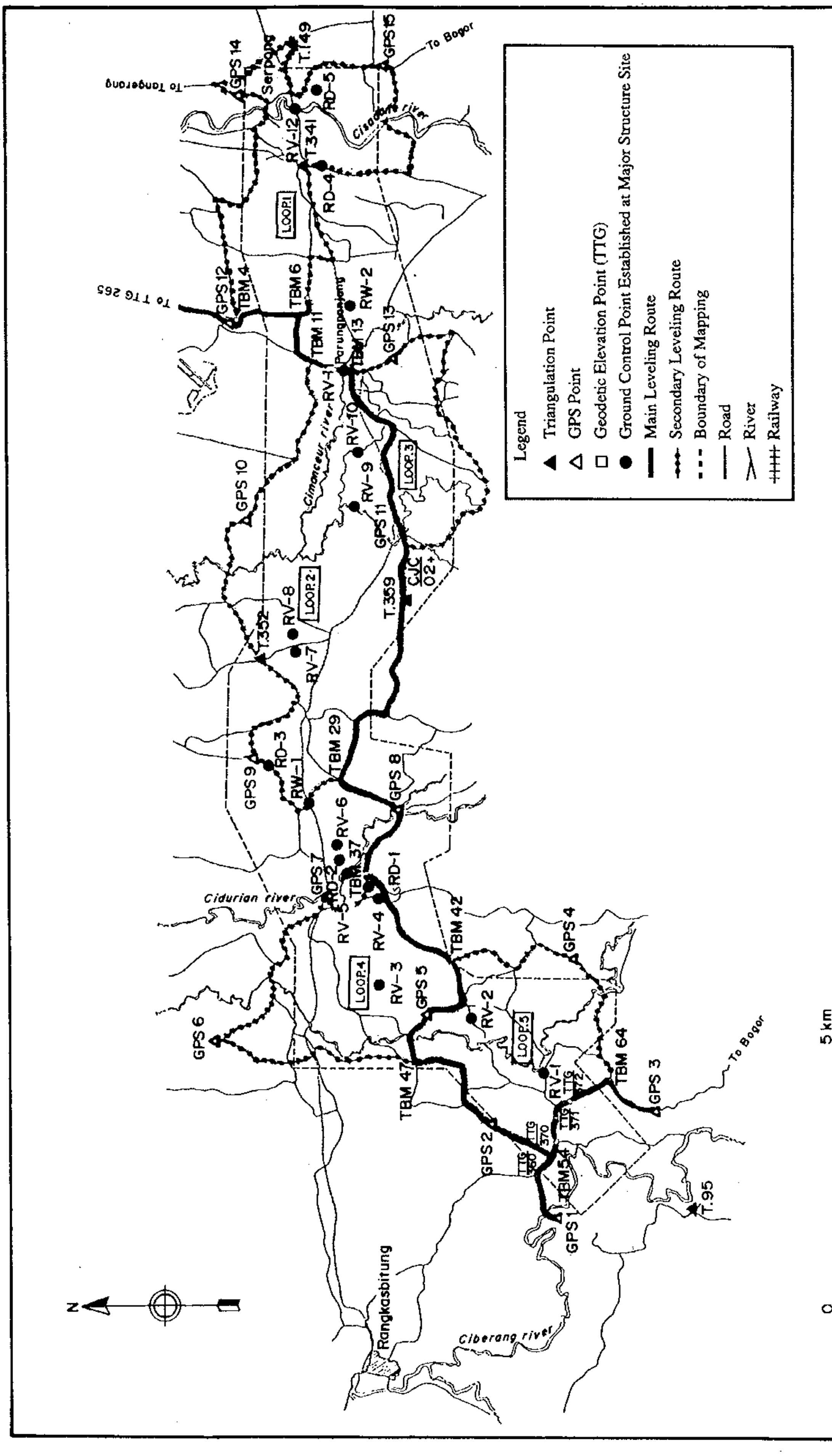


Figure 5 GROUND CONTROL POINTS ESTABLISHED BY THE STUDY ON CIUJUNG-CIDURIAN INTEGRATED WATER RESOURCES

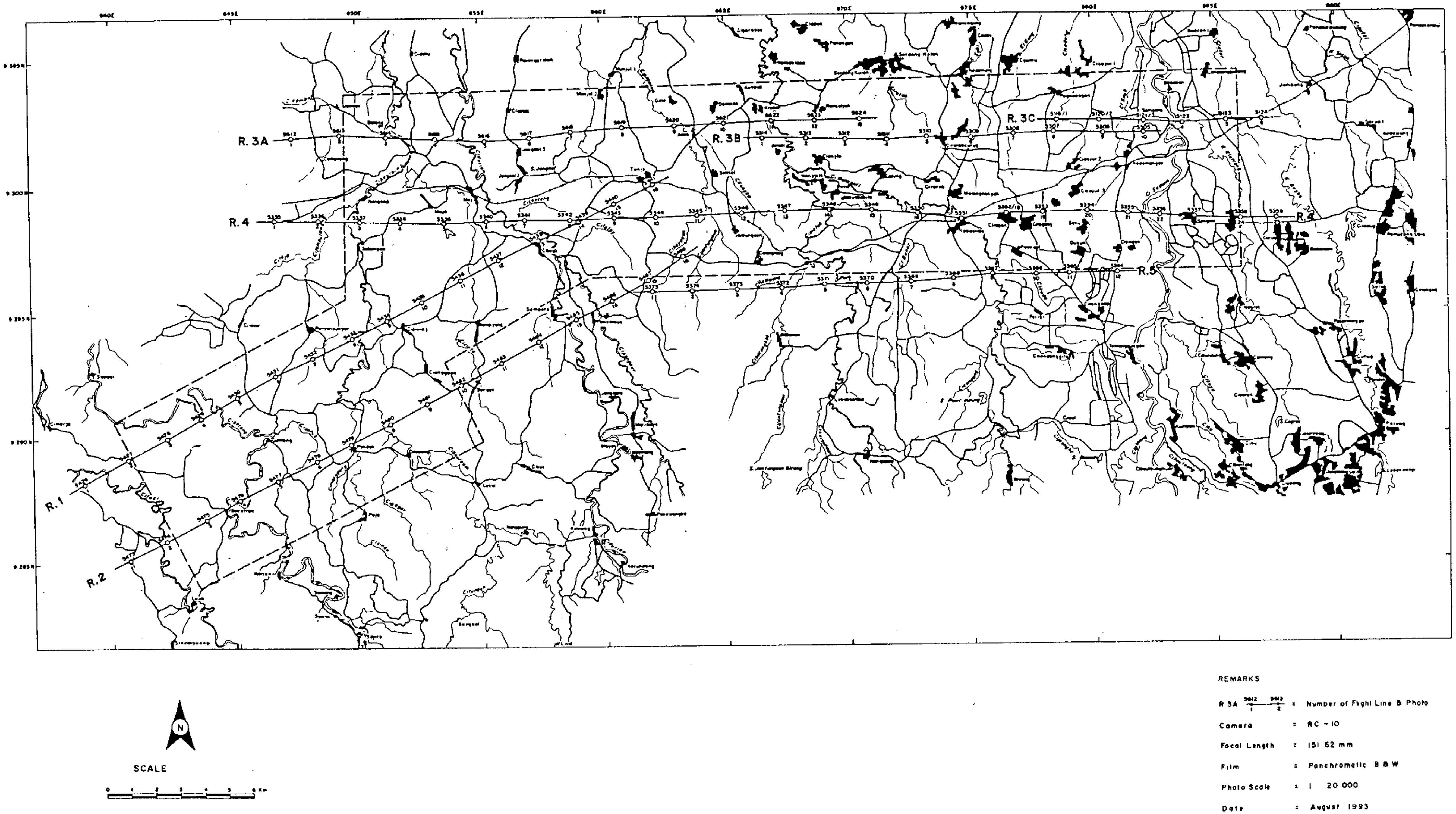


Figure 6 FLIGHT INDEX MAP OF PHOTOGRAMMETRIC SURVEY

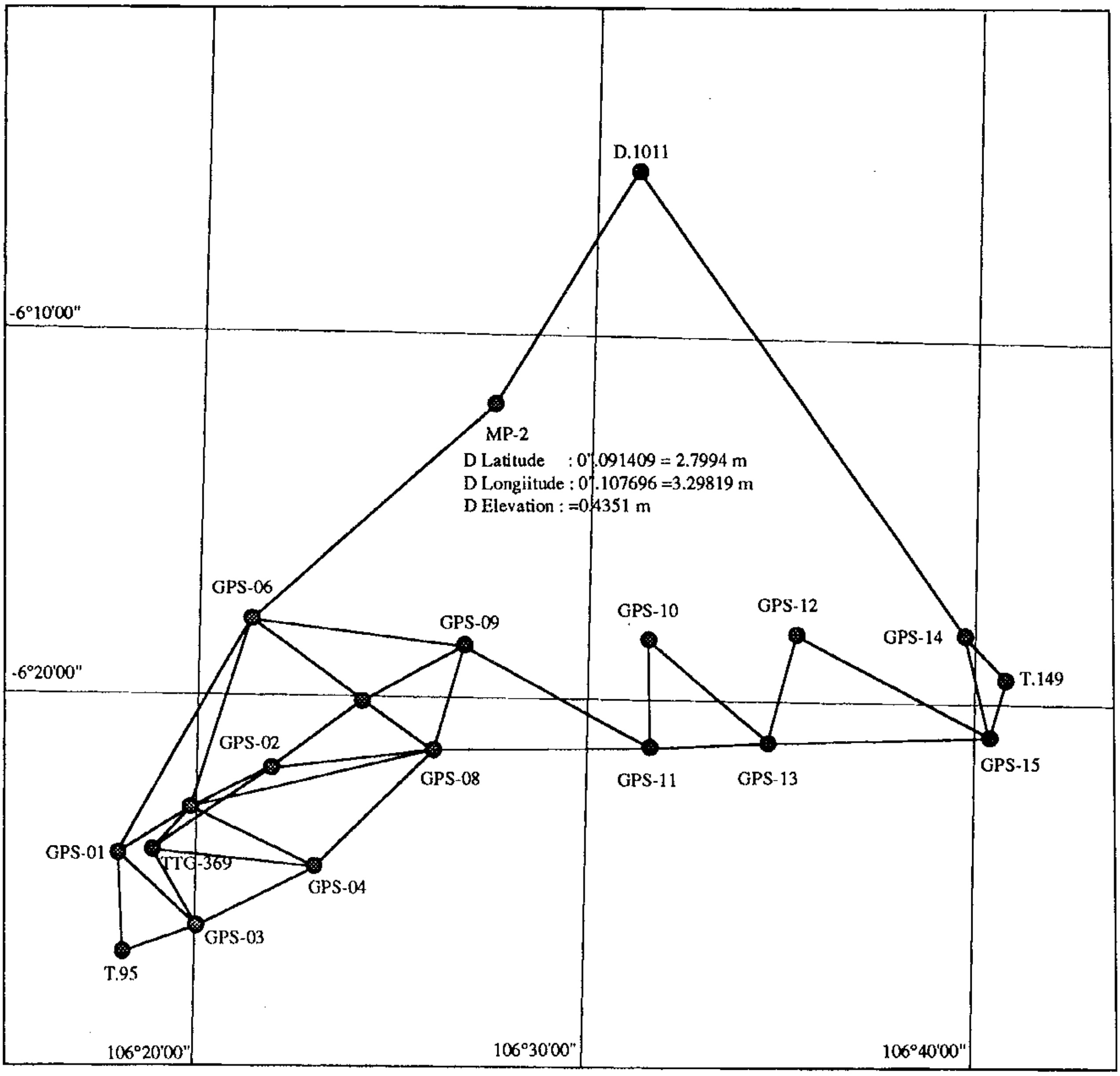
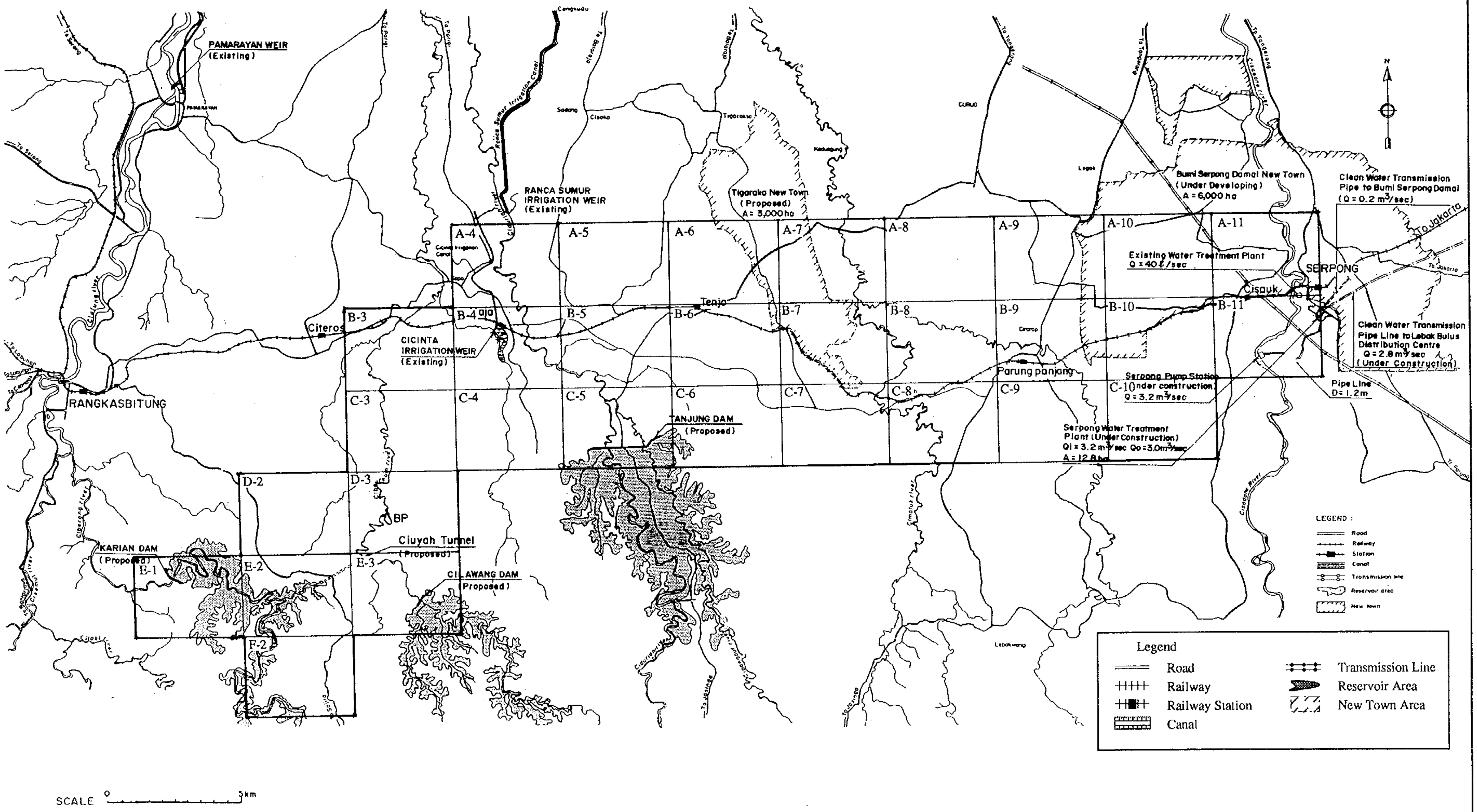


Figure 7 GPS NETWORM



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THE STUDY ON CIUJUNG-CIDURIAN INTEGRATED WATER RESOURCES

Annex 6 Geotechnical Investigation for Karian-Serpong Conveyance System

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1. INTRODUCTION

Geotechnical investigation was carried out along the water conveyance system from Ciuyah tunnel to Serpong as shown in Figure 1, in order to obtain the geotechnical information necessary for the design of Karian-Serpong conveyance system at feasibility study level.

The main objectives of the investigation are to obtain the following information:

- Geological conditions along the water conveyance system,
- Geotechnical feature of foundations and cut slopes, and
- Physical and mechanical properties of construction materials.

The preliminary geotechnical investigation was performed by means of field reconnaissance and collection of existing data to grasp the topographical and geological outlines in the project area. Based on those outlines, necessary field investigation and laboratory tests were planned and executed by the JICA study team.

In the beginning of June 1994, JICA study team made an agreement with the local contractor, PT. IKI Engineering selected on a basis of competitive tender, and the field investigation was commenced in the middle of June 1994 and completed in the middle of September, 1994 under the supervision of the experts of JICA study team and DGWRD.

Forty core drillings with standard penetration test (SPT) and test pittings with disturbed sampling were performed in the field, and a series of physical and mechanical property tests was also carried out in the Contractor's laboratory for the above-mentioned objectives.

This report describes geological and geotechnical aspects of the water conveyance route and recommendations of design parameters.

2. GEOLOGY

2.1 General Geology

According to the field reconnaissance and the geological literature published by Geological Research and Development Center of the Directorate General of Geology and Mineral Resources, geology in the study area is composed of alluvial of Holocene, terrace deposit of Pleistocene, tuffaceous sedimentary rocks of Pliocene to Miocene, and southern volcanoes of Miocene. The sedimentary formations of Miocene to Pleistocene comprise several formations, i.e., Rengganis Formation, Bojongmanik Formation, Genteng Formation and Serpong Formation, which are superposed monoclinal from south to north and from lower to upper horizons in order. They are mainly composed of fine to coarse tuffaceous sandstone and pumice tuffs with interbedding of lapilli tuffs which belong to the Genteng Formation of Late Miosen to Pliocene in this study area.

The southern volcanic mountains were formed by basalt, volcanic breccia and andesite, which erupted and/or intruded along the faulting zones in Miocene. Tectonic activity in this area is reflected in the presence of a large number of folds and faults. In general, beddings dips in low angles and are gently folded, indicating a relatively minor tectonic activity. Most of lineaments and fault lines with NW-SE and NE-SW directions are found out on aerial photographs. The geological map in and around the study area is given in Figure 2 and the stratigraphy of the project area is shown in Figure 3.

The topography of the study area is classified into three main features; 1) the mountainous area comprising volcanoes located in the south and northwestern part of the study area, ii) the area of rolling hills in the southern part of Rangkasbitung and western part of Bogor, and iii) the low land plain in the northern part of study area lower than 100 m in elevation.

The Gunung Endut (EL. 1277 m), Gunung Halimun (EL. 1929 m) and Gunung Salak (EL. 2211 m) from east to west in order, are members of the southern mountains. The northwestern mountainous area is represented by the Gunung Karang (EL. 1778 m).

The rolling hills develop in the southern side of Pandeglang-Rangkasbitung-Bogor line. Altitude of hills ranges from EL. 200 m to EL. 500 m and lowers towards the north (low hills). In the northern area of these hills, low-land plain spreads along the coastal line. Cibeureum, Cidurian, Cimanceuri, and Cisadane are the main rivers in the study area, which originate in the southern mountains. These rivers are strongly meandering and alluvial deposits have been developed on both the banks.

2.2 Karian-Serpong Conveyance System

Based on the result of field investigation, the project area is divided into the following stretches:

- Ciuyah - Tenjo:

Most of subsurface layers in this stretch belongs to Genteng Formation of Miocene to Pliocene which is covered by Banten Tuff of Pleistocene. Alluvial deposits are formed along rivers. Serpong Formation of Pliocene and Bojonmanic Formation of Miocene was locally observed.

- Tenjo - Parungpanjang:

In this stretch Genteng Formation and Bojonmanic Formation are the majority of subsurface layers. Young Volcanic of Pleistocene covers the subsurface layers.

- Parungpanjang - Serpong:

This stretch can be characterized by Genteng Formation. The surface layers consist of Alluvial Fan and Young Volcanic.

Sedimentation in this area commenced in late Miocene with the Bojongmanik Formation in environment varying between shallow neritic and brackish water, when this area was uplifted and folded.

During early Pliocene a subsidence took place, which was accompanied by sedimentation of Genteng Formation with the material of debris derived from the Bojongmanik Formation and products of volcanic activity. Afterwards, the area was subject to slow uplifting (epirogenetic) movement which lasted actively until early Pleistocene.

In Plio-Pleistocene, this area was uplifted and folded again, which process was also accompanied by volcanic activity. Such activity increased steadily and culminated in the outburst of the Danau volcano and the formation of a caldera. During those events a huge amount of pumiceous tuff was ejected from volcanos, which is nowadays known as Banten Tuffs.

The old river deposits, Serpong Formation, increase towards the north east portion of the project area. In early Pleistocene, the geological activity was young volcanic and therefotre, the erosion and landslidings resulted alluvial fan deposits. The erosion and denudation, which has been continuing, resulted in alluvial deposits along the river.

3. GEOTECHNICAL INVESTIGATION WORKS

3.1 General

Site reconnaissance, core drillings, test pittings and laboratory tests were carried out to collect geotechnical data in the project area and characteristics of construction materials, i.e. embankment materials and concrete aggregate. Since it was found through the site reconnaisance that concrete aggregate of high quality would be available in the project area, the investigation works was focused on examining geotechnical characteristics of foundations and embankment materials.

In the vicinity of the project area, concrete aggregate is supplied from quarry sites in the southern volcanic mountains formed by andesite, such as G.Dago, G.Maloko, PR.Djeruk and so on, which were developed by local private companies and have been producing construction materials. The rock materials from those quarry sites are fresh andesite and the quality seems good enough for concrete aggregate

Sand material for concrete is provided from the rivers such as the Cisadane river, the Cidurian river, and so on. It seems that appreciable quantity of natural sand for fine aggregate can be obtained from the rivers in the vicinity of the project area.

However, it is desirable to perform the detailed survey on concrete aggregate in the next stage in order to confirm its quality, quantity and cost.

3.2 Work Items and Quantities

Work items and quantities of the geotechnical investigation works in the field and the laboratory are shown in Table 1. Totally, forty drillings with Standard Penetration Test (SPT) were carried out to obtain geological and geotechnical conditions of the project area.

A series of laboratory test was conducted on samples taken from bore holes, which were disturbed samples taken by SPT and undisturbed samples taken by thin wall sampler.

Ten test pittings were performed to observe the surface geology and to take disturbed samples. Laboratory tests for the samples were also made in order to obtain engineering parameters of embankment materials.

3.3 Location of Investigation Works

Locations of field works comprising core drillings and test pittings are shown in Figure 1. For core drillings, twenty two (22) locations at rivers, three (3) at intersections of road and two (2) at intersections of the existing railway line were selected to obtain geological profiles and geotechnical information for the design of structures for the water conveyance way. In order to identify geological conditions for cut slopes and embankment foundations, seven (7) locations at embankment sites and six (6) locations at excavation sites were chosen as shown in Figure 1.

Locations of test pittings were selected at excavation sites between Ciuyah and Serpong, in which different embankment materials such as sandy tuff, silt or clay were expected to be obtained.

3.4 Field Works

(1) Core drilling

Core drillings with SPT, of which diameters and depths were 64 mm and less than 25m respectively, were carried out to obtain geological and geotechnical information of subsurface layers along the water way. Table 2 shows the field equipment that were used for the core drillings. Undisturbed samples, of which diameter and length were 70 mm and length was 500 mm respectively, were taken from the bore holes with thin wall samplers as well as disturbed samples taken by SPT for the laboratory test.

Platforms for drilling machine were set up at places such as paddy field or rivers as required. In the Cisadane river and the Cidurian river, where drillings were carried out in the center of a river section, drilling machines were set on the platforms installed on floating boats in the rivers.

(2) Test pitting

Test pittings were made at ten (10) locations of excavation sites for observation of the surface geology and disturbed soil sampling of embankment materials for the laboratory test.

Excavation of test pittings were made by 2 m deep and 1.5 m x 1.5 m cross-sectional area and the outcrops was carefully observed. Disturbed sample of about 150kg weight was taken from every test pit.

(3) Results of field works

Drilling logs with results of SPT and test pit excavation logs are compiled into the data book in the volume IV of the Final Report.

3.5 Laboratory Tests

(1) Tests on samples from bore holes

Both physical property test and mechanical property test were conducted on undisturbed samples taken with thin wall sampler, and the physical property test was carried out on disturbed samples taken by SPT.

The physical property tests were carried out to classify and identify the characteristics of soils and also strength and compressibility of soils were examined by the following mechanical property tests:

Physical Property Test	Mechanical Property Test
Moisture content	Unconfined compression
Soil particle density	Triaxial compression
Particle size	One dimensional consolidation
Liquid limit	
Plastic limit	
Density	

(2) Tests on samples from test pits

The following tests were performed on samples taken from test pits to obtain engineering parameters as embankment materials:

Physical Property Test	Mechanical Property Test
Moisture content	Compaction
Soil particle density	Permeability
Particle size	Triaxial compression
Liquid limit	One dimensional consolidation
Plastic limit	
Density	

(3) Testing standards

The laboratory tests were conducted in accordance with the standards shown in Table 3. The variable head permeability test was carried out by the method that accepted by the Expert of JICA since neither ASTM nor USBR has the standards of the test.

(4) Test results

Summary of laboratory test results on bore hale samples are shown in Tables 4 to 8 and results on test pit materials are given in Table 9.

Figures 4 to 12 show the physical properties of bore hole samples. Figure 13 indicates the physical properties of test pit samples.

4. GEOTECHNICAL EVALUATION OF THE PROJECT AREA

4.1 Geological Features along the Water Conveyance System

4.1.1 Ciuyah tunnel

The Ciuyah tunnel, which was proposed to connect the Karian reservoir and the Cibeureum river in the feasibility study report on Karian multipurpose Dam in 1985, has a length of about 1.2 km and is located in the hilly area with gentle slopes. The overburden of the tunnel ranges from 10 m to 50 m except for the entrances of the tunnel.

According to result of the previous geological investigation, the geology of the tunnel site is mainly composed of tuffaceous fine- to medium-grained sandstone with intercalation of pumice tuff, conglomerate and claystone which belong to Genteng Formation, and many slicken sides were observed at each bore hole, which indicates that the tunnel site may be a fractured zone.

The coefficient of permeability of rocks tested in the previous investigation at each bore hole ranges 10^{-4} to 10^{-6} cm/sec. The velocity of elastic wave propagation at the elevation of the tunnel is in a range of 1.8 km/sec to 2.2 km/sec according to the seismic exploration carried out in 1983.

4.1.2 Stretch between Ciuyah and Tenjo (about 33 km)

Subsurface layers in the southern and north-east part of this stretch belong to the Genteng Formation and the layers in the northern part of this stretch belong to the Banten Tuff as shown in Figure 2. The topography along this stretch indicates gentle sloped hilly landforms with top elevations being 55 m to 80 m. The elevations of old and existing river channels are about 30 m.

The following drillings were carried out in this stretch and the geological profiles are described as follows:

(1) Cibeureum river (BBG-1, BBG-2)

Figure 15 shows the geological profile of the Cibeureum river. The lower layers of the Genteng Formation, which are observed in the right bank (BBG-2) below the depth of 12.4 m, comprise slightly to moderately weathered tuffaceous sandstone with intercalation of tuffaceous siltstone. The sandstone is medium- to course-grained and well cemented.

The upper layers of the Genteng Formation, which are observed above the depth of 12.4 m in the right bank (BBG-2) and in the left bank (BBG-1), are highly to moderately weathered pumice tuff, pebble sandstone/conglomerate with intercalation of claystone and/or sandstone. These layers strike N124°E to N155°E and dip 9° to 15°. The layers in the left bank are more weathered than those of right bank. N-values of these layers are more than 50, though some data show less than 50 locally in the left bank.

The overburden mainly consists of silt, clayey silt and clay, and have a thickness of 3.0 m on the left bank and 2.35 m in the right bank. N-values of the overburden are less than 30.

(2) Cipanggang river (BBG-3)

The geological profile at Cipanggang river based on BBG-3 is shown in Figure 16. This area is underlain by the Genteng Formation which comprises pebbly sandstone with tuffaceous sand matrix and claystone. The layer of the pebbly sandstone is moderately to slightly weathered and contains fragments of andesite, clay, quarts and pumice, the maximum size of which is 5 mm. The claystone is slightly weathered and well cemented. N-values of the Genteng Formation are more than 50. The beddings dip 5°.

The old river deposit, unconformably overlying the Genteng Formation, is a mixture of silt, sand and gravel with silicified wood, and its N-value ranges 13 to more than 50. The clay layer which covers the old river deposit is soft and plastic, being deposited from 0.4 m to 2.40 m in depth under the top soil. N-values of this layer are less than 13. The ground water level was observed in the bore hole at the depth of 1.5 m from the ground surface.

(3) Ciruruh river (BBG-4)

The subsurface layers in this area belong to Banten Tuff, which are covered by overburden and topsoil as shown in Figure 16. Banten Tuff in this area consists of tuffaceous siltstone and tuffaceous sandstone which are completely to highly weathered, fine-grained, and poorly cemented. N-values of the Banten Tuff are mostly more than 50 except for the top portion of this formation. The beddings dip 10°.

The overburden consists of silt and clay which are soft and plastic, and its N-values range 5 to 10. The overburden results from weathered tuff of Banten Tuff. The ground water level was observed to be 1 m deep from the ground surface.

(4) Cicinta river (BBG-5, BBG-6)

The subsurface layers of this area consist of Banten tuff which strike N245°E to N240°E and dip 5° and overburden. The ground water level was observed to be 1.20 to 2.30 m from the ground surface. Banten tuff of this area consists of alternation of pumice tuff, tuff and tuffaceous sandstone as shown in Figure 16. The thickness of top soil and overburden are only 2m.

The pumice tuff of this area is medium grained with some fragments of Pumice, well cemented and medium to slightly weathered. N-values in the pumice tuff layer are more than 50. The tuff layers are highly to medium weathered, fine- to medium-grained and well cemented. N-values are more than 50. The tuffaceous sandstone which appears at the depth of about 17 m below the ground surface includes many pyroclastic fragments and slightly weathered with N-value being more than 50.

(5) Road 1 (BRD-1)

The geological condition of this area is similar to that of the Cicinta river located within a short distance. As shown in Figure 22, the subsurface layers of this area mainly consist of Banten tuff comprising tuffaceous siltstone and tuffaceous sandstone, both of which are highly weathered. Banten tuff is covered by overburden derived from decomposition of Banten tuffs.

The tuffaceous sandstone is poorly cemented and contains some pumice. N-values of tuffaceous sandstone are more than 50 except for the upper boundary .

(6) Cidurian river (BBG-7, 8 and 9)

The geological profile of the Cidurian river is shown in Figure 17. Two major formations were observed in this area, the Bojongmanik Formation and the Serpong Formation which overlies the former unconformably. The Bojongmanik Formation consists of alternation of tuffaceous sandstone, claystone and conglomerate. The ground water level was observed in a range of 2.0 m to 4.0 m in depth.

The tuffaceous sandstone is well cemented, fine- to coarse-grained and well bedded with N-values being more than 50. The claystone with intercalation of lignite is medium to hard and have N-values more than 50.

The Serpong formation in this area, consists of sandy tuff, gravel (sand to gravel), silty tuff and sandstone, which are old river deposits in the Pliocene. N-value in the upper layer ranges 25 to 35, and lower layer 35 to more than 50. Sandy tuff, which is fine- to medium-grained and completely to highly weathered, was observed only in the left bank(BBG-7). Silty tuff is fine- to medium-grained, highly weathered and poorly cemented.

The overburden in this area mainly consists of weathered and decomposed materials, silt and clay. The overburden is 5.60 m thick with N-values of less than 25 in the left bank and 4.25 m thick with N-values of less than 10 in the right bank.

(7) Cikasungka river (BBG-10)

As shown in Figure 18, the geology of this area consists of mainly Genteng Formation, covered by overburden. The Genteng Formation is composed of moderately to highly weathered tuffaceous sandstone, moderately to highly weathered siltstone and completely to highly weathered sandy tuff, and its N-values are more than 50 except for upper boundary.

Overburden consists of very soft clay and silt with some fine sand and its N-value ranges 0 to 18. The ground water level was observed at a depth of 4.0 m.

(8) Railway 1 (BRY-1)

In this area, the Bojongmanik Formation, unconformably underlying the Genteng Formation, is extensively distributed and the overburden layers cover these formations as shown in Figure 23.

The Bojongmanik formation consists of claystone that is intercalated with lignite, siltstone, tuffaceous sandstone and decomposed sandstone. The clay stone and the silt stone are moderately weathered and well cemented. The tuffaceous siltstone and tuffaceous sandstone are moderately to highly weathered and poorly cemented. N-values of the Bojongmanik Formation are more than 50. On the unconformity plane between two formations lies a thin decomposed sand which is poorly cemented.

The Genteng formation is composed of alternation of tuffaceous sandstone and tuffaceous claystone which are derived from weathered pumice tuff. N-values in the upper portion of this formation are 30 to 50, and more than 50 in the lower portion.

The overburden consists of silt which is formed of weathered and decomposed tuff and pumice tuff of the Genteng formation. N-values of this layer range 7 to 15.

(9) Road 2 (BRD-2)

The geological condition in this area is similar to that of Railway 1 described above, consisting of the Bojongmanik formation, the Genteng formation and overburden layers as shown in Figure 22.

The Bojongmanik formation consists of tuffaceous sandstone which is medium cemented, rich in local plant remains and is intercalated with lignite. N-values of this layer are more than 50.

The Genteng formation consists of claystone and siltstone which are derived from weathered pumice tuff, and N-values range 12 to 28. The overburden in this area, which has a thickness of 2.8 m, consists of clay and silt. N-values of the overburden is about 10.

4.1.3 Stretch between Tenjo and Parungpanjang (about 13 km)

The water conveyance route between Tenjo and Parungpanjang is planned to run through Bojongmanik formation, Genteng formation, Quartenary volcanics and alluvial plains. The Bojongmanik formation is composed of marls and clays with brown coal, tuff sandstone, andesite gravel (lower part) and pumice tuffs and is distributed at the southern part in this area. The Genteng formation is widely distributed around this area and is exposed at the river bank and superficial soil layers have the thickness of 3 m to 7 m. The Quartenary volcanic deposit occupies the northern part of this stretch and is composed of laharic breccia, pillow lava, tuffaceous sandstone and fine tuff. Its outcrops are frequently found in the sand borrow pits at the Cicayur old river channel. These deposits are characterized by well consolidated feature and high bearing capacity.

The alluvial deposit composed of unconsolidated and soft sandy-silty clay is found at surrounding area of river channels and is well developed especially in the Cimanceuri, Cimantuk and Payaheun rivers.

Topography around this stretch indicates a gently sloped hilly landform with top elevation of EL. 50 m to 70 m and old and existing river channels of bed elevation of EL. 30 m to EL. 40 m.

The following drillings were carried out in this stretch and the geological profiles are described as follows:

(1) Payaheun river (BBG-11)

The drilling log of BBG-11 indicates that this area is underlain by Genteng Formation which is covered by the overburden layers as shown in Figure 18. The Genteng formation in this area is composed of alternation of tuffaceous sandstone, pebbly sandstone and siltstone. The ground water was observed at the depth of 0.6 m.

The tuffaceous sandstone and the pebble sandstone are fine- to course-grained, poorly cemented, and their N-values are more than 50. The pebbly sandstone contains fragments of andesite and quartz, diameters of which are about 1 cm. The siltstone is highly weathered and fine-grained, and its N-values are more than 50.

The overburden layers consist of clay and silt, which are products of intensive weathering of Genteng formation. The thickness of the overburden is about 2.0 m and its N-values are less than 25.

(2) Cicalengka river (BBG-12)

The superficial geological condition at the Cicalengka river, which is similar to that of BBG-11, mainly consists of Genteng formation and overburden layers. Figure 20 shows the geological profile of the Cicalengka river. The ground water level was observed to be 0.5 m deep. The Genteng formation in this area consists of alternation of tuffaceous siltstone, tuffaceous sandstone, tuffaceous claystone and claystone. N-values of Genteng Formation are more than 50.

The tuffaceous sandstone is fine- to medium-grained, highly weathered and well bedded, and its N-values are more than 50. The tuffaceous claystone and the tuffaceous siltstone are highly weathered and contains lignite. N-values are more than 50.

The overburden layers are composed of clay and silt, thickness of which is 6.0 m. N-values range 7 to 13.

(3) Cimantuk river (BBG-13 and BBG-14)

In this area the Genteng formation is unconformably overlain by the Serpong formation which results from old river deposit. As shown in Figure 19, the left bank is occupied by the Genteng formation while Serpong formation exists in the right bank. The existence of a normal fault is estimated consequently. The Genteng Formation in the left bank consists of tuffaceous sandstone and alternation of claystone, sandy tuff and pumice tuff.

In the left bank the layers of alternation of claystone, sandy tuff and pumice tuff are highly to moderately weathered and fine to medium grained, and their N-values are more than 50. The tuffaceous sandstone results from weathered pumice tuff and its N-values are more than 50 except for the upper portion.

The Serpong formation in the right bank, which is deposited up to 11.5m from the ground surface, is composed of sand and gravel, clay, sand and silt. Those layers are poorly cemented and have N-values of 3 to 13.

(4) Cibunar river (BBG-15 and BBG-16)

The Bojongmanik Formation covered by overburden layers was observed in the bore holes of BBG-15 and BBG-16 as shown in Figure 20. The ground water level was observed at the depth of 2.10 to 2.30 m in depth in the bore holes. The Bojongmanik formation consists of claystone, sandstone, limestone and sandstone with intercalation of claystone.

The sandstone is completely to highly weathered and poorly cemented but its N-values are more than 50. The claystone which is intercalated with limestone and sandstone is well bedded, completely to highly weathered and poorly cemented. Its N-values are more than 50.

Overburden layers which covers Bojongmanik formation consist of clay and silt layers and its thickness is 6.45 m in the left bank and 5.45 m in the right bank. N-values range 8 to 19.

(5) Cimanceuri river (BBG-17, BBG-18 and BRD-3)

The subsurface geology of this area is underlain by the Bojongmanik Formation which strikes N345°E to N360°E and dip 15°. The ground water level was observed to be 3.1 m to 4.7 m deep. The Bojongmanik Formation consists of alternation of sandstone and claystone which intercalate limestone and siltstone in the lower portion observed in the bore holes of BBG-17 and BBG-18, and sandy tuff and tuff in the upper layers observed in the bore hole of BRD-3 as shown in Figure 21. N-values of the Bojongmanik Formation are more than 50.

In the upper portion of the Bojongmanik Formation, the tuff layer is fine-grained, well cemented and completely to highly weathered, and the sandy tuff layer is fine- to medium-grained, poorly graded and completely weathered. N-values of these layers are more than 50. In the lower portion, the siltstone is fine to medium grained, highly weathered, the claystone is very fine grained, well cemented and well bedded and the sandstone is silty and gravely, fine- to medium-grained, completely weathered and poorly cemented. N-values of the lower portion of the Bojongmanik Formation are more than 50.

The overburden layers mainly consist of clay, silt, and sand which are formed from intensively weathered tuff and the thickness of the overburden is 7 m at the Cimanceuri river. N-values of the overburden layers range 3 to 12.

4.1.4 Stretch between Parungpanjang and Serpong (about 10 km)

The water conveyance route in this section encounters mainly Genteng Formation, Quarternary volcanic deposits and alluvial plans. The Genteng Formation is covered by top soil layer with thickness of 2 to 6 m, and dips of bedding is close to horizontal. It is well exposed at the excavated zone along the railway and at banks of river channels.

The Quarternary volcanic is composed of laharic breccia, pillow lave, tuffaceous sandstone and fine tuffs and is distributed in the northern part of this stretch. The vertical outcrops are seen in the sand borrow pits in the old river channels at the Cicayur and the formation is well consolidated. The alluvial deposits are mainly composed of soft silty-sandy clay and distributed only along the river channels.

Serpong water treatment plant is being constructed on the young volcanic deposits with good bearing capacity, which are distributed on the alluvial fans and composed of bedded fine tuff, sandy tuff and interbedded conglomerate tuff.

In general, topographic condition between Parungpanjang and Serpong ranges from EL. 45 m to EL. 55 m.

The following drillings were carried out in this stretch and the geological profiles are described as follows:

The oldest formation along this route is the Bojongmanik formation, which is of late Miocene age, overlain unconformably by the Genteng formation of early Pliocene, which is again overlain unconformably by the Serpong formation (old river product), of late Pliocene. The bedrocks are covered by alluvial fan deposit of middle Pleistocene.

(1) Railway 2 (BRY-2)

This area is underlain by the Bojongmanik formation which consists of alternation of tuffaceous claystone and tuffaceous sandstone as shown in Figure 23. N-values of the Bojongmanik formation are more than 50. The ground water level was observed at 2.60 m in depth.

Tuffaceous claystone is very fine grained, completely weathered and poorly cemented. Tuffaceous sandstone is fine to medium grained, completely weathered, poorly cemented, well bedded.

Overburden layers, covering the Bojongmanik formation, consist of silt and clay and are 5.45 m in total thickness.

(2) Cisadane river (BBG-19, 20, 21 and 22)

As shown in Figure 24, the Genteng formation is unconformably overlain by the Serpong Formation which is covered by alluvial fan and overburden at the Cisadane river. The existence of a normal fault is estimated on the left bank to terminate bound the area of Serpong Formation.

Genteng formation, which are observed in the bore holes of BBG-19, BBG-20 and BBG-22, consists of alternation of tuffaceous sandstone and conglomerate, conglomerate, breccia, pebbly sandstone, pumice tuff, tuff and tuffaceous sandstone. These layers are well bedded and dip 25° to west in the right bank. They dip 2 to 5° in the left bank. N-values of the Genteng Formation are more than 50.

Serpong formation, which are observed in the bore holes of BBG-21 and BBG-22, consists of sandy gravel, gravel, tuff, sandstone and pumice tuff. The pumice tuff of Serpong Formation is poorly cemented, compared with that of Genteng Formation, and is intercalated with black sandy thin layers with cross bedding structure. According to SPT at BBG21, N-value ranges 5 to 18 in the upper portion up to 8.45 m from the river bed, and more than 50 below 8.45 m. N-values of the Serpong Formation at BBG-22 are in a range of 15 to 17.

Alluvial fan, which is observed at BBG-22, is about 11 m thick and consists of silt and clay derived from weathered tuff and pumice tuff. N-values of this layer ranges 7 to 19.

The thickness of the overburden layers in the left bank is 13 m at BBG-19 and 4.3m at BBG-20. The overburden consists of sandy clay and silt layers, N-value of which ranges 12 to 40.

4.2 Structure Foundations

4.2.1 General

The project area is generally underlain by Tertiary taffaceous sedimentary stones of the Genteng Formation and/or the Bojongmanic formation, which are covered by the Serpong Formation, and Young Volcanic and/or Alluvial Deposits with overburden layers, as described in the previous section (4.1).

Taffaceous sedimentary rocks of the Genteng Formation and the Bojongmanic formation are generally classified into soft rock from the geotechnical point of view. In general, the top portion of the soft rock layers, of which thickness ranges 1 to more than 10 m, is weathered and disintegrated into small fragments, and N values are often less than 50. However, the fresh rock portion has enough strength for foundations of structures for the water conveyance way.

The surface soil layers, overburden and top soil, which have a thickness of 2 to 10 m and N values of 3 to more than 50, are not appropriate for the bearing strata for heavy structures such as bridges because of low strength and high compressibility. Embankments will cause settlement of overburden layers due to consolidation, which will be locally long term and large. Drilling logs which are carried out at embankment sites and indicate the subsurface geology are shown in Figure 25.

4.2.2 Shearing Strength of Foundation

(1) Overburden and Top soil

Unconsolidated undrained triaxial tests (UU-test) were carried out to obtain shearing strength characteristics of surface clay and silt layers, which samples were taken within 5 m from the ground surface. Figure 26 show Mohr's circles and envelops. Table 10 shows the summary of the triaxial tests.

In Figure 26, Mohr's circles of BEM-2, BEM-7 and BEX-6 show very low strength among others due to natural water contents of those samples being close to their liquid limits. However, such soft layers are superficial and the thickness of which are thin in general. Those layers must be removed before construction.

Theoretically, the friction angle ϕ of UU-test must be zero if the test is done on 100% saturated clayey soil. However, Mohr's envelop lines in Figure 26 are not horizontal (this means that ϕ - values are greater than zero) because the samples were unsaturated. Figure 27, the relationship between degree of saturation Sr and ϕ of UU-test, shows that ϕ decreases with increasing of Sr. It can be concluded that ϕ - value of the overburden can be greater than zero if the ground water level is low.

The strength parameters of the overburden for design should be determined based on all the Mohr's envelops of test results except for the weak ones mentioned above. As the test results show a wide scatter as shown in Table 10, the design value should be determined in the conservative side. The following values are recommendable for design:

Strength Parameter (Undrained): $C = 3.0\ t/m^2$, $\phi = 10°$
Wet Density: 1.65 t/m^3

(2) Soft rocks

Although no laboratory test has been carried out on soft rocks, the shearing strength is high enough for the foundation of structures of water conveyance way because N-values are more than 50 in the portion of fresh rock. Consequently, at least the following strength can be expected:

Strength Parameter (Drained) $C = 10.0\ t/m^2$ $\phi = 30°$
Wet Density 1.80 t/m^3

4.2.3 Excavation of foundation rocks

Since most of intersections of the water conveyance way and rivers, roads and railways are planned to be syphon, rock excavation will be executed at many intersections.

In general the excavation method of rock is determined based on the elastic wave velocity Vp of rocks and observation of rocks. According to the F/S report of Karian Multipurpose Dam issued in 1985, the elastic wave velocity of the soft rocks up to about 20m deep from the ground surface in this area is estimated in a range of 1.0 to 1.5 km/sec, which means mechanical excavation is possible. In addition to the above data, observation of the boring cores and outcrops and inspection of existing excavated slopes around the project area indicates that mechanical excavation can be done in the soft rock layers.

4.2.4 Consolidation characteristics

In order to obtain consolidation characteristics of the foundation, especially overburden layers and Alluvial deposits, consolidation tests were carried out on undisturbed samples.

Figure 29 shows the results of consolidation tests and test results are summarized in Table 11. The consolidation yield stresses, Pc, range from 6.0 to 19.5 kgf/cm^2. Figure 30, which shows the relationship between present effective overburden pressure S_v versus, indicates that all the samples are overconsolidated and the overconsolidation ratio, $r = Pc/S_v$, ranges 2.0 to 8.0.

The coefficient of compression, Cc, ranging from 0.16 to 0.56 the compressibility of the samples are small to medium. The average of Cc is 0.36.

4.3 Cut slopes

4.3.1 General

In order to obtain the geological conditions and mechanical properties of cut slopes, six drillings, BEX-1 to BEX-6, were carried out at the places where excavation is planned along the water conveyance way.

Figure 31 shows the drilling logs and results of SPT of BEX-1 to BEX-6. According to the figure, the cut slopes are to be composed of two different layers, namely overburden layers comprising clay, silt and sandy tuff and soft rock layers consisting of sandy tuff, tuffaceous sandstone and claystone. Since the geotechnical characteristics of those two layers are quite different from each other, different countermeasures against erosion should be applied to stabilize them.

4.3.2 Shearing strength of cut slopes

Two consolidated and drained test (CD-test) were carried out on sandy tuff in order to obtain long-term and overconsolidated shearing strength characteristics of cut slopes after being unloaded by excavation.

Figure 32 shows the More circles and the failure envelope line of the CD-test and the results are summarized in Table 12. The failure envelope line were drawn with the assumption that the yield stress was about 2.0 kgf/cm^2. The strength parameters C and ϕ of both sample are very similar to each other. The following parameters are recommended for the design:

- Normally consolidated condition: C = 0.0 kgf/cm^2, $\phi = 30.0°$
- Over consolidated condition: C = 0.4 kgf/cm^2, $\phi = 23.0°$

Since the geological classification of soft rock in cut slopes is basically same as that of foundation, the strength parameters recommended for foundations in the previous section (4.2) can be also used for soft rock layers on cut slopes.

4.3.3 Slope protection

Although large scale slope failures may not occur because the soft rock layers in cut slopes is strong enough, local slope failures are anticipated to be caused by gully erosion. Through the field reconnaissance at cut slopes of existing canals and rail ways, it was frequently observed that sod facing works were partly washed out and small scale slope failures were caused by gully erosion. Therefore, slope protection against erosion for cut slopes is necessary to stabilize the slopes and to reduce frequent maintenance works.

4.4 Embankment Materials

4.4.1 General

The embankment material investigation comprising test pittings and laboratory tests was carried out in order to obtain the soil characteristics of various kinds of soils. The locations of test pittings were distributed at excavation sites along the water conveyance route as shown in Figure 1. Test samples were taken mainly from overburden layers and tuffaceous rock layers.

4.4.2 Physical properties

As shown in Figure 13, grading curves of embankment materials can be classified into two groups, i.e. one group is sandy materials, TP-1, 7, 8, 9, which contains sand 40 to 50 %, the other group is clayey materials, TP-2,3,4,5,6,10, which contain sand less than 20%. The sandy material is composed of mainly sandy tuff or decomposed tuffaceous rock and the clayey materials consists of silt and clay of overburden or Alluvial deposits. Table 13 is the summary of the physical properties of test samples.

According to the drillings at excavation sites, the embankment materials will be the mixture of two different materials, however, the volume of the sandy material is estimated to be double of that of clayey material.

Standard compaction tests were carried out on the embankment materials in order to obtain the density and optimum moisture content (OMC) of embankment. Figure 33 shows compaction curves of all samples tested in the laboratory. In the figure, compaction curves of TP-7,8,9 are located in the upper position than others because those samples are sandy material. However, although the grading curve of TP-1 shows sandy material, the compaction curve of TP-1 is plotted in the lower position. The reason may be that the particles of the material of TP-1 are collapsible by compaction energy.

The test results are summarized in Table 13. The value of OMC of each sample is close to the natural water contents except for TP-1 and TP-10.

The density of the embankment for design was calculated with the following assumptions:

- the volume of sandy material is double of that of clayey material
- the density of the embankment is 95% of the maximum density of compaction test

The design values are as follows:

- Average density of sandy materials: $\rho_{ts} = 1.754$ t/m^3
- Average density of clayey materials: $\rho_{tc} = 1.639$ t/m^3
- Density of embankment for design: $\rho_t = 0.95 \times (2 \times \rho_{ts} + \rho_{tc})/3 = 1.630$ t/m^3

4.4.3 Mechanical properties

(1) Shearing strength

In order to examine the shearing strength of embankment materials, triaxial UU-tests were carried out on clayey materials and triaxial CD-tests were performed on sandy materials. Figures 34 and 35 show Mohr circles for UU and CD tests respectively. The following parameters were obtained from the average envelope lines.

Drainage condition	Cohesion C t/m^2	Friction Angle ϕ°
UU-test	8.0	26
CD-test	4.0	27

The ϕ value of UU-test should be zero if the specimen is completely saturated. However, the above table shows large friction angle because the specimens are unsaturated.

It is recommended that the design value of shearing parameters for the embankment material be used the average value of CD-test because sandy material is the majority of the embankment material and the value is more conservative.

(2) Compressibility

Figure 36 shows the results of consolidation tests carried out on the compacted embankment materials and the test results are summarized in Table 14. In general, it is difficult to find linear portion in the e - log p curves of embankment materials shown in Figure 36, and to define the compression index Cc is not easy accordingly. The values of Cc were defined with the assumption that the e - log p curves between P = 0.1 and 3.0 kgf/cm^2 are linear

The weighted averages of Cc and Cv were calculated to obtain design values for settlement analysis by assuming that the volume of sandy material is double of that of clayey material.

- Average values of sandy materials: Cc = 0.06, Cv = 533
- Average values of clayey materials: Cc = 0.095, Cv = 525
- Weighted average for design value: Cc = (2 x 0.06 + 0.095)/3 = 0.07,
  Cv = (2 x 533 + 525)/3 = 531

(3) Permeability

Variable head permeability tests were performed on embankment materials that were compacted to be 95% of maximum density obtained from the compaction test. The permeability coefficients k cm/sec are summarized in Table 15. The table indicates that the range of k is between 10^{-8} and 10^{-7}, which means the permeability of the embankment materials are very low.

4.5 Stability and Settlement of Embankment

4.5.1 Stability of the embankment

Slip circle analysis was executed to examine the stability of the embankment on clayey foundation. The typical analysis model is shown in Figure 37. The thickness of clayey layer in the foundation was assumed to be 10m, which is the maximum thickness in the project area.

The conventional slip circle analysis method, Fellenius Method, was employed and the calculation was carried out with a computer program on PC.

(1) Input parameters

The following parameters determined based on the laboratory test results were used for the analysis:

- Embankment $C = 4.0\ t/m^2$, $\phi = 27°$ (CD-condition)
  $\rho t = 1.63\ t/m^3$
- Foundation
  Case-1: end of construction
  $C = 3.0\ t/m^2$, $\phi = 10°$ (UU-condition)
  $\rho t = 1.65\ t/m^3$
  Case-2: after consolidation has finished
  $C = 7.0\ t/m^2$?, $\phi = 10°$ (UU-condition) ?
  $\rho t = 1.65\ t/m^3$

(2) Calculation case

Case-1: End of construction (without earthquake force)

In general, when the embankment is completed, the safety factor Fs of the embankment becomes minimum if the earthquake force is not considered. Unconsolidated-undrained strength parameters were used for the foundation clayey layer because the foundation is not consolidated yet at the end of construction. The stability analysis was executed for three heights of embankment, i.e. 5, 10, 15 m.

Case-2: Earthquake condition

In this case, the design seismic coefficient k_h, 0.15 determined based on the seismic risk analysis described in chapter 5, was applied. Since consolidation of the clayey layer in the foundation can be assumed to have finished in this case, the increment of strength of the clayey layer due to consolidation was considered in the analysis. The rate of increment of strength C/P was assumed to be 1/3. The embankment heights calculated in this case are same as case-1.

(3) Results of analysis

The results of stability analysis are summarized in Table 16 and the change of safety factor with increase of embankment height is shown in Figure 38. The safety factor is more than 1.2 in any analysis case. As far as this analysis is concerned, it can be concluded that the embankment is stable .

4.5.2 Settlement of embankment

In order to estimate the volume of extra embankment roughly, a preliminary calculation of settlement of embankment was executed based on Terzaghi's one-dimensional consolidation theory with the following parameters, which are weighted average values calculated from laboratory test results:

- Embankment $Cc = 0.07$, $Cv = 530\ cm^2/day$, $\rho t = 1.63\ t/m^3$
  $e_o = 1.103$ (at $P = 1.0\ t/m^2$)
- Foundation $Cc = 0.36$, $Cv = 360\ cm^2/day$, $\rho t = 1.65\ t/m^3$
  $e_o = 1.551$ (at $P = Pc$), $Pc = 10.0\ t/m^2$

a) Final settlement

The final settlement of the primary consolidation was calculated by the following equation:

$$S_f = Cc \cdot H \cdot \log((p + \Delta p)/p)/(1 + e_o)$$

where
- S_f: Final Settlement
- e_o: Initial void ratio
- H: Thickness of clay layer
- p: Initial effective vertical pressure
- Δp: Increment of vertical pressure

Table 17 shows the summary of the final settlement of the embankment and the foundation, and Figure 39 illustrates the result of the calculation.

b) Time - settlement relationship

The settlement at arbitrary time was obtained with the following calculation procedure:

- calculate the settlement - time relationship for instantaneous loading based on the relationship between the time factor Tv and the degree of consolidation Uv shown in Figure 40, and the equation $T_v = C_v \cdot t/H^2$, where t is time and H is the length of drainage(one-half of the thickness of the consolidation stratum if double drainage).

- compute the settlement after loading with the following rule, assuming that the load increment is linear and the increment rate is 5m/month.

The settlement at any time t during the construction period is determined by
settlement = (settlement for instantaneous loading, computed using 0.5•t1) x
(fraction of final load in place)

Following the construction period of duration t1, the settlement is computed by
settlement = (settlement for instantaneous loading, computed using t - 0.5•t1)

Figures 41 to 43 and Table 18 show the time - settlement relationships of various conditions which were calculated with the above assumptions. Table 19 shows the residual settlement, which is the difference between the settlement at arbitrary time and the final setlement.

In Table 19, the value at DT = 0 means the residual settlement at the end of construction, which also means the required thickness of extra embankment for each calculation case. It is clear from the table that the residual settlement would be getting small rapidly with passing time. Since the height of embankment for the water conveyance way is less than 10 m in most cases and the thickness of soft foundation is approximately 5 m in the project area in general, the residual settlement S_r of the embankment might be negligible small if the embankment is left for more than 6 months after construction.

Some high embankments on thick clayey foundations are planned along the water way. Among them, embankments at the Cidurian river and the Cikasungka river are the maximum ones, of which h is 15 m and d is 10 m approximately. Figure 43 shows time-settlement relationships for the case that h = 15 m. In the figure, if d = 5m, S_r is less than 20 cm at six months after construction. However, if d = 10 m, the embankment should be left for more than one and half years to reduce Sr to be less than 20 cm. Therefore, countermeasures, such as pre-loading, foundation treatment or other methods, should be considered to reduce the residual settlement.

5. SEISMICITY

5.1 General

Indonesian archipelago is surrounded by boundaries of tectonic plates, such as the Eurasian continental plate, the Philippine sea plate, the Pacific oceanic plate, and the Indian Ocean-Australian plate as shown Figure 44.

In the south of Java island, there lies the boundary between the Indian Ocean-Australian plate and the Eurasian continental plate, and big earthquakes have happened frequently along the boundary of the plates. Thus, the region of West Java is one of the most seismic area in Indonesia.

5.2 Seismic Data

The historical seismic data in Indonesia during the period from 1970 to 1993, which comprise date, time, coordinates of epicenters and magnitude of earthquake, were provided by the Meteorological and Geophysical Agency of Ministry of Communication. Figures 45 to 47 show the distribution of epicenters of earthquakes in West Java and its vicinity. The data are compiled into the data book in the volume IV of the Final Report.

5.3 Seismic Risk Analysis

A statistic analysis using the historical earthquake data was carried out to obtain the expectancy of the maximum peak ground acceleration (PGA).

(1) Probable earthquake in the project area and its vicinity

Figure 48 shows the logarithmic frequency of magnitude of earthquakes. The following relationship between magnitude and frequency:

$$\log y = 6.12 - 1.07 \cdot M$$

where, y: frequency (1/year)
M: magnitude of earthquake

According to the above equation, the following magnitudes and return periods are expected:

Return Period	Magnitude
10	6.7
50	7.3
100	7.6

(2) Expectancy of PGA in the project area

The relationship between the maximum acceleration and frequency was calculated by using the following attenuation equation, which was developed by the Public Works Research Institute of Ministry of Construction of Japan.

$$\alpha_{max} = 232.5 \cdot 10^{0.313M} \cdot (\Delta+30)^{-1.218} \text{ (Ground type II)}$$

where, α_{max}: Peak Ground Acceleration (PGA) (gal)
M: Magnitude of earthquake
D: Distance from epicenter (km)

Figure 49 shows the relationship between acceleration and frequency governed by the following equation:

$$\log y = 3.85 - 2.52 \cdot \log x$$

where, y: frequency (1/year)
x: PGA (gal)

The expectancy of PGA in the project area is as follows:

Return Period	PGA (gal)
10	84
50	159
100	210

5.4 Design Seismic Coefficient

There is no definite relationship established between PGA and seismic coefficient for design k_h. However, k_h used for the design of structures will be multiplied by the mass of the structure and applied to the structure as a horizontal force while PGA applies to the structure at a moment. Therefore k_h must be less than PGA.

In general, the ratio of k_h and PGA used for the design is usually taken between 1/3 to 2/3 and the return period is determined based on the service life of the structure. It is appropriate that the ratio k_h/PGA, 2/3, and return period, 100 years, are used for the design of the water conveyance system.

The expectancy of PGA for the return period of 100 years is 210 gal. Consequently, it is recommended that 0.15 be used for the design.

TABLES

Table 1 ITEMS AND QUANTITIES FOR GEOTECHNICAL INVESTIGATION WORKS

Work Item		Unit	Quantity
1.	FIELD WORKS		
1.1	Core drilling and Testing in bore holes		
1.1.1	Mobilization and Demobilization	L.S	1
1.1.2	Assembling and Dismantling	nos.	40
1.1.3	Preparation work for core drilling in the river	nos.	2
1.1.4	Core drilling from 0 m to 5 m in depth	m	200
1.1.5	Core drilling over 5 m in depth	m	485
1.1.6	Standard penetration test	nos.	425
1.1.7	Undisturbed sampling	nos.	14
1.2	Test Pitting		
1.2.1	Test pitting with disturbed sampling	nos.	10
2	LABORATORY TEST		
2.1	Phisical Property Test		
2.1.1	Moisture content	nos.	201
2.1.2	Soil particle density	nos.	201
2.1.3	Particle size analysis	nos.	201
2.1.4	Atterberd limits	nos.	101
2.1.5	Density	nos.	14
2.2	Mechanical Property Test		
2.2.6	Compaction test	nos.	10
2.2.7	Variable head permeability test	nos.	8
2.2.8	Uncofined compression test	nos.	11
2.2.9	One dimensional consolidation test	nos.	18
2.2.10	Triaxial compression test (UU)	nos.	18
2.2.11	Triaxial compression test (CD)	nos.	6

Table 2 EQUIPMENT FOR FIELD INVESTIGATION AND LABORATORY TEST

(1) Field Equipment

Item	Quantity	Model No.	Capacity		Power
			Drill hole	Depth	(HP)
Drilling Equipment					
	3	YBM-05	AW(43.7mm)	50m	6.5
	1	YSO-1	AW(43.7mm)	100m	7.5
	1	KOKEN OE-21	AW(43.7mm)	100m	7.5
Water pump	3	YBM SP-70	75 lt/min		
	2	YBM SP -100	105 lt/min		
	1	MG -10	100 lt/min		

(2) Laboratory Test Equipment

Item	Quantity	Model No.	Capacity
Triaxial Test	6	SOILTEST Model T.520.D	Max. Press. = 10 kgf/cm2 Max.Load = 500 kgf D = 35, 50 mm
Unconfined Test	2	Type U.160	Max Load = 150 kgf
Consolidation Test	10 2		25.6 kgf/cm2 50.0 kgf/cm2
Compaction Test	2	Standard Proctor	
Permeability Test	1	Variable Head	

Table 3 TESTING STANDARDS

Test Item	Standard
1. Moisture content	ASTM D2216-90
2. Soil particle density test	ASTM D854-83
3. Particle size analysis	ASTM D422-63
4. Liquid limit test	ASTM D4318-84
5. Plastic limit test	ASTM D4318-85
6. Density test	USBR 5370-89
7. Compaction test	ASTM D698-78
8. Permeability test	Variable head
9. Unconfined compression test	ASTM D2166-85
10. One dimensional consolidation test	ASTM D2435-90
11. Triaxial compression test (UU-test)	ASTM D2850-87
12. Triaxial compression test (CD-test)	USBR 5755-89

Table 4 SUMMARY OF LABORATORY TEST RESULTS ON BORE HOLE SAMPLES (1/5)

Location	Sample No.	Sample Type	Depth from	Depth to	USCS Symbol	Water Content	Liquid Limit	Plastic Limit	Plast. Index	Dry Density	Specific Density	Particle Size Distribution (% passing Sieve mm) 4.76	2.00	0.84	0.42	.177	.074	.030	.010	.003	.001	Uncon. C.-Str.	Triaxial Testing Type	Friction	Cohesion	Compr. Index	Compaction MDD	OMC	Coeff. Perm.
	—	—	—	—	—	Wn	LL	PL	PI	Rho(d)	Rho(s)	—	—	—	—	—	—	—	—	—	—	qu	—	Φ	c	Cc	MDD	OMC	k
	—	—	m	m	—	%	%	%	%	t/m3	t/m3	%	%	%	%	%	%	%	%	%	%	kg/cm2	—	°	kg/cm2	—	t/m3	%	cm/sec
BBG-1	2	SPI	1.55	2.00	CH	36.82	116.00	21.28	94.72		2.658	100.0	98.7	97.0	95.6	90.9	80.3	70.7	61.4	48.6	36.7								
	3	SPI	2.55	3.00	CH	36.52	58.25	22.94	35.31		2.661	100.0	97.4	92.5	88.3	81.2	68.7	43.9	29.2	20.3	13.1								
	5	SPI	4.55	5.00		28.89					2.796	99.0	88.5	73.3	61.0	50.6	43.4	20.3	14.4	7.6	3.1								
	10	SPI	9.55	10.00		46.48					2.791	99.4	99.2	98.1	94.5	73.1	56.0	44.7	32.0	19.7	12.4								
	14	SPI	13.55	14.00		45.45					2.750	100.0	99.3	93.6	80.1	59.2	40.0	24.3	13.4	6.0	2.0								
BBG-2	1	SPI	1.00	1.45	CH	37.04	108.00	22.69	85.31		2.608	100.0	99.6	98.4	97.4	95.8	93.4	85.1	71.3	42.0	24.2								
	2	SPI	2.00	2.45	CH	36.51	73.80	16.15	57.66		2.617	97.6	94.6	91.8	90.0	86.6	79.2	61.9	37.3	18.7	6.9								
BBG-3	1	SPI	1.00	1.45	CH	53.21	88.80	28.75	60.05		2.792	100.0	100.0	99.2	96.8	84.0	68.2	46.4	36.1	17.1	6.2								
	3	SPI	3.00	3.45	MH	49.50	80.70	45.61	35.09		2.796	100.0	99.8	94.8	78.2	66.2	57.4	42.3	32.0	11.3	3.4								
	6	SPI	9.00	9.10		22.05					2.705	85.4	56.4	39.4	30.2	23.6	18.4	7.4	3.1	0.0	0.0								
BBG-4	2	SPI	2.00	2.45	CH	46.19	76.85	29.61	47.24		2.667	100.0	99.6	97.6	92.1	81.2	73.5	64.7	57.5	46.8	32.7								
	5	SPI	5.00	5.45	CH	50.16	78.40	33.95	44.45		2.608	99.4	98.2	94.6	86.0	71.4	62.5	42.8	36.8	28.8	19.6								
	8	SPI	8.00	8.45		43.02					2.643	100.0	100.0	96.2	86.0	70.9	58.6	40.1	24.2	10.5	5.2								
	12	SPI	12.00	12.45		46.01					2.685	100.0	99.5	90.7	78.7	65.5	57.5	33.6	19.7	8.5	5.1								
BBG-5	1	SPI	1.00	1.45	CL	19.56	37.70	14.81	22.89		2.614	100.0	100.0	97.5	89.2	55.3	36.6	30.6	19.4	12.6	6.9								
	2	SPI	2.00	2.45	CH	39.89	77.20	22.89	54.31		2.644	100.0	99.6	97.4	89.9	79.8	72.7	58.9	52.4	43.0	29.2								
	3	SPI	3.00	3.45		38.82					2.602	100.0	98.9	96.4	89.4	79.3	68.3	47.1	25.8	12.7	7.0								
BBG-6	1	SPI	1.00	1.45	CH	63.73	77.85	26.54	51.31		2.694	100.0	100.0	100.0	99.3	87.8	75.4	56.2	45.9	34.4	21.4								
	2	SPI	2.00	2.45	CH	37.07	64.80	30.92	33.88		2.543	100.0	100.0	99.4	98.7	95.5	84.0	67.8	53.0	30.1	17.9								
	3	SPI	3.00	3.45		41.59					2.522	100.0	100.0	99.5	98.0	91.1	77.0	55.1	37.1	19.4	9.0								
BBG-7	2	SPI	2.00	2.45	CH	52.82	72.50	30.77	41.73		2.535	98.2	97.2	95.8	94.8	89.8	80.0	57.3	21.3	4.7	0.6								
	5	SPI	5.00	5.45	CH	48.28	63.55	28.57	34.98		2.536	100.0	100.0	99.8	96.2	84.2	70.0	47.2	17.5	6.7	2.2								
	7	SPI	7.00	7.45		45.06					2.546	100.0	100.0	99.9	99.7	96.9	73.7	37.0	10.2	3.2	0.7								
	11	SPI	11.00	11.32		30.23					2.677	97.8	92.0	73.4	44.4	30.6	26.8	15.4	9.3	2.6	0.6								
	14	SPI	14.00	14.45		30.06					2.654	99.6	98.6	91.8	66.6	35.2	26.0	14.2	7.4	2.6	0.6								
	18	SPI	18.00	18.45		59.65					2.603	100.0	98.8	90.6	78.0	53.0	31.0	18.4	11.6	6.5	2.1								
BBG-8	2	SPI	2.00	2.45	MH	33.72	56.20	34.86	21.34		2.709	98.2	86.0	71.8	65.8	57.2	52.8	37.2	19.1	6.4	3.5								
	4	SPI	8.00	8.32		40.93					2.733	100.0	99.6	97.8	92.2	67.2	48.0	23.2	16.9	10.3	6.4								
	5	SPI	9.00	9.10		38.87					2.677	100.0	97.8	93.6	87.0	68.0	44.6	21.1	14.9	8.1	4.9								
	7	SPI	11.00	11.24		41.88					2.787	99.2	98.8	96.2	93.2	88.2	82.2	54.3	45.7	35.7	23.8								
BBG-9	3	SPI	3.00	3.45	CH	62.83	57.20	21.50	35.70		2.748	100.0	100.0	99.6	98.0	88.0	75.6	57.6	37.5	14.1	6.6								
	5	SPI	5.00	5.45		32.25					2.758	100.0	99.3	95.5	81.8	60.0	40.0	19.3	13.1	6.2	2.0								
	8	SPI	8.00	8.45		21.73					2.745	100.0	99.8	97.8	82.5	70.3	58.6	43.9	24.7	6.4	2.1								
	11	SPI	11.00	11.45		38.41					2.774	100.0	99.8	98.8	82.6	67.0	59.2	36.9	23.5	6.2	2.0								
	13	SPI	13.00	13.45		47.59					2.667	100.0	99.9	99.1	96.3	82.7	67.9	52.5	32.8	10.4	3.6								
	16	SPI	16.00	16.43		44.04					2.742	100.0	99.6	97.6	91.0	74.0	58.0	33.2	18.6	6.2	2.0								
BBG-10	2	SPI	2.00	2.45	CH	55.50	137.00	29.14	107.86		2.773	100.0	99.8	99.5	99.1	98.7	98.3	87.7	77.5	56.8	42.4								
	4	SPI	4.00	4.45	CH	54.65	125.00	29.76	92.21		2.677	100.0	100.0	99.6	99.0	97.8	96.0	84.6	74.3	55.3	40.8								
	6	SPI	6.00	6.45		40.75					2.740	98.9	98.0	92.2	73.9	52.0	46.3	31.0	20.2	6.0	2.0								
	8	SPI	8.00	8.45		46.52					2.665	100.0	100.0	99.6	98.8	96.4	88.8	73.0	60.7	39.6	25.0								

Table 5 SUMMARY OF LABORATORY TEST RESULTS ON BORE HOLE SAMPLES (2/5)

Location	Sample No.	Sample Type	Depth from	Depth to	USCS Symbol	Water Content	Liquid Limit	Plastic Limit	Plast. Index	Dry Density	Specific Density	4.76	2.00	0.84	0.42	.177	.074	.030	.010	.003	.001	Uncon. C.-Str.	Triaxial Type	Triaxial Friction	Triaxial Cohesion	Compr. Index	Compaction MDD	Compaction OMC	Coeff. Perm.
	—	—	—	—	—	Wn	LL	PL	PI	Rho(d)	Rho(s)	—	—	—	—	—	—	—	—	—	—	qu	—	Φ	c	Cc	MDD	OMC	k
	—	—	m	m	—	%	%	%	%	t/m3	t/m3	%	%	%	%	%	%	%	%	%	%	kg/cm2	—	°	kg/cm2	—	t/m3	%	cm/sec
BBG-11	2	SPT	3.50	3.95	CH	46.20	118.40	24.31	94.09		2.636	100.0	100.0	99.5	97.8	89.0	76.8	65.5	60.2	51.1	37.2								
	4	SPT	5.50	5.95	MH	43.76	82.20	46.45	35.75		2.618	100.0	99.7	92.9	79.3	63.8	42.7	19.9	11.5	4.6	2.1								
	5	SPT	9.50	9.95		20.66					2.672	100.0	99.0	84.8	76.2	57.6	42.2	22.0	17.2	10.2	5.0								
	7	SPT	12.45	12.95		43.13					2.662	100.0	98.0	80.8	57.8	36.7	24.9	11.9	7.1	2.4	0.5								
BBG-12	1	SPT	1.00	1.45	CH	55.60	62.70	18.52	44.18		2.731	100.0	99.0	94.9	88.5	77.8	69.0	51.5	40.0	27.9	12.7								
	2	SPT	2.55	3.00	CL	26.41	42.40	17.04	25.36		2.744	100.0	96.8	76.8	49.6	38.0	33.6	23.6	18.9	7.5	0.5								
	3	SPT	4.00	4.45		39.85					2.693	100.0	97.4	91.0	84.2	76.2	66.8	43.7	27.0	7.8	0.5								
	4	SPT	5.55	6.00		43.01					2.672	100.0	100.0	99.0	94.6	85.8	78.8	50.2	34.6	24.4	11.5								
	5	SPT	7.00	7.45		46.47					2.774	100.0	100.0	99.0	95.0	84.0	76.0	63.1	54.7	41.7	23.9								
BBG-13	1	SPT	1.00	1.45	ML	41.18	49.30	32.00	17.30		2.673	99.5	99.1	95.5	81.9	65.5	55.3	39.6	28.4	10.3	3.6								
	2	SPT	2.00	2.45		30.84					2.661	100.0	98.0	90.0	70.6	49.6	39.2	17.7	7.9	2.4	0.0								
	3	SPT	3.00	3.45		26.79					2.647	99.6	94.2	64.2	40.0	27.8	25.8	7.4	3.2	0.2	0.0								
	4	SPT	4.00	4.45		31.35					2.659	100.0	99.6	93.2	63.2	37.6	31.0	11.8	7.3	2.4	0.0								
	5	SPT	5.00	5.45		41.95					2.666	98.2	90.8	78.0	60.0	42.0	28.2	11.6	7.3	2.4	0.0								
BBG-14	2	SPT	2.00	2.45	CH	40.66	58.60	19.46	39.14		2.662	100.0	100.0	99.9	99.1	87.3	64.3	52.6	38.0	18.5	8.4								
	3	SPT	3.00	3.45	CH	36.12	55.70	20.38	35.32		2.669	100.0	100.0	99.4	95.4	73.4	52.2	31.6	19.9	6.3	2.1								
	7	SPT	7.00	7.45		46.24					2.686	100.0	100.0	99.6	96.8	90.2	75.0	58.3	36.9	14.2	5.1								
	11	SPT	11.00	11.45		60.19					2.668	100.0	96.8	88.4	80.6	68.8	56.6	37.6	26.3	12.3	5.2								
	13	SPT	16.00	16.45		84.17					2.673	98.2	93.6	88.8	74.4	69.8	66.8	56.5	41.4	20.4	8.4								
BBG-15	3	SPT	3.00	3.45	CH	31.70	79.79	20.89	55.81		2.619	100.0	100.0	99.5	97.1	83.7	72.7	36.1	27.5	19.0	12.1								
	5	SPT	5.00	5.45	CL	31.11	44.80	14.28	30.52		2.676	100.0	98.6	97.2	79.2	59.2	45.7	29.6	22.3	12.4	6.8								
	7	SPT	7.00	7.45		58.76					2.619	100.0	100.0	99.0	94.2	80.2	72.8	53.1	31.1	10.6	5.3								
	9	SPT	9.00	9.45		32.58					2.606	100.0	99.7	97.5	90.7	67.2	51.6	32.1	22.7	12.6	5.3								
	10	SPT	10.00	10.45		42.86					2.614	100.0	99.8	99.0	96.3	90.7	87.8	73.6	57.7	33.4	18.8								
BBG-16	2	SPT	2.00	2.45	CH	36.27	77.20	18.44	55.76		2.689	100.0	97.8	93.6	77.6	64.2	60.2	39.5	29.3	12.1	5.1								
	3	SPT	3.00	3.45	CH	30.03	68.40	17.04	51.36		2.636	100.0	99.4	98.4	95.4	79.4	61.6	39.5	29.4	14.4	8.4								
	4	SPT	4.00	4.45		67.36					2.689	98.2	96.8	94.8	93.2	89.8	86.6	72.3	56.4	32.7	18.3								
	5	SPT	5.00	5.45		70.94					2.680	100.0	100.0	99.5	98.8	96.8	94.2	78.5	65.4	42.9	27.3								
	6	SPT	6.00	6.45		53.84					2.684	100.0	99.7	99.2	97.6	95.0	90.6	74.4	56.4	32.8	18.3								
BBG-17	3	SPT	3.00	3.45	CH	38.77	77.30	23.63	53.67		2.663	100.0	99.9	99.7	99.1	96.7	85.3	58.6	39.0	18.4	9.9								
	4	SPT	4.00	4.45	CH	46.25	69.60	19.48	50.12		2.633	100.0	99.0	97.6	95.6	91.0	78.4	63.8	46.9	28.9	18.6								
	5	SPT	5.00	5.45		43.13					2.616	100.0	99.8	99.5	99.1	98.3	85.7	66.3	49.3	31.2	17.0								
	7	SPT	7.00	7.45		41.19					2.649	99.4	89.0	81.4	70.0	56.4	40.2	20.6	2.2	0.0	0.0								
	9	SPT	9.00	9.20		32.15					2.747	97.8	96.8	92.6	85.2	70.4	54.2	36.8	25.6	20.1	14.2								
BBG-18	3	SPT	3.00	3.45	CL	40.90	49.10	20.35	28.75		2.774	100.0	100.0	98.4	95.4	77.4	53.4	37.9	16.3	6.2	3.4								
	4	SPT	4.00	4.45	CH	46.65	52.60	20.59	32.01		2.721	100.0	99.8	99.4	98.8	90.4	63.4	43.0	24.5	10.1	5.0								
	5	SPT	5.00	5.45		37.73					2.721	100.0	99.2	98.0	94.6	87.6	82.2	66.3	48.0	21.9	9.6								
	7	SPT	7.00	7.45		39.42					2.731	99.7	99.3	98.5	96.7	89.7	72.7	57.7	41.1	21.9	11.1								
	9	SPT	9.00	9.45		35.00					2.777	100.0	99.8	99.2	94.4	79.9	56.7	35.8	14.2	5.9	1.9								

Particle Size Distribution (% passing Sieve mm) covers columns 4.76 through .001.

Table 6 SUMMARY OF LABORATORY TEST RESULTS ON BORE HOLE SAMPLES (3/5)

Location	Sample No.	Sample Type	Depth from	Depth to	USCS Symbol	Water Content Wn	Liquid Limit LL	Plastic Limit PL	Plast. Index PI	Dry Density Rho(d)	Specific Density Rho(s)	Particle Size Distribution (% passing Sieve mm) 4.76	2.00	0.84	0.42	.177	.074	.030	.010	.003	.001	Uncon. C. Str. qu	Triaxial Testing Type	Friction Φ	Cohesion c	Compr. Index Cc	Compaction MDD	OMC	Coeff. Perm. k
—	—	—	m	m	—	%	%	%	%	t/m3	t/m3	%	%	%	%	%	%	%	%	%	%	kg/cm2	—	°	kg/cm2	—	t/m3	%	cm/sec
BBG-19	3	SPT	3.00	3.45	CH	54.02	146.40	47.45	98.95		2.677	100.0	100.0	99.3	98.3	96.4	93.3	84.9	78.3	71.0	67.6								
	5	IWT	4.60	5.00	CH	62.98	187.00	43.80	143.20	0.994	2.767	100.0	97.6	95.6	93.4	90.6	86.4	67.8	53.1	41.6	31.1	1.138	UU	17.00	0.16	0.337			
	6	SPT	5.00	5.45	MH	54.39	98.80	46.30	52.50		2.643	100.0	100.0	99.8	99.6	98.9	95.1	84.2	72.7	49.8	35.0								
	8	SPT	7.00	7.45		53.39					2.748	100.0	95.3	90.5	85.8	75.9	62.0	43.2	31.8	18.0	11.1								
	10	SPT	9.00	9.45		65.49					2.714	100.0	100.0	99.7	99.4	98.2	96.2	90.7	84.0	74.9	62.5								
	12	SPT	11.00	11.45		59.71					2.611	100.0	100.0	99.7	99.0	93.6	86.0	68.1	58.1	41.5	29.8								
	13	SPT	12.00	12.45		58.35					2.692	100.0	100.0	99.7	98.9	93.6	86.0	66.6	52.3	36.5	23.1								
BBG-20	1	SPT	1.00	1.45	MH	60.56	90.30	43.09	47.21		2.675	100.0	99.2	98.2	96.0	88.4	72.0	43.9	28.1	10.0	2.0								
	2	SPT	2.00	2.45	MH	56.80	97.40	44.44	52.96		2.682	100.0	99.6	98.6	96.4	91.7	82.5	60.8	27.1	10.0	2.0								
	3	SPT	3.00	3.45		39.70					2.627	98.8	92.6	85.8	79.2	68.8	54.2	34.3	20.1	6.2	0.6								
	4	SPT	4.00	4.32		31.78					2.605	100.0	93.4	80.0	65.8	45.8	31.0	14.3	9.3	2.6	0.6								
BBG-21	4	SPT	4.00	4.45	MH	59.88	66.55	39.73	26.82		2.633	100.0	98.4	97.2	95.8	87.8	70.8	53.0	28.7	8.4	3.7								
	6	SPT	6.00	6.45	CH	56.20	59.20	28.88	30.32		2.615	100.0	100.0	98.6	97.8	91.2	66.0	51.2	30.0	8.5	3.7								
	8	SPT	8.00	8.45		42.20					2.750	100.0	99.6	98.0	90.8	60.4	34.0	20.2	7.0	2.4	0.5								
	9	SPT	9.00	9.45		56.24					2.689	94.8	85.6	67.2	48.2	32.2	24.6	9.9	5.1	0.7	0.0								
BBG-22	2	SPT	3.00	3.45	CH	46.44	131.40	41.50	85.50		2.786	100.0	98.4	96.8	95.2	91.2	84.0	74.8	67.9	57.3	44.0								
	5	SPT	5.00	5.45	MH	49.61	109.00	45.13	63.87		2.722	100.0	100.0	99.7	98.9	96.3	92.5	82.6	68.8	48.4	32.0								
	7	SPT	7.00	7.45		51.90					2.622	100.0	100.0	99.8	99.2	97.5	93.9	82.9	69.8	45.0	30.8								
	9	SPT	9.00	9.45		63.05					2.642	100.0	100.0	100.0	99.7	99.3	98.2	89.5	78.8	57.6	41.1								
	10	SPT	10.00	10.45		56.94					2.670	100.0	100.0	100.0	99.5	98.6	96.7	90.9	84.3	67.1	52.3								
	12	SPT	12.00	12.45		55.05					2.635	100.0	100.0	99.3	98.6	95.5	91.1	82.1	72.7	55.3	39.3								
BEM-1	1	SPT	1.00	1.45	CH	41.38	99.20	29.41	69.79		2.671	100.0	100.0	99.7	98.0	90.4	82.0	70.7	66.1	56.9	44.5								
	3	SPT	3.00	3.45	CH	50.91	87.30	31.21	56.09		2.665	100.0	100.0	100.0	99.1	96.1	93.7	85.1	78.5	71.2	58.2								
	8	SPT	8.00	8.45		46.23					2.679	100.0	99.7	96.4	90.5	79.0	57.5	29.2	13.9	5.7	0.7								
BEM-2	2	IWT	1.45	1.85	CH	45.89	50.20	18.02	32.18	1.208	2.633	99.2	95.2	84.8	68.5	57.7	50.7	36.6	30.8	22.8	12.9	0.084	UU	3.50	0.09				
	4	SPT	3.00	3.45	CH	29.60	55.50	29.32	26.18		2.712	98.8	88.2	66.5	55.3	47.4	39.9	29.3	23.1	12.2	6.5								
	7	SPT	6.00	6.45	MH	50.50	59.95	38.30	21.65		2.681	98.8	98.4	85.7	65.9	50.1	42.8	29.6	20.0	10.5	6.7								
	10	SPT	9.00	9.45		37.98					2.650	99.2	97.6	87.8	74.6	57.5	40.0	27.8	21.5	10.4	5.2								
BEM-3	2	SPT	2.00	2.45	CH	52.46	64.70	26.16	38.54		2.772	100.0	97.4	91.4	80.6	70.0	65.2	44.6	30.9	13.7	6.3								
	4	SPT	4.00	4.45	CH	48.38	65.70	26.44	39.26		2.716	100.0	100.0	99.7	98.3	83.3	65.3	35.3	25.0	12.3	6.7								
	8	SPT	8.00	8.45		24.78					2.744	100.0	97.4	90.4	77.2	72.0	62.8	36.9	25.0	9.9	3.9								
BEM-4	1	SPT	1.00	1.45	CH	18.73	100.60	22.60	78.00		2.682	100.0	100.0	97.3	85.5	71.8	55.4	37.4	25.9	12.3	7.5								
	2	IWT	1.45	1.90	CH	52.45	113.40	44.25	69.15	1.063	2.667	100.0	100.0	99.6	98.5	92.8	86.2	68.6	52.1	30.7	16.5	0.694	UU	17.00	0.50	0.322			
	5	SPT	4.00	4.45	MH	56.93	96.10	49.56	46.54		2.672	100.0	99.7	98.1	65.5	94.9	88.5	74.7	59.0	34.9	20.2								
	7	SPT	6.00	6.45		41.35					2.716	97.4	91.0	73.7	55.0	34.8	21.6	9.4	5.2	0.6	0.0								
BEM-5	2	SPT	2.00	2.45	CH	42.56	106.30	23.53	82.77		2.674	100.0	99.8	98.6	95.6	90.0	86.0	68.6	52.0	28.6	14.8								
	4	SPT	4.00	4.45	CH	54.32	108.55	24.14	84.41		2.677	100.0	99.8	99.0	98.0	96.2	93.4	80.5	69.6	47.0	34.4								
	9	SPT	9.00	9.45		62.28					2.735	100.0	99.8	98.6	93.6	84.4	77.6	63.6	46.4	25.9	14.9								

Table 7 SUMMARY OF LABORATORY TEST RESULTS ON BORE HOLE SAMPLES (4/5)

Location	Sample		Depth		USCS	Water Content	Liquid Limit	Plastic Limit	Plast. Index	Dry Density	Specific Density	Particle Size Distribution (% passing Sieve mm)										Uncon. C.-Str.	Triaxial Testing			Compr. Index	Compaction		Coeff. Perm.
	No.	Type	from	to	Symbol	Wn	LL	PL	PI	Rho(d)	Rho(s)	4.76	2.00	0.84	0.42	.177	.074	.030	.010	.003	.001	qu	Type	Friction Φ	Cohesion c	Cc	MDD	OMC	k
—	—	—	m	m	—	%	%	%	%	t/m3	t/m3	%	%	%	%	%	%	%	%	%	%	kg/cm2	—	°	kg/cm2	—	t/m3	%	cm/sec
BEM-6	1	SPT	1.00	1.45	CH	48.64	114.30	24.54	89.76		2.688	100.0	99.8	99.2	98.4	95.4	91.8	80.2	73.7	58.6	38.1								
	2	TWT	1.45	1.85	CH	45.84	121.40	29.20	92.20	1.174	2.649	100.0	99.8	99.0	98.0	96.0	91.0	78.3	69.3	42.8	25.0	1.460	UU	7.50	0.67	0.295			
	5	SPT	4.00	4.45		32.88					2.799	100.0	97.7	93.7	79.1	62.7	46.9	29.4	17.4	2.4	0.5								
	8	SPT	7.00	7.45		39.74					2.678	99.0	97.8	96.2	84.2	51.4	30.8	11.3	5.0	0.6	0.0								
BEM-7	1	SPT	1.00	1.45	CL	31.76	43.85	22.56	21.76		2.757	99.6	99.0	96.6	91.1	86.1	79.6	65.2	44.9	23.6	11.0								
	2	TWT	1.45	1.90	CH	68.62	103.50	38.21	65.29	0.919	2.755	99.6	99.0	96.6	89.6	86.0	79.2	61.3	42.9	23.6	11.0	0.137	UU	3.50	0.08	0.490			
	4	SPT	3.00	3.45	CH	38.55	97.60	33.57	64.03		2.763	100.0	99.5	97.8	95.4	90.8	85.2	67.1	49.0	29.7	17.4								
	5	SPT	6.00	6.45		28.92					2.764	99.6	99.0	97.1	90.1	87.1	80.7	62.5	44.6	26.5	13.1								
BEX-1	1	SPT	1.00	1.45	CH	52.01	78.30	33.33	44.97		2.665	100.0	100.0	99.8	99.4	98.4	96.8	75.9	63.5	35.1	20.0								
	2	TWT	1.45	1.85	CH	49.62	91.40	38.05	53.35		2.614	100.0	100.0	99.7	99.2	98.3	96.5	80.8	64.6	45.8	29.7	0.133	UU	11.50	0.50				
	3	SPT	3.00	3.45		47.64					2.609	100.0	100.0	99.8	99.2	97.8	96.0	85.1	73.5	58.2	44.0								
BEX-2	2	SPT	2.00	2.45	CH	62.58	108.50	43.09	65.41		2.656	100.0	100.0	99.9	99.7	99.3	98.7	84.8	76.7	52.0	40.8								
	4	SPT	4.00	4.45	CH	62.19	124.80	36.76	88.04		2.642	100.0	99.6	98.2	95.7	91.3	87.7	68.5	49.5	26.0	14.1								
	7	SPT	7.00	7.45		35.32					2.630	100.0	100.0	99.8	99.0	96.4	91.4	76.7	63.7	35.3	20.3								
	12	SPT	12.00	12.45		61.63					2.674	100.0	100.0	99.8	99.2	97.6	93.6	75.7	62.6	34.8	19.9								
	16	SPT	16.00	16.13		34.28					2.607	100.0	100.0	99.8	99.4	96.0	88.0	65.7	47.5	27.1	13.6								
BEX-3	2	SPT	2.00	2.45	CH	26.64	53.30	21.05	32.25		2.724	100.0	90.8	79.2	61.2	47.6	38.2	19.3	9.5	4.4	2.0								
	3	TWT	2.45	3.00	CH	29.31	87.20	20.56	66.64	1.387	2.743	100.0	99.2	87.8	73.0	57.1	43.5	25.1	14.0	4.3	2.0	0.763	CD	32.90	0.01				
	5	SPT	4.00	4.45	CH	34.32	55.00	21.95	33.00		2.758	99.6	99.0	89.6	73.8	59.8	48.8	32.8	22.1	7.7	2.0								
	8	SPT	7.00	7.30		46.19					2.687	100.0	99.4	98.0	91.4	76.4	67.2	41.5	24.5	6.1	2.0								
	10	SPT	9.00	9.30		58.75					2.748	100.0	100.0	99.8	97.4	78.2	56.8	29.0	14.1	2.3	0.5								
	15	SPT	14.00	14.45		66.92					2.778	100.0	99.8	98.0	92.6	78.6	62.4	36.8	22.6	7.1	1.9								
BEX-4	1	SPT	1.00	1.45	CH	57.68	119.40	30.32	89.08		2.744	100.0	99.8	99.4	98.2	95.2	91.0	75.4	53.4	23.7	11.1								
	2	SPT	2.00	2.45	CH	68.39	127.10	46.83	80.80		2.687	100.0	100.0	99.0	97.2	93.6	89.2	71.2	53.9	26.4	13.0								
	3	SPT	3.00	3.45		32.94					2.581	97.8	87.0	75.4	61.4	44.4	35.4	20.6	12.8	4.8	2.2								
	4	SPT	4.00	4.45		40.96					2.525	95.8	84.0	70.4	57.6	45.4	39.2	24.2	12.8	4.8	2.2								
BEX-5	2	SPT	2.00	2.45	CH	42.95	96.00	33.33	62.67		2.658	100.0	99.7	97.7	92.7	83.2	68.5	43.8	33.7	16.4	8.4								
	3	TWT	2.45	3.00	CH	43.68	82.10	24.65	57.41	1.144	2.752	100.0	99.8	97.0	83.4	66.4	58.6	42.0	27.8	6.6	2.1	0.376	UU	11.00	0.10				
	4	TWT	3.45	4.00	CH	44.00	87.60	24.60	63.00		2.721	100.0	99.8	96.4	87.8	78.6	71.4	55.9	40.7	18.0	6.6		CD	27.00	0.27				
	6	SPT	4.00	4.45		57.89					2.712	100.0	99.8	99.2	96.8	92.0	79.8	66.0	51.7	28.4	14.7								
	7	SPT	5.00	5.45		54.90					2.688	100.0	99.8	99.4	97.0	91.6	81.8	64.3	46.8	24.5	11.5								
	9	SPT	7.00	7.45		35.31					2.645	100.0	99.7	98.3	91.9	70.9	59.7	37.8	27.5	10.3	3.6								
BEX-6	2	SPT	2.00	2.45	CH	90.07	153.60	45.22	108.38		2.678	100.0	99.0	98.4	97.4	94.0	90.1	74.5	58.4	34.7	19.8								
	3	TWT	2.45	3.00	CH	146.76	184.20	36.75	147.45	0.527	2.587	100.0	98.6	98.0	97.4	96.0	94.2	77.8	64.5	42.3	26.3		UU	2.00	0.02				
	4	SPT	3.00	3.45	CH	92.82	138.00	47.15	90.85		2.677	100.0	99.8	99.1	97.6	93.8	88.4	74.5	58.5	34.7	19.8								
	5	TWT	3.45	4.00	MH	111.18	119.90	50.00	69.90		2.665	100.0	99.6	98.6	94.2	89.6	84.8	68.7	52.1	32.8	20.0		CD	19.70	0.52				
BRD-1	2	SPT	2.00	2.45	CH	57.55	134.40	36.57	97.83		2.720	100.0	99.6	98.7	97.0	95.2	91.0	76.4	67.0	54.4	39.4								
	4	SPT	4.00	4.45	CH	67.52	91.60	37.50	54.10		2.526	100.0	99.5	97.0	91.4	85.4	77.0	57.2	42.2	25.8	16.0								
	7	SPT	7.00	7.45		39.73					2.600	99.3	94.3	74.9	54.0	32.0	24.0	14.7	9.8	4.8	2.2								
	10	SPT	10.00	10.45		33.74					2.625	99.3	92.9	73.0	54.0	42.0	31.0	18.6	13.8	6.5	0.6								

Table 8 SUMMARY OF LABORATORY TEST RESULTS ON BORE HOLE SAMPLES (5/5)

Location	Sample No.	Sample Type	Depth from	Depth to	USCS Symbol	Water Content Wn	Liquid Limit LL	Plastic Limit PL	Plast. Index PI	Dry Density Rho(d)	Specific Density Rho(s)	Particle Size Distribution (% passing Sieve mm) 4.76	2.00	0.84	0.42	.177	.074	.030	.010	.003	.001	Uncon. C.-Str. qu	Triaxial Testing Type	Friction Φ	Cohesion c	Compr. Index Cc	Compaction MDD	OMC	Coeff. Perm. k
—	—	—	m	m	—	%	%	%	%	t/m3	t/m3	%	%	%	%	%	%	%	%	%	%	kg/cm2	—	°	kg/cm2	—	t/m3	%	cm/sec
BRD-2	2	SPT	2.00	2.45	CH	54.16	96.00	36.88	59.12		2.702	100.0	99.4	97.6	94.8	90.8	86.2	72.1	55.0	40.5	28.4								
	4	SPT	4.00	4.45	MH	53.58	103.30	50.86	52.44		2.674	100.0	100.0	99.8	99.3	96.1	88.9	70.5	61.2	48.8	40.4								
	7	SPT	7.00	7.45		61.25					2.740	100.0	100.0	99.7	98.1	94.5	85.9	69.4	54.9	33.9	20.9								
	12	SPT	12.00	12.45		33.01					2.675	100.0	99.8	96.0	82.2	68.6	58.8	41.4	28.0	14.3	9.2								
BRD-3	1	SPT	1.00	1.45	CH	29.47	95.00	33.13	61.87		2.673	98.6	98.2	97.8	97.5	91.9	81.9	61.2	48.3	28.6	18.2								
	2	SPT	2.00	2.45	CH	20.51	60.75	26.62	34.13		2.766	100.0	99.6	96.6	87.4	65.0	37.4	18.8	9.3	2.5	0.5								
	3	SPT	3.00	3.45		51.34					2.652	99.2	97.8	95.4	90.4	75.6	54.2	33.3	14.7	4.5	2.1								
	4	SPT	4.00	4.45		47.57					2.659	99.6	98.4	96.4	93.2	84.6	75.2	59.0	39.1	14.2	5.2								
BRY-1	1	SPT	1.00	1.45	CH	45.84	101.40	28.87	72.53		2.677	100.0	100.0	99.8	99.4	96.8	93.8	78.5	65.3	46.8	30.6								
	2	TWT	1.45	1.90	CH	36.20	124.00	33.33	90.67	1.206	2.753	100.0	99.7	96.3	87.5	76.1	70.1	50.7	40.1	19.7	9.8	1.073	UU	14.00	0.25	0.361			
	4	SPT	3.00	3.45	CH	50.97	119.50	28.58	90.97		2.747	100.0	99.7	96.7	88.7	78.8	73.5	60.3	45.2	24.3	13.1								
	7	SPT	6.00	6.45		42.36					2.686	100.0	98.6	95.4	86.8	71.2	57.8	38.8	28.0	9.9	3.6								
	9	SPT	8.00	8.45		43.46					2.772	100.0	98.4	95.2	89.4	69.6	48.4	36.2	19.0	6.5	2.2								
	11	SPT	10.00	10.25		25.36					2.728	100.0	99.8	97.8	92.4	76.6	62.4	41.0	27.8	8.2	3.5								
BRY-2	2	TWT	1.55	2.00	CH	61.77	140.60	34.21	106.39	0.919	2.674	100.0	100.0	99.8	99.4	97.8	95.4	82.7	70.1	51.2	34.9	0.378	UU	15.00	0.19				
	3	SPT	2.00	2.45	MH	69.53	125.65	61.54	64.06		2.677	100.0	100.0	99.0	98.8	98.3	95.7	80.6	67.8	47.1	33.0								
	4	SPT	3.00	3.45	MH	59.05	124.00	71.43	52.57		2.674	100.0	99.4	98.0	96.2	93.6	88.4	77.6	56.6	30.8	16.6								
	5	SPT	4.00	4.45		73.43					2.742	100.0	99.6	99.3	97.9	80.1	62.1	33.2	24.8	12.2	6.6								
	6	SPT	5.00	5.45		63.56					2.674	100.0	100.0	99.9	99.0	97.7	95.5	80.7	67.7	45.1	31.1								
	7	SPT	6.00	6.45		47.06					2.679	100.0	100.0	98.3	96.3	86.3	65.1	43.6	31.5	18.4	9.9								

Table 9 SUMMARY OF LABORATORY TEST RESULTS ON TEST PIT MATERIALS

Location	Sample		Depth		USCS	Water Content	Liquid Limit	Plastic Limit	Plast. Index	Dry Density	Specific Density	Particle Size Distribution (% passing Sieve mm)										Uncon. C.-Str.	Triaxial Testing			Compr. Index	Compaction		Coeff. Perm.
	No.	Type	from	to	Symbol	Wn	LL	PL	PI	Rho(d)	Rho(s)	4.76	2.00	0.84	0.42	.177	.074	.030	.010	.003	.001	qu	Type	Friction Φ	Cohesion c	Cc	MDD	OMC	k
	—	—	m	m	—	%	%	%	%	t/m3	t/m3	%	%	%	%	%	%	%	%	%	%	kg/cm2	—	°	kg/cm2	—	t/m3	%	cm/sec
TP-1	1	EXC.	0.50	1.00	CH	27.23	69.90	31.91	37.99		2.631	100.0	98.8	95.2	88.2	73.6	60.4	44.6	28.7	12.5	6.8		UU CD	28.00 44.00	4.50 0.28	0.145	1.125	38.00	7.32E-08
TP-2	1	EXC.	0.75	2.00	CH	43.33	120.40	30.65	89.75		2.682	100.0	99.0	98.8	98.6	98.2	98.0	83.9	71.9	50.7	36.7		UU	25.50	0.95	0.230	1.175	42.20	4.53E-08
TP-3	1	EXC.	0.00	2.00	MH	47.29	110.40	43.44	66.96		2.673	100.0	99.0	97.6	95.9	94.0	92.0	76.3	65.5	48.9	36.5		UU	26.00	0.90	0.227	1.158	45.00	4.75E-08
TP-4	1	EXC.	0.00	2.00	MH	47.29	111.50	52.38	59.12		2.713	100.0	100.0	99.8	99.5	96.8	94.0	79.5	65.6	50.3	39.6		UU	23.50	0.55	0.157	1.090	48.50	1.48E-07
TP-5	1	EXC.	0.00	2.00	CH	42.48	125.20	46.02	79.18		2.719	98.2	96.2	94.8	92.8	89.6	85.6	69.1	54.0	29.3	16.9		UU	29.00	0.75	0.390	1.152	45.00	7.57E-08
TP-6	1	EXC.	0.80	2.00	CH	45.47	108.60	44.88	63.72		2.718	100.0	99.6	97.8	94.2	89.2	84.2	68.4	51.1	30.2	17.8		UU	25.00	0.90	0.223	1.135	44.30	
TP-7	1	EXC.	2.90	3.00		30.65					2.714	100.0	99.8	96.0	78.0	59.0	51.0	33.2	22.5	7.9	2.0		CD	20.20	0.53	0.195	1.360	27.00	5.15E-08
TP-8	1	EXC.	1.00	2.00		29.66					2.779	98.8	94.4	86.8	74.8	63.2	58.4	34.8	23.3	9.1	0.5		CD	25.90	0.28	0.193	1.550	23.60	4.42E-08
TP-9	1	EXC.	0.60	1.00	CH	20.06	56.80	25.91	30.89		2.609	99.8	98.4	95.4	90.6	78.8	63.4	30.2	13.1	2.6	0.6		CD	34.90	0.47	0.098	1.255	29.00	5.12E-07
TP-10	1	EXC.	1.60	2.00		29.54					2.724	100.0	99.0	97.4	95.0	87.0	80.4	64.1	46.6	28.1	16.0		CD	27.40	0.43	0.413	0.936	58.50	5.53E-08

Table 10 SUMMARY OF TRIAXIAL TEXT ON UNDISTURBED SAMPLE (UU-TEST)

Drilling No.	Depth (m)	Soil type	LL (%)	wn (%)	Sr (%)	C(t/m2)	ϕ
BBG-19	4.65 ~ 5.00	clay	187.0	58.0	95.4	1.5	18.0
BEM-2	1.45 ~ 2.00	silty sand	50.0	37.0	99.0	1.1	2.5
BEM-4	1.45 ~ 1.90	sandy tuff	113.4	52.0	93.0	4.7	17.7
BEM-6	1.45 ~ 1.85	clay	121.0	46.0	97.0	6.5	8.5
BEM-7	1.60 ~ 2.00	silty sand	103.0	69.0	95.0	1.2	2.9
BEX-1	1.45 ~ 1.85	w. s. stone	91.0	51.0	87.0	0.5	11.9
BEX-6	2.45 ~ 3.00	sandy clay	184.0	147.0	97.0	0.3	3.0
BRY-1	1.45 ~ 1.90	silt	124.0	36.0	78.0	5.0	6.7
BRY-2	1.55 ~ 2.00	clay	141.0	62.0	87.0	1.5	15.5

Table 11 SUMMARY OF CONSOLIDATION TEST ON UNDISTURBED SAMPLE

Drilling No.	Depth (m)	Soil type	LL (%)	wn (%)	eo	Pc(t/m2)	Cc	Cv(cm2/d)
BBG-19	4.65 ~ 5.00	clay	187.0	58.0	1.689	15.8	0.30	150
BEM-2	1.45 ~ 2.00	silty sand	50.0	37.0	0.974	9.0	0.16	500
BEM-4	1.45 ~ 2.00	sandy tuff	113.4	52.0	1.509	11.4	0.31	500
BEM-6	1.45 ~ 1.85	clay	121.0	46.0	1.256	19.5	0.31	250
BEM-7	1.60 ~ 2.00	silty sand	103.0	69.0	1.998	6.0	0.48	350
BRY-1	1.45 ~ 1.90	silt	124.0	36.0	1.283	6.2	0.34	350
BRY-2	1.55 ~ 2.00	clay	141.0	62.0	1.909	18.5	0.56	500

Table 12 SUMMARY OF TRIAXIAL TEST ON UNDISTURBE SAMPLE (CD-TEST)

Drilling No.	Depth (m)	Soil type	LL (%)	wn (%)	Sr (%)	Normally Consolidated		Over Consolidated	
						C(t/m2)	ϕ	C(t/m2)	ϕ
BBG-19	2.45 ~ 3.00	sandy tuff	82.0	44.0	100.0	0.0	31.0	4.0	22.5
BEM-2	3.45 ~ 4.00	sandy tuff	120.0	114.0	100.0	0.0	28.0	4.0	23.0

Table 13 PHYSICAL PROPERTIES OF EMBANKMENT MATERIALS

Pit No.	Material Type	Pasing #200 (%)	Wn (%)	OMC (%)	Max. dry density t/m3	Max. wet density t/m3	Specific Gravity t/m3
TP-1	sandy	60.4	27.2	38.0	1.130	1.559	2.631
TP-2	clayey	98.0	43.3	42.2	1.174	1.669	2.682
TP-3	clayey	92.0	47.3	45.0	1.157	1.678	2.676
TP-4	clayey	94.0	47.3	48.5	1.090	1.619	2.713
TP-5	clayey	85.6	42.5	45.0	1.152	1.670	2.791
TP-6	clayey	84.2	45.5	44.3	1.135	1.638	2.718
TP-7	sandy	51.0	30.7	27.0	1.360	1.727	2.714
TP-8	sandy	58.4	30.0	23.6	1.550	1.916	2.779
TP-9	sandy	63.4	20.1	29.0	1.255	1.619	2.609
TP-10	clayey	80.4	29.5	58.5	0.936	1.484	2.724

Table 14 SUMMARY OF CONSOLIDATION TEST ON EMBANKMENT MATERIALS

Pit No.	Material Type	e0 (P=1.0 kgf/cm2)	Cc	Cv (cm2/day)
TP-1	sandy	1.202	0.07	650
TP-2	clayey	1.337	0.14	350
TP-3	clayey	1.341	0.08	500
TP-4	clayey	1.341	0.07	450
TP-5	clayey	1.745	0.15	700
TP-6	clayey	1.462	0.06	500
TP-7	sandy	1.004	0.06	500
TP-8	sandy	0.801	0.06	500
TP-9	sandy	1.050	0.06	600
TP-10	clayey	2.305	0.09	1050

Note: Cc is the avarage slope between P = 1.0 to 30.0 t/m2

Table 15 SUMMARY OF PERMEABILITY TEST ON EMBANKMENT MATERIALS
(Variable head permeability test)

Pit No.	Coefficient of Permeability (cm/sec)
TP-1	7.323×10^{-8}
TP-2	4.525×10^{-8}
TP-3	4.752×10^{-8}
TP-4	1.475×10^{-7}
TP-5	7.572×10^{-8}
TP-7	5.15×10^{-8}
TP-8	4.416×10^{-8}
TP-9	5.118×10^{-7}
TP-10	5.527×10^{-8}

Table 16 SUMMARY OF STABILITY ANALYSIS

Height of Embankment (m)	Safety Factor	
	Case -1 End of Construction (without earthquake)	Case- 2 Earthquake Condition (kh = 0.15)
5	3.224	2.029
10	2.041	1.435
15	1.597	1.276
Remarks	Strength parameters under UU-condition for foundation were used	Strength increase of foundation due to consolidation was considered

Table 17 FINAL SETTLEMENT OF EMBANKMENT AND FOUNDATION

Height of Embankment (m)	(1) Settlement of Embankment (m)	d = 5m		d = 10 m	
		(2) Settlement of Foundation (m)	Total Settlement (1)+(2) (m)	(3) Settlement of Foundation (m)	Total Settlement (1)+(3) (m)
5	0.104	0.064	0.168	0.307	0.411
10	0.289	0.221	0.510	0.557	0.846
15	0.512	0.325	0.837	0.734	1.246
20	0.760	0.403	1.163	0.872	1.632

Note: "d" denotes the thickness of the soft foundation where consolidation would occur

Table 18 TIME- SETTLEMENT RELATIONSHIP

(Unit: m)

Time	h=5 m		h=10 m		h=15 m	
(Month)	d=5 m	10 m	5 m	10 m	5 m	10 m
1	0.06	0.09				
2	0.11	0.16	0.19	0.21		
3	0.13	0.20	0.26	0.30	0.30	0.32
4	0.15	0.23	0.32	0.37	0.38	0.41
5	0.15	0.25	0.35	0.42	0.45	0.51
6	0.16	0.27	0.38	0.47	0.49	0.57
7	0.16	0.29	0.40	0.51	0.53	0.63
8	0.16	0.30	0.42	0.56	0.56	0.69
9	0.17	0.31	0.44	0.59	0.58	0.74
10	0.17	0.32	0.45	0.62	0.61	0.78
11	0.17	0.33	0.46	0.64	0.62	0.82
12	0.17	0.34	0.47	0.67	0.64	0.86
14	0.17	0.35	0.48	0.70	0.66	0.92
16	0.17	0.37	0.49	0.74	0.68	0.96
18	0.17	0.37	0.49	0.75	0.71	1.02
20	0.17	0.38	0.50	0.77	0.73	1.05
24	0.17	0.39	0.51	0.80	0.76	1.11
∞	0.17	0.41	0.51	0.85	0.84	1.25

Note: Time denotes time from commencement of construction
d denotes thickness of the clay layer of foundation
h denotes height of the embankment

Table 19 RESIDUAL SETTLEMENT

(Unit: m)

DT	h=5 m		h=10 m		h=15 m	
(Month)	d=5 m	10 m	5 m	10 m	5 m	10 m
0	0.11	0.32	0.32	0.64	0.53	0.92
6	0.01	0.13	0.09	0.29	0.26	0.51
12	0.00	0.06	0.03	0.14	0.15	0.29
18	0.00	0.04	0.01	0.07	0.11	0.19
24	0.00	0.02	0.00	0.03	0.07	0.11

Note: DT denotes time from completion of construction
d denotes thickness of the clay layer of foundation
h denotes height of the embankment

FIGURES

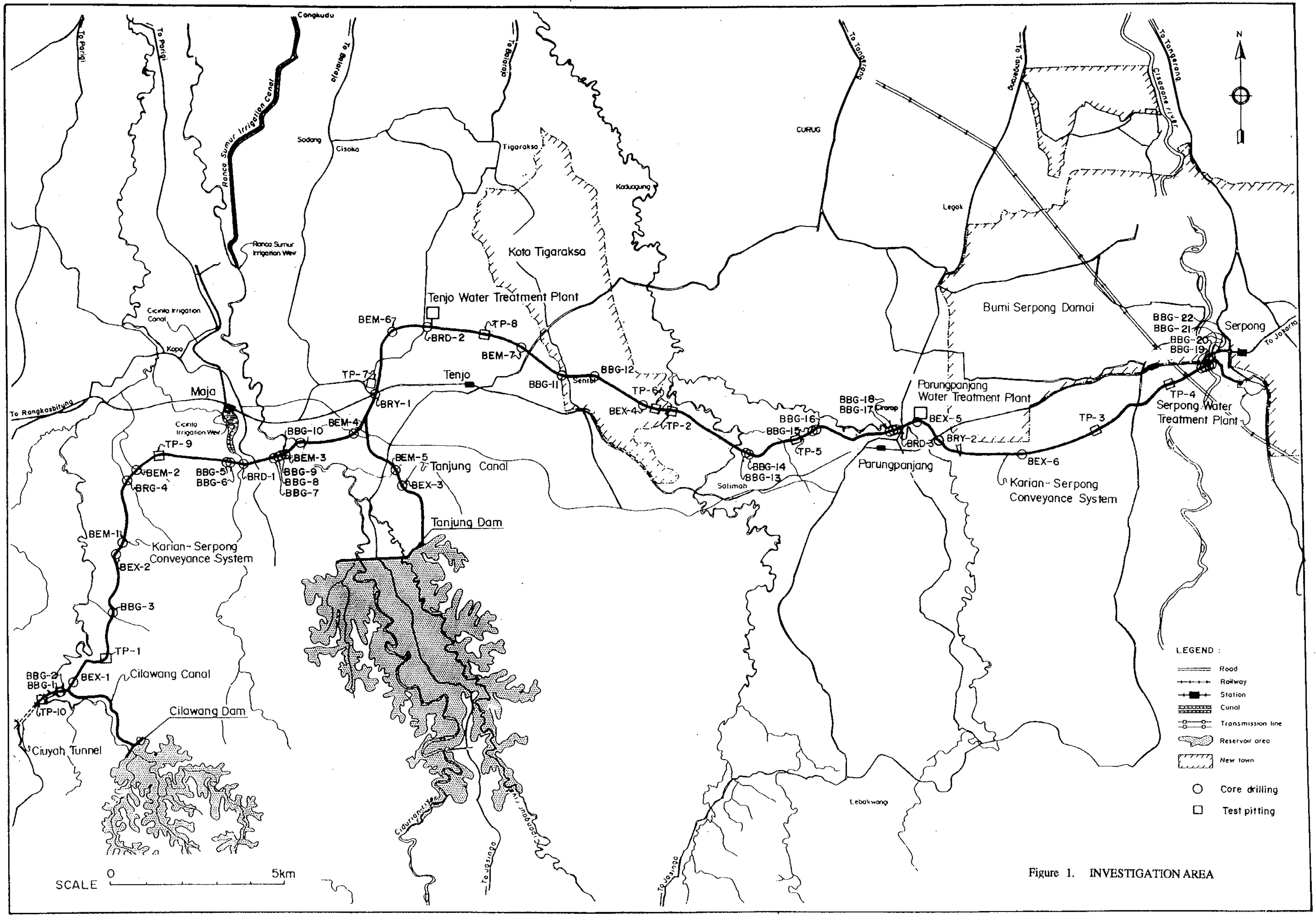


Figure 1. INVESTIGATION AREA

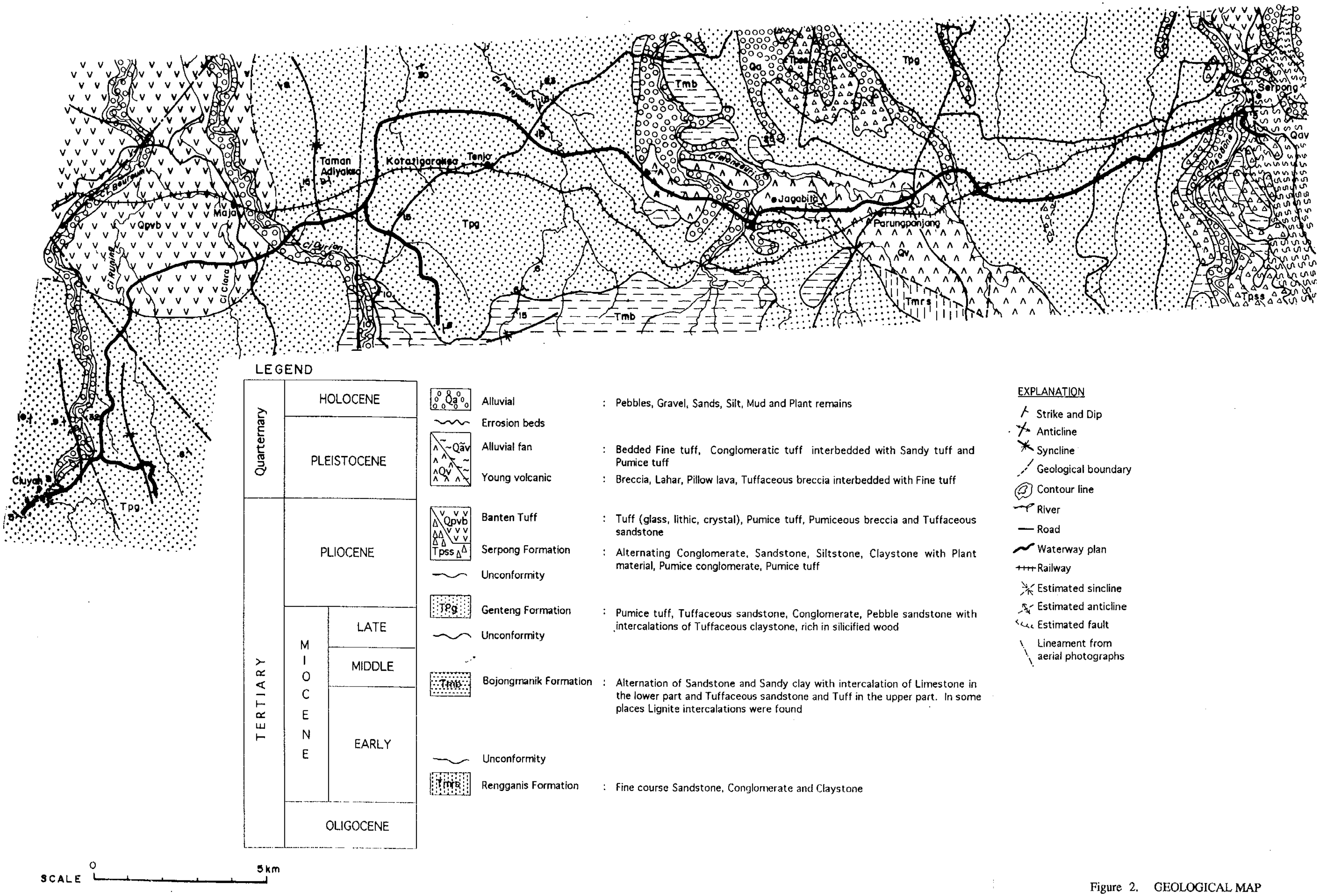
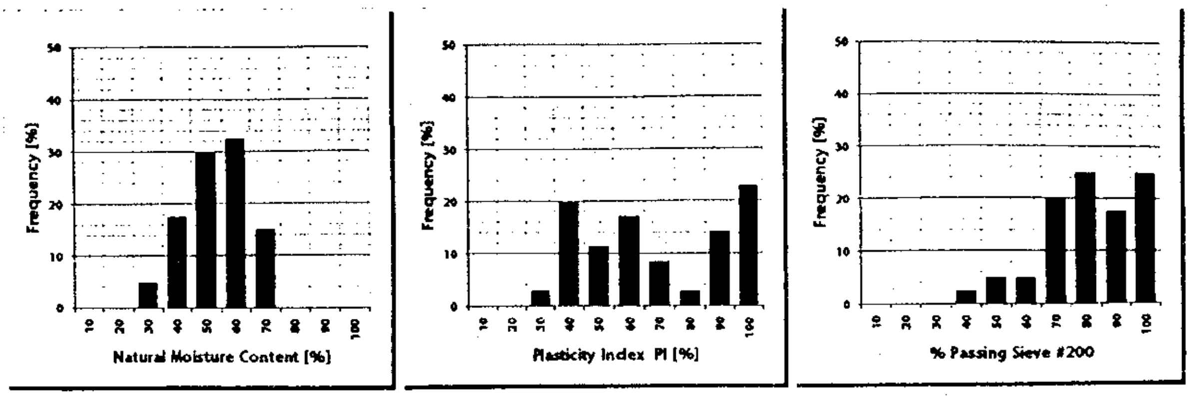


Figure 2. GEOLOGICAL MAP

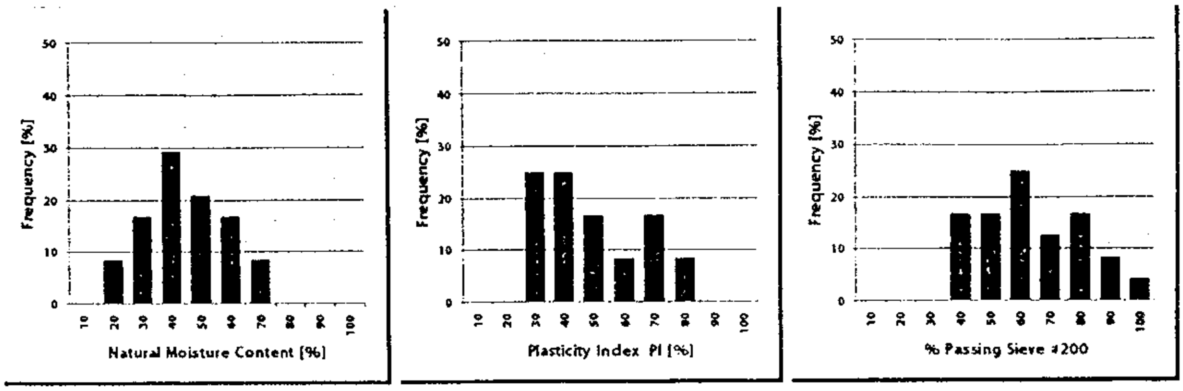
SCALE 10⁶ Th	AGE			SYMBOLS	FORMATION & LITHOLOGY UNIT	LITHOLOGY	SEDIMENTARY ENVIRONMENT
	Quarternary	HOLOCENE		Qa	Alluvial	Pebbles, Gravel, Sands, Silt, Mud and Plant remains	Fluviatile
					Errosion beds		
		PLEISTOCENE		Qav	Alluvial fan	Bedded Fine tuff, Conglomeratic tuff interbedded with Sandy tuff and Pumice tuff	Terrestic
				Qv	Young volcanic	Breccia, Lahar, Pillow lava, Tuffaceous breccia interbedded with Fine tuff	Terrestic
	TERTIARY	PLIOCENE		Qpvb	Banten Tuff	Tuff (glass, lithic, crystal), Pumice tuff, Pumiceous breccia and Tuffaceous sandstone	Terrestrial to Tidal
				Tpss	Serpong Formation	Alternating Conglomerate, Sandstone, Siltstone, Claystone with Plant material, Pumice conglomerate, Pumice tuff	Fluviatile (Braided old river)
					Unconformity		
5		MIOCENE	LATE	TPg	Genteng Formation	Pumice tuff, Tuffaceous sandstone, Conglomerate, Pebble sandstone with intercalations of Tuffaceous claystone, rich in silicified wood	Littoral to Terrestic
					Unconformity		
10, 15			MIDDLE	Tmb	Bojongmanik Formation	Alternation of Sandstone and Sandy clay with intercalation of Limestone in the lower part and Tuffaceous sandstone and Tuff in the upper part. In some places Lignite intercalations were found	Shallow neritic to Brackish water
20			EARLY		Unconformity		
				Tmrs	Rengganis Formation	Fine course Sandstone, Conglomerate and Claystone	Marine
		OLIGOCENE					

Figure 3. LOCAL STRATIGRAPHY LOG

Silt or Clay



Sand or Tuff



Tuffaceous Stones or Stones

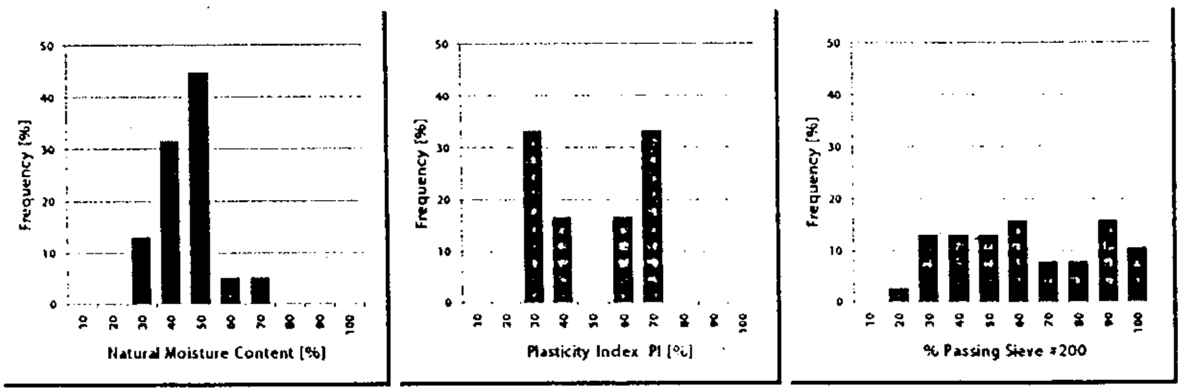
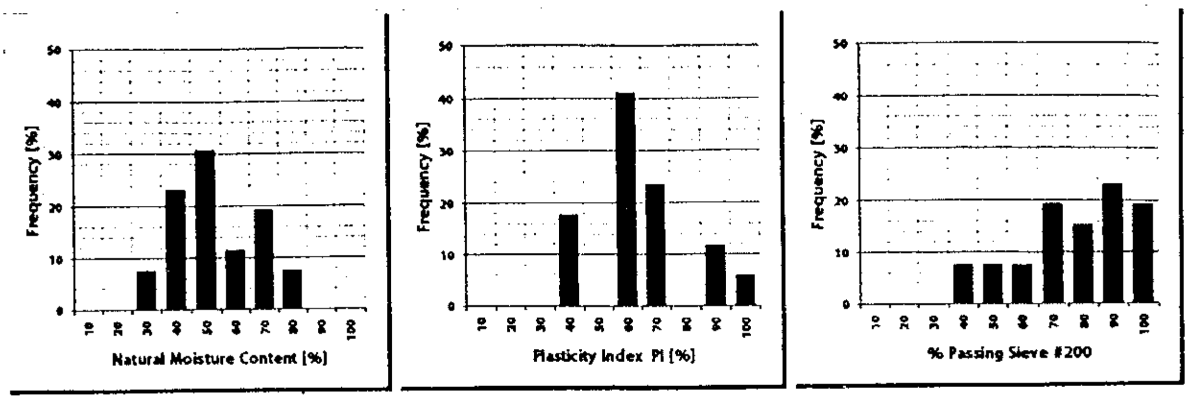
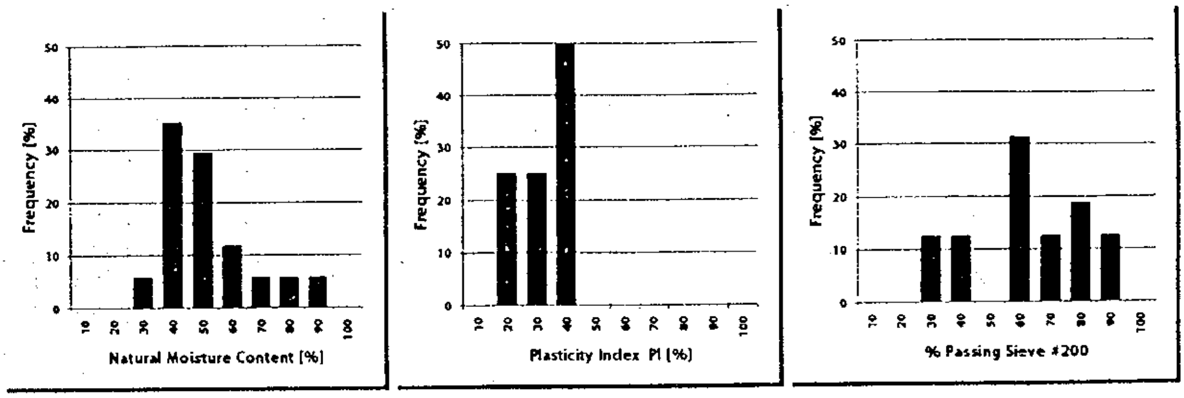


Figure 4. FREQUENCY DISTRIBUTION CHARTS (BORE HOLE SAMPLES), SECTION : CIUYAH-TENJO

Silt or Clay



Sand or Tuff



Tuffaceous Stones or Stones

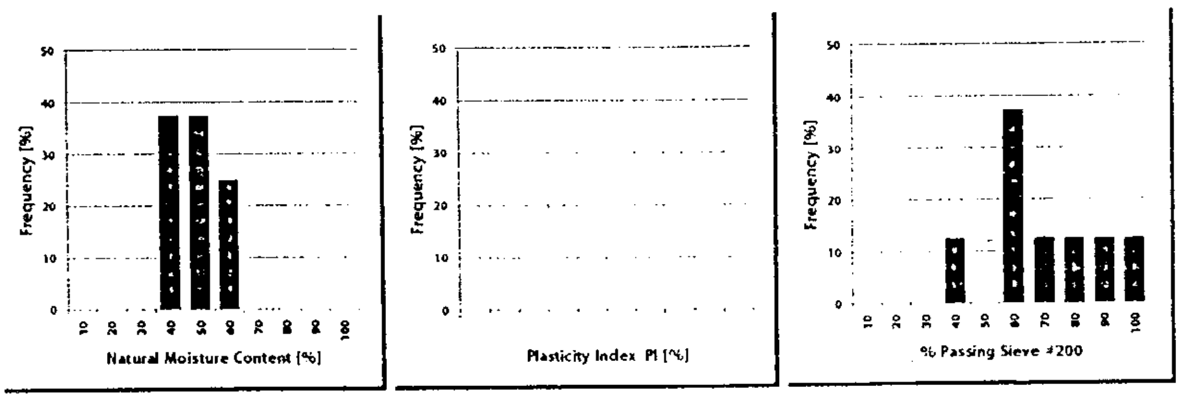
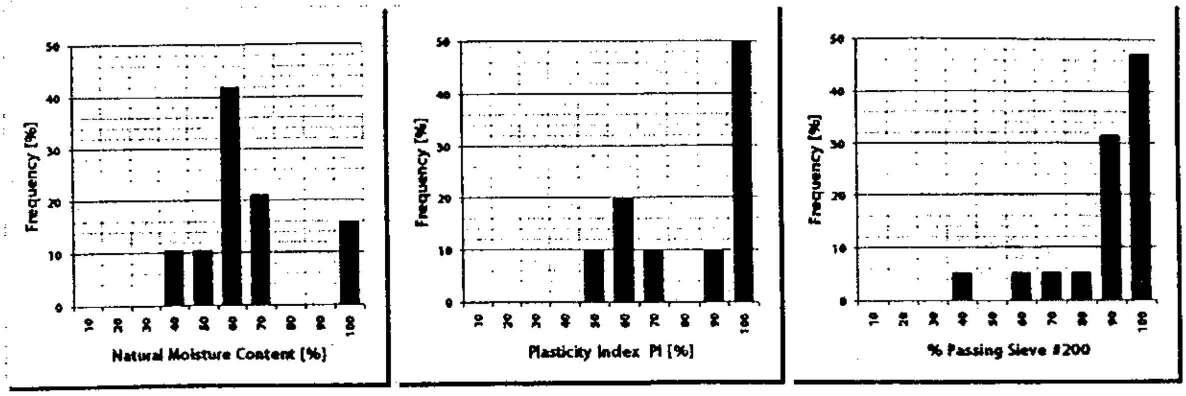


Figure 5. FREQUENCY DISTRIBUTION CHARTS (BORE HOLE SAMPLES), SECTION : TENJO-PARUNGPANJANG

Silt or Clay



Sand or Tuff

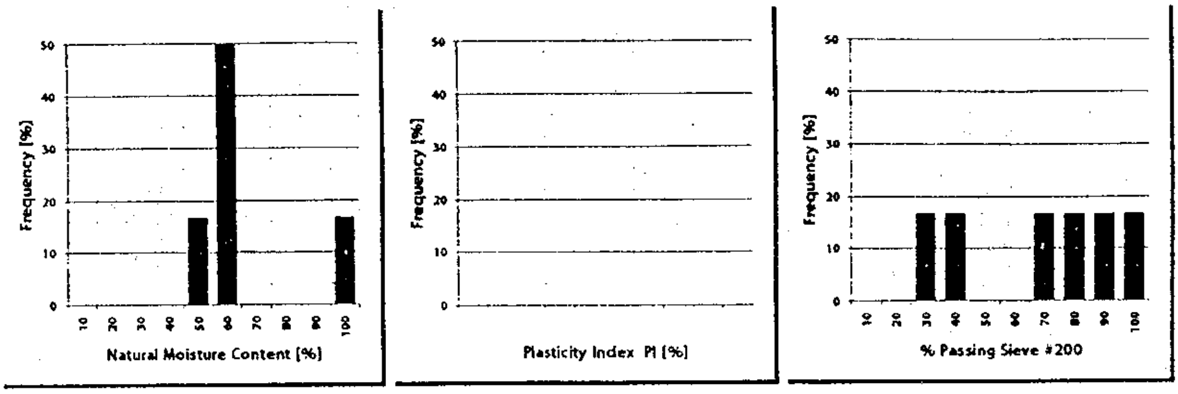
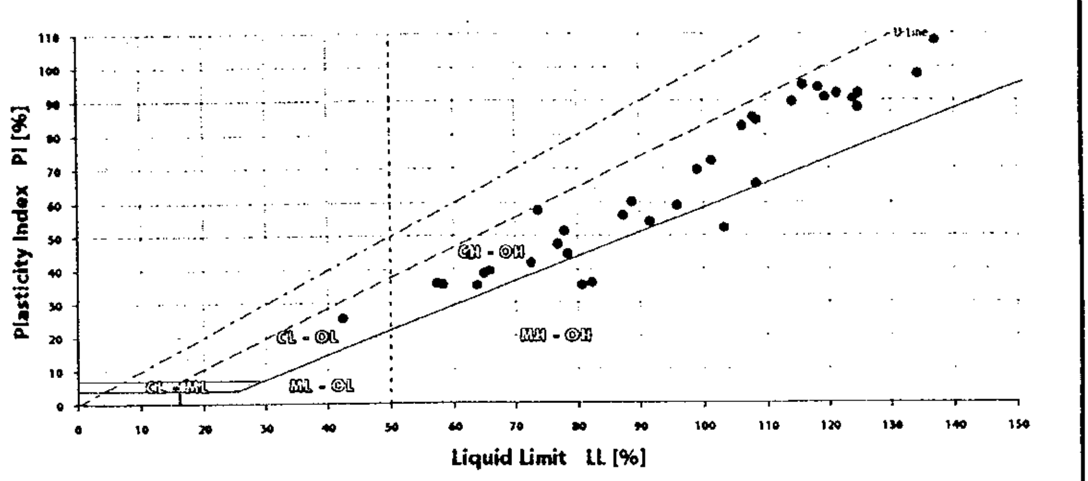
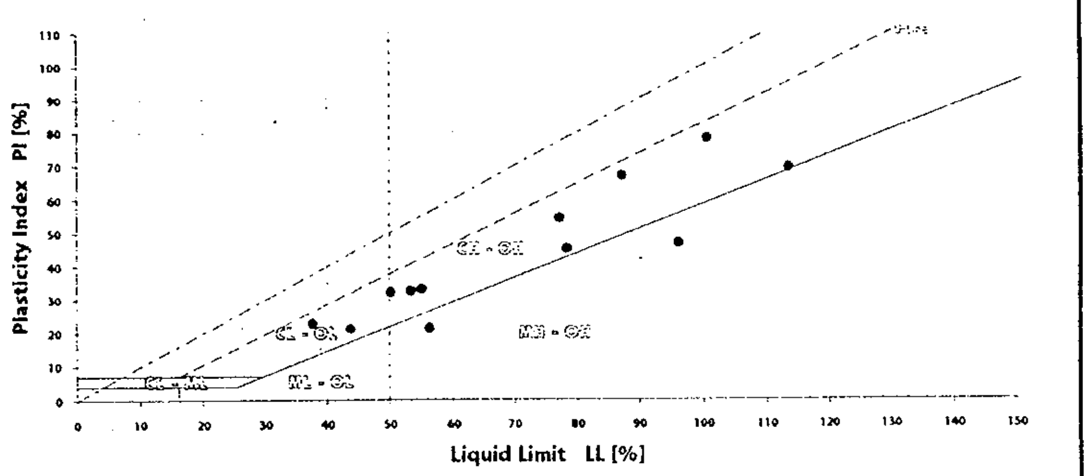


Figure 6. FREQUENCY DISTRIBUTION CHARTS (BORE HOLE SAMPLES),
SECTION : PARUNGPANJANG-SERPONG

Silt or Clay



Sand or Tuff



Tuffaceous Stones or Stones

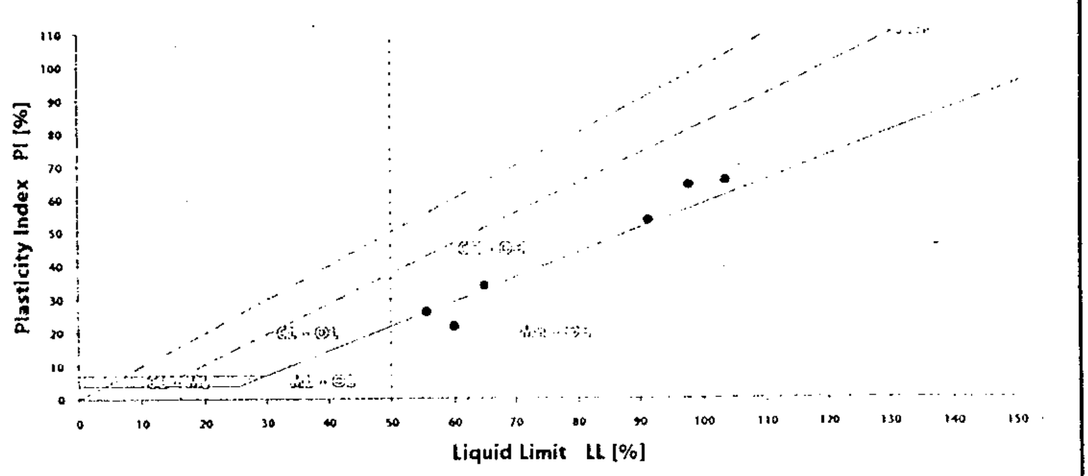
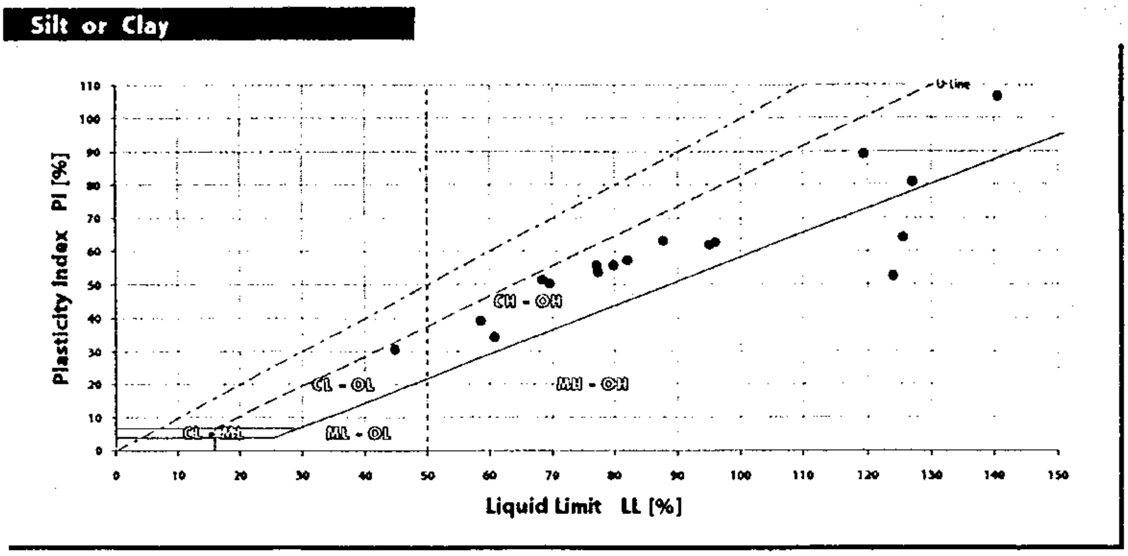


Figure 7. PRASTICITY CHARTS (BORE HOLE SAMPLES), SECTION : CIUYAH-TENJO



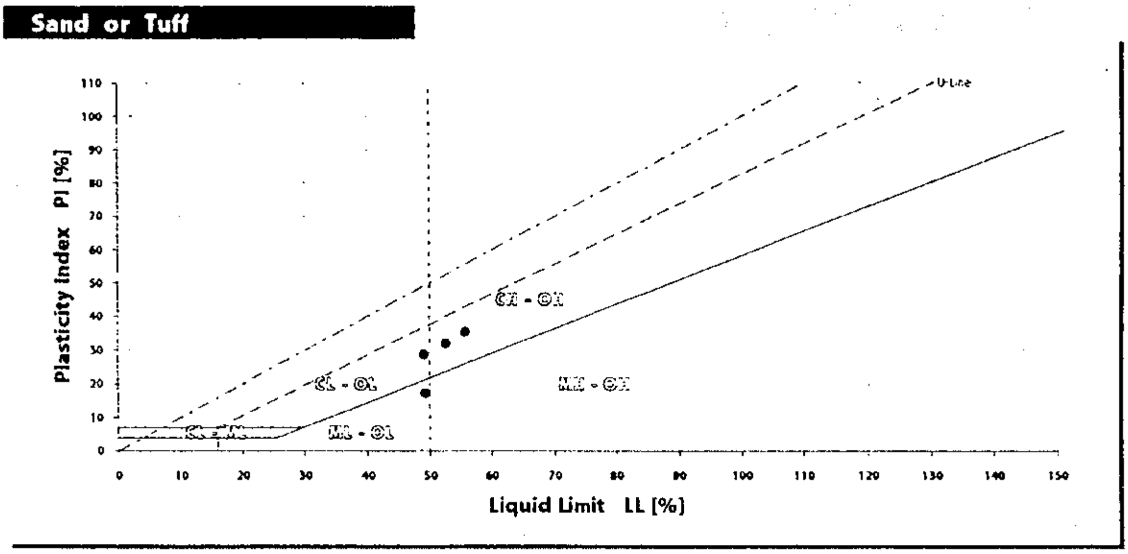
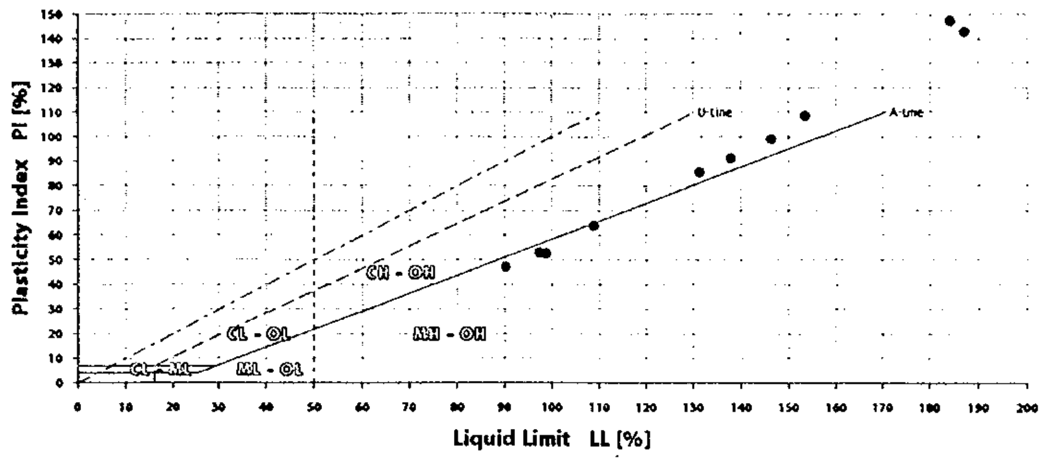


Figure 8. PRASTICITY CHARTS (BORE HOLE SAMPLES), SECTION : TENJO-PARUNGPANJANG

Silt or Clay



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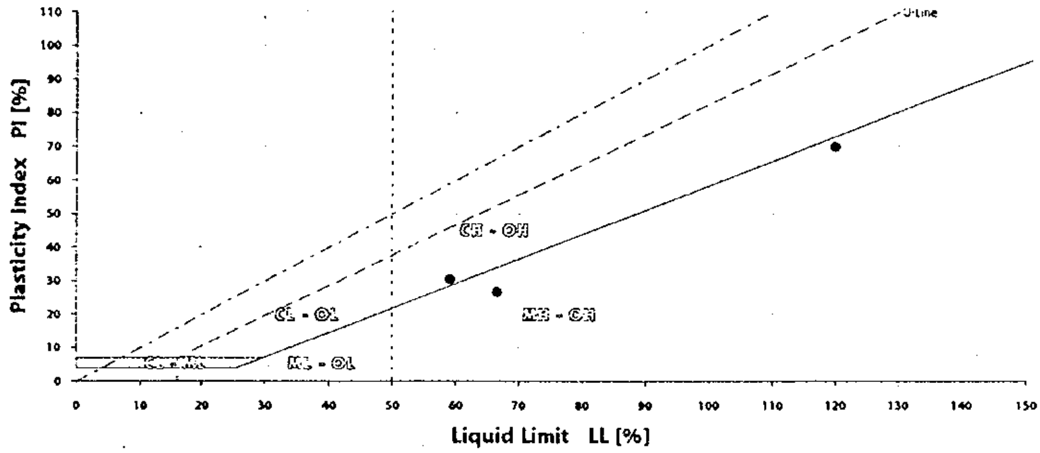
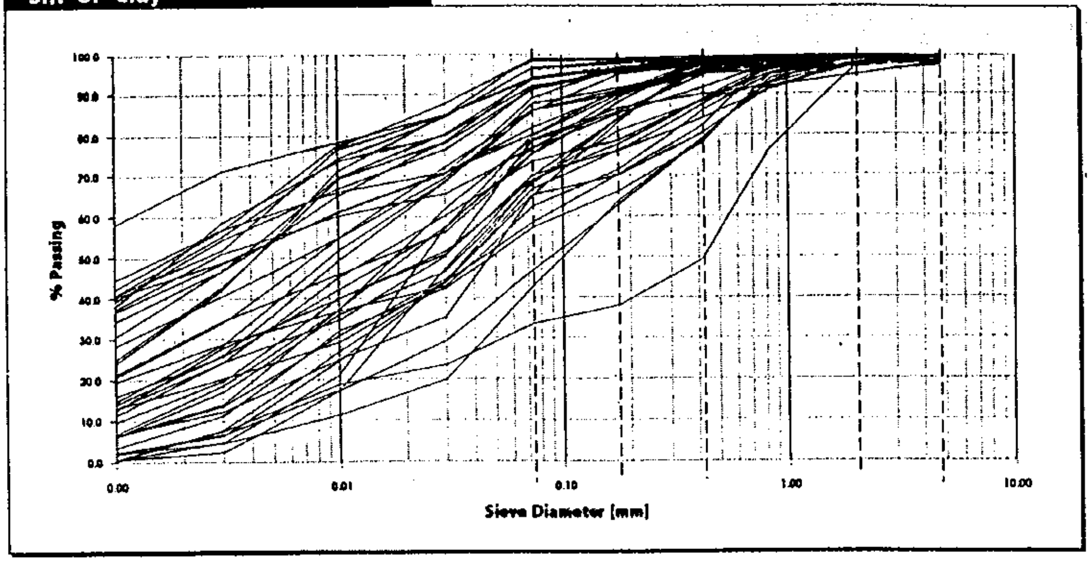
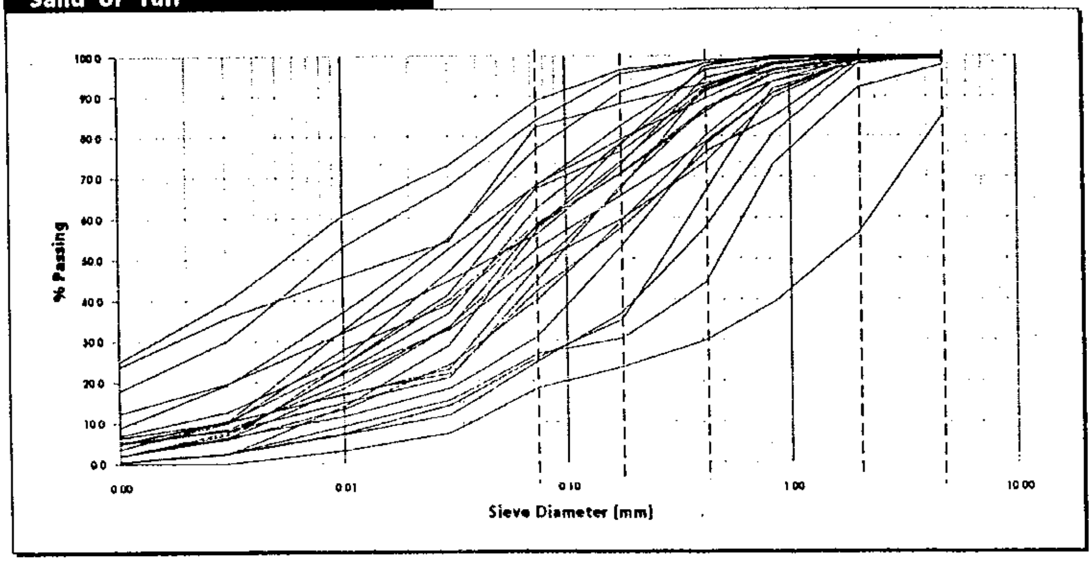


Figure 9. PRASTICITY CHARTS (BORE HOLE SAMPLES), SECTION : PARUNGPANJANG-SERPONG

Silt or Clay



Sand or Tuff



Tuffaceous Stones or Stones

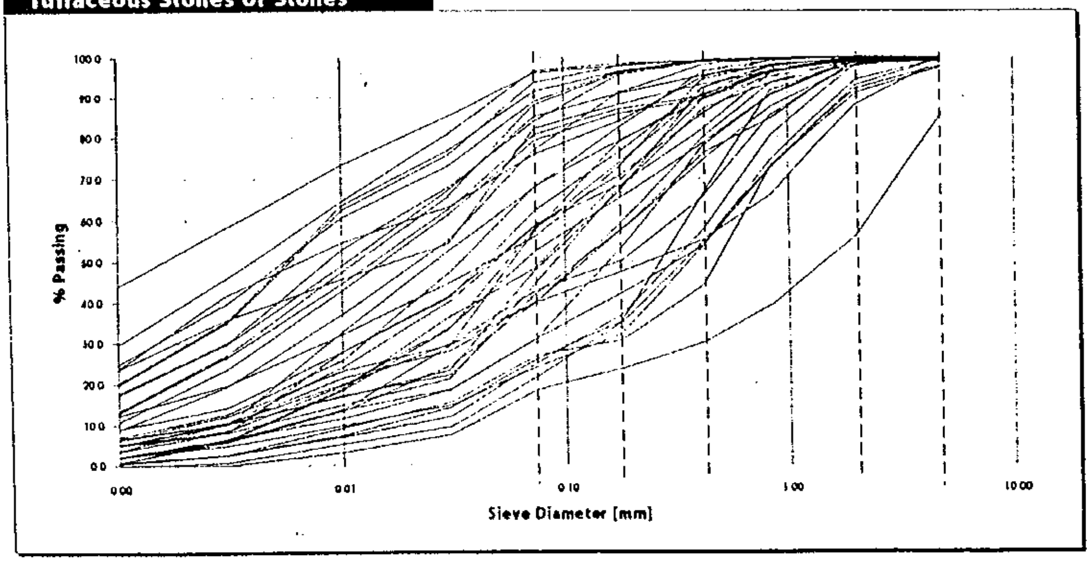
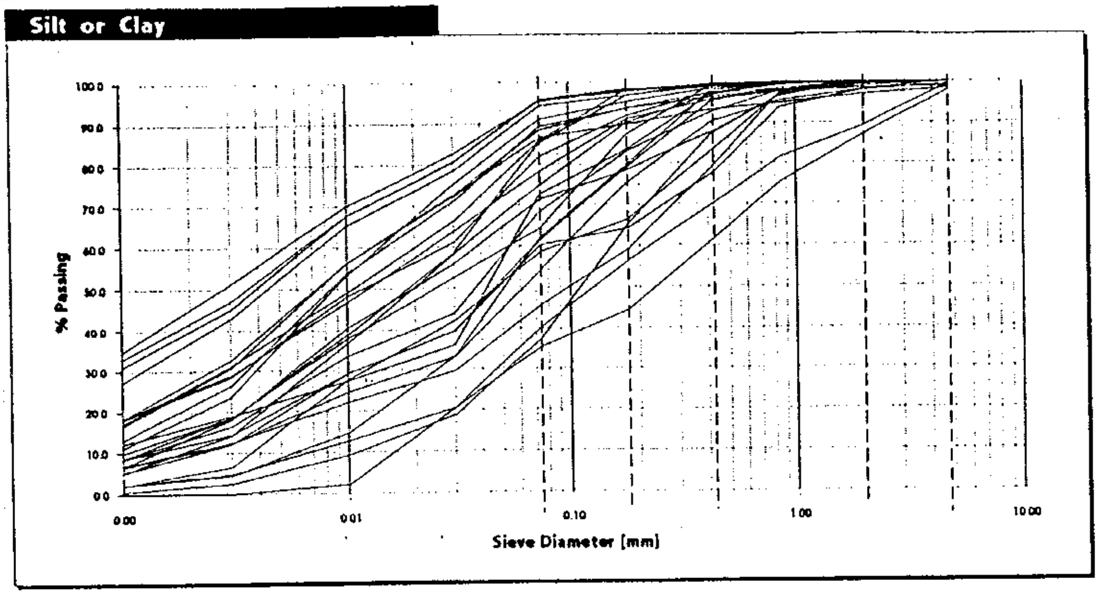
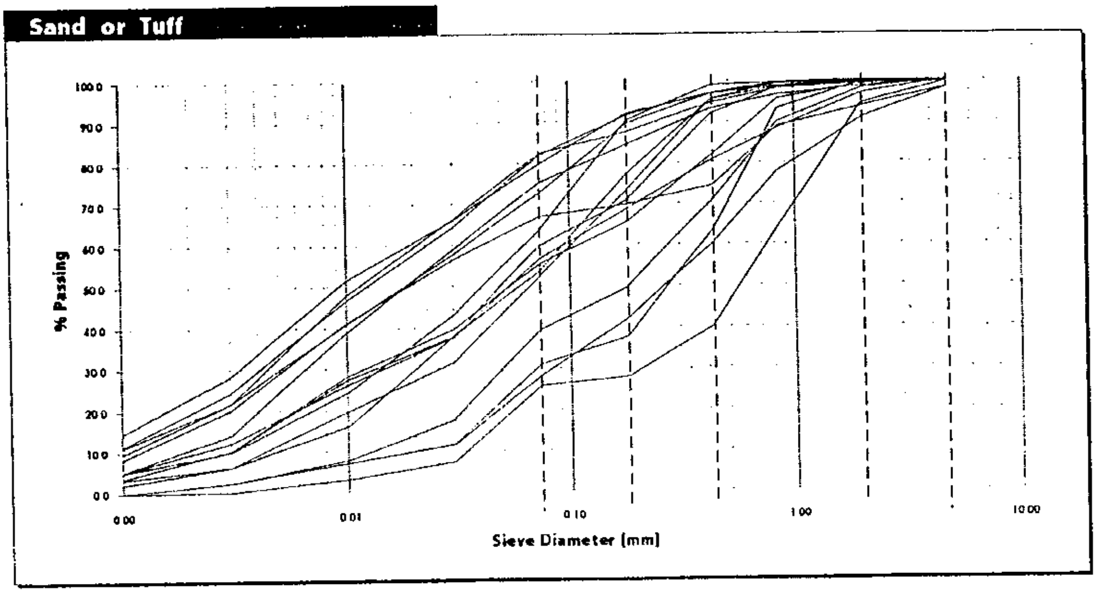


Figure 10. PARTICLE SIZE DISTRIBUTION CURVES (BORE HOLE SAMPLES), SECTION : CIUYAH-TENJO





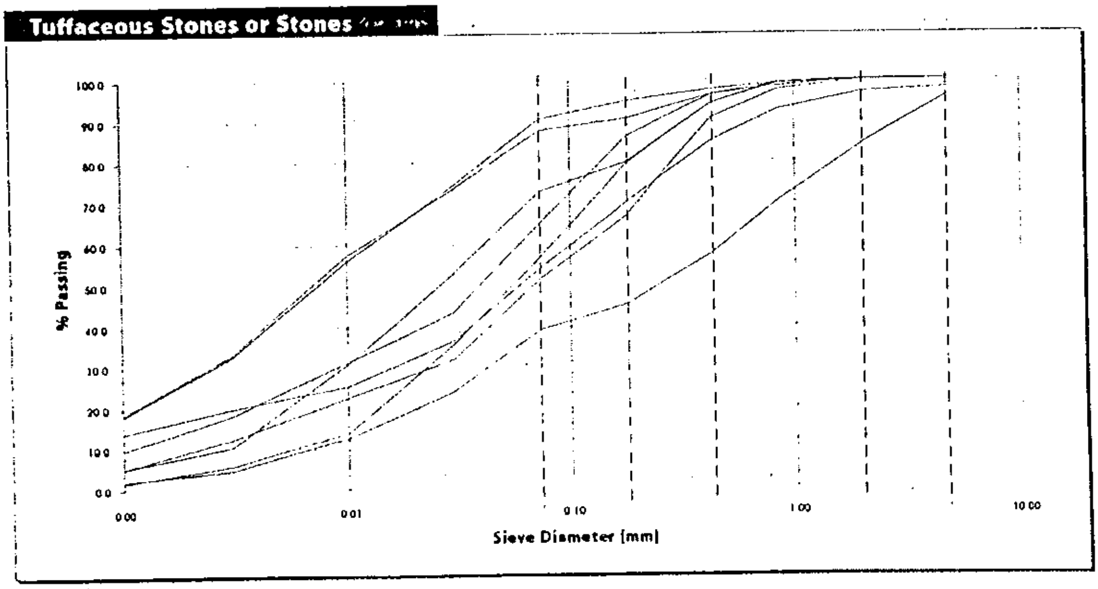
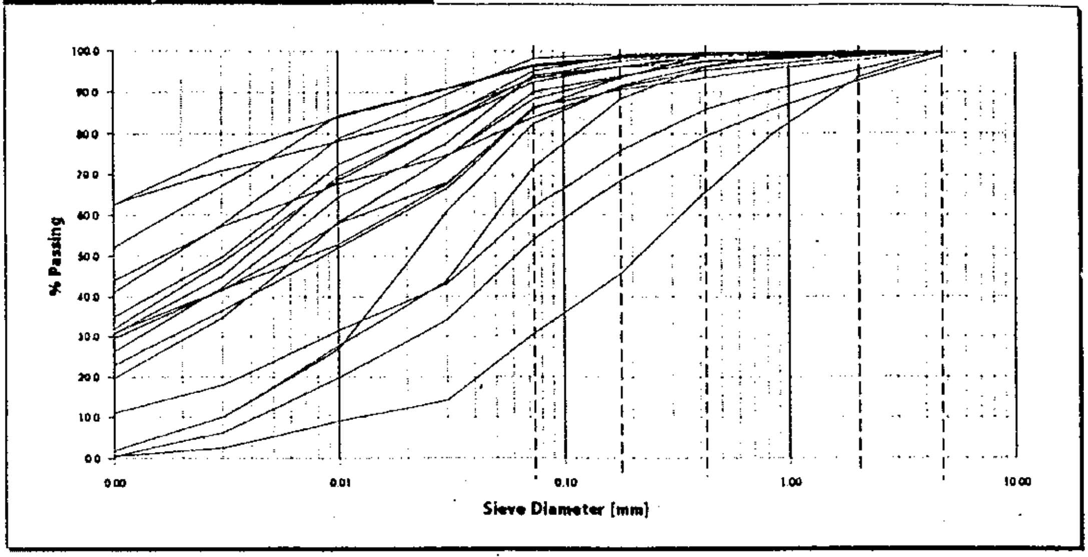


Figure 11. PARTICLE SIZE DISTRIBUTION CURVES (BORE HOLE SAMPLES), SECTION : TENJO-PARUNGPANJANG

Silt or Clay



Sand or Tuff

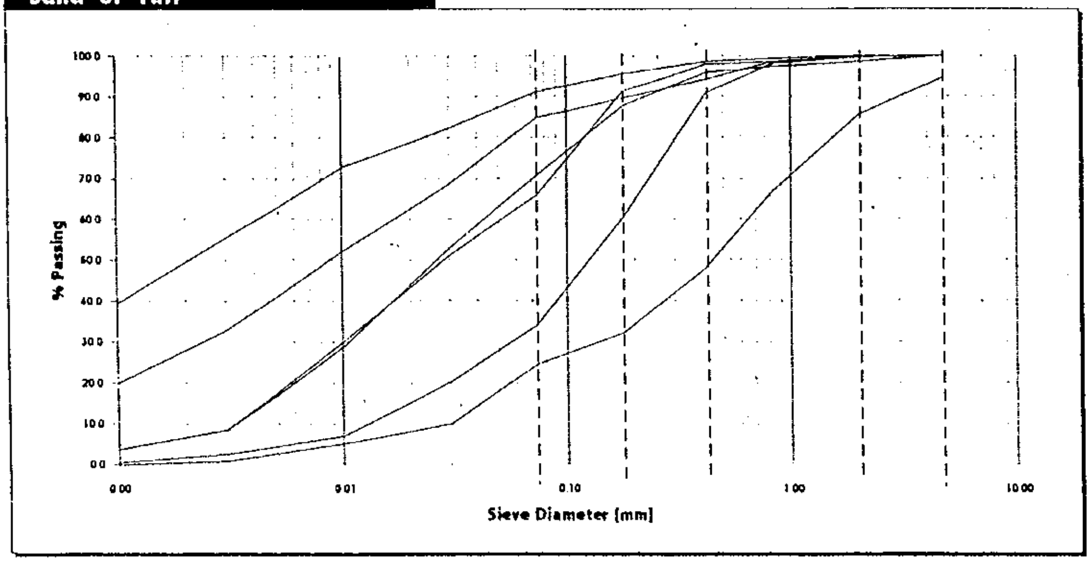
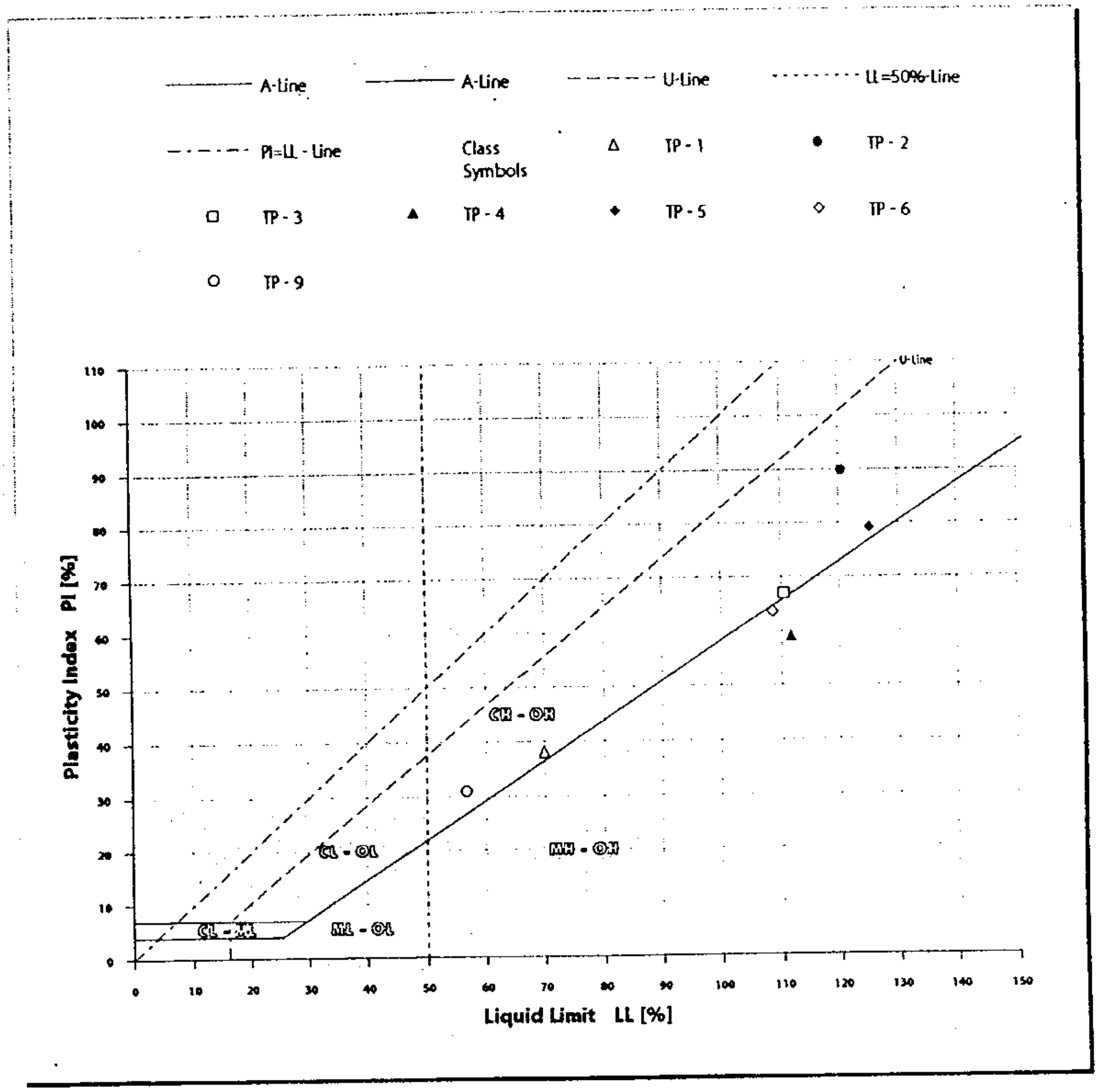
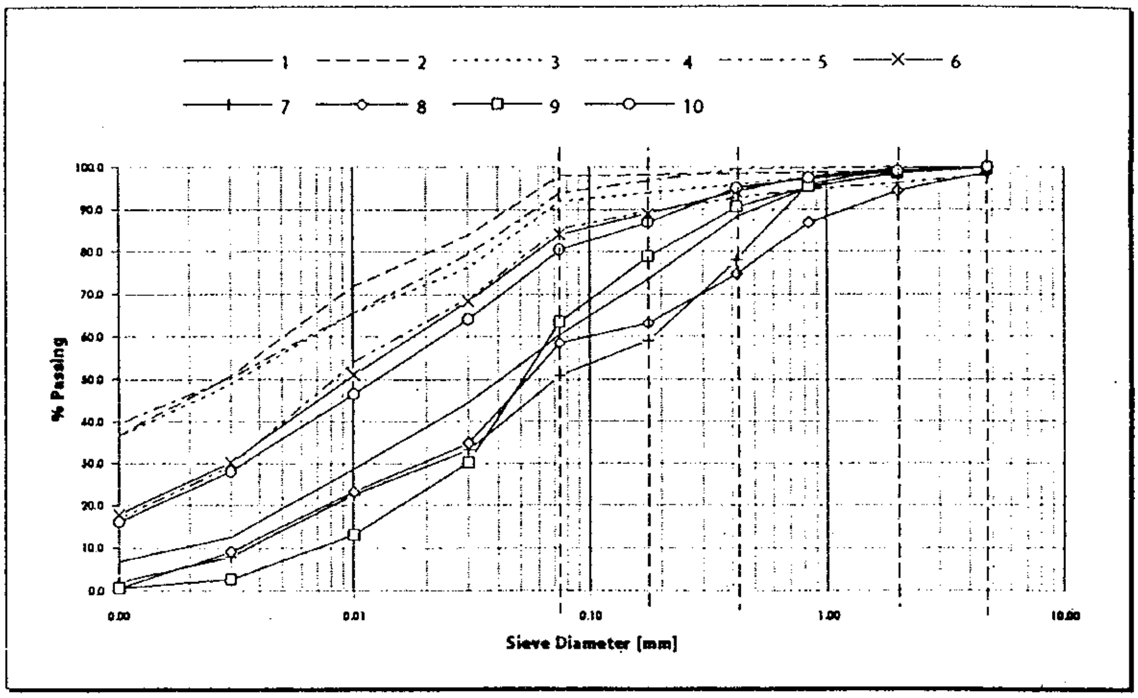


Figure 12. PARTICLE SIZE DISTRIBUTION CURVES (BORE HOLE SAMPLES), SECTION : PARUNGPANJANG-SERPONG



Location	Sample No.	Sample Type	Depth from (m)	Depth to (m)	USCS Symbol	Water Content Wn (%)	Liquid Limit LL (%)	Plastic Limit PL (%)	Plast. Index PI (%)
TP - 1	1	EXC.	0.50	1.00	CH	27.23	69.90	31.91	37.99
TP - 2	1	EXC.	0.75	2.00	CH	43.33	120.40	30.65	89.75
TP - 3	1	EXC.	0.00	2.00	CH	47.29	110.40	43.44	66.96
TP - 4	1	EXC.	0.00	2.00	MH	47.29	111.50	52.38	59.12
TP - 5	1	EXC.	0.00	2.00	CH	42.48	125.20	46.02	79.18
TP - 6	1	EXC.	0.80	2.00	MH	45.47	108.60	44.88	63.72
TP - 9	1	EXC.	0.60	1.00	CH	20.06	56.80	25.91	30.89

Figure 13. PRASTICITY CHARTS (TEST PIT MATERIAL)



Location	Sample No.	Sample Type	Depth from (m)	Depth to (m)	USCS Symbol	4.76 (%)	2.00 (%)	0.84 (%)	0.42 (%)	.177 (%)	.074 (%)	.030 (%)	.010 (%)	.003 (%)	.001 (%)
						Particle Size Distribution [% passing Sieve mm]									
TP - 1	1	EXC.	0.50	1.00	CH	100.0	98.8	95.2	88.2	73.6	60.4	44.6	28.7	12.5	6.8
TP - 2	1	EXC.	0.75	2.00	CH	100.0	99.0	98.8	98.6	98.2	98.0	83.9	71.9	50.7	36.7
TP - 3	1	EXC.	0.00	2.00	CH	100.0	99.0	97.6	95.9	94.0	92.0	76.3	65.5	48.9	36.5
TP - 4	1	EXC.	0.00	2.00	MH	100.0	100.0	99.8	99.5	96.8	94.0	79.5	65.6	50.3	39.6
TP - 5	1	EXC.	0.00	2.00	CH	98.2	96.2	94.8	92.8	89.6	85.6	69.1	54.0	29.3	16.9
TP - 6	1	EXC.	0.80	2.00	MH	100.0	99.6	97.8	94.2	89.2	84.2	68.4	51.1	30.2	17.8
TP - 7	1	EXC.	2.90	3.00		100.0	99.8	96.0	78.0	59.0	51.0	33.2	22.5	7.9	2.0
TP - 8	1	EXC.	1.00	2.00		98.8	94.4	86.8	74.8	63.2	58.4	34.8	23.3	9.1	0.5
TP - 9	1	EXC.	0.60	1.00	CH	99.8	98.4	95.4	90.6	78.8	63.4	30.2	13.1	2.6	0.6
TP -10	1	EXC.	1.60	2.00		100.0	99.0	97.4	95.0	87.0	80.4	64.1	46.6	28.1	16.0

Figure 14. PARTICLE SIZE DISTRIBUTION CURVES (TEST PIT MATERIAL)

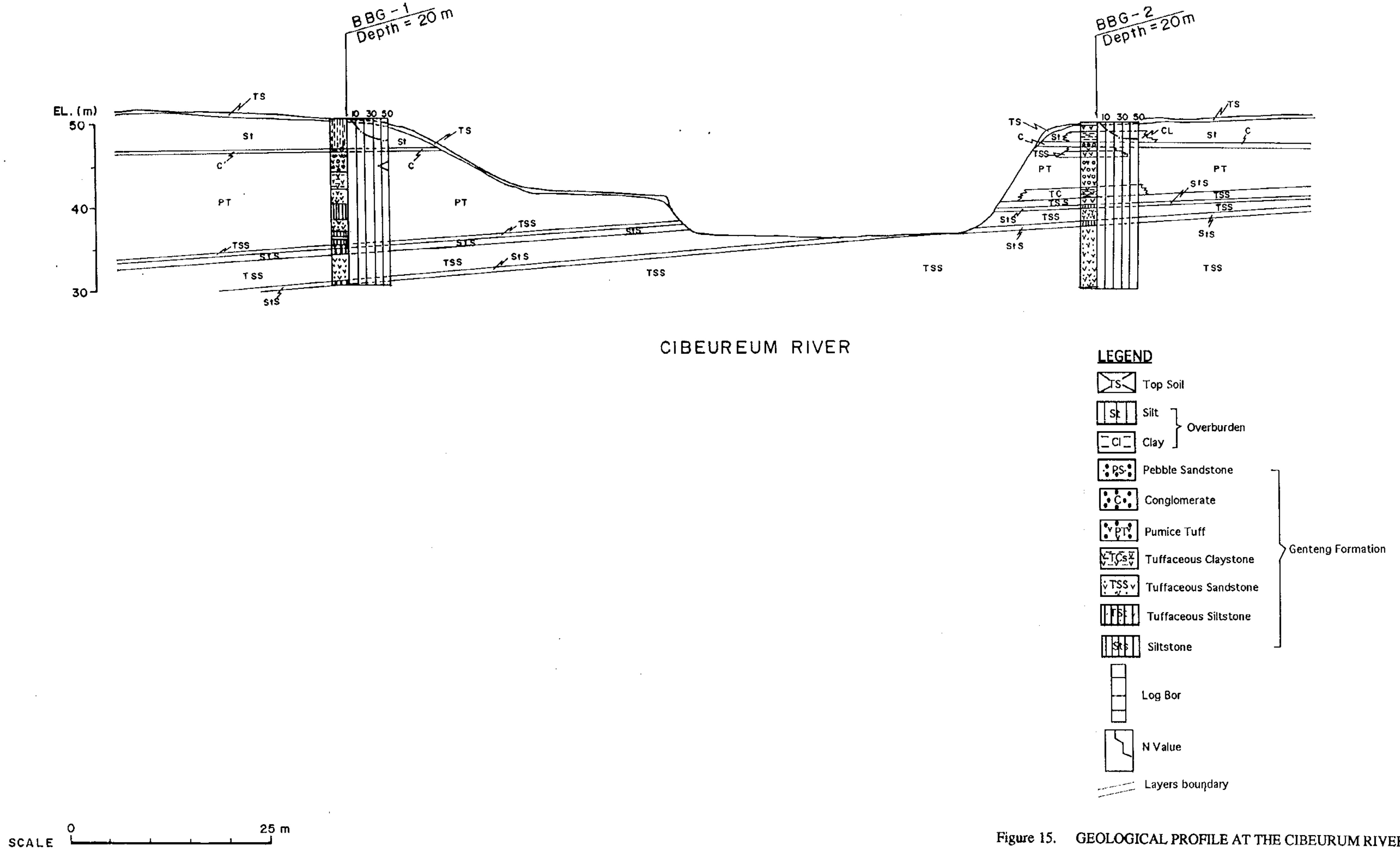


Figure 15. GEOLOGICAL PROFILE AT THE CIBEURUM RIVER

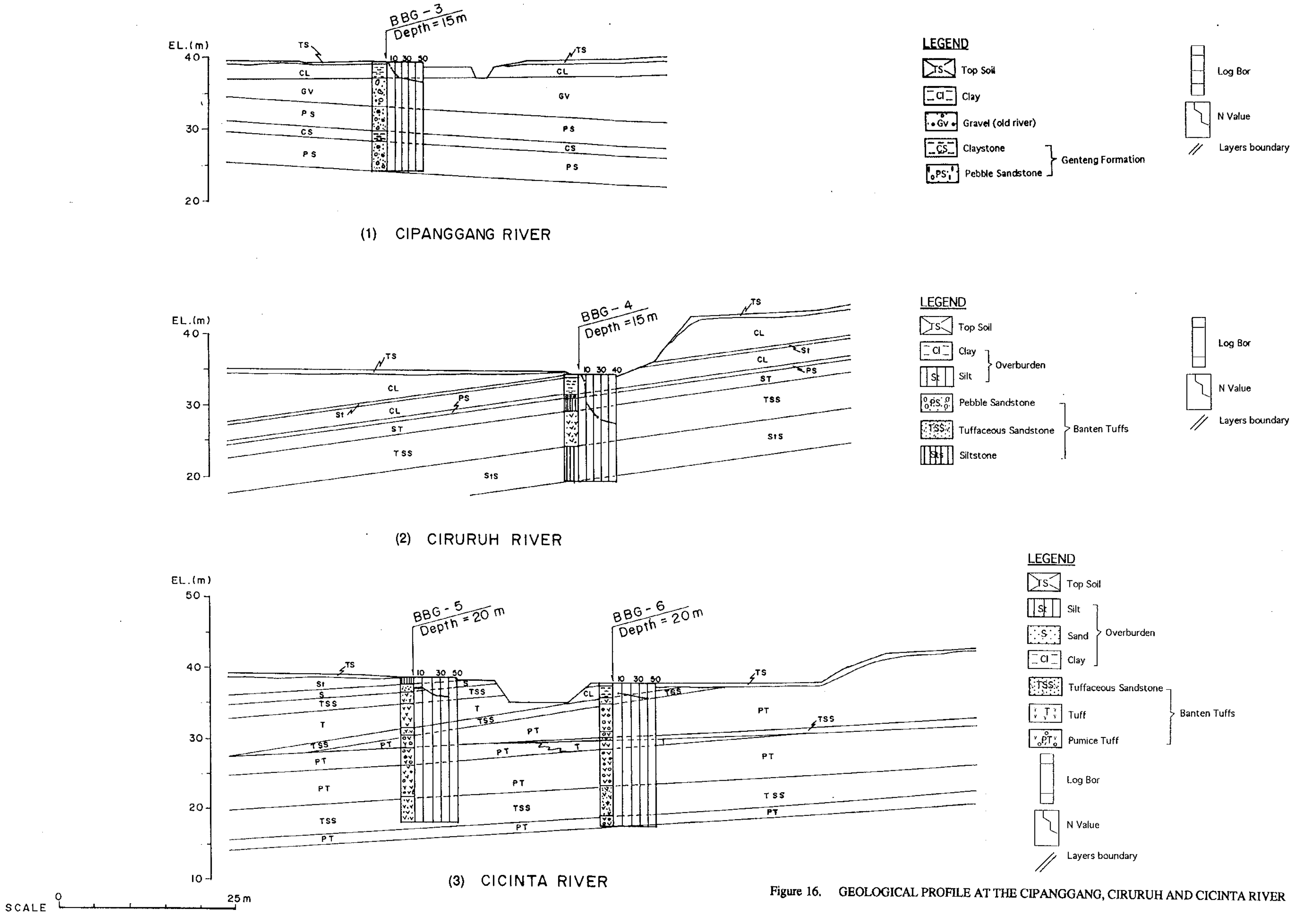


Figure 16. GEOLOGICAL PROFILE AT THE CIPANGGANG, CIRURUH AND CICINTA RIVER

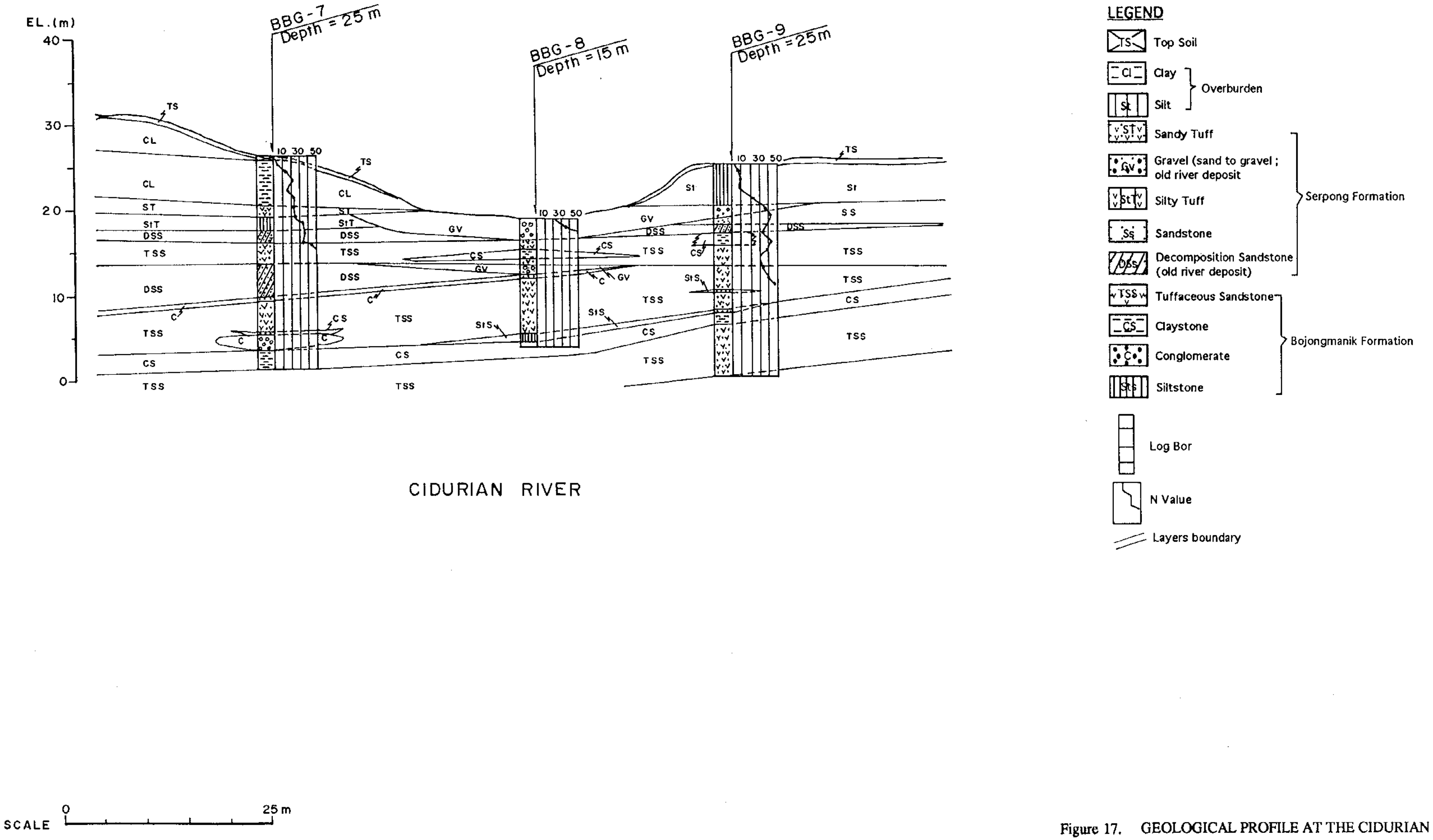


Figure 17. GEOLOGICAL PROFILE AT THE CIDURIAN RIVER

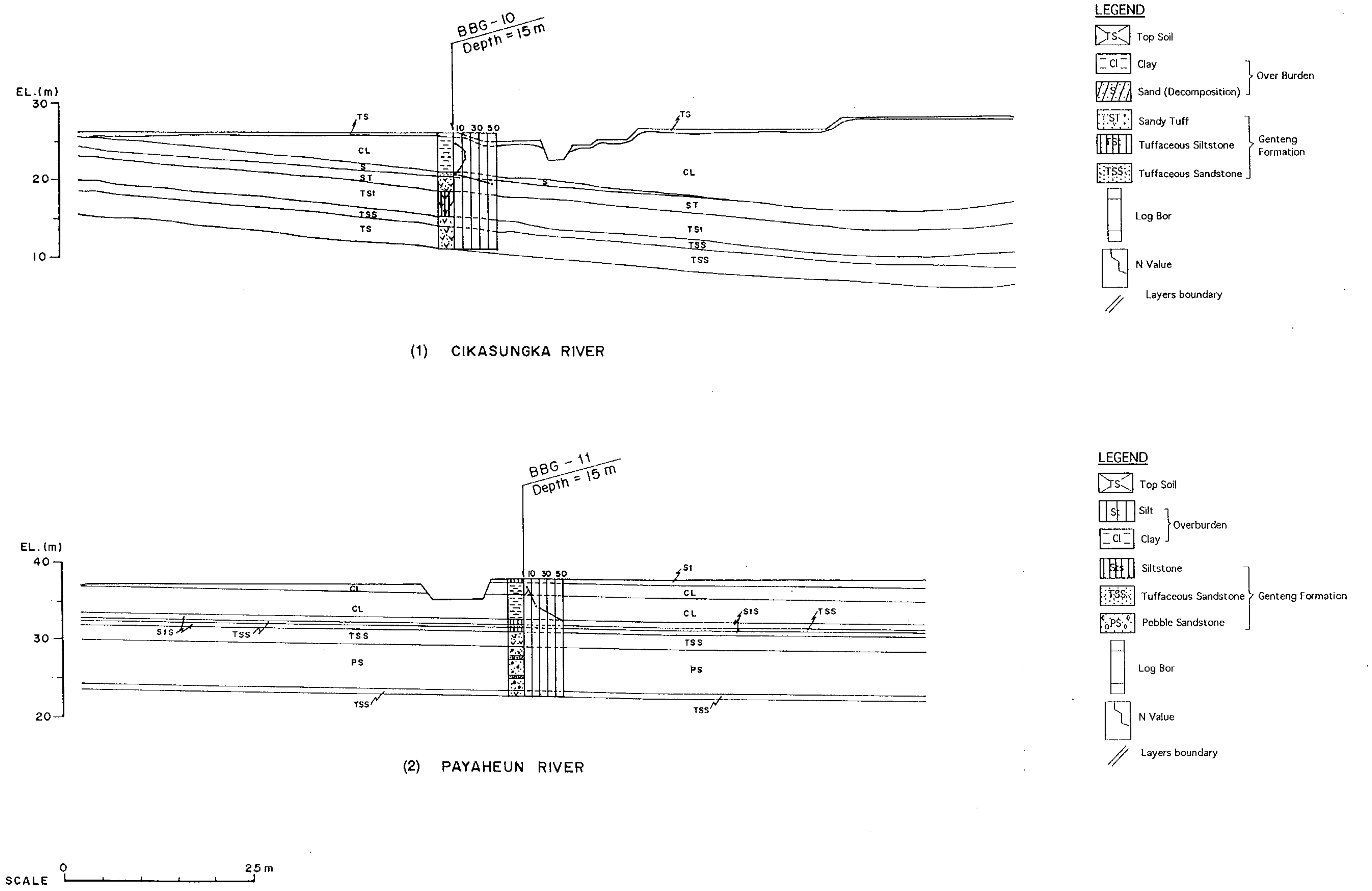


Figure 18. GEOLOGICAL PROFILE AT THE CIKASUNGKA AND PAYAHEUM RIVER

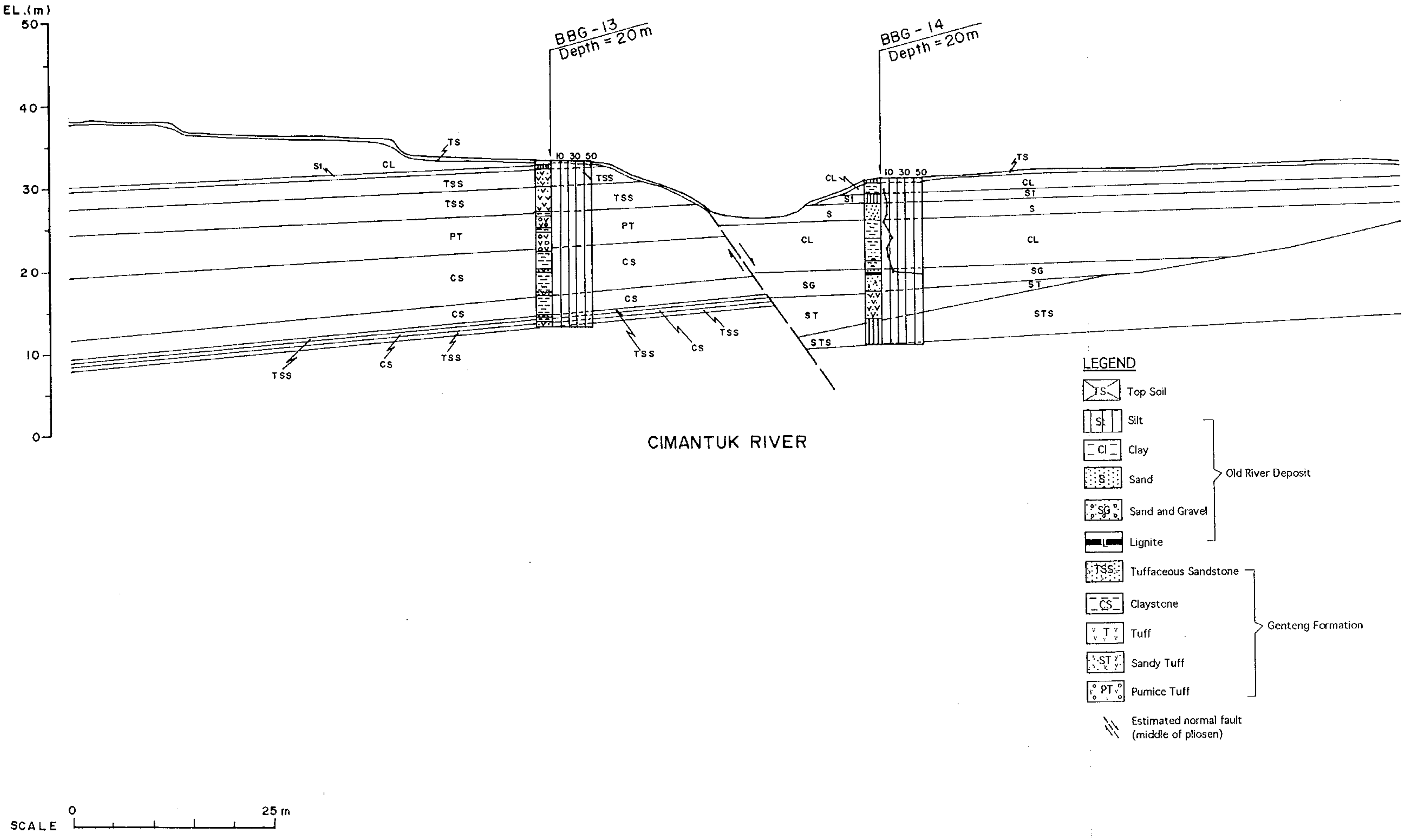
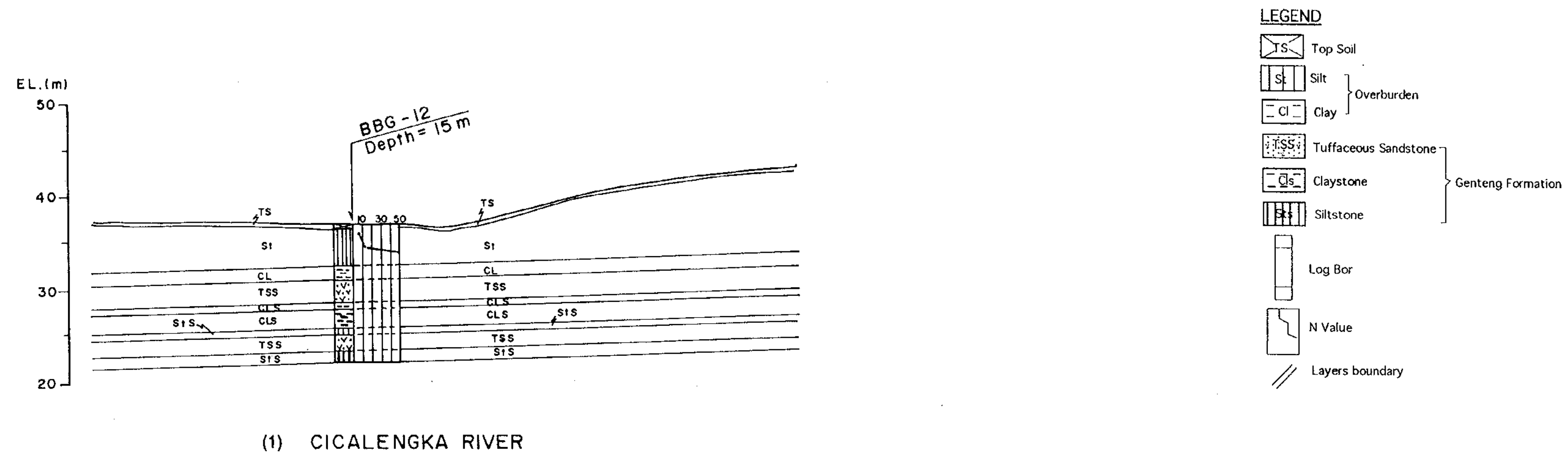


Figure 19. GEOLOGICAL PROFILE AT THE CIMANTUK RIVER



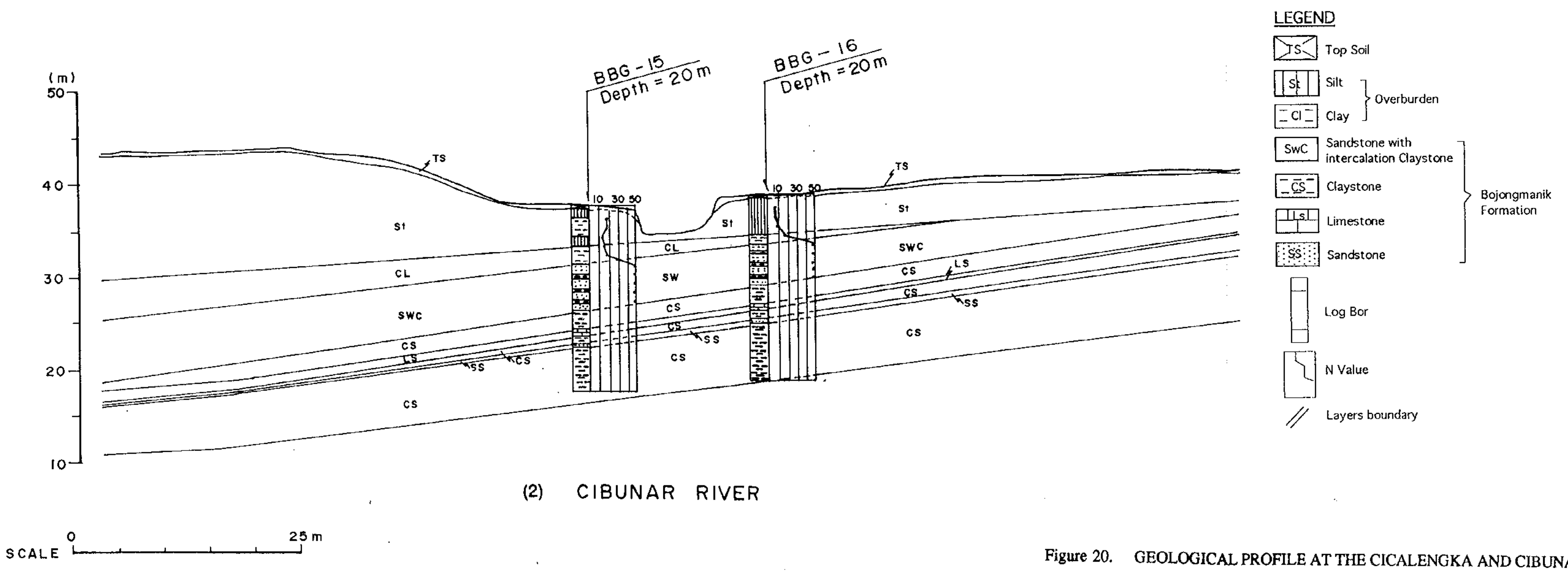


Figure 20. GEOLOGICAL PROFILE AT THE CICALENGKA AND CIBUNAR RIVER

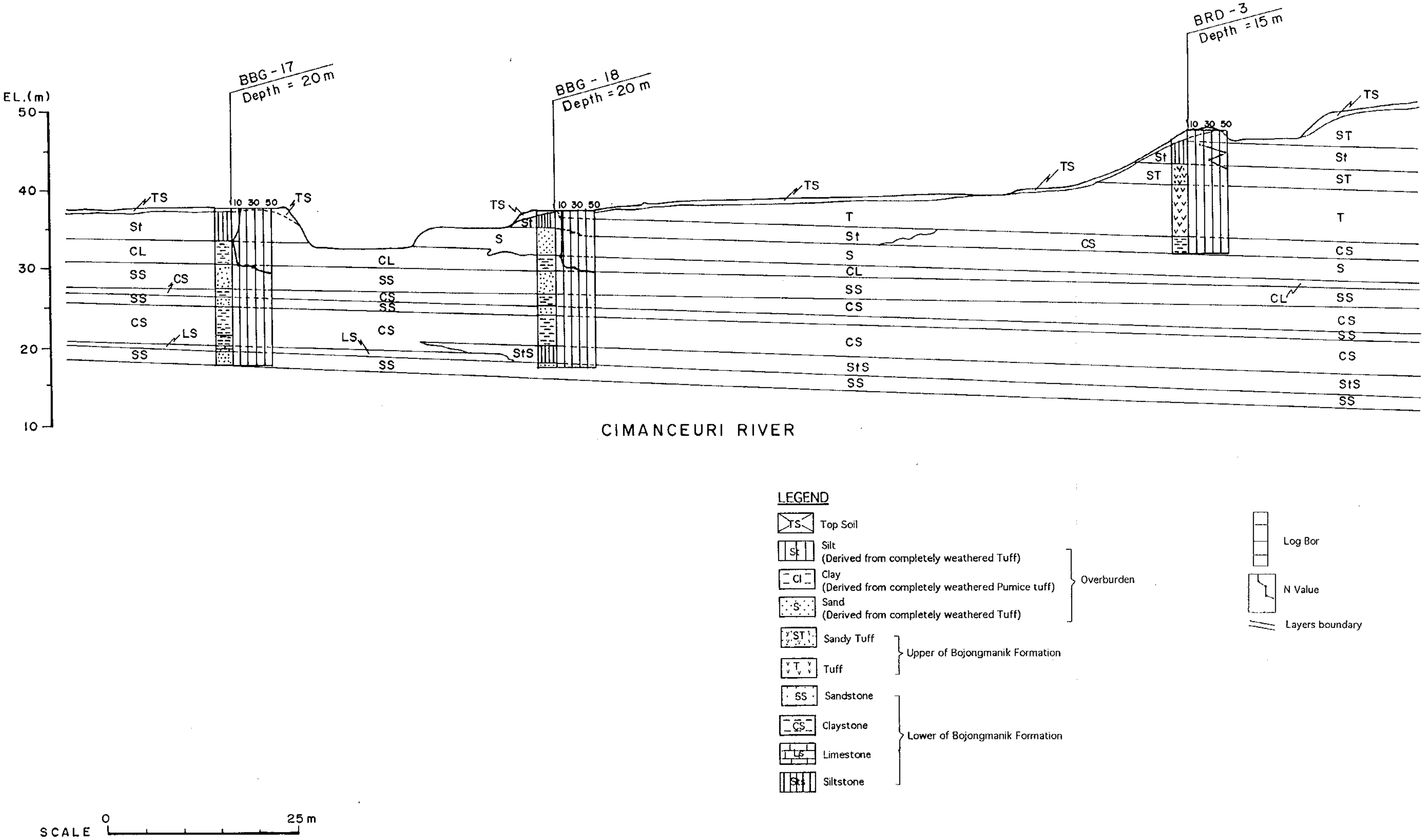


Figure 21. GEOLOGICAL PROFILE AT THE CIMANCEURI RIVER

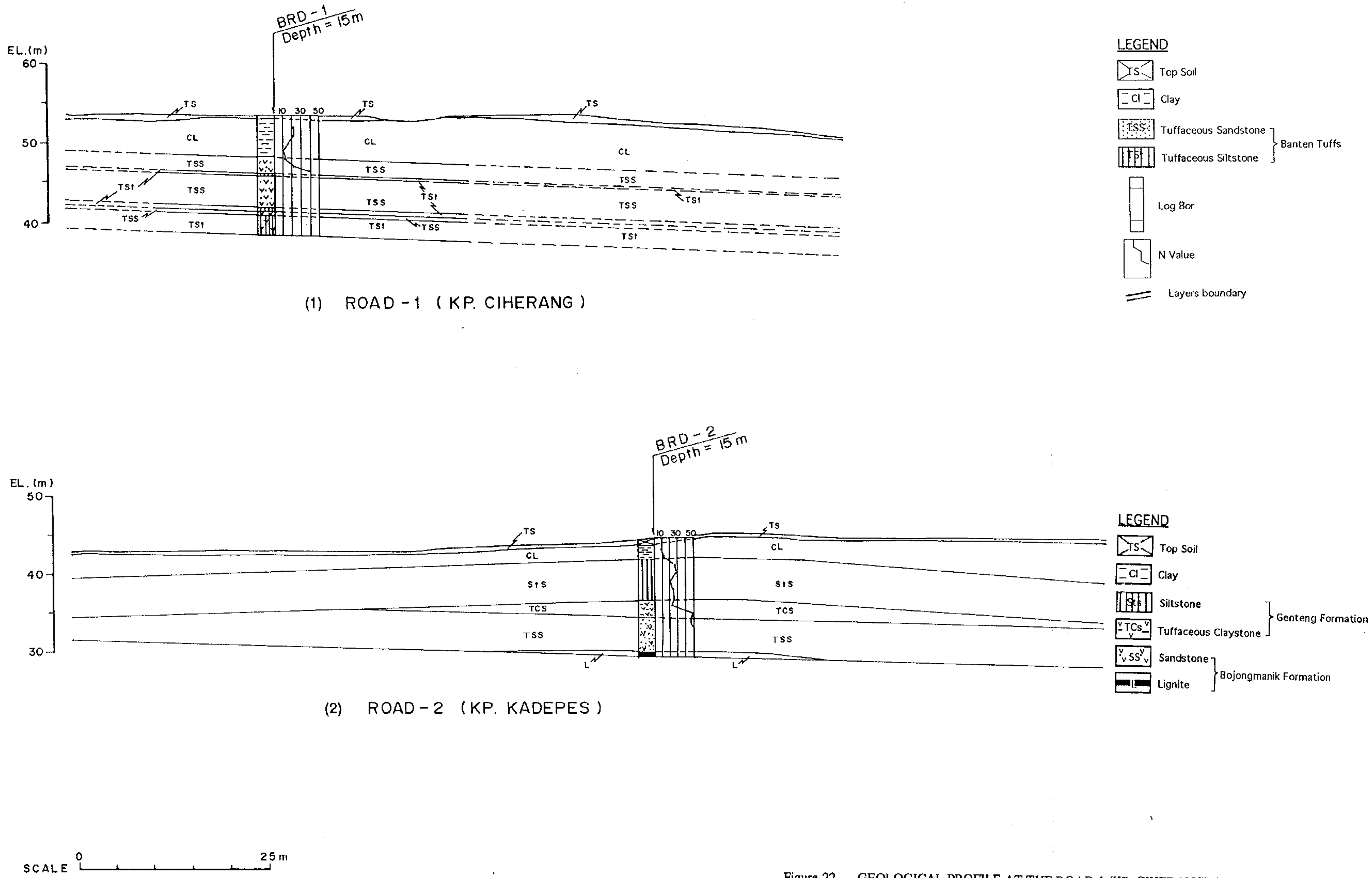


Figure 22. GEOLOGICAL PROFILE AT THE ROAD-1 (KP. CIHERANG) AND ROAD-2 (KP. KADEPES)

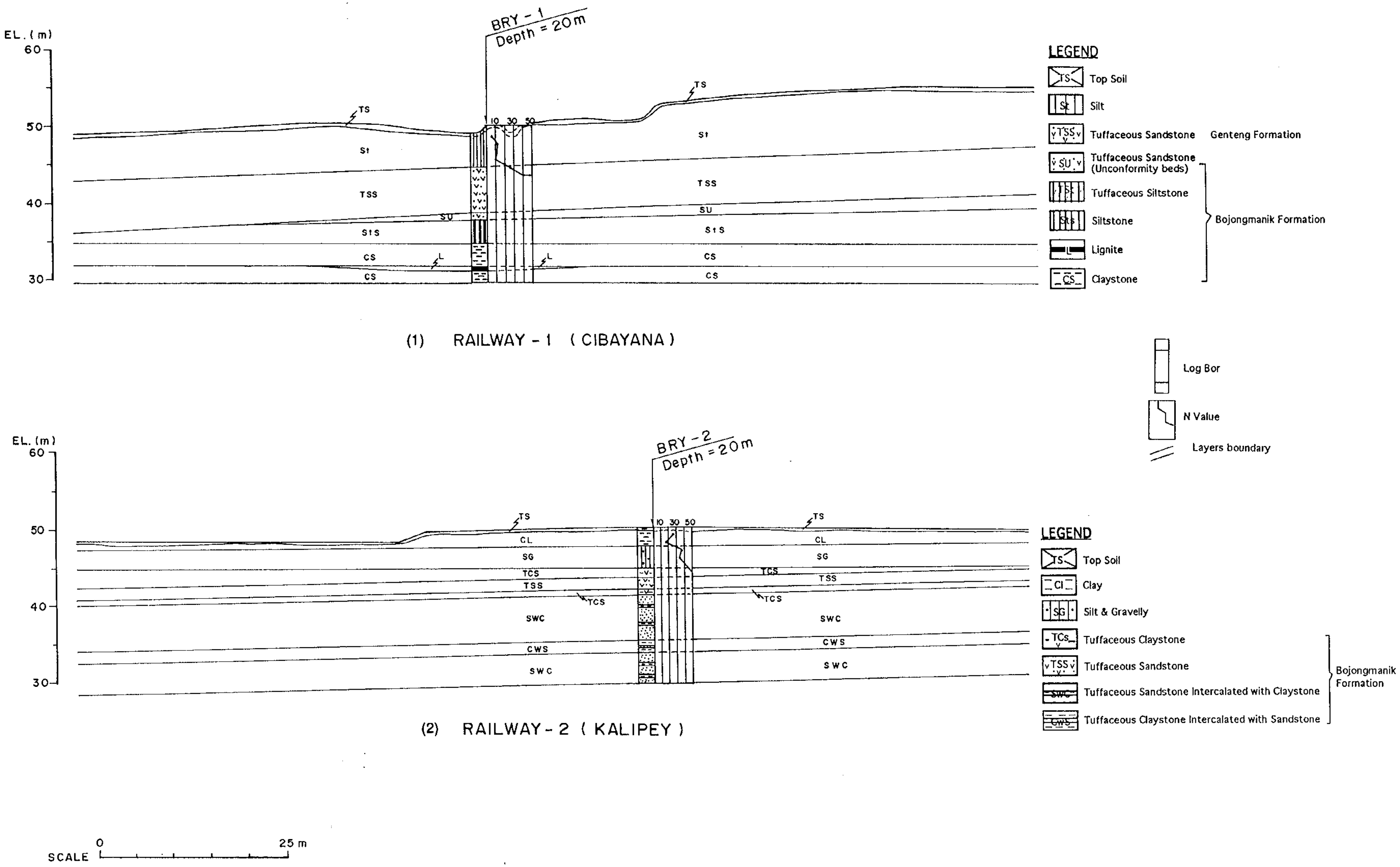


Figure 23. GEOLOGICAL PROFILE AT THE RAILWAY-1 (CIBAYANA) AND RAILWAY-2 (KALIPEY)

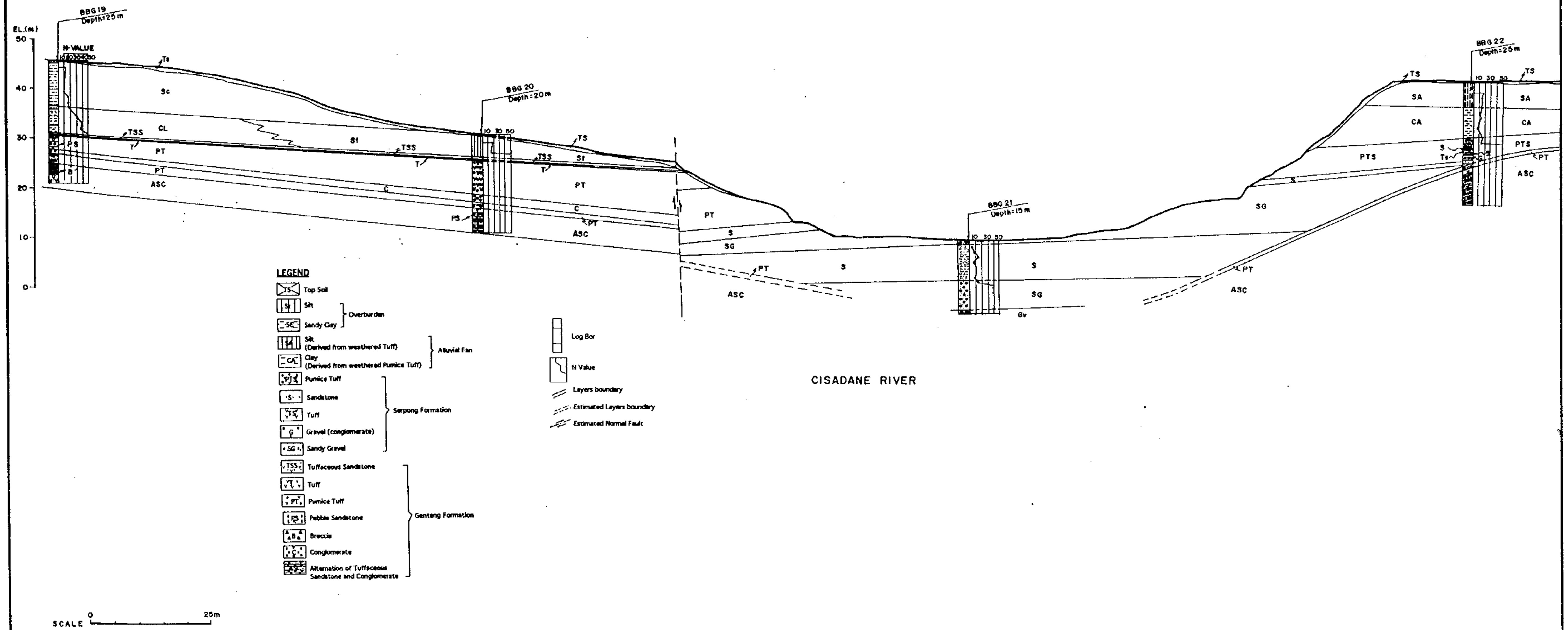
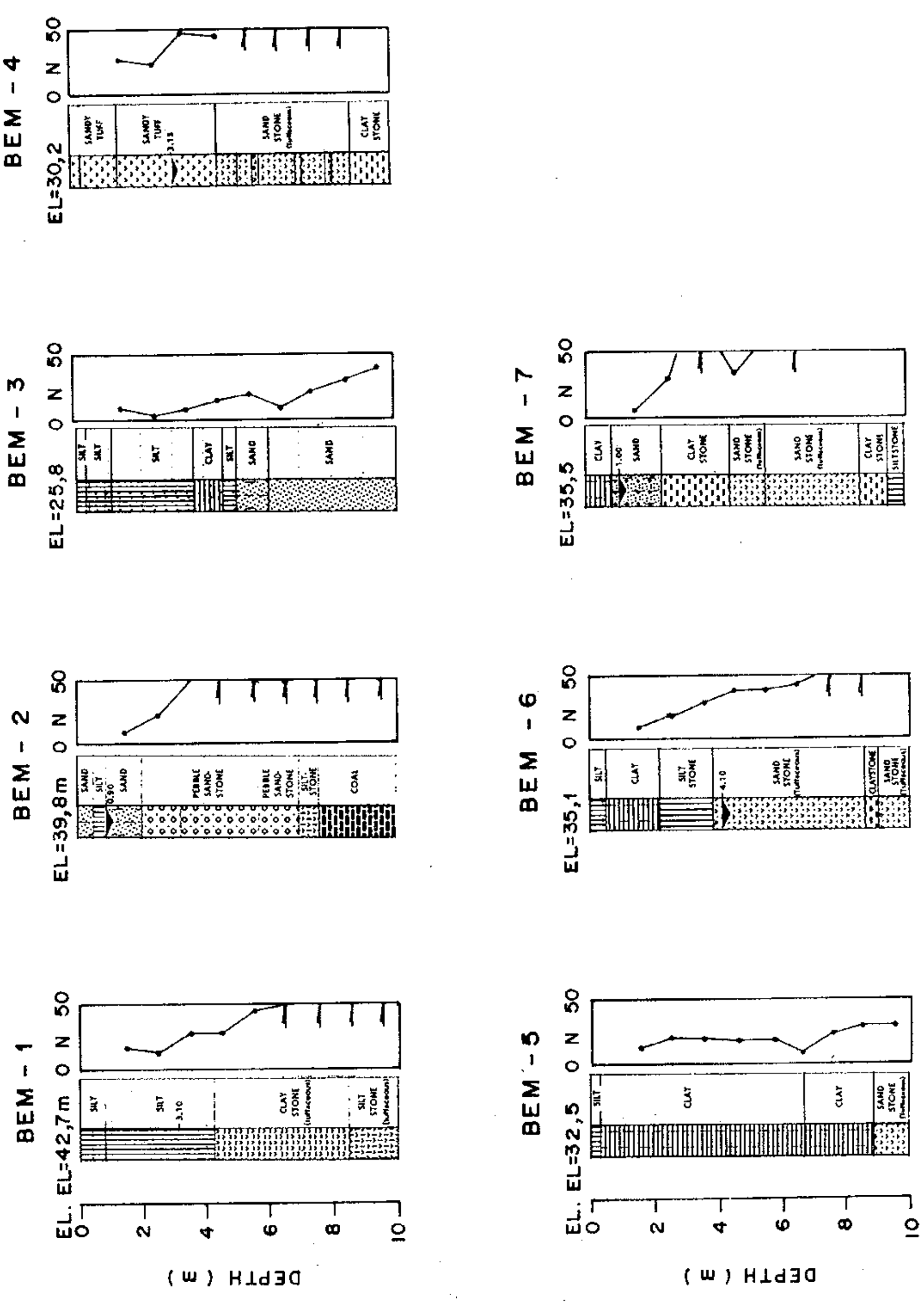


Figure 24. GEOLOGICAL PROFILE AT THE CISADANE RIVER



Note : Location of drilling sites are shown in Figure 3.1

Figure 25. DRILLING LOGS OF FOUNDATIONS FOR EMBANKMENT

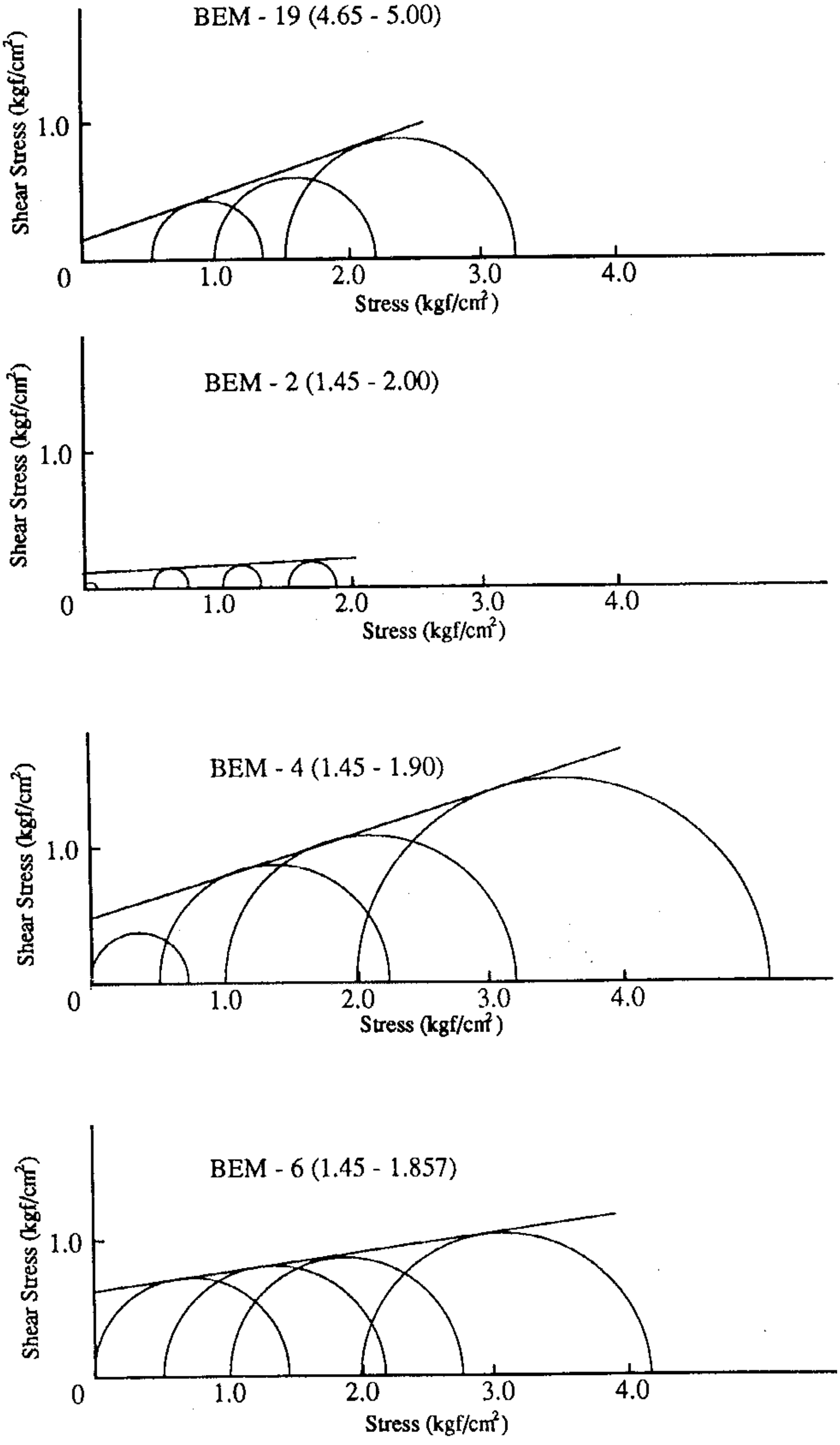


Figure 26. MOHR'S CIRCLE AND ENVELOP LINE OF UU-TEST (FOUNDATION) (1/2)

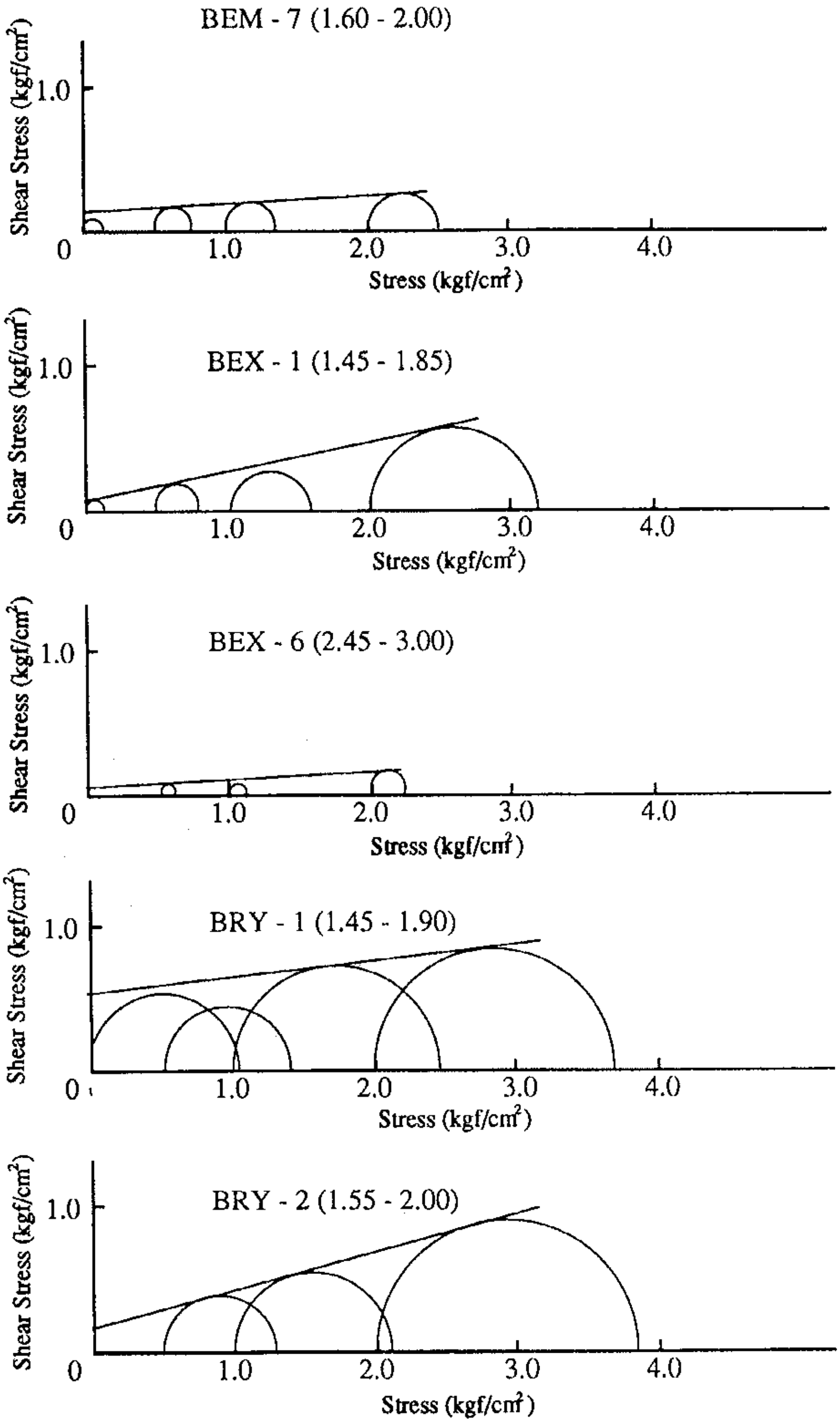


Figure 27. MOHR'S CIRCLE AND ENVELOP LINE OF UU-TEST (FOUNDATION) (2/2)

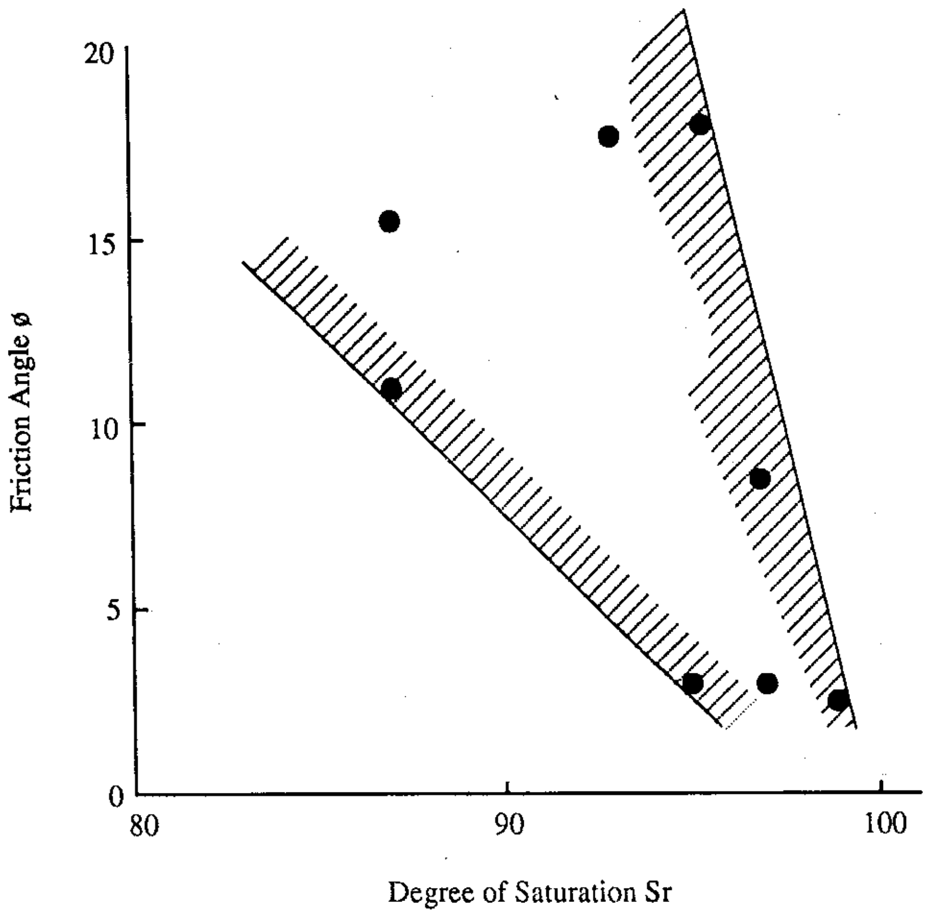


Figure 28. Sr - ϕ RELATIONSHIP

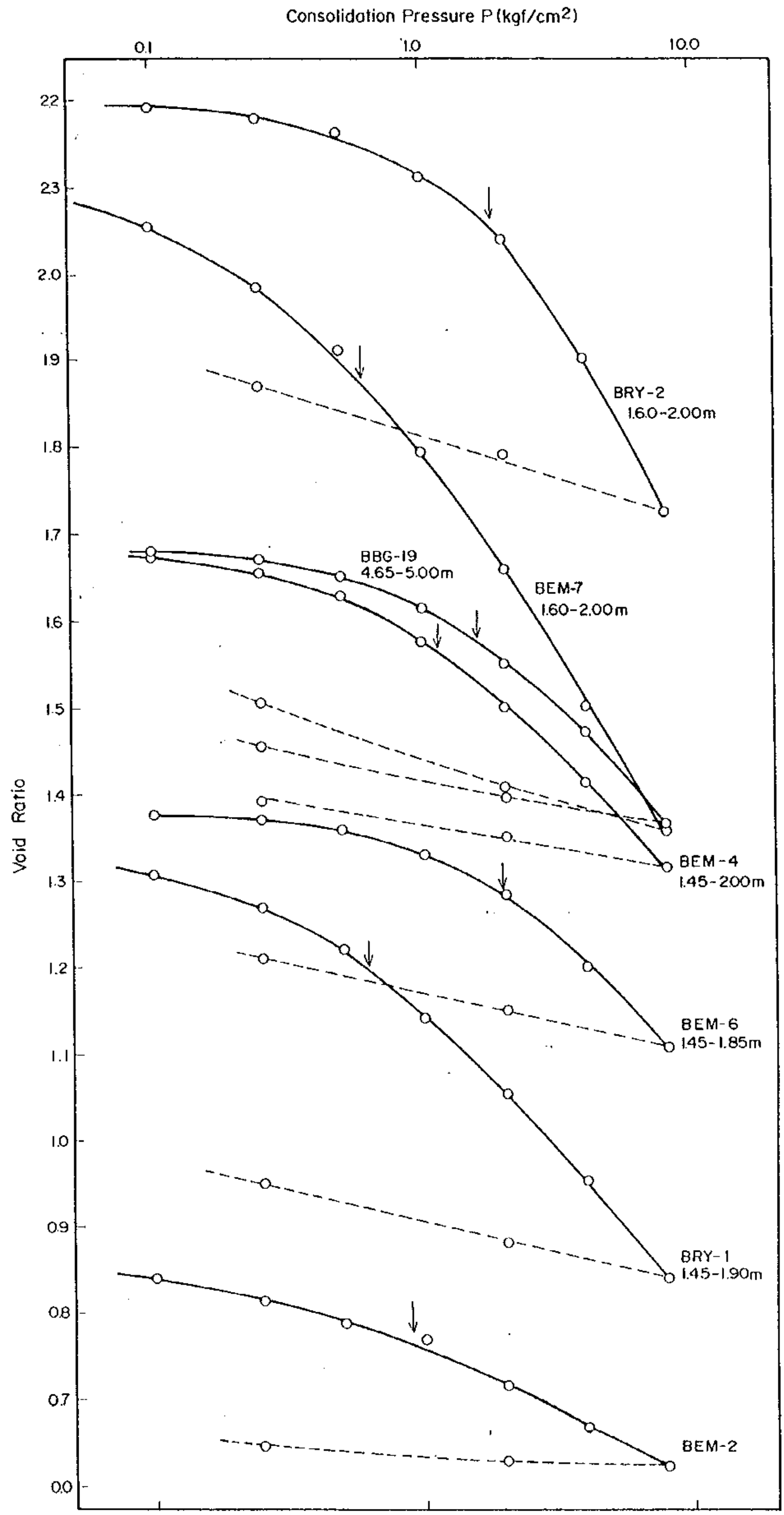


Figure 29. e - logp RELATIONS OF FOUNDATION

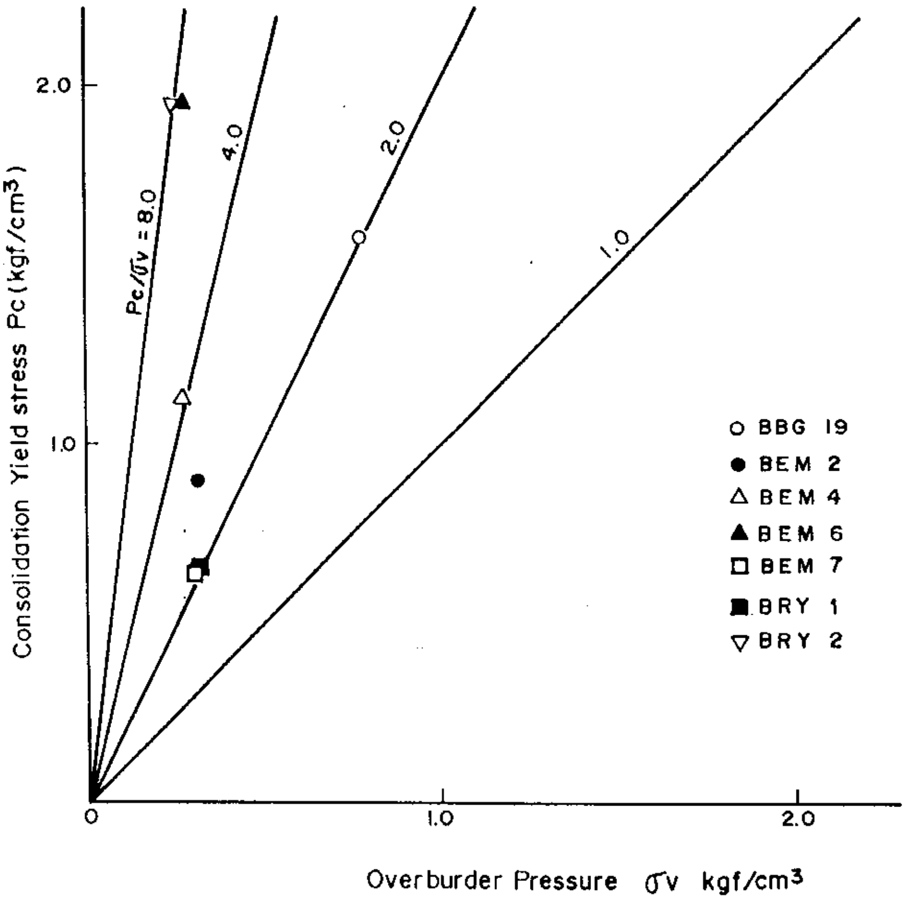
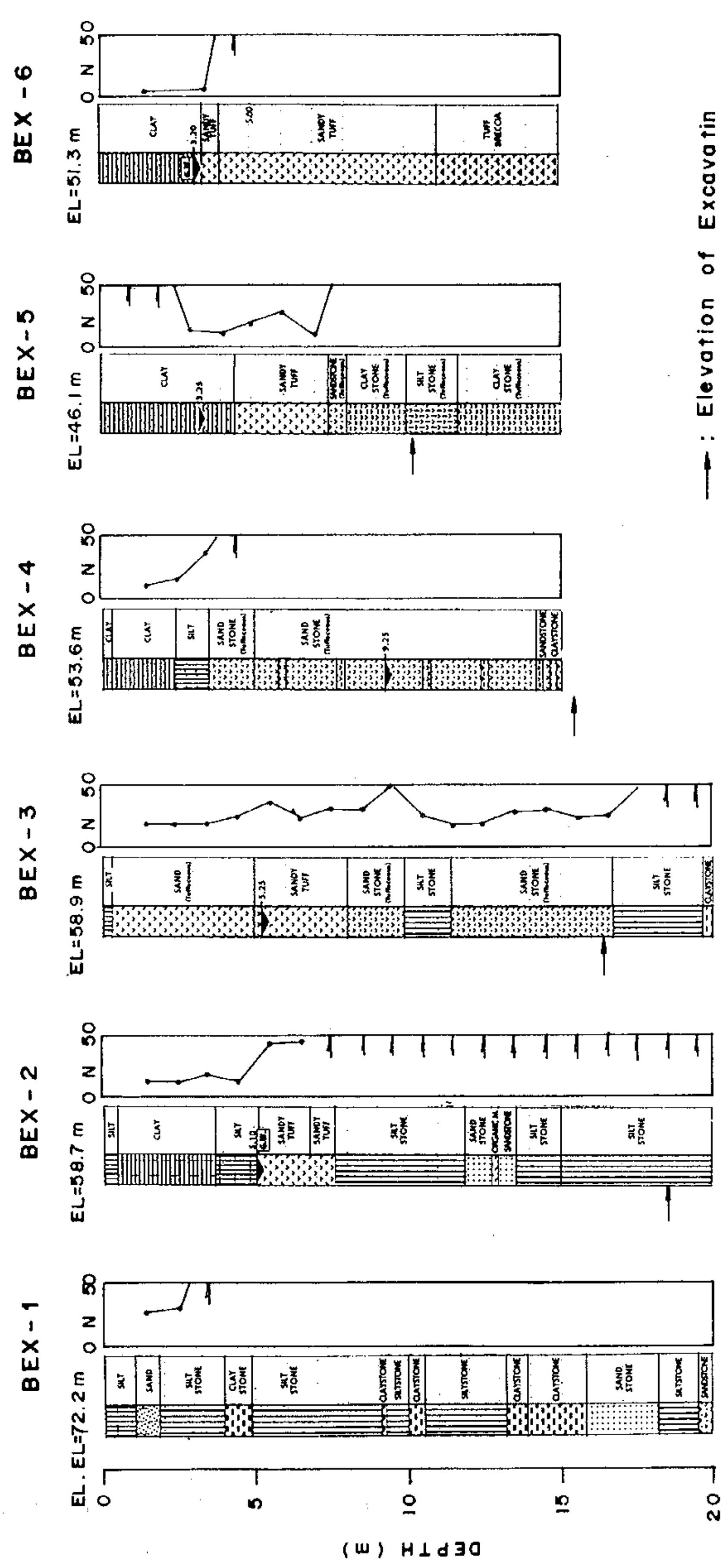
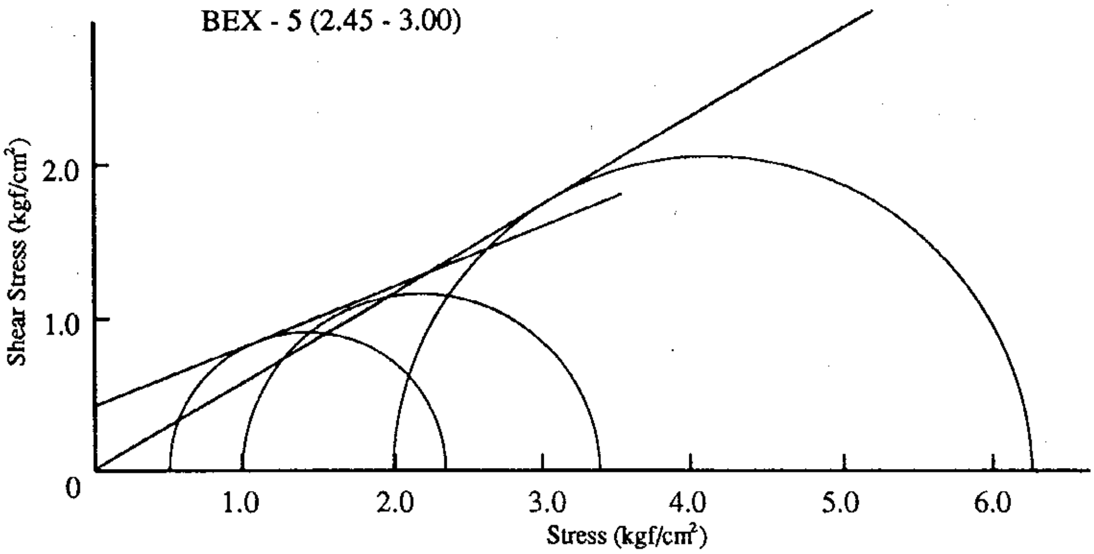


Figure 30. sv - Pc RELATIONSHIP



Note : Location of drilling sites are shown in Figure 3.1

Figure 31. DRILLING LOGS OF EXCAVATION SITES



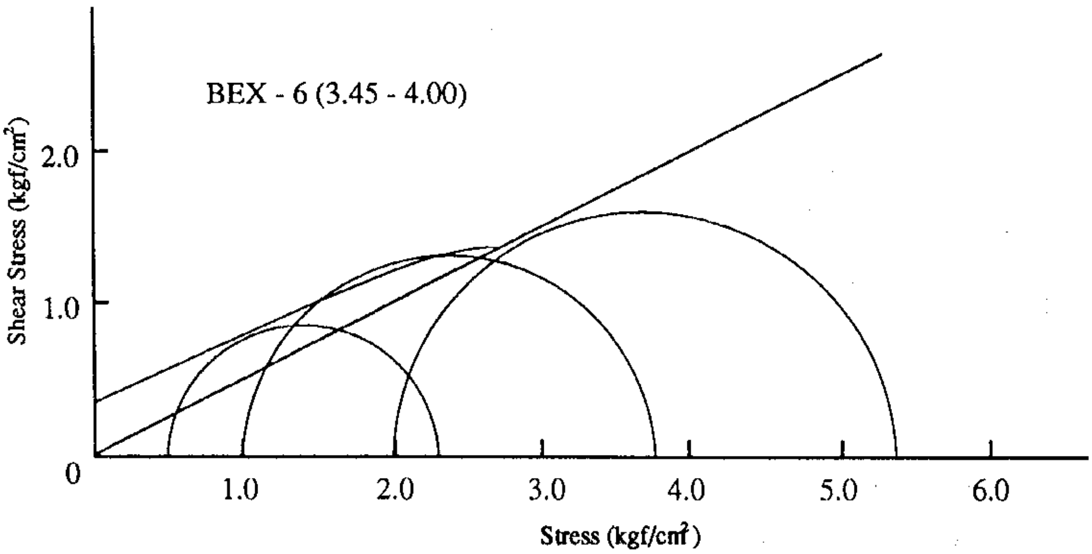


Figure 32. MOHR'S CIRCLE AND ENVELOP LINE OF CD-TEST (FOUNDATION)

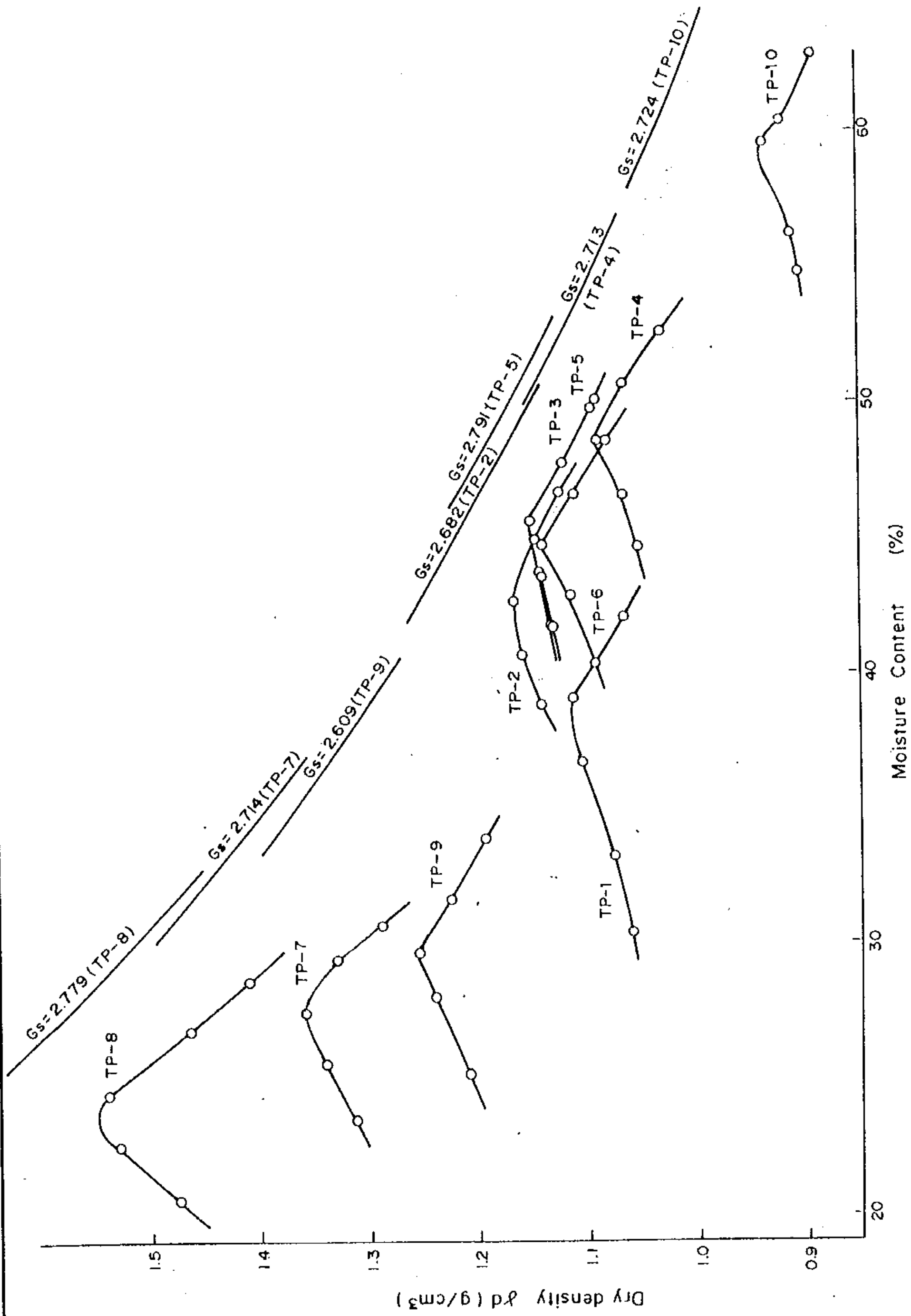


Figure 33. COMPACTION CURVES

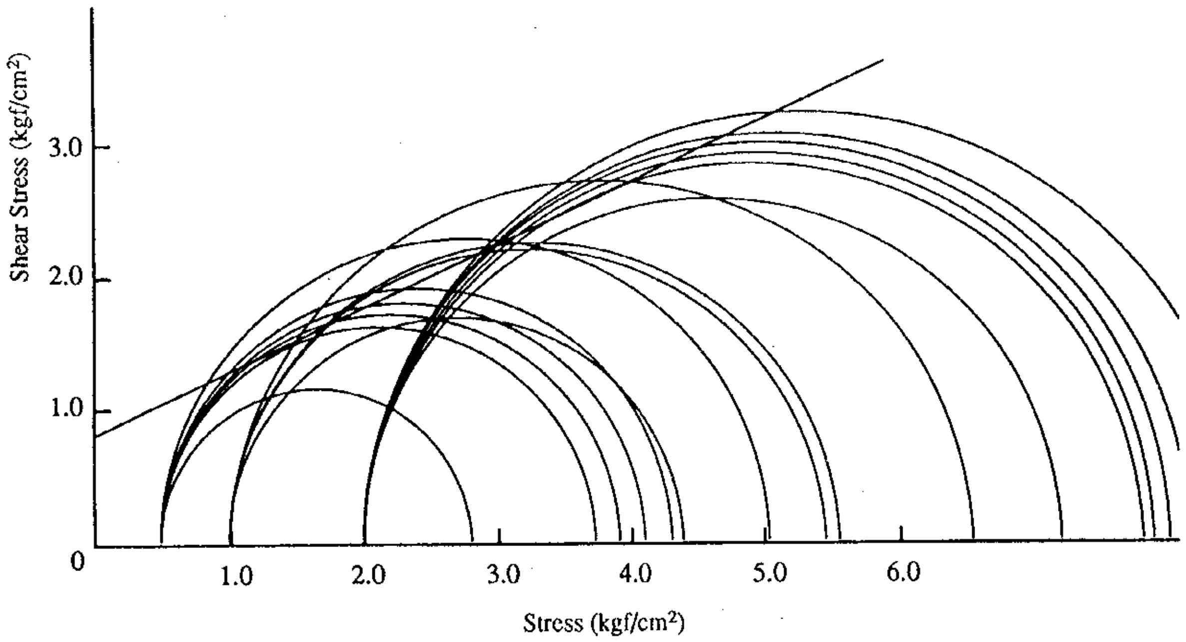


Figure 34 MOHR'S CIRCLE AND ENVELOP LINE OF CD-TEST (EMBANKMENT MATERIAL)

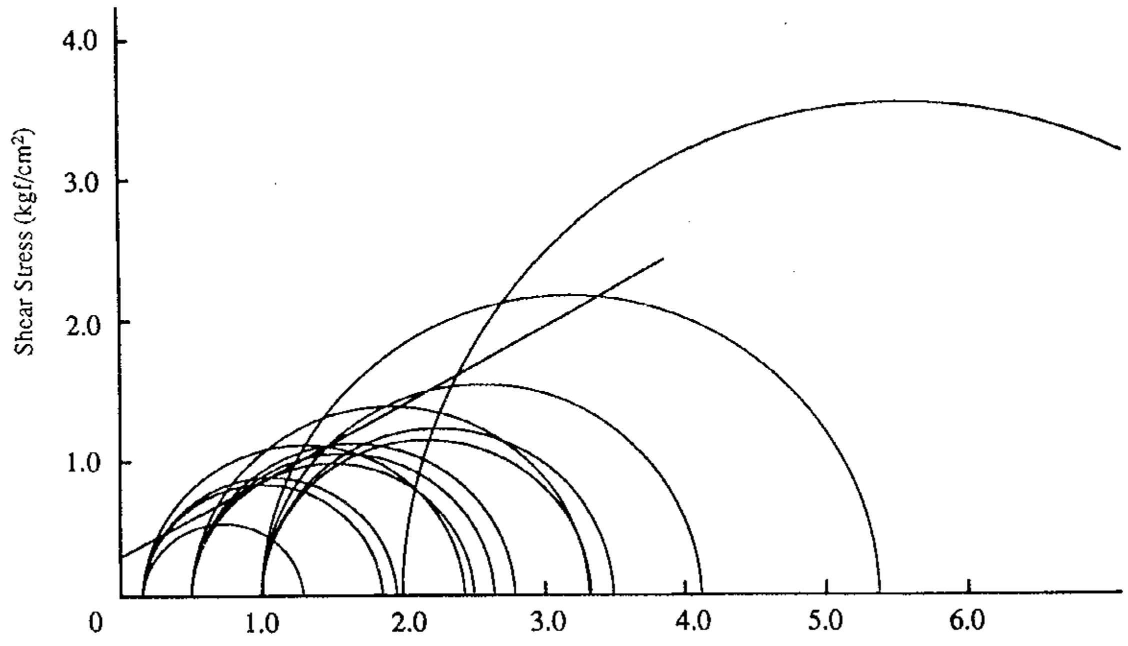


Figure 35 MOHR'S CIRCLE AND ENVELOP LINE OF UU-TEST (EMBANKMENT MATERIAL)

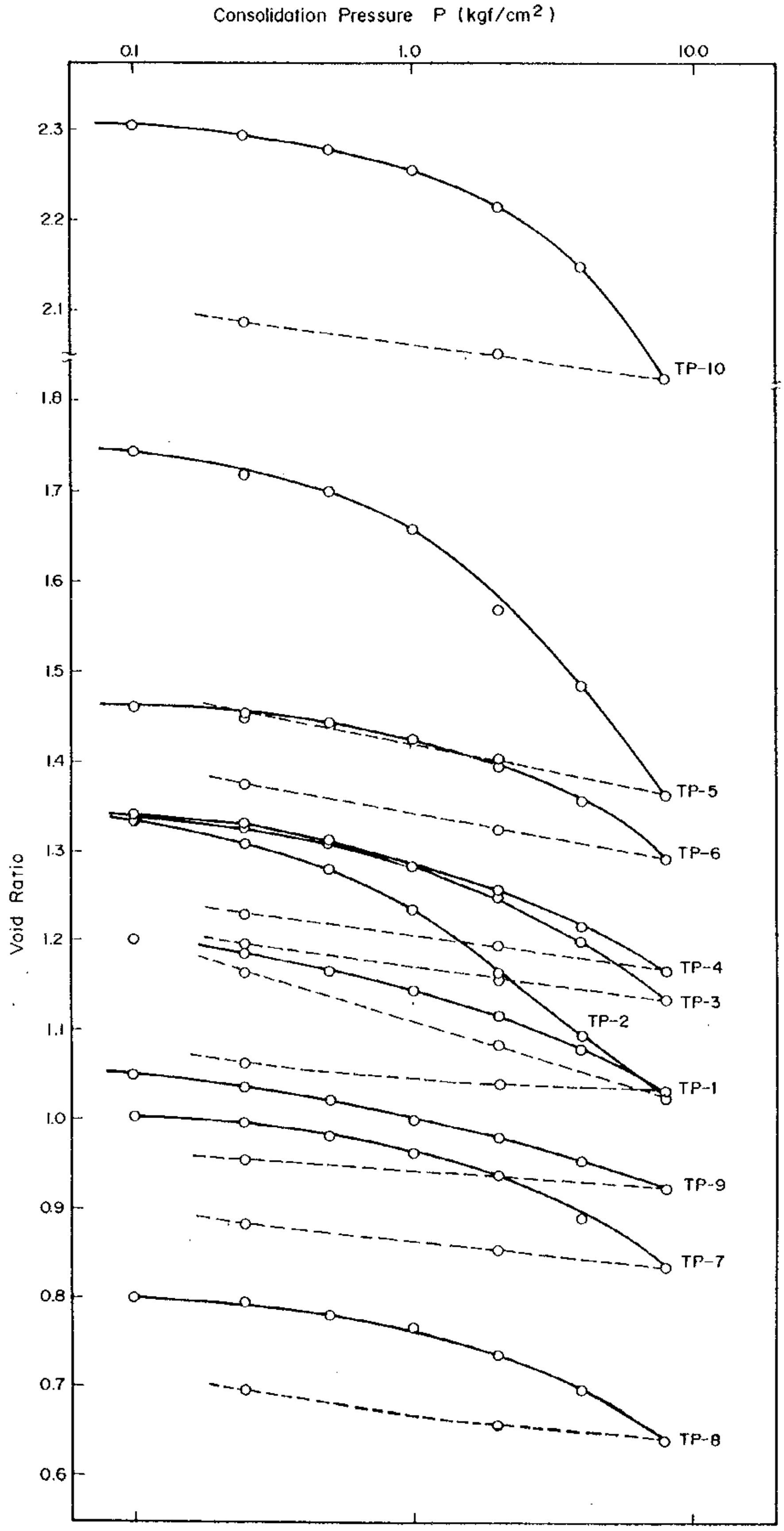


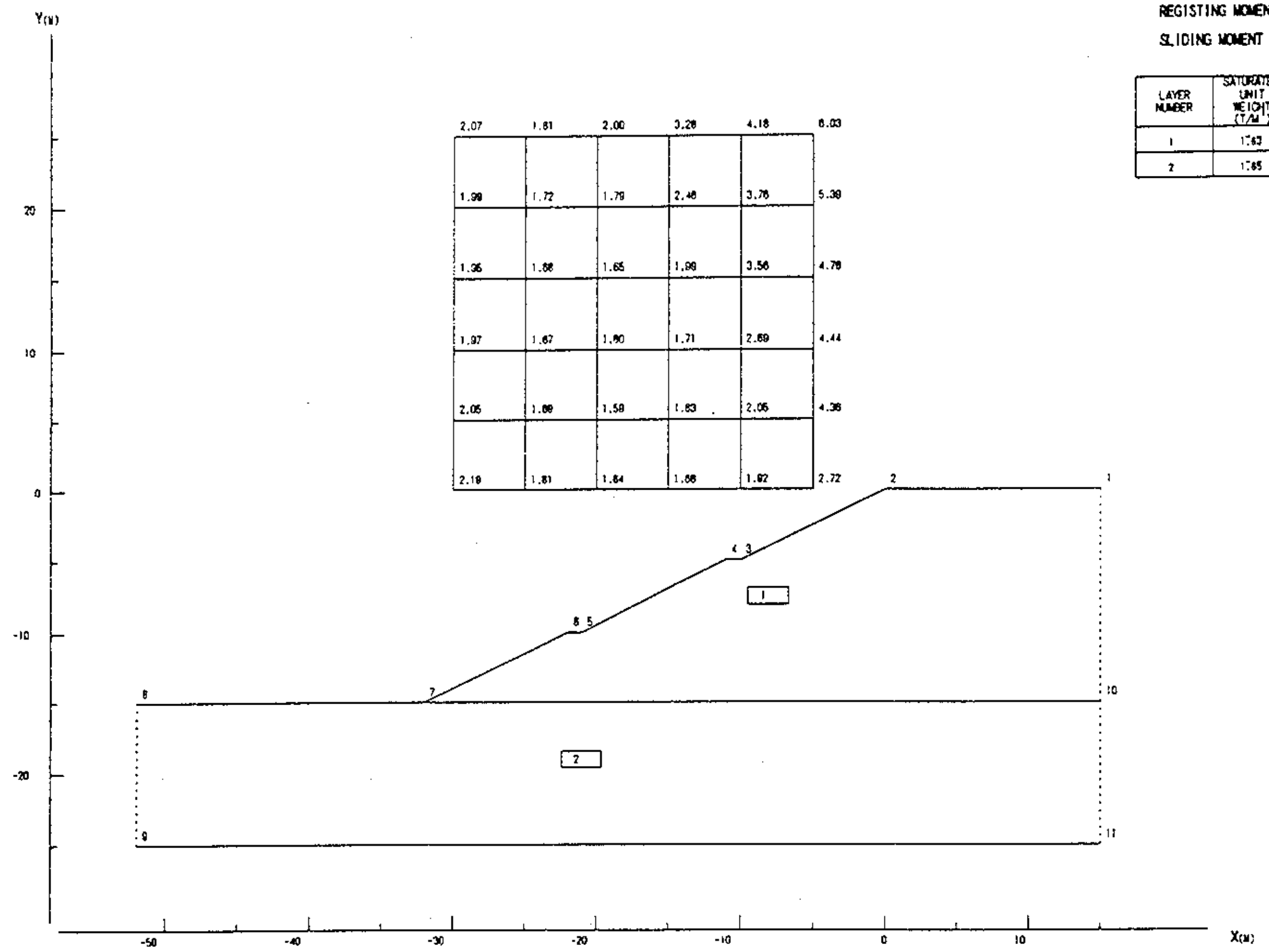
Figure 36. e - logp RELATIONS OF EMBANKMENT MATERIALS

Ciujung-Cidurian Embankment

SCALE 1 / 500

MINIMUM SAFETY FACTOR		=	1.59	
CENTER OF CIRCLE	X	=	-20.00	(M)
	Y	=	5.00	(M)
RADIUS	R	=	30.00	(M)
REGISTING MOMENT	M_R	=	12103.58	(T*M)
SLIDING MOMENT	M_D	=	7578.77	(T*M)

LAYER NUMBER	SATURATED UNIT WEIGHT (T/M³)	WETTED UNIT WEIGHT (T/M³)	INTERNAL FRICTION ANGLE (DEGREE)	COHESION (T/M²)	INCREMENT OF COHESION	HORIZONTAL SEISMIC COEFFICIENT	VERTICAL SEISMIC COEFFICIENT
1	1.63	1.83	27.0	4.00	0.000	0.000	0.000
2	1.65	1.65	16.0	3.00	0.000	0.000	0.000



SAFETY FACTOR (ORDINARY CONDITION)

Figure 37. STABILITY ANALYSIS MODEL OF EMBANKMENT

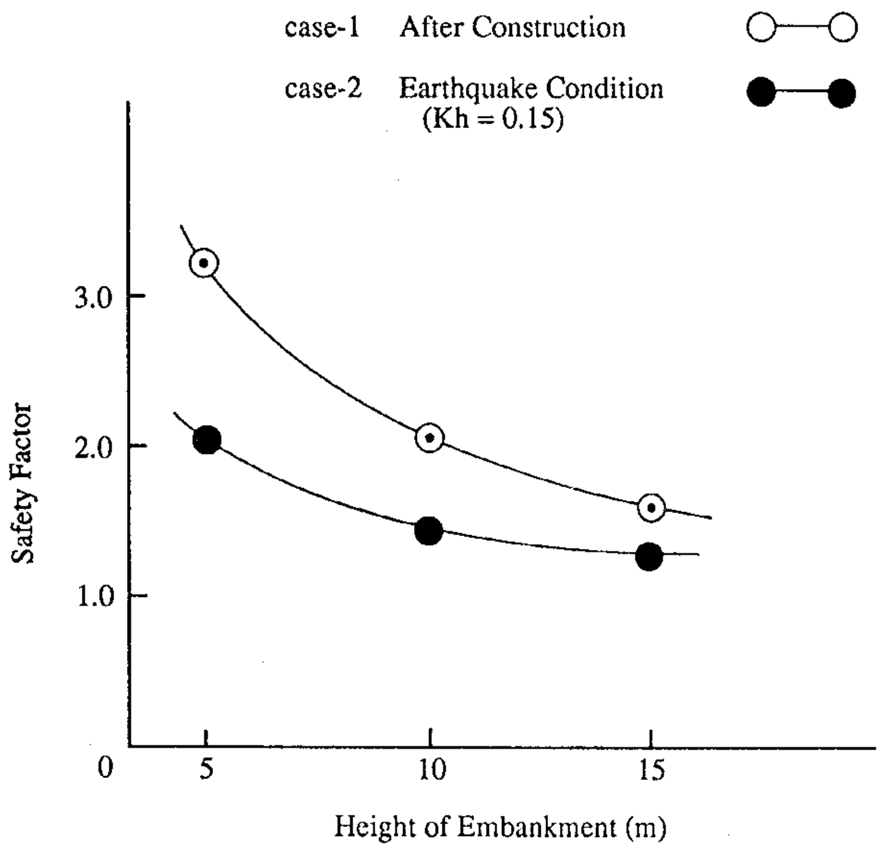


Figure 38. SAFETY FACTOR OF EMBANKMENT

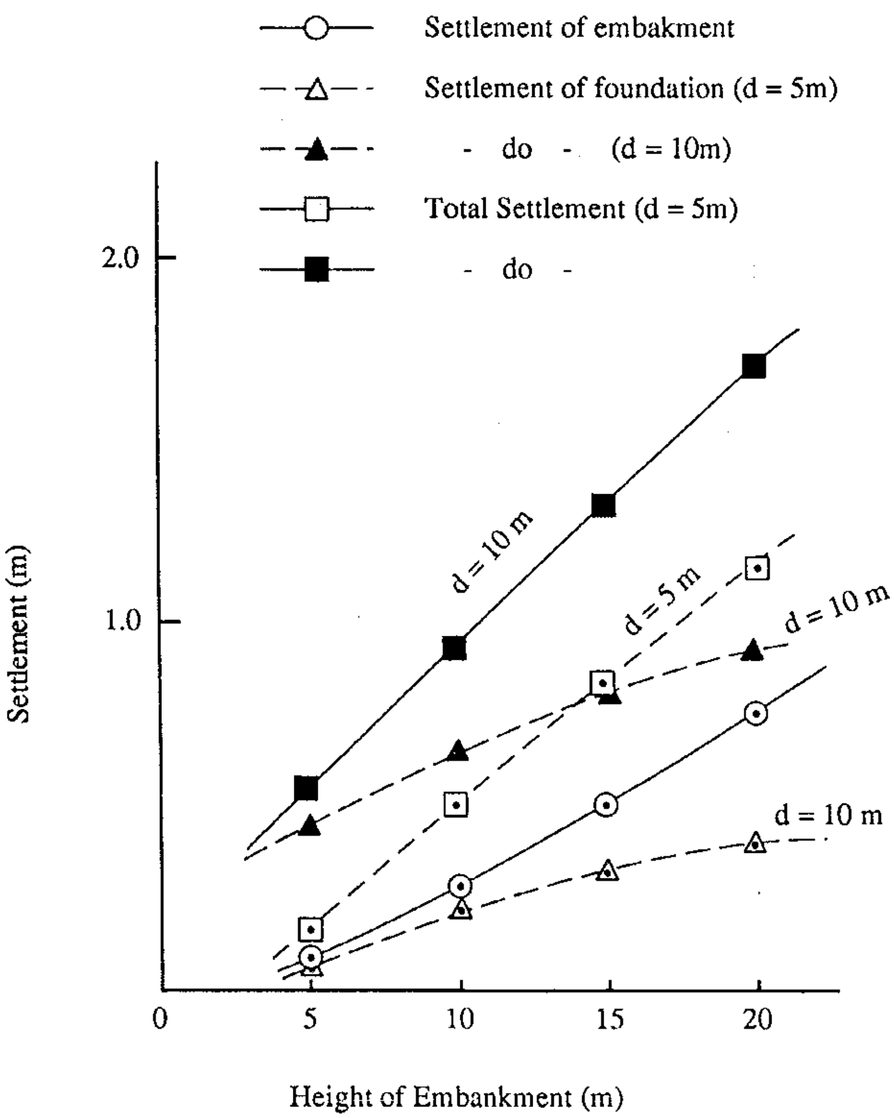


Figure 39. FINAL SETTLEMENT OF EMBANKMENT

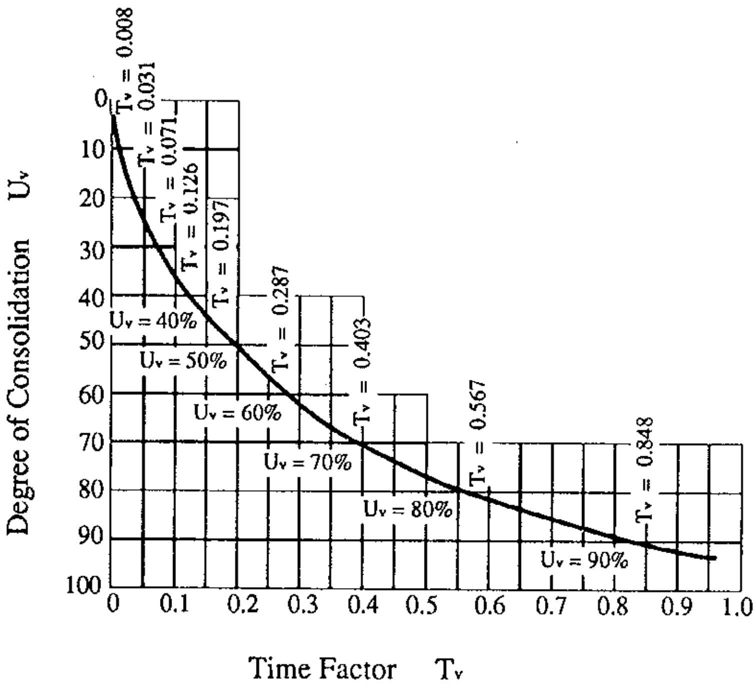


Figure 40. Tv VERSUS Uv RELATIONSHIP

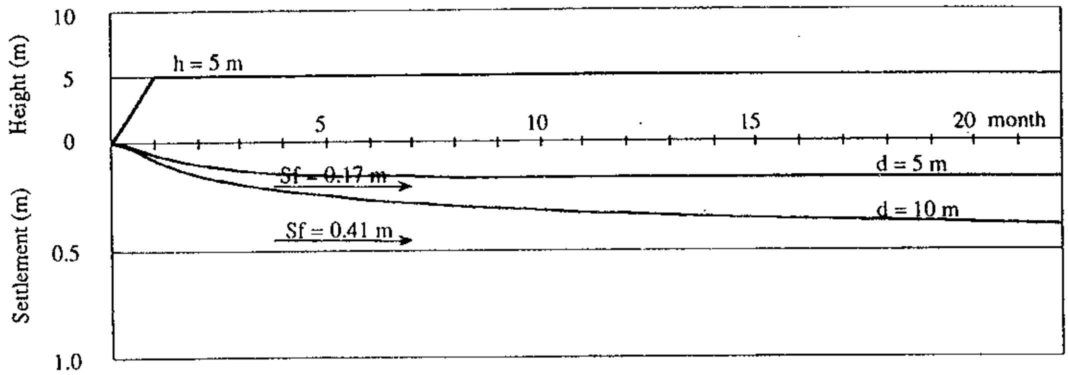


Figure 41 SETTLEMENT CURVE (h = 5 m)

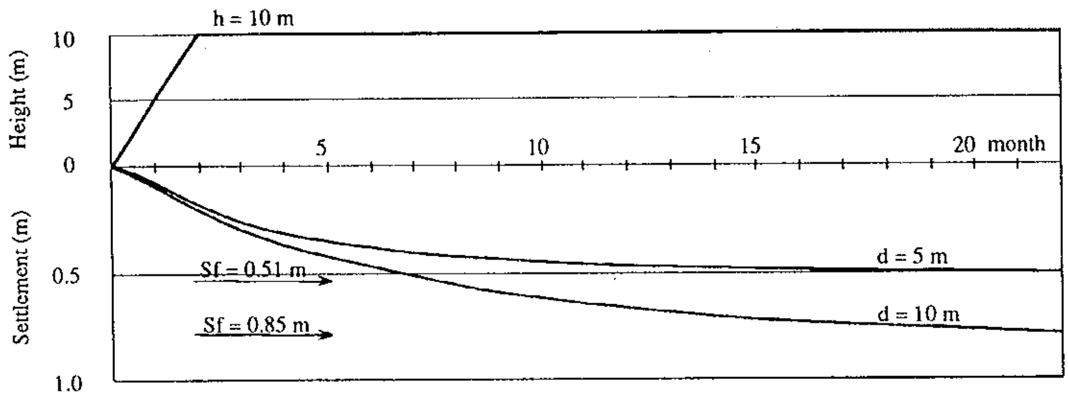


Figure 42 SETTLEMENT CURVE (h = 10 m)

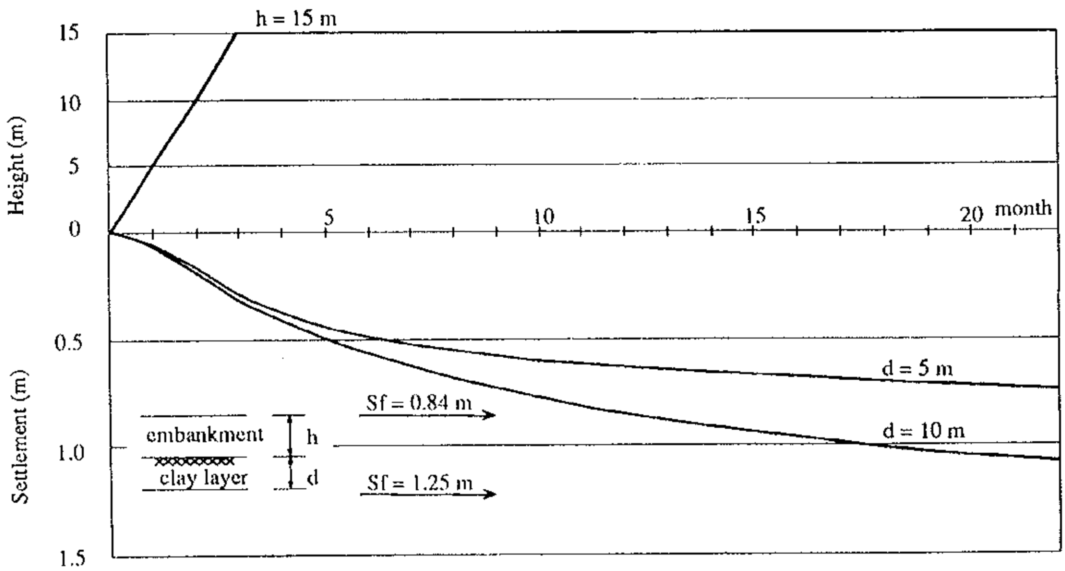


Figure 43 SETTLEMENT CURVE (h = 15 m)

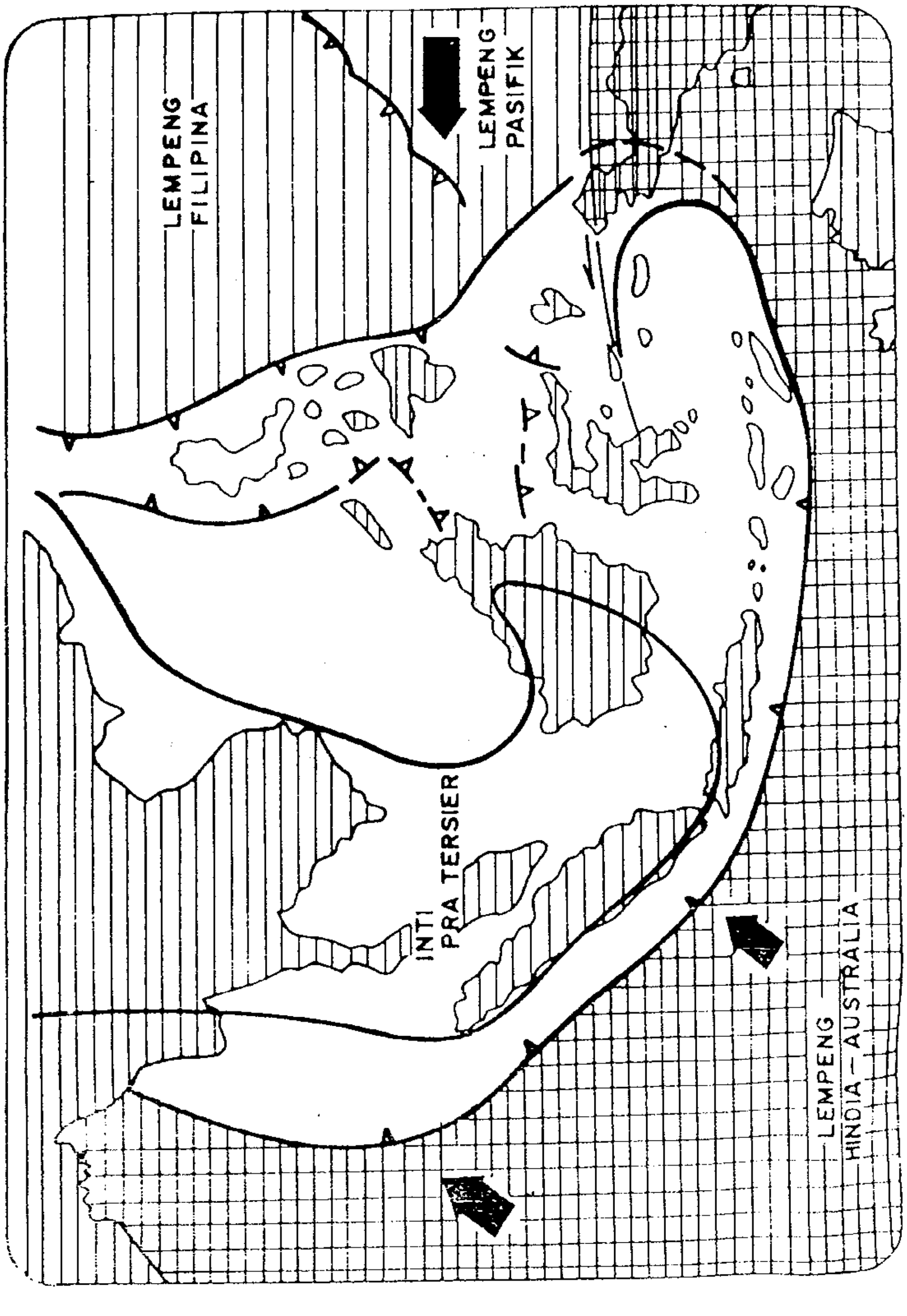


Figure 44. TECTONIC PLATES AROUND INDONESIA

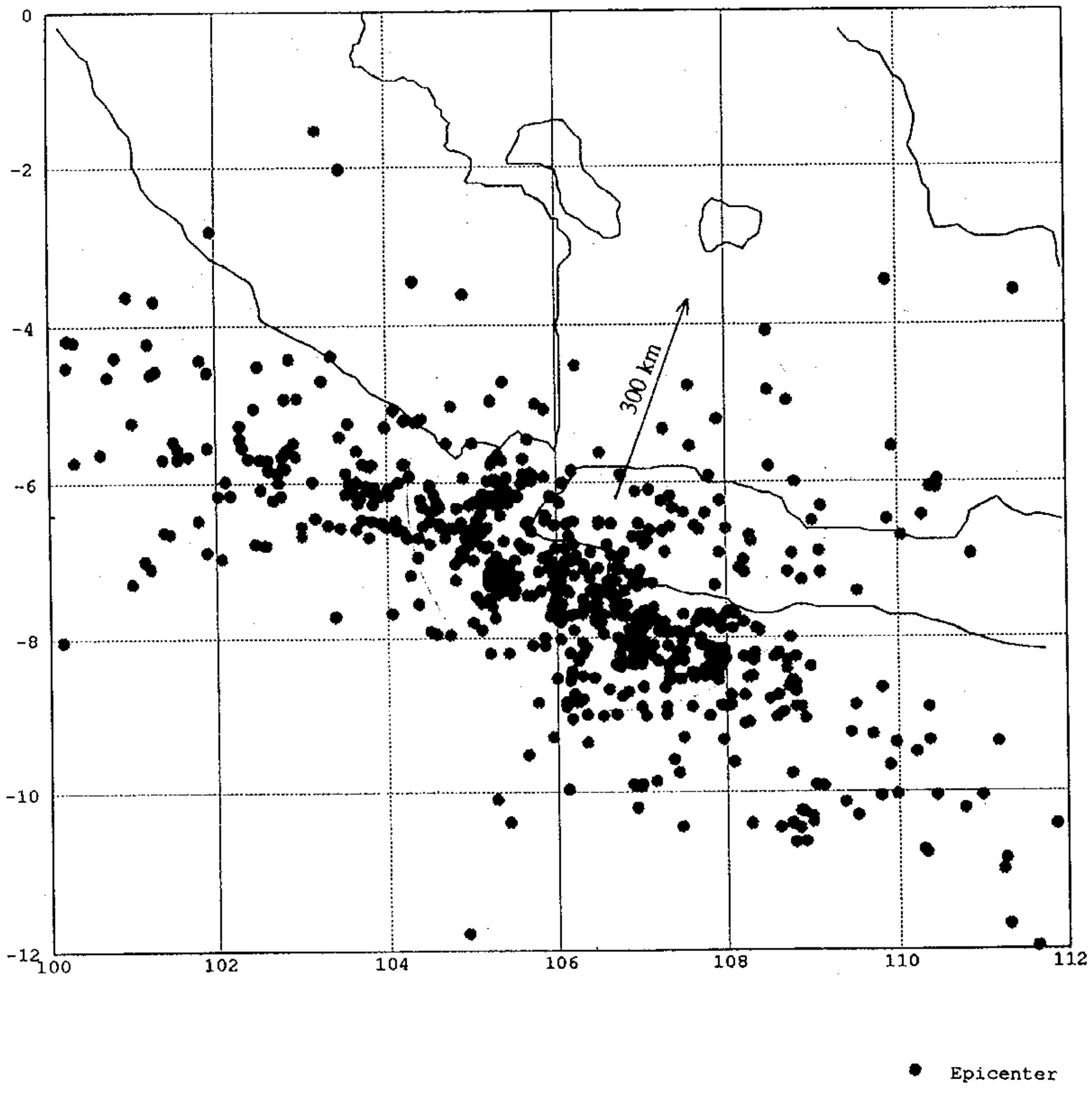


Figure 45. SEISMICITY MAP IN WEST JAVA AND ITS VICINITY (M = 4.0 - 4.9 SR)

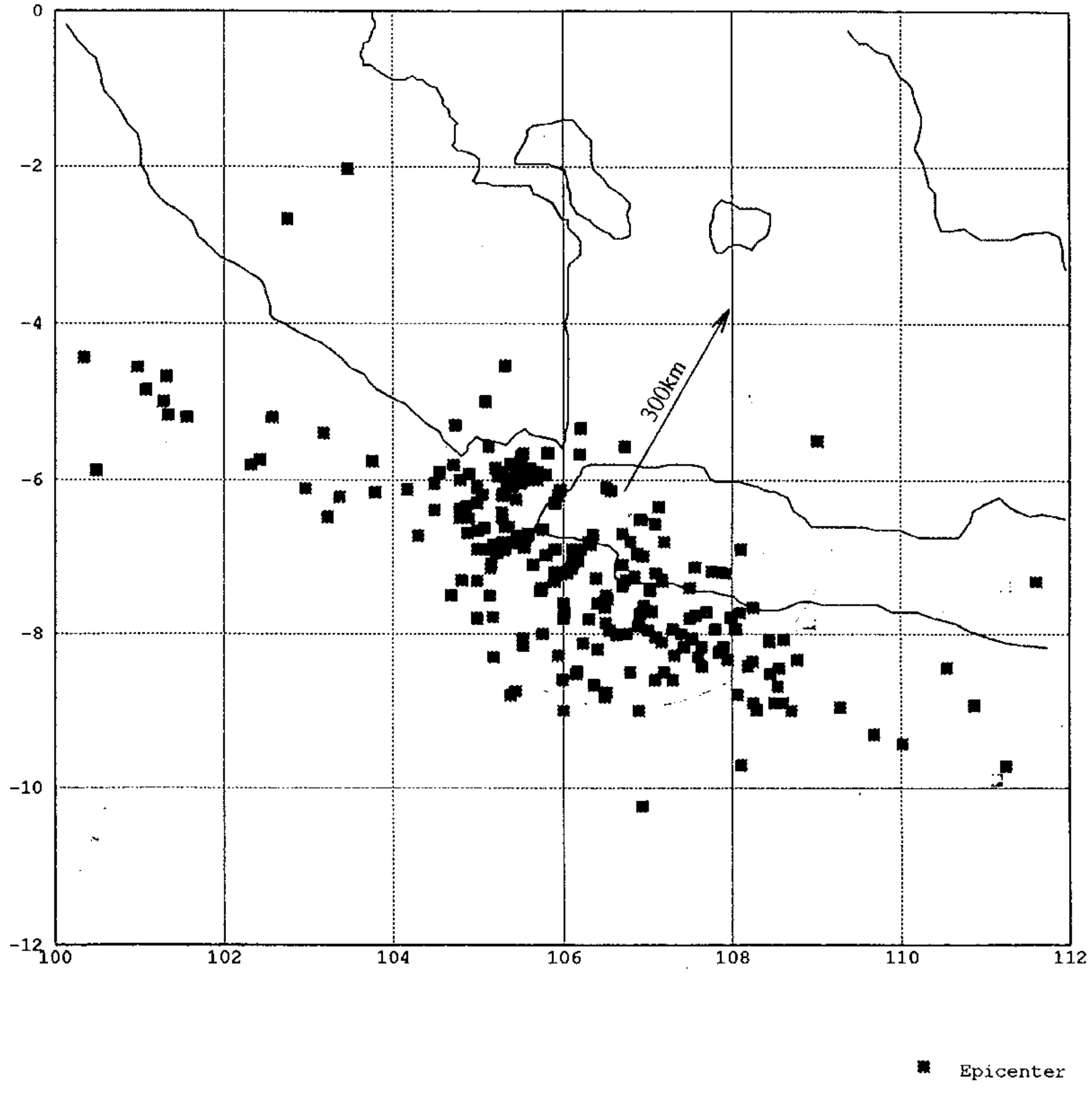


Figure 46. SEISMICITY MAP IN WEST JAVA AND ITS VICINITY (M = 5.0 - 5.9 SR)

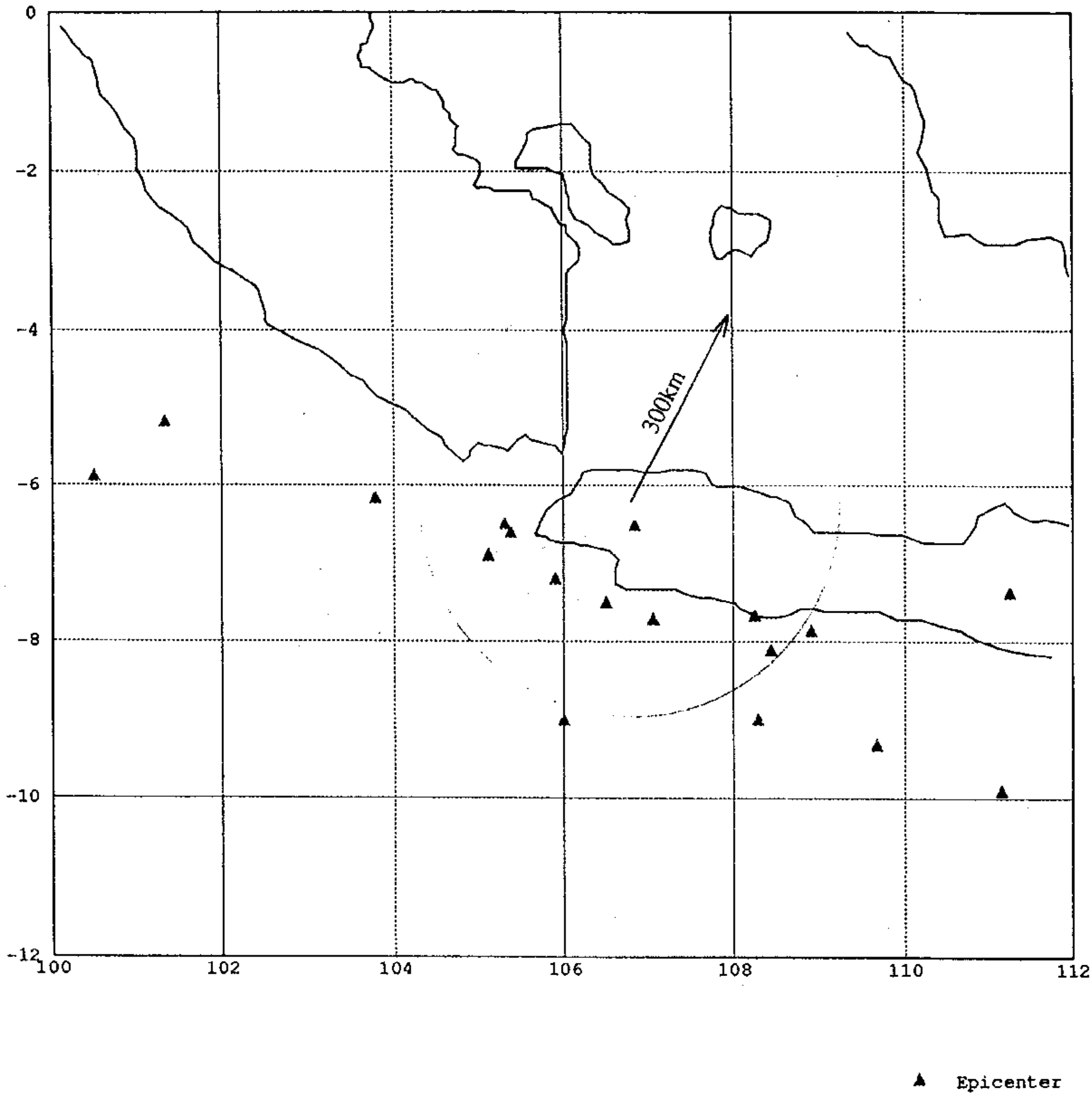
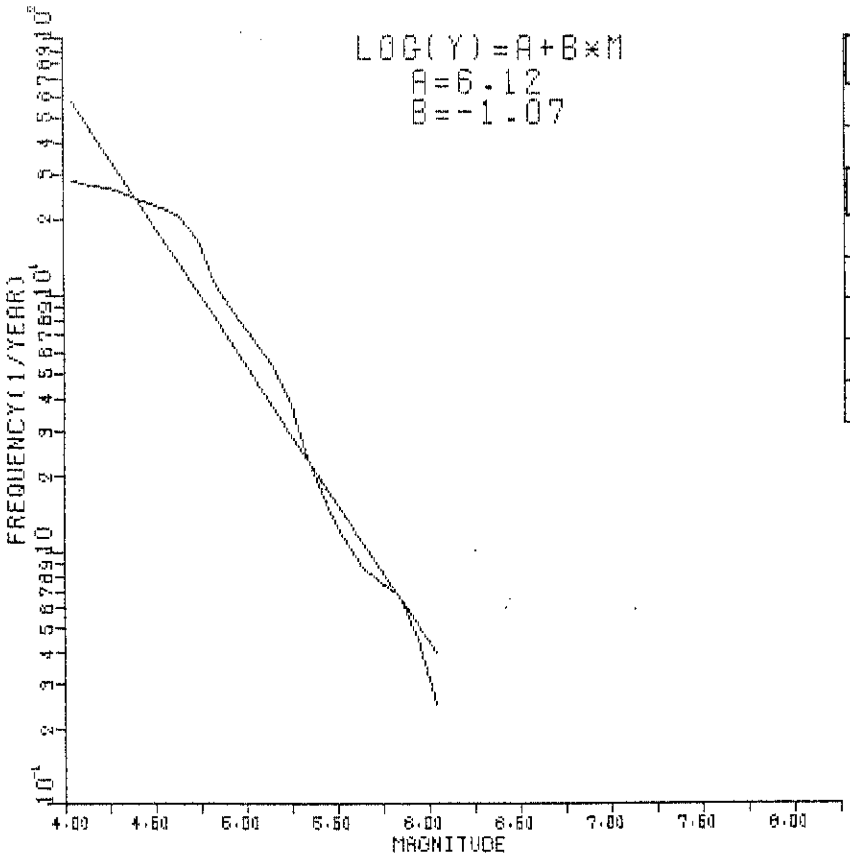
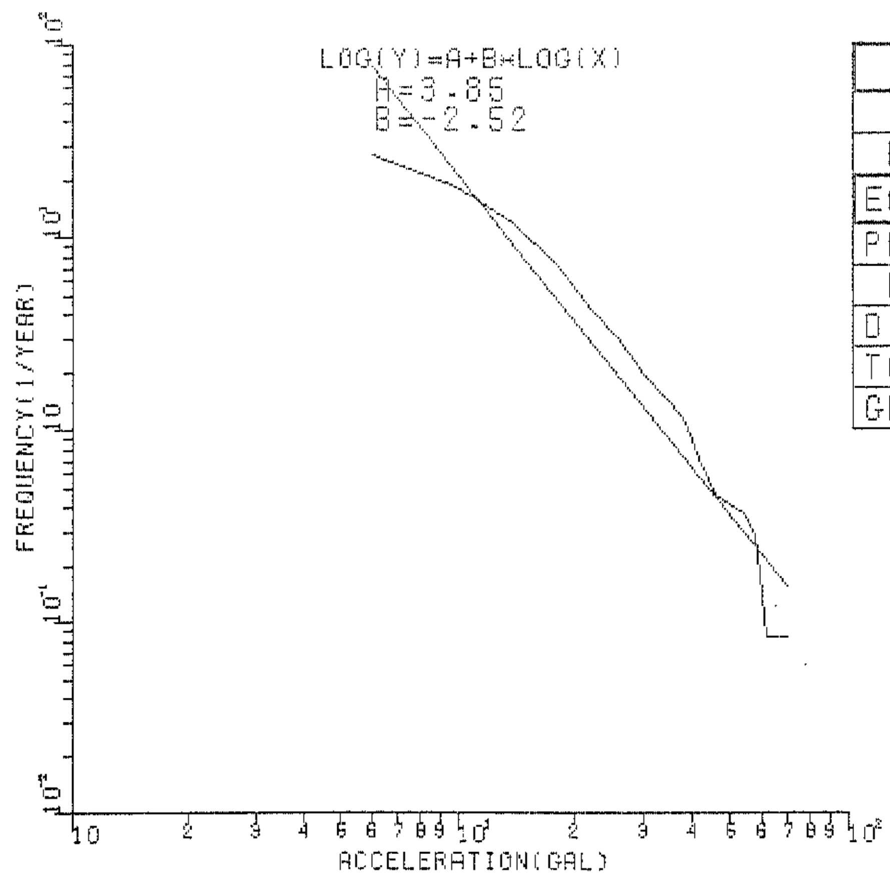


Figure 47. SEISMICITY MAP IN WEST JAVA AND ITS VICINITY (M > 6.0 SR)



STATION LOCATION	
LAT.(DEG)	-6.40
LONG.(DEG)	106.50
EARTHQUAKES CONSIDERED	
PERIOD(A.D.)	1970-1993
MAGNITUDE	4.0-6.7
DISTANCE(KM)	0 -300
TOTAL NUMBER	698
GROUND COND.TYPE	

Figure 48. LOG FREQUENCY OF MAGNITUDE



STATION LOCATION	
LAT.(DEG)	-6.40
LONG.(DEG)	106.50
EARTHQUAKES CONSIDERED	
PERIOD(A.D.)	1970-1993
MAGNITUDE	4.0-6.7
DISTANCE(KM)	0 -300
TOTAL NUMBER	698
GROUND COND.TYPE	2

Figure 49. LOG FREQUENCY OF ACCELERATION

ANNEX 7

KARIAN-SERPONG CONVEYANCE SYSTEM

THE STUDY ON CIUJUNG-CIDURIAN INTEGRATED WATER RESOURCES

Annex 7 : Karian Serpong Conveyance System

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1. INTRODUCTION

The Karian-Serpong water conveyance system (KSCS) is planned to convey the stored river water in the Karian, Cilawang and Tanjung reservoirs as shown in Figure 1 to the envisaged water treatment plants (WTP) at Tenjo, Parungpanjang and Serpong for the municipal and industrial water supply to DKI Jakarta and Tangerang, Serpong, Balaraja and Tigaraksa areas in Kab. Tangerang. The former two (2) WTP was proposed by the water supply master plan by the JWRMS and later one is under construction by PDAM Tangerang.

The study on the Karian-Serpong conveyance mainly made selection of an optimum route of KSCS including type of conveyance method and preliminary design of the major structures such as intakes at the reservoirs, waterway, river and road crossing structures and cross drains.

The optimization study on route alignment, structure and flow types for the water conveyance system was executed to meet the following requirements in due consideration of the present conditions along the route:

- Safe drinking water supply,
- Minimization of social and natural environmental impact, and
- Minimum operation and maintenance cost.

Preliminary design for the KSCS with the optimized route, type and gradient was conducted for the proposed raw water supply plan.

2. ALTERNATIVES STUDY ON WATER CONVEYANCE ROUTE

2.1 Screening of Alternative Routes from Ciuyah Tunnel to Serpong WTP

2.1.1 Basic conditions for first screening

(1) Conveyance method applied

Topographic condition along the route of water conveyance system was studied based on the field investigation, the aerial photographs with a scale of 1:20,000 and the available topographic maps with a scale of 1:5,000 to 1:10,000 produced by the previous studies and projects.

The general topography along the route of water conveyance system is illustrated in Figure 2 based on the above topographic maps. The southern part of the existing railway line between Ciuyah and Serpong, planned to be one of alternative routes, is covered with a hilly area with an elevation more than 50 m. Along the northern part, its altitude varies from EL. 40 m to EL. 50 m in general although high land more than EL. 50 m partly occupies the area between the right bank of the Cidurian river and left bank of the Cimanceuri river. While, along the river channel of the Cidurian, Cimanceuri and Cisadane rivers, there exist locally low land areas with an altitude from EL. 25 m to EL. 30 m, where there are old river channel traces formed by the aforesaid rivers. The width of these low land areas are about 500 m along the Cidurian river and 200 m to 800 m along the Cisadane river at Serpong. The hilly and low lands form many small scale valleys with height of 20 m to 40 m along the area between the Ciuyah tunnel outlet and Serpong water treatment plant.

Taking into account the low water level of EL. 46.0 m in the Karian reservoir and ground level of around 50 m at Serpong WTP and the topographic condition along the route with elevation of 40 m to 50 m, combination of gravity and pumping-up conveyance method was applied for examination.

While, application of pumping-up method was considered to be minimized in order to reduce operation cost of pumping facilities since financial arrangement for operation cost is in very tight situation in Indonesia.

From the above, a location of pumping-up was selected at the right bank side of the Cisadane river and the gravity conveyance method was applied for other stretches of the KSCS in the first screening.

(2) Connection of the Karian reservoirs with KSCS

The feasibility study for the Karian multipurpose dam construction project in 1985 proposed to construct the Buyut weir to take the water released through the Ciuyah tunnel from the Karian reservoir and flowing in the river channel of the Cibeureum river from the Cilawang reservoir for the supply of irrigation water to the K-C-C area. However, the main purpose of the reservoirs has been changed from irrigation water supply to the municipal and industrial water supply in this study.

Relating with the above situation, the intake method for the KSCS was studied from the points of view of safe drinking water supply and construction and water treatment costs before starting the alternative study on the route of the KSCS.

There are broadly the following two (2) alternatives to introduce the water from the Karian reservoir (and also Cilawang reservoir) to the KSCS as shown in Figure 3.

Alternative 1 : Karian ⇒ Ciuyah tunnel ⇒ Cibeureum river ⇒ Buyut weir ⇒ KSCS
Alternative 2 : Karian ⇒ Ciuyah tunnel ⇒ KSCS

In order to select the preferable one from the aspects of construction and operation costs including treatment cost, a cost comparison was made and the result revealed that the total cost is almost same in both methods as tabulated below:

Alternative	Cost Items	Cost (billion Rp.)
1.	a) Construction of Buyut weir	20.0
	b) Construction of sand trap basin	2.0
	c) Water treatment cost	5.0 to 10.0
	Total	27.0 to 32.0
2.	a) Construction of canal between Ciuyah tunnel and KSCS	23.0
	b) Construction of canal between Cilawang dam and KSCS	6.6
	Total	29.6

The alternative 2 directly connecting the Ciuyah tunnel with the KSCS was proposed based on the result of cost comparison and in consideration of particularly clean water supply and also uncertainties to be involved in maintenance works for sedimentation at the Buyut weir and waterway, and more complicated operation and maintenance of gates to be required for the Buyut weir in the alternative 1.

While, the design low water level (LWL) of the Karian reservoir was determined at EL. 46.0 m in the feasibility study and a hollow jet valve of 1.2 m in diameter was proposed to be equipped in the Ciuyah tunnel to discharge 8 m^3/s for K-C-C irrigation area. However, due to change of the connection type and design discharge from 8 m^3/s to 12.4 m^3/s, each one set of slide gate and sleeve valve was proposed to be provided in order to make the outlet water level as high as possible and to minimize construction cost of waterway and operation cost thereby.

(3) Waterway type of water conveyance system

In screening, cost estimate of KSCS was carried out for the preliminary design of water conveyance system, assuming discharge capacities of 2 m^3/sec to 30 m^3/sec.

Alternative waterway types applicable to the water conveyance system between reservoirs and each water treatment plant are listed below and illustrated in Figure 4.

Option-1 : Unlined trapezoidal channel
Option-2 : Masonry lined trapezoidal channel
Option-3 : Concrete lined trapezoidal channel
Option-4 : Masonry concrete rectangular channel
Option-5 : Reinforced concrete rectangular channel
Option-6 : Box culvert channel
Option-7 : Steel pipeline
Option-8 : Reinforced concrete pipeline

For screening the alternatives, a comparison was made from the aspects of hydraulic advantages, construction cost, operation and maintenance, environmental impact. Result is indicated in Table 1 and Figure 5. The applied unit rates were based on those adopted in the draft final report of JWRMS, Annex 4 "Ranking of Measures" and on-going projects in Indonesia.

Since the water conveyance system aims at supplying municipal and industrial (M&I) water supply from the reservoirs to the envisaged water treatment plants (WTPs) at Tenjo, Parungpanjang and Serpong, the waterway shall meet the following requirements which are the concepts established by the JWRMS:

- Safe drinking water supply, and
- Gravity supply so as to minimize the operation and maintenance cost.

Based on preliminary assessment of the alternatives, reinforced concrete rectangular channel and box culvert were recommended taking into account the order of construction cost, degree of difficulty of maintenance, less water conveyance loss, degree of possibility of water pollution, and magnitude of environmental impacts, especially on land acquisition. In selecting the type, special consideration was given to necessity of slope protection of the channel type structure since slope failures along the existing canals are remarkably and therefore needs frequent maintenance works. Furthermore, reduction of water conveyance loss has significant importance because of the effective use of available water resources.

To meet the the mentioned requirements, a box culvert type of waterway is a preferable option for the waterway under the gravity conveyance method because of free from water pollution due to intrusion of rain drainage and by inhabitant and livestock. However, the box culvert waterway costs about 30% higher than that of the reinforced rectangular channel (U-channel) estimated in the preliminary study. Also, the U-channel which will be free from the water pollution by providing fence along or covering on the channel in accordance with expansion of the urbanization along the route so as to keep inhabitant off from the channel in residential areas.

There is a possibility of concrete pipeline for the waterway. Since the maximum pre-cast concrete pipe available in Indonesia is 2.6 m in diameter so far and the design discharge is so large as 4.1 m^3/sec to 13.8 m^3/sec for each waterway, the pipe line cost is much higher than other type in case of gravity flow. For example, two or three lanes of pipeline with a diameter of 2.6 m will be required for the design discharge of 6 m^3/sec between Parungpanjang and Serpong and its cost will be around 25% higher than that of box culvert under the condition without pump structure. Therefore, the pipeline waterway was discarded for the preliminary route selection.

2.1.2 Alternative route of water conveyance system

Several alternative routes were set out in order to select the optimum one mainly from the aspect of the least construction cost. Taking into account topographic conditions and length of water conveyance route of about 50 km, the total cost of earth and concrete works of the waterway was counted for the cost comparison considering that they occupy the major part of construction cost. To compare the order of the construction cost due to difference of topographic condition, four (4) alternative routes were set out as illustrated in Figure 6.

As shown in the figure, all the alternative routes pass the same course in the stretches from the outlet of the Ciuyah tunnel to crossing points with the Cidurian river (BP to IP.1), and from Parungpanjang to Serpong WTP (IP.2 to EP). In the former stretch, the water conveyance route is aligned along the contour line with about EL. 50 m. This alignment is considered to give the least construction cost for this stretch since further northern route needs longer stretch and southern one produces vast amount of excavation volume for passing hilly land with an elevation of 60 m to 70 m. While, the stretch with a length of 8.25 km near Serpong is delineated to detour the northern area of the existing railway line where there are development plans for housing and industrial uses by the Bumi Serpong Damai (BSD) in order to avoid possible serious land acquisition problem. This consideration was given for all alternative routes.

In the stretch between IP.1 and IP.2, the routes runs along the following contour lines:

Alternative Routes	Topographic Condition	Length (km)
N-1	Northern edge of contour line with EL. 50 m till Tenjo and EL. 40 m till IP.2 near Parungpanjang	47.1
N-2	Northern edge of contour line with EL. 50 m till IP.2 near Parungpanjang	47.2
N-3	Similar to N-2 but shortened by running in slightly southern area	46.2
S-1	Along the existing railway line with an elevation of 40 m to 60 m, which is the shortest one among the alternatives.	45.7

In delineating alternative routes, it was further considered not to cause significant land acquisition problems in the existing towns and villages, land acquisition areas along the Cisadane river near Serpong and the areas planned to be developed for industrial and housing uses such as Bumi Serpong Damai and Tigaraksa New Towns as much as possible.

2.1.3 Cost comparison among the alternative routes

The cost comparison was made by combining the several flow capacities constant through the waterway from the Ciuyah tunnel to Serpong WTP and several canal bed slopes. The flow capacities were set at 8 m^3/s, 15 m^3/s, 20 m^3/s and 30 m^3/s taking into account the released discharge from the Karian dam planned in the previous studies, that is 8 m^3/s in the feasibility study on the Karian multi-purpose dam project and 24 m^3/s in the Cisadane-Cimanuk integrated water resources development study. While, the canal bed slopes were set at 1/1000, 1/2500, 1/5000, 1/7500, 1/10000 and 1/12500, which are possible ones judged from the topographic condition along the KSCS.

The construction cost of each alternative route estimated under the above mentioned conditions was converted into the present value assuming the discount rate of 12 %, construction period of 4 years, project life of 50 years, replacement of pump with an interval of 25 years, operation and maintenance cost of 1 % to construction cost and electric tariff of Rp. 150/kWh.

The result of cost comparison is tabulated below and topographic profile of the alternatives is illustrated in Figure 7.

Route	Canal Bed Slope	Present Value (billion Rp.) 8 m^3/s	15 m^3/s	20 m^3/s	30 m^3/s
N-1	1/5000	132.7	175.2	192.5	226.4
N-2	1/5000	129.0	163.5	180.2	213.0
N-3	1/10,000	135.5	170.2	187.6	221.1
S-1	1/5000	156.7	191.6	209.9	243.5

As indicated above, among the alternative routes, the routes of N-2 and N-3 are prospective ones for all the flow capacity under the condition with gravity conveyance method till the right bank of the Cisadane river and pumping-up to Serpong WTP.

Through the above cost comparison, the optimum route of the KSCS was judged to be aligned along the alternative routes of N-2 or N-3.

2.2 Verification of Optimum Route

Based on the raw water supply plan established in the study and topographic map, covering the entire route of KSCS from the Ciuyah tunnel to Serpong WTP, with a scale of 1/5,000 produced by the study, the construction cost for the prospective routes of N-2 and N-3 was verified.

Construction costs including land acquisition cost of the alternative routes N-2 and N-3 were estimated for the following design discharge proposed for the scenarios A and C, assuming waterway with one lane of concrete rectangular channel:

(unit: m^3/sec)

Scenario	Waterway				
	Section 0	Section 1	Section 2	Section 3	Section 4
A	12.4	16.5	16.50	11.25	6.00
C	12.4	16.5	26.20	16.10	6.00

The present value of construction and operation maintenance costs of waterway and pumping-up facilities were estimated as follows:

(unit: billion Rp.)

Scenario	Route N-2	Route N-3
A	245	249
	(1/5,000)	(1/10,000)
C	257	259
	(1/5,000)	(1/10,000)

Note : Values in parenthesis show the waterway bed slope.

From the above verification on the cost for the prospective rotes of N-2 and N-3, the route of N-2 is proposed to be an optimum route for the KSCS.

However, the waterway along the route N-2 between Parungpanjang and Serpong is aligned through the hilly area with an altitude of about 60 m in order to detour the developing area of Bumi Serpong Damai. Therefore, comparing construction cost per unit conveyed water amount in this section of the route with that for the upstream route of Parungpanjang, it was judged to be significantly expensive due to vast amount of excavation work to form a gravity conveyance waterway in the hilly area with an altitude of EL. 60 m against waterway bed elevation of around El. 40 m. The application of pumping-up method with pipeline conveyance of this section will significantly reduce the construction cost at around 50 % against gravity conveyance method.

Through the verification of construction cost, the route of N-2 was confirmed to be the optimum route, and gravity conveyance from the Ciuyah tunnel to Parungpanjang WTP and pressure flow type conveyance from Parungpanjang WTP to Serpong WTP were revealed to give the least construction cost.

2.3 Route between Parungpanjang and DKI Jakarta

Serpong WTP is planned to be connected with two (2) distribution centers; R.4 distribution center and Lebakbulus distribution center in DKI Jakarta. Therefore, further alternative routes from Parungpanjang WTP to these distribution centers were investigated in consideration of the locations of these distribution center. Results are described below.

2.3.1 Water supply plan in DKI Jakarta

In the water supply master plan in Jabotabek area established by the JWRMS, the M&I water of 6 m^3/sec is planned to be conveyed from the western water sources to DKI Jakarta from the year of 2015. Also, it is suggested in the master plan that the water amount of 3 m^3/s currently taken in from the Cisadane river for the Serpong WTP is needed to be replaced by the aforesaid water amount of 6 m^3/s, if the serious water pollution problem in the Cisadane river will not be solved.

While, the water amount of 3 m^3/s from the Serpong WTP is planned to cover zones 4 and 5 of the PAM Jaya System, which has R.4 and Lebakbulus distribution centers, respectively. According to the Jakarta Water Supply Master Plan in 1985, supply capacities of these distribution centers were planned to be 1.1 m^3/s for R.4 and 1.8 m^3/s for Lebakbulus as a target year of 2005. At present, the PDAM of Kab. Tangerang is constructing pipeline conveyance system from Serpong WTP to these distribution centers with the maximum capacity of 2.8 m^3/s and diameter of 1.5 m between Serpong and branch point, 1.2 m between the branch point and Lebakbulus distribution center, and 1.0 m between the branch point and R.4 distribution center.

In the comparative study, destination of the envisaged raw and treated water conveyance system route were set up at the aforesaid two distribution centers. Also, the water supply amount to the centers are assumed to be 3 m^3/s after 2015 for both the centers since population in zone 4 located in Kec. Jakarta Barat is rapidly increasing with a higher average growth rate of 4 % than that in Kec. Jakarta Selatan and future served population is expected to be at same order in zones 4 and 5 though the current population in Kec. Jakarta Selatan is larger than that in Jakarta Barat.

2.3.2 Alternative routes

Alternative routes illustrated in Figure 8, which have two destination of R.4 and Lebakbulus distribution centers (DC), are set up for the comparative study as follows:

(1) Possible routes to Lebakbulus through Serpong WTP

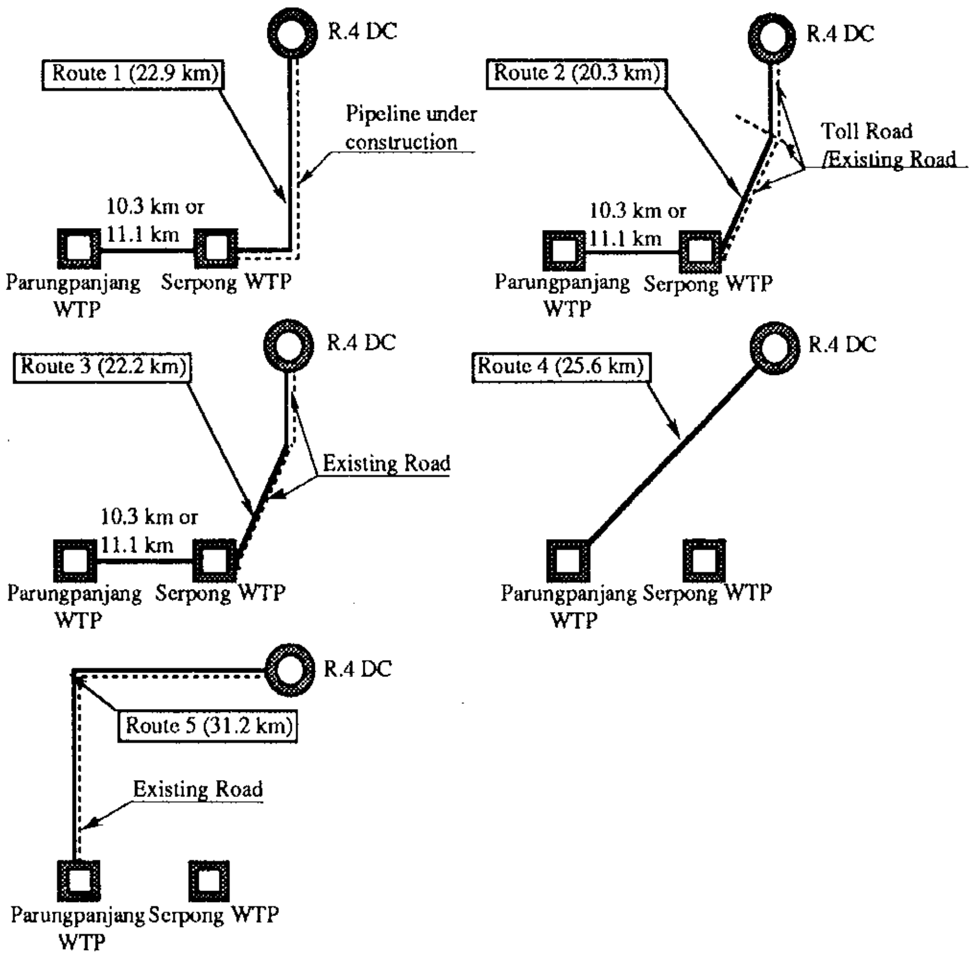
There are two possible alternative routes between Parungpanjang and Serpong WTP; one is the northern route of the existing railway (Route 1N) along which the Bumi Serpong Damai (BSD) is implementing housing development; and the other is a route south of the railway (Route 1S). The Route 1N has an advantage on length of waterway but disadvantage on land acquisition due to alignment in the BSD area.

The water conveyance system with a steel pipeline along the route 0 from the Serpong WTP to Lebakbulus and R.4 DC, which has the maximum capacity of 2.8 m^3/s, is under construction and scheduled to be completed in the fiscal year 1994/1995. Assuming that the replacement period of about 20 years, this system is required to be reconstructed when the water conveyance system for the western water sources will be provided after 2015. Regarding a route between Serpong WTP to Lebakbulus DC, the route for the pipeline under construction is considered to be the most cheapest because of the shortest length and no proper road system connecting these destinations without significant problems on land acquisition. Therefore, the route 0 from the Serpong WTP to Lebakbulus is only provided for the cost comparison.

From the above-mentioned, two (2) alternative routes to Lebakbulus DC are examined to convey raw and treated water to Lebakbulus, that is, 1) the route along 1S and 0; and 2) the route along 1N and 0.

(2) Possible routes to R.4 DC

It is possible to align the following five (5) alternative routes between Parungpanjang and R.4 DC:



Since the area between Parungpanjang and DKI Jakarta is being developed or developed for housing or industrialization, land acquisition for the construction of water conveyance system is judged to be one of important issues related to realization of the project. Therefore, the alternatives 1 to 3 and 5 is set up based on the basic principles using the existing road or planned highway and touring the less developed area. While, the route 4 is examined assuming that the shortest length of water conveyance system have an advantage on less construction cost.

The route 1 is aligned along the pipeline under construction to R.4 DC through Serpong WTP, where is expected to be less developed area. Also, the routes 2 and 3 are planned to be delineated along the existing roads, the planned outer ring road or highway connecting Serpong with the aforesaid outer ring road. While, the route 4 have the shortest length among 5 alternative routes but it is considered significant land acquisition problems since this alternative route runs through the BSD area and urbanized area between Tangerang and DKI Jakarta. The route 5 is planned to run along the existing roads as much as possible.

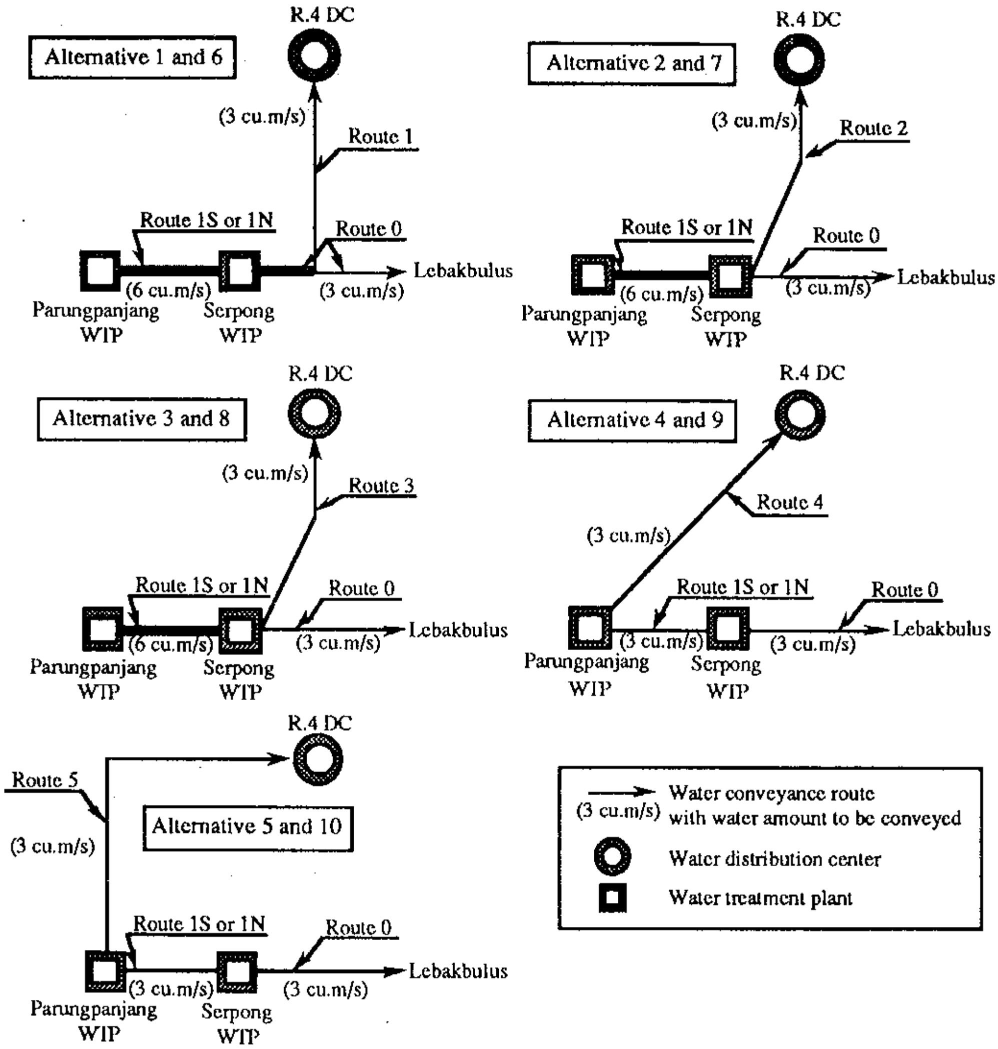
Combining the possible routes to Lebakbulus and R.4 DC, 10 alternative routes in total were considered as follows:

Symbol of Alternative Route		Destination		Total Distance (km)
		Lebakbulus DC	R.4 DC	
(1)	1S + 0 + 1	Route 1S and pipeline under construction between Serpong WTP and Lebakbulus	Route 1	35.7
(2)	1S + 0 + 2	ditto	Route 2	43.6
(3)	1S + 0 + 3	ditto	Route 3	45.6
(4)	1S + 0 + 4	ditto	Route 4	48.9
(5)	1S + 0 + 5	ditto	Route 5	54.6
(6)	1N + 0 + 1	Route 1N and pipeline under construction between Serpong WTP and Lebakbulus	Route 1	34.9
(7)	1N + 0 + 2	ditto	Route 2	42.8
(8)	1N + 0 + 3	ditto	Route 3	44.8
(9)	1N + 0 + 4	ditto	Route 4	48.1
(10)	1N + 0 + 5	ditto	Route 5	53.8

2.3.3 Basic conditions and assumptions for cost comparison of the alternative routes

(1) Design discharge

The design discharge of raw and treated water conveyance system was assumed as follows:



As indicated in the figure, no discharge is distributed to the pipeline under construction for all the alternative routes taking into account necessity of replacement of the steel pipeline system under construction at 2015 as stated above.

(2) Type of water conveyance system

Since most of the area between Parungpanjang WTP and Serpong WTP along the route 1S and 1N is assumed to be developed by BSD and topographic characteristics along the routes requires pumping-up to convey raw water to Serpong WTP, pipeline conveyance system with pump facility is judged to be effective for reducing not only construction cost but also