8	14		100	36	5	2	1.5	0.7	0		19	-								"
Present Kenya (Specification)	14		100	85 ~ 100	0 ~ 05	0 ~ 7		0 ~ 2			20									
Sample																				
9													17.4	20.8	1.7	good	2.4	5		Phnolite (T V P3)
10													14~21	17~22	1.5~3.5	good	2.7	7	N.P	"
11													17.8	21.4	2.5	good				"

A.L.D - Average Least Dimension, A.C.V - Aggregate Crushing Valve, L.A.A - Las Angeles Abrasion, S.S.S - Sodium Sulphate Soundness

Fig. VII-5-9

LOCATION MAP OF
FINE AGGREGATES



(8) Others

Additional soil investigation was carried out in the section from the beginning point to 5.5 km point. Two test pits (T.P. 23 and T.P. 24) were dug and thickness of black cotton soil layer were found 0.8 m and 0.7 m respectively. There is tuff under the black cotton soil. Test pits were dug to the bottom of the black cotton soil layer, namely to the surface of tuff, because the major object of the additional investigation is to know the thickness of the black cotton soil.

Prior to the additional soil investigation, a reconnaisance was carried out along the fence of the Nairobi National Park, there is a road inside the fence and soft rock is seen at the surface of the road, the road has been simply built on the soft rock by stripping the surface soil (black cotton soil) of natural ground. The thickness of black cotton soil is recognized average 0.5 m by observing the difference between the road surface and natural ground surface.