GOVERNMENT OF MALAYSIA

FEASIBILITY STUDY
SMALL SCALE HYDROELECTRIC POWER PROJECTS IN SARAWAK

VOLUME- II
APPENDIX
FOR
FEASIBILITY STUDY
ON
MUKOH HYDROELECTRIC POWER PROJECT

JULY 1988

JICA

JAPAN INTERNATIONAL COOPERATION AGENCY

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CHAPTER 1. INTRODUCTION

Field investigation for the Mukoh project was carried out for approximately two months from June to July, 1987. In this Appendix-I, geological condition of the project site is discussed based on the results of field investigation.

Geology of the project site was surveyed through the geological mapping, core drilling with the standard penetration and water pressure tests in the boreholes and seismic prospecting, of which survey volume was as follows:

Survey Item	Quantity
Geological mapping	2 km^2 are in 1:10,00 scale
Core drilling	118.70m, at 6 boreholes
Standard penetration test	29 points, in 4 boreholes
Water pressure test	9 stages in 3 boreholes
Seismic prospecting	1,120 m long in 9 lines

Distribution of drilling points and seismic prospecting line profiles is shown in Fig. I-1, Location Map of Geotechnical Investigation.

The survey area can be divided into three sites for the sake of report discussion; i.e. the dam, waterway and powerhouse. The field campaign of core drilling and seismic prospecting was deployed into these sites.

Geological mapping was performed by Sarawak Electricity Supply Corporation (SESCO) and Geological Survey Department of Sarawak at the request of SESCO.

Core drilling was performed by contractor, Geotechnique East Malaysia Pte Ltd Co., under the supervision of SESCO staff and JICA expert.

Seismic prospecting survey was performed by the subcontractor, Strata Recon Sdn. Bhd. under the supervision of SESCO staff and JICA expert.

CHAPTER 2 GENERAL GEOLOGY

2.1 General

State of Sarawak having an area of about 124,000 km^2 along the north-west coast of the island of Borneo lies on immediately north of the Equator, between latitude 0 50' and 5 00' N and longitude 109 36' and 115 40'. It is bounded by Brunei and Sabah on the North and Kalimantan (Indonesia) in the Southwest.

Topography of Sarawak is dominated by the alluvial plain stretched over some 700 km along the coast and eastern mountainous region. Cities and towns in Sarawak are situated sporadically on the Quaternary coastal plain.

Geology of the mountainous region mainly consists of sedimentary rocks from Paleozoic to Tertiary era.

Igneous rocks are sporadically distributed in the central and southern part of Sarawak. Strata is folded, faulted, and has a complicated geological structure. In general, younger strata is distributed at the northern part of Sarawak. The main rivers in Sarawak such as the Rajang River not only flow towards west parallel to the geological structure, but also towards the north at right angle with the geological structure.

2.2 Topography

The project area of Mukoh is located on the northwestern part of mountainous region with elevation of 800 to 1,200 m, about 25 km southwest of Kapit town situated in central part of Sarawak.

The Mukoh River, which is the subtributary of the Rajang River, changes its course repeatedly to the north and northwest in the region and flows through the easterly-striking ridge connected with Mt. Bakak (1,005 m above mean sea level) and Mt. Tingan at (840 m above mean sea level). A gorge has been formed by the Mukoh River at about 4 km upstream reach from the big bend turning from the north to the west direction near Rumah Kilat. Damsite is planned at about 120m upstream from the gorge.

2.3 Regional Geology

The project area is underlain by Stage II (reference No. 5, the Kapit member) of the Belaga Formation of Palaeocene to Eocene age. The formation consists of a thick succession of weakly metamophosed shale with intercalation of graywacke (sandstone) and subgraywacke.

Rocks related to the project area consist of essentially two lithologic units. One is of shale intercalated with thin beds of sandstones. The other consists of massive sandstone. The shale unit which accounts for about 80% coverage of the area is slightly metamorphosed, fractured and folded. The sandstone unit can be found at the gorge, headrace tunnel near the surge tank of alternative-2 plan and near the powerhouse of alternative-3 plan (refer to Fig. I-1).

Folding and fault in the area is recognized. Folding commonly occurs in the shale unit and the most common form is isoclinal folding. Associated with the folding are the cleavages, usually striking N80 W and dipping steeply NE-SW.

Faulting is common too. Only one major fault was observed at the upstream from the proposed powerhouse of alternative-3 with striking N80W and dipping vertically. Breccia is observed along the faulting plain consisting of sandstone and shale fragments in hard sandstone matrix.

In general, the shale units in the area have been subjected to highly weathered, although fresh and hard shale can be found in the riverbed. Lateritic residual soil zone distributes thickly on the ridges and mountain side slopes.

With the rocks mentioned above as the bedrock, Quaternary terrace deposits and talus (slopewashed) deposits along the river, especially in the downstream area from the gorge being formed by sandstone unit, are distributed in a small scale.

Fig. I-2 shows the geological map in a scale of 1 to 10,000. A detailed geological map on a scale of 1 to 500 will be prepared by the hand of SESCO after settling the local problems.

CHAPTER 3 SEISMICITY

3.1 General

Sarawak is located outside the Circum-Pacific seismic zone[1/] and is situated on the Sunda Shield, stable block where almost no recent activity or block tectonics have been recorded.

During the period of late Tertiary and Quaternary, extensive volcanism occurred in the folded Upper Tertiary strata of Central Sarawak. Volcanic eruptions and subsequent basaltic extensions built the Hose Mountain Range, the Usun Apau plateau and the Linau Balia plateau. The youngest igneous rock in Western Sarawak is an andesitic lava at Sematan, possibly of early Quaternary age.

In Sarawak no volcanic activity has been detected recently. The possibility of earthquake by volcanic activity may be scarce.

3.2 Earthquake Records around the Proposed Project Site

Earthquake records in Sarawak are available in "Micro-Seismic Study of Malaysia and Adjacent Area" prepared by Malaysian Meteological Service, in which 17 events in Peninsula Malaysia, 7 events in Sabah and 2 events in Sarawak were recorded during the period from 1896 to 1976 (See Fig. I-3).

Two earthquake records in Sarawak are as follows:

a. Year and Date : 1958 June 30th
   Place : Kuching
   Intensity (MM scale) : V
   Report of damages : Two tremors reported sleepers awakened.
   Source : North Borneo News and Sabah Times, Jessel. July 5, 1958 Sabah State Library

b. Year and Date : 1965 July 21
   Place : Niah and Bekenu, Fourth Divison of Sarawak
   Intensity (MM scale) : IV
   Report of Damages : Light tremors slammed doors and smashed window panes, but no major damages were reported.
   Source : The Sarawak Tribune July 22 1965 Sabah State Library.

Description of MMCM is as follows:

Modified Mercalli Intensity Scale

Intensity		Max. Acc. mm/s/s	Remarks
I	Instrumental	less than 10	Not felt, except by very few under exceptionally favourable circumstances.
II	Very feeble	over 10	Felt only by a few persons at rest especially on upper floors of buildings. Suspended objeccts may swing.
III	Slight	over 25	Felt by quite noticeably indoors, especially on upper floors, like passing of a truck. Standing motorcars may rock slighly.
IV	Moderate	over 50	During day felt indoors, but some in outdoors. At night some awakened. Dishes, windows, doors, loose objects disturbed. Standing motorcars rock noticeably.
V	Rather strong	over 100	Felt by nearly everyone; many awakened. Some dishes, windows, etc. broken; unstable objects overturned. Church bells ring, pendulum clocks may stop.
VI	Strong	over 250	Felt by all, some people frightened. Damages slight, some plaster cracked.
VII	Very strong	over 500	Alarm general; damages negligible in buildings of sound construction. Felt by persons in moving cars.

Modified Mercalli Intensity Scale

Intensity		Max. Acc. mm/s/s	Remarks
VIII	Destructive	over 1000	Chimneys fall; damages in substantial building. Persons driving motorcars disturbed.
IX	Ruinous	over 2500	Great damage in substantial structures. Ground cracked, pipes broken
X	Disastrous	over 5000	Many building destroy.
XI	Very disastrous	over 7500	Few structures left standing; broad fissures in ground.
XII	Catastrophic	over 9800	Total destruction. Waves seen on ground surface.

3.3 Evaluation on Seismic Coefficient

According to the Malaysian Meteological Service, it is stated that Sarawak was considered seismically stable, and that there were only few cases of slight tremors recorded in this state.

Two earthquake occurrences were reported at two towns in the coastal plain along the South China Sea as discussed in the preceding section, but no reports in inland area. For safty reason, it is prudent to assume that there is a possibility of earthquake occurrence in inland area.

Malaysian Meteological Service recommended that engineers and building planners in Sabah should take into account the earthquake risk factor in building design.

Although Sarawak is considered seismically stable, the seismic design coefficient of the Batang Ai rockfill type dam (1985) has adopted K=0.05g, while K=0.15g for the Bakun rockfill type dam.

In consideration of the site geology and scale of main structures as well as the past design in Sarawak, the proposed horizontal ground acceleration of 0.05g is proposed for Mukoh project.

Note: 1/ Circum-Pacific Seismic Zone

PACIFIC SERIES, PROVINCE or SUITE
One of two great groups of igneous rocks (along with the Atrantic group) based on their tectonic setting. Originally described as occurring on the margins of the pacific basin, hence the Circum-Pacific province. Characterized by the tholeiitic magma type, yielding saturated or over-saturated resides. Seismic zone occurs along the above province.

CHAPTER 4 GEOLOGICAL INVESTIGATION

4.1 Core Drilling

Borehole location and length

Totally 118.70 m in length has been drilled at six locations, out of which two holes are at the damsite, two holes along the waterway, two holes at the power site.

The drilled length as well as the number of the field permeability test and points of the standard penetration test in a borehole is as follows:

Site	Core drilling		S.P.T1/	W.P.T2/	Seismic P3/	
	Holes	Length(m)	(Points)	(Stages)	Lines	Length(m)
Damsite	2	30.00	2	7	3	320
Waterway4/	2	45.10	23	-	5	690
Powerhouse	2	43.60	4	2	1	110
Total	6	118.70	29	9	9	1,120

Notes: 1/ : S.P.T = standard penetration test
2/ : W.P.T = water pressure test
3/ : seismic P = Seismic prospecting
4/ : Including the surge tank site and penstock line

Drilling operation

Core drilling was done by the contractor. They used one hydraulic feed rotary type drilling machine (Model: YBM-05) and drilled with a double tube core barrel.

Recovered core samples were arranged in a box in order and stored in the warehouse of SESCO in Kuching.

Logging

Drill logs have been prepared by SESCO and compiled in Data Book.

In the drill log, RQD is measured, which is an index termed the Rock Quality Designation which is obtained by examining the core recovered from a borehole, discarding sections of core less than 10 cm long, and expressing the remainder as a percentage of the total core length drilled. RQD is mathematically expressed as follows:

$$RQD = \frac{\text{total length of cores longer than 10 cm}}{\text{total length drilled}} \times 100\%$$

RQD was examined every one meter in this survey, so that the above equation is modified as follows:

$$RQD = \frac{\text{total length of cores longer than 10 cm}}{\text{100 cm}} \times 100\%$$

4.2 Field Permeability Test

In-situ permeability was determined by the "water pressure test (or Lugeon Test)" for consolidated formation, in which a single rubber sleeve packer was suited to seal tightly.

Water pressure testing method

For the water pressure test (or Lugeon test), a plug seal (rubber sleeve packer) was inserted at about 5 m from the base of the hole and then water was applied under pressure through a pipe extending through the plug to the base of the hole. The flow of water was measured at various pressures as discussed in the next paragraph. The permeability of the rock was assessed in both terms of Lugeon units and permeability coefficient. One Lugeon unit is defined as a flow of 1 lit/min per linear-meter of hole at a standard applied pressure of 10 kg/cm^2; one Lugeon equals to about 10^{-5} cm/sec permeability coefficient, although the precise equivalence is dependent upon the diameter of test borehole and the depth to the water table. The Lugeon units and the permeability coefficient were calculated by the following equations:

Lugeon Unit

$$Lu = \frac{Q}{L.P} \times 10$$

where, Lu : Lugeon units
Q : the constant rate of flow into the hole (lit/min)
L : the length of test section (m)
P : the pumping pressure applied (kg/cm^2).

Permeability Coefficient

(from the packer test in "Earth Manual" USBR)

$$K = \frac{Q}{2 . L . H} \times \log \frac{L}{r} \quad (cm/sec)$$

where, K : the permeability (cm/sec)
Q : the constant rate of flow into the hole cm^3/sec
L : the length of test section (cm)
H : the differential head of water (gravity plus pressure) (cm)
r : the radius of the hole tested (cm).

The testing pressure was applied changing in seven steps such as 1 kg/cm^2, 2 kg/cm^2, 3 kg/cm^2, 5 kg/cm^2, 3 kg/cm^2, 2 kg/cm^2, and 1 kg/cm^2 in order at the top of injection pipe in principle. However, in the case that the injection water rate became very large beyond the pump capacity, the test was ceased at the maximum pressure obtained.

Permeability test result

The records of the test are shown in the Data Book (Volume III). Determined permeability coefficients and Lugeon values are summarized in Fig. I-4.

4.3 Standard Penetration Test (SPT)

Purpose of SPT

SPT has been performed in order to obtain a record of the resistance of subsoils to the penetration of the Raymond sampler and to obtain disturbed samples of the soil for identification purposes. The test and identification information are used to outline surface conditions with respect to bearing capacity for foundation design. The penetration resistance is expressed as the number of blows required to force that the sampler penetrates 30 cm into the soil.

Field operation

After the drilling reached to the depth for testing, cuttings remained in the bottom of the hole were removed, and the Raymond sampler connected with drill rod was inserted to the bottom of the hole. The apparatus consists of a 65 kg hammer with a tripping device that releases the hammer at a height of 76 cm. The falling energy is then transmitted via an anvil and drill rod to a standard spoon of 5.08 cm outer diameter and 3.49 cm inner diameter at the bottom of the cleaned-out borehole. The number of blows to penetrate 45 cm into the soil is recorded and the number of blows required to penetrate the final 30 cm is recorded as 'N' value of SPT (excluding first 15 cm seating drive).

N-values obtained

N-values obtained by SPT are shown in Fig. I-5.

4.4 Seismic Prospecting

Profile line arrangement

According to the investigation plan, seismic refraction profile lines were arranged as shown in Fig. I-1. Profile length was 1,120 m in total. Survey length was distributed as follows:

Site	Profile lines and length	Profile No.
Damsite	3 lines, 320 m	Line A,H,I
Waterway (including penstock line)	5 lines, 690 m	Line B,C,D,E,F
Powerhouse site	1 lines, 110 m	Line G
Total	9 lines, 1,120 m	A to I

Field operation

The arrangement of shots and detectors was planned to be laid out on a line (profile shooting). Before the field recording began, ground surface profiles were surveyed and shot and detector stations were marked by pegs.

In a cycle of operation, the distance range was arranged in such a manner that five to seven shots of less than 30 m intervals were picked up by 24 geophones which were spreaded at regular intervals of 5 m horizontal distance. The shot locations and geophone spreads of one operation cycle were moved progressively to give complete coverage over the refraction profile lines.

Main instruments and materials used are as follows:

Geophone

One unit of OYO MCSEIS 1500 24-Channel System comprising the following units;

- amplifier unit (TR-7)
- digital enhancement unit (Model 1197A)
- CRT display and printer unit (Model 1216A)
- disc recording and processing unit (Model 5744)
- 2 sets of 12-channel take-out geophone cables
- 28 units of 14hz. geophones c/w spares
- 1 set of 200 m extension geophone cable.

Seis-gun

(1) Dimensions

- Full assembled length : 1.5 m
- Diameter of bore : 12 gauge

(2) Component parts

- T-handle with trigger connector to seismograph
- Firing piston shaft with control switch
- Extension shaft
- Firing pin double-ended connector
- Firing block and barrel

(3) Capacity

- Single shot of 12 gauge sheets
- Signal and energy level is dependent on shell type.

Time distance plot and profile interpretation

Travel time of the seismic wave (primary wave) was read from recording paper to the accurancy of 1/1,000 second, and plotted on the time-distance graph. From this time-distance relation, the profile of velocity layers was deduced mainly by the Hagiwara's method. The time-distance curves and the profile interpretations are summarized in the Data Book.

CHAPTER 5 SITE GEOLOGY AND ASSESSMENT ON ENGINEERING GEOLOGY

Mukoh Small Hydro Electric project consists of three Alternative plans; Alternative-1, Alternative-2 and Alternative-3.

The three Alternative plans are making use of the same dam. The following describe the condition of foundation rock based on the interpretation and evaluation of the geological data.

5.1 Alternative-1 Plan

Since the powerhouse is located just behind the dam at the left bank, geological assessment of powerhouse is discussed with the dam.

5.1.1 Damsite and powerhouse

Damsite is planned at about 120 m upstream side from the gorge which has been formed by sandstone. The width of riverbed at the damsite and powerhouse site is about 40 m. The slope at the left abutment of the dam has a gradient of 40 degrees while the right abutment has a gradient of 50 degrees, however, the slope above 25 m from the riverbed is 30 degrees. One small stream flows into the left bank of the Mukoh River between the gorge and the dam axis.

Two horeholes, BMk-1 and BMk-2, were drilled at the dam axis. A summary of these drilling and field tests is as follows:

BMk-1 : Vertical hole, 15 m in length, left bank

0 to 1.20 m Residual soil. Yellowish brown clayey soil.

1.20 to 15.00 m Shale intercalated with thin beds of sandstone. Slightly weathered rocks.
core recovery : 100%
R.Q.D : 100%
Lu-value : 1 (to 1.5)

BMk-2 : Vertical hole, 15 m in length, right bank

0 to 3.70 m Very stiff to hard residual soil. Yellowish brown clayey soil with friable shale gravels.
N-value : 45 to 50

3.70 to 15.00 m Shale intercalated with thin beds of sandstone.
3.70 to 8.60 m : moderately weathered
8.60 to 15.00 m : slightly weathered
core recovery : 100%
R.Q.D : 55%
Lu-value : 4.8

According to results of seismic prospecting, the geology of the damsite can be classified into three or four layers by its velocity as shown below:

MkA line : Dam axis

1st layer 300 m/s (1 to 2 meter in thickness)
2nd layer 1,000 m/s (3 to 5 meter in thickness)
3rd layer 1,500 m/s (2 to 10 meter in thickness)
4th layer 4,500 m/s

MkH line : Left bank along the river course

1st layer 500 m/s (0.5 to 1.5 m in thickness)
2nd layer 1,500 m/s (2.0 to 2.5 m in thickness)
3rd layer 3,800 m/s

MkI line : Right bank along the river course

1st layer 500 m/s (0.5 to 1 m in thickness)
2nd layer 1,500 m/s (2.0 to 3 m in thickness)
3rd layer 3,800 m/s.

Judging from these seismic velocities of MkA line, the first layer is thought to correspond to topsoil or residual soil, the second layer to very stiff to hard residual soil or highly weathered rock, the third layer to modelately weathered rock and the fourth layer to slightly weathered to fresh rock.

On the other hand, each seismic velocity along the profile of MkA line is relatively faster than others. It is thought that difference of these velocities is due to the anisotorophy of rock property which is the condition of having different properties in different direction, so that the second to third layers of MkA line are thought to correspond to the first and second layer of MkH and MkI lines, and fourth layer of MkA line corresponds to third layers of MkH and MkI as well.

Geology of the dam and powerhouse sites is underlain by shale intercalated with thin beds of sandstone (see Fig. I-6, Geological Profile of Dam Axis). The beds of shale are striking at about right angle to river course and dipping 70 to 80 degrees towards upstream. At the riverbed of the left bank, the shale is exposed in range of 10 m up-downstream from the dam axis, however, downstream side from the outcrop is covered by slope wash deposits consisted of gravel and sand.

From these field data, slightly weathered to fresh shale intercalated with thin beds of sandstone will be adequate for the dam foundation. To meet the foundation rock, stripping for 5 m from ground surface at the riverbed of right bank and 10 m at the left bank will be sufficient.

The powerhouse site is covered with substantial amount of gravel and silt. It is necessary to remove them to meet the foundation rock of powerhouse, slightly weathered to fresh shale intercalated with sandstone.

5.2 Alternativ-2 Plan

Geology of damsite is described in the preceding Section 5.1.1, Damsite and powerhouse.

Powerhouse of the Alternaive-2 plan is located on the left bank about 950 m downstream from the damsite.

5.2.1 Waterway

Waterway consists of intake, headrace tunnel, surge tank and penstock line.

(1) Intake

The intake of waterway is planned at the left bank of immediately upstream side of the dam.

Geology of the intake area is underlain by shale intercalated with thin beds of sandstone. This shale will not give problems for the foundation rock of intake structure.

(2) Headrace tunnel

Headrace tunnel is about 1,100 m long from the intake portal to surge tank located along the protuberant ridge of left bank. The tunnel will pass under stream named the Angkat River.

The shale intercalated with thin beds of sandstone and two thick massive sandstone units will be exposed inside the headrace tunnel. The two sandstone units are dipping 70 to 80 degrees towards downstream and are exposed in two sections, i.e. 250 to 400 m and 850 to 1,150 m from the intake towards surge tank.

The Angkat River area between two sandstone units forms a gentle slope consisting of slope wash deposits, and highly weathered shale outcrops are common along the Mukoh River. The slightly weathered sandstone outcrops are having rather wide opening joint pattern along the Mukoh River.

Under the Angkat River, thickness of rock mass covering the tunnel is estimated at about 100 m from the map of 1:50,000 scale, however, the true thickness will be less than this value and slope wash deposits of unknown thickness also are discovered there.

Judging from these geological conditions, the tunnel will pass through the slightly weathered rocks. It is a high possibility that water appears inside tunnel under construction near the Angkat River area.

(3) Surge tank and penstock line

Surge tank and penstock line are located on the mountain slope with the gradient of 40 degrees. The geology of the area is underlain by weathered shale intercalated with thin beds of sandstone. Therefore the surge tank will sit on the moderately weathered rock and anchor blocks of penstock line will sit on moderately weathered rock.

5.2.2 Powerhouse

Powerhouse is planned on the left bank near the river side. Geology of powerhouse site consists of moderately to slightly weathered shale intercalated with thin beds of sandstone. Therefore rock foundation of the powerhouse will base on the slightly weathered shale with sufficient bearing force.

5.3 Alternative-3 Plan

Geology of damsite is described in the preceding Section 5.1.1, Damsite and powerhouse.

The powerhouse of alternative-3 plan is located on the right bank about 1,600 m downstream from the damsite.

5.3.1 Waterway

Waterway consists of intake, headrace tunnel and penstock line.

(1) Intake

Intake is planned at the right bank of immediately upstream side of the dam.

Geology of the intake area is underlain by shale intercalated with thin beds of sandstone. This shale will not give problems for the foundation rock of intake structure.

(2) Headrace tunnel

Headrace tunnel is about 1,600 m long from the intake to surge tank which is located on the mountain slope. This tunnel will pass under four streams including the Poncur River which is eroded deeply on the mountain slope. A thin ridge, landslides and a stream are found near the mountain of surge tank side.

Field investigation was carried out at both sides, such as intake site and surge tank side. Seismic prospecting (Mk B) was performed along the headrace tunnel at intake site, and drilling of borehole (BMk-3) and seismic prospecting of three lines (Mk C,D and E) were performed at the surge tank site.

According to the result of seismic lines survey, geology of the intake area can be classified into the four layer by its velocity as shown below:

<u>MkB line</u>

1st layer 250 m/s (less than 3 m in thickness)
2nd layer 600 m/s (2 to 6 m in thickness)
3rd layer 1,200 to 1,300 m/s (3 to 9 m in thickness)
4th layer 3,000 to 4,500 m/s.

Furthermore, the seismic result shows the low velocity layer of 2,000 m/s and 2,700 m/s in the fourth layer. These low velocity layers, judging from the geological condition along the Mukoh River, may be due to differences in weathering conditon on the variance of lithology.

On the other hand, the results of borehole (BMk-3) at the thin ridge of surge tank side are as follows:

BMk-3 : vertical 24.80 m in linear length

0 to 6.50 m	:	reddish pink clayey silt with friable lateritic gravels, N=27 to 50
6.50 to 18.00 m	:	highly weathered, grey clayey silt to light brown clayey silt to shale, N > 50
18.00 to 24.80 m	:	moderatly to slightly weathered shale, cracky, RQD=0 to 22%, core recovery 75 to 100%. Final water level in borehole : Nil.

According to the results of seismic prospecting line survey, geology of the surge tank can be classified into four layers by its velocity as shown below:

<u>MkC line</u> along the thin ridge passing through BMk-3 borehole.

1st layer 250 m/s (1 to 2 m in thickness)
2nd layer 600 m/s (1.5 to 3.5 m in thickness)
3rd layer 1,300 m/s (2 to 8 m in thickness)
4th layer 3,500 m/s (2 to 8 m in thichness)

MkD line a right angle to the thin ridge

1st layer 250 m/s (1 to 1.5 m in thickness)
2nd layer 600 m/s (1.5 to 5 m in thickness)
3rd layer 1,300 m/s (4 to 14 m in thickness)
4th layer 3,500 m/s

MkE line along the thin ridge

1st layer 250 m/s (1 to 1.5 m in thickness)
2nd layer 600 m/s (1.5 to 5 m in thickness)
3rd layer 1,300 m/s (4 to 14 m in thickness)
4th layer 3,500 m/s

Judging from these seismic velocities of MkC,D and E lines, the first and second layers are thought to correspond to the weathered lateritic clayey shale and siltstone, third layer to the moderately weathered clayey to soft shale and siltstone and fourth layer to slightly to fresh shale and siltstone.

Geology along this tunnel consists of the shale intercalated with thin beds of sandstone, massive sandstone and shale to siltstone. Among these lithofacies, the shale intercalated with thin beds of sandstone will be mainly exposed inside the headrace tunnel. Massive sandstone will dip 70 to 80 degrees towards downstream and be exposed in two sections, i.e. 400 to 600 m and 900 to 1,100 m from the intake. Shale to siltstone is distributed in the surge tank side area.

From the map of scale 1:50,000, rock mass covering the tunnel is calculated to be 130 to 200 m in thickness in the central part of the tunnel. The true thickness is expected to be less than this value near the four stream areas. Furthermore, rock covered in the tunnel of intake side area and surge tank side area is less than 40 m.

Judging from these geological and topographic conditions, the tunnel will mainly pass a good geological condition corresponding to the fourth velocity layer of 3,000 to 4,500 m/s. However, the third layer corresponding to moderately weathered rock will be exposed inside tunnel from the stream to the surge tank. Groundwater will possibly appear inside the tunnel near the Poncur River area where massive sandstone is located.

Furthermore, it is a high possibility that the geological condition of the low velocity layers is similar to seismic line MkB along the headrace tunnel.

(3) Surge tank and pentock line

Surge tank is located on the mountain slope with the gradient of 30 degrees and penstock line is planned on the terrace developed along the Mukoh River.

Core drilling of one borehole (BMk-4) and seismic prospecting of one line (MkF) were performed in the area as follows:

<u>BMk-4</u> : vertical hole 20.30 m in length

0 to 5.0 m	:	reddish brown sandy clayey silt with lateritic gravel, N=19 to 22	
5.0 to 9.0 m	:	completely weathered clayey siltstone, N= 30 to 49	
9.0 to 11.70 m	:	completely weathered clayey siltstone, N= 49 to 50	
11.70 to 17.50 m	:	highly weathered greyish brown clayey siltstone to soft siltstone	
17.50 to 20.30 m	:	moderately weathered shale laminated with weathered and cracky sandstone,	
		RQD	: 18.0 to 19.0 m, 10%
			: 19.0 to 20.0 m, 50%
		core recovery	: 100%
		Final water level	: Nil

According to the result of seismic prospecting (MkF line), geology of these sites can be classified into four layers by its velocity as follows:

<u>MkE line</u> along the penstock line between surge tank and powerhouse

1st layer 250 m/s (1 to 2 m in thickness)
2nd layer 600 m/s (3 to 5 m in thickness)
3rd layer 1,300 m/s (7 to 12 m in thickness)
4th layer 3,500 m/s, 4,500 m/s

From these seismic velocity results, the first and second layers are corresponding to top soil, slopewash and completely weathered rock, the third layer to highly to moderately weathered rock and the fourth layer to moderately to slightly weathered or even fresh cracky shale and laminated sandstone.

No fault was discovered in the profile of MkF line.

The surge tank will design to sit on highly to moderately weathered siltstone; N-value SPT Test of over 50, velocity layer of 1,300 m/s to 9 to 10 m in depth from ground surface. Anchor blocks of the penstock line will base to the moderately weathered siltstone; N-value of over 30, 1,300 m/s layer and deeper than 5 m from ground surface.

5.3.2 Powerhouse

Powerhouse is planned on a small terrace at the right bank of the Mukoh River. Terrace plain forms a gentle slope because of being covered by slope wash deposits.

Core drilling of two boreholes (BMk-5 and 6) and seismic propesting lines (MkF and G) were performed in the powerhouse area.

A summary of these boreholes and field tests is as follows:

<u>BMk-5</u> : vertical hole 19.30 m in length

0 to 4.0 m	:	moderately weathered shale RQD : 20 to 40% core recovery : 100%
4 to 10.4 m	:	slightly weathered shale RQD : 100% core recovery : 100%
10.4 to 19.3 m	:	slightly weathered to fresh shale RQD : 0 to 60% core recovery : 90 to 100%

<u>BMk-6</u> : vetical hole 24.3 m in length

0 to 8.2 m	:	slope wash deposit Terrace deposit gravels and boulders of sandstone and shale, N > 50
8.2 to 11.0 m	:	highly to moderately cracky shale RQD = 10%
11.0 to 24.3 m	:	slightly weathered shale RQD = 60 to 95%

According to the results of seismic prospecting line (MkG line), geology of the powerhouse area can be classified into four layers by its velocity as shown below:

<u>MkG line</u> along the river course of the Mukoh River

1st layer 250 m/s (0.5 to 1.5 m in thickness)
2nd layer 600 m/s (3 to 4 m in thickness)
3rd layer 1,300 m/s (6 to 7 m in thickness)
4th layer 4,500 m/s

Judging from these seismic velocities, the first layer is corresponding to top soil or residual soil or slope wash material, the second and third layers to highly to moderately weathered material and cracky shale, the fourth layer to slightly weathered to fresh shale.

Geology of the powerhouse is underlain by shale interbedded with thinly laminated sandstone covered by terrace and slopewash deposits of about 8.20 m thick.

From the above information, the powerhouse will have a base on slightly weathered shale by stripping terrace deposits and highly to moderately weathered shale.

CHAPTER 6 RECOMMENDATION FOR FURTHER WORK

The following are recommendations for the foundation rock of Alternative-1 plan based on the interpretations and evaluations of the geological data obtained:

(1) The shale intercalated with thin beds of sandstone at the site where the dam and powerhouse will be constructed is covered by gravels and silty-sand of river deposit and slope wash materials with unknown property and thickness. It is therefore recommended that more detailed field investigation to confirm the foundation rock condition, property and thickness of slopewash materials by drillings and seismic survey shall be carried out.

(2) From the results of material survey, the concrete aggregates will be obtained from a quarry. The proposed quarry site is the sandstone area formed a ridge at 800 m downstream side from the dam axis on the left bank of the Mukoh River. It is recommended that more detailed field investigation for confirming condition of the sandstone shall be carried out by drilling and seismic survey.

REFERENCE

1. Geological Survey Department, 1987. "Geology of the Mukoh Small Scale Hydro Electric Project Area, Kapit Division, Sarawak"

2. Malaysian Meteological Service, 1983. "Mirco-seismic of Malaysia and Adjacent Areas"

3. Geotechnique East Malaysia Sdn Bhd. Core drilling materials investigation report for Mukoh Small Scale Hydro Electric Project, August 1987

4. Strata Recon Sdn Bhd, Seismic Prefraction survey report for Mukoh and Medamit-2 Small Hydro Electric Project, 20 August 1987

5. Wolfender, E.B., (1960). The Geology and Mineral Resources of Lower Rajang and Adjoining Area. Sarawak, Memoir 11, Geological Survey Department, British Territories in Borneo.

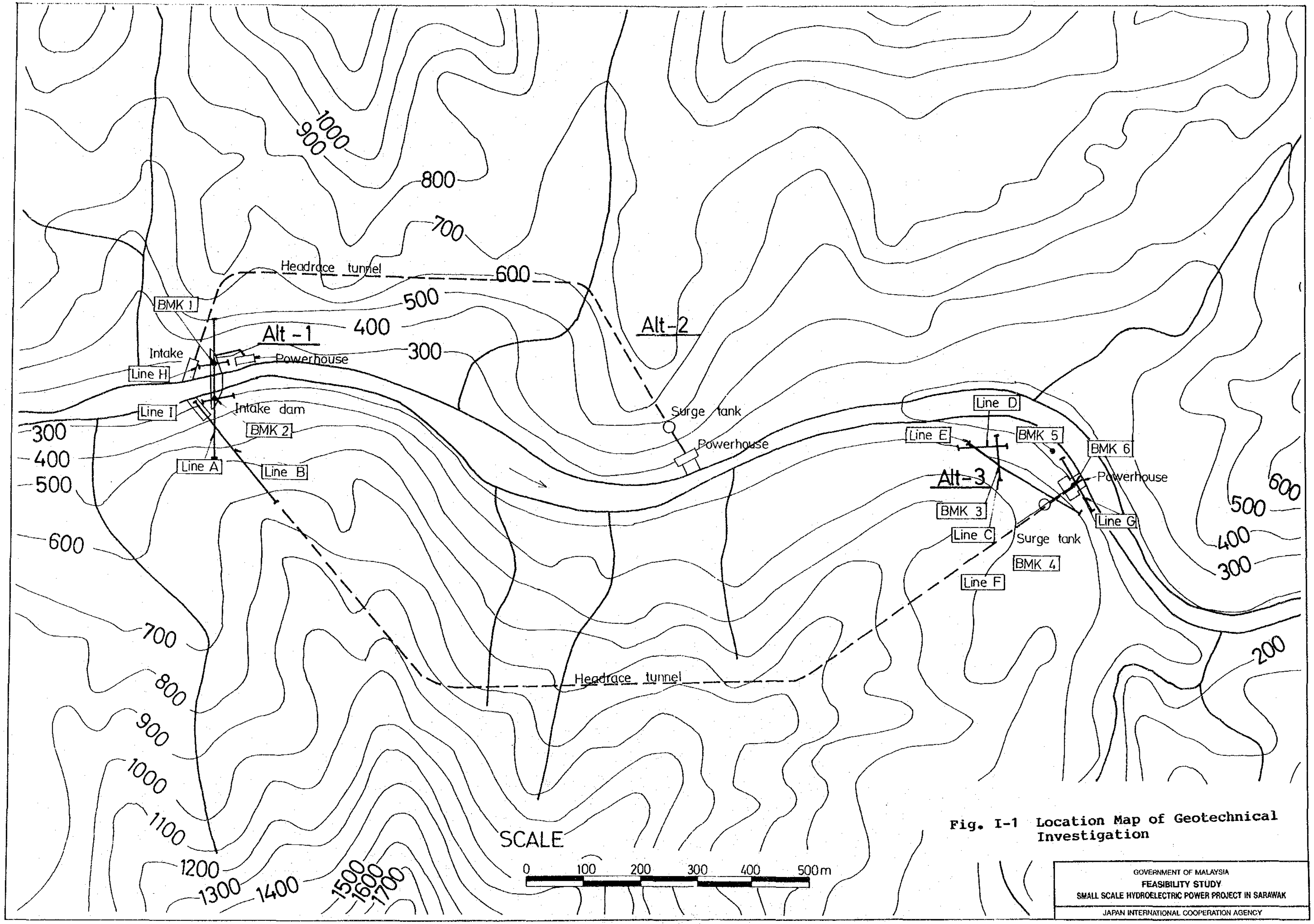

Fig. I-1 Location Map of Geotechnical Investigation

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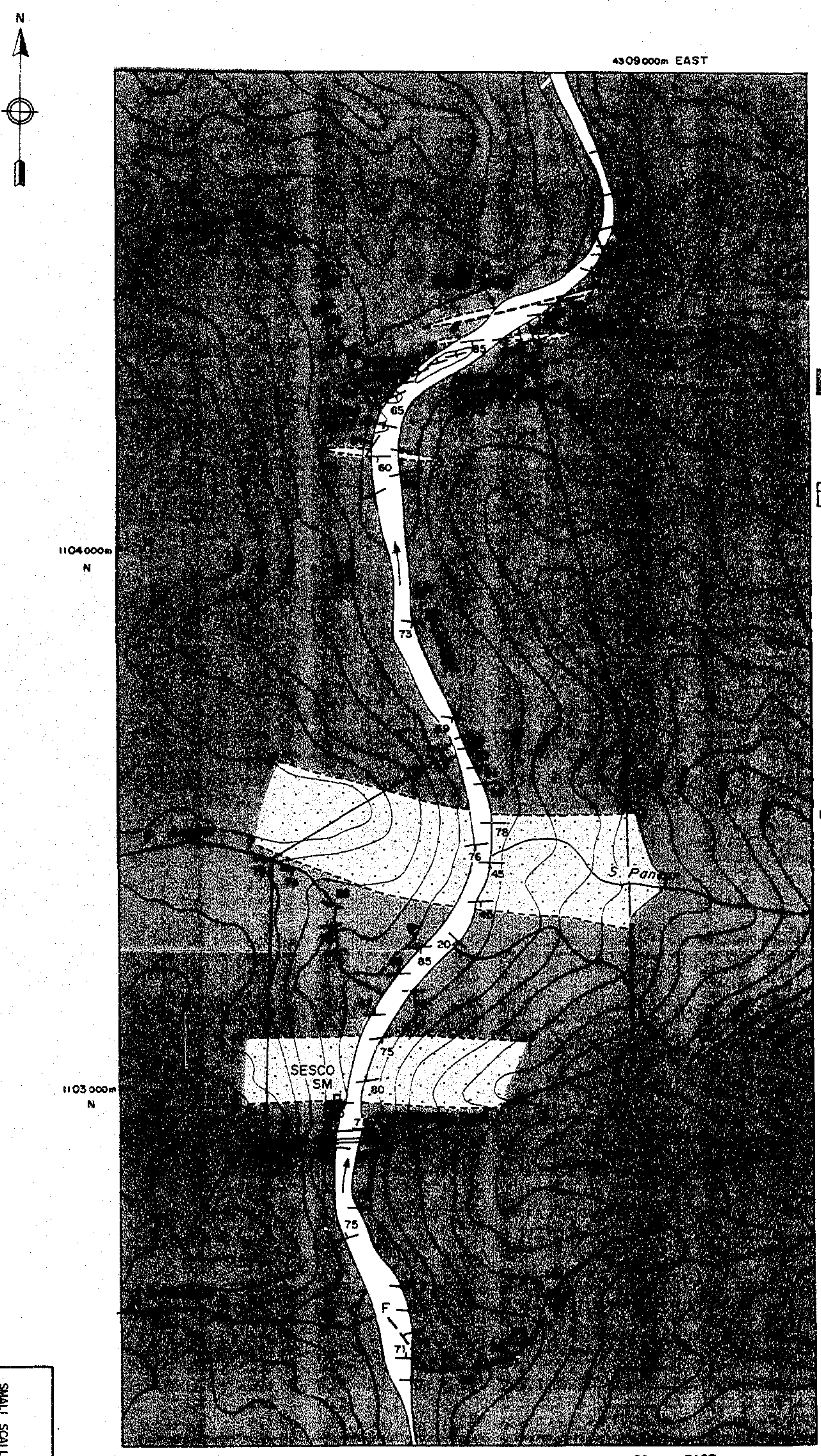


SCALE

0 250 500m

Shale : Hard, fresh, slightly metamorphosed, thinly and steeply bedded with a minor amount of thin sandstone intercalations Tightly folded, faulted and fractured

Sandstone : Hard, fresh fine grained, slightly metamorphosed, thickly bedded, faulted and fractured

75 Attitude of beds in degrees

Vertical beds

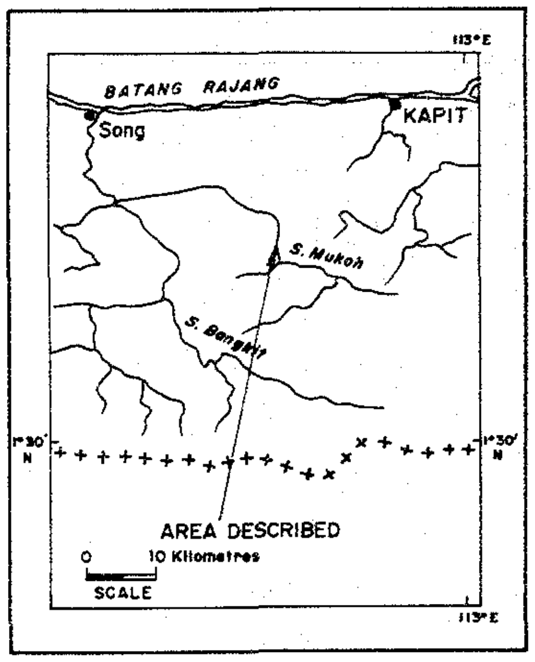
Landslide

Contour at 100 feet interval

F —— F Fault

River flow direction

LOCALITY MAP



[Base Map (scale 1:10,000) is an enlargment of Topographic map sheet 1/112/4 (scale 1: 50,000) published by the Director of Survey, Ministry of Defence, United Kingdom, 1968]

Fig. I - 2 GEOLOGICAL MAP OF SUNGAI MUKOH - A PROPOSED SITE FOR SMALL SCALE HYDROELECTRIC PROJECT.

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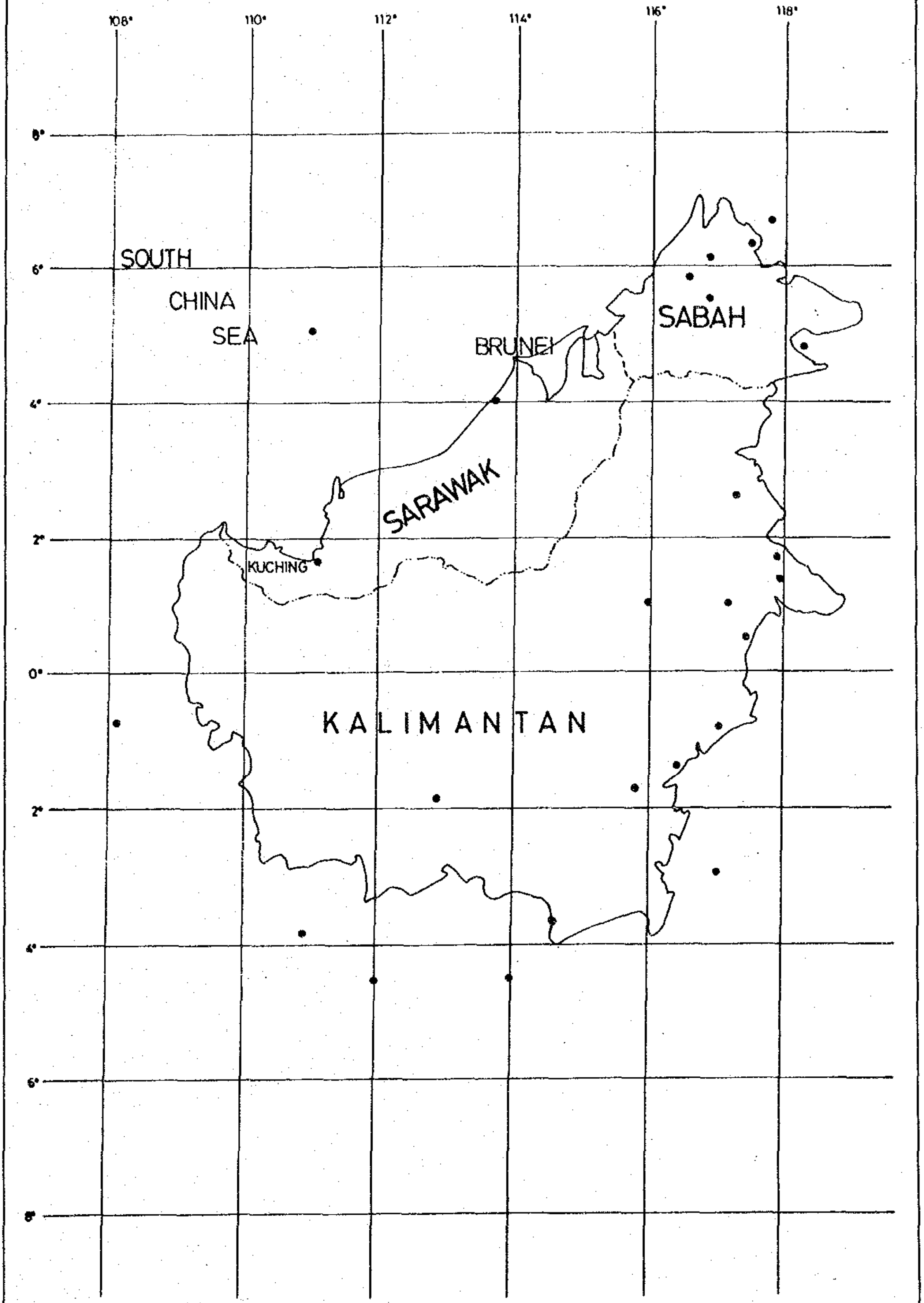

Fig. I-3 Epicentres of Seismic Events in Sarawak and Sabah, 1896 to 1976

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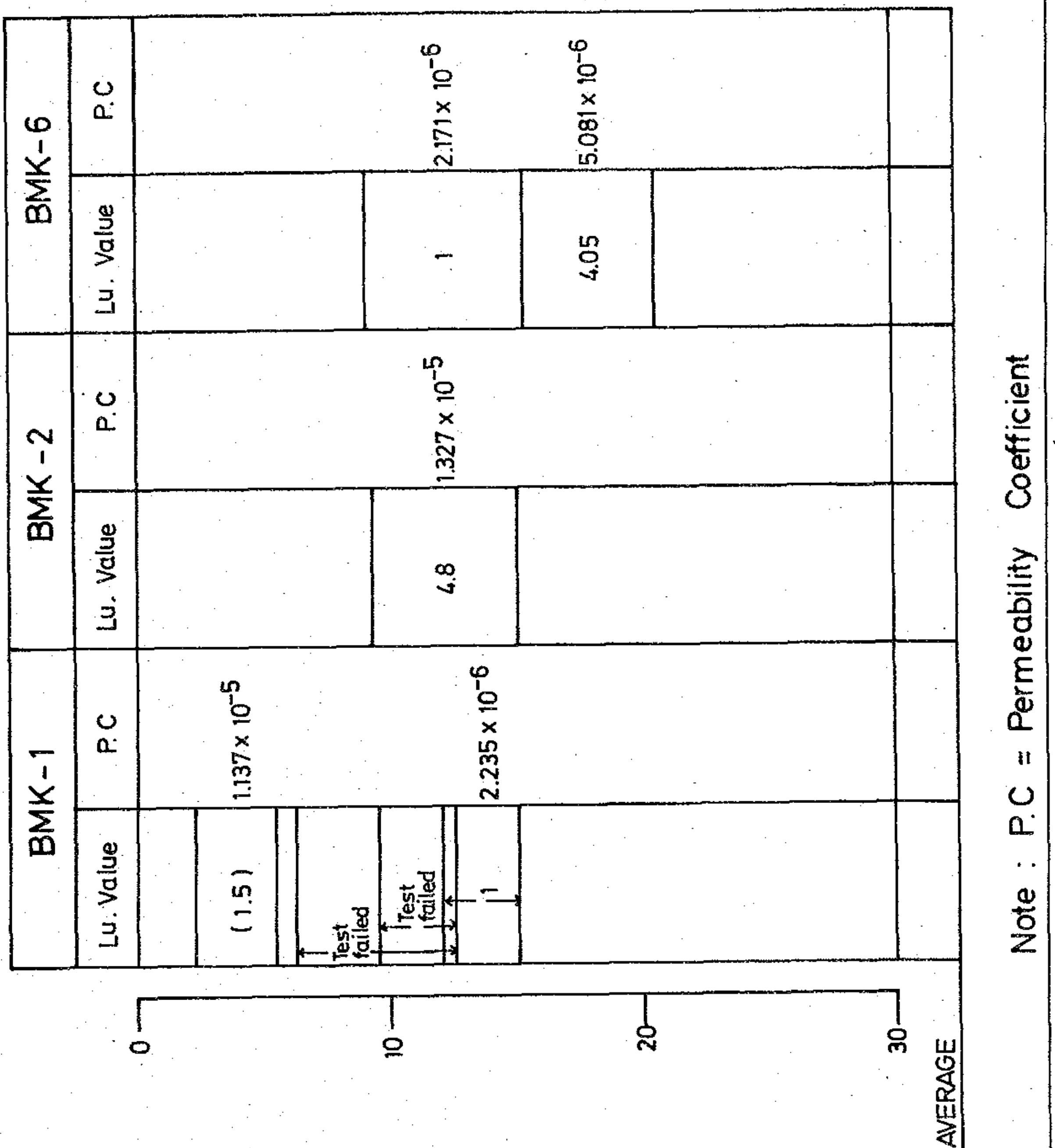

Fig. I-4 Lugeon Test Results at at Mukoh Site

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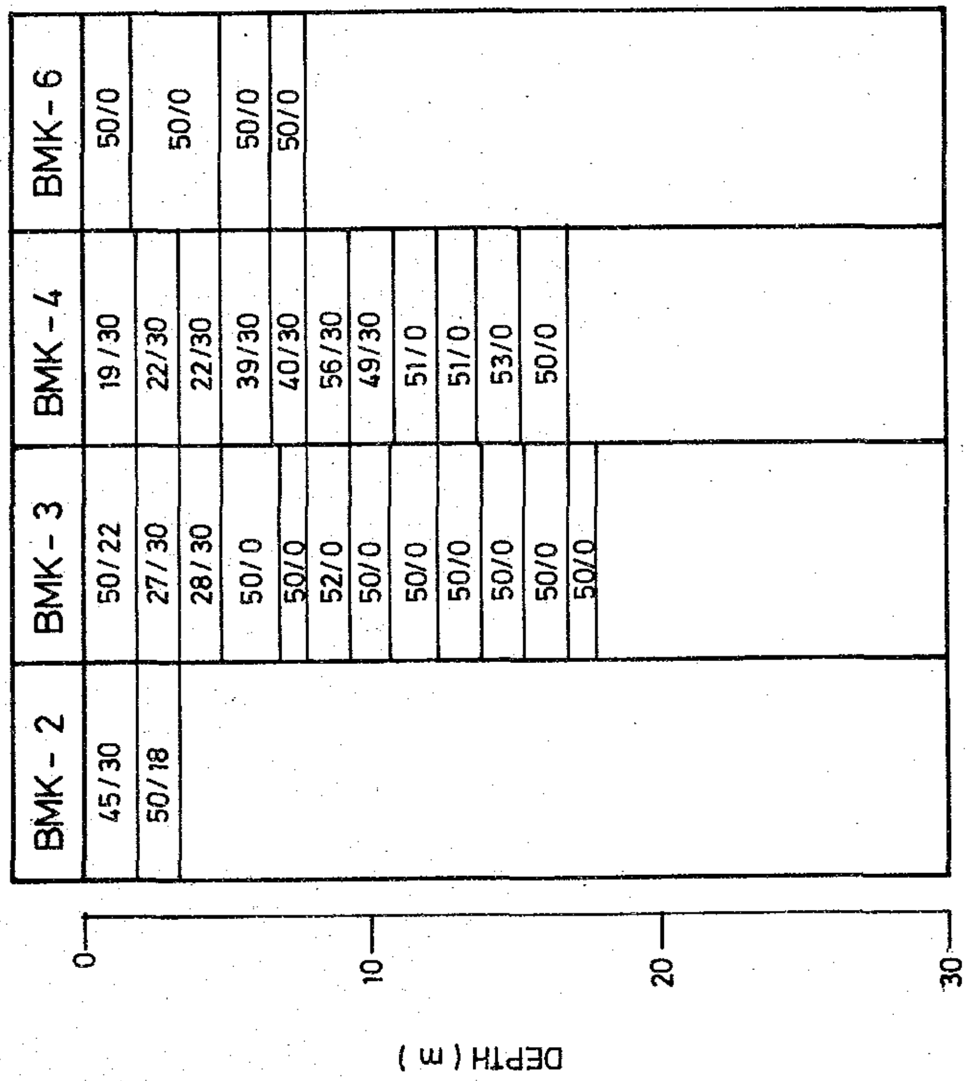

NOTE.
1) S.P.T is the abbreviation of Standard Penetration Test.
2) Figures before and after slash are shown in the number of blows (times) and the penetrated length (cm) respectively.

Fig. I-5 S.P.T N-value at Mukoh Site

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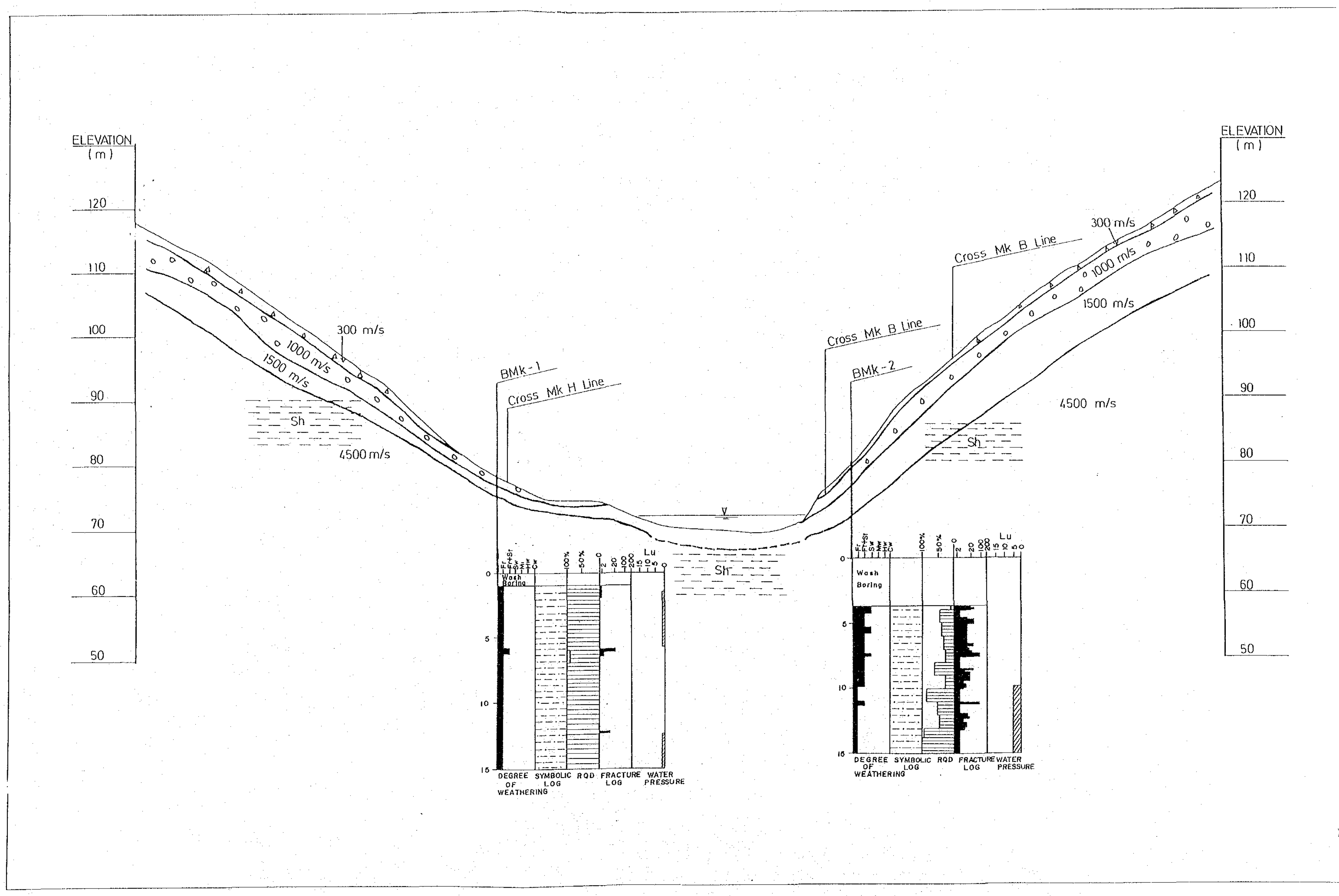
ELEVATION (m)
120
110
100
90
80
70
60
50
300 m/s
1000 m/s
1500 m/s
4500 m/s
Sh
BMk-1
Cross Mk H Line
BMk-2
Cross Mk B Line
Cross Mk B Line
Wash Boring
DEGREE OF WEATHERING
SYMBOLIC LOG
RQD
FRACTURE LOG
WATER PRESSURE
Lu
100%
50%
0
5
10
15

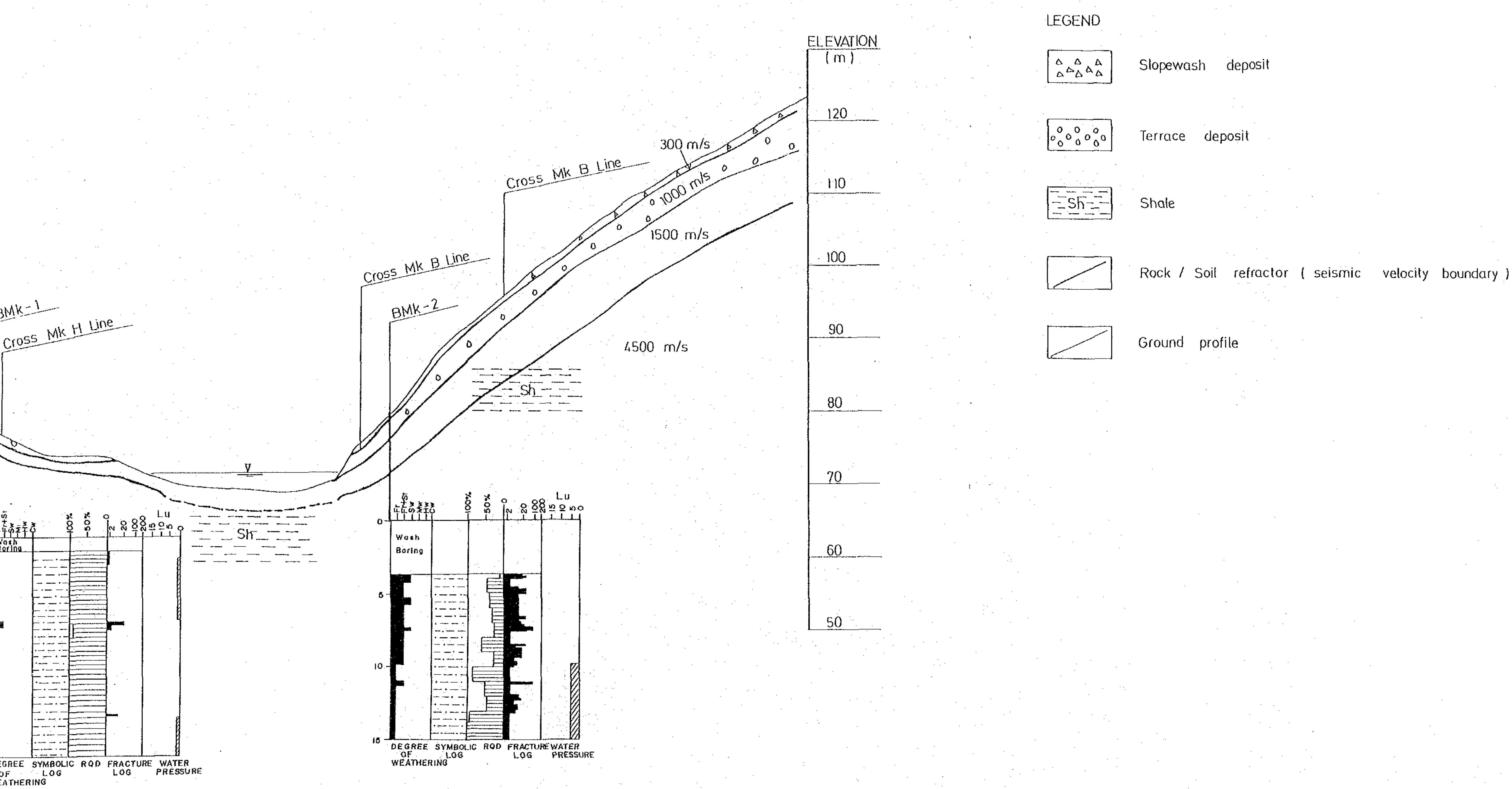

Fig. I-6 Geological Profile at Dam Axis

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