ANNEX-B

GEOLOGY AND GEOTECHNICAL ENGINEERING

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GEOLOGY AND GEOTECHNICAL ENGINEERING

1. INTRODUCTION

This Annex deals the geology of project area and engineering geology of the project facility for the Project for Lower Moshi Integrated Agriculture and Rural Development Project.

Chapter 2 presents the general geology and regional geology of the project area.

Chapter 3 shows the scope of investigations and summary of investigation results which have been carried out during Phase-I and II periods in Tanzania.

Chapter 4 presents the engineering geology and assessment for the major project facilities which have been designed for the project works on the feasibility study level.

Chapter 5 and 6 indicate the test results and engineering assessment for the aggregates and embankment materials for the application to the design of project works.

2. GENERAL GEOLOGY

2.1 GENERAL GEOLOGY OF PROJECT AREA

2.1.1 Topography

The Study area is extended along the south foot of Mt. Kilimanjaro, and its topography conditions are characterized as follows:

- High land area : planned headworks site, and about 50 % of planned diversion channel route from headworks site
- Alluvial low land area : remaining 50 % of planned diversion channel route after passing high land area, Existing Lower Moshi Area, Extension Area and Expanded Area

(1) High Land Area

The planned headworks site is located at the Kikuletwa river flowing in a vast plain ranging from EL.700 m to EL.850 m in elevation, at the south-southwest of Mt. Kilimanjaro(EL.5,895 m). The planned diversion channel route runs in the high land area covering a comparatively flat surface with the elevation of EL.780 m to EL.800 m.

(2) Alluvial Low Land Area

The topography conditions of the alluvial low land area are generally composed of gently sloping land with an average gradient of 0.5 %. The highest elevation is about EL.760 m at the northwest of the Study Area and the lowest is about EL.700 m at the southeast.

2.1.2 Regional Geology

The Study Area can be broadly divided geologically into the following areas:

- Volcanic Rock Area : planned headworks site, and about 50 % of proposed diversion channel route from headworks site
- Alluvial plain area : about 50 % of planned diversion channel route after high land area, Existing Lower Moshi Area, Extension Area and Expanded Area

(1) Volcanic rock area

Volcanic products of Mt. Kilimanjaro are spread widely over the volcanic rock area. Gneissic rocks of the Usangran System of the Pre-Cambrian Age are distributed widely over the gneissic rock area. The geological conditions in the volcanic rock area, where the geology investigation work was performed for the proposed Headworks sites area described as follows:

Radiometric dating of volcanic rocks in Kenya has yielded a value of 13 to 15 x 10^6 years BP, so that Mt. Kilimanjaro's volcanic activity is thought to have started between the Miocene and Pliocene eras. It is thought that the frequency of activity gradually decreased from the Pleistocene to Holocene eras. In present time, volcanic activity is limited to localized eruption.

Past volcanic activity can be divided into three(3) stages, which were respectively involved in forming Kilimanjaro's three main peaks, known as Shira, Mawenzi, and Kibo. Shira, composed predominantly of lava with pyroclastic rocks, is considered the result of the first of these stages. Mawenzi developed at next stage, with volcanic products, chiefly basaltic

lava accompanied by tuff breccia and agglomerate, flowing mainly down Kilimanjaro's southern and eastern faces. Kibo is the formation of most recent activity, during which volcanic products were released mainly on the northern and southern sides. The lava of Kibo is divided into the following 10 groups:

- Inner Crater Group
- Caldera Rim Group
- Small Rhomb Porphyry Group
- Lent Group
- Rhomb Porphyry Group
- Upper Rectangle Porphyry Group
- Upper Trachyandesite Group
- Lower Rectangle Porphyry Group
- Lava Tower Trachyte Group
- Lower Trachyandesite Group

These lava mainly consist of volcanic rocks or porphyry such as trachyandesite, trachyte, phonolite, and rhomb porphyry. In addition, a volcanic deposit known as "Lahar" is also present where the Kibo volcanic products are distributed. The proposed Kikuletwa headworks is located in the area of the Kibo volcanic product distribution and the volcanic products are of the Rhomb Porphyry Group partially overlaid with Lahar.

(2) Alluvium plain area

The alluvium plain is extended over the Lower Moshi to Arusha Chini has about 25 km length at east-west end and about 30 km at south-north end. Plain is enclosed by Kibo volcanic hill at west end, Mawenzi volcanic hill at north-east end and Usagaran system of Mozambiquim organic belt zone at southeast and east-west end, and opens only at the southern end. The plain consists of thick alluvial deposits and pyroclasic flows overlaying Pre-Cambrian cryatalling metamorphicc rocks. Faulting and volcanism continued from place to place throughout the Miocene and Plioone times, and terminated in recent times. Fault-trough associated with lift movement is most important structural feature. The Pre-Cambrian rocks are the basement rocks, which lie at a depth of more than 200 m.

The regional geology map is provided in Figure B.2.1. (Source: "Geological Map of Kilimanjaro" by Ministry of Industries, Mineral Resources and Power, 1965)

3. FIELD INVESTIGATION

3.1 General

In order to collect the basic geology data required for the feasibility study of the project concerned, the following investigation were carried out during the study period.

- Core drilling investigations
- Concrete aggregate investigations
- Surface geology investigations for diversion channel
- Soil mechanical test for embankment material

3.2 Core Drilling Investigation

Core drilling investigation and permeability test utilizing drilling holes were carried out during Phase-I study in Tanzania. The extent and locations of investigation are as shown in Table B.3.1 and Figure B.3.1. Boring logs of 18 bore holes are presented in Attachment of this Annex.

3.3 Concrete Aggregate Investigation

Investigation was made at the proposed quarry site to serve as source for concrete aggregates during Phase-II study in Tanzania. The proposed quarry site was selected at the downstream part of Longoi river. The extent and locations of quarry site are as shown in Table B.3.2 and in Figure B.3.1.

3.4 Surface Geology Investigations for Diversion Channel

Surface geology investigation was carried out on the route of high land area of the diversion channel to grasp the depth of overlaid deposits. The investigation was done during Phase-II study in Tanzania. Investigation was carried out every 100 m pitch by excavating of pits and result are summarized in Table B.3.3.

3.5 Soil Mechanical Test for Embankment Material

Soil mechanical test for the embankment material of the diversion channel and flood dike of the Expanded area was carried out during Phase-II study. The extent and locations of samplings are as shown in Table B.3.4 and in Figure B.3.1.

4. ENGINEERING GEOLOGY

4.1 Headworks

4.1.1 Selection of Site

In accordance with the study of water source development plan, the location of headworks site would be selected at the downstream portion of existing TANESCO power station. The first screening of selection of site was made within the range of 12 km from the existing power station. After examination of sites taking into account of the topography and geology views, the sites were further concentrated at the range of 3.3 km from the existing power station mainly from the view points of topography conditions and 2 alternative sites(Site-B and Site-C) were proposed.

The plan of Kikuletwa river indicated the alteranative sites and location of boring site is shown in Figure B.4.1 and the geology profile of Kikuletwa river is shown in Figure B.4.2.

(1) Geology Site-B(Upstream plan)

This site is located approximately 2 km downstream of the existing power station. At this site, 2 core drilling(BH-17 & BH-18) were done. From the topography view points, both left and right sides of abutment are forming gentle slope with 1: 5 to 1: 8, of elevation from 800 m to 840 m and average river bed gradient is 1/500. The headworks site is composed of Tuff Breccia and it was found the limestone layer about 20 m depth below ground level. The limestone lens is limited to the vicinity of the headworks site. All of the bedroks are found generally hard, and except at the surface layer of right bank of the headworks site, the permeability coefficients indicated 10^{-4} to 10^{-5} cm/sec. Unconsolidated deposits, consisting of talus deposits and alluvium over lie the basement rocks. These deposits, however, are extremely thin. An existing of limestone will be considered the foundation treatment both improvement of permeability and strength of bedrocks. The geology section of Site-B is presented in Figure B.4.3.

(2) Geology Site-C(Downstream plan)

This site is located approximately 3 km downstream of the existing power station. At this site, 4 core drilling(BH-12, 13, 14 & BH-15) were carried out. Abutment of site forms steep "V" shaped valley with 20 to 30 m width and 30 m height, of elevation with 790 m and averaged river bed gradient is 1/30. The site is composed of Tuff breccia and bedrocks are hard, and no alluvium deposit is existed. The permeability coefficients are found at the range of 10^{-5} to 10^{-6} cm/sec. The geology section of Site-C is presented in Figure B.4.4.

(3) Selection of site

The comparison study was made to determined the proposed location of headworks site and "Site -C" was selected mainly from the view point of construction costs.(Details are presented in ANNEX-J: Water Source Development)

4.1.2 Engineering Geology

(1) Excavation line of foundation rock

Abutment of selected site forms a "V" shaped valley with 20 m to 25 m river width at river bed level and approximately 50 m width at crest level of headworks, descending with meandering slightly. An elevation of riverbed is EL.790 m and gradient of river bed is 1/30. both side of abutment, there are found overhung rocks with unstable conditions. The type of headworks is determined as "concrete gravity type" with approximately height of 30 m.

The excavation line of foundation rock is determined based on the i) bearing capacity of rock and ii) groutability. The foundation rock is classified into A, B, C, D classes depending upon number of seam, crack, and permeability, etc. From the view point of scale of structure

and estimated load acting on the foundation(approximately 50 tf/m^2), excavation line is determined on C_M class at the riverbed portion and C_L class at other portion. This criteria was also applied for the weir body and spillway portions. In addition to the above basic consideration, excavation line of the abutment portion is determined at i)workability during construction and ii) stability of contact condition between concrete and foundation rock.

The excavation line on the axis of headworks is presented in Figure B.4.5.

(2) Foundation grout

After foundation rock excavation, consolidation and curtain grout by cement milk will be executed for the following purpose:

(a) To secure contact between concrete and foundation rock

(b) To fill crack and seam in bedrock which are created by blasting

(c) To improve permeability up to 10^{-6} cm/sec order(less than 5 lugeon)

Arrangement of holes and rows are determined as below based on the geology condition and scale of structure.

Consolidation grout	Depth	: 5 m
	Pitch	: 5 m grid
	Hole size	: not less than 46 mm
	Max. pressure	: 3 kgf/cm^2
Curtain grout	Depth	: 10 m by stage method
	Row and distance	: 2 rows, 5 m pitch, alternative
	Hole size	: not less than 46 mm
	Max. pressure	: 7.5 kgf/cm^2

(3) Estimate of shearing strength

Based on the similar rock(Tuff Breccia) and rock classifications(C_M - C_L), shearing strength of foundation rock is estimated as follows:

$$\tau = \tau_o + \sigma \tan \phi$$

where,

τ : shearing strength (kgf/cm^2)

τ_o : initial shearing strength (kgf/cm^2)

σ : vertical load (kgf/cm^2)

ϕ : internal friction angle ($^\circ$)

From the figure indicated in right side, τ_o and ϕ are estimated based on the rock classification. (Estimate is applied for an average of upper limits of C_M and C_L class) As a result, design values are determined as follows:

τ_o =1/2(24 +10)
=17 kgf/cm^2

ϕ =1/2(45° + 38°)
=41.5°

For the safety side, vertical load σ =0(kgf/cm^2) is adopted and applied shearing strength of foundation rock for design is

determined τ =17 (kgf/cm^2).

4.2 Diversion Channel

4.2.1 Topography and Geology

The topography and geology conditions on the diversion channel route are charactically classified into two categories; high land area and low land area; and a borderline is found at F1 fault which runs the east end of tableland toward north to south.

(a) High land area

High land area is classified to the igneous rock zone and composed of Tuff Breccia. Surface of Tuff Breccia is slightly weathered and covered by alluvium deposits having 0.30 m to 0.50 m depth. Length of the channel passing to this area is estimated at approximately 12 km from headworks site up to borderline of F1 fault. Elevations on the route are ranging EL.840 m to EL.760 m, and small hill with elevation of EL.840 to EL.830 m lays at initial 1 km portion.

(b) Low land area

Length of diversion channel in this area is about 9 km up to the bifurcation structure of the Existing Lower Moshi Area and the Extension Area and further 3 km up to the Rau river. Elevations on the route are ranging EL.755 m to EL.740 m. The route is fully covered with hard alluvium deposits about 5 m to 8 m thick in top layer and followed by gravel and sand layer.

4.2.2 Engineering Geology

(1) Geology profile

To grasp the geology conditions on the route, i)core boring and ii)surface geology investigations were executed. Total 10 numbers of core boring were carried out; 4 numbers at high land area, and 6 numbers at low land area. Surface geology investigation was carried out to confirm the covering depth of alluvium deposit on the rock at high land area to apply for the design of channel section and cost estimate. Investigation at the low land area was carried out to check the bearing capacity of soil foundation by standard penetration test(SPT).

(2) Excavation and equipment

(a) High land area

At initial 1 km portion, deep excavation with 10 m to 15 m deep would be required. After deep excavation portion, averaged excavation depth of the high land portion is expected within 4 m. Rock, mainly Tuff Breccia, is composed of Rhomb porphyry and well consolidated. Excavation would be carried out by blasting method and for the slope shaping, giant breaker will be used.

(b) Low land area

Geology of low land area are indicated with following condition based on the results of core boring:

1) F1 fault to Kikafu river : laterite layer(N>50)

2) Kikafu river to Weruweru river : 0-2m river deposit(N<5)
2-5m gravel and sand(5<N<25)
more than 5 m gravel and sand(N>50)

3) Weruweru to bifurcation	0-3m sand, silt, clay(N=5 to 30) more than 3 m sand and gravel(N>30-50)

As seen above, soils of route are composed of laterite and sand/gravel. Ground water levels are found at within 3 m at the right bank side of Weruweru river and 5 m to 7 m at the left bank side of Weruweru river. Judging from the above conditions, excavation of low land area will be carried out by backhoe shovel and assisted by bulldozer.

(3) Channel section

(a) High land area

Tuff Breccia is formed massive consolidated rock and stable against weathering. Side slope of channel is determined 1: 0.30 taking into consideration of i)reduction of rock excavation and ii) stability of slope after construction. Excavated slope above channel is determined 1:0.50 as same consideration of channel section. To protect fall down of surface rock and to minimize seepage loss from excavated section, lining to the channel section is to be considered. Selection of lining materials is to be considered from the view points of i)economical view, ii) design view of hydraulic requirement, iii)workability, iv)stability, etc., and as a result, a shotcrete lining method is selected mainly i)workability and ii) economical view points. Voids and caves would be existed on the surface of excavated slope after excavation, and these would be filled by concrete.

(b) Low land area

Channel section of low land area is determined based on the soil property of excavated ground and feature of embankment material. After examination of soil property and topography conditions, side slope of channel is determined 1:1.25 with lining. Selection of lining materials was made and precasted concrete lining was selected mainly economical view point and workability during construction.

(4) Foundation of major structure site

On the route of diversion channel, channel crosses the Longoi, Kikafu and Weruweru rivers. Structures of river crossing at respective rivers are planned as follows:

- Longoi	:	Inverted type steel pipe and concrete combined type siphon
- Kikafu	:	Concrete box culvert type siphon and concrete bridge
- Weruweru	:	Concrete aqueduct and concrete bridge

Preliminary estimate of loads acting on the foundation level are 50 tf/m^2 at Longoi siphon, and 20 tf/m^2 at both Kikafu and Weruweru sites. Estimates of bearing capacity were made at respective sites and following allowable bearing capacity are calculated:

- Longoi site	:	100 tf/m^2(rock foundation)
- Kikafu & Weruweru	:	30 tf/m^2(gravel and sand foundation, by Terzaghi formula)

From above estimate, no foundation piles are considered for the respective structures.

The geology profile of diversion channel is shown in FigureB.4.6 and the geology section of the respective sites are shown in Figure B.4.7, respectively.

4.3 Hydropower Station

4.3.1 No.1 Power Station

(1) Topography and geology

No.1 power station is located at 5.3 km point from the headworks site. Elevations are EL.810m at headtank and EL.798 m at tailrace portion. Slope of ground surface between headtank and tailrace is about 1 to 20. Ground surface of site is covered by alluvium deposits with 0.3m depth and following to Tuff Breccia as bedrock which is found very hard and less cracks and seams.

(2) Engineering geology

Structures of power station are composed of i)headtank, ii)penstock and iii)powerhouse. Excavation depth for structure is expected about 10 m at deepest portion, and estimated bearing capacity of excavated portion is more than 100 tf/m^2 from and this value shows stable conditions for foundation of structures. Excavation of rock would be carried out by blasting, therefore, attention shall be paid to protect the creation of cracks which would be caused by blasting.

4.3.2 No.2 Power Station

(1) Topography and geology

No.2 power station is located at 11.65 km to 11.8 km points from the headworks site. Elevations are EL.790 m at headtank portion and EL.755 m at tailrace portion. Slope of ground surface between headtank and tailrace is about 1 to 5. As mentioned in the previous section, F1 fault runs at the end of tableland from north to south and make a clear boundary between high land area and low land area and shows typical fault topography. Ground surface of high land area site is covered by extremely thin alluvium deposits and following to Tuff Breccia as bedrock which are found very hard and less cracks and seams. After F1 fault, low land area is extended to downstream site composing of very hard laterite soil.

(2) Engineering geology

Due to exist of fault, a special attention should be paid for the determination of alignment of structures. To avoid the fault and to use the topography head, a penstock and powerhouse structures should be located before fault line. An estimated bearing capacity of Tuff Breccia is more than 100 tf/m^2, and laterite is 50 tf/m^2 and these value shows the stable foundation conditions for power hose and foundation of tailrace. Excavation of rock would be carried out by blasting, therefore, attention shall be paid to protect the creation of cracks which would be caused by blasting.

The geology profile of No.2 power station is shown in Figure B.4.8.

5. CONCRETE AGGREGATE

5.1 Quarry Site

The quarry site was selected at the downstream part of Longoi river as shown in Figure B.2.1 after examination of several proposed sites. Extent of site is approximately 30 m x 500 m x 6 m depth and aggregates on the river bed is exposed and would be collected directly. Surrounding this proposed site, same quantity of quarry site is further available, however, covered by silt and clay with 0.5 m depth.

5.2 Sampling and Laboratory Tests

(1) Test item

Sampling of aggregate was carried out and following laboratory tests were executed.

- Physical test : - Moisture content, - Specific gravity, - Grain size analysis
- Stability test : - Alkali reactivity test, - Abrasion test, - Soundness test, - Water absorption test

(2) Test result

The test results are shown in Table B.3.2 and B.5.1 and summarized as below:

Test Results

Test Items	Test Results
(a) Classification of aggregates	: 1) Andesite:13 % 2) Olivine basalt:16% 3) Agglomerate:21% 4) Tracyte:16% 5) Vescicular basalt:17% 6) Andesite basalt:1% 7) Ponolite:1% 8) Pumice:0.3% 9) Basalt:15%
(b) Grain size under natural condition	: 1) Over 37.5 mm: 23.1 % 2) Coarse aggregate(37.5 mm - 5 mm): 34.5 % 3) Fine aggregate(5 mm - 0.15 mm): 37.2 % 4) Dust: 5.2 %
(c) Absorption	: 0.4 % at minimum, 4.8 % at maximum and average 2.5 % (excluding pumice)
(d) Specific gravity	: 2.33 at minimum, 2.73 at maximum and average 2.50
(e) Abrasion	: 26 % at minimum, 31 % at maximum and average 28 %
(f) Alkali-Aggregate reactivity	: 0.14 % at minimum, 0.20% at maximum and average 0.16 % (Test result of Alkali reactivity is shown in Figure B.5.1)

5.3 Engineering Assessment

(1) Suitability for aggregates

Results of aggregate tests showed that the absorption, specific gravity, alkali reactivity are in the range usable as aggregates. However, it is recommended that the materials contain quantity of fines of under 0.15 mm, therefore, removal of washing be necessary before material used. (Suitability was checked by JIS A 5005)

(2) Available quantity at quarry site

Based on the field investigations and laboratory tests of materials, the availability quantity of aggregates are estimated as follows.

- Coarse aggregate : 63,000 m^3
- Fine aggregate : 70,000 m^3

(3) Crushing plant

To reduce the loss and use the materials as much as possible, crushing plant with screening and washing facility would be equipped. Water source for washing is to be supplied by Longoi river.

6. EMBANKMENT MATERIAL

6.1 Embankment Material for Diversion Channel

6.1.1 Sampling and Test Item

Number of sampling is 5 places(TP-1 to TP-5) along the diversion channel and these locations are as shown in Figure B.2.1. Test items carried out at the laboratory are as follows:

- Physical test: Moisture content, Grain size analysis, Consistency test
- Soil mechanical test: Compaction test, C.B.R test, Triaxial compression test, Permeability test

6.1.2 Test Result

The test results are as shown in Table B.3.4 and Figure B.6.1 and summarized as follows:

Test Results

Test Items	Results
(a) Moisture Content	:17.8 % at minimum and 25 % at maximum
(b) Grain size analysis	: See Figure B.6.1
(c) Consistency	: Plastic index PI=11 at minimum and 28 at maximum
(d) Soil classification	: CH, ML, SC
(e) Max. dry density under compaction test	: 1.50 g/cm^3 at minimum and 1.90 g/cm^{3}at maximum
(f) Optimum moisture content	: 13.7 % at minimum and 27.1 % at maximum
(g) Permeability	: k=2 x 10^{-6} cm/sec at minimum and 1 x 10^{-5} cm/sec at maximum under wet side of 95 % density
(h) Internal friction angle	: 12° at minimum and 26° at maximum
(i) Cohesion	: 4.6 tf/m^2 at minimum and 10.2 tf/m^2 at maximum

6.1.3 Engineering Assessment

(1) Suitability for embankment material

Test results are evaluated in line wih the soil classification (CH, ML,SC), permeability, shear strength, compressibility and workability mentioned in the " Engineering Use Chart of Earth Manual (USBR)" which is given in Table B.6.1. As a result, the materials tested were judged to be used as embankment materials although careful control such as soil moisture content is necessary for the materials classified as CH.

(2) Degree of compaction for quality control

Standard compaction degree for the quality control of embankment shall be D=95 % at wet side

(3) Criteria for structure design

Design value for the design of structure shall be as follows:

- Unit weight of soil : Dry γ_d = 1.60 tf/m^3
  Wet γ_t = 1.80 tf/m^3
- Internal friction angle : Ø=20°
- Cohesion : C=4 tf/m^2

6.2 Embankment Material for Flood Dike

6.2.1 Sampling and Test Item

Number of sampling is 3 places(TP-6 to TP-8) on the left side of Rau river and these locations are shown in Figure B.2.1. Test items carried out at the laboratory are as follows as well as the diversion channel:

- Physical test : Moisture content, - Grain size analysis, Consistency test
- Soil mechanical test : Compaction test, - C.B.R test, Triaxial compression test, Permeability test

6.2.2 Test Result

The test results are shown in Table B.3.4 and Figure B.6.1 and summarized as follows:

Test Results

Test Items	Test Results
(a) Moisture contents	: 21.9 % at minimum and 33.2 % at maximum
(b) Grain size analysis	: See Figure B.6.1
(c) Consistency	: Plastic index PI=15 at minimum and 21 at maximum
(d) Soil classification	: CH, ML
(e) Max. dry density under compaction test:	: 1.48 g/cm^3 at minimum and 1.54 g/cm^3 at maximum
(f) Optimum moisture content	: 25.6 % at minimum and 28.5 % at maximum
(g) Permeability	: k= 7 x 10^{-6} cm/sec under wet side of 95 % density
(h) Internal friction angle	: 12° at minimum and 35° at maximum
(i) Cohesion	: 7.1 tf/m^2 at minimum and 13.8 tf/m^2 at maximum

6.2.3 Engineering Assessment

(1) Suitability for embankment material

As mentioned in Sub-section 6.1.3, moisture content for the soil categorised as CH shall be carefully controlled when compaction work is carried out.

(2) Degree of compaction for quality control

Standard compaction degree for the quality control of embankment shall be D=95 % at wet side.

(3) Criteria for structure design

Design value for the design of structure shall be as follows:

- Unit weight of soil : Dry γ_d = 1.60 tf/m^3
  Wet γ_t = 1.80 tf/m^3
- Internal friction angle : Ø=20°
- Cohesion : C=5 tf/m^2

Tables

Table B.3.1 Summary of Core Drilling Works

BH.No	EL.(m)	Depth(m)	Soil Classification	SPT(times)	Water pressure Test(times)	Location
1	749.08	10	Soil/gravel	9	-	Low land
2	749.93	10	Soil/gravel	9	-	Low land
3	753.90	6	Soil/gravel	5	-	Low land
4	751.49	20	Soil/gravel	19	-	Low land
5	754.58	10	Soil/gravel	12	-	Low land
6	754.77	15	Laterite	6	-	Low land
7	756.03	10	Tuff	-	2	High land
8	752.60	15	Tuff	-	3	Longoi river
9	748.00	6	Gravel	-	-	Longoi river
10	756.49	10	Tuff	-	1	High land
Sub-total		122		60	6	
11	795.60	10	Tuff	-	2	High land
12	824.50	15	Tuff	-	3	High land
13	817.30	35	Tuff	-	7	Headworks-C
14	824.10	10	Tuff	-	3	Headworks-C
15	814.10	40	Porphyry	-	8	Headworks-C
16	819.90	15	Tuff	-	3	Headworks-C
17	821.00	20	Limestone	-	4	Headworks-B
18	823.50	22	Limestone	-	2	Headworks-B
Sub-total		168			32	
Total	-	290		60	38	

Table B.3.2 Summary of Aggregate Test

Name of Deposit	Volume in %	Absorption(%)	Specific Gravity
1. Andesite	13.30	0.97	2.44
2. Olivine basalt	16.00	3.78	2.67
3. Vescicular basalt	16.70	3.28	2.43
4. Agglomerate	21.30	4.88	2.33
5. Tracyte	16.10	3.85	2.73
6. Andesitic balast	1.30	0.74	2.56
7. Ponolite	0.60	0.43	2.37
8. Basalt	14.40	1.82	2.43
9. Pumice	0.30	18.75	2.00

Table B.3.3 Summary of Surface Geology of Diversion Channel

Station No. (pitch 100m)	SL.No	Rock Surface from GL.(m)	Station No. (pitch 100m)	SL.No	Rock Surface from GL.(m)	Station No. (pitch 100m)	SL.No	Rock Surface from GL.(m)
BP 0+000	1	0.00	4+000	41	0.40	8+000	81	0.02
100	2	0.00	100	42	0.24	100	82	0.15
200	3	0.00	200	43	0.39	200	83	0.08
300	4	0.00	300	44	0.41	300	84	0.23
400	5	0.00	400	45	0.64	400	85	0.09
500	6	0.00	500	46	0.87	500	86	0.19
600	7	0.00	600	47	0.41	600	87	0.20
700	8	0.00	700	48	0.54	700	88	0.03
800	9	0.00	800	49	0.57	800	89	0.21
900	10	0.82	900	50	0.66	900	90	0.66
1+000	11	0.77	5+000	51	0.44	9+000	91	0.41
100	12	0.81	100	52	0.27	100	92	0.16
200	13	0.57	200	53	0.21	200	93	0.48
300	14	0.63	300	54	0.09	300	94	0.13
400	15	0.49	400	55	0.38	400	95	0.21
500	16	0.24	500	56	0.69	500	96	0.09
600	17	0.49	600	57	0.63	600	97	0.30
700	18	0.48	700	58	0.33	700	98	0.50
800	19	0.31	800	59	0.51	800	99	0.10
900	20	0.44	900	60	0.09	900	100	0.47
2+000	21	0.46	6+000	61	0.64	10+000	101	0.11
100	22	0.36	100	62	0.79	100	102	0.52
200	23	0.34	200	63	0.69	200	103	0.56
300	24	0.12	300	64	0.65	300	104	0.64
400	25	0.29	400	65	0.15	400	105	0.29
500	26	0.17	500	66	0.30	500	106	0.21
600	27	0.37	600	67	0.54	600	107	0.18
700	28	0.33	700	68	0.22	700	108	0.14
800	29	0.40	800	69	1.10	800	109	0.13
900	30	0.44	900	70	0.23	900	110	0.07
3+000	31	0.66	7+000	71	0.66	11+000	111	0.26
100	32	0.40	100	72	0.43	100	112	0.19
200	33	0.28	200	73	0.23	200	113	0.06
300	34	0.37	300	74	0.36	300	114	0.19
400	35	0.51	400	75	0.47	400	115	over 2m
500	36	0.34	500	76	0.32	500	116	over 2m
600	37	0.40	600	77	0.20	600	117	over 2m
700	38	0.30	700	78	0.00	700	118	over 2m
800	39	0.48	800	79	0.18	800	119	over 2m
900	40	0.45	900	80	0.27	900	120	over 2m

Table B.3.4 Summary of Soil Mechanical Test

Description	Unit	Diversion Channel					Flood Dike		
		TP-1	TP-2	TP-3	TP-4	TP-5	TP-6	TP-7	TP-8
1 Moisture content	%	23.9	25.3	19.8	11	7.8	33.2	21.9	29.9
2 Consistency									
Liquid limit(LL)	%	53	48	42	29	33	46	44	50
Plastic limit(PL)	%	25	26	19	18	16	28	29	29
Plasity Index(PI)	%	28	22	11	11	17	18	15	21
3 Specific Gravity	g/cm^3	2.64	2.63	2.61	2.60	2.59	2.68	2.68	2.69
4 Grain size									
Gravel	%	1	1	20	44	3	0	1	0
Sand	%	8	15	39	30	39	10	4	9
Fines	%	91	84	41	26	58	90	95	91
5 Classification	-	CH	ML	SC	SC	ML	ML	ML	CH
6 Standard Compaction Test									
Max.density	g/cm^3	1.525	1.500	1.735	1.895	1.795	1.480	1.550	1.540
Wopt	%	26.6	27.1	18.3	13.7	16.6	28.5	27.1	25.6
Permeability : D95 dry	(10^{-6} cm/s)	2	17	5	128	79	35	32	28
: D100 opt	(10^{-6} cm/s)	0.4	1	1	58	9	5	7	4
: D95 wet	(10^{-6} cm/s)	0.6	15	2	67	10	7	8	7
7 C.B.R	%	10	7	13	11	5	7	6	6
8 Tri-axial test									
Cohesion(UU)	kg/cm^2	1.02	0.56	0.46	0.92	0.71	1.27	1.38	0.71
Internal angle	degree	20	12	24	26	23	28	35	12

Table B.5.1 Summary of Test Result of Aggregate

Description	unit	Sampling No.					
		AG1	AG2	AG3	AG4	AG5	AG6
1. Alkali reactivity	%	0.15	0.15	0.14	0.15	0.15	0.16
2. Rc value	mmol/l	25	25	24	25	24	25
3. Sc value	mmol/l	5.08	5.1	4.68	5.01	4.92	5.21
4. Abrasion	%	31.3	29	26.1	27.2	31.8	28.6
5. Soundness	%	19.5	12.5	21.3	25.2	24.2	30.1
6. Absorption	%	0.85	0.74	1.82	0.43	1.78	3.23

Description	unit	Sampling No.					
		AG7	AG8	AG9	AG10	AG11	AG12
1. Alkali reactivity	%	0.2	0.15	0.16	0.14	0.15	0.15
2. Rc value	mmol/l	24	24	25	24	25	25
3. Sc value	mmol/l	4.99	4.89	5.24	4.66	5	5.01
4. Abrasion	%	30.6	31	27.4	32.3	30.7	29.6
5. Soundness	%	14.3	16	24.5	25.6	14.3	16.2
6. Absorption	%	0.97	1.2	1.96	1.63	2.87	2.02

Table B.6.1 Engineering Properties of Embankment Material

TYPICAL NAMES OF SOIL GROUPS	GROUP SYMBOLS	IMPORTANT ENGINEERING PROPERTIES			WORKABILITY AS A CONSTRUCTION MATERIAL
		PERMEABILITY WHEN COMPACTED	SHEAR STRENGTH WHEN COMPACTED AND SATURATED	COMPRESSIBILITY WHEN COMPACTED AND SATURATED	
WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GW	PERVIOUS	EXCELLENT	NEGLIGIBLE	EXCELLENT
POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GP	VERY PERVIOUS	GOOD	NEGLIGIBLE	GOOD
SILTY GRAVELS, POORLY-GRADED GRAVEL-SAND-SILT MIXTURES	GM	SEMIPERVIOUS TO IMPERVIOUS	GOOD	NEGLIGIBLE	GOOD
CLAYEY GRAVELS, POORLY-GRADED GRAVEL-SAND-CLAY MIXTURES	GC	IMPERVIOUS	GOOD TO FAIR	VERY LOW	GOOD
WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SW	PERVIOUS	EXCELLENT	NEGLIGIBLE	EXCELLENT
POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SP	PERVIOUS	GOOD	VERY LOW	FAIR
SILTY SANDS, POORLY-GRADED SAND-SILT MIXTURES	SM	SEMIPERVIOUS TO IMPERVIOUS	GOOD	LOW	FAIR
CLAYEY SANDS, POORLY-GRADED SAND-CLAY MIXTURES	SC	IMPERVIOUS	GOOD TO FAIR	LOW	GOOD
INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS WITH SLIGHT PLASTICITY	ML	SEMIPERVIOUS TO IMPERVIOUS	FAIR	MEDIUM	FAIR
INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS	CL	IMPERVIOUS	FAIR	MEDIUM	GOOD TO FAIR
ORGANIC SILTS AND ORGANIC SILT-CLAYS OF LOW PLASTICITY	OL	SEMIPERVIOUS TO IMPERVIOUS	POOR	MEDIUM	FAIR
INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS	MH	SEMIPERVIOUS TO IMPERVIOUS	FAIR TO POOR	HIGH	POOR
INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	CH	IMPERVIOUS	POOR	HIGH	POOR
ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY	OH	IMPERVIOUS	POOR	HIGH	POOR
PEAT AND OTHER HIGHLY ORGANIC SOILS	PT	——	——	——	——

(Source: EARTH MANUAL; second edition)

Figures

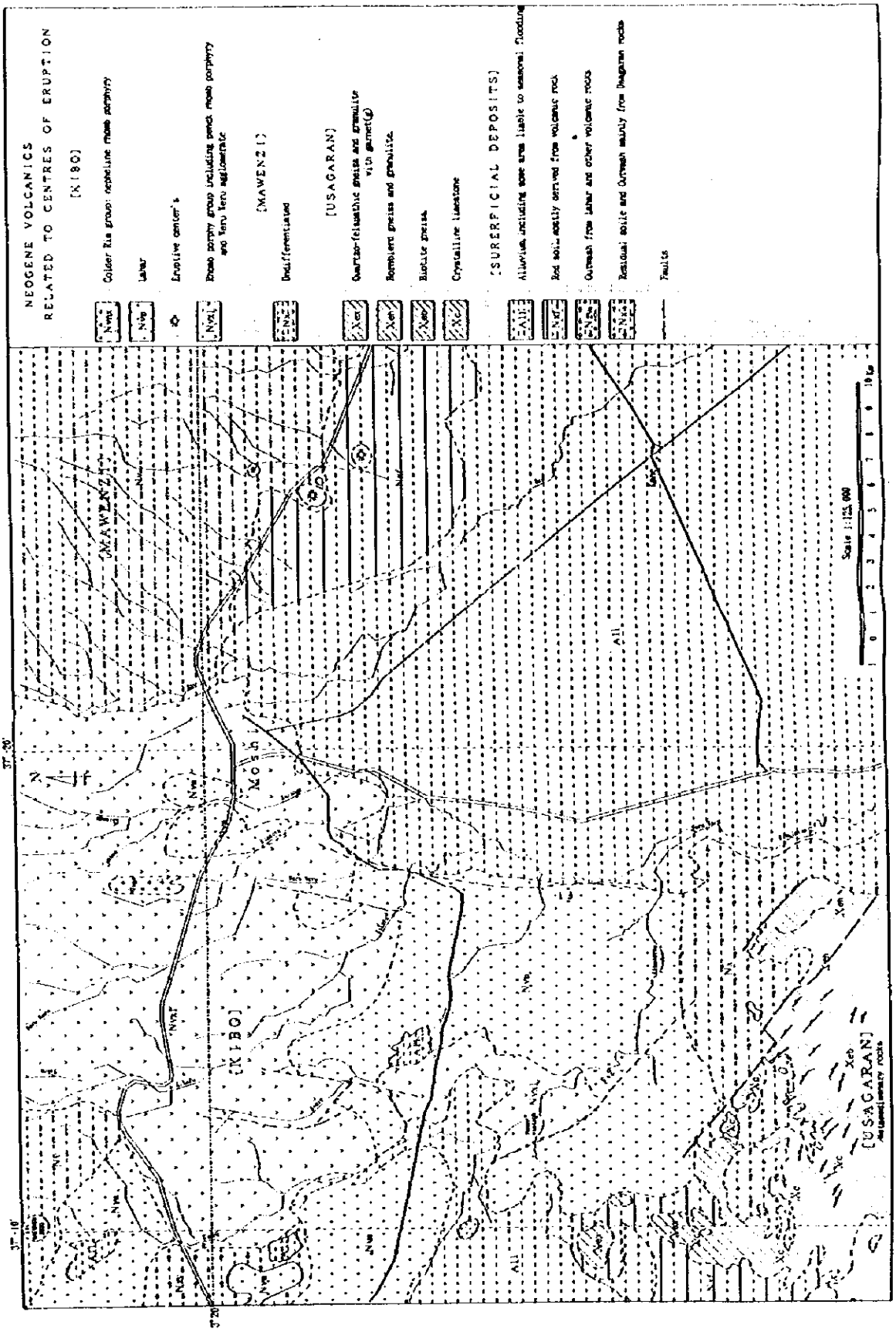


Figure B.2.1
Regional Geology Map

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

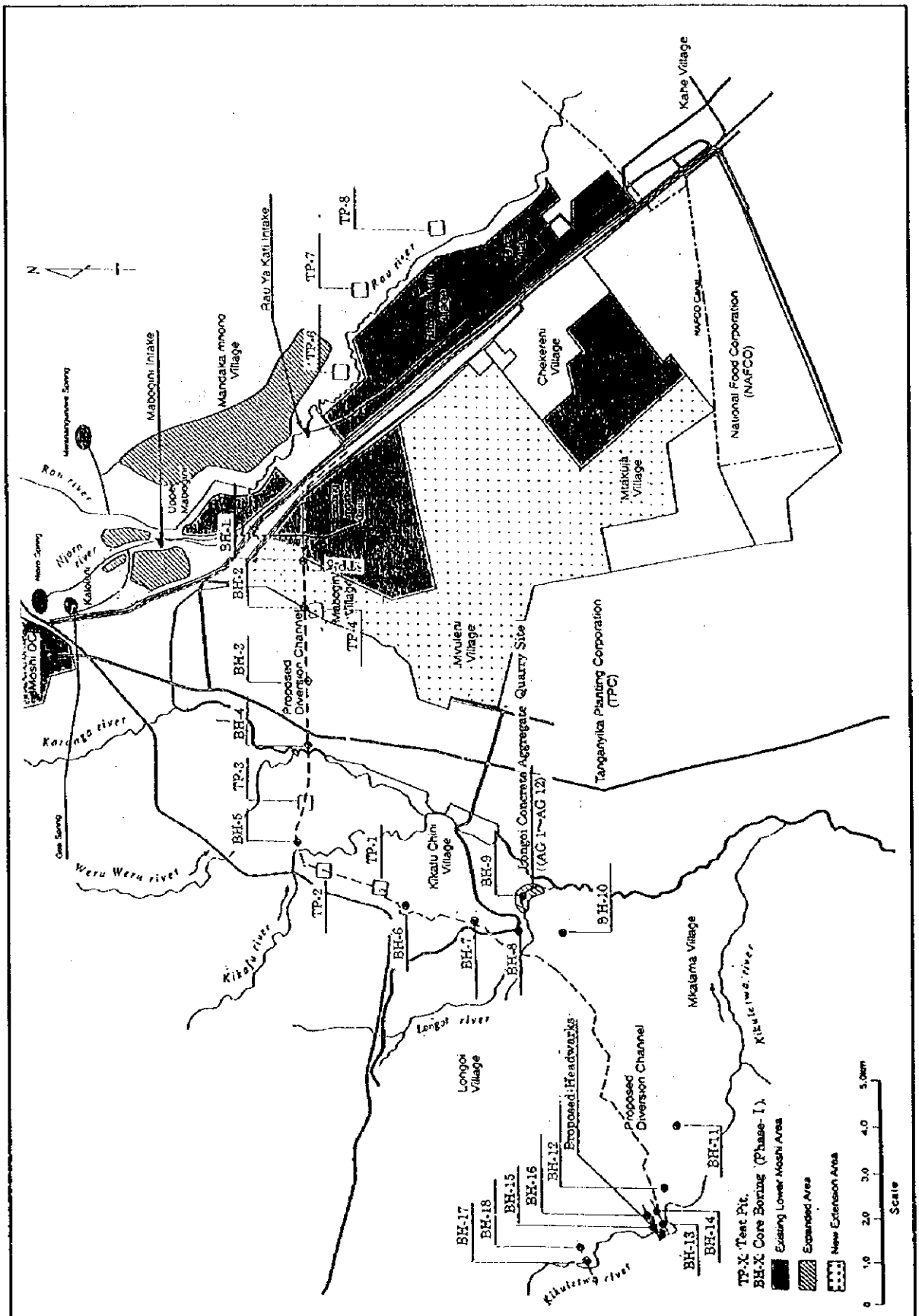


Figure B.3.1

Location Map of Field Investigation

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

Figure B.4.1
Location Map of Alternative Sites

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

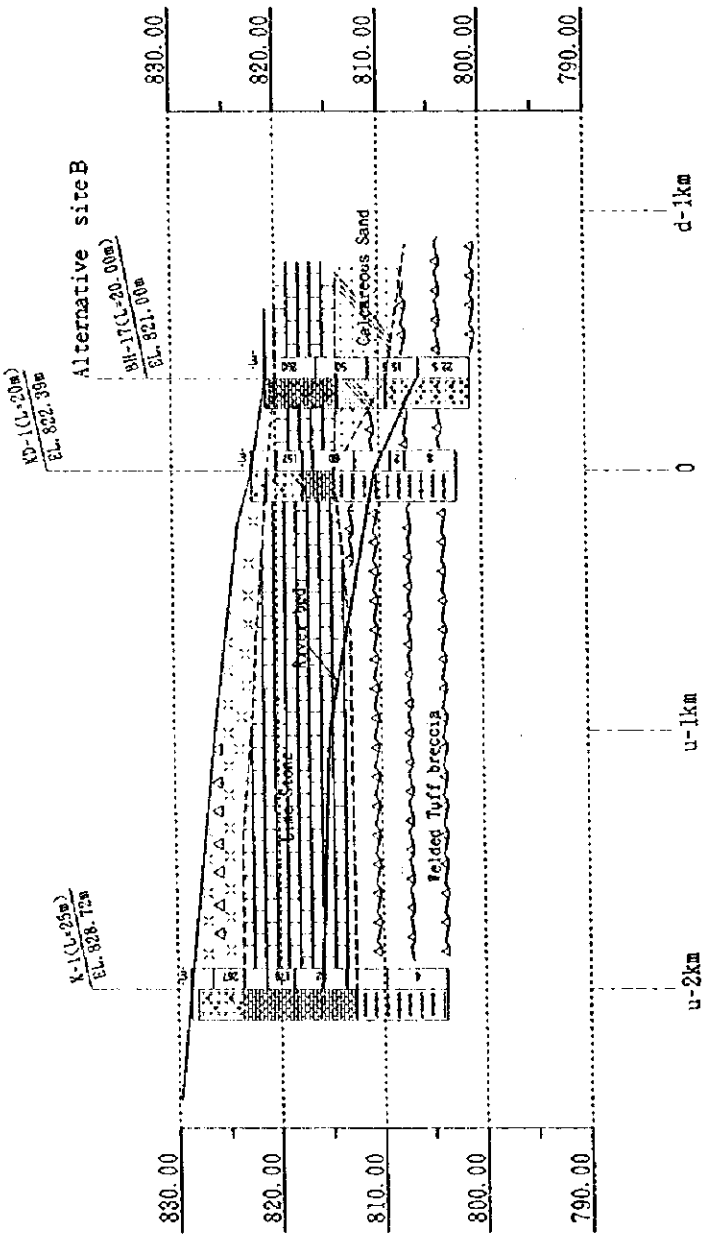


Figure B.4.2
Geology Profile of Kikuletwa River (1/3)

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania
Japan International Cooperation Agency

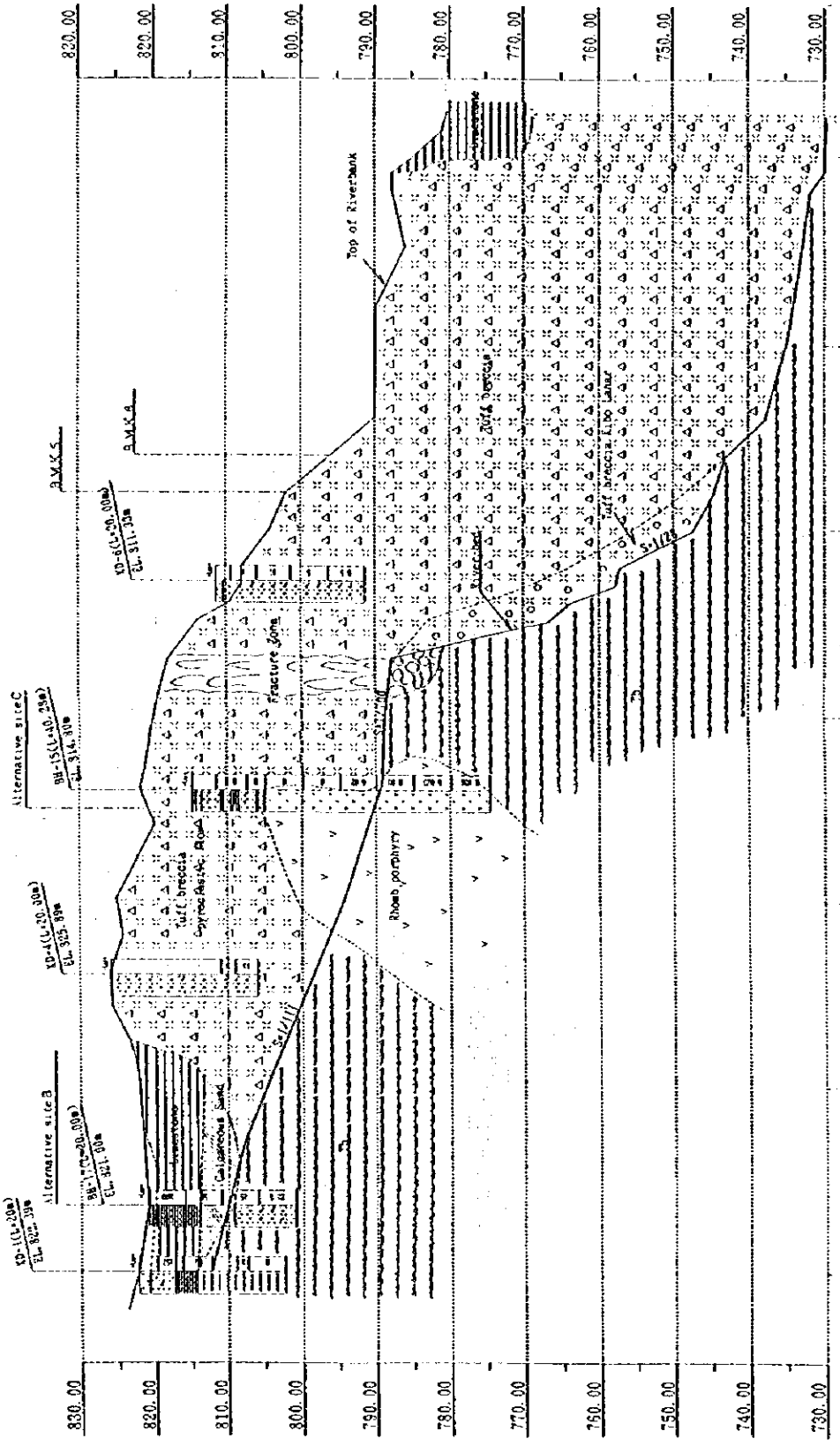


Figure B.4.2
Geology Profile of Kikuletwa River (2/3)

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

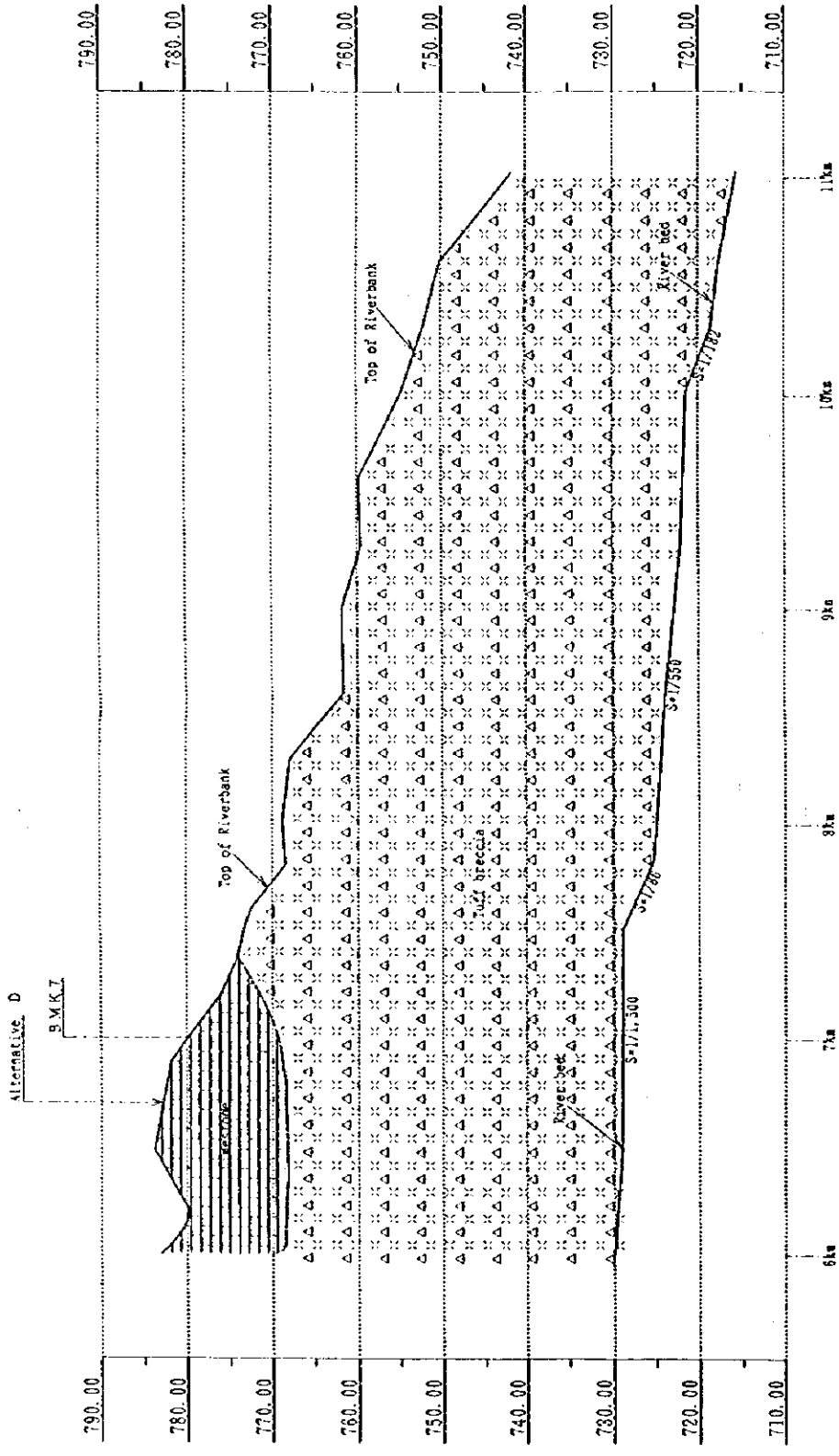


Figure B.4.2

Geology Profile of Kikuletwa River (3/3)

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

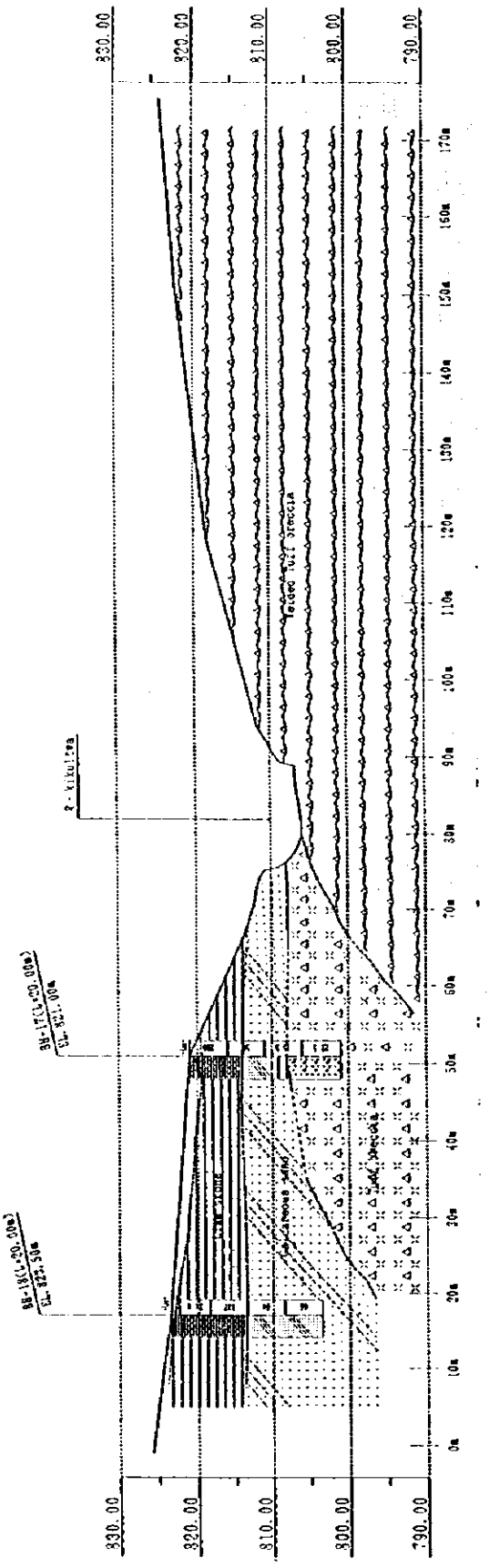


Figure B.4.3
Geology Section of Site-B

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

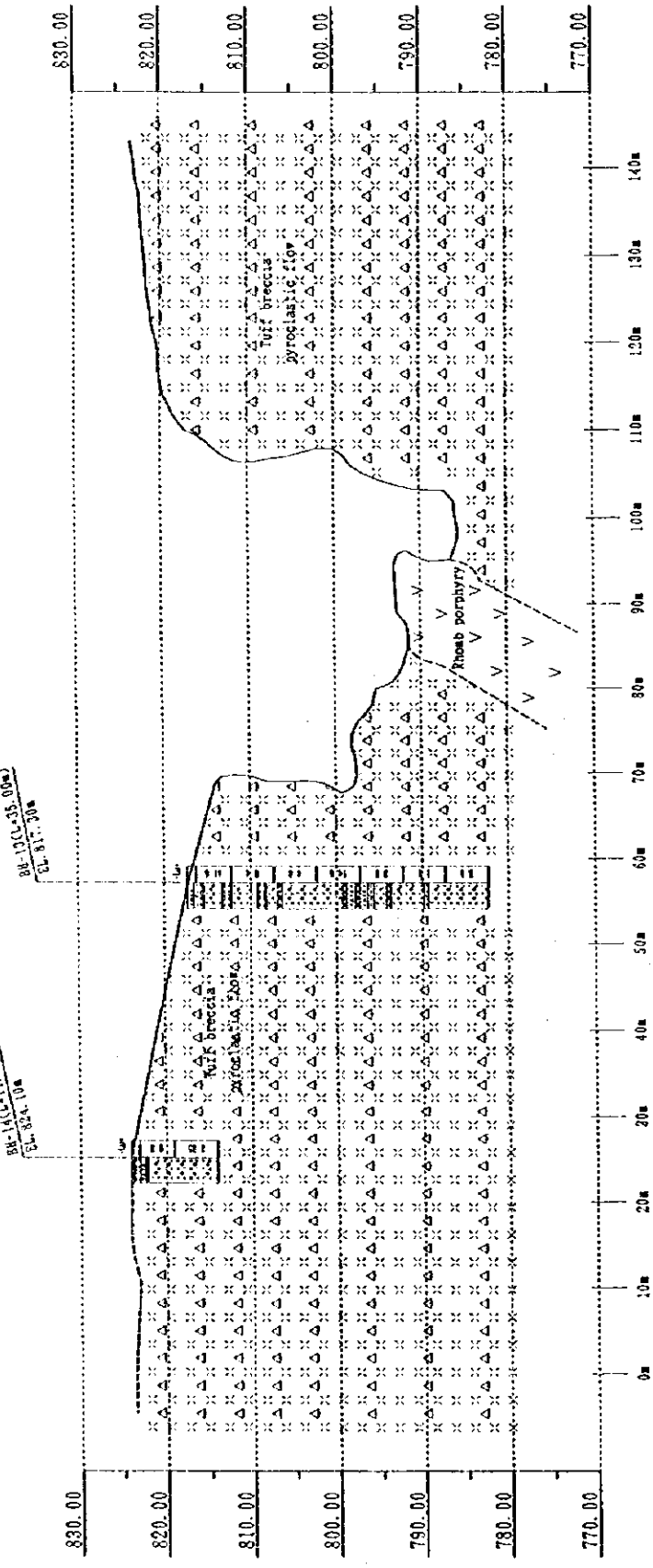
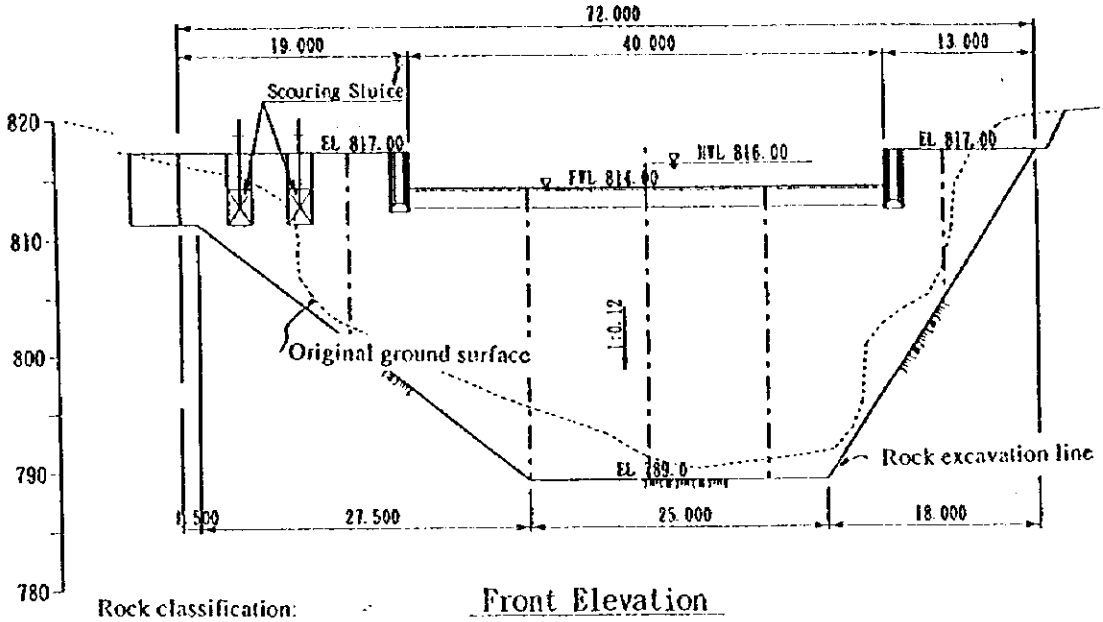


Figure B.4.4
Geology Section of Site-C

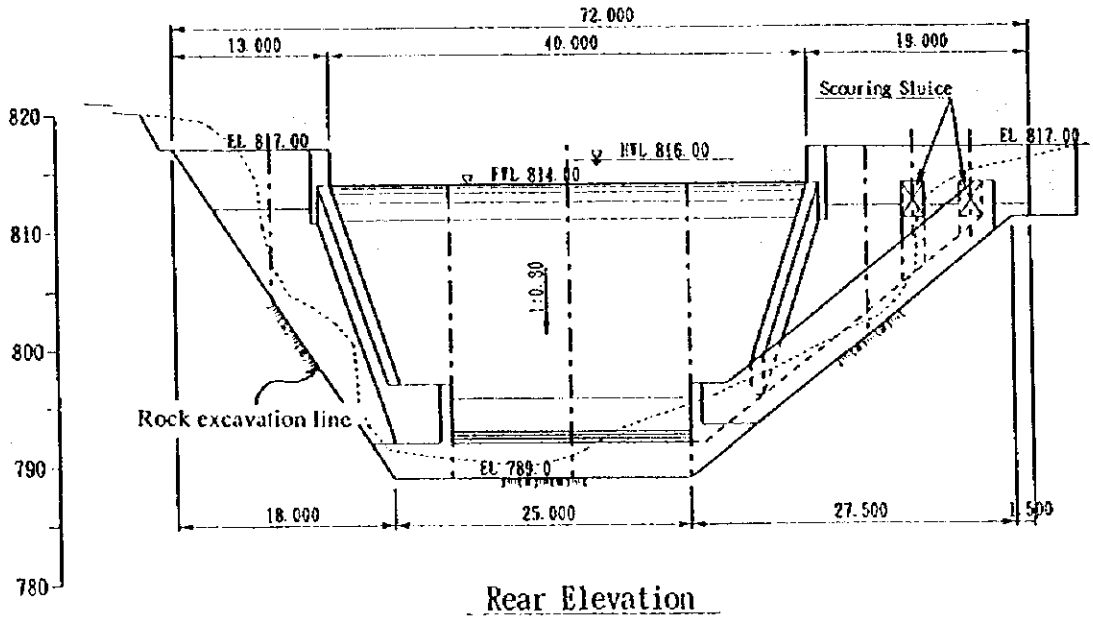
The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency



Front Elevation

Rock classification:
C_M : Bottom to EL.800 m
C_L : Above EL.800 m



Rear Elevation

Figure B.4.5
Excavation Line of Headworks

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

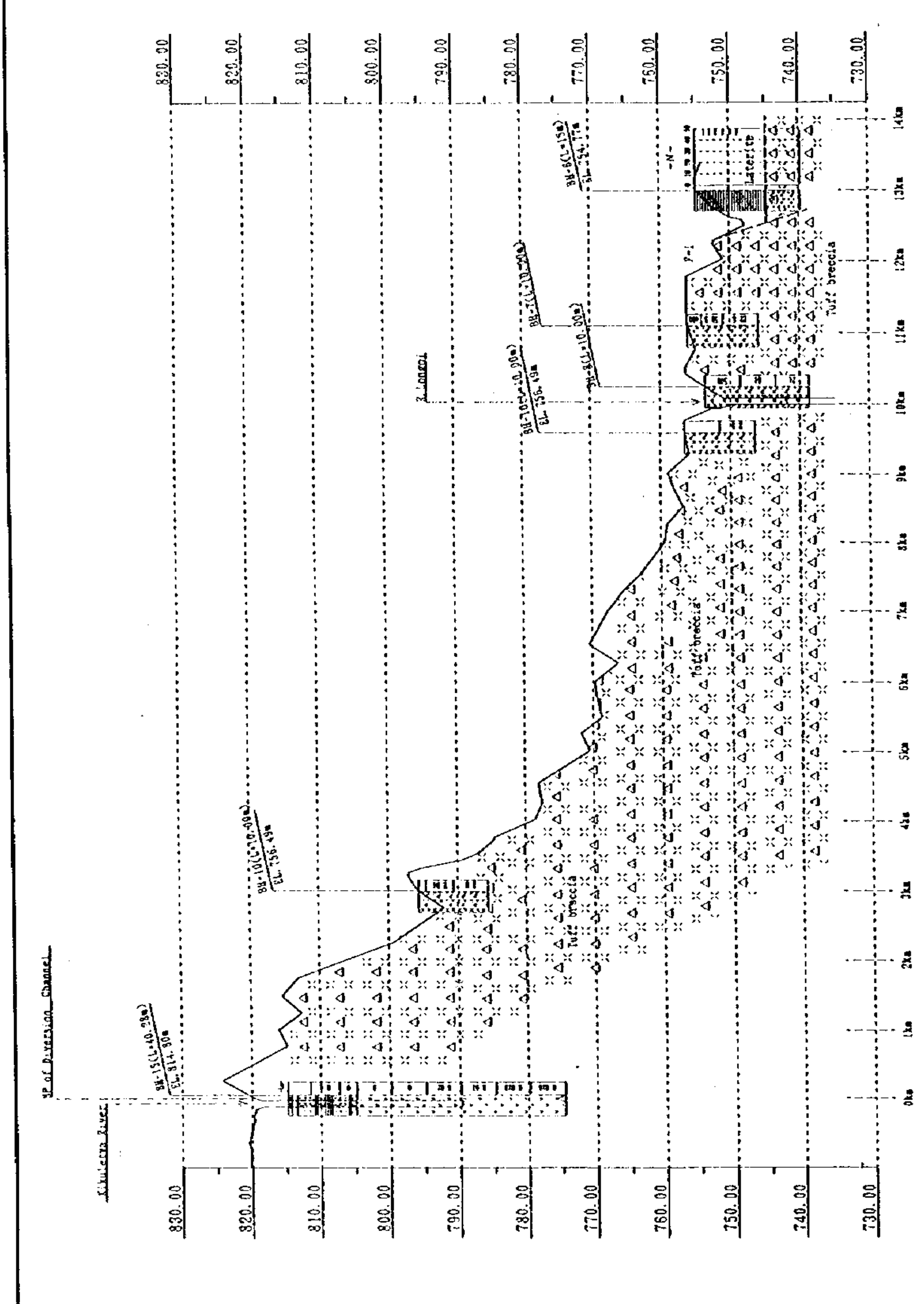


Figure B.4.6 **Geology Profile of Diversion Channel (1/2)**	**The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania** Japan International Cooperation Agency

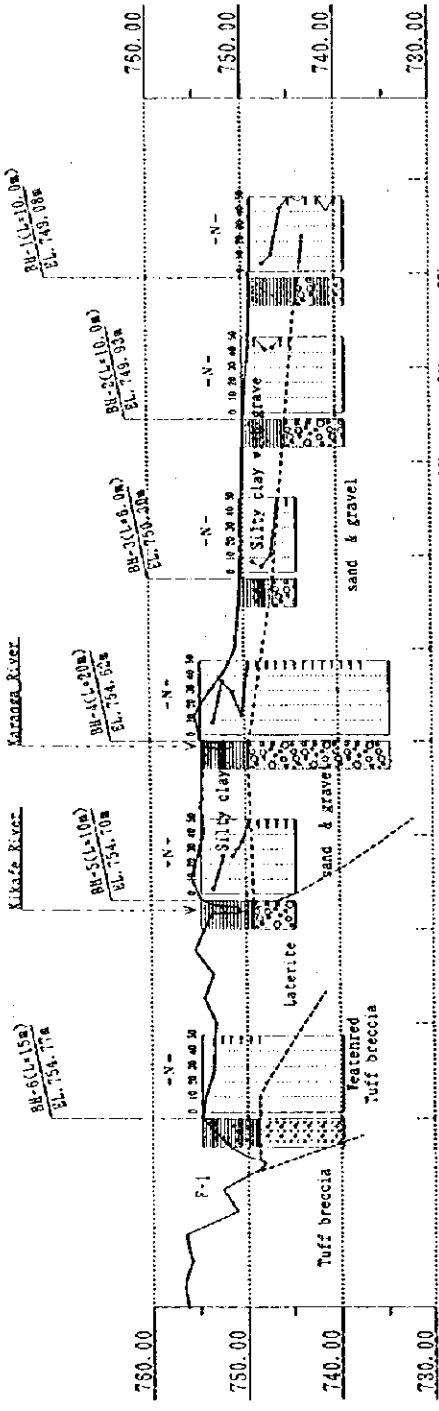


Figure B.4.6

Geology Profile of Diversion Channel (2/2)

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

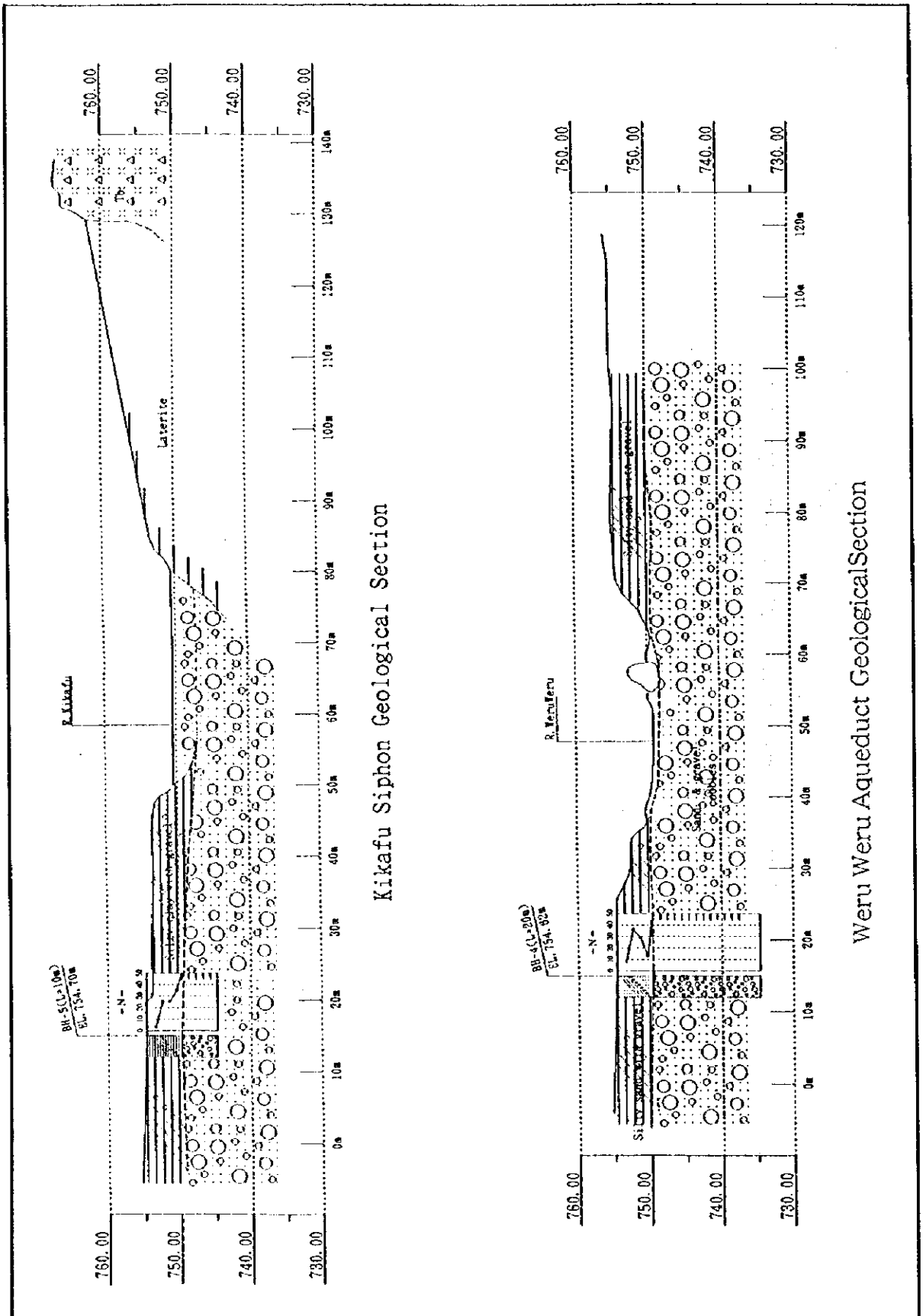


Figure B.4.7
Geology Section of Structure Sites

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

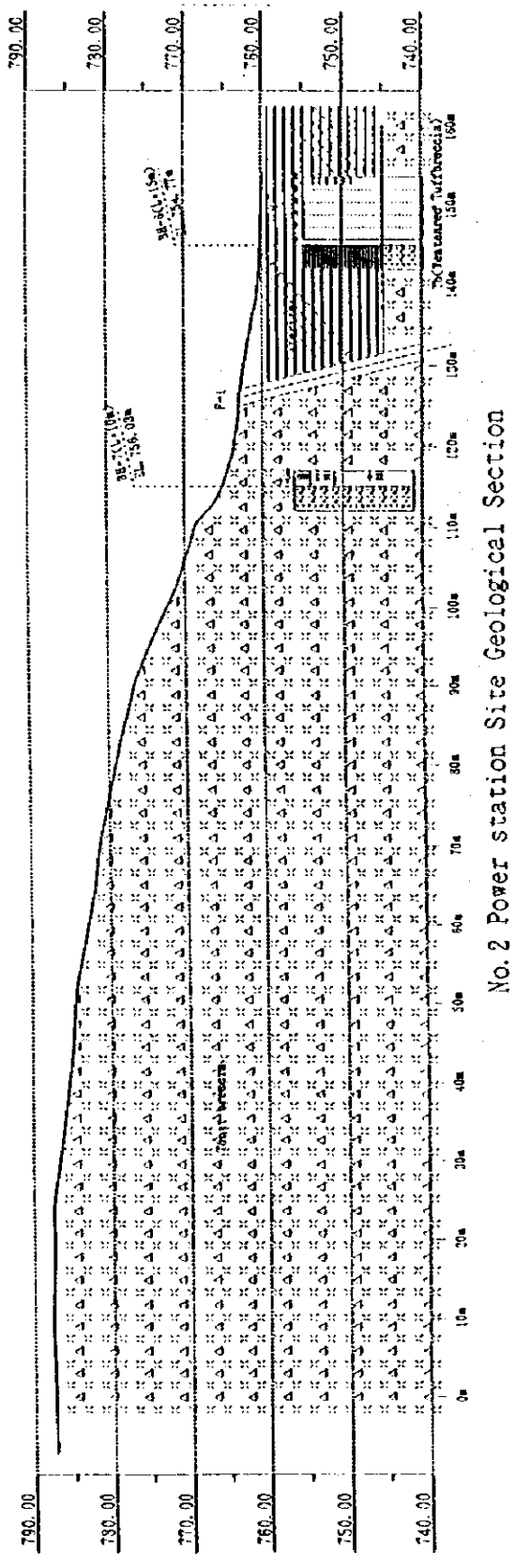
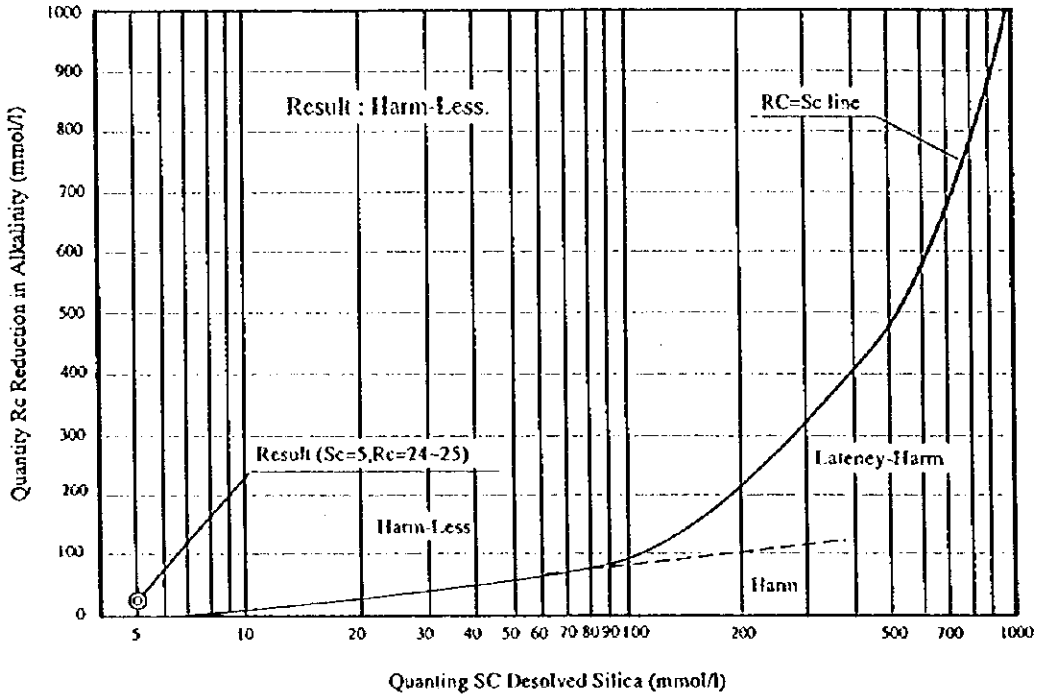


Figure B.4.8
Geology Section of No.2 Power Station Site

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency



Test Result of Alkali Reactivity
(By JIS A 5308)

Figure B.5.1 **Test Result of Alkali Reactivity**	**The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania** Japan International Cooperation Agency

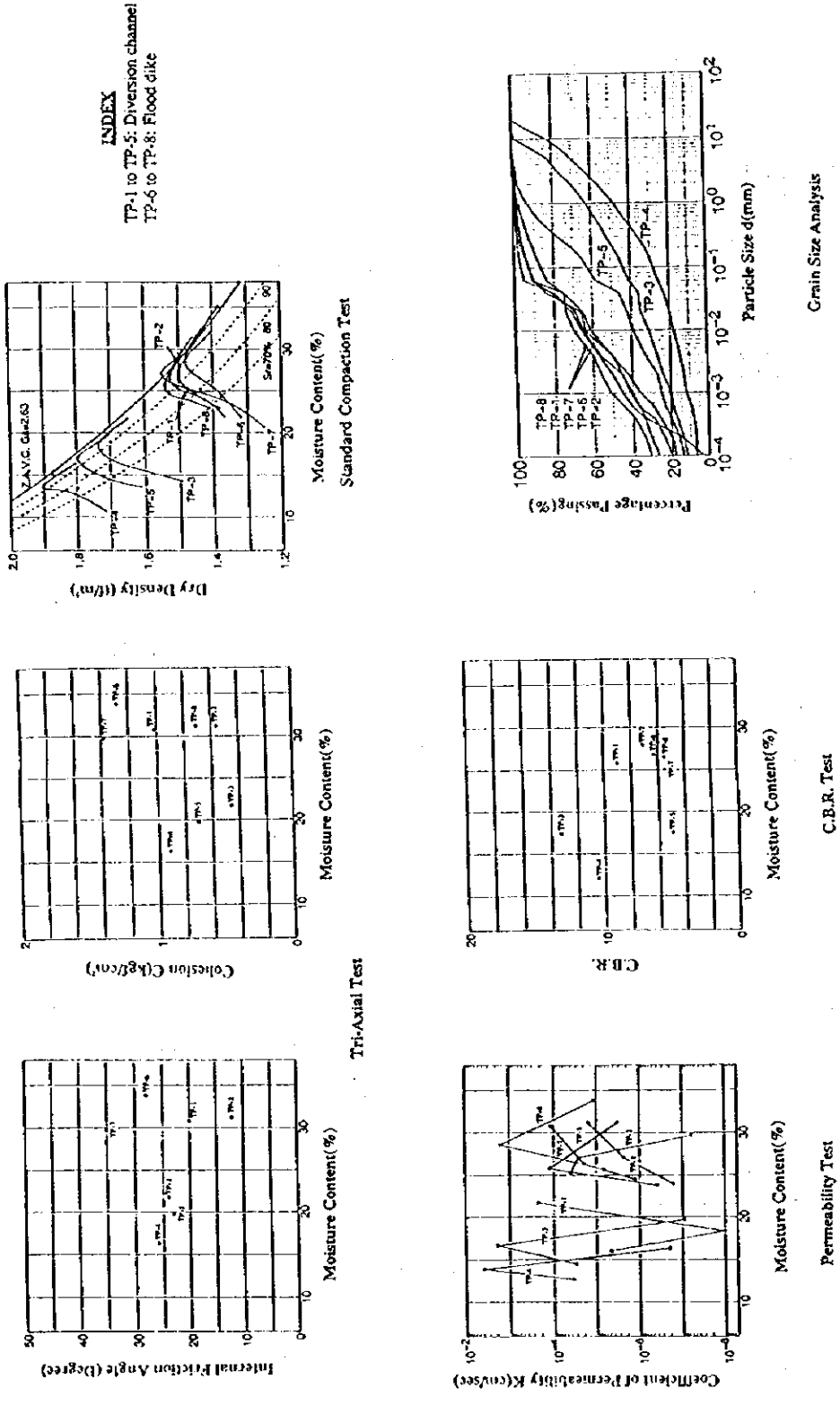


Figure B.6.1
Test Result of Soil Mechanical Test

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

ATTACHMENT-B.1

BORING LOGS (BH-1 TO BH-19)

SPT AND LOG

PROJECT : LMIARD WEIGHT OF HAMMER 65 kg TOTAL DEPTH OF HOLE 10.0 m
HOLE NUMBER : 1 HEIGHT OF DROP 76 cm
GROUND ELEVATION : 749.08 m HOLE LOGGED BY F.R. & S.M

DEPTH (M)	LAYER DEPTH (M)	LAYER THICKNESS (M)	SOIL LOG	COLOUR	DESCRIPTION AND CLASSICATION OF MATERIAL		REMARKS
0							
	0.16	0.16		Dark Brown	Sandy SILTY CLAY	SC-SM	
1	1.00	0.84			CORE LOSS		
2	2.00	1.00		Dark Brown	Sandy silty CLAY of medium to high plasticity.	SC-SM	
	2.45	0.45		"	silty clayey sandy GRAVEL	GC	
3	3.00	0.55		Brown	gravelly sandy silty CLAY	SC-SM	
4	4.34	1.34		"	clayey GRAVELLY SANDY SILT	SM-GM	
5	5.00	0.66		"	Sandy Silty Clayey GRAVEL	GC	
	5.26	0.26		GREY	gravelly SAND	SP	
	5.45	0.19		Brown	Sandy clayey SILT / GRAVEL	GC-GM	
6	6.00	0.55		"	Clayey Silty Sandy GRAVEL	GM	
	6.27	0.27		Brown Grey	Silty sandy GRAVELS	GM-SM	
7	7.00	0.73			CORE LOSS (washed out silty sandy GRAVEL) — GROUND WATER ZONE	GM-SM	collapsed back to 6.0 m depth.
	7.45	0.45		Brown	Sandy Clayey SILT	SM-SC	
8	8.00	0.55			CORE LOSS		
	8.45	0.45		Brown	Sandy Clayey SILT	SM-SC	
9	9.00	0.55		"	Silty Clayey Sandy GRAVEL	GC-SC	
	9.31	0.31		"	Clayey SANDY/GRAVELLY SILT	GM-SM	
10	10.0	0.69		Dark Grey	Sandy Coarse GRAVEL	GP	
11							
12							
13							
14							
15							

DATE	WATER LEVEL (m)
30/5/1997	5.65 m
31/5/1997	6.52
2/6/1997	7.50
3/6/1997	7.85
4/6/1997	7.90 → Mud.

SPT

DEPTH (M)	N/CM	BLOWS (10 20 30 40 50)
1.00		
SPT1	5/30	
1.45 2.00		
SPT2	11/30	
2.45 3.00		
SPT3	42/30	
3.45 4.00		
SPT4	50/19	
4.34 5.00		
SPT5	47/30	
5.45 6.00		
SPT6	50/12	
6.27 7.00		
SPT7	50/30	
7.45 8.00		
SPT8	49/30	
8.45 9.00		
SPT9	50/16	
9.31		

BH1-1

SPT AND LOG

PROJECT LMIARD WEIGHT OF HAMMER 65 kg. TOTAL DEPTH OF HOLE 10.0 m.
HOLE NUMBER 2 HEIGHT OF DROP 76 cm.
GROUND ELEVATION 749.93 m. HOLE LOGGED BY: F.R. & S.M.

	DEPTH(M)	LAYER DEPTH(M)	LAYER THICKNESS (M)	SOIL LOG	COLOUR	DESCRIPTION AND CLASSIFICATION OF MATERIAL	
		0.25	0.25		Dark Brown	Top soil sandy CLAY of medium plasticity	SC
1		1.00	0.75		Dark Brown	Sandy silty CLAY of high plasticity	CH
		1.45	0.45		"	sandy silty CLAY with GRAVELS	SC-CH
		1.85	0.40		"	sandy silty CLAY with little gravels	SC-CH
2		2.00	0.15		"	sandy silty CLAY / GRAVELS	SC-GC
		2.65	0.65		Greyish Brown	clayey sandy GRAVEL	GC
3		3.00	0.35		Dark Brown		
		3.45	0.45		"	Sandy silty CLAY of medium to high plasticity	CH
4		4.00	0.55		Greyish Brown	clayey sandy medium GRAVEL	GC
		4.45	0.45		Brown	clayey silty SAND	SM
5		5.00	0.55		Greyish Brown	clayey sandy GRAVEL	GC
		6.00	1.00		Brown	clayey sandy silty GRAVEL	GM
6		6.23	0.23		Brown	clayey silty SAND	SM
7					Brown	clayey silty sandy GRAVEL	GM
8		8.00	1.77				
		8.44	0.44		Brown	silty sandy GRAVEL (shoe - sandy SILT)	GM-SM
9						WATER FORMATION	
10		10.00	1.56			CORE LOST - only one COBBLE recovered at 10.00 m depth.	
11							
12							
13							
14							
15							

DATE	WATER LEVER
26/5/1997	2.75 m
28/5/1997	6.03 m
30/5/1997	6.57 m
31/5/1997	6.60 m
3/6/1997	6.86 m
4/6/1997	6.86 m Mud level

REMARKS: SPT_1 very high due to friction losses

SPT

	DEPTH (M)	N/CM	BLOWS 10 20 30 40 50
1	1.00		
	SPT1	94/30	
2	1.45		
	2.20		
	SPT2	42/30	
3	2.65		
	SPT3	43/30	
4	3.45		
	4.00		
	SPT4	50/24	
5	4.35		
	5.00	50/3	
	SPT5		
	5.18		
6	6.00		
	SPT6	50/8	
	6.18		
7	7.00		
	SPT7	50/18	
	7.33		
8	8.00		
	SPT8	50/19	
	8.44		
9			
10			
11			
12			
13			
14			
15			

BH-2

SPT AND LOG

PROJECT : LMIARD WEIGHT OF HAMMER 65kg TOTAL DEPTH OF HOLE 6·0m
HOLE NUMBER : 3 HEIGHT OF DROP 76cm
GROUND ELEVATION 750·3m HOLE LOGGED BY F·RWEYEMAMU

DEPTH(m)	LAYER DEPTH(m)	LAYER THICKNESS(m)	SOIL LOG	COLOUR	DESCRIPTION AND CLASSIFICATION OF MATERIAL		REMARKS
0	0·20	0·20		Brown	Top soil-sandy clayey SILT	SM-SC	
1	1·45	1·25		"	sandy silty CLAY	SC-SM	
2	2·00	0·55		"	silty sandy CLAYEY / GRAVEL	GC	
	2·45	0·45		"	silty SAND	SM	V 2.20, 7/6/1997 2.35, 17/6/1997
3	3·00	0·55		"	clayey silty sandy GRAVEL	GM-SM	2.50 2/6/1997 2.70, 11/7/1997
	3·45	0·45		"	silty sandy GRAVEL	GM-SM	
4	4·00	0·55		Dark Grey	silty sandy GRAVEL / COBBLES		At 3.50m boulder encountered.
5	5·00	1·00		"	washed out fine - medium SAND (CORE LOSS) GROUND WATER ZONE		Boulders - bit ground by boulders caving in back to 3.0 m.
	5·40	0·40		"	boulder recovered (very hard)		Double core barrel damaged.
6	6·00	0·60		"	silty fine sandy COBBLES		Bit badly damaged.
7							
8							
9							
10							
11							
12							
13							
14							
15							

DATE	WATER LEVEL (m)
2/6/1997	2·50
3/6/1997	2·10
4/6/1997	2·12
7/6/1997	2·20
17/6/1997	2·35

DEPTH (m)	N/cm
1·00 SPT 1 1·45	6/30
2·00 SPT 2 2·45	4/30
3·00 SPT 3 3·45	12/30
4·00 4·02	50/2
5·00 5·03	50/3
6·00 6·02	50/2

SPT

BLOWS 10 20 30 40 50

SPT AND LOG

PROJECT: LMIARD WEIGHT OF HAMMER 65 kg TOTAL DEPTH OF HOLE 20.0m
HOLE NUMBER: 4 HEIGHT OF DROP 76 cm
GROUND ELEVATION: 754.62m HOLE LOGGED BY F.R & S.M

DEPTH (M)	LAYER DEPTH (M)	LAYER THICKNESS (M)	SOIL LOG	COLOUR	DESCRIPTION AND CLASSIFICATION OF MATERIAL		REMARKS
0	0.22	0.22		Dark Brown	Sandy silty CLAY (Top soil)	SC-SM	
1	1.00	0.78		Brown	Gravelly sandy silty CLAY	SC-SM	
2	2.00	1.00		Brown	Sandy silty CLAY	SC-SM	
	2.45	0.45		"	Silty sandy GRAVEL/CLAY	GC-GM	
3	3.00	0.55		"	Silty clayey sandy GRAVEL	GC	
	3.45	0.45		"	Silty sandy gravelly CLAY	GC	
4	4.45	1.00		"	Sand SILTY CLAY	SC-SM	▽-A.18-7/6
5	5.00	0.55			CORE LOSS		▽ 5.05 - 11/6 ▽ 5.05 - 7/7 5.20 - 11/7
6	6.00	1.00		Black	Washed out coarse SAND BOULDERS		
7	7.00	1.00		Black	Washed out coarse SAND BOULDERS (WATER FORMATION)		Caving in back to 5.50m Drilling water Loss
8	8.70	1.70			COBBLES WITH SAND AT 8.70m caving in back to 6.50m. Drilling water Loss		
9				Dark Brown	Washed out fine SAND with COBBLES		
10							
11	11.00	2.30					
12	12.00	1.00		"	Washed out silty fine SAND COBBLES		
13				"	Washed out silty SAND (Cobbles not caught but being ground by the bit during drilling)		
14							
15							
16	16.0	4.0					

SPT

DEPTH (M)	N/CM	BLOWS 10 20 30 40 50
1.00		
SPT1 1.46	8/30	
2.00		
SPT2 2.46	36/30	
3.00		
SPT3 3.46	29/30	
4.00		
SPT4 4.46	13/30	
5.00	50/3	
5.08		
6.00	50/2	
6.02		
7.00	50/2	
7.02		
8.00	50/4	
8.04		
9.00	50/3	
9.03		
10.00	50/3	
10.03		
11.00	50/2	
11.02		
12.00	50/2	
12.02		
13.00	50/3	
13.02		
14.00	50/2	
14.02		
15.00	50/2	
15.02		
16.00	50/2	
16.02		

SPT AND LOG

PROJECT : LMIARD WEIGHT OF HAMMER 65kg TOTAL DEPTH OF HOLE 10-0m
HOLE NUMBER 5 HEIGHT OF DROP 76cm
GROUND ELEVATION 754·70 HOLE LOGGED BY F. RWEYEMAMU

DEPTH (m)	LAYER DEPTH(M)	LAYER THICKNESS (m)	SOIL LOG	COLOUR	DESCRIPTION AND CLASSIFICATION OF MATERIAL		REMARKS
0							
	0·20	0·20		Dark Brown	Top soil sandy silty CLAY	Sc - Sm	
1	1·00	0·80		Brown	Gravelly silty sandy CLAY	SC-SM	
2	2·00	1·00		Brown	Silty sandy GRAVELLY / CLAY	GC-GM	1·80-11/7/97
	2·45	0·45		"	Clayey silty sandy GRAVEL	GM-SM	-2·00-18/6/1997
3	3·00	0·55		"	silty sandy CLAYEY GRAVEL	GC-GM	
	3·45	0·45		"	clayey silty sandy GRAVEL	GM-SM	
4	4·00	0·55		"	silty sandy CLAYEY GRAVEL	GC-GM	
	4·45	0·45		dark Brown	gravelly clayey silty SAND	SM-SC	
5	5·00	0·55			core loss, boulder ground at 5·0m		bit got stuck at 5·0m depth on 12/6/1997 and removed on 17/6/1997, completely damaged.
6	6·00	1·00		Dark Grey & Brown	Washed out sandy GRAVEL with COBBLES, Water struck at 5·50m.		
7	7·00	1·00		Grey & Brown	Washed out silty sandy GRAVEL		
8	8·00	1·00		Dark Grey + Brown	Washed out SAND (fine medium) + COBBLES, LOSS of mud circulation Broken weathered rock		
	8·70	0·70		Dark Grey	Washed out SAND with COBBLES. At 8.7m:- boulders.		
9							
10	10·0	1·30		Dark Grey	Washed out silty SAND with COBBLES- At 10·0m bit damaged (stopped)		
11							
12							
13							
14							
15							

SPT

DEPTH (m)	N/cm	BLOWS 10 20 30 40 50
1·00		
SPT1	3/30	← Sample test
1·45		
2·00		
SPT2	25/30	
2·45		
3·00		
SPT3	25/30	← Sample test
3·45		
4·00		
SPT4	35/30	
4·45		
5·00	50/2	
5·02		
6·00	50/3	
6·03		
7·00	50/3	
7·03		
8·00	50/2	
8·02		
9·00	50/2	
9·02		
10·00	50/2	
10·02		

III-5

SPT AND LOG

PROJECT: LMIARD WEIGHT OF HAMMER 65kg. TOTAL DEPTH OF HOLE 15.0m.
HOLE NUMBER 6 HEIGHT OF DROP 76cm
GROUND ELEVATION 754.77m. HOLE LOGGED BY F. RWEYEMAMU

DEPTH (M)	LAYER DEPTH (M)	LAYER THICKNESS (M)	SOIL LOG	COLOUR	DESCRIPTION AND CLASSIFICATION OF MATERIAL		REMARKS
0							
1	1.00	1.00		Reddish Brown	sandy silty CLAY of medium to high plasticity	SC-SM	
	1.43	0.43		"	gravelly. sandy silty CLAY	SC-GC	
2				Brown	sandy silty CLAY	SC-SM	
3	3.00	1.57					▽ - 2.70m 26/6
				Brown	gravelly sandy silty CLAY	SC-GC	
4	4.00	1.00					
	4.17	0.17		"	silty SANDY CLAY (highly consolidated)	SC	
	4.50	0.33		Brown	washed out SAND		
5	5.00	0.50		L/Brown	gravelly sandy silty CLAY.	SC-SM	
	5.23	0.23			SPT done, the sampler got stuck not recovered		
	5.80	0.57		Brown	silty clayey SAND	SC-SM	
6	6.00	0.20		"	gravelly sandy silty CLAY + BOULDERS		
	7.00	1.00		Brownish Grey	Washed out SAND (fine to medium)		
7							
	8.00	1.00		"	Washed out SAND (fine to coarse) Water zone.		
8							▽ - 8.20m 27/6
	9.00	1.00		"	Washed out SAND (fine to Medium) Weathered rock ground.		
9							
10	10.00	1.00		"	Washed out fine SAND		
11	11.00	1.00		Grey	Washed out SAND (fine to coarse) Weathered rock ground.		
12				Dark Grey	Washed out SAND (Medium to coarse) (Broken weathered rock)		
13	13.00	2.00					
	13.50	0.50		"	Washed out gravelly coarse SAND (Broken weathered rock)		
	13.80	0.30		"	Washed out SAND		
14	14.00	0.20		"	core recovered		
	14.50	0.50		"	Washed out SAND (fine to Medium)		
15	15.00	0.50		"	Washed out SAND (medium to coarse)		
					11/7/1997 - WATER LEVEL - Dry		

SPT

DEPTH (M)	N/CM	BLOWS 10 20 30 40 50
1	1.00	
	SPT1 50/28	
	1.43	
2	2.00	
	SPT2 50/15	← TEST
	2.25	
3	3.00	
	3.02	
4	4.00	
	SPT4 50/7	← TEST
	4.17	
5	5.00	
	SPT5 50/23	
	5.23	
6	6.00	
	6.02	
7		
8		
9		
10		
11		
12		
13		
14		
15		

BH1-6

GEOLOGIC LOG OF DRILL HOLE

BH-7

PROJECT : LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 7

LOCATION UPARENI DEPTH OF HOLE 10 m. ELEVATION

ANGLE FROM HORIZONTAL -90° LOGGED BY MTOI I.R.K.

BEARING OF ANGLE HOLE CORE RECOVERY 22 %

DEPTH	ROCK NAME	LOG	% CORE RECOVERY	CEMENTATION KIND OF BIT CASING	OBSERVATION OF CORE: COLOUR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE / WATER PRESSURE TEST / LEAKAGE OF DRILLING WATER	DEPTH	ELEVATION
0m	TUFF BRECCIA				BROWN	5	5	5	Top clayey soil	Lu>400		
1			0			3	3	3				
			80			4	4	4	Loss of circulation from 0 - 2m observed but recovered in lower depths.	K>4x10⁻³ cm/s		
			20			2	2	2				
2			100		GREYISH BROWN	5	5	5				
			0			2	2	2		Lu=50.5		
3			100			5	5	5				
			0						Weathered tuff breccia with occasional resistant boulders of rhombo porphyry rich tuff. The tuff is mainly scory and boulders are jointed.	K=5.86x10⁻⁴ cm/s		
4												
5			1<			5	5	5		Lu=22.6		
6												
7												
8			95			3	3	3		K=2.92x10⁻⁴ cm/s		
			0			5	5	5				
9			99			2	2	2				
			0			5	5	5				
10			0			5	5	5				
1												
2												
3												
4												
5												
6												
7												
8												
9												
20												

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GEOLOGIC LOG OF DRILL HOLE

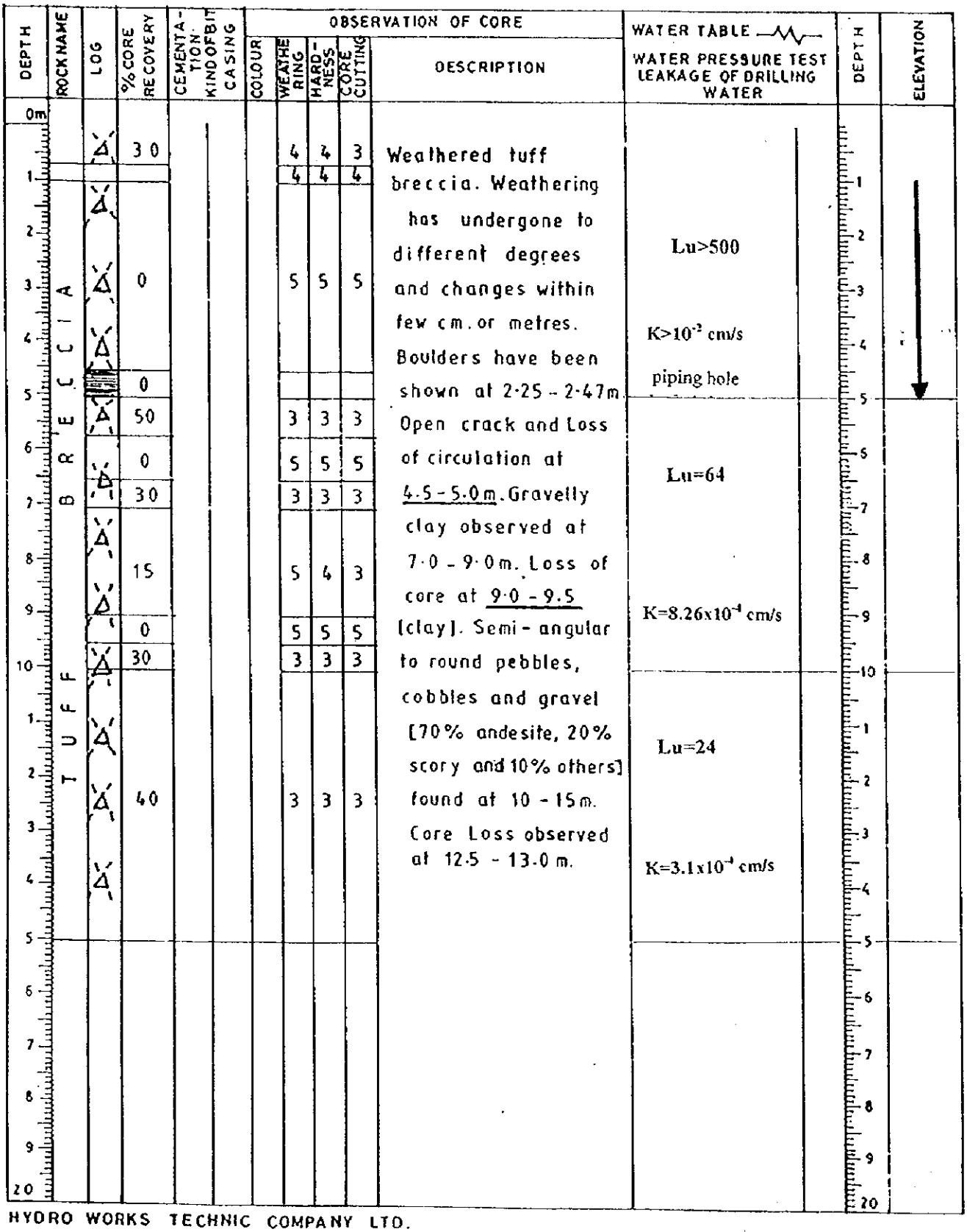
BH-8

PROJECT : LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 8

LOCATION UPARE NI DEPTH OF HOLE 15 m ELEVATION

ANGLE FROM HORIZONTAL -90° LOGGED BY MTOI I.R.K.

BEARING OF ANGLE HOLE CORE RECOVERY 22 %



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GEOLOGIC LOG OF DRILL HOLE

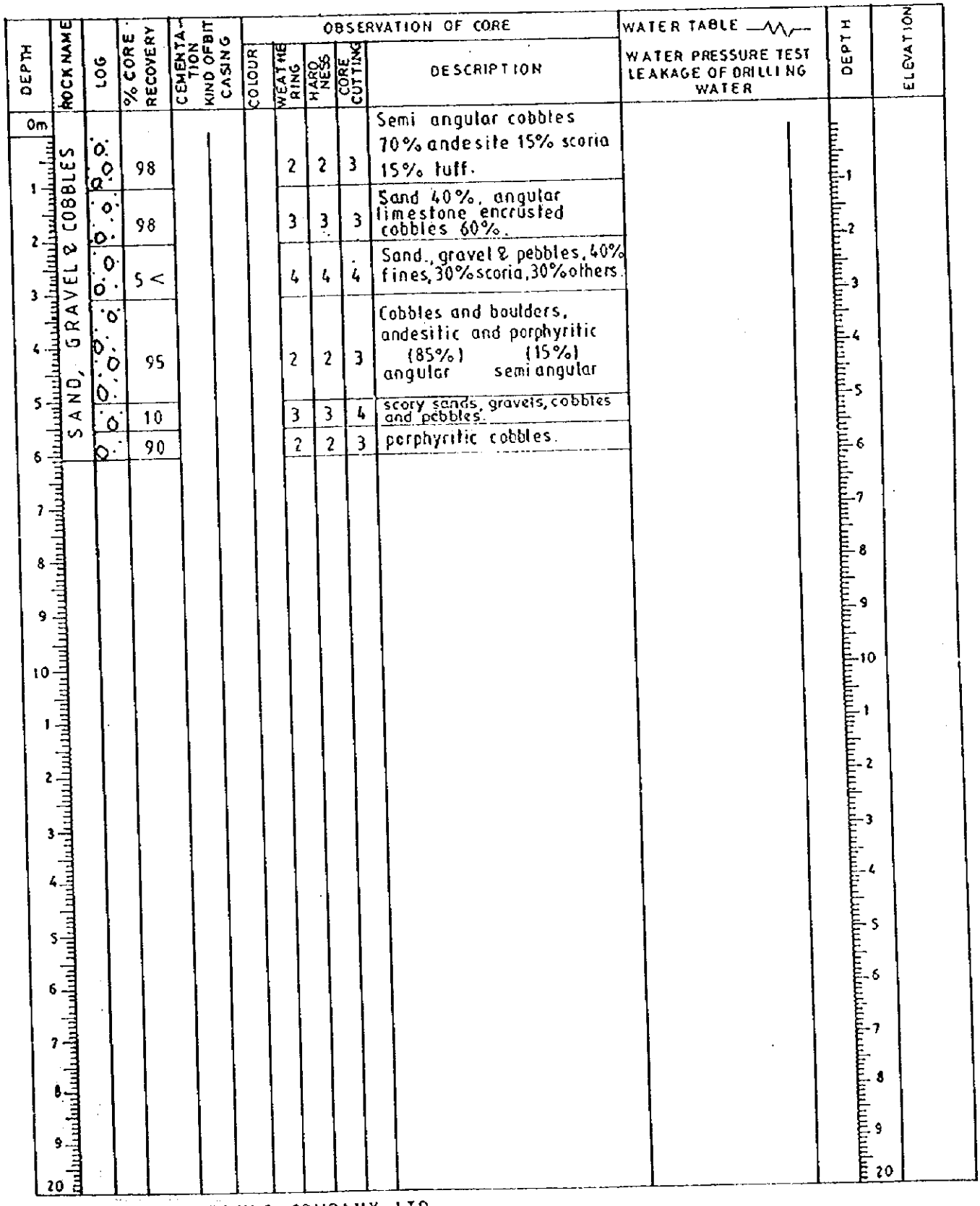
BH-9

PROJECT : LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 9

LOCATION UPARENI DEPTH OF HOLE 6 m. ELEVATION

ANGLE FROM HORIZONTAL -90° LOGGED BY MTOI I.R.K.

BEARING OF ANGLE HOLE CORE RECOVERY 85%



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GEOLOGIC LOG OF DRILL HOLE

BH-10

PROJECT : LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 10

LOCATION LONGOI RIVER DEPTH OF HOLE 10 m ELEVATION 756·49 m

ANGLE FROM HORIZONTAL - 90° LOGGED BY MTOI I.R.K.

BEARING OF ANGLE HOLE CORE RECOVERY 20 %

DEPTH	ROCK NAME	LOG	% CORE RECOVERY	CEMENTATION KIND OF BIT CASING	OBSERVATION OF CORE: COLOUR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE / WATER PRESSURE TEST LEAKAGE OF DRILLING WATER
0m	BRECCIA TUFF		0		BROWN	5	5	5	Top soil light brown	
1			0			4	4	4	Weathered tuff formation	
2			0			3	3	4	Gravel and pebbles and coarse sand	
3			0			4	4	4	Sand, medium angular to semi angular	
4			10			4	4	4	Pebbly weathered formation	Lu=2.9
5			0			5	5	5		
6			95			2	2	2	Tuff Breccia	K=3.74x10⁻⁵ cm/s
7			2<			4	4	4	Weathered tuff with boulders at 9·5–10·0m	
8										
9										
10										
20										

DEPTH / ELEVATION

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GEOLOGIC LOG OF DRILL HOLE

BII-11

PROJECT LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 11

LOCATION _____ DEPTH OF HOLE 10 ELEVATION 795.60 m

ANGLE FROM HORIZONTAL -90° LOGGED BY MTOI I.R.K

BEARING OF ANGLE HOLE _____ CORE RECOVERY 20%

DEPTH	ROCK NAME	LOG	% CORE RECOVERY	CEMENTATION KIND OF BIT CASING	OBSERVATION OF CORE: COLOUR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE / WATER PRESSURE TEST LEAKAGE OF DRILLING WATER	DEPTH	ELEVATION
0 m	TUFF BRECCIA				DARK BROWN	5	5	5	Top Soil			
			0			4	5	5				
1			96					3	Weathered tuff Breccia, fine medium grain size to 5m. Coarse from 5-8 m and medium 9-10 m.		1	
						5	5	5				
2			96			2	2	3			2	
										Lu=2.84		
3			0			5	5	5			3	
4										K=3.52x10⁻⁵ cm/s	4	
5			98			3	3	4	Rhombo porphyry boulders observed at 0.7-1m; 1.61-2.0 m, 4.85-5.0 m, 6.37-6.77 m and 8.77-9 m.		5	
						4	5	5				
6											6	
			95			3	3	4		Lu=1.8		
7											7	
			0			4	5	5				
8										K=2.32x10⁻⁵ cm/s	8	
9			95			3	3	4			9	
			0			5	5	5				
10											10	
20											20	

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GEOLOGIC LOG OF DRILL HOLE

BH-12

PROJECT : LOWER MOSHI INT. AGR AND RURAL DEVELOPMENT HOLE No. 12

LOCATION

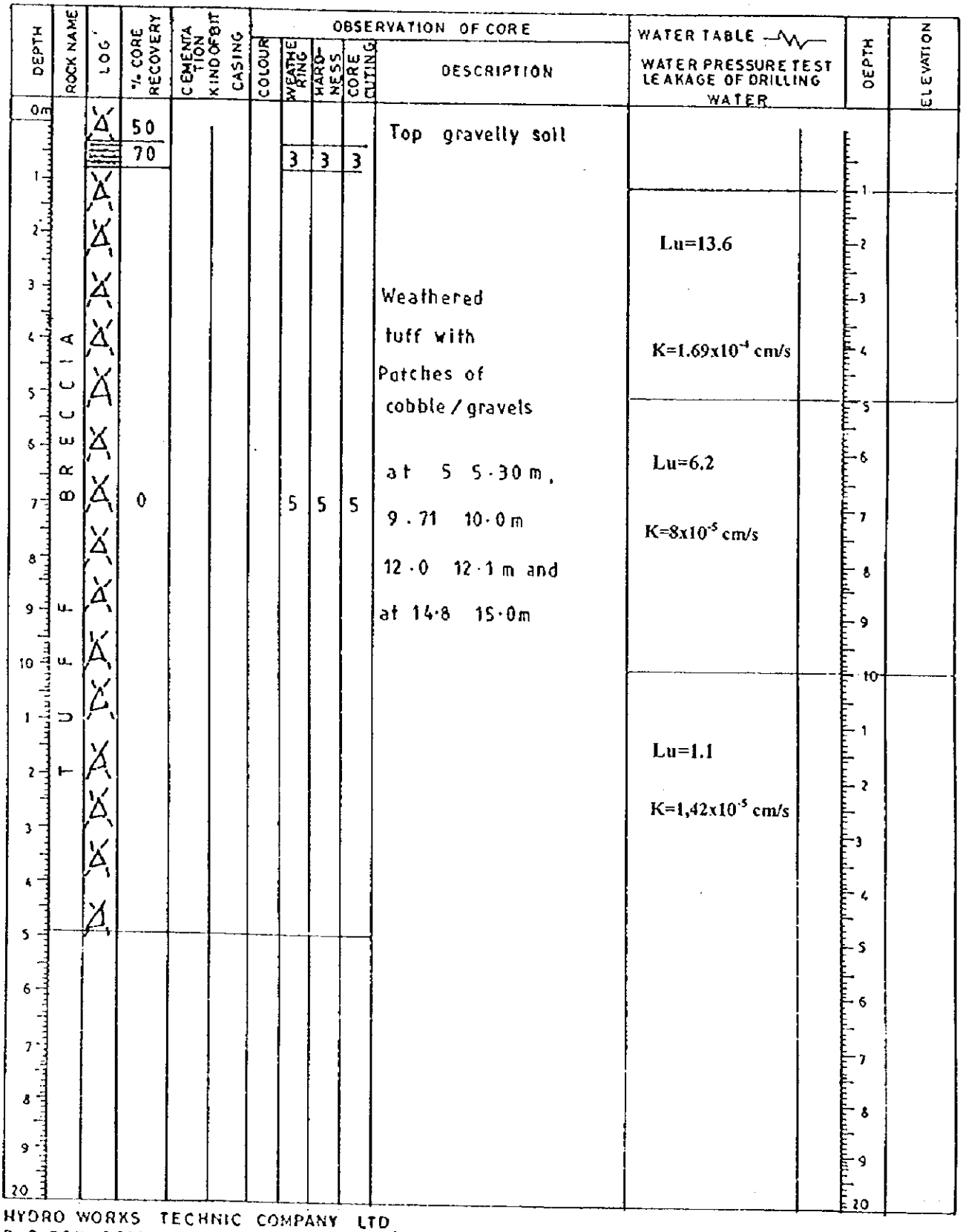
ANGLE FROM HORIZONTAL - 90°

BEARING OF ANGLE HOLE

DEPTH OF HOLE 15 m ELEVATION 824.5 m

LOGGED BY MTOI I.R.K.

CORE RECOVERY 5 < %



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GEOLOGIC LOG OF DRILL HOLE

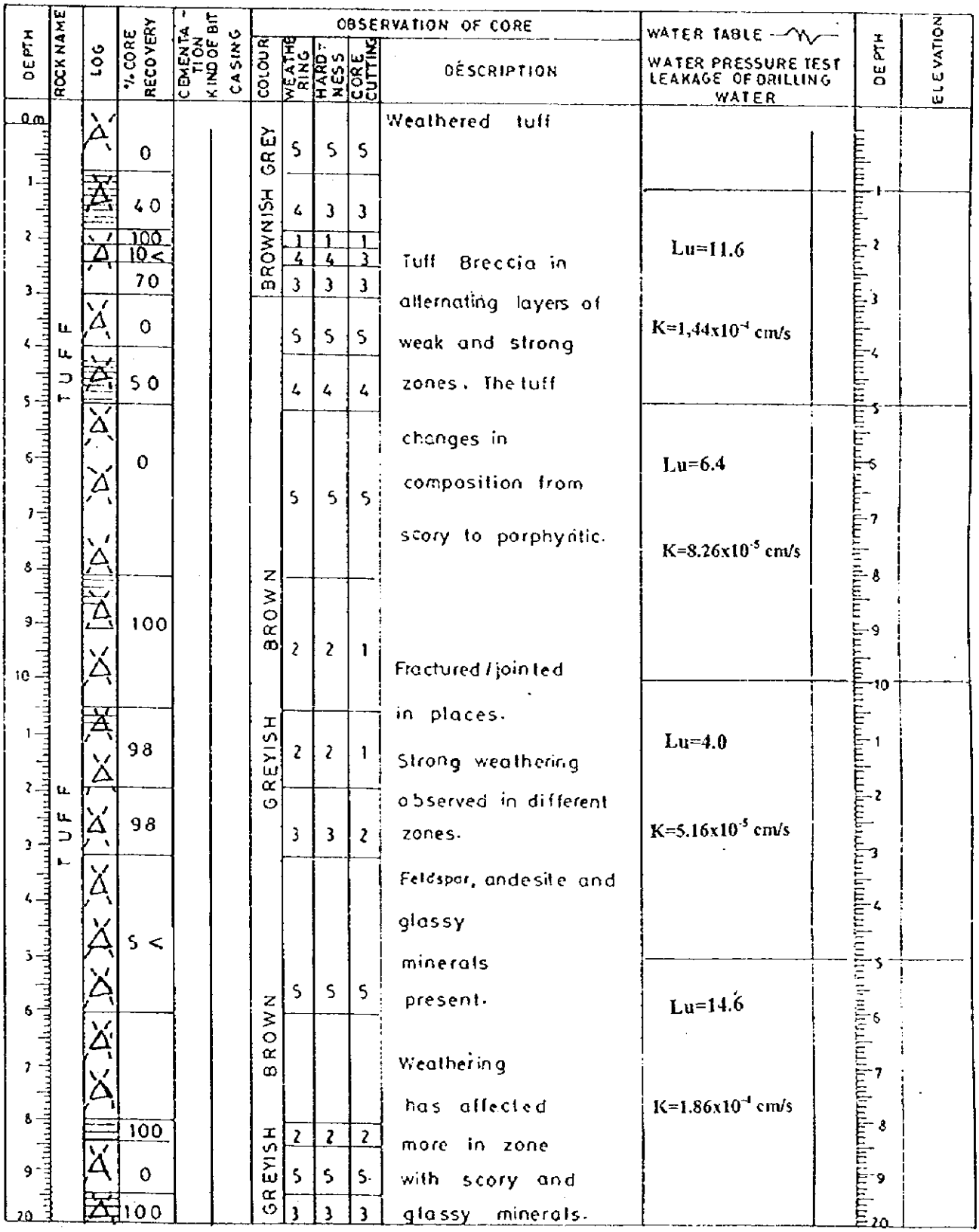
BH-13

PROJECT : LOWER MOSHI INT. AGR. AND RURAL DEVELOMENT HOLE No. 13

LOCATION _____ DEPTH OF HOLE _____ ELEVATION 817.3m

ANGLE FROM HORIZONTAL -90° LOGGED BY MTOI I.R.K.

BEARING OF ANGLE HOLE _____ CORE RECOVERY 80 %



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GEOLOGIC LOG OF DRILL HOLE

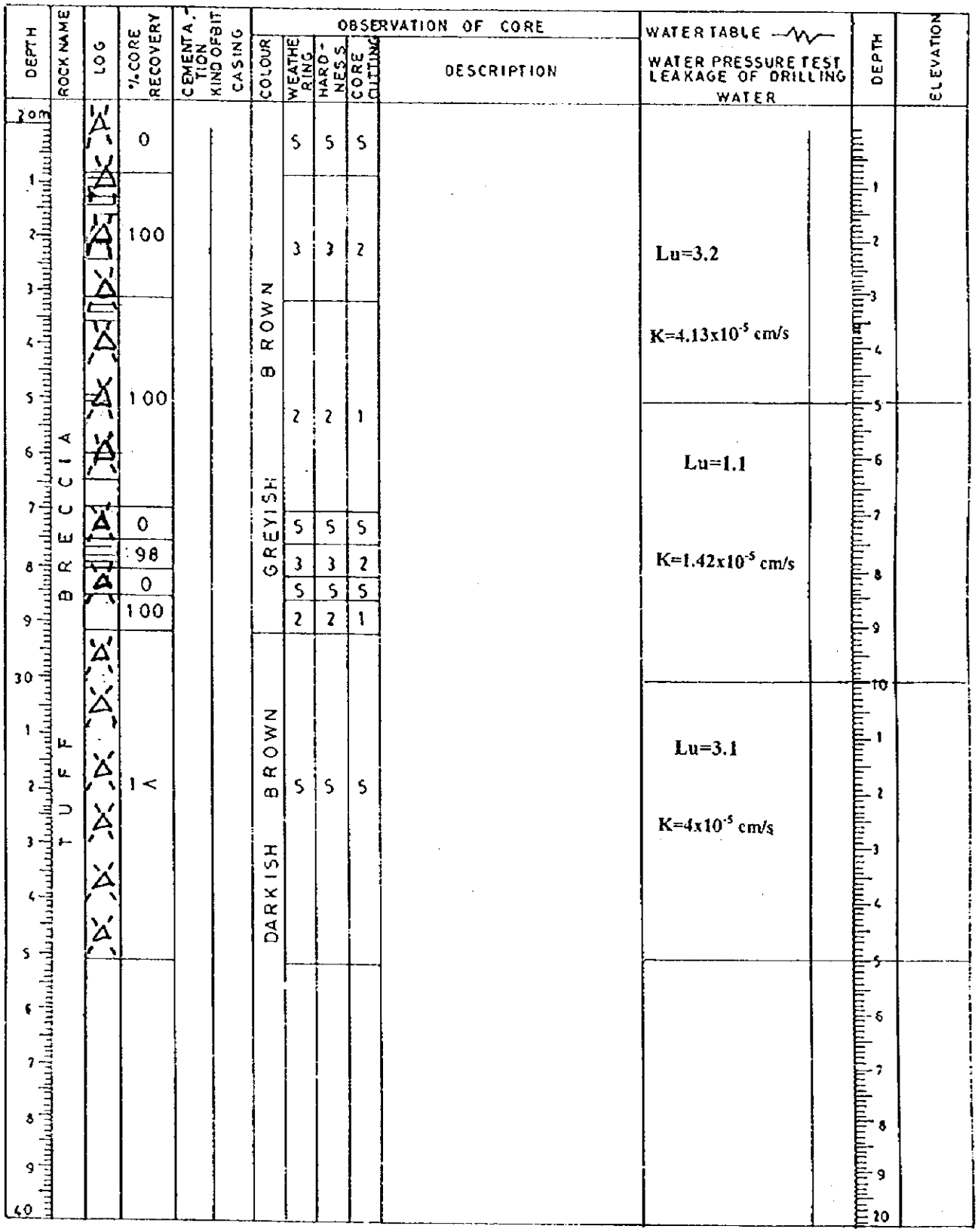
BH-13

PROJECT : LOWER MOSHI INT.AGR.AND RURAL DEVELOPMENT HOLE No. 13

LOCATION _____ DEPTH OF HOLE _____ ELEVATION 817.3m

ANGLE FROM HORIZONTAL -90° LOGGED BY MTOI I.R.K.

BEARING OF ANGLE HOLE _____ CORE RECOVERY 80 %



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GEOLOGIC LOG OF DRILL HOLE

BH-14

PROJECT LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 14

LOCATION

ANGLE FROM HORIZONTAL - 90°

BEARING OF ANGLE HOLE

DEPTH OF HOLE 11

LOGGED BY MTOI I.R.K

CORE RECOVERY 99

ELEVATION 824.1 m

DEPTH	ROCK NAME	LOG	% CORE RECOVERY	CEMENTATION KIND OF BIT CASING	OBSERVATION OF CORE: COLOUR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE / WATER PRESSURE TEST LEAKAGE OF DRILLING WATER	DEPTH	ELEVATION
0m	BRECCIA TUFF		98		GREYISH BROWN	2	2	4	Tuff Breccia 50% ash. 50% (Scoria, felds pars, andesite and glassy minerals joints 0-2m but no open joints. Many small gas pores present. Bedding almost horiz-ontal. Embeded pebbles are 0.4-3cm in diameter.			
1			98			2	2	2		Lu=9.3	1	
2			98			2	2	3			2	
3						2	2	1		$K=1.15\times10^{-4}$ cm/s	3	
4			98			2	2	2			4	
5						2	2	1			5	
6			100			2	2	1		Lu=1.35	6	
7						2	2	2		$K=1.76\times10^{-5}$ cm/s	7	
8											8	
9						2	2	1			9	
10											10	
1											1	
2											2	
3											3	
4											4	
5											5	
6											6	
7											7	
8											8	
9											9	
20											20	

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GEOLOGIC LOG OF DRILL HOLE

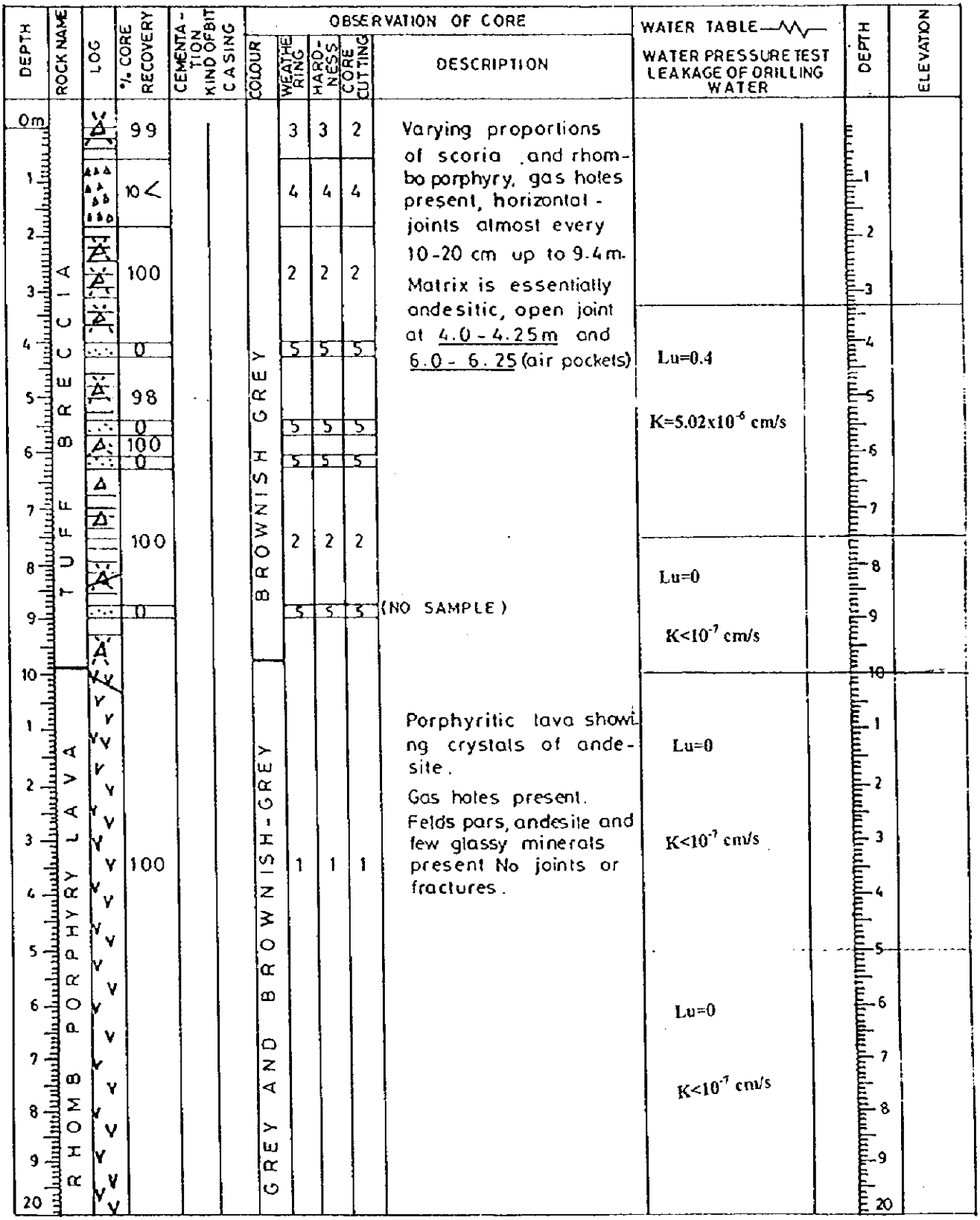
BH-15

PROJECT LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 15

LOCATION _____ DEPTH OF HOLE 40.28 m ELEVATION 814.8 m

ANGLE FROM HORIZONTAL - 90° LOGGED BY MTOI I.R.K

BEARING OF ANGLE HOLE _____ CORE RECOVERY 96.4 %



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DAR ES SALAAM.

—— Fractured / Jointed
—— Welded bed

GEOLOGIC LOG OF DRILL HOLE

BH-15

PROJECT LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 15

LOCATION _____ DEPTH OF HOLE 40.28 m ELEVATION 814.8 m

ANGLE FROM HORIZONTAL 90° LOGGED BY MTOI I.R.K

BEARING OF ANGLE HOLE _____ CORE RECOVERY 96.4 %

DEPTH	ROCK NAME	LOG	% CORE RECOVERY	CEMENTATION KIND OF BIT CASING	OBSERVATION OF CORE: COLOUR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE — WATER PRESSURE TEST LEAKAGE OF DRILLING WATER
0m–5m	RHOMBO PORPHYR LAVA		100		BROWNISH GREY	1	1	1	Porphyritic lava with felds pars, andesite and glass minerals gas pores present and jointed at an angle and in places horizontally jointed. Matrix is andesitic.	Lu=0.02 K=2.4x10⁻⁷ cm/s
5m–10m					DARKISH GREY	2	2	2	Porphyritic lava welded to more darkish matrix at 29.56. more gas pores present and more glassy minerals. Less porphyritic compared to section above core slightly attacked by water in places. Glassy minerals, felds pars and andesite present matrix is trachytic.	Lu=0.03 K=4.4x10⁻⁷ cm/s
10m–35.82m										Lu=0.023 K=2.97x10⁻⁷ cm/s
35.82m–40.28m			100		BROWNISH GREY	1	1	1	Porphyritic lava, few gas pores. Felds pars andesite and few glass present strong to water attack, More gas pores at 35.82m matrix is andesitic.	Lu=0.026 K=3.35x10⁻⁷ cm/s

40.28

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GEOLOGIC LOG OF DRILL HOLE

BH-16

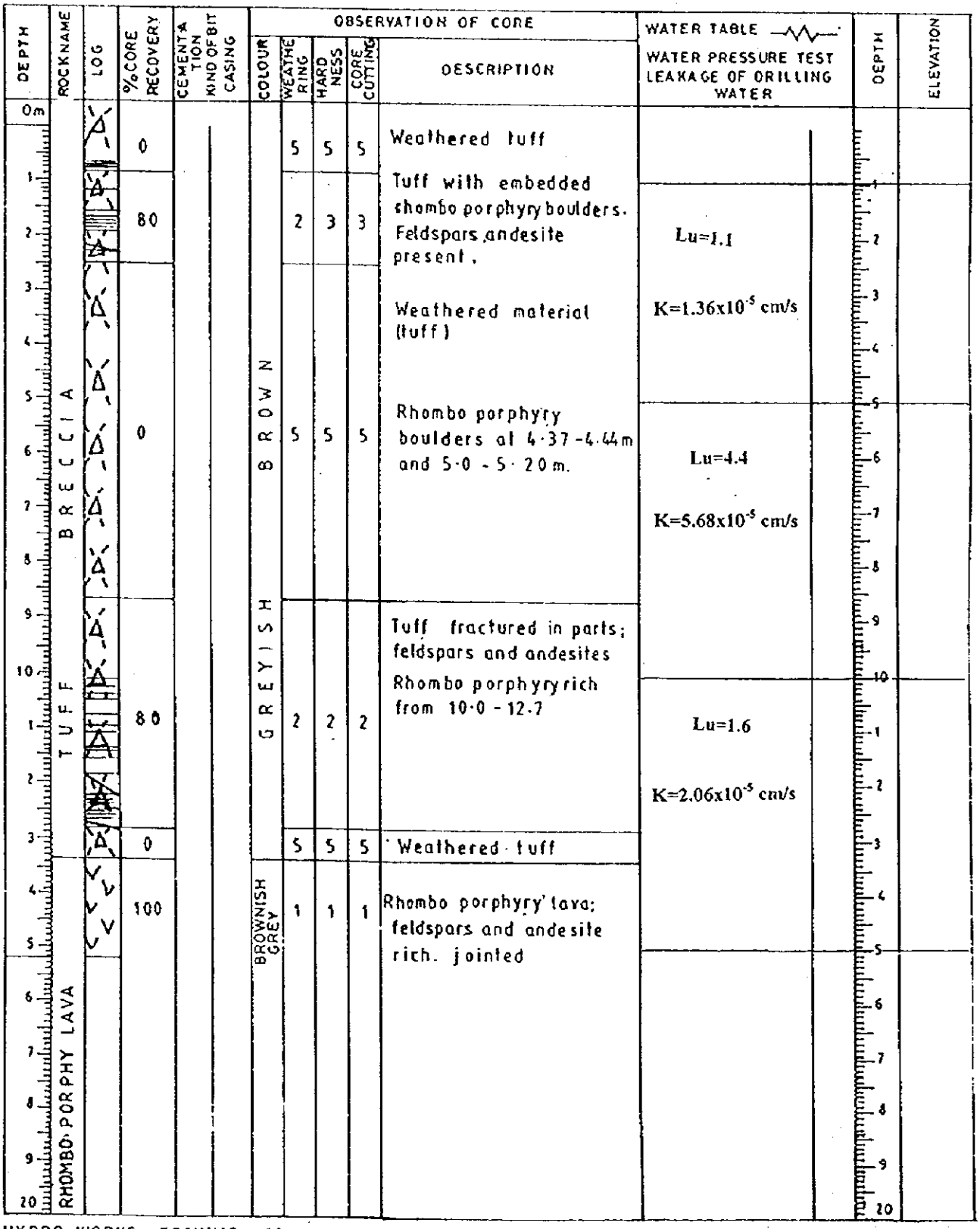
PROJECT : LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 16

LOCATION

ANGLE FROM HORIZONTAL -90° DEPTH OF HOLE 15 m ELEVATION 819.9 m.

BEARING OF ANGLE HOLE LOGGED BY MTOI I.R.K.

CORE RECOVERY 44.8 %



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DAR ES SALAAM

—— Fractured / Jointed

—— Welded bed

GEOLOGIC LOG OF DRILL HOLE

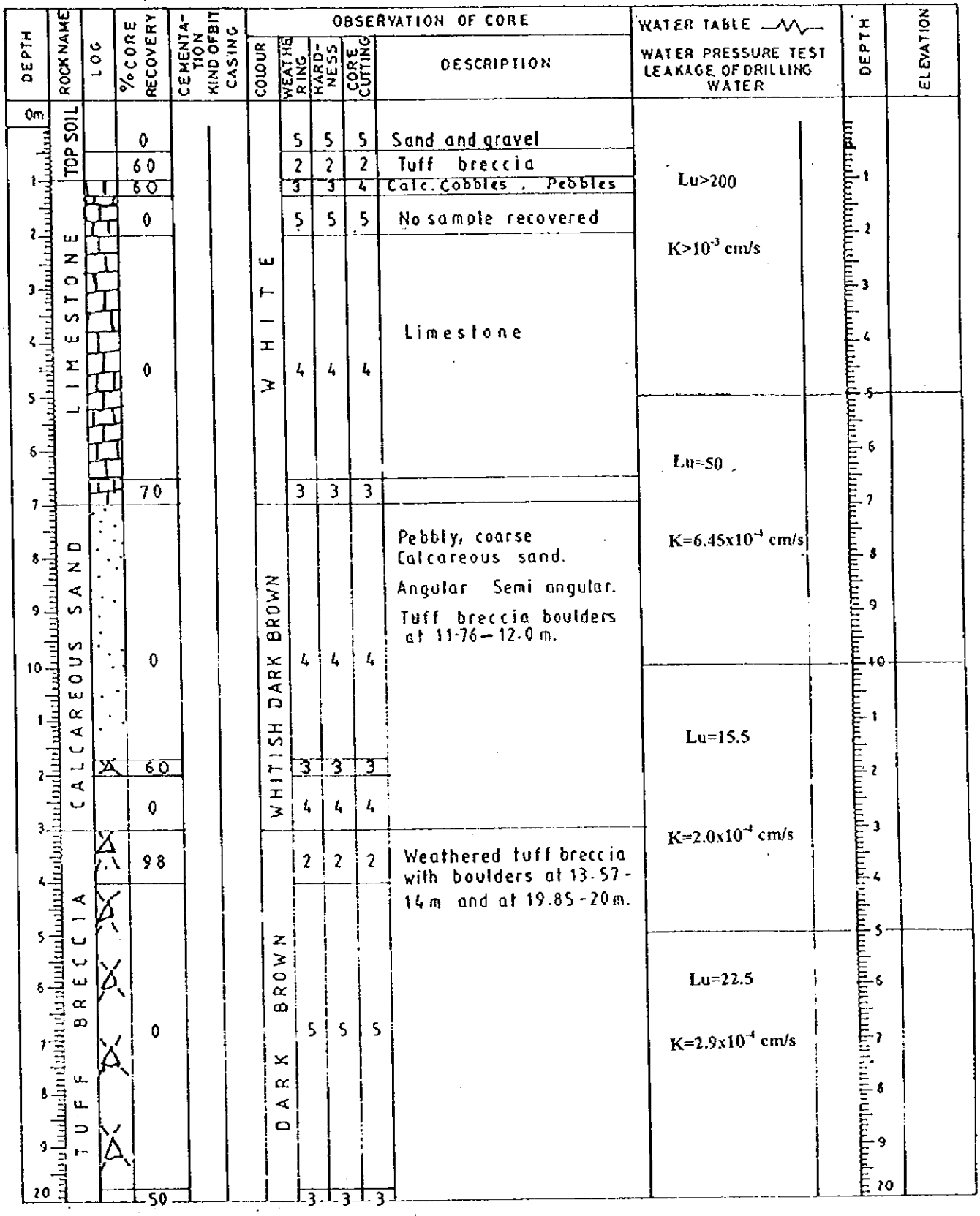
BH-17

PROJECT : LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 17

LOCATION DEPTH OF HOLE 20 m. ELEVATION 821.0m.

ANGLE FROM HORIZONTAL -90° LOGGED BY MTOI I.R.K.

BEARING OF ANGLE HOLE CORE RECOVERY 6 %



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GEOLOGIC LOG OF DRILL HOLE

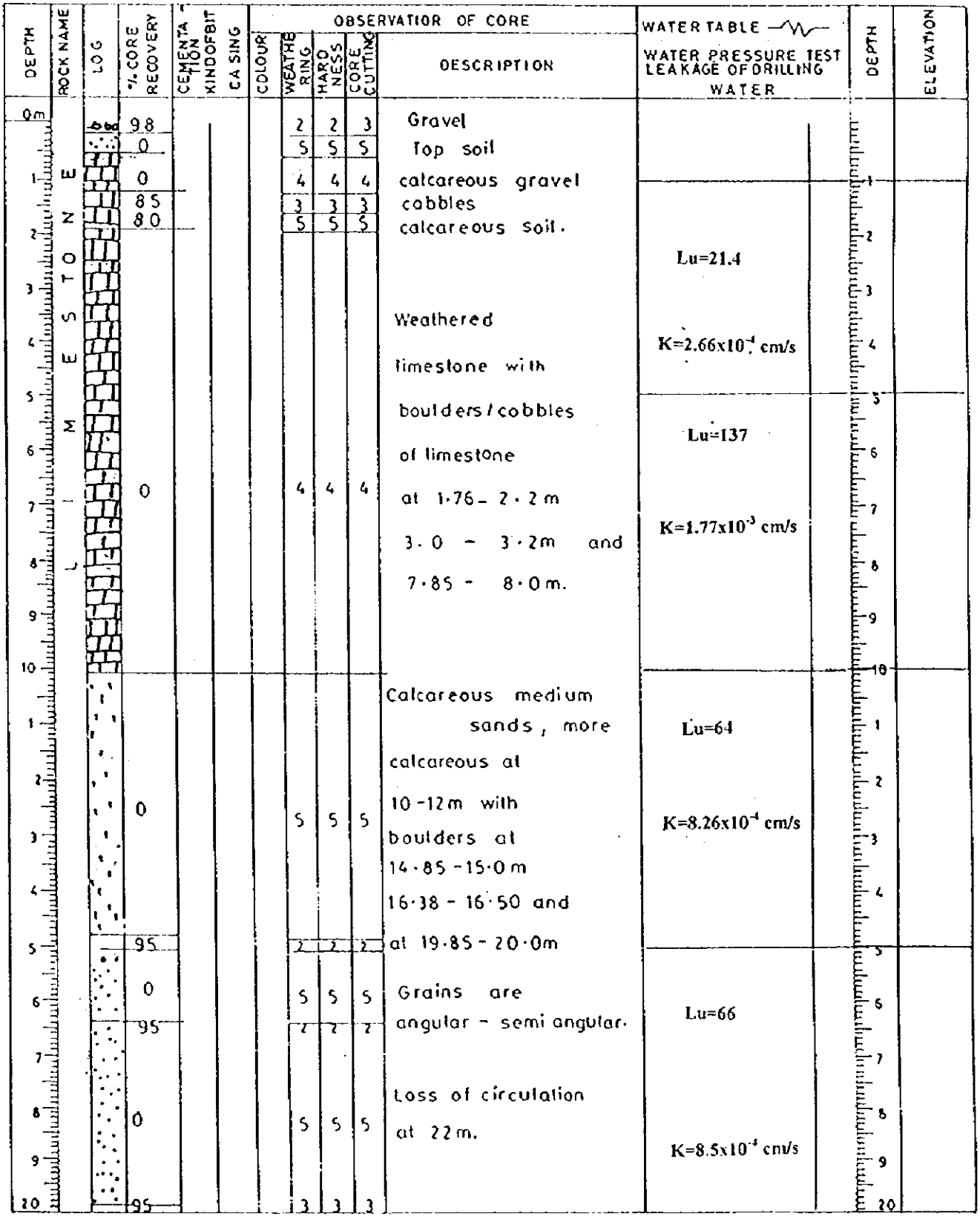
BH-18

PROJECT : LOWER MOSHI INT. AGR. AND RURAL DEVELOPMENT HOLE No. 18

LOCATION _____ DEPTH OF HOLE 20 m ELEVATION 823.5 m

ANGLE FROM HORIZONTAL - 90° LOGGED BY MTOI I.R.K.

BEARING OF ANGLE HOLE _____ CORE RECOVERY 1 < %



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SUMMARY OF PERMEABILITY TEST

BH.No	Testing Depth(m)	Lugeon Unit (Lu)	Permeability k (cm/s)
BH-7	0 - 2	Over 400	$4.0x10^{-3}$
	2 - 5	50.5	$2.9x10^{-4}$
	5 - 10	22.6	$2.9x10^{-4}$
BH-8	0 - 5	Over 500	$>10^{-2}$
	5 - 10	64	$8.3x10^{-4}$
	10 - 15	24	$3.1x10^{-4}$
BH-10	5 - 10	2.9	$3.7x10^{-5}$
BH-11	1 - 5	2.8	$3.5x10^{-5}$
	5 - 10	1.8	$2.3x10^{-5}$
BH-12	1- 5	13.6	$1.7x10^{-4}$
	5 - 10	6.2	$8x10^{-5}$
	10 - 15	1.1	$1.4x10^{-5}$
BH-13	1- 5	11.6	$1.44x10^{-4}$
	5 - 10	6.4	$8.3x10^{-5}$
	10 - 15	4	$5.2x10^{-5}$
	15 -20	14.6	$1.9x10^{-4}$
	20 -25	3.2	$4.1x10^{-5}$
	25 - 30	1.1	$1.4x10^{-5}$
	30 - 35	3.1	$4x10^{-5}$
BH-14	1 - 5	9.3	$1.2x10^{-4}$
	5 - 10	1.4	$1.8x10^{-5}$
BH-15	3.3 - 7.5	0.4	$5.0x10^{-6}$
	7.5 -10	0	less than 10^{-7}
	10 - 15	0	less than 10^{-7}
	15 - 20	0	less than 10^{-7}
	20 - 25	0	less than 10^{-7}
	25 - 30	0	less than 10^{-7}
	30 - 35	0	less than 10^{-7}
	35 - 40	0	less than 10^{-7}
BH-16	1 - 5	1.1	$1.4x10^{-5}$
	5 - 10	4.4	$5.7x10^{-5}$
	10 -15	1.6	$2.1x10^{-5}$
BH-17	0 - 5	Over 200	$K>10^{-3}$
	5 - 10	50	$6.5x10^{-4}$
	10 - 15	15.5	$2.0x10^{-4}$
	15 - 20	22.5	$2.9x10^{-4}$
BH-18	1 - 5	21.4	$2.7x10^{-4}$
	5 - 10	137	$1.8x10^{-3}$
	10 - 15	64	$8.3x10^{-4}$
	15 - 20	66	$8.5x10^{-4}$

ANNEX-C

PHOTOGRAMMETRIC MAPPING AND TOPOGAPHIC SURVEY

ANNEX --C

PHOTOGRAMMETRIC MAPPING AND TOPOGRAPHIC SURVEY

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ANNEX - C

PHOTOGRAMMETRIC MAPPING AND TOPOGRAPHIC SURVEY

1 INTRODUCTION

This ANNEX states the details of the phtogrammetric survey executed in Phase I, the subsequent production of 1/5,000 scale topographic maps by digital photogrammetric mapping method, and topographic survey for the Kikuletwa headworks site, diversion channel route, main canal routes and major structure sites executed in Phase II.

Chapter 1 presents the work volume, work method and final results of phtogrammetric survey executed in Phase I period which were carried out on the sub-contract basis under the supervision of the JICA Study Team.

Chapter 2 states the photogrammetric mapping based on the results of aerial photography and control point surveying conducted in Phase I. As a result, 1/5,000 scale topographic maps were produced by digital photogrammetric mapping method for the proposed headworks site, the proposed diversion channel route and the irrigation area.

Chapter 3 gives the method and results of monumentation, GPS survey, second order levelling, supplementary traversing, longitudinal profile/cross section surveying and plane table survey for the headworks site, diversion channel, irrigation area, and major structure sites, which were executed based on 1/5,000 scale maps and other survey results and information obtained in Phase I.

2 PHOTOGRAMMETRIC SURVEY

Photogrammetic survey including monumentation, pricking, aerial photography, GPS survey, minor order levelling and field verification were carried out by PHOTOMAP INTERNATIONAL in Kenya under the supervision of the JICA Study Team. Details of the survey executed during this field stage are as follows.

2.1 Work Volumes

(a)	Monumentation	:	21 points
(b)	Pricking	:	21 points
(c)	Aerial Photography	:	12 courses, 204 photographs
(d)	GPS Survey	:	21 points
(e)	Minor Order Levelling	:	125 km
(f)	Field Verification	:	170 km^2

2.2 Work Method

2.2.1 Monumentation

Monuments of photo control points were buried at places suitable for maintenance and future use, and monumentation were executed prior to GPS survey in conformity with the Tanzanian specifications. Each of 11 concrete beacons as a control point has been imprinted with a point name and JICA on its surface. Specifications on monumentation are given below, details for which are given in Table C.2.1:

(1) Concrete Beacon

(a)	Number of points	:	11 points
(b)	Size	:	25 cm x 25 cm x 80cm
(c)	Point name	:	GPS4, GPS7, GPS8, GPS10, GPS11, GPS12, GPS15, GPS16, GPS17, GPS18, GPS21

(2) Wooden Peg with Iron Bar

(a)	Number of points	:	10 points
(b)	Size	:	6 cm x 6 cm x 60cm with iron bar dia. 16mm x 1.0 m long
(c)	Point name	:	GPS1, GPS2, GPS3, GPS5, GPS6, GPS9, GPS13, GPS14, GP19,

2.2.2 Pricking of Photo Control Points

Pricking of these 21 horizontal control points were performed on two times enlargements. As for 7 control points which could not be pricked at their precise horizontal positions on the two times enlargements, auxiliary points such as GPS 6AZ, GPS 7AZ, GPS 12AZ, GPS 15AZ, GPS 16AZ, GPS 18AZ, and GPS 21AZ, were selected at nearby features which were clearly identifiable on the enlargements, and then pricked on the enlargements. In order to determine the co-ordinates of these auxiliary points, observations were made for their eccentric elements.

Vertical photo-control points were set up about 500m apart along the minor order levelling routes at points clearly identifiable on the two times enlargements where they were pricked.

2.2.3 Aerial Photography

The following photos were produced for 170,000 ha. of the photogrammetric mapping area:

Roll No.	Run No.	Counter Nos.	No. of Photo Sheets	Photographed Dates
1	C1	1776 - 1787	12	May 17, 1997
1	C2	1792 - 1805	14	May 17, 1997
1	C3	1811 - 1827	17	May 21, 1997
1	C4A	1834 - 1848	15	May 21, 1997
1	C4B	1874 - 1881	8	May 25, 1997
1	C5A	1757 - 1769	11	May 17, 1997
1	C5B	1860 - 1870	13	May 25, 1997
1	C5C	1885 - 1894	10	May 27, 1997
1	C6	1898 - 1926	29	May 27, 1997
1	C7	1930 - 1958	29	May 31, 1997
1	C8	1960 - 1986	27	May 31, 1997
1	C9	1994 - 2012	19	May 31, 1997

Figure C.2.1 indicates the flight index map.

(1) Specifications

(a) Photographing scale : 1/12,500
(b) Aircraft : Piper Navajo
(c) Camera : Wild RC 10, C.F.L=151.19mm
(d) Forward overlap : 60% between plus 5% and minus 5%
(e) Lateral overlap : 30% between plus 5% and minus 5%
(f) Tip and tilt : Not exceed 5 degrees
(g) Film : Panchromatic Aerographic Type (Kodak)

(2) Weather Conditions

It was the rainy season but the weather was relatively good in the Study Area. After the first aerial photography was flown on May 17, 1997, five photographic flights were conducted in total.

(3) Inspection

An inspection of the photographs taken revealed that Photograph No. 1814 in Run 3 had cloud coverage but it did not affect photogrammetric mapping. The photographs thus satisfied the given specifications.

2.2.4 Ground Survey

The ground survey including GPS survey, minor order levelling, field verification, computation and preparation of the descriptions of control points were carried out during Phase I field work.

(1) GPS Survey

GPS survey was carried out for horizontal control of the photogrammetric mapping. By referring to TTP63, 56ST5, 56ST3 and 188ST6 (trigonometrical points) as given points, 21 points from GPS1 to GPS21 were newly established at initially planned locations in the Study Area, and observation and computation were made for these points in the following manner (see Figure C.2.2):

(a) Signals from more than four GPS satellites were received at each control point

simultaneously.

(b) Observation angle of the satellites were more than 15 degrees of the elevation angle.
(c) The observation duration was more than one hour.
(d) The co-ordinate values calculated by GPS survey were referred to WGS-84 ellipsoid.

Observation was made by using three units of Leica GPS receivers. Co-ordinate computation was performed with SKI software, GPS-Net, that comes with the receiver. The co-ordinates as referred to WGS-84 system were converted into values of the Clarke 1880 (Modified New 1960 Arc) ellipsoid of the geodetic co-ordinates system, and then reconverted to plane co-ordinate values of UTM zone 37.

Their horizontal and elevation accuracy met the following requirements:

(a) Horizontal : Plus or minus 10 PPM X distance between simultaneously observed points
(b) Elevation : Plus or minus 10 PPM X distance between simultaneously observed points

(2) Minor Order Levelling

In order to determine the elevations of GPS points and vertical photo control points which were installed at intervals of approximately 500 m on the levelling routes (125 km in total), direct levelling was conducted in five loops and eleven hanging routes as shown in Figure C.2.2. Levelling has started at a given point along the railroad (Bench Mark; A25/1) and closed at other given points (Bench Mark; A25/13. A24/46 and A24/47). Hanging routes which did not connect with any existing point and formed no loop, were surveyed by double running observation. Observation was made using three units of Zeiss Ni2 levels. The results of loop closure and difference of double running observation of hanging routes were within the specified accuracy requirements of 5 cm times square root S (Where S: length of single run in km).

(3) Field Verification

Field verification was made for administrative boundaries, names of rivers, locations of public buildings, land use symbols, etc. with two times enlargements in hand.

(4) Inspection of Ground Survey Results

An inspection of ground survey results (monumentation, GPS survey, minor order levelling, field verification) showed that ground survey were executed within the accuracy requirements as originally planned.

2.3 Final Results of Photogrammetric Survey

(1) Aerial Photography

- Film positives : 1 set
- Contact prints : 3 sets
- Two times enlargements : 1 set
- A flight index map : 1 set

(2) Ground Survey

- Observation data and computation notes of control points : 1 set
- Index chart of control points : 1 set

3 PHOTOGRAMMETRIC MAPPING

Photogrammetric mapping was made from the aerial photographs and ground surveying results. Aerial triangulation, digital mapping, compilation and output were carried out to produce 1/5,000 scale topographic maps.

3.1 Work Volumes

The executed work volumes are shown in Figure C.3.1, and summarized below:

(a)	Aerial triangulation	: 164 models
(b)	Digital mapping	: 170km^2 (1/5,000), 29 sheets (A1 size)
(c)	Compilation	: 29 sheets
(d)	Output	: 29 sheets

3.2 Work Method

3.2.1 Aerial Triangulation

Aerial triangulation was performed on the 1/12,500 scale diapositive films with photo co-ordinates of control points determined using a coordinategraph which included tie points, GPS stations, bench marks, pricked points, as necessary for plotting, and adjustment computations. It was also based on the camera calibration report and GPS surveying/levelling results. Horizontal and vertical co-ordinate values and orientation elements were obtained using the independent model program for digital mapping. The horizontal co-ordinate values were transformed to the Transverse Mercator (TM) map grids projection system.

3.2.2 Digital Mapping

Mapping was made by placing a pair of consecutive aerial photographs (diapositive films) side by side in the analytical stereo-plotter and recreating the photographed features in stereo (by setting orientation elements of the aerial photographs involving positions, rotation, tilts, etc.). By observing the stereo images thus created, 1/5,000 scale map data were generated on all items necessary for map preparation.

Intermediate contour lines were shown at intervals of 1 metres (In some parts of the flat lands, supplementary contour lines were delineated at 0.5-metre intervals). Spot heights were represented by one point for each 5cm by 5cm area.

3.2.3 Compilation

The map data were compiled according to the map symbols and their application rules while referring to the field survey data, and made into 1/5,000 scale topographic maps. Map symbols and their application rules, and marginal design were agreed upon through discussion with the counterparts of Tanzania based on the results of field verification.

3.2.4 Output

Based on the compiled map data, original topographic maps were printed on the polyester base (#500) least subject to expansion/contraction in black ink by laser plotter according to the map symbols and their application rules. The map sheet size was 60cm by 80cm, or A1 size, as measured along the inside neatlines.

3.3 Principal Instruments Employed

(a)	Aerial triangulation	FACOM M760-4 (Fujitsu)	:	1 set
(b)	Digital Mapping	Autograph A8 (with digital recorder)	:	4 sets
(c)	Compilation	Compaq (DISKPRO 5166, etc.)	:	6 sets
(d)	Output	Laser photo plotter	:	1 set

3.4 Final Results of Photogrammetric Mapping

(a) Results of aerial triangulation

- Observation notes/computation sheets : 1 set
- Index chart : 1 sheet

(b) Results of output

-1/5,000 scale original topographic maps : 29 sheets
-1/5,000 scale duplicated topographic maps (sheet No.1to 29) : 1 set

4 TOPOGRAPHIC SURVEY

Topographic survey for the proposed project facility was carried out by Norconsult Limited according to Phase II contract under the supervision of the survey experts of the JICA Study Team. The survey work executed during this field stage is described as follows.

4.1 Scope of Work and Accuracy

(1) Scope of Work

The scope of work under the contract is as follows, details for which are given in Figure C.4.1:

(a) Ground control survey
- Monumentation : 11 points
- GPS Survey : 11 points
- Second Order Levelling : 59 km
- Supplementary Traversing : 100 points

(b) Plane Table Survey : 160,000 m^2

(c) Axis Survey at Headworks : 200 m

(d) Route Survey for Diversion Channel : 24 km

(e) Route Survey for Irrigation Canals : 26 km

(2) Accuracy

Following criteria are applied for the accuracy of survey work:

Item	Limitation	Remarks
GPS survey	± 10 PPM	Table C.4.1
Second order levelling	5 mm square root S	S in km, TableC.4.2
Supplementary traversing		
- Angle	± 30 second square root N	N in total number of angles
- Horizontal	1/1000	
Minor order levelling	5 mm square root S	S in km
Cross section survey		
- Horizontal coordinate	1/300	
- Vertical	5 cm ± 15 cm square root S	S in km
Topographic survey		
- Horizontal	1/4000	
- Vertical	2 cm square root S	S in km

(3) Drawing Scale

Drawing scale of survey results are as follows:

(a) Plane table survey
- Scale;1:200,contour interval;0.5m

(b) Axis survey at headworks

Section	Horizontal scale	Vertical scale
Longitudinal section	1:200	1:200
Cross section	1:100	1:100

(c) Longitudinal and cross section survey

Section	Horizontal scale	Vertical scale
Longitudinal section	1:2000	1:100
Cross section	1:100	1:100

The index chart for topographic survey is shown in Figure C.4.1

4.2 Ground Control Point Survey

The method of ground control point survey instead of traversing was employed for GPS observation. The control point survey was executed to cover the entire survey area, and established the bench marks (concrete monument: 0.15 m x 0.15 m x 0.60 m) prior to the commencement of survey work. The work was executed by referring to BMK4, GPS13, and other points as given points with known X-Y co-ordinates.

After the establishment of the GPS control points, second order levelling was performed to establish a levelling network. Total length of levelling work executed was approximately 59 km along the diversion channel route from the headworks site to the irrigation area as well as along canals in the irrigation area. For the levelling work, existing bench marks of A24/46,A25/1,A25/5 were referred to as given points.

In addition to the said survey, supplementary control points with approximately 100 points were established at respective survey sites such as the headworks site, diversion channel route and irrigation canal route.

4.3 Axis Survey at Headworks Site

Axis survey at the headworks was executed with following criteria:

(a) longitudinal profile : length 200m
(b) Cross section : pitch 10m

4.4 Route Survey of Diversion Channel and Irrigation Canals

Route survey for the diversion channel and irrigation canals at the extension area and expanded area were executed by referring to the GPS control points and supplemental control points.

On the centre line and I.P. points, wooden pegs having dimensions of 6 cm x 6 cm x 70 cm were installed, and a pitches of centre pegs were 50 m. In line with the centre line survey, cross section survey was also executed at each centre line point with a width of 50 m for diversion channel, and 20 m for irrigation canals.

4.5 Plane Table Survey

Plane table survey with a scale of 1:200 was executed at the headworks site, diversion channel route and irrigation area at the extension and expanded area.

The total area surveyed was 160,000 m^2 and details are as follows:

(a) Headwork : 20,000m^2
(b) Diversion channel : 93,000m^2 (6 sites)
(c) Irrigation canals : 31,000m^2 (4 sites)
(d) Others : 16,000m^2 (3 sites)

Tables

Table C.2.1 Final Height & Coordinates of GPS and Auxiliary Points

Point Name	Elevation in m		Co-ordinates in m	
	Pricking	Ground	N	E
GPS 1	788.891	788.20	9,628,358.195	316,127.127
GPS 2	768.403	768.31	9,626,398.362	316,085.246
GPS 3	765.419	765.22	9,626,707.901	321,808.592
GPS 4	774.025	774.00	9,624,859.330	311,573.115
GPS 5	749.522		9,624,810.996	321,622.470
GPS 6	753.266	752.92	9,622,869.627	312,875.224
GPS 6AZ	752.998		9,622,929.351	312,858.877
GPS 7	744.903	744.71	9,623,130.506	318,803.461
GPS 7AZ	744.603		9,622,964.105	318,950.195
GPS 8	809.461		9,620,886.898	308,253.510
GPS 9	724.387	724.31	9,620,868.213	324,767.431
GPS 10	832.198		9,618,992.361	300,519.653
GPS 11	728.078	728.09	9,618,771.400	319,209.421
GPS 12	831.781		9,616,695.712	300,610.359
GPS 12AZ	831.787		9,616,622.303	300,600.133
GPS 13	726.635	726.45	9,617,056.989	316,865.937
GPS 14	717.224		9,616,603.432	326,250.965
GPS 15	824.016	824.12	9,614,944.325	302,542.297
GPS 15AZ	822.750		9,614,935.538	302,594.720
GPS 16	757.658		9,615,426.801	309,452.479
GPS 16AZ	759.304		9,615,532.063	309,430.240
GPS 17	713.303		9,614,866.533	323,978.575
GPS 18	800.363		9,612,947.013	304,575.906
GPS 18AZ	801.001		9,612,882.385	304,545.795
GPS 19	711.069		9,613,061.094	320,735.168
GPS 20	710.164	708.94	9,610,830.339	314,017.492
GPS 21	771.654		9,618,442.062	308,938.370
GPS 21AZ	758.459		9,618,275.774	309,077.861

Table C.4.1 Accuracy Control Table for GPS Survey (1/2)

ROTATION UNKNOWN

Group no.	Gon/degree	S.D.
1	0.00025	0.00005

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SATELLITE - OBSERVATIONS

Station	Target	Grid bear. / Vert.angle / Distance	Correction	S.D.	Limit *	Judgement
RAVJI	BM04	162.39155	-0.00007	0.00006		
		90.33300	-0.00015	0.00011		
		6602.693	-0.00569	0.01474	0.06602	Accepted
RAVJI	BM05	168.07057	0.00000	0.00012		
		90.34012	0.00000	0.00023		
		6587.701	0.00000	0.01821	0.06587	Accepted
RAVJI	BMK4	224.49032	-0.00002	0.00002		
		89.56261	0.00044	0.00006		
		16798.268	-0.01997	0.03173	0.16798	Accepted
BM04	BM02	245.44149	0.00003	0.00003		
		89.39304	0.00034	0.00007		
		12096.886	-0.00692	0.01461	0.12096	Accepted
RAVJI	BM02	218.47153	-0.00001	0.00003		
		89.58086	0.00029	0.00007		
		14462.609	-0.00761	0.02971	0.14462	Accepted
BM04	BM03	269.39336	-0.00000	0.00007		
		89.33575	0.00004	0.00017		
		7875.823	-0.00018	0.01989	0.07875	Accepted
RAVJI	BM03	222.56036	-0.00002	0.00007		
		90.01510	-0.00004	0.00016		
		8672.220	0.00048	0.02229	0.08672	Accepted
BM04	BM08	356.33553	-0.00003	0.00006		
		89.43173	0.00006	0.00013		
		5795.803	0.01867	0.01342	0.05795	Accepted
RAVJI	BM08	107.41114	0.00004	0.00010		
		91.13007	-0.00007	0.00022		
		1701.723	0.00007	0.00563	0.01701	Accepted
BM04	BM011	165.01178	0.00003	0.00012		
		90.13122	0.00002	0.00021		
		4792.435	0.00366	0.01310	0.04792	Accepted
BM08	BM011	171.20324	-0.00002	0.00007		
		90.15122	-0.00005	0.00011		
		10535.083	-0.01790	0.02268	0.10535	Accepted

* Limit = Distance x 10 PPM = Distance x 0.00001

Table C.4.1 Accuracy Control Table for GPS Survey (2/2)

SATELLITE - OBSERVATIONS
****

Station	Target	Grid bear. / Vert.angle / Distance	Correction	S.D.	Limit *	Judgement
BM04	BM06	97.31247	0.00001	0.00007		
		90.08363	-0.00017	0.00016		
		3881.804	0.00073	0.00972	0.03881	Accepted
BM08	BM06	146.18402	-0.00009	0.00006		
		90.17128	-0.00009	0.00012		
		7563.973	-0.01015	0.01772	0.07563	Accepted
BM04	BM07	104.02090	0.00000	0.00012		
		90.09015	0.00000	0.00023		
		4392.483	0.00000	0.01250	0.04392	Accepted
BM04	BM09	16.45243	-0.00000	0.00008		
		89.49278	0.00001	0.00018		
		5980.618	-0.00341	0.01526	0.05980	Accepted
BM06	BM09	341.11126	0.00006	0.00008		
		89.45229	-0.00001	0.00016		
		6586.811	0.00272	0.01747	0.06586	Accepted
BM04	GPS13	174.41033	0.00010	0.00008		
		90.14165	-0.00033	0.00017		
		4044.152	0.00524	0.01080	0.04044	Accepted
BM06	GPS13	224.37589	0.00005	0.00008		
		90.04565	-0.00028	0.00016		
		4944.359	0.00534	0.01453	0.04944	Accepted
BM04	BM10	22.58502	-0.00001	0.00008		
		89.50066	-0.00000	0.00017		
		6115.957	0.00020	0.01577	0.06115	Accepted
BM06	BM10	346.36597	0.00000	0.00008		
		89.45083	0.00000	0.00017		
		6310.204	-0.00082	0.01673	0.06310	Accepted
BM02	BM01	177.40226	-0.00003	0.00016		
		90.25058	0.00001	0.00021		
		304.517	-0.00042	0.00220	0.00304	Accepted
RAVJI	BM01	218.00243	-0.00001	0.00003		
		89.58397	0.00047	0.00007		
		14693.354	0.03334	0.03048	0.14693	Accepted
BM02	BM01	177.40226	-0.00003	0.00016		
		90.25058	0.00001	0.00021		
		304.517	-0.00042	0.00220	0.00304	Accepted
BM02	BMK4	256.59045	-0.00008	0.00010		
		89.48339	0.00032	0.00022		
		2853.706	-0.00004	0.00765	0.02853	Accepted

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* Limit = Distance x 10 PPM = Distance x 0.00001

Table C.4.2 Accuracy Control Table for Levelling

Differences in the Leveling Routes

Route No	Distance (km)	Err (mm)	Limit (mm)	Judgement
I	9.388	+2	15	Accepted
II	14.829	−2	19	Accepted
III	18.721	+7	21	Accepted
IV	0.616	+1	3	Accepted
V	9.444	−4	15	Accepted
VI	4.772	−3	10	Accepted
VII	0.745	+1	4	Accepted
VIII	0.932	+1	4	Accepted
Total	59.447			
Loop I	22.466	10	23	Accepted
Loop II	8.517	11	14	Accepted

* Limit = 5mm$\sqrt{\text{Distance (km)}}$

Figures

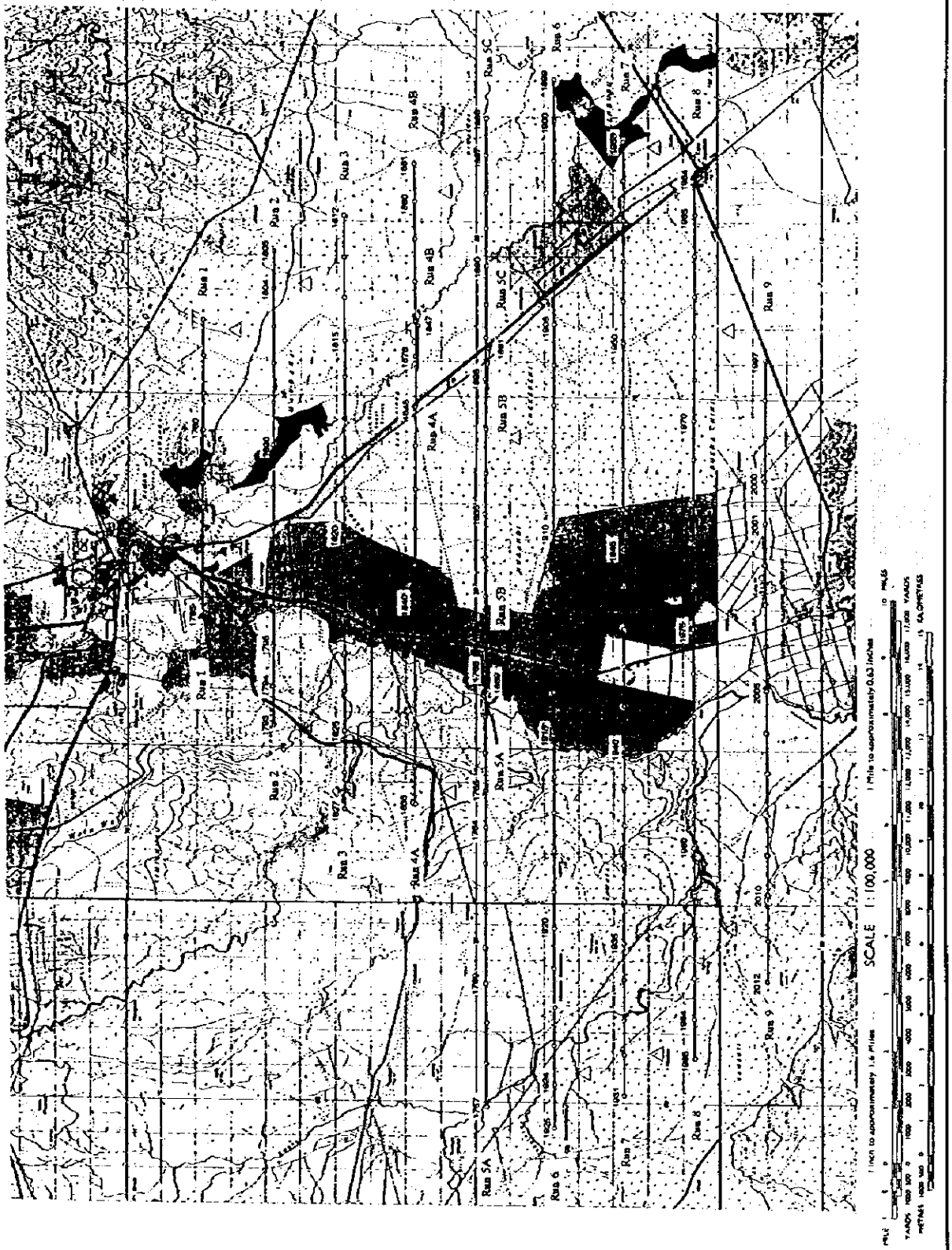

Figure C.2.1
Flight Index Map

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

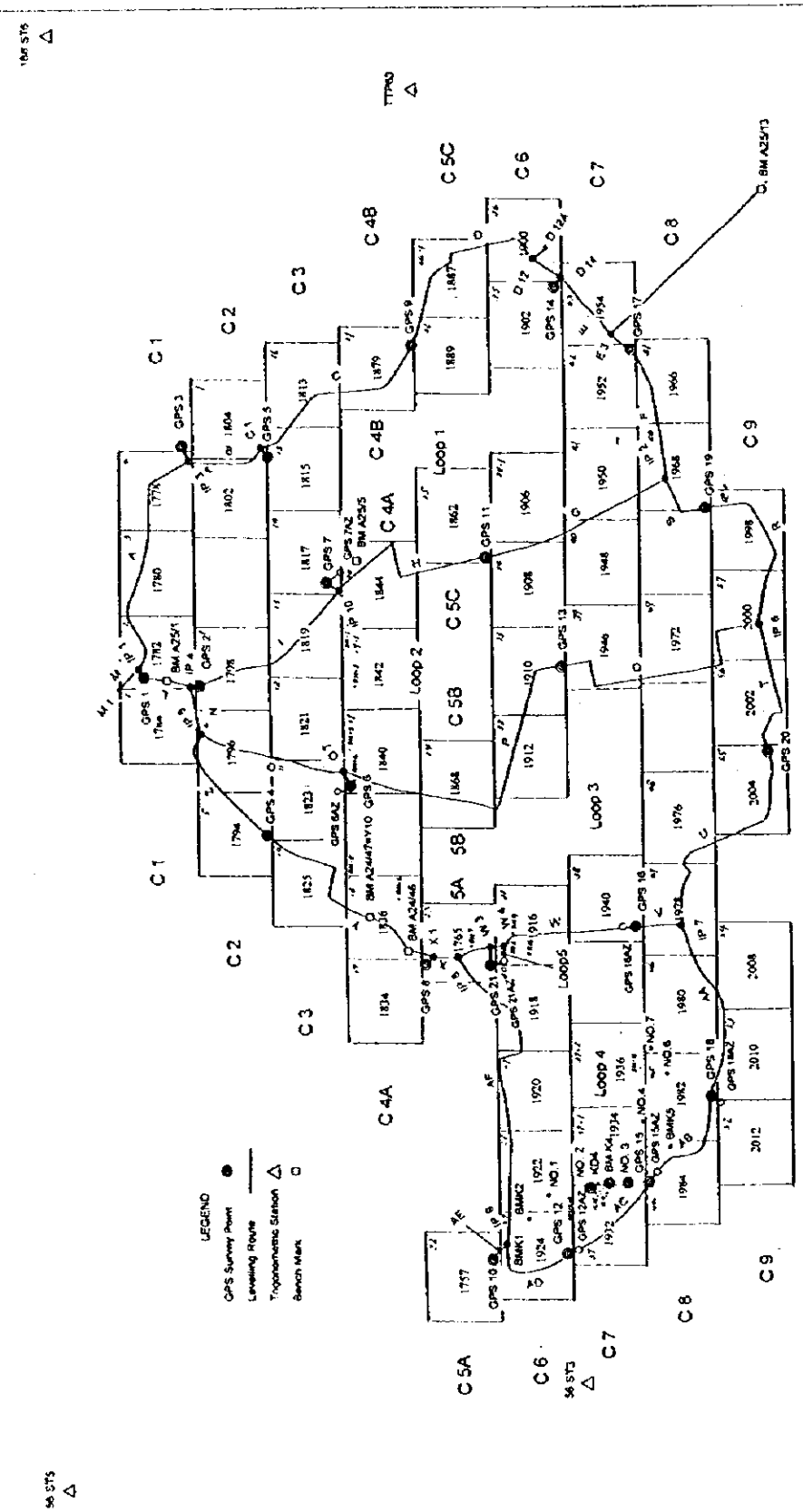

Figure C.2.2
Index Chart for GPS Survey and Levelling

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

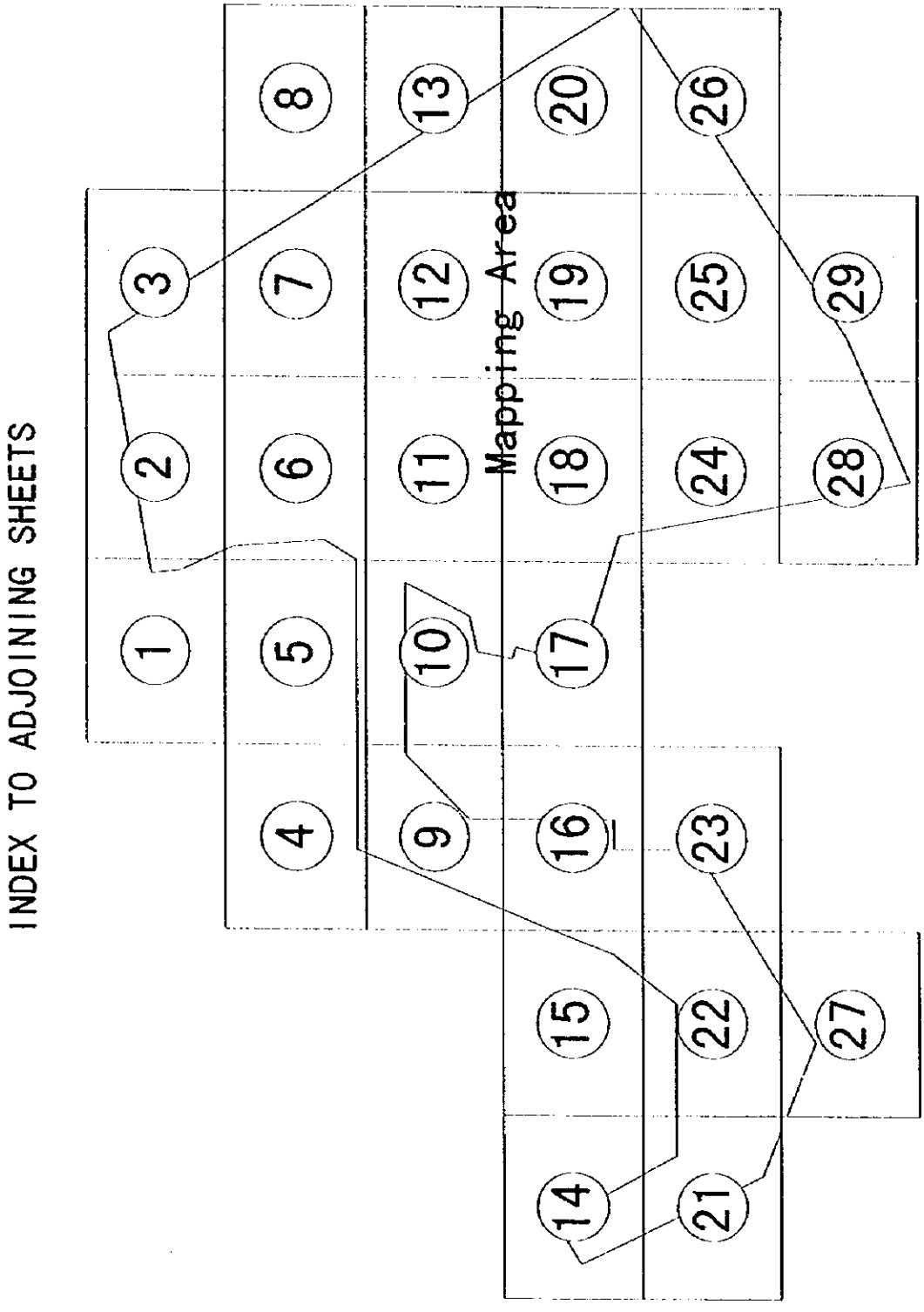

Figure C.3.1
Index to Adjoining Sheets

The Feasibility Study on Lower Moshi Integrated Agriculture and Rural Development Project in the United Republic of Tanzania

Japan International Cooperation Agency

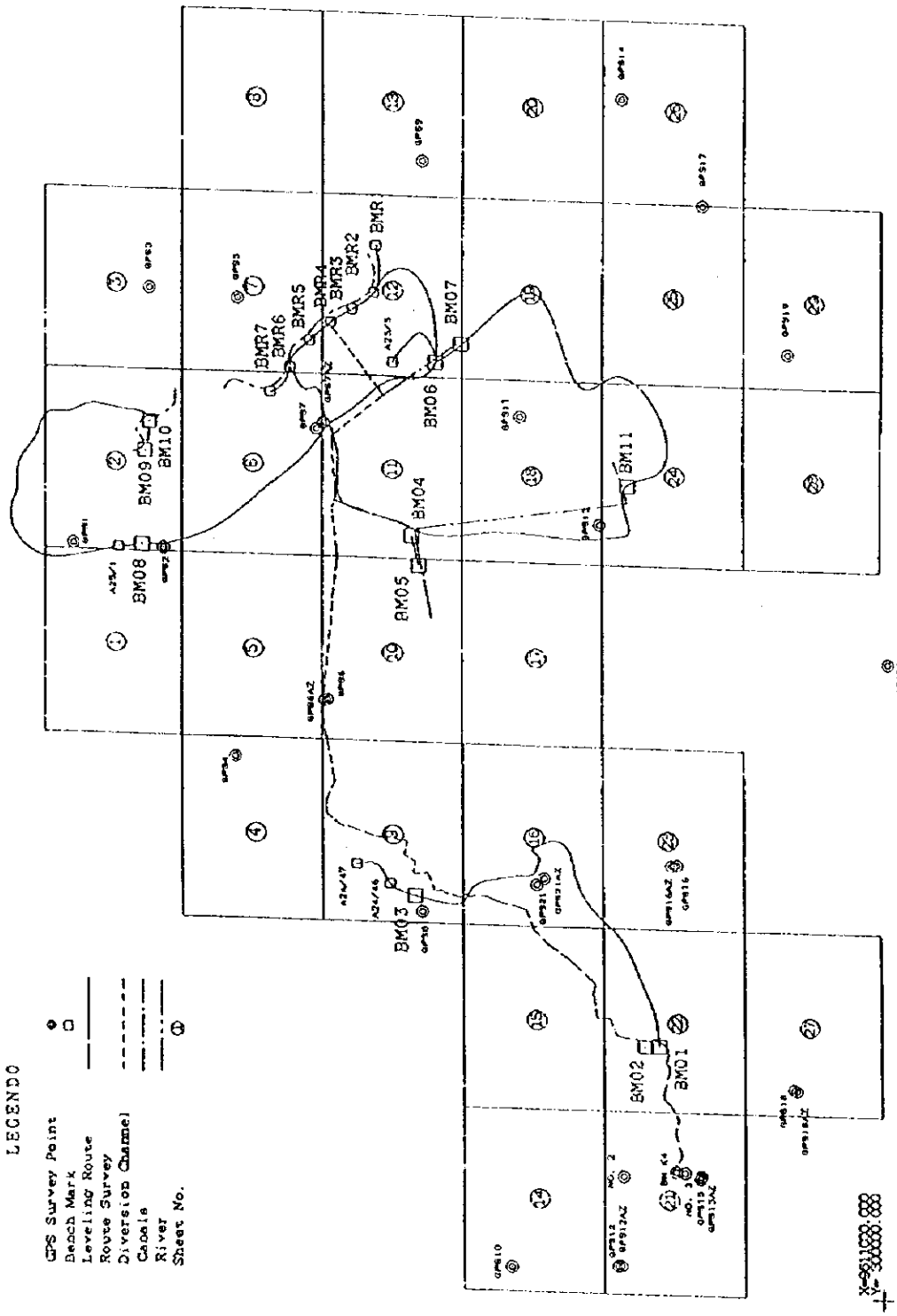

Figure C.4.1
Index Chart for Topographic Survey

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