by the existence of discontinuities (faults, lithological contacts) or pervious rock formations (karstic limestone), draining the reservoir water outside of the basin. The main structural features of the reservoir are presented in Fig. IV.4.5.

4.2.1 Structural Discontinuities

In the Kuantan reservoir, two potential leakage passes have been identified:

- Lineament through the Niyaman - Karing river valleys; and
- Contact limestone/quartzite at Padangtarap.

Lineament

As discussed in Subsection 4.1.2, the lineament can be interpreted as a strike-slip fault, but there is no solid evidence so far. The lineament can be followed over a long distance to the north of the Kuantan River. On the south side it disappears before reaching the reservoir rim. Along this lineament the rock has been weakened, mineralized, and a red-yellow soil covers especially the south side of the area. The soil is clayey and silty, probably the residue of weathered shale.

At this stage of investigation it is difficult to judge if this structure will cause any leakage. Other experience mentioned in the geological literature shows that strike-slip faults, on the contrary, can function as a shield and keep the water inside the basin.

Contact Limestone/Other Lithology

The contact between the limestone and the other member of the Kuantan formation can be followed from Padangtarap to the south, along the river. Mineralization occurs along this contact and both, the limestone and the quartzites/shales have been affected. The rocks have a black color. This contact can be followed as far as the reservoir rim. It has been interpreted as a stratigraphical unconformity. In view of its extent, this structure could drain the reservoir water outside of the basin. More detailed investigation will be required in the future.

4.2.2 Limestone

The main limestone bodies are presented on the map in Fig. IV.4.5. It is assumed that the different limestone bodies are not interconnected below the surface and should therefore be treated as different units, separated by the shale member of the Kuantan formation. This is clearly illustrated by the cross-section in Fig. IV.4.7. All units cross the basin from NW to SE.

Units I and II underlie topographic flats with an average elevation of 120 m. The limestone is covered by clayey or sandy soil 1 to 5 m thick. Unit II develops from Galogah village to the SE and has no direct communication with the Kuantan River or the reservoir. It is not further considered in this report.

Units III and IV are high limestone ridges, with elevations above 900 m. Unit IV lies outside of the reservoir area and shall not be discussed in this report.

Leakage from Reservoir

The limestone units are separated by impervious rock formations and therefore the only possible leakage path for the reservoir water will be parallel to the strike of the units, NW-SE. The water will circulate through fractures or karstic channels and cavities.

The limestone of Unit III is karstified: big caves develop at about 250 m of elevation. The karstic aquifer in the limestone is recharged by rainwater infiltrating through fractures and fissures, in the top zone of the mountain. Every karstic aquifer has also a discharge level, which is where the water table intersects the ground surface. This level is marked by springs, river resurgences, swamps. Such features have been found on the east side of Unit III (refer to Fig. IV.4.7).

Examples are the springs at the village of Paruh, a small river south of the village, the Liau River. These features occur around EL 150 m, meaning the discharge level is located at the same altitude. If this is the case, the karstic aquifer discharges above the level of the reservoir (supposed to be EL 120 m) and leakage from the reservoir will not happen.

The limestone of Unit I has been eroded to a topographic flat. After construction of the dam the flat will be submerged. This area is the widest and most extensive portion of the reservoir. Unit I crosses the watershed and extends into the neighboring river basin. It was therefore important to know the elevation of the ground water table at the watershed.

(1) Leakage Zones

The limestone of Unit I is covered by 2-5 m thick sandy and clayey soil. This soil will function as an impervious blanket and stop the water infiltration at the bottom of the reservoir. The platform is dissected by many small rivers organized in a parallel system. In the riverbeds limestone is exposed. Many cavities and dissolution features can be seen. Once submerged, water will infiltrate through these cavities and penetrate the limestone body.

The possible leakage (infiltration) zones as shown on Fig. IV.4.5 are numerous and no countermeasures are possible.

(2) Drilling Investigation

To investigate water leakage outside the river basin through the limestone bodies, the water level at the watershed had to be checked. For this purpose, three drillings were made, RB-1 to RB-3, located as in Fig. IV.4.5. The logs are given in the DATA BOOK, under the code RB. The water table was monitored during the period January to March 1995 and the results are presented in Fig. IV.4.6.

In drillhole RB-1 at Galogah, no limestone has been encountered. The basement consists of diabase, an intrusive, crystalline rock, meaning, that the structure of the sub-surface is more complicated than it can be seen in outcrops.

The above result indicates that the limestone of Unit II does not continue to the north of Galogah. The diabase has no porosity and thus, the limestone is surrounded by impervious rocks, without connection to the Kuantan River or the other limestone units. No leakage will occur through Unit II.

The data from holes RB-2 and RB-3 give information about the behavior of the karstic limestone aquifer in Unit I. Both holes are located close to the watershed. The ground water level is higher than that of the reservoir, supposed at EL 120 m.

Hole RB-3 is 150 m deep. It penetrates through compact limestone, matrix supported (fine), slightly crystalline and very hard. The limestone permeability as presented in Table IV.4.3, varies between 10^{-4} and 10^{-5} cm/s over the whole length of the drillhole. The rock is relatively hard and no disturbance occurred during the testing. The rock has almost no porosity and therefore the ground water circulates through the fractures and fissures.

The ground water level is artesian. During the whole period of the drilling the water level was close to the surface. At 78 m of depth the first artesian water was recorded. During further drilling the artesian height increased. The karstic aquifer is probably composed of layers, defined by fractured zones. The lower layers are confined. The water level recorded after the completion of the hole is an average water level over 150 m of depth. No explicit information about the water level in the upper layers was obtained.

In this area, there are many shallow water wells (> 5 m), excavated in soil deposits. From local information, the rock underneath seems to be dry.

On the other hand, monitoring has been done during the rainy season, for a short period of time. It is probable that the water level will draw down during the dry season. Therefore, one year monitoring is recommended.

From the information obtained so far, the water level at the watershed is higher than the planned reservoir level, 130 m in RB-2 and 160 m in RB-3. No high leakage zone has been detected so far. Nevertheless, it shall be kept in mind that limestone areas are not homogeneously developed. Zones of high permeability can exist at many places. The results obtained from the drilling, showing low permeability and high water table cannot be extrapolated to the entire area. To do this, a grid of survey holes has to be planned.

4.3 Design Values

At the damsite, the geological conditions are judged to be satisfactory for the construction of a 70 to 80 m high concrete gravity dam. The inhomogeneous character of the foundation bed and the disruption of rock by joints and fractures are characteristic for the entire region.

Design values of the dam foundation are:

Location	Shear Strength	Angle of Friction
Right Bank	20 kg/cm^2	40°
Left Bank	15 kg/cm^2	35°

In the future detailed design stage excavation of test adits and in situ testing of the rock strength are recommended. Although not evidenced, leakage from the reservoir is not excluded to occur. The nature of the rocks, the ground water and permeability data obtained so far suggest that even if it occurs, it will be within tolerable limits.

Detailed and systematic hydrogeological investigation of the reservoir area are suggested for the future studies.

CHAPTER 5 SOIL INVESTIGATION IN KAMPAR RIVER BASIN

5.1 Kuok Intake Weir Site

The intake weir is located at the foot of the mountains and the beginning of the alluvial plain of the Kampar River. The mountains upstream consist of Tertiary sandstones and shales and Carboniferous shales, wackes and schists. At the weir location the river sediments are thin. The basement rock has been encountered at 10 m of depth, EL 30 m.

The locations of drillholes conducted in this study are as shown in Fig. IV.5.1. Fig. IV.5.2 presents a geological cross-section at the intake weir. The subsurface consists of three distinctive and continuous layers:

- River Sediments: sand, 3 m thick only on the right bank; gravel, 3.5 m thick in the river banks, 1 m thick in the river channel;
- Residual Soil: silt or clayey sand 4-7 m thick, absent on the right river bank; and
- Bedrock: claystone with thin sandstone intercalations, covered by 3 m completely weathered rock on the left riverbank.

5.1.1 General Soil Characteristics

The river sediments consist of fine brown sand, loose, locally silty and of clean gravel, well graded, mixed composition with sub-angular pebbles and boulder fragments.

The residual soil consists of sandy silt or clay, low plastic, gray and fragments of weathered, fine sandstone, very stiff.

The bedrock belongs to the Tertiary Petani formation. It consists of black clay- and siltstones with intercalations of fine, white sandstone. The rock is laminated and splits parallel to the laminations. The sandstones contain white shells and thin coal levels. It is considered a weak rock and depending on its degree of weathering it has been designated as CM, CL or D.

5.1.2 Laboratory Test Results

The results of the identification tests and the mechanical tests are summarized in Table IV.5.1. Only the residual soil and the underlying weathered claystone have been analyzed. Their properties are similar and therefore they are discussed together. For the description of the river deposits one should refer to Section 5.2.

Grainsize

All samples contain between 89% and 100% fines. The grainsize distribution curves are represented together in Fig. IV.5.3. The residual soil and few other samples contain 10% of fine sand.

Atterberg Limits

The Liquid Limit is 58% for the residual soil and 75 to 85% for the claystone. The Plasticity Index is 38% and 48 to 57%, respectively. In spite of this data the residual soil is considered to be silt or sandy clay of low to medium plasticity. The weathered claystone has the properties of a high plastic clay (CH) (refer to Fig. IV.5.3).

Natural Water Content

The water content varies between 30 and 47% in the claystones.

Specific Gravity

All samples have close values of specific gravity, 2.60 to 2.66.

Wet Density

Wet density values range between 1.69 and 1.75 t/m^3, for all samples.

Consolidation

Only claystone samples have been tested (refer to Table IV.5.2). From Fig. IV.5.4, the consolidation yeld pressure Pc is 0.9 kg/cm^2, indicating normal to over-consolidated soils, or in this case a soft rock. The average coefficient of consolidation (Cv) is 400 cm^2/day (refer to Fig. IV.5.5) and the coefficient of compression (Cc) is 0.15. These values characterize a silty rather than a clayey soil and therefore the real values are expected to be lower than the test values.

Unconfined Compressive Strength

Several samples were tested and the results are given in Table IV.5.3. The unconfined compressive strength varies between 0.82 kg/cm^2 and 3.85 kg/cm^2 and the undrained shear strength between 0.41 and 1.92 kg/cm^2. Based on this results the claystone is considered to be a very weak rock.

5.1.3 Geotechnical Considerations for Weir Foundation

As shown in Fig. IV.5.2 the uppermost layer consists of gravels and sands, 0.5 m thick in the river channel to 6 m thick on the right riverbank.

The bedrock was encountered at 6 to 8 m from the ground surface. On the left bank, the upper 3 m are completely weathered, rather close to soil. The bedrock underneath is moderately weathered. On the right bank the rock is strongly weathered, till the depth of 15 m. The river channel is underlain by 8 m residual soil, thinning out towards the right bank.

If the foundation of the weir is shallow (EL 34 to 30 m) it will be partly placed on residual soil (left side of the section) and partly on moderate to strongly weathered rock (right side of the section), having similar characteristics. The foundation bed consists of very fine material and, especially in the silty residual soil, the possibility of piping shall be considered.

Bearing Strength

The standard penetration tests show a N-value > 50 blows for the whole length of boreholes (refer to Fig. IV.5.2). Accordingly, the bearing strength of the foundation is considered to be sufficient, whether it is placed on the residual soil or on weak, weathered claystone.

The bearing strength of the claystone has been calculated with Terzaghi's formula for a minimal cohesion value of 0.4 kg/cm^2 (according to the laboratory test value in WB-3) and an estimated angle of friction of 25°. The foundation depth has been chosen at 6 m (in WB-3) and the foundation width at 1 m. The resulting bearing strength is approximately 15 kg/cm^2 and the allowable bearing strength 5 kg/cm^2, respectively.

Permeability

The permeability has been tested in situ, in drillholes WB-1 and WB-3, on both riverbanks. Table IV.5.4 contains the in-situ test values, generally considered to be low. The residual soil has a permeability of 2×10^{-5} cm/s, almost impervious.

The permeability of the claystone varies between 4×10^{-5} and 6×10^{-4} cm/s, depending on its degree of weathering, sand content and cleavage. The claystone can be considered a semi-pervious rock.

The permeability of the river sediments is not known, but it is estimated around 10^{-2} to 10^{-3} cm/s. Seepage protection works will be necessary for the weir foundation.

Conclusion

Claystone is most recommendable as foundation bed. A shallower foundation, partly on residual soil, is conceivable as well. Both layers have sufficient bearing strength and low permeability. Sheet piles may be required down to the bottom of the residual soil layer for seepage prevention.

5.2 Area Downstream from Kuok Intake Weir

Downstream from the weir site, the thickness of the river deposits increases progressively, from 12 m in Drillhole LB-1-94 to 18 m in Drillhole SB-2-94. The bedrock has been encountered only in one drillhole, SB-1-94, at EL 24 m. Fig. IV.5.1 shows the locations of drillholes.

The results of the drilling work are presented and in Fig. IV.5.6. This figure presents the profile along the right riverbank. The subsurface consists of the following layers:

- River sediment: sand, locally replaced by silt, from 3.5 to 10 m thick; peat, 1.4 m thick (only in LB-4-95); gravel, 0 to more than 13 m thick; and organic clay, 5 m thick (only in SB-2-94, at EL 1.0 m)
- Bedrock: claystone with thin sandstone intercalations and residual clay at the bottom of SB-2-94.

5.2.1 General Soil Characteristics

The subsurface of the area consists of the following layers from top to bottom:

- Fine brown to gray sand, with clay pockets, medium dense. Locally brown-yellow silt, medium consistency, with pockets of clean sand, low plasticity, predominates.
- The peat is black, very porous and light soil.
- The gravel is fine or coarse with sub-angular to round pebbles and boulders, generally clean, mixed in composition (mainly quartzite and igneous rocks). The average pebble size is 1-2.5 cm, the maximum size is 9 cm. The gravel is often mixed with clean, well graded sand, up to 50%.
- Bedrock is a weak claystone, intercalated with sandstone, laminated structure. It contains white shells and thin coal levels.
- Alternation of clay and organic soil (clay and coal) as encountered at the bottom of Drillhole SB-2. It is very stiff, medium plastic, and contains sand pockets. It is supposed to be weathered bedrock.

5.2.2 Laboratory Test Results

The results of the identification tests and the mechanical tests are given in Table IV.5.1.

Grainsize

The upper layer consists mainly of silty fine sand, the silt percentage varies from 16 to 50%. At some locations, the silt predominates, more than 80%. Poorly graded clean fine sand has been found in drillholes SB-2-94 and LB-5-95. The most representative gradation curves are shown in Fig. IV.5.7.

The organic clay encountered in hole SB-2-95 consists of 80% of fines. The bedrock consists of pure claystone, more than 80% of fines, or claystone/sandstone intercalations with 45% of fine sand and 55% of fines. Representative grading curves are shown in Fig. IV.5.7.

Atterberg Limits

The test results are shown in Fig. IV.5.8. The results obtained for the silts and the organic soils are doubtful. The three samples plotting between 35 and 55% of Liquid Limit are supposed to have lower Plasticity Index and to plot below the A-line.

An anomalous result has been obtained for a silt sample from hole LB-4 (not presented), of which Liquid Limit is 135%. Such results are usually obtained for organic soils. On the other hand, the Liquid Limit of the peat sample from LB-4 is too low (53%).

The claystone samples plot in the area of the high plastic clays , with 60 to 85% of Liquid Limit and 30 to 60% for the Plasticity Index. The variations are due to the presence of sand.

Natural Water Content

The water content is less than 12% for sand and 20-35% for silty sand. Here again, the values obtained for peat and organic soil are lower than expected. Presumably the samples have partly dried before the testing. The values for claystone range between 35 and 43%.

Specific Gravity

The average specific gravity for sand and silty sand is 2.64, and 2.65 for peat.

Wet Density

Wet density has been measured only on the claystone, 1.7 to 1.76 kg/cm^3.

Consolidation

One sandy claystone sample from hole SB-1 has been analyzed (refer to Fig. IV.5.5 and Table IV.5.2). The yield pressure is 0.66 kg/cm^2. The average coefficient of consolidation (Cv) is 750 cm^2/day and the Consolidation Index (Cc) is 0.236.

Unconfined Compressive Strength

The test results are presented in Table IV.5.3. The unconfined compressive strength (qu) for claystone and sandstone is 2.59 and 2.85 kg/cm^2, respectively. Accordingly, the recommendable design cohesion value is 1.2 kg/cm^2.

5.2.3 Geotechnical Considerations

The profile in Fig. IV.5.6 clearly shows an increase of the thickness of the river sediments in downstream direction. The main sediment layers (sand and gravel layers) are continuous. The bedrock has been encountered only at one location (SB-1) at EL 24 m.

Upper Sediment Layer

The upper layer consists of fine non-cohesive material, sand and silt, in average 5 m thick. The N-value is generally more than 10 blows. According to Terzaghi, the angle of friction is estimated to be 26°. The cohesion value is 0 kg/cm^2.

An exceptional situation exists around Borehole LB-4, where 1.4 m thick peat has been found, at 6 m deep. Above the peat layer the soil is very soft, SPT-value only 1 or 2. Loading of such a soil will result in quick consolidation settlement.

The permeability values are estimated to be between 10^{-3} and 10^{-4} cm/s. Fine sand and silt are particularly vulnerable to erosion by percolating water.

Lower Sediment Layer

This layer consists of gravel, underlain by organic clay. The gravel is well graded, with a poor content in fines. Such gravels are generally characterized by high permeabilities, angles of friction close to 35°, sufficient bearing strength. The organic clay has been found only in hole SB-2. The Standard Penetration Test values exceed 50 blows, indicating a very stiff, over-consolidated material.

For the foundation of dikes and sluiceways the upper sediment layer is generally satisfactory. Its permeability and vulnerability to erosion may have to be considered. Special considerations may be required as well in the area around hole LB-4, due to the weakness of the sediment.

CHAPTER 6 SOIL INVESTIGATION IN INDRAGIRI RIVER BASIN

6.1 Lubukjambi Intake Weir Site

The weir is located at a distance of 5 km from the foot of the mountains, and at 10 km downstream of the damsite, in the alluvial plain (refer to Fig. IV.6.1). The river channel shows a meandering pattern.

The results of the drilling investigation are summarized in Fig. IV.6.2. The figure represents a cross section along the axis of the proposed weir.

The alluvial plain is underlain by Tertiary rock formations. In the vicinity of Lubuk Ambacang there are outcrops of the so-called Telisa formation which consist of clayey marl and glauconitic sandstone, nodular, containing concretions. At the weir site, river sediments are thin. The bedrock has been encountered at 9 m deep from the ground surface (WL-3-95), at EL 51.7 m.

The subsurface consists of two distinctive and continuous layers:

- River Sediment: 9 to 10.5 m thick
- Bedrock: claystone/siltstone with thin sandstone intercalations, minimal 20 m thick.

6.1.1 General Soil and Bedrock Characteristics

River Sediment

In stratigraphical order, two main beds were distinguished:

(a) Sand bed

The sand bed is 4.5 to 6 m thick, brown, fine sand, loose, composed mainly of quartz, rounded to sub-rounded grains and angular white mica (muscovite; less than 5%). Most of the sand is silty or clayey. Clay beds are intercalated, maximum 1.8 m thick, medium consistency to stiff.

(b) Gravel bed

The gravel bed is 4 to 6 m thick, well graded, gray, composed of pebbles and rock fragments in sand matrix. The components are quartzite, sand-siltstone, igneous rock (dark), shale and coal. The pebbles are subrounded 5 to 6 cm in diameter. The sand matrix is fine, partly silty.

Bedrock

The bedrock consists of black, laminated claystone or siltstone with mm-thick laminae of sandstone, very weak (CL). The fines are predominant. The rock splits parallel to the laminations. Strongly weathered zones consist of medium to highly plastic clay and fine, white sand. In Drillhole WL-1, the upper claystone contains 10% of pebbles.

6.1.2 Laboratory Test Results

Four sediment samples and one bedrock sample have been analyzed. The results of identification and mechanical tests are summarized in Table IV.6.1.

Grainsize

The gradation curves of the clayey/silty sands of the first sediment bed contain 25 to 35% of fines (refer to Fig. IV.6.3). The remaining percent is poorly graded fine sand. The clay sample from WL-1 contains 73% of fines. The second sediment bed consists of coarse gravel with 25% of fines (GM).

Atterberg Limits

The clayey/silty sands have the characteristics of low plastic soils (CL). The clays have a slightly higher liquid limit and medium plasticity (refer to Fig. IV.6.3).

Natural Water Content

The water content is 33 to 38% in the clayey samples and only 8% in the gravels.

Specific Gravity

The clays have the lowest specific gravity, 2.61. The specific gravity increases with the percentage of sand and non-cohesive fines (refer to Table IV.6.1) to a maximum value of 2.70 in silty sand.

Wet Density

The average density for clayey/silty sand is 1.85 kg/cm^3.

Consolidation

The results of the consolidation tests are shown in Fig. IV.6.4 and Table IV.6.4. The consolidation yield stress varies from 0.55 kg/cm^2 to 2.35 kg/cm^2 and all samples are over-consolidated. The average coefficient of consolidation (Cv) is 450 cm^2/day (refer to Fig. IV.6.5), and the average Coefficient of Compression (Cc) is 0.2. These values are representative for mixed soils of mainly silt and sand, rather than clay.

Triaxial Compression Test

The samples of the upper sediment layer have been tested under unconsolidated and undrained conditions. The test results are given in Table IV.6.2, but they are difficult to interpret. In general, the cohesion values are too low. These test values cannot be recommended for design.

The estimated design values for mixed soils are 0.3 kg/cm^2 for cohesion and 20° for internal angle of friction.

Unconfined Compression Test

One compact soil sample from hole WL-1 has been tested and the obtained unconfined compression value is 1.08 kg/cm^2 indicating a stiff soil. Accordingly, the cohesion value is 0.54 kg/cm^2 (refer to Table IV.6.3).

The three tested silt-/sandstone samples give very similar values, 6.7 kg/cm^2 for the unconfined compressive strength. Accordingly, the cohesion value is 3.35 kg/cm^2.

6.1.3 Geotechnical Considerations for Weir Foundation

As shown in Fig. IV.6.2, the subsurface consists of three continuous layers. The two upper layers are river sediments, 10 m thick. Under the sediments there is weak bedrock. In case of a shallow foundation, less than 10 m from the ground surface, the foundation bed will be sand or gravel. Their geotechnical characteristics are discussed below.

Bearing Strength

The bearing strength of the sand bed can be estimated from the Standard Penetration Test values by Terzaghi's formula. The N-value is usually 4 blows. Accordingly, the internal angle of friction is 20°. The cohesion value is estimated to be 0.3 kg/cm^2. If the foundation depth is 3 m and the minimum width of the structure base is 1 m, the bearing strength will be 7.8 kg/cm^2. The allowable bearing strength value is 2.6 kg/cm^2.

The gravel bed has not been tested but from empirical data gravels have an angle of friction close to 30° and the cohesion is 0 kg/cm^2. Such deposits have sufficient bearing strength.

Both the N-value of the bedrock (more than 50 blows) and the results of the unconfined compression test show that the bedrock is moderately weak and it has sufficient bearing strength. The recommended design criteria are 35° for the angle of friction and 3 kg/cm^2 of cohesion.

Permeability

The permeability has been tested in-situ in all the drillholes. The results are given in Table IV.6.5.

The permeability between 0 and 5 m of depth is 5×10^{-3} to 10^{-2} cm/s. This corresponds to sandy material. As a foundation bed the sand is rather pervious and underseepage will occur.

The permeability of the underlying gravel, tested between 9 and 10 m of depth, is close to 10^{-3} cm/s in hole WL-1 and 10^{-5} cm/s in hole WL-2. The first result corresponds better to the nature of the soil and this value shall be taken as reference further on.

The permeability of the bedrock ranges between 5×10^{-6} and 10^{-5} cm/s. The bedrock is considered to be impervious. If the foundation is placed on river sediment countermeasures will be required to stop the underseepage.

Piping

Piping is most likely to occur in the sand bed , because of its fine grainsize.

Settlement

Based on the results of the consolidation tests, settlement of the upper clayey/silty sand is estimated at about 40 cm.

6.2 Rengat Area

The Rengat area is an area of flat, low topography, EL 0 to 7 m. The water table is close to the surface and swamps cover a significant part of the land surface, on the right riverbank. The results of the drilling investigation are summarized in Fig. IV.6.6. The locations of the drillholes is presented in Fig. IV.6.1.

Fig. IV.6.6 is a profile along the planned ring dike structure. Vertically and laterally, the different beds are discontinuous. Roughly, two zones can be distinguished as follows:

- Zone I: between the river and the main road (holes SR-3, SR-4 and LR-6 to LR-8).
- Zone II: south of the main road (holes LR-9 and LR-10).

In Zone I, the subsurface consists of two main layers, as follows:

- Upper Layer: alternation of anorganic and organic fine soils, 3.5 to more than 7 m thick
- Lower Layer: fine river sands, minimum 8 m thick.

The subsurface of Zone II consists of only one layer of fine, organic sediments, minimum 10 m thick.

6.2.1 General Soil Characteristics

The Rengat area is covered by young Quaternary sediments, thickness unknown. River and swamp sediments interfere. The sediments of Zone I are river terrace deposits, anorganic fine sands, silts and clays deposited by the river. The clays and silts are yellow-brown to gray, low to medium plastic, medium consistency, contain sand pockets. Some deposits contain 30-40% organic material concentrated in black zones, generally soft.

The sands are brown-gray, subrounded grains, predominant grainsize 0.5 mm, mostly quartz and angular, dark rock fragments, medium dense, contain silt pockets.

In Zone II, sedimentation takes place in swamps and the influence of the river is limited to the flood periods. During floods of the Indragiri River, a wide area is set under water. The water carries fine materials in suspension, which sink to the bottom. Silts and clays are deposited in this way.

The soils are silty clays or clayey silts of low to medium plasticity, contain organic material up to 30%, gray brown or white, very soft.

The abundant vegetation of Zone II is a source of organic material. Thick peat layers and organic soils are the other main component of the subsurface.

The peat is black, spongy aspect, material is very fine with some preserved wood fragments, light porous and very soft.

6.2.2 Laboratory Test Results

The results of the laboratory tests are summarized in Table IV.6.1.

Grainsize

The representative gradation curves are shown in Fig. IV.6.7.

The curves representing the upper layer samples are dispersed over a wide zone, meaning the soils have a variable size distribution. The results are rather difficult to interpret. Most of the samples contain between 72 and 96% of fines. Mixed samples contain 40-60% of fines and the remaining percentage is fine sand. The lower layer consists of 60% of fine sand, less than 5% of fines and the remaining is medium sand.

Atterberg Limits

The results of this test shall be considered with some reservation. According to the field observations and the results from other tests, organic and anorganic silts/clays of low plasticity are frequent in the studied area. The corresponding classes of soils are ML/CL and OL/OH. This is not reflected by the plot of the laboratory test results in Fig. IV.6.8. Here, most of the samples plot in the area of medium to high plastic clay, relatively close to the A-line. Therefore, it is advisable to take the denominations of soils figuring in the drill logs and in figures as characteristic for the Rengat area.

Natural Water Content

The water content is 40 to 80% in the fine soils, with generally higher values in the organic soils. The pure organic soils, like peat, have very high water contents, 450 to 770%. The water content of the sands is lower than 20%.

Specific Gravity

The Specific Gravity values of all analyzed samples, except for the peat, range between 2.60 and 2.68, for the organic and anorganic soils. The value for peat is much lower, 2.21 , reflecting the high porosity of the material.

Wet density

The density of the fine anorganic soils is 1.7 t/m^3. The organic soil densities vary between 1.2 t/m^3 for peat, to 1.8 t/m^3 measured in organic silt.

Consolidation

The results of the consolidation tests are summarized in Table IV.6.6 and the consolidation curves, except for sample SR-3, 2.45 - 3 m deep, are presented in Fig. IV.6.9. Except for sample LR-9, 5 - 5.6 m deep, the curves gather together in the area where mixed soils (silt and clayey silts, sandy) are expected to plot. This is not entirely in accordance with the results obtained in the Atterberg Limit test. Sample LR-9 is a peat sample. It plots separately in the area where clayey soils are usually expected to figure.

The consolidation yield stress varies from 0.52 kg/cm^2 to 1.7 kg/cm^2 and all samples are over-consolidated. The yield stress calculated for sample SR-4, depth 14.45 to 15 m, is erroneous and shall not be considered.

The coefficient of consolidation (Cv) are presented in Fig. IV.6.10. The organic soils range between 180 and 280 cm^2/day, with the lowest value for peat. The other samples range between 400 and 700 cm^2/day, values which characterize silt and sandy silt.

The coefficient of compression Cc ranges between 0.14 and 0.52 for organic and anorganic soils, except for the peat sample. Such values characterize silty soils or clayey silty soils, with low to medium compressibility.

The peat sample LR-9 has a Cc value of 2.96, which means high compressibility. Such a result is according to the expectations.

Triaxial Compression Test

The samples of the upper sediment layer have been tested under unconsolidated and undrained conditions. The test results are given in Table IV.6.7.

All samples are saturated, suggesting a clayey composition of the tested soils. Nevertheless the obtained cohesion (c) values are very low, less than 0.7 t/m^3.

Theoretically, the friction angle of the UU-test must be zero when the test is done on 100% saturated clayey soils. The envelops to the Mohr circles in Fig. IV.6.11 are not parallel to the x-axis (not zero).

Given the fact that the composition of soils is a mixture of silt, clay and organic material, the test results may be affected.

6.2.3 Geotechnical Characteristics of Foundation

As shown in Fig. IV.6.6, the subsurface conditions change as the distance from the river increases. Consequently, Zones I and II will show slight differences in geotechnical characteristics and will be discussed separately. The soils in the Rengat area are very soft and contain a large amount of organic material. Such soils are of poor quality as foundation beds.

Ground Water Table

The ground water table in the Rengat area is generally high. Especially in the rainy season, the ground water table in Zone II is up to the ground surface. This is one of the reasons why the consolidation rates in this area are slow.

Bearing Strength

(1) Zone I

The upper layer of Zone I consist of soft silts and clays. The Standard Penetration Test N-value is often 4 blows. An exception is hole LR-7, where 3.5 m thick organic clay is intercalated between anorganic sediments. Here, the N-value is only 2 blows.

In a conservative way, according to Terzaghi's criteria, such soils shall be treated as weak soils, with an angle of friction of 0°. From correlation figures between N-values and Compressive Strength, cohesion for the soils give 0.5 to 2 t/m^2.

From the results of the UU-tests (refer to Table IV.6.7), the angle of friction is greater than zero. Therefore, the recommended design criteria are:

- Wet density = 1.7-1.8 t/m^3
- $c = 1\ t/m^2$
- $\varnothing = 5°$

The lower layer consists of silty or clean river sands. The N-value is 4 blows and more than 10 blows respectively. Based on the Terzaghi and Peck criteria, such soils have the following characteristics:

- Wet density = 1.8-1.9 t/m^3 (presumed)
- $c = 0\ t/m^2$
- $\varnothing = 20\text{-}30°$

(2) Zone II

The sediments of this zone are mainly organic very soft silt, clay and peat. The Standard Penetration Test value is N = 1 blow from 0 to 10 m deep. The following design criteria are recommended:

- Wet density: 1.2-1.5 t/m^3
- $c = 0.5\ t/m^2$

- $\varnothing = 0°$.

The peat bed is treated as clayey soil as well and it is assumed to have the same criteria.

Settlement

(1) Zone I

The thickness and the composition of the upper layer varies along the profile in Fig. IV.6.6 from 6 m in SR-4 to 9 m in SR-3. The settlement value of the anorganic sediment increases from 0.1 m in SR-4 to 0.3 m in SR-3. In hole LR-7, the sediment is composed of mostly organic clay and the settlement value is higher, 0.64 m.

(2) Zone II

Peat and highly organic soils are characterized by high compressibility. In this zone the settlement increases with the percentage of peat and organic components as illustrated bellow. In hole LR-9 the upper 7 m contain 70% peat. The settlement of this layer is 1.68 m. In hole LR-10 the upper 6 m contains only 30% peat. The settlement is accordingly lower, 0.67 cm.

The settlement values of Zone II are much higher than in Zone I. This fact shall be considered in the design of the reparian structures.

Permeability

No permeability tests have been done in this area. In general the clayey and silty soils are impervious to semi-pervious. The sand layer underlying zone I is pervious, 10^{-2} to 10^{-3} cm/s but not continuous in Zone II. The sediments in Zone II have low permeability values except for the peat beds.

Remarks

The soils in the Rengat area, especially in Zone II, are poor quality foundation beds. The water table is high, organic soils are frequent, the bearing strength is low, and the settlement values are important.

In Zone I, it is recommended to excavate the upper 1 m of soil, which is often a very soft silt. Special attention shall be given to the area around hole LR-7, where organic soils are interbedded and the foundation bed is even weaker.

In Zone II, peat beds are widely spread. Such soils are characterized by very high compressibility, high porosity and permeability. Especially, the first characteristic makes them undesirable as foundation beds. It shall be in general avoided to place the foundation on organic soils.

Peat beds occur till the depth of 7 m from the ground surface and cannot be excavated. Countermeasures other than replacement shall be considered for Zone II. Slow, gradual construction of embankment, giving the soil the possibility to consolidate, could be a solution for Zone I.

Such a method is ineffective on the type of soils of Zone II. Here, prestressing of the foundation by means of counterweigh and forcing it to slide, would be a more adequate approach, before the construction is started.

CHAPTER 7 CONSTRUCTION MATERIAL INVESTIGATION

7.1 Aggregates for Concrete

In the vicinity of the Kuantan damsite, aggregates for concrete can be taken from the riverbed and the quarry sites, and they were investigated as mentioned below.

7.1.1 Aggregates from Riverbed

Five different locations have been investigated downstream from the damsite (Fig. IV.7.1).

During low water level, several sediment bars are visible in the riverbed. These are elongated bodies, several hundreds of meters long, 50-100 m wide and they stick out, approximately 1 m above the water level. The exploitable layer is minimum 3 m thick.

More aggregates can be recovered by systematic dredging of the river channel, using a pump barge. The recoverable volumes are estimated as follows:

- 450,000 m^3 at Lubukambacang, between AL-2 and AL-5.
- At least 5 times of the above volume, at Sungai Manau, sites AL-1, Al-3 and AL-4.

<u>General Characteristics of Aggregates</u>

The sediments in the river channel consist of interbedded gravel and sand. Once extracted, the fine and coarse aggregates have to be separated by screening.

The gravels are well graded and consist of round to subrounded pebbles, mostly quartzite. Shale and igneous rocks are the other main components. Sporadically, coal pebbles have been found.

The sands are medium to fine-grained, clean, containing mainly quartz grains, some rock fragments and a small percentage of white mica.

Generally, the aggregates from the Kuantan River are physically sound: strong enough and capable to resist weathering. Nevertheless, their quality could be affected by the following two factors:

- Abundance of shale/phyllite components: the reactive minerals in them affect the chemical soundness;
- Floods: big amounts of trees and bushes are carried by the river and deposited together with the sediment. Local accumulations of organic material in the river sediment are common.

Results of Laboratory Tests

(1) Grading

The results of the sieve analysis are presented in Fig. IV.7.2. The thick lines delimit the zone of ideal aggregates. Most of the grain size curves are close to this zone except sample AL-3, which plots below. The grainsize curves have been obtained from mixed samples of coarse and fine aggregates.

The contents of gravel and sand are to be considered respectively. Therefore, for the construction work, coarse and fine aggregates will be batched separately; the grading of each type shall be checked and controlled.

The samples shown in Fig. IV.7.2 and Table IV.7.1 are rather coarse, as indicated by the high coefficients of fineness, ranging between 7 and 8.7, meaning that gravels are predominant in these deposits. The contents of fines, silt and clay are negligible.

(2) Specific Gravity

Specific gravity values are presented in Table IV.7.1. For the mixed samples of coarse and fine aggregates, the absolute and apparent specific gravity values are 2.63. For the fine aggregates, the mean absolute value specific gravity is 2.54 and the mean apparent value is 2.68. These values correspond to the specific gravity of quartzite, 2.6-2.7, which is the main component of the deposits in this area.

(3) Absorption

Absorption values shall be slightly over 1% for a good quality aggregate. For the mixed samples in Table IV.7.1, the absorption is close to 1%. For the fine samples, the absorption value is higher and irregular. Especially, AL-3 shows a high absorption value of 3.93%, suggesting a poor quality of aggregate.

(4) Soundness

The results of this test are an indication for the ability of the aggregates to resist weathering. For coarse aggregates the tolerated weight loss values must be inferior to 18%, according to the ASTM standards. The analyzed samples range far below this limit ,with a mean value of 1.1% and are therefore considered to be physically sound.

(5) Alkali Reactivity

The determined values for Dissolved Silica (Sc) and Reduction in Alkali (Rc) are presented in Table IV.7.1. According to the ASTM standards, the samples from AL-1 and AL-2 are considered potentially deleterious. All the other samples are innocuous. The deleterious aggregates contain reactive silica, probably from the shale/phyllite components. Shales are widely spread in the Kuantan river basin and are therefore an inevitable component of the river deposits. In future investigations, the chemical soundness of aggregates shall be carefully considered (refer to Fig. IV.7.3).

(6) Abrasion

According to ASTM standards, the acceptable limit for this test is 50%. All samples range far below this value (refer to Table IV.7.1). The average toughness of sampled aggregates is 21.7%.

(7) Organic Impurities

The applied test procedure gives only a qualitative appreciation. The samples from AL-1 to AL-4 do not contain significant amounts of organic impurities. Samples from AL-5 are considered organically impure, exceeding the requirements of the ASTM specification. Before use, sands extracted from this site will have to be waterlogged to remove organic materials.

7.1.2 Aggregates from Quarry Site

At the Kuantan damsite, aggregates can be obtained from crushed quarry rock, especially quartzite, which are abundant. Generally, the quartzite is alternating with shale beds and selective quarrying may be required. Fresh quartzite is a physically sound rock and when crushed it gives high quality aggregates.

Four quarry sites have been sampled (refer to Fig. IV.7.1). All of them are located in the vicinity of the Kuantan damsite. Quarry sites Q-I and Q-II are inadequate because of their location and composition (presence of shale), respectively. At sites Q-III and Q-IV, rock quality and composition are satisactory, but the volume of available quarry rock would be sufficient for the construction works only at site Q-IV.

General Characteristics and Laboratory Test Results

The index properties are presented in Table IV.7.2. The mean specific gravity of the tested samples is:

- Apparent Specific Gravity = 2.38
- Absolute Specific Gravity = 2.57

The water absorption values vary between 1 and 2.3% and are considered to be low. The mean natural density of the tested samples is 2.38 t/m^3.

The strength of the aggregates has been estimated by the unconfined compressive tests. The values obtained range between 512 and 915 kg/cm^2. The empirical values of strength for pure quartzitic rock are 2 to 3 times higher. The weakening of quartzite in the Kuantan area is a result of the intensive jointing, affecting the entire region.

As a reference, it is noticed that excellent quality aggregates have compressive strength values above 800 kg/cm^2. The aggregates in the Kuantan area show a mean compressive strength value of 643 kg/cm^2 and are judged to be sufficiently strong for the construction purposes.

7.2 Dike Embankment Material

The superficial soil material which can be used for dike embankment has a uniform composition over the entire area between the Kampar and Indragiri rivers. It has two origins:

- The Young Alluvium: Holocene sands and clays
- The Petani and Minas Formations: Pliocene sandstone, siltstone and mudstone, and Pleistocene gravels and clays.

Most frequently used for road embankments and replacement soil is the weathered material of the Petani formation.

The Petani formation forms low hills, EL 100 to 200 m, with gentle slopes. The weathered upper portion, a few tens of m thick, is a yellow-red silty and sandy soil, with intercalations of gray, plastic clay and weathered white sandstone. Outcrops of the Petani formation can often be seen in road sections.

In the area between Muaralembu - Taluk Kuantan and Baserah, the hills contain a significant amount of gravel. The soil is mixed material of the Petani and Minas formations. The gravel is composed of round, white quartz and quartzite pebbles, disposed in a few meters thick beds. At Lubukjambi and between Airmolek and Rengat the material contains more clay.

7.2.1 Kampar River Basin

Several sites have been investigated, most of them located in the vicinity of the main roads (refer to Fig. IV.5.1).

<u>Physical and Mechanical Soil Characteristics</u>

Several samples have been tested in the laboratory and the results are given in Table IV.7.3.

(1) Grainsize

The grainsize curves are presented in Fig. IV.7.4. Three types of soil can be distinguished:

- Sands, medium to fine, 30% fines;
- Clays and silts, less than 15% of sand; and
- Mixed soils, 60-75% of fines and 25-40% of sand.

(2) Atterberg Limits

In Fig. IV.7.5, most samples plot in the area of clays with low and medium plasticity (CL-CH) and two of them are high plastic silts.

(3) Compaction

The compaction curves are presented in Fig. IV.7.6. The sandy sample TB-2 plots on the upper portion of the figure. Its density is 1.81 t/m^3 for an optimum moisture content (OMC) of 13.7%. The sample TB-3 is clayey and plots separately from the other samples, in the lower part of the figure. The obtained density is 1.24 t/m^3 for an OMC of 40%.

The remaining samples are mixed or clayey and plot close to each other with an average density of 1.45 t/m^3 for an OMC of between 25 and 32%.

For all the analyzed samples the OMC is 20-30% lower than the natural water content, meaning, the soils have to be dried to obtain better compaction results.

(4) Consolidated Undrained Triaxial Compression

Consolidated Undrained tests have been carried out after compaction of the samples and the results are presented in Table IV.7.4 and Fig. IV.7.7. The following parameters were obtained:

- Effective Shear Stress : $c = 0.16$ kg/cm^2; $\phi = 27.6°$

These parameters represent the average values for the mixed and clayey samples. Since most of the soils in this area fall under this category, the values above can be used as design values for the embankment.

The soils in the Kampar area consist mainly of fines. For embankment material those soils containig 20-30% of sand have the best compaction characteristics and are the most desirable.

7.2.2 Lubukjambi - Talukkuantan Area

The locations of the investigated sites are epresented in Fig. IV.6.1. The soils, except sample TT-3, are the weathering product of the Petani formation covering all the low hills in this area. A sufficient volume of embankment material is available, gravelly at Talukkuantan and clayey at Lubukjambi.

Physical and Mechanical Soil Characteristics

Several samples have been tested in the laboratory and the results are summarized in Table IV.7.3.

(1) Grainsize

The grainsize curves are presented in Fig. IV.7.8. The following types of soil can be distinguished:

- Clays and silts, contain between 10 and 30% of well graded sand;
- Mixed soils , contain between 30 and 50% of fines; and
- Gravels, contain less than 30% fines and 15-30% sand.

(2) Atterberg Limits

The fine soil fractions of all samples behave as clays. The high plastic clays predominate (refer to Fig. IV.7.9).

(3) Compaction

The curves in Fig. IV.7.10 spread out over a large area because of the differences in the composition of soils.

The clayey soils have dry densities between 1.1 and 1.3 t/m^3 for an optimum moisture content (OMC) of 36 to 4 %. The mixed soils have dry densities between 1.3 and 1.6 t/m^3 for an OMC of 20 to 30%. The gravely soils have dry densities between 1.6 and 1.8 t/m^3 for an OMC of 15-20%.

The optimum moisture contents for soil samples TL-1, TL-2 and TT-3 are close to there natural water contents. For the mixed samples the natural water content is much higher than the OMC value.

(4) Consolidated Undrained Triaxial Compression Test

Consolidated undrained tests have been carried out after compaction of the samples and the results are presented in Table IV.7.5 and Fig. IV.7.11. The following parameters were obtained:

For Clayey and Mixed Soils:

- Effective Shear Stress : $c = 0.23$ kg/cm^2; $\phi = 31.2°$
- Total Stress : $c = 0.3$ kg/cm^2; $\phi = 20°$

For Gravely Soils:

- Effective Shear Stress : $c = 0.045$ kg/cm^2; $\phi = 38°$
- Total Stress : Results are not reliable.

Most of the soils in this area have a mixed character and the corresponding parameters shall be taken as design values for the embankment in this area. The soils which can be used for embankment in this area are generally mixed soils. Less frequently, the gravely soils have low shearing stress.

7.2.3 Airmolek - Rengat Area

The locations of the investigated soils are presented in Fig. IV.6.1. Most of the soils are the residual products of the Petani formations and are similar to those described so far.

At Rengat, in the swampy area south of the main road, peat and organic soils predominate. Such soils cannot be used for embankment. In the following description one example is included for reference. Also at Rengat, test pit TR-16 has been located close to the river, in alluvial silty sand.

Physical and Mechanical Soil Characteristics

Several samples have been tested in the laboratory and the results are summarized in Table IV.7.3.

(1) Grainsize

According to the grainsize curves in Fig. IV.7.12, the following soils are distinguished:

- Clayey soils, less than 10% of sand.
- Mixed soils: 20 to 70% of sand, 20- 40% of gravel and 40-70% of fines.
- Sandy soils: 0 to 40% of fines.
- Peat: 73% of fines.

In some test pits there are layers of clayey and mixed soils, which have been sampled separately.

(2) Atterberg Limits

The results are shown in Fig. IV.7.13. Most of the fine soils behave as high plastic soils, and high liquid limits are frequent. The peat has a high liquid limit and a high natural moisture content (154%).

(3) Compaction

The test results are presented in Fig. IV.7.14. Many samples plot in the upper portion of the graphs corresponding to their sandy nature. The dry densities for these soils are 1.8 to 1.9 t/m^3 for an optimum moisture content (OMC) of 10-15%.

The mixed samples have dry densities of between 1.4 t/m^3 and 1.6 t/m^3 for an OMC of around 20%. The clayey samples have dry densities of 1.3 t/m^3 and the OMC is 32%.

The peat sample TR-17 is presented separately. From the shape of the curve in the figure, it can be concluded that such soil is not compactable; its density does not improve.

The optimum moisture contents are below the natural water contents for all of the samples.

(4) Consolidated Undrained Triaxial Compression Test

Triaxial tests have been done on the compacted soils and the results are shown in Table IV.7.6 and Fig. IV.7.15. Every type of soil represents one-third of the total number of samples. The following average parameters are therefore recommended for the design:

- Effective Shear Stress : $c = 0.18$ kg/cm^2; $\phi = 32.2°$
- Total Stress : $c = 0.24$ kg/cm^2; $\phi = 21.8°$

Soils containing more than 30% of fines and at least 30% of sand can be used for embankment. In the vicinity of Rengat the soils contain organic material or peat and cannot be used for embankment. The embankment soils have to be brought from the area of Japura, 15 to 20 km east of Rengat.

CHAPTER 8 SEISMICITY

The study area is located at the foot of the Barisan Mountain Range. A recognized active fault zone, called the Great Sumatran Fault System, runs on the western slope of the Barisan Range, parallel to the axis of the island.

The project site is located within a distance of 100 km from this fault zone. Records of movement at several locations in its lineation suggest that the Great Sumatran Fault could be a source of shallow earthquakes. The number of earthquake epicenters on this fault zone for the last 90 years is rather limited and far less than that in the coastal region.

Several dam projects have been studied up to the present, all located on the east side of the Barisan Range. An overview of the seismic criteria calculated for these projects is shown in Table IV.8.1.

Fig. IV.8.1 shows the seismic zoning map used as a standard for structural design in Indonesia. According to this map, the project area is located on the border of two zones characterized by the following coefficients:

- z = 0.56 b1 = 2.76 b2 = 0.71; and
- z = 1.00 b1 = 2.76 b2 = 0.71.

The seismic coefficient has been calculated for the zone with the highest earthquake intensity, z = 1. In this study, the design seismic acceleration is taken as 101 gal.

TABLES

IV GEOLOGY AND SOIL MECHANICS

Table IV.1.1 LIST OF DRILLING HOLES

Drill Holes		Location		
Code	Purpose	Latitude(S)	Longitude(E)	Altitude (El.m)
		Kuantan Damsite		
DA-1-95	dam axis	0°36.48'	101°19.34'	90.53
DA-2-95	dam axis	0°36.48'	101°19.34'	73.38
DA-3-95	dam axis	0°36.48'	101°19.34'	75.14
DA-4-95	dam axis	0°36.48'	101°19.34'	105.02
		Kuantan Reservoir		
RB-1-95	reservoir area	0°46.72'	101°18.21'	162.16
RB-2-95	reservoir area	0°47.47'	101°23.97'	133.83
RB-3-94	reservoir area	0°49.32'	101°28.63'	159.28
		Bangkinang		
LB-1-94	levee	0°20.00'	101°58.45'	37.88
LB-2-95	levee	0°21.60'	101°04.63'	30.56
LB-3-95	levee	0°21.46'	101°28.22'	24.86
LB-4-95	levee	0°20.66'	101°06.00'	19.80
LB-5-95	levee	0°21.52'	101°28.63'	16.00
		Rengat		
LR-6-95	levee	0°22.06'	102°32.35'	7.77
LR-7-95	levee	0°22.93'	102°33.55'	5.29
LR-8-95	levee	0°23.36'	102°34.73'	5.27
LR-9-95	levee	0°23.51'	102°33.35'	4.98
LR-10-54	levee	0°23.52'	102°32.53'	6.08
SB-1-95	sluiceway	0°20.87'	101°01.73'	29.67
SB-2-95	sluiceway	0°21.21'	101°12.04'	18.00
SR-3-95	sluiceway	0°24.11'	102°35.11'	6.55
SR-4-54	sluiceway	0°22.11'	102°31.38'	7.77
		Kuok		
WB-1-94	weir	0°18.62'	101°55.02'	39.52
WB-2-94	weir	in river		4.00
WB-3-94	weir	0°18.55'	101°55.24'	40.69
		Lubukjambi		
WL-1-95	weir	0°35.96'	101°24.67'	61.36
WL-2-95	weir	0°36.11'	101°24.69'	61.10
WL-3-95	weir	0°36.17'	101°24.66'	60.68

Table IV.1.2 LIST OF QUARRY SITES AND TEST PITS

Code	Location	Latitude	Longitude
Quarry Sites for Concrete Aggregates			
QI-94	vicinity dam		
QII-94	vicinity dam		
QIII-94	vicinity dam		
QIV-95	vicinity dam		
Borrow Sites for Concrete Aggregates			
AL-1-94	Sungaimanau		
AL-2-94	P. Tempurung		
AL-3-94	Sungaimanau		
AL-4-94	P. Tengah		
AL-5-94	Lubukambacang		
Test Pits for Embankment Materials			
Bangkinang			
TB-1-94	Pulautarap	0°19.28'N	101°56.36'E
TB-2-94	Airmanis	0°18.63'N	101°59.4'E
TB-3-95	Pulaulawas	0°21.46'N	101°2.72'E
TB-4-94	Kubu	0°21.22'N	101°5.00'E
TB-5-94	Rumbia	0°20.78'N	101°7.00'E
TB-6-94	Pulaucehorok	0°21.40'N	101°10.65'E
TB-7-95	Permbahan	none	none
TB-8-95	Padang terap	none	none
Taluk Kuantan			
TT-3-94	Kubu	0°30.97'S	101°35.28'E
TL-1-94	Sungaipinang	0°36.20'S	101°24.7'E
TL-2-94	Manau	0°38.41'S	101°26.12'E
TT-4-94	Setarajo	0°33.20'S	101°31.70'E
TT-5-94	Beringin	0°31.00'S	101°34.50'E
TT-6-94	Simandolak	0°28.36'S	101°37.23'E
TT-7-94	road T. Kuantan	0°24.29'S	101°38.45'E
TT-8-94	Kotapangean	0°25.48'S	101°40.41'E
TT-9-95	Kampungmeda	0°25.78'S	101°42.21'E
TT-10-95	Bedengsukuran	0°29.41'S	101°50.28'E
Airmolek			
TA-11-95	Sungaimalin	0°29.47'S	102°2.02'E
TA-12-95	Simpang Kelayang	0°27.53'S	102°8.91'E
TA-13-95	Batangborong	0°25.35'S	102°11.54'E
TA-14-95	Batugajah	0°21.91'S	102°15.67'E
TA-15-95	Japura	0°21.74'S	102°20.95'E
Rengat			
TR-16-95	Kotaraja	0°21.94'S	102°31.57'E
TR-17-95	Rengat	0°22.55'S	102°32.08'E
TR-18-95	Pematangreba	0°23.91'S	102°26.7'E
TR-19-95	Pematangreba	0°23.61'S	102°26.00'E
TR-20-95	Sungaiberingin	none	none

Table IV.3.1 STRATIGRAPHY OF POSSIBLE DAMSITES

(1) Kampar Kiri No.1 Damsite

Formation Name	Member	Code	Age	Lithology
River Alluvium		Qal	Quaternary	Clay, sand, gravel
Palembang Formation	lower	Tpl	Pliocene	Claystone, Some Sandstone
Telisa Formation	lower	Tmtl	Miocene	Clayey marl, sandstone
Kuantan Formation	upper	PCks	Permian-Carboniferous	Shale, phyllite, Some Sandstone
	middle	PCkl		Limestone

(2) Kampar Kiri No.2 Damsite

Formation Name	Member	Code	Age	Lithology
Palembang Formation	middle	Tpm	Tertiary	Sandstone and claystone
	lower	Tpl	Tertiary	Claystone and some Sandstone
Telisa Formation	lower	Tmtl	Tertiary	Clayey marl, Sandstone
Tuhur Formation	upper	Trts	Triassic	Slate, shale, radiolarite and silicified shale
Kuantan Formation	upper	PCks	Permian-Carboniferous	Shale, phyllite, Same Sandstone sandstone

(3) Kuantan Damsite

Formation Name	Member	Code	Age	Lithology
Quaternary alluvium		Qal	Quaternary	Clay, sand and gravel
Telisa Formation	upper	Tmtu	Tertiary	Shale, marly limestone
	lower	Tmtl	Tertiary	Clayey marl, sandstone,chert
Granite		g	Cretaceous	Leucogranite to quartz monzonite
Kuantan Formation	upper	PCks	Permo-Carboniferous	Shale, phyllite, sandstone, some quartzite
	middle	PCkl		Limestone
	lower	PCkq		Quartzite

(4) Upper Sinamar Damsite

Formation Name	Member	Code	Age	Lithology
Pumice Tuff Formation		Qpt	Quaternary	Rhyolitic, white pumice
Andesite of Malintang Mountain	upper	Qamg	Quaternary	Andesitic-basaltic breccia, agglomerates, lahar deposits
Granite		g	Upper Cretaceous	Leucogranite to quartz monzonite
Kuantan Formation	upper	PCks	Permo-Carboniferous	shale, phyllite, some sandstone and quartzite
	middle	PCkl		limestone

(5) Sukam Damsite

Formation Name	Member	Code	Age	Lithology
Ombilin Formation	upper	Tmou	Early Miocene	Clay, marl, intercalations of sandstone
	lower	Tmol	Tertiary	Quartz sandstone, locally metamorphic, coal seams
Granite		g	Cretaceous	Leucogranite to quartz monzonite

Note : based on the geological map Solok, 1/ 250,000

Table IV.3.2 GEOLOGICAL CONDITIONS OF SELECTED DAMSITES FOR OVERALL DEVELOPMENT PLAN

(1) Kampar Kiri No.1 Dam

Place	Location	Lithology	Strike/ Dip	Geological Structure
Dam axis	S 0°11'18" E101°04'00"	lb: mudstone/shale rb: shale/ sandstone/ quartzite	lb: 025/82° rb: 100/10°	slightly metamorphic rock
Reservoir		mudstone/ shale/ siltstone/ sandstone		asymmetrical folds/ fault at Muarabio

Note: lb= left bank; rb= right bank.

(2) Kampar Kiri No.2 Dam

Place	Location	Lithology	Strike/ Dip	Geological Structure
Dam axis	S 0°25'06" E101°17'50"	quartzite/ sandstone	048/55° and 210/75° (measured upstream)	both river banks: no outcrops
Reservoir		sandstone/ quartzite marl/ conglomerate river terrace deposits		sandstones are folded limited marl outcrops reversed fault at Sepuh

(3) Kuantan Dam

Place	Location	Lithology	Strike/ Dip	Geological Structure
Dam axis	S 0°36'48" E 101°19'34"	rb: quartzite lb: shale &quartzite	lb: 196/64°	quartzite is jointed
Reservoir				lineaments
		quartzite/ sandstone	changing	tight folds in quartzite, vertical axial palnes, fold span 30 m
		mudstone/ shale	changing	mineralized
		limestone	not visible	karstified
		granite	none	

Note: lb= left bank; rb = right bank.

Table IV.4.1 SUMMARY OF LABORATORY TEST RESULTS - KUANTAN DAMSITE

Sample	Depth (m)	Rock Type	Specific Gravity		Natural Density (g/cm^3)	Absorbtion (%)	Unconfined Compressive Strength (kg/cm^2)
			Apparent	Absolute			
DA-1-95	24-24.35	quartzite	2.50	2.64	2.51	2.18	487
	32.67-33	quartzite	2.53	2.67	2.55	2.04	308
	49.65-49.9	shale	2.32	2.74	2.38	6.53	59
	66.5-65.85	shale	1.98	2.42	2.08	9.28	75
DA-2-95	3-3.3	quartzite	2.55	2.81	2.59	3.61	486
	32.12-32.31	quartzite	2.54	2.65	2.55	1.67	1,021
	65.55-65.85	shale	1.90	2.58	1.92	13.73	29
DA-3-95	9-9.22	shale	2.16	2.48	2.20	6.10	55
	15.45-15.7	shale	2.13	2.51	2.22	6.95	168
	33.65-33.95	shale	2.16	2.54	2.19	7.13	71
DA-4-95	46.7-46.85	quartzite	2.58	2.66	2.59	1.11	320
	51.25-51.6	quartzite	2.54	2.61	2.56	1.13	343
	69.15-69.35	shale	2.11	2.47	2.17	6.92	70

Table IV.4.2 PERMEABILITY TEST RESULTS - KUANTAN DAMSITE

Hole	Depth (m)	Permeability (cm/s)	Lugeon Value (Lu)	Hole	Depth (m)	Permeability (cm/s)	Lugeon Value (Lu)
DA-1-95	5.0	3.40E-04		DA-3-95	5.0	1.29E-03	
	10.0	3.63E-03			7.0	1.69E-03	
	10.0-15.0	5.71E-05	4.4		10.0-15.0	2.78E-05	2.1
	15.0-20.0	5.97E-05	4.6		15.0-20.0	1.99E-05	1.5
	20.0-25.0	2.93E-05	2.2		20.0-25.0	1.87E-05	1.4
	25.0-30.0	2.31E-05	1.8		25.0-30.0	2.04E-05	1.6
	30.0-35.0	1.07E-05	0.8		30.0-35.0	2.03E-05	1.5
	35.0-40.0	9.49E-05	0.7		35.0-40.0	2.00E-05	1.5
	40.0-45.0	1.68E-05	1.3		40.0-45.0	1.96E-04	15.0
	45.0-50.0	1.31E-05	1.0		45.0-50.0	1.57E-05	1.2
	50.0-55.0	9.86E-05	0.8		50.0-55.0	1.34E-05	1.0
	55.0-60.0	1.27E-05	1.0		55.0-60.0	1.18E-05	0.9
	60.0-65.0	1.76E-05	1.3		60.0-65.0	1.78E-05	1.3
	65.0-70.0	1.28E-05	0.9		65.0-70.0	1.27E-05	1.0
	Average	3.14E-04	1.7		Average	1.60E-04	2.5
DA-2-95	3.0-5.0	2.59E-03		DA-4-95	3.0-5.0	6.60E-06	
	10.0-15.0	3.79E-05	2.9		5.0-10.0	4.90E-05	3.8
	15.0-20.0	7.09E-05	5.4		10.0-15.0	7.72E-05	6.0
	20.0-25.0	8.07E-05	6.1		15.0-20.0	4.45E-05	3.4
	25.0-30.0	5.76E-05	4.4		20.0-25.0	4.05E-05	3.1
	30.0-35.0	3.38E-05	2.6		25.0-30.0	4.97E-05	3.8
	35.0-40.0	1.78E-05	1.4		30.0-35.0	1.44E-05	11.0
	40.0-45.0	1.22E-05	0.9		35.0-40.0	6.06E-05	4.7
	45.0-50.0	1.09E-05	0.8		40.0-45.0	3.73E-05	2.8
	50.0-55.0	1.75E-05	1.3		45.0-50.0	3.63E-05	2.8
	55.0-60.0	1.44E-05	1.1		50.0-55.0	2.77E-05	2.1
	60.0-65.0	1.27E-05	1.0		55.0-60.0	1.87E-05	1.4
	65.0-70.0	7.78E-05	0.6		60.0-65.0	2.77E-05	2.1
					65.0-70.0	1.52E-05	1.1
	Average	2.33E-04	2.4		Averge	3.84E-05	3.7

Table IV.4.3 PERMEABILITY TEST RESULTS - KUANTAN RESERVOIR AREA

Hole	Depth (m)	Permeability (cm/s)	Lugeon Value (Lu)
RB - 1	0-5	2.24E-05	
	5.00-10.0	1.27E-05	
	10.0-15.0	2.14E-04	
	15.0-20.0	9.60E-05	
	20.0-25.0	2.69E-04	21.8
	25.0-30.0	1.08E-04	8.3
RB - 2	0-5	1.45E-03	
	5.00-10.0	1.18E-05	0.9
	10.0-15.0	2.19E-05	1.7
	15.0-20.0	3.37E-05	2.6
	20.0-25.0	1.63E-05	1.3
	25.0-30.0	3.48E-05	2.7
RB -3	0-5	7.30E-04	
	5.00-10.0	4.15E-05	3.2
	10.0-15.0	9.13E-05	7.1
	15.0-20.0	2.11E-05	1.6
	20.0-25.0	1.20E-05	0.9
	25.0-30.0	1.57E-05	1.2
	30.0-35.0	6.94E-05	4.7
	35.0-40.0	7.73E-05	6.0
	40.0-45.0	3.51E-05	2.7
	45.0-50.0	4.28E-05	3.3
	50.0-55.0	6.85E-05	5.3
	55.0-60.0	6.57E-05	5.1
	60.0-65.0	4.98E-05	3.9
	65.0-70.0	5.43E-05	4.2
	70.0-75.0	8.22E-05	6.4
	75.0-80.0	5.50E-05	4.3
RB -3	80.0-85.0	5.00E-05	3.9
	85.0-90.0	6.62E-05	5.1
	90.0-95.0	6.32E-05	4.9
	95.0-100.0	5.25E-05	4.1
	100.0-105.0	4.61E-05	3.6
	105.0-110.0	7.97E-05	6.2
	110.0-115.0	7.72E-05	6.0
	115.0-120.0	4.94E-05	3.8
	120.0-125.0	4.51E-05	3.5
	125.0-130.0	7.44E-05	5.8
	130.0-135.0	6.45E-05	5.0
	135.0-140.0	8.43E-05	6.5
	140.0-145.0	7.52E-05	5.8
	145.0-150.0	9.68E-05	7.5

Table IV.5.1 LABORATORY TEST RESULTS - KAMPAR RIVER BASIN

Sample	Depth (m)	Soil Type	% passing 200 sieve	Atterberg Limits			Wn (%)	Sr(%)	Gs	Density (t/m^3)			Triaxial Tests			Unconf. Compression	
				LL(%)	PL(%)	PI(%)				Wet	Dry	Saturated	Type	C (kg/cm^2)	ϕ	qu(kg/cm^2)	su(kg/cm^2)
WB-1-94	3.7-4	sandy silt	90.8	58.4	20.7	37.7	38.8		2.61	1.71	1.23	1.76				1.52	0.76
WB-1-94	7.7-8	claystone	--	-	-	-	-		2.63	-	-	-					
WB-1-94	12.32-12.45	claystone	94.4	80.8	23.4	57.4	30.4		2.61	1.76	1.35	1.83				3.85	1.93
WB-1-94	12.7-13	claystone	94.9	75.8	23.7	52.1	35.1		2.64	1.75	1.29	1.80				3.62	1.81
WB-2-94	7.7-7.95	claystone	88.2	76.5	20.1	56.4	41.2		2.62	1.69	1.19	1.74				3.28	1.64
WB-2-94	5.4-5.7	sand and clay	--				-		2.67	-	-	-					
WB-3-94	12.25-12.45	claystone	88.8	73.2	21.3	52.0	42.1		2.66	1.69	1.19	1.74				2.23	1.12
WB-3-94	18.7-19	claystone	99.2	84.5	26.8	57.7	30.8		2.62	1.80	1.38	1.85				1.78	0.89
WB-3-94	6.5-6.75	clay	98.1	77.9	29.4	48.5	47.2		2.61	1.79	1.21	1.79				0.82	0.41
WB-3-94	8.6-8.9	sandy clay							2.66								
LB-1-94	4.7-5	gravel/sand	6.6				2.1		2.62								
LB-2-95	3.7-4	silty sand	47.7				19.8		2.66								
LB-2-95	6.5-6.8	sand	37.8				8.8		2.66								
LB-3-95	4.4-4.7	sand	15.9				7.4		2.64								
LB-4-95	3.45-3.8	silt/clayey silt	83.2	134.9		60.7	117.1		2.58								
LB-4-95	6.15-6.45	peat	21.5	53.1		28.1	48.2		2.65								
LB-5-95	3.45-3.85	silty sand	56.8	37.2		20.5	29.0		2.64								
LB-5-95	6.7-7	sand	16.8				12.1		2.62								
SB-1-95	5.75-6	claystone	94.8	84.2	25.9	58.3	40.1		2.62	1.70	1.21	1.75				2.59	1.23
SB-1-95	11.1-11.4	clay/sandstone	56.2	63.9	21.1	42.9	34.6		2.64	1.76	1.31	1.81				2.85	1.43
SB-1-95	16.2-16.5	sandstone	79.6	64.8	23.3	41.5	42.6		2.64	1.77	1.24	1.77				2.86	1.43
SB-1-95	22.35-22.65	claystone	96.2	83.7		56.7	38.6		2.62	1.72	1.24	1.77				2.28	1.14
SB-2-95	18.7-19	organic soil	80.4	48.4	19.1	29.3	25.5		2.63								
SB-2-95	4.45-4.8	sand/ silt	52.2	66.6	30.8	35.8	35.8		2.64								
SB-2-95	9.5-9.8	gravel	16.9				8.8		2.64								

Table IV.5.2 CONSOLIDATION TEST RESULTS - KUOK INTAKE WEIR SITE

Sample	Depth (m)	Soil Type	LL(%)	Wn(%)	eo	Pc (kg/cm^2)	Cc	Cv (cm^2/day)
WB-1-94	12.32-12.45	claystone	80.8	30.4	0.943	0.9	0.156	600
WB-3-94	18.7-19	claystone	84.5	30.8	0.908	18.7	0.153	300
SB-1-94	16.2-16.5	sandstone	64.8	42.6	1.131	0.7	0.236	650

Table IV.5.3 UNCONFINED COMPRESSIVE STRENGTH TEST RESULTS - KUOK INTAKE WEIR SITE

Sample	Depth (m)	Soil Type	LL	Wn(%)	Sr(%)	qu (kg/cm^2)	su (kg/cm^2)
WB-1-94	3.7-4	sandy silt	58.35	38.7	89.4	1.52	0.76
WB-1-94	12.32-12.45	claystone	80.75	30.4	83.2	3.85	1.92
WB-1-94	12.7-13	claystone	75.80	35.1	88.4	3.62	1.81
WB-2-94	7.7-7.95	claystone	76.50	41.2	89.4	3.28	1.64
WB-3-94	12.25-12.45	claystone	73.20	42.5	91.5	2.23	1.11
WB-3-94	18.7-19	claystone	84.50	30.8	88.0	1.79	0.89
WB-3-94	6.5-6.75	clay	77.90	47.2	105.4	0.82	0.41
SB-1-94	5.75-6	claystone	84.15	40.1	89.7	2.59	1.30
SB-1-94	11.1-11.4	clay/sandstone	63.90	34.5	89.4	2.85	1.43
SB-1-94	16.2-16.5	sandstone	64.75	42.6	99.0	2.86	1.43
SB-1-94	22.35-22.65	claystone	83.70	38.6	90.0	2.28	1.14
WL-1-94	8.45-9.00	gravel		7.6	75.7	1.07	0.54

Note : qu=unconfined compressive strength; su=undrained shear strength

Table IV.5.4 PERMEABILITY TEST RESULTS - KUOK INTAKE WEIR SITE

Sample	Depth (m)	Permeability (cm/s)	Hole	Depth (m)	Permeability (cm/s)
WB-1-94	1.84-5	1.93E-05	WB-3-94	4.8-5	5.94E-06
	10.0	5.85E-04		9.6-10	7.14E-04
	13-15	2.86E-04		14-15	3.74E-05
				18-20	9.47E-05

Table IV.6.1 LABORATORY TEST RESULTS - INDRAGIRI RIVER BASIN

			% passing	Atterberg Limits						Density (t/m^3)			Triaxial Tests			Unconfined Comp.	
Sample	Depth (m)	Soil Type	200 sieve	LL(%)	PL(%)	PI(%)	Wn (%)	Sr(%)	Gs	Wet	Dry	Saturated	Type	C (kg/cm^2)	ϕ	qu(kg/cm^2)	su(kg/cm^2)
LR-6-95	3.45-3.75	organic silt	96.4	63.8		37.8	51.5		2.61								
LR-6-95	8.6-9	sand	3.2				17.5		2.64								
LR-7-95	3.45-4	silt/clay org.	76.5	84.3		56.0	79.9	97.2	2.68	1.51	0.84	1.52	UU	0.005	2.2		
LR-7-95	5.5-6	organic clay	58.8	70.9		40.3	55.4		2.66								
LR-8-95	3-3.5	clay					39.5			1.69	1.21		UU	0.005	6.8		
LR-8-95	8.5-9	sand	2.9				18.9		2.62								
LR-8-95	2.5-3	org. silty clay	96.3	80.0		52.5	82.5		2.61								
LR-9-95	5-5.6	peat	92.3	63.5		20.4	449.3	100.0	2.21	1.23	0.22	1.23					
LR-9-95	7.45-8	org silt	41.4	50.1		33.8	40.8	100.0	2.63	1.82	1.30	1.82	UU	0.077	11.3		
LR-10-95	2.4-3	peat	---				762.1		---								
LR-10-95	4.45-5	clayey silt	72.5	101.4		75.5	52.6	100.0	2.63	1.71	1.12	1.71	UU	0.036	7.2		
LR-10-95	8.5-9	silt	61.5	48.0		27.9	44.3		2.62								
SR-3-95	2.45-3	clayey silt	95.3	62.2		34.3	48.2	100.0	2.62	1.73	1.17	1.73	UU	0.028	8.7		
SR-3-95	8.45-9	clayey silt	77.7	49.2		23.4	53.1	100.0	2.63	1.72	1.12	1.72	UU	0.018	1.5		
SR-3-95	19.5-20	sand	5.9				20.8		2.66								
SR-4-95	5.45-6	silty clay	70.8	51.6		37.7	44.8	100.0	2.62				UU	0.006	5.9		
SR-4-95	6.5-7	sandy silt	48.5	35.1		17.7	33.4		2.64								
SR-4-95	14.45-15	organic clay	87.4	90.9		62.3	54.4	98.2	2.68	1.67	1.08	1.68	UU	0.044	2.4		
WL-1-95	4-4.35	clay	72.4	50.6	19.4	31.2	33.1		2.61				UU	0.017	6.3		
WL-1-95	4-4.35	clay	72.4	50.6	19.4	31.2	33.1		2.61				UU	0.000	9.0		
WL-1-95	8.45-9	gravel	25.5	-	-	-	8.3		2.68								
WL-1-95	> 8.5 m	gravely siltstone							2.68							1.08	0.54
WL-2-95	4-4.6	clayey sand	25.2	44.3	20.4	24.0	32.9		2.66	1.87	1.41	1.88	UU	0.110	21.3		
WL-3-95	3-3.6	silty sand	34.2	39.4	18.8	20.6	37.8		2.70	1.78	1.29	1.81	UU	0.046	8.1		
WL-1-95	11.4-11.65	silt/sandstone					35.0	71.0	2.46	1.21	0.90	1.53				6.79	3.39
WL-2-95	12-12.2	silt/sandstone					35.3	71.4	2.38	1.19	0.88	1.51				6.68	3.34
WL-3-95	10-10.2	silt/sandstone					34.1	68.2	2.43	1.23	0.92	1.54				6.65	3.32

Table IV.6.2 UNCONFINED UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS - LUBUKJAMBI INTAKE WEIR SITE

Sample	Depth (m)	Soil Type	LL (%)	PI (%)	Wn (%)	Sr (%)	C (kg/cm^2)	ϕ
WL-1-95	4-4.35	clay	50.6	19.4	33.1	101.0	0.00	9.0
WL-1-95	4-4.35	clay	50.6	19.4	33.1	101.0	0.02	6.3
WL-2-95	4-4.6	clayey sand	44.3	20.4	32.1	100.1	0.11	21.3
WL-3-95	3-3.6	silty sand	39.4	18.8	40.5	99.5	0.05	8.1

Table IV.6.3 UNCONFINED COMPRESSION TEST RESULTS- LUBUKJAMBI INTAKE WEIR SITE

Sample	Depth (m)	Soil Type	Wn (%)	Sr (%)	qu (kg/cm^2)	su (kg/cm^2)
WL-1-95	>8.5	gravely siltstone			1.08	0.54
WL-1-95	11.4-11.65	silt/sandstone	35.0	71.0	6.79	3.39
WL-2-95	12-12.2	silt/sandstone	35.3	71.4	6.68	3.34
WL-3-95	10-10.2	silt/sandstone	34.1	68.2	6.65	3.32

Table IV.6.4 CONSOLIDATION TEST RESULTS - LUBUKJAMBI INTAKE WEIR SITE

Sample	Depth (m)	Soil type	LL(%)	Wn(%)	eo	Pc (kg/cm^2)	Cc	Cv (cm^2/day)
WL-1-95	4-4.35	clay	50.6	33.05	0.86	2.35	0.23	450
WL-2-95	4.1-4.6	clayey sand	44.3	32.1	0.89	0.88	0.20	400
WL-3-95	3-3.5	silty sand	39.4	40.54	1.07	0.55	0.18	

Table IV.6.5 PERMEABILITY TEST RESULTS - LUBUKJAMBI INTAKE WEIR SITE

Sample	Depth (m)	Permeability (cm/s)	Sample	Depth (m)	Permeability (cm/s)
WL-1-95	0-5	1.93E-02	WL-2-95	4.8-5.0	4.01E-03
	9.0-10	1.45E-05		9.8-10.0	7.82E-04
	14-14.35	3.30E-05		14.8-15.0	3.55E-05
	15-20	4.02E-06	WL-3-95	4.8-5	9.31E-06
	15-25	2.33E-06			
	16-31	5.44E-07			

Table IV.6.6 CONSOLIDATION TEST RESULTS - RENGAT AREA

Sample	Depth (m)	Soil Type	LL(%)	Wn(%)	eo	Pc (kg/cm^2)	Cc	Cv (cm^2/day)
LR-7-95	3.45-4	silt/clay org.	84.3	79.9	2.201	0.52	0.515	280
LR-9-95	5-5.6	peat	63.5	449.3	9.938	0.29	2.963	180
LR-9-95	7.45-8	org. silt	50.1	40.8	1.075	1.69	0.299	550
LR-10-95	4.45-5	clayey silt	101.4	52.6	1.383	0.75	0.409	450
SR-3-95	2.45-3	clayey silt	62.2	48.2	1.270	1.70		
SR-3-95	8.45-9	clayey silt	49.2	53.1	1.395	1.38	0.176	700
SR-4-95	5.45-6	silty clay	51.6	44.8	1.176	1.16	0.146	400
SR-4-95	14.45-15	organic clay	90.9	54.4	1.483	0.53	0.385	240

Table IV.6.7 UNCONFINED UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS - RENGAT AREA

Sample	Depth (m)	Soil Type	LL (%)	PI (%)	Wn (%)	Sr (%)	C (kg/cm^2)	ϕ
LR-7-95	3.45-4	silt/clay, org.	84.3	56.0	86.3	98.2	0.005	2.2
LR-8-95	3-3.5	clay			38.2		0.005	6.8
LR-9-95	7.45-8	org silt	50.1	33.8	40.1	102.4	0.077	11.3
LR-10-95	4.45-5	clayey silt	101.4	75.5	54.5	100.0	0.036	7.2
SR-3-95	2.45-3	clayey silt	62.2	34.3	49.0	100.0	0.028	8.7
SR-3-95	8.45-9	clayey silt	49.2	23.4	50.3	100.0	0.018	1.5
SR-4-95	5.45-6	silty clay	51.6	37.7	40.0	100.0	0.006	5.9
SR-4-95	14.45-15	organic clay	90.9	62.3	53.3	100.0	0.044	2.4

Table IV.7.1 LABORATORY TEST RESULTS FOR AGGREGATES FROM INDRAGIRI RIVERBED

Sample	Depth (m)	Coefficient of Fineness (%)	Specific Gravity		Absorption(%)	Soundness	Alkali Reactivity		Abrasion (%)
			Absolute	Apparent		Weight Loss (%)	Rc(mmol/l)	Sc(mmol/l)	
AL-1	0-1	7.79	2.64	2.71	1.10	1.49	113.40	106.56	22.90
AL-1	1.0-2.0	6.05	2.59	2.67	1.15	0.75	113.40	108.22	25.90
AL-2(lb)	0-1	7.63	2.68	2.73	0.76	0.72	113.40	101.23	23.70
AL-2(rb)	0-1	7.05	2.61	2.67	0.90	1.08	113.40	97.90	21.80
AL-3	0-1	8.66	2.61	2.69	1.14	1.08	164.43	57.61	29.30
AL-4	0-1	6.27	2.63	2.70	0.84	1.47	68.04	53.62	8.50
AL-5	0-1	7.50	2.62	2.69	0.79	1.09	102.06	57.61	19.80
	Average	7.28	2.63	2.69	0.95	1.10	112.59	83.25	21.70
AL-5 (fines)	0-1		2.53	2.65	1.79				
AL-1 (fines)	0-1		2.60	2.69	1.40				
AL-1 (fines)	1.0-2.0		2.55	2.64	1.35				
AL-2 (lb; fines)	0-1		2.53	2.67	1.98				
AL-2(lb;fines)	0-1		2.53	2.68	2.19				
AL-3 (fines)	0-1		2.47	2.74	3.93				
AL-4 (fines)	0-1		2.59	2.70	1.67				
	Average		2.54	2.68	2.04				

Table IV.7.2 LABORATORY TEST RESULTS FOR AGGREGATES FROM QUARRY SITES

Sample	Specific Gravity		Natural Density (g/cm^3)	Absorbtion (%)	Unconfined Compressive Strength (kg/cm^2)
	Apparent	Absolute			
QI	2.46	2.66	2.48	1.00	915.42
QII	2.34	2.57	2.36	1.67	631.73
QIII	2.30	2.52	2.33	2.30	512.35
QIV	2.40	2.53	2.42	1.53	512.67

Table IV.7.3 PHYSICAL PROPERTIES OF EMBANKMENT MATERIALS (1/2)

Sample	Depth (m)	Soil Type	% passing	Atterberg Limits			Wn (%)	Sr(%)	Gs	Compaction		
			200 sieve	LL(%)	PL(%)	PI(%)				W opt. (%)	Max.dry density (t/m³)	Max. wet density (t/m³)
TB-1-94	0.45-1.25	sandy silt	77.7	40.8	19.5	21.3			2.70			
	1.35-2.00	silt	71.2	46.0	20.4	25.6	30.3	88.0	2.61	26.2	1.47	1.85
TB-2-94	0.35-2.00	gravely sand	31.6						2.62			
	1.00-4.50	silty sand	49.6	48.3	14.9	33.4	17.6	80.8	2.61	13.7	1.81	2.06
TB-3-94	0.25-1.25	silt	92.4	67.8	34.9	32.9			2.62			
	1.35-2.00	silt	90.6	93.4	42.9	50.5	54.1	94.1	2.66	40.4	1.24	1.74
TB-4-94	0.25-1.00	silt	63.6	66.0	24.3	41.7	38.5	87.8	2.63	24.7	1.51	1.89
TB-5-94	0.30-1.00	silt	87.4	80.3	32.3	48.0	58.6	90.4	2.62	32.8	1.34	1.79
TB-6-94	0.20-1.00	silt	90.4	59.0	22.2	36.8	39.8	86.9	2.62	25.4	1.48	1.86
TB-7-95	0.30-1.10	silty clay	99.6	82.0	26.1	55.9	33.7	91.3	2.61	28.6	1.44	1.85
TB-8-95	0.20-0.50	silt	65.2	37.9	15.2	22.7			2.66			
	0.60-2.00	silt	93.8	61.5	22.1	39.4	33.7	89.6	2.68	26.2	1.50	1.89
TL-1-94	0.30-2.00	silt	71.5	46.5	18.6	27.9	27.7	85.8	2.66	23.0	1.55	1.91
TL-2-94	0.40-3.70	silt	89.9	71.8	26.8	45.0	33.7	93.6	2.64	32.0	1.39	1.83
TT-3-94	0.90-3.10	sand	62.2						2.63			
	3.10-3.30	silt	76.6	45.2	20.9	24.4	28.3	85.6	2.60	28.0	1.41	1.80
TT-4-94	0.40-1.90	silt	85.9	112.2	36.0	76.1	45.0	88.6	2.68	36.6	1.27	1.74
	1.90-3.00	clayey silt	82.7	113.8	40.0	73.8	53.1	94.3	2.64	37.4	1.29	1.77
TT-5-94	0.25-1.50	silt	38.8	88.4	30.3	58.1	64.5	89.6	2.62	26.4	1.48	1.87
	0.50-6.00	gravely silt	94.6	88.8	33.3	55.5	47.8		2.62			
TT-6-94	0.25-1.50	silt	78.0	111.3	48.6	62.7	64.8	90.3	2.61	46.0	1.15	1.65
	0.00-6.00	silt	48.7	79.5	29.0	50.5	58.0		2.61			
TT-7-94	0.50-1.50	silt	98.0	68.1	22.4	45.7	21.0		2.66			
	1.50-3.00	silt	39.1	61.5	30.2	31.3	43.8	80.9	2.64	21.4	1.62	1.93
	0.00-6.00	silt	29.6	46.4	21.5	24.9	34.7		2.62			
TT-8-94	0.20-1.50	clayey silt	97.4	105.5	35.1	70.4	41.3	86.5	2.62	41.4	1.17	1.65
TT-9-95	0.10-0.45	silt	28.9	45.7	16.4	29.3			2.66			
	0.55-2.00	clayey silt	13.4	46.2	20.9	25.3	15.0	78.9	2.68	15.0	1.77	2.04
TT-10-95	0.05-1.25	sandy silt	71.6	54.1	17.3	36.8	38.8	83.2	2.70	21.0	1.60	1.94

Table IV.7.3 PHYSICAL PROPERTIES OF EMBANKMENT MATERIALS (2/2)

Sample	Depth (m)	Soil Type	% passing	Atterberg Limits			Wn (%)	Sr(%)	Gs	Compaction		
			200 sieve	LL(%)	PL(%)	PI(%)				W opt. (%)	Max.dry density (t/m^3)	Max. wet density (t/m^3)
TA-11-95	0.10-0.75	silt	71.7	67.7	17.6	50.1	22.7		2.64			
	0.85-1.15	silt	56.4	65.8	23.0	42.8	44.5		2.65			
	1.25-2.20	clayey silt	73.6	54.5	17.2	37.3	59.3	85.8	2.68	22.6	1.57	1.93
TA-12-95	0.25-2.20	sand	24.7	41.8	15.6	26.2	20.4	72.0	2.68	11.0	1.90	2.11
	2.20-3.50	sand	38.2	67.5	17.2	49.7	22.8	78.8	2.68	14.6	1.79	2.05
TA-13-95	0.25-1.35	silt	67.2	80.7	21.1	59.6	32.4		2.68			
	1.40-3.10	silt/sand	26.2	38.3	16.5	21.8	37.6	78.3	2.68	12.4	1.88	2.11
TA-14-95	0.30-2.10	gravely silt	91.0	110.0	33.7	76.3	40.3	92.1	2.69	33.2	1.37	1.82
TA-15-95	0.10-0.30	silt	62.2	63.4	19.9	43.5	29.4	91.1	2.64	22.0	1.61	1.97
TR-16-95	0.19-0.85	sand	0.0				27.1		2.68			
	0.95-1.20	silt	44.2	36.4	16.3	20.1	29.8	83.0	2.66	20.0	1.62	1.94
TR-17-95	0.00-1.00	organic silt	72.6	194.0	81.0	113.0	154.5	88.7	2.55	81.6	0.75	1.36
TR-18-95	0.20-1.50	silt	65.4	64.2	23.9	40.3	27.0		2.64			
	0.00-5.00	silt	26.9	49.9	20.4	29.5	11.4	83.3	2.70	15.6	1.79	2.07
TR-19-95	0.25-1.30	silt	94.2	83.0	23.6	59.4	38.3	87.0	2.66	26.8	1.46	1.85
TR-20-95	0.20-0.75	silt	93.8	77.1	28.7	48.4	44.7	88.9	2.63	32.0	1.35	1.78

Table IV.7.4 CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS - KAMPAR RIVER BASIN

Sample	Soil Type	LL (%)	Wn (%)	Sr (%)	Effective Shear Stress		Total Shear Stress	
					C (kg/cm^2)	ϕ	C (kg/cm^2)	ϕ
TB-1	mixed	46.0	28.2	88.0	0.16	33.4	0.29	23.1
TB-2	sandy	48.0	15.7	80.8	0.09	28.3	0.11	18.6
TB-3	clayey	93.4	42.4	94.0	0.11	36.1	0.14	27.1
TB-4	mixed	66.0	26.7	87.8	0.12	36.3	0.10	29.5
TB-5	clayey	80.3	34.8	90.4	0.10	22.8	0.07	32.3
TB-6	clayey	59.0	27.4	86.9	0.29	19.8	0.11	31.8
TB-7	clayey	82.0	30.6	91.0	0.13	24.4	0.13	31.9
TB-8	mixed	61.5	28.2	89.6	0.19	20.2	0.11	31.1

Table IV.7.5 CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS - LUBUKJAMBI - TALUKKUANTAN AREA

Sample	Soil Type	LL (%)	Wn (%)	Sr (%)	Effective Shear Stress		Total Shear Stress	
					C (kg/cm^2)	ϕ	C (kg/cm^2)	ϕ
TL-1	mixed	46.5	25.0	85.8	0.25	24.7	0.32	15.3
TL-2	clayey	71.8	34.0	93.6	0.24	37.7	0.32	22.7
TT-3	mixed	45.2	30.0	85.4	0.29	33.0	0.42	23.7
TT-4	clayey	112.2	39.4	88.6	0.22	35.7	0.34	17.3
TT-5	mixed	88.4	28.4	89.6	0.17	34.4	0.29	21.8
TT-6	mixed	111.3	46.0	90.2	0.01	30.4	0.03	22.6
TT-7	gravely	61.5	21.4	80.9	0.04	39.5	0.03	32.7
TT-8	mixed	105.5	43.3	86.5	0.17	25.9	0.17	17.7
TT-9	gravely	46.2	17.0	78.9	0.05	38.2	0.22	23.6
TT-10	mixed	54.1	23.0	83.2	0.27	27.2	0.29	21.8

Table IV.7.6 CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS - AIRMOLEK - RENGAT AREA

Sample	Soil Type	LL (%)	Wn (%)	Sr (%)	Effective Shear Stress		Total Shear Stress	
					C (kg/cm^2)	ϕ	C (kg/cm^2)	ϕ
TA-11	mixed	54.5	24.6	85.8	0.28	33.2	0.27	28.1
TA-12	sandy	67.5	16.6	78.8	0.25	33.6	0.29	20.0
TA-13	sandy	38.3	14.4	78.3	0.06	39.0	0.12	26.8
TA-14	clayey	110.0	35.2	92.1	0.26	25.4	0.26	18.0
TA-15	mixed	63.4	24.0	91.1	0.24	33.5	0.32	22.1
TR-16	mixed alluvial	36.4	22.0	82.9	0.27	31.7	0.57	17.5
TR-17	peat	194.0	83.6	88.7	-	-	-	-
TR-18	sandy	49.9	17.6	83.3	0.12	30.8	0.17	19.6
TR-19	clayey	83.0	28.8	87.0	0.06	28.2		
TR-20	clayey	77.1	34.0	88.9	0.07	35.7	0.09	23.2

Table IV.8.1 DESIGN SEISMIC COEFFICIENTS

Project Name	Return Period (year)	Maximum Peak Horizontal Acceleration (gal)	
		Kawasumi	Plotting Position
Besai	100	297	208
	200	414	463
Peusangan	100	101	-
	200	253	-
Musi	100	352	270
	200	498	596

FIGURES

IV GEOLOGY AND SOIL MECHANICS

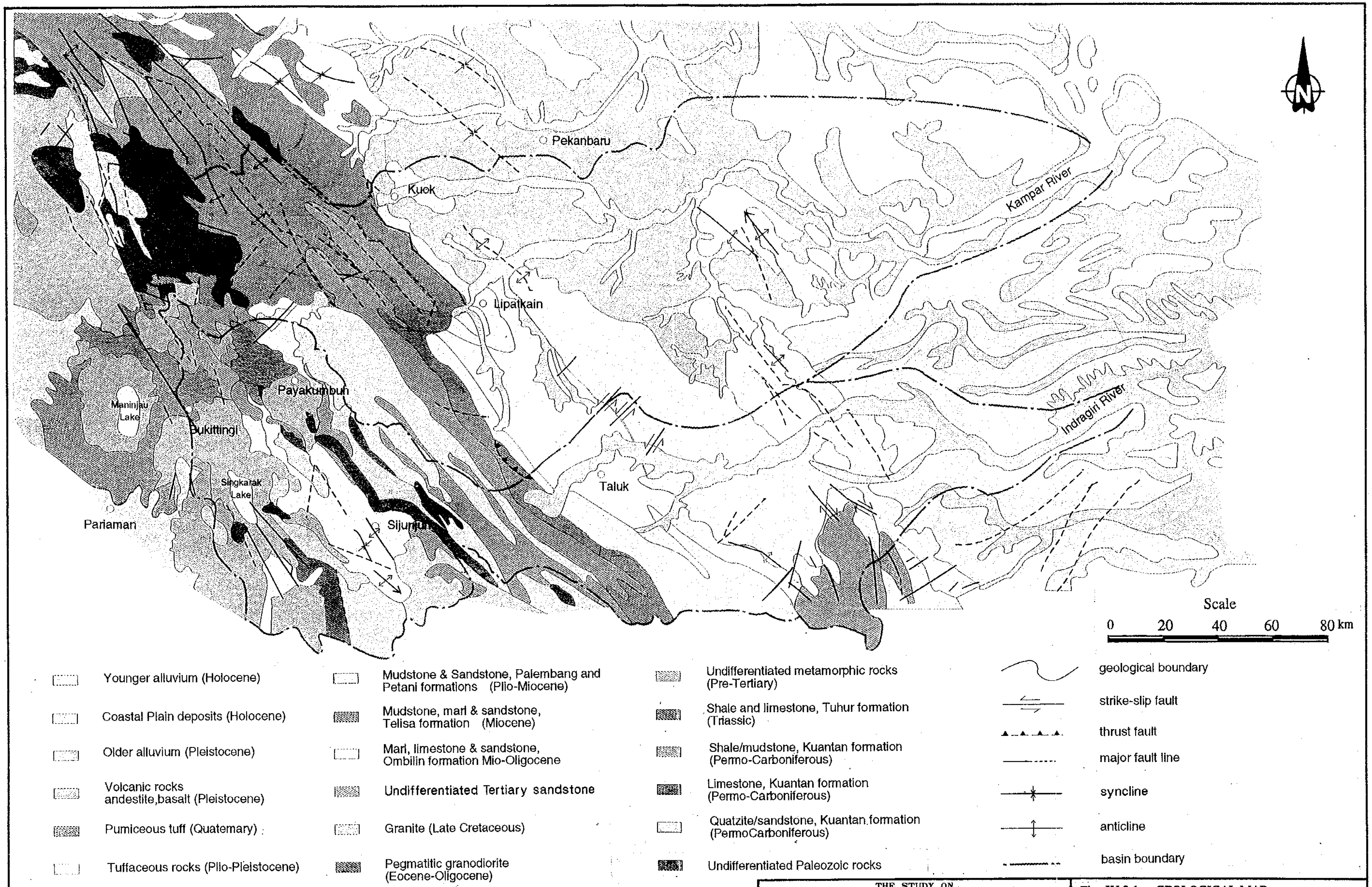

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Fig. IV.2.1 GEOLOGICAL MAP [illegible] AREA

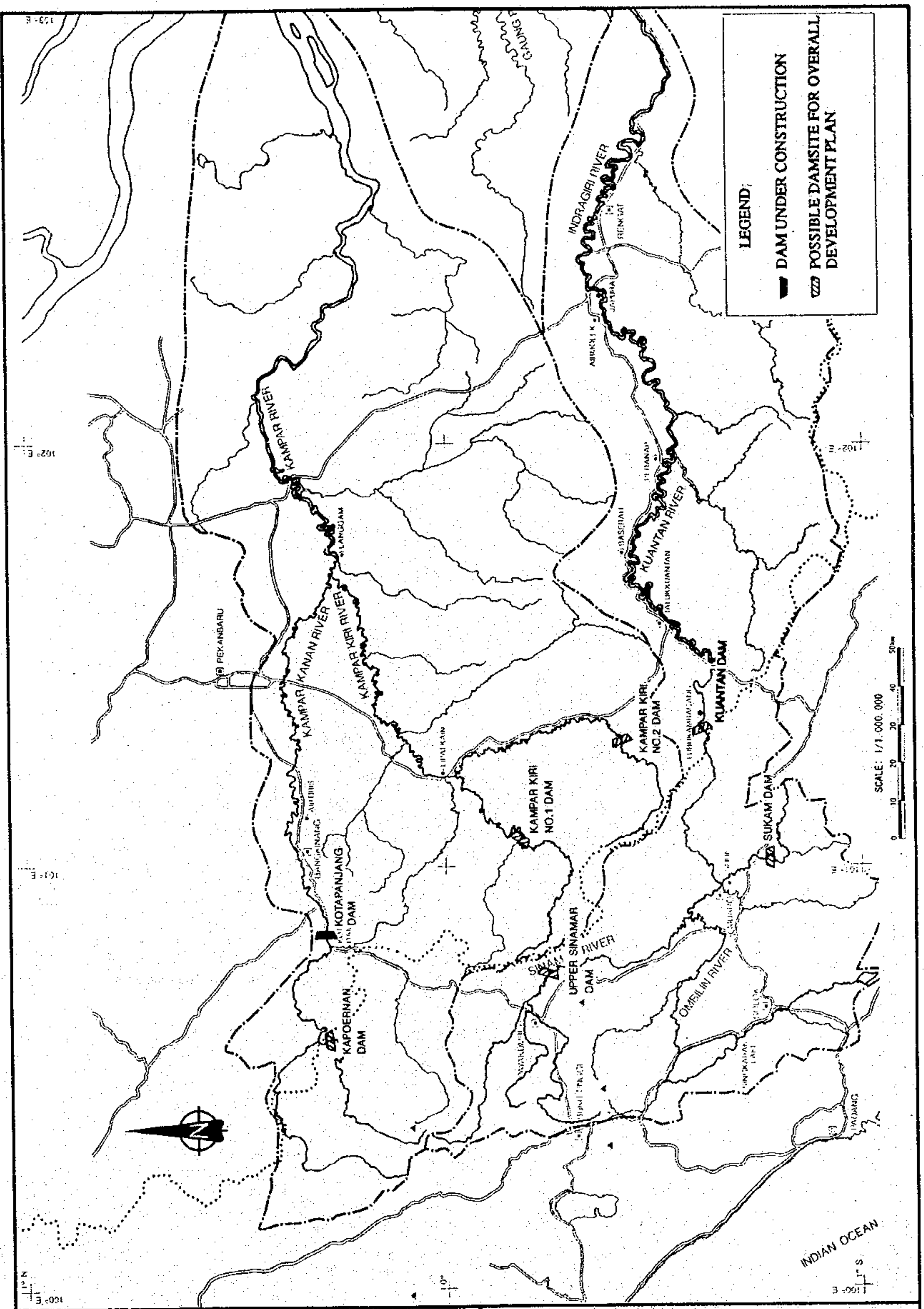

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Fig. IV.3.1 LOCATION OF POSSIBLE DAMSITES

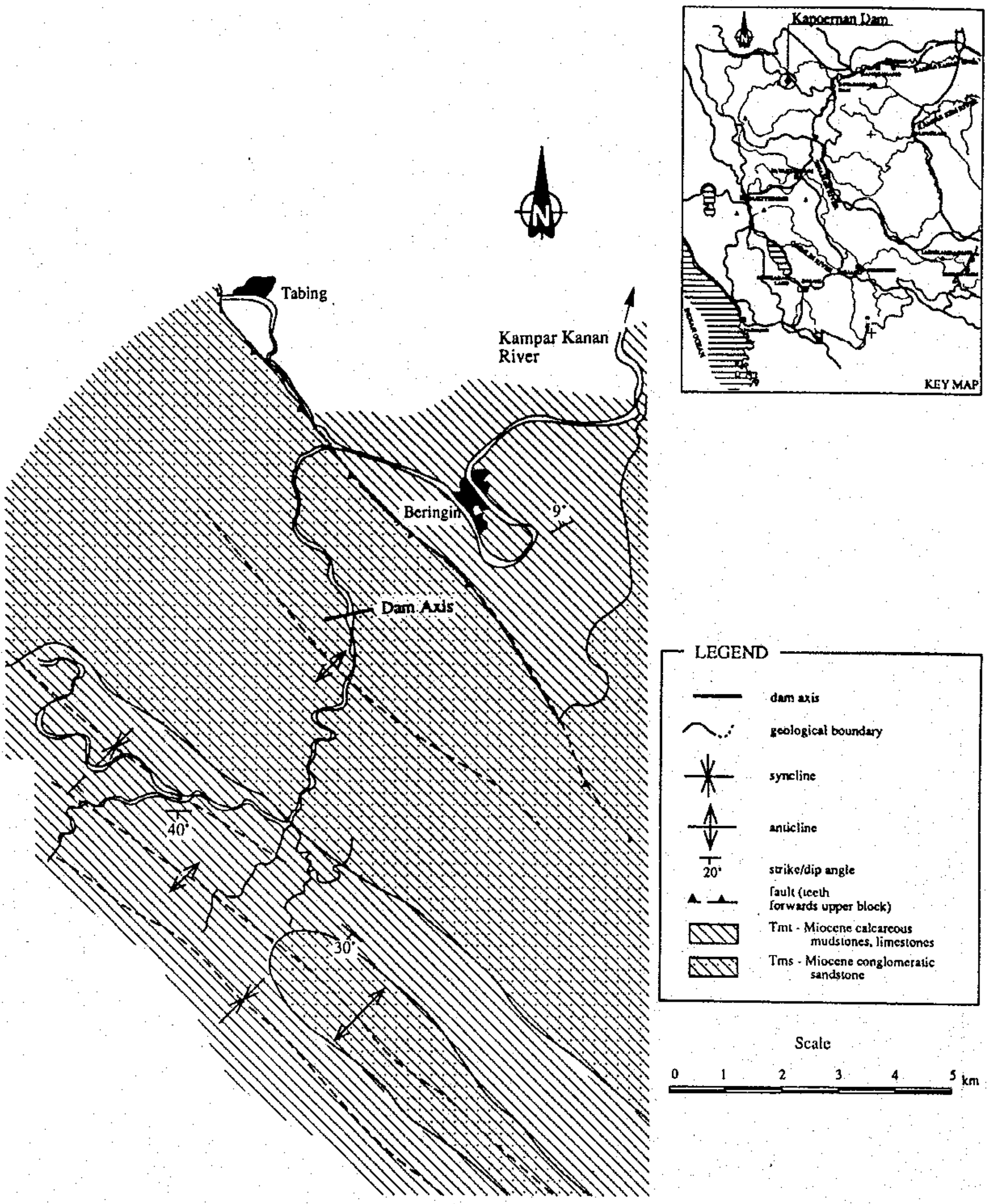

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Fig. IV.3.2 (1/6) **GEOLOGICAL MAP AT POSSIBLE DAMSITES (KAPOERNAN DAM)**

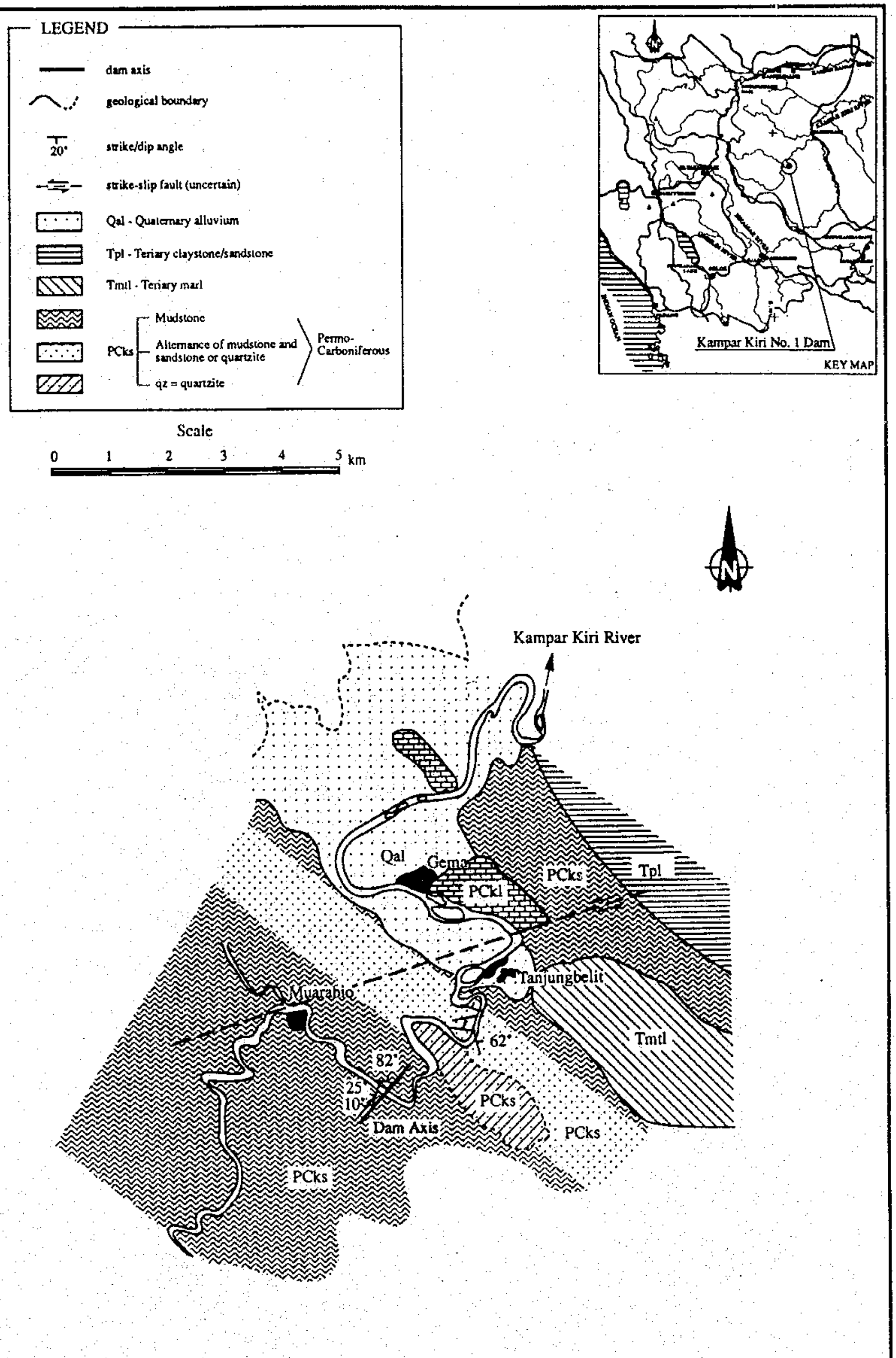

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Fig. IV.3.2 (2/6) GEOLOGICAL MAP AT POSSIBLE DAMSITES (KAMPAR KIRI NO.1 DAM)

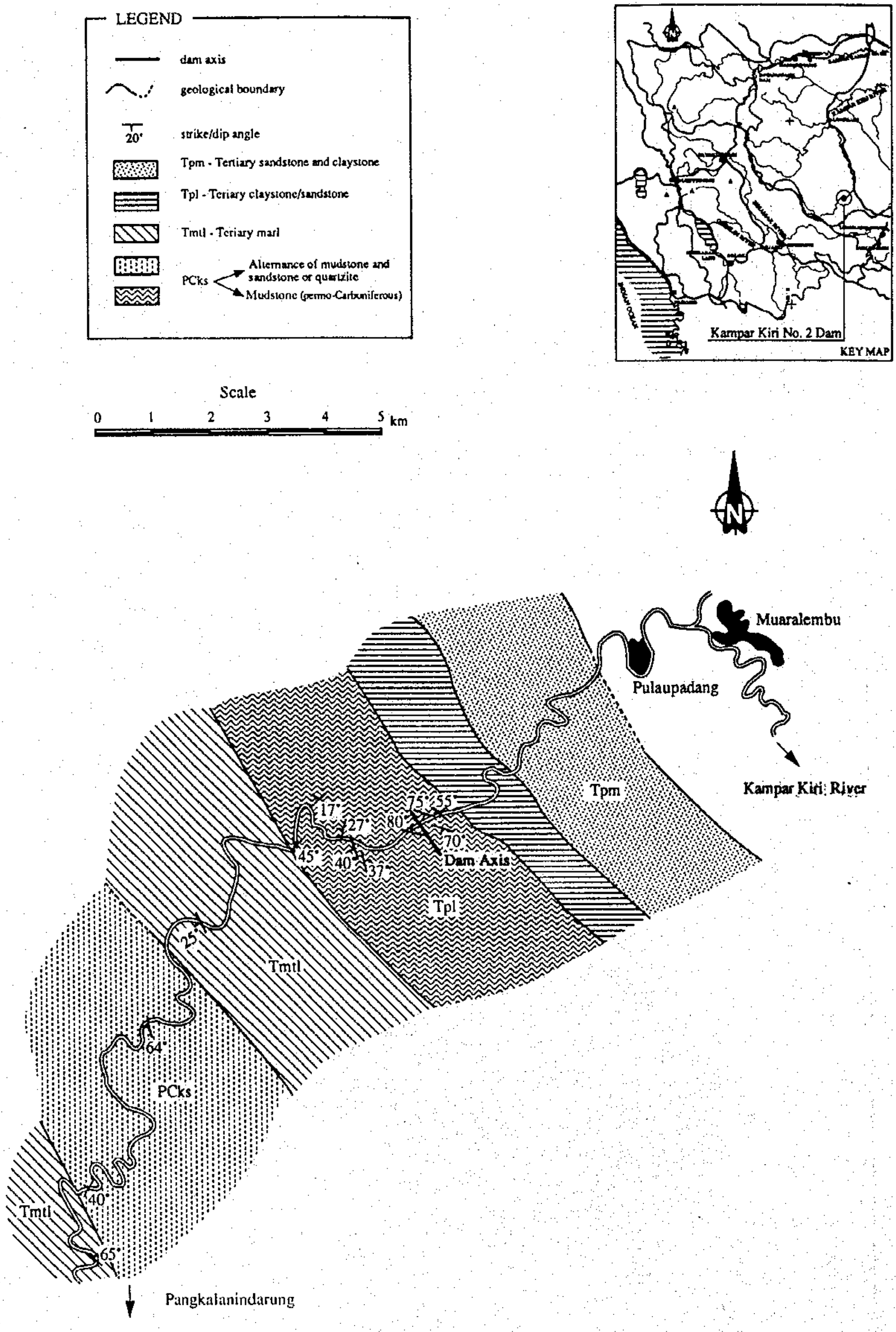

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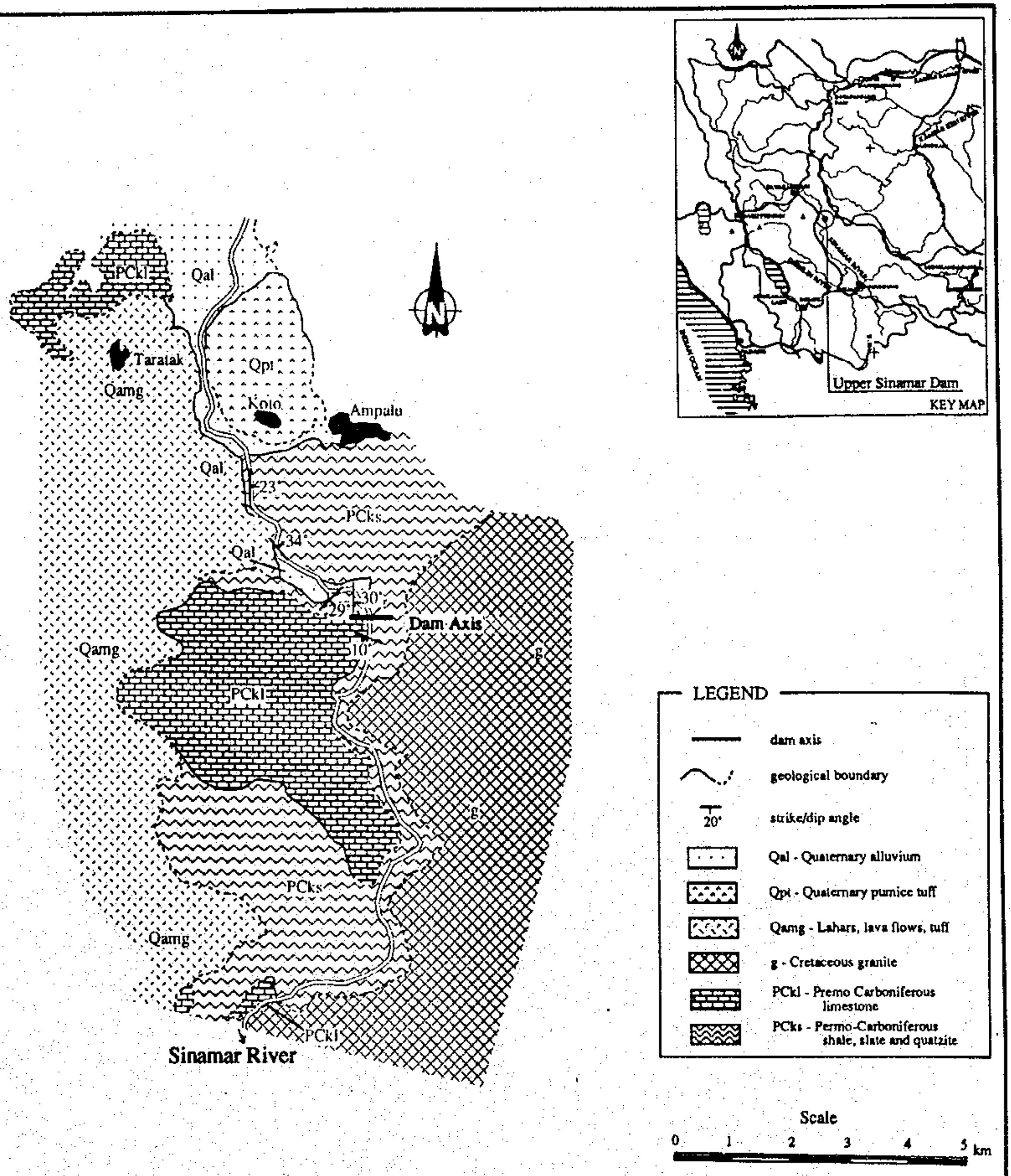
Fig. IV.3.2 (3/6) **GEOLOGICAL MAP AT POSSIBLE DAMSITES (KAMPAR KIRI NO.2 DAM)**



THE STUDY ON KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT IN THE REPUBLIC OF INDONESIA	Fig. IV.3.2 (4/6)	GEOLOGICAL MAP AT POSSIBLE DAMSITES (UPPER SINAMAR DAM)
JAPAN INTERNATIONAL COOPERATION AGENCY		

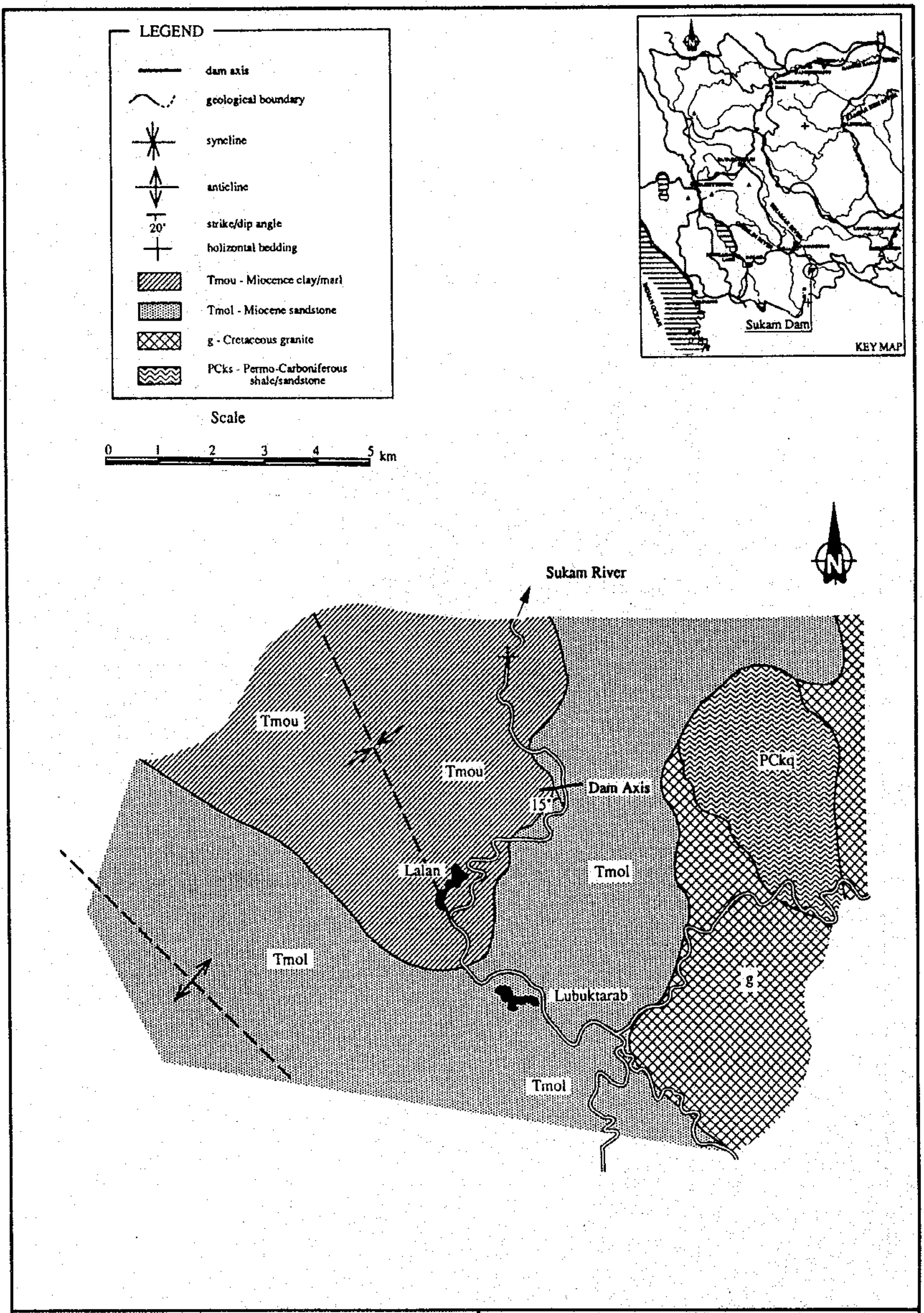


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Fig. IV.3.2 (5/6) GEOLOGICAL MAP AT POSSIBLE DAMSITES (SUKAM DAM)

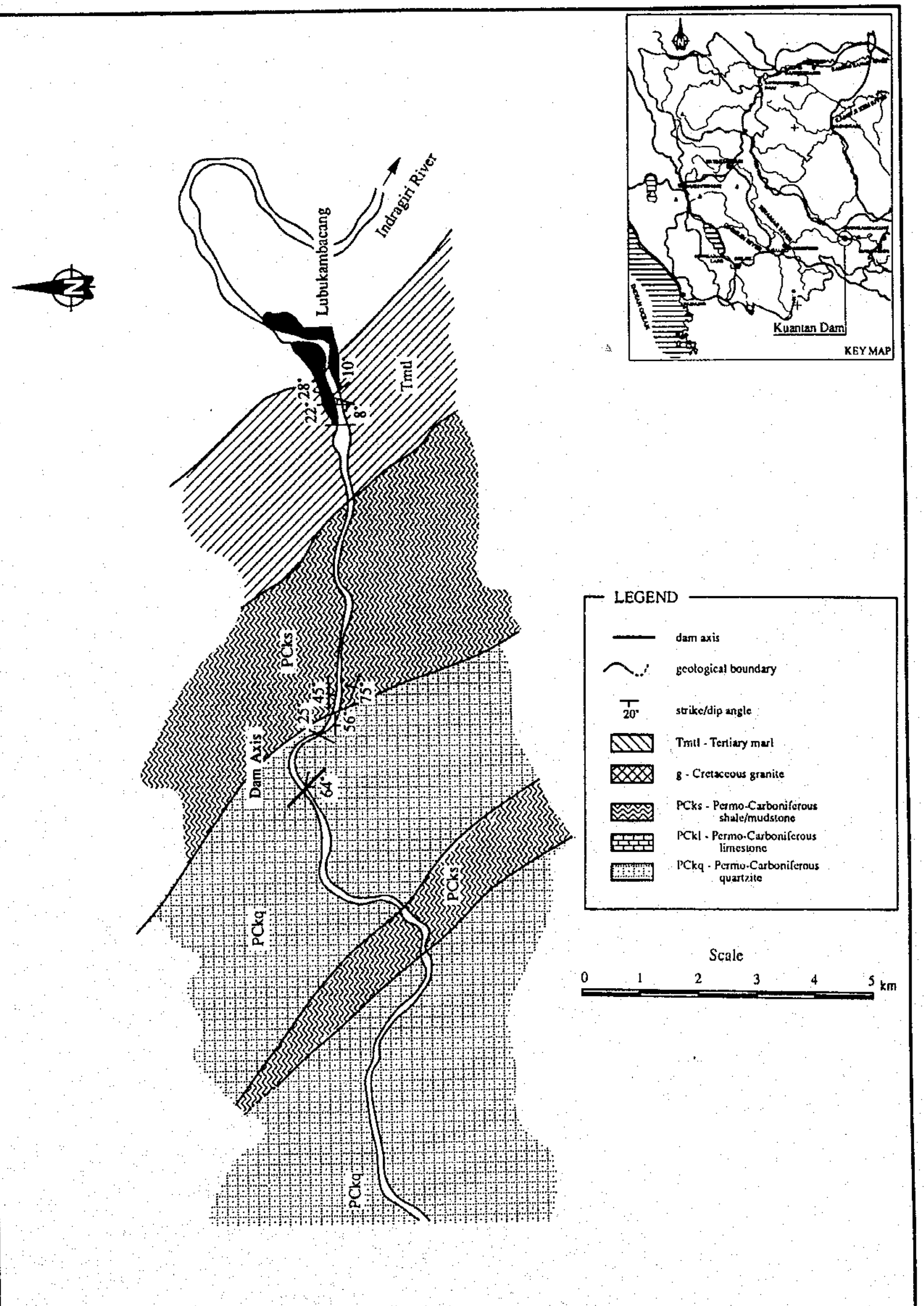

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Fig. IV.3.2 (6/6) GEOLOGICAL MAP AT POSSIBLE DAMSITES (KUANTAN DAM)

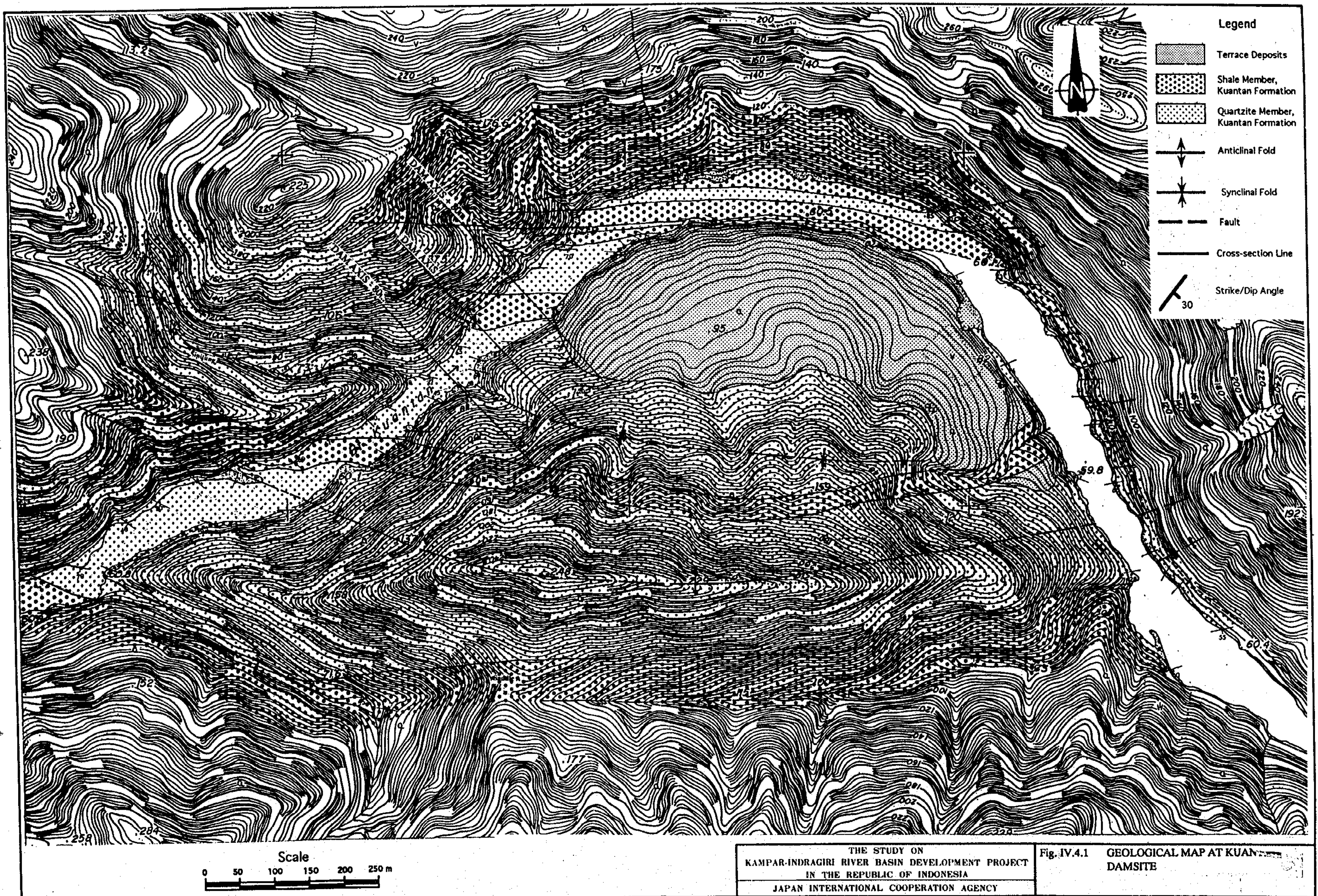

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Fig. IV.4.1 GEOLOGICAL MAP AT KUAN[illegible] DAMSITE

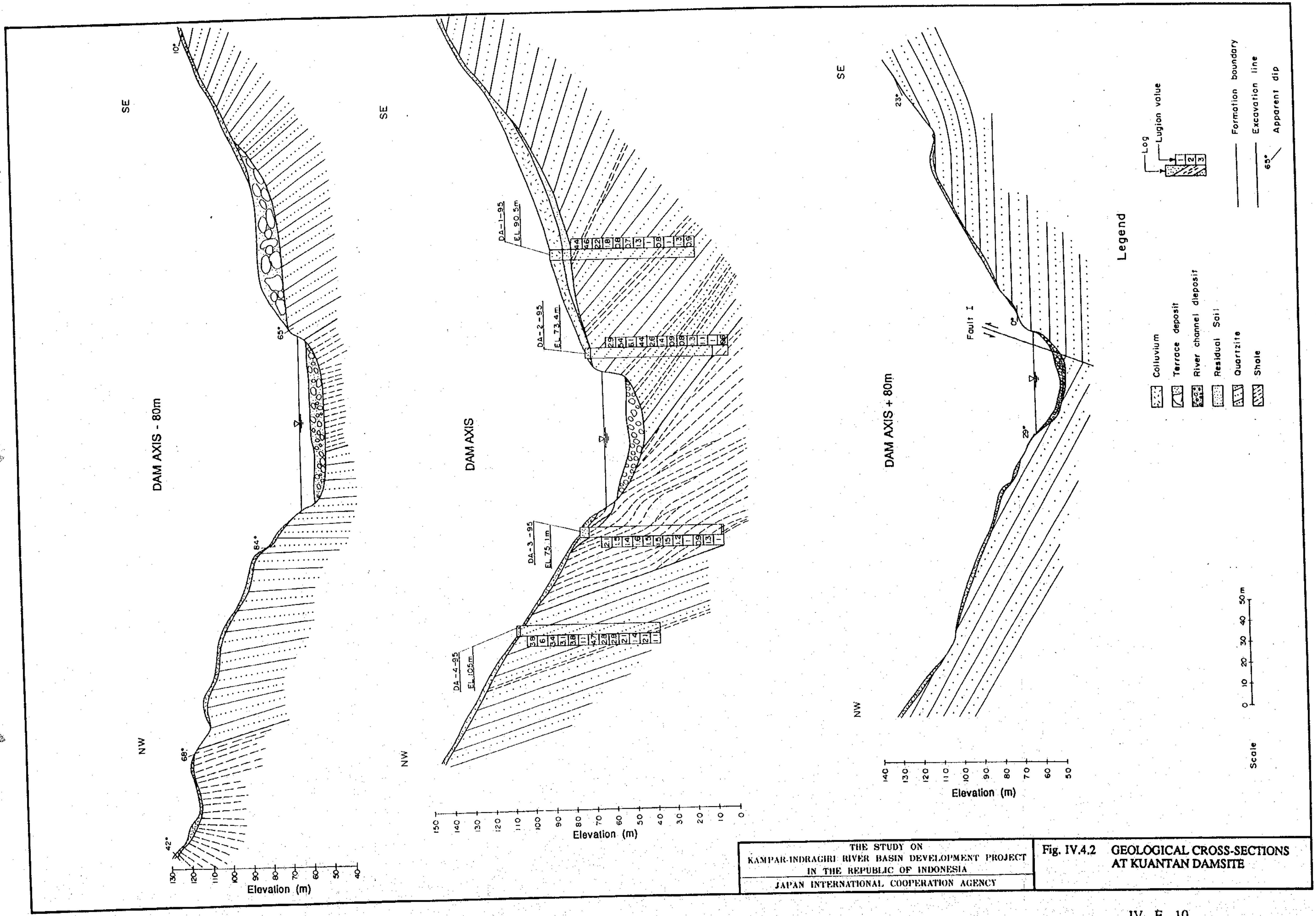

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Fig. IV.4.2 GEOLOGICAL CROSS-SECTIONS AT KUANTAN DAMSITE

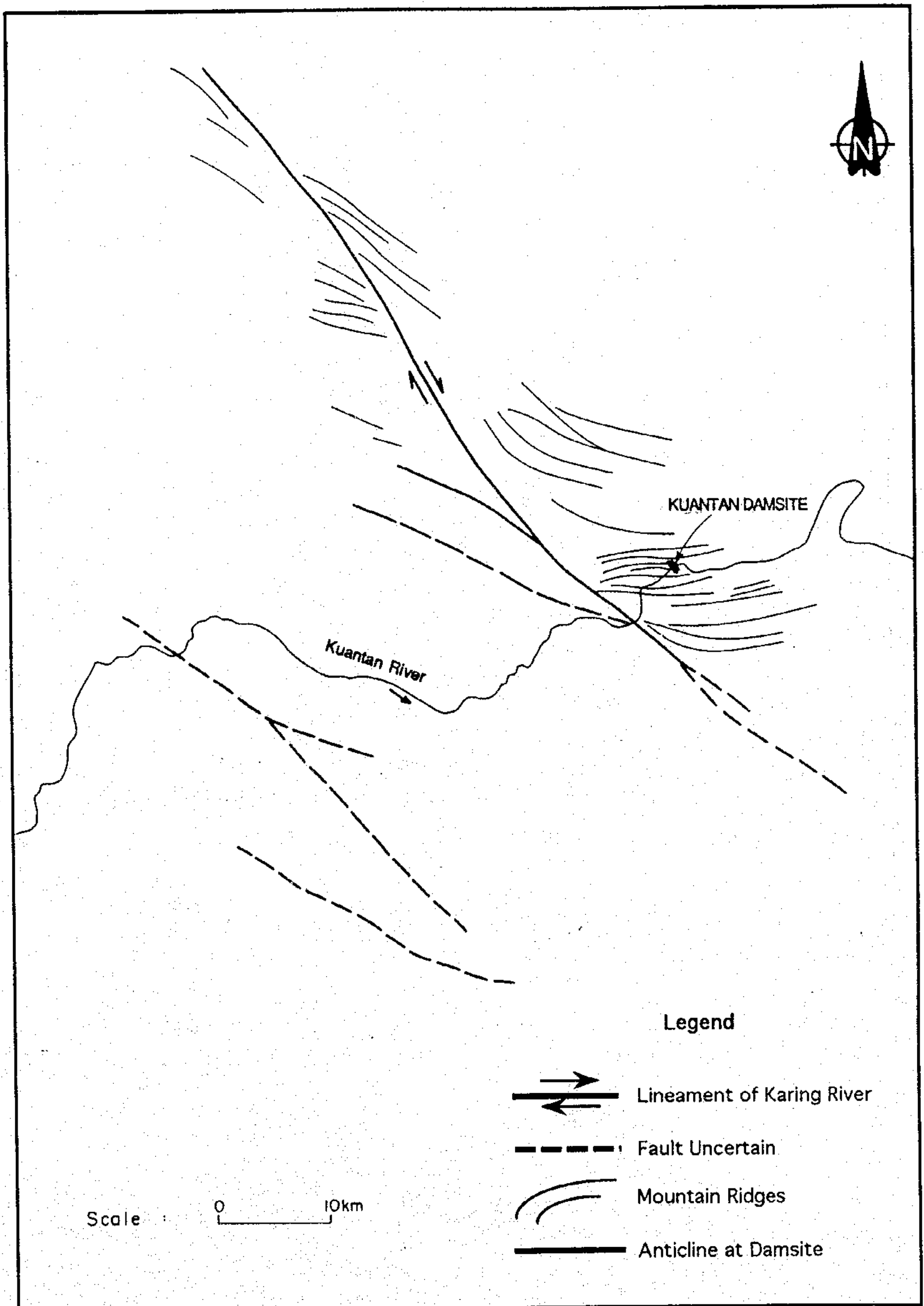

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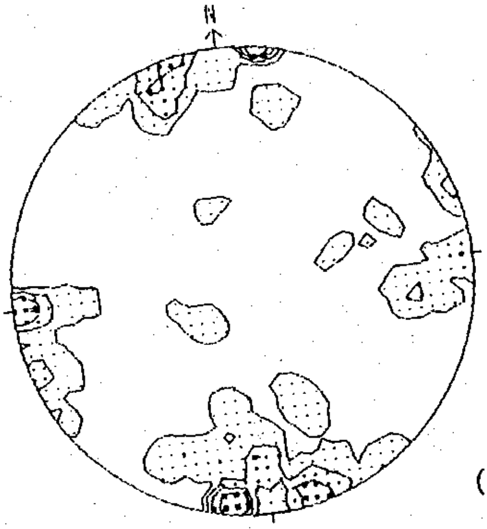
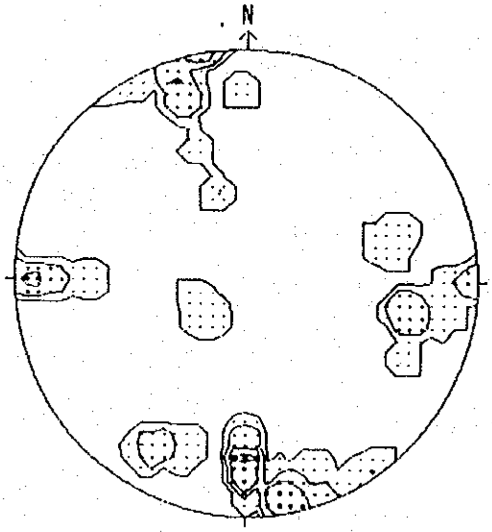
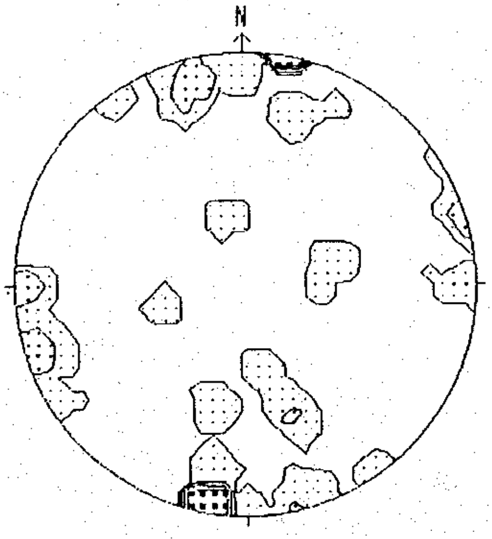
Fig. IV.4.3 REGIONAL GEOLOGICAL STRUCTURES AT KUANTAN DAMSITE



(a) Left and Right River Banks



(b) Right River Bank



(c) Left River Bank

Legend

1.0 % ⁙

5.0 % ⁙

10.0 % ⁙

15.0 % ⁙

THE STUDY ON KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT IN THE REPUBLIC OF INDONESIA	Fig. IV.4.4 STEREOGRAPHICAL PROJECTION OF MAIN JOINT SYSTEMS AT KUANTAN DAMSITE
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