REPUBLIC OF KENYA

MINISTRY OF PUBLIC WORKS

DETAILED DESIGN STUDY
ON
THE NAIROBI BYPASS PROJECT

FACTUAL MATERIALS REPORT

SEPTEMBER 1992

Japan International
Cooperation Agency

The Permanent Secretary
Ministry of Public Works
P.O.Box 30260
NAIROBI

The Chief Engineer (Roads)
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CONTENTS

1. GENERAL

(1) Project Road

The Nirobi Bypass extends about 30 km of the Trans-African Highway. The Bypass starts at the North-East edge of the Nairobi National Park on the A104 and terminates at the Kikuyu Junction of A104 and C63.

The location of the project road is shown in Fig. 1.1.1.

(2) Scope of this Report

This material report covers the material investigations carried out during the design of the Nairobi Bypass Project. These include the testing of alignment soils, material site investigations and bridge site drillings.

(3) Scope of the Material Survey

1) Aim

The materials survey was conducted to identify the subsurface geological condition of the road structures, the geological specification of the subgrade as well as the specification of the pavement materials, which will be used as basic data for road design.

Investigation covered mainly the following are as:-

a. Foundation of Bridges

b. Foundation of Embankments

c. Cutting and Embankment Works

d. Subgrade Condition

e. Stability Angle and Protection of Slopes

f. Present State of Existing Quarries

g. Location, Quality and Quantity of New Quarries

h. Ground Condition of Soak Pit

2) Survey Item and Number

The survey item and number are shown in Tables 1.1.1 and 1.1.2.

3) Location of The Survey Points

The location of the survey points on the proposed alignment are shown in Fig. 1.1.1, Table 1.1.3 to 1.1.7 and APPENDIX 1, while the locations of the investigated quarries are shown in Fig. 1.1.2, Table 1.1.7 and APPENDIX 6 and 7.

4) Conclusions and Opinions Expressed in this Report

The conclusions drawn and opinions expressed in this report have been based upon the evidence described in the text and the test results and site measurements recorded in the Appendices. They are not intended in any way to be definitive statements on any materials aspect connected with the proposed construction works and materials sources. The Contractor shall be expected to peruse the evidence recorded in the report, supplement it with his or other sources and draw relevant conclusions on the basis of his own expertise.

Table 1.1.1 (1) The First Survey Item and Number

Item No.	Description	Quantity
1	**Earthworks and Subgrade Study**	
1-a	Rotary Drilling (core drills, 7~13 m depth, total 77 m depth)	8 points
1-b	Standard Penetration test (1 time/1 m)	22 times
1-c	Test Pit (1 ~ 4 m depth)	30 points
1-d	Basic Test	
1)	Grading to 0.075 mm sieve	36 samples
2)	Atterberg Limits	36 samples
3)	Compaction test (2.5 kg rammer)	36 samples
4)	CBR and swell on samples moulded at 100% M.D.D. and O.M.C.	36 samples
5)	Traiaxial Compression test (Unconsolidated Untrained)	3 samples
6)	Consolidation test	3 samples
1-e	Subgrade Soils Test	
1)	Compaction test (4.5 kg rammer)	6 samples
2)	3 point CBR test	6 samples
2	**Borrow Pits Study (New Gravel sites)**	
2-a	Test Pit (0.6 ~ 2.3 m depth)	96 points
2-b	Soil Test	
1)	Grading to 0.075 mm sieve	34 samples
2)	Atterberg Limits	34 samples
3)	Compaction test (4.5 kg rammer)	34 samples
4)	CBR test	34 samples
5)	CBR (cement stabilization)	14 samples
6)	CBR (lime stabilization)	14 samples
3	**Foundation Study for Bridges and Box-culvert**	
3-a	Rotary Drilling (core drills, 5 ~ 16 m depth, total 31 m)	4 points
3-b	Standard Penetration test (1 time/1 m)	48 times
4	**Foundation Study for Embankment**	
4-a	Test Pits (1 m depth)	10 points
4-b	Soil Test	
1)	Grain-Size Analysis	9 samples
2)	Grading to 0.075 mm sieve	6 samples
3)	Atterberg Limits	21 samples
4)	Specific Gravity	9 samples
5)	Natural Water Content	9 samples
6)	Unit Weight	5 samples
7)	Consolidation test	2 samples
8)	Triaxial Compression test (Unconsolidated Undrained)	2 samples
9)	Compaction test (2.5 kg rammer)	10 samples
10)	Compaction test (4.5 kg rammer)	1 samples
11)	CBR and swell on samples moulded at 100% M.D.D and O.M.C.	10 samples
12)	3 point CBR test	1 samples
13)	Free Swelling test	9 samples
14)	Swelling Pressure test	5 samples
15)	Linear Shrinkage test	5 samples

Table 1.1.1 (2) The First Survey Item and Number

Item No.	Description	Quantity
5	**Hard Stone Quarry Study**	
5-a	Rotary Drilling (core drills, 10~15 m depth, total 65 m depth)	5 points
5-b	Crushed Stone Test	6 samples
1)	Grading to 0.075 mm sieve	6 samples
2)	Los Angeles Abrasion	6 samples
3)	Aggregate Crushing Value	6 samples
4)	Sodium Sulphate Soundness	6 samples
5)	Plasticity Index on L.A.A. fines	6 samples
6)	Specific Gravity	6 samples
7)	Bitument Affinity	6 samples
8)	FI	6 samples
6	**Ground condition Study for Soak Pit**	
6-a	Rotary Drilling (core drills, 10~15 m depth, total 25 m depth)	2 points
6-b	In-situ Permeability test	1 time

Table 1.1.2 The Additional Survey Item and Number

Item No.	Description	Unit	Quantity
1	**Earthworks and Subgrade Study**		
1-a	Rotary Drilling (core drills, 14 m depth)	point	1
1-b	Standard Penetration test (1 time/ 1 m)	times	7
1-c	Test Pit (1 ~ 4 m depth)		
	1 m depth	points	3
	2 m depth	points	1
	3 m depth	points	2
	4 m depth	points	1
1-d	Field Soil Density Test (Sand Replacement Method)	points	5
1-e	Basic Test		
1)	Grading to 0.075 mm sieve	samples	11
2)	Atterberg Limits	samples	11
3)	Linear Shrinkage test	samples	11
4)	Compaction test (2.5 kg rammer)	samples	11
5)	CBR and swell on samples moulded at 100% M.D.. and O.M.C	samples	11
1-f	Soil Test for Black cotton soil		
1)	Natural Water Content	samples	3
2)	Free Swelling test	samples	3
3)	Swelling Pressure test	samples	3

Table 1.1.3 The List of Mechanical Boring (First Survey)

Bore hole name	Location	Depth of boring (m)	S.P.T (No.)	Note
BE-1	KM. 9 +125 m	0	0	cutting
BE-2	KM. 10 +840 m	8	8	"
BE-3	KM. 14 +380 m	8	6	"
BE-4	KM. 18 +820 m	10	5	"
BE-5	KM. 19 +835 m	9	8	"
BE-6	KM. 21 +485 m	11	4	"
BE-7	KM. 21 +952 m	11	6	"
BE-8	KM. 24 +713 m	6	5	"
BE-9	KM. 26 +150 m	13	7	"
BF-1	KM. 0 +373 m	5	0	Bridge foundation
BF-2	KM. 0 +432 m	5	0	"
BF-3	KM. 15 +550 m	5	5	Box-culvert foundation
BF-4	KM. 27 +915 m	16	16	Bridge foundation
BK-1	KITENGELA ROCK QUARRY	15	0	Crushed stone
BK-2	"	15	0	"
BK-3	"	10	0	"
BM-1	MUTHIGA ROCK QUARRY	15	0	"
BM-2	"	15	0	"
BM-3	"	10	0	"
Total		187	70	

Table 1.1.4 The List of Mechanical Boring (Additional Survey)

Bore hole name	Location	Depth of boring (m)	S.P.T (No.)	Note
BE-10	KM.10 +000 m	14	7	cutting

Table 1.1.5 The List of Test Pit for Embankment Foundation (First Survey)

Test pit name	Location	Depth (m)	Disturbed Sampling (No.)	Block Sampling (No.)
Tb-1	KM.0 +900 m	1.1	1	1
Tb-2	KM.1 +435 m	1.9	1	0
Tb-3	KM.1 +900 m	1.5	1	1
Tb-4	KM.2 +400 m	1.0	1	0
Tb-5	KM.2 +900 m	1.0	1	1
Tb-6	KM.3 +400 m	0.65	1	0
Tb-7	KM.3 +900 m	0.6	1	1
Tb-8	KM.4 +400 m	1.0	1	0
Tb-9	KM.4 +895 m	0.8	1	1
Tb-10	KM.5 +400m	1.5	1	0
Total		11.05	10	5

Note; Disturbed Sampling from Black Cotton Soil Block Sampling from Under Layer of Black Cotton Soil

Table 1.1.6 The List of Test Pit for Subgrade (First Survey)

Test pit name	Location	Depth of pit (m)	Disturbed Sampling (No.)	Note
Tc-1	KM.5 +920 m	0.8	1	
Tc-2	KM.7 +400 m	0.85	"	
Tc-3	KM.7 +800 m	0.7	"	
Tc-4	KM.8 +600 m	1.2	"	
Tc-5	KM.9 +110 m	1.1	"	
Tc-6	OLD KM.9 +900 m	1.7	"	
Tc-7	OLD KM.10 +840 m	2.0	"	
Tc-8	OLD KM.12 +100 m	0.7	"	
Tc-9	OLD KM.12 +500 m	1.4	"	
Tc-10	OLD KM.13 +180 m	0.5	"	
Tc-11	OLD KM.14 +380 m	2.0	"	
Tc-12	OLD KM.15 +185 m	3.7	"	
Tc-13	KM.16 + 90 m	4.0	"	
Tc-14	KM.16 +700 m	0.7	"	
Tc-15	KM.17 +150 m	4.0	"	
Tc-16	KM.18 +820 m	2.0	"	
Tc-17	KM.19 +305 m	3.7	"	
Tc-18	KM.21 +480 m	2.25	"	
Tc-19	KM.21 +955 m	2.1	"	
Tc-20	KM.24 +178 m	2.2	"	
Tc-21	KM.24 +705 m	1.9	"	
Tc-22	KM.25 +288 m	3.7	"	
Tc-23	KM.25 +775 m	2.8	"	
Tc-24	KM.26 +158 m	2.1	"	
Tc-25	KM.26 +778 m	1.2	"	
Tc-26	KM.27 +178 m	1.4	"	
Tc-27	KM.27 +678 m	1.1	"	
Tc-28	KM.28 +103 m	1.1	"	
Tc-29	Aline KM.0 +420 m	4.0	"	
Tc-30	Aline KM.0 +870 m	1.0	"	
Total		71.5		

Table 1.1.7 The List of Test Pit for Subgrade (Additional Survey)

Test pit name	Location	Depth (m)	Desturbed Sampling (No.)	Block Sampling (No.)	Field Soil Density (No.)
Tc-31	KM.10 +400 m	2.5	2	0	1
Tc-32	KM.11 +380 m	3.0	2	0	1
Tc-33	KM.11 +880 m	0.8	2	1	1
Tc-34	KM.13 +660 m	1.5	1	1	0
Tc-35	KM.14 +155 m	1.0	1	0	1
Tc-36	KM.14 +650 m	4.0	2	0	1
Tc-37	KM.12 +575 m	0.9	1	1	0
Total		13.7	11	3	5

Table 1.1.8 The List of Test Pit for Borrow pit (GRAVEL MATERIAL SITE)

Test pit name	Depth (m)	Disturbed Sampling (No.)
KIRIBA		6
TP1	1.2	
TP2	1.5	
TP3	1.6	
TP4	1.0	
TP5	0.9	
TP6	1.5	
TP7	1.7	
TP8	0.9	
TP9	1.2	
TP10	0.6	
TP11	1.7	
TP12	1.8	
TP13	1.4	
TP15	1.7	
THANDI		6
TP1	1.9	
TP2	1.1	
TP3	1.4	
TP4	1.6	
TP5	1.0	
TP6	0.9	
TP7	0.4	
TP8	1.3	
TP9	1.3	
TP10	0.8	
TP11	1.8	
TP12	1.6	
TP13	1.4	
DAGORETTI		0
TP1	0.6	
TP2	0.9	
TP3	1.0	
TP4	1.5	
TP5	1.8	
TP6	1.2	
TP7	1.1	
TP8	0.7	
TP9	1.2	
TP10	1.4	
FOREST		0
GUARD		
TP1	0.7	
TP2	1.1	
TP3	1.3	
TP4	1.5	
TP5	1.8	
TP6	1.1	
TP7	1.0	
TP8	1.2	
TP9	1.0	
TP10	1.0	
CHURCH		4
TP1	1.1	
TP2	1.3	
TP3	1.1	
TP4	1.4	
TP5	1.4	
TP6	1.2	
TP7	1.3	
TP8	1.6	
TP9	1.9	
TP10	2.2	
TP11	2.3	
TP12	1.5	
TP13	1.9	
TP14	1.6	
TP15	1.5	
TP16	1.8	
CALSHEET		6
TP1	2.0	
TP2	2.5	
TP3	2.0	
TP4	2.5	
TP5	2.5	
TP6	2.0	
TP7	0.3	
TP8	0.2	
TP9	0.3	
TP10	0.4	
KAREN		4
TP1	1.3	
TP2	1.5	
TP3	1.4	
TP4	1.4	
TP5	1.7	
TP6	1.7	
TP7	1.3	
TP8	1.0	
TP9	1.0	
TP10	1.4	
TP11	1.0	
TP12	1.1	
TP13	1.2	
TP14	1.0	
Total	116.1	26

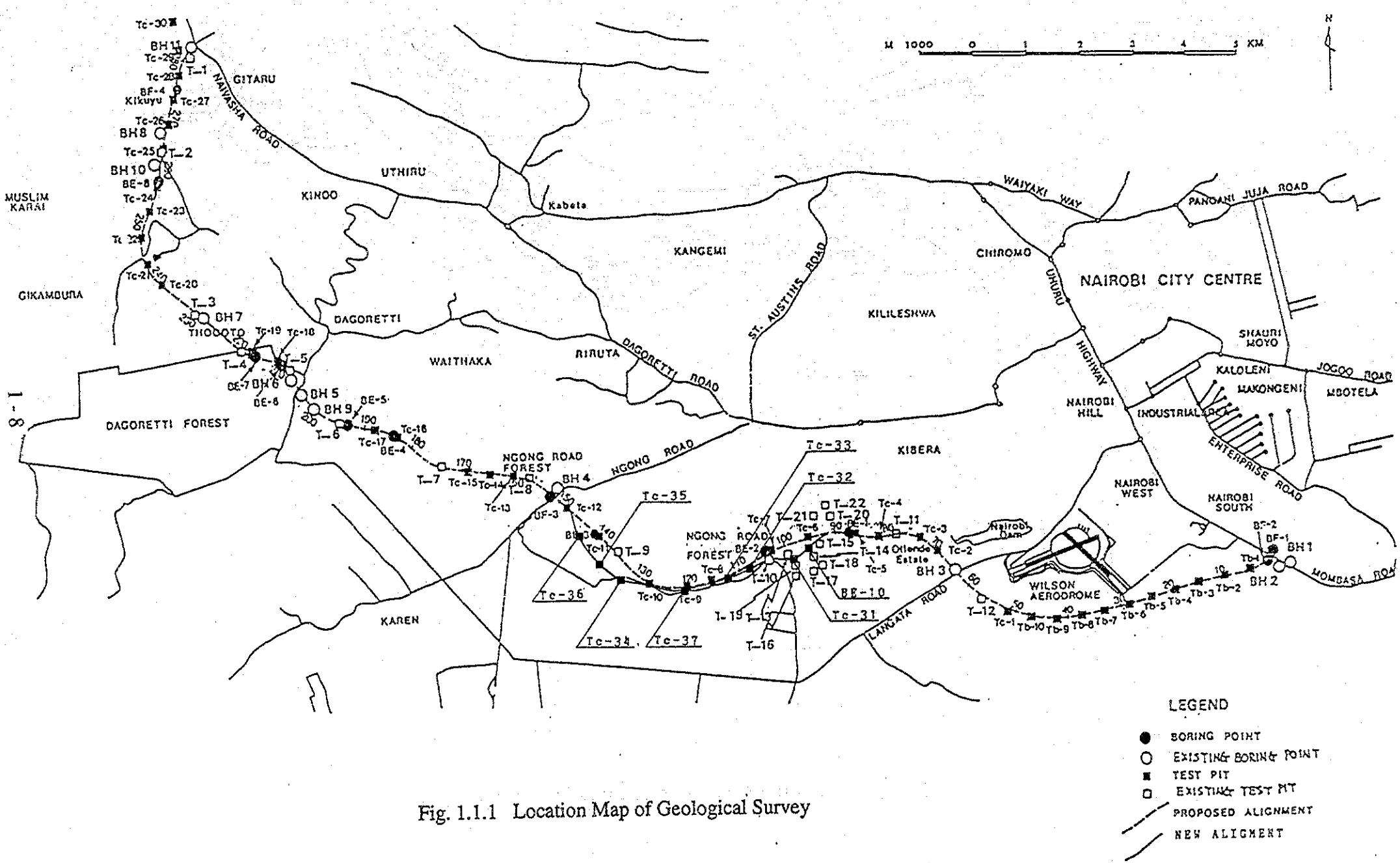


Fig. 1.1.1 Location Map of Geological Survey

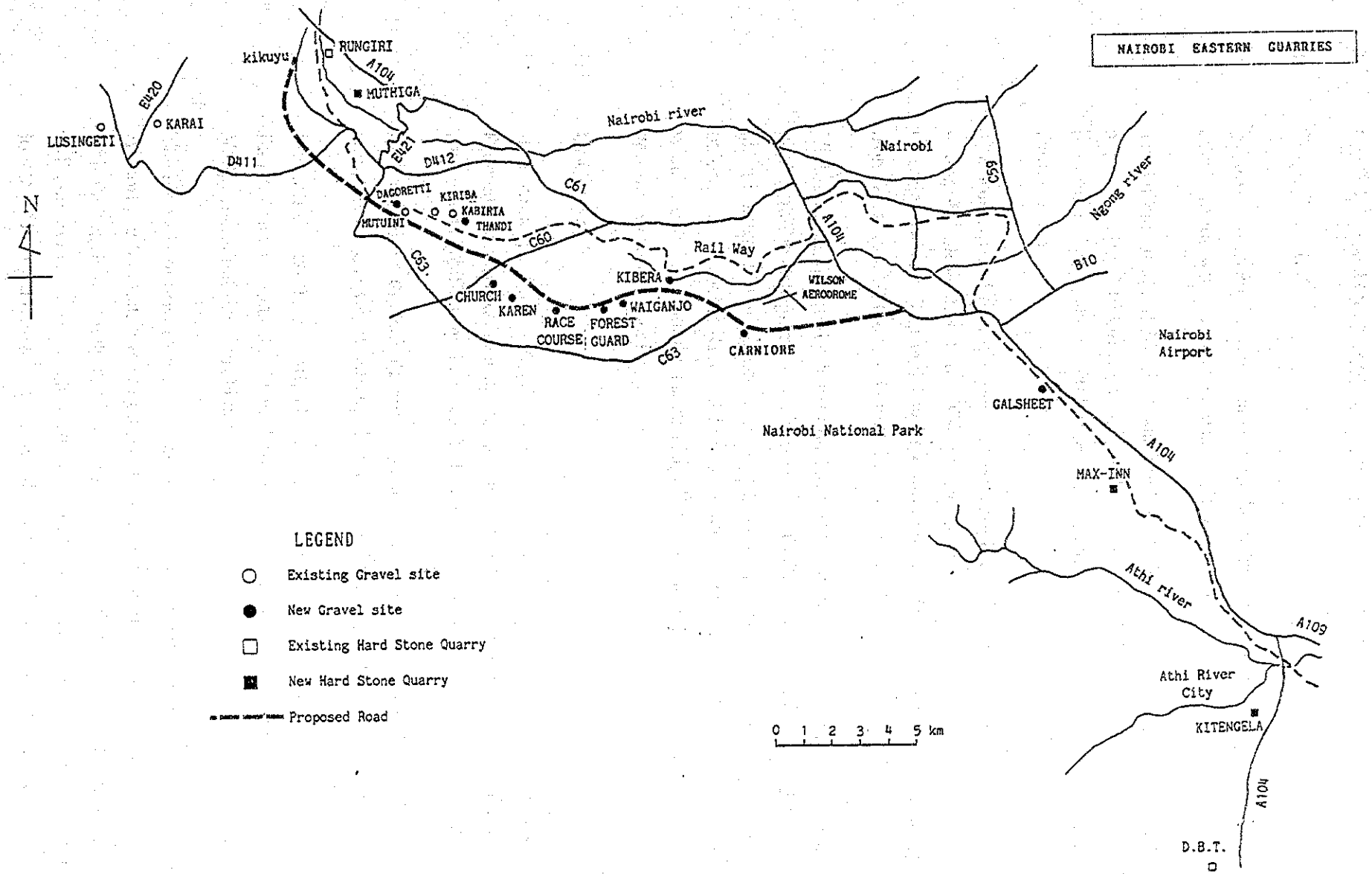


Fig. 1.1.2 Location of the Investigated Quarries

2. OUTLINE OF TOPOGRAPHY, GEOLOGY AND CLIMATE

2.1 TOPOGRAPHY

Nairobi and its environs are located on the east side highland of the Rift Valley at an altitude which ranges between 1,600 and 2,000 m.

The latitude is about 36° East, and the longitude is about 1° South. The city is approximately 140 km South of the Equator, with the port of Mombassa, on the Indian Ocean about 490 km distant. Lake Victoria is about 340 km away from Nairobi.

The western and northern parts of Nairobi are hilly land such as Nairobi hill which is below 2,000 m. The southern and eastern parts of Nairobi are spreaded on the Athi and Kapiti Plains and are below 1,800 m. Traveling from West to East the topography inclines gently.

Highland regions to the West and North of Nairobi are mainly used as farm-land with the exception of town areas and forestation. The surface of the Athi plain is covered with Black cotton soil, which is an expansive clay. This area belongs to the Athi River Drainage System and is crossed by many rivers which flow East from the eastern highlands of the Rift Valley forming alluvial deposits in some places.

2.2 GEOLOGY

Bed rock 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 which runs from North to South.

Bed rock along the Rift Valley has been cut by many faults, and the Rift Valley environs were covered with thick volcanic ash following the tertiary period.

Phonolite, Trachyte, Tuff, etc. spouted sometime between the tertiary and Pleistocene periods and was distributed on the East highlands of the Rift Valley including the Nairobi area.

The oldest lava flow forms the eastern plains where the Industrial Area and the Airport are located, it is called the Nairobi Phonolite. The next flow was the Nairobi Trachyte which terminates just northwest of the City Centre at Nairobi Hill and swings westward to form the heights on which Karen and Langata are located. During a pause in the volcanic activity, deep valleys were eroded into

the Trachyte block and then filled with material from the subsequent eruptions. These are known as the Kirichwa Valley Tuffs. They have been used extensively for building purposes, under the name Nairobi Stone, which accounts for the drab gray color of so many buildings in the area.

The youngest lava flow is called Limuru Trachytes which is located in western Nairobi.

Surface soil in the northwest highland region of Nairobi is composed of soil from volcanic ash, weathered volcanic rocks, etc. While black cotton soil, which is cohesive and expansive is distributed in the Athi Plain. The study area is crossed by many rivers belonging to the Athi River Drainage System and there is some intermittent distribution of the alluvial deposits.

A Geological Map of Nairobi is shown in Fig. 2.2.1.

2.3 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.

(1) 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, are as follows:

STATION NAME	MEAN TEMPERATURE		
	MAX	MIN	ALTITUDE
Nairobi (J.K.A.)	24.4°	12.3°	1,624 m
Wilson Airport	24.8°	13.1°	1,683 m
Dagoretti	23.4°	11.9°	1,798 m
Muguga K.A.R.I.	20.9°	10.8°	2,096 m

(2) 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.

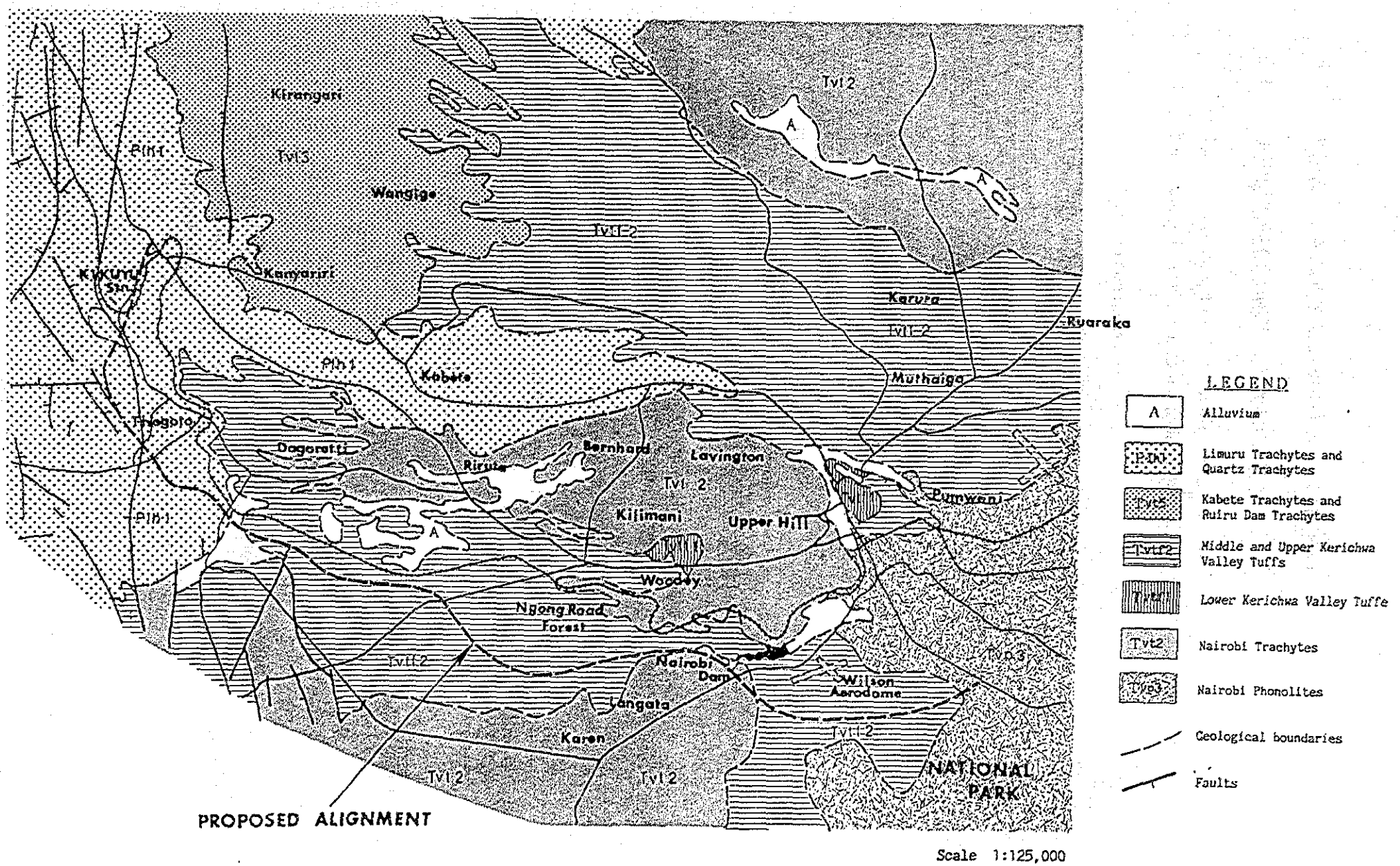


Fig. 2.2.1 Geological Map of Nairobi

3. INVESTIGATIONS ALONG THE ALIGNMENT

3.1 SUBSURFACE GROUND CONDITIONS

The subsurface geological conditions are as shown in APPENDIX 3. They can roughly be divided into the following areas:

– Black cotton soil areas

– Red Soil areas

– Pyroclastic tuff areas

– Trachyte areas

– Other areas

3.2. FOUNDATION OF BRIDGES

(1) Mombasa road Junction Bridge (KM 0+369 m - 0+426 m)

Boring BF-1 and -2 were made at the Mombasa road junction. The geological sections are shown in APPENDIX 2 .

(2) Uhuru Monument Junction Bridge (KM 6+676 m - 6+714 m)

The geological sections and geological conditions are as shown in the F/S Report.

(3) Railway Bridge (KM 27+00 m)

The geological sections and geological conditions are as shown in the F/S Report.

(4) Kikuyu Town Overbridge (KM 27+920 m)

Boring BF-4 was conducted as a study for the proposed Kikuyu Town overbridge. The geological sections obtained are as shown in APPENDIX 2.

3.3. FOUNDATION OF EMBANKMENTS

3.3.1 BLACK COTTON SOIL

The distribution of black cotton soil is shown in Chapter 3. This soil is mainly found in the National Park area and in the Ngong Road Forest area.

Results of soil tests, on samples collected from each area, are shown in Table 3.3.2, Fig. 3.3.1, Fig. 3.3.2 and Appendix 7.

3.3.2 SOFT GROUND

As described in Section 3.1, alluvium soil is found mainly at the Ngong Road Junction, the Dagoretti Forest Junction and at the high bank of Alliance Boys High School.

3.3.3 OTHERS

Other foundation soils are mostly red soil.

Table 3.3.1 Classification of Black Cotton Soil

Soil Parameter	Classification		
	Moderate Swellability	High Swellability	Very High Swellability
1. Dry Density γd (KN/m^3)	< 15	15 ≤γd≤15.75	> 15.75
2. Clay Content < 0.002mm (%)	< 40	40≤0.002≤55	> 55
3. Liquid Limit W_{LL} (%)	< 48	48≤LL≤65	>65
4. Plasticity Index PI	< 30	30≤P.I≤40	>40
5. Shrinkage Index $I_S = W_{LL} - W_{SL}$	0~20 (Small)	30~60	> 60
	20~30 (Moderate)		
6. Swell Pressure σs (KN/m^2)	<120	120≤σs≤600	>600
7. Swell Potential $\frac{\Delta h}{ho} = h'$ (%)	< 4.5	h' > 4.5 < 13	h' > 20 < 13

Source: F.J.Gichaga, B.K.Sahu and T.G. Visweswaraya University of Nairobi 19 June 1987. "Prediction of Swell of black cotton soil in Nairobi"

Table 3.3.2 Soil Test Results Summary Sheet of Black Cotton Soil

	Pit No.	Station	Liquid Limit L.L (%)	Plasticity Index P I	Moisture Content W (%)	Specific Gravity	Bulk Density (kg/m³)	Shrinkage Limit S L (%)	Free Swell (%)	Swell at 100% MDD, 4days Soak (%)	Swelling Pressure (KN/m²)	Is= LL−SL (%)	* Swellability
NATIONAL PARK	Tb− 1	0+900m	78	33	34.2	2.40	1,545	16	130	4.5	80	62	High～Very high
	Tb− 2	1+435m	73	30	—	—	—	——	—	——	—	—	——
	Tb− 3	1+900m	80	42	40.5	2.50	1,507	20	160	5.0	44	60	High～Very high
	Tb− 4	2+400m	73	40	—	—	—	——	—	——	—	—	——
	Tb− 5	2+900m	78	30	40.3	2.44	1,568	14	165	4.4	0	64	High～Very high
	Tb− 6	3+400m	79	42	—	—	—	——	—	——	—	—	——
	Tb− 7	3+900m	74	43	30.5	2.40	1,619	20	140	5.5	0	54	High～Very high
	Tb− 8	4+400m	73	32	—	—	—	——	—	——	—	—	——
	Tb− 9	4+895m	39	14	16.3	2.48	1,658	8	80	——	0	31	Moderate～High
	Tb−10	5+400m	83	30	—	—	—	——	—	5.2	—	—	——
	Tc− 8	12+100m	80	38	—	—	—	——	—	4.6	—	—	——
	Tc−10	13+ 80m	64	26	—	—	—	——	—	4.4	—	—	——
NGONG	Tc−33	11+880m	37	16	21.0	—	—	8	98	3.6	101.9	29	Moderate
	Tc−37	12+575m	40	18	20.0	—	—	9	68	4.2	32.2	31	Moderate
	Tc−34	13+660m	59	30	26.0	—	—	14	78	5.2	72.4	45	High
	Tc−14	16+700m	50	21	—	—	—	——	—	0.5	—	—	Low
	Tc−17	19+305m	39	14	—	—	—	——	—	0.7	—	—	Low

* See Table 3.3.1

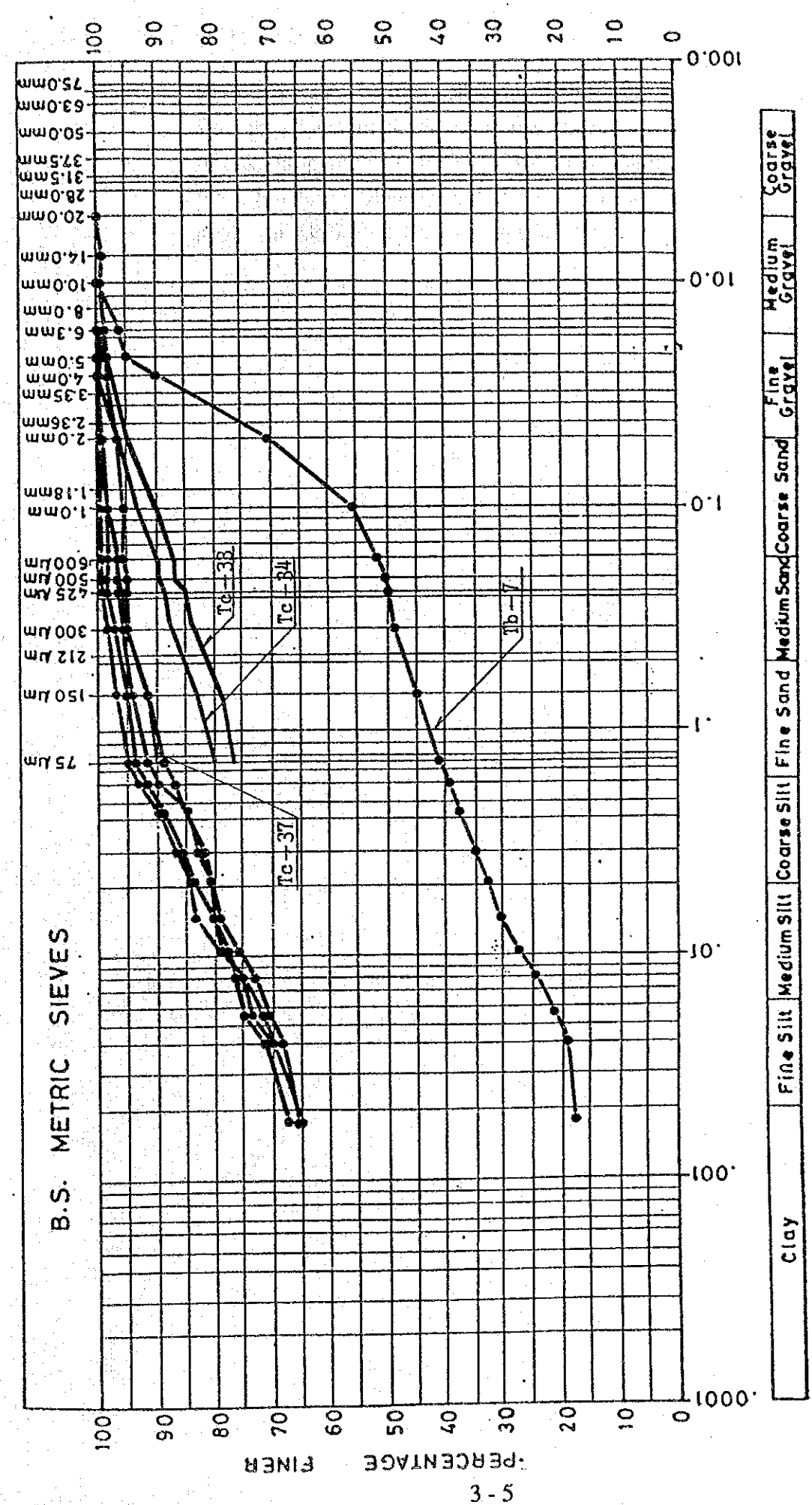


Fig. 3.3.1 Particle Size Distribution of Black Cotton Soil

3.4 EARTHWORKS

Embankments will all be built using a fill material which will be obtained from the alignment cutting operation. Consequently, fill material consists of red soil, pyroclasitc tuff, trachyte and some lateritic gravel. Most of the fill material however, will be read soil. Results of the soil test are shown in APPENDIX 6 and Fig.s 3.4.1 to Fig. 3.4.5.

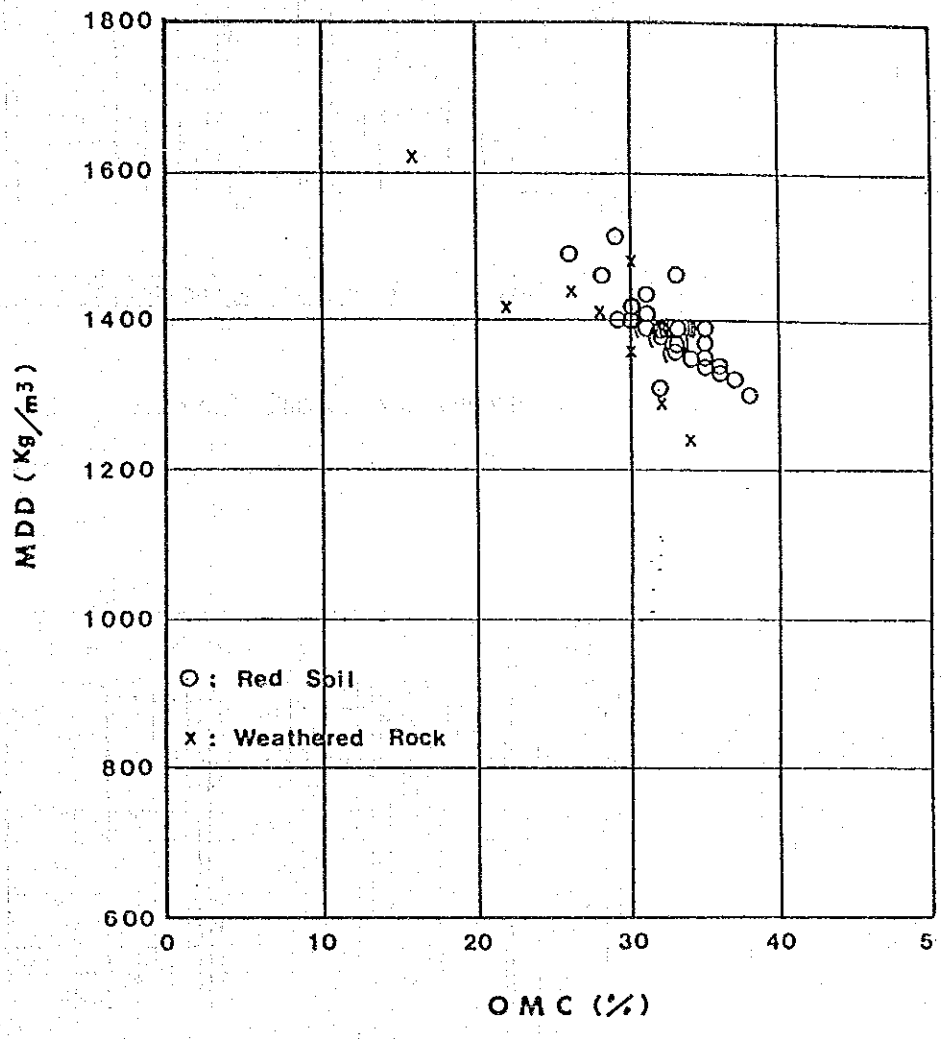


Fig. 3.4.1 OMC-MDD at Standard Compaction

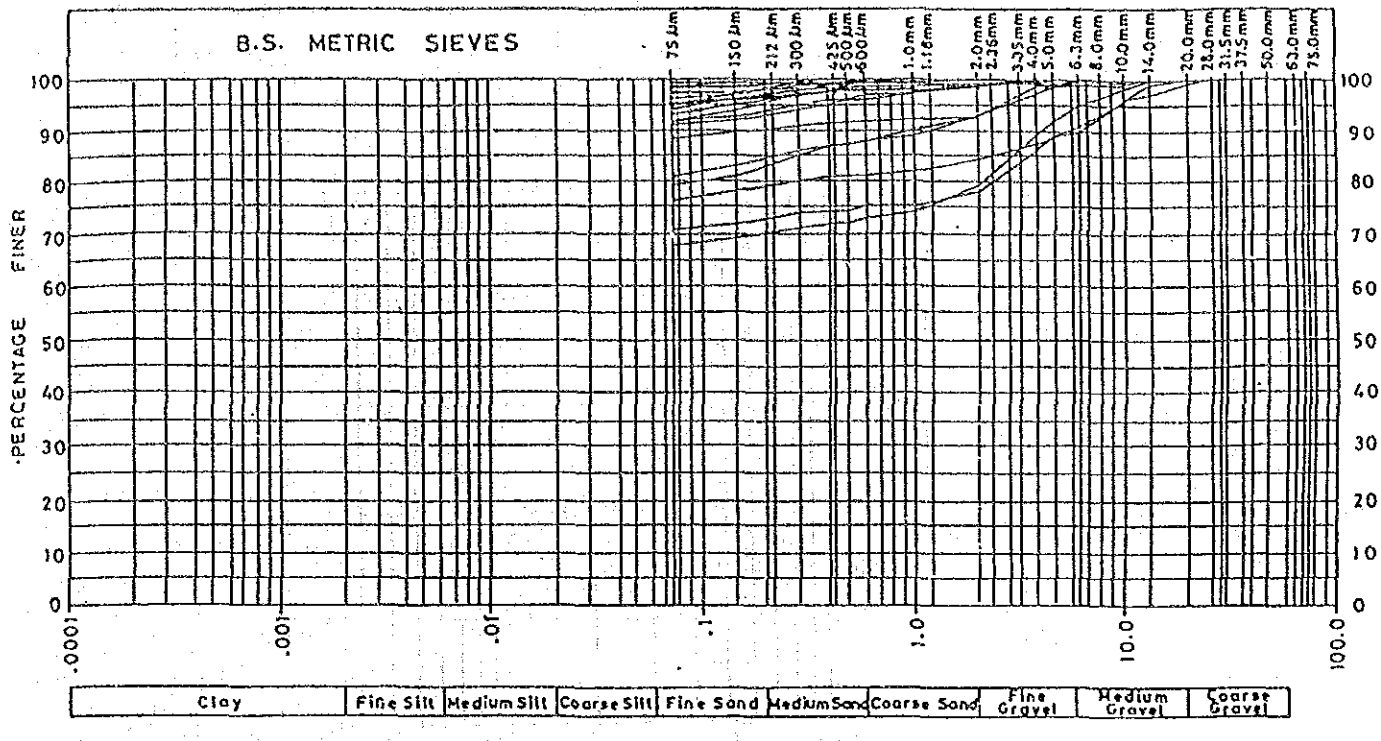


Fig. 3.4.2 Particle Size Distribution of Red Soil

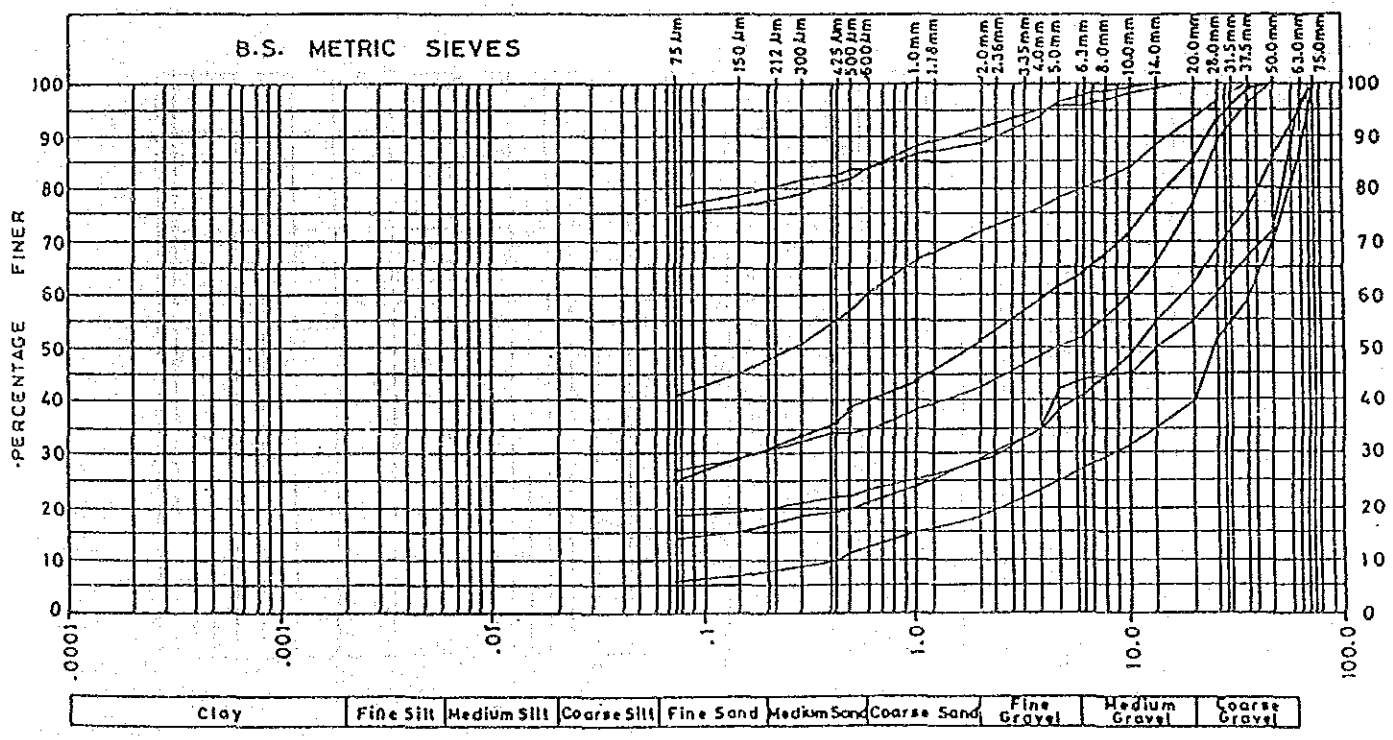


Fig. 3.4.3 Particle Size Distributio of Weathered Pyroclastic Tuff and Trachyte

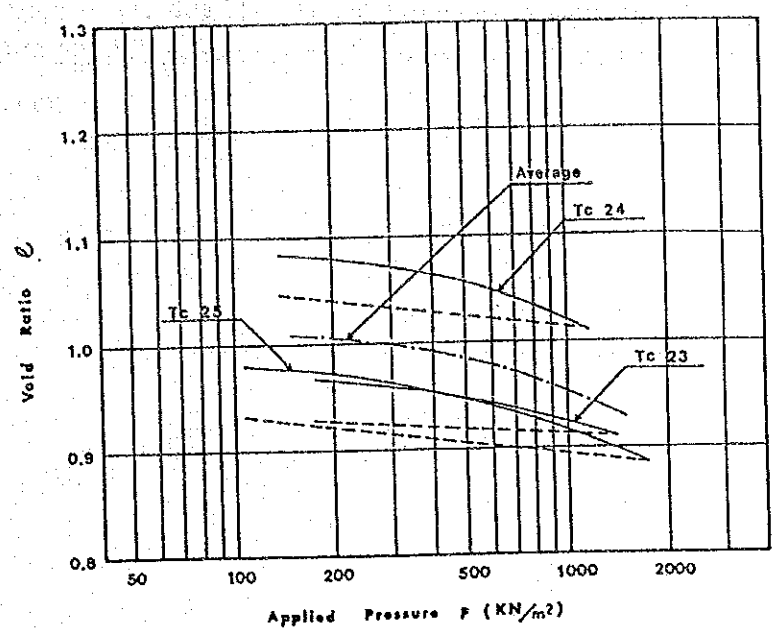


Fig. 3.4.4 e-log P Curve of Red Soil

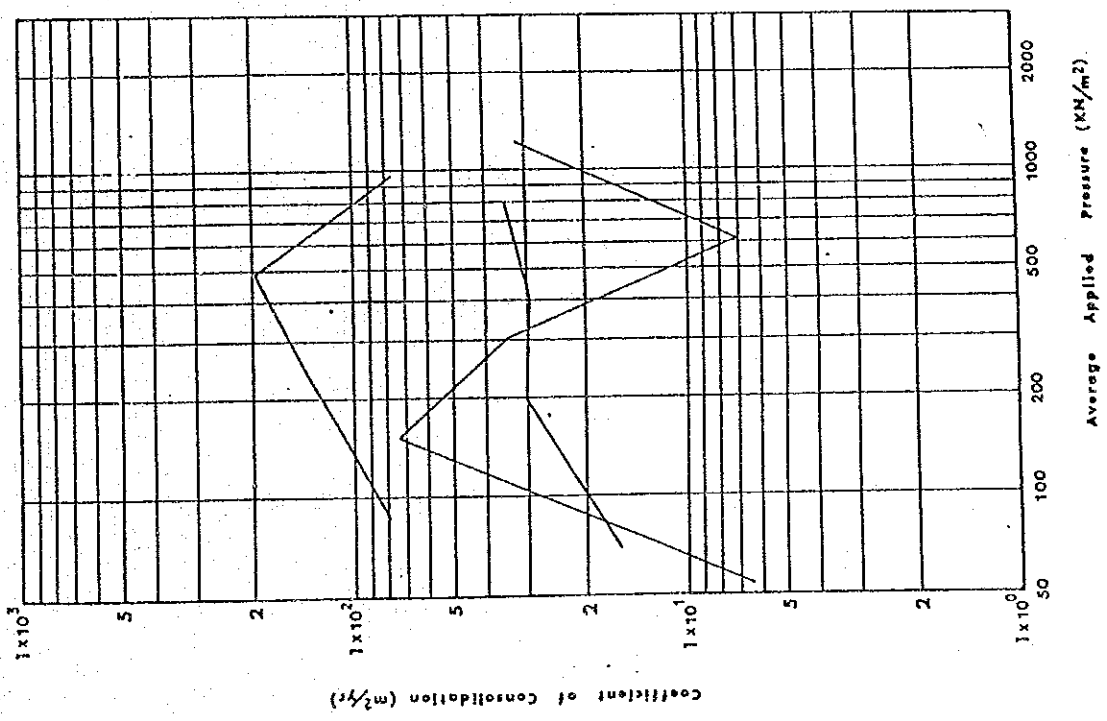


Fig. 3.4.5 log Cv - log P Curve of Red Soil $\overline{P}$

3.5 SUBGRADE CONDITIONS

Test pits were dug at Sixty-one points to investigate the subgrade conditions. APPENDIX 6 shows the results of the soil test on samples obtained from each test pit.

4. MATERIAL INVESTIGATION

4.1 GENERAL

The survey was carried out by conducting site investigations for both hard rock and gravel sites. Samples have been collected from some sites and taken for testing. At other sites no samples were collected, either because the material was obviously poor or because there was not enough available. With both the rock and gravel samples various tests were carried out in accordance with the MOPW's Road Design Manual Part III.

4.2 GRAVEL

4.2.1 GRAVEL MATERIAL SITES

The location, site plans and test results of existing and new sites are shown in Fig. 1.1.2 and Appendix 4.

4.2.2 QUALITY

Items for soil tests at each material site are as given below and test results are as shown in Table 4.2.1 and in APPENDIX 8.

- Grading to 0.075 mm sieve
- Atterberg Limtis (LL. PL. LS. PM)
- Compaction test (Heavy Compaction: 4.5 kg)
- CBR and swell at 4 days soak on specimens mounded at O.M.C. (Heavy Compaction) at 90, 95 and 100% MDD.
- Cement Stabilization 2, 4 and 6% (Compaction test (Heavy Compaction), CBR at 7 days cure plus 7 days soak on specimens moulded at OMC and 95% MDD)
- Lime Stabilization 2, 4 and 6% (Same cement method)

Table 4.2.1 Laboratory Test Results of Gravel

Site	Atterberg Limits		Linear Shrinkage (%)	Plasticity Modulus (%)	Grading (%)			Compaction (heavy)		CBR (%)		
	LL(%)	PI			Clay & Silt	Sand	Gravel	M.D.D. (kg/m³)	O.M.C. (%)	% of M.D.D.	4 day Soak	Swell
Mutuini	45~49	13~19	7~9	312~722	19~34	13~16	50~68	1540~1760	20~24	95	30~35	0.1 ~0.4
Kiriba	44~51	16~20	9~10	204~860	9~38	7~11	51~81	1750~1960	15~27	90~91	14~160	0.02~0.04
										95~96	19~190	0.04~0.07
										100~101	22~209	0.05~0.15
Thandi	35~51	13~19	7~10	260~836	16~39	12~15	49~69	1730~1890	15~20	90	7~26	0.04~0.2
										95	20~30	0.07~0.33
										100	27~45	0.08~0.47
Galsheet	46~72	11~31	6~15	143~558	7~20	3~14	73~79	1540~1710	20~28	90~91	3	0.5 ~0.7
										95~96	3~30	0.4 ~1.8
										100	5	1.1 ~3.4
Carnivore	41~51	13~18	6~9	65~615	3~39	8~14	53~86	1630~2000	14~20	90~91	6~40	0.1 ~0.3
										95	7~50	0.2 ~0.6
										100~101	10~170	0.2 ~1.1
Forest Guard	44	17	8	110	5	16	79	2030	15	96	90	0.1
Karen	34~41	11~13	5~7	240	10~17	9~12	71~78	1710~1970	15~17	90	12~26	0.11~0.16
										95	21~65	0.22~0.28
										100	30~110	0.28~0.39
Church	37~51	10~15	5~8	180~465	15~26	11~14	60~74	1710~1910	18~21	90~91	16~85	0.05~0.09
										95~96	35~100	0.13~0.18
										100~101	75~170	0.18~0.23
Waiganjo	NP	NP	2	0	2	19	79	1240	29	90	90	0.2
										95	90	0.3
										101	190	0.4
Kibera	50	19	9	437	20	8	72	1510	24	89	11	0.1
										95	13	0.1
										100	24	0.2

4.3 HARD STONE

4.3.1 HAND STONE QUARRY SITES

(1) Existing Quarries

1) Nairobi Eastern Quarries

Seventeen existing commercial rock quarries were identified. Sixteen of them are concentrated in the Eastern side of Nairobi in the vicinity of the Kariobangi, Dandora and Kayole housing estates.

They exist as a chain close to each other but are spread over an area of approximately 20 sq. km.

The rock in this area is Nairobi phonolite which is hard and can be used for all the layers of the road pavement (i.e. sub-base, base and wearing surface). Each one of the quarries has abundant material and the proprietors are willing to enter into negotiation with the road construction contractor. Indeed, some quarry owners are themselves road contractors and, no doubt, shall seek the opportunity to make a tender for the Nairobi Bypass. More significantly, however, is the fact that the material has been used in the construction of roads in the vicinity including the Kangundo-Dandora road which was constructed in mid 1970's for the Government of Kenya.

These quarries are fairly large areas of land which are pieces either owned or hired on long leases. At the time of the study most of the leases still had an average of 40 years before they expire. The land is leased, for the most part, from the Nairobi City Commission. It is otherwise useless land along the banks of the Nairobi and Ngong rivers and/or lying on the Electrical Power Wayleaves.

The sites appear potentially expansive but there is a problem since these quarries have been recently issued a stoppage notice by the Kenya Power and Lighting Co. The notice is the result of dust from the quarries causing serious damage to the high tension electric cables in the Vicinity. This notice will expire at the end of the year. The Quarry operators have launched an appeal against the notice however, it is unknown it will be successful.

2) DBT Quarry

This is the seventeenth existing commercial rock quarry. It is situated about 25 km from the starting point of the proposed road. The existing crushing plant produces an aggregate of reasonable quality which can be considered as a possible source. A sample was collected and taken for testing.

3) Rungiri Quarry

This rock quarry was in the process of being opened by the contractor for the Kabete-Limuru Road Project. A sample was collected and taken for testing.

(2) New Quarry Sites

1) Kitengela Quarry

This quarry is located off Namanga-Arusha (A 104) about 2 km from Athi River Town. The site is extensive and lies on Government Land. Visual inspection indicates that it has very high quality rocks. A sample from this site was collected by drilling for testing of its quality characteristics. This source is approximately 23 km away from the project. Average overburden is 1.1 m. The estimated quantity in this site is in excess of 324,000 m^3.

2) Muthiga Rock Quarry

This site is about 2 km from the Kikuyu Turn off on the Nairobi-Nakuru Road (A 104) which is near the western end of the proposed road. The site is located in a highly agriculture productive area which is served by both electricity and piped water. The quarry site is on the banks of the Nairobi river. A rock sample was collected from the surface and taken for testing. (see Appendix) Drilling was carried out, on the basis of the results obtained, to determine both the quantity and quality available.

3) Max-Inn Rock Quarry (National Park)

This site is off Mombasa Road opposite the existing weigh-bridge site. The site is located within the National Park. A rock sample was collected and taken for testing.

4) Kibera Rock Quarry

This quarry can only be regarded as a source of soft rock so further investigations were not necessary.

5) Carnivore Rock Quarry

This quarry was observed to contain medium hard rock. A rock sample was extracted and taken for testing of its quality characteristics. The site is just next to the proposed road.

4.3.2 QUALITY

(1) New Quarry site

Items for the soil tests conducted at each site are as follows with the results given in Table 4.3.1 and in APPENDIX 9:

- Los Angeles Abrasion (LAA)
- Aggregate Crushing Value (ACV)
- Sodium Sulphate Soundness (S.S.S)
- Specific Gravity (oven-dry method)
- Plasticity Index on L.A.A. fines
- Bitumin Affinity (Binder: MC3000, KI-60, 80/100)
- Grading to 0.075 mm sieve *
- Flakiness Index * (FI)

Note: * Grading and FI sample should be crushed with a small Jaw crusher, to a size which depends on the proposed use of the stone (20 mm to 40 mm).

(2) Existing Quarry Sites

Tests were conducted at the quarry site (Rungiri) on the Kabete-Limuru Road. DBT, which is not scheduled for relocation, was also tested in the same manner as the new quarry sites. The results are given in Table 4.3.1 and APPENDIX 11. The quality of aggregate that can be supplied from the existing quarries in the area included in the relocation plan is shown in Table 4.3.2. Rungiri produces Trachyte which is too soft for aggregate as is the Trachyte available from the new quarries.

Other existing quarries can supply Phonolite which is hard and suitable as aggregate with ACV (16% - 22%), LAA (12% - 27%), Bitumen affinity (good). However, FI gives a large value of more than 30% at DBT and Diamond and is liable to be broken in flat. At the other sites, FI = 15 to 20 which is believed to be due to the difference in crushing methods used since any substantial change in rock characteristics is inconceivable.

Table 4.3.1 Laboratory Test Results of Quarry Site

Site	Rock Type	Grading % passing								ACV (%)	LAA (%)	PI on LAA Fines	FI (%)	Bitumen Afinity (%)			S.S.S. (%)	Specific Gravity	Water Absorption (%)
		37.5 mm	20 mm	10 mm	6.3 mm	2.36 mm	1.18 mm	425 μm	75 μm					KI-60	MC 300	80/100			
Kitengela	Kapiti Phonolite	90～100	55～69	29～31	16～17	7～8	4	0～2	0～1	17～18	18～22	NP	26～35	>95	>95	>95	2.0～5.1	2.35～2.71	2.0～4.4
Muthiga	Limuru Trachyte	100	79	35	23	12	8	4	1	37	55	NP	20	>95	>95	>95	28.1～39.5	2.45～2.82	5.1
Kibera	Middle and Upper Kerichwo Valley Tuff	100	81～88	43～53	31～41	18～27	12～20	6～12	1～2	42～48	47～63	NP	10～20	<95	<95	<95	22.0～48.2	1.53～2.82	16.4～24.3
Max-inn	Nairobi Phonolite	100	67	27	15	7	4	2	0	21	22	NP	39	>95	>95	>95	2.9～3.1	2.43～2.65	2.9
Carnivore	Nairobi Trachyte	100	81	41	30	18	13	9	3	31	46	NP	22	>95	>95	>95	37.7～59.5	2.40～2.77	4.9
Existing DBT	Kapiti Phonolite	100	73	31	20	10	7	4	1	22	27	NP	34	>95	>95	>95	4.3～4.9	2.42～2.60	3.2
Existing Rungiri	Limuru Trachyte	100	80	33	21	11	8	5	3	34	45	NP	17	>95	>95	>95	21.7～30.8	2.40～2.68	4.6

Table 4.3.2 Test Results from Existing Hardstone Quarries
(availed from quarry sites)

QUARRY NAME	SAMPLE No.	ACV	LAA	FI	BITUMEN AFFINITY				
					80/100	MC 3000	KI-60	A 360	MC 5
H.Z & COMPANY	1	17	24	18	——	——	——	——	——
	2	19	12	15	——	——	——	——	——
	3	21	19	18	——	——	——	——	——
BHIMJI RAMJI	4	18	22.6	20	Good	Poor	Good	Good	——
DIAMOND	5	15.9	18.8	16	Good	——	Good	Good	Good
	6	19	22	32	Good	——	Good	Good	Good

4.4 SAND

No sand is found in the vicinity of the projected alignment. Sand available in Nairobi is mostly supplied from Machakos. Consequently, sand must be obtained as purchased material.

For information on sand at Machakos see the Feasibility Study Report.

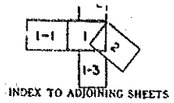
4.5 WATER SUPPLY

Water can be easily obtained from the Motone River, which the projected alignment runs along. To use this water, it is first necessary to secure an agreement with the holder of the water rights.

1. DETAILED LOCATION MAP OF GEOLOGICAL SURVEY ON ALIGNMENT

THE DETAILED DESIGN STUDY ON THE NAIROBI BYPASS PROJECT

SHEET NO. 1



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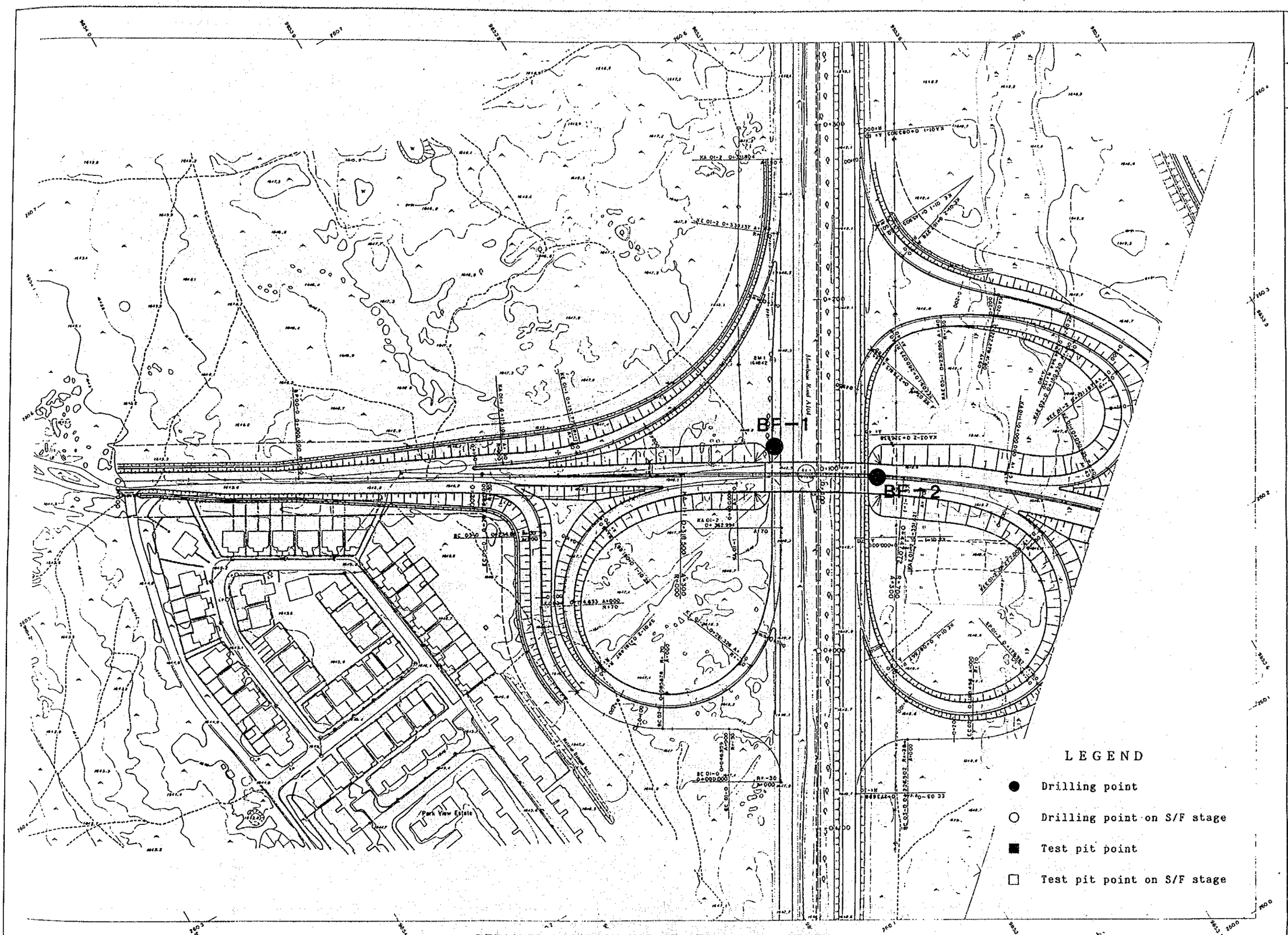

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- Bench Mark
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- 1234.5 Spot Height
- Contours (V.I.1m)
- Outcrop (Rock)
- Building, Permanent
- Building, Others
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- Plantation
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- Planting Partition

LEGEND

- ● Drilling point
- ○ Drilling point on S/F stage
- ■ Test pit point
- □ Test pit point on S/F stage

HORIZONTAL DATUM: UTM ZONE 37 CLARKE 1880 SPHEROID

VERTICAL DATUM : MEAN SEA LEVEL

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DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

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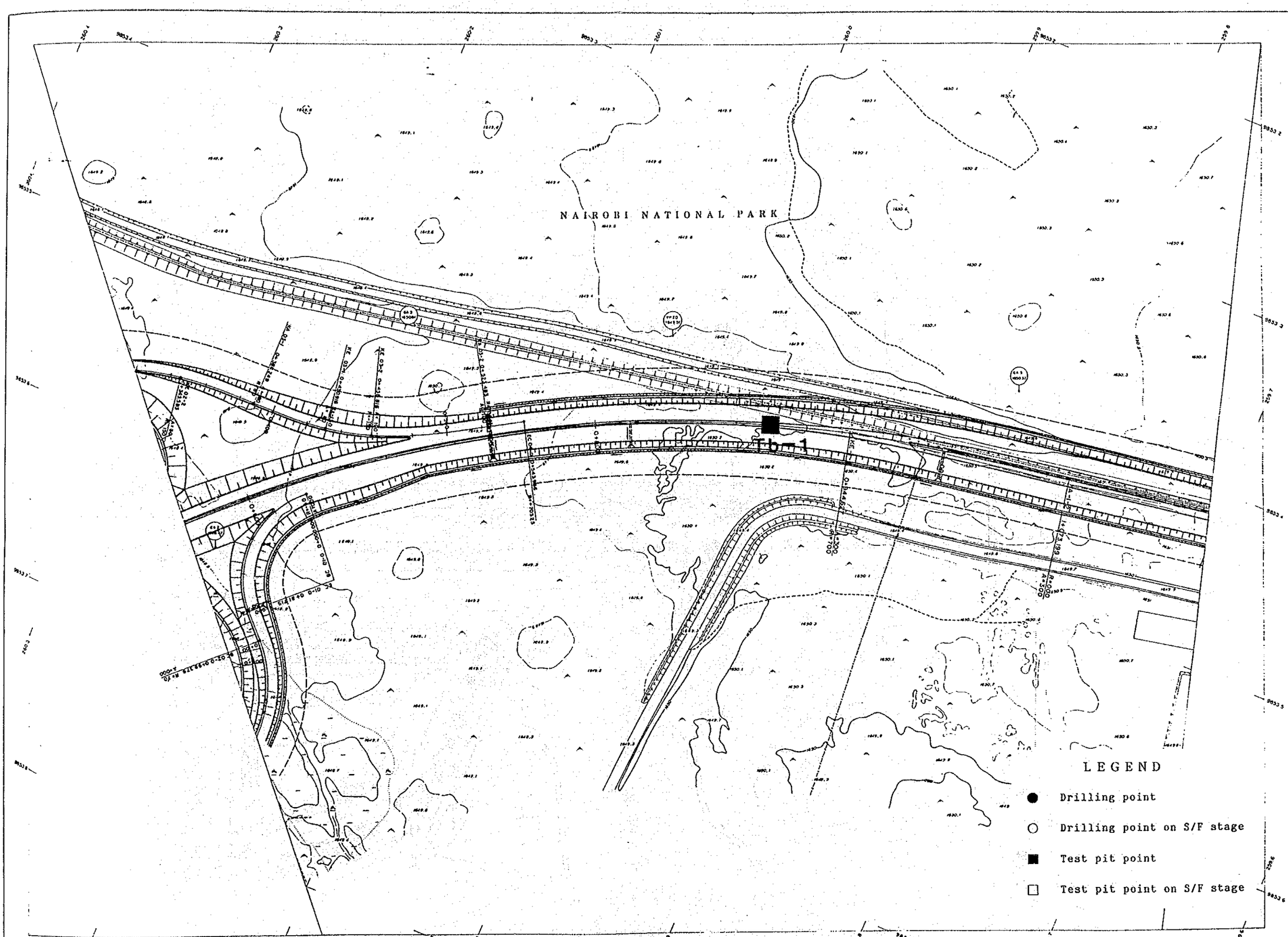

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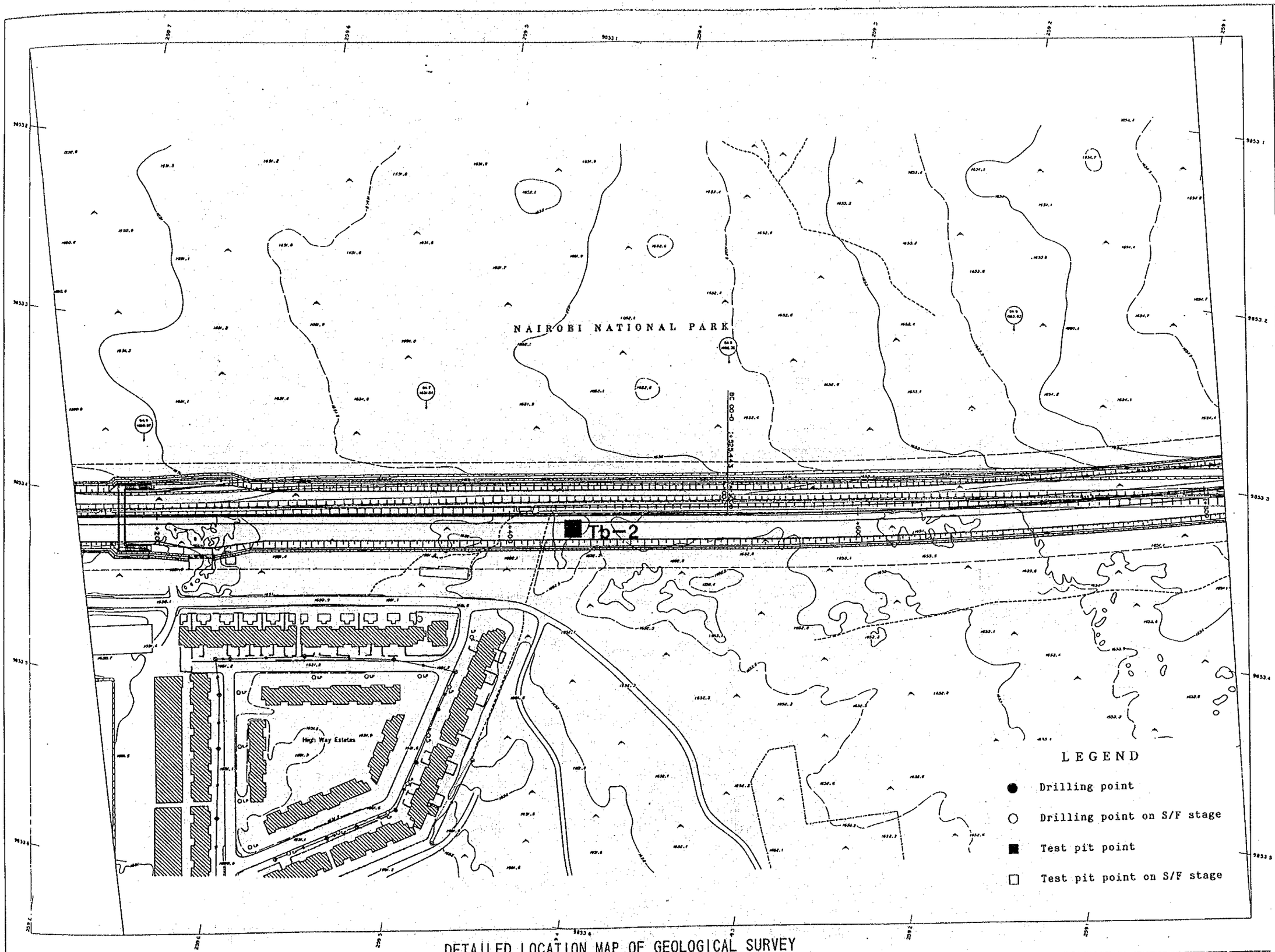

DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

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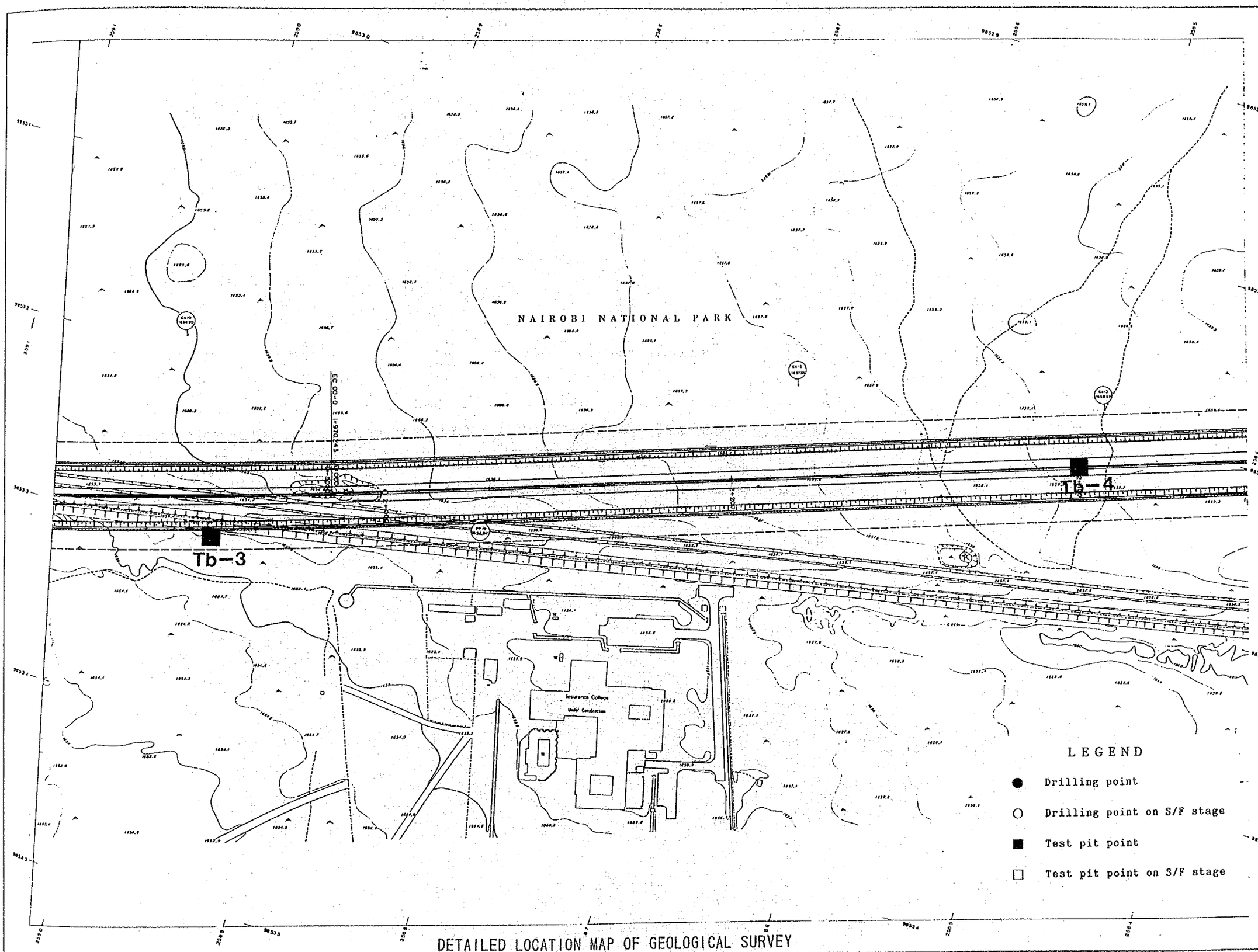

DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

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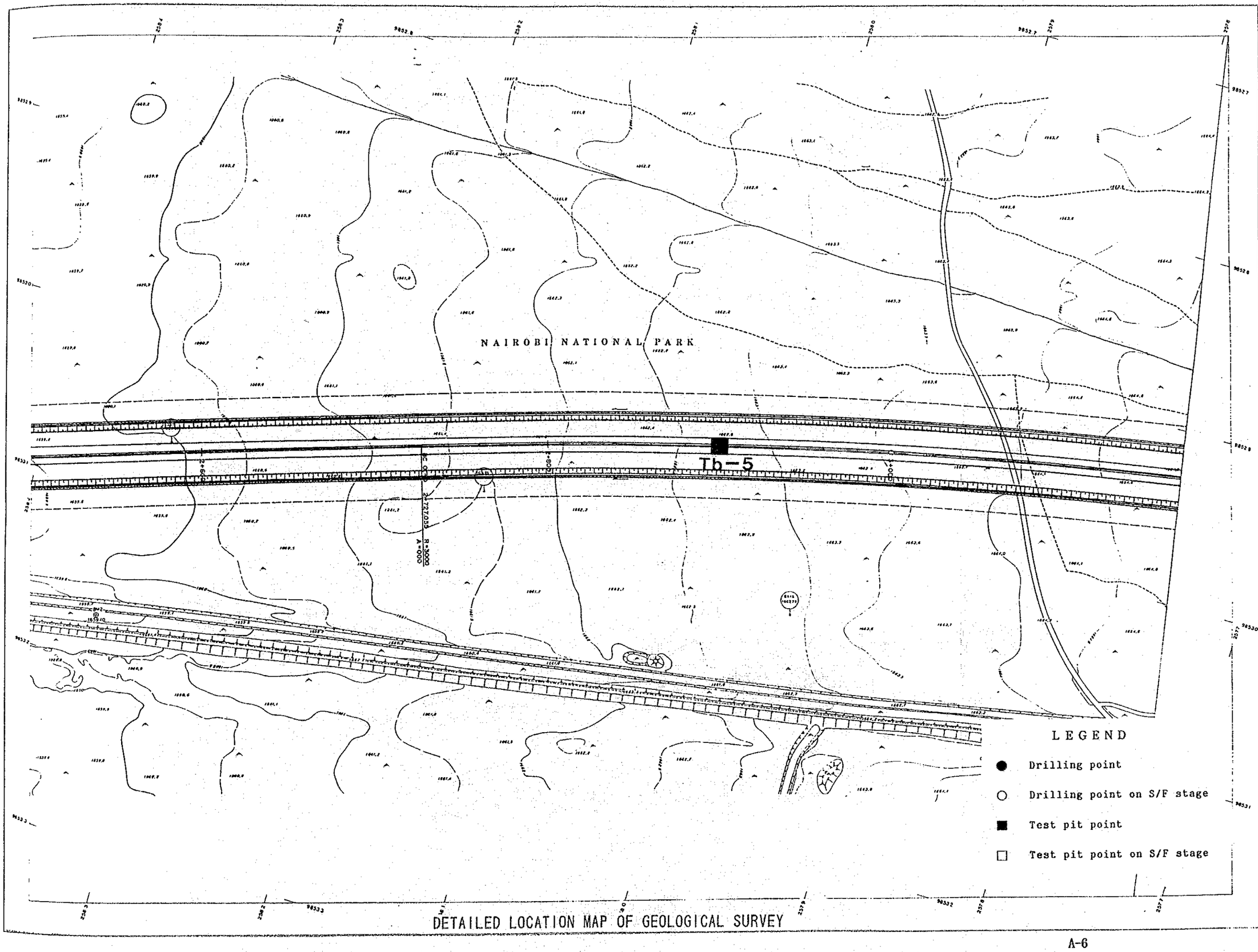

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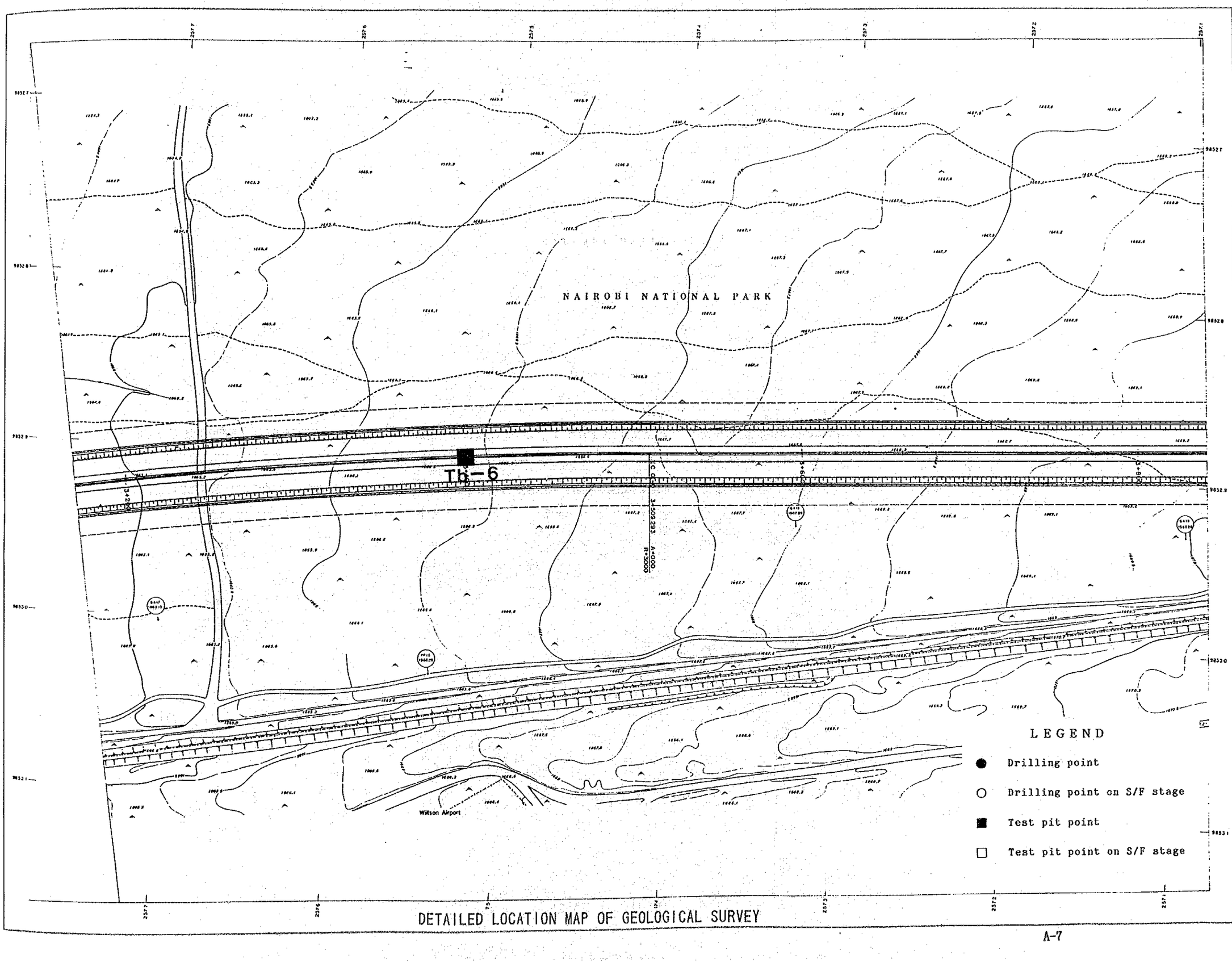

DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

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- Fence, Gate
- Hedge
- Stone Wall
- Dump or Mound
- Quarry, Pit
- Cutting
- Embankment
- Cultivated Lands
- Orchad or Permanent
- Plantation
- Grassland
- Bush
- Forest
- Swamp
- Vegetation Boundary
- Planting Partition

HORIZONTAL DATUM: UTM ZONE 3
(CLARKE 1880 SPHE

VERTICAL DATUM :MEAN SEA LEVI

AERIAL PHOTOGRAPHED BY:
Japan International Cooperation A
Decemb

GROUND CONTROL SURVEYED BY:
Decemb

STEREO PLOTTED BY:
MARCI

CARTOGRAPHED BY:
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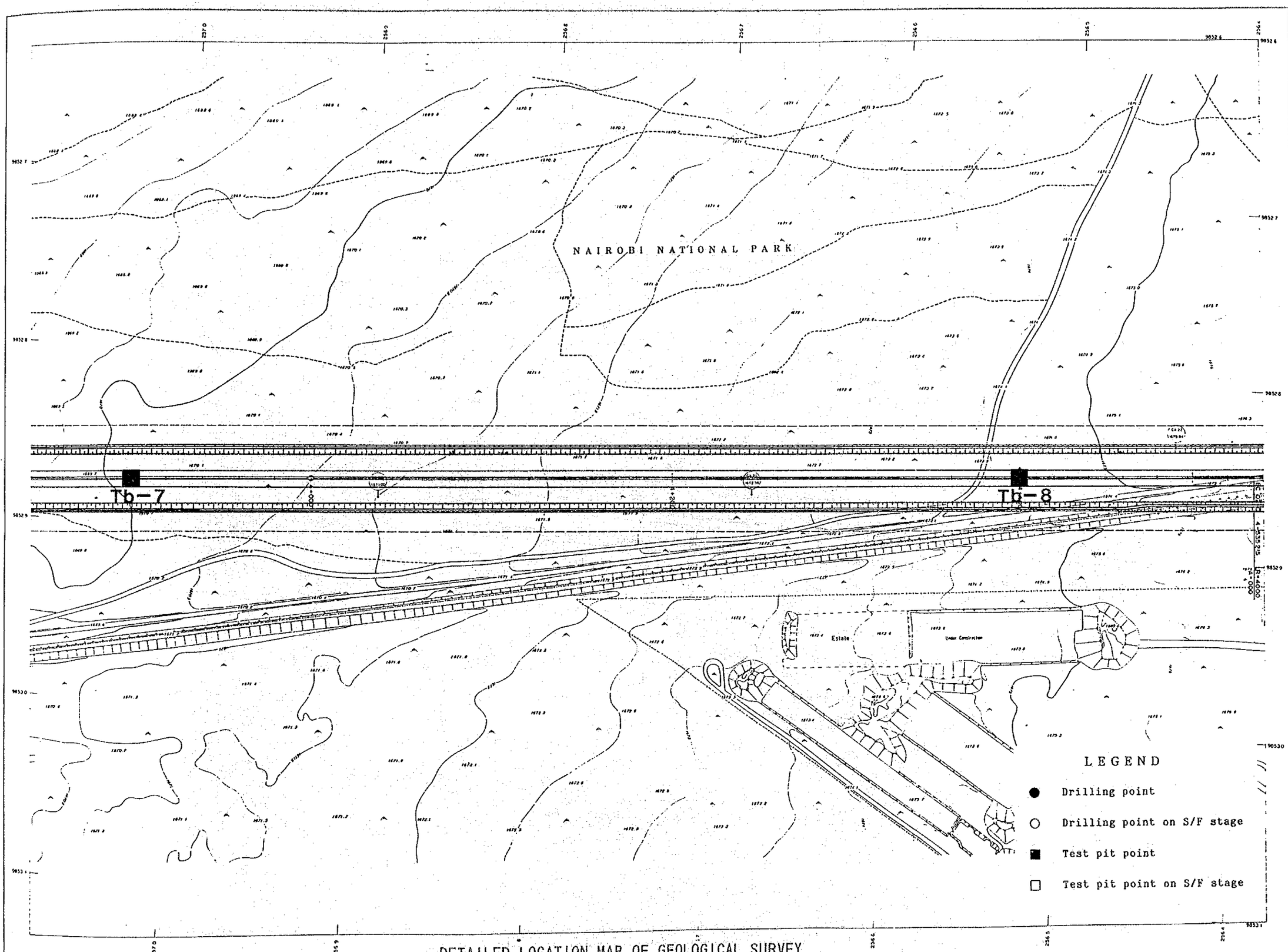

DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

N

Scale 1:2,000
HEIGHTS IN METERS

LEGEND

- GPS Point
- Traverse Point
- Bench Mark
- 1234.5 Direct Leveling Heigh
- Spot Height
- Contours (V.I.1m)
- Outcrop (Rock)
- Building, Permanent
- Building, Others
- Bituminised Road
- Road
- Track
- Railway
- Bridge, Culvert
- River
- Stream
- Dam
- Pond
- Water Tank
- Power Line
- Telephone Line
- Fence, Gate
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HORIZONTAL DATUM: UTM ZONE 3
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VERTICAL DATUM : MEAN SEA LEV

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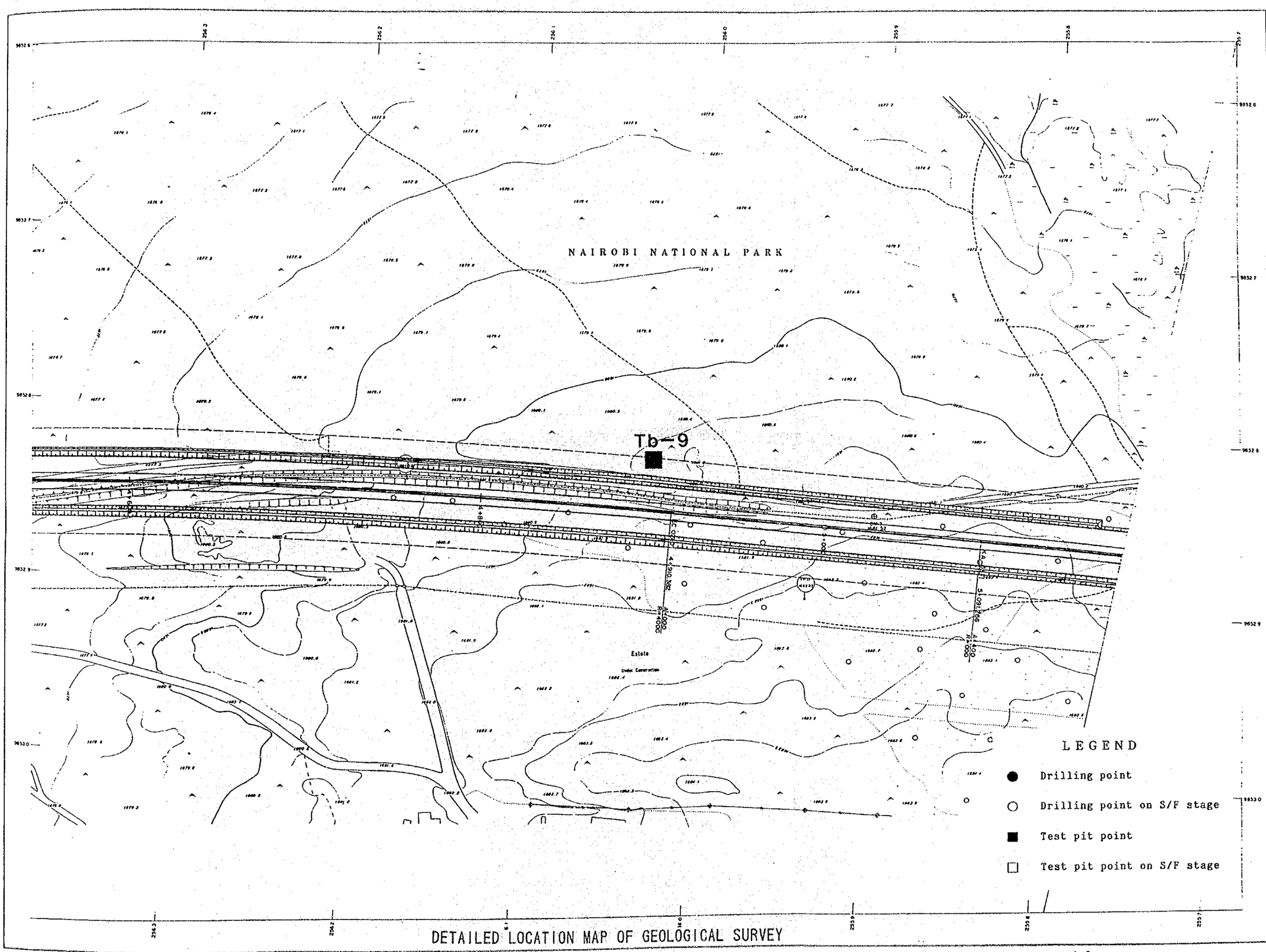

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Scale 1:2,000
HEIGHTS IN METERS

LEGEND

- GPS Point
- Traverse Point
- Bench Mark
- 1234.5 Direct Leveling Heig
- 1234.5 Spot Height
- 1234 Contours (V.I.1m)
- Outcrop (Rock)
- Building, Parmanent
- Building, Others
- Bituminised Road
- Road
- Track
- Railway
- Bridge, Culvert
- River
- Stream
- Dam
- Pond
- Water Tank
- Power Line
- Telephone Line
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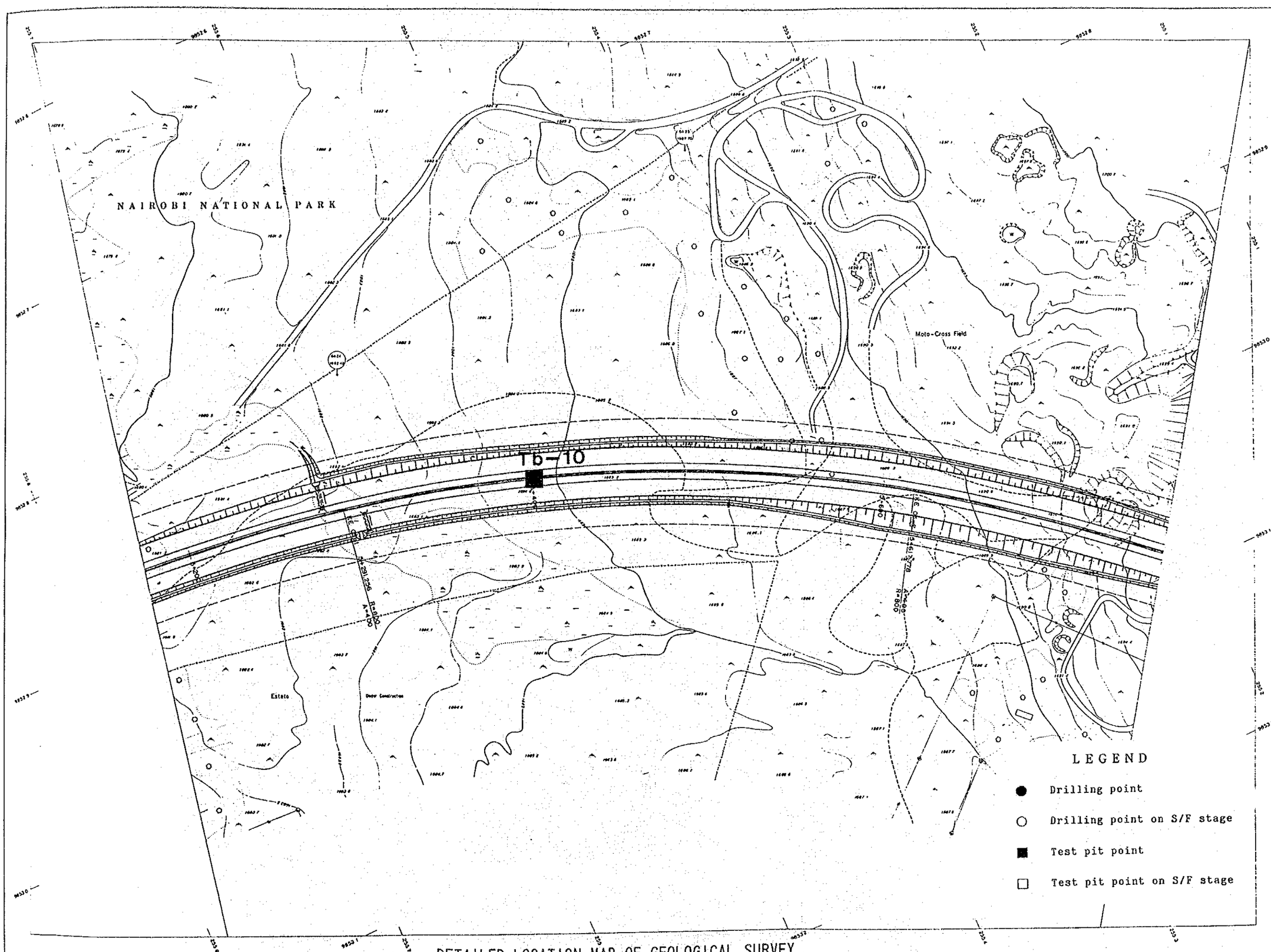

DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

Scale 1:2,000
HEIGHTS IN METERS

LEGEND

- GPS Point
- Traverse Point
- Bench Mark
- 1234.5 Direct Leveling Heigh
- 1234.5 Spot Height
- Contours (V.I.1m)
- Outcrop (Rock)
- Building, Parmanent
- Building, Others
- Bituminized Road
- Road
- Track
- Railway
- Bridge, Culvert
- River
- Stream
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- Water Tank
- Power Line
- Telephone Line
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- Stone Wall
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- Cutting
- Embankment
- Cultivated Lands
- Orchard or Permanent C
- Plantation
- Grassland
- Bush
- Forest
- Swamp
- Vegetation Boundary
- Planting Partition

HORIZONTAL DATUM: UTM ZONE 37 (CLARKE 1880 SPHER

VERTICAL DATUM : MEAN SEA LEVE

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STEREO PLOTTED BY: J MARCH

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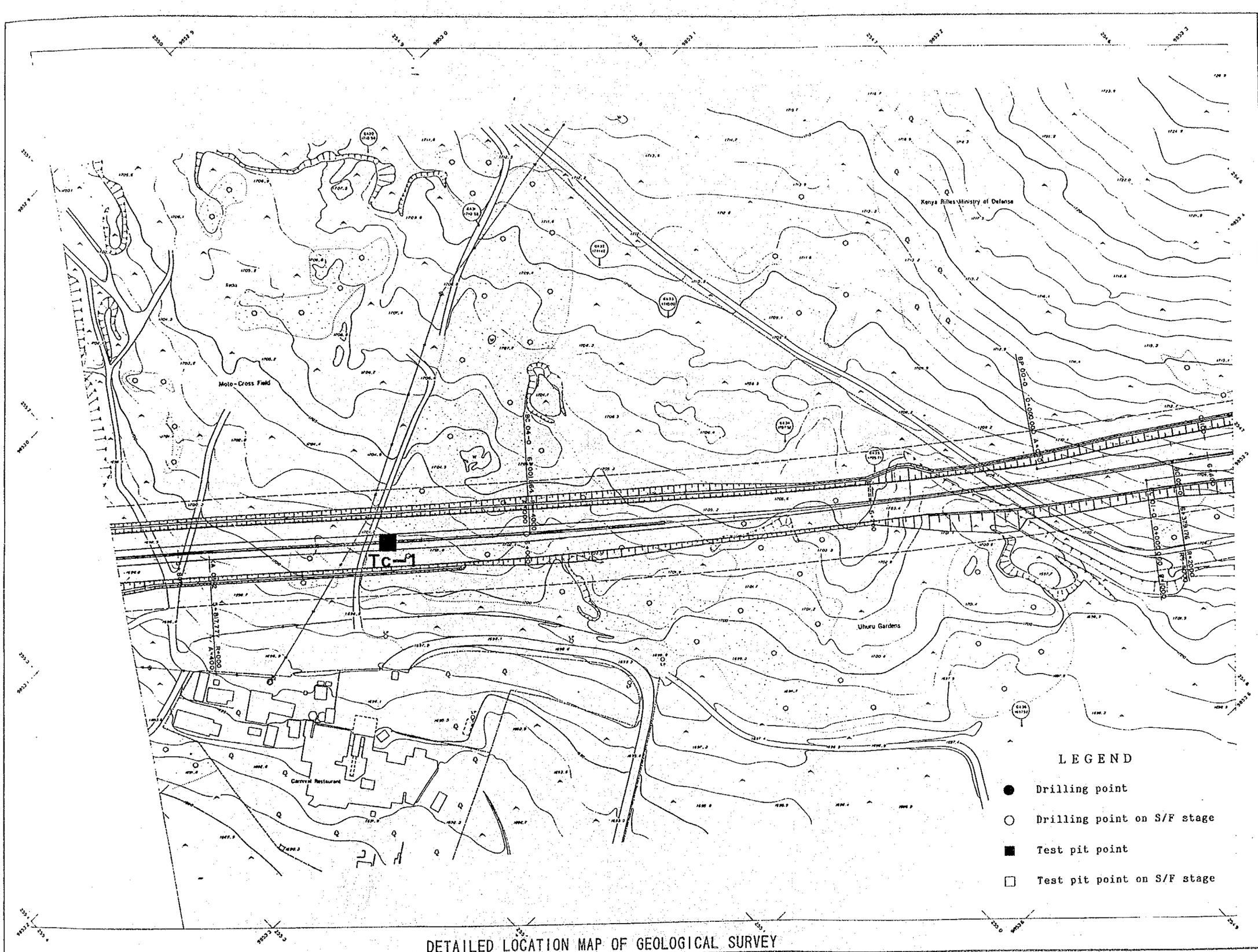

DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

Scale 1:2,000
HEIGHTS IN METERS

LEGEND

- GPS Point
- Traverse Point
- Bench Mark
- Direct Leveling Hgt
- Spot Height
- Contours (V. Int)
- Outcrop (Rock)
- Building, Permanent
- Building, Others
- Bituminized Road
- Road
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- Railway
- Bridge, Culvert
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HORIZONTAL DATUM UTM ZONE 3
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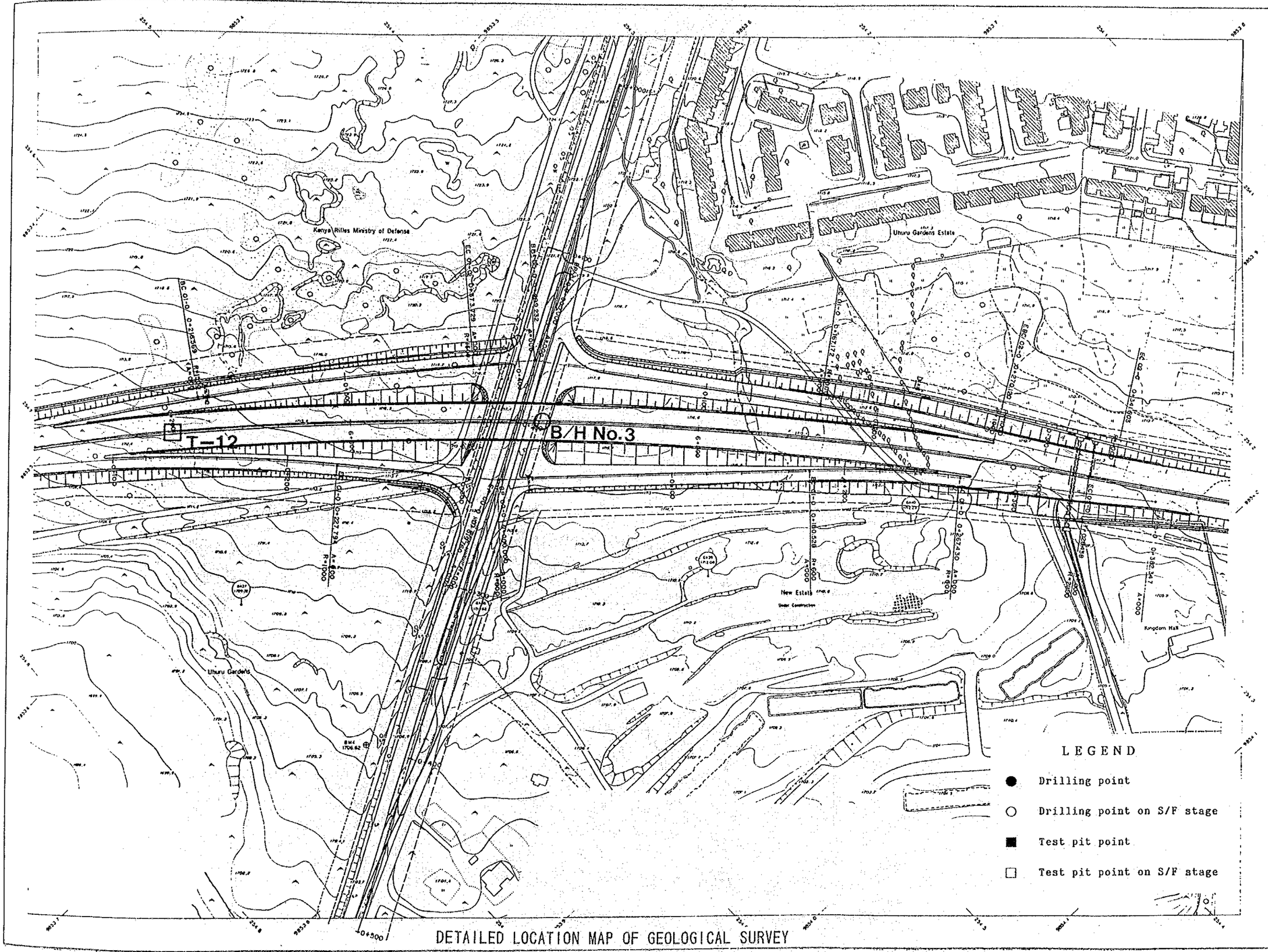

DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

Scale 1:2,000
HEIGHTS IN METERS

LEGEND

- GPS Point
- Traverse Point
- Bench Mark
- 1234.5 Direct Leveling Height
- Spot Height
- Contours (V.I.1m)
- Outcrop (Rock)
- Building, Permanent
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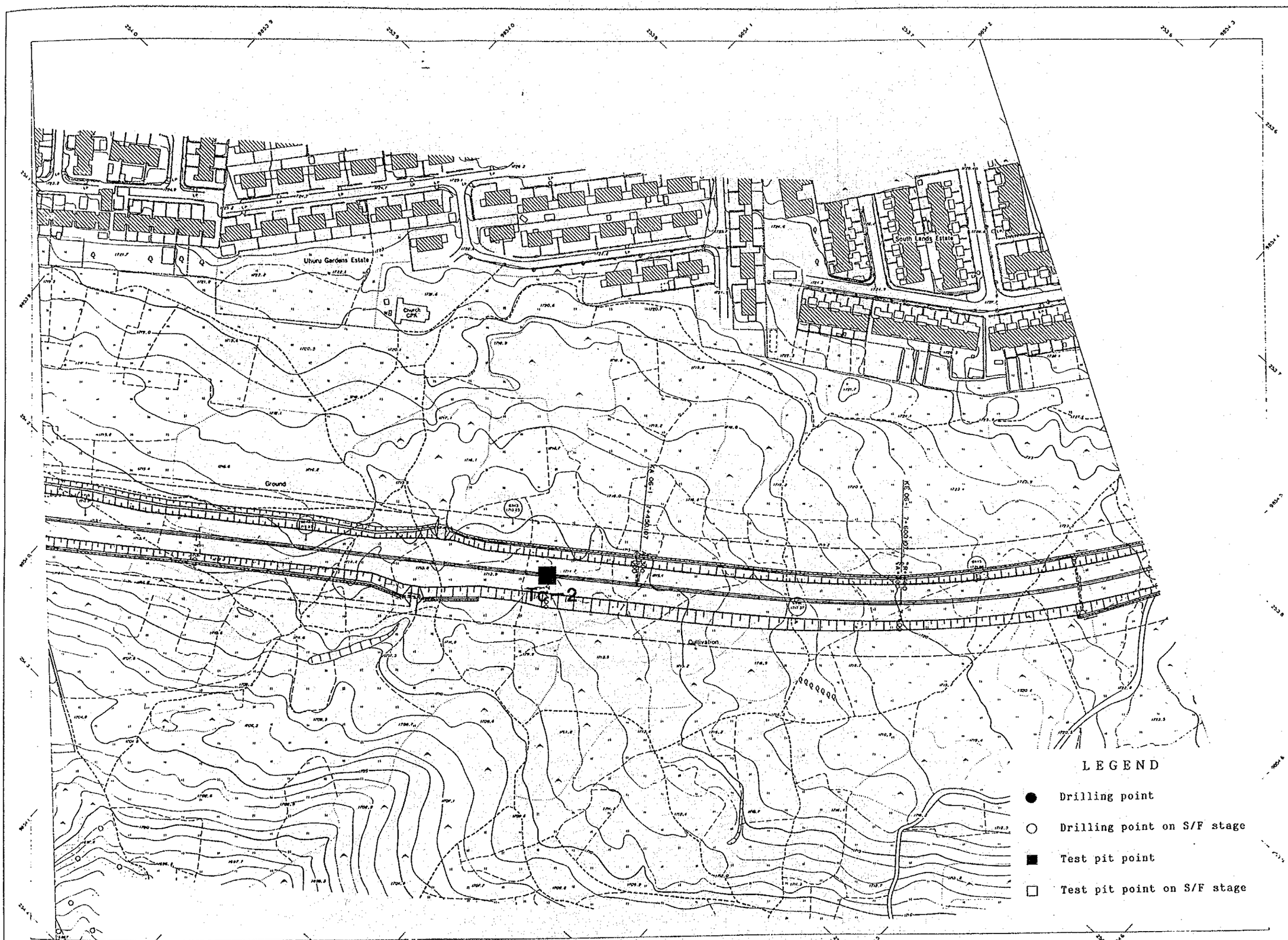

DETAILED LOCATION MAP OF GEOLOGICAL SURVEY

LEGEND

- Drilling point
- Drilling point on S/F stage
- Test pit point
- Test pit point on S/F stage

Scale 1:2,000
HEIGHTS IN METERS

LEGEND

- GIS Point
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