CHAPTER 10

STUDIES ON RELATIVE DEVELOPMENT PLANS

Chapter 10 Studies on Relative Development Plans

10.1. General

The Tekai Hydro-electric Power Development Project consists of upper dam with a gross reservoir storage of $3,400 \times 10^6$ m^3 and lower dam with that of 265×10^6 m^3.

The primary objective of the project is to provide peak power generation which is considered valuable at the upper dam and to cope with flat power generation at the lower dam. Necessary studies were made in connection with flood control, water utilization, diversion scheme and a pumped-storage scheme by means of these dams.

The Pahang River Basin includes very few catchment as the catchment area of the Tekai River Basin. Much expectation will hardly be entertained of flood control.

The Project has no definite provision for water utilization. As stable stream regimen into the Pahan River can be expected due to discharge following power generation and the large scale reservoir to be created by the upper dam will sufficiently meet water requirements, it is believed that latent water utilization effect to be provided by this Project will be relatively remarkable.

The diversion scheme is judged to be in appropriate in view of the estimated construction costs of intake facilities and power generation benefits.

The pumped-storage schemes should be determined in due consideration of a trend of power demand in the future, daily load curve and availability of surplus electric power during midnights.

The favorable storage efficiency and less head fluctuation of the upper and lower dams indicate that this Project will be technologically possible.

10.2. Flood Control

In the lower reaches from the lower dam site up to the confluence of the Tembeling River with the Tekai River, there are only houses perhaps belonging to a minority mountain group, and industrial facilities are hardly observed.

Accordingly, no great expectation can be anticipated of effects to be caused by flood control by the upper dam and lower dam upon the main Tekai River.

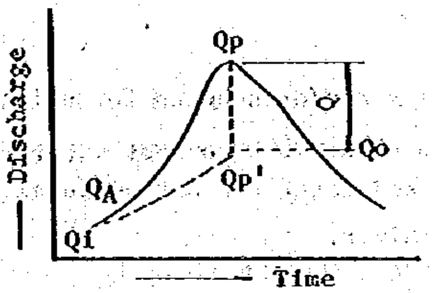
Land at a lower elevation located in Temerloh and adjacent areas was seriously damaged during the floods occurred in 1926, 1971 and 1972. (Refer to Fig. 10-1)

Since the catchment area of the Tekai River Basin accounts for a very few percentage in the catchment area of the Pahan River Basin where Temerloh site is located, the effect of flood control by Tekai Dam will be small.

Fig. 10-2 indicates relation between inflow and water level at the lower dam site when design flood is mitigated by means of spillway for the upper dam.

Fig. 10-3 also gives relations between the maximum discharge and flood control discharge in case flood is controlled by means of gates for flood control at the upper dam.

According to the method of flood control, water from the flood will be stored at a certain ratio against the inflow up to the peak inflow. After reaching the peak inflow, a certain quantity of water will be discharged.



(Constant Ratio and Quantity Discharge Method)

$$Q = \frac{Q_o - Q_A}{Qi - Q_A} = \text{Constant}$$

where,

Qi ; Inflow
Q_A ; Discharge on mitigation start
Qp ; Peak Discharge
Qp' ; Peak Discharge after mitigation
Q_o ; Outflow

10.3. Water Utilization

No concrete plans and/or schemes for utilization of water from the Tekai River have been worked out to meet water requirement for water supply, industrial water and water for agricultural use in the areas down-stream of the Tekai River.

Water discharged from the upper dam will be used for meeting peak demand. Such water will be kept constant by the lower dam.

This will ensure stable water supply to the main Pahang River. Some of such water will be utilized for meeting the irrigation requirements of agricultural land in the areas, representing latent or potential effect of water utilization.

The plan of operation for irrigation work in the Pahang River Basin is as given in Fig. 10-4. The said plan is being implemented as the National Small Scale Irrigation Project on the responsibility of the Ministry of Agriculture irrespective of hydro-electric dam projects.

Data and findings on promising crops, acreage under cultivation, irrigation efficiency, agricultural production systems, manning schedules (schedules for mobilization of man power) are not available. Incidentally, benefits accruing water utilization are not incorporated in the economic analysis.

10.4. Diversion Shceme

Benefits caused by increase in electric energy generation due to intake of water from the upper steam of the Tembeling River to the Tekai River are studied in the economic analysis.

For the purpose of undertaking the work, selection of three candidate sites was made by means of a topographical map on a scale of 1/63,360. Then, calculation of electric energy generation and estimates of costs of intake facilities were prepared by reference to the length of diversion tunnels and the catchment area, thereby obtaining the figure of B/C and B-C. (Refer to Fig. 10-5)

Benefits were calculated under the following basic conditions.

i) The discharge at the intake is to be equivalent to a catchment conversion ratio of discharge at the upper dam site.

$$Qq = \frac{Aq}{Au} \times Qu$$

where,

Qq = Intake Discharge

Qu = Discharge at Upper Dam

Aq = Catchment Area of Intake (84.4 km^2)

Au = Catchment Area of Upper Dam (1,200 km^2)

ii) The wet discharge (Q: 185 days' firm discharge in a year) and normal discharge (Q: 95 days' firm discharge in a year) at the intake are so small as 3.1 m^3/sec and 1.9 m^3/sec. Therefore, the maximum intake volume has been determined according to the minimum section of a tunnel.

Maximum Intake Volume = 3.5 m^3/sec

D = 1.8 m

iii) Electric energy generation and rated output were calculated upon establishment of the optimum scale of upper dam.

The results of this study are as shown in Tables 10-1 and 10-2. It is not judged that this diversion scheme is effective.

10.5. Pumped-storage Scheme

It is apparent that a pure pumped-storage scheme commonly implemented in overseas countries is not suitable topographically, geological and from an economic standpoint in formulating a pumped-storage scheme on the Tekai River. Only a mixed pumped-storage scheme will be conceivable as far as the Tekai River is concerned. The characteristics of the Tekai River has a very gentle gradient with an open valley.

A favorable storage efficiency of a reservoir (ratio of reservoir storage over dam volume) can be expected if a reservoir is constructed at the gorge construction of a canyon of which geological conditions seem to be favorable.

In view of the above conditions, it will be possible for a large quantity of storage to be obtained if damming up is made to some extent.

Accordingly, a shallow effective depth will ensure a reservoir storage capacity only for pumped-storage purposes. Since there are few fluctuations in the head, the area will be suitable for a mixed pumped-storaged power scheme.

It is proposed that necessary studies be made on a mixed pumped-storaged scheme to be implemented together with the series (two dams) development scheme, one of the components included in the Tekai Hydro-electric Power Development Project, described in this report.

(a) Storage Capacity for Pumped-storage

The effective reservoir storage of the upper reservoir and the lower reservoir involved in the series (two dams) development scheme is 3,400 x 10^6 m^3 and 265 x 10^6 m^3, respectively.

The available storage capacity of the upper reservoir will not need a reservoir storage capacity merely for pumped-storage purposes as the effective reservoir storage of the above mentioned reservoir is sufficiently large.

In the event that the full supply level of the lower reservoir under the present scheme should be dammed up by 0.5 m, it will be possible to ensure a reservoir storage capacity of approximately 10^6 m^3 only for the pumped-storage purpose.

(b) Scale of Pumped-storage Power Generation

If the above-mentioned reservoir storage capacity is used for six hours of peak duration identical with the operation hours for peak duration for a power plant in the upstream, the following formula can be expressed in order to obtain a scale of 350,000 kW as a maximum output of the said power plant.

$$\frac{12,000,000\ m^3}{6\ hr \times 3,600\ sec/hr} = 556\ m^3/sec\ \text{(Maximum Turbine Discharge)}$$

$$9.8 \times 0.82 \times 556\ m^3/sec \times 79\ m \fallingdotseq 350,000\ kW$$

(c) Time of Addition of Plant Units for Pumped-storage Power Plant

The time of addition of plant unit(s) for a pumped-storage power plant will be dependent upon a general trend of power demand, configuration of load curve, availability of surplus electric power during the midnight.

Now that the subjects are yet to be studied, it is, of course, impossible to decide on such time of installing additional units.

It is suggested that the same portions of work be carried out in making advance investments beforehand on the occasion of undertaking required works involved in the series (two dams) development scheme in anticipation of addition of units to a pumped-storage power plant in the future.

(d) Desirable Works to Be Undertaken by Advance Investments

Structures of which addition will not be possible or will require an enormous amount of costs at the time of additing plant units to a pumped-storage power plant will be;

(1) Portions to be dammed up for lower dam

(2) Screen and gate of intake for pumped-storage power plant

(3) Foundation for power plant

(4) Draft cube and draft gate

CHAPTER II

DESIGN OF FACILITIES AND STRUCTURES

The conception of a basic design for upper and lower dams is summarized as follows:

(a) Design Flood

The design flood will be a flood with a probability of 1/1,000 year and its hydrograph is drawn according to the tank model method by Type A of a rainfall pattern. (Refer to Fig. 11-1)

Design flood at upper damsite: $Q_D = 4,500\ m^3/sec.$,
Design flood at lower damsite: $Q_D = 5,000\ m^3/sec.$

(Source ; 3.5.13, Vol. 3 Pahang River Basin Study)

(b) Damming-up

The height of damming-up will be 5 m.

The design flood discharge of the diversion tunnel has been determined with a probability of 1/20 year flood in case of a fill-type dam and with that of 1/10 year flood in case of a concrete dam.

As far as a dam of fill-type is concerned, floods accuring during construction will be treated only by means of diversion tunnels.

In case of a concrete type dam, arrangements have been made to enable such flood to be inflowed through a bypass on the main dam in addition to the said diversion tunnels for a rockfill type dam so that the burden of the diversion tunnels can be reduced.

(c) Type of Dam

A type of dam which seems most suitable by topography and geology at the dam site has been selected. The types of dams are as follows:

Upper damsite ..... Rockfill type dam
Lower damsite ..... Concrete gravity type dam

The dam slope in the upper face of dam has been determined, based upon data concerning Kenyir dam and others. Detailed studies on configuration of the dam are to be made at the next stage with the aim of reducing embankment and economizing construction costs of such dam.

Upstream Batter of Upper Dam	1:1.80
Downstream Batter of Upper Dam	1:1.75
Upstream Batter of Lower Dam	1:0.10
Downstream Batter of Lower Dam	1:0.70

(d) Spillway

Studies were made on which side of both banks spillways with gates should be constructed.

As a result of the studies, it has been concluded that spillways should be constructed on the left side bank because the construction costs of the spillways are less.

Both cases of discharge by a free overflow weir and by a regulating gate were studied in connection with the above-mentioned spillways. Because of economical aspects, a spillway with gates has been adopted.

		Construction Cost (10^6M$)
Spillway	with gates on the right bank	52
	with gates on the left bank	36
	without gates on the left bank	41

Spillways with gates for control of discharge for lower dam seems to be more suitable than those with a free overflow weir, which will reduce the effective head of the upper dam and will cause damming up.

A radial gate will be employed as a gate for control of discharge. The volume of the reservoir is so large as to be 3,400 x 10^6 m^3 in case of the upper dam. The spillway has been determined upon calculation of reservoir operation in view of a reservoir storage effect.

As for the lower dam, spillways have been designed in the section where the maximum inflow depending on discharge from the upper dam and inflow from the catchment area can be discharged.

(e) Stilling Pool

It has been designed that a stilling facility at the end of a spillway be provided with a vertical apron and end sill.

(f) Foundation Treatment

Blanket grouting and curtain grouting as foundation treatment will be required for the purpose of stopping water to infiltrate into a core zone of the dam. Consolidation for improving the conditions of a foundation in loose portions close to the surface of the foundation and consolidation grouting for stopping water will be also required.

(g) Intake and Penstock

The depth of deposited silt in the reservoir was calculated based on deposition of sediments for a period of 100 years. However, the intake for lower dam will be provided with an inclined type inlet, which will be more economical more than a intake of tower type. A roller gate will be adopted as a gate for controlling discharge.

As far as the lower dam is concerned, a multi-stage gate fixed with the dam will be constructed to meet the irrigation requirements in the future. The number of lines of the penstocks will be two in consideration of maintenance and inspection.

At the entrance of a turbine, a butterfly valve will be equipped with. At the outlet of a turbine draft, a roller gate commonly usable for two outlets will be provided thereby enabling turbine and drafts to be repaired and checked.

(h) Hydraulic Turbine

A francis type turbine is advantageous in respect of handling and maintenance. Costs of manufacturing of and civil works for the said turbine are less expensive, compared with a turbine of Kaplan type. Accordingly, a francis type turbine has been selected for the upper dam.

(i) Power Plant and Switchyard

The power plant is to be located immediately downstream of the dam. Likewise, the layout of providing an outlet immediately downstream of the power plant has been prepared.

Since a favourable foundation depth is foreseeable, it is proposed to adopt a barrel type foundation which is more economical. The switchyard is to be constructed close to the power plant in any case because of availability of suitable land.

CHAPTER 12

CONSTRUCTION COST ESTIMATES

Chapter 12 Construction Cost Estimates

12.1. General

The estimated construction costs are composed of (a) Costs of civil works, (b) Costs of electro-mechanical equipment, (c) Engineering fee, (d) Administrative costs and (e) Contingencies.

Items of estimation are limited to major ones included in the costs of civil works conceivable at the preliminary study stage. In order to make up for items of work which are not incorporated in the major itmes, costs equivalent to approximately 5 to 10 percent of these of civil works are enumerated as an item of miscellaneous costs by reference to the actually recorded construction costs of the Trengganu Project.

13 percent of the costs of civil works stated in (a) plus those of electro/mechanical equipment is regarded as the engineering fee in (c). The administrative costs in (d) are equivalent to 10 percent of the total costs of civil works in (a) and the electro/mechanical equipment in (b). The contingencies are equivalent to five percent of a total of costs of (a), (b), (c) and (d).

12.2. Unit Rate

The unit rates used for estimation of the construction costs are based on those for the Trengganu project under construction by reference to unit rates involved in projects of a similar nature, such as Temengor, Kenering and Bersia Projects.

In settlement of these unit rates, contractual conditions of works, escalation and inflation were also taken into account. In order to refine the work, it is deemed necessary that detailed studies be undertaken in connection with the number of working days in the respective seasons, kinds of construction tools and instruments, determination of the number of the said tools and instruments, computation of hire and rent, transportation distance etc.

The unit rates for civil works are as summarized in Table 12-1.

12.3. Estimates of Construction Costs

Estimated construction costs of the optimum plans viewed from the economical aspects of upper single (one dam) development scheme, lower single (one dam) development scheme and series (two dams) development scheme were as shown in Tables 12-2, 12-3, 12-4 and 12-5.

CHAPTER 13

BENEFIT

Chapter 13 Benefit

13.1. General

The meaning of the benefit in this chapter is the benefit gained from the alternative thermal power plant for justifying the most optimum size of the project, though detail analysis of the benefit of the Tekai hydro-electric project will be carried through detail feasibility study of the project.

In calculating the benefit out of the alternative thermal power plant, the value in the following table is employed on the assumption that the Tekai project has the undermentioned installed capacity and generating energy. Another assumption, Tekai hydro power station bears the daily load similar to the Sultan Idris II (SIHY) hydro power station is also adopted.

Items / Location	Installed Capacity (kW)	Annual Generating Energy (10^6 kWh)	Plant Factor
Upper Site	70,000	243.7	0.40
Lower Site	24,000	62.3	0.30
Total	94,000	306.0	0.37

13.2. Benefit Cost of the Alternative Thermal Power Plant

Five (5) units of package type 22 MW gas turbine are finally picked out as for the total output 94,000 kW on the point of view that the plant cost is lower and operation cost is cheaper compared with another alternative power plant consisting of two (2) units of 22 MW gas turbine and one (1) unit of 50 MW steam power plant.

Daily running hours for these five (5) units are established shown as Fig. 13-1.

Daily operation time, annual energy generation, plant efficiency, annual fuel consumption for generating energy, operation days, fuel consumption for start-up of these five (5) units are calculated as shown in Table 13-1.

Fig. 13-1 Model Daily Power Generating Curve of Alternative Thermal Power Station

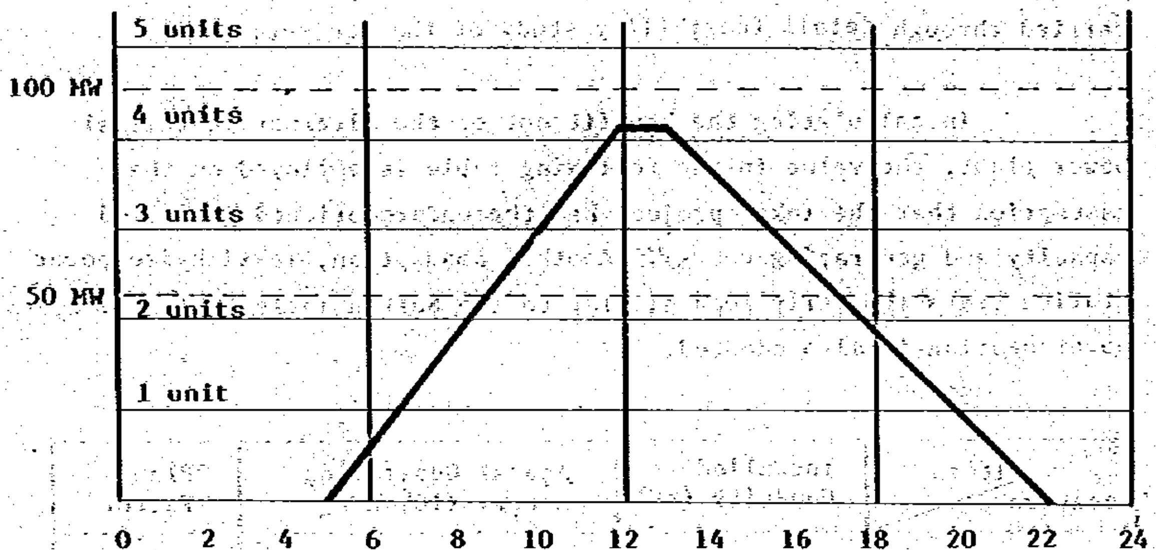


Table 13-1 Annual Fuel Consumption

Item / Unit	Daily Running Hour	Annual Generating Energy $(10^6/kWh)$	Thermal Efficiency (%)	Fuel Consumption (ton)	Annual Running Days (day)	Annual Fuel Consumption for Starting up (ton)	Annual Station Service Use (ton)	Total Fuel Consumption (ton)
1	17	117.81	27.5	33,458	365	110	985	34,553
2	13.5	91.54	27.0	26,455	365	110	782	27,247
3	10	62.24	27.0	17,987	365	110	580	18,677
4	6	33.31	26.0	9,993	365	110	348	10,451
5	2.5	1.10	20.0	394	180	54	145	593
Total		306.00		88,287		494	2,840	91,521

Remarks: 1) Gas turbine requires 300 kg fuel oil for only starting up.

2) Fuel is residual oil with heat value of 11,000 kcal/kg.

3) Fuel consumption for station service use is 2.5% of installed capacity 22 MW.

13.2.1. Calculation Formula for Benefit Cost

Benefit cost is expressed by the following formula;

B = Annual fixed cost + Annual variable cost

1) Annual Fixed Cost

(a) Construction cost/kW

Construction cost of 22 MW gas turbine unit on turn key basis is assumed to be US$250/kW.

US$250/kW x 2.2 = M$550/kW (1 US$ = 2.2 M$)

Annual capital cost is:

M$550 x 0.1076 = M$55.89/kW .... (1)

Presumed life of G/T : 15 years

Interest rate : 6.6%

CRF : 0.1076

(b) Operation cost/kW

Operation shift: 4 persons x 5 group = 20 person

daytime shift = 10 person

Total = 30 person

Annual personnel expense:

M$8,500 x 30 person = M$255,000

(Personnel expense: M$8,500/year person)

Annual personnel expense per kW

M$255,000 ÷ 94,000 kW = M$2.7/kW .... (2)

(c) Maintenance cost/kW

M$550/kW x 0.03 = M$16.5/kW .... (3)

(3% of construction cost/kW)

Accordingly, annual fixed cost of (1) + (2) + (3) is
55.89 + 2.7 + 16.5 = M$75.09/kW

2) Variable Cost

Total annual fuel consumption for gas turbine is 91.521 ton as given in Table 13.2.
Assuming the fuel cost of M$506/ton for residual oil, fuel cost per kWH will be M$0.15/kWH.

$$91.521 \text{ ton} \times \text{M\$}506 + 306 \times 10^6 \text{ kWH} = \text{M\$}0.15/\text{kWH}$$

Therefore, Benefit cost (B) is:

$$B = 75.09P + 0.15E \text{ (M\$)}$$

Note: P = Output of Tekai hydro station (kW)
E = Annual energy of Tekai hydro station (kWH)

13.2.2. Benefit Cost

Benefit cost of the series (tow dams) development is calculated as follows;

$$\begin{aligned} B &= (102.3 \text{ kW} + 11.5 \text{ kW}) \times 10^3 \times 75.09 \\ &\quad + (224.6 \text{ kWH} + 101.7 \text{ kWH}) \times 10^6 \times 0.15 \\ &= \text{M\$}57.49 \times 10^6 \end{aligned}$$

	Installed Capacity (kW)	Annual Energy (10^6 kWH)
i) Upper Dam	102.3	224.6
ii) Lower Dam	11.5	101.7

In case of alterntive power plant consisting of two (2) units of 22 MW gas turbine and one (1) unit of steam power plant, benefit cost is expressed by the following formula;

$$B = 137.1p + 0.151E \text{ (M\$)}$$

CHAPTER 14

CONSTRUCTION SCHEDULE

Chapter 14 Construction Schedule

As a result of making studies on various alternatives, it has been proposed that upper dam be 90.00 m high and of rockfill type and that the installed capacity of a power plant be 104 MW as the major features of a series (two dams) development scheme in connection with the Tekai Hydro-electric Power Development Project.

Likewise, it is also considered optimal from economic standpoints that the lower dam will be 38.00 m in height and be of concrete gravity type in addition to a power plant with an installed capacity of 12 MW.

This construction schedule has been prepared on the assumption that work involved in the proposed scheme is to be undertaken in a normally conceived standard manner.

As for a construction schedule prior to the commencement of construction work, this feasibility study is expected to be completed around in the middle of 1983. Then necessary investigations, studies, analysis and computations required for the performance of definite studies (designs) will be performed for approximately two years.

Preparation of design reports, bidding documents including specifications, various forms and price tables, bidding for selection of contractors, approaches to financial sources and contract award will require a period of one year.

Accordingly, construction work will be commenced at around the middle of 1986.

The construction schedule after commencement of construction work is as shown in Fig. 14-1. Since construction work is undertaken regarding the series (two dams) development scheme, steps of beginning construction work should be further studied at a stage when the scheme will be finalized.

The following items were fully taken into consideration in preparation of the construction schedule.

i) A construction schedule for construction of upper dam of which construction scale will be large and relevant power plant by preference should be considered.

ii) Construction of lower dam and relevant power plant should be commenced belatedly. Their completion time is to be synchronized with the completion of upper dam and relevant power plant, in order that the said facilities may be put into operation at the same time.

iii) As for the reservoirs, it will be preferable to commence submergence at a stage when banking and concrete placing for the main dam will be progressed to some extent.

In connection with upper dam and relevant power plant, access roads for construction, temporary buildings, and living quarters will be constructed and arrangement for motive power and telecommunication facilities will be made in the first year.

In the second year temporary closure, construction of temporary diversion tunnels will be undertaken. Construction of the main dams will be completed in the third and fourth years.

Submergence should be commenced in the middle of the fourth year when construction of the main dams will be progressed to some degree.

Construction of spillways, intakes and serge tanks which have no direct relations with diversion tunnels should be commenced in the third year.

It is also suitable to commence construction of the powerhouse and switchyard in the fourth year to be in time for installation of electro/mechanical equipment which will begin at around the middle of the fourth year.

Commissioning of the dam and power plant at the end of the fifth year can be anticipated provided that the proposed construction schedule is to be put into practice smoothly.

However approximately twenty two months are allotted to the work of banking the main dam (especially a core zone) which raises the most serious problem in connection with construction work in tropical weather areas with much precipitation.

This period of time will be more than enough to complete the work stated hereinabove. So far as lower dam and relevant power plant are concerened, construction of both facilities may be commenced in the second year because main access roads will have been constructed expect for access roads of which partial portions in a banking area will require construction for transport of materials and equipment.

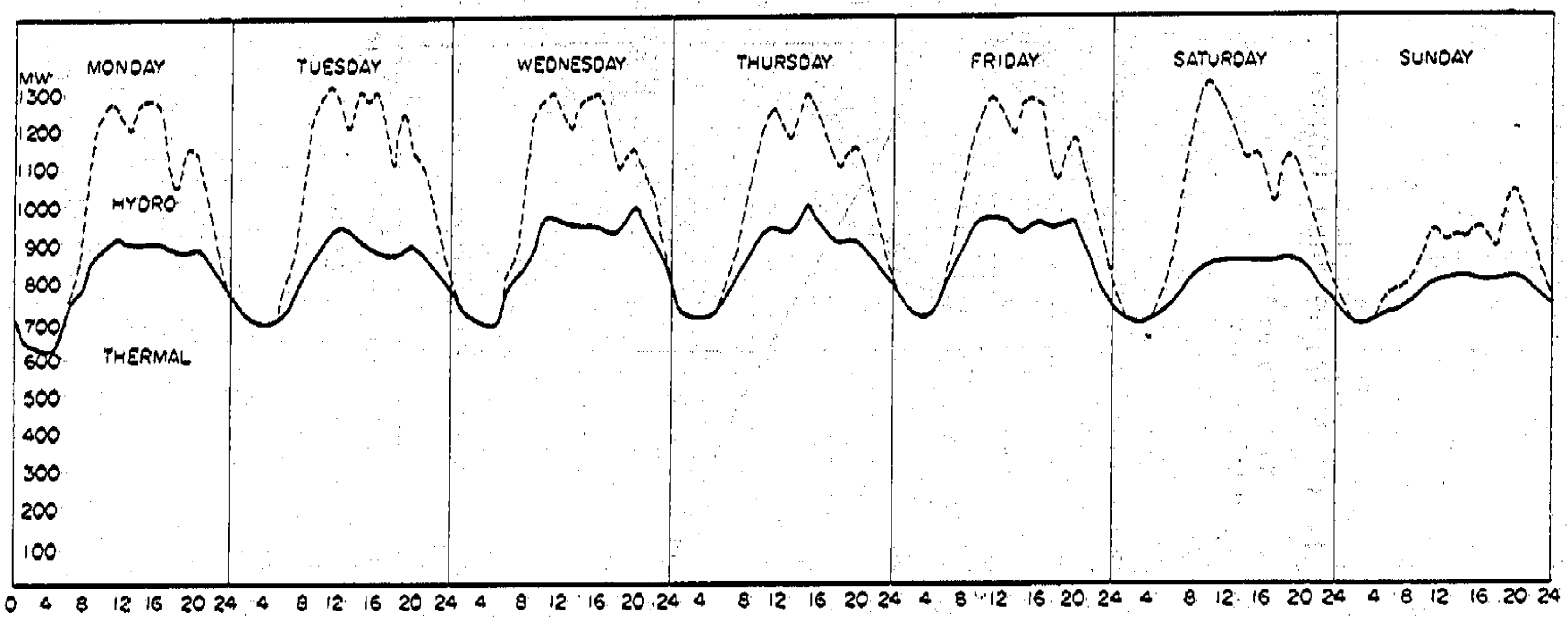
At the end of the third year temporary closure and temporary diversion tunnels will be completed. It will be possible proceed to construction of the main dam in the fourth year.

In the event submergence should be commenced slightly before completion of the dam, say early in the fifth year, it is anticipated that commencement of dam operation will be materialized at the end of the fifth year.

APPENDIX

FIGURE AND TABLES

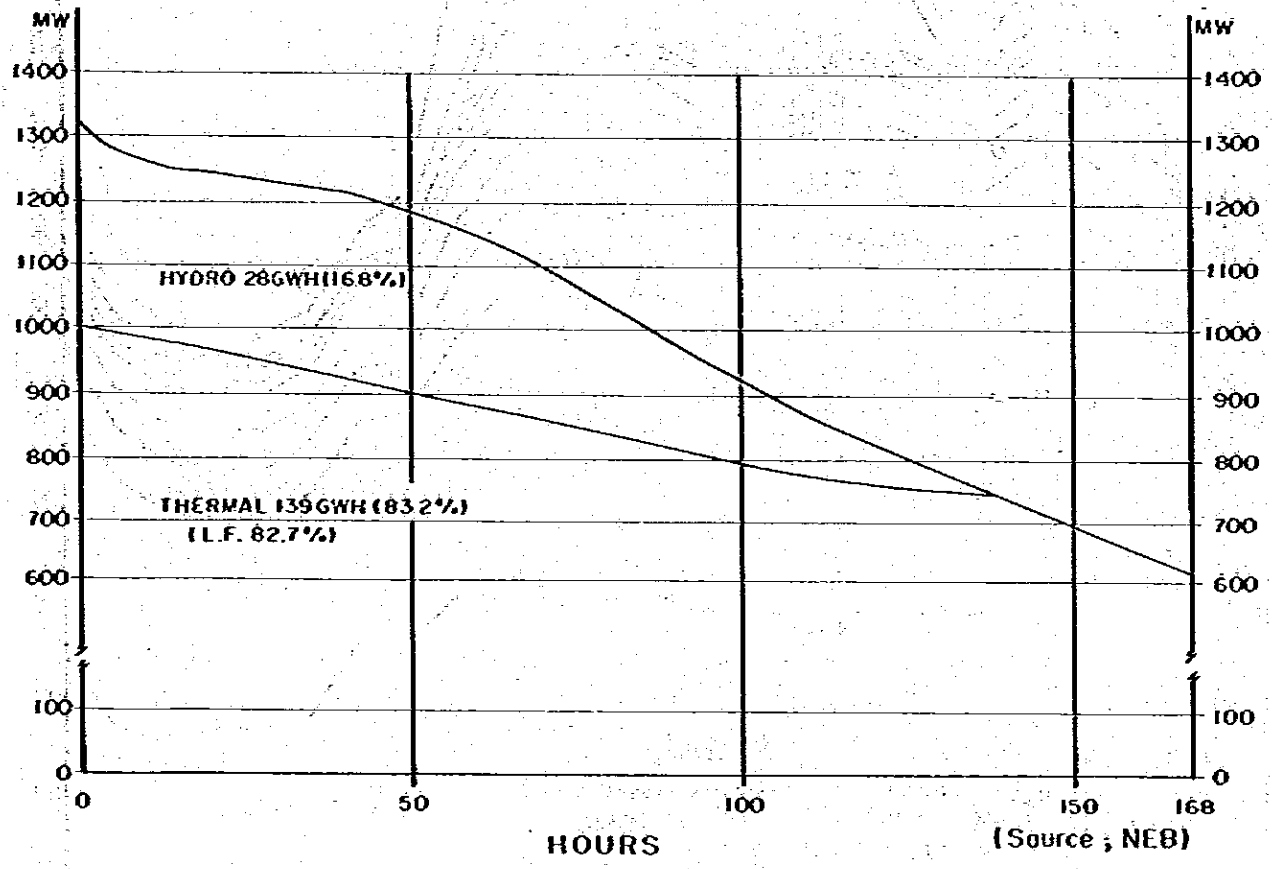
Fig. 5-1 TYPICAL DAILY LOAD CURVE (MAY, 1981)



(Source; NEB)

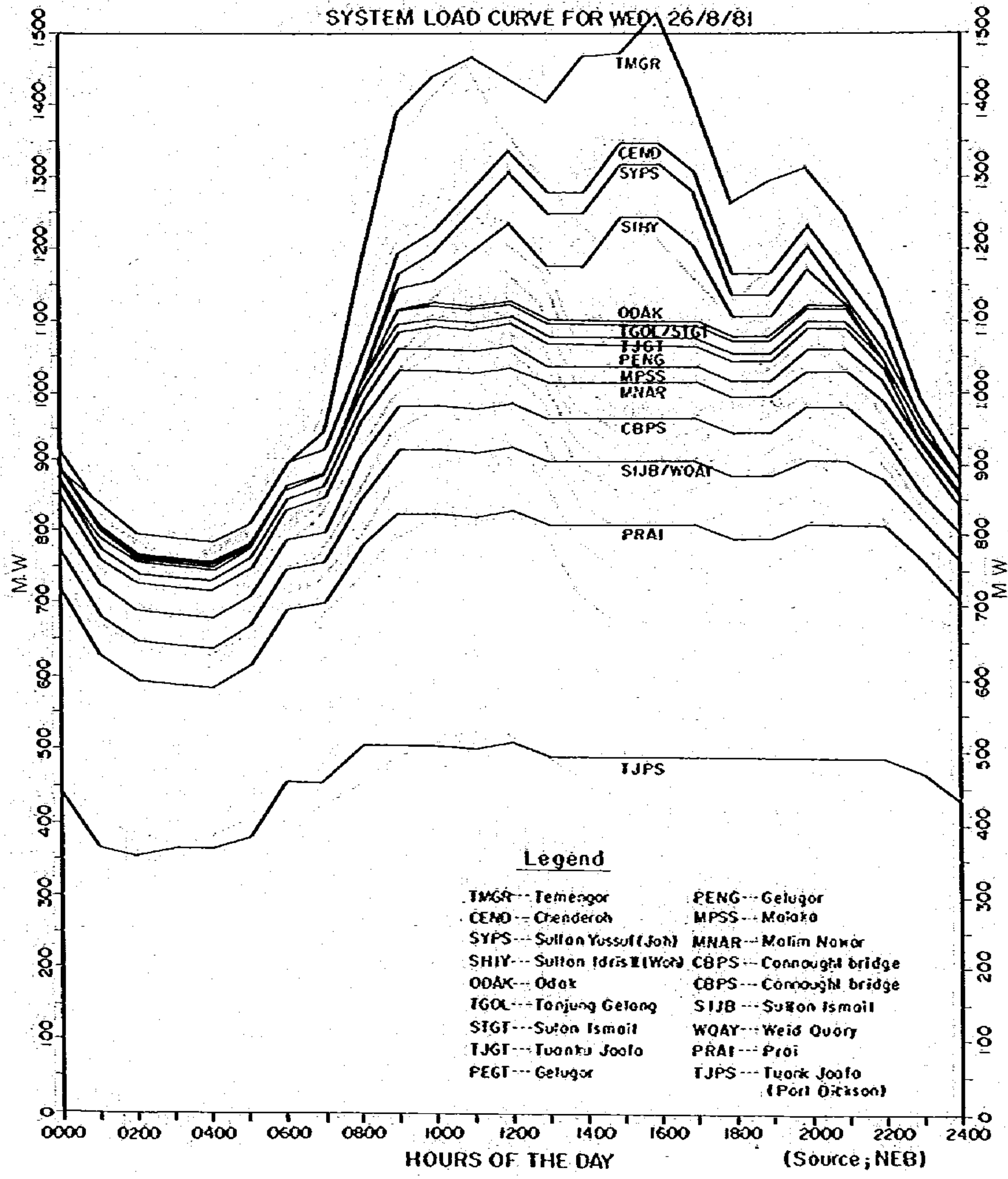
Fig.5-2 TYPICAL LOAD DURATION CURVE

(Total; 167 GWH
MD; 1320 MW, LF; 75.3%)



(Source ; NEB)

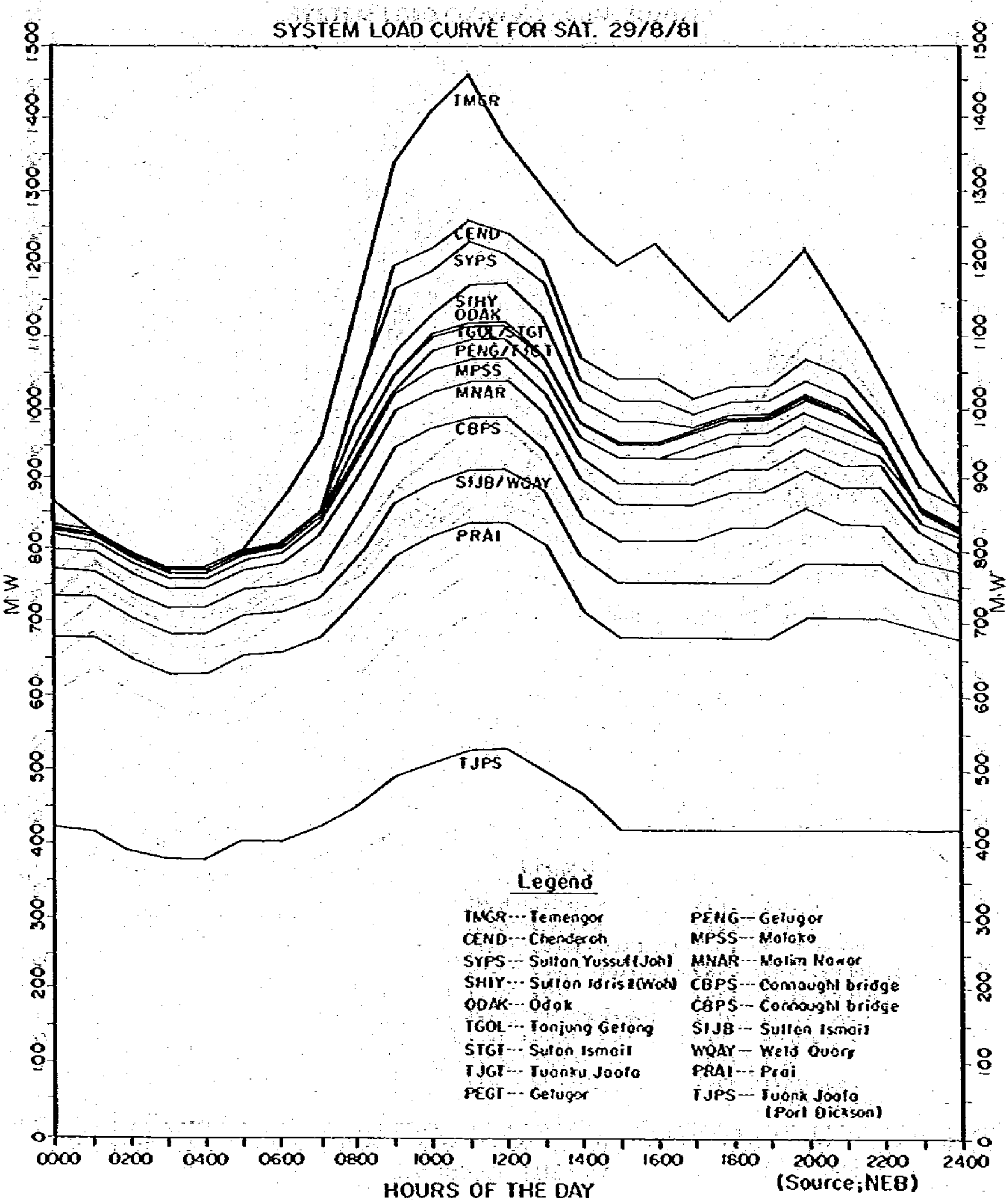
Fig. 5-3 SYSTEM LOAD CURVE (I)



SYSTEM LOAD CURVE FOR WED. 26/8/81

(Source; NEB)

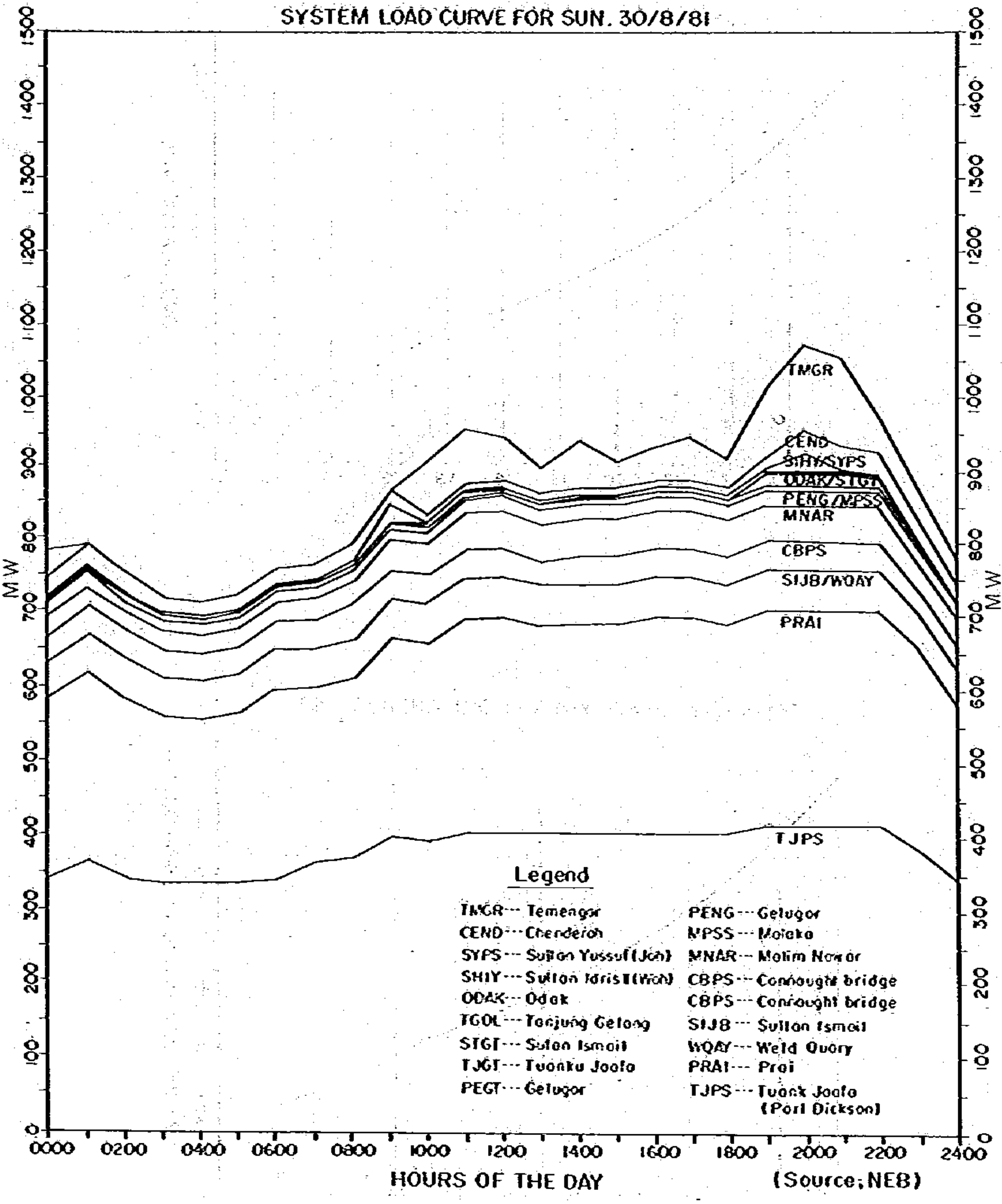
Fig. 5-4 SYSTEM LOAD CURVE (2)



SYSTEM LOAD CURVE FOR SAT. 29/8/81

(Source;NEB)

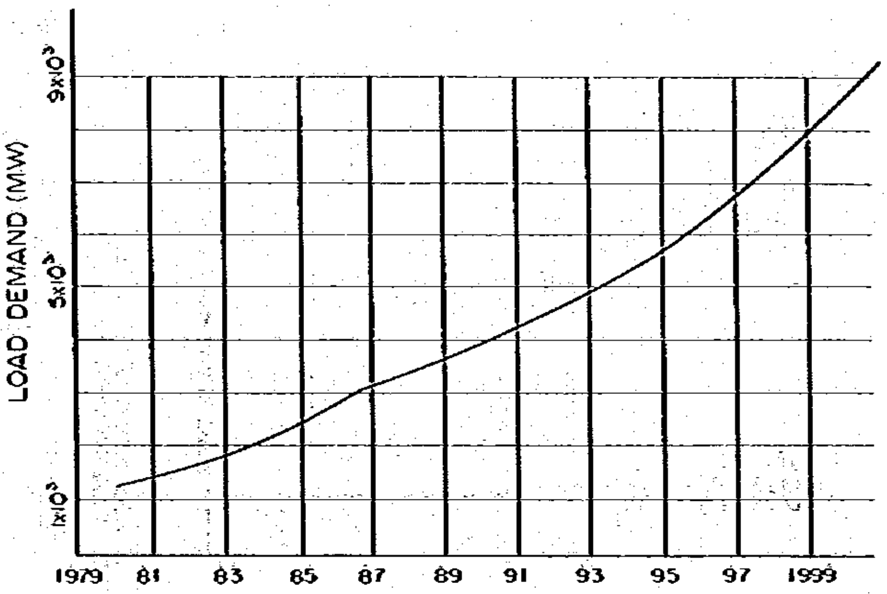
Fig. 5-5 SYSTEM LOAD CURVE (3)



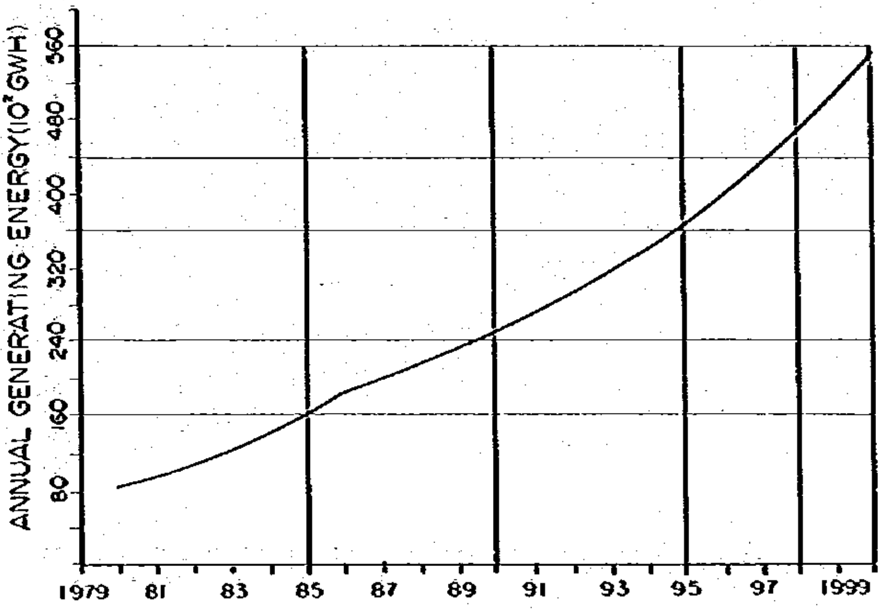
(Source; NEB)

Fig. 5-6 LOAD FORECAST

(1) MAXIMUM OUTPUT (MW) 1981~2000

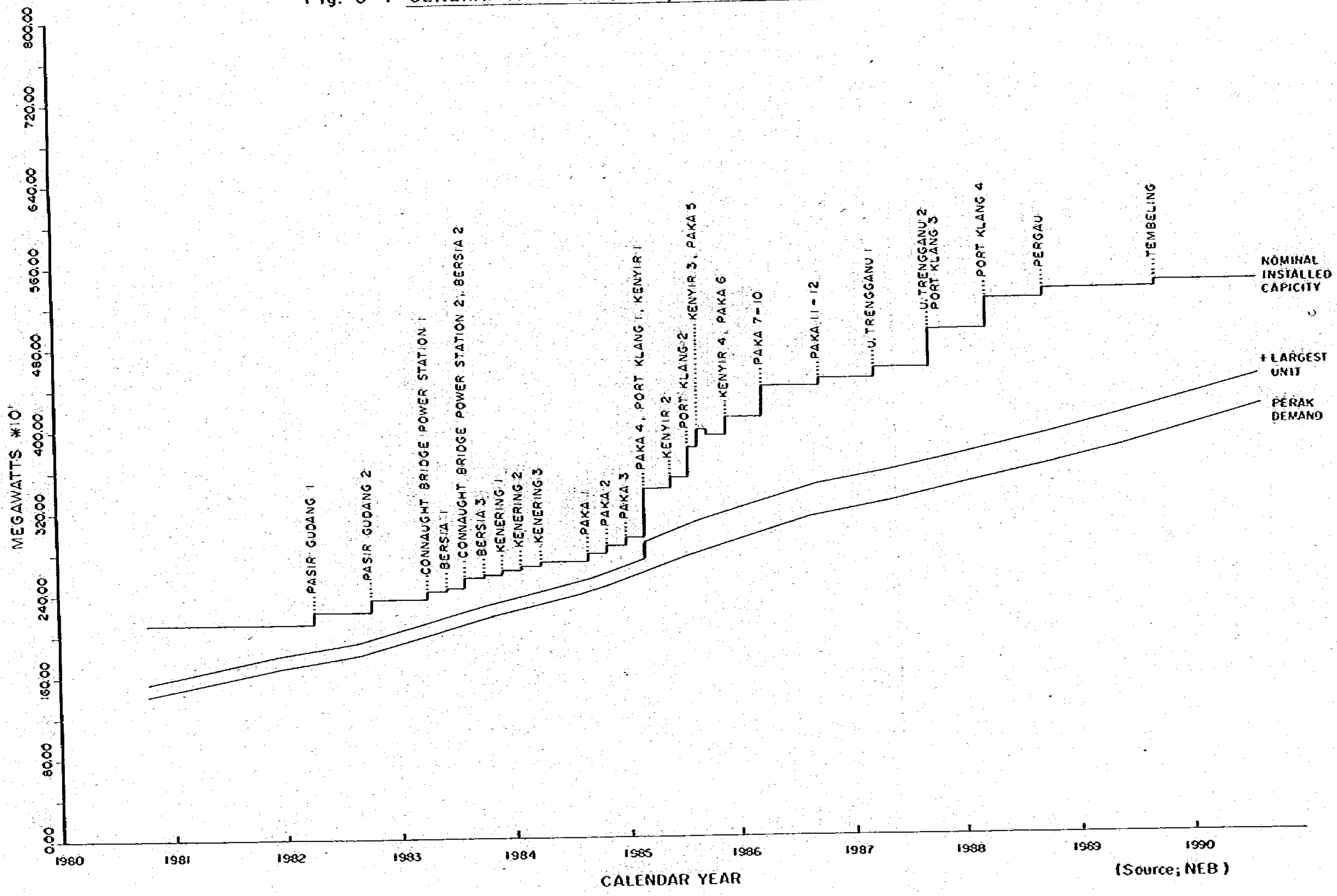


(2) GENERATING ENERGY (GWH) 1981~2000



(Source ; NEB)

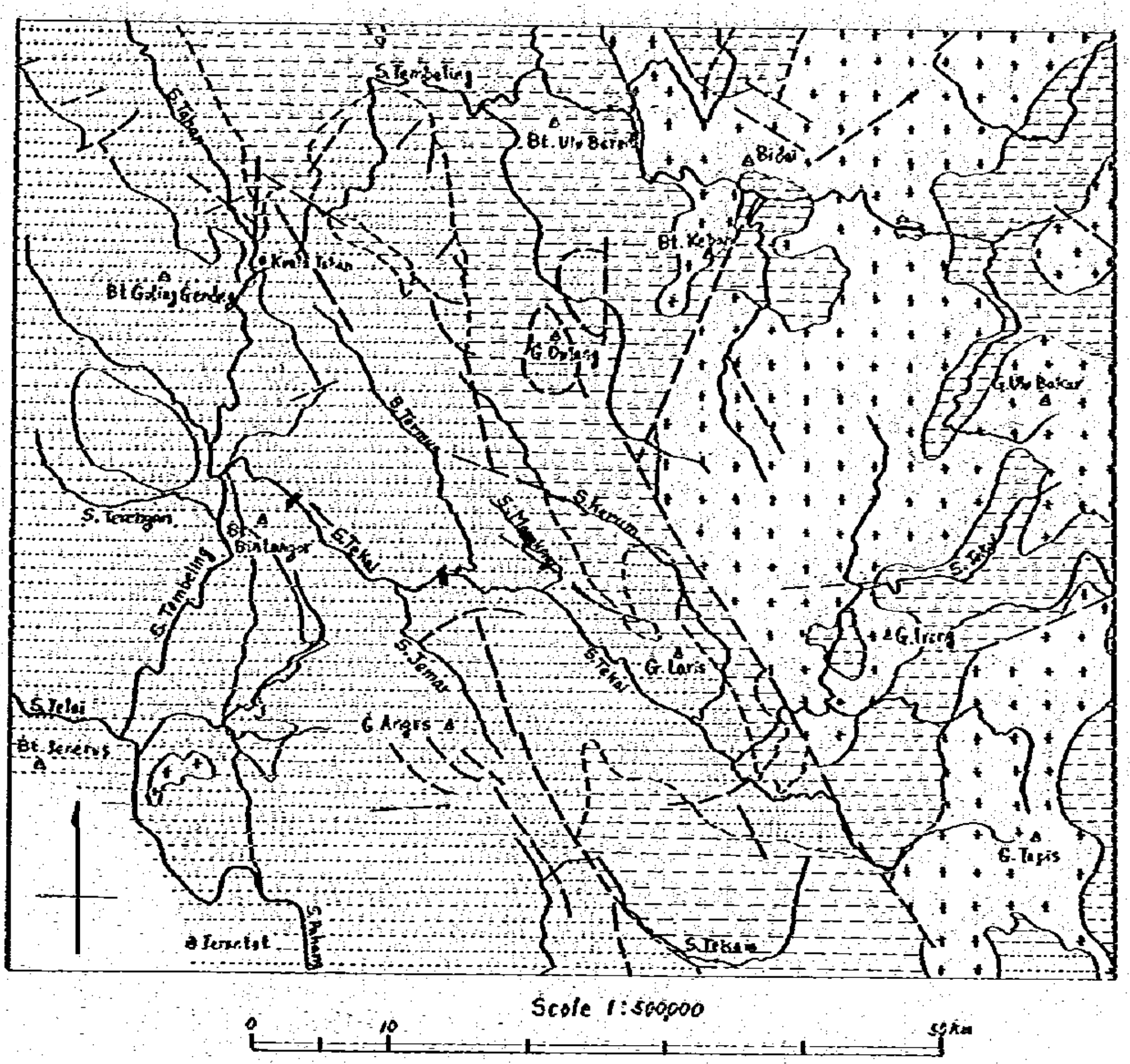
Fig. 5-7 GENERATION DEVELOPMENT, 1981~1990 (L12)



(Source; NEB)

Fig.6-1 DISTRIBUTION OF MOUNTAINS AND RIVERS IN THE TEKAI RIVER BASIN

(From 1/500,000 Geological Map of West Malaysia,
Geological Survey, Malaysia)



LEGEND

▤ Tembeling group (MESOZOIC)

☰ Metasedimets (PALEOZOIC)

⁺ Granitic rocks

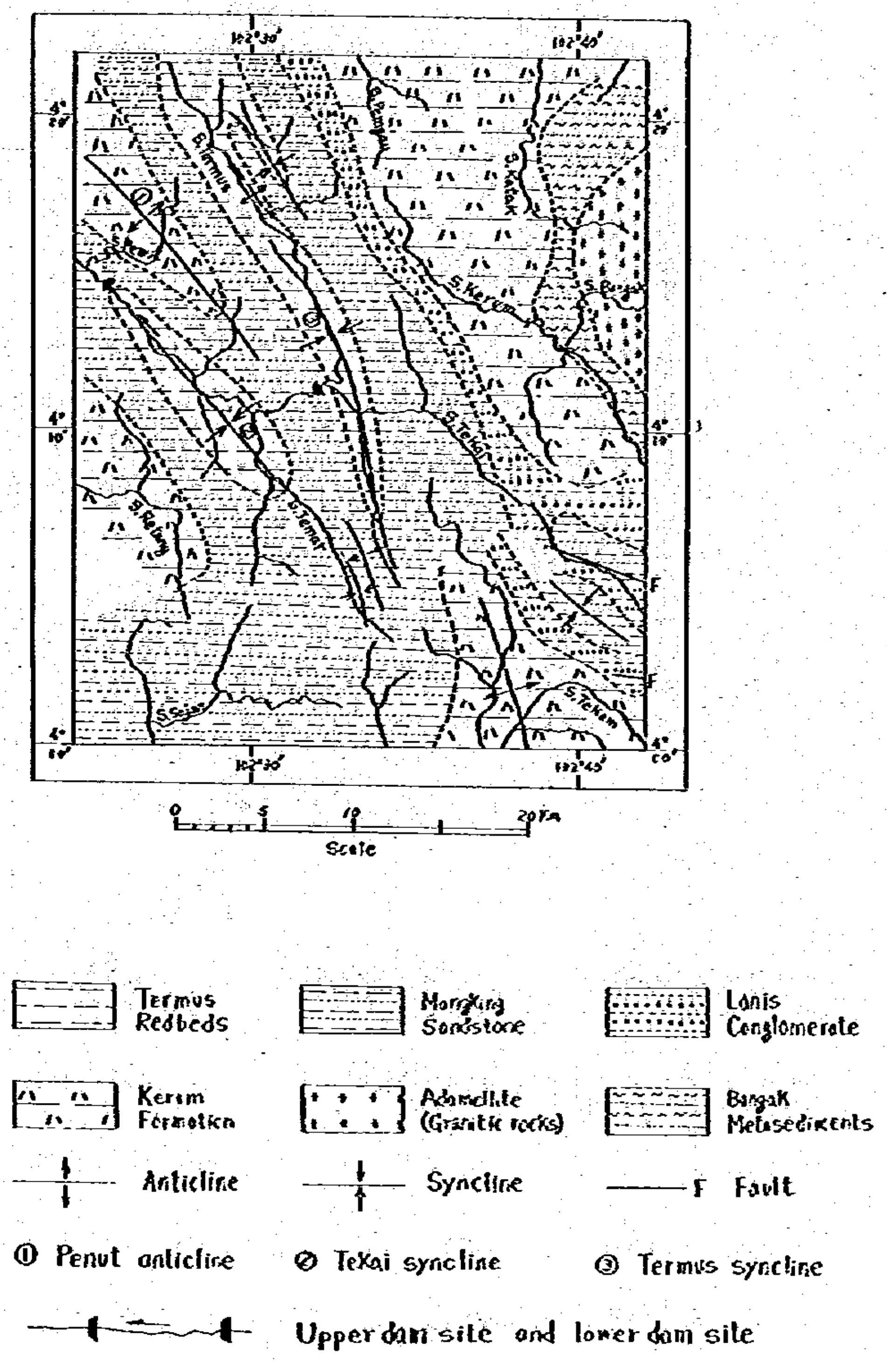
╌ Foult

/ Chronologic boundaries

┤— S.Tekai —┤ Upper dam site and lower dam site

Fig. 6-2 OUTLINE OF GEOLOGY IN THE SUNGAI TEKAI AREA

(after KHOO HAN PENG, 1977, page 93, Annual report of the geological survey of Malaysia)



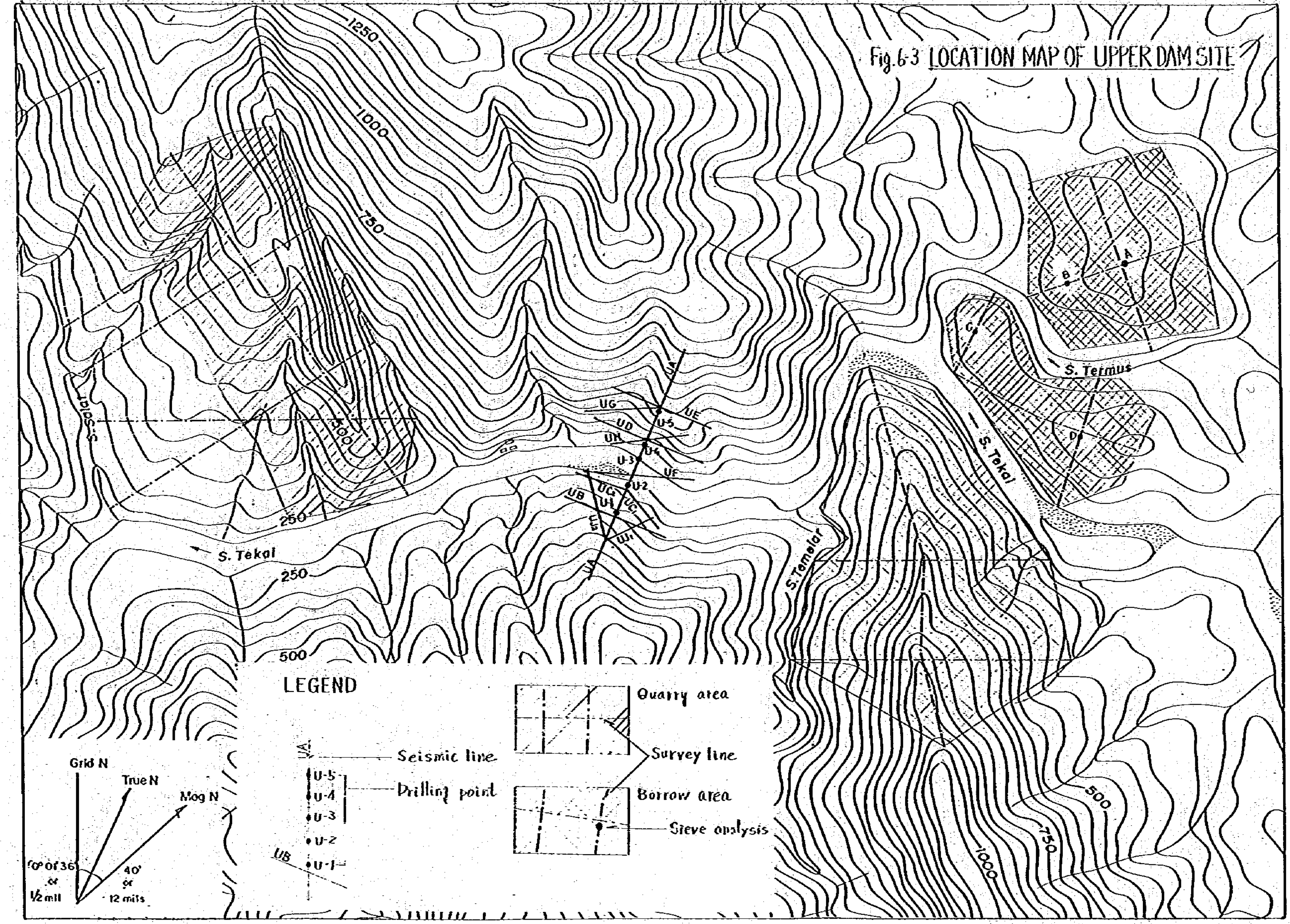


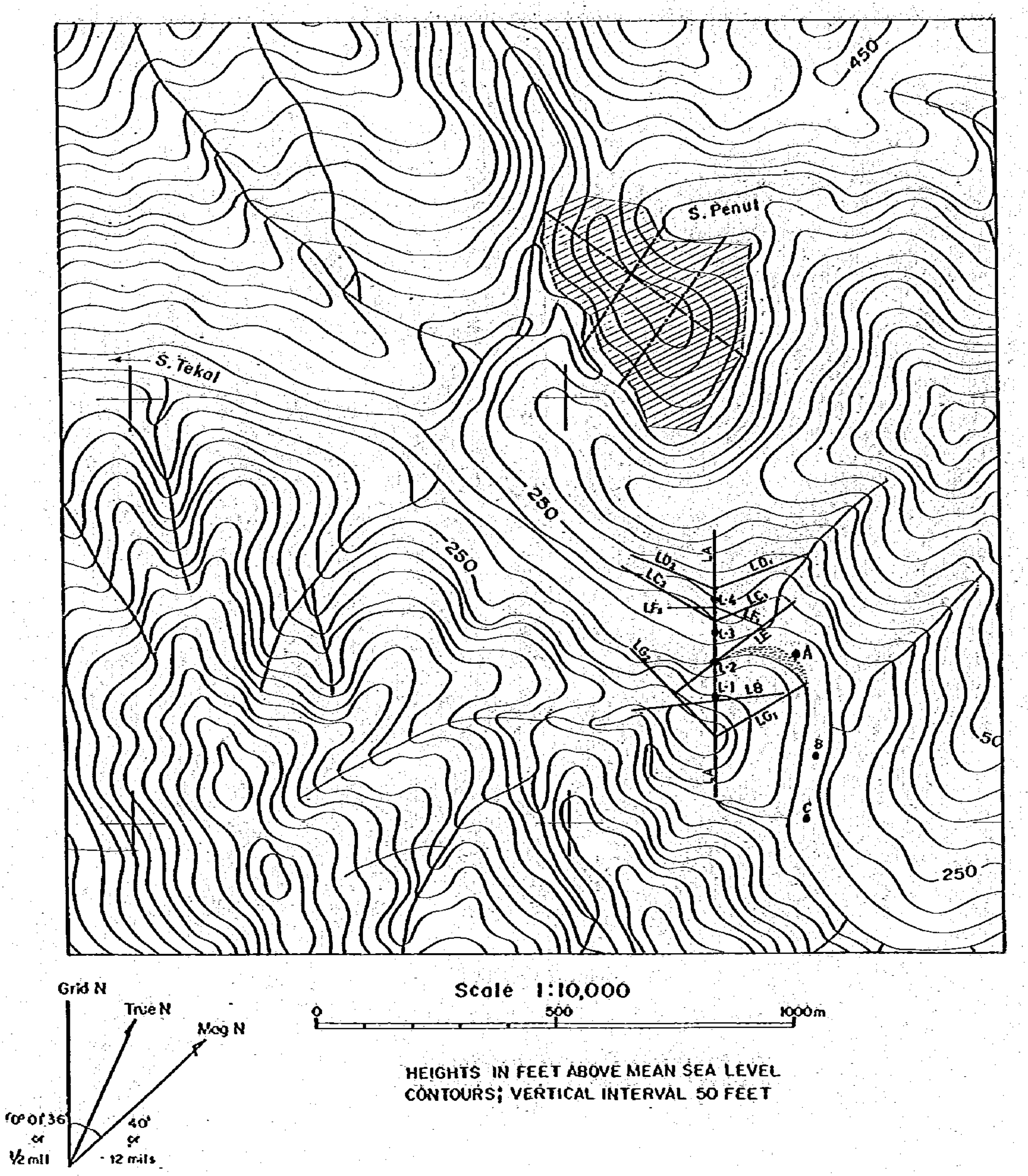
Fig. 6-3 LOCATION MAP OF UPPER DAM SITE

HEIGHTS IN FEET ABOVE MEAN SEA LEVEL
CONTOURS; VERTICAL INTERVAL 50 FEET

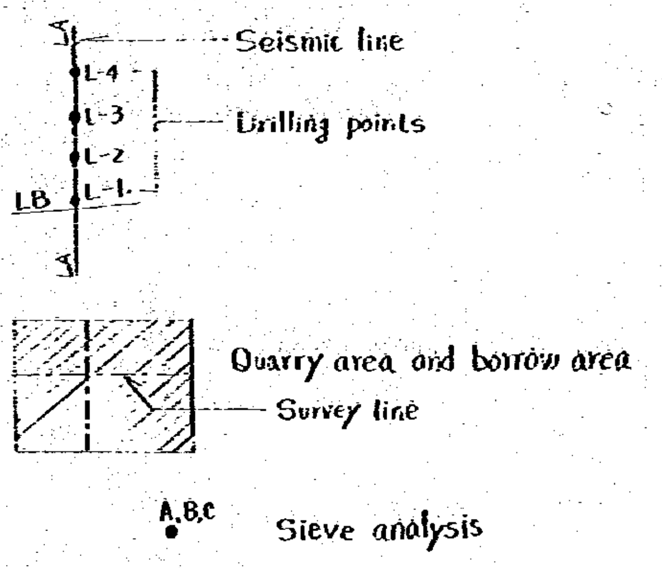
Scale 1:10,000

0 500 1000m

Fig. 64 LOCATION MAP OF LOWER DAM SITE



LEGEND



Seismic line

Drilling points

Quarry area and borrow area

Survey line

Sieve analysis


True N
MSst
TSh
MShl
1250
TSh
MSst
Sh2
Malt
MSst
Qlr
S. Termus
Iglg
Malt
S. Tekai
Qlr
Sh2
r
S. Tekai
250
Malt
500
MSht
r
TSh
Qlr
750
MSst
MSh
1000
250
Mal2
MSst
Scale 1 : 10,000
0
500
1,000m
HEIGHTS IN FEET ABOVE MEAN SEA LEVEL
CONTOURS ; VERTICAL INTERVAL 50 FEET

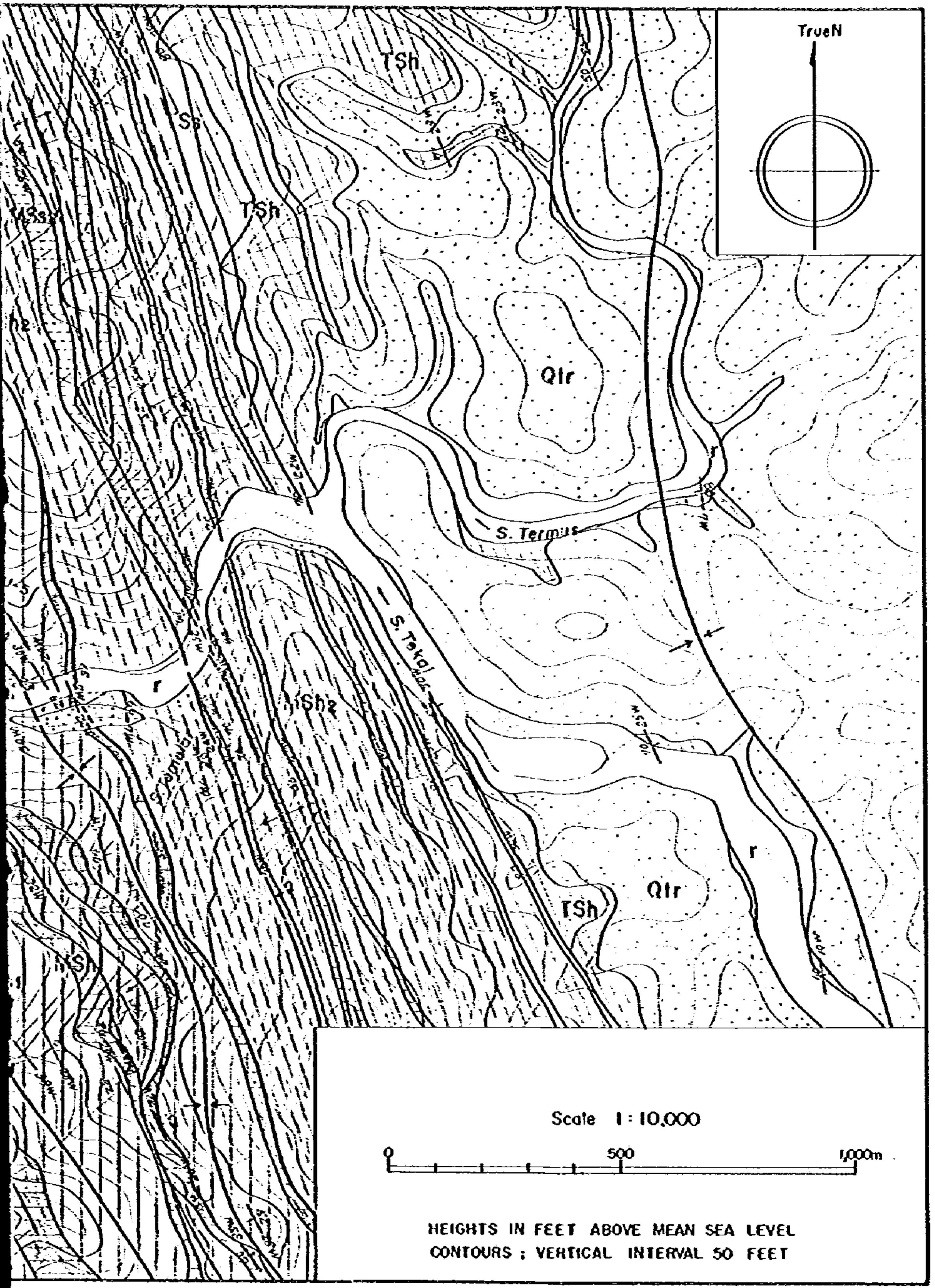


Fig. 6.5 GEOLOGICAL MAP OF TEKAI UPPER SITE

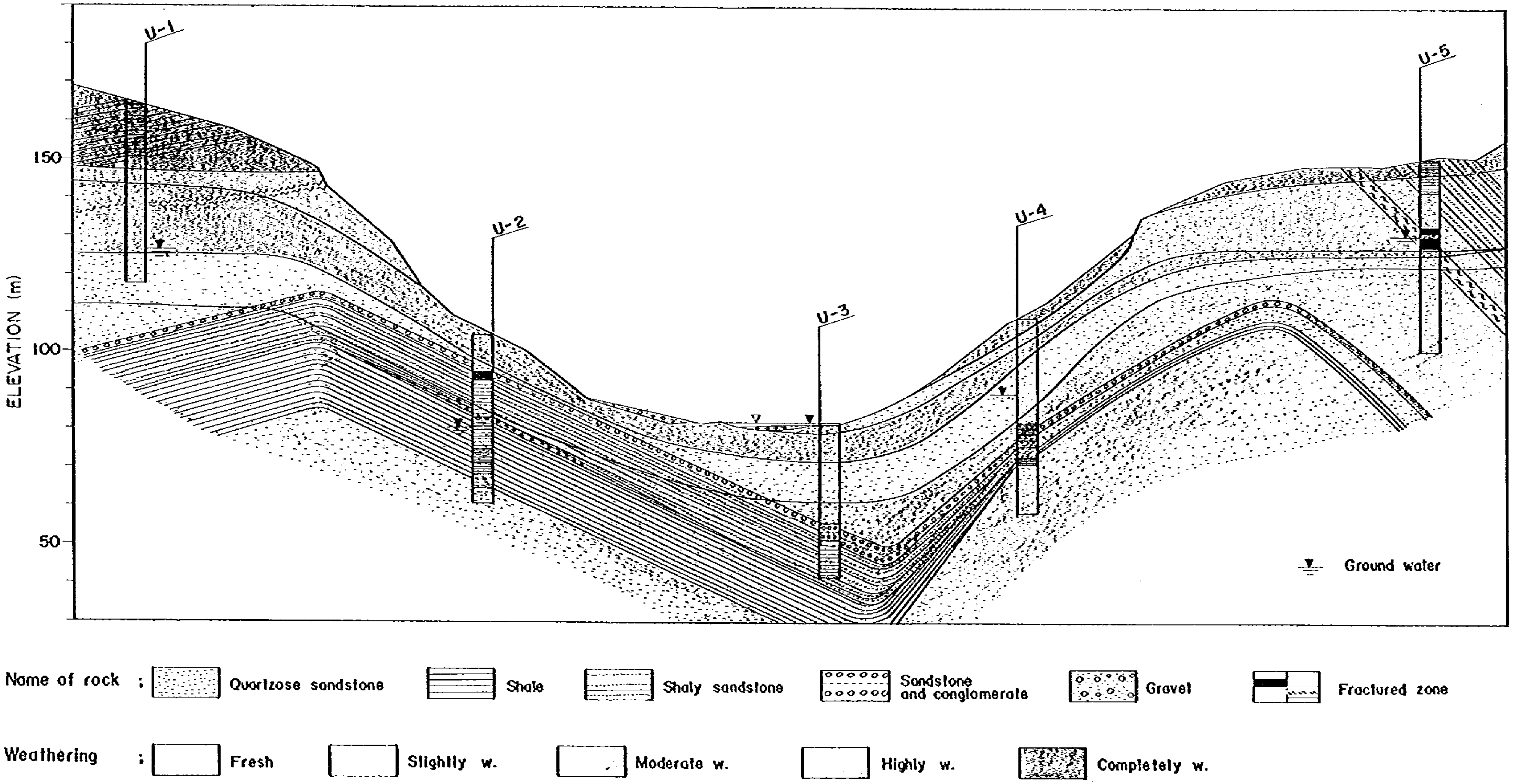
LEGEND

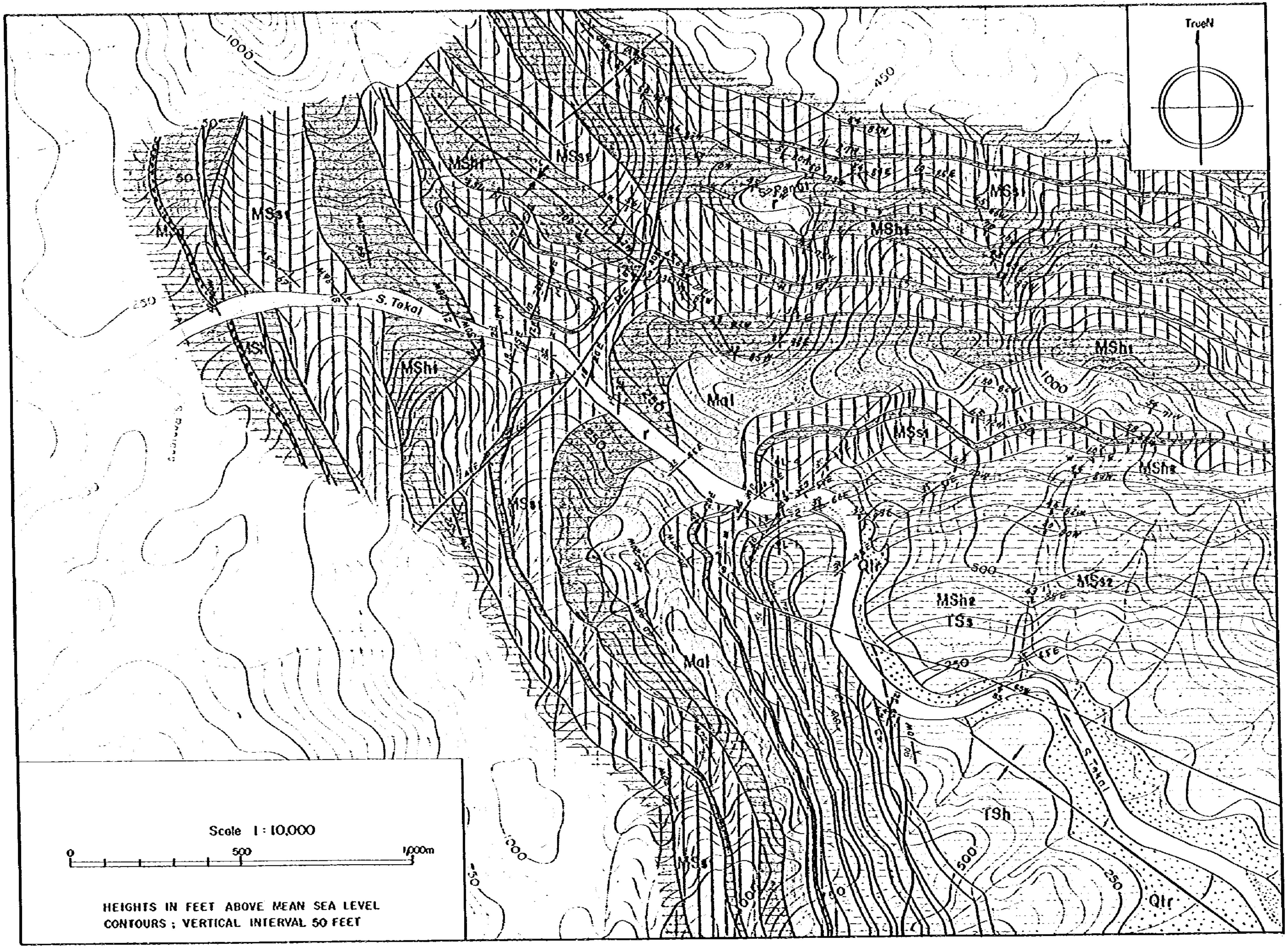
GEOLOGICAL AGE		COLOR	SYMBOL	FORMATION	LITHOLOGY
CENOZOIC	QUATERNARY		r	River Bed Deposits	Mainly quartz sand containing silt and gravel
		▨	Qlr	Terrace Deposits	Mainly clay containing gravel and organic material
MESOZOIC	LOWER CRETACEOUS	▨	TSh	Termus Redbeds	Reddish/purplish-red shale interbeded with mudstone and sandstone
			TSs		Quartzose sandstone and sandstone
	UPPER JURASSIC	▨	MSh2	Mangking Sandstone	Purplish-red shale interbeded with mudstone and sandstone
		▨	MSs2		Predominantly quartzose sandstone interbeded with greylsh shale
		▨	Mal 2		Alternation of sandstone and shale
		▨	Mal 1		Alternation of sandstone and shale interbeded with shaly sandstone and quartzose sandstone
		▨	MSh 1		Dark-grey and greyish shale interbeded with fine sandstone
		▨	MSs 1		Mainly quartzose sandstone interbeded with shale. siltstone and shaly sandstone

20 24W	Strike and dip of stratum
	Anticline (—> Plunging)
	Syncline (—> Plunging)
52 13W	Strike and dip of fault
U-1~U-5	Drilling point

Fig. 6.6 GEOLOGICAL PROFILE OF UPPER DAM SITE

(Scale 1:1,000)





HEIGHTS IN FEET ABOVE MEAN SEA LEVEL
CONTOURS ; VERTICAL INTERVAL 50 FEET

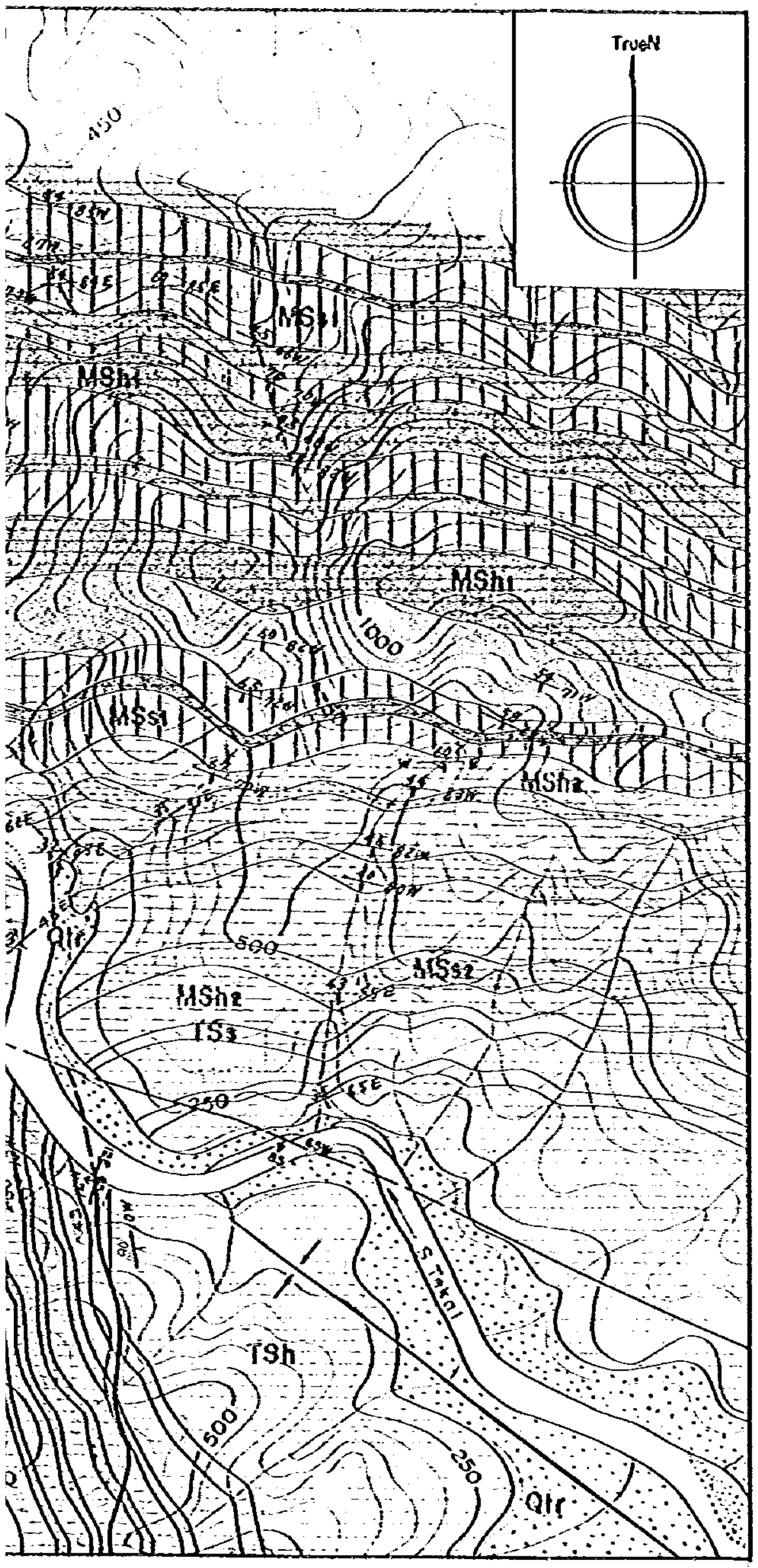


Fig. 6.7 GEOLOGICAL MAP OF TEKAI LOWER SITE

LEGEND

GEOLOGICAL AGE		COLOR	SYMBOL	FORMATION	LITHOLOGY
CENOZOIC	QUATERNARY		r	River Bed Deposits	Mainly quartz sand containing silt and gravel
		⁙	Qtr	Terrace Deposits	Mainly clay containing organic material and gravel
MESOZOIC	LOWER CRETACEOUS	▤	TSh	Termus Redbeds	Reddish/purplish-red shale interbeded with yellow ocher mudstone
			TSs		Predominantly quartzose sandstone and sandstone
	UPPER JURASSIC	▤	MSh2	Mangking Sandstone	Purplish-red shale interbeded with purplish sandstone
		▤	MSs2		Predominantly quartzose sandstone and sandstone
		⁙	Mal		Alternation of quartzose sandstone and shale
		▦	MSh1		Dark-grey and greyish shale interbeded with fine sandstone
		▥	MSs1		Mainly quartzose sandstone interbeded with shale and shaly sandstone
		⁙	MCg		Conglomerate interbeded with shale

36 45E	Strike and dip of stratum
	Syncline
87 30E	Strike and dip of fault
L-1~L-4	Drilling point

Fig. 6.8 GEOLOGICAL PROFILE OF LOWER DAM SITE
(Scale 1 : 1,000)

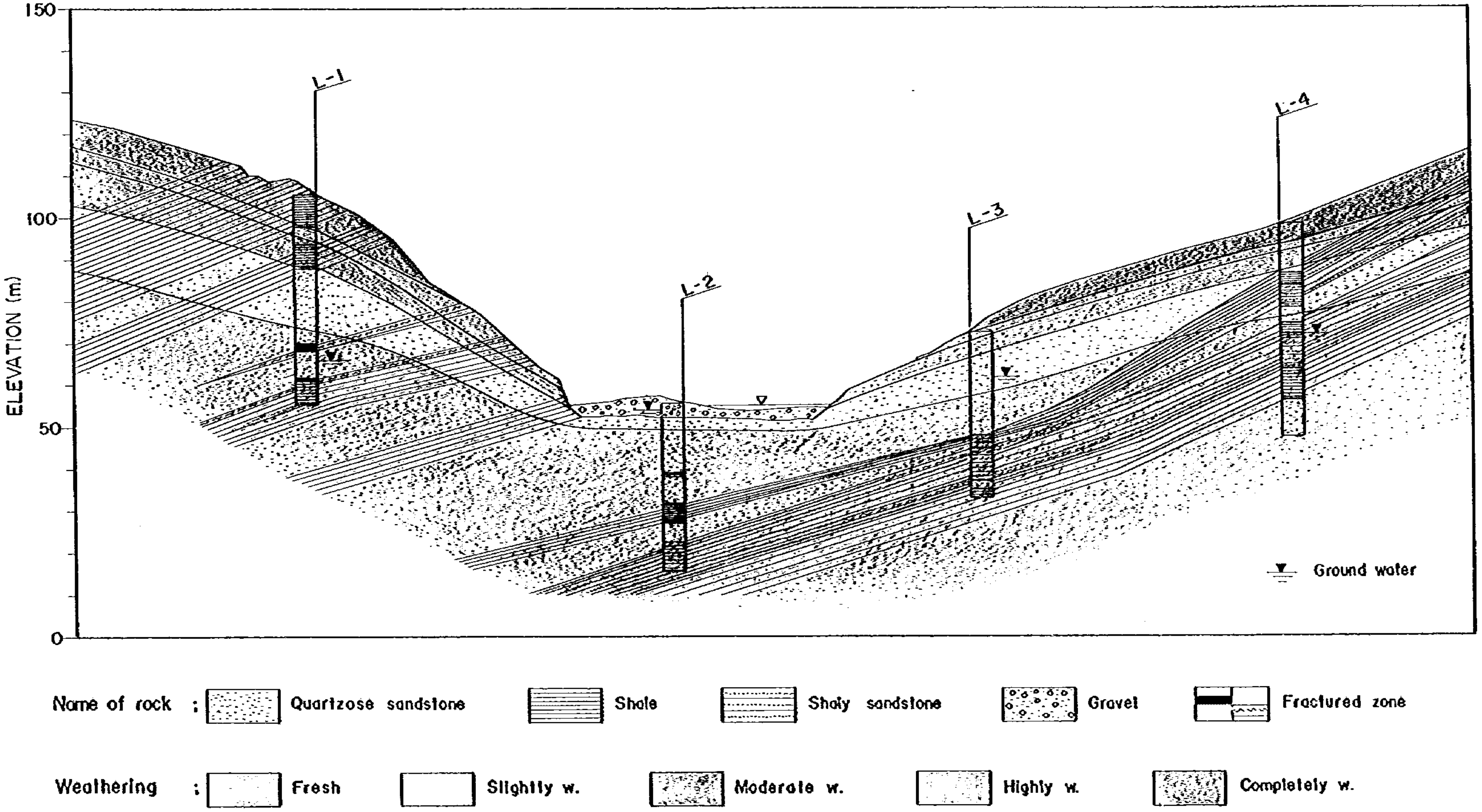


Fig. 6.9(a) RELATIONSHIP BETWEEN R.Q.D. AND QUALITY CLASSIFICATION OF ROCK

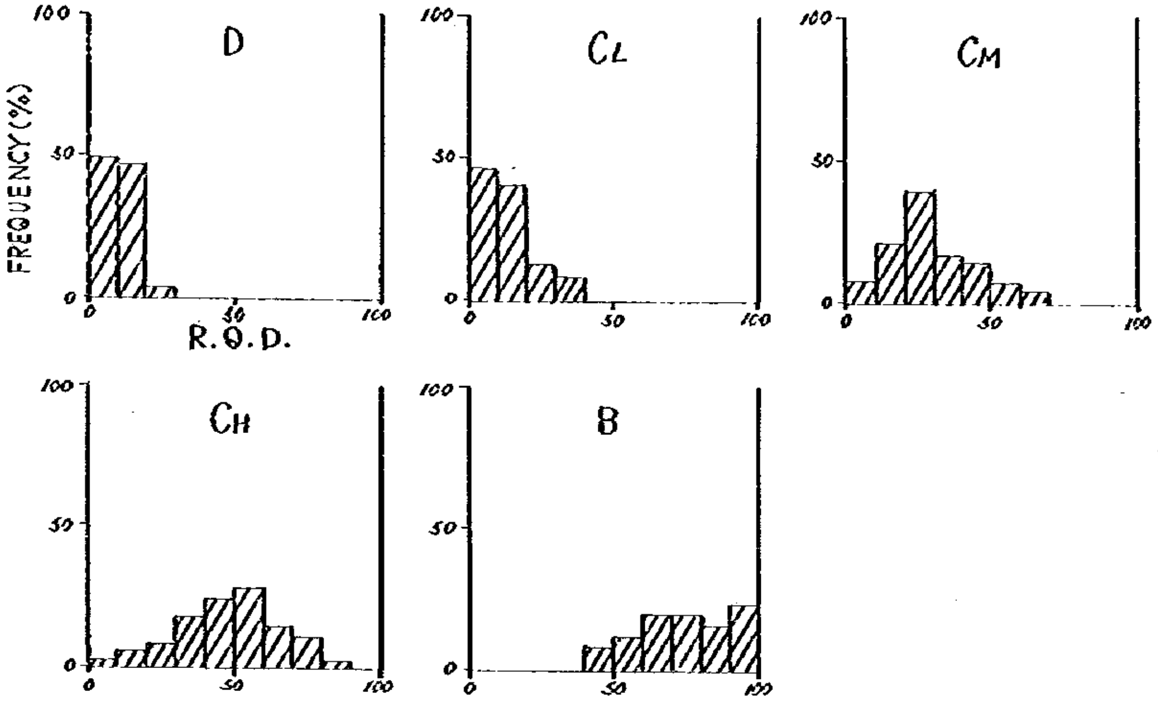


Fig. 6.9(b) RELATIONSHIP BETWEEN R.Q.D. AND GRADE OF WEATHERING

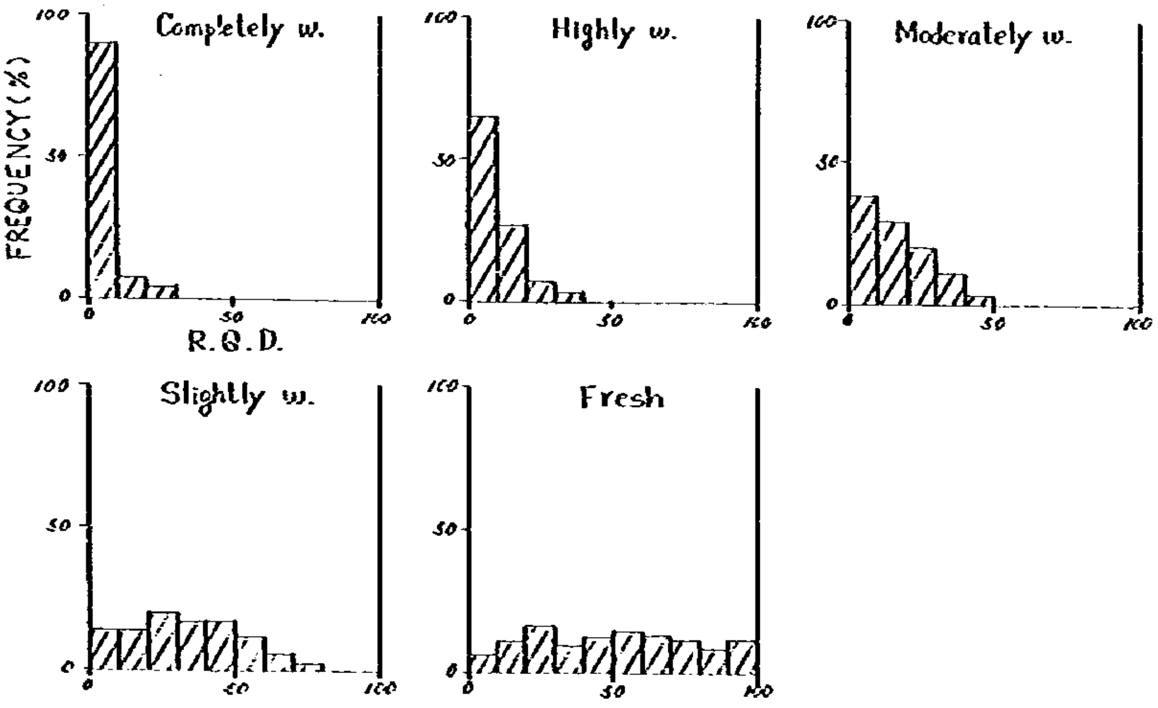
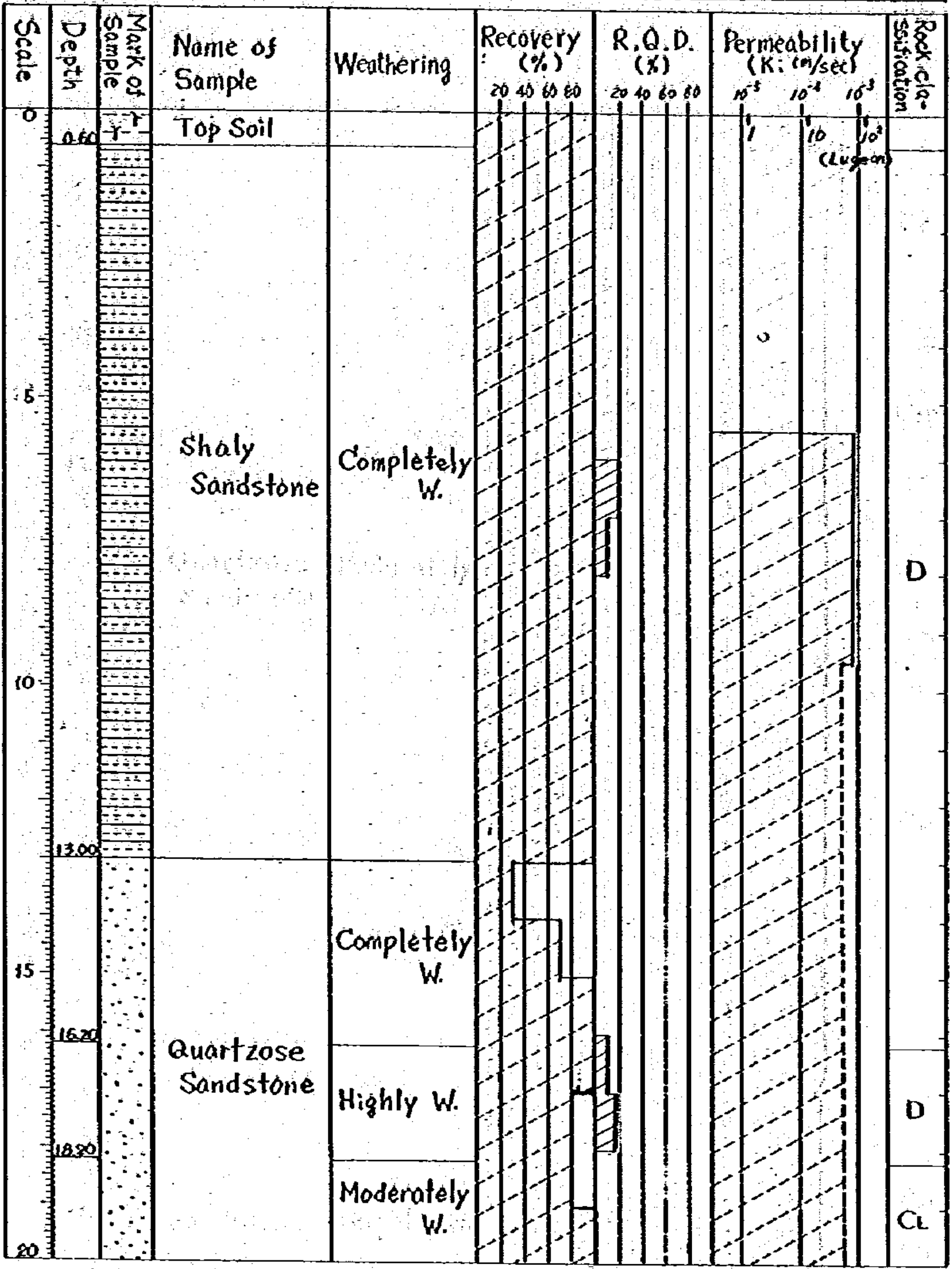


Fig. 6-10 (a1) **Geological Log**

Project Name	TeKoi Hydro-electric Development Project		Site Name	Upper Dam Site	
Hole NO.	U - 1	Elevation of Ground Level	163.47 m	Ground water Level	37.2 m
Date	Beginning	August 30, 1981	Operator		
			Site Manager		
	Ending	September 14, 1981	Supervisor	TAKUJI SUGIMOTO	

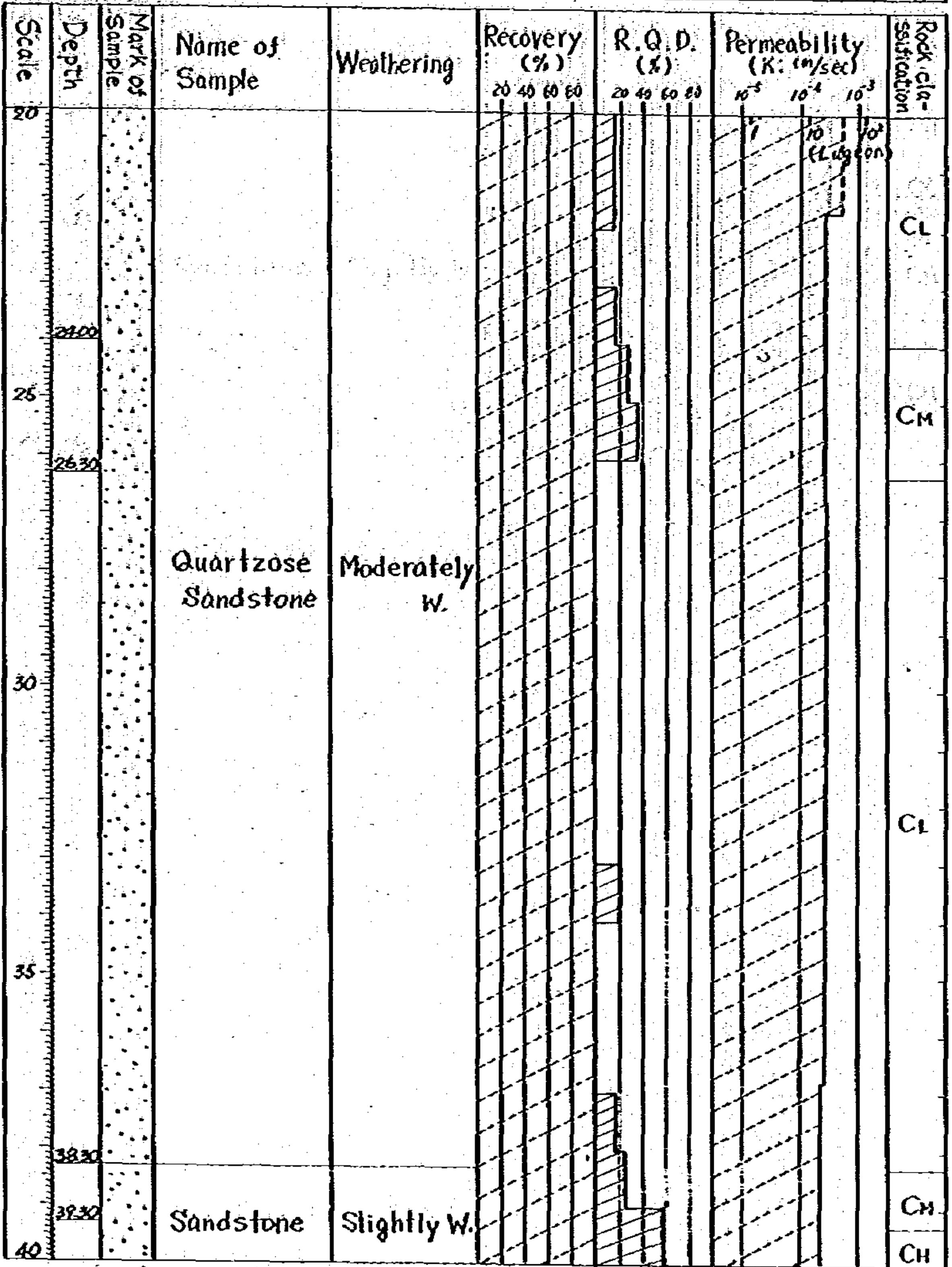


Bit Size ; NMLC (76 m/m)

R.Q.D. ; Rock Quality Designation

Fig. 6-10 (a2) **Geological Log**

Project Name	TeKoi Hydro-electric Development Project		Site Name		
Hole NO.	U - 1	Elevation of Ground Level	m	Ground water Level	m
Date	Beginning		Operator		
	Ending		Site Manager		
			Supervisor		

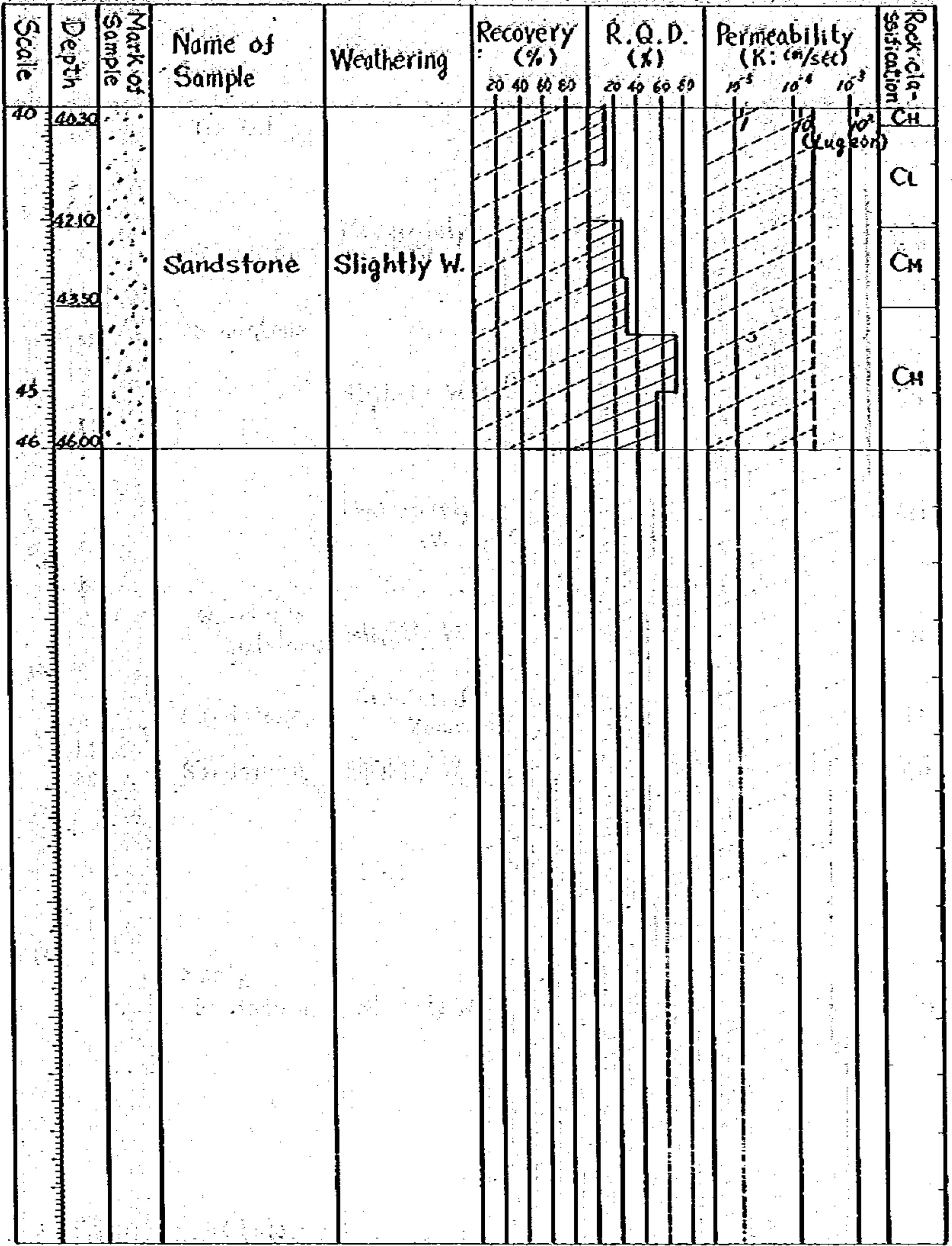


Bit Size ; NMLC (76 m/m)

R.Q.D. ; Rock Quality Designation

Fig. 6·10 (a3) **Geological Log**

Project Name	TeKoi Hydro-electric Development Project		Site Name		
Hole NO.	U - 1	Elevation of Ground Level	m	Ground water Level	m
Date	Beginning		Operator		
			Site Manager		
	Ending		Supervisor		

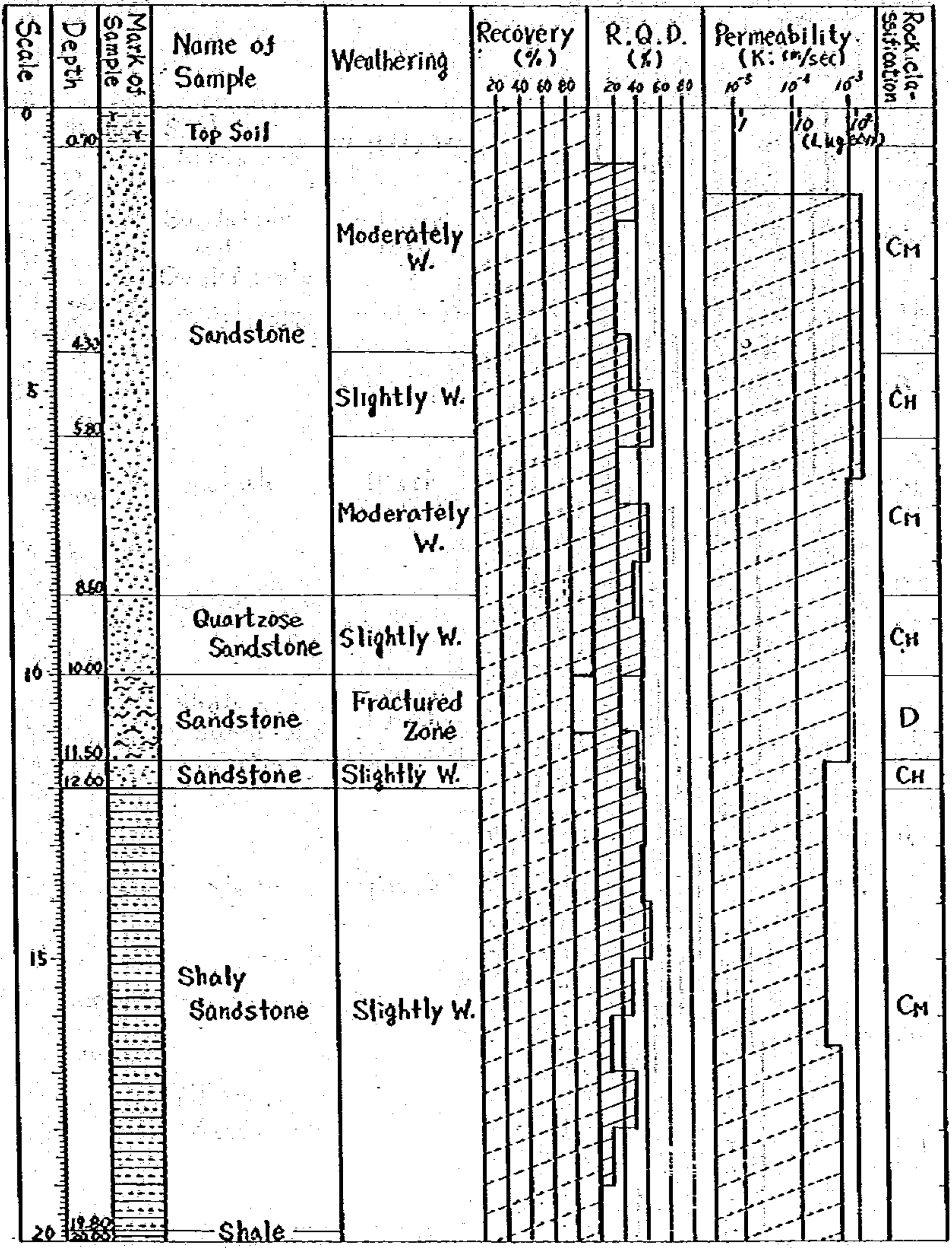


Bit Size : NMLC (76 m/m)

R.Q.D. : Rock Quality Designation

Fig. 6-10(b1) Geological Log

Project Name	TeKoi Hydro-electric Development Project		Site Name	Upper Dam Site	
Hole NO.	U-2	Elevation of Ground Level	104.49 m	Ground water Level	23.80 m
Date	Beginning	September 23, 1981	Operator		
			Site Manager		
	Ending	October 1, 1981	Supervisor	TAKUJI SUGIMOTO	



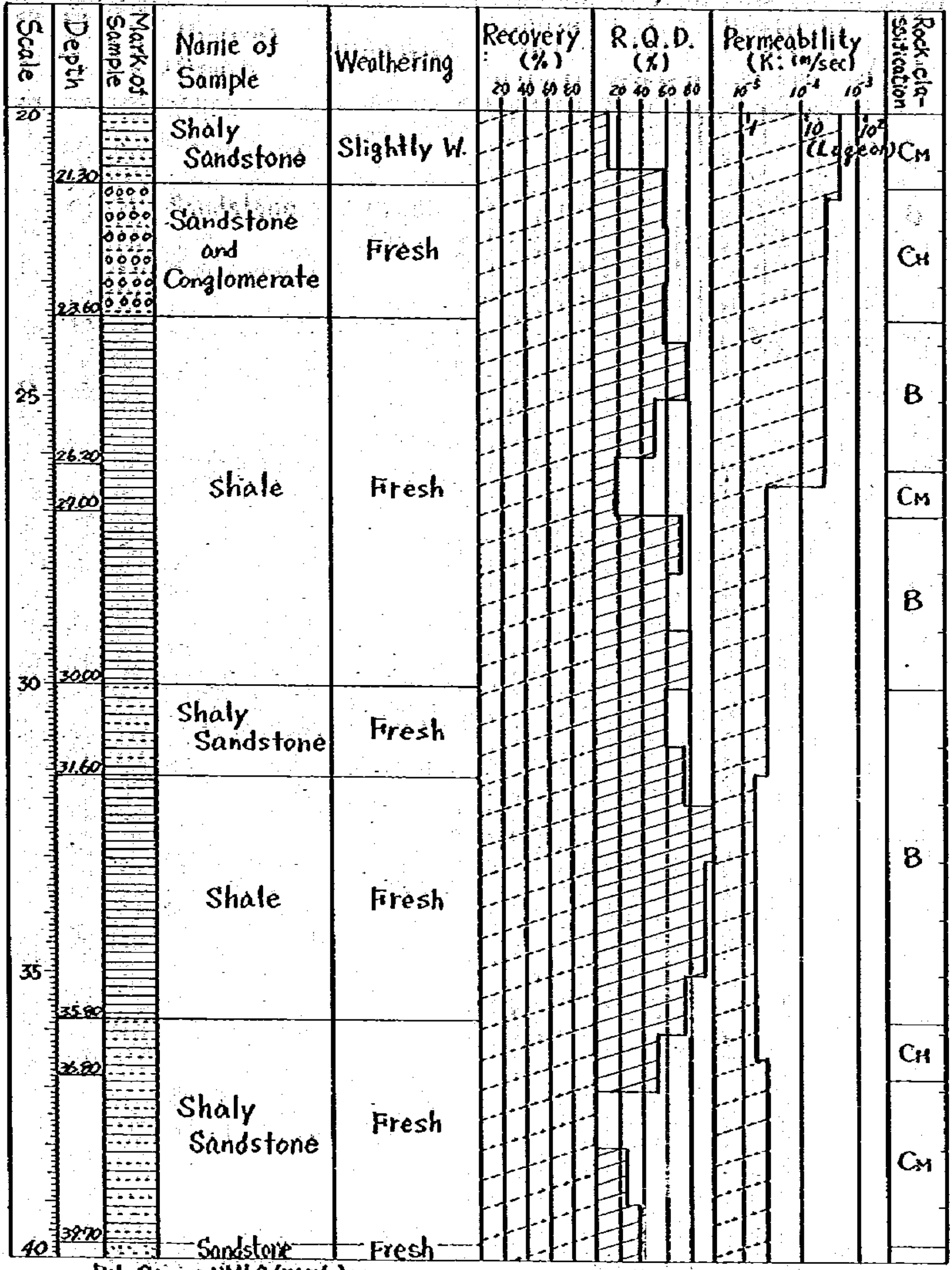
Bit Size : NMLC (76 m/m)

R.Q.D. ; Rock Quality Designation

Fig. 6·10 (b2)

Geological Log

Project Name	TeKoi Hydro-electric Development Project		Site Name		
Hole NO.	U - 2	Elevation of Ground Level	m	Ground water Level	m
Date	Beginning		Operator		
	Ending		Site Manager		
			Supervisor		

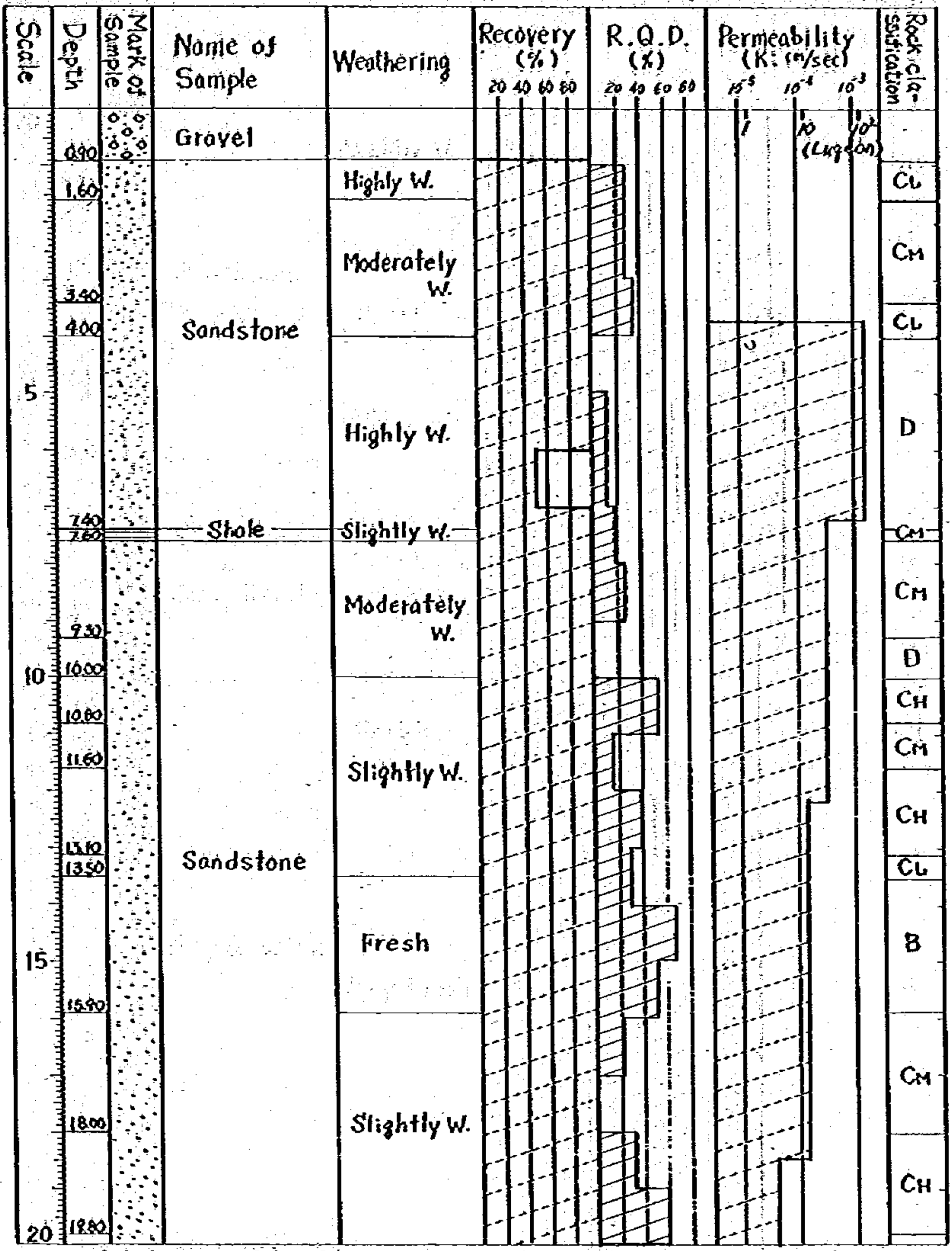


Bit Size ; NMLC (76m/m)

R.Q.D. ; Rock Quality Designation

Fig.6-10(c1) Geological Log

Project Name	TeKoi Hydro-electric Development Project		Site Name	Upper Dam Site	
Hole NO.	U-3	Elevation of Ground Level	81.98 m	Ground water Level	0.0 m
Date	Beginning	August 26, 1981	Operator		
			Site Manager		
	Ending	September 11, 1981	Supervisor	TAKUJI SUGIMOTO	

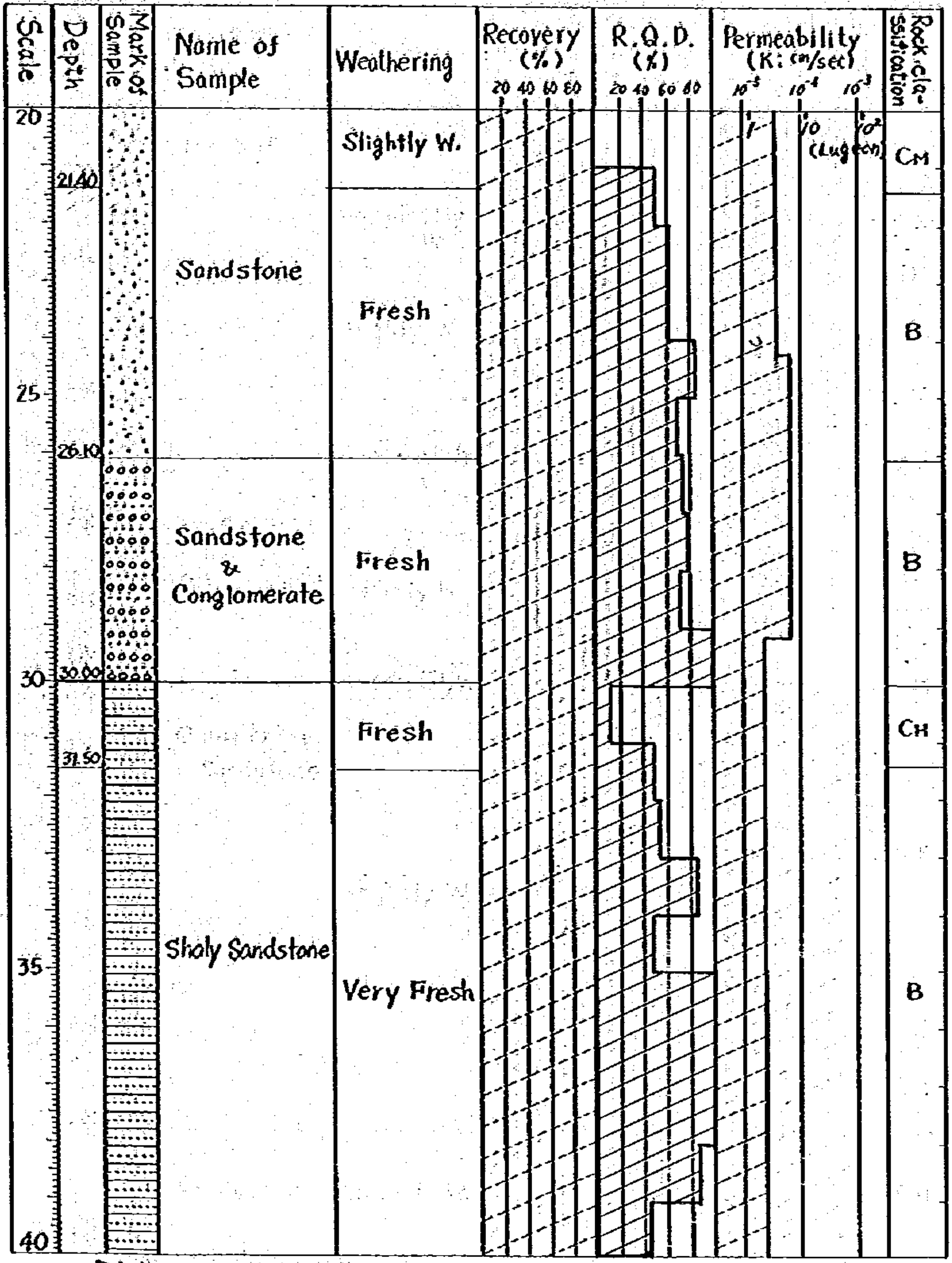


Bit Size ; NMLC (76m/m)

R.Q.D. ; Rock Quality Designation

Fig. 6·10 (c2) Geological Log

Project Name	TeKoi Hydro-electric Development Project		Site Name		
Hole NO.	U - 3	Elevation of Ground Level	m	Ground water Level	m
Date	Beginning		Operator		
	Ending		Site Manager		
			Supervisor		

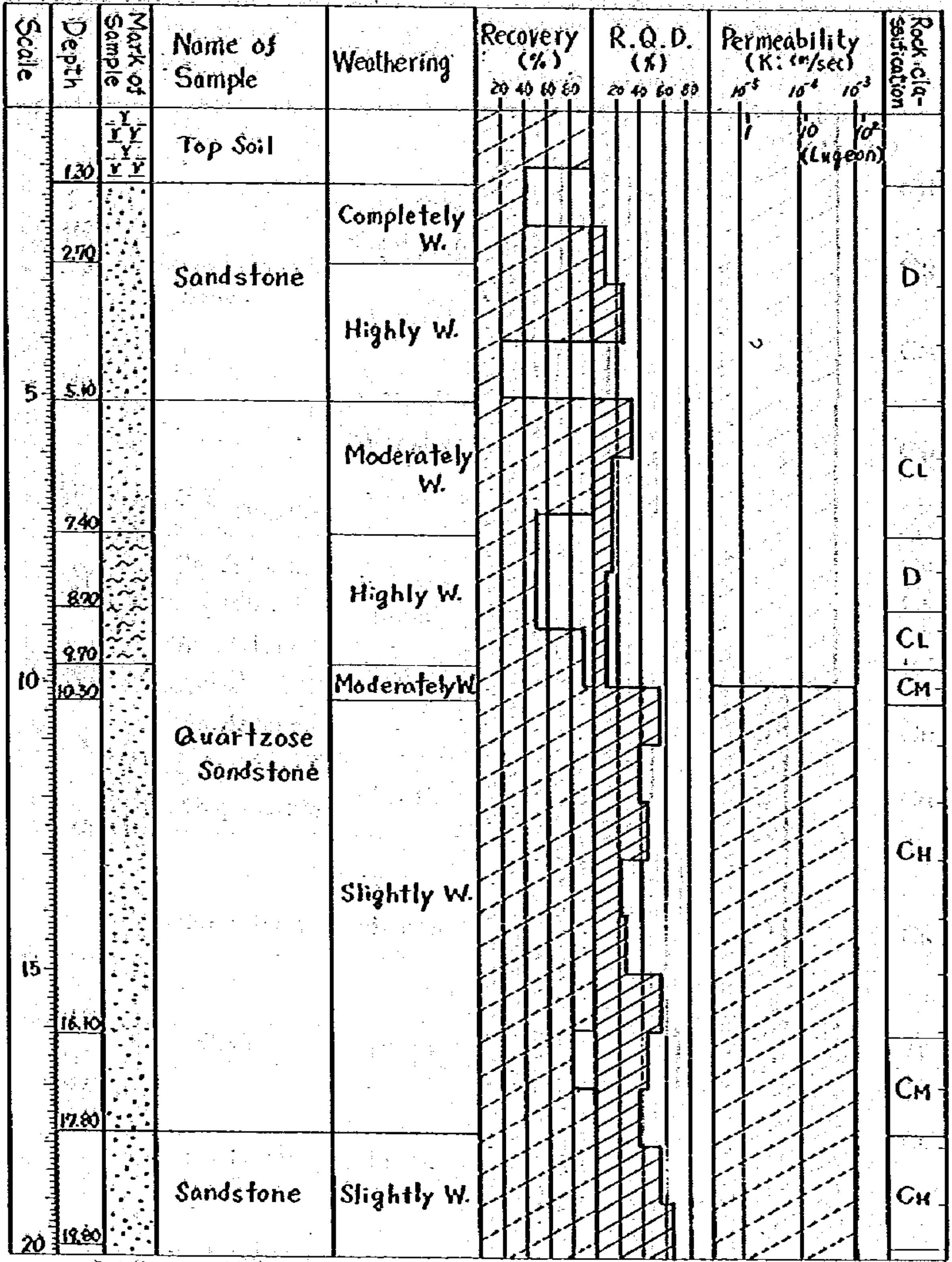


Bit Size ; NMLC (76m/m)

R.Q.D. ; Rock Quality Designation

Fig. 6.10(d1) Geological Log

Project Name	TeKoi Hydro-electric Development Project		Site Name	Upper Dam Site	
Hole NO.	U-4	Elevation of Ground Level	108.57 m	Ground water Level	14.10 m
Date	Beginning	September 15, 1981	Operator		
			Site Manager		
	Ending	September 29, 1981	Supervisor	TAKUJI SUGIMOTO	

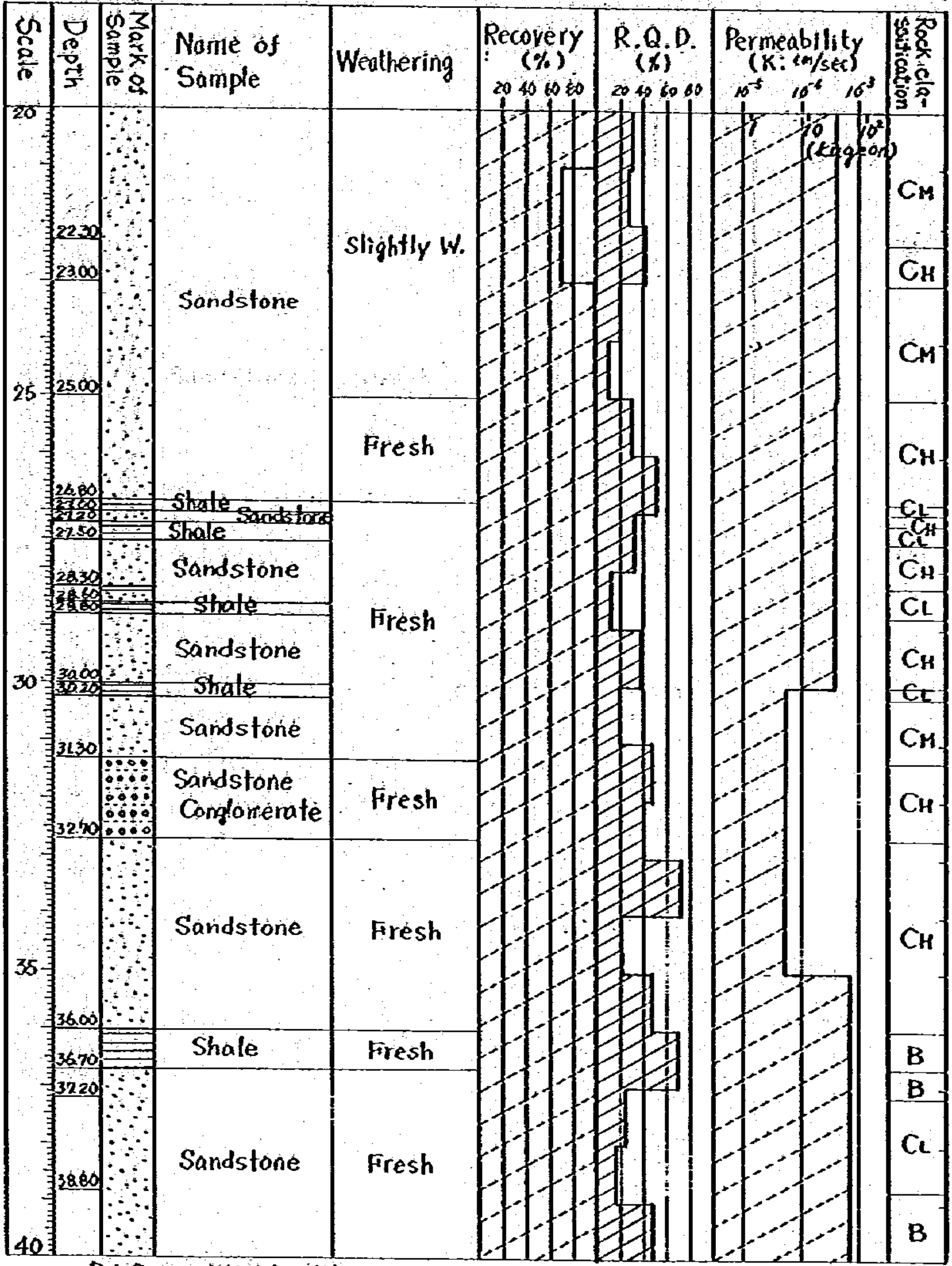


Bit Size : NMLC (76 m/m)

R.Q.D. : Rock Quality Designation

Fig. 6-10(d2) **Geological Log**

Project Name	TeKoi Hydro-electric Development Project		Site Name	Upper Dam Site	
Hole NO.	U-4	Elevation of Ground Level	108.57 m	Ground water Level	19.10 m
Date	Beginning	September 15, 1981	Operator		
			Site Manager		
	Ending	September 29, 1981	Supervisor	TAKUJI SUGIMOTO	

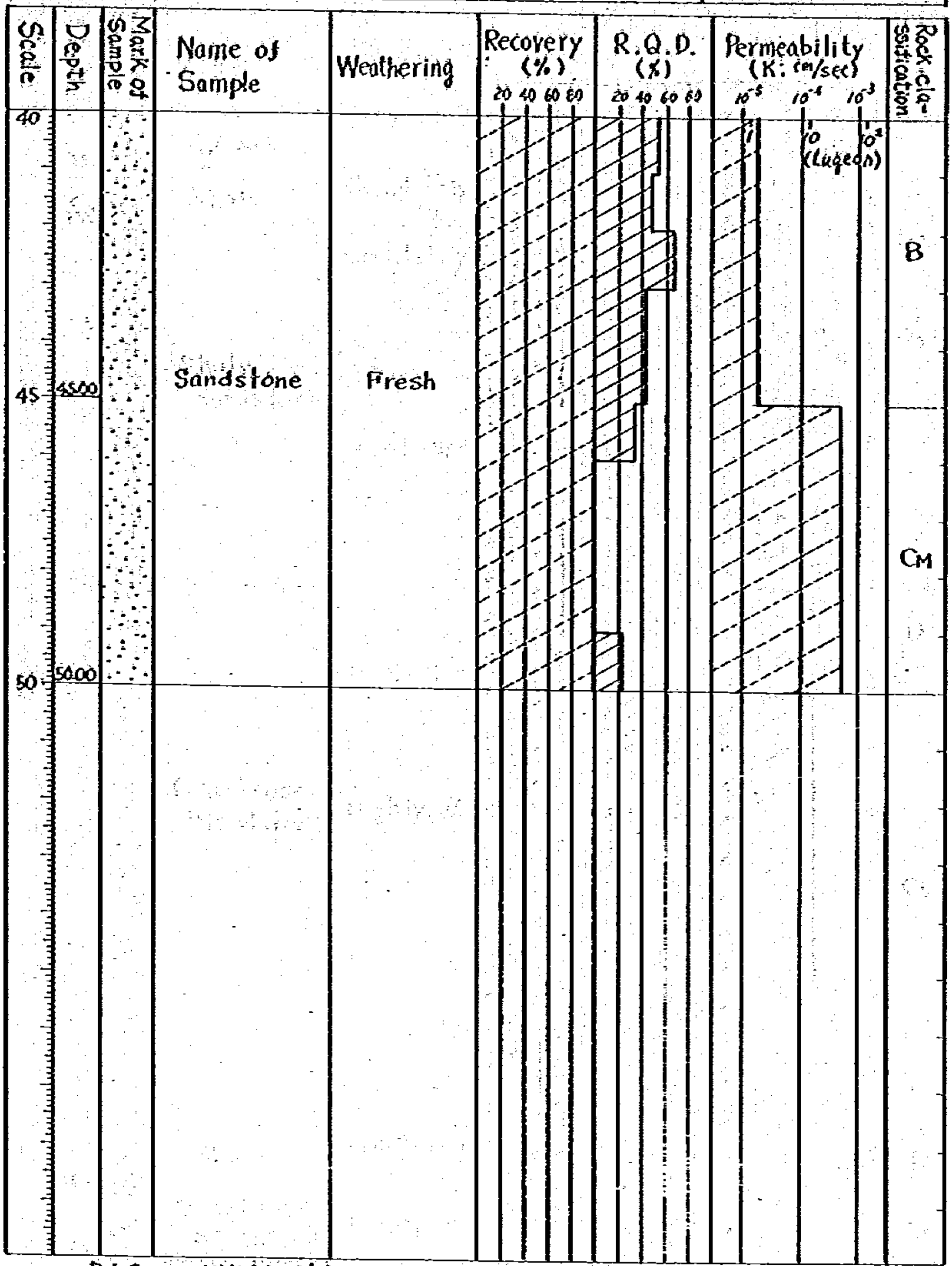


Bit Size ; NMLC (76m/m)

R.Q.D. ; Rock Quality Designation

Fig. 6.10 (d3) **Geological Log**

Project Name	TeKoi Hydro-electric Development Project		Site Name	Upper Dam Site	
Hole NO.	U - 4	Elevation of Ground Level	108.57 m	Ground water Level	19.10 m
Date	Beginning	September 15, 1981	Operator		
			Site Manager		
	Ending	September 29, 1981	Supervisor	TAKUJI SUGIMOTO	



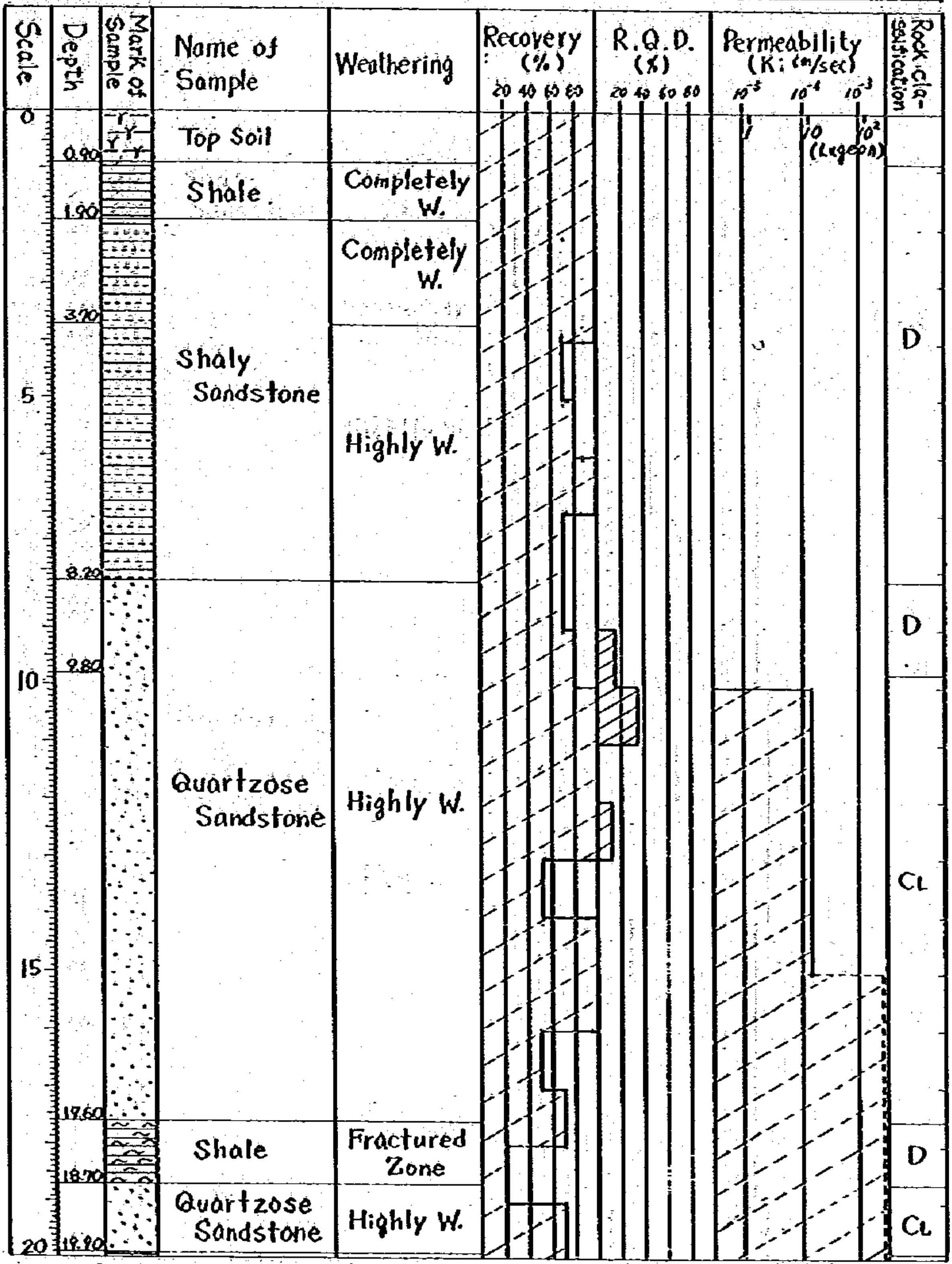
Bit Size ; NMLC (76 m/m)

R.Q.D. ; Rock Quality Designation

Fig. 6-10 (e1)

Geological Log

Project Name	TeKoi Hydro-electric Development Project		Site Name	Upper Dam Site	
Hole NO.	U-5	Elevation of Ground Level	150.83 m	Ground water Level	19.70 m
Date	Beginning	October 1, 1981	Operator		
	Ending	October 11, 1981	Site Manager		
			Supervisor	TAKUJI SUGIMOTO	

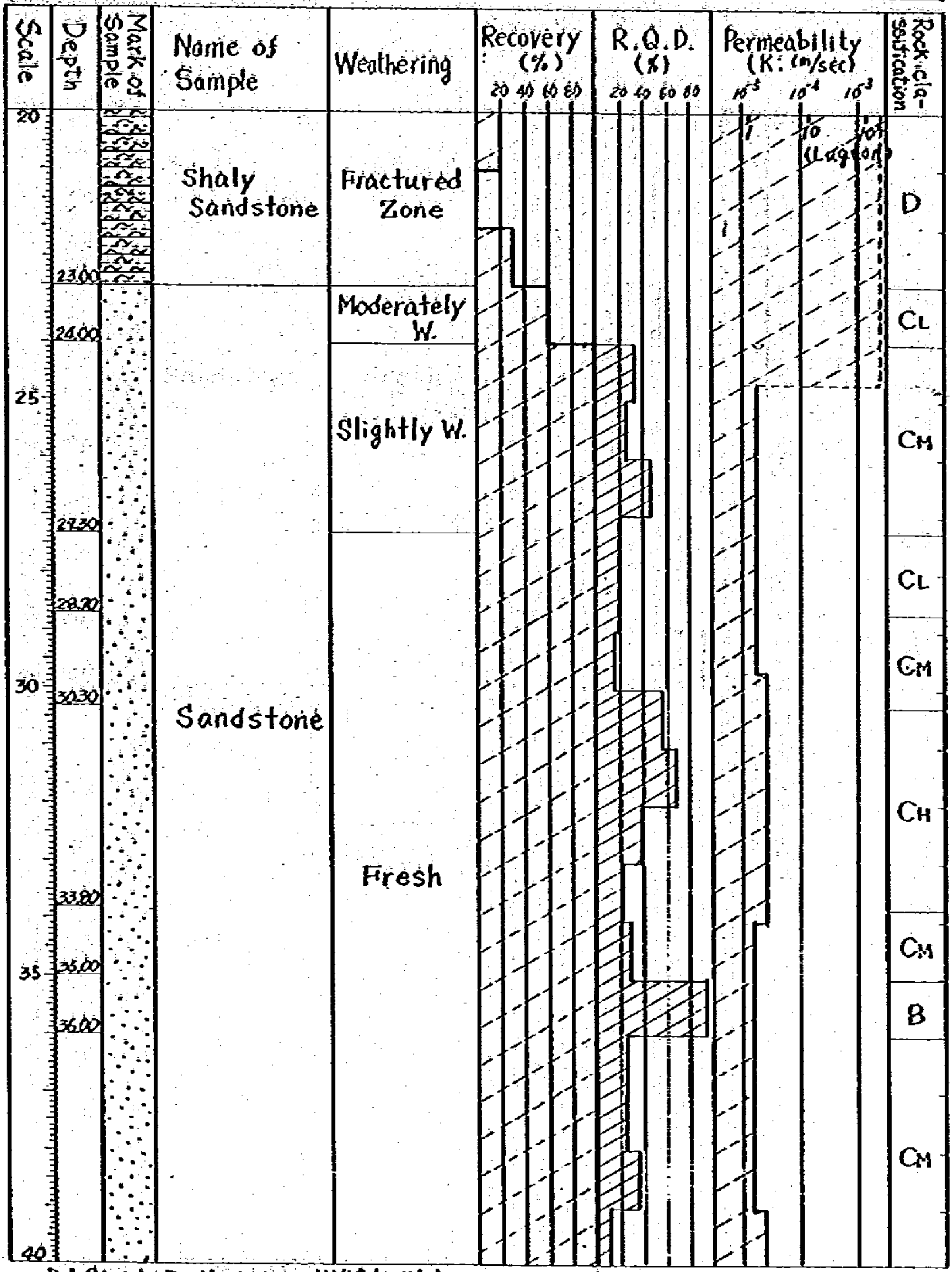


Bit Size ; NMLC (76 m/m)

R.Q.D. ; Rock Quality Designation

Fig. 6-10(e2) Geological Log

Project Name	TeKoi Hydro-electric Development Project		Site Name		
Hole NO.	U - 5	Elevation of Ground Level	m	Ground water Level	m
Date	Beginning		Operator		
			Site Manager		
	Ending		Supervisor		

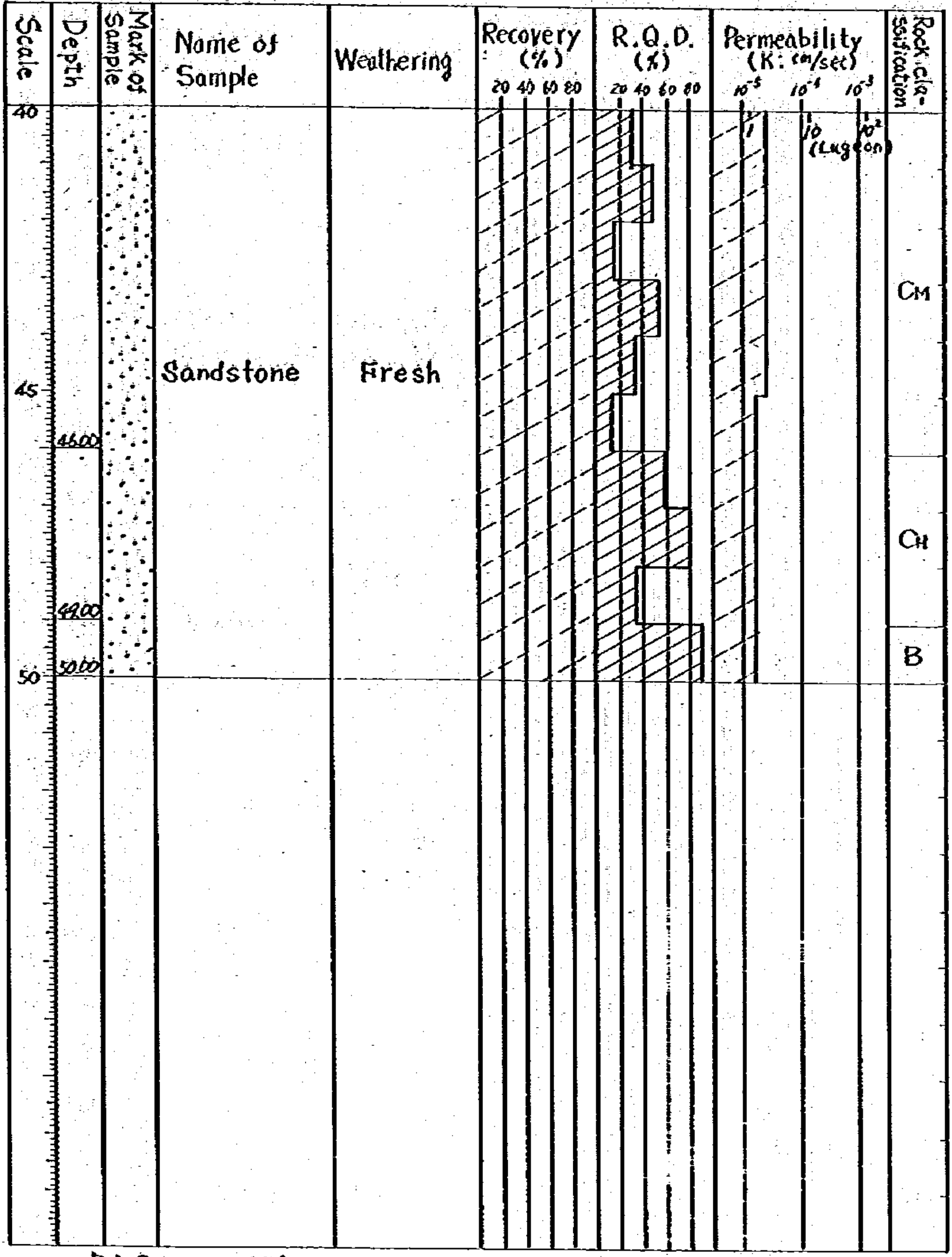


Bit Size ; Depth 20~24m = NMLC (76m/m)
Depth 24~40m = 66 m/m

R.Q.D. ; Rock Quality Designation

Fig. 6-10(e3) **Geological Log**

Project Name	TeKoi Hydro-electric Development Project		Site Name		
Hole NO.	U − 5	Elevation of Ground Level	m	Ground water Level	m
Date	Beginning		Operator		
	Ending		Site Manager		
			Supervisor		

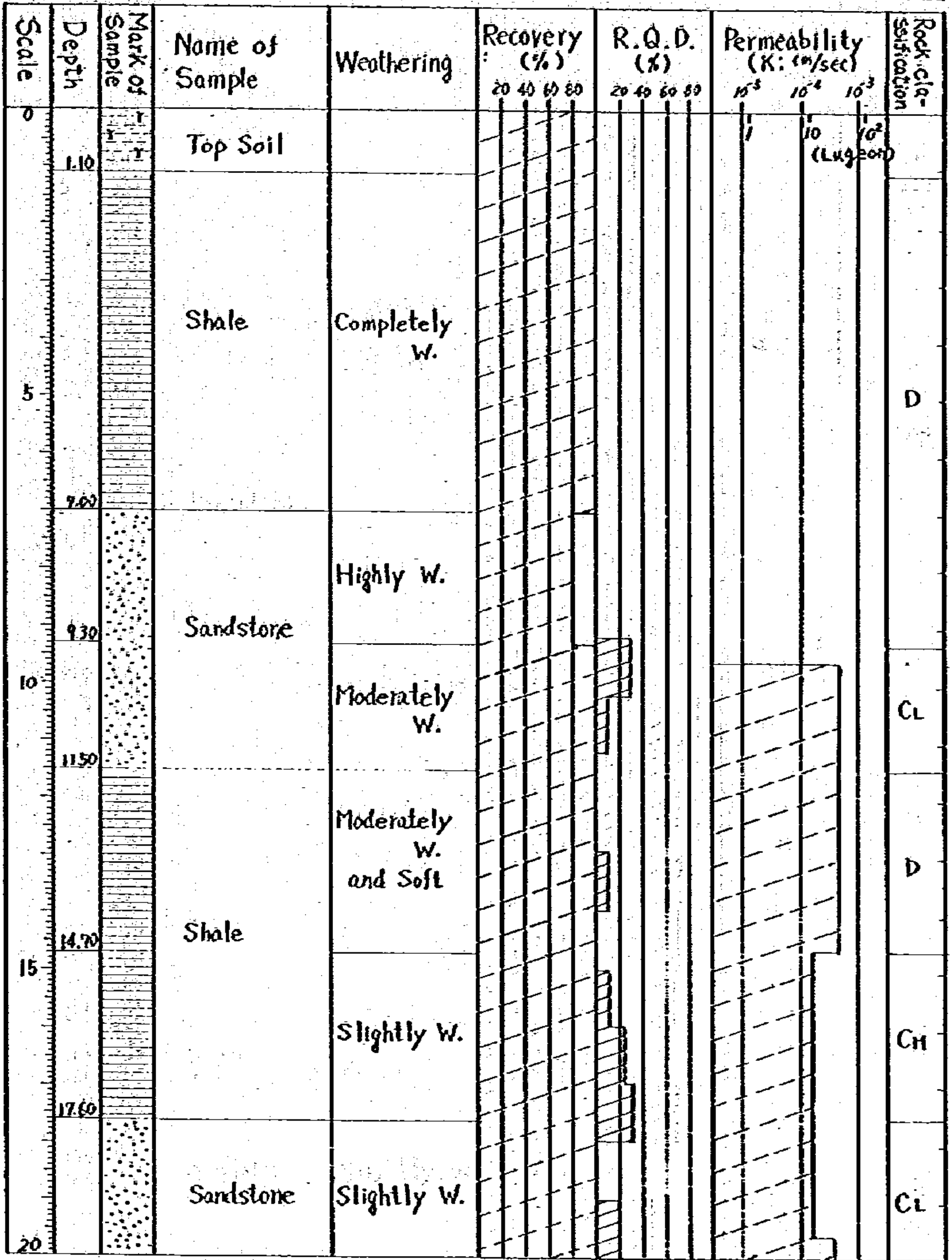


Bit Size : 66 m/m

R.Q.D. : Rock Quality Designation

Fig. 6-11 (a1) Geological Log

Project Name	TeKoi Hydro-electric Development Project		Site Name	Lower Dam Site	
Hole NO.	L - 1	Elevation of Ground Level	105.29 m	Ground water Level	39.6 m
Date	Beginning	July 17 1981	Operator		
	Ending	August 14 1981	Site Manager		
			Supervisor	TAKUJI SUGIMOTO	



Bit Size : NMLC (76 m/m)

R.Q.D. : Rock Quality Designation