CHAPTER IV

SEDIMENTARY FACIES AND AQUIFER ANALYSES

The concept of facies has been used in the geological context for quite a considerable long time after the term was first introduced by Gressly in 1838. However, the term "facies" has been the subject of debate and is used in many different senses, namely,

a) In the strictly observational sense of a rock product, e.g. 'sandstone facies';

b) In a genetic sence for the products of a process by which a rock is thought to have formed, e.g. 'turbidite facies' for the products of turbidity currents;

c) In an environmental sense for the environment in which a rock or suite of mixed rocks is thought to have formed, e.g. 'fluvial facies' or 'shallow marine facies'; and

d) As a tecto-facies, e.g. 'post-orogenic facies' or 'molasse facies'.

However, in this study the sedimentary facies is defined as a distinctive rock that forms under certain condition of sedimentation (Reading, 1978)

In addition, the term sedimentary environment refered to simply means the place of deposition and to the physical, chemical and biological conditions which characterized the depositional setting. These conditions may leave an imprint on the deposited sediments from which record of the past can be interpreted through the analogy of modern condition.

With in the study area of Bangkok Metropolis there are fortunately numurous groundwater wells densely distributed and penetrating to a considerable depth of 200-250 meters. The information from these wells regarding the lithological, geophysical and geohydrological are available for the correlation. As a result are the subsurface geology in terms of sedimentary facies, depositional environment and characteristic of aquifer are well defined in this study.

The information of these groundwater wells is, however, further classified into 3 different categories according to the level of their completeness and their significance. First, the primary reference wells which are consisting of 18 geophysical-logged wells and 15 complete lithological logged wells. Second, primary wells of approximately 200 in number with are consisting of the lithologically interpreted data. Third, the secondary wells which are consisting of partially complete well data.

The information previously described is employed in the synthesis of sedimentary facies and aquifer of the study area. As a result, the subsurface geology particularly within the depth range at 0-250 meters is graphically represented by 12 cross-sectional profiles and 2 fence diagrams illustrating the lithostratigraphy and the depositional environment respectively. The procedural technique concerned have been discussed in detailed in chapter 3.

On the basis of conceptual framework referred to in chapter 2, the detailed interpretation of the sedimentary facies and aquifer is accordingly discussed in this chapter

4.1 Sedimentary environment of deposition.

The combination of studies of modern depositional environment and of ancient stratigraphic records has led to the concept that there are certain association of environments and environmental control that repeatedly occur through the geological time. These recurring combination give rise through large-scale association of facies with can be recognized again and again in the stratigraphic record. The unique but similar between certain groups of stratigraphic record is distinctive and can be generalized as facie model. (Visher, 1965)

The interpretation of sedimentary environment of deposition in this study is mostly carried out by means of the electrical logs obtained from 18 primary reference wells. The advantage of using the electrical logs is that the information of each well from the ground surface to the deepest part of the well is continuously recorded. The initial interpretation of the self-potential and resistivity logs are the nuture of lithology and the characteristics of pore-fluid. Then, the interpretation on the environment of deposition of the entire length of each well is made. Eventually the depositional model is synthesized and presented as in the form of a 3-dimentional fence diagram (Plate 2).

It is apparent that 2 types of depositional environments, namely, the shelf environment and the deltaic environment are recognized.

4.1.1 <u>The shelf environment</u>.

The channel sea, or shelf environment, lies between those parts of the sea dominated by nearshore processes and those parts of dominated by oceanic processes. It has moderate depth of approximately 10-200 meters. A dynamic model of shelf sedimentation was proposed by Curray (1964, 1965) and Swift (1969a, 1970) who looked at patterns of shelf sediment distribution with regard to processes. They recognized three main shelf facies :

a) Shelf relict sand blanket comprising pre-Holocene deposits in disequilibrium with present-day processes,

b) Nearshore modern sand prism comprising shoreline beaches, barriers and shoreface, and including a seaward thinning nearshore sand zone, and

c) Modern shelf mud blanket consisting of fine-grained sediment which has bypassed the nearshore zone and been deposited on various parts of the shelf.

The shelf model used in this study is the shelf mud blanket type. This environment appears on the uppermost of the sequence and is characterized by the massive mud facies of approximately 10-20 meters in thickness. The facies is extensively distributed throughout the study area with tendency to gradually decrease in thickness from the middle and southern parts toward the north. Besides, the electrical logs indicate the presence of salts in the pore fluid system of the mud facies.

4.1.2 The deltaic environment.

Numerous sedimentological studies of modern deltas particularly the classic works on the Mississippi delta (Trowbridge, 1930; Russell, 1936; Russell and Russell, 1939; Fisk, 1944, 1947). has led to the delta model. The model was strengthened later on by a number of workers (Fisk, 1959, 1960; Coleman and Gagliano, 1964; Coleman, Gagliano and Webb, 1964). However, there appears to be many variation of delta in structure and lithology. On the basis of a qualitative comparison of modern deltas, (Fisher, et.al., 1969) distinguish high-constructive deltas dominated by fluvial processes from high-destructive deltas dominated by basinal processes. Lobate and bird foot types are recognized in the high-constructive class, whilst wave-dominated and tide-dominated types are distinguished in the high-destructive class (Figure 20). Each type is illustrated by a characteristics morphology and facies pattern, described in terms of vertical sequences, aerial facies distribution and sand body geometry.

Due to the variability of modern delta one single delta model is not adequate, a serie of model is required instead. Several schemes

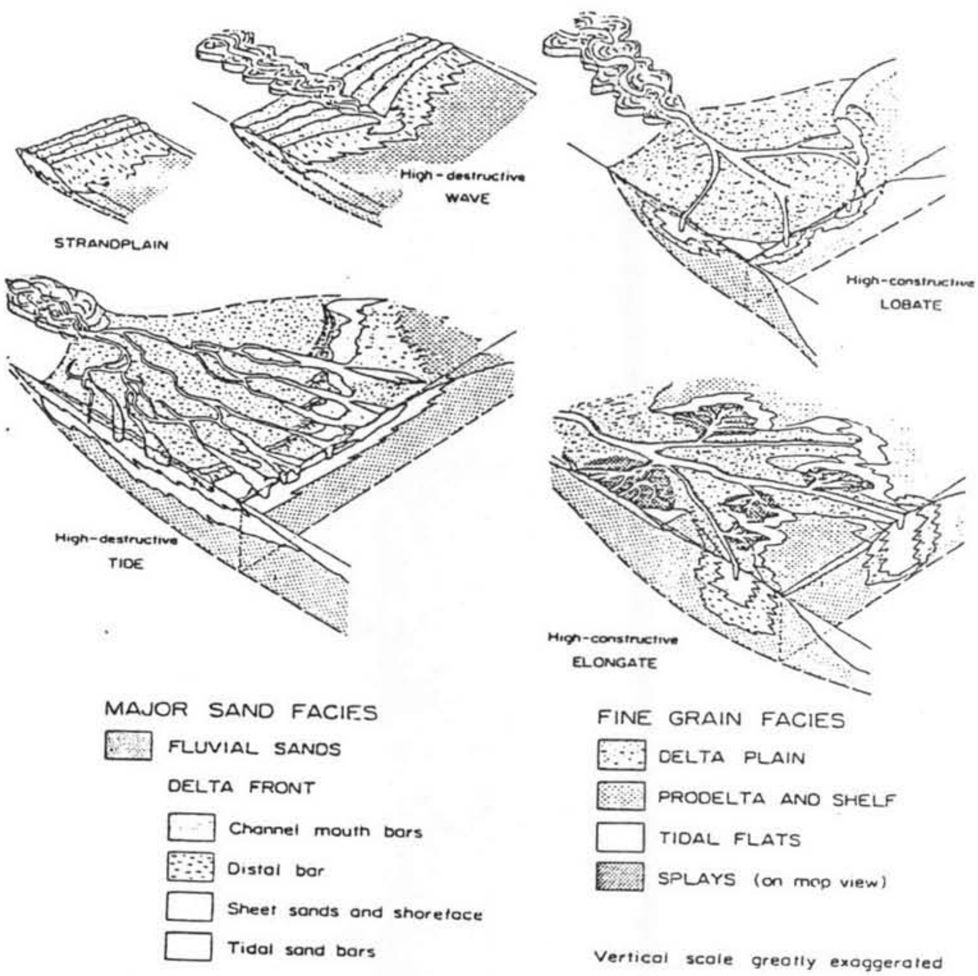


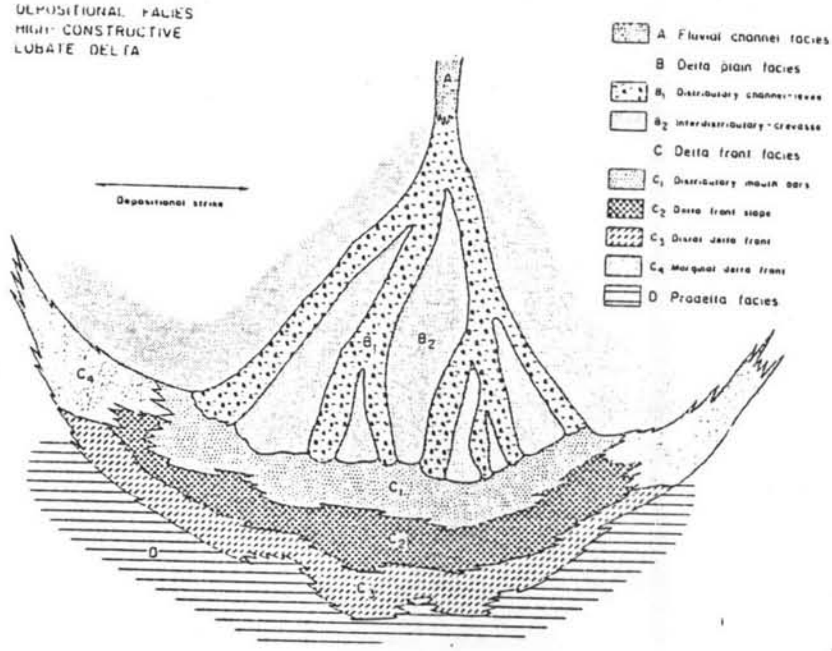
Figure 20 High-constructive and high-destructive delta types as defined by Fisher et al. (1969).

have recently been proposed (Fisher et.al., 1969; coleman and Wright, 1975; Galloway, 1975).

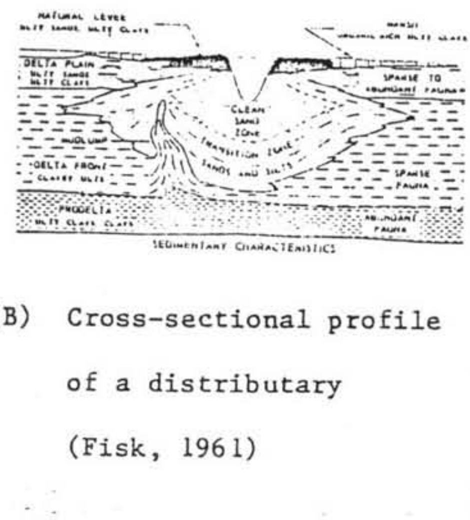
Evidences from the study of electrical logs of 18 primary reference wells, covering on area of approximately 700 square kilometers, show the presence of deltaic plain facies, delta front facies and distributary mouth bar facies. However, it is remarkable to note that the reworked facies of delta, namely, strandplain facies, stacked coastal barrier facies, strandplain shelf facies, and strandplain-lagoon-marsh facies are entirely absent in the study area. It is therefore conclusively enough to point out that the deltaic model of this study is of high-constructive lobate type (Fisher et.al., 1969). The idealized model of high-constructive lobate delta is presented in Figure 21.

Throughout the study area, 2 cycles of deltaic environment have been recognized within the depth range of 0 to 250 meters.

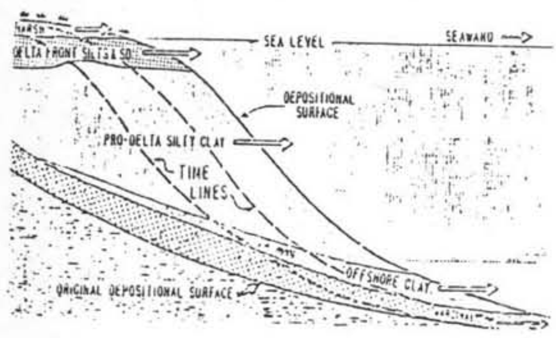
A) Lower cycle The uppermost boundary of lower cycle delta appears at the depth range of 110 to 200 meters below the ground surface as a deltaic plain facies. The lower boundary of the cycle seems to be present below the depth of 250 meters not penetrated by all wells in the study area. The upper surface of the deltaic plain facies is rather uneven and the surface is generally present at a relatively great depth in the northern part as compared with that of in the southern part. It is believed that the other 2 facies, namely, delta front facies and pro-delta facies must be underlying the delta plain facies. However, the bore hole evidence regarding these 2 facies is unfortunately not



(A) Aerial distribution of facies



(B) Cross-sectional profile of a distributary (Fisk, 1961)



(C) Illustrating seaward migration of depositional environment. (Scruton, 1960)

Figure 21 Depositional facies of high constructive lobate delta models. (Fisher et.al., 1969) available. The lithology of this deltaic plain facies is largely consisting of sand and clay layers shapely interbedded or as a repeated fining upward sequences.

B) Upper cycle Overlying the lower deltaic cycle is the 2 facies, namely, deltaic plain facies and delta front facies of the upper deltaic cycle. The eustatic change of the sea level is believed to be responsible for the development of these 2 deltaic cycles. However, the evidence of the break of deposition between these 2 cycles is not distinctive, but the interpreted boundary between them. (Plate 2). The second deltaic cycle persists throughout the study area with the thickness falls in the range of 100-170 meters. The second deltaic cycle is overlain by the shelf facies previously described.

Within the upper deltaic cycle, 2 types of facies are distinguished, they are:

a) Deltaic plain facies which is developed as the upper facies of upper deltaic cycle overlying both delta front & sheet sand subfacies and distributary mouth bar subfacies (Plate 2). This facies appears in the western part and central part of the study area with its thickness decreases from the west to the east. The thickness varies within the range of 50-130 meters and the depth to top of this facies is approximately 10-20 meters. The lithology of this facies is characterized by the presence of sand and clay either in the form of a distinctive interbedding manner repeated fining upward sequences.

b) Delta front facies which is developed as the lower facies of upper deltaic cycle, lying between the two deltaic plain facies of both deltaic cycles. The depth to the top of facies ranging from 20-130 meters and its thickness is between 40-160 meters. This facies is uniformly distributed throughout the study area except in the mid-western part where it is relatively thinner. This facies can be further subdivided into 2 subfacies.

b.1) Distributary mouth bar subfacies is developed as the top unit overlying delta front and sheet sand subfacies. But in fact this subfacies appear on the upper portion of the delta front facies (Figure 18). This subfacies is distributed from northwestern to central and southeastern part of the study area with its thickness increase toward the central part. The total thickness of this facies varies within the range of 30-100 meters. The lithology of the facies is characterized by the domination of sand body overlying distal sand and silt interbeds.

b.2) Delta front and sheet sand subfacies is normally developed in the lower part of the delta front facies. The aerial distribution of this facies is almost entirely covering the study area except at Wat Bang Yikan (Grid reference 613226). The thickness of the facies is between 10-120 meters and gradually decreases toward the western part. The lithology of this facies is characterized by the presence of dominated silt and clay alternating with sheet sand in some parts and exhibiting the coarsening upward nature.

Table 16 : Distribution and thickness of sedimentary facies

DEPOSITIONAL ENVIRONMENT		DISTRIBUTION	THICKNESS
FACIE	SUBFACIE		
Shelf mud	-	Throughout	Increase to the South
Deltaic plain upper cycle	-	Westernpart & Middlepart	Increase to the West
Delta front upper cycle	Distributary mouth bar	Except at Southwesternpart	Increase to the Middle
	Delta front & sheet sand	Except at Midwesternpart	Decrease to the West
Deltaic plain lower cycle	-	Throughout	?

4.2 Stratigraphic correlation.

Previous investigation of the uppermost sequence of sediments in the Lower Chao Phraya Basin reveal that relatively thin fluviatile sediments overlying inner neritic sediments or shelf sediments (Piancharoen and Chuamthaisong, 1976). However, the investigations in the Gulf of Thailand further report that approximately 200 meters depth of inner neritic sediments are found underlying the sea floor (Achalabhuti, 1974; Paul and Lian, 1975; and Woollands and Haw, 1976). Many lines of evidence from the present study show that the uppermost 20 meters of sediments in Bangkok Metropolis area are essentially composed of the marine shelf mud with very thin overlying fluviatile sediments throughout the area. Evidences from the characteristic of sediments reflect that within the uppermost 20 meters, the depositional environment has abruptly changed from the inner neritic shelf into the fluvial coastal one very recently. Therefore the most recent regression occurs after a relatively longer period of transgression. There is no obvious evidence indicating the break of deposition within the transgression-regression sequences of the upper most 20 meters of sediments.

Below the depth of 20 meters down to the depth range of 110-200 meters in the study area, sediments are identified to be of upper deltaic cycle (delta front and deltaic plain facies). It is therefore concluded that the transgression must have reached the maximum during the deposition of delta front facies of upper deltaic cycle and then gradually decreased its influence in order to results the almost complete deltaic sequence. While the transgression progressively decreases its influence toward the top of the sedimentary sequence the regression concurrently increases. The lower boundary of the upper deltaic cycle appears as irregular surface within the depth range of 110-200 meters. Below the upper deltaic cycle is the break of deposition which is reduced from the different deltaic facies above and below this break. That is the deltaic plain facies of the lower deltaic cycle appear just below the break of deposition overlying by the delta front and deltaic plain facies of the upper deltaic cycle respectively. The change in depositional environment from deltaic plain facies of the lower deltaic cycle to delta front facies of the upper deltaic cycle can be well explained in term of the change in the eustatic sea level. Evidences from the sediment in the Gulf of Thailand in the correspondings depth level reveal that they are of neritic origin which could be well correlated with the two deltaic cycles of the study area. Sediments deposited below the depth of 250 meters are beyond the scope of the present study.

Considering the paleogeography of the present Bangkok Metropolis and the Gulf of Thailand particularly during the Pleistocene Epoch, the seaward neritic sediments in the Gulf which fall in the floral zone of Podocarpus (Figure 22) are equivalent with the two deltaic cycles of the Lower Chao Phraya Basin which are deposited further north much closer to the land. Besides, evidences from the study of Piancharoen and Chuamthaisong (1976) reveal that sediments in the Bangkok Metropolitan area with the depth range of 250-600 meters deposited in Pliocene Epoch (Table 8). It is interesting to note that the break of deposition

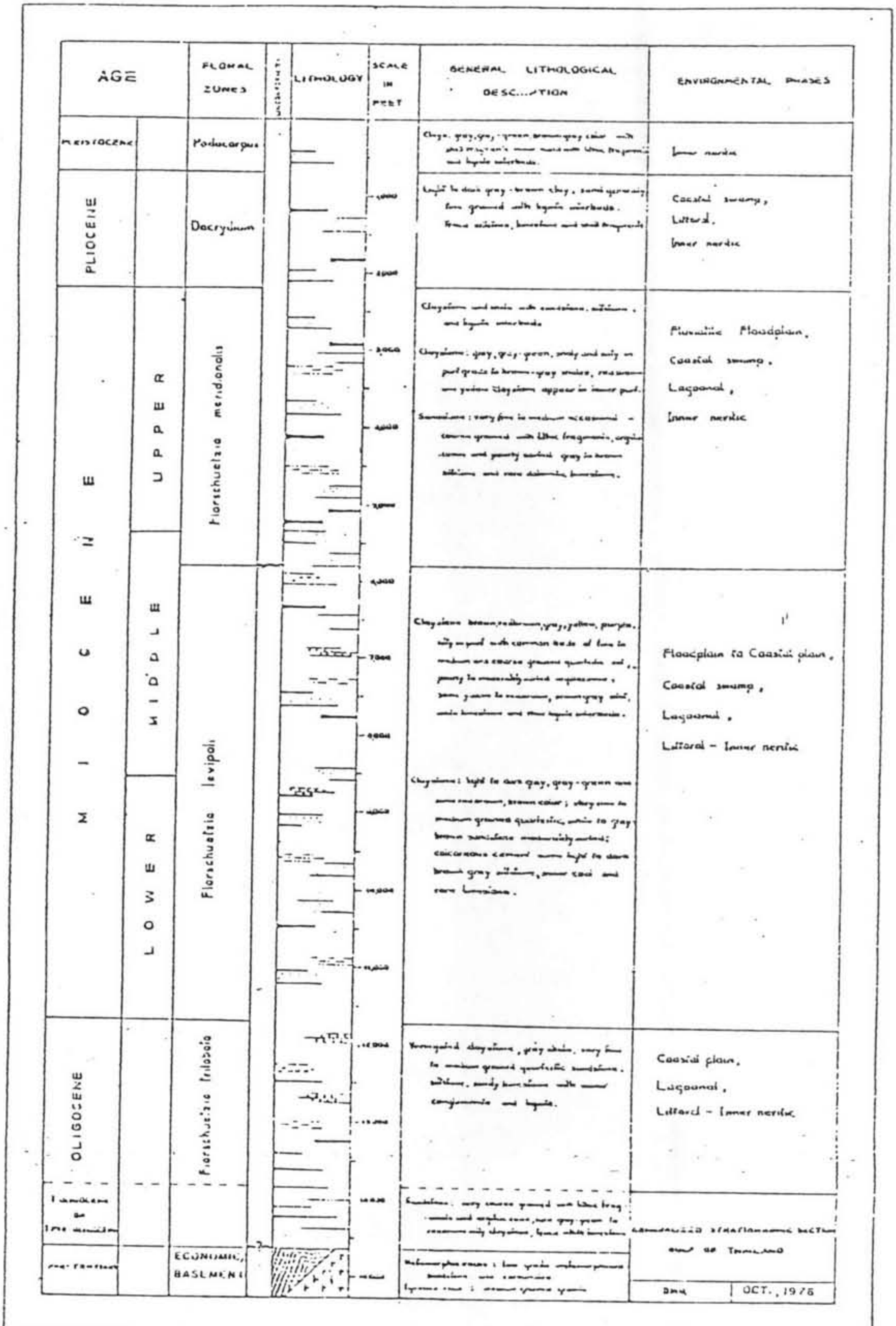


Figure 22 Stratigraphy of Gulf of Thailand (Pariwat, 1976).

between the lower and upper deltaic cycles does not extend into the neritic sediment of the Gulf of the same age. This can be explained in term of the geographic location; the fluctuation of the sea level could obviously have strong effect on the change of the depositional environment in the marginal area of sedimentary basin than those of in the deeper part.

The marine shelf facies in the upperpart of sedimentary sequence of the Lower Chao Phraya Basin and the uppermost fluvial facies are believed to be deposited in the Holocene Epoch. This deduction would results in the rate of sedimentation approximately 1-2 milimeter per year in the 10,000 year B.P. of Holocene Epoch. Depositional rates in similar environment during the same period of time elsewhere have the similar figure, namely, Norwegian fjord = 1.5 m.m./year and Gulf of California = 1 m.m./year (Kuenen, 1950); Santa Barbara Basin = 2 m.m./year (Emery and Rittenberg, 1952); and Santa Monica and San Pedro Basins = 1.44 m.m./year (Emery, 1960).

4.3 Aquifer.

All underlying sediments of the study area in the Lower Chao Phraya Basin are unconsolidated in nature. The aquifers in this unconsolidate sequence can be classified as great plain flank highlands or mountains type (Thomas, 1952). This type of aquifer is composed of stream deposited sand and gravel occuring beneath the plains in broad belts. Sand and gravel underlie parts of coastal plains where formations are partly marine and partly fluviatile in origin. Aquifers of

Depth (m.)		Depositional Environtment	Age	Eustatic Sea Level	
				Transgression	Regression
0	thin veneer	Fluvial facies	Holocene		
20	thin veneer to 10-20	Shelf facies	Holocene		
40 60 80 100	10-20 to 60-150	Deltaic plain facies	Pleistocene		
120 140	60-150 to 110-200	Delta front facies	Pleistocene		
160	Break of deposition (110-200 m.)				
180 200 220 240	110-200 to ?	Deltaic plain facies	Pleistocene		

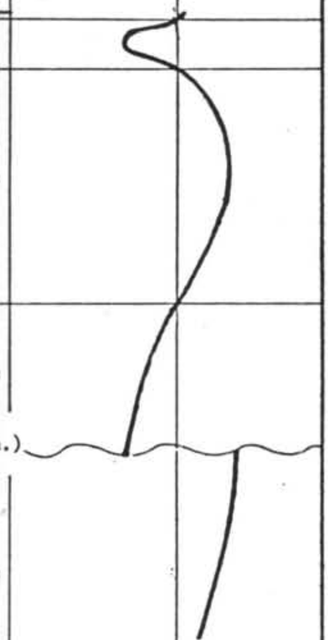


Figure 23 Depositional framework of sedimentary sequence underlying Bangkok Metropolis.

these plains are recharged directly from precipitation and from streams. Many stratigraphic units along coastal plains grade oceanward from partly alluvial deposits into entirely marine units. This gradation is accompanied by a tendency for the sediments to become progressively finer grained.

All aquifers in the study area particularly within the depth range 0-250 meters are essentially composed of sand and gravel with clay layers interbedded in some parts. Each aquifer is separated by clay and silt layers of variable thickness but of relative large aerial extent (Plates 3 and 4).

The aquifers concerned are illustrated in the litho-stratigraphic cross sections and fence diagram which are designated as permeable unit. Altogether there are 4 aquifers in the depth range of 0-250 meters. It is interesting to note that the upper three aquifers, though separated by impermeable silt and clay layers, are partly interconnected. In contrast, the lowest aquifer of the study area is entirely separated from the other upper three ones (Figure 24).

The detailed characteristics of the 4 aquifers are as follows:

4.3.1 <u>The first aquifer</u>. This aquifer is found within the depth range of 20-90 meters from the ground surface throughout the study area. However, the thickness varies considerably from less than 1 to 80 meters. The subsurface analyses of this aquifer indicate that it can be further divided into two subaquifers, particularly in the southern part of the study area.

A) Upper subaquifer which directly underlies the uppermost clay strata and persists almost throughout the study are within the depth range of 20-50 meters. The thickness considerably varies from less than 1 to 30 meters. The lithology of this subaquifer is predominantly consisting of very fine to very coarse sand of grayish orange to yellowish gray color. The sand are generally very angular to subrounded with a tendency to be more subangular, poor to moderately sorted. The grain composition is mainly quartz with small amount of opaque minerals, rock fragments and iron accretionary granules.

B) Lower subaquifer. In the northern part of the study area, the upper subaquifer completely merges with the lower subaquifer. However they are partly separated or interconnected in the southern part of study area. The lower subaquifer occurs in the depth range of 30-80 meters with thickness varying from less than 1 to 50 meters. The sediments are predominantly fine to very coarse sand with some gravel and clay layers interbedded. The color is medium gray to dark yellowish orange. The textural characteristics of sediments are very angular to subrounded with a tendency to be more subangular, dominated by the low sphericity with poor to well sorted. The grain composition appears to be similar to that of the upper subaquifer.

Previous investigations (Piancharoen and Chuamthaisong, 1976; Metcalf & Eddy Inc., 1977) reported that the two subaquifers of the uppermost aquifer or Bangkok aquifer could be clearly separated.

The present investigation reveals a different finding, that is they are partly completely merged together and partly separated but still interconnected.

The sedimentary facies analyses of the uppermost aquifer or Bangkok aquifer indicates that it is a deltaic plain facies of the second delta cycle deposited in the Pleistocene Epoch. The sandy characteristics of the aquifer is concluded to be a channel sheet sand of the deltaic plain.

Although the first aquifer or Bangkok aquifer is extended throughout the study area, the depth to the top of aquifer varies from place to place. Generally, it appears to be more than 30 meters in the central part of the study area with a tendency to be shallower (less than 30 meters) in the surrounded outer zone. (Figure 24-1)

4.3.2 The second aquifer. This aquifer is called Phra Pradaeng aquifer by the Department of Mineral Resources. It is found the depth range of 60-150 meters from the ground surface between and the thickness varies from less than 15 to 80 meters. The sediments are consisting mainly of very fine to very coarse sand and gravel with thin clay layer interbedded. The color of sediments is yellowish gray to moderate yellowish brown. Sediments are characterized by angular to subangular and poor to moderately sorted. The grain composition is essentially quartz with small amount of opaque minerals, rock fragments and iron accretionary granules.

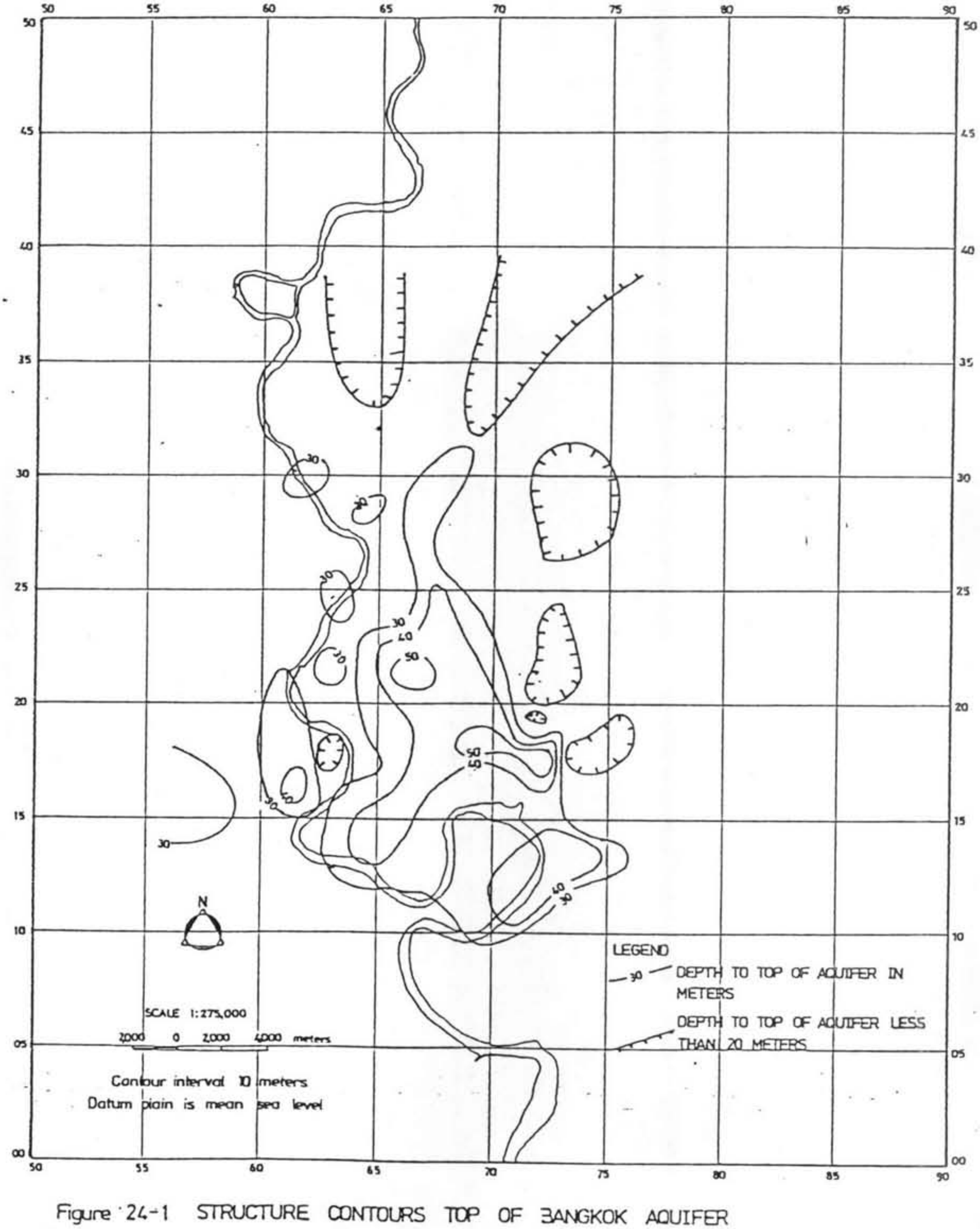


Figure 24-1 STRUCTURE CONTOURS TOP OF BANGKOK AQUIFER

The aquifer is found extensively throughout the study area with the depth to top of aquifer increasing westward ranging from 60 to 100 meters. It is important to indicate that at least there are 6 zones where the first aquifer is interconnected with the second (Figure 24-2)

Analyses of sedimentary facies indicate that Phra Pradaeng aquifer is a delta front facies of the second delta cycle deposited in the Pleistocene Epoch. This aquifer composed of sheet sands of distributary mouth bar and delta front.

4.3.3 The third aquifer. This aquifer locates within the depth range of 110-190 meters from the ground surface throughout the study area. Its thickness varies from less than 15 to 75 meters. The lithology of this aquifer is predominantly consisting of fine to very coarse sand and gravel with thin clay and silts layer interbedded. The color is very pale orange to medium dark gray. The characteristics of sediments are angular to subangular, dominated by the low sphericity with poor to moderately sorted. The grain composition is essentially quartz with small amount of opaque minerals, rock fragments and iron accretionary granules.

This aquifer is called Nakhon Luang aquifer by the Department of Mineral Resources. It is found extensively throughout the study area, the depth to top of aquifer varies from 110-160 meters. Generally, it appears to be more than 140 meters in the central part of the study area with a tendency to be shallower (less than 140 meters) in the

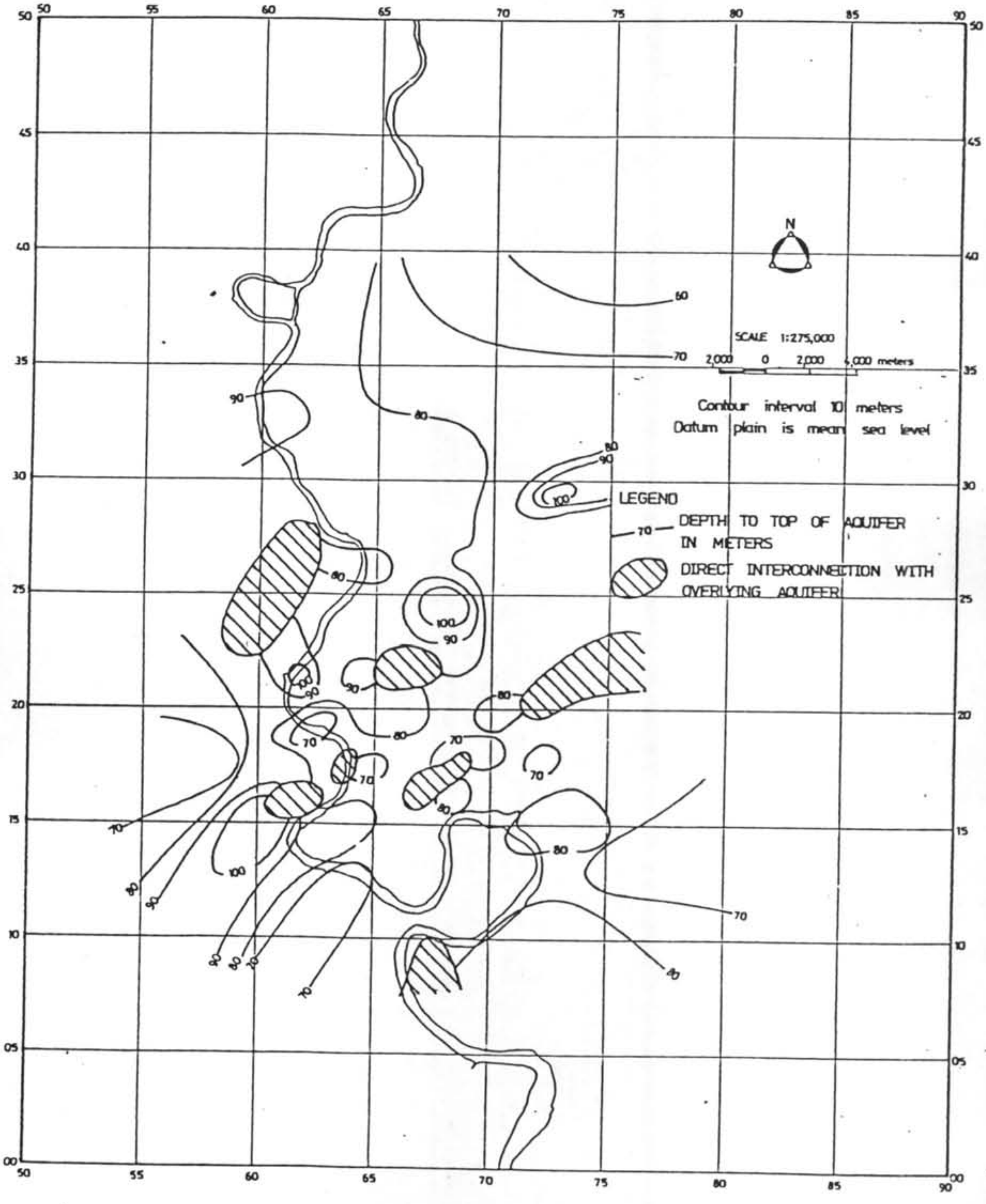


Figure 24-2 STRUCTURE CONTOURS TOP OF PHRA PRADAENG AQUIFER

surrounded outer zone. (Figur 24-3). Besides, there are 7 zones where the second aquifer is interconnected with the third (Figure 24-3).

The sedimentary facies analyses of the Nakhon Luang aquifer indicates that it is a deltaic plain facies of the lower delta cycle deposited in the Pleistocene Epoch. The sandy characteristics of the Nakhon Luang aquifer are similar to that of the Bangkok aquifer.

4.3.4 The fourth aquifer. This aquifer is called Nonthaburi aquifer by the Department of Mineral Resources. The depth to top of aquifer ranges from 180-200 meters. Its thickness is unable to identify due to the limitation of available well data. The sediments are consisting mainly of fine to very coarse sand and gravel with clay and silt layers interbedded. The color of sediments is very pale orange to light gray. Sediments are characterized by subangular to subrounded and moderately sorted. The grain composition is similar to the third aquifer.

From stratigraphic cross sections and fence diagram (Plate 4 and 3), this aquifer is definitely separated from the uppermost three aquifers. While, Metcalf & Eddy Inc. (1977) reported that, on the basis of water quality and the hydraulic aspects of the aquifers, the evidence leads one to believe that the third and fourth aquifer is interconnected. However, available geological information does not entirely support this point of view. Therefore, it is concluded that the fourth aquifer might indirectly interconnect with the third aquifer.

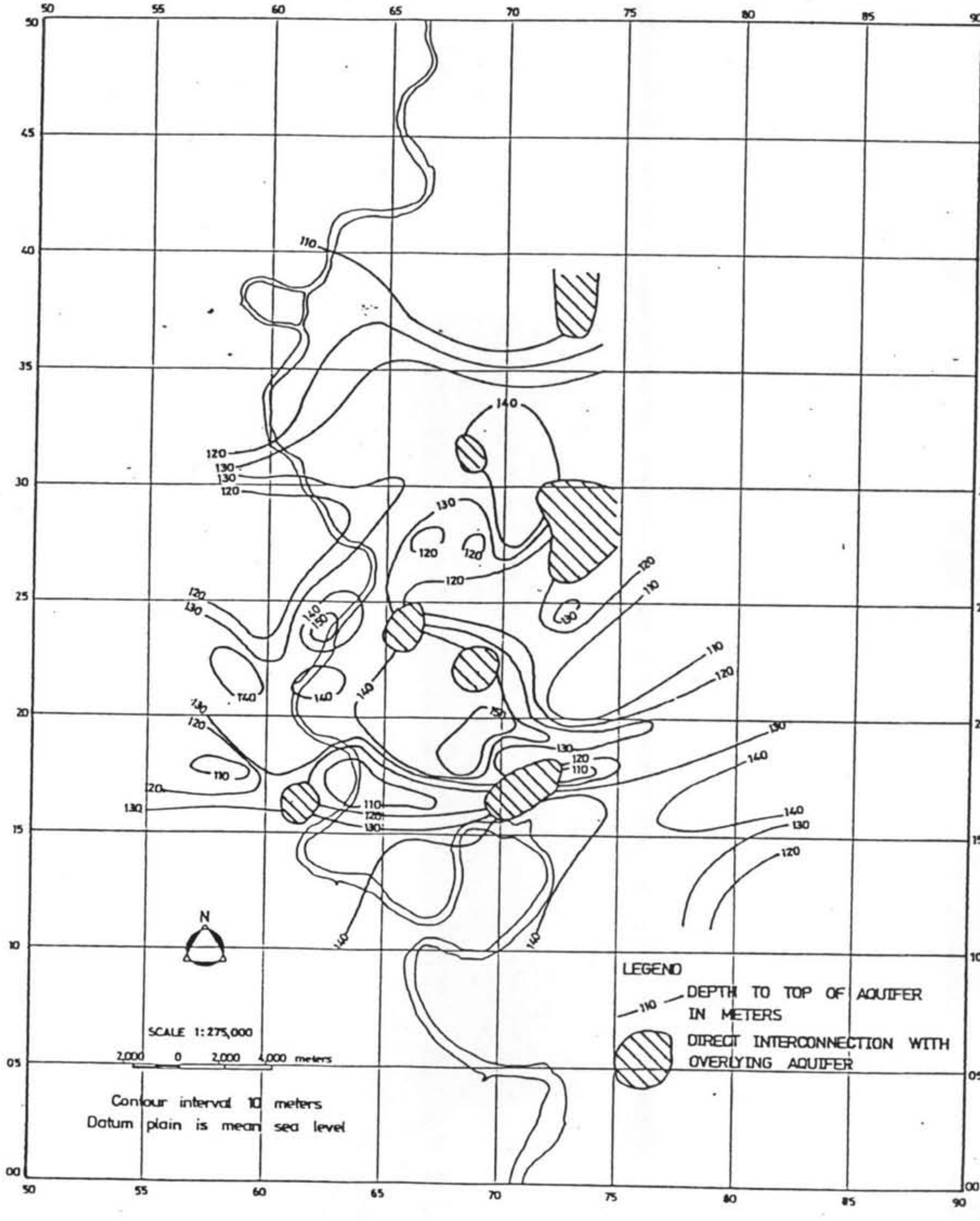


Figure 24-3 STRUCTURE CONTOURS TOP OF NAKHON LUANG AQUIFER

The aquifer is found extensively throughout the study area with the depth to top of aquifer varies from olace to palce. Generally, it appears to be than 190 meters in the central part of the study area with a tendency to be deeper (more than 190 meters) in the surrounded outer zone (Figure 24-4).

Analyses of sedimentary facies indicate that Nonthaburi aquifer is a deltaic plain facies, similar to Nakhon Luang aquifer, but of the first delta cycle.

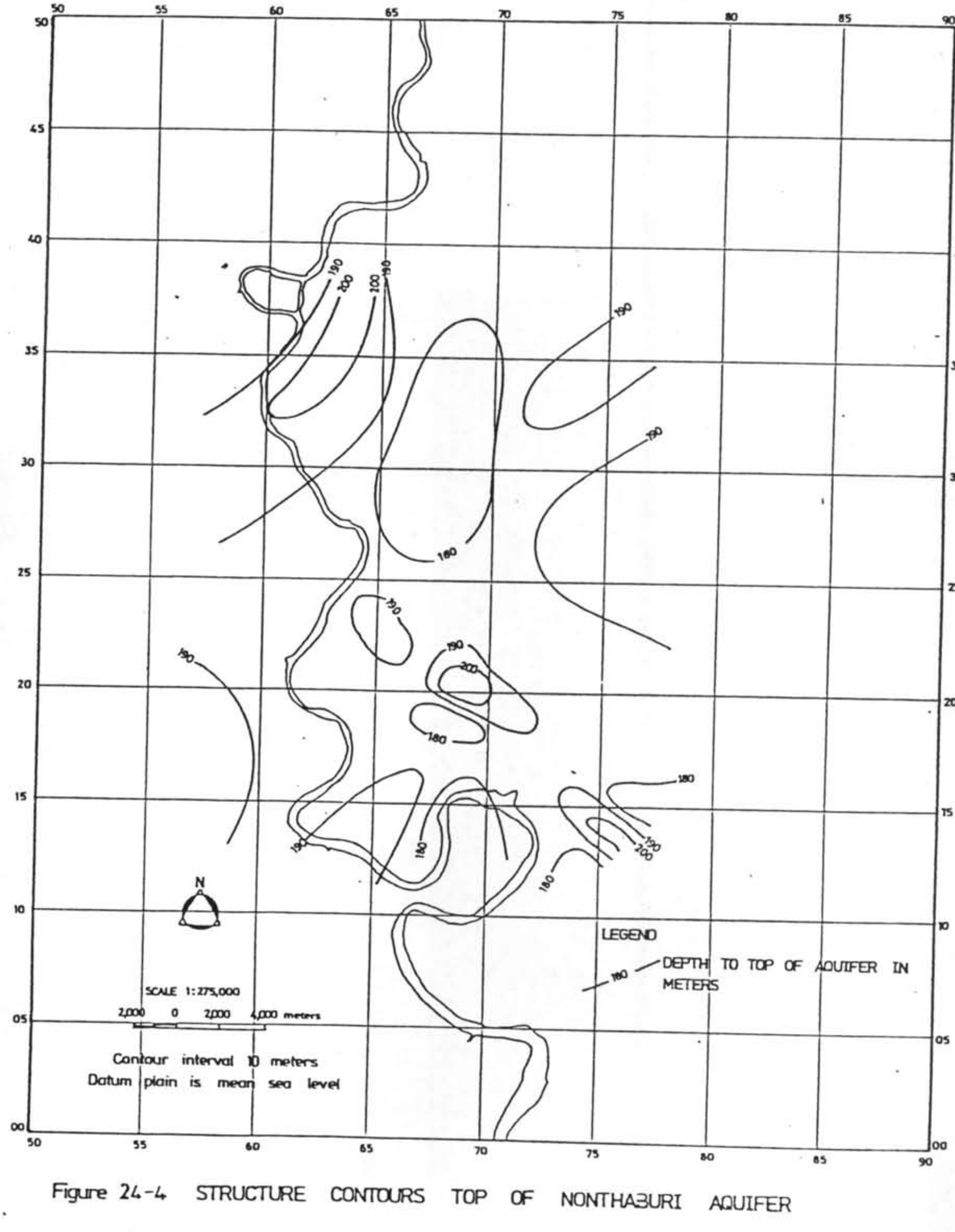


Figure 24-4 STRUCTURE CONTOURS TOP OF NONTHABURI AQUIFER

Table 17 : Relationships between aquifers and sedimentary facies.

Aquifer	Depth to top of aquifer (m.)	Thickness (m.)	Sedimentary Facies	Remarks
First aquifer (Bangkok aquifer)	20 - 30	< 1 - 80	Deltaic plain facies of upper delta cycle	
Second aquifer (Phra Pradaeng aquifer)	60 - 100	< 15 - 80	Delta front facies of upper delta cycle	Partly inter-connected
Third aquifer (Nakhon Luang aquifer)	110 - 160	< 15 - 75	Deltaic plain facies of lower delta cycle	Partly inter-connected
Fourth aquifer (Nonthaburi aquifer)	180 - 200	unidentified	Deltaic plain facies of lower delta cycle	indirectly connected (?)