社会開発調査部報告書

REPUBLIC OF KENYA

MINISTRY OF PUBLIC WORKS

THE FEASIBILITY STUDY ON THE NAIROBI BYPASS PROJECT

SUMMARY

REPUBLIC OF KENYA

MINISTRY OF PUBLIC WORKS

DETAILED DESIGN STUDY

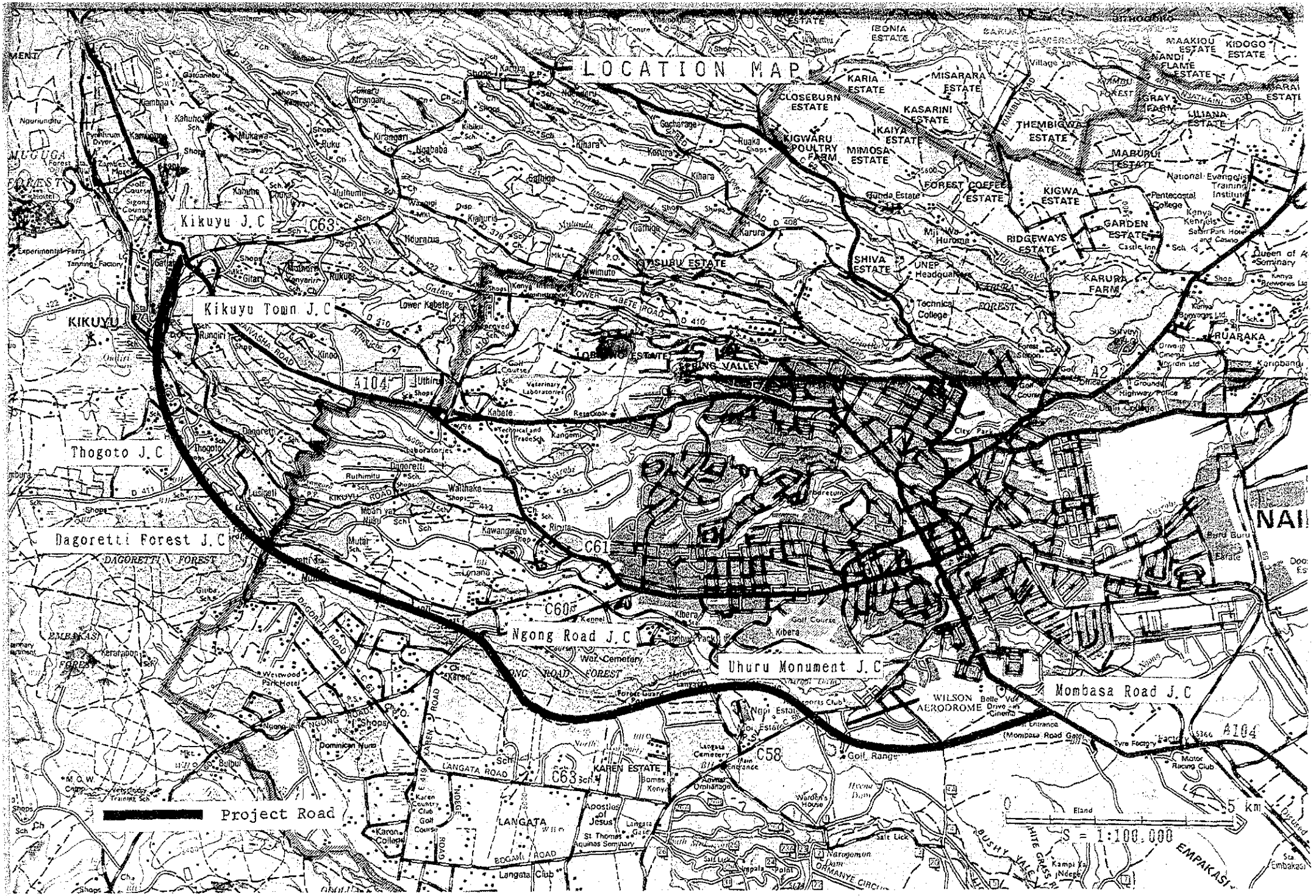
ON

THE NAIROBI BYPASS PROJECT

SUMMARY

SEPTEMBER 1992

JAPAN INTERNATIONAL COOPERATION AGENCY


LOCATION MAP
Kikuyu J.C
Kikuyu Town J.C
Thogoto J.C
Dagoretti Forest J.C
Ngong Road J.C
Uhuru Monument J.C
Mombasa Road J.C
Project Road
S = 1:100,000
5 km

CONTENTS

1. INTRODUCTION

1.1 TERMS OF REFERENCE

In response to the request of the Government of Kenya (GOK), the Government of Japan agreed to provide technical expertise in conducting the Detailed Design Study for the Nairobi Bypass Project. Accordingly, the Japan International Cooperation Agency (JICA) sent a preliminary survey technical team, headed by Mr. Y. Adachi of Ministry of Construction of Japan, to Kenya in February 1989 for discussion on the Scope of Work of the Study with the officials of Kenya's Ministry of Public Works (MOPW) and other relevant authorities.

Based on the agreement, mentioned above, the JICA Study Team submitted an Inception Report in October, 1989 and the preliminary design study was carried out for the proposed Nairobi Bypass and other relevant roads, as well as intersections of roads (see location map). Principally, the work of the study, carried out prior to the detailed design, was conducted in Kenya in close cooperation between the Japanese expert staff and the counter-part staff of Kenya.

In accordance with the change of social conditions and increase of traffic accidents since the Feasibility Study stage, the whole route of the Bypass was planned to have adequate grade separated crossings to cater for vehicular and pedestrian traffic crossing the Bypass (Expressway with limited access).

Some sections of the project route in the Ngong Forest have been sifted to the edge of the forest to conserve the indigenous part after the Preliminary Design in response to a request made by the Government of Kenya.

1.2 LOCATION OF THE NEW ROAD

The proposed new dual carriageway is a class A international trunk road, approximately 29.2 km long, situated in the City of Nairobi and in the Kikuyu Division of Kiambu District, Central Province. It starts from Mombasa Road (A104) near the eastern gateway of Nairobi National Park and terminates on Nairobi-Nakuru road (A104) on the western outskirts of Kikuyu Town.

1.3 TOPOGRAPHY

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

Nairobi and its environs are located on the east-side highland of the Rift Valley. Nairobi's western and northern parts are hilly land which are located about 2,000 m above sea level. The southern and eastern parts of Nairobi are spread on the Athi and Kapiti Plains 1,890 m above sea-level. From west to east, the topography inclines gently.

Rocky mountains lie in Machakos District about 50 - 60 km south-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 plains 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.

1.4 CLIMATE

The proposed route of the Bypass will be a section of the Trans-African Highway, and it is located almost at the equator.

The project area is located on a highland in the central area of Kenya at altitudes which range from 1,700 to 2,000 m. It is about 500 km from the eastern cost of Kenya, which faces the Indian Ocean, so the project area is not affected by the trade wind and is dry and calm except during the two rainy seasons from March to June and from the end of October to December.

(i) Temperature

Changes in temperature have been minimal over the years. The past average temperatures, according to records at four meteorological stations in the project area, is around 18°C.

(ii) Wind

Generally, wind blows calmly in the project area throughout the year. From May to September, there is a frequent mild wind. From October to April, the wind at noon blows comparatively stronger than in the morning. The maximum wind speed is around 6.5 m/sec.

(iii) Precipitation

Annual rainfall in the project area ranges from 800 mm to 1,100 mm. Most rain falls during the main rainy season (March to June) and the lesser rainy season (October to December) similar to other areas of Kenya.

1.5 LAND USE

Present land use has been assessed and summarized by each link as follows:-

(1) Link 1: A104 (Mombasa Road) - C58 Uhuru Monument Junction (C58)

a) Area : 4.2 km^2

b) Main Figures : New Residential quarters, Nairobi National Park, Wilson Airport, Independence Monument

c) Present Land : Low density residential area with open space

d) Development Potential : High density residential area and institutional area

(2) Link 2: Uhuru Monument Junction (C58) - Ngong Road Junction (C60)

a) Area : 6.0 km^2

b) Main Figures : Nairobi Dam, New Residential Quarters, Langata Prison, Army Quarters, Moi Estate, Langata Cemetery, Karen Estate, Ngong Road Forest

c) Present Land : High density residential area
Reserved for forest

d) Development Potential : Residential area

(3) Link 3: Ngong Road Junction (C60) - Dagoretti Road Junction (C63)

a) Area : 6.6 km^2

b) Main Figures : Karen Estate, Motoine Stream, Mutuini Primary School, Railway

c) Present Land : High income low density residential area Reserved for forest

d) Development Potential : Medium density residential area with water pipeline installations and sub-divisions of land

(4) Link 4: Dagoretti Road Junction (C63) - Thogoto Junction A104 (Naivasha Road)

a) Area : 7.0 km^2

b) Main Figures : Railway, Dagoretti Forest, D411 (Feeder Road), Kikuyu DNK High School, Alliance Boys High School, Alliance Girls High School, Nairobi University, Church University, Thogoto Technical College, Kikuyu Hospital, Ondiri Swamp, Route E422

c) Present Land : Medium income residential area, use Education Institutes

d) Development Potential : High density residential area, Educational (Thogoto) and Commercial (Kikuyu) zone

1.6 REVIEW OF THE FEASIBILITY STUDY

Review of the Feasibility Study (especially traffic forecast and traffic planning) and the Study of Possibility of Stage Construction for Nairobi Bypass were carried out in close consultation with the relevant engineers of Development Planning Division and Road Department (Design) of the MOPW.

The review study report was submitted by the team in November 1989 and it was approved by the Chief Engineer (Roads).

A detailed description of the review of the Feasibility Study is given in "The STUDY REPORT-1, on REVIEW OF TRAFFIC DEMAND FORECAST AND TRAFFIC PLANNING, POSSIBILITY OF STAGE CONSTRUCTION".

2. OUTLINE OF THE DETAILED DESIGN STUDY

2.1 GENERAL

All geometric design work was carried out based on the "Road Design Manual Part I" and discussions between the MOPW and the JICA study team.

The following is a brief description of the project road.

(1) Length of Road : Approximately 29.2 km

(2) Road Standard : Class A international trunk road (Express way)

(3) Section (see location map)

Starting point : 400 m from crossing of Mombasa Road (A104) Road.

Ending point : Kabete Limuru Road (A104)

(4) Design Speed : 80 - 100 km/hr

(5) Number of lanes : 4 lanes (dual carriageway) of 7 meters carriage way and 1.5 meters shoulders

(6) Number of junctions : 7

Mombasa Road Junction
Uhuru Monument Junction
Ngong Road Junction
Dagoretti Forest Junction
Thogoto Junction
Kikuyu Town Junction
Kikuyu Junction

(7) Number of Main Structures

Mombasa Road Junction Bridge	:	One (1)
Uhuru Monument Junction Bridge	:	One (1)
Railway Bridge	:	One (1)
Pedestrian Bridge	:	Two (2)
Vehicle Over Bridge	:	Two (2)
Box Culverts	:	Sixteen (16)

(8) Bus Stops

Bus stops are proposed at sixteen places on the both shoulders of the Bypass.

2.2 ORGANIZATION AND ASSIGNMENTS OF THE STUDY TEAM

The design was executed by the JICA study team under the guidance of the Advisory Committee comprising of Japanese government officials.

The Ministry of Public Works is the counterpart authority to the JICA study team.

In conducting the study, the design study team maintained a close collaboration with the counterpart team organized by MOPW.

The work flow, organization chart and assignment schedule of the design study team are presented in Fig. 2.1, Fig. 2.2 and Fig. 2.3.

Figure 2.1 OVERALL WORK FLOW

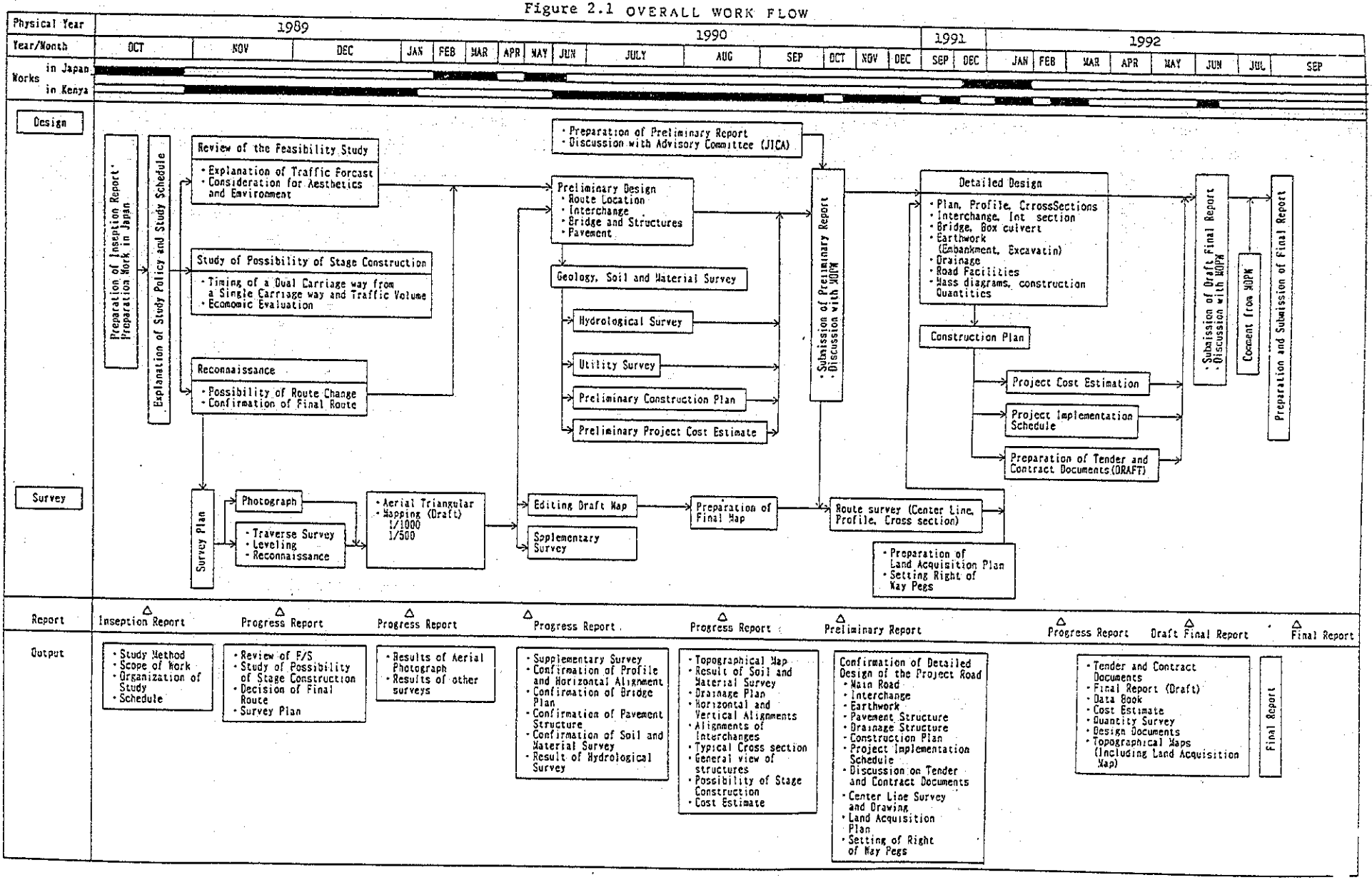


Figure 2.2 Organisation of the Detailed Design Study

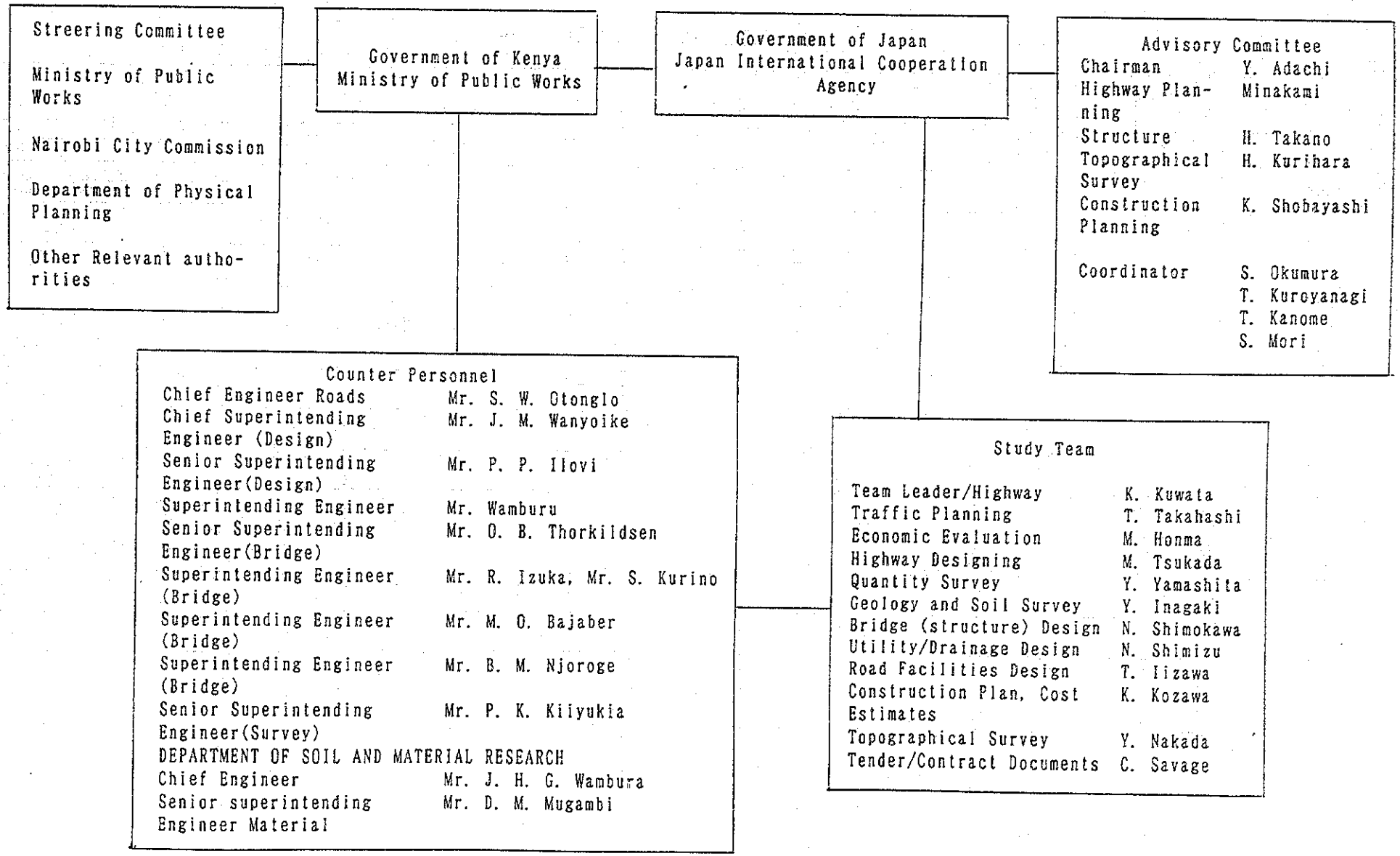
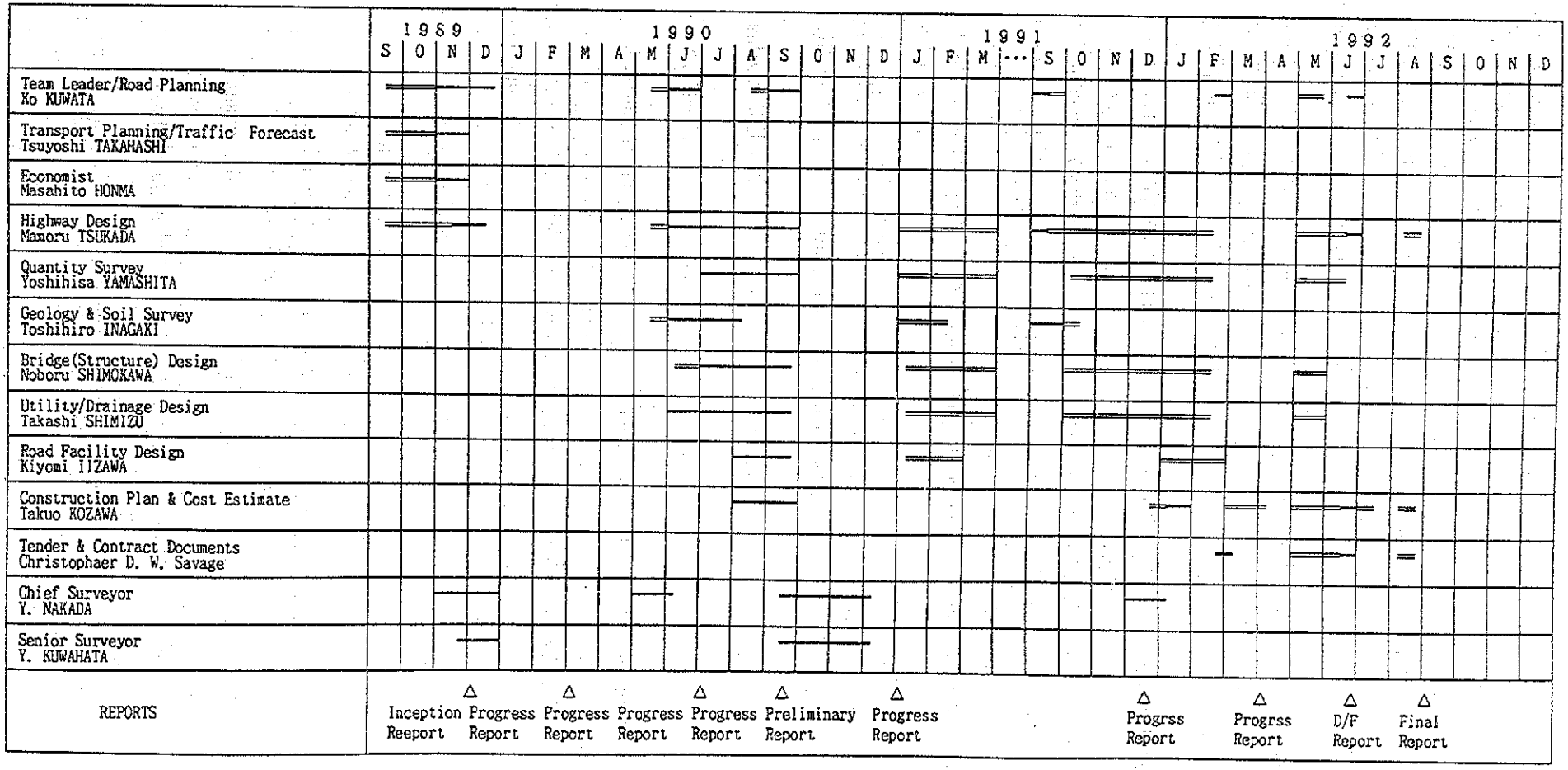


Figure 2.3 ASSIGNMENT SCHEDULE OF THE SUTDY TEAM



2.3. TRAFFIC STUDIES

Prior to starting the Detailed Design (including the Preliminary Design) the JICA study team carried out a review of the Feasibility Study (the traffic survey, traffic forecast) and a study of the possibility of a stage construction in December of 1989. The results of these investigations have been accepted by the Chief Engineer (Roads), MOPW. Therefore, the future traffic volume for the road design work was depended on the traffic forecast in the Feasibility Study of the Nairobi Bypass Construction Project.

In 1991, an oil pipeline project started between Nairobi and Kisumu/Eldoret. Oil transportation was scheduled to start in 1993. Traffic volume (P.C.U) of oil tankers, however, has been forecasted at 2 or 3 % of total traffic on the Nairobi Bypass in the year 2000 referring to the Feasibility Study, and percentage of oil-tankers in heavy vehicles is about 33 % according to the Material Branch Report No. 333. This trend is not changed by the recent traffic survey.

Therefore, the reduction of oil-tanker traffic due to the opening of the pipeline, will not be a major influence on the road design.

2.4. ROAD DESIGN

2.4.1 GENERAL

The geometric design of the road, which is the basis of road design work, is based on the Road Design Manual Part I. Issues not referred in the Manual, were discussed and the design specification were decided based on recommendations made by the JICA Team to the MOPW.

(1) Geometric Design Standard for Main Road

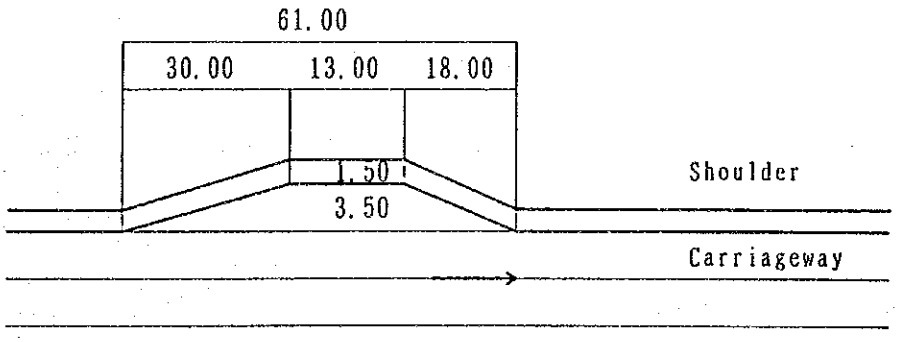
Road classification	Class A
Design Speed	
Mombasa junction - Uhuru monument junction	100 km/hr
Uhuru monument junction - Kikuyu junction	80 km/hr
Lane width	3.50 m
Lane number	4 lanes
Shoulder width	
Right	1.00 m
Left	1.50 m

Central Reserve		
Mombasa junction - Uhuru monument junction		11.00 m
Uhuru monument junction - Kikuyu junction		3.50 m
Superelevation		2.50 %
Maximum Gradient		5.00 %
Minimum Horizontal Curve Radius		600 m
Right of Way		60 m
Vertical Clearance		5.50 m
Horizontal Clearance (from the edge of shoulder)		1.50 m

(2) Geometric Design Standard for Intersections

Design Speed		40 km/hr - 50 km/hr
Lane width	One way	4.00 m
	Two way 6.00 (Thogoto J, C) -	8.00 m
Shoulder width		
Right	One way 1.00 (Thogoto J, C) -	1.50 m
Left		1.00 m
Two way		1.00 m
Superelevation		2.50 %
Minimum Horizontal Curve Radius		30.00 m
Maximum Gradient		7.00 %
Speed change lane (including length of taper)		
Design speed of main road	80 km/hr	100 km/hr
Acceleration lane	160+40=200 m	180+50=230 m
Deceleration lane	50+40= 90 m	70+50=120 m

(3) Geometric Design Standard for Bus Stops



(4) Service roads

Design Speed		20 km/hr - 30 km/hr
Lane width	One way	4.00 m
	Two way	6.00 m

2.4.2 HORIZONTAL ALIGNMENT

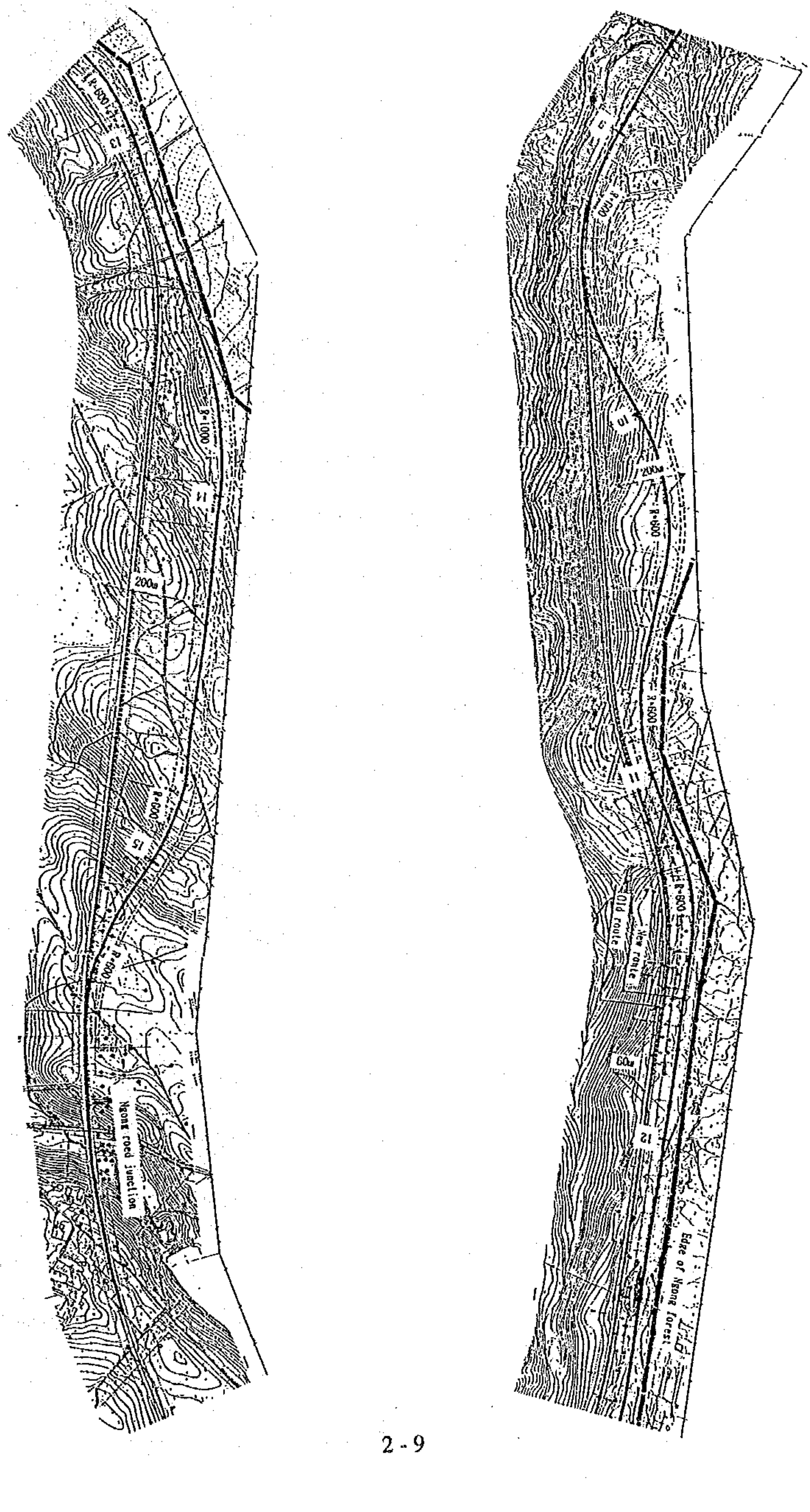
The horizontal alignment largely reflects the locations suggested by the Feasibility Study and strict control is exercised at the following sections.

- Mombasa Road Junction - Uhuru Monument Junction (CH.0 + 000 to CH.7 + 300)

  The center-line is introduced in this section at the center of the 60 m wide zone near the urbanized area (right-hand side) of the 120 m wide road reserve which includes the Trans African Highway and the railway tracks.

- CH9+500 - CH15+300 (Ngong Road Junction)

  This section transverses the Ngong natural forest. The road location was changed to the edge of the Ngong forest after the completion of the Preliminary Design in response to a request made by the Government of Kenya in order to minimize damage to the environment.


Ngong road junction
R=600
R=1000
200m
Old route
New route
60m
Edge of Ngong forest

2.4.3 VERTICAL ALIGNMENT

(1) Basic Principles

In principle, the vertical alignment involves grade separation vis-a-vis all roads crossing the Bypass with a vertical clearance of 5.5 m being secured. The maximum gradient of the main road is set at 5 %. The following conditions are generally taken into consideration in deciding the vertical alignment.

- Crossing or underpassing by roads or other facilities
- Crossing by road drainage facilities
- Balance between cutting and embankment volumes
- Balance between vertical alignment and horizontal alignment
- Desirable length and location of particular gradient

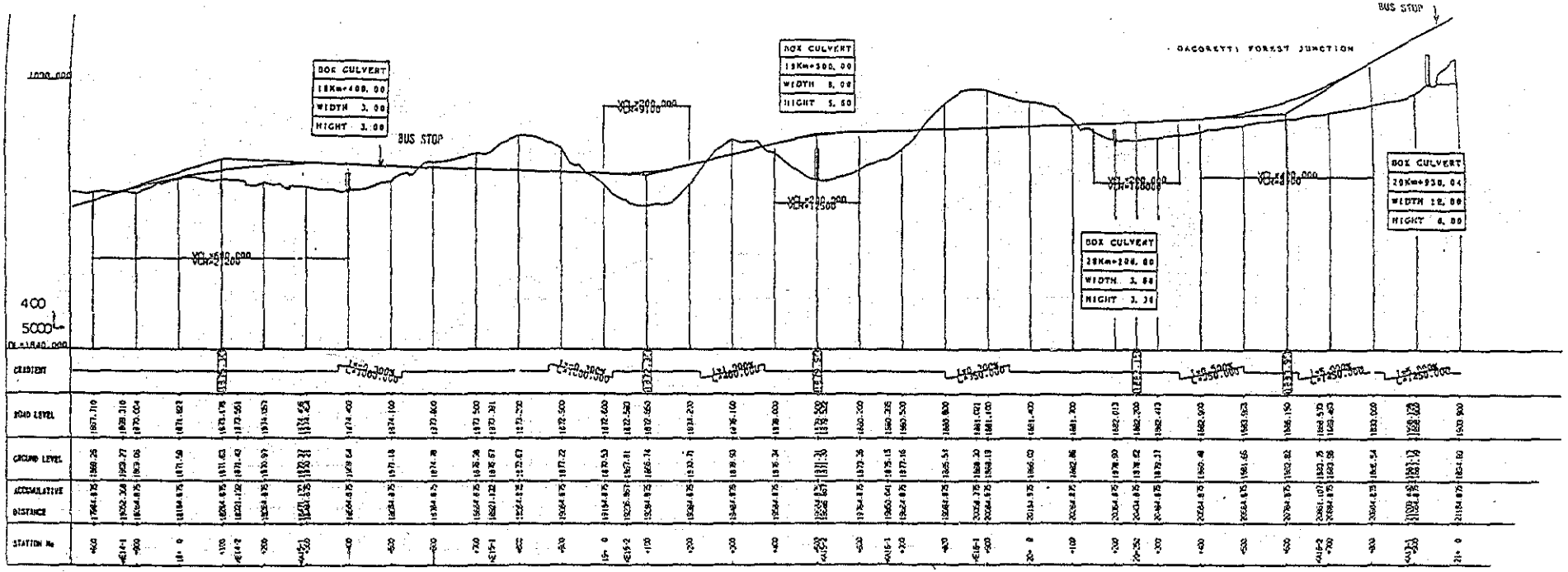
The above conditions, particularly the extent of earth work, play a crucial role in determining the construction cost. The adoption of a gentle gradient is preferable to facilitate smooth traffic flow although it leads to an increase in the initial investment cost. In the long run however, a road with a gentle gradient has a lower running cost as well as a lower maintenance cost than a road with a steep gradient.

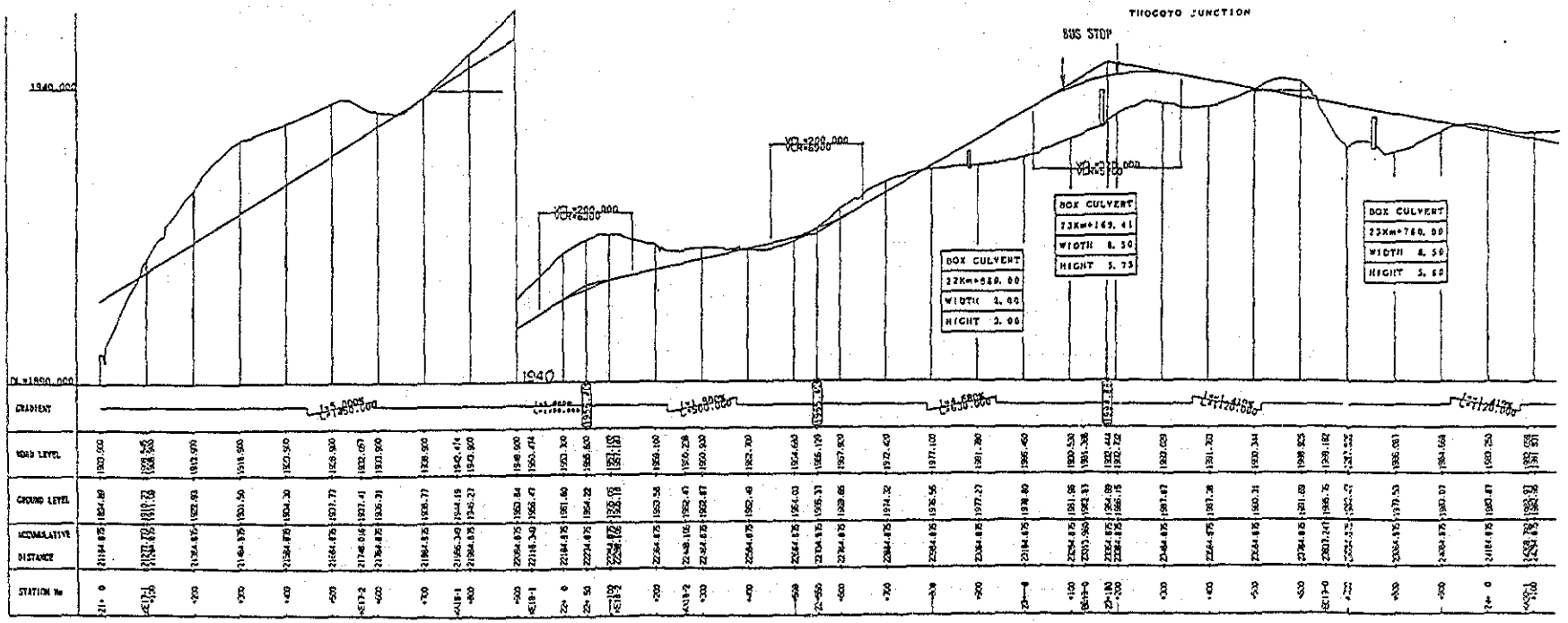
The final road design was carried out by taking all the above-described conditions into consideration. The profile of the main road is shown on the following sheets.

MOMBASA ROAD JUNCTION
MOMBASA ROAD JUNCTION BRIDGE
OVER BRIDGE
BUS STOP
STATION No
ACCUMULATIVE DISTANCE
GROUND LEVEL
ROAD LEVEL
GRADIENT

JURONG HONOMENT JUNCTION
JURONG HONUMENT JUNCTION BRIDGE
BUS STOP
GRADIENT
ROAD LEVEL
GROUND LEVEL
ACCUMULATIVE DISTANCE
STATION No

BOX CULVERT
WIDTH 3.00
HIGHT 3.00
BOX CULVERT
WIDTH 2.00
HIGHT 2.00
BOX CULVERT
WIDTH 3.50
HIGHT 3.00
BOX CULVERT
WIDTH 10.00
HIGHT 5.50
OVER BRIDGE
NGONG ROAD JUNCTION
BUS STOP
400
5000


BUS STOP
OACOREYTI FOREST JUNCTION
BOX CULVERT
18Km+408.00
WIDTH 3.00
HIGHT 3.00
BUS STOP
BOX CULVERT
19Km+300.00
WIDTH 8.00
HIGHT 5.50
BOX CULVERT
20Km+930.04
WIDTH 12.00
HIGHT 6.80
BOX CULVERT
20Km+206.80
WIDTH 3.00
HIGHT 3.30
GRADIENT
ROAD LEVEL
GROUND LEVEL
ACCUMULATIVE DISTANCE
STATION No


TIOCOTO JUNCTION
BUS STOP
BOX CULVERT
22Km+589.00
WIDTH 3.00
HIGHT 3.00
BOX CULVERT
23Km+169.41
WIDTH 8.50
HIGHT 5.75
BOX CULVERT
23Km+760.00
WIDTH 8.50
HIGHT 5.50
GRADIENT
ROAD LEVEL
GROUND LEVEL
ACCUMULATIVE DISTANCE
STATION No

⑤
BUS STOP
KIKUYU JUNCTION
KIKUYU TOWN JUNCTION
RAILWAY BRIDGE
OVER BRIDGE
BOX CULVERT
STATION No
ACCUMULATIVE DISTANCE
GROUND LEVEL
ROAD LEVEL
GRADIENT

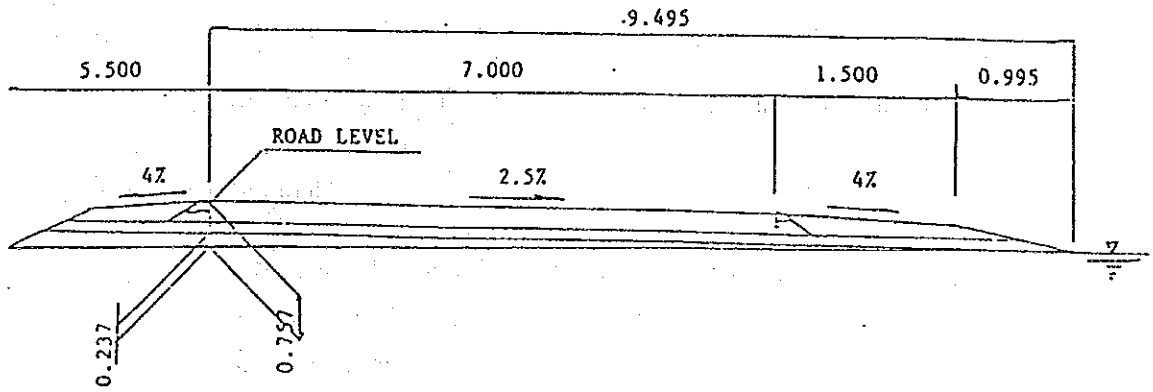
(2) Outline of Each Section

1) Mombasa Road Junction - Uhuru Monument Junction (CH.0 + 000 to CH.7 + 300)

Given the clover-leaf configuration of this junction which produces weaving on the main road, the vertical alignment (vertical curve) of the main road should be gentle enough to ensure sufficient visibility.

The section, approximately 6 km in length, which traverses the Nairobi National Park between the Mombasa Road Junction and Uhuru Monument Junction is covered by a 50-70 cm thick layer of black cotton soil. Since this soil is unsuitable for filling, it must be replaced by good fill material which can be obtained from a borrow pit located between CH9 and CH10+400. The following two conditions must be met for satisfactory earth work.

- The embankment height should be kept to a minimum to reduce the filling volume
- Road level should be raised up to keep out subbase from submergence by flood.



2.4.4 EARTH WORKS

(1) Design of Slopes

The various slopes were obtained from the MOPW Design Manual Part I. However, after investigations, the cut slope for red soil was altered.

In cut areas with height exceeding 5.0 m, berms with a width of 2.0 m shall be constructed. The top of the slope must be rounded.

(2) Site Clearance and Topsoil Stripping

Site clearance shall be conducted in the cutting and embankment section by 3.0 m over the each edge of the cutting and embankment within the road reserve. Top-soil shall be removed from the whole area of the construction to a depth of 10 cm.

(3) Fill on the including ground

In places where filling is required on inclined ground having a side slope greater than 1 in 5, the stepping shall be carried out.

(4) Scheme of Haul

1) Bulking of Soil

After comparing the bulking factors of Kenyan and Japanese road manuals, it was found that the Japanese Manual had higher factors. For this reason, it was decided to adopt the values in the Japanese Manual.

Fill material required, in addition to that provided by the excavation of cuttings, shall be obtained from the widening of cuttings within the road reserve.

(5) Grassing and Top Soiling

Grassing shall be carried out under the following conditions.

- Where the slope is less than 1 : 0.5, grass should be planted.
- Indigenous "runner" type grass should be used.

Top soil should be used in the following places.

- Embankment slopes where top soil is required:

  It should be laid to a thickness of 75 mm.

- Side borrow sections:

  After side borrow work is finished, top soil shall be placed.

- Spoil banks of black cotton soil:

- Spoil banks of black cotton soil, beside the road and around the Mombasa Road Junction require top soil with thickness 200 mm.

- Rubbish dumps (from CH8+850 to CH9+30):

  Dumps within the road reserve require top soil to thickness 600 mm.

- Traffic islands at junctions and the Central reserve of Langata Road.

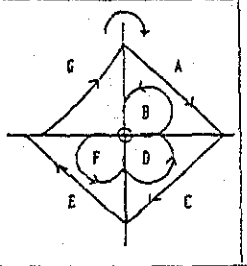
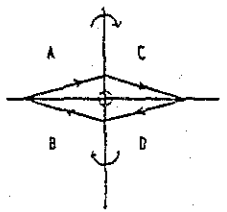
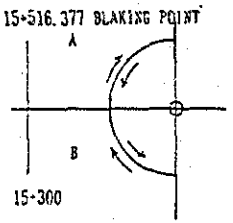
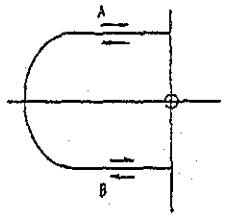
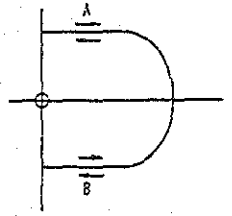
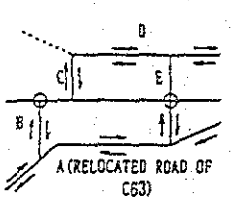
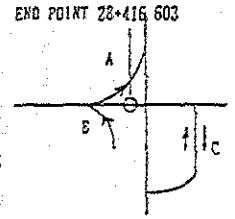
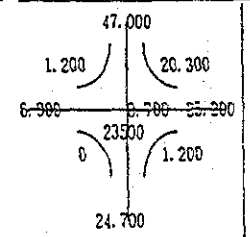
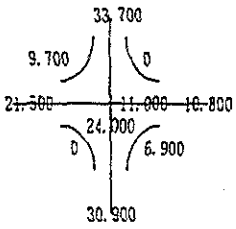
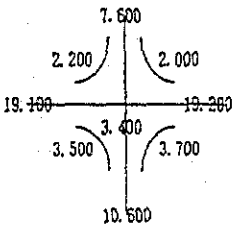
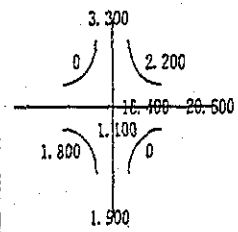
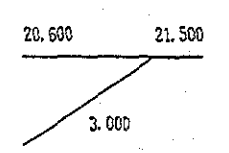
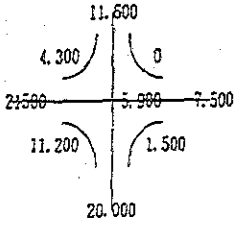
2.4.5 DESIGN OF JUNCTIONS

The Nairobi Bypass has a full control system throughout, with seven junctions.

- Mombasa Road Junction
- Uhuru Monument Junction
- Ngong Road Junction
- Dagoretti Forest Junction
- Thogoto Junction
- Kikuyu Town Junction
- Kikuyu Junction

The design conditions of these junctions are described in the following page.

CONSIDERATIONS OF INTERSECTOINS

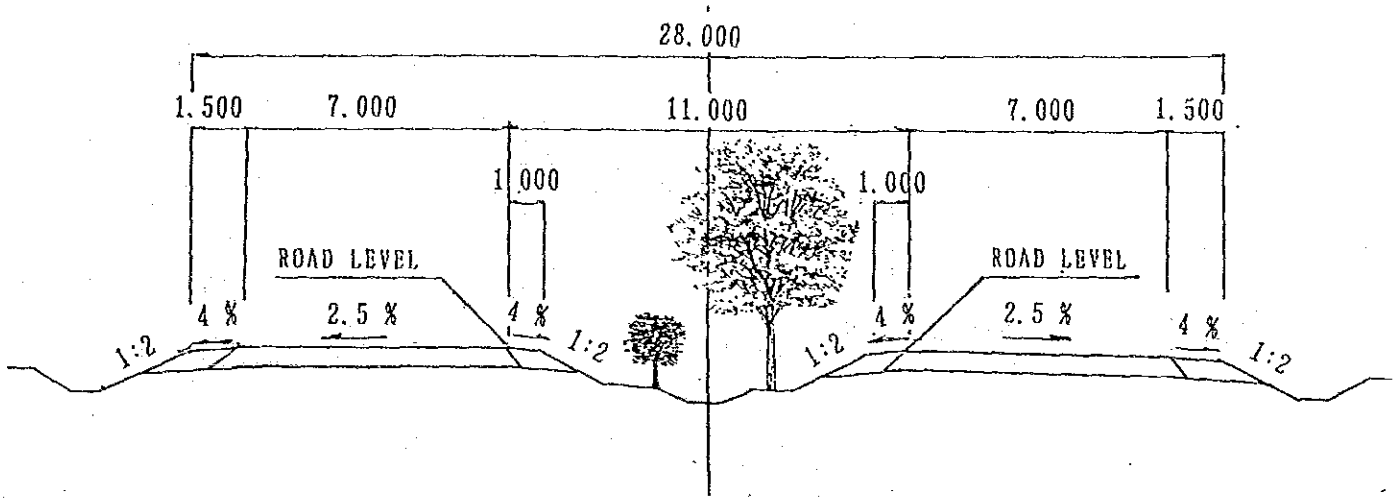
NAME OF JUNCTION		MOMBASA ROAD J.C	UHURU MONUMENT J.C	NGONG ROAD J.C	DAGORETTI FOREST J.C	THOGOTO J.C	KIKUYU TOWN J.C	KIKUYU J.C	
INTERVAL (m)		397.568	6297.369	9036.295	5413.668	2239.368	3430.587	1320.000	496.603 / 28601.478
DESIGN SPEED	MAIN ROAD	80Km/hr	100Km/hr	80Km/hr					
	SLIP ROAD	50Km/hr	40Km/hr						40 ～ 50Km/hr
NAME OF ACCESS ROAD		MOMBASA ROAD , LIKONI ROAD	LANGATA ROAD(C58)	NGONG ROAD(60)	DAGORETTI ROAD(C63)	THOGOTO ROAD(D411)	DAGORETTI ROAD(C63)	KABETE LIMURU ROAD(A104)	
SKETCH OF JUNCTION NAME OF SLIP ROAD									
TRAFFIC VOLUME AADT IN 2003						NO DATA			
COMPOSITION OF WIDTH	APPROACH ROAD (m)	MOMBASA ROAD(A104) 4 LANE S C M C S 3.50+7.00+28.50+7.00+3.50 LIKONI ROAD S C S 1.50+7.00+1.50=10.00	LANGATA ROAD(C58) 4 LANE P G C M C 2.00+4.75+7.50+6.50+7.00 G P +4.75+2.00=34.50 TEMPORARY ROAD S C S 1.50+3.50+1.00=6.00	NGONG ROAD(C60) 2 LANE S C S 1.50+7.00+1.50=10.00 WITH RIGHT TURN LANE S C S 1.50+10.50+1.50=13.50	DAGORETTI ROAD(C63) 2 LANE S C S 1.50+7.00+1.50=10.00 WITH RIGHT TURN LANE S C S 1.50+10.50+1.50=13.50	THOGOTO ROAD(D411) 2 LANE S C S 1.25+6.00+1.25= 8.50 WITH RIGHT TURN LANE S C S 1.25+ 9.00+1.25=11.50	DAGORETTI ROAD(C63) A,B,C,D,E 5 SLIP ROAD A SLIP ROAD(RELOCATED ROAD) S C S CH 00～1+324 1.50+7.00+1.50=10.00 S C S CH 1+324～500 1.50+4.00+1.00=6.50 B SLIP ROAD S C S 1.50+5.50X2+1.50=14.00 C SLIP ROAD S C S 1.50+8.00+1.50=11.00 D SLIP ROAD CH 00～629 S C S 1.50+7.00+1.50=10.00 S C S CH 629 ～768 1.25+6.00+1.25= 8.50 E SLIP ROAD 1.50+7.00+1.50=10.00	KABETE LIMURU ROAD(A104) 4 LANE S C M C S 1.50+10.50+1.50+7.00+1.50 =22.10(INCLUDING CLIMBING LANE)	
P:PEDESTRIAN G:GREEN BELT C:CARRIAGE WAY M:MEDIAN STRIP	SLIP ROAD	A,B,C,D,E,F,G 6 SLIP ROAD ONE LANE S C S 1.50+4.00+1.00=6.50	A,B,C,D 4 SLIP ROAD ONE LANE S C S 1.50+4.00+1.00=6.50	A,B 2 SLIP ROAD TWO LANE S C S 1.50+8.00+1.50=11.00	A,B 2 SLIP ROAD TWO LANE S C S 1.50+8.00+1.50=11.00	A,B 2 SLIP ROAD TWO LANE S C S 1.00+6.00+1.00= 8.00		A,B,C 3 SLIP ROAD A SLIP ROAD 1 LANE S C S 1.50+4.00+1.00=6.50 B SLIP ROAD 1 LANE S C S 1.50+3.50+1.00= 6.00 C SLIP ROAD 2 LANE S C S 1.50+8.00+1.50=11.00	

2.4.6 TYPICAL CROSS-SECTION

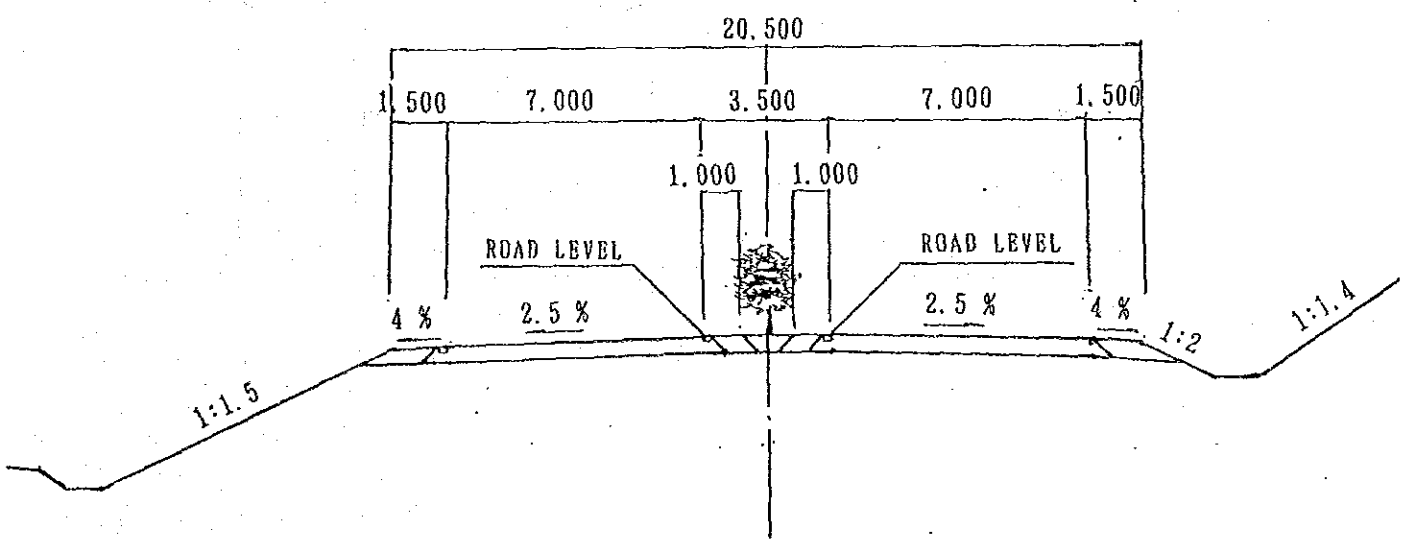
The Typical cross-section for the Nairobi Bypass was decided through consultations with the MOPW pursuant to the Geometric Design Manual Part I. The width of the central reserve is narrowed for the section between the Uhuru Monument Junction and the Kikuyu junction to reduce the cost of construction involving the excavation of rock and high embankment.

M A I N R O A D

Mombasa road junction ~ Uhuru monument junction

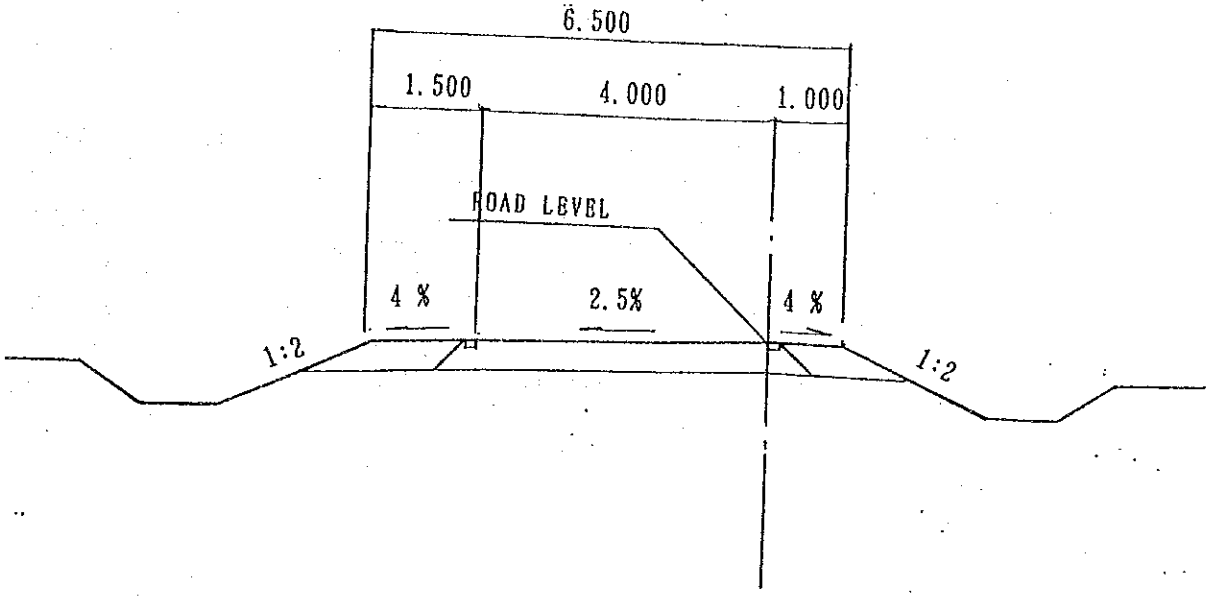


Uhuru monument junction ~ Kikuyu junction

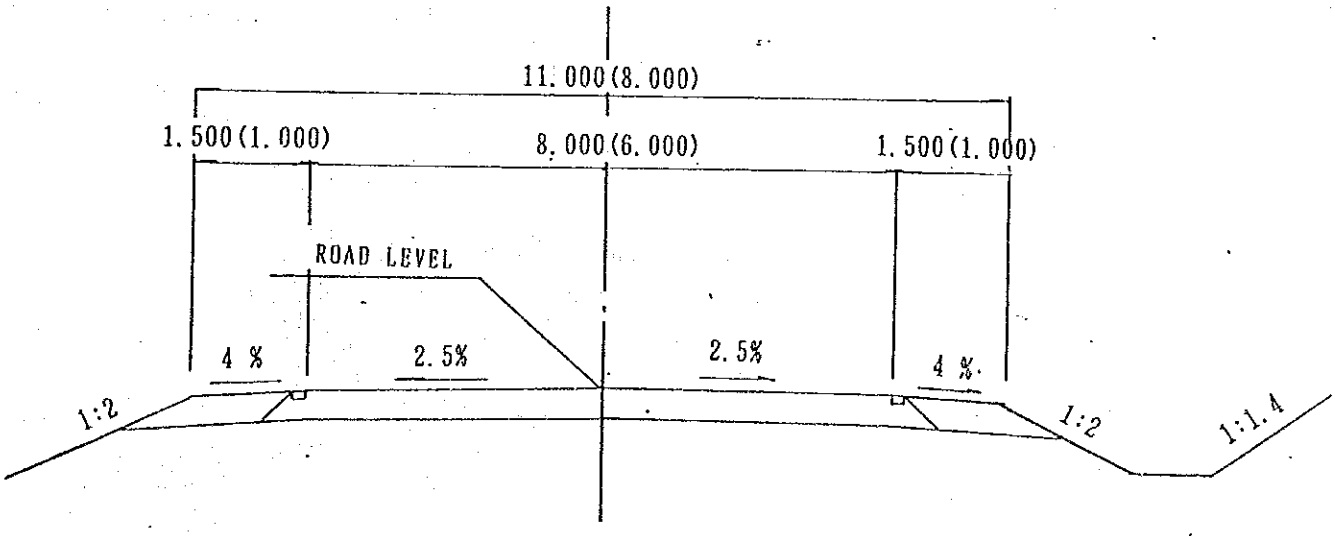


S L I P R O A D

One lane



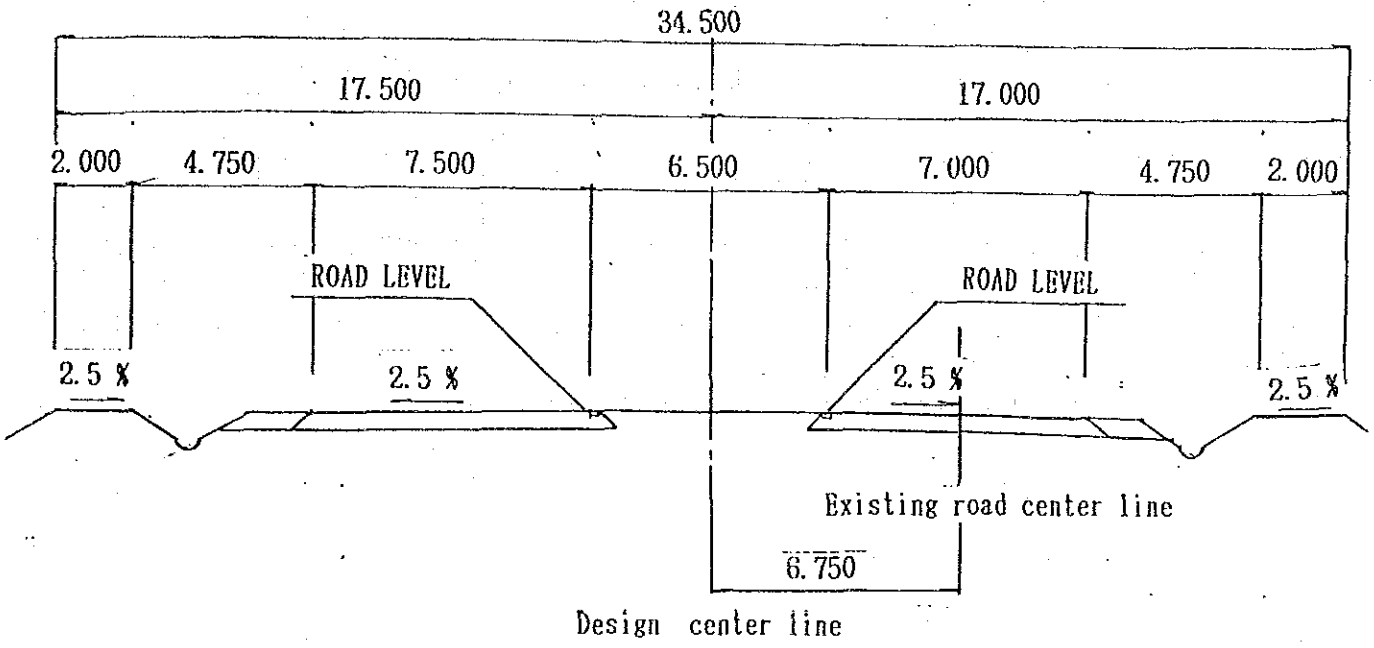
Two lane



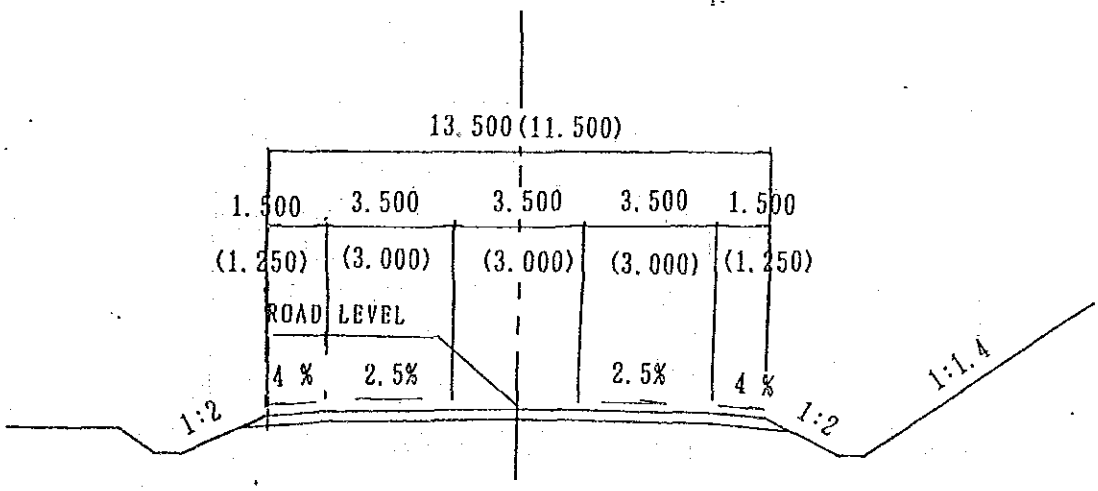
Note ( ) show at Thogoto junction

A P P R O A C H R O A D

Uhuru monument J,C (Langata road)



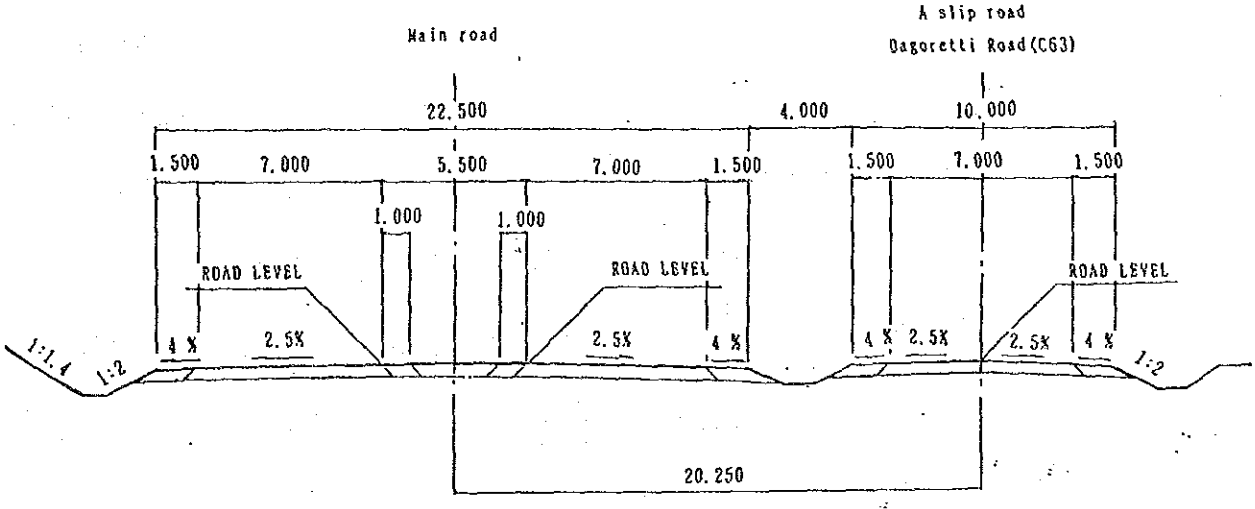
Ngong Road J,C Dagoretti Forest J,C Thogoto J,C



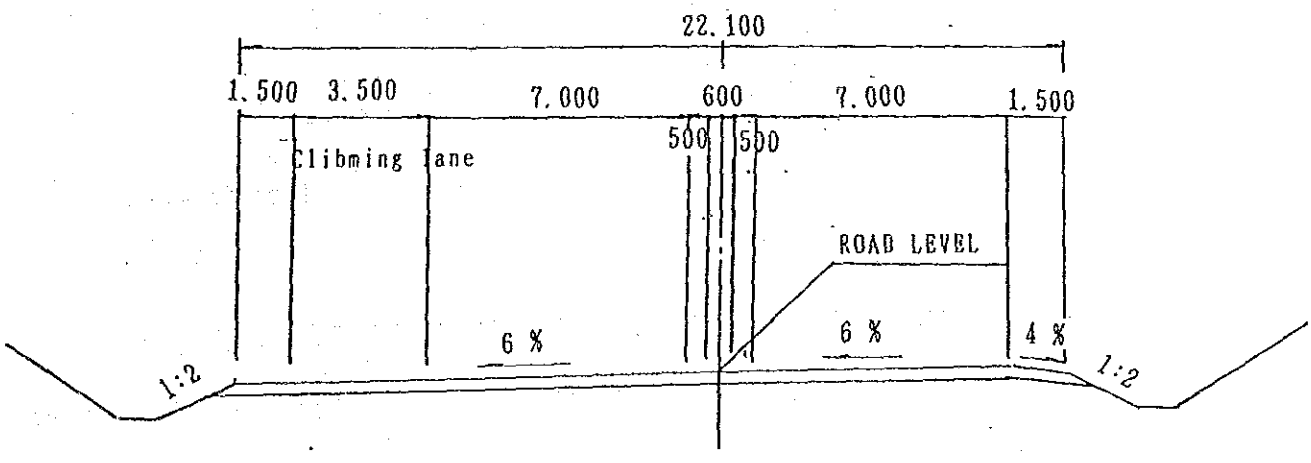
To be improved at section with right turn lane

Note ( ) show at Thogoto junction

Kikuyu Town J.C

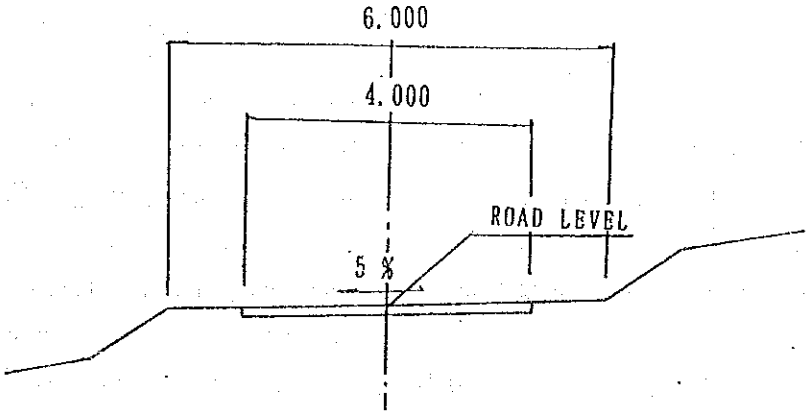


Kabete-Limuru road

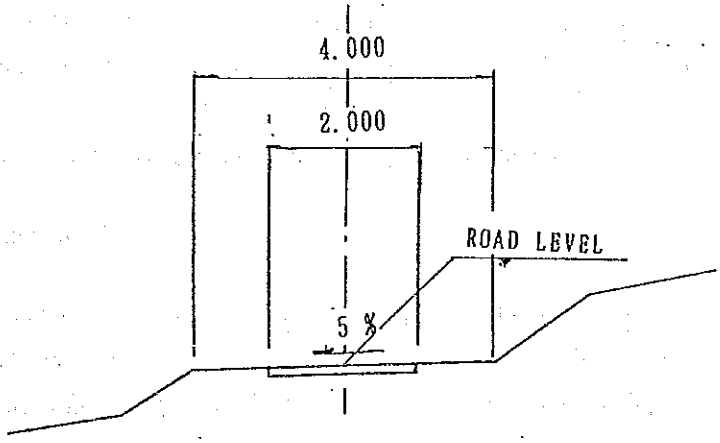


SERVICE ROAD

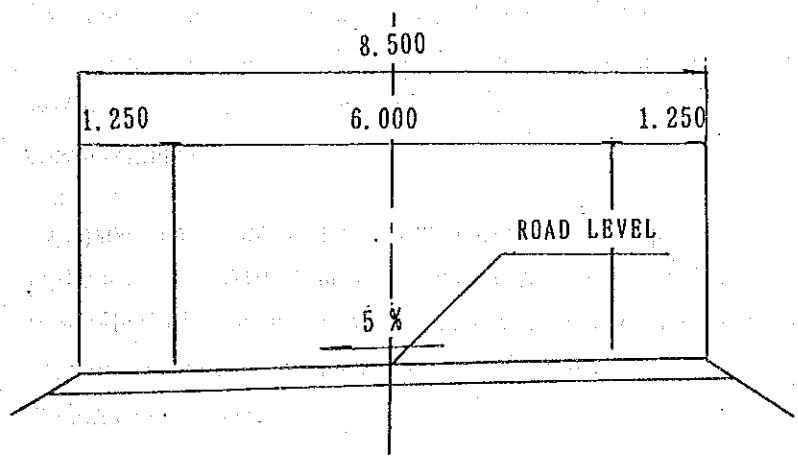
For vehicle



For pedestrian



Approach road at box culvert



2.4.7 PAVEMENT DESIGN

(1) General

Pavement design was carried out in close consultation with the material branch of the MOPW referring to the "Road Design Manual Part III" issued by the MOPW.

The pavement was designed separately by four design methods, i.e. Road Design Manual Part III, Road Note No. 29, AASHTO Guide for Design of Pavement Structures and Manual for Design and Construction of Asphalt Pavement (Japan Road Association) which were later compared. After a discussion on the pavement design between the JICA study team and material branch of the MOPW, the pavement design by Road Note No. 29 was recommended.

A major factor in pavement design is the cumulative number of equivalent standard axles (ESA) in the design period. The cumulative number of equivalent standard axles during the design period was calculated from the forecast of future traffic in the feasibility study which was reviewed by the JICA study team and which was accepted by the Planning Department of MOPW in the end of 1989.

(2) Main Road

In 1991, a concrete plan was set for the construction of the Oil Pipeline from Nairobi to Kisumu/Eldoret. use of the pipeline by KPC for oil will commence in 1993, before the completion of Nairobi Bypass. Therefore the pavement design of the main road of the bypass took this into consideration.

The pavement structure was designed separately by four design methods as mentioned above. The design results were compared and the pavement structure designed by Road Note No. 29 has been recommended.

The pavement structures, especially the types of base were also studied and compared. After that lean concrete base was recommended in view of availability of base materials, construction method, preventing cracks into the bottom of the base due to oxidization, construction cost and saving foreign currency.

Recommended pavement structure is as follows:

Surfacing (Asphalt concrete)	:	120 mm
Base (Lean concrete)	:	200 mm
Subbase (Graded crushed stone)	:	150 mm

(3) Ramp (Slip road)

Pavement design of slip roads of each interchanges (at grade junction) was carried out with the same procedure as the main road.

The commutative number of ESA for each ramp was based on the future traffic forecast in the Feasibility Study Report.

Recommended pavement structure for each junction are as follows:

	Thickness of Layer (mm)		(Wearing course +)
Road	Subbase	Base	Surfacing (Base course)
Junction			
Mombasa	150	200	200 (40 + 80)
Uhuru Monument	150	180	100 (40 + 60)
Ngong Road	150	180	100 (40 + 60)
Dagoretti	150	180	100 (40 + 60)
Thogoto	150	180	100 (40 + 60)
Kikuyu Town	150	180	100 (40 + 60)
Kikuyu	150	200	200 (40 + 80)

Pavement material

Subbase	:	Graded crushed stone
Base	:	Lean concrete (High qualitative cement-stabilized material)
Surfacing	:	Asphalt concrete

(4) Approach Roads

The pavement structure of the approach roads to the junctions is the same as the existing pavement structure except underpass (C58) at UHURU MONUMENT JUNCTION.

Route C58 has been planned by the city council to improve it into dual carriage way, then the pavement structure was designed with the traffic forecast in the Feasibility Study Report for Nairobi Bypass Project. The pavement structure for approach roads and route C58 are as follows:

Pavement structure of existing "C" class road

Surface dressing	:	25 mm
Base (G.C.S)	:	130 mm
Subbase (G.C.S)	:	100 mm

Pavement structure of underpass (C58) of UHURU MONUMENT JUNCTION

Surfacing (Asphalt concrete)	:	150 mm
Base (Lean concrete)	:	200 mm
Subbase (G.C.S)	:	150 mm

(5) Service Road

The pavement of the service roads along the Bypass is basically same pavement as existing one. It, however, was designed in accordance with the Road Design Manual Part III as follows:

Pavement structure for the service road:

General wearing course D1 : 150 mm

as: traffic T = 15-50 (both directions)

2.4.8 BRIDGES AND BOX CULVERTS DESIGN

(1) General

Design work for two highway bridges, one railway bridge, two vehicle overbridge, two pedestrian bridges, seven box culverts for vehicles four box culverts for pedestrian and five box culverts for drainage was carried out in close consultation with the MOPW bridge section.

(2) Design Standard

The design standard for structure design is referred to BS5400 (BS153 for the Railway Bridge), technical data for the design of bridges in regard to earthquake, temperature, wind, rainfall, etc., and Road Design Manual Part IV in consultation with the Bridge section of the MOPW. The width and clearance of the road referred to Road Design Manual Part I (MOPW) and the results of discussion between the MOPW and JICA teams. Design criteria of the railway bridge is also based on BS5400 and BS153. For detailed design, BS5400 was adopted as a design standard after discussion between engineers from Kenya Railway and the Nairobi Bypass project design team.

(3) Type, Size and Location of Structure

1) Bridges

Types of bridges, their location and their scale on Nairobi Bypass are as follows:

Type	No.	Location	Length (m)	Width (m)
For Road	1	Mombasa Road JC Bridge (Starting point of Bypass Road)	57.0	17.0
	2	Uhuru Monument JC Bridge (Crossing of C58 Road)	58.0	20.5
	3	Railway Bridge Over Bypass in CH27 + 20.0 m	56.85	11.4
Over Bridge	2	Over Bypass CH15 + 980.0 m	30.1	6.0
	4	Over Bypass CH15 + 920.0 m	28.1	10.0
Footpath	1	Over Bypass CH1 + 180.0 m	38.20	3.0
	2	Over Bypass CH1 + 220.0 m	48.40	3.0

2) Box Culverts

Types, location and scale of Box Culverts are as follows:-

Type	No.	Location	Length (m)	Width b x h (m)
For Road	1	Crossing of C60 Ngong Road CH15 + 540.0	32.3	10.0 x 5.5
	2	Crossing of CH19 + 500.0	37.5	8.0 x 5.5
	3	Crossing of Rump for Dagoretti JC CH20 + 930.0	32.0	10.0 x 5.5
	4	Crossing of D411 Thogoto Road CH23 + 193.0	26.7	8.5 x 5.5
	5	Crossing of Public Road (E) CH23 + 169.4	26.7	8.5 x 5.5
	6	Crossing of Public Road CH24 + 980.0	25.5	8.5 x 5.5
	7	Crossing of D422 Ondiri Road CH26 + 464.0	50.2	8.5 x 5.5
For Drainage	1	Ruora River in Ngong Forest CH13 + 978.0	59.0	3.0 x 3.0
	2	Motoine River in Ngong Forest CH14 + 934.0	34.2	3.0 x 2.0
	3	Motoine River in Ngong Forest CH15 + 560.0	67.0	3.5 x 3.0
	4	Motoine River in Ngong Forest CH0 + 157.0 (Ngong JC-Rump)	40.0	3.5 x 3.0
	5	Ondiri River CH26 + 355.0	132.0	3.5 x 3.5 (Double)
Footpath	1	CH18 + 400.0	28.0	3.3 x 3.0
	2	CH20 + 200.0	21.5	3.0 x 3.0
	3	CH22 + 880.0	21.5	3.0 x 3.0
	4	CH26 + 220.0	22.1	3.0 x 3.0

2.4.9. ROAD FURNITURE

(1) General

Road furniture of the Nairobi bypass was planned on the basis of Chapter 8, Manual for Traffic Signs in Kenya Part I and II, June 1975, of the Road Design Manual Part I, January 1979.

(2) Road Furniture

1) Traffic Islands and Kerbs

Flush kerbs are installed on the main road, ramps, and approach roads. Raised kerbs are installed on the traffic islands and bus stops on the main road and ramps to prevent vehicles from riding on them. Traffic islands on approach road are paved with hatched and chevron markings.

2) Marker Posts

Marker posts shall be installed on the guardrails at dangerous points where the horizontal alignment of the ramp is sharply curved.

3) Guardrails

Guardrails are planned on the bases of the guardrail installation chart shown on Fig. 8.5.1 of the Road Design Manual Part I.

A guardrail will be installed at those points were the value of the Guardrail Need Index (G.N.I.) on the chart is 60 or greater and at other points where the installation of a guardrail is considered necessary.

4) Fences and Gates

Fences are installed along the portion of the bypass that passes through the pasture of the Alliance high school to prevent cattle from entering the road.

5) Traffic Signs and Markings

Traffic signs and markings are planned on the basis on the Manual for Traffic Signs in Kenya Part I and II, June 1975 and upon consultation with the MOPW.

6) Planting of trees and shrubs

Shrubs shall be planted on the central reserve of a width of 3.5 m, at intervals of 4 m where a guardrail is installed and at intervals of 5 m where no guardrail is installed, to reduce the light from cars in the opposite lane. Shrubs shall be planted at intervals of 4 m where a guardrail on the road side is installed to guide driver's eyes. Trees and shrubs shall be planted on the central reserve of a width of 11 m and at the Mombasa road junction to provide a good view. Refer to the drawings for the details of planting.

3 TOPOGRAPHICAL SURVEY

3.1 WORK IN FIRST PHASE AT FIELD

Field survey works in the first phase commenced on 27th November, 1989, and were completed on 9th January, 1990 by GEOMAPS (P.O. Box 61071, Nairobi, Kenya). The Aerial Photography work was carried out in December 1989 by PHOTOMAP (P.O. Box 43850, Nairobi, Kenya). The respective works were commissioned by the JICA study team.

1) Premaking of Photo Control Points
2) Aerial Photography
3) Ground Control Survey
4) Reconnaissance
5) Polygon Survey
6) Leveling Observations

3.2 WORK IN FIRST PHASE IN JAPAN

Works in the first phase in Japan are as follows:-

1) Aerials Triangulation
2) Stereo Potting 6 Compilation

3.3 WORK IN SECOND PHASE

3.3.1 SUPPLEMENTARY SURVEY

A total of 46 sheets of 1/1,000 scaled transparently duplicated maps covering the proposed road corridor, and a total of 32 sheets of 1/500 scaled transparently duplicated maps were prepared, sheet by sheet, in A1 size from original compiled maps for supplementary survey work.

3.3.2 FAIR DRAWINGS OF THE MAPS

The features, spot heights, and contouring on both scaled maps were reviewed in Japan based on the findings of the supplementary survey at the project sites, and on fair drawings by inking methods made to finalize products.

3.3.3 CENTER LINE STAKING & PROFILE SURVEY

On the basis of the tentative main route alignment, the chainage points and principal points were staked out between January and March, 1991. In addition, a longitudinal profile survey on the alignment was conducted during the same period. All principal points on the alignment were replaced by concrete monuments.

3.4 WORK IN THIRD PHASE

The works in third phase entailed the following aspects.

a) Staking out the chainage pegs of the center-line for all interchanges.

b) Setting out the principal points along the center-line of all the interchanges including monumentation.

c) Carrying out items a) and b) above for the changed main route in the Ngong Road Forest.

d) Longitudinal profile survey for the routes in item a), b) and c) above.

e) Longitudinal profile chart drawing for item d) above.

f) Cross-section survey and chart drawing for the entire main route and interchanges.

g) Staking out right of way pegs including beaconing of witness marks for the monuments along main route and interchanges.

h) Point descriptions for all the monuments established.

i) Preration of Land acquisition drawings along the entire route.

3.5 RESULTS TO BE DELIVERED

The topographical and line survey results which were submitted by the study team to the JICA Head Office in Tokyo are as follows:-

a) Aerial Photographs

Contact prints	scale 1:6,000.....	1 set
	scale 1:4,000.....	1 set
Enlarged prints	scale 1:3,000.....	1 set
Negative rolls.....		1 set

(submitted to the MOPW)

b) Aerial Triangulation Results

Computation result	for 1:1,000 plotting.....	1 Vol.
	for 1:500 plotting.....	1 Vol.
Contact prints and dia-positive films		
	scale 1:6,000.....	1 set
	scale 1:4,000.....	1 set

c) Topographical maps with road center-lines

	scale 1:1,000.....	1 set
	scale 1:500.....	1 set

d) Longitudinal profile charts..... 1 set

e) Cross-sections profile charts..... 1 set

f) Land acquisition maps..... 1 set

g) Survey data book Vol. I, Vol. II and Vol. III..... 20 Vol.

4. SOIL AND MATERIAL INVESTIGATIONS

4.1 OUTLINE OF INVESTIGATIONS

Primary soil and material investigations along the proposed alignment were conducted between June 20th and October 30th, 1990, taking the findings of the Feasibility Study into consideration. Following the decision to change the alignment, an additional investigation was conducted between September 20th and October 30th, 1991. These investigations actually consisted of drilling investigation at 9 sites, test pit investigation at 47 sites and general soil tests, etc. The specific soil test on black cotton soil (expansive clay) was also carried out.

The main component of the material investigation was examination of gravel materials and hard stone materials in relation to their use as subgrade, aggregate for surfacing and concrete. While it was originally planned to purchase the materials to be investigated from existing quarries, the capability of these quarries to guarantee a stable supply was judged to be doubtful. In order to find promising new quarry sites, drilling investigations were conducted at 5 sites, test pit investigations at 96 sites and various material tests were also done. The detailed investigation results are given in the Material Report and are summarized below.

4.2 SOIL INVESTIGATION RESULTS ALONG THE ALIGNMENT

Based on the soil characteristics, the areas along the proposed alignment are classified into 5 areas, i.e. black cotton soil area, red soil area, pyroclastic tuff area, trachyte area and other area. Black cotton soil areas are scattered in Nairobi National Park and Ngong Road Forest where black cotton soil (expansive clay) of some 0.3 - 1.0 m in thickness lies on top of weathered bedrock. These areas are problematic as the extremely low CBR value and the possible repetition of expansion and contraction make black cotton soil and inferior base, necessitating its replacement by better soil. Red soil areas dominate areas along the alignment and are made up of hard clayey soil which is weathered residual soil. While red soil provides a generally favorable base, it is liable to erosion when dry. Careful attention should be paid to the prevention of slope erosion. Pyroclastic tuff areas are found near the Moi Otiende Estate in Langata and near Ngong Road Forest. A pyroclastic tuff is classified somewhere between soft rock and medium hard rock, ripper work is required during cutting work. This requirement was taken into consideration

in the decision on the longitudinal slope of the road. Trachyte areas are found in the area between the Carnivore Restaurant and the Moi Otiende Estate and parts of Dagoretti Forest. It is of a sedimentary state around Kikiyu due to strong weathering and is covered by red soil. However, the trachyte found along the alignment is generally fresh and is classified as hard rock, necessitating blasting work as part of the cutting work. Other areas include a site near Langata Prison where rubbish is scattered due to the use of the site for tipping purposes. Alluvial deposits are found near Ngong Road Junction, Dagoretti and Ondiri Swamp. While alluvial deposits are generally hard, a very soft peat layer exists near Ondiri Swamp although it is rather thin (1.5 m). Banking material for C63 Road is found around Kikuyu.

In general, the ground along the alignment provides a favorable foundation for a bridge. Weathered red soil and strongly weathered trachyte are found around Kikuyu Town Overbridge and the N value is low (4-24) upto 9 m below the ground surface.

The banking materials to be used are mainly red soil and weathered rock, both of which are reasonably good but which require water sprinkling to regulate the water content. The design bulking factor (C) is 0.85 for soil, 1.0 for soft rock and 1.2 for hard rock.

Previous investigations on cut and banked slopes indicate a predominance of red soil which is liable to erosion. Therefore, it was decided that the appropriate stable gradient was 37° for cutting and 30° - 35° for banking. The study on the stability of high banking near Alliance Boys High School found that the slope was stable with a gradient of 1:1.5 and subsidence was minimal.

The CBR value for subgrade is 10 - 30 < which is classified into S4 - S6 based on the MOPW soil class criteria.

4.3 RESULTS OF MATERIAL INVESTIGATION

The distribution of lateritic gravel along the alignment was confirmed but its thin layer cannot provide sufficient quantity to meet the demand. The anticipated poor quarrying efficiency is an additional disadvantage. Quality improvement is also necessary for its use as a subgrade material.

In regard to rocks, the trachyte along the alignment is much weathered and its use as gravel is questionable in terms of quality.

The Kitengela Site by Namanga-Arusha Road (A104), located some 2 km from Athi River Town, appears to be a good quarry site for phonolite which is mostly of good quality except that the FI value is a little bit above the standard value and can be used for surfacing and as an aggregate material.

No sand deposits are available along the route and sand must, therefore, be purchased. The water required for construction work can be easily obtained from Motoine River which runs along the proposed alignment.

5. HYDROLOGICAL SURVEY AND DRAINAGE DESIGN

5.1 GENERAL

Hydrological and drainage survey were carried out to obtain data to assist in planning and designing the drainage system to avoid flooding the road.

5.2 HYDROLOGICAL SURVEY

Hydrological Survey was carried out to review and check rainfall data in feasibility study stage.

To collect the date from Meteorological Department a station which controls and observes all rainfalls in Kenya is shown as following;

(1) "The Rainfall Frequency Atlas of Kenya (January, 1978)"

(2) Rainfall data at Dagoretti Head Quarter

(January 1978 to May, 1990)

(3) Rainfall data at Wilson Airport Station

(February, 1980 to May, 1990)

The nearest rainfall observation stations for this project were Wilson Airport Station and Dagoretti Head Quarter. In this stage, maximum rainfall data of Dagoretti Head Quarter (Fig. C.1) was used.

The rainfall frequency Atlas of Kenya (January, 1978) was used to obtain rainfall data at feasibility study stage. These data was used in the preliminary design stage after it was compared with above mentioned data (1) and (3).

5.3 DRAINAGE SURVEY

Drainage Survey was carried out to determine the various places where the surface run-off could be discharged. Efforts were made to avoid discharging water into people's land without channelising it. The surface run-off was discharged into Nairobi Dam, a pond within the national park and existing drainage wayleaves. In one place at around Thogoto College, the water was directed into a proposed drainage pond.

5.4 DRAINAGE DESIGN

Catchment areas have been taken from 1/50,000 and 1/5,000 scale maps and field inspection. The adequency of existing culverts, bridges and channels have been assessed wherever possible by interviewing local residents about frequency and maximum water levels observed and comparing these observations with calculated floods. Peak floods have been estimated using the "The TRRL (EA) flood mode" and "The rainfall Frequency Atlas Method for 25 years return period.

5.5 DRAINAGE POND

Between Thogoto College and Ondiri Swanp there exists a valley. In this valley there is no stream or river where the surface run-off can be drained. From the history of the area, ponding has been experienced. However, after the road is constructed, the run-off is expected to be increased. To alleviate this problem, it was proposed to construct a pond for drainage at the valley and then channelize the run-off from the road in this stage.

In Preliminary Design Stage, it was proposed to construction a soak pit. The reason was that soak pits for sewerage under construction near here and it was judged that soil of the location had enough coefficient of infiltration. But it was found that soil of the location is not enough coefficient of infiltration after boring survey and soil test.

6. UTILITIES SURVEY

GENERAL

Relocation of existing utilities is one of the most awkward aspect in constructing roads in urban areas due to involvement of many authorities having different policies, technical standards, development plans and their implementation schedule.

Data on existing utilities were collected from the following authorities;

(i) Water and Sewerage Department of Nairobi City Commission.

(ii) Water Department of Ministry of Water Development.

(iii) Kenya Posts & Telecommunications.

(iv) Kenya Power & Lighting Co., Ltd.

(v) Kenya Railways Corporation

(vi) Kenya Wildlife Service

(vii) City Engineer's Dept., Highway

(viii) Kenya Rifles Ministry of Defense

MOPW should discuss about the relocation of existing utilities budgetary requirements, relocation/replacement methods and scheduling with the relevant authorities after detailed design. However, during this stage, estimate envisaged were obtained from the affected authorities.

Site investigations were also carried out along the whole length on Nairobi Bypass.

7. COST ESTIMATES

The cost estimates have been made by JICA study team.

Description of the project cost was excluded from this "Main Report", and is reported in one (1) volume as follows:

"Cost Estimate Report"

The report describes the total project cost, basic data for cost estimates, estimated cost by Group of Specifications, foreign currency component of the cost, annual disbursement, unit price breakdown, and prepared under "Confidential" cover.

The period Bill of Quantities is also prepared in the same volume.