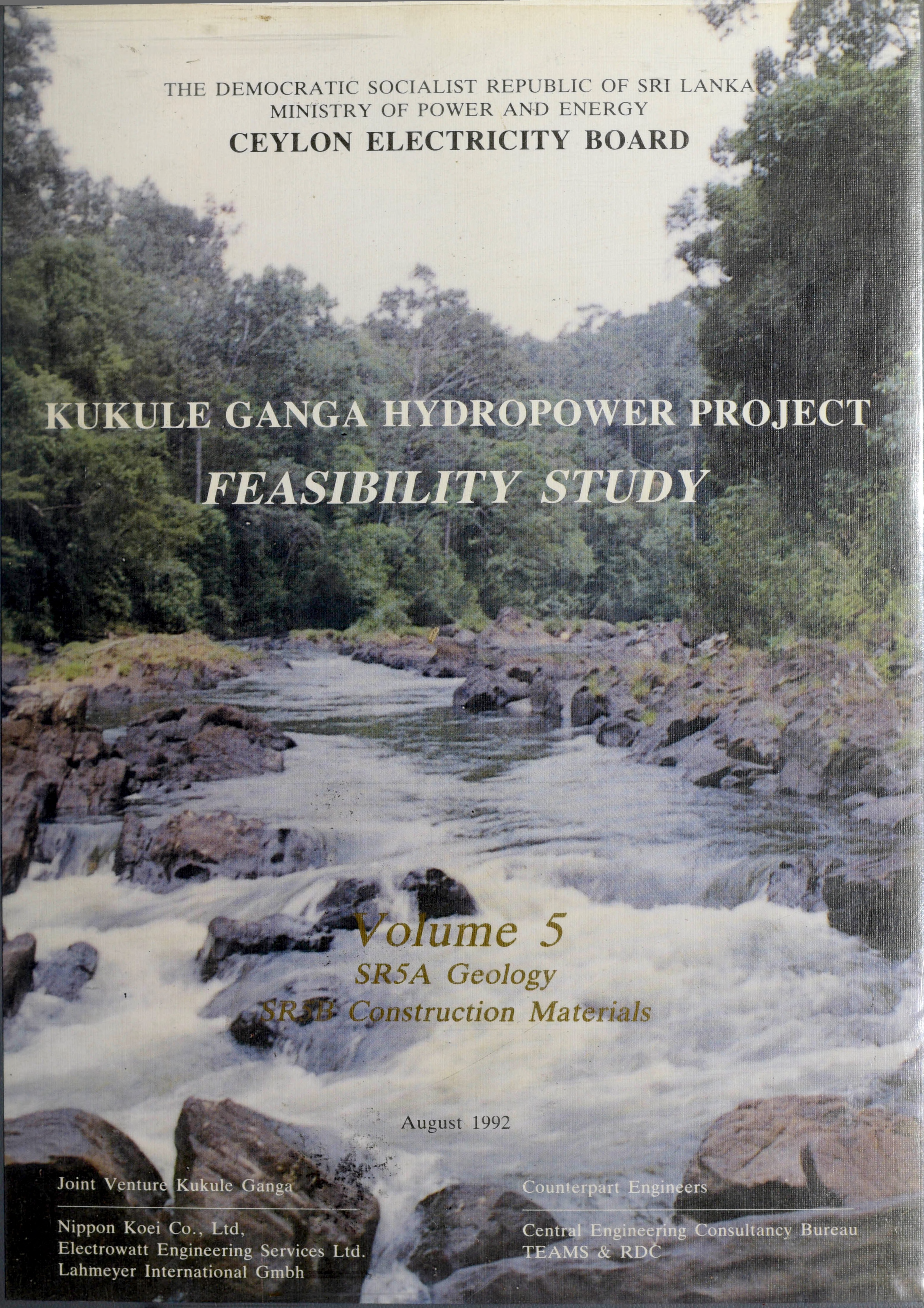

THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA
MINISTRY OF POWER AND ENERGY
CEYLON ELECTRICITY BOARD

KUKULE GANGA HYDROPOWER PROJECT
FEASIBILITY STUDY

Volume 5
SR5A Geology
SR5B Construction Materials

August 1992

Joint Venture Kukule Ganga

Nippon Koei Co., Ltd,
Electrowatt Engineering Services Ltd.
Lahmeyer International Gmbh

Counterpart Engineers

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FEASIBILITY STUDY OF KUKULE GANGA HYDROPOWER PROJECT

FEASIBILITY STUDY REPORT

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Text

CHAPTER 1. INTRODUCTION

1.1 General

The geological - geotechnical investigations for the feasibility study were conducted in two phases: II-a and II-b.

During phase II-a of the study a geological - geotechnical investigation programme was carried out from 17th August 1991 to 16th December 1991 with the ultimate aim of obtaining the required information for conceptual design work.

During this phase geotechnical work was done at locations pertinent to all alternative schemes then under consideration, namely Kukule-Peleng and Kukule-Kukule both for reservoir and run-of-river type development plans. Geological investigations covered also the reservoir areas associated with above referred schemes.

The investigation programme of phase II-b which was prepared in December 1991 was mainly to be based on general observations since results of investigations of phase II-a were not yet available. However, by March, to the arrival of the Panel of Experts, a certain amount of information became accessible. On the basis of that information, and with the acceptance of the run-of-river alternative, a new investigation programme was prepared for the D/S location [see figure No. 2(1/9), 2(3/9), 2(4/9) and 3]; total amount of drilling was 695 m.

1.2 Geological - Geotechnical Investigations

1.2.1 Previous Studies and Data

In 1961 the Kukule Ganga Project was studied as a constituent of the three basin study by ECI (Engineering Consultants Inc. U.S.A.).

Geotechnical investigations of foundations comprised core drilling, excavation of test pits & auger boring. Nine exploratory holes with a total of 426.3

drilling metres were sunk along two dam axes. Further, two pits and two auger borings were executed to augment the above mentioned drilling results.

For materials three borrow areas (A, B & C), located about one and two km upstream of the dam axis on the RB (area A) and LB (area B & C), respectively were investigated by 36 auger borings reaching various depths up to 20 ft. 35 disturbed samples were subjected to grain size analysis, consistency & specific gravity tests. Also, five undisturbed samples were tested for optimum moisture content, consolidation, shear strength etc. These were obtained from five pits dug in barrow areas A and B.

In 1989 in the process of the Masterplan Study for the Electricity Supply of Sri Lanka, a desk study was done on Kukule Ganga Project considering it as a single purpose project for hydroelectric power.

Almost simultaneously, in 1989, TAMS of U.S.A. conducted a pre-feasibility study of Kukule Ganga Project also with emphasis on hydropower generation, and it was concluded that the project was economically feasible with the following project components: rockfill dam with FSL at 242 m MSL, active storage 300 M m^3, underground power house with 144 MW installed capacity, along with a 6 km transbasin tunnel outfalling to Peleng Ganga.

1.2.2 Geological and Geotechnical Investigations

Out of the three conceived alternative schemes only Kukule-Peleng and Kukule-Kukule (including run-of-river plan) were geotechnically investigated during phase II-a, whereas on Kukule-Delwitiya scheme only geological investigations such as geo-mapping, photo geology, geomorphological and structural analysis etc., were performed.

A geophysical survey was conducted on locations of dam sites and waterways of these two schemes, and a preliminary geological survey was carried out in the reservoir areas of both schemes.

(1) Kukule - Peleng Plan

During phase II-a this alternative was investigated by means of core drilling, (water pressure testing, core sampling etc.) and a micro-seismic survey, conducted at the dam site, waterways, high pressure system and power house.

(2) Kukule - Kukule Plan

This scheme, including the "run of river" alternative, consisting of weir, waterways, underground powerhouse and surge shaft was investigated by means of core drilling and seismic survey conducted in the areas of structural foundations.

For both above programmes pitting was included but was not executed.

Investigations of phase II-b were mainly directed towards Kukule-Kukule R-O-R 205 alternative, and the initial programme which was prepared for this purpose is shown in Figure No. 2.2/9. Subsequently, this programme was altered with the decision to shift the R-O-R weir axis to the D/S, present location (see Figure No. 2.1/9). The final programme with progress up to 17th August 92 is shown on Figure No. 3 and Table No. 1.

This programme comprised geotechnical-geological and seismic investigations including pitting, test adit and rock mechanical testing.

CEB awarded geotechnical works of phase II-a in two contract packages to two government organizations, i.e. Geological Survey Department (G.S.D.) and Irrigation Department (I.D.). The original drilling programme consisted of 20 holes with a total of 1,100 m along with water pressure tests, SPT, constant head tests, etc. This programme was to be executed from mid August to end of November 1991.

However, due to delayed commencement and poor progress of work the above referred investigation programme was revised on 4th October 1991 (see Table 1), which introduced a reduction of the total quantity of drilling metres from 1,100 m to 700 m. The locations of drilling investigations and seismic profiles are shown on Figure 2. The progress of work as per 10th December 1991 is tabulated on Figure 3.

Final investigation programme for phase II-b, prepared in March 1992, was to be executed by both G.S.D. and I.D. However, when Phases II-a drilling work was completed, I.D. was reluctant to continue with the works and as a consequence the total job was awarded to G.S.D.

1.2.3 Methodology of Geotechnical and Geological Investigations

(1) Geotechnical Investigations:

Considering the prevailing geological geomorphological and geo-structural conditions as well as the availability of data needed for the assessment of foundation conditions for major structures and underground excavation conditions the following investigation methods were adopted for phase II of this study:

1. Core drilling
2. Bore-hole testing
3. Bore-hole instrumentation
4. Point load strength testing
5. Geophysical investigations
6. Pitting
7. Test adit excavation
8. Laboratory testing of rock (to be excuted following adit excavation).

(2) Geological investigations

The methods adopted were:

1. Geological mapping (scales: 1:10,000, 1:2,000 and 1:100)
2. Geomorphological survey
3. Geo-structural analysis

1.2.4. Scope of Geotechnical Investigations

(1) Core Drilling

During phase II-a investigations were carried out for both alternatives: Kukule-Peleng plan and Kukule-Kukule (including run-of-river) plan (see Table 1).

During phase II-b mainly the R-O-R 205 (new) alternative was considered (see Tables No. 1 and 5).

(2) Bore Hole Testing

Water pressure tests (Lugeon-type) with a complete pressure cycle (5 steps) reaching a maximum of 10 bars (30 bars in surge shaft and powerhouse holes) were performed in all drill holes (below the overburden and decomposed rock) in rock where packers could be installed properly. In overburden and decomposed rock constant head tests and standard penetration tests (SPT) were conducted. The results of these tests are shown on drill logs and geotechnical sections.

(3) Borehole Instrumentation

A total number of 15 piezometers (old and new programmes) were installed in the vertical holes (see Tables No. 1, 5 and 12).

(4) Point Load Strength Testing

As drilling progressed six rock types were subjected to testing as soon as possible after core samples became available.

(5) Geophysical Survey

During phase II-a seismic survey covering 3.8 km of profile lengths was carried out (for locations see Figures 2.2/9, 2.3/9 and 2.8/9). This work commenced on 1st November and was completed by end of December 1991.

During phase II-b, seismic survey covered 2.1 km of profiles (see Figures 2.3/9 and 2.4/9. This work commenced on 15th March and results were available by end of June 1992.

(6) Test Pitting

Programme for pitting is shown below:

Location	No. of Pits
Weir Site	10
Switch yard	5
Outfall structure	5
Depression (left bank of the bend u/s of weir site)	5

As of 17th August 1992 all work on pitting is completed apart from one pit at the intake of the access tunnel.

(7) Laboratory Testing of Rock (Petrographic Analysis)

Petrographic analyses on the rock samples, partly obtained from drill cores, for the purpose of rock classification was carried out at the petrographic laboratory of Peradeniya University (see Table 2).

1.2.5 Remaining Geotechnical Investigations of Phase II-b Programme

(1) Exploratory Drilling

The remaining drilling works comprise about 100 m in drill hole KK 43 (powerhouse), 30 m in KK 41 (access tunnel) and 50 m in additional drill hole KK 44 (saddle near surge shaft). It is expected that all drilling will be completed by about end of September.

(2) Soil Testing

On soil samples obtained from test pits the following tests were proposed: gradation, moisture content, bulk/dry density and plastic limits. Results were not available at the time of report compilation (17th August 1992).

(3) Rock Mechanical Testing

(A) Laboratory Tests

1. Uni-axial Compression Test
   Required 10 nos. per rock type: total 30 nos.

2. Triaxial Compressive Test
Required 6 nos. per rock type: total 18 nos.

3. Brazil Test
Required 6 nos. per rock type: total 18 nos.

It is being considered to reduce above outlined laboratory testing programme considerably if the good quality rock, that is currently expected in the powerhouse area, would be confirmed by the adit. In this case about 10 nos. of uni-axial compression tests would suffice in order to calibrate results of point load testing.

(B) In-situ tests

1. Dilatometer tests are to be conducted in the exploratory adit. Required are about 6 Nos. per rock type encountered (These tests could be omitted if adit excavation confirms good quality rock as currently anticipated).

2. Primary Stress Tests - Flat jack tests and hydraulic fracturing tests are to be conducted for this purpose.

3. Exploratory Adit - As a part of the exploratory programme it is anticipated to excavate a horse-shoe shape adit with height of 3.0 m and 2.5 m invert width. Three alternatives with various inclinations and lengths (lengths: 680 m, 420 m and 330 m) reaching the power house cavern were proposed.

1.2.6 Presentation of data

Results of geological and geotechnical investigations are presented in the form of geological sections & maps, structural diagrams, geotechnical sections, classification charts etc. These classification systems and certain modes of geological data presentation are described below:

Classification of Rock Mass According to the Degree of Weathering

The presented classification is based on B.S. 5930 of 1981, which describes the weathering of the rock mass in relation to the distribution of rock material within the same mass and the effect of weathering on discontinuities. This classification is given in Table 3.

Geomechanics Classification of Jointed Rock Masses (CSIR)

The Geomechanics Classification System (10) derives a rock mass rating (RMR), obtained by summing 5 parameter values and adjusting this total by taking into account the joint orientations (rock material strength, RQD, joint spacing, joint roughness and separation, groundwater). The descriptions and corresponding ratings for these parameters are given in Tab. 4.

NGI System of Rock Mass Classification

The NGI system of classification (8) is based on three aspects: rock block size (RQD/Jn), joint shear strength (Jr/Ja) and confining stress (Jw/SRF).

The rock mass quality number Q is calculated from:

$Q = RQD/Jn \times Jr/Ja \times Jw/SRF.$

The corresponding values to be substituted into the equation for Q are given in the respective geotechnical sections.

CHAPTER 2. REGIONAL GEOLOGY

2.1 Geomorphology

The geomorphology of Sri Lanka is characterized by the presence of three distinct topographic levels, so-called peneplains. The lowermost peneplain or coastal plain, is generally flat with elevations of less than 30 m. Towards the central mountainous complex elevations rise up to 90-120 m. In the south and east of the island the central hills rise with sharp escarpments to the next higher peneplain at elevations of about 750 m, while from the western to the northern and eastern arc the hills slope more gently. The uppermost erosional level is at about 1500 to 1800 m with individual peaks of up to 2500 m.

2.2 Stratigraphy

About nine-tenth of the area of Sri Lanka consist of high grade metamorphic rock belonging to the granulite and amphibolite facies. Sedimentary rock is found in the northern and northwestern part of the island where Jurassic sandstone beds as well as Miocene limestones and sandstones occur. Remarkably, there is a tiny outcrop of Miocene limestone at the southeastern tip of the island to be found.

The metamorphic rocks have been subdivided into two groups:

Highland Group
Vijayan Complex

The Vijayan Complex is geographically separated into western and eastern sectors by the 'linear-arcuate fold belt' (Vitanage) of the Highland Group. Within the Highland Group a Southwestern Group has been differentiated.

The stratigraphic and tectonic relationship between the above mentioned lithostratigraphic units is subject to controversial discussion. Radiometric age determinations of recent years could not satisfactorily clarify the stratigraphic sequence so that still three hypotheses are maintained by their respective authors:

The earliest view on the metamorphic rock was that the Vijayan Complex is a basement to the Highland Group of rocks (Coates, Wadia, Fernando). Vitanage believes that the Vijayan rocks are of the 'supra-crustal' type whereas others (Cooray, Berger, and Jayasinghe) believe in a younger Vijayan being formed by retrograde metamorphism of the pre-existing Highland Group rocks.

2.3 Lithology

2.3.1 Highland Group

The rocks of the Highland Group represent the metamorphosed equivalents of sedimentary rocks such as claystone, limestone and sandstone. Common rock types are (see Figure 4):

Garnet Gneiss

This rock type is characterized by the presence of alumina-rich minerals such as sillimanite and garnet. The garnets often are large and their presence gives the rock a typical 'plum pudding' appearance.

Quartz-Feldspar Gneiss

The typical rock is light coloured and is chiefly made up of quartz and feldspar. Gneissic texture is generally well developed.

Quartzite and Quartzitic Gneisses

Quartzites are chiefly made up of quartz, accessory minerals being sillimanite, garnet and magnetite. Typical quartzites are whitish in colour and glassy in appearance. Grain size is generally medium to coarse.

Marbles and Calc-Silicate Gneisses

Marbles and impure marbles are characteristic rock types of the Highland Group. Calcite and dolomite are the main constituents of this rock type accessory minerals being olivine, phlogopite, diopside etc. Solution of the calcite component may lead to karstification, particularly near the surface.

Charnockite and Granulitic Gneiss

Charnockites are the most striking rock type of the Highland Group. By some authors they have been divided in a sub-group of the Highland Group. There are several varieties of charnockites. A common property of all types is a greenish-grey to bluish-grey colour due to the unusual dark colour of its quartz constituents. According to their geochemical composition basic, intermediate and acid charnockites can be distinguished. Texture is often granulitic. Therefore, they are grouped together with granulites and granulitic gneisses.

2.3.2 Southwestern Group

The Southwestern Group is lithologically a sub-division of the Highland Group. The metasedimentary sequence is characterized by slightly lower grade of metamorphism. Characteristic mineral assemblages include cordierite, wollastonite and scapolite occurring in rock types such as cordierite bearing garnet sillimanite gneisses, wollastonite bearing calc-granulites etc. Texture of Southwestern Group rocks is often granitic or migmatitic.

2.3.3 Vijayan Complex

Rocks of the Vijayan Complex make up most of the coastal plains. The western Vijayan Complex (see para on stratigraphy) consists of biotite gneisses, migmatite, pink granite gneisses and granitoids. The eastern Vijayan unit is mainly made up of biotite-hornblende gneisses with scattered bands of metasediments. Towards the east coast occurrence of small granite plutons and acidic charnockites can be observed.

2.4 Structural Geology

The tectonic pattern of the different litho-stratigraphic units exhibits a marked contrast. The tectonic style of the Highland Group is characterized by tight folding into anticlines and synclines ranging from first order folds with amplitudes of several km to small scale folding of cm to dm scale. A variety of fold pictures may be found from isoclinal to recumbent folds. Shear zones are frequently found along axial planes of folds in the Highland Group.

Fracture zones which are often continuous over 10 to 15 km are generally perpendicular to the folding pattern. They often control the drainage system. Some of these features are reportedly faults.

There is a remarkable influence of the structural geology on the land forms and the drainage pattern, particularly in the area occupied by the Highland Group. In this group three dominant structural trends can be recognized:

NW-SE to NNW-SSE trends in the central part of the Highland Group and in the Southwestern Group,

N-S to NE-SW trends in the north and northeast,

A sharp E-W and NE-SW swing of fold axes in the southwest upland and highland areas (Rakwana, Nuwara Eliya etc).

The project area is situated within the tectonic unit that is characterized by NW-SE to NNW-SSE trending fold elements (see Figure 5). The aforementioned inventory of structural elements such as first order folds, small scale folding, fracture zones etc. are also present in the project area.

2.5 Economic Minerals

In the pre-feasibility study (26) it is pointed out that the river basins of the Kalu Ganga and its tributaries including the Kukule Ganga are famous for producing valuable gem varieties. Gems are usually found in stream beds, in the gravel layers of alluvial deposits, in river terraces and in buried river channels.

In the small pond that will be created by the proposed K-K 205 R-O-R scheme the potential for significant gem deposits is certainly limited. On the other hand, the large areas that would have been inundated by the previously considered high dam alternative are highly prospective gem areas with a great potential for presently unknown and unexploited gem deposits that are potentially of high economic value. This is true even though exploitation of gem deposits is currently of little significance in the area.

2.6 Seismicity and Seismic Risk

Sri Lanka is located within the Indian ocean region of world earthquake zones. The region comprises a complex pattern of ocean ridges and tectonic features which permits a certain active volcanism of mostly basaltic type. The seismicity bound to these features is considered to be of shallow character.

Epicentres of the magnitude of about M=5.0 are rather scarce (see Tab. 7.1) and irregularly distributed some 70 to 400 km off Sri Lanka's shoreline (see Fig. 6); no events of similar magnitude have been recorded onshore during the observation period which covers about 50 years. Maximum ground accelerations in central Sri Lanka (project area) resulting from the severest event (1973 earthquake: 5.9 M) can be calculated to about 0.001 g.

First results of a microseismic network set up with the Kotmale hydropower project confirm that Sri Lanka is not entirely as aseismic as previously assumed, but is rather seismically active at a M=2.0 level (21). So far no earthquakes, even micro-earthquakes, have been recorded whose focii appeared to be located in the close vicinity of the reservoirs and whose magnitudes were higher than normal for the region.

The seismicity of Sri Lanka and respective project areas was evaluated for all major hydropower projects constructed during the past decade; the ground acceleration factor (horizontal acceleration) adopted in those projects ranges between 0.05 (Samanalawewa) and 0.1 g (all other projects).

For the feasibility study of the Kukule project the following factors seem essential:

- seismic level of Sri Lanka in general is low which is confirmed by seismic records covering a period of over 50 years as well as by historic reports of the past 100 years (maximum ground acceleration experienced in the island during past 50 years is about 0.001 g, refer to above said);

- seismic risk of the project area in particular is not apparently elevated since there are no lineaments of regional significance in the close vicinity (say 20 km);

- no high dam cum large reservoir is to be constructed so that no particular risk of reservoir induced (man-made) seismicity is to be expected;

- the proposed structures are of types and sizes which are inherently insensitive to earthquakes (31);

- all structures will be founded on rock or even located inside the rock mass so that no amplification effect could take place;

Summarizing the above said it is proposed that all structures should be designed to resist a ground acceleration of at least 0.05 g without any damage. In designing for these conditions probably no special provisions will be required.

CHAPTER 3. RESERVOIR GEOLOGY

3.1 Geomorphology

In the vicinity of the proposed K-K 205 weir site the Kukule Ganga forms a narrow, gorge-like valley with an approximately V-shaped cross section. About 3 km upstream of the weir site the valley widens and its dominant shape is that of a trough with broad and flat flood plains bordered by generally medium steep slopes. Mountain crest levels range from 400 to 800 feet above valley bottom in the vicinity of the dam site while they are exceeding 1,000 feet near the southern limits of the project area.

Orientations of the valleys of the Kukule Ganga and its tributaries reflect the structural conditions which are controlled by the orientation of folding (NW-SE to NNW-SSE) and more or less perpendicular fracture zones. General geological conditions as indicated by weathering depth, prevailing rock types, structural conditions etc. are manifested in moderate slope angles, straight river courses oriented in a strikingly rectangular pattern and almost complete absence of steep and high rock faces and cliffs as well as the relatively scarce occurrence of rock outcrops.

3.2 Rock Types

Geological mapping of dam site areas and related reservoir areas as well as results of core drilling revealed the presence of a variety of rock types including biotite gneiss, hornblende-biotite gneiss, charnockitic gneiss, amphibolite, quartz-feldspar gneiss and garnet gneiss which occasionally may contain small patches of graphite. In the western part of the project area rock types have generally a massive appearance because gneissic fabric is poorly developed and spacing of fractures is moderate to wide, this is in marked contrast to the eastern regions where rock tend to be more intensively fractured.

Owing to their mineral content (see Tab. 2) rock types develop different susceptibility to weathering. The quartz-rich rock types such as biotite gneiss and some varieties of charnockitic gneisses are not easily weathered. These rocks often form the centres of prominent ridges and, on the other hand, have shallow weathering profiles developed on them. In contrast, weathering is deep on rocks that contain high proportions of biotite and/or feldspar; particularly easily weathered are graphite bearing rock types. Interbedding of rocks with different weathering characteristics results in a very irregular and occasionally deep weathering profile. At some sites, for instance at previous K-P axes and at Watugala dam site, a characteristic feature is observed that assumes the form of a sandwich-like interbedding of weathered and fresh rock, and which may occur down to considerable depths. It appears that weathering is generally more intensive and deep in the eastern project region (reservoir area of high dam alternative).

Widespread occurrence of calcareous rock types is a matter of particular concern in any hydropower project since that could be hazardous to the project (water tightness of the reservoir, under seepage of the dam, instability of slopes etc.). However, extensive geological and geotechnical investigations have not revealed the presence of such rocks at K-K 205 weir site nor within the associated reservoir area. At K-K 205 weir site as well as at alternative dam sites, which will be located within the pondage area of this site, a considerable number of drill holes was sunk. However, the recovered core material does not reveal the presence of calcareous or any other soluble material.

Two small scale occurrences of metamorphosed limestone which were observed near the town of Kalawana, and which would have been situated within the reservoir area of a K-K 242 dam scheme, seem to be isolated and of local significance according to spatial distribution and characteristics of these rocks.

Summarizing it can be stated that geological mapping and geomorphological analysis of the reservoir area of K-K 205 as well as drilling results confirm the absence of rock types which may be of any potentially hazardous consequences to project structures, human settlements and the natural environment that may arise due to reservoir operation.

3.3 Structural Geology

The analysis of the structural conditions of the project area was done in the field, simultaneously with geological mapping, as well as using photo-interpretation technique, the latter being particularly useful with respect to macro-structural elements and geo-dynamic features. Results suggest that the project area can be structurally divided into at least two structural domains, which also exhibit marked lithological contrasts, with the following characteristics and demarcations:

Firstly, the area comprising the dam site, including all dam site alternatives, and associated waterways is characterized by very massive and competent rock types such as quartz-rich biotite gneiss, charnockite, amphibolite etc. The tectonic style of these rock types is characterized by tight folding, and numerous anticlinal and synclinal axes have been identified. Sizes of fold elements range from first order folds to small scale folding including flow-folding. Longitudinal extension even of large folds often cannot be traced for any long distance which may sometimes be attributed to the great lithological variability of the rock. According to the measured dip directions and dip values folds are mostly isoclinal, while in some places fold limbs appear to be slightly overturned resulting in a slight NE-vergence. Small scale folds show great variability and may range from isoclinal to recumbent fold pictures.

The fold system is dissected by an E-W to NE-SW oriented pattern of fracture zones (photo-lineaments) which can be easily identified on aerial photos. On rock outcrops, for instance in gullies, they can occasionally be directly observed in the field. Such features are assumed to cause most of the gullies which dissect the slopes at the dam site areas. They can also be found along the waterways alignments.

Structural geology and lithology result in a remarkably strict orientation of mountain ridges and river courses. Long and mostly narrow ridges follow precisely orientations prescribed by the fold pattern (foliation strike) while river valleys change their directions abruptly following sometimes for a certain stretch foliation whereas for some distance perpendicularly oriented fracture zones may control the orientation of a given valley.

Secondly, geological mapping and photo-interpretation of the upstream areas of the previously considered high dam cum reservoir revealed the presence of a structural and lithological inventory which is markedly different from the aforementioned tectonic domain. Lithologically this area is made up of rock types which are relatively incompetent and are more easily weathered as for instance garnet gneiss which often contains patches of graphite, quartz-feldspar gneiss, well foliated biotite gneiss, etc. Owing to the lack of outcrops there is less information regarding the number, extension, size and form of tectonic elements. There seems to be more intensive tectonization along shear zones, fold axes, etc. However, it appears that basically the structural inventory of both domains comprises the same elements. Consequently, resulting landforms and drainage pattern are more irregular and morphology is generally softer with wide trough shaped valleys, gentle slopes and many isolated small hillocks compared to the aforesaid pronounced mountain ridges.

3.4 Stability of Reservoir Rims

Along reservoir rims slope failures can often be related to:
- presence of thick overburden or weathered rock
- occurrence in sound bedrock of unfavourably oriented discontinuities.

Reservoirs can have an impact on slope stability along their rims since most soils and weathered rock types that come under the impact of reservoir operation, i.e. alternating saturated and drained conditions, have the tendency to alter strength characteristics, while in bedrock along joints pore pressures can vary thus perturbing the equilibrium of forces within the slope.

In the course of geological investigations stability of reservoir slopes was assessed with respect to the presence of potentially hazardous conditions of either type. The results of the survey can be summarized as follows:

Slopes along both banks of K-K 205 reservoir are mostly covered by overburden in form of talus which consists mostly of boulders of variable sizes embedded in a slightly clayey silty-sandy matrix. Thickness of overburden is generally in the range of about 5-10 m. According to results of drill holes talus overburden is relatively thick in the upstream reaches of K-K 205 reservoir, about 20 m in drill holes KP-1 and KP-3. Angle of repose of talus is about 30 to 35° while slope angles of existing slopes vary between 25 and 30° so that soil slopes can be considered stable provided no excessive pore pressures would develop.

This assumption is in line with field evidence, because no significant zones of potential instability of overburden and highly weathered rock, which has similar geomechanical characteristics, were identified along both banks of the reservoir. There is only one example of an existing small scale landslide which was observed at the left bank reservoir rim about 250 m upstream of KP dam axis at an elevation of about 210 to 220 m above MSL, i.e somewhat above proposed reservoir level. The slide took place in thick overburden and assumes the form of a rotational slide. The scar and the bulging of the sliding mass are still visible. The total volume which was affected by the slide may be in the range of 1000 - 2000 m^3.

However, it may be inferred that the talus slopes which exist on both banks along the reservoir rim could develop some instability in places, where the toe of such a talus accumulation is wetted, which may take the form of progressive creep. That could result in the destabilization of the overburden cover further up in the slope. However, areas and volumes which could be affected would certainly be relatively small.

There are only short stretches of the rim, where outcropping rock forms the slopes of the reservoir. Along right bank rims foliation dip has generally a component into the slope which makes sliding unlikely. Similar structural conditions exist in some stretches along left bank slopes. This is due to the presence of a major anticline axis which approaches the valley. Further towards upstream the fold axis runs along the upper left bank slopes, so that the lower slope sections form part of the northeastern limb of the structure. Slopes are consequently dip slopes, i.e. foliation is sub-parallel to slopes, which, in general terms, could result in unfavourable conditions if foliation is undercut. However, dip of foliation is generally steeper than slopes so that instability due to daylighting foliation need not be anticipated. However, no recent rock slides are evident along the reservoir rims. Along limited sections of the rim rock falls rather than rock slides tend to occur (this feature is frequently observed downstream of the Kukule waterfalls).

Rock falls are most likely to result from intersections of foliation dipping out of the slope with near vertical joints. However, due to the massive character of the rock mass there is only a limited potential for rock falls, which would be of small scale, along short stretches of the reservoir rim.

Summarizing the above said, it is assumed that the potential for large scale slides, that could endanger the safety of the reservoir and the dam, as well as reservoir induced slope instability, that could be hazardous to settlements or the natural environment, is rather limited considering the absence of steep or very high slopes of large extension or any of the above mentioned unfavourable criteria.

3.5 Watertightness of Reservoir

Water seepage from the reservoir towards adjoining catchments, or around the dam into the same river, could potentially occur along faults and major fracture zones. Additionally, a potential cause for water losses could be the presence of marble (metamorphosed limestone) and calc-silicate gneisses due to their potential of solution (karstification).

Elsewhere in Sri Lanka (Kotmale, Samanalawewa) severe seepage and stability problems were encountered which stem from the presence of these limestones and calc-silicate gneisses. Hazardous behaviour is predominantly through the loss in volume associated with their solution. For instance, as these layers approach the ground surface and become weathered, the loss in volume results in subsidence of the overlying beds. If the zone of subsidence is located on slopes, it can be sufficient to set off land sliding in the material at higher elevations. An additional aspect of solution of these rock types is obviously the high potential of seepage through these rocks.

Calc-silicate gneisses occur at numerous locations in the Highland Series. The layers are typically thin, one or two metres, but may have considerable lateral extension (Kotmale Reservoir, Samanalawewa Reservoir). The calcitic content occurs as thin veins within the layers and also in form of the minerals diopside and scapolite. Feldspar and quartz usually make up the bulk of the other constituents. The calcitic fraction of the layers may be partially lost at depth, by solution, or wholly lost during the weathering process. In addition, the diopside has been found to alter to hornblende. Since limestones deform more readily than gneisses under tectonic pressures, the layers of calc-silicate often exhibit micro-folding and small to large scale boudinage effects in the formation (frequently observed at Laxapana).

Consequently the presence of marble, calc-silicate gneisses and their derivate weathering products was given particular attention during logging of drill cores and geological mapping of dam site and reservoir areas. While the presence of marble and calc-silicate gneisses would be quite evident in drill cores, it is generally difficult to trace them in the field since these rocks, particularly marble, are seldom found in form of sound rock pieces. Generally, direct evidence of calcareous rock types is scarce, mostly it is indirect for instance in form of presence of typical soils, presence of morphological features as for instance subsidence or landslides, typical groundwater regime etc. While above features are quite pronounced in marbles they are less developed in calc-silicate rocks due to the lower content of calcareous components.

With respect to above mentioned problematic behaviour of calacareous rock types particular attention was given to the occurrence of such material in bore holes at dam sites as well as in the reservoir areas of K-K 205 and of other alternatives. However, no evidence of calcareous rock types, including above described adverse features, was found in the drill cores at the weir site nor during reservoir mapping. Also, at present there is no indication, according to available results of drill holes as well as field observations, that limestone or calc-silicate geisses could occur along the waterways or in the powerhouse area. However, a conclusive answer to this latter question can be only given when results of test adit excavation will be available.

Hence, with the results of core drilling and geological mapping currently in hand, the following model of trans-basin seepage (underseepage and seepage around the weir will be discussed in chapter 4.2.2) can be developed:

Seepage into neighbouring valleys would generally have to develop through mountainous watersheds formed by gneissic rocks including their overburden cover of varying thickness. However, watersheds at reservoir level are rather wide while, on the other hand, reservoir induced hydraulic head in watershed areas is relatively low resulting in low to very low hydraulic gradients whereby the water would have to pass through zones of massive rock of low permeabilities, as results of water pressure test indicate which were performed in drill holes KK-29 and KK-42, and a blanket of more or less impervious soil and decomposed rock.

Summarizing the above said, it can be assumed that watertightness of the reservoir is not a major concern.

In this context it shall be mentioned, that during mapping of the reservoir area of K-K 242 dam scheme two small scale occurrences of limestone were observed near the town of Kalawana. This location would have been within the reservoir area if a reservoir level at 242 m FSL were considered. Available information regarding tectonic position, continuity of the rock and typical rock characteristics suggested at that time that the limestone occurrence is isolated and does not extend any great distance. It was then assumed, that it is unlikely that it would provide potential seepage paths into the adjoining river basin. Since then more thought has been given to this problem and now it would appear in a different light (refer to above discussion), in the sense, that additional investigations would be needed to definitely confirm this statement.

3.6 Geological Aspects of Environmental Impacts

Evaluation of the above topics is being focused on the selected project alternative, i.e. K-K 205 R-O-R scheme. Geological aspects may be relevant for the following groups of environmental elements which could potentially be affected by the different components of the proposed hydropower project:

- Landscape,
- Landslide hazard and other dangers,
- Groundwater,
- Surface water (regime, quality)
- Gem mining

In the following discussion only the major structural components are considered, since other elements such as access roads, quarries, switchyard and dump sites for excavated materials, particularly for the selected project layout, have too small dimensions as to cause significant disturbances of a.m. environmental elements, apart, possibly, from slope instability which, however, will be looked after during engineering design.

Landscape

Obviously, during construction of any hydroelectric project, also of its appurtenant structures, considerable re-shaping of the natural landscape is done. In this context excavation of cut slopes is the main concern. As regards stability of these man-made slopes proper design (appropriate slope angles, protective measures) will exclude any damage to the existing environment.

Groundwater regime may be locally disturbed but will be of limited impact due to the relatively small size (excavation depth) of relevant structures.

Landslide Hazard and other Dangers

Landslide potential is discussed in detail in chapter 3.4 and it is concluded that the proposed reservoir would not result in an increase of the existing low risk situation.

"Other dangers" refers mainly to the risk of reservoir induced earthquakes. In chapter 2.6 the seismic risk associated with the project is discussed. In this context it may be mentioned that the large reservoirs (Kotmale, Victoria, Randenigala), which have been built in Sri Lanka during the last decade, have not led to a significant increase of the seismic level in the vicinity of the reservoirs. In 1983 Joint Venture Randenigala did a preliminary evaluation of the then available records of the Kotmale micro-seismic network and came to the conclusion that most recordings were related to the ongoing construction work at Randenigala. Only few records were correlated with tectonic seismicity and no indications were found of elevated seismic activity. Final evaluation of the Kotmale seismic records are still not available, but above preliminary results will probably be confirmed, with one amendment to this statement: along the so-called Mahaweli lineament which forms the morphological escarpment of the eastern slopes of the central highlands, seismic activity and intensity was elevated to about M=3 level during the initial years after impounding of the newly constructed large reservoirs, but has presently dropped to the original M=2 level (verbal information by Dr. Wijeratne, CECB).

Summarizing the above said it can be stated, that size and volume of the proposed K-K 205 reservoir will be so small that man-made earthquakes and related hazards can be excluded.

Groundwater

The main impact on the groundwater regime results potentially from the weir/reservoir and the underground works. Other structures are too small and/or related excavations too superficial as to result in a significant change of the groundwater table.

As to the weir/reservoir impact, it can be said that the reservoir level is only few metres above valley bottom and will inundate only the lower slope sections along the reservoir rim. That will certainly result in a rise of the water table in these lower slopes, particularly during the dry season. On the other hand, it was found during drilling and also by inspection of existing wells, that during the normally 9-month long wet period the groundwater table is generally close to surface level, so that during this period the impact is insignificant, while during the normally short dry period it may be relevant to the flora, particularly should sensitive plants grow in this area.

During construction phase of the underground works these will act as a drainage to the surrounding rock mass. Depending on the presence of major waterpaths, for instance along fracture zones, large rock mass volumes may be dewatered. Currently, information is scarce as to the nature and extend of fracture zones. However, during the extended drought from January to May 1992, presence of perennial springs and almost unaffected discharge of the artesian aquifer encountered in drill hole KK-3, suggest that rock mass portions with relatively large volumes of stored groundwater exist which would be drained if cut through during tunnel construction.

As to the impact of the potential lowering of the groundwater table of this mountain ridge a twofold effect may be expected:

Firstly, the watersupply of the settlers in the powerhouse and surge shaft area (few households) may be disrupted during the construction period.

Secondly, vegetation might potentially be affected, particularly during exceptionally long dry periods, whereas, if a normal weather pattern would prevail, the retention potential of the overburden cover and weathered rock profile should be sufficient to bridge over moderate dry periods between wet seasons.

There is one important aspect to note: These adverse environmental impacts are temporary and only applicable during the construction phase of say three to four years, since all waterways will be lined and made impervious against the natural groundwater. It is of course difficult to judge, whether any already occurred damage to the prevailing flora would be reversible.

Surface Water (Regime, Quality)

Apart from the obvious impact on the regime of the Kukule Ganga along the river section between the weir site and the outfall structure no adverse variation of the surface water regime and/or quality due to geological reasons is anticipated. As is discussed in chapter 3.5 no water seepage into adjoining catchments is to be expected including the potential effect of solution and associated change in water quality.

Gem Mining

A restricted potential only appears to be existing for economically relevant resources of valuable gems, which is mostly due to the limited extend of alluvial deposits in the small reservoir area of K-K 205 R-O-R scheme (see also chapter 2.5).

CHAPTER 4. GEOLOGICAL-GEOTECHNICAL ASPECTS OF THE AREA OF SELECTED K-K 205

4.1 General

This alternative dam site was identified during phase II-a investigations but was not considered competitive with the upstream site at that time due to hydraulic as well as geologic considerations. Later it was realized, however, that this was mainly due to site conditions prevailing at the time of the field visit when the water level was high.

In the course of investigations at the eliminated site it became obvious that foundation conditions of the desander at the left bank flood plain are quite unfavourable and would require deep excavations of unsuitable rock (up to 20 m). On the other hand, when the results of the topographic survey became available, it became apparent that considerable rock excavation would have been required to improve hydraulic conditions downstream of the desander. Consequently, and with the advise of the P.o.E (30), the downstream site was selected as the definite weir site.

4.2 Dam and Appurtenant Structures

4.2.1 Topography and Geomorphology

At the selected K-K 205 dam site the valley is relatively narrow. The cross section is almost V-shaped and has somewhat flat limbs on a relatively narrow basis of about 60 m width. At the dam axis abutments are relatively low, about 60 m above weir crest; towards downstream valley slopes rise more than 100 m above river level. Slopes are more or less regular.

The typical cross section along the dam axis has the following slopes: At the left bank average slope angle up to dam crest level is about 18°. Due to the more favourable structural pattern, foliation dip is into the slope, right bank is slightly steeper (about 28°).

4.2.2 Geological Assessment

(1) Weathering and Overburden

At the dam site bedrock is exposed in the river section (during dry weather conditions) on both banks up to elevations of about 200 m above MSL. The outcrop extends some 80 m upstream of the dam axis; towards downstream exposed rock forms the river channel beyond the rapids, some 120 m from the dam axis. Existing drill holes as well as results of the seismic survey indicate the following:

At the left bank intake of the inflow channel drill hole KK 34 shows that overburden and weathered rock are only about 1 m thick. Results of drill hole KK 35 indicate that a thin cover of overburden (1.4 m) exists at the left bank weir axis. In drill hole KK 36 which is located at the slope side of the desander, some 130 m downstream from the intake, overburden and weathered rock are about 12 m thick.

On the right abutment the weathering profile is of similar depth owing to the favourable structural conditions (see para (4) of this chapter). According to the result of drill hole KK 33 depth of overburden and weathered rock is about 11.5 m at dam crest level (see Fig. 10).

(2) Rock Types and Rock Mass Parameters

According to results of dam site mapping and results of already executed drill holes dominant foundation rock consists of the following rock types (description of the mineral composition is partly based on petrographic analyses of samples taken from drill cores at weir site):

Biotite Gneiss and Garnet-Biotite Gneiss

This is the dominant rock type that will make up the major part of the dam and desander foundation areas. Main constituents are quartz, plagioclase, biotite, hornblende, some garnet and accessoric minerals (see Tab. 2). The typical variety exhibits pronounced gneissic fabric. The quartz-rich variety which has a massive appearance is practically absent at the dam site area.

The presence of hornblende-biotite gneiss and quartz-feldspar gneiss was also observed, but is of no consequence for foundation conditions.

Rock strength can be extrapolated with sufficient accuracy from a great number of point load tests. Average uniaxial compressive strength of the sound rock material is about 150 to 200 MPa; respective values of the slightly to faintly weathered rock which will be available at foundation level is about 80 to 150 MPa (Tab. 10, 1/3).

Fracturation (degree and orientation) of the rock mass in the weir foundation area could be observed during the extended dry period, from December 1991 to mid April 1992, when great portions of the river section were exposed. Dominant discontinuity set is foliation in addition to which two joint sets were observed:

Spacing of foliation joints is moderately wide on an average of 0.3 to 1.0 m; locally it is >1m. This gives the foundation rock mass a relatively massive appearance though, as was already mentioned, gneissic structure of the main rock type is well pronounced. It appears that foliation joints are mostly tight and, hence, do not significantly contribute to the rock mass permeability. Foliation joints are mostly plane or slightly undulating and smooth which is mainly due to some biotitic coating (JRC = 2-4).

Average spacing of joint set No. 1 (JS 1) is about 1 to 3 m, and locally it is 5 m. Surfaces of joints are mostly slightly rough (JRC = 6-10) and joint wall rock is generally hard; only occasionally may soft joint wall rock occur on weathered joints. Based on field observations as well as water pressure tests in already drilled holes some separation of individual joints may be expected down to a depth of about 10 m; below 10 m joints are more or less tight (separation <1 mm).

According to the results of a joint survey done during detailed mapping Joint Set No. 2 (JS 2) has similar characteristics: spacing = 1-3 m, max. 7 m ; JRC = 8-10.

On the basis of above data collection a preliminary rock mass description and classification was done using NGI and CSIR classification systems (summary of results is given in Tab. 10,1/3):

Q-values (NGI-classification) range from 6.6 to 14.5, while average RMR-value (CSIR-classification) is 64. Such values are characteristic of a foundation rock which in general terms could be described as good quality rock mass. Based on this classification and field observations on joint conditions geomechanical parameters of the foundation rock mass may be taken as follows:

Shear Strength (Rock Mass) ϕ = 40-45°; c = 1-2 MPa
E-Module (Rock Mass) E = 10-20 GPa

Shear Strength (Foliation) ϕ = 25-30°; c = 0.1 MPa
Shear Strength (Joints) ϕ = 35-40°; c = 0.2 MPa

(3) Structural Geology

(A) General

During geological mapping a first order anticline was identified to run along the left bank of the Kukule valley. At K-P dam site the axis of the anticline is at a distance of about 250 m from the river and approaches the river in a downstream direction finally reaching the river at the upper end of the S-shaped bend, upstream of K-K 205 dam site. Consequently, with respect to the fold pattern the dam site assumes a position at the NE-limb of the anticline.

The fold system is dissected by an E-W to NE-SW oriented pattern of fracture zones which, according to field evidence, are zones of closely jointed rock of a few to several tens of metres width. On aerial photos these fracture zones appear as linear topographic features which can sometimes be traced for distances of up to 15 km. This type of fracturation is perpendicular to the fold geometry and, hence, genetically probably tensional. Its age cannot be determined, it is likely, however, to have been developed soon after metamorphism. At the dam site this type of structural feature is represented by joint set No. 1.

At various locations of the project area a second joint set (at the dam site referred to as JS 2) has been observed which is oblique to the fold pattern (foliation). It appears to be also tensional and somewhat less pronounced (possibly related to the upheaval of the Sri Lankan land mass).

In addition to above structural elements there are features of random direction. One such feature occurs at the S-shaped bend upstream of the dam site, where the valley is intersected by a pronounced linear topographic feature of E-W orientation. The nature of this feature was for a short while disclosed in the river bed when the water level was low. The visible part consisted of a set of intensively jointed rock zones, however, the weakest material was probably not exposed but carved out, and/or covered, by the stream channels. Such characteristics are typical of a fault or shear zone which would probably be of ancient origin related to metamorphism and/or folding.

(B) Foliation

Orientation of foliation is perpendicular to the dam axis. Owing to the above outlined tectonic position on the northeastern limb of an anticlinal structure dip direction is towards NE at medium steep angles (59-76°), i.e. orientation is with the slope at the left abutment while it is with a component into the slope at the right abutment.

Orientation of foliation is quite regular as can be seen from the well pronounced maximum (see Fig 14.1/2):

Fol = 060-076/59-76°

(C) Jointing

Two main joint sets were observed at the dam site area. JS 1 is subparallel to the dam axis and dip is at steep angles towards upstream. This joint set is parallel to above mentioned system of fracture zones. Owing to its direction this joint set does not directly contribute to underseepage of the dam, but may indirectly add to it by connecting upstream-downstream seepage paths. The second joint set (JS 2) is oblique to the dam axis, hence providing potential upstream-downstream seepage paths. The following distribution was measured (see Fig. 14.1/2):

JS 1 = 168-188/40-58°
JS 2 = 305-324/34-49°

4.2.3 Geotechnical Investigations

Core Drilling

At the sites of the weir structure, intake and desander a total number of 8 drill holes was carried out amounting to a total of 180 drilling metres (see Tab. 1). All drill holes were performed with rotary drilling equipment using double tube core barrels in hard rock. In soft rock such as residual soil, talus and decomposed rock dry drilling techniques were partly employed using single tube core barrels. Drill holes were mostly vertical except for two inclined holes (KK 31, KK 32) in the river section.

A summary of the results including collar elevations, coordinates, length of drill hole, elevation of weathering grades of rock, overburden and instrumentation with piezometers is shown on Tab. 5. Geological and drilling details of drill holes are given in the "Logs for Engineering Purposes" (see Tab. 13).

Objectives of drill holes at various sites included the following:

- Identification of zones of weathering and close fracturation (weir axis),
- Assessment of permeability (weir axis),
- Investigation of depth and type of overburden (all structures),
- Assessment of prevailing foundation conditions with respect to availability and quality of rock (all structures).

Borehole Tests and Instrumentation

Water pressure tests (Lugeon-type) were carried out in drill hole sections where packers could be sealed properly (results are shown in drill logs, Tab. 13).

Installation of piezometers was done in three drill holes.

Geophysical Investigations

Two seismic profiles, one along the weir axis and a second one along the axis of the desander, were executed for assessment of the weathering profile (locations see Fig. 2, 1/9).

Test Pits

A total number of 10 test pits was executed along the intake and desander axes. Objective was to establish the presence and character of soils and weathered rock and to collect samples for material testing (classification) (locations see Fig 2-5/9, 2-6/9, 2-7/9; results are shown on geologic logs of test pits, Fig. 27).

Material Testing

Point load tests were carried out on rock cores recovered from drill holes as soon as possible after this material became accessible, so that test conditions were more or less corresponding to natural moisture conditions (test records are given in Tab. 14).

On soil samples obtained from tests pits the following tests were proposed to be carry out: gradation, moisture content, bulk/dry density and plastic limits. However, results were not available at the time of report compilation (17.8.92).

Petrographic analyses on core samples were done at the petrographic laboratory of Peradeniya University in order to determine mineral content (for instance percentage of abrasive minerals), texture, structure, mineral fracturation, etc. (results are shown on Tab. 2).

4.2.4 Geotechnical Assessment

(1) Excavation

On the basis of eight drill holes on both river banks, detailed geological mapping and two seismic profils, parallel to the weir axis and along the desander axis, the following excavation conditions are anticipated (see Fig. 10.1/2 and 10.2/2):

The weir structure can be founded on sound rock with need of only very little excavation. In the river section as well as on the lower slopes basically only trimming of the exposed rock down to the designed excavation grades is needed. According to the results of drill hole KK 35 which is located at dam crest level on the left abutment excavation will comprise about 2 m of overburden and weathered rock. On the right abutment excavation conditions appear to be somewhat less favourable: in drill hole KK 33, located at weir crest level, residual soil and decomposed rock are found down to a depth of 11.5 m. However, all currently available information indicates that at the designed foundation levels, more or less throughout the entire dam foundation, the rock is sound and of good quality. Only, it appears that there are several linear features hidden by the stream channel. The inclined drill hole KK 31 intersects the downward extension of two such features the upper one, at about 3 m depth, consisting of 30 cm weathered material and the lower one, at about 11 m depth, manifested by a 25 cm tectonized zone which is probably one foliation shear. Such features can be treated by dental concrete near surface and by grouting in their downward extension.

The desander structure including appurtenant structures are to be founded on rock. Results of core drilling and seismic survey indicate that at designed foundation levels rock of good quality will be available. In drill hole KK 36, located at the hillside slope of the desander, overburden and highly weathered rock are found down to about 12 m, which is about 213 m amsl, and are underlain by sound and massive biotite and garnetiferous biotite gneiss, so that the designed foundation level of the structure falls within the sound rock.

In the area of the flushing tunnel no drill hole was carried out due to limited resources. Extrapolating the results of drill hole KK 36, which is the most closely located hole, it may be concluded that a sufficiently long section of the proposed flushing tunnel can be driven in rock.

(2) Permeability and Grouting

The prevailing structural pattern, i.e. foliation as well as joint set No. 2, has an unfavourable orientation with respect to underseepage of the weir, at least speaking in general terms. Strike of both is perpendicular or near perpendicular to the dam axis, hence, potentially providing direct seepage paths from the reservoir to the downstream toe of the dam. Results of water pressure tests executed in drill holes KK 31, KK 34 and KK 35, located along the left bank weir axis and the intake, respectively, as well as drill holes KK 32 and KK 33 on the right bank, indicate generally low rock mass permeability. Moderate permeability is related to narrow zones of jointed rock mass. This is in accordance with the low degree of fracturation observed in the field as well as with high RQD-values which are on average between 90 and 100 %. Relatively higher water losses, in the order of about 14 to 17 Lugeon, were encountered in the inclined drill hole KK 31 where it intercepts two small either weathered or sheared zones (see previous para).

With respect to the actual potential of underseepage of the weir some remarks may be added regarding the necessity of grouting:

According to observations in the field as well as on the recovered core material it appears that foliation joints are mostly tight. On the other hand, joint set No.1 does not directly contribute to the upstream / downstream component of permeability, but may indirectly connect such waterpaths. Both discontinuity sets would contribute to the overall rock mass permeability, but only a fraction of the measured water losses is relevant for the actual under-seepage of the structure. In conclusion, it would be reasonable to assume that the actual water losses due to under-seepage would be less than those calculated from the measured Lugeon-values.

However, a more relevant aspect as to the need of grouting seems to be the high economic value of water with respect to the R-O-R project concept and the available small storage volume. Additionally, the potential uplift pressures seem to be mostly related to individual pervious zones, as those intercepted in drill hole KK 31. Number and location of such zones are not known, whereas their orientation can be assumed to be mainly upstream / downstream. Consequently, in order to conserve as much water as possible and to limit uplift pressures it is strongly recommended to provide for a grout curtain.

On the basis of currently available data specifications for curtain grouting may be assumed as follows:

Rows:	2
Depth:	10 m
Spacing of Holes:	3 m
Specific Grout Take:	50 kg/m
Overall Length:	225 m (extension see Fig. 10, 1/2)

(3) Stability of Foundations and Slopes

Currently, it is assumed that at designed foundation levels of the weir and appurtenant structures sound rock in form of slightly to faintly weathered rock will be available. The foundation rock is generally poorly fractured and, hence, has low to very low deformability (see Tab. 9). Variations in rock types are of no consequence. Locally the foundation area will be traversed by thin bands of weathered or tectonized material which extend in linear form more or less perpendicular to the dam axis. These features can be treated by slush grout or dental concrete near the surface, while they will be intercepted by the grout curtain at depth.

Since some open joints may be expected in the surface near zone of the foundation area (as well as shattering due to blasting) it is suggested to provide for consolidation grouting of the foundation area of the weir structure in order to homogenize and consolidate this rock zone. Currently, the following specifications may be tentatively assumed:

Depth of Holes:	3 m
Spacing of Holes (staggered):	3 m
Specific Grout Take:	50 kg/m

With respect to foundation stability one more aspect is of concern: in rock foundations stability is often controlled by the orientation of discontinuities. The structural diagramme given in Fig. 14, 2/2 indicates that foliation joints and JS 2 form wedges which have theoretically some freedom for movement in a downstream direction along JS 1. However, the actual potential for such movement depends on the magnitude and the direction of the stress vector created by the dam. A rough estimate suggests that safety against sliding is very high. Nevertheless, it is felt that this should be confirmed by somewhat more detailed computations using for instance a computer programme such as

GEODAT (geomechanical parameters may be taken as given in para (2) of the previous chapter).

In order to assess stability conditions of rock slopes, existing natural as well as cut slopes required for construction, a structural analysis was carried out result of which is summarized in the Great Circle Diagramme given in Fig. 16, 2/2. The diagramme shows the potential wedges that can be formed by intersection of the prevailing major joint sets. It also gives the directions of potential movements in relation to main slope directions, and additionally, by representing the assumed range of friction angles of relevant discontinuities, it permits to roughly assess the possibilities of sliding.

The results show that at left bank slopes rock wedges are formed by the intersection of foliation and JS 2 as well as by foliation and JS 1. The first one has no sliding potential for its direction of movement is more or less parallel to the slopes and for the second family of wedges only a very limited possibility of sliding exists, firstly, because direction of movement forms an angle of about 35^{o} with the slopes, i.e. main component is parallel to the slope, and secondly, sliding angle is about 40^{o}, which is about equal to the friction angle on joints.

At right bank slopes, and on right hand side slopes of the desander, rock wedges are formed by intersection of JS 1 and JS 2. The sliding angle has an inclination of about 20^{o} which is much less than friction angles on foliation ($> 25^{o}$) and joints (about 40^{o}).

Regarding soil slopes, it is currently assumed that some of moderate height will have be excavated, for instance along the desander. The nature of overburden and decomposed rock has been inspected in test pits and was found to consist mostly of residual soil and talus material of two different categories (rich in matrix and rich in boulders, respectively) (results of laboratory testing are not yet available). For feasibility design geomechanical parameters of this material, slope inclinations, bench heights etc. may be taken as tentatively given in Tab. 9 (these values are based on experience and literature).

4.3 Waterways

4.3.1 Topography and Geomorphology

The intake portal of the headrace tunnel is located at the downstream end of the desander on a moderately steep slope (dip slope of about 30°). Orientation of the initial sections of the headrace is about W 300° N and S 256° W, i.e. oblique to the mountain ridge (and paralleling foliation), which is to keep distance to the adjoining tributary valley. In this initial section mountain crest levels are about 420 m asl, while valley bottoms are about 250 m asl. Following a sharp bend at Stat. 2+343 the tunnel is almost in the centre of a massive NW-SE ridge which almost parallels foliation strike with crest levels of about 380 m asl. This route is more or less identical with the old alignment but is adjusted to conform the new power house location.

The tailrace tunnel maintains more or less the same orientation but shifts closer to the western slopes of the ridge with its crest levels decreasing towards NW. The outfall of the tailrace is in a relatively thin rocky nose that marks the NW-end of the ridge.

4.3.2 Geological Assessment

(1) Weathering and Overburden

Weathering conditions along waterways can be currently concluded from 8 drill holes, including 1 drill hole along the previous route, as well as field observations during geological mapping. Additionally, results of 3 seismic profiles are available to establish the weathering profile.

The headrace intake has been investigated by one drill hole, KK 39, which shows about 1.5 m of overburden and decomposed rock and about 3.5 m of highly weathered rock overlying sound and massive rock.

Drill hole KK 6 was drilled in order to investigate geological conditions at the bottom of the Hulukiri valley along the previous tunnel alignment. Overburden is practically absent and sound rock is availble at about 1.5 m. This was then supported by the results of one seismic profile which indicated shallow weathering across the valley bottom. Abundant rock outcrops are found elsewhere in the valley suggesting similar conditions along the valley.

On the other hand, general geological considerations suggest that the valley was formed along some zone of weakness which may be composed of one or more zones of sheared rock or a less resistant rock layer(s), probably quite narrow, which would not be detected by seismic investigations and would only incidentally be intercepted by drilling.

Similar geological conditions may be expected along the ridge which contains the headrace and tailrace tunnels in points where it is traversed by saddles and depressions.

To date only one such saddle, near the previous surge shaft location, has been investigated by drilling (KK 29), and showed sound rock at about 9 m below surface. One additional inclined drill hole (KK 44) was proposed recently (on advice of P.o.E.). It will be drilled in the saddle area adjoining the surge shaft (new location) towards upstream and will be inclined in such a way as to intercept sub-vertically directed joints.

Additionally, results of three seismic profiles, each about 400 m long, are available to assess weathering depth in saddle areas of the ridge. Results indicate that the 'top of sound rock' is generally only slightly deeper than elsewhere along the ridge. However, geologically it is most likely that strong and massive rock make up the ridge crests whereas points where the ridge is crossed by narrow zones and/or bands of fractured rock or weaker rock layers, which cannot be depicted by seismicity, are morphologically delineated by saddles and depressions.

Ridge crests were investigated at the locations of the previous surge shaft (drill hole KK 7) and the relocated surge shaft (drill hole KK 42) and is presently being investigated at the powerhouse site. In drill hole KK 7 sound rock is found at shallow depths (about 3 m) while at the present surge shaft and powerhouse locations it is available at about 20 m and 15 m, respectively.

Similar conditions prevail at the tailrace outfall which is accommodated in the narrow rocky nose that marks the NW-end of the main ridge. Along the crest of this narrow ridge two drill holes (KK 8 and KK 28) were located showing thin overburden of about 2.5 m thickness while sound rock was found at about 3 to 7 m, respectively.

(2) Rock Types and Rock Mass Parameters

Geological mapping and core drilling revealed the presence of a variety of gneissic rock types along the alignment of the headrace and tailrace tunnels. Common rock types are (description is based on previous petrographic analyses and visual examination):

Biotite Gneiss and Garnet-Biotite Gneiss

This is the dominant rock type in which waterways tunnels would be driven. Main constituents are quartz, plagioclase, biotite, hornblende, i.p. garnet, and accessoric minerals. The typical variety exhibits pronounced gneissic structure whereas the quartz-rich variety has a massive appearance.

Charnockite and Charnockitic Gneiss

According to geological mapping it is likely that major portions of the tunnels would be driven in this rock type. Its mineral assemlage includes: quartz, plagioclase, hypersthene as well as diopside, hornblende etc.
A typical property is the greenish-grey to bluish-grey colour due to the dark colour of the quartz component. According to their geochemical composition the local varieties appear to belong to the intermediate family. Structure is often granulitic and contributes to the massive appearance of this rock.

Quartz-Feldspar Gneiss

This rock type is occasionally found in drill holes; it is less frequently observed in the field. The rock is chiefly made up of quartz, feldspar (plagioclase, orthoclase, microcline, perthite) as well as biotite, hornblende and accessoric minerals. Gneissic fabric of the medium coarse rock is less pronounced than in biotite gneiss but is poorly developed in the coarse grained variety.

Additional rock types that may be locally encountered in the tunnels are hornblende-biotite gneiss, amphibolite, vein quartz, pegmatite etc..

Geomechanical parameters relevant for design, excavation and support of the headrace and tailrace tunnels will vary considerably along the tunnel route. Parameters such as deformability and shear strength of the rock mass, as well as shear strength of discontinuities (relevant for local instability of rock wedges), depend generally on rock type, rock strength (rock wall strength), degree of fracturation, conditions of fractures, groundwater conditions, etc. On the other hand, these physical characteristics of a given rock type are modified for instance by weathering (apart from the influence of excavation method, magnitude and orientation of the primary stress field and the orientation of the tunnel with regard to such parameters).

According to point load tests on similar material from previous dam site alternatives the strength of fresh material of any of the above mentioned rock types is quite high, in the range of 150 to 200 (and above) MPa. However, it was observed that weathering reduces rock strength (see Tab. 14).

Degree of fracturation is a function of local tectonic intensity as well as weathering and is also reflected by reduced RQD-values.

Conditions of joints are related to their genetic origin (tension, compression, stress magnitude, displacement,etc.), rock type, weathering, etc.

Groundwater conditions in the rock mass at hand depend mainly on the degree of fracturation at a given location along the tunnel alignment.

As mentioned above, due to their variability along the tunnel route it is infeasible to estimate to a reasonable degree of accuracy individual parameters at a given location, particularly considering the lack of firm data. However, it appears realistic to adequately assess a group of parameters in the form of rock mass classification which has become a universally accepted method for feasibility studies (see para 4.3.2). Regarding data collection of the fresh rock mass reference is made to above para (4.3.1).

Resulting values which are interpreted on the basis of recent publications are given in Tab. 9.

(3) Structural Geology

The area along the headrace and tailrace tunnel routes is not easily accessible and due to the sparce population road infra structure consists of only few foot paths along rivers and across the ridge that accommodates the tunnels. Therefore, geological mapping consisted basically of a few traverses across the ridge (foliation strike) and detailed mapping of outcrops found along river courses and on the ridge. Due to the variability of rock types, particularly the absence of any marker bands, structural assessment relys solely on measurements of foliation supported by photo-geology and extrapolation of results from nearby areas. It is felt that on this basis a structural map of the area could be prepared that depicts with some confidence the general structural set up, and probably also some structural details. Results of this work are presented on the geological map of the project area (Fig. 7) and on the geotechnical section along waterways (Fig. 12). Tectonic conditions along the tunnels may be summarized as follows:

The initial section of the headrace tunnel traverses the axial zones of three major fold elements at about Stat. 0+500, Stat. 1+700 and Stat. 2+200; respective angles formed between tunnel route and fold axes are about 35° and 5°.

Following a sharp bend the headrace alignment runs slightly oblique to the fold pattern (foliation) at an angle of about 20°. The tailrace line is slightly turned and angle formed between foliation and tunnel is about 25°.

In the area of the power house information is scarce as to the structural attitude. In adjoining areas a number of minor fold axes was identified, hence, relative irregular structural conditions may prevail. Obviously, test adit excavation would be needed to draw a more accurate picture.

According to field evidence the nature of fold axes is often characterized by close fracturation, foliation shears and shear zones; width of such features may be several tens of metres.

The fold system is dissected by E-W to NE-SW oriented fracture zones which, according to field evidence, are zones of closely jointed rock of a few to several tens of metres width, in which fracturation takes the form of individual joints, mostly of sub-vertical orientation, spaced at about 0.05 to 0.3 m. On aerial photos these fracture zones appear as linear topographic features which can sometimes be traced for considerable distances. It is particularly this feature that is supposed to form the morphologic saddles separating hill crests along the ridge containing the waterways arrangement.

At various locations of the project area a second joint set has been observed which is oblique to the fold pattern.

In addition to above structural elements there are features of random direction. One such feature is assumed to form the tributary valley that falls into the Kukule valley at the S-shaped bend upstream of the dam site. The nature of this feature was for a short while disclosed in the river bed when the water level was low. The visible part consisted of a set of intensively jointed rock zones, however, the weakest material was probably not exposed but carved out, and/or covered, by the stream channels. Such characteristics are typical of fault or shear zones.

4.3.3 Geotechnical Investigations

Core Drilling

At the sites of the headrace intake, headrace tunnel, tailrace tunnel and tailrace outfall a total number of 6 drill holes was proposed (including site of old surge shaft and additional inclined hole at saddle) amounting to a total of 435 drilling metres (see Tab. 1 and 5). At the time of report compilation (August 17th) 5 drill holes were completed (385 m).

All drill holes were (are to be) performed with rotary drilling equipment (for some more drilling details refer to chapter 4.2.3). All drill holes were vertical. A summary of the results including collar elevations, coordinates, length of drill hole, elevation of weathering grades of rock, overburden and instrumentation with piezometers is shown on Tab. 5. Geological and drilling details of drill holes are given in the "Logs for Engineering Purposes" (see Tab. 13).

Objectives of drill holes at various sites included the following:

- Investigation of depth and nature of overburden, rock types, rock characteristics etc.,
- Identification of zones of weathering and close fracturation,
- Assessment of prevailing foundation conditions with respect to availability and quality of rock,
- Assessment of groundwater conditions (permeability).

Borehole Tests and Instrumentation

Water pressure tests (Lugeon-type) were carried out in drill hole sections were packers could be sealed properly (results are shown in drill logs, Tab. 13).

All drill holes are constructed in such a way as to enable water table readings after completion.

Geophysical Investigations

Three seismic profiles along ridge saddles are at hand for assessment of weathering depths (locations see Fig. 2, 4/9). Additionally, two seismic profiles at Hulukiri Dola (old alignment) provide useful information to establish the weathering profile (locations see Fig. 2, 3/9).

Test Pits

A total number of 9 test pits was proposed at the tailrace outfall, switchyard and access tunnel areas. Objective was to establish the presence and character of soils and weathered rock and to collect samples for material testing (classification); to date 8 pits have been excavated.

Material Testing

A great number of point load tests have been carried out on core material of respective drill holes.

On soil samples obtained from tests pits the following tests are proposed to be carry out: gradation, moisture content, bulk/dry density and plastic limits; at this time results of such tests are not yet available.

Test Adit and Rock Mechanical Testing.

(refer to chapter 4.4.3)

4.3.4 Geotechnical Assessment

(1) Rock Mass Classification and Support

Currently rock mass parameters for design of underground structures cannot be based on in-situ or laboratory testing. In previous reports and by the P.o.E. (30) it has been stated that for final design such test results, including informations that can be obtained by test adit inspection, would be needed in order to make final design assumptions with sufficient confidence. However, the data presently available are certainly adequate for feasibility design. Also, rock mass classification methods, which have been employed in this study to arrive at the required parameters, are now so well developed that parameters adequate for feasibility design can be acquired with a limited amount of testing.

The tentative rock mass classification was done with the objective to provide information on the rock quality that could be expected along the tunnel alignment. The classification is based mainly on field observations in form of detailed rock mass descriptions (assessment of rock strength by means of point load testing, measurements of discontinuity spacing, description of joint conditions, measurements of joint continuity, assessment of joint wall strength by means of Schmidt hammer rebound values, etc.), collection of general data regarding rock types, rock structure, nature of rock mass, type of weathering, weathering depth, groundwater conditions, geomorphology including evaluation of results of drill holes and seismic profiles. These observations were only partly made along the tunnel line, partly they were extrapolated from representative locations and, finally, conservative assumptions were made on the basis of geological considerations.

In order to check on the confidence of the rock mass classification two methods which both are extensively used in civil projects were employed, namely the CSIR and NGI classification methods. Both classification methods provide guidelines for the selection of support measures. On the basis of these guidelines and with respect to the limited amount of firm data it was considered adequate to develop a specific "classification adopted in the project" minimizing the number of rock support classes (three/four numbers). However, with respect to the lack of data no details regarding dimensions, capacity, etc of support measures were specified. It may be noted that this classification is considered tentative and that the final support design will be done by the rock mechanics engineer after test adit excavation and rock mechanical testing is completed. Results of the preliminary classification are summarized in Fig. 12.

(2) Geotechnical Sections along Tunnel Alignments

The tunnel route was divided into a number of structural regions (domains) for which identical geological-geotechnical conditions were assumed. The resulting geotechnical situation along the new tunnel alignment is summarized in the geotechnical profile presented in Fig. 12, and is described in short as follows (confidence level is discussed above):

In the area of the tunnel intake one drill hole (KK 39) has been carried out. It can be assumed that limited soil and rock excavation is needed to construct the tunnel intake portal.

From the portal up to about Stat. 0+070 it is assumed that rock support corresponding classes III and IV is required due to the expected effect of weathering on rock strength, fracturation etc.

The following section up to about Stat. 0+470 is assumed to be composed of strong and poorly fractured rock mass. Also, the tunnel is expected to be excavated under dry conditions, and no support will be required (class I/II).

From Stat. 0+470 to 0+570 the tunnel will traverse the axial region of one anticline which is thought to be weakened by fracturation and some shearing; additionally, some moderate water inflow may be expected. This section is therefore thought to require in some parts systematic rock bolting (classes I/II and III).

Corresponding geological conditions resulting in equivalent excavation conditions (classes I/II and III) are expected to be found at the following tunnel sections: Stat. 1+600 to 1+700, Stat. 2+200 to 2+900, Stat. 3+200 to 3+750.

For the tunnel portions between above stations it is assumed that tunnel excavation will be mainly in sound and massive gneissic rock mass requiring no support (class I/II).

Along the remaining section up to the upstream surge shaft the headrace tunnel is thought to traverse three fracture zones. Current evidence is that each fracture zone consists of one or more portions of closely jointed rock of up to a few tens of metres width. These are likely to be water bearing and at several points considerable water inflow which may be under moderate pressure may be anticipated (classes I/II and III). Stations were such conditions may be expected are as follows: Stat. 4+350 to 4+450, Stat. 5+050 to 5+150 and Stat. 5+300 to 5+400. Tunnel sections between such fractured regions are assumed to consist of sound and relatively unfractured rock mass which would be generally dry or moist, only, requiring no supports (class I/II).

The initial portion of the tailrace tunnel (Stat. 5+760 to 5+860), powerhouse area is described separately in the following para, is thougth to traverse one more fracture zone presumably of above described nature and corresponding excavation conditions (classes I/II and III). One further fracture zone of similar nature may be expected between Stat. 6+760 and 6+860.

Tunnel sections adjoining the outfall portal were investigated by two drill holes, KK 8 and KK 28, which encountered sound rock at shallow depth. However, tunnel sections with burden less than 50 m above tunnel roof are thought to possibly encounter locally rock mass which is slightly weakened by weathering, hence, requiring systematic rock bolting etc. (class III, Stat. 7+210 to 7+310), and in places rock strength may be markedly reduced requiring steel ribs etc.(class IV, Stat. 7+310 to 7+360).

According to the results of core drilling and pitting excavation for portal construction will comprise relatively small volumes of overburden and highly weathered rock.

(3) Geotechnical Aspects of Design and Construction Conditions

Following is a brief discussion on some geological - rock mechanical aspects of certain design and construction considerations:

Feasibility design provides for concrete lining of the headrace and tailrace tunnels. With regard to the external and internal hydrostatic pressures acting on the lining and as to dealing with them the following assumptions should be made:

- Head of external water pressures should be taken as to equal surface levels above tunnel roof since field observations suggest that during the rainy season ground water levels are generally close to surface;

- Along lined tunnel sections contact grouting and consolidation grouting of the surrounding rock should be foreseen to consolidate rock shattered due to blasting. However, there are no tunnel sections where internal pressures are greater than external pressures, hence, requiring consolidation grouting to prevent leakage from the tunnel into the surrounding rock mass; this is due to topographic conditions.

As to excavation conditions some general remarks may be adequate:

During excavation pervious fracture zones will be intersected and provisions will have to be made as to dealing with such conditions (technical and contractual)(30).

4.4 Powerhouse, Surge Shaft and High Pressure System

4.4.1 Topography and Geomorphology

The new location of the powerhouse, surge shaft and high pressure system is within an isolated hill along the ridge which is surrounded by pronounced saddles, valleys and ravines. Morphological elements such as these are generally related to geological features. Elsewhere in the project area it was observed that saddles, gullies etc. are controlled by fracture zones which consist of one or more zones of closely fractured rock of a few metres up to some ten or twenty metres width. They may also be related to tectonized or less weathering-resistant rock. Currently the nature of these geological features is not known. On the other hand, indirect information obtained from seismic survey does not suggest the occurrence of highly fractured or weak rock including deep reaching weathering in saddle areas, for such features would be reflected by lower velocities. However, as is pointed out by P.o.E. (30), it would be prudent to maintain as much distance between them and the underground structures as possible.

4.4.2 Geological Assessment

(1) Weathering and Overburden

With respect to the weathering profile on the morphological knob that accomodates the powerhouse cavern and related structures results of two drill holes - KK 42 (new surge shaft) and KK 43 (powerhouse, in progress) - are at hand. Additionally, relevant information can be obtained from drill holes KK 7 (old surge shaft) and KK 29 (saddle near old surge shaft). Findings are that depth of weathering is relatively shallow to moderately deep. In drill holes KK 42 and KK 43 fresh rock is available at depths ranging from about 15 m (KK 43) to 20 m (KK 42). Water pressure tests in drill hole KK 42 reveal some moderate permeability (10 and 5 Lugeon at low pressures) of fractured sections (at about 45 and 65 m, respectively), and no oxidation was observed on joints at that depth. On the other hand, rock cover above power cavern is about 180 m, so that influence of weathering need not be expected.

(2) Rock Types and Rock Mass Parameters

According to results of drill holes KK 42 (surge shaft) and KK 43 (powerhouse), the latter one having currently a depth of about 140 m, as well as geological mapping and results of relatively nearby drill hole KK 7, dominant foundation rock types include biotite gneiss, garnetiferous biotite gneiss, charnockitic gneiss and quartz-feldspar gneiss. Occasionally layers of quartz-rich biotite gneiss, hornblende-biotite gneiss, amphibolite and pegmatitic quartz-feldspar gneiss were found (for some more petrographic details of rock types refer to chapter 4.3.2, para (2).

Strength of intact rock material can be extrapolated from point load tests done on core material of drill hole KK 42 and nearby KK 7. Uniaxial compressive strength of all rock types is high, about 150 to >200 MPa, and petrographic variations are of no significance for the strength of the rock mass.

With respect to further parameters required for rock mass classification as for instance RQD, spacing and conditions of joints as well as groundwater conditions evidence currently at hand is of satisfactory degree of confidence for feasibility design assumptions:

- RQD values are available from drill holes KK 42 and KK 43; on average values are high ranging between about 90 to 100%;

- With respect to spacing of foliation joints it can be said that gneissic fabric of biotite gneiss is generally well developed whereas it is less pronounced in charnockitic gneiss and quartz-feldspar gneiss resulting in about 1-3 m and > 3m spacing, respectively;

- Estimates of joint spacing from core material is somewhat problematic, however, on the assumption that two major joint sets are present (in addition to foliation) and inclination is generally steep, about 70 to 80°, average spacing of both joint sets is estimated at about 1 to 3 m, which is true, of course, only for the sound rock mass portions between fracture zones which are thought to occur at the periphery of the cavern;

- Conditions of joints can be observed on core material with sufficient accuracy; joint planes are predominantly slightly rough and somewhat undulated (JRC = 6 - 10) whereas foliation planes are often smooth due to biotitic coating (JRC = 2 - 4);

- Groundwater conditions can be assessed on the basis of water pressure tests that have been continuously carried out in drill holes KK 42 and KK 43. Test results indicate virtually impervious rock even at relatively high pressures of 30 bars that have been applied. Low to moderate permeability was observed in only three sections of drill hole KK 42 (39 to 45 m, 63 to 66 m and 100 to 103 m).

(3) Structural Geology

The area of the powerhouse and appurtenant structures is difficult to access and, therefore, information on structural geology is scarce. It appears that overall dip direction of the rock mass of the entire ridge is towards W to SW, i.e. towards Makeliya Dola. In adjoining areas a number of minor fold axes was identified, hence, relative irregular structural conditions may be assumed to prevail at the powerhouse site. Tentatively, average orientation of foliation may be taken as:

Fol = 240-260/50-70°

As was already mentioned, the hill containing the powerhouse and appurtenant structures is framed by a number of linear topographic features i.e. saddles, valleys, gullies etc., which most certainly are related to geological features probably in the form of fracture zones consisting of closely jointed, possibly also sheared rock portions. Based on photo-geology it is assumed that dip is more or less subvertical while approximate strike directions are as follows:

Zone 1 = N 070° E
Zone 2 = E 110-115° S

4.4.3 Geotechnical Investigations

Core Drilling

At the sites of the powerhouse cavern and the upstream surge shaft two drill holes were proposed each 230 m deep (see Tab. 1). At the time of report compilation (August 17th) the powerhouse hole was still in progress (140 m).

Drill holes were/are to be performed with rotary drilling equipment (for some more drilling details refer to chapter 4.2.3). Both drill holes are vertical. It certainly would have been desirable to measure the orientation of such deep holes, however, no adequate measuring device could be made available by the contractor or the client. On the other hand, it need not be assumed that deviation of the drill holes could be so substantial that interpretation could be hampered. Geological and drilling details of drill holes KK 42 and KK 43, up to present depth, are given in the "Logs for Engineering Purposes" (see Tab. 13).

Objectives of drill holes in the powerhouse area include the following:

- Investigation of depth and nature of overburden (open cut excavation of surge shaft), rock types, rock characteristics etc. (rock mass classification),
- Identification of zones of close fracturation (powerhouse location, stability),
- Assessment of prevailing rock mass conditions with respect to quality of rock (stability),
- Assessment of groundwater conditions (permeability),
- Provide test sections for hydrofracturing tests.

Borehole Tests and Instrumentation

Water pressure tests (Lugeon-type) were (are to be) carried out to assess permeability conditions and to provide additional information on rock quality (high pressures to be applied) (results are shown in drill logs, Tab. 13).

Drill holes were/are to be constructed in such a way as to enable performance of hydraulic fracturing tests later on as well as to measure water tables after completion.

Material Testing

Point load tests will continue as additional core material becomes accessible to provide additional input data for rock mass classification.

Test Adit

Three alternative alignments for test adit excavation were proposed. It is the primary objective of the adit to provide first hand information on geologic structure and, secondly, to provide locations for rock mechanical testing.

Proposals of three local firms are available and are currently being evaluated. It is JVK's and the P.o.E.'s opinion that only alternative no. 2 (medium steep slope and medium length) which could be developed for use as a permanent cable tunnel should receive further consideration.

Rock Mechanical Testing

Considering the new test adit alignment and the subsequent change of available test locations the previously proposed rock mechanical testing programme has to be modified:

- In-situ Testing

1. Hydraulic Fracturing Tests

   a. Surge Shaft
   10 tests in existing drill hole (KK 42) (in order to measure minimum principal stress);

   b. Power Cavern
   Required 3 drill holes (45° to each other), 10 tests per drill hole: total of 30 tests;

2. Small Flat Jack Tests
   Required 10 nos.

3. Dilatometer Tests
   Required 6 nos. in 3 drill holes of different orientation: total of 18 tests.

- Laboratory Tests

1. Uniaxial Compressive Tests
   Required 10 nos. per rock type: total of 30 tests

2. Triaxial Compressive Tests
   Required 6 nos. per rock type: total of 18 tests

3. Brazil Tests
   Required 16 nos. per rock type: total of 18 tests

Currently it is assumed that the rock mass in the area of the powerhouse and appurtenant structures is of excellent physical characteristics. If this assumption would be confirmed by test adit excavation it will be considercd to reduce the amount of in-situ and lab testing (reduction of hydrofracturing tests to about 5 tests per hole; omission or reduction of dilatometer tests; omission of lab tests apart from about 10 uniaxial compression tests to calibrate point load tests). Decission could be made after excavation of the initial 100 m of the test adit.

4.4.4 Geotechnical Assessment

(1) Rock Mass Classification and Support

Presently rock mass classifications relevant for the area of the powerhouse and appurtenant structures are being based on a limited amount of firm data. Main available evidence is the core recovery of the surge shaft drill hole KK 42 and the powerhouse drill hole KK 43 which is currently about 140 m deep. As to the geological parameters used for classifications reference is made to para 4.4.2. It should be noted that this classification is strictly relevant only for the sound rock mass between assumed fracture zones (for results see Fig. 13).

For fracture zones assumed to occur at the periphery of the powerhouse no data are at hand as to the relevant geomechanical parameters. In order to present at least the possible range of rock mass quality that can reasonably be expected, parameters are extrapolated from observations of similar features elsewhere in the project area. Results of rock mass classification are summarized in one geotechnical section (Fig. 13).

No attempt was made to estimate the required support due to the preliminary character of the available data. Additionally, it should be noted that geotechnical section and employed data are considered preliminary and will be updated as more data become available in the course of ongoing investigations (drilling, test adit, rock mechanical testing).

(2) Geotechnical Domains at Powerhouse and Appurtenant Structures

The rock mass in which the structures are to be excavated is divided into a number of domains, i.e. zones in which certain geological features are more or less uniform within each region. It is currently assumed, which is of course quite arbitrary but is due to the lack of relevant data, that the powerhouse as well as the lower section of the upstream surge shaft including pressure shaft and the entire downstream surge shaft are located within one structural domain which is characterized by sound and massive rock. Rock mass quality values resulting from classification based on above refered rock characteristics indicate very good rock mass quality of this material with RMR ratings ranging from 82 to 92 and Q values ranging from 30 to 33 (see Fig. 13). The resulting preliminary rock mass parameters may be taken from Tab. 9.

Above mentioned fracture zones are tentatively assumed to be located at the periphery of the structures which will have to be confirmed by test adit excavation.

The upper sections of the upstream surge shaft would have to be grouped into separate domains, of more or less horizontal extension, which is due to the influence of weathering on rock mass quality and related geotechnical conditions (see Fig. 13). Based on the results of drill holes KK 42 and KK 43 (presently at 140 m) three separate geotechnical domains can be identified. The uppermost zone from 0.00 to 10.00 m below ground level corresponds essentially soil mechanical conditions. From 10.00 to about 20.00 m rock mass classification yields RMR ratings from 44 to 58 and Q values from 4.8 to 29 corresponding fair quality rock (see Tab. 6).

(3) Geotechnical Aspects of Design and Construction Conditions

Major considerations in the design of a large underground structures are orientation, shape, dimensioning, support and reinforcement requirements and excavation sequence. Obviously, at this date when firm data are lacking, it appears unconvenient to indulge in speculations on, for instance, magnitude and direction of primary stresses, location and nature of fracture or fault zones etc. Following are, therefore, only a few general remarks on some of the above aspects:

- Orientation

The feasibility design provides for the longitudinal axis of the cavern to be perpendicular to foliation which is thought to be the dominant discontinuity set. However, this assumption will have to be confirmed by test adit excavation. There is a possibility that cavern side walls are parallel to a major discontinuity set (E-W joints) which may be geomechanically more relevant. This is of particular concern if a cavern with vertical side walls would be considered.

On the other hand, if high stress conditions are to prevail, which is however not very likely, magnitudes and directions of principal stresses are of equal importance as to the general objective to orientate the structure in such a manner that minimizes instability. In intact rock instability implies failure due to excavation-induced stresses higher than rock strength. In closely jointed rock it is related to sliding of rock wedges into the opening. Size, shape and orientation of each block depends on joint orientation whereas the normal and shear forces developed along discontinuity planes depend on the stress state.

Above stated clearly indicates the significance of the test adit and rock mechanical testing for final design assumptions.

- Shape

Currently the shape of the power cavern is designed to suite its function and to minimize stress concentrations and accumulation of stored strain energy in order to optimize stability. P.o.E. recommends to consider a vertical sided cavern. There are indications that this would be acceptable since it is unlikely that the in-situ stress field is high in comparison to rock mass strength. Most certainly, however, orientation of the cavern would have to be optimized with respect to the geomechanically relevant discontinuity set. This again indicates the relevance of rock mechanical investigations and test adit excavation.

- Dimensioning

  Dimensions of the cavern are of course governed by functional aspects. However, with respect to the assumed presence of fracture zones at the periphery of the cavern there appears to be a possibility for optimization of dimensions, this is also true with regard to the location of the cavern, in order to avoid intersection with closely jointed rock zones and related instability. In this context the need for the test adit becomes evident one more time.

- Support and Reinforcement, Excavation Sequence

  These design steps are typically done by numerical modelling for which information on the in-situ stress state is of paramount importance.

  With respect to geotechnical conditions prevailing at the high pressure shaft, main aspect is as to what extent steel lining is required. Present indication is that the rock mass is sufficiently strong and sound to prevent leakage and hydraulic fracturing in the high pressure shaft so that steel lining beyond the currently designed levels would not be needed. Obviously, final decision can be made only after results of rock mechanical testing are at hand.

CHAPTER 5. COMPARATIVE ASSESSMENT OF ELIMINATED CANDIDATE SITES

5.1 General

5.2 Geological-Geotechnical Aspects of the Area of Eliminated K-K 205

5.2.1 General

When K-K plan was initially formulated as an alternative to K-P plan two alternative dam sites were identified about 1.3 and 1.65 km downstream of K-P dam site. The downstream site (K-K 205) was considered suitable only for a diversion structure due to topographic conditions while the upstream site (K-K 230) was designated for a low CFR-type dam as well as for a concrete weir.

5.2.2 Topography and Geomorphology

At K-K 205 dam site the valley bottom is relatively wide thus providing sufficient space for the desilting basin of a diversion weir. Slope angles at the left bank are moderate at about 20^{o} while right bank slopes rise relatively steeply at about 30^{o}.

Orientation of the initial section of the headrace tunnel is about W 305 N so that it would traverse at more or less right angles a series of parallel ridges and intercalated valleys. Mountain crest levels rise to about 420 m, while valley bottoms are at about 250 m. Following a sharp bend, tunnel alignments of all alternatives are identical and more or less in the centre of a NW-SE massive ridge. The ridge and, hence, the tunnel alignment are sub parallel to foliation. The ridge is intersected by saddle zones reflecting E-W fracture zones (photo-lineaments). Crest levels between saddle areas are at elevations of about 380 m amsl.

5.2.3 Geological Assessment

(1) Weathering and Overburden

At K-K 205 dam site the left bank flood plain is about 100 m wide. Due to analogous geological conditions for the river section and adjoining flood plain the weathering profile corresponds more or less to that of the adjoining upstream K-K 230 site (see Fig 15). That was confirmed by the results of 8 drill holes and 1600 m seismic survey.

Along right abutment slopes an average of about 8 m weathered rock may be tentatively assumed while at the left bank thickness is about 15 m.

Along waterways alignments rock outcrops are frequently found to make up mountain crests and steep slopes. Similarly, along river beds such as Hulukiri and Makeliya Dola rock is often exposed. On slopes it appears that weathering is relatively deeper on flat slopes. However, this latter statement cannot be based on drilling results but on field observations only.

(2) Rock Types and Rock Mass Parameters

According to results of core drilling at K-K 205 rock types including biotite gneiss, amphibolite and charnockite would make up the foundation of a diversion weir. However, in general terms it can be stated that sound rock of any of the prevailing gneissic rock types would make up a suitable foundation. For more petrographic details refer to chapter 4.2.2 and 4.3.2.

At the left bank flood plain overburden consists of residual soil, talus and alluvium. Nature of this material is generally very heterogeneous. To investigate soil mechanical characteristics a number of test pits was proposed. However, excavation was delayed so that no first hand information is available. Only source to estimate strength characteristics are results of SPT tests carried out in drill holes (see Tab. 11). For estimated soil mechanical characteristics refer to Tab. 9.

Along waterways alignments a variety of gneissic rock types was identified during geological mapping including biotite gneiss, hornblende-biotite gneiss, charnockite, amphibolite etc. The observed rock mass is generally massive but is traversed at irregular intervals by fracture zones. In massive portions spacing of discontinuities is about 1-3 m, while it is about 0.05-0.3 m in fracture zones. This observation is supported by results of core drilling which show high RQD values between about 90 and 100 %. For some more details on rock types and rock mass parameters along waterways reference is made to chapter 4.3.2.

(3) Structural Geology

(A) General

At the dam site area a first order anticline was identified by geological mapping to traverse the dam foundation of K-K 205 dam site at the left bank flood plain. The axis of the anticline can be traced further upstream where it is found at the upper slopes of the left abutment of K-P dam site, while towards downstream subhorizontal foliation planes in the river bed, some 300 m downstream of the dam axis, are assumed to reflect the vertex of the anticline.

Geological mapping along the waterways alignment revealed the presence of three fold structures of regional extension. Additionally, a number of minor fold elements could be located (see Fig 15).

Prominent fracture zones are oriented E-W to NE-SW. Morphologically they are represented by saddles as well as gullies which can be found at both dam site areas as well as along the mountain ridge that accommodates the waterways structures. Additionally, a NW-SE photo-lineament, that traverses the dam site area about 300 m downstream of K-K 205 dam axis, is currently interpreted as manifestation of a fracture zone.

(B) Foliation

Orientation of foliation is perpendicular to K-K 205 dam axis. Due to the presence of above mentioned anticline dip is towards SW at the left abutment while it is towards NE at the river section and the right abutment, so that at both abutments foliation dips into the slope which is, in general terms, favourable with respect to stability of natural or cut slopes. The following maxima were obtained (see Fig. 18):

Fol_1 = 224-260°/33-50°
Fol_2 = 052-074°/46-68°

As was mentioned above a number of minor and major fold elements exists along the waterways alignment resulting in both SW as well as NE dip direction of foliation (locations can be seen on Fig 17). The following distribution was measured (see Fig. 17):

Fol_1 = 245-265°/50-70° (prominent)
Fol_2 = 065-085°/50-70°

(C) Jointing

At K-K 205 dam sites outcrops are too scarce to obtain a great number of joint readings. However, sufficient readings were taken at representative locations further upstream and downstream indicating the presence of two major joint sets. JS 1 is more or less parallel to the dam axis with steep dip angles towards downstream and occasionally upstream. This joint set represents above mentioned E-W fracture zones. The second joint set is perpendicular to the dam axis corresponding to the longitudinal system with respect to fold geometry.

The following distribution was measured (see Fig. 18):

JS 1 = 172-194°/65-90°

JS 1A = 343-360°/70-90°

JS 2 = 298-308°/70-80°

JS 2A = 110-120°/55-65°

Photo-geology and field observations suggest that both joint sets will be present along the alignment of waterways.

(D) Faults

There is no physical evidence for the presence of a fault or shear zone of any significance. However, at K-K 230 dam site a mylonitic seam was encountered in drill hole KK 3 possibly representing a shear zone which would probably run parallel to above mentioned anticline axis. According to the prevailing general structural conditions the presence of similar elements may be inferred.

5.2.4 Geotechnical Investigations

Core Drilling

At the sites of the weir structure, intake and desander a total number of 8 drill holes was carried out amounting to a total of 205 drilling metres (see Tab. 1).

All drill holes were performed with rotary drilling equipment using double tube core barrels in hard rock. In soft rock such as residual soil, talus and decomposed rock dry drilling techniques were partly employed using single tube core barrels. Drill holes were vertical. A summary of the results including collar elevations, coordinates, length of drill hole, elevation of weathering grades of rock, overburden and instrumentation with piezometers is shown on Tab. 5. Geological and drilling details of drill holes are given in the "Logs for Engineering Purposes" (see Tab. 13).

Objectives of drill holes at various sites included the following:

- Identification of zones of weathering and close fracturation (weir axis),
- Assessment of permeability (weir axis),
- Investigation of depth and type of overburden (all structures),
- Assessment of prevailing foundation conditions with respect to availability and quality of rock (all structures).

Borehole Tests and Instrumentation

Water pressure tests (Lugeon-type) were carried out in drill hole sections where packers could be sealed properly (results are shown in drill logs, Tab. 13).

In soil sections of drill holes Constant Head tests were carried out in order to determine permeabilities.

In order to assess strength characteristics of soils SPT tests were carried out.

Installation of piezometers was done in three drill holes.

Geophysical Investigations

Four seismic profiles along the weir axis, on either bank of the river and along the headrace tunnel intake were carried out for assessment of the weathering profile (locations see Fig. 2. 3/9).

Test Pits

A total number of 21 test pits was proposed at the weir and desander areas. Objective was to establish the presence and character of soils and weathered rock and to collect samples for material testing. Excavation was delayed and later on skipped owing to the relocation of the weir site.

Material Testing

Point load tests were carried out on rock cores recovered from drill holes (see Tab. 14).

5.2.5 Geotechnical Assessment

(1) Weir and Appurtenant Structures

(A) Foundation Conditions of Weir

(a) Excavation

On the basis of 8 drill holes, located at both banks of K-K 205 dam site, 1600 m of seismic profils along the dam axis and along both banks of the river, which included the longitudinal axis of the desander, as well as field observations during geological mapping the following approximate foundation levels would be assumed at K-K 205 dam site (see Fig. 15):

The concrete weir should be founded on bedrock owing to the expected heterogeneity and poor geomechanical characteristics of the weathered material. The bedrock level appears to be irregular. Along the dam axis suitable rock is available at depths ranging from 3 to 15 m while at the left bank, immediately upstream and downstream of the axis, weathered material may extend as deep as 15 to 20 m.

At the left bank flood plain excavation would comprise up to 12 m of unsuitable weathered rock while in the river section only trimming of about 3 to 5 m slightly weathered rock would be needed; alluvial deposits seem to be more or less absent in the river bed. On the right abutment lower slopes about 10 to 15 m of highly weathered rock are likely to be encountered, whereas on the upper slope sections unsuitable weathered rock may extend only down to about 3 to 5 m.

(b) Permeability and grouting

Rock mass permeability has been investigated by a considerable number of water pressure tests which have been conducted in drill holes along the dam axis (KK 9, KK 10 and KK 20) in the foundation area of the desander (KK 16, KK 18, KK 20 and KK 21) as well as in the tunnel intake area (KK 11, KK 12).

Summarizing it can be said that generally low water absorptions (Lugeon values ranging from 0 to about 5) reflect the predominantly massive character of the rock mass and its low overall permeability. In places moderate water absorption was recorded (Lugeon values up to about 20) where narrow zones of close rock fracturation were intercepted.

As to the effect of the structural pattern to underseepage of the weir orientation of foliation and longitudinal joints is clearly unfavourable. These discontinuity sets are perpendicular to the dam axis thus providing direct upstream/downstream seepage paths. A third joint set has been identified which is more or less parallel to the dam axis. However, interpretation of the water pressure tests is quite complex as to the proportion of water losses each discontinuity set contributes to the overall rock mass permeability (see discussion in chapter 4.2.4).

As to the need of grouting works, considering the type of structure as well as the prevailing foundation conditions, curtain grouting of similar specifications as proposed for the new weir site would appear adequate (see chapter 4.2.4). No significant problems would have to be expected in execution of an effective grout curtain.

(c) Stability of foundations and slopes

With respect to foundation stability it can be stated that the sound rock has sufficient strength to support a dam and appurtenant structures of the envisaged size. Orientation of foliation, which is the dominant structural element, is perpendicular to the dam axis and would therefore have no hazardous effect on foundation stability.

A plot of main discontinuity sets shows that there is no potential for unfavourable intersections and consequent formation of unstable rock wedges.

Due to the presence of the above mentioned anticline structure within the dam foundation area there is a possibility that features of similar nature and orientation of that observed at KK 230 dam site would occur. However, such features could be easily treated by dental concrete at foundation levels while at depth they would be intercepted by the grout curtain.

Slope stability conditions would be favourable owing to the presence of above mentioned anticline structure which results in components of foliation dip being directed into the slope at either abutment.

(B) Diversion

Diversion would be done through the desander and, hence, no separate structure would be needed.

(C) Desander

The desander should also be founded on rock, firstly, because underseepage would be difficult to control if it was to be founded on soil of heterogeneous characteristics and, secondly, because of the extremely irregular "top of sound rock" level which would result in extremely different bearing capacities at any intermediate foundations level.

Consequently, due to the great depth of overburden and weathered rock (see Fig. 16) a tremendous amount of soil and rock excavation would be needed.

(2) Waterways

Tunnel alignments of K-K 205 and K-K 230 alternatives are for most sections identical. Even in the initial sections, which take slightly different routes, geological conditions can be considered analoguos. Therefore, geotechnical situation of both alignments is summarized in one single geotechnical profile presented in Fig. 17. The information contained in the section is mainly based on geological mapping as well as on three drill holes located at the crossing of the Hulukiri Dola (KK 6), at the location of the surge shaft (KK 7) and at the saddle near the surge shaft (KK 29).

It is not possible to indicate specific rock types in particular tunnel sections which is due to difficult access and the lack of outcrops as well as the variability of the prevailing rock types (biotite gneiss, hornblende-biotite gneiss and charnockite, for further petrographic details see chapter 4.3.2). However, an attempt was made to delineate the structural pattern along the tunnel alignment. About two distinct homogeneous zones with respect to structural conditions can be differentiated:

From the portal to about station 3+000 wide spanned folding is predominant. Orientation of the dominant structural element is more or less perpendicular to the tunnel axis.

In the following tunnel section up to the outfall structure foliation is sub-parallel to the tunnel alignment. Geological mapping revealed the presence of a number of anticlinal and synclinal fold elements so that foliation dip is at medium steep angles towards either SW (dominant) or NE. In general terms such a situation can be considered fair, particularly with regard to the massive character of the prevailing rock types.

Classification of the rock mass along the tunnel alignment (CSIR and NGI classification and a project-specific support classification are adopted) shows that in both tunnels good to very good rock will be available for most tunnel sections (86 % class I in headrace tunnel and 83 % class I in tailrace tunnel). Relative length of other rock classes is shown in Fig 17.

(3) Powerhouse, Surge Shaft and High Pressure System

The underground powerhouse and associated structures are located in a massive northwest-southeast trending ridge. Burden above the cavern roof is about 300 m. Therefore it can be assumed that the rock mass is not affected by weathering.

No firm data on rock types and rock mass parameters are available that are based on geotechnical investigations. The main source of information are field observations during geological mapping along some accessible sections of the tunnel alignment as well as results of one drill hole located at the surge shaft. Additionally, extrapolations can be made from investigations conducted at the new powerhouse location. The following assumptions are tentatively made:

The prevailing rock comprises biotite and hornblende-biotite gneiss, as well as charnockitic gneisses. Uniaxial strength is high and is between 150 and 200 MPa, with some charnockitic and quartz-rich gneisses even exceeding 200 MPa. Spacing and conditions of discontinuities are thought to be similar to those described for the new powerhouse location (see chapter 4.4.2).

On the basis of such information it could be assumed that underground excavation conditions for the power cavern and surge shaft facilities are very favourable. It appears that this location is situated in a more massive portion of the ridge than the new powerhouse site, it would, therefore, seem that in a direct comparison with the new powerhouse location this site would present more favourable conditions.

However, this powerhouse site was omitted on considerations regarding length of access tunnel and separate cable and ventilation tunnels.

5.3 Geological-geotechnical Aspects of the Area of K-K 230

5.3.1 General

K-K plan was formulated as an alternative to K-P plan. Two alternative dam sites were identified about 1.3 and 1.65 km downstream of K-P dam site. The upstream site (K-K 230) was designated for a low CFR-type dam as well as for a concrete weir.

5.3.2 Topography and Geomorphology

At K-K 230 dam site the valley cross section is narrow and V-shaped. Slopes are more or less regular and average slope angle, up to about 240 m asl elevation, is about 35° at the left bank, while it is about 25° at the right bank.

Towards upward slopes continue with flat sections of about 22° at the left bank and of about 18° at the right bank.

In its initial section headrace tunnel alignment will at right angles traverse a series of parallel mountain chains and intercalated valleys. Ridge crest levels are about 420 m asl, while valley bottoms are at about 250 m asl. Following a sharp bend, tunnel alignment is more or less in the centre of a NW-SE massive ridge with crest levels of about 380 m asl.

5.3.3 Geological Assessment

(1) Weathering and Overburden

Weathering conditions can be concluded from the results of three drill holes (KK 1 through 3), one seismic profile along the dam axis as well as field observations made during geological mapping of the dam site area (see Fig. 19).

At the lower slope sections of the left abutment continuous outcrops of sound and massive rock can be observed. Towards the upper slope sections the sound rock is covered by a thin layer of overburden, which is revealed by the results of seismic profiling.

Core material recovered from drill hole KK 3 shows that at the left bank flood plain weathered talus material occurs to a depth of 9 m underlain by 0.3 m of alluvial clay and followed by 1.7 m of moderately weathered rock. That suggests the existence of a re-filled river channel which is possibly filled with ancient landslide material. On the other hand, outcrops of slightly weathered rock, some 100 m upstream of K-K 230 dam axis, indicate that at the central part of the river section sound foundation rock will be available at shallow depths.

At the right abutment few outcrops of highly weathered rock can be seen along a shallow gully just downstream of the dam axis. According to results of two drill holes, which confirm the findings of the seismic survey, considerable depth of weathering can be expected: sound rock would be available at about 15 to 20 m at the lower slope sections, while at upper slopes it would be found about 10 m deep. Character, depth and shape of the weathering profile are very similar to those found at K-P dam site where corresponding geologic-geomorphologic conditions are found.

Along waterways alignments rock outcrops are frequently found to make up mountain crests and steep slopes and, similarly, rock is often exposed along river beds such as Hulukiri and Makeliya Dola. Drilling results of drill holes KK 6 (Hulukiri crossing), KK 7 (surge shaft of eliminated K-K 205), KK 29 (saddle near surge shaft) and results of drill hole KK 42 (surge shaft of selected K-K 205) as well as results of seismic survey confirm the field observations. On the other hand, deep weathering may be inferred on moderate and flat slopes.

(2) Rock Types and Rock Mass Parameters

Rock outcrops are scarce except for the lower sections of the left abutment where massive biotite gneisses would make up the foundation of a low dam. According to results of drill holes KK 3 and KK 2 biotite gneiss with intercalated charnockite and hornblende-biotite gneiss forms the river section and the lower right bank slopes, whereas charnockite makes up the upper right bank slope sections as shown by the recovered core material of drill hole KK 1.

Apart from above mentioned left bank outcrop of massive gneiss the nature of the rock mass has to be derived from drill cores. Core material of KK 3 has high RQD values indicating that the massive character of the rock mass continues, at least partly, underneath the left bank flood plain. The excellent quality of this material is underlined by its complete impermeability (according to WPT). Nature of the core material of KK 1 and KK 2 is somewhat irregular which is manifested by relatively variable RQD-values which are generally high but are nil in places. Water pressure tests generally reflect such inconsistency. However, water takes are generally low to moderate, so that in general terms it can be stated that sound rock of any of the prevailing gneissic rock types would make up a suitable foundation (for rock mass parameters see Tab. 9).

Along waterways alignments a variety of gneissic rock types was identified during geological mapping including biotite gneiss, hornblende-biotite gneiss,

charnockite, amphibolite etc. The observed rock mass is generally massive but is traversed at irregular intervals by fracture zones.
For further details reference is made to chapters 4.3.4 and 5.2.5.

(3) Structural Geology

(A) General

At the dam site area a first order anticline was identified by geological mapping to traverse the dam foundation at the left bank flood plain. The axis of the anticline can be traced further upstream where it is found at the upper slopes of the left abutment of K-P dam site, while towards downstream it approaches the river channel. Subhorizontal foliation in the river bed at the upstream end of the S-shaped riverbend, some 600 m downstream of K-K 230 dam axis, may reflect the vertex of the anticline.

Geological mapping along the waterways alignment revealed the presence of three fold structures of regional extension. Additionally, a number of minor fold elements could be located (see Fig. 17).

Prominent photo-lineaments are oriented E-W to NE-SW. Morphologically they are represented by saddles as well as gullies which can be found at the dam site area as well as along the mountain ridge which accommodates the waterways structures. Additionally, a very prominent NW-SE photo-lineament, which can be traced for about 15 km, crosses the dam site area about 600 m downstream of K-K 230 dam axis, and is interpreted as manifestation of a fracture or fault zone.

(B) Foliation

Orientation of foliation is perpendicular to K-K 230 dam axis. Due to the presence of above mentioned anticline dip is towards SW at the left abutment while it is towards NE at the river section and the right abutment, so that at both abutments foliation dips into the slope which is, in general terms, favourable with respect to stability of natural or cut slopes. The following maxima were obtained (see Fig. 20):

Fol_1 = 054-079°/44-72°
Fol_2 = 227-253°/32-45°

As was mentioned above a number of minor and major fold elements exists along the waterways alignment resulting in both SW as well as NE dip direction of foliation (locations can be seen on Fig 17). The following distribution was measured (see Fig. 17):

Fol_1 = 245-265°/50-70° (prominent)
Fol_2 = 065-085°/50-70°

(C) Jointing

At K-K 230 dam site outcrops are too scarce as to obtain sufficient numbers of joint readings. However, some readings were taken further upstream and downstream at representative locations indicating the presence of two major joint sets. JS 1 is more or less parallel to the dam axis with steep dip angles towards downstream and occasionally upstream. This joint set represents above mentioned E-W fracture zones. The second joint set is perpendicular to the dam axis corresponding to the longitudinal system with respect to fold geometry.

The following distribution was measured (see Fig. 20):

JS 1 = 188-208°/56-75°
JS 2 = 287-316°/43-63°

Photo-geology and field observations suggest that both joint sets will be present along the alignment of waterways.

(D) Faults

In drill hole KK 3 a mylonitic seam of 0.5 m width was encountered at a depth of about 49 m possibly representing a shear zone running parallel to above mentioned anticline axis. The fault seems to act as an aquiclude for an eruption of artesian water in this drill hole. In drill hole KK 2 corresponding conditions were encountered. At almost identical depth the hole struck artesian water of almost identical chemical composition (see Tab. 16) so that it is reasonable to infer that sources are of the same origin.

5.3.4 Geotechnical Investigations

Core Drilling

Along the dam axis a total number of 3 drill holes was carried out amounting to a total of 200 drilling metres (see Tab. 1).

All drill holes were performed with rotary drilling equipment using double tube core barrels in hard rock. In soft rock such as residual soil, talus and decomposed rock dry drilling techniques were partly employed using single tube core barrels. Drill holes were vertical except for drill hole KK 2 which was inclined to investigate the river section. A summary of the results including collar elevations, coordinates, length of drill hole, elevation of weathering grades of rock, overburden and instrumentation with piezometers is shown on Tab. 5. Geological and drilling details of drill holes are given in the "Logs for Engineering Purposes" (see Tab. 13).

Objectives of drill holes at various sites included the following:

Identification of zones of weathering and close fracturation (dam axis),

Assessment of permeability (dam axis),

Investigation of depth and type of overburden (all structures),

Assessment of prevailing foundation conditions with respect to availability and quality of rock (all structures).

Borehole Tests and Instrumentation

Water pressure tests (Lugeon-type) were carried out in drill hole sections were packers could be sealed properly (results are shown in drill logs, Tab. 13).

In soil sections of drill holes Constant Head tests were carried out in order to determine permeabilities.

In order to assess strength characteristics of soils SPT tests were carried out.

Installation of piezometers was done in two drill holes.

Geophysical Investigations

One seismic profile was carried out along the weir axis for assessment of the weathering profile (location see Fig. 2. 3/9).

Material Testing

Point load tests were carried out on rock cores recovered from drill holes (see Tab. 14).

5.3.5 Geotechnical Assessment

(1) Dams and Appurtenant Structures

(A) Foundation Conditions of Dams

(a) Excavation

On the basis of three drill hole, results of seismic survey as well as field observations during geological mapping the following foundation levels may be assumed at K-K 230 dam site (see Fig 21):

The shell of a CFR dam would need minimal excavation at the left abutment slope. At the adjoining section of the left bank flood plain excavation would comprise up to 12 m of unsuitable weathered rock while in the river section only trimming of about 3 to 5 m slightly weathered rock would be needed since alluvial deposits seem to be more or less absent in the river bed. On the right abutment lower slopes about 10 to 15 m of highly weathered rock would be encountered, whereas on the upper slope sections unsuitable weathered rock extends only down to about 3 to 5 m.

For the plinth foundation additional excavation of about 5 m beyond shell excavation grades may be assumed.

A concrete weir should be founded on sound bedrock to avoid extensive foundation treatment that would be needed due to the heterogeneity and poor geomechanics parameters of the decomposed and highly weathered rock.

(b) Permeability and Grouting

Water pressure tests have been conducted in rock portions of all drill holes (KK 1, KK 2 and KK 3). Results show that the massive biotite gneiss making up the left abutment and most parts of the river section are practically impervious apart from the uppermost section of drill hole KK 2 where maximum water takes correspond to about 25 Lugeon. No water absorption was recorded in drill hole KK 3. Water pressure tests of some of these sections seem, however, not to adequately represent the recovered core material. In drill hole KK 1 which is located at the upper right abutment of a high dam water losses corresponding to about 15 to 30 Lugeon extend about 20 m deep. Summarizing the results of water pressure tests it can be assumed that the overall rock mass permeability is generally low to moderate in fresh and slightly weathered rock due to the predominantly massive character of the rock mass.

As to the effect of the structural pattern with regard to underseepage orientation of foliation and longitudinal joints is clearly unfavourable. These discontinuity sets are perpendicular to the dam axis thus providing direct upstream/downstream seepage paths.

However, scarce information on the joint pattern does not permit a conclusive interpretation of the water pressure tests regarding the question as to the proportion of the water losses each discontinuity sets contributes to the overall rock mass permeability. Drill cores show that foliation planes are mostly tight and, hence, do not significantly contribute to the overall rock mass permeability. Joints of the two principal joint sets are also frequently tight but individual joint planes may be moderately open. This can be indirectly concluded from the results of water pressure tests which suggest mostly turbulent flow conditions to be attributed to few open joints.

As to the necessity of grouting works it is proposed that with respect to the considered type of structures as well as regarding the prevailing structural pattern grouting should be considered for both, a low CFR-type dam as well as for a diversion weir. The above said would suggest that groutability of the rock mass would be good and that no significant problems would have to be expected in the execution of an effective grout curtain. A low to moderate grout take could be expected.

(c) Stability of Foundations and Slopes

With respect to foundation stability it can be stated that the sound rock has sufficient strength to support a dam and appurtenant structures of the envisaged order. Orientation of above mentioned mylonitic zone is probably perpendicular to the dam axis and would therefore have no hazardous effect on foundation stability provided there is no extreme increase in thickness. Due to the presence of the above mentioned anticlinal structure there is a possibility that additional features of similar nature and orientation could occur within the dam foundation area. However, such features could be easily treated.

Slope stability conditions can be considered favourable owing to the presence of above mentioned anticline structure which results in foliation dip being directed into the slope at both abutments.

(B) Spillway

For the K-K 230 dam the conceptual design layout provides for a spillway at the left abutment. According to assumed weathering depths the spillway foundation would be more or less completely on sound bedrock (at designed levels). No slope stability problems are anticipated.

(C) Diversion

The layout for conceptual design provides for two diversion tunnels at the left abutment. With respect to the design concept it is proposed that distance between tunnels should not be less than 2.5 diameters. Also, in order to avoid interference with the grout curtain the tunnel alignment should be located sufficiently deep inside the abutment which would result in that tunnel excavation would be mostly in good rock.

(2) Waterways

The layout provides for a headrace tunnel of 5495 m length; tailrace tunnel length is 2535 m. The initial section of the headrace tunnel, up to about station 3+000, is about E-W, i.e. almost perpendicular to the orientation of foliation, while the remaining sections of the headrace and tailrace tunnels would be driven more or less parallel to the strike of foliation.

The geotechnical situation of the tunnel alignment, as currently assumed, is summarized in the geotechnical profile presented in Fig. 17. The information contained in the section is mainly based on geological mapping as well as on results of three drill holes located at the crossing of the Hulukiri Dola (KK 6), at the location of the surge shaft

(KK 7) and at the saddle near the surge shaft (KK 29).

Due to difficult access and the lack of outcrops as well as the variability of the prevailing rock types, biotite gneiss, hornblende-biotite gneiss and charnockite are grading into each other, pinching out etc., it is not possible to indicate specific rock types in particular tunnel sections . However, an attempt was made to delineate the structural pattern along the tunnel alignment. About two distinct homogeneous zones with respect to structural conditions can be differentiated: from the portal to about station 3+000 wide spanned folding is predominant. Orientation of the dominant structural element is perpendicular to the tunnel axis. That can be considered very favourable assuming that direction of tunnel drive will be with the dip.

In the following tunnel section up to the outfall structure foliation is parallel to the tunnel alignment. Geological mapping revealed the presence of a number of anticlinal and synclinal fold elements so that foliation dip is at medium steep angles towards either SW (dominant) or NE. In general terms such a situation can be considered fair, particularly with regard to the massive character of the prevailing rock types.

Classification of the rock mass along the tunnel alignment (CSIR and NGI classification and a project-specific support classification are adopted) shows that in both tunnels good to very good rock will be available for most tunnel sections (86 % class I in headrace tunnel and 83 % class I in tailrace tunnel). Relative length of other rock classes is shown in Fig 17.

(3) Powerhouse, Surge Shaft and High Pressure System

The underground powerhouse and appurtenant structures of this alternative are identical with those of Alternative K-K 205, reference is therefore made to chapter 4.4.4.

5.4 Geological-Geotechnical Aspects of the Area of K-P Alternatives (205, 230, 242) and of Alternatives Abandoned after Phase I

5.4.1 General

At the proposed dam site three alternative layouts, namely CFR-type dams with 242 m FSL and 230 m FSL, respectively, and diversion weir with 205 m FSL were considered in the conceptual design.

5.4.2 Geological Assessment

(1) Topography and Geomorphology

At the selected dam site the general orientation of the river is NW-SE, i.e. parallel to foliation. Abutment slopes are medium steeply inclined. The gradient of the left abutment is quite steady at about 27^{o} while at the right abutment a number of low scarps interrupts the regular gradient of the slope which is at an average of about 31°. Shallow gullies occur in the vicinity of the site probably following local fracture zones.

A morphological feature, that resembles strongly to a landslide, occurs at the left abutment some 100 m downstream of the dam axis. There the valley opens abruptly without an obvious structural control. However, apart from morphology, there are no other indications to support the notion of a landslide. It is therefore assumed that the morphological depression is formed due to the oblique intersection with the valley of a less weathering resistant rock layer, the tectonic position of which is controlled by the left bank anticline (see para on Structural Geology).

The tunnel alignment of Alternative IV, which was selected for geotechnical investigations of phase II-a, will traverse a series of parallel mountain chains with crest levels of about 400 m asl. Orientation of the mountain ridges is strikingly regular since it is strictly controlled by the prevailing structural pattern, i.e. a set of parallel anticlinal and synclinal structures. Intra-mountainous valleys of the same orientation probably reflect the presence of rock types that are somewhat more easily weathered and, additionally, there may be some influence of structural features as for instance fold axes, narrow shear zones etc. The results of seismic profiling indicate, however, that the rock mass in valleys is about as competent as in the adjoining mountain ridge.

(2) Weathering and Overburden

At the dam site parts of the river section, extending from about 250 m upstream of the dam axis towards some 20 m downstream, are made up of outcropping fresh to slightly weathered rock. At the abutment slopes scarce outcrops of highly and moderately weathered rock can be found indicating surface-near presence of sound bedrock. A thin deposit of sandy alluvium exists along the left river bank, while at the toe of the right bank slope blocky talus is accumulated.

Depth and character of the weathering profile have been investigated by two drill holes, one on either side of the river as well as by seismic survey. Results can be summarized as follows: Below a thin cover of about 2 m of residual soil, decomposed and highly weathered rock is found down to a depth of about 10 to 15 m and 15 to 25 m, on the left and right abutment, respectively. Sound bedrock follows below a transition zone of moderately weathered rock of about 5 to 10 m (see Fig 22 and Tab 5). Results of geological investigations suggest that generally sound rock is closer to the surface at upper slopes at the right bank, while at upper slope sections at left bank it is at relatively greater depth. At the position of drill holes, about mid-level of abutment slopes, weathering extends to greatest depths, particularly at the right abutment (for details see Fig. 22).

Along waterways alignment hill tops, steep slopes as well as some valley sections are frequently made up of outcropping rock. Generally, however a weathering profile is developed depth of which depends on the character of the parent rock: massive and weathering resistant rock types such as charnockite, amphibolite, quartz-rich biotite gneiss etc. produce blocky talus material of shallow depth while on more easily weathered biotite and feldspar containing rocks a deep weathering profile develops. This is confirmed by drilling as well as by seismic survey.

According to drill hole KP 8, which is located at the power outfall on a slope made up of charnockite, depth of weathered material consisting of residual soil and boulders is only about 5 m. In drill hole KP 7, which was located to investigate the rock mass characteristics at the tunnel crossing at Peleng Ganga, fresh rock is found at about 7 m. Field evidence as well as results of seismic survey show that along river beds, including Peleng Ganga and Maha Dola, top of sound rock is often close to the surface or rock is even exposed; deep weathering at the dam site was already mentioned.

(3) Rock Types and Rock Mass Parameters

According to results of dam site mapping and core drilling the prevailing dam foundation rock comprises biotite, hornblende-biotite gneiss, charnockitic gneiss and garnetiferous quartz-feldspar gneiss. A number of Point Load tests have been done on fresh as well as on weathered material. Results indicate that uniaxial compressive strength of the fresh rock is between 150 and 200 MPa, with some charnockite varieties and quartz-rich biotite gneisses even exceeding 200 MPa (see Tab. 9).

Spacing of foliation is about 0.3 to 1 m, while spacing of joint sets No 1 and 2 is about 1 to 3 m, locally it is >3 m. Foliation joints of the recovered core material are generally plane and smooth due to chloritic and biotitic staining. Opening widths of surface near discontinuities were observed to exceed 1 mm in places.

Rock mechanical parameters derived from above tests and field observations are summarized in Tab. 9.

In order to investigate geological and structural conditions as well as geomechanical parameters along the waterways alignment detailed geological mapping was carried out along the relevant sections of Kalutara-Ratnapura road and other roads in the vicinity of the waterways alignment. The survey revealed the following: Rock inventory comprises biotite gneiss which is frequently rich in quartz, hornblende-biotite gneiss, charnockite, amphibolite, garnetiferous quartz-feldspar gneiss and calc-silicate rock. Most rock types exhibit a massive character, and rock mass parameters along distinct sections of the tunnel alignment can be derived from rock mass classifications shown in the relevant geotechnical section (Fig. 23).

(4) Structural Geology

(A) General

During geological mapping of the dam site area two first order fold elements could be identified. The course of the Kukule valley assumes a tectonic position between an anticline at the left and a syncline at the right bank of the river. At K-P dam site the axis of the anticline is at a distance of about 250 m from the river while it approaches the river in its extension towards NW. The axis of the synclinal element traverses the area at a distance of about 350 m from the river (see Fig. 21).

Along the waterways alignment 6 major fold elements would be traversed according to results of geological mapping. Additionally, there is a number of anticlines and synclines that may not be continuous for any great distance (projected locations are shown in Fig. 23).

The fold system is dissected by an E-W to NE-SW oriented pattern of fracture zones that can be easily identified on aerial photos. Such tectonic features are assumed to cause above mentioned shallow gullies that locally dissect the dam site area. Owing to their regional occurrence they are also found along the tunnel alignment.

(B) Foliation

Orientation of foliation is perpendicular to the dam axis. Due to the above outlined tectonic position on the limbs of an anticlinal element towards SW and a synclinal structure towards NE dip direction is towards NE at medium steep angles (50 to 60°), i.e. orientation is with the slope at the left abutment while it is into the slope at the right abutment.

Orientation of foliation is quite regular as indicated by well pronounced maxima (see Fig. 24):

Fol = 040-070°/50-60°

Orientation of foliation along the tunnel trace, as shown in Fig. 23, is extrapolated from geological mapping of adjoining areas.

(C) Jointing

Two main joint sets were observed at the dam site area. JS 1 is more or less parallel to the dam axis and dip is at steep angles to either upstream or downstream. This joint set corresponds to the above mentioned set of fracture zones. Genetically the joint set represents h00-direction, i.e. it is perpendicular to the fold geometry. The second joint set is perpendicular to the dam axis, hence providing potential upstream-downstream seepage paths. With respect to the fold symmetry this set represents 0k0-direction, i.e. the longitudinal orientation. The following distribution was measured (see Fig. 26):

JS 1 = 170-210°/70-90° and 000-020°/70-90°
JS 2 = 270-295°/70-90°

Since these joint sets are of regional occurrence they are also found along the tunnel alignment (see Fig. 26).

5.4.3 Geotechnical Assessment

(1) Dam and Appurtenant Structures

(A) Foundation Conditions of Dams

(a) Excavation

On the basis of geological mapping, of a seismic survey as well as of two drill holes on either abutment the following approximate foundation levels may be anticipated (see Fig. 22):

For the shell of a rockfill dam excavation would comprise soil and highly weathered rock. On the upper and lower sections of both abutments excavation depths would range between about 5 to 15 m. Along slope mid-levels up to 20 m unsuitable rock would have to be excavated, while in the river section about 3 m of rock trimming would be needed.

For the plinth foundation excavation of about 5 to 10 m weathered rock, starting from the shell foundation level, would be needed. Field observations and results of previous core drilling suggest that some practical difficulties of foundation works may be expected due to irregularity of the "top of sound rock" level.

A concrete weir, though of minor dimensions, should be founded on sound rock due to the expected heterogeneity of the decomposed and highly weathered rock. To avoid extensive foundation treatment it would be advisable to consider the same excavation levels as for plinth foundation.

(b) Permeability and Grouting

The prevailing structural pattern, i.e. foliation and longitudinal joints, has an unfavourable orientation with respect to underseepage of the dam. Strike of both is perpendicular to the dam axis thus providing direct seepage paths from the reservoir to the downstream toe of the dam. However, results of water pressure tests executed in two drill holes indicate low to moderate water takes of the unweathered rock mass with permeability ranging between 5 and 10 Lugeon. WPT results are in accordance with the low degree of fracturation observed in the field as well as in the recovered core material which mostly shows good RQD-values in excess of 80 %.

Groutability of the unweathered bedrock is assumed to be good, since, according to the available core material, joints of rock grades II and I do generally not contain joint fillings that could obstruct grouting. With respect to grout take low values can be assumed since high takes,for instance due to hydraulic fracturing, need not be expected owing to the competence of the rock mass.

Scarcity of data on rock mass permeability obviously does not permit final conclusions on the necessity and amount of grouting works, it may, however, be prudent to assume that grouting, even though not excessive, would be needed for the plinth foundation as well as for a small concrete weir.

(c) Stability of Foundations and Slopes

The bearing capacity of the rock mass prevailing at this dam site is mainly a function of the degree of weathering. The sound and slightly weathered foundation rock has a low to very low deformability. Variations in rock types are of little significance for the rock mass strength. For phase II-a stage of the study rock mass parameters were given on the basis of experience and comparison with test results from similar projects in Sri Lanka (see Tab. 8 and 9).

The magnitude of values for weathered rock mass, given in above table, indicates that grade III, or even grade III-IV rock, has sufficient strength to support the shell of a rockfill dam. It may be assumed that the range of strength values within a given weathering grade does not exceed tolerable limits. On the other hand, it cannot be excluded that at a given foundation level, due to differential weathering, rock of dissimilar weathering grade and, hence, strength could be found next to each other. That could lead to differential settlement as well as to practical difficulties of foundation work.

With respect to foundation stability it was pointed out in the conceptual design report, that if this alternative would have been selected for further investigations, a more detailed structural analysis, particularly with respect to the presence (orientation and character) of joints and faults of random orientation that could be hazardous to foundation stability, would have to be carried out to confirm above mentioned preliminary assumptions.

(B) Spillway

The conceptual design provides for the spillway structure to be located at the right abutment. According to assumptions on weathering depths, as outlined above, the structure could be founded on sound rock. As to the stability of slope cuts no problems were anticipated during that stage of the study due to the favourable dip of the dominant discontinuity set, i.e. foliation, which was found to be directed into the slope (refer to above discussion).

(C) Diversion

Design of the conceptual design stage provides for two diversion tunnels to be located at the right abutment. It would probably be advantageous to locate the tunnels further into the slope, more or less below the spillway structure, to increase tunnel sections in good rock and, additionally, to avoid interference with the grout curtain.

(2) Waterways

Alternative IV of K-P plan alternative was considered in the preliminary design. Waterways of this alternative consist of a headrace tunnel of 4350 m length that links the reservoir with the upstream surge shaft and a tailrace tunnel of 3050 m length connecting downstream surge shaft and the outfall structure.

Both tunnels would be driven perpendicular to the orientation of major structural elements, i.e. foliation. In general terms, such situation can be considered very favourable to fair depending on the dip angle and drive direction (with or against steeply dipping discontinuities). Burden above tunnel roof is generally exceeding 100 m, so that weathering would not affect the rock mass.

The geotechnical situation of the then considered tunnel alignment is summarized in the geotechnical profile presented in Fig. 23. The information contained in the section is mainly based on geological mapping, one seismic profile as well as on two drill holes which are located at the crossing of Peleng Ganga and at the outfall structure. At the respective level of the study it was not possible to indicate individual rock types prevailing in particular tunnel section due to the variability of the gneissic rocks. However, an attempt was made to delineate the structural pattern along the tunnel alignment. About three distinct zones of more or less homogeneous conditions, with respect to structural characteristics, could be differentiated: from the portal to about station 3+000 wide spanned folding is predominant followed by a generally uniformly dipping rock sequence with local occurrence of minor folds. This section extends up to about station 6+500. The remaining portion up to the outfall is again characterized by wide folds of greater extension.

In the geotechnical section the rock mass is classified according to two widely used classification systems, namely the CSIR and NGI classifications. Obviously, at that stage of the study with relatively limited data available on relevant individual rock mass parameters the classification is somewhat crude, but probably allows to roughly outline the potential influence of fracture zones, weathering etc. on support requirements.

In view of the crudeness of the rock quality classification a support classification has been developed considering only three instead of the commonly used five or more rock classes (Tab. 6).

According to the classification result the bulk of underground excavation works would be in very good quality rock mass, respective length of class I being 86% in the headrace tunnel, while it would be 94 % in the tailrace tunnel. In sections where the tunnels cross tributary valleys, it was then assumed that these would reflect fracture zones, or the presence of less weathering resistant rock types, hence fair quality rock mass according to rock class II was expected; respective length being 13 % in the headrace tunnel and 5 % in the tailrace tunnel. Poor quality rock corresponding to rock mass class III was assumed to be restricted to the portal sections.

(3) Powerhouse, Surge Shaft and High Pressure System

For conceptual design the underground powerhouse and associated structures were located in a massive mountain ridge. Burden above the cavern roof would be about 300 m. Therefore it was assumed that the rock mass would not be affected by weathering.

No data on rock types and rock mass parameters were available which were based on geotechnical investigations. The only source of information was the geological profile exposed along the slope cut of the nearby Kalutara-Ratnapura road. The following assumptions were made:

The prevailing rock comprises biotite and hornblende-biotite gneiss, including quartz-rich varieties, as well as charnockitic gneisses. Uniaxial strength is between 150 and 200 MPa, with some charnockitic and quartz-rich varieties even exceeding 200 MPa. Spacing of foliation is about 1 to 3 m, locally it is >3 m. Information is insufficient regarding joint orientation and spacing. E-W oriented joints are present and spacing is probably wide. Since no core material is available no information is at hand as to the conditions of discontinuities of the fresh rock.

Based on such, however general, information it was assumed that underground excavation conditions would be favourable. However, it was stated that in order to definitely assess underground excavation conditions, detailed information would be needed on rock mass parameters such as rock types, orientation, spacing and conditions of joints, presence of individual rock defects (shear zones etc.), magnitude and orientation of primary stress field etc. which could be obtained by a comprehensive geotechnical and rock mechanical investigation programme.

5.4.4 Comparative Assessment of Alternatives Abandoned after Phase I

(1) General

During phase I of the study four alternative layouts (Alternatives I through IV) were prepared for the power system of the K-P Plan including waterway and powerhouse for which preliminary comparison studies were carried out. As an additional alternative K-D plan was identified and investigated at the respective level.

(2) Geological-Geotechnical Aspects of Abandoned K-P Alternatives (I-III)

Based on the preliminary overall assessment it was then concluded that (28):

Alternative II is geotechnically better than Alternative I due to its rock cover above the headrace tunnel. For both, Alternative I and II some problems could be expected regarding dewatering of the deep excavation pit for the open-air powerhouse. On the other hand, Alternative II (open-air powerhouse layout) and Alternative III (underground powerhouse layout) are economically competitive.

Consequently, Alternative IV (underground power house layout with about 15% larger head than the others) is the most beneficial layout, since the power outfall will be situated at a river water level of some 20 m asl.

(3) Geological-Geotechnical Aspects of the Area of K-D Plan

Results of preliminary assessment during phase I can be summarized as follows:

The dam site has unfavourable topographical conditions presumably reflecting unfavourable geological conditions. Consequently a large dam volume and a considerable amount of excavation work were anticipated. For cost estimates a random-fill dam with integrated concrete section was then considered (regarding expected excavation depths refer to Fig. 25).

With respect to dam foundation quality moderate rock mass permeability with corresponding groutability was assumed and no major problems regarding slope stability were anticipated.

The layout provided for a headrace tunnel of about 4.6 km length and a tailrace tunnel of about 3.7 km length. Underground excavation conditions were considered as favourable. For relative length of rock classes see Fig. 26.

The underground powerhouse of this alternative was located in a relative massive mountain ridge. On the basis of the then available information it was assumed, that, in general terms, underground excavation conditions would be favourable.

Tables

TABLE 1 SUMMARY OF GEOTECHNICAL INVESTIGATION WORKS.

WORK AND LOCATION	REFERENCE	NUMBER	QUANTITY AS PER17/08/92
DRILL HOLES			
KK 205(NEW)DAM AXIS AND RELATED STRUCTURES	,KK 31, KK 32, KK33, KK34 KK 35, KK 36 KK37, KK39	8	180/180 M
KK 205(NEW/OLD) HEAD RACE	KK 6, KK 29,KK44	2	190/140 M
KK205 (NEW)SURGE TANK	KK 42	1	230/230 M
KK205 (NEW)POWER HOUSE	KK 43	1	230/AT 120?
KK205 (NEW/OLD) TAILRACE	KK 8 , KK 28	2	90/90 M
KK205 (NEW)ACCESS TUNNEL	KK 41	1	50/NIL
KK 205(NEW/OLD) DAM - QUARRY	KK 4	1	20/20 M
KK205(NEW/OLD) P.H. QUARRY	KK 5	1	20/20 M
KK 205 (OLD)DAM AXIS AND RELATED STRUCTURES	KK 9, KK 10, KK11, KK12, KK 16, KK 18, KK20, KK21	8	205/205 M
KK205(OLD)SURGE TANK	KK7	1	175/175
KK230 DAM SITE	KK 1,KK2,KK3	3	200/200
KP DAM AXIS	KP 1 , KP 3	2	100/100 M
KP WATERWAYS	KP 7, KP 8	2	70/70 M
TOTAL		33	**1710/1550 M**
PIEZOMETERS			
KK 205(NEW)DAM AXIS AND RELATED STRUCTURES	KK 33, KK 35 KK 37	3	
KK205(NEW/OLD) HEADRACE	KK 6, KK 29	2	
KK205(NEW)SURGE TANK	KK 41	1	
KK205(NEW)POWER HOUSE	KK 42	1	
KK205(NEW)TAILRACE OUTFALL	KK8	1	
KK 205(OLD)DAM AXIS AND RELATED STRUCTURES	KK 11, KK 18	2	
KK205(OLD)SURGE TANK	KK7	1	
KK 230 DAM AXIS	KK 1, KK 3	2	
KP DAM SITE	KP 1, KP 3	2	
TOTAL		15	
SEISMIC SURVEY			Linear Metreage Proposed/Executed
KK205 (NEW) DAM SITE	DR-1-S,DR-2-S DR-3-S	3	1000/1000
KK205(NEW/OLD) WATER WAYS	KK -6-S, KK-7-S, KK -8-S , KK-9-S KK-10-S	5	2200/2200
KK 205(OLD)DAM SITE	KK -2 - S, KK - 3 - S KK - 4 - S, KK - 5 - S	4	1600/1600 M
KK 230 DAM AXIS	KK -1 - S	1	300/300 M
KP DAM SITE	KP -1 - S	1	400/400 M
KP WATERWAYS	KP -2- S	1	500/500 M
TOTAL		15	**6000/6000**
TEST PITS			No of pits Proposed/Executed
KK205(NEW) DAM SITE		10	10/10
PANGALA ELLA AREA		5	5/6
KK205(NEW) OUTFALL & SWITCH YARD		10	10/8
KK205(NEW) ACCESS TUNNEL		0	1/NIL
TOTAL		25	25/25

TABLE-2 MINERAL COMPOSITION OF ROCK TYPES OF THE PROJECT AREA

ROCK CLASSIFICATION	Quartzo-feldspathic gneiss					Biotite gneiss					Charnockitic gneiss						Amphibolite		Calc silicat gneiss	Marble
						Horblende-Biotite gneiss	Biotite gneiss	Garnet-Biotite gneiss		Garnet-silimanite-biotite gneiss										
SAMPLE No >>	2	6	7	12	20	8	17	16	18	13	4	5	10	14	15	19	9	11	3	1
FELDSPARS																				
ORTHOCLASE	•				•		•	•		•		•		•	•	•		•		
MICROCLINE			•		•				•											
PLAGIOCLASE	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
ALBITE-OLIGOCLASE																				
PERTHITE	•	•	•	•	•	•	•	•	•	•	•		•		•					
QUARTZ	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•		•	
MICA GROUP																				
LIGHT COLOURED MICA																				
MUSCOVITE			•		•															
PHENGITE																				
PHLOGOPITE																				
SERICITE	•																			
BOITITE	•	•	•	•	•	•	•	•	•	•			•	•	•			•		
PYROXENE GROUP																				
HYPERSTHENE											•	•	•	•	•	•	•	•	•	
DIOPSIDE											•	•	•	•		•	•	•	•	•
AMPHIBOLE GROUP																				
HORNBLENDE	•					•					•	•		•		•	•	•		
PARAGASITE																				
GARNET GROUP		•	•	•			•	•	•	•			•		•					
OLIVINE GROUP																				
FORISTERITE																				
OLIVINE																				
EPIDOTE GROUP		•																		

CONTINUED ...

TABLE-2 MINERAL COMPOSITION OF ROCK TYPES OF THE PROJECT AREA

ROCK CLASSIFICATION	Quartzo-feldspathic gneiss					Biotite gneiss					Charnockitic gneiss						Amphibolite		Calc silicat gneiss	Marble
						Horblende-Biotite gneiss	Biotite gneiss	Garnet-Biotite gneiss		Garnet-silimanite-biotite gneiss										
SAMPLE No >>	2	6	7	12	20	8	17	16	18	13	4	5	10	14	15	19	9	11	3	1
CARBONATE																				
CALCITE			•				•												•	•
DOLOMITE																				
LIMONITE																				
CHLORITE			•				•										•	•	•	
SERPENTINE																				
CHRYSOTILE																				
ANTLGORSITE																				
SMECTITE																				
KOLINITE																				
ZIRCON	•	•	•	•		•		•	•		•	•	•	•	•		•			
APATITE	•			•	•	•		•			•	•		•	•	•	•		•	
MAGNATITE	•	•	•	•		•	•		•	•	•	•	•	•	•		•	•	•	
SPHENE																			•	
PYRITE										•				•		•				

NOTE:PETROGRAPHIC ANALYSIS OF THIN SECTIONS WERE CARRIED OUT BY THE DEPT. OF GEOLOGY
UNIVERSITY OF PERADENIYA

Table 3 CLASSIFICATION OF WEATHERING GRADES OF ROCK MASS

TERM	DESCRIPTION	GRADE
Fresh	No visible sign of rock material weathering ; perhaps slight discoloration on major discontinuity surfaces.	I
Slightly weathered	discoloration indicates weathering of rock material and disontinuity surfaces. All the rock material may be discoloured by weathering.	II
Moderately weathered	Less than half of the rock material is decomposed or disintergrated to soil. Fresh or dicoloured rock is present either as a continuous framework or as corestones.	III
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to soil. Fresh or dicoloured rock is present either as a discontinuous framework or as corestones.	IV
Decomposed	All rock material is decomposed and /or disintegrated to soil. The original mass structure is still largely intact	V
Residual soil	All rock matirial is converted to soil. The mass structure and material fabric are destroyed . There is a large change in volume,but the soil has not been significantly transported.	VI

This chart is based on BS 5930:1981 classification

GEOMECHANICS CLASSIFICATION OF JOINTED ROCK MASSES					
ROCK MASS INDEX DETERMINED FROM TOTAL RATINGS					
INDEX	DESCRIPTION	RATING	Friction angle of the rock mass	Cohesion of the rock mass	Average stand-up time
1	Very good rock	100 - 81	> 45°	> 300 kPa	10years for 5 m span
2	Good rock	80 - 61	40° - 45°	200 - 300kPa	6months for 4m span
3	Fair rock	60 - 41	35° - 45°	150 - 200kPa	1week for 3m span
4	Poor rock	40 - 21	30° - 35°	100 - 150kPa	5hours for 1.5m span
5	Very poor rock	< 20	< 30°	< 100kPa	10min for 0.5m span

THE EFFECT OF JOINT STRIKE AND DIP ORIENTATIONS						
Very favourable	Favourable	Fair	Unfavourable	Very unfavourable	Fair	Unfavourable
Strike perpendicular to tunnel axis				Strike parallel to tunnel axis		Dip 0° - 20° irrespective of strike
Drive with dip		Drive against dip				
Dip 45° - 90°	Dip 20° - 45°	Dip 45° - 90°	Dip 20° - 45°	Dip 45° - 90°	Dip 20° - 45°	
Strike parallel or near parallel (≤ ± 45°) to foundation axis					perpendicular or near perpendicular (≤ ± 45°) to axis of foundation	Dip 0° - 20° irrespective of strike
Dip towards u/s		Dip towards d/s				
Dip 45° - 90°	Dip 20° - 45°	Dip 45° - 90°	Dip 20° - 45°	Dip 0° - 20°	Dip 20° - 90°	
Strike parallel or near parallel (≤ ± 45°) to slope					perpendicular or near perpendicular (≤ ± 45°) to slope	
Dip into slope		Dip with slope				
Dip 45° - 90°	Dip 0° - 45°	Dip 45° - 90°	Dip 20° - 45°	Dip 0° 20°	Dip 0° 90°	

RATING SYSTEM									
PARAMETER			RANGES OF VALUES						
1	Strength of intact rock material	Point load strength index	> 8 MPa	4 - 8MPa	2 - 4MPa	1 - 2MPa	For this low range uniaxial compressive test is preferred		
		Uniaxial compressive strength	> 200MPa	100 - 200MPa	50 - 100MPa	25 - 50MPa	10 - 25 MPa	3 - 10 MPa	1 - 3 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Fracturing		Massive	Poorly Fractured	Fractured	Highly Fractured	Crushed		
	Rating		20	17	13	8	3		
3	Spacing of joints		> 3m	1 - 3m	0.3 - 1m	50 - 300mm	< 50 mm		
	Rating		30	25	20	10	5		
4	Condition of joints		Very rough surfaces Not continuous No separation Hard joint wall rock	Slightly rough surfaces Separation < 1mm Hard joint wall rock	Slightly rough surfaces Separation < 1mm Soft joint wall rocks	Slickensided surfaces or Gouge 5mm thick or joints open 1 - 5mm Continuous joints	Soft gouge 5mm thick or joints open > 5 mm Continuous joints		
	Rating		25	20	12	6	0		
5	Ground water	Inflow per 10 m tunnel length	None		< 25 litres/min	25-125 litres/min	> 125 litres/min		
		OR							
		Ratio $\frac{\text{joint water pressure}}{\text{major principal stress}}$	0		0.0 - 0.2	0.2 - 0.5	> 0.5		
		OR							
			Completely dry		Moist only (interstitial water)	Water under moderate pressure	Severe water problems		
	Rating		10		7	4	0		
6	Strike and dip orientations of joints		Very favourable	Favourable	Fair	Unfavourable	Very unfavourable		
	Ratings	Tunnels	0	-2	-5	-10	-12		
		Foundations	0	-2	-7	-15	-25		
		Slopes	0	-5	-25	-50	-60		

Table 4 : GEOMECHANICS CLASSIFICATION OF JOINTED ROCK MASS (CSIR) (Slightly Modified)

TABLE: 5 SUMMARY OF RESULTS OF DRILLING UP TO 17.08.92

	Hole No	Depth m.	Inclination from vertical Degrees	Bearing Degrees	Collar Elevation m.	Coordinates m.		LOCATION	DEPTH TO ROCK GRADE					INSTRUMENTATION
						N	E		V	IV	III	II	I	
KP PLAN	KP1	50.19	0	-	223.220	151777.350	151710.310	DAM AXIS	4.5	21.60	-	25.00		PZ(S)
DAM	KP3	50.22	0	-	217.120	151691.430	151609.190	DAM AXIS	3.4	13.1	-	20.60		PZ(S)
KK PLAN	KK1	50.23	0	-	229.655	152858.690	150859.480	DAM AXIS	1.2	4.90	-	10.00		PZ(D)
230DAM	KK2	100.00	40	229	196.000	152813.430	150813.350	DAM AXIS	5.6	-	-	18.00		-
	KK3	53.37	0	-	197.920	152775.150	150757.250	DAM AXIS	1.4	-	-	11.00		PZ(S)
KK PLAN	KK9	20.45	0	-	211.210	153148.970	150612.970	WEIR AXIS	5.8	7.80	-	10.00		PZ(S)
205 DAM	KK10	30.56	0	-	199.010	153100.409	150563.453	WEIR AXIS	6.5	-	-	16.9		-
(ELEMINATED)	KK11	30.10	0	-	211.580	153143.450	150444.280	DESANDER	1.0	1.88		-	14.9	PZ(S)
	KK12	30.03	0	-	238.350	153148.070	150359.850	HEAD RACE intake	-	-	-	1.6		-
	KK16	15.26	0	-	197.634	153131.507	150598.432	WEIR AXIS	2.9	-	-	3.6		-
	KK18	20.16	0	-	205.960	153173.429	150580.528	WEIR foundation	0.5	3.90	-	4.5		PZ (S)
	KK20	35.00	0	-	205.511	153055.970	150564.440	INTAKE	-	2.80		20.1		-
	KK21	25.20	0	-	199.710	153198.088	150457.897	DESANDER	4.5	6.90	-	11.85		-
KK PLAN	KK31	30.35	40	065	193.146	153564.959	150549.751	WEIR AXIS	-	-	-	-	0.00	-
205 DAM	KK32	30.15	40	245	194.219	153581.020	150582.437	WEIR AXIS	-	-	-	-	0.00	-
(SELECTED)	KK33	20.15	0	-	210.762	153542.786	150638.605	WEIR AXIS	-	-	-	-	11.45	PZ (S)
	KK34	20.00	0	-	196.308	153509.846	150525.369	WEIR intake	-	0.50	-	-	1.05	-
	KK35	20.20	0	-	204.348	153547.133	150507.887	DESANDER	1.4	-	-	-	1.5	PZ (S)
	KK36	23.00	0	-	212.878	153634.570	150482.244	DESANDER	1	10.60	-	-	13.65	-
	KK37	20.25	0	-	202.497	153703.967	150487.696	DESANDER	-	-	-	-	2.9	PZ (S)
	KK39	20.15	0	-	217.907	153740.168	150439.820	Headrace intake	0.5	1.50	-	-	5.15	-
KP PLAN	KP7	50.11	40	222	56.465	149226.699	146221.652	Peleng river cross	-	-	-	4.5		-
WATERWAYS	KP8	20.02	0	-	31.857	149019.933	144689.314	OUTFALL	-	-	-	2.4	-	-
KK PLAN	KK6	40.20	0	-	242.552	153099.483	148849.029	Hulukiri stream cross	-	-	-	-	1.3	PZ(S)
WATERWAYS	KK7	175.11	0	-	301.487	155621.922	146881.772	Surge shft (alternat.)	-	-	-	-	2.8	PZ(S)
	KK8	40.05	0	-	40.568	157538.671	144926.924	OUTFALL	2.5	-	30	7.2		PZ(S)
	KK28	50.10	0	-	65.711	157515.196	144984.544	OUTFALL	0.8	1.00		3.2		
	KK29	99.86	0	-	254.637	155463.130	146967.893	SADDLE	9.2	-	-	-	10.59	PZ(S)
	KK41 *	*	0	-				Intake access tunnel						PZ(S)
	KK42	230.07	0	-	230.900			SURGE SHAFT	3.1	7.02	-	9.15	19.54	PZ(S)
	KK43 *	+	0	-				POWER HOUSE						
KK PLAN	KK 4	20.20	0	-	218.430	153464.350	149995.030	QUARRT (DAM)	-	-	-	9.7		-
	KK5	20.13	0	-	136.580	155482.030	145860.896	Quarry(Power House)	3	-	-	3.4		-

TABLE : 6 ROCK CLASSIFICATION ADOPTED IN PROJECT

CLASS	SUPPORT	CORRESPONDING RATINGS CSIR (RMR)	NGI (Q)
I / II	NO SUPPORTS / LOCAL BOLTS AND SHOTCRETE	>60	>6.0
III	SYSTEMATIC BOLTS, WIRE MESH AND SHOTCRETE	20-30	0.1 - 6
IV	LIGHT TO MEDIUM STEEL RIBS, BOLTS, WIRE MESH + SHOTCRETE	<20	<0.1

TABLE: 7.1 SEISMIC EVENTS

DAY	MONTH	YEAR	LATITUDE Deg.	LONGITUDE Deg.	FOCAL DEPTH(KM)	MAGNITUDE MS
17	3	1937	9.00 N	83.40 E		
10	9	1938	6.00 N	77.00 E		
10	9	1938	7.70 N	79.20 E		
10	9	1938	7.50 N	79.00 E		5.60
7	8	1939	4.00 N	78.00 E		
7	8	1939	4.00 N	77.50 E		5.50
28	11	1949	8.10 N	83.20 E		
7	12	1949	3.59 N	83.00 E		
29	1	1953	6.70 N	82.50 E		5.00
15	12	1956	6.50 N	78.00 E		
13	6	1961	8.70 N	83.20 E	43	
28	8	1964	10.37 N	83.44 E		
8	1	1966	11.60 N	84.93 E		5.20
5	4	1967	12.30 N	83.00 E		
3	4	1971	10.50 N	83.00 E		
24	11	1972	11.67 N	85.34 E		
30	8	1973	7.10 N	84.31 E	33	5.90

NOTE : DATA ACCORDING TO LIST OF REFERENCE NOS: (18) , (21)

TABLE : 7.2 HISTORIC SEISMIC EVENTS (ACC. FERNANDO ,1986)

No	Date	Remarks
(1)	7 APR 1891	
(2)	25 APR 1891	
(3)	19 AUG 1892	
(4)	8 NOV 1892	
(5)	12 NOV 1892	
(6)	23 NOV 1892	
(7)	17 NOV 1897	
(8)	10 FEB 1900	
(9)	10 SEP 1900	
(10)	4 MAY 1904	
(11)	4 MAR 1907	
(12)	14 MAR 1990	
(13)	6 OCT 1911	
(14)	19 JAN 1913	
(15)	9 MAY 1916	
(16)	18 APR 1917	
(17)	11 AUG 1917	
(18)	21 DEC 1917	
(19)	20 DEC 1917	
(20)	27 AUG 1919	
(21)	11 FEB 1920	
(22)	26 FEB 1920	
(23)	5 APR 1921	
(24)	23 AUG 1921	
(25)	7 FEB 1928	
(26)	9 MAR 1928	
(27)	5 JAN 1930	
(28)	6 FEB 1930	
(29)	5 JAN 1931	
(30)	20 JAN 1935	
(31)	2 APR 1935	
(32)	23 SEP 1935	
(33)	4 JAN 1936	
(34)	7 SEP 1938	
(35)	11 SEP 1938	MM scale V , seismograph put out of action
(36)	23 SEP 1938	
(37)	2 FEB 1939	
(38)	21 MAR 1939	
(39)	8 AUG 1939	
(40)	26 JUN 1941	
(41)	29 FEB 1944	MM scale II
(42)	25 JAN 1951	Tremor felt by many, MM scale III
(43)	4 OCT 1962	Felt at mahailuppallama 0657 h,R.F.scale II -III
(44)	6 MAY 1964	1756 h, felt at many places MM scale II-III
(45)	29 NOV 1966	0505h ,felt at Badulla
(46)	24 APR 1967	Record only 2033-2040 h
(47)	22 JUN 1968	2107 h. felt in hill country MM scale II (no seismograph charts)
(48)	31 AUG 1973	0121 h(local time),epicentre-350 m. MM scale II exact epicentre 7 LM. 84.3E
(49)	28 JUN 1974	13.47 h local time . felt Agrapatana ,balangoda , Gurutalawa
(50)	29 JUN 1974	0344 h local time, Bogawantalawa
(51)	7 JUL 1975	1826 h local time . Query by press seismograph record.letter of H.B.Senaratna of Galewela gives date as 6 July 1975
(52)	23 NOV 1976	2100 to 2230 h local time . Tangalle
(53)	9 OCT 1979	1617-1618 h. felt in Spring Valley estate Badulla Passara , recorded on seismograph. intensity II -III

TABLE : 8 POINT LOAD STRENGTH OF KUKULE ROCKS IN RELATION TO ROCK MECHANICS PARAMETERS OF OTHER SRI LANKAN SITES

ROCK TYPE	POL/ LAX	VICTORIA	SAMANALA	KOTMALE		UPPER KOTMALE					KUKULE
	P.L MPa	uniaxial MPa	u (PO)	P.L ,MPa	uniaxial MPa	M kg/cm	C / O	uniaxial MPa	T.M kg/cm	(PO) u	P.L MPa
CHARNOCKITE	6.5 (8.4 - 4.1)	-	0.27	7.1	125.1	65.6	1.51/62.7	165	2.26	0.33	
CALC SILICATE	4.7 (8.4-1.5)	-	-	11.5	115	-	-	-	-	-	
QUARTZITE	4.3 (6.4 - 2.4)	-	0.2	5.1	60.2	-	-	132	0.71	-	
BIOTITE GNEISS	4.7 (7.7 - 1.5)	106	0.26	7.05	93.2	95.2	1.84/50.1	65	1.42	0.23	
GARNET GNEISS	4.9 (6.1 - 3.5)	159.2		7.1	105.6	-	36.3/70.8	130.65	2.11	0.36	
Quartz Feldspar gneiss											6.9 - 12.3 (14.0)
Garnetiferous Biotite gneiss											4.9 - 11.8
Biotite gneiss -quartz rich											5.4 - 10.8
Hornblende Biotite gneiss											9.4 - 12.3
Charnockitic gneiss											5.6 - 12.1

ABBRREVIATIONS

POL-POLPITIYA
LAX-LAXAPANA

TABLE: 9 GEOMECHANICAL CHARACTERISTICS OF SOIL AND ROCK

WEATHERING GRADE	RQD %	SHEAR STRENGTH		E-MODULE GPa	BEARING CAPACITY MPa	SLOPE INCLINATION
		Ø	C (KN/m2)			
TALUS(BLOCKY)	0	30-35°	10	0.02-0.1	0.02-0.1	1V:1H
TALUS, (RICH IN MATRIX) RESIDUAL SOIL (vi)	0	25-30°	10-30	0.01-0.05	0.1-0.3	1V:1.5H
ROCK Gr. V ROCK Gr. IV -V	0	30-35°	10-50	0.5-1.0	0.5-1.0	1V:1H
ROCK Gr. IV	0-25	35°	150	1-2	1-3	1V:0.25H
ROCK Gr. III - IV	25-50	40°	150	2-5	3-6.5	1V:.0.33H
ROCK Gr. III	50-90	40°	200	5-10	6.5-15	1V:0.1H
ROCK Gr. II	90-100	45°	300	10-25	15-25	1V:0.1H
ROCK Gr. I	100	≥45°	≥400	≥ 25	≥25	1V:0.1H

NOTE: 1. PARAMETERS ARE BASED ON ESTIMATE AND LITERATURE

2. WEATHERING GRADE -RQD-RELATION IS ACC. GEOTECHNICAL CONTROL OFFICE HONG KONG ,BUT SLIGHTLY MODIFIED

3. RQD - BEARING CAPACITY -RELATION IS ACC. PECK AT AL. 1974 BUT SLIGHTLY MODIFIED

KUKULE GANGA HYDRO POWER PROJECT

ROCK MASS DESCRIPTION AND CLASSIFICATION SHEET

SHEET No. 1

SITE LOCATION : DAM SITE

DOMAIN: DAM FOUNDATION

1. **ROCK TYPE** BIOTITE GNEISS

2. **INTACT MATERIAL STRENGTH**

SOIL
VERY SOFT ROCK
SOFT ROCK
HARD ROCK
VERY HARD ROCK 80-150MPa (3)
EXTREMELY HARD ROCK

SCHMIDT HAMMER REBOUND VALUES[1]
POINT LOAD INDEX[2]
ESTIMATED[3]
UNIAXIAL COMPRESSIVE STRENGTH[4]

5. **DESCRIPTION OF WEATHERING**

OXIDATION ON JOINTS IN PLACES THIN BANDS OF MEATHERED MATERIAL

6. **GROUNDWATER CONDITIONS**

MODERATE INFLOW ALONG MEATHERED OR TECTONIZED BANDS

7. **BLASTING EFFECTS (if any)**

9. **CLASSIFICATIONS**

9.1 **ROCK MASS QUALITY, Q**

$Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF}$

$Q = \frac{90-100}{3} \times \frac{3(2)}{2(1)} \times \frac{0.66}{1}$

$Q = 6.6 - 14.5$

9.2 **ROCK MASS RATING, RMR**

$RMR = \sigma c + RQD + SPACING + COND + GW + ORIENTATION$

$RMR = 12+15+20+12+7+(-2)$

$RMR = 64$

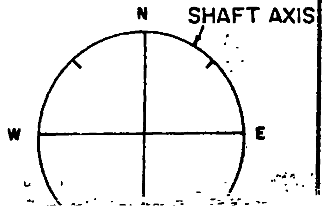
3. **ROCK MASS DISCONTINUITIES**

SET N°	TYPE	ORIENTATION DIP DERECTION / DIP	SPACING MIN.	MAX.	AVE.	N°/ METRE	ROUGHNESS	ALTERATION	CONTINUITY DIP LENGTH(m)	ENDS	STRIKE LENGTH (m)	ENDS
FOL	FOLIATION	060-076°/59-76°	0.15	3.5	0.3-1	2	2-4 (JRC)	NONE	2 m	LIMITS NOT VISIBLE	MAX. 29m	LIMITS NOT VISIBLE
JS1	TENSION	168-180°/40-58°	0.20	5.0	1-3	1	6-10 (JRC)	LOCALLY OXIDE	3	LIMITS NOT VISIBLE	MAX. 25m	LIMITS NOT VISIBLE
JS2	TENSION	305-324°/34-49°	0.30	7.0	1-3	0.5	8-10 (JRC)	LOCALLY OXIDE	5	LIMITS NOT VISIBLE	MAX. 13m	VISIBLE

4. **RQD (EQUIVALENT)**

AVERAGE 90 (-100)

8. **RELATIVE JOINTING ORIENTATIONS**



10. **COMMENTS ON SUPPORT INSTALLATION (if any)**

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC

TABLE 10 (1/3)
ROCK MASS DESCRIPTIO
KK-205 DAM SITE (NEW)

KUKULE GANGA HYDRO POWER PROJECT

ROCK MASS DESCRIPTION AND CLASSIFICATION SHEET

SHEET Nº. 1/2

SITE LOCATION : SURGE SHAFT

DOMAIN: ELEVATION 0.00 TO 10.00

1. ROCK TYPE

RESIDUAL SOIL, WEATHERED CHARNOCKITE

2. INTACT MATERIAL STRENGTH

SOIL 0.05 - 0.2 MPa (3)
VERY SOFT ROCK 1 - 3 MPa (3)
SOFT ROCK 3 - 25 MPa
HARD ROCK ——
VERY HARD ROCK ——
EXTREMELY HARD ROCK ——

SCHMIDT HAMMER REBOUND VALUES (1)
POINT LOAD INDEX (2)
ESTIMATED (3)
UNIAXIAL COMPRESSIVE STRENGTH (4)

5. DESCRIPTION OF WEATHERING

SOIL AND DECOMPOSED ROCK

6. GROUNDWATER CONDITIONS

7. BLASTING EFFECTS (if any)

9. CLASSIFICATIONS

9.1 ROCK MASS QUALITY, Q

$Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF}$

NOT APPLICATED

9.2 ROCK MASS RATING, RMR

RMR = σc + RQD + SPACING + COND + GW + ORIENTATION
= (0-2) + 3 + 5 + (0-6) + 4 + (-2)
= 10 - 18

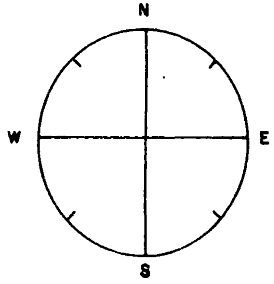
3. ROCK MASS DISCONTINUITIES

SET Nº	TYPE	ORIENTATION DIP DERECTION / DIP	SPACING MIN.	SPACING MAX.	SPACING AVE.	Nº / METRE	ROUGHNESS	ALTERATION	CONTINUITY DIP LENGTH (m)	CONTINUITY DIP ENDS	CONTINUITY STRIKE LENGTH (m)	CONTINUITY STRIKE ENDS
–	–	–										

4. RQD (EQUIVALENT)

0 %

8. RELATIVE JOINTING ORIENTATIONS



10. COMMENTS ON SUPPORT INSTALLATION (if any)

NOTE : DESCRIPTION IS BASED ON RESULTS OF DRILL HOLE KK - 42

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

CECB, TEAMS, RDC

TABLE 10 (2/3)
ROCK MASS DESCRIPTION
KK-205, SURGE SHAFT

KUKULE GANGA HYDRO POWER PROJECT

ROCK MASS DESCRIPTION AND CLASSIFICATION SHEET

SHEET N0. 2/2

SITE LOCATION : SURGE SHAFT

DOMAIN : ELEV. 10.00-20m

1. ROCK TYPE

CHARNOCKITE

2. INTACT MATERIAL STRENGTH

SOIL ___	SCHMIDT HAMMER REBOUND VALUES(1)
VERY SOFT ROCK ___	POINT LOAD INDEX(2)
SOFT ROCK ___	ESTIMATED(3)
HARD ROCK 50-100 MPA(3)	UNIAXIAL COMPRESSIVE STRENGTH(4)
VERY HARD ROCK ___	
EXTREMELY HARD ROCK ___	

5. DESCRIPTION OF WEATHERING

WEATHERING ON JOINTS

6. GROUNDWATER CONDITIONS

7. BLASTING EFFECTS (if any)

9. CLASSIFICATIONS

9.1 ROCK MASS QUALITY, Q

$$Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF}$$

$$= \frac{66\text{-}100}{3} \times \frac{15\text{-}3}{1\text{-}2} \times \frac{0.66}{1}$$

$$= 4.8\text{-}29.0$$

9.2 ROCK MASS RATING, RMR

RMR = δc + RQD + SPACING + COND + GW + ORIENTATION

= 7 + (13-17) + (10-20) + 12 + 4 + (-2)

= 44-58

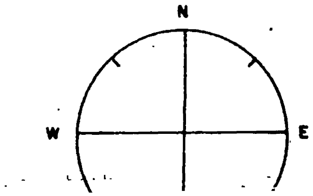
3. ROCK MASS DISCONTINUITIES

SET N°	TYPE	ORIENTATION DIP DERECTION / DIP	SPACING MIN.	SPACING MAX.	SPACING AVE.	N°/METRE	ROUGHNESS	ALTERATION	CONTINUITY DIP LENGTH(m)	CONTINUITY DIP ENDS	CONTINUITY STRIKE LENGTH(m)	CONTINUITY STRIKE ENDS
FOL.	FOLIATION	-/45-60°					JRC=2-4	WEATHERED				
JS1(3)	TENSION	-/65°					JRC=6-10	WEATH; OXIDE				
JS2(3)	TENSION	-/70°-85°					JRC=6-10	WEATH; OXIDE				

4. RQD (EQUIVALENT)

66-100 %

8. RELATIVE JOINTING ORIENTATIONS



10. COMMENTS ON SUPPORT INSTALLATION (if any)

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

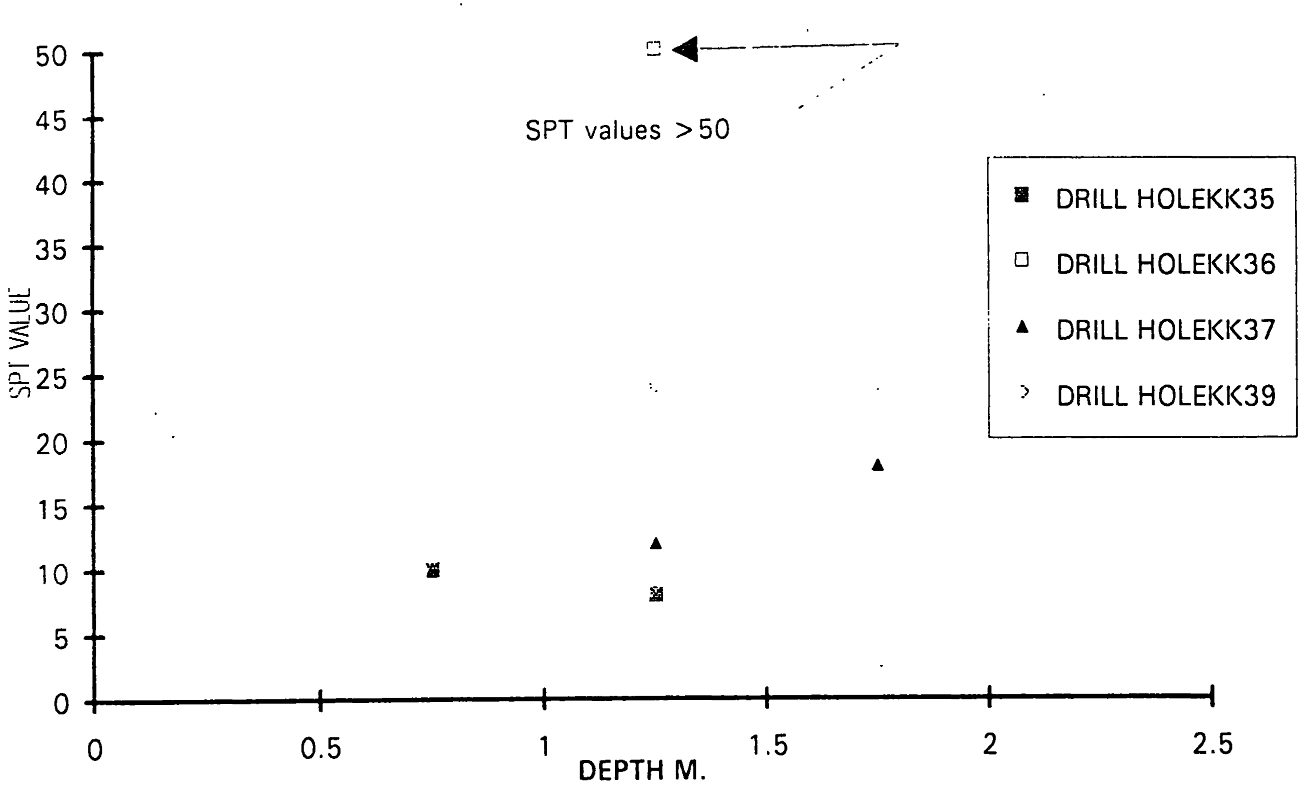
CECB, TEAMS, RDC

TABLE : 10 (3/3)

ROCK MASS DESCRIPTIO

KK-205 SURGE SHAFT

TABLE II (1/4) S.P.T. VALUES VERSUS DEPTH-KK 205 (NEW) DAM SITE

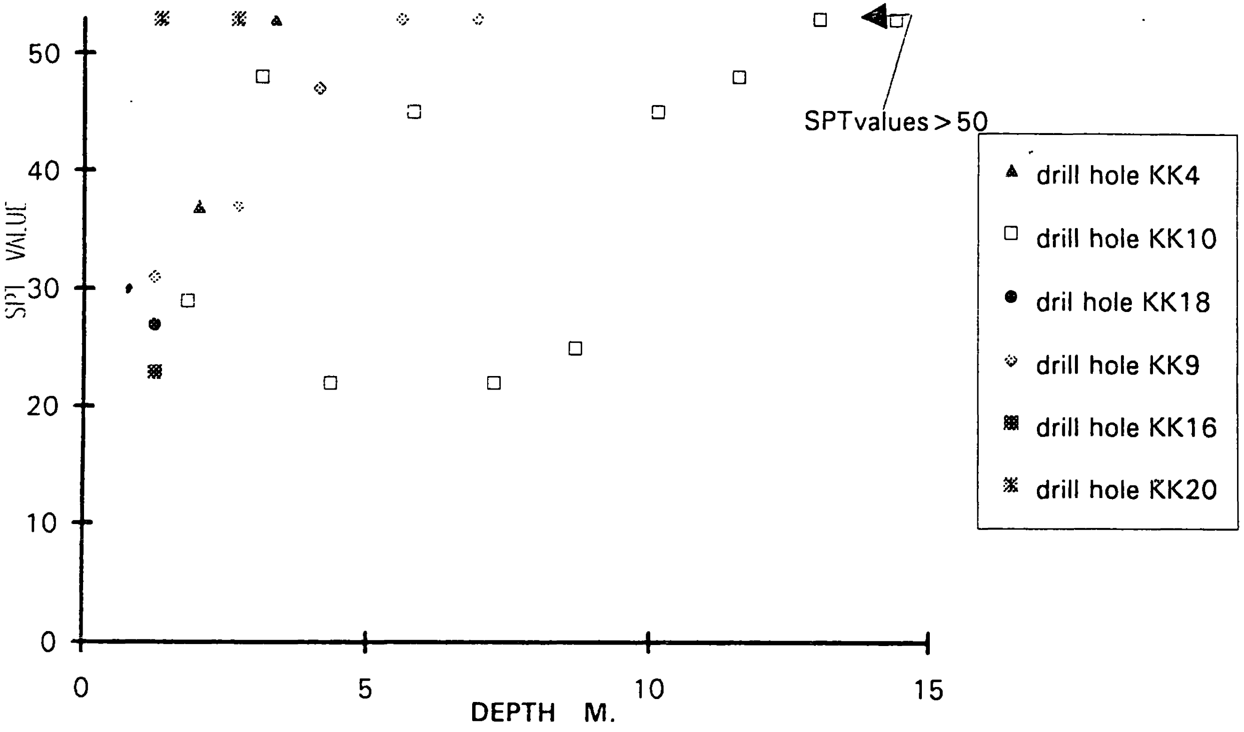


S.P.T RESULTS
KK205 DAM SITE (NEW)

DEPTH M.		SPT VALUE
FROM	TO	
		drill holeKK31
-	-	NO TESTS
		drill holeKK32
		NO TESTS
		drill holeKK33
		in progress
		drill holeKK34
-	-	NO TESTS
		drill holeKK35
0.50	1.00	10
1.00	1.50	8
		drill holeKK36
0.50	1.00	45
1.00	1.50	56
		drill hoieKK37
0.50	1.00	10
1.00	1.50	12
1.50	2.00	18
2.00	2.50	21
		drill holeKK39
1.00	1.50	24

TABLE II (2/4) S.P.T VALUES VERSUS DEPTH - KK 205 (OLD) DAM SITE

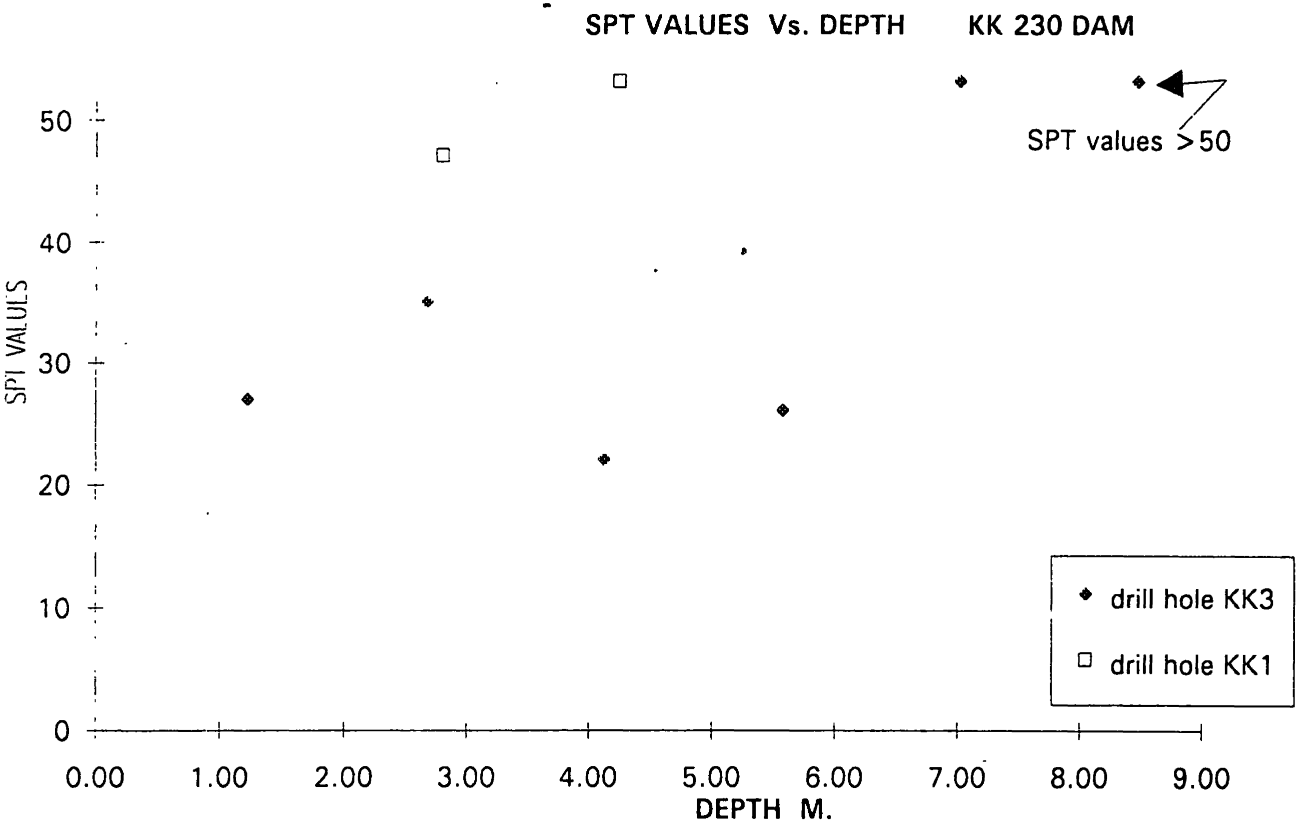
SPT VALUES Vs. DEPTH KK205 DAMSITE



SPT RESULTS
KK205 DAM SITE

DEPTH		SPT VALUE
FROM	TO	
		drill hole KK4
1.77	2.22	37
3.22	3.45	>50
		drill hole KK10
1.58	2.03	29
2.88	3.33	48
4.11	4.56	22
5.56	6.01	45
7.00	7.45	22
8.45	8.90	25
9.90	10.35	45
11.35	11.80	48
12.80	13.25	86
14.25	14.55	>82
		dril hole KK18
1.00	1.45	27
		drill hole KK9
1.00	1.45	31
2.45	2.90	37
3.90	4.35	47
5.35	5.80	63
6.80	7.00	96
		drill hole KK16
1.00	1.45	23
2.45	2.90	66
		drill hole KK20
1.10	1.55	62
[illegible]	[illegible]	150

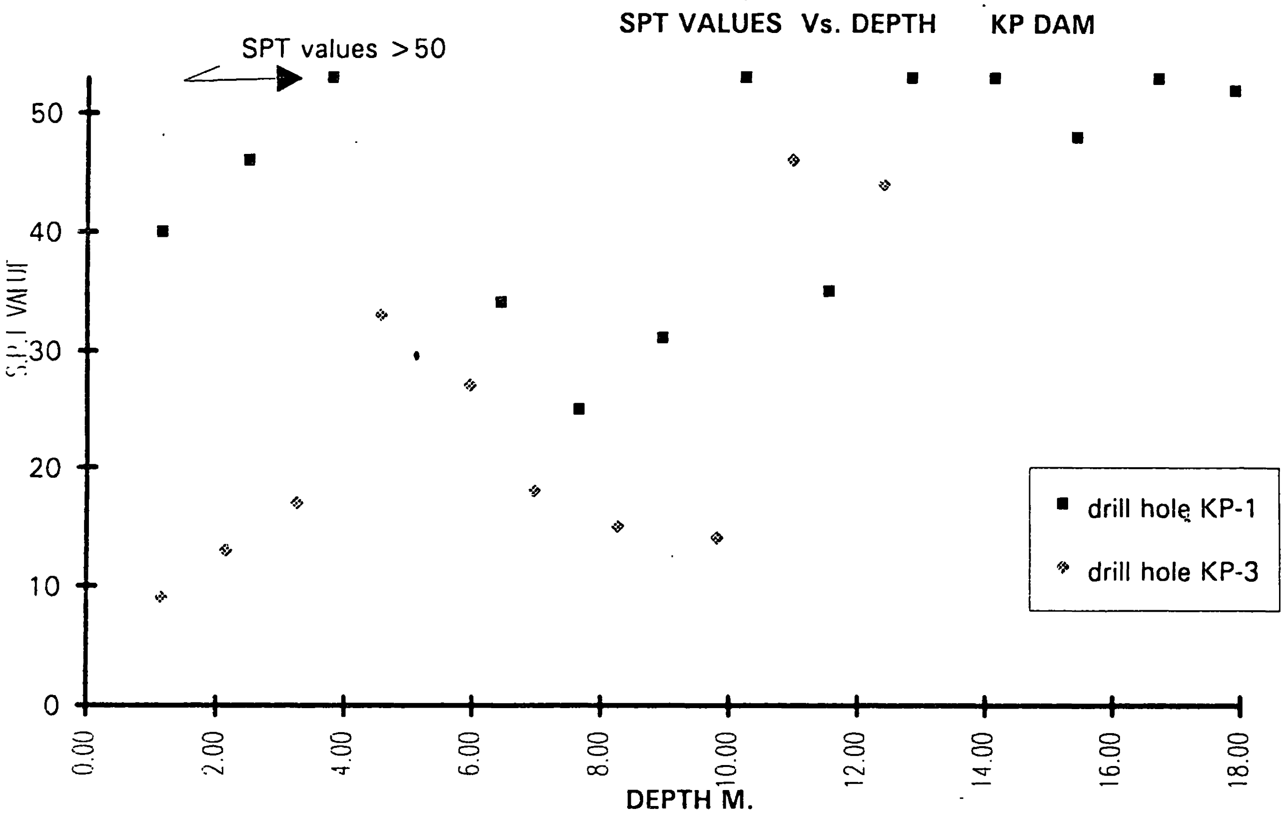
TABLE II (3/4) S.P.T VALUES DEPTH - KK 230 DAM SITE



SPT RESULTS
KK 230 DAM SITE

DEPTH M.		SPT VALUE
FROM	TO	
		drill hole KK3
1.00	1.45	27
2.45	2.90	35
3.90	4.35	22
5.35	5.80	26
6.80	7.25	56
8.25	8.70	89
		drill hole KK1
2.58	3.03	47
4.03	4.48	>50

TABLE II (4/4) S.P.T VALUES VERSUS DEPTH - KP DAM SITE



S.P.T RESULTS
KP DAMSITE

DEPTH M.		SPT VALUE
FROM	TO	
		drill hole KP-1
1.00	1.30	40
2.35	2.65	46
3.65	3.95	54
6.28	6.59	34
7.50	7.80	25
8.80	9.10	31
10.10	10.40	54
11.40	11.70	35
12.70	13.00	56
14.00	14.30	53
15.30	15.60	48
16.60	16.90	67
17.90	18.00	52
		drill holeKP-3
1.00	1.30	9
2.00	2.30	13
3.11	3.41	17
4.41	4.71	33
5.81	6.11	27
6.80	7.10	18
8.10	8.40	15
9.66	9.96	14
10.69	11.26	46
12.26	12.56	44

TABLE : 12 PIEZOMETER INSTALLATION

DRILL HOLE No	ELEVATION OF			MEASURED WATER LEVEL M.	
	COLLAR M.S.L	FILTER SECTION M.S.L			
		TOP	BOTTOM	FROM	TO
K-P DAM SITE					
KP1	223.220	195.220	173.720	13.91	18.35
KP3	217.120	195.820	167.620	8.46	11.49
K-K230 DAM AXIS					
KK1 (PZ 1)	229.655	221.950	196.950	8.47	9.38
KK1 (PZ 2)	229.655	191.650	179.650	19.80	21.00
KK3	197.920	150.920	147.920	ARTESIAN CONDITION	
K-K205 (OLD) DAM SITE					
KK11	211.580	209.580	181.480	12.34	13.74
KK9	211.210	200.710	190.760	7.56	11.40
KK18	205.960	200.960	185.800	6.20	8.80
K-K205 (NEW) DAM SITE					
KK33	210.762	198.262	190.613	10.00	12.65
KK35	204.348	201.348	184.148	0.50	2.30
KK37	212.878	208.878	192.628	2.80	4.80
K-K WATERWAYS					
KK6	242.552	240.552	202.352	0.90	1.14
KK29	254.637	243.637	154.777	0.80	3.13
KK 205(OLD)/230 SURGE TANK					
KK7	301.487	298.487	126.377	23.40	40.03
KK 205 (NEW)SURGE TANK					
KK42	230.900	220.900	0.830	15.65	18.48
KK 205 (NEW)POWER HOUSE					
KK43	#				
KK 205 (NEW) OUTFALL					
KK8	40.568	3.568	0.518	9.00	9.25

- HOLE TO BE COMPLETED

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

B.H KK I | SHEET OF

FEATURE - KK 230 , DAM AXIS

DRILLING DATA

STARTED 92.01.04 COMPLETED 92.01.24
INTERRUPTIONS (DAYS) 04
MACHINE TYPE
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN ID LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 152052.69N
Y-COORDINATE 150859.48E
ELEVATION (COLLAR) 229.655
ELEVATION (BOTTOM) 179.425
FINAL DEPTH 50.23M.
INCLINATION FROM VERTICAL: 0°
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION

V = very tight		< 0.1mm
T = tight		0.1-1.0mm
MO = moderat open		1.0-5.0mm
O = open		> 5.0mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
P.L.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.0
weak	B	1.0 – 5.0
	C	5.0-25 0
moderately strong		25 0-50 0
strong		50 0-100
very strong		100.0-25
extremely strong		> 250

DRILLING

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS
1.28			DRY DRILLING		
2.58	2.58 01/04				
3.03					
4.03					
4.94	4.94 01/05	4.94 01/05	YELLOWISH / GREYISH		
		5.60 01/08			
6.15					8.2 01/06
	8.37 01/06				
9.67	10.27 01/08				7.79 01/08
12.77					7.79 01/09
15.04	15.04 01/09		GREYISH		7.79 01/10
18.15	19.06 01/10				8.1 01/11
21.28	21.28 01/11				8.36 01/12
	24.46 01/13				
25.05					8.42 01/14
	27.7 01/1				

TESTS

TEST	RESULT
SPT	47
SPT	>50

JOINTS

JOINT SET NO.	ROUGHNESS	SEPARATION
I	R	O
II	R	O
III	R	O
I	R	O
I	R	MO
I	R	MO
I	R	MO
I	R	MO
II	R	MO
II	R	T
II	R	T
II	R	MO
I	SL	T
II	SL	T
III	SL	T
II	SL	T
III	SL	T
III	SL	T
I	SL	T
III	SL	T
I	SL	T
II	SR	T
IV	SL	T
I	S	T
III	S	T
II	S	T
III	S	T
II	R	T
III	R	T
II	R	T
III	R	T
II	R	T

SPACING: < 0.05m, 0.05-0.30m, 0.30-1.00m, 1.00-3.00m, > 3.00m

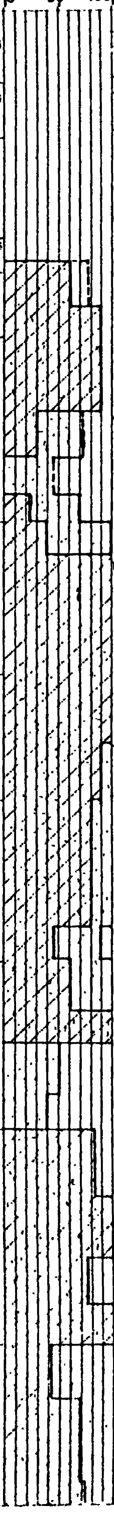
PERMEABILITY

DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
0.0	1.28			K=1.207×10⁻⁵
1.28	2.58			K=5.53×10⁻⁶
2.58	4.03			K=2.96×10⁻⁶
4.03	4.94			K=5.86×10⁻⁶
6.15	9.67	1	39.0	73.7
		3	54.0	27.6
		45*	63.5	36.1
		3	55.2	44.8
		1	39.5	74.7
9.75	12.77	1	9.5	18.1
		3	11.5	10.1
		6	14.0	6.8
		3	11.9	10.4
		1	10.2	18.9
12.77	15.04	1	6.4	16.7
		3	7.3	8.7
		6	8.8	6.5
		3	8.3	9.9
		1	6.8	17.7
15.04	18.15	1	14.3	25.4
		3	16.1	13.6
		6	18.9	8.9
		3	17.2	14.5
		1	14.6	25.9
17.76	21.28	1	17.2	31.1
		3	25.6	20.4
		6	36.0	15.6
		3	26.2	20.8
		1	17.8	32.2
21.53	25.05	1	7.8	14.1
		3	9.7	7.7
		6	12.4	5.4
		3	10.2	8.1
		1	8.1	14.7
24.61	28.13	1	6.0	10.7
		3	7.4	5.8
		6	9.2	4.0
		3	7.5	5.9
		1	6.2	11.0

* PRESSURE COULD NOT BE DEVELOPED

RECOVERY

CORE RECOVERY % AND R Q D %
0 50 100



GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc · scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

TOP SOIL DARK BROWN CLAYEY SAND
COBBLE (AMPHIBOLITE)
RESIDUAL SOIL. REDDISH BROWN CLAYEY SAND
COBBLE (CHARNOKITE)
COM WEATHERED ROCK REDDISH BROWN

WHITISH TO YELLOWISH BROWN KAOLINE RICH ROCK

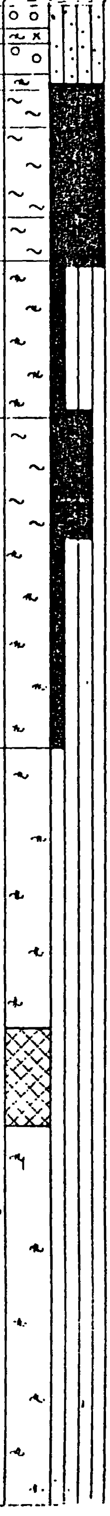
REDDISH BROWN ROCK

CHARNOCKITIC GNEISS, GREY MEDIUM GRAINED GNEISSIC. MAIN COMPONENTS Qu, FD, Py WITH HORNBLENDE-ENRICHED BANDS
FROM 4.94 TO 5.5 CL SPACED WITH FJ
AT 5.3, 5.4, 6.35 FJ/70° WEATH.
AT 5.2, WEATH J/60°
AT 5.29 WEATH J/15°

WHITISH, MEDIUM GRAINED WEAK TO MODERATELY STRONG GNEISSIC ROCK.
FROM 7.78 TO 8.37 CL. SP WETH FJ/40°
FROM 8.37 TO 9.07 WETH F/J CLOSLY SPACED
AT 9.08, 9.20, 9.29, 9.38, 9.41, 9.72, 9.75, 9.87 FJ WETH
CHARNOCKITIC GNEISS. GREY TO DARK GREY. MEDIUM GRAINED. IN PATCHES WITH BLACKISH, THIN HORNBLENDE-RICH LAYERS.
AT 9.67 TO 9.88 WEATH J/85°
AT 9.68, 9.94 WEATH J/10°
AT 11.86, 12.10, 12.87, 13.56 J/60°
FROM 13.8 TO 14.25 WEATH J/70°
AT 14.09 WEATH J/85° (OPEN)

CHARNOCKITIC GNEISS AS ABOVE.
AT 15.04, 17.08, 17.18, J/35°
AT 17.05 FJ/60°
FROM 17.08 TO 17.25 J/80°
AT 17.34, 17.82, 17.88, 17.94, 18.04, 18.60, 18.82, 18.88, 18.92 J/50° CHL FILLED
FROM 17.95 TO 18.15 J/80°
AT 17.91, 18.15 J/20°
AT 18.92, 18.93, 18.95 J/40°
FROM 19.50 TO 21.28 TECTONIZED ZONE CL. SPACED CHL SL J/70° AND 30°
AT 21.44, 21.66, 22.16, 21.27 SL (SILICA FILLED 1mm) J/30°
AT 21.40, 24.10 J/60°
AT 22.35, 22.53, 23.24, 23.44 CHL. J/10°
AT 22.96 SL WEATH FJ/60°
AT 23.68, 23.80, 24.44, 24.46 CHL. J/10°
AT 23.58 SL WEATH J/10°
AT 25.44, 25.58, 25.70, 25.05, 26.18, 26.60, 26.50, 26.66, 27.18, 27.41, 27.57, 27.68, 27.70, 28.0 J/10°
AT 26.87, 26.95, 27.08, 27.19, 26.27, 27.92 J/60°

GRAPHIC LOG | WEATHERING



ENGINEERING ASPECTS

ROCK STRENGTH

REMARKS (with respect to excavation, grouting, permeability, rock quality etc.)

KUKULĒ GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 230, DAM AXIS

B.H. KK1 — SHEET 02 OF 02

DRILLING DATA

RTED 92 01 04 COMPLETED 92 01 24
RRUPTIONS (DAYS) 04
HINE TYPE
LING METHOD ROTARY
E BARREL, BIT NX
EMAN ID LOGGED BY
STORED AT
DISCARDED, DATE

BOREHOLE DATA

X-COORDINATE 152852 69N
Y-COORDINATE 150859 48E
ELEVATION (COLLAR) 229 655
ELEVATION (BOTTOM) 179 425
FINAL DEPTH 50 23M
INCLINATION 0° FROM VERTICAL:
BEARING
LOCATION (see)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0 1mm
R = rough	T = tight	0 1-1 0mm
SR = slightly rough	MO = moderately open	1.0-5 0mm
S = smooth	O = open	> 5 0mm
SL = slickensided		

RECOVERY

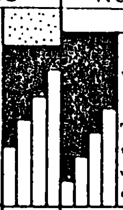
▒ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS

PL.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh



ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1 0 - 5.00
	C	5 0-25 00
moderately strong		25 0-50 00
strong		50 0-100 00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING: DAILY ADVANCE; CASING / CEMENT; DRILL WATER (COLOR, LOSS); RATE OF DRILLING; WATER LEVELS

TESTS: TEST; RESULT

JOINTS: JOINT SET NO.; ROUGHNESS; SEPARATION; SPACING (< 0.05m, 0.05-0.30m, 0.30-1.00m, 1.00-3.00m, > 3.00m)

PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total Litres/minute); LUGEON or PERMEABILITY m/sec

RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)

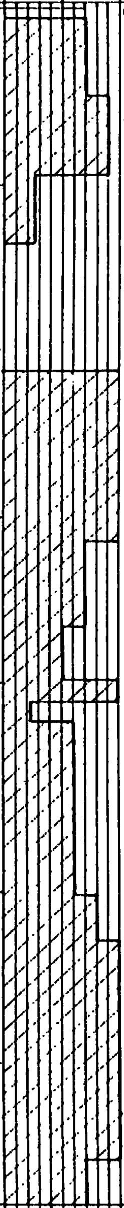
GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc · scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

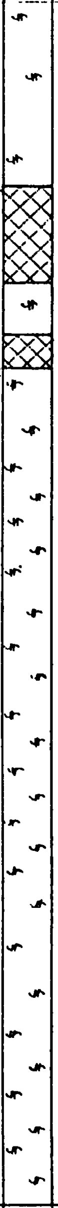
GRAPHIC LOG; WEATHERING

ENGINEERING ASPECTS: ROCK STRENGTH; REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

DEPTH (m)

DAILY ADVANCE	WATER LEVELS	JOINT SET NO.	ROUGHNESS	SEPARATION	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON	GENERAL DESCRIPTION	DEPTH (m)
		III	R	T	27.78					CHARNOCKITIC GNEISS AS ABOVE	
		II	R	T			1	7.6	13.5		
8		III	R	T			3	9.2	7.3	AT 28 04, 28 10, 28 13, 29 03 CHL J/10°- 20°	
	8.47 01/15						6	11.4	4.9		
		II	R	T			3	9 4	7.4	AT 28 64, 28 65, 28 82, 28 94, 29 08, 29 09, 29.15, 29.50 J/60°	
		III	R	T			1	7.7	13.6		
08 /15						31 3					31.06
		II	S	T	30 87					AT 29 96, 31.28, 33 30, 33 42, 33 94 J/20°	
		III	S	T			1	8.2	12.6		
							3	10.2	7.5		
	8.58	I	S	T			6	12.6	5.2	AT 30 41, 30.44, 30 74, 31 32, 33 23, 33 60, 33 89, 34 06, 34.22, 34 39 CHL/ SILICA FILLED J/60°	
	01/16	II	SL	T			3	10.3	7.6		
10 1/16		III	S	T		34.39	1	8 4	12.9		34 0
		III	SL	T	34 02						
							1	8.4	13.0	FROM 31 50 TO 33.20 TECTONIZED ZONE CLOS. SPACED CHL J	
		I	S	T			3	10.8	8.0		
		II	S	MO			6	13.4	5.6	AT 33.15 CHL FILLED FJ/50°	
11.1 /17	9.38 01/17						3	11.0	8.1		[illegible] 1
		II	R	T			1	8.6	13.3	FROM 34 39 TO 34 90 TECTONIZED ZONE CL. SPACED	
		III	R	T							
		III	R	T		37.54				AT 35.44, 36 10, 37 30 J/20°	
					37.28						
10 /18										AT 35 26, 36.10, 36 64, 37.54 J/50°, 60°	38 0
		I	R	T			1	8.8	12.9		
		II	R	T			3	11.4	8.1	AT 38.53 FJ/60°	
							6	14.8	6.0	AT 38 13, 38 23, 38 24, 38 64, 39 26, 39.62, 39.66, 39.88, 39 92, 40.35 CHL FILLED J/50°- 60°	
	9.8 01/10						3	11.8	8.4		
		I	S	T			1	9.0	13.2		
18 /19		II	S	T		40.8				AT 39 55 CaCO$_3$ FILLED (2mm) J/05°	40.8
					4. 21						
.38 /20		II	R	T			1	2.8	4.2	FROM 40 52 TO 40 68 CL SPACED FJ/65°	41 38
							3	3.6	2.6		
		II	R	T			6	4.6	1.9	AT 41 05, 41 18, 42 50, 42 95, 44 42 CHL FILLED J/50°-60°	
		III	R	T			3	3.6	2.6	AT 43 21, 43 32, 44.46, 44 48, 44 50, 45.0 CHL FILLED J/40°	
	20.72 01/20						1	2.9	4.3		
						44.4					
					44.43						
		III	SL	T			1	3.1	5.0		
	21.0						3	4.9	3.8	AT 46 63, 46 77, 48 10, 49.5, 99.52 49.54, 49 62, 49 65, 49 79, 49 88 CHL FILLED J/50°- 60°	
	01/23						6	6.2	2.7		
546 1/23							3	5.1	3.9		4[illegible] 45
		II	R	T			1	3 3	5.3		
						47.65					
					47.85					AT 46 60, 49 96 CHL FILLED FJ/60	
		II	R	T			1	2.9	6.8		
	21.0						3	3.7	4.1		
	01/23						6	5.6	3.5		
							3	4.3	4.7		
		I	R	T							
		II	R	T		50 23	1	3.1	7.2		





HOLE COMPLETED AT THE DEPTH OF 50.23m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

B.H. KK2 SHE OF

FEATURE – KK 230, DAM. AXIS

DRILLING DATA

STARTED. 91.12.15 COMPLETED 92.02.14
INTERRUPTIONS (DAYS): 21 days
MACHINE TYPE
DRILLING METHOD. ROTARY
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 152813·43 N
Y-COORDINATE 180,813·35 E
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH. 100·0 m
INCLINATION FROM VERTICAL: 30°
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION
VR = very rough	V = very tight < 0.1mm
R = rough	T = tight 0.1-1.0mm
SR = slightly rough	MO = moderat open 1.0-5.0mm
S = smooth	O = open > 5.0mm
SL = slickensided	

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
P.L.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▽ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGT

	MN/m²	
	A	
weak	B	1.0 -
	C	5.0 -
moderately strong		25.0 -
strong		50.0
very strong		100.
extremely strong		

DRILLING | TESTS | JOINTS | PERMEABILITY | RECOVERY | GENERAL DESCRIPTION | ENGINEERING ASPE

Column headings: DEPTH (m); DRILLING: DAILY ADVANCE, CASING/CEMENT, DRILLWATER (COLOR, LOSS), RATE OF DRILLING, WATER LEVELS; TESTS: TEST, RESULT; JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, > 3.00 m); PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec; RECOVERY: CORE RECOVERY % AND R.Q.D % (0 50 100); GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ROCK STRENGTH; REMARKS (with respect to excavation, grouting, permeability, rock etc.)

DEPTH (m)	DAILY ADVANCE	DRILLWATER (COLOR, LOSS)	JOINT SET NO.	ROUGHNESS	SEPARATION	DEPTH FROM TOP	DEPTH TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
	1.83 12/15									
	6.0 12/19									
	12.0 20/12	BROWNISH						NO TESTS WERE PERFORMED		
	18.3 21/12		I	T	R	18.85				
18.75			II	T	R					
			I	MO	R			1	4.0	11.1
19.8	19.8 22/12		II	MO	R			3	7.0	6.6
			I	T	R			6	9.6	4.5
			II	T	R			3	7.8	7.4
								1	6.2	17.2
21.5			I	T	SL					
	22.35 25/12						22.35			
						21.98				
			I	T	SL			1	8.1	22.5
			II	T	SL			3	10.7	10.1
								6	13.5	6.4
24.88		GREYISH						3	11.1	10.5
	25.48		I	T	SL			1	8.9	24.7
	26/12		II	T	R		25.48			
			II	T	R	25.20		1		
								3		
26.27			I	T	S			6	NIL	NIL
			II	T	S			3		
								1		
27.73			I	T	S					

TOP SOIL, SILTY CLAY

RESIDUAL SOIL YELLOWISH BROWN TO REDDISH BROWN CLAYEYSAND

WASH SAMPLE, COMPLETELY WEATHERED ROCK

GARNETIFEROUS BIOTITE GNEISS LIGHT GREY MEDIUM GRAINED, MAIN COMPONENTS Qu, Fd, Bi, GA WITH INTERCALATION OF DARK COLOURED HORNBLENDE – BIOTITE GNEISS

FROM	TO
18·50	18 9
21 50	21·8
25·3	25 48
26 27	26·40
27·73	28·93
51·08	52·70

AT 18·34, 18 46, 18·50, 18·70, 18 7 FJ
AT 18 65, 18 72 J/60°

AT 18 8, 19 8 (3mm SILICA FILL) SLS FJ

FROM 19 30 TO 19 37 CL.SP FJ
AT 19 39, 19 50 (SL.W) 19 63 FJ

SL.W J/70° FROM 18·78 TO 1903
19 12 TO 19·4, 19 8 TO 19 80 (3mm FILL)

AT 19 93, 19 95, 20 25, 20 47, 20 75
20 82, 21 08 FJ
FROM 21 32 TO 21 50 CL Sp FJ
FROM 20 35 TO 20·55, 20 50 TO 20 68
20 70 TO 20·86, 21·0 TO 21 5 J/65
FROM 21·5 TO 22 35 TECTONIZED ZONE
.CL SP CHL, SLS, SLIGHTLY WEATHERED
FROM 22 35 TO 24 72
TECTONIZED ZONE

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES **TAB. 13**

FEATURE – KK 230, DAM. AXIS

B.H KK2 SHEET 02 OF 04

DRILLING DATA

RTED. 91.12.15 COMPLETED 92·02·14
RRUPTIONS (DAYS). 21 days
HINE TYPE
LING METHOD ROTARY
EY BARREL, BIT· NX
EMAN· LOGGED BY·
E STORED AT
DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 152813·43 N
Y-COORDINATE 160,813·38 E
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH. 100·0 m
INCLINATION FROM VERTICAL: 30°
BEARING
LOCATION (see f.g

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0.1 mm
T = tight 0.1-1.0 mm
MO = moderat open 1.0-5.0 mm
O = open > 5.0 mm

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

OTHER SYMBOLS
PL S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0-25 00
moderately strong		25 0-50 00
strong		50.0-100 00
very strong		100.0-250 00
extremely strong		> 250.00

DRILLING — DAILY ADVANCE, CASING/CEMENT, DRILL WATER (COLOR, LOSS), RATE OF DRILLING, WATER LEVELS

TESTS — TEST, RESULT

JOINTS — JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, > 3.00 m)

PERMEABILITY — DEPTH (m): FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total Litres/minute); LUGEON or PERMEABILITY m/sec

RECOVERY — CORE RECOVERY % AND R Q D % (0, 50, 100)

GENERAL DESCRIPTION — rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

GRAPHIC LOG — WEATHERING

ENGINEERING ASPECTS — ROCK STRENGTH; REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.); DEPTH (m)

JOINT SET NO.	ROUGHNESS	SEPARATION	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON	GENERAL DESCRIPTION
I III	T T	R R		28·7				GARNETIFEROUS BIOTITE GNEISS AS ABOVE.
I I	T T	S R	28 24	31 74	1 3 6 3 1	NIL	NIL	AT 24 87 (GRAPHITE TRACES) 24·89, 25·07 (SLS), 25 32 (3 mm SILICA FILL) FROM 24·87 TO 24·96, 25·13 TO 25 24 AND FROM 25 67 TO 25·95 J/80° AT 26 42, 26 67, 26 76, 26 80 FJ AT 27·0, 27·25, 27·56 J/60° AT 27·34, 27·65, 28·45, 27·85 J/30°
I I I	T T T	R S R	31 67	35 17	1 3 6 3 1	NIL	NIL	FROM 28·35 TO 28 46 J/85° AT 27·8, 27·92, 28·33, 28·58, 28 70 FJ FROM 28 7 TO 28 85 CI SP. J CHL, MYLONITE LAYER 8CM THICK AT 28·02, 28 28, 28·35, 29·16, 29 27 29·43, 30 65 FJ.
I II II I	T T T T	R R S S	34 89	38 39	1 3 6 3 1	NIL	NIL	AT 31·20, 31·42, 31·74, 32·3, 32·68, 33·3, 33·70, 33 78, 33·87 34·5, 35·17, 35·32, 35·37 35 95, 36·15 FJ/35° FROM 36 22 TO 36·42 J/70° FROM 36 42 TO 36 56, 36·45-36 72 36·71 TO 36·92 J/80°
I I	T T	SR SR	38 39	41 86	1 3 6 3 1	NIL	NIL	AT 39·46, 39 49, 39 36, 39 54 40 15, 40 68, 41 41, 41 86 FJ/28°
I II I II III	T T T T T	R R R R R	41·7	45·2	1 3 6 3 1	NIL	NIL	AT 42 30 J/50°, 43,65 J/60° FROM 42 82 TO 43·8 J/80° AT 44 54 J/20°
I II I II	T T T T	SR R SR SR	45·1	48 6	1 3 6 3 1	4·8 6·3 8·2 6·6 5·1	13·3 5·9 3 9 6·2 14·1	AT 46 26, 46 50, 46 62, 47 0, 47·5, 47 75, 48·6, 48·34, 49·24, 49·56, 49 83, 50 06, 50·66, 50·98, 59 02 FJ/25-35 FROM 49·90, TO 50 0, 50·56 TO 52 02 J/70°
I II I	T T T	SR SR R	48 62	52 02	1 3 6 3 1	1·2 1·4 1·6 1·4 1·1	3·3 1·3 0·8 1·3 3·0	AT 52 64, 52 80, 54·40, 54·53 55·23, 55 65, 55 8, 56 30 FJ/30°
I II I	T T T	R R R	51·73	55 23	1 3 6 3 1	1·6 2 5 3 6 2·7 1·9	4·4 2·4 1·7 2·5 5·3	AT 52 81 J/60° AT 56 68, 56 77, 56 86, 56 98, 57·85, 58·04, 58·08, 58 14 58·30, 58·58 FJ/28°
I	T	R						

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 230, DAM. AXIS

B.H KK2 SH OF

DRILLING DATA

STARTED. 91.12.15 COMPLETED 92·02·14
INTERRUPTIONS (DAYS) 21 days
MACHINE TYPE
DRILLING METHOD. ROTARY
CORE BARREL, BIT · NX
FOREMAN · LOGGED BY ·
CORE STORED AT ·
CORE DISCARDED, DATE ·

BOREHOLE DATA

X-COORDINATE 182813·43 N
Y-COORDINATE 180,813·38 E
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH. 100·0 m
INCLINATION FROM VERTICAL: 30°
BEARING
LOCATION (see f.g

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
▒ CORE RECOVERY (%)
▨ R.Q.D (%)

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1–1.0mm
MO = moderat. open 1.0–5.0mm
O = open > 5.0mm

OTHER SYMBOLS
PL.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENG

MN/m²
A
weak B 1.
C 5.
moderately strong 25
strong 5
very strong 10
extremely strong

DRILLING · TESTS · JOINTS · PERMEABILITY · RECOVERY · GENERAL DESCRIPTION · ENGINEERING ASPE

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	GENERAL DESCRIPTION (rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints)	REMARKS (with respect to excavation, grouting, permeability, rock etc.)
58·43	58·62 14/01							I	R	T			1 3 6 3 1	2·1 2·8 3·9 3·0 2·3	5·8 2·6 1·8 2·8 6·4	GARNETIFEROUS BIOTITE GNEISS AS ABOVE. AT 58·75, 59·12, 59·16, 59·26, 59·33, 59·42, 59·51 FJ/30° AT 58·86, 59·26, 59·55 J/60°	
59·6 60·89	61·94 15/01							I II I II I	R R SR SR SR	T T T MO T	58·44	61·94	1 3 6 3 1	6·3 8·8 12·8 9·7 7·0		FROM 59·60 TO 59·99 MYLONITE FILLED (2 mm) J/85° AT 59·7, 59·83, 59·98, 60·02, 60·24 FJ/25° – 35° GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY, MEDIUM GRAINED. MAIN COMPONENTS Qu, FD, GA, BI WITH HORNBLENDE-RICH BAND AT 62·52 TO 64 90 AT 61·10, 61·3, 61·4, 61 94 FJ/20°	
	62·65 16/01 63·28 21/01 63·96 23/01							III II III	SR SR R	MO T T	61·82	65·32	1 3 6 3 1	1·8 2·7 3·9 3·0 2·0	4·3 2·2 1·6 2·5 4·8	AT 62·46, 62·54, 62·58 J/10° OPEN J/15° AT 62·63, 62·70, 62·85, 62·68, 62·77 FROM 62·85 TO 63·98 Cl. SP. (2–3 cm) J/15° FROM 62·98 TO 63·95 J/85°	
65·32	67·12 24/01							I I	R R	MO T	65·32	68·77	1 3 6 3 1	0·8 1·2 1·8 1·3 0·9	2·2 1·1 0·8 1·2 2·5	AT 64·3, 64·36, 64·58, 64·76, 64·90 J/15° SL. WETH FJ AT 65 5, 65 53, 65·57, 65·64, 65·69, 65·75, 65·96, 66·06, 66·17, 66·38, 66·88, 67·10	
68·77	71·38 23/01 72·22 26/01		GREYISH					I II I	R R R	T T T	68·72	72·22	1 3 6 3 1	NIL	NIL	AT 69·60 J/45° AT 68·66, 69·32, 70·02, 70·28, 70·32, 71·66, 72·22 FJ/10°–15° FROM 72·53 TO 72·76 J/85° FROM 73·02 TO 73·20 03 Nos. SUBVERTICAL, PARALLEL J	
73·22 74·59	75·50 27/01							II I II I II	R R R R R	T T T T T	72·0	75·5	1 3 6 3 1	NIL	NIL	GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY, MEDIUM GRAINED, MAIN COMPONENTS Qu, FD, GA, BI WITH INTERCALATION OF CHARNOCKITIC GNEISS AND HORNBLENDE RICH LAYERS	
76·57	77·69 28/01 78·83 03/02							I I I II I II	R R SR SL SR SR	T T T T T T	75·33	78·83	1 3 6 3 1	1·2 1·6 2·1 1·4 1·0	3·3 1·5 1·0 1·3 2·8	AT 74·10, 75 20, 75 44, 75·72, 76 26, 76·30, 76·36, 76·44, 76 58 FJ/15° FROM 75·5 TO 75·80 J/80° HORNBLENDE-RICH LAYERS AT 75·20 TO 75·75 76·50 TO 76·90 78·20 TO 79·25	
79·96 80·85 81·46	80·87 04/02 82·30 05/02							I II II I	SR R R SR	T T T O	78·8	82·30	1 3 6 3 1	22·0 36·8 40·2 31·4 23·0	62·9 35·0 19·1 29·9 65·7	AT 76·63, 76·74, 76·79, 76·82, 76·83, 76·88, 76·95, 77·0, 77·59 FJ/20° FROM 76·60 TO 76 80 J/70° FROM 77·0 TO 77·5 J/80° FROM 77·36 TO 77·65 03 Nos. SLS. J/75° AT 78·3, 78·38, 78·4, 78·48, 79·13, 79·46, 79·59 J/15° FROM 78·16 TO 78·55 J/80° AT 80·80 J/60°	ARTESIAN CONDITION REACHING THE DEPT 82 3 FLOW RATE MA MIN (ON 14 02 92)
83·8								II	SR	T	82 21					FROM 81·0 TO 81·40, 82·0 TO 82·35 J/80° AT 81 72 OPEN FJ FROM 83 7 TO 84·05 03 Nos. OF II J/60°–80°	

RECOVERY: CORE RECOVERY % AND R.Q.D % 0 50 100

GRAPHIC LOG · WEATHERING · ROCK STRENGTH

SPACING: < 0.05 · 0.05–0.30 · 0.30–1.00 · 1.00–3.00 · > 3.00

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 230, DAM AXIS

B.H KK2 SHEET 04 OF 04

DRILLING DATA

ARTED 91 12.15 COMPLETED 92·02·14
ERRUPTIONS (DAYS) 21 days
CHINE TYPE
LLING METHOD ROTARY
RE BARREL, BIT: NX
REMAN: LOGGED BY:
E STORED AT
E DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 152813·43 N
Y-COORDINATE 180,813·35 E
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH 100 0 m
INCLINATION FROM VERTICAL: 30°
BEARING
LOCATION (see

KEY

JOINT ROUGHNESS	JOINT SEPARATION
VR = very rough	V = very tight < 0.1mm
R = rough	T = tight 0.1–1.0mm
SR = slightly rough	MO = moderat open 1.0–5.0mm
S = smooth	O = open > 5.0mm
SL = slickensided	

RECOVERY	OTHER SYMBOLS
▒ CORE RECOVERY (%)	PL.SI = point load strength index
▨ R.Q.D (%)	U.C.S = uniaxial compressive strength
	▼ = first ground water
	R = rock sample
	W = water sample

WEATHERING

soil: unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING | TESTS | JOINTS | PERMEABILITY | RECOVERY | GENERAL DESCRIPTION | ENGINEERING ASPECTS

Column headings: DAILY ADVANCE; CASING/CEMENT; DRILL WATER (COLOR, LOSS); RATE OF DRILLING; WATER LEVELS; TEST; RESULT; JOINT SET NO.; ROUGHNESS; SEPARATION; SPACING (< 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m); DEPTH (m) FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total Litres/minute); LUGEON or PERMEABILITY m/sec; CORE RECOVERY % AND R Q D % (0 50 100); GRAPHIC LOG; WEATHERING; ROCK STRENGTH; REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.); DEPTH (m)

General description: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

Joints

JOINT SET NO.	ROUGHNESS	SEPARATION
II	SR	T
II	SR	T
I	SR	MO
I	SR	MO
I	SR	T
III	SR	T
I	SR	T
II	SR	T
I	SR	T
II	R	T
III	R	T
I	R	T
II	R	T
I	R	T
I	R	T
I	R	MO
III	R	T
III	R	O
II	R	T
I	R	T
II	R	MO
II	R	T
I	R	T
II	R	T
I	R	T

Permeability

FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
	85·71	1	10·8	33·9
		3	17·2	16·9
		6	24·4	11·8
		3	19·0	18·7
		1	12·3	38·6
85·31	88·8	1	2·7	8·5
		3	3·9	3·8
		6	5·7	2·8
		3	4·0	3·9
		1	2·9	9·1
88·71	92·21	1	0·8	2·5
		3	1·4	1·4
		6	2·1	1·0
		3	1·5	1·5
		1	1·0	3·1
92·19	95·69	1	NIL	NIL
		3		
		6		
		3		
		1		
95·45	98·95	1	3·8	11·9
		3	5·1	5·0
		6	6·8	3·3
		3	5·6	5·5
		1	4·6	14·4

General description

GARNETIFEROUS BIOTITE GNEISS AS ABOVE FROM 84·04 TO 84·12, 84·87 TO 86·10 J/80°

AT 84·9, 85·10, 85·48, 85·8, 85·92 85·98, 86·12, 86·43, 86·82, 86·84, 86·92 FJ/10°–15°
AT 85·28, 87·42, 88·19, 88·93, 89·42, 89·70, 89·80 J/15°
AT 87·52, 88 10, 88·21, 88·25, 88·64, 88·75 FJ/15°
AT 89·08, 89·43, 89·90, 91·30 J/85°
FROM 89·50 TO 89·86 02 No. J/85°

HORNBLENDE-RICH LAYERS

FROM	TO
89·55	90·25
97·38	97·88

FROM 91·41 TO 91·66 03 No. J/70°

AT 90·18, 90·32, 90·53, 90·75 91·22, 91·41, 92·92, 93·16, 93·65, 93·72 FJ/15°
AT 90·06, 90·08, 90·18, 90·40 J/20°
AT 90·06, 90·08, 90·18, 90·40 J/20°
AT 90·55, 93·55 J/60°
AT 94·53, 94·77, 94·80, 96·60, 97·82, 99·12, 99·48, 99·52, 99·58, 99·68, 99·77, 99·83, 99·90 FJ/15°
AT 96·02, 96·12, 96·15, 96·21, 96·23, 96·42, 96·57, 96·86, 97·86, 97·90, 98·0 J/30°
WETH. J AT 98·12, 98·16, 98·19 J/25°
FROM 98·16 TO 98·32 J/80°
FROM 98·46 TO 98 74 CI.SP 6
OPEN J/50° (LEACHED)
AT 98·95, 99·10, 99 45, 99·95 J/60°

Depth (m)

84 07
88 17
88 81
91 72
95 69
98 36
99 45

HOLE COMPLETED AT THE DEPTH OF 100·0 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

FEATURE – KK 230 , DAM AXIS

B.H KK3 SH OF

DRILLING DATA

STARTED: 17 11. 91 COMPLETED 06.12.91
INTERRUPTIONS (DAYS): 02
MACHINE TYPE ACKER
DRILLING METHOD ROTARY
CORE BARREL, BIT: NX
FOREMAN: ID LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 152775.15
Y-COORDINATE 150757.25
ELEVATION (COLLAR) 197 92
ELEVATION (BOTTOM) 147 55
FINAL DEPTH 50.37 m
INCLINATION 0° FROM VERTICAL :
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1–1.0mm
MO = moderat. open 1.0–5.0mm
O = open > 5.0mm

OTHER SYMBOLS
P.L.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▽ = first ground water
R = rock sample
W = water sample

WEATHERING
soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENG
MN/m²
A
weak B
C
moderately strong
strong
very strong
extremely strong

DEPTH (m)	DRILLING: DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TESTS: TEST	RESULT	JOINTS: JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING <0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, >3.00 m	PERMEABILITY: DEPTH (m) FROM TOP	TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)	GENERAL DESCRIPTION rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ENGINEERING ASPECTS: ROCK STRENGTH	REMARKS (with respect to excavation, grout, permeability, rock etc.)
0·18																		TOP SOIL				
1·0												0·0	1·45			[illegible]·44 x 10^{-5}		RESIDUAL SOIL YELLOWISH BROWN CLAYEY SAND				
1 45																						
2·45						SPT	39					1·45	2·90			1·28 x 10^{-5}						
2 90																						
3·90	11/17					SPT	22					2·90	4·35			1·899 x 10^{-5}						
4·35																						
5·35												4·35	5·80			1·22 x 10^{-5}						
5·80						SPT	26															
6·80	18/11											5·8	7·25			3·109 x 10^{-6}		GARNETIFEROUS ROCK, WHITISH, BROWNISH				
7·25						SPT	56															
8·25												7·25	8·7			1·55 x 10^{-6}						
8·70						SPT	>50					8·7	9·7			6·84 x 10^{-7}		CLAY BLACKISH				
9·70	20/11											9·7	10·7			5·86 x 10^{-7}		GARNETIFEROUS ROCK, WHITISH (FROM 9·7 TO 10 7 WASH SAMPLE)				
10 70	21/11																	GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY MEDIUM GRAINED PREDOMINANTLY GNEISSIC, MAIN COMPONENTS Qu, BI, GA				
11·40																						
11·75	22/11																					
12·91												12·13										
14·0	23/11				2 06								15 65	1 3 6 3 1	NIL	NIL						
15·07																		AT 15 07 F/J 30°				
15·08	24/11											15·03						AT 15 22, 16 23 J/60°				
16·98													18 55	1 3 6 3 1	NIL	NIL		AT 19·70 J/70° CHLORITISIZED				
18·55	27/11											18·03						CHARNOCKITE, DARK GREY, MEDIUM TO FINE GRAINED, MASSIVE, IN PARTS GNEISSIC, MAIN COMPONENTS Fd, Qu Ga.				
20·04			GRAYISH										21·55	1 3 6 5 1	NIL	NIL		HORNBLENDE – BIOTITE GNEISS, DARK GREY, MEDIUM GRAINED, GNEISSIC, MAIN COMPONENTS, HO, BI, GA AT 20 04, 20·10, 22, 70, 24·38 F/J 40-50° FROM 20·85 TO 20 90 J/85°				
21 ·55	29/11											21 06										
23 00													24 57	1 3 6 5 1	NIL	NIL						
24·57	29/11											24 18						AT 25·02, 25 80 CN FILLED J/50° AT 27·68, 27·70 J/40°				
25 80														1 3 6 5 1	NIL	NIL						
26·62																		GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY, MEDIUM GRAINED, GNEISSIC				
27 70	30/11											27·63	27·7									

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

FEATURE – KK 230 , DAM AXIS

B.H KK3 SHEET 02 OF 02

DRILLING DATA

ARTED: 17.11.91 COMPLETED 06.12.91
ERRUPTIONS (DAYS) · 02
CHINE TYPE ACKER
LLING METHOD ROTARY
CRE BARREL, BIT · NX
REMAN: ID LOGGED BY:
E STORED AT:
E DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 152775.15
Y-COORDINATE 150757 25
ELEVATION (COLLAR) 197 92
ELEVATION (BOTTOM) 147 55
FINAL DEPTH 50 37 m
INCLINATION 0° FROM VERTICAL.
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1mm
R = rough	T = tight	0.1–1.0mm
SR = slightly rough	MO = moderat open	1.0–5.0mm
S = smooth	O = open	> 5.0mm
SL = slickensided		

RECOVERY	OTHER SYMBOLS
▨ CORE RECOVERY (%)	PL S = point load strength index
▨ R.Q.D (%)	U.C.S = uniaxial compressive strength
	▼ = first ground water
	R = rock sample
	W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

	MN/m²	
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25 00
moderately strong		25 0 – 50 00
strong		50 0 – 100 00
very strong		100.0 – 250.00
extremely strong		> 250 00

DRILLING · TESTS · JOINTS · PERMEABILITY · RECOVERY · GENERAL DESCRIPTION · ENGINEERING ASPECTS

Column headings: DRILLING: DAILY ADVANCE, CASING/CEMENT, DRILL WATER (COLOR, LOSS), RATE OF DRILLING, WATER LEVELS; TESTS: TEST, RESULT; JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 1.00 m); PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec; RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100); GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc · scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ROCK STRENGTH; REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.); DEPTH (m)

DAILY ADVANCE	DRILL WATER (COLOR, LOSS)	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON	GENERAL DESCRIPTION	REMARKS	DEPTH (m)
				1 3 6 3 1	NIL	NIL	CHARNOCKITE, GREYISH, MEDIUM GRAINED, MASSIVE AT 27·68, 27 70 J/40° FROM 28·25 TO 28 45 J/70°		29·7 29·1
1/12			30·55				QUARTZ-FELDSPAR PEGMATITE, LIGHT COLOURED, MASSIVE, MAIN COMPONENTS Qu, Fd.		30 55
		30 34		1 3 6 3 1	NIL	NIL	GARNETIFEROUS BIOTITE GNEISS, LIGHT COLOURED MEDIUM GRAINED, GNEISSIC, MAIN COMPONENTS Qu, Bl, GA AT 33·86, 36 07, 37 45 FJ/50°		31·0 32 83
2/12			33 86						33 86
		33·53		1 3 6 3 1	NIL	NIL	HORNBLENDE-BIOTITE GNEISS, DARK GREY MEDIUM GRAINED, GNEISSIC, MAIN COMPONENTS Ho, Bl		34 7 35 38
			37·05						37 05
3/12		36·65		1 3 6 3 1	NIL	NIL			38 43
			40·37				AT 41·1, 42 2 FJ/40°		40 37
	GRAYISH	40·13		1 3 6 3 1	NIL	NIL	AT 43·0, 43·64, 43·66 J/70° FROM 46 60 TO 46 78 AND 47·60 TO 47·85 J/70°		41·77
1/12			43·65						43 65
		43 35		1 3 6 3 1	NIL	NIL			44 6 46 43
1/12		46 85	47 03						47 03
				PRESSURE COULD NOT BE DEVELOPED MORE THAN 0·5 BARS			MYLONITE LAYER FROM 48·40 TO 48·95 LIGHT GREEN, SILTY AT 48 4, 48 95 J/50° AT 49·35, 49 55 J/55°	ARTESIAN CONDITION AFTER REACHING THE DEPTH OF 48 9 m.	48 4 49 2 49 86
1/12			50 3	0·5	21·4	190·2			50 37

HOLE COMPLETED AT THE DEPTH OF 50·37 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (NEW/OLD), DAM - QUARRY

BHKK4 SHEE OF

DRILLING DATA

STARTED 23 01 92 COMPLETED 06 02 92
INTERRUPTIONS (DAYS) 06
MACHINE TYPE ACKER
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN ID LOGGED BY
CORE STORED AT.
CORE DISCARDED, DATE

BOREHOLE DATA

X - COORDINATE 153464 38 N
Y - COORDINATE 149995 03 E
ELEVATION (COLLAR) 218·43
ELEVATION (BOTTOM) 198·23
FINAL DEPTH 20·20 m
INCLINATION FROM VERTICAL
BEARING
LOCATION (see)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
▒ CORE RECOVERY (%)
▨ R Q D (%)

JOINT SEPARATION

V = very tight	< 0.1mm	
T = tight	0.1 - 1.0mm	
MO = moderat open	1.0 - 5.0mm	
O = open	> 5.0mm	

OTHER SYMBOLS
PL.SI = point load strength index
UCS = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

MN/m²

	A	< 1.
weak	B	1.0 - 5.
	C	5.0 - 25
moderately strong		25.0 - 5
strong		50.0 -
very strong		100.0 - 2
extremely strong		> 2

DRILLING | TESTS | JOINTS | PERMEABILITY | RECOVERY

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOUR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total litres/minute)	LUGEON or PERMEABILITY m/sec
1															
1 77	1 77 23/1														
2						SPT	37								
3	3 5 26/01	3 6 27 01				SPT	>50								
4															
5	5 55 28/01	5 05 28 01													
6			DRY DRILLING												
7															
8	8 0														
9															
9 74	9 74	9 74													
10							II	R	T						
							III II	R	T						
11							I	R	T						
	11 7				11 02 2/02		II	R	T		11 20		1	7 2	
12							I	R	T				3	8 9	
													6	11. 4	
							II	R	T						
13							III	R	T				3	10 2	
							II	R	T				1	7. 1	
14							I	R	T						
	14 78				8 5		III	R	T			14 78			
15			GREYISH								14 78				
							II	SLS	T				1	NIL	
16													3	NIL	
							III	R	T				6	NIL	0·0
17	17 01				8 4 2/02								3	NIL	
													1	NIL	
18												18 36			
							I	R	T						
19							II	R	T						
20	20 2				11 5										
21															

HOLE COMPLETED AT THE DEPTH OF 20.2

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

TOP SOIL : BROWNISH CLAYEY SAND

COBBLES: CHARNOCKITE
GARNETIFEROUS ROCK, REDDISH BROWN TO YELLOWISH BROWN

GARNETIFEROUS ROCK YELLOWISH BROWN TO DARK BROWN

GARNETIFEROUS ROCK REDDISH BROWN

RESIDUAL SOIL. REDDISH BROWN CLEYEY SAND

RESIDUAL SOIL DARK BROWN WITH WEATH COBBLES UP TO 3 cm

CHARNOCKITE DARK GREY, MEDIUM GRAINED, MAIN COMPONENTS QU, FD, PY, GA
AT 10 08, 10 18, 10 26, 10 32, 10 5, 10 54 J/70°
AT 10 4, 10 65 J/15°- 20°
AT 10 81 FJ/30°

AMPHIBOLITE DARK GREY TO BLACKISH, MEDIUM GRAINED, MAIN COMPONENTS HO, FD WITH INTERCOLATIONS OF COARSE GRAINED CHARNOCKITE

CHARNOCKITE, DARK GREY, MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Qu, FD, PY, GA WITH INTERCALATIONS OF HORNBLENDE-ENRICHED LAYER
AT 10 82, 10 84, 10 85, 11 14, 11 15, 11 23, 11 24 11 38, 11 62, 12 15, 12 80 J/60°
AT 13 07, 13 10, 10 82 FJ/45°
AT 14 05, 14 3, 14 64, 14 72 J/65° 70°
AT 14 53 OXIDIZED J/25°
FROM 15 25 TO 16 0 AND 18 60 TO 19 20 Fd RICH COARSE GRAINED PEGMATITE
FROM 17 9 TO 18 10 Mo/cl J/70°
AT 18 3, 18 45, 18 47, 18 40 J/70°
AT 19.15, 19 18, 19 21, 19 23 FJ/30°
AT 19 46 J/55°

ENGINEERING ASPECT

REMARKS (with respect to excavation, grouting, permeability, rock quality etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (NEW/OLD), P. H. – QUARRY

BH KK5 SHEET 01 OF 01

DRILLING DATA

[illegible]TED 15.12.91 COMPLETED 18.12.91
[illegible]DITIONS [illegible]
[illegible]INE TYPE [illegible]
[illegible]LING METHOD ROTARY
[illegible] BARREL, BIT [illegible]
[illegible]MAN [illegible] LOGGED BY:
[illegible] STORED AT
[illegible] DISCARDED, DATE:

BOREHOLE DATA

X COORDINATE [illegible]
Y COORDINATE [illegible]
ELEVATION (COLLAR) [illegible]
ELEVATION (BOTTOM) [illegible]
FINAL DEPTH 20.13 m
INCLINATION 0° FROM VERTICAL
BEARING
LOCATION [illegible]

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1 mm
R = rough	T = tight	0.1 – 1.0 mm
SR = slightly rough	MO = moderately open	1.0 – 5.0 mm
S = smooth	O = open	> 5.0 mm
SL = slickensided		

RECOVERY
CORE RECOVERY (%)
R Q D (%)

OTHER SYMBOLS
PL.SI = point load strength index
U C S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil (unconsolidated material)
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING | TESTS | JOINTS | PERMEABILITY | RECOVERY | GENERAL DESCRIPTION | ENGINEERING ASPECTS

DRILLING: CASING/CEMENT; DRILL WATER (COLOR, LOSS); RATE OF DRILLING; WATER LEVELS
TESTS: TEST; RESULT
JOINTS: JOINT SET NO.; ROUGHNESS; SEPARATION; SPACING (< 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m)
PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total litres/minute); LUGEON or PERMEABILITY m/sec
RECOVERY: CORE RECOVERY % AND R Q D % (0 – 50 – 100)
GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, vesicular, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints
GRAPHIC LOG; WEATHERING; ROCK STRENGTH
REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)
DEPTH (m)

DRILLING: GRAY DRY DRILLING; DRILL WATER LOSS

PERMEABILITY: WATER PRESSURE TESTS HAVE NOT BEEN CARRIED OUT

GENERAL DESCRIPTION	DEPTH (m)
TOP SOIL YELLOWISH BROWN CLAYEY SAND	0.3
RESIDUAL SOIL REDDISH BROWN CLAYEY SILT/CLAYEY SAND	2.2
AMPHIBOLITE (COBBLE)	
RESIDUAL SOIL DARK REDDISH BROWN CLAYEY SAND	3.05
AMPHIBOLITE MEDIUM TO COARSE GRAINED, DARK GREY TO BLACK, GNEISSIC, MAIN COMPONENTS Ol, Ho, Fd FROM 4.83 TO 5.00 WEATH. CLOSELY SPACED, FRACTURED ZONE J/20°	3.44 4.00 4.83 6.41 7.20 7.93 9.0 9.15
BIOTITE GNEISS (HIGHLY Qu), LIGHT COLOURED, FINE TO MEDIUM GRAINED, GNEISSIC, MAIN COMPONENTS, Bi, Qu	10.52 11.45 11.75
AMPHIBOLITE, DARK GREY TO BLACK, MEDIUM TO COARSE GRAINED, GNEISSIC, MAIN COMPONENTS Qu, Ho, Fd	12.3
BIOTITE GNEISS (HIGHLY Qu) WITH OCCASIONAL GARNETS AND BIOTITE LAYERS OF VARYING THICKNESS UP TO 2 cm LIGHT COLOURED, FINE TO MEDIUM GRAINED, MAIN COMPONENTS Qu, Bi, Fd	12.97 13.60 14.19 15.51 15.94 16.25 17.35 18.00 18.83 19.17 20.13

HOLE COMPLETED AT THE DEPTH OF 20.13 m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (OLD)/230, HEADRACE (HULUKIRI)

BHKK6 SHE OF

DRILLING DATA

STARTED 17 11 81 COMPLETED 02 12 91
INTERRUPTIONS (DAYS)
MACHINE TYPE DRILL-TONE-TDEL
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN GSD LOGGED BY
CORE STORED AT
CORE DISCARDED, DATE

BOREHOLE DATA

X COORDINATE 153092 403
Y COORDINATE 149089 029
ELEVATION (COLLAR) 212 552
ELEVATION (BOTTOM) 202 152
FINAL DEPTH 40 2 m
INCLINATION FROM VERTICAL:
BEARING
LOCATION (see ...)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0 1mm
R = rough	T = tight	0 1 – 1 0mm
SR = slightly rough	MO = moderately open	1 0 – 5 0mm
S = smooth	O = open	> 5 0mm
SL = slickensided		

RECOVERY
▨ CORE RECOVERY (%)
▨ R Q D (%)

OTHER SYMBOLS
PL, BI = point load strength index
U C S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil (unconsolidated material)
completely
highly
moderately
slightly
fresh

ROCK STRENG

MN/m²

	A	
weak	B	1
	C	5
moderately strong		25
strong		50
very strong		100
extremely strong		

DRILLING

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	WATER LEVELS
1.0			BROWNISH	0.35 18/11 0.7 19/11 0.9 22/11 1.3 3/11
1.3	17/11	1.35 18/11		
3.0			LIGHT GRAY	
4.05	18/11			
5.4	19/11			
6.0				
6.6	20/11			
9.0	21/11			
12.8				
14.0				
14.7				
15.0	23/11			
17.8				
19.0	24/11			
21.0	25/11			
22.8				
23.5				
24.0	26/11			
24.5				
26.5	27/11			

TESTS: TEST, RESULT

JOINTS / PERMEABILITY

Joint spacing scale: < 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m

JOINT SET NO.	ROUGHNESS	SEPARATION	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON PERMEABILITY m/sec
I II III	R R R	T T T					
I	R	T	3.0	6.0	1 3 6 3 1	NIL	0.0
I	R	T	6.0	9.0	1 3 6 3 1	NIL	0.0
II	R	O	9.0	12.0	1 3 6 3 1	0,45 0,9.5 0,1.8 0,1 3 0 9	1.4 1.0 1.0 1 4 2.8
I I	R R	T MO	12.0	15.0	1 3 6 3 1	1,3 2,2 2,9 2,3 1,4	4.0 2.4 1.6 2.5 4 3
			15.0	18.0	1 3 6 3 1	NIL	0.0
I II	R R	MO T	18.0	21.0	1 3 6 3 1	1.4 2.3 3.2 2.3 1.4	4.3 2.5 1.8 2.5 4.3
I	R	T	21.0	24.0	1 3 6 3 1	NIL	0 0
I I	R R	T T	24.0	27.0	1 3 6 3 1	NIL	0.0

RECOVERY: CORE RECOVERY % AND R Q D % (0 – 50 – 100)

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc · scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

TOP SOIL - BROWNISH CLAYEY SAND

ALLUVIUM - BROWNISH CLAYEY SILT

ALLUVIUM - COARSE SAND

CHARNOCKITIC GNEISS DARK GREY MEDIUM GRAINED, PARTLY GNEISSIC MAIN COMPONENTS Qu, Fd, PY

AT 2 8, 5 88, 8.25, 9 45 (SI W) FJ / 20°- 30°
FROM 1 65 TO 1 85 J/80°
AT 1 85 CHL. J/40°

FROM 9 43 TO 9.58 CI Spn
X Nos J (SI.W)/75°
FROM 11.5 TO 11 90 J/90°

HORNBLENDE - BIOTITE GNEISS, GREYISH, MEDIUM GRAINED, GNEISSIC MAIN COMPONENTS Qu, Ho, BI

AMPHIBOLITE - DARK GREY, MEDIUM TO COARSE GRAINED, MAIN COMPONENT Ho, Qu, Fd

PEGMATITE - COARSE GRAINED MAIN COMPONENTS Qu, Fd.

HORNBLENDE-BIOTITE GNEISS, GREYISH, FINE TO MEDIUM GRAINED, MAIN COMPONENTS Qu, Ho, BI

AT 12 05, 12.55, 12 60, 12.72 12 98, 13 70, 14 58 CHL FJ/30°- 40°

CHARNOCKITE DARK GREY, MEDIUM GRAINED, MAIN COMPONENTS Qu, Fd, Py

AMPHIBOLITE - DARK GREY, MEDIUM TO COARSE GRAINED, MASSIVE, MAIN COMPONENTS Qu, Ho

AT 19 32, 22 65, 25 75, 28 0 (SL.W) FJ / 30°- 40°

AT 18 95, 19 36, 20 45, 24 05, 24 96, 27 90 J/60°

CHARNOCKITE - DARK GREY, MEDIUM GRAINED, MAIN COMPONENTS Qu, Fd, Py

GARNETIFEROUS BIOTITE GNEISS, LIGHT COLOURED, FINE TO MEDIUM GRAINED, MAIN COMPONENTS Qu, BI GA

CHARNOCKITE DARK GREY, MEDIUM GRAINED MASSIVE, MAIN COMPONENTS Qu, Fd, Py

GARNETIFEROUS BIOTITE GNEISS, FINE TO MEDIUM GRAINED, LIGHT GREY, MAIN COMPONENTS Qu, BI, GA.

GRAPHIC LOG | WEATHERING | ROCK STRENGTH

ENGINEERING ASPE

REMARKS (with respect to excavation, grouting, permeability, rock etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (OLD)/230, HEADRACE (HULUKIRI) **BHKK6** **SHEET 02 OF 02**

DRILLING DATA	BOREHOLE DATA
RTED 17 11 91 COMPLETED 02 12 91	X-COORDINATE 153093 485
RRUPTIONS (DAYS) –	Y-COORDINATE 148849 929
HINE TYPE DRILL-TONE-TDC1	ELEVATION (COLLAR) 242 552
LING METHOD ROTARY	ELEVATION (BOTTOM) 202 182
E BARREL, BIT NX	FINAL DEPTH 40 2 m
EMAN GSD LOGGED BY	INCLINATION FROM VERTICAL:
E STORED AT	BEARING
E DISCARDED, DATE	LOCATION (see r.)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1 mm
R = rough	T = tight	0.1 – 1.0 mm
SR = slightly rough	MO = moderately open	1.0 – 5.0 mm
S = smooth	O = open	> 5.0 mm
SL = slickensided		

RECOVERY	OTHER SYMBOLS
CORE RECOVERY (%)	PL.SI = point load strength index
R Q D (%)	UCS = uniaxial compressive strength
	▼ = first ground water
	R = rock sample
	W = water sample

WEATHERING

- soil unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING (DAILY ADVANCE; CASING/CEMENT; DRILL WATER (COLOR, LOSS); RATE OF DRILLING; WATER LEVELS) – **TESTS** (TEST; RESULT) – **JOINTS** (JOINT SET NO; ROUGHNESS; SEPARATION; SPACING < 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m) – **PERMEABILITY** (DEPTH (m): FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total Litres/minute); LUGEON / PERMEABILITY m/sec) – **RECOVERY** (CORE RECOVERY %; AND R Q D %; 0 50 100)

DAILY ADVANCE	DRILL WATER (COLOR, LOSS)	JOINT SET NO	ROUGHNESS	SEPARATION	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
	LIGHT GRAY	I	R	MO	27.0	30.0	1	1.1	3.3
							3	1.8	1.9
		II	R	T			6	2.6	1.4
							3	1.8	1.9
8/11							1	1.1	3.3
		II	R	T	30.0	33.0	1	1.2	3.7
							3	2.0	2.2
							6	2.8	1.5
							3	1.9	2.0
29/11							1	1.2	3.7
		II	R	T	33.0	36.0	1	0.5	1.5
							3	0.8	0.9
		III	R	T			6	1.2	0.7
							3	0.8	0.9
30/11							1	0.4	0.2
					36.0	39.0	1 3 6 3 1	NIL	
01/12									
		I	R	T	39.0	40.2	1 3 6 3 1	NIL	
02/12									

GENERAL DESCRIPTION (rock type, colour, grain size, texture and structure massive, cleaved, twisted, jointed, flow banded, gneissose, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints) – GRAPHIC LOG – WEATHERING – ROCK STRENGTH – **ENGINEERING ASPECTS** (REMARKS with respect to excavation, grouting, permeability, rock quality, etc.) – DEPTH (m)

GENERAL DESCRIPTION	DEPTH (m)
GARNETIFEROUS BIOTITE GNEISS AS ABOVE	28 7
CHARNOCKITE DARK GREY, MEDIUM GRAINED, MAIN COMPONENTS Qu, Fd, PY, GA	30 0 30 7
AMPHIBOLITE, DARK GREY TO BLACKISH, COARSE GRAINED MASSIVE. MAIN COMPONENTS Ho, Qu, Bi FROM TO 31·15 31·66 32·60 32 96 33·07 33 35 33·25 33 52 33·57 33 60 34·15 34 38 ALL CHL J/80° – 85°	33 0 34 0
CHARNOCKITE, DARK GREY, MEDIUM GRAINED, MASSIVE, MAIN COMPONENTS Qu, Fd, PY	35 6
AMPHIBOLITE – DARK GREY, MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Ho, Bi, Qu AT 39·8 FJ/50°	36 0 37 0 39 0 39 85
CHARNOCKITE DARK GREY MEDIUM GRAINED, MASSIVE	40 2

HOLE COMPLETED AT THE DEPTH OF 40·2 m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES **TAB. 13**

FEATURE - KK 205 (OLD)/230, SURGE TANK

BH KK-7 SHEET OF

DRILLING DATA

STARTED 06/12/91 COMPLETED 21/01/92
INTERRUPTIONS (DAYS) 02
MACHINE TYPE JO/
DRILLING METHOD ROTARY
CORE BARREL, BIT' NX
FOREMAN GSD LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 155621.922
Y-COORDINATE 146801 722
ELEVATION (COLLAR) 301 487
ELEVATION (BOTTOM) 126.377
FINAL DEPTH 175 11 m
INCLINATION FROM VERTICAL:
BEARING
LOCATION (see f.)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR=very rough	V=very tight	< 0 1mm
R =rough	T =tight	0.1-1 0mm
SR=slightly rough	MO=moderat open	1 0-5 0mm
S =smooth	O =open	> 5 0mm
SL=slickensided		

RECOVERY
CORE RECOVERY (%)
R Q D (%)

OTHER SYMBOLS
PL,BI=point load strength index
UCS =uniaxial compressive strength
▽ =first ground water
R =rock sample
W =water sample

WEATHERING

soil unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1 00
weak	B	1.0 - 5.00
	C	5.0-25 00
moderately strong		25 0-50 00
strong		50 0-100 00
very strong		100.0-250 00
extremely strong		> 250.00

DEPTH (m)	DRILLING: DAILY ADVANCE	DRILLING: CASING/CEMENT	DRILLING: WATER LEVELS	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	GENERAL DESCRIPTION rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints
												TOP SOIL-DARK BROWN CLAYEY SAND
0.6												RESIDUAL SOIL - REDDISH BROWN CLAYEY SAND
2.64		3.0 06/12										BIOTITE GNEISS. LIGHT COLOURED, MEDIUM GRAINED GNEISSIC MAIN COMPONENTS Qu, Fd, Bi AT 272, 2 74 WEATHER J/45°
3.4	06/12			III	R	T	3.35					
									1	16.3	40 5	
			3 43 6/12						3	9.0	9 0	
									6	5 8	3.0	
5 65									3	7.7	7 7	HORNBLENDE - BIOTITE GNEISS DARK GREY, MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Ho, Bi, GA
								6 35	1	13.2	32.8	
6.62							6. 35		1	16.4	40.4	GARNETIFEROUS BIOTITE GNEISS, LIGHT COLOURED FINE TO MEDIUM GRAINED, GNEISSIC MAIN COMPONENTS Qu (50%) Bi, Fd, GA.
			3.08 07/12	I	R	T			3	14.3	13. 9	
									6	14 0	7 2	
									3	13.0	12.7	AT 7 70, 7.9 FJ/65°
8 6	07/12								1	15 2	37.5	AT 8.7, 9 4, 11.55, 11 95 J/5²(P
				IV	R	T		9 43				
							9.43		1			
			2 9 8/12	IV	R	T			3 6 3	NIL	0.0	FROM 11 0 TO 12 34 CONCENTRATIONS OF Ho AND Bi
12 4	08/12							12 44	1			AT 14 84, 16.13, 16 50, 17 93 J/15°
							12 44		1			
				IV	R	T			3 6 3	NIL	0.0	FROM 15 72 TO 15 85 CONCENTRATIONS OF COARSE GRAINED GA
			2 9 9/12					15 55	1			FROM 15 85 TO 15.96 : LAYER RICH IN Ho, Bi
				IV	R	T	15 55					
16.62									1 3 6	NIL	0. 0	FROM 16 62 TO 19 82 GARNETIFEROUS BIOTITE GNEISS AS ABOVE WITH COARSE GRAINED GARNETS MAIN COMPONENTS Qu, Fd, BI, GA.
17. 3	09/12			IV	R	T			3 1			
								18.58				AT 18.04, 20.28 J/15°
							18 58		1			AT 20.14, 21 25 J/35°
			2.9 10/12	III IV	R R	T T			3 6 3	NIL	0 0	FROM 18 10 TO 18 58 DARK COLOURED LAYER RICH IN Ho, Bi
									1			
21 5	10/12							21 55				
				III	R	T	21 55		1 3 6 3 1	NIL	0 0	
24 3	11/12							24 39				
							24 28		1	21 9	56 1	AT 26 02 J/15° CHI
				IV	R	T			3	25 0	24 4	
			2 3 11/12						6	29 3	14 8	
									3	28 6	27.9	
									1	29 4	75 3	

ENGINEERING ASPECTS

REMARKS
(with respect to excavation, grouting, permeability, rock quality, etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD)/230, SURGE TANK

BH KK-7 SHEET 2 OF 7

DRILLING DATA

ARTED 06/12/91 COMPLETED 21/01/92
ERRUPTIONS (DAYS) 02
CHINE TYPE JOI
ILLING METHOD ROTARY
RE BARREL, BIT NX
REMAN GSD LOGGED BY
RE STORED AT
RE DISCARDED, DATE

BOREHOLE DATA

X-COORDINATE 155621 022
Y-COORDINATE 146801 722
ELEVATION (COLLAR) 301 407
ELEVATION (BOTTOM) 126 377
FINAL DEPTH 175.11 m
INCLINATION FROM VERTICAL
BEARING
LOCATION

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
CORE RECOVERY (%)
R Q D (%)

JOINT SEPARATION
V = very tight < 0.1 mm
T = tight 0.1-1.0 mm
MO = moderat open 1.0-5.0 mm
O = open > 5.0 mm

OTHER SYMBOLS
PL S1 = point load strength index
UCS = uniaxial compressive strength
F = first ground water
B = rock sample
W = water sample

WEATHERING

soil unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH MN/m²

	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING: DAILY ADVANCE	DRILLING: WATER LEVELS	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PERMEABILITY: PRESSURE (BARG) (manometer reading)	PERMEABILITY: WATER LOSS (total Litres/minute)	PERMEABILITY: LUGEON or PERMEABILITY m/sec	GENERAL DESCRIPTION rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	DEPTH (m)
2/12					27.55	30.4	1 3 6 3 1	NIL	0.0	GARNETIFEROUS BIOTITE GNEISS AS ABOVE WITH OCCASIONAL INTERCALATIONS OF HORNBLENDE BIOTITE GNEISS, LAYERS UP TO 20 cm AND GARNET CONCENTRATIONS UP TO 15 cm THICKNESS AT 31.63, 31.03, 31.06, 33.64 J/15° AT 32.05 FJ/55°	
3/12	2.3 13/12	I IV	R R	T T	30.4	33.64	1 3 6 3 1	NIL	0.0	CHANOCKITIC GNEISS, DARK GREY, MEDIUM GRAINED, MAIN COMPONENTS Qu, Fd, Py, GA WITH INTERCALATIONS OF COARSE GRAINED QUARTZO-FELDSPATIC GNEISS AND DARK COLOURED HORNBLENDE-BIOTITE GNEISS	31.77
		III	R	T	33.64	36.6	1 3 6 3 1	NIL	0.0	AT 34.85, 38.28, J/15° AT 34.85 TO 35.0 SUB VERTICAL JOINTS	35.85
4/12	2.3 14/12	IV	R	T	36.6	39.74	1 3 6 3 1	NIL	0.0.	AT 40.10, 42.28 J/15° AT 38.74, 47.16, 47.26, 47.33 J/80°	
5/12	2.3 15/12	IV	R	T	39.74	42.79	1 3 6 3 1	NIL	0.0		
	2.3 16/12	I	R	T	42.79	45.96	1 3 6 3 1	NIL	0.0	AT 43.35, 45.56, 48.42, 48.49, 48.48 FJ/65°-70° FROM 47.10 TO 47.38 FD RICH COARSE GRAINED PEGMATITE LAYER	
/12	2.3 17/12	I II	R R	T T	45.96	49.19	1 3 6 3 1	16.3 15.1 14.2 15.5 15.9	41.0 14.5 7.1 14.9 40.0	FROM 49.90 TO 49.26 J/80° AT 49.80, 50.70 J/15°	
1/12		II IV	R R	T T	49.19	52.26	1 3 6 3 1	NIL	0.0	QUARTZO-FELDSPATHIC GNEISS, LIGHT COLOURED, MEDIUM GRAINED, GNEISSIC, MAIN COMPONENTS Qu, PINK FD FROM 50.02 TO 50.10 J/75° AT 50.70, 51.40, 51.67, 52.5, 53.10, 53.20, 53.70 J/20°	49.49
	2.3 18/12	I IV	R R	T T	52.26		1 3 6 3 1	NIL	0.0	AT 52.02, 55.12 FJ/60° AT 54.70 J/50°	

ENGINEERING ASPECTS

REMARKS (with respect to excavation, grouting, cement ility, rock quality, etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD)/230, SURGE TANK

B.H KK-7 SHE OF

DRILLING DATA

STARTED 06/12/91 COMPLETED 21/01/92
INTERRUPTIONS (DAYS) 02
MACHINE TYPE JOY
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN GSD LOGGED BY
CORE STORED AT
CORE DISCARDED, DATE

BOREHOLE DATA

X-COORDINATE 155621 922
Y-COORDINATE 146801 722
ELEVATION (COLLAR) 301 487
ELEVATION (BOTTOM) 126.377
FINAL DEPTH 175 11 m
INCLINATION FROM VERTICAL
BEARING
LOCATION (see

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
▨ CORE RECOVERY (%)
▨ R Q D (%)

JOINT SEPARATION
V = very tight < 0 1 mm
T = slight 0.1 - 1 0 mm
MO = moderately open 1 0 - 5 0 mm
O = open > 5 0 mm

OTHER SYMBOLS
PL.SI = point load strength index
UCS = uniaxial compressive strength
▽ = first ground water
□ = rock sample
▽ = water sample

WEATHERING

soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

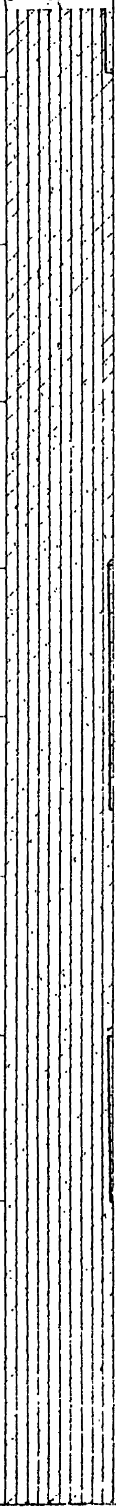
MN/m²

	A	
weak	B	1 0
	C	5 0-
moderately strong		25 0
strong		50 0
very strong		100 0
extremely strong		>

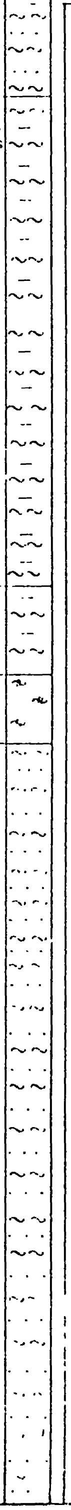
DEPTH (m)	DRILLING: DAILY ADVANCE	CASING/CEMENT-	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVEL	TESTS: TEST	RESULT	JOINTS: JOINT SET NO.	ROUGHNESS	SEPARATION	PERMEABILITY: DEPTH (m) FROM TOP	TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	GENERAL DESCRIPTION rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints
																FROM 55 72 TO 55 85 J/85° AT 55 66 J/55° AT 55 85, 56 24, 57 72 J/15°
55 3	18/12											55 33				
55.72								II IV	R R	T T	55 33		1 3 6 3 1	NIL	0 0	GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY, MEDIUM GRAINED, MAIN COMPONENTS Qu, Fd, Bi WITH GARNET CONCENTRATIONS UP TO 30cm
												58 52				
59 8	19/12							IV	R	T	58 52		1 3 6 3 1	NIL	0.0	AT 59 43, 60 0, 60 5 J/15°
												61.54				
				2 3 19/12				I	R	T	61 54		1 3 6 3 1	NIL	0 0	AT 63 23, 63.37 FJ/65°
64 4	20/12											64 49				
64 95											64 49		1 3 6 3 1	NIL	0 0	HORNBLENDE - BIOTITE GNEISS, DARK GREY, MEDIUM GRAINED
66 60								I	R	T						
67 4	21/12											67 46				CHARNOCKITIC GNEISS, GREY, MEDIUM GRAINED
67 9											67 46		1 3 6 3 1	NIL	0 0	QUARTZO - FELDSPATHIC GNEISS, MEDIUM TO COARSE GRAINED, LIGHT COLOURED, GNEISSIC, MAIN COMPONENTS Qu PINK FD
68 96																AT 68 82, 68 86 FJ/70°
70 4	23/12											70 44				
								IV	R	T	70 44		1 3 6 3 1	NIL	0 0	AT 71 10 J/15° FROM 71 85 TO 73 53 COARSE GRAINED DARK GREY CHARNOCKITIC GNEISS LAYER
73.3	24/12				0.0 24/12							73 35				
					0.5 25/12			II IV	R R	T T	73 35		1 3 6 3 1	NIL	0.0	AT 75 5, 75 56 J/70°
												76 46				
77 1	25/12										76.46		1 3 6 3 1	NIL	0.0	AT 76 30 J/05°
												79 45				
								IV	R	T	79 45		1 3 6 3 1	NIL	0.0	

SPACING: <0 05, 0 05-0 30, 0 30-1.00, 1 00-3 00, >3 00

RECOVERY: CORE RECOVERY % AND R Q D % 0 50 100



GRAPHIC LOG WEATHERING



ENGINEERING ASPEC ROCK STRENGTH REMARKS (with respect to excavation, grouting, permeability, rock ... etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD)/230, SURGE TANK

BH KK-7 SHEET 4 OF 7

DRILLING DATA

TED 06/12/91 COMPLETED 21/01/92
RUPTIONS (DAYS) 02
INE TYPE JOY
ING METHOD ROTARY
BARREL, BIT: NX
MAN: GSO LOGGED BY
STORED AT
DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 155621 922
Y-COORDINATE 146801 722
ELEVATION (COLLAR) 301.487
ELEVATION (BOTTOM) 126.377
FINAL DEPTH 175.11 m
INCLINATION FROM VERTICAL
BEARING
LOCATION (see

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1-1.0mm
MO = moderately open 1.0-5.0mm
O = open > 5.0mm

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

OTHER SYMBOLS
PL.SI = point load strength index
UCS = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil: unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING				TESTS		JOINTS				PERMEABILITY					RECOVERY	GENERAL DESCRIPTION			ENGINEERING ASPECTS		
CASING/CEMENT.	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	CORE RECOVERY % AND RQD % (0 50 100)	rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc · scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)	DEPTH (m)
																QUARTZO-FELDSPATHIC GNEISS AS ABOVE AT 82 38 J/20°					
																GARNETIFEROUS CHARNOCKITIC GNEISS, DARK GREY, MEDIUM TO COARSE GRAINED, GNEISSIC, MAIN COMPONENTS Qu, Fd, GA, PI AND CONCENTRATIONS OF GARNETS UPTO 30 cm.					82 45
											83 2										
			5.25 27/12			III V	R R	T T		83 2		1 3 6 3 1	NIL	0.0		AT 85 0 J/30°					
											86 25					AT 86.07 J/20°					
						I II IV	R R R	T T T		86.25		1 3 6 3 1	11 7 12 8 10 8 15.1 17.2	23.0 10.9 5.0 12 8 33 8		AT 86.52 CHL FILL J/25°					
																BIOTITE GNEISS, LIGHT GREY, MEDIUM TO COARSE GRAINED GNEISSIC, MAIN COMPONENTS Qu, Fd, Py, GA. AT 87.25 FJ/70° FROM 87 25 TO 87 30 SUBVERTICAL JOINT					87 45
											89 59										
						I	R	T		89 59		1 3 6 3 1	NIL	0 0		GARNETIFEROUS QUARTZO-FELDSPATHIC GNEISS, COARSE TO MEDIUM GRAINED, LIGHT COLOURED, MAIN COMPONENTS Qu, Fd, GA AT 92 83 FJ/75°					90 0
											92 83										92 83
						I	R	T		92 83		1 3 6 3 1	NIL	0 0		BIOTITE GNEISS, LIGHT GREY, FINE TO MEDIUM GRAINED, GNEISSIC, MAIN COMPONENTS Qu, Fd, Bi, GA (OCCASIONALLY) WITH INTERCALATION OF HORNBLENDE-BIOTITE GNEISS LAYERS (THICKNESS UPTO 2M) AND GARNET-ENRICHED BANDS UPTO 2cm					
											96.0										
			5.2 31/1			II	R	T		96.0		1 3 6 3 1	NIL	0 0		AT 95.5, 95.7 CHL FILL J/65°-70° AT 97 8, 97 84 J/65° AT 98.67 J/15°					
											99.16										
						I III IV	R R R	T T T		99.16		1 3 6 3 1	NIL	0.0		AT 100.96, 101 76, 102 13, 102 17 J/30°-35°					
											102.17										
										102 17		1 3 6 3 1	NIL	0 0		AT 102 0 FJ/60°					103 5
											105 14										
			5.2 02/1							105 14		1 3 6 3 1	NIL	0 0		GARNETIFEROUS BIOTITE GNEISS, COARSE TO MEDIUM GRAINED, LIGHT GREY, MAIN COMPONENTS Qu, Fd, GA, Bi					106 28

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES **TAB. 13**

FEATURE - KK 205 (OLD)/ 230, SURGE TANK

BH KK-7 SH OF

DRILLING DATA

STARTED: 06/12/91 COMPLETED 21/01/92
INTERRUPTIONS (DAYS) 02
MACHINE TYPE JOY
DRILLING METHOD ROTARY
CORE BARREL, BIT: NX
FOREMAN: GSO LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X - COORDINATE 155621 922
Y - COORDINATE 146801 7.2
ELEVATION (COLLAR) 301 487
ELEVATION (BOTTOM) 126 377
FINAL DEPTH 175 11 m
INCLINATION FROM VERTICAL
BEARING
LOCATION (see)

KEY

JOINT ROUGHNESS
VR very rough
R rough
SR slightly rough
S smooth
SL slickensided

JOINT SEPARATION
V very tight <0.1mm
T tight 0.1-1.0mm
MO moderately open 1.0-5.0mm
O open >5.0mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
PL.SI point load strength index
UCS uniaxial compressive strength
▼ first ground water
R rock sample
W water sample

WEATHERING

soil: unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENG

MN/m²
A
weak B 1
C 1
moderately strong 2
strong 5
very strong 100
extremely strong

DEPTH (m)	DRILLING: DAILY ADVANCE	DRILLING: WATER LEVELS	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	GENERAL DESCRIPTION
109.7	02/01					108 19	111 3	1 3 6 3 1	NIL	0 0	GARNETIFEROUS BIOTITE GNEISS AS ABOVE AT 114.22 J/25°
112.3			II III	R R	T T	111 3	114.4	1 3 6 3 1	NIL	0.0	CHARNOCKITIC GNEISS, COARSE TO MEDIUM GRAINED, DARK GREY, GNEISSIC, MAIN COMPONENTS, Qu, Bi, Fd, GA WITH GARNET LAYERS AT 114.3 J/60°
114.4	03/0	5.2 03/0				114 4	117.33	1 3 6 3 1	NIL	0.0	
117.3 120.10	04/0					117.33	120.44	1 3 6 3 1	NIL	0.0	
121.3	05/0	28.5 06/0	I III	S S	T T	120.44	123.48	1 3 6 3 1	NIL	0.0	GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY, FINE TO MEDIUM GRAINED, MAIN COMPONENTS Qu, Fd, Py WITH GARNET LAYERS AT 122.05, 122.54, 122.55 FJ/55° AT 122.53 J/15°
125 3	06/0		I II IV	T T T	R R R	123 48	126.45	1 3 6 3 1	NIL	0 0	AT 124 75 FJ/60° AT 124.72, 124.76 J/10° FROM 124 80 TO 124.97 SUBVERTICAL J
127 09 129 4	08/0	28.5 08/0				126 45	129.48	1 3 6 3 1	NIL	0.0	
132 5	09/0	31.0 [illegible]				129 40	132 50	1 3 6 3 1	NIL	0.0	
			III	T	R	132 50		1 3 6 3 1	NIL	0.0	AT 134.79 J/20°

GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

RECOVERY: CORE RECOVERY % AND R Q D % 0 50 100

ENGINEERING ASPE

REMARKS (with respect to excavation, grouting, permeability, rock etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES **TAB. 13**

FEATURE - KK 205 (OLD)/230, SURGE TANK

BH KK-7 SHEET 6 OF 7

DRILLING DATA

'ED 06/12/91 COMPLETED 21/01/92
RUPTIONS (DAYS) 02
NE TYPE JOY
ING METHOD ROTARY
'BARREL, BIT' NX
MAN: GSO LOGGED BY'
STORED AT'
DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 155621 922
Y-COORDINATE 146H01 722
ELEVATION (COLLAR) 301 487
ELEVATION (BOTTOM) 126.377
FINAL DEPTH 175 11 m
INCLINATION FROM VERTICAL.
BEARING
LOCATION (see (,

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0 1mm
T = tight 0 1 - 1 0mm
MO = moderat open 1 0 - 5 0mm
O = open > 5 0mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R Q D (%)

OTHER SYMBOLS
PL.S.I = point load strength index
UCS = uniaxial compressive strength
▽ = first ground water
R = rock sample
W = water sample

WEATHERING

soil unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

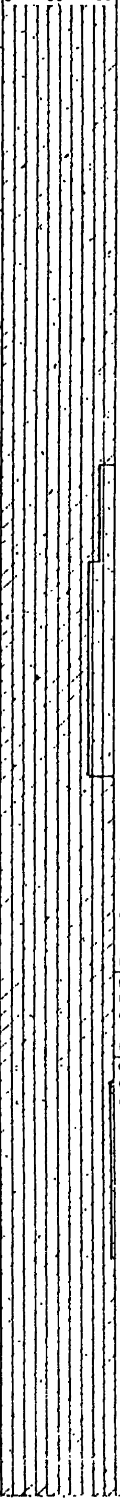
		MN/m²
	A	< 1 00
weak	B	1 0 - 5.00
	C	5 0 - 25 00
moderately strong		25 0 - 50 00
strong		50 0 - 100 00
very strong		100.0 - 250 00
extremely strong		> 250 00

DRILLING | TESTS | JOINTS | PERMEABILITY

CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING (< 0.05 m; 0.05-0.30 m; 0.30-1.00 m; 1.00-3.00 m; > 3.00 m)	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
											135 86			
						II	T	R		135·86	138·78	1 3 6 3 1	NIL	0 0
			31·0 12/01			IV	T	R		138 96	141·07	1 3 6 3 1	NIL	0 0
			39·8 12/01							141 07	143 98	1 3 6 3 1	NIL	0 0
			39·3 13/01			IV IV	S SL	T T		143 98	146·21	1 3 6 3 1	42·9 47·5 47·8 46·5 47·2	38.6 30.5 21.5 29 9 42.5
						IV III II	SL SI T	T T R		146 21	149·58	1 3 6 3 1	5·1 4 4 4·0 5·1 6·3	3.0 1.9 1.2 2.2 3 8
			39 0 15/01			II IV	R R	T T		149 58	152 58	1 3 6 3 1	4·7 5·9 5·2 5·9 6·1	3 1 2.8 1.7 2.8 4.1
			39 0 16/01			II IV	S S	T T		152·58	155·54	1 3 6 3 1	NIL	0:0
			39·3 18/01			II	T	R		155 54	158 69	1 3 6 3 1	NIL	0.0
			39 8 18/01							158 69	161 85	1 3 6 3 1	NIL	0.0
						IV	T	R		161 85				

RECOVERY

CORE RECOVERY % AND R Q D %



GENERAL DESCRIPTION | GRAPHIC LOG | WEATHERING | ROCK STRENGTH | ENGINEERING ASPECTS

GENERAL DESCRIPTION (rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints)	REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)	DEPTH (m)
GARNETIFEROUS BIOTITE GNEISS AS ABOVE		135·8
AT 137 45, 138 32 J/60°		
CHARNOCKITIC GNEISS, DARK GREY, MEDIUM GRAINED, GNEISSIC, MAIN COMPONENTS Qu, FD, PY, GA		137·72
Qu RICH BIOTITE GNEISS WITH GARNETS, LIGHT COLOURED, MEDIUM GRAINED		138 76
AT 139·3, 0·5 mm THICK CALCITE FILL J/15°		140·0
AT 139·66 IRON PYRITE STAINED		
AT 140·18 CALCITE FILL J/10°		
FROM 141·40 TO 143·78 CHARNOCKITIC GNEISS WITH BIOTITE BANDS, MEDIUM GRAINED		141·40
AT 142 3, 143·62 CHL J/10°		143·78 143 9
AT 144·0, 144·32, 144·66, 144·81, 144·98 PYRITE FILM ON JOINT SURFACE J/20°		145 57 146·2
AT 145·0, 145·07, 145·13, 145·18, 145·21, 145·22 SLS J/20°		
AT 145·19 2 Nos. J/60°		
FROM 145 57 TO 146 04 Clo. Spa. J/10° - 15° SLS.		
AT 146·18, 146·22, 146·38 SLS J/20°		149·5
AT 146·52, 146·93 PYRITE - STAINED J/50°		
AT 147·04, 147·82, 147·94 SLS J/60°		
AT 147·14, 147·38, 149·18, 149·35 J/40°		152·5
AT 150·63, 150·78, 151·0, 151·23 J/70°		
FROM 151 95 TO 152·52 J/85°		
BIOTITE GNEISS, LIGHT GREY, MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Bi, Ru, Fd		153 06
FROM 152 80 TO 153·44 J/85°		
FROM 153 15 TO 153·42 J/85°		
CHARNOCKITE, DARK GREY, MEDIUM GRAINED, MASSIVE, MAIN COMPONENTS Qu, FD, PY		154·7 155·5
AT 153·54, 153·96, 154 0 J/20°		
AT 156·4, 156 41, 156·80 PYRITE - STAINED J/60°		
AT 157·72, 157 80 FJ/60°		158 6

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD)/230, SURGE TANK

BH KK-7 SHEE OF

DRILLING DATA	BOREHOLE DATA
STARTED 06/12/91 COMPLETED 21/01/92	X-COORDINATE 155621 322
INTERRUPTIONS (DAYS) 02	Y-COORDINATE 146801 722
MACHINE TYPE JOY	ELEVATION (COLLAR) 301. 487
DRILLING METHOD ROTARY	ELEVATION (BOTTOM) 126 377
CORE BARREL, BIT NX	FINAL DEPTH 175 11 m
FOREMAN GSO LOGGED BY	INCLINATION FROM VERTICAL :
CORE STORED AT	BEARING
CORE DISCARDED, DATE :	LOCATION (see ...)

KEY

JOINT ROUGHNESS	
VR	very rough
R	rough
SR	slightly rough
S	smooth
SL	slickensided

RECOVERY

- ▨ CORE RECOVERY (%)
- ▨ R.Q.D (%)

JOINT SEPARATION		
V	very tight	< 0 1mm
T	tight	0.1-1 0mm
MO	moderat open	1.0-5 0mm
O	open	> 5 0mm

OTHER SYMBOLS	
PL SI	point load strength index
UCS	uniaxial compressive strength
▽	first ground water
R	rock sample
W	water sample

WEATHERING

- soil unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH

		MN/m²
	A	< 1
weak	B	1 0 - 5.0
	C	5.0 - 25
moderately strong		25.0 - 50
strong		50 0 - 100
very strong		100.0 - 250
extremely strong		> 25

DEPTH (m)	DRILLING: DAILY ADVANCE	DRILLING: CASING/CEMENT	DRILLING: DRILL WATER (COLOR, LOSS)	DRILLING: RATE OF DRILLING	DRILLING: WATER LEVELS	TESTS: TEST	TESTS: RESULT	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	JOINTS: SPACING (< 0.05, 0.05-0.30, 0.30-1.00, 1.00-3.00, > 3.00)	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PERMEABILITY: PRESSURE (BARS) (manometer reading)	PERMEABILITY: WATER LOSS (total Litres/minute)	PERMEABILITY: LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)	GENERAL DESCRIPTION rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	ENGINEERING ASPECTS: REMARKS (with respect to excavation, grouting, permeability, rock quality etc.)
162.8	19/01				39.8 20/01								164.88	1 3 6 3 1	NIL	0.0		CHARNOCKITE AS ABOVE, MEDIUM TO COARSE GRAINED AT 163.05, 163.50 J/10°				
167.6	20/01							II IV	T T	R R		164.88	168.01	1 3 6 3 1	NIL	0.0.		AT 165 65 02 Nos J/60° AT 165.7 J/10° FROM 166.0 TO 167 75 Qu RICH BIOTITE GNEISS WITH GARNETS, MEDIUM GRAINED				
169.58					48.0 21/01							168.01	171.06	1 3 6 3 1	NIL	0 0.						
171.06	21/01 22/01				40.0 22/01							171.06	175.11	1 3 6 3 1	NIL	0 0		FROM 174.50 TO 174.50 COARSE GRAINED Qu – Fd PEGMATITE				

HOLE COMPLETED AT THE DEPTH OF 175.11m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (NEW/OLD), TAILRACE OUTFALL

B.H. KK8 SHEET 01 OF 02

DRILLING DATA	BOREHOLE DATA
RTED: COMPLETED:	X-COORDINATE:
ERRUPTIONS (DAYS):	Y-COORDINATE:
HINE TYPE.	ELEVATION (COLLAR):
LLING METHOD:	ELEVATION (BOTTOM):
E BARREL, BIT:	FINAL DEPTH:
EMAN: LOGGED BY:	INCLINATION FROM VERTICAL:
E STORED AT:	BEARING:
E DISCARDED, DATE:	LOCATION (see Fig.)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1mm
R = rough	T = tight	0.1–1.0mm
SR = slightly rough	MO = moderat. open	1.0–5.0mm
S = smooth	O = open	> 5.0mm
SL = slickensided		

RECOVERY	OTHER SYMBOLS
▒ CORE RECOVERY (%)	PL.B.I. = point load strength index
▨ R.Q.D (%)	U.C.S = uniaxial compressive strength
	▽ = first ground water
	R = rock sample
	W = water sample

WEATHERING

- soil : unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING: DAILY ADVANCE · CASING/CEMENT · DRILL WATER (COLOR, LOSS) · RATE OF DRILLING · WATER LEVELS
TESTS: TEST · RESULT
JOINTS: JOINT SET NO. · ROUGHNESS · SEPARATION · SPACING (0.03 / 0.03–0.05 / 0.05–0.30 / 0.30–1.00 / 1.00–3.00 / > 3.00 m)
PERMEABILITY: DEPTH (m) FROM TOP · TO BOTTOM · PRESSURE (BARS) (manometer reading) · WATER LOSS (total Litres/minute) · LUGEON or PERMEABILITY m/sec
RECOVERY: CORE RECOVERY % AND R.Q.D % (0 – 50 – 100)
GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints
GRAPHIC LOG · WEATHERING
ENGINEERING ASPECTS: ROCK STRENGTH · REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.) · DEPTH (m)

DRILLING

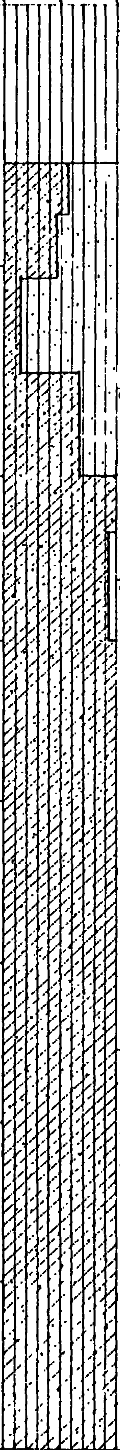
DAILY ADVANCE	CASING/CEMENT	WATER LEVELS
1/12	21/12	
	30/12	
2/12	02/01	
	04/01	
13/12		
4/12		
8/12		10.0 26/12
7/12		9.6 27/12
8/12		9.3 28/12
9/12		
9/12		
1/12		9.6 31/12
/12		

JOINTS

JOINT SET NO.	ROUGHNESS	SEPARATION
I	R	MO
IV	R	MO
IV	R	MO
II	R	MO
IV	R	MO
IV	R	T
II	R	T
IV	R	T
II	R	T
III	R	T
IV	R	T
I	R	T
II	R	T
	T	
IV	R	T

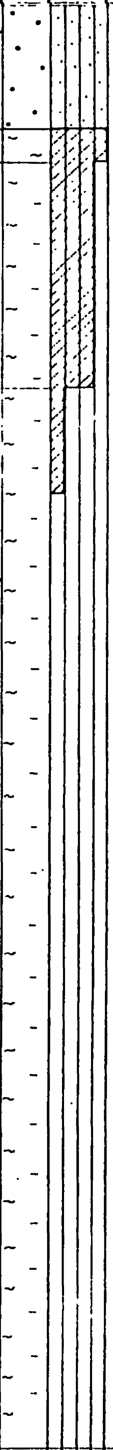
PERMEABILITY

FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
6.0	9.0	1	15.2	50.7
		3	23.9	26.6
		6	31.8	17.7
		3	22.0	24.4
		1	15.0	50.0
9.0	12.0	1	13.0	43.3
		3	18.0	20.0
		6	28.2	15.7
		3	22.4	24.9
		1	17.6	58.7
12.0	15.0	1 3 6 3 1	NIL	0.0
15.0	18.0	1 3 6 3 1	NIL	0.0
18.0	21.0	1 3 6 3 1	NIL	0.0
21.0	24.0	1 3 6 3 1	NIL	0.0
24.0	27.0	1 3 6 3 1	NIL	0.0



GENERAL DESCRIPTION

GENERAL DESCRIPTION	DEPTH (m)
TOP SOIL CLAYEY SAND, DARK BROWN	0.4
RESIDUAL SOIL, REDDISH BROWN CLAYEY SAND	2.5
SAND BROWNISH (WASH MATERIAL FROM COMPL. WEATH. ROCK)	3.0
GARNETIFEROUS BIOTITE GNEISS, MEDIUM TO COARSE GRAINED, DISCOLOURED, GNEISSIC, MAIN COMPONENTS Qu, Fd, GA AT 3·24 (w) 3 45(w) 6 23 PJ/ 60° AT 3 07 wJ/45° AT 3 38 wJ/05° AT 3 7 wJ/20° AT 4 1 (w) 4 23(w) 4·27 (w) 4·3(w) 4 49(w) J/18° AT 4·18 CLAY FILL J/25° AT 4·8 5·0 wJ/55° AT 5·00(w) 5 1(w) 5 23(w) J/10° FROM 5·0 – 5·1 wJ/80°	4.0 5.3 7.0
GARNETIFEROUS BIOTITE GNEISS, MEDIUM GRAINED WITH OCCASIONAL PLUM PUDDING GARNETS, LIGHT GREY FROM 6·3 TO 7·0 CLOSELY SPASED WITH SUB HOR. J. FROM 6 38 TO 6 65 $CACO_3$ FILL J FROM 7 0 TO 7·25 AND 8·20 TO 8·82 CI SPASED WEATH J/10° FROM 7·0 TO 7·15 WJ/85° FROM 9·0 TO 9·4 AND 10·5 TO 10·9 HORNBLENDE-BIOTITE GN. MEDIUM GRAINED	7.2 9.0 9.15 10.0
GARNETIFEROUS BIOTITE GNEISS, LIGHT COLOURED, MEDIUM GRAINED WITH OCCASIONAL COARSE PLUM PUDDING GARNETS, GNEISSIC, MAIN COMPONENTS QU, Fd, BI, GA AT 9·15 WJ/20° OPEN AT 9 15 WJ/20° OPEN AT 9·88, 10·0 BI WJ/15° FROM 10·16 TO 10·35 AND 11·9 TO 12·2 J/80° FROM 13 0 TO 13 30 AND 14·7 TO 14 9 HORNBLENDE – BIOTITE RICH BANDS FROM 16·10 TO 16 25, 16·38 TO 16 48 AND 16·65 TO 16 85 FJ/65°	10.9 12.0 13.5 15.0 16.0 17.0 18.0
GARNETIFEROUS BIOTITE GNEISS, LIGHT COLOURED, MEDIUM GRAINED BUT WITH OCCASIONAL PINK COLOUR, COARSE GRAINED Fd. RICH LAYERS GNEISSIC, MAIN COMPONENTS Qu, Fd, BI, GA AT 25·77 J/25	19.94 21.0 24.0 25.0 27.0



KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (NEW/OLD), TAILRACE OUTFALL

B.H KK8 SHEE OF

DRILLING DATA

STARTED 21·12·81 COMPLETED 06·01·92
INTERRUPTIONS (DAYS) 02
MACHINE TYPE DRILL - TONE
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN GD LOGGED BY
CORE STORED AT
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 157538·671
Y COORDINATE 144026·924
ELEVATION (COLLAR) 40·568
ELEVATION (BOTTOM) 0·518
FINAL DEPTH 40·05
INCLINATION FROM VERTICAL: VERTICAL
BEARING
LOCATION (...):

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1-1.0mm
MO = moderately open 1.0-5.0mm
O = open > 5.0mm

RECOVERY
CORE RECOVERY (%)
R.Q.D. (%)

OTHER SYMBOLS
P.L.S. = point load strength index
U.C.S. = uniaxial compressive strength
▽ = first ground water
R = rock sample
W = auger sample

WEATHERING

soil ; unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

	MN/m²	
	A	< 1.
weak	B	1.0 - 5.0
	C	5.0 - 25
moderately strong		25.0 - 50
strong		50.0 - 100
very strong		100.0 - 250
extremely strong		> 25

DEPTH (m)	DRILLING: DAILY ADVANCE	CASING/CEMENT	(DRILL WATER (COLOUR, LOSS))	RATE OF DRILLING	WATER LEVELS	TESTS: TEST	RESULT	JOINTS: JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING (<0.05m, 0.05-0.30m, 0.30-1.00m, 1.00-3.00m, >3.00m)	PERMEABILITY: DEPTH (m) FROM TOP	TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R.Q.D. % (0 50 100)	GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	ENGINEERING ASPECTS: REMARKS (with respect to excavation, grouting, permeability, rock quality etc.)
30·1	01/01 02/01				10·4 01/01 10·4			I	R	T		27·0	30·0	1 3 6 3 1	NIL	0 0		GARNETIFEROUS BIOTITE GNEISS AS ABOVE AT 27·32 FJ/60				
33·0					02/01							30·0	33·0	1 3 6 3 1	NIL	0 0						
36·0	04/01				10·4							33·0	36·0	1 3 6 3 1	NIL	0 0						
39·0	05/01				04/01 10·4			II	R	T		36·0		1 3 6 3 1	8.0 11.2 13 7 10 0 7.8	20.0 9 3 5 7 8 3 19.5		FROM 38·08 TO 38·22 CHL FILLED FJ/70°				
40·05	06/01				05/01 10·4								40·05									
					06/01																	

HOLE COMPLETED AT THE DEPTH OF 40·05m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD), WEIR AXIS

BHKK9 SHEET 01 OF 01

DRILLING DATA

[illegible] 24.02.92 COMPLETED 04 03 92
[illegible] (DAYS) 02
[illegible] TYPE ACKER
[illegible] METHOD ROTARY
BARREL, BIT NX
MAN ID LOGGED BY
CHECKED AT
[illegible], DATE

BOREHOLE DATA

X-COORDINATE 153,148·970
Y-COORDINATE 150,612·970
ELEVATION (COLLAR) 211 21
ELEVATION (BOTTOM) 190·76
FINAL DEPTH 20.45m
INCLINATION FROM VERTICAL 0°
BEARING
LOCATION (see [illegible])

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1-1.0mm
MO = moderat open 1.0-5.0mm
O = open > 5.0mm

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

OTHER SYMBOLS
PL.S.I = point load strength index
UCS = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil / unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0 - 25.00
moderately strong		25.0 - 50.00
strong		50.0 - 100.00
very strong		100.0 - 250.00
extremely strong		> 250.00

DRILLING

CASING / CEMENT
DRILL WATER (COLOR, LOSS): DRY DRILLING; YELLOWISH; GREYISH
RATE OF DRILLING
WATER LEVELS: 6.2 / 26/02; 8.7 / 28/02; 07 / 02; 9.5 / 28/02; 10.7 / 03/03; 10.72 / 03/03; 1 42 / 04/03

TESTS

TEST	RESULT
SPT	31
SPT	37
SPT	47
SPT	>50
SPT	>50

JOINTS

JOINT SET NO.	ROUGHNESS	SEPARATION
II	R	T
III	R	T
III	R	O
I	R	O
II	R	O
III	R	T
III	R	T
I	R	T
II	R	T
III	R	O
I	R	T
II	R	T
II	R	T
I	R	T
II	R	T

SPACING: < 0.05 m; 0.05-0.30 m; 0.30-1.00 m; 1.00-3.00 m; > 3.00 m

PERMEABILITY

DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
0.0	1.45			$K=1.92\times10^{-5}$
1.45	2.9			$K=8.68\times10^{-6}$
2.9	4.35			$K=5.78\times10^{-6}$
4.35	5.8			$K=3.99\times10^{-6}$
5.8	7.0			$K=3.66\times10^{-6}$
7.0	7.8			$K=5.04\times10^{-6}$
7.8	8.8			$K=4.38\times10^{-6}$
8.8	9.8			$K=3.32\times10^{-6}$
11.57	15.09	1	1.6	2.2
		3	2.1	1.5
		6	2.8	1.1
		3	2.0	1.4
		1	1.4	1.9
14.58	18.10	1	1.2	1.6
		3	1.6	1.1
		6	2.2	0.9
		3	1.5	1.0
		1	1.2	1.6
16.93	20.45	1	1.8	2.4
		3	2.4	1.6
		6	3.2	1.3
		3	2.2	1.5
		1	1.6	2.1

RECOVERY

CORE RECOVERY % AND R Q D %
0 50 100

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

TOP SOIL, DARK BROWN CLAYEY SAND

RESIDUAL SOIL YELLOWISH BROWN CLAYEY SAND WITH COBBLES

RESIDUAL SOIL YELLOWISH BROWN/ REDDISH BROWN CLAYEY SAND WITH TRACES OF GRAPHITE.

RESIDUAL SOIL YELLOW/YELLOWISH BROWN CLAYEY SAND WITH TRACES OF GRAPHITE

WHITISH TO LIGHT BROWN WEAK ROCK WITH TRACES OF GRAPHITE.

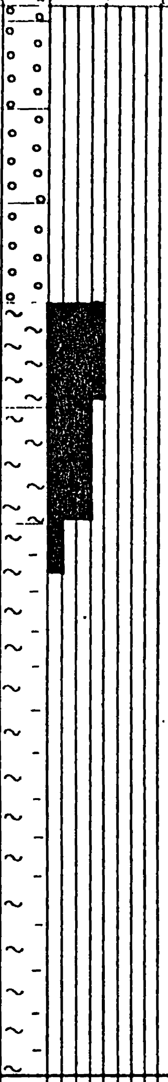
WHITISH TO LIGHT BROWN GARNETI-FEROUS, GRAPHITE.

FROM 7 8 TO 9 8 WEATHERED JOINTS

GARNETIFEROUS BIOTITE GNEISS WITH COARSE GARNETS, LIGHT COLOURED MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Qu, FD, GA.

FROM 9 8 TO 10.2 CLOSELY SPACED WEATHERED J
AT 10 2, 10.65 J/60°
AT 10.44 J/30° 10 84 J/10°
AT 10 96 J/10°
AT 11.40 SL WEATH J/60°
AT 12 10 SL WEATH FJ/65°
AT 11.46, 11 50 J/20°
AT 12.96 J/30°
AT ~~14~~63, 17.24 F J/60°
AT 14 8, 16.07, 16 56 J/50°
AT 15 35 J/30°
AT 18.06 J/70°
AT 19.64 FJ/70°
FROM 19.8 TO 19.94 J/65°

GRAPHIC LOG — WEATHERING — ROCK STRENGTH



ENGINEERING ASPECTS

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

DEPTH (m): 0 25; 2 0; 3.9; 5.8; 7 8; 10 0; 11 57; 15.09; 18 10

HOLE COMPLETED AT THE DEPT OF 20.45 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD), WEIR AXIS

B.H-KK10 SHEE OF 02

DRILLING DATA	BOREHOLE DATA
STARTED: 12.12.91 COMPLETED: 26.12.91	X-COORDINATE 153,000.409
INTERRUPTIONS (DAYS): 03	Y-COORDINATE 150,563.453
MACHINE TYPE ACKER	ELEVATION (COLLAR) 199.01
DRILLING METHOD ROTARY	ELEVATION (BOTTOM) 168.45
CORE BARREL, BIT: NX	FINAL DEPTH 30.56m
FOREMAN: ID LOGGED BY:	INCLINATION FROM VERTICAL: 0°
CORE STORED AT:	BEARING
CORE DISCARDED, DATE:	LOCATION (see Fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1mm
R = rough	T = tight	0.1-1.0mm
SR = slightly rough	MO = moderat open	1.0-5.0mm
S = smooth	O = open	> 5.0mm
SL = sollickensided		

RECOVERY
- ▒ CORE RECOVERY (%)
- ▨ R.Q.D (%)

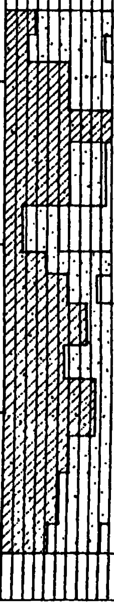
OTHER SYMBOLS
- PL.S.I. = point load strength index
- U.C.S = uniaxial compressive strength
- ▼ = first ground water
- R = rock sample
- W = water sample

WEATHERING
- soil: unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH

		MN/m²
	A	<1.
weak	B	1.0-5.0
	C	5.0-25
moderately strong		25.0-100
strong		50.0-100
very strong		100.0-250
extremely strong		> 25

DEPTH (m)	DRILLING: DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TESTS: TEST	RESULT	JOINTS: JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING 0.05 / 0.05-0.30m / 0.30-1.00m / 1.00-3.00m	PERMEABILITY: DEPTH (m) FROM TOP	TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)	GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	ENGINEERING ASPECT: REMARKS (with respect to excavation, grouting, permeability, rock qual etc.)
0.82	12/12											0.0	0.82			5.355x10⁻⁵		TOP SOIL YELLOWISH BROWN CLAYEY SAND	
1.58																		BOULDER- CHARNOCKITE GNEISS DARK GREY	
2.03						SPT	29					1.58	2.68			2.045x10⁻⁶		RESIDUAL SOIL - YELLOWISH BROWN CLAYEY SAND	
2.53	14/12																	RESIDUAL SOIL: REDDISH BROWN CLAYEY SAND	
2.88						SPT	48											COMPLETELY WEATH GARNETIFEROUS ROCK, YELLOWISH BROWN	
3.33												2.68	4.11			2.787x10⁻⁶		RESIDUAL SOIL LIGHT BROWN	
3.50																		ALLUVIAL DEPOSITS DARK BROWN SANDY CLAY	
3.60																		DARK GREY, PLASTIC SILTY CLAY	
4.11	15/12					SPT	22											COMP. WEATH GARNETIFEROUS ROCK	
4.58												4.11	5.56			2.02x10⁻⁶		ALLUVIUM - CLAYEY SAND YELLOWISH BROWN	
																		ALLUVISM - CLAYEY GRAVELLY SAND (ROUNDED GRAVEL)	
5.56						SPT	46											ALLUVIUM - GRAVELLY SAND, LIGHT BROWN	
6.50												5.56	7.00			2.344x10⁻⁶			
	16/12					SPT	22					7.0	8.45			1.020x10⁻⁶		GARNETIFEROUS ROCK, COMP. WEATH. PINKISH GREY. WEAK FROM 6.7 TO 7.0- SILTY CLAY VERY LIGHT GREENISH WHITE (MYLONITE)	
						SPT	25												
9.00												8.45	9.90			2.186x10⁻⁶		KAOLINE-RICH COMP. WEATH. ROCK. YELLOWISH, WEAK (BRECCIA)	
	17/12											9.90	11.35			1.457x10⁻⁶			
11.15						SPT	48					11.35	12.8			2.76x10⁻⁶		COMP. WEATH. FELDSPATHIC ROCK. WHITISH, WEAK	
12.60						SPT	>50											GARNETIFEROUS ROCK, COMP. WEATH. WEAK, YELLOWISH BROWN.	
	18/12											12.8	14.25			4.37x10⁻⁶			
14.55						SPT	>50											GARNETIFEROUS ROCK. COMP. WEATH. BROWNISH	
	19/12											14.25	15.55			4.45x10⁻⁶			
												15.55	16.55			4.24x10⁻⁶			
16.55																		GREYISH GNEISSIC ROCK	
16.90																		GARNETIFEROUS BIOTITE GNEISS, LIGHT COLOURED, GNEISSIC. MEDIUM GRAINED, MAIN COMPONENTS: Qu, Fd, Bi, GA. AT 17.10, 17.15, 17.19 FJ/60° AT 17.53, 17.57, 17.65 WEATH. J/80° AT 17.92 J/20° AT 17.92, 17.93, 18.72 (SL. WEATH.) FJ/60° AT 18.10, 18.12, 18.18, 18.26, 18.27, 18.50 J/30° AT 19.38, 19.92, 20.05 J/20° FROM 22.92 TO 22.98 HORNBLENDE-BIOTITE LAYER, DARK GREY. MEDIUM GRAINED AT 20.08, 20.25, 20.73 (SL.W) FJ/60° AT 20.27, 20.34, 20.36, 20.45 J/50° FROM 20.46 TO 20.55 Cl. Sp. J/50° AT 20.75 (SL.W) 20.8, 20.82, 21.44 J/50° AT 21.67, 21.69, 21.72 J/20° FROM 24.28 TO 24.45 AND FROM 25.58 TO 25.68 HORNBLENDE-BIOTITE LAYERS. DARK GREY, MEDIUM GRAINED AT 22.06, 22.08, 22.10, 22.15 J/20° AT 22.75, 22.97, 23.22, 23.30, 23.60 FJ/60° FROM 23.4-23.7 WEATH. J/80°	
17.27																			
17.92	20/12																		
18.72												18.3		1	7.2	14.3			
19.38														3	9.8	8.1			
														6	12.6	5.6			
														3	10.2	8.5			
20.73	21/12													1	7.4	14.7			
21.45													21.82						
21.82												21.39							
														1	5.6	11.0			
22.48														3	8.6	7.1			
														6	10.8	4.8			
23.40																			
23.70														3	9.0	7.4			
23.86	24/12													1	5.8	11.4			
24.91												24.45	24.91						
														1	5.8	11.2			
25.60														3	7.1	5.8			
														6	8.7	3.8			
26.45														3	7.2	5.9			
														1	6.0	11.5			



KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

EATURE - KK 205 (OLD), WEIR AXIS

B.H-KK10 SHEET 02 OF 02

DRILLING DATA

ED 12·12·91 COMPLETED 26·12·91
UPTIONS (DAYS): 03
E TYPE ACKER
NG METHOD ROTARY
ARREL, BIT: NX
IAN: ID LOGGED BY:
STORED AT:
DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 153,000·409
Y-COORDINATE 150,563·453
ELEVATION (COLLAR) 199·01
ELEVATION (BOTTOM) 168·45
FINAL DEPTH 30·56m
INCLINATION FROM VERTICAL: 0°
BEARING
LOCATION (see Fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	<0.1mm
R = rough	T = tight	0.1-1.0mm
SR = slightly rough	MO = moderat open	1.0-5.0mm
S = smooth	O = open	>5.0mm
SL = slickensided		

RECOVERY	OTHER SYMBOLS
░ CORE RECOVERY (%)	P.L.S.I. = point load strength index
▨ R.Q.D (%)	U.C.S = uniaxial compressive strength
	▼ = first ground water
	R = rock sample
	W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING: CASING/CEMENT	DRILLING: DRILL WATER (COLOR, LOSS)	DRILLING: RATE OF DRILLING	DRILLING: WATER LEVELS	TESTS: TEST	TESTS: RESULT	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	JOINTS: SPACING (0·05-0·30m, 0·30-1·00m, 1·00-[illegible])	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PERMEABILITY: PRESSURE (BARS) (manometer reading)	PERMEABILITY: WATER LOSS (total Litres/minute)	PERMEABILITY: LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)	GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc; scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	ENGINEERING ASPECTS: REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)	DEPTH (m)
											27·95					AT 23·96, 24·66, 24·82, 30·25 J/75°					27 95
										27·04		1 3 6 3 1	6·2 7·8 9·4 8·1 6·3	11·9 6·4 4·1 6·6 12·1		AT 24·02, 24·36, 25·84, 26 43 (SL.W) 26·45 ( ) SL. 28·58, 28·0 28·95 FJ/45—50° AT 25·06, 25·15, 25·6, 25 67, 25·9 25·95, 25·99, 27·56, 27·95, 28 12 28·18, 29·16, 29·35 J/20°					29 48
											30 56										30 56

HOLE COMPLETED AT THE DEPTH OF 30·56 M.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD), DESANDER

B.H. KK11 | SHEE OF 02

DRILLING DATA

STARTED COMPLETED.15 03·92
INTERRUPTIONS (DAYS).
MACHINE TYPE TONE - TDC 1
DRILLING METHOD. ROTARY
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 153143.450
Y-COORDINATE 150444.280
ELEVATION (COLLAR) 211.58
ELEVATION (BOTTOM) 181.48
FINAL DEPTH 30·10m
INCLINATION FROM VERTICAL, 0°
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1mm
R = rough	T = tight	0.1-1.0mm
SR = slightly rough	MO = moderat. open	1.0-5.0mm
S = smooth	O = open	> 5.0mm
SL = slickensided		

RECOVERY

▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS

P.L.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

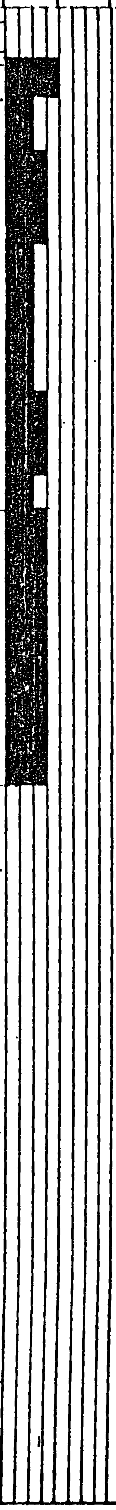
ROCK STRENGTH

MN/m²		
	A	< 1.0
weak	B	1.0 - 5.0
	C	5.0-25.0
moderately strong		25.0-50.0
strong		50.0-100.0
very strong		100.0-250
extremely strong		> 25

DRILLING – TESTS – JOINTS – PERMEABILITY – RECOVERY – GENERAL DESCRIPTION – ENGINEERING ASPECTS

Column heads: DEPTH (m); DRILLING: DAILY ADVANCE, CASING/CEMENT, DRILLWATER (COLOR, LOSS), RATE OF DRILLING, WATER LEVELS; TESTS: TEST, RESULT; JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05m, 0.05-0.30m, 0.30-1.00m, 1.00-3.00m, > 3.00m); PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec; RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100); GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ENGINEERING ASPECTS: ROCK STRENGTH, REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

DEPTH (m)	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON	GENERAL DESCRIPTION
0·2		SPT	20									TOP SOIL BLACKISH CLAYEYSAND
0·78												RESIDUAL SOIL. LIGHT BROWN, CLAYEY SILT
												RESIDUAL SOIL. YELLOWISH BROWN CLAYEY SAND/SILT
1·88												GARNETIFEROUS ROCK VERY WEAK, WHITISH TO REDDISH BROWN
2·47												GARNETIFEROUS ROCK (CHARNOCKITE ?) DISCLOURED. COARSE TO MEDIUM GRAINED
3·76												
5·0												
6·62												
8·0												
9·0							9·0					
9·82	0·0 10/03								1	9·5	15·4	GARNETIFEROUS BIOTITE GNEISS DISCOLOURED, MEDIUM GRAINED, CORE SEPARATED INTO PIECES BY EVENLY SPACED WEATHERED FOLIATION JOINTS ∠ 15° - 20°
									3	18·0	14·8	
									6	27·6	13·0	
									3	18·5	15·2	
								12·0		9·8	15·9	
12·0				I	R	T/MO	12·0					
									1	10·0	14·9	
									3	19·2	15·1	
	12·0 11/03								6	28·0	12·9	
									3	19·6	15·4	
									1	11·0	16·4	
14·9								15·0				GARNETIFEROUS BIOTITE GNEISS, LIGHT COLOURED. COARSE TO MEDIUM GRAINED. MAIN COMPONENTS Qu, FD, BI AT 15·03, 15·17, 15·35, 15·50, 15·70 F J/20° AT 15·12, 15 13, 15·87, 16 06, 15·38 J/50°-60°
15·0							15·0					
				I	R	T/MO			1	3·2	4·8	
16·10									3	5·7	4·5	
16·21	12·0 12/03			II	R	T			6	11·0	5·1	CHARNOCKITIC GNEISS WITH COARSE GRAINED GARNET RICH BANDS UP TO 30 Cm. GREY MEDIUM TO COARSE GRAINED, GNEISSIC, MAIN COMPONENTS Qu, FD, PY AT 16·70 FJ/20° AT 16·26, 16·27 J/50°
									3	5·5	4·3	
									1	3·0	4·5	
								18·0				
18·0							18·0					
				I	R	T			1	2·8	4·2	
									3	5·0	3·9	
				II	R	T			6	10·0	4·6	AT 18·0, 18·84, 19 52, 20·22 20 36, 21 0 FJ/20°
	12·25 12/03			III	R	T			3	5·3	4·2	AT 20·68 J/40°
									1	2·9	4·3	AT 20·70 J/60°
21·0							21·0	21·0				GARNETIFEROUS BIOTITE GNEISS, LIGHT COLOURED. MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Qu, FD, BI, GA AT 21 0 FJ/25°
				I	R	T			1 3 6	NIL	0·0	
	12·35 13/03			II	R	T			3			AT 21·70, 21·92 J/50°
									1			
24·0							24·0	24·0				AT 24 12, 24 51, 24 57, 24 7, 24·82, 25·15, 25·56, 25·75 FJ/25°
				I	R	T			1			
									3	NIL	0·0	
	12·35 14/03			II	R	T			6			AT 25·45 J/60°
									3 1			
27·0							27·0	27·0				AT 27·20 J/60°



KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD), DESANDER	BH KKII	SHEET 02 OF 02

DRILLING DATA

ATED COMPLETED.15 05·92
RRUPTIONS (DAYS)
HINE TYPE TONE - TDC I
LING METHOD ROTARY
E BARREL, BIT: NX
E MAN: LOGGED BY:
E STORED AT:
E DISCARDED, DATE:

BOREHOLE DATA

X - COORDINATE 153143 450
Y - COORDINATE 150444 280
ELEVATION (COLLAR) 211 58
ELEVATION (BOTTOM) 181 48
FINAL DEPTH 30·10m
INCLINATION FROM VERTICAL 0°
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0 1-1 0mm
MO = moderat open 1.0-5 0mm
O = open > 5 0mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
P.L.S = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 - 5.00
	C	5 0-25.00
moderately strong		25 0-50 00
strong		50 0-100 00
very strong		100 0-250.00
extremely strong		> 250.00

DRILLING					TESTS		JOINTS				PERMEABILITY					RECOVERY	GENERAL DESCRIPTION			ENGINEERING ASPECTS		
DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	CORE RECOVERY % AND R Q D % (0 50 100)	rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	REMARKS (with respect to excavation, grouting, permeability, rock quality, etc)	DEPTH (m)
				12·4 15/05			I II	R R	T T			30·10	1 3 6 3 1	NIL	0·0		AT 28·39 FJ/ 28°					
					HOLE						COMPLETED				AT	THE	DEPTH OF 30·10 m					

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

B.H KK12

FEATURE - KK 205 (OLD), HEADRACE INTAKE

DRILLING DATA

STARTED 92-02-03 COMPLETED 92-02-17
INTERRUPTIONS (DAYS): 02
MACHINE TYPE TONE
DRILLING METHOD: ROTARY
CORE BARREL, BIT: NX
FOREMAN: GSD LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 158128,550 N
Y-COORDINATE 150359,850 E
ELEVATION (COLLAR) 238·33
ELEVATION (BOTTOM) 208·30
FINAL DEPTH 30·03 m
INCLINATION FROM VERTICAL: 0°
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0.1 mm
T = tight 0.1-1.0 mm
MO = moderately open 1.0-5.0 mm
O = open > 5.0 mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
PL.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil (unconsolidated material)
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

MN/m²
A
weak B
C
moderately strong
strong
very strong
extremely strong

DRILLING / TESTS

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	WATER LEVELS	TEST	RESULT
	1·45 02/03		DRY DRILLING		SPT	>50
1·6						
1·95		2·0				
2·14	2·41					
2·87	02/05			2·7 02/04		
3·4						
4·6	4·6 02/06					
5·8				6·1 02/07		
7·6	7·6 02/07			6·25 02/08		
10·6	10·6 02/08		CREAMY TO WHITSH			
12·2				6·25 02/10		
13·6	13·6 02/10			7·12 02/11		
				16·5 02/12		
16·7	18 3 02/11					
18·2	18·6 02/12			17·15 02/13		
	11 7 02/13					
	20·8 02/13		LOSS OF WATER	18·0 02/14		
22·6	22·6 02/14			17·4 02/15		
24·19				17·48 02/16		
25·7	25·7 02/15			17·75 02/18		

JOINTS

JOINT SET NO.	ROUGHNESS	SEPARATION
II	R	MO
III	R	MO
II	R	MO
II	R	MO
III	R	MO
II	R	T
III	R	T
III	R	T
I	R	T
II	R	T
III	R	T
II	R	T
II	R	T
III	R	T
IV	R	MO
II	R	MO
IV	R	O
II	R	T
IV	R	T
I	SR	T
IV	SR	T

SPACING: 0·06 m; 0·06-0·30 m; 0·30-1·00 m; 1·00-3·00 m; > 3·00 m

PERMEABILITY

DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
0·0	1·6			K =
1·6	4·6	1	0·5	1·4
		3	0·8	0·8
		6	1·2	0·6
		3	0·6	0·6
		1	0·4	1·1
4·6	7·6	1 3 6 3 1	NIL	0·0
7·6	10·6	1 3 6 3 1	NIL	0·0
10·6	13·6	1 3 6 3 1	NIL	0·0
13·6	16·7	1	14·3	18·2
		3	23·8	18·6
		6	PRESSURE NOT	DEVELOPED
		3	24·9	17·8
		1	15·4	19·8
16·7	19·7	1 3 6 3 1	PRESSURE COULD NOT BE DEVELOPED	
19·7	22·6	1 3 6 3 1	NIL	0·0
22·6	25·7	1 3 6 3 1	NIL	0·0
25·7		1 3 6 3 1	NIL 1‾	0·0

RECOVERY

CORE RECOVERY % AND R Q D %
0 50 100

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, injected, flow banded, gneissose, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

TOP SOIL - DARK BROWN CLAYEY SAND

RESIDUAL SOIL - REDDISH BROWN CLAYEY SAND

RESIDUAL SOIL - DARK BROWN TO REDDISH BROWN CLAYEY SAND

COMPLETLY WEATHERED

RESIDUAL SOIL - REDDISH BROWN CLAYEY SAND

GARNETIFEROUS BIOTITE GNEISS, COARSE TO MEDIUM GRAINED, LIGHT COLOURED, MAIN COMPONENTS Qu, Fd, B B COARSE GRAINED GARNETS

CHARNOCKITE, DARK GRAY, MEDIUM GRAINED, MASSIVE, MAIN COMPONENTS, Qu, Fd, PY WITH INTERCALATION OF DARK GREY HORNEBLNDE BIOTITE LAYERS UP TO 40 cm AT 1·65, 1·75 2·22, 2·82, 3·02 WEATH J/65°
AT 1·82, 1·79, 1·95 WEATH J/15°

AT 2·45 SI WEATH J/25°

AT 3·38, 5·76 J/25°

AT 6·65, 6·73 FJ/60°

AT 11·72, 12·47, 14·20, 14·50
14·54, 15·03 J/35° - 40°
AT 11·10, 11·26 J/65°
FROM 14·5 TO 14·85 J/85°

GARNETIFEROUS QUARTZ - FELDSPAR GNEISS, LIGHT COLOURED MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Qu, Fd, GA, BI AT 16·71, 16·97 17·08, 17·35, 17·38 ALL WITH J/15° - 25°
AT 17·06 WITH J/60°

AT 18·0, 18·06, 19·10, 19·82, 19·84, 20 83, 20·88, 21·28 J/10°

FROM 20·89 TO 21·22 J/85°

AT 25·85, 25·67 FJ/65°

CHARNOCKITIC GNEISS WITH BIOTITE ENRICHED LAYES UP TO 2 cm, DARK GREY, MEDIUM GRAINED, MAIN COMPONENTS Qu, Fd, PY, GA
AT 26·5 J/35°

HORNBLENDE - BIOTTE GNEISS

GRAPHIC LOG | WEATHERING

ENGINEERING AS

ROCK STRENGTH

REMARK
(with respect to excavation, gr permeability, r. etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD), HEADRACE INTAKE

B.H KK12 SHEET 02 OF 02

DRILLING DATA

ARTED 92-02-03 COMPLETED 92-02-17
ERRUPTIONS (DAYS) 02
CHINE TYPE TONE
ILLING METHOD ROTARY
RE BARREL, BIT: NX
REMAN: GSD LOGGED BY:
RE STORED AT:
RE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 153126,550 N
Y-COORDINATE 150359,850 E
ELEVATION (COLLAR) 238·33
ELEVATION (BOTTOM) 208·30
FINAL DEPTH 30·03 m
INCLINATION FROM VERTICAL: 0°
BEARING
LOCATION (see Fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION

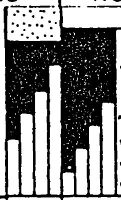
V = very tight	< 0.1 mm
T = tight	0.1-1.0 mm
MO = moderat open	1.0-5.0 mm
O = open	> 5.0 mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
PL.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil - unconsolidated material
completely
highly
moderately
slightly
fresh



ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING					TESTS		JOINTS				PERMEABILITY					RECOVERY	GENERAL DESCRIPTION			ENGINEERING ASPECTS		
DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	CORE RECOVERY % AND R Q D % (0 50 100)	rock type, colour, grain size, texture and structure (massive, cleaved, foliated, inected, flow banded, gneissose, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)	DEPTH (m)
28·4 02/4												28·7					DARK GREY TO BLACKISH, MEDIUM GRAINED, MAIN COMPONENTS HO, BI					
							IV	SR	T								AT 29·88, 29·90 J/10°					

HOLE COMPLETED AT THE DEPTH OF 30·03 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (OLD), WEIR AXIS

BHKK16

SHE
OF

DRILLING DATA

STARTED 09 03.92 COMPLETED 13 03 92
INTERRUPTIONS (DAYS) —
MACHINE TYPE ACKER
DRILLING METHOD ROTARY
CORE BARREL, BIT: NX
FOREMAN: ID LOGGED BY
CORE STORED AT
CORE DISCARDED, DATE

BOREHOLE DATA

X-COORDINATE 153,131·507
Y-COORDINATE 150,598·432
ELEVATION (COLLAR) 197·63
ELEVATION. (BOTTOM) 182·37
FINAL DEPTH 15.26m
INCLINATION FROM VERTICAL 0°
BEARING
LOCATION (see f.g

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR=very rough	V =very tight	<0.1mm
R =rough	T =tight	0.1–1.0mm
SR=slightly rough	MO=moderat.open	1.0–5.0mm
S =smooth	O =open	> 5.0mm
SL=slickensided		

RECOVERY

- ▒ CORE RECOVERY (%)
- ▨ R.Q.D (%)

OTHER SYMBOLS

P.L.S.I.=point load strength index
U.C.S =uniaxial compressive strength
▽ =first ground water
R =rock sample
W =water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGT

	MN/m²	
	A	<
weak	B	1.0–
	C	5.0–2
moderately strong		25.0–5
strong		50.0–
very strong		100.0/
extremely strong		>

DRILLING · TESTS · JOINTS

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION
0 72			DRY DRILLING							
1 0										
1 45						SPT	23			
	2.45 09.03									
2. 9						SPT	>50			
3.42		3 4 10.03								
3. 8								II	R	T
3 9								II	R	T
								III	R	T
4. 45					1.62 10.03			II	R	T
4 88	4 88 10.03							II	R	T
								III	R	T
6 03								II	R	T
6.72										
7.13								III	R	T
7.42	7.42 11.03									
8 39			GREYISH		2 91 11.03			I	R	T
								III	R	T
9. 92								II	R	T
10.65										
11 48	11.48 12.03				2.9 12.03			II	R	O
								III	R	T
12.92								III	R	T
14.16					2.9 13.03					
15 0										

SPACING: 0.05 / 0.05–0.30 / 0.30–1.00 / 1.00–3.00 / >3.00

PERMEABILITY

DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (totalLitres/minute)	LUGEON or PERMEABILITY m/sec
0 0	1.0			$K=1.12\times10^{-5}$
1.0	2.45			$K=1.21\times10^{-6}$
2 45	3.42			$K=1673\times10^{-5}$
3.9	7.42	1	2.8	6 2
		3	4.6	4.0
		6	6.8	3.1
		3	4.9	4.2
		1	3.0	6.6
7.13	10.65	1 3 6 3 1	NIL	0.0
10.64	14.16	1	7.0	19.9
		3	11.2	10.6
		6	16.2	7.6
		3	11 8	11.2
		1	7.4	21.0
13.24	15.26	1 3 6 3 1	NIL	0.0

RECOVERY

CORE RECOVERY % AND R.Q.D %
0 50 100

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

DEPTH (m)	GENERAL DESCRIPTION
0 0	TOP SOIL. DARK BROWN SANDY CLAY WITH PLANT ROOTS
0 72	COBBLE: AMPHIBOLITE, DARK GREY
1 0	RESIDUAL SOIL. YELLOWISH BROWN TO REDDISH BROWN CLAYEY SAND.
2.45	RESIDUAL SOIL. WHITISH TO YELLOWISH BROWN CLAYEY SILT
2. 9	YELLOWISH BROWN VERY WEAK ROCK
3.42	CHARNOCKITIC GNEISS. WITH INTERCALATION OF HORNBLENDE-BIOTITE GNEISS BANDS UP TO 10cm. GREY, MEDIUM GRAINED, GNEISS, MAIN COMPONENTS Qu, FD, Py. FROM 3.42 TO 3.8 CLOSELY SPACED J/50° AT 3.86, 3.89, 4.3, 4.42, J/50 -60 AT 4 06, 4 12 CHL J/50° AT 4.0, 4.05, 4.10, 4.32, 4.38 CHL. J/10-15° AT 4.87 J/45°, 4 88 J/70° FROM 4.95 TO 5 34 CHL, CLOSELY SPACED J/70° AT 5.20, 5 34, 7.24 J/15° FROM 5.78 TO 5 93 J/65° FROM 6.24 TO 6.34, 6 43 TO 6.62 J/70° AT 8 89 FJ/50° AT 8.91, 9.15 J/15-20° AT 10 15 AND FROM 10 12 TO 10.24 J/70° FROM 11.58 TO 11 68 WEATHERED (5mm THICK) J/50°) AT 11.9 OPEN WEATH J/5° AT 11 77, 11.94, 11.96, 12.20 WEATH. J/15° FROM 11.93 TO 12.08 J/70° AT 13 90 J/20°

GRAPHIC LOG | WEATHERING

ENGINEERING ASPEC

ROCK STRENGTH

REMARKS (with respect to excavation, grouting, permeability, rock qu etc.)

OBSERVED OVERFLOW OF WATER AT THE RATE OF 2LITRES/MIN

HOLE COMPLETED AT THE DEPTH OF 15.26 m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

EATURE - KK 205 (OLD), WEIR AXIS

BHKK18 SHEET 01 OF 01

RILLING DATA	BOREHOLE DATA
28.03.92 COMPLETED 04.04.92	X-COORDINATE 153,173·423
PTIONS (DAYS) 04	Y-COORDINATE 150,580·528
TYPE ACKER	ELEVATION (COLLAR) 205·960
G METHOD ROTARY	ELEVATION (BOTTOM) 185·800
ARREL, BIT NX	FINAL DEPTH 20.16
N 10 LOGGED BY	INCLINATION FROM 0° VERTICAL
TORED AT	BEARING
SCARDED, DATE	LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION
VR=very rough	V =very tight < 0.1mm
R =rough	T =tight 0.1-1.0mm
SR=slightly rough	MO=moderat.open 1.0-5.0mm
S =smooth	O =open > 5.0mm
SL=slickensided	

RECOVERY	OTHER SYMBOLS
CORE RECOVERY (%)	P.L.S I.=point load strength index
R.Q.D (%)	U.C.S =uniaxial compressive strength
	▼ =first ground water
	R =rock sample
	W =water sample

WEATHERING.

- soil : unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0 - 25.00
moderately strong		25.0 - 50.00
strong		50.0 - 100.00
very strong		100.0 - 250.00
extremely strong		> 250.00

ILLING: CASING/CEMENT; DRILL WATER (COLOUR, LOSS); RATE OF DRILLING; WATER LEVELS — TESTS: TEST; RESULT — JOINTS: JOINT SET NO.; ROUGHNESS; SEPARATION; SPACING (< 0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, > 3.00 m) — PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total Litres/minute); LUGEON or PERMEABILITY m/sec — RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100) — GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints — GRAPHIC LOG — WEATHERING — ENGINEERING ASPECTS: ROCK STRENGTH; REMARKS (with respect to excavation, grouting, permeability, rock quality, etc) — DEPTH (m)

Drilling

CASING/CEMENT	DRILL WATER (COLOUR, LOSS)	WATER LEVELS
1.45 / 0.08	DRY DRILLING	
	LIGHT BROWN	
	GREYISH	5.7 / 01.04
		8.05 / 02.04
		8.7 / 03.04
		8.7 / 04.04

Tests

TEST	RESULT
SPT	27

Joints

JOINT SET NO.	ROUGHNESS	SEPARATION
I	R	T
I	R	T
II	R	T
III	R	T
II	R	MO
III	R	MO
I	R	T
II	R	MO
III	R	MO
III	R	T
III	R	T
II	R	T
III	R	T
III	R	T
III	R	T
III	R	T
II	R	T
I	R	T
II	R	T
II	R	T
III	R	T
II	R	T
III	R	MO

Permeability

FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON or PERMEABILITY m/sec
0.0	1.45			K =4·15x10^{-5}
5.9	9.0	1 3 6 3 1	2.0 2.8 3.7 2.6 1.6	
8.68	12.16	1 3 6 3 1	3.8 4.6 6.1 5.1 4.2	
13.19	16.69	1 3 6 3 1	3.7 5.1 7.2 5.2 3.9	
16.68	20.16	1 3 6 3 1	3.7 4.3 5.1 4.1 3.0	

GENERAL DESCRIPTION

GENERAL DESCRIPTION	DEPTH (m)
RESIDUAL SOIL. YELLOWISH BROWN CLAYEY SAND	0.45
YELLOWISH BROWN VERY WEAK ROCK	1.55
CHARNOCKITE (CORE STONE)	2.15
YELLOWISH BROWN TO REDDISH BROWN VERY WEAK ROCK.	3.90
CHARNOCKITE LIGHT YELLOWISH BROWN. WEAK	4.45
CHARNOCKITIC GNEISS. WITH INTERCALATION OF HORNBLENDE-BIOTITE BANDS, THICKNESS UP TO 10 cm. GREY, MEDIUM GRAINED MAIN COMPONENTS Qu, FD, Py.	5.0
	6.2
AT 4.72, 4.89 FJ/65°	7.28
AT 5.67, 5.72, 5.76 SL.WEATH FJ/60°	7.82
FROM 5.82 TO 6.05 WEATH.J/80°	8.68
AT 5.47, 5.82, 6.05 WEATH.J/20°	9.0 9.34
AT 7.28, 7.28, 7.68, 7.71, 7.75, 7.78, 7.82 ALL WEATH.J/20°-25°	
AT 8.20 WEATH. J/60°	
AT 9.92, 10.37, 10.55 FJ/60°	
FROM 10.68 TO 10.94 WEATH. J/70°-80°	11.11
AT 10.63 WEATH.J/10°	12.18
AT 11.29, 11.40, 12.12, 12.65, 12.75 CHLORITISIZED J/20°-30°	
AT 12.84, 12.86, 12.90 J/25° WITH PYRITE STAIN.	13.21 13.30
AT 13.33 SL.WEATH. J/60°	13.85
AT 13.29, 13.34 SL.WEATH.J/25°	
AT 13.36, 13.42, 13.48, 13.48, 13.93, 14.20, 14.46, 14.84, 15.18, 15.10 CHLORITISIZED J/15° 25°	14.62
	15.7
	16.3
AT 15.0, 15.08 SL.WEATH.J/20°	16.69
AT 15.26, 15.70, 15.74, 15.75, 15.82 CHL.J/45°	17.25
AT 16.67, 16.69 CHL J/50°	
FROM 16.69 TO 16.80 TECTONIZED ZONE CHLORITISIZATION ALONG DISCONTINUTIES.	18.13
AT 19.18, 19.68, 19.70, 19.73 WEATH.J/15°20°	
FROM 18.92 TO 19.10 WEATH. J/75°	
FROM 19.53 TO 20.16 J/85°	19.53
AT 19.18, 20.16 J/80°	
AT 19.78, 19.87, 20.11, 20.16 J/15-20°	

HOLE COMPLETED AT THE DEPTH OF 20.16 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES **TAB. 13**

FEATURE - KK 205 (OLD), DESANDER INTAKE

BHKK20 SHEET OF

DRILLING DATA

STARTED 25 02 92 COMPLETED 19.03 92
INTERRUPTIONS (DAYS) 09
MACHINE TYPE ACKER
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN LOGGED BY.
CORE STORED AT
CORE DISCARDED, DATE.

BOREHOLE DATA

X-COORDINATE 153,055·970
Y-COORDINATE 150,564·440
ELEVATION (COLLAR) 205·51
ELEVATION (BOTTOM) 170·00
FINAL DEPTH 35.0 m
INCLINATION FROM VERTICAL 0°
BEARING
LOCATION (see) .

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

JOINT SEPARATION

V = very tight	< 0.1mm
T = tight	0.1–1.0mm
MO = moderat open	1.0–5.0mm
O = open	> 5.0mm

OTHER SYMBOLS
P.L.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil: unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

MN/m²

	A	< 1.00
weak	B	1.0–5.00
	C	5.0–25.00
moderately strong		25.0–50.00
strong		50.0–100.00
very strong		100.0–250.00
extremely strong		> 250

DEPTH (m)	DRILLING: DAILY ADVANCE	DRILLING: CASING/CEMENT	DRILLING: DRILL WATER (COLOUR, LOSS)	DRILLING: RATE OF DRILLING	DRILLING: WATER LEVELS	TESTS: TEST	TESTS: RESULT	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	JOINTS: SPACING (0.05–0.30m, 0.30–1.00m, 1.00–3.00m, >3.00m)	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PERMEABILITY: PRESSURE (BARS) (manometer reading)	PERMEABILITY: WATER LOSS (total Litres/minute)	PERMEABILITY: LUGEON / PERMEABILITY m/sec	GENERAL DESCRIPTION (rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints)
0.3 0.4	0.4 25/02			BROWN GREYISH - DRY DRILLING								0.0				K = 1.88x10	TOP SOIL DARK BROWN CLAYEY SAND WITH ROOTS COBBLE RESIDUAL SOIL. REDDISH CLAYEY SILT
						SPT	>50						1.55				
												1.55				K = 3.61x10	
2.8	2.8 26/02					SPT	>50						2.80				AMPHIBOLITES. DARK GREY. MEDIUM GRAINED. MAIN COMPONENTS- AMP, BI FROM 2.8 TO 4.03 WEATH JOINTS PREDOMINENTLY ALONG FOLIATION.
3.41												3.45					
4.03														1	3.8	7.0	
														3	4.7	3.8	
														6	5.9	2.6	
					5.56 28/02												
5.35				GREYISH										3	4.9	3.9	AT 6.27, 6.46, 6.47, 6.49 WEATH FJ/30°. FROM 5.87 TO 5.96 WEATH. J/75° AT 7.2(CHL) 7.86(WEATH.) J/60° FROM 5.35 TO 5.7 CLOSELY SPACED UNDIFERENCIATED J.
								I	R	MO				1	4.3	7.9	
6.27	6.27 27/02	6.27 02/27						II	R	MO			6.95				
6.95								III	R	MO		6.95					
7.85														1	2.0	3.7	WASH SAMPLE (AMPHIBOLITE ?)
														3	2.8	2.2	
8.9														6	3.4	1.5	
9.0					5.94 28/02									3	2.7	2.2	
														1	2.1	3.9	
													10.45				
10.45												10.3					
11.0														1	3.8		
11.35	11.35 28/02				8.3 01/03									3	CANNOT SEAT THE PACKER		AMPHIBOLITE DARK GREY. MEDIUM GRAINED.
														6			
12.0														3			GARNETIFEROUS ROCK WHITISH TO LIGHT BROWN, MEDIUM TO COARSE GRAINED.
														1			
12.9																	
13.8													13.8				
14.5												NO WATER PRESSURE TESTS WERE EXECUTED PACKER CAN NOT SET					
15.3																	
15.9	15.9 03/03			LIGHT BROWN													FROM 11.8 TO 18.15 UNDIFFERENCIATED WEATHERED JOINTS CAN BE SEEN IN PRESEVED CORE. CORE BROKEN INTO PIECES UP TO 7cm. OTHER PARTS REPRESENTED WITH WASH SAMPLES.
16.5					8.6 03/04												
17.43																	
18.15																	
19.4								I	R	MO							
20.06	20.0 04/03			GREYISH				II	R	T		19.96					AMPHIBOLITE. DARK GREY MEDIUM GRAINED. MAIN COMPONENTS- AM, BI
20.55														1	3.6	5.3	
21.05		21.10 04/03												3	4.9	3.6	CORE IN PIECES WEATHERED FOLIATION AND STEEP CROSSED JOINTS SEEN AT 21.05, 21.64 WEATH. J/15° 20° AT 22.23, 22.27 WEATH. J.
								III	R	T				6	7.0	2.9	
					9.4 03/08									3	5.5	4.0	
22.27								III	R	T				1	4.3	6.3	
22.72																	
23.18	23.18 05/03												23.44				
23.44	23.44 06/03											23.44					CHARNOCKITIC GNEISS WITH INTERCALATIONS OF HORNBLENDE BIOTITE GNEISS. GREY, MEDIUM GRAINED MAIN COMPONENTS QU, FD, Py
								II	R	T				1	4.8	6.9	
								III	R	T				3	5.6	4.0	
					9.42 08/12									6	8.2	3.3	
25.25								III	R	T				3	5.2	3.7	GARNETIFEROUS BIOTITE GNEISS. LIGHT COLOURED MEDIUM TO COARSE GRAINED.
														1	4.4	6.4	
26.4								I	R	T			27.0				FROM 25.25 TO 26.40 CORE IN PIECES OF 5-7 cm SEPERATION ALONG J/15° 45° (FILLED GAUGE WASHED OUT) AT 26.4, 26.62, 26.68 FJ/60°
27.0	27.0 03/12							I	R	T		27.0					

RECOVERY: CORE RECOVERY % AND R Q D % 0 50 100

GRAPHIC LOG | WEATHERING | ROCK STRENGTH

ENGINEERING ASPECTS

REMARKS (with respect to excavation, grouting, permeability, rock quality etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (OLD), DESANDER INTAKE | BHKK20 | SHEET 02 OF 02

DRILLING DATA

ARTED 25 02 92 COMPLETED 19 03 92
INTERRUPTIONS (DAYS) 09
MACHINE TYPE ACKER
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN LOGGED BY
CORE STORED AT
CORE DISCARDED, DATE

BOREHOLE DATA

X - COORDINATE 153,055·970
Y - COORDINATE 150,564·440
ELEVATION (COLLAR) 205·51
ELEVATION (BOTTOM) 170·00
FINAL DEPTH 35 0 m
INCLINATION FROM 0° VERTICAL
BEARING
LOCATION (see

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR very rough	V very tight	< 0.1mm
R rough	T tight	0 1 - 1 0mm
SR slightly rough	MO moderately open	1.0 - 5 0mm
S smooth	O open	> 5 0mm
SL slickensided		

RECOVERY	OTHER SYMBOLS
▨ CORE RECOVERY (%)	P.L.S. point load strength index
▨ R.Q.D (%)	U.C.S uniaxial compressive strength
	first ground water
	rock sample
	water sample

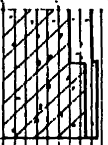
WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

	MN / m²	
	A	< 1 00
weak	B	1 0 - 5.00
	C	5.0 - 25 00
moderately strong		25 0 - 50 00
strong		50 0 - 100 00
very strong		100 . 0 - 250 00
extremely strong		> 250 00

DRILLING: DAILY ADVANCE	CASING / CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TESTS: TEST	RESULT	JOINTS: JOINT SET NO.	ROUGHNESS	SEPARATION	PERMEABILITY: DEPTH (m) FROM TOP	TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres / minute)	LUGEON // PERMEABILITY m/sec	GENERAL DESCRIPTION (rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc, scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints)	ENGINEERING ASPECTS: REMARKS (with respect to excavation, grouting, permeability, rock quality, etc)
		GREYISH		9.36 03/13			II III	R R	T T			1 3 6 3 1	4.4 5.1 6.8 4.9 4.0	6.5 3.7 2.8 3.6 5.9	GARNETIFEROUS BIOTITE GNEISS AS ABOVE. AT 27.3, 28.0 FJ / 65° AT 27 03, 27.37, 27.76 J / 20° AT 27 63 J/50° AT 30 25 SL WEATH. J / 25°	
09 /15							III	R	O		30.5					
5 /16				9.84 03/17						30.5		1 3 6 3 1	NIL	0.0	AT 33.45, 34.10, 34.2, 34.3, 34.76 J / 25° AT 34.45 FJ / 55° AT 34 22, 34.29 CHL. J / 50°	
165 /17							III	R	T		33.65					
							I II III	R R R	T T T							



HOLE COMPLETED AT THE DEPTH OF 35.0m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES **TAB. 13**

FEATURE – KK 205 (OLD), DESANDER

BHKK21 SHEET OF

DRILLING DATA

STARTED 20 03 92 COMPLETED 26.03 92
INTERRUPTIONS (DAYS)
MACHINE TYPE TONE – TDCI
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN LOGGED BY
CORE STORED AT
CORE DISCARDED, DATE

BOREHOLE DATA

X COORDINATE 153,198·088
Y COORDINATE 150,457·897
ELEVATION (COLLAR) 199·71
ELEVATION (BOTTOM) 174·51
FINAL DEPTH 25 2m
INCLINATION FROM 0°
BEARING
LOCATION

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
▒ CORE RECOVERY (%)
▨ R.Q.D (%)

JOINT SEPARATION

V = very tight		< 0.1mm
T = tight		0.1–1.0mm
MO = moderat open		1.0–5.0mm
O = open		> 5.0mm

OTHER SYMBOLS
P.L.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

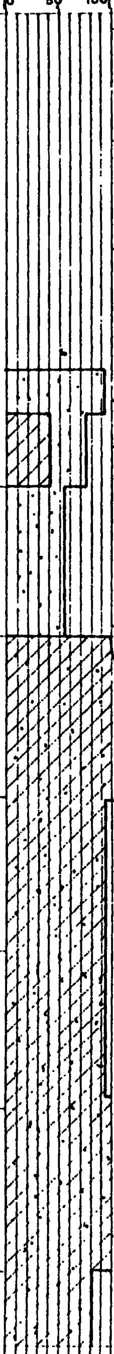
soil: unconsolidated material
completely
highly
moderately
slightly
fresh

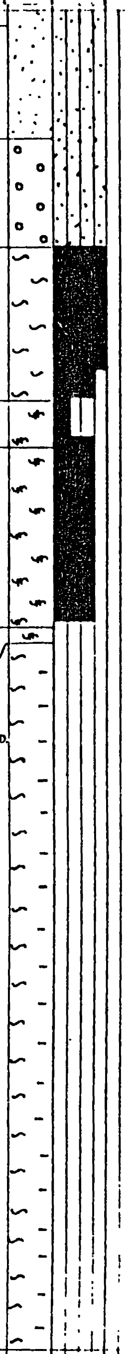
ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250

DEPTH (m)	DRILLING: WATER LEVELS	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	GENERAL DESCRIPTION
										TOP SOIL: BLACKISH CLAYEY SAND
0.15										ALLUVIUM BROWNISH, MEDIUM GRAINED CLAYEY SAND.
2.35										RESIDUAL SOIL. REDDISH BROWN CLAYEY SAND.
4.5										GARNETIFEROUS ROCK. BROWNISH, MEDIUM GRAINED.
6.9										
7.3										
7.5										GARNETIFEROUS CHARNOCKITE, COARSE TO MEDIUM GRAINED
8.15										GARNETIFEROUS ROCK. (CHARNOCKITE) BROWNISH. MEDIUM GRAINED.
9.0					9.00		1	9.0	18.8	
	6.0 28/0						3	16.5	15.3	
							6	22.0	11.1	
							3	17.0	15.7	
							1	10.0	20.8	
11.85						12.00				CHARNOCKITE. GREY, MEDIUM GRAINED, MAIN COMPONENTS Qu, FD, Py.
12.0					12.00					GARNETIFEROUS BIOTITE GNEISS. Qu. RICH WITH INTERCALATIONS OF HORNBLENDE-BIOTITE GNEISS LAYERS UP TO 40cm MEDIUM TO COARSE GRAINED. MAIN COMPONENTS Qu, FD, Bi.
		I	R	T			1	2.0	4.2	
	5.5 23/0	II	R	T			3	3.0	2.8	
							6	5.4	2.7	
							3	2.9	2.7	
							1	2.2	4.6	
15.0					15.00	15.00				
		I	R	T			1	3.7	7.7	AT 12 35 FJ/20°
							3	52	4.8	AT 12.82, 13 10 J/25°
	6.0 24/0	II	R	T			6	13.0	6.6	AT. 15.5 FJ/35°
							3	5.0	46	AT 16.95, 17 25, 17.90, 17 92 J/3[illegible]
						18.00	1	4.0	8.3	
18.0					18.00			/		
		I	R	T			1	3.2	67	
							3	43	4.0	
	5.70 25/0	III	R	T			6	65	33	AT 18.93, 18.99, 19.01, 19 59 J/30°
							3	65	3.9	
							1	3.0	6.3	AT 20.56, 20.90 FJ/30°
20.9						21.0				
					21.0		1	40	8.3	
							3	6.0	5.6	
	6.0 26/0	II	R	T			6	14.5	7.3	AT 22.45, 22 80 J/50°
							3	59	5.5	
							1	41	8.5	
24.0						24.0				AT 24.09, 24.12, 24.13, 24 25, 24.26, 24.27, 24.28 FJ/30°
		I	SR	T						
25.20										

Column headings also printed: DAILY ADVANCE, CASING/CEMENT, DRILL.WATER (COLOR, LOSS), RATE OF DRILLING, TESTS: TEST, RESULT, JOINTS: SPACING (< 0.05m, 0.05–0.30m, 0.30–1.00m, 1.00–3.00m, > 3.00m), RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100), GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ENGINEERING ASPECTS: ROCK STRENGTH, REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)





HOLE COMPLETED AT THE DEPTH OF 25.2 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (NEW/OLD) , TAILRACE OUTFALL

B.H.KK 28 SHEET 01 OF 02

DRILLING DATA	BOREHOLE DATA
RTED: 26.05 92 COMPLETED 21.02.92	X-COORDINATE 157518 · 196
RRUPTIONS (DAYS)	Y-COORDINATE 144984 544
HINE TYPE TONE - TOC I	ELEVATION (COLLAR) 65 711
LING METHOD ROTARY	ELEVATION (BOTTOM) 15 · 611
E BARREL, BIT: NX	FINAL DEPTH 50.10m.
MAN: LOGGED BY.	INCLINATION FROM VERTICAL
E STORED AT:	BEARING
DISCARDED, DATE:	LOCATION (see f.)

KEY

JOINT ROUGHNESS	JOINT SEPARATION
VR=very rough	V =very tight <0.1mm
R =rough	T =tight 0.1-1.0mm
SR=slightly rough	MO=moderat open 1.0-5.0mm
S =smooth	O =open >5.0mm
SL=slickensided	

RECOVERY	OTHER SYMBOLS
░ CORE RECOVERY (%)	P.L.S.I.=point load strength index
▨ R.Q.D (%)	U.C.S =uniaxial compressive strength
	▽ =first ground water
	R =rock sample
	W =water sample

WEATHERING

- soil : unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0 - 25.00
moderately strong		25.0 - 50.00
strong		50.0 - 100.00
very strong		100.0 - 250.00
extremely strong		> 250.00

DRILLING: DAILY ADVANCE | CASING/CEMENT | DRILLWATER(COLOR, LOSS) | RATE OF DRILLING | WATER LEVELS

TESTS: TEST | RESULT

JOINTS

JOINT SET NO.	ROUGHNESS	SEPARATION
I	R	O
III	R	MO
III	R	MO
I	R	T
II	R	T
II	R	T
III	R	T
III	R	T
I	R	T
I	R	T
III	R	T

SPACING: <0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, >3.00 m

PERMEABILITY

DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
6 0	9.0	1 3 6 3 1	4 0 9.2 12 0 10 0 4.2	9.4 9.0 6.2 9.7 9 9
9.0	12.0	1 3 6 3 1	NIL	0.0
12 0	15.0	1 3 6 3 1	NIL	0.0
15 0	18.0	1 3 6 3 1	NIL	0.0
18.0	21.0	1 3 6 3 1	NIL	0.0
21.0	24.0	1 3 6 3 1	NIL	0.0
24.0	27.0	1 3 6 3 1	NIL	0.0
27.0				

RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc · scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

GENERAL DESCRIPTION	DEPTH (m)
TOP SOIL. BROWNISH CLAYEY SAND	
RESIDUAL SOIL LIGHT BROWN SANDY CLAY	0. 3
LIGHT BROWN WEAK ROCK	0. 8
GARNETIFEROUS ROCK. MEDIUM TO COARSE GRAINED. DISCOLOURED.	2.0
Qu RICH BIOTITE GNEISS WITH OCCASIONAL COARSE GRAINED GARNET-ENRICHED BANDS UP TO 10 cm. LIGHT COLOURED, MEDIUM GRAINED, MAIN COMPONENTS Qu, FD, GA, BI FROM 1.0 TO 2.40 CLOSELY SPACED UNDIFIRENCIATED JOINTS. ALL JOINTS WEATHERED. SLIGHTLY WEATHERED FOLIATION JOINTS AT 2 58, 2.65, 2 68, 2.72, 2 75, 3.0, 3 02, 3.05, 3 10, 3.15, 3.22, 3.75, 3.81, 3.83 < 50° AT 3.03, 3 46, 3.56, 3 58, 3 68 SL. WEATHERED J / 25° AT 4.0, 4 40 J/15° AT 5 2, 5.3, 6.95, 6.17 FJ/45° AT 7.86 J/60° FROM 8.05 TO 8 22 AND FROM 8.70 TO 8.87 $CaCO_3$ FILL J/80° AT 10.90 J / 20°	2.0 3.25
GARNETIFEROUS BIOTITE GNEISS, COARSE TO MEDIUM GRAINED WITH PLUM PUDDING COARSE GRAINED GARNETS. LIGHT COLOURED. MAIN COMPONENTS Qu, FD, GA, BI AT 12.10 J/20° AT 14 30, 17 08 J/45° AT 19.70 J/15°	11. 2

GRAPHIC LOG | WEATHERING

ENGINEERING ASPECTS: ROCK STRENGTH | REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.) | DEPTH (m)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (NEW/OLD) , TAILRACE OUTFALL

BHKK 28 SHEET OF

DRILLING DATA

STARTED. 26.05.92 COMPLETED 21.02.92
INTERRUPTIONS (DAYS)
MACHINE TYPE TONE - TOC I
DRILLING METHOD ROTARY
CORE BARREL, BIT · NX
FOREMAN · LOGGED BY:
CORE STORED AT ·
CORE DISCARDED, DATE ·

BOREHOLE DATA

X-COORDINATE 187515 · 196
Y-COORDINATE 144984 544
ELEVATION (COLLAR) 65 · 711
ELEVATION (BOTTOM) 15 · 611
FINAL DEPTH 50.10m.
INCLINATION FROM VERTICAL
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1–1.0mm
MO = moderat open 1.0–5.0mm
O = open > 5.0mm

OTHER SYMBOLS
P.L.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH MN/m²

	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250

DEPTH (m)	DRILLING: DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TESTS: TEST	RESULT	JOINTS: JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING (0.05–0.30m, 0.30–1.00m, 1.00–3.00m, >3.00m)	PERMEABILITY: DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)	GENERAL DESCRIPTION (rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints)	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	ENGINEERING ASPECTS: REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)
29.0													30.0	1 3 6 3 1	NIL	0 0		GARNETIFEROUS BIOTITE GNEISS AS ABOVE INTERCALATION OF DARK COLOURED HORNBLENDE-BIOTITE GNEISS				
30.0 31.0 32.0												30.0	33.0	1 3 6 3 1	NIL	0 0		FROM TO 36.10 37.20 40.66 41 05 45.00 46.50				
33.0 34.0 35.0												33.0	36.0	1 3 6 3 1	NIL	0.0		FROM 34.20 TO 34.40 CORE HAS BEEN BROKEN INTO PIECES OF 2-3cm IN SIZE. JOINTS CAN NOT BE IDENTIFIED PROBABLY DUE TO VIBRATION EFECTS OF THE MACHINE.				
36.0 37.0 38.0												36.0	39.0	1 3 6 3 1	NIL	0.0						
39.0 40.0 41.0												39.0	420	1 3 6 3 1	NIL	0.0						
42.0 43.0 44.0												42.0	45.0	1 3 6 3 1	NIL	0.0						
45.0 46.0 47.0												45.0	48.0	1 3 6 3 1	NIL	0 0						
48.0 49.0 50.0																						

HOLE COMPLETED AT THE DEPTH OF 50.10m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (NEW/OLD), HEADRACE (SADDLE)

B.H KK29 SHEET 01 OF 04

DRILLING DATA

IARTED 24 02 92 COMPLETED 27.03 92
ITERRUPTIONS (DAYS) 06
ACHINE TYPE JOY
RILLING METHOD ROTARY
ORE BARREL, BIT NX
OREMAN: LOGGED BY.
RE STORED AT:
RE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 155,463·130
Y-COORDINATE 146,967 893
ELEVATION (COLLAR) 254·637
ELEVATION (BOTTOM) 154·777
FINAL DEPTH 99 86 m
INCLINATION FROM 0° VERTICAL
BEARING
LOCATION (see Fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1mm
R = rough	T = tight	0.1-1.0mm
SR = slightly rough	MO = moderately open	1.0-5.0mm
S = smooth	O = open	> 5.0mm
SL = slickensided		

RECOVERY

- ▨ CORE RECOVERY (%)
- ▨ R.Q.D (%)

OTHER SYMBOLS

- PL.S.I. = point load strength index
- U.C.S = uniaxial compressive strength
- ▼ = first ground water
- R = rock sample
- W = water sample

WEATHERING

- soil : unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING

DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS
24/2		DRY DRILLING		
6.1 / 25/02				
9.15 / 27/02				
	10.37 / 27/2			
			1.05 / 27/28	
14.41 / 27/02				
			1.06 / 28/28	
17.26 / 28/02		CREAMY		
			1.01 / 29/02	
20.42 / 19/02				
			1.05 / 01/03	
24.47 / 1/[illegible]				
			1.04 / [illegible]	
26.31 / 2/0[illegible]				
			1.01 / [illegible]	

TESTS

TEST	RESULT

JOINTS

JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING
II	SL	T	
II	R	T	
I	R	T	
I	R	T	
II	R	T	
I	R	T	
I	R	T	
II	R	T	
III	R	T	
II	R	T	
II	R	T	
III	R	T	

PERMEABILITY

DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
0.0	3 05			K =
3 05	6 10			K =
6 10	9 15			K =
11.11	14.11	1 3 6 3 1	NIL	0.0
14.11	17 26	1 3 6 3 1	NIL	0.0
17 26	2042	1 3 6 3 1	5.2 5.7 5 8 6.3 6.0	
20 42	24 47	1 3 6 3 1	21 27 33 33 31	
23.47	26 31	1 3 6 3 1	NIL	0 0
26 31		1 3	NIL	0 0

RECOVERY

CORE RECOVERY % AND R Q D % (0 50 100)

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

GENERAL DESCRIPTION	DEPTH (m)
TOP SOIL. BLACKISH CLAYEY SAND	0 6
COBBLE (WEATHERED BIOTITE (GNEISS)	1 20
COBBLE (WEATHERED AMPHIROLITE)	1.8
WASH SAMPLE (COARSE SAND)	3.05
COBBLE – (WEATHERED BIOTITE GNEISS)	4 0
WASH SAMPLE (GRAVEL)	5 0
WASH SAMPLE (COARSE SAND)	6 0
RESIDUAL SOIL. LIGHT BROWN BROWN SILTY COARSE SAND.	9.15
GREYISH WEAK ROCK WITH TRACES OF BIOTITE.	10 37 10 59 10 89
Qu. RICH BIOTITE GNEISS, LIGHT COLOURED MEDIUM GRAINED, MAIN COMPONENTS Qu, FD, BI. FROM 10.54 TO 10.89 CLOSELY SPACED SLICKENSIDED JOINTS CHLORITICIZED < 60°: TECTONIZED ZONE AT 11.06, 11.24, 11 29, 11 43 J/25° AT 13.72 FJ/60°	15 37
CHARNOCKITIC GNEISS, GREY, MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Qu, FD, Py AT 17.26 FJ/65° AT 17.5, 18.0 CHL J/60° AT 19.50 CALCITE FILL (3mm) J/60° AT 18.25, 18.45 CHL FJ/70° AT 20.30 CHL. J/70°	20.5
HORNBLENDE – BIOTITE GNEISS. DARK GREY. MEDIUM GRAINED	21.2
CHARNOCKITIC GNEISS, GREY MEDIUM TO COARSE GRAINED, MAIN COMPONETS Qu, FD, Py. FROM 20 52 TO 20 70 J/70° AT 21.0 J/50° FROM 21.20 TO 21 .36 CHL. J/60° FROM 23 26 TO 23.55 CHL J/85° AT 23 .66 FJ/60° AT 21 50, 22 80 J/20° 30° AT 23 [illegible], 25 06, 25.98, 26 .17 J/60° FROM 27.98 TO 28 30 J/80° AT 27 54, 27 62, 27 90, 28 05 J/ 30°	

GRAPHIC LOG | WEATHERING

ENGINEERING ASPECTS

ROCK STRENGTH

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (NEW/OLD), HEADRACE (SADDLE)

BH KK29 SHE OF

DRILLING DATA

STARTED 24 02 92 COMPLETED 27 03 92
INTERRUPTIONS (DAYS) 06
MACHINE TYPE JOY
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN LOGGED BY
CORE STORED AT
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 155,463·130
Y-COORDINATE 146,967·893
ELEVATION (COLLAR) 254 637
ELEVATION (BOTTOM) 154 777
FINAL DEPTH 99 86 m
INCLINATION FROM 0° VERTICAL
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

JOINT SEPARATION
V = very tight <0.1mm
T = tight 0.1-1.0mm
MO = moderately open 1.0-5.0mm
O = open >5.0mm

OTHER SYMBOLS
PL.S Lapomt load strength index
U.C.S Uniaxial compressive strength
▼ first ground water
R rock sample
W water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENG

MN/m²

	A	
weak	B	1.0
	C	5.0
moderately strong		25.0
strong		50 0
very strong		100.0
extremely strong		

DEPTH (m)	DRILLING: DAILY ADVANCE	DRILLING: CASING/CEMENT	DRILLING: DRILL WATER (COLOR, LOSS)	DRILLING: RATE OF DRILLING	DRILLING: WATER LEVELS	TESTS: TEST	TESTS: RESULT	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	JOINTS: SPACING	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PERMEABILITY: PRESSURE (BARS) (manometer reading)	PERMEABILITY: WATER LOSS (total Litres/minute)	PERMEABILITY: LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R.Q.D % (0 50 100)	GENERAL DESCRIPTION rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ENGINEERING ASPE: ROCK STRENGTH	ENGINEERING ASPE: REMARKS (with respect to excavation, grouting, permeability, rock etc.)
	28.62 12/03		CREAMY										29 20	6 3 1	NIL	0. 0		CHARNOCKITIC GNEISS AS ABOVE AT 29.29, 31.03, 31 08, 31.10 31 50, 31.56, 32.14 CHL FJ/50° 60°				
29 29								I	R	T								AT 31.54 J/65° AT 32.30, 32.38 J/20° FROM 32.10 TO 32.34 J/80°				
30 25								II III	R R	T T								HORNBLENDE - BIOTITE GNEISS DARK GREY. MEDIUM GRAINED, MAIN COMPONENTS Amp.BI				
32.10	32.51 03/03				1.35 04/03			II III	R SL	T T		32 51	35.47	1 3 6 3 1	NIL	0.0		BIOTITE GNEISS. LIGHT COLOURED IN PLACES GARNETIFEROUS. MEDIUM GRAINED, MAIN COMPONENTS FD,Qu,BI AT 32.51, 32.55 J/20° AT 32.55, 37.58 J/40° 50°				
35.47	35.84 04/13				1.35 05/03							35.47	38.51	1 3 6 3 1	NIL	0.0		AT 38.7, 39.0 J/60° FROM 40.90 TO 41.15 J/75°				
38.51					1.30 06/03			III	R	T		38.51	41 50	1 3 6 3 1	1.6 2.1 2.3 2.0 1.9			AT 40.1, 40.38, 40.66, 41.7 J/40°				
41.58	41.58 05/13		PINKISH		1.36 06/03							41.58	44.64	1 3 6 3 1	NIL	0.0		FROM 40.5 TO 40.74 J/85° WITH A CALCITE FILL 1mm AT 42.1 J/.25 CALCITE FILL 1mm AT 44.0, 44.20 J/15°				
44 05	44.64 06/03											44.64						GARNETIFEROUS BIOTITE GNEISS (ENRICHED WITH HIGH PERCENTAGE OF GARNETS) PINKISH, MEDIUM TO COARSE GRAINED				
46 0					1.53 07/03			II	R	T			47.57	1 3 6 3 1	1 9 2.1 2 0 1 9 1. 6			QUARTZ - FELDSPAR PEGMATITE WITH GARNETS, MEDIUM TO COARSE GRAINED AT 46 26 J/60° FROM 46 26 TO 46 53, FROM 46.7 TO 47 12 J/80°				
47.57	47.57 12/13											47 57										
48.7					1.52 08/03			III	R	T			50.52	1 3 6 3 1	2 4 1 9 2 2 2.0 2.3			BIOTITE GNEISS, LIGHT COLOURED, MEDIUM GRAINED, MAIN COMPONENTS Qu, FD, BI AT 48.2 J/25°				
50 52								I	R	T		50 52										
51 05	52.08 18/11		CREAMY		1.53 12/03			III	R	T			53 55	1 3 6 3 1	2.0 2.2 2 6 1.6 1.5			AT 51.78 FJ/50°				
53 35								II III	R R	T T								AT 53 30 J/20° AT 53 62, 54 3, 54 58, 54.80 J/20° AT 53 75, FROM 53 98 TO 54.10 J/70° AT 55.0 CALCITE (2mm) FILL J/20°				
55 2								II	R	T								BIOTITE GNEISS, (WITH HIGH PERCENT-AGE OF BIOTITE)				

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (NEW/OLD), HEADRACE (SADDLE)

B.H KK29 SHEET 03 OF 04

DRILLING DATA

STARTED 24.02.92 COMPLETED 27.03.92
INTERRUPTIONS (DAYS) 06
MACHINE TYPE JOY
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN LOGGED BY
CORE STORED AT
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 155,463·130
Y-COORDINATE 146,967·893
ELEVATION (COLLAR) 254·637
ELEVATION (BOTTOM) 154 777
FINAL DEPTH 99 86 m
INCLINATION FROM 0° VERTICAL
BEARING
LOCATION (see fig.

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION

V = very tight		< 0.1mm
T = tight		0.1–1.0mm
MO = moderat open		1.0–5.0mm
O = open		> 5.0mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
PL.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING | TESTS | JOINTS | PERMEABILITY | RECOVERY | GENERAL DESCRIPTION | ENGINEERING ASPECTS

Column headings: DAILY ADVANCE; CASING/CEMENT; DRILL WATER (COLOR, LOSS); RATE OF DRILLING; WATER LEVELS; TEST; RESULT; JOINT SET NO.; ROUGHNESS; SEPARATION; SPACING (<0.05m, 0.05–0.30m, 0.30–1.00m, 1.00–3.00m, >3.00m); DEPTH (m) FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total Litres/minute); LUGEON or PERMEABILITY m/sec; CORE RECOVERY % AND R.Q.D % (0, 50, 100); GENERAL DESCRIPTION (rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints); GRAPHIC LOG; WEATHERING; ROCK STRENGTH; REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.); DEPTH (m)

Drill water colour: CREAMY / GREYISH; CREAMY; GREYISH

Daily advance	Water levels	Joint set no.	Roughness	Separation	Depth from top	Depth to bottom	Pressure (bars)	Water loss (l/min)	Lugeon
56.6 12/03	1.58 03/	II	R	T	56.60	59 60	1 3 6 3 1	2.3 2.7 3 3 2 5 1 9	
61.12 13/14	1.58 11/	II	R	T	59 60	62.6	1 3 6 3 1	NIL	0.0
65.6 13/15	1.85 07/	III	R	T	62.6	65.6	1 3 6 3 1	NIL	0.0
68.6 16/16	1.85 03/6	III	R	T	65.6	68.6	1 3 6 3 1	NIL	0.0
	2.55 17/				68.6	71.58	1 3 6 3 1	NIL	0.0
72.18 /03	2.56 18/0				70 58	74.73	1 3 6 3 1	NIL	0 0
73 03	2.59 21/0	I III	R R	T T	74.73	77 92	1 3 6 3 1	3.9 4.5 5.5 4.9 4.8	
86	2.58 22/0	II III II	R R R	T T T	77 92	80 96	1 3 6 3 1	NIL	0.0
96 0	2.58 22/0	II III	R R	T T	80 96	84 14	1 3 6 3 1	NIL	0.0

GENERAL DESCRIPTION

BIOTITE GNEISS (WITH HIGH PERCENTAGE OF (BI) LIGHT COLOURED MEDIUM TO COARSE GRAINED, MAIN COMPONENTS Qu, FD, Bi — 56.60

BIOTITE GNEISS, LIGHT COLOURED, MEDIUM GRAINED — 57.63

CHARNOCKITE DARK GREY. COARSE GRAINED, MAIN COMPONENTS Qu, FD, Py

FROM 55.10 TO 55.70 CHL FILL SUBVERTICAL J
AT 55.26 J/60°
AT 56.94, 57 27, 57.47, 57.67 J/50
FROM 59 0 TO 59.22 CHL J/70°
AT 62.04, 62.50 J/50°
AT 62.94, 63.35, 63.85, 63 95 65.0, 65.47 J/25°-30°
AT 63.65 SLS J/30°
AT 65.83, 65.94, 66.24, 66.50 J/25°
AT 75.32, 76.73, 77 02, 77.26 77 75 J/40°
FROM 76.0 TO 76.20 J/80°

QUARTZ - FELDSPAR - BIOTITE PEGMATITE — 77.5

FROM 77 95 TO 78 20 CALCITE FILLED (2mm) IRON STAINED J/60°-90° (IRREGULAR ANGLE) — 78.86

BIOTITE GNEISS. LIGHT COLOURED, MEDIUM GRAINED, MAIN COMPONENTS Qu, FD, BI — 79.95
AT 77.95

QUARTZ - FELDSPAR - BIOTITE PEGMATITE — 81 7
AT 82 86 J/60°
FROM 81 48 TO 81 60 J/70°
AT 83 53 SLS J/40°
AT 83.30 J/40°

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (NEW/OLD), HEADRACE (SADDLE)

B.H KK29 SHEE OF

DRILLING DATA

STARTED 24.02.92 COMPLETED 27.03.92
INTERRUPTIONS (DAYS) 06
MACHINE TYPE JOY
DRILLING METHOD ROTARY
CORE BARREL, BIT: NX
FOREMAN LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 155,463 130
Y-COORDINATE 146,967 893
ELEVATION (COLLAR) 254 637
ELEVATION (BOTTOM) 154 777
FINAL DEPTH 99 86 m
INCLINATION FROM 0° VERTICAL
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1-1.0mm
MO = moderately open 1.0-5.0mm
O = open > 5.0mm

OTHER SYMBOLS
P.L.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGT

MN/m²
A <
weak B 1.0-
C 5.0-2
moderately strong 25.0-5
strong 50.0
very strong 100.0
extremely strong >

DEPTH (m)	DRILLING: DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TESTS: TEST	RESULT	JOINTS: JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING <0.05 / 0.05-0.30 / 0.30-1.00 / 1.00-3.00 / >3.00	PERMEABILITY: DEPTH (m) FROM TOP	TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY, m/sec	RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)	GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	ENGINEERING ASPECT: REMARKS (with respect to excavation, grouting, permeability, rock qua etc.)
	84.14 22.03																	PEGMATITE AS ABOVE				
84.7					3.11 23.03			II	R	T		84.14	87.64	1 3 6 3 1	NIL	0.0		GARNETIFEROUS CHARNOCKITIC GNEISS AT PLACES ENRICHED WITH COARSE GRAINED GARNETS. GREY, MEDIUM TO COARSE GRAINED MAIN COMPONENTS Qu, FD, Py, GA				
87 64	88.17 23.03		CREAMY		3.11 23.03			III	R	T		87.64	90.92	1 3 6 3 1	NIL	0.0		AT 86.40 J/50° AT 88 10, 88.15 CHL. J/25°				
90 92	92.57 24.03		GREYISH		3.11 24.03							90.92	94.05	1 3 6 3 1	NIL	0.0						
94.05	95.9 25.03				3.12 25.03							94.05	97.02	1 3 6 3 1	NIL	0.0						
97.02			CREAMY									97.02	99.86	1 3 6 3 1	NIL	0.0		AT 97.20, 98 55, 98.73, 99 70 J/60°				
98.2	99.0 26.03				3.1 26.03			II	R	T								GARNETIFEROUS BIOTITE GNEISS, LIGHT COLORED MEDIUM GRAINED.				

HOLE COMPLETED AT DEPTH OF 99.86 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (NEW), WEIR AXIS /

BHKK31 SHEET 01 OF 02

DRILLING DATA

ITED 03 04 92 COMPLETED-09 04 92
RRUPTIONS (DAYS):
HINE TYPE TONE - TDC I
LING METHOD: ROTARY
BARREL, BIT: NX
MAN GSD LOGGED BY:
STORED AT:
DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE
Y-COORDINATE
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH 30.35m
INCLINATION FROM 40° VERTICAL.
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION
VR=very rough	V =very tight <0.1mm
R =rough	T =tight 0.1-1.0mm
SR=slightly rough	MO=moderat open 1.0-5.0mm
S =smooth	O =open > 50mm
SL=slickensided	

RECOVERY	OTHER SYMBOLS
CORE RECOVERY (%)	P.L.S.I.=point load strength index
R.Q.D (%)	U.C.S =uniaxial compressive strength
	▼ =first ground water
	R =rock sample
	W =water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0-25.00
moderately strong		25.0-50 00
strong		50.0-100 00
very strong		100.0-250 00
extremely strong		> 250.00

DRILLING				TESTS		JOINTS				PERMEABILITY					RECOVERY	GENERAL DESCRIPTION				ENGINEERING ASPECTS	
CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING <0.05m 0.05-0.30m 0.30-1.00m 1.00-3.00m >3.00m	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	CORE RECOVERY % AND R Q D % 0 50 100	rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc · scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)	DEPTH (m)
										0,0		1	45	17·3		GARNETIFEROUS BIOTITE GNEISS AT PLACES WITH PINK COLOUR FELDSPAR. Qu, RICH LIGHT COLOURED. MEDIUM GRAINED. LAYERS RICH IN BIOTITE AND GARNETS UP TO 1cm					
			2·0			I	R	MO				3	125	14·5							
						II	R	MO				6	280	15·9		AT 0.55, 0 65 WEATH. FJ/60°.					
												3	124	14·4		FROM 0 82 TO 0 9 CLOSELY SPACED WEATHERED FJ/60°					
											3·0	1	48	18·5							2.45
										3·0		1				FROM 2 45 TO 2.58 OPEN FJ/60°					2 85
			2 0			II	R	T				3				3 Nos. WEATHERING PENETRATED UP TO 2 cm					
												6									
	LIGHT GRAY					III	R	T				3	NIL	NIL							
											6·0	1				AT 0.54, 0 58 WETH. J/60° FROM 0 7 TO 0.9 WETH J/70°80°					
										6·0		1				AT 3.34, 4 15 J/55-65° AT 5 2, 5 33, 8 0 J/30-40°					5.9
						I	R	T				3				AT 7 75, 8.35, 8.55, 11.55 FJ/60°					
			2·0			III	R	T				6	NIL	NIL		HORNBLENDE-BIOTITE GNEISS, DARK COLOURED. MEDIUM GRAINED.					7.6
												3				GARNETIFEROUS BIOTITE GNEISS LIGHT COLOURED. MEDIUM GRAINED. MAIN COMPONENTS Qu, FD, Bi					8 5
											9·0	1									
						I II III	R S R	T T T		9·0		1	22	8·5		FROM 9 65 TO 9.82 CALCITE COATED HEALED J/70°					9 55
												3	80	9·3		AT 10. 45, 10.57 CHL J/10°					
			2 0			I	SL	T				6	240	13·6		TECTONIZED ZONE. SHEARED ALONG FOLIATION					10.95
												3	75	8·7							11.25
											12·0	1	20	7·7		HORNBLENDE-BIOTITE GNEISS DARK COLORED MEDIUM GRAINED					11.80
						II	R	T		12·0		1				FROM 11 9 TO 12 15 CHL J/75°					
						III	R	T				3 6 3	NIL	NIL		AT 11.95 J/10°					13 15
											15·0	1				GARNETIFEROUS BIOTITE GNEISS, Qu. RICH WITH COARSE GRAINED GARNETS LIGHT COLOURED. MEDIUM GRAINED, MAIN COMPONENTS Qu, FD, Bi, GA					13 .85
										15·0		1									
												3									
			2·0			I	R	T				6									
	LIGHT GRAY											3	NIL	NIL		HORNBLENDE-BIOTITE GNEISS, DARK COLOURED. MEDIUM GRAINED, MAIN COMPONENTS Ho, Bi					15.7
											18·0	1				AT 15.84 FJ/50° CHLORITISIZED					
						II	R	T		18 0		1				FROM 17.3 TO 18.53 CHL J/70°					17.75
												3									
			2 0									6	NIL	NIL							18 75
												3									
											21·0	1									
										21 0		1									20 75
												3									
			2 0									6	NIL	NIL							
												3				AT 26.8 CHL J/50°					
											24 0	1									
										24 0		1				CHLORITISIZED JOINTS AT 26 82 J/10°, 26 85 J/30° 27.58 J/20°					24 0
												3									
												6	NIL.	NIL							
												3				GARNETIFEROUS BIOTITE GNEISS WITH COARSE GARNETS MEDIUM TO COARSE GRAINED LIGHT COLOURED.					26 0
											27 0	1				Qu RICHED BIOTITE GNEIS LIGHT COLOURED MEDIUM GRAINED					26.6 26.75
						III	R	T		27 0											27 55

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES **TAB. 13**

FEATURE - KK 205 (NEW), WEIR AXIS /

BHKK31 SHEE OF

DRILLING DATA	BOREHOLE DATA
STARTED 03 04 92 COMPLETED 09 04 92	X-COORDINATE
INTERRUPTIONS (DAYS)	Y-COORDINATE
MACHINE TYPE TONE-TOC1	ELEVATION (COLLAR)
DRILLING METHOD. ROTARY	ELEVATION (BOTTOM)
CORE BARREL, BIT: NX	FINAL DEPTH 30.35m
FOREMAN GSD LOGGED BY:	INCLINATION FROM 40° VERTICAL.
CORE STORED AT.	BEARING
CORE DISCARDED, DATE:	LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION
VR = very rough	V = very tight <0.1mm
R = rough	T = tight 0.1-1.0mm
SR = slightly rough	MO = moderat open 1.0-5.0mm
S = smooth	O = open >5.0mm
SL = slickensided	

RECOVERY	OTHER SYMBOLS
CORE RECOVERY (%)	PL.S.I. = point load strength index
R.Q.D (%)	U.C.S = uniaxial compressive strength
	▼ = first ground water
	R = rock sample
	W = water sample

WEATHERING

- soil : unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH MN/m²

	A	<
weak	B	1.0-
	C	5.0-
moderately strong		25.0-
strong		50.0-
very strong		100.0-
extremely strong		>

DRILLING						TESTS		JOINTS				PERMEABILITY					RECOVERY	GENERAL DESCRIPTION			ENGINEERING ASPECT	
DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING <0.05m 0.05-0.30m 0.30-1.00m 1.00-3.00m >3.00m	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	CORE RECOVERY % AND R.Q.D % (0 50 100)	rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	REMARKS (with respect to excavation, grouting, permeability, rock quc, etc.)
			LIGHT GRAY											1	NIL.	NIL		HORNBLENDE-BIOTITE GNEISS DARK COLOURED, MEDIUM GRAINED, MAIN COMPONENTS Ho, Bi	∽			
														3								
29.27					2.0									6					∽			
														3				BIOTITE GNEISS LIGHT COLOURED, MEDIUM GRAINED. AT 29.42 CHL. J/40°				
	30.35 09.04													1					∽			

HOLE COMPLETED AT THE DEPTH OF 30.55 m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (NEW), WEIR AXIS

B.H. KK32 SHEET 01 OF 02

DRILLING DATA

STARTED: 06/07/92 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE TONE TDCI
DRILLING METHOD:
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE: 155,581·020
Y-COORDINATE: 150,582·487
ELEVATION (COLLAR):
ELEVATION (BOTTOM).
FINAL DEPTH. 30·15
INCLINATION FROM VERTICAL: 40°
BEARING:
LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1mm
R = rough	T = tight	0.1–1.0mm
SR = slightly rough	MO = moderat. open	1.0–5.0mm
S = smooth	O = open	> 5.0mm
SL = slickensided		

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

OTHER SYMBOLS
P.L.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING / TESTS / JOINTS / PERMEABILITY / RECOVERY / GENERAL DESCRIPTION / ENGINEERING ASPECTS

Column headings: DEPTH (m); DRILLING: DAILY ADVANCE, CASING/CEMENT, DRILL WATER (COLOR, LOSS), RATE OF DRILLING, WATER LEVELS; TESTS: TEST, RESULT; JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m); PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec; RECOVERY: CORE RECOVERY % AND R Q D % (0, 50, 100); GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ENGINEERING ASPECTS: ROCK STRENGTH, REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.); DEPTH (m)

Depth marks: 1, 1 3, 2, 3, 4, 4·4, 5, 6, 7, 7·6, 8, 9, 9·6, 10, 11, 12, 13, 14, 15, 15·3, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28

Drilling

DAILY ADVANCE	DATE
3·85	06/07
7·5	07/07
11·8	09/07
16·15	10/07
20·55	11/07
25·2	12/07

DRILL WATER (COLOR, LOSS): LIGHT GRAY

WATER LEVELS: 07/07 0·6 10/07

Joints

JOINT SET NO.	ROUGHNESS	SEPARATION
I	R	T
I	R	T
II	R	T
II	R	T
II	R	T
II	R	T
II	R	T

Permeability

FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
0,0	2·95	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
2·55	6·15	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
	9·05	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
9.06	12.00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
12.00	15.00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
15.00	18.00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
18.00	21.00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
21.00	24.00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
24.00	27.00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
27.00				

General Description

BIOTITE GNEISS

HORNBLENDE – BIOTITE GNEISS, DARK GREY, MEDIUM GRAINED

AT 0·57, 2 12, 4 85, 4 59, 4·63 FOLIATION JOINTS

BIOTITE GNEISS

AT 6·68, 7·13, 7 2 28, 8·20 FOLIATION JOINTS. ON SOME CHLORITE STAINS
A 7·45 J/60°

AMPHIBOLITE, BLACK, MEDIUM GRAINED.
AT

BIOTITE GNEISS, GREY, MEDIUM GRAINED
AT 11·28 J/60°

AT 13 9, 14·87, 15·38 J/60°

AMPHIBOLITE, BLACK, MEDIUM GRAINED

AT 20·87, J/60°
AT 23·38 J/60°

BIOTITE GNEISS, GREY, MEDIUM GRAINED

AT 24·92 J/60°
AT 27 70, 27·84 J/40° CHLORITE FILLED.
AT 28·55 J/90° CHLORITE FILLING

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

BH KK32 SHEET OF

FEATURE – KK 205 (NEW), WEIR AXIS

DRILLING DATA

STARTED: 06/07/92 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE TONE TDCI
DRILLING METHOD:
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE: 155,581·020
Y-COORDINATE: 150,582·437
ELEVATION (COLLAR):
ELEVATION (BOTTOM):
FINAL DEPTH 30·15
INCLINATION FROM VERTICAL: 40°
BEARING:
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION

V	very tight	< 0.1mm
T	tight	0.1-1.0mm
MO	moderately open	1.0-5.0mm
O	open	> 5.0mm

RECOVERY
▒ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
P.L.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▽ = first ground water
R = rock sample
W = water sample

WEATHERING

soil: unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DEPTH (m)	DRILLING: DAILY ADVANCE	DRILLING: CASING/CEMENT	DRILLING: DRILL WATER (COLOR, LOSS)	DRILLING: RATE OF DRILLING	DRILLING: WATER LEVELS	TESTS: TEST	TESTS: RESULT	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	JOINTS: SPACING (<0.05m, 0.05-0.30m, 0.30-1.00m, 1.00-3.00m)	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PERMEABILITY: PRESSURE (BARS) (manometer reading)	PERMEABILITY: WATER LOSS (total Litres/minute)	PERMEABILITY: LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100)	GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ENGINEERING ASPECTS: ROCK STRENGTH	ENGINEERING ASPECTS: REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)
28·16	28·5 13/07		LIGHT GRAY											1	0	0		AMPHIBOLITE, BLACK, MEDIUM GRAINED.				
29														3	0	0						
														6	0	0						
														3	0	0						
30	3015 14/07												3015	1	0	0						

HOLE COMPLETED AT 30·15 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KK 205 (NEW), DESANDER

BHKK34 SHEET 01 OF 01

DRILLING DATA

STARTED: COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE.
DRILLING METHOD:
CORE BARREL, BIT:
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE:
Y-COORDINATE:
ELEVATION (COLLAR):
ELEVATION (BOTTOM):
FINAL DEPTH:
INCLINATION FROM VERTICAL:
BEARING.
LOCATION (see Fig.)

KEY

JOINT ROUGHNESS

VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION

V = very tight		< 0.1 mm
T = slight		0.1–1.0 mm
MO = moderat. open		1.0–5.0 mm
O = open		> 5.0 mm

RECOVERY

░ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS

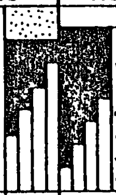
P.L.S.I. = point load strength index
U.C.S = uniaxial compressive strength
▽ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00



DRILLING — TESTS — JOINTS — PERMEABILITY — RECOVERY — GENERAL DESCRIPTION — ENGINEERING ASPECTS

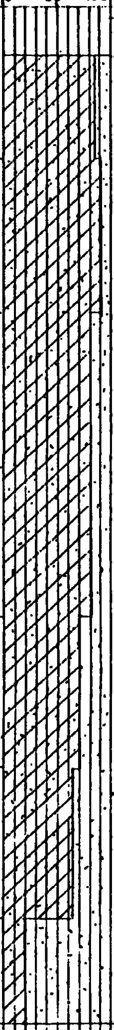
Column headings: DEPTH (m); DAILY ADVANCE; CASING/CEMENT; DRILL WATER (COLOR, LOSS); RATE OF DRILLING; WATER LEVELS; TEST; RESULT; JOINT SET NO.; ROUGHNESS; SEPARATION; SPACING (< 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m); DEPTH (m) FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total Litres/minute); LUGEON or PERMEABILITY m/sec; CORE RECOVERY % AND R Q D % (0, 50, 100); GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ROCK STRENGTH; REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.); DEPTH (m)

Drilling

Daily advance	Water levels	Drill water (colour, loss)
	0.2 05/05	
	1.1 02/05	
4.00 01/05		LIGHT GRAY
7.5 02/05		
10.0 03/05		
12.5 04/05		
15.0 05/05		
18.0 06/05		
20.0 07/05		

Joints and permeability

Joint set no.	Roughness	Separation	Pressure (bars)	Water loss	Lugeon
II	R	T			
III	R	T			
			1	3·0	7·7
II	R	T	3	9·5	9·6
			6	21·0	11·1
III	R	T/MO	3	10·0	10·1
			1	3·4	8·7
			1	0	0
II	R	T	3	0	0
			6	0	0
III	R	T	3	0	0
			1	0	0
I	R	T	1	0	0
II	R	T	3	0	0
			6	0	0
III	R	T	3	0	0
			1	0	0
II	R	T	1	0	0
			3	0	0
			6	0	0
III	R/SR	T	3	0	0
			1	0	0
			1	0	0
II	R	T	3	0	0
			6	0	0
III	R	T	3	0	0
			1	0	0
			1	0	0
II	R	T	3	0	0
			6	0	0
III	R	T	3	0	0
			1	0	0



General description

TOP SOIL, BLACKISH CLEYEY SILT.

GREY SILTY SAND.

BLACKISH AMPHIBOLITE COBBLES.

GARNETIFEROUS AMPHIBOLITE, BLACK, MEDIUM/COARSE GRAINED,

AT 1·10 FJ / 60°
AT 1·6 J / 60°
AT 2·25, 2·43 J / 50°
AT 2·77, 2·86 J/15°
AT 4·50, 4·60 J / 50°
AT 3·83, 4·12 J/15°–20°
AT 4·68 WEATHERED, OPEN J/20°

GARNETIFEROUS QUARTZ-FELDSPAR GNEISS. WHITE, MEDIUM TO COARSE GRAINED, MAIN COMPONENTS QUARTZ, FELDSPAR, GARNET.

FROM 11·10 TO 11·70 BAND OF HORNBLENDE – BIOTITE GNEISS

AT 8·48 J/50°
AT 7·77 J/15°–20°
AT 7·80, 8·00, 8·10, 8·12, 8·14, 8·16, 8·25, 8·33 J/15°–20°
AT 11·50, 11 56, 11·64 FJ/75°
AT 10·08, 12 00 J/50°
AT 9·00, 9·18, 9·20, 9·21, 9 23, 11·00, 11 10, 11·90 J/20°
AT 12·34, 12·56, 13·16, 13·24, 14·12 J/55°
AT 13·30, 13·34 CHLORITE COATED J/20°
AT 12·44, 12·56, 14·0 J/20°–30°
AT 15·09, 15·42, 15·78, 16·16 J/50°
FROM 17·68 TO 17·96 FRACTURE ZONE, IRON STAINED JOINTS AT 1–3 Cm.
AT 15·23, 15·24, 15·25, 15·67, 16·59, 17·04, 17·05, 17·28, 17·42, 17·45 17·57, 17·68, 18·0 J/15°–20°
AT 18·20 J/60°
AT 18·57, 18·8, 18·94, 19·49, 19·86, 19·94, 19·97 J/70°–80°
FROM 18·70 TO 19·40 FRACTURE ZONE JOINTS 20°–25° AT 3–4 Cm.

HOLE COMPLETED AT 20·0 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

BHKK35 SHEET OF

FEATURE :- KK 205 (NEW), DESANDER

DRILLING DATA

STARTED 14.05.92 COMPLETED 21.05.92
[illegible]
MACHINE TYPE TONE TDC1
DRILLING METHOD ROTARY
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
[illegible]
[illegible]

BOREHOLE DATA

X COORDINATE
Y COORDINATE
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH 20.20
INCLINATION FROM VERTICAL
BEARING
LOCATION (see fig.)

KEY

JOINT ROUGHNESS: VR very rough; R rough; SR slightly rough; S smooth; SL polished/slickensided
JOINT SEPARATION: V very tight < 0.1mm; T tight 0.1-1.0mm; MO moderately open 1.0-5.0mm; O open > 5.0mm
RECOVERY: CORE RECOVERY (%); R Q D (%)
OTHER SYMBOLS: PL point load strength index; U.C.S uniaxial compressive strength; ▼ first ground water; [illegible]; [illegible]

WEATHERING: soil / unconsolidated material; completely; highly; moderately; slightly; fresh

ROCK STRENGTH MN/m²: [illegible] < 1.00; weak 1.0-5.0; [illegible] 5.0-25.0; moderately strong 25.0-50.0; strong 50.0-100; very strong 100-250; extremely strong > 250

GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, layered, foliated, banded, flow banded, gneissose, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

ENGINEERING ASPECTS – REMARKS (with respect to excavation, grouting, permeability, rock quality etc.)

Drill water colour: LIGHT GRAY

Depth (m)	Daily advance	Casing	Water levels	Test	Result	Joint set no.	Roughness	Separation	Perm. from top	Perm. to bottom	Pressure (bars)	Water loss	Lugeon	General description
0.95														TOP SOIL, BLACKISH CLAYEY SAND
1.0				SPT	10									RESIDUAL SOIL, REDDISH BROWN CLAYEY SAND
1.40		1.5 14/05		SPT	8									
2.0			2.3			I	R	T						GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY, MEDIUM GRAINED,
3.0	2.7 14/05					II	R	T	3.0		1	1.2	3.1	
											3	3.1	3.1	AT 3.98 FOLIATION J/60°
4.0											6	6.0	4.2	AT 3.13 J/50°
											3	3.0	3.0	AT 2.05, 2.20, 2.66, 2.72, 2.92, 2.97, 3.10 J/25°
5.0										6.0	1	1.0	2.6	
6.0 6.1	6.1 15/05								6.0		1	0	0	AT 6.17, 6.35, 6.29, 6.66 J/50°
											3	0	0	
7.0						II	R	T			6	0	0	
8.0											3	0	0	
										9.0	1	0	0	
9 9.1	9.5 16/05								9.0		1	0	0	AT 9.30, 9.44 J/50°
10.0						II	R	T			3	0	0	
											6	0	0	
11.0											3	0	0	
										12.0	1	0	0	
12.0 12.1	12.1 19/05								12.0		1	0	0	
13.0											3	0	0	AT 12.20, 15.00 J/50°
						II	R	T			6	0	0	
14.0											3	0	0	
										15.0	1	0	0	
15.0 15.1									15.0		1	0	0	AT 15.80, 16.34 FJ/68°
16.0						I	R	T			3	0	0	AT 17.95 J/45°
	16.5 20/05					II	R	T			6	0	0	
17.0											3	0	0	
										18.0	1	0	0	
18.0						II	R	T						AT 18.95, 20.10 J/50°
19.0						III	R	T						AT 18.98, 19.05, 19.12 J/30°
20.0	20.2 21/05													

HOLE COMPLETED AT 20.20m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 , (NEW) DESANDER

BHKK36 SHEET 01 OF 01

DRILLING DATA

STARTED 27/05/02 COMPLETED 31/05/02
INTERRUPTIONS (DAYS)
MACHINE TYPE TONE TOC 1
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X COORDINATE
Y COORDINATE
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH 23.00
INCLINATION FROM VERTICAL
BEARING
LOCATION (see e.g.)

KEY

JOINT ROUGHNESS
VR very rough
R rough
SR slightly rough
S smooth
SL slickensided

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

JOINT SEPARATION
V very tight <0.1mm
T tight 0.1-1.0mm
MO moderately open 1.0-5.0mm
O open >5.0mm

OTHER SYMBOLS
PI point load strength index
UCS uniaxial compressive strength
first ground water
S stock sample
W water sample

WEATHERING

soil (unconsolidated material)
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	<1.00
weak	B	1.0 - 5.00
	C	5.0 - 25.00
moderately strong		25.0 - 50.00
strong		50.0 - 100.00
very strong		100.0 - 250.00
extremely strong		>250.00

DRILLING | TESTS | JOINTS | PERMEABILITY | RECOVERY | GENERAL DESCRIPTION | ENGINEERING ASPECTS

GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, banded, flow banded, gneissose, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

TOP 0.15, BROWN CLAYEY SAND

RESIDUAL SOIL REDDISH BROWN CLAYEY SAND

WEATHERED GARNETIFEROUS ROCK

WEATHERED ROCK (WASH SAMPLE)

GARNETIFEROUS BIOTITE GNEISS, GREY, MEDIUM GRAINED.

FOL ~ 80°

BROWN

LIGHT GRAY

20.1 30/05

23.0 31/05

FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
14.0	17.0	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
17.0	20.0	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
20.0	23.0	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0

HOLE COMPLETED AT 23.00 m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KK 205 (NEW), DESANDER

BHKK37 SHEET O
OF O

DRILLING DATA

STARTED:09/06/92 COMPLETED:14/06/92
INTERRUPTIONS (DAYS)
MACHINE TYPE TONE TDC 1
DRILLING METHOD ROTORY
CORE BARREL, BIT. NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH
INCLINATION FROM VERTICAL.
BEARING
LOCATION (see 1.1)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR=very rough	V =very tight	< 0.1mm
R =rough	T =tight	0.1-1.0mm
SR=slightly rough	MO=moderat open	1.0-5.0mm
S =smooth	O =open	> 5.0mm
SL=slickensided		

RECOVERY

▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS

PL.S I=point load strength index
U.C.S =uniaxial compressive strength
▼ =first ground water
R =rock sample
W =water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DEPTH (m)	DRILLING: DAILY ADVANCE	DRILLING: CASING/CEMENT	DRILLING: DRILL WATER (COLOR, LOSS)	DRILLING: RATE OF DRILLING	DRILLING: WATER LEVELS	TESTS: TEST	TESTS: RESULT	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	JOINTS: SPACING (<0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, >3.00 m)	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PERMEABILITY: PRESSURE (BARS) (manometer reading)	PERMEABILITY: WATER LOSS (total Litres/minute)	PERMEABILITY: LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R.Q.D % (0 50 100)	GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ENGINEERING ASPECTS: ROCK STRENGTH	ENGINEERING ASPECTS: REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)
0·15																		TOP SOIL, CLAYEY SAND				
0·55																		CLAYEY SAND				
1						SPT SPT	10 12											RESIDUAL SOIL, BROWN CLAYEY SAND.				
2						SPT SPT	18 21															
2·9 4 5 5 55 6	3·10 09/06	3 0 09/06			2 8 4/06 4·8 11/06							3·0	6·0	1 3 6 3 1	0 0 0 0 0	0 0 0 0 0		AMPHIBOLITE, DARK GREY MEDIUM GRAINED. (COMPONENTS : HORNBLENDE, DARK COLOURED FELDSPARS, PYROXENES)				
6·15 7 8 9	7 15 10/06							III II	R R	MO MO		6·0	9·0	1 3 6 3 1	0 0 0 0 0	0 0 0 0 0		AT 8 63 WEATHERED J/15° AT 8·65 WEATHERED J/60° AT 8 86 J/60°				
10 11	11 4 11/06											9·0	12 0	1 3 6 3 1	0 0 0 0 0	0 0 0 0 0						
12 13 14			LIGHT GRAY					II- III	R R	T T		12·0	15·0	1 3 6 3 1	0 0 0 0 0	0 0 0 0 0		AT 15·85, 16 09 J/50° AT 16 68, 16 89, 17·50 J/60° AT 14·32, 14 28, 14·62, 14·82 J/20° AT 15 05, 15·73, 15 75, 15 79 16·05, 17·02, 17·48 17 62 J/15°				
15 16 17 17·95	15 45 12/06											15·0	18 0	1 3 6 3 1	0 0 0 0 0	0 0 0 0 0						
18 19 20	18·6 13/06 20 25 14/06							II III	R R	T T		18·0	20 25	1 3 6 3 1	0 0 0 0 0	0 0 0 0 0		AT 18·0 J/60° AT 19 88 J/45° AT 19·85 J/20°				

HOLE COMPLETED AT 20·25 m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE — KK 205 (NEW), HEADRACE INTAKE

B.H. KK 39 | SHEET 01 OF 01

DRILLING DATA

STARTED: 21/06/92 COMPLETED: 26/06/92
INTERRUPTIONS (DAYS):
MACHINE TYPE TONE TDC.I
DRILLING METHOD: ROTORY
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE
Y-COORDINATE
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH
INCLINATION FROM VERTICAL:
BEARING
LOCATION (see f.)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1mm
R = rough	T = tight	0.1–1.0mm
SR = slightly rough	MO = moderately open	1.0–5.0mm
S = smooth	O = open	> 5.0mm
SL = slickensided		

RECOVERY	OTHER SYMBOLS
CORE RECOVERY (%)	P.L.S = point load strength index
R Q D (%)	U.C.S = uniaxial compressive strength
	▼ = first ground water
	R = rock sample
	W = water sample

WEATHERING

soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0–5.00
	C	5.0–25.00
moderately strong		25.0–50.00
strong		50.0–100.00
very strong		100.0–250.00
extremely strong		> 250.00

DRILLING — DEPTH (m); DAILY ADVANCE; CASING/CEMENT; DRILL WATER (COLOR, LOSS); RATE OF DRILLING; WATER LEVELS

TESTS — TEST; RESULT

JOINTS — JOINT SET NO.; ROUGHNESS; SEPARATION; SPACING (<0.05m, 0.05–0.30m, 0.30–1.00m, 1.00–3.00m, >3.00m)

PERMEABILITY — DEPTH (m) FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (total Litres/minute); LUGEON or PERMEABILITY m/sec

RECOVERY — CORE RECOVERY % AND R Q D % (0, 50, 100)

GENERAL DESCRIPTION — rock type, colour, grain size, texture and structure (massive, cleaved, foliated, bedded, flow banded, gneissose, porphyritic, etc; scale or for joint spacing), weathering, alteration, mineral lithological characteristics, strength, joints

GRAPHIC LOG; WEATHERING

ENGINEERING ASPECTS — ROCK STRENGTH; REMARKS with respect to excavation, grouting, permeability, rock quality, etc.; DEPTH (m)

Daily advance: 3·15 21/06; 6·84 22/06; 10·40 23/06; 14·15 24/06; 18·10 25/06

Casing/cement: 5·8 22/06

Drill water colour: BROWN; LIGHT GRAY

Water levels: 2·8 22/06; 4·1 25/06

Test: SPT — Result: 24

JOINT SET NO.	ROUGHNESS	SEPARATION
I	R	T
II	R	T
III	R	T

FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
6·00	9·00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
9·00	12·00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
12·00	15·00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
15·00	18·00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
18·00	20·00	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0

TOP SOIL BROWNISH

RESIDUAL SOIL, REDDISH, BROWN, CLAYEY SAND

COMPLETELY WEATHERED ROCK

HIGHLY WEATHERD
QUARTZ – FELDSPAR GNEISS
FOL ~ 80°

QUARTZ — FELDSPAR GNEISS,
MEDIUM / COARSE GRAINED
LIGHT GREY
AT 6·28 J/65°
AT 8·15 J/80°

AT 8 00, 9 17 J/20°

FOL ~ 80°

HOLE COMPLETED AT 20·15 m

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE :- KK 205 (NEW), SURGE SHAFT

B.H.KK42 SHEET OF

DRILLING DATA

STARTED 09.05.92 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY
DRILLING METHOD:
CORE BARREL, BIT.
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE
ELEVATION (COLLAR) 230·90
ELEVATION (BOTTOM)
FINAL DEPTH 230·07
INCLINATION FROM VERTICAL:
BEARING.
LOCATION (see fig)

KEY

JOINT ROUGHNESS

- VR = very rough
- R = rough
- SR = slightly rough
- S = smooth
- SL = slickensided

JOINT SEPARATION

V	= very tight	< 0.1 mm
T	= tight	0.1-1.0 mm
MO	= moderately open	1.0-5.0 mm
O	= open	> 5.0 mm

RECOVERY

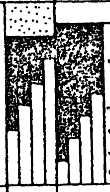
- ▨ CORE RECOVERY (%)
- ▨ R.Q.D (%)

OTHER SYMBOLS

- PL.SI = point load strength index
- U.C.S = uniaxial compressive strength
- F = first ground water
- R = rock sample
- W = water sample

WEATHERING

- soil : unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh



ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING / TESTS / JOINTS / GENERAL DESCRIPTION

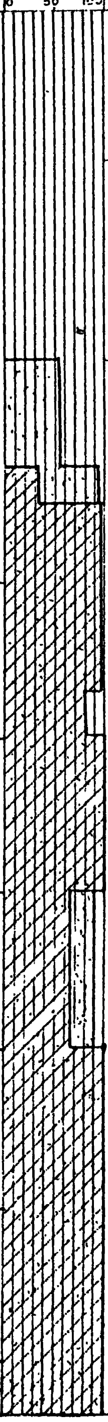
DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING < 0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, > 3.00 m	GENERAL DESCRIPTION rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints
1.0			BROWNISH, 10 %									RESIDUAL SOIL, REDDISH BROWN CLAYEY SAND.
2.0												
3.05			REDDISH, 10 %									COMPLETELY WEATHERED ROCK.
4.0												
5.0												
6.0	6.1 09/05											
7.02			GREENISH GRAY, 80 %									
8.0												
9.15		9.4 10/05						I III	R R			CHARNOCKITIC GNEISS, BLACKISH, MEDIUM GRAINED
10.0												AT 9.7 WEATHERED J/60°
11.0	10.99 10/05											AT 9.4, 9.5, 9.55, 9.85. WEATHERED J/25°
12.0			BROWNISH GRAY, 40%					III	R	MO		AT 12.6, 12.66, 12.70 WEATHERED J/15°-25°
13.0												FROM 12.6 TO 12.8 HIGHLY WEATHERED.
14.0	14.59 11/05							III	R	MO		AT 14.8 WEATHERED ZONE J/10°
15.0			GREENISH GRAY		15.6 11/06			II	R	T		AT 17.16 J/50
16.0												
17.0					16.7 26/06			III				AT 14.86 WEATHERED J/10° AT 17.87 J/10°
18.0					17.7 30/07 19.6 13/05							
19.0	19.2 12/05							II				FROM 19.05 TO 19.58 HIGHLY WEATHERED ZONE WITH CLOSELY SPACED FOLIATION JOINTS.
19.54			BROWNISH									
20.0												
21.0			GREENISH GRAY									
22.0								III	R	T		AT 21.05, 21.88 J/15°-20°
23.0												
24.0	23.92 13/05											
25.0												
26.0												
27.0	26.92 14/05											
28.0												

PERMEABILITY

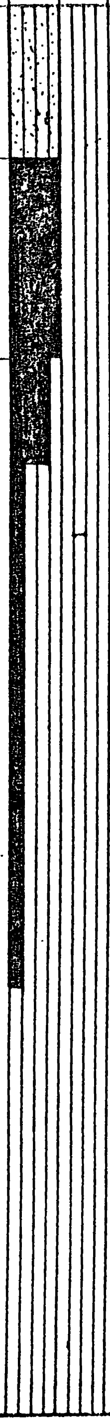
DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
11.64	14.59	1	4.9	7·0
		3	6.8	5·2
		6	8.3	3·7
		3	6.5	4·9
		1	5.2	7·4
14.59	17.67	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
17.67	20.73	1	58.0	63.8
		3	60.6	40.7
		6	68.8	28.6
		3	61.5	41.3
		1	55.5	63.0
20.73	23.82	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	.0
23.82	26.92	1	0	0
		3	0	0
		6	0	0
		3	0	0
		1	0	0
26.92				

RECOVERY

CORE RECOVERY % AND R Q D %



GRAPHIC LOG / WEATHERING / ROCK STRENGTH



ENGINEERING ASPECTS

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

FEATURE :- KK 205 (NEW), SURGE SHAFT

B.H.KK42 SHEET 02 OF 09

DRILLING DATA

STARTED 09.05 92 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY
DRILLING METHOD:
CORE BARREL, BIT
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE
ELEVATION (COLLAR) 230·90
ELEVATION (BOTTOM)
FINAL DEPTH 230·07
INCLINATION FROM VERTICAL.
BEARING.
LOCATION (see Fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR very rough	V very tight	< 0.1 mm
R rough	T tight	0.1–1.0 mm
SR slightly rough	MO moderately open	1.0–5.0 mm
S smooth	O open	> 5.0 mm
SL slickensided		

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

OTHER SYMBOLS
PL.S point load strength index
U.C.S uniaxial compressive strength
T first ground water
R rock sample
W water sample

WEATHERING

soil; unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

	MN/m²	
	A	< 1.00
weak	B	1.0–5.00
	C	5.0–25.00
moderately strong		25.0–50.00
strong		50.0–100.00
very strong		100.0–250.00
extremely strong		> 250.00

DRILLING — DEPTH (m), DAILY ADVANCE, CASING/CEMENT, DRILLWATER (COLOUR, LOSS), RATE OF DRILLING, WATER LEVELS
TESTS — TEST, RESULT
JOINTS — JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m)
PERMEABILITY — DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec
RECOVERY — CORE RECOVERY % AND R.Q.D. % (0, 50, 100)
GENERAL DESCRIPTION — rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc. scale or for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints
GRAPHIC LOG, WEATHERING, ROCK STRENGTH
ENGINEERING ASPECTS — REMARKS (with respect to excavation, grouting, permeability, rock quality etc.), DEPTH (m)

Daily advance	Drillwater (colour)	Joint set no.	Roughness	Separation	From top	To bottom	Pressure (bars)	Water loss	Lugeon
	LIGHT GRAY						1	0	0
							3	0	0
							6	0	0
							3	0	0
						30·19	1	0	0
		II	R	T	30·19		1	0	0
							3	0	0
31·72 15/05							6	0	0
		III	R	T			3	0	0
						33·08	1	0	0
		II	R	T	33·08		1	0	0
							3	0	0
							6	0	0
		III	R	T			3	0	0
36·1 17/05						36·1	1	0	0
					36·1		1	0	0
							3	0	0
							6	0	0
							3	0	0
						39·07	1	0	0
39·07 18/05	LIGHT GRAY	I	R	T	39·07 TEST LENGTH 6 m	TEST LENGTH 3 m	1	7·7	8·8
		II	R	T			3	8·5	5·7
		III	R	T			6	9·7	4·1
		III	R	MO			3	8·8	5·9
						42·1	1	8·6	9·8
		I	R	T			3	10·8	3·6
43·24 19/05		II	R	T			6	12·3	2·5
							10	15·5	2·1
		III	R	T			6	14·9	3·1
						45·22	3	14·3	4·8
		I	R	T	45·22		3	0	0
		II	R	T			6	0	0
							10	0	0
47·45 20/05		III	R	T			6	0	0
						48·45	3	0	0
					48·45		3	0	0
							6	0	0
							10	0	0
							6	0	0
51·69 21/05						51·69	3	0	0
	PINKISH GRAY				51·69		3	0	0
							6	0	0
							10	0	0
							6	0	0
						54·78	3	0	0
					54·78				

GENERAL DESCRIPTION

CHARNOCKITIC GNEISS, BLACKISH, MEDIUM GRAINED FROM 30·0 TO 31·10 QUARTZ– RICH BIOTITE GNEISS LAYER.
FROM 34·10 TO 34 90 AND FROM 35·20 TO 35·80 QUARTZ-FELDSPAR PEGMATITE.
AT 30·19 J/60°
AT 31·10 J/35°

AT 34·25 J/70°
34 15 J/50°
35·55, 35·66 J/65°
AT 34·35, 34 40, 34·66, 34·8, 34·86, J/35°

QUARTZ RICH BIOTITE GNEISS LIGHT GREY, COARSE GRAINED.

AT 41 86 FOLIATION J/45°
AT 40·8 J/80°
AT 39·9, 39·94, 40·14, 40·63 J/15°

FROM 41·50 – 41·58 CLOSELY SPACED JOINTS J/15°
AT 39·73 IRONSTAINED J/15°
AT 42·9, 4·94, 43·54, 43·56, 43·64 FOLIATION J/35°
AT 42·11 J/40°
AT 43·20 J/20°

AT 44·19, 44·22 FOLIATION J/40°
AT 45·07, 48·19, 48·27 J/70°
FROM 48 2 TO 48·45 J/90°
AT 44·3, 44·45, 44 72, 45·7, 46·16, 46·24, 46 8, 47·15, 47·35, 47·51, 47·57, 47·63 J/15° – 25°

GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

B.H.KK42 SHEET 03 OF 09

FEATURE :- KK 205 (NEW), SURGE SHAFT

DRILLING DATA

STARTED 09.05 92 COMPLETED
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY
DRILLING METHOD
CORE BARREL, BIT
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE.
ELEVATION (COLLAR) 230·90
ELEVATION (BOTTOM)
FINAL DEPTH 230·07
INCLINATION FROM VERTICAL:
BEARING:
LOCATION (see Fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR very rough	V very tight	< 0.1mm
R rough	T tight	0.1-1.0mm
SR slightly rough	MO moderately open	1.0-5.0mm
S smooth	O open	> 5.0mm
SL slickensided		

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
P.L.S point load strength index
U.C.S uniaxial compressive strength
▼ first ground water
R rock sample
W water sample

WEATHERING

soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING						TESTS		JOINTS				PERMEABILITY					RECOVERY	GENERAL DESCRIPTION			ENGINEERING ASPECTS		
DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILLWATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING 0.05-0.30, 0.30-1.00, 1.00-3.00	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	CORE RECOVERY % AND R Q D % (0 50 100)	rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	REMARKS (with respect to excavation, grouting, permeability, rock quality, etc)	DEPTH (m)
														3	0	0		AT 57 92 J/65°					
														6	0	0							
	56.79 22/05													10	0	0							
								II	R	T				6	0	0							
57													57·29	3	0	0							
57 92												57 29		3	0	0							
58														6	0	0							
														10	0	0							
59														6	0	0							
60	60·14												60·14	3	0	0		GARNETIFEROUS BIOTITE GNEISS. LIGHT GREY.					
	23/05		PINKISH GRAY									60 14		3	0	0							
61								III	R	T				6	0	0		FRONT 70 60 TO 71 65					
														10	0	0		AND FROM 82·23 TO 86 24 GARNET - RICH BANDS					
62														6	0	0		AT 61·0 J/40°					
63													63·16	3	0	0							
								I	R	T		63·16		3	6·8	4·6		AT 63 96. FOLIATION J/40°					
64								II	R	T				6	7·3	3·0		AT 65·70 FOLIATION J/60°					
								III	R	T				10	8·7	2·4		AT 65·40, 65·27, J/70° AT 65 74, 66 0 J/50°					
65	65.0 24/05													6	8·0	3 3		AT 64 30 J/30°					
66													66 26	3	7·9	5·4							
														3	0	0							
67														6	0	0							
68								I	R	T				10	0	0		AT 67·83 J/50°					
														6	0	0							
69	69·3													3	0	0							
70	25/05		LIGHT GRAY									69·3		3	0	0							
								II	R	T				6	0	0		AT 70 8 J/60° AT 71·75 J/65°					
														10	0	0							
71														6	0	0							
72													72 48	3	0	0							
73												72·48		5	0	0							
														10	0	0							
74														15	0	0							
75														10	0	0							
	75.68												75·68	5	0	0							
76	26/05											75·68		5	0	0							
														10	0	0							
77														15	0	0							
78														10	0	0							
79													78·9	5	0	0							
												78 9		5	0	0							
80														10	0	0		AT 80 67 J/30°					
	80 44 27/05							III	R	T				15	0	0							
81														10	0	0							
82													82 23	5	0	0							
												82 23		5	0	0							
														10	0	0							
83								III	R	T				15	0	0		AT 84 80 J/30°					
														10	0	0							
84														5	0	0							

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

FEATURE :- KK 205 (NEW), SURGE SHAFT

B.H KK42 SHEET 04 OF 09

DRILLING DATA

STARTED 09.05.92 COMPLETED
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY
DRILLING METHOD:
CORE BARREL, BIT:
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE
ELEVATION (COLLAR) 230·90
ELEVATION (BOTTOM)
FINAL DEPTH 230·07
INCLINATION FROM VERTICAL:
BEARING.
LOCATION (see Fig)

KEY

JOINT ROUGHNESS
VR very rough
R rough
SR slightly rough
S smooth
SL slickensided

JOINT SEPARATION
V very tight <0.1mm
T tight 0.1-1.0mm
MO moderately open 1.0-5.0mm
O open >5.0mm

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

OTHER SYMBOLS
PLS point load strength index
UCS uniaxial compressive strength
▼ first ground water
R rock sample
W water sample

WEATHERING

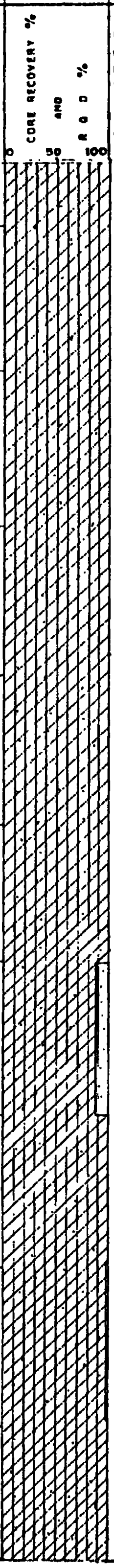
soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	<1.00
weak	B	1.0–5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		>250.00

DEPTH (m)	DRILLING					TESTS		JOINTS				PERMEABILITY					GENERAL DESCRIPTION	GRAPHIC LOG	WEATHERING	ENGINEERING ASPECTS		DEPTH (m)
	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale of for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints			ROCK STRENGTH	REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)	
85	85.20 26/05												85.28									
			LIGHT GRAY									85.26		5	0	0						
86														10	0	0						
								II	R	T				15	0	0						
87														10	0	0	GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY					
														5	0	0						
88	88.22 29/05		PINKISH GRAY										88.22				AT 86.30 J/50°					
												88.22		5	0	0						
89														10	0	0						
														15	0	0						
90														10	0	0						
91													91.35	5	0	0						
												91.38		8	0	0						
92														15	0	0						
														30	0	0						
93	92.83 30/05													15	0	0						
														8	0	0						
94													94.4									
												94.4		8	0	0						
95								III	R	T				15	0	0	AT 96.50, 97.4 J/25°					
														25	0	0						
96														15	0	0						
														8	0	0						
97	97.40 31/05												97.4									
												97.4		8	0	0						
98														15	0	0						
								III	R	T				25	0	0	AT 97.53, 99.0 J/15°					
99														15	0	0						
														8	0	0						
00	100.09 01/06												100.09									
												100.09		8	55.5	18.8						
01														15	50.2	9.9	AT 101.17, 107.26, 101.27					
								I	R	T				25	43.1	4.5	FOLIATION J/60°					
02														15	43.3	8.5	FROM 107.48 TO 101.56 4 NOS.					
			LIGHT GRAY											8	42.7	14.5	FOLIATION J/60°					
03	103.14 02/06												103.14									
												103.14		8	0	0						
04														15	0	0						
														25	0	0	AT 104.4, 104.82, 105.62 J/40°					
05								III	R	T				15	0	0						
														8	0	0						
06													106.18									
												106.18		8	0	0						
07														15	0	0	AT 107.92, 107.95 J/60°					
	107.69 03/06													25	0	0						
08								II	R	T				15	0	0						
														8	0	0						
09													109.33									
												109.33		8	0	0	FROM 111.7 TO 112.4 J/90°					
10								II	R	T				15	0	0						
														25	0	0	AT 111.4, 111.94 J/25°					
11	111.0 04/06							III	R	T				15	0	0						
														8	0	0						
2																						

RECOVERY



KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES **TAB. 13**

FEATURE :- KK 205 (NEW), SURGE SHAFT

B.H. KK42 SHEET OF

DRILLING DATA

STARTED 09.05.92 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY
DRILLING METHOD: --
CORE BARREL, BIT.
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE
ELEVATION (COLLAR) 230·90
ELEVATION (BOTTOM)
FINAL DEPTH 230·07
INCLINATION FROM VERTICAL:
BEARING.
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION

V	very tight	< 0.1 mm
T	tight	0.1-1.0 mm
MO	moderately open	1.0-5.0 mm
O	open	> 5.0 mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
P.L.S = point load strength index
U.C.S = uniaxial compressive strength
F = first ground water
R = rock sample
W = water sample

WEATHERING

soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

MN/m²

	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DEPTH (m)	DRILLING: DAILY ADVANCE	CASING/CEMENT	DRILLWATER (COLOR LOSS)	RATE OF DRILLING	WATER LEVELS	TESTS: TEST	RESULT	JOINTS: JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING <0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, >3.00 m	PERMEABILITY: DEPTH (m) FROM TOP	TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	RECOVERY: CORE RECOVERY % AND R.Q.D % (0 50 100)	GENERAL DESCRIPTION rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	GRAPHIC LOG	WEATHERING	ROCK STRENGTH	ENGINEERING ASPECTS: REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)
		LIGHT GRAY											112·53					GARNETIFEROUS BIOTITE GNEISS				
112·86												112·53		8	0	0		GARNET-RICH AMPHIBOLITE, BLACKISH, COARSE GRAINED.				
113														15	0	0						
														25	0	0						
114														15	0	0						
														8	0	0						
115	115·7												115·71									
115·8 116	05/06											115·71		8	0	0		GARNETIFEROUS BIOTITE GNEISS, COARSE GRAINED				
								II	R	T				15	0	0						
116·8 117														25	0	0		HORNBLENDE-BIOTITE GNEISS, COARSE GRAINED				
														15	0	0						
118														8	0	0		AT 117·05, 118·60 J/50°				
	118·76												118·76									
119	06/06											118·76		8	0	0		AT 119·56, 119·89, 120·30 J/40°				
								II	R	T				15	0	0						
119·8 120																		QUARTZ-RICH BIOTITE GNEISS				
								III	R	T				25	0	0		AT 128·86 J/90°				
121														15	0	0		AT 128·86 J/40°				
121·3														8	0	0						
													121·89									
122		PINKISH GRAY										121·89		8	0	0						
														15	0	0						
123	123·4													25	0	0		GARNETIFEROUS BIOTITE GNEISS WITH COARSE GRAINED GARNETS				
	07/06							II	R	T				15	0	0						
124														0	0	0						
													124·92					AT 121·92 J/60°				
125												124·92		8	0	0						
														15	0	0						
126														25	0	0						
127														15	0	0						
														8	0	0						
	127·98												127·93									
128	08/06											127·93		8	0	0						
129														15	0	0						
														25	0	0						
130														15	0	0						
														8	0	0						
	130·98												130·98									
131	09/06											130·98		8	0	0						
132														15	0	0						
														25	0	0						
133														15	0	0						
														8	0	0						
134													134·1									
												134·1		8	0	0						
135														15	0	0		AT 134·25 J/50°				
	135·6							II	R	T				30	0	0						
136	10/06													15	0	0						
														8	0	0						
													136·85									
137		LIGHT GRAY										136·85		8	0	0						
														15	0	0						
138								III	R	T				25	0	0		AT 139·58 J/20°				
139														15	0	0						
														8	0	0						
140	139·98 11/06												139·98									

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

FEATURE :- KK 205 (NEW), SURGE SHAFT

B.H KK42 SHEET 06 OF 09

DRILLING DATA

STARTED 09.05.92 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY
DRILLING METHOD:
CORE BARREL, BIT:
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE
ELEVATION (COLLAR) 230·90
ELEVATION (BOTTOM)
FINAL DEPTH 230·07
INCLINATION FROM VERTICAL:
BEARING..
LOCATION (see Fig)

KEY

JOINT ROUGHNESS
VR very rough
R rough
SR slightly rough
S smooth
SL slickensided

JOINT SEPARATION
V very tight <0 1mm
T tight 0 1-1 0mm
MO moderat open 1.0-5 0mm
O open >5 0mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
P.L.S point load strength index
U.C.S uniaxial compressive strength
▼ first ground water
R rock sample
W water sample

WEATHERING

soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1 00
weak	B	1.0 – 5 00
	C	5 0-25 00
moderately strong		25 0-50 00
strong		50 0-100 00
very strong		100.0-250 00
extremely strong		> 250 00

DRILLING: DEPTH (m), DAILY ADVANCE, CASING/CEMENT, DRILL WATER (COLOR, LOSS), RATE OF DRILLING, WATER LEVELS — TESTS: TEST, RESULT — JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (<0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, >3.00 m) — PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec — RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100) — GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc. scale or for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints — GRAPHIC LOG — WEATHERING — ENGINEERING ASPECTS: ROCK STRENGTH, REMARKS (with respect to excavation, grouting, permeability, rock quality, etc) — DEPTH (m)

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	JOINT SET NO.	ROUGHNESS	SEPARATION	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON	GENERAL DESCRIPTION	DEPTH (m)
						139·98		8	0	0		
								15.	0	0		
41								25	0	0		
								15	0	0		
42								8	0	0	GARNETIFEROUS BIOTITE GNEISS WITH COARSE GRAINED GARNETS.	
							143·03					
43	143·03 12/06	LIGHT GRAY				143·03		8	0	0		
								15	0	0		
34								25	0	0		
45								15	0	0		
								8	0	0		
							146·02					
18						146·02		8	0	0		
17								15	0	0		
	147·49 13/06	PINKISH GRAY						30	0	0		
18								15	0	0		
9								8	0	0		
							149·36					
0						149·65		8	0	0		
								15	0	0		
1								30	0	0		
								15	0	0		
2	151·88 14/06							8	0	0		
							152·52					
3						152·52		8	0	0		
								15	0	0		
4								30	0	0		
								15	0	0		
5								8	0	0		
							155·54					
0	155·54 15/06					155·54		8	0	0		
		PINKISH GRAY						15	0	0		
7								30	0	0		
								15	0	0		
3								8	0	0		
							158·59					
9	158·59 16/06					158 59		8	0	0		
								15	0	0		
)								30	0	0		
								15	0	0		
								8	0	0		
							161·64					
	161·64 17/06					161·64		8	0	0		
								15	0	0		
3			II	R	T			30	0	0	AT 164·10 J/70°	
								15	0	0		
3·9 4								8	0	0	BIOTITE GNEISS	
							164·64					
5						164 64		8	0	0	GARNETIFEROUS BIOTITE GNEISS	
								15	0	0		
5	166·13 18/06	LIGHT GRAY	III	R	T			30	0	0	AT 167·82 J/40°	
								15	0	0		
3								8	0	0		167·3
							167·82				QUARTZ-RICH BIOTITE GNEISS.	

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

FEATURE :- KK 205 (NEW), SURGE SHAFT

B.H.KK42 SHEET OF

DRILLING DATA

STARTED 09.05 92 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY
DRILLING METHOD:
CORE BARREL, BIT.
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE:
ELEVATION (COLLAR) 230·90
ELEVATION (BOTTOM)
FINAL DEPTH 230·07.
INCLINATION FROM VERTICAL:
BEARING:
LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR very rough	V very tight	< 0.1 mm
R rough	T tight	0.1 – 1.0 mm
SR slightly rough	MO moderately open	1.0 – 5.0 mm
S smooth	O open	> 5.0 mm
SL slickensided		

RECOVERY	OTHER SYMBOLS
▨ CORE RECOVERY (%)	P.L.B point load strength index
▨ R.Q.D (%)	U.C.S uniaxial compressive strength
	▼ first ground water
	R rock sample
	W water sample

WEATHERING

soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

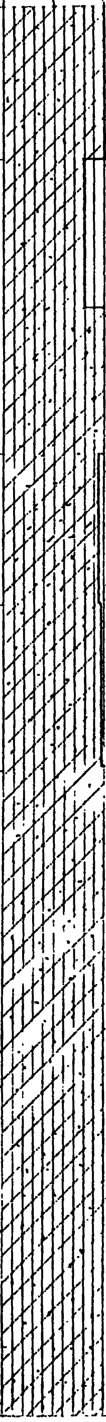
		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING / TESTS / JOINTS / PERMEABILITY / RECOVERY / GENERAL DESCRIPTION / ENGINEERING ASPECTS

Column headings: DEPTH (m); DRILLING: DAILY ADVANCE, CASING/CEMENT, (DRILL WATER COLOR, LOSS), RATE OF DRILLING, WATER LEVELS; TESTS: TEST, RESULT; JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (·05-0·30, 0·30-1·00, 1·00-3·00); PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec; RECOVERY: CORE RECOVERY % AND R Q D % (0 50 100); GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, faulted, lineated, flow banded, gneissose, porphyritic, etc. same as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ENGINEERING ASPECTS: ROCK STRENGTH, REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT (colour)
169		LIGHT GRAY
170	170·2 / 9/06	LIGHT GRAY
171		LIGHT GRAY
-171 2		
172		GREENISH GRAY
-172 7		GREENISH GRAY
173		GREENISH GRAY
174	174·1 / 20/06	GREENISH GRAY
-174 2		GREENISH GRAY
175		GREENISH GRAY
176		GREENISH GRAY
177	177·07 / 21/06	GREENISH GRAY
-177 4		GREENISH GRAY
178		
179		
-179·7		
180		
181	180·98 / 23/06	
182		
-182·7		
183		
184		
185		
186	185·54 / 24/06	
187		
188		
189	189·0 / 25/06	LIGHT GRAY
-189 6		LIGHT GRAY
190		LIGHT GRAY
191	191·1 / 27/06	LIGHT GRAY
-191·8		
192		
193		
194		
195	194·62 / 28/06	
196		

JOINT SET NO.	ROUGHNESS	SEPARATION	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
			167·82	171·11	8	0	0
II	R	T			15	0	0
					30	0	0
					15	0	0
					8	0	0
			171·11	174·1	8	0	0
II	R	T			15	0	0
II	R	T			30	0	0
					15	0	0
					8	0	0
			174·1	177·07	8	0	0
					15	0	0
II	R	T			30	0	0
					15	0	0
					8	0	0
			177·07	180·15	8	0	0
II	R	T			15	0	0
					30	0	0
III	R	T			15	0	0
					8	0	0
			180·15	183·33	8	0	0
					15	0	0
II	R	T			30	0	0
III	R	T			15	0	0
					8	0	0
			183·33	186·48	8	0	0
I	R	T			15	0	0
II	R	T			30	0	0
III	R	T			15	0	0
					8	0	0
			186·48	189·56	8	0	0
II	R	T			15	0	0
					30	0	0
					15	0	0
					8	0	0
			189·56	192·43	8	0	0
II	R	T			15	0	0
					30	0	0
					15	0	0
					8	0	0
			192·43	195·62	8	0	0
III	R	T			15	0	0
—					30	0	0
					15	0	0
II	R	T			8	0	0



QUARTZ – RICH BIOTITE GNEISS.
AT 170 60 J/60°
AT 171 11 J/65°
AT 167·95, 168 66, 168 96
169 02 J/30°

HORNBLENDE – BIOTITE GNEISS, COARSE GRAINED.
FROM 173·3 TO 173 8 TIGHT JOINTS 60°- 70° AT 1-2 Cm SPACING

QUARTZ – FELDSPAR PEGMATITE, COARSE GRAINED
AT 172·78, 173·25, 173·44 J/60°
AT 172 98 J/79°
AT 172 7 J/30°

HORNBLENDE – BIOTITE GNEISS
AT 174 62, 174 64, 175·98
J/65°

QUARTZ – RICH BIOTITE GNEISS.
AT 178·70 J/60°
AT 177·70, 178·18 J/30°
AT 179·30, 179·50, 179·60 J/40°

HORNBLENDE – BIOTITE GNEISS.
AT 180 3, 180 55, 181 08,
181·15, 181·64 J/50°
AT 182·8, 183·20 J/70°
AT 182·0, 183 05 J/40°

QUARTZ – FELDSPAR GNEISS
AT 185·77 FOLIATION J/60°
AT 184 63, 184·74, J/50°
AT 183·40 J/25°
AT 185 48 J/30°

AT 186 66 J/70°
AT 188 00, 189·06, 189 18
J/50°

HORNBLENDE – BIOTITE GNEISS
AT 189 15, 171 9 J/60°
AT 192·28 J/65°

QUARTZ – FELDSPAR GNEISS
AT 192·77 J/25°
AT 193 7, 193·9, 195 05
195·63 J/60°

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES

TAB. 13

FEATURE :- KK 205 (NEW), SURGE SHAFT

B.H KK42 SHEET 08 OF 09

DRILLING DATA

STARTED 09.05.92 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY
DRILLING METHOD
CORE BARREL, BIT.
FOREMAN. LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE
ELEVATION (COLLAR) 230·90
ELEVATION (BOTTOM)
FINAL DEPTH 230·07
INCLINATION FROM VERTICAL:
BEARING.
LOCATION (see Fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION
VR very rough	V very tight <0.1mm
R rough	T tight 0.1-1.0mm
SR slightly rough	MO moderately open 1.0-5.0mm
S smooth	O open >5.0mm
SL slickensided	

RECOVERY	OTHER SYMBOLS
CORE RECOVERY (%)	PL.S point load strength index
R.Q.D (%)	UCS uniaxial compressive strength
	Y first ground water
	R rock sample
	W water sample

WEATHERING

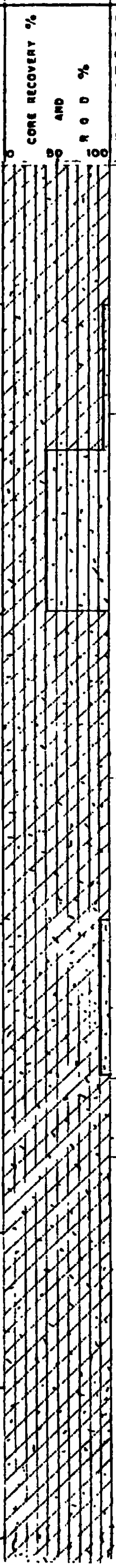
soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	<1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		>250.00

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING <0.05 m / 0.05-0.30 m / 0.30-1.00 m / 1.00-3.00 m / >3.00 m	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec	DEPTH (m)
		LIGHT GRAY										19562		8	0	0	
														15	0	0	
197								II	SR	T				30	0	0	197
								II	SL	T							
	1978 29/06													15	0	0	
198								III	SR	T				8	0	0	198
													198.71				
199												19871		8	0	0	199
								II	R	T				15	0	0	
200														30	0	0	200
								III	R	T				15	0	0	
201	201·0 30/06													8	0	0	201
													20174				
202												20174		8	0	0	202
		GREENISH GRAY												15	0	0	
203								II	SL	T				30	0	0	203
														15	0	0	
204	20409 01/07													8	0	0	204
								I	SL	T							
													20509				
205																	205
												209 03		8	0	0	
206														15	0	0	206
														30	0	0	
207								II	SL	T				15	0	0	207
	2076 02/07	LIGHT GRAY						II	SR	T				8	0	0	
208													20829				208
208.5												20829		8	0	0	
209														15	0	0	209
														30	0	0	
210														15	0	0	210
	2052 03/07													8	0	0	
211													21.33				211
								I	R	T		2133		8	0	0	
212														15	0	0	212
								II	R	T				30	0	0	
213														15	0	0	213
	213·4 04/07	PINKISH GRAY												8	0	0	
214													214.44				214
214.4												21444					
215														8	0	0	215
														15	0	0	
216														30	0	0	216
								III	R	T							
	216 8 05/07													15	0	0	
217								II	R	T			217.5	8	0	0	217
217.5												217.5					
218														8	0	0	218
														15	0	0	
219														30	0	0	219
								II	R	T							
														15	0	0	
220														8	0	0	220
	220·55 06/07												22055				
221												22055		8	0	0	221
														15	0	0	
222														30	0	0	222
														15	0	0	
														8	0	0	
223																	223
	22355 07/07												22355				
224																	224

RECOVERY



GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

QUARTZ – FELDSPAR GNEISS.
AT 196.30, 196 65 J / 70°
AT 196.65 SLICKENSIDED J / 70°
AT 196.90 J < 30°
AT 197.1, 197.13 J / 20°
AT 201.35, 201 12 J/60°
AT 199.12, 199.15, 199 19 J/40°
AT 201 10, 201 55, 201.64, J/20°

HORNBLENDE-BIOTITE GNEISS, BLACK, MEDIUM GRAINED
AT 201.77 J / 70° 2mm CHLORITE FILLING.
AT 202 32 J/50° CHLORITE.
AT 204 15, 204 45, 204 55, 204.75 204 95 CHLORITE STAINED SLICKENSIDED J/60°
FROM 202.78 TO 204.95 FOLIATION SHEAR ZONE
202.78 TO 203 8. 2-3mm CHLORITE FILLING ALONG SLICKENSIDED JOINTS / 70°
AT 205.56 J / 50° SLICKENSIDED
AT 207.46, 207 65 J/45°

GARNETIFEROUS BIOTITE GNEISS. GREY, MEDIUM GRAINED
AT 212.06 FOLIATION J / 50°
AT 212 22 FOLIATION J / 65°
AT 212.5, 212.7 SILICA COATINGS J / 70°
AT 212.55 J / 45° SILICA COATINGS

HORNBLENDE-BIOTITE GNEISS. BLACK.

GARNETIFEROUS BIOTITE GNEISS. GREY, MEDIUM GRAINED.

QUARTZ- RICH BIOTITE GNEISS, GREY, MEDIUM GRAINED.
BAND OF HORNBLENDE-BIOTITE GNEISS FROM 219.1 TO 220.5.
AT 217.2 J/45°
AT 214.62, 214 83 J / 30°
AT 220.7 J/45°

GRAPHIC LOG | WEATHERING

ENGINEERING ASPECTS

ROCK STRENGTH

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – POWER HOUSE

B.H KK43 SHEET 02 OF 05

DRILLING DATA

STARTED: 92-07-18 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE
DRILLING METHOD: ROTARY
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE:
ELEVATION (COLLAR):
ELEVATION (BOTTOM)
FINAL DEPTH
INCLINATION FROM 0° VERTICAL:
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1mm
R = rough	T = tight	0.1-1.0mm
SR = slightly rough	MO = moderately open	1.0-5.0mm
S = smooth	O = open	> 5.0mm
SL = slickensided		

RECOVERY
- CORE RECOVERY (%)
- R.Q.D (%)

OTHER SYMBOLS
- PL.S.I = point load strength index
- U.C.S = uniaxial compressive strength
- ▼ = first ground water
- R = rock sample
- W = water sample

WEATHERING

- soil · unconsolidated material
- completely
- highly
- moderately
- slightly
- fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING / TESTS / JOINTS / PERMEABILITY / RECOVERY

Column headings: DEPTH (m); DRILLING: DAILY ADVANCE, CASING/CEMENT, DRILL WATER (COLOUR, LOSS), RATE OF DRILLING, WATER LEVELS; TESTS: TEST, RESULT; JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (0.05–0.10 m, 0.10–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m); PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec; RECOVERY: CORE RECOVERY % AND R.Q.D % (0 50 100).

Drill water (colour): CREAMY

DEPTH (m)	DAILY ADVANCE	WATER LEVELS	JOINT SET NO.	ROUGHNESS	SEPARATION	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
28·56 28·81 29 29·86 30 30·9 31	25/07 (at 28·81)	11·07 / 26/07	I II III	R R R	T T T	28·19	31·03	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0
31·03 32 33 33·03 34	26/07		I II	R R	T T	31·03	34·26	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0
34·26 35 36 37		12·50 / 27/07	I II	R R	T T	34·26	37·23	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0
37·23 38 39 40	27/07 (at 37·23)	12·50 / 28/07	I II	R R	T T	37·23	40·42	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0
40·42 40·70 41 41·47 42 43	28/07 (at 40·42)	12·58 / 29/07	II I II	R R R	T T T	40·47	43·45	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0
43·45 44 45 45·01 45·54 46	29/07 (at 45·01)		I II III	R R R	T T T	43·45	46·45	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0
46·45 47 48 49		12·58 / 30/07				46·45	49·49	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0
49·49 50 51 52	30/07 (at 49·49)	12·58 / 31/07	II	R	T	49·49	52·75	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0
52·75 53 54 55 55·81	31/07 (at 52·75)	12·59 / [illegible]				52·75	55·81	3 6 10 6 3	0 0 0 0 0	0 0 0 0 0

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc · scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

HORNBLENDE BIOTITE GNEISS AS ABOVE

Qu RICH BIOTITE GNEISS FINE TO MEDIUM GRAINED
AT 28·50 FJ/45°
AT 29·20 J/60°
AT 29·68 J/35°

HORNBLENDE BIOTITE GNEISS DARK COLOURED, MEDIUM GRAINED

Qu RICH BIOTITE GNEISS LIGHT COLOURED MEDIUM GRAINED
AT 31·10, 32·83, 32·68, 32 70, 32 87, 32·95, 33·10 FJ/40°- 50°
31·92 – 32 12, 32·34 – 32·53 J/70°-80
AT 32·80, 33·10 J/60°

HORNBLENDE BIOTITE GNEISS DARK GREY MEDIUM TO COARSE GRAINED.
AT 35·88 FJ/60°
AT 36·0 J/60°
AT 36·93 FJ/45°
AT 38 40 FJ/40°
AT 40·20 J/60°

Qu-RICH BIOTITE GNEISS LIGHT COLOURED. MEDIUM GRAINED.
AT 40·72, 40·85, 40·92, 41·07, 41·12, 41·23, 41 28, 41·36 J/60° - 70°
AT 41·55, 42·30, 42·74, 42·8, 43·58 J/60°
FROM 42·42 TO 42·6 J/80°
AT 42 36 J/30°
AT 43·94, 47·79 FJ/55°-60°

Qu-RICH LIGHT COLOURED BIOTITE GNEISS ENRICHED WITH COARSE GRAINED GARNETS AND INTERCOLATIONS OF HORNBLENDE BIOTITE GNEISS LAYERS UP TO 30cm THICKNESS.
AT 44·12, 44·23, 44·46, 45 24, 45·54, 45·58 J/60° - 65°
AT 45·04 FJ/50°
AT 52·04 J/50°

GRAPHIC LOG | WEATHERING

ENGINEERING ASPECTS

ROCK STRENGTH

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

DEPTH (m): 28·5 29 29·86 30 31 31·0 32 33 34 34·2 35 36 37 37·2 38 39 40 40·42 40·70 41 41·47 42 43 43·45 44 45 46 46·45 47 48 49 50 51 52 53 54 55

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - POWER HOUSE

B.H KK 43 SHEET 03 OF 05

DRILLING DATA

STARTED: 97-07 18 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE
DRILLING METHOD: ROTARY
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE:
Y-COORDINATE
ELEVATION (COLLAR):
ELEVATION (BOTTOM)
FINAL DEPTH
INCLINATION FROM 0° VERTICAL:
BEARING
LOCATION (see Fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1-1.0mm
MO = moderately open 1.0-5.0mm
O = open > 5.0mm

OTHER SYMBOLS
PL.SI = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil: unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

	MN/m²	
	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0 25.00
moderately strong		25.0 50.00
strong		50.0-100.00
very strong		100.0 250.00
extremely strong		> 250.00

DRILLING · TESTS · JOINTS · PERMEABILITY · RECOVERY · GENERAL DESCRIPTION · ENGINEERING ASPECTS

Column headings: DEPTH (m); DRILLING: DAILY ADVANCE, CASING/CEMENT, DRILL WATER (COLOUR/LOSS), RATE OF DRILLING, WATER LEVELS; TESTS: TEST, RESULT; JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05 m, 0.05-0.30 m, 0.30-1.00 m, 1.00-3.00 m, > 3.00 m); PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec; RECOVERY: CORE RECOVERY % AND R Q D % (0, 50, 100); GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc: scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ENGINEERING ASPECTS: ROCK STRENGTH, REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.); DEPTH (m)

DEPTH (m)	DAILY ADVANCE	DRILL WATER (COLOUR/LOSS)	WATER LEVELS	JOINT SET NO.	ROUGHNESS	SEPARATION	FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON	GENERAL DESCRIPTION	DEPTH (m)
							55·81					BIOTITE GNEISS AS ABOVE	
56·94 57									3	0	0	AT 56·53, 57·87, 58·10 FJ/40°-50°	56·94 57
				I	R	T							
57·81 58	02/08			II	R	T			6	0	0	AT 57·64, 57·74 J/65°	58
59									10	0	0		59
59·49			1258 03/08										59·49
60									6	0	0		60
									3	0	0		
61 61·09													61 61·09
61 99 62	03/08						61·99	61·99					62
63									3	0	0		63
64			1258 04/08						6	0	0		64
65 65·01									10	0	0		65 65 01
66				I	R	T			6	0	0		66
67									3	0	0	AT 67·75 FJ/40°	67
67·21	04/08												
68							6799	67·99					68
69			1255 05/08	II	R	T			3	0	0		69
70 70·05		CREAMY							6	0	0	Qu-RICH BIOTITE GNEISS MEDIUM GRAINED. LIGHT COLOURED.	70
71 71·34									10	0	0		71 71 34
71·88 72	05/08								6	0	0	AT 70·98 J/65°	72
73									3	0	0		73
74 74·14			1259 06/08				74·14	74·14					74
74·90 75									3	0	0	Qu-RICH BIOTITE GNEISS LIGHT COLOURED, MEDIUM GRAINED WITH COARSE GRAINED GARNETS.	74 91 75
76 76·47	06/08			I	R	T			6	0	0	AT 75·88, 76·08, 76·20, 76·57 FJ/65°	76
77									10	0	0		77
78 78·02									6	0	0		78
									3	0	0	AT 76·46, 76·72 FJ/60°	
79			1256 07/08	II	R	T							79
80							79·78	79·78				AT 79·06 J/65°	80
81 81·28	07/08								3	0	0		81
									6	0	0		
82									10	0	0		82
82·81 83			1255 09/08						6	0	0		82·81 83
									3	0	0		

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES   TAB. 13

BH KK43 | SHEET OF 05

FEATURE — POWER HOUSE

DRILLING DATA

STARTED 09.07.18 COMPLETED
DIFFERENT ROCK TYPES
MACHINE TYPE
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X COORDINATE
Y COORDINATE
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH
INCLINATION FROM 0° VERTICAL
BEARING
LOCATION (see fig.)

KEY

JOINT ROUGHNESS
VR very rough
R rough
SR slightly rough
S smooth
SL slickensided

RECOVERY
CORE RECOVERY (%)
R Q D (%)

JOINT SEPARATION
V very tight
T tight
MO moderately open
O open

OTHER SYMBOLS
PI point load strength index
UCS uniaxial compressive strength
▼ ground water
S core sample
W water sample

WEATHERING

soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH MN/m²

	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0 - 25.00
moderately strong		25.0 - 50.00
strong		50.0 - 100.00
very strong		100.0 - 250.00
extremely strong		> 250.00

DRILLING | TESTS | JOINTS | PERMEABILITY | RECOVERY | GENERAL DESCRIPTION | ENGINEERING ASPECTS

GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, banded, flow banded, gneissose, porphyritic, etc.; scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

Depth (m)	Joints	Pressure (bars)	Water loss	Lugeon	General description
					BIOTITE GNEISS AS ABOVE
85					
85.40					
86					
86.45		5	0	0	
87		5	0	0	
88		10	0	0	
88.55					
89		5	0	0	
90		5	0	0	
91					
92		5	0	0	
93		5	0	0	
94		10	0	0	
95		5	0	0	
	III II I	3	0	0	
96					
96.70					AT [illegible] J/60°
97					
98		5	0	0	
99	II II I	15	0	0	QZ. RICH BIOTITE GNEISS LIGHT COLOURED, MEDIUM GRAINED
100		30	0	0	
100.2					AT [illegible] J/55°
101		15	0	0	
	II II I	5	0	0	
102					
103					
104	I II I	5	0	0	AT 104.04 J/55°
	III II I				AT 104.55 J/40°
105		15	0	0	
106		30	0	0	
		15	0	0	
107	II II I	5	0	0	AT 107.80, 108.02 J/80°
108					
109					AT 109.44 J/55°
110		5	0	0	
	II II I	15	0	0	FROM 111.54 TO 111.74 SILICA COATED J/75°
111		30	0	0	AT 111.8 J/45°

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – POWER HOUSE

B.H KK43 SHEET 05 OF 05

DRILLING DATA

STARTED: 92-07-18 COMPLETED:
INTERRUPTIONS (DAYS):
MACHINE TYPE
DRILLING METHOD: ROTARY
CORE BARREL, BIT: NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE
Y-COORDINATE
ELEVATION (COLLAR)
ELEVATION (BOTTOM)
FINAL DEPTH
INCLINATION FROM VERTICAL:
BEARING
LOCATION (see fig.)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

RECOVERY
▨ CORE RECOVERY (%)
☐ R Q D (%)

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1-1.0mm
MO = moderately open 1.0-5.0mm
O = open > 5.0mm

OTHER SYMBOLS
PL.S = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil - unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

MN/m²		
	A	< 1.00
weak	B	1.0 - 5.00
	C	5.0 - 25.00
moderately strong		25.0 - 50.00
strong		50.0 - 100.00
very strong		100.0 - 250.00
extremely strong		> 250.00

DEPTH (m)	DRILLING: DAILY ADVANCE	DRILLING: DRILL WATER (COLOR, LOSS)	DRILLING: WATER LEVELS	JOINTS: JOINT SET NO.	JOINTS: ROUGHNESS	JOINTS: SEPARATION	PERMEABILITY: DEPTH (m) FROM TOP	PERMEABILITY: DEPTH (m) TO BOTTOM	PERMEABILITY: PRESSURE (BARS)	PERMEABILITY: WATER LOSS (total litres/minute)	PERMEABILITY: LUGEON or PERMEABILITY m/sec	GENERAL DESCRIPTION (rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc. scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints)	DEPTH (m)
17												BIOTITE GNEISS AS ABOVE	112·17
									15	0	0		113
				I	R	T			8	0	0		
			12·5 14/08									AT 114·70 FJ/40°	114
8							115·18	115·18					115 115·18
	116·1 14/08			II	R	T			8	0	0		116
				III	R	T			15	0	0	AT 117·26, J/45° AT 117·50, 117·9, 118·02, 118·06 J/50°	117
									30	0	0		
37									15	0	0		118 118·37
			12·55 15/08						8	0	0	Qu – RICH BIOTITE GNEISS ENRICHED WITH COARSE GRAINED GARNETS LIGHT COLOURED 118·18 – 118·32 J/75° AT 118·32 J/65°	119
				I	R	T							120
												BIOTITE GNEISS FINE TO MEDIUM GRAINED, LIGHT COLOURED AT 119·95, 120·05 FJ/50°	121
14	121·44 15/08						121·44	121·44	8	0	0		121·44 122
									15	0	0		123
67									30	0	0	AT 123·80 J/65° AT 124·80 J/40°	123·67
				II	R	T							124
				III	R	T			15	0	0		125
31									8	0	0	FROM 125·8 TO 125·93 J/80°	125·31 126
		CREAMY		II	R	T						AT 126·92 J/60°	127
13							128·33	128·33					128
									8	10·9	1·9	BIOTITE GNEISS, LIGHT COLOURED WITH COARSE GRAINED GARNETS	129
									15	11·7	1·2		130
3 5									30	13·4	0·7	HORNBLENDE BIOTITE GNEISS AT 134·22 J/45°, AT 134·25 SLICKENSIDED J/40°	131 131·43 131·55
5				II	R	T			15	12·8	1·3	Qu – RICH BIOTITE GNEISS MEDIUM GRAINED WITH COARSE GRAINED GARNETS, LIGHT COLOURED	132 132·15
				II	R	SL			8	12·6	2·2		133
24								134·51					134
8							134·51					HORNBLENDE BIOTITE GNEISS MEDIUM TO COARSE GRAINED	135
									8	0	0	Qu – RICH BIOTITE GNEISS MEDIUM GRAINED, LIGHT COLOURED WITH COARSE GRAINED GARNETS & INTERCOLATION OF HORNBLENDE BIOTITE GNEISS LAYERS UP TO 15cm	136
									15	0	0		137
11									30	0	0		137·61
									15	0	0		138
									8	0	0		139
								140·7					140

ENGINEERING ASPECTS

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

B.H. KP3 | SHEET (OF 02

FEATURE – KP DAM AXIS

DRILLING DATA

STARTED 91-10-07 COMPLETED 91-11-03
INTERRUPTIONS (DAYS): 01
MACHINE TYPE
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 151, 691·43 N
Y-COORDINATE 151, 777·35 E
ELEVATION (COLLAR) 217·12
ELEVATION (BOTTOM) 186·92
FINAL DEPTH 50·2
INCLINATION FROM VERTICAL: 0°
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0·1mm
T = tight 0·1–1·0mm
MO = moderately open 1·0–5·0mm
O = open > 5·0mm

RECOVERY
CORE RECOVERY (%)
R Q D (%)

OTHER SYMBOLS
P.L.S = point load strength index
U C S = uniaxial compressive strength
▼ = first ground water
■ = rock sample
▼ = water sample

WEATHERING

soil: unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

	MN/m²	
	A	< 1·00
weak	B	1·0–5·00
	C	5·0–25·00
moderately strong		25·0–50·00
strong		50·0–100·00
very strong		100·0–250·00
extremely strong		> 250·00

DRILLING / TESTS

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOUR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT
0·05							
0·64							
1·00						SPT	N=9
1·40	07/10						
2·00						SPT	N=13
2·30							
3·11						SPT	N=17
3·41							
4·41	08/10					SPT	N=33
4·71							
5·81						SPT	N=27
6·11	09/10						
6·80			DRY DRILLING			SPT	N=18
7·10							
8·10	11/10					SPT	N=15
8·40							
9·66				DRY DRILLING		SPT	N=14
9·96							
10·98						SPT	N=46
11·28	12/10						
12·26	13/10	14/10 12·26		DRY	9·9 13/10	SPT	N=44
12·58							
13·17	15/10				10·4 15/10		
					10·8 16/10		
15·59	16/10	17/10 15·59	GRAY		11·1 17/10		
17·84	18/10	18/10 17·84	BROWNISH		10·7 19/10		
20·69		19/10 20·69	GRAY		10·2 20/10		
21·69							
22·94							
25·75	20/10				8·46 21/10		
26·15	21/10						
27·20	22/10						
27·32							
27·75							

JOINTS

DEPTH (m)	JOINT SET NO.	ROUGHNESS	SEPARATION
15·59–17·84	I	R	O
	II	R	MO
	III	R	O
17·84–20·69	I	R	O
	II	R	O
20·69–21·69	I	R	T
	II	R	T
	III	R	MO
21·69–22·94	I	R	T
	II	R	T
	III	R	T
22·94–25·75	I	R	MO
25·75–26·15	I	R	T
26·15–27·32	I	R	MO
	II	R	MO
27·32–27·75	I	R	T

SPACING: < 0·05m; 0·05–0·30m; 0·30–1·00m; 1·00–3·00m; > 3·00m

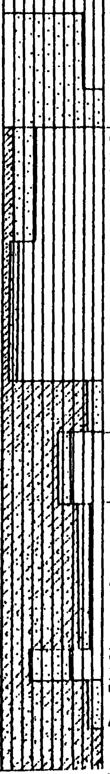
PERMEABILITY

NO PERMEABILITY TESTS HAVE BEEN EXECUTED.

DEPTH FROM TOP (m)	DEPTH TO BOTTOM (m)	PRESSURE (BARS) manometer reading	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
22·23	25·75	3	6·8	5·92
		4	10·2	7·04
		5	16·0	9·13
		4	11·2	7·72
		3	7·8	6·79
25·23		1	0·2	0·41
		3	0·1	0·09
		6	NIL	00
		3	NIL	00
		1	NIL	00

RECOVERY

CORE RECOVERY % AND R Q D %



GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc. scale or for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

TOP SOIL – BLACKISH

RESIDUAL SOIL – REDDISH BROWN CLAYEY SAND

PINK COLOUR CLAYEY WITH WHITSH CORE STONES

RESIDUAL SOIL REDDISH BROWN SILTY CLAY

COMPLETELY WEATHERED ROCK WITH CORE STONES PINK TO WHITISH

COMPLETELY WEATHERED GARNETIFEROUS ROCK, PINK TO LIGHT BROWN

PINK COLOUR CLAYEY SAND, WASH SAMPLE OF COMPLETE WEATHERED ROCK

COMPLETELY WEATHERED GARNETIFEROUS ROCK, PINK TO LIGHT BROWN

COMPLETELY WEATHERED MICACEOUS ROCK WHITISH TO LIGHT BROWN

COMPLETELY WEATHERED ROCK, REDDISH BROWN

COMPLETELY WEATHERED ROCK, WHITISH TO PINK AND REDDISH BROWN

WEATHERED GARNETIFEROUS GNEISS, DISCOLOURED

GARNETIFEROUS BIOTITE GNEISS DISCOLOURED, FINE TO MEDIUM GRAINED FULLY DEVELOPED GNEISSIC TEXTURE MAIN COMPONENTS Qu, Fd, Bi
FROM 16 49 TO 20 24 WEATH FRACTURED ZONE
AT 20·24, 20 44, 20·69 WEATH F/J

AT 21·75 WEATH J/05°
AT 21·69, 22·90 F/J
FROM 22·70 – 22·94 J/80°

AT 23·24, 23·29, 23·94, 25·25, 25·70 WEATH F/J
AT 22·50, 24·15, 25·27 F/J
AT 23 80, 24 05 WE J/15°
AT 23·31, 23·77 J/20°

AT 25 90, 26 67, 27 00
SL. WEATH F/J

FROM 27·0 – 27·25 WEATH J/70

AT 27·5, 27 75 F/J

GRAPHIC LOG | WEATHERING

ENGINEERING ASPECTS

ROCK STRENGTH

REMARKS
(with respect to excavation, grouting, permeability, rock quality, etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE – KP DAM AXIS

B.H. KP3 SHEET 02 OF 02

DRILLING DATA

STARTED 91 10·07 COMPLETED 91 11 03
INTERRUPTIONS (DAYS) 01
MACHINE TYPE
DRILLING METHOD ROTARY
CORE BARREL, BIT NX
FOREMAN: LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE 151, 691 43 N
Y-COORDINATE 151, 777·35 E
ELEVATION (COLLAR) 217 12
ELEVATION (BOTTOM) 186·92
FINAL DEPTH 50·2
INCLINATION FROM VERTICAL: 0°
BEARING
LOCATION (see fig. 1

KEY

JOINT ROUGHNESS	JOINT SEPARATION
VR very rough	V very tight < 0.1mm
R rough	T tight 0.1–1.0mm
SR slightly rough	MO moderately open 1.0–5.0mm
S smooth	O open > 5.0mm
SL slickensided	

RECOVERY	OTHER SYMBOLS
CORE RECOVERY (%)	P.L.S point load strength index
R Q D (%)	U C S uniaxial compressive strength
	▼ first ground water
	B block sample
	W water sample

WEATHERING

soil, unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

	MN/m²	
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING — DEPTH (m), DAILY ADVANCE, CASING/CEMENT, DRILL WATER (COLOR, LOSS), RATE OF DRILLING, WATER LEVELS

TESTS — TEST, RESULT

JOINTS — JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m)

PERMEABILITY — DEPTH (m) FROM TOP, TO BOTTOM; PRESSURE (BARS) (manometer reading); WATER LOSS (litres/minute); LUGEON / PERMEABILITY m/sec

RECOVERY — CORE RECOVERY %, R Q D % (0, 50, 100)

GENERAL DESCRIPTION — rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc.), scale of the joint spacing, weathering, alteration, mineral, lithological characteristics, strength, joints

GRAPHIC LOG — WEATHERING — ROCK STRENGTH

ENGINEERING ASPECTS — REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

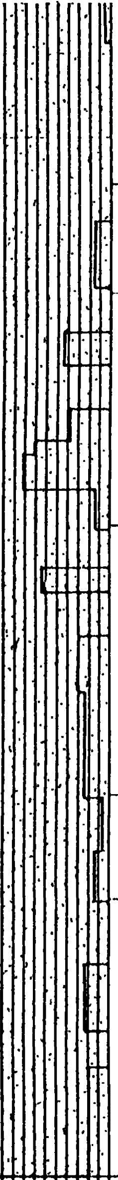
DEPTH (m)

DAILY ADVANCE	CASING/CEMENT	WATER LEVELS
23/10	28/10 28 7	3.45 23.1
25/10		
26/10		8.65 27.10
27/10	29/10 36.4	10.17 30/10
30/10		10.8 31/10
31/10		11.2 01/11
01/11		11.2 02/11
02/11		11.2 03/11
03/11		

DRILL WATER: WHITISH

JOINT SET NO.	ROUGHNESS	SEPARATION
I	S	T
I	R	T
I	S	T
I	S	T
II	S	T
III	S	T
I	T	R
II	S	T
II	S	MO
II	S	T
I	R	T
II	S	MO
I	SR	T
II	R	T
I	S	MO
I	S	MO
I	SR	T
II	SL	ST
II	R	T
I	SR	MO
II	SR	T
I	R	T
II	R	MO
II	S	T
II	SL	MO
II	SL	MO
II	R	MO
II	R	T
II	R	T
II	R	MO
III	R	T
I	R	T
II	R	T

FROM TOP	TO BOTTOM	PRESSURE (BARS)	WATER LOSS	LUGEON
27.23	28.75	1	NIL	00
		3	NIL	00
		6	NIL	00
		3	NIL	00
30.23	30.75	1	NIL	00
		3	NIL	00
		6	NIL	00
		3	NIL	00
		1	NIL	00
32.96	33.75	1	9.6	15.15
		3	14.6	10.91
		6	18.5	7.72
		3	15.1	11.2
		1	10.0	15.78
36.92	36.48	1	7.0	9.9
		3	9.2	6.5
		6	12.0	4 87
		3	9.8	6.96
		1	7.5	10.65
40.16	40.44	1	5.0	6.76
		3	7.0	4.85
		6	9 5	3.80
		3	7.4	5.12
		1	5.2	7.03
43.29	43.68	1	3.0	4.05
		3	4.7	3.25
		6	6.7	2.68
		3	5.1	3.53
		1	3.3	4.46
46.7	46.81	1	3.8	5.17
		3	5.4	3.76
		6	7.6	3.06
		3	5.9	4.11
		1	4.2	5.71
	50.2			



AT 28.7 F/J

AT 29.32, 29.75 F/J

CHARNOCKITIC GNEISS, LIGHT GREY, FINE TO MEDIUM GRAINED, MASSIVE TO GNEISSIC, MAIN COMPONENTS Q, Fd, GA

GARNETIFEROUS BIOTITE GNEISS, LIGHT GREY, MEDIUM TO FINE GRAINED, MAIN COMPONENTS QU, BI, Fd

AT 32.62, 33.10, 33.40 SL. WETH F/J

FROM 32.81 - 33.22 J/85°

AT 36.44, 36 2, 36.48 F/J

AT 36.48, 36.68, 36.73, 36.82 36 86 F/J IRON ST

FROM 36 67 - 36.86 J/70°

AT 36.97, 37.24, 37.36, 37.38 F/J

CHARNOCKITIC GNEISS, DARK GREY, FINE TO MEDIUM GRAINED, GNEISSIC

FROM 37.05 - 37.26, 37.2 - 37.4 37.22 - 37.34, 37.36 - 37.57 (03 Nos.) 37.7 - 37.82, 38 1 - 38.22 J/75°

AT 39.14, 39.25, 39.37, 46.44 IRON STAINED J.

FROM 39.46 - 39.65 J/60°

AT 40.64, 40.66, 40.68, 41.35, 41.47 IRON ST. J

FROM 41.61 - 41.8, 41.82 - 41.90, 41.96 - 42 01, 41.92 - 42.01 J/70° 42.72 - 43.16 J/75°

CHARNOCKITIC GNEISS, MEDIUM TO COURSE GRAINED, GREYISH

FROM 43.47 - 43.6 & 43.63 - 43.77 J/75°

CHARNOCKITIC GNEISS, MEDIUM GRAINED, GREYISH

FROM 45.52 - 45.68, 46.05 - 46.17 46.75 - 46.81, 46.85 - 47.05, 47.25 - 47.55, 47.70 - 47.80, 47.75 - 47.90, 47.95 - 48.90 J/70°-80° ON J.

SURFACE TRACES OF PYRITE.

AT 48.85, 50.03, 50.09 F/J

FROM 49.08 – 50.22 02 Nos. OF J/80°

DEPTH (m): 28·75, 29 79, 30·75, 31·61, 32 30, 33 75, 34·65, 35 02, 35 51, 35 94, 36 48, 36 88, 37·64, 38·33, 39 09, 39·46, 40·44, 41·61, 43 68, 44·71, 45·71, 46·81, 48 09, 48 98, 50 22

HOLE COMPLETED AT THE DEPTH OF 50·22 m.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KP WATERWAYS

B.H KP7 SHEET OF 02

DRILLING DATA

STARTED: 19.10.91 COMPLETED: 31.10.91
INTERRUPTIONS (DAYS): -
MACHINE TYPE JOY 12B
DRILLING METHOD: ROTARY
CORE BARREL, BIT: NX
FOREMAN: LM OSD LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE
Y-COORDINATE
ELEVATION (COLLAR) 56.465
ELEVATION (BOTTOM) 6.355
FINAL DEPTH
INCLINATION FROM VERTICAL: 40°
BEARING.
LOCATION (see fig)

KEY

JOINT ROUGHNESS
VR = very rough
R = rough
SR = slightly rough
S = smooth
SL = slickensided

JOINT SEPARATION
V = very tight < 0.1mm
T = tight 0.1-1.0mm
MO = moderately open 1.0-5.0mm
O = open > 5.0mm

RECOVERY
▨ CORE RECOVERY (%)
▨ R.Q.D (%)

OTHER SYMBOLS
P.L.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil: unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0-5.00
	C	5.0-25.00
moderately strong		25.0-50.00
strong		50.0-100.00
very strong		100.0-250.00
extremely strong		> 250.00

DRILLING / TESTS / JOINTS / PERMEABILITY

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	RATE OF DRILLING	WATER LEVELS	TEST	RESULT	JOINT SET NO.	ROUGHNESS	SEPARATION	SPACING 0.05-0.30m, 0.30-1.00m, 1.00-3.00m, >3.00m	DEPTH (m) FROM TOP	DEPTH (m) TO BOTTOM	PRESSURE (BARS) (manometer reading)	WATER LOSS (total Litres/minute)	LUGEON or PERMEABILITY m/sec
0.97																
	19.10															
1.45																
2.49																
3.71																
4.57		4.87														
4.95	20/10							I	R	MO						
			GREY/BLACK CREAMY									5.06		01	47.5	121.79
6.78														03	50.2	52.29
														06	47.0	24.86
					3.07			I	S	V				03	52.2	54.37
					21/10			II	S	T			8.06	01	54.0	138.46
8.06								II	SR	T		8.06		01	54.1	139.45
9.05	21/10															
9.83			CREAMY		3.08 22/10			III	R	O				03	45.8	43.50
								I	R	T				06	23.0	11.44
								II	R	T				03	32.4	30.77
11.25									R	T			11.25	01	39.5	95.24
			CREAMY/GREY									11.25		01	NIL	00
									S	T				03		
12.75					2.78 23/10									06		
	22/10							II	S	T				03		
								III	S	D			14.23	01		
14.23																
14.77			CREAMY TO BROWN					II	R	T		14.23		01	49.5	160.7
								III	S	T				03	62.9	68.0
15.77														06	82.3	44.5
					3.19 23/10			I	SL	T				03	59.7	64.6
								III	R	T			17.31	01	44.2	143.5
17.31	23/10															
17.72			CREAMY									17.31		01	NIL	00
								I	R	T				03		
19.0														06		
					3.03 23/10									03		
								I	R	T				01		
20.42													20.42			
	24/10		CREAMY/GREY									20.42		01	74.5	794.26
								III	SL	T				03	54.7	51.5
21.84														06	42.4	22.81
					3.01 25/10			I	SL	T				03	56.0	57.5
														01	58.6	152.8
23.37												23.37	23.37			
								III	R	T				01	21.6	57.29
24.67	25/10		CREAMY / GREY											03	22.6	23.80
					3.01 26/10									06	17.8	9.74
														03	20.5	21.42
26.27													26.27	01	25.1	66.5
												26.27		01	21.7	58.56
27.57														03	21.8	23.18
					2.95 26/1									06	13.1	7.29
														03	19.9	21.15

RECOVERY: CORE RECOVERY % AND R.Q.D % (0 – 50 – 100)

GENERAL DESCRIPTION

rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc scale as for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints

TOP SOIL - FINE TO COARSE GRAINED CLAY-SAND-GREYISH

BOULDER

BOULDER (HORNBLENDE-BIOTITE GNEISS)

BOULDER (HORNBLENDE BIOTITE GNEISS)

BOULDER ZONE WITH RIVER SAND

HORNBLENDE-BIOTITE GN. DARK GREY, FINE TO MEDIUM GRAINED FOLIATED. MAIN COMPONENTS QU, BI, HO, FS
FROM 7.98 - 8.06 J/F CHL. FILLED
FROM 8.01 - 8.85 J/85° WEATH.

FROM 8.75 TO 14.79 BIOTITE GNEISS LIGHT GREY, FINE TO MEDIUM GRAINED, HIGHLY QU.
AT 10.5 J/85°

FROM 12.79 - 13.02 J/85°
FROM 13.91 - 14.85 J/80°
FROM 14.65 - 14.79 J/70°
FROM 14.60 - 14.70 J/20° WEATH. ZONE

FROM 14.79 TO 23.37 HORNBLENDE-BIOTITE GN., GREYISH
AT 15.4, 15.6, 15.62 J/F
FROM 15.90 - 16.05 SL. WEATH. J/60°
AT 15.87, 16.16, 16.6, 17.2 F/J

AT 19.26, 19.46, 19.65, 20.06 J/F

F/J TECTONIZED ZONE FROM 22.44 TO 24.14

FROM 23.37 TO 24.67 BIOTITE GNEISS, LIGHT GREY, HIGHLY QU

24.67 TO 24.57 HORNBLENDE-BIOTITE GNEISS, GREYISH.

GRAPHIC LOG | WEATHERING | ROCK STRENGTH

ENGINEERING ASPECTS

REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.)

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE - KP WATERWAYS

BH KP7 | SHEET 02 OF 02

DRILLING DATA

STARTED 10.10.91 COMPLETED 31.10.91

DRILL TYPE JOY 12B

DRILLING METHOD: ROTARY

CORE BARREL, BIT: NX

FOREMAN LOGGED BY:

CORE STORED AT:

BOREHOLE DATA

X COORDINATE

Y COORDINATE

ELEVATION (COLLAR) 486

ELEVATION (BOTTOM)

FINAL DEPTH

INCLINATION 40°

BEARING

LOCATION (see fig. 1)

KEY

JOINT ROUGHNESS: very rough, R rough, slightly rough, S smooth, SL slickensided

JOINT SEPARATION: very tight, tight, moderately open, open

RECOVERY: CORE RECOVERY (%), R.Q.D. (%)

OTHER SYMBOLS: PL point load strength index, UCS uniaxial compressive strength, static ground water

WEATHERING

soil, completely, highly, moderately, slightly, fresh

ROCK STRENGTH

MN/m²

DRILLING	TESTS	JOINTS	PERMEABILITY	RECOVERY	GENERAL DESCRIPTION	ENGINEERING ASPECTS
					rock type, colour, grain size, texture and structure (massive, cleaved, foliated, banded, flow banded, vesicular, porphyritic, etc. size or for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints	REMARKS with respect to excavation, grouting, permeability, core quality, etc.

Stage depth (m)	Pressure stage	Water loss	Lugeon	General description	Depth (m)
29.17	01	24.0	84.77	FROM 27.87 TO 30.87 BIOTITE GNEISS, LIGHT GREY, HIGHLY GU	29.11
	01	70.0	191.70	FROM 29.10 TO 29.05 GNEISS PARALLEL F/J	30.17
	03	71.1	87.00		
	06	61.5	52.20	FROM 30.87 TO 38.78 HORNBLENDE-BIOTITE GN DARK GREY, MEDIUM TO FINE GRAINED	30.87
	03	81.0	48.78		
	01	58.0	135.6		
32.2	01	17.5	41.8	AT 33.72, 33.78, 33.77, 33.78, 33.80 SLO F/J	32.20
	03	20.1	10.15	AT 33.40, 33.60, 33.84 J/60	
	06	20.0	13.97		33.84
	03	21.4	20.30		
	01	13.2	31.93	AT 38.88 CaCO₃ FILL J/48	
35.43	01	NIL	0.0		35.47
	03	NIL	0.0	FROM 38.78 TO 41.49 BIOTITE GNEISS, LIGHT GREY, HIGHLY GU	38.78
	06	NIL	0.0		
	03	NIL	0.0		
	01	NIL	0.0		
38.47	01	10.4	20.40	AT 38.50 F/J	38.47
	03	7.5	7.82	AT 38.75 J/28	
	06	0.7	0.30		
	03	NIL	0.0		
	01	NIL	0.0		40.87
41.4	01	31.6	71.40	FROM 41.49 TO 42.84 BIOTITE GNEISS, LIGHT GREY, VERY HIGHLY GU	41.49
	03	20.5	20.20	FROM 42.72 TO 42.18 J/70 AT 42.08, 42.15 CaCO₃ FILLED J/28	
	06	20.7	11.09	AT 42.87, 43.16, 43.19, 43.33 AND 43.38 SILICA FILLED J/28	42.84
	03	20.7	23.70	FROM 43.78 44.95 J/88	
	01	20.3	84.02	FROM 42.84 TO 50.11 HORNBLENDE BIOTITE GNEISS, LIGHT GREY WITH DARK COLOURED BI-RICH OCCASIONAL BANDS WITH GARNETS	
44.0	01	0.9	32.40		44.81
	03	13.0	17.02		
	06	16.7	11.27		46.90
	03	15.3	19.72		
	01	14.3	40.01		
47.10	01	22.9	80.71		47.10
	03	17.7	18.18		
	06	15.9	8.55		
	03	4.1	9.41		49.07
	01	NIL	00		
50.1					50.11

HOLE COMPLETED AT THE DEPTH OF 50.11 M.

KUKULE GANGA HYDRO POWER PROJECT

BOREHOLE LOG FOR ENGINEERING PURPOSES TAB. 13

FEATURE — KP WATERWAYS

BH KP8 SHEET 01 OF 01

DRILLING DATA

STARTED: 08.11.91 COMPLETED: 11.11.91
INTERRUPTIONS (DAYS):
MACHINE TYPE JOY 12 B
DRILLING METHOD: ROTARY
CORE BARREL, BIT: NX
FOREMAN: LM G.SD LOGGED BY:
CORE STORED AT:
CORE DISCARDED, DATE:

BOREHOLE DATA

X-COORDINATE.
Y-COORDINATE:
ELEVATION (COLLAR) 31 857
ELEVATION (BOTTOM) 11 837
FINAL DEPTH
INCLINATION FROM VERTICAL:
BEARING
LOCATION (see fig)

KEY

JOINT ROUGHNESS	JOINT SEPARATION	
VR = very rough	V = very tight	< 0.1 mm
R = rough	T = tight	0.1–1.0 mm
SR = slightly rough	MO = moderately open	1.0–5.0 mm
S = smooth	O = open	> 5.0 mm
SL = slickensided		

RECOVERY
CORE RECOVERY (%)
R.Q.D (%)

OTHER SYMBOLS
P.L.S.I = point load strength index
U.C.S = uniaxial compressive strength
▼ = first ground water
R = rock sample
W = water sample

WEATHERING

soil : unconsolidated material
completely
highly
moderately
slightly
fresh

ROCK STRENGTH

		MN/m²
	A	< 1.00
weak	B	1.0 – 5.00
	C	5.0 – 25.00
moderately strong		25.0 – 50.00
strong		50.0 – 100.00
very strong		100.0 – 250.00
extremely strong		> 250.00

DRILLING – TESTS – JOINTS – PERMEABILITY – RECOVERY – GENERAL DESCRIPTION – ENGINEERING ASPECTS

Column headings: DEPTH (m); DRILLING: DAILY ADVANCE, CASING/CEMENT, DRILL WATER (COLOR, LOSS), RATE OF DRILLING, WATER LEVELS; TESTS: TEST, RESULT; JOINTS: JOINT SET NO., ROUGHNESS, SEPARATION, SPACING (< 0.05 m, 0.05–0.30 m, 0.30–1.00 m, 1.00–3.00 m, > 3.00 m); PERMEABILITY: DEPTH (m) FROM TOP, TO BOTTOM, PRESSURE (BARS) (manometer reading), WATER LOSS (total Litres/minute), LUGEON or PERMEABILITY m/sec; RECOVERY: CORE RECOVERY % AND R.Q.D % (0, 50, 100); GENERAL DESCRIPTION: rock type, colour, grain size, texture and structure (massive, cleaved, foliated, lineated, flow banded, gneissose, porphyritic, etc. scale or for joint spacing), weathering, alteration, minor lithological characteristics, strength, joints; GRAPHIC LOG; WEATHERING; ENGINEERING ASPECTS: ROCK STRENGTH, REMARKS (with respect to excavation, grouting, permeability, rock quality, etc.); DEPTH (m)

DEPTH (m)	DAILY ADVANCE	CASING/CEMENT	DRILL WATER (COLOR, LOSS)	WATER LEVELS	JOINT SET NO.	ROUGHNESS	SEPARATION	GENERAL DESCRIPTION	DEPTH (m)
0·6			DRY DRILLING					RESIDUAL SOIL – YELLOWISH BROWNISH CLAYEY SAND	0
1 2								RESIDUAL SOIL – REDDISH BROWN CLAYEY SAND	1
1·8								BOULDER RESIDUAL SOIL – DARK BROWN	1
2·43		2·43 / 08/11			I	R	O	CHARNOCKITIC GNEISS, LIGHT GREY, PREDOMINANTLY MASSIVE, GNEISSIC TEXTURE IN PARTS, WEATHERING PENETRATED ALONG JOINT PLANES OCCASIONALLY, FROM 4·03 – 4·75 WEATHERED J/70°	2·
3·91	08/11		CREAMY	1·43 / 09/11					3
5·48					II	R	O		5·
6·55									6
7·58									7
8 65					I II	R R	MO MO	FROM 9·69 – 10·58 WEATH J/80°	8 6
9 50	09/11			4 82 / 09/11					9 5
9·84			DARK BROWN		II	R	MO	FROM 10·06 – 11·11 WEATH (02 Nos.) J/85°	9 8
11 11					I	R	MO	FROM 12 86 – 13·18 F/J 60° ZONE WEATH	11·11
13·14									13·14
15·00			CREAMY						15 0
16·05	10/11			4 88 / 10/11	I II III	R R R	MO T MO	AT 16·05 100% FROM 17·30 – 18 27 COM. WEATHERED FR. ZONE FJ/CORE LOSS 62 cm.	16·05
19·22					I III	R R	MO T	18·13 – 19·06 J/85	19·22
20 02	11/11			4 82 / 11/11					20·07

HOLE COMPLETED AT THE DEPTH OF 20·02 m.

Table 14 Point Load Test Records

RAM AREA = 14.426 CM^2

G.B.G - GARNETIFEROUS BIOTITE GNEISS
B.G - BIOTITE GNEISS
H.B.G - HORNBLENDE BIOTITE GNEISS

G.Ch.G - GARNETIFEROUS CHARNOCKITIC GNEISS
Ch.G - CHARNOCKITIC GNEISS
Q.F.G - QUARTZ FELDSPAR GNEISS

Peg. - PEGMATITE
(QR) - QUARTZ RICH
D -DIAMETRAL TEST

mod - moderately sl - slightly fr - fresh

Hole	Depth m.	Rock type	Weathering	Moisture	Test type	sample Width cm.	Dia. cm.	Gauge pressure kg/cm^2	REMARKS	Direction of foliation	P.I Kg/cm^2	U.C.S MPa
KK-8	3.75	G.B.G	mod	dry	D	14	5.4	invalid test	invalid test		*----	*----
KK-8	3.45	G.BG	mod	dry	D	7.5	5.4	17.5		|||	8.66	20.78
KK-8	4.40	G.B.G(QR)	sl	dry	D	11	5.4	50		|||	24.74	59.37
KK-8	4.90	G.B.G	mod	dry	D	8	5.4	20		|||	9.89	23.75
KK-8	5.55	G.B.G	mod	dry	D	15	5.4	14		—	6.93	16.62
KK-8	6.55	B.G	mod	dry	D	8.5	5.4	45		—	22.26	53.43
KK-8	7.25	B.G	sl	dry	D	7.2	5.4	70		—	34.63	83.11
KK-8	8.55	B.G	sl	dry	D	14.5	5.4	105		|||	51.95	124.67
KK-8	8.88	G.B.G	sl	dry	D	17	5.4	25		—	12.37	29.68
KK-8	10.85	G.B.G	sl	dry	D	11.5	5.4	105		—	51.95	124.67
KK-8	12.22	G.B.G	fr	dry	D	21	5.4	100		|||	49.47	118.73
KK-8	12.40	B.G(QR)	fr	dry	D	16.5	5.4	160		—	79.16	189.97
KK-8	13.40	B.G(QR)	fr	dry	D	13.5	5.4	110		|||	54.42	130.61
KK-8	14.90	B.G(QR)	fr	dry	D	11	5.4	150		—	74.21	178.10
KK-8	16.80	B.G(QR)	fr	dry	D	11	5.4	110		|||	54.42	130.61
KK-8	25.05	G.B.G	fr	dry	D	8.5	5.4	100		—	49.47	118.73
KK-8	26.25	G.B.G	fr	dry	D	12	5.4	125		|||	61.84	148.42
KK-8	28.25	G.B.G	fr	dry	D	10	5.4	105		—	51.95	124.67
KK7	8.30	G,B.G(QR)	fr	dry	D		5.4	160		—	79.16	189.97
KK7	8.40	G,B.G(QR)	fr	dry	D		5.4	150		—	74.21	178.10
KK7	8.50	G,B.G(QR)	fr	dry	D		5.4	110		—	54.42	130.61
KK7	9.93	G,B.G(QR)	fr	dry	D		5.4	170		—	84.10	201.85
KK7	9.86	G,B.G(QR)	fr	dry	D		5.4	150		—	74.21	178.10
KK7	9.76	G,B.G(QR)	fr	dry	D		5.4	175		—	86.58	207.78

Table 14 Point Load Test Records

RAM AREA = 14.426 CM^2

G.B.G - GARNETIFEROUS BIOTITE GNEISS
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Ch.G - CHARNOCKITIC GNEISS
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Peg. - PEGMATITE
(QR) - QUARTZ RICH
D -DIAMETRAL TEST

mod - moderately sl - slightly fr - fresh

Hole	Depth m.	Rock type	Weathering	Moisture	Test type	sample Width cm.	Dia. cm.	Gauge pressure kg/cm^2	REMARKS	Direction of foliation	P.I Kg/cm^2	U.C.S MPa
KK7	11.06	G,B.G(QR)	fr	dry	D		5.4	170		—	84.10	201.85
KK7	11.16	G,B.G(QR)	fr	dry	D		5.4	160		—	79.16	189.97
KK7	11.34	G,B.G(QR)	fr	dry	D		5.4	175		—	86.58	207.78
KK7	11.42	G,B.G(QR)	fr	dry	D		5.4	190		—	94.00	225.59
KK7	11.48	G,B.G(QR)	fr	dry	D		5.4	190		—	94.00	225.59
KK7	11.75	G,B.G(QR)	fr	dry	D		5.4	180		—	89.05	213.72
KK7	11.67	G,B.G(QR)	fr	dry	D		5.4	220		—	108.84	261.21
KK7	11.61	G,B.G(QR)	fr	dry	D		5.4	160		—	79.16	189.97
KK7	12.14	H.B.G	fr	dry	D		5.4	170		—	84.10	201.85
KK7	12.82	G.B.G(QR)	fr	dry	D		5.4	200		—	98.94	237.47
KK7	12.68	G.B.G(QR)	fr	dry	D		5.4	160		—	79.16	189.97
KK7	12.52	G.B.G(QR)	fr	dry	D		5.4	150		—	74.21	178.10
KK7	13.07	G.B.G(QR)	fr	dry	D		5.4	150		—	74.21	178.10
KK7	13.15	G.B.G(QR)	fr	dry	D		5.4	155		—	76.68	184.04
KK7	13.21	G.B.G(QR)	fr	dry	D		5.4	155		—	76.68	184.04
KK7	13.35	G.B.G(QR)	fr	dry	D		5.4	200		—	98.94	237.47
KK7	13.42	G.B.G(QR)	fr	dry	D		5.4	175		—	86.58	207.78
KK7	13.49	G.B.G(QR)	fr	dry	D		5.4	160		—	79.16	189.97
KK7	13.53	G.B.G(QR)	fr	dry	D		5.4	165		—	81.63	195.91
KK7	13.65	G.B.G(QR)	fr	dry	D		5.4	200		—	98.94	237.47
KK7	13.74	G.B.G(QR)	fr	dry	D		5.4	185		—	91.52	219.66
KK7	13.80	G.B.G(QR)	fr	dry	D		5.4	90		—	44.52	106.86
KK7	13.92	G.B.G(QR)	fr	dry	D		5.4	180		—	89.05	213.72
KK7	13.99	G.B.G(QR)	fr	dry	D		5.4	190		—	94.00	225.59
KK7	14.17	G.B.G(QR)	fr	dry	D		5.4	210		—	103.89	249.34

Table 14 Point Load Test Records

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Ch.G - CHARNOCKITIC GNEISS
Q.F.G - QUARTZ FELDSPAR GNEISS
Peg. - PEGMATITE
(QR) - QUARTZ RICH
D - DIAMETRAL TEST
mod - moderately sl - slightly fr - fresh

Hole	Depth m.	Rock type	Weathering	Moisture	Test type	sample Width cm.	Dia. cm.	Gauge pressure kg cm^2	REMARKS	Direction of foliation	P.I Kg cm^2	U.C.S MPa
KK7	14.28	G.B.G(QR)	fr	dry	D		5.4	175		—	86.58	207.73
KK7	14.36	G.B.G(QR)	fr	dry	D		5.4	115		—	56.89	136.54
KK7	14.48	G.B.G(QR)	fr	dry	D		5.4	155		|||	76.68	184.04
KK7	14.57	G.B.G(QR)	fr	dry	D		5.4	145		|||	71.73	172.16
KK7	14.64	G.B.G(QR)	fr	dry	D		5.4	145		|||	71.73	172.16
KK7	14.77	G.B.G(QR)	fr	dry	D		5.4	155		|||	76.68	184.04
KK7	16.60	G.B.G(QR)	fr	dry	D		5.4	165		|||	81.63	195.91
KK7	16.67	G.B.G(QR)	fr	dry	D		5.4	175	<<invalid test	|||	*——	*——
KK7	18.19	H.B.G	fr	dry	D		5.4	225		—	111.31	267.15
KK7	18.24	H.B.G	fr	dry	D		5.4	240		—	118.73	284.96
KK7	18.29	H.B.G	fr	dry	D		5.4		<<invalid test	|||	*——	*——
KK7	18.42	H.B.G	fr	dry	D		5.4	240		—	118.73	284.96
KK7	18.47	H.B.G	fr	dry	D		5.4	250		—	123.68	296.83
KK7	18.53	H.B.G	fr	dry	D		5.4	190		|||	94.00	225.59
KK7	19.07	G.B.G	fr	dry	D		5.4	165		—	81.63	195.91
KK7	19.15	G.B.G	fr	dry	D		5.4	145		—	71.73	172.16
KK7	19.23	G.B.G	fr	dry	D		5.4	160		—	79.16	189.97
KK7	19.29	G.B.G	fr	dry	D		5.4	115		|||	56.89	136.54
KK7	19.77	G.B.G	fr	dry	D		5.4	130		|||	64.31	154.35
KK7	19.69	G.B.G	fr	dry	D		5.4	120		|||	59.37	142.48
KK7	19.64	G.B.G	fr	dry	D		5.4	125		—	61.84	148.42
KK7	19.57	G.B.G	fr	dry	D		5.4	115		—	56.89	136.54
KK7	19.51	G.B.G	fr	dry	D		5.4	130		—	64.31	154.35
KK7	19.45	G.B.G	fr	dry	D		5.4	125		|||	61.84	148.42
KK7	35.45	G.Ch.G	fr	dry	D		5.4	275		—	106.36	255.27

Table 14 Point Load Test Records

RAM AREA = 14.426 CM^2

G.B.G - GARNETIFEROUS BIOTITE GNEISS
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Ch.G - CHARNOCKITIC GNEISS
Q.F.G - QUARTZ FELDSPAR GNEISS

Peg. - PEGMATITE
(QR) - QUARTZ RICH
D -DIAMETRAL TEST

mod - moderately sl - slightly fr - fresh

Hole	Depth m.	Rock type	Weathering	Moisture	Test type	sample Width cm.	Dia. cm.	Gauge pressure kg/cm^2	REMARKS	Direction of foliation	P.I Kg/cm^2	U.C.S MPa
KK7	35.39	G.Ch.G	fr	dry	D		5.4	260		—	128.63	308.70
KK7	35.33	G.Ch.G	fr	dry	D		5.4	270		—	133.57	320.58
KK7	35.26	G.Ch.G	fr	dry	D		5.4	240		—	118.73	284.96
KK7	35.16	G.Ch.G	fr	dry	D		5.4	140		—	69.26	166.23
KK7	37.81	G.Ch.G	fr	dry	D		5.4	225		—	111.31	267.15
KK7	37.91	G.Ch.G	fr	dry	D		5.4	225		—	111.31	267.15
KK7	37.97	G.Ch.G	fr	dry	D		5.4	190		—	94.00	225.59
KK7	38.04	G.Ch.G	fr	dry	D		5.4	190		—	94.00	225.59
KK7	38.10	G.Ch.G	fr	dry	D		5.4	155	<<not valid ,incipient joint	—	*----------	*----------
KK7	38.16	G.Ch.G	fr	dry	D		5.4	225		—	111.31	267.15
KK7	40.19	G.Ch.G	fr	dry	D		5.4	250		—	123.68	296.83
KK7	43.80	Q.F.G	fr	dry	D		5.4	140		—	69.26	166.23
KK7	44.63	Q.F.G	fr	dry	D		5.4	160		—	79.16	189.97
KK7	44.68	Q.F.G	fr	dry	D		5.4	175		—	86.58	207.78
KK7	44.78	Q.F.G	fr	dry	D		5.4	225		—	111.31	267.15
KK7	44.83	Q.F.G	fr	dry	D		5.4	250		—	123.68	296.83
KK7	45.00	Q.F.G	fr	dry	D		5.4	225		—	111.31	267.15
KK7	49.27	Ch.G	fr	dry	D		5.4	150		—	74.21	178.10
KK7	49.32	Ch.G	fr	dry	D		5.4	200	broken along foliation	—	98.94	237.47
KK7	49.42	Ch.G	fr	dry	D		5.4	250		—	123.68	296.83
KK7	49.59	Q.F.G	fr	dry	D		5.4	285		—	140.99	338.39
KK7	42.38	Q.F.G	fr	dry	D		5.4	115		|||	56.89	136.54
KK7	42.46	Q.F.G	fr	dry	D		5.4		test failed	—	*----------	*----------
KK7	42.52	Q.F.G	fr	dry	D		5.4	250		—	123.68	296.83
KK7	42.57	Q.F.G	fr	dry	D		5.4	230		—	113.79	273.08

Table 14 Point Load Test Records

RAM AREA = 14.426 CM^2

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Peg. - PEGMATITE
(QR) - QUARTZ RICH
D - DIAMETRAL TEST

mod - moderately sl - slightly fr - fresh

Hole	Depth m.	Rock type	Weathering	Moisture	Test type	sample Width cm.	Dia. cm.	Gauge pressure kg/cm^2	REMARKS	Direction of foliation	P.I Kg/cm^2	U.C.S MPa
KK7	42.67	Q.F.G	fr	dry	D		5.4	150		|||	74.21	178.10
KK7	42.74	Q.F.G	fr	dry	D		5.4	140		|||	69.26	166.23
KK11	16.36	Ch.G	fr	dry	D		5.4	115		—	56.89	136.54
KK11	16.40	Ch.G	fr	dry	D		5.4	80		—	39.58	94.99
KK11	16.50	Ch.G	fr	dry	D		5.4	155		—	76.68	184.04
KK11	16.66	Ch.G	fr	dry	D		5.4	175		—	86.58	207.78
KK11	16.78	Ch.G	fr	dry	D		5.4	80	broken alon biotite rich layer	—	39.58	94.99
KK11	16.84	Ch.G	fr	dry	D		5.4	190		—	94.00	225.59
KK11	16.90	Ch.G	fr	dry	D		5.4	230		—	113.79	273.08
KK11	17.02	Ch.G	fr	dry	D		5.4	230		—	113.79	273.08
KK11	22.18	Ch.G	fr	dry	D		5.4	225		—	111.31	267.15
KK11	22.24	Ch.G	fr	dry	D		5.4	245		—	121.21	290.89
KK11	22.30	Ch.G	fr	dry	D		5.4	200	biotite rich	—	98.94	237.47
KK11	22.36	Ch.G	fr	dry	D		5.4	225		—	111.31	267.15
KK11	17.55	Ch.G	fr	dry	D		5.4	110	biotite rich section	—	54.42	130.61
KK11	17.61	Ch.G	fr	dry	D		5.4	230		—	113.79	273.08
KK11	17.95	Ch.G	fr	dry	D		5.4	215		|||	106.36	255.27
KK11	18.05	Ch.G	fr	dry	D		5.4	165		|||	81.63	195.91
KK11	18.20	Ch.G	fr	dry	D		5.4	150	garnet rich	|||	74.21	178.10
KK11	18.37	Ch.G	fr	dry	D		5.4	225	typical charnockite	|||	111.31	267.15
KK11	18.43	Ch.G	fr	dry	D		5.4	240		|||	118.73	284.96
KK11	18.75	Ch.G	fr	dry	D		5.4	145	with biotite	|||	71.73	172.16
KK11	18.92	Ch.G	fr	dry	D		5.4	225		|||	111.31	267.15
KK11	18.98	Peg.	fr	dry	D		5.4	175	<<not valid ,incipient joint	no n.	*---------	*---------
KK11	19.10	C.h.G	fr	dry	D		5.4	250		|||	123.68	296.83

Table 14 Point Load Test Records

RAM AREA = 14.426 CM^2

G.B.G - GARNETIFEROUS BIOTITE GNEISS
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Ch.G - CHARNOCKITIC GNEISS
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Peg. - PEGMATITE
(QR) - QUARTZ RICH
D -DIAMETRAL TEST

mod - moderately sl - slightly fr - fresh

Hole	Depth m.	Rock type	Weathering	Moisture	Test type	sample Width cm.	Dia. cm.	Gauge pressure kg/cm^2	REMARKS	Direction of foliation	P.I Kg/cm^2	U.C.S MPa
KK11	19.31	C.h.G	fr	dry	D		5.4	225		|||	111.31	267.15
KK11	19.36	C.h.G	fr	dry	D		5.4	170	part coarse grained quartz	|||	84.10	201.85
KK11	19.42	C.h.G	fr	dry	D		5.4	230	typical charnockite	|||	113.79	273.08
KK11	19.46	C.h.G	fr	dry	D		5.4	250	typical charnockite	|||	123.68	296.83
KK11	19.64	C.h.G	fr	dry	D		5.4	190	typical charnockite	|||	94.00	225.59
KK11	19.70	C.h.G	fr	dry	D		5.4	230	typical charnockite	|||	113.79	273.08
KK11	19.76	C.h.G	fr	dry	D		5.4	225	typical charnockite	|||	111.31	267.15
KK11	19.82	C.h.G	fr	dry	D		5.4	240	typical charnockite	|||	118.73	284.96
KK11	20.00	C.h.G	fr	dry	D		5.4	175		|||	86.58	207.78
KK11	20.06	C.h.G	fr	dry	D		5.4	175		|||	86.58	207.78
KK11	20.14	C.h.G	fr	dry	D		5.4	190		|||	94.00	225.59
KK11	20.21	C.h.G	fr	dry	D		5.4	240		|||	118.73	284.96
KK11	22.20	G.B.G	fr	dry	D		5.4	110	broken along graphite rich area	—	54.42	130.61
KK11	22.26	G.B.G	fr	dry	D		5.4	220	little graphite	—	108.84	261.21
KK11	22.32	G.B.G	fr	dry	D		5.4	185	traces of graphite	—	91.52	219.66
KK11	22.38	G.B.G	fr	dry	D		5.4	240	traces of graphite	—	118.73	284.96
KK11	22.44	G.B.G	fr	dry	D		5.4	200		—	98.94	237.47
KK11	22.50	G.B.G	fr	dry	D		5.4	140	<<invalid test	—	*---------	*---------
KK11	22.60	G.B.G	fr	dry	D		5.4	200		—	98.94	237.47
KK11	22.68	G.B.G	fr	dry	D		5.4	215		—	106.36	255.27
KK11	23.23	G.B.G	fr	dry	D		5.4	75	graphite on broken surface	—	37.10	89.05
KK11	23.29	G.B.G	fr	dry	D		5.4	175		—	86.58	207.78
KK11	23.35	G.B.G	fr	dry	D		5.4	100	traces of graphite	—	49.47	118.73
KK11	23.41	G.B.G	fr	dry	D		5.4	200	no graphite	—	98.94	237.47
KK11	23.46	G.B.G	fr	dry	D		5.4	175		—	86.58	207.78

Table 14 Point Load Test Records

RAM AREA = 14.426 CM^2

G.B.G - GARNETIFEROUS BIOTITE GNEISS
B.G - BIOTITE GNEISS
H.B.G - HORNBLENDE BIOTITE GNEISS
G.Ch.G - GARNETIFEROUS CHARNOCKITIC GNEISS
Ch.G - CHARNOCKITIC GNEISS
Q.F.G - QUARTZ FELDSPAR GNEISS
Peg. - PEGMATITE
(QR) - QUARTZ RICH
D - DIAMETRAL TEST

mod - moderately sl - slightly fr - fresh

Hole	Depth m.	Rock type	Weathering	Moisture	Test type	sample Width cm.	Dia. cm.	Gauge pressure kg/cm^2	REMARKS	Direction of foliation	P.I Kg/cm^2	U.C.S MPa
KK11	24.18	G.B.G	fr	dry	D		5.4	100	biotite rich area traces of graphite	|||	49.47	118.73
KK11	24.24	G.B.G	fr	dry	D		5.4	140	traces of graphite	|||	69.26	166.23
KK11	24.30	G.B.G	fr	dry	D		5.4	135	traces of graphite	|||	66.79	160.29
KK11	24.36	G.B.G	fr	dry	D		5.4	85	broken along foliation with graphite and biotite	|||	42.05	100.92
KK11	24.42	G.B.G	fr	dry	D		5.4	180		|||	89.05	213.72
KK11	24.88	G.B.G	fr	dry	D		5.4	100	broken along biotite rich layer	|||	49.47	118.73
KK11	24.94	G.B.G	fr	dry	D		5.4	30	broken along biotite rich layerwith graphite	|||	14.84	35.62
KK11	25.00	G.B.G	fr	dry	D		5.4	110	broken along biotite rich layer	|||	54.42	130.61
KK11	25.22	G.B.G	fr	dry	D		5.4	150		|||	74.21	178.10
KK11	22.28	G.B.G	fr	dry	D		5.4	75		|||	37.10	89.05
KK11	22.34	G.B.G	fr	dry	D		5.4	100		|||	49.47	118.73
KK11	22.40	G.B.G	fr	dry	D		5.4	140		|||	69.26	166.23
KK11	22.46	G.B.G	fr	dry	D		5.4	165		|||	81.63	195.91
KK11	27.48	G.B.G	fr	dry	D		5.4	190		|||	94.00	225.59
KK11	27.54	G.B.G	fr	dry	D		5.4	205	no graphite	|||	101.42	243.40
KK11	27.60	G.B.G	fr	dry	D		5.4	205		|||	101.42	243.40
KK11	27.66	G.B.G	fr	dry	D		5.4	160		|||	79.16	189.97
KK11	27.72	G.B.G	fr	dry	D		5.4	225	quartz rich	|||	111.31	267.15
KK11	27.78	G.B.G	fr	dry	D		5.4	140	biotite rich	|||	69.26	166.23
KK11	28.06	Ch.G	fr	dry	D		5.4	65	invalid test	|||	*----------	*----------
KK11	28.12	G.B.G	fr	dry	D		5.4	150		|||	74.21	178.10
KK11	28.18	G.B.G	fr	dry	D		5.4	110		|||	54.42	130.61
KK11	28.24	G.B.G	fr	dry	D		5.4	125		|||	61.84	148.42
KK11	28.30	G.B.G	fr	dry	D		5.4	145		|||	71.73	172.16
KK11	28.46	G.B.G	fr	dry	D		5.4	95		|||	47.00	112.80

Table 14 Point Load Test Records

RAM AREA = 14.426 CM^2

G.B.G - GARNETIFEROUS BIOTITE GNEISS
B.G - BIOTITE GNEISS
H.B.G - HORNBLENDE BIOTITE GNEISS

G.Ch.G - GARNETIFEROUS CHARNOCKITIC GNEISS
Ch.G - CHARNOCKITIC GNEISS
Q.F.G - QUARTZ FELDSPAR GNEISS

Peg. - PEGMATITE
(QR) - QUARTZ RICH
D - DIAMETRAL TEST

mod - moderately sl - slightly fr - fresh

Hole	Depth m.	Rock type	Weathering	Moisture	Test type	sample Width cm.	Dia. cm.	Gauge pressure kg/cm^2	REMARKS	Direction of foliation	P.I Kg/cm^2	U.C.S MPa
KK11	28.50	G.B.G	fr	dry	D		5.4	105		[illegible]	51.95	124.67
KK11	28.56	G.B.G	fr	dry	D		5.4	125		[illegible]	61.84	148.42
KK11	28.62	G.B.G	fr	dry	D		5.4	110		[illegible]	54.42	130.61
KK11	28.68	G.B.G	fr	dry	D		5.4	100		[illegible]	49.47	118.73
KK11	28.74	G.B.G	fr	dry	D		5.4	120		[illegible]	59.37	142.48
KK11	28.80	G.B.G	fr	dry	D		5.4	125		[illegible]	61.84	148.42
KK11	28.86	G.B.G	fr	dry	D		5.4	105		[illegible]	51.95	124.67
KK11	28.94	G.B.G	fr	dry	D		5.4	65		[illegible]	32.16	77.18
KK11	29.00	G.B.G	fr	dry	D		5.4	105		[illegible]	51.95	124.67
KK11	29.56	G.B.G	fr	dry	D		5.4	180		[illegible]	89.05	213.72
KK11	29.62	G.B.G	fr	dry	D		5.4	180		[illegible]	89.05	213.72
KK11	29.68	G.B.G	fr	dry	D		5.4	170		[illegible]	84.10	201.85
KK11	29.74	G.B.G	fr	dry	D		5.4	170		[illegible]	84.10	201.85
KK11	29.80	G.B.G	fr	dry	D		5.4	165		[illegible]	81.63	195.91
KK11	29.86	G.B.G	fr	dry	D		5.4	165		[illegible]	81.63	195.91
KK11	29.94	G.B.G	fr	dry	D		5.4	165		[illegible]	81.63	195.91
KK11	30.00	G.B.G	fr	dry	D		5.4	210		[illegible]	103.89	249.34

G.B.G - GARNETIFEROUS BIOTITE GNEISS
B.G - BIOTITE GNEISS
H.B.G - HORNBLENDE BIOTITE GNEISS

G.Ch.G - GARNETIFEROUS CHARNOCKITIC GNEISS
Ch.G - CHARNOCKITIC GNEISS
Q.F.G - QUARTZ FELDSPAR GNEISS

Peg. - PEGMATITE
(QR) - QUARTZ RICH
D - DIAMETRAL TEST

TABLE 15 (1/4) PERMEABILITY TEST RECORDS

KK 205 DAM SITE (NEW)

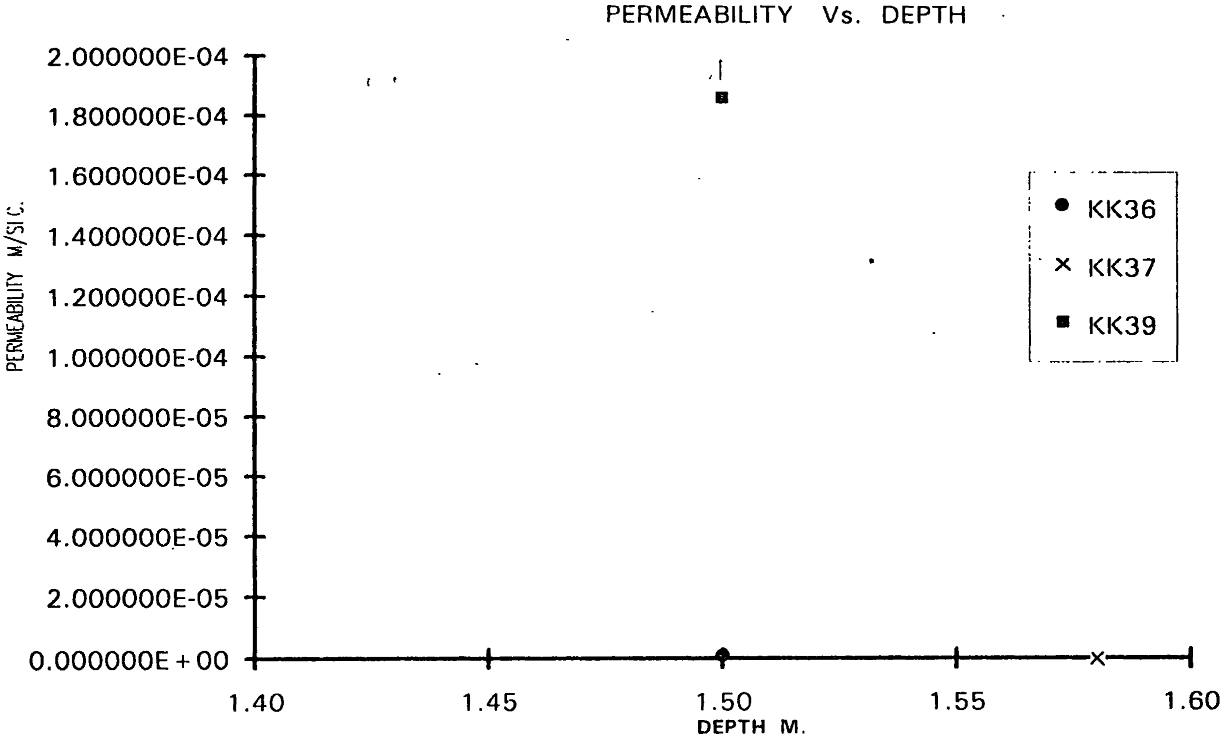


TABLE :15 (1 /4) PERMEABILITY TEST RECORDS KK205 DAM SITE (NEW)		
hole no	DEPTH M.	Permeability m/min.
KK36	1.50	9.291916E-07
KK37	1.58	6.385027E-07
KK39	1.50	>1.858383E-04

TABLE 15 (2/4) PERMEABILITY TEST RECORDS - KK 205 (OLD)

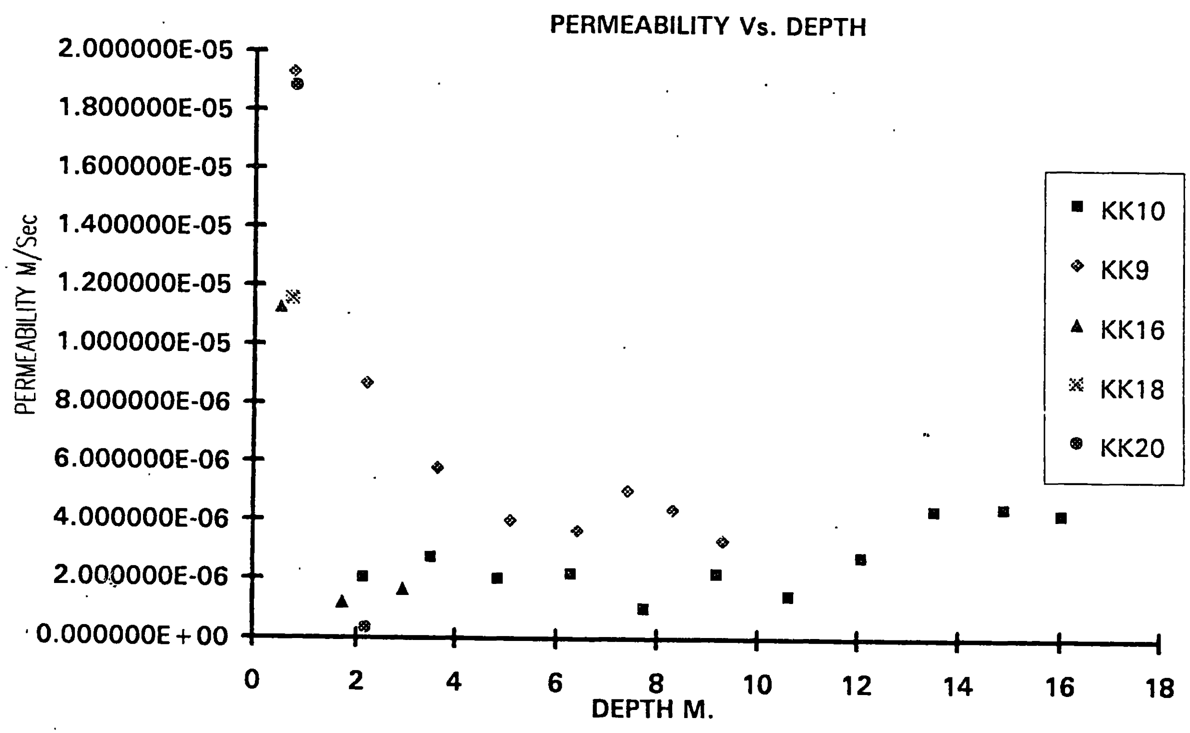


TABLE: 20 (2 /4)PERMEABILITY TEST RECORDS		
KK205 DAM SITE(OLD)		Permeability m/min.
hole no	DEPTH M.	KK10
KK-10	2.13	2.045178E-06
KK-10	3.495	2.737980E-06
KK-10	4.835	2.025566E-06
KK-10	6.28	2.198179E-06
KK-10	7.725	1.020168E-06
KK-10	9.175	2.186074E-06
KK-10	10.625	1.457383E-06
KK-10	12.075	2.769028E-06
KK-10	13.525	4.372149E-06
KK-10	14.9	4.451561E-06
KK-10	16.025	4.242693E-06
KK9	0.725	1.929776E-05
KK9	2.175	8.683992E-06
KK9	3.625	5.789328E-06
KK9	5.075	3.997393E-06
KK9	6.4	3.666679E-06
KK9	7.4	5.046817E-06
KK9	8.3	4.386700E-06
KK9	9.3	3.324215E-06
KK16	0.5	1.127231E-05
KK16	1.725	1.216598E-06
KK16	2.935	1.673358E-06
KK18	0.725	1.157866E-05
KK20	0.775	1.882781E-05
KK20	2.175	3.619715E-07

TABLE 15 (3/4) PERMEABILITY TEST RECORDS - KK 230

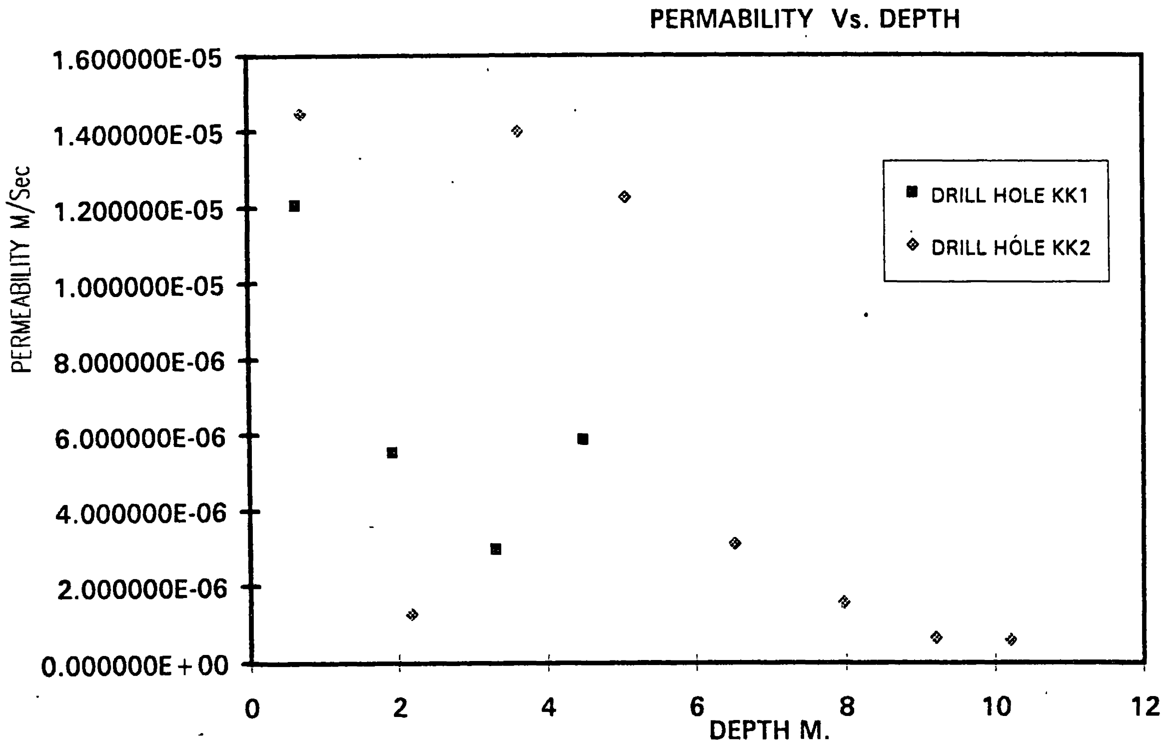


TABLE: 20 (3 / 4) PERMEABILITY TEST RECORDS		
hole no	DEPTH M.	Permeability m/min.
KK1	0.64	1.207172E-05
KK1	1.93	5.535620E-06
KK1	3.305	2.963272E-06
KK1	4.485	5.865251E-06
KK3	0.725	1.447332E-05
KK3	2.175	1.286517E-06
KK3	3.625	1.399088E-05
KK3	5.075	1.224202E-05
KK3	6.525	3.109084E-06
KK3	7.975	1.554542E-06
KK3	9.2	6.347019E-07
KK3	10.2	5.863659E-07

TABLE 15 (4/4) PERMEABILITY TEST RECORDS - KP PLAN

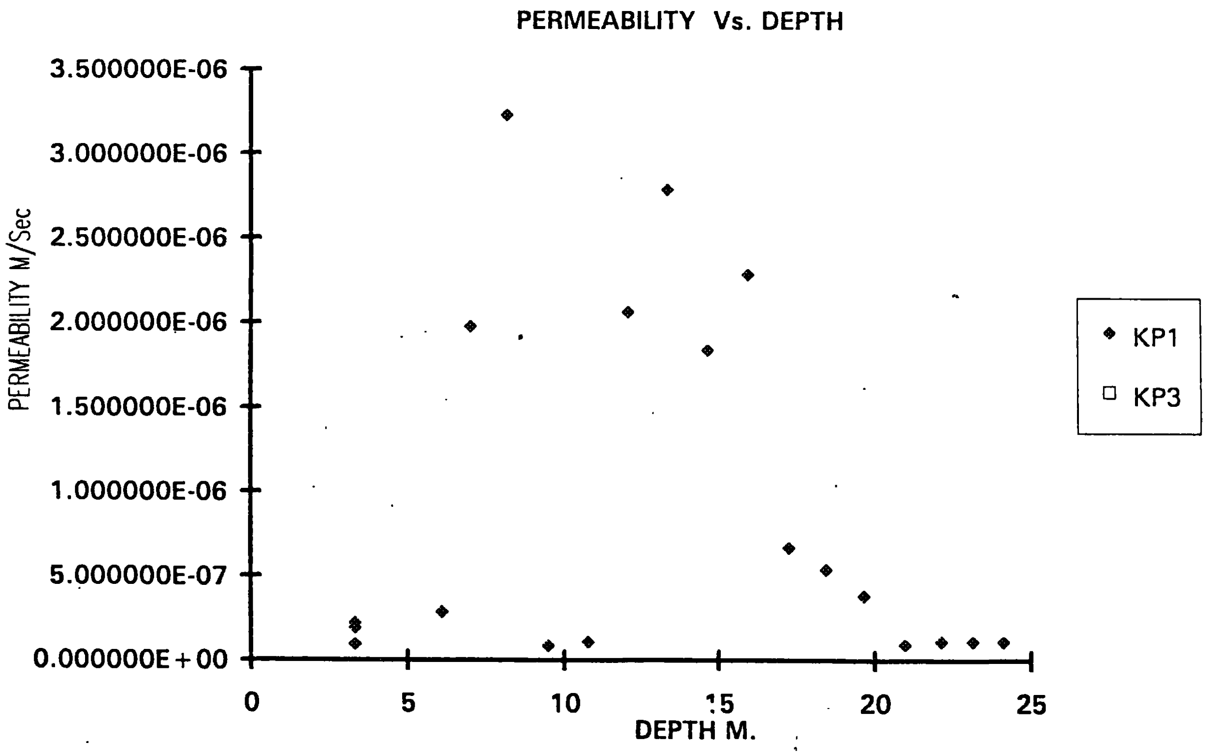


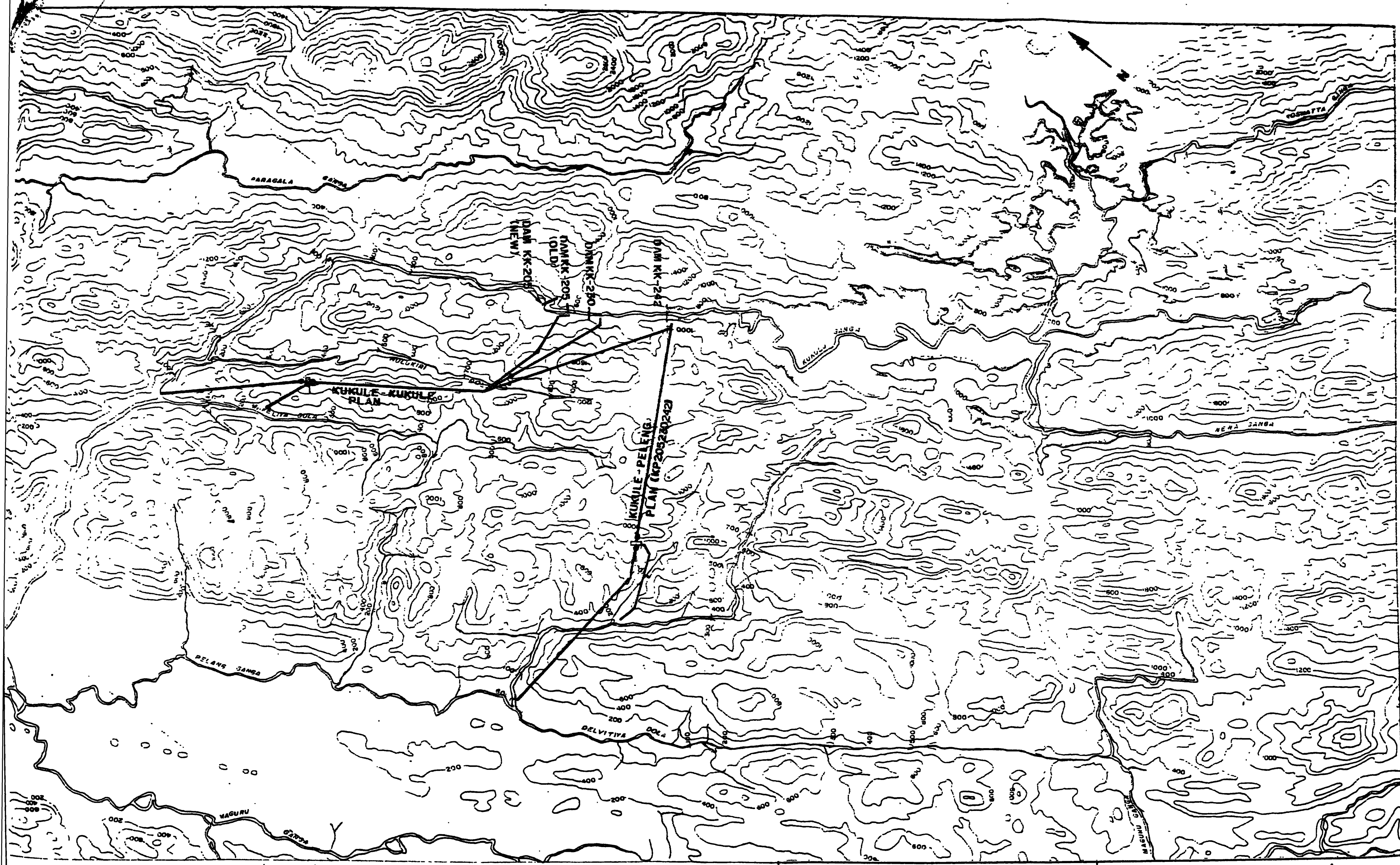
TABLE : 20 (4 / 4) PERMEABILITY TEST RECORDS

hole no	DEPTH M.	Permeability m/min.
KP-1	3.295	9.533990E-08
KP-1	3.295	2.224598E-07
KP-1	3.295	1.906798E-07
KP-1	6.09	2.884975E-07
KP-1	6.09	2.884975E-07
KP-1	6.09	2.884975E-07
KP-1	7	1.979662E-06
KP-1	8.15	3.228227E-06
KP-1	9.45	8.953287E-08
KP-1	10.75	1.085247E-07
KP-1	12.05	2.061969E-06
KP-1	13.35	2.785467E-06
KP-1	14.65	1.836572E-06
KP-1	15.95	2.283737E-06
KP-1	17.25	6.685121E-07
KP-1	18.45	5.374638E-07
KP-1	19.65	3.827360E-07
KP-1	20.95	9.568400E-08
KP-1	22.1	1.157095E-07
KP-1	23.1	1.157095E-07
KP-1	24.1	1.157095E-07

TABLE : 16 RESULTS OF ANALYSIS OF WATER OBTAINED FROM DRILL HOLES AT KK 230 DAM AXIS

	SPECIMEN 1 from drill hole KK2	SPECIMEN 1 from drill hole KK3
Sodium(as Na) , mg/l	7	7
Potassium (as K) , Mg/l	4	4
Calcium (as Ca) , mg/l	16	16
Magnesium (as Mg) , mg/l	4	4
Ion (as Fe) , mg/l	0.5	0.6
Manganese (as Mn) ,mg/l	0.03	0.03
Chloride (as Cl) , mg/l	7	7
Bicarbonate (as HCO_3) , mg/l	26	26
Fluoride (as F) at 25 °C , mg/l	0.03	0.13
Sulphate (as SO_4) ,mg/l	11	13
Total hardness (as $CaCO_3$) ,mg/l	137	138
Electrical conductivity at 25 °C , μs/cm	300	300
pH at 25 °C	7.1	7.2
Acidity (as $CaCO_3$) , mg/l	less than 1	less than 1
Total alkalinity (as $CaCO_3$), mg/l	42	42

Figures

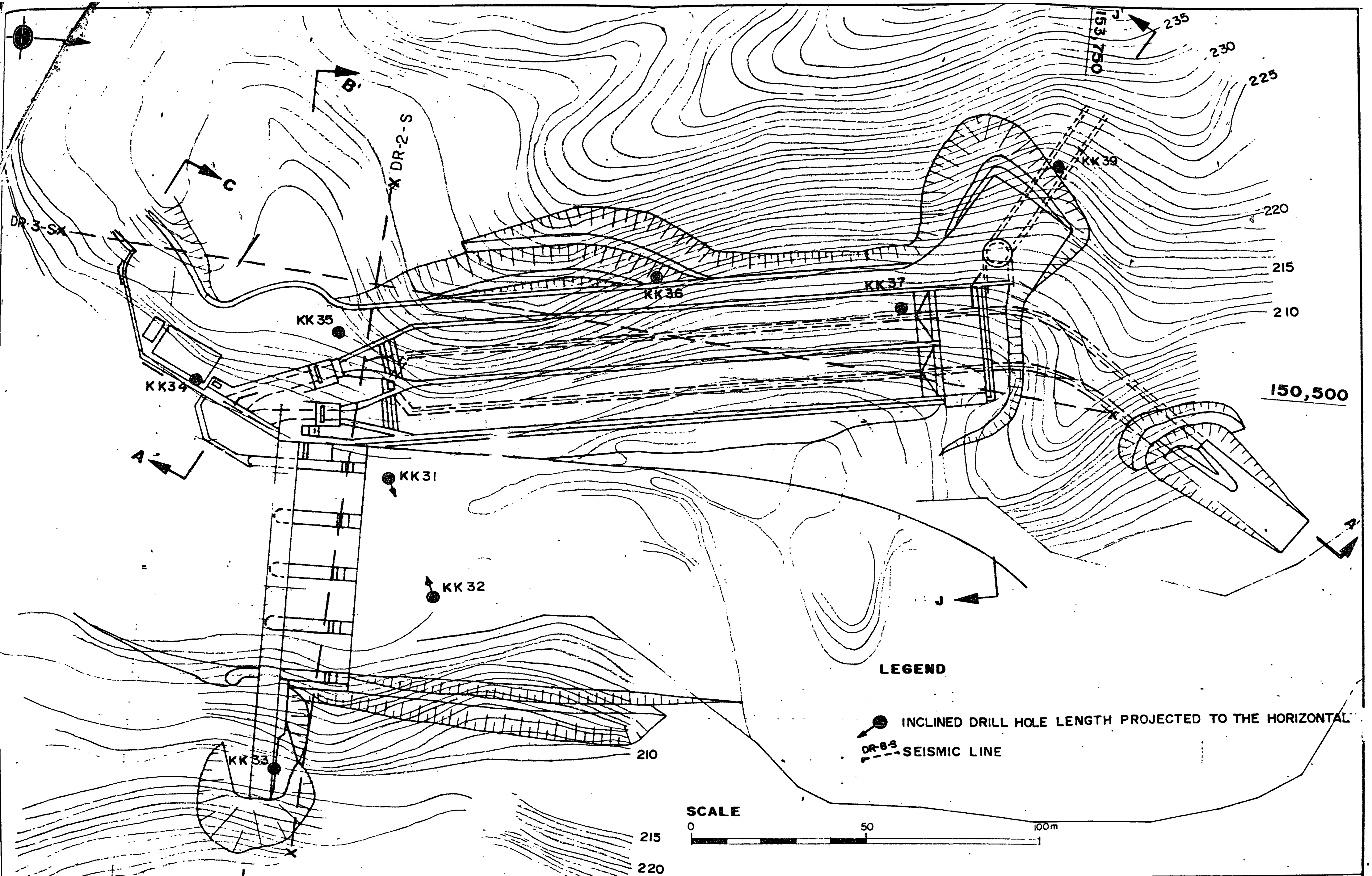


KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI
Ceylon Electricity Board	CECB, TEAMS, RDC

FIGURE : 1

Locations of KK and KP Plans



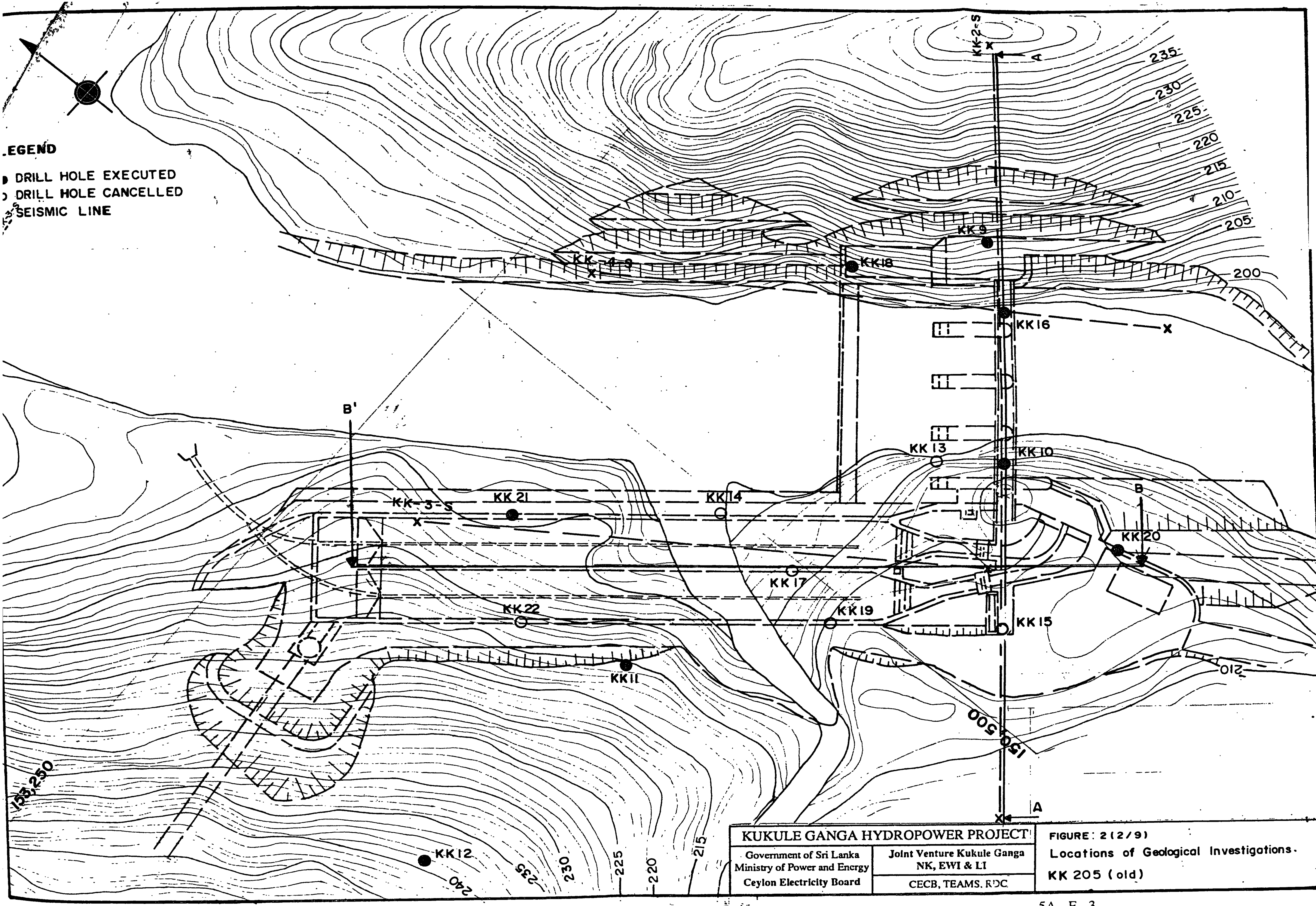
KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

CECB, TEAMS, RDC

FIGURE : 2 (1/9)
Location Map of Geological Investigations
KK 205 (New)



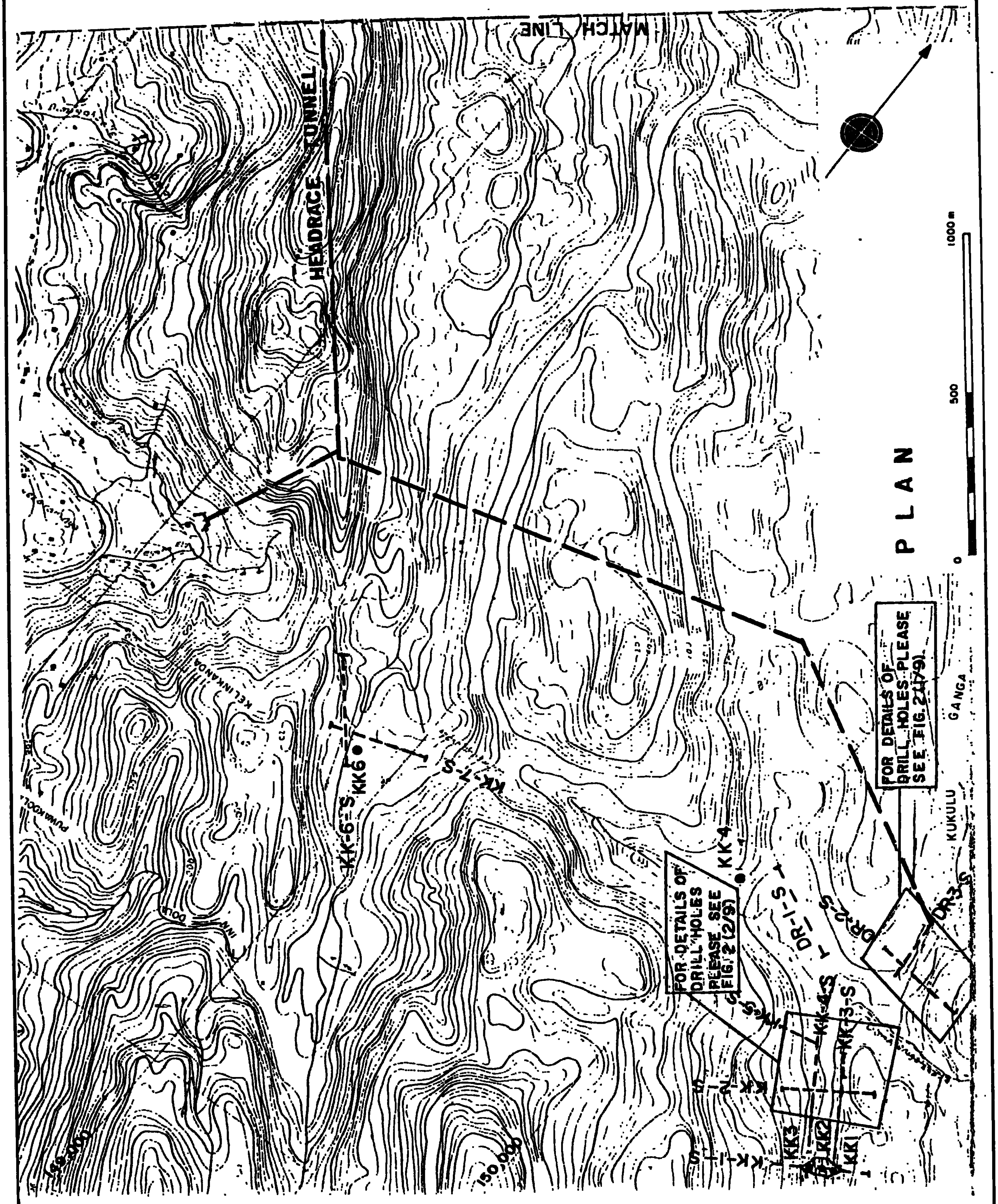
KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC

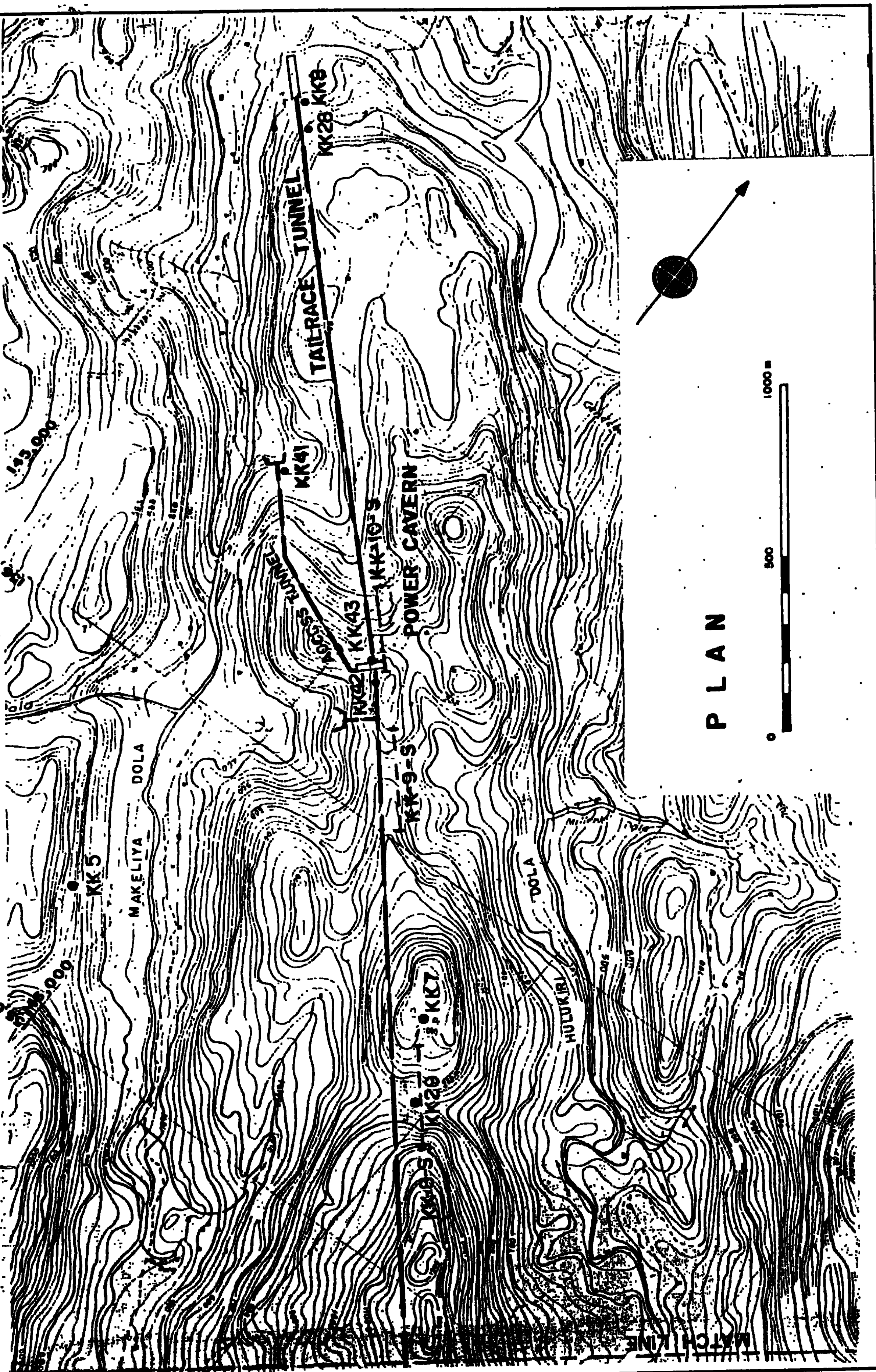
FIGURE: 2 (2/9)

Locations of Geological Investigations.

KK 205 (old)

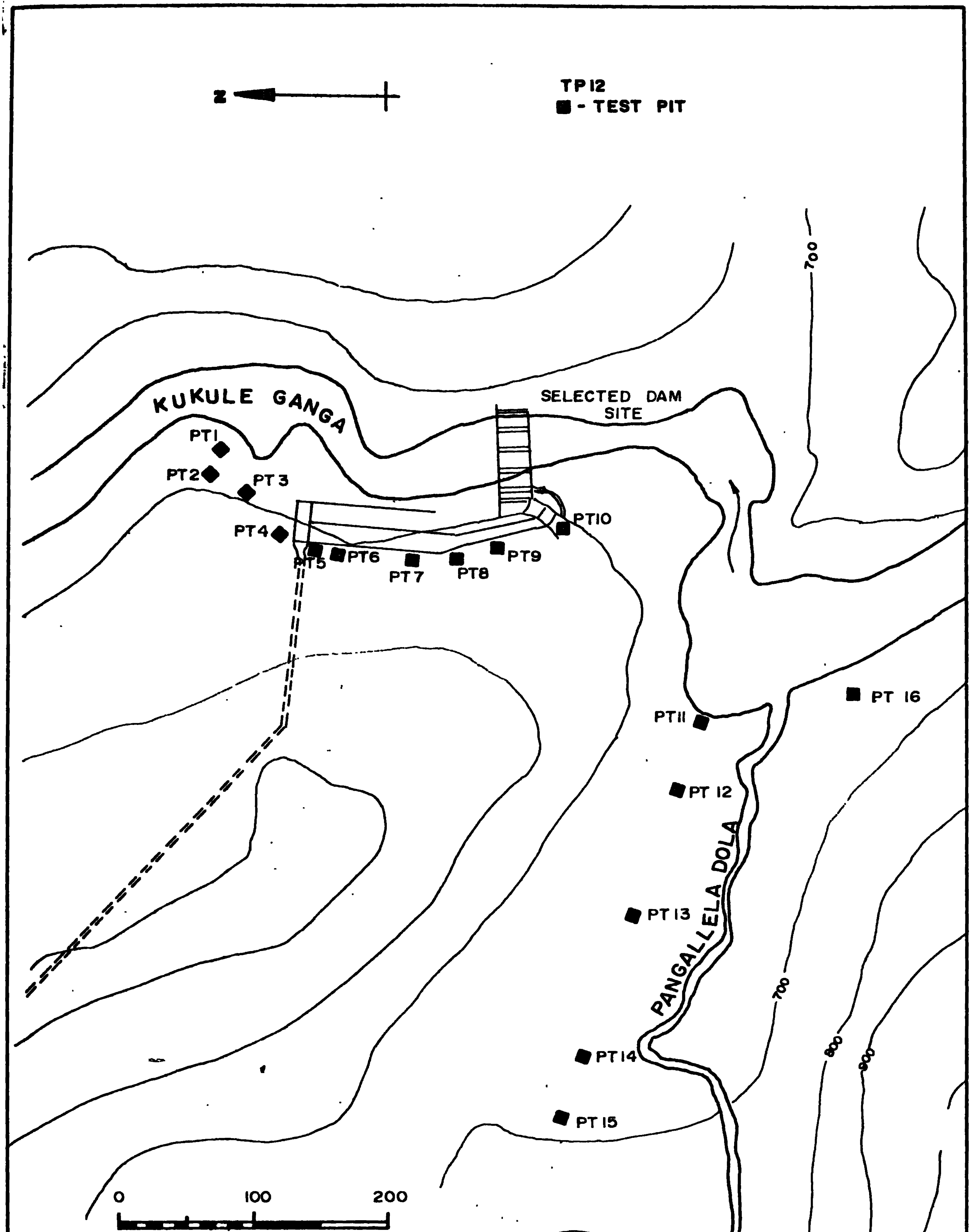


KUKULE GANGA HYDROPOWER PROJECT		FIGURE : 2 (3/9) Locations of Geological Investigations KK Plan
Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI	
Ceylon Electricity Board	CECB, TEAMS, RDC	



KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI	FIGURE: 2 (4/9) Locations of Geological Investigations KK Plan.
Ceylon Electricity Board	CECB, TEAMS, RDC	



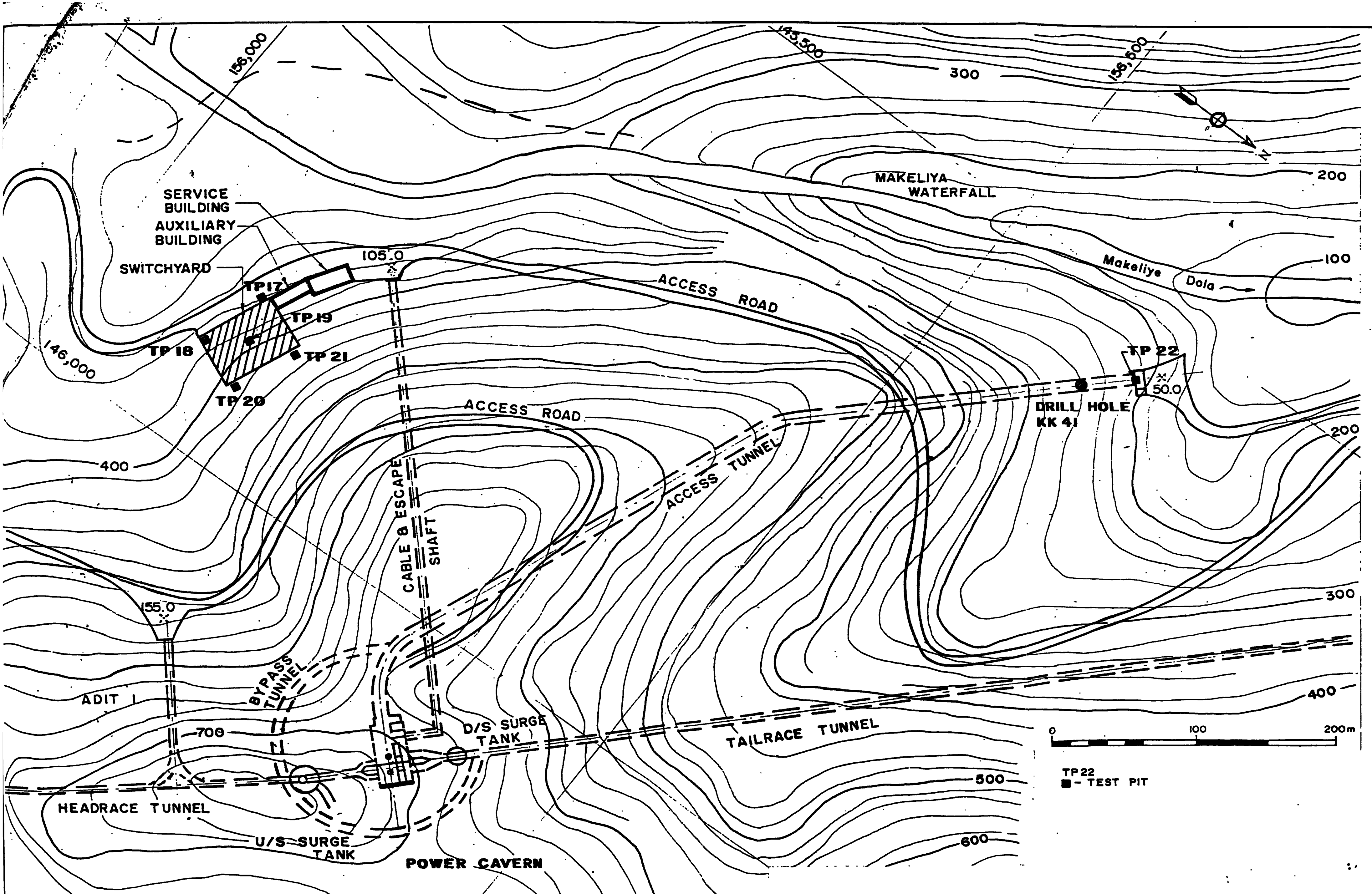
KUKULE GANGA HYDROPOWER PROJECT

Ceylon Electricity Board
(IDA)

Joint Venture Kukule Ganga
NK, EWI & LI

CECB, TEAMS

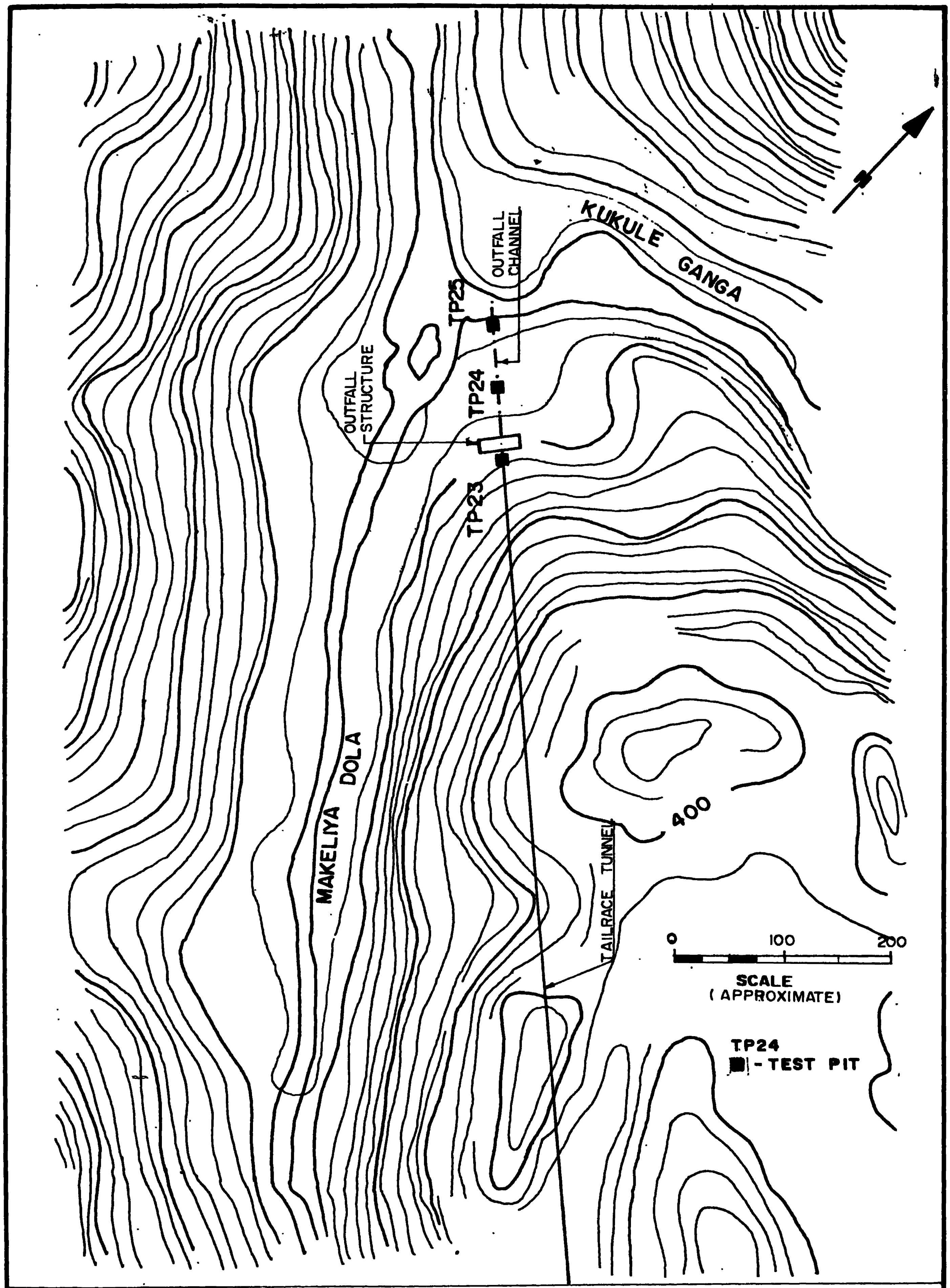
FIGURE: 2 (5/9)
Locations of Geological Investigations
KK . 205(New)



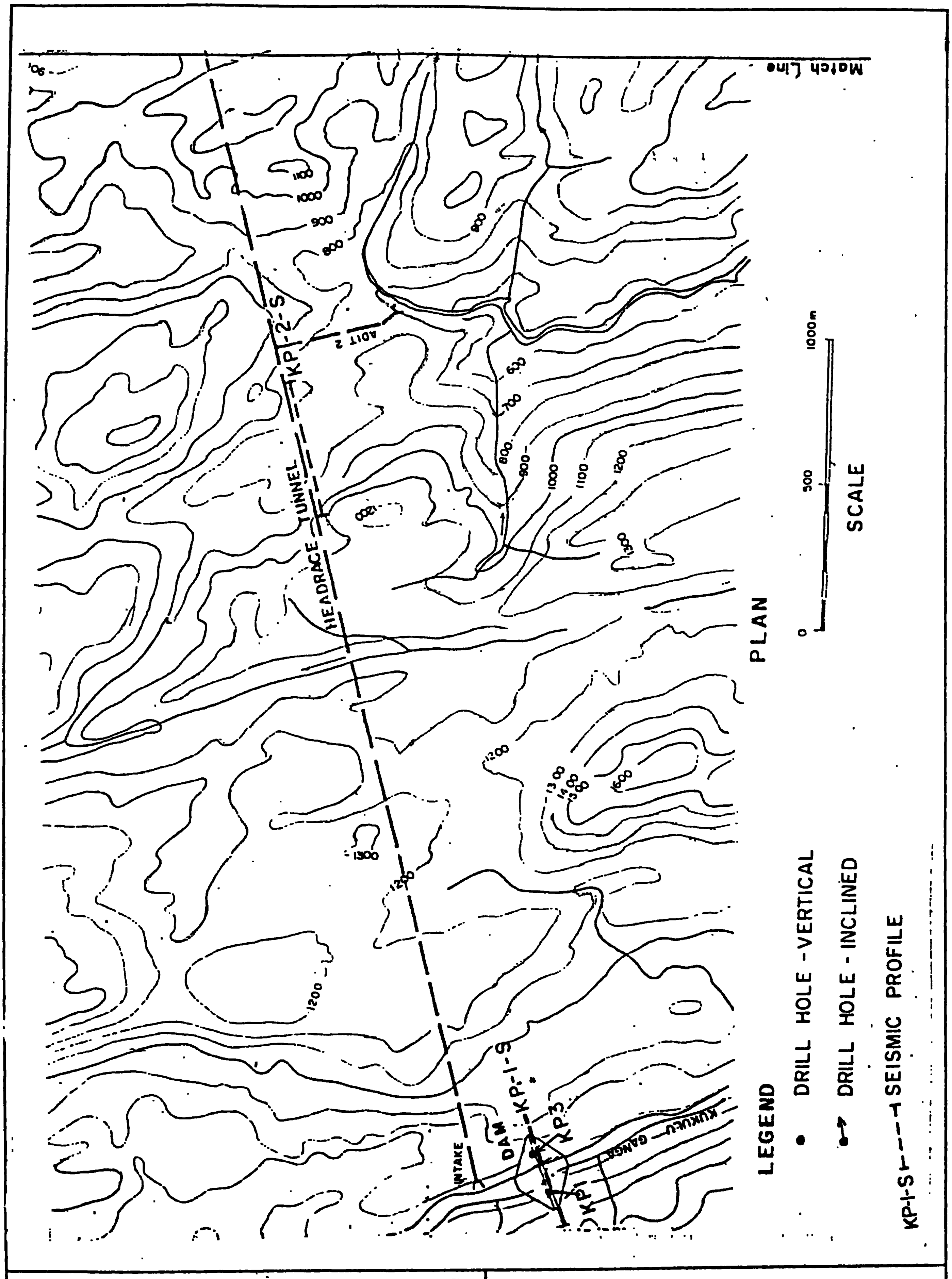
NOTE: THE CONTOUR LINES ARE IN FEET

KUKULE GANGA HYDROPOWER PROJECT	
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI
	CECB, TEAMS

FIGURE: 2 (6/9)
Locations of Geological Investigations
KK Plan.



KUKULE GANGA HYDROPOWER PROJECT		FIGURE: 2 (7/9) Locations of Geological Investigations KK PLAN
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS	

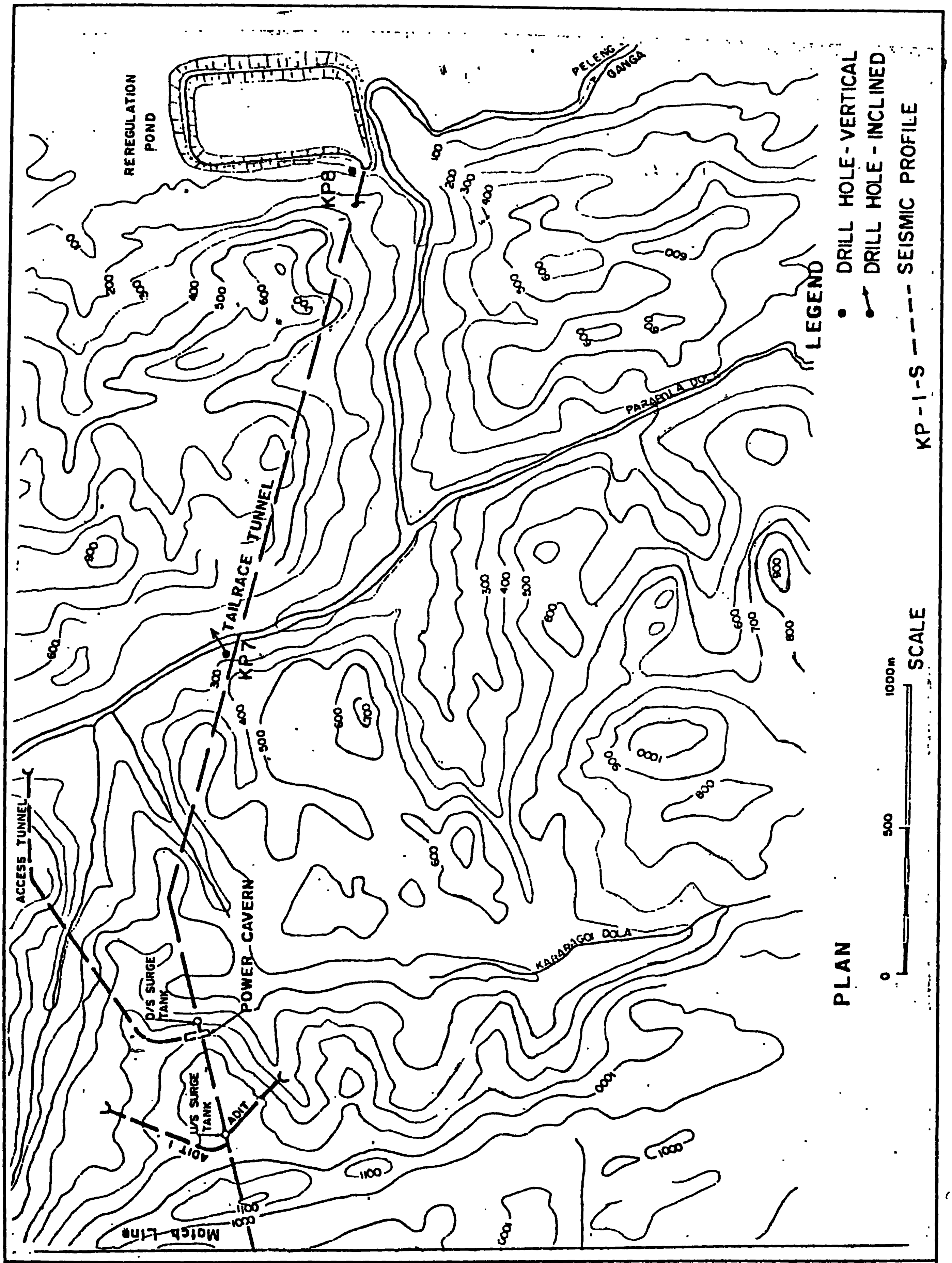


KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI
CECB, TEAMS, RDC

FIGURE : 2 (8/9)
Locations of Geological Investigations
KP Plan.



KUKULE GANGA HYDROPOWER PROJECT

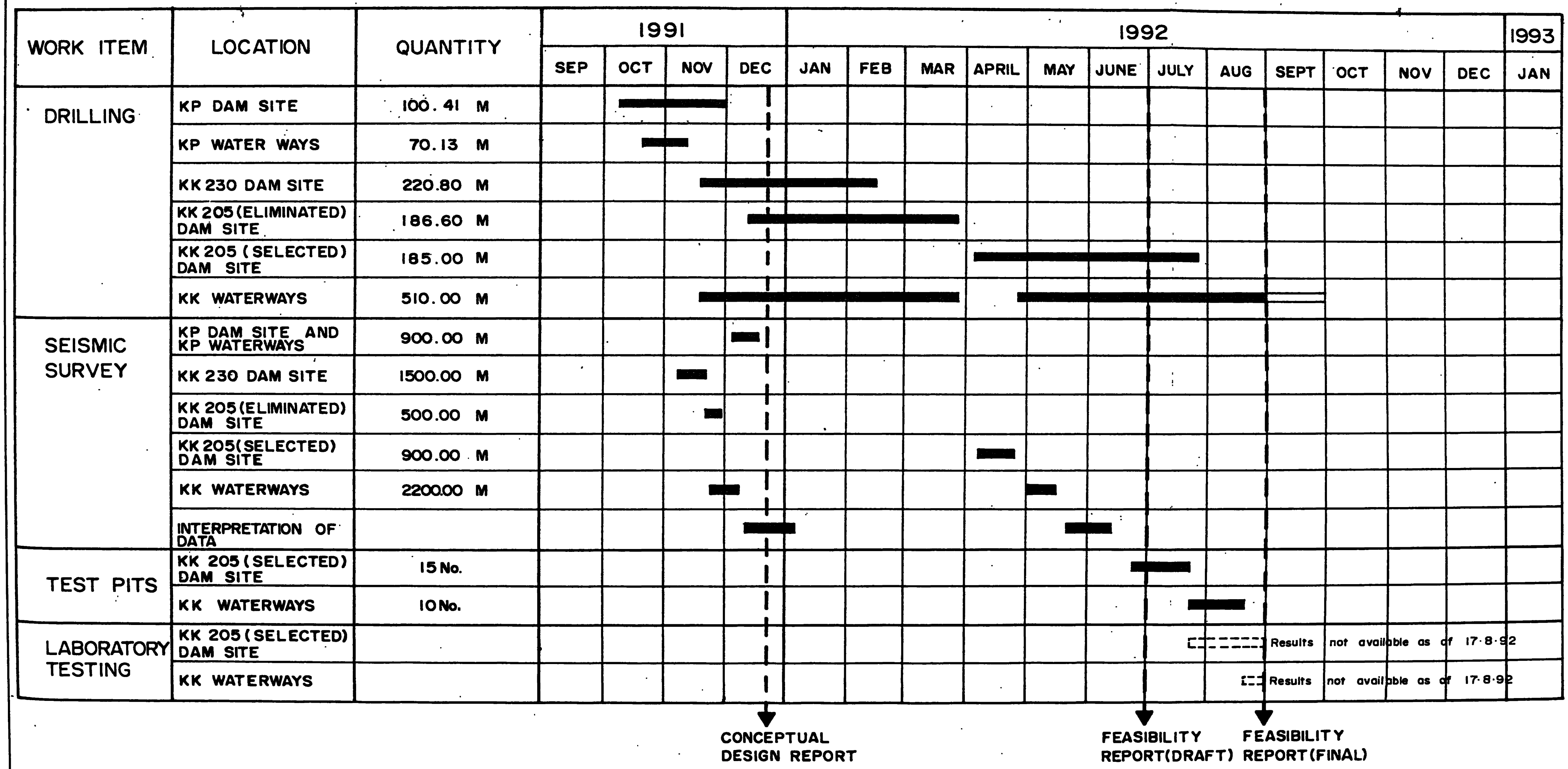
Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI
CECB, TEAMS, RDC

FIGURE : 2 (9/9)

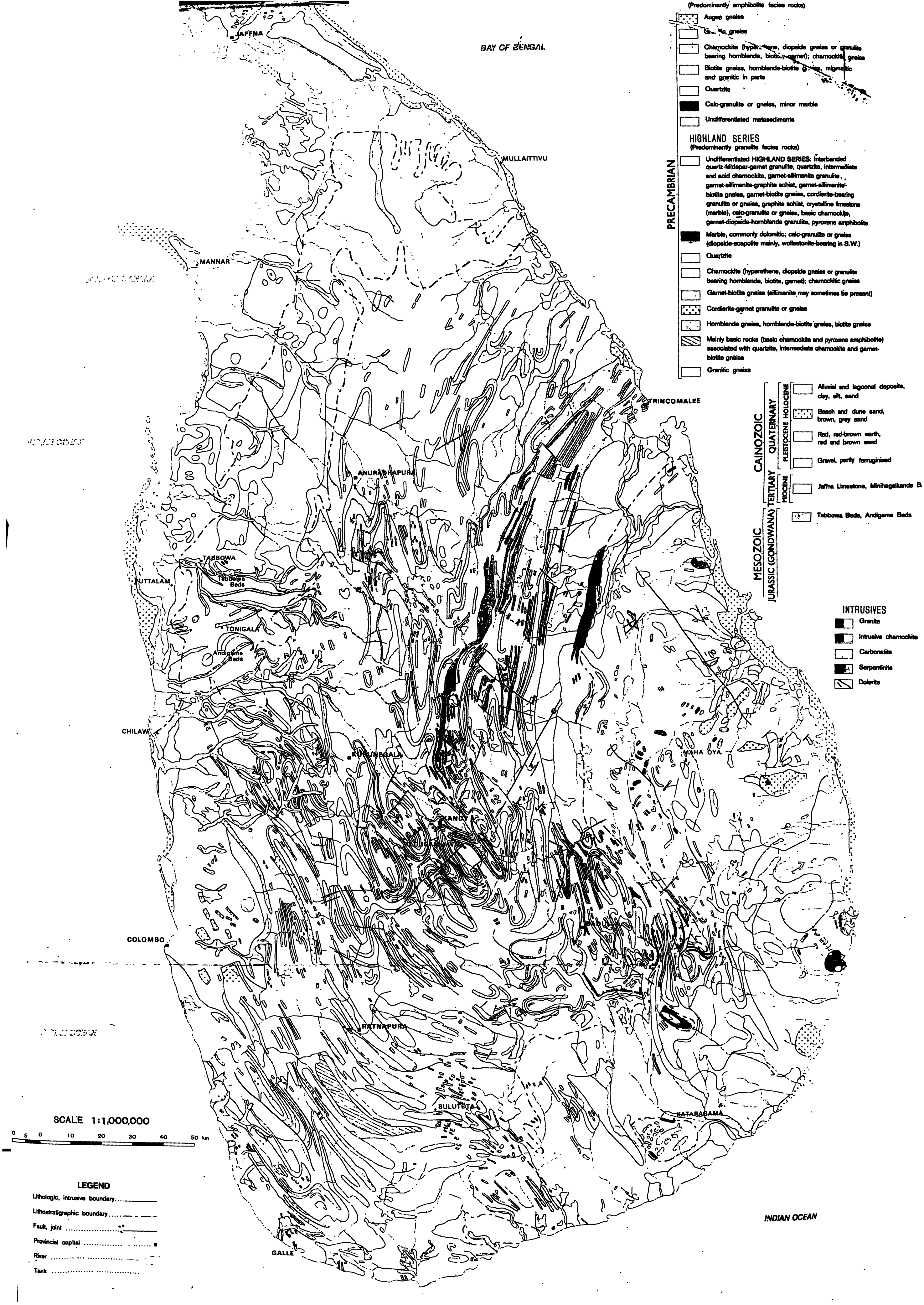
Locations of Geological Investigations
KP Plan.

WORK TIME SCHEDULE OF GEOLOGICAL INVESTIGATIONS AND PROGRESS



WORK ITEM	LOCATION	QUANTITY
DRILLING	KP DAM SITE	100.41 M
	KP WATER WAYS	70.13 M
	KK 230 DAM SITE	220.80 M
	KK 205 (ELIMINATED) DAM SITE	186.60 M
	KK 205 (SELECTED) DAM SITE	185.00 M
	KK WATERWAYS	510.00 M
SEISMIC SURVEY	KP DAM SITE AND KP WATERWAYS	900.00 M
	KK 230 DAM SITE	1500.00 M
	KK 205 (ELIMINATED) DAM SITE	500.00 M
	KK 205 (SELECTED) DAM SITE	900.00 M
	KK WATERWAYS	2200.00 M
	INTERPRETATION OF DATA	
TEST PITS	KK 205 (SELECTED) DAM SITE	15 No.
	KK WATERWAYS	10 No.
LABORATORY TESTING	KK 205 (SELECTED) DAM SITE	
	KK WATERWAYS	

KUKULE GANGA HYDROPOWER PROJECT		FIGURE: 3 Work Time Schedule And Progress
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	


VIJAYAN COMPLEX
(Predominantly amphibolite facies rocks)
Augen gneiss
Granitic gneiss
Charnockite (hypersthene, diopside gneiss or granulite bearing hornblende, biotite, garnet); charnockitic gneiss
Biotite gneiss, hornblende-biotite gneiss, migmatitic and granitic in parts
Quartzite
Calc-granulite or gneiss, minor marble
Undifferentiated metasediments
HIGHLAND SERIES
(Predominantly granulite facies rocks)
Undifferentiated HIGHLAND SERIES: Interbanded quartz-feldspar-garnet granulite, quartzite, intermediate and acid charnockite, garnet-sillimanite granulite, garnet-sillimanite-graphite schist, garnet-sillimanite-biotite gneiss, garnet-biotite gneiss, cordierite-bearing granulite or gneiss, graphite schist, crystalline limestone (marble), calc-granulite or gneiss, basic charnockite, garnet-diopside-hornblende granulite, pyroxene amphibolite
Marble, commonly dolomitic; calc-granulite or gneiss (diopside-scapolite mainly, wollastonite-bearing in S.W.)
Quartzite
Charnockite (hypersthene, diopside gneiss or granulite bearing hornblende, biotite, garnet); charnockitic gneiss
Garnet-biotite gneiss (sillimanite may sometimes be present)
Cordierite-garnet granulite or gneiss
Hornblende gneiss, hornblende-biotite gneiss, biotite gneiss
Mainly basic rocks (basic charnockite and pyroxene amphibolite) associated with quartzite, intermediate charnockite and garnet-biotite gneiss
Granitic gneiss
PRECAMBRIAN
CAINOZOIC
QUATERNARY
HOLOCENE
PLEISTOCENE
Alluvial and lagoonal deposits, clay, silt, sand
Beach and dune sand, brown, grey sand
Red, red-brown earth, red and brown sand
Gravel, partly ferruginized
TERTIARY
MIOCENE
Jaffna Limestone, Minihagalkanda B
MESOZOIC
JURASSIC (GONDWANA)
Tabbowa Beds, Andigama Beds
INTRUSIVES
Granite
Intrusive charnockite
Carbonatite
Serpentinite
Dolerite
JAFFNA
BAY OF BENGAL
MULLAITTIVU
MANNAR
TRINCOMALEE
ANURADHAPURA
TABBOWA
PUTTALAM
Tabbowa Beds
TONIGALA
Andigama Beds
CHILAW
KURUNEGALA
KANDY
MAHA OYA
COLOMBO
RATNAPURA
BULUTOTA
KATARAGAMA
INDIAN OCEAN
GALLE
SCALE 1:1,000,000
0 5 0 10 20 30 40 50 km
LEGEND
Lithologic, intrusive boundary
Lithostratigraphic boundary
Fault, joint
Provincial capital
River
Tank

of Sri Lanka is essentially an extension of ndia which forms part of the Gondwana geologically remote times. It has neither ubmerged by the sea nor has it been he violent crustal upheavals which have led tion of the great mountain chains of the only major submergence was in Tertiary Miocene sediments were laid down and elevated to form the north western belt of cluding the Jaffna Peninsula and the off s. The various geological formations in the country are summarised below, age and starting with the oldest.

Formations

(a) Charnockite to Sedimentary Series (Highland Series).

Quartzites, quartz-schists, granulites, garnet-sillimanite graphite schists, sillimanite gneisses, cordierite gneisses, calc-gneisses, crystalline limestone, dolomites and charnockites.

(b) Vijayan Series – granites, granitic gneisses, biotite gneisses, biotite-hornblends gneisses, pegmatites and charnockites.

Sandstones, arkoses, grits, shales and carbonaceous shales.

Garnet-sillimanite-graphite schists

These rocks are distinctive because of the large size of the garnets. Sillimanite and graphite are common and the garnets are often surrounded by sheaves of sillimanite.

Quartzites

Quartzites are perhaps the most prominent members of the Series and occur as ubiquitous bands, several hundreds of metres in thickness in places, which can be traced for many kilometres along the strike. They are widely distributed but attain their greatest development in parts of the hill country and in the region of Minneriya and Polonnaruwa, terminating on the east coast at Trincomalee.

Crystalline Limestones

Marbles occupy a very prominent place in the Series and occur interbanded with quartzites, charnockites and garnet sillimanite-graphite schists. The association with the last named rock type is particularly striking in the Matale and Matale North districts.

Wollastonite-bearing granulites gneisses

Wollastonite-scapolite-diopside gneisses are distributed in the south-west coastal region between Kalutara and Ahangama and they are best developed in the immediate neighbourhood of Galle.

Cordierite gneisses

A distinctive group of cordierite-bearing rocks occur in

Miocene

These rocks which are mainly limestones are best developed in the Jaffna peninsula. The limestones vary in texture from porous to massive, highly fossiliferous rock capped by thin layers of red soil of the 'terra rosa' type. The thickness of the limestone is probably of the order of several hundred metres.

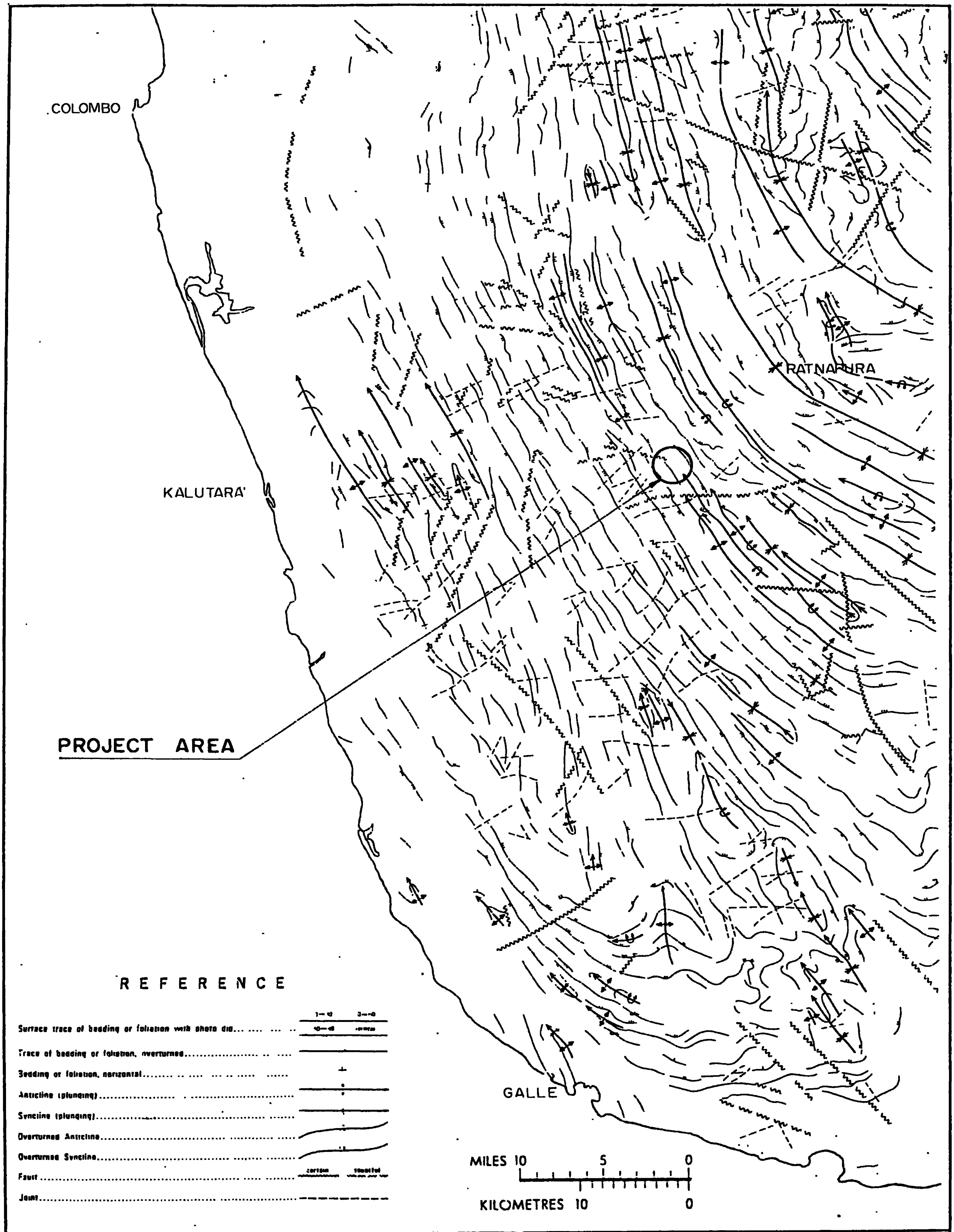
The miocene limestones of the peninsula extend southwards along the north-west coastal belt towards Puttalam. Near the southern end of the belt the limestones are well exposed; they resemble the Jaffna limestones in appearance and in chemical composition but in this region are interbedded with aranaceous limestones.

Pleistocene

Red earths and gravels

The pleistocene consists of two formations – an upper red earth formation and a lower gravel deposit. The two formations are fairly well defined though locally they appear to merge into each other both vertically and laterally. The red earth varies considerably in thickness from a few metres up to 30 metres.

The gravels are mottled and show various shades of red and brown in a grey clayey matrix. The gravel which consists mainly of quartz grains is not always present and their distribution is patchy. Where they are absent, the red earths directly overlie Miocene or Precambrian rocks.



KUKULE GANGA HYDROPOWER PROJECT

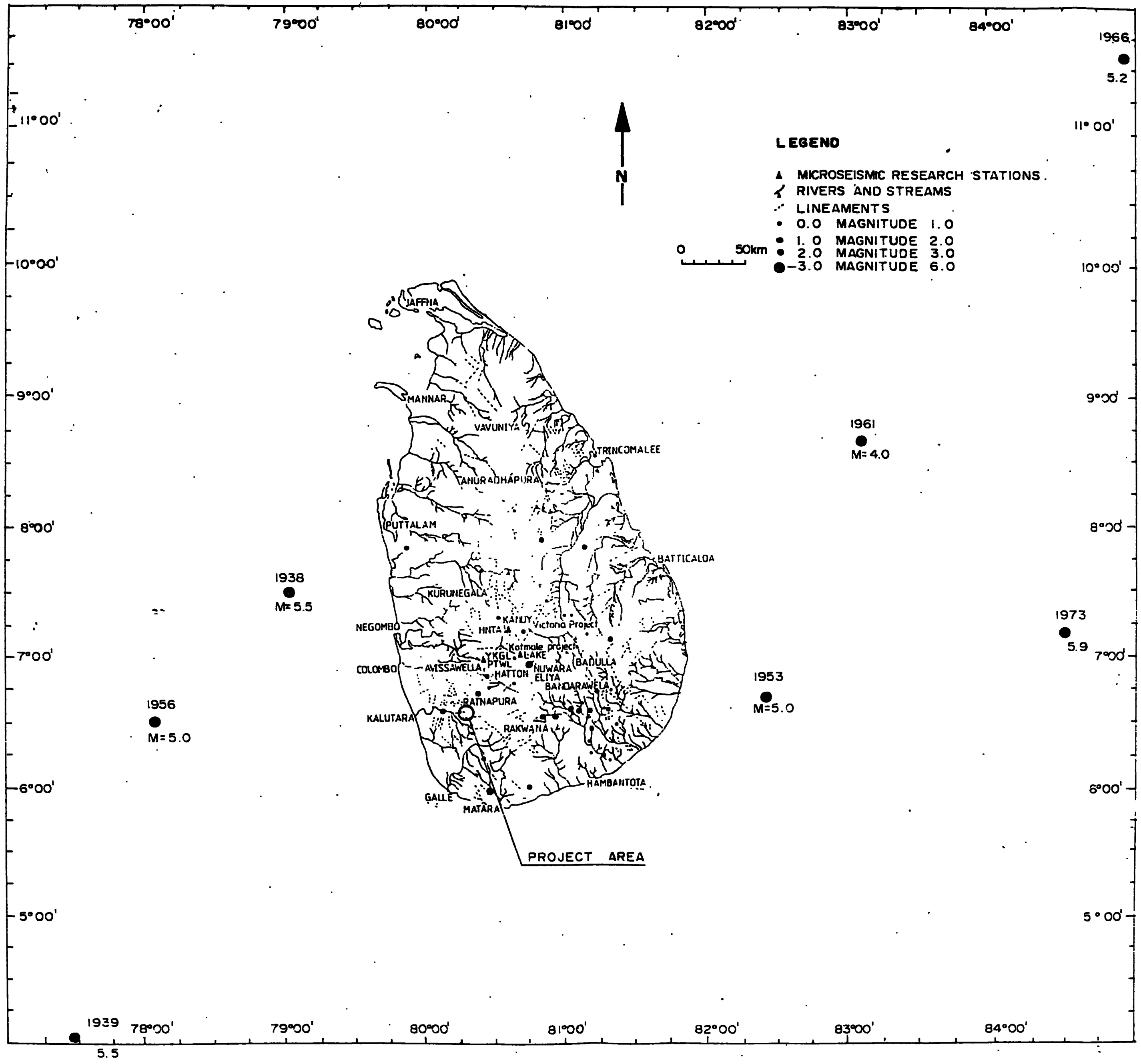
Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

CECB, TEAMS, RDC

FIGURE: 5

Regional Geology
Structural Map
Reference: Geo. Survey Dept. 1983

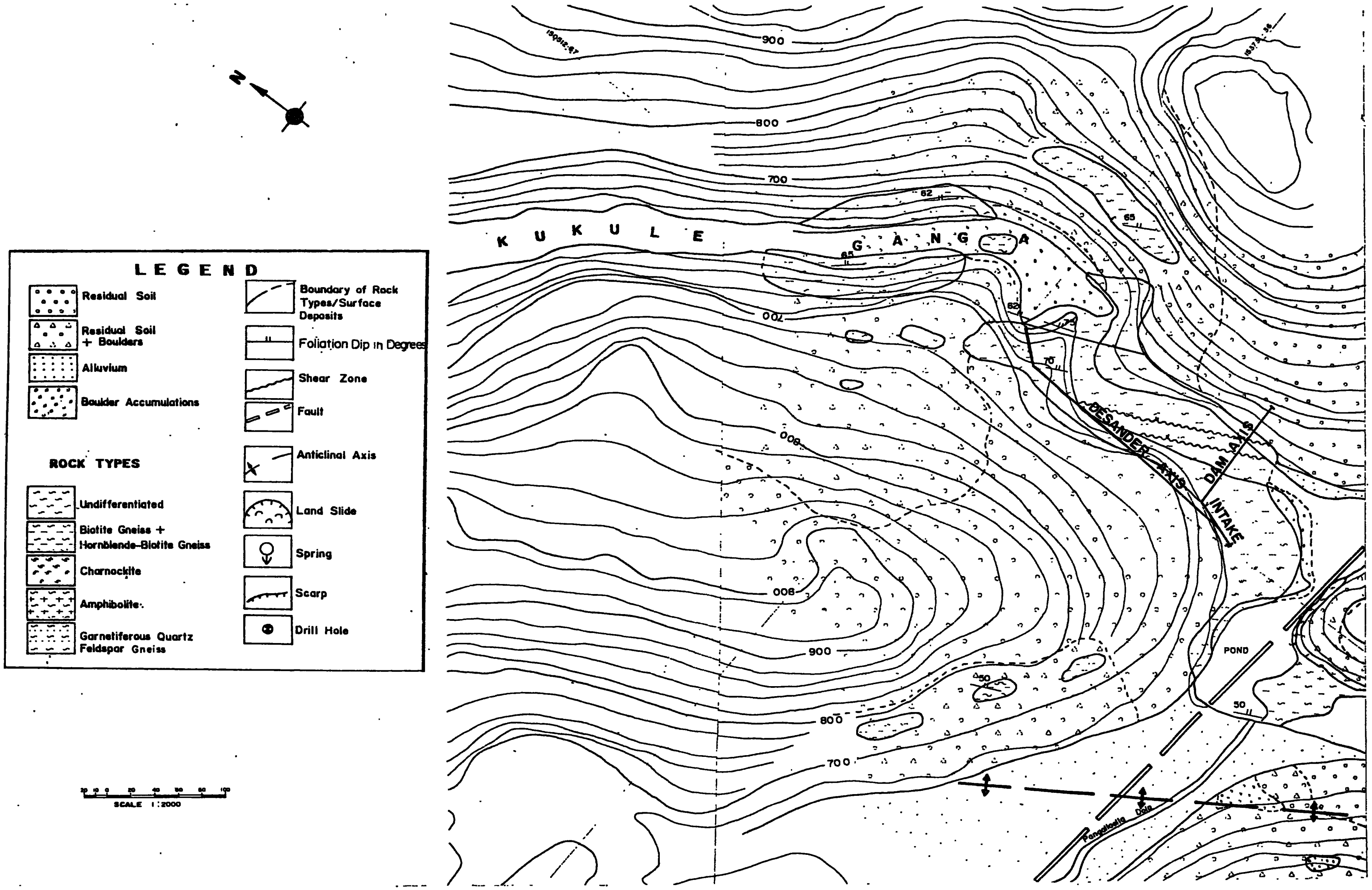


KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC

FIGURE : 6

Locations of Seismic Events



KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI
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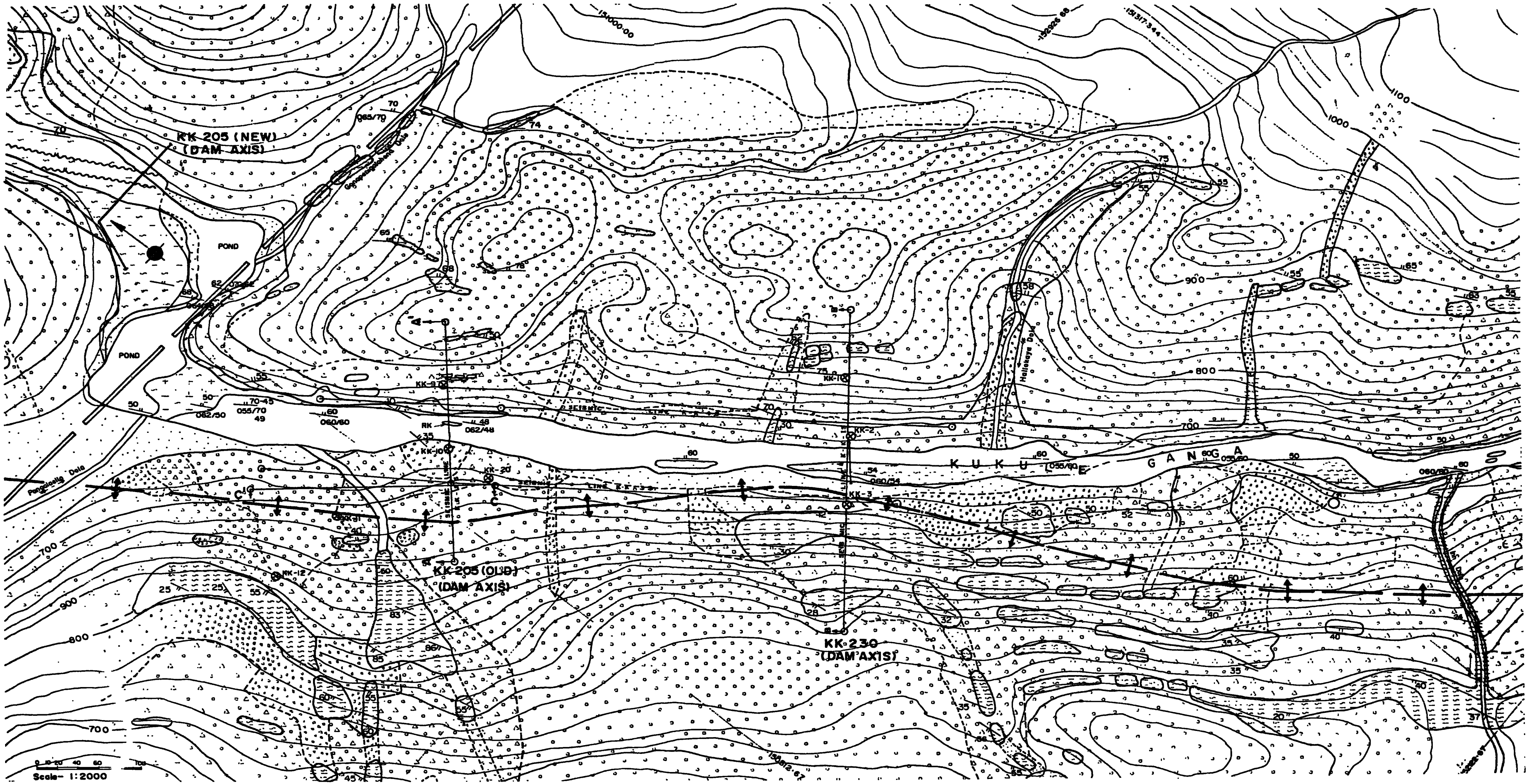
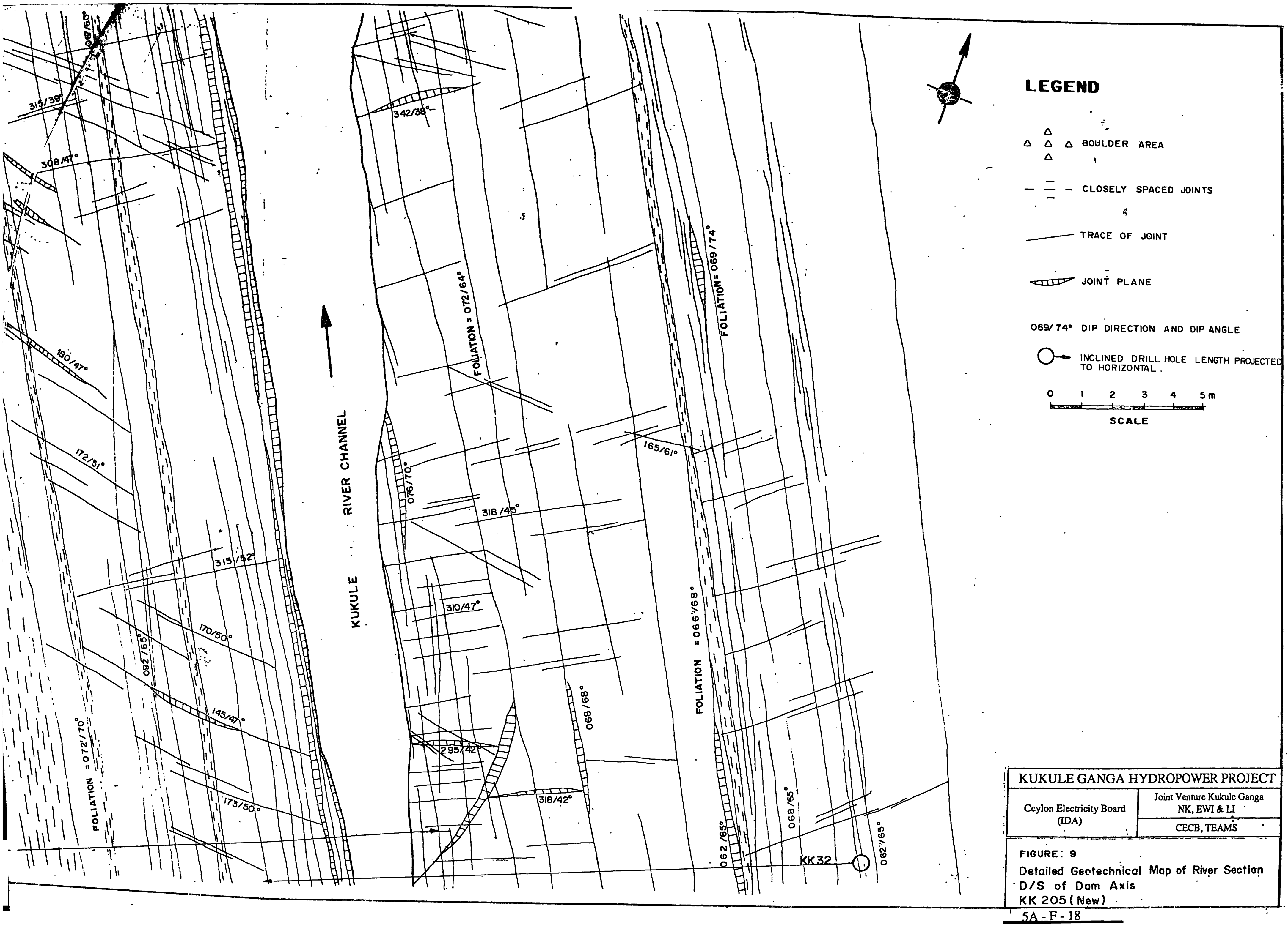
FIGURE : 8 (1/2)
Geological Map of Dam Site Areas - KK Plan



KUKULE GANGA HYDROPOWER PROJECT		FIGURE : 8 (2/2) Geological Map of Dam Site Areas -KK Plan.
Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI	
Ceylon Electricity Board	CECB, TEAMS, RDC	



KUKULE GANGA HYDROPOWER PROJECT

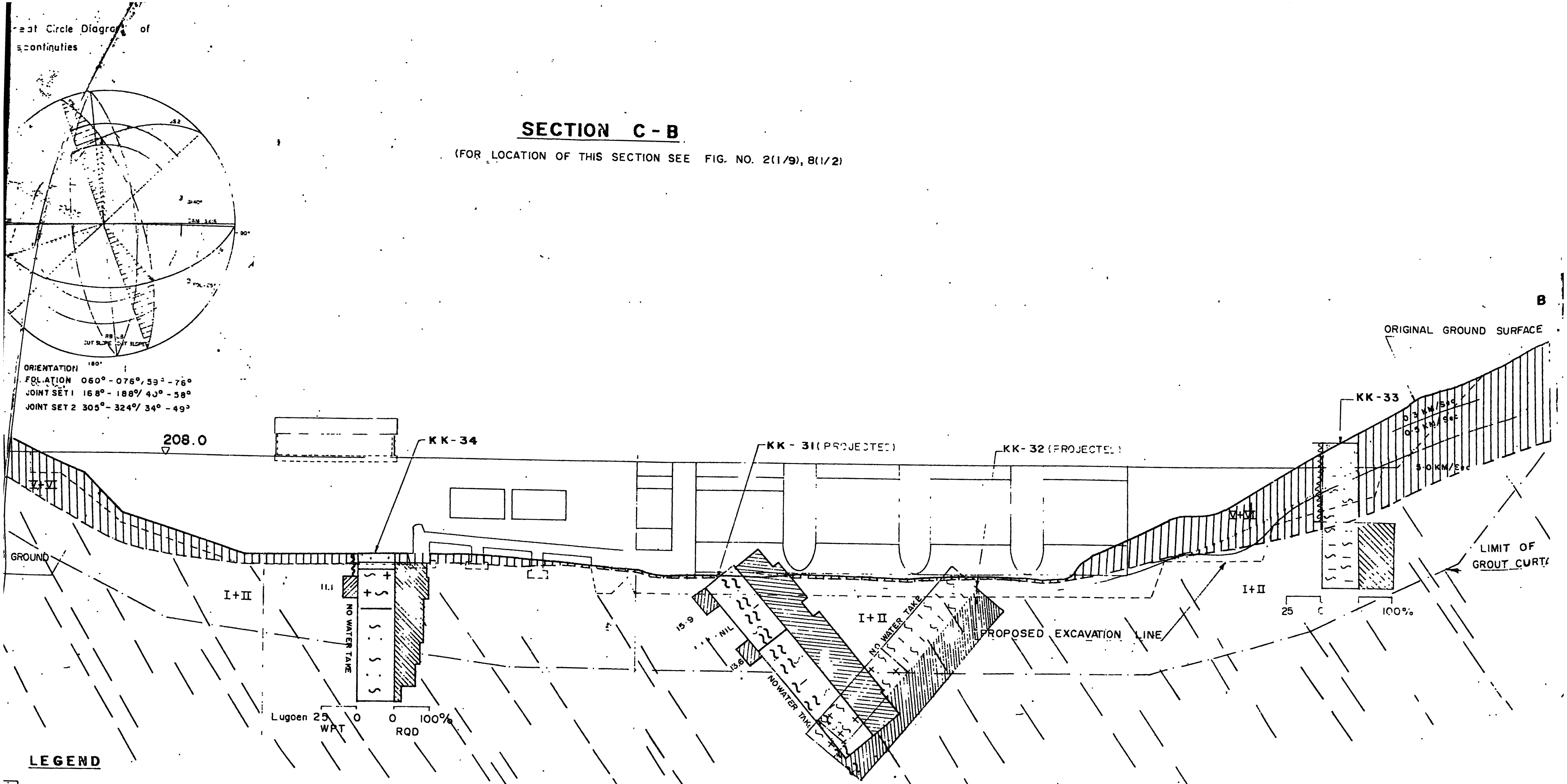
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI
	CECB, TEAMS

FIGURE: 9
Detailed Geotechnical Map of River Section D/S of Dam Axis
KK 205 (New)

5A - F - 18

SECTION C - B

(FOR LOCATION OF THIS SECTION SEE FIG. NO. 2(1/9), 8(1/2)



LEGEND

- OVERBURDEN
- CHARNOCKITIC GNEISS
- AMPHIBOLITE
- QUARTZ' FELDSPAR GNEISS
- BIOTITE GNEISS, HORNBLENDE BIOTITE GNEISS
- TRACE OF FOLIATION
- SHEAR ZONE
- BOUNDARY BETWEEN SEISMIC WAVE VELOCITY LAYER
- BOUNDARY BETWEEN ROCK GRADES
- PROPOSED LIMIT OF GROUT CURTAIN
- KK-21 · DRILL HOLE NUMBER

ROCK GRADES

- Ⅴ, Ⅴ-Ⅵ
- Ⅳ, Ⅳ-Ⅴ
- Ⅲ, Ⅲ-Ⅳ

WPT RQD

NO WATER PRESS-URE TEST PERFORMED

LUGEON 25 0 0 100%

SCALE - 1 : 500

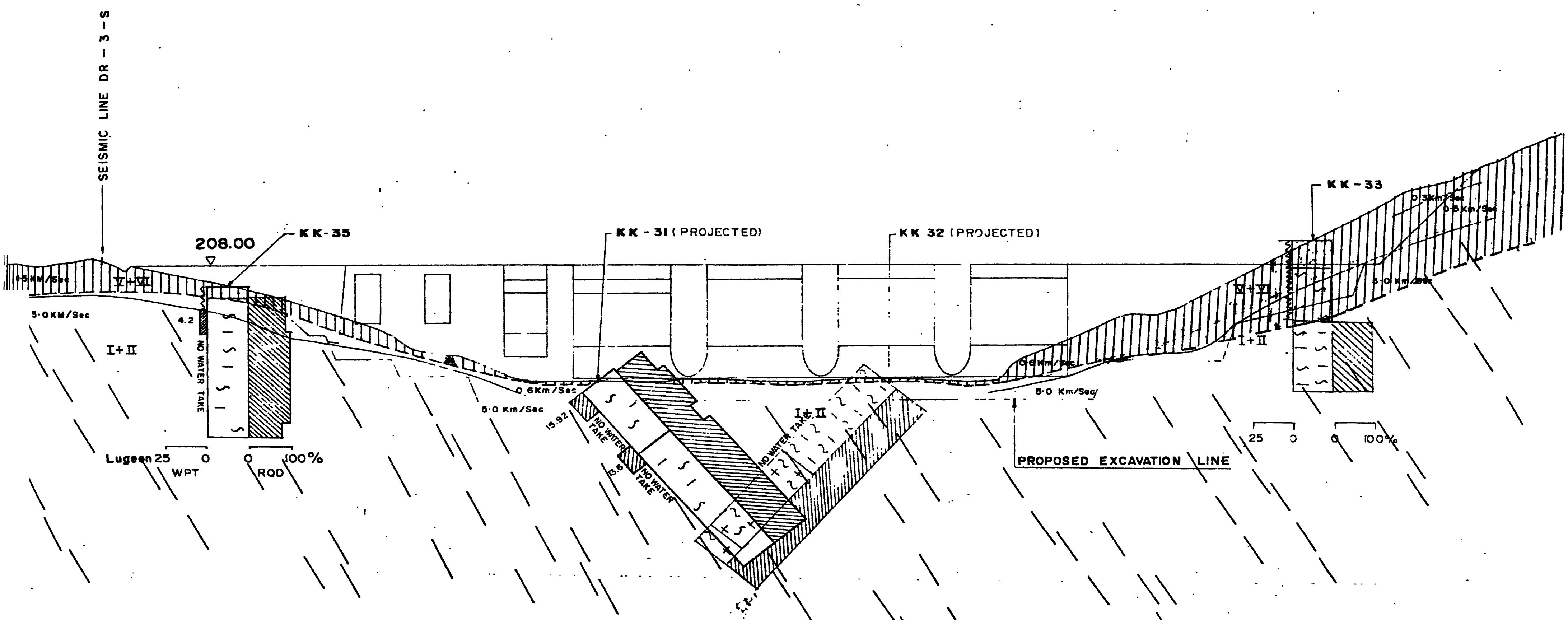
0 5 10 15 20m

NOTE. OUTLINES OF STRUCTURES PROJECTED IN TO THE GEOTECHNICAL SECTION.

KUKULE GANGA HYDROPOWER PROJECT		FIGURE 10 (1/2)
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	Geotechnical Section Along KK - 205 (New) Dam Axis

SECTION B - B'

(FOR LOCATION OF THIS SECTION SEE FIG. NO. 2(1/6), 8(1/2)

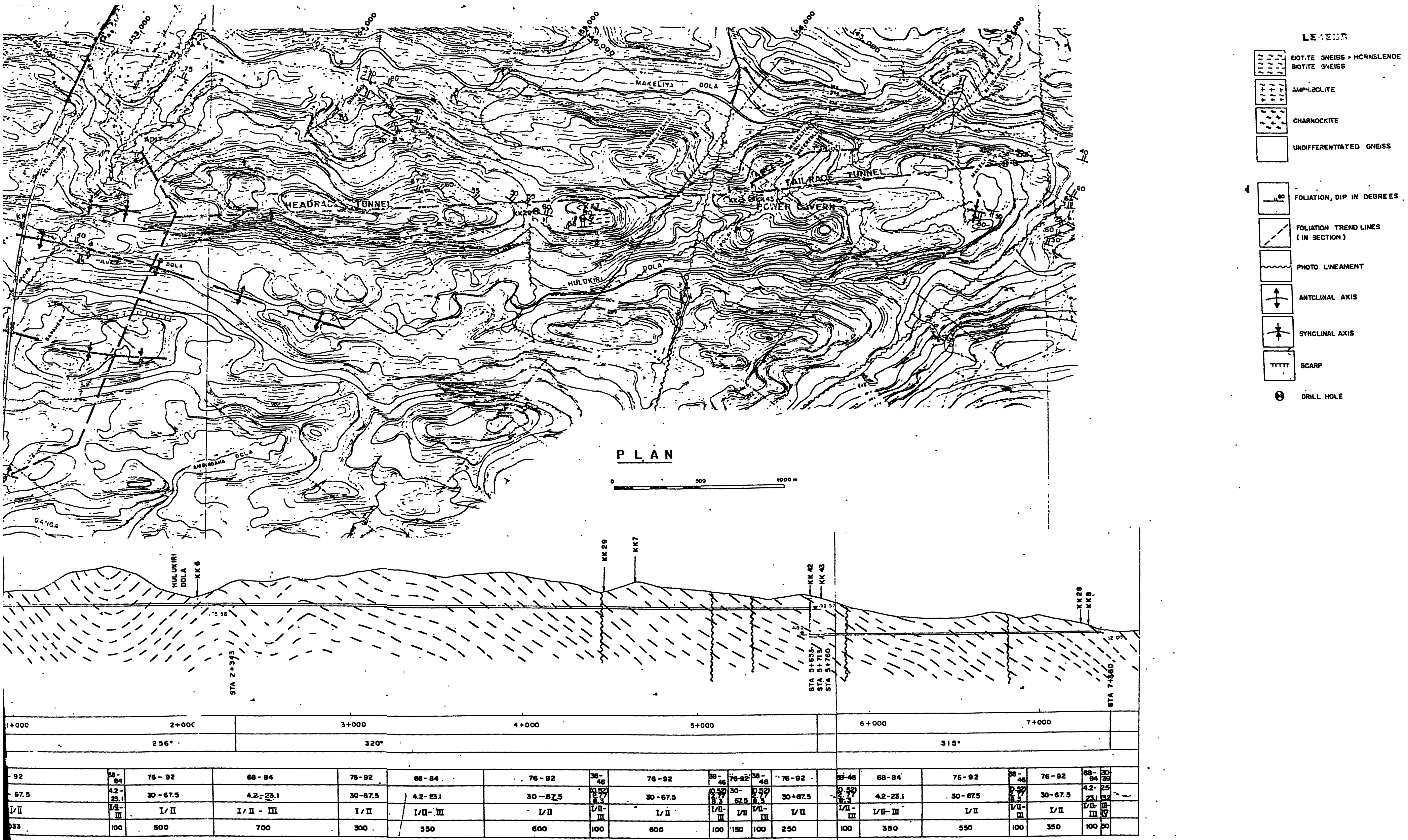


SCALE - 1 : 500

0 5 10 15 20 m

NOTE : OUT LINE OF STRUCTURES PROJECTED
IN TO THE GEOLOGICAL SECTION
FOR LEGEND SEE FIG. 10 (1/2)

KUKULE GANGA HYDROPOWER PROJECT		FIGURE 10 (2/2)
Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI	Geotechnical Section Along KK - 205 (New) Dam Axis
Ceylon Electricity Board	CECB, TEAMS, RDC	



IVE LENGTH%	
91.7	
7.7	
0.6	
100.0	

TAILRACE TUNNEL

ROCK MASS CLASS	LENGTH OF SECTION (m)	RELATIVE LENGTH%
I/II	75+255+550+75+350+75=1390	86.9
III	25+85+25+25+25 = 185	11.6
IV	25	1.5
	TOTAL LENGTH =1600	100.0

ROCK MASS CLASSIFICATION ADOPTED IN PROJECT

CLASS	SUPPORT	CORRESPONDING RATING	
		CSIR (RMR)	NGI (Q)
I/II	NO SUPPORT; LOCAL BOLTS AND SHOTCRETE	> 60	>6.0
III	SYSTEMATIC BOLTS, WIRE MESH AND SHOTCRET	20 - 60	0.1 - 6.0
IV	LIGHT TO MEDIUM STEEL RIBS, BOLTS, WIRE MESH+SHOTCRETE.	< 20	< 0.10

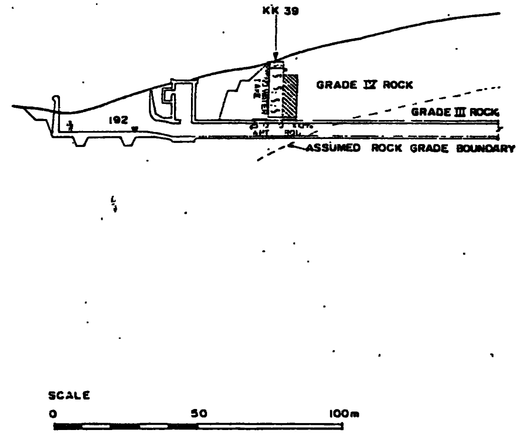
KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

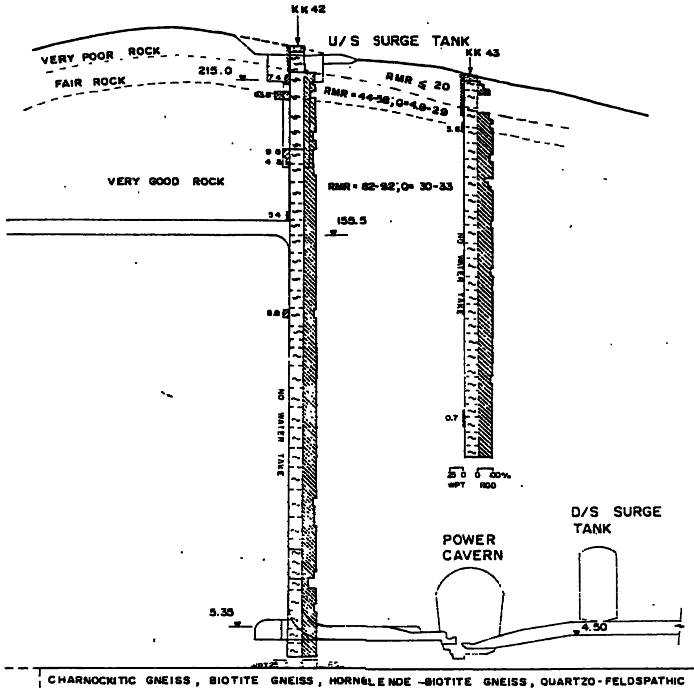
Joint Venture Kukule Ganga
NK; EWI & LI
CECB, TEAMS, RDC

FIGURE : 12
Geological Section Along Waterways
KK 205 (New)

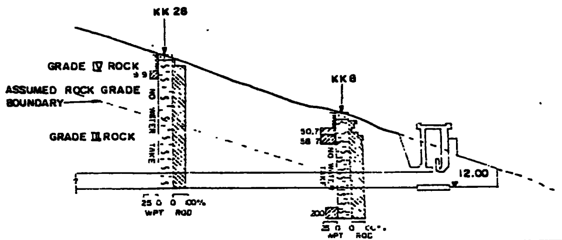
HEADRACE INTAKE



POWER CAVERN - SURGE FACILITIES



TAILRACE OUTFALL

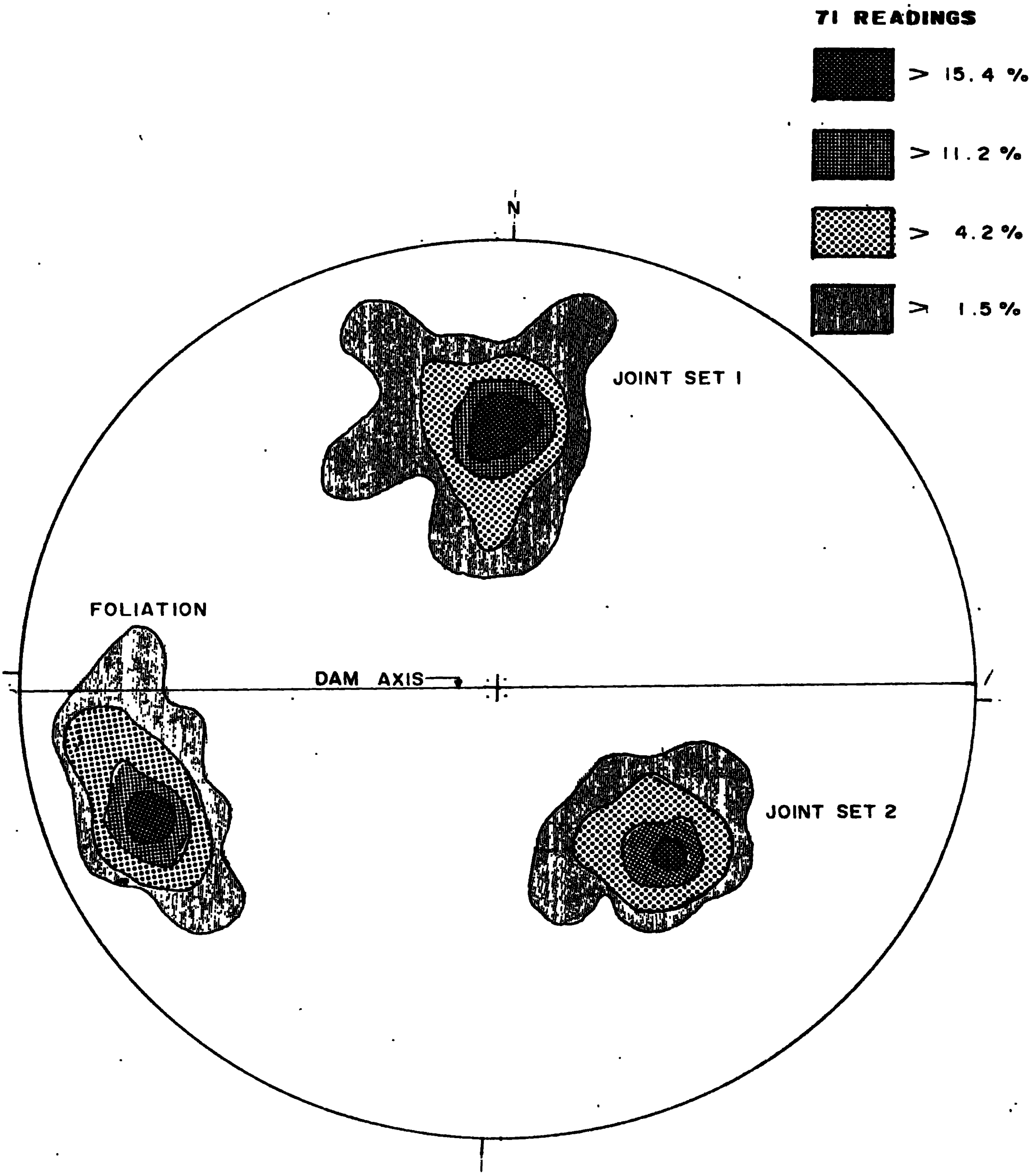


	ROCK TYPE	BIOTITE GNEISS, HORNBLENDE - BIOTITE GNEISS		CHARNOCKITIC GNEISS, BIOTITE GNEISS, HORNBLENDE -BIOTITE GNEISS, QUARTZO-FELDSPATHIC GNEISS		BIOTITE GNEISS, GARNETIFEROUS BIOTITE GNEISS	
CISR CLASSIFICATION	UCS	10-25 TO 25-50 MPA	50-100 TO 100-200 MPA	150 - ≥ 200 MPa		50 - 100 TO 100 - 200 MPA	10-25 TO 25 - 50MPA
	RQD	≤ 25% TO 25-50%	75 - 90%	90 - 100%	50 - 75%	75 - 90%	≤25% TO 25 - 50
	SPACING OF JOINTS	0.05 TO 0.30m	50-200mm TO 0.3-1m	1 - 3m	0.3-1m / 0.05-0.5m	50-200mm TO 0.3-1m	0.05 - 0.30m
	CONDITION OF JOINTS	JOINTS OPEN 1-5mm, IN PARTS JOINTS OPEN < 5mm	SOFT JOINT WALL ROCK IN PARTS JOINTS OPEN 1-5mm	FOLIATION; JRC=2-6; JOINTS; JRC=6-10, PREDOMINANTLY NO SEPERATION, HARD JOINT WALL ROCK	I.P SLICKENSIDED I.P JRC 4-6	SOFT JOINT WALL ROCK, IN PARTS JOINTS OPEN 1-5mm	JOINTS OPEN 1-5mm, IN PARTS JOINTS OPEN > 5mm
	GROUND WATER	WATER UNDER MODERATE PRESSURE.	WATER UNDER MODERATE PRESSURE.	MOIST, IN PLACES LOW INFLOW	MODERATE INFLOW	WATER UNDER MODERATE PRESSURE	WATER UNDER MODERATE PRESSURE.
	ORIENTATION	FAVOURABLE	FAVOURABLE	FAVOURABLE TO VERY FAVOURABLE	FAVOURABLE	FAVOURABLE	FAVOURABLE
	TOTAL RATING (RMR)	≤19 - 30	42 - 63	82 - 92	36 - 67	42 - 63	≤ 19 - 30
NGI CLASSIFICATION	RQD	≤ 25 TO 25-50%	50 - 75%	90 - 100%	50 - 75%	50 - 75	≤25% TO 25 - 50
	J_n	9 - 12	9	9	9 - 12	9	9 - 12
	J_r	1.0	1.0 - 1.5	3	1.5 - 3	1.0 - 1.5	1.0
	J_a	2 - 6	2	1	1 - 2	2	2.6
	J_w	0.66	0.66	1	0.66	0.66	0.66
	SRF	1	1	1	1	1	1
	ROCK QUALITY (Q)	≤ 0.1 - 1.8	1.8 - 4.1	30 - 33.3	2.1 - 16.4	1.8 - 4.1	≤ 0.1 - 1.8
CLASSIFICATION ADOPTED IN PROJECT		IV	III	I/II	I/II - III	III	IV
				MASSIVE ROCK	FRACTURED ROCK		

NOTE : FOR LOCATIONS SEE FIG. 2 (1/9), FIG.12

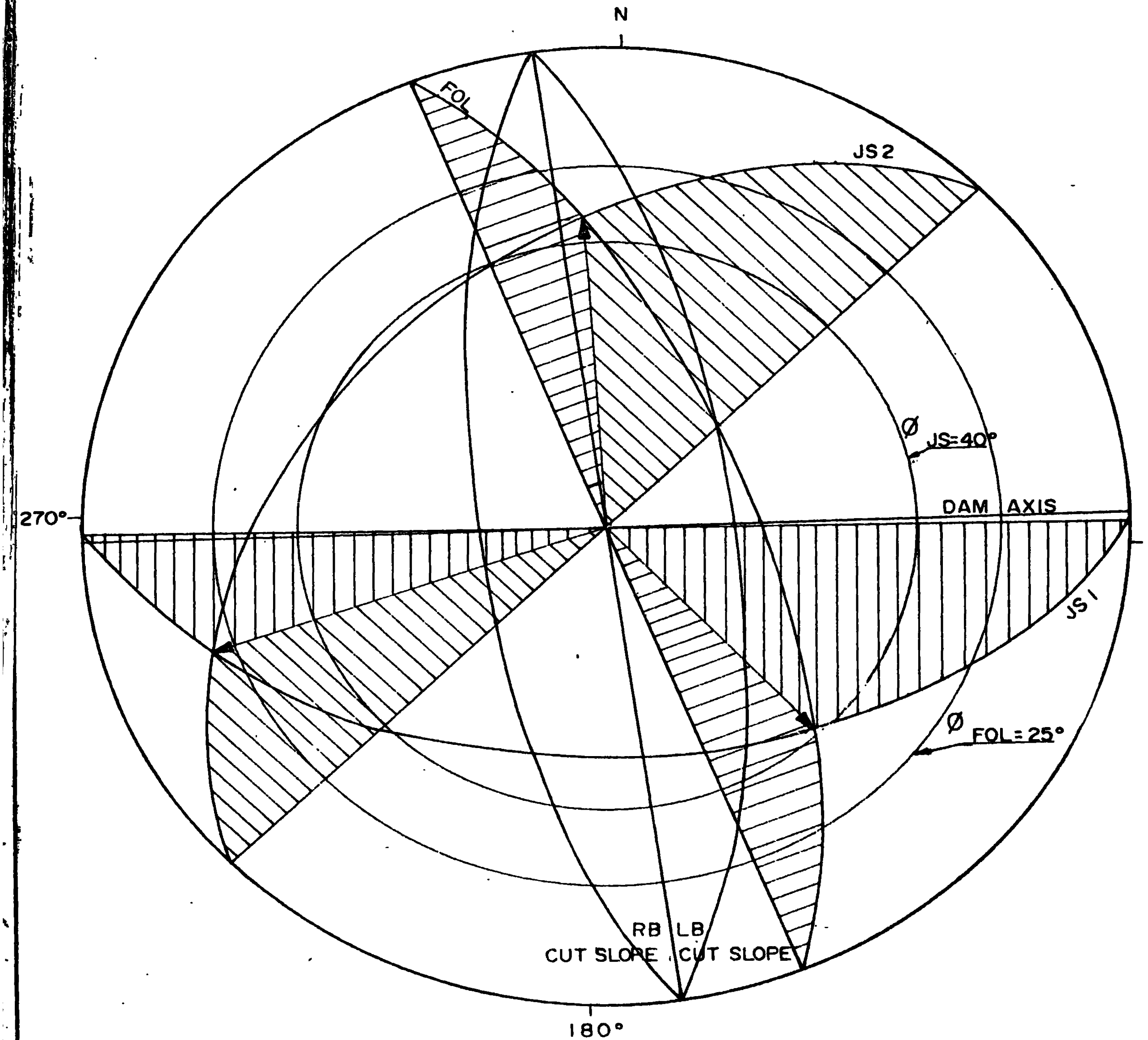
KUKULE GANGA HYDROPOWER PROJECT		FIGURE : 13 Geotechnical Sections of Power House Area, Headrace Intake, Tailrace Outfall. KK 205 (New)
Ceylon Electricity Board (IDA)	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS	

POLAR EQUAL AREA PROJECTION LOWER HEMISPHERE



FOLIATION : 060°-076°/ 59°-76°
JOINT SET 1 : 168°- 188°/ 40°-58°
JOINT SET 2 : 305°- 324°/ 34°-49°

KUKULE GANGA HYDROPOWER PROJECT		FIGURE : 14 (1/2)
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	**Structural Diagrams** **Distribution of Foliations and Joints** **KK 205 Dam Site (New)**



ORIENTATION :		
	FOLIATION	060°-076°/59°-76°
	JOINT SET 1	168°-188°/ 40°-58°
	JOINT SET 2	305 - 324°/ 34°- 49°

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

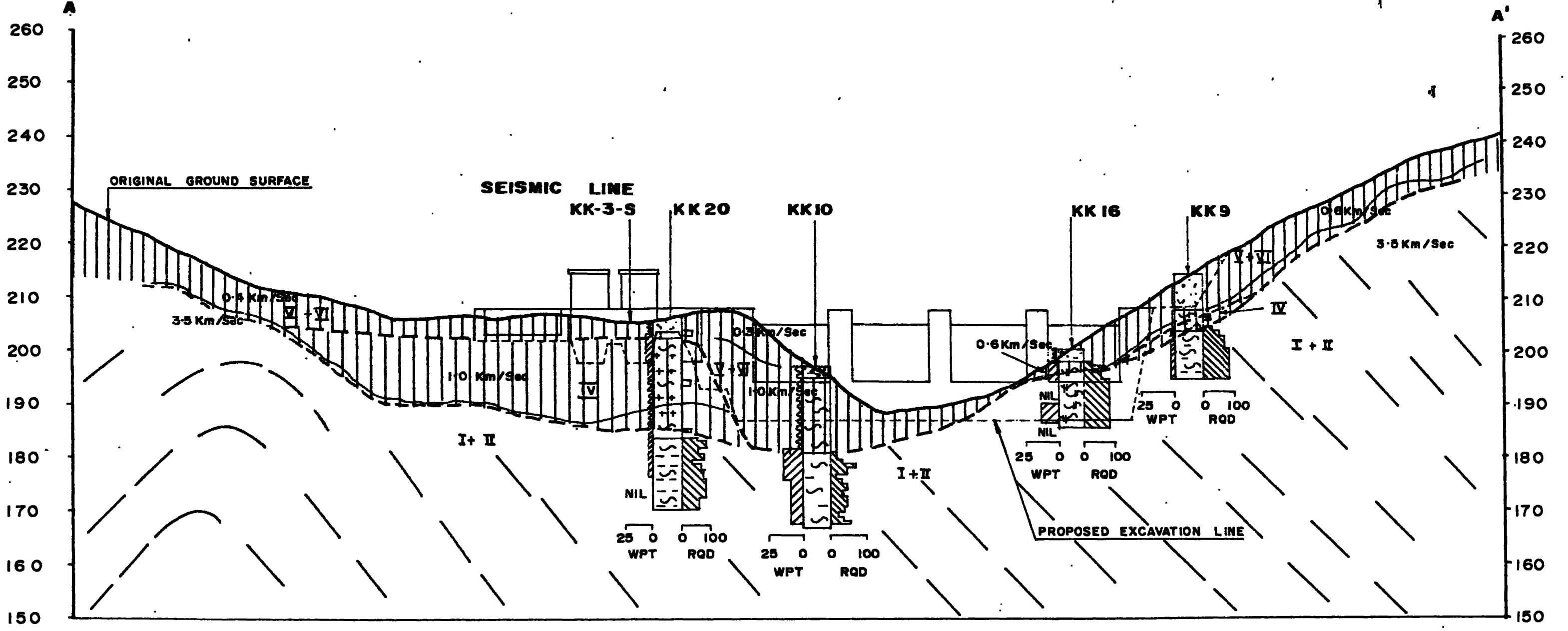
CECB, TEAMS, RDC

FIGURE : 14 (2/2)

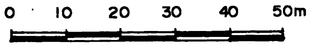
Structural Diagrams
Great Circle Diagram of Discontinuities

SECTION ALONG A-A'

(FOR LOCATION OF THIS SECTION SEE FIG. No.2 (2/6) FIG. 8 (2/2)



SCALE: 1 : 1000

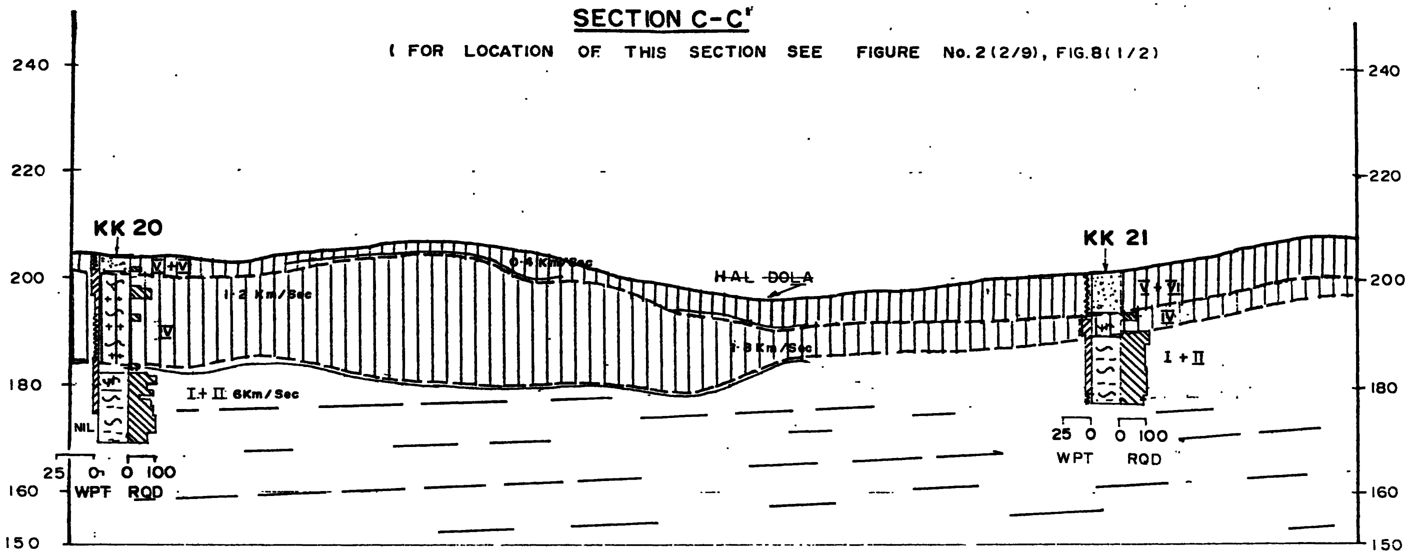


NOTE : OUTLINES OF STRUCTURES PROJECTED INTO THE GEOTECHNICAL SECTION; LEGEND SEE FIG. 10 (1/2)

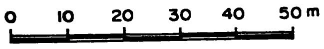
KUKULE GANGA HYDROPOWER PROJECT		FIGURE - 15
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	Geotechnical Section Along 205 Dam Axis (Old)

SECTION C-C'

(FOR LOCATION OF THIS SECTION SEE FIGURE No.2(2/9), FIG.8(1/2)



SCALE - 1 : 1000



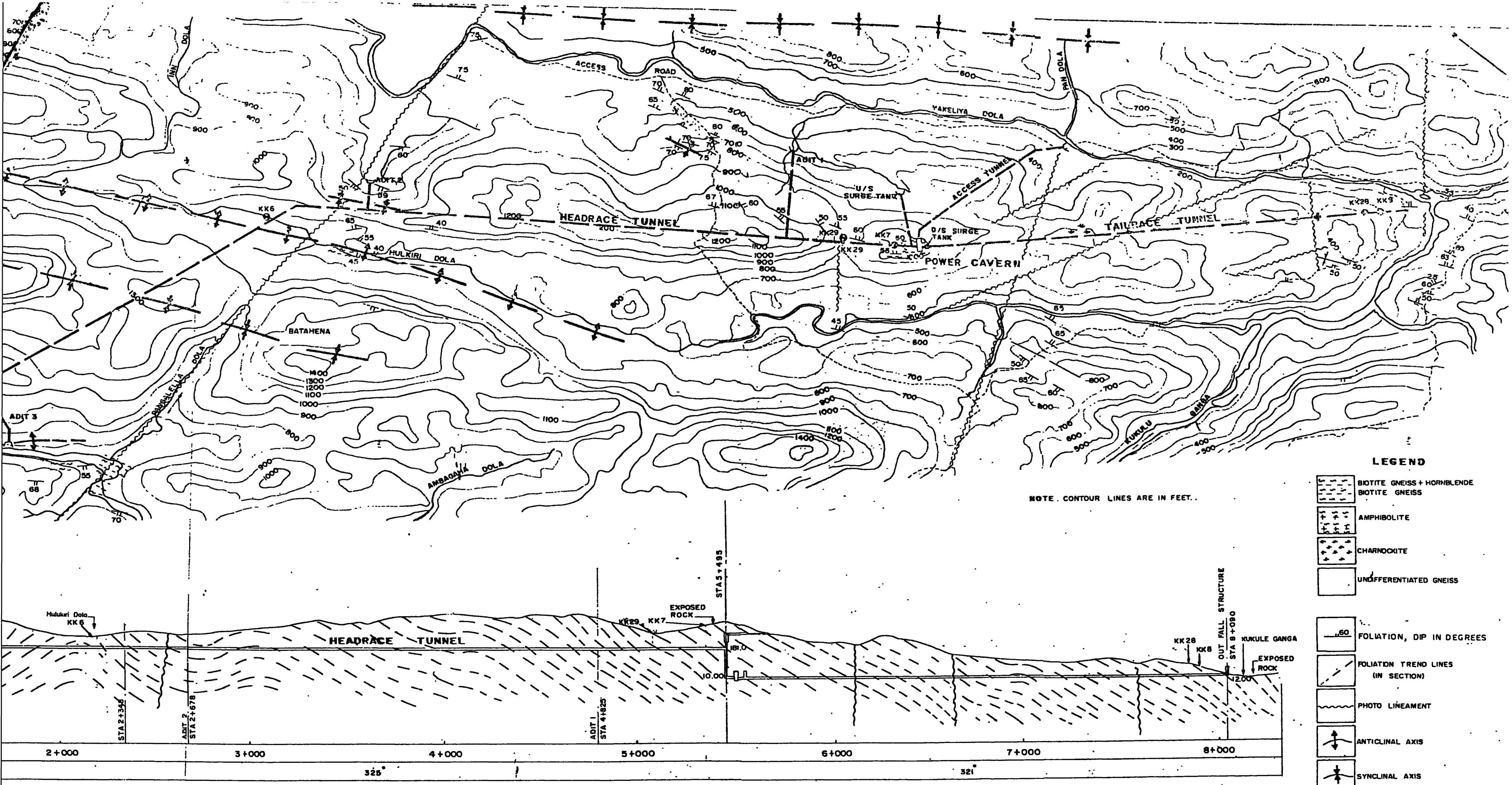
KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI
CECB, TEAMS, RDC

FIGURE : 16

Geotechnical Section Along Desander of KK 205 Dam (Old)



6 - 92	68 - 84	76-92	49-68	68 - 84	56-64	76 - 92		76 - 92	49-68	76-92	49-68	56 - 64	76 - 92	49-68	76 - 92	68-84	30-35
3 - 200	13 - 81	33-200	2 - 14	13 - 81	3-9	33 - 200		33 - 200	2 - 14	33-200	2 - 14	3 - 9	33 - 200	2-14	33 - 200	13-81	02-20
I/II	I/II	I/II	I/II-III	I/II	I/II-III	I/II		I	I/II-III	I/II	I/II-III	I/II-III	I/II-III	I-II	I/II	I/II	IV
650	200	200	100	950	1250	700		475	100	485	100	450	425	100	250	100	50

LRACE TUNNEL

CK MASS CLASS	LENGTH OF SECTION (m)	RELATIVE LENGTH%
I / II	475-50-485-50-225-50 425-250 = 2110	83.2
III	50-50-225-50 = 375	14.8
IV	50	2.0
	TOTAL LENGTH = 2535	100.0

500 1000

RIZONTAL AND VERTICAL SCALE

ROCK MASS CLASSIFICATION ADOPTED IN PROJECT

CLASS	SUPPORT	CORRESPONDING RATING	
		CSIR (RMR)	NGI (Q)
I/II	NO SUPPORT, LOCAL BOLTS	> 60	>6.0
III	SYSTEMATIC BOLTS WIRE MESH AND SHOTCRETE	20 - 60	0.1 - 6.0
IV	LIGHT TO MEDIUM STEEL RIBS. BOLTS WIRE MESH + SHOTCRETE	< 20	<0.1

KUKULE GANGA HYDROPOWER PROJECT

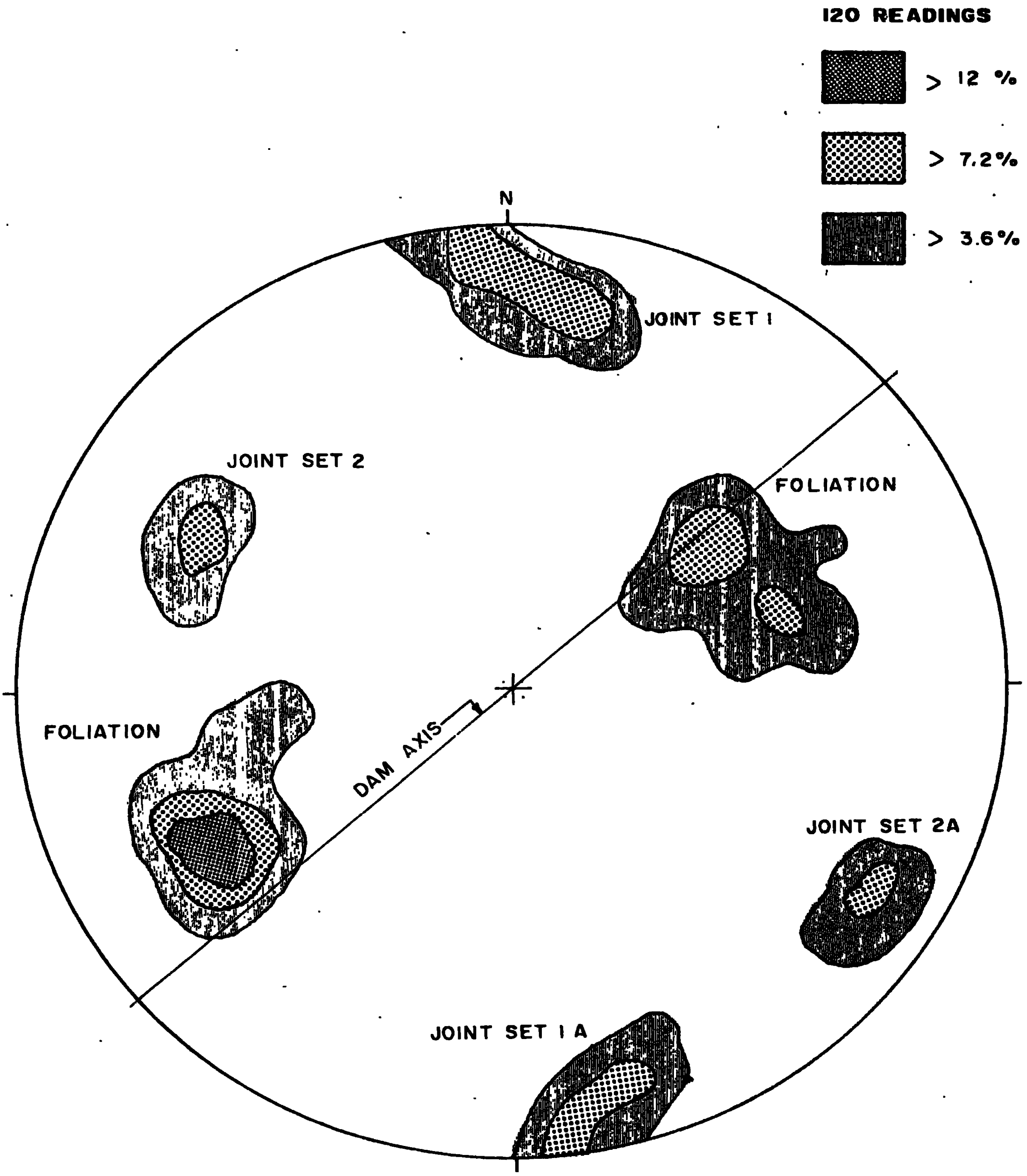
Ceylon Electricity Board
(IDA)

Joint Venture Kukule Ganga
NK, EWI & LI

CECB, TEAMS

FIGURE : 17
Geotechnical Section Along Waterways
KK 205/230 (Old)

POLAR EQUAL AREA PROJECTION LOWER HEMISPHERE



FOLIATION : 052°-074°/ 46°-68°
224°-260°/ 33°-50°
JOINT SET1 : 172°-194°/ 65°-90°
JOINT SET 1A : 343°-360°/ 70°-90°
JOINT SET 2 : 298°-308°/ 70°-80°
JOINT SET 2A : 110°-120°/ 55°-65°

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

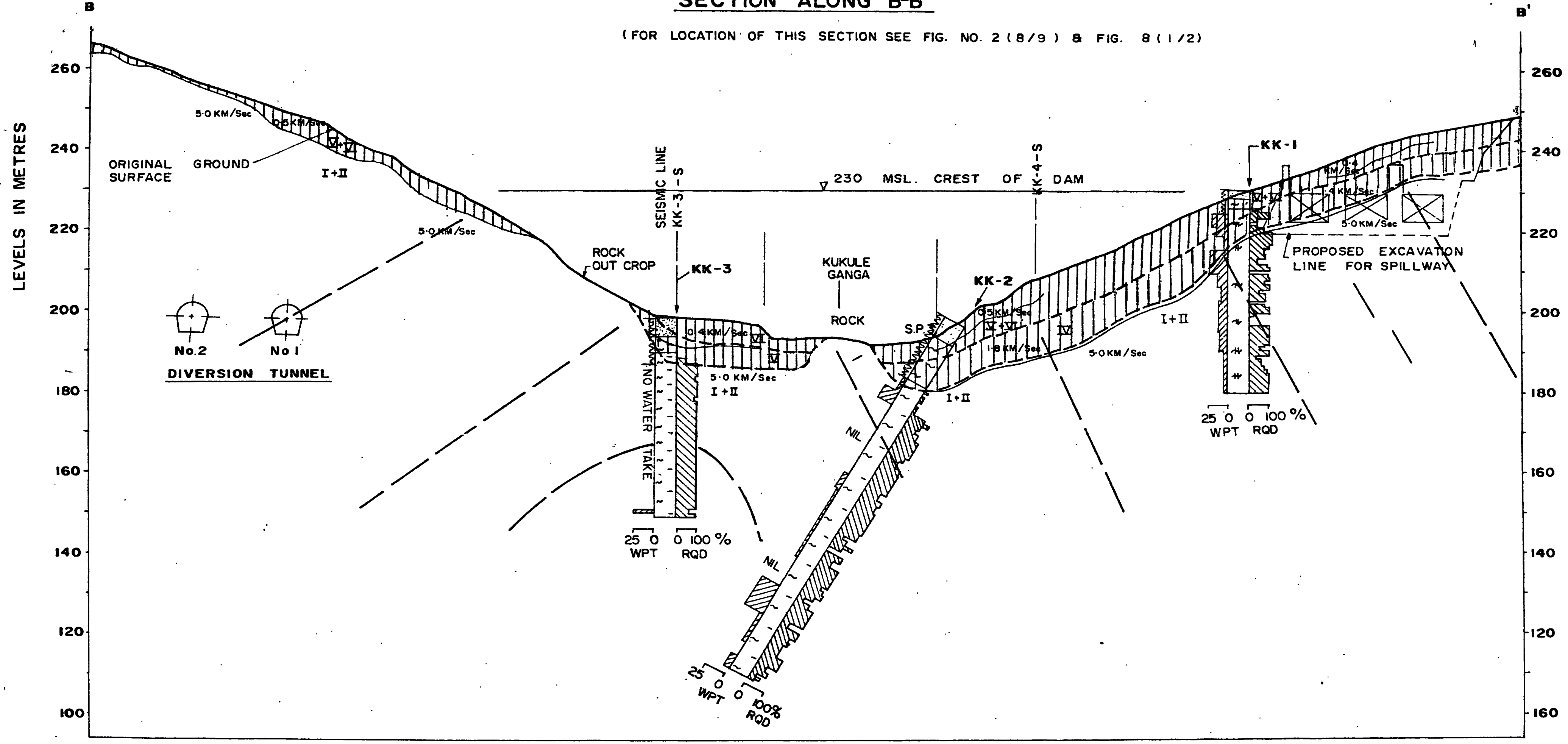
Joint Venture Kukule Ganga
NK, EWI & LI

CECB, TEAMS, RDC

FIGURE : 18
Structural Diagrams
Distribution of Foliations and Joints
KK 205 Dam Site (Old)

SECTION ALONG B-B'

(FOR LOCATION OF THIS SECTION SEE FIG. NO. 2 (8/9) & FIG. 8 (1/2)



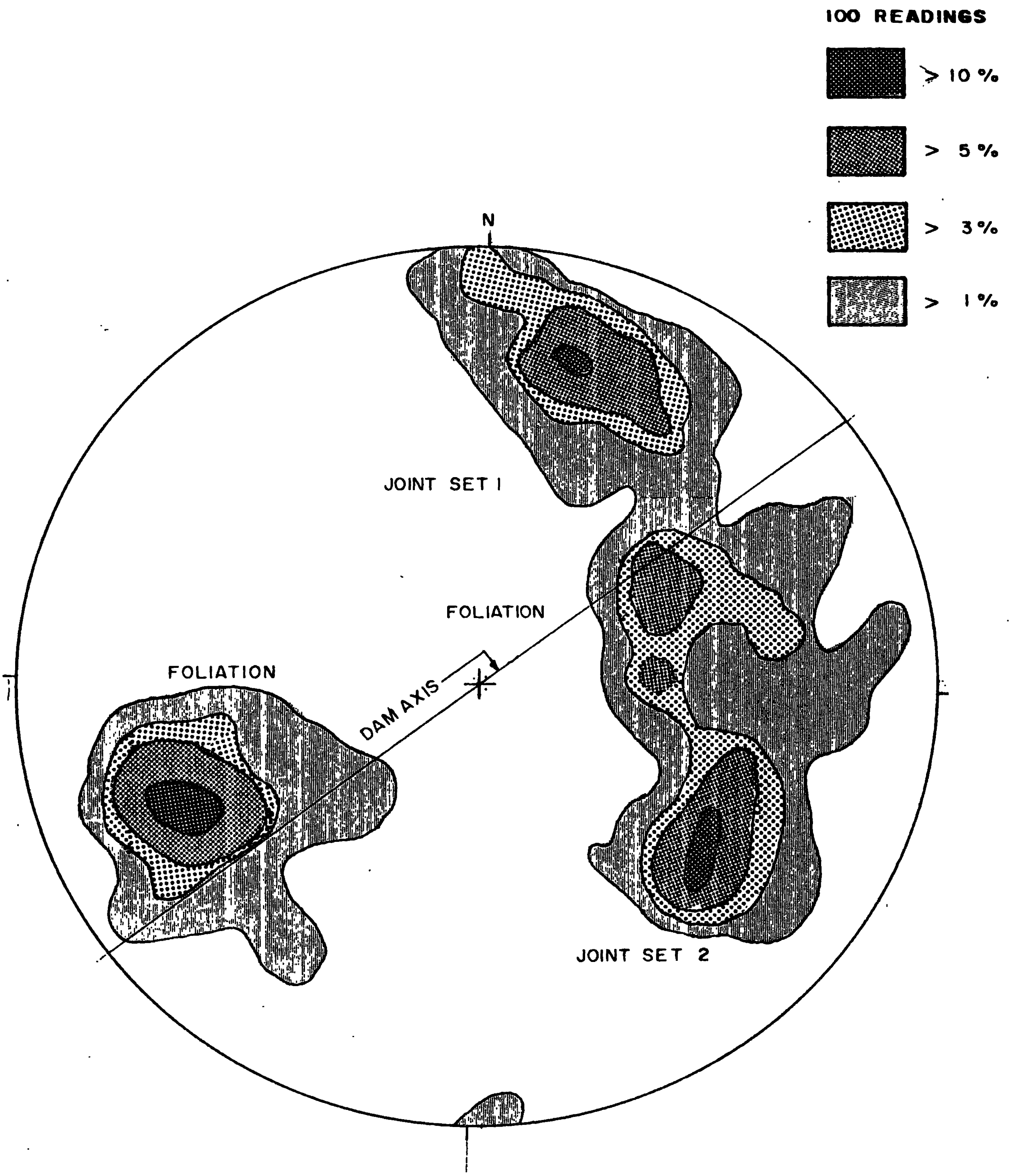
NOTE

FOR LEGEND SEE FIG. NO. 10 (1/2)
OUTLINES OF STRUCTURES PROJECTED
INTO THE GEOTECHNICAL SECTION

SCALE - HORIZONTAL 1 : 1000
VERTICAL 1 : 1000
0 10 20 30 40 50 m

KUKULE GANGA HYDROPOWER PROJECT		FIGURE : 19 Geotechnical Section Along Dam Axis KK - 230
Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI	
Ceylon Electricity Board	CECB, TEAMS, RDC	

POLAR EQUAL AREA PROJECTION LOWER HEMISPHERE



FOLIATION : 054°- 079° / 44°- 72°
FOLIATION : 227°- 253° / 32°- 45°
JOINT SET I : 188°- 208° / 56°- 75°
JOINT SET 2 : 287°- 316° / 43°- 63°

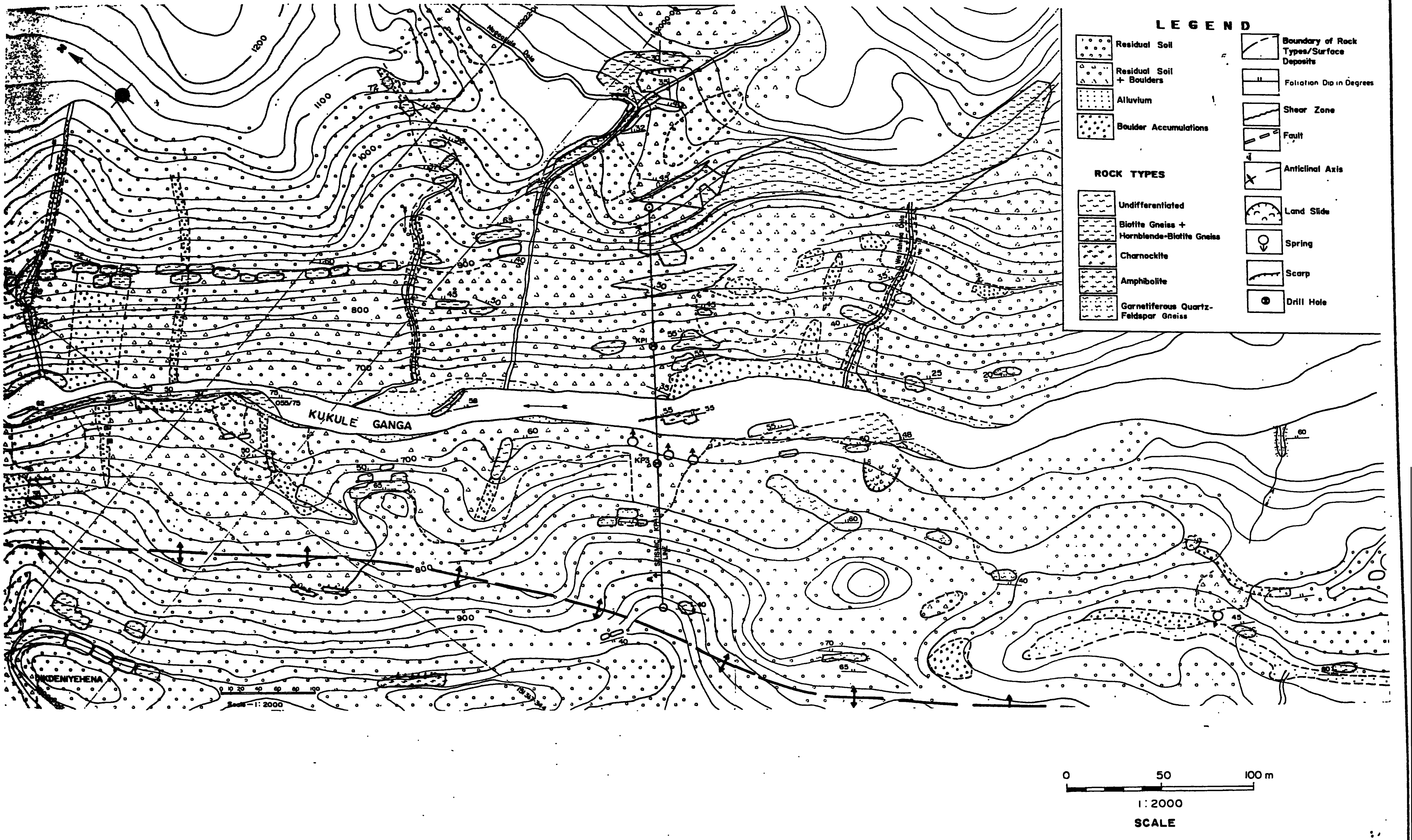
KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

CECB, TEAMS, RDC

FIGURE : 20
Structural Diagrams
Distribution of Foliations and Joints
K K 230 Dam (Eliminated)



KUKULE GANGA HYDROPOWER PROJECT

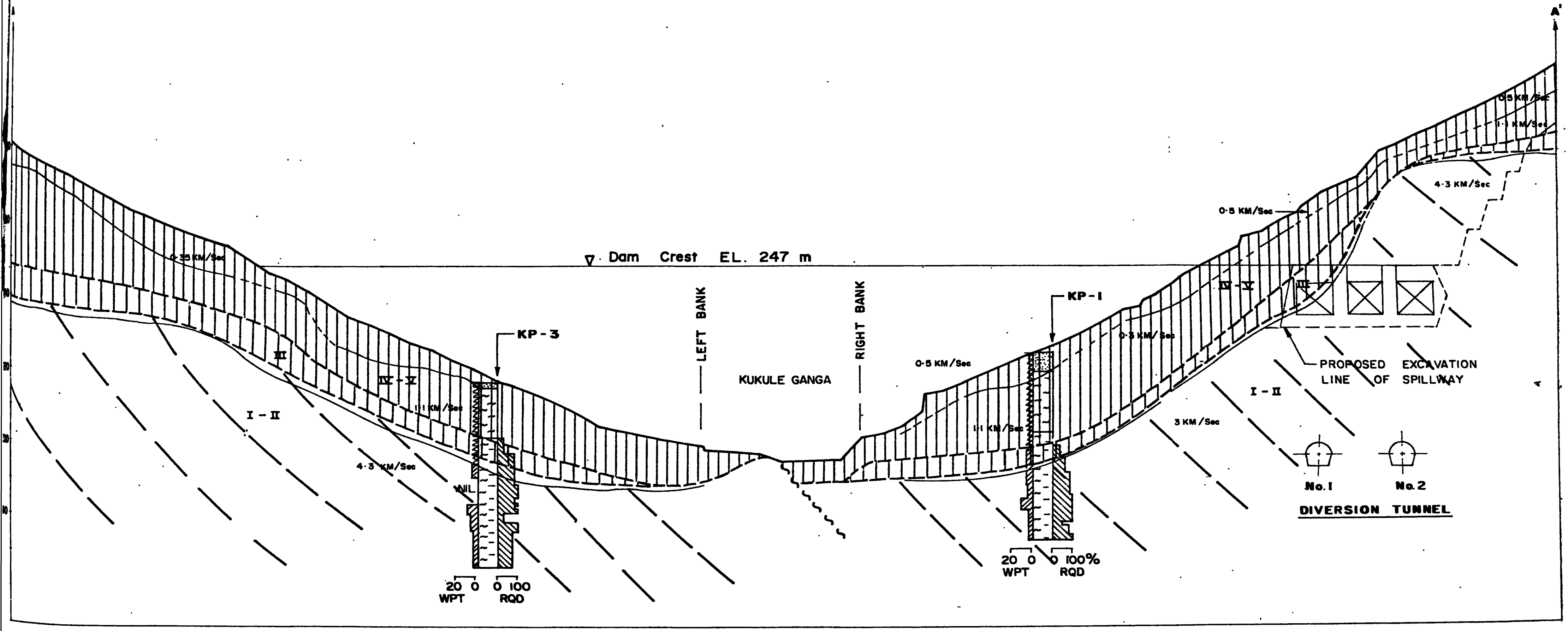
Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI
Ceylon Electricity Board	CECB, TEAMS, RDC

FIGURE : 21

Geological Map of Dam Site Area - KP Plan.

SECTION ALONG A-A'

(FOR LOCATION OF THIS SECTION SEE FIG. NO. 23)



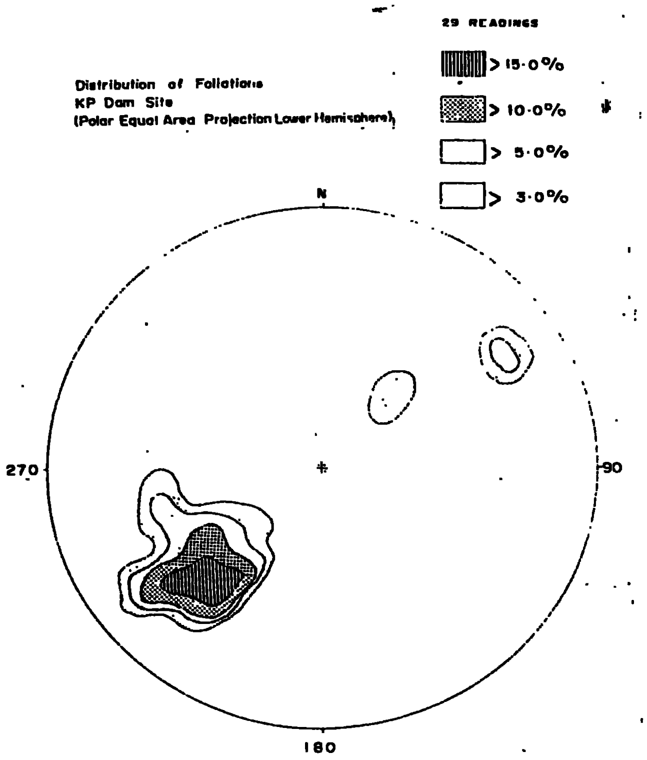
FOR LEGEND SEE FIG. NO.

SCALE - HORIZONTAL 1:1000
VERTICAL 1:1000

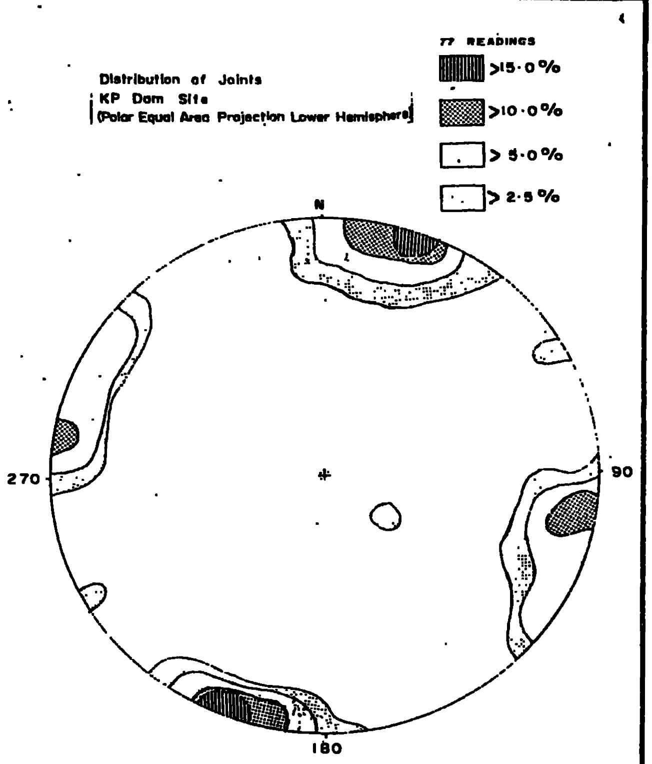
0 10 20 30 40 50 m

KUKULE GANGA HYDROPOWER PROJECT
Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board
Joint Venture Kukule Ganga
NK, EWI & LI.
CECB, TEAMS, RDC

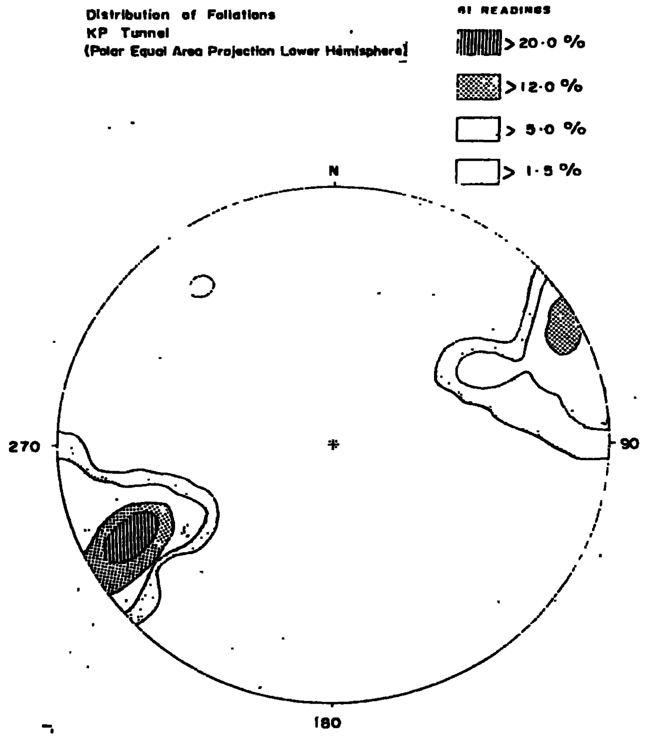
FIGURE : 22 .
Geotechnical Section Along Dam Axis KP



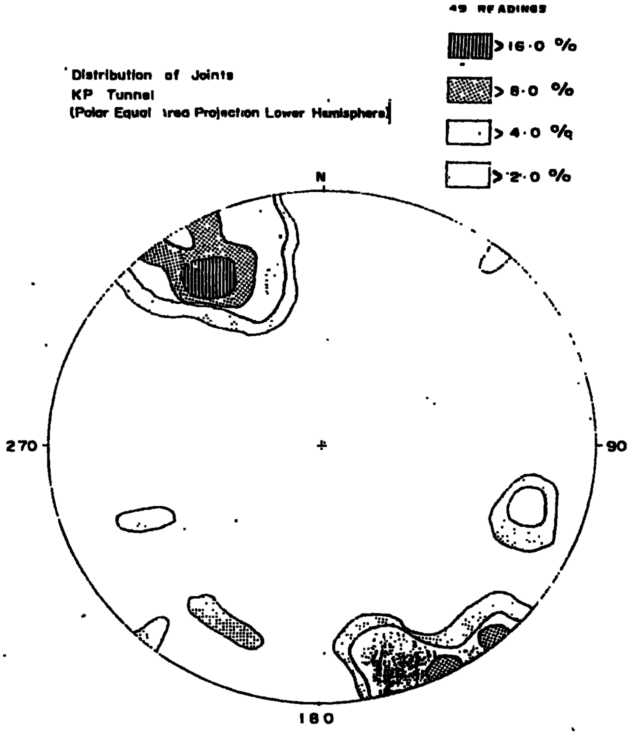
Distribution of Foliations
KP Dam Site
(Polar Equal Area Projection Lower Hemisphere)



Distribution of Joints
KP Dam Site
(Polar Equal Area Projection Lower Hemisphere)



Distribution of Foliations
KP Tunnel
(Polar Equal Area Projection Lower Hemisphere)



Distribution of Joints
KP Tunnel
(Polar Equal Area Projection Lower Hemisphere)

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	FIGURE : 24 Structural Diagrams K-P Plan

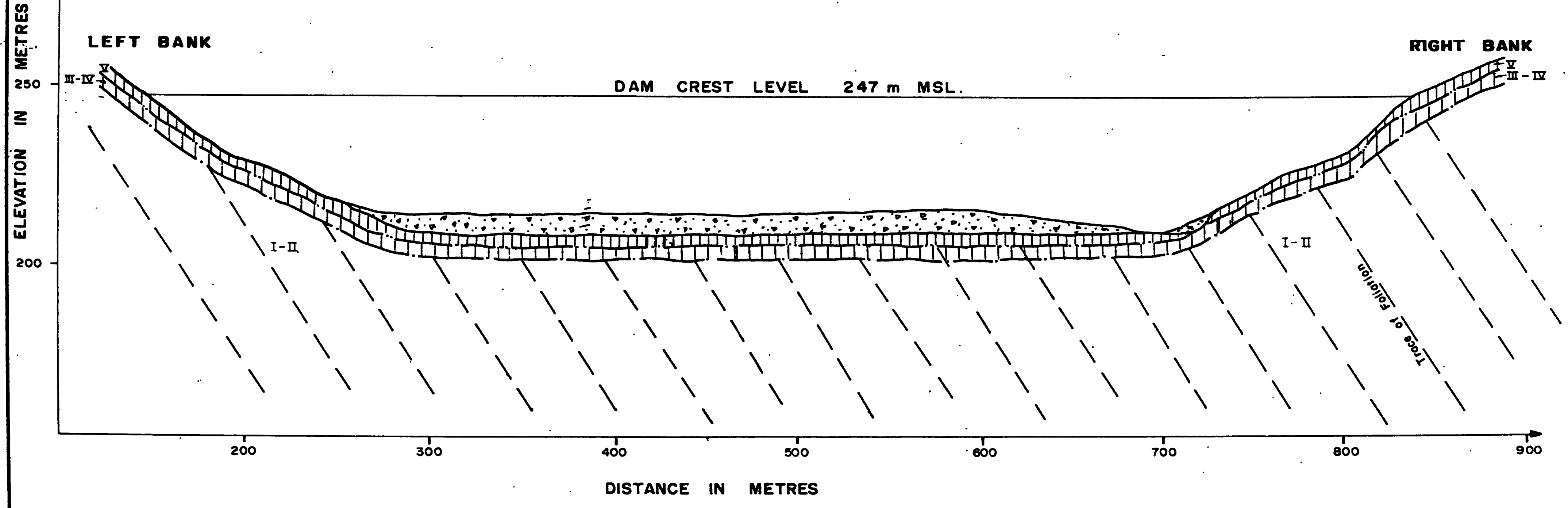
ORIENTATION OF DAM AXIS ~ N 62° E

WEATHERING

Left Bank
Grade III - IV : 2 - 4 m
Grade I - II : 4 - 8 m

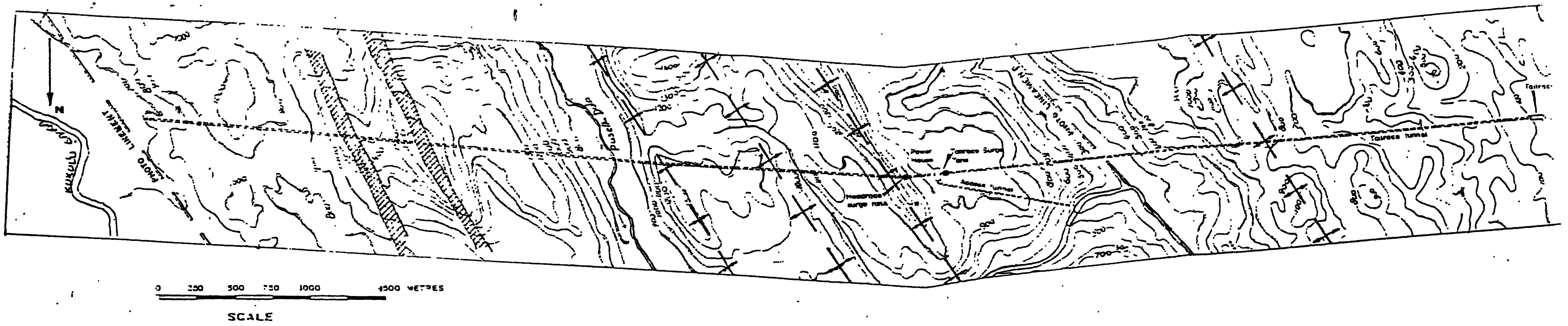
Flood Plain
Alluvium : 5 - 7 m
Grade III - IV : 7 - 13 m
Grade I - II : 9 - 17 m

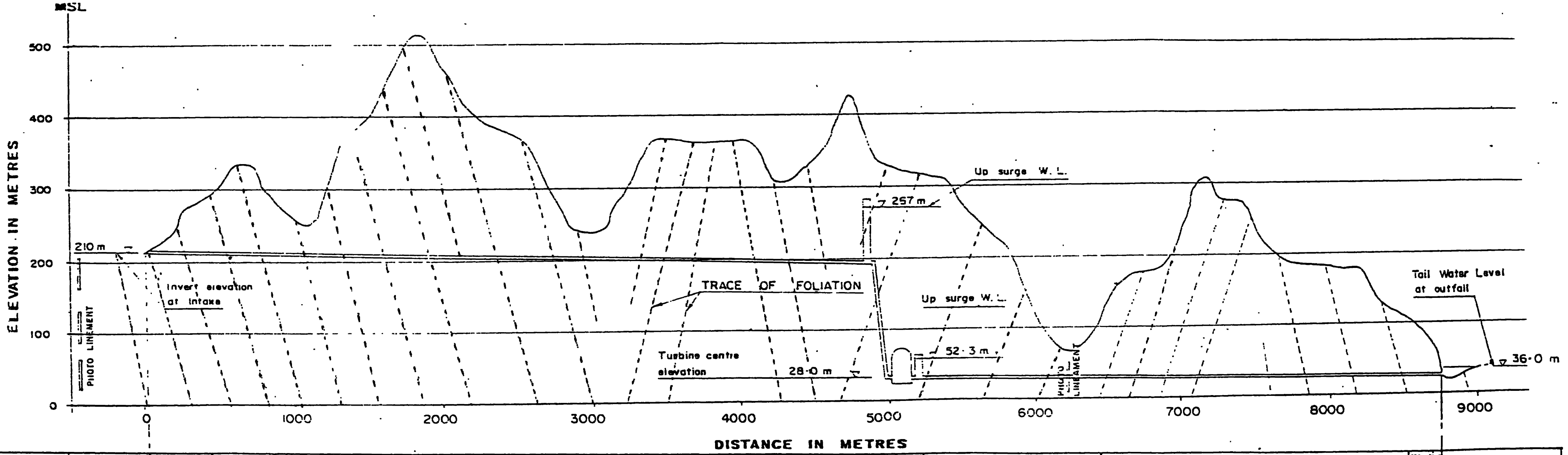
Right Bank
Grade III - IV : 2 - 6 m
Grade I - II : 4 - 10 m



SCALE : Vertical 1 : 1000
Horizontal 1 : 1000

KUKULE GANGA HYDROPOWER PROJECT		FIGURE : 25
Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI	Geotechnical Section Along Dam Axis K-D Plan.
Ceylon Electricity Board	CECB, TEAMS, RDC	





ROCK MASS													
Quality.		iii - iV	i - ii	iii - iV	i - ii	iii - iV	i - ii		i - ii	iii - iV	i - ii	iii-iV	
Support		+	*	+	*	+	*		*	+	*	+	
SECTION LENGTH (m)		410	450	330	1465	400	1585		850	405	2225	250	

HEADRACE TUNNEL

Rock Mass Class	Length of Section (m)	Relative Length %
I	335 + 1100 + 1190 = 2625	56 6
ii	115 + 365 + 395 = 875	18·9
iii	385 + 290 + 360 = 1035	22·2
iV	25 + 40 + 40 = 105	2·3
	TOTAL LENGTH = 4640	100·0

TAILRACE TUNNEL

Rock Mass Class	Length of Section (m)	Relative Length %
i	640 + 1670 = 2310	61·9
ii	210 + 555 = 765	20·5
iii	355 + 225 = 580	15·5
iV	50 + 25 = 75	2·1
	TOTAL LENGTH = 3730	100·0

LEGEND

\+ SYSTEMATIC BOLTS, WIRE MESH & SHOTCRETE / LIGHT TO MEDIUM STEEL RIBS, BOLTS, WIRE MESH & SHOTCRETE IN CROWN & SIDE WALLS

* NO SUPPORTS / LOCAL BOLTS IN CROWN.

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

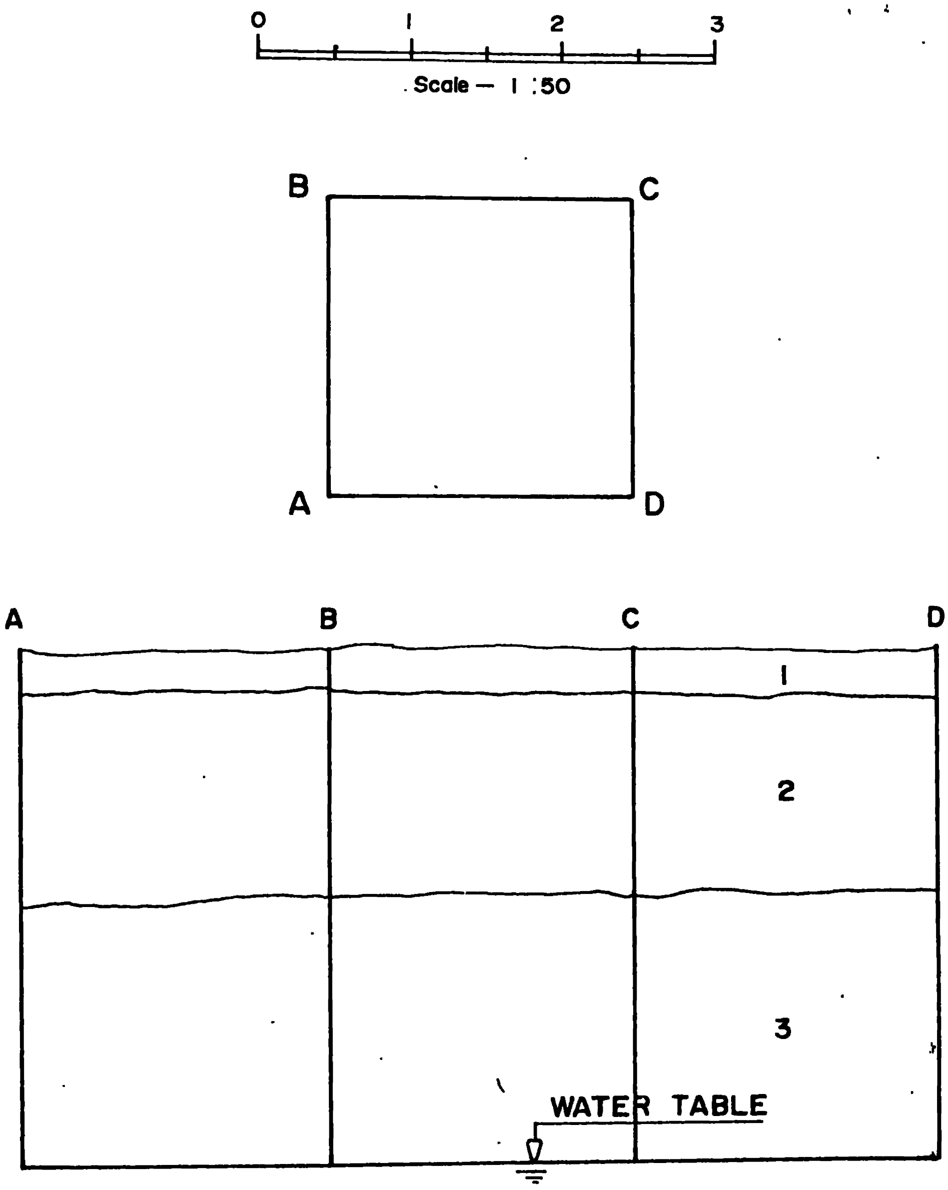
Joint Venture Kukule Ganga
NK, EWI & LI

CECB, TEAMS, RDC

FIGURE : 26
Geotechnical Section Along Waterways
K-D Plan.

GEOLOGIC LOG OF TEST PIT No. I

LOCATION- KK 205 DAM / DESANDER

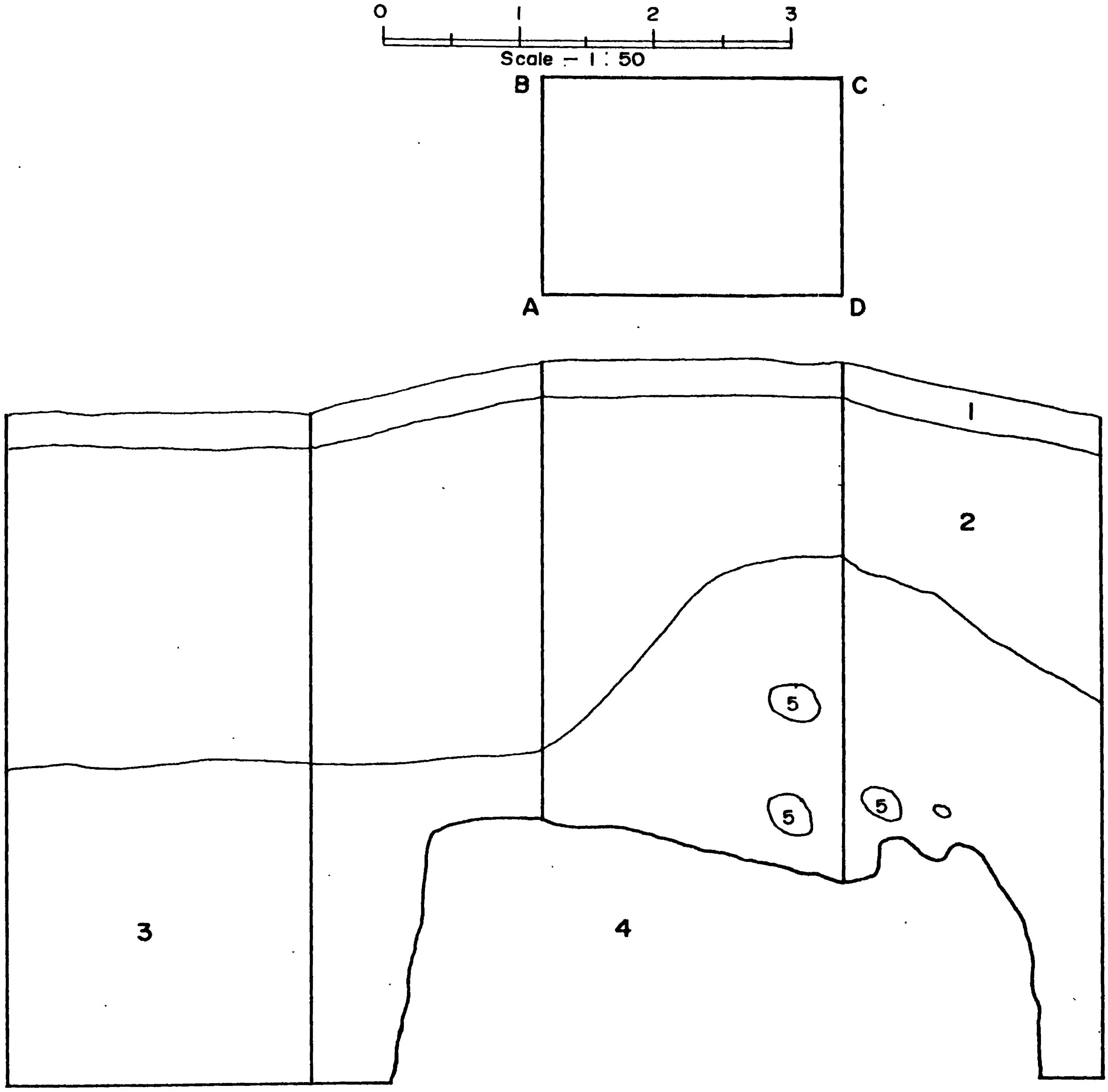


1. BLACK CLAYEY TOP SOIL
2. YELLOWISH BROWN CLAYEY GRAVELLY SAND (ALLUVIUM)
   (ROUNDED GRAVEL 5-25 mm)
3. SUBROUNDED
   WEATHERED BOULDERS (30 Cm - Im)
   OF GARNETIFEROUS GNEISS WITH ROUNDED GRAVEL (ALLUVIUM)

KULE GANGA HYDROPOWER PROJECT		Figure 27 (1/24)
ernment of Sri Lanka y of Power and Energy n Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	Geologic Log of Test Pit

GEOLOGIC LOG OF TEST PIT No. 2

LOCATION - KK 205 DAM / DESANDER

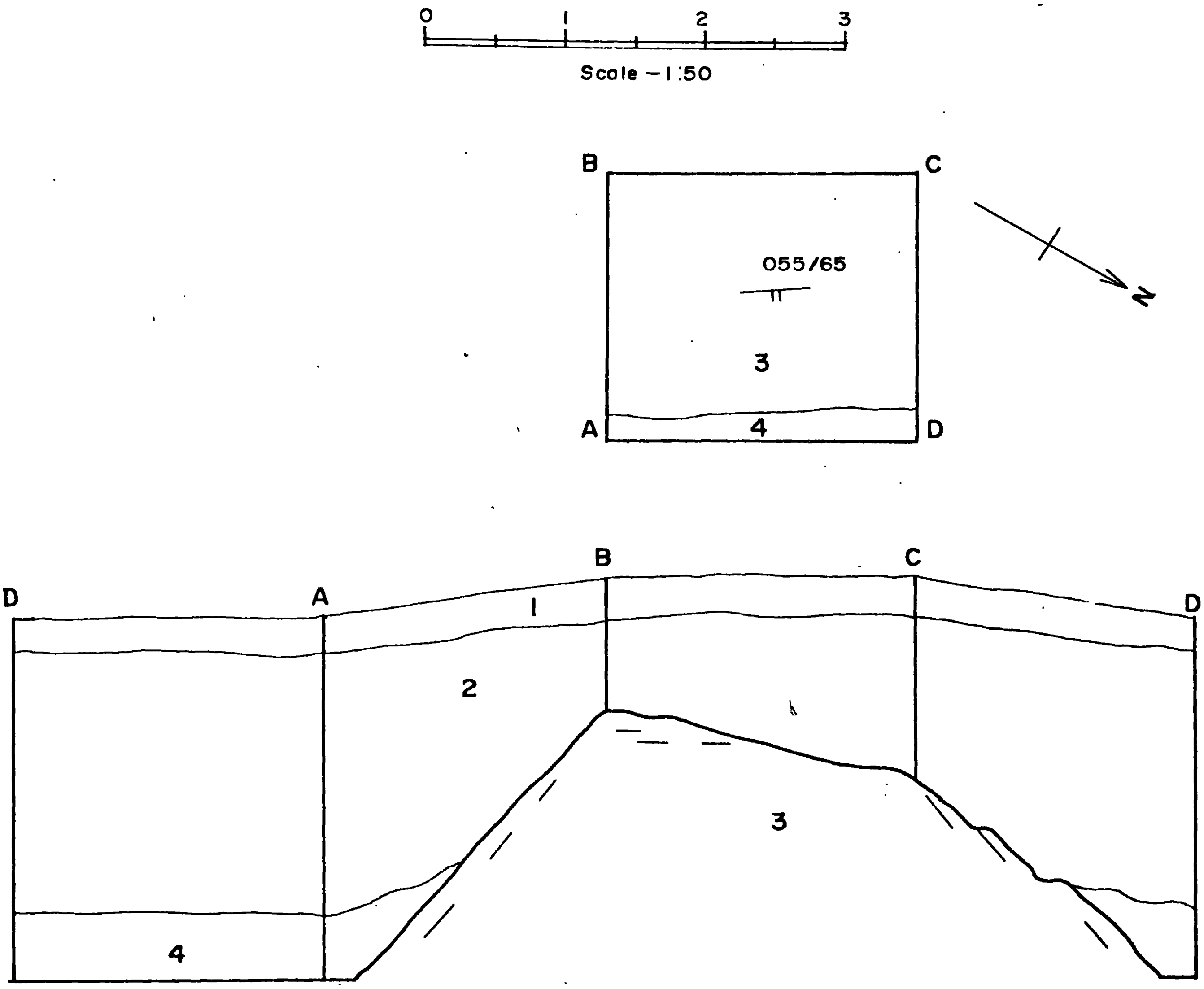


1. BLACK CLAYEY TOP SOIL
2. YELLOWISH SANDY CLAY
3. REDDISH SANDY GRAVEL WITH COBBLES OF WEATHERED GNEISS
4. MODERATELY WEATHERED STRONG GARNETIFEROUS BIOTITE GNEISS
5. CORE STONES

KUKULE GANGA HYDROPOWER PROJECT		**Figure 27 (2/24)**
Government of Sri Lanka **Ministry of Power and Energy**	**Joint Venture Kukule Ganga** **NK, EWI & LI**	**Geologic Log of Test Pit**
Ceylon Electricity Board	CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 3

LOCATION- KK 205 DAM/ DESANDER



1 BLACK CLAYEY TOP SOIL WITH HUMUS

2 RESIDUALSOIL, YELLOWISH/ REDDISH BROWN CLAYEY SAND WITH GRAVEL

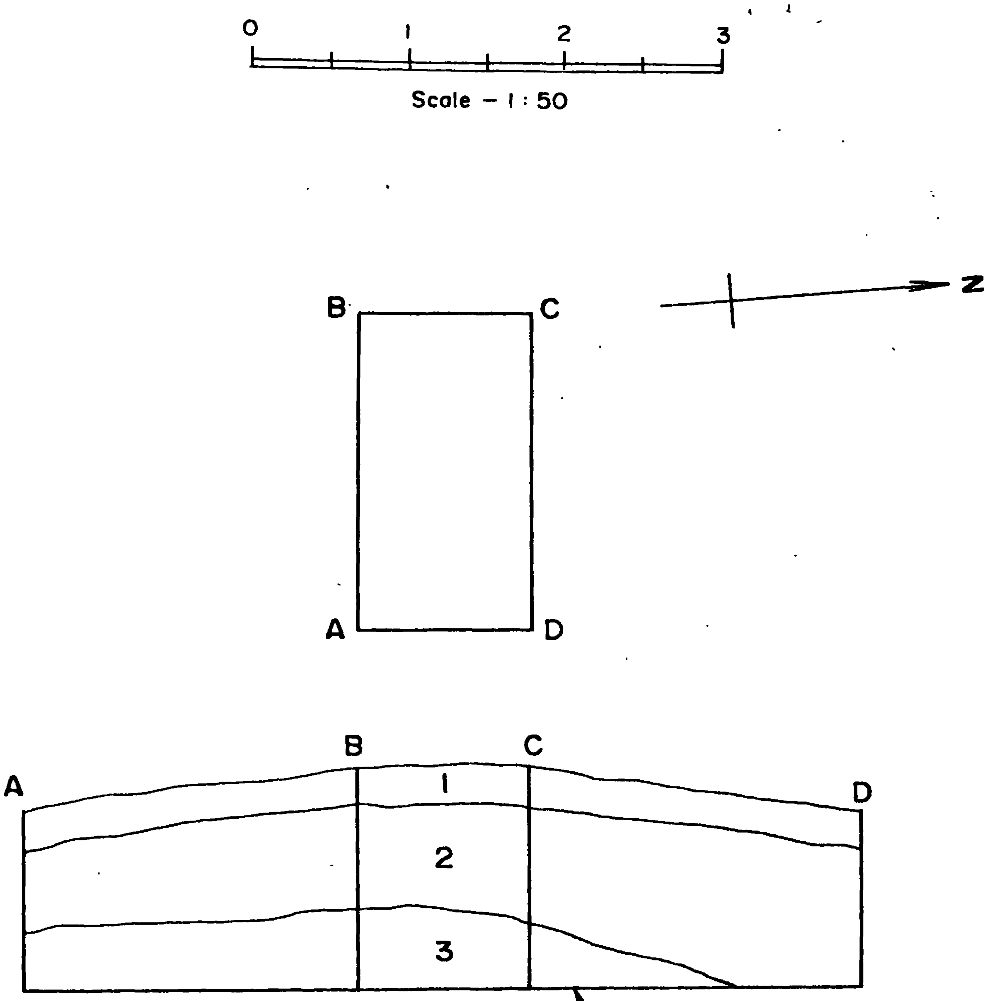
3 HARD MODERATELY TO HIGHLY WEATHERED GARNETIFEROUS BIOTITE GNEISS WITH FRESH CORE STONES

4 COMPLETELY WEATHERED ROCK (REDDISH BROWN CLAYEY SAND)

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (3/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 4

LOCATION – KK 205 DAM/ DESANDER



AT THE BOTTOM HIGHLY WEATHERED AMPHIBOLITE. CANNOT BE EKCAVATED MANUALLY

1. BLACKISH CLAYEY TOP SOIL WITH HUMUS

2. RESIDUAL SOIL, YELLOWISH BROWN CLAYEY SAND, MEDIUM GRANED

3. COMPLETELY WEATHERED AMPHIBOLITE (YELLOWISH BROWN CLAYEY GRVEL WITH COBBLES)

KUKULE GANGA HYDROPOWER PROJECT

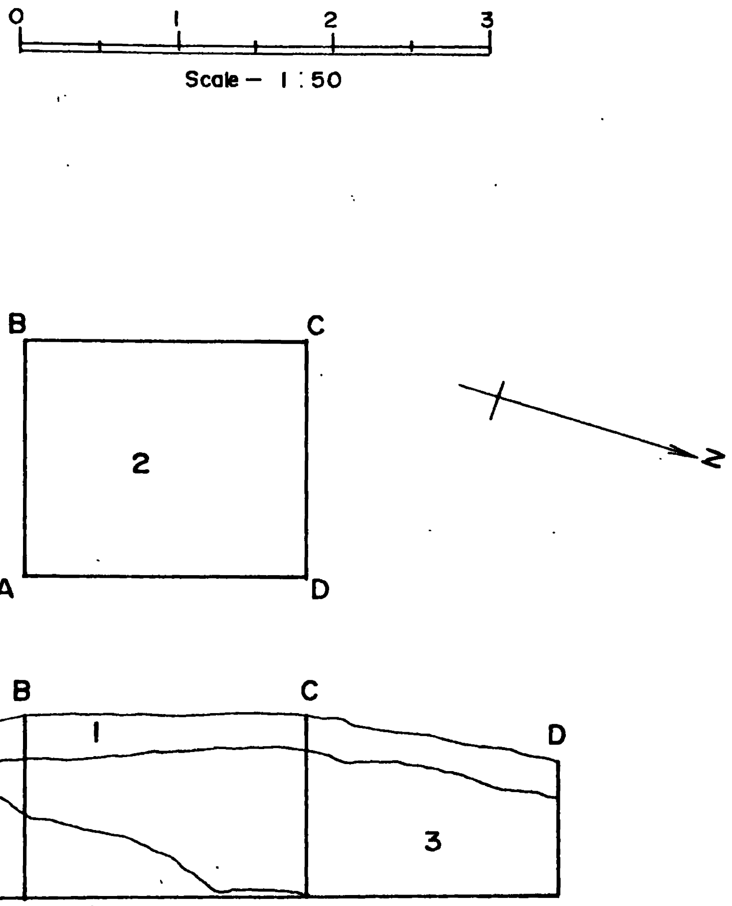
Government of Sri Lanka Ministry of Power and Energy	Joint Venture Kukule Ganga NK, EWI & LI
Ceylon Electricity Board	CECB, TEAMS, RDC

Figure 27 (4/24)

Geologic Log of Test Pit

GEOLOGIC LOG OF TEST PIT No. 5

LOCATION - KK 205 DAM/ DESANDER



1. BLCK CLAYEY TOP SOIL WITH HUMUS

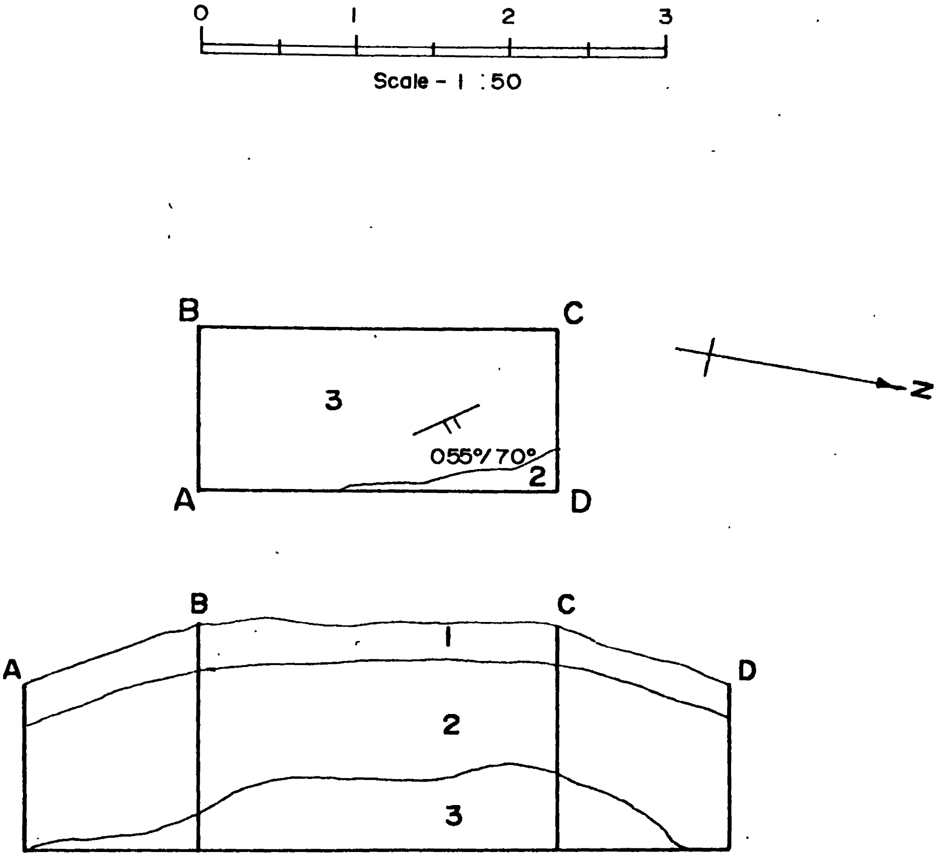
2. HARD HIGHLY WEATHERED ROCK WITH FRESH AMPHIBOLITE CORE STONES

3. RESIDUAL SOIL CLAYEY GRAVEL

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (5/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 6

LOCATION - KK 205 DAM / DESANDER



1. BLACK CLAYEY / SILTY TOP SOIL WITH HUMUS

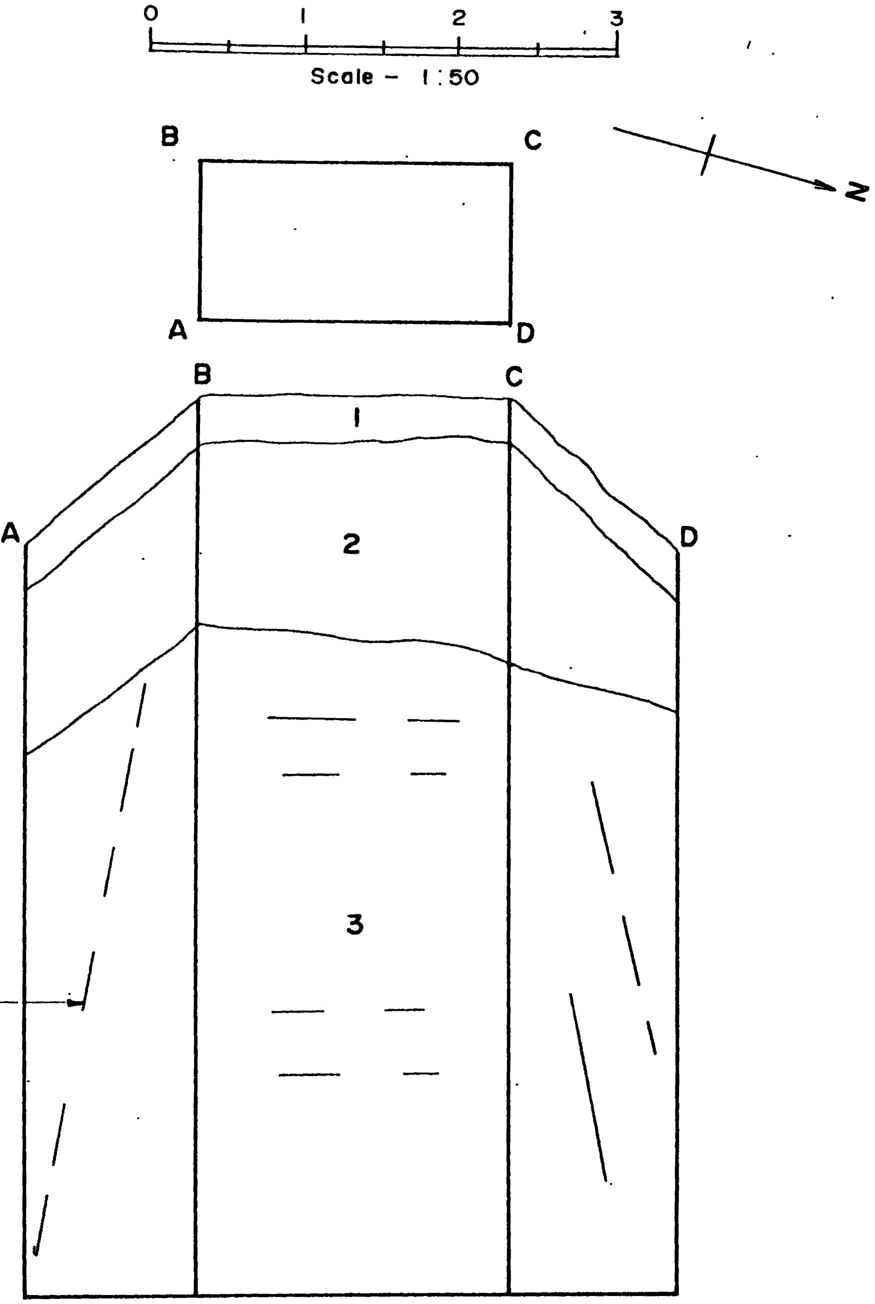
2. RESIDUALSOIL YELLOWISH BROWN CLAYEY SAND/GRAVEL

3. BROWNISH RED HIGHLY WEATHERED ROCK, HARD

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (6/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 7

LOCATION - KK 205 DAM / DESANDER

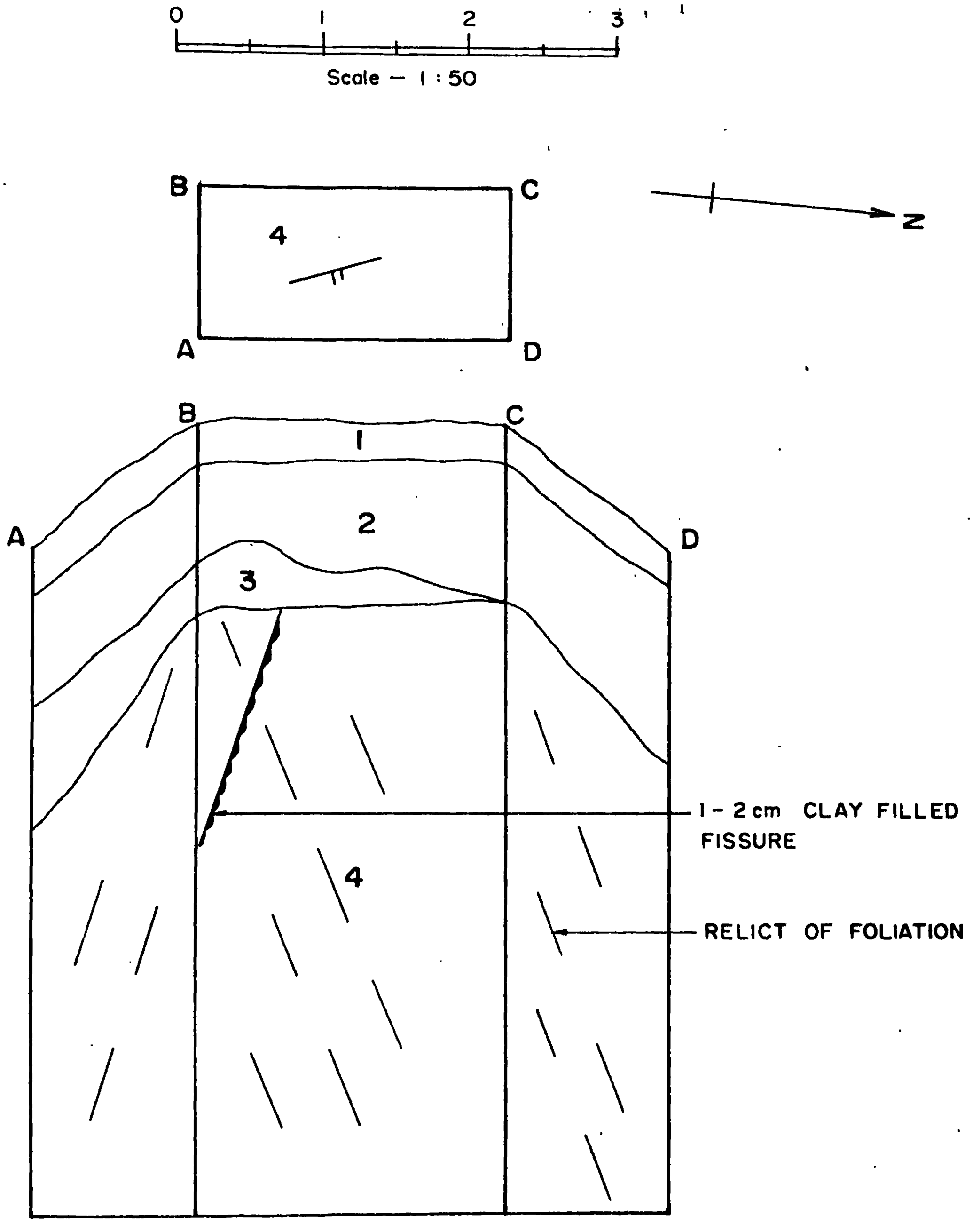


1. BLACK CLAYEY TOP SOIL WITH HUMUS
2. RESIDUAL SOIL YELLOWISH BROWN CLAYEY COARSE SAND / CLAYEY GRAVEL WITH COBBLES
3. REDDISH BROWN / REDDISH COMPLETELY WEATHERED GARNETIFEROUS ROCK WITH HIGHLY WEATHERED CORE STONES. WEAK (CLAYEY SAND / COARSE GRAVEL WITH COBBLE UPTO 30 Cm.)

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (7/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 8

LOCATION - KK 205 DAM / DESANDER

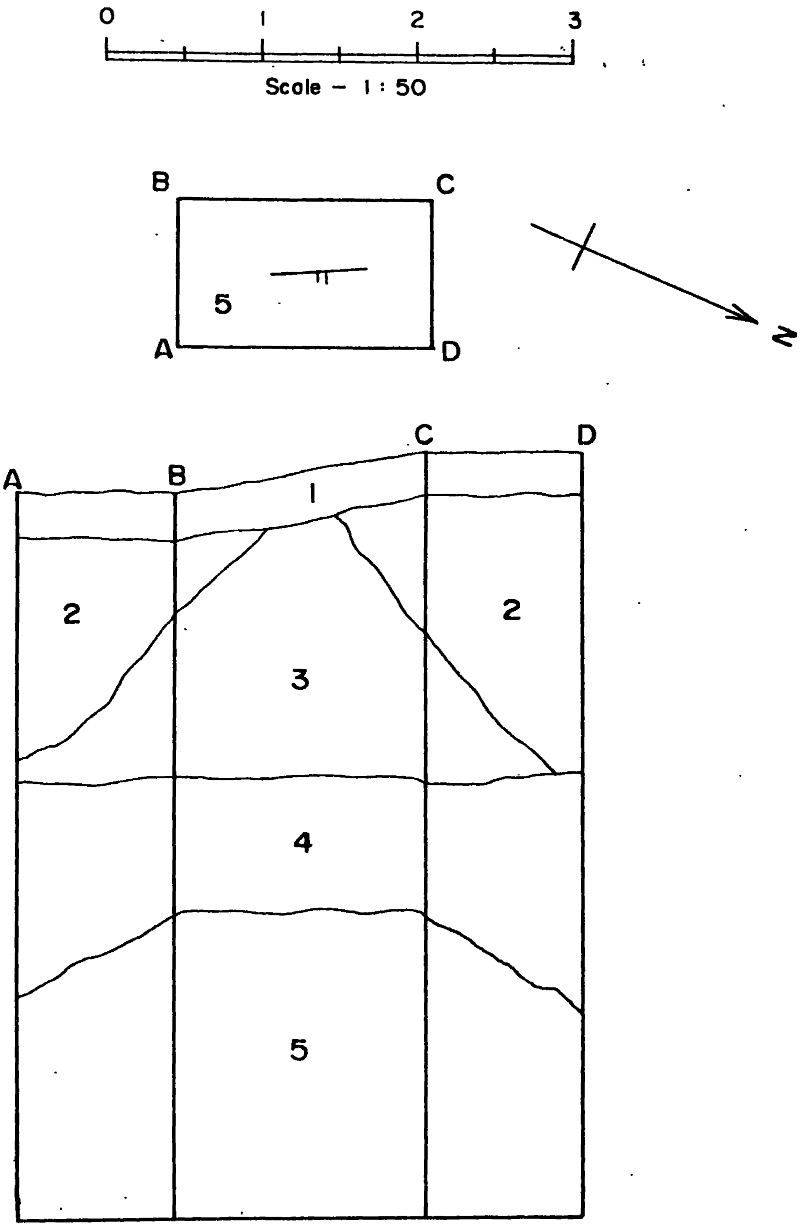


1. BLACK CLAYEY TOP SOIL WITH HUMUS
2. RESIDUAL SOIL BROWN VERY CLAYEY COARSE SAND /GRAVEL
3. REDDISH LATERITE. WEAK
4. REDDISH BROWN COMPLETELY WEATHERED GARNETIFEROUS ROCK
   (VERY CLAYEY SAND/GRAVEL WITH WEATHERED COBBLES 30 - 40 Cm)

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (8/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 9

LOCATION - KK 205 DAM / DESANDER

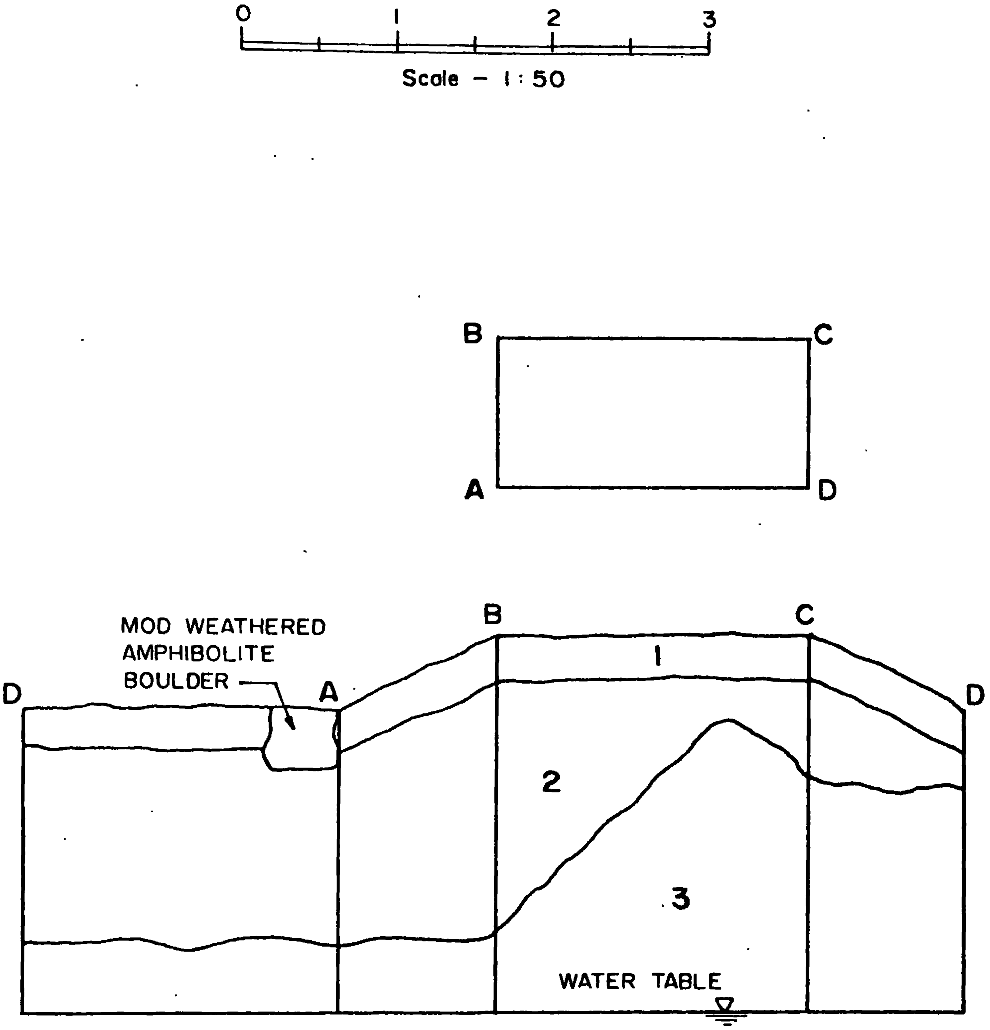


1. BLACK CLAYEY TOP SOIL WITH HUMUS
2. BROWN CLAYEY COARSE SAND WITH COBBLES, PLANT ROOTS
3. HARD REDDISH LATERITE
4. REDDISH BROWN VERY CLAYEY SAND
5. WEAK COMPLETELY WEATHERED GARNETIFEROUS ROCK

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (9/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 10

LOCATION - KK 205 DAM / DESANDER



1. BLACK TOP SOIL CLAYEY SAND WITH ROOTS

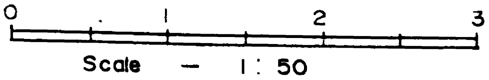
2. REDDISH LATERITE

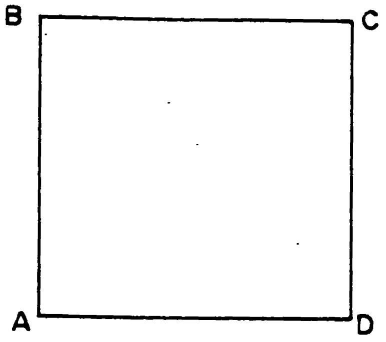
3. YELLOWISH BROWN VERY CLAYEY COARSE SAND/CLAYEY FINE SUBANGLAR GRAVEL

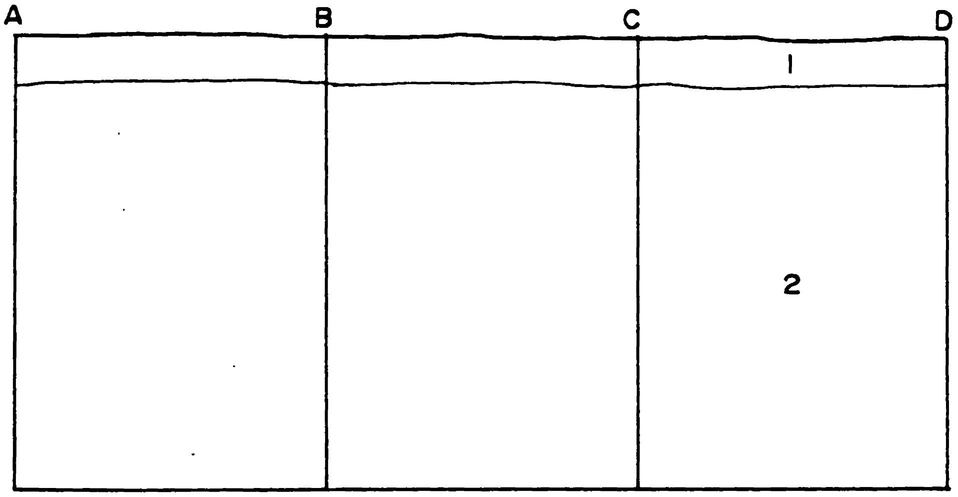
KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (10/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 11

LOCATION - DEPRESSION AT PANGALAELLA







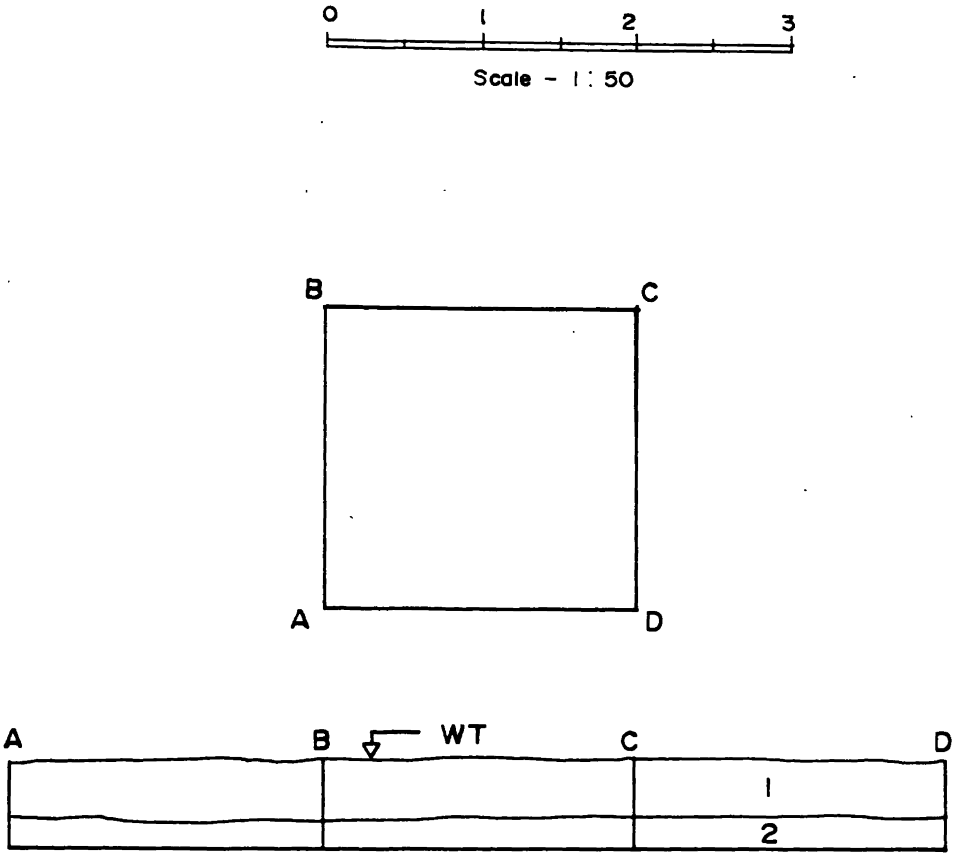
1. BLACK SILTY TOP SOIL

2. YELLOWISH BROWN SILTY FINE / MEDIUM SAND

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (11/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 12

LOCATION - DEPRESSION AT PANGALAELLA



WATER OVERFLOWING

1. CLAYEY BLACK TOP SOIL

2. GRAVELLY CLAY

KUKULE GANGA HYDROPOWER PROJECT

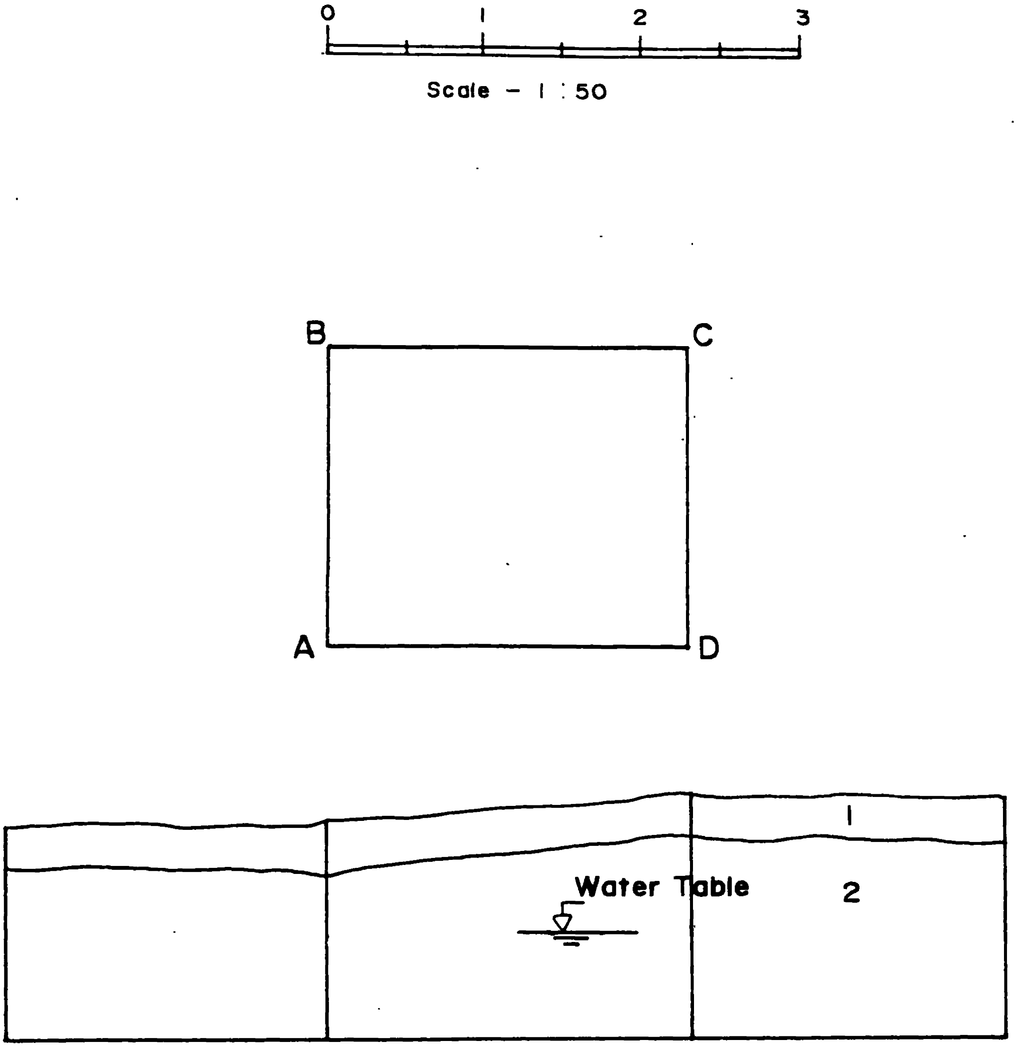
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC

Figure 27 (12/24)

Geologic Log of Test Pit

GEOLOGIC LOG OF TEST PIT No. 13

LOCATION - DEPRESSION AT PANGALAELLA



1. BLACK CLAYEY TOP SOIL

2. YELLOWISH FINESAND / SILT

KULE GANGA HYDROPOWER PROJECT

vernment of Sri Lanka.
try of Power and Energy
lon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

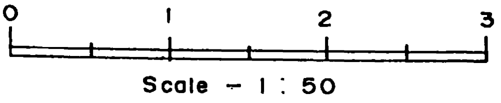
CECB, TEAMS, RDC

Figure 27 (13/24)

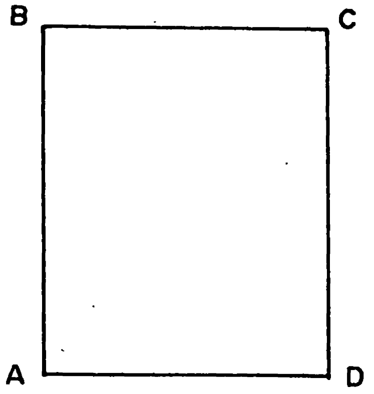
Geologic Log of Test Pit

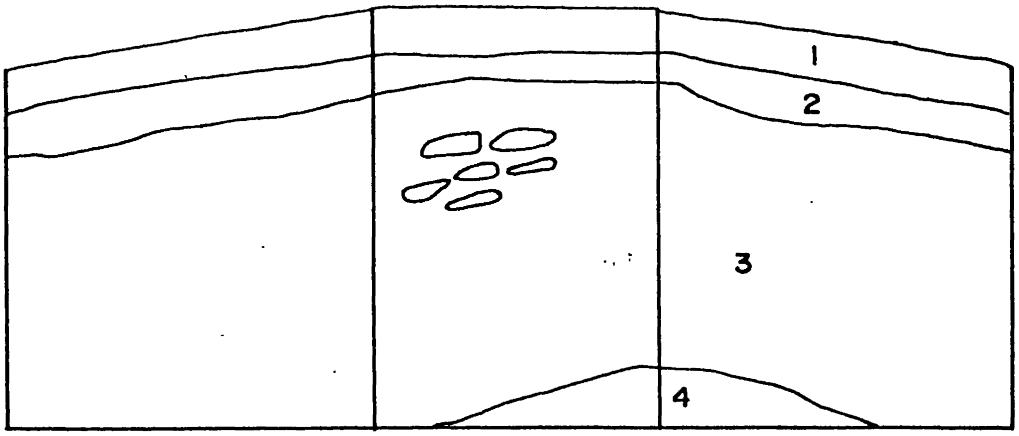
GEOLOGIC LOG OF TEST PIT No.14

LOCATION - DEPRESSION AT PANGALAELLA.



Scale - 1 : 50



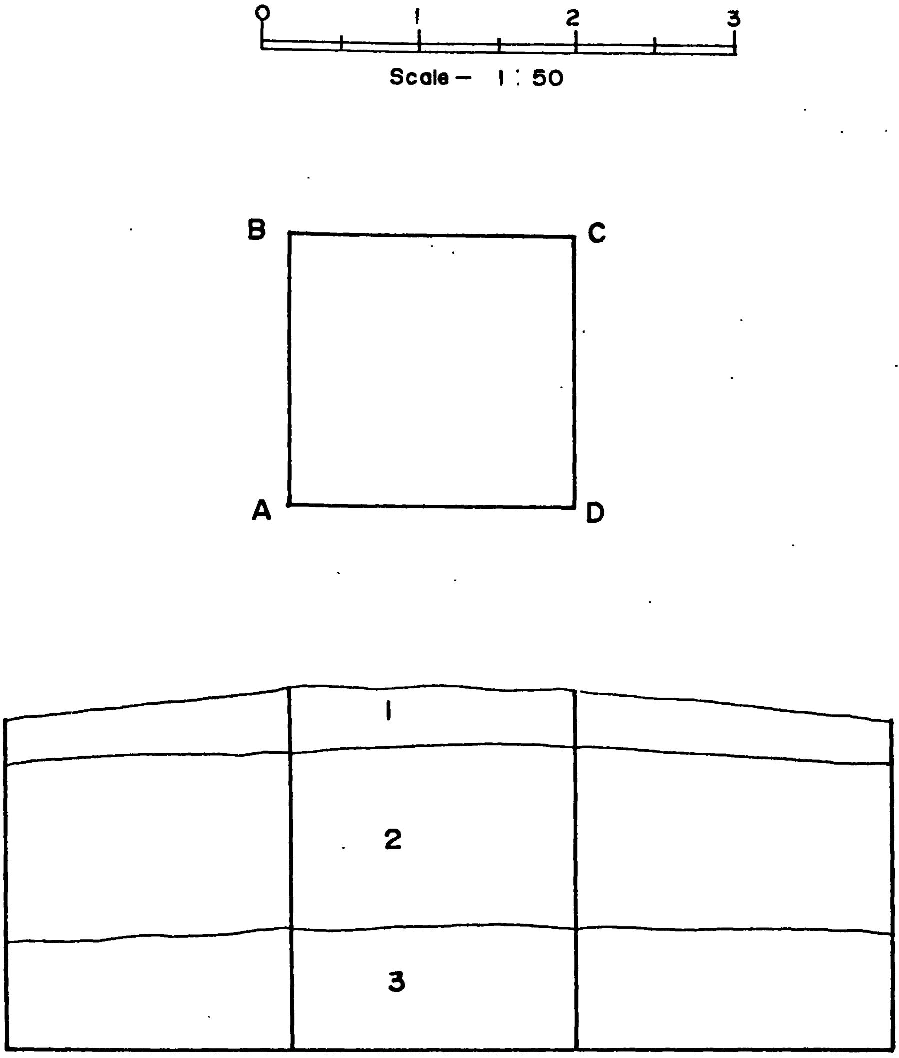


1. BLACK CLAYEY TOP SOIL
2. CLAYEY GRAVEL
3. COMPLETELY / HIGHLY WEATHERED ROCK (COBBLES WITH YELLOWISH CLAYEY SAND 80% COBBLES 30Cm.)
4. YELLOW HIGHLY WEATHERED ROCK, STRONG

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (14/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No.15

LOCATION - DEPRESSION AT PANGALAELLA

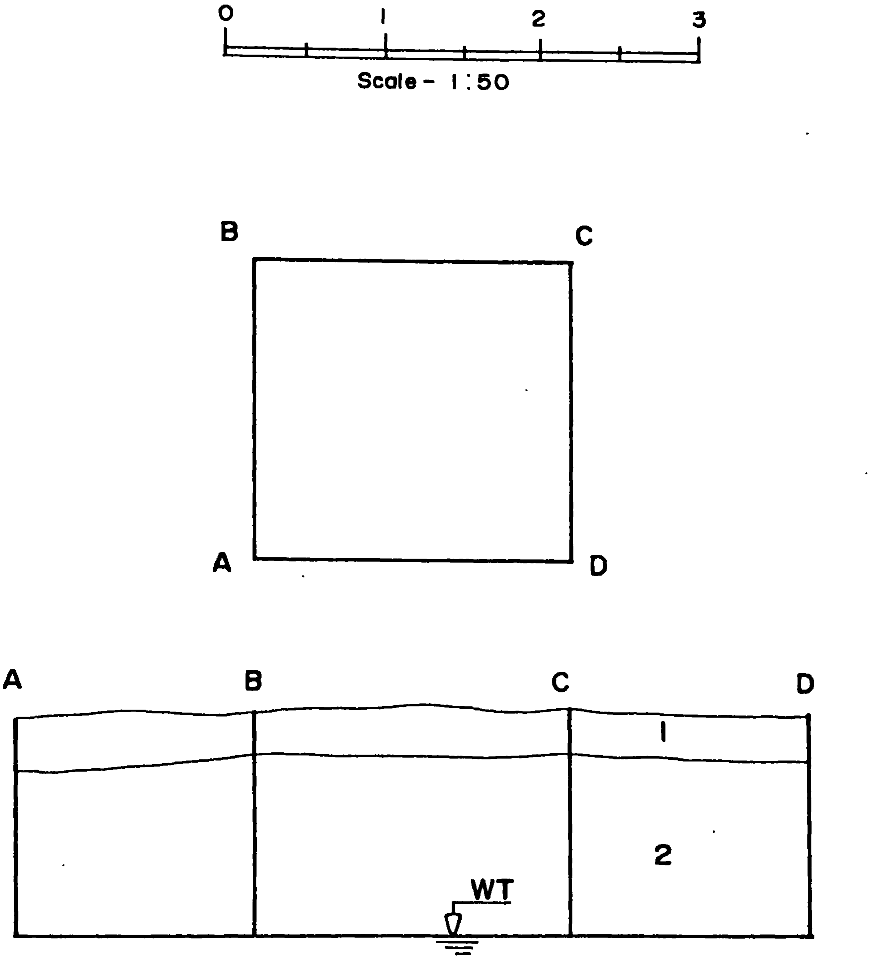


1. BLACK CLAYEY TOP SOIL
2. REDDISH CLAYEY GRAVEL (2 – 150 mm) WITH RARE COBBLES
3. MOTTLED REDDISH YELLOW GRAVELY CLAY
   (WEAK LATERITE)

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (15/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 16

LOCATION - DEPRESSION AT PANGALAELLA



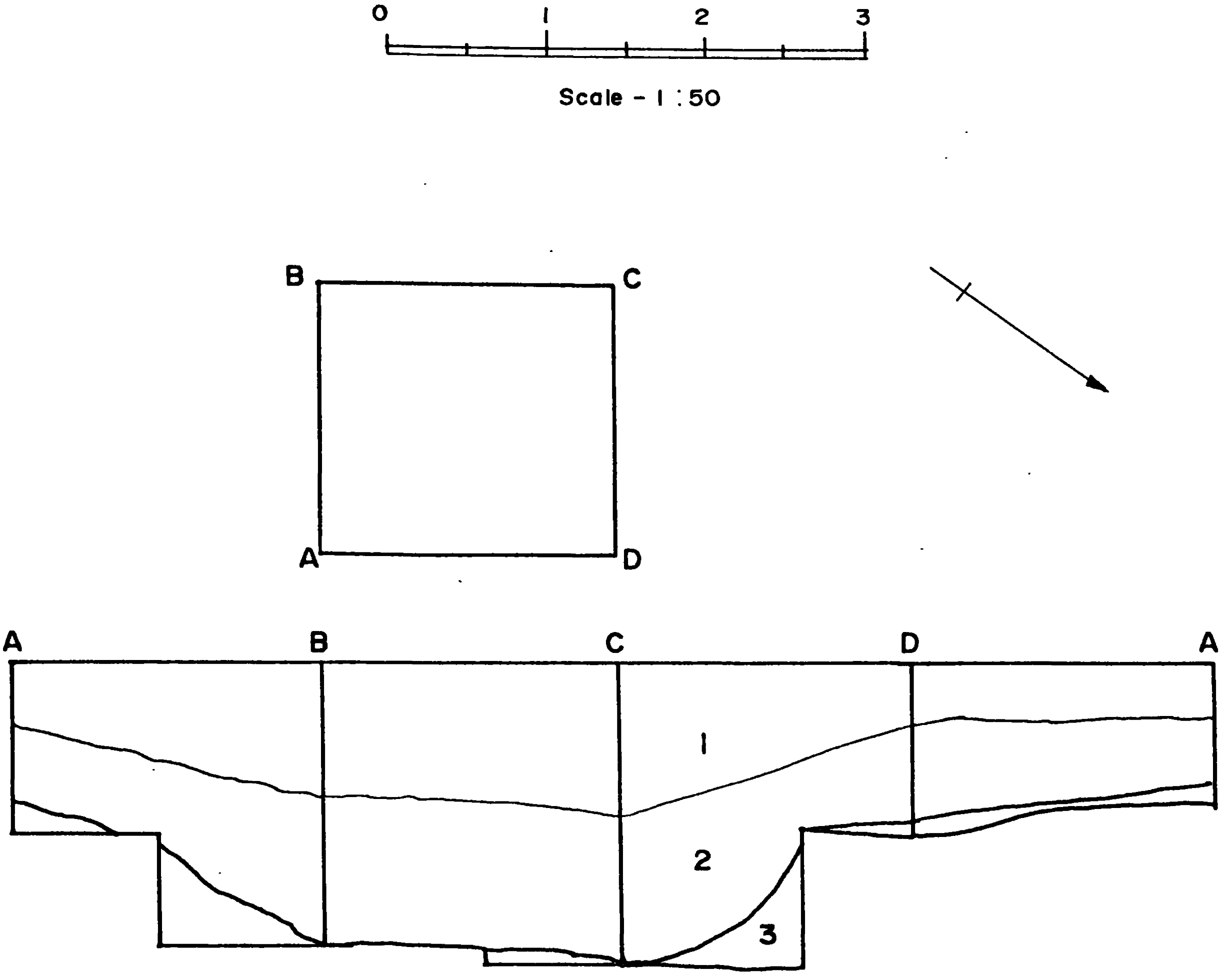
1. BLACK CLAYEY TOP SOIL

2. YELLOWISH CLAYEY GRAVEL WITH RARE COBBLES

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (16/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No 17

LOCATION - SWITCHYARD AREA



1. TOP SOIL WITH ROOTS, CONSIST OF COBBLES (IRREGULAR SHAPE) PEBBLES (MAX. SIZE = 10Cm) IN A MATRIX OF SLIGHTLY CLAYEY SILTY SANDY MATERIL BLACKISH TO DARK BROWN

2. COARSE SAND TO MEDIUM GRAVEL IN A MATRIX OF SLIGHTLY CLAYEY SILTLY SAND POORLY GRADED. OCCATIONAL WEATHERED BOULDERS UP TO 0·4 m YELLOWISH BROWN

3. COMPLETELY WEATHERED ROCK QUARTZ RICH. REDDISH BROWN

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

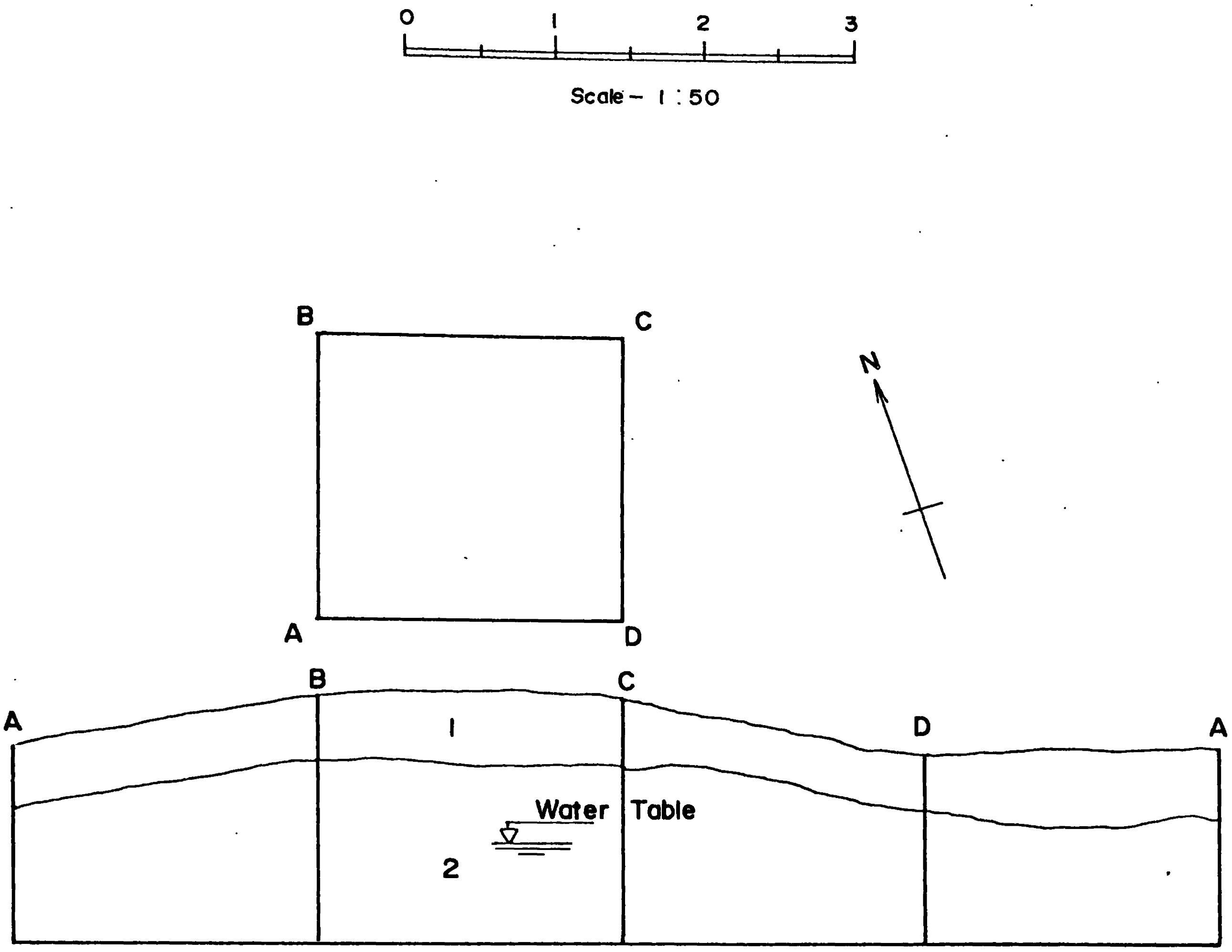
CECB, TEAMS, RDC

Figure 27 (17/24)

Geologic Log of Test Pit

GEOLOGIC LOG OF TEST PIT No.18

LOCATION - SWITCHYARD AREA



1. TOP SOIL CONTAINING ROOTS ORGANIC MATTER. VERY SLIGHTLY CLAYEY SILTY GRAVELLY SAND WITH PEBBLES. BLACKISH

2 PEBBLE, COBBLES, BOULDER LAYER IN A MATRIX OF CLAYEY SANDY GRAVELLY MATERIAL (PREDOMINENTLY COARSE MATERIAL - MAX. SIZE OF BOULDERS - 0·6 m)

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

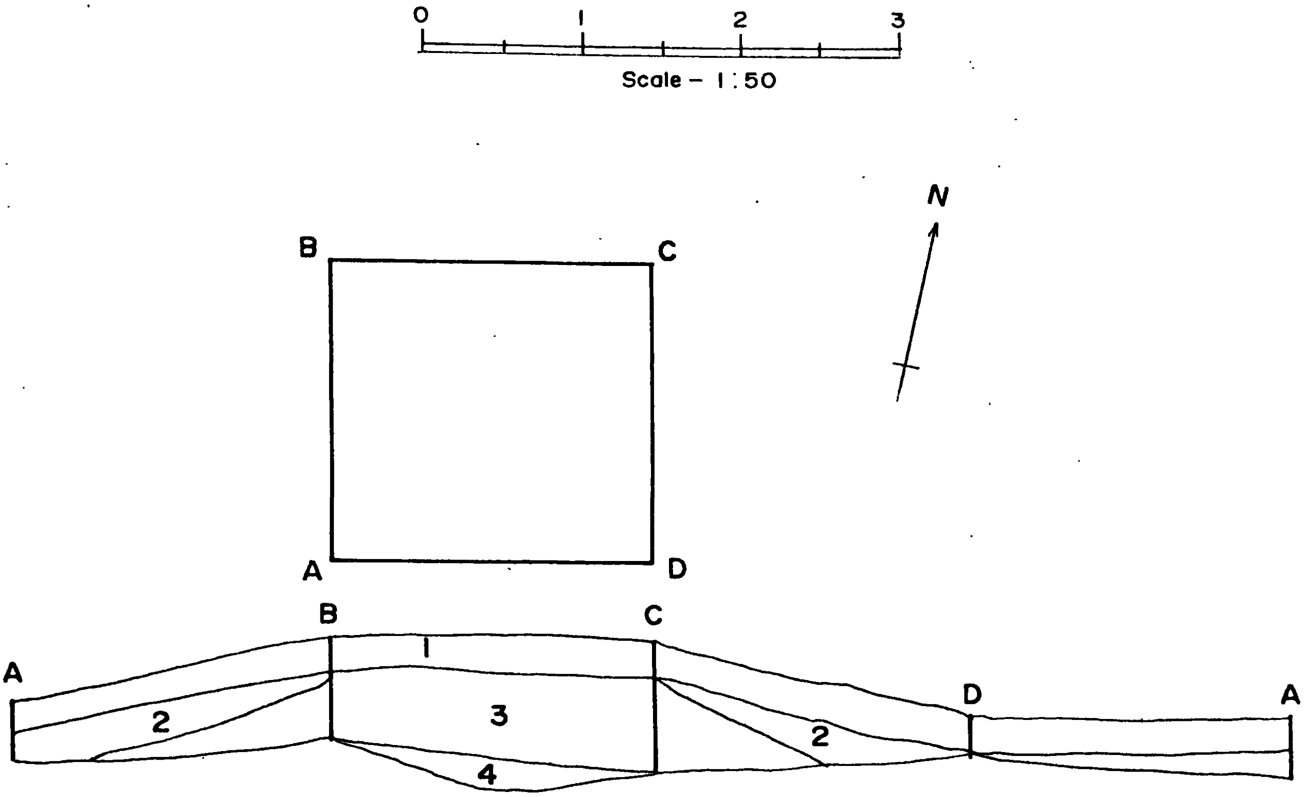
CECB, TEAMS, RDC

Figure 27 (18/24)

Geologic Log of Test Pit

GEOLOGIC LOG OF TEST PIT No. 19

LOCATION - SWITCHYARD AREA

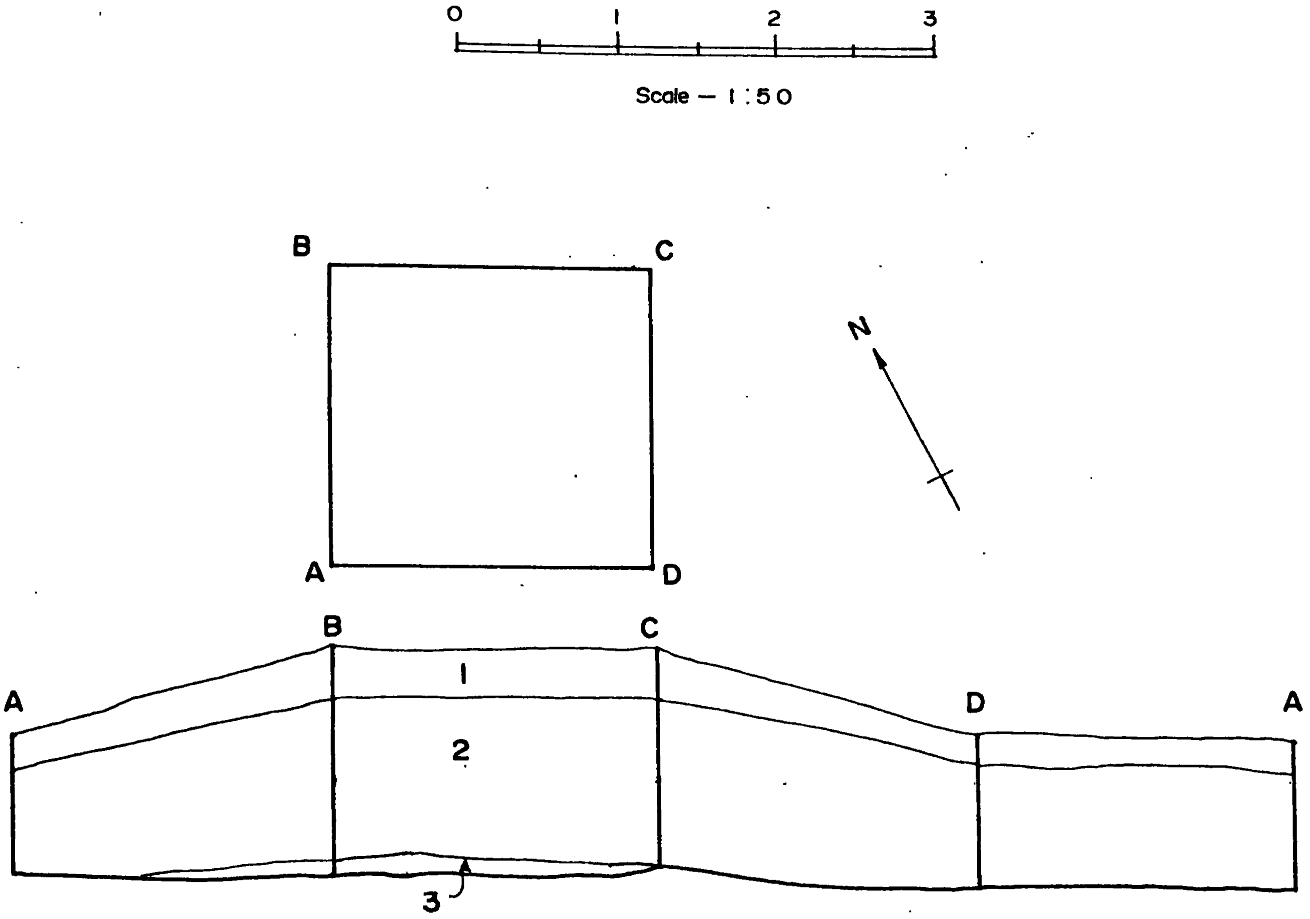


1. BOULDERS AND PEBBLES MAX. SIZE - 15-20 Cm. IN A MATRIX OF VERY SLIGHTLY CLAYEY SILTY SAND WITH ROOTS. DARK BROWN TO BLACKISH
2. RESIDUAL SOIL. YELLOWISH BROWN CLAYEY SAND WITH OCCATIONAL CORE STONES
3. COMPLETELY WEATHERED ROCK
4. HIGHLY TO MODERATLY WEATHERED ROCK EXPOSED AT THE BOTTOM OF THE PIT. BIOTITE GNEISS

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (19/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 20

LOCATION - SWITCHYARD AREA



1. TOP SOIL WITH ROOTS VERY SLIGHTLY CLAYEY SILTY SAND WITH PEBBLES AND ORGANIC MATTER. YELLOWISH BROWN TO BLACK

2. VERY SLIGHTLY SILTY SAND MATRIX WITH GRAVEL YELLOWISH BROWN

3. COMPLETELY TO HIGHLY WEATHERED ROCK

KUKULE GANGA HYDROPOWER PROJECT

Government of Sri Lanka
Ministry of Power and Energy
Ceylon Electricity Board

Joint Venture Kukule Ganga
NK, EWI & LI

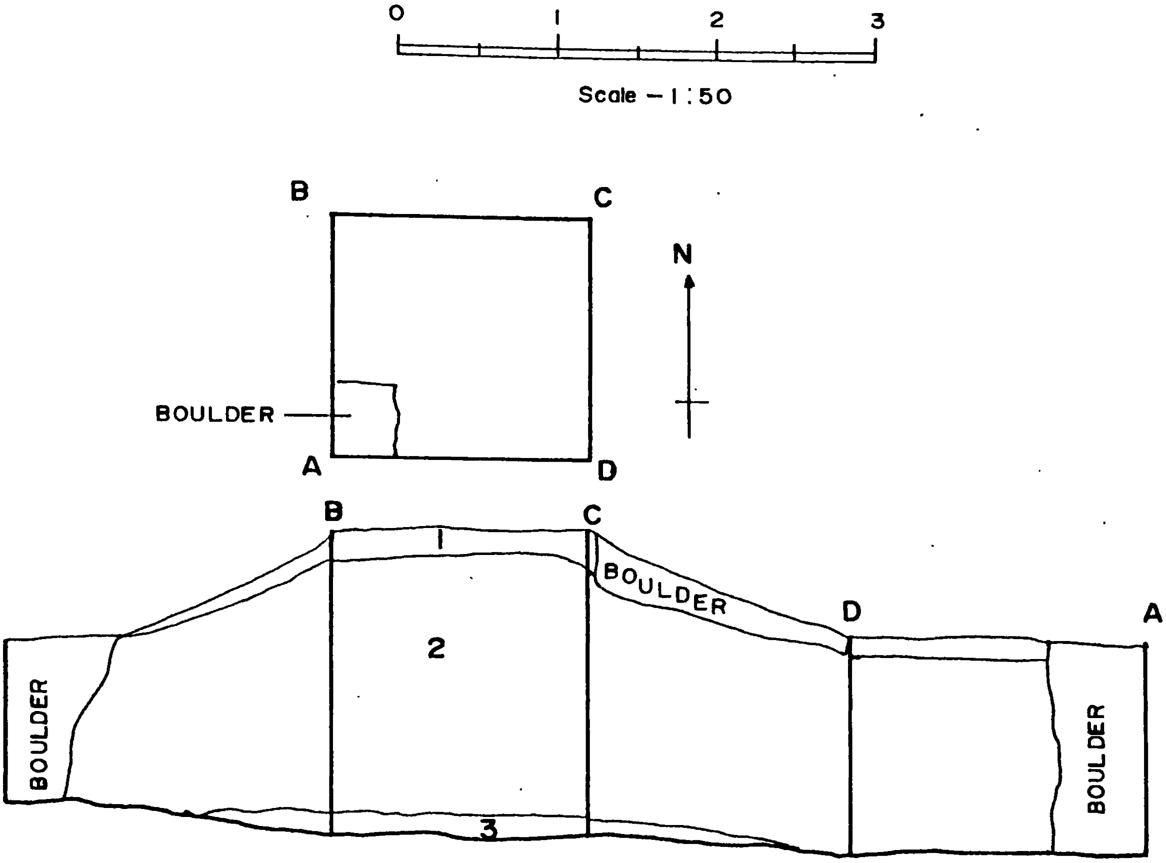
CECB, TEAMS, RDC

Figure 27 (20/24)

Geologic Log of Test Pit

GEOLOGIC LOG OF TEST PIT No. 21

LOCATION- SWITCHYARD AREA

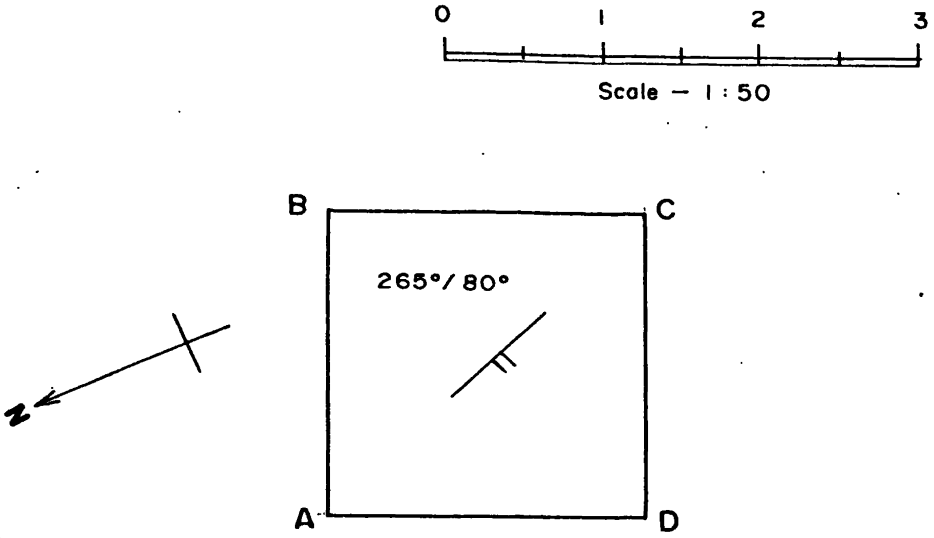


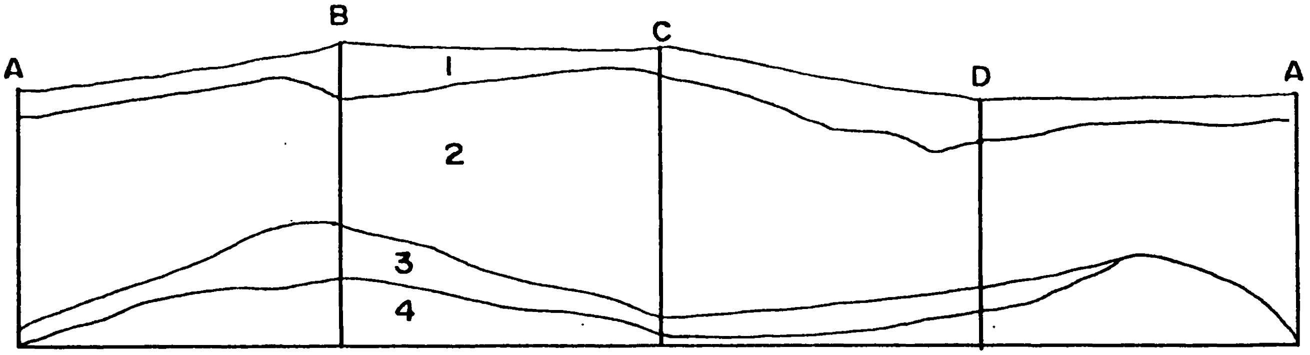
1. TOP SOIL WITH ROOTS DARK BROWN TO BLACKISH CLAYEY SAND
2. COARSE SAND TO MEDIUM GRAVEL IN A MATRIX OF SILGHTLY CLAYEY SILTY SAND. OCCATIONAL BOULDERS (SIZE 0·2 – 0·3 m.) ROOTS PENETRATED DEEPLY. YELLOWISH BROWN
3. COMPLETELY WEATHERED ROCK . YELLOWISH BROWN

KUKULE GANGA HYDROPOWER PROJECT		**Figure 27 (21/24)**
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	**Geologic Log of Test Pit**

GEOLOGIC LOG OF TEST PIT No. 23

LOCATION- OUTFALL AREA



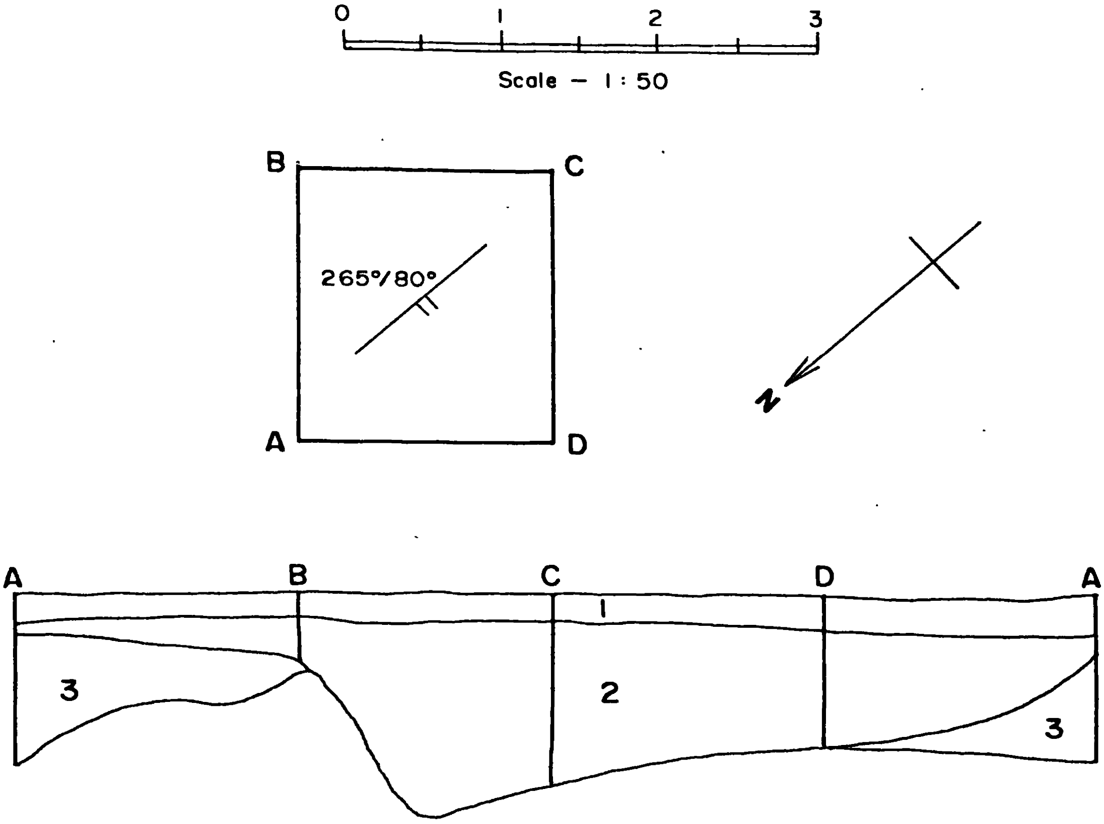


1. TOP SOIL WITH ROOTS - SILTY SANDY GRAVEL WITH ORGANIC MATTER - BLAKISH
2. PEBBLES IN SILTY SANDY MATRIX YELLOWISH BROWN
3. HIGHLY TO COMPLETLY WEATHERED ROCK
4. MODERATLY WEATHERED ROCK - BIOTITE GNEISS WITH GARNETS

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (22/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 24

LOCATION - OUTFALL AREA



1. TOP SOIL - WITH ROOTS PEBBLES & COBBLES IN A CLAYEY SILTY SANDY MATRIX BLACKISH

2. BOULDERS & COBBLES IN A MATRIX OF SILTY SAND BLACKISH TO DARK BROWN BOULDER UP TO 0·5 m

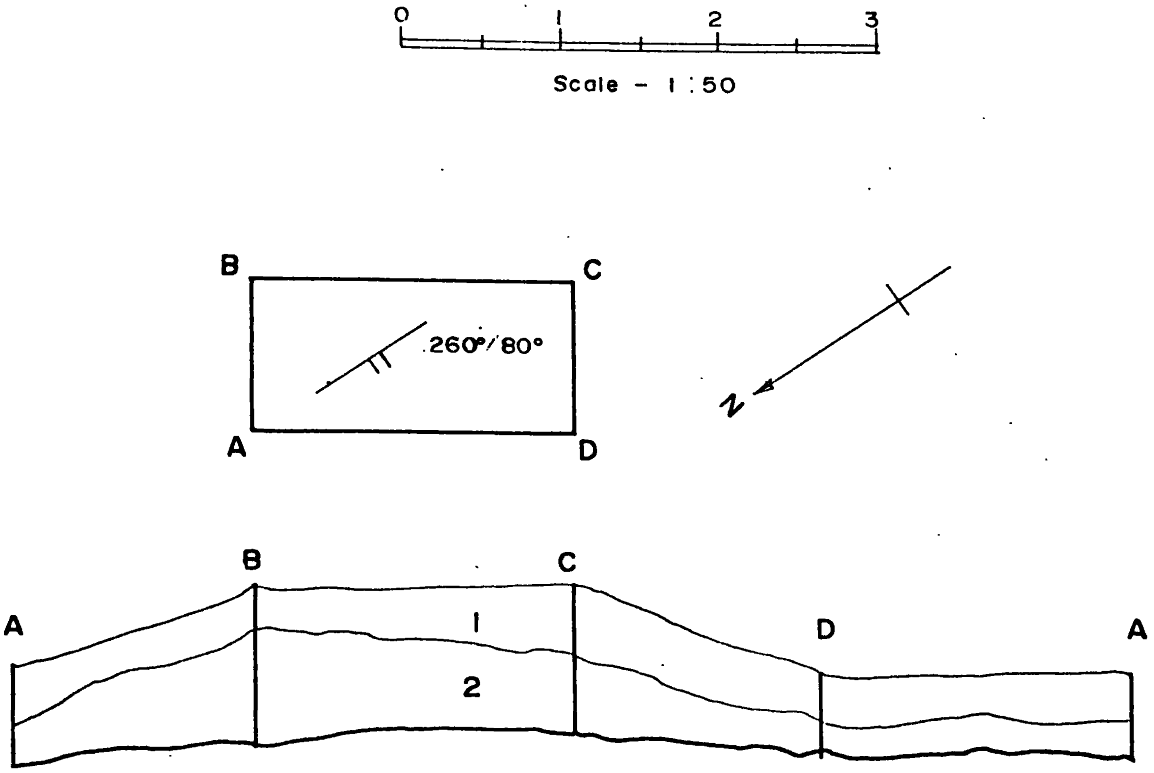
3. COMPLETELY TO HIGHLY WEATHERED ROCK

AT THE BOTTOM OF THE PIT HIGHLY TO MODERATLY WEATHERED ROCK IS EXPOSED

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (23/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

GEOLOGIC LOG OF TEST PIT No. 25

LOCATION - OUTFALL AREA



1. TOP SOIL WITH ROOTS (WITH ORGANIC MATTER. BOULDERS COBBLES AND PEBBLES IN A MATRIX OF CLAYEY SILTY SANDY MATERIAL DARK BROWN TO BLACKISH MAX. SIZE OF BOULDERS-0·5m

2. COM. WEATHERED ROCK.
AT THE BOTTOM OF THE PIT H. W. TO M.W ROCK IS EXPOSED

KUKULE GANGA HYDROPOWER PROJECT		Figure 27 (24/24) Geologic Log of Test Pit
Government of Sri Lanka Ministry of Power and Energy Ceylon Electricity Board	Joint Venture Kukule Ganga NK, EWI & LI CECB, TEAMS, RDC	

THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

MINISTRY OF POWER AND ENERGY

CEYLON ELECTRICITY BOARD

KUKULE GANGA HYDROPOWER PROJECT

FEASIBILITY STUDY

SR5B Construction Materials

August 1992

Joint Venture Kukule Ganga

Nippon Koei Co., Ltd.
Electrowatt Engineering Services Ltd.
Lahmeyer International Gmbh

Counterpart Engineers

Central Engineering Consultancy Bureau
TEAMS & RDC

FEASIBILITY STUDY
OF
KUKULE GANGA HYDROPOWER PROJECT

SR5A CONSTRUCTION MATERIALS

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Summary of laboratory tests on soils of borrow area in the three basins study

Annex-5B.1

Concrete Aggregate Materials

1.1 Petrographic examination

Appendix A - 1

Petrographic Examination and Drill Hole log

Dam Site Quarry (No. KK4)

Drill hole log

Depth(m)	Description	Section	Sample for Petrographic Work
0 - 9.74	Weathered Soil overburden.	4 A	
9.74-11.70	Garnet quartz feldspar rock.(Garnet granulite). Not weathered Not fractured Foliation not developed Granular rock.	4 B	Piece No.19 for petrographic work at 11.70 m depth.
13.80-17.01	Hornblende biotite gneiss with charnockitic bands. 3 types of fracture planes. Occasional pegmatitic layers. Foliation developed. 45^{o} dip*	4 C	Piece No.31 for petrographic work at 15 m depth.
17.01-19.56	Charnockite, Fractures not found. Foliation not developed. Coarse grained pegmatitic layers found.	4 D	Piece No.56 for petrographic work at 18.36 depth.
19.56-20.21	Garnet biotite granitic gneiss. Fractures not developed. Foliation well developed.	4 E	

* Considering the drill hole is vertical.

Petrographic Examination

Dam Site quarry (No. KK4)

No. of samples tested = 3.

Depth (m)	Sample No.
11.7	4B / 19
15.00	4C / 31
18.36	4D / 56

Sample No. 4B/19

General Description

Rock type: Garnet quartz feldspar rock (Garnet granulite)

Colour : Light Colour.

Nature : Heterogeneous rock. Medium grained.

Mineral Content

Model Analysis: (500 grains)

Quartz - 34 %
Feldspar - 38 % (Microcline 18%, Orthoclase 12% Plagioclase 8%)
Garnet - 16 %
Biotite - 6 %
Fe ore - 2 % (Magnetite & Hematite)

Accessories - **4 %** **(Apatite, Sphene, Monozite, Rutile)**

Calcareous or highly soluble minerals - No $CaCO_3$ or other highly dissolvable minerals.

Clays - Except few grains of sericite and chlorite no clay minerals are found.

Flaky minerals - Biotite is the only flaky mineral found with approx. 6 % in the total rock. Very low flaky mineral content.

Arrangement of grains

Grain Size - Medium grained. Well interlocked. Garnet appear as pokioblastic grains.

Minor fractures - none.

Cataclastic/Sheared grains - none.

Foliations/Schistosity - not well developed. Granular rock.

Sample No. 4C/31

General Description

Rock type: Hornblende biotite gneiss.

Colour : Dark Colour.

Nature : Homogeneous. Fine grained.

Mineral Content

Model Analysis: (500 grains)

Quartz - 30 %
Feldspar - 28 % (Microcline 12%, Orthoclase 7% Plagioclase 9%)
Biotite - 18 %
Hornblende - 12 %
Pyroxenes - 6 %
Fe ore - 4 % (Magnetite & Hematite)

Accessories - 2 % (Calcite, Sphene, Apatite, Monozite, Muscovite)

Calcareous or highly soluble minerals - $CaCO_3$ occurs less than 0.25% of the r

Clays - none.

Flaky minerals - Biotite is the only flaky mineral f
8 % of the rock.
Fairly high content.

Arrangement of grains

Grain Size - fine grained. Well interlocked.

Minor fractures - none.

Cataclastic/Sheared grains - none.

Foliations/Schistosity - Well developed foliation. Alternate layers of Biotite, Hornblende and Pyroxene with Quartz and Feldspar make the foliation.

Sample No. 4D/56

General Description

Rock type:	Charnockite
Colour :	Dark Colour.
Nature :	Heterogeneous rock. Coarse to medium grained.

Mineral Content

Model Analysis:(500 grains)

Quartz -	30 %	
Feldspar -	36 %	(Microcline 13%, Orthoclase 10% Plagioclase 13%)
Pyroxenes -	14 %	(Mainly hypersthene)
Biotite -	10 %	
Hornblende -	6 %	
Fe ore -	2 %	(Mainly Magnetite)
Accessories -	2 %	(Calcite, Apatite, Monozite, Sphene)

Calcareous or highly soluble minerals - Calcite contains less than 0.25% in the rock.

Clays - Few sericite grains are found. No clays.

Flaky minerals - Biotite is the only flaky mineral found. Content is approximately 10 %.

Arrangement of grains

Grain Size - Coarse to medium grained. Very large grains of Biotite occur as pokioblasts.

Minor fractures - 1 minor fracture was found for 2 cm^2 area of the thin section.

Cataclastic/Sheared grains - none.

Foliations/Schistosity - not developed.

Power House Quarry (No. KK5)

Drill hole log

Depth(m)	Description	Section	Sample for Petrograph Work
0 - 3.30	Soil overburden	5 A	-
3.30-12.50	Hornblende biotite gneiss. Weathered rock. Highly fractured. 2-3 well developed joint patterns. Well developed foliation with 70° dip*	5 B	-
12.50-13.20	Rock same as 5 B. Not weathered and less fractured compared to 5 B.	5 C	Piece No. for petrograph work at 12.90 m.
13.20-20.13	Biotite gneiss with occasional garnet patches. Not weathered. Fractures not well developed. Vertical fracture pattern exist*. Dip at 70° Flaky mineral content (mainly biotite) is less compared to 5B and 5C.	5 D	Piece No.6 for petrograph work at 19.00 m depth.

* Considering the drill hole is vertical.

Petrographic Examination.

Power House Quarry (No. KK5)

No. of samples tested = 2.

Depth (m)	Sample No.
12.90	5C / 34
19.00	5D / 60

Sample No. 5C/34

General Description

Rock type: Hornblende biotite gneiss

Colour : Dark Colour.

Nature : Homogeneous. Fine grained.

Mineral Content

Model Analysis: (500 grains)

Quartz - 28 %
Feldspar - 27 % (Microcline 10%, Orthoclase 7% Plagioclase 10%)
Hornblende - 14 %
Biotite - 20 %
Pyroxenes - 5 %
Fe ore - 3 % (Magnetite & Hematite)

Accessories - 3 % (Calcite, Sphene, Apatite, Monozi)

Calcareous or highly soluble minerals - Calcite content is less than 0.1 %. No other minerals.

Clays - none.

Flaky minerals - Biotite is the only flaky mineral fou 20 % of biotite content. This is high and effects the flakiness of the rock

Arrangement of grains

Grain Size - Fine grained. Well interlocked.

Minor fractures - none.

Cataclastic/Sheared grains - none.

Foliations/Schistosity - well developed.

Sample No. 5D/60

General Description

Rock type: Biotite gneiss(quartz feldspar gneiss)

Colour : Light Colour.

Nature : Heterogeneous - Medium to coarse grained.

Mineral Content

Model Analysis:(500 grains)

Quartz -	48 %	
Feldspar -	42 %	(Microcline 22%, Orthoclase 12% Plagioclase 8%)
Biotite -	6 %	
Accessories -	4 %	(Sericite, Magnetite, Muscovite, Apatite)

Calcareous or highly soluble minerals - none

Clays - Feldspar grains alteration into clay has been observed. However clay content(Kaolinite) is less than 1 %.

Flaky minerals - Biotite is the only flaky mineral found. 6 % of biotite. This is very low and does not effect the flakiness of the rock.

Arrangement of grains

Grain Size - Medium to coarse grained. Well interlocked.
Edges of feldspar grains show alteration into clays.

Minor fractures - none.

Cataclastic/Sheared grains - none.

Foliations/Schistosity - Foliation not well developed. However occasionally biotite rich layers show foliation pattern.

1.2 Specific gravity and Absorption

1.3 Unit weight of drilled core

Specific Gravity and Absorption, Unit Weight.

ASTM Standard : C 127 - 84

Project : Kukule Ganga Hydro Electric Project Feasibility Study.

Sample Type : A (for drilled Cores)

1. Location: Dam Site Quarry Borehole No. KK4

Depth (m)		9.75		12.15	13.80		14.80		15.80	16.80		17.80		18.80			20.20
Specific Gravity	Bulk	2.84	2.69		2.77	2.74	2.83	2.82	2.62	2.71	2.73	2.76	2.76	2.61	2.63	2.65	
	Bulk(SSD)	2.84	2.70		2.77	2.74	2.83	2.83	2.64	2.72	2.73	2.77	2.76	2.61	2.64	2.66	
	Apparent	2.86	2.73		2.78	2.76	2.84	2.83	2.67	2.72	2.74	2.77	2.77	2.62	2.65	2.67	
Absorption %		0.2	0.5		0.2	0.3	0.1	0.1	0.7	0.2	0.2	0.1	0.1	0.2	0.2	0.4	
Unit Weight (kg/m³)		2815	2646		2638	2710	2808	2802	2601	2692	2691	2750	2743	2575	2594	2609	

2. Location: Power House Quarry Borehole No. KK5

Depth (m)		12.5		13.5		14.5		15.5		16.5		17.5		18.5		19.5		20.0
Specific Gravity	Bulk	3.13	3.16	2.69	2.65	2.68	2.66	2.68	2.64	2.68	2.67	2.63	2.66	2.66	2.65	2.66		
	Bulk(SSD)	3.13	3.16	2.69	2.66	2.68	2.66	2.69	2.64	2.68	2.68	2.64	2.66	2.66	2.66	2.67		
	Apparent	3.13	3.17	2.69	2.66	2.69	2.67	2.70	2.65	2.69	2.69	2.65	2.67	2.67	2.66	2.68		
Absorption %		0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2		
Unit Weight (kg/m³)		3087	3134	2653	2604	2663	2622	2646	2627	2660	2631	2628	2623	2631	2636	2625	2572	

1.4 Unconfined compression test

Appendix A - 3

Unconfined Compression Test

ASTM Standard D2938 - 79

Project : Kukule Ganga Hydro Electric Project Feasibility Study.

Sample Type : A (for drilled cores)

1. Location : Dam Site Quarry Borehole No. KK4

Depth (m)	9.75	12.15	13.80	14.80	15.80	16.80	17.80	18.80	20.20
Unconfined Compressive Strength (MPa)	102.60 25.88		97.55	81.15 32.32	33.01	69.08 74.01	103.02 81.15	37.15 27.38 25.69	

2. Location : Power House Quarry Borehole No: KK5

Depth (m)	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.0
Unconfined Compressive Strength (MPa)	82.05 82.98	85.19 87.46	84.69 71.18	64.23 56.98	50.65 56.99	45.21 51.38	56.56 56.76	43.06	

1.5 Elastic moduli

Appendix A - 4

Elastic Moduli

ASTM Standard : D 3148 - 80

Project : Kukule Ganga Hydro Electric Project Feasibility Study.

Sample Type : A (for drilled cores)

Test Date: 02 - 04 - 92

Rate of Loading = 160 N/s or 1 tonne/min

Physical Description : Refer to Annexure A-1

Moisture Condition : Laboratory air - dry

1. Location: Dam Site Quarry Borehole No. KK4

Depth (m) : 9.75 - 12.15

Specimen diameter = 54.5 mm
height = 126.0 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.21	88
2.00	8.41	149
3.00	12.62	198
4.00	16.82	256
5.00	21.03	312
6.00	25.23	386
7.00	29.44	514
8.00	33.64	663

Stress Vs Axial Strain curve is shown in figure A.4.1.

Ultimate Strength = 35.24 MPa

Young's modulus

Average Modulus for Linear Portion = 78.6 GPa

Depth (m) : 13.80 - 15.80

Specimen diameter = 54.9 mm
height = 119.5 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.14	93
2.00	8.29	163
3.00	12.43	223
4.00	16.58	288
5.00	20.72	356
6.00	24.86	428
7.00	29.01	488
8.00	33.15	530
9.00	37.30	572
10.00	41.44	619
11.00	45.58	674
12.00	49.73	721

Stress Vs Axial Strain curve is shown in figure A.4.2

Ultimate strength = 53.87 MPa.

Young's modulus.

Average Modulus for Linear Portion = 64.4 GPa

Specimen diameter = 54.6 mm
height = 125.8 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.19	35
2.00	8.38	84
3.00	12.57	135
4.00	16.76	177
5.00	20.95	223
6.00	25.14	274
7.00	29.33	316
8.00	33.52	363
9.00	37.71	405
10.00	41.90	447

Stress Vs Axial Strain curve is shown in figure A.4.3

Ultimate Strength = 71.81 MPa.

Young's modulus

Average Modulus for Linear Portion = 90.1 GPa.

Depth (m) : 15.80 - 17.80

Specimen diameter = 54.6 mm

height = 125.7 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.19	144
2.00	8.38	274
3.00	12.57	540

Stress Vs Axial Strain curve is shown in figure A.4.4

Ultimate strength = 25.14 MPa.

Young's modulus

Average Modulus = 29.1 GPa
for Linear Portion

Specimen diameter = 54.6 mm
height = 125.4 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.19	70
2.00	8.38	126
3.00	12.57	181
4.00	16.76	237
5.00	20.95	281
6.00	25.14	335
7.00	29.33	391
8.00	33.52	437
9.00	37.71	479
10.00	41.90	526

Stress Vs Axial Strain curves is shown in figure A.4.5

Ultimate Strength = 77.26 MPa

Young's Modulus

Average Modulus for Linear Portion = 79.1 GPa

Depth (m) : 17.80 - 20.20

Specimen diameter = 54.4 mm
height = 125.2 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.22	33
2.00	8.44	65
3.00	12.66	105
4.00	16.88	144
5.00	21.10	179
6.00	25.32	195
7.00	29.54	260
8.00	33.77	302
9.00	37.99	344
10.00	42.21	381
11.00	46.43	428
12.00	50.65	463

Stress Vs Axial Strain curve is shown in figure A.4.6

Ultimate strength = 81.04 MPa.

Young's Modulus

Average Modulus for Linear Portion = 106.0 GPa

Specimen diameter = 54.5 mm
height = 126.0 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.0	4.21	121
2.0	8.41	195
3.0	12.62	270
4.0	16.82	391
5.0	21.03	693

Stress Vs Axial Strain curve is shown in figure A.4.7

Ultimate Strength = 28.60

Young's modulus

Average Modulus for Linear Portion = 56.4 GPa

Specimen diameters = 54.6 mm
height = 125.4 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.19	70
2.00	8.78	135
3.00	12.57	186
4.00	16.76	242
5.00	20.95	293
6.00	25.14	335
7.00	29.33	377
8.00	33.52	414
9.00	37.71	451
10.00	41.90	488
11.00	46.09	521
12.00	50.28	553
13.00	54.47	595
14.00	58.66	670

Stress Vs Axial Strain curve is shown in figure A.4.8

Ultimate strength > 83.80 MPa

Young's modulus

Average Modulus for Linear Portion = 102.2 GPa

2. <u>Location: Power House Quarry Borehole No. KK5</u>

<u>Depth (m) : 14.5 - 16.5</u>

Specimen diameter = 54.5 mm
height = 125.4 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.21	60
2.00	8.41	105
3.00	12.62	158
4.00	16.82	193
5.00	21.03	237
6.00	25.23	270
7.00	29.44	305
8.00	33.64	340
9.00	37.85	377
10.00	42.05	414
11.00	46.26	456
12.00	50.46	502
13.00	54.67	549
14.00	58.87	595
15.00	63.08	651
16.00	67.28	684
17.00	71.49	735

Stress Vs Axial Strain curve is shown in figure A.4.9.

Ultimate strength = 74.68 MPa.

Young's modulus

Average Modulus = 110.0 GPa
for Linear Portion

Depth (m) : 18.5 - 20.0

Specimen diameter = 54.3 mm
height = 125.4 mm

Applied Load (tonne)	Stress (MPa)	Axial Strain (μm/m)
1.00	4.24	326
2.00	8.47	567
3.00	12.71	753
4.00	16.94	916
5.00	21.18	1070
6.00	25.42	1216
7.00	29.65	1398
8.00	33.89	1647

Stress Vs Axial Strain curve is shown in figure A.4.10

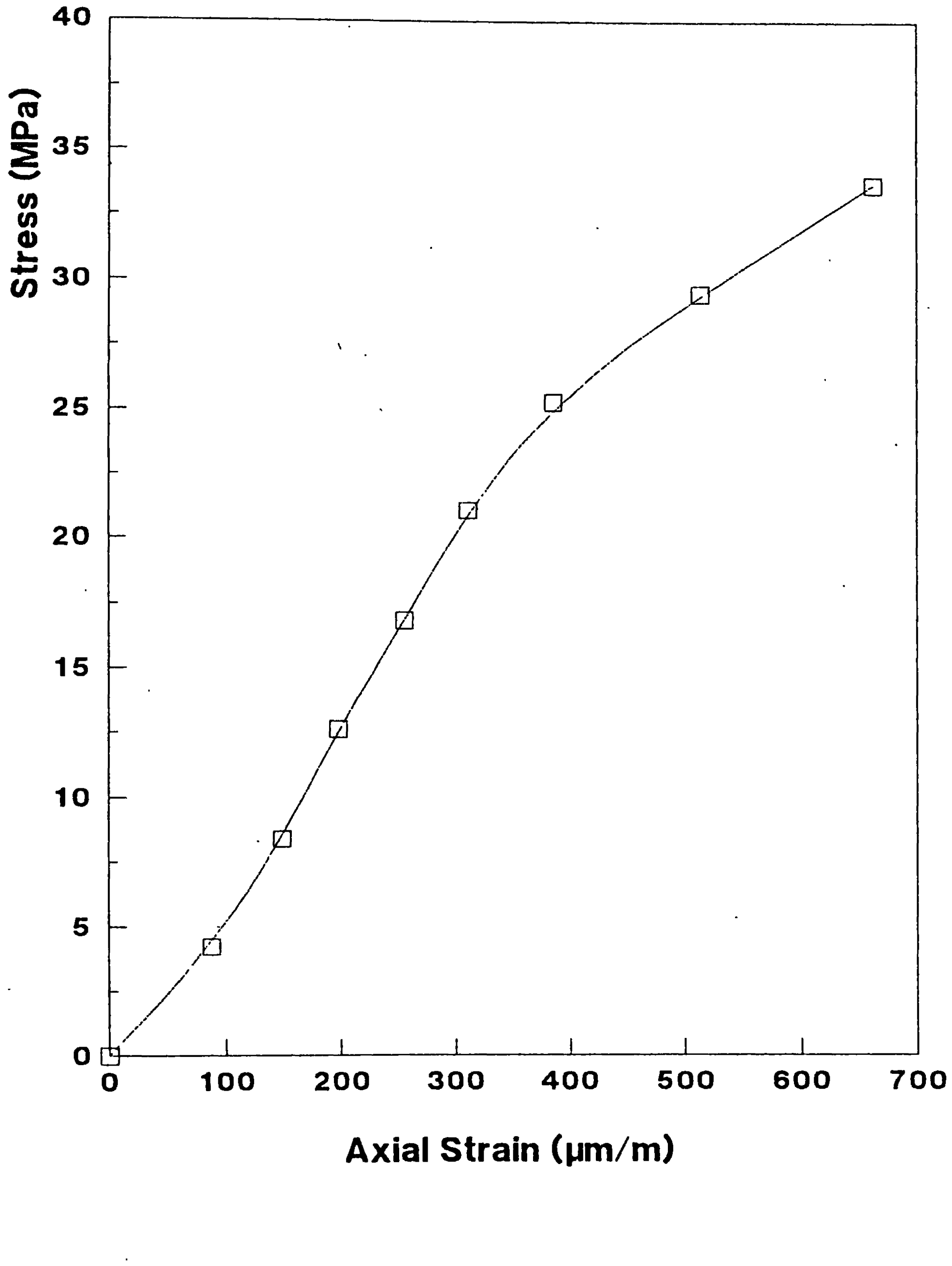
Ultimate Strength = 43.63 MPa.

Young's modulus

Average Modulus for Linear Portion = 27.5 GPa

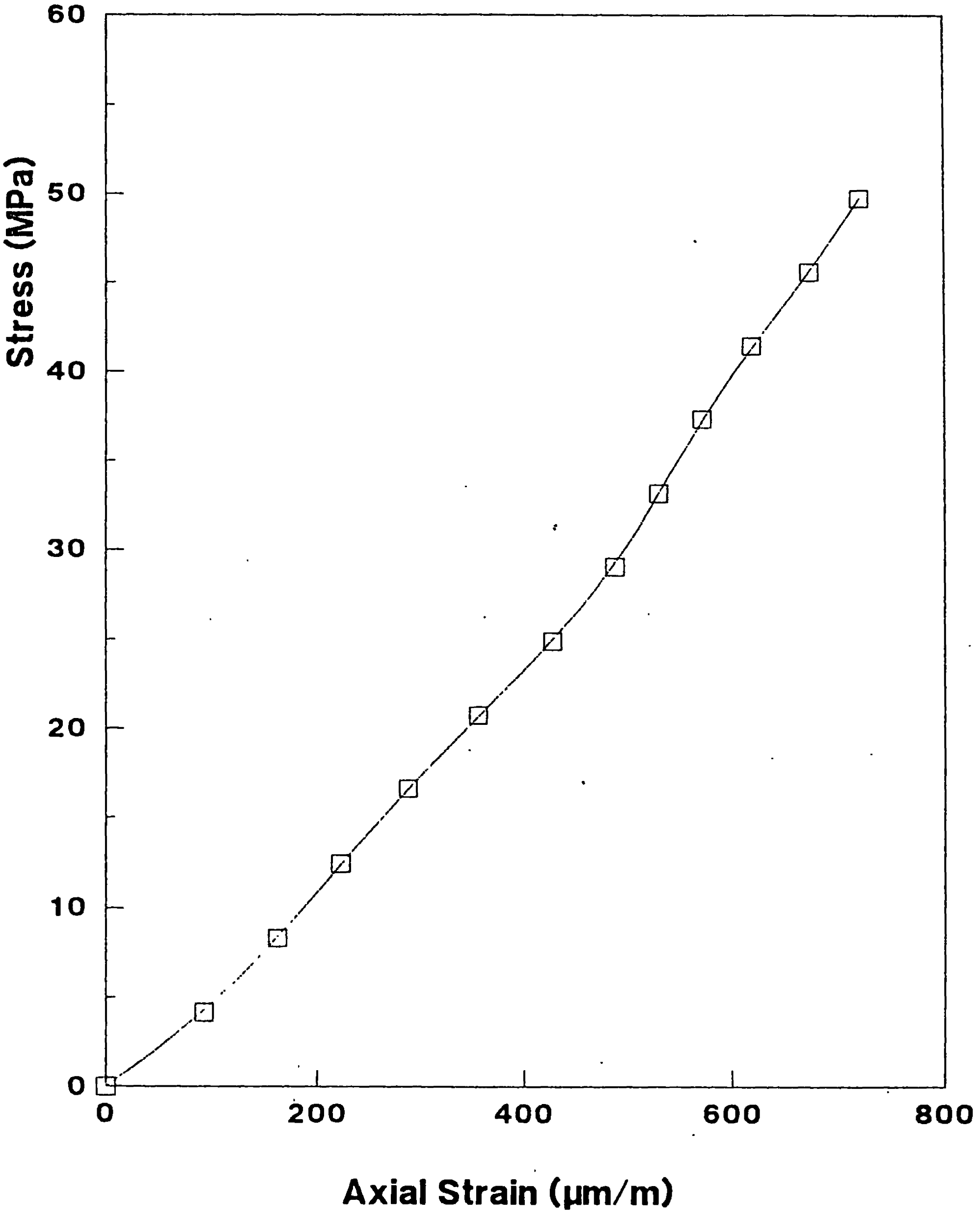
Stress vs Axial Strain

Fig. A.4.1



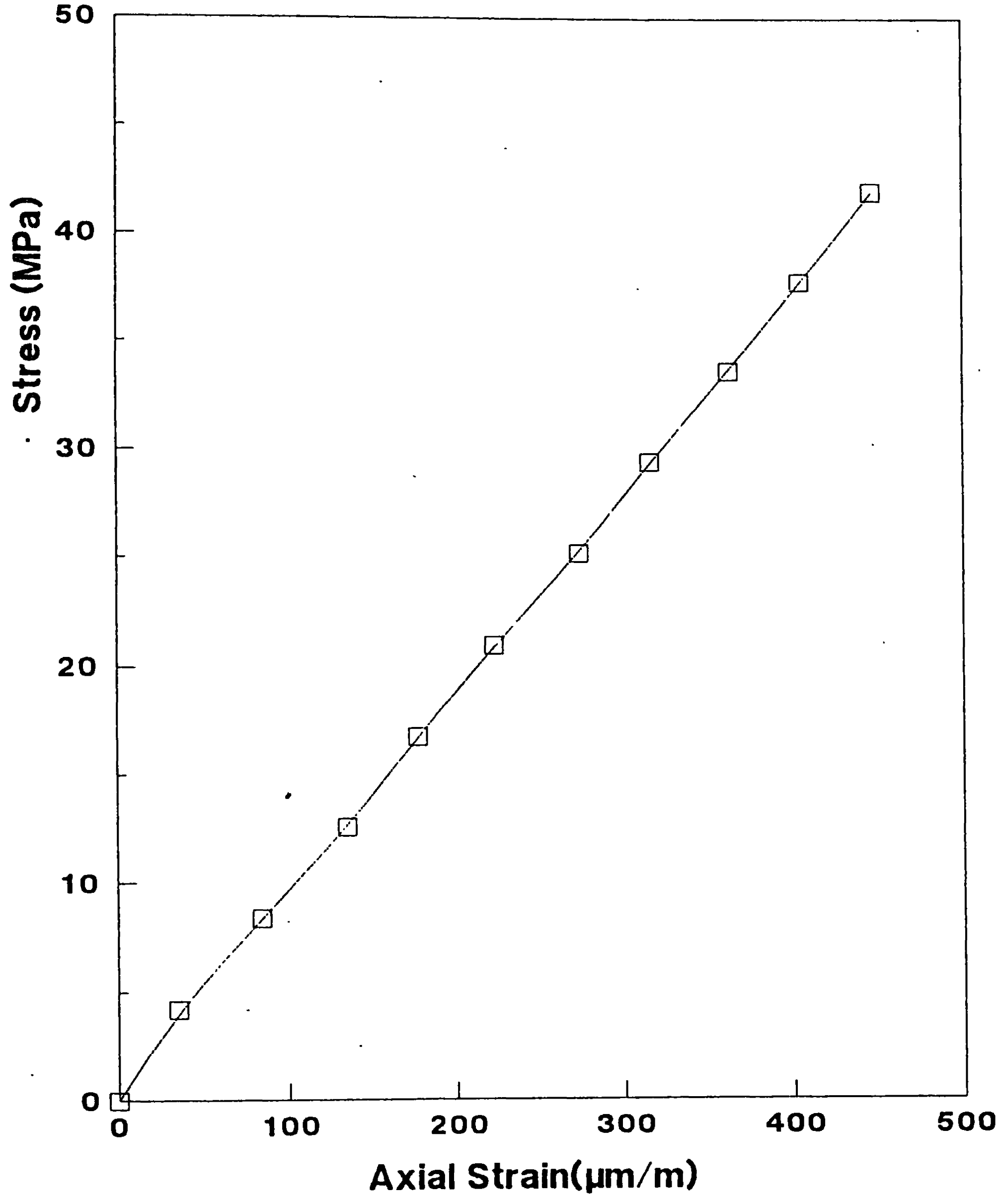
Stress vs Axial Strain

Fig.A.4.2



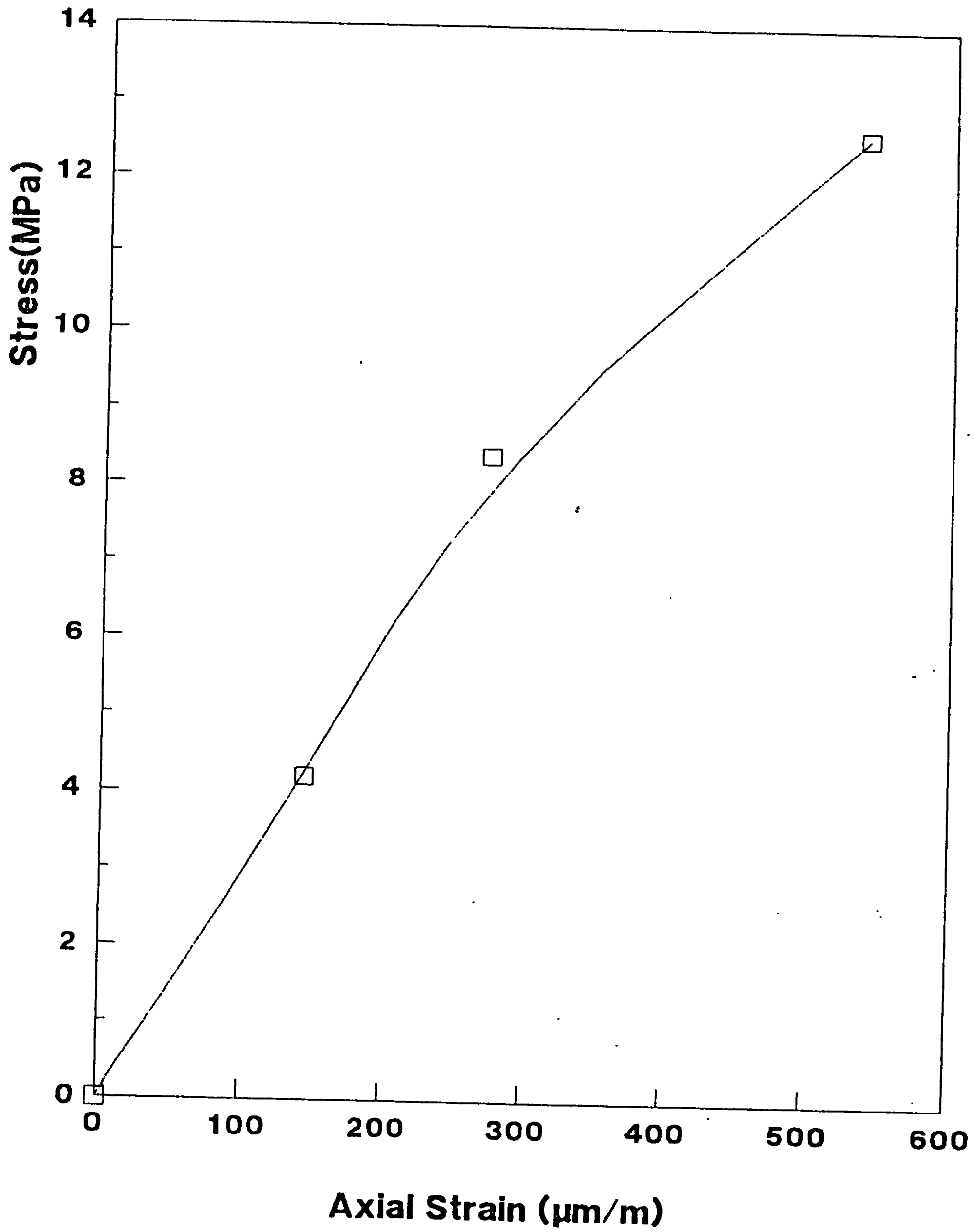
Stress vs Axial Strain

Fig. A.4.3



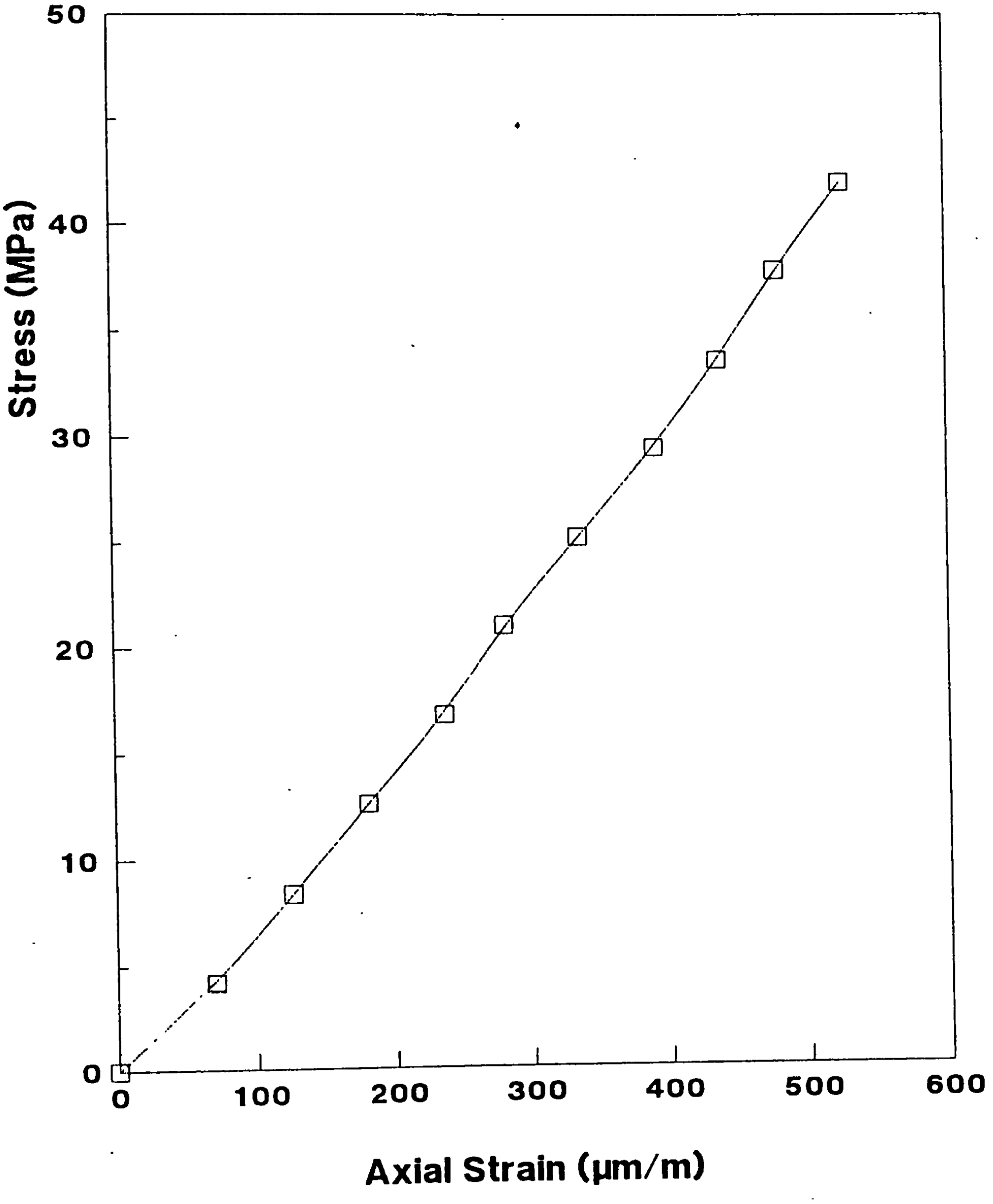
Stress vs Axial Strain

Fig. A.4.4



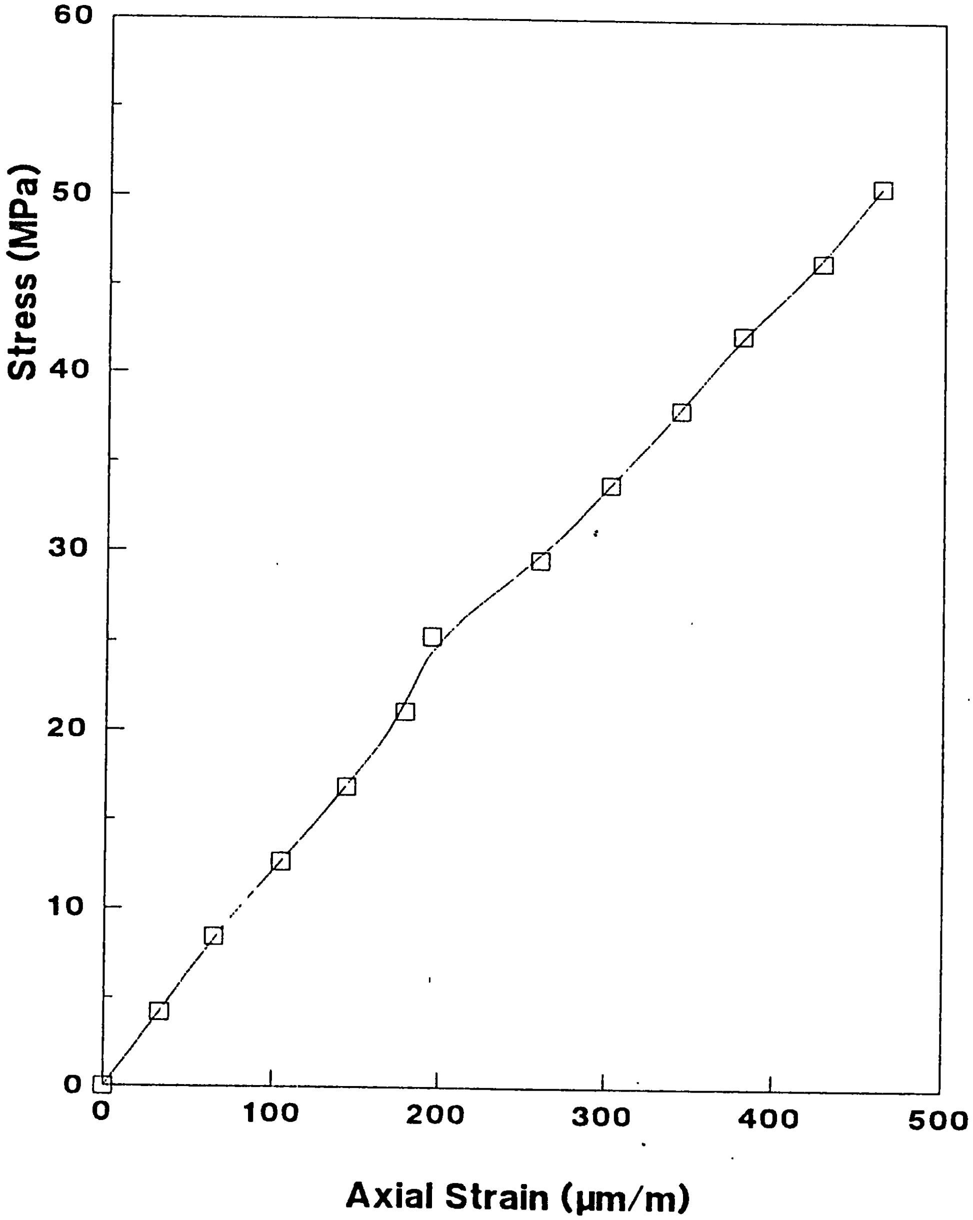
Stress vs Axial Strain

Fig. A.4.5



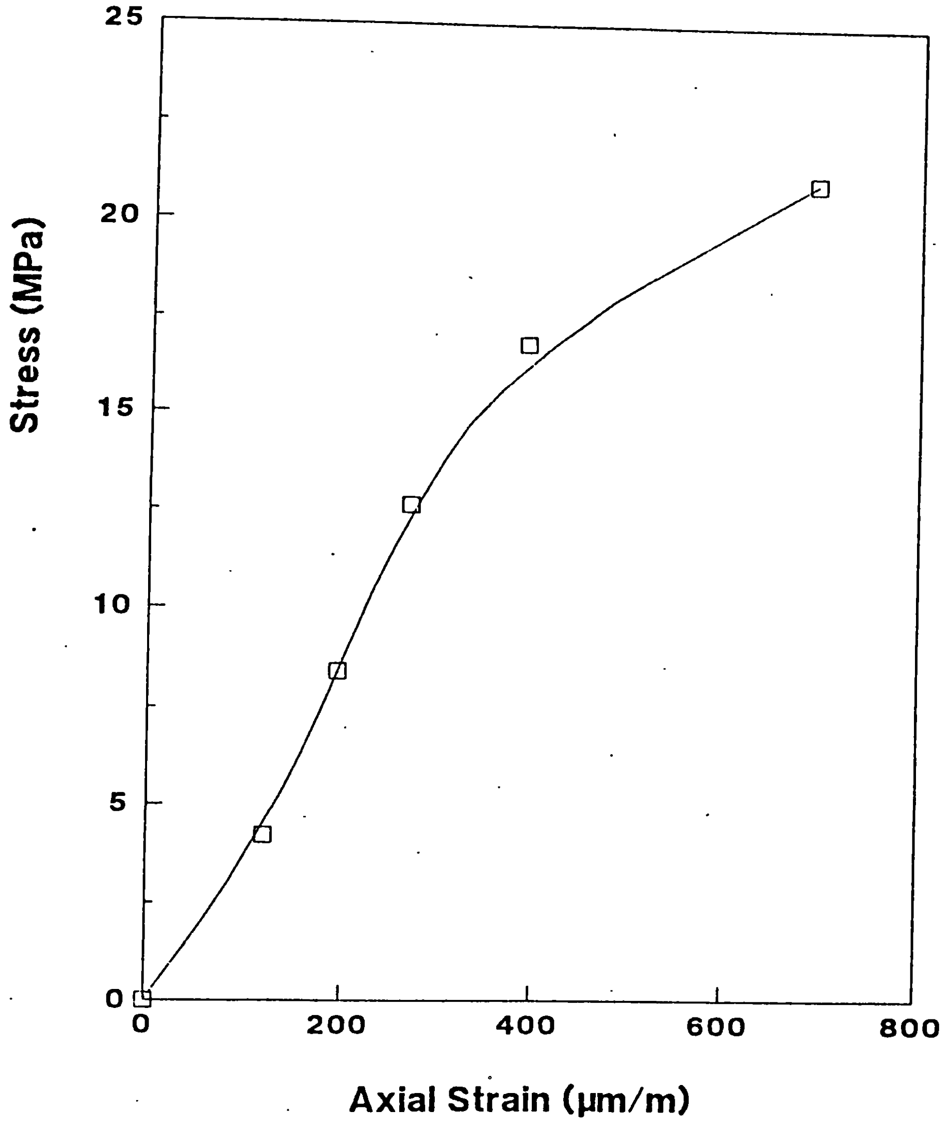
Stress vs Axial Strain

Fig.A.4.6



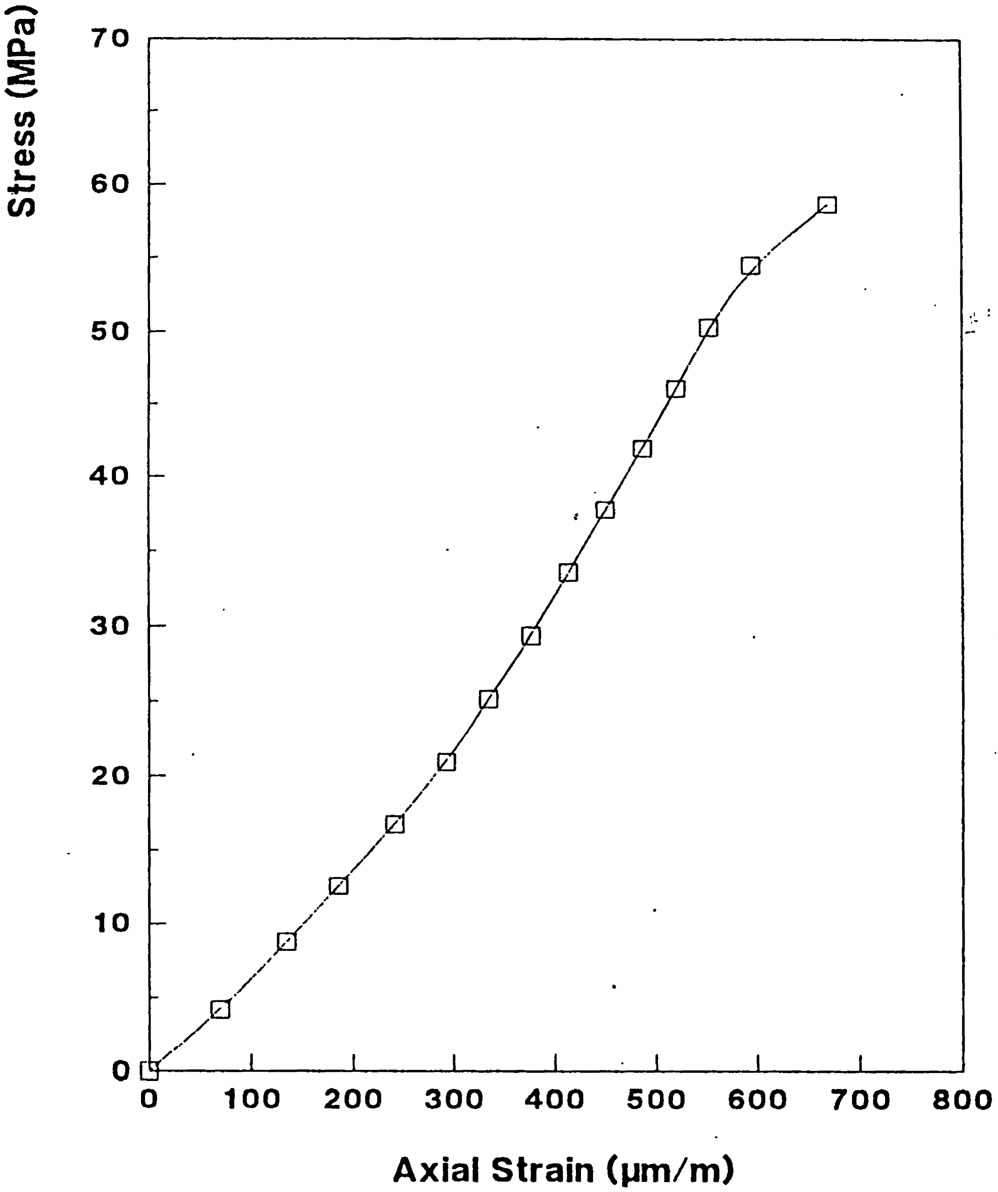
Stress vs Axial strain

Fig. A.4.7



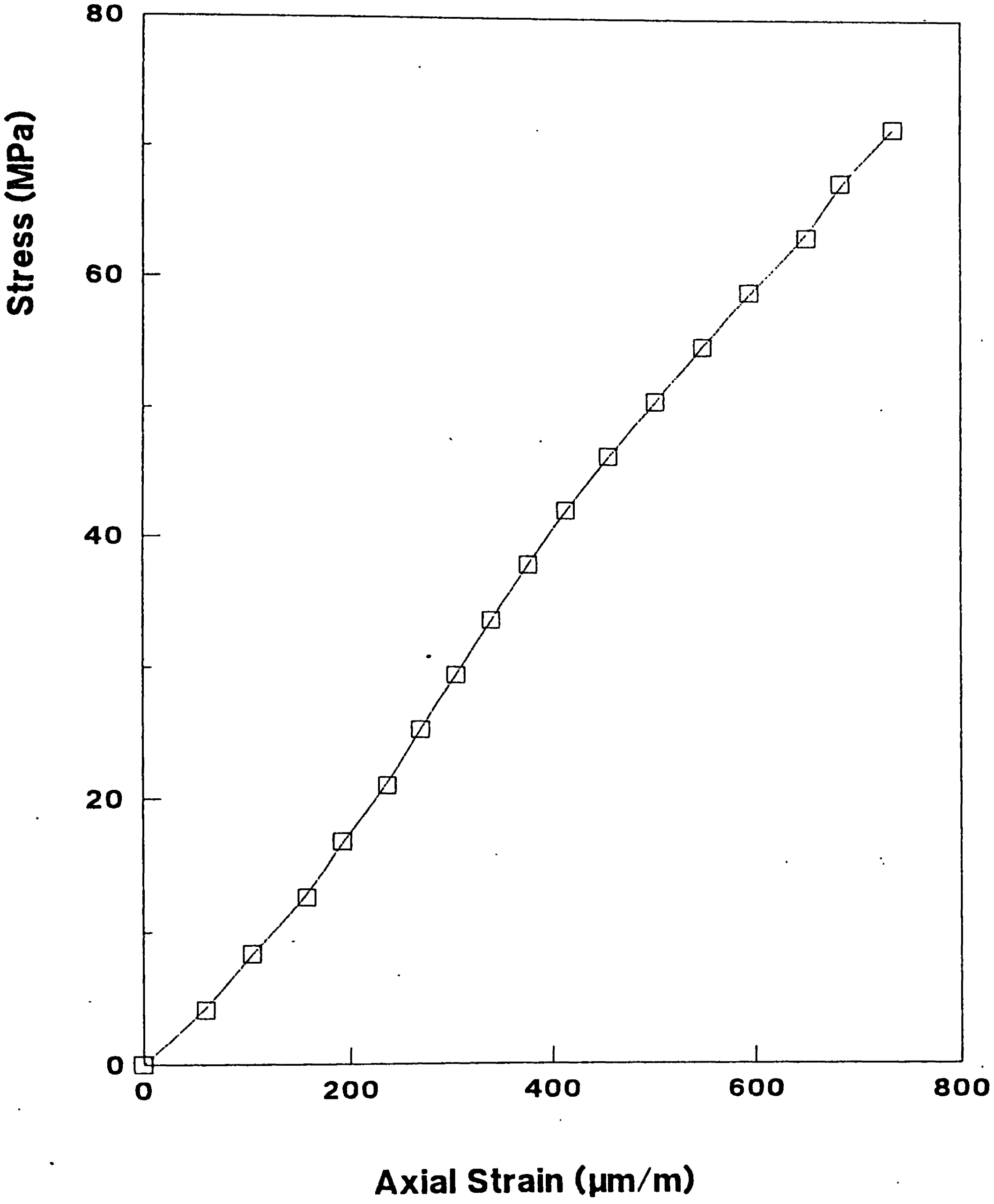
Stress vs Axial Strain

Fig. A.4.8



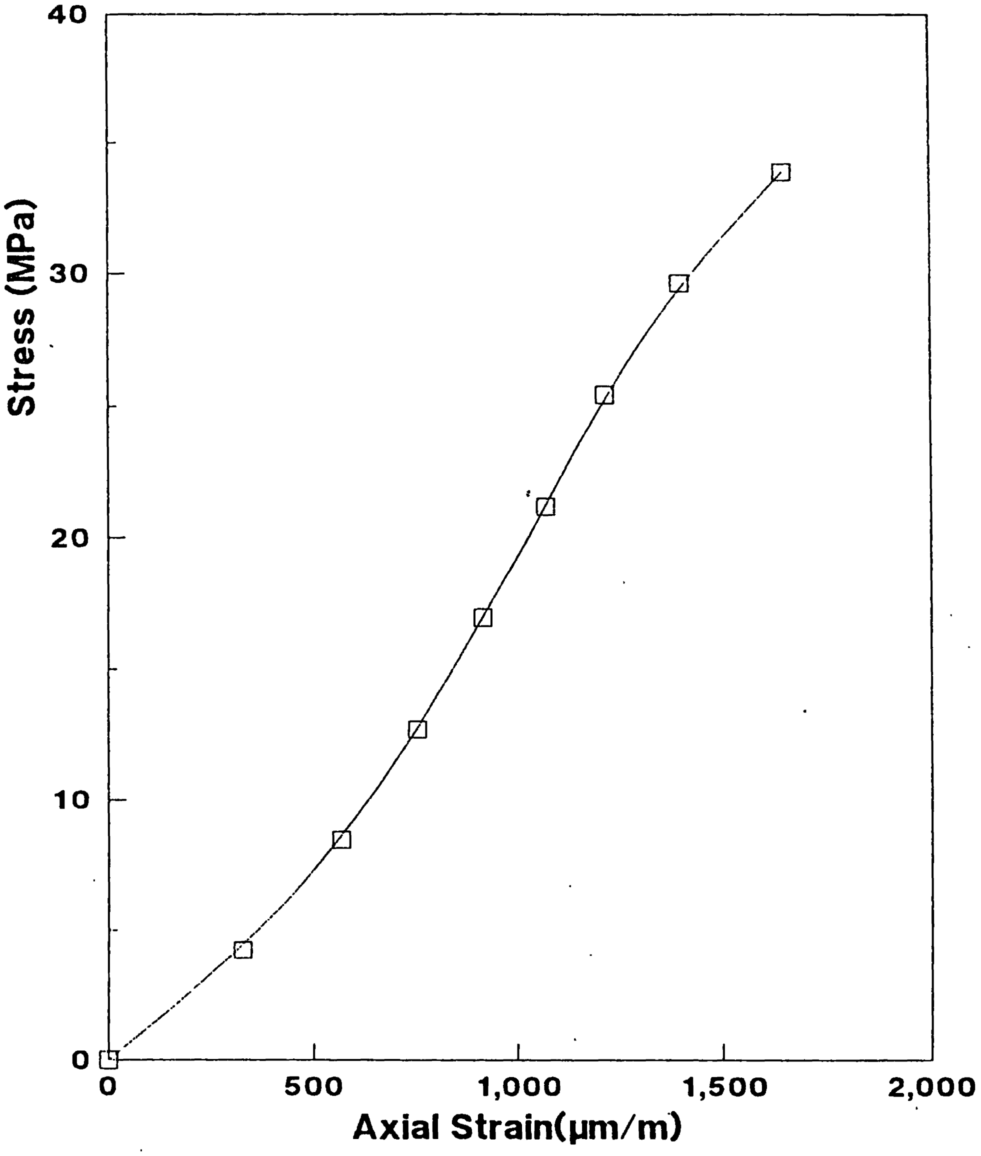
Stress vs Axial Strain

Fig. A.4.9



Stress vs axial Strain

Fig. A.4.10



1.6 Potential reactivity (chemical method)

Appendix A - 5

Potential Reactivity (Chemical Method)

Sample Type = A (Using drilled cores)

ASTM Standards = C 289 - 81

(1.) Dam Site Quarry (No. KK4).

Depth (m)	Concentration of SiO_2 m mols/l		
	I	II	III
10.37	13.653	12.987	6.660
17.5	22.64	11.32	29.637
19.9	35.631	23.976	32.634
14.78	14.319	37.962	23.976

Power House Quarry (No. KK5)

Depth (m)	Concentration of SiO_2 m mols/l		
	I	II	III
16.35	5.382	9.657	3.663
17.0	2.664	8.325	4.329
19.0	6.993	1.665	2.999
14.19	10.656	8.658	16.317

Reduction in Alkalinity

Dam site Quarry (No. KK4)

Depth (m)	Reduction in Alkalinity mmol/l		
	I	II	III
10.37	360	390	165
17.5	185	265	320
19.9	245	170	420
14.78	280	180	150

Power House Quarry (No. KK5)

Depth (m)	Reduction in Alkalinity mmol/l		
	I	II	III
16.35	420	370	310
17.0	460	365	590
19.0	245	170	420
14.19	260	270	480

Interpretation of results

When the three values of R_c, S_c are plotted on the semilog graph provided, for each of the eight samples, it can be seen that the points are all lying on the innocuous side of the solid curve.

Thus the samples from both the dam site and the power house site from the depths mentioned in the report can all be considered innocuous in respect of their degree of alkali reactivity.

....
(Mrs.) N. Ratnayake,
Senior Lecturer.

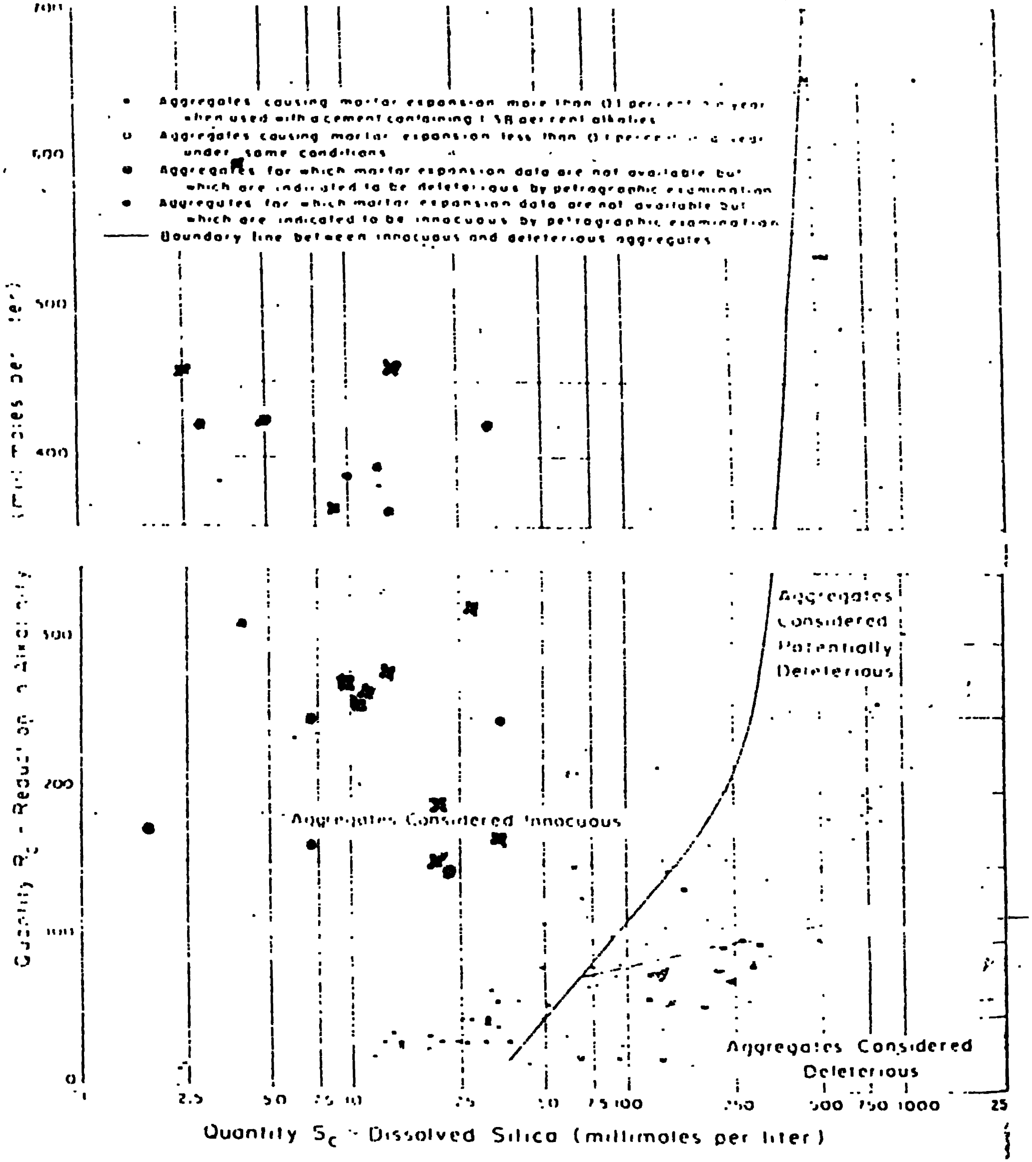


FIG. 2 Illustration of Division Between Innocuous and Deleterious Aggregates on Basis of Reduction in Alkalinity Test

Dam Site (No. KK4)

Depth (m)	
10.37	•
17.50	✱
19.90	•
14.78	✱

Power House Site (No.

Depth (m)	
16.35	•
17.00	✱
19.00	•
14.19	✱

1.7 Clay lumps and friable particles

Appendix B - 1

Soft Rock Amount

Sample Type = B (Blasted rock packed in bags)

ASTM Standard = C 142 - 78

(1) Dam Site Quarry (No. KK4).

No. of samples tested = 01.

Size Fraction (mm)	Percentage of Friable Particles
4.75 to 9.5	0.22 %
9.5 to 19.0	0.15 %
Percentage of soft (friable) particles = 0.22 %	

(2) Power House Quarry (No. KK5)

No. of samples tested = 01.

Size Fraction (mm)	Percentage of Friable Particles
4.75 to 9.5	1.14 %
9.5 to 19.0	2.08 %
Percentage of soft (friable) particles = 2.1 %	

Note: (1) Test samples were obtained by breaking the rock samples supplied. The quantity of samples was sufficient to obtain only two size fractions (4.75 mm to 9.5 mm and 9.5 mm to 19.0 mm).

(2) No clay lumps were present in the test samples.

(3) As grading of the samples was not available, the largest percentage of soft particles in the two size fractions tested is given as the percentage of soft particles in the sample.

1.8 Abrasion test by Los Angeles method

Appendix B - 2

Abrasion Test by Los Angeles Method

Sample type : B (using blasted rock)

ASTM Standard : C - 131

Grading : A

(1) Dam Site Quarry (No. KK4)

Test No.	1	2
Los Angeles Abrasion Value(%)	36.0	37.9

(2) Power House Quarry (No. KK5)

Test No.	1	2
Los Angeles Abrasion Value(%)	85.8	85.6

Additional Testing

Kukule Ganga Feasilbility Study

Abrasion Test by Los Angeles Method

Sample Type : A (using material from drilled core)
ASTM Standard : C-131
Grading : A

Power House Quarry (No. KK5)

Depth : (15.31 - 17.35) m

Los Angeles Abrasion Value = 59.7 %

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6/4/92

1.9 Soundness test

Appendix B - 3

Soundness Test

Sample Type = B (Blasted rock)
ASTM Standard = C 88 - 83.
Solution used = Sodium Sulphate Solution
No. of Cycles = 5
Test samples :- Obtained by breaking the rock samples supplied.

(1) Dam Site Quarry (No. KK4)
No. of samples tested = 02

(a) Sample 1

Sieve Size (mm)	Grading of Original Sample	Percentage Passing Designated Sieve after test	Weighted Percentage Loss.
37.5 to 19.0	45.2 %	1.04	0.47
19.0 to 9.5	33.1 %	1.14	0.38
9.5 to 4.75	21.6 %	0.40	0.09

Maximum percentage loss = 1.14 %

Weighted percentage loss = 0.94 %

Qualitative examination of particles larger than 19.0 mm

Excessive splitting, crumbling or cracking was not observed.

No. of particles before test = 71
No. of particles after test = 72

(b) Sample 2

Sieve Size (mm)	Grading of Original Sample	Percentage Passing	Weighted Percentage Loss.
37.5 to 19.0	45.2	0.77	0.35
19.0 to 9.5	33.1	0.72	0.24
9.5 to 4.75	21.6	1.80	0.39

Maximum percentage loss = 1.80 %
Weighted percentage loss = 0.98 %

Qualitative examination of particles larger than 19.0 mm

Excessive of cracking, splitting or crumbling was not observed
Number of particles before test = 71
Number of particles after test = 71

(2) Power House Quarry. (No. KK5)

Number of samples tested = 02

(a) sample 1:

Sieve Size (mm)	Grading of Original Sample	Percentage Passing after the test	Weighted Percentage Loss.
37.5 to 19.0	32.9	2.36	0.78
19.0 to 9.5	32.1	1.25	0.40
9.5 to 4.75	35.0	2.53	0.89

Maximum percentage loss = 2.53 %
Weighted percentage loss = 2.07 %

Qualitative examination of particles larger than 19.0 mm.

Excessive splitting, cracking or crumbling was not observed
Number of particles before test = 57
Number of particles after test = 60

(b) Sample 2

Sieve Size (mm)	Grading of Original Sample	Percentage Passing after the test	Weighted Percentage Loss.
37.5 to 19.0	32.9	2.1	0.69
19.0 to 9.5	32.1	1.61	0.52
9.5 to 4.75	35.0	2.40	0.84

Maximum percentage loss = 2.40 %
Weighted percentage loss = 2.05 %

Qualitative examination of particles larger than 19.0 mm.

Excessive cracking, splitting or crumbling was not observed.
Number of particles before test = 52
Number of particles after test = 58

Note: (1) The maximum percentage loss given above is the largest percentage loss of the three size fractions tested.

(2) The grading of the original sample was based on the total weight of each size fraction after the rock samples were broken.

1.10 Ten percent fines

Appendix B - 4

Ten Percent Fines Value

Sample Type = B (Blasted rock)

British Standard = B S 812 : Part 3 (1975)

Test samples :- Samples of standard size (10 mm to 14 mm) obtained by breaking the rock samples supplied were used.

(1) Dam Site Quarry (No. KK4)

No. of samples tested = 01.

Ten percent fines value = 150 kN.

(2) Power House Quarry (No. KK5)

No. of Samples tested = 01

Ten percent fines value = 35 kN.

Ten Percent Fines Value

Surge Shaft Site (KK 7)

Sample Type : A (for drilled Cores)

British standard : BS 812 : Part 3 (1975)

Test Samples : Obtained by crushing drilled cores.

No. of samples Tested : 02.

Sample 1 :

Depth = 4.75 m to 6.90 m.

Ten Percent fines value = 140 kN

Sample 2 :

Depth = 9.5 m to 11.0 m

Ten Percent fines Value = 100 kN.

B. K. [illegible]

6/4/92

Ten Percent Fines Value:

Power House Quarry (KK-5)

Sample Type : Sample A (drilled cores)

Depth :

British Standards : 135 812: Part 3 (1975)

Test Samples : Test samples were obtained by breaking drilled cores.

Results : Ten percent Fines value = 70 kN.

21/4/92

1.11 Results of quality control tests
on
concrete aggregates during construction
of
the Samanalawewa Project

Table 3.4.6 Tests Results of Quality Control on Aggregate

Test Item	Gradation	Range
1. Specific gravity	0 - 5 mm	2.71 - 2.81
	5 - 20 mm	2.75 - 2.85
	20 - 40 mm	2.78 - 2.89
	40 - 80 mm	2.81 - 2.88
2. Absorption (%)	0 - 5 mm	0.91 - 1.28
	5 - 20 mm	0.54 - 0.96
	20 - 40 mm	0.23 - 0.58
	40 - 80 mm	0.13 - 0.19
3. Washing value (%)	0 - 5 mm	3.30 - 5.49
	5 - 20 mm	0.69 - 1.33
	20 - 40 mm	0.53 - 1.09
4. 10% finess value (kN)		65 - 120
5. Los Angeles abrasion (%)	A	40 - 66
	B	38 - 70
6. Flakiness index (Average)	0 - 20 mm	19.7 - 25.3
	20 - 40 mm	15.0 - 25.6
7. Fineness modulus (Average)	0 - 5 mm	2.42 - 2.62
	5 - 20 mm	6.50 - 6.79
	20 - 40 mm	7.81 - 7.95
	40 - 80 mm	8.62 - 8.95

TEST RESULTS OF MONTHLY QUALITY CONTROL

ON

CONCRETE AGGREGATES

LOT II CONCRETE MATERIAL

TABLE G RESULTS OF AGGREGATE TESTS (1/2)

TEST		1988 OCT	1988 NOV	1988 DEC	1989 JAN	1989 FEB	1989 MAR	1989 APR	1989 MAY	1989 JUN	1989 JUL	1989 AUG	1989 SEP	1989 OCT	1989 NOV	1989 DEC	1990 JAN	1990 FEB	1990 MAR
1.Specific Gravity																			
0 - 5 mm.		2.81	2.79	2.77	2.78	2.78	2.77	-	2.75	2.74	-	2.71	2.73	2.75	2.73	2.74	2.736	2.73	2.73
5 - 20 mm.		2.83	2.80	2.80	2.82	2.80	2.85	-	2.81	2.81	-	2.79	2.83	2.83	2.83	2.84	2.840	2.80	2.81
20 - 40 mm.		2.84	2.84	2.80	2.83	2.84	2.89	-	2.84	2.84	-	2.80	2.85	2.88	2.86	2.86	2.870	2.84	2.84
80 - 40 mm.		2.81	2.86	-	2.88	2.85	-												
2.Absorption																			
0 - 5 mm.		1.20	1.10	1.15	1.28	1.11	1.09	-	1.09	1.10	-	1.16	1.14	1.01	1.11	1.09	1.10	100	1.02
5 - 20 mm.		0.60	0.96	0.61	0.56	0.63	0.72	-	0.62	0.65	-	0.74	0.67	0.70	0.76	0.54	0.55	0.62	0.61
20 - 40 mm.		0.03	0.33	0.41	0.23	0.40	0.48	-	0.31	0.36	-	0.58	0.55	0.52	0.51	0.45	0.42	0.50	0.48
80 - 40 mm.		0.04	0.19	-	0.16	0.13	-												
3.Washing Value																			
0 - 5 mm.		3.30	5.00	5.49	5.30	5.43	4.39	4.51	4.38	4.36	4.16	3.85	3.79	4.04	4.69	4.54	4.33	4.89	4.88
5 - 20 mm.		-	-	-	-	-	0.74	-	0.84	0.78	1.20	-	0.89	0.83	0.86	0.97	0.98	0.90	0.69
20 - 40 mm.		-	-	-	-	-	-	-	0.75	0.77	1.09		0.63	0.86	0.80	0.92	0.76	0.53	0.79
4. 10 % fines value		-	-	-	-	-	-	-	-	-	-	-	-	120	90	100	82	110	110
5.Los Angelese Abrasion																			
Gradation - A, % loss		-	-	-	-	-	-	-	-	-	-	44	42	40	44	42	44	42	40
Gradation - B, % loss		-	-	-	-	-	-	-	-	-	-	-	-	38	43	44	-	42	41
6.Flakiness Index																			
0 - 20mm.	No.	-	-	-	-	-	01	23	23	28	24	07	33	23	31	13	25	33	36
	Average						21	25.3	22.4	23.6	23.6	20.9	22.0	22.2	23.3	24	24.7	23.9	21.9
	Maximum						21	38	27	33	32	27	32	33	29	30	28	33	28
20 - 40mm.	No.	-	-	-	-	-	-	13	22	37	24	04	29	20	33	16	25	36	35
	Average							25.6	25.0	24.1	24.5	22.5	22.2	20.2	20.3	19.1	19.8	19.8	20.1
	Maximum							32	35	33	31	30	31	28	27	24	27	27	26
7.Fineness Modulus																			
0 - 5 mm.	No.	6	4	8	8	10	10	10	10	10	10	10	10	10	53	41	49	35	39
	Average	2.58	2.50	2.62	2.55	2.44	2.46	2.52	2.53	2.51	2.47	2.52	2.53	2.43	2.44	2.44	2.42	2.45	2.50
	Std. Dev.	0.04	0.17	0.05	0.10	0.08	0.05	0.09	0.09	0.04	0.05	0.04	0.06	0.04	0.11	0.10	0.11	0.08	0.11
5 - 20mm.	No.	4	5	5	8	10	10	10	10	10	10	10	10	10	53	37	48	35	38
	Average	6.59	6.57	6.55	6.50	6.75	6.76	6.77	6.72	6.68	6.70	6.71	6.73	6.71	6.77	6.72	6.70	6.74	6.76
	Std. Dev.	0.06	0.03	0.05	0.05	0.04	0.03	0.07	0.04	0.03	0.04	0.04	0.05	0.06	0.06	0.12	0.09	0.09	0.06
20 - 4 mm	No.	5	5	7	8	6	8	10	10	10	10	10	10	10	47	30	37	30	34
	Average	7.92	7.88	7.91	7.92	7.95	7.90	7.86	7.91	7.94	7.89	7.91	7.89	7.90	7.90	7.88	7.84	7.82	7.81
	Std. Dev.	0.08	0.02	0.04	0.03	0.03	0.02	0.08	0.05	0.04	0.04	0.03	0.04	0.04	0.04	0.06	0.07	0.06	0.05
40 - 8 mm.	No.	4	5	4	5	4	-	-	02	06	02	03	04	02	05	01	01	-	-
	Average	8.90	8.88	8.90	8.88	8.94			8.91	8.92	8.91	8.79	8.95	8.95	8.62	8.81	8.91		
	Std. Dev.	0.22	0.04	0.05	0.09	0.01			-	0.10	-	0.03	0.08		0.46				

Annex-5B.2

Embankment Materials

THREE BASINS PROJECT - KALU GANGA (ECI)

KUKULE DAM BORROW AREAS MATERIALS

SUMMARY OF LABORATORY TESTS

SAMPLE NO.	AUGER HOLE OR PIT NO.	DEPTH IN FEET BELOW G.L.	BORROW AREA	UNIFIED SOIL CLASSIFICATION	IN SITU MOISTURE CONTENT % DRY WEIGHT	IN SITU DRY DENSITY LBS/CU FT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	SPECIFIC GRAVITY	MECHANICAL ANALYSIS									COMPACTION & PENETRATION			TRIAXIAL SHEAR**		PERCOLA. & SETTLEMENT	
											% CLAY < 0.002 MM	% SILT 0.002 – 0.06 MM	% FINE SAND 0.06 – 0.2 MM	% MED. SAND 0.2 – 0.5 MM	% COARSE SAND 0.5 – 2.0 MM	% GRAVEL > 2 MM	% COBBLES & BOULDERS > 3/4	% PASS 1/4" MESH	% PASS 200 MESH	OPTIMUM MOIST. CONT. % DRY WT.	MAX. DRY DENS. LBS/CU FT	PENETRATION RESISTANCE LBS/SQ FT	TAN Ø	COHESION LBS/SQ FT	PERCOLATION RATE CM/SEC	% CONSOLIDATION
1	M1		A	CH			50.5	27.6	22.9	2.73	32	25	18	8	8	9	0	96	60	22.6	98.8	1676	0.34	13.0	.021735	.001818
2	M1		A	CH			51.6	24.7	26.9	2.74	29	21	17	10	10	12	1	90	56	20.4	103.0	650	0.29	20.0	.01759	.00059
3	M1		A	SW						2.81	8	6	5	10	24	42	5	72	15	14.1	120.8	1200	0.84	4.5	.009833	.00088
23	5	0'–6'	A				50.3	26.5	23.8	2.72			89	9	1	1	0	100	63							
24	5	6'–9'	A				63.4	33.5	29.9	2.63			78	11	7	4	0	99	67							
25	5	9'–10'	A				38.4	21.0	17.4	2.69			74	17	1	8	0	94	37							
26	6	0'–4'	A				59.6	37.1	22.5	2.62		86	13	0	1	0	0	100	90							
27	6	4'–6'	A				55.0	33.3	21.7	2.67		70	8	6	3	13	0	89	71							
28	6	6'–7'	A				35.4	19.7	15.7	2.68			51	22	12	15	0	89	28							
29	7	0'–4'	A				35.7	19.9	15.8	2.60		80	14	2	4	0	0	100	83							
30	7	9'–17'	A				76.1	43.7	32.4	2.76			62	8	7	22	0	84	55							
31	8	0'–7'	A				45.8	21.9	23.9			59	28	6	4	3	0	99	63							
32	8	9'–14'	A				16.4	–	–				80	18	1	1	0	100	26							
33	8	14'–16'	A				33.4	17.1	16.3			50	31	9	1	9	0	92	53							
34	8	16'–20'	A				18.1					16	17	21	9	37	0	70	19							

* At 1 TSF

** Sample at maximum dry density.

See Figure V-G for sample locations.

SAMPLE NO.	AUGER HOLE OR PIT NO.	DEPTH IN FEET BELOW G.L.	BORROW AREA	UNIFIED SOIL CLASSIFICATION	IN SITU MOISTURE CONTENT % DRY WEIGHT	IN SITU DRY DENSITY LBS/CU FT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	SPECIFIC GRAVITY	MECHANICAL ANALYSIS % CLAY < 0.002 MM	% SILT 0.002 – 0.06 MM	% FINE SAND 0.06 – 0.2 MM	% MED. SAND 0.2 – 0.6 MM	% COARSE SAND 0.6 – 2.0 MM	% GRAVEL > 2 MM	% COBBLES & BOULDERS > 3/4"	% PASS 1/4" MESH	% PASS 200 MESH	COMPACTION & PENETRATION OPTIMUM MOIST. CONT. % DRY WT.	MAX. DRY DENS. LBS/CU FT	PENETRATION RESISTANCE LBS/SQ FT	TRIAXIAL SHEAR ** TAN Ø	COHESION LBS/SQ FT	PERCOLA. & SETTLEMENT PERCOLATION RATE CM./SEC	% CONSOLIDA-TION
35	9A	5'–12'	A				35.1	18.3	16.8			32	45	8	4	11	0	92	36							
39	10A	3'–7'	A				20.8	–	–				50	15	22	13	0	93	20							
40	10A	10'–18'	A				32.8	21.0	11.7			46	16	23	10	5	0	96	49							
4	M2		B	CI			38.6	16.8	21.8	2.71	25	21	41	8	3	2	0	99	57	15.9	111.0	1400	.43	18.0	.00766	.0008
5	M2		B	SC/CI			49.8	18.1	31.7	2.72	27	17	41	11	2	2	0	100	50	17.0	109.5	1500	.54	13.5	.01179	.00063
11	1	10'–13'	B									25	37	38	0	0	0	100	27							
12	1	13'–14'	B				24.8	–	–	2.73			55	44	0	1	0	100	23							
13	1	14'–15'	B							2.75			54	45	0	1	0	100	13							
14	2	10'–12'	B				34.1	16.8	17.3	2.72			60	38	1	1	0	100	33							
15	2	12'–13'	B				18.2	–	–	2.77		16	33	36	9	6	0	100	19							
16	2	13'–15'	B				37.3	18.3	19.3	2.68			25	37	24	14	0	93	17							
17	3	0'–8'	B				63.2	36.3	26.9	2.66		92	7	1	0	0	0	100	94							
18	3	8'–10'	B				65.6	24.6	21.0	2.71			74	15	3	8	0	93	45							
19	3	10'–16'	B				35.8	16.5	19.2	2.69			64	33	2	1	0	100	33							
20	3	16'–20'	B							2.68		22	53	23	2	0	0	100	25							

* At 1 TSF

** Sample at maximum dry density.

See Figure V-G for sample locations.

SAMPLE NO.	AUGER HOLE OR PIT NO.	DEPTH IN FEET BELOW G.L.	BORROW AREA	UNIFIED SOIL CLASSIFICATION	IN SITU MOISTURE CONTENT % DRY WEIGHT	IN SITU DRY DENSITY LBS/CU FT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	SPECIFIC GRAVITY	MECHANICAL ANALYSIS % CLAY < 0.002 MM	% SILT 0.002–0.06 MM	% FINE SAND 0.06–0.2 MM	% MED. SAND 0.2 – 0.6 MM	% COARSE SAND 0.6 – 2.0 MM	% GRAVEL > 2 MM	% COBBLES & BOULDERS > 3/4"	% PASS 1/4" MESH	% PASS 200 MESH	COMPACTION & PENETRATION OPTIMUM MOIST. CONT. % DRY WT.	MAX. DRY DENS. LBS/CU FT	PENETRATION RESISTANCE LBS/SQ FT	TRIAXIAL SHEAR** TAN Ø	COHESION LBS/SQ FT	PERCOLA. & SETTLEMENT PERCOLATION RATE CM/SEC	% CONSOLIDA-TION*
21	4A	0'–8'	B				52.4	29.8	22.6	2.69		75	24	0	1	0	0	100	80							
22	4A	8'–11'	B				34.7	19.3	15.3	2.68		30	31	19	17	3	0	100	34							1
46	13	0'–8'	C				74.0	41.7	32.3				60	10	13	17	0	95	45							
47	13	8'–20'	C				42.6	26.0	16.6				58	26	11	5	0	99	45							
48	14	0'–10'	C				65.5	31.7	33.8			31	17	18	22	12	0	93	34							
49	14	10'–20'	C				43.4	29.5	13.9			48	15	21	12	4	0	100	50							
50	15	0'–8'	C				70.4	32.2	38.2			44	15	15	16	10	0	98	47							
51	15	8'–12'	C				57.0	29.4	27.6			41	16	17	22	4	0	99	43							
52	15	12'–16'	C				68.4	39.2	29.2				48	12	20	20	0	88	39							
53	15	16'–20'	C				66.4	48.1	18.3				67	8	17	8	0	99	58							

* At 1 TSF

** Sample at maximum dry density.

See Figure V–G for sample locations.

Annex-5B.3

Water Quality Test for Concrete

ලංකා විද්‍යාත්මක හා කාර්මික පර්යේෂණ ආයතනය
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විදුලි පණිවුඩ / தந்தி / Cables: සීඅයිඑස්අයිආර් / சி ஐ எஸ் ஐ ஆர் / CISIR
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ANALYSIS OF ONE SPECIMEN OF WATER

Report No. TS : C - 6300

KUKULE GANGA PROJECT
FEASIBILITY STUDY
19 1992
CEYLON ELECTRICITY BOARD

REPORT TO:

Kukule Ganga Hydro Electric Project
Feasibility Study,
Ceylon Electricity Board,
New Kelani Bridge Road,
Wellampitiya.

07th May 1992

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"தொலைத் தொடர்புகளுடையவர் பெயரில் எழுதவும்"
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363, බෞද්ධාලෝක මාවත,
කොළඹ-7, ශ්‍රී ලංකා.

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ANALYSIS OF ONE SPECIMEN OF WATER

Report No. TS : C - 6300

CLIENT : Kukule Ganga Hydro Electric Project
Feasibility Study,
Ceylon Electricity Board,
New Kelani Bridge Road,
Wellampitiya.

REFERENCE : Client's letters of 18th February 1992 and 22nd April 1992 (with reference DGM(GP)/KFS/30) confirmed on 27th April 1992.

SPECIMEN : A total of approximately 06 litres of water contained in two plastic containers each labelled as follows:

CEB
KUKULE

The contents of the two containers were mixed and treated as one specimen.

METHOD OF ANALYSIS : Suitability for mixing concrete

The analysis was carried out as per British Standard Methods to test for water for making concrete (including notes on suitability of the water) BS : 3148 : 1980.

Contd...02/.

The specimen/~~s~~ tested was/~~were~~ submitted by the client. It was/~~They were~~ NOT sampled by C. I. S. I. R. officers. The report is therefore limited specifically to this/~~these~~ specimen/~~s~~.

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"சகல தபால்களும் அதிபர் பெயரில் எழுதவும்"
"PLEASE ADDRESS ALL ENVELOPES TO THE DIRECTOR"

Aggresiveness to concrete structures

The analysis was carried out as per Indian Standard Code of Practice for Treatment of Water for industrial cooling systems, IS 8188 : 1976.

Aggresiveness for turbines

The analysis was carried out as detailed in Appendix 1 of Client's letter dated 18th February 1992.

RESULTS : Suitability for mixing concrete

Appearance - Clear with settlable matter
Colour - 30 Hazen Units
Odour - Unobjectionable
pH at 20°C - 5.4
Electrical conductivity at 25°C - 40 µS/cm
Total dissolved solids at 180°C - 35 mg/l
Suspended solids at 105°C - 26 mg/l
Chloride (as Cl) - 10 mg/l
Sulphate (as SO_3) - 11 mg/l
Alkali Carbonate (as $CaCO_3$) - Nil
Alkali Bicarbonate (as $CaCO_3$) - 8 mg/l

Contd...03/.

Aggresiveness to concrete structures

pH at 20°C	-	5.4
Total residue at 180°C	-	67 mg/l
Calcium hardness (as $CaCO_3$)	-	8 mg/l
Total alkalinity (as $CaCO_3$)	-	8 mg/l
Ryznar Index at 20°C (calculated)	-	14.41
Langelier Index at 20°C (calculated)	-	- 4.51

Aggresiveness for turbines

Total dissolved solids	-	35 mg/l
Alkalinity to Phenolphthalein (as $CaCO_3$)	-	Nil
Alkalinity to Methyl Orange (as $CaCO_3$)	-	8 mg/l
Total hardness (as $CaCO_3$)	-	12 mg/l
Chloride (as Cl)	-	10 mg/l
Calcium (as Ca)	-	3 mg/l
Magnesium (as Mg)	-	1 mg/l
Sodium and Potassium (as Na)	-	4 mg/l
Free Carbon di oxide (as CO_2)	-	2 mg/l
Sulphate (as SO_4)	-	13 mg/l

Contd...04/.

N.B:

The specimen/~~s~~ tested was/~~were~~ submitted by the client. It was/~~They were~~ NOT sampled by C. I. S. I. R. officers. The report is therefore limited specifically to this/~~these~~ specimen/~~s~~.

Residue loss on ignition at 550°C - 11 mg/l

pH at 20°C - 5.4

Total Iron (as Fe) - 1.3 mg/l

Soluble Iron (as Fe) - 0.3 mg/l

Suspended solids including sediments - 26 mg/l

Hardness of suspended solids (inclusive of sediments) (as $CaCO_3$) - 2 mg/l

COMMENTS : Suitability for mixing concrete

The specimen of water analysed meets the requirements as specified in British Standards Methods of Tests for water for making concrete, BS 3148 : 1980 with respect to all parameters tested.

Aggresiveness to concrete structures

The Langelier Index and Ryznar Index indicates that the water has corrosive tendencies.

....
M. Fernando,
TECHNICAL ASSISTANT.

....
Dr. Nirmala M. Pieris,
HEAD/ANALYTICAL CHEMISTRY SECTION.

MF:NMP:nmg,
920507.

N.B:
The specimen/~~s~~ tested was/~~were~~ submitted by the client. It was/~~They were~~ NOT sampled by C. I. S. I. R. officers. The report is therefore limited specifically to this/~~these~~ specimen/~~s~~

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கொழும்பு 7, ஸ்ரீ லங்கா.

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363, බෞද්ධාලෝක මාවත,
කොළඹ 7, ශ්‍රී ලංකාව.

P. O. Bo
363, Bauddhalo
Colombo 7, Sri

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698

ANALYSIS OF ONE SPECIMEN OF WATER

Report No. TS : C - 6538

KUKULE GANGA PROJECT
FEASIBILITY STUDY
09 - 6 1992
CEYLON ELECTRICITY BOARD

REPORT TO:

Kukule Ganga Hydro Electric Project
Feasibility Study,
Ceylon Electricity Board,
New Kelani Bridge Road,
Wellampitiya.

04th June 1992

"සියලු ම ලිපි කවර අධ්‍යක්ෂ වෙත යොමු කළ යුතුයි"
"தொலைத் தொடர்புகளுடையவர் பெயரில் எழுதவும்"
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කොළඹ - 7, ශ්‍රී ලංකා.

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ANALYSIS OF ONE SPECIMEN OF WATER

Report No. TS : C - 6538

CLIENT : Kukule Ganga Hydro Electric Project
Feasibility Study,
Ceylon Electricity Board,
New Kelani Bridge Road,
Wellampitiya.

REFERENCE : Client's letter of 25th May 1992 (with reference KFS/30) confirmed on 01st June 1992.

SPECIMEN : Approximately 05 litres of water contained in a plastic container with no label.

METHOD OF ANALYSIS : Suitability for mixing concrete

The analysis was carried out as per British Standard Methods to test for water for making concrete (including notes on suitability of the water) BS : 3148 : 1980.

Contd...02/.

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"சகல தபால்களும் அதிபர் பெயரில் எழுதவும்"

"PLEASE ADDRESS ALL ENVELOPES TO THE DIRECTOR"

Aggresiveness to concrete structure

The analysis was carried out as per Indian Standa Code of Practice for Treatment of Water for industri cooling systems, IS 8188 : 1976.

Aggresiveness for turbines

The analysis was carried out as detailed in Append 1 of Client's letter dated 18th February 1992.

RESULTS : **Suitability for mixing concrete**

Appearance	-	Clear with settl matter
Colour	-	15 Hazen Units
Odour	-	Unobjectionable
pH at 25°C	-	5.9
Electrical conductivity at 20°C	-	40 µS/cm
Total dissolved solids at 180°C	-	30 mg/l
Suspended solids at 105°C	-	12 mg/l
Chloride (as Cl)	-	8 mg/l
Sulphate (as SO_3)	-	less than 1 mg/l
Alkali carbonate (as $CaCO_3$)	-	Nil
Alkali bicarbonate (as $CaCO_3$)	-	8 mg/l

Contd...03/.

Aggresiveness to concrete structures

pH at 20°C - 5.9

Total residue at 180°C - 48 mg/l

Calcium hardness (as $CaCO_3$) - 9 mg/l

Total alkalinity (as $CaCO_3$) - 8 mg/l

Ryznar Index at 20°C (calculated) - 13.50

Langelier Index at 20°C (calculated) - - 3.80

Aggresiveness for turbines

Total dissolved solids at 180°C - 30 mg/l

Alkalinity to Phenolphthalein (as $CaCO_3$) - Nil

Alkalinity to Methyl Orange (as $CaCO_3$) - 8 mg/l

Total hardness (as $CaCO_3$) - 12 mg/l

Chloride (as Cl) - 8 mg/l

Calcium (as Ca) - 3 mg/l

Magnesium (as Mg) - 1 mg/l

Sodium and Potassium (as Na) - 2 mg/l

Free carbon di oxide (as CO_2) - 6 mg/l

Sulphate (as SO_4) - less thatn 1 mg/l

Contd...04/.

N.B:
The specimen/~~s~~ tested was/~~were~~ submitted by the client. It was/~~They were~~ NOT sampled by C. I. S. I. R. officers. The report is therefore limited specifically to this/~~these~~ specimen/~~s~~.

TS : C - 6538

Residue loss on ignition at 550°C	-	10 mg/l
pH at 20°C	-	5.9
Total Iron (as Fe)	-	0.4 mg/l
Soluble Iron (as Fe)	-	0.2 mg/l
Suspended solids at 105°C (including sediments)	-	12 mg/l
Hardness of suspended solids (inclusive of sediments) (as $CaCO_3$)	-	2 mg/l

COMMENTS : Suitability for mixing concrete

The specimen of water analysed meets the requirement as specified in British Standards Methods of Test for water for making concrete, BS 3148 : 1980 wit respect to all parameters tested.

Aggresiveness to concrete structures

The Langelier Index and Ryznar Index indicates the the water has corrosive tendencies.

S.K.D Sarath Kumara,
TECHNICAL ASSISTANT.

Dr. Nirmala M. Pieris,
HEAD/ANALYTICAL CHEMISTRY SECTION.

SKDSK:NMP:nmg,
920604.

N.B:
The specimen/~~s~~ tested was/~~were~~ submitted by the client. It was/~~They were~~ NOT sampled by C. I. S. I. R. officers. The report is therefore limited specifically to this/~~these~~ specimen/~~s~~.

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ANALYSIS OF ONE SPECIMEN OF WATER

Report No. TS : C - 6784

REPORT TO:

Kukule Ganga Hydro Electric Project
Feasibility Study,
Ceylon Electricity Board,
New Kelani Bridge Road,
Wellampitiya.

04th July 1992

"සියලු ම ලිපි කවර අධ්‍යක්ෂ වෙත යොමු කළ යුතුයි"
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ANALYSIS OF ONE SPECIMEN OF WATER

Report No. TS : C - 6784

CLIENT : Kukule Ganga Hydro Electric Project
Feasibility Study,
Ceylon Electricity Board,
New Kelani Bridge Road,
Wellampitiya.

REFERENCE : Client's letter of 22nd June 1992 confirmed on 07th July 1992.

SPECIMEN : Approximately 04 litres of water contained in a plastic container labelled as follows:

Kukula Ganga
CEB
Water
23.06.92

METHOD OF ANALYSIS : Suitability for mixing concrete

The analysis was carried out as per British Standard Methods to test for water for making concrete (including notes on suitability of the water) BS : 3148 : 1980.

Contd...02/.

The specimen/~~s~~ tested was/~~were~~ submitted by the client. It was/~~They were~~ NOT sampled by C. I. S. I. R. officers. The report is therefore limited specifically to this/~~these~~ specimen/~~s~~.

"සියලුම ලිපි කවර අධ්‍යක්ෂ වෙත ආමන්ත්‍රිත කළ යුතුයි"
"சகல தபால்களும் அதிபர் பெயரில் எழுதவும்"
"PLEASE ADDRESS ALL ENVELOPES TO THE DIRECTOR"

Aggresiveness to concrete structure

The analysis was carried out as per Indian Standard Code of Practice for Treatment of Water for industrial cooling systems, IS 8188 : 1976.

Aggresiveness for turbines

The analysis was carried out as detailed in Appendix 1 of Client's letter dated 18th February 1992.

RESULTS : **Suitability for mixing concrete**

Appearance	-	Clear
Colour	-	8 Hazen Units
Odour	-	Unobjectionable
pH at 25°C	-	6.9
Electrical conductivity at 20°C	-	30 µS/cm
Total dissolved solids at 180°C	-	23 mg/l
Suspended solids at 105°C	-	2 mg/l
Chloride (as Cl)	-	1 mg/l
Sulphate (as SO_3)	-	less than 1 mg/l
Alkali carbonate (as $CaCO_3$)	-	Nil
Alkali bicarbonate (as $CaCO_3$)	-	23 mg/l

Contd...03/.

Aggresiveness to concrete structures

pH at 20°C - 6.9

Total residue at 180°C - 28 mg/1

Calcium hardness (as $CaCO_3$) - 18 mg/1

Total alkalinity (as $CaCO_3$) - 23 mg/1

Ryznar index at 20°C (calculated) - 11.50

Langelier index at 20°C (calculated) - - 2.30

Aggresiveness for turbines

Total dissolved solids at 180°C - 23 mg/1

Alkalinity to Phenolphthalein (as $CaCO_3$) - Nil

Alkalinity to Methyl Orange (as $CaCO_3$) - 23 mg/1

Total hardness (as $CaCO_3$) - 21 mg/1

Chloride (as Cl) - 1 mg/1

Calcium (as Ca) - 7 mg/1

Magnesium (as Mg) - less than 1 mg/1

Sodium and Potassium (as Na) - 2 mg/1

Free Carbon di oxide (as CO_2) - 2 mg/1

Sulphate (as SO_4) - less than 1 mg/1

Contd...04/.

N.B:
The specimen/~~s~~ tested was/~~were~~ submitted by the client. It was/~~They were~~ NOT sampled by C. I. S. I. R. officers. The report is therefore limited specifically to this/~~these~~ specimen/~~s~~.

Residue loss on ignition at 550°C - 6 mg/l

pH at 20°C - 6.9

Total Iron (as Fe) - 0.4 mg/l

Soluble Iron (as Fe) - 0.4 mg/l

Suspended solids at 105°C (including sediments) - 2 mg/l

Hardness of suspended solids (inclusive of sediments) (as $CaCO_3$) - 1 mg/l

COMMENTS : **Suitability for mixing concrete**

The specimen of water analysed meets the requirements as specified in British Standards Methods of Tests for water for making concrete, BS 3148 : 1980 with respect to all parameters tested.

Aggresiveness to concrete structures

The Langelier index and Ryznar index indicates that the water has corrosive tendencies.

S.K.D Sarath Kumara,
TECHNICAL ASSISTANT.

Dr. Nirmala M. Pieris,
HEAD/ANALYTICAL CHEMISTRY SECTION.

SKDSK:NMP:mmg,
920704.

N.B:
The specimen/~~s~~ tested was/~~were~~ submitted by the client. It was/~~They were~~ NOT sampled by C. I. S. I. R. officers. The report is therefore limited specifically to this/~~these~~ specimen/~~s~~.

Annex-5B.4

Inspection Report on Alkali-Aggregate Reaction in Concrete Work

KUKULE FESIBILITY STUDY PROJECT
INSPECTION REPORT

SUBJECT Alkali-aggregate reaction in concrete work

DATES OF INSPECTION: 22.04.92 to 24.04.92

PARTICIPANTS:
Mr. T. Aida, consultant Material Testing Engineer
Mr. R.M. Sunil Shantha, Civil Design Engineer, CECB

LOCATIONS:
(1) Canyon
(2) Laxapana
(3) Polpitiya
(4) Kotmale
(5) Randenigala
(6) Victoria
(7) Polgolla, Ukuwela
(8) Bowathenna

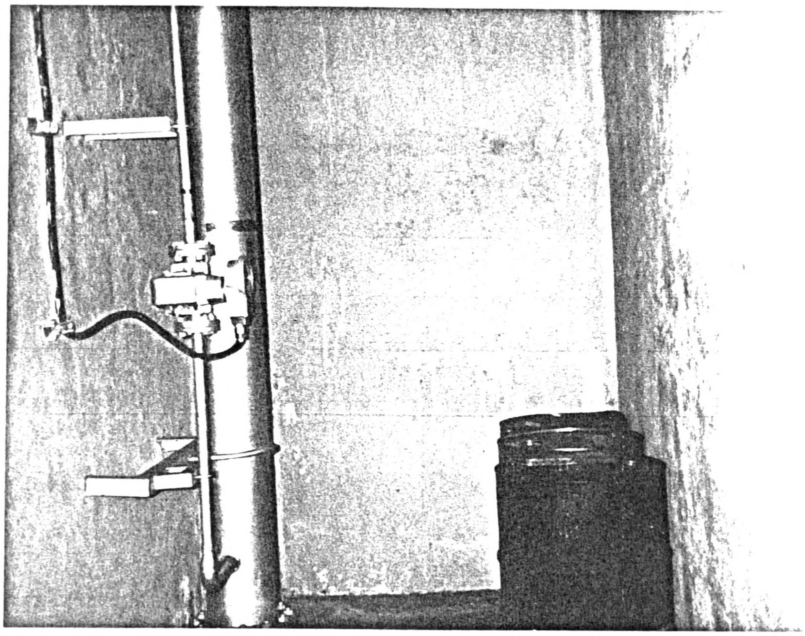
RESULTS ON INSPECTION

(1) Summary of the inspection results is shown in Table-01. Photos and the answers to the inquiries by the personnels incharge for the operation and maintenance of the respective project are also attached.

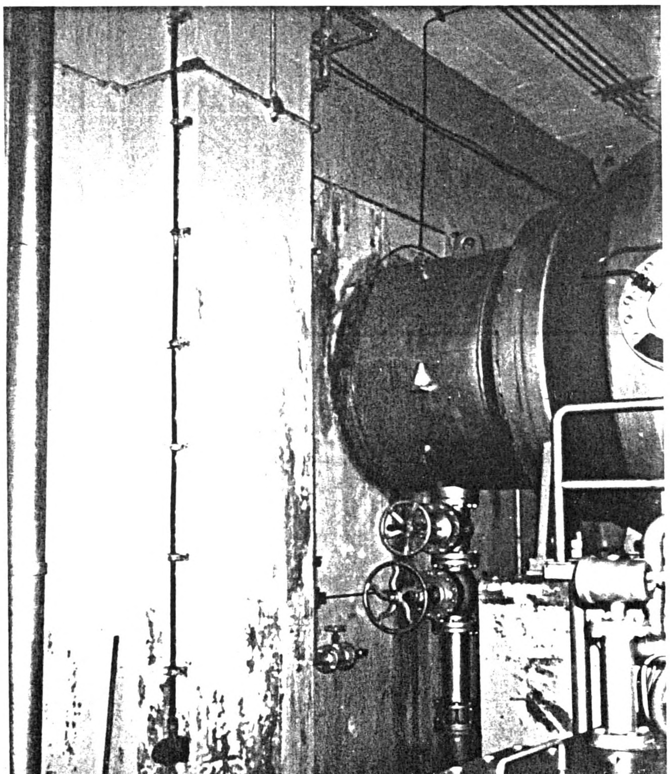
(2) In conclusion, some seepages are observed in some locations , mostly through the construction joints.
No electrical and mechanical troubles were reported in relation with probable cause of deformation in concrete works.

Project Name	Year of Completion	1	2	Inquiry 3	4	5	Results of Inspection & Discussion
Canyon	1983	No	No	No	No	No	It was observedthat some seepage of water is experianced through the concrete walls in the MIV floor. But these are through the horizontal and vertical construction joints.
Old/New Laxapana	1950 1974	No	No	No	No	No	Nothing to comment..
Polpitiya	1969	No	No	No	No	No	Nothing to comment.
Kotmale	1985	No	No	No	No	Yes	In the power station, in few locations some seepage of water is experianced through the concrete walls in the turbine floor which are through the horizontal and vertical construction joints. In spillway structure and plinth of the dam,some diagonal cracks are visible in concrete surface. Most of the cracks are through horizontal construction joints.
Randenigala	1986	No	No	No	No	No	In the power station, in few locations some seepage of water is experianced through concrete walls in MIV floor which are through the horizontal construction joints.
Victoria	1984	No	No	No	No	No	It was observed in few locations some seepage of water is experianced through the horizontal construction joints in MIV floor of the power station.
Ukuwela Power Station	1976	No	No	No	N/A	N/A	Nothing to comment.
Polgolla Dam	1976	N/A	N/A	N/A	No	No	Nothing to comment.
Bowathenna	1981	No	No	No	No	No	It was observed that some seepage of water is experianced through the horizontal construction joints in the MIV floor of the power station.
	Notes:						
	1	Longitudinal cracking of generator floors of the power house.					
	2	Out-of-round distortion of turbine openings in power house.					
	3	The need for frequent realignment of units in the power house.					
	4	Jamming of gates in the spillway.					
	5	Cracks in dam or weir.					

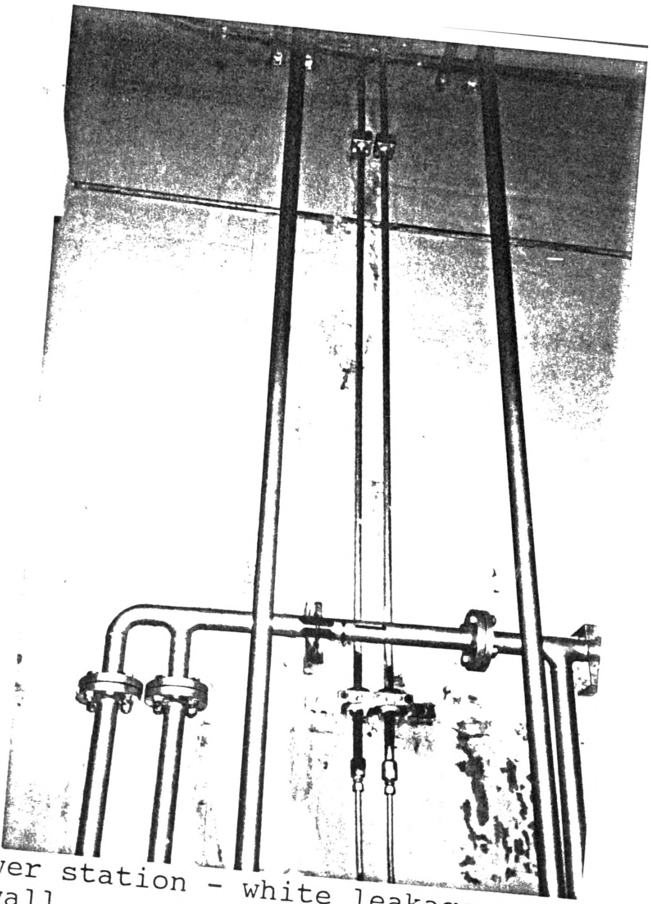
TABLE - 01



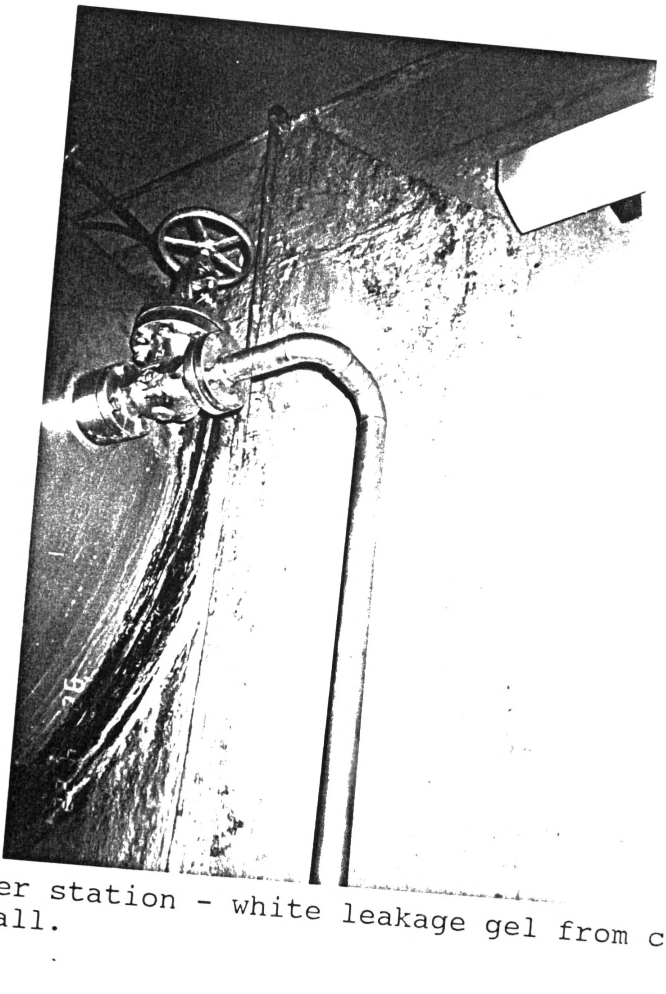
(1) Canyon power station - white leakage gel from the construction joint of the basement wall.



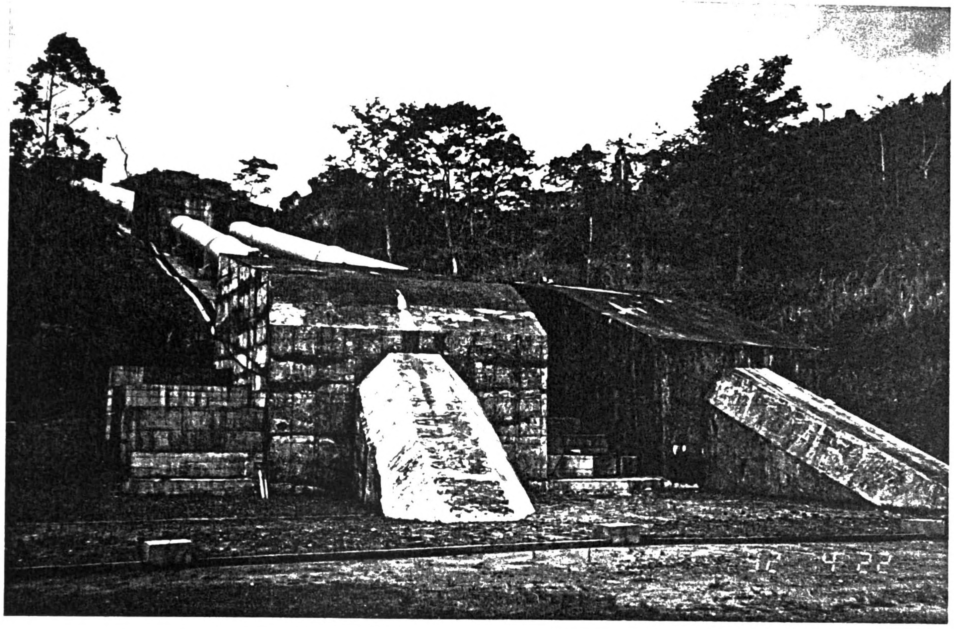
(2) Canyon power station - white leakage gel from the construction joint of the basement wall and column.



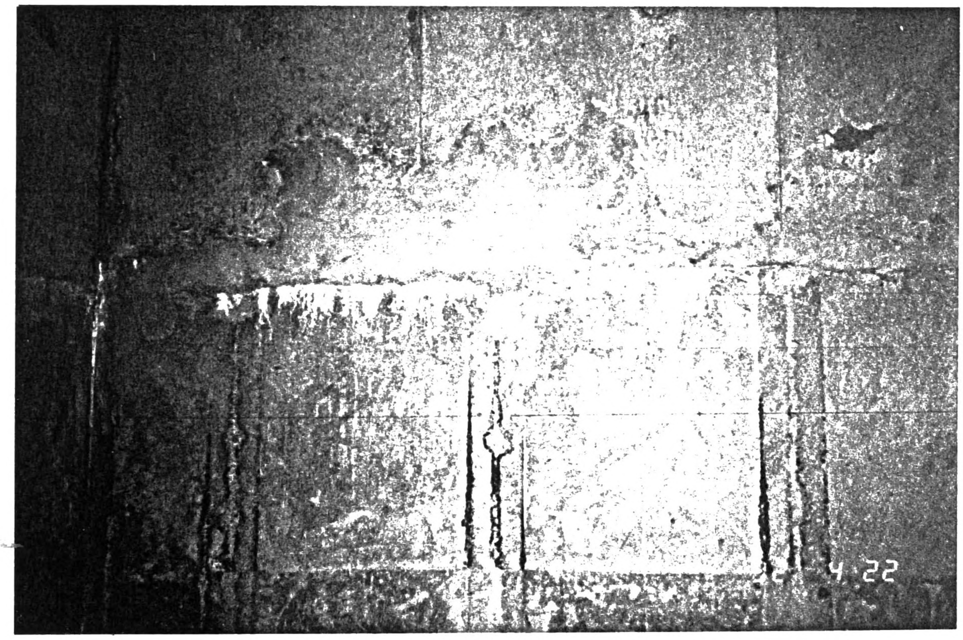
(3) Canyon power station - white leakage gel from cracks on the basement wall.



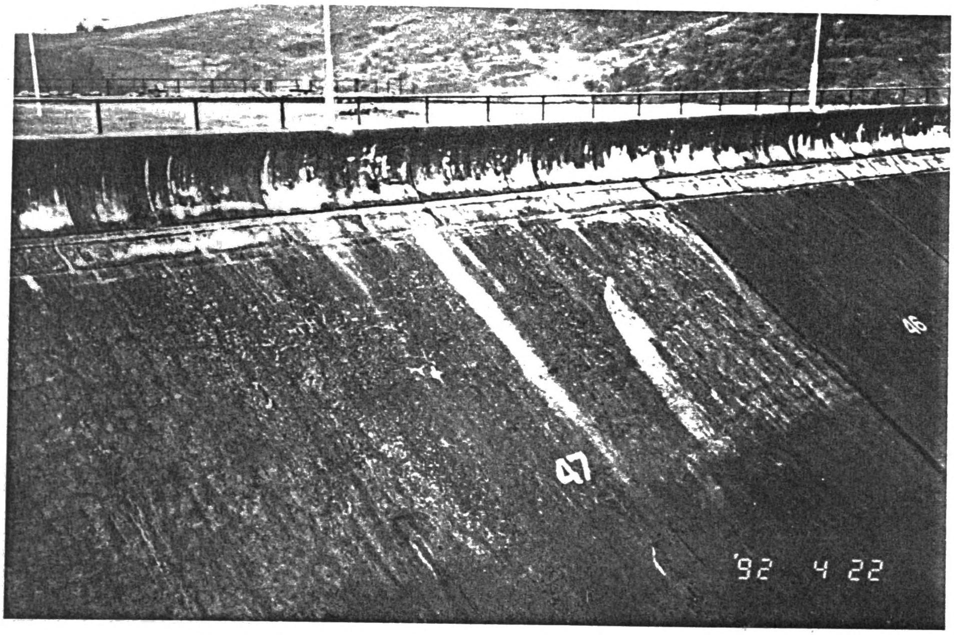
(4) Canyon power station - white leakage gel from cracks on the basement wall.



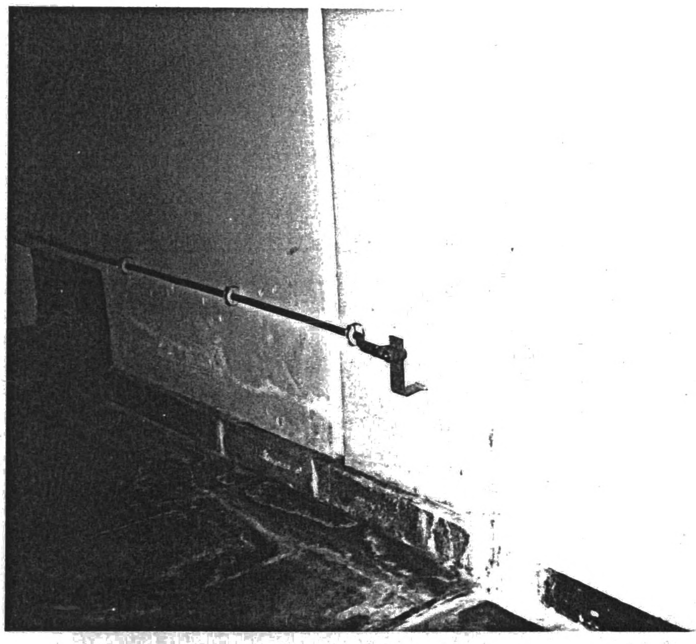
(5) Canyon power station - penstock and anchor block some cracks are visible.



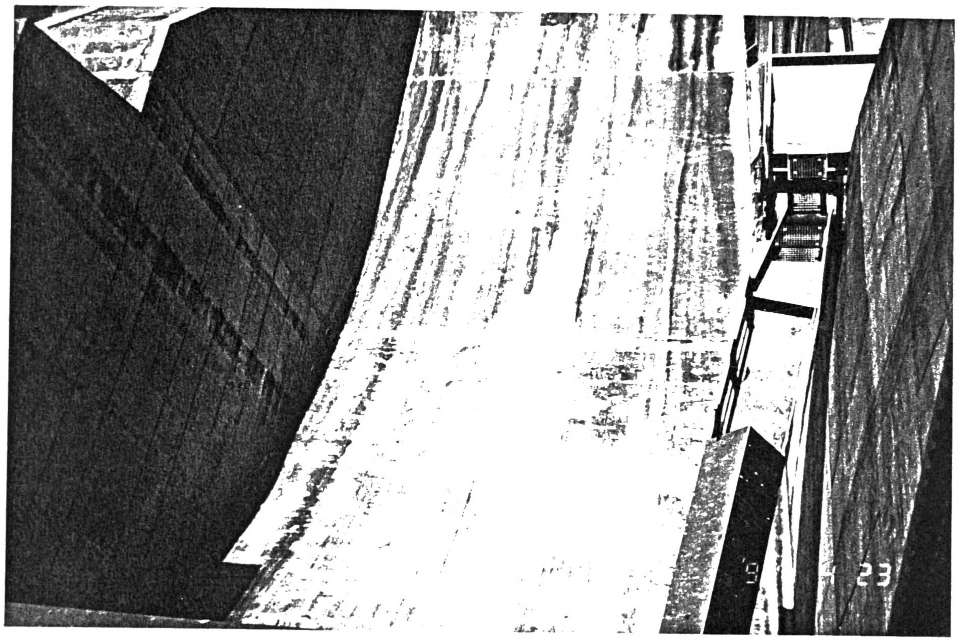
(6) Kotmale power station - leakage gel from the construction joint on the wall.



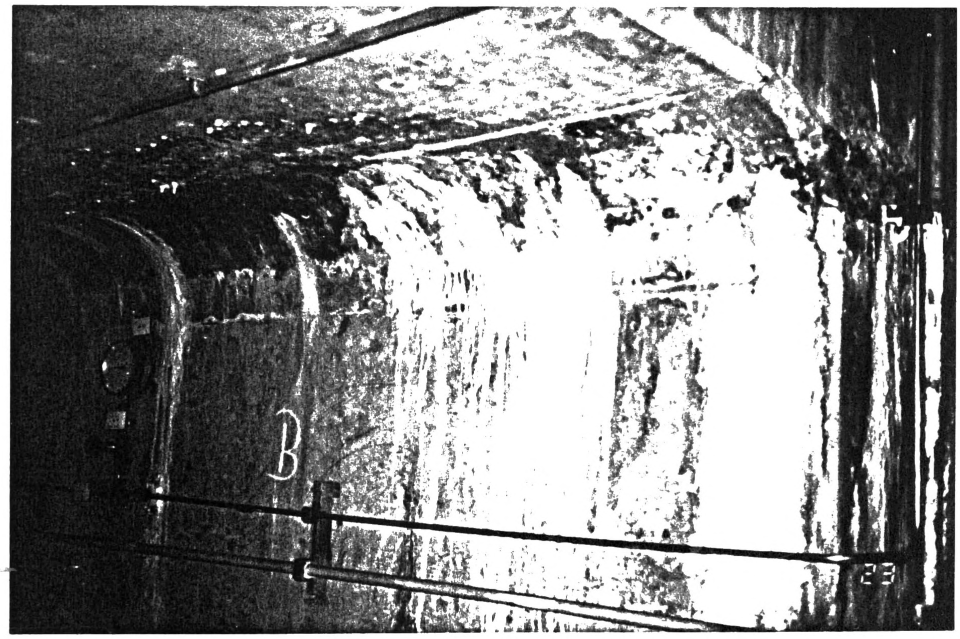
(7) Upstream slope of kotmale dam.



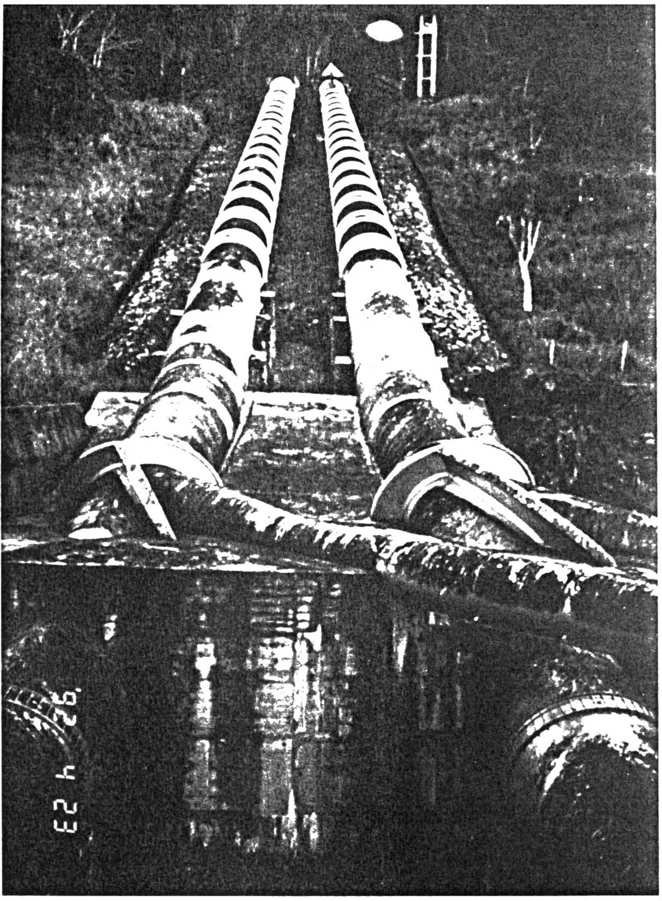
(8) Randenigala power station - white leakage gel from the vertical construction joint on the basement wall.



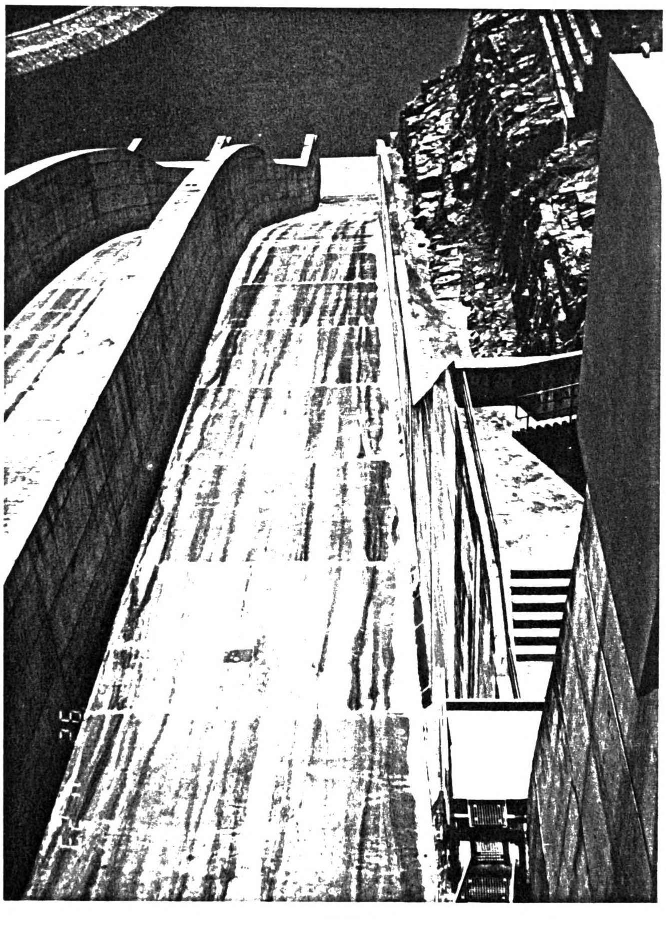
(9) Randenigala dam - spillway chute. some cracks are visible along the horizontal construction joint.



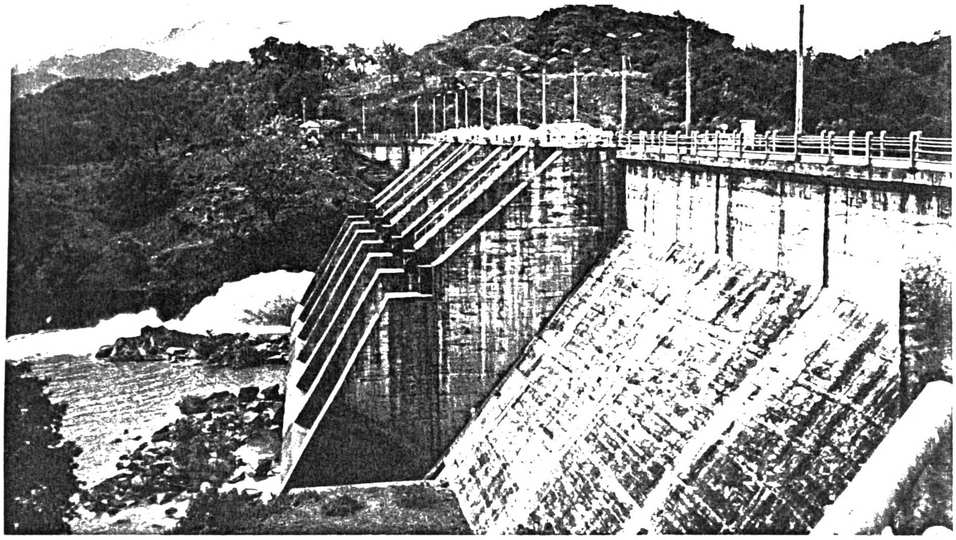
(10) Victoria power station - white leakage gel from cracks on the wall of MIV floor.



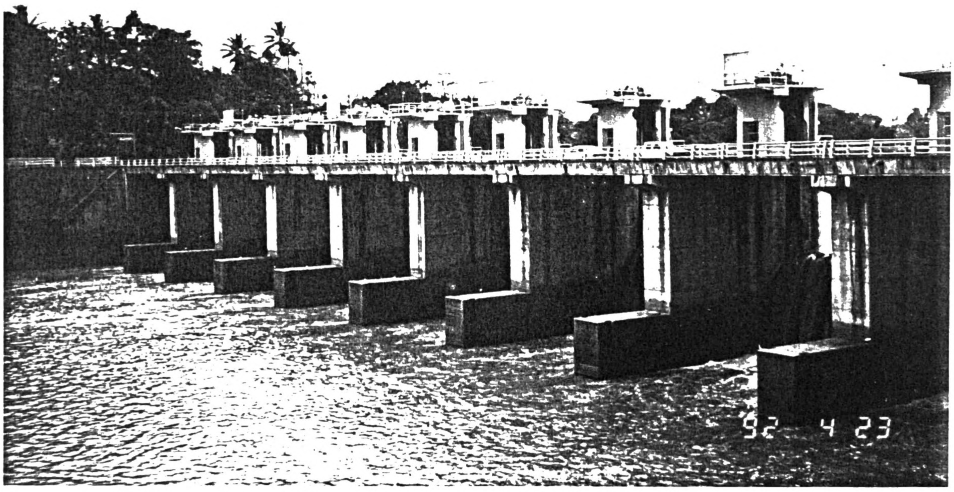
(11) Ukuwela Power Station- Penstock



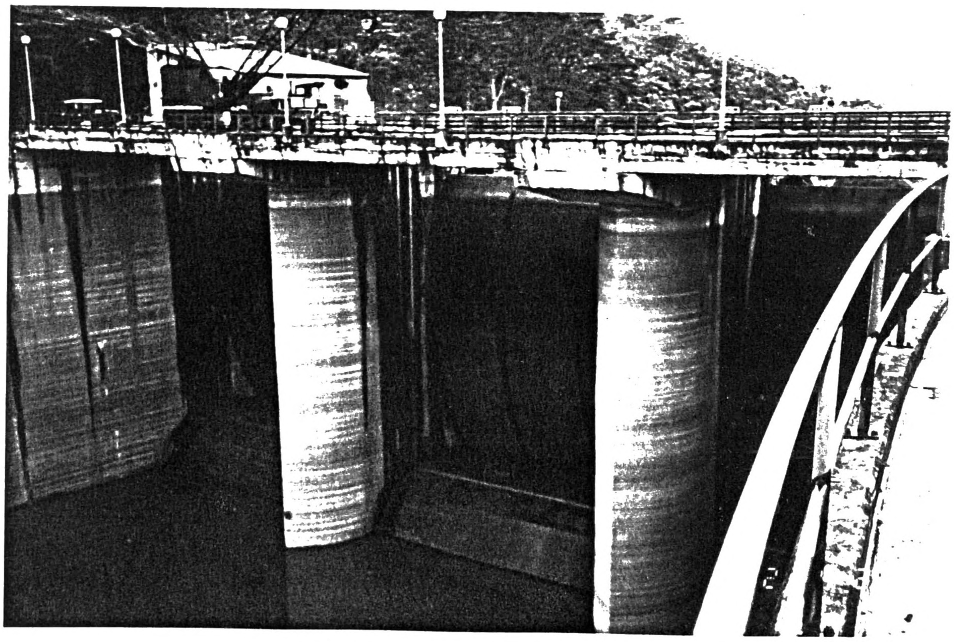
(12) Spillway chute of Randenigala dam.



(13) Bowathenna Dam



(14) Downstream view of Polgolla Weir



(15) Spillway gates of Kotmale Dam.

Inquiry Sheet

Hydro Plant Name: Canyon Date: 92/04/22

We are carring out a inspection on the Alkali-Aggregate Reaction in the existing concrete structures of CEB's power plants. Therefore, you are kindly requested to reply the following inquiry.

1. Do you have the following troubles in your powerhouse?

(1) longitudinal cracking of generator floors – yes [✓ no]

(2) out-of-round distortion of turbine openings – yes [✓ no]

(3) the need for frequent realignment of units – yes [✓ no]

2. Do you have a trouble in spillway?

(1) jamming of gates – yes [✓ no]

3. Do you have any cracks in dam or weir? – yes [✓ no]

(Please reply 4, 5 and 6 if your reply is yes.)

4. Where is the location of cracks or trouble if you have?

N/A

5. What is the reason of causing cracks or trouble?

6. when did you find cracks or trouble?

92/04/22

E.E. Canyon

Thank you for your cooperation.

Joint Venture Kukule Ganga

Inquiry Sheet

Hydro Plant Name: Old/New Laxapana Date: 22-04-92

We are carring out a inspection on the Alkali-Aggregate Reaction in the existing concrete structures of CEB's power plants. Therefore, you are kindly requested to reply the following inquiry.

1. Do you have the following troubles in your powerhouse?

(1) longitudinal cracking of generator floors - yes [✓ no]

(2) out-of-round distortion of turbine openings - yes [✓ no]

(3) the need for frequent realignment of units - yes [✓ no]

2. Do you have a trouble in spillway?

(1) jamming of gates - yes [✓ no]

3. Do you have any cracks in dam or weir? - yes [✓ no]
(Please reply 4, 5 and 6 if your reply is yes.)

4. Where is the location of cracks or trouble if you have?

5. What is the reason of causing cracks or trouble?

6. when did you find cracks or trouble?

Thank you for your cooperation.

Joint Venture Kukule Ganga

Inquiry Sheet

Hydro Plant Name: Samanala (Polpitiya Date: 22.04.92

Mr. Hemawansa
Electrical Superintendent (CEB,

We are carring out a inspection on the Alkali-Aggregate Reaction in the existing concrete structures of CEB's power plants. Therefore, you are kindly requested to reply the following inquiry.

1. Do you have the following troubles in your powerhouse?

(1) longitudinal cracking of generator floors − yes [✓ no]

(2) out-of-round distortion of turbine openings − yes [✓ no]

(3) the need for frequent realignment of units − yes [✓ no]

2. Do you have a trouble in spillway?

(1) jamming of gates − yes no

3. Do you have any cracks in dam or weir? − yes no

(Please reply 4, 5 and 6 if your reply is yes.)

4. Where is the location of cracks or trouble if you have?

5. What is the reason of causing cracks or trouble?

6. when did you find cracks or trouble?

Thank you for your cooperation.

Joint Venture Kukule Ganga

M. Anura Herath.

Inquiry Sheet

Hydro Plant Name: Ukuwela Date: 22/04/92

We are carring out a inspection on the Alkali-Aggregate Reaction in the existing concrete structures of CEB's power plants. Therefore, you are kindly requested to reply the following inquiry.

1. Do you have the following troubles in your powerhouse?

(1) longitudinal cracking of generator floors - yes [✓ no]

(2) out-of-round distortion of turbine openings - yes [✓ no]

(3) the need for frequent realignment of units - yes [✓ no]

2. Do you have a trouble in spillway?

(1) jamming of gates - yes no

3. Do you have any cracks in dam or weir? - yes no
(Please reply 4, 5 and 6 if your reply is yes.)

4. Where is the location of cracks or trouble if you have?

5. What is the reason of causing cracks or trouble?

6. when did you find cracks or trouble?

Thank you for your cooperation.

Joint Venture Kukule Ganga

Inquiry Sheet

Hydro Plant Name: Randenigala Date: 23.04.91

We are carring out a inspection on the Alkali-Aggregate Reaction in the existing concrete structures of CEB's power plants. Therefore, you are kindly requested to reply the following inquiry.

1. Do you have the following troubles in your powerhouse?

(1) longitudinal cracking of generator floors - yes [✓ no]

(2) out-of-round distortion of turbine openings - yes [✓ no]

(3) the need for frequent realignment of units - yes [✓ no]

2. Do you have a trouble in spillway?

(1) jamming of gates - yes no

3. Do you have any cracks in dam or weir? - yes no

(Please reply 4, 5 and 6 if your reply is yes.)

4. Where is the location of cracks or trouble if you have?

5. What is the reason of causing cracks or trouble?

6. when did you find cracks or trouble?

Thank you for your cooperation.

Joint Venture Kukule Ganga

A. T. Jayamanne

PS

Inquiry Sheet

Hydro Plant Name: Victoria Date: 23 April 1992

We are carring out a inspection on the Alkali-Aggregate Reaction in the existing concrete structures of CEB's power plants. Therefore, you are kindly requested to reply the following inquiry.

1. Do you have the following troubles in your powerhouse?

(1) longitudinal cracking of generator floors – yes [✓ no]

(2) out-of-round distortion of turbine openings – yes [✓ no]

(3) the need for frequent realignment of units – yes [✓ no]

2. Do you have a trouble in spillway?

(1) jamming of gates – yes [✓ no]

3. Do you have any cracks in dam or weir? – yes [✓ no]
(Please reply 4, 5 and 6 if your reply is yes.)

4. Where is the location of cracks or trouble if you have?

5. What is the reason of causing cracks or trouble?

6. when did you find cracks or trouble?

Thank you for your cooperation.

Joint Venture Kukule Ganga

Inquiry Sheet

Hydro Plant Name: Ukuwela P.S. Date: 23 - 04 - 92

We are carring out a inspection on the Alkali-Aggregate Reaction in the existing concrete structures of CEB's power plants. Therefore, you are kindly requested to reply the following inquiry.

1. Do you have the following troubles in your powerhouse?

   (1) longitudinal cracking of generator floors ~~yes~~ [✓ no]

   (2) out-of-round distortion of turbine openings ~~yes~~ [✓ no]

   (3) the need for frequent realignment of units ~~yes~~ [✓ no]

2. Do you have a trouble in spillway?

   (1) jamming of gates ~~yes~~ [✓ no]

3. Do you have any cracks in dam or weir? yes [✓ no] Polgolla
   (Please reply 4, 5 and 6 if your reply is yes.)

4. Where is the location of cracks or trouble if you have?

5. What is the reason of causing cracks or trouble?

6. when did you find cracks or trouble?

Thank you for your cooperation.

Joint Venture Kukule Ganga

Mr. H.A.D.B. Perera
Snr. E.E. Mahaweli
Complex

Inquiry Sheet

Hydro Plant Name: Bowatenna Date: 24/04/92

We are carring out a inspection on the Alkali-Aggregate Reaction in the existing concrete structures of CEB's power plants. Therefore, you are kindly requested to reply the following inquiry.

1. Do you have the following troubles in your powerhouse?

(1) longitudinal cracking of generator floors - yes [✓ no]

(2) out-of-round distortion of turbine openings - yes [✓ no]

(3) the need for frequent realignment of units - yes [✓ no]

2. Do you have a trouble in spillway?

(1) jamming of gates - yes [✓ no]

3. Do you have any cracks in dam or weir? - yes [✓ no]
(Please reply 4, 5 and 6 if your reply is yes.)

4. Where is the location of cracks or trouble if you have?

5. What is the reason of causing cracks or trouble?

6. when did you find cracks or trouble?

Thank you for your cooperation.

Joint Venture Kukule Ganga

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