Annex B

Geological Investigation

Annex B GEOLOGICAL INVESTIGATION

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Annex B: GEOLOGICAL INVESTIGATION

B1 Introduction

The geological investigation in the Feasibility Study (Phase II) in 2002 was performed primarily for the sites of water resources and water conveyance structures involved in the Project on which a feasibility study is planned to be carried out in the Master Plan Study (Phase I) in 2001. These structure sites comprise the following:

i) Agos Dam site,

ii) Agos Afterbay Weir site on the Agos mainstream,

iii) Kaliwa Low Dam site on the Kaliwa River,

iv) Kaliwa~Taytay Waterway Route consisting of;

- Tunnel No.1 connecting the Kaliwa Intake Structure on the Kaliwa River and Water treatment plant via, Lagundi powerhouse, and
- Morong water treatment plant (WTP), Pipeline No.1, Valve House No.2, Pipeline No.2, Antipolo Pump Station, Antipolo and Taytay Service Reservoirs in the Morong~Teresa~Antipolo~Taytay area.

Out of the above structures involved in the Project, the Agos Afterbay Weir and Lagundi powerhouse proposed in the Master Plan Study stage were discarded from the Project components in the course of the Feasibility Study, although the geological investigation in the Feasibility Study encompassed these structure sites.

This Annex B describes the geological assessment for the structure sites stated above.

The references that were referred to in performing the geological investigation and preparing this Annex B are listed at the end the text.

B2 General Geology

B2.1 Regional Geology

The Philippine Islands are situated on the circumpacific seismic belt, which is one of the areas in the world that is most conspicuously subject to earthquake. The Philippine archipelago is bounded on the east by active subduction faults known as the Philippine Trough and Mindanao Trough. Another fault known as the Philippine Master Fault crosses Central Luzon southeastwards from Lingayan Gulf to Dingalan Bay in Quezon Province, then trends southwards close to the east coast of Quezon Province and along the west coast of Bicol Peninsula to eastern Visayas, and then to Mindanao where it divides and forms the graben between the Province of Surigao and Bukidnon (Reference 3). The regional geological structure is shown in Figure B2.1).

Geologically, the Project Area is located in the Central Basin, which is mainly characterized by the Palaeogene and older clastic and volcanic deposits. The Central Basin is bounded by the Philippine Fault system (Philippine Fault Zone: PFZ) on the east and northeast (a branch of which was identified near Infanta) and by the Valley Fault system on the west and southwest (see Figure B2.2). Morphology indicates that the fault near Infanta has been active at the comparatively recent geological times.

Land of the Project Area, from the lithological viewpoint, consists mainly of eight (8) geological units, which include the Quaternary Alluvium, Laguna, Tignoan, Madlum, Angat, Maybangain, Kinabuan, and Barenas-Baito Formations[1]as follows (Reference 39):

(a) Quaternary Alluvium (Qal)
Detrital deposits consisting mostly of silt, sand, and gravel.

(b) Laguna Formation ≈ Guadalupe Formation (Qg or GF)
Layers of thin to medium bedded fine-grained tuffs, agglomerate, volcanic breccia and associated tuffaceous sediments.

(c) Tignoan Formation (Nt or Ntf)
Agglomerate, volcanic breccia and tuff with interbedded fine sedimentary clastic rocks and volcanic flows.

(d) Madlum Formation (MF)
Upper middle and lower members, of which the upper member is fairly fossiliferous, massive or obscurely bedded limestone. While, the middle member includes the basalt and the lower clastic member is calcareous sandstone and shale with conglomerate at the base.

(e) Angat Formation (AF)
Well bedded massive limestone with siliceous layers and limy sandstone, calcareous shale, clayey sandstone, sandy limestone and conglomerate.

1 : Symbol and description for each geological unit is based on geological maps by MGB (Mines and Geosciences Bureau)

(f) Maybangain Formation ≈ Bayagas Formation (Pm)
Equivalent to Bayagas, Masungi and Kanan formations, consisting of andesitic to basaltic flows, agglomerate, volcanic breccia, lapilli and lithic tuff with intercalated sedimentary rocks composed of siltstones, shaly sandstone, conglomerate and limestone.

(g) Kinabuan Formation (Kk or KF)
Thinly interbedded silty shale and calcareous sandstone with tuffaceous and siliceous layers capped by thin beds of limestone.

(h) Barenas-Baito Formation (Kbb)
Pillow and massive basalt, red chert, red siliceous mudstone/shale and basaltic sedimentary rocks consisting mostly of sandstone and pyroclastics.

Table B2.1 summarizes the geological formations in the Project Area.

B2.2 Active Fault

The previous studies pointed out that the Project Area is situated within a zone of active tectonics represented by the Philippine Fault (Philippine Fault Zone: PFZ) and the Valley Fault system as shown in Figure B2.2. Especially, many large-scale earthquakes along the Philippine Fault were recorded in the past and the relative movement of 6 cm was observed for the period form 1991 to1993 (Reference 27). Therefore, it can be said that the Philippine Fault has a potential to cause a very high seismic activity. According to the PHILVOLCS data, several "active faults" or "assumed active faults" lie in the Project Area and some of them pass through near the proposed Agos damsite, and Tunnel No.1 constituting the upper part of the Kaliwa-Taytay Waterway (Reference 33).

In the case an active fault passes through near the proposed structure, the following two issues and problems should be solved:

(i) Seismicity caused by earthquake along active fault, and

(ii) Deformation in foundation of the structure caused by the movement of active fault.

In this Study, with regard to (i) above, the seismic analysis to estimate the seismic coefficient for the Agos Dam is carried out as described in Chapter B5 hereinafter. In relation to (ii) above, the succeeding Subsection B4.1.3 and Subsection B4.5.1 present the results of the assessment for the Agos Dam site and Tunnel No.1 route, respectively.

B3 Geological Investigation Works

B3.1 General

The following geotechnical investigations were carried out on local contract basis in this Study:

i) Core drilling : 1,700m in total

ii) Geophysical exploration

- Seismic Refraction Prospecting : 11.5 km in total
- Electric Prospecting : 5.0 km in total

iii) Laboratory test : 1 set

iv) Geomorphological analysis : 1 set

The detailed work quantities of each geological investigation investigation item are shown in Tables B3.1to B3.4.

B3.2 Core Drilling

Core drilling was carried out at 32 sites in total to clarify the geological conditions of the Agos damsite, Agos Afterbay Weir site, Kaliwa Low Dam site, Daraitan limestone area, Tunnel No.1 route and other Kaliwa-Taytay Waterway facilities' sites. The standard penetration tests (SPT), water pressure test (WPT), and temperature logging were also performed inside the selected boreholes. The following table shows the work quantities of core drilling at each of the main structure sites:

Work Quantities of Core Drilling

Site/Location	Hole No	Number of Holes	Total Length (m)
Agos Dam Site	AD-1~8	8	400
Agos Afterbay Weir Site	BD-1~3	3	100
Kaliwa Low Dam Site	KD-1~5	5	120
Daraitan limestone area	LD-1~2	2	350
Tunnel No.1 Route	TD-1~6	6	550
Other Kaliwa-Taytay Waterway Facilities	WD-1~8	8	180
Total		32	1700

The results of above tests in the boreholes are summarized in Tables B3.5 to B3.12.

B3.3 Geophysical Prospecting

(1) Seismic Refraction Prospecting

A total of seven (7) seismic prospecting was conducted along the Agos Dam axes, Agos spillway, Kaliwa Low Dam axis and Tunnel No.1 route, and at the proposed Morong water treatment plant (WTP) site in order to clarify the geological conditions as summarized below:

Quantities of Seismic Prospecting

Site/Location	Line No.	Number of Lines	Total Length (m)
Agos Dam Site	AS-1~3	3	4,500
Kaliwa Low Dam Site	KS-1	1	600
Tunnel No.1 Route	TS-1~2	2	5,000
Morong Water Treatment Plant	WS-1	1	1,400
Total		7	11,500

(2) Electric Prospecting (two-dimensional resistivity profiling)

The electric prospecting of 5 km in total length was carried out to confirm the continuity of the Daraitan limestone mass toward south applying the two-dimensional resistivity profiling method.

The results of the above geophysical explorations are presented in Volume VI: Data Book.

B3.4 Laboratory Tests

Laboratory tests were conducted to clarify physical and engineering properties of construction materials, i.e. rockfill material, concrete aggregates and filter materials, and earth materials that will be used for construction of the Agos Dam, Kaliwa Low Dam and Kaliwa-Taytay Waterway Structures. The rock samples for the laboratory tests were obtained from drilled cores and outcrops, while soil, sand and gravel were sampled from a total of 35 test pits. The results of the laboratory tests are also utilized to assess the geological conditions of foundations at the aforesaid main structures sites.

The laboratory test results are compiled in Volume VI: Data Book.

B3.5 Morphological Analysis

The morphological analysis is carried out through the interpretation and analysis of aerial and satellite photographs taken at several different times, and literature searching. The purpose of the morphological analysis is as follows:

i) To confirm the location and certainty of active faults in the area of 10 km in radius around the Agos damsite.

ii) Identification of the landslide blocks around the Agos damsite.

iii) Assessment of the history of geomorphological development on Infanta Peninsula.

B4 Geology of Project Sites

B4.1 Agos Dam Site

B4.1.1 General

The Agos damsite is located about 1km downstream of the junction of the Kanan and Kaliwa Rivers or about 15 km distant from the Agos River mouth. The comparatively steep topographic features are formed over the 8 km downstream stretch of the proposed Agos damsite. The rocks at the Agos damsite consist of the Maybangain Formation and Tignoan Formation of early to middle stage in the Palaeogene period. The geology of the Agos damsite is characterized by the active Philippine Fault (Infanta Fault), which extends in the N-S direction and passes 7 to 8 km east of the Agos damsite. According to the historical earthquake records, many large-scale earthquakes have taken place along the Philippine Fault up to now.

The both banks at the Agos damsite are sloped with angles of 20-25 degrees as a whole, along which several narrow gullies with seasonal streamflow are observed. The riverbed elevation at the Agos damsite is 40 m and the river gradient thereat is approximately 1/300.

In the Master Plan Study stage in 2001, the following four (4) issues were pointed out for the Agos damsite originally proposed by the 1981 JICA study (Reference 5):

i) Thick river deposit in the riverbed
ii) Thick residual soil or decomposed rock zone on the right abutment
iii) Fault in the riverbed and on the right bank
iv) Assumed active fault along the Kanan River that is indicated by PHILVOLCS

In this Study, the alternative damsite was selected 700 m downstream from the original damsite taking into account the above issues. In the Feasibility Study stage in 2002, the geotechnical investigations including core drilling, seismic prospecting, laboratory test and interpretation of aerial photographs were performed for both upstream and downstream Agos damsites.

Figures B4.1 to B4.6 show the locations of the geological investigation performed in the Feasibility Study stage, as well as the geological conditions of the Agos damsites clarified through the geological investigation.

B4.1.2 Geological Condition

The base rock of the both damsites consists of sandstone and conglomerate in the Palaeogene period. The “sandstone” was referred to as “greywacke” in the previous 1981 JICA report.

The grain sizes of sandstone are generally medium to coarse. The conglomerate consists of sandy matrix and gravel of 0.5 to 5 cm in diameter. The rocks are mostly stiff and massive with a little bedding plane except for the parts intercalated by thin layers of fine sandstone and shale. The bedding planes show N15-55° E in strike with dip of 35-45° SE. Joints have two (2) trends such as N10-30° E and N65-80° W in strike with high dip of 70-90° . Most of the joint surface is oxidized at and above the groundwater level, indicating brownish color.

The talus deposits composed of rock fragments and creeped residual soil are formed at the foot of the bank slopes along the Agos River.

The Agos River deposits consisting of sand and gravel have a thickness of 30 to 40 m along both upstream and downstream dam axes. From the topographic and geographical points of view, it appeared that depth of deposit was too thick as compared with the river width of some 120 m. Hence, the geological investigation in the Feasibility Study Stage also focussed on the clarification of the deep river deposit at the Agos damsite.

Figure B4.3 shows a geological map of the Agos damsite.

B4.1.3 Engineering Geology

(a) Assumed active fault along the Kanan River by PHILVOLCS

According to the PHILVOLCS data, there exist several "active faults" or "assumed active faults" in the Project Area and some of them pass through near the Agos damsite (Reference 33).

In the case an active fault passes through near the proposed Agos damsite, the two issues are conceivable as discussed in the foregoing Subsection B2.2. In this Study, therefore, an analysis on the seismic activity was carried out through the interpretation of aerial photographs to confirm the distribution and certainty of the suspected active faults near the Agos damsite. The photographic analysis was carried out through the assessment of lineament and topographical features of the Quaternary formations in the area of 10 km in radius around the Agos damsite. The certainty of active fault is classified into three categories of Class I, II, III. The Class I means the high certainty, while the Class III indicates the low certainty for the active fault in the Japanese standard.

According to the data of PHILVOLCS, the "assumed active fault" runs 500 m upstream from Agos Dam axis, almost in parallel to the Kanan River as indicated as "F6" in Figure B4.1.

As a result, however, the "F6" fault is classified as Class III in which no specific factors suspecting as active fault were found in the aerial photo interpretation. The "F6" is assessed to be an alignment by old fault based on the field reconnaissance. Therefore, it can be said that "active fault that needs careful attention" does not exist near the Agos damsite.

Meanwhile, the Agos damsite is located only 7-8 km distant from the active Philippine Fault Zone (Infanta Fault) and large earthquakes have been recorded in the 17th to19th century around the Agos area. The photographic analysis classifies the Infanta Fault into Class I and other two (2) faults near the Infanta Fault into Class II. In the design of Agos Dam and its appurtenant structures, therefore, high seismic risk should be taken into account as described in the succeeding Chapter B5.

(b) Foundation Rock

Classification of rock type in the project area is shown in Table B4.2. The base rocks of both upstream and downstream damsites consist mainly of firm and impermeable sandstone and conglomerate. The fresh rocks of the foundations of both damsites seem to have enough shear strength to support the proposed fill type dam (CFRD) according to the results of the laboratory tests as shown in the following table:

Results of Rock Tests for Foundation Rock of Agos Dam

Rock Type (Fresh Part)	Unconfined Compression Test	Triaxial Compression Test	
	Compressive Strength (MPa)	Cohesion (MPa)	Friction Angle (degree)
Sandstone	50-60	6.4-6.8	46-48
Conglomerate	-	7.1-7.3	47-48

The above laboratory tests were carried out using specimens taken from the boring cores drilled in this Study. It is recommended that the in-situ shear strength test be performed in the next detailed design stage.

The Agos Dam designed of CFRD is founded on the fresh rock over one third of the dam base including the plinth. Therefore, the decomposed rock, residual soil zone and cracky weathered rock zone need to be excavated, because they have medium to high permeability and low shear strength as shown in Figures B4.4 and B4.5. In addition, the foundation treatment needs to be performed by consolidation and curtain grouting for the plinth which is founded on the fresh rock zone of more than 5 Lugeon value as shown in Figure 4.6.

(c) Thick Sand and Gravel Layer of Riverbed

In this Study, core drilling and seismic prospecting were carried out to confirm the thickness of riverbed deposit. As a result, it is clarified that the river deposit of sand and gravel has a thickness of 30 to 40 m concerning both upstream and downstream sites of Agos Dam as shown in Figures B4.4 and B4.5.

The thick layer of river deposit emerges as the low velocity zone in the profile as a result of the seismic exploration. Moreover, it is confirmed that the depth of river deposit is 36.50m in Borehole No.AD-2 and is 38.50m in Borehole No.AD-6.

From the topographic and geographical points of view, the depth of the river deposit seemed too thick as compared with the river width of some 120 m as mentioned above. The large thickness of the river deposit, however, can be explained by the marine transgression according to the results of the geomorphological analysis.

About 20,000 years ago, the sea level was assumed to be more than 100 m below the present level and the V-shaped valley was formed along the Ago River. The valley might be filled by the thick sand and gravel after the glacial period.

The river deposit is composed of medium to coarse sand and round-shaped gravel. The diameter of gravel is 1 to 30 cm on the average and 70 to 100 cm on the maximum. Although the deposit seems to have enough bearing capacity as a foundation of a fill dam, it shows high permeability. Some water-tight measure is required at the foundation of impermeable zone in case the deposit is not be removed from the foundation.

(d) Potential Landslide on the Abutments

On the right abutment of the upstream damsite, the residual soil and decomposed rock zones are 20 to 30 m thick in the area below EL.120 m. On the other side, the 10 to 20 m thick zones are identified on the left abutment. These weathered zones consisting of talus and terrace deposits, which are formed at the foot of the bank slopes, need to be excavated during the dam construction as shown in Figures B4.4 and B4.5.

Such a thick weathered layer is possibly caused by existence of landslide. According to the analysis of aerial photographs, several potential landslide blocks are observed at and around the Agos damsites as shown in Figure B4.3. Especially, the potential landslide blocks distribute on both banks of the upstream damsite. On the other hand, there seem to be no factors showing the slope instability except for only one unclear landslide block along the downstream dam axis.

In case of the upstream damsite, most of potential landslide blocks will be excavated and removed during the construction of the Agos main dam and spillway. The remaining volume of potential landslide blocks is estimated at about 980,000 m^3. The excavation works need to be performed paying enough attention to the stability of the potential landslide areas during the construction.

(e) Distribution of Fault

There exist six (6) low velocity zones in the base rocks of the damsites that are clarified through the seismic exploration. The five (5) of them may be faults extending in the E-W direction as shown in Figures B4.3 to B4.5. The faults running in the E-W direction will not cause much problems for the stability of the proposed Agos Dam, since they cross with the dam axis at a right angle.

The replacement of and grouting works for the fractured zones, however, will be required to prevent the water from leaking from upstream side to downstream side beneath the Agos Dam body.

Out of the five (5) suspected faults, the only one located in the middle part of the right abutment could be investigated by the core drilling (Borehole No.AD-3) conducted in this Study. Therefore, core drilling will have to be performed at other four (4) suspected faults in the next detailed design stage in order to clarify such characteristics thereof as permeability and extents of the fractured zones.

(f) Comparison of Upstream and Downstream Damsites

The upstream damsite or dam axis is recommended as the Agos damsite from the following geological aspects and layout of the Agos Dam and its appurtenant structures:

i) It is considered that both upstream and downstream damsites have almost same conditions concerning the thickness of riverbed deposit, shear strength of base rock and existence of faults.

ii) In case of the downstream site, on the other hand, most of the potential landslide blocks identified at and around the Agos damsite will be impounded by the Agos Reservoir to be created. The cost of the treatment works to stabilize the potential landslide areas is estimated to be much higher than that of the upstream site.

iii) The left bank of the downstream damsite is formed by a narrow ridge, which seems to indicate a large hydraulic gradient.

iv) Cost comparison study separately conducted (See Volume IV) has revealed that the construction of dam at the downstream axis is more costly than the upstream site.

B4.2 Agos Reservoir Area

B4.2.1 General

The Agos damsite is located just downstream of the junction of the Kanan and Kaliwa Rivers, about 15 km distant from the Agos River mouth. The Agos Reservoir whose full supply level (FSL) is optimized at EL.159 m as discussed in Chapter VI of Volume IV extends about 12 km upstream along the Kanan River course and about 15 km upstream along the Kaliwa River course by the air distance. Situated in the deep narrow gorges, the Agos Reservoir area is surrounded by the high ridges. It seems that there are several potential landslide blocks on the abutments of the reservoir area as a result of the preliminary interpretaion of the aerial photographs for the reservoir area. Geologically, the reservoir area is composed mostly of sandstone, conglomerate, shale, and pyroclastic rock which belong to the Maybangain and Tignoan Formations in the age of Cretaceous to Miocene (Reference 39). The fresh parts of the rocks are generally firm and impervious.

B4.2.2 Watertightness of Daraitan Limestone Mass

The most important geological concern on the Agos Reservoir area is the Daraitan limestone mass with a width of 1.5 to 2.0 km that is situated on the Kaliwa River, forming the upstream part of the reservoir area. The Daraitan limestone mass distributes in the N-S direction. As for the Agos Reservoir area, the previous studies focused on the possibility of water leakage toward south through the solution cavities in the limestone area. In the site reconnaissance performed in the course of this Study, many cavities, holes, and water-spring points were identified in the Daraitan limestone area. This indicates the possibility of existence of many natural water routes inside the limestone mass.

In this Study, two pieces of core drilling of 350 m in total length and electric prospecting of 5 km in total length were carried out to confirm the continuity of the Daraitan limestone mass toward south. The two-dimensional resistivity profiling method was adopted in the electric exploration.

The distribution of the Daraitan limestone body is presented in Figure B4.7. Figure B4.8 shows the profile of the Daraitan limestone mass clarified on the basis of the results of the electric prospecting. The limestone emerges as the zone which has more than 300 Chm-m in the resistivity as shown in Figure B4.8.

It is judged that the water leakage from the limestone mass is negligible based on the result of the above geological investigation and concurrent discharge measurement on the Kaliwa River as mentioned below:

i) The loss of water through the fault zone or limestone in the northerly direction is physically impossible.

ii) The permeable limestone mass wedges out to the south before the Makmira village at the 3 km southern point from the Kaliwa River as shown in Figures B4.7 and B4.8. The other impervious beds seem to distribute between the Makmira village and Laguna Bay, preventing water losses from taking place in the direction.

iii) No loss of the Kaliwa River water in the sections of limestone area was observed according to the results of the concurrent discharge measurement on the Kaliwa River as explained in Section 4.3 of Volume IV.

iv) Groundwater level seems to be shallow around the Makmira to Santiago village area, judging from the existence of many small streams and the distribution of impervious bed rocks.

B4.2.3 Potential Landslide Blocks in Reservoir Area

According to the results of the analysis utilizing the aerial photographs at 1:50,000 scale, some potential landslide blocks are preliminarily identified in the Agos Reservoir area in addition to those at and around the the Agos damsite as mentioned above. Figure B4.9 shows the distribution of the suspected landslide areas. The potential landslide areas in the entire Agos Reservoir area need to be investigated in the next detailed design stage in order to clarify the stability and volume of the landslide blocks in more detail.

B4.2.4 Assessment of Reservoir Induced Seismicity (RIS)

The assessment of reservoir induced seismicity (RIS) is still under study in the world. However, it is reported that the possibility of occurrence of RIS is few in the small reservoir and also in the reservoir area where mainly reverse and/or thrust faults distribute.

In case of the Agos Reservoir, the volume of water storage is as large as 880 millions m^3. In addition, there is no evidence that all faults in the reservoir area are reverse and/or thrust faults. Therefore, it can not be said that there would be no possibility of RIS in impounding the Agos Reservoir.

However, concern for RIS is not considered to be a decisive factor for denying the dam construction. It is recommended to install an accelerometer at several sites in the damsite and reservoir area in the next detailed design in order to monitor the local seismic activity for some years before and after impoundment of the reservoir.

Anyway, the occurrence of RIS depends largely on whether the active fault exists in the reservoir area. In the Feasibility Study, no active fault was observed in the area of 10 km in radius around the Agos damsite as a result of interpretation of aerial photographs. In the next detailed design stage, it is recommended to carry out the same investigation for the entire reservoir area, paying the special attention to the "assumed active fault" indicated by PHILVOLCS at the location of 12 km upstream from the Agos damsite along the Kaliwa River as shown in Figure B4.2. In the next detailed design, in addition, it is recommended to examine the records of RIS at existing damsites in the world which have the similar tectonic conditions to that of the Agos damsite.

B4.3 Agos Afterbay Weir Site Initially Planned

B4.3.1 General

The 1981 JICA study examined the construction of a floating type weir on the Agos mainstream at the location of about 6 km downstream of the Agos Dam site, where the river width is some 260 m (Reference 5). In this Study, the new Afterbay Weir site was initially planned for field investigation at a point of 600 m upstream from the former from a view point of the river morphology (flushing of sediments). Three (3) core drillings of 100 m in total length including Standard Penetration Test (SPT) and Water Pressure Test (WPT) were conducted along the weir axis.

B4.3.2 Geological Condition

The base rock of the Agos Afterbay Weir site is composed of stiff conglomerate with thin layers of sandstone which is same as the rocks distributing at the Agos damsite. The thickness of riverbed deposit along weir axis, which consists of sand and gravel, appears to be 45 m at the maximum. Figures B4.10 and B4.11 show the geological conditions of the Agos Afterbay Weir site.

B4.3.3 Engineering Geology

In this Study, a concrete weir of floating foundation type (with piles as required) was initially proposed as the weir type for the Agos Afterbay Weir. The possible leakage through the river deposit under the weir body, which is highly pervious but might not be effectively grouted, will be controlled by securing long seepage lines through the provision of apron and/or blanket. This will reduce the possibility of occurrence of piping in the foundation.

The firm rock is observed on the outcrop of left bank, where the excavation for weir foundation will be almost unnecessary. While, the weathered zone on the right bank consists of residual soil and cracky rock of 10 to 30 m in thickness. The fresh rock of the right bank seems to have the enough bearing capacity to support the proposed gate structure.

As the result of plan formulation study, however, the Agos Afterbay Weir was finally discarded from the Project components as discussed in Chapter VI of Volume IV, since the Agos powerstation is finally proposed as the semi-base load power station in the Feasibility Study.

B4.4 Kaliwa Low Dam Site

B4.4.1 General

The Kaliwa Low Dam site is located on the Kaliwa River, approximately 5 km downstream of Daraitan village, where the river bed elevation is around EL.95 m. The site is situated between the Ligundinan and Queboroso creeks, both being the right bank side tributaries of the Kaliwa River. The distribution of stiff rock forms comparatively narrow valley at the site. The both banks at the Kaliwa Low Dam site have steep slopes of 45 to 50 degrees on the average except for the gentle slopes of 20 degrees formed above EL. 120m on the right bank. The width of riverbed is 30 to 35 m at the Kaliwa Low Dam site.

The seismic exploration of 0.6 km in length and three (3) holes of core drilling of 60 m in total length were carried out along the proposed Kaliwa Low Dam axis. In addition, other two (2) holes of core drilling of 100 m in total length were performed at the Kaliwa Intake Structure site and near the Tunnel No.1 portal. Figure B4.12 shows the location of the geological investigation sites, as well as the geological conditions of the Kaliwa Low Dam site clarified through the geological investigation.

B4.4.2 Geological Condition

The base rock of the Kaliwa Low Dam site consists mainly of alternate layers of conglomerate, sandstone and shale of several cm to 1 m in thickness. The rocks belong to the Maibangain Formation of the early Palaeogene period. The conglomerate consists of sandy matrix and gravel of 0.5 to 5 cm in diameter. As for the upper weathered layer of conglomerate, the matrix part is of less strength as compared with the hard gravel part. The fine to coarse grains form sandstone in which clear graded bedding is observed frequently. Bedding planes show N20-35° E in strike with 60-80° SE of dip. Joints tends to have N40-45° W in strike with 60-90° of dip. The thickness of riverbed deposit consisting of sand and gravel is thin at 1 to 2 m. Figures B4.12 and B4.13 show the geological conditions of the Kaliwa Low Dam Site.

B4.4.3 Engineering Geology

Most of the fresh part of foundation rock at the Kaliwa Low Dam site is stiff and massive with enough shear strength and low permeability. The geological condition is suitable for construction of the proposed fill type dam. Most of foundation rock along the Kaliwa Low Dam axis indicates the low Lugeon value of less than 5.

It is confirmed that the weathered bedrock is deeper on the right bank where the slope is gentler than on the left bank as mentioned above. Especially on the right abutment, the cracky weathered zone of approximately 5 m thickness needs to be excavated in the construction.

The Kaliwa Intake Structure is proposed on the right bank of the Kaliwa Low Dam site. The base rock is same as that along the Kaliwa Low Dam axis and has enough bearing capacity for the proposed intake structure. The weathered cracky surface zone at the Kaliwa Intake Structure site seems to be comparatively thin at 5 to 10 m in thickness and needs to be excavated in the construction.

During the site reconnaissance conducted during the Study, a confined hot spring was found at a point of about 600m upstream from the Kaliwa Low Dam site. The spring water temperature was about 40 to 50 degrees without taste and smell. The water quality analysis carried out under the Study indicates the contents of sulfates and chlorides, but these values are below the allowable standard values of the Philippine National Standard for Drinking Water (1993). From the regional geologic point of view, there is no sign of active volcanic belt or new plutonic rock. Hence, the source mechanism of the hot spring is not clear. In any case, the hot spring seems to have some relation with the lineament such as fault.

In this Study, the temperature logging at 1 m interval was done in each borehole drilled at the Kaliwa Low Dam site which is shown in Table B3.12. As a result, geothermal gradient shows the normal condition and there is no sign of hot water in any boreholes. However, an attention needs to be paid to inflow of confined hot water during the construction, especially during the tunnel excavation.

B4.5 Waterway Tunnel

B4.5.1 Tunnel No.1

In the early stage of the Feasibility Study, the Tunnel No.1 route was initially planned to be laid out to connect the Kaliwa Intake Structure located on the right bank of the Kaliwa Low Dam site and Lagundi powerhouse. However, this tunnel alignment was changed to the new one from the viewpoint that the initial tunnel route has a possibility to encounter an active fault designated by PHILVOLCS (2000) in the section of 22.7 to 24.2 km from the Kaliwa Intake Structure site.

On the other hand, the Tunnel No.1 finally selected in this Study is laid out to connect the Kaliwa Intake Structure and Valve House No.1 to be provided just upstream of the Morong water treatment plant (WTP). The total length of the Tunnel No.1 along the new route is about 27.5 km.

Figures B4.14 to B4.16 show the location of the geological investigation for the Tunnel No.1 as well as the geological conditions thereof clarified through the geological investigation.

The finally proposed tunnel route is geologically assessed as follows:

i) Since the Tunnel No.1 is aligned along the mountain ridges, there will be no particular problem on ground cover and unbalanced ground pressure.

ii) The Tunnel No.1 will pass through the relatively homogeneous and hard geological layers such as shale, sandstone, conglomerate and tuff breccia of the Cretaceous to Old Tertiary period. Thus, it would not encounter the Quarternary layers. According to the results of the laboratory tests in this Study, the unconfined compressive strength of fresh foundation rock was estimated at 40-55 MPa (410-570 kgf/cm2). Accordingly, the tunneling by TBM will be effective. However, the unconfined compressive strength of

40-55 MPa was derived from the core pieces sampled on the tunnel route. In consideration of the data obtained in the previous studies (Reference 5 and Reference 10) and the existence of velocity layer of 5.0 to 5.2 km/sec in seismic prospecting performed in this Study, some parts of foundation rocks seem to have larger unconfined compressive strength of more than 50-70 Mpa (510-710 kgf/cm2).

iii) The Kaliwa Intake Structure is proposed on the right bank of the Kaliwa Low Dam site. The base rock has enough bearing capacity to support the proposed intake structure. The weathered cracky surface zone at the Kaliwa Intake Structure site seems to be comparatively thin at 5 to 10 m in thickness or less than that.

iv) In the 0-3.0 km section from the Kaliwa Intake Structure, it should be paid enough attention to the unexpected fault with inflow of confined hot water as described in the foregoing Subsection B4.4.3. The confined hot spring was identified at a point of about 600 m upstream from the Kaliwa Low Dam site. The spring seems to have some relation with the lineaments in the 0-3.0 km section of Tunnel No.1 route. Especially at around 1.3 km point, there is an assumed active fault indicated by PHILVOLCS (2000).

v) In the tunnel sections composed of the fault-fracture zones and limestone sections, the tunnel construction may encounter the difficulties due to the excessive water seepage and unstable ground.

There may be several faults on the Tunnel No.1 route as long as the results of seismic exploration and geological map designated by MGB (Mines and Geosciences Bureau) show.

In the 17.5-22.0 km section, the large Masunguit limestone body is chopped up on the surface. The bottom elevation of the limestone mass seems to be higher than EL. 200m, which is approximately 100m higher than the level of tunnel route.

In the next detail design stage, it is recommended to confirm the distribution of limestone in more detail. Concrete lining will be prerequisite in the limestone sections if encountered.

vi) The Tunnel No.1 will encounter the “assumed active fault” designated by PHILVOLCS (2000) at 25.0 km point from the Kaliwa Intake Structure. This fault can be identified clearly with interpretation of satellite imagery (Reference 41). Therefore, the tunnel alignment was laid out to cross with the “assumed active fault” at a right angle to minimize the distance affected thereby. NATM should be planned for the sections upstream of the fault.

According to the observation of core sample in Borehole No.TD-4 drilled at the fault zone, it is considered that the permeable zone is formed to the depth where the Tunnel No.1 is to pass. Therefore, a large water inflow may take place during the tunnel excavation at around 25.0 km point from the Kaliwa Intake Structure site.

vii) The base rock of tunnel outlet is composed of tuff breccia at the old age. The thickness of surface weathered layer consisting of decomposed or cracky rock and/or consolidated sediments is approximately 15 to 20 m. There seems to be no landslide area at the Tunnel No.1 portal area.

B4.5.2 Tunnel No.2

The Tunnel No.2 is laid out through the Antipolo plateau to reach the Taytay Service Reservoir. The total length is about 5.3 km. In this Study, two (2) holes of core drilling of 60 m in total length was conducted at the inlet and outlet portal sites of the Tunnel No.2. The proposed tunnel route is geologically evaluated as follows:

i) Most parts of the tunnel route seem to be composed of hard and impervious rocks which belong to the Kinabuan Formation of the Cretaceous-Old Tertiary period.

ii) While, the limestone mass distribute in the section of 0-0.7 km from the upstream tunnel portal for which concrete lining will be essential. In the 0-0.2 km section, notably, the tunnel passes through near the boundary between the soft Quaternary sediments and limestone. Therefore, it should be paid enough attention to the stability of tunnel foundation during and after the tunnel excavation.

iii) In the 1.3-3.3 km section, there is a potentiality that the tunneling encounters the Guadalupe Formation instead of the Kinabuan Formation. The Guadalupe Formation is composed of complex mixture of such various materials as soil, soft rock and hard rock. The lowest layer of the Guadalupe Formation is confined aquifer which is source of water for the wells in the Antipolo plateau. The head of water may exist in the zones of around 150 to 170 m in elevation according to the previous report (Reference 17). The subsurface investigation is required in the next detailed design stage.

iii) Faults exist at 0.3 km, 0.7 km and 3.6 km points. In the fault-fracture zones, the tunnel excavation may encounter the difficulties due to the excessive water seepage and unstable ground.

iv) The massive, firm and stable rock mass of basalt distributes at upstream portal site of the Tunnel No.2. There is no landslide area thereat.

Figure B4.17 shows a geological profile along the Tunnel No.2 route that is worked out based mainly on the geological map presented by the said 1992 JICA study report.

B4.6 Waterway Facilities

B4.6.1 Valve House No.1

The proposed Valve House No.1 site is situated in the adjacent area to the Morong water treatment plant (WTP) site. In the early stage of the Feasibility Study, any geological survey had not been planned for the new structure, since the Valve House No.1 has been newly proposed in the course of the Feasibility Study instead of the Lagundi powerhouse. Hence, the geological conditions of the Valve House No.1 are assessed based on the results of the geological investigation performed for the nearby structures such as the Morong WTP site and Lagundi powerhouse site.

From the results of the geological investigation for the Morong WTP site, the surface layer of several meters in thickness seems to consist of overburden material such as plastic clay. The bed rock line seems to emerge at around 5 to10 m depth below the ground surface, although the weathered rock distributes above the bed rock line. The bed rock and weathered rock zones seem to have enough bearing capacity to support the proposed structure. The blasting or ripping will be required to excavate the the rock zone which seems to consist of tuff breccia of the Tertiary formation.

B4.6.2 Morong Water Treatment Plant

A total of 1500 m x 650 m net plant compound area will be developed to provide the Morong water treatment plant (WTP) through excavation and embankment works. One (1) line of seismic exploration of 1.4 km in length and two (2) holes of core drilling of 40 m in total length were carried out at the proposed Morong WTP site.

The site is located in gentle-hilly area formed mostly by the Quaternary deposits. These deposits belong to the Guadalupe Formation mainly composed of alternate layers of tuffaceous sandstone and tuff breccia and are generally of compacted layers except for the extremely weathered part near the surface. The fresh part of the sediment layers have the enough bearing capacity to support the proposed structure. The excavation by blasting will be necessary at the hill side in the southern part of the Morong WTP site because of the existence of hard basalt mass, while most of the other areas will be able to be excavated by bulldozer with blading and ripping.

On the other hand, the ground is suitable as the basement for embankment except for the soft alluvial deposit distributing in northern part of the Morong WTP site.

Figure B4.18 shows the location of geological investigation performed for the Morong WTP. The geological profiles worked out based on the results of the geological investigation are presented in Figure B4.23.

B4.6.3 Lagundi Power House Initially Planned

The initially planned powerhouse site is situated on the area near a small creek. One (1) borehole of 20m in length was drilled, although the strcuture was finally discarded from the Project components and the Valve House No.1 is proposed to be provided instead of the Lagundi powerhouse.

At the Lagundi powerhouse site, the 3 m thick surface layer consists of such overburden materials as plastic clay. The bed rock line emerges at around 15 m depth below the surface, although thick decomposed rock of 50 in N-value distribute above the bed rock line. The bed rock and most of the decomposed zone seem to have enough bearing capacity to support the Lagundi powerhouse. The ripping or blasting will be required for excavation of the fresh bed rock which consists of alternate layers of shale, sandstone and conglomerate of the Cretaceous-early Paleocene Formation.

The location of the geological investigation is shown in Figure B4.19. Figure B4.24 presents the geological profiles at the Lagundi powerhouse site.

B4.6.4 Valve House No.2

The Valve House No.2 is proposed at the low flat area formed by alluvial deposits such as soft clay, silt or sand. The surface alluvial deposits have the thickness of 5 to 10 m and pile works are recommended as the foundation of the proposed structure.

B4.6.5 Antipolo Pump Station

The structure is designed to have a space of 150 m x 120 m in the gentle hilly area. One (1) core drilling was carried out at the Antipolo Pump Station site as shown in Figure B4.20. The ground consists mainly of compacted gravelly sand which is the weathered part of volcanic sediment and tuffaceous sandstone of the Pleistocene Formation. The 4 m thick surface layer consists of soft plastic clay as the overburden. The ground below the surface overburden has enough bearing capacity of around 37-50 in N-value (see Figure B4.24).

On the other hand, a small portion of the Antipolo Pump Station site seems to be located in the low flat area near a creek. Pile works will be required in case main structure will have to be founded on the flat alluvial area.

B4.6.6 Antipolo Service Reservoir

The Antipolo Service Reservoir is situated on the top of hill, requiring a space of 600 m x 110 m as shown in Figure B4.21. The basement is composed of the extremely weathered pyroclastic sediments. According to the results of core drilling, the soft overburden layer distributes at the depth of 0 to 0.8 m. At the depth of 5 to 20 m, the extremely weathered tuff breccia emerges, which has a N value of 50 as shown in Figure B4.25. For excavation of the planned reservoir, dozing and ripping by bulldozer are deemed to be suitable.

B4.6.7 Taytay Service Reservoir

The embankment works are required to construct the Taytay Service Reservoir with a total space of 780 m x 290 as shown in Figure B4.22. The site is located around the boundary between gentle-hilly area and a little steep-hilly area near the developed residential area. The excavation portion consisting mostly of the weathered rock belongs to the Kinabuan Formation of the Cretaceous-early Paleocene. According to the results of core drilling, the alternate layers of sandstone and shale distribute in the gentle-hilly area, while the very firm basalt exists in the steep-hilly area. The bedrock line emerges at around 10 to 15 m depth below the surface on the average, although the thick extremely weathered rock of 50 in N-value distributes above the bed rock line as shown in Figure B4.25.

The excavation will be conducted by ripper, while blasting will also be necessary in case of excavation in the fresh rock zone.

B4.6.8 Pipeline

A total of 9.3 km long pipeline routes is planned to connect between the Morong WTP and Valve House No.2 and between the Valve House No.2 and Antipolo Service Reservoir. While 63 % of the pipeline route passes through the gentle-hilly area, the remaining 37 % is aligned in the low-flat area. The low-flat area seems to be composed of soft clay, silt or sand materials. During the construction, excavation with sheet-piling is recommended for latter 37 % of the pipeline route. In the next detailed design stage, the ground condition along the pipeline routes needs to be clarified through the subsurface investigation such as the Swedish sounding and/or hand-auger boring, etc.

B5 Seismicity

B5.1 General

The previous studies pointed out that the Project Area is situated within a zone of active tectonics represented by the Philippine Fault (Philippine Fault Zone: PFZ) and the Valley Fault system as shown in Figure B2.2. According to the previous studies, it is considered that most of the proposed five damsites: i.e. Laiban, Agos, Kanan B1, Kanan No.1 and Kanan No.2 would be subject to high peak acceleration and exposed to generally high degree of seismicity.

Especially in the areas along the Philippine Fault, many large-scale earthquakes were recorded in the past and the relative movement of 6 cm was observed for the period from 1991 to 1993. The various reports and aerial photo interpretation describe that the Philippine Fault indicates the left-lateral movement.

The Agos damsite is located only 7 to 8 km distant from the active Philippine Fault as shown in Figure B4.1 and large earthquakes in the areas have been recorded. The 1981 JICA study and 1991 ELC study indicate 0.58 g as the peak acceleration and 0.15~0.20 g as the horizontal earthquake coefficient for the design of the Agos Dam. In this Study, the earthquake analysis is carried out on the basis of the earthquake records for the period from 1907 to 2000.

B5.2 Study of Seismic Coefficient for Agos Dam

In this Study, the recent earthquake records in and around the Agos Dam site which satisfy the following conditions were collected from PHILVOLCS (Philippine Institute of Volcanology and Seismology).

Period	: 1907-2001
Magnitude	: More than M5 in Richter scale
Epicenter	: Within 500 km distance from the Agos damsite

The collected earthquake data are shown in Tables B5.1 to 5.3. Figure B5.1 presents a distribution map of the significant earthquake records around the Agos Dam site.

The equations used for the earthquake analysis are as follows:

<u>Kawasumi's formula</u>

$$Ij = Mk - 0.00183(d - 100) - 4.605 \log(d/100) \quad \text{(when } d>=100\text{km)} \quad \cdots(1)$$

$$Ij = Mk + 4.605 \log(Do/D) + 2k(D - Do) \log(e) \quad \text{(when } d<100\text{km)} \quad \cdots(2)$$

Where;
- Ij : Intensity in JMA (Japan Meteorological Agency) scale
- Mk : Magnitude in Kawasumi's scale*
  - * JMA intensity at the distance of 100 km from the epicenter (Magnitude in Richter scale M = 4.85 + 0.5 Mk)
- d : Distance from the epicenter (km)
- D : Distance from the focus (km)

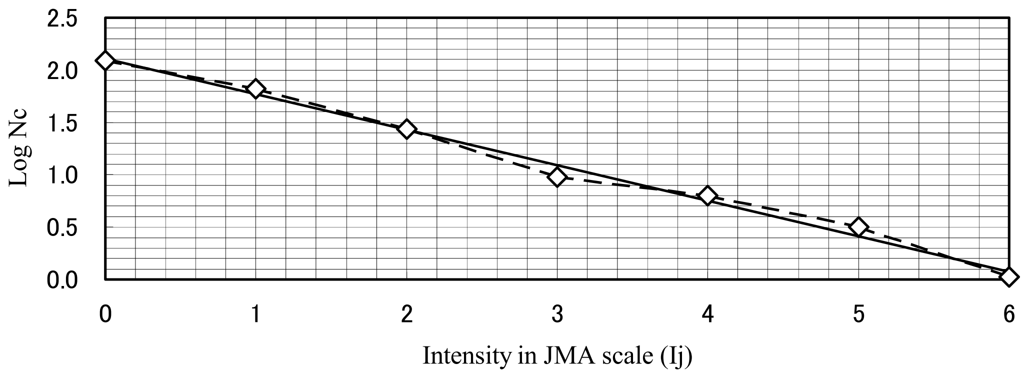
Do : Distance from the focus to the point of d=100km

K : Damping rate of S-wave (0.0192/km)

The frequency of earthquakes in each grade of the JMA intensity for 95 years from 1907 to 2001 is converted into the frequency in 100 years. From the relation between the intensity (Ij) and cumulative number of frequency (Nc), the probable maximum intensity and probable maximum acceleration in a return period of 100 years are obtained.

Earthquake Intensity and Frequency of Collected Data

Intensity (Ij)	Frequency in 95 years	Frequency in 100 years	Cumulative number for 100 years (Nc)
0 (less than 0.6)	54	56.84	123.16
1 (0.6-1.5)	37	38.95	66.32
2 (1.6-2.5)	17	17.89	27.37
3 (2.6-3.5)	3	3.16	9.47
4 (3.6-4.5)	3	3.16	6.32
5 (4.6-5.5)	2	2.11	3.16
6 (5.6-6.5)	1	1.05	1.05
Total	117	123.16	



Relation between Intensity (Ij) and Frequency (Nc)

In case the minimum square method is applied, the relation between Ij and Nc is derived as shown below:

$$\log Nc = 2.110 - 0.339 \cdot Ij$$

In case of Nc=1, the probable maximum intensity in a return period of 100 years is obtained to be Ij = 6.2.

According to Dr. Kawasumi, the relation between the intensity Ij and the maximum acceleration α of the earthquake motion is very closely approximated by the following relation:

$$\alpha = 0.45 \times 10^{0.51Ij} \quad \text{(gal)}$$

Accordingly, the probable maximum acceleration in a return period of 100 years is derived to be 566gal or 0.58g.

Practically, such a large value is not taken for design, because the maximum acceleration of the earthquake motion will act only for a fraction of a second so that it cannot cause such significant deformation in case it is considered as a lasting static force. For fill type dam in the strong earthquake region in Japan, 0.15g is recommended as the design seismic coefficient.

In consideration of the similarity of tectnic and seismic situation between the Philippines and Japan, the design value for the ground seismicity coefficient is recommended to be 0.15 to 0.2g.

In the next detailed design stage, however, a dynamic analysis is required to be carried out to confirm the stability of the Agos Dam against large-scale earthquake.

B6 Construction Materials

B6.1 General

In the initial part of the Feasibility Study, the borrow site and/or quarry sites were identified at the locations adjacent to the main structures such as the Agos Dam, Kaliwa Low Dam, Morong WTP and Taytay Service Reservoir. The geological investigation works consisting of core drilling, test pitting and field reconnaissance were carried out to confirm the conditions of the borrow and quarry sites from the qualitative and quantitative aspects.

In addition, the laboratory tests were conducted to confirm the physical and engineering properties of construction materials, i.e. rockfill material, concrete aggregates/filter material and earth materials, which will be used for construction of the main structures. The rock samples for the laboratory tests were obtained from the drilled cores and outcrops, while soil, sand and gravel were sampled from 35 test pits. Tables B6.2 to B6.10 summarize the results of the laboratory tests.

B6.2 Agos Dam

Table B6.1 shows the necessary volume of construction materials and recommended sources for the Agos Dam. The quarry and borrow sites identified for the Agos Dam are shown in Figure B6.1.

The Agos quarry site from which rock materials are to be obtained is selected just upstream of the confluence of the Kaliwa and Kanan Rivers. The thickness of upper weathered layer at the quarry site is estimated to be 5 to 10 m and partially less than 5m based on the results of the geological investigation. The base rock consists of stiff sandstone which has enough specific gravity and compressive strength required for both of rockfill material and concrete aggregates material. The excavated volume at the quarry site is estimated to be approximately 400 m in length, 250 m in width and 100m in height. It is noted that calcite veins are observed in the base rock around the southern hilly area of the Agos quarry site as long as the Borehole No.AD-8 shows. The calcite veins may indicate the existence of fractured zone. Therefore, it is recommended to carry out further investigation in the next detailed design stage in order to clarify the quality of the rock materials. Figures B6.2 and B6.3 present the geological map and profiles of the Agos quarry site.

Rock material can also be collected from the excavation of dam foundation, spillway and diversion tunnel. The fresh foundation rock consists mainly of sound sandstone and conglomerate with the unconfined compressive strength of 50-60 Mpa (510-610 kgf/cm^2), which is hard and stable enough to be used for rockfill embankment. According to the previous 1981 JICA study report, however, the unconfined compressive strength of 1160 to 1430 kgf/cm^2 was derived from the laboratory tests for the 3 core pieces sampled from nearby location of the Agos quarry site (Reference 5).

Filter and coarse aggregate materials will be acquired from the riverbed deposits at the Agos damsite and along the Agos River as shown in Figure B6.1, as well as crashed rock from the Agos quarry site. The river deposit is composed mainly of fine to coarse sand and round-shaped gravel. The gravel is stiff and stable sandstone having the similar quality to that of the base rock of the Agos Dam foundation. It is suitable for transition materials for the Agos Dam and coarse aggregate materials, although they are poorly graded with the maximum grain size of more than 75 mm in diameter.

The highly to completely weathered rock distributing in and around the Agos Dam abutments can be used for impervious fill materials. Most parts of the extremely weathered rock (residual soil) consist of silty clay with high plasticity. Therefore, the soil material needs to be mixed with gravel collected from river deposit and/or crashed rock fragments.

B6.3 Kaliwa Low Dam

At the Kaliwa Low Dam site, the construction materials such as random fill, impervious fill, riprap materials for dam body and concrete aggregates for intake structure will be required.

As the source of concrete aggregates for Kaliwa Intake Structure and Tunnel No.1 lining, the Kaliwa quarry site was selected on the left bank of the Kaliwa River, 400 to 500 m downstream from an axis of the Kaliwa Low Dam. The Kaliwa quarry site is composed of alternate layers of sandstone and conglomerate at the old age. The fresh part of base rock is firm and stable with 2.59-2.68 of specific gravity. The thickness of upper weathered layer is estimated to be less than 5 to10 m. Figures B4.12 and B4.13 present the geological condition of the Kaliwa quarry site.

The random fill and rock materials will be obtained from the excavation of the Kaliwa Intake Structure and Tunnel No.1. The rocks consist mainly of alternation of conglomerate and sandstone which are firm and stable, being same as those at the Kaliwa quarry site.

With regard to concrete aggregates, riverbed deposit at the Kaliwa Low Dam site is suitable. They consist of sand and gravel which are rounded, firm and stable, though the gradation of sand is on coarser side. Rock from the excavation of tunnel and intake, moreover, would also be suitable for concrete aggregate after crushing.

It appears that the residual soil in extremely weathered zone on the bank slopes is usable for the impervious material. In using residual soil as the impervious fill material, the soil composed of silty clay with high plasticity should be mixed with gravel taken from the riverbed and/or crashed rock fragments.

B6.4 Waterway Facilities

(1) Morong Water Treatment Plant

For preparing a large flat space required to construct the Morong WTP, soil material is required for embankment. It is adequate to use the soil material to be produced from the excavation of the weathered Quarternary deposits for the embankment. According to the test pitting and laboratory test, upper 3-m layer below the surface is generally composed of silty clay or clayey silt with high liquid limit index of more than 50 %. The soil materials in the surface layers are not suitable for embankment material due to the high moisture content as well as the insufficient trafficability during the construction. Therefore, it is recommended to blend crashed rock fragments with the silty clay and/or clayey silt. A large quantity of rock fragments can be acquired from excavation in the old tuff breccia and basalt area. The location of geological investigation for the Morong WTP is presented in Figure B4.18.

(2) Taytay Service Reservoir

The large volume of embankment works will be required for the land formation work at the Taytay Service Reservoir site due to its undulating topography.

At the construction site, thick extremely weathered rock distributes above the bed rock line emerging at 10 to 15 m depth below the surface in average. According to the laboratory test results, the extremely weathered layer consists of silty clay, which indicates high plasticity index of 62-73 % in liquid limit. The silty clay mixed with crashed rock fragments can be used for embankment material. The crushed rock fragments will be obtained from excavation in the areas composed of base rock such as sandstone, shale and basalt. Figure B4.22 shows the location of geological investigation for the Taytay Service Reservoir.

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Tables

Table B2.1 Table of Geological Formation

Time		Formation	Symbol	Explanation
Quaternary	Holocene	Quaternary Alluvium	Qal	Detrital deposits, mostly silt, sand, and gravel.
	Pleistocene	Laguna Formation ≅ Guadalupe Formation	Qg or GF	Layers of thin to medium bedded, fine-grained tuffs, agglomerate, volcamic breccia and associated tuffaceous sediments.
Tertiary	Middle Miocene	Tignoan Formation	Nt or Ntf	Agglomerate, volcanic breccia and tuff with interbedded fine sedimentary clastic rocks and volcanic flows.
		Madlum Formation	MF	Consist of upper, middle and lower members. Upper member is fairly fossiliferous, massive or obscurely bedded limestone. Middle includes the basalt. Lower clastic member is calcareous sandstone and shale with conglomerate at the base.
	Early Miocene	Angat Formation	AF	Well bedded massive limestone with siliceous layers and limy sandstone, calcareous shale, clayey sandstone, sandy limestone and conglomerate.
	Paleocene~Eocene	Maybangain Formation ≅Bayagas Formation	Pm	Equivalent to Bayabas, Masungi and Kanan formation; consists of andesitic to basaltic flows, agglomerate, volcanic breccia, lapili and lithic tuff with intercalated sedimentary rocks composed of siltstones, shaly sandstone conglomerate and limestone.
Cretaceous		Kinabuan Formation	Kk or KF	Thinly interbedded silty shale and calcereous sandstone with tuffaceous and siliceous layers capped by thin beds of limestone.
		Barenas-Baito Formation	Kbb	Pillow and massive basalt, red chert, red siliceous mudstone/shale and basaltic sedimentary rocks mostly sandstone and pyroclastics.

Table B3.1 Quantity of Core Drilling

Borehole No.	Coordinates		Collar Elev. (m)	Inclination	Depth (m)	Location
	Northing	Easting				
Agos Dam Site						
AD - 1	1,625,000	557,185	105.00	Vertical	50.00	Dam Axis, Left Bank
AD - 2	1,624,848	557,237	40.20	Vertical	70.00	Dam Axis, Riverbed
AD - 3	1,624,633	557,376	117.92	Vertical	50.00	Dam Axis, Right Bank
AD - 4	1,625,310	558,038	98.00	Vertical	50.00	Alternative DA, Left Bank
AD - 5	1,624,887	557,910	90.00	Vertical	50.00	Alternative DA, Right Bank
AD - 6	1,625,060	557,973	39.80	Vertical	70.00	Alternative DA, Riverbed
AD - 7	1,624,623	556,318	175.15	Vertical	30.00	Quarry Site
AD - 8	1,624,203	556,060	187.08	Vertical	30.00	Quarry Site
Agos Afterbay Weir Site						
BD - 1	1,626,053	562,060	24.12	Vertical	50.00	Weir Axis, Riverbed
BD - 2	1,625,958	562,103	23.20	Vertical	25.00	Weir Axis, Right Bank
BD - 3	1,625,858	562,165	50.06	Vertical	25.00	Weir Axis, Right Bank
Kaliwa Low Dam Site						
KD-1	1,616,408	550,675	101.50	Vertical	20.00	Dam Axis, Left Bank
KD-2	1,616,340	550,642	99.50	Vertical	20.00	Dam Axis, Riverbed
KD-3	1,616,318	550,632	122.00	Vertical	20.00	Dam Axis, Right Bank
KD-4	1,616,272	551,042	226.00	Vertical	30.00	Quarry Site
KD-5	1,616,100	551,065	145.00	Vertical	30.00	Quarry Site
Daraitan Limestone Area						
LD-1	$14^0$35'13.2"	$121^0$26'07.2"	393.00	Vertical	150.00	Ridge
LD-2	$14^0$34'19.2"	$121^0$26'13.2"	370.00	Vertical	200.00	Ridge
Transfer Tunnel No.1 Route						
TD-1	1,616,300	550,915	135.00	Inclined	30.00	Intake
TD-2	1,616,180	550,570	180.00	Vertical	70.00	Intake
TD-3	$14^0$34'24"	$121^0$26'13.2"	252.00	Vertical	200.00	Alignment
TD-4	1,612,380	529,970	220.00	Vertical	150.00	Alignment
TD-5	1,612,530	527,380	158.00	Vertical	70.00	Surge Tank
TD-6	1,611,305	527,132	114.00	Inclined	30.00	Outlet
Waterway Facilities						
WD - 1	1,612,435	527,135	107.00	Vertical	20.00	Lagundi Power House
WD - 2	1,610,980	527,102	105.70	Vertical	20.00	Morong Water Teatment Plant
WD - 3	1,610,722	526,840	104.00	Vertical	20.00	Morong Water Teatment Plant
WD - 4	1,612,780	521,016	74.00	Vertical	20.00	Antipolo Pump Station
WD - 5	1,610,175	516,676	83.00	Vertical	20.00	Taytay Service Reservoir
WD - 6	1,614,176	520,995	254.00	Vertical	20.00	Antipolo Service Reservoir
WD - 7	1,611,421	521,068	98.00	Inclined	30.00	Water Tunnel No.2
WD - 8	1,610,150	516,838	82.00	Inclined	30.00	Water Tunnel No.2

Table B3.2 Quantity of Seismic Prospecting

Site/Location		Line No.	Length (m)	Remarks
Agos Dam Site	Dam axis	AS-1	1,500	-
	Alternative axis	AS-2	1,500	-
	Spillway	AS-3	1,500	-
	Subtotal		**4,500**	
Kaliwa Low Dam Site	Dam site	KS-1	600	-
	Subtotal		**600**	
No.1 Transfer Tunnel Route	Alignment	TS-1	2,500	-
	- do -	TS-2	2,500	-
	Subtotal		**5,000**	
Morong Water Treatment Plant	Basement	WS-1	1,400	-
	Sub-total		**1,400**	
Total			**11,500**	

Table B3.3 Quantities of Electric Prospecting

Site/Location		Line No.	Length (m)	Remarks
(1) Daraitan Limestone Area	Limestone area	LE-1	5,000	-
	Subtotal (1)		**5,000**	
Total			**5,000**	

Table B3.4 Quatity of Test Pitting

Test Pit No.	Coordinates		Collar Elev. (m)	Depth (m)	Location
	Northing	Easting			
Agos Dam & Afterbay Weir					
ATP-1	1,623,845	556,235	54.0	3.00	Agos Sand & Gravel
ATP-2	1,623,875	556,557	53.0	3.00	Agos Sand & Gravel
ATP-3	1,624,290	556,515	47.0	3.00	Agos Sand & Gravel
ATP-4	1,624,465	556,540	47.5	3.00	Agos Sand & Gravel
ATP-5	1,624,805	557,087	44.0	2.60	Agos Sand & Gravel
ATP-6	1,624,900	558,220	47.0	3.00	Agos Sand & Gravel
ATP-7	1,624,235	559,123	38.0	3.00	Agos Sand & Gravel
ATP-8	1,625,600	560,866	26.6	3.00	Agos Afterbay Sand & Gravel
ATP-9	1,625,906	562,065	23.1	3.00	Agos Afterbay Sand & Gravel
ATP-10	1,625,948	562,502	24.9	3.00	Agos Afterbay Sand & Gravel
ATP-11	1,624,565	556,254	123.0	3.00	Agos Soil Material
ATP-12	1,624,260	556,130	103.0	3.00	Agos Soil Material
ATP-13	1,625,085	557,092	152.0	3.00	Agos Soil Material
ATP-14	1,624,550	557,402	160.0	3.00	Agos Soil Material
ATP-15	1,625,175	557,055	50.0	3.00	Agos Soil Material
AQ-1	1,624,500	556,258	75.0	Chipped sample from outcrop	Agos Quarry
AQ-2	1,624,370	556,160	70.0		Agos Quarry
AQ-3	1,624,600	556,130	105.0		Agos Quarry
Kaliwa Low Dam					
KTP-1	1,616,140	550,915	99.5	3.00	Kaliwa Sand & Gravel
KTP-2	1,615,895	551,122	99.4	3.00	Kaliwa Sand & Gravel
KTP-3	1,615,900	551,155	99.3	3.00	Kaliwa Sand & Gravel
KTP-4	1,616,180	551,300	99.0	3.00	Kaliwa Sand & Gravel
KTP-5	1,616,325	551,560	99.0	3.00	Kaliwa Sand & Gravel
KTP-6	1,616,190	551,050	192.0	3.00	Kaliwa Soil Material
KTP-7	1,616,060	550,820	150.0	3.00	Kaliwa Soil Material
KTP-8	1,615,920	550,862	140.0	3.00	Kaliwa Soil Material
KTP-9	$14^0$35'29.16"	$121^0$28'13.52	448.0	3.00	Kaliwa Soil Material
KTP-10	$14^0$35'22.7"	$121^0$28'18.59	463.5	3.00	Kaliwa Soil Material
KQ-1	1,616,140	551,000	103.0	Chipped sample from outcrop	Kaliwa Quarry
KQ-2	1,616,025	551,238	104.0		Kaliwa Quarry
KQ-3	1,616,250	551,218	103.0		Kaliwa Quarry
Waterway Facilities					
WTP-1	1,611,380	527,017	115.0	3.00	WTP Soil Material
WTP-2	1,611,130	527,260	107.0	3.00	WTP Soil Material
WTP-3	1,610,890	527,510	124.0	3.00	WTP Soil Material
WTP-4	1,611,122	526,750	106.0	3.00	WTP Soil Material
WTP-5	1,610,867	526,988	124.5	3.00	WTP Soil Material
WTP-6	1,610,622	527,235	92.0	3.00	WTP Soil Material
WTP-7	1,610,245	515,928	72.0	3.00	Taytay S/R Soil Material
WTP-8	1,610,300	516,738	97.0	3.00	Taytay S/R Soil Material
WTP-9	1,610,050	516,600	63.0	3.00	Taytay S/R Soil Material
WTP-10	1,610,092	516,780	72.0	3.00	Taytay S/R Soil Material

Table B3.5 Groundwater Table of Each Borehole and Test Pit

Borehole No.	Groundwater Table (GL-m)	Location
Agos Dam Site		
AD-1	29.00	Dam Axis, Left Bank
AD-2	0.40	Dam Axis, Riverbed
AD -3	18.50	Dam Axis, Right Bank
AD-4	22.50	Alternative DA, Left Bank
AD-5	34.55	Alternative DA, Right Bank
AD-6	1.80	Alternative DA, Riverbed
AD-7	4.50	Quarry Site
AD-8	COLLAR	Quarry Site
Agos Afterbay Weir Site		
BD - 1	COLLAR	Weir Axis, Riverbed
BD - 2	5.40	Weir Axis, Right Bank
BD - 3	13.30	Weir Axis, Right Bank
Kaliwa Low Dam Site		
KD-1	1.75	Dam Axis, Left Bank
KD-2	2.50	Dam Axis, Riverbed
KD-3	2.40	Dam Axis, Right Bank
KD-4	16.20	Quarry Site
KD-5	16.00	Quarry Site
Daraitan Limestone Area		
LD - 1	dry	Ridge
LD - 2	108.90	Ridge
Transfer Tunnel No.1 Route		
TD-1	4.50	Intake
TD-2	11.00	Intake
TD-3	16.50	Alignment
TD-4	55.00	Alignment
TD-5	36.00	Surge Tank
TD-6	7.20	Outlet
Waterway Facilities		
WD-1	6.70	Lagundi Power House
WD-2	7.80	Morong Water Treatment Plant
WD-3	16.20	Morong Water Treatment Plant
WD-4	2.30	Antipolo Pump Station
WD-5	5.00	Taytay Service Reservoir
WD-6	1.30	Antipolo Service Reservoir
WD-7	1.30	Water Tunnel No.2
WD-8	7.30	Water Tunnel No.2

Test Pit No.	Groundwater Table (GL-m)	Location
Agos Dam Site		
ATP-1	2.70	Agos Sand and Gravel
ATP-2	2.80	Agos Sand and Gravel
ATP -3	2.70	Agos Sand and Gravel
ATP-4	2.80	Agos Sand and Gravel
ATP-5	2.20	Agos Sand and Gravel
ATP-6	DRY	Agos Sand and Gravel
ATP-7	DRY	Agos Sand and Gravel
ATP-8	2.70	Agos Sand and Gravel
ATP-9	2.60	Agos Sand and Gravel
ATP-10	2.90	Agos Sand and Gravel
ATP-11	DRY	Agos Soil Material
ATP-12	DRY	Agos Soil Material
ATP-13	DRY	Agos Soil Material
ATP-14	DRY	Agos Soil Material
ATP-15	DRY	Agos Soil Material
Kaliwa Low Dam Site		
KTP-1	2.80	Kaliwa Sand Gravel
KTP-2	2.90	Kaliwa Sand Gravel
KTP-3	2.80	Kaliwa Sand Gravel
KTP-4	2.70	Kaliwa Sand Gravel
KTP-5	2.80	Kaliwa Sand Gravel
KTP-6	2.90	Kaliwa Soil Material
KTP-7	DRY	Kaliwa Soil Material
KTP-8	DRY	Kaliwa Soil Material
KTP-9	DRY	Kaliwa Soil Material
KTP-10	DRY	Kaliwa Soil Material
Waterway Facilities		
WTP-1	DRY	WTP Soil Material
WTP-2	DRY	WTP Soil Material
WTP-3	DRY	WTP Soil Material
WTP-4	DRY	WTP Soil Material
WTP-5	DRY	WTP Soil Material
WTP-6	DRY	WTP Soil Material
WTP-7	DRY	Taytay S/R Soil Material
WTP-8	DRY	Taytay S/R Soil Material
WTP-9	DRY	Taytay S/R Soil Material
WTP-10	DRY	Taytay S/R Soil Material

Table B3.6 Summary of Borehole SPT (1)

Borehole No.	SPT No.	Depth (m)	Blows/Run 15 cm.	15 cm.	15 cm.	N-Value
AD-1	SPT-1	0.55-1.0	3	5	8	13
	SPT-2	1.55-2.0	5	5	9	14
	SPT-3	2.55-3.0	4	8	11	19
	SPT-4	3.55-3.90	8	15	50/5	50+
AD-3	SPT-1	0.55-1.0	3	3	4	7
	SPT-2	1.55-2.0	4	4	4	8
	SPT-3	2.55-3.0	4	6	5	11
	SPT-4	3.55-4.0	5	8	7	15
	SPT-5	4.55-5.0	7	8	9	17
	SPT-6	5.55-6.0	9	12	14	26
	SPT-7	6.55-7.0	8	14	14	28
	SPT-8	7.55-8.0	10	14	17	31
	SPT-9	8.55-9.0	12	15	18	33
	SPT-10	9.55-10.0	10	18	20	38
	SPT-11	10.55-10.95	14	22	50/10	50+
AD-4	SPT-1	0.55-1.0	3	4	4	8
	SPT-2	1.55-2.0	4	4	6	10
	SPT-3	2.00-2.45	4	5	7	12
	SPT-4	3.00-3.45	12	14	17	31
	SPT-5	4.00-4.45	15	18	21	39
	SPT-6	5.00-5.40	25	38	50/10	50+
AD-5	SPT-1	0.55-1.00	2	3	5	8
	SPT-2	1.55-2.00	3	12	16	28
	SPT-3	2.55-3.00	6	8	7	15
	SPT-4	3.55-4.00	5	8	10	18
	SPT-5	4.55-5.00	4	10	12	22
	SPT-6	5.55-6.00	3	8	9	17
	SPT-7	6.55-7.00	4	9	12	21
	SPT-8	7.55-8.00	5	12	13	25
	SPT-9	8.55-8.95	6	15	50/10	50+
AD-7	SPT-1	0.55-1.0	3	5	7	12
	SPT-2	1.55-2.0	4	5	8	13
	SPT-3	2.55-3.0	9	12	14	26
	SPT-4	3.55-4.0	12	26	50/12	50+
BD-3	SPT-1	0.55-1.0	6	7	7	14
	SPT-2	1.55-2.0	10	13	15	28
	SPT-3	2.55-3.0	9	14	18	32

Table B3.7 Summary of Borehole SPT (2)

Borehole No.	SPT No.	Depth (m)	Blows/Run			N-Value
			15 cm.	15 cm.	15 cm.	
WD-1	SPT-1	0.55-1.0	8	10	13	23
	SPT-2	1.55-1.70	50	-	-	50+
WD-2	SPT-1	0.55-1.0	7	7	10	17
	SPT-2	1.55-2.0	6	8	12	20
	SPT-3	2.55-3.0	5	6	9	15
	SPT-4	3.55-4.0	7	8	11	19
	SPT-5	4.55-5.0	8	7	11	18
	SPT-6	5.55-6.0	4	7	10	17
	SPT-7	6.55-7.0	9	9	11	20
	SPT-8	7.55-8.0	6	9	11	20
	SPT-9	8.55-9.0	9	11	13	24
	SPT-10	9.55-10.0	8	12	15	27
	SPT-11	10.55-11.0	10	10	15	25
	SPT-12	11.55-12.0	7	9	10	19
	SPT-13	12.55-13.0	9	10	10	20
	SPT-14	13.55-14.0	12	15	17	32
	SPT-15	14.55-16.0	11	13	14	27
	SPT-16	16.55-17.0	16	27	49	50+
	SPT-17	17.55-18.0	13	19	29	48
WD-3	SPT-1	0.55-1.0	12	14	14	28
	SPT-2	1.55-2.0	21	34	50	50+
WD-4	SPT-1	0.55-1.0	4	6	8	14
	SPT-2	1.55-2.0	4	5	9	14
	SPT-3	2.55-3.0	4	6	10	16
	SPT-4	3.55-4.0	5	6	12	18
	SPT-5	4.55-5.0	30	30	50	50+
	SPT-6	8.55-9.0	16	30	30	50+
	SPT-7	9.55-10.0	12	17	20	37
	SPT-8	10.55-11.0	15	20	30	50
	SPT-9	11.55-12.0	16	18	21	39
	SPT-10	12.55-13.0	14	17	21	38
	SPT-11	13.55-14.0	15	18	25	43
	SPT-12	14.55-15.0	10	20	26	46
	SPT-13	15.55-16.0	15	22	30	52
	SPT-14	16.55-17.0	15	21	32	53
	SPT-15	17.55-18.0	16	25	35	60
	SPT-16	18.55-19.0	16	28	32	60
	SPT-17	19.55-20.0	18	29	37	66
WD-5	SPT-1	0.55-1.0	6	10	14	24
	SPT-2	1.55-2.0	10	20	42	50+
	SPT-3	2.55-3.0	5	18	35	50+
	SPT-4	3.55-4.0	7	28	45	50+
	SPT-5	4.55-5.0	18	27	46	50+
	SPT-6	5.55-5.85	27	50	-	50+
	SPT-7	6.55-7.0	15	38	48	50+
	SPT-8	7.55-8.0	17	34	44	50+
	SPT-9	8.55-9.0	14	31	47	50+
WD-6	SPT-1	0.55-1.0	8	12	16	28
	SPT-2	1.55-2.0	8	17	22	39
	SPT-3	4.55-5.0	10	19	37	50+

Table B3.8 Summary of Borehole Permeability Test (1)

Bore Hole No.	Depth			Test Length(m)	Lu	Lu'	Pc
AD-1	11.50m	-	14.50m	3.00	-	6.5	4.1
	15.00m	-	20.00m	5.00	-	6.6	4.9
	20.00m	-	25.00m	5.00	-	11.0	3.7
	25.00m	-	30.00m	5.00	-	7.7	-
	30.00m	-	35.00m	5.00	-	5.4	7.4
	35.00m	-	40.00m	5.00	3.7	-	-
	40.00m	-	45.00m	5.00	-	8.1	6.9
	45.00m	-	50.00m	5.00	-	10.7	6.7
AD-2	37.00m	-	40.00m	3.00	-	4.1	6.0
	40.00m	-	45.00m	5.00	-	2.0	6.1
	45.00m	-	50.00m	5.00	-	3.1	5.6
	50.00m	-	55.00m	5.00	-	2.0	4.2
	55.00m	-	60.00m	5.00	-	2.1	4.2
	60.00m	-	65.00m	5.00	-	1.8	5.8
	65.00m	-	70.00m	5.00	-	1.5	6.5
AD-3	15.00m	-	20.00m	5.00	-	7.5	5.2
	20.00m	-	25.00m	5.00	-	6.2	6.1
	25.00m	-	30.00m	5.00	-	5.6	7.8
	30.00m	-	35.00m	5.00	-	12.0	-
	35.00m	-	39.80m	4.80	-	6.5	7.8
	40.00m	-	44.75m	4.75	-	5.8	6.8
	45.00m	-	50.00m	5.00	-	14.5	-
AD-4	15.00m	-	20.00m	5.00	-	4.4	4.5
	20.00m	-	25.00m	5.00	-	5.7	7.8
	25.00m	-	30.00m	5.00	-	5.6	-
	30.00m	-	35.00m	5.00	-	5.2	-
	35.00m	-	40.00m	5.00	-	3.1	-
	40.00m	-	45.00m	5.00	-	4.0	-
	45.00m	-	50.00m	5.00	-	2.3	8.4
AD-5	30.00m	-	35.00m	5.00	-	6.2	8.8
	35.00m	-	40.00m	5.00	-	4.5	-
AD-6	40.00m	-	45.00m	5.00	-	6.7	4.0
	45.00m	-	50.00m	5.00	-	3.6	4.2
	50.00m	-	55.00m	5.00	5.0	-	-
	55.00m	-	60.00m	5.00	-	3.5	4.2
	60.00m	-	65.00m	5.00	-	3.3	4.2
	65.00m	-	70.00m	5.00	5.3	-	-
BD-1	30.00m	-	35.00m	5.00	-	3.3	4.0
	35.00m	-	40.00m	5.00	-	3.2	4.0
	40.00m	-	45.00m	5.00	-	3.5	4.0
	45.00m	-	50.00m	5.00	-	3.3	4.0
BD-2	31.00m	-	35.00m	4.00	-	10.1	4.3
	35.00m	-	40.00m	5.00	-	9.1	4.3
	40.00m	-	45.00m	5.00	-	7.1	4.3
BD-3	15.00m	-	20.00m	5.00	-	2.3	5.1
	20.00m	-	25.00m	5.00	-	2.3	5.3
KD-1	5.00m	-	10.00m	5.00	-	2.6	4.1
	10.00m	-	15.00m	5.00	-	2.6	4.1
	15.00m	-	20.00m	5.00	-	3.0	4.1
KD-2	5.00m	-	10.00m	5.00	-	3.6	7.0
	10.00m	-	15.00m	5.00	-	5.5	-
	15.00m	-	20.00m	5.00	-	5.7	-
KD-3	5.00m	-	10.00m	5.00	-	4.6	7.0
	10.00m	-	15.00m	5.00	5.0	-	-
	15.00m	-	20.00m	5.00	4.8	-	-

Table B3.9 Summary of Borehole Permeability Test (2)

Bore Hole No.	Depth			Test Length(m)	Lu	Lu'	Pc
LD-1	15.10m	-	20.10m	5.00	Water Inflow		
	20.60m	-	25.60m	5.00	Water Inflow		
	30.00m	-	35.00m	5.00	Water Inflow		
	35.00m	-	40.00m	5.00	Water Inflow		
	40.00m	-	45.00m	5.00	Water Inflow		
	45.00m	-	50.00m	5.00	Water Inflow		
	50.00m	-	54.85m	4.85	Water Inflow		
	55.00m	-	59.35m	4.35	Water Inflow		
	60.00m	-	65.00m	5.00	Water Inflow		
	65.00m	-	70.00m	5.00	Water Inflow		
	70.00m	-	75.00m	5.00	Water Inflow		
	75.00m	-	80.00m	5.00	Water Inflow		
	80.00m	-	84.70m	4.70	Water Inflow		
	85.00m	-	90.00m	5.00	Water Inflow		
	90.00m	-	95.00m	5.00	Water Inflow		
	95.00m	-	100.00m	5.00	Water Inflow		
	100.00m	-	105.00m	5.00	Water Inflow		
	105.00m	-	110.00m	5.00	Water Inflow		
	110.00m	-	115.00m	5.00	Water Inflow		
	115.00m	-	120.00m	5.00	Water Inflow		
	120.00m	-	125.00m	5.00	Water Inflow		
	125.00m	-	129.85m	4.85	Water Inflow		
	130.00m	-	135.00m	5.00	Water Inflow		
	135.00m	-	140.00m	5.00	Water Inflow		
	140.00m	-	145.00m	5.00	Water Inflow		
LD-2	62.00m	-	67.00m	5.00	Water Inflow		
	67.00m	-	72.00m	5.00	Water Inflow		
	72.00m	-	77.00m	5.00	-	3.7	-
	77.00m	-	82.00m	5.00	3.6	-	-
	82.00m	-	87.00m	5.00	5.1	-	-
	87.00m	-	90.00m	3.00	Water Inflow		
	92.00m	-	97.00m	5.00	-	(2.1)	(9.5)
	97.00m	-	102.00m	5.00	-	(0.5)	-
	102.00m	-	107.00m	5.00	-	(0.5)	-
	107.00m	-	112.00m	5.00	-	(0.7)	-
	112.00m	-	117.00m	5.00	-	(0.4)	-
	117.00m	-	122.00m	5.00	-	(0.3)	-
	122.00m	-	127.00m	5.00	-	(0.4)	-
	127.00m	-	132.00m	5.00	-	(0.4)	-
	132.00m	-	137.00m	5.00	-	(0.5)	-
	137.00m	-	142.00m	5.00	-	(0.5)	-
	142.00m	-	147.00m	5.00	-	(0.8)	-
	147.00m	-	152.00m	5.00	-	(0.8)	-
	152.00m	-	157.00m	5.00	-	(1.0)	-
	157.00m	-	162.00m	5.00	-	(0.8)	-
	162.00m	-	167.00m	5.00	-	(0.3)	-
	167.00m	-	172.00m	5.00	-	(0.5)	-
	172.00m	-	177.00m	5.00	-	(0.4)	-
	177.00m	-	182.00m	5.00	-	(0.6)	-
	182.00m	-	187.00m	5.00	-	(0.8)	-
	187.00m	-	192.00m	5.00	-	(0.9)	-
	192.00m	-	197.00m	5.00	-	(0.4)	-
	197.00m	-	200.00m	3.00	-	(1.0)	-

Table B3.10 Summary of Borehole Permeability Test (3)

Bore Hole No.	Depth			Test Length(m)	Lu	Lu'	Pc
TD-1	5.00m	-	10.00m	5.00	-	4.0	8.3
	10.00m	-	15.00m	5.00	-	2.8	4.3
	15.00m	-	20.00m	5.00	-	3.3	6.5
	20.00m	-	25.00m	5.00	-	4.0	7.2
	25.00m	-	30.00m	5.00	-	3.4	7.0
TD-2	5.00m	-	10.00m	5.00	4.2	-	-
	10.00m	-	15.00m	5.00	-	4.0	9.7
	15.00m	-	20.00m	5.00	-	3.7	9.4
	20.00m	-	25.00m	5.00	-	3.8	9.6
	25.00m	-	30.00m	5.00	-	3.5	9.1
	30.00m	-	35.00m	5.00	-	2.7	4.6
	35.00m	-	40.00m	5.00	-	3.1	7.5
	40.00m	-	45.00m	5.00	-	3.0	8.7
	45.00m	-	50.00m	5.00	-	4.5	-
	50.00m	-	55.00m	5.00	-	3.3	-
	55.00m	-	60.00m	5.00	3.1	-	-
	60.00m	-	65.00m	5.00	3.1	-	-
	65.00m	-	70.00m	5.00	-	4.2	-
TD-3	15.00m	-	20.00m	5.00	-	4.7	4.2
	20.00m	-	25.00m	5.00	-	2.4	4.5
	25.00m	-	30.00m	5.00	-	4.4	8.1
	30.00m	-	35.00m	5.00	6.7	-	-
	35.00m	-	40.00m	5.00	8.0	-	-
	40.00m	-	45.00m	5.00	-	4.6	8.2
	45.00m	-	50.00m	5.00	-	3.2	7.7
	50.00m	-	55.00m	5.00	-	4.5	7.2
	55.00m	-	60.00m	5.00	-	4.7	4.8
	60.00m	-	65.00m	5.00	-	4.5	7.0
	65.00m	-	70.00m	5.00	-	4.2	7.9
	70.00m	-	75.00m	5.00	-	4.5	6.2
	75.00m	-	80.00m	5.00	-	7.0	4.8
	80.00m	-	85.00m	5.00	-	4.8	4.8
	85.00m	-	90.00m	5.00	-	3.6	5.5
	90.00m	-	95.00m	5.00	-	4.2	9.3
	95.00m	-	100.00m	5.00	4.3	-	-
	100.00m	-	105.00m	5.00	5.0	-	-
	105.00m	-	110.00m	5.00	-	4.0	-
	110.00m	-	115.00m	5.00	-	5.3	5.0
	115.00m	-	120.00m	5.00	-	2.0	5.1
	120.00m	-	125.00m	5.00	-	7.4	9.8
	125.00m	-	130.00m	5.00	-	6.6	-
	130.00m	-	135.00m	5.00	-	4.0	5.0
	135.00m	-	140.00m	5.00	-	3.3	6.0
	140.00m	-	145.00m	5.00	-	11.0	-
	145.00m	-	150.00m	5.00	-	4.7	9.4
	150.00m	-	155.00m	5.00	-	3.7	8.0
	155.00m	-	160.00m	5.00	7.1	-	-
	160.00m	-	165.00m	5.00	-	6.1	-
	165.00m	-	170.00m	5.00	-	4.5	5.1
	170.00m	-	175.00m	5.00	-	3.3	5.1
	175.00m	-	180.00m	5.00	-	3.2	5.1
	180.00m	-	185.00m	5.00	-	10.2	-
	185.00m	-	190.00m	5.00	-	11.2	-
	190.00m	-	195.00m	5.00	-	12.1	-
	195.00m	-	200.00m	5.00	-	12.1	-

Table B3.11 Summary of Borehole Permeability Test (4)

Bore Hole No.	Depth			Test Length(m)	Lu	Lu'	Pc
TD-4	35.00m	-	40.00m	5.00	5.6	-	-
	40.00m	-	45.00m	5.00	5.9	-	-
	45.00m	-	50.00m	5.00	7.2	-	-
	50.00m	-	55.00m	5.00	-	2.5	6.3
	55.00m	-	60.00m	5.00	-	2.5	6.2
	60.00m	-	65.00m	5.00	-	1.9	8.0
	65.00m	-	70.00m	5.00	-	2.0	8.0
	70.00m	-	75.00m	5.00	-	2.2	8.0
	75.00m	-	80.00m	5.00	-	1.9	8.3
	80.00m	-	85.00m	5.00	-	1.8	8.3
	85.00m	-	90.00m	5.00	-	2.7	8.1
	90.00m	-	95.00m	5.00	-	2.9	8.1
	95.00m	-	100.00m	5.00	-	2.3	8.1
	100.00m	-	105.00m	5.00	-	2.1	8.1
	105.00m	-	110.00m	5.00	-	2.3	8.1
	110.00m	-	115.00m	5.00	-	1.7	8.1
	115.00m	-	120.00m	5.00	-	1.8	8.1
	120.00m	-	125.00m	5.00	-	1.8	8.1
	125.00m	-	130.00m	5.00	-	2.5	8.1
	130.00m	-	135.00m	5.00	-	2.8	8.1
	135.00m	-	140.00m	5.00	-	3.0	8.1
	140.00m	-	145.00m	5.00	-	1.8	8.1
	145.00m	-	150.00m	5.00	-	2.2	8.1
TD-5	5.00m	-	10.00m	5.00	-	1.8	-
	10.00m	-	15.00m	5.00	-	1.2	6.3
	15.00m	-	20.00m	5.00	-	1.1	7.1
	20.00m	-	25.00m	5.00	-	0.9	5.0
	25.00m	-	30.00m	5.00	-	1.1	8.5
	30.00m	-	35.00m	5.00	-	1.2	8.9
	35.00m	-	40.00m	5.00	-	1.0	8.7
	40.00m	-	45.00m	5.00	-	0.9	5.9
	45.00m	-	50.00m	5.00	-	0.9	8.0
	50.00m	-	55.00m	5.00	-	1.0	8.1
	55.00m	-	60.00m	5.00	-	1.2	8.6
	60.00m	-	65.00m	5.00	-	1.0	8.7
	65.00m	-	70.00m	5.00	-	0.8	6.2
TD-6	8.00m	-	13.00m	5.00	-	3.7	-
	13.00m	-	18.00m	5.00	-	2.5	7.7
	18.00m	-	23.00m	5.00	-	3.2	-
	23.00m	-	28.00m	5.00	-	3.3	-
WD-8	10.00m	-	15.00m	5.00	-	5.9	-
	15.00m	-	20.00m	5.00	-	1.8	4.7
	20.00m	-	25.00m	5.00	-	1.3	4.8
	25.00m	-	30.00m	5.00	-	1.1	6.8

Lu: Lugeon Value
Lu': Calculated Lugeon Value
Pc: Critical Pressure (kg/cm^2)

Table B3.12 Summary of Borehole Temperature Logging

Borehole No. KD-1 (Kaliwa low dam axis)	
Observation Depth (m)	Temp. Reading (0C)
0	28.60
1	29.20
2	29.00
3	28.20
4	28.30
5	28.40
6	28.60
7	28.80
8	28.90
9	29.20
10	29.30
11	29.40
12	29.50
13	29.60
14	29.90
15	30.20
16	30.70
17	30.90
18	31.40
19	31.90
20	32.30

Borehole No. KD-2 (Kaliwa low dam axis)	
Observation Depth (m)	Temp. Reading (0C)
0	29.60
1	28.30
2	28.40
3	28.10
4	28.30
5	28.40
6	28.40
7	28.60
8	28.70
9	28.90
10	29.00
11	29.10
12	29.20
13	29.50
14	29.70
15	29.80
16	30.00
17	30.30
18	30.50
19	30.80
20	31.00

Borehole No. KD-5 (Kaliwa quarry site)	
Observation Depth (m)	Temp. Reading (0C)
0	28.70
1	29.16
2	28.90
3	28.20
4	28.30
5	28.40
6	28.50
7	28.80
8	29.10
9	29.20
10	29.30
11	29.40
12	29.50
13	29.80
14	30.10
15	30.60
16	30.80
17	31.00
18	31.10
19	31.30
20	31.50
21	31.70
22	32.00
23	32.20
24	32.30
25	32.60
26	32.80
27	33.00
28	33.10
29	33.20
30	33.40

Borehole No. TD-2 (Tunnel intake)	
Observation Depth (m)	Temp. Reading (0C)
0	28.60
1	28.50
2	28.60
3	28.30
4	28.50
5	28.60
6	28.70
7	28.80
8	28.90
9	29.00
10	29.20
11	29.40
12	29.50
13	29.70
14	29.90
15	30.10
16	30.20
17	30.30
18	30.50
19	30.70
20	30.80
21	31.00
22	31.10
23	31.20
24	31.30
25	31.50
26	31.60
27	31.70
28	31.80
29	31.90
30	32.00
31	32.10
32	32.20
33	32.30
34	32.50
35	32.60

Borehole No. KD-3 (Kaliwa low dam axis)	
0	29.70
1	28.40
2	28.50
3	28.20
4	28.40
5	28.50
6	28.60
7	28.70
8	28.80
9	28.90
10	29.10
11	29.30
12	29.40
13	29.60
14	29.80
15	30.00
16	30.10
17	30.20
18	30.40
19	30.60
20	30.70

Borehole No. KD-4 (Kaliwa quarry site)	
0	28.50
1	29.10
2	28.90
3	28.10
4	29.00
5	28.10
6	28.20
7	28.40
8	28.80
9	29.10
10	29.20
11	29.30
12	29.50
13	29.80
14	30.00
15	30.20
16	30.60
17	30.80
18	31.30
19	32.10
20	32.20

Table B4.1 Quantity of Previous Investigations

Site	Geological Investigations		Project					
	Item	Unit	Manila Water Supply Project III (MWSS); Electrowatt (1979) *Ref.3	Agos River Hydropower Project (NPC) -Feasibility Study-; JICA (1981) *Ref.5	Agos Project (NPC) -Feasibility Study-; elc (1991) *Ref.14	Groundwater Development in Metro Manila (MWSS); JICA (1992) *Ref.17	Manila Water Supply Project III (MWSS) -Project Review-; Electrowatt & Renardet (1997) *Ref.19	Agos River Multi-Purpose Development (MWSS) -Pre-Feasibility Study-; EDCOP (2001) *Ref.23
Agos Dam Site	Core drilling	(holes)		37	-			
		length (m)		1892				
	Seismic prospecting	(lines)		13				
		length (km)		10.7				
	Test Adit	(holes)		2	-			-
		length (m)	-	53		-	-	
	Test pitting	(holes)		13				
		length (m)		142				
	Laboratory test	(set)		1	1			
	Geomorphological analysi	(set)		-	-			
	Evaluation and reporting	(set)		1	1			1
Agos Afterbay Weir Site	Core drilling	(holes)		7				
		length (m)		320				
	Seismic prospecting	(lines)		5				-
		length (km)	-	2.1	-	-	-	
	Test pitting	(holes)		-				
	Laboratory test	(set)		-				
	Evaluation and reporting	(set)		1				1
Kaliwa Low Dam Site	Core drilling	(holes)						
		length (m)						
	Seismic prospecting	(lines)	-					-
		length (km)		-	-	-	-	
	Test pitting	(holes)						
	Laboratory test	(set)						
	Evaluation and reporting	(set)	1					1
Draitan Limestone Area	Core drilling	(holes)						
		length (m)	-	-	-			-
	Electric resistibity survey	(lines)				-	-	
		length (km)						
	Evaluation and reporting	(set)	1	1	1			1
Transfer Tunnel No.1 Route	Core drilling	(holes)						
		length (m)						
	Seismic prospecting	(lines)						-
		length (km)	-	-	-	-	-	
	Laboratory test	(set)						
	Evaluation and reporting	(set)						1
Water Conveyance Facilities (Morong-Antipolo-Taytay)	Core drilling	(holes)				Carried out around Tunnel No.2 route		
		length (m)						
	Seismic prospecting	(lines)				-		
		length (km)						
	Electric resistibity survey	(lines)	-	-	-	Carried out around Tunnel No.2 route	-	-
		length (km)						
	Laboratory test	(set)				ditto		
	Test pitting	(set)				-		
	Evaluation and reporting	(set)				1	1	1

Table B4.2 Classification of Rock Type around Agos Damsite

Rock Type	Description						Result of Seismic Test	Result of Laboratory Tests		
	General	Geology	Weathering	Hardness	Joint	Japanese Rock Classification	Layer of P-wave Velocity (km/sec)	Unconfined Compressive Strength (MPa)	Shear Strength ($\tau = c + \sigma \tan\phi$)	
									c: Cohesion (Mpa)	ϕ : Friction Angle (degrees)
Decomposed rock or residual soil	Clay to sand with rock fragments and blocks.	Sandstone and Conglomerate	Extremely weathered. Reddish brown.	Extremely soft. Crushed by light hammer blow.	No joint observed.	D	0.3-0.4 0.6-0.7 Upper of 1.1-1.3	Not operated	Not operated	Not operated
Wheatered cracky rock	Cracky rock with many open-joints.		Moderately to slightly weathered, mainly along crack surface.	Somewhat soft. Small rock blocks are separated by light hammer blow.	Open. Brown stained by limonite. Thin clay layer remained on joint plane.	CL	1.1-1.3 Upper of 1.9-2.1	Not operated	Not operated	Not operated
Fresh rock	Mostly hard, tight and stable rock for the fill-dam foundation.		Fresh to generally fresh. Occasionally weathered slightly only along crack surface.	Hard. Pitted a little by strong hammer blow.	Tight to less open. Partly brown stained by limonite.	CM+	1.9-2.1 3.2-3.4 5.4-5.6	50-60 (Sandstone)	6.4-6.8 (Sandstone) 7.1-7.3 (Conglomerate)	46-48 (Sandstone) 47-48 (Conglomerate)

Table B5.1 Earthquake Intensity Felt around the Project Area (1)

No.	Date		Epicenter		Depth	Magnitude	Distance		Intensity Felt at
			Latitude (N)	Longitude (E)	(km)		Epicenter	Focal	the Site (Ij)
1	1907	Apr. 4	14.00	123.00	33.0	7.6	176.13	179.19	4.2
2		Apr. 4	13.50	123.10	33.0	7.4	200.62	203.32	3.5
3	1919	Mar. 3	13.00	123.00	50.0	6.5	245.97	251.00	1.2
4	1927	Apr. 4	16.00	120.00	100.0	6.7	218.60	240.39	1.9
5	1928	Sep. 9	16.10	119.50	33.0	6.3	244.16	246.38	0.9
6	1932	Jul. 7	14.00	120.00	100.0	6.0	182.61	208.20	0.9
7		Jul. 7	16.50	120.50	33.0	6.3	247.67	249.86	0.8
8	1933	Jun. 6	14.00	120.00	33.0	6.3	182.61	185.57	1.5
9		Sep. 9	13.00	121.00	100.0	6.5	196.70	220.66	1.8
10	1934	Feb. 2	17.50	119.10	33.0	7.6	429.15	430.41	2.0
11		Jul. 7	15.10	119.70	33.0	5.6	155.82	159.27	0.5
12		Nov. 11	14.20	120.20	33.0	6.3	135.54	139.50	2.2
13	1935	Feb. 2	13.50	122.70	33.0	6.0	200.62	203.32	0.7
14	1937	Mar. 3	18.00	121.00	100.0	6.5	369.57	382.86	0.2
15		Agu. 8	14.50	121.50	33.0	7.5	35.51	48.47	5.9
16	1941	May 5	14.20	122.10	33.0	6.8	79.40	85.99	4.0
17	1942	Apr. 4	13.20	120.60	33.0	7.7	161.80	165.13	4.6
18	1949	Dec. 12	17.50	121.50	33.0	7.2	348.19	349.75	1.8
19	1954	Jul. 7	13.00	124.00	60.0	6.7	326.27	331.74	0.9
20	1956	Jul. 7	15.10	120.50	33.0	5.7	91.30	97.08	1.7
21		Oct. 10	13.50	120.50	100.0	6.7	122.05	157.79	3.3
22		Oct. 10	14.10	123.50	33.0	6.7	254.90	257.03	1.5
23	1961	Feb. 2	15.50	121.10	32.0	6.1	131.43	135.27	1.9
24		Jun. 6	13.10	121.50	56.0	5.7	172.70	181.55	0.5
25		Jul. 7	13.23	120.58	60.0	5.7	158.00	169.01	0.7
26	1963	Feb. 2	15.58	121.49	61.0	5.5	143.41	155.84	0.5
27	1964	Jun. 6	13.67	120.55	72.0	5.1	92.66	117.35	0.5
28	1966	Agu. 8	13.28	121.36	24.0	5.5	136.63	138.72	0.6
29		Agu. 8	13.40	120.80	86.0	5.3	116.34	144.67	0.6
30		Dec. 12	14.57	122.17	32.0	5.3	85.33	91.13	1.0
31	1968	Jun. 6	14.90	119.90	53.0	5.3	142.02	151.59	0.1
32		Agu. 8	16.30	122.10	31.0	7.3	210.42	212.69	3.2
33		Agu. 8	16.45	122.31	52.0	6.1	250.10	255.45	0.4
34		Agu. 8	15.41	121.59	86.0	5.1	119.06	146.87	0.1
35		Agu. 8	15.08	122.51	15.0	5.5	149.54	150.29	0.4
36		Dec. 12	13.60	120.54	46.0	5.2	103.26	113.05	0.6
37	1969	Oct. 10	14.99	120.11	66.0	5.6	179.13	190.90	0.2
38	1970	Apr. 4	13.97	120.37	88.0	5.2	99.16	132.58	0.7
39		Apr. 4	15.78	121.71	40.0	6.5	190.27	194.43	1.8
40		Apr. 4	15.25	122.40	47.0	5.6	145.37	152.78	0.7
41		Apr. 4	15.53	121.86	33.0	5.5	162.73	166.05	0.2
42		Apr. 4	15.38	121.63	4.0	5.2	117.24	117.31	0.4
43		Apr. 4	15.40	121.75	7.0	5.7	131.79	131.97	1.1
44		Apr. 4	15.08	122.01	25.0	5.8	70.73	75.01	2.1
45		Apr. 4	15.00	122.00	18.0	5.1	60.20	62.83	0.8
46		Apr. 4	15.21	122.04	18.0	5.5	91.98	93.72	1.3
47		Apr. 4	15.10	122.40	29.0	5.2	132.40	135.53	0.1
48		Apr. 4	15.17	122.51	32.0	5.4	155.61	158.87	0.1
49		Apr. 4	15.08	122.05	29.0	5.0	76.15	81.49	0.4
50		Apr. 4	15.12	122.05	39.0	5.1	80.99	89.89	0.6

Table B5.2 Earthquake Intensity Felt around the Project Area (2)

No.	Date		Epicenter		Depth	Magnitude	Distance		Intensity Felt at the Site (Ij)
			Latitude (N)	Longitude (E)	(km)		Epicenter	Focal	
51	1970	Apr. 4	15.07	122.51	26.0	5.4	148.96	151.22	0.2
52		Apr. 4	15.26	122.24	5.0	5.2	123.55	123.65	0.2
53		Apr. 4	15.11	122.71	50.0	5.6	185.37	191.99	0.1
54		Jun. 6	15.10	122.00	19.0	5.1	72.01	74.48	0.7
55		Jul. 7	13.93	120.42	89.0	5.5	91.29	127.49	1.3
56		Nov. 11	15.01	120.13	53.0	5.5	145.95	155.28	0.5
57	1971	Apr. 4	13.00	122.30	90.0	6.0	215.14	233.21	0.6
58		Jul. 7	15.60	121.87	30.0	5.5	174.28	176.84	0.1
59		Jul. 7	15.60	121.85	50.0	5.5	172.28	179.39	0.1
60		Jul. 7	15.27	120.26	33.0	5.4	144.46	148.18	0.3
61	1972	Apr. 4	14.20	120.30	33.0	5.3	118.53	123.03	0.5
62		Apr. 4	13.52	120.52	33.0	5.4	116.93	121.50	0.8
63		Apr. 4	13.51	120.51	72.0	5.1	119.49	139.51	0.1
64		Apr. 4	13.55	120.55	33.0	5.2	109.25	114.12	0.5
65		Apr. 4	13.49	120.61	63.0	5.0	112.51	128.95	0.0
66		Apr. 4	13.49	120.67	71.0	5.3	107.57	128.89	0.7
67		Apr. 4	13.43	120.58	53.0	5.2	124.80	135.59	0.2
68		Apr. 4	13.51	120.68	72.0	5.4	103.47	126.05	1.0
69		Apr. 4	13.40	120.50	33.0	5.3	137.03	140.95	0.2
70		Apr. 4	13.35	120.64	56.0	5.2	133.41	144.69	0.1
71		Apr. 4	13.54	120.54	56.0	5.5	111.81	125.05	1.1
72		Apr. 4	13.61	120.49	66.0	5.3	108.12	126.67	0.7
73		May 5	13.36	119.88	37.0	5.7	167.53	171.57	0.5
74		May 5	13.37	120.65	46.0	5.2	131.44	139.26	0.1
75		Jun. 6	13.46	120.51	75.0	5.2	126.88	147.39	0.2
76		Agu. 8	13.44	120.35	33.0	5.3	148.15	151.78	0.0
77	1973	May 5	13.64	120.75	1.0	5.3	76.44	76.45	1.0
78		May 5	13.73	120.89	40.0	5.2	53.74	66.99	1.0
79		Oct. 10	13.79	120.24	63.0	5.6	129.30	143.83	0.9
80		Nov. 11	13.45	121.02	39.0	5.1	118.14	124.41	0.1
81	1974	Feb. 2	13.60	120.40	88.0	5.4	121.39	149.93	0.7
82		Feb. 2	14.00	122.20	17.0	5.7	115.94	117.18	1.4
83		Oct. 10	13.48	120.57	41.0	5.2	117.80	124.73	0.3
84	1975	Apr. 4	13.70	120.80	33.0	5.6	62.82	70.96	1.7
85	1987	Jun. 6	15.60	121.00	45.0	5.6	154.81	161.22	0.5
86	1989	Mar. 3	14.41	119.70	0.0	5.5	147.19	147.19	0.4
87	1990	May 5	13.37	121.23	11.0	5.1	120.94	121.44	0.1
88		Jul. 7	15.68	121.17	25.0	7.8	160.84	162.77	4.8
89		Jul. 7	16.29	120.88	33.0	5.7	197.44	200.18	0.2
90		Jul. 7	16.43	120.84	18.0	6.0	223.59	224.31	0.5
91		Jul. 7	16.50	120.98	23.0	6.6	236.29	237.40	1.5
92		Jul. 7	16.06	121.04	6.0	6.3	162.80	162.91	1.8
93		Oct. 10	13.74	121.03	33.0	5.1	73.35	80.43	0.6
94		Nov. 11	14.44	121.89	16.0	5.2	102.36	103.60	0.6
95		Dec. 12	14.48	121.97	13.0	5.9	117.16	117.88	1.8
96	1991	Jan. 1	15.44	121.21	9.0	5.4	116.01	116.36	0.8
97		Feb. 2	13.66	120.67	11.0	5.2	80.16	80.91	0.8
98		Jun. 6	15.15	120.27	12.0	5.8	131.45	131.99	1.3
99		Jun. 6	15.15	120.46	9.0	5.0	102.48	102.87	0.2
100		Jun. 6	15.05	120.32	24.0	5.1	115.65	118.11	0.2

Table B5.3 Earthquake Intensity Felt around the Project Area (3)

No.	Date		Epicenter		Depth	Magnitude	Distance		Intensity Felt at
			Latitude (N)	Longitude (E)	(km)		Epicenter	Focal	the Site (Ij)
101	1991	Jun. 6	15.04	120.24	27.0	5.2	128.51	131.32	0.1
102		Jul. 7	15.21	120.44	8.0	5.8	112.12	112.41	1.6
103		Sep. 9	15.15	120.34	48.0	5.3	120.46	129.67	0.5
104	1993	Mar. 3	13.41	120.62	22.0	5.3	124.75	126.68	0.4
105	1994	Nov. 11	13.50	121.35	7.0	7.1	96.03	96.29	4.5
106		Nov. 11	13.70	120.92	70.0	6.0	59.00	91.55	2.4
107		Nov. 11	13.41	120.63	33.0	5.3	123.98	128.30	0.4
108	1996	Jul. 7	13.85	120.34	82.0	5.3	108.78	136.22	0.7
109		Jul. 7	14.70	119.50	7.0	5.8	190.01	190.14	0.5
110	1997	Mar. 3	13.61	121.01	12.0	5.9	93.92	94.68	2.1
111		May 5	15.15	119.92	14.0	5.5	123.57	124.36	0.8
112	1998	Jan. 1	14.80	121.94	3.0	5.4	131.36	131.40	0.5
113		Agu. 8	14.73	119.90	35.0	6.1	124.98	129.79	2.0
114	1999	Dec. 12	15.85	119.67	65.0	6.8	243.23	251.77	1.9
115	2000	Jan. 1	16.25	119.78	37.0	5.9	231.46	234.40	0.2
116		Agu. 8	15.10	122.31	81.0	5.2	117.71	142.88	0.3
117	2001	Jul. 7	13.59	120.84	8.0	5.0	80.58	80.98	0.4

Table B6.1 Necessary Materials for Agos Dam Construction

Necessary Materials			Proposed Source
Structure	Material	Volume (m3)	
Main Dam	Rock material	12,000,000	Agos quarry site (4,000,000 m3)
			Excavation of dam foundation, spillway and diversion tunnel (8,000,000 m3)
	Filter material	500,000	Excavation of riverbed deposit at the damsite
			Riverbed deposit along Agos river
	Impermeable material	200,000	Residual soil on the abutments blended with rock fragments
	Random material	760,000	Excavation of dam foundation, spillway and diversion tunnel
Coffer Dams	Rock material	280,000	Excavation of dam foundation, spillway, diversion tunnel and Agos quarry site
	Random material	640,000	
Concrete for face slab of main dam, spillway, diversion tunnel and hydropower facilities		290,000	Riverbed deposit along Agos river
			Crashed rock from Agos quarry site

Table B6.2 Summary of Laboratory Test (Soil) (1)

Laboratory Tests of Soil Material　　　Concrete Aggregates and Filter Material

Location			Pit	Pit No.	Sample			Classification	Description	Grain size analysis				pecific gravity and water absorption of gravel/sa			
						Depth								Fine		Coarse	
					No	from	to			Maximum Grain Size (mm)	gravel (%)	sand (%)	silt/clay (%)	Specific Gravity (Bulk S.S.D.)	Absorption (%)	Average Specific Gravity (Bulk S.S.D.)	Average Absorption (%)
Agos Dam Site and Afterbay Weir Site	Agos River arround Dam Site	Concrete Aggregates	Test pit	ATP-1	1	0.00	3.00		Poorly graded Gravel	101.5+	79.44	15.68	4.88	2.63	2.80	2.64	1.86
				ATP-2	1	0.00	3.00		Poorly graded Gravel	44.45	70.90	27.69	1.41	2.63	2.69	2.65	1.83
				ATP-3	1	0.00	1.80		Poorly graded Gravel	63.5+	72.18	24.89	2.93	2.63	2.84	2.63	1.79
					2	1.80	3.00		Poorly graded Gravel	88.9+	84.78	12.15	3.07	2.62	2.90	2.65	1.71
				ATP-4	1	0.00	0.90		Poorly graded Gravel	76.2+	62.45	33.50	4.05	2.62	2.50	2.65	1.47
					2	0.90	3.00		Poorly graded Gravel	101.6+	90.20	8.19	1.61	2.63	2.56	2.66	1.41
					1&2	0.00	3.00		Poorly graded Gravel								
				ATP-5	1	0.00	1.50		Poorly graded Gravel	38.1+	83.95	14.39	1.66	2.66	2.42	2.66	1.43
					2	1.50	3.00		Poorly graded Gravel	38.1+	80.25	16.54	3.21	2.65	2.44	2.65	1.48
					1&2	0.00	3.00		Poorly graded Gravel								
				ATP-6	1	0.00	3.00		Poorly graded Gravel	63.5+	86.62	11.37	2.01	2.65	2.63	2.65	1.51
				ATP-7	1	0.00	0.70		Silty Sand	4.76+	0.39	70.40	29.21	2.61	3.80	2.62	1.78
					2	0.70	3.00		Poorly graded Gravel	101.5+	85.21	13.09	1.70				
	Agos River around Weir Site			ATP-8	1	0.00	2.00		Poorly graded Gravel	76.2+	83.46	11.15	5.39	2.64	2.75	2.68	1.62
					2	2.00	3.00		Poorly graded Gravel with Silt	63.5+	69.80	24.67	5.53	2.62	2.75	2.68	1.60
				ATP-9	1	0.00	0.90		Poorly graded Gravel	101.5+	81.36	15.01	3.63				
					2	0.90	3.00		Poorly graded Gravel	101.5+	82.19	12.37	5.44	2.67	2.35	2.67	1.33
					1&2	0.00	3.00		Poorly graded Gravel								
				ATP-10	1	0.00	3.00		Poorly graded Gravel	101.5+	83.31	13.46	3.23	2.62	2.75	2.67	1.61
kaliwa Low Dam Site	Kaliwa River	Concrete Aggregates and Filter Material		KTP-1	1	0.00	3.00		Poorly graded Gravel	50.8+	59.75	36.62	3.63	2.62	2.86	2.60	1.58
				KTP-2	1	0.00	3.00		Poorly graded Gravel	50.8+	73.25	22.50	4.25	2.62	2.88	2.61	1.60
				KTP-3	1	0.00	3.00		Poorly graded Sand	76.2+	53.25	43.81	2.94	2.61	3.05	2.59	1.66
				KTP-4	1	0.00	3.00		Poorly graded Sand	63.5+	59.75	36.30	3.95	2.61	3.11	2.60	1.66
				KTP-5	1	0.00	3.00		Poorly graded Gravel	50.8+	68.58	26.73	4.69	2.60	3.22	2.61	1.62

Table B6.3 Summary of Laboratory Test (Soil) (2)

Laboratory Tests of Soil Material

Location			Pit	Pit No.	Sample No	Depth from	Depth to	Classification	Description	Clay lumps and friable particles 1 1/2 (%)	1 1/2 to 3/4 (%)	3/4 to 3/8 (%)	16 (%)	Soundness test (gravel and coarse/fine Coarse Aggregate (%)	Fine Aggregate (%)
Agos Dam Site and Afterbay Weir Site	Agos River arround Dam Site	Concrete Aggregates	Test pit	ATP-1	1	0.00	3.00		Poorly graded Gravel						
				ATP-2	1	0.00	3.00		Poorly graded Gravel						
				ATP-3	1	0.00	1.80		Poorly graded Gravel						
					2	1.80	3.00		Poorly graded Gravel						
				ATP-4	1	0.00	0.90		Poorly graded Gravel						
					2	0.90	3.00		Poorly graded Gravel						
					1&2	0.00	3.00		Poorly graded Gravel	1.37	1.23	3.44	3.17	2.61	2.73
				ATP-5	1	0.00	1.50		Poorly graded Gravel						
					2	1.50	3.00		Poorly graded Gravel						
					1&2	0.00	3.00		Poorly graded Gravel	0.86	3.11	2.58	2.65	0.90	1.47
				ATP-6	1	0.00	3.00		Poorly graded Gravel	1.06	2.65	3.20	2.75	1.63	2.49
				ATP-7	1	0.00	0.70		Silty Sand						
					2	0.70	3.00		Poorly graded Gravel						
	Agos River around Weir Site			ATP-8	1	0.00	2.00		Poorly graded Gravel						
					2	2.00	3.00		Poorly graded Gravel with Silt						
				ATP-9	1	0.00	0.90		Poorly graded Gravel						
					2	0.90	3.00		Poorly graded Gravel						
					1&2	0.00	3.00		Poorly graded Gravel	0.56	3.22	2.14	2.73	1.14	2.57
				ATP-10	1	0.00	3.00		Poorly graded Gravel						
kaliwa Low Dam Site	Kaliwa River	Concrete Aggregates and Filter Material		KTP-1	1	0.00	3.00		Poorly graded Gravel	2.02	4.22	3.19	2.91	1.68	3.39
				KTP-2	1	0.00	3.00		Poorly graded Gravel						
				KTP-3	1	0.00	3.00		Poorly graded Sand	1.32	3.92	5.17	3.77		
				KTP-4	1	0.00	3.00		Poorly graded Sand						
				KTP-5	1	0.00	3.00		Poorly graded Gravel						

Table B6.4 Summary of Laboratory Test (Soil) (3)

Laboratory Tests of Soil Material

Location			Pit	Pit No.	Sample			Classification	Description	Compaction Test		Permeability Test		Abrasion test by Los Angeles machine	Chemical(alkali) reactivity test		
					No	Depth from	Depth to			M.D.D. (g/cc)	O.M.C. (%)	K_T (cm/sec.)	K_{20} (cm/sec.)	(%)	Results	MDL	DLR
Agos Dam Site and Afterbay Weir Site	Agos River arround Dam Site	Concrete Aggregates	Test pit	ATP-1	1	0.00	3.00		Poorly graded Gravel								
				ATP-2	1	0.00	3.00		Poorly graded Gravel						331	1.0	1.0
				ATP-3	1	0.00	1.80		Poorly graded Gravel								
					2	1.80	3.00		Poorly graded Gravel								
				ATP-4	1	0.00	0.90		Poorly graded Gravel								
					2	0.90	3.00		Poorly graded Gravel								
					1&2	0.00	3.00		Poorly graded Gravel	2.096	8.40	2.20×10^{-2}	2.10×10^{-2}	24.42			
				ATP-5	1	0.00	1.50		Poorly graded Gravel								
					2	1.50	3.00		Poorly graded Gravel								
					1&2	0.00	3.00		Poorly graded Gravel	2.120	7.85	2.00×10^{-2}	1.90×10^{-2}	22.36			
				ATP-6	1	0.00	3.00		Poorly graded Gravel	2.088	8.10	2.10×10^{-2}	2.00×10^{-2}	24.85			
				ATP-7	1	0.00	0.70		Silty Sand					28.32			
					2	0.70	3.00		Poorly graded Gravel					25.37	705	1.0	1.0
	Agos River around Weir Site			ATP-8	1	0.00	2.00		Poorly graded Gravel								
					2	2.00	3.00		Poorly graded Gravel with Silt								
				ATP-9	1	0.00	0.90		Poorly graded Gravel								
					2	0.90	3.00		Poorly graded Gravel								
					1&2	0.00	3.00		Poorly graded Gravel	2.150	7.40	2.40×10^{-2}	2.30×10^{-2}	20.46			
				ATP-10	1	0.00	3.00		Poorly graded Gravel					26.13	871	1.0	1.0
kaliwa Low Dam Site	Kaliwa River	Concrete Aggregates and Filter Material		KTP-1	1	0.00	3.00		Poorly graded Gravel	2.044	9.00	1.80×10^{-2}	1.70×10^{-2}	28.66			
				KTP-2	1	0.00	3.00		Poorly graded Gravel								
				KTP-3	1	0.00	3.00		Poorly graded Sand	2.030	9.80	2.00×10^{-2}	2.00×10^{-2}	31.35			
				KTP-4	1	0.00	3.00		Poorly graded Sand								
				KTP-5	1	0.00	3.00		Poorly graded Gravel					31.84			

Table B6.5 Summary of Laboratory Test (Soil) (4)

Laboratory Tests of Soil Material Core and Embankment Material

Location			Pit	Pit No.	Sample No	Depth from	Depth to	Classification	Description	Maximum Grain Size (mm)	gravel (%)	sand (%)	silt (%)	clay (%)	Liquid Limit	Plastic Limit	Plasticity Index	M.D.D. (g/cc)	O.M.C. (%)
Agos Dam Site and Afterbay Weir Site	Slope around Quarry Site	Core and Embankment Material	Test Pit	ATP-11	1	0.00	3.00	SC	Clayey Sand	44.45	21.78	34.60	28.06	15.56	47	33	14		
				ATP-12	2	1.30	3.00	MH	Clayey Silt	7.14	11.05	24.45	46.72	17.78	56	34	22		
					1&2	0.00	3.00	MH	Clayey Silt	7.14								1.460	21.20
	Abutement of Dam Site			ATP-13	1	0.00	3.00	CH	Silty Clay	7.14	5.55	20.97	40.15	33.33	70	28	42	1.435	23.00
				ATP-14	1	0.00	3.00	CH	Silty Clay	3.57	1.61	19.04	34.91	44.44	72	30	42	1.375	26.30
				ATP-15	1	0.00	3.00	CH	Silty Clay	7.14	7.16	21.69	40.04	31.11	70	28	42	1.420	22.80
kaliwa Low Dam Site	Slope around Dam Site	Core and Embankment Material	Test Pit	KTP-6	1	0.00	3.00	MH	Clayey Silt	7.14	15.52	15.15	45.44	23.89	55	33	22		
				KTP-7	1	0.00	3.00	CH	Silty Clay	3.57	1.19	9.57	47.02	42.22	77	30	47		
				KTP-8	1	0.00	3.00	CH	Silty Clay	7.14	4.88	10.71	46.63	37.78	79	29	50	1.390	26.00
	Slope around Access Road			KTP-9	1	0.00	3.00	CH	Silty Clay	11.11	3.63	21.25	36.23	38.89	73	30	43	1.400	25.00
				KTP-10	1	0.00	3.00	CH	Silty Clay	3.57	1.05	22.64	41.87	34.44	77	31	46		

Table B6.6 Summary of Laboratory Test (Soil) (5)

Laboratory Tests of Soil Material   Core and Embankment Material

Location			Pit	Pit No.	Sample			Classification	Description	Consolidation test					Permeability test	Triaxial compression, U-U		Triaxial compression, C-U			
						Depth										Maximum Deviator		Maximum Deviator		Maximum Stress Ratio Criterion	
					No	from	to			Cc	Gs	Wo (%)	Wf (%)	Wet Unit Wt (g/cc)	(cm/sec.)	ϕ (°)	C' (MPa)	ϕ (°)	C' (MPa)	ϕ (°)	C' (MPa)
Agos Dam Site and Afterbay Weir Site	Slope around Quarry Site	Core and Embankment Material	Test Pit	ATP-11	1	0.00	3.00	SC	Clayey Sand												
				ATP-12	2	1.30	3.00	MH	Clayey Silt	0.1250	2.69	21.6	16.5	1.76	1.07×10-7	15	0.77	19	0.44	18	0.44
					1&2	0.00	3.00	MH	Clayey Silt												
	Abutement of Dam Site			ATP-13	1	0.00	3.00	CH	Silty Clay	0.1422	2.70	22.2	14.3	1.75	5.20×10-7	14	0.35	17	0.45	17	0.45
				ATP-14	1	0.00	3.00	CH	Silty Clay	0.2130	2.74	25.0	16.5	1.74	5.20×10-7	14	0.34	16	0.43	15	0.44
				ATP-15	1	0.00	3.00	CH	Silty Clay	0.2296	2.71	22.3	14.3	1.74	8.19×10-7	13	0.31	17	0.40	17	0.41
kaliwa Low Dam Site	Slope around Dam Site	Core and Embankment Material	Test Pit	KTP-6	1	0.00	3.00	MH	Clayey Silt												
				KTP-7	1	0.00	3.00	CH	Silty Clay												
				KTP-8	1	0.00	3.00	CH	Silty Clay	0.2525	2.73	26.5	17.5	1.75	5.26×10-7	14	0.41	15	0.57	15	0.57
	Slope around Access Road			KTP-9	1	0.00	3.00	CH	Silty Clay	0.2339	2.72	24.7	17.3	1.75	8.19×10-7	14	0.32	15	0.51	15	0.50
				KTP-10	1	0.00	3.00	CH	Silty Clay												

Table B6.7 Summary of Laboratory Test (Soil) (6)

Laboratory Tests of Soil Material　　Core and Embankment Material

Location			Pit	Pit No.	Sample No	Depth from	Depth to	Classification	Description	Particle size analysis by sieve & hydrometer: Maximum Grain Size (mm)	gravel (%)	sand (%)	silt (%)	clay (%)	Liquid limit, Plastic limit, Plastic index: Liquid Limit	Plastic Limit	Plasticity Index	Compaction test: M.D.D. (g/cc)	O.M.C. (%)
Water Treatment Plant	Outlet	Embankment Material	Test Pit	WTP-1	1	0.00	3.00	CH	Silty Clay	7.14	4.54	8.18	50.61	36.67	76	30	46		
				WTP-2	1	0.00	3.00	CH	Silty Clay	7.14	1.70	9.05	53.69	35.56	79	29	50		
				WTP-3	1	0.00	3.00	MH	Clayey Silt	7.14	14.84	33.50	33.88	17.78	52	32	20		
				WTP-4	1	0.00	3.00	MH	Clayey Silt	7.14	12.05	34.41	37.98	15.56	54	33	21		
				WTP-5	1	0.00	3.00	SC	Clayey San	11.11	38.38	14.08	34.21	13.33	46	32	14		
				WTP-6	1	0.00	3.00	MH	Clayey Silt	15.9	29.74	19.98	35.84	14.44	50	33	17		
Taytay Service Reservoir	Outlet	Embankment Material	Test Pit	WTP-7	1	0.00	3.00	CH	Silty Clay	0.63	0.00	7.47	48.64	43.89	73	32	41		
				WTP-8	1	0.00	3.00	CH	Silty Clay	1.42	0.00	6.58	51.20	42.22	75	32	43		
				WTP-9	1	0.00	3.00	CH	Silty Clay	1.42	0.00	11.80	55.42	32.78	72	32	40		
				WTP-10	1	0.00	3.00	CH	Clayey Silt	14.31	11.65	19.77	47.47	21.11	62	32	30		

Table B6.8 Summary of Laboratory Test (Rock) (1)

Laboratory Tests of Rock — Dam Foudation, Shell Material and Aggregates

Location			Pit	Pit No.	Sample Depth from	Sample Depth to	Classification	Description	Water absorption and bulk specific gravity: Coarse — Average Specific Gravity (Bulk S.S.D.)	Unconfined compression of rock core specimen: q_u (kg/cm^2)	Unconfined compression of rock core specimen: Strain(failure) (%)	Triaxial compression test of rock core specimen: ϕ (°)	Triaxial compression test of rock core specimen: C' (MPa)
Agos Dam Site and Afterbay Weir Site	Dam Foundation of Upstream Site	Dam Foundation, Shell material and Aggregates	Drilled Core	AD-1	29.40	29.60		Andesite				48	6.40
					42.60	42.80		Sandstone; dark gray		540.08	0.89		
				AD-2A	37.80	38.00		Andesite				50	5.40
				AD-2B	55.20	55.40		Andesite				48	7.10
				AD-2	37.00	37.80		Sandstone	2.70	374.88	0.89		
				AD-3	42.00	42.20		Andesite				48	6.80
					41.20	41.40		Sandstone; dark gray		501.39	1.00		
	Dam Foundation of Dowmstream Site			AD-4	48.80	49.00		Andesite				47	7.30
					16.40	16.60		Sandstone; gray	2.75	531.93	1.22		
				AD-5	46.40	46.60		Andesite				46	6.81
					35.70	35.85		Sandstone	2.72	570.56	1.11		
				AD-6	42.30	42.50		Andesite				44	7.70
					59.40	59.55		Sandstone	2.72	599.52	1.22		
	Agos Quarry Site			AD-7A	16.20	16.40		Sandstone; gray	2.79	584.55	0.89		
				AD-7B	16.20	16.40		Sandstone; light gray	2.76	558.51	1.00		
				AD-8A	15.25	15.40		Sandstone; gray	2.68	413.46	0.78		
				AD-8B	23.15	23.30		Sandstone		609.28	1.00		
					23.15	23.58			2.78				
			Quarry	AQ-1				Gravel					
				AQ-2				Gravel					
				AQ-3				Gravel					

Table B6.9 Summary of Laboratory Test (Rock) (2)

Laboratory Tests of Rock

Dam Foudation, Shell Material and Aggregates

Location			Pit	PitNo.	Sample Depth from	Sample Depth to	Classsification	Description	Specific gravity and water absorption, Coarse: Average Specific Gravity (Bulk S.S.D.)	Specific gravity and water absorption, Coarse: Average Absorption (%)	Soundness test: Coarse Aggregate (%)	Abration test by Los Angeles machine (%)	Chemical(alkali) reactivity test: Results	Chemical(alkali) reactivity test: MDL	Chemical(alkali) reactivity test: DLR
Agos Dam Site and Afterbay Weir Site	Agos Quarry Site	Dam Foundation, Shell material and Aggregates	Quarry	AQ-1				Gravel	2.66	1.49	2.4	23.40			
				AQ-2				Gravel	2.68	1.36	2.76	24.01	237	1.0	1.0
				AQ-3				Gravel	2.68	1.32	2.32	22.70			
kaliwa Low Dam Site	Kaliwa Dam Foundation	Dam Foundation, Shell material and Aggregates	Drilled Core	KD-1											
				KD-2											
				KD-3											
	Kaliwa Quarry Site			KD-4											
				KD-5											
			Quarry	KQ-1				Gravel	2.63	2.06	3.01	25.66			
				KQ-2				Gravel	2.60	2.27	2.83	24.01			
				KQ-3				Gravel	2.59	2.30	3.32	25.42			

Table B6.10 Summary of Laboratory Test (Rock) (3)

Laboratory Tests of Rock — Tunnel Foundation

Location			Pit	Pit No.	Sample Depth from	Sample Depth to	Classification	Description	Water absorption and bulk specific gravity, Coarse: Average Specific Gravity (Bulk S.S.D.)	Water absorption and bulk specific gravity, Coarse: Average Absorption (%)	Unconfined compression of rock core specimen: q_u (kg/cm^2)	Unconfined compression of rock core specimen: Strain(failure) (%)
No.1 Tunnel	Intake	Tunnel Foundation	Drilled Core	TD-1								
No.1 Tunnel	Intake	Tunnel Foundation	Drilled Core	TD-2								
No.1 Tunnel	Alignment	Tunnel Foundation	Drilled Core	LD-2								
No.1 Tunnel	Alignment	Tunnel Foundation	Drilled Core	TD-3	100.00	100.20			2.79	1.10	571.85	0.89
No.1 Tunnel	Alignment	Tunnel Foundation	Drilled Core		142.70	142.90			2.77	1.14	456.45	1.11
No.1 Tunnel	Alignment	Tunnel Foundation	Drilled Core		154.60	154.80			2.73	1.18	412.54	1.00
No.1 Tunnel	Alignment	Tunnel Foundation	Drilled Core	TD-4								
No.1 Tunnel	Outlet	Tunnel Foundation	Drilled Core	TD-5								
No.1 Tunnel	Outlet	Tunnel Foundation	Drilled Core	TD-6								