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STUDY

GOVERNMENT OF MALAYSIA

STUDY
ON
KELANTAN RIVER BASIN-WIDE
FLOOD MITIGATION

FINAL REPORT

PART IV

GEOLOGICAL AND MATERIAL INVESTIGATIONS

FOR

DABONG AND KEMUBU DAMSITES

NOVEMBER, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

A List of Reports

1. Executive Summary

2. Master Plan Study
   (Main Report)

3. Master Plan Study
   (Supporting Report)

4. Pre-feasibility Study on Combination Plan
   of Lebir Dam, Kemubu Dam and River Improvement
   (Main Report)

5. Pre-feasibility Study on Combination Plan
   of Lebir Dam, Kemubu Dam and River Improvement
   (Supporting Report)

6. Additional Survey for 1988 Flood

7. Geological and Material Investigations
   for Dabong and Kemubu Damsites

8. Data Book
   (Cross Sectional Survey)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ATTACHED GEOLOGICAL DATA

1. Drilling Logs

2. Test-pitting Logs

3. P-Q Curve of Lugeon Test

4. Friction Loss Test Result

5. Gradation Analysis Result of Test-pit Samples

I. INTRODUCTION

Five damsites, i.e. Dabong, Kemubu, Lower Pergau, Nenggiri and Lebir, are proposed as conceivable damsites in the Study on the Kelantan River Basin-wide Flood Mitigation.

Out of these five damsites, the feasibility study for Nenggiri dam has been carried out by ELC in 1986 and the feasibility study for Lebir dam has been completed by JICA for the purpose of hydropower generation. However, only master plan studies have been carried out for the Dabong, Kemubu and Lower Pergau schemes.

The geological investigation of both Dabong and Kemubu damsites has been executed in order to obtain geological data of dam foundation and construction materials during the period from the middle of September, 1988 to the beginning of April, 1989. The investigation consists of core-boring, test-pitting, geological mapping and laboratory test, etc.

This report describes the geological conditions and evaluations of both Dabong and Kemubu damsites based on their geological investigation results. The location of project area and proposed damsites are shown in Fig. 1.

II. REGIONAL GEOLOGY

The Kelantan River lies in the north-eastern part of Peninsular Malaysia and originates from the mountain ridge which forms the border with the State of Perak.

The Kelantan River meanders northwardly through hilly areas in the middle reaches and flat plain areas in the downstream reaches, finally draining into the South China Sea. The total catchment area of the Kelantan River basin is 13,100 km^2 corresponding to 85% of the State of Kelantan.

The Dabong and Kemubu damsites are located in the middle stream reaches as shown in Fig. 2. Although the mountain slope in the middle reaches is generally gentle, the area at and around the damsites consists of steep mountains ranging northwardly with heights of 150 m to 200 m.

With regard to geological conditions, the middle stream reaches consist mainly of Permian and Triassic rocks, which comprise phyllite, slate, shale, limestone, tuff, volcanics and metamorphic rocks as shown in Fig. 3.

Most of the rocks in the middle stream reaches develop foliations parallel to the bedding plane, which are altered, more or less, due to wide-spread metamorphism.

The distribution of Permian and Triassic rocks is complicated. However, these strata trend almost in the same north-south or northwest-southeast directions.

The Permian rocks are divided into four groups; arenaceous, argillaceous, volcanic and metamorphic rocks. Metamorphic rocks, consisting mainly of schist with developed foliations comprise mica-garnet schist, quartz mica schist and amphibole schist.

Volcanic rocks consist of acid volcanics and basic volcanics. Acid volcanics are comprised of tuffs, agglomerates and rhyolites, together with quartz mica schist and quartzite. Schist at the Dabong and Kemubu damsites is sound and massive.

Argillaceous and arenaceous rocks occur mainly in the centre of this area together with limestone. The limestone, distributed sporadically, forms spectacular vertical cliffs and irregularly-shaped caves in their structures.

On the other hand, Triassic rocks consist mainly of shale and mudstone. Sandstones/metasandstones, conglomerates, tuffaceous varieties and limestones are included in these rocks. The shale, greyish to black, is generally thinly laminated and strongly fissile.

During the period from Late Carboniferous to Tertiary, granite predominated as intrusive rock in the western part of the middle stream reaches. As a result of its soundness and massiveness, it formed steep mountain slopes with waterfalls and rapids.

Major faults trend in the north-south or northwest-southeast direction, but are sometimes intersected by other groups of faults trending in the northwest to southwest direction.

III. SITE GEOLOGY

3.1 Dabong Damsite

The Dabong damsite is located about 5 km downstream from the confluence of the Pergau River as shown in Fig.2. At the damsite, the Galas River passed through a narrow gorge created by a 300 m high ridge running from north to south.

The East Coast Railway passes through a tunnel (No. 5) at the right abutment.

The riverbed at the damsite is approximately 50 m wide and EL. 24 m high. The slope on the left bank rises at a gradient of about 45°. On the other hand, the slope on the right bank rises at a gradient of 30° up to 20 m in height from the riverbed and becomes as steep as 50° to 55° above it.

The bedrock consists of greenish or pinkish-white schist which is fairly hard and massive despite considerable foliation.

Schistosity, parallel to the bedding plane, strikes and dips NS/55° - 70°W.

Some of the joints run nearly parallel to schistosity, but others strike and dip at N40°W/50°NW and N80°E/90°. No evidence of any significant fault was observed.

3.2 Kemubu Damsite

The Kemubu damsite is located about 18 km upstream from the railway bridge in Kemubu village as shown in Fig.2. At the damsite, the Galas River, passing through a narrow gorge, changes its direction from west to northwest.

The riverbed at the damsite is about 40 m wide and around EL. 37 m high. The slope on the left bank rises at a gradient of about 45° to 50° up to 15 m in height from the river brink and ends up about 40° above it.

On the other hand, the slope on the right bank rises at a gradient of about 20° up to 10 m in height from the river brink and changes gradient to 40° above it.

The bedrock, massive and relatively sound, consists mainly of schist which is foliated due to metamorphism. The rock is exposed along the river brink and slopes of both banks, up to 15 - 20 m above the riverbed.

Schistosity, parallel to the bedding plane, strikes and dips N60° - 80°W/70° - 80°W. The existence of small-scale faults is estimated by the aerophotograph interpretation and the field mapping but no major fault is found at the damsite.

IV. GEOLOGICAL INVESTIGATION FOR DABONG DAMSITE

4.1 General

The Dabong dam is proposed as a concrete gravity type dam for flood mitigation and hydropower generation with a crest height of EL. 80.0 m in maximum.

Geological investigation for the Dabong damsite consists of field geological mapping using a topographic map with a scale of 1:25,000, core boring together with borehole permeability tests, test-pitting and dam construction material tests.

The items and quantities performed for the Dabong dam scheme are listed below:

	Item	Quantities
1.	Field geological mapping	7.5 km^2
2.	Core borings	2 holes (40 metres each)
3.	Borehole permeability tests	14 nos.
4.	Test-pittings	4 pits
5.	Dam construction material tests (gradation tests)	5 samples

4.2 Field Geological Mapping

Field geological mapping was performed for the purpose of obtaining geological and geomorphological data at and around the damsite. The geological map with a scale of 1 to 25,000 is shown in Fig. 4 and descriptions of thin sections from the rock samples, made by the Geological Department of Malaysia, Kelantan, are attached in Appendix.

The result of field geological mapping is summarized below.

(1) General

According to the Geological Map of Peninsular Malaysia published by the Director of the Geological Survey Department as reproduced in Fig. 3 for the project area, the proposed Dabong damsite is underlain by Permian volcanics. In the State of Kelantan, Triassic and Permian sediments are reported to be conformable. Regional metamorphism is widespread and older rocks are said to show a greater degree of metamorphism.

The present mapping exercise showed that the entire area is underlain by metasediments consisting mostly of tightly folded quartz mica schist, schist, and limestone (Fig. 4). Lithic

fragments frequently occur suggesting a volcanic origin for the metasediments. If both Permian and Triassic metasediments were present, it had not been possible to differentiate them.

The combination of complicated folding, insufficient contrast in topographic characteristics between rock units, and limited rock exposure, makes it impossible to interpret the structural geology in detail.

Limestone which forms characteristically steep sided hills is easily identified on aerial photographs. The other metasediments in the area are divided for the purpose of this study into schist/slate, quartz mica schist, and calcareous quartz mica schist on the basis of topographic characteristics and field observation of the lithology. The most recent geological units are the river terraces and sand bars along the rivers.

(2) Geological Facies

Limestone

Limestone occurs as steep sided hills around the Gua Ikan area in the southern part of Fig. 4. Solution by water has resulted in huge caves in the limestone hill.

The rock is generally white to medium grey. Recrystallisatin has obliterated any primary texture or early features that might have existed so that it is now fine grained, dense, and breaks without any preferred orientation. There is little impurity other than carbon.

Schist/Slate

Under this lithological division are all the rocks forming low hills in contrast to the quartz mica schist which expresses a more rugged relief. At many outcrops along the Pergau and Galas rivers, the rock is dark grey and well foliated and may be classified as slate although quartz mica schist also occurs at other outcrops in between. Foliation follows the primary bedding where both are present in an outcrop.

Folding of the schist is indicated by the variable orientation of the schist even within short distances. Actual folds have not been observed.

Quartz mica schist

Around the proposed damsite, a particularly quartz-rich sequence of metasediments occurs to form a belt of hilly country about 2 km wide extended approximately north-south across the map (Fig. 4). Rocks exposed here are generally more quartz-rich and therefore, more resistant. The rocks exposed along the Galas and Pergau rivers and other tributaries draining into them are mostly quartz mica schist often greenish grey. Occasionally, metaconglomerate consisting of quartz pebbles is encountered.

Quartz poor sections, presumably more susceptible to weathering, are less represented at river outcrops but on land. They are exposed along road cuts, unpaved tracks and other cleared surfaces in the form of stiff to hard clay in which the original banding is still visible in shades of grey, red, brown, and yellow.

Although the quartz mica schist appears to be a north-south band across the map with strikes generally in the same direction, aerial photographic study suggests that the rock may actually be very tightly folded.

<u>Quartz mica schist (calcareous)</u>

At the both abutments of the proposed damsite, the quartz mica schist is particularly hard probably owing much of its strength to high quartz content as well as recementation by calcite.

Exposed at the left abutment is a very hard massive metaquartzite. Schistosity varies from very slight to pronounced depending on the amount of mica in the rock. Cores obtained from the site indicate that the fresh rock is pale greenish grey with some joints developed parallel to the foliation. In a thin section of the core, the rock appears to consist of sericite and cryptocrystalline quartz, some in aggregates to form larger clasts. Some sections of the core are calcareous. At the right abutment the rock is essentially the same as the left abutment.

At both abutments, the rock dips at about 70 to 80 degrees towards the compass direction of 280 degrees. At the right abutment this results rockfall with slabs of rock 0.3 to 0.5 m thick breaking off along the foliation/bedding planes.

The similarity of the rock on both sides of the river valley, the limited extend along strike, and the interpretation from aerial photographs suggest that this calcareous quartz mica schist may be two limbs of a very tight syncline along which this section of the Galas River flows. However, this will have to be confirmed with further investigation.

<u>River terraces</u>

Along the river valleys, "river terraces" are spread in the meandering corner.

They consist of a mixture of colluvium and alluvium deposited by the rivers at the time of flooding. The alluvium consists of silt with mica and a trace of organic matter. It is plastic and generally medium brown. At many points along the Galas River, these terraces could be seen to have outcrops of metasediments extending above the water surface of the river and topped by alluvium as thin as metre forming the bank.

<u>Sand bars</u>

Sand and gravel bars formed at the inside of bends and

around particularly large rocky sections along the Galas and Pergau rivers were examined and sampled in test pits (Fig. 4). The pits were dug down to the water table or maximum of 3 metres.

Results of the investigation (see test pitting logs in the Attached Geological Data) show that the material making up the bars ranges from cobbles to clay with a predominance of sand. Cobbles are randomly distributed in the sand, while clay and silt are confined to be lenses with mostly less than 0.1 m thick. Wood fragments and finer organic matter are abundant but decrease with depth. The sand is loose and ranges from coarse to fine. It consists of subrounded quartz grains. Mica flakes are abundant. Silt is soft and contains abundant organic matter.

4.3 Core Boring

Core boring was conducted at 2 locations along the dam axis, with drilling length of 40 m respectively, using the hydraulic-driven rotary drilling machine.

Out of the two boreholes shown in Fig. 4, the D.BH-1 borehole is located at the left bank, about 10 m in height above the riverbed and the D.BH-2 borehole, at the right bank, is also 10 m in height above the riverbed.

The data of drilling logs for the boreholes is given in the Attached Geological Data. The field geological mapping result is shown in Figs.5 and 6. The result is also summarized in Section 4.7.

4.4 Borehole Permeability Test

The borehole permeability tests (or Lugeon tests), based on the "Earth Manual, USBR" were performed at 5 m intervals down the length of the boreholes by the use of an air packer. Basically eight different pressures were adopted to the test, i.e. 1 kg/cm^2, 3 kg/cm^2, 5 kg/cm^2, 7 kg/cm^2, 10 kg/cm^2, 8 kg/cm^2, 6 kg/cm^2, 4 kg/cm^2 and 2 kg/cm^2. However, in cases where the injection water rate became very large beyond the pump capacity, the test was terminated at the maximum obtained pressure.

The calculated Lugeon units and the permeability coefficients were computed by the following equations:

<u>Calculated Lugeon unit</u>

$$Lu = \frac{Q}{H} \times 10$$

where, Lu : calculated Lugeon unit
Q : water injection rate (l/m/min)
H : total pressure (kg/cm^2)

$$H = P_G + \frac{G_h + W_L}{10} - F_1$$

where,
- P_G : gauge pressure (kg/cm^2)
- G_h : gauge height (m)
- W_L : depth to ground water level (m)
- F_1 : pipe friction loss shown in the Attached Geological Data (kg/cm^2)

Permeability coefficient

$$K = \frac{Q}{2H \times 60} \ln \frac{l}{2r} = \frac{Q}{H} \times 0.036$$

where,
- K : permeability coefficient (cm/sec)
- Q : water injection rate (1/m/min)
- H : total head (kg/cm^2)
- l : length of the test section (cm)
- r : hole radius (cm).

The Lugeon units, described in the drilling logs and the geological section, are obtained from the H and Q relation curves shown in the Lugeon unit analysis results of the Attached Geological Data.

The records of the permeability tests and the friction loss test results are added to the Attached Geological Data.

The results of the tests are summarized as follows:

(1) In general, schist predominating at the damsite is found to be impermeable except for the high Lugeon unit zones.

(2) The high Lugeon unit is considered to be the result of the open cracks which are parallel to schistosity.

(3) Impermeable zones, with maximum Lugeon units of less than 2, are identified at depths of 20 m to 30 m below the ground surface. None of foundation treatment for permeability is required.

(4) From the geological conditions, grouting is judged to be available for foundation treatment with its Lugeon unit of more than 2.

4.5 Test-pitting

Test-pitting was carried out at 2 km and 7 km upstream of the Dabong damsite for the purpose of revealing the possibility of using river deposits for fine concrete aggregate.

The test-pits, 2 m circular or square in shape, were

excavated by manpower to a maximum depth of 3 m under the ground surface or upon reaching ground water whichever comes first.

The location of the test-pits is shown in Fig. 4. The result is summarized as follows:

(1) The test-pitting result is listed in the following tables:

Location	Test-pit Number	Depth (m)	Description
2 km upstream of Dabong damsite	D.TP-1	3.0	Sand with thin layers of clay
- do -	D.TP-1'	2.0	Sand
7 km upstream of Dabong damsite	D.TP-2	1.9	Sand, sand/ gravel
- do -	D.TP-3	3.0	Sand

(2) Sand is distributed on the left bank as alluvial terrace deposit, 2 km upstream of the Dabong damsite. This sand, fine to medium, together with organic matter and small wood fragment sporadically includes thin layers of clay. Its components are quartz, felspar, mica, etc. Grass roots are found above the 0.3 - 0.4 m depth level except for places not covered by vegetation.

(3) Sand and sand/gravel are distributed on the river-bar, 7 km upstream of the Dabong damsite. This sand is fine to coarse, with very thin layers of slit and clay.

The content of organic matter and small wood fragment is low compared with the Test-pits D.TP-1 and D.TP-1'.

On the other hand, sand/gravel with very thin layers of clay predominates at and around the brink of the river-bar. This gravel consists mainly of quartzite, granite, slate and schist with scattered cobbles up to a maximum size of 15 cm.

The grass roots reach down to a depth of about 0.4 m under the vegetation-covered ground surface.

(4) Sand and sand/gravel are concluded to be available for fine concrete aggregate on the condition that organic matter, wood fragment and silt/clay will be removed by means of washing before using.

(5) The potential quantity of sand and sand/gravel for use as fine concrete aggregate for the Dabong dam is roughly estimated as listed below:

Borrow Site	Location 1/	Area (m^2)	Thickness 2/ (m)	Volume 3/ (m^3)
D.B-1	2 km upstream	7.0×10^4	3	2.1×10^5
D.B-2	3 km upstream	2.5×10^4	3	6.0×10^4
D.B-3	4.5 km upstream	1.0×10^4	3	3.0×10^4
D.B-4	7 km upstream	3.6×10^4	3	1.1×10^5

Notes: 1/ Location is shown in Fig. 4.
2/ Thickness is presumed to be 3 m according to test-pitting results.
3/ Volume = Area x Thickness

4.6 Dam Construction Material Test

The gradation tests of 4 disturbed samples from the test-pits were carried out in accordance with the method specified in Concrete Manual Designation 6. The result is summarized as follows:

(1) The gradation test result is listed in the following table and its detailed result is shown in the Attached Geological Data:

Gradation (%)	D.TP-1 (2.5m)	D.TP-1' (0.75m)	D.TP-2 (0.65m)	D.TP-2 (1.5m)	D.TP-3 (2.0m)
Cobble	-	-	5.0	-	-
Gravel	2.0	1.8	27.4	12.6	-
Sand	97.9	98.2	67.5	87.3	98.0
Silt-clay	0.1	-	0.1	0.1	2.0

(2) Sand and gravel, distributed on the alluvial terraces and river-bars, are judged to be available for fine concrete aggregate by the gradation curves shown in the Attached Geological Data, since the material composition is mainly sand and sand/gravel, together with less than a few percent of silt-clay.

4.7 Engineering Consideration

In this Section, geotechnical consideration is described for the Dabong dam scheme based on the geological data obtained from the geological investigations.

(1) Geological condition of damsite

The bedrock consisting of calcareous schist is fairly hard

and massive despite considerable foliation. Schistosity, parallel to the bedding plane, strikes and dips NS/55°W.

Some of the joints run nearly parallel to schistosity while others strike and dip at N40°W/50°NW and N80°E/90°. No evidence of any significant fault was observed.

The weathering zone, pinkish-grey, develops to a depth of 5 m to 10 m from the ground surface and forms the 'cracky' zone. Particularly, the developed weathering zone is estimated to be present on the left bank higher than EL. 60 m.

Overburdens are generally thin because of wide exposure of bedrocks around the site. However, the talus with angular to sub-angular rocks having a diameter range of 0.5 m to 1.0 m exists upto a height of 20 m from the riverbed on the right bank. Its thickness is estimated to be from 1 m to 3 m. On the other hand, the talus, consisting mainly of residual soil, is present from the location of the gauge hut of elevation around EL. 45 m up to more than EL. 90 m, and its thickness is considered to be in the range of 1 m to 2 m.

Slope stability at the damsite shall be taken into account, particularly on the right bank where the schists dip steeply into the river. Shallow rock-sliding, parallel to the schistosity planes, and rockfall are possible during excavation. However, large-scale slides are not expected at the damsite.

(2) Strength of bedrocks

From the viewpoint of engineering geology, the foundation strength of the bedrocks, as listed below, is estimated based on rock classification:

Rock classification		Shear strength	
Rock class	Characteristic	Cohesion (kgf/cm)	Internal angle (degree)
CL	Weathered zone or 'cracky' zone	less than 5	30 to 35
CM	Slightly weathered, sound, massive	10 to 15	40 to 45
CH	Sound, massive	20	45 to 50

The bedrocks at the damsite, showing rock class of CM or CH, are evaluated to be sufficient for the construction of 50 m high class concrete gravity dam. No serious deformation is expected since the foundation is massive and sound.

(3) Permeability of bedrocks

In general, the bedrocks are considered to be impermeable

except for the open cracks and weathering zone. From the geological condition, grouting is available for foundation improvement regarding permeability.

(4) Dam construction materials

Limestones, located 4 km south of the damsite and around Kemubu village, are considered to be available for concrete aggregates. While, sand and sand/gravel, present as river deposits at the river banks and river-bars around the Dabong damsite are found to be suitable for fine concrete aggregates in quality but its amount is limited. If the limestones, famous for their unique caves in the bodies, will not be available due to the reason of sightseeing aspects, granites predominating widely 10 km west of damsite are recommended as new concrete aggregates despite its long hauling distance and its thick weathered layer.

The schist exposed at the damsite is judged to be unsuitable for concrete aggregate due to the flakiness of its rock fragments. An aplite, intruded into the sedimentary rock, is distributed at the opposite side of Dabong village. According to the field survey, no large fresh aplite is found around this area.

(5) Saddle dams

Two saddle dams are proposed at the locations of 6 km and 15 km north of the damsite. The rock of the damsites is considered to be sandstone and slate or schist with its strike and dip of about N60 - $70^{o}/60$ - 80^{o}E.

Since the foundation is not evaluated to be strong because of its intensive weathering, earth type dam or rock fill type dam is considered to be acceptable. Earth materials, decomposed rock and residual soil, are obtainable around the saddle damsites except for rock materials.

V. GEOLOGICAL INVESTIGATION FOR KEMUBU DAMSITE

5.1 General

The Kemubu dam is proposed as a concrete gravity type dam for flood mitigation with a crest height of EL. 82.0 m in maximum.

Geological investigation for the Kemubu damsite consists of field geological mapping using a topographic map with a scale of 1:25,000, core borings together with borehole permeability tests, test-pitting and dam construction material tests.

The items and quantities performed for the Kemubu dam scheme are listed below:

	Item	Quantity
1.	Field geological mapping	7.5 km^2
2.	Core borings	2 holes (40 metres each)
3.	Borehole permeability tests (Lugeon test)	14 nos.
4.	Test-pittings	4 pits
5.	Dam construction material tests (gradation tests)	5 samples

5.2 Field Geological Mapping

Field geological mapping was performed for the purpose of obtaining geological and geomorphological data. The geological map with a scale of 1:25,000 is shown in Fig. 7.

The result of field geological mapping is summarized below.

(1) General

According to Fig. 3, Triassic and Permian sedimentary rocks predominate at and around the Kemubu damsite. Bedrocks consist mainly of schist and volcanics moderately foliated due to metamorphism. These rocks are exposed along the river brinks and slopes of the both banks up to 15-30 m above the river bed.

Limestone forming characteristically steep hills is present 6 km northwest of the damsite.

Terrace deposits and river bars are identified as most recent geological units along the both banks sporadically.

Fault in the direction of northwest is found 1 km south of the damsite and small-scale fractured zones are identified in the rocks exposing around the damsite.

(2) Geological facies

Quartz mica schist

Around the proposed damsite, quartz mica schist forms a mountainous belt about 2 km wide stretching approximately north-south. This kind of rocks, greenish grey and pale pinkish grey, is massive because of high quartz contents.

Schistosity of quartz mica schist strikes and dips probably NW-N30^{o}W/60 - 80W parallel to the bedding plane.

Quartz mica schist (calcareous)

At the proposed damsite on both abutments the quartz mica schist is particularly hard due to its recementation by calcite.

Limestone

Limestone characterized by spectacular cliffs standing vertically is distributed 6 km northwest of the damsite. The rock, generally white to grey and very hard, is expected to have huge caves in its body.

Terrace deposit

Along the river course, terrace deposits are spread in the meandering corner. They consist of a mixture of colluvium and alluvium deposited in the river.

Sand bar

Sand bars distributed in the river consist of sand and gravel with silt, clay and organic matter.

Gravel ranging from cobble to pebble is randomly scattered in the sand while silt and clay are confined to be lenses with mostly less than 0.1 m thick. Wood fragments and fine organic matter are abundant but decrease with depth.

5.3 Core Boring

Core boring using the hydraulic-driven rotary drilling machine was carried out at 2 locations, of the left and right banks along the dam axis with drilling length of 40 m each as shown in Fig. 7.

Out of the two boreholes, the K-1 borehole is located at the left bank about 10 m in height above the river bed and the K-2 at the right bank also 10 m.

The data on drilling logs of the boreholes is shown in the Attached Geological Data. The field geological mapping result, is given in Figs.8 and 9.

The result is also summarized in Section 5.7.

5.4 Borehole Permeability Test

The permeability test (Lugeon test) was carried out by the same manner as did at the Dabong damsite (Refer to Section 4.4).

As a result of test, the P-Q curve as given in Geological Data (relation between pressure and quantity of water) is prepared, and the Lugeon value is determined as an index of permeability for the dam foundation.

High permeability, larger than 50 in the Lugeon value, was measured in the weathered zone, 10 to 20 m deep from the ground surface. On the other hand, in the part of sound bedrock the small Lugeon value (1 to 5) was measured.

5.5 Test-pitting

Test-pitting was carried out at 2 km downstream and 1 km upstream of the Kemubu damsite for the purpose of revealing the possibility of using river deposits for fine concrete aggregate.

The test-pits, 2 m circular or square in shape, were excavated by manpower to a maximum depth of 3 m under the ground surface or upon reaching ground water whichever comes first.

The location of the test-pits is shown in Fig. 7. The result is summarized as follows.

(1) The test-pitting results are listed in the following table:

Location	Test-pit Number	Depth (m)	Description
2 km downstream of Kemubu damsite	K.TP-1	2.5	Sand
1 km upstream of Kemubu damsite	K.TP-2	2.5	Sand, sand/gravel

(2) Sand distributed on the river-bar is fine to coarse with small amount of organic matter and wood fragment sporadically. Its components are quartz, felspar, mica, etc. Grass roots are found above the 0.3-0.4 m depth level except for places not covered by vegetation.

(3) Gravel consists mainly of quartzite, meta-sand stone and chert up to 15 cm in maximum size and is well graded as shown in the Attached Geological Data.

(4) The grass roots reach down to a depth of about 0.4 m under the vegetation-covered ground surface.

(5) Sand and sand/gravel are found to be available for fine concrete aggregate on the condition that organic matter and wood fragment will be removed by means of washing before using.

5.6 Dam Construction Material Test

The gradation tests of 4 distributed samples from the test-pits were carried out in accordance with the method specified in Concrete Manual Designations.

The result is summarized below:

(1) The gradation test results are listed in the following table and its detailed result is shown in the Attached Geological Data:

Gradation (%)	K.TP-1 (1.0 m)	K.TP-1 (2.5 m)	K.TP-2 (0.8 m)	K.TP-2 (2.0 m)
Cobble	-	-	-	8
Gravel	-	3	3	32
Sand	99	96	94	58
Slit-clay	1	1	3	2

(2) Sand and gravel of the river bars are judged to be available for fine concrete aggregate by the gradation curves.

5.7 Engineering Consideration

Geotechnical consideration is described for the Kemubu dam scheme based on the geological data obtained from the geological investigations.

(1) Geological conditions of damsite

The bedrock consists of calcareous quartz-mica schist which clearly exposes in series along the both banks of the damsite. On the other hand, the overburden of 2 m to 5 m thickness is present on the left bank slope.

Weathered and decomposed zones are estimated to be 5 m to 10 m at the left bank and 10 m to 15 m at the right bank.

Generally, the bedrock of the damsite strikes in the N-S direction which intersects the river at the nearly right angle and dips 70° to 85° toward the west.

A main group of joints runs in parallel with the schistocity plane at an interval of 0.5 m to 1 m.

No major fault is found at the damsite by the investigation but several minor faults parallel to the schistocity locally

appear in the bedrock.

(2) Strength of bedrock

From the view point of engineering geology, the foundation strength of the bedrocks is estimated as listed below:

Rock classification		Shear strength	
Rock class	Characteristic	Cohesion (kgf/cm^2)	Internal angle (degree)
CL	Weathered zone or 'cracky' zone	less than 5	30 to 35
CM	Slightly weathered, sound, massive	10 to 15	40 to 45
CH	Sound, massive	20	45 to 50

The bedrocks at the damsite, showing rock class of CM or CH, are evaluated to be sufficient for the construction of a 50 m high class concrete gravity dam. No serious deformation is expected since the foundation is massive and sound.

(3) Permeability of bedrock

According to the Lugeon test, the weathered zone is in high permeability. On the other hand, the sound rock which lies below 15 m in depth shows impermeability. However, there may be some possibility to encounter the places with high permeability due to cracky zone of schist in relation to schistocity.

Grouting is considered as an effective measure for the improvement of high permeability.

(4) Dam construction materials

(i) Concrete aggregate

Limestone is suitable for the concrete aggregate. Probable rock quarry site of limestone is situated in 5 km south-west of the damsite as shown in Fig.10. The geomorphology shows cliffs which are useful for taking the aggregate.

On the other hand, schist which is the major rock type in the project area is judged to be unsuitable for the aggregate due to the flaky condition with schistosity.

While, sand and sand/gravel, present as river deposits at the river bar around the Kemubu damsite, are found to be suitable for fine concrete aggregates in quality but its amount is limited.

Potential quantity of the river bar deposits shall be examined by the detailed investigation such as sounding and laboratory test.

Description of Thin Sections from Rock Samples for Dabong Damsite

1018-1 : Slate

This rock highly consists of very fine-grained quartz, chlorite, sericite and graphite. Very fine-grained felspar and calcite are also present. Pyrite and iron-oxide are also noted.

1018-2,3 & DBH-2 : Quartz-mica-calcite-schist

It is composed of fine to coarse-grained quartz. The fine-grained schists consist of mica and sericite. Quartz grains, mostly sub-angular, are randomly distributed in between this schist. Some of the quartz grains consist of recrystallized minerals. The quartz grains are also surrounded by cryptocrystalline quartz. Abundant amounts of calcite minerals were formed along the schistosity. Disseminated pyrite is also abundant.

11018-4 : Graphite - slate

This rock consists of abundant amounts of graphite associated with chlorite, sericite and very fine-grained quartz. Iron-oxide and iron pyrite are also present.

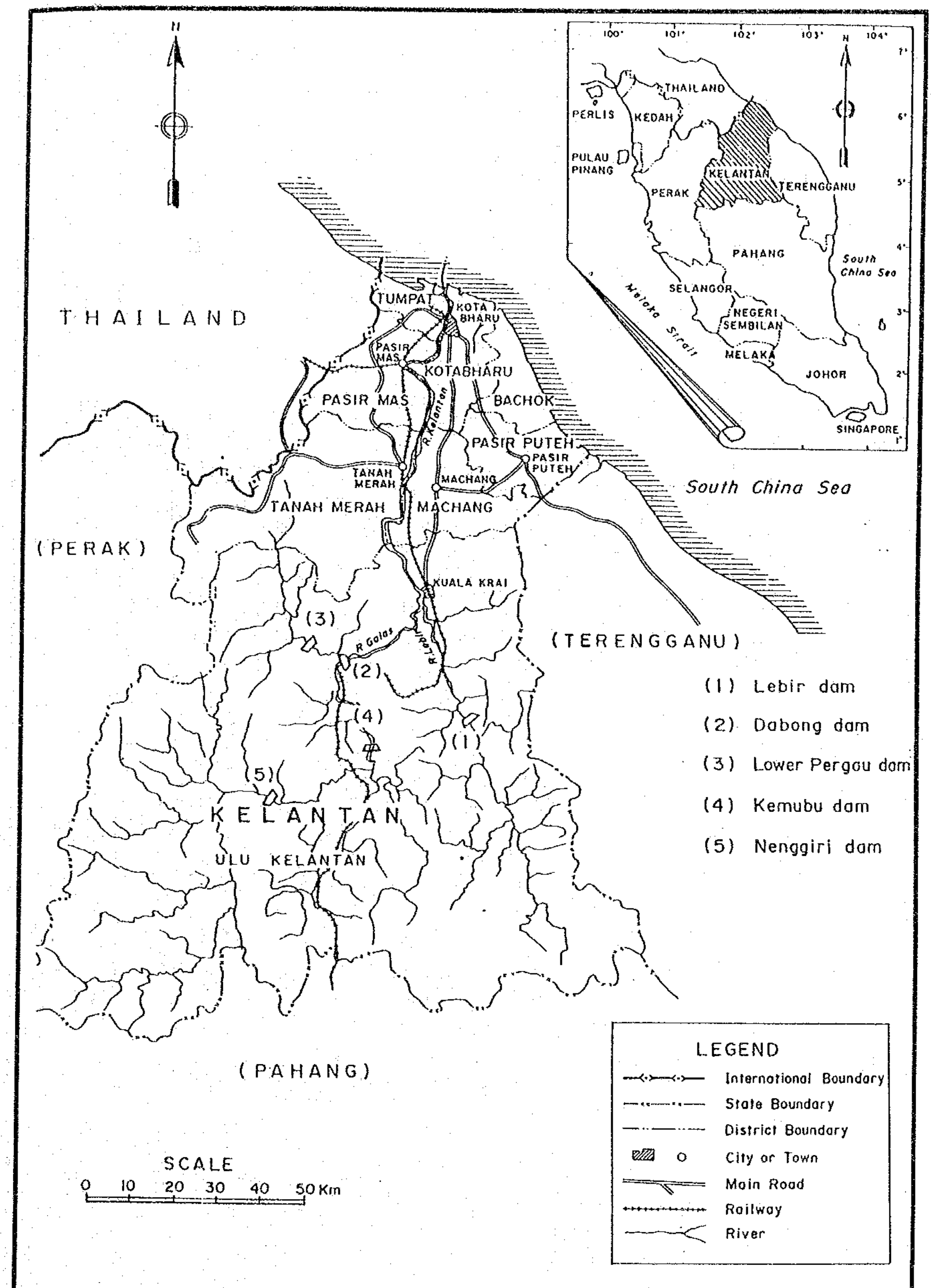

Fig.1 Location Map of Project Area

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ON
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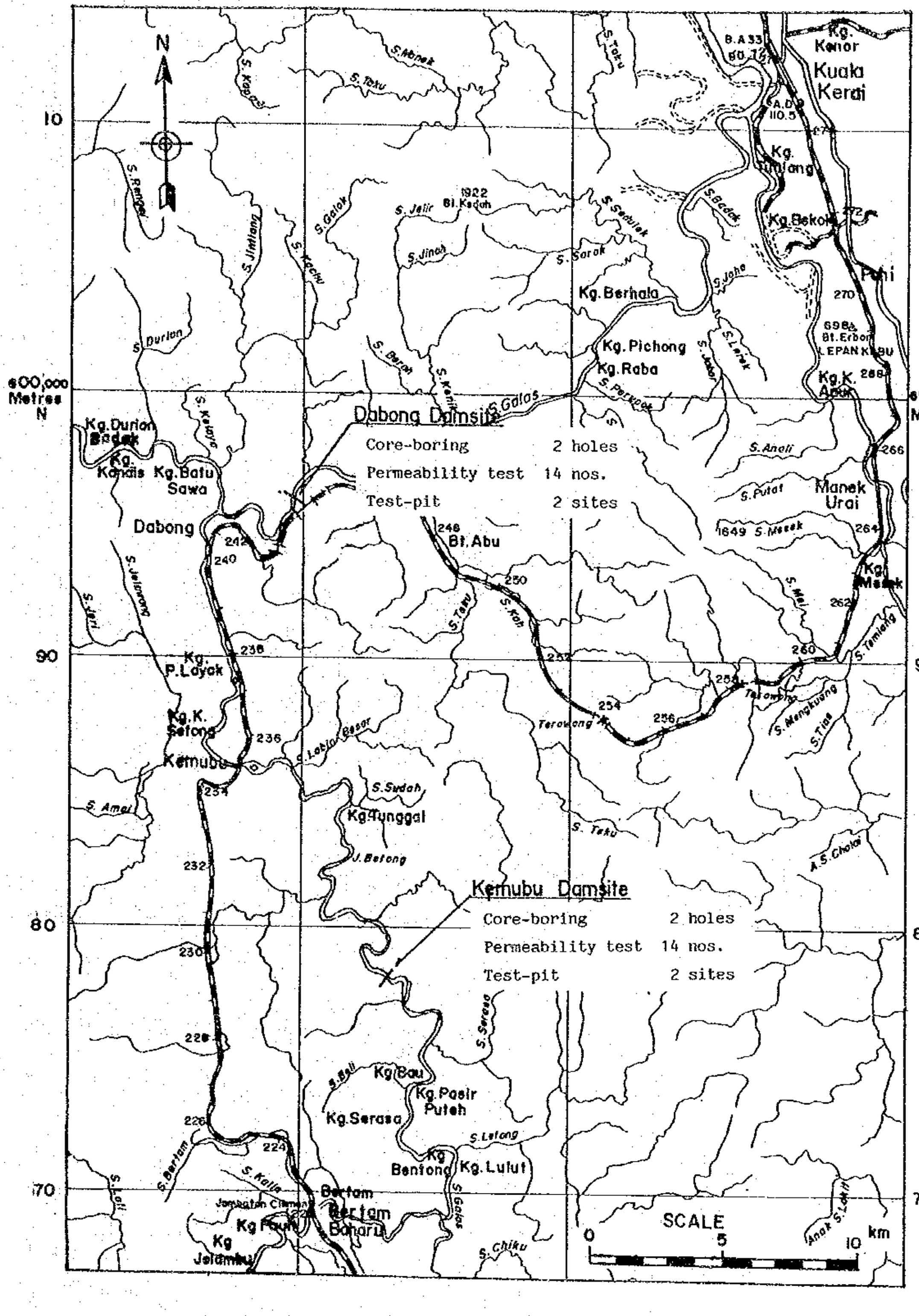

Fig.2 Location Map of Damsites

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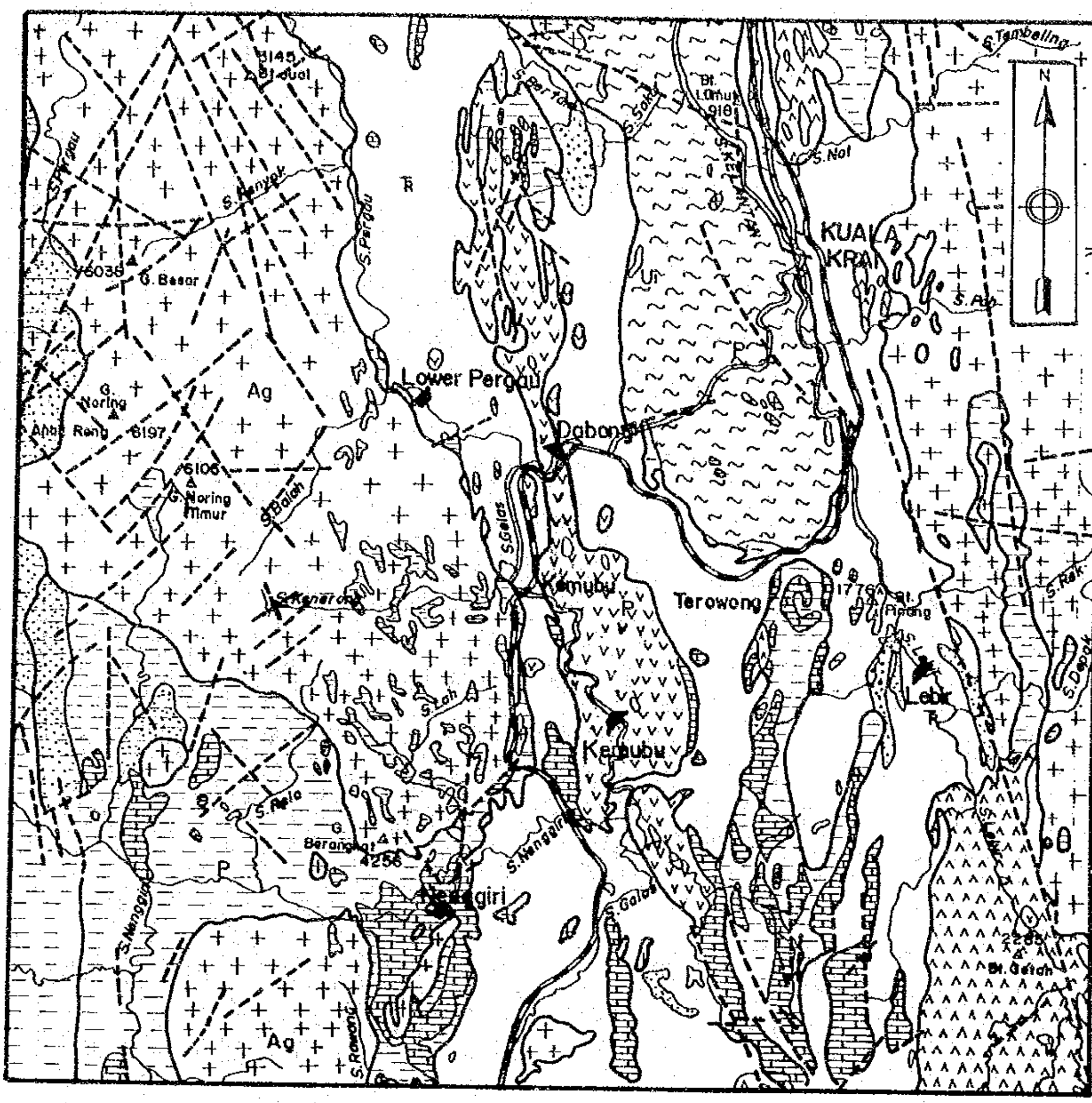

LEGEND

Era	Period	Symbol	Description
Mesozoic	Triassic		Sandstone, Siltstone, Shale, Schist, Limestone, Volcanics.
			Conglomerate.
Palaeozoic	Permian		Phyllite, Slate, Shale, Schist, Limestone, Volcanics.
			Limestone.
			Conglomerate.
			Schist.
			Quartz - mica - schist (around damsites), Acid volcanics mainly pyroclastics
			Basic volcanics mainly pyroclastics.

+ + : Acid intrusive, mainly granite.

: Fault. : Geological Boundary.

: Proposed damsite

: National railway.

SCALE

0 10 20 30 40 Km

Fig. 3 Regional Geological Map of Damsites

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STUDY
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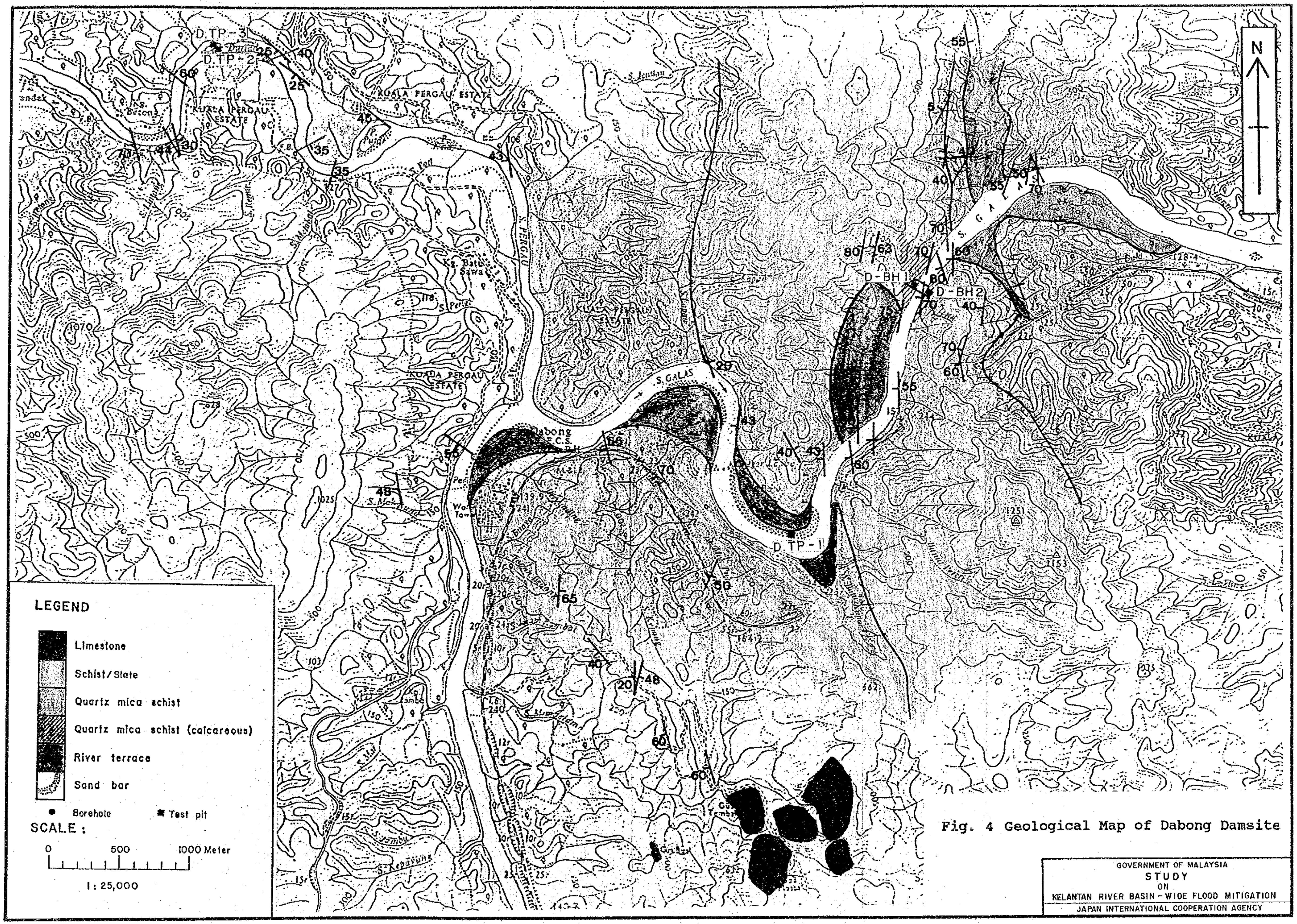

Fig. 4 Geological Map of Dabong Damsite

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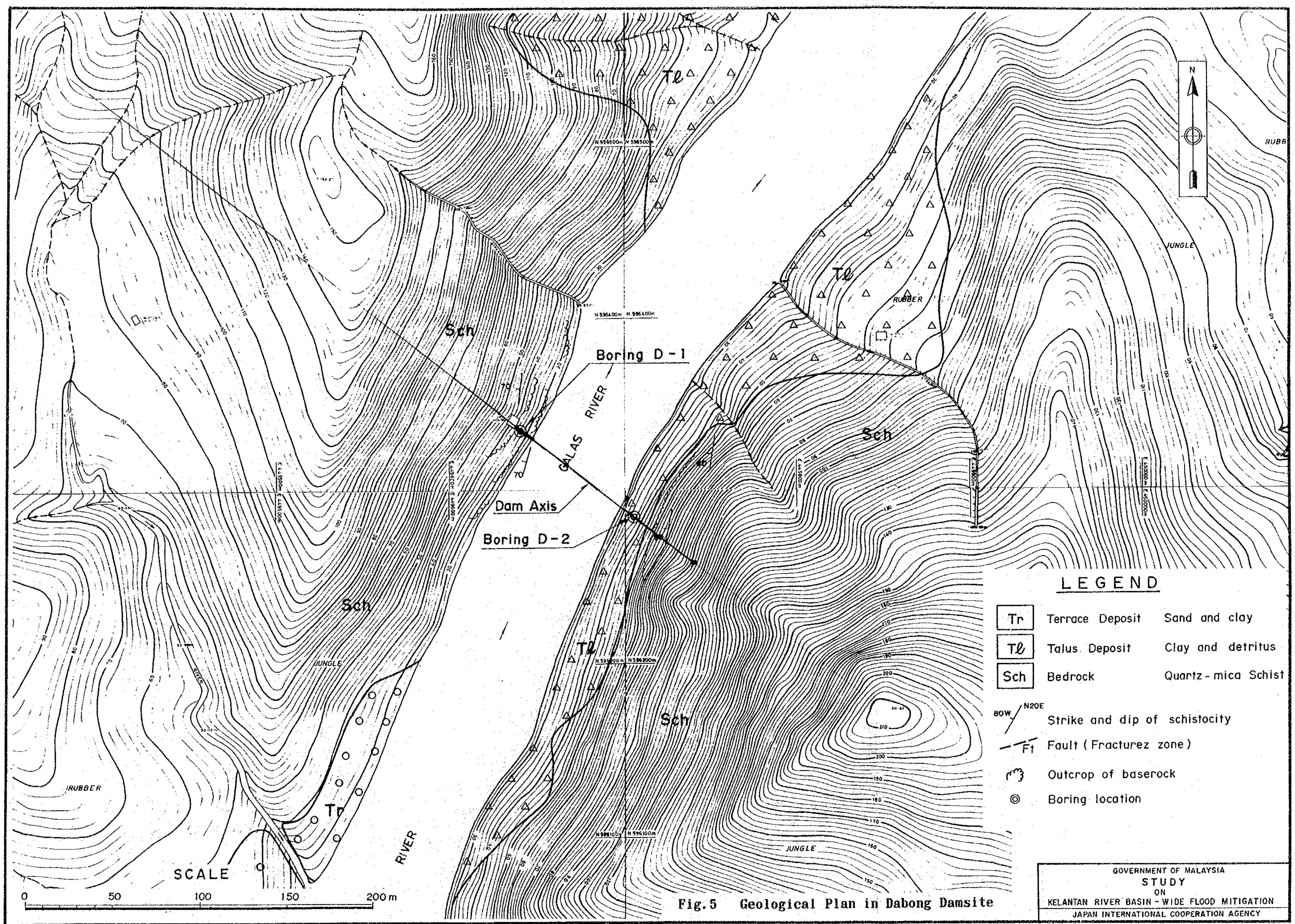

Fig.5 Geological Plan in Dabong Damsite

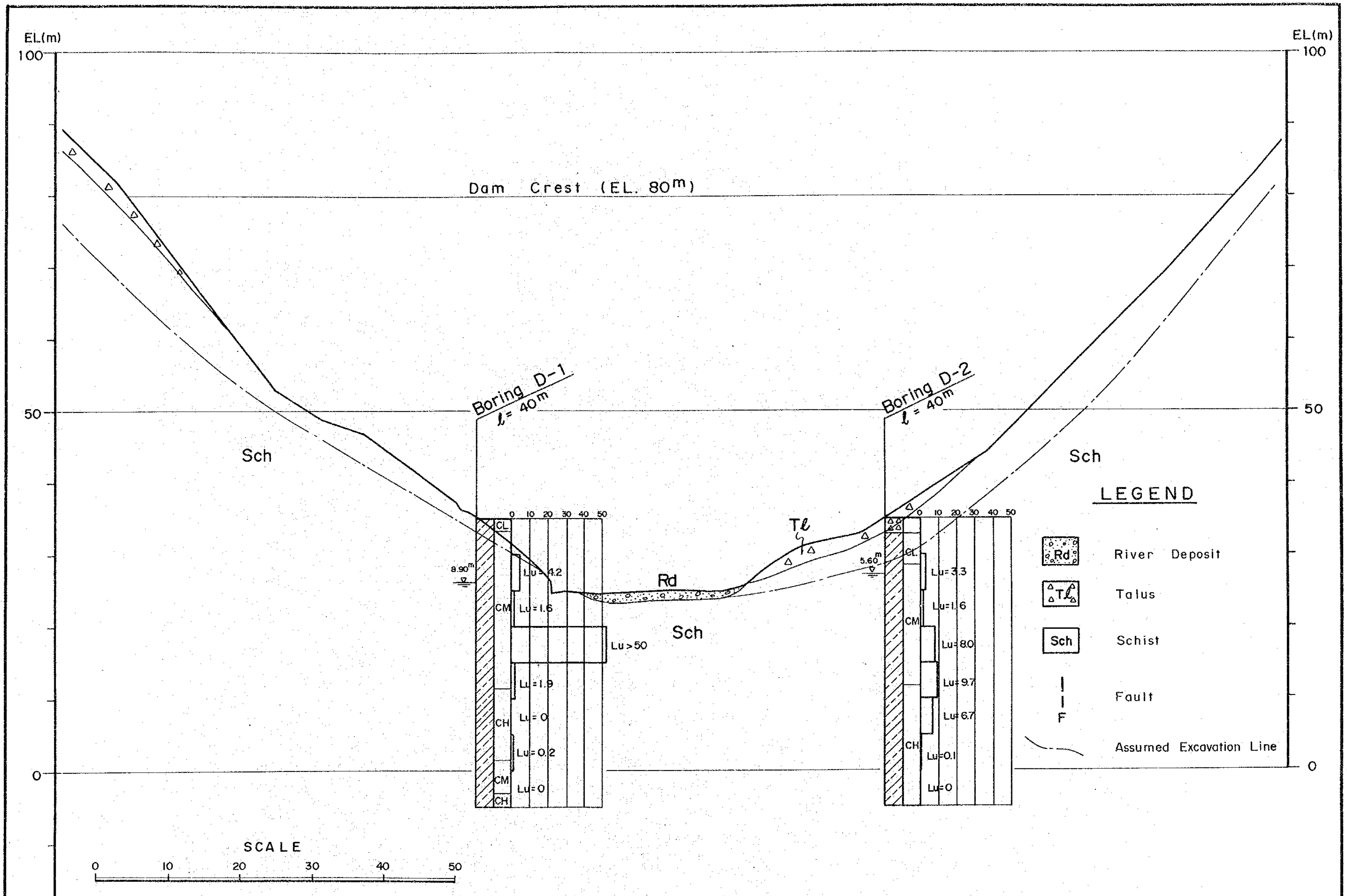

Fig. 6 Geological Profile of Dabong Damsite

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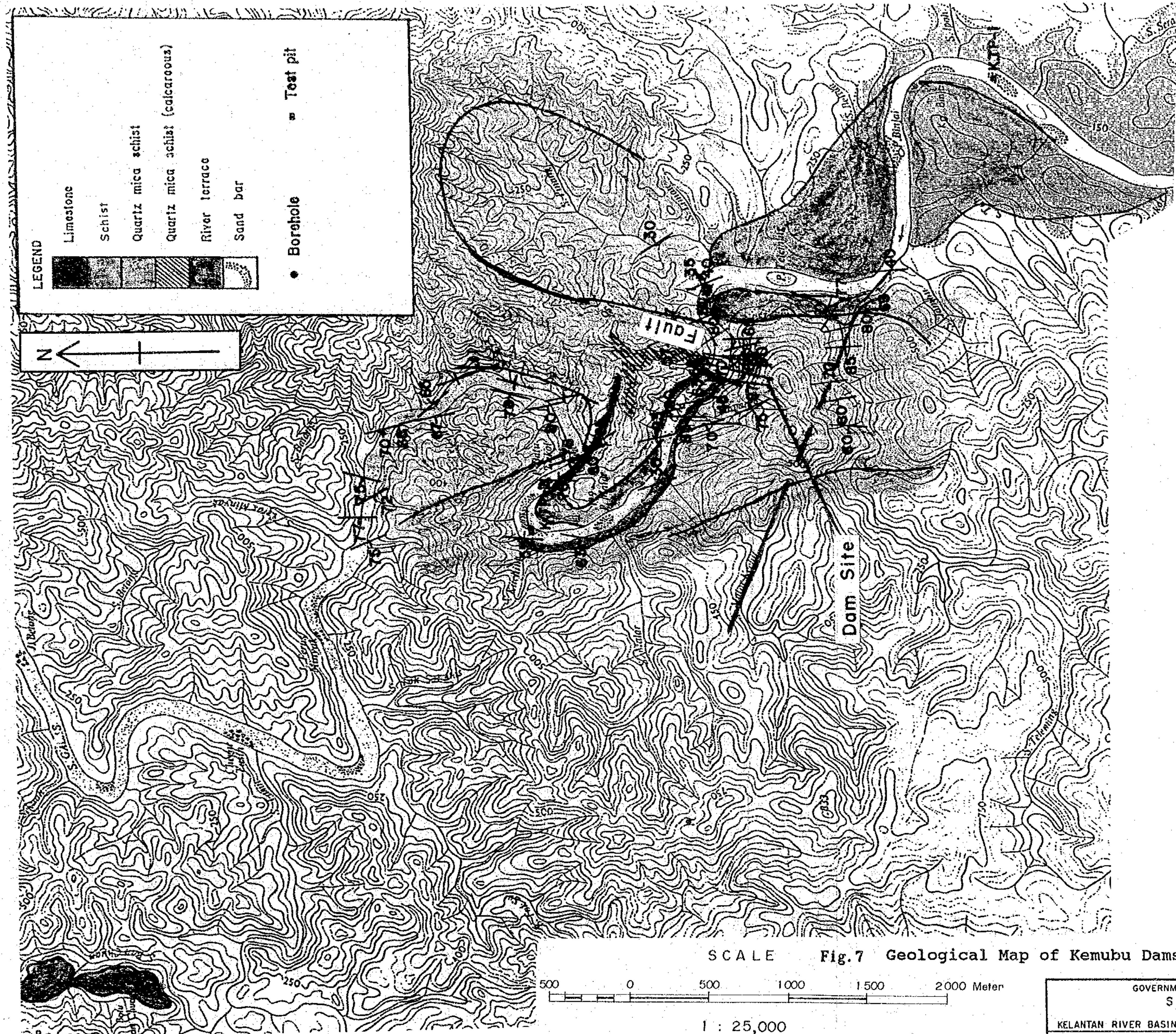

Fig.7 Geological Map of Kemubu Damsite

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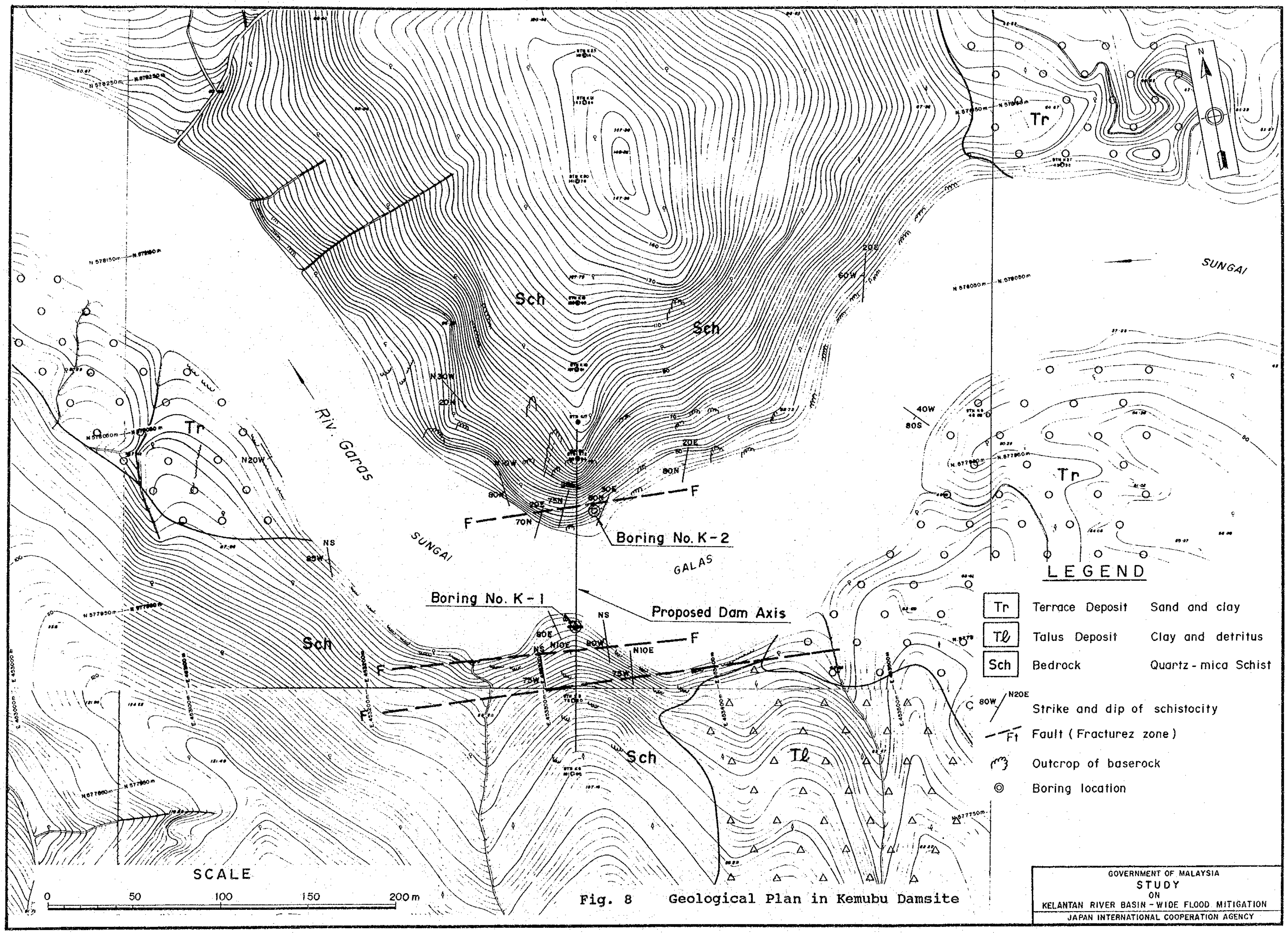

Fig. 8 Geological Plan in Kemubu Damsite

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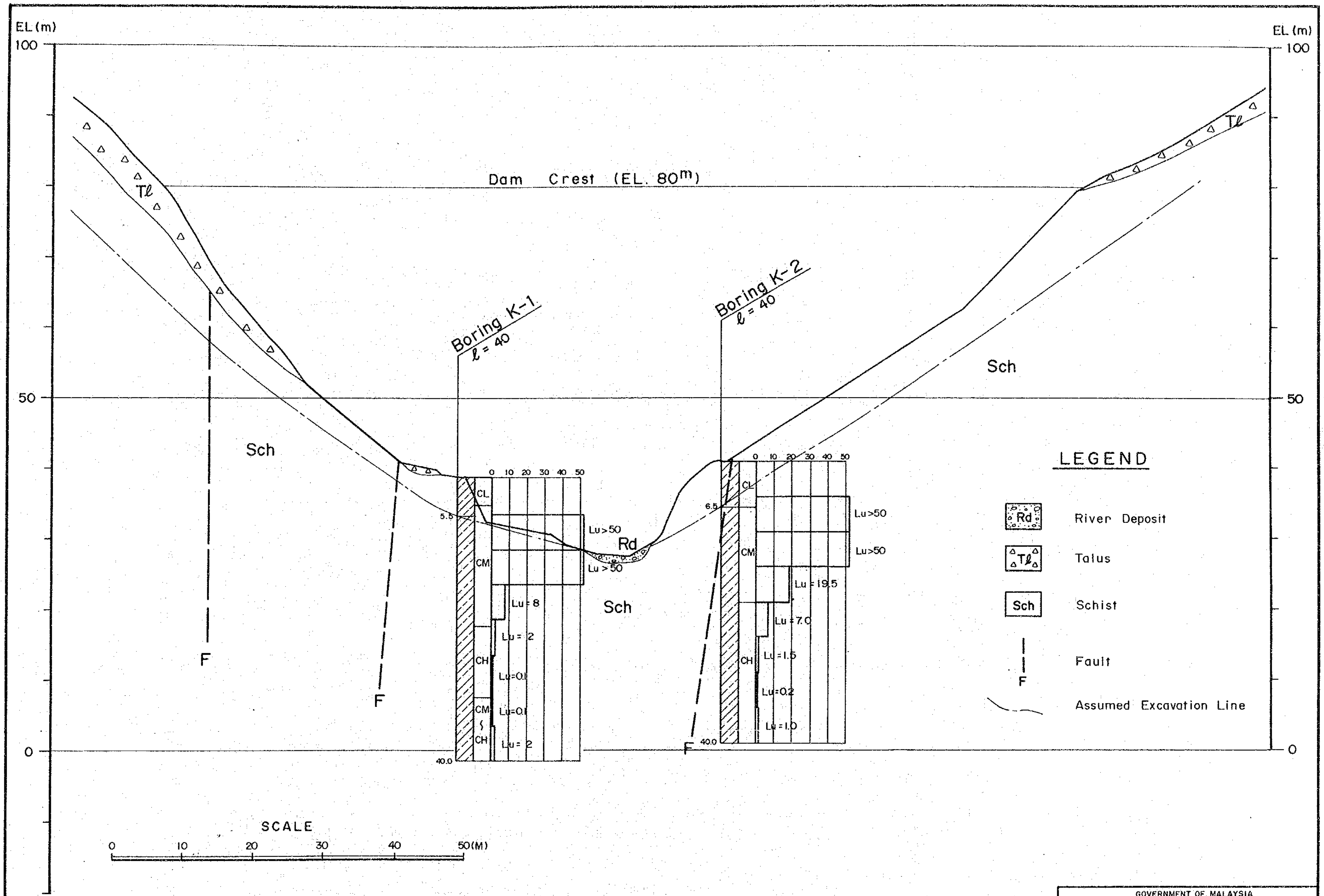

Fig. 9 Geological Profile of Kemubu Damsite

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