CHAPTER IV
SEDIMENT DEPOSITION AND HEAVY METAL DISTRIBUTION IN LAKE

In this chapter, focus is placed on the rate of sedimentation and heavy metal concentration in the Songkhla Lake. At present it is likely that the present anthropogenic inputs of heavy metals into the environment far exceed natural inputs (Nriagu and Pacyna, 1988); the former may pose health risks in areas where metals accumulate. The impact of heavy metal pollution to coastal and estuarine areas could be substantial because of the variety of inputs to these areas; potential sources include riverine inputs, local runoff, atmospheric deposition, and coastal waters. Local runoff and riverine inputs can carry treated and untreated sewage (Galloway, 1979) and industrial effluents (Gross, 1978), and these inputs have been shown to carry high levels of heavy metals in many areas (Helz, 1976). Coastal waters and atmospheric deposition may also have a major effect on heavy metal concentrations in some estuarine situations. Recent interest in protecting lake areas has stimulated increased monitoring of pollutants in these environments and resulted in sharply decreased inputs of heavy metals to coastal lake and estuarine areas (O'Connor and Ehler, 1991; Valette-Silver *et al.*, 1993).

In addition to monitoring present additions of pollutants into coastal areas, there is interest in determining historic additions and accumulation rates in coastal environments. Sediments have been used extensively as indicators of chronological pollution of coastal areas, including both subtidal sediments (Santschi *et al.*, 1984; Schmidt and Reimers, 1991; Swartz *et al.*, 1991; Valette-Silver, 1993) and intertidal wetland sediments (Griffin *et al.*, 1989; Bricker, 1993). Recent studies in coastal wetlands have successfully developed chronologies of metal additions (McCaffrey and Thomson, 1980; Bricker, 1993; Zwolsman *et al.*, 1993). One of the consistent findings of many of these studies is the recent decrease in heavy metal concentrations in sediments (Macdonald *et al.*, 1991), especially for lead (Evans and Dillon, 1982; Trefry *et al.*, 1985; D6rr *et al.*, 1991). These results have also been confirmed by observed

decreases in metal concentrations in snow deposits from Greenland (Boutron *et al.*, 1991; Candelone *et al.*, 1995).

As stated earlier, recent sedimentation in the Songkhla Lake was studied by Chittrakarn et al. (1996) and Dumrongrittamatt (2005) using CS-dating. The average sedimentation rate is 5.0 mm/year. In the same year Ministry of Natural Resource and Environments (2005) reported the rate of sedimentation of the Songkhla Lake using comparison of the bathymetry provided by Royal Port Department of the year 1975 and the year 2002 using echo-sounding data. They concluded that the maximum shallowness of about 15 mm/year was at the northernmost part of the SKL study area whereas the southern part of the SKL study area showed the deepness rate of more than 15 mm/year.

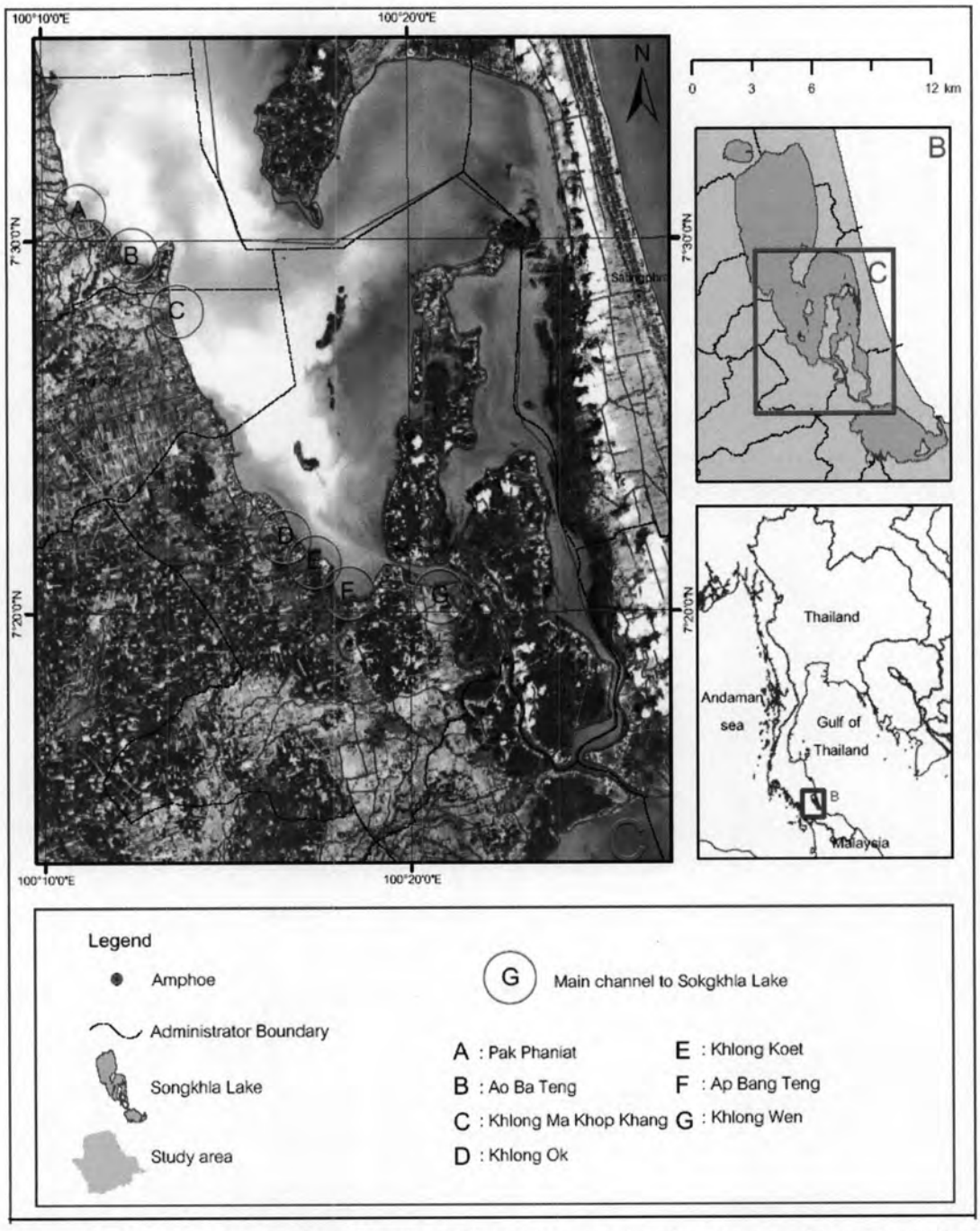


Figure 4.1 Landsat image covering the SKL study area showing geography and location of major stream channels.

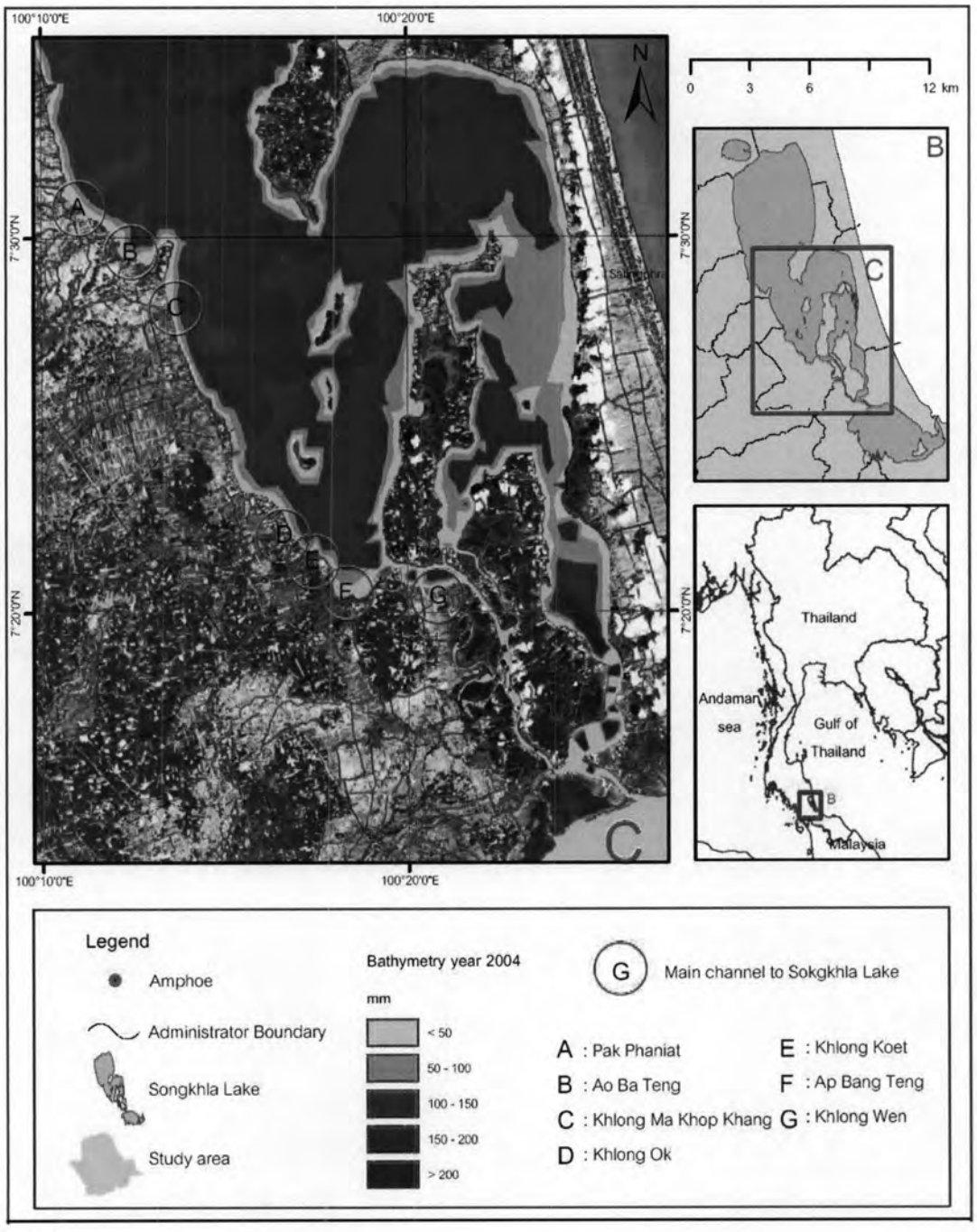


Figure 4.2 Landsat TM5 and bathymetry map of the SKL study area.

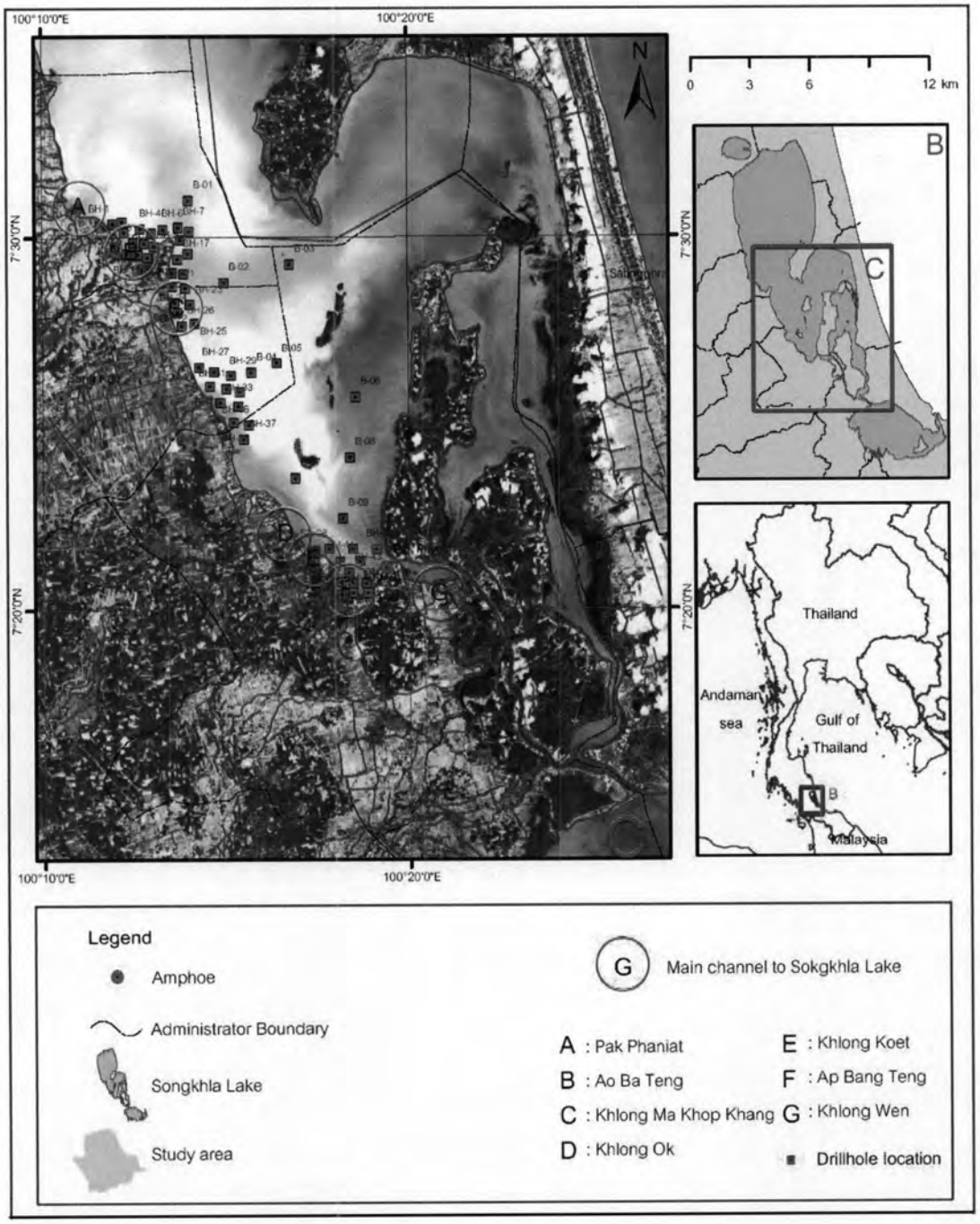


Figure 4.3 Landsat TM5 and bathymetry map with drillhole locations of the SKL study area.

4.1 Lithological Analysis

Drilled core data were derived from rotary drilling machine equipped on the man-made pontoon (3x8x0.6m) connected by the four-pod-poles. Undisturbed core samples from individual drill holes were collected from the drill-core depths of about 1.0, 2.0, 3.0, and 3.5 m. To avoid sunlight and contamination, all these samples were wrapped using waxy paper. Each selected core samples were splitted into 8 parts: 1 part for sedimentological and chemical analysis, 1 part for reference sediment sample, 3 parts for thermoluminesecence dating analysis and 3 for reference dating sample

In this study visual observation was made for lithological description for the whole column of the drill-cores granulometric analysis was done on the selective samples for grain-size variation on both vertical and horizontal scales. These data were subsequently used for the interpretation of the SKL depositional environments. Both lithological and granulometric results show that the lake sediments are of 2 size ranges, one being the coarse-grained sediment, or sand dominant and the other being the fine-grained sediment, or clay-dominant. Frequency distribution curve and cumulative frequency curve data with the non-systematic kurtosis pattern can provide the low-energy deltaic environment. The appearance of the sand layers (10%of the total volume) suggested the river system or the so-called distributary channels of the delta. The clay-dominated sequences (90%) can explain the depositional environment being of the low-energy system. However, in some areas, there exist 2 clusters of distribution, suggestive of more than 1 provenances.

The detailed results on the lithological analysis by areas are described below. They are presented in the forms of stratigraphic logs and fence diagrams.

4.1.1 Area1: Ao Ba Teng (See Figure 4.4 and 4.6)

At least 5 sedimentary layers are recognized from the drill holes of area 1. Stratigraphic logs and fence diagram are shown in Figures 4.7 and 4.8 respectively.

Layers 1 to 4 from top to bottom are sediments deposited in the Holocene epoch and the oldest layer-layer 5 occurred in the Pleistocene epoch

Layer1 which is the youngest layer consists mainly of black to dark brown, organic-rich clay with wood fragments. The thickness is from 0.25 to 2 m. from the west to east.

Layer2 is the light brown to brown clay layer with the thickness varying from 0.5 to 1 m. The organic clay is intercalated in some part.

Layer3 comprises the greenish gray to light gray clay with ferricrete and sand lenses (1-2 cm.). The thickness varies from 0.5 to 1.5 m.

Layer4 consists mainly of the red to pinkish gray clay with high ferric oxides and few sand lenses. Iron-stained patches are very characteristic (>30%). The thickness of this layer ranges from 0.25 to 1 m. The original color is considered to be gray.

Layer5 is the oldest unit and consists of light brown to yellow clay, with the minority of iron-stained patches. The layer shows 2 cycles of graded-bedding sediments. The thickness varies from 1 to 1.5 m. This Plietocence unit is quite shallow and has a gentle slope surface.

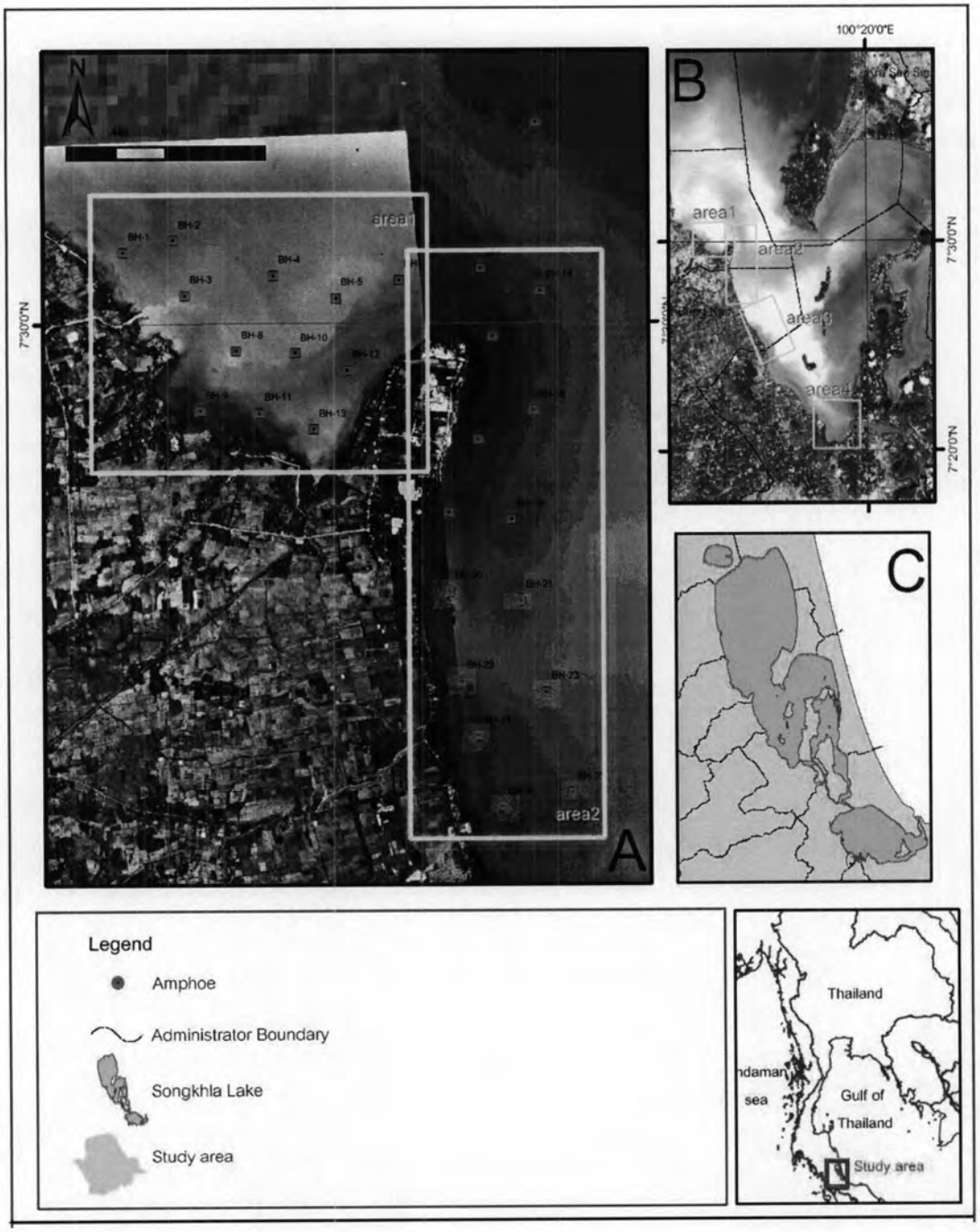


Figure 4.4 Aerial photos (A) showing physiography of the coastal area and location of drillholes in Area 1 and Area 2 of the SKL study area (C), Southern Thailand.

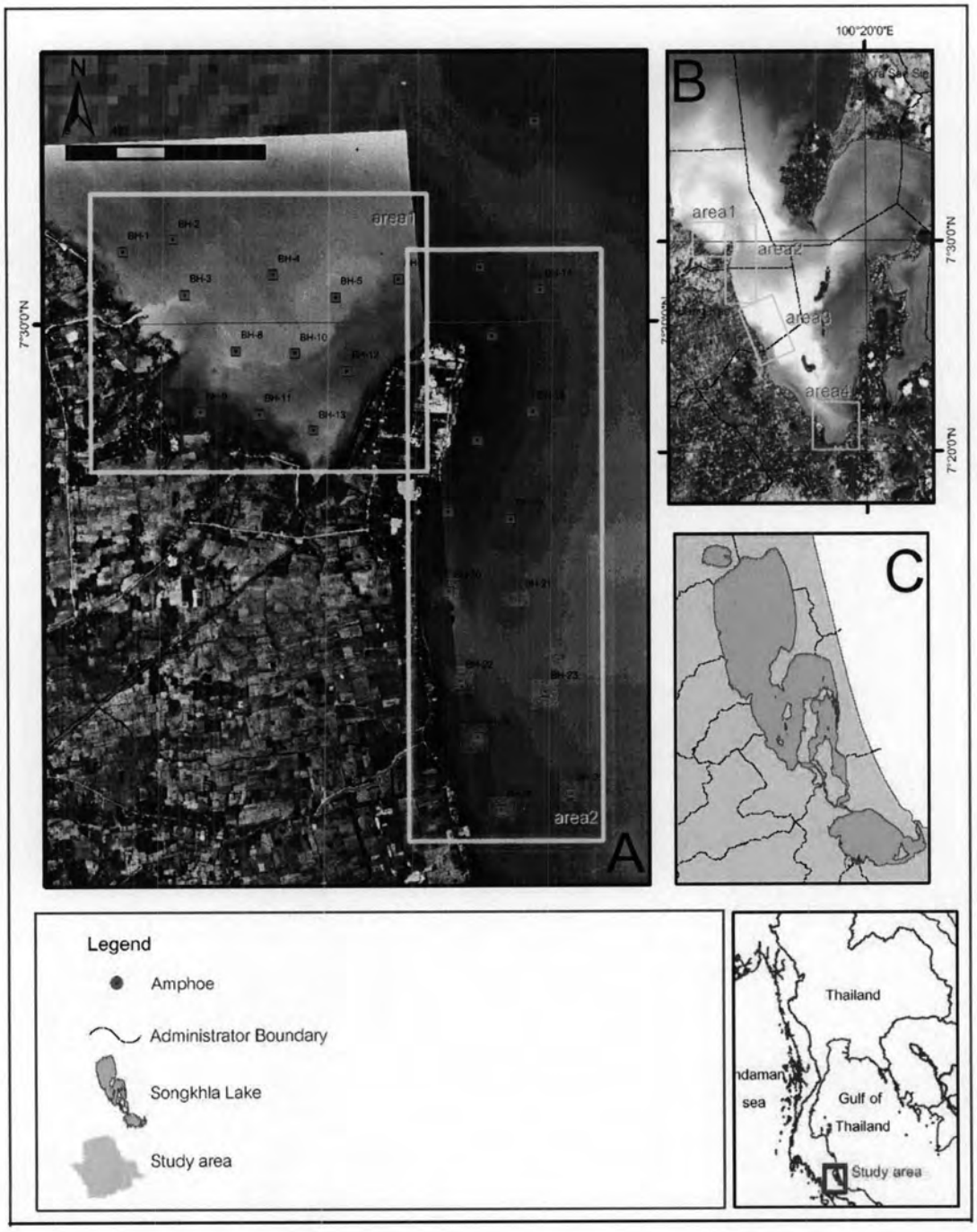


Figure 4.5 Aerial photos (A) showing physiography of the coastal area and location of drillholes in Area 1 and Area 2 of the SKL study area (C), Southern Thailand.

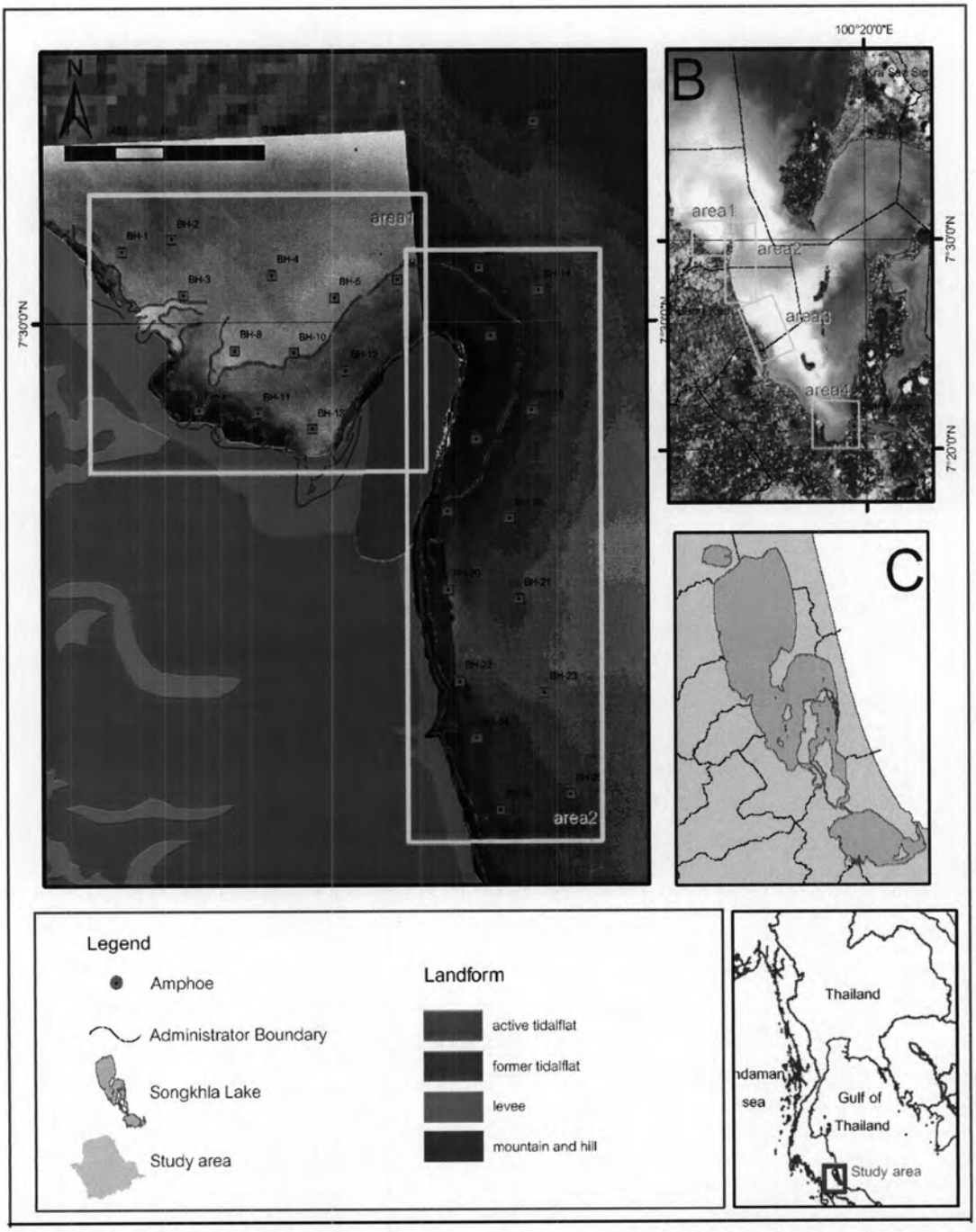


Figure 4.6 Interpretation map (A) from aerial photos (Figure 4.4) showing major landforms of the coastal area nearly Area 1 and Area 2 (B) of the SKL study area (C), Southern Thailand, also shown location of drillholes.

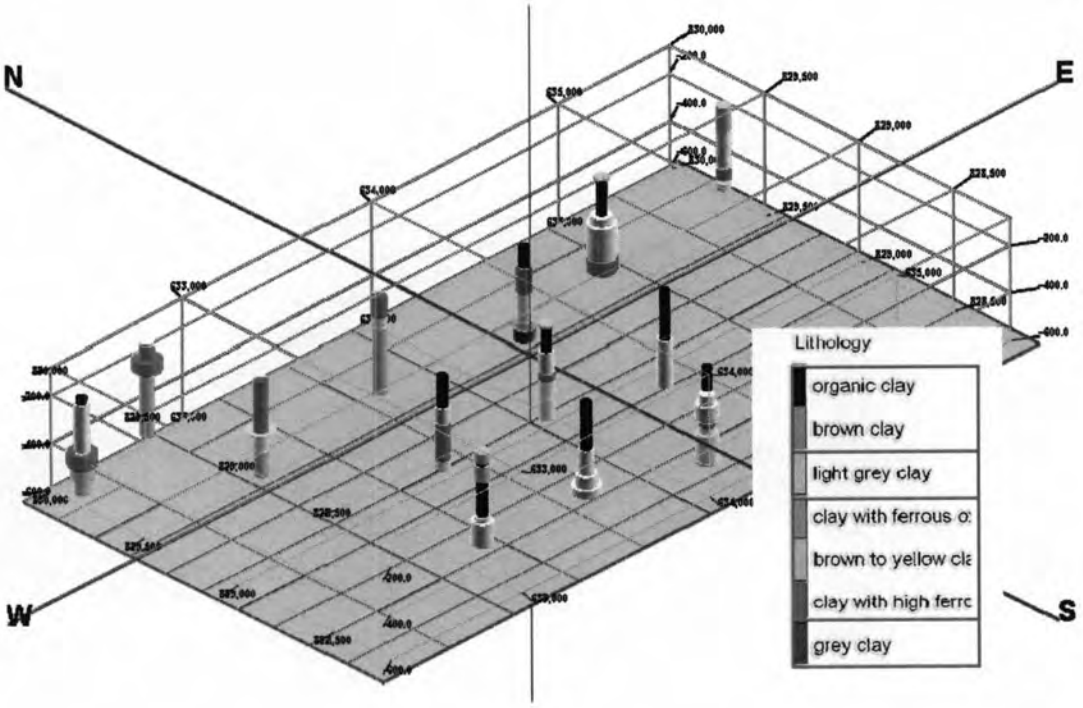


Figure 4.7 Stratigraphic logs showing lithology of the drill holes in Area 1 of the SKL study area.

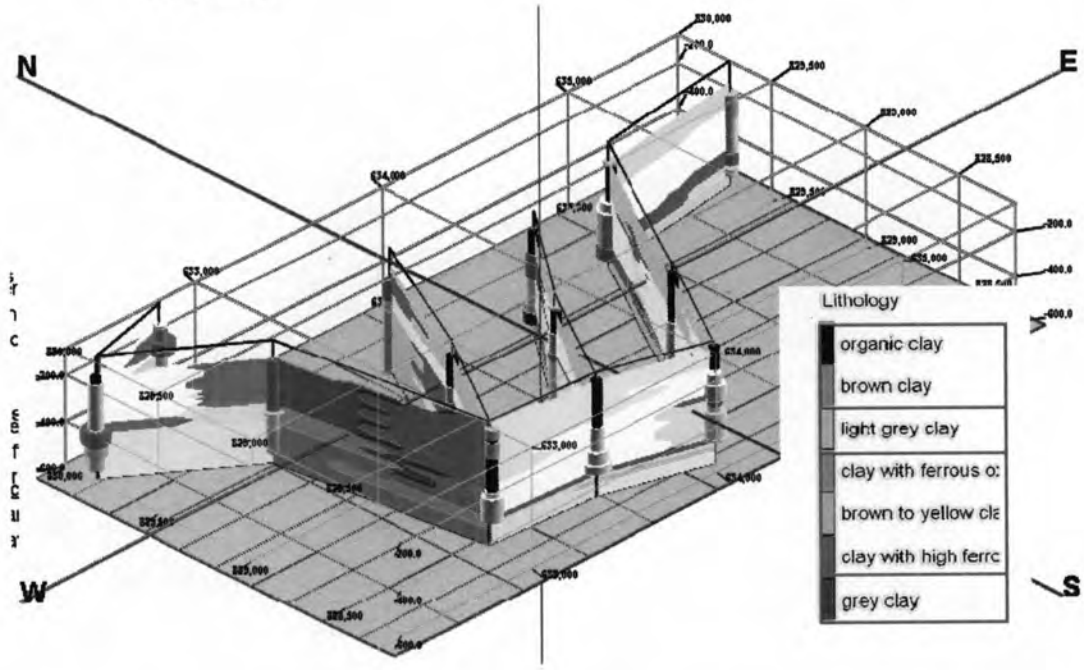


Figure 4.8 Fence diagram interpreted form Stratigraphic correlation in Figure 4.11 in Area 1 of the SKL study area.

4.1.2 Area 2: Khlong Khop Khang (see Figure 4.4 and 4.6)

Five sedimentary layers can be identified from the drill holes of the area 2. Stratigraphic logs and fence diagram are shown in figure 4.9 and 4.10, respectively. Two upper layers (layer 1 and 2) belong to layers deposited in the Holocene epoch, the third layers (layer 3) becomes the transition zone between the Holocene and Pleistocene times. Two lower layers belong to non-marine layer deposited in the Pleistocene time.

Layer 1 is characterized by brown to light brown clay containing high organic content. The thickness of the unit 1 varies from 20 to 50 cm. This unit is equivalent to layer 2 of area 1.

Layer 2 consists largely of greenish to light gray clay with widely distributed ferricretes and sand lenses (1-2 cm) mainly in the lower.
The thickness varies considerably from 0.5 to 2 cm. this unit is equivalent to layer 3 of area 1.

Layer 3 comprises mainly deep red to purplish red with high ferris oxide and few sand lenses. The thickness ranges from 0.25 to 1 m. this layer is very similar to layer 4 of area 1.

Layer 4 is chiefly composed of light brown to yellow clay with ferri crete more than layer 3. This layer contains 2 cycles of graded bedding, and can be correlated with the layer 5 of area1.

Layer 5, the oldest unit, is greenish similar to the layer 2 (greenish gray clay). But this layer contains more abundant ferricrest and become harder or more consolidated than the layer 2. The layers also contain sand in the higher percentages than unit 2. The thickness varies from 0.5 to 1 m.

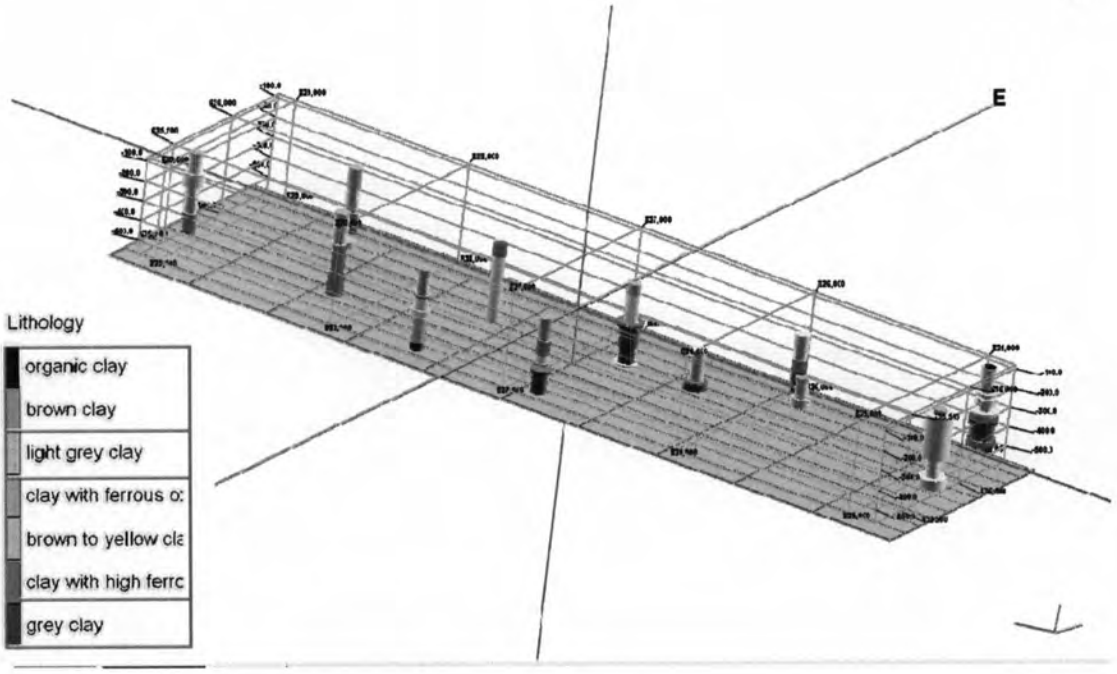


Figure 4.9 Stratigraphic logs showing lithology of the drill holes in Area 1 of the SKL study area.

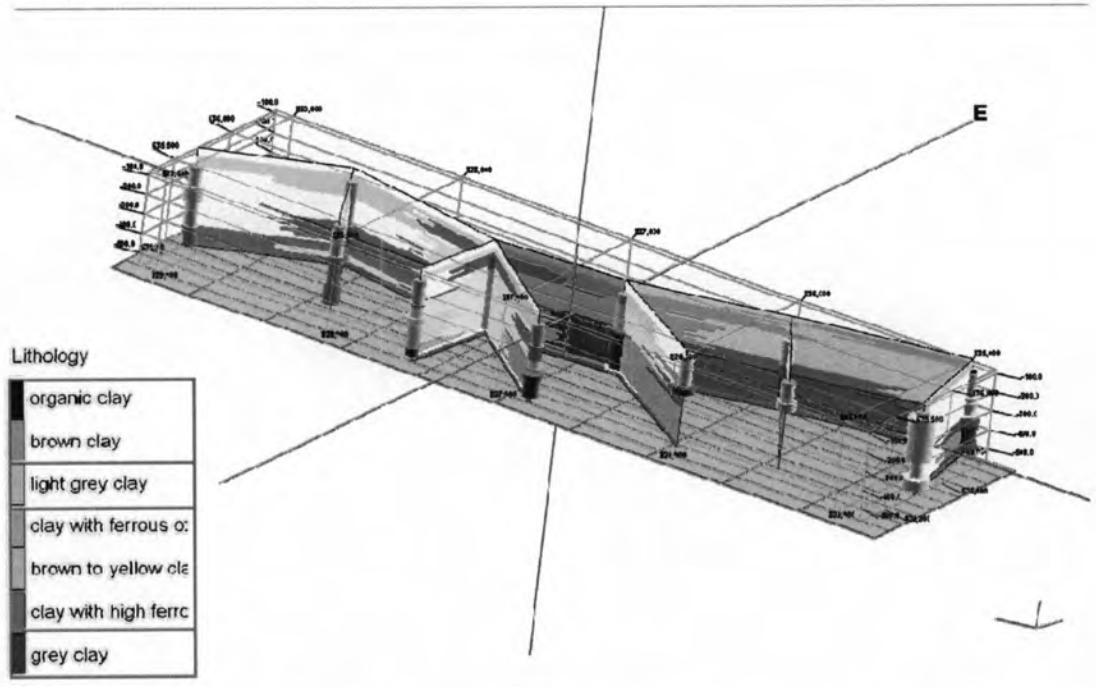


Figure 4.10 Fence diagram interpreted form Stratigraphic correlation in Figure 4.11 in Area 1 of the SKL study area.

4.1.3 Area 3: Khlong Ok (see Figure 4.11, 4.12, and 4.13)

Only three well defined layers are identified from drill holes of area 3. These layers show simple forms with obvious vertical graded beds. All layers are interpreted to have deposited in the Holocene epoch. Stratigraphic logs and fence diagram are shown in Figure 4.14 and 4.15.

Layer 1 which is the youngest layer consists of brown to light brown clay with high content of organic matter. This layer was found in only drill hole, and it has a thickness of about 20 cm.

Layer 2 is characterized by light to greenish gray clay with sparsely distributed ferricrete and sand lenses (1-2 cm). The layer denstes distinct vertical graded beds. The thickness varied considerably from 0.5 to 3.5 m.

Layer 3 is light brown to yellow clay layer showing 2-3 cycles of vertical graded from sand at the bottom and clay at the top. Iron-stained patches vary in amount from 10 to 20% of the total volume.

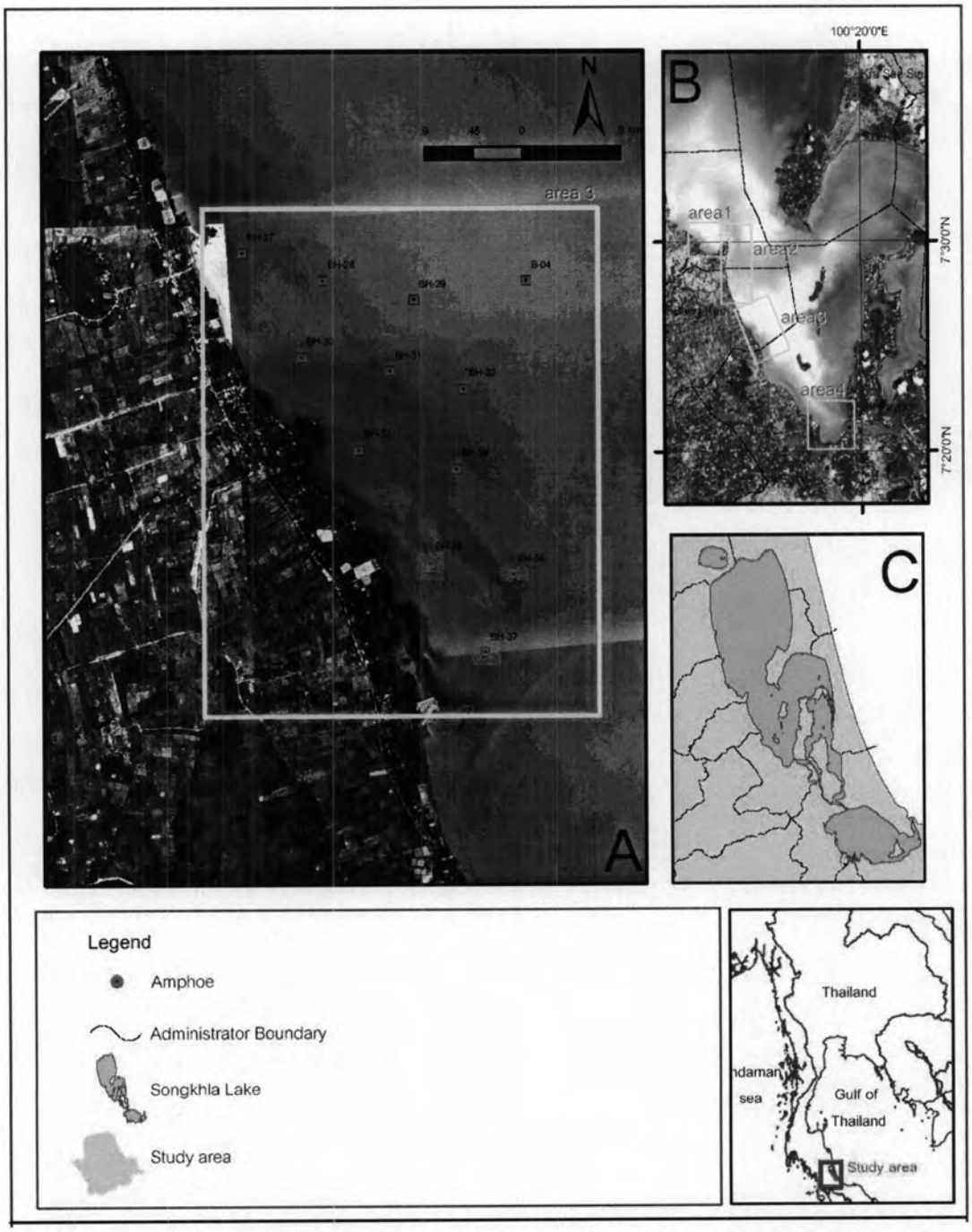


Figure 4.11 Aerial photos (A) showing physiography of the coastal area and location of drillholes in Area 3 of the SKL study area (C), Southern Thailand.

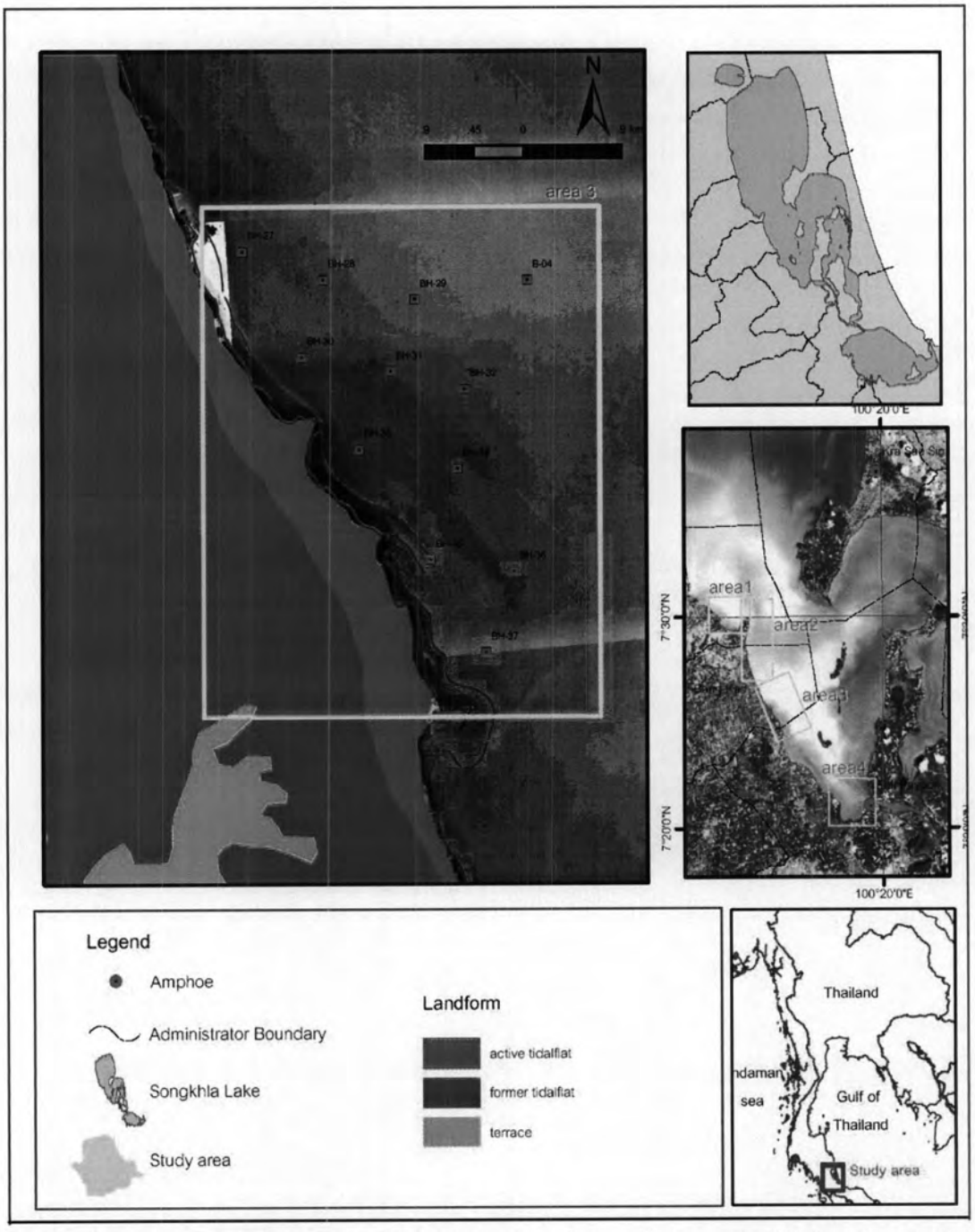


Figure 4.12 Interpretation map (A) from aerial photos (Figure 4.11) showing major landforms of the coastal area nearby Area 3 (B) of the SKL study area (C), Southern Thailand (D). Also shown location of drillholes.

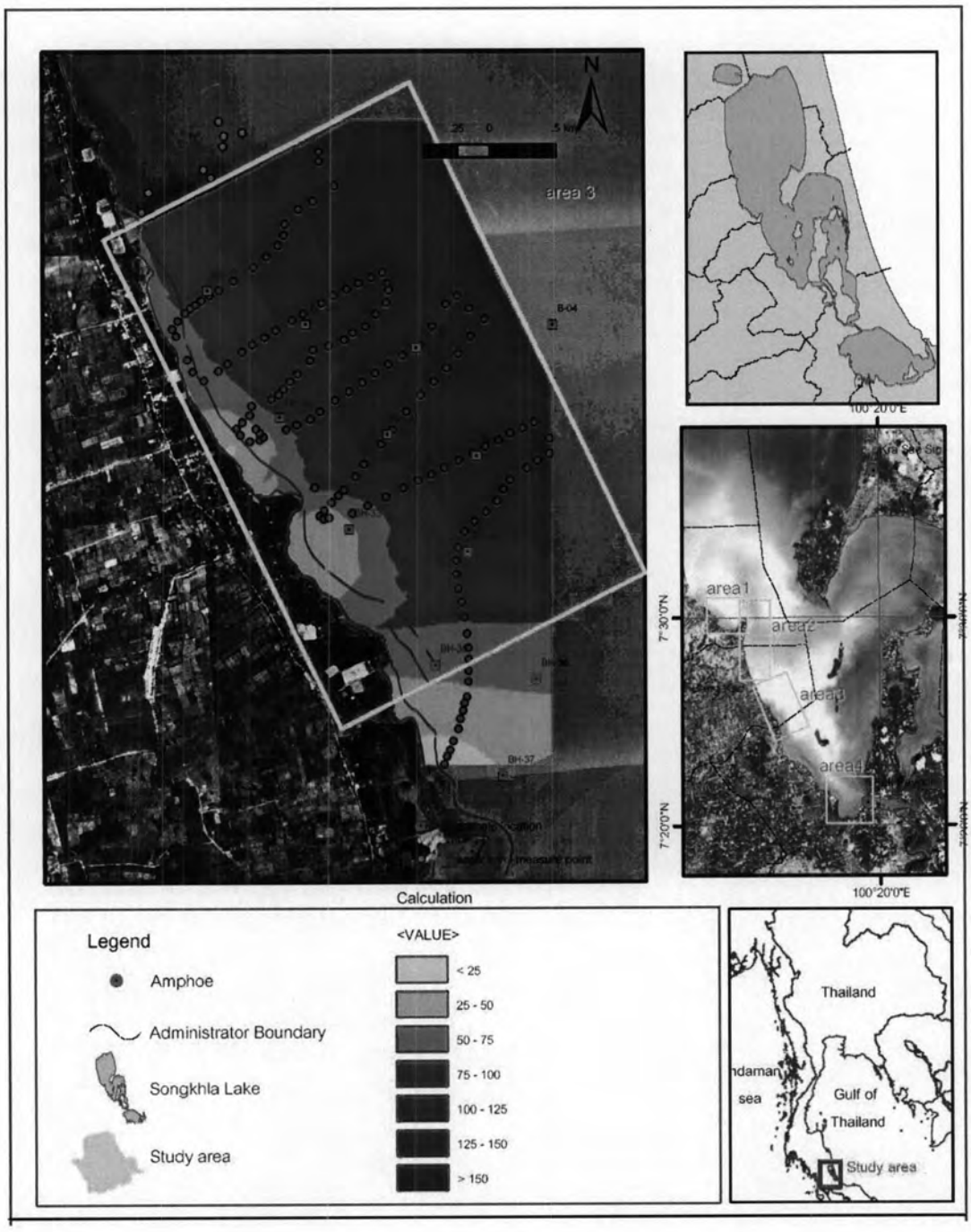


Figure 4.13 Aerial photos with drillhole locations and water level measuring sites in Area 3 (B) of the SKL study area.

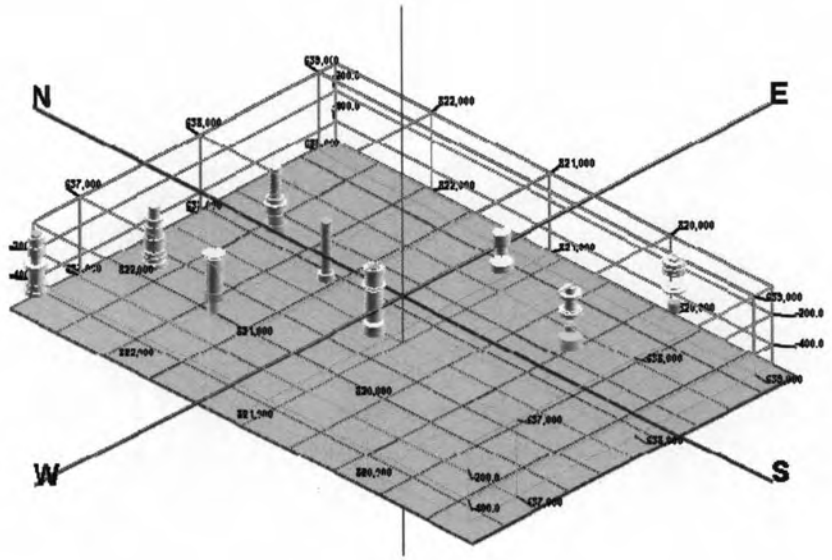


Figure 4.14 Stratigraphic logs showing lithology of the drill holes in Area 3 of the SKL study area.

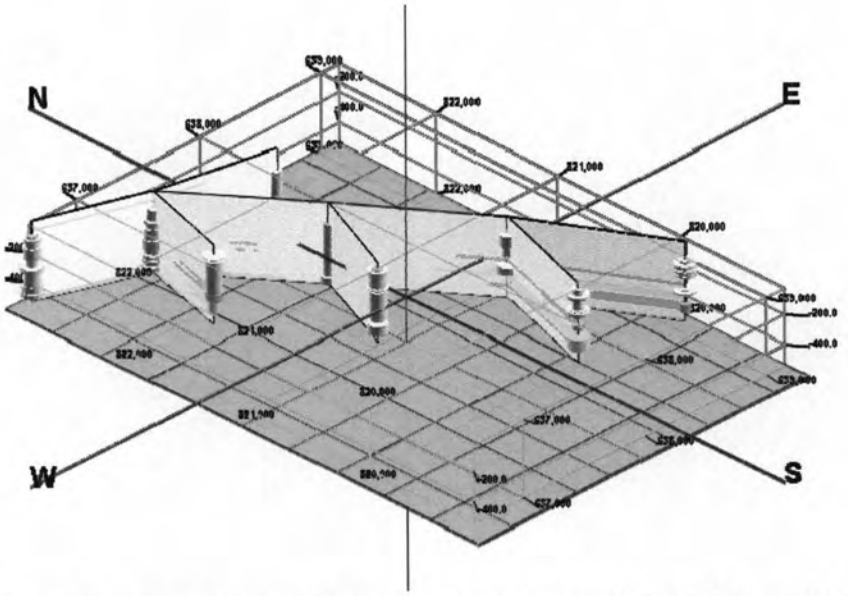


Figure 4.15 Fence diagram interpreted form Stratigraphic correlation in Figure 4.14 in Area 3 of the SKL study area.

4.1.4 Area 4: Ao Bang Teng (see Figure 4.17, 4.18, and 4.19)

Based on the remote-sensing and drill-hole data, it is clear that among the SKL sub-study area 1 to 4, the area 4 is the layers river mouth-the Pak Prayoon Mouth. Area 4 contains largely greenish gray clay. In comparison with the other area, the area 4 contains both the marine and non-marine clay and the age of deposition is within the Holocene epoch. Area 4 contains three distinct sediment layers.

Layer 1 consists predominantly of black to dark brown organic clay with abundant wood fragments. The thickness varies considerably from 0.25 to 2 m.

Layer 2 is the brown to light brown clay unit containing organic-rich component. However at some depth, it is intercalated with organic clay. The layer has the limited thickness of 0.2 to 0.5 m.

Layer 3 is composed chiefly of greenish to light gray clay to sandy clay with few ferricrete and sand lenses (1-2 cm thick) at the lower part. The thickness ranges considerably from 0.5 to 3 m.

4.2 Rate of sediment deposition

As shown in Table 4.1, Thermoluminesecence (TL) age dating result indicate that all the ages are within the Holocene times.

Age of sediment (6 samples) range from 3,400 to 15,400 year ago in Area1; about 1 sample 50,000 year ago in Area 2, about 10 samples from with the age range of 19,600 to 33,600 year ago, and about 10 samples from Area 4 with the age vibration of 20,500 to 56,900 years ago.

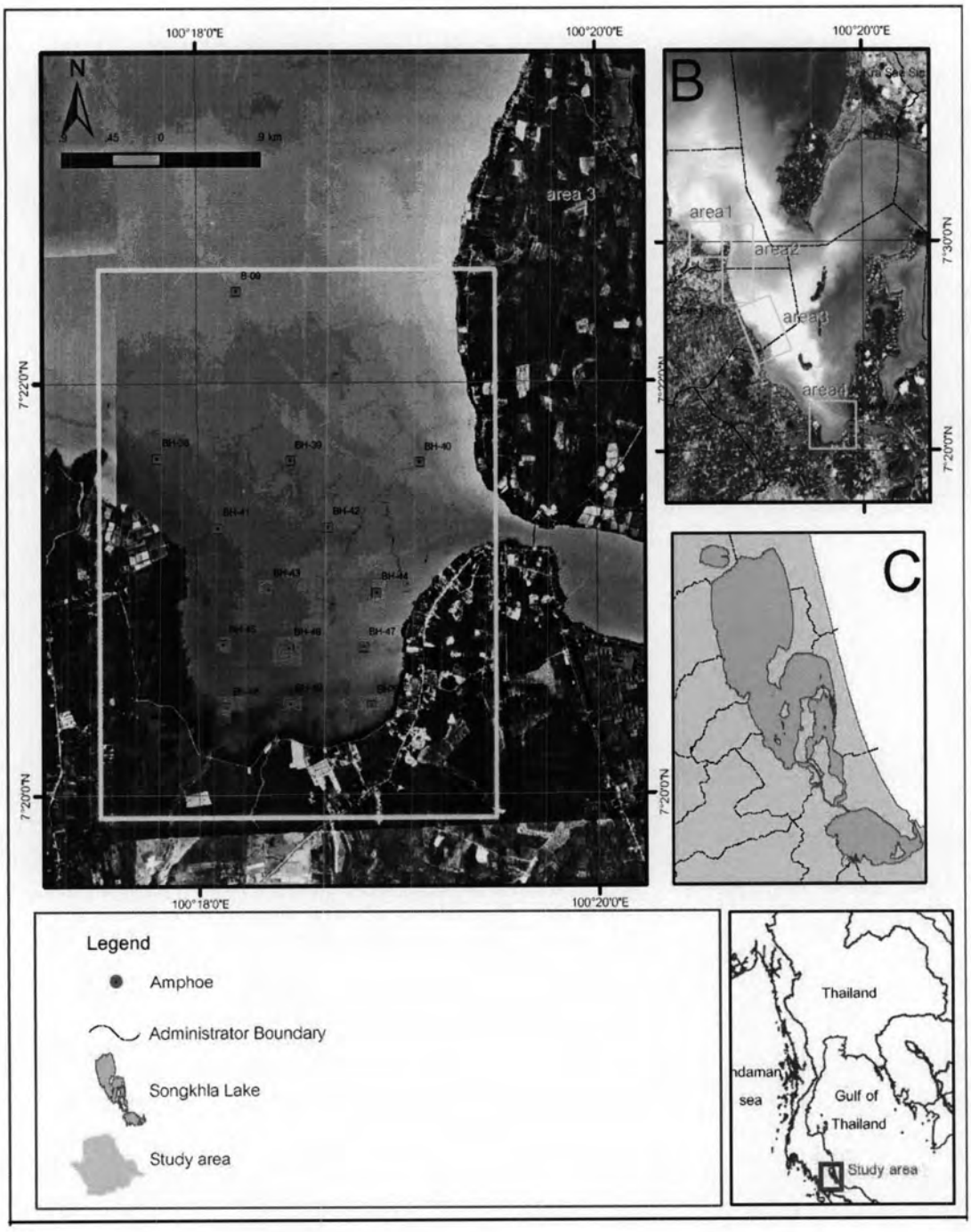


Figure 4.16 Aerial photos (A) showing physiography of the coastal area and location of drillholes in Area 4 of the SKL study area (C), Southern Thailand.

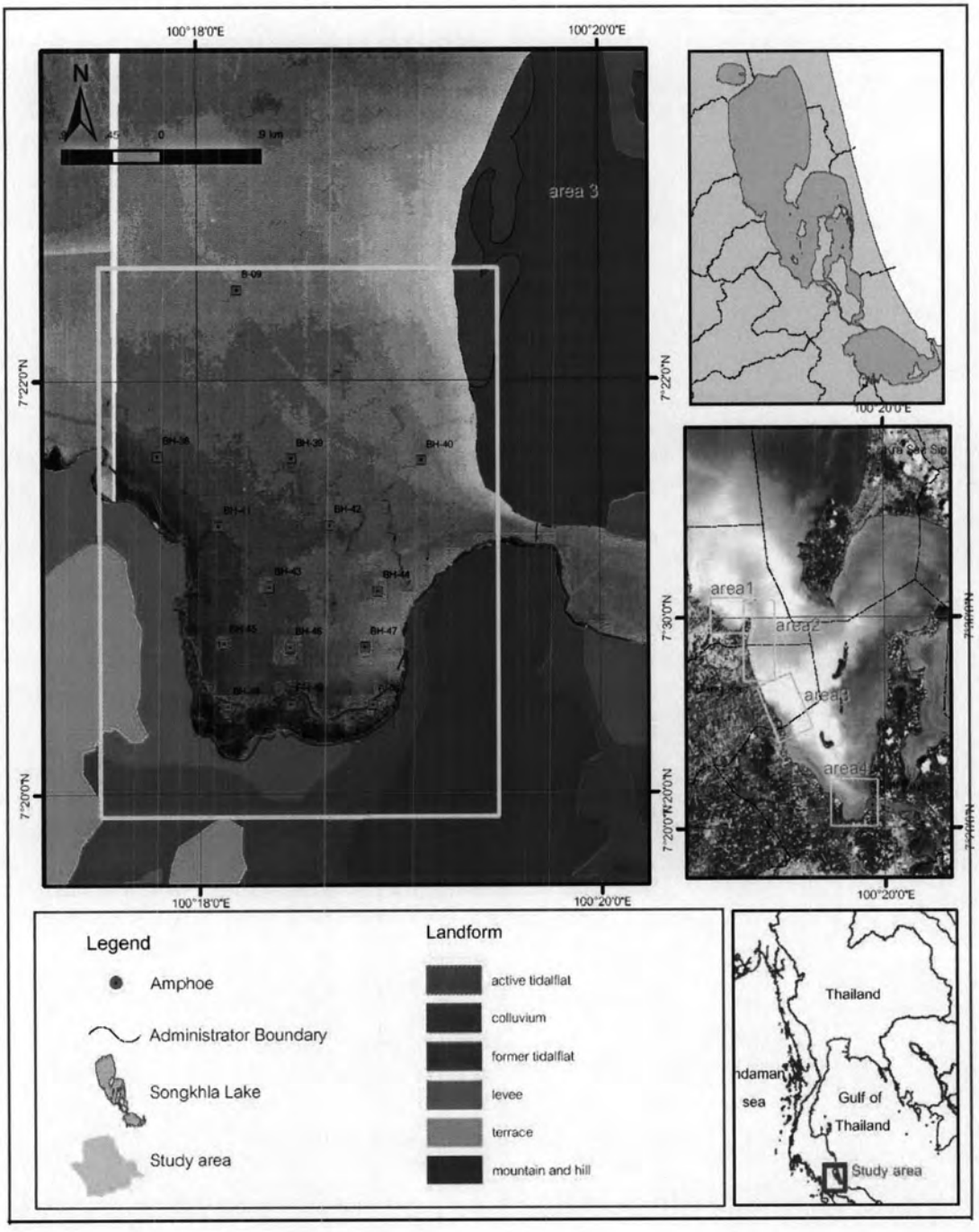


Figure 4.17 Interpretation map (A) from aerial photos (Figure 4.16) showing major landforms of the coastal area nearby Area 4 (B) of the SKL study area (C), Southern Thailand (D). Also shown location of drillholes.

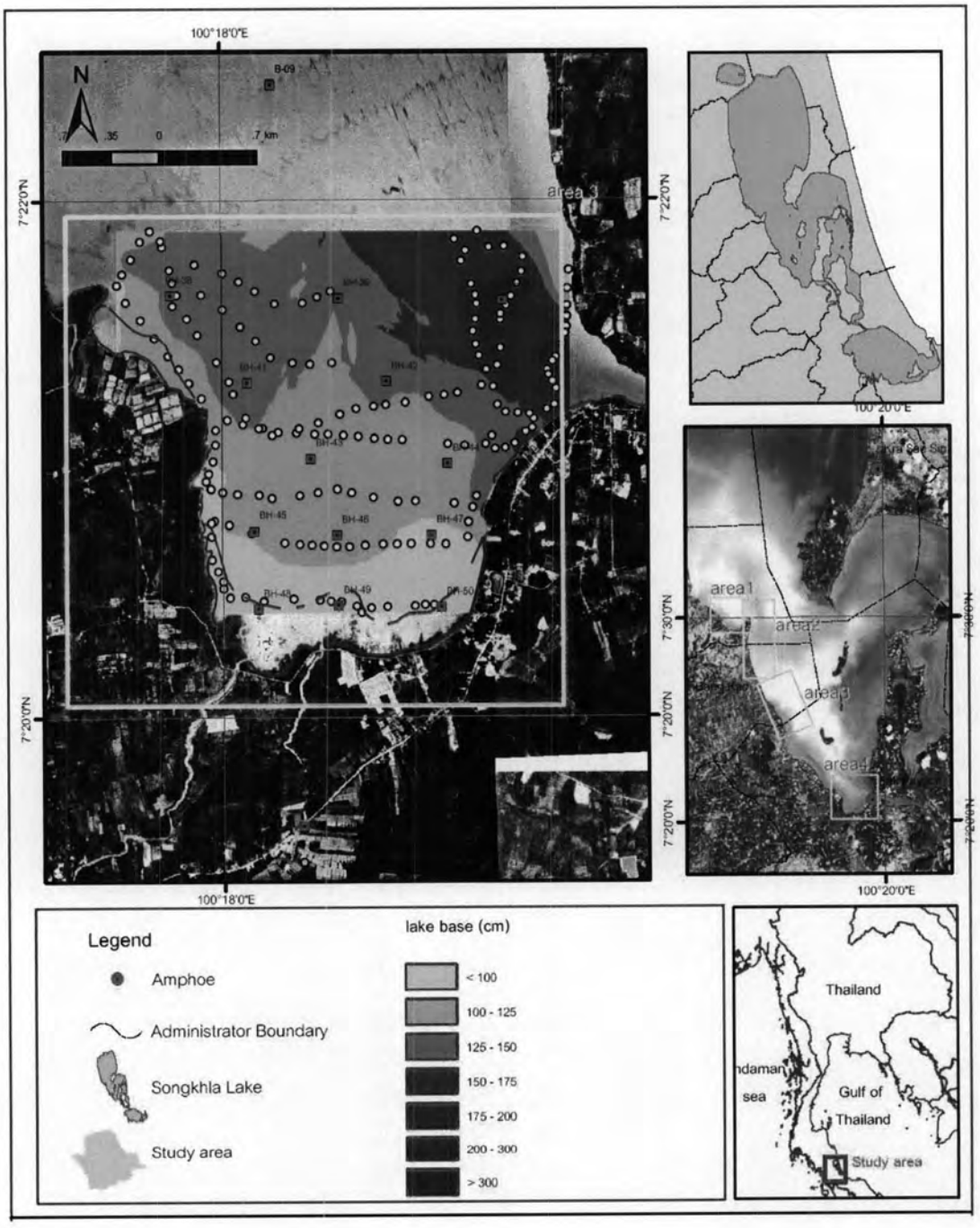


Figure 4.18 Aerial photos with drillhole locations and water level measuring sites in Area 4 (B) of the SKL study area.

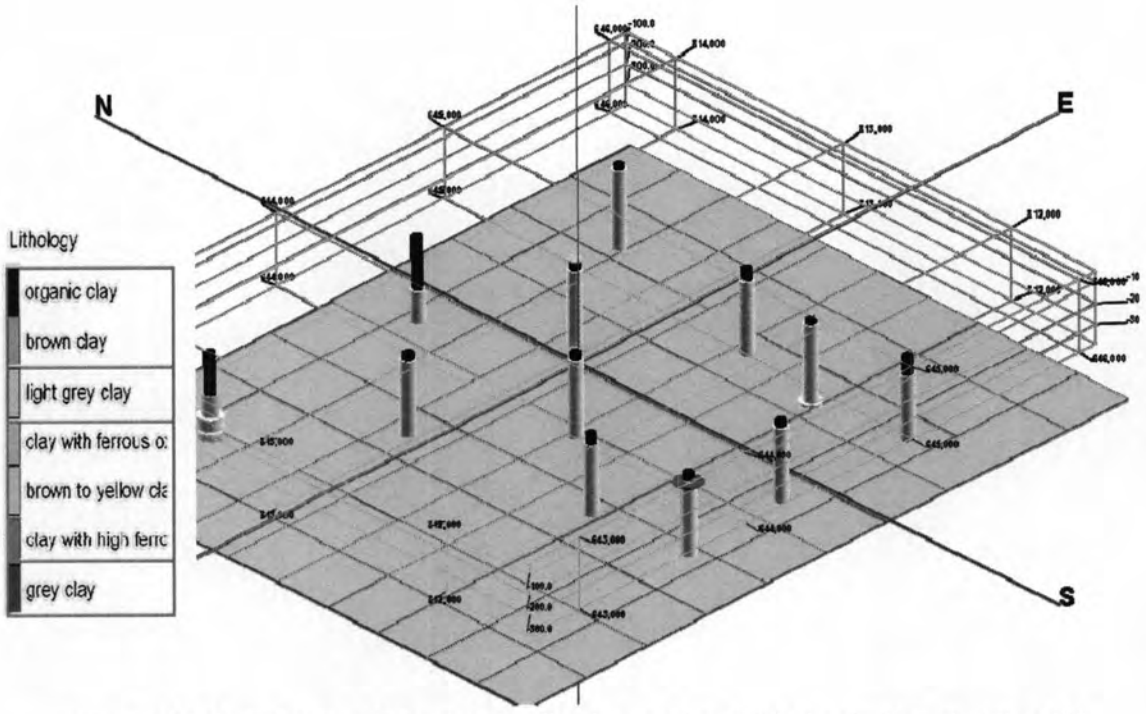


Figure 4.19 Stratigraphic logs showing lithology of the drill holes in Area 4 of the SKL study area.

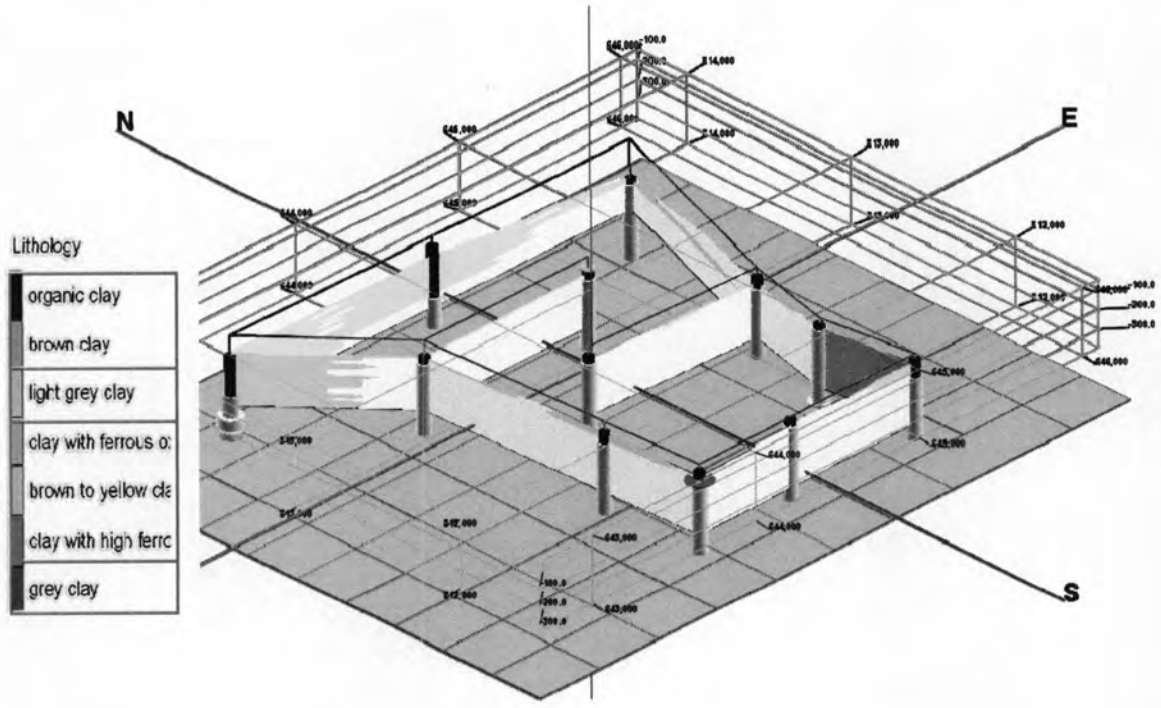


Figure 4.20 Fence diagram interpreted form Stratigraphic correlation in Figure 4.20 in Area 4 of the SKL study area.

Based on these TL geochronological results, it is likely that the ages of individual layers are shown below

A. Organic-clay layer is about recent to 3,400 years ago;

B. Brown-clay layer is about recent to 3,400 years ago;

C. Greenish to light gray clay layer is about 3.400 to 9,000 years ago;

D. Red to pinkish gray clay layers is about 9,000 to 19,000 years ago;

E. Light brown to yellow clay layer is about 19,000 to 37,500 years ago;

F. Greenish gray clay (semi-consolidated) layer is more than 37,000 years ago.

Rate of deposition is estimated from the integrated result of the stratigraphic logs, frence diagrams, and TL dating data.

Summarized data for rate of sedimentation are concluded in Table 4.2. It can be separated into two ages as Holocene and Pleistocene sediments, the dated Holocene sediments are located in B-01 and BH-12 in area 1. The sedimentation rated are about 0.07 and 0.14 in drillhole no. B-01 and BH-21, respectively.

In the another way, the sedimentation rate is can be calculated from TL-dating data correlation from 2 drillholes.

As shown in the composite stratigraphy of Figure 4.21 that the Holocene sedimentary sequence has the overall thickness of about 35 cm (from the lake bottom surface). This thickness is confirmed by the use of data sand-rich layer at 310 -330 cm depth with yield the TL age of about ca. 8,830 ± 272 years old for the drill hole B01 (see location in Figure 4.3).

Additionally, this age data is also supported by the other TL date of the other sand-rich lens (located NE of the area1) at the depth of about 140-350 cm from the bottom surface. This layer yield the TL date of about ca. 9,065 ± 155 years from the drill hole no.BH-12 (see location in Figure 4.3)

It is quiet possible that the rate of sedimentation can be estimated by using the average depth sand layer of drill hole B-01 at 320 cm and it average age of about 8,800 years and the average depth of the sand layer of drill hole BH-12 at 345 cm and its average of about 9,600 years.

The difference in ages of about 200 years and in sedimentation of about 25 cm can give rise to the sedimentation rate of about 1.25 mm per year. This rate of deposition is applied for the deposition during early Holocene. However, the other approach is introduced for the calculation of the Holocene average sedimentation in the Songkhla Lake. By using 320 cm and 345 cm for the thickness of the Holocene sedimentary sequences and 8,800 years and 9,000 years for their ages respectively. It is likely that the overall sedimentation rate for the Holocene is about 0.36 to 0.38 mm/year.

From Table 4.2, it can be noted that, the rate ranges in Pleistocene sediment from 0.8 to 1.5 mm/year that the mean is about 0.33 mm/year.

On the other hand, the sedimentation rates were estimated from Cs-dating and bathymetric changes techniques, however it did not work for this study. Cs-dating data from Chittrakarn (1998) are distributed mainly in center part of Songkhla Lake and the sedimentation rates are quite too high. For the problem from bathymetric changes, the accuracy should be low, due to the measurement locations for depth measurement are different from two periods.

Table 4.1 Results of TL-dating in the study area.

Sample no.	Easting	Northing	Calibrated TL age (year)
B01-ST6	632312	829850	5,190+/-415
B01-ST7	632312	829850	8,830+/-872
B02-ST5	632768	829958	13,350+/-2,777
B02-ST7	632768	829958	20,640+/-5,053
BH6-ST3	634831	829596	15,388+/-2,731
BH9-ST4	633012	828422	13,064+/-556
BH12-ST5T	634353	828782	3,407+/-647
BH12-ST5B	634353	828782	9,065+/-155
BH23-ST5	636168	825903	49,878+/-8,537
BH27-ST3	636619	822792	22,454+/-2,668
BH27-ST7	636619	822792	30,557+/-8,856
BH29-ST4	638200	822365	19,705+/-3,914
BH29-ST6	638200	822365	33,426+/-1,755
BH30-ST3	637162	821846	24,137+/2,649
BH30-ST9	637162	821846	37,547+/-1,663
BH31-ST8	637977	821720	28,904+/-4,052
BH34-ST3	638588	820856	19,605+/-1,171
BH34-ST6	638588	820856	33,639+/3,326
BH36-ST3	639106	819922	30,218+/-2,340
BH38-ST9T	643114	813815	47,861+/-13,522
BH38-ST9B	643114	813815	48,093+/-12,240
BH40-ST5	645526	813780	35,914+/-3,280
BH40-ST9	645526	813780	56,922+/-15,750
BH43-ST5	644128	812647	32,023+/-4,939
BH49-ST4	644327	811612	20,489+/-7,685

Table 4.2 Rate of sedimentary deposit in the study area using by TL-dating.

Area	Sample no.	Lithology	Geological age	Age (year)	Average deposition rate (mm/yr)
1	BH12-ST5T	Greenish gray soft sandy clay	Quaternary	3,407+/-647	
1	BH12-ST5B	Greenish gray sandy clay		9,065+/-155	0.071
1	B01-ST6	Light grey soft sandy clay		5,190+/-415	
1	B01-ST7	Grey soft sandy clay		8,830+/-872	0.137
2	B02-ST5	Greenish grey sandy clay	Pleistocene	13,350+/-2,777	
2	B02-ST7	Light grey sandy clay		20,640+/-5,053	0.137
3	BH34-ST3	White soft sand		19,605+/-1,171	
3	BH34-ST6	Light grey sand		33,639+/-3,326	0.11
3	BH29-ST4	Yellow clay		19,705+/-3,914	
3	BH29-ST6	Light grey sand		33,426+/-1,755	0.077
3	BH27-ST3	Light grey clay		22,454+/-2,668	
3	BH27-ST7	Light grey sandy clay		30,557+/-8,856	0.207
3	BH30-ST3	Light grey sandy clay		24,137+/-2,649	
3	BH30-ST9	Light grey sandy clay		37,547+/-1,663	0.211
4	BH38-ST9T	Light grey to yellow soft clay		47,861+/-13,522	
4	BH38-ST9B	Yellow soft sand		48,093+/-12,240	1.509
4	BH40-ST5	Light grey stiff sandy clay		35,914+/-3,280	
4	BH40-ST9	Pinkish grey clay		56,922+/-15,750	0.1

4.3 Heavy Metal Distribution

The geochemical data of sediment from selected drill-cores samples were provided by Department of Mineral Resource (2006). Drill hole numbers and their locations are shown in Figure 4.3. The selected data are shown in Table 4.2 and 4.3 and only some selected elements with high concentration, including As, Cr, Cu, Ni, Pb, and Zi were used for analyses.

Arsenic element varies in concentration from 3 to 63 ppm and has the average value of 12.8 ppm in Area 1. In Area 2 it ranges from 3 to 12 ppm with the average concentration of 6.22 ppm. In Area 3 it ranges from 3 to 57 ppm with the average concentration of 10.64 ppm that is the maximum concentration in whole four areas. In Area 4 it ranges from 3 to 16 ppm with the average concentration of 8.7 ppm. The arsenic has high concentration in organic clay layer with the average about 17.08 ppm and maximum concentration is about 63.00 ppm in 1.80 to 2.00 m-depth in area 1. The second of high average concentration is in light brown, light grey to yellow clay layer (13.60 ppm).

Chromuim element varies in concentration from 5 to 61 ppm and has the average value of 14.00 ppm in Area 1. In Area 2 it ranges from 5 to 33 ppm with the average concentration of 13.22 ppm. In Area 3 it ranges from 3 to 62 ppm with the average concentration of 18.15 ppm that is the maximum concentration in whole four areas. In Area 4 it ranges from 8 to 27 ppm with the average concentration of 15.42 ppm. The chromium has high concentration in light brown, light grey to yellow clay layer with the average about 21.57 ppm and maximum concentration is about 62.00 ppm in red to pinkish grey clay layer in 3.50-3.65 m-depth in area 3. The second of high average concentration is in (19.00 ppm).

Copper element varies in concentration from 1.80 to 365.00 ppm and has the average value of 42.71 ppm in Area 1. In Area 2 it ranges from 2.10 to 68.30 ppm with

the average concentration of 16.51 ppm. In Area 3 it ranges from 1.10 to 242.00 ppm with the average concentration of 51.87 ppm that is the maximum concentration in whole four areas. In Area 4 it ranges from 2.40 to 70.40 ppm with the average concentration of 15.18 ppm. The copper has high concentration in red to pinkish clay layer with the average about 43.81 ppm and maximum concentration is about 365.00 ppm in 2.35 to 2.50 m-depth in area 1. The second of high average concentration is in light grey to greenish grey clay (semi-consolidate) layer (37.29 ppm).

Lead element varies in concentration from 7 to 73 ppm and has the average value of 32.50 ppm in Area 1 that is the maximum concentration in whole four areas. In Area 2 it ranges from 7 to 67 ppm with the average concentration of 32.50 ppm. In Area 3 it ranges from 4 to 241 ppm with the average concentration of 31.31 ppm. In Area 4 it ranges from 2 to 94 ppm with the average concentration of 28.08 ppm. The lead has high concentration in light grey to greenish grey clay layer with the average about 38.41 ppm and maximum concentration is about 241.00 ppm in 2.50 to 2.60 m-depth in area 3. The second of high average concentration is in organic clay layer (34.69 ppm).

Zinc element varies in concentration from 2.30 to 1,920.00 ppm and has the average value of 94.54 ppm in Area 1 that is the maximum concentration in whole four areas. In Area 2 it ranges from 1.20 to 19.10 ppm with the average concentration of 7.86 ppm. In Area 3 it ranges from 0.60 to 72.20 ppm with the average concentration of 19.60 ppm. In Area 4 it ranges from 1.90 to 44.20 ppm with the average concentration of 18.59 ppm. The zinc has high concentration in light grey to greenish grey clay layer with the average about 86.53 ppm and maximum concentration is about 1,920 ppm in 3.00 to 3.15 m-depth in area 1. The second of high average concentration is in organic clay layer (21.83 ppm).

As shown in Figure 4.29 to 4.33, variation in heavy metal concentrations through depth of drill holes and stratigraphy are shown in Figure 4.29, 4.30, 4.31 and 4.32 for Area 1 and 2. It is interesting noted that arsenic content is quite high in layer 3 which is

3,400 of 9,000 age whereas the other elements such as Cu and Zn shows high concentration in layers 3 and 2, respectively. It is important to note herein that the high elements concentrations in the SKL study area are not derived from the recent Holocene sediments (i.e., within 50 years ago). However, several elements are derived from the depth of about 0.2 to 4.0 m which corresponds to the lower sequence of the Holocene stratigraphy.

It can be recognized that As concentration in Area 1, Cu and Zn concentrations in Area 2, and As, Cu, Ni, and Zn concentrations in Area 4 are significantly upward increasing to the lake bottom surface as displayed in Figure 4.30A, 4.32C, 4.32F, 4.36A, 4.36C. 4.36D, and 4.36F, repectively.

Table 4.3 Statistic of the Heavy metal variation Area 1 to 4.

		As-ppm	Cr-ppm	Cu-ppm	Ni-ppm	Pb-ppm	Zn-ppm
Area 1	Mean	12.81	14.00	42.71	6.62	32.50	94.54
	Max.	63.00	61.00	365.00	33.00	73.00	1920.00
	Min.	3.00	5.00	1.80	2.00	7.00	2.30
	SD	15.62	10.48	83.47	6.97	19.07	373.42
Area 2	Mean	6.22	13.22	16.51	4.22	22.00	7.86
	Max.	12.00	33.00	68.30	15.00	67.00	19.10
	Min.	3.00	5.00	2.10	1.00	7.00	1.20
	SD	3.49	8.60	22.80	5.85	17.92	7.22
Area 3	Mean	10.64	18.15	51.87	6.68	31.31	19.60
	Max.	57.00	62.00	242.00	30.00	241.00	72.20
	Min.	3.00	3.00	1.10	2.00	4.00	0.60
	SD	13.68	17.04	69.60	8.18	43.90	20.93
Area 4	Mean	7.67	15.42	15.18	11.79	28.08	18.59
	Max.	16.00	27.00	70.40	35.00	94.00	44.20
	Min.	3.00	8.00	2.40	1.00	2.00	1.90
	SD	5.02	5.12	21.92	9.78	18.08	14.40

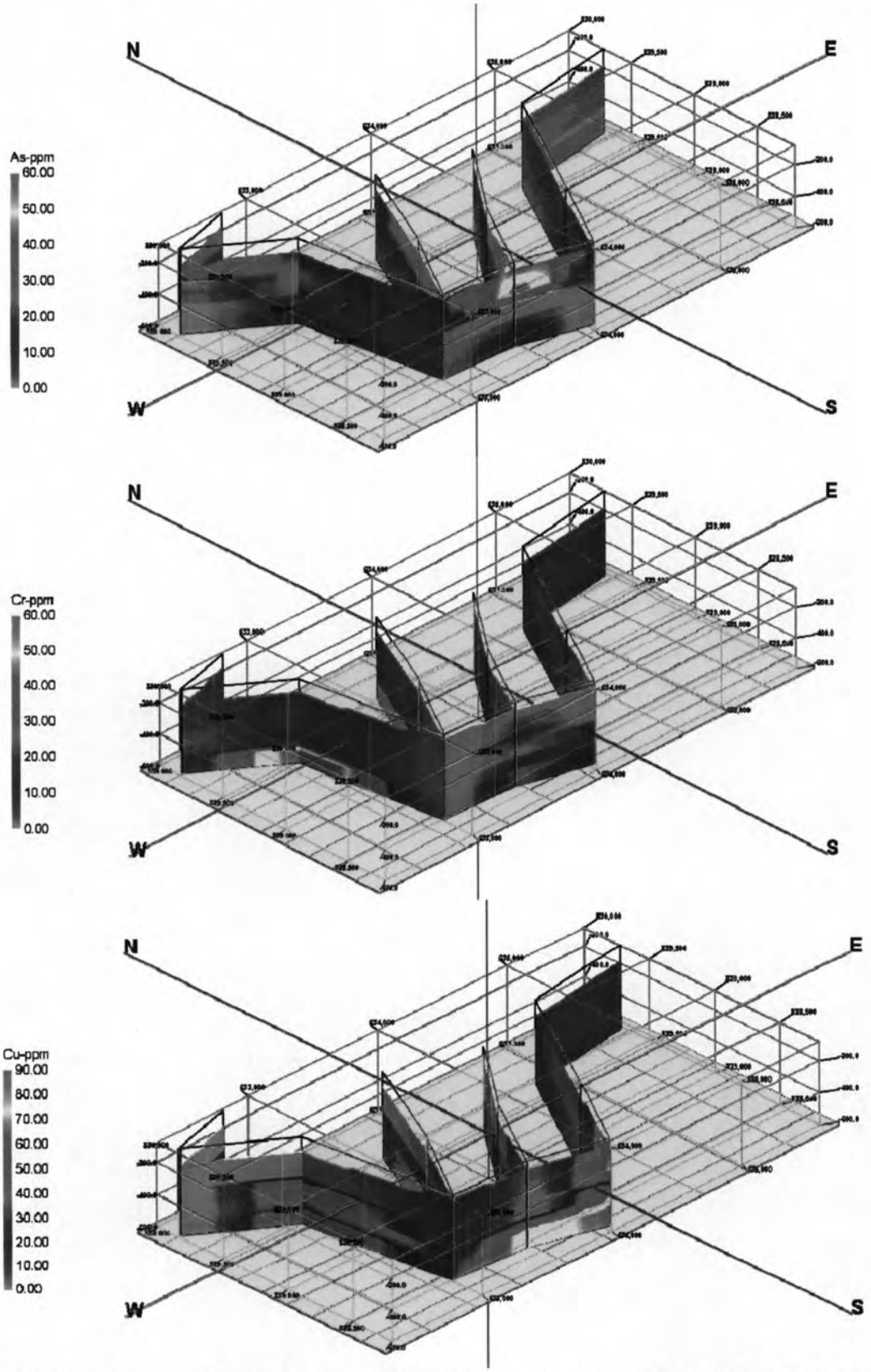
Max. = maximum

Min. = minimum

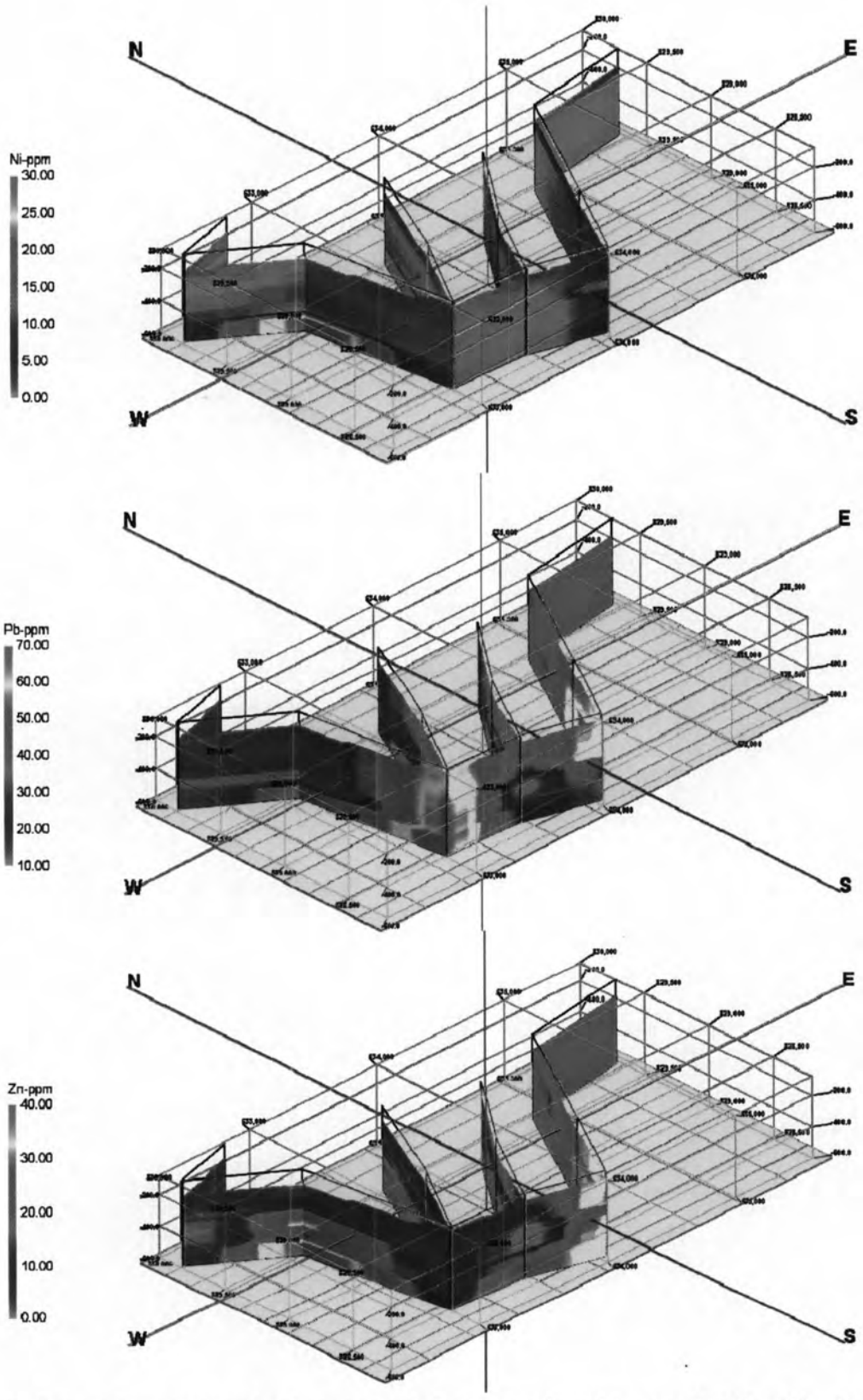
SD = standard deviation

Table 4.4 Statistic of the Heavy metal variation by sedimentary layer.

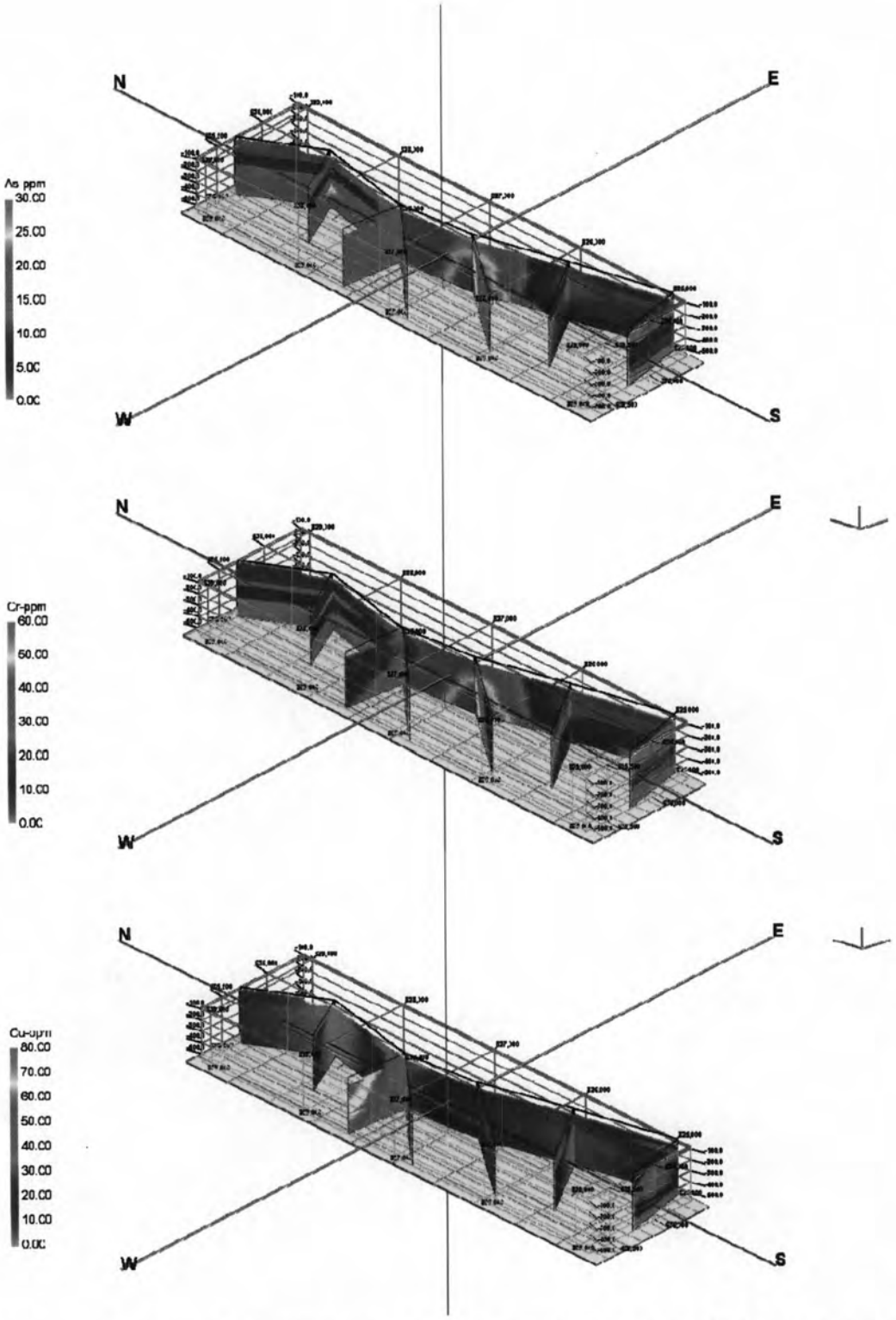
	As-ppm	Cr-ppm	Cu-ppm	Ni-ppm	Pb-ppm	Zn-ppm
Organic clay						
Mean	17.08	12.13	25.29	13.20	34.69	21.83
Max.	63.00	23.00	79.10	35.00	94.00	44.20
Min.	6.00	6.00	3.30	2.00	15.00	5.90
SD	16.40	4.79	28.63	11.67	19.78	13.35
Light grey to greenish grey clay						
Mean	7.59	15.94	37.29	5.70	21.85	13.81
Max.	12.00	62.00	242.00	30.00	67.00	72.20
Min.	3.00	3.00	1.10	1.00	4.00	0.60
SD	2.74	15.51	60.43	7.82	12.26	18.25
Light grey to greenish grey clay						
Mean	12.65	14.56	24.46	6.52	38.41	86.53
Max.	56.00	27.00	242.00	21.00	241.00	1920.00
Min.	4.00	5.00	2.00	1.00	7.00	1.50
SD	12.11	5.24	54.24	4.96	43.36	366.72
Clay with high ferrous oxide						
Mean	10.45	19.00	43.81	7.42	27.08	21.75
Max.	24.00	61.00	365.00	33.00	67.00	146.00
Min.	3.00	7.00	2.40	2.00	14.00	2.80
SD	6.39	15.54	103.83	9.20	14.64	40.79
Light brown, light grey to yellow clay						
Mean	13.60	21.57	32.14	4.71	27.43	20.03
Max.	28.00	55.00	90.40	9.00	66.00	40.20
Min.	5.00	11.00	4.80	2.00	13.00	4.60
SD	9.18	15.04	38.46	2.29	17.43	15.26



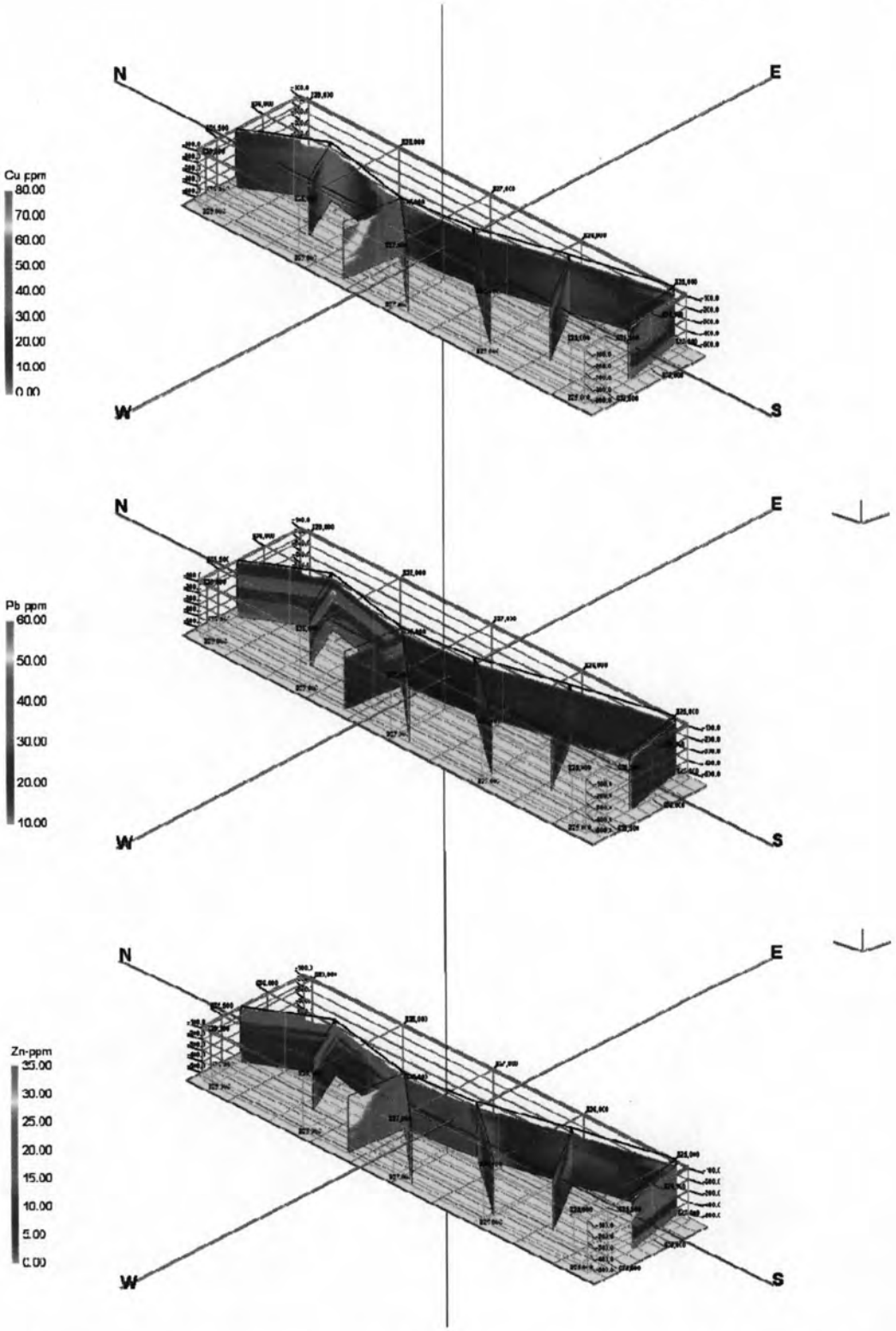
4.22 Fence diagram showing heavy metal distribution (ppm) in area 1 of the SKL study area. A=As, B=Cr, C=Cu, D=Ni, E=Pb, and F=Zn concentrations.



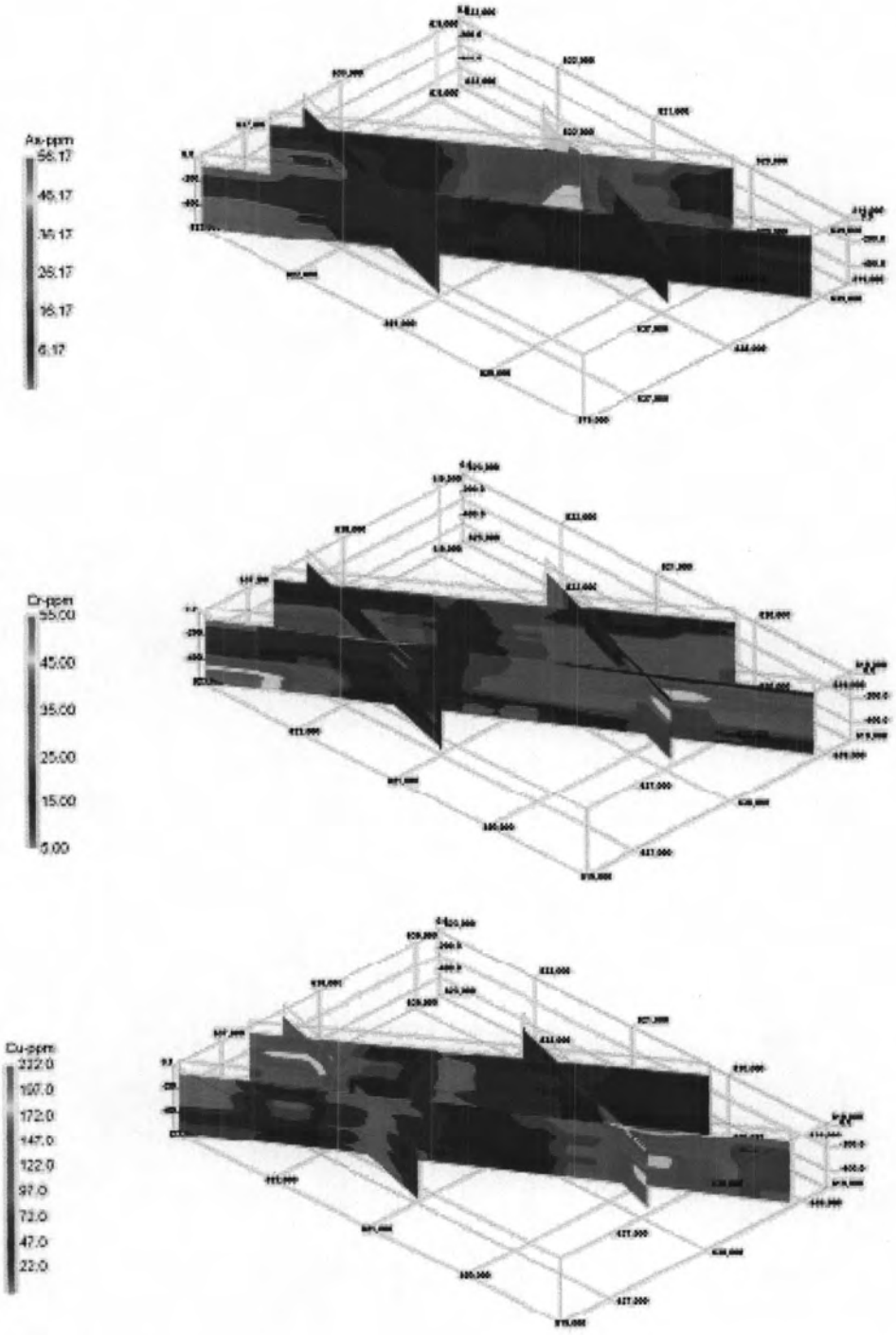
4.22 Fence diagram showing heavy metal distribution (ppm) in area 1 of the SKL study area. A=As, B=Cr, C=Cu, D=Ni, E=Pb, and F=Zn concentrations. (cont.)



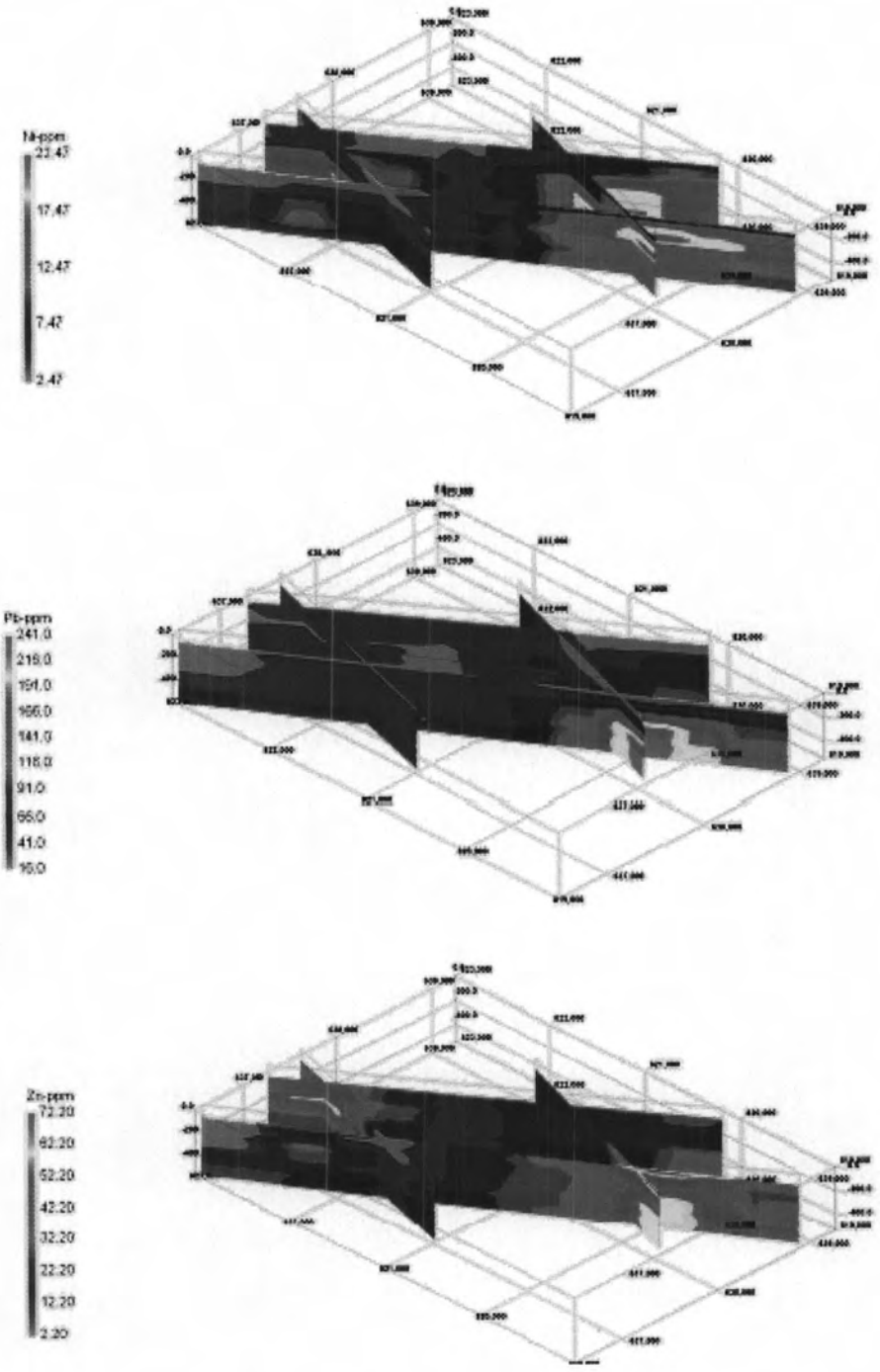
4.23 Fence diagram showing heavy metal distribution (ppm) in Area 2 of the SKL study area. A=As, B=Cr, C=Cu, D=Ni, E=Pb, and F=Zn concentrations.



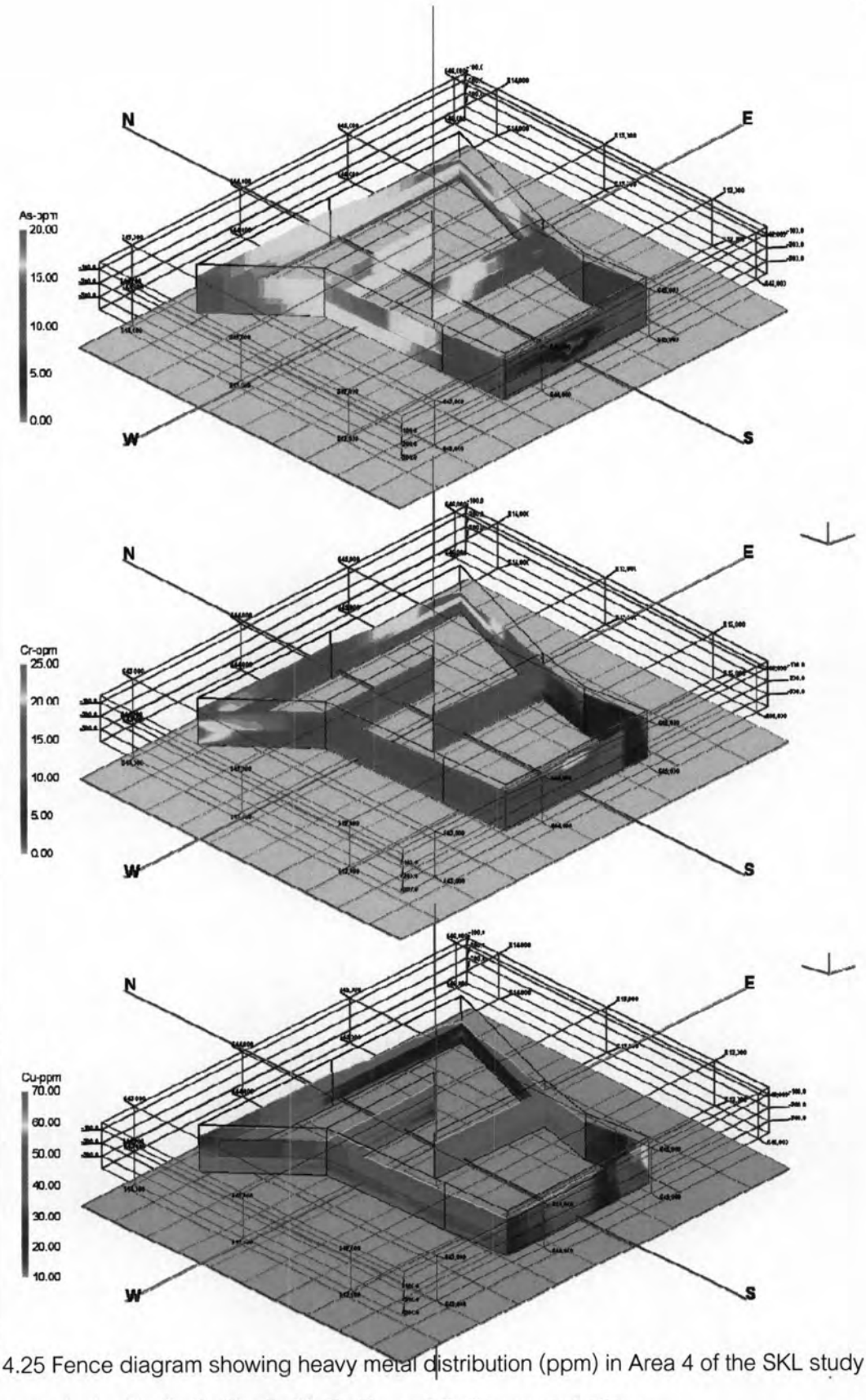
4.23 Fence diagram showing heavy metal distribution (ppm) in Area 2 of the SKL study area. A=As, B=Cr, C=Cu, D=Ni, E=Pb, and F=Zn concentrations. (cont.)



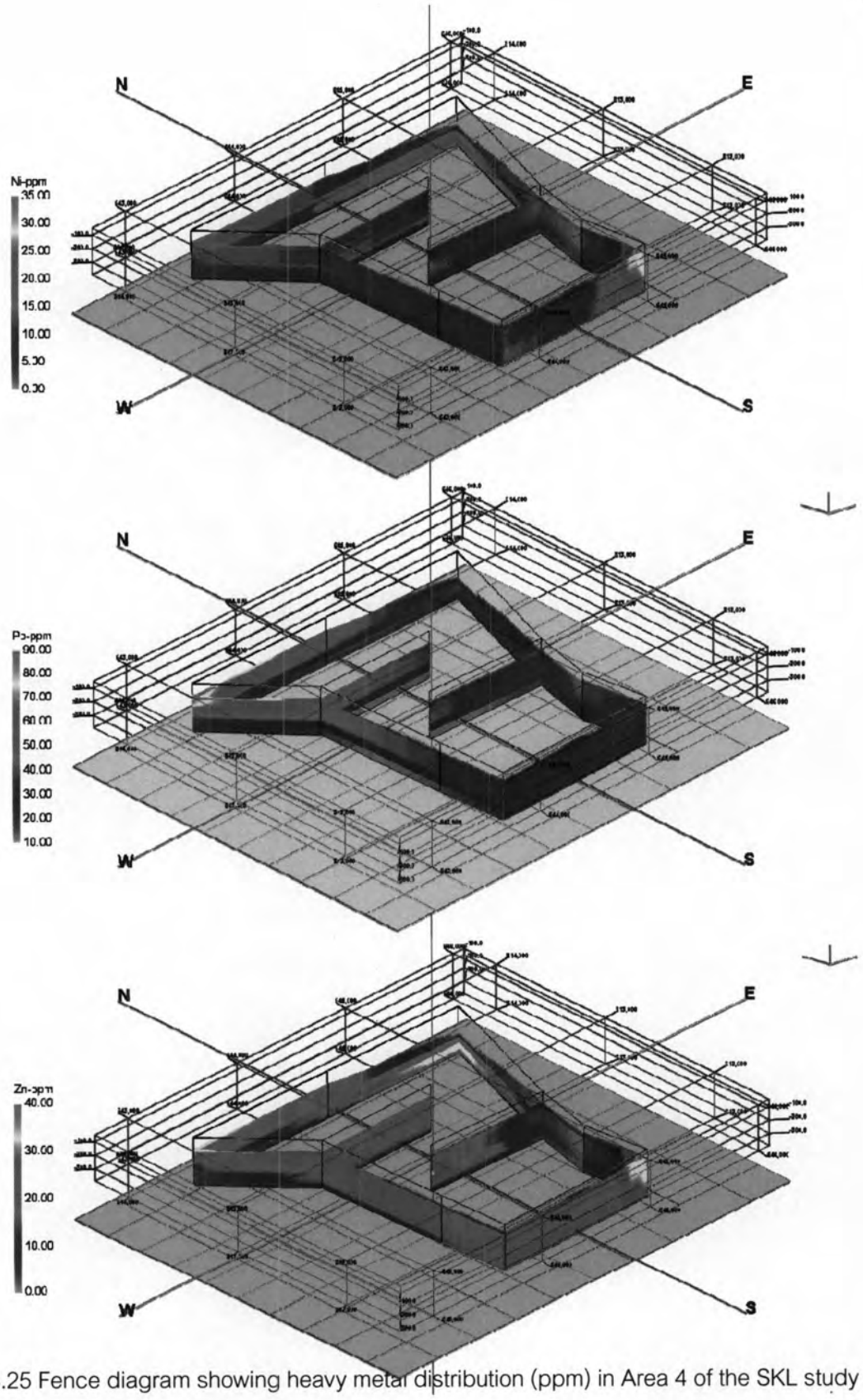
4.24 Fence diagram showing heavy metal distribution (ppm) in Area 3 of the SKL study area. A=As, B=Cr, C=Cu, D=Ni, E=Pb, and F=Zn concentrations.



4.24 Fence diagram showing heavy metal distribution (ppm) in Area 3 of the SKL study area. A=As, B=Cr, C=Cu, D=Ni, E=Pb, and F=Zn concentrations. (cont.)



4.25 Fence diagram showing heavy metal distribution (ppm) in Area 4 of the SKL study area. A=As, B=Cr, C=Cu, D=Ni, E=Pb, and F=Zn concentrations.



4.25 Fence diagram showing heavy metal distribution (ppm) in Area 4 of the SKL study area. A=As, B=Cr, C=Cu, D=Ni, E=Pb, and F=Zn concentrations. (cont.)

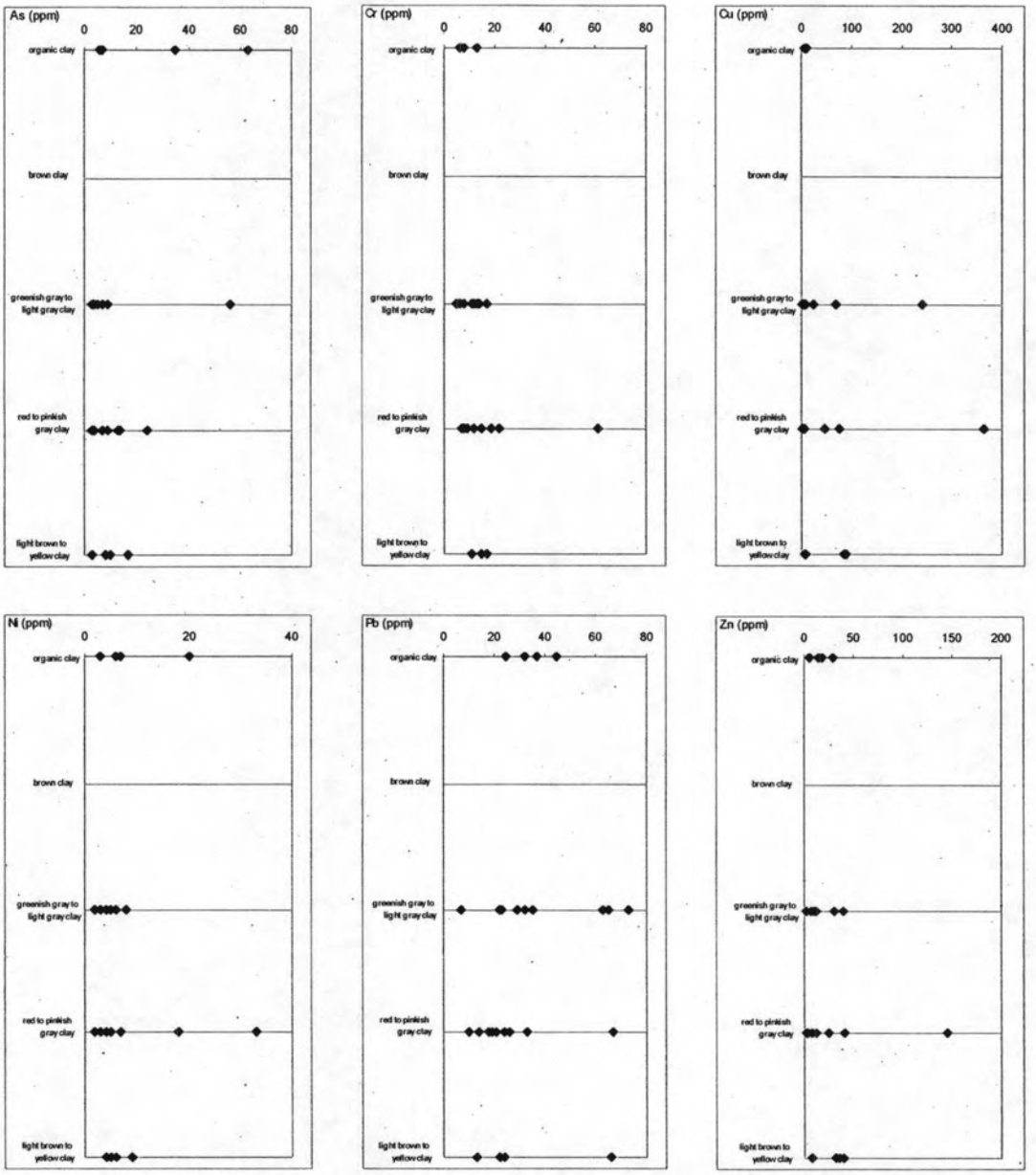


Figure 4.26 Variation of heavy metal concentrations (ppm) in sedimentary layer of Area 1 the SKL study area.

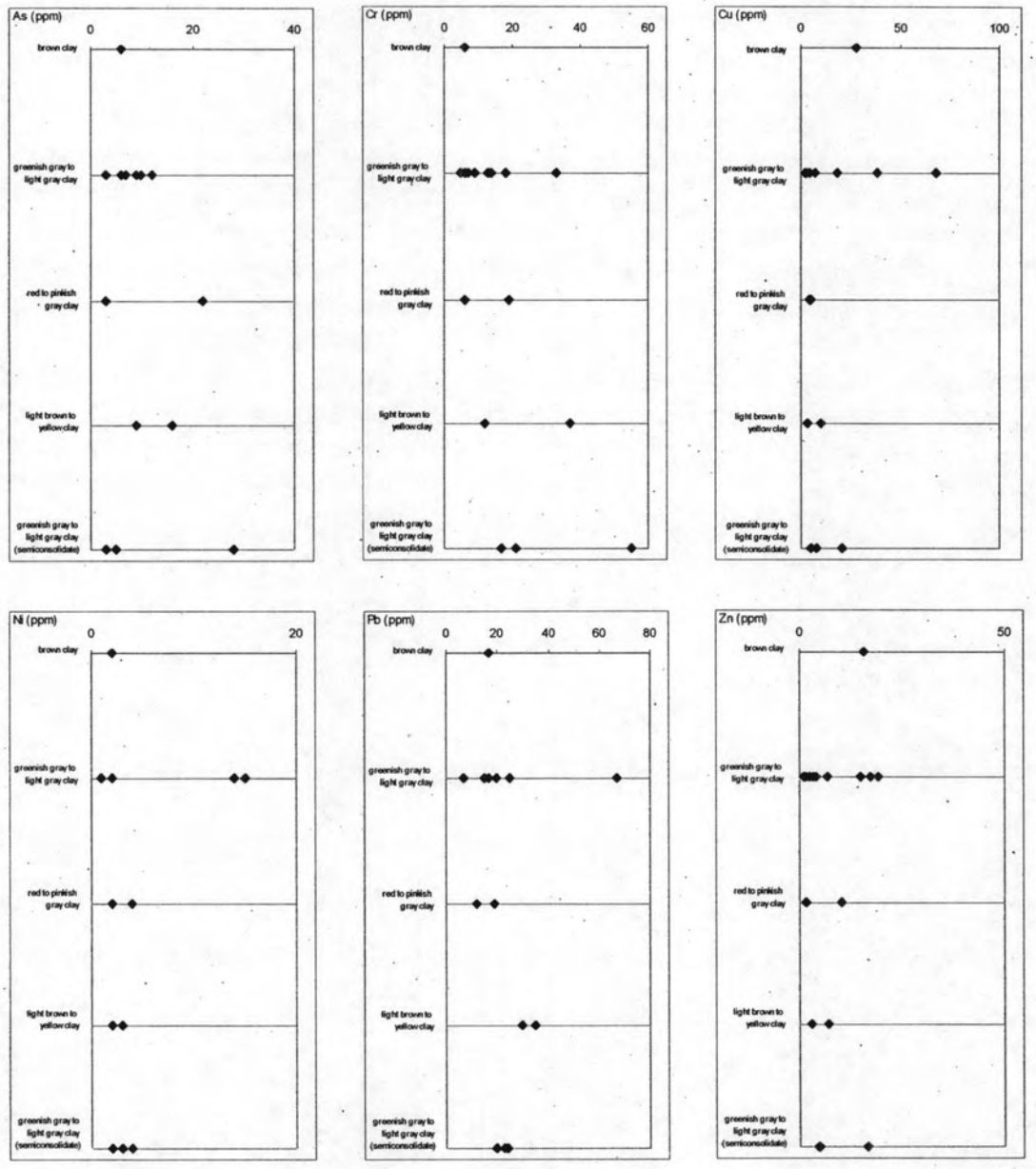


Figure 4.27 Variation of heavy metal concentrations (ppm) in sedimentary layer of Area 2 the SKL study area.

Figure 4.28 Variation of heavy metal concentrations (ppm) in sedimentary layer of Area 3 the SKL study area.

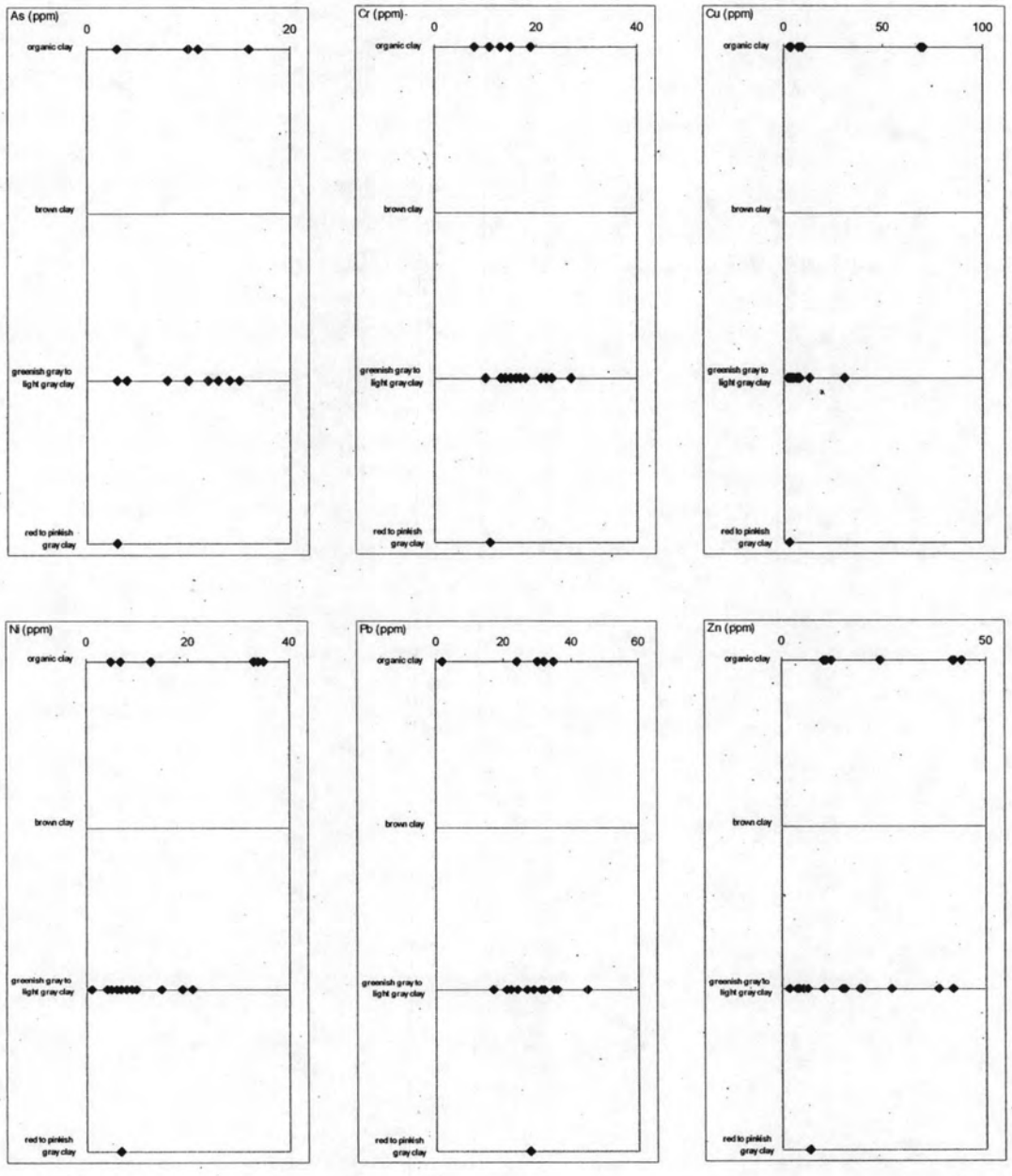


Figure 4.29 Variation of heavy metal concentrations (ppm) in sedimentary layer of Area 4 the SKL study area.

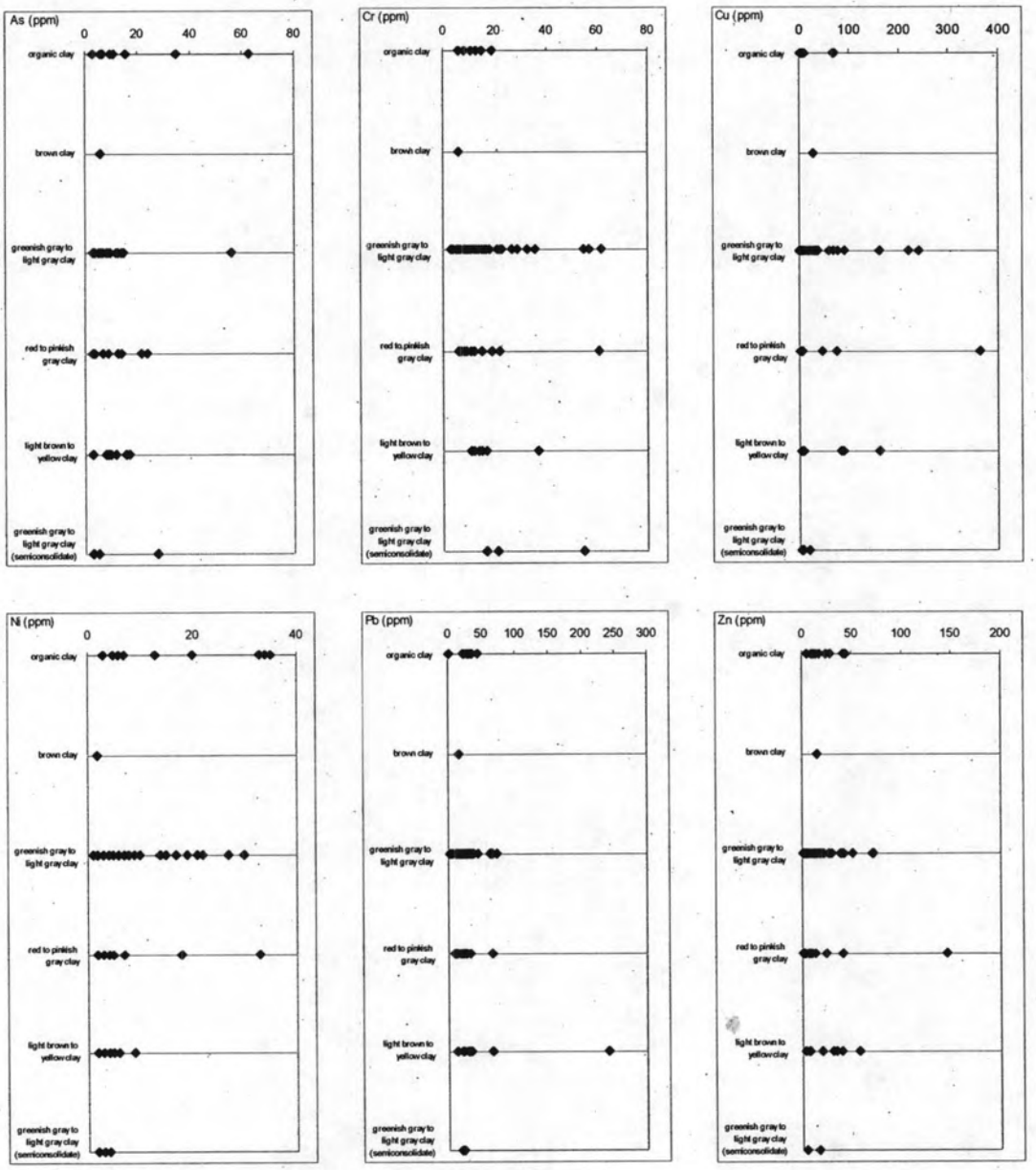


Figure 4.30 Variation of heavy metal concentrations (ppm) in sedimentary layer of the SKL study area.

4.3 Conclusions

From the study in this part, it can be concluded that;

The stratigraphy of Songkhla Lake can be concluded in to 6 layer. For individual layer as shown bellows;

A. Organic-clay layer is about recent to 3,400 years ago;

B. Brown-clay layer is about recent to 3,400 years ago;

C. Greenish to light gray clay layer is about 3.400 to 9,000 years ago;

D. Red to pinkish gray clay layers is about 9,000 to 19,000 years ago;

E. Light brown to yellow clay layer is about 19,000 to 37,500 years ago;

F. Greenish gray clay (semi-consolidated) layer is more than 37,000 years ago.

The rate of sedimentation in this area are calculated from TL-dating data that mainly located in Area 1 that the average is about 0.36 to 0.38 mm/yr for all Holocene sediment deposition rate.

Area 1, Ao Ba Teng location, has high concentration of Arsenic, Lead, and Zinc through the average concentrations of these elements are 12.8, 32.5, and 94.54 ppm, respectively. Area 3, Khlong Ok location, has high concentration of Chromium (18.15 ppm) and Copper (51.87 ppm). Area 4, Ao Bang Teng location has high concentration of Nickel (11.79 ppm).

The organic clay layer has high arsenic and nickel concentration (17.08 and 13.20 ppm, respectively). Light grey to greenish grey clay has high lead and zinc concentrations (38.41 and 86.53 ppm, respectively). Pinkish to red clay and light brown, light grey to yellow clay layer have high copper and chromium concentration that are 43.81 and 21.57 ppm, respectively.

After this step, the results from this Chapter and Chapter III will be combined and discussed in three topics, namely, correlation the rate of sedimentation and soil

erosion, sources and transportation of heavy metals, and Heavy metals contamination in Songkhla Lake and its catchment area as displayed in next chapter.