No. 5

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
ELECTRICITY OF VIETNAM
THE SOCIALIST REPUBLIC OF VIETNAM

FEASIBILITY STUDY ON DONG NAI NO.3 AND NO.4 COMBINED HYDROPOWER PROJECT IN THE MIDDLE REACHES OF THE DONG NAI RIVER IN THE SOCIALIST REPUBLIC OF VIETNAM

FINAL REPORT

VOLUME III-1
SUPPORTING REPORT

Appendix A : Geological Investigation

MARCH 2000

NIPPON KOEI CO., LTD.
TOKYO ELECTRIC POWER SERVICES CO., LTD.

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Composition of the Final Report

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Currency Exchange Rates Adopted for the Study

US$1.00 = VND 13,870
VND 1.00= ¥ 0.008219
(in March 1999)

Appendix A :

Geological Investigation

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Appendix A : Geological Investigation

A1 INTRODUCTION

Area of the Dong Nai No. 3 and No. 4 Combined Hydropower Project (hereinafter referred to as "the Project") is located at around 11°52' northern latitude and 107°55' eastern longitude, and the middle reaches of the Dong Nai river, covering two provinces of Lam Dong on the left bank and Dak Lak on the right bank.

The project area is located at about 250 kilometers northeast of Ho Chi Minh City and 40 kilometers southeast of Gia Nghia town. It is accessible from Ho Chi Minh City to the project site through the three national highways, No.3-No.4 and No.28. The national highway No.28 runs along the middle reach of the Dong Nai river in the vicinity of the project area, which connects the Gia Nghia town and entrance points of paths linking to the Dong Nai No. 3 and Dong Nai No. 4 dam sites. There is also a 80 kilometer provincial road, which connects the Bao Loc City and the left bank of Dong Nai No4 site.

The previous geologic investigation on Dong Nai No. 4 site was performed by the Power Engineering Consulting Company No.1 (PECC 1) in 1991-1993 and on Dong Nai No. 3 site by the Power Engineering Consulting Company No.2 (PECC 2) in 1997-1998. The item and quantities are shown as follows:

Site	Core Drilling		Permeability Test		Laboratory Test			
	Hole	Total length (m)	Lugeon test	Pouring test	Soil	Rock	Sand	Water
Dong Nai No. 3	5	313.5	23	42	41	17	5	10
Dong Nai No. 4	52	2018.9	177	107	248	156	30	

The latest geological investigation for the Feasibility Study on the Dong Nai No. 3 and No. 4 Combined Hydropower Project has been performed by PECC 2 based on the specifications and supervision of the JICA Study Team from June to September 1999, for the items and quantities as mentioned below:

(1) Core drilling at 25 locations and for the total length of 1,550 metres,

(2) Standard penetration test for 129 times in 19 boreholes,

(3) Lugeon test for water seepage in bedrock at 147 stages in 12 boreholes,

(4) Permeability test in uncemented deposit at 16 levels in 8 boreholes,

(5) Seismic refraction prospecting with 11 prospecting lines for the total length of 15,000 metres,

(6) Test pitting by EVN at 23 locations and for the total depth of 97 metres in earth borrow areas,

(7) Laboratory tests of the earth embankment material for 38 samples, laboratory tests of the rock material for 40 samples and laboratory tests of the fine aggregate for concrete for 6 samples.

Detailed quantities of the geological investigation are shown in Tables A3-1 to A3-3. Locations of the core drilling and the seismic refraction lines are shown in Figures A3.1 and A3.2.

A2 REGIONAL GEOLOGY

A2.1 Regional Geological Setting

From the tectonic point of view, the land of Vietnam is largely divided into two parts by the Red River that develops in the direction from northwest to southeast along a major fault zone. The Red River Fault is a sort of transform fault between a couple of plates with different movement, that is, the South China plate on the north side and the Indochina plate on the south. Major part of Vietnam is situated on the Indochina plate and tectonically sub-divided into a few blocks.

Geology of Vietnam covers from Archaean (of Pre-Cambrian era) to Quaternary. The area south of the Red River and north of Qui Nhon is charaterised by Palaeozoic fold system with axes of northwest-southeast trend.

Tay Nguyen, or the Central Highland, in the central to southern part of Vietnam forms the core of Indosinian Continent, named Indochina Platform, that was built in Mesozoic, developed and stabilised till the recent age. In the northern part of the Indochina Platform develops an up-lifted Kon Tum Massif where the Pre-Cambrian metamorphic and igneous rocks, the oldest in Vietnam, are exposed. Da Lat Zone, southwest of the Kon Tum Massif and a part of the Indochina Platform, is an area of Mesozoic tectonic movement, marine sediment and granite intrusion and Plio-Pleistocene effusion of basalt flow.

The Da Lat Zone, where the Dong Nai Project is located, is composed mainly of the Jurassic sandstone, siltstone and shale with granite or granodiorite masses, covered widely with basalt flow. The Dong Nai River flows through the hills of Mesozoic sediments between Da Lat and Ho Chi Minh City.

Main bedrock of the upper Dong Nai area is Lower to Middle Jurassic sediment of La Nga Formation, which consists of light or dark grey shale, siltstone and sandstone, partly altered to hornfels or quartzite. The La Nga Formation is reported to have total thickness of 700 to 800 metres in Gia Nghia along the highway No.28. In spite of faults and folds, the strike of the beds shows almost constantly around N45°E. Intrusive granodiorite is located in parts as shown in Table A2.1.

Plio-Pleistocene Tuc Trung basalt flow is wide-spread over the ground surface at altitude of 600 metres or higher and unconformably covers the La Nga Formation. The basalt flow makes flat surfaces of plateau at elevation 550 metres to 800 metres and separated by dissection of valleys.

Tectonic activity in Vietnam has for the most part completed before the Quaternary age, except in the Red River fault zone in the furthest northern part of the country. The land of the Indochina Platform is generally stabilised and has only a few earthquakes on its marginas shown in Figures A2.1 and A2.2.

A2.2 Geological Structure

According to the tectonic map compiled by the Institute of Geophysics of Vietnam, the project area is situated in the western part of the Dalat magma-tectonic activation zone, which is bounded by the KonTum uplift in the north and major faults of Rach Gia-Tuy Hoa, Nha Trang-Tanh Linh, Ca Na- Duc Trong and Phan Thiet in the northwest, the south, the east and the southwest, respectively. The major faults have been formed by the tectonic movements in Mesozoic to Tertiary ages, and show main orientations of the northeast-to-southwest and the north-south trends. Smaller faults in Degree III of the northwest-to-southeast trend are also frequent as shown in Figure A2.1.

The regional geological map shows the major faults of Degree II in the Project area developing in two main directions of northeast-southwest and north-south.

Oriented in the northeast-southwest direction are two major faults, named Rach Gia – Tuy Hoa and Ta Lai – Dak Mo Rung. The Rach Gia – Tuy Hoa Fault is located in the west and downstream of the Dong Nai No. 4 powerhouse, stretching over 300 km of length, with the slipping surface plunging northwest and indicating a right slip tendency. The Ta Lai – Dak Mo Rung Fault develops across the Dong Nai No. 3 reservoir. It is the normal fault and plunges southeast with the northwestern hanging wall and the southeastern footwall.

A major fault of the north-south trend is a Dak Nong – Tanh Linh Fault developing across the Dong Nai No. 3 headrace tunnel. It was confirmed by Nguyen Dinh Xuyen (1997) to divide two geological blocks of the eastern hanging wall and the western footwall. This fault has the vertical slipping surface.

The minor faults of northwest–southeast trend are reported to have vertical slipping surfaces.

The tectonic structures as shown in Figure A2.1 were classified in accordance with Vietnamese standard relating to the degree of faulting, shearing and fracturing and to the length and width of the shear zone and influence zone. Definition of the classification is shown in the following table:

Feature	Degree	Shear Zone		Extent of influence Zone	Spacing
		Length	Width		
Major fault	II	30-350 km	10 - 100 m	Hundreds meters	
Fault	III	3-30 km	1 - 10 m	10 -100 m	1-5 km
	IV	0.3-3 km	0.1 - 1 m	3 - 30 m	0.2-3km
Fractures and joints	V	30-300 m	3 - 100 mm	0.3 - 3 m	10-30 m
	VI	10-30 m	3 - 30 mm	3 - 30 cm	3-10 m
	VII	<10 m	0.5 - 3 mm	1 - 3 cm	0.3-3 m

A3 Geological Investigation

A3.1 General

Geological investigation for the feasibility study of the Dong Nai No.3 and No.4 Combined Hydropower Project has been performed during the period from June to October 1999.

Geological and geotechnical conditions of the project sites for both the Dong Nai No.3 and the Dong Nai No.4 were studied by means of the core drilling with the standard penetration test and the borehole permeability test, the seismic refraction prospecting, the test pitting and the laboratory test.

Locations of the core drilling and the seismic refraction prospecting are shown in Figures A3.1 and A3.2. Quantities of the investigations by the seismic prospecting, the drilling and the test pits for each site are summarised in the following list and detailed in Tables A3.1 to A3.3:

Area	Core drilling		SPT 1/	CHT 2/	Lu 3/	Seismic R. 4/		Test Pitting	
	Holes	Length	Points	Stage		Lines	Length	Pits	Length
Dong Nai No. 3									
Dam site	6	460	46	8	73	1	900		
Headrace tunnel 5/	2	80	34			2	8,500		
Penstock 6/	3	170	16			1	700		
Quarry	3	150				1	1,000		
Soil borrow								13	47
Sub total	14	860	96	8	73	5	11,100	13	47
Dong Nai No. 4									
Dam site	6	460	21	8	74	1	600		
Headrace tunnel 5/	2	80	12			2	1400		
Penstock 6/						1	900		
Quarry	3	150				2	1000		
Soil borrow								10	50
Sub total	11	690	33	8	74	6	3,900	10	50
Total	25	1,550	129	16	147	11	15,000	23	97

Notes:

1: SPT= The standard penetration test

2: Lu= Lugeon Test in bedrock

3: CHT= Constant Head Test in uncemented deposit

4: Seismic R = The seismic refraction prospecting

5: Including the Intake site

6: Including the surge tank and powerhouse site

A3.2 Seismic Refraction Prospecting

A3.2.1 Profile Line Arrangement

Following the investigation plan, seismic refraction prospecting lines were arranged as shown in Figures A3.1 and A3.2 . The total length is 15,000 metres as shown in Table A3.1.

The seismic refraction prospecting was conducted with digital instrument, Model Strataview – 24 made in U.S.A including the following apparatus, tools and materials:

- Oscillograph-Amplifier-Recorder, Model Strataview 24, 24-channels : 1 set
- Detector (Geophone), 14 Hz : 30 pcs.
- Land cable : 4 rolls
- Blasting cable : 3 rolls
- Telephone : 3 sets
- High voltage blaster : 2 nos.
- Tester, battery, battery charger, etc. : 1 set
- Dynamite : 500 kg
- Detonator (Electric, instantaneous) : 600 pcs.

A3.2.2 Field Operation

Firstly, ground surface profile of every traverse line was surveyed at a scale of 1/1,000. Shot points and detector points were marked with wooden stakes and pegs numbered with distance from an end of each traverse line.

Arrangement of the shot points and the detector points was planned for each line for the recording work.

In the recording in each spread, the shot points were set at intervals of 57.5 metres or 115 metres. Twenty-four (24) detectors were arranged at the regular interval of 5 m for each spread on the prospecting traverse lines in the dam sites, the intake sites and the penstock to powerhouse sites. For the headrace tunnel route, the detectors were arranged at 10 metre intervals to make each 230 m long spread. The shot points and the detector points were moved spread by spread to give complete coverage over the prospecting traverse lines. A few shot points and a detector point were shared by two adjacent spreads to keep a continuity in the records.

A3.2.3 Time-Distance Plot and Profile Interpretation

Travel-time of the seismic wave (the primary wave) was read from recording paper to the accuracy of 1/1,000 second, and plotted on the time-distance graph with scale of 1 centimetre for 10 metres on the axis of abscissa and of 1 centimetre for 10 milliseconds on the axis of ordinate. From this time-distance relation, the profile of velocity layers was deduced by the intercept-time method. The time-distance curves and the profile interpretations are compiled in Geological Data 3 of Attachment to this Appendix A.

A3.3 Core Drilling

A3.3.1 Hole Location and Length

Core drilling was performed at 25 locations and for the total length of 1,550 metres. The drilling holes are listed in Table A3.2 with the drilled length, the number of sections of the filed permeability test and the number of the standard penetration test in the boreholes.

A3.3.2 Drilling Operation

The core drilling was carried out by mobilising eleven hydraulic-feed rotary type drilling rigs (Model: XJ-100, CKB-4; 3UB-150) and with a double-tube core barrel.

Recovered core samples were arranged in a core box in order and stored in the warehouse of PECC2.

Drill logs have been prepared and are attached in this Appendix A.

In the drill log, RQD means the Rock Quality Designation that represents continuity of the drilling core samples. Since the core was examined for every meter length, the RQD was calculated by the following formula:

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

A3.4 Field Permeability Test

In-situ permeability was determined by the open-end pipe test for loose and/or soft formation composed of soil or intensively weathered rock, and by the water pressure test or Lugeon test for well cemented rock in which a rubber packer could be set tightly.

A3.4.1 Open-End Pipe Testing Method

This test was made through the open end of casing pipe which had been sunk to the bottom of borehole at the testing depth. Before commencement of the test, the inside of casing pipe was cleared of sand and rock fragments to the bottom and then the test was begun by adding clean water into the hole to maintain a constant head. Measurement of the constant head, the constant rate of flow into the hole, size of the casing pipe, and elevation at the top and the bottom of the casing were recorded. The permeability was obtained from the following equation quoted from "Earth Manual" by USBR.

$$K = Q/5.5rH$$

Where, k : Permeability (cm/sec)

Q : Constant rate of flow into the hole (cm^3/sec) to maintain a constant head,
R : Internal radius of the casing (cm), and
H : Differential head of water (cm)

A3.4.2 Water Pressure Testing Method

The water pressure test or Lugeon test was carried out by 5 metre stage, or for every 5 metre section of the hole. The rubber packer was inserted and installed in the borehole to seal the section at every 5 metres' progress of the drilling. Pressured water was injected by a pipe system extending through the packer to the test section. The injection rate of water was measured under varied pressures. The permeability of the rock was assessed in both terms of Lugeon units and permeability coefficient. One Lugeon unit is defined as a flow of 1 lit/min per linear-meter of hole at the pressure of 10 kg/cm^2; and close to the permeability coefficient of 10-5cm/sec, though the precise correlation depends upon the diameter of the borehole. The Lugeon units and the permeability coefficient were calculated by the following equations:

<u>Lugeon units</u>

$$Lu = 10Q/LP$$

Where, Lu : Lugeon unit,
Q : Constant rate of flow into the hole (lit/min),
L : Length of test section (m), and
P : Differential water pressure (kg/cm^2).
P = P_1 (the static pressure above the test section or above the groundwater table) + P_2 (the pumping pressure)

<u>Permeability coefficient</u>

(From the packer test in " Earth manual " USBR)

$$k = Q \log e(L/r)/2\pi LH$$

Where, k : Coefficient of permeability (cm/sec),
Q : Constant rate of flow into the hole (cm^3/sec)
L : Length of test section (cm),
H : Differential head of water (cm)
H= H1 (the head above the centre of the test section or above the groundwater table) + H2 (the pumping pressure), and
r : the radius of hole tested.

The testing pressure was changed at seven steps of 1 kg/cm^2, 4 kg/cm^2, 7kg/cm^2 , 10 kg/cm^2 , 7 kg/cm^2 , 4 kg/cm^2 and 1 kg/cm^2 in order as measured at the top of injection pipe. However, in case that the injection water rate became very large beyond the pump capacity, the test was ceased at the attainable maximum pressure.

The records of the test are shown in Geological Data 2 of Attachment to this Appendix A.

A3.5 Standard Penetration Test (SPT)

SPT has been performed in order to obtain a record of the resistance of sub-soils to the penetration of the Raymond sampler (the split-tube sampler) and to obtain disturbed samples of the soil for identification purposes. The test is used to evaluate subsurface conditions with respect to bearing capacity for foundation design. The penetration resistance is expressed as the number of blows required to force the sampler by 30cm into the soil.

After drilling reached to the depth for testing, all cutting sludge remaining in the bottom of the hole was removed, and the Raymond sampler connected with drill rod was inserted to the bottom of the hole, and driven by the initial 15 cm for a pre-knocking by blow of the standard hammer of 63.5kg in weight on the knocking block attached to the rod.

The penetration test was then started, and the number of blows by 75cm drops of the 63.5kg heavy drive hammer for penetration of another 30 cm was recorded, that is, the N-value. The number of the blows were recorded for every 10 cm of penetration. The SPT was performed in principle at 1.5 m intervals in soil.

The N-values obtained by SPT are shown in the drilling logs in Geological Data 1 of Attachment of this Appendix A.

A3.6 Test Pitting

Test pits were dug at 23 locations in total in two borrow areas for Dong Nai No. 3 and No. 4 dams, where forty soil samples were taken and tested in laboratory. Total length of the pits was 47 metres.

Every test pit was round in the horizontal section with diameter of 2 m. For each sample the soil material of 80 kg in weight was taken and half (0.5) kilogram of the same sample was put in a polyethylene bag for the test of natural water content.

Records of the test pits are shown in Geological Data 5 of Attachment to this Appendix A.

A3.7 Laboratory Test

A3.7.1 Laboratory Rock Test

The laboratory rock test was performed on drilling core samples from the dam site and the quarry sites. Tested items are as follows:

- Water absorption and bulk specific gravity (ASTM 127)
- Unconfined compression test with measurement of Poisson's ratio (ASTM, D2938)
- Super-sonic wave velocity test

- Soundness tests by sodium sulfate (ASTM C88)

- Chemical (alkali) reactivity test (ASTM C289)

The results of the laboratory rock test are summarized in Table A6.1.

The unconfined compressive strength was to be determined by a specimen with a length-to-diameter ratio (L/D) of 2 in principle. Apparent compressive strength measured on a core specimen with L/D less than 2 was corrected by the following equation:

$$C = \frac{Ca}{0.88 + 0.24b/h}$$

Where, C : Corrected compressive strength to an equivalent of the specimen with the L/C proportion of 2,

Ca : Measured compressive strength of the specimen tested,

B : Diameter of the tested core sample, and

H : Height of the tested core sample.

A3.7.2 Laboratory Soil Test

The laboratory soil test was performed on soil samples which had been obtained from test pitting. Test items are as follows:

- Particle size analysis by sieve & hydrometer (ASTM D422)
- Liquid limit, plastic limit, plastic index (ASTM D431)
- Specific gravity of soil (ASTM D854)
- Natural water content of soil (ASTM D4959)
- Proctor compaction test (ASTM D698)
- Permeability test (USBR E-13, refer to Earth Manual)
- Triaxial compression, UU (ASTM D2850)
- Triaxial compression with pore pressure observation (ASTM D4767)
- Dispersive characteristics (ASTM D4221)

The results of the laboratory soil test are summarized in Tables A6.2 and A6.3, in which the sampling locations and the soil sample numbers are also shown.

A3.7.3 Concrete Aggregate Test

For fine concrete aggregate, sand samples were obtained from the Krong Kno River and the Srepok River. Test items are as follows:

- Sieve analysis of aggregates (ASTM C136)
- Specific gravity and water absorption (fine) (ASTM C128)

- Clay lumps and friable particles in aggregate (ASTM C142)
- Soundness tests by sodium sulfate (ASTM C88)
- Chemical (alkali) reactivity test (ASTM C289)

The results of the concrete aggregate test are summarized in Table A6.4, in which the sampling location and the sample numbers are also shown.

A3.8 Rock Classification by Weathering

Bedrock within the project site consist of shale, sandstone siltstone of the La Nga Formation and basalt of the Tuc Trung Formation.

The rock was classified according to the degree of weathering, and also the strength and joint conditions as follows:

- Fresh rock (Fr)

No visible sign of weathering is seen except for slight discoloration on major discontinuity surfaces. The rock is strong to very strong with unconfined compressive strength ranges from 60 MPa (600 kgf/cm^2) to 120 MPa (1200 kgf/cm^2).

- Slightly weathered rock (SW)

All or some parts of the rock may be slightly discolored by weathering and may be somewhat weaker externally than in its fresh condition

The rock in this classification is characterised by oxidized joints with local infilling of some clay gouge. The strength of rock is medium to strong

- Moderately weathered rock (MW)

Less than half part of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discolored rock presents either as discontinuous frameworks or as corestones

- Highly weathered rock (HW)

More than half of the rock is decomposed and/or disintegrated to a soil. The typical thickness of MW or HW varies from 1-2m to 15-20m.

- Completely weathered rock (CW)

Completely weathered rock is fully decomposed and/or disintegrated. However the soil has not been transported and the original mass structure is still largely remain intact.

- Overburden deposits consisting of:

- Residual soil or topsoil of clay and clayey soil containing laterite and rock fragments; and

- Alluvial deposits found along the Dong Nai River and its tributary

Residual soils generally cover all of the project area with the exceptions of streambeds, and local steep slopes

A4 GEOLOGY

A4.1 Dong Nai No.3 Scheme

A4.1.1 Reservoir

The catchment area of the Dong Nai No.3 is approximately 3,600 km^2 and is surrounded by steep mountain ranges of about 700 m to 1,000 m in altitude.

The Dong Nai No.3 dam is designed to create an reservoir area of about 54 km^2 at full supply level (EL. 590 m). The Dong Nai river in the reservoir area is not over 100m wide with rather thin or no riverbed deposit. It flows meandering but from southeast to northwest largely turns its direction to the west just upstream of the Dong Nai No.3 dam site.

Geologically, the reservoir area is underlain by sandstone, shale and siltstone of the La Nga formation. The rocks are weathered from 5 m to 40 m in depth and are covered by overburden of topsoil, terrace and alluvial deposit with thickness from 3 to 10 metres.

A major fault, named Ta Lai - Dak Mo Rung and three minor fault (degree III) run across the reservoir area. These fault strike NE-SW or NW-SE and dip 70°-80° east or west.

According to the topographic map at a scale of 1:10,000, neither remarkable slope collapses or landslide have been observed in the reservoir, except for an area on the right bank 500 metres upstream of the Dong Nai No.3 dam site.

A land of gentle slope at 15 degrees and less from horizontal is developed in a 600 metre wide and 700 metre long area upstream of the Dong Nai No.3 dam site. It is located on the right bank of the Dong Nai River and more than 500 metres upstream of the downstream alternative dam site. Landslide was suspected of this area in the Master Plan Study as was suggested from its topographic feature and colluvial deposits as usually seen in land slide areas. In the previous studies, however, the possibility of a landslide has never been positively proved through detailed investigation.

An unusual feature of this potential land slide area is that it is blocked at its foot by a low ridge stretching from the upstream side, forming a sort of barrier against the slide with a constricted outlet to the river. While there could be some doubt against the interpretation of landslide, it is duly conservative to assume existence of an old land slide.

Trunks of trees remaining after a burning-and-cultivating operation by the local inhabitants are all straight and vertical in this potential land slide area, indicating that the land has been stable at least for a few tens of years. Even if it has once stabilised, the balance would be lost and a slide movement might be resumed on the reservoir impounding up to the high water level, which corresponds to the middle height of the land slide area.

Resumption of the land slide, however, would not cause any serious trouble upon the safety of the reservoir or the dam. Volume of the colluvial deposit entering in the reservoir by the landslide is estimated at approximately 10 million cubic metres (10,000,000 m^3) or less. This sliding material will replace only a minor part of the dead water that has about 70 m of thickness between the low water level (El. 560 m) and the river bed (El. 490 m) in front of the land slide area. The sliding volume may actually be far less because of the said barrier ridge hindering the movement. Slide of the colluvial deposit on a low-angled sliding surface, if occurs, can be too slow to jeopardize the safety of the reservoir and the dam by rapidly raising the water surface or generating high waves.

This potential land slide, therefore, has no significance for the safety of the structures.

Judging from the following topographical and hydrological conditions, it can be assumed that the reservoir area is watertight.

A4.1.2 Dam Site

The contemplated Dong Nai No. 3 dam site is located in the middle reaches of the Dong Nai river. The river runs in the east-to-west direction at the dam site whereas it flows from south to north till it turns at a few hundred metres upstream.

On the profile along the dam axis, the width of the valley is about 400m at the full supply level (FSL). Both banks on the planned dam axis have steep slopes with angle of 30° to 35° from horizontal and are covered by dense vegetation.

The seismic refraction prospecting was performed on a line S 901 U, and the core drilling at six locations, from BD 901U to BD 906 U, with permeability tests were conducted along the dam axis and its geologic profile is shown in Figure A4.1.2.

The core drilling shows the bedrock of sandstone interbedding with shale and siltstone, which are overlain by very thick overburden including completely weathered rock. Thickness of the overburden consisting of soil and a few soft fragments varies from 15 metres to 33.5 metres on the left bank and 3 metres to 11 metres on the right bank. As shown in Figure A4.1.2, the highly and moderately weathered rock (HW-MW) is encountered at the depth of 18 m to 35 m on the left bank and 3m to 15m on the right bank.

Slightly weathered and fresh hard rock of sedimentary formation is exposed on the river bed, with the northeast-southwest strike across the river channel and dips around 50 degrees southeast or upstream.

A fault runs along the river channel, downstream of the dam site and crosses the left bank of dam site dipping towards the hill. On the order hand, the borehole BD 905U drilled on the left bank slope exhibits the weak rock fragment and clay gouge at the depth of 36 to 40 m. The borehole BD 903 U has intercepted an andesite dyke.

On the other hand, the results of Lugeon tests indicate rather high permeability. The open-end static permeability test of the soil and highly weathered rock zone shows about 1.5×10^{-4} cm/sec in average.

The fresh or slightly weathered bed rock in the dam site is very sound. The unconfined compressive strength determined in the laboratory test on fresh core samples ranges from 90 MPa to 120 MPa (900-1200 kgf/cm^2).

Seismic refraction profile indicates that seismic wave velocity in the fresh rock ranges from 5.5 km/sec to 6.0 km/sec. Low velocity zonesw that may correspond with faults are found among the freswh rock at places.

A4.1.3 Headrace Tunnel and Intake

Intake of the headrace tunnel is planned at the foot of the hill on the right bank 400 m upstream of the dam site. The headrace tunnel route initially runs north from south and then turns west and stretches under the hill slope. Four major gullies cross the headrace tunnel route.

The seismic refraction prospecting was performed on two lines S902U and S903U along the intake and tunnel. Two boreholes, BI907U and BI908U were drilled in the intake area. No drilling was performed on the headrace tunnel.

The geologic profiles of the intake and the headrace tunnel are shown in Figures A.4.1.3 and A.4.1.4.

Core drilling at BI907U and BI908U in the intake shows that sandstone and shale of the La Nga Formation are covered by very thick overburden except at the foot of hill. The thickness of the overburden including the completely weathered rock varies in these holes from 24 m to 28 m and moderately weathered rock is reached at the depth of 39 m (BI907U).

According to the surface geological observation and the seismic refraction profile, the headrace tunnel will pass through the La Nga sandstone and shale. The basalt of Tuc Trung Formation overlies the La Nga Formation unconformably. As the seismic profile indicates, the tunnel alignment will be contained in the fresh rock zone except near its portals and in the vicinities of low velocity zones or fault zones.

The sandstone and shale beds observede on outcrops show strikes of NE-SW and dips of 60 to 70 degrees NW or SE, reflecting the fold.

No tectonic lines were identified in the field because of the deep weathering and the dense vegetation, except for a few that were indicated by topographic lineament or by low velocity zones of the seismic prospecting.

A4.1.4 Surge Tank, Penstock and Powerhouse

The surge tank and the penstock will be situated on the hill slope on the right bank of the Dong Nai River. The powerhouse is situated at the foot of the slope. There are two gullies on this slope descending southward at the angle of about 35 degrees. Ground-surface is covered by trees

The route of the penstock line was investigated with a seismic refraction prospecting on the line S904U and three boreholes, BP909U, BP910U and BP 911U, as shown in the geological profile in Figure A4.1.5.

The core drilling show sandstone with inter-bedding shale being overlain by rather thick overburden. The overburden consisting of soil and weak rock fragment has the thickness of about 20 metres around the surge tank and decreasing downwards gradually to 3 to 5 metres along the penstock and a few metres in the powerhouse area. The bedrock is moderately to slightly weathered on the outcrops at the powerhouse site and along the Dong Nai River. The slightly weathered rock is encountered at the depth of only a few metres near the powerhouse as indicated by the core drilling of the hole BP911U. The borehole BP909U crossed an andesite dyke.

The core drilling also found highly fractured rock. The unconfined compressive strength of unit rock specimen, however, ranged from 80 MPa to 110 MPa (800 kgf/cm^2 to 1,100 kgf/cm^2).

A4.2. Dong Nai No.4 Scheme

A4.2.1 Reservoir

The Dong Nai No.4 dam will create a reservoir with the surface area of about 4.2 km^2 at the full supply level of elevation 440 metres, which is surrounded by mountain ranges of elevation 500 metres to 800 metres.

The Dong Nai River within the proposed reservoir area flows from east to west and turns direction to northwest at about 6 km upstream of the Dong Nai No. 4 dam site. Neither cultivated land nor inhabitants are found in the reservoir area.

Geologically, the reservoir area is underlain by sandstone, shale and siltstone of the La Nga Formation and are covered by overburden composed of topsoil, talus deposit terrace and alluvial deposits of 3 to 20 metres in thickness and up to 40 m at some places. The rock is strong when it is fresh, but soft when highly weathered.

Some faults of degree III run in the reservoir area nearly along the river channel, some striking NE-SW and the others NW-SE and dipping at 70°-80°

Neither remarkable slope collapse nor landslide has been observed in the reservoir area, while the slopes on the reservoir rim are as steep as 35 degrees or more. Local slides of no serious effect might occur on the reservoir impoundment.

The surface of the reservoir at elevation 440 metres will stay lower than the bottom of the Tuc Trung Basalt which can be the only possible water leakage path, and no substantial problem is envisaged against the reservoir water-tightness.

A4.2.2 Dam Site

The contemplated Dong Nai No.4 dam site is located on a northwest-bound channel of the meandering Dong Nai River, approximately 8 kilometres west-southwest of the Quang Khe village on the national highway route No.28. The river bed is at elevation 355 metres with a 40 metre wide river channel. Including the terrace on both sides of the channel, the valley floor has about 70 metres of width. The bedrock of sandstone with minor shale and siltstone layers, of the Jurassic La Nga Formation, is widely exposed on the valley floor, whereas the slopes on both banks are thickly covered by forests. The bedrock shows the strike right angle to the river channel and the dip of 55 to 60 degrees northwest or toward the downstream. On the right bank, the slope rises at a gradient of 1 Vertical / 1 Horizontal from the end of the terrace but the angle changes as gentler as 1/1.5 in the higher part. On the left bank, the slope is a little steeper than 1/1 up to the contemplated dam crest height near elevation 450 metres. Width of the valley at this elevation is approximately 260 metres. The Dong Nai valley forms a steep and narrow gorge at this dam site as shown in Figure A4.2.2.

The seismic refraction prospecting on the line S906D and the core drilling with permeability test at six locations from SD915D to BD920D were conducted on the dam axis, of which the geologic profile is shown in Figure A4.2.2.

The bedrock of sandstone interbedded with shale and siltstone is covered by a layer of surface soil including soft rock fragments, 3 to 9 metres thick on the left bank and 2 to 20 metres on the right bank. Highly to moderately weathered rock zone develops within the depth of 5 metres at the middle-height part of the slopes and about 10 m to 20 m at elevation over 460 m. On the foot of the both banks including the river channel, moderately to slightly weathered rock and fresh rock are widely exposed.

The solid foundation of slightly weathered rock is reached by excavation to the depth of 25 metres on dam abutments on both banks, except in its lower parts and the valley floor where the only 5 metre deep foundation excavation will be sufficient to expose strong foundation. Seepage potential is generally low in the slightly weathered rock, as represented by Lugeon values lower than 10. On the right abutment, however, some high water-takes over 40 Lugeon unit were observed in depths between 30 metres and 60 metres, presumably due to fractured zones in the slightly weathered rock. A sub-vertical cracky zone has also been found at the valley floor. This sort of highly pervious zone in considerable depth shall be treated to water-tightness by cement grouting. Where the fractured zones appear on the surface of the foundation rock, they shall be excavated deeper than its width and replaced with concrete.

The fresh or slightly weathered bedrock in the dam site is sound, with the unconfined compressive strength ranging from 40 MPa (400kgf/cm^2) to 130 MPa (1300 kgf/cm^2). Seismic wave velocity of the slightly weathered rock zone shows around 3.0 km/sec and the fresh rock ranges from 4.6 km/sec to 6.0 km/sec, except low velocity zones intercalated at some places.

A4.2.3 Headrace Tunnel and Intake

The contemplated intake site is situated in a small gully and on a slope of about 40 degrees' gradient, about 2 km upstream of the dam site and on the left bank of the Dong Nai River.

The headrace tunnel route, approximately 5,400 metres long, is designed to pass under the hill on the left bank of the river

Four major gullys run across the headrace tunnel route. The elevation of the lowest portion over the headrace tunnel, except the intake and the surge tank sites, is about elevation 500 metres as against the tunnel formation height of elevation 413 metres, with 80 metre thick cover over the tunnel.

The seismic refraction prospecting was done on two lines, S907D and S908D, along the intake and the intake. The core drilling was performed at two locations, BI 924D and BI 925D at the intake. No drilling was made on the headrace tunnel route in this field investigation, because information from some of the previous investigation was available.

Geologic profile of the intake and the headrace tunnel route are shown in Figures A4.2.3

and A4.2.4.

According to the core drilling BI924D at the intake, the moderately weathered sandstone and shale that are acceptable for the intake portal are reached at the depth of 5 metres through the cover of completely and highly weathered rock.

The tunnel will be driven under the hill which is covered by basalt of Tuc Trung formation. Core drilling in the previously investigation shows that the sub-horizontal boundary of the basalt and the underlying La Nga Formation is higher than the tunnel formation height. The headrace tunnel will pass through the fresh sandstone, shale and siltstone of the La Nga Formation, except for localised sections of weathered or fractured rock at portals and in the vicinity of faults.

The sedimentary rock of La Nga formation on several outcrops shows strikes of NE-SW and dips of 60 to 70 degrees to either direction of NW or SE. The headrace tunnel will cross the fold beds.

As shown in regional geologic map a major fault named Tanh Linh - Dak Nong with a north-south strike will cross in the middle part of the tunnel alignment, while it is difficult to observe it at the field for the lack of outcrops. Other smaller faults of Degree III could also be encountered. Faults of minor grade are much more difficult to find because of the thick overburden or weathering and the dense vegetation.

A4.2.4 Surge Tank, Penstock and Powerhouse

The surge tank and the penstock are situated on the hill slope on the left bank of the Dong Nai River flowing southwest. There are two small gullies cutting this slope on both upstream and downstream sides of the penstock route.

No drilling was performed in the current geological investigation because the geologic information had been well obtained by the drilling in the previous investigation.

A seismic refraction prospecting on a line S909D was performed along the contemplated surge tank – penstock route. Its geologic profile is shown in Figure A4.2.5.

The bedrock around the surge tank and the penstock sites consists of sandstone and shale covered by rather thick overburden. Thickness of the overburden ranges from 13 m to 20 m and gradually decreases down the slope to a few metres at the powerhouse site on the river bank.

In the surge tank area, the core drilling DN5 in the previous investigation shows that the sandstone-shale are overlain by the 50 metre thick basalt of the Tuc Trung formation. Also found in the previous core drilling was a 6 metre thick residual soil layer, consisting of clay with fragments of sedimentary rock, that was formed between the basalt and the La Nga sandstone-shale.

At the powerhouse site, the fresh sandstone and shale is covered with a few metre thick colluvial deposit and a 5 to 10 metre thick weathered rock as shown in Figure A4.2.5. Slightly weathered or fresh rock outcrops on the river bank of the Dong Nai and in two small gullies near the site. Talus is formed at the foot of the slope.

The rock beds dip against the hill slope, rather favorable for the slope stability. A steeply dipped cracky zone develops parallel to the river behind the powerhouse site. The rock is generally sound and medium to highly strong.

A5 SEISMICITY

The land of Vietnam, except its farthest northern part, is situated on a craton or a stabilised continental mass called Sunda Shelf. This area is characterised by low seismicity and little earthquake.

In the Institute of Geophysics, Hanoi, a set of earthquake record was obtained, that covered twenty-four (24) events for the period from 1715 to 1992. A probabilistic estimate of the maximum earthquake acceleration was tried, though the number of data is not always relevant enough for this process. Ruling out three data before 1990, probable maximum earthquakes were sought on twenty-one (21) data in 70 years between 1923 and 1992 for the return periods of 100 years and 200 years as shown in Table A5.1.

Earthquake intensity that could be felt at the middle part between Dong Nai dam sites No.3 and No.4 (11°52'N, 107°50'E) was initially estimated for each of the recorded earthquake by use of attenuation formulae of Cornell and Kawasumi. Cornell's formula has given some low intensities, while effects of the earthquakes to the dam sites are all zero (0) according to Kawasumi as shown in Table A5.1.

Those formulae are as follows:

- Formula according to Cornell

  (Cornell, C.A., 1968, Engineering seismic analysis, Bull. Seism. Soc. Am. Vol.58, pp.1583-1606)

  $I = 8.0 + 1.5\,M - 2.5\,\mathrm{Ln}\,r$

  where,

  I : Earthquake Intensity in Modified Mercalli Scale felt at the dam site

  M : Magnitude in Richter Scale

  R : Focal distance in kilometer, $r = (d^2 + h^2 + 400)^{0.5}$

  d: Epicentral distance (km)

  h: Focal depth (km)

  $\log A = 0.014 + 0.30\,I$ *

  where,

  A: Peak horizontal acceleration (cm/sec^2 or gal)

  (*Trifunac, M.D. and Brady, A.G., 1975, on the correlation of seismic intensity scales with the peak of recorded strong ground motion, Bull. Seism. Soc. Am. Vol.65, pp.139-162)

- Formula according to Kawasumi

  (Kawasumi, H., 1951, Measures of earthquake danger and expectancy of maximum intensity throughout Japan as inferred from the seismic activity in historical times, Bull. Earthq. Res. Inst., 21, pp469-482.)

  $I_j = 2\,M - 4.6052\,\log d - 0.00183\,d - 0.307$ (when d is not less than 100 km)

$I_j = 2(M - \log r) - 0.01668\, r - 3.9916$ (when d is less than 100 km)

$A = 0.45 \times 10^{(I_j/2)}$ (when Ij is not more than 5.5)

$A = 20 \times 10^{(I_j/5)}$ (when $5.5 < I_j < 7.0$)

where,

Ij : Earthquake intensity in Japan Meteorological Agency Scale (JMA)

M : Magnitude in Richter Scale

d : Epicentral distance (km)

r : Focal distance (km)

A : Peak ground acceleration (cm/sec^2 or gal)

The probabilistic calculation, therefore, was made only on Cornell's intensities that were supposed to be felt at the dam sites in sixteen (16) events of the earthquakes out of twenty-one (21). The estimate is shown in Figure A5, giving the probable maximum accelerations of;

0.009g	for 100 years of return period,
0.014g	for 200 years of return period.

Since the estimated probable earthquake acceleration is very low, the design earthquake acceleration should be determined largely in reference with the international standard approach and examples in other similar projects located nearby. For instance, the earthquake factor is 0.035 for rock-base structures in the Ham Thuan – Da Mi Hydropower Project and 0.07 for earth-base structures, while the study of design criteria for the Dai Ninh Project proposed 0.1. The value of 0.1 will be taken for the Dong Nai No.3 and No.4 dams as a conservative minimum value for the design.

The reservoir-induced earthquake is not conceivable. Although faults of various sizes are reported from interpretation of topographic lineament, the sedimentary bedrock is little disturbed and shows almost constant trend of bedding around N45°E in the strike without serious distortion in spite of folds. The land is tectonically stable as self-evident in the study of the earthquake data mentioned above.

A6 CONSTRUCTION MATERIAL

A6.1 General

Quest for sources of concrete aggregates and dam embankment materials was conducted with a series of test pitting for earth borrow areas, core drilling for quarry sites and laboratory test of samples. Samples were also taken from deposits along the Krong Kno River and the Srepok River for laboratory tests of fine concrete aggregate. The characteristics of the earth material, the quarry rock and the river sand are summarized in Tables A6.1, A6.2, A6.3 and A6.4.

A6.2 Rock Material

A6.2.1 Quarry Site for Dong Nai No. 3 Scheme

Quarry site for the Dong Nai No.3 scheme is proposed at the basalt plateau on the right bank of the Dong Nai river approximately 1.5 km northwest from the dam site where the Tuc Trung Basalt flow is widely exposed on a long escarpment.

Elevation of ground surface of the proposed quarry is about 800m-825m.

The quarry site was investigated by the seismic refraction prospecting on the line S905U and three boreholes located 100 to 200 metres behind the edge of the escarpment. Six core samples were tested in laboratory .

The core drilling shows that the hard rock of slightly weathered and fresh basalt is covered by very thick overburden including the highly-to-moderately weathered rocks. Its thickness varies from 20 m to 40 m.

As shown on the drill logs, the basalt is generally dense, but has some vesicular and porous layers. The unconfined compressive strength of the dense basalt ranges from 90 MPa (900 kgf/cm^2) to 115 MPa (1,150 kgf/cm^2). Two soundness tests resulted in the weight losses of 0.23 percent and 0.42 percent, which are acceptable for concrete aggregate. The porous basalt, however, would not be suitable for coarse concrete aggregate due to its low strength and density. Highly or moderately weathered soft basalt that is not suitable for the rock material is occasionally found intercalated among the hard solid basalt. Such soft rock may be usable for transition zone of the rockfill dam.

The results of the laboratory tests are as shown in Table A6.1.

A6.2.2 Quarry Site for Dong Nai No. 4 Scheme

A quarry site for the Dong Nai No.4 scheme is proposed on a plateau higher than EL. 650 m at the top of the slope on the right bank of the Dong Nai River and approximately 4 km north of the dam site where the hard basalt is well exposed forming an escarpment with a water-fall.

Two seismic refraction profiles and three boreholes were surveyed and six core samples were tested in laboratory.

The core drilling showed that the hard and solid basalt is covered by very thick overburden including the highly to moderately weathered rocks. Their thickness varies from 27 m to 48 m. Two types of basalt, dense and porous, were encountered.

The results of laboratory tests show that the rock condition in this quarry is similar to that of the Dong Nai No. 3 quarry.

The core drilling found that the fresh or only slightly weathered basalt is intercalated with thin layers of highly or moderately weathered rock at places. A summary of physical and mechanical characteristics of the rock samples is shown in Table A6.1.

6.3 Earth Core Materials

6.3.1 Earth Material for Dong Nai No. 3 Scheme

An earth material source is proposed on the basalt plateau on the right bank of the Dong Nai River and approximately 2 km northeast from the dam site. The borrow area is located near the proposed quarry.

Thirteen (13) test pits were dug and eighteen (18) soil samples were taken for the test in laboratory.

The earth material in this area is reddish brown lateritic clay that is the product of intensive weathering of the basalt.

The test results indicate that the earth material is a mixture of 25 percent clay, 30 percent sand and 45 percent gravel, and falls under GC of the Unified Soil Classification of the U.S. Bureau of Reclamation (USBR).

A summary of the laboratory test results for this borrow area is shown in Tables A6.2.

6.3.2 Earth Material for Dong Nai No. 4 Dam Scheme

An earth borrow area for the Dong Nai No.4 scheme is proposed on a flat plateau higher than El 600m on the right bank of the Dong Nai River and approximately 1 km northeast from the dam site.

Ten (10) test pits were dug and twenty (20) soil samples were taken for the laboratory tests.

Observation in the test pits shows that the soil material derived from weathered basalt contains 10 to 40 percent of reddish brown lateritic clay in the zone deeper than 3 metres.

The test results indicate that the soil material has 30 % average content of particles finer than 0.005mm, the liquid limit of 70%, the plastic limit of 41% and the natural moisture content of 36.8%. The material is generally wetter than the optimum moisture content and is considerably dryer than the plastic limit. The plasticity characteristic of soil indicates the high plastic silt classified as MH.

A summary of soil material in this borrow area is shown in Tables A6.3and A6.3.

6.4 Sand Borrow Pits

Sand deposit that is sufficient in volume for concrete aggregates and filter material of the fill-type dam is absent near the project area. River deposits on the Dong Nai River are too scarce and scattered in small scale. The nearest substantial deposits so far found is located on the Krong Kno River and the Srepok River to the north and at Thong Nhat sand pit on the downstream Dong Nai river to the southwest, all at the distance more than 100 kilometers from the dam site. It will be reasonable and economical to produce filter material and concrete aggregates by crushing quarry rock. Locations of the sand pits are shown in Figure A1.

6.4.1 Sand Borrow Pit on the Krong Kno River

Sand borrow pit is located in the vicinity of the Quang Phu village on the Krong Kno Rriver, upstream of the Srepok River. This sand borrow pit can be reached from the project area by approximately 120 km long way through the provincial road 693 and the national highway No.28.

The sand deposit lies along the river channel and on the river banks.

Three sand samples along the river were taken and tested in laboratory. The results indicate that the sand is clean and well graded material and not chemically reactive in the alkali reactivity tests.

In the previous investigation, the reserve has been estimated at 447,000 m^3.

6.4.2 Sand Borrow Pit on the Srepok River

This sand borrow pit is located on the Srepok river and it has a distance about 170 kilometers from the dam sites through the national highway No. 14 and No. 28.

The sand deposit lies along the river channel and generally under the water.

Three sand samples were taken in the site and tested in laboratory. The results indicate that the sand is clean and well graded material and not chemically reactive in the alkali reactivity tests. In the previous study, the reserve has been estimated at 2,577,000 m^3.

A summary of laboratory tests of two above sites is shown in Table A6.4.

6.4.3 Sand Borrow Pit on the Dong Nai River (Thong Nhat)

This sand pit is located on the Dong Nai River downstream of the project area and in Thong Nhat commune - Bu Dang district. It has a distance about 150 kilometers from the project area and there is a 30 km long earth road to connect the sand pit site to the highway No.14.

A part of this sand borrow was exploited to supply the construction materials for the Thac Mo hydropower project.

The proven reserve is 1,200,000 m^3.

Appendix A

Tables

Table A2.1 Summary of Stratigraphy

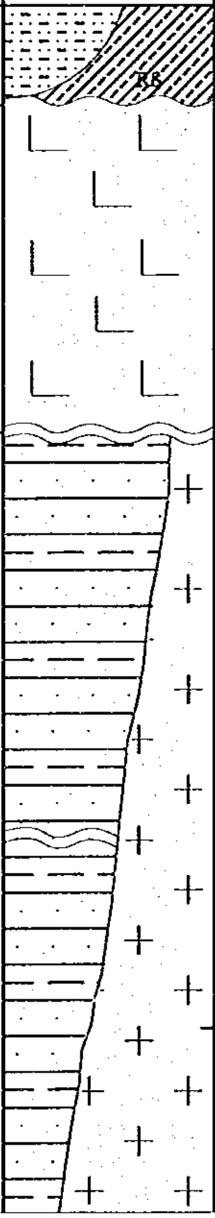
Era	Period	Series	Formation	Geologic Index	Lithology	Thickness (m)	Summary Description
CENOZOIC	QUATERNARY	HOLOCENE		aQ_{IV}	 	1-5	Alluvium of river, stream: Sandy clay, clayeysand, sand, gravel. Residual soil: Clay with laterite or soft rock fragments
CENOZOIC	QUATERNARY NEOGENE	PLEISTOCENE PLIOCENE	TUC TRUNG	βN_2-Q_1tt		50 - 150	Basalt of Tuc Trung formation: Oviline basalt, plagioclase basalt, porous and dense structure.
MESOZOIC	JURASSIC	MIDDLE	LA NGA	J_2ln		700 - 800	La Nga formation: Sandstone, shale interbedded with siltstone Ca Na Complex: Leucocratic granite, two mica granite with fine grained

Table A3.1 Quantity of Seismic Refraction Prospecting

Site	Location	Line No	Length (m)	Remark
Dong Nai No. 3	Dam site	S 901 U	900	Dam axis
	Intake	S 902 U	1,500	
	Waterway	S 903 U	7,000	
	Penstock	S 904 U	700	
	Quarry	S 905 U	1000	
	Subtotal		11, 100	
Dong Nai No. 4	Dam site	S 906 D	600	Dam axis
	Intake	S 907 D	400	
	Waterway	S 908 D	1000	
	Penstock	S 909 D	900	
	Quarry	S 910 D	500	
		S 911 D	500	
	Subtotal		3, 900	
Total			15,000	

Table A3.2 Quantity of Core Drilling and Borehole Test

Site	Location	Borehole No	Drilled length (m)	Coordinates		Elevation (m)	Open-end Pipe Test (stages)	Lugeon test (stages)	SPT (Points)
				N	E				
No.3	Dam site	BD 901U	80.0	1314 016.54	815 344.65	634.14	2	11	8
		BD 902U	80.0	1313 933.66	815 286.79	582.99	2	13	6
		BD 903U	70.0	1313 857.14	815 233.19	506.44	-	14	-
		BD 904U	70.0	1313 731.60	815 146.16	508.74	-	13	-
		BD 905U	80.0	1313 638.03	815 080.41	578.41	2	10	20
		BD 906U	80.0	1313 512.63	814 998.45	639.61	2	12	12
	Subtotal		460.0				8	73	46
	Intake	BI 907U	40.0	1313 842.87	815 574.91	581.34			15
		BI 908U	40.0	1313 909.97	815 553.11	616.29			19
	Surge tank	BP 909U	90.0	1314 582.21	809 222.14	631.38			13
	Penstock	BP 910U	50.0	1314 480.69	809 203.45	556.23			3
	Powerhouse	BP 911U	30.0	1314 388.57	809 186.53	485.57			-
	Subtotal		250.0				0	0	50
	Quarry site	BQ 912U	50.0	1315 281.46	816 197.37	822.36			
		BQ 913U	50.0	1315 136.98	816 409.12	807.21			
		BQ 914U	50.0	1314 994.39	816 618.08	822.98			
	Subtotal		150.0				0	0	0
Total (No.3)			860.0				8	73	96
No.4	Dam site	BD 915D	80.0	1315 097.97	797 880.42	499.18	2	8	12
		BD 916D	80.0	1315 052.97	797 822.04	449.84	2	11	1
		BD 917D	70.0	1314 989.66	797 739.92	366.50		14	-
		BD 918D	70.0	1314 948.57	797 686.62	360.50		14	-
		BD 919D	80.0	1314 892.65	797 614.06	449.94	2	14	2
		BD 920D	80.0	1319 533.58	798 954.36	650.29	2	13	6
	Subtotal		460.0				8	74	21
	Quarry site	BQ 921D	50.0	1314 836.61	797 541.36	476.22			
		BQ 922D	50.0	1319 696.33	798 816.54	663.56			
		BQ 923D	50.0	1319 684.84	798 965.99	673.08			
	Subtotal		150.0				0	0	0
	Intake	BI 924D	40.0	1314 149.37	797 330.43	451.03			2
		BI 925D	40.0	1314 231.14	797 271.31	507.31			10
	Subtotal		80.0				0	0	12
Total (No.4)			690.0				8	74	33
Grand Total			1550.0				16	147	129

Table A3.3 Quantity of Test Pits

Site	Location	Test Pit No	Depth (m)	Coordinates		Elevation (m)
				N	E	
No.3	Borrow area	TP 01U	1.0	1314 811.76	817 204.26	826.78
		TP 02U	2.5	1314 916.91	817 083.54	820.31
		TP 03U	2.5	1315 111.03	816 697.67	826.97
		TP 04U	2.5	1315 210.81	896 547.94	828.30
		TP 05U	5.0	1315 346.49	816 314.96	823.88
		TP 06U	4.0	1315 465.08	816 087.40	822.23
		TP 07U	5.0	1315 424.06	815 854.05	814.43
		TP 08U	2.5	1315 290.48	815 631.03	781.28
		TP 09U	5.0	1315 260.35	815 391.24	787.94
		TP 10U	5.0	1315 203.20	815 164.31	788.18
		TP 11U	3.0	1315 433.46	816 315.52	772.15
		TP 12U	4.0	1315 663.58	816 111.88	779.12
		TP 13U	5.0	1315 555.91	815 442.64	778.83
Total (No.3)			47.0			
No.4	Borrow area	TP 01D	5.0	1315 825.15	799 630.14	662.17
		TP 02D	5.0	1315 940.57	799 552.34	653.96
		TP 03D	5.0	1316 027.92	799 390.01	659.65
		TP 04D	5.0	1316 067.43	798 877.63	657.92
		TP 05D	5.0	1315 947.75	798 648.63	654.66
		TP 06D	5.0	1315 864.46	798 508.49	651.15
		TP 07D	5.0	1316 700.07	798 400.95	637.22
		TP 08D	5.0	1315 530.25	798 289.17	617.38
		TP 09D	5.0	1315 956.12	798 267.84	618.60
		TP 10D	5.0	1316 016.44	798 040.29	606.56
Total (No.4)			50.0			
Grand Total			97.0			

Table A4.1 Engineering Grade Classification of Weathered Rock

Grade		Weathering	Description
PIDC2	ISRM		
IIB	I/Fr	Very Fresh	No visible sign of material weathering, very strong, shape of cores 0.3-1.0 m. Physical mechanical property is high and does not change by depth. The permeability is very low and does not change by depth.
IIA		Fresh	No visible sign of material weathering. Perhaps, slight discoloration on major discontinuity surfaces, very strong, shape of cores 0.3-1.0 m. Physical mechanical property is high and change by depth. The permeability is low and changes by depth.
IB	II/SW	Slightly weathered	All or some of the rock material may be discolored by weathering and may be somewhat weaker extremely then when fresh, hard rock shape of cores 0.05-0.1 m. Physico-mechanical property is high and decreases by depth. The permeability is high and changes by depth.
IA2	III/MW	Moderately weathered	< Half the rock material is decomposed and disintegrated to a soil. Fresh and discolored rock is present as either continuous framework or corestones.
IA1	IV/HW	Highly weathered	> Half the rock material is decomposed and disintegrated to a soil. Fresh and discolored rock is present as either continuous framework or corestones.
dQ - eQ	V/CW	Completely weathered	All rock material is decomposed and/or disintegrated to or soil. The original mass structure is still largely intact.

Term	Description
Fresh	No visible sigh of weathering of the rock material.
Discolored	The color of the original fresh rock material is changed. The degree of chang from the original color should be indicated. If the color change is confined t particular mineral constituents this should be mentioned.
Decomposed	The rock is weathered to the condition of a soil in which the original materia fabric is still intact, but some or all of the mineral grains are decomposed.
Disintegrated	The rock is weathered to the condition of a soil in which the original fabric is stil intact. The rock is friable, but the mineral grains are not decomposed.

The stages of weathering described above may be subdivided using qualifying terms, for example "slightly discolored", "moderately discolored", "highly discolored".

Table A5.1 Earthquake Intensity Felt in the Project Area

Earthquake Intensity According to Cornell and Kawasumi

Y/M/D	Latitude	Longitude	Depth (km)	Magnitude (Richter s)	Distance (km) Epicentral	Focal	Intensity by Cornell	Kawasumi
1923/2/15	10.1	109.0	10	5.1	234.36	234.57	2.0	0
1923/5/2	10.1	109.0	17	5.1	234.36	234.97	2.0	0
1924/12/27	14.1	109.0	33	5.1	276.96	278.92	1.6	0
1926/7/15	14.1	109.0	33	5.1	276.96	278.92	1.6	0
1928/6/?	13.3	108.5	10	5.3	174.00	174.29	3.0	0
1950/?/?	13.1	109.3	15	4.8	213.97	214.49	1.8	0
1955/?/?	11.1	108.4	15	3.4	107.14	108.18	1.3	0
1960/?/?	11.1	109.1	15	4.1	167.19	167.86	1.3	0
1963/7/5	12.1	109.1	15	4.1	146.84	147.60	1.6	0
1963/7/7	11.9	109.4	15	4.1	178.11	178.74	1.2	0
1964/8/8	10.3	106.8	15	4.1	203.88	204.43	0.8	0
1964/10/26	11.5	106.6	15	2.7	139.49	140.30	0.0	0
1967/3/13	12.1	108.7	15	4.1	103.25	104.33	2.5	0
1970/4/12	13.4	108.9	13	5.3	206.64	207.05	2.6	0
1972/5/24	13.6	108.8	13	5.3	218.67	219.05	2.5	0
1977/5/5	10.6	108.3	15	2.7	148.96	149.71	0.0	0
1990/10/15	10.4	107.5	10	3.7	163.38	163.69	0.8	0
1990/10/18	10.3	107.4	10	2.3	176.52	176.81	0.0	0
1990/10/19	10.4	108.3	10	2.1	169.34	169.64	0.0	0
1991/6/?	10.6	107.9	10	4.1	138.62	138.98	1.8	0
1992/2/2	13.6	108.2	10	3.1	193.42	193.68	0.0	0

* Intensities are in the Modified Mercalli Scale.

Table A6.1 Summary of Laboratory Test Result of Rock Material (Taken from Drilling Core)

Location	No.	Drillhole	Depth (m) From	Depth (m) To	Type of Rock	Absorption (%)	Bulk Density (g/cm³)	Relative Density	Uniaxial Compressive Strength (kgf/cm²)	Poisson's ratio	Sound Velocity (m/s)	Soundness test (%)	Reduction in Alkalinity Rc (mmol/lit.)	Concentration of SiO_2 Sc (mmol/lit.)
No.3 Damsite Right bank	1	BD901U	57.00	57.27	Ss/Sl (80-90°)	0.19	2.71	2.73	1,094	0.24	6,818	1.00	816.5	0.0
	2		70.56	70.81	Ss	0.12	2.70	2.72	1,019	0.18	6,134	-	-	-
	3	BD902U	44.00	44.58	Ss>>Sl (40°)	0.08	2.66	2.70	2,211	0.21	6,933	1.30	724.4	12.7
	4		52.55	52.85	Ss>>Sl (60°)	0.21	2.72	2.74	1,012	0.22	6,938	-	-	-
	5	BD903U	13.70	14.00	fine-Ss/Sl (45°)	0.09	2.73	2.75	1,081	0.17	6,869	-	-	-
	6		26.00	26.35	Ss (55°)	0.06	2.71	2.76	1,078	0.09	6,356	-	-	-
	7		47.30	47.70	Ss	0.08	2.70	2.73	1,057	0.19	6,668	-	-	-
Left bank	8	BD904U	5.75	6.00	Sl-Ss (90°)	0.25	2.70	2.75	1,026	0.24	8,468	-	-	-
	9		19.63	19.94	Ss>>Sl (0°)	0.12	2.73	2.77	1,169	0.11	6,275	-	-	-
	10		43.61	43.88	Ss (Massive 90°)	0.07	2.68	2.72	964	0.19	5,619	-	-	-
	11	BD905U	50.50	50.85	Ss(60°)	0.16	2.71	2.75	1,179	0.11	5,823	-	-	-
	12		57.40	57.60	fine-Ss	0.18	2.76	2.79	1,763	0.10	6,523	-	-	-
	13	BD906U	30.50	30.80	Sl(f-Ss)	0.19	2.77	2.80	1,446	0.09	6,247	-	-	-
	14		40.00	40.40	Ss>>Sl(45°)	0.13	2.79	2.81	1,615	0.09	6,292	-	-	-
No.3 P/S	15	BP911U	17.50	18.00	Sl>>Ss(25°)	1.05	2.71	2.75	799	0.13	5,396	-	-	-
	16		22.30	22.60	Ss(Massive)	0.21	2.69	2.74	1,171	0.18	5,888	-	-	-
Quarry (No.3)	17	BQ912U	35.00	35.33	Ba (Slightly Porous)	1.51	2.48	2.93	1,148	0.08	5,152	-	-	-
	18		41.00	41.33	Ba (Massive)	2.05	2.56	2.89	1,038	0.02	4,676	-	-	-
	19	BQ913U	21.00	21.28	Ba (Porous)	2.11	2.23	2.60	418	0.04	4,915	0.23	227.5	110.5
	20		32.43	32.73	Ba (Massive)	1.07	2.62	2.91	922	0.05	3,663	0.42	305.2	78.4
	21	BQ914U	33.55	33.80	Ba (Porous)	2.66	2.53	2.63	865	0.15	4,940	-	-	-
	22		46.16	46.38	Ba (Massive)	1.25	2.65	2.90	1,017	0.23	4,738	0.86	223.4	46.7
No.4 Damsite Right bank	23	BD915D	69.00	69.40	Ss/Sl (60°)	0.81	2.68	2.79	348 *1	0.13	5,931	-	-	-
	24		70.00	70.65	Ss/Sl (50°)	0.13	2.72	2.76	977	0.12	5,862	0.90	312.7	125.1
	25	BD916D	64.80	65.05	Ss (Massive)	0.95	2.69	2.75	1,057	0.20	4,004	-	-	-
	26		72.65	73.00	Sl>>Ss (60°)	0.44	2.71	2.75	607 *1	0.15	6,110	0.80	679.3	22.0
Left bank	27	BD917D	23.23	23.60	Sl>Ss(60°)	0.20	2.73	2.78	619	0.10	6,246	-	-	-
	28		25.00	25.35	Sl(50°)	0.31	2.72	2.75	545	0.07	5,670	-	-	-
	29		34.00	34.50	Sl>Ss(60°)	0.25	2.74	2.77	498	0.21	6,154	-	-	-
	30	BD918D	19.20	19.60	Sl>>Ss(50°)	0.19	2.76	2.81	389	0.06	6,018	-	-	-
	31		37.13	37.50	Sl>>Ss (50°)	0.41	2.77	2.82	784	0.08	5,906	-	-	-
	32	BD919D	55.70	56.00	Sl(f-Ss)(60°)	0.24	2.74	2.79	770	0.15	6,182	-	-	-
	33		57.30	57.55	Ss(Massive)	0.14	2.72	2.76	1,343	0.10	6,201	-	-	-
	34	BD920D	74.00	74.30	Sl>>Ss (60°)	0.26	2.74	2.78	620	0.13	6,108	-	-	-
Quarry (No.4)	35	BQ921D	45.65	45.91	Ba (Massive)	0.91	2.70	2.76	1,221	0.21	4,669	1.40	205.3	197.6
	36		46.50	46.75	Ba (Slightly Porous)	1.17	2.70	2.88	1,027	0.09	4,428	-	-	-
	37	BQ922D	38.00	38.16	Ba (Extremely Porous & MW)	8.06	1.80	2.58	93	0.37	3,007	-	-	-
	38		40.50	40.65	Ba (Massive)	1.66	2.68	2.86	1,043	0.10	4,491	-	-	-
	39	BQ923D	37.30	37.60	Ba (Massive)	1.15	2.67	2.74	916	0.25	5,560	1.20	480.9	243.4
	40		39.23	39.50	Ba (Extremely Porous & M-HW)	8.38	1.80	2.64	83	0.39	2,810	97.34	621.0	0.0

Note: *1; The failue is mainly influenced by the cleavage.

Table A6.2 Summary of Laboratory Test of Soil Materials of Dong Nai No.3 (1/2)

Sample No.		Depth	Particle of grain size finer (mm); % passing											Dispersive ratio	Atteberg Limits			Specific gravity
			3	2	$1^{1/2}$	3/4	3/8	No.4	No.10	No.40	No.200				Liquid Limit	Plastic Limit	Plasticity Index	
Test Pit No.	Sample	(m)	75	50	38.1	19.1	9.5	4.75	2.0	0.42	0.074	0.005	0.002	%	w_L (%)	w_P (%)	I_P (%)	Gs
TP1U	-1	-																
	-2	-																
TP2U	-1	1.0-2.5		100.0	92.2	81.7	64.3	44.8	34.5	26.6	20.4	9.0	7.0	-	65.5	40.0	25.5	3.025
	-2	-																
TP3U	-1	1.0-2.5	100.0	86.0	83.0	66.0	61.0	46.0	33.0	24.0	18.0	11.0	10.0	-	56.5	37.8	18.7	2.909
	-2	-																
TP4U	-1	1.0-2.5		100.0	98.0	87.0	82.0	64.0	55.0	44.0	34.0	16.0	11.0	-	64.0	41.0	23	2.941
	-2	-																
TP5U	-1	1.0-2.5			100.0	86.0	75.0	51.0	35.0	25.0	22.0	16.0	13.0	-	61.3	37.0	24.3	2.887
	-2	2.5-5.0			100.0	87.0	81.0	56.0	44.0	33.0	28.0	18.0	5.0	3.9	63.5	38.5	25.0	2.917
TP6U	-1	1.0-2.5		100.0	98.0	76.0	71.0	54.0	42.0	26.0	19.0	13.0	12.0	-	60.1	35.5	24.6	2.898
	-2	2.5-4.0		100.0	95.0	84.0	76.0	52.0	38.0	29.0	21.0	12.0	10.0	-	59.1	36.5	22.6	3.047
TP7U	-1	1.0-2.5						100.0	98.0	97.0	94.0	42.0	23.0	-	52.5	33.5	19.0	2.753
	-2	2.5-5.0						100.0	97.0	95.0	90.0	37.0	25.0	8.3	51.4	30.1	21.3	2.778
TP8U	-1	1.0-2.5						100.0	96.0	93.0	81.0	34.0	28.0	11.4	47.1	28.6	18.5	2.807
	-2	-																
TP9U	-1	1.0-2.5		100.0	90.0	77.3	65.8	51.6	40.9	30.0	21.6	10.0	8.0	-	62.9	35.7	27.2	2.907
	-2	2.5-5.0				100	94	80	72.0	66.0	60.0	28.0	23.0	-	50.9	30.4	20.5	2.778
TP10U	-1	1.0-2.5		100.0	95.0	75.0	68.0	49.0	36.0	27.0	21.0	13.0	11.0	-	58.1	38.0	20.1	3.030
	-2	2.5-5.0		100.0	96.0	72.0	65.0	49.0	36.0	28.0	23.0	12.0	10.0	3.4	49.2	31.3	17.9	2.919
TP11U	-1	0.5-2.5			100.0	95.0	85.0	68.0	51.0	39.0	30.0	21.0	18.5	-	58.1	38.8	19.3	2.9
TP12U	-1	1.0-3.0			100.0	95.0	85.0	68.0	51.0	42.0	37.0	22.0	20.0	3.3	59.0	33.7	25.3	2.9
TP13U	-1	0.5-2.5	100.0	94.0	90.0	76.0	57.0	45.0	33.0	25.0	20.0	11.8	10.0	-	50.5	30.7	19.8	2.9
	-2	2.5-5.0	100.0	94.0	90.0	76.0	55.0	44.0	34.0	26.0	21.0	14.8	13.5	-	52.4	31.1	21.3	3.0

Table A6.2 Summary of Laboratory Test of Soil Materials of Nong Nai No.3 (2/2)

Sample No.		Depth	Specific gravity	Natural moisuture	Proctor compaction test			Triaxial Test (UU)		Triaxial Test (CU)			
					MDD[*1]	OMC[*2]	Permeability			Total stress		Efffective stress	
Test Pit No.	Sample	(m)	Gs	w_N%	ρ_{dry} (g/cm^3)	%	cm/sec	c_U (kgf/cm^2)	ϕ_U	c_{CU} (kgf/cm^2)	ϕ_{CU}	c' (kgf/cm^2)	ϕ'
TP1U	-1	-											
	-2	-											
TP2U	-1	1.0-2.5	3.025	30.5	1.750	20.0	4.78×10^{-6}	0.608	18°33′	0.651	20°48′	0.630	23°06′
	-2	-											
TP3U	-1	1.0-2.5	2.909	20.4	1.725	20.5	8.82×10^{-7}						
	-2	-											
TP4U	-1	1.0-2.5	2.941	24.0	1.714	21.0	1.19×10^{-6}						
	-2	-											
TP5U	-1	1.0-2.5	2.887	26.7	1.725	20.2	5.20×10^{-6}						
	-2	2.5-5.0	2.917	27.5	1.750	19.5	2.25×10^{-6}	0.581	18°18′	0.636	19°49′	0.633	22°33′
TP6U	-1	1.0-2.5	2.898	21.7	1.685	21.4	1.17×10^{-6}						
	-2	2.5-4.0	3.047	24.7	1.700	22.0	8.00×10^{-7}						
TP7U	-1	1.0-2.5	2.753	28.2	1.590	22.8	7.06×10^{-7}						
	-2	2.5-5.0	2.778	26.8	1.590	23.0	5.50×10^{-7}	0.22	11°07′	0.37	17°23′	0.322	20°50′
TP8U	-1	1.0-2.5	2.807	24.7	1.675	20.5	3.32×10^{-7}						
	-2	-											
TP9U	-1	1.0-2.5	2.907	20.7	1.733	19.5	2.22×10^{-6}						
	-2	2.5-5.0	2.778	31.3	1.670	19.8	8.90×10^{-7}						
TP10U	-1	1.0-2.5	3.030	16.4	1.710	21.2	2.20×10^{-6}						
	-2	2.5-5.0	2.919	24.4	1.714	20.5	2.56×10^{-6}	0.599	17°44′	0.614	20°13′	0.59	23°33′
TP11U	-1	0.5-2.5	2.865	44.4	1.600	23.0	1.08×10^{-6}						
	-2	-											
TP12U	-1	1.0-3.0	2.887	22.5	1.650	21.2	8.9×10^{-7}	0.364	14°41′	0.512	17°11′	0.478	20°17′
	-2	-											
TP13U	-1	0.5-2.5	2.887	36.8	1.675	20.3	1.99×10^{-6}						
	-2	2.5-5.0	3.004	34.4	1.690	20.5	1.29×10^{-6}						

*1 : MDD is the abbreviation for Maximum Dry Dencity.

*2 : OMC is the abbreviation for Optimum Moisture Content.

Table A6.3 Summary of Laboratory Test of Soil Materials of Nong Nai No.4 (1/2)

Sample No.		Depth	*Particle of grain size finer (mm); % passing*											Dispersive ratio	*Atteberg Limits*			Specific gravity
			3	2	$1^{1/2}$	3/4	3/8	No.4	No.10	No.40	No.200				Liquid Limit	Plastic Limit	Plasticity Index	
Test Pit No.	Sample	(m)	75	50	38.1	19.1	9.5	4.75	2.0	0.42	0.074	0.005	0.002	%	w_L (%)	w_P (%)	I_P (%)	Gs
TP1D	-1	2.0-2.5						100.0	97.0	92.0	60.0	29.5	27.6		78.5	44.9	33.6	2.853
	-2	4.5-5.0			100.0	96.0	89.5	78.5	66.0	42.2	34.0	14.0	11.0		62.5	37.0	25.5	2.946
TP2D	-1	2.0-2.5						100.0	99.0	94.0	72.0	40.5	37.5		69.8	40.5	29.3	2.905
	-2	4.5-5.0				100.0	91.5	74.0	5.1	35.5	28.0	15.5	13.0	6.5	59.6	35.7	23.9	2.981
TP3D	-1	2.0-2.5						100.0	98.0	94.0	75.0	42.0	38.0		69.0	43.2	25.8	2.972
	-2	4.5-5.0	92.0	81.0	77.0	69.0	61.0	51.0	43.0	35.6	28.2	14.0	12.0		62.0	37.2	24.8	3.067
TP4D	-1	2.0-2.5							100.0	96.0	80.0	45.0	40.0	2.1	72.6	41.0	31.6	2.920
	-2	4.5-5.0				100.0	95.0	89.0	84.0	76.0	56.0	28.5	25.5		69.1	42.7	26.4	3.010
TP5D	-1	2.0-2.5							100.0	95.0	74.0	38.5	33.6		76.0	43.0	33.0	2.899
	-2	4.5-5.0					100.0	97.0	96.0	92.0	71.0	37.0	32.0		77.5	43.9	33.6	2.922
TP6D	-1	2.0-2.5					100.0	98.0	96.0	90.0	63.0	32.0	28.0		69.9	42.3	27.6	2.840
	-2	4.5-5.0							100.0	93.0	63.0	27.0	22.6	8.2	79.6	45.4	34.2	2.845
TP7D	-1	2.0-2.5			100.0	82.2	79.4	71.5	60.9	43.0	27.0	16.0	13.0		67.6	41.5	26.1	2.917
	-2	4.5-5.0	100.0	93.0	89.0	83.5	80.5	75.0	63.0	44.5	29.5	15.5	12.0		69.0	43.2	25.8	2.945
TP8D	-1	2.0-2.5							100.0	95.0	75.0	42.5	39.5		76.9	41.2	35.7	2.880
	-2	4.5-5.0						100.0	98.0	92.0	74.0	34.5	31.0		74.5	41.4	33.1	2.884
TP9D	-1	2.0-2.5						100.0	99.0	95.0	73.0	34.0	29.6		73.4	43.1	30.3	2.842
	-2	4.5-5.0							100.0	93.0	72.0	36.0	31.6	9.1	81.2	45.1	36.1	2.879
TP10D	-1	2.0-2.5		100.0	95.8	84.8	73.5	60.5	52.0	44.0	27.0	14.0	12.0		65.2	38.7	26.5	3.012
	-2	4.5-5.0			100.0	91.5	73.0	60.4	49.0	41.0	31.0	15.0	13.0	8.5	56.0	31.6	24.4	3.050

Table A6.3 Summary of Laboratory Test of Soil Materials of Dong Nai No.4 (2/2)

Sample No.		Depth	Specific gravity	Natural moisuture	Proctor compaction test			Triaxial Test (UU)		Triaxial Test (CU)			
					MDD*1	OMC*2	Permeability			Total stress		Efffective stress	
Test Pit No.	Sample	(m)	Gs	w_N%	ρ_{dry} (g/cm^3)	%	cm/sec	c_U (kgf/cm^2)	ϕ_U	c_{CU} (kgf/cm^2)	ϕ_{CU}	c' (kgf/cm^2)	ϕ'
TP1D	-1	2.0-2.5	2.853	39.1	1.340	34.5	3.18×10^{-6}						
	-2	4.5-5.0	2.946	23.0	1.498	29.0	3.13×10^{-6}						
TP2D	-1	2.0-2.5	2.905	38.6	1.326	37.3	2.25×10^{-6}						
	-2	4.5-5.0	2.981	37.5	1.455	29.4	5.68×10^{-6}	0.381	16°32′	0.453	19°36′	0.448	22°31′
TP3D	-1	2.0-2.5	2.972	38.4	1.382	34.0	2.30×10^{-6}						
	-2	4.5-5.0	3.067	26.8	1.602	26.0	5.10×10^{-6}						
TP4D	-1	2.0-2.5	2.920	40.5	1.369	35.5	4.09×10^{-7}	0.309	13°49′	0.306	16°34′	0.274	19°45′
	-2	4.5-5.0	3.010	37.3	1.375	34.9	1.80×10^{-6}						
TP5D	-1	2.0-2.5	2.899	41.8	1.325	37.0	7.20×10^{-7}						
	-2	4.5-5.0	2.922	40.3	1.313	36.4	9.90×10^{-7}						
TP6D	-1	2.0-2.5	2.840	39.4	1.338	34.4	5.31×10^{-7}						
	-2	4.5-5.0	2.845	34.4	1.332	35.5	2.50×10^{-6}	0.271	15°47′	0.28	18°51′	0.272	21°10′
TP7D	-1	2.0-2.5	2.917	38.1	1.450	30.7	2.94×10^{-6}						
	-2	4.5-5.0	2.945	38.0	1.401	33.5	5.50×10^{-6}						
TP8D	-1	2.0-2.5	2.880	40.1	1.325	36.0	6.82×10^{-7}						
	-2	4.5-5.0	2.884	40.9	1.350	34.5	2.20×10^{-6}						
TP9D	-1	2.0-2.5	2.842	41.0	1.365	34.0	7.97×10^{-7}						
	-2	4.5-5.0	2.879	37.0	1.331	35.6	6.73×10^{-7}	0.297	14°37′	0.296	17°37′	0.273	20°28′
TP10D	-1	2.0-2.5	3.012	36.5	1.612	25.3	1.64×10^{-5}						
	-2	4.5-5.0	3.050	28.1	1.675	23.5	3.53×10^{-5}	0.563	16°51′	0.616	19°44′	0.612	22°40′

*1 : MDD is the abbreviation for Maximum Dry Dencity.

*2 : OMC is the abbreviation for Optimum Moisture Content.

Table A6.4 Summry of Laboratory Test of Fine Concrete Aggregate (Sand material)

Location	Sample	Percent accumulative retained (%)							F.M.*	Specific gravity	Absorption	Clay lumps & friable particles	Soundness	Reduction in Alkalinity (Rc) mmol/lit.	Concentration of SiO2 (Sc) mmol/lit.
		5	2.5	1.25	0.63	0.315	0.15	Pan							
Sre Pok	SP1	2	15	50	78	95	99	100	3.4	2.64	0.8	0.6	1.23	228.0	88.17
	SP2	1	4	20	62	95	99	100	2.8	2.65	1.2	0.4	1.43	383.0	9.14
	SP3	1	5	24	58	91	99	100	2.8	2.65	1.1	0.4	1.46	257.8	15.29
Quang Phu	QP1	1	4	34	76	97	99	100	3.1	2.63	1.7	0.1	1.21	283.0	59.78
	QP2	1	3	14	39	73	93	100	2.2	2.64	2.7	0.8	0.74	285.7	46.25
	QP3	0	0	5	26	71	95	100	2.0	2.65	3.0	0.6	0.77	372.5	0.00

* : F.M.; Finess modulus