The geology of this area consists of Precambrian gneiss as the basement, non-metamorphosed and low grade metamorphosed Paleozoic sedimentary rocks ranging from Cambrian to Permian time, and granitic rocks intruded accompanied with the orogenies. Sediments from Tertiary to Quarternary time are distributed in the lowlands along rivers in small scales. In mountainous area of gentle ups and downs, lateritic residual soil, which is a remain of weathered rocks unique to the tropics, is observed often.

Generalized geological sequence of the project area is shown in Table 5-4-1

5.5 Geology of Each Project Area

(1) Mae Pai Project area

i) Geology of project area

- Topography

  Mae Pai River starts in the mountainous area of 1,300 to 1,800 m (MSL) high at the north edge of the project area making the border between Burma and Thailand and flows toward south. The river changes the direction greatly in the downstream of Amphoe Pai, cutting the geological structure of the north-south direction from east to west.

  Six (6) dam sites have been proposed, numbered from No. 1 to No. 6 from the upstream to downstream but, as explained in Clause 5.2, two sites of No. 1 and No. 6 were chosen for this project.

  Mae Pai River meanders in the upstream of the No. 1 site and the river sides are generally open and flat.

The river width at the part between the No. 1 and No. 6 sites is narrowed and the both sides are in steep topography. As a whole, this part is in topography suitable for dam site, but there are many landslide configurations around the No. 2 site and in the slopes of both sides of the upstream.

Khong River, which is the largest tributary of Mae Pai River, flows nearly straight to south and joins with the Mae Pai River at the upstream of the No. 6 site.

The most significant topographical feature of the Mae Pai River basin is the Karst topography in the area of north of Mae Pai River and in the east and west sides of Khong River where Permian limestone is distributed. The Karst area is especially broad in the east side of Khong River and generally it is in the topography of platform. This Karst platform has heights ranging from 600 to 1,200 m (MSL) with the dges forming steep cliffs, but inside of the platform is generally in a pan shape with shallow bottom. Large and small sink holes are observable in everywhere of the platform, and many unique protruded hills with round top are seen.

The basin size of the Karst platform is about 500 km^2, and rivers in the platform like Nam Lang have no outlet. Water of these rivers seem to go underground at the bottom part of the pan shape topography.

- Geology

The geology of this area consists of non-metamorphosed and low grade metamorphosed Paleozoic sedimentary rocks ranging from Cambrian to Permian time and granitic rocks intruded during Carboniferous and Triassic time.

The Cambrian - Ordovician strata that forms the lowest strata of this area consist of low grade metamorphosed sedimentary rocks. This strata are mainly composed of quartzite, and are distributed around the No. 6 site.

The Ordovician strata (Thung Song group) mainly consist of limestone, and are distributed widely in the No. 6 site reservoir. The limestone is often interbedded with shale and sandstone. Karst topography is not too apparent in the distribution area of this strata.

The Silurian - Devonian strata consist of shale, sandstone and chert. This strata are distributed in higher parts along Mae Pai River overlying the Ordovician strata.

The Carboniferous strata consist of shale, sandstone and conglomerate, and are distributed widely along Khong River.

The Permian strata (Rat Buri group) consist of limestone, and are widely distributed in higher parts along Khong River overlying the Carboniferous strata. As exaplained above, in the area where this strata are distributed, the Karst topography is very significant.

Granitic rocks are distributed widely in the east part of the

No. 1 site. The mountains composed of granitic rocks are in shape of gentle slope with fine pleats, therefore granitic rocks seem to have been deeply weathered.

Semi-consolidated or unconsolidated sediments of Tertiary and Quarternary age are distributed in the lowlands along Mae Pai River in the upstream of the No. 1 site and downstream of the No. 6 site.

Geological structure of this area is generally in the north-south direction. The strata of this area are folded and faulted. Faults in the north-south direction are very prominent and some of them are thrust fault. The thrust fault existing in the downstream of about 2 km from the No. 6 site is very large in the scale and very clear fault topography is recognizable.

ii) Site geology

a) Mae Pai No. 1

- Dam site

The river width at the upstream dam site is slightly broad but the slopes at the both banks are comparatively steep. Huai Mi, one of the tributaries of Mae Pai River, flows in at the left side of about 600 m upstream of the dam site in a form of deep valley. The mountain body of left bank of the dam site is in a form of narrow ridge stretching in the east-west direction.

The downstream dam site is situated at about 2 km down of the upstream dam site. The river width at this site is about the same as that of the upstream site, but the slopes are fairly steep. A landslide configuration is found on the right side slope about 1 km up of the dam site.

The elevation of the river surface is about 400 m (MSL) at both dam sites.

The bedrocks of the upstream dam site consist of limestone mainly. The limestone shows generally banded texture of dark and bright, and are recrystallized some degree.

In the outcrops at the right bank of the dam site there exists caves of 2 to 30 cm diameter and solution cracks of 10 to 30 cm width formed along joints. The limestone around the upstream site is often interbedded with shale and sandstone.

The strata strike NE-SW crossing with the river direction almost squarely, and steeply dip toward the downstream.

In the slopes at both banks of the dam site, rocks are exposed and obverburden is generally thin. The river deposits mainly consist of fine sand with less gravel.

The bedrocks of the downstream dam site consist of limestone, likewise as the upstream site, but no interbedding with shale and sandstone is recognizable. Based on observation the outcrops at the right bank of the dam site, there are caves and solution cracks in the limestone, same as those in the upstream site. Some of the stalactites hanging from these caves and solution cracks are as large as 30 to 40 cm in the diameter and 2 m in the length.

The strata strike NW-SE, crossing with the river direction diagonally, and dip gently toward the downstream.

Rocks are exposed in both banks of the dam site and the overburden is thin. At the higher parts of the slopes, continuous limestone makes cliffs. The river deposits are mostly fine sand with less gravel.

Landslide configuration of about 500 m wide and 200 m high is found in the right bank in the upstream of 700 to 1,200 m from the dam site. In this slope, sediments mixed with rock blocks fallen from the upper slope are thickly deposited and slide of these sediments in small scales are often recognized.

In consideration of all these topographical and geological conditions, the upstream site seems to be better as a dam site. In other words, topographically the downstream site is suitable as a dam site but, the bedrock of downstream site consist of limestone having well developed caves and solution cracks, therefore it contains leakage problems. Also, in its immediate upstream, there is a landslide configuration and landslide is feared after ponding.

On the other hand, though in the upstream site bedrocks consist of limestone, same as the downstream site, in view of the fact that "it is interbedded with water tight strata of shale or sandstone" and "the strata strike almost square to the river flow direction, and steeply dip", the upstream site seems to be less possibility of leakage than in the downstream site.

Based on the above geological judgement, we consider that the upstream site should be taken up as the objective of the project. However, one thing to be noted is that the left bank ridge of the upstream site is narrow in the width and since the strata strike in the direction of crossing the ridge, there may be water leakage from the reservoir to the dam site downstream crossing this ridge.

- Reservoir area

Mae Pai River keeps meandering in the upstream area from the point of about 1.5 km up of the upstream site and a broad flat plane develops along the river. Except the landslide configuration observed at the right bank of immediately up of the downstream site, there is no topography that would cause problems after ponding. The reservoir geology is composed of granitic rocks mostly. Strata that mainly consist of limestone are distributed in the downstream area from about 1 km up of the upstream site.

No topographical and geological problems can be foreseen as a reservoir, but within the reservoir in the distance of about 20 km up of the upstream site, there is a fluorite mine.

- Construction material

In the upstream from about 2 km up of the dam site, gentle slopes develop along Mae Pai River and there are sediments of weathered granites. As seen at the left side, these sediments are arenaceous and though may not be appropriate, some of them may be used as soil materials. Especially, at some places of the right side, there are areas where the sediments are thick, and soil materials are expected from these places.

As to the sand and gravel materials, we consider that fine grained materials are obtainable from the sediments of weathered granites mentioned above and from the riverbed deposits area located at 5 to 10 km upstream of the dam site. Existence of coarse grained materials are expected in the river deposits area mentioned above.

Rock materials are probably available in the limestone area around the dam site. However, the quarry site must be carefully selected since limestone in the area are often interbedded with shale and if too much shale is interbedded, it may cause problems with the rock quality.

b) Mae Pai No. 6

- Dam site

The topography of the dam site forms a V-shaped valley, with a narrow river width and the steep slopes. The elevation of the river surface is about 230 m (MSL).

The bedrocks of the dam site consist of quartzite and argillite.

The quartzite is fine to medium grained, massive, dense and hard rock in color from light grey to greenish light grey. Joints along the bedding plane are prominent in this rock, and some of the joints are open. The argillite is fine grained, massive, dense and hard rock in colors of grey, greenish grey or purplish grey. Prominent bedding plane is locally observed, but splitting along it is not noticeable. According to microscopic observation of thin sections, the argillite consists of quartz grains of 0.1 to 3 mm diameter and the matrix mainly composed of microcrystalline quartz, sericite and chlorite and rarely muscovite.

The strata strike NNE-SSW crossing with the dam axis diagonally, and dip generally 20 to 40° toward the downstream.

Generally, minor folds are developed, and at about 200 m upstream of the dam site, anticlinal fold is noticed.

No large photo lineaments are observed around the dam site but at the right bank of the dam site, there are sheared zones in widths of several centimeters to about 10 m nearly along the bedding plane. There are many cracks at fine intervals in these sheared zones, but the crack faces are contacting very closely and no clay is interbedded in the cracks. In some sheared zones, however, springs through cracks are observed.

The rocks crop out up to 50 to 60 m of the relative height at both banks of the dam site. In the slopes higher than that, outcrops are rare and as evidenced with the DH-3 hole drilled at the right bank of the dam site, some parts have thick overburden of 7.5 m.

Distribution area of river deposits is narrow.

At this site, drilling of 3 holes was executed on the dam axis. The results indicate that at the DH-1 point (446.22 m altitude) of the left abutment, rocks are weathered in depth of 4 m from the surface and they are loosened. Rocks in parts deeper than 4 m seem to bear no problem as foundation of a rock-fill dam generally, although some have been slightly weathered and partially interbedded with sheared zones.

Permeability was found to be large, 8 to 25 Lu, up to the depth of about 50 m, but beyond the depth, it is about 1 Lu.

The DH-2 point (228.96 m altitude) of the river bed has extremely good bedrock, and the permeability is below 5 Lu.

At the DH-3 point (387.79 altitude) of the right abutment, overbuden is distributed up to the depth of 7.5 m from the surface. The bedrock in the area of deeper than 7.5 m is slightly weathered up to 32.0 m and interbedded with cracky zones. However, the bedrock deeper than 14 m is fairly hard and it seems to bear no problem as foundation of a rock-fill dam.

The permeability is generally below 5 Lu, except in area of 27 to 30 m, large permeability of 39.4 Lu was noticed.

Thus, this site bears comparatively less problem as a dam site both topographically and geologically. There seems to be no problem on the bearing strength of the sheared zones existing in the right bank, but since the permeability appears large, the characteristics must be checked further.

- Reservoir area

  The reservoir is branched to two (2) rivers; Mae Pai River and its right tributary, Khong River. Both rivers form gorges generally, but Khong River has a slightly open tendency.

There are many large scale landslide configurations in the mountain slopes of the Mae Pai River upstream. These configurations are observed in the slopes of both sides in places where the elevation of the river surface is 350 to 400 m (MSL).

Karst topography is developed apparently in the vast area of east of Khong River with the south end limited by Mae Pai River. Also, this topography is noticeable in small scale in the west of Khong River.

In the area along Mae Pai River, there exist strata of Cambrian to Ordovician, Silurian to Devonian and Carboniferous age. Among them, the Cambrian to Ordovician strata consist of quartzite and argillite, and major parts of the Sulurian to Devonian and Carboniferous strata are shale and sandstone.

Limestone of the Ordovician is distributed widely in the reservoir. This limestone is often interbedded with shale and sandstone and Karst topography like sink holes is not too apparent. Landslide configurations are often noticed in the distribution area of this limestone.

The Carboniferous strata are distributed in the area along Khong River and limestone of the Permian overlies these strata. Karst topography is very apparently developed in the distribution area of this limestone. Generally, the limestone is distributed in places higher than 600 to 700 m (MSL). The lowest limit of the distribution is not clear because of talus deposits under cliffs of limestone, but it seems to be higher than 400 m (MSL).

Thus, the base of this limestone seems to be located at higher levels than the planned high water level (400 m MSL), and there seems to be no leakage problem related to this limestone. However, the base of the limestone must be checked at the field.

There seems to be less fears of leakage from the reservoir through limestone of the Ordovician in consideration that "the limestone is frequently interbedded with watertight beds like shale and sandstone", "no large fluctuation is noticed in the running water of Mae Pai River in the limestone distribution area" and "Karst topography has not been developed prominently". However, this view must be confirmed through hydrogeological surveys from now on.

The landslide configurations existing in the reservoir upstream are large in the scale, and their actual condition must be checked at the field to review influence after ponding.

- Construction material

  NEA has already carried out a preliminary survey on soil, sand and gravel materials.

  The location for soil materials is about 13 km northwest of the dam site. The materials available here are residual clay of limestone and weathered secondary sediments of shale and sandstone. These materials must be mixed with coarse grained materials since they do not have enough coarse grains. The coarse grained materials seem to be available in the area south of it where shale and sandstone are distributed. The shale and sandstone in this area are fairly weathered and these materials may be used as soil materials.

The site for sand and gravel materials is located in the area of river bed deposits, 3 to 7 km down of the dam site. It seems enough sand and gravel materials are available in the area. But, there is a hot spring in the near area, thus in case of using the material as concrete aggregates, whether or not deteriorating elements are in it must be checked.

For rock materials, quartzite in area of 2 km down from the dam site, sandstone in the area of about 5 km down from the dam site, and limestone in the north of above mentioned soil materials area are being planned. These rocks seem to be usable as rock materials from the viewpoint of rock quality.

(2) Mae Chaem Project area

i) Geology of project area

- Topography

Mae Chaem River starts at the watershed with Mae Pai River at a height of 1,000 to 1,400 m (MSL) and flows toward south with meandering.

Five dam sites are proposed on Mae Chaem River, No. 1 through No. 5 from upstream.

Mae Chaem River changes the flow direction greatly at about 25 km up of the No. 5 site, from northwest to southwest and joins with Mae Ping River at about 20 m down of the No. 5 site.

The river gradient is generally gentle and both sides are open. In the downstream of the No. 4 original site, there spreads a plane in width of about 2 km and in length of about 6 km and in it the village of Amphoe Mae Chaem exists.

The elevation of the eastern and western watershed of Mae Chaem River is 1,000 to 1,800 m (MSL). Doi Inthanon of 2,590 m high (MSL), the highest mountain in Thailand stands in a great shape at northeast of Amphoe Mae Chaem.

- Geology

The geology of this area consists of Precambrian gneiss, non-metamorphosed and low grade metamorphosed Paleozoic sedimentary rocks ranging from Cambrian to Carboniferous time, and granitic rocks intruded during Carboniferous and Triassic time. No Permian limestone which has prominent Karst phenomena exists in this area.

Precambrian gneiss makes the basement of this area and it is widely distributed in the No. 5 site and around the eastern watershed of Mae Chaem River.

The Cambrian-Ordovician strata consist of low grade metamorphosed sedimentary rocks mainly composed of quartzite, and are distributed in small scale in the No. 5 site reservoir and catchment area.

The Ordovician strata (Thung Song group) mainly consist of limestone, and are distributed mainly around the No. 3 and No. 4 sites and in the reservoir of the No. 5 site. No Karst topography like sink holes is observable in the area where this strata are distributed.

The Silurian - Devonian strata consist of shale, sandstone and chert, and are widely distributed along Mae Chaem River in the upstream of the No. 4 site.

The Carboniferous strata consist of shale, sandstone, and conglomerate, and are distributed in the west area of Mae Chaem River in the upstream of the No. 3 site.

Granitic rocks are widely distributed in the upstream of the No. 1 site and west and east mountainous areas of Mae Chaem River.

Semi-consolidated or unconsolidated sediments of Tertiary and Quarternary age are distributed in a small scale, in the lowland along the river.

The geological structure of this area is generally in south-north direction, and south-north trending folds are well developed. Photo lineaments in the NW-SE and NE-SW directions are prominent.

ii) Site geology

a) Mae Chaem No. 1

- Dam site

The dam site forms asymmetric topography with the gentle slope at right bank. Mae Chaem River meanders often in the dam site area. The elevation of the river surface is about 760 m (MSL).

It seems that the bedrocks of the dam site consist of strata mainly composed of shale, sandstone and conglomerate. Photo lineaments in the NW-SE direction area well developed around the dam site but are not observed in the dam site itself.

Thus, no geological problems as a dam site can be seen in this site, but the topographical conditions are not too favorable for a dam site.

- Reservoir area

  Topography along Mae Chaem River is comparatively open. There is a saddle-back of about 900 m high (MSL) in the east of Doi Khan Huai Bong (1,127 m high (MSL)) in the right bank of the reservoir.

  The aerial photo geological interpretation was not carried out to the whole reservoir area but within the interpreted area, there is no particular topography that bears problems in relation to ponding.

  The geology of the reservoir area consists of shale, sandstone, conglomerate and granitic rocks, and the Tertiary strata area partially distributed.

  Thus, this area has no significant topographical and geological problems for a reservoir but attention must be paid to the existence of the saddle-back of about 900 m high (MSL) and the apparent photo lineament in the NW-SE direction.

b) Mae Chaem No. 2

- Dam site

  The dam site forms a comparatively gentle valley with broad river width. Though there is a small saddle-back at the right bank of the dam site, the topography is comparatively steady. At the slope of the right bank, there are several creeks.

The elevation of the river surface is about 700 m (MSL).

The bedrocks of the dam site seem to mainly consist of shale. No apparent photo lineament is recognized around the dam site. Existence of thick talus deposits are expected in the lower part of the slopes at the both banks.

Thus, no particular geological problems are recognized except the thick overburden at the lower part of the slopes, but the topographical conditions do not seem to be too suitable for a dam site.

- Reservoir area

Mae Chaem River gathers many tributaries and meanders in small scale. The topography along the river including the tributaries is slightly open.

No topography like landslide that would cause problems in relation to ponding is recognized within the reservoir.

The geology of the reservoir consists of limestone and shale. Karst topography like sink holes is almost never recognized in the limestone distribution area.

It is considered that possibility of leakage from the reservoir is very small, though there is limestone in the reservoir since hardly any Karst topography is recognizable in the limestone and in consideration of the reservoir geological strcuture.

c) Mae Chaem No. 3

- Dam site

The dam site forms a slightly gentle valley with broad river width, but the upper part of the left bank slope makes continuous steep cliffs. The elevation of the river surface is about 600 m (MSL).

The bedrocks of the dam site consist of shale and limestone.

The shale is a dense and hard rock in color of dark grey, but has tendency of easily broken along the bedding plane generally.

The limestone is a dense and hard rock having banded texture in color of light grey to grey. The limestone is distributed at places higher than relative height of about 120 m from the river surface, and conformably overlies shale. Generally the limestone makes cliffs. Many caves of 2 to 30 cm diameters and solution cracks along the joint exist on this limestone. Large caves of 10 m diameter are found in the outcrop at the right bank of the dam site downstream.

The strata strike crossing with the watercourse direction almost squarely, and dip gently toward the downstream.

Sediments consisting of limestone blocks are distributed in the lower slope of the limestone cliffs at the right bank. Judging from the slope gradient, the sediments seem to be thick.

The river deposit consists of fine sand with less gravel.

There is a hot spring in the riverbed in immediate upstream of the dam axis. Blowing of the hot spring is not much but the temperature is high. Sand around the outlet is blackish and the air around has sulphur odor.

Judging from that the valley is open, and the existence of hot spring in the riverbed, which bears possibility of existence of weak zone like alteration zone, and assumption of the overburden being thick at the left bank, this site does not seem to be so suitable as a dam site.

The limestone around the dam site do not seem to have possibility of water leakage since the distribution is limited to higher parts about 120 m relative height from the river surface in the dam axis and its upstream.

- Reservoir area

Mae Chaem River gathers many tributaries and meanders in small scale. Topography along the rivers including the tributaries is open slightly. No topography like landslide that would cause problems in relation to ponding is recognized within the reservoir.

The geology of the reservoir mainly consists of shale, and limestone exists in the reservoir close to the dam site. The characteristics of this limestone are not too clear at present, but it seems to be in a different stratigraphic horizon from the limestone existing around the dam site.

Accordingly, the key geological point of this site as a reservoir is how this limestone is distributed.

d) Mae Chaem No. 4

- Dam site

The originally planned dam site forms asymmetric topography with steep slope at the left bank and gentle slope at the right bank. The river width is comparatively wide. The elevation of the river surface is about 500 m (MSL).

The bedrocks of the original site consist of shale and limestone.

The shale is a hard and dense rock in color of dark grey, but generally has tendency of being easily broken along the bedding plane. The shale around the dam site has been distributed much by the folding and prominent weathering is also recognizable. The shale is widely distributed in the right bank of the dam site.

In the right bank of the dam site downstream, the shale is inter-bedded with alternating beds of shale and limestone, each having a thickness of 1 to 5 cm. The limestone in the fine alternating beds is soluted, resulting in a sandwich appearance of the thin shale layer being protruded.

The limestone is a hard and dense rock in color of grey to dark grey, and generally has a banded texture of dark and bright color tone. This limestone is widely distributed in the right bank of the dam site and in the reservoir. Many caves of 2 to 30 cm diameter and solution cracks exist on this limestone. Sometimes, large caves of 5 m diameter are found. The outcrops along the river are soluted laterally up to 1 to 2 m high above river surface.

Almost no overburden exists at the left abutment. At the right abutment, residual soils are distributed in a thickness of about 2 m, but the bedrock has been weathered deeply.

The river bed deposits consist of fine sand with less gravel.

The alternative dam site is located at about 6 km upstream of the above mentioned originally planned dam site.

The alternative dam site forms gentle topography with very gentle slope at left bank. The river width is comparatively wide. The mountains at the both banks of the dam site form ridge stretching in the east-west direction, and narrow width saddle-backs of about 620 m high (MSL) exist at the both sides.

The river meanders in large bends at the dam site upstream. The elevation of the river surface is about 510 m (MSL).

The basement of the dam site consists of shale. Conglomerate and breccia, that seem to be of the Palaeogene, overlie the basement.

The shale is a hard and dense rock in color of dark grey, and has tendency of being easily broken along the bedding plane. This shale is exposed in creeks at the left bank around the dam site.

The conglomerate and breccia are distributed around the dam site overlying the shale. The conglomerate contains pebbles of chert, shale and sandstone of 1 to 30 cm diameter, and the matrix consists of sand or clayey sand of brownish tone. This conglomerate is firmly consolidated.

The breccia consists of rubbles of shale of 1 to 20 cm diameter and the matrix consists of fine grains of shale. Often, rubbles of limestone are recognized in breccia. The breccia is also firmly consolidated.

It seems that the conglomerate and breccia are gradational. Breccia is developed in the right bank of the dam site and upper part of the left bank.

Terrace deposits are distributed in the lower part of the dam site right bank overlying conglomerate and breccia. Topsoil and talus deposits are distributed widely covering the slopes. These deposits are thicker at the right bank, and the thickness is assumed to be 4 to 5 m.

The river deposits consist of fine sand, but sometimes, granite boulders of 20 to 100 cm diameter are observable.

The original site is topographically superior to the alternative site. However, as mentioned in the above, at the original site, limestone with many caves and solution cracks is distributed around the dam site and within the reservoir. Therefore, water leakage from around the dam site is feared. In the alternative site, saddle-backs exist at the both sides and leakage from these areas is feared.

Thus, both sites are not free from anticipation of leakage, but in expectation of possibly solving the problem by foundation treatments and in view of easiness of the investigation, this master plan adopts the alternative site for the project.

This does not mean discarding the original site. Hydrogeological investigation must be proceeded in the limestone distributed area of the original site along with the investigation works in the alternative site. Final review can be made based on these investigation results.

The conglomerate and breccia of the alternative site seem to belong to young geological time, but as a whole, they are consolidated firmly. Therefore, it seems they have not so problems in their bearing strength as a rock-fill dam foundation. The cementation between grains is strong and there are only few cracks, so that permeability problem will be less. However, these views are only based on the surface reconnaissance and since the origin of these conglomerate and breccia have not been clarified up to present, whether or not they would be suitable for the foundation rock of dam must be investigated further.

- Reservoir area

The reservoir is divided into two (2); Mae Chaem River and its tributary, Huai Mae Yai River. Both rivers meander and topography along the rivers are open. Except the three saddle-backs existing in the neighborhood of the alternative site, there is no particular topography that would cause problems in relation to ponding.

The bedrocks of the reservoir mainly consist of shale, but limestone is distributed in the area between the original and alternative sites. Karst topography like sink holes is hardly recognizable in aerial photos, but in the outcrops along the river a number of large and small caves are developed. In the neighborhood and upstream of the alternative site, granitic rocks and Tertiary strata exist.

Accordingly, the problems as a reservoir are distribution and property of limestone in the original site and geological conditions of the saddle-backs in the alternative site, all of which are the same problems as those of the dam sites.

- Construction material

  In the original site, residual soil and weathered shale at the dam site right bank or the Tertiary strata at the dam site downstream may be used as the soil materials. The sand and gravel materials would be obtained from the river bed deposits distributed area along Mae Chaem River at the area of 5 to 10 km downstream of the dam site. Limestone is available in the dam site area for the rock materials.

  In the alternative site, the soil materials are expected at the Quarternary sediments existing in the plane of about 3 km east of the dam site. Also, limestone is distributed in this area, which might be used as the rock materials. Furthermor, limestone is available from the dam site downstream for the rock materials. The sand and gravel materials would be available from the terrace deposits distributed area in the neighborhood of Ban Sob Wak of about 1 km upstream of the dam site.

e) Mae Chaem No. 5

- Dam site

The dam site forms gentle topography with developed river terraces at the left bank. The slopes at the both banks are in gentle gradient up to the relative height of about 100 m above the river surface and beyond it, the slopes are steep with about 40°. The elevation of the river surface is about 330 m (MSL).

The bedrocks of the dam site consist of gneiss, granitic rocks, and pegmatite veins. Gneiss intercatates thin lime-silicate rocks partly.

The gneiss is medium to coarse grained, massive, hard and dense rock of grey. The gneiss has gneissosity arranged with colored minerals (mainly biotite). The biotite rich zones are weak and are apt to break along the gneissosity. The gneiss is widely distributed around the dam site.

On the outcrops at the national highway of the right bank of the dam site, weathering and joints are observed prominently. However, in the outcrops at higher parts of both banks, joints are hardly observed, and the weathering is limited to the surface only.

The granitic rocks are fine to medium grained, massive, hard and dense rock,of light grey. The granitic rocks intrude into the gneiss irregularly or in parallel to the gneissosity. The granitic rocks are usually massive but weak gneissosity is recognized partially.

The pegmatite is coarse grained rocks of light grey. Grain size of the mineral is 1 to 3 cm usually, but occasionally large sizes of about 5 cm can be seen. The pegmatite, occurring in the form of veins in gneiss and granitic rocks, is generally small in scale.

The lime-silicate rock is fine to medium grained, hard and dense rock of light greenish grey. The rock is locally intercalated in gneiss in thickness of 1 to 2 m. The contact of lime-silicate rock and gneiss is very close, and no trace of solution is recognizable.

Overburden of slopes at the both banks is thin and weathering of the bedrock seems to be not too deep generally. However, thick sediments consisting of silt to fine grained sand are deposited along the river. The DMC5-2 drill hole in the riverbed indicates that the silt to fine grained sand are deposited in thickness of 20 m from the river bed level.

Drilling of three holes on the dam axis and one hole each at the intake and power house site was carried out. The drilling results on the dam axis indicates favorable bedrock conditions at higher parts (480 m altitude) of the both abutments. Sediments consisting of silt to fine grained sand are deposited thickly in the riverbed as described before. The bedrock below have no problem as a dam foundation.

At the DMC5-4 hole (464.4 m altitude) of the intake, depth down to 3 m from the surface is residual soil, and the area between

4 m and 9 m is slightly weathered and loose bedrock, but depth from 9 m on is hard and dense bedrock.

At the DMC5-5 hole (343.4 m altitude) of the power house, depth down to about 3.5 m from the surface is residual soil, and the area between 3.5 m and 7 m is weathered and brittle bedrock, but depth from 7 m on is hard and dense bedrock.

As far as the permeability test results of the DMC5-2 hole of the riverbed indicate, the permeability is very small with a few exceptions.

As has been explained, this site does not seen to be so suitable for a dam site topographically since the valley is open. However, geologically, there is no particular problem except the thick sediments in the riverbed.

- Reservoir area

Upstream of the reservoir forms gorge topography, but in the downstream from the confluence with its tributary, Huai Mae Ka, planes are developed along the river. Topography like landslide configuration that would cause problems in relation to ponding is not recognized in the reservoir.

The geology of the reservoir mainly consists of gneiss and limestone. Granitic rocks and the Tertiary strata exist partially. The limestone is mainly distributed in the midstream left side. Karst topography like sink holes is hardly recognizable in this limestone. The limestone is distributed in the form of being surrounded by gneiss, granitic rocks and the Cambrian -Ordovician strata.

Therefore, this site seems to have no topographical and geological problems as a reservoir.

- Construction material

According to NEA's preliminary survey, the Tertiary and Quarternary strata distributed area in the upstream of about 10 km from the dam site is the objective soil materials area.

Results of grading analysis on two samples indicate that the materials are usable as the soil materials. It seems that the same quality materials exist in place closer to the dam site. Therefore, further investigations should be conducted in this place.

The location of the sand and gravel materials is the river deposits distributed area of about 5 km upstream from the dam site.

The rock materials are available from limestone distributed in the area of about 20 km northwest of the dam site, but the distance might be too long. Gneiss have tendency of being easily broken along the gneissosity generally. However, the gneiss exposing in the both abutments of the dam site forms massive body, and massive granitic rocks are often intruded in the gneiss.

There is a possibility of discovering gneiss that can be used as the rock material near to the dam site.

(3) Mae Khan Project area

i) Geology of project area

- Topography

Mae Khan River starts at the watershed with Mae Pai River and Mae Chaem River, having a height of 800 to 1,400 m (MSL) and flows toward southeast with meandering. Two (2) dam sites are proposed to Mae Khan River; No. 1 and No. 2 from the upstream. The river joins with Mae Ping River at a point of about 25 km down from the No. 2 site.

- Geology

The geology of this area consists of the Precambrian gneiss as the basement and sedimentary rocks of Ordovician, Silurian - Devonian and Carboniferous age and granitic rocks that intruded during Carboniferous or Triassic age.

The Precambrian gneiss is widely distributed along Mae Khan River.

The Ordovician strata (Thung Song group) mainly consists of limestone, and are distributed in the northeast part of this area.

The Silurian - Devonian strata consist of shale, sandstone and chert. These strata are distributed in the north and northeast parts of the area in the form of thrusting over the gneiss.

The Carboniferous strata consist of shale, sandstone and conglomerate, and is distributed in the northwest and east parts of the area.

The granitic rocks are distributed in the southwest part of the area.

Semi-consolidated or unconsolidated sediments of Tertiary or Quarternary age are distributed in small scale.

Geological structure of this area is generally in the NW-SE direction. Photo lineaments in the NW-SE or NNW-SSE direction are prominent. Especially, the thrust fault at the north of Mae Khan River is continuous for a long distance and the scale is very large.

ii) Site geology

a) Mae Khan No. 1

- Dam site

The dam site forms gentle topography with wide river width. The elevation of the river surface is about 600 m (MSL).

The bedrocks of the dam site consist of gneiss, but at the higher part of the left bank, strata consisting of shale, sandstone and chert seem to be thrust over the gneiss. The fault estimated in the dam site downstream seems to extend to the river bed of this area.

Development of open cracks along the gneissosity is assumed on the gneiss, as will be explained in the No. 2 site. Also, from the look of gentle topography of the dam site, deep weathering of the slopes at the both banks is assumed. Judging from these points and possibility of fault existence as mentioned before, this site seems to have geological problems as a dam site.

- Reservoir area

  Mae Khan River meanders and topography along the river is generally open.

  The geology of the reservoir mainly consists of gneiss, and in some parts, strata consisting of shale, sandstone and chert are thrust over the gneiss.

  The key point for a reservoir geology is the distribution and property of this thrust fault.

b) Mae Khan No. 2

- Dam site

  The dam site forms gentle topography, with comparatively narrow river width.

  The bedrocks of the dam site consist of gneiss.

  The gneiss is medium grained, dense and hard rock of grey. Gneissosity with colored mineral (mainly biotite) arrangement is developed in the gneiss. The gneissosity strikes almost square to the watercourse direction, and dips gentle, at 10 to 20°, toward the downstream.

  Joints along the gneissosity are prominent. These joints are open at the surface frequently and some are as wide as 50 cm. The surface of these open joints are smooth.

  The overburden is generally thin and in the slopes at the both banks hard bare rocks are found up to a relative height of 10 to 15 m above the river surface. Weathered rocks exist sporadically in the upper slopes.

Hard gneiss is exposed in the riverbed, but it is assumed that weathering is deeper in the upper slopes.

Open joints of low angles are prominent along the gneissosity in the outcrops of the riverbed. In this site, property of open joints will be a problem.

- Reservoir area

  Mae Khan River flows straight generally, and no plane develops alongside the river.

  The geology of the reservoir mainly consists of gneiss. In some parts, strata consisting of shale, sandstone and chert are thrust over the gneiss.

  The key point for a reservoir geology is the distribution and property of this thrust fault.

(4) Mae Pai -Mae Chaem Transbasin Scheme site

In this master plan, transbasin scheme is reviewed in two ways; to pump up to Mae Chaem River from the point of about 4 km up of the Mae Pai No. 1 site, and from the point of about 8 km down of the No. 1 site (for details, refer to Chapter 6).

Extension of the water tunnel is about 14 km for the upstream plan and about 24 km for the downstream plan.

a) Upstream route

The bedrocks of the upstream plan route are expected to be granitic rocks mostly. Topography of this area is general gentle and deep weathering of the granitic rocks is expected.

Several photo lineaments in the direction of ENE-WSW and WNW-ESE are recognized in the water tunnel route. One of these photo lineaments may be related to the hot spring existing in Huai Ban Paeng that joins with Mae Pai River at about 8 km upstream of the No. 1 site.

b) Downstream route

The bedrocks of the downstream plan route are expected to be strata consisting of shale, sandstone and chert mainly. In addition, limestone and granitic rocks are distributed partially.

In the water tunnel route, several photo lineaments in the direction of WNW-ESE are recognized.

References

5.1 Geological Map of Northern Thailand
1:250,000 scale Sheet No. 2 and 3 (1976 and 1977)
" Sheet No. 4 and 5 (1970)
German Geological Mission in Thailand

5.2 Geological Map of Thailand
1:250,000 scale Changwat Lampang sheet (Sept. 1971)
Royal Thai Department of Mineral Resources

5.3 Field Reconnaissance of Nam Pai Dam Sites
Engineering Consultants, Inc. (Jan. 1972)

5.4 Final Report of the German Geological Mission to Thailand
Geological Survey of the Federal Republic of Germany
(July 1972)

5.5 Foundation Investigation of the Proposed Nam Pai Dam Sites,
Nam Pai Project
Srisusarp (Dec. 1974)

5.6 Preliminary Geological Investigation of Mae Chaem No. 4 Project
NEA (1979)

5.7 Preliminary Geological Investigation, Nam Mae Chaem Project No. 5
NEA (1979)

5.8 Geological Investigation of Reservoir Area, Nam Pai Project,
Mae Hong Song
NEA (1979)

5.9 Report of Preliminary Investigation,
Mae Pai and Mae Chaem River Hydroelectric Power Development Plan
in the Kingdom of Thailand
JICA (Mar. 1980)

5.10 The geology of the Nam Pai Dam Site VI and Reservoir Area,
Nam Pai Project
NEA (Sept. 1980)

5.11 Geologic Log of Drill Hole of Mae Chaem No. 5 Project Dam Site
NEA (1980)

Appendix

Collected Data (Data collected in Thailand during the last survey mission. Aerial photos were kept in Thailand due regulations.)

Geology

1. Aerial photograph

Mae Pai River basin		101 sheets
Mae Chaem River basin		165 sheets
	Total	266 sheets

2. Geological map

a) Geological map of Northern Thailand
1:250,000 scale Sheet No. 2 and 3 (1976 and 1977)
" Sheet No. 4 and 5 (1970)
German Geological Mission in Thailand

b) Geological map of Thailand
1:250,000 scale Changwat Lampong Sheet (Original)
Royal Thai Department of Mineral Resources (Sept. 1971)

3. Previous geological data

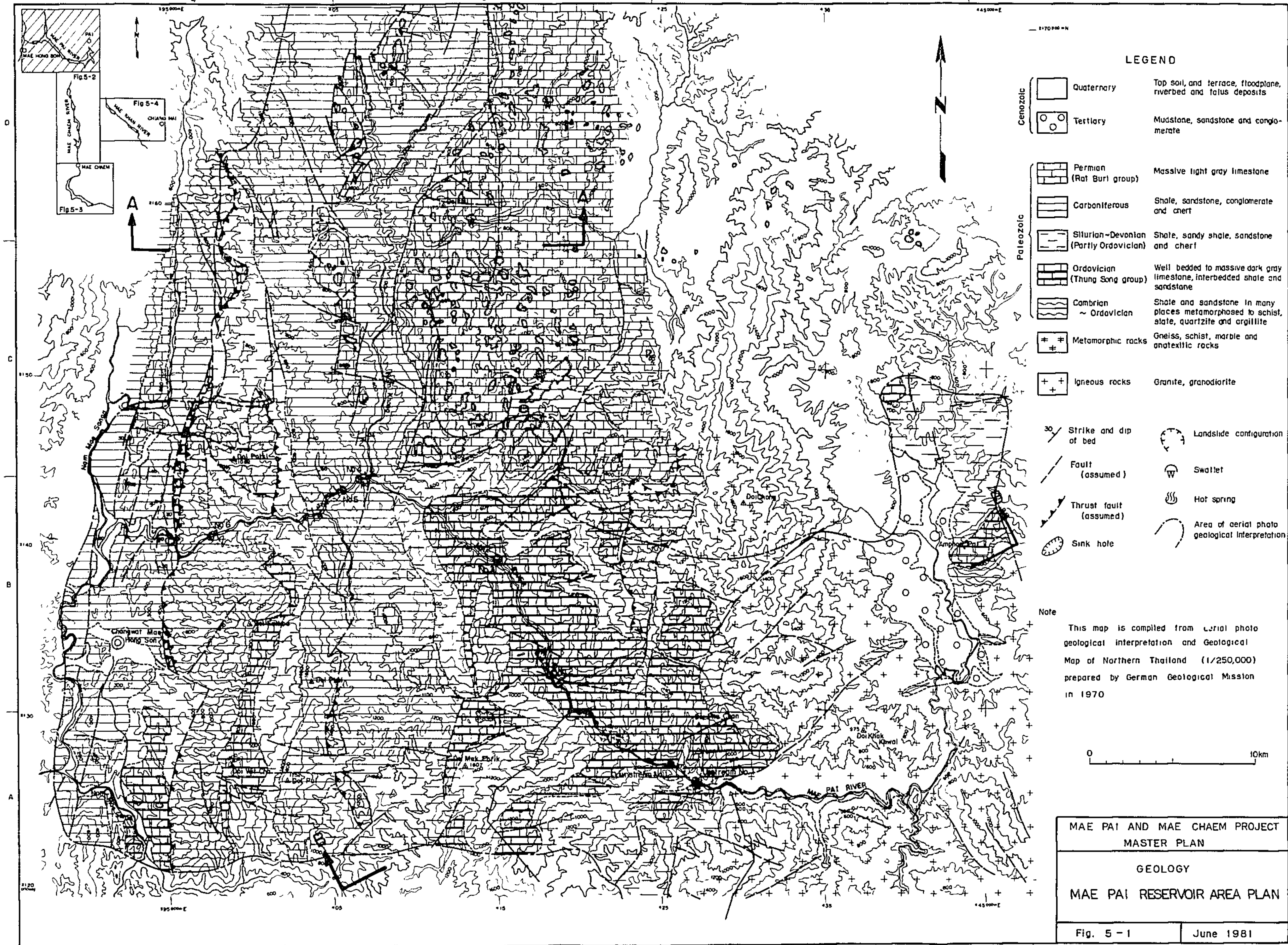
a) Foundation investigation of the proposed Nam Pai Dam Sites, Nam Pai Project
Srisusarp V (Dec. 1974)

b) The geology of the Nam Pai Dam Site VI and Reservoir area, Nam Pai Project, Vol. I, II_c and III
Engineering Geology Section, NEA (Sept. 1980)

c) Data of drill hole
Geologic log of drill hole of Mae Chaem No. 5 Project Dam Site, drill hole No. DMC5-2, DMC5-4 and DMC5-5
Engineering Geology Section, NEA (1980)

4. Report on earthquake

Seismic activities and major faults in Northern Part of Thailand for Geothermal Energy Research Project
EGAT (Jan. 1980)



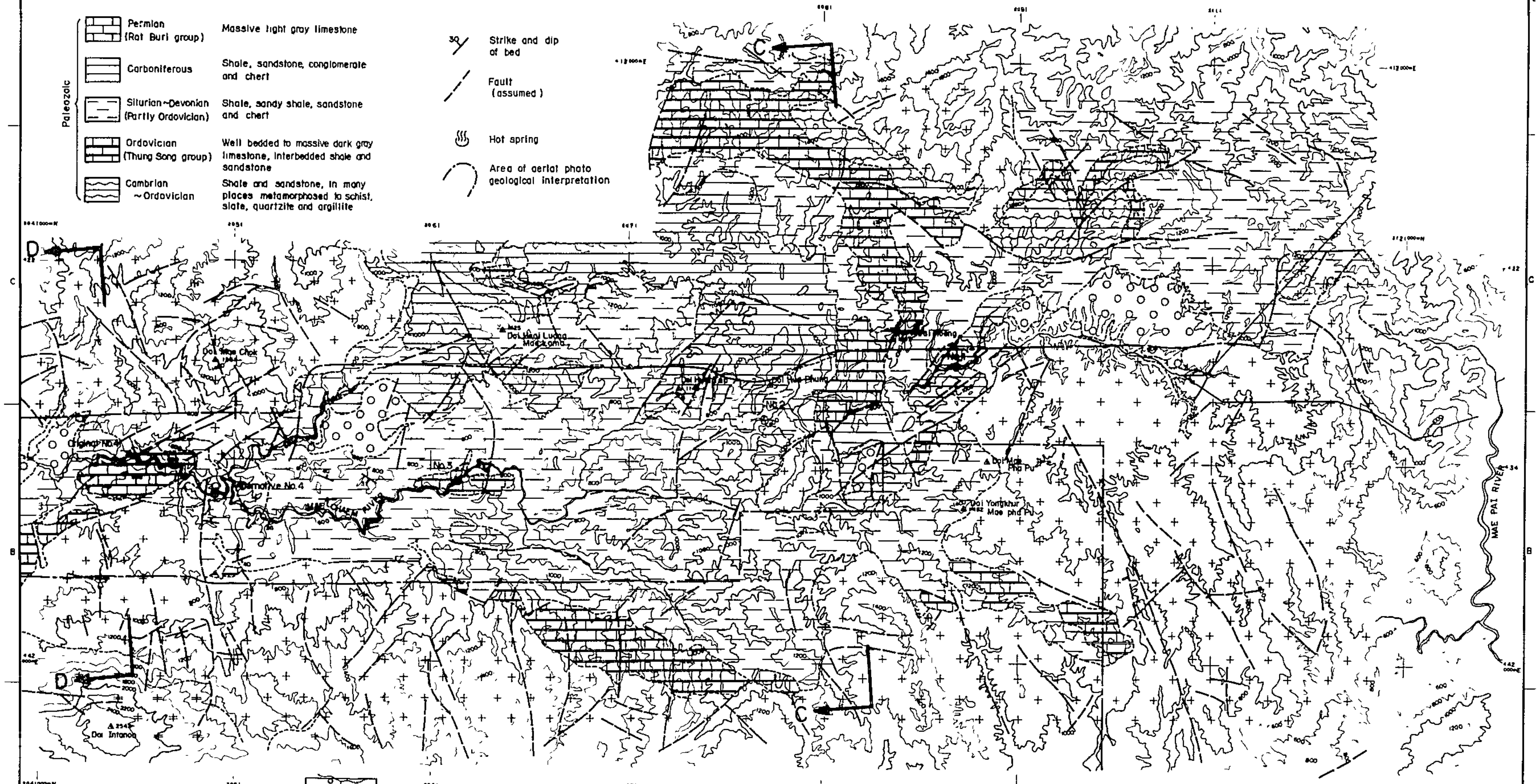
MAE PAI AND MAE CHAEM PROJECT MASTER PLAN

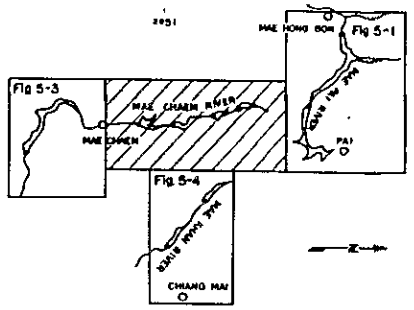
GEOLOGY

MAE PAI RESERVOIR AREA PLAN

Fig. 5 - 1 | June 1981

SHEET NO OF





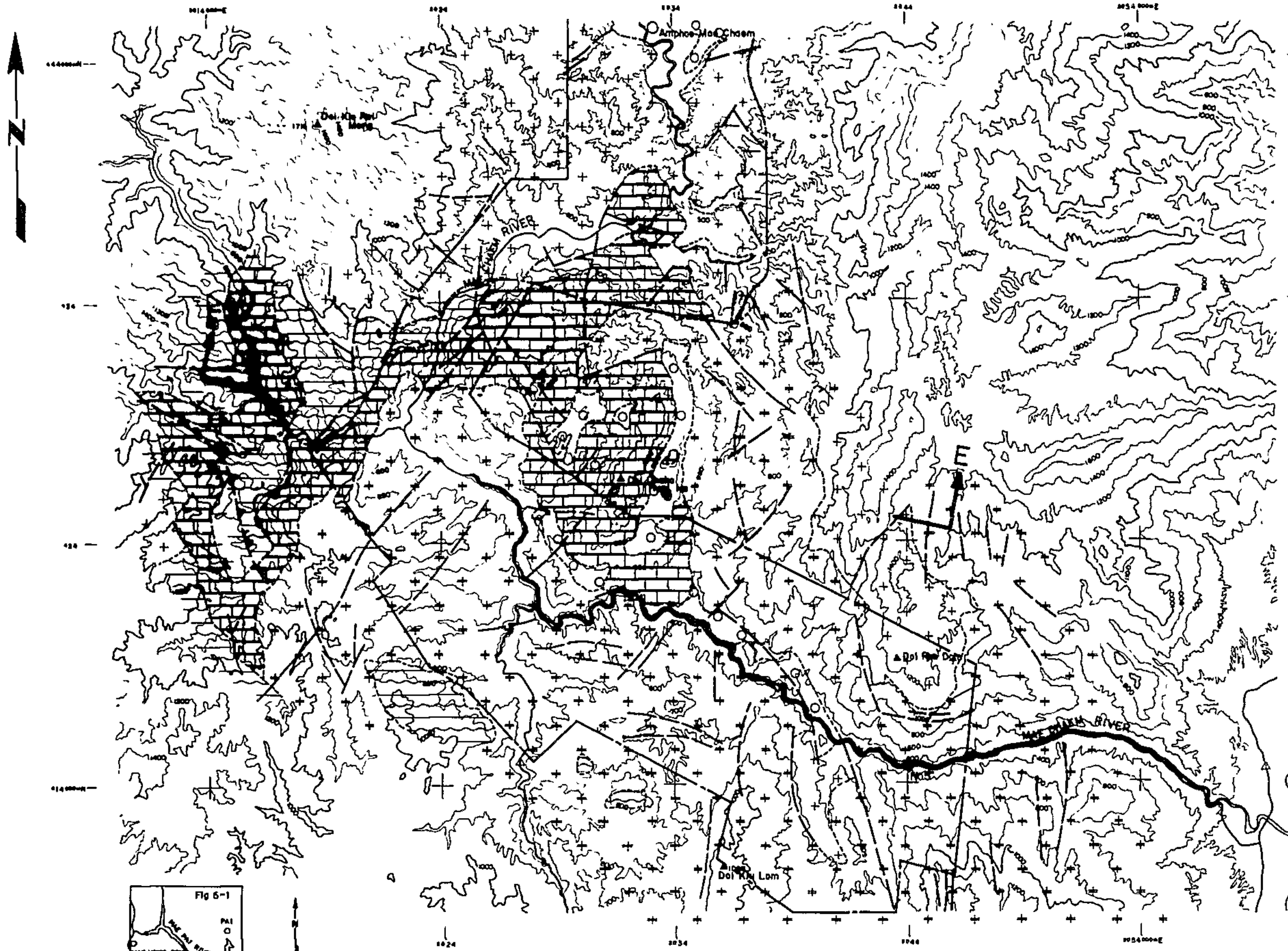
Note

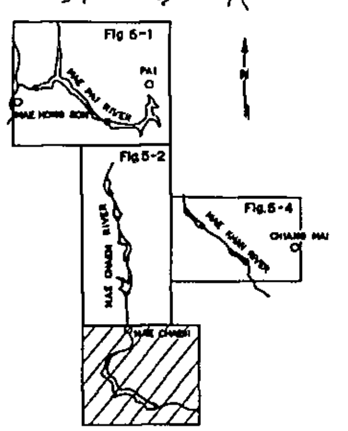
This map is compiled from aerial photo geological interpretation and Geological Map of Northern Thailand (1/250,000) prepared by German Geological Mission in 1970

0 10km

MAE PAI AND MAE CHAEM PROJECT MASTER PLAN	
GEOLOGY MAE CHAEM RESERVOIR AREA PLAN (1)	
Fig 5 - 2	June. 1981

SHEET NO. OF





LEGEND

Cenozoic	Quaternary	Top soil, and terrace, floodplane, riverbed and talus deposits
	Tertiary	Mudstone, sandstone and conglomerate
Paleozoic	Permian (Rat Buri group)	Massive light gray limestone
	Carboniferous	Shale, sandstone, conglomerate and chert
	Silurian~Devonian (Partly Ordovician)	Shale, sandy shale, sandstone and chert
	Ordovician (Thung Song group)	Well bedded to massive dark gray limestone, interbedded shale and sandstone
	Cambrian ~ Ordovician	Shale and sandstone, in many places metamorphosed to schist, slate, quartzite and argillite
	Metamorphic rocks	Gneiss, schist, marble and anatexitic rocks
	Igneous rocks	Granite, granodiorite

30 Strike and dip of bed

Area of aerial photo geological interpretation

Fault (assumed)

Thrust fault (assumed)

Sink hole

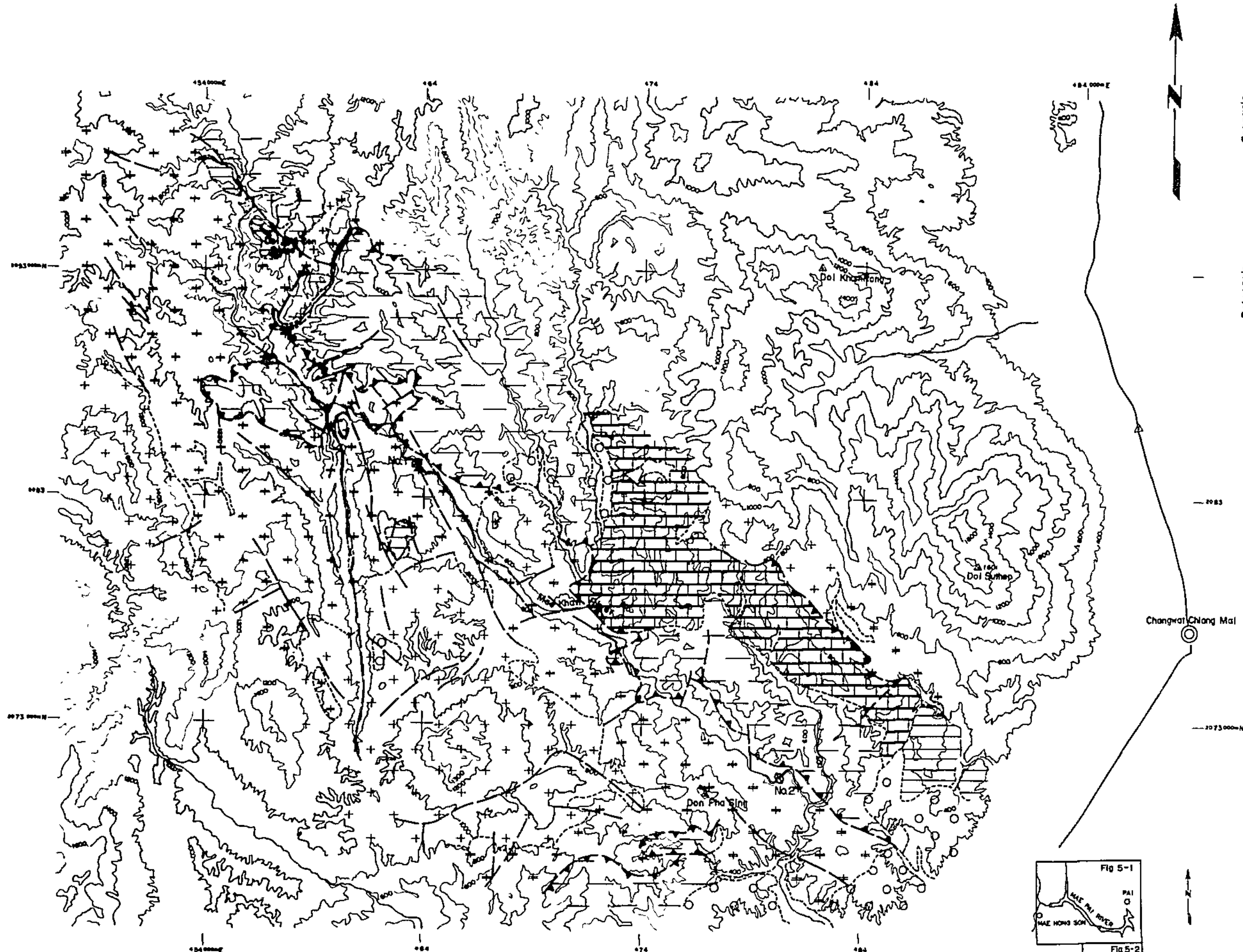
0 10km

Note :

This map is compiled from aerial photo geological interpretation and Geological Map of Northern Thailand (1/250,000) prepared by German Geological Mission in 1970

MAE PAI AND MAE CHAEM PROJECT MASTER PLAN	
GEOLOGY MAE CHAEM RESERVOIR AREA PLAN (2)	
Fig. 5 - 3	June. 1981

SHEET NO. OF



LEGEND

Cenozoic	Quaternary	Top soil, and terrace, floodplane, riverbed and talus deposits
	Tertiary	Mudstone, sandstone and conglomerate
Paleozoic	Permian (Rat Buri group)	Massive light gray limestone
	Carboniferous	Shale, sandstone, conglomerate and chert
	Silurian~Devonian (Partly Ordovician)	Shale, sandy shale, sandstone and chert
	Ordovician (Thung Song group)	Well bedded to massive dark gray limestone, interbedded shale and sandstone
	Cambrian ~Ordovician	Shale and sandstone, in many places metamorphosed to schist, slate, quartzite and argillite
	Metamorphic rocks	Gneiss, schist, marble and anatexitic rocks
	Igneous rocks	Granite, granodiorite

30 Strike and dip of bed

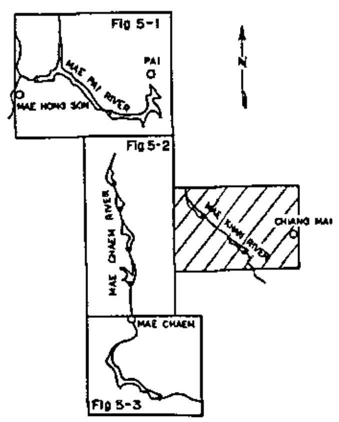
Fault (assumed)

Thrust fault (assumed)

Note :

This map is compiled from Geological Map of Northern Thailand (1/250,000) prepared by German Geological Mission in 1970

0 10km



MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN

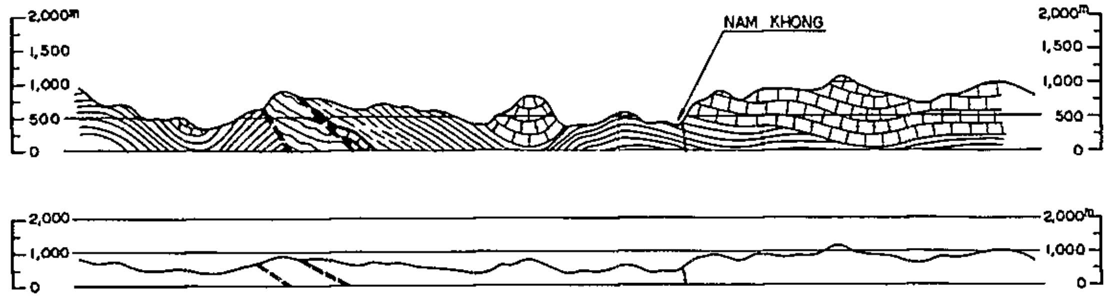
GEOLOGY

MAE KHAN RESERVOIR AREA PLAN

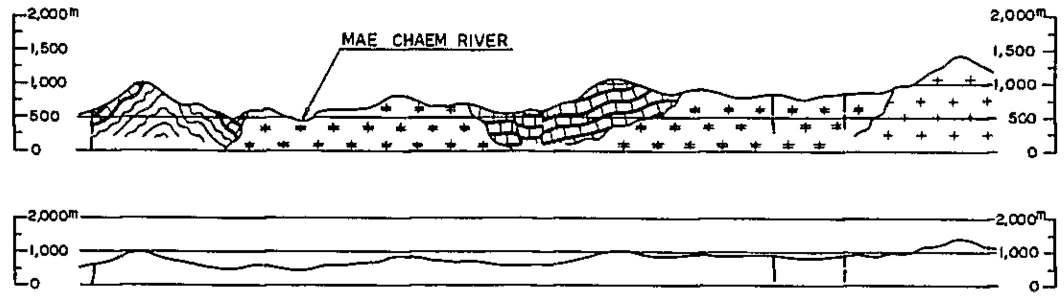
Fig 5 - 4	June 1981

SHEET NO OF

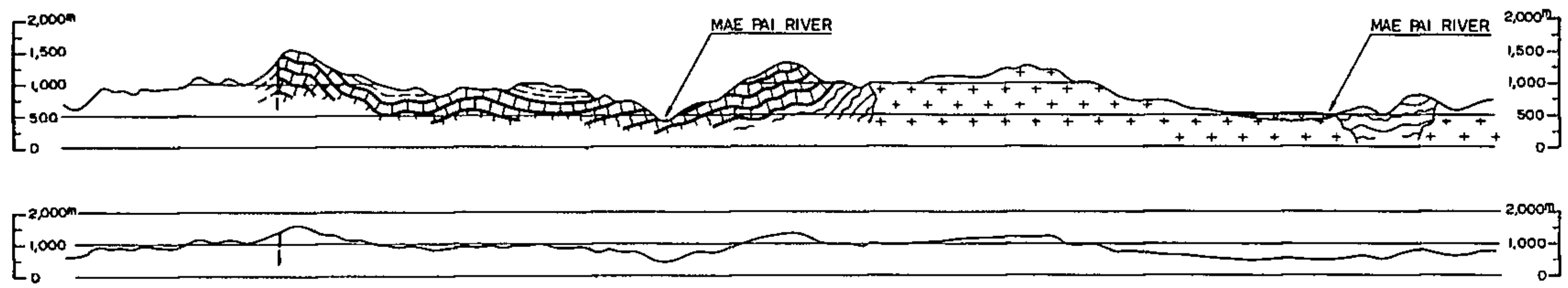
SECTION A-A (MAE PAI Basin)



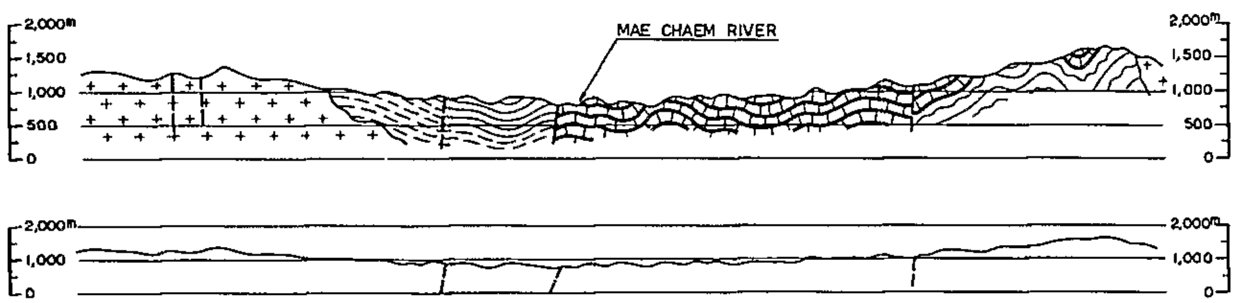
SECTION E-E (MAE CHAEM Basin)



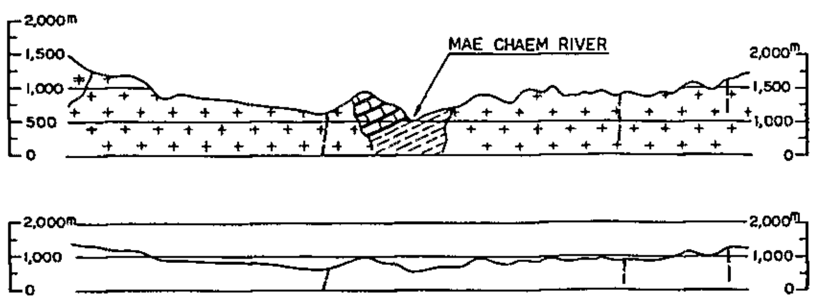
SECTION B-B (MAE PAI Basin)



SECTION C-C (MAE CHAEM Basin)



SECTION D-D (MAE CHAEM Basin)



LEGEND

Cenozoic	Quaternary	Top soil, and terrace, floodplane, riverbed and talus deposits
	Tertiary	Mudstone, sandstone and conglomerate
Paleozoic	Permian (Rat Buri group)	Massive light gray limestone
	Carboniferous	Shale, sandstone, conglomerate and chert
	Silurian~Devonian (Partly Ordovician)	Shale, sandy shale, sandstone and chert
	Ordovician (Thung Song group)	Well bedded to massive dark gray limestone, interbedded shale and sandstone
	Cambrian ~ Ordovician	Shale and sandstone, in many places metamorphosed to schist, slate, quartzite and argillite
	Metamorphic rocks	Gneiss, schist, marble and anatexitic rocks
	Igneous rocks	Granite, granodiorite

Fault (assumed)

Thrust fault (assumed)

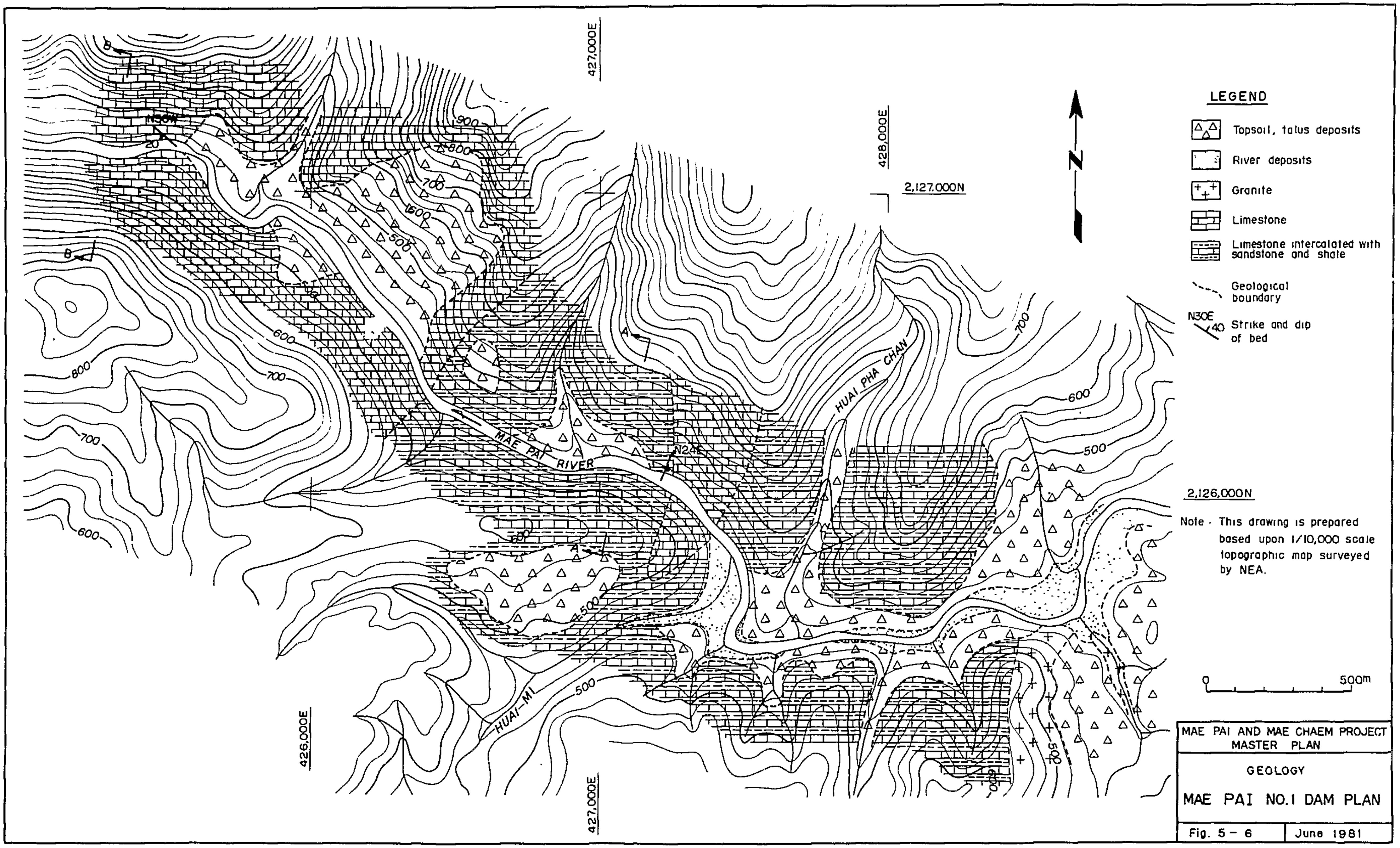
Note

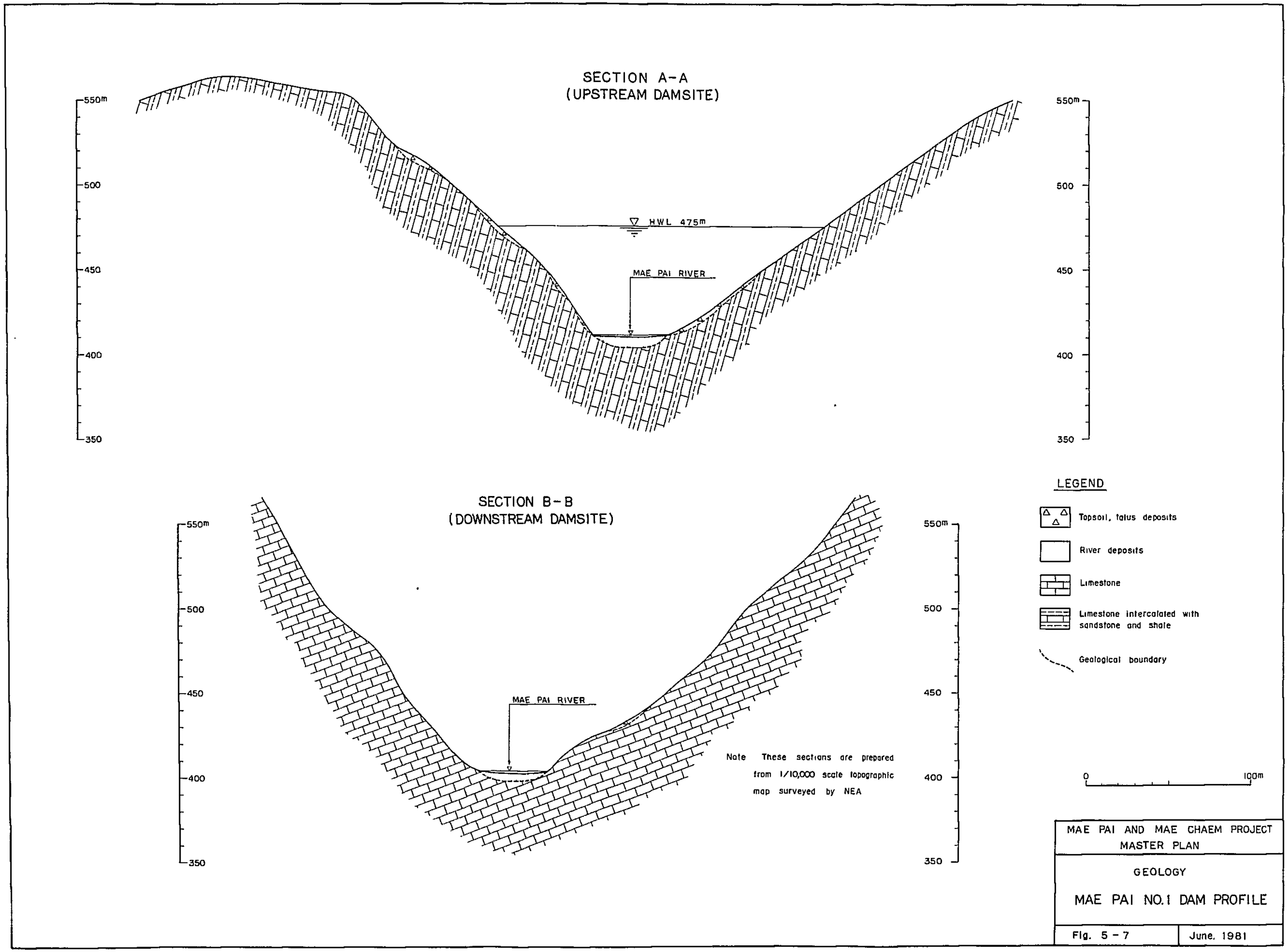
This map is compiled from aerial photo geological interpretation and Geological Map of Northern Thailand (1/250,000) prepared by German Geological Mission in 1970

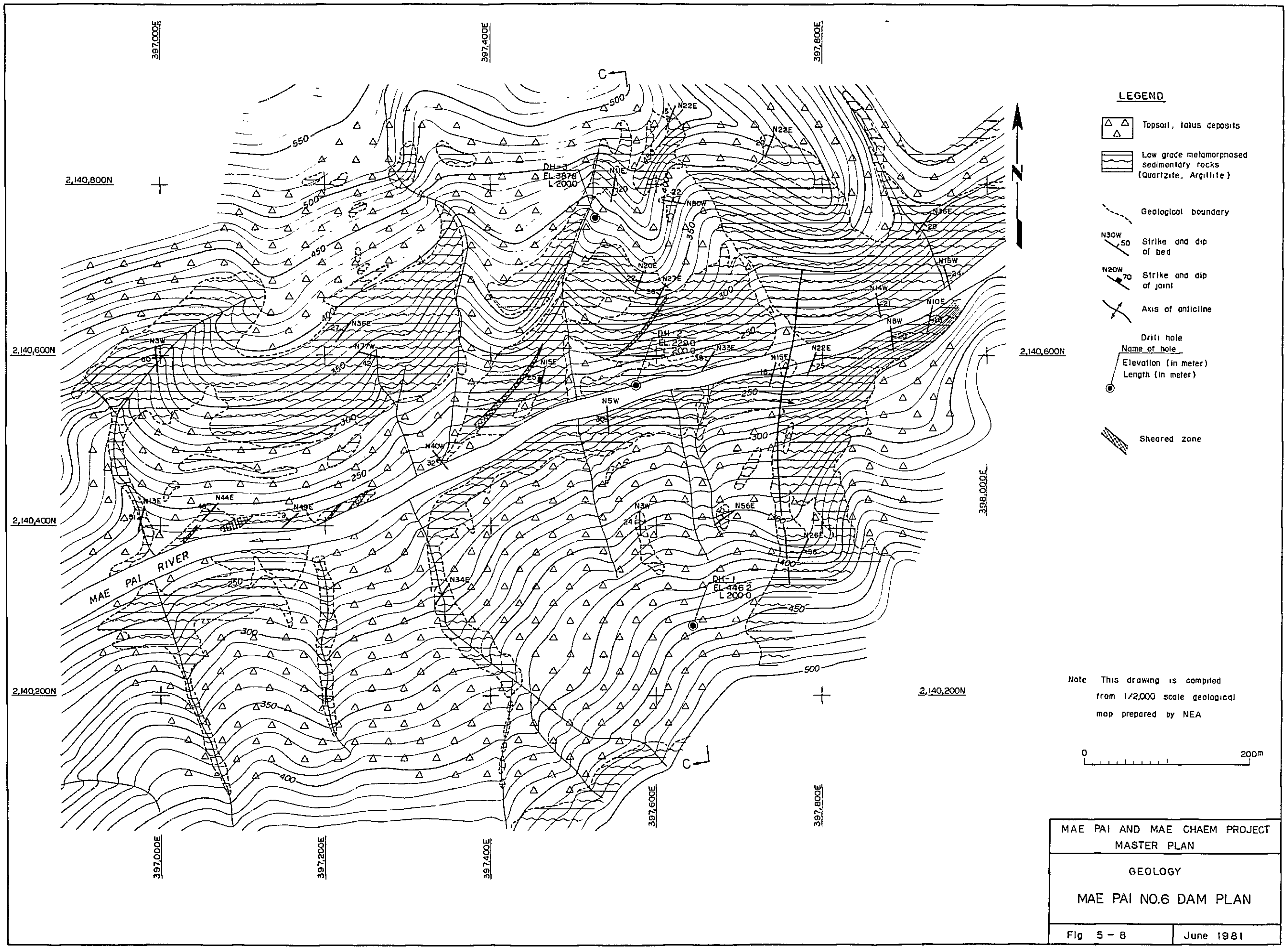
The geologic section is drawn on a different scale for vertical and horizontal The real topographic profile in natural scale is shown below each geologic section

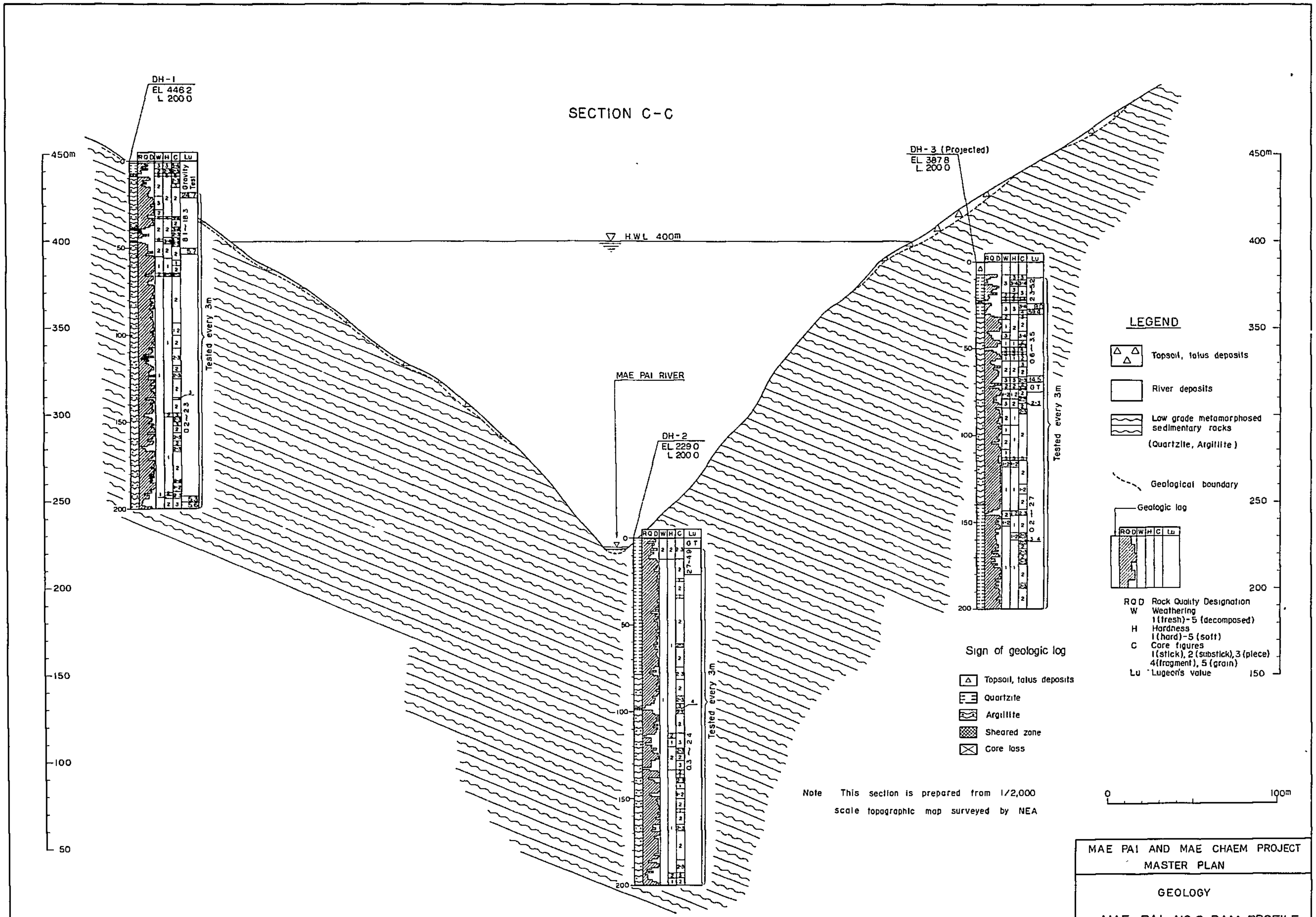
0 10km
(Horizontal scale)

MAE PAI AND MAE CHAEM PROJECT MASTER PLAN	
GEOLOGY	
RESERVOIR AREA PROFILE	
Fig. 5 - 5	June 1981


LEGEND
Topsoil, talus deposits
River deposits
Granite
Limestone
Limestone intercalated with sandstone and shale
Geological boundary
N30E 40 Strike and dip of bed
Note - This drawing is prepared based upon 1/10,000 scale topographic map surveyed by NEA.
427,000E
428,000E
426,000E
2,127,000N
2,126,000N
MAE PAI RIVER
HUAI PHA CHAN
HUAI-MI
N30W
N24E
0
500m
MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN
GEOLOGY
MAE PAI NO.1 DAM PLAN
Fig. 5 - 6
June 1981


SECTION A-A
(UPSTREAM DAMSITE)
550m
500
450
400
350
HWL 475m
MAE PAI RIVER
SECTION B-B
(DOWNSTREAM DAMSITE)
MAE PAI RIVER
Note These sections are prepared from 1/10,000 scale topographic map surveyed by NEA
LEGEND
Topsoil, talus deposits
River deposits
Limestone
Limestone intercalated with sandstone and shale
Geological boundary
0
100m
MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN
GEOLOGY
MAE PAI NO.1 DAM PROFILE
Fig. 5 - 7
June, 1981


LEGEND
Topsoil, talus deposits
Low grade metamorphosed sedimentary rocks (Quartzite, Argillite)
Geological boundary
Strike and dip of bed
Strike and dip of joint
Axis of anticline
Drill hole
Name of hole
Elevation (in meter)
Length (in meter)
Sheared zone
Note This drawing is compiled from 1/2,000 scale geological map prepared by NEA
0
200m
MAE PAI RIVER
DH-3
EL 387.8
L 200.0
DH-2
EL 229.0
L 200.0
DH-1
EL 446.2
L 200.0
2,140,800N
2,140,600N
2,140,400N
2,140,200N
397,000E
397,200E
397,400E
397,600E
397,800E
398,000E
MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN
GEOLOGY
MAE PAI NO.6 DAM PLAN
Fig 5-8
June 1981

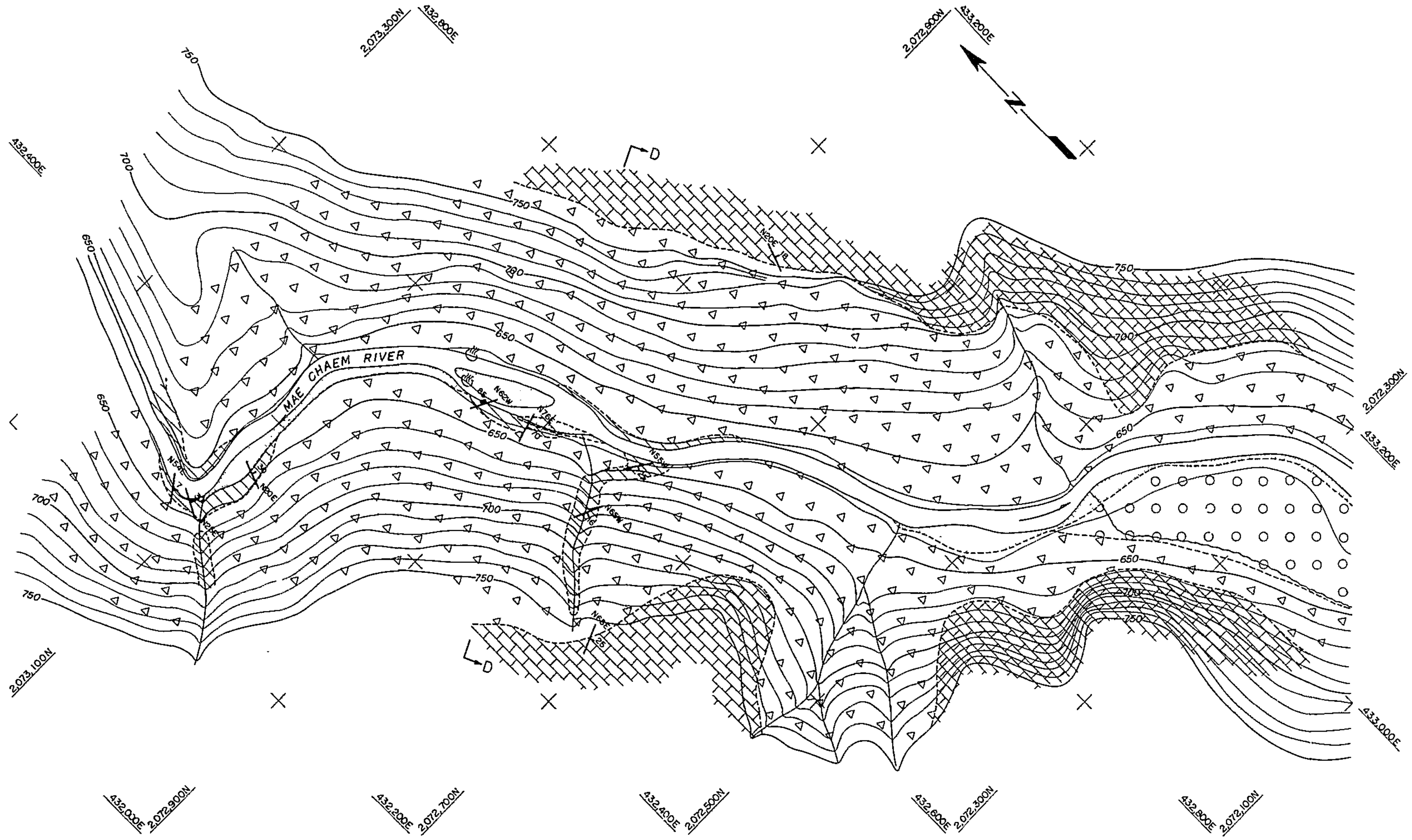


MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN

GEOLOGY

MAE PAI NO.6 DAM PROFILE

Fig 5 - 9 | June 1981



LEGEND

- Topsoil, talus deposits
- River deposits
- Terrace deposits
- Limestone
- Shale
- Geological boundary
- N30W 50 Strike and dip of bed
- N20W 70 Strike and dip of joint
- Hot spring

Note This drawing is prepared based upon 1/2,000 scale topographic map surveyed by NEA

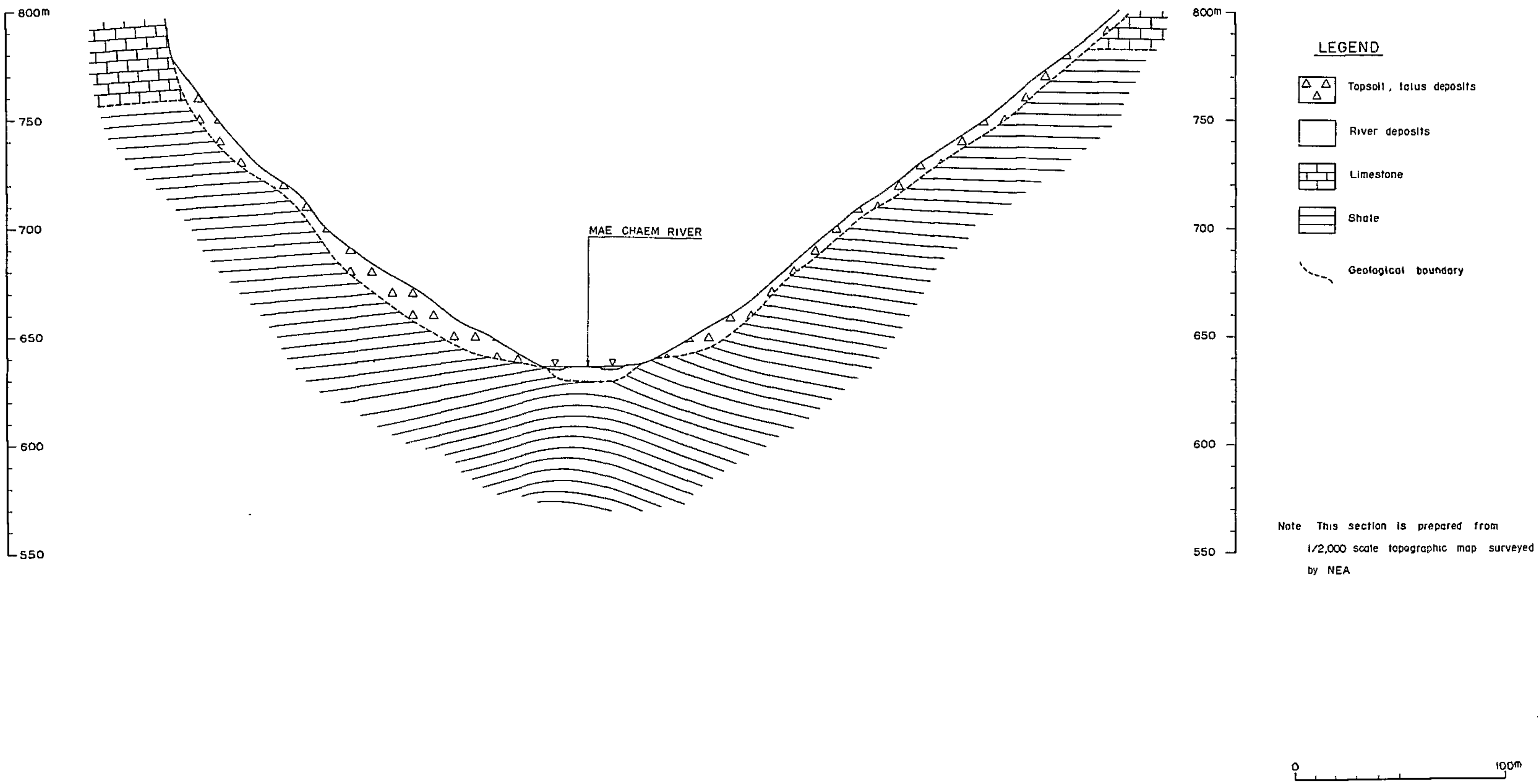
MAE PAI AND MAE CHAEM PROJECT MASTER PLAN

GEOLOGY

MAE CHAEM NO 3 DAM PLAN

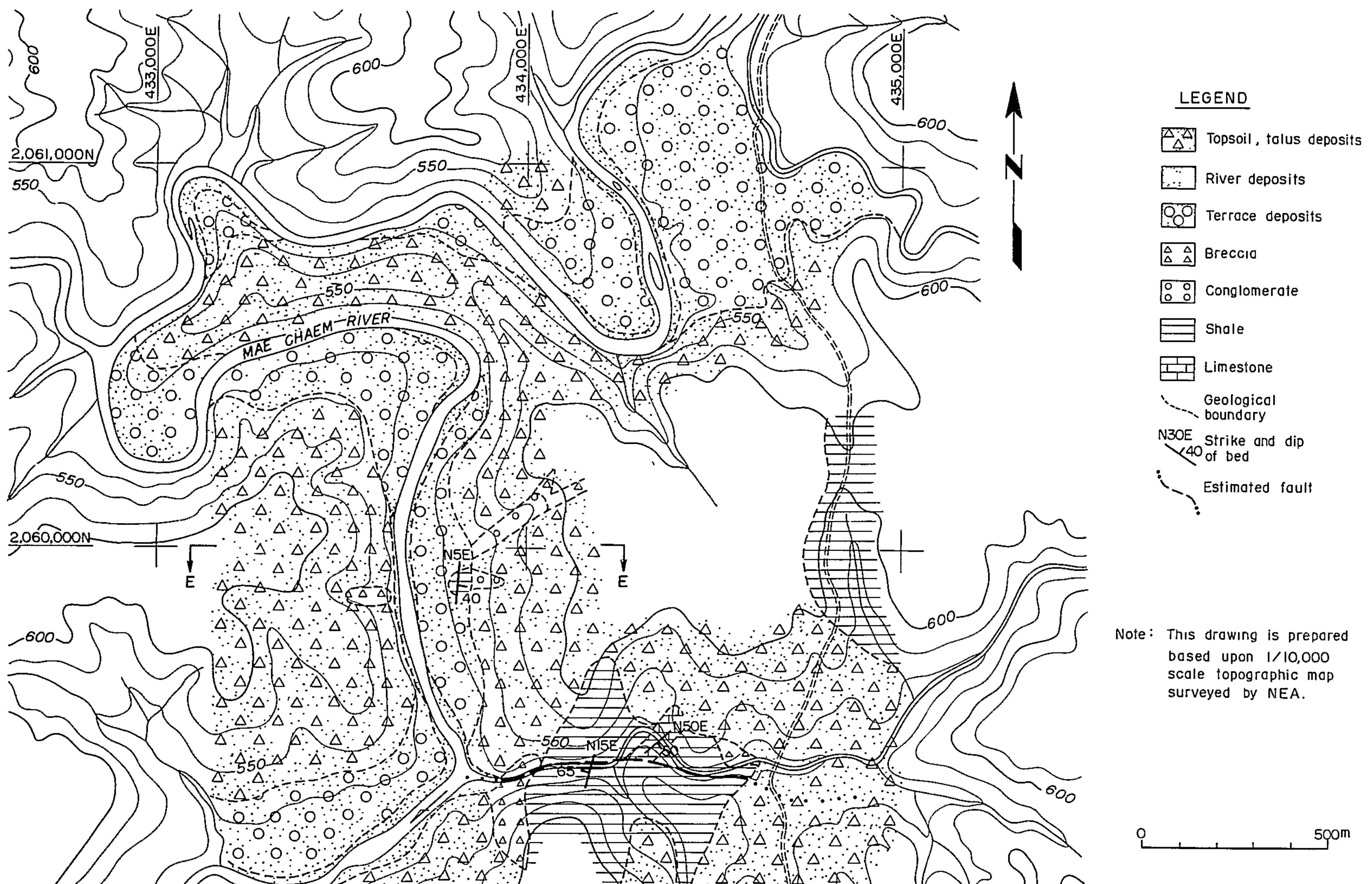
Fig. 5-10 June 1981

SECTION D-D



Note This section is prepared from 1/2,000 scale topographic map surveyed by NEA

MAE PAI AND MAE CHAEM PROJECT MASTER PLAN	
GEOLOGY	
MAE CHAEM NO.3 DAM PROFILE	
Fig 5-11	June 1981

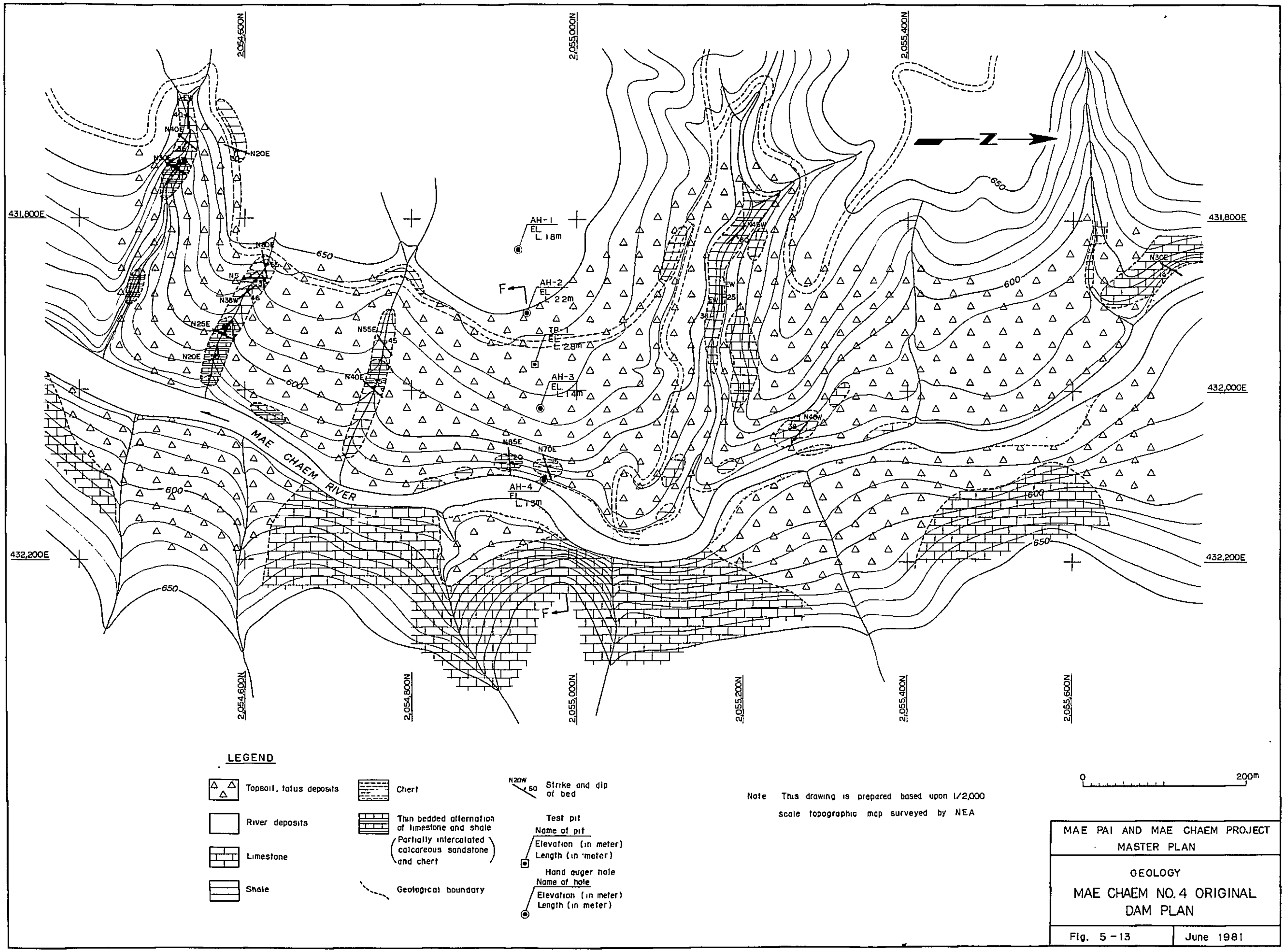


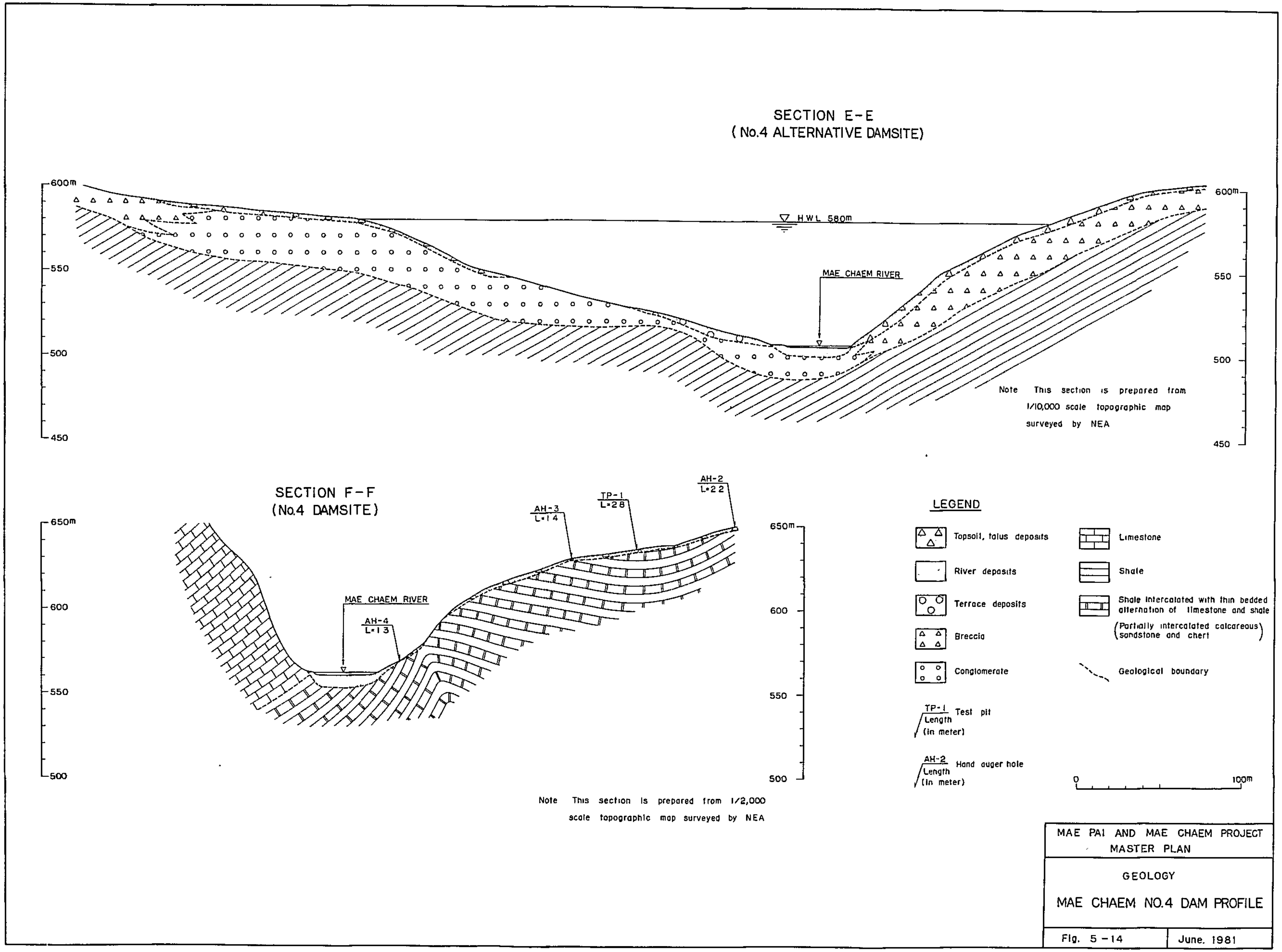
MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN

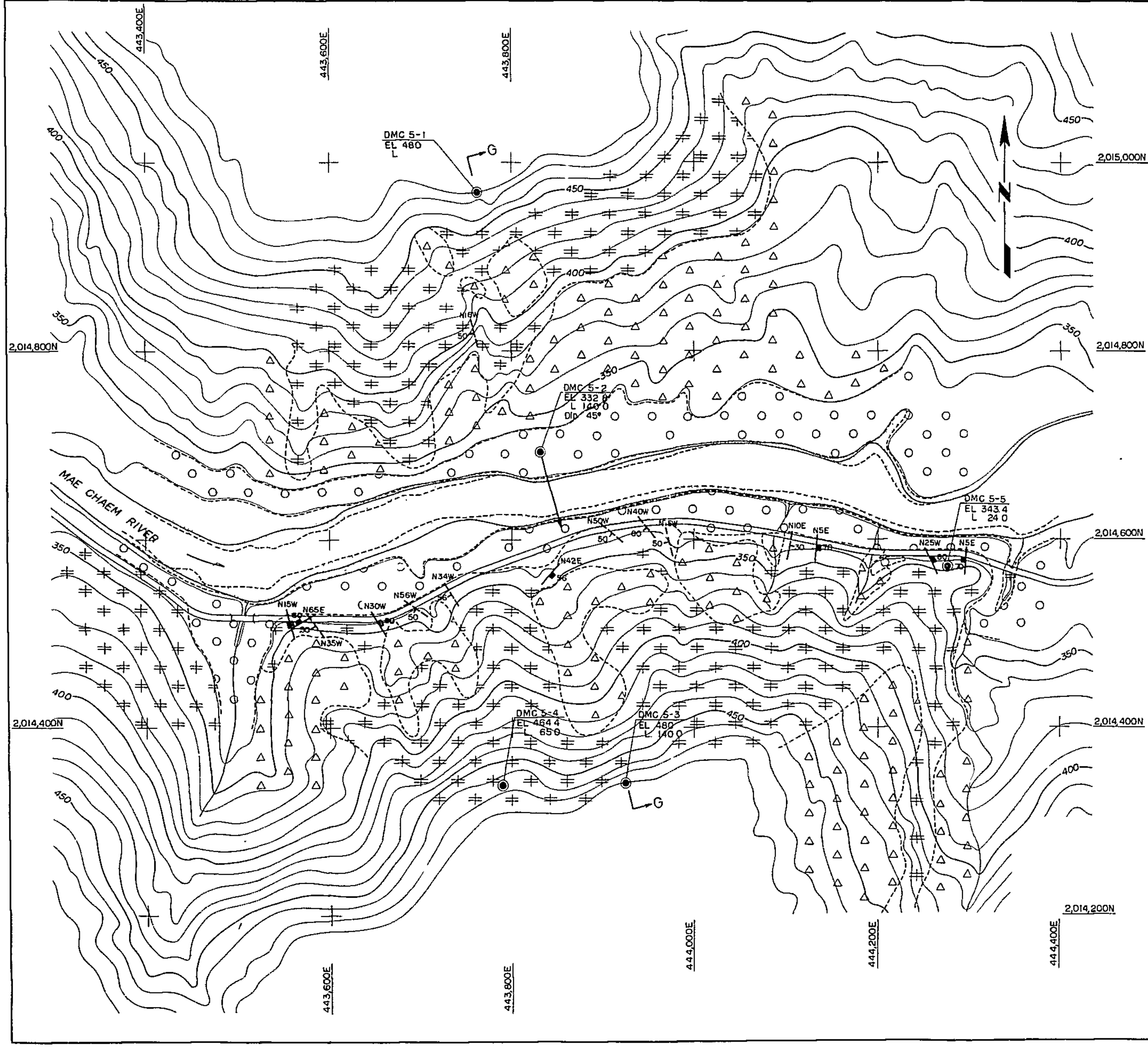
GEOLOGY

MAE CHAEM NO.4 ALTERNATIVE
DAM PLAN

Fig. 5 − 12	June. 1981


MAE CHAEM RIVER
AH-1 EL L 1.8m
AH-2 EL L 2.2m
TP-1 EL L 2.8m
AH-3 EL L 1.4m
AH-4 EL L 1.3m
2,054,600N
2,055,000N
2,055,400N
2,054,800N
2,055,200N
2,055,600N
431,800E
432,000E
432,200E
LEGEND
Topsoil, talus deposits
River deposits
Limestone
Shale
Chert
Thin bedded alternation of limestone and shale (Partially intercalated calcareous sandstone and chert)
Geological boundary
Strike and dip of bed
Test pit
Name of pit
Elevation (in meter)
Length (in meter)
Hand auger hole
Name of hole
Elevation (in meter)
Length (in meter)
Note This drawing is prepared based upon 1/2,000 scale topographic map surveyed by NEA
0
200m
MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN
GEOLOGY
MAE CHAEM NO. 4 ORIGINAL DAM PLAN
Fig. 5 - 13
June 1981


SECTION E-E
(No.4 ALTERNATIVE DAMSITE)
600m
550
500
450
HWL 580m
MAE CHAEM RIVER
Note This section is prepared from 1/10,000 scale topographic map surveyed by NEA
SECTION F-F
(No.4 DAMSITE)
650m
600
550
500
MAE CHAEM RIVER
AH-4 L=13
AH-3 L=14
TP-1 L=28
AH-2 L=22
Note This section is prepared from 1/2,000 scale topographic map surveyed by NEA
LEGEND
Topsoil, talus deposits
River deposits
Terrace deposits
Breccia
Conglomerate
Limestone
Shale
Shale intercalated with thin bedded alternation of limestone and shale
(Partially intercalated calcareous sandstone and chert)
Geological boundary
TP-1 Length (in meter) Test pit
AH-2 Length (in meter) Hand auger hole
0
100m
MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN
GEOLOGY
MAE CHAEM NO.4 DAM PROFILE
Fig. 5-14
June. 1981



LEGEND

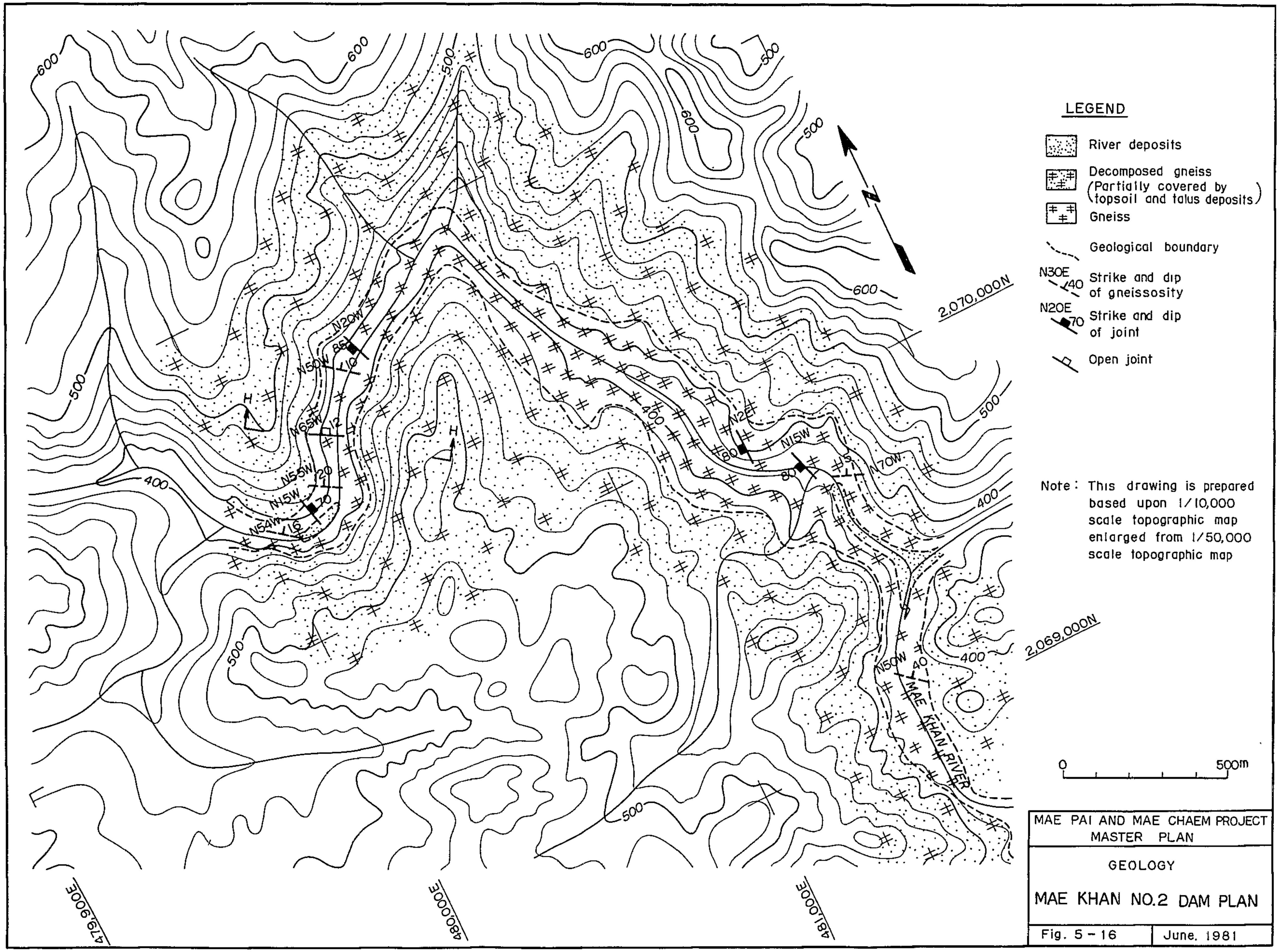
- Topsoil, talus deposits
- River deposits
- Terrace deposits
- Gneiss and granitic rock (partially intruded by pegmatite)
- Geological boundary
- N30W 50 — Strike and dip of gneissosity
- N20W 70 — Strike and dip of joint
- Drill hole: Name of hole / Elevation (in meter) / Length (in meter)

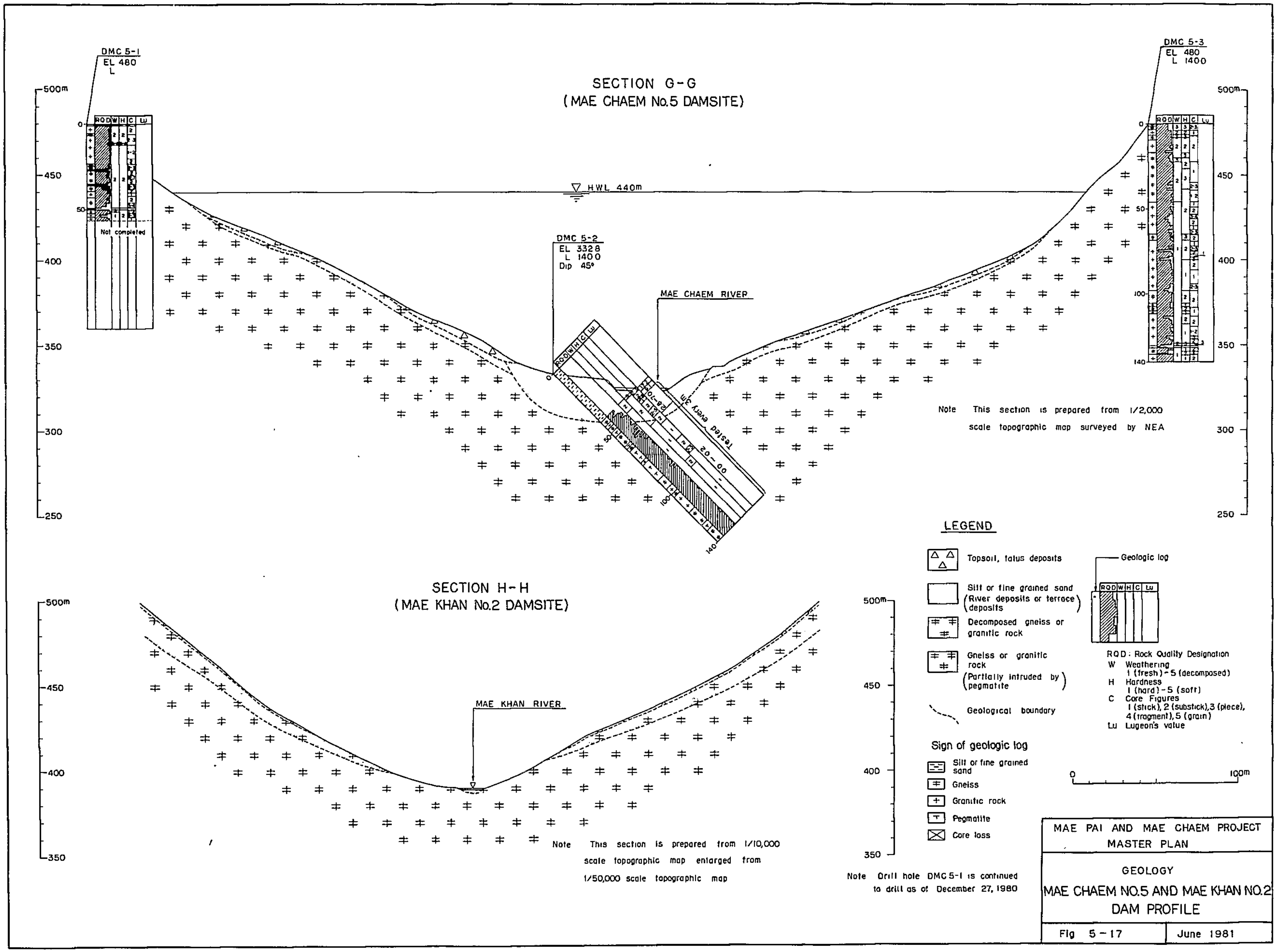
Note Arrow mark indicates inclined drill hole

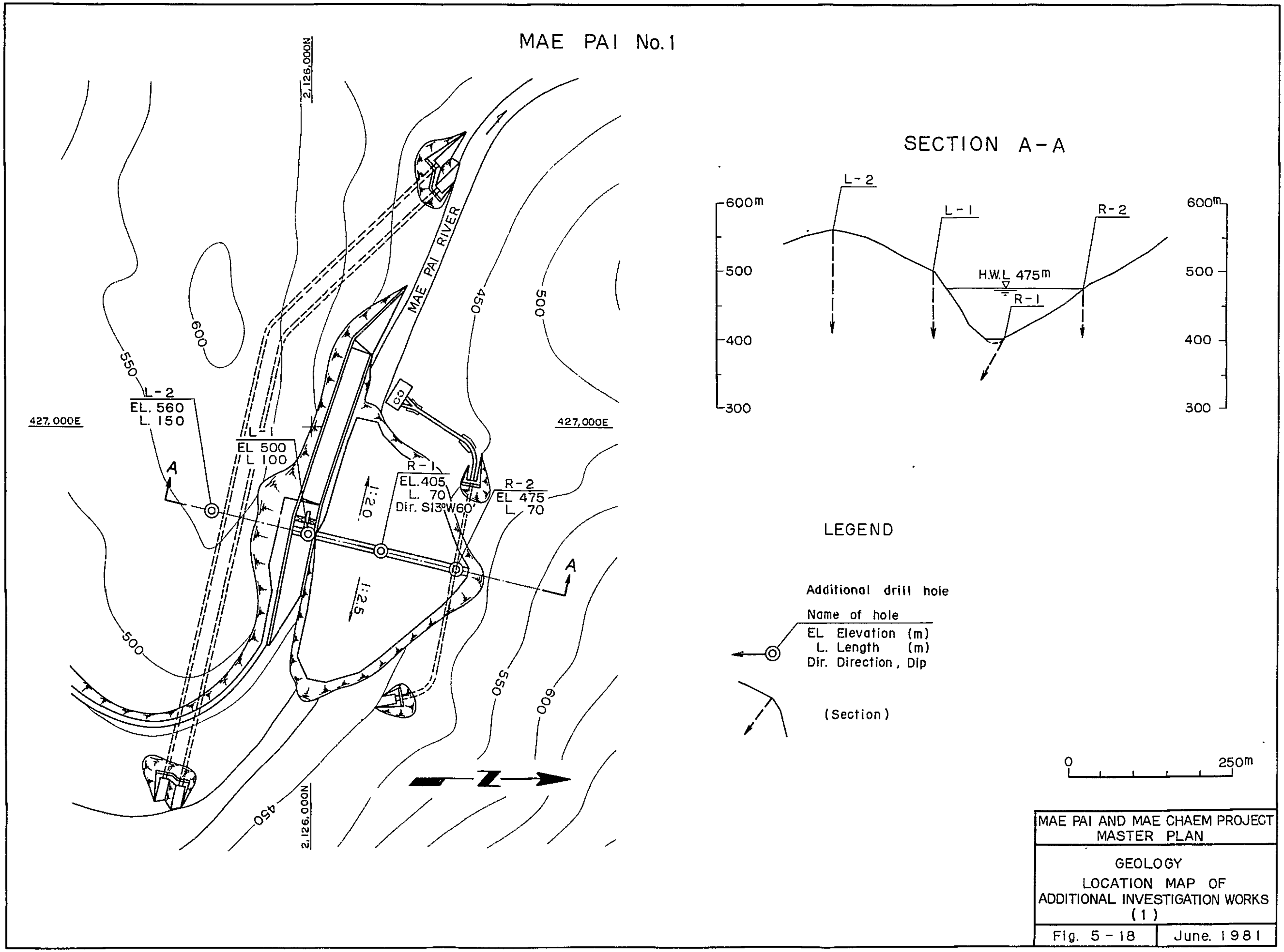
Note This drawing is prepared based upon 1/2,000 scale topographic map surveyed by NEA

0 200m

MAE PAI AND MAE CHAEM PROJECT MASTER PLAN	
GEOLOGY	
MAE CHAEM NO5 DAM PLAN	
Fig 5 - 15	June 1981


LEGEND
River deposits
Decomposed gneiss (Partially covered by topsoil and talus deposits)
Gneiss
Geological boundary
N30E 40 Strike and dip of gneissosity
N20E 70 Strike and dip of joint
Open joint
Note: This drawing is prepared based upon 1/10,000 scale topographic map enlarged from 1/50,000 scale topographic map
0 500m
2,070,000N
2,069,000N
479,900E
480,000E
481,000E
MAE KHAN RIVER
MAE PAI AND MAE CHAEM PROJECT MASTER PLAN
GEOLOGY
MAE KHAN NO.2 DAM PLAN
Fig. 5 - 16
June. 1981

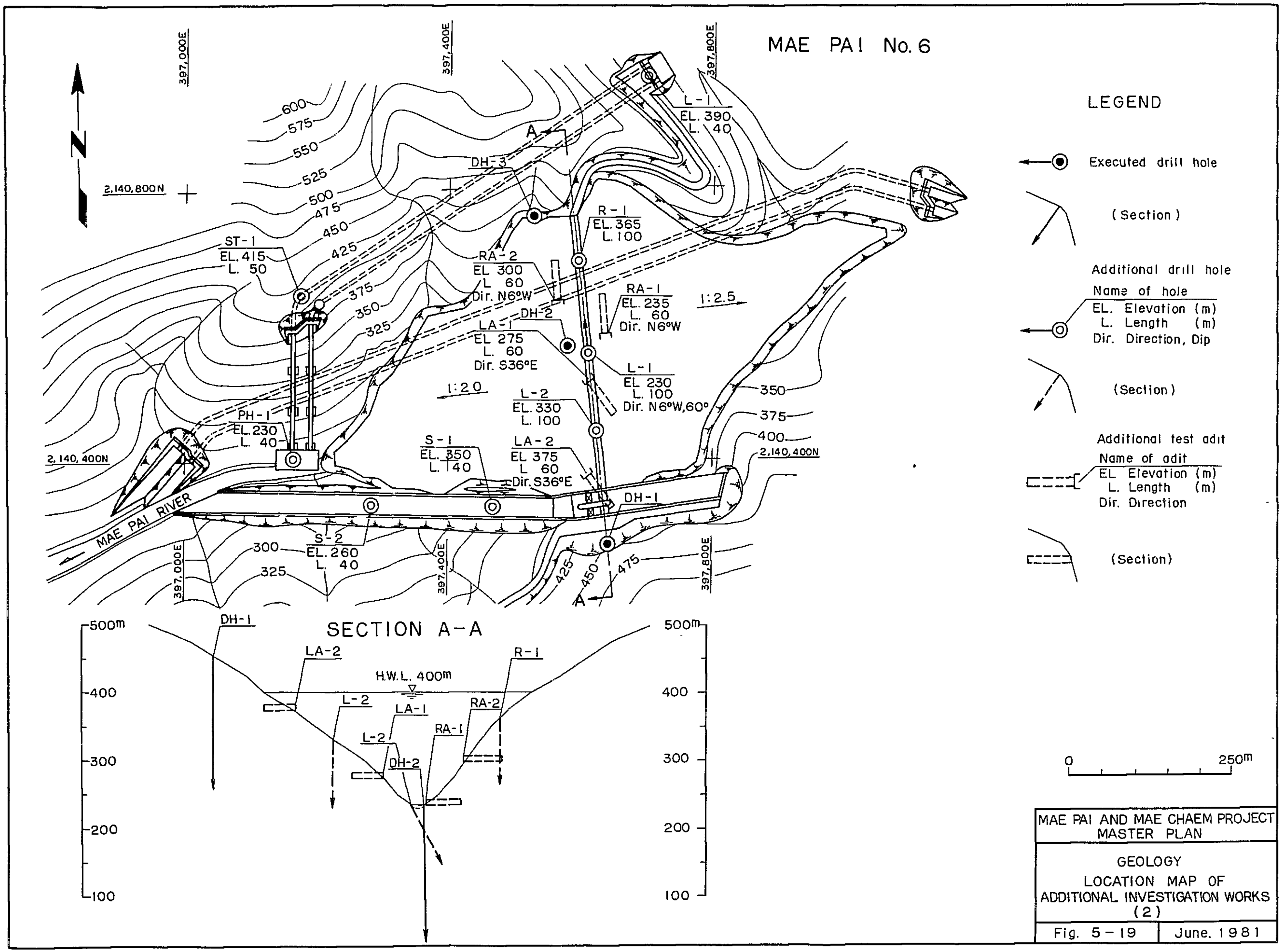

SECTION G-G
(MAE CHAEM No.5 DAMSITE)
DMC 5-1
EL 480
L
RQD W H C Lu
Not completed
HWL 440m
DMC 5-2
EL 332.8
L 140.0
Dip 45°
MAE CHAEM RIVER
Tested every 5m
DMC 5-3
EL 480
L 140.0
500m
450
400
350
300
250
Note This section is prepared from 1/2,000 scale topographic map surveyed by NEA
SECTION H-H
(MAE KHAN No.2 DAMSITE)
MAE KHAN RIVER
Note This section is prepared from 1/10,000 scale topographic map enlarged from 1/50,000 scale topographic map
LEGEND
Topsoil, talus deposits
Silt or fine grained sand (River deposits or terrace deposits)
Decomposed gneiss or granitic rock
Gneiss or granitic rock (Partially intruded by pegmatite)
Geological boundary
Geologic log
RQD : Rock Quality Designation
W Weathering 1 (fresh) - 5 (decomposed)
H Hardness 1 (hard) - 5 (soft)
C Core Figures 1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 (grain)
Lu Lugeon's value
Sign of geologic log
Silt or fine grained sand
Gneiss
Granitic rock
Pegmatite
Core loss
0 100m
Note Drill hole DMC 5-1 is continued to drill as of December 27, 1980
MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN
GEOLOGY
MAE CHAEM NO.5 AND MAE KHAN NO.2
DAM PROFILE
Fig 5 - 17
June 1981



MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN

GEOLOGY
LOCATION MAP OF
ADDITIONAL INVESTIGATION WORKS
(1)

Fig. 5-18 | June. 1981

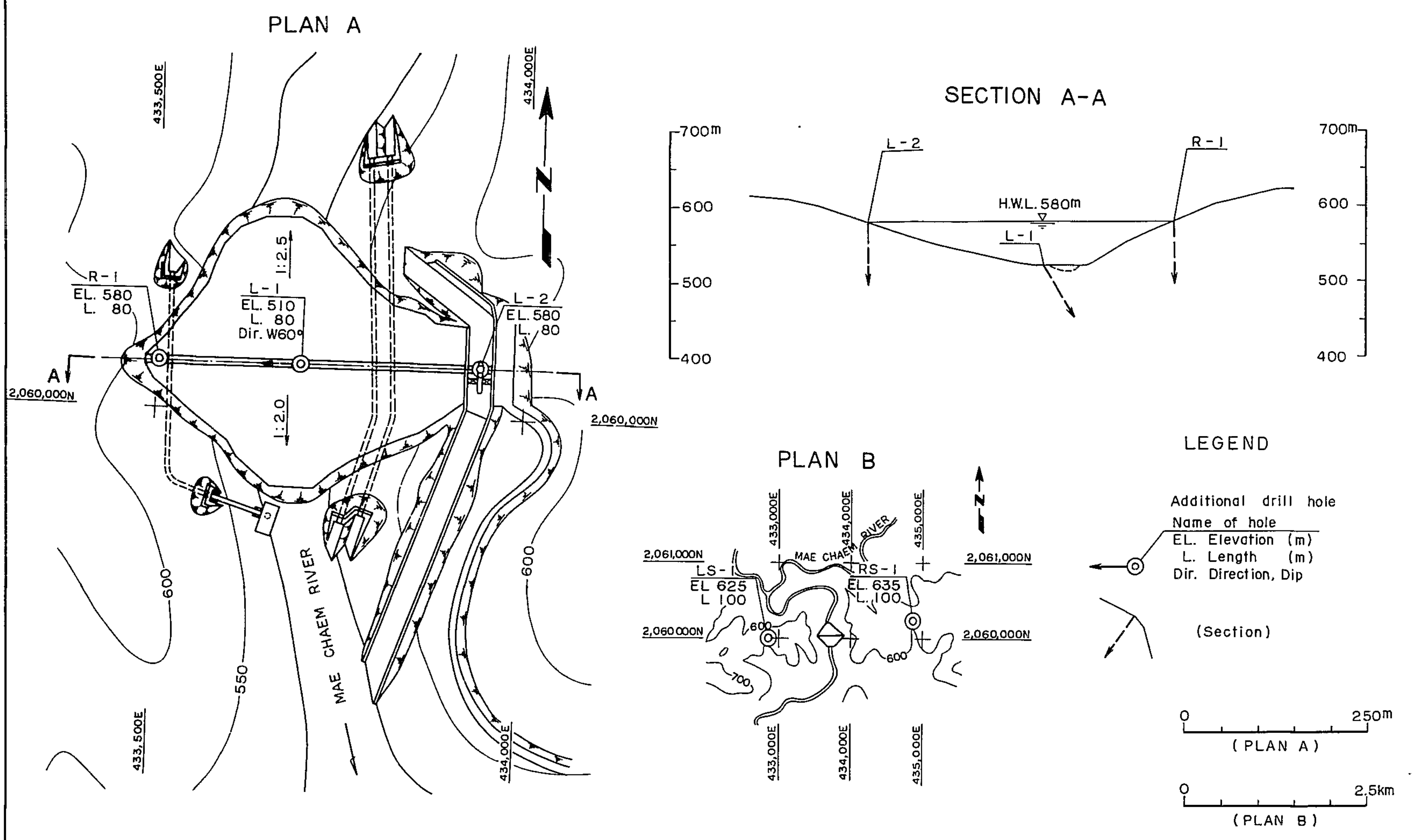


MAE PAI AND MAE CHAEM PROJECT MASTER PLAN

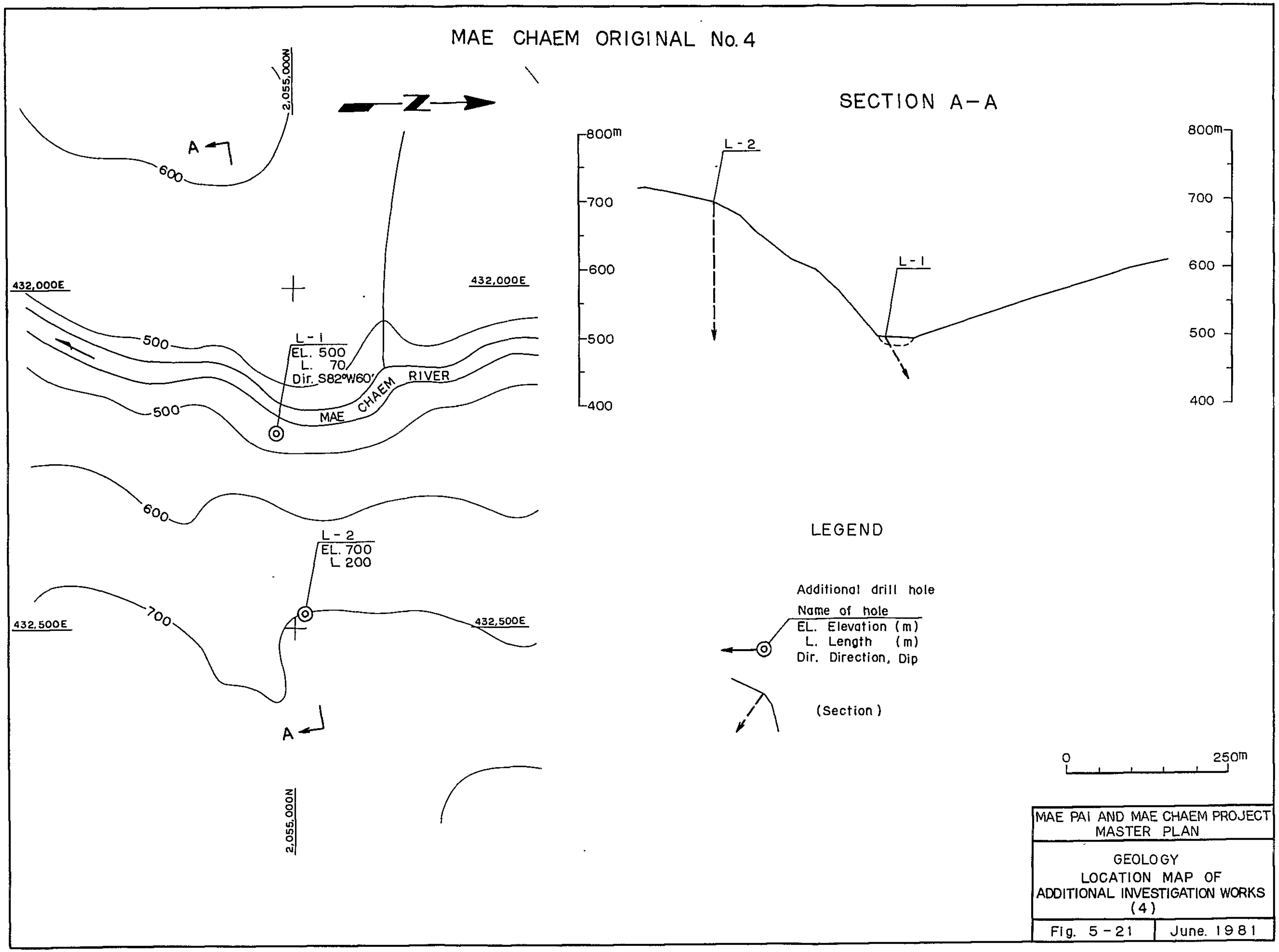
GEOLOGY
LOCATION MAP OF ADDITIONAL INVESTIGATION WORKS (2)

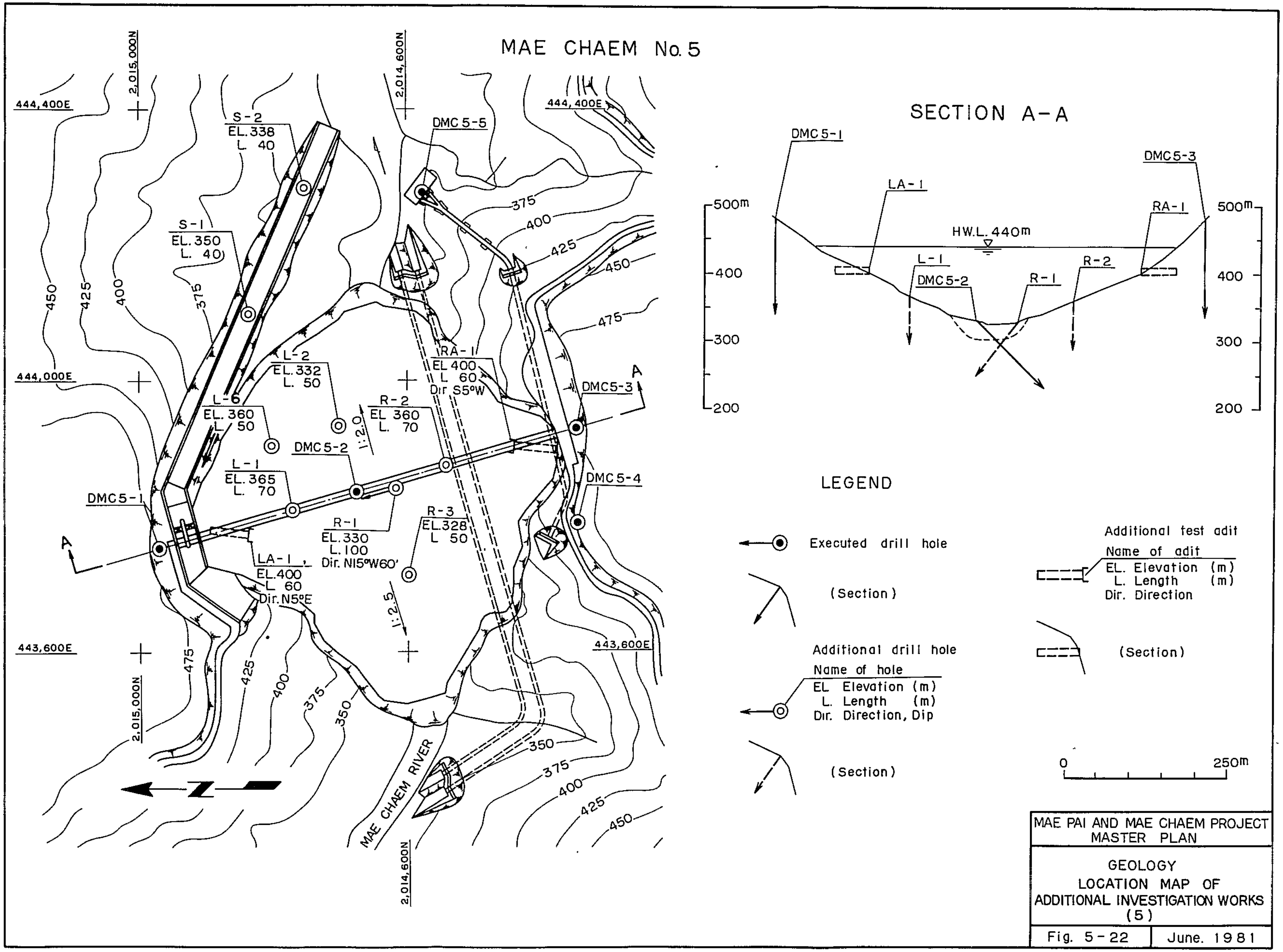
Fig. 5-19 | June. 1981

MAE CHAEM ALTERNATIVE No. 4



MAE PAI AND MAE CHAEM PROJECT MASTER PLAN	
GEOLOGY LOCATION MAP OF ADDITIONAL INVESTIGATION WORKS (3)	
Fig. 5-20	June. 1981

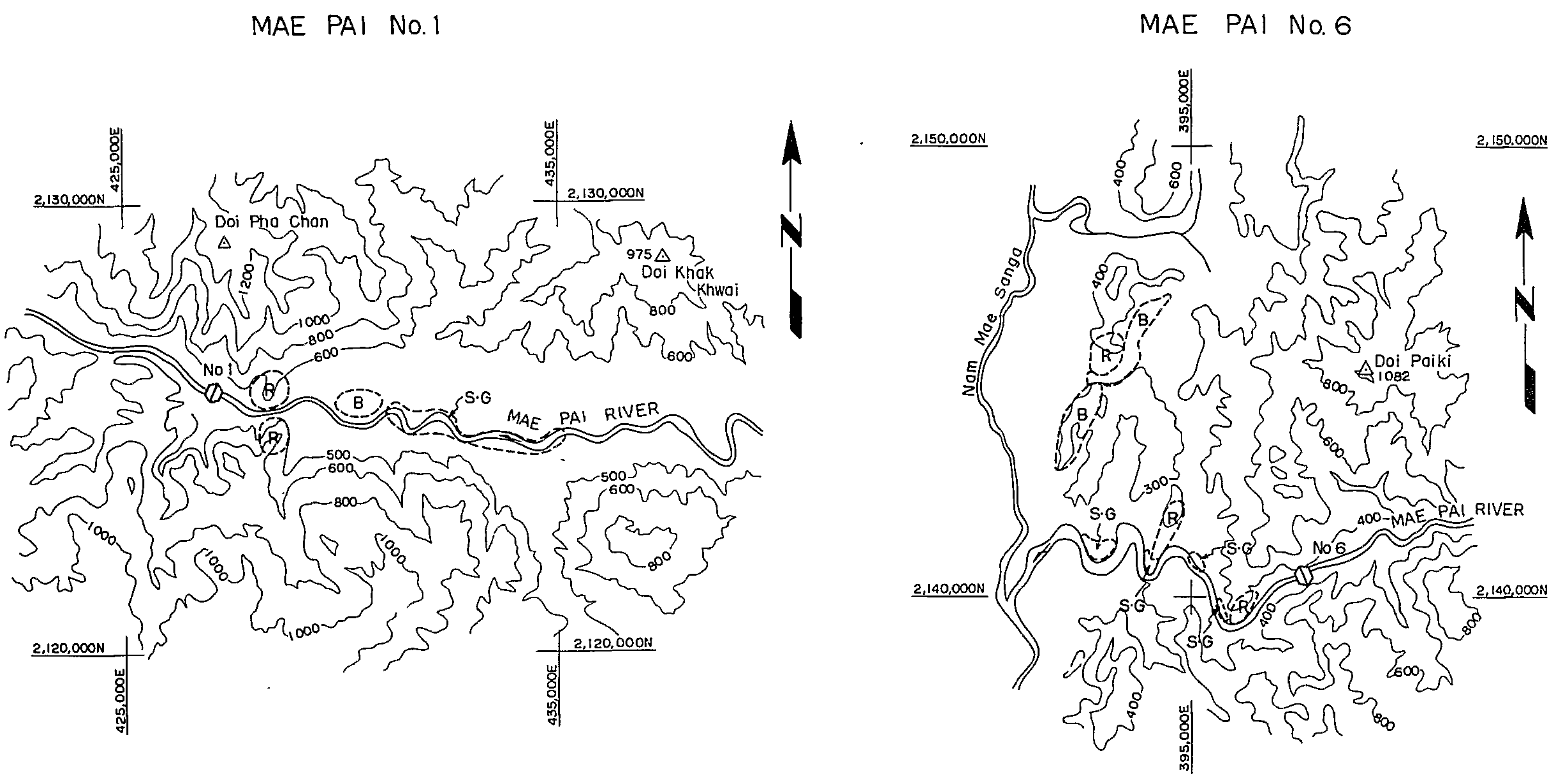

MAE CHAEM ORIGINAL No. 4
SECTION A-A
Z
A
A
2,055,000N
2,055,000N
432,000E
432,000E
432,500E
432,500E
600
600
500
500
700
L - 1
EL. 500
L. 70
Dir. S82°W60°
MAE CHAEM RIVER
L - 2
EL. 700
L. 200
800m
700
600
500
400
L - 2
L - 1
LEGEND
Additional drill hole
Name of hole
EL. Elevation (m)
L. Length (m)
Dir. Direction, Dip
(Section)
0
250m
MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN
GEOLOGY
LOCATION MAP OF
ADDITIONAL INVESTIGATION WORKS
(4)
Fig. 5-21
June. 1981



MAE PAI AND MAE CHAEM PROJECT MASTER PLAN

GEOLOGY
LOCATION MAP OF ADDITIONAL INVESTIGATION WORKS (5)

Fig. 5-22	June. 1981



LEGEND

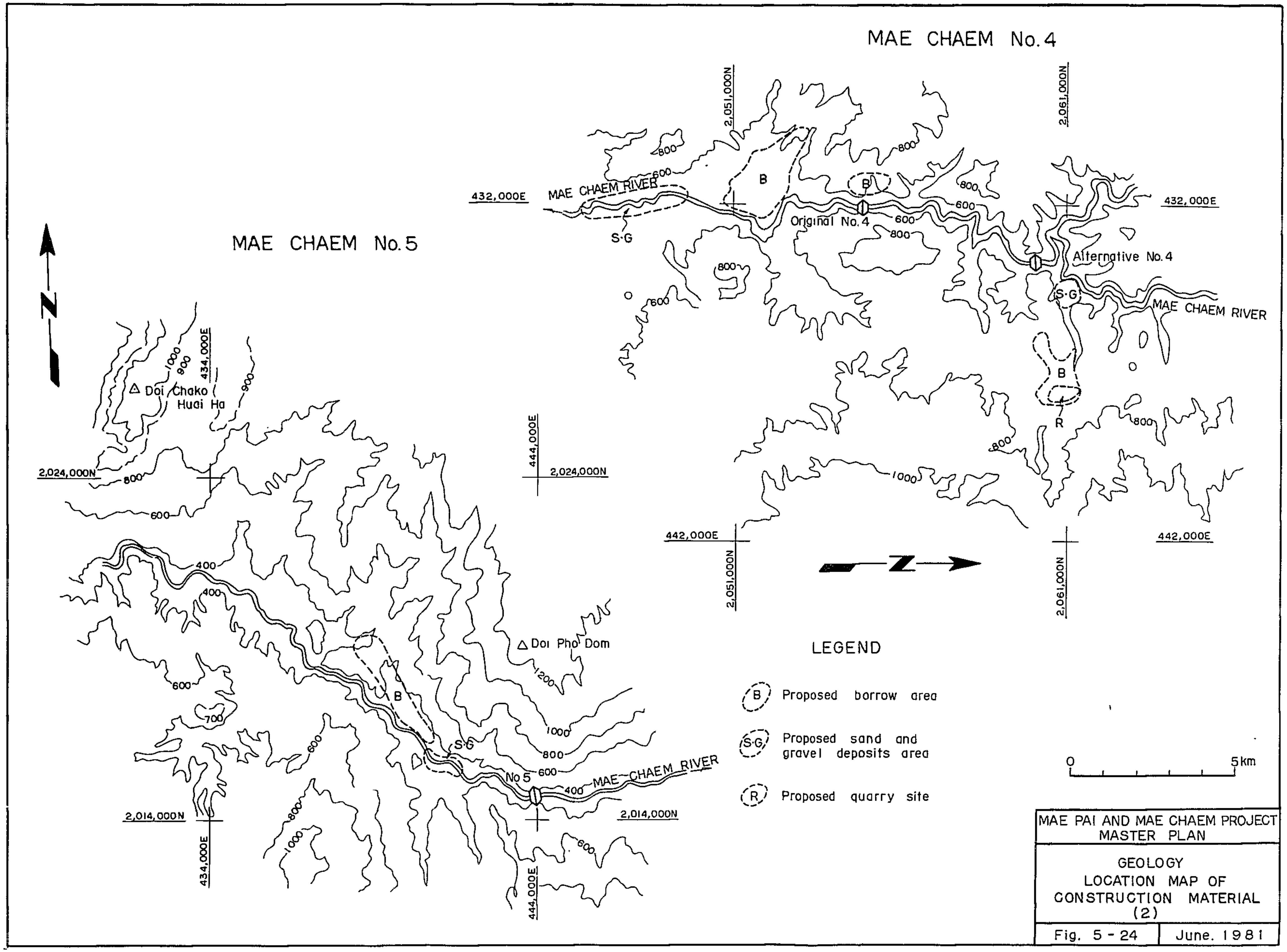
(B) Proposed borrow area

(S·G) Proposed sand and gravel deposits area

(R) Proposed quarry site

0 5km

MAE PAI AND MAE CHAEM PROJECT MASTER PLAN	
GEOLOGY LOCATION MAP OF CONSTRUCTION MATERIAL (1)	
Fig. 5 - 23	June 1981



MAE CHAEM No. 4
MAE CHAEM No. 5
MAE CHAEM RIVER
Original No. 4
Alternative No. 4
S·G
B
R
Δ Doi Chako
Huai Ha
Δ Doi Pho Dom
No 5
432,000E
442,000E
434,000E
444,000E
2,051,000N
2,061,000N
2,024,000N
2,014,000N
N
LEGEND
B Proposed borrow area
S·G Proposed sand and gravel deposits area
R Proposed quarry site
0 5km
MAE PAI AND MAE CHAEM PROJECT MASTER PLAN
GEOLOGY
LOCATION MAP OF CONSTRUCTION MATERIAL (2)
Fig. 5 - 24
June. 1981

Table 5-3-1 List of Previous Investigation Works at Mae Pai Project Area

Area Name	Position	Investigation	Hole Name	Drilling Depth (m)	Remarks
Mae Pai No. 4	Left of dam axis	Drill hole	DH1/L-1	183.4	Permeability test
	River bed of dam axis	"	DH1/M-1	100.0	
	Right of dam axis	"	DH1/R-1	200.0	
Maei Pai No. 5	River bed of dam axis	Drill hole	DH2/M-1	102.1	
Mae Pai No. 6	Left of dam axis	Drill hole	DH-1	200.0	
	River bed of dam axis	"	DH-2	200.0	
	Right of dam axis	"	DH-3	200.0	
	Core material area	Test pit	TH-1 ∿ TH-13	Total 25.0	Laboratory test
		Hand auger	AH-1 ∿ AH-6	" 30.5	
	Quarry site	Test pit	T-1 ∿ T-37	Total 62.0	

Note: The drill cores of the No. 6 site are stored in the NEA Mae Hong Song power station warehouse. The cores of the No. 4 and No. 5 sites were washed out by heavy rainfall and do not exist.

Table 5-3-2 List of Previous Investigation Works at Mae Chaem Project Area

Area name	Position	Investigation	Hole Name	Drilling Depth (m)	Remarks
Mae Chaem No. 4 Original site	Right of dam axis	Test pit	TP-1	2.8	
	Right of dam axis	Hand auger	AH-1 ∿ AH-3	Total 5.6	
	River bed of dam axis	"	AH-4	1.3	
	Borrow area	Hand auger	BA·AH-1 ∿BA·AH-5	Total 15.6	
Mae Chaem No. 5	Left of dam axis	Drill hole	DMC5-1	(Not completed) 56.0	Permeability test
	River bed of dam axis	"	DMC5-2	140.0	
	Right of dam axis	"	DMC5-3	150.0	
	Intake area	"	DMC5-4	65.0	
	Power house area	"	DMC5-5	24.0	
	Right of dam axis	Hand auger	AH-1	4.55	
	"	"	AH-2	2.5	
	Borrow area	Hand auger	AH-3	4.55	Laboratory test
	Quarry site	Test pit	TP-1	1.2	
		"	TP-2	1.25	

Note: The No. 5 site drill cores are stored in the NEA office, north of Chiang Mai.

Table 5-4-1 Generalized Geological Sequence of Project Area

Era	Period	Group	Lithology	Igneous Rocks and Metamorphic Rocks	Main Distribution Area
Cenozoic	Pleistocene-Holocene		Unconsolidated clay, silt, sand, and gravel of stream channels, flood plains, and terraces. Residual lateritic deposits.		In the basins of Amphoe Pai, Ban Paeng and Amphoe Mae Chaem
	Tertiary		Semi-consolidated fluviatile and lacustrine deposits of clay, sand gravel, calcareous tufa and minor lignite.		In the basis of Amphoe Pai and Amphoe Mae Chaem Hilly area in the west of the Chiang Mai plane
Mesozoic	Teriassic			Biotite granite, granodiorite	East of the Mae Pai No. 1 site Mountainous area along Mae Chaem River in the upstream of Amphoe Mae Chaem
Paleozoic	Permian	Rat Buri	Massive light gray limestone.		North of Mae Pai River
	Carboniferous		Shale, sandstone, conglomerate and chert	Biotite-muscovite granite	Igneous rocks: Mountainous area in west of the Chiang Mai plane Sedimentary rocks: Along Khong River West of Mae Chaem River in the upstream of the Mae Chaem No. 3 site
	Silurian-Devonian		Shale, sandstone, sandy shale and chert. In some places interbedded with limestone.		Along Mae Chaem River in the upstream of the Mae Chaem No. 4 site South of Mae Pai River
	Ordovician	Thung Song	Well bedded to massive dark gray limestone. In some places inter-bedded with shale and sandstone.		Along Mae Chaem River in the upstream of the Mae Chaem No. 5 site Along Mae Pai River between the Mae Pai No. 6 and No. 1 sites
	Cambrian-Ordovician		Shale and sandstone, in many places metamorphosed to schist, slate, quartzite and argillite		Around the Mae Pai No. 6 site
Precambrian				Gneiss, schist, marble and anatexitic rocks	Around the Mae Chaem No. 5 site and around the east side of drainage divide of Mae Chaem River Along Mae Khan River

CHAPTER 6

DEVELOPMENT PLAN

CHAPTER 6 DEVELOPMENT PLAN

6.1 Studies Carried out in the Past

The present project has been subject of studies of reconnaissance level by the Japanese Government and by a US Consultant, and the following reports have been presented so far.

1. Kingdom of Thailand
   Nam Pai River Hydroelectric Power Development Project Reconnaissance Report
   Overseas Technical Cooperation Agency - July 1971

2. Pai River Project   Pre-Investment Report
   Engineering Consultant Inc. - March 1971

3. Nam Pai Project   Economic Study of Dam Site
   Engineering Consultant Inc. - December 1971

4. Inventory of Hydro-Power Potential in Thailand   Volume I. Main Report
   Sverdrup & Parcel and Associates Inc. (SPA)
   Southeast Asia Technology Co. (SATC) - February 1978

The documents 1) and 4) listed above seem to have been used as bases of the project. Please refer to each of them for further details on the contents of respective project.

6.2 Study of the Development Project Alternatives

6.2.1 Basic Items

(1) Selection and location of the dam sites

According to the various reports mentioned in the preceding paragraph, 6 project sites have been proposed along the Mae Pai River, 5 along the Mae Chaem River and 2 along the Mae Khan River.

For the sake of preparation of the present Master Plan, the 9 sites listed below have been selected, by taking into consideration the results of the field surveying mentioned in the paragraph 2.4.

Site Name	Coordinates (Km)		Catchment Area	River Bed Elevation
	N	E	(Km^2)	(E.L. m)
Mae Pai No. 1	2,126.07	427.25	1,817	402
Mae Pai No. 6	2,140.57	397.56	3,725	224
*Mae Chaem No. 1	2,097.75	427.22	337	765
Mae Chaem No. 2	2,088.04	429.95	654	697
Mae Chaem No. 3	2,072.36	432.97	969	600
*Mae Chaem No. 4	2,060.06	433.66	1,955	510
Mae Chaem No. 5	2,014.64	443.82	3,735	327
*Mae Khan No. 1	2,084.37	463.77	535	590
Mae Khan No. 2	2,070.56	480.34	1,038	393

The dam waterway type is also taken into consideration in the sites marked with (*).

(2) Catchment area and storage capacity curve

The 3 types of topographical maps listed below can be utilized in the present project.

Scale	1 : 50,000	Whole project area
Scale	1 : 10,000	Part of the planned storage reservoir. Maps referring to the Khan River are not available.
Scale	1 : 2,000	Surroundings of the Mae Pai No. 6 and Mae Chaem No. 3 and No. 5 dam sites.

Topographical maps with 1 : 50,000 scale are used at the occasion of the calculation of the catchment area and reservoir area storage capacity curve, which are the bases of the project. Properly speaking, the 1 : 10,000 scale topographical map should be used for the purpose of preparation of the reservoir area - storage capacity curve, but maps with that scale covering the whole reservoir area are not available, being therefore impossible to use them in the present case. It is required to carry out futurely complementary survey in order to make the corrections in the said curves.

Topographical maps with 1 : 2,000 scale and 1 : 50,000 scale have been used to calculate the approximate construction cost of the dam of the present project. It was verified later at the occasion of the measurement of the catchment area that at the plateau composed of limestone, located at the right bank of the upstream side of the Mae Pai No. 6 site and at the upstream of the Mae Khong River there are ground water flows having catchment areas of approximately

500 km^2 and 130 km^2, respectively. In the present study it is assumed that these ground water flows do not have any influence upon the project itself, in view of the relative positions of the dam site and the basic water gauging stations.

However, at the stage of the feasibility study or definite study it will be required to carry out the survey of the flowing out point of this ground water. The installation of a new water gauging station at the Mae Khong River, which joins at the right bank side of the upstream of the Mae Pai No. 6 site can be taken into consideration as a means for execution of the said survey. Prior to the return of the Survey Team to Japan, the matter was discussed with the NEA, and was recorded in the Minutes of Meeting as a advice item.

The reservoir area - storage capacity curve of the various planned storage reservoirs are presented in the Figs. 6-1 through 6-9.

(3) Plan of study

As mentioned in the Inception Report presented previously, the present study will be carried by dividing it into the phases listed below, taking into consideration the characteristics of the project.

a) Individual development at each dam site in each River.

b) Water pumping and diversion project.

Following are presented the reasons which led to the division mentioned above, in correspondence to each item.

(Individual development at each dam site in each river)
In this scheme the volume of water to be pumped and diverted is not taken into consideration, and the development project is prepared

for the discharge of each individual river, in order to make a discrimination of its economical advantages. The reason leading to this scheme is the fact that the promotion of the development project is possible at the sites where the individual development is feasible from the economical point of view regardless of the water pumping and diversion scheme, being recommendable its soonest materialization.

(Water pumping and diversion project)

After carrying out the studies mentioned above for each river, the project referring to the pumping and diversion of water from the Mae Pai River will be studied, taking as object the sites where the individual development is considered feasible. The irrigation and the water supply projects are studied together with the power generation project, but after discussions with the Thai side, the benefits resulting from the reinforcement of the water resources attained as a consequence of the materialization of the present project are assumed to be due exclusively to the power generation and the irrigation, since the benefits from the water supply projects do not have the clear discrimination criteria.

(4) Mass curves of the each site

The mass curves which will be the base for the purpose of the reservoirs planning have been prepared based upon the discharge at the various sites, studied in the paragraph 4.3). The premises for preparation of the mass curves are as follows.

The natural inflows at the various sites are used for that purpose, assuming that the inflow of the reservoirs located at the downstream is not influenced by the control of the reservoirs located at the upstream. Following are listed as the reasons why an integrated system study from upstream to downstream was not carried out.

- Among all project sites, only the Mae Pai No. 6 and the Mae Chaem No. 5 sites have the surveying works at a relatively advanced stage, and all other sites have many uncertainty factors.
- The access to the various sites with exception of the Mae Chaem No. 5 is very bad, and a rapid progress of the surveying works in a near future can not be expected.
- As mentioned in the Field Investigation Report, the results of the field reconnaissance and interpretation of the air photographs suggest that it is not possible to say that all planned sites are adequate for construction of the dam.
- Even if a project site is judged to be economically feasible it is another question whether the site is geologically feasible for dam construction, and it will be judged by future investigation. Such investigation, however, takes long time to be accomplished due to the local condition.
- Consequently, it is not realistic at present stage to consider this project is to be developed one by one from upstream.
- In view of the facts described above, it is recommendable to study initially the scheme of the individual development of each site, with subsequent execution of the Feasibility Study of the each site, starting from those with higher degree of priority.

In addition, even when the development scale is determined independently for a given site, the reservoir of the site in question will have its function reinforced in case of construction of a dam at the upstream side, and consequently there is not any disadvantage at all with regard to this alternative.

In view of the reasons mentioned above, the system study based upon the premise of the development starting from the upstream side is not carried out in the present study. The mass curve of the each site is presented in the Figs. 6-10 through 6-18.

6.3 Individual Development Scheme

6.3.1 Selection of the Cases for Study

The cases for study are selected by taking into consideration the mass curves of the various sites and the results of the field reconnaissance. The prepared mass curves refer to the period of 13 years lasting from 1966 through 1978 in the Mae Pai River, to the period of 25 years lasting from 1955 through 1979 in the Mae Chaem River and to the period of 7 years lasting from 1962 through 1968 in the Mae Khan River.

According to these mass curves, the period of most pronounced drought was the period of 3 years lasting from 1968 through 1970 in the Mae Pai River, the period of 3 years lasting from 1957 through 1959 in the Mae Chaem River, and the period of 2 years lasting from 1965 through 1966 in the Mae Khan River. The selection of the reservoir scale considered as object of comparative study is conducted, assuming that it has a capacity sufficient to allow a continuous supply of discharge during the drought seasons mentioned above, in addition to an effective capacity making possible a control rate of 35% through 40% with regard to the average inflow. Accordingly, the effective storage capacity is assumed to have in principle a constant value, even when the dam height is changed. However, the effective storage capacity will be reduced when the dam has a small height, because the 100 year sedimentation is assumed with reference to the quantity of sand accumulated in the storage reservoir. On the other hand, the control rate of 35% through 40% does not have any special meaning, and this value is adopted as a reference, because a capacity of this order is assumed to be sufficient to prevent any inconvenience at the occasion of the operation of the storage reservoir with regard to the mass curve.

The reservoir scale was selected based upon the criteria described above, and by taking also into consideration the points of view resulting from the field reconnaissance.

As for the design output of the power station, it is assumed to have a capacity making possible the operation at the standard output with a daily load factor of 20% even in the year of the most pronounced drought mentioned above.

The normal head is determined by the following expression:

$$\text{Normal head} = \left(\frac{\text{Normal high water level} - \text{Available drawdown}}{3}\right)$$
$$- \text{Tailwater level} - \text{Head loss}$$

* Value in the parentheses is water level derived from gravity center in the resevoir.

The number of study cases of the individual development project alternative are as follows.

Mae Chaem No. 1	Dam type	3 cases	
Mae Chaem No. 1	Dam waterway type	3 cases	Waterway length 3,300 m
Mae Chaem No. 1	Dam waterway type	3 cases	Waterway length 8,500 m
Mae Chaem No. 2	Dam type	3 cases	
Mae Chaem No. 3	Dam type	4 cases	
Mae Chaem No. 4	Dam type	2 cases	
Mae Chaem No. 4	Dam waterway type	2 cases	
Mae Chaem No. 5	Dam type	5 cases	
Mae Pai No. 1	Dam type	1 case	
Mae Pai No. 6	Dam type	4 cases	

Mae Khan No. 1	Dam type	3 cases
Mae Khan No. 1	Dam waterway type	3 cases
Mae Khan No. 2	Dam type	3 cases
	Total	39 cases

The characteristics of the various cases for study of the various sites selected in accordance with the criteria above are presented in Tables 6-1 through 6-7 and in Figs. 6-19 through 6-21.

6.3.2 Calculation of Energy

The energy is calculated for the various cases selected in accordance with the contents of the preceding paragraph, based upon the mass curve of the each site.

The period of calculation coincides with the periods of the various mass curves, and the energy is calculated with computers, based upon the values of the monthly discharges. The heads are calculated by using as a reference the water level occurring at the end of the month, in the operation of the reservoirs.

The calculated energy is divided into firm energy referring to the portion of energy required during the peak hours and secondary energy that required during the other hours for the purpose of calculation of the benefits.

The evaporation from the storage reservoir surface is taken into consideration for the purpose of calculation of the turbine discharge.

Before the construction of the storage reservoir, the evaporation from the reservoir can be replaced by the evapotranspiration from the flora and accordingly, the actual evaporation is calculated as a difference between the evapotranspiration and the evaporation from the reservoir surface.

The evapotranspiration from the flora is calculated by the Blaney-Criddle Formula. The results of the calculation are presented in Tables 6-8 through 6-10.

The calculation indicates that the actual evaporation is approximately 380 mm in the Mae Pai River, approximately 400 mm in the Mae Chaem River and approximately 160 mm in the Mae Khan River.

The summaries referring to the energy generated at the 4 sites considered adequate in the discussion presented in the next paragraph are presented in Tables 6-11 through 6-14.

6.3.3 Economic Evaluation and Determination of the Development Scale at the Proposed Sites

Details referring to the economic evaluation are presented in Chapter 12. In this Chapter the site to be developed will be selected by carring out the economic evaluation at the generating sites, and the optimum scale at the Master Plan level will be also studied.

The economic evaluation is done based upon the benefit-cost ratio (B/C) and the surplus benefit (B-C) of the sites.

The alternative thermal electric power, which is used as a criterion for calculation of the benefit, is assumed to generate power with imported coal. The unit price of the benefit is assumed to be as follows.

kW price	:	139.9 US$	2,868฿ (20.5฿/US$)
kWh Price (Firm)	:	0.03387 US$	0.6943฿
kWh Price (Secondary)	:	0.03315 US$	0.6796฿

On the other hand, with regard to the costs, the approximate construction cost is calculated for each case in accordance with the method described in the Chapter 11 and the annual costs are calculated through the capital recovery factor. The interest rate is assumed to be 10%.

The results of these calculations are presented in Figs. 6-22 through 6-23 and in Tables 6-15 through 6-17. According to these results, the Nam Pai No. 1 and No. 6 and the Mae Chaem No. 5 sites are considered economically feasible. As for Mae Chaem No. 4, it can not be considered economically advantageous at the present time, but depending upon the method of economic evaluation and the future progress of the studies, its evaluation may suffer changes. Accordingly, it is recommended in the present Master Plan to carry out the Pre-Feasibility Study or the Feasibility Study of the 4 sites listed above.

Next, the optimum scale for these 4 sites is determined by taking into consideration the benefit-cost ratio (B/C) and the surplus benefit (B-C) as follows.

However, it goes without saying that the scale of development should be analyzed once again at the next stage.

Mae Pai No. 1	HWL	475.0 m
	Pmax.	48.9 MW
Mae Pai No. 6	HWL	400.0 m
	Pmax.	291 MW
Mae Chaem No. 4	HWL	580.0 m
	Pmax.	27.6 MW
Mae Chaem No. 5	HWL	440.0 m
	Pmax.	103.0 MW

The specifications of the development plan referring to the 4 sites above are summarized in Table 6-18.

6.4 Water Pumping and Diversion Project

6.4.1 Basic Conditions

As discussed in the Paragraph 6.3.3, among the cases of individual development alternatives studied in the present study, only the 2 sites at the Mae Chaem River are economically feasible as subject of water pumping and diversion.

In the Mae Khan River the dam type and the dam waterway type of the No. 1 dam site and the dam type scheme at the No. 2 site present less economic advantage. As a consequence, only the Mae Chaem River is taken into consideration as object of water diversion from the Mae Pai River. The basic methodology and the cases for study are as follows.

(1) As for the facility conditions at the Mae Pai side, the 2 stage development and the single stage development schemes will be assumed

as basic ones, and both the No. 1 and the No. 6 dams are assumed to have been already developed in accordance with the scale mentioned in the paragraph 6.3.3 for either development scheme.

(2) As for the volume of pumped water, the whole inflow of the Pai No. 1 site is assumed to be diverted. Accordingly, the design is studied by assuming that the maximum volume of pumped water is basically that corresponding to the discharge of the wet season of 2 years lasting from November of 1973 through November of 1975, during the period of 13 years lasting from 1966 through 1978.

(3) The daily pumping hours are assumed to be 8 hours, by taking into consideration the daily load within the EGAT System. Accordingly, the maximum volume of pumped water will be as follows.

$$\text{Maximum volume of pumped water} = 25.7 \times \frac{24}{8} = 77 \ m^3/s$$

This volume will be pumped from the Pai No. 1 reservoir, but it is assumed that the same volume will be also applied to the case pumping from the Pai No. 6 reservoir in the present study.

(4) The 4 cases listed below will be studied in the present study.

- Case referring to the pumping of water from the Pai No. 1 reservoir to the Mae Chaem No. 4 and No. 5 and the Bhumibol reservoirs.
- Case referring to the pumping of water from the Pai No. 1 reservoir to the Mae Chaem No. 5 and Bhumibol reservoirs.
- The 2 cases referring to the pumping of water from the Pai No. 6 reservoir to each reservoir mentioned in the 2 preceeding items.

6.4.2 Pumping Energy

The volume of water to be pumped and the water level of the reservoirs, which are the basic data required for calculation of the energy for water pumping and diversion, are calculated by using the mass curves of the Mae Pai No. 1 and No. 6 sites. The mass curve of the Mae Pai No. 1 site is shown in Fig. 6-24. As mentioned in the preceeding paragraph, the maximum volume of water to be pumped is based upon the discharge of the wet season and accordingly the pumping energy required in the other years is less than that required in the wet season. The specification of the pumping facilities required for calculation of the water pumping energy are as follows. The tailwater level at the Mae Chaem River should be studied in such a way to have its value optimized by taking into consideration the relation between the length of the water diversion tunnel and the head, but in the present case it is assumed to be located at EL.900m.

	From Pai No. 1	From Pai No. 6
Intake level (m)	456	387
Tailwater level (m)	900	900
Pumping head (m)	444	513
Gross pumping head (m)	466	556
Maximum pumped discharge (m^3/s)	77	77
Maximum pumping power (MW)	428	512

The conceptual configuration of the water pumping facilities is presented in Fig. 6-25. The results of calculation of the water pumping energy at the Mae Pai No. 1 site are presented in Table 6-19.

6.4.3 Economical Evaluation

The economical evaluation of the water pumping project is done based upon the benefit-cost ratio (B/C) and upon the surplus benefit (B-C), like in the individual river development project.

The costs and the benefits taken into consideration in the water pumping and water diversion project are as follows.

(1) Costs

- Construction costs of the water pumping facilities.

  Intake, intake tunnel, pump station, penstock, upper pond water diversion tunnel, hydraulic equipment, electric equipment, etc.

  The costs for construction of the Pai No. 1 and No. 6 dams are not included, because they are assumed to have been already constructed.

- Costs for construction of the Mae Chaem No. 4 and No. 5 power stations

  Intake, headrace, penstock, power station, outlet, switchyard, hydraulic equipment, electric equipment, etc.

- Pumping energy cost

  The whole energy used for water pumping purpose is to be the secondary energy, and the unit cost per kWh 0.03315US$ is applied.

- Costs related to the agriculture

  Cost per unit volume of pumped water ฿ 0.44/m^3 is applied.

(2) Benefits

- kW and kWh benefits of the Mae Chaem No. 4 and No. 5 power stations.
- Increment of kWh benefit of the presently existing Bhumibol power station.
- Agricultural benefits resulting from the irrigation.

  ฿0.8 per m^3 of pumped water.
- Benefit of kWh reduced from Pai No. 1 and No. 6 power stations, resulting from water diversion.

  The evaluation of the kW price is not included in the present report, because it depends upon when the water pumping project will be materialized after the completion of the Pai No. 1 and No. 6 power stations.

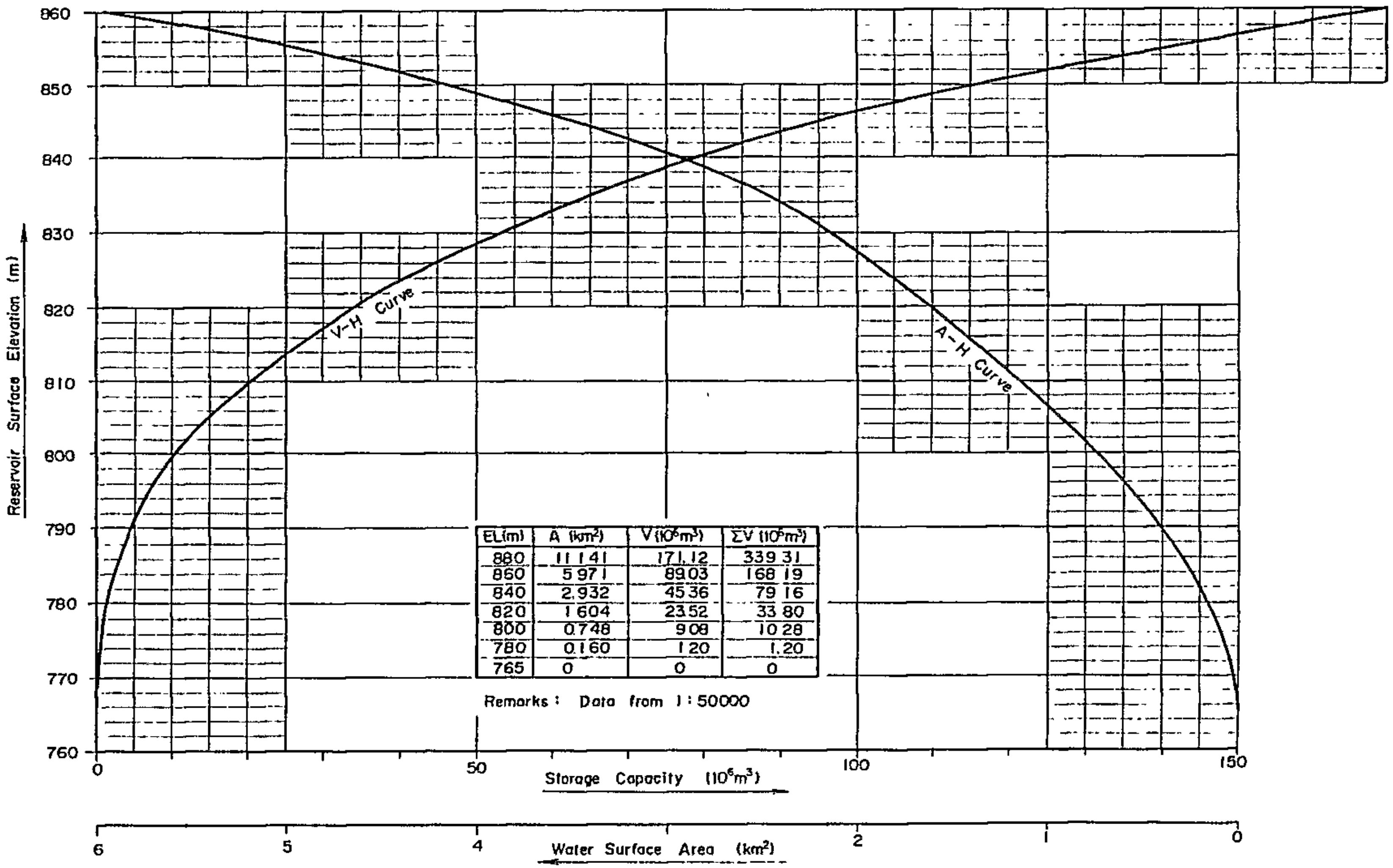
The 4 cases in question are studied based upon the casts and benefits mentioned above. The results of the study are presented in Table 6-20.

The results of the said study evidence that the case assuming the diversion of water to the Mae Chaem River and construction of the No. 4 and No. 5 power stations after the 2 stage development of the Mae Pai River brings the most advantageous results. However, it is unavoidable to state that in any case the project is not economically profitable.

Moreover, if pumping up facilities are actually constructed, certain technical difficulties are expected to occur, with regard to the construction of the underground water pumping station, penstock and especially the construction of the long diversion tunnel. In addition, there are many factors closely related to the increase of costs.

Fig. 6-1 Mae Chaem No. 1 Reservoir Area and Capacity Curves

(C.A. = 337 Km^2)

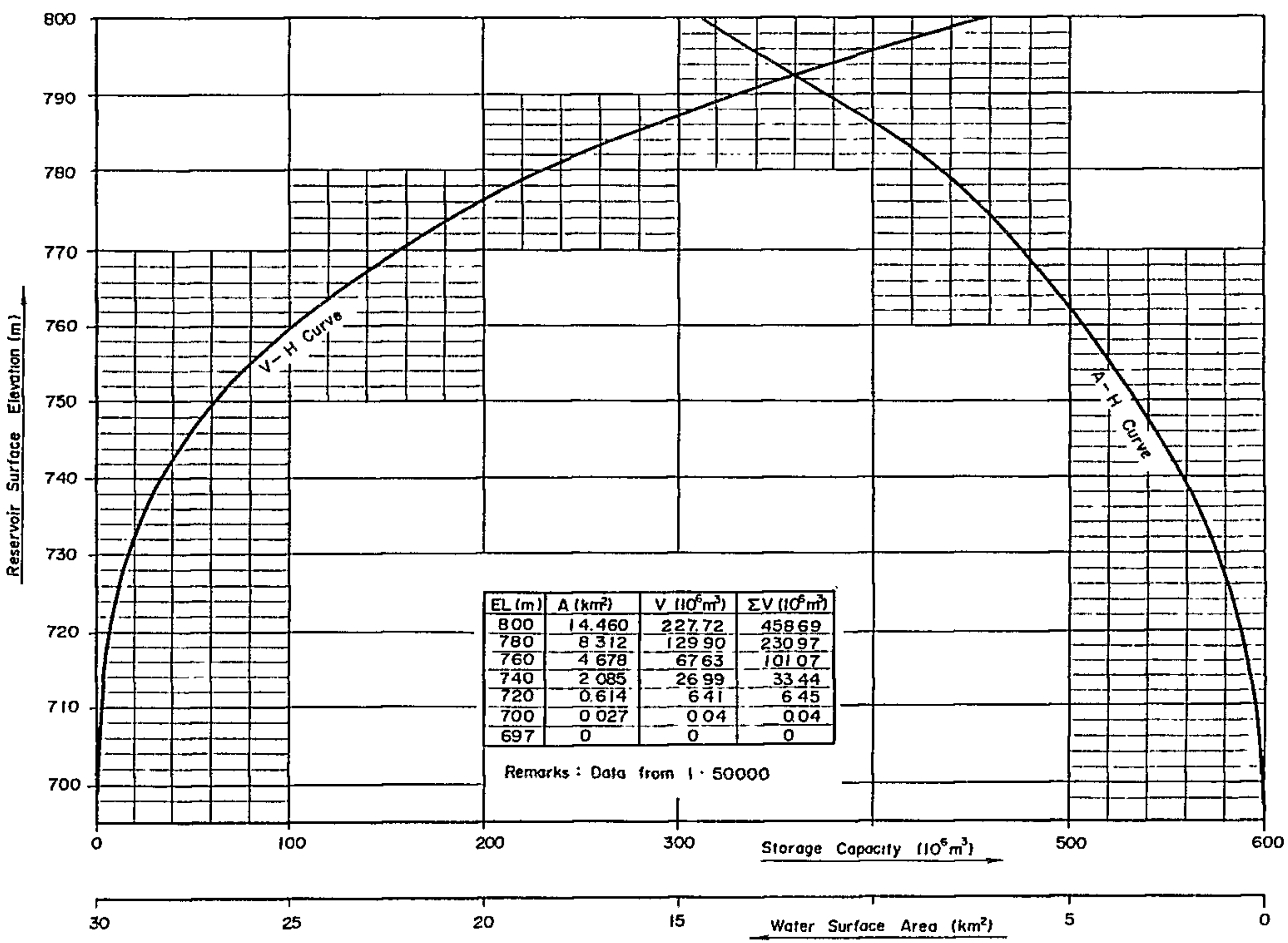


EL(m)	A (km^2)	V($10^6 m^3$)	ΣV ($10^6 m^3$)
880	11.141	171.12	339.31
860	5.971	89.03	168.19
840	2.932	45.36	79.16
820	1.604	23.52	33.80
800	0.748	9.08	10.28
780	0.160	1.20	1.20
765	0	0	0

Remarks : Data from 1 : 50000

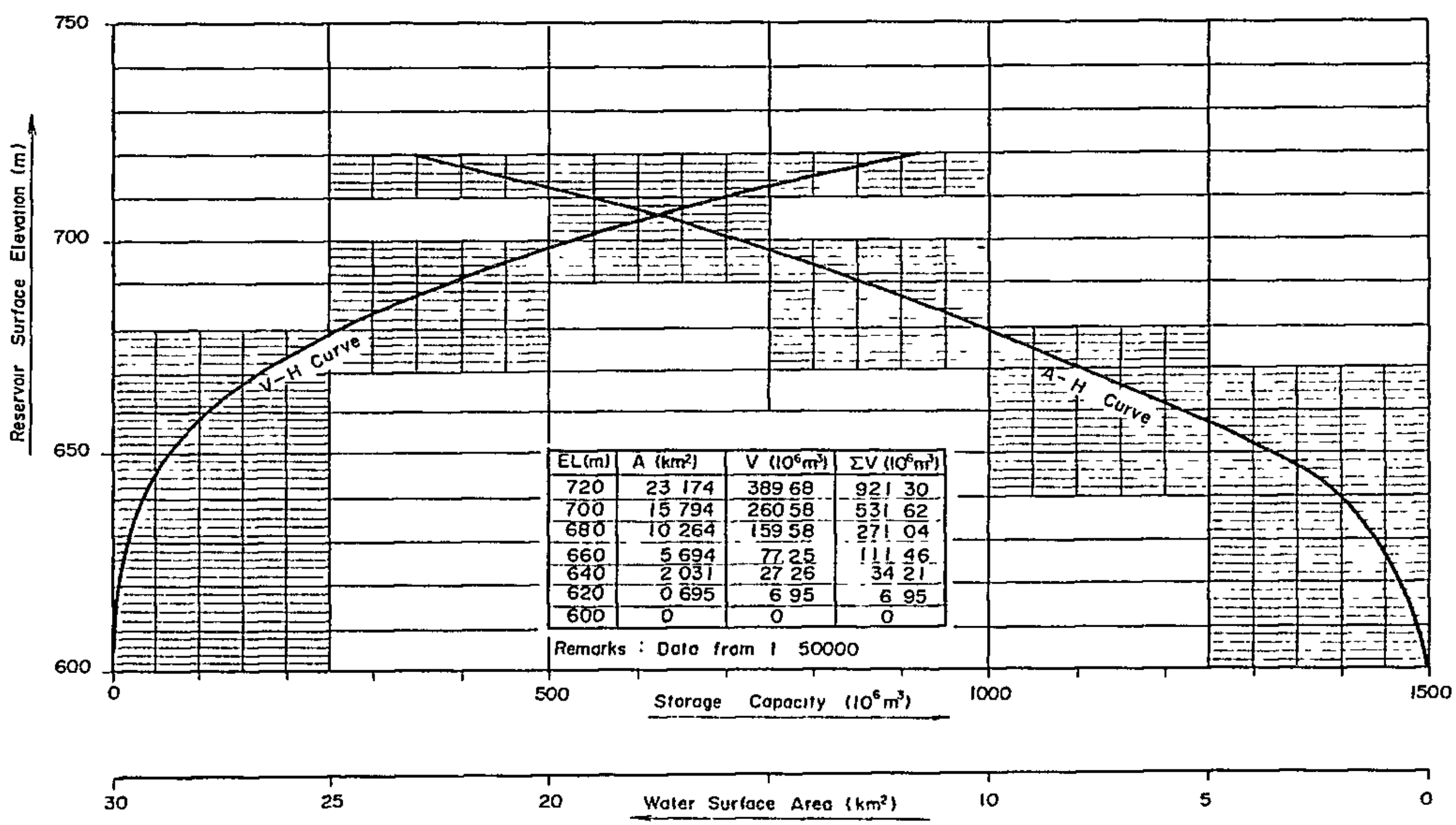
Fig. 6-2 Mae Chaem No.2 Reservoir Area and Capacity Curves

(C.A.= 654 Km²)



EL (m)	A (km^2)	V ($10^6 m^3$)	ΣV ($10^6 m^3$)
800	14.460	227.72	458.69
780	8.312	129.90	230.97
760	4.678	67.63	101.07
740	2.085	26.99	33.44
720	0.614	6.41	6.45
700	0.027	0.04	0.04
697	0	0	0

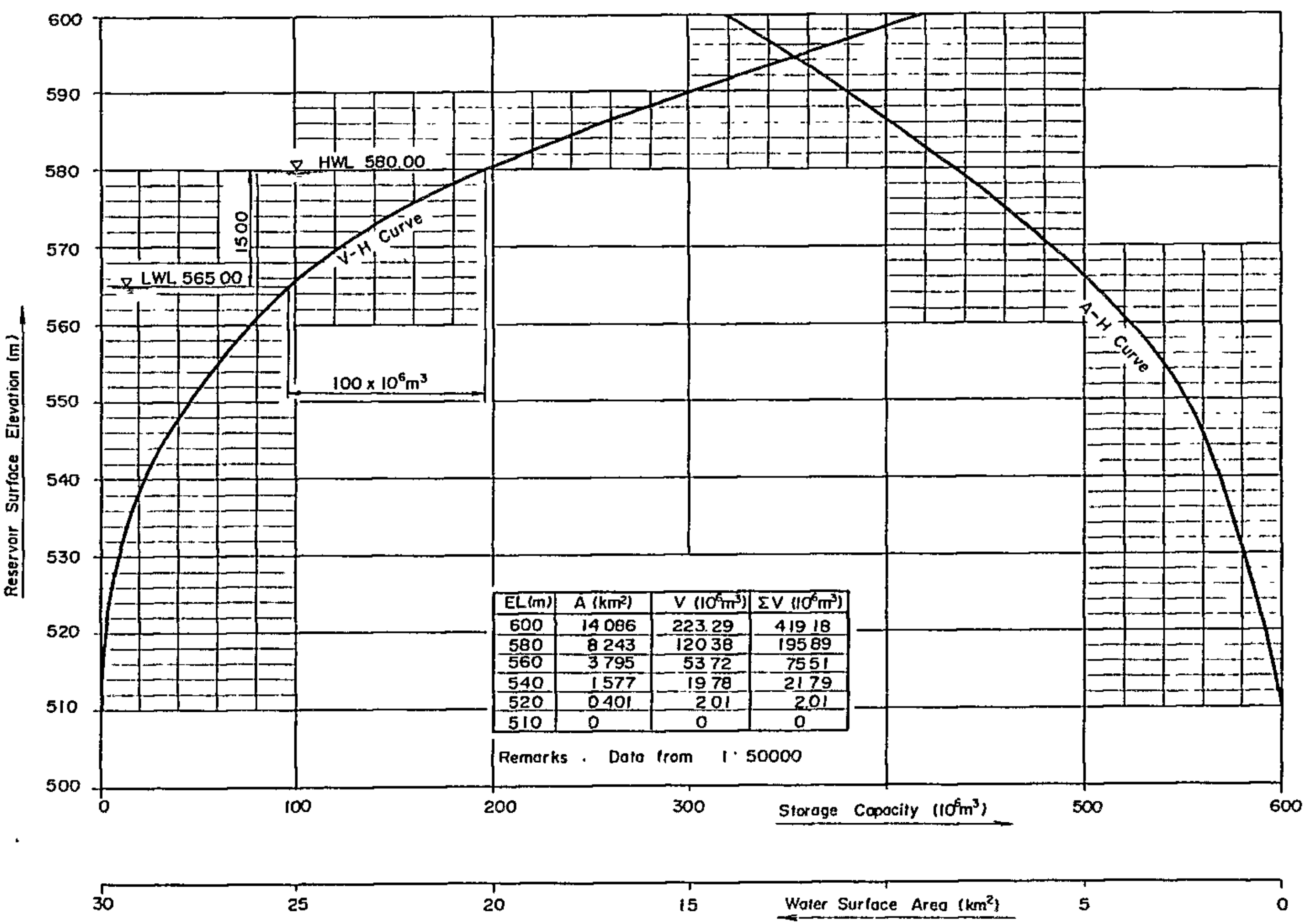
Fig. 6-3 Mae Chaem No.3 Reservoir Area and Capacity Curves



EL(m)	A (km²)	V (10⁶m³)	ΣV (10⁶m³)
720	23 174	389 68	921 30
700	15 794	260 58	531 62
680	10 264	159 58	271 04
660	5 694	77 25	111 46
640	2 031	27 26	34 21
620	0 695	6 95	6 95
600	0	0	0

Remarks : Data from 1 50000

Fig. 6-4 Mae Chaem No. 4 Reservoir Area and Capacity Curves (C.A.= 1955 km²)

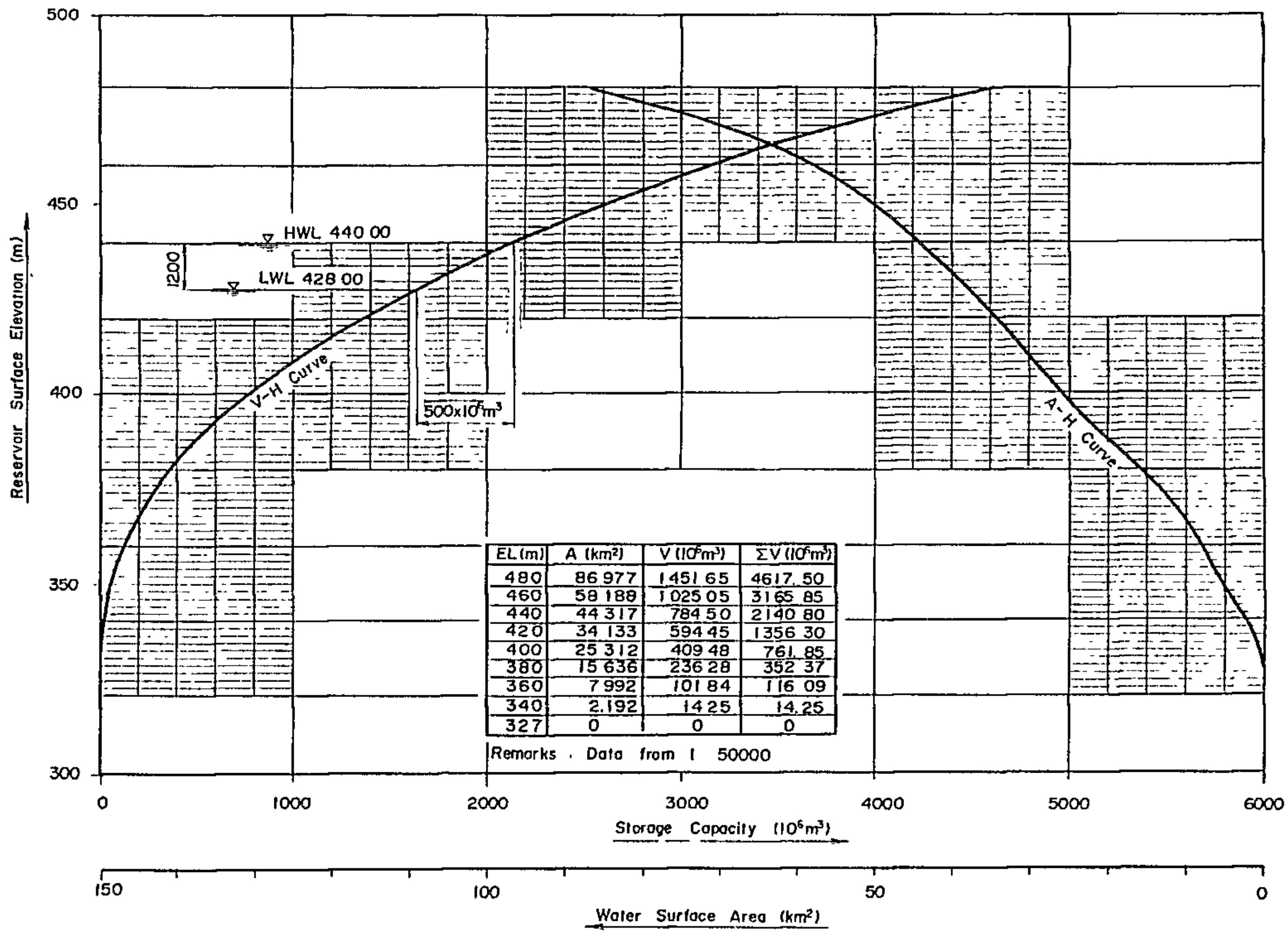


EL(m)	A (km²)	V (10⁶m³)	ΣV (10⁶m³)
600	14 086	223.29	419 18
580	8 243	120 38	195 89
560	3 795	53 72	75 51
540	1 577	19 78	21 79
520	0 401	2 01	2.01
510	0	0	0

Remarks . Data from 1 : 50000

Fig. 6-5 Mae Chaem No.5 Reservoir Area and Capacity Curves

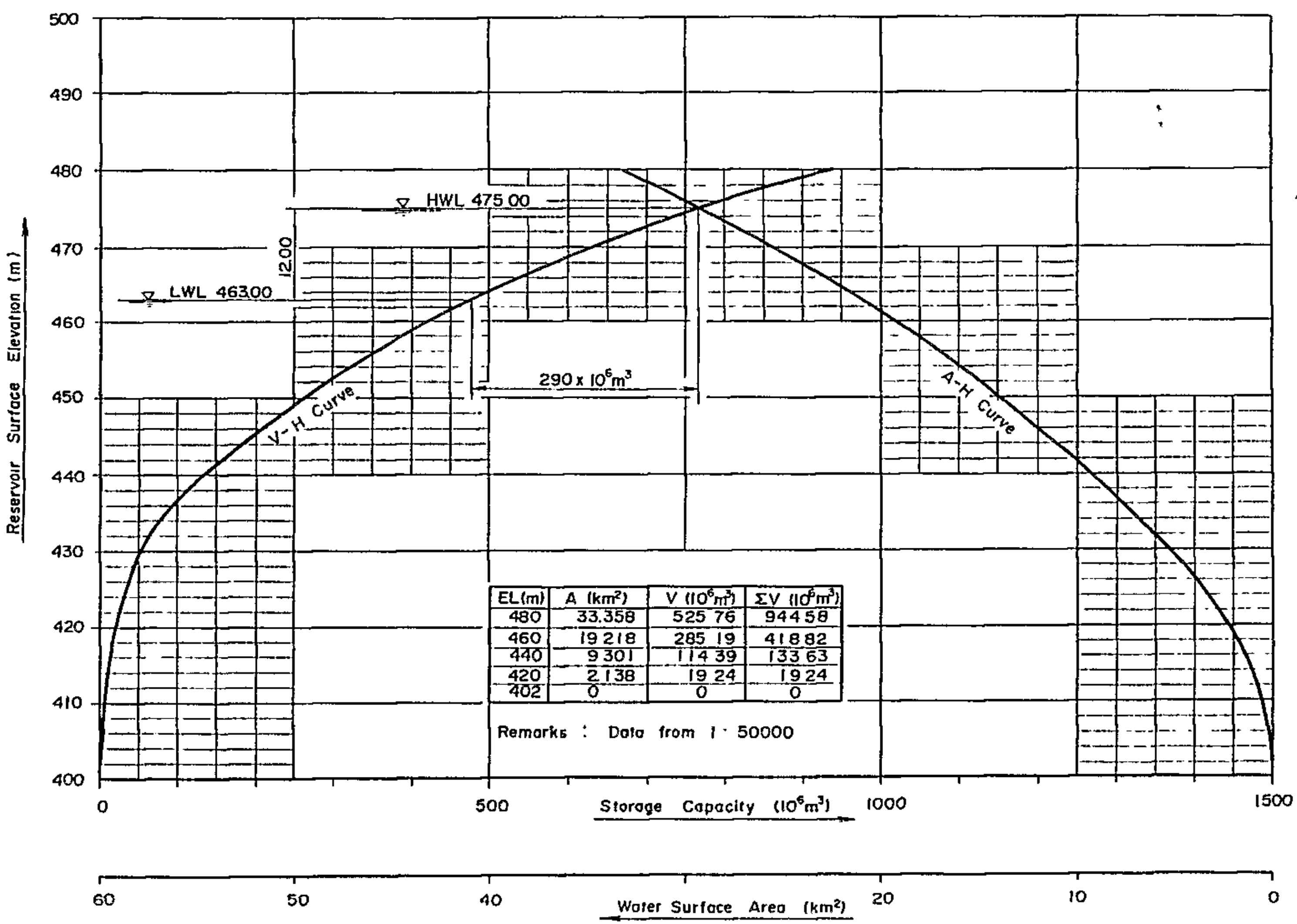
(C.A.= 3735 Km²)



EL(m)	A (km²)	V (10⁶m³)	ΣV (10⁶m³)
480	86 977	1451 65	4617. 50
460	58 188	1025 05	3165 85
440	44 317	784 50	2140 80
420	34 133	594 45	1356 30
400	25 312	409 48	761. 85
380	15 636	236 28	352 37
360	7 992	101 84	116 09
340	2.192	14 25	14. 25
327	0	0	0

Remarks . Data from 1 50000

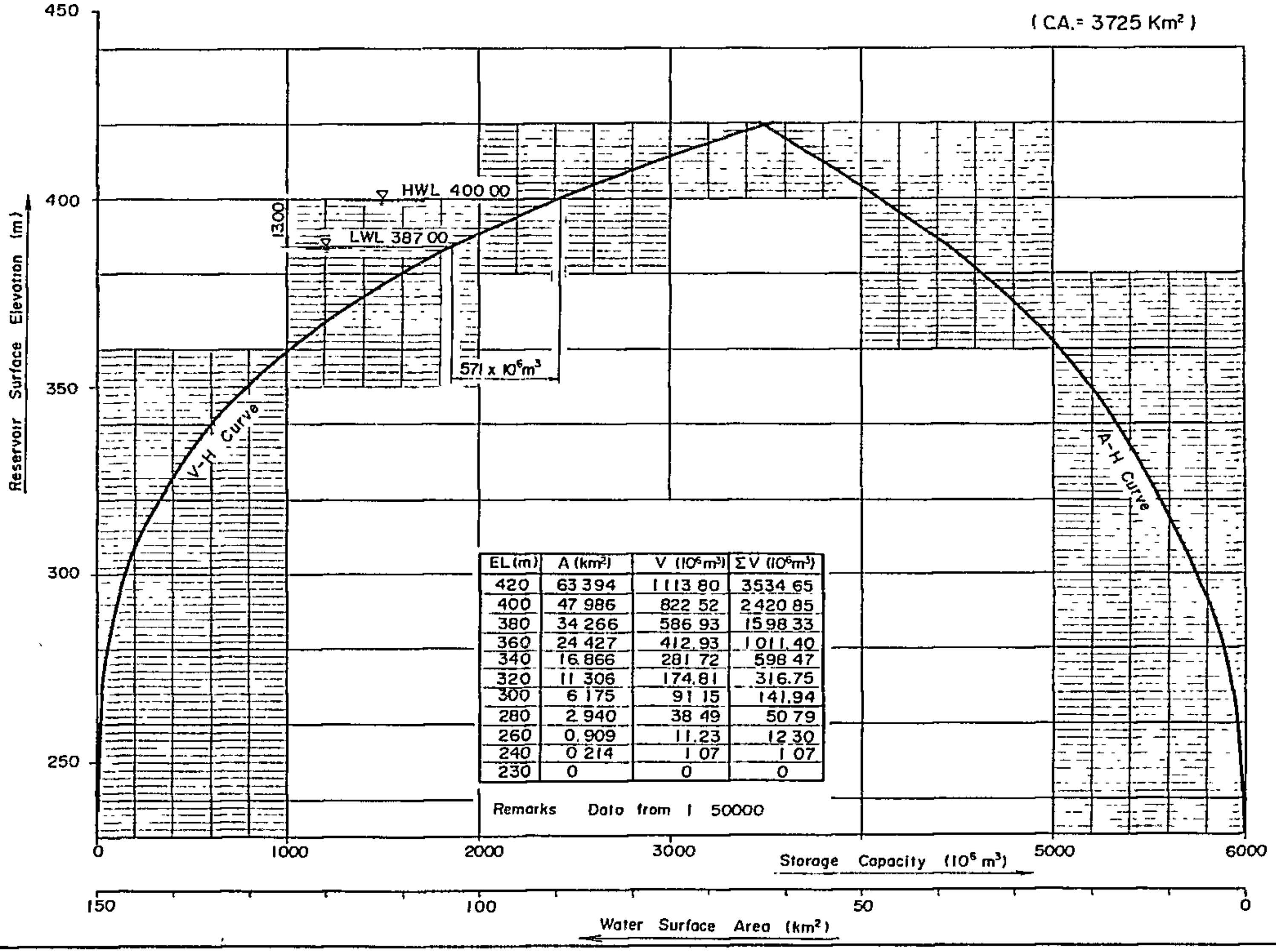
Fig. 6-6 Mae Pai No.1 Resevoir Area and Capacity Curves (CA = 1817 Km²)



EL(m)	A (km²)	V (10⁶m³)	ΣV (10⁶m³)
480	33.358	525 76	944 58
460	19 218	285 19	418 82
440	9 301	114 39	133 63
420	2 138	19 24	19 24
402	0	0	0

Remarks : Data from 1 : 50000

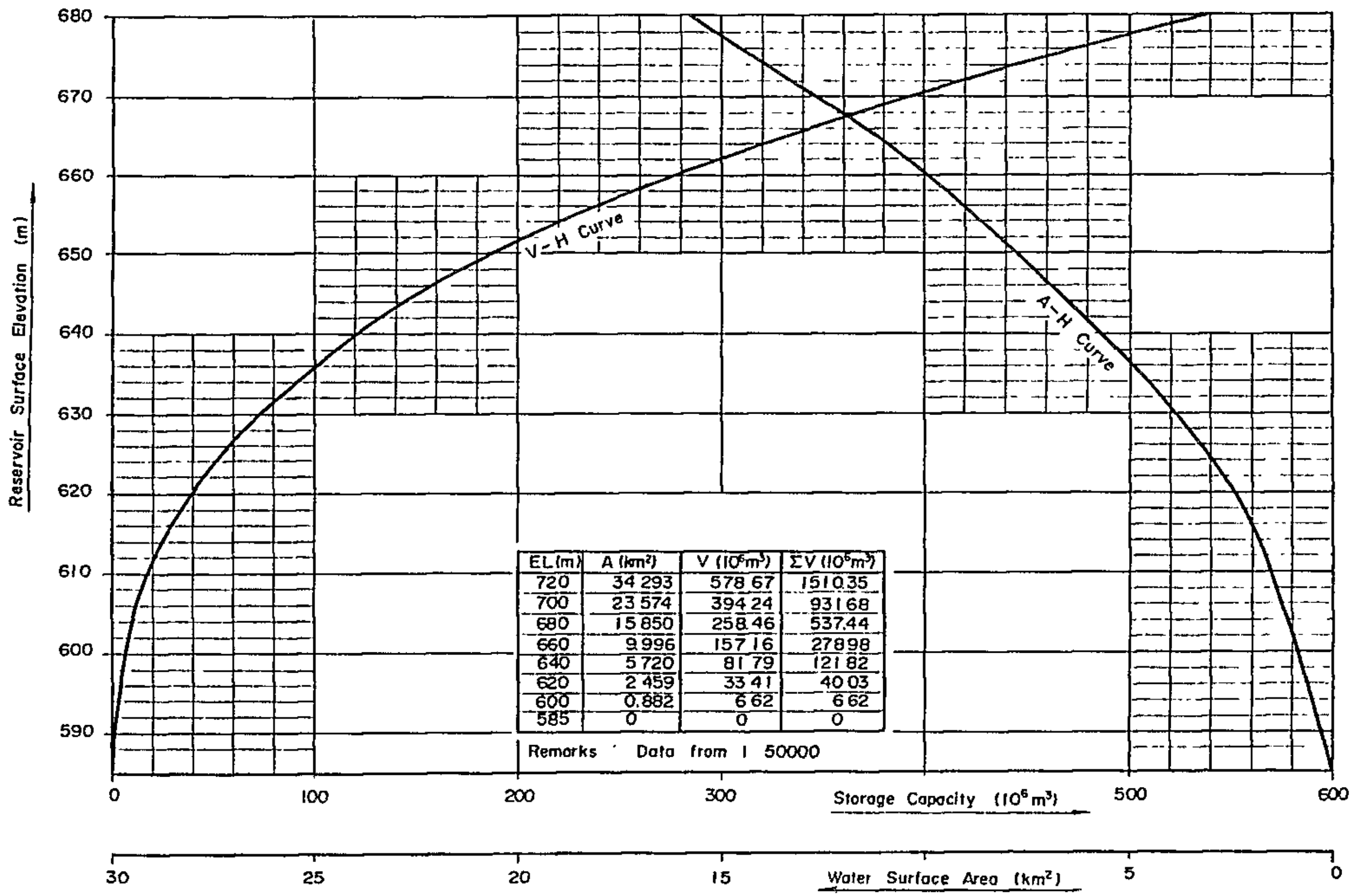
Fig. 6-7 Mae Pai No. 6 Reservoir Ares and Capacity Curves



EL (m)	A (km²)	V (10⁶m³)	ΣV (10⁶m³)
420	63.394	1 113.80	3534.65
400	47.986	822.52	2 420.85
380	34.266	586.93	1598.33
360	24.427	412.93	1 011.40
340	16.866	281.72	598.47
320	11.306	174.81	316.75
300	6.175	91.15	141.94
280	2.940	38.49	50.79
260	0.909	11.23	12.30
240	0.214	1.07	1.07
230	0	0	0

Remarks Data from 1 : 50000

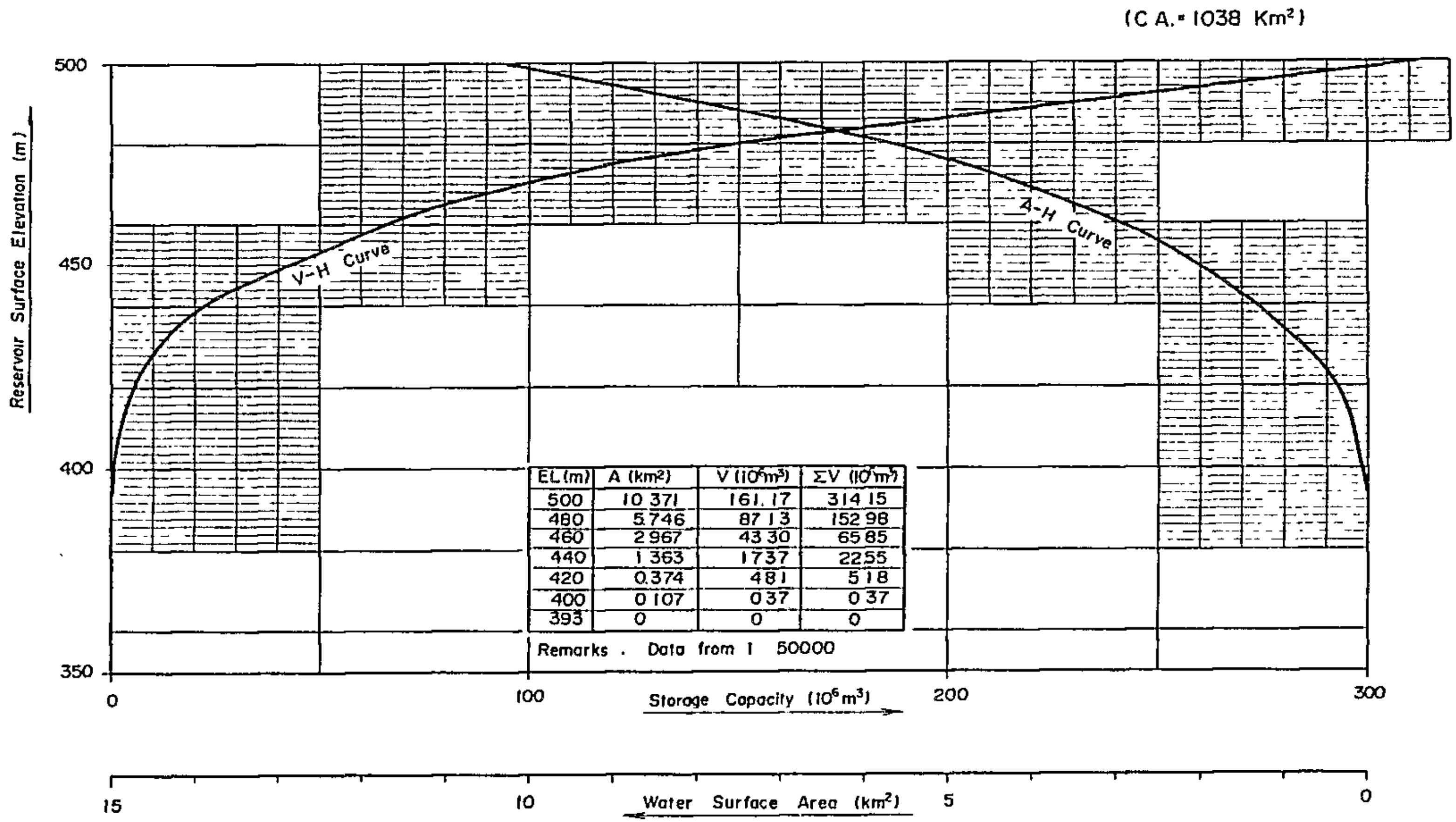
Fig. 6-8 Mae Khan No.1 Reservoir Area and Capacity Curves (C.A.=535 Km²)



EL (m)	A (km^2)	V ($10^6 m^3$)	ΣV ($10^6 m^3$)
720	34 293	578 67	1510.35
700	23 574	394 24	931 68
680	15 850	258.46	537.44
660	9.996	157 16	278 98
640	5 720	81 79	121 82
620	2 459	33 41	40 03
600	0.882	6 62	6 62
585	0	0	0

Remarks : Data from 1 : 50000

Fig. 6-9 Mae Khan No. 2 Reservoir Area and Capacity Curves



EL (m)	A (km^2)	V ($10^6 m^3$)	ΣV ($10^6 m^3$)
500	10.371	161.17	314.15
480	5.746	87.13	152.98
460	2.967	43.30	65.85
440	1.363	17.37	22.55
420	0.374	4.81	5.18
400	0.107	0.37	0.37
393	0	0	0

Remarks . Data from 1 : 50000

Fig 6 - 10 Mass Curve at Mae Chaem NO.1 Site

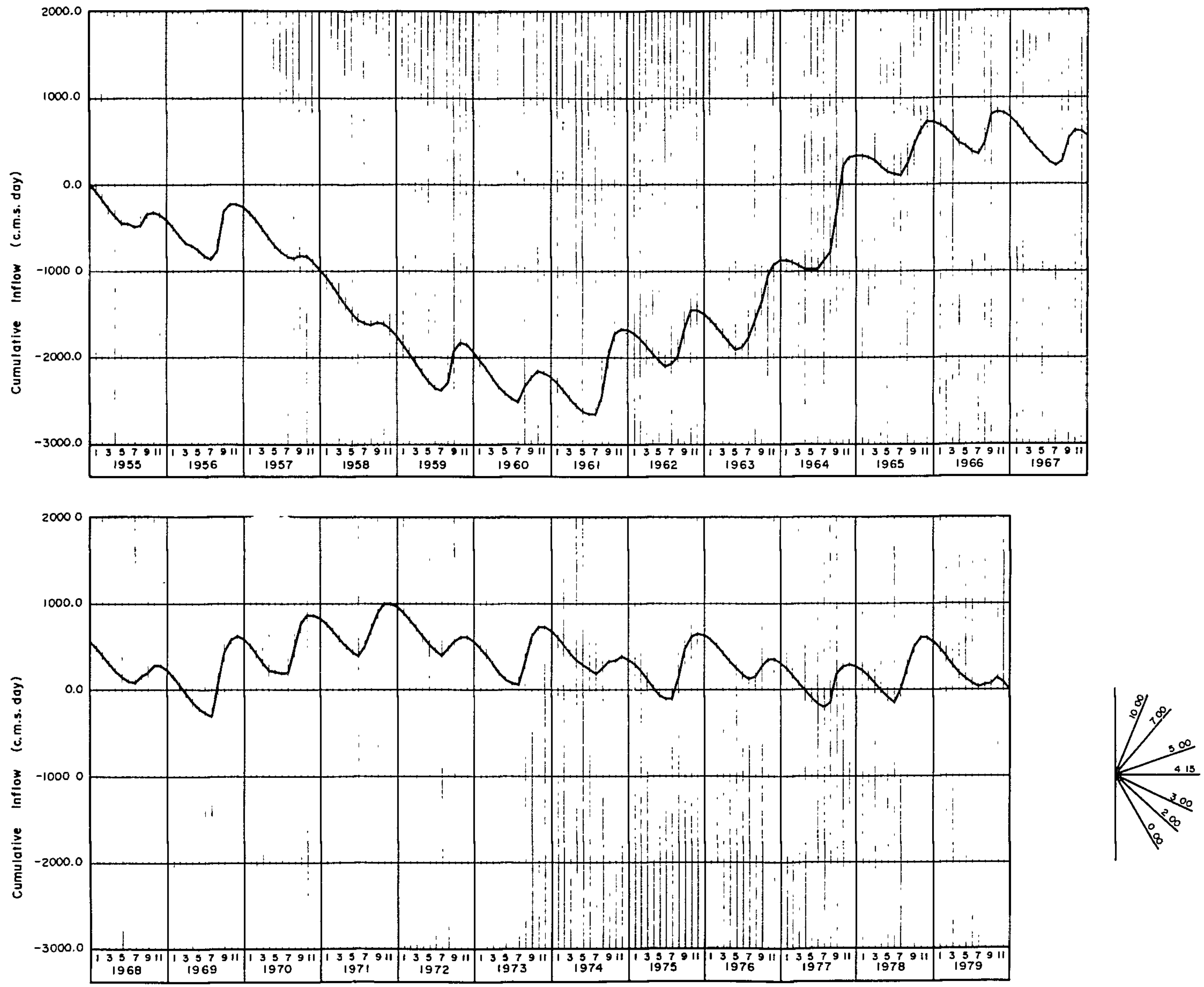
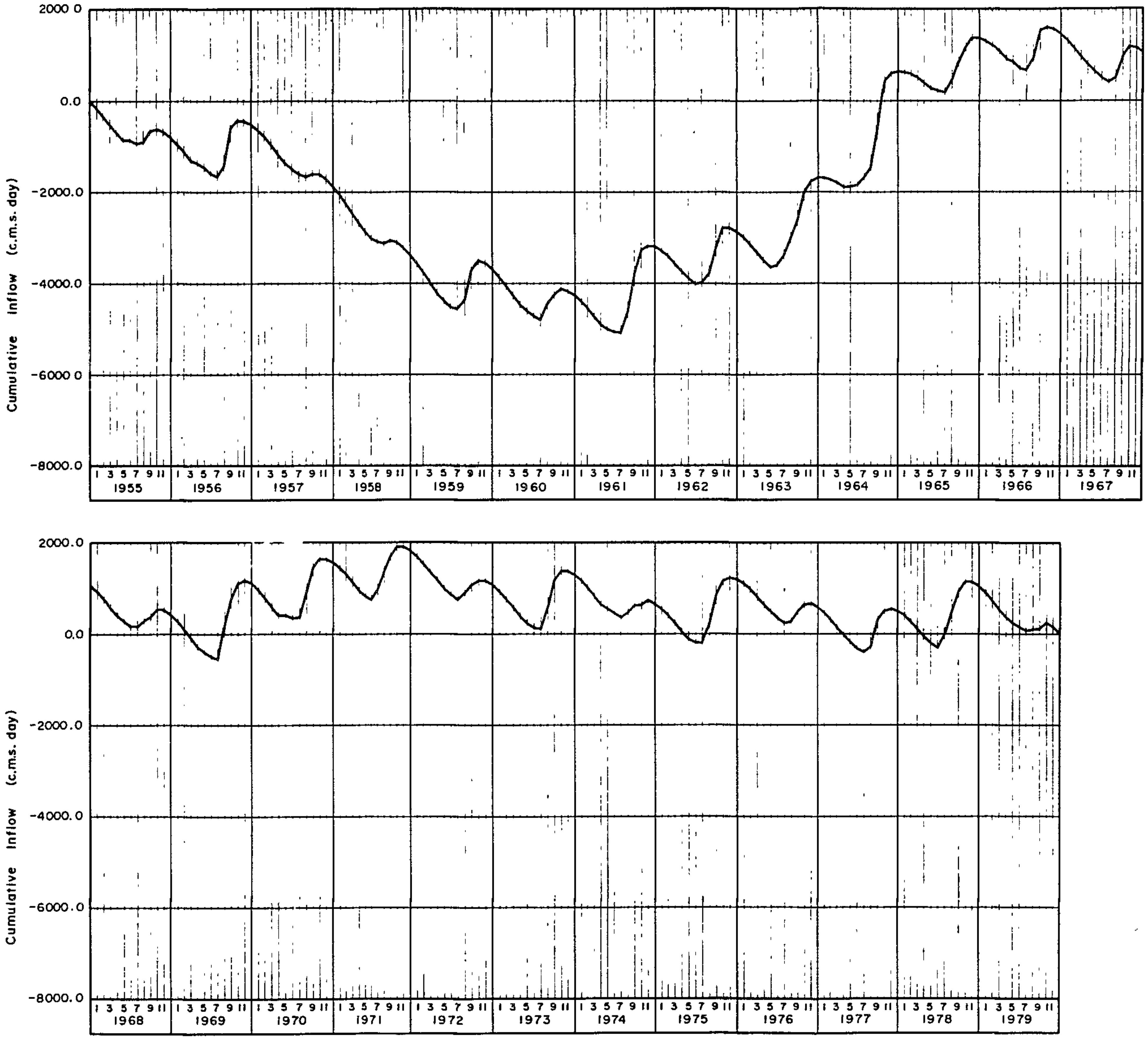


Fig 6-11 Mass Curve at Mae Chaem NO.2 Site



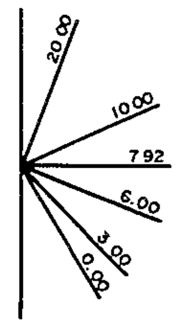


Fig 6-12 Mass Curve at Mae Chaem NO.3 Site

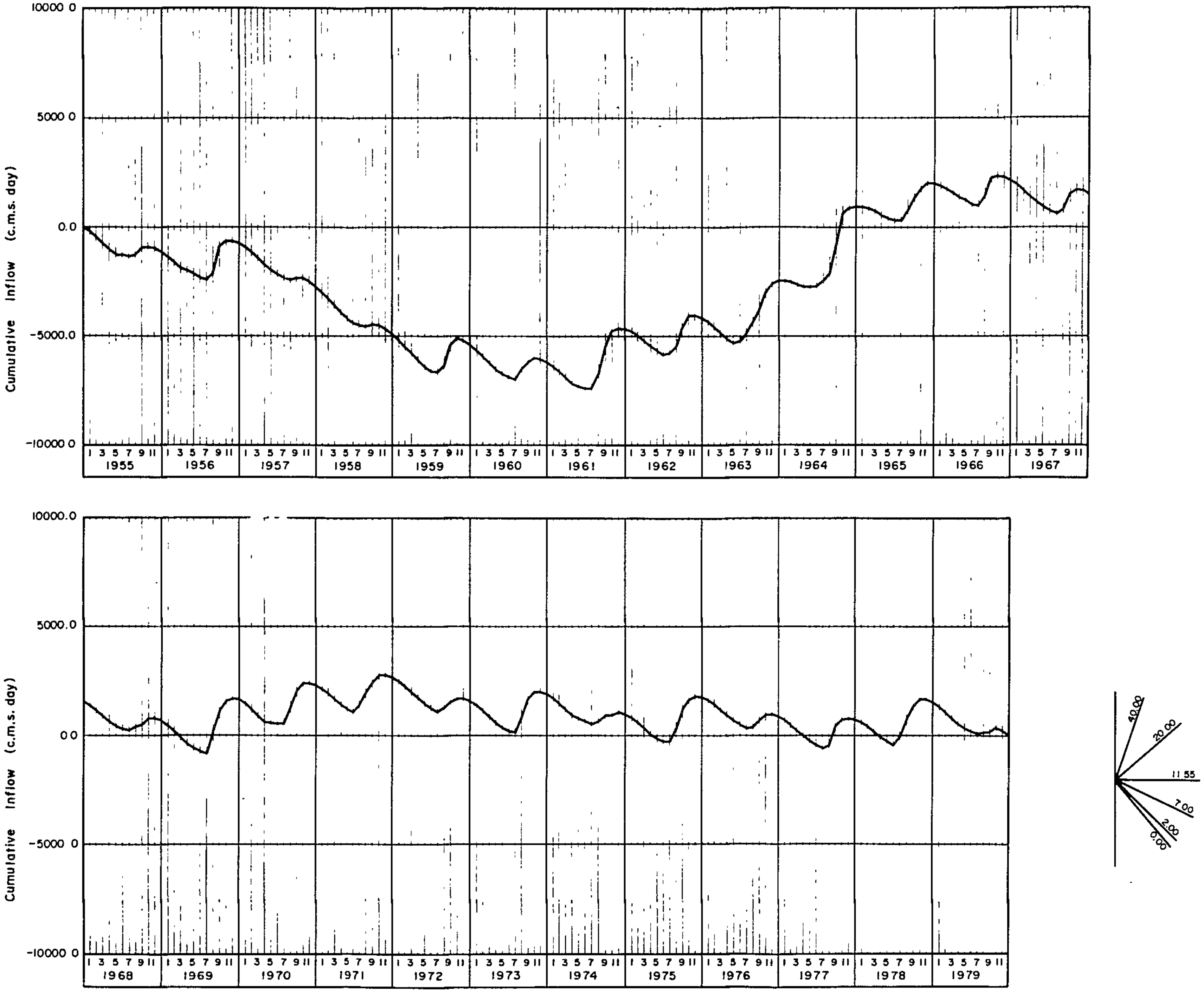


Fig 6-13 Mass Curve at Mae Chaem NO.4 Site

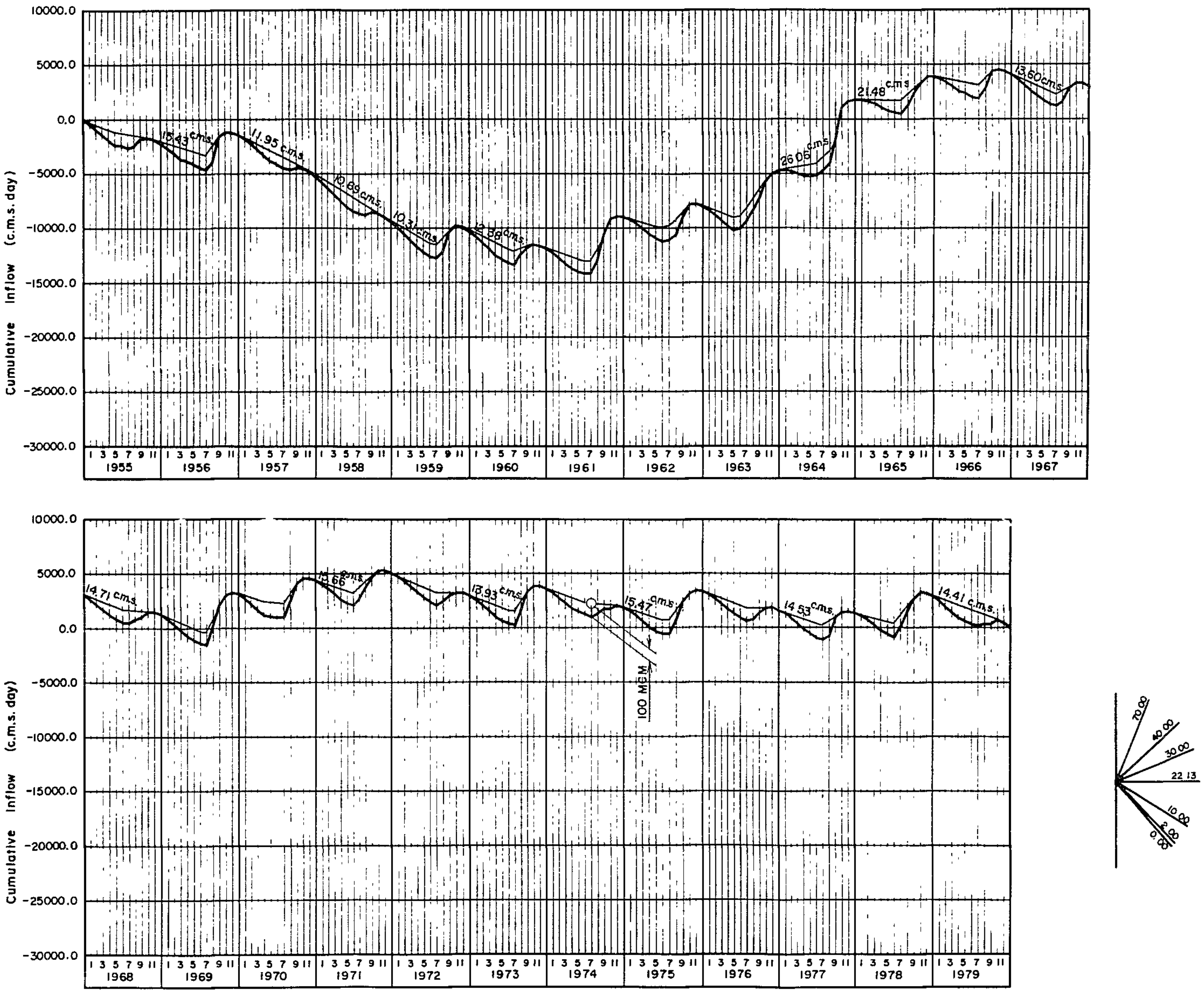


Fig 6-14 Mass Curve at Mae Chaem NO.5 Site

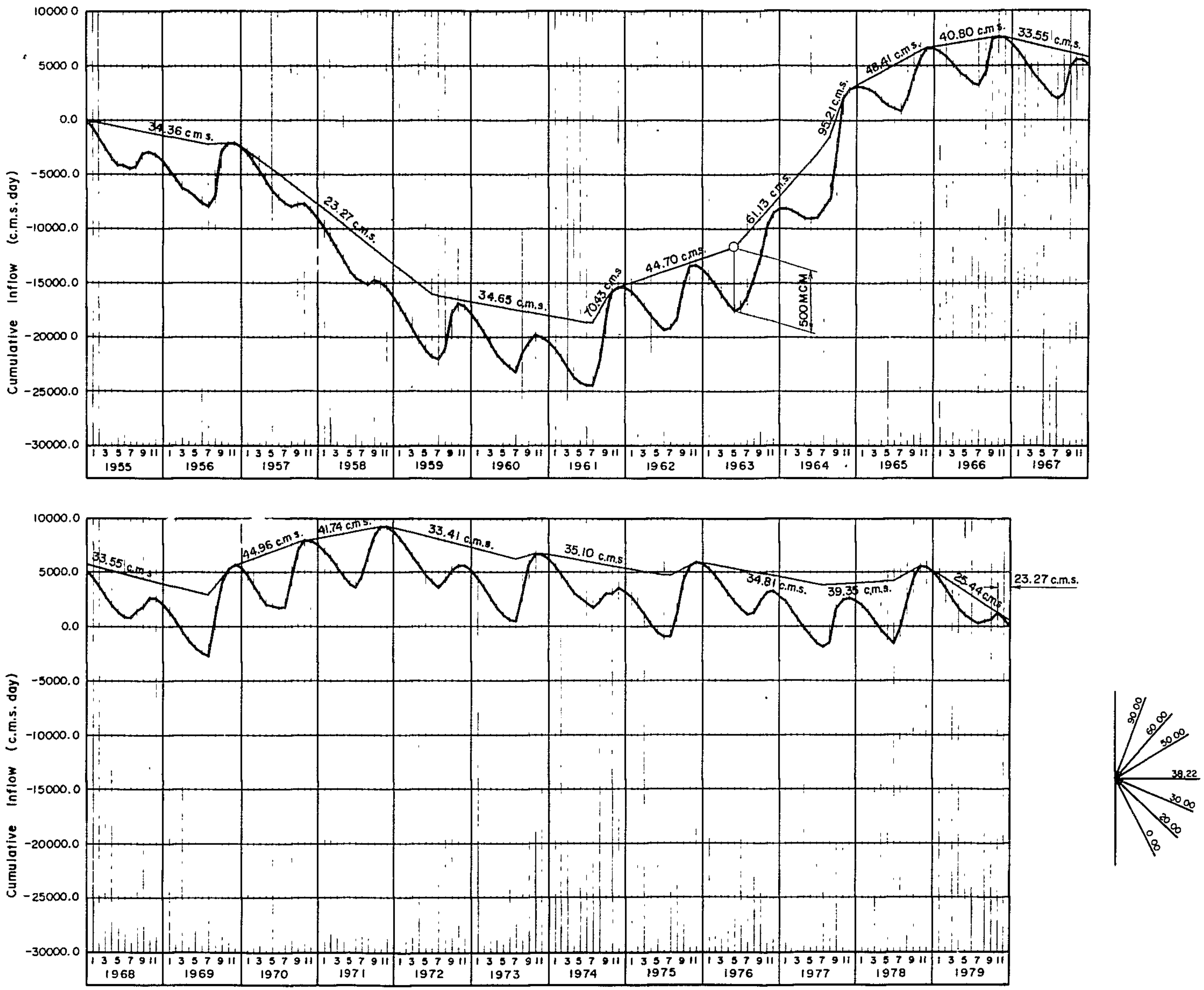


Fig 6-15 Mass Curve at Mae Pai NO.1 Site

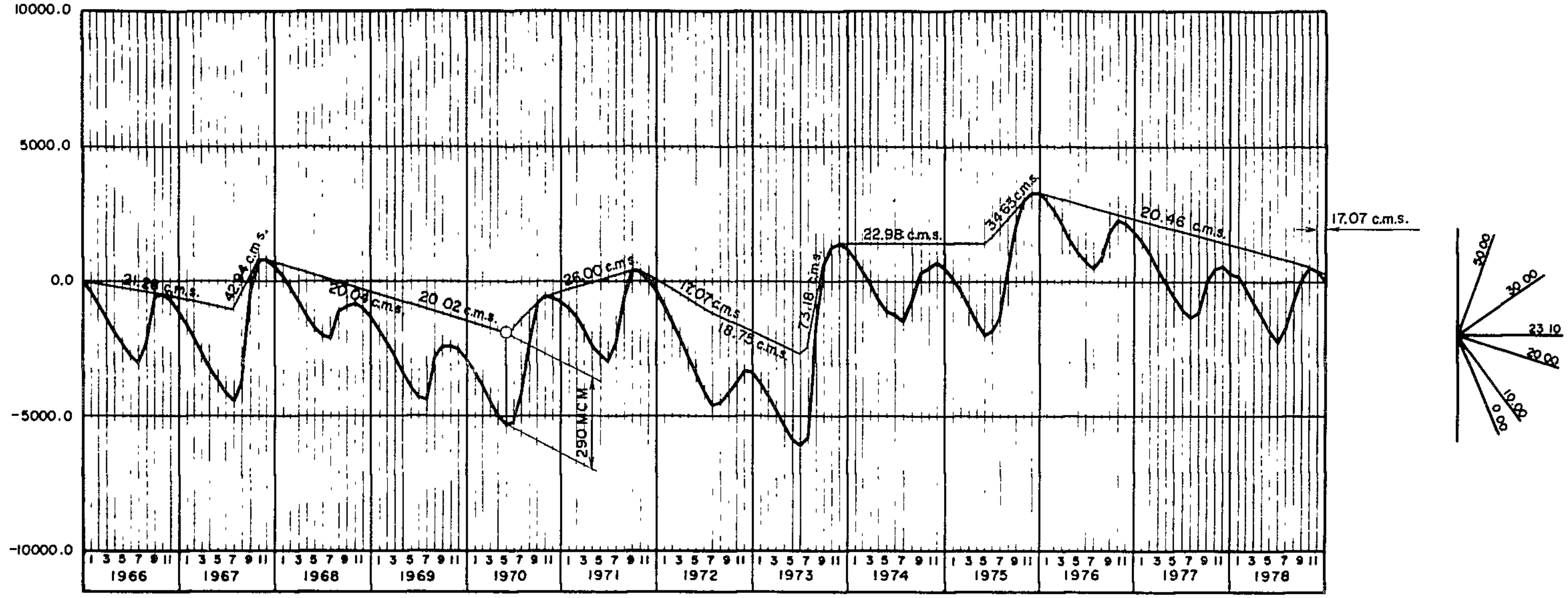


Fig 6-16 Mass Curve at Mae Pai NO.6 Site

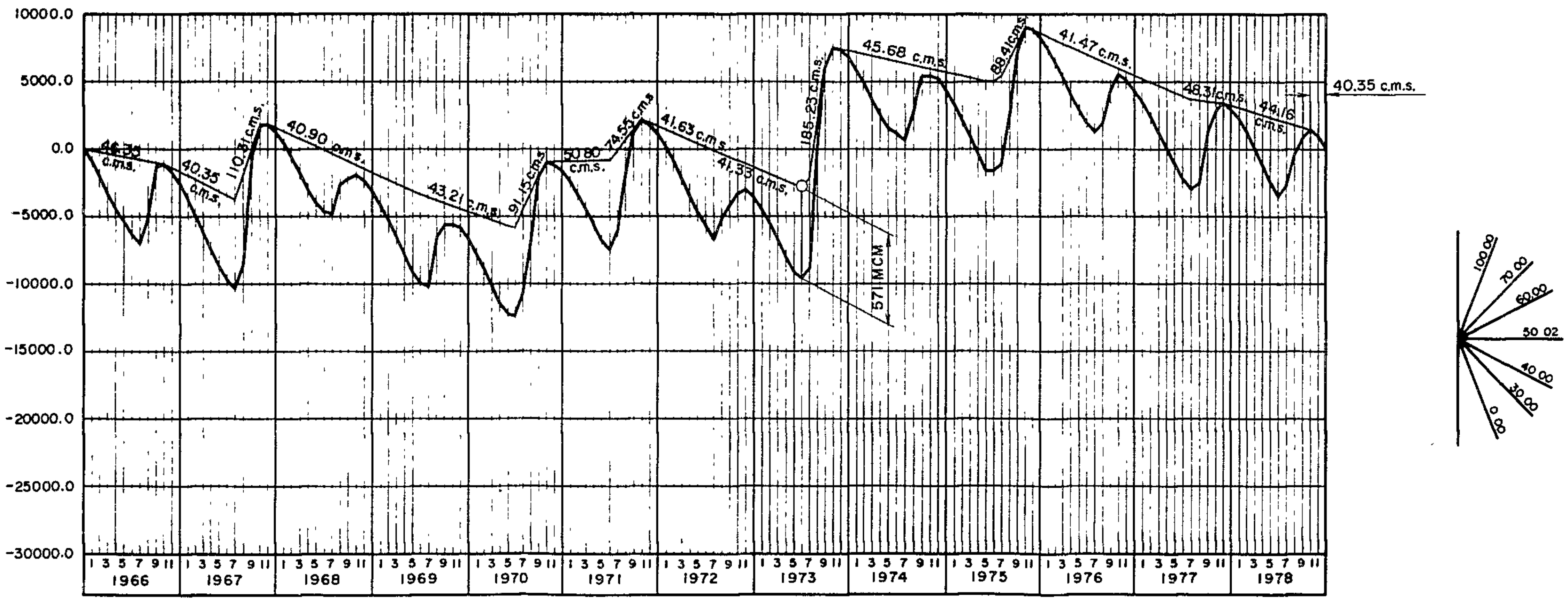


Fig 6-17 Mass Curve at Mae Khan NO.1 Site

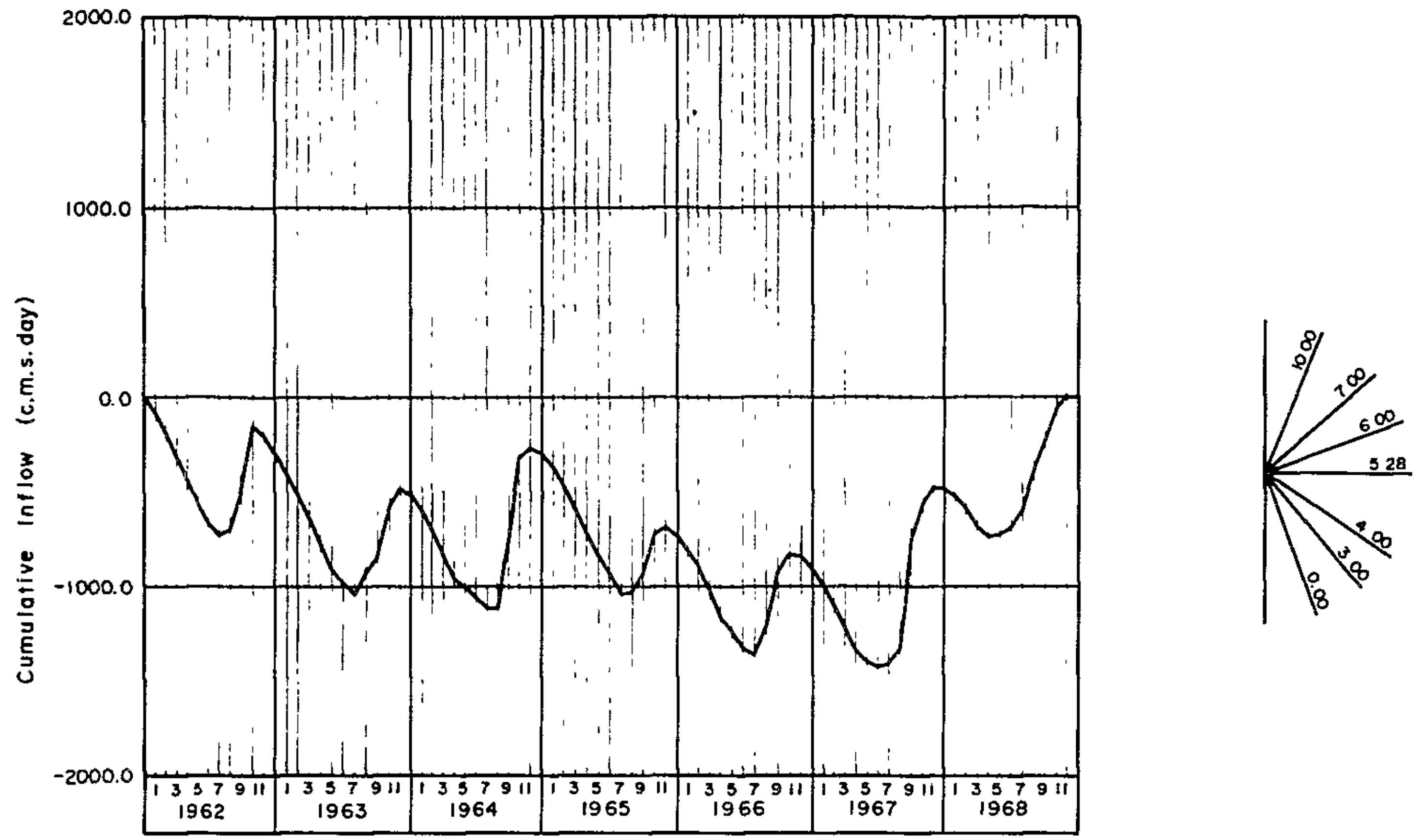


Fig 6-18 Mass Curve at Mae Khan NO.2 Site

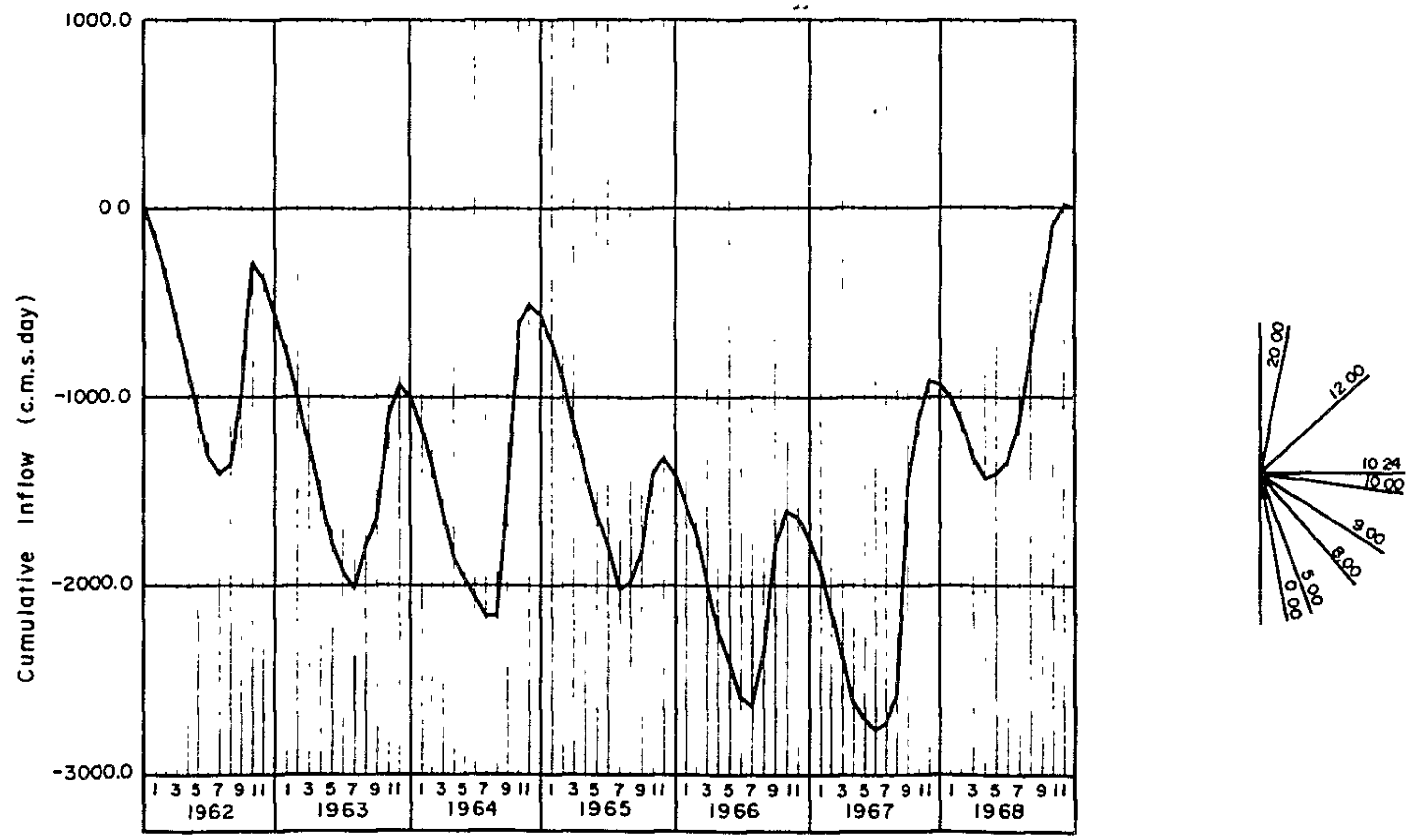
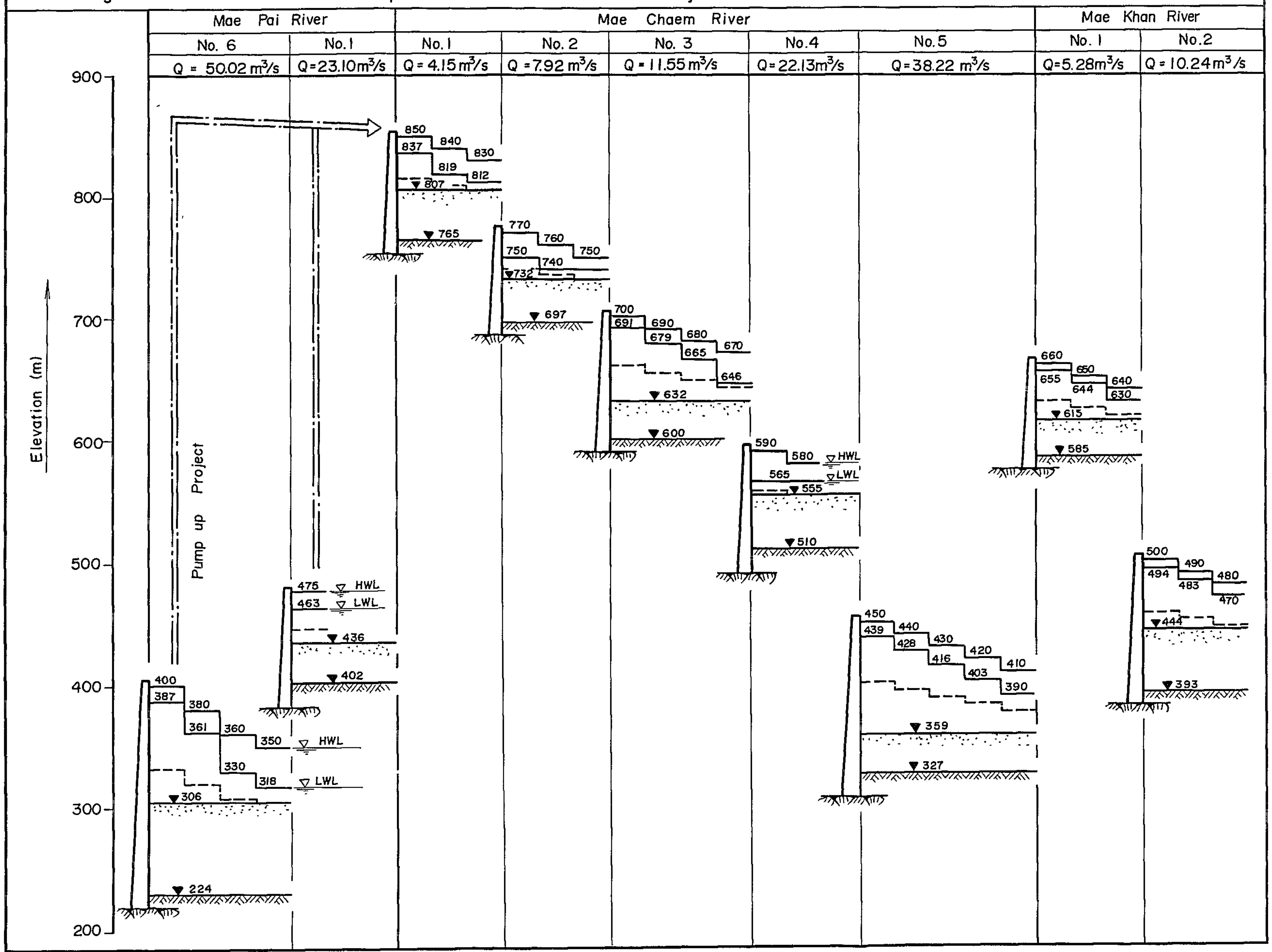


Fig. 6-19 General Conception of the Studied Project



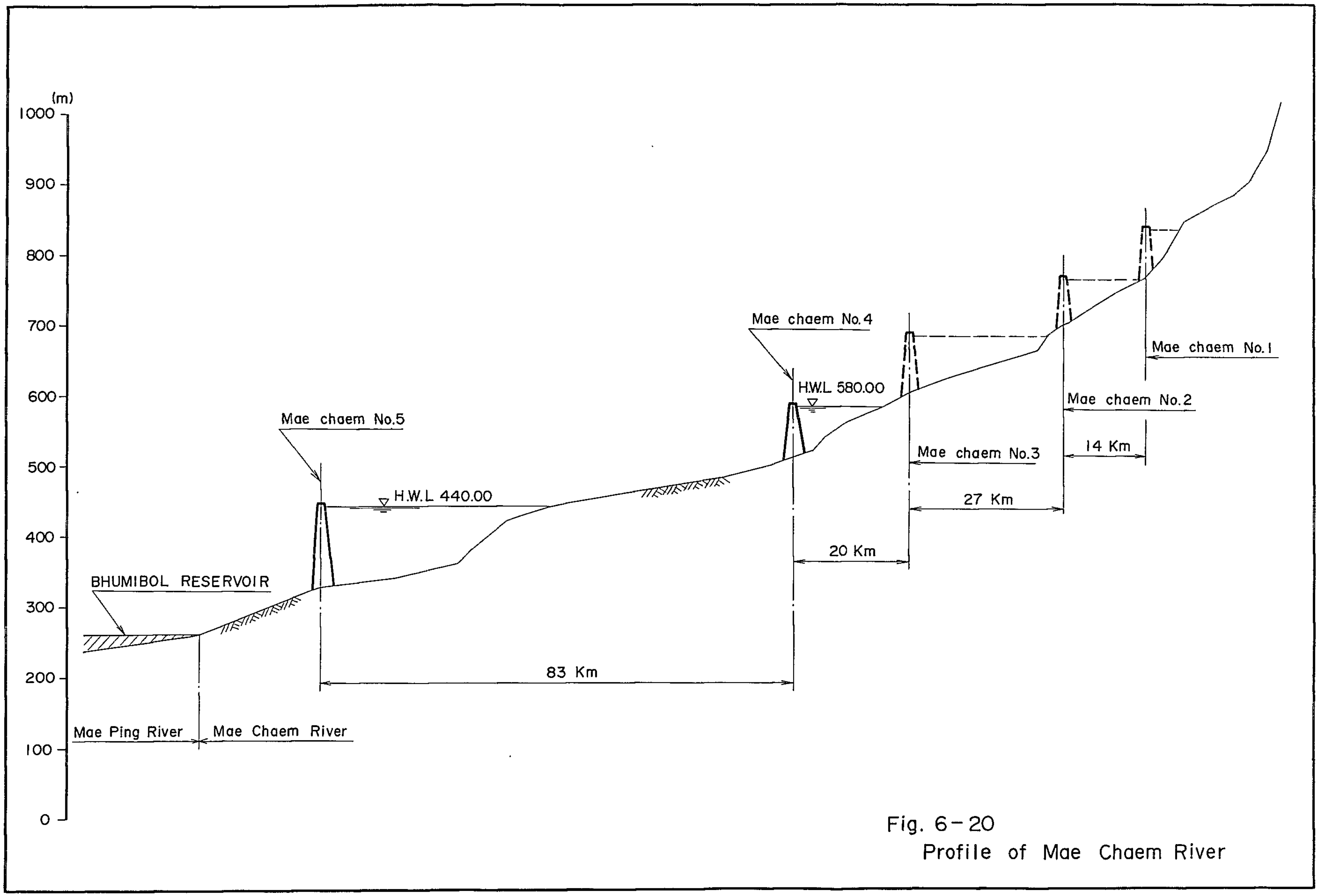


Fig. 6-20
Profile of Mae Chaem River

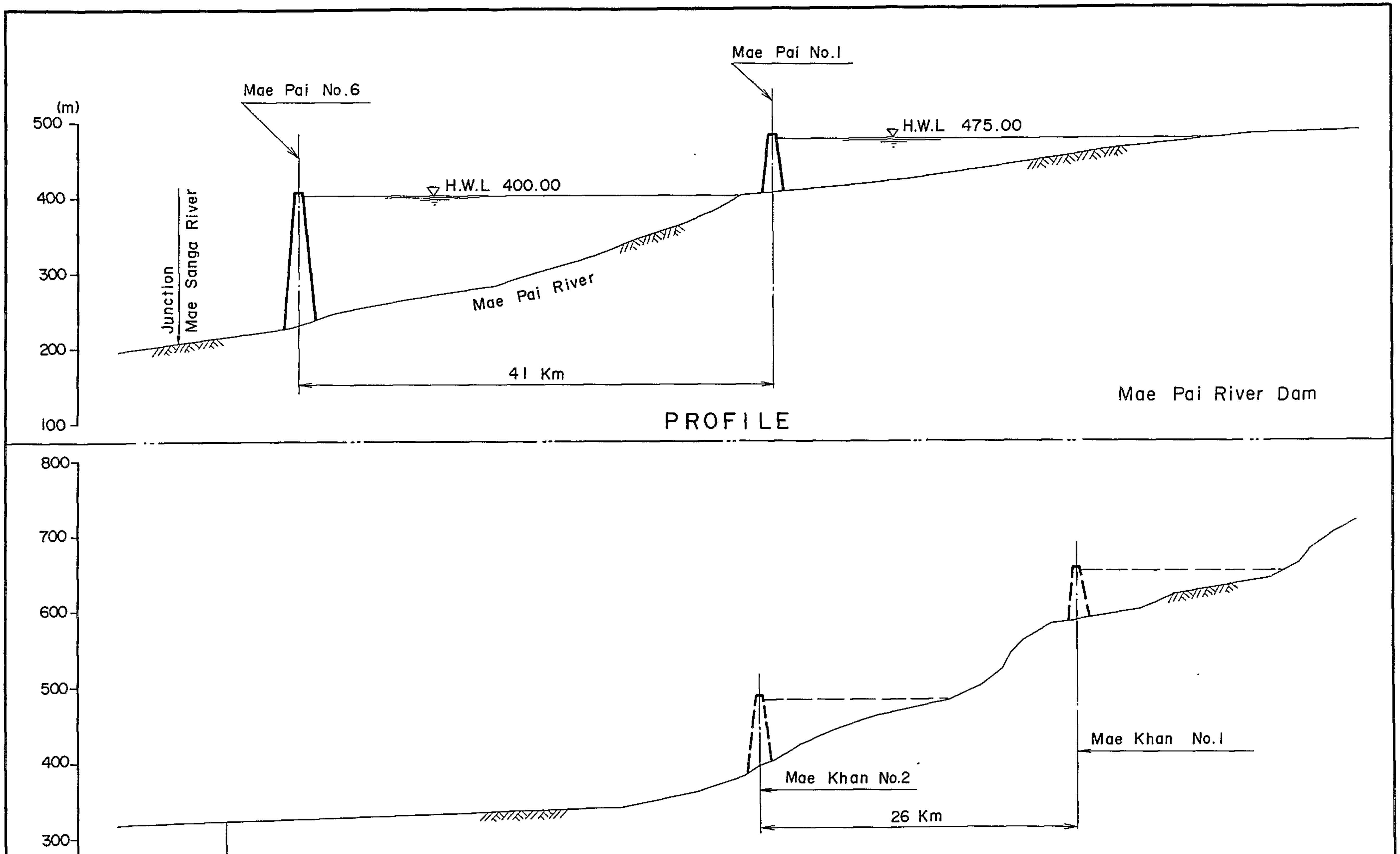


Fig. 6-21

Profile of Mae Khan River Dams

Fig. 6-22 Surplus Benefit Curve

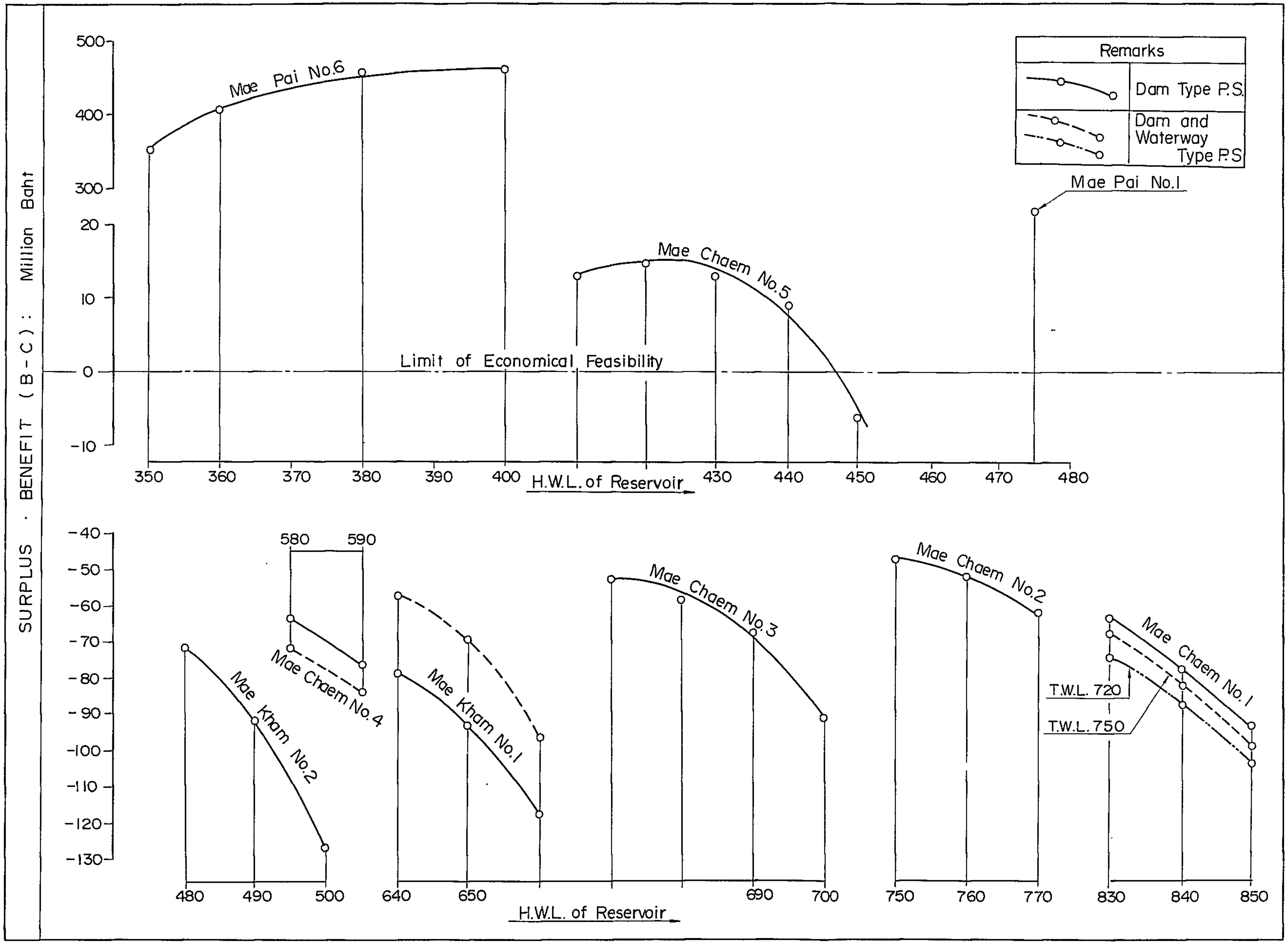


Fig.6-23 Benefit-Cost Ratio Curve

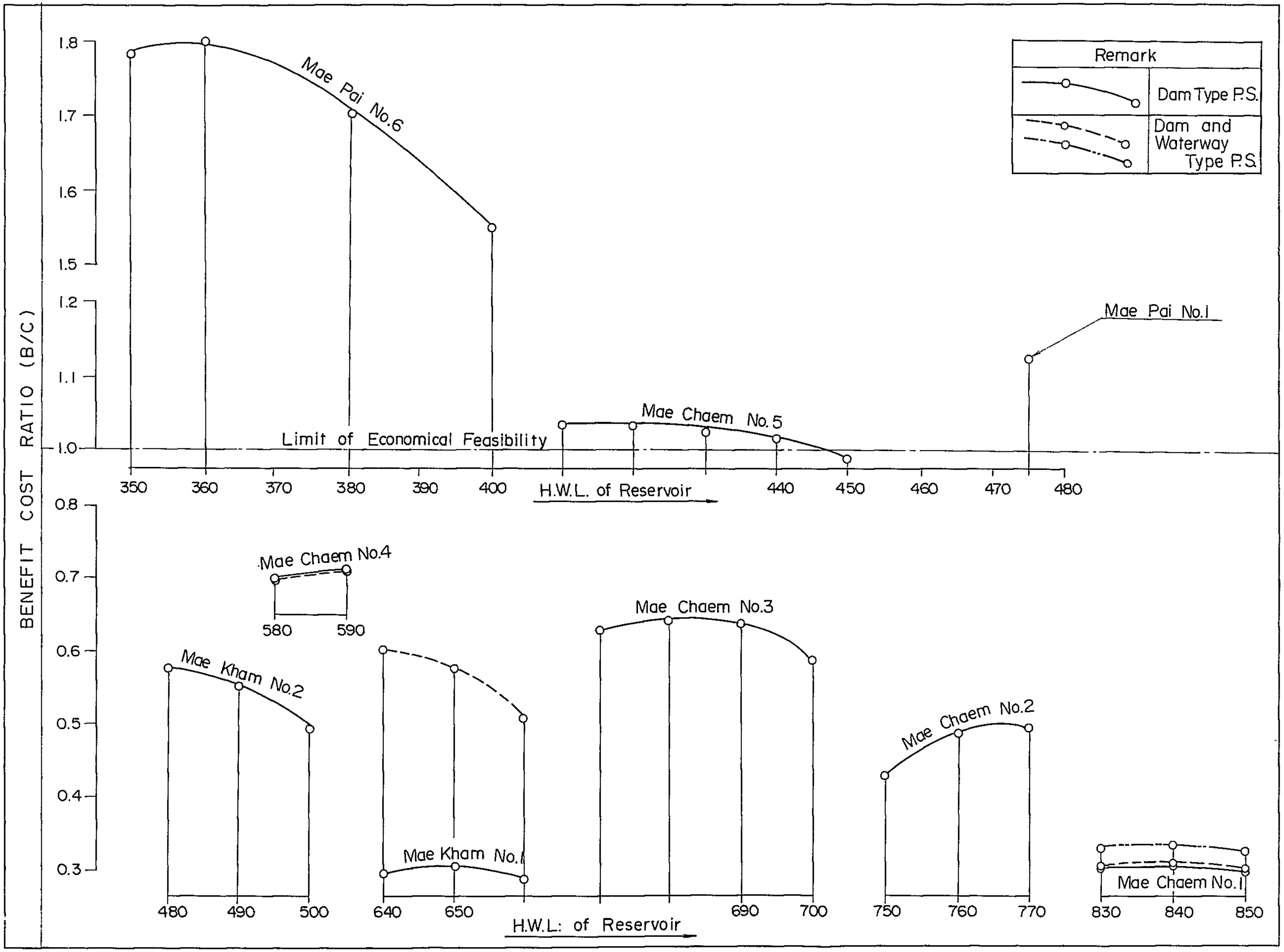


Fig 6-24 Mass Curve at Mae Pai NO.1 Site (Pumping Project)

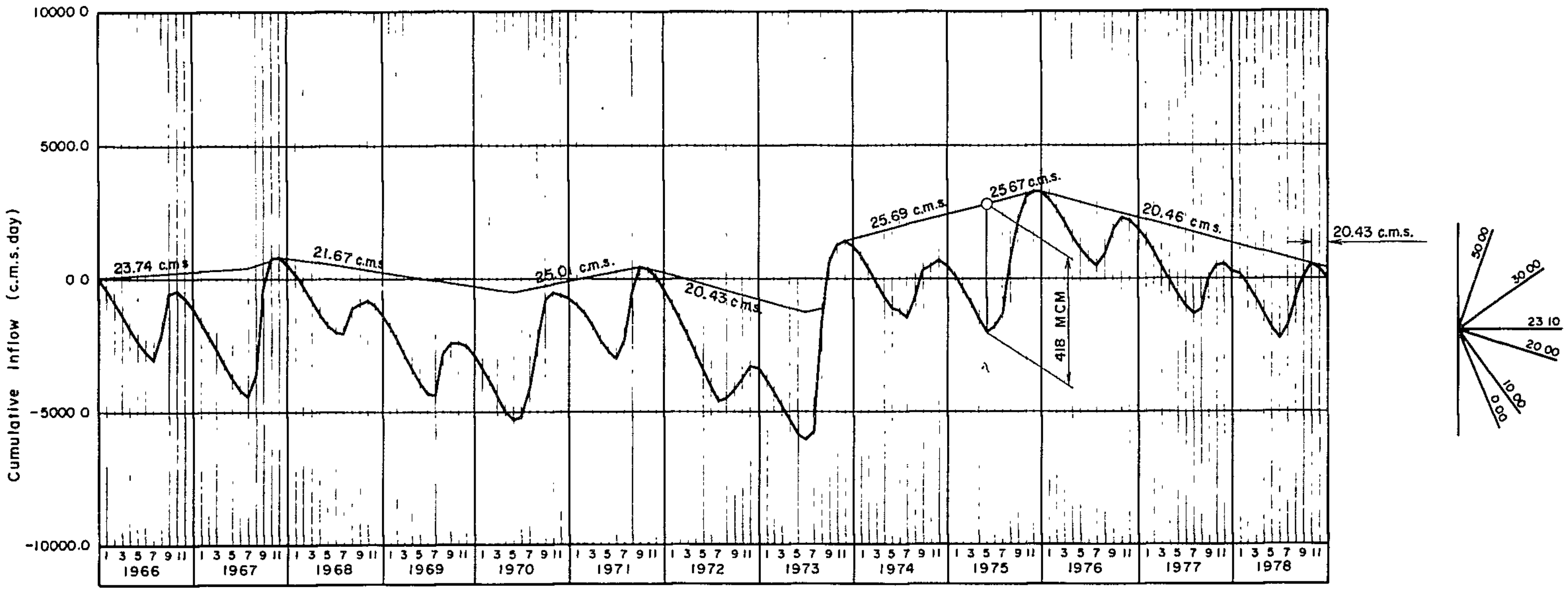


Fig.6-25 General Conception of Transbasin Scheme

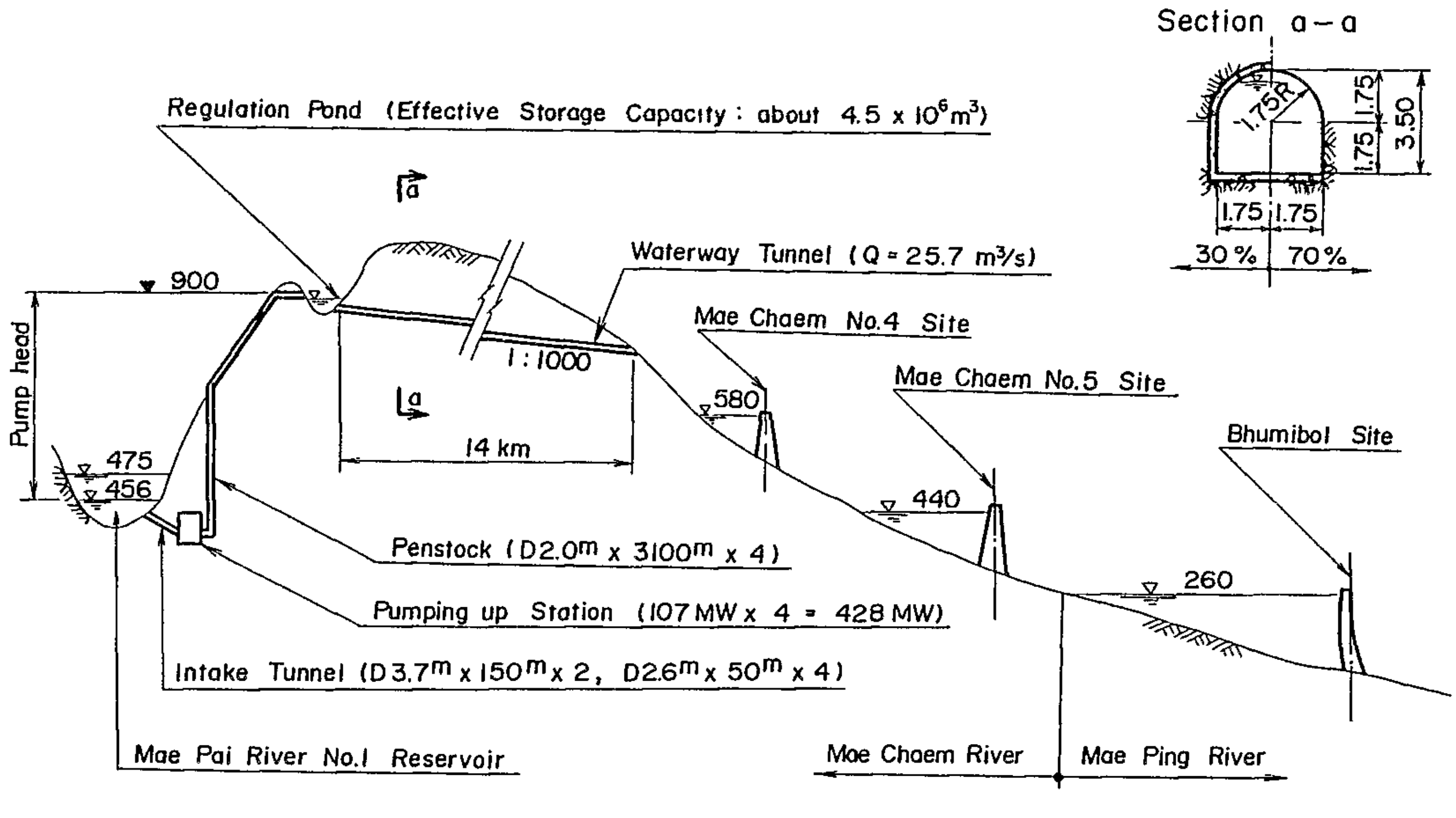


Table 6-1 Mae Chaem No. 1 Site

Dam type: 3 cases

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
Normal high water level	EL.m	850	840	830		
Total storage capacity	$10^6 m^3$	116	79	53		
Effective storage capacity	"	46	46	30		
Available drawdown	m	13	21	18		
Dam height	"	100	90	80		
Normal water level	EL.m	845.7	833.0	824.0		
Tailwater level	"	765	765	765		
Normal effective head	m	76.3	64.2	55.0		
Maximum discharge	m^3/s	12.1	12.1	11.1		
Maximum output	MW	7.8	6.6	5.2		

Mae Chaem No. 1 Site

Dam waterway type: 3 cases
Waterway length: 3,300 m

Item	Unit	Case 1	Case 2	Case 3
Normal high water level	EL.m	850	840	830
Total storage capacity	$10^6 m^3$	116	79	53
Effective storage capacity	"	46	46	30
Available drawdown	m	13	21	18
Dam height	"	100	90	80
Normal water level	EL.m	845.7	833	824.0
Tailwater level	"	750	750	750
Normal effeciive head	m	81.8	69.6	59.8
Maximum discharge	m^3/s	12.1	12.1	11.1
Maximum output	MW	8.4	7.2	5.6

Table 6-2 Mae Chaem No. 1 Site

Dam waterway type: 3 cases
Waterway length: 8,500 m

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
Normal high water level	EL.m	850	840	830		
Total storage capacity	10^6m^3	116	79	53		
Effective storage capacity	"	46	46	30		
Available drawdown	m	13	21	18		
Dam height	"	100	90	80		
Normal water level	EL.m	845.7	833.0	824.0		
Tailwater level	"	720	720	720		
Normal effective head	m	95.3	83.1	72.1		
Maximum discharge	m^3/s	12.1	12.1	11.1		
Maximum output	MW	9.8	8.5	6.8		

Mae Chaem No. 2 Site

Dam type: 3 cases

Item	Unit	Case 1	Case 2	Case 3
Normal high water level	EL.m	770	760	750
Total storage capacity	10^6m^3	157	101	62
Effective storage capacity	"	95	67	28
Available drawdown	m	20	20	10
Dam height	"	90	80	70
Normal water level	EL.m	763.3	753.3	746.7
Tailwater level	"	697	697	697
Normal effective head	m	63.6	53.7	46.8
Maximum discharge	m^3/s	23.6	22.0	16.4
Maximum output	MW	12.8	10.0	6.5

Table 6-3 Mae Chaem No. 3 Site

Dam type: 4 cases

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
Normal high water level	EL.m	700	690	680	670	
Total storage capacity	$10^6 m^3$	532	387	271	180	
Effective storage capacity	"	128	128	128	128	
Available drawdown	m	9	11	15	24	
Dam height	"	115	105	95	85	
Normal water level	EL.m	697.0	686.3	675.0	662.0	
Tailwater level	"	600	600	600	600	
Normal effective head	m	94.0	83.6	72.4	59.6	
Maximum discharge	m^3/s	33.7	33.7	33.7	33.7	
Maximum output	MW	26.9	23.9	20.7	17.1	

Mae Chaem No. 4 Site

Dam type: 2 cases

Item	Unit	Case 1	Case 2
Normal high water level	EL.m	590	580
Total storage capacity	$10^6 m^3$	302	196
Effective storage capacity	"	206	100
Available drawdown	m	25	15
Dam height	"	105	95
Normal water level	EL.m	581.7	575.0
Tailwater level	"	510	510
Normal effective head	m	69.7	62.9
Maximum discharge	m^3/s	62.1	51.6
Maximum output	MW	36.8	27.6

Table 6-4

Mae Chaem No. 4 Site

Dam waterway type: 2 cases
Waterway length: 3,100 m

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
Normal high water level	EL.m	590	580			
Total storage capacity	$10^6 m^3$	302	196			
Effective storage capacity	"	206	100			
Available drawdown	m	25	15			
Dam height	"	105	95			
Normal water level	EL.m	581.7	575.0			
Tailwater level	"	497	497			
Normal effective head	m	76.5	69.6			
Maximum discharge	m^3/s	62.1	51.6			
Maximum output	MW	40.4	30.5			

Mae Chaem No. 5 Site

Dam type: 5 cases

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
Normal high water level	EL.m	450	440	430	420	410
Total storage capacity	$10^6 m^3$	2,620	2,141	1,720	1,356	1,040
Effective storage capacity	"	500	500	500	500	500
Available drawdown	m	11	12	14	17	20
Dam height	"	150	140	130	120	110
Normal water level	EL.m	446.3	436.0	425.3	414.3	403.3
Tailwater level	"	330	330	330	330	330
Normal effective head	m	114.4	104.1	93.5	82.6	71.6
Maximum discharge	m^3/s	116	116	116	116	116
Maximum output	MW	112.8	102.6	92.2	81.4	70.6

Table 6-5 Mae Pai No. 1 Site

Dam type: 1 case

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
Normal high water level	EL.m	475				
Total storage capacity	10^6m^3	765				
Effective storage capacity	"	290				
Available drawdown	m	12				
Dam height	"	100				
Normal water level	EL.m	471				
Tailwater level	"	402				
Normal effective head	m	67.3				
Maximum discharge	m^3/s	85.4				
Maximum output	MW	48.9				

Mae Pai No. 6 Site

Dam type: 4 cases

Item	Unit	Case 1	Case 2	Case 3	Case 4
Normal high water level	EL.m	400	380	360	350
Total storage capacity	10^6m^3	2,421	1,598	1,011	790
Effective storage capacity	"	571	571	571	490
Available drawdown	m	13	19	30	32
Dam height	"	185	165	145	135
Normal water level	EL.m	395.7	373.7	350	339.3
Tailwater level	"	224	224	224	224
Normal effective head	m	169.2	147.3	123.8	113.1
Maximum discharge	m^3/s	202	202	202	185
Maximum output	MW	291	253	213	178

Table 6-6 Mae Khan No. 1 Site

Dam type: 3 cases

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5
Normal high water level	EL.m	660	650	640		
Total storage capacity	10^6m^3	279	192	122		
Effective storage capacity	"	48	48	48		
Available drawdown	m	5	6	10		
Dam height	"	90	80	70		
Normal water level	EL.m	658.3	648	636.7		
Tailwater level	"	590	590	590		
Normal effective head	m	65.2	55.1	44.1		
Maximum discharge	m^3/s	20.2	20.2	20.2		
Maximum output	MW	11.2	9.5	7.6		

Mae Khan No. 1 Site

Dam waterway type: 3 cases
Waterway length: 9,200 m

Item	Unit	Case 1	Case 2	Case 3
Normal high water level	EL.m	660	650	640
Total storage capacity	10^6m^3	279	192	122
Effective storage capacity	"	48	48	48
Available drawdown	m	5	6	10
Dam height	"	90	80	70
Normal water level	EL.m	658.3	648	636.7
Tailwater level	"	490	490	490
Normal effective head	m	136.8	126.7	115.7
Maximum discharge	m^3/s	20.2	20.2	20.2
Maximum output	MW	23.5	21.8	19.9

Table 6-7 Mae Khan No. 2 Site

Dam type: 3 cases

Item	Unit	Case 1	Case 3	Case 3	Case 4	Case 5
Normal high water level	EL.m	500	490	480		
Total storage capacity	10^6m^3	314	232	153		
Effective storage capacity	"	53	53	53		
Available drawdown	m	6	7	10		
Dam height	"	120	110	100		
Normal water level	EL.m	498	487.7	476.7		
Tailwater level	"	393	393	393		
Normal effective head	m	101.5	91.4	80.7		
Maximum discharge	m^3/s	29.6	29.6	29.6		
Maximum output	MW	25.5	23.0	20.3		

Table 6-8 Net Evaporation Loss (Mae Chaem River)

Month	① (°C)	② (%)	③	④	⑤=③×④(mm)	⑥ (mm)	⑦=⑥×0.8	⑧ (mm)	⑨ (mm)	⑩=⑧-⑨(mm)	⑪
	t	P	$K_1=k\cdot p$	$K_2=\frac{(45.7t+813)}{100}$	Evapotranspiration obtained by Blaney-Criddle	Precipitation	Available Precipitation for Crop Consumption	Evapotranspiration	Evaporation from Reservoir Water Surface	Net Evaporation Loss	Remarks
Jan.	20.7	7.74	4.64	17.59	81.6	20.9	16.7	16.7	81.3	-64.6	
Feb.	24.0	7.25	4.35	19.10	83.1	4.1	3.3	3.3	111.2	-107.9	
Mar.	26.9	8.41	5.05	20.42	103.1	22.7	18.2	18.2	147.0	-128.8	
Apr.	30.0	8.52	5.11	21.84	111.6	47.2	37.8	37.8	155.6	-117.8	
May	28.5	9.15	5.49	21.15	116.1	206.6	165.3	116.1	112.0	+4.1	
Jun.	28.0	9.00	5.40	20.93	113.0	140.5	112.4	112.4	94.2	+18.2	
Jul.	27.4	9.25	5.55	20.65	114.6	140.2	112.2	112.2	90.4	+21.8	
Aug.	26.7	8.96	5.38	20.33	109.4	173.0	138.4	109.4	78.7	+30.7	
Sep.	26.0	8.30	4.98	20.01	99.6	220.0	176.0	99.6	77.2	+22.4	
Oct.	25.6	8.18	4.91	19.83	97.4	132.0	105.6	97.4	81.8	+15.6	
Nov.	23.1	7.58	4.55	18.69	85.0	48.0	38.4	38.4	72.2	-33.8	
Dec.	21.5	7.66	4.60	17.96	82.6	12.8	10.2	10.2	70.6	-60.4	
Total	-	100	-	-	1,197.1	1,168.0	934.5	771.7	1,172.2	-400.5	

Remarks: t: Mean temperature at Ban Obb Luang from 1972 to 1980.

P: Monthly percent of daytime hours of the year, can be obtained from a table prepared by Blaney-Criddle, according to the location of the proposed reservoir site (about Lat. 18°40'N, Long. 98°20'E).

K: Empirical coefficient to be estimated 0.6 by kind of crop or vegetation.

Table 6-9 Net Evaporation Loss (Mae Pai River)

	① (°C)	② (%)	③	④	⑤=③×④(mm)	⑥ (mm)	⑦=⑥×0.8	⑧ (mm)	⑨ (mm)	10=⑧-⑨(mm)	⑪
Month	t	P	$K_1=k \cdot p$	$K_2=\frac{(45.7t+813)}{100}$	Evapotranspiration obtained by Blaney-Criddle	Precipitation	Available Precipitation for Crop Consumption	Evapotranspiration	Evaporation from Reservoir Water Surface	Net Evaporation Loss	Remarks
Jan.	21.7	7.74	4.64	18.05	83.8	20.2	16.2	16.2	69.7	-53.5	
Feb.	23.4	7.25	4.35	18.82	81.9	1.7	1.4	1.4	88.2	-86.8	
Mar.	26.5	8.41	5.05	20.24	102.2	7.3	5.8	5.8	117.1	-111.3	
Apr.	29.8	8.52	5.11	21.75	111.14	36.5	29.2	29.2	143.2	-114.0	
May	30.1	9.15	5.49	21.89	120.2	175.9	140.7	120.2	131.2	-11.0	
Jun.	28.8	9.00	5.40	21.29	115.0	193.5	154.8	115.0	95.5	+19.5	
Jul.	27.6	9.25	5.55	20.74	115.1	227.4	181.9	115.1	80.9	+34.2	
Aug.	27.2	8.96	5.38	20.56	110.6	315.5	252.4	110.6	74.3	+36.3	
Sep.	27.5	8.30	4.98	20.70	103.1	237.0	189.6	103.1	83.4	+19.7	
Oct.	26.7	8.18	4.91	20.33	99.8	101.6	81.3	81.3	89.4	-8.1	
Nov.	24.9	7.58	4.55	19.51	88.8	35.8	28.6	28.6	75.0	-46.4	
Dec.	22.1	7.66	4.60	18.23	83.9	16.8	13.4	13.4	67.6	-54.2	
Total	-	100	-	-	2,215.8	1,369.2	1,095.3	739.9	1,115.5	-375.6	

Remarks:
- t: Mean temperature at Pang Mu from 1966 to 1978.
- P: Monthly percent of daytime hours of the year, can be obtained from a table prepared by Blaney-Criddle, according to the location of the proposed reservoir site (about Lat. 19°15'N, Long. 98°10'E).
- K: Empirical coefficient to be estimated 0.6 by kind of crop or vegetation.

Table 6-10 Net Evaporation Loss (Mae Khan River)

Month	① (°C)	② (%)	③	④	⑤=③×④(mm)	⑥ (mm)	⑦=⑥×0.8	⑧ (mm)	⑨ (mm)	⑩=⑧-⑨(mm)	⑪
	t	P	$K_1=k\cdot p$	$K_2=\frac{(45.7t+813)}{100}$	Evapotranspiration obtained by Blaney-Criddle	Precipitation	Available Precipitation for Crop Consumption	Evapotranspiration	Evaporation from Reservoir Water Surface	Net Evaporation Loss	Remarks
Jan.	20.3	7.74	4.64	17.41	80.8	23.0	18.4	18.4	61.7	-43.3	
Feb.	23.5	7.25	4.35	18.87	82.1	2.5	2.0	2.0	83.0	-81.0	
Mar.	26.4	8.41	5.05	20.19	102.0	23.5	18.8	18.8	115.8	-97.0	
Apr.	28.9	8.52	5.11	21.34	109.0	56.9	45.5	45.5	116.2	-70.7	
May	27.4	9.15	5.49	20.65	113.4	197.7	158.2	113.4	96.9	+16.5	
Jun.	27.6	9.00	5.40	20.74	112.0	136.2	109.4	109.0	78.1	+30.9	
Jul.	27.3	9.25	5.55	20.61	114.4	179.1	143.3	114.4	66.9	+47.5	
Aug.	26.6	8.96	5.38	20.29	109.2	267.8	214.2	109.2	63.2	+46.0	
Sep.	26.7	8.30	4.98	20.33	101.2	274.8	219.8	101.2	70.1	+31.1	
Oct.	25.6	8.18	4.91	19.83	97.4	139.1	111.3	97.4	74.7	+22.7	
Nov.	24.2	7.58	4.55	19.19	87.3	42.8	34.2	34.2	57.4	-23.2	
Dec.	21.8	7.66	4.60	18.09	83.2	21.4	17.1	17.1	53.1	-36.0	
Total	-	100	-	-	1,192.0	1,364.8	1,091.8	780.6	937.1	-156.5	

Remarks: t: Mean temperature at San Pa Tong from 1972 to 1978.

P: Monthly percent of daytime hours of the year, can be obtained from a table prepared by Blaney-Criddle, according to the location of the proposed reservoir site (about Lat. 18°45'N, Long. 98°45'E).

K: Empirical coefficient to be estimated 0.6 by kind of crop or vegetation.

Table 6-11 Annual Energy Production at Mae Chaem No. 4 P.S.

Unit: 10^6 kWH

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1955	5.77	4.98	5.19	4.71	4.64	6.30	6.27	7.00	7.94	8.34	7.08	6.46	74.68
1956	6.25	5.54	5.40	5.32	5.47	5.01	5.31	14.09	21.46	15.00	8.97	7.04	104.86
1957	5.03	4.42	4.75	4.38	4.42	4.21	4.34	4.56	4.83	5.15	4.58	4.47	55.14
1958	4.40	3.81	4.01	3.69	3.67	3.47	3.87	4.13	4.44	4.71	4.37	4.31	48.88
1959	4.23	3.65	3.84	3.50	3.52	3.35	6.15	12.88	17.80	17.55	6.76	5.20	88.43
1960	5.09	4.56	4.58	4.09	4.15	4.02	4.62	12.55	12.68	13.28	6.80	6.63	83.05
1961	6.43	5.56	5.74	5.10	5.17	5.62	7.09	18.67	21.46	22.17	12.20	8.82	124.03
1962	6.76	5.95	6.31	5.75	5.70	5.19	8.77	12.45	19.71	21.55	9.50	6.32	113.96
1963	6.23	5.42	5.67	5.10	5.00	8.93	13.44	18.11	18.64	21.93	19.03	12.38	139.88
1964	11.02	9.97	10.05	8.89	9.02	8.45	12.68	13.26	21.46	22.17	15.70	11.11	153.78
1965	9.14	8.12	8.78	7.99	7.77	7.20	7.21	14.04	15.62	17.06	16.86	9.44	129.23
1966	7.73	6.82	7.28	6.45	6.69	5.93	6.22	14.53	17.91	11.76	8.01	5.75	105.08
1967	5.67	4.92	5.19	4.73	4.81	4.38	4.57	10.07	13.84	14.54	8.60	6.21	87.53
1968	6.11	5.47	5.50	5.00	5.04	4.78	6.79	8.15	8.32	9.22	8.61	5.82	78.81
1969	5.71	4.93	5.14	4.60	4.68	4.47	5.69	21.53	21.47	21.11	12.11	7.20	118.64
1970	6.34	5.43	5.52	4.88	6.94	6.04	7.76	20.14	21.46	16.66	8.83	7.06	117.06
1971	6.54	5.69	5.97	5.33	5.28	5.08	13.75	15.18	16.01	16.63	9.17	6.25	110.88
1972	5.63	5.09	5.23	4.86	4.77	4.43	4.50	8.46	8.99	9.56	9.32	5.90	76.74
1973	5.80	5.02	5.27	4.70	4.68	4.52	6.59	19.50	21.46	17.44	9.44	6.43	110.85
1974	6.32	5.47	5.68	5.06	5.24	5.04	5.09	7.46	8.04	8.41	8.22	8.32	78.35
1975	6.42	5.57	5.79	5.11	3.45	5.04	7.31	18.61	21.29	21.50	12.01	8.14	120.24
1976	6.25	5.69	5.85	5.36	5.36	4.94	4.96	7.86	8.85	9.71	9.92	6.14	80.89
1977	6.11	5.33	5.62	5.18	5.19	4.72	5.01	10.55	16.56	16.98	10.52	7.35	99.12
1978	6.71	5.87	6.20	5.57	5.51	4.34	16.17	18.60	19.34	18.30	9.03	6.10	121.74
1979	5.99	5.18	5.36	4.79	4.83	4.67	4.94	5.78	5.96	6.66	5.20	4.32	63.68
Total	157.68	138.46	143.92	130.14	131.00	130.13	179.10	318.16	375.54	367.39	240.84	173.17	2,485.53
Mean	6.31	5.54	5.76	5.20	5.24	5.20	7.16	12.73	15.02	14.70	9.63	6.93	99.42

Table 6-12 Annual Energy Production at Mae Chaem No. 5 P.S.

Unit: 10^6 kWH

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1955	22.42	19.50	21.20	20.32	21.96	21.43	22.07	22.31	22.06	22.84	21.54	21.80	259.45
1956	21.51	19.41	20.29	19.65	21.28	20.48	21.02	24.91	26.03	27.26	24.40	18.80	265.12
1957	15.09	13.01	14.21	13.71	15.38	14.97	15.47	15.62	15.24	15.79	14.72	14.86	178.07
1958	14.72	12.69	13.82	13.32	14.85	14.43	14.97	15.13	14.80	15.32	14.29	14.42	172.76
1959	14.27	12.30	13.37	12.86	14.26	13.85	19.45	21.81	22.51	23.63	22.26	22.53	213.10
1960	22.21	20.03	20.93	19.97	21.53	20.77	21.33	22.27	21.96	22.97	21.65	22.02	257.64
1961	21.75	18.93	20.54	19.64	21.22	20.59	22.44	44.12	45.41	48.34	33.28	29.60	345.86
1962	29.27	25.59	27.75	26.41	27.97	26.72	27.64	28.09	28.52	30.51	28.89	29.27	336.63
1963	28.82	25.12	27.16	25.79	27.18	28.14	37.57	38.59	38.20	41.02	39.54	40.35	397.48
1964	39.86	36.25	37.86	35.92	37.75	36.11	39.94	41.82	59.05	65.28	42.90	32.29	505.03
1965	31.97	28.12	30.69	29.28	31.01	29.79	30.49	31.14	31.00	32.74	31.66	27.14	365.03
1966	26.84	23.52	25.64	24.45	26.35	25.27	25.99	26.64	27.24	28.08	26.40	21.95	308.37
1967	21.71	18.89	20.54	19.69	21.35	20.55	21.12	21.45	21.70	22.77	21.53	21.86	253.16
1968	21.63	19.52	20.45	19.63	21.30	20.59	21.33	21.76	21.21	22.26	21.06	21.37	252.11
1969	21.09	18.33	19.90	19.02	20.56	18.08	18.01	40.89	41.26	43.26	33.03	29.68	323.11
1970	29.17	25.38	27.39	26.02	27.87	26.86	27.69	29.14	29.50	30.92	27.09	27.48	334.51
1971	27.11	23.65	25.66	24.44	26.02	25.05	26.42	27.43	27.31	28.72	24.94	21.96	308.71
1972	21.75	19.64	20.61	19.79	21.38	20.60	21.14	21.60	21.25	22.13	20.98	21.30	252.17
1973	21.04	18.29	19.87	18.98	20.49	19.74	20.80	26.93	27.39	28.79	25.69	23.08	271.09
1974	22.84	19.89	21.62	20.70	22.47	21.75	22.32	22.67	22.27	23.00	22.00	22.34	263.87
1975	22.16	19.31	20.97	20.03	21.50	20.77	23.07	30.17	30.76	32.47	30.98	23.07	295.26
1976	22.81	20.65	21.67	20.78	22.47	21.64	22.20	22.42	22.13	23.19	22.01	22.33	264.30
1977	22.14	19.28	20.95	20.08	21.63	20.77	21.31	24.45	25.11	26.25	24.95	25.39	272.31
1978	25.15	21.96	23.85	22.75	24.30	23.29	30.43	31.83	31.78	33.37	24.55	16.68	309.94
1979	16.49	14.26	15.55	15.00	16.74	16.34	16.91	17.19	16.71	17.57	14.99	15.08	192.83
Total	583.82	513.52	552.49	528.23	568.82	548.58	591.13	670.38	690.40	728.48	635.33	587.73	7,197 91
Mean	23.25	20.54	22.10	21.13	22.75	21.94	23.65	26.82	27.62	29.14	25.41	23.47	287 92

Table 6-13 Annual Energy Production at Mae Pai No. 1 P.S.

Unit: 10^6 kWH

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1966	9.20	8.00	8.60	8.11	8.63	8.28	8.49	8.96	9.34	9.55	8.98	9.12	105.26
1967	8.95	7.76	8.32	7.82	8.22	7.83	6.50	16.47	18.45	19.31	10.37	8.70	128.70
1968	8.61	7.77	8.07	7.64	8.17	7.93	8.26	8.76	8.51	8.77	8.27	8.42	99.18
1969	8.28	7.19	7.72	7.25	7.64	7.33	7.73	8.48	8.36	8.57	8.12	8.24	94.91
1970	8.09	7.01	7.50	7.02	7.47	9.87	13.73	14.91	15.22	14.15	11.03	11.27	127.27
1971	11.11	9.70	10.36	9.68	10.10	9.63	10.41	11.41	11.43	9.61	7.18	7.30	117.92
1972	7.20	6.46	6.69	6.31	6.73	6.43	6.50	7.27	7.21	7.61	7.45	7.69	83.55
1973	7.57	6.58	7.07	6.65	7.03	6.86	12.61	31.97	32.01	19.87	11.28	10.02	159.52
1974	9.86	8.57	9.18	8.63	9.10	8.85	9.04	9.51	9.66	9.94	9.53	9.73	111.60
1975	9.57	8.29	8.86	8.26	8.58	10.99	14.47	14.51	14.81	15.57	12.86	9.94	136.71
1976	8.88	8.04	8.36	7.90	8.45	8.16	8.40	8.64	8.74	9.12	8.63	8.79	102.11
1977	8.69	7.54	8.10	7.63	8.11	7.74	7.93	8.09	8.34	8.79	8.40	8.56	97.92
1978	8.56	7.44	8.00	7.53	7.95	7.60	8.22	8.76	8.82	9.18	7.44	7.37	96.87
Total	114.57	100.35	106.83	100.43	106.18	107.50	122.29	157.74	160.90	150.04	119.54	115.15	1,461.52
Mean	8.81	7.72	8.22	7.72	8.17	8.27	9.41	12.13	12.38	11.54	9.19	8.86	112.42

Table 6-14 Annual Energy Production at Mae Pai No. 6 P.S.

Unit: 10^6 kWH

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1966	49.28	43.32	47.09	44.91	47.72	46.25	47.72	48.83	49.34	50.68	41.77	42.69	559.60
1967	42.29	37.15	40.45	38.65	41.29	40.09	41.45	112.59	116.25	120.86	55.06	43.62	729.75
1968	43.32	39.49	41.46	39.65	42.40	41.34	43.01	44.38	43.04	44.29	42.06	43.06	507.50
1969	42.68	37.54	40.86	39.04	41.65	40.46	44.36	46.41	45.29	46.44	44.20	45.19	514.12
1970	44.75	39.38	42.87	41.00	43.67	44.01	93.59	96.14	97.13	91.56	52.89	54.25	741.24
1971	53.72	47.28	51.42	49.03	51.79	50.18	76.78	79.72	79.33	81.62	43.21	44.28	708.36
1972	43.91	40.02	42.00	40.15	42.78	41.54	42.75	43.33	42.29	43.87	42.02	43.14	507.80
1973	42.83	37.71	41.11	39.30	41.88	40.88	76.83	200.34	197.02	108.37	47.58	48.72	922.57
1974	48.28	42.48	46.22	44.14	46.96	45.80	47.37	48.58	48.42	49.61	47.22	48.18	563.26
1975	47.71	41.97	45.66	43.62	45.63	48.93	68.10	92.94	93.40	96.83	45.27	44.21	714.27
1976	43.90	40.06	42.07	40.20	42.93	41.71	43.13	43.52	43.26	45.11	42.82	43.79	512.50
1977	43.49	38.26	41.66	39.85	42.55	41.25	42.58	49.82	50.07	52.40	50.38	47.14	539.45
1978	46.91	41.24	44.87	42.81	45.51	44.11	46.27	47.67	46.75	48.29	41.80	42.72	538.95
Total	593.07	525.90	567.74	542.35	576.76	566.55	713.94	954.27	951.59	879.93	596.28	590.99	8,059.37
Mean	45.62	40.45	43.67	41.72	44.37	43.58	54.92	73.40	73.20	67.69	45.87	45.46	619.95

Table 6-15 Comparative Study of the Project (Individual River Development Plan. Dam Type Power Station 2-1)

Case		Mae Chaem No. 1			Mae Chaem No. 2			Mae Chaem No. 3				Mae Chaem No. 4		Mae Chaem No. 5	
		Case-1	Case-2	Case-3	Case-1	Case-2	Case-3	Case-1	Case-2	Case-3	Case-4	Case-1	Case-2	Case-1	Case-2
Catchment area	km^2	337	337	337	654	654	654	969	969	969	969	1,955	1,955	3,735	3,735
Average annual run-off	10^6m^3	130.89	130.89	130.89	250.02	250.02	250.02	364.55	364.55	364.55	364.55	698.34	698.34	1,206.02	1,206.02
Normal high water level	m	850	840	830	770	760	750	700	690	680	670	590	580	450	440
Reservoir area	km^2	4.1	2.9	2.1	6.3	4.7	3.3	15.8	12.9	10.3	7.9	11.1	8.2	50.5	37.7
Total storage capacity	10^6m^3	116	79	53	157	101	62	532	387	271	180	302	196	2,620	2,141
Effective storage capacity	"	46	46	30	95	67	28	128	128	128	128	206	100	500	500
Available drawdown	m	13	21	18	20	20	10	9	11	15	24	25	15	11	12
Type of dam		Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill
Height x Crest length	m	100x290	90x260	80x230	90x260	80x230	70x210	115x360	105x320	95x300	85x280	105x470	95x440	150x580	140x555
Dam volume	10^3m^3	2,810	2,130	1,530	2,130	1,530	1,110	4,830	3,670	2,870	2,200	5,360	4,110	12,080	10,120
Headrace (DxLxN)	m	2.3x290 x 1	2.3x330 x 1	2.2x310 x 1	3.0x330 x 1	2.9x330 x 1	2.6x280 x 1	3.5x280 x 1	3.5x290 x 1	3.5x310 x 1	3.5x350 x 1	4.5x350 x 1	4.2x300 x 1	5.9x385 x 1	5.9x385 x 1
Penstock (DxLxN)	m	1.6x170 x 1	1.6x130 x 1	1.5x120 x 1	2.3x130 x 1	2.2x110 x 1	1.9x120 x 1	2.7x210 x 1	2.7x180 x 1	2.7x160 x 1	2.7x120 x 1	3.7x130 x 1	3.3x130 x 1	5.0x230 x 1	5.0x210 x 1
Normal intake level	m	845.7	833.0	824.0	763.3	753.3	746.7	697.0	686.3	675.0	662.0	581.7	575.0	446.3	436.0
Tailwater level	m	765.0	765.0	765.0	697.0	697.0	697.0	600.0	600.0	600.0	600.0	510.0	510.0	330.0	330.0
Normal effective head	m	76.3	64.2	55.0	63.6	53.7	46.8	94.0	83.6	72.4	59.6	69.7	62.9	114.4	104.1
Maximum discharge	m^3/s	12.1	12.1	11.1	23.6	22.0	16.4	33.7	33.7	33.7	33.7	62.1	51.6	116.0	116.0
Maximum output	MW	7.8	6.6	5.2	12.8	10.0	6.5	26.9	23.9	20.7	17.1	36.8	27.6	112.8	102.6
Average annual energy	10^6KWH	22.95	19.22	16.16	36.44	30.56	25.50	78.52	69.91	60.59	49.74	112.02	99.42	321.85	287.92
" Firm energy	10^6KWH	13.26	11.13	8.65	21.49	16.87	11.02	45.19	40.32	35.02	28.80	62.48	46.86	193.85	173.63
" Secondary energy	10^6KWH	9.69	8.09	7.51	14.95	13.69	14.48	33.33	29.59	25.57	20.94	49.54	52.56	128.00	114.29
Total cost	10^6฿	1,192	991	807	1,126	923	758	2,019	1,680	1,438	1,227	2,323	1,900	4,995	4,373
Cost per KW	10^3฿	152.8	150.2	155.2	88.0	92.3	116.6	75.1	70.3	69.5	71.8	63.1	68.8	44.3	42.6
Cost per KWH	฿	51.9	51.6	49.9	30.9	30.2	29.7	25.7	24.0	23.7	24.7	20.7	19.1	15.5	15.2
Surplus benefit	10^6฿	Δ93.9	Δ77.7	Δ63.5	Δ63.1	Δ52.6	Δ48.0	Δ92.6	Δ69.6	Δ58.4	Δ52.8	Δ74.9	Δ63.2	Δ8.8	7.6
Benefit-Cost ratio		0.289	0.293	0.291	0.495	0.486	0.430	0.586	0.626	0.634	0.612	0.709	0.700	0.984	1.016

Table 6-16 Comparative Study of the Project (Individual River Development Plan. Dam Type Power Station 2-2)

Case		Mae Chaem No. 5			Mae Pai No. 1	Mae Pai No. 6				Mae Khan No. 1			Mae Khan No. 2		
		Case-3	Case-4	Case-5	Case-1	Case-1	Case-2	Case-3	Case-4	Case-1	Case-2	Case-3	Case-1	Case-2	Case-3
Catchment area	km^2	3,735	3,735	3,735	1,817	3,725	3,725	3,725	3,725	535	535	535	1,038	1,038	1,038
Average annual run-off	10^6m^3	1,206.02	1,206.02	1,206.02	729.07	1,578.32	1,578.32	1,578.32	1,578.32	166.50	166.50	166.50	323.05	323.05	353.05
Normal high water level	m	430	420	410	475	400	380	360	350	660	650	640	500	490	480
Reservoir area	km^2	38.7	34.1	30.0	29.4	48.0	34.3	24.4	20.5	10.0	7.8	5.7	10.4	7.9	5.8
Total storage capacity	10^6m^3	1,720	1,356	1,040	765	2,421	1,598	1,011	790	279	192	122	314	232	153
Effective storage capacity	10^6m^3	500	500	500	290	571	571	571	490	48	48	48	53	53	53
Available drawdown	m	14	17	20	12	13	19	30	32	5	6	10	6	7	10
Type of dam		Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill
Height x Crest length	m	130x540	120x515	110x490	100x230	185x400	165x350	145x300	135x270	90x480	80x420	70x390	120x470	110x400	100x360
Dam volume	10^3m^3	8,460	6,890	5,510	2,450	13,500	9,400	6,300	4,900	3,400	2,390	1,740	5,890	4,380	3,350
Headrace (DxLxN)	m	5.9x400 x 1	5.9x410 x 1	5.9x430 x 1	5.2x350 x 1	5.6x660 x 2	5.6x720 x 2	5.6x820 x 2	5.4x840 x 2	2.8x260 x 1	2.8x270 x 1	2.8x280 x 1	3.3x270 x 1	3.3x270 x 1	3.3x290 x 1
Penstock (DxLxN)	m	5.0x190 x 1	5.0x160 x 1	5.0x140 x 1	4.3x140 x 1	4.6x330 x 2	4.6x280 x 2	4.6x220 x 2	4.4x190 x 2	2.1x160 x 1	2.1x140 x 1	2.1x110 x 1	2.5x230 x 1	2.5x210 x 1	2.5x180 x 1
Normal intake level	m	425.3	414.3	403.3	471.0	395.7	373.7	350.0	339.3	658.3	648.0	636.7	498.0	487.7	476.7
Tailwater level	m	330.0	330.0	330.0	402.0	224.0	224.0	224.0	224.0	590.0	590.0	590.0	393.0	393.0	393.0
Normal effective head	m	93.5	82.6	71.6	67.3	169.2	147.3	123.8	113.1	65.2	55.1	44.1	101.5	91.4	80.7
Maximum discharge	m^3/s	116.0	116.0	116.0	85.4	202.0	202.0	202.0	185.0	20.2	20.2	20.2	29.6	29.6	29.6
Maximum output	MW	92.2	81.4	70.6	48.9	291.0	253.0	213.0	178.0	11.2	9.5	7.6	25.5	23.0	20.3
Average annual energy	10^6KWH	2,583.4	227.66	196.03	112.42	619.95	541.31	452.83	413.83	25.13	21.22	16.71	76.48	68.67	60.53
" Firm energy	10^6KWH	155.96	137.57	118.54	82.36	495.98	433.06	361.61	303.54	19.10	16.13	12.69	43.87	39.39	34.69
" Secondary energy	10^6KWH	102.38	90.09	77.49	30.06	123.97	108.25	91.22	110.29	6.03	5.09	4.02	32.61	29.28	25.84
Total cost	10^6฿	3,922	3,399	2,929	1,749	7,276	5,804	4,639	4,020	1,523	1,226	1,024	2,285	1,864	1,561
Cost per KW	10^3฿	42.5	41.8	41.5	35.8	25.0	22.9	21.8	22.6	136.0	129.1	134.7	89.6	81.0	76.9
Cost per KWH	฿	15.2	14.9	14.9	15.6	11.7	10.7	10.2	9.7	60.6	57.8	61.3	29.9	271.1	25.8
Surplus benefit	10^6฿	10.9	13.4	12.7	23.9	456.5	456.4	409.6	350.4	Δ119.3	Δ94.1	Δ80.2	Δ127.7	Δ93.4	Δ73.1
Benefit-Cost ratio		1.025	1.035	1.039	1.123	1.566	1.709	1.796	1.786	0.293	0.308	0.294	0.496	0.548	0.577

Table 6-17 Comparative Study of the Project
(Individual River Development Plan. Dam and Conduit Type Power Station)

Case		Mae Chaem No. 1 Case-4	Mae Chaem No. 1 Case-5	Mae Chaem No. 1 Case-6	Mae Chaem No. 1 Case-7	Mae Chaem No. 1 Case-8	Mae Chaem No. 1 Case-9	Mae Chaem No. 4 Case-3	Mae Chaem No. 4 Case-4	Mae Chan No. 1 Case-1	Mae Chan No. 1 Case-2	Mae Chan No. 1 Case-3
Catchment area	km^2	337	337	337	337	337	337	1,955	1,955	535	535	535
Average annual run-off	10^6m^3	130.89	130.89	130.89	130.89	130.89	130.89	698.34	698.34	166.50	166.50	166.50
Normal high water level	m	850	840	830	850	840	830	590	580	660	650	640
Reservoir area	km^2	4.1	2.9	2.1	4.1	2.9	2.1	11.1	8.2	10.0	7.8	5.7
Total storage capacity	10^6m^3	116	79	53	116	79	53	302	196	279	192	122
Effective storage capacity	10^6m^3	46	46	30	46	46	30	206	100	48	48	48
Available drawdown	m	13	21	18	13	21	18	25	15	5	6	10
Type of dam		Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill
Height x Crest length	m	100x290	90x260	80x230	100x290	90x260	80x230	105x530	95x490	90x480	80x420	70x390
Dam volume	10^3m^3	2,810	2,130	1,530	2,810	2,130	1,530	5,360	4,110	3,400	2,390	1,740
Headrace (DxLxN)	m	2.3x3,300 x 1	2.3x3,330 x 1	2.2x3,300 x 1	2.3x8,500 x 1	2.3x8,500 x 1	2.2x8,500 x 1	4.5x3,100 x 1	4.2x3,100 x 1	2.8x9,200 x 1	2.8x9,200 x 1	2.8x9,200 x 1
Penstock (DxLxN)	m	1.6x200 x 1	1.6x170 x 1	1.5x150 x 1	1.6x250 x 1	1.6x220 x 1	1.5x200 x 1	3.7x160 x 1	3.3x160 x 1	2.1x350 x 1	2.1x330 x 1	2.1x310 x 1
Normal intake level	m	845.7	833.0	824.0	845.7	833.0	824.0	581.7	575.0	658.3	648.0	636.7
Tailwter level	m	750.0	750.0	750.0	720.0	720.0	720.0	497.0	497.0	490.0	490.0	490.0
Normal effective head	m	81.8	69.6	59.8	95.2	83.1	72.1	76.5	69.6	136.8	126.7	115.7
Maximum discharge	m^3/s	12.1	12.1	11.1	12.1	12.1	11.1	62.1	51.6	20.2	20.2	20.2
Maximum output	MW	8.4	7.2	5.6	9.8	8.5	6.8	40.4	30.5	23.5	21.8	19.9
Average annual energy	10^6KWH	24.61	20.87	17.60	28.74	25.01	21.32	123.20	110.08	53.00	49.16	44.69
" Firm energy	10^6KWH	14.22	12.09	9.42	16.61	14.49	11.43	68.74	51.93	40.33	37.42	34.01
" Secondary energy	10^6KWH	10.39	8.78	8.18	12.13	10.52	9.89	54.46	58.15	12.67	11.74	10.68
Total cost	10^6฿	1,265	1,064	874	1,375	1,172	976	2,557	2,104	1,815	1,517	1,316
Cost per KW	10^3฿	150.6	147.8	156.1	140.3	137.9	143.5	63.3	69.0	72.2	69.6	66.1
Cost per KWH	฿	51.4	51.0	49.7	47.8	46.9	45.8	20.8	19.1	34.2	30.9	29.4
Surplus benefit	10^6฿	Δ99.3	Δ82.9	Δ68.7	Δ104.6	Δ88.3	Δ74.0	Δ82.9	Δ70.2	Δ97.3	Δ71.7	Δ58.0
Benefit-Cost ratio		0.292	0.297	0.291	0.314	0.320	0.316	0.708	0.699	0.517	0.574	0.603

Table 6-18 Individual River Development Plan Recommendation of the Feasible Project

		Mae Pai River		Mae Chaem River	
		Mae Pai No. 6	Mae Pai No. 1	Mae Chaem no. 5	Mae Chaem No. 4
Catchment area	km^2	3,725	1,817	3,735	1,955
Average annual run-off	$10^6 m^3$	1,578.32	729.07	1,206.02	698.34
Normal high water level	m	400	475	440	580
Reservoir area	km^2	48.0	29.4	37.7	8.2
Total storage capacity	$10^6 m^3$	2,421	765	2,141	196
Effective storage capacity	$10^6 m^3$	571	290	500	100
Available drawdown	m	13	12	12	15
Type of dam		Rockfill	Rockfill	Rockfill	Rockfill
Height x Crest length	m	185 x 400	100 x 230	140 x 555	95 x 440
Dam volume	$10^3 m^3$	13,500	2,450	10,120	4,110
Headrace (DxLxN)	m	5.6 x 660 x 2	5.2 x 350 x 1	5.9 x 385 x 1	4.2 x 300 x 1
Penstock (DxLxN)	m	4.6 x 330 x 2	4.3 x 140 x 1	5.0 x 210 x 1	3.3 x 130 x 1
Normal intake level	m	395.7	471.0	436.0	575.0
Tailwater level	m	224.0	402.0	330.0	510.0
Normal effective head	m	169.2	67.3	104.1	62.9
Maximum discharge	m^3/s	202.0	85.4	116.0	51.6
Maximum output	MW	291.0	48.9	102.6	27.6
Average annual energy	10^6KWH	619.95	112.42	287.92	99.42
Total cost	10^6฿	7,276	1,749	4,373	1,900
Cost per KW	10^3฿	25.0	35.8	42.6	68.8
Cost per KWH	฿	11.7	15.6	15.2	19.1
Surplus benefit	10^6฿	456.5	23.9	7.6	Δ63.2
Benefit-Cost ratio	-	1.566	1.123	1.016	0.700
	KV/km	230/95	230/10	115/130	115/50

Table 6-19 Required Pumping Energy at Mae Pai No. 1

Unit: 10^6 kWH

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1966	94.66	85.76	95.33	92.63	96.09	93.36	96.72	96.01	91.81	94.80	91.93	95.29	1,124.39
1967	95.65	86.73	96.54	93.93	97.57	94.89	98.37	105.66	99.51	102.10	93.42	86.24	1,150.61
1968	86.46	81.11	87.02	84.47	87.60	84.96	87.79	87.07	84.14	86.82	84.12	87.11	1,028.67
1969	87.40	79.21	88.09	85.66	88.94	86.41	89.33	87.90	84.75	87.52	84.75	87.84	1,037.80
1970	88.17	79.99	89.02	86.63	89.79	100.24	102.58	100.93	96.56	99.64	96.54	99.89	1,129.98
1971	100.09	90.64	100.80	98.02	101.69	98.71	101.40	100.09	96.21	85.06	78.72	81.56	1,132.99
1972	81.82	76.81	82.45	80.18	83.30	81.04	84.14	83.98	80.95	83.23	80.14	82.81	980.85
1973	83.09	75.31	83.74	81.43	84.54	81.92	106.44	103.24	98.80	102.10	98.80	102.28	1,101.69
1974	102.60	93.02	103.47	100.66	104.47	101.28	105.00	104.29	100.13	103.40	99.97	103.53	1,221.82
1975	103.92	94.32	105.07	102.36	106.44	102.80	105.77	104.81	99.44	102.11	98.73	90.00	1,215.77
1976	81.44	76.35	81.86	79.48	82.35	79.87	82.66	82.35	79.09	81.42	78.81	81.47	967.15
1977	81.73	74.05	82.27	79.90	82.84	80.46	83.29	83.09	79.62	81.91	79.16	81.93	970.25
1978	81.95	74.20	82.42	80.08	83.07	80.64	82.89	82.18	78.99	81.33	78.63	81.40	967.78
Total	1,168.98	1,067.50	1,178.08	1,145.43	1,188.69	1,166.58	1,226.38	1,221.60	1,170.00	1,191.44	1,143.72	1,161.35	14,029.75
Mean	89.92	82.11	90.62	88.11	91.44	89.74	94.34	93.97	90.00	91.65	87.98	89.33	1,079.21

Table 6-20 Study of Transbasin Scheme

Case	River	Dam Site	H.W.L. (m)	Inflow ($10^6 m^3$)	Diverted Discharge ($10^6 m^3$)	Max. Output (MW)	Pumping Energy (10^6 kWH)	Energy (10^6 kWH) Firm	Secondary	Total	Construction Cost (10^6 B)	Economic Evaluation (10^6 B) Benefit (B)	Cost (C)	B - C	B/C
Case-1	Mae Pai	No. 6	400	(I) 1,578.32		-		Δ234.27	Δ 47.52	Δ 281.79	-				
	"	"	"	(D) Δ715.43		-		-	-	-	-				
	"	No. 1	475	(I) 729.07		(Δ 48.9)		Δ 82.36	Δ 30.06	Δ 112.42	-				
	"	"	"	(D) Δ715.43		(Δ428.0)	1,079.21	-	Δ1,079.21	Δ1,079.21	3,881				
	Mae Chaem	No. 4	580	(IN) 715.43	715.43	69.1		93.75	10.37	104.12	636				
	"	No. 5	440	(IN) 715.43	715.43	113.4		155.96	17.25	173.21	813				
	Mae Ping	BHUMIBOL	260	(IN) 715.43	715.43	-		157.90	17.47	175.37	-				
	Total					182.5	1,079.21	90.98	Δ1,111.70	Δ1,020.72	5,330	(PG) Δ168.9 (A) 572.3 Total 403.4	(PG) 590.9 (A) 314.8 Total 905.7	Δ 502.3	0.445
Case-2	Mae Pai	No. 6	400	(I) 1,578.32		-		Δ234.27	Δ 47.52	Δ 281.79	-				
	"	"	"	(D) Δ715.43		-		-	-	-	-				
	"	No. 1	475	(I) 729.07		(Δ 48.9)		Δ 82.36	Δ 30.06	Δ 112.42	-				
	"	"	"	(D) Δ715.43		(Δ428.0)	1,079.21	-	Δ1,079.21	Δ1,079.21	3,881				
	Mae Chaem	No. 5	440	(IN) 715.43	715.43	113.4		155.96	17.25	173.21	813				
	Mae Ping	BHUMIBOL	260	(IN) 715.43	715.43	-		157.90	17.47	175.37	-				
	Total					113.4	1,079.21	Δ 2.77	Δ1,122.07	Δ1,124.84	4,694	(PG) Δ439.3 (A) 572.3 Total 133.0	(PG) 520.4 (A) 314.8 Total 835.2	Δ 702.2	0.159
Case-3	Mae Pai	No. 6	400	(I) 1,578.32		-		Δ193.15	Δ 123.97	Δ 317.12	-				
	"	"	"	(D) Δ810.47		(Δ512.0)	1,472.65	-	Δ1,472.65	Δ1,472.65	6,390				
	Mae Chaem	No. 4	580	(IN) 810.47	810.47	69.1		117.94	0	117.94	636				
	"	No. 5	440	(IN) 810.47	810.47	113.4		196.20	0	196.20	813				
	Mae Ping	BHUMIBOL	260	(IN) 810.47	810.47	-		198.63	0	198.63	-				
	Total					182.5	1,472.65	319.62	Δ1,596.62	Δ1,277.00	7,839	(PG) Δ339.7 (A) 648.4 Total 308.6	(PG) 869.0 (A) 356.6 Total 1,225.6	Δ 917.0	0.252
Case-4	Mae Pai	No. 6	400	(I) 1,578.32		-		Δ193.15	Δ 123.97	Δ 317.12	-				
	"	"	"	(D) Δ810.47		(Δ512.0)	1,472.65	-	Δ1,472.65	Δ1,472.65	6,390				
	Mae Chaem	No. 5	440	(IN) 810.47	810.47	113.4		196.20	0	196.20	813				
	Mae Ping	BHUMIBOL	260	(IN) 810.47	810.47	-		198.63	0	198.63	-				
	Total					113.4	1,472.65	201.68	Δ1,596.62	Δ1,394.94	7,203	(PG) Δ619.8 (A) 648.4 Total 28.6	(PG) 798.5 (A) 356.6 Total 1,155.1	Δ1126.5	0.025

Remarks: (I): Individual develpoment scheme
(D): Diversion scheme
(IN): Increment of facilities

(PG) : Power generation
(A) : Agriculture