IV GEOLOGY IN THE PROSPECTIVE DAMSITES

(1) 1 Dummon Dam

Geography

The proposed damsite Dummon Dam is located at some 10 km east of Barrio Capisayan, upper-stream area of Dummon river. Dummon river is remarkably meandering in the periphery of damsite. The drainage pattern around the damsite shows rough trellis texture oriented ENE-WSE and NNW-SSE. Relative altitude of mountains is generally low, and very gently sloping. Alluvial plains such as terrace and flood plain are extending along Dummon river, above all on the downstream area of damsite.

Geology/Geological Structure

Local rocks belong to Ilagan formation of Pliocene, which consist of sandstone, siltstone and conglomerate. The bedrock is highly weathered, medium hard to soft rock, especially the surface of bedrock often weathered into lateritic soil.

The beds seems to be very gently dipping. The fault is estimating on the 2 km S of damsite, which is oriented E-W.

Construction Materials

Residual clay of alluvial plan, extending western area of damsite, is available for core materials. River gravels along Dummon river, up and down of damsite, is available for filter materials and concrete aggregate. And metavolcanics, 3 km N of damsite, is available for rock fill materials.

Remarks

This damsite is regarded as quite possible for rock fill dam construction.

(2) 4 Chico No. 4 Dam (Damsite and Reservoir)

Rocks along the Chico river shows four stratigraphical formation, from the youngest to oldest these are the:

Halocene deposits
Volcanic intrusion
Ilagan formation
Mabaca River group

(Description of these formations have been discussed in the Geology of Cagayan Basin)

The uplift of the basement as the dominantly active tectonic feature and the compression of the adjacent regions led to the folding and faulting of the sedimentary rocks representing Kalinga foothills. Later intrusion of igneous rock change existing fold and fault pattern in several places.

The Kalinga fault is an extension of the north-south running Hapao fault, runs through the reservoir in north-north-easterly direction and later merges into the Kabugao fault near Connor. The chico river fault runs parallel to the river on its right bank onto Tanglag where it crosses the river and later still passes the Pasil river.

Damsite Geology

Both abutments of the dam are covered by slopewash, and consists of yellowish-brownish loam and strongly weathered or decomposed angular to subangular shaped sandstone fragments of gravel to cobble size, which are irregularly distributed. The outcropping rocks in the foundation area are sequence of conglomerate and sandstone, agglomerate with thin siltstone.

The post miocene tectonical process led to folding and faulting of the sedimentary rocks units of the dam foundation area. Three different fault types could be distinguished at the damsite, these are dip slip faults, strike slip faults and thrust faulting. Thrustfaulting is limited to the left abutment only.

Reservoir Geology

Rock outcrops in the reservoir area are sedimentary sequence of siltstone and sandstones and occasional conglomerates/agglomerates, generally strike parallel to the river-flow direction. In some area, the strike direction alters to west-east and northwest-southeast. The dipping of the beds varies strongly depending on the geostructural situation. The latter is highly complex due to two major faults: the Kalinga and the Chico river faults, both of which pass through the entire reservoir. In general, the dipping of the beds is steep.

The composition, sequence of rocks, geostructural situation and low gradient to the neighboring catchment area of the Tanudan river indicates that the assumption of a tight reservoir is justified. The overall drainage pattern, as well as a continuous water discharge from spring at high elevations, supports this assumption. Water losses may occur only through seepage under and around the dam.

Construction Material

The rockfill material such as grey wacke, conglomerate is provided at the ridge, over 800 m downstream of the right side valley Filters, concrete aggregate and riprap can be obtained in the Chico river bed, such as boulder, cobbles and sand. The loam deposits of weathered rocks are available for core material, in both flanks around the damsite.

(3) 6 Chico No. 2 Dam (Damsite and Reservoir)

Damsite Geology

In general, rocks outcrop in Chico No. 2 damsite is classified as sound bedrock. On the right slope, the bedrock consists of basic volcanic rock which near the surface is slightly jointed and weathered. In fault and shear zones deep weathering is to be expected. On the left valley slope massive rock predominates, mostly slightly jointed and covered only in the eroded cuts with thin slope talus or thin grass cover.

Both valley flanks are traversed by faults and shear planes. The fault planes strike predominantly at acute angles or parallel to the right slope, dipping parallel to the slope or steeper. Faults running diagonally to the direction of slope dip mainly upstream.

On the left slope, no unfavourable fault planes have been discovered so far which could adversely affect the acceptance of the resultant force or the foundation of an arch dam.

The large fault zone about 200 m downstream of the damsite is accompanied by faults dipping steeply to the SW, striking at about 145^{o}.

Reservoir Geology

The valley slopes of the middle reservoir are composed of basic volcanic rock. Petrographic composition, structural formation and bedding conditions are similar to those found at the damsite and downstream of the damsite. Dikes and a large number of pillow lava structure were observed especially on the right slope the rock is under severe tectonic strain almost throughout, and is partially even mylonitized. The whole section of the valley lies in the area of the large Hapao fault zone which follows the valley of the Talubin river east Tucuan.

At the upstream exist from the village of Tucuan, in a Northwesterly to northerly direction, runs the boundary between the basaltic series of the Cretaceous-Paleogene and the later (Neogene) plutonic intruded diorite. The northwest edge of the batholith in the area of the river and the Bontoc basin is partially faulted and deeply decomposed. This zone is also intensely mineralized in places.

Some sliding were observed within the faulted basalt series in the middle of the reservoir area, particularly on the right slope. On the left slope, slides are likely to occur in small areas due to loosening of the rock and to unfavourable intersections of faults.

Considering the geological composition of the area, the reservoir may be regarded as watertight. This is supported by the numerous springs emerging in the eroded slope cuts above the storage level. The only possible hydraulic connection between the reservoir and the tailwater is in the area of the large fault zone traversing the ridges on the left bank. Appreciable water losses through this zone can be ruled out since it is to a large extent sealed by mylonite, decomposed material and mineral deposits. Water losses from the reservoir are therefore only possible by seepage under or around the dam.

Construction Material

The concrete aggregate of fresh basalt can be obtained from the excabation of the headrace tunnel of the right side.

(4) 8 Chico-Mallig Dam

Geography

The proposed damsite Chico-Mallig is located at 3 km west from (new-) Tabuk, and 700 m downstream from the bridge of National Highway 6. Chico river turns from E-W to NNE-SSW in the periphery of damsite. The river channel of damsite is very wide, about 1 km. The terrace is developing on the both bank; the terrace of left bank is relatively low (new), which relative altitude is 20 to 30 m, and the right one is high (old), which relative altitude is about 100 m.

The mountains behind the left bank form the hills with some ups and downs. The right slope, which corresponds to the terrace scarp, has medium to gentle inclination.

The irrigation canal flow through left bank.

Geology

The bedrock belongs to Cabagan formation of Upper Miocene, and it is overlain by Tabuk formation of Pleistocene. Cabagan formation which is observed at right bank (terrace scarp) and behind the left bank, consists of medium-sandstones which alternate with relatively thin shales, and rings dull note when struck with hammer. Tabuk formation which forms extended low to high terrace plane along Chico river, consists of unconsolidated stream deposited sand and bouldery gravels. The gravels at left bank is over 20 m thick, and the permeability of the deposit is considered as very high.

Geological Structure

The general structure of bedrock (Cabagan formation) is syncline which axis generally trend NE-SW on the southern area of damsite, therefore the strata faces the north-western wing of sycline. The beds at right bank strikes N 25° E, dips 54° NW. And the terrace deposits (Tabuk formation) piled horizontally.

Construction Material

Upland terrace deposits and residual soils westside or above 5 km west from damsite is assumed to be available for core materials. Sufficient amount of river gravels along Chico river is available for concrete agglegate and filter materials. Rock materials can be obtained from hard meta-sediments at over 8 km west, northside of Chico river.

Remarks

Dam construction is regarded as quite possible. However, river gravel and terrace deposit are require to be removed by excabation at core zone, and the excabation will be large.

(5) 10 Matalag Dam

Geography

The proposed damsite Matalag is located at downstream part of Matalag river, north-western area from Tauo.

The natural feature around the damsite is marked by cuesta which back inclines toward SE. The river channel is narrow at damsite, so that it is topographically regarded as good damsite. the left flank is rather steep: around 45^{o}.

Geology

The proposed area belongs to Cabagan formation of Upper Miocene. The beds is made up of conglomerate with sandstone intercalation. Conglomerate is generally predominant around the damsite, except the damaxis. At dam abutment, sandstone is alternating with conglomerate and also includes thin shale. The bed thickness is about 0.3 - 1 m.

Conglomerate mostly consists of pebble, but granule at dam axis, and it is massive, soft, moderately weathered rock. Sandstone is arkoselike, and moderately to highly weathered soft rock. Shale is highly weathered. The beds well-jointed, in places. Some debris and residual soil is observed at both banks some 200 to 300 m downstream from damsite.

Geological Structure

The beds shows homocline, and also correspond to south-eastern wing of anticline. The beds strikes N 38^{o} to 45^{o} E, dips 35^{o} to 40^{o} SE.

Construction Materials

The residual soil and talus deposit, extending on the hills upstream left bank, are available for core materials. The river gravels along the river in the upstream/downstream are available for concrete agglegate and filter materials. Hard rocks cannot be obtained near the damsite.

Remarks

The permeability of bed rock may be rather high, because of high weathering in places, however, dam construction is regarded as quite possible. Any way, some foundation treatment will be required.

(6) 12 Pinukpuk Dam

Geography

The proposed damsite pinukpuk is located at some 2 km upstream from junction where Saltan river joins Chico river. The river meanders significantly at damsite. The right flank of damsite corresponds to undercut slope which is gentle and seems to be old collapse: another landslide-like slope is also observed about 1.5 km SW from damsite, Barrio Oya.

The landform around the damsite is characterized by rather clear cuesta which back inclines SE. Upstream area from damsite, especialy left slope, is very steep: around 50^{o}.

Geology

The bedrocks belong to Cabagan formation of Upper Miocene. The damsite is located on the alternating beds of conglomerate and sandstone, accompanied by taffaceous siltstone in places, and conglomerate generally predominant in the beds. Conglomerate consists of well-rounded pebble to granule, and generally soft, partly hard. Bed rocks are often exposed along the river bed (very hard) and the road (relatively soft). By the way, the bedrocks are well-jointed, sometimes opened on the outcrop surface, though, joints are regarded as intact inside. Large amount of talus deposit including big boulders is observed at right slope, which might be caused by old landslide.

Geological Structure

The beds strikes N 30° to 40° E, dips 32° to 45° SE, on the other hand, the bed trend N 15° E in the north-eastern area.

Construction-Materials

Sufficient gravels extending along Chico river channel, 2 km downstream from damsite, are available for concrete agglegate and filter materials etc. Residual soil and talus deposit in the right slope upstream from damsite, are available for core materials. However, hardrocks for rock fill materials cannot be obtained near the proposed area.

Remarks

The foundation is very satisfactory for dam construction such as earth-fill dam, however, some foundation treatment will be necessary. And the gentle slope where thick boulder-like talus deposits extend, should be avoid for dam axis.

Extended gentle slope at Barrio Oya, about 1.5 km SW from damsite, is regarded as landslide by aerophotograph interpretation and reconnaissance in which residual soil is merely observed. That should be confirmed at next stage study, and will become good source of core materials.

(7) 14 Babaca Dam

Geography

The proposed damsite Babaca Dam is located at the downstream part of Babaca river, and 9 km upstream of junction in which Babaca river confluents into Saltan river.

The landforms in the vicinity of damsite is generally very steep. Mountain range oriented NNE-SSW is structural landform controlled by geological structure. The river slopes at damsite are also very steep, and very narrow. Terrace deposits are well-developing at western and eastern area of damsite along the Babaca river.

Geology/Geological Structure

Local rocks belong to Cabagan formation of Upper-Miocene. Bedrocks consist of sandstone, siltstone, conglomerate (alternation). The beds strikes N 20^{o} E, and dips steeply W. The weak zone is recognized, like a strike fault, by aerophotograph analysis at 1 km east, it is parallel to the bedding.

Construction Materials

Residual clay, 5 km downstream of damsite, is available for core materials. Sand, gravel of terrace deposits, extending 1 km up and 1 km down of damsite, is available for filter materials and concrete aggregate. Hard volcanics such as agglomerate can be available for rock materials.

Remarks

This damsite is regarded as very satisfactory for rock-fill dam construction.

(8) 15 Bitag Dam

Geography

The proposed damsite Bitag is located at the middle part of Pered river, and at west end of the basin in which Barrio San Jose locates. Pered river is joined by several rivers and creeks in the basin, and flow through gorge-like channel toward west.

Mountain tops around the damsite generally incline to west quite gently. The river channel of damsite is very wide,d about 400 m wide; therefore dam length will become about 500 m wide. The left bank of dam axis shows gentle slope, but partly step-like, on the other, some relatively small landslide (creep) is observed.

Geology

The bedrock belongs to Cabagan formation of Upper Miocene. The bedrock is occupied by medium sandstone that is massive, well-consolidated, but moderately to highly weathered into brown, and sometimes well jointed. Sound rock cannot be observed. Residual soil develops on the surface of the rocks. Many fine deposits extend on the flood plain, that consist of silt to fine sand or clay.

Geological Structure

The bedrock at damsite is almost massive and non-bedded, however, the bedding is observed near the bridge some 1.5 km downstream from damsite: N 45^{o} E/10^{o} NW.

Construction Materials

Sufficient fine deposits (sand, silt, clay) on the flood plain are available for core materials. The gravels along the river bed downstream from damsite are available for concrete agglegate or filter materials, but generally fine (pebble).

Since hardrock is not existing near the damsite, rock materials cannot be obtained until some 10 km east from damsite.

Remarks

While river channel is rather wide and bedrocks are highly weathered, dam construction is possible. However, some-excavation and foundation treatment will be necessary, at river bed and both abutments.

(9) 19 Aggugadan Dam

Geography

The proposed damsite Aggugadan is located at about 3 km east from Barrio Aggugadan, Pinacanauan de Tuguegarao river across the mountain range which trends N-S, and relative altitude is about 300 m. The mountain tops around the damsite incline westward quite gently. And karst landform is observed in places, such as doline, cave (Callao) and karst window, because that is composed of limestone. Most of river flanks are very steep rocky cliff. However, only left bank slope is very gentle, and this slope also correspond to slip-off slope.

Geology

The bedrock limestone around the damsite belongs to Callao Limestone of Upper Miocene. It is composed of reef limestone which is mostly massive, and yields many calcareous fossils such as coral and molluscs. The bedrock sometimes rather weathered, and shows solutive textures and even open-, well-jointed along the bedding planes.

By the way, the karst landform, especially limestone cave like Callao Cave, is not so remarkable, and rock is mostly tight layered or massive, however porous and highly weathered zone, to brownish-yellow, is observed in places. Weathering seems to be most proceeded near the damsite. The left slope at damsite is overlain by residual soil and debris.

Geological Structure

The limestone beds trend N-S to NNE-SSW at strike, and dips west very gently: 5^{o} W.

Construction Materials

River gravels, pebble to cobble, which extend above 3 km west and above 2 km east from damsite, are available for filter materials and concrete aggregate. Alluvial soils, which extend inside of the basin eastward from damsite, are available for core materials and fill materials. And hard rocks will be obtained at mountain land, over 10 km east, in which hard rocks such as andesite, diorite, tuff-breccia etc. are assigned.

Remarks

Dam construction is regarded as possible any way, however, the limestone has serious problem of permeability. Therefore foundation treatment will be necessary and more difficult.

(10) 24 Siffu No. 1 (A) Dam

Geography

The proposed Siffu No. 1 (A) damsite is located at 1 km upstream of existing Siffu Weir (NIA), in the downstream area of Siffu river.

The landform is marked by cuesta which has prominent ridges extending N to S. Siffu river meanders at upstream (western) from proposed damsite. And it flows straight at downstream from damsite. This straight section (from proposed are to 1.5 km downstream) correspond to collapse zone, in which so many collapses are taking place. Most of collapse structure are existing on the cut edge slopes of the strata.

The proposed damsite is narrow, and the left bank forms rock cliff. The right bank has a moderate topography, though, the downstream part lead to that collapse zone.

Geology

The proposed area belongs to Ilagan formation of Pliocene age. The strata consists of pebble conglomerate with alternating sandstone. The conglomerate has well-rounded pebble, sandstone has fine to medium grain. Above the river level, rocks are highly weathered to yellowish to brownish soft rock. Generally, the rock strength is medium to weak. They have both carbonaceous texture that is often observed at matrix. So that the collapse may concentrate in the zone of pebble conglomerate.

Geological Structure

The beds strikes N 10° W, dips 20° - 26° E. The structure is apparently homocline, however, it is correspond to eastern part of syncline. The collapse zone above-mentioned was seemed to be active fault, especially eastern limit of it, by pre-reconnaissance interpretation of LANDSAT image and aerophotograph. Actually, evident fault could not observed, however the collapse zone may relate to some active structure such as flexure or normal fault.

Construction Materials

The residual soil that lie on the lowlands upstream, is available for impervious core materials. Other river gravel, loose conglomerate at 0.8 km downstream and weathered rock is available for concrete aggregate and filter materials. However, hardrock cannot be obtained in the periphery of proposed area.

Remarks

The proposed dam site is fairy good topographically, and very satisfactory for construction of earth fill dam. The collapse zone above-mentioned is assumed to be resulted from carbonaceous attribute of rocks, however, the cause of collapse and the relation to active movements should be investigated.

By the way, this site Siffu No. 1 (A) will be correlated to Mallig No. 1 site, both topographically and geologically.

(11) 24' Siffu No. 1 (B) Dam

Geography

The proposed damsite Siffu No. 1 (B) is located at downstream part of Siffu River, some 5.5 km west of existing Siffu Weir (NIA).

Siffu river is remarkably meandering, some terrace deposit and river gravel extend along the river. The landforms around the proposed area is characterised by cuesta, but not so remarkable. The mountain ridges are generally oriented NNW-SSE which is parallel to fold structure. Many collapse are concentrating at undercut slopes along the main stream. The proposed site is a little bit wide in the river width.

Geology

The proposed area belongs to Cabagan Formation of Upper Miocene. The bedrock consists of sandstone, shale and conglomerate. That sandstones are often alternating with shales.

The left slope upstream from proposed site is collapsing, in which the rocks are dominant by alternation of sandstone and shale. The left bank of damsite is composed of soft rock which is moderately weathered, and that makes relatively round shape. Some amount of talus deposits distribute on the mountain foots, at the right bank of the proposed area. The talus deposits are creeping, though, the scale is relatively small.

Geological Structure

In the vicinity of proposed are, the bed strikes N 15^{o} W to N 25^{o} W and 35^{o} to 40^{o} NE. the fold axis westward from the proposed damsite generally trends NNW-SSE.

On the other hand, the collapse upstream of proposed area will be resulted from weak shaly rock, and that zone is interpreted as lineament by aerophotograph.

Construction Materials

The residual soil which extend around the upstream area of damsite is available for core materials. River gravel located along the river is available for concrete agglegate or filter materials. Hard rocks cannot be obtained near the proposed area and it will be over 10 km westward until the hard rock can be obtained.

Remarks

Although the bedrock is not hard, geologically and topographycally no special problem has observed on the damsite, so that dam construction is quite possible. Since hard rocks cannot be obtained around the damsite, earth fill dam seems to be suitable. By the way, the collapse (weak zone) upstream from damsite should be verified whether it has some relation with active fault movement.

(12) 25 Siffu No. 2 Dam

Geography/Geology

The mountain lands in the periphery of proposed damsite are marked generally by massive attitude. The river channel of damsite is narrow, and the profile is V-shape that is very good for dam construction.

Local rocks seems to be metamorphosed volcanics such as basalt and andesite of Cretaceous to Paleogene age, that correspond to Kpg on the geological map. Many outcrops usually little are observed on the mountain slopes and river bed. Bedrocks especially on the river bed will be hard, and generally slightly weathered. River gravels extend along the river channel, though the quantity is not so sufficient. In the far West area from damsite, more than 3 km upstream, talus deposits and terrace deposits are emplaced along the main stream.

Construction Materials

The core materials will be borrowed from talus deposit and residual soil at western and southern area from damsite. Concrete agglegate will be borrowed from river gravels, and rock materials from parent rocks near the damsite.

Remarms

The proposed damsite is topographically, geologically very good, and highly recommended for dam construction.

(13) 26 Mallig No. 1 Dam

Geography

The proposed damsite Mallig No. 1 is located at 10 km NW of Barrio Mallig. Mallig river flow through narrow channel of the mountain range from west to east. The landform around the damsite present typical cuesta which backslope inclines east, crests trend N-S and relative altitude is about 100 m. The damsite is relatively narrow, but right slope is step-like because of cuesta, and left slope is very gentle.

Geology

Local bed belongs to Ilagan formation of Pliocene. The bedrock consists of conglomerate alternating with sandstone. The conglomerate is composed of well-rounded pebble, and it is slightly carbonaceous. Sandstone is composed of medium grain. The bedrock is very hard on the river bed, which rings dull note when struck with hammer. In contrast to this, the bedrock on the bank and slope is highly weathered into brownish-yellow soft rock. And the cycle of cuesta is about 20 to 40 m, which will reflect the cycle of resistant and unresistant strata. Some talus deposits are overlying on the left bank.

Geological Structure

The bed strikes N 15° to 20° W, dips 20° to 30° E, and the strike slightly change N 4° E to 10° E at downstream of damsite.

The collapse zone is interpreted by aerophotograph on the section of 500 to 800 m downstream of damsite, which trend N-S. It is not necessarily fault or sheared zone, actually the fault plane is not recognized, but very many collapses and gullies are observed on the scarp face of cuesta. The active movement of fault or flexure structure is not definite, though, it is regarded as possible weak zone related to some structural movements, at the same time to the carbonaceous attribute of bedrock.

By the way, the collapse zone will lead to southern area and become wider.

Construction Materials

The residual soil extensively overlying on the hills over 1 km east of damsite is available for core materials. The river gravel along the river bed is available for concrete agglegate. Soft rock around the damsite is available for filter or rock materials, and pebbles within the conglomerate may available for concrete aggregate and others.

Remarks

While the weathering of bedrock is proceeding, except on the river bed, the dam construction is quite possible. However, the excavation of abutment will be large. The collapse zone of downstream from damsite is regarded as being little influenced to damsite foundation.

(14) 27 Mallig No. 2 Dam

Geography

The proposed Mallig No. 2 damsite is located at 3 km east of Barangay Calaccad, downstream of Mallig River.

The landform of around Mallig No. 2 damsite shows hogback whose ridge trends N-S and back-slope gently dips to East. The river channel shows gordge-like narrow channel at damsite.

Geology/Geological Structure

The bedrock of proposed damsite belongs to Cabagan Formation of Upper Miocene. In the whole, the geology around the damsite is long interval alternating bed that mudstone dominates sandstone. On the other hand, bedrock of the damsite is occupied by sandstone with thin interbeds of conglomerate. This sandstone is generally massive or thick bedded, slightly-medium weathered, hard-medium hard, sounds dull metalic note when struck with hammer. Weathering is rather proceeding at both abutment. A fet Joints are found in the body. The beds is more than 400 meters in thickness.

The bedding of bedrock trends N 10^{o} W, dips 60^{o} E.

The characteristic lowland, 200 to 800 meters upstream of damsite, was found to be weak zone of thick mudstone which extremely tends to cause slaking.

Construction Material

1) The residual soil and weathered rock are available for earth fill material, locating at 2.5 km SW of damsite, upstream right bank. However, the material are not so suitable, because of including slaking argillaceous rock.

2) The gravel of 11 km north from damsite including cobble-boulder is available for rock material and concrete aggregate. Abundant residual soil overlying at western lowland.

Remarks

this damsite is adequately possible for fill-type dam because of consolidated sandstone bedrock. In cases, even the concrete gravity dam may be possible, but the in-Site mechanical test is necessary to decide.

The lowland western part of damsite was at first estimated by interpretation of aerophotograph. However, it was confirmed that the weak zone was caused from lithological quality of mudstone. Finally, it is regarded as no influence to the damsite.

(15) 28 Ilagan No. 1 Dam

Geography

The proposed Ilagan No. 1 damsite is located at the middle of the main tributary of the Ilagan river. From the town of San Mariano, the river meanders for about 35 km upstream before reaching the site. In the area, flat surfaces of mountain peaks was observed at an elevation of 250 to 300 m and the river curs deep with a U-shaped valley section. Terrace topography was also observed and extended downstream from the proposed site.

Geology/Geological Structure

The proposed area belongs to the volcanic rock of Cretaceous to Paleogene age. The rock facies are dominantly meta-andesite and diorite with small outcrops of agglomerate along the upstream of the riverbank.

Rock hardness of proposed area is hard to very hard, however, small dissemination of dotted pyrite was observed. Because of this minerals, rock bodies was slightly altered to reddish brown color. On the left bank, 30 m to 500 m upstream of the damsite a gully-like collapse of rock was also observed.

Weathering and alteration are both taking place along the right bank of the proposed damsite and on the top of the flat surface (terrace) there are thick lateritic residual clay.

Exposures of bedrock at damsite shows a clear joint set; N 17° W/65° E, N 17° W/30° W, N 88° E/55° S. It is also observed that the diorite intruded the andesite bodies.

Construction Materials

The residual clay which lie on the higher elevation and terrace plane of Barangay Buyasan, is available for impervious core materials, and the hard rock bodies along the right bank more than 1 km upstream from proposed damsite is suitable for rock fill materials. There are also sufficient river gravel deposits along the river bed downstream of damsite, and good for making concrete.

However, those rock with weathered and altered minerals located around the junction near the damsite is not recommended for concrete.

Remarks

In this area, the foundation is very good although the dam height is limited according to the topography, concrete gravity dam might be possible in terms of geological condition.

(16) 29 Ilagan No. 2 Dam (Damsite and Reservoir)

At least, six stratigraphic rock units are recognized in the project area. They are listed below in the order decreasing geologic age, that is, from oldest to youngest.

Unit 1 - 1 Metavolcanics and Metasediments
Unit 2 - Paleogene Intrusives
Unit 3 - Lubuangan Formation and Sicalao Limestone
Unit 4 - Cabagan Formation and Callao Limestone
Unit 5 - Ilagan Formation
Unit 6 - Alluvial Deposits

These sedimentary formation were found in the field investigations of this project study, to have been deeply incised by the river channel, exposing the underlying Cretaceous to Paleogene basement rocks, mainly andesite flows, which comprise the exposed bedrock at the damsite. The Miocene formations occur as cap rocks overlying the basement unit and were observed among the moderate to gentle terrains up above dam creast levels.

Diorite-quartz diorite generally intrude the andesite. Rocks of these type were encountered along Ilagan river about 4 kilometers upstream of the dam axis. Exposures extend to more than 10 kilometers headward, presuming a batholitic body. The boreholes along the dam axis also encountered dioritic and quartz dioritic sections within the predominant andesite. Such sections are believed to be apohyses of the diorite batholith upstream.

Andesitic dikes generally cut both the diorites and the andesite. These dikes range from several centimeters to a few meters thick, not exceeding 2 meters at the average. They were observed to be relatively more pervasive in the diorite. At least one such dike was encountered cutting the bedrock at the damsite.

There are no major faults directly observed within the dam embankment area. Indications of the faults traced from the regional geologic maps, which were mainly derived from aerial photographs, are the major topographic trends of ridges, valleys and stream channels. Surface manifestation were not encountered. Observable structure at the site are flow layering, joints and some shears.

Dam Embankment

Andesite and diorites are geotechnically classified as very sound rocks and would provide god foundation for the dam. The rocks are indurated and considered the hardest within the project area.

Reservoir and Wartershed

The diorite batholith, discussed earlier in the general geologic setting of the damsite, comprises the greater area of the envisaged reservoir. From its contact with the andesite, 4 kilometers upstream of the damsite, the diorite extend more than 10 kilometers headward along the Ilagan river, and occupies almost wholly the reservoir area along the Diwago Creek and its tributaries. The diorite is generally strongly jointed, sometimes sheared. It shows slight degrees of weathering, but locally intense weathering was observed. Immediately upstream of the contact up to the Diwago Creek confluence, the diorite is cut by numerous dikes of andesitic composition. The dikes are from several centimeters to a few meters thick, averaging not more than 2 meters. They are mostly fine grained to porphyritic Aplitic ones are rare. At some sections of the reservoir flanks, thick overburden may occur over the diorite as such is a common result of the surficial weathering of the rock.

Geological structures within the reservoir and watershed were interpreted mainly by previous works from aerial photographs.

Field observations indicate that the structural traces seemingly coincide with the major topographic trends such as ridges and the rectangular configuration of the Ilagan river and its major tributaries. Major fault trend range from north-northeast to northwest. Others have easterly strikes. Shears and strong joints were observed along the river sections. These fracture systems could have played important roles in the control and emplacement of the dikes and may have direct relationships to deeper seated structures. Joint sets occur at various orientations but those with north-south and east-west trends appear to be dominant, wherein occasional shearing have also taken place. Along some shears, thin pyrite veinlets are present. At least one such shear was observed to have associated specular hematite.

(17) 33 Disabungan Dam

Geography

The proposed damsite Disabungan is located at 3.5 km NEE from San Mariano, and about 5 km upstream from junction where Disabungan river confluents with Pinacaunan de Ilagan river.

The landform in the periphery of damsite is hill which rise and fall in gentle slopes. Around the damsite, the mountains on the left bank is relatively low and very gentle, on the right bank, the mountain tops is relatively high and slope is long in which the small surface landslide (creep) and significant post-landslide are recognized; may be no significant influence to damsite. At damsite, the terrace deposits extend along the river, which is composed of boulders and soils. Left bank shows elongated island-like landform, therefore, the river flow zigzag.

Geology

The geology of this site will be mainly devided into two groups, that is undifferentiated volcanics (right bank) ranging Cretaceous to Paleogene age and Ilagan formationn (left bank) of Pliocene age. Volcanics is composed moderately-jointed hard andesite lava and other pyroclastics; the surface of bedrocks is rather weathered, and the post-landslide is regarded that caused by caprock structure. Ilagan formation is composed of fine to medium consolidated sandstone; the surface of bedrocks is extensively highly weathered, developing into lateritic soil.

Construction Materials

Developed lateritic residual soil and terrace deposit around the damsite are available for core materials. The river gravel along the river bed is available for filter materials and concrete aggregate. Hard-rock, will be obtained at 1 km upstream right bank for rock fill material.

Geological Structure

The geological history and structure is assumed to be as follows:

history - (1) undifferentiated volcanic rock (andesite, etc.) emplaced at Cretaceous to Paleogene age.
- (2) granitic rock intruded into volcanic rock at Paleogene to Middle Miocene.
- (3) Ilagan formation (sandstone) overlay the former strata.

structure - almost horizontal, above all sandstone of Ilagan formation.

Remarks

While the weathering of upland bedrock is proceeding, dam construction is regarded as quite possible. The earth-fill dam will be suitable for this site. However, the distribution of geology is not necessarily definite because of thick residual soil, therefore further study is required.

(18) 34 Catalangan Dam

Geography

The proposed damsite Catalangan Dam is located at 13 km east of San Mariano. The proposed area shows relatively highlands, both east side and southern-west side of damsite are lowlands. River channel at damsite is very narrow, will be suitable for dam construction. The river, Catalagan is complicatedly meandering up and down of damsite. And the damsite area is well-vegitated by tall trees. The left slope is steep because of undercutting by river flow.

Geology/Geological Structure

The bed rock is formed of undifferentiated metasediments and metavolcanics of Cretaceous to Paleogen age; andesite, pyloclastics and agglomerate. Andesite dikes strike N 30° W, dip vertically. Fault strikes NE, dips steeply SE, but not significant and not continuous. Bed rock is generally hard near the damsite.

Construction Materials

Residual clay at 2 km W of damsite and talous deposit at 2.5 km NE, are available for core materials. Andesite near the damsite is available for rockfill materials. Sand and gravel at 8 km WSW of damsite along Disabungan river, is available for filter materials and concrete aggregate.

Remarks

Geological condition and topographical feature are both very good, the proposed area therefore highly recommended for dam construction.

(19) 37 Alimit No. 1 (A) Dam

Geography

The proposed damsite Alimit No. 1 (A) is located at downstream part of Alimit river, and 12 km up from junction in which Alimit river confluents to Magat River; high water level of Magat dam reservoir reaches near the proposed damsite, so that it is accessible by boat to some 3 km down from proposed site.

The altitude of mountain tops around the damsite is 400 to 600 m, and that shows the landform like a peneplain. In the vicinity of damsite the valley is opened V-shape, relative altitude is 200 to 300 m. The tectonic valley, Anco Creek flow N to S, east of damsite. In the periphery of damsite, several lineaments NW-SE is interpreted by aerophotograph, that is regarded as reflection of geological structure. On the dam axis, while left flank shows moderately inclined linear profile, right flank has step-like profile which seems to be relics of terrace.

Geology

Local rocks is not yet differentiated, and the age range from Cretaceous to Paleogene. The beds are composed of metasediments: sandstone, shale, tuff, and metavolcanics: agglomerate, andesitic basaltic lava flows, pyroclastics. Agglomerate is predominant in the vicinity of damsite, with intercalated andesite. On the other hand, very hard sandstone with shale is observed at 2.5 km east from damsite (about 30 m thick), and thin sandstones often intercalated with volcanic rocks around the damsite. The beds are generally very hard, slightly weathered sound rock, though, weathering is somewhat proceeding at dam abutment than other section.

Geological Structure

The beds strikes N 50° to 60° W, dips 50° NE around the damsite, on the other, that trends N 35°W, 80° W to vertical in the 2.5 km east area. And the rocks slightly-jointed. River channel is regarded as being regulated by the structure such as bedding plane, especially lava flows, and joints.

Construction Materials

The residual soil which extends mainly on the plateau of southern area is available for core materials. River gravels along the river channel is available for concrete aggregate and filter materials, but the quantity is not so sufficient. And every island-like land mass upstream in which hard rock can be obtained will be available for rock materials.

Remarks

This damsite is geologically and topographically very good, highly recommended for dam construction even concrete gravity dam.

(20) 41 Matuno No. 1 Dam (Damsite and Reservoir)

Geologically, the Project area is composed of sedimentary and intrusive rock of post Cenozoic Tertiary formation. The mountainous part of the Matuno river basin is made up of widely distributed conglomerate and sandstone of Miocenic Natbang formation. This formation has a cover of nonconformable limestone of the Macde formation in the lower basin area as well as near the mountain summits along both banks of the Matuno river.

The bedrock of the proposed damsite is conglomerate and the river bed is covered by deposits a maximum of 15 m thick. The fresh part of the rock is massive and hard. Although it has a slightly high permeability due to open cracks, the rock is judged suitable for the dam foundation.

The geology of the Matuno river basin is mainly composed of Tertiary sedimentary rocks, such as sandstones, conglomerates, limestones, etc. with some intrusions. The dominant facies of the Natbang Formation in the Matuno river valley is conglomerate which contains gravels of andesite, porphyrite, chert limestone and slate, round or sub-round, a few millimeters up to 20 cm in diameter. The matrix is hard to moderately hard, fine to medium silty sandstone in some layers and grit composed of coarse angular particles in the others. The Macde limestone is located in the higher parts of the mountains in this river basin mostly in the level higher than EL. 900 m overlying unconformably the above Natbang conglomerates.

As for the foundation of the "A", "B1" and "B2" damsites all the foundation rocks are composed of hard to moderately hard conglomerates. The river bed is normally covered with river deposit consisting of illsorted round gravels and cobbles with sand. Their gravel sources are the Natbang conglomerates and the Macde limestones. The thickness of those river deposits is normally in the range of 10 to 15 meters with a several meters weathered rock layer underneath. Those conglomerates are normally massive and hard enough to support the proposed dams safely although some parts where cracks prevail requires sufficient treatment.

The Alignment of surge tank-penstock-power house is extensively covered with thick talus deposits and slope-washes from the limestone ridge at the top of the slope. Some rate outcrops are only of andesite, hard but frequently jointed. The foundation of the penstock line is mostly composed of hard tuff and also the surge tank site is composed of the same fresh tuff.

The geology along the proposed tunnel alignment was judged by ground reconnaissance and aerial photographs. It is presumed that the upper half of about 4 km in length would pass through the hard to moderately hard Natbang conglomerates. It suggests no difficulty for tunnel excavation, sometimes without steel supports. But the lower 2 km part beyond the major North-South fault will pass through soft tuff with many joints, suggesting heavy support requirement all through. The major fault part, probably several tens meter, will require most careful works, such as sufficient draining facilities to be prepared before cross excavation.

The proposed reservoir area to be submerged is so thickly covered by natural jungle without so heavy cutting of trees that is judged that no large scale land sliding may happen except some minor ones of overburden. At present some land slides of topsoil layers are seen at several places on the steep rock cliffs but not the scale of endangering the dam and other structures.

The proposed canal route skirts the mountains of the Magat subbasin flowing along the slopes of isolated hills. The said route may be categorized into two areas, one composed of talus deposits and one of alluvial plain. Construction of the canals and canal structures will present no major problem. However, some quantity of limestone boulders and rock excavation at the foothills may happen within the Project area. Suitable drainage may be required during excavation of alluvial plain for canal construction.

Construction Material

On the other hand, wide extended sand and gravel containing boulder for concrete aggregate are obtained at around the confluence of Matuno and Magat river, some 10.5 km SW from propose damsite.

The quarry site is selected at 3 km W, upstream of Matuno river. And the borrow areas are assumed within 2 km, west, northwest, north from damsite. Relatively small amount of sand and gravel along the Matuno river bed are available for concrete aggregate, and fill material in case of rockfill type dam.

(21) 47 Cagayan No. 1 Dam

Geography

The proposed Cagayan No. 1 damsite is located 5 km NE of Maddela, Nueva Vizcaya. The river slightly meander from the town of Maddela and San Pedro and turn to northern course upon reaching the proposed damsite.

At Barangay Tungcab, upstream of Cagayan No. 1 damsite the river width is narrow and both banks are cliff that continuous for a distance of about 4 kilometers. The rightbank of the proposed site represents bench like figure that can be mistaken as a landslide. This configuration generally attributed to the layered limestone that formed due to some weaknesses on the surfaces of the bedding plane.

At the leftbank, a cave that measured some 10 m high and 2-3 m width was observed, this is a solution cavity, and may be long.

Geology

The proposed area belongs to Callao limestone of Upper Miocene. The limestone of this type is well distributed along Cagayan river and spreads widely in southeastern part of Cagayan basin.

Generally, the limestone bodies in the site are massive and hard except along the bedding plane where some opening cracks or solution cavities are observed due to meteoric water (rainfall). Fossils such as molluscs and corals are also visible in the rocks of the limestone. These fossils were observed as partly or slightly crystallized as included in the limestone bodies. The degree or crystallization seems to be more advanced at the proposed dam area, but there are irregular surfaces due to solution and rockfall within the upstream area of proposed site.

Geological structure

The bed strikes N-S and dips 7^{o} to 8^{o} West and almost flat in some areas.

There is an open crack/solution cavity, and N 50^{o} W/23^{o} SW at the vertical slope of the left bank.
The limestone bodies upstream of the right bank is often separated by vertical cracks and form into blocks of big rocks.

Construction Materials

River deposits consist of sand to boulder extend upstream and downstream from the proposed site is available, and suitable as concrete aggregate.

Remarks

Field reconnaissance survey in this area shows that limestone bodies below the river bed level are generally hard and massive, but above this elevation limestone shows solution cavities and rock weakness along the bedding plane and some broken blocky rocks are also observed in the dam site.

Considering the result of exploratory drilling works, it is concluded as follows:

- (1) this limestone bedrock is relatively soluble and unstable for the rainfall and river stream which includes carbonic acid.

- (2) but, the bedrock is rather stable in case it is covered by thick residual soil and weathered rock and/or it underlies the ground water level.

- (3) there is some fear of significant leakage through the cavern of limestone, especialy in the southeastern area of Cagayan river, which is estimated from new topo-map in scale 1:25,000.

It is necessary to verify the extent of limestone rock body, and degree of dissolution structure, size of cavern and porosity on the southeastern area of the Cagayan river especially, in the future study.

(22) 48 Cagayan No. 2 Dam

Geography

The proposed damsite Cagayan No. 2 is located at some 16 km SSW from Barrio Maddela, and west of the basin of Pongo (Cabingatan). Cagayan river is well-meandering, and curves at right angle at damsite. The river channel is relatively very narrow at damsite. The left slope is very steep and the central part is collapsing, and the right ridge is more gentle.

Geology

Damsite is composed of limestone, that belongs to Sicalao Limestone of Middle Miocene.
the limestone is hard and massive or well-bedded and well-jointed, especially on the left bank open cracks are observed. The limestone yield abundant molluscs, corals and other fossils, and crystallization is slight.

Geological Structure

The limestone bodies generally trend NE-SW or NNE-SSW, and crop out intermittently, along the Cagayan river. The strata is about 150 to 200 m thick. The beds nearly strikes NNE-SSW, and dips about 12^{o} W.

Construction Materials

The residual soils, overlying low hills western area and terrace deposits over 1.5 km south from damsite, are available for core materials. The river gravels and terrace deposits of upstream area along the river is available for concrete aggregate and filter materials. The hard rocks, volcanics, for rock materials will be obtained above 2.5 km NW from damsite.

Remarks

This site is regarded as possible for dam construction. However, foundation treatment will be hard and very expensive, because of many fissures and progressive weathering of limestone.

(23) 49 Casecnan (Conwap) Dam (Damsite, etc.)

Conwap dam site is found in a rather symmetrical section of Casecnan river, some 800 m downstream from the Conwap river confluence. The right flank of the section is rough and carved out by creeks and gullies. The left flank is formed by a smoother spur, also carved by creeks and gullies. No deep instability signs are observed on the flanks, where soil and debris overburden is generally thin. The river channel is occupied by an alluvium layer whose maximum thickness has been verified towards the right bank (22.5 m).

Local rocks belong to the Mamparang Formation of the Upper Oligocene, and consist of agglomerate with minor tuff beds, intercalated with basaltic-andesitic flows. The agglomerate is made up of subrounded to subangular pyroclasts in a fine-grained matrix. Lava flows constitute a minor part of the formation. They are fine to medium grained, hard and sometimes porphyritic. Intercalated with the agglomerate, they follow their general attitude.

Mamparang volcanics at the site are thickly bedded, indicating a general NE-SW orientation, with a slight (20-30) dip to the north.

The abutment rocks are generally massive. Large faults are not closely manifested at the surface; minor shears were delineated. Sheared zones appear very often recemented with quartz veinlets.

The rocks at the dam site showed a low permeability. A conventional grout operation will produce complete waterlightness for the dam section. No special difficulties are predicted for the dam foundation at either abutment. An average 2 to 6 m deep excavation for the impervious core can be indicated at the abutments. The alluvial layer of the river channel will represent a problem for watertightness of the dam foundation. It is to be excavated (complex operation) or in some way impermeabilized.

The spillway route, at the left side of the section, is also underlain by agglomerate and basalt flows. Weathering of the rock is very deep at he spillway crest and flip bucket. Along the chute rock conditions improve. A sound rock foundation is granted for the structure, but the excavated cuts are to be kept within a conservative slope and interrupted by berms. Anchoring and concrete lining are to be applied for stability.

Excavation conditions for the two diversion tunnels at the right side of the section will not be uniform, stretches of difficult excavation will be often encounted, requiring heavy supports and stabilization devices. No problems, on the contrary, are expected in relation to seepage water.

Reservoir

The right flank of the Casecnan reservoir is entirely occupied by volcanic rocks, whose watertightness can be taken as granted.

The left flank, including Conwap river valley, is underlain by rocks belonging to the Mamparang Formation, including thick limestone beds. Karstic signs are widespread, but elevations and structural features of the formation, as well as the general topography of the surrounding country indicate that hydrogeological anomalies through the karstic limestone will be confined within the reservoir area, without possibility of important leakage towards areas external to Casecnan reservoir. This situation will be confirmed by means of additional field investigations.

Transbasin Tunnel

The tunnel, 25.7 km long and 6.25 m in diameter passes through rugged, wild, mountainous country.

The intake structure, in the upper part of Casecnan reservoir, will be founded on volcanics of Mamparang Formation (agglomerate and lava flows). No special foundation problems are envisaged for the structure.

The transbasin tunnel cover ranges up to a maximum 900 m thickness. The entire tunnel route goes through a series of volcanic and intrusive rocks. At the contract zones between volcanics and intrusives, minor metamorphism developed. The volcanic rocks are mostly andesite, basalt and agglomerates, all belonging to the Cretaceous Caraballo Group. They are irregularly distributed along the tunnel route except in the downstream section where they are dominant.

The intrusive rocks consist usually of small stocks and dikes of diorite and quartz diorite, fault and fracture-controlled. They occur intermittently along the alignment, especially at Balingtugon, Be-de and Taan river crossings.

The volcanic rocks are gently folded. They are moderately jointed, and generally hard. Intrusive rocks, too, are hard and massive, but around the contact zones between the two formations large scale shearing is to be expected.

Large faults and shears dissect the volcanic mass. The most prevalent orientation and dips are as follows:

(1) - NW-SE strike, steep SW dip
(2) - NW-SE strike, NE dip
(3) - N-NE strike, moderate to steep SE dip
(4) - NE-SW strike, vertical dip
(5) - E-W strike, vertical dip

Of special interest can be considered the Danip fault, a huge regional structure, traceable for more than 80 km across the country.

Deep weathering can also be expected especially beneath the depressions, generally indicating fault transit.

Large amounts of infiltrating water can be expected inside the excavation, in scattered stretches alternating with dry stretches.

Serious stability problems will be encountered in the excavation of the surge tank, especially in the upper levels, where argillified and deeply weathered rocks will be prone to swell and collapse.

Powerhous and Appurtenant Works

These works are to be constructed in San Juan river valley, on the left side. The penstock will be underground with a maximum back cover of 110 m, above the valve chamber. The rocks are here the same volcanics of Caraballo Group, extensively jointed and weathered for a variable thickness (max. 19 m). Considering these conditions, the shaft is expected to have a back cover ranging from 10 to 120 m of fresh or slightly weathered rock, moderately blocky and seamy. These rocks conditions can be considered fair fair for the excavation.

The powerhouse is located in the foothills, where the soil overburden ranges in thickness from 3 to 8 m. Andesite of the Caraballo Group is the underlying rock. Deep weather reaches 19 m depth; the foundation levels of the main building will reach 30 m below the surface; in these conditions the powerhouse will be founded on rock of good mechanical conditions but the excavated cuts will pose serious stability problems. Remedial measures should be applied for the stabilization of the slopes.

The tailrace excavation will be 10 m below the surface. At this depth, rock conditions will be fair, but the cut slopes are to be fully concrete lined.

Masiway Tunnel

Upper Pliocene Pantabangan Formation constitutes the rock type along the entire tunnel route, 6.1 km long, with a maximum cover of 270 m. Thick beds of well cemented and highly consolidated pebble conglomerate, including thin to medium thick beds of sandstone and mudstone, are the rocks to be crossed by the excavation. The conglomerate and sandstone are generally hard and massive. The mudstone is very much less competent but it usually occurs as thin interbeds.

Near the inlet up to Sta. 2+500 the dominant lithology is conglomerate with thin beds of mudstone and sandstone. The remaining length of the tunnel will be occupied by massive conglomerate.

The main bedding orientation is E-W, nearly parallel to the tunnel axis, but in some sections the bedding orientation is normal to the tunnel axis. Faults and shears were not observed along the alignment except in the downstream stretch where the vicinity of the Philippine Fault System could introduce important tectonic discontinuities.

Seepage water is not expected in troublesome amounts in the excavation. Additional investigations are needed for a better understanding of the geological conditions of this excavation.

Construction Materials

The rock material of fresh volcanic agglomerate can be obtained mainly from excavation of Spillway and/or diversion tunnel with the remainder from rock quarry. Gravel and san ranging in size from boulder to fine sand are available for rockfill material and concrete aggregate, and the borrow area is assumed at riverbed up to 9 km downstream. Abundant clay extending at the mountain tops within 2 km around the proposed damsite are available for core material.

(24) 50 Addalam (A) Dam

Geography

The proposed damsite Addalam (A) is located at downstream part of Addalam river, about 6.5 km NW from Mt. Difun. Addalam river is remarkably meandering and which river channel is generally wide.

Left slope of damsite is rather steep around 45^{o}, and many outcrops is observed, because the slope correspond to undercut slope. On the contrary, opposite right slope is very gentle, because of slip-off slope. And on the left land there is low saddle that may regulate the dam height with the low mountains which extend left side upstream of damsite.

By the way, the limestone (Sicalao-) extends around the northeastern area above 1.0 km far from damsite.

Geology

Local rocks is not yet differentiated, and the age range from Cretaceous to Poleogene. The beds are mainly composed of andesitic agglomerate with intercalation of thin taffaceous sandstone. Porphyrite with feldspar mega-cryst and andesite lava are also observed on the left bank. The bedrocks are generally medium to very hard at left bank, on the other side, weathering is rather proceeding; left slope of damsite is overlain by redish-brown residual soil.

Geological Structure

the beds strikes N 60° W, dips 10° SW that is measured at sandstone intercalation on the riverbed.

Construction Materials

The redish-brown residual soil extending on the hills upstream leftside, and right slope, is available for core materials. Hard volcanics such as agglomerate and lave which distribute extensively in the reservoir area, is available for rock materials and concrete aggregate.

Remarks

Dam length will be long about 1 km, however, geological condition is good, so dam construction is regarded as very satisfactory. Sufficient quantity of construction materials is available.

(25) 51 Diduyon Dam (Damsite, etc.)

General Geologic Condition

The river basin consists of Oligocene pyroclastic rocks and quartz porphyries or porphyrites which penetrate the Oligence pyroclastic rocks. Generally the pyroclastic rocks are designated as agglomerate and the quartz porphyries as diorites in this area.

The presence of many faults with strikes toward NW-SE and NE-SW was anticipated from the topography of the area. In the field reconnaissance carried out during the study, no large scale faults to obstruct the continuation of the Project could be observed, except for the fractured diorites in a wideth of 20 m exposed at the logging road on the left bank, 1 km upstream of the No. 3 Damesite. At the upstream end of the outcrop the existence of something like a fault with a strike toward N 20 W - 30 E is recognized, but any fault clay is not found on the same place.

Generally, the fresh rocks are exposed on the riverbed, but the rocks on the ridges and the mountain slopes are weathered, hard and turn almost clayey. The weathering is supposed to reach down to the depth of more than 20 to 30 m beneath the ground surface. The overburdens except on the riverbed range between 1 and 3 and reach more than 3 m in places. Along the river near Papalongan terrace, gravel beds are observed.

Limestone in the Diduyon reservoir area is distributed in the barangays of Malabing, Kapisaan, Alayan, and Belet with an approximate area of ten (10) km^2 in total. This limestone, probably a capping, has no indications of interbedding nor interlayering with the volcanics. Neither calcareous sandstone interface nor its indications was observed in the limestone volcanics contact. Only a small outcrops of what seems to be a basal conglomerate of limestone with rounded to subrounded pebbles of volcanic rocks and limestone fragments was observed.

Damsite (No. 3 Damsite)

Rocks underlying this particular damsite is composed of agglomerate intruded by andesite dikes. this agglomerate forms a monoclinic structure trending N 35 50 E 25 35 E. Three prominent sets of structures (faults and joints) exist in this area. These trend N 50, N 30 - 35 E and N 65 - 70 E. Dips of these structures are steeply dipping to vertical. Calcite, rhodochrosite and silica occupy or cement the interstices of these structures.

The important geologic problem on this site lies on the saddle part of the right bank. Drill core data, indicate that a weak zone exists in the area. A low angle fault which exists at the feet of the right bank at the proposed dam axis may cause some problems on the stability of the foundation. This fault trending NS 4 E and dipping 32 NW was followed for eight meters at adit DR-1. The shear zone is thirty four centimeters wide.

Waterway

General geology of the waterway route is composed of both agglomerate and andesite, the former predominant near the intake and the latter near the surge tank. Geologic problem lies where the tunnel alignment seemingly coincides with the predominant trend of geologic structure. Surge tank, Penstock and Powerhouse (open type) Area.

The bedrock in these areas are andesites, sandstones and conglomerate intercalated with andesite and porphyritic trachyte. The proposed powerhouse site overlay a wide river terrace which consists of boulders, cobbles and pebbles of andesite with silt, sand, and clay matrix. Thickness of this terrace has an average of ten meters.

The penstock and surge tank area is underlain by andesite. The andesite at surge tank is highly jointed while these at the penstock are blocky. Overburden in the penstock route has average of ten meters. The most prominent fault observed in the area is a gravity fault trending 30 E and dipping 64 SE. It has a fifteen meter shear zone with sulfuric emanations. This large scale fault which is inferred to be several kilometers long may not affect the stability of the foundation in the area as no recent movements were observed.

Powerhouse (Underground Type)

The site where the underground powerhouse is projected forms a massive mountain composed of agglomerate and andesite, partially bearing tuff. It was found as a result of one 400 m longdrilling that rock itself was sound in general and had few cracks especially on higher elevations, but slightly altered ones. It is anticipated that the geologic conditions around the underground powerhouse will involve considerable problems, at least in the lower elevation where the powerhouse will be encased.

Reservoir Area (Limestone Belt)

The limestone belt in the reservoir area at Malabing river is distributed in the barangays of Malabing, Kapisaan, Alayan and Belet. Approximate total area is 10 km^2. The lowest elevations of these limestone outcrops vary between El. 610 M AND El. 750 M.

The main problem concerning this area is leakage as this limestone may extend to the eastern rim of projected reservoir limit. But, investigations on the eastern rim did not reveal any extension.

Mountains bounding this eastern rim is biotite bearing porphyrite andesite. The limestone strata in this region overlay andesite and trachite in a state of unconformity. Therefore, it is reason that water leakage from the reservoir will not occur.

Seismicity

After studying the geologic conditions and past earthquakes in the Philippines, it is considered adequate to adopt the design acceleration of earthquake of 120 gals for the Diduyon Dam and pertinent structures as well.

(26) 52 Dibuluan Dam

Geography

The proposed damsite Dibuluan is located at about 30 km upstream of junction, in which Dibuluan river confluents into Cagayan river. The mountains in the periphery of damsite are generally very steep. The river channel at damsite is relatively narrow, it is suitable for dam construction.

Geology/geological structure

Local rocks are undifferentiated metasediments, ranging Cretaceous to Paleogene age. Metasediments consist of sandstones and siltstones. Bedrock is medium hard or possibly very hard in places.

The bed strikes generally NE-SW, dips 30^{o} to 60^{o} NW, and well-bedded.

Construction Materials

Residual clay, on the terrace 11 km downstream of damsite, is available for core materials. River gravel, along Dibuluan river 5 km downstream of damsite, is available for filter materials and concrete aggregate.

Remarks

This damsite is regarded as very satisfactory, recommended for rock fill dam construction.

These results of geological survey in the prospective damsites are shown in Tables 4.1 and 4.2, and the construction materials at each damsite are summarized to Table 4.3.

V GEOLOGY IN THE PROPOSED DAMSITE AND PUMP STATION FOR IRRIGATION

(1) Zinundungan Damsite

The bedrocks around the proposed damsite belong to Sicalao Limestone of Early-Middle Miocene, and Cabagan Formation of Upper Miocene. Although damsite and its reservoir area are not confirmed by field survey the limestone seems to distribute in the reservoir area, especially on the upstream left side area of Zinundungan river, according to the existing geologic map. This limestone area shows characteristic land form, Karst, such as doline-like sink holes and residual-hills. And there is some possibility that the bedrock of proposed damsite is also occupied by limestone, because of the river channel is unnaturally very narrow on the proposed site.

On the other hand another area, Cabagan Formation, consist of calcareous sandstone, siltstone, claystone.

At last, the damsite and reservoir area should be geologically surveyed, particularly in the point of distribution rock facies and permeability of limestone.

If the foundation of damsite is limestone, low dam will be possible to construct by intensive foundation treatment.

(2) Paranan Dam

The landform around the proposed damsite is hill which relative altitude is low and slope angle is very gentle.

The bedrock belongs to Cabagan Formation of Upper Miocene. Cabagan Formation consists of calcareous sandstone, siltstone and claystone with conglomerate. The bedrock is well-indulated but soft rock, and its permeability seems to be relatively high.

This damsite is regarded as suitable for low rock fill dam or earth fill dam. As for construction materials, the hard limestone is distributed at 4 km east, earth materials are abundant in the periphery of damsite, and concrete aggregate is not sufficient.

(3) Tumauini Dam

The landform around the proposed damsite is mountain land which relative altitude is over 300 meters, mountain slopes are generally rather steep. The river channel is fairy narrow like a gorge.

The bedrock belongs to Cretaceous-Paleogene strata which is composed of metasediments: graywacke sandstone, shale, mudstone and metavolcanics: basalt, andesite, dacite, diabase tuff. They are generally well-consolidated.

This damsite is geologically and topographycally assumed to be suitable for dam construction of rock fill dam, even or concrete gravity dam. The construction materials such as rock material are easily obtained near the damsite, but the gravel for concrete aggregate is not sufficient.

(4) West Tuguegarao Pump Station

The bedrock of West Tuguegarao pump station belongs to Ilagan Formation of Pliocene age, Late Tertiary. Ilagan Formation consists of well indurated sandstone, siltstone and mudstone. Above to them, Alluvial sand which was transported by Cagayan river overlying at the riverside, proposed pump site. The sand grain is estimated fine to medium Bearing capacity of this ground is presumably adequate for construction of pump station.

Although a fault extending N-S is estimating, it will be small problem. As the proposed site lies at undercut slope, the revetment will be necessary.

(5) East Tuguegarao Pump Station

The bedrock East Tuguegarao pump station belongs to Ilagan Formation of Pliocene, and Tabuk Formation of Pleistocene, Early Quarternary. Tabuk Formation unformably overlies Ilagan Formation. Ilagan Formation consists of sandstone, siltstone and mudstone, and slightly inclines to West. Tabuk Formation consists of unconsolidated sand, grave Either Ilagan and Tabuk Formation has presumably adequate bearing capacity.

As the proposed site locates at undercut slope of the Tuguegarao river which meanders extremely the revetment will be indispensable.

(6) Lulutan Pump Station

The ground of Lulutan Pump Station belongs to Tabuk Formation of Pleistocene, Quarternary. Tabuk Formation consists of unconsolidated sand, silt and gravel. The bearing capacity is presumably adequate for construction of pump station.

(7) Ilagan River Pump Station

The bedrock of proposed pump station belongs to Ilagan Formation of Pliocene, Late Tertiary. Ilagan Formation consists of weathered sandstone and siltstone, and the beds are almost horizontal.

The bearing capacity is presumably adequate for construction of pump station.

(8) Gappal Pump Station

The ground of proposed site belongs to Tabuk Formation of Pleistocene, Early Quarternary. Tabuk Formation consists of unconsolidated sand, gravel and siltstone.

The bearing capacity is presumably adequate for construction of pump station. As the pump station locates at undercut slope along extremely meandering Cagayan river, there is fear of scouring. The revetment is indispensable.

VI GEOLOGY AROUND MAGAPIT NARROW

The flood water level reveals extraordinary high in the upstream of Magapit Narrows, Cagayan river (30 km). Cagayan river channel shows gorge-like landform, therefore, the upstream area is tend to flood, and it is required to improve, such as short-cut or expansion of channel.

Fig. 6.1 shows general landform classification around Magapit narrows. The landform is composed of mountains and hills which relative altitude is 30 to 60 m, and terrace or flood plain which relative altitude is 3 to 7 m.

Bedrock of mountains and hills on the left bank consist of sandstones alternating with mudstones, they belong to Cabagan formation of Upper Miocene, and partly of limestone (Callao-) on the right bank. The bed is almost horizontal, but dips very gently 5^{o} NNW. The bedrock is well-indurated and medium to slightly hard: it is easy to pare by knife, or sometimes rings dull note when struck by hammer. The limestone shows rithmic alternation with argillaceous bed which color is buffy-yellow.

On constructing to rehabilitation, terrace deposit and flood plain deposit is fairy easy to excavate: bulldozer is available. On the other hand, the bedrock (sandstone, mudstone) cannot be excavated by bulldozer, it is assumed to be possible to excavate by ripper-dozer and the like. Anyway, the excavation possibility of bed rock should be confirmed by seismic prospecting and boring.

On the other hand, according to the geologic inspection along the river from Lal-Lo (25 km) to Amulung (90 km) soft or well-indurated sandstone, mudstone and conglomerate of Cabayan Formation and Ilagan Formation of Upper Tertiary are distributed with long interval gentle folding which axis trends NNE-SSW. Many outcrops are observed on the riverside, especially on the anticlinal section. As the bedding is almost horizontal, and the limestone is relatively hard, the riverside is almost exposured near the Magapit narrows. In addition, it is verified that the rocks tend to crop out in the riverbed in which side rock exposures are observed, by the simple sounding device namely the sinker with rop. The surface of the rock in the river seems to be rather undurate and irregular, dozens cm to 1m rough, especially in the interval from 30 km to 37 km of Cagayan River Reversely sandy sediments seems to be deposited on the riverbed in which side no outcrops can be observed.

After all, the roughness of riverbed above mentioned seems to seriously affect to the coefficient of roughness. Because of this reason, the flood water level is regarded to be raised unnaturally.

VII THE RESULTS OF EXAMINATION

7.1 Estimation of Overburden/Excavation for Selected Dam

The overburden i.e. total depth of surface soil and weathered rock is assumed by the field inspecting at each proposed damsite, regarding the outcrop and/or degree of weathering of the bedrock, extension of loam and river gravel. Thus the required depth of foundation excavation is classified into three classes; Class A with 3 meters, Class B with 5 meters and Class C with 7 meters. Excavation at each proposed damsite is shown in Table 7.1.

7.2 Proposed Dam Type for Selected Damsites

Dam type is restricted by both damsite foundation and construction material. The concrete gravity dam is possible to construct when the foundation is sound rock, and fill-type dam will suitable in case of weathered soft foundation.

Dam types of selected 9 dam from 1st screening and 2nd screening in the Master Plan were determined as Table 7.2, considering foundation and construction material.

From foundation: Judgeing from each dam foundation, fill-type is suitable for every damsite. And, concrete gravity-type is also possible on the basis of sound rock at Ilagan No. 1, Alimit No. 1, Cagayan No. 1 and No. 2. Though, gravity-type is not suitable for other damsite, because of that the bedrocks belong to soft rock of younger for motion. In cases, lower concrete gravity dam may possible at Mallig No. 2 Dam.

From construction material: Construction materials, core material and rock material for fill-type dam, concrete aggregate for concrete gravity dam, can be got at most of selected damsites; therefore any types of dam seem to be possible to construct. However, only earth fill type is possible at Siffu No. 1, because concrete aggregate and rock material cannot be got around the damsite.

In conclusion, concrete gravity dam is suitable at Ilagan No. 1, Alimit No. 1, Cagayan No. 2, rock fill dam or earth fill dam is appropriate for other proposed damsites.

7.3 Grouting Plan for Selected Damsites

Grouting of damsite generally aims to form the cut off wall and to improve the foundation at dam axis. Curtain grouting and blanket grouting in fill-type dam, and consolidation grouting in concrete gravity dam are as Table 7.3.

Curtain grouting:

Depth of curtain grouting is determined by following expression.

$$h = \frac{H}{3} + c$$

where h; grouting depth (m)
H; dam height (m)
c; constant = 25 m

In this way, h almost ranges from 0.7 H to 0.8 H.

Number of line is fixed upon two (2) lines as standard.

However, in case that he bedrock is composed of limestone such as Cagayan No. 1 and No. 2, grouting depth (h) was increased to 1.0 H, and the number of grouting line to three (3) lines, considering the unpredictable rock condition like a cave or open crack.

Blanket/consolidation grouting:

Depth of blanket/consolidation grouting is fixed upon 5 to 10 meters as standard, and arranged grid of 2.5 to 3 meters. However the grid was enlarged to 5 meters in case of hard bedrock.

Grouting material:

Cement mortar and cement milk is regarded as adoptable for intrusion material, however, the special materials like a chemical grouting may be required in cases such as porous limestone or very soft rock.

7.4 Consideration of Drilling Work at Cagayan No. 1 Dam

The bedrock of proposed Cagayan No. 1 damsite and reservoir area turned out to be limestone of late Miocene. The karst landform is not remarkable in this limestone rock body. Though, generally, limestone rock body shows high permeability, and foundation treatment is rather difficult. Accordingly, it is necessary to confirm the sub-surface rock condition by preliminary drilling work before feasibility study. In connection with these conditions, exploratory drilling works was carried out by courtesy of GOP. The main purposes of drilling are to verify rock facies, rock quality, size and frequency of void/cave, permeability.

The specifications are as follows:

Borehole No.	DDH-1	DDH-2
Location	L/A, Upstream of Cagan No. 1 Dam	- do -
Coordinates	On the mountain top of the left abutment	1.3 km upstream, left bank Vertical
Direction	Vertical	Vertical
Total Depth in m	115	45
Core Barrel	Tone-NQ, WL	- do -
In Situ Testing	Water Pressure Test (at every 5 m by double packer method.)	- do -
Date	Sept. 1986	Aug. 1986

Fig. 7.1 - 7.2 shows summary of drilling log.

The results of drilling are as follows:

- Rock facies ; weathered residual soil overlies the bedrock, at several meters thickness. Bedrock is limestone.
- Rock quality ; almost fresh-slightly weathered limestone, medium hard-broken in some sections. partly conglomeratic or argillaceous at a few sections.
- Color ; almost creamy white, but buff-brownish is some sections.

- Bedding plane ; horizontal-20° or 30, and
- Joints ; interval is from 0.1 - 1 meters, reaches more than 1 meters in some sections.
  generally tight but opened and rusty at sections.
- Core recovery ; almost 100%.
- R.Q.D. ; Rock Quality Designation range from 40 to 90 in percentage. The mean of R.Q.D. reaches over 70 percent.
  (R.Q.D. is defined by counting the total length of core pieces as percentage that reaches over 4 inches of the coring interval.)
- Permeability ; permeability coefficient range in the order from 10^{-7} to 10^{-4} cm/sec, and classed as impervious or semi-pervious. The mean is about 10^{-6} to 10^{-5} cm/sec.

In this way, the sub-surface bedrock is regarded as almost hard-very hard rock that shows generally high R.Q.D. and rather low permeability at inland a little far from Cagayan river.

On the other hand, surface outlock of bedrock shows extremely cracky and soluble structure with cave at riverside of Cagayan river. According to the available topo-map in scale 1:25,000, characteristic doline-line depressions are scattering on the southeastern zone that parallel to the Cagayan river and some 1.0 to 1.5 km far from the river.

After all, these aspects can be interpreted as follows:

- (1) this limestone bedrock is relatively soluble and unstable for the rainfall and riverstream which inclueds carbonic acid.
- (2) but, the bedrock is rather stable in case it is covered by thick residual soil and weathered rock and/or underlies the ground water level.
- (3) there are possibility that the bedrock is rather porous and karst land forms are developing on the southeastern portion. The leakage may become extremely high like a headrace tunnel, in case of ponding.

It is necessary to verify the extent of limestone rock body, and degree of dissolution structure, size of cavern and porosity on the southeastern area of the Cagayan river especially, in the future study.

Table 4.1 Summary of Geological Survey (1)

*: no reconnaissance
-: underlined is selected dam by 1st/2nd screening

No.	Dam Name	Geology	Geological Age	Strike/Dip	Hardness/Weathering	Fault, Fracture Zone	Remarks	Comments
(1) 1	Dummon *	sandstone, conglomerate	Pliocene	Strike: E-W dip : S	Soft/partly highly weathered to red clay.	fault (E-W) exists in southern area	satisfactory	small collapse and landslide.
(2) 4	Chico No.4 (F/S)	sandstone, shale, siltstone	Upper Miocene	N60°W/70°NE	hard-medium/moderately weathered (upland)	fault is present at the abutment	highly recommended.	bed rock is fairy good.
(3) 6	Chico No.2 (Pre-F/S)	basic volcanics (basalt-spilite, diabase)	Cretaceous-Paleogene	-	generally very hard	-	excellent site	-
(4) 8	Chico-Mallig	sandstone alternation with shale	Upper Miocene	N25°E/54°NW (right bank)	soft/moderately-highly weathered	-	satisfactory, excavation will be large.	extended river gravel, terrace deposit.
(5) 10	Matalag	conglomerate, sandstone	Upper Miocene	N40°E/35-45°SE	soft, partly hard/ moderately weathered	-	very satisfactory.	remarkable cuesta.
(6) 12	Pinukpuk	conglomerate, sandstone	Upper Miocene	N30°E/30°SE	soft-partly hard	-	very satisfactory.	remarkable cuesta. lanslides upstream right slope.
(7) 14	Babaca *	conglomerate, sandstone	Upper Miocene	Strike:NNE-SSW, dip:W	hard-medium	strike fault is estimated on E-area.	very satisfactory.	little problem about fault.
(8) 15	Bitag	sandstone	Upper Miocene	N45°E/10°W	very soft/highly	-	satisfactory	wide riverbed. extended sandy river deposit.
(9) 19	Aggugadan	limestone	Upper Miocene	strike: N-S dip:5°W	very hard/weathering is proceeding	-	satisfactory	wall-layered, cracky rocks. Callao Cave at downstream.
(10) 24	Shiffu No.1 (A)	pebble-conglomerate	Pliocene	strike:N-S dip: 30°E	soft/moderately to highly weathered	active structure infered may be no problem.	very satisfactory.	remarkable cuesta. wide collapse zone to be investigated.
(11) 24'	Shiffu No.1 (B)	sandstone, shale, conglomerate	Upper Miocene	N25°W/40°E	soft-medium/moderately weathered	-	very satisfactory.	collapse existing upstream. may be no problem.
(12) 25	Shiffu No.2 *	volcanic rocks (basalt, andesite)	Cretaceous-Paleogene	-	generally hard/slightly -moderately weathered	-	highly recommended.	-
(13) 26	Mullig No.1	conglomerate, sandstone	Upper Miocene	N15 - 20°E/20-30°E	hard (river bed), soft (upland)/highly-moderately weathered	active structure is inferred.	very satisfactory.	wide collapse zone at down-stream may be no problem. abutment excabation large.
(14) 27	Mallig No.2	sandstone with conglomerate, mudstone	Upper Miocene	N10°W/60°E	soft-med./moderately weathered	-	very satisfactory.	remarkable slaking zone (upstream)
(15) 28	Ilagan No.1	meta-ancesite, diorite	Cretaceous-Paleogene	-	very hard-med./slightly altered.	-	highly recommended.	slight pyrite dissemination. sufficient river gravel.
(16) 29	Ilagan No.2	meta-andesite, agglomerate, diorite	Cretaceous-Paleogene	-	very hard-medium/highly weathered to red clay.	-	highly recommended.	
(17) 33	Disabungan	sandstone, andesite granodiorite	Cretaceous-Paleogene/ Pliocene	almost horizontal (sandstone)	very soft, highly (upland)/hard (river bank)	-	very satisfactory	hardrock only river bed level. right abutment should be excabated.

(to be continued)

Table 4.2 Summary of Geological Survey (2)

*: no reconnaissance

No.	Dam Name	Geology	Geological Age	Strike/Dip	Hardness/Weathering	Fault, Fracture Zone	Remarks	Comments
(18) 34	Catalangan *	andesite, pyroclastics, agglomerate	Cretaceous-Paleogene	-	hard-med.	-	highly recommended.	many outcrops on the river bed.
(19) 37	Alimit No.1 (A)	agglomerate, andesite	Cretaceous-Paleogene	N50-60°W/50°NE	generally hard/slightly-moderately weathered	-	highly recommended.	many outcrops on the river bed.
(20) 41	Matuno No.1 (F/S)	conglomerate, sandstone	Middle Miocene	strike: E-W, dip : 30-40°N	hard/moderately weathered	-	satisfactory, foundation treatment necessary.	so high bedrock permeability.
(21) 47	Cagayan No.1	limestone (Callao-)	Upper Miocene	strike: N-S dip : 7 - 8°W	hard/slightly-moderately, with solutive texture.	-	satisfactory.	many opened craks in places.
(22) 48	Cagayan No.2	limestone (Sicalao-	Middle Miocene	strike: NE-SW dip : 10°NW	hard-med./moderately weathered.	-	satisfactory.	many cracks. progressive weathering.
(23) 49	Casecnan (F/S) (conwap)	agglomerate	Upper Oligocene	strike: NE-SW dip : 20-30°N	hard, massive	sheared zone, consolidated.	very satisfactory	no special problem.
(24) 50	Addalam (A)	agglomerate	Oligocene	N60°W/10°SW	med.-very hard/slightly-highly weathered (right)	-	very satisfactory	-
(25) 51	Diduyon (F/S)	agglomerate, andesite	Oligocene	N35-50°NE/25-35°E	hard/generally fresh	fault right bank	satisfactory. foundation treatment necessary.	weak zone in the right bank.
(26) 52	Dibuluan	metasediments	Cretaceous-paleogene	strike: NE-SW dip : NW	medium hard/moderately weathered	-	very satisfactory.	-

Table 4.3 Proposed Construction Material for Selected Dam

(from surface inspection)

Number	Dam Name	Location	Material	Description	Class
1	Pinukpuk	2 km downstream (Chico River channel)	sand, gravel	including cobble-boulder, hard	A
2	Siffu No. 1	0.8 km downstream both banks	conglomerate, sand-stone (Late Tertiary)	very loose, moderately weathered	B
3	Mallig No.2	*2.5 km SW right bank	sandstone, mud-stone (Late Tertiary)	moderately-highly weathered soft rock	C
		**11 km NW (Chico River channel)	sand, gravel	including cobble-boulder, hard	A
4	Ilagan No. 1	2 km downstream and 5 km upstream river bed	sand, gravel	including cobble-boulder, hard	A
5	Disabungan	1 km upstream, right bank	andesite etc. (metavolcanics) (Not to be specified)	moderately weathered soft rock	B
6	Alimit No. 1	1-2 km upstream, right bank	agglomerate (Cretaceous)	slightly-moderately weathered	A
7	Cagayan No. 1	3-5 km upstream river bed	sand, gravel	including cobble-boulder, hard	A
8	Cagayan No. 2	0.5-3 km upstream, river bed	sand, gravel	including cobble-boulder, hard	A
9	Addalam	4 km SW, both banks (upstream)	agglomerate (Cretaceous)	slightly-moderately weathered	A

Notes: * and ** means alternative plan each other

Class - A: fresh-moderately weathered hard rock
- B: moderately weathered soft rock
- C: moderately-highly weathered soft rock

Table 7.1 Assumed Overburden/Excavation at Proposed Damsite

Number	Dam Name	Class of Overburden/ Excavation	Remarks
1	Pinukpuk	B	-
2	Siffu No.1	B	-
3	Mallig No.2	A	exposed narrow channel
4	Ilagan No.1	A	sound rock, partly weathered
5	Disabungan	C	highly weathered
6	Alimit No.1	A	outcrop in the riverbed
7	Cagayan No.1	C	cracky limestone with cave
8	Cagayan No.2	C	cracky limestone
9	Addalam	B	-

* Notes: Class - A: relatively thin overburden below 1 m, excavation is estimated to be about 3 m.

B: moderate overburden about 1.5 m, excavation is estimated to be about 5 m.

C: relatively thick overburden above 2 m, excavation is estimated to be over 7 m.

Table 7.2 Possible Dam Type and Proposed Dam Type

Dam Name	from damsite foundation			from construction material			Total evaluation
	C/G	R/F	E/F	C/G	R/F	E/F	
1. Pinukpuk	×	o	o	o	o	o	R/F
2. Shiffu No. 1	×	o	o	×	×	o	E/F
3. Mallig No. 2	Δ	o	o	o	o	o	R/F
4. Ilagan No. 1	o	o	o	o	o	o	C/G
5. Disabungan	×	o	o	o	o	o	R/F
6. Alimit No. 1	o	o	o	o	o	o	C/G
7. Cagayan No. 1	o	o	o	o	o	o	C/G
8. Cagayan No. 2	o	o	o	o	o	o	C/G
9. Addalam	×	o	o	o	o	o	R/F

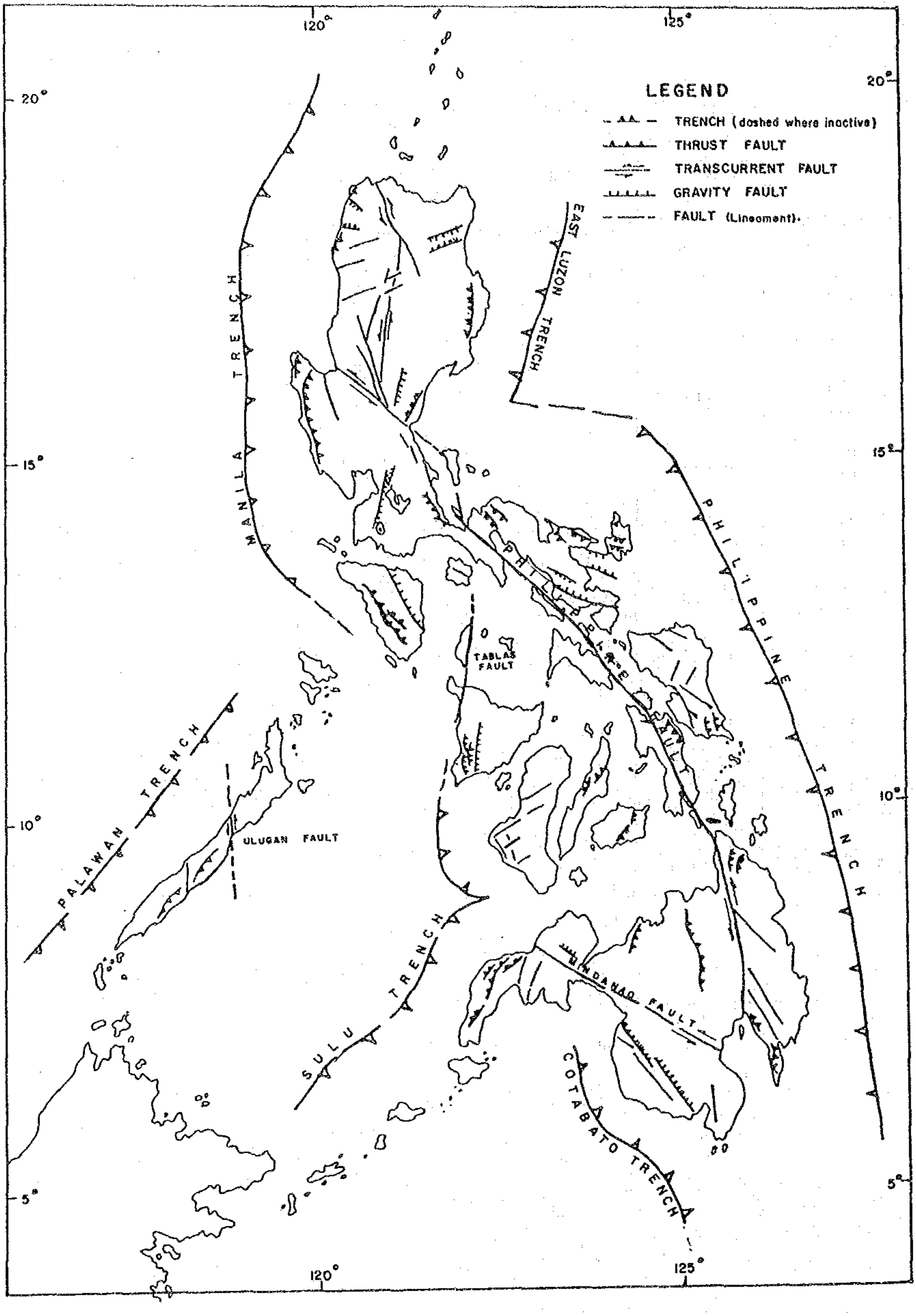
Note: C/G ; concrete gravity dam
R/F ; rock fill dam
E/F ; earth fill dam
o ; suitable
Δ ; possible in cases
× ; not adaptable

Table 7.3 Grouting Plan for Dam Foundation

Dam Name	Dam Type	Curtain Grouting				1 Blanket Grouting/ 2 Consolidation Grouting			
		Depth of hole	Number of line	Number of hole	Subtotal of curtain	Depth of hole	Inter-val of hole	Number of hole	Subtotal of B. or C.
		m			m	m	m		m
1. Pinukpuk	Rockfill	28∿40	2	530	18,260	7	2.5	780	5,160
2. Shiffu No.1	Earthfill	32∿45	2	420	15,930	7	2.5	670	4,690
3. Mallig No.2	Rockfill	32∿45	2	300	11,200	5	3	450	2,250
4. Ilagan No.1	Concrete Gravity	35∿50	2	600	25,000	5	3	1,710	8,550
5. Disa-bungan	Rockfill	32∿45	2	960	36,250	7	3	1,800	12,600
6. Alimit No.1	Concrete Gravity	46∿65	2	560	32,200	7	5	990	6,930
7. Cagayan No.1	Concrete Gravity	55	3	450	24,750	10	3	660	6,600
8. Cagayan No.2	Concrete Gravity	80	3	900	72,000	10	3	2,060	20,600
9. Addalam	Rockfill	32∿45	2	770	30,100	7	3	1,380	9,660

Note) 1 ; grouting for fill-type dam.

2 ; grouting for concrete gravity dam.



Modified from:
Geological Map of the Philippines
1:1,000,000 scale
1964 edition

Fig. 3.1 CRUSTAL FRACTURES

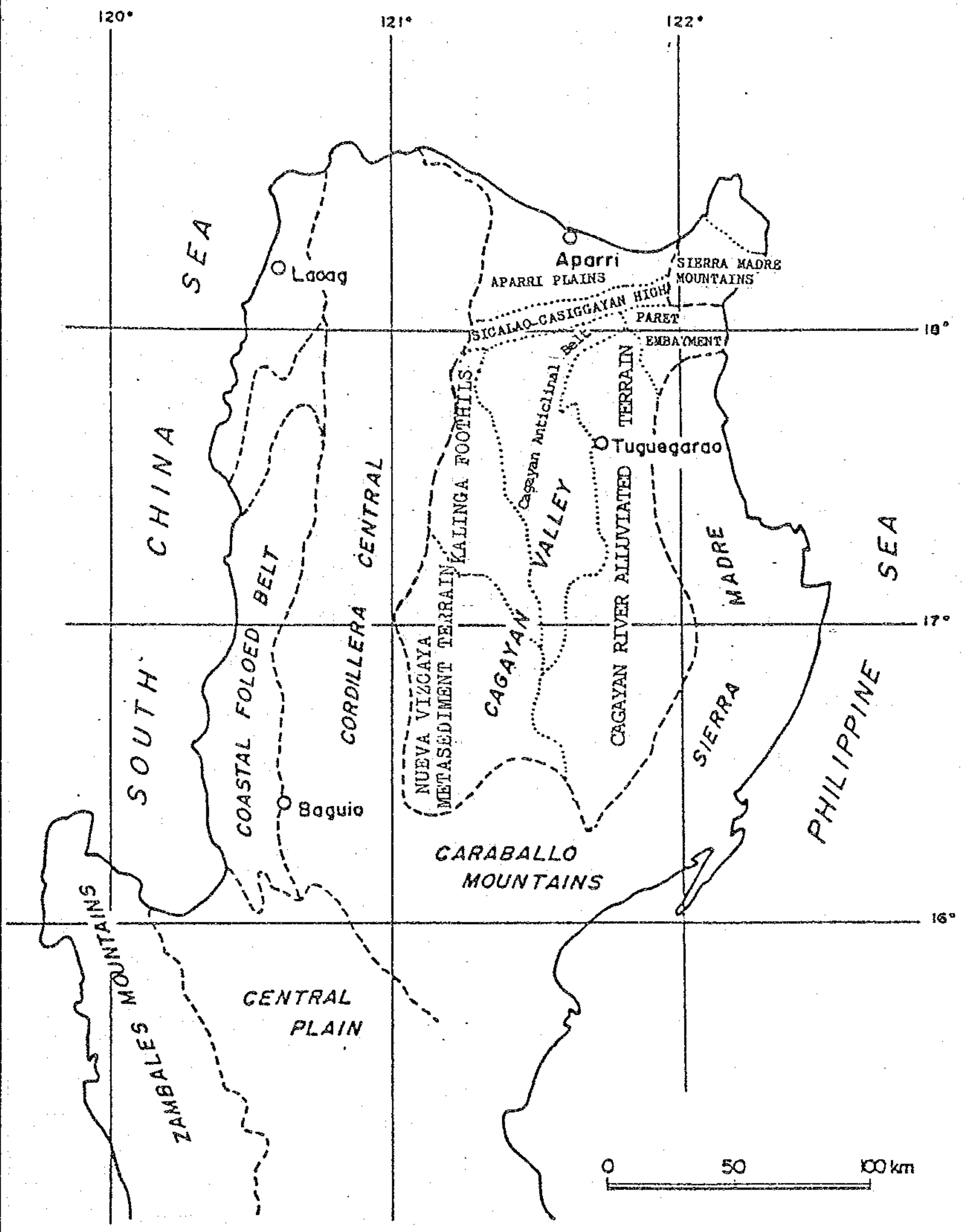
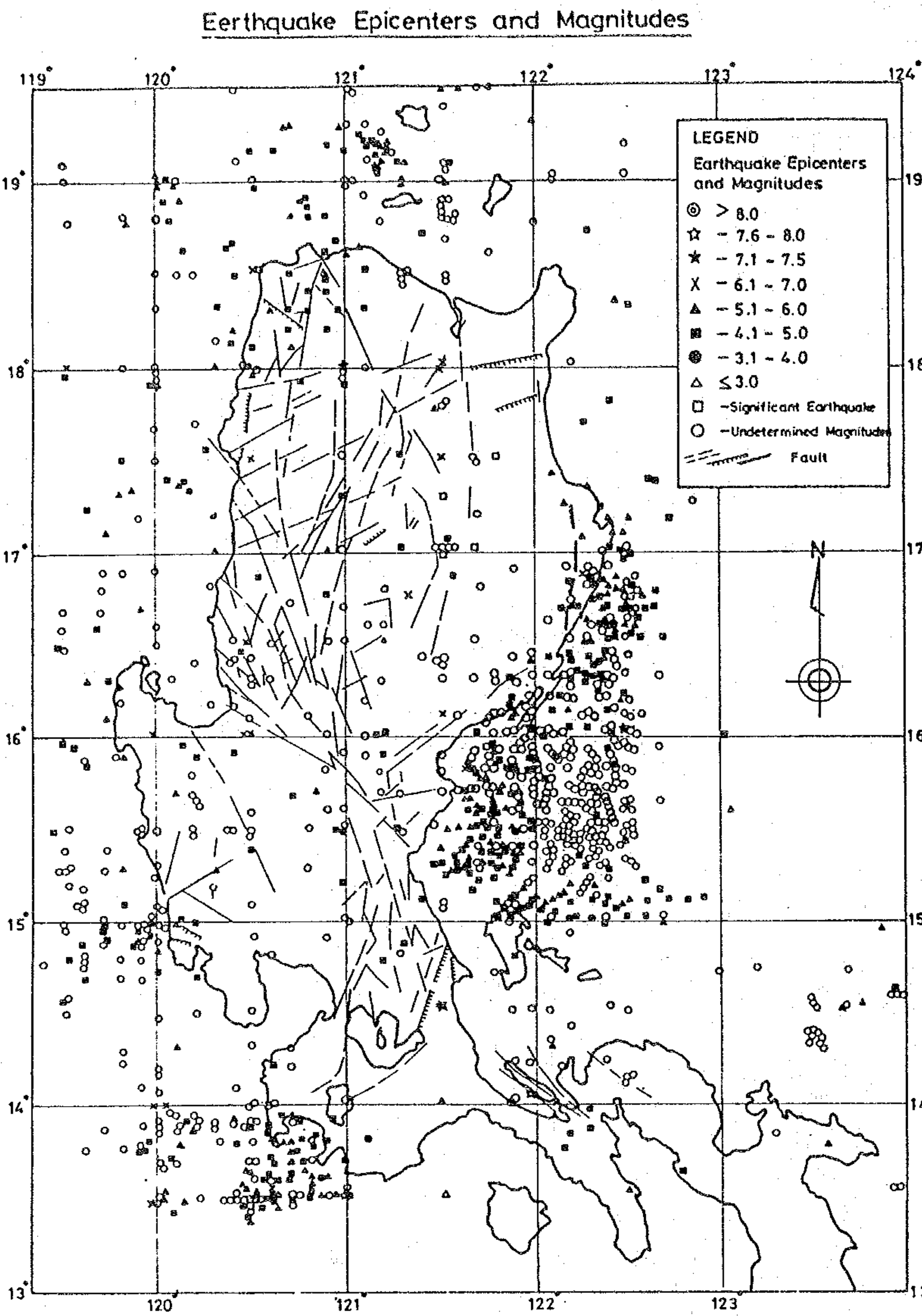


Fig. 3.2 PHYSIOGRAPHIC AND STRUCTURAL PROVINCES OF NORTHERN LUZON



(quoted from the report of "Diduyon HydroelectricPProject",Oct. 1980)

Fig. 3.3 EARTHQUAKE EPICENTERS AND MAGNITUDES

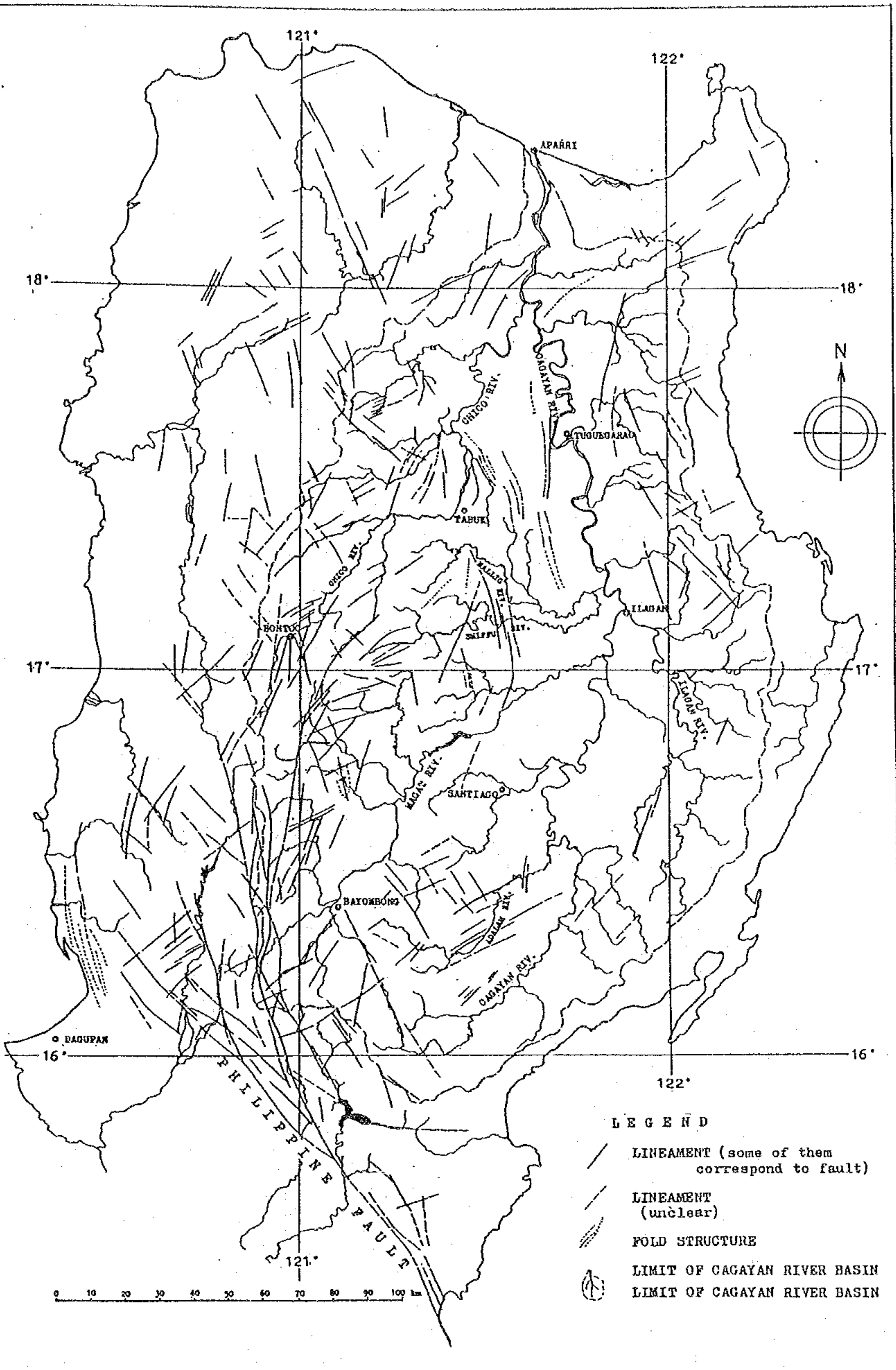
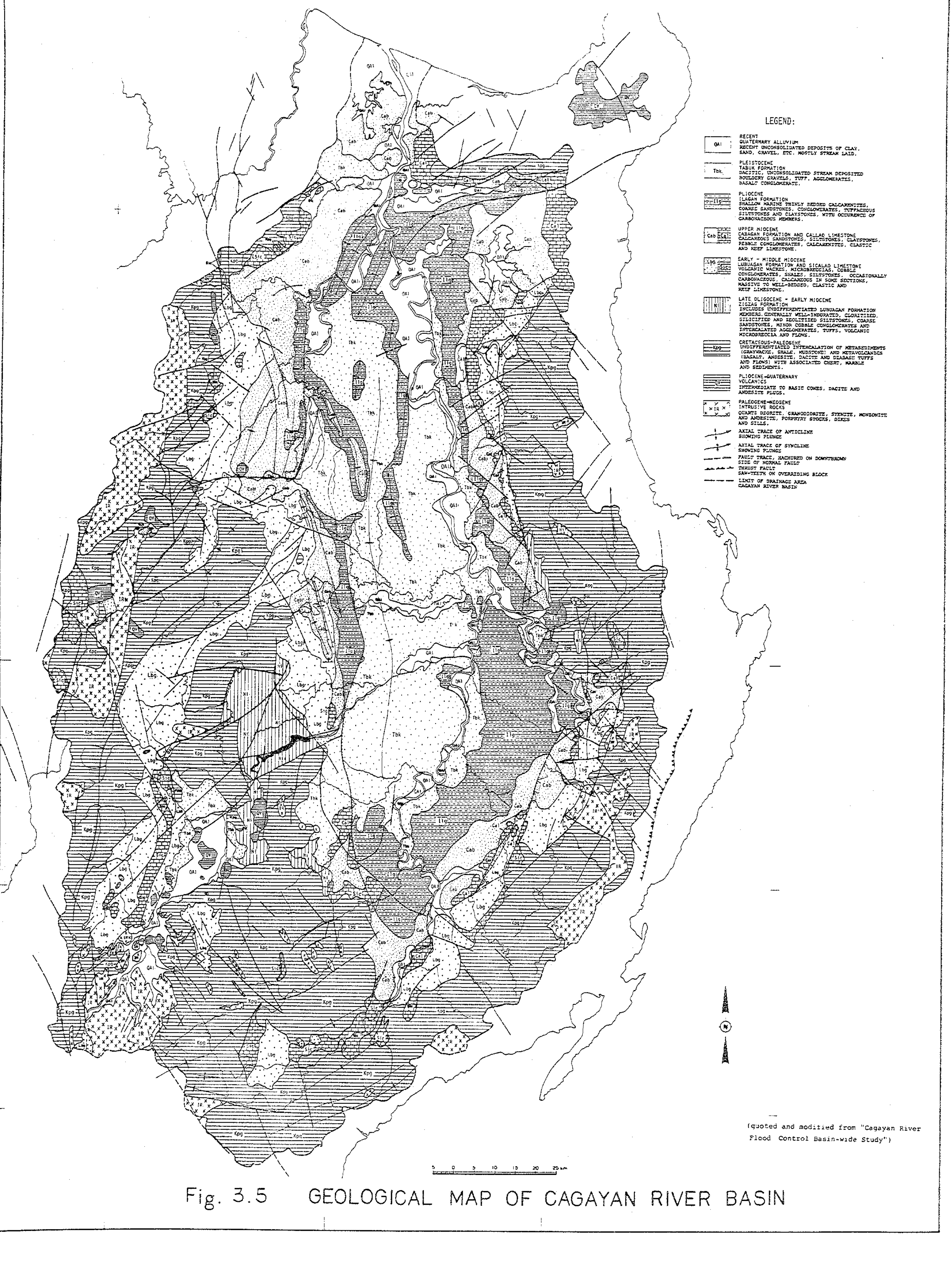


Fig. 3.4 STRUCTURAL ANALYSIS MAP OF LANDSAT IMAGE (ORIGINAL)



(quoted and modified from "Cagayan River Flood Control Basin-wide Study")

Fig. 3.5 GEOLOGICAL MAP OF CAGAYAN RIVER BASIN

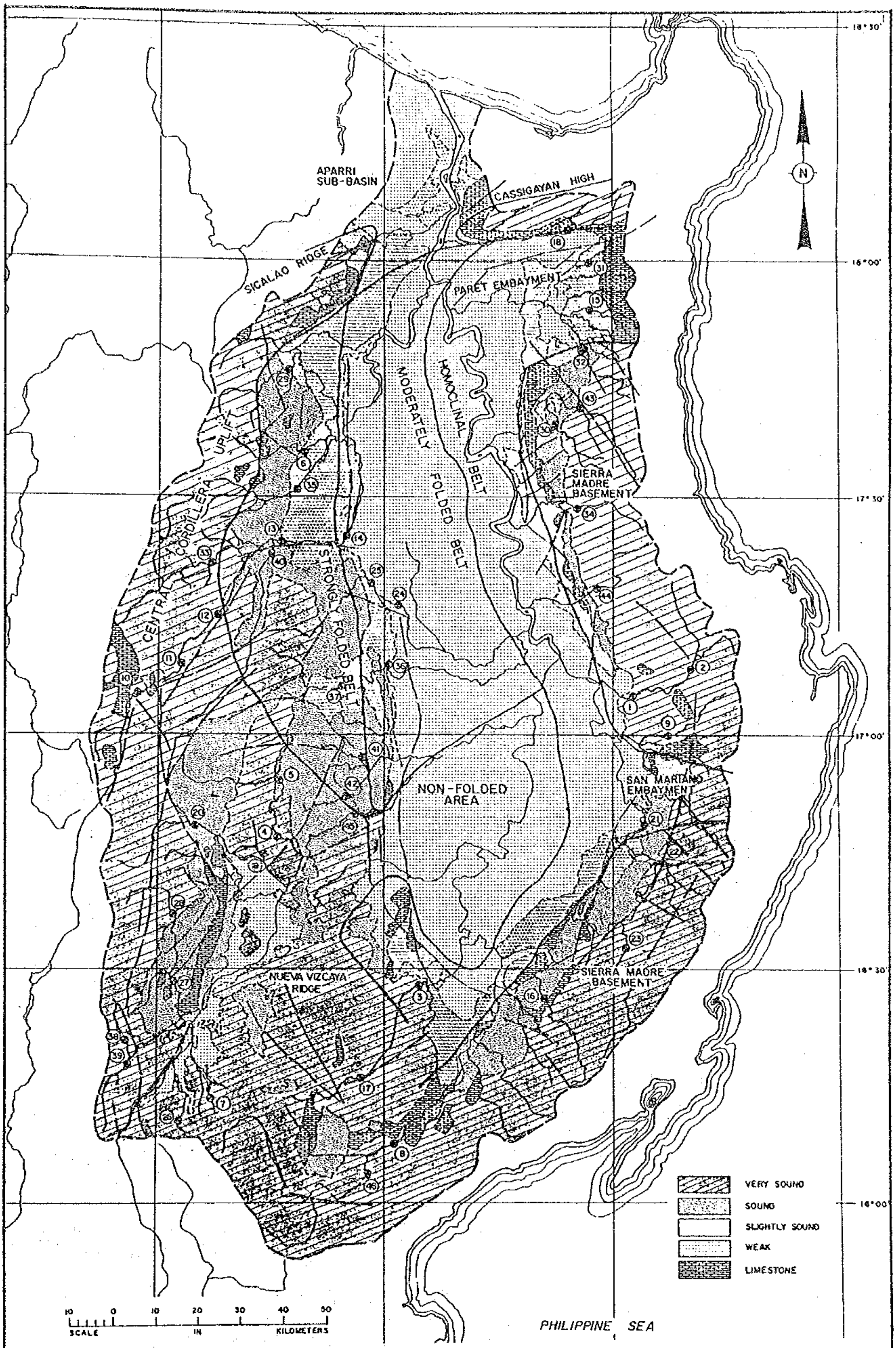


Fig. 3.6 REGIONAL GEOTECHNICAL MAP

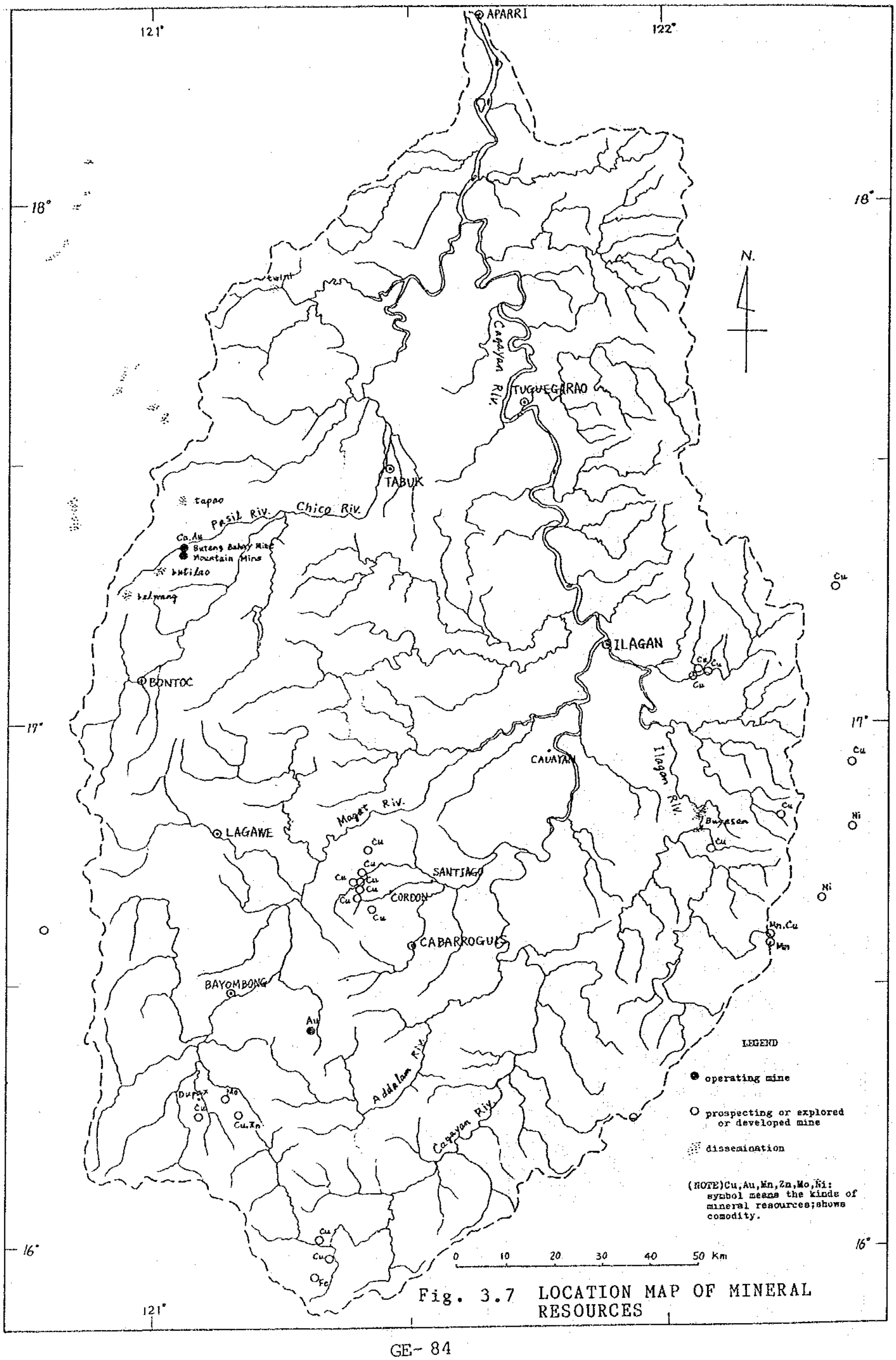


Fig. 3.7 LOCATION MAP OF MINERAL RESOURCES

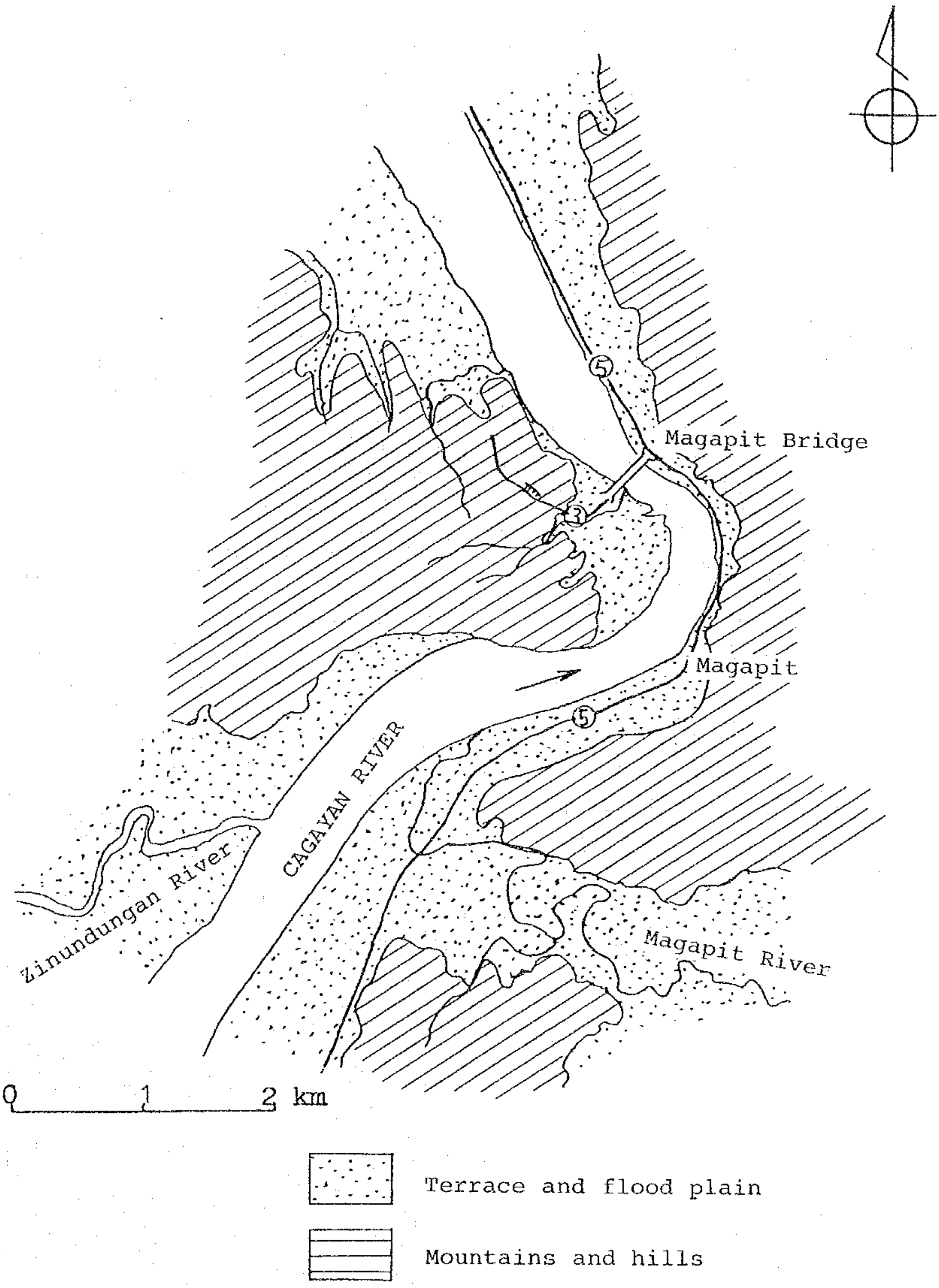


Fig. 6.1 GENERAL LANDFORM CLASSIFICATION MAP OF MAGAPIT

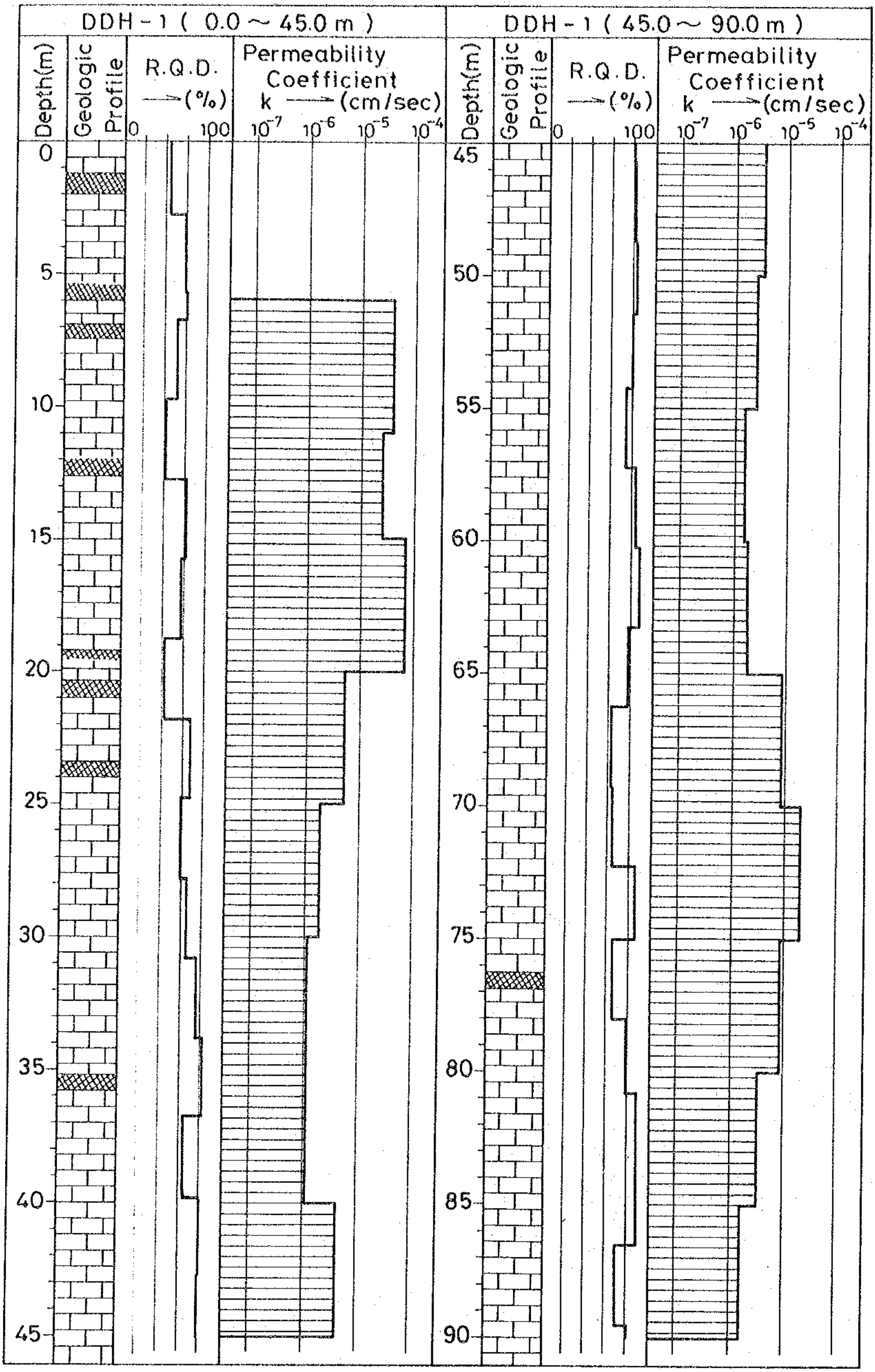


Fig. 7.1 SCHEMATIC DRILLING LOG OF CAGAYAN NO. 1 DAM

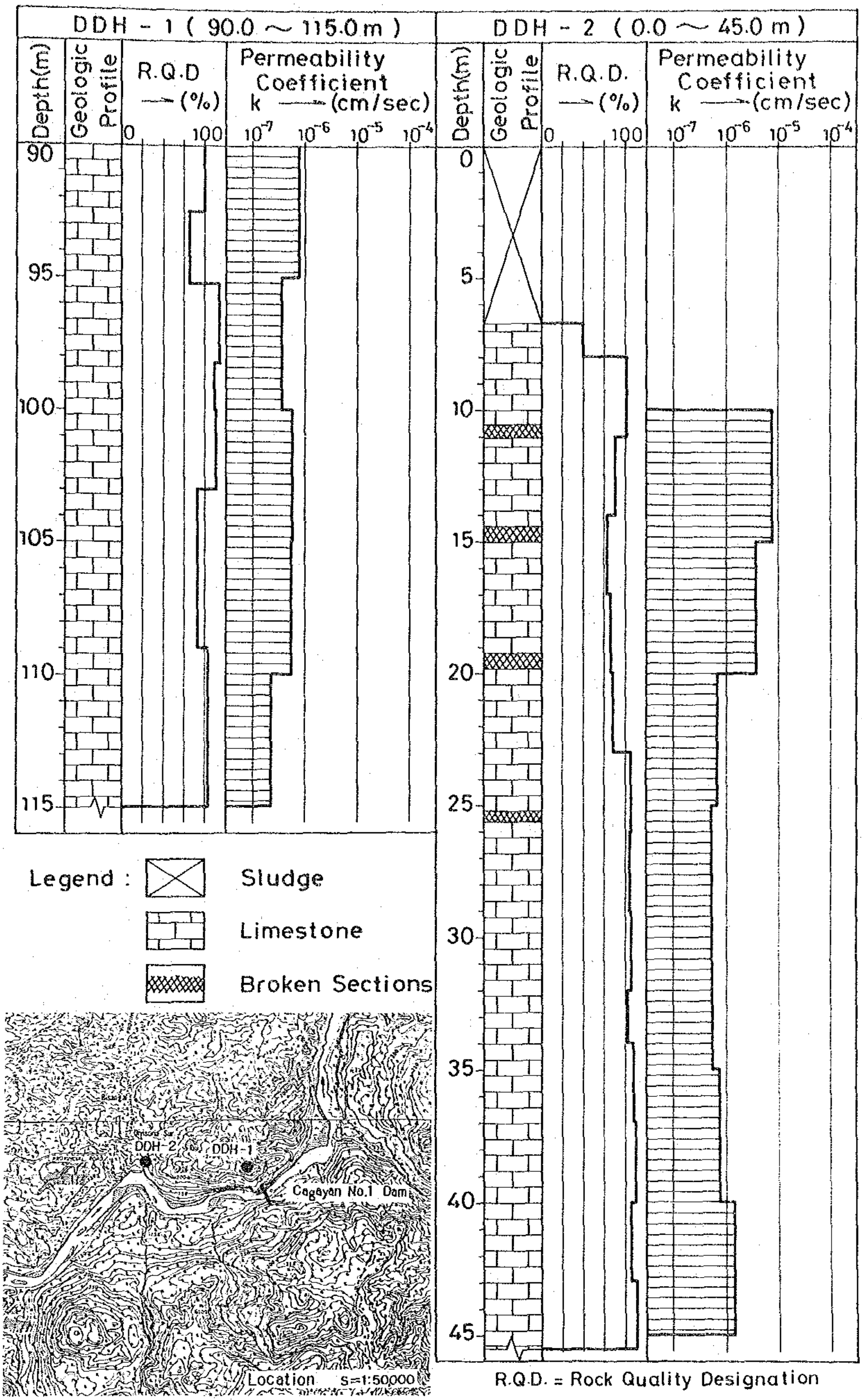


Fig. 7.2 SCHEMATIC DRILLING LOG OF CAGAYAN NO. 1 DAM

Attachment A. List of Collected Data

Ref.No.	Title	Author	Date of Issue
GE-101	Catalogue of Philippine Earthquakes	PAGASA	
GE-102	Landsat Image, Scale 1:500,000		1983
GE-103	Aerophotograph, Scale 1:60,000	BFD	1980-1981

Attachment B. List of Collected Project Reports

Ref.No.	Title	Author	Date of Issue
GE-201	Feasibility Study Chico IV Hydropower Project in the Chico River	LAHMAYER	May 1981
GE-202	Cagayan River Flood Control Basin-Wide Study	PHILTECH	Jul.1981
GE-203	Feasibility Study on Diduyon Hydroelectric Development Project	JICA	Dec.1980
GE-204	Feasibility Study on the Matuno River Development Project	JICA	Feb.1984
GE-205	Casecnan Transbasin Diversion Project Feasibility Study	ELC	Jan.1982

Attachment C. List of Collected Publications

Ref.No.	Title	Author	Date of Issue
GE-301	Geology and Mineral Resources of Philippines	BOM	1982
GE-302	Data on Philippine Mineral Resources	BOM	1972
GE-303	Geology and Mineral Resources of Nueva Vizcaya Province	BOM	1974
GE-304	Geology and Mineral Resources of Isabela Province	BOM	1974
GE-305	Geological Map of the Philippines	BOM	1963

ANNEX FC

FLOOD CONTROL

ANNEX FC

Table of Contents

List of Tables

List of Figures

List of Attachment

I. PREVIOUS FLOOD CONTROL STUDIES

1.1. Nationwide Flood Control Plan and River Dredging Program

Study Report on Nationwide Flood Control Plan and River Dredging Program (RDP-II) was prepared for the Ministry of Public Works and Highways, by Nippon Koei Co., Ltd. in association with Nikken Consultants, Inc. and Basic Team Corporation, in November 1982, with a financial aid of Overseas Economic Cooperation Fund, Japan.

The report includes studies on flood control plans and river dredging programs of the 14 major river basins in the Philippines such as the Cagayan, Agno, Pampanga, Bicol and Laoag rivers in Luzon Island; the Panay and Jalaur rivers in Panay Island; the Ilog river in Negros Island; the Tagoloan, Agusan and Mindanao (Cotabato) rivers in Mindanao Island; and the Amnay and Patrick rivers in Mindoro Island.

The study of flood control plan for the Cagayan river basin is initiated from clarifying the present situation of the basin from various aspects such as water resources development, land and water use, and river condition. On the basis of the findings of river's present situation, study on the flood control plan was conducted. Present condition of the Cagayan river basin is outlined in Table 1.1.

As a result of study a basic flood control plan and first phase plan were formulated. The basic flood control plan is a target for the phased flood control works and the first phase plan is a recommendable basinwide flood control plan for its implementation.

In formulating the basic flood control plan, 5 multipurpose dams such as Magat multipurpose dam and other 4 proposed dams of which intensive studies were then on-going were taken in the plan as a fundamental condition of runoff analysis for the study. Diking system to confine flood water was a basic flood control measures. Improvement of Magapit narrows stretching from Catayauan up to Alcala was studied as an alternative scheme. However, the selection of alternative schemes with and without improvement of Magapit narrows could not finally be made, since the construction costs for these two schemes were almost same. Principal features of the basic flood control plan are shown in and Table 1.2.

In order to select an appropriate scale of flood control plan for the first phase, the channel improvement schemes for the probable floods of 10, 25, 50 and 100 years were studies. Only Magat dam was taken into account in this study. Finally, the 25-year plan was selected as the first phase plan in consideration of the results of economic evaluation, magnitude of the biggest recorded flood and project scale of the other rivers under study.

The first phase plan requires a total economic cost of ₱7,102,000,000 for its construction and the plan was deemed difficult to pursue in a short period. The stepwise execution was, therefore, studied within the frame of the first phase plan. In due consideration of the importance and urgency for implementation of works, the following works were selected for the first step works:

1) Confining dike on the right bank of the Cagayan river from the Pared river (Sta.65 km) to the Pinacanauan de Tuguegarao river (Sta.139.8 km) to protect towns and villages including Tuguegarao and its hinter lands from flooding.
2) Cut-off channels at Gabut (Sta.68 km to 76.5 km) and Ugac (Sta.89.5 km to 101.5 km) to normalize the channel alignment.
3) Bank protection works on the right side banks in critical condition to protect national highway and towns/villages from erosion.

Furthermore, urgent works were proposed for the immediate implementation. Among the first step works, selected for the urgent works were the bank protection along the main Cagayan river to protect public facilities and villages from land erosion. The following sites were proposed for the urgent works:

1) Aparri : 1.0 km long, to protect Aparri town
2) Catayauan : 6.0 km long, to protect village houses and national highway
3) Gattaran : 1.0 km long, to protect village houses and national highway
4) Tuguegarao : 4.5 km long, to protect Tuguegarao town
5) Balug : 1.0 km long, to protect national highway

Principal features of the first phase flood control plan including the first step and urgent works are shown in the Table 1.2.

1.2 Cagayan River Flood Control Basinwide Study

Study Report on Cagayan River Flood Control Basinwide Study (CRFC) was prepared for the Ministry of Public Works and Highways by Philippines Technical Consultants, Inc., in January 1983.

The main objective of the study was to evolve an integrated scheme of flood on a basinwide scale for the vast Cagayan river basin. Aside from flood control, the study was also aimed towards the tapping of potentials from hydropower generation and irrigation. The study was divided into four parts. They are:

1) Part-A : Feasibility study of two dam and reservoir projects, i.e., Ilagan river No.2 and Tuguegarao;
2) Part-B : Prefeasibility study of two dam and reservoir projects, i.e., Matuno river No.1 and Sta. Cruz river No.2;
3) Part-C : Identification study of potential dam and reservoir projects in the Cagayan river basin, and;
4) Part-D : Conceptual flood control scheme for the main valley.

As a result of study, the dam-and reservoir projects subject to feasibility study, Ilagan river No.2 and Tuguegarao were found to be both technically feasible, and economically and financially viable. These two projects have hydropower generation, irrigation and flood control purposes.

The two dam-and reservoir projects under prefeasibility study, Matuno river No.1 and Sta. Cruz river No.2 protects, were both technically feasible. However, the Sta. Cruz river No.2 project was not economically viable. The Matuno river No. 1 project has hydropower generation, irrigation and flood control purposes.

Overall flood control scheme for the main valley of the Cagayan river and its tributaries were discusses in Part-D. The overall flood control scheme emcompasses upstream and downstream flood control schemes. The upstream flood control scheme would be attained by the development of dam and reservoir projects in the upstream reaches to compliment downstream flood control measures attenuating floods.

The downstream flood control scheme consists of following nine program packages including 29 specific project components.

1) Aparri and vicinity flood control program
2) Baggao flood control program
3) Piat flood control program
4) Iguig-Alcala flood control program
5) Tuguegarao flood control program
6) Siffu-Mallig flood control program
7) Naguilian flood control program
8) Santiago flood control program
9) Nueva Vizcaya flood control program

The total budgetary investment cost for the whole program was estimated to be ₱6.2 billion. Because of large development cost, the project components were categorized into short, medium and long-range projects for implementation. Among the project components of the downstream flood control scheme, following works were selected for the short-range project:

1) Pared river channel improvement at Baggao
2) Piat groin system at Piat
3) Tuguegarao road dike system
4) Naguilian groin system
5) Bambang road dike system
6) Bambang groin system
7) Bayombong-Solano road dike system
8) Bayombong groin system
9) Batu viaduct

II. PRESENT RIVER CONDITIONS

2.1. River Basin

The feather-shaped Cagayan river basin is bounded by the Sierra Madre Mountains in the east, the Cordillera Mountains in the west and the Caraballo Mountains in the south (Fig.2.1). The Cagayan river rises in the Caraballo Mountains. It travels some 520 km in the Cagayan Valley from the south to north in the northern part of Luzon Island. It drains the catchment area of 27,300 km^2. Since the Cagayan river takes route closer to the Sierra Madre Mountains, the right tributaries are generally of steep slope and small scale.

The basin areas of the main Cagayan river and tributaries are shown in Fig.2.2. The catchment areas of four major tributaries of the Chico (4,551 km^2), Siffu-Mallig (2,015 km^2), Ilagan (3,132 km^2)and Magat (5,113 km^2) rivers tally 14,800 km^2 or 54 % of total basin area.

2.2 Existing River Channels

Overall longitudinal profile of the Cagayan river and major tributaries were prepared based on the topographic map of scale 1/50,000 and 1/25,000, and shown in Fig.2.3.

Wider flood plains exist along the main Cagayan from Alcala (Sta. 65 km) to around Magat junctions (Sta. 233 km). In the reaches of the upper Cagayan and tributaires, flood plains are small except those in braided reaches. It is noteworthy that in the downstream from Alcala (Sta.65 km) to Magapit (Sta.30 km), hereinafter referred to as Magapit narrows, the main Cagayan is narrowed by hilly lands and just in the upstream of Alcala the river meanders remarkably.

Characteristics of the existing river channels are illustrated in Fig.2.4. The carrying capacity of the existing channels was calculated by non-uniform flow for each surveyed section. The result is shown in Table 2.1, which is summarized below:

Rivers/stretches	Ave. capacity(range) (m^3/s)	Specific capacity ($m^3/s/km^2$)
1. Main Cagayan R.		
- Mouth to Alcala	11,500(7,300-36,600)	0.42
- Alcala to Tuguegarao	4,700(2,500-7,000)	0.23
- Tuguegarao to Magat jct.	7,000(2,300-14,600)	0.37
- Magat jct. to Pangal Norte	7,100(2,100-15,300)	1.07
2. Chico R. (Sta.0-94 km)	4,000(1,100-8,700)	0.88
3. Tuguegarao R. (Sta.0-8 km)	320(160-460)	0.49
4. Siffu-Mallig R.		
- Siffu-Mallig R.	1,900(1,800-2,100)	0.94
- Siffu R. (Sta.5-8 km)	820(440-1,100)	0.77
- Mallig R. (Sta.0-5.5 km)	740(490-1,100)	0.78
5. Ilagan R. (Sta.0-36 m)	2,700(580-4,830)	0.86
6. Magat R. (Sta.0-50 km)	3,300(920-9,070)	0.65

Carrying capacities in the stretch from Alcala to Tuguegarao of the main Cagayan river are extremely small, while those in the upper Cagayan and tributaries are relatively large.

2.3 Floods and Inundations

For grasping the seasonal changes of rainfall and flood events in the basin, monthly rainfalls at Aparri, Tuguegarao, and Ilagan stations are shown in Fig.2.5 together with flood frequency distribution prepared based on flood damage data from the Office of Civil Defence (OCD). Floods in the basin usually occur from the period June to November, among which October shows the highest frequency of flood occurence.

The biggest flood in recent years occurred in 1973 (Nov.23 to 26) by typhoon Openg and in 1980 (Nov. 1 to 7) by Typhoon Aring. The 1973-flood is said the worst flood since 1906 and the 1980-flood since 1973.

Flood marks of 1973 and 1980 floods were surveyed along the main Cagayan from Aparri to Ilagan. The result is shown in Fig.2.6. From this figure, following could be seen:

1) At least in the lower reaches from Tuguegarao, water levels at 1973-flood are higher than those at 1980-flood.
2) Inundated depth is large in particular in the reaches just upstream of Magapit narrows.
3) Flood water surface slope is milder in the stretch from upper end of Magapit narrows to Tuguegarao.

Based on the flood marks, the discharge of 1980-flood was estimated to be about 14,500 m^3/s for the stretch from Tuguegarao to Ilagan by nonuniform flow calculation assuming roughness coefficient n=0.040 and 0.1 for ordinary river channel and for flood plain respectively. Discharge of 1973-flood was also estimated to be similar amount, though the flood marks available were limited.

The intensive interview surveys were conducted in order to identify the flooding areas in the Cagayan river basin for the 1973 and 1980 floods. The interview survey results were checked up with the recorded water levels, topographic maps and flood marks. Finally the boundaries of flooded areas were delineated as shown in Fig.2.7. The figure shows that the inundated areas are similar for both floods. The inundated areas are estimated to be 1,860 km^2 for the flood in 1973 and 1,740 km^2 for the flood in 1980.

There are 106 municipalities which comprise the Cagayan river basin. Among these, 52 municipalities are susceptible of floodings. Most of these municipalities are in the provinces of Cagayan, Isabela and Nueva Vizcaya. Total population of the Cagayan river basin was estimated at 1,885,000 in 1980, of which 63% distributes in the flood susceptible municipalities. Tuguegarao, Ilagan, Santiago and Cagayan are the four biggest municipalities in the basin with the population more than 60,000 each. These are among the flood susceptible municipalities.

Office of Civil Defense (OCD) has recorded flood damages. Table shows the past flood damages prepared based on the data filed by OCD. Unfortunately damage data for 1973 floods are not available.

2.4 River Bank Erosion

Figure 2.8 shows the shifting of river course and average shifting rate during 25 years from 1964 to 1979. The bank erosion takes place in almost all the reaches of the main Cagayan and tributaries except those confined by the hilly areas. This indicates that peoples in the basin have been suffering from considerable bank erosion damages. Bank erosion are active in particular in the main Cagayan river from Alcala to Tuguegarao and the Chico river.

2.5 Magapit Narrows

According to the flood mark survey result presented in section 3.3, the Magapit narrows raise flood water level in the upstream reaches up to Tuguegarao as shown in Fig.2.6. The flood water surface slopes in the main Cagayan are as follows:

Stretches	Bed slope	Surface slope
1. Mouth to Alcala	1/8,680	1/3,450
2. Alcala to Tuguegarao	1/8,680	1/12,080
3. Tuguegarao to Ilagan	1/5,620	1/5,670

The flood surface slope is steeper in the stretch of Magapit narrows comparing with the other reaches. By the non-uniform flow calculation using the surveyed river sections, gorge sections could not be specified in the narrow reaches from Magapit (Sta.30 km) to Alcala (Sta.65 km). In order to specify the gorge sections in the narrows, (1) detailed site inspections from land and boat by our river engineers and geologist and (2) detailed flood mark survey were conducted.

By the detailed site inspection, geological formation of site, exposed rocks along river banks, river bed conditions were inspected site by site along the narrow reaches.

On the other hand, the detailed flood mark survey were conducted along the national highway on the right side bank of the Cagayan river. The flood water levels of 1973 and 1980 floods were surveyed at the intervals of about 0.5 km along the narrow reaches. Most of the flood water level data were collected in the form of verbal information. But, some invaluable flood marks on the buildings and structures were also collected. Leveling survey were conducted for all of them. Results of flood mark survey are shown in Table 2.3.

Figure 2.9 shows the summary of detailed survey of Magapit narrows. From this figure, two sections were identified as possible gorges, i.e., Magapit section and Nassiping section.

2.6 Flood Control and Drainage Facilities

Existing flood control facilities in the basin includes spur-dikes, revetments, cut-off channels, earth dikes, etc. Inventory and locations of the existing flood control facilities are shown in Table 2.4 and Fig.2.10. These facilities except earth dike fall under the category of bank protection measures. The bank protection measures share majority of flood control works in the basin, while flood prevention facilities like earth dike are few.

There are six drainage systems in Aparri, Tuguegarao, Cabagan, Naguilian, Santiago and Bagabag as shown in Table 2.5. Most of these drainage works seem to be remedial measures for emergency. The drainage system of Tuguegarao is being constructed on the basis of the Master Plan prepared by MPWH in 1964.

In spite of incessant efforts by the agencies concerned, the existing flood control and drainage facilities are of small scale and are executed sporadically, owing to the deficit of flood control budget. In these years annual flood control budget ranges ₱240 million to ₱700 million over the country and ₱4 million to ₱30 million for Region II(Table 2.6).

2.7 Other River Facilities

NIA constructed the Magat and MARIS dams in the upper reach of the Magat river. NIA also constructed Chico diversion weir with siphon in the upper reaches of the Chico river. The principal features of those structures are shown in Tables 2.7 and 2.8. Other diversion weirs are likewise located in the upper reaches of the Siffu and Mallig rivers.

The existing Magat dam has no flood control space in its reservoir. According to Operations Maintenance Dam Safety Manual, the reservoir shall be held at or below El.185 m at the end of June and July, and El.190 m at the end of August and September. For the rest of the period, the reservoir shall be held at or below full supply level (El.193 m). In other words the dam provides more or less flood control space during a limited period from June (about 276 MCM) to September (about 110 MCM). Operation rule curve of the Magat reservoir is shown in Fig.2.11. The Manual also mentions an intention to install an Early Flood Warning System by which Magat dam could have the ability to reduce flood peaks by drawing down the reservoir in advance of the flood arrival.

On the other hand, reservoir monitoring records prove that the dam has been substantially contributing to flood peak reduction during these years since its start of operation. Figure 2.12 shows the flood control effects of the existing Magat dam estimated based on the reservoir monitoring records since its start of operation in 1983. Taking an example of the biggest flood in October 19 to 20, 1985, the peak inflow to the dam reservoir of about 7,700 m^3/s was reduced up to peak outflow of about 4,500 m^3/s. The storage capacity actually used was 182 MCM during 24 hrs.

As for the other river facilities, five pumping stations for irrigation are located along the Cagayan river between Magapit and Tuguegarao. Despite manifest shiftings of river course, four stations are in operation without being affected. While the other one, Tuguegarao station is not functioning well since 1983 due to clogging by silting. The total intake volume from those stations is estimated to be 32.9 m^3/s at maximum. General features of these stations are shown in Table 2.9.

Principal features of the major bridges crossing and along the Cagayan river are shown in Table 2.10. The superstructures of these bridges are of truss or metal girder of I-beam. The substructures thereof are reinforced concrete piers and abutments. Abutments and piers of Jones, Minanga, Mallig and Batu Ferry bridges are damaged due to side erosion and scouring action. Foundation structures of these bridges are not known because drawings are not available.

2.8 Saline Water Intrusion

Saline water intrusion is a common phenomenon near a estuary. This phenomenon is resulted from a complicated dynamic interplay between the sea and river water. The phenomenon is generally clasified into three types from its mixing condition, i.e., weak, moderate and strong mixture. In the weak mixture zone, sea water forms a salt wedge intruding into the river. According to a preliminary survey, the lower Cagayan river seemed to fall under the weak mixture type.

The field investigation was conducted on March 8 and 9 in 1986 at the sites shown in Fig.2.13. Electric conductivities of river water at variable water depth were measured together with temperatures of water and discharges at reference sections. The electric conductivities were then converted to chloride concentration. Results of investigation are shown in Fig.2.14.

According to the longitudinal distribution of chloride concentration shown in Fig.2.14, resistant factor between the layers of saline and fresh water was estimated to be k = 0.0037. In estimating the resistant factor, distribution of chloride concentration for 500 ppm was used.

Farmer-Morgan's formula was applied to estimate the intrusion lengths of saline water for given discharges using the estimated resistant factor. Result of estimation is shown in Fig.2.15. From this figure tip of salt wedge reaches up to around Magapit bridge.

III. PRINCIPLES AND METHODOLOGY

3.1. Conceivable Flood Control Measures

In order to mitigate the flood damages in the Cagayan river basin, flood prevention and bank protection works are necessary. Revetment and groyne works are the principal measures for bank erosion by protecting river banks directly from flood flow or stabilizing river courses. Channel normalization can also be a measure for this purpose by keeping flood flow away from the critical banks. These bank protection measures can be taken spotly where they are needed.

As for the flood prevention, diking system and channel normalization are the direct measures to remove obstacles to flood flow. Construction of cut-off channels and improvement of Magapit narrows are conceivable as a measure of channel normalization. Since these flood prevention measures induce, more or less, concentration of flood runoff in the lower reaches, flood prevention measures should be planned from basinwide viewpoint.

Flood control dams contribute to the flood prevention by lowering the flood peak over the extensive lower reaches.

Suitable sites for effective retarding basin were not found in the basin. Instead, the channels of the upper Cagayan and tributaries were deemed to have considerable retardation functions contributing to the flood peak reduction in the middle and lower reaches of the main Cagayan.

According to the discussions in the above paragraphs, conceivable flood control measures are shown in Fig. 3.1. The flood control framework plan will be studied in line with the following principles:

1) Flood control dam should be considered in the upper watershed. The dam reduces peak flood runoff over the extensive lower reaches.

2) The existing channel retardation function should be conserved in the upper reaches of the main Cagayan river and tributaries. To these extent, efforts should be concentrated on bank protection measures.

3) For the middle and lower reaches of the main Cagayan, diking system should be provided as well as bank protection measures so as to protect lowlying lands from flooding due to runoffs from the extensive upper basins. The channel normalizaton to accelerate smooth and swift drainage of flood water should also be undertaken. Improvement of Magapit narrows could be a key to the flood control in these reaches.

3.2. Criteria for Planning

The flood control framework plan will be studied in line with the following criteria:

(1) General

1) Framework plan shall be studied based on the flood with 100-year return period. The 25-year flood will be applied to the long-term, master, and short-term plans.

2) Non-uniform flow shall be applied to channel flow calcutation of the main river and major tributaries. The following coefficients of roughness shall be adopted:

   $n = 0.040$: for low water channel
   $n = 0.060$: for high water channel confined by dikes
   $n = 0.10$: for flood plain

(2) Diking System

1) River width between dikes (W : m) shall be more than $10\sqrt{A}$, where A is basin area in km^2. This relationship was derived based on the design values of rivers in Japan (Fig. 3.2.)

2) Dike alignment shall be delineated with smooth line so as to

envelop existing river courses and lowlying lands along the river and to protect existing builtup areas and public facilities as much as possible.

3) The dike shall not be provided, in the present study, where the lands to be protected by the dike are narrower than the design river width as a whole. In these reaches channel retardation function shall be conserved.

4) Dike section shown in Fig.3.3 shall be applied. The section follows the Technical Standards for River and Sabo Works, Ministry of Construction, Japan.

(3) Flood Control Dams

1) Dam with single purpose for flood control shall be planned. Concrete gravity type dam is assumed.

2) The constant-ratio constant-amount outflow method was assumed for reservoir operation.

3) The flood control shall be started when the inflow reaches to an amount equivalent to the minimum specific discharges corresoponding to the minimum channel capacity in the lower reaches of the dam or average channel capacity in the reaches from Alcala to Tuguegarao.

4) Flood storgae capacity shall be decided as large as possible considering the site conditions. However, the outflow ratio shall be more than 0.1 for 100-year frequency flood hydrograph so that the flood control space may be recovered within a short period ready for coming floods. The outflow ratio (Rout) is defined as follows:

$$Rout = (Qout - Qcs) / (Qin - Qcs)$$

where

Qout : Outflow

Qin : Inflow

Qcs : Control staring discharge