Chapter 2
Bera Lake

Abstract The comprehensive view of applied limnology comprises catchment area and lake. Therefore, this book represents characteristics of Bera Lake in scale of watershed and lake area. The total catchment area is 593 km^2 with the area of cleared land, rubber and oil palm plantations covering some 340 km^2. The remaining area is covered by wetlands and reed swamps. This catchment has been separated into the 12 sub-catchments in which main open water with 1.11 km^2 area is located at most northern part. Overall water flow is directed northward and stream patterns of the fourth to twelfth sub-catchments have been joined and ultimately connect and drain into the south of Bera Lake. Gravelius coefficient of this catchment is 1.57 which illustrates its semi-elongate shape. Bera Lake catchment (BLC) is located in the geological central belt of Malaysia. Catchment area is covered by Semantan formation, Bera formation as well as granitic rock unit. Evidences support the effects of strike-slip faults (N110°) in shaping BLC valleys and controlled elongate shape of wetlands and open waters. Probably, accumulation of detritus sediments at the depths of 8–9 m of Bera Lake has been taken place 5,500–6,500 year BP due to a tilting and rapid steepness of the main valley. In addition, forest and reed swamps have developed mainly along depressions which already created by the strike-slip faults especially in the first, third, fourth, sixth, and the twelfth sub-catchments. The first one meter thickness of Bera Lake sediment profile is composed of five distinct layers. These layers with different thickness differentiated along all cores or at whole lake area. The annual mean water level fluctuation in Bera Lake has been 2.7 m since 2007. Bera Lake volume or storage capacity is 2,995,998 m^3. Annual water and sediment discharge into the Bera Lake are 24.2 (km^3) and 2,042.58 (ton), respectively. Overall classification of Bera Lake water quality before and after land development project is classified IV and V which is suitable for irrigation only and requires extensive treatment for drinking. Consequently, morphology, ecology, water and sediment quality of Bera Lake has been changed since 1972 due to extensive land use changes at catchment area.

M. Gharibreza and M.A. Ashraf, *Applied Limnology: Comprehensive View from Watershed to Lake*, DOI 10.1007/978-4-431-54980-2_2, © Springer Japan 2014

Keywords Bera Lake • Land use changes • Trap efficiency • Water level • Water quality

2.1 Catchment Area

2.1.1 Physiographic Particulars

The study area, BLC is located in the central part of Peninsular Malaysia, in southwestern Pahang State and northeastern Negeri Sembilan State (Fig. 2.1), between 2°, 53′, 00″–3°, 10′, 00″ longitudes and 102°, 30′, 30″–102°, 47′, 00″ longitudes. This lake can be inversely trough as an island of water surrounded by a sea of rain forest. Two very low but parallel mountain ranges [around 500 m high] flank Bera Lake into existence within a corridor. The mountain range the Bertangga/Cermingat at east, and the Batu Beras/Palong range at west guides water within the lowland. The southern edge is a flat lowland gradually dominated the undulating "waves lands" of Johor.

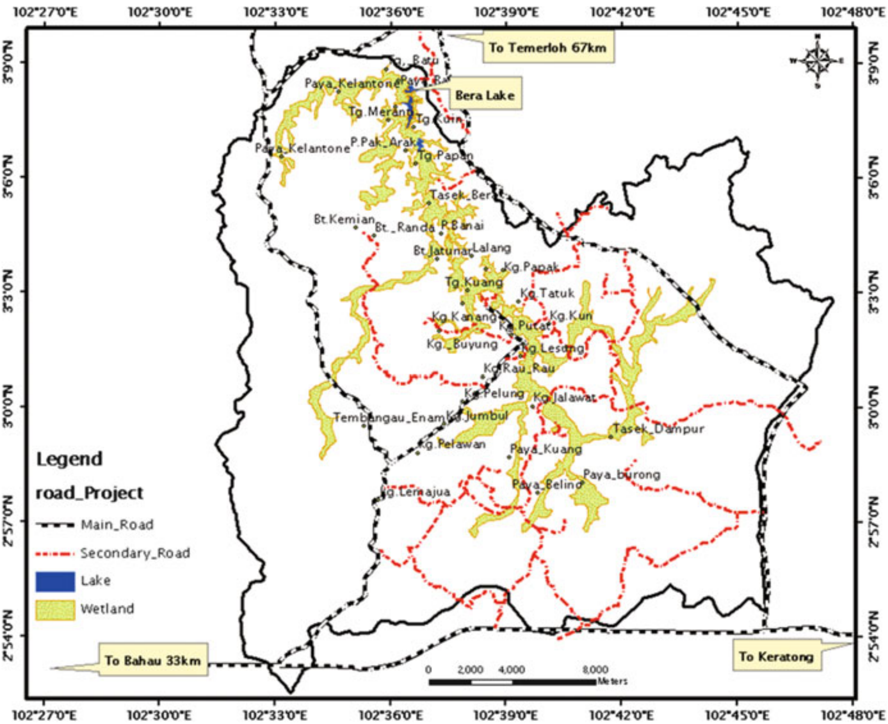

Fig. 2.1 Geographical position of BLC in Peninsular Malaysia

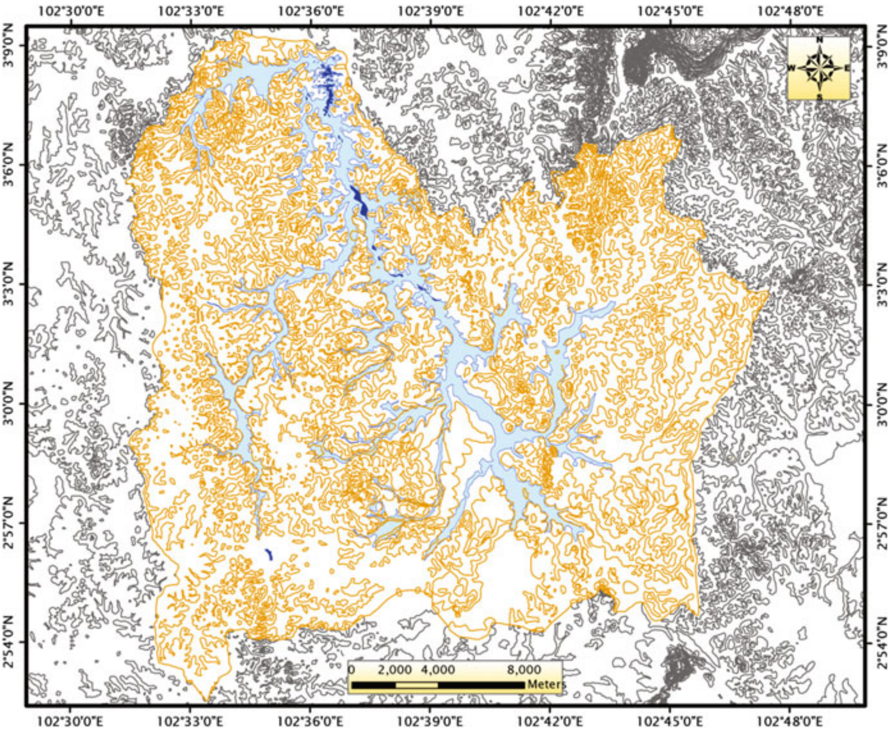

Fig. 2.2 The topographic map of BLC and surrounding area

As previously mentioned, the latest physiographic characteristics of study area have been created using the digital topographic maps of 1:25,000 scale (Series L8028) and a satellite image (Spot 5, 2009) of spatial resolution 10 m and GIS media. The total catchment area was determined to be 593.1 km^2 with the area of cleared land, rubber and oil palm plantations covering some 340 km^2, and open water involving some 1.11 km^2 (Fig. 2.1). The remaining area is covered by wetlands and pristine (forest and reed swamps) lowland rain forests. The highest hills in BLC are up to 140 m above sea level and the lowest elevation is 7 m at outlet point of Bera Lake (Fig. 2.2). River valleys mostly have developed from elevation of 40 m and mean water level elevation is obtained 7 m. Digital elevation model was developed in order to draw BLC slope map. Resultant slope map (Fig. 2.3) in degree shows that up to half of study area is composed of low land area with slope of 0–2°.

Geomorphology of drainage pattern in Bera Lake is controlled by geological formation and topographic criteria. The common drainage pattern is dendritic (Fig. 2.3). A dendritic drainage pattern is the most common form in regions underlain by homogeneous material. That is, the subsurface geology has a similar resistance to weathering so there is no apparent control over the direction the tributaries take. Dendritic pattern is continued in wetlands and open waters as

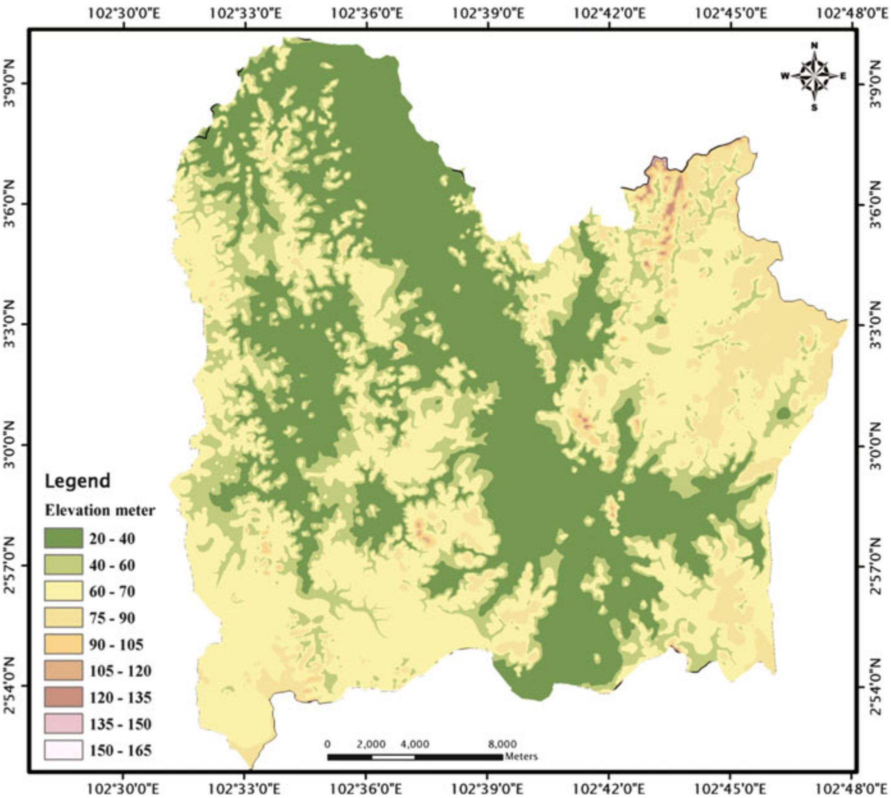

Fig. 2.3 Digital elevation model of BLC

well. Several distributaries and elongate open waters have shaped the Bera Lake at northern part of catchment. Indeed, Bera Lake is topographically trapped body of water which has developed into the dendritic distributaries.

The total length of stream pattern in BLC area and drainage density were obtained 1,316.844 km and 2.248 km, using geographical information system. The BLC has been separated into the 12 sub-catchments (Fig. 2.4) in which main open water is located at most northern part, at the third sub-catchment. Overall water flow is directed northward and stream patterns of the fourth to twelfth sub-catchments have been joined and ultimately connect and drain into the south of Bera Lake (Fig. 2.5). Two other streams from the first sub-catchment (Kelangton stream), and second, drain into the middle, and northern parts, of Bera Lake, respectively. This leaves only one outlet—excess water over spilling into channels in the north where all join Bera River which ultimately ends into Pahang River.

In addition, BLC and its sub-catchments were studied in order to calculate physiographic and drainage characteristics (Table 2.1). Catchment form is an essential factor which controls hydrological parameter like time of concentration and water discharge . As a result, the round shape catchments drain faster than elongate

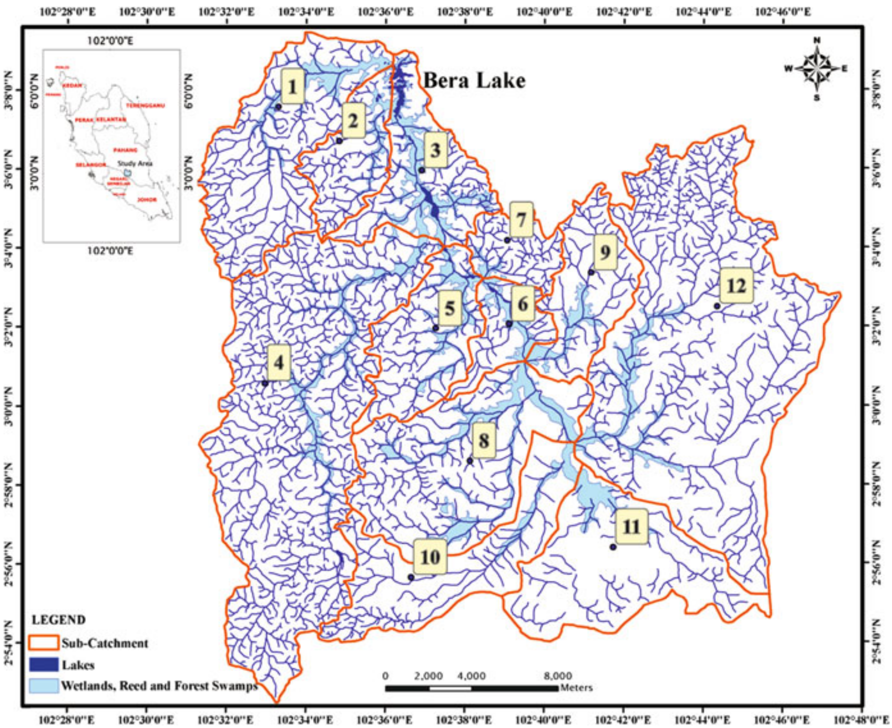

Fig. 2.4 Stream pattern and sub-catchment of Bera Lake watershed

shape ones. Therefore, catchment form has been studied using shape factor, Gravelius coefficient (Gravelius 1914), and Horton form factor (Horton 1932).

The highest and lowest Gravelius values were obtained 1.99 and 0.14 for the tenth and seventh sub-catchment, respectively. Gravelius coefficient of BLC was obtained 1.57 which illustrates its semi-elongate shape. Horton form factor is also an indicator of watershed circulatory representing form factor of 1 for circular shape and values less than 1 show diversion from roundness. Horton form factor was calculated for BLC is 1.12, points out a basin with a semi-elongate shape.

Time of concentration is a fundamental watershed parameter, which is the longest time required for a particle to travel from the watershed divide to the watershed outlet. It is used to compute the peak discharge for a watershed. The peak discharge is a function of the rainfall intensity, which is based on the time of concentration. Time of concentration of Bera Lake basin was calculated based on the Kirpich equations (Kirpich 1940). Time of concentration in BLC is obtained 8.53 h. In addition, this value is decreasing in order of $7.79 > 6.42 > 3.61 > 3.38 > 3.11 > 2.94 > 2.84 > 2.45 > 2.09 > 1.45 > 1.05 > 0.89$ h in the sub-catchments 4, 12, 8, 3, 1, 5, 9, 2, 10, 6, 11, and 7, respectively. Resultant time of concentrations is in accordance to shape of sub-catchment where the most circulate has been the seventh one, indicating the lowest time of concentration 0.89 h.

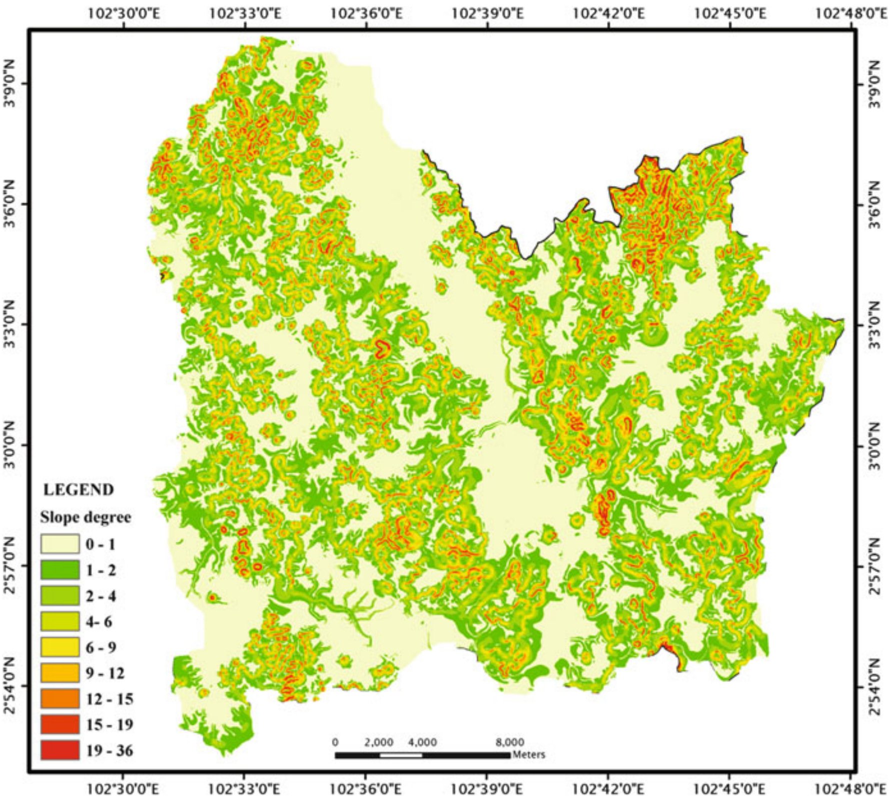

Fig. 2.5 Slope categories at BLC

2.1.2 Geology

Geological setting is one of the most important characteristics of BLC in terms of its contribution in sedimentary processes and evolution of basin. BLC is located in the geological central belt of Malaysia. The central belt significantly is different with western and eastern belts in terms of historical evolution, tectonic and structural, and stratigraphy settings (Hutchison and Tan 2009). Figure 2.6 illustrates the Lebir fault and Bentong Suture as a boundary between eastern and western margin of the Central Belt, which covers the entire state of Kelantan, the western and central parts of Pahang, the eastern part of Negeri Sembilan, and the western part of Johor (Ismail et al. 2007). Central Belt involves the Kepis, Lop, Bera, Kaling, Paloh, Ma'Okil, Gemas, Semantan, Tembeling and Koh Formations, and the Gua Musang Group and the Bertangga Sandstone, which range in age from Permian to Cretaceous (Ismail et al. 2007) (Fig. 2.7).

Table 2.1 Physiographic and drainage characteristics of Bera Lake watershed

	Bera Lake sub-catchment												
Parameter	1	2	3	4	5	6	7	8	9	10	11	12	Whole catchment
Area (km^2)	50.4	18.18	29.9	125.93	28.13	12.93	12.42	60.11	25.56	38.97	49.49	141.1	592.84
Perimeter (km)	39.9	23.53	33.4	69.95	28.65	20.2	17.61	37.31	27.83	44.45	38.2	65.8	138.195
Length (km)	9.58	7	10.33	21.28	8.97	4.96	3.25	10.9	8.85	6.8	3.74	17.86	23
Gravelius coefficient	1.57	1.55	1.71	1.75	1.51	1.61	0.14	1.35	1.54	1.99	1.52	1.55	1.59
Horton form factor	0.55	0.37	0.28	0.28	0.35	0.5	1.18	0.51	0.33	0.84	3.54	0.44	1.12
Concentration time (h)[a]	3.11	2.45	3.38	7.79	2.9	1.45	0.89	3.61	2.84	2.09	1.05	6.42	8.53

Gravelius Equation [($Kc=28P/A^{0.5}$) A: area (km^2), P: perimeter (km)]
Form Factor in Horton Equation [($F=A/L^2$) A: area (km^2), L: Length (km)]
[a]Kripich Equation [($Tc(hr)=0.0003L^{0.77}*S^{-0.385}$) L: Length of main stream (km)]

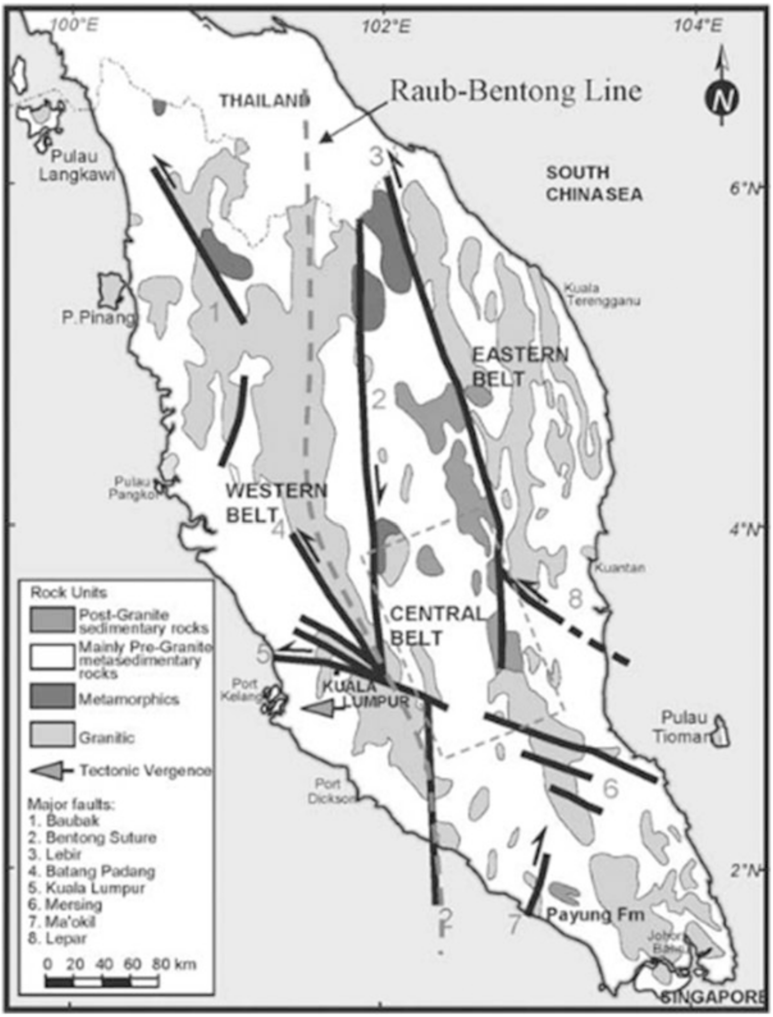

Fig. 2.6 Geological map of Peninsular Malaysia after (Hutchison and Tan 2009)

Age		CENTRAL BELT			
		South Kelantan		Pahang	Johor
Cretaceous	Upper	Non Deposition			
	Lower	Gagau group		Koh Formation Tembeling Group	Ulu Endau Formation; Panti Sst Tebak Formation
Jurassic	Upper				
	Middle	Non Deposition		Non Deposition	Non Deposition
	Lower				
Triassic	Rhaetian				
	Norian			Kaling Formation (Lipis Group)	
	Carnian	Gunung Rabong Formation	Telong Formation	Semantan Formation	Gemas/Ma'Okil Formation
	Ladinian				
	Anisian	Gua Musang Formation	Non Deposition		
	Scythian		Aring Formation	Non Deposition	Non Deposition
				Palaeozoic	Upper Palaeozoic

Fig. 2.7 Mesozoic stratigraphic column of Central Belt. In (Ismail et al. 2007)

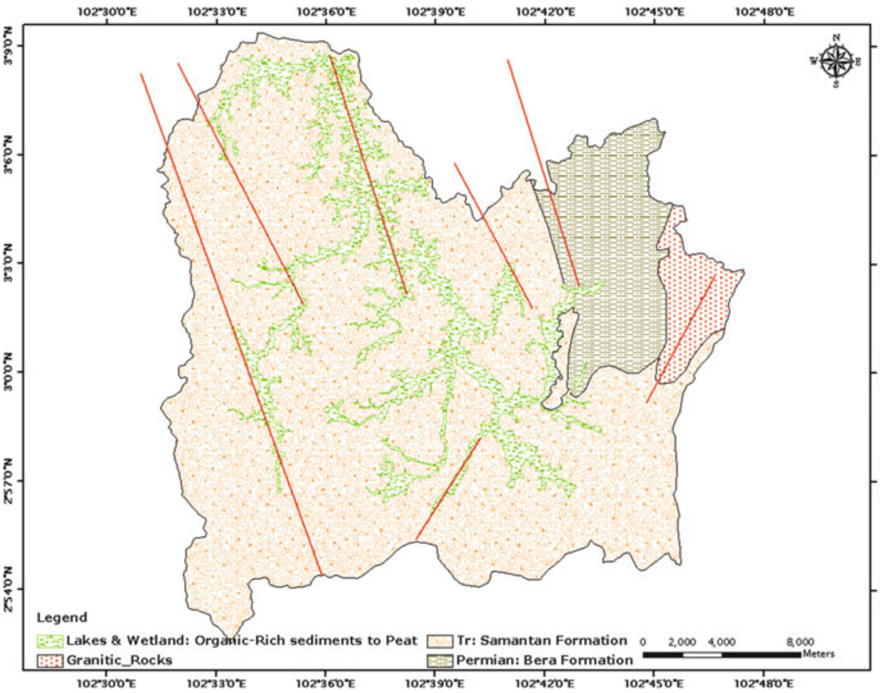

Fig. 2.8 Geological map of BLC

2.1.2.1 Stratigraphy

2.1.2.1.1 Bera Formation

The Bera Formation was introduced by Sone and Shafeea Leman (2000) for recently exposed Permian layers on the eastern side of Bera Lake (Fig. 2.8). Bedding strata of the Bera Formation was recorded N130° (NE-SE), 60°SW at the 12th sub-catchment, east of Bera Lake (Figs. 2.9 and 2.10).

Lithology of the Bera Formation is composed of massive mudstone (Fig. 2.10), thick to massive tuffaceous sandstone, siltstone, and thin-bedded siliceous mudstone in its lower part, and thin-bedded shale, siltstone sandstone and subordinate conglomerate in its upper part. Several fossiliferous horizons give general middle Permian (Roadian to Capitanain) age. This formation has showed highly weathered and undifferentiated intrusions, probably the Triassic igneous rocks.

Iron oxide nodules appear as Gusan Zone is common product of highly chemical weathering of igneous rocks in study area which represents position of previous original rocks. Another source of iron-rich strata in the Bera Formation probably came from the final and dilute intrusion phases of igneous rocks which have been penetrated between sedimentary layers. Hutchison and Tan (2009) stated that the

Fig. 2.9 Bera Formation bedding and lithology in east of study area

Fig. 2.10 Thick outcrop of mudstone, Bera Formation at the twelfth sub-catchment

Bera Formation sediments initially were deposited in a shallow marine environment within a closed basin, with rapid sedimentation rate and volcanic input from the surrounding area. Overall sequence of the Bera Formation has been accumulated at a shallow upward to a littoral basin.

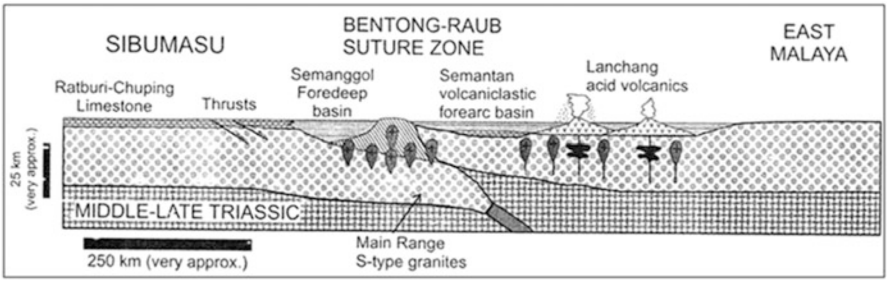

Fig. 2.11 Accumulation of the Semantan Formation in a forearc basin (after Hutchison and Tan 2009)

2.1.2.1.2 Semantan Formation

The Semantan Formation is one of the Paleo-Tethyan deposits which have been reported as Middle to Upper Triassic in age. Convergence between of the Eastmal/Indosinia and Sibumasu blocks resulted in closure of the Paleo-Tethys ocean in Late Triassic times (Hutchison and Tan 2009) (Fig. 2.11).

The upper and lower contacts of the Semantan Formation are not exposed at the type locality. Lower boundary in BLC is not exposed and overlaid with an unconformity by Redbeds formation and quaternary deposits. Lithology of the Semantan Formation comprises a rapidly alternating sequence of carbonaceous shale, siltstone and rhyolite tuff with a few lenses of chert, conglomerate and recrystallized limestone.

The best outcrops of Semantan Formation at BLC was found at the third sub-catchment where a sequence of fine sandstone with medium bedding layers interbedded with gray calcareous shale thin bedded layers (Fig. 2.12). Another outcrop of the Semantan Formation has sharp contacts with lower and upper formations were found close to open water. It appeared different feature where deeply weathered brown-yellowish argillaceous layer was dominated lithology, overlaid the basal conglomerate at lower contact and beneath the quaternary conglomerate by disconformity (Fig. 2.13). Hutchison and Tan (2009) introduced basal as red beds from Karak to Cheroh along the foothills of the Main Range with an age of pre-Triassic, specifically pre-Anisian or pre-Semantan. Disconformity at the top surface has pointed out the unknown time period of erosion or situation without any deposition. It seems thickness of the Semantan Formation in study area remarkably has been reduced because of severe erosion. Figure 2.13 indicates 10 cm thickness and dark color paleosols at disconformity surface. Figure 2.14 represents another outcrop of Semantan Formation at most northern part of catchment area which points out decrease in its thickness. Several acidic to intermediate igneous intrusion is reported in this formation (Hutchison and Tan 2009). Mohamed (1996) stated that Semantan formation has been appeared by a inter-fingering outcrops and it is comparable with other formations; Raub Series; Calcareous

Fig. 2.12 Lithological sequence of Semantan Formation in BLC

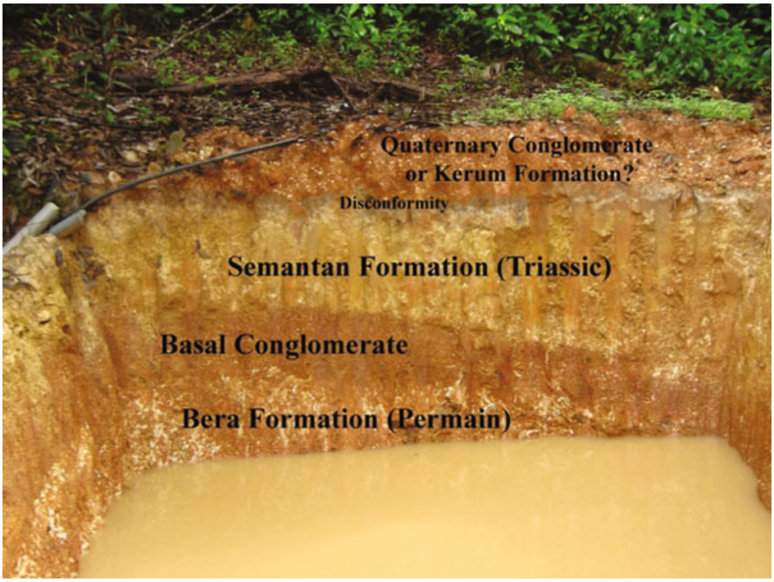

Fig. 2.13 Stratigraphic sequences of geological formations in study area

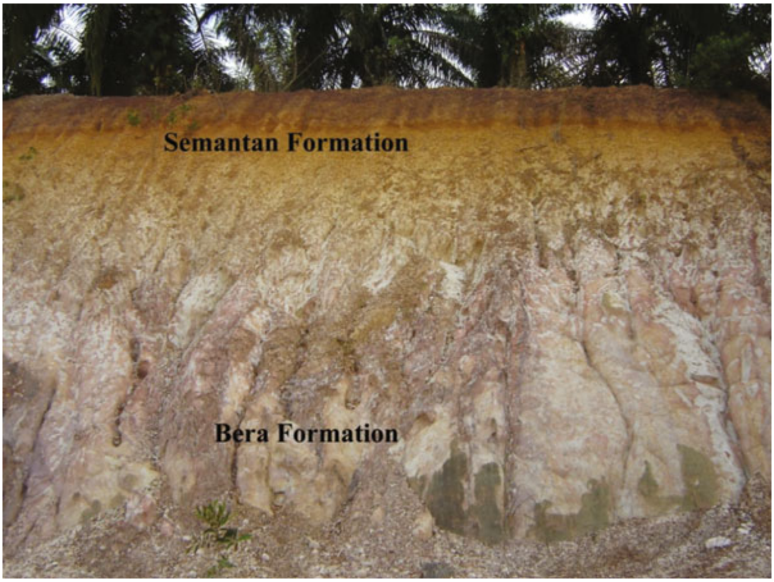

Fig. 2.14 Common stratigraphic sequences of formations in BLC

Formation; Calcareous Series; Younger arenaceous Series; Raub Group; Jengka Pass Formation; Kerdau Formation; part of Jelai Formation; Gemas Formation; Jurong Formation; Pahang Volcanic Series in the different areas.

2.1.2.1.3 Post-Semantan Formation Redbeds

One of stratigraphic units with a wide distribution in Central Belt is Redbeds Formation which forms large km-sized folds. It is composed of conglomerate, pebbly sandstone and sandstone whereas the upper part is dominantly comprised by mudstone with subordinate sandstone (Hutchison and Tan 2009).

In general view conglomerate layer has been partly covered the Semantan Formation at BLC with the variable thickness. Redbeds Formation outcrop seems to be lenticular and it is not in the form of thick continues beds. The texture is composed of rounded quartz, schist, chert, volcanic fragments and iron oxide phenoclasts, size is varying between 2 and 20 mm. Grain supported texture with different portion of sandy to muddy sand matrix was obtained in the grain size analysis. Redbeds Formation strata have cemented with silica and yellow to red iron oxide cements. Field observations revealed that Redbeds Formation directly deposited on the Bera Formation with an erosional contact especially in fourth and twelfth sub-catchments, east and west of study area, respectively (Fig. 2.15).

Fig. 2.15 Redbeds conglomerates overlays the Bera Formation in sub-catchment 4

Granitic rocks in BLC have been exposed in the twelfth sub-catchment at the eastern part. This rock unit has been well studied by MacDonald (1970) especially at Bukit Pandan which is close to BLC with a cliffy morphology and a steep valley. Their topography seemingly shaped by faulting and uplifting mechanisms. The main granite body of BLC has appeared at few outcrops. Field observations especially in the twelfth sub-catchment and soil analysis has been confirmed the granitic character of the plutonic rock from which it is derived. It appears that at the twelfth sub-catchment the granite body is located at a shallow depth beneath the capping of sedimentary strata. The common feature of few exposed granites bodies has been deeply altered and sericitized surface. MacDonald (1970) also has reported hornblende in a minor constituent, and epidote, garnet, pyrite, and clinozoisite as accessories.

2.1.2.1.4 Quaternary Deposits

There is a long history into investigation of quaternary deposits in BLC. The geological setting and evolution of the Bera Lake basin as well as deposition of peat and more recent palynological aspects have been studied (Morley 1981; Phillips and Bustin 1998; Wüst and Bustin 2001, 2003, 2004; Wüst et al. 2002, 2003, 2008). Several boreholes which have been analyzed by Morley (1981) and Wüst and Bustin (2004) revealed sequence of inorganic and organic deposits in

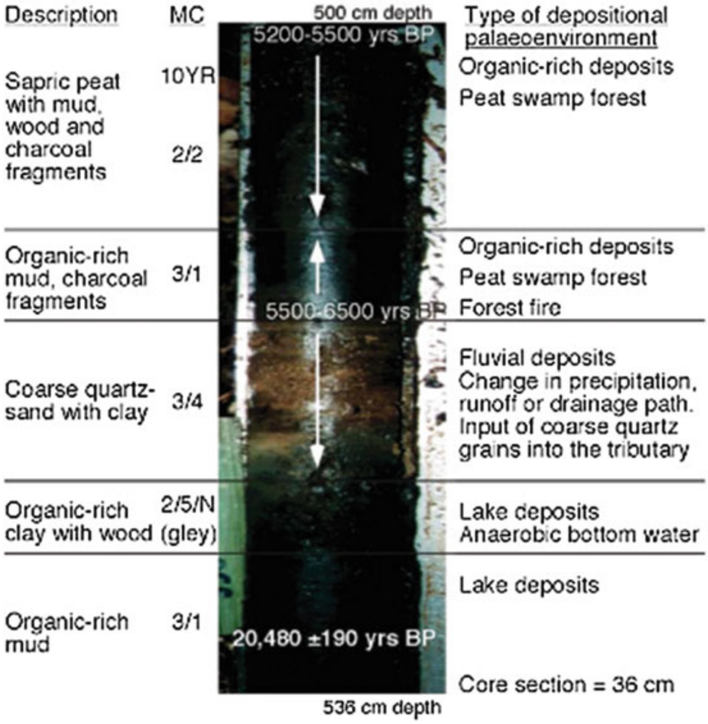

Fig. 2.16 Historical sedimentation profiles in Bera Lake, after Wüst and Bustin (2004)

wetlands and open waters. According to the longest borehole log description; basal deposits is composed of detritus sands and coarse debris which may have been deposited at a time when river current flowed in a steep valley. Contribution of forest taxa in the basal deposits has been maximum between other organic taxa which approved by pollen records. Morley (1981) believed that inorganic alluvial sediments have been deposited only during the mid-Holocene; ca. 4,500 radiocarbon years BP. Wüst and Bustin (2004) represented a core in which stated that deposition of detritus sediments have been occurred before 5,500–6,500 year BP has been created by a wet world season and heavily precipitation and runoff (Fig. 2.16). They have introduced organic-rich lake sediments with an age of 20,480 ± 190 year BP. In the other word, they believed that accumulation of organic matter occurred in local lakes during the LGM, but widespread peat deposition did not start until 5,300 BP when climatic changes led to the evolution of a wetland system. According to Morley (1981) contribution of non-forest and swampy pollens and spores have remarkably increased and preserved in sediments since 660 ± 75 year BP. Transition to swampy condition has been rapid and is thought to have been caused by a reduction in gradient of the stream resulting from minor tilting of the area by tectonic movements.

2.1.2.2 Structural Geology

Peninsular Malaysia has been structurally divided into three major belts with a less clearly defined fourth domain in the NW direction. Tectonic developments in the Mesozoic have been responsible for configuration of structural belts. BLC is located in the central belt and close to eastern belt. The boundary between the Central and Eastern Belts is marked by the Lebir Fault Zone (Hutchison and Tan 2009) (Fig. 2.17). Structural geology of study area has been partially studied by MacDonald (1970) which divided the tectonic activities into three consecutive phases:

(1) Folding due to earth movements along NW-SE lines, and minor faulting along axial planes.
(2) East-West trend folding and emplacement of the granites bodies
(3) Major north-south faulting

MacDonald (1970) has stated a dominate fold structures which are open anticlines and synclines with a northwest-southeast trend, and pitching gently to the southeast. Bera and Semantan Formations outcrops in BLC has revealed significant effects of granites mass emplacement in the folding of Permian and Triassic rock units. Overall orientation of recorded bedding showed that rock units at BLC are located at right flank of a wide syncline, trending NW-SE and layers inclined 45–60° SE. Although Hutchison and Tan (2009) introduced Bera Fault as a Jurassic-Cretaceous faulting system (Figs. 2.4, 2.5, 2.6, 2.7, and 2.8) which developed between Mersing and Lepar fault zones, that has been active mid-Holocene as quaternary fault in terms of reshaping of Bera Lake basin. Faulting has played remarkable role in the final configuration of BLC.

As shown in Figs. 2.4, 2.5, 2.6, 2.7, and 2.8 there are five faults trending NW-NE and two faults are in NE-SW direction. Faults were recognized from aerial photos, stream pattern and confirmed using digital topographic maps. Evidences support the effects of strike-slip faults in shaping BLC valleys and controlled elongate shape of wetlands and open waters.

Probably, accumulation of detritus sediments at the depths of 8–9 m of Bera Lake has been taken place 5,500–6,500 year BP due to a tilting and rapid steepness of the main valley. In addition, forest and reed swamps have developed mainly along depressions which already created by the strike-slip faults especially in the first, third, fourth, sixth, and the twelfth sub-catchments.

Intensive chemical weathering of rock units resulted in coverage of fractures and joints in study area except at Semantan Formation where exposed with semi-fresh layers at northwest of catchment (Figs. 2.18 and 2.19). Join and fractures were studied in order to find contribution of major fault system in the development of failure surfaces, and faults. Joint studies (Fig. 2.20) showed that the main faults and joints trends can be classified in four groups of N350°, N60°, N90°, and N110°, with 5, 25, 30, and 35 % of frequency respectively.

Geological map and field observation demonstrated that N350° fault system has played a vital role in the development of fractures even though the maximum

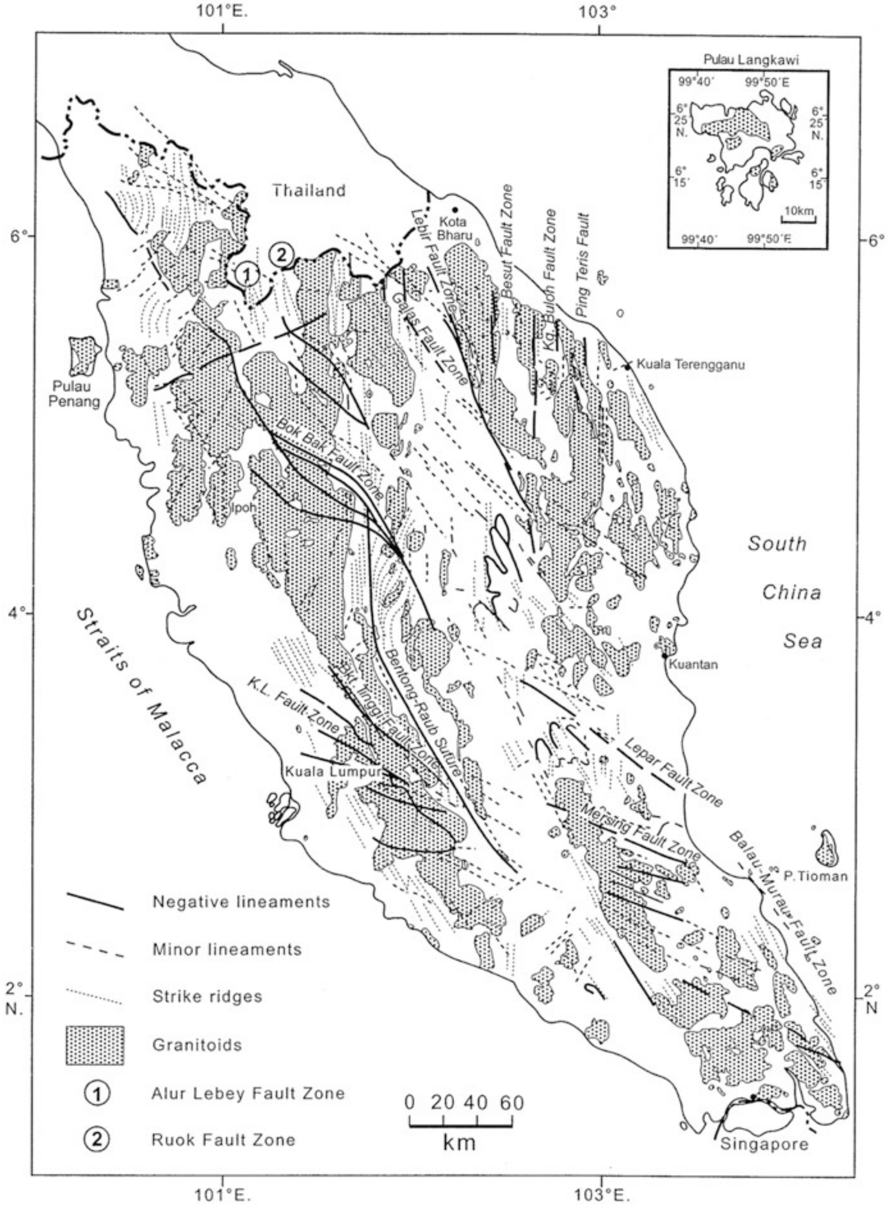

Fig. 2.17 Major and minor faults and structural zones of Peninsular Malaysia (after Hutchison and Tan 2009)

frequency of joint trend was appeared at N110°. This maximum joint trend (N110°) can be part of the Mersing Faulting Zone while main faults are representing effects of major faults which separated Central and Eastern Belts.

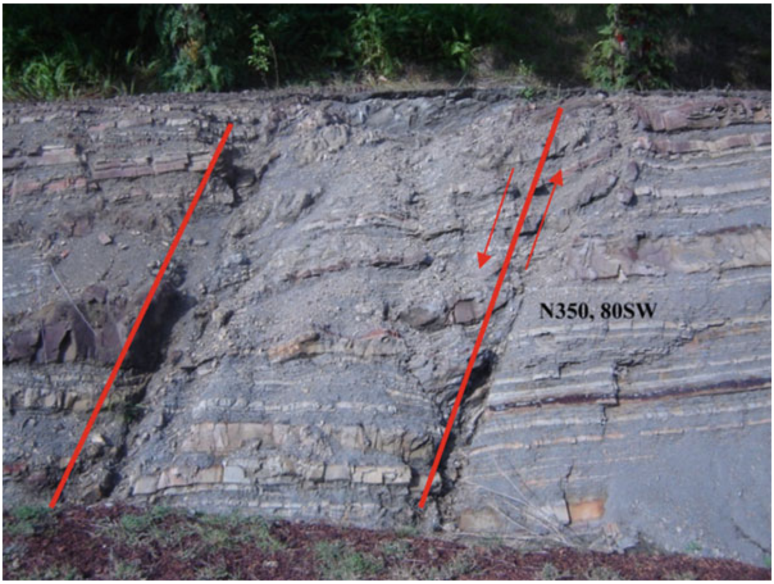

Fig. 2.18 Major fault trends in catchment with 5 % frequency

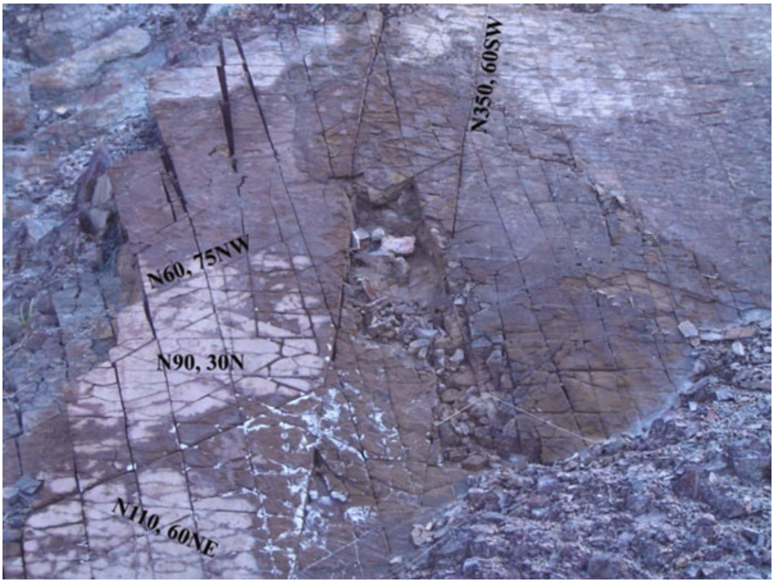

Fig. 2.19 Joint system appeared in the Semantan Formation

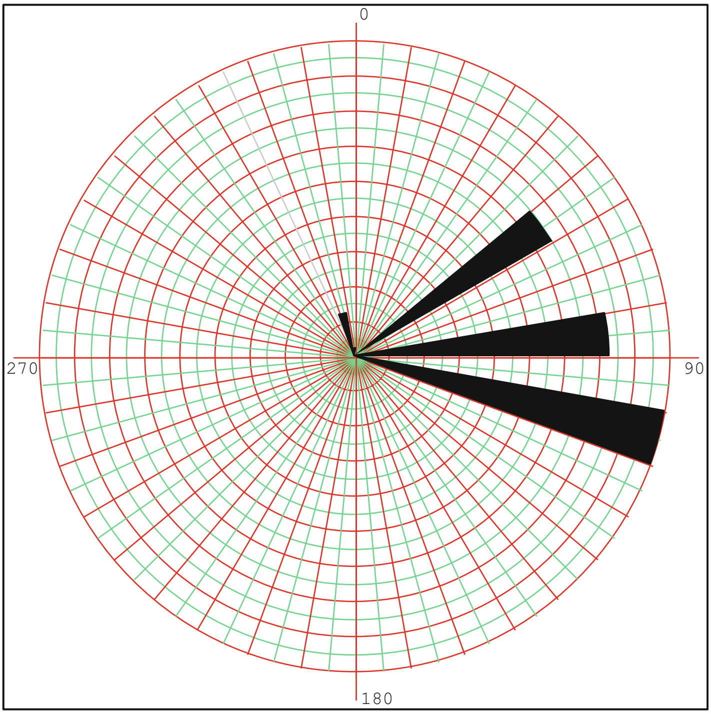

Fig. 2.20 Rose diagram showing direction of joints and fractures in study area

2.1.3 Climatology

The climate of Peninsular Malaysia, can be distinguished four seasons namely, the southwest monsoon, northeast monsoon and two shorter periods of inter-monsoon seasons. The southwest monsoon season is usually established in the latter half of May or early June and ends in September. The prevailing wind flow is generally southwesterly and light, below 15 knots (MMD 2011).

The northeast monsoon season usually commences in early November and ends in March. During this season, steady easterly or northeasterly winds of 10–20 knots prevail. The winds over the Penang state may reach 30 knots or more during periods of strong surges of cold air (cold surges) from the north (MMD 2011).

During the two inter-monsoon seasons, the winds are generally light and variable. During these seasons, the equatorial trough lies over Malaysia. As Malaysia is mainly a maritime country, the effect of land and sea breezes on the general wind flow pattern is very marked especially during days with clear skies. On bright sunny afternoons, sea breezes of 10–15 knots very often develop and reach up to several tens of kilometers inland. On clear nights, the reverse process takes place and land breezes of weaker strength can also develop over the coastal areas (MMD 2011).

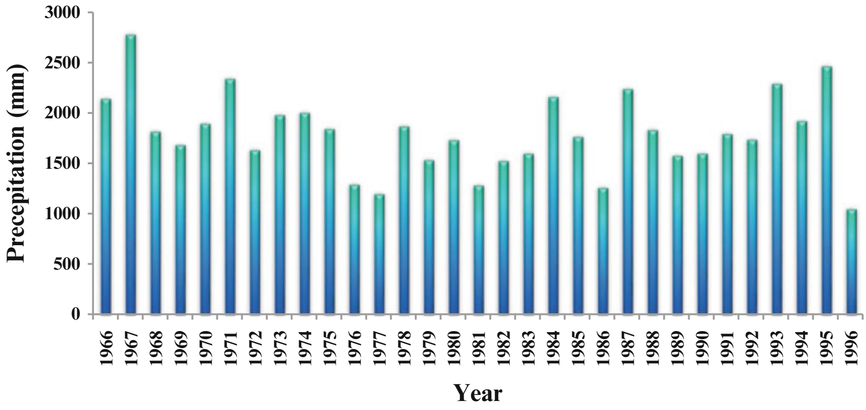

Fig. 2.21 Annual precipitation of Triang station 1966–1996

The mean monthly relative humidity is between 70 and 90 %, varying from place to place of study area and from month to month. The minimum range of mean relative humidity is varying from a low 80 % in February to a high of only 88 % in November. It is observed that in Peninsular Malaysia, the minimum relative humidity is normally found in the months of January and February. The maximum is however generally found in the month of November (MMD 2011).

Mean annual temperature is approximately 30 °C, varying from 25 °C to 38 °C (Chee and Abdulla 1998). A number of occasions have been recorded on which the temperature did not rise above 24 °C which is quite frequently the lowest temperature reached during the night in most areas. Night temperatures do not vary to the same extent, the average usually being between 21 and 24 °C. Individual values can fall much below this at nearly all stations, the coolest nights commonly followed some of the hottest days (MMD 2011). Rainfall records from 1970 to 2009 at the Pos (Fort) Iskandar station, which is located at the mid-point of the BLC, show that minimum, and maximum, annual rainfall is in the range of 1,000, and 2,602 mm.

Available rainfall data of the eight nearest rainfall stations (Fort Iskandar, Triang, Gambir, Kemayan152, Buto CGA Mak, Kuala Bera86, Chenor 88, Bukit Imbam) were evaluated in order to find the most reliable and complete one. The nearest rainfall station to the Bera Lake is Triang station which has the most complete rainfall data particularly during the land development projects 1966–1996 (Figs. 2.21, and 2.22).

The regulative effect of the forest canopy results in a lower evapotranspiration net water loss (Wüst and Bustin 2004). Potential evapotranspiration of the Pahang state as estimated by Penman Method was 1,515 mm year^{-1}, ranging from 1,449 to 1,509 mm (Nik 1988). In addition, evapotranspiration rate in the study area is reported 4–4.5 mm/day (Nik 1988).

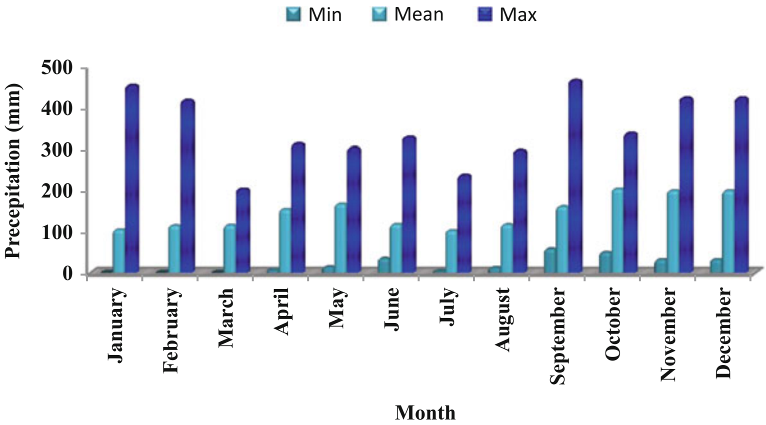

Fig. 2.22 Long-term mean monthly rainfall between 1966 and 1996 in Triang station

2.1.4 Land Use

Land use is an essential characteristic of each catchment which determines physical and chemical properties and rate of sediment delivery in empirical models and assigns rate of soil loss in radioisotopes conversion models. Investigate and updating of land use data was one of current research objectives.

The BLC is located in Pahang State, Malaysia which has experienced the most extensive land use change in the last four decades. FELDA has been the main executive for land use change in Malaysia and has implemented 164 schemes in Pahang State which has 40 % of all the land development in the country until 1990 (Henson 1994). During five FELDA (MPOC 2007) land development programmes from 1970 until 1995, some 292.86 km^2 of original forest was converted to oil palm and rubber plantations in the BLC area. FELDA land development districts maps were derived from the digital topographic maps of series L8028 (1:25,000 scale) which could be find in the Appendix. Bera Lake was designated under the Convention of Wetlands as the first RAMSAR site in Malaysia in November 1994 with the FELDA districts being known as Buffer Zone.

A new land use map of the BLC area has been developed using GIS, a satellite image (Spot5, 2009) of spatial resolution 10 m and an on-screen digitizing method. New land use map has remarkably revealed continues land use change and encroachment into the Bera Lake RAMSAR site. Between 1994 and 2009 the oil palm and rubber plantations and newly opened lands has been increased 47.14 km^2 and some 340 km^2 area has been established for forested lands (Fig. 2.23). Lake or open waters and original forests are eco-heritage of study area have been restricted to 3.44 and 196 km^2, respectively (Table 2.2).

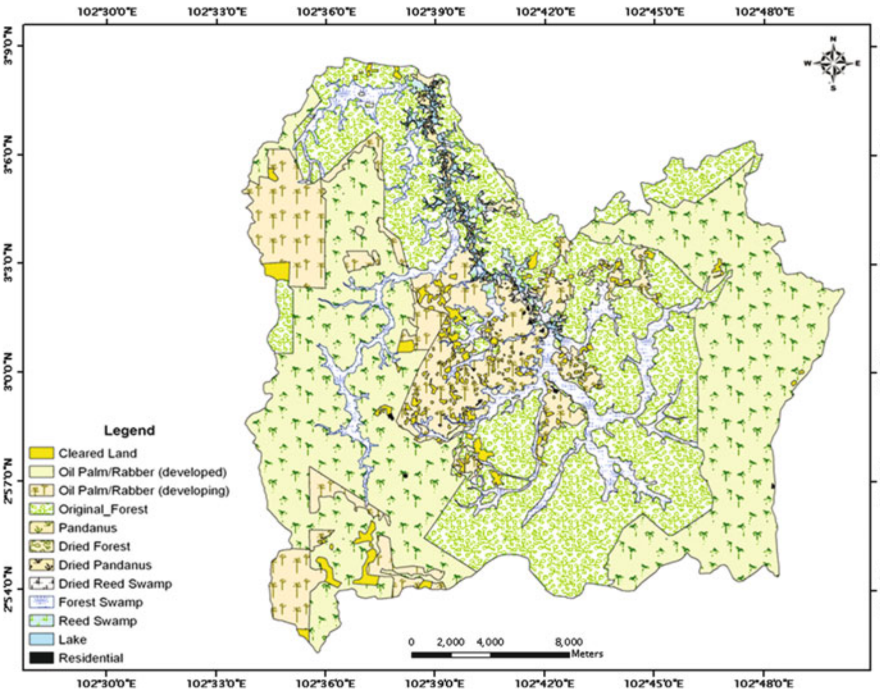

Fig. 2.23 Land use map of BLC

Table 2.2 Land use and natural land cover of BLC based on developed land use map

Land use	Area (ha)
Dried forest	17.93
Dried Pandanus	73.58
Dried reed swamp	132.12
Forest swamp	4,269.97
Reed swamp	613.60
Pandanus	197.24
Lake	344.15
Developed oil palm/rubber	23,954.03
Developing oil palm/rubber	8,667.32
Cleared lands	1,406.35
Original forest	19,576.04
Residential	52.30

2.2 Lake Characteristic

2.2.1 Hydrology

Lake Hydrology is known as essential knowledge about each lake that can lead sedimentary regime study in a proper way. Hydrology of a lake can serve as wide range of data from current discharge into and from the lake, water level and balance, efficiency trap, flood retention, and determine agricultural water balance in catchment area.

Drainage pattern in study area drains into Bera Lake at most northern part of catchment at the third sub-catchment. It is evident, that Bera Lake hydrology can reveals remarkable data about historical sedimentary events of catchment area and provides reasonable data for interpreting of sedimentation rate in Bera Lake. Long and short term water and sediment monitoring provides valuable information about basin sedimentary regime. However, hydrology data is the shortage and significant gap of available data in BLC. Although Bera Lake is the largest natural lake in Malaysia, but its hydrological data has been main informational gap between other studies. There is not any hydrological gauge or station in BLC and lack of data encouraged this research to plan field works to a seasonal survey of water and sediment discharge into and from Bera Lake basin.

2.2.1.1 Water and Sediment Discharge

Three hydrological sections were selected based on two main water and sediment entry points and one main departure streams from Bera Lake. The first and the most important section was at south of Bera Lake and another section was on the Kelantong stream which terminated to the lake at north-west of basin. Outlet section was marked on the main channel which drains the lake before the junction with Bera River (Sungai Bera). Water and sediment discharge into and from Bera Lake were measured in the two wet seasons (February and August, 2010) and one dry season (October, 2010), respectively. As already mentioned above, water and sediment discharge to and from the Bera Lake were measured in the two wet seasons (February and April, 2010) and one dry season (October, 2009), and result are presented in the Figs. 2.24, 2.25, and 2.26, respectively. A moderate correlation between wet and dry seasons and water balance has been revealed at Bera Lake. The mean contribution of the south and north inlets in terms of water supply obtained were 75.87, and 6.44 %, respectively. Water discharge survey was pointed out as minor contribution of streams and channels in water and sediment supply in the October. Results also showed that hydraulic slope in Bera Lake still tend to drains water into the Bera River even in dry season. Besides, a contribution of 95.7 % for Bera Lake sediment supply has been revealed for the south inlet in February. The mean contribution of the south and north inlets in terms of sediment supply were obtained 87.38, and 7.73 %, respectively. Whenever the water contribution of north inlet decreased to 1 %, its contribution to sediment supply has been increased to 10 %, Table 2.3.

A significant correlation between water volume from the south inlet of Bera Lake and residual sediment was observed. Furthermore, 30–40 % of sediment during wet seasons has been drained from Bera Lake to the Bera River. Capability of Bera Lake for sediment trapping can be increase up to 70 % when water supply increases especially from the south inlet. Elongate shape and abundance of distributaries are among the other reasons for increase of sediment residual in Bera Lake.

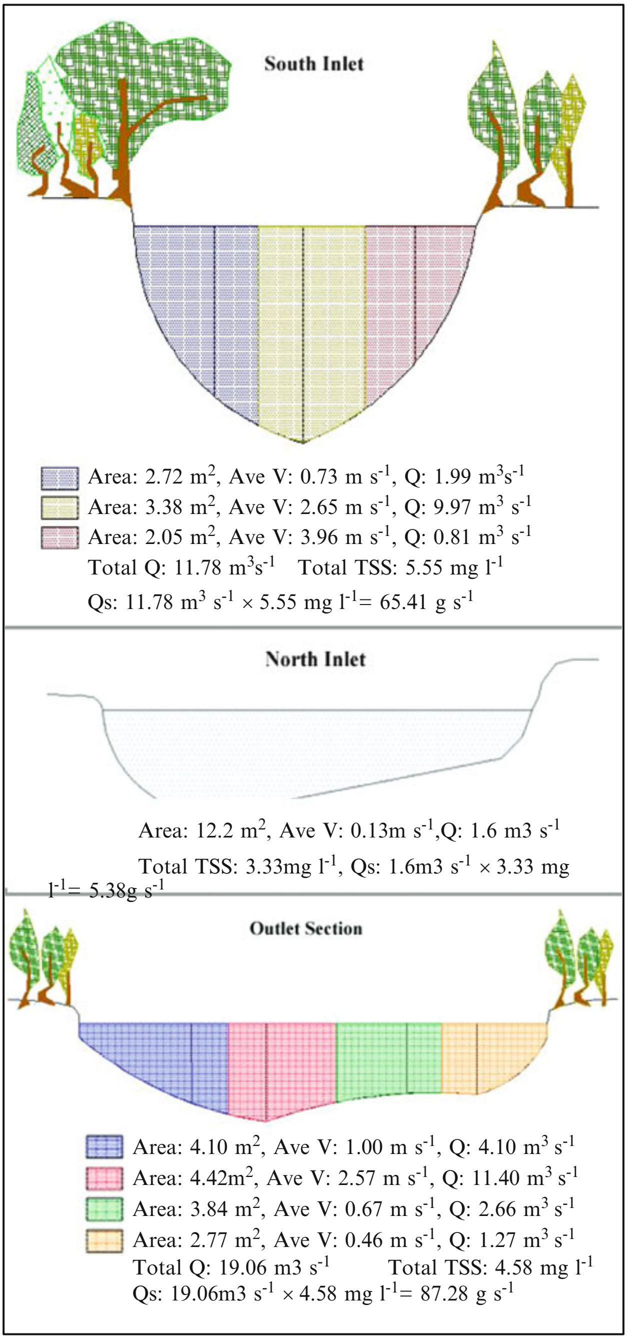

Fig. 2.24 Water and sediment discharge into and from Bera Lake

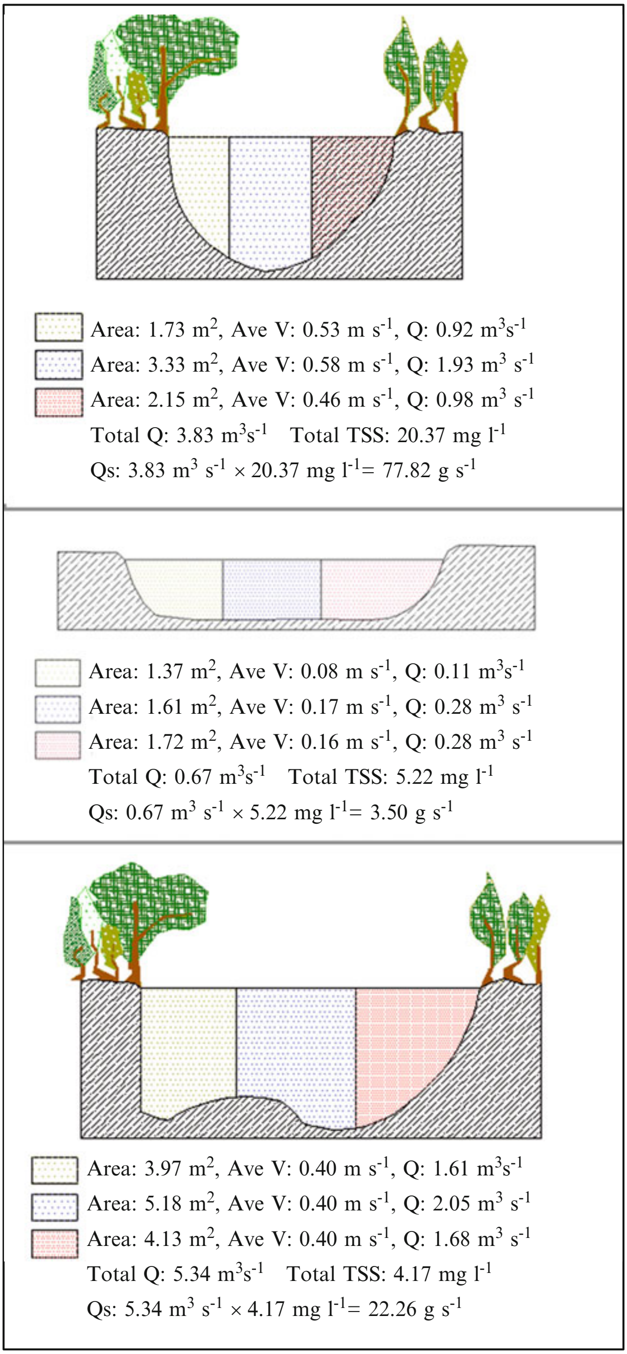

Fig. 2.25 Water and sediment discharge into and from Bera Lake

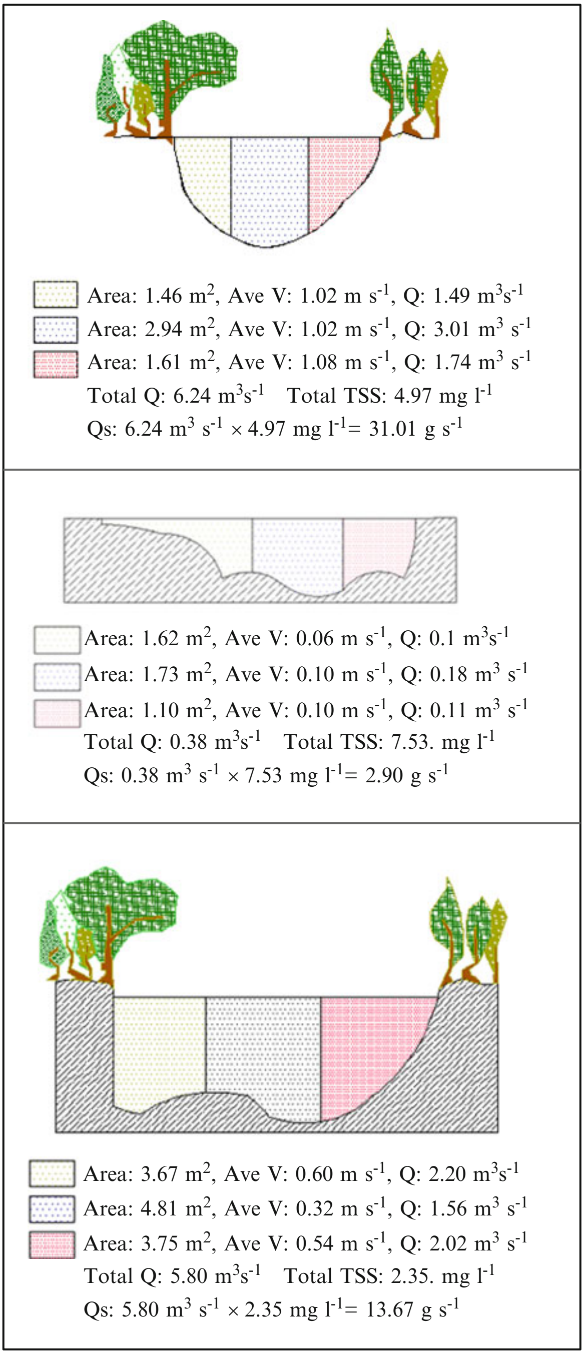

Fig. 2.26 Water and sediment discharge into and from Bera Lake

Table 2.3 Contribution of water and sediment entry points in Bera Lake based on implemented measurement

Water gates	Water contribution (%)			Sediment contribution (%)			Water discharge ($m^3 s^{-1}$)			Sediment discharge ($g s^{-1}$)		
	Feb	Apr	Oct	Feb	Apr	Oct	Feb	Apr	Oct	Feb	Apr	Oct
South inlet	71.6	94.2	61.8	95.7	91.4	74.94	3.83	6.24	11.78	77.82	31	65.41
North inlet	12.5	5.82	1	4.3	8.56	10.35	0.669	0.386	0.115	3.45	7.53	9.04
Others (wetlands)	15.9	–	37.33	–	–	14.7[a]	0.841	–	7.11	–	–	–
Residual	0	12.6	0	72.61	59.7	0	–	–	–	–	–	–
Outlet	–	–	–	–	–	–	5.34	5.8	19.05	22.26	13.67	87.28

[a]Minus balance of sediment in Bera Lake

Conversely, sediment discharge from Bera Lake could be remarkably increased during dry season, when about 15 % of residual sediments drain in the compensate lack of sediment supply from the south inlet.

Water level fluctuation is another hydrology character of Bera Lake that has recently recorded by RAMSAR site directory staff (Fig. 2.27). Results show that the maximum water level recorded during December 2007, October 2008, January 2009, and January 2010 were 8.21, 8.29, 9.2, 8.25 m respectively. On the other hand, the lowest water levels recorded were 6.3, 6.0, 5.0, 5.8 m in March 2007, 2008 July, 2009 August, and March 2010 respectively. The mean Bera Lake water levels obtained were 7.19, 7.6, 7.33, 6.87 m in 2007, 2008, 2009, and 2010, respectively. The annual mean water level fluctuation in Bera Lake has been 2.7 m since 2007. Available data are reliable except for a short period of time which a huge flood event that has happened in the December, 2007, when water level has dramatically rose 11 m and whole wetlands and open waters of catchment has been drowned. This significant event is not recorded in that available data and reports due to its intense destructive effects.

2.2.2 Bathymetry

Bathymetric map is an essential geo-spatial character of lakes and reservoirs which illustrates bed morphology and provides significant information about study area especially sampling site selection and sedimentary sub-basins. Bed morphology is vital information for core sampling and evaluation of sedimentary processes of basin. Trap efficiency of reservoirs and lakes is another important parameter that could be achievable using bathymetric map. Bathymetric map is another geo-spatial data gap in Bera Lake although the AWB implemented multidisciplinary projects (DANCED 1998) in order to complete geo-spatial data in study area.

2.2.2.1 Hydrographic Operation

Although Bera Lake nominated as the first RAMSAR site in Malaysia 1994, but hydrographic surveying has been not performed before this research. As a result, a comprehensive hydrographic operation was designated to survey bed morphology in order to provide require information for further studies.

The most efficient horizontal positioning method is meter-level, code phase DGPS or private provider networks. Alternately, electronic total stations may be used for small lake or impoundment basins; however, this may require locating or establishing additional horizontal control points around the basin, adding considerable time and cost to the survey.

Kertau RSO Malay Meter Projection System has been used as horizontal positioning projection system in horizontal positioning system. The best bathymetric scale of 1:500 or 20×20 m network has been applied to make best density of coverage in the hydrographic operation. The package of horizontal positioning

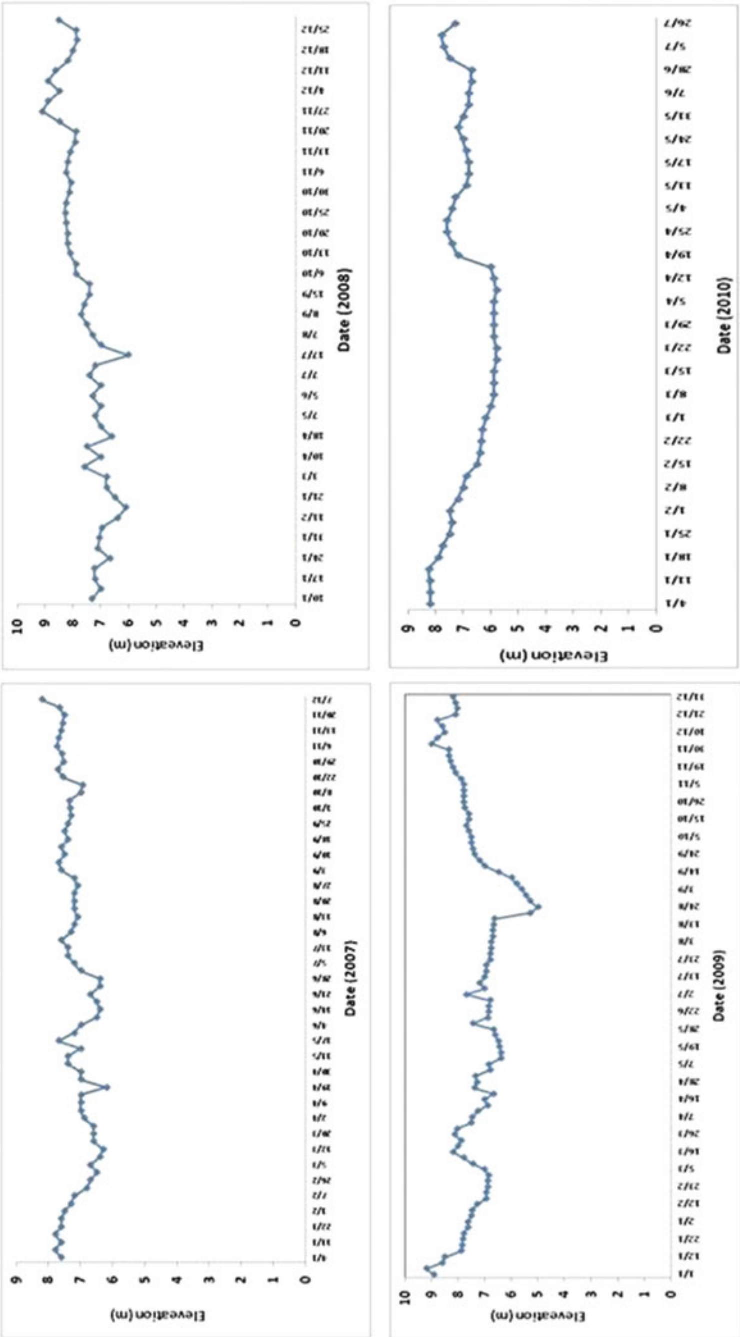

Fig. 2.27 Bera Lake water level fluctuations since 2007

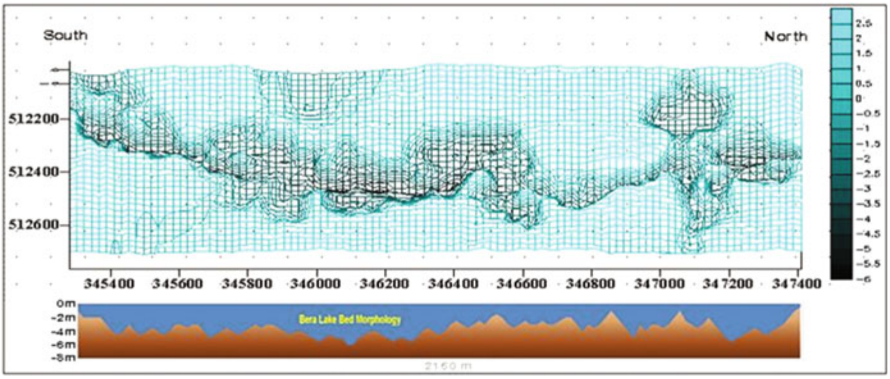

Fig. 2.28 Bera Lake cross section and bed morphology

records in this research involved 1,000 points as well as 300 point of shoreline records. Vertical surveying in hydrographic operation was designed based on capability of available Echosounder Garmin 400C (Fig. 2.28). Depth accuracy of such Echosounder is ±10 cm. Depth correlation refers to the BM (benchmarks) datum, is necessity procedure for preparing a topographical and bathymetric seamless map. This procedure was implemented by correlation of depth records with the nearest reported datum in the digital topographic maps of 1:25,000 scale (Series L8028).

Figure 2.28 depicts Bera Lake bed morphology, non-uniform bed surface and several troughs and obstacles especially at northern part of open water. Maximum depth was recorded 7 m at center middle of open water and along the main channel. Bera Lake bathymetric map (Fig. 2.29) showed appropriately sedimentary sub-basins in different parts of Bera Lake. Several distributaries represents shallow zone with depths of 0–1 m. Probably these branches are water storages with high capacity for wet seasons and have directly connected to wetlands, forest swamps, and reed swamps.

Bera Lake volume or storage capacity was calculated 2,995,998 m^3 (~3 km^3) according to Eq. (2.1) in which sum of two sequential depth interval areas divided on 2 and multiply to depth difference between two surfaces ($\Delta E = 1$m).

$$V = \tfrac{1}{2}H(A_1 + A_2) \qquad (2.1)$$

Bera Lake trap efficiency was calculated based on Eqs. ((2.2), and (2.3)).

$$\Delta\tau = \frac{V}{Q} \qquad (2.2)$$

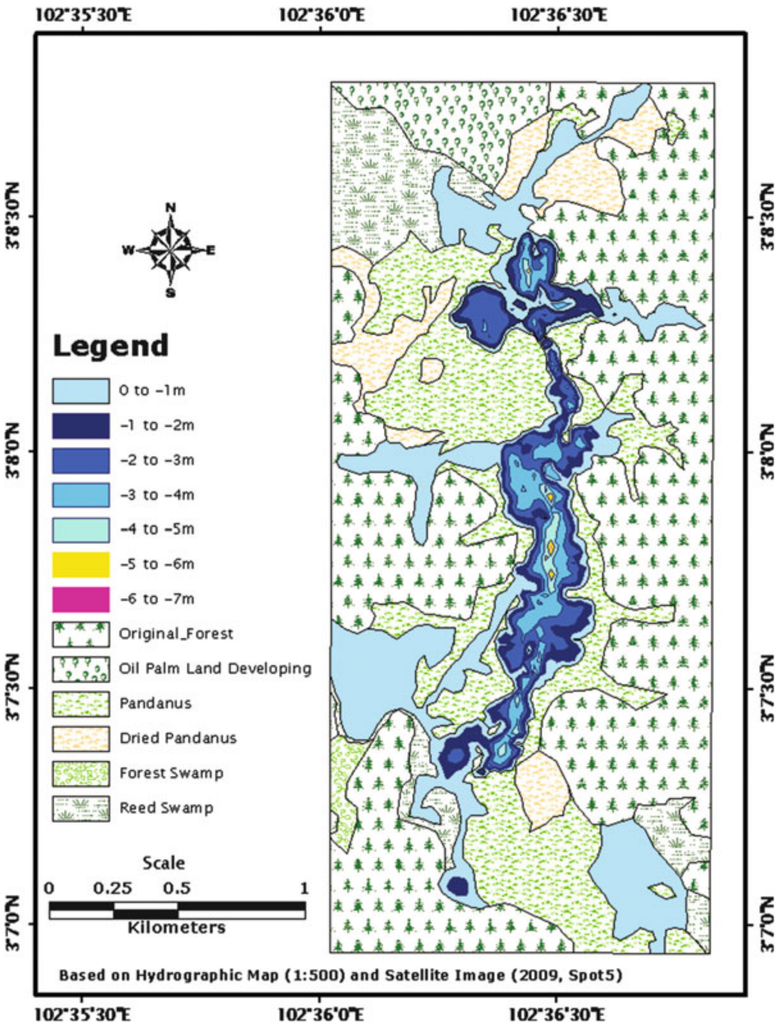

Fig. 2.29 Bathymetric map of Bera Lake (accuracy1:500)

$$TE = 1 - \frac{0.05}{\sqrt{\Delta\tau}} \tag{2.3}$$

Where V is storage capacity (km^3) and Q is discharge at the mouth of basin (km^3 a^{-1}) and $\Delta\tau$ is residence time of basin, and *TE* is trap efficiency. According to seasonal hydrological surveys, annual water and sediment discharge into the Bera Lake were calculated to be 24.2 (km^3 a^{-1}) and 2,042.58 (t a^{-1}), respectively. Application of Eqs. (2.2), and (2.3) residence time and trap efficiency of Bera Lake

Table 2.4 Water quality characters of Pos Iskandar open water (IBP 1972)

Depth (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ph	4.8	4.9	4.7	5.0	4.8	5.0	5.1	5.0	4.8	4.9	4.8	4.8
Transparency (m)	1.2	1.5	1.6	1.7	2.0	1.9	2.1	1.8	2.7	2.5	2.2	2.1
Do (mg/L)	1.1	1.3	1.5	1.3	1.7	2.0	2.4	2.7	2.3	2.3	2.3	1.7

obtained were 0.124 (year) and 86 %, respectively. Results show that Bera Lake is still capable to capture a large amount of sediments that are distributed into the basin. As a result, the annual sediment accumulation rate in Bera Lake could be 1,756.6 t. According to submerged density of the uppermost layer of Bera Lake sediment profile, annual accumulation rate could be 12,547.14 m^3. In conclusion, the relative sedimentation rate based on the 1,126,315 m^2 of Bera Lake area can be estimated 1.11 cm/year.

2.2.3 *Water Quality*

Inland fresh water bodies play an important role in human, animals, and aquatic lives and has recognized as source of water for drinking and several activities like fishery, recreation, agriculture, industry, and navigation. Bera Lake is the largest natural fresh water reservoir in Malaysia and has vital environmental and ecological importance for human and wild lives. However, long-term water quality has not recorded in BLC. In addition, few records of water quality by RAMSAR site directory staff in the some cross sections along the Bera Lake are reported but not published.

The most reliable water quality report has published by Malaysian-Japanese committee prior to land development projects (IBP 1972). This water quality analysis revealed that the area of open water adjacent to Pos Iskandar at the center of catchment is degraded. The brief available results presented in Table 2.4. According to IBP (1972) the mean TN, NO_3^{2-}, NO_2^{-1}, NH_4^{+1} and organic nitrogen have been 1.12, 0.11, 0.008, 0.33, and 0.58 mg L^{-1}, respectively. The mean PO_4 concentration was reported 0.021 (0.00–0.065). The ratio of reactive to un-reactive phosphorus has been 1/21 on the average.

2.2.3.1 In-Situ Water Quality Recording

Evaluate of available data about Bera Lake water quality showed that most of published reports about water quality were back dated to 1972, by Malaysian-Japanese committee (IBP 1972) prior to FELDA land development projects. Presently, the directory of RAMSAR site has been taken water samples from 5 stations. Many attempts to access to the resultant data were not successful.

Fig. 2.30 Surveying of Bera Lake water qualities by Hydrolab DS5 apparatus

As a result, lack of reliable water quality information especially previous land development projects have encouraged to conduct Bera Lake water quality assessment comprehensively. In quality surveying was implemented using calibrated fully automated Hydrolab DS 5 USA (Fig. 2.30). Eleven parameters include temperature (°C), depth of sampling (m), salinity (ppt), Turbidity (NTU), TDS (mg L^{-1}), pH, NH_4^{+1} (mg L^{-1}), NO_3^{-2} (mg L^{-1}), Cl^- (mg L^{-1}), LDO (mg L^{-1}), DO (mg L^{-1}) and EC (mS cm^{-1}) were recorded at three levels of 0.2, 0.5, and 0.8 water depth. In-situ water quality was recorded in the 100×100 m network and is also based on the morphology of open waters. The mean value of water quality characters are presented in Tables 2.4, 2.5 and graphical distribution of some important parameters are illustrated in Figs. 2.31, 2.32, 2.33, 2.34, 2.35, 2.36, and 2.37.

National Water Quality Standards for Malaysia (NWQS) (DOE 2006) and Water Quality Index (Brian 2010) were used to evaluate Bera Lake quality (Table 2.6). Overall classification of Bera Lake water quality before and after land development project is classified IV and V which is suitable for irrigation only and requires extensive treatment for drinking.

Water temperature is one of climate effects parameters which significantly affects kinds of aquatic life, regulate the maximum DO value of water, and influences the rate of chemical and biological reactions. Seasonal water temperature dictate organism age and life stage and higher biological and chemical reactions expect in the higher water temperature (Brian 2010). In-situ water analyzes showed that Bera Lake mean water temperature is same as Malaysia mean temperature and expects that the mean annual Bera Lake water temperature variation is less than 5 °C. In other word, annual Bera Lake chemical and biological reactions happening in limited variation and seasonal water quality represents minor differences.

Vertical water quality analysis has revealed a clear stratification in Bera Lake water profile in terms of temperature, DO, Cl^{-1}, NO_3^{2-}, pH, and EC parameters. Clear downward reduction of DO in Bera Lake water profile indicates effects of temperature. Maximum coefficient of variation of 0.5 was obtained for vertical variation of DO. Dissolved oxygen was appeared with different concentration in

Table 2.5 Bera Lake in-situ water quality sampling results

Station no.	Temp (°C)	Sal (ppt)	TDS (mg L^{-1})	Turb NTUs	pH units	NH_4^+ (mg/L–N)	NO_3^- (mg/L–N)	Cl^- (mg L^{-1})	LDO% Sat	LDO (mg L^{-1})	SpCond (mS cm^{-1})
1	28.9	0.000	23.20	1,000	5.13	0.40	0.38	2.90	29.2	2.25	36.23
2	29.1	0.000	23.18	1,000	5.18	0.35	0.58	3.39	31.9	2.45	36.25
3	29.5	0.000	23.20	1,000	5.29	0.28	0.68	3.55	33.8	2.58	36.23
4	28.7	0.000	22.97	1,000	5.88	0.33	0.38	4.16	28.0	2.17	35.90
5	28.8	0.000	23.13	1,000	5.41	0.28	0.55	4.00	30.4	2.34	36.03
6	28.8	0.000	23.10	1,000	5.37	0.27	0.69	3.77	29.7	2.29	36.03
7	28.8	0.000	23.07	1,000	5.32	0.28	0.74	3.32	28.2	2.17	36.03
8	29.3	0.003	23.73	1,000	5.39	0.31	0.78	3.12	36.1	2.77	37.17
9	29.0	0.000	23.57	1,000	5.34	0.30	0.81	3.08	22.2	1.71	36.83
10	29.1	0.000	23.27	1,000	5.39	0.29	0.78	3.13	28.9	2.22	36.33
11	28.9	0.003	23.63	1,000	5.48	0.27	1.12	3.46	28.4	2.18	36.93
12	29.1	0.007	29.67	667	5.54	0.41	1.58	3.92	24.4	1.87	36.70
13	29.0	0.000	23.03	1,000	5.44	0.26	1.29	3.43	34.5	2.65	35.93
14	28.9	0.000	23.30	1,000	5.44	0.23	1.63	3.74	28.8	2.21	36.48
15	28.9	0.000	23.10	1,000	5.48	0.23	1.39	3.90	34.6	2.65	36.03
16	28.9	0.000	23.03	1,000	5.42	0.23	1.42	3.73	32.6	2.51	35.97
17	28.9	0.000	23.03	1,000	5.36	0.23	1.59	3.49	31.0	2.38	36.10
18	28.8	0.000	23.03	1,000	5.37	0.24	1.48	3.58	31.9	2.46	36.00
19	29.0	0.000	23.00	1,000	5.31	0.24	1.49	3.32	33.8	2.60	35.97
20	29.0	0.000	23.23	1,000	5.34	0.25	1.63	3.26	34.3	2.64	36.47
21	28.6	0.000	23.17	1,000	5.38	0.25	1.71	3.15	27.0	2.08	36.17
22	28.9	0.000	23.10	1,000	5.38	0.22	1.57	3.79	28.3	2.18	36.10
23	28.9	0.000	23.07	1,000	5.32	0.23	1.58	3.29	31.5	2.43	36.00
24	28.9	0.000	22.97	1,000	5.42	0.21	2.01	4.43	32.5	2.50	35.93
25	28.9	0.000	23.08	1,000	5.43	0.22	1.78	3.76	32.8	2.53	36.08
26	28.9	0.000	23.07	1,000	5.37	0.23	1.63	3.60	32.6	2.51	36.03
27	28.8	0.000	22.93	1,000	5.35	0.24	1.40	3.11	28.3	2.18	35.80

28	28.8	0.000	23.33	1,000	5.39	0.25	1.68	3.28	23.7	1.83	35.87
29	29.0	0.003	24.73	1,000	5.40	0.29	1.82	3.58	29.1	2.23	38.70
30	29.0	0.000	23.07	1,000	5.34	0.23	1.72	3.52	29.3	2.25	35.97
31	28.9	0.000	23.03	1,000	5.45	0.22	1.64	3.56	32.0	2.47	36.03
32	26.6	0.007	26.17	1,000	5.66	0.31	1.45	2.88	25.9	2.07	52.30
33	27.1	0.000	23.80	1,000	5.47	0.34	1.19	2.47	31.6	2.50	37.15
34	28.9	0.000	23.03	1,000	5.58	0.23	1.46	3.46	36.8	2.84	35.97
35	29.0	0.000	23.10	1,000	5.42	0.19	1.99	3.88	31.4	2.42	36.10
36	29.0	0.000	22.93	1,000	5.32	0.26	1.65	3.00	32.4	2.49	35.87
37	28.8	0.003	24.73	1,000	5.42	0.24	2.27	4.07	27.8	2.14	38.33
38	29.0	0.000	22.90	1,000	5.37	0.26	1.79	3.30	34.0	2.61	35.87
39	28.8	0.003	25.63	1,000	5.43	0.24	2.61	3.43	26.5	2.04	39.43
40	29.1	0.000	22.87	1,000	5.38	0.25	2.00	3.00	36.4	2.80	35.93
41	29.0	0.000	23.10	1,000	5.37	0.25	1.91	3.04	27.7	2.13	36.13
42	29.1	0.000	23.10	1,000	5.34	0.26	1.57	2.74	34.5	2.64	36.10
43	28.9	0.000	23.13	1,000	5.36	0.25	1.63	3.11	29.0	2.23	36.17
44	29.0	0.000	23.07	1,000	5.39	0.24	1.89	3.29	34.0	2.61	36.00
45	29.1	0.000	23.10	1,000	5.33	0.26	1.65	2.60	32.9	2.53	36.10
46	29.0	0.000	23.17	1,000	5.33	0.26	1.53	2.75	27.9	2.15	36.17
47	28.9	0.000	23.17	1,000	5.27	0.25	1.67	2.85	28.9	2.22	36.23
48	29.4	0.000	23.02	1,000	5.33	0.23	1.93	3.07	37.7	2.88	35.92
49	29.4	0.003	24.47	1,000	5.47	0.26	2.13	3.32	29.5	2.24	38.23
50	29.3	0.000	23.20	1,000	5.40	0.32	2.07	2.74	35.2	2.69	36.23
51	29.2	0.000	23.10	1,000	5.31	0.25	1.88	2.93	35.1	2.69	36.10
	28.9	0.001	23.47	993	5.39	0.26	1.49	3.36	30.9	2.38	36.68
							1.75				

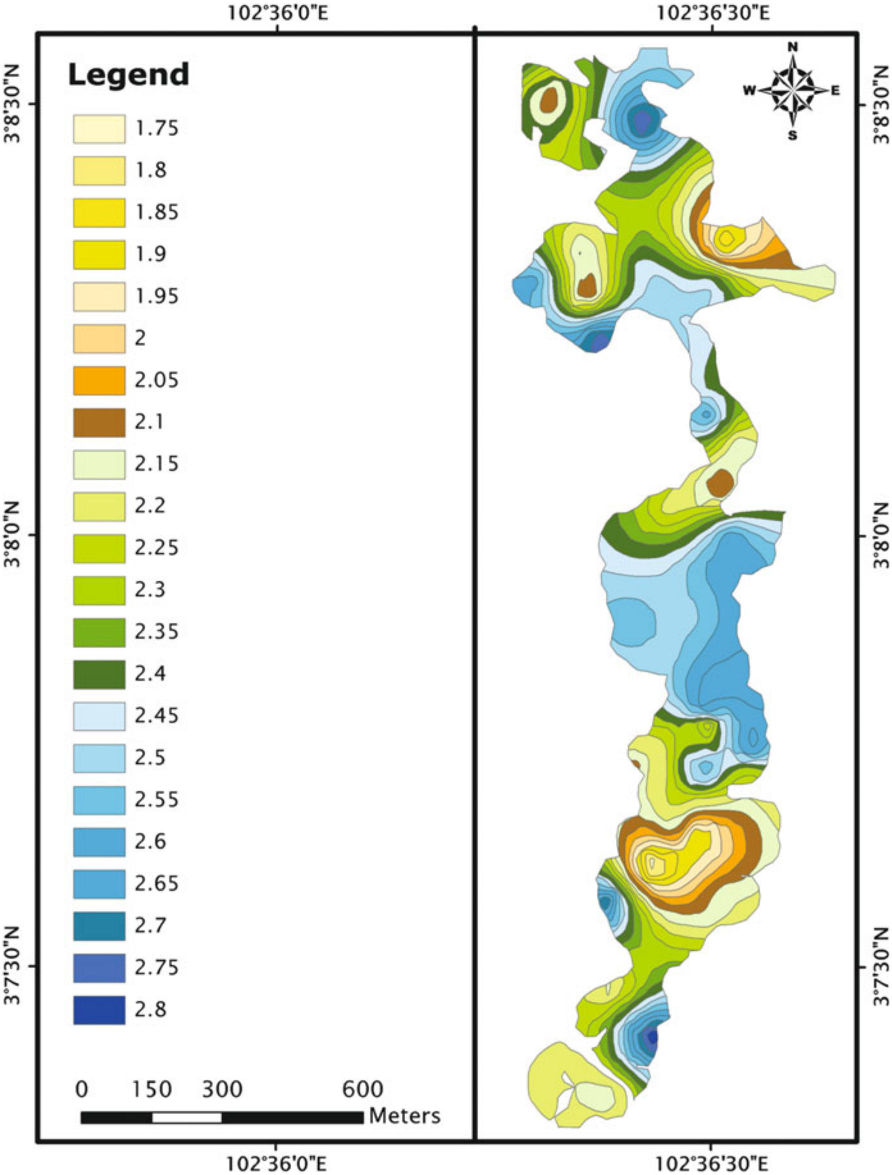

Fig. 2.31 Situation of DO (mg L^{-1}) in Bera Lake

Bera Lake (Fig. 2.31) as well as its variation with depth. The lowest DO values were recorded at the south and northeast open waters which probably have a weak water circulation and partially restricted by some plant species such as *Pandanus*. These areas were recognized as the worst locations for biological activities. The mean Do

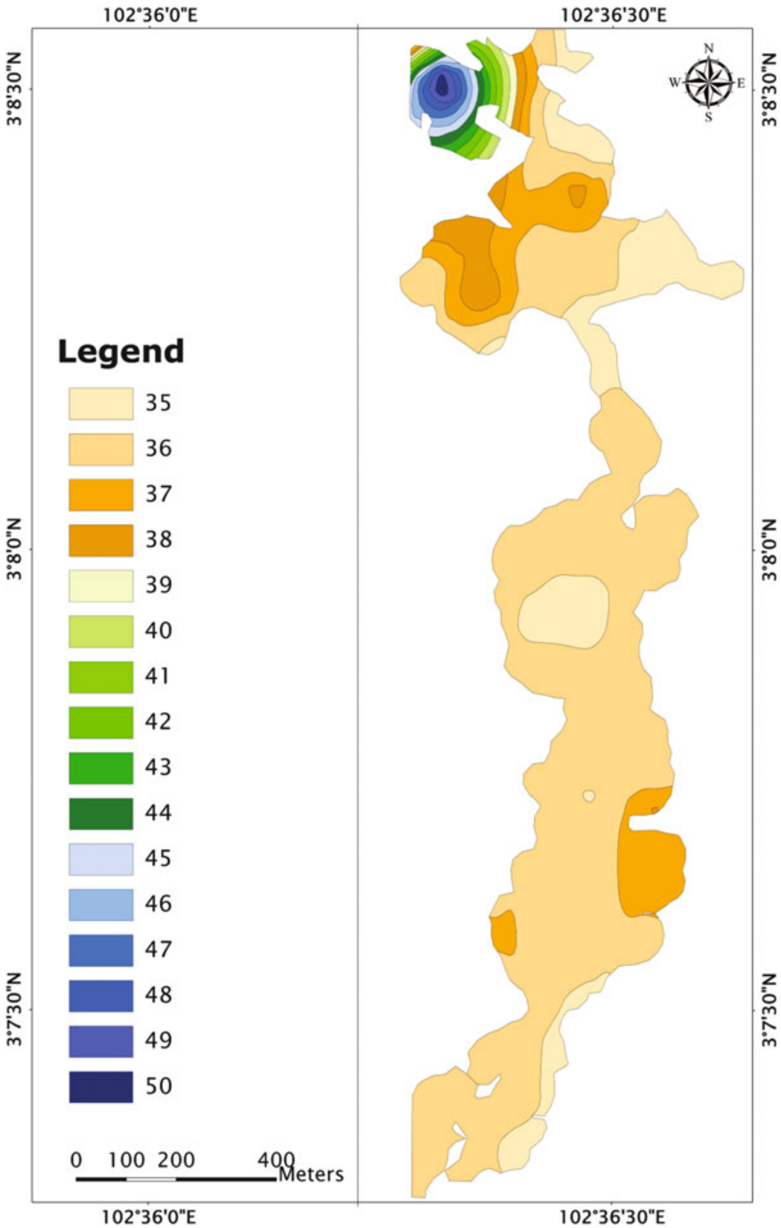

Fig. 2.32 EC (mS cm^{-1}) of water in Bera Lake

value obtained was 2.38 mg L^{-1} may adversely affect the functioning and survival of biological communities. The microbial activity (respiration) has enhanced during the degradation of the organic and nutrients rich waste water, resulted in DO values reduction (Chapman and Kimstach 1996).

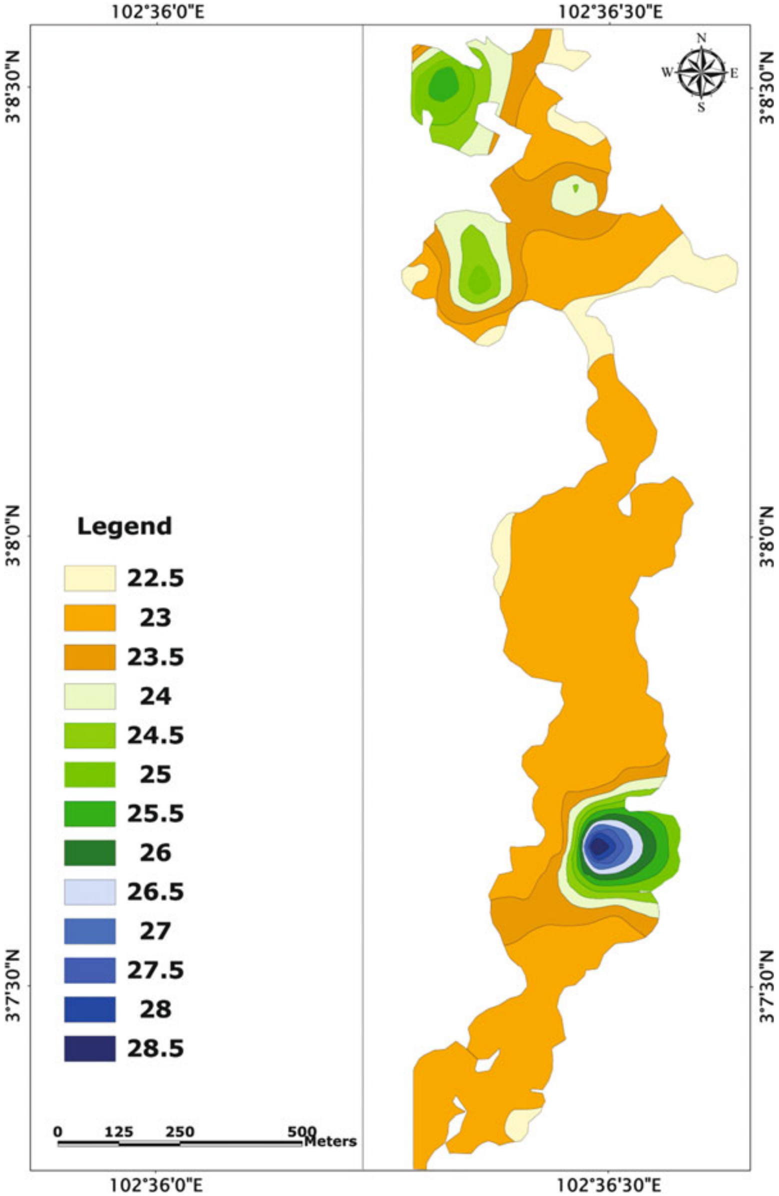

Fig. 2.33 TDS (mg L^{-1}) levels in Bera Lake

Figure 2.34 depicts that Bera Lake water is moderately homogenous in terms of electrical conductivity and total dissolved solid except at northwest part or Kelantong water entry point. A significant correlation between distribution of TDS and EC values was revealed in Bera Lake. Minimum variations in EC and TDS values were recorded in vertical water profile. Dramatic increment of EC and TDS

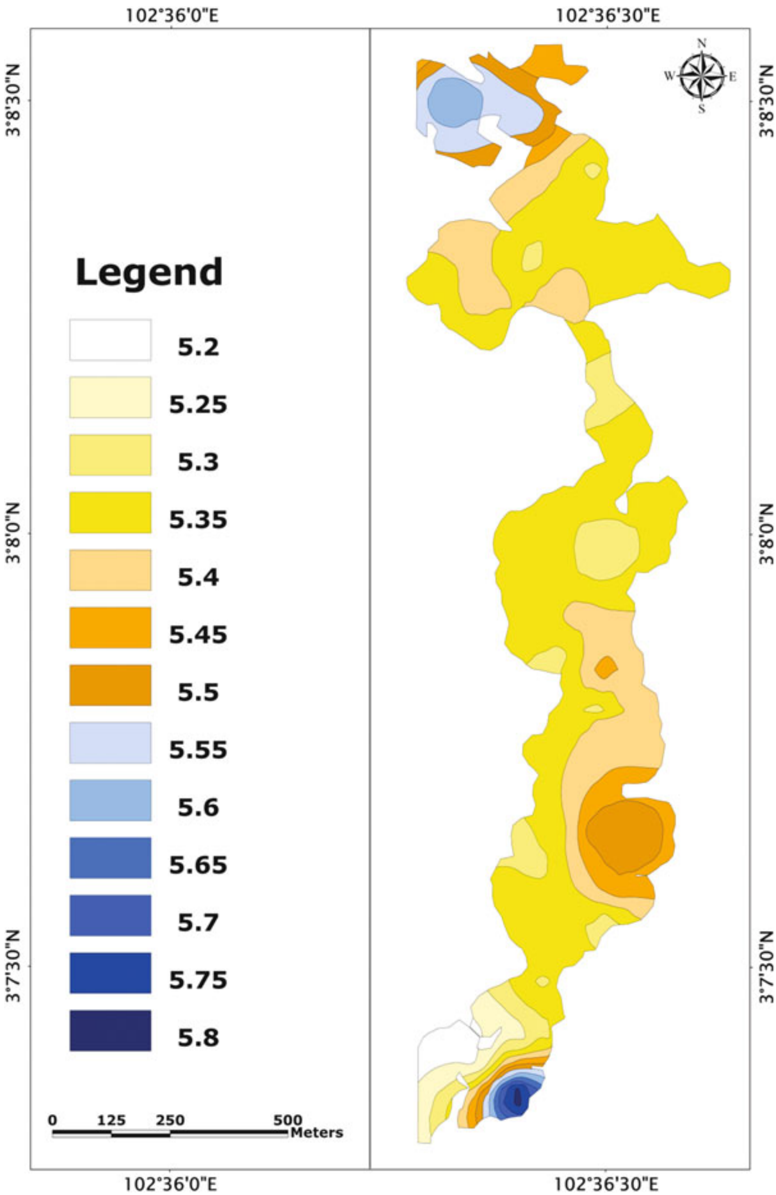

Fig. 2.34 Distribution of water acidity (pH) in Bera Lake

should implication of polluted water (Chapman and Kimstach 1996). In addition, semi-closed open waters and reed swamp at northwest of Bera Lake represents high evaporation and increase of total dissolved solid as well as electrical conductivity.

The acidity of water depends on the strong mineral acids, weak acids such as carbonic, humic and fulvic, and hydrolyzing salts of metals (e.g. iron, aluminum),

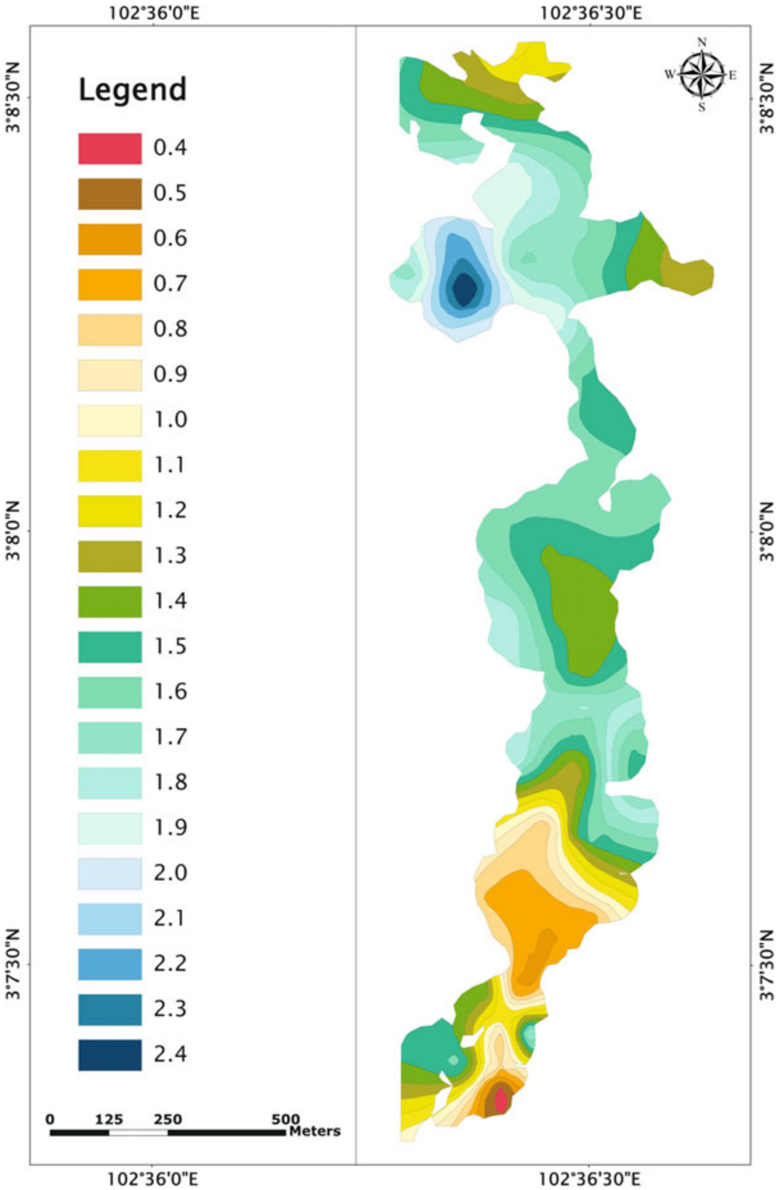

Fig. 2.35 NO_3^{2-} (mg L^{-1}) levels in Bera Lake

as well as strong acids. Bera Lake represents acidic condition with the mean average of 5.39. In such condition bottom-dwelling decomposing bacteria begin to die off and leaf litter and dead plant and animal materials begin to deposition. With regards to heavy metals, the degrees to which they are soluble usually

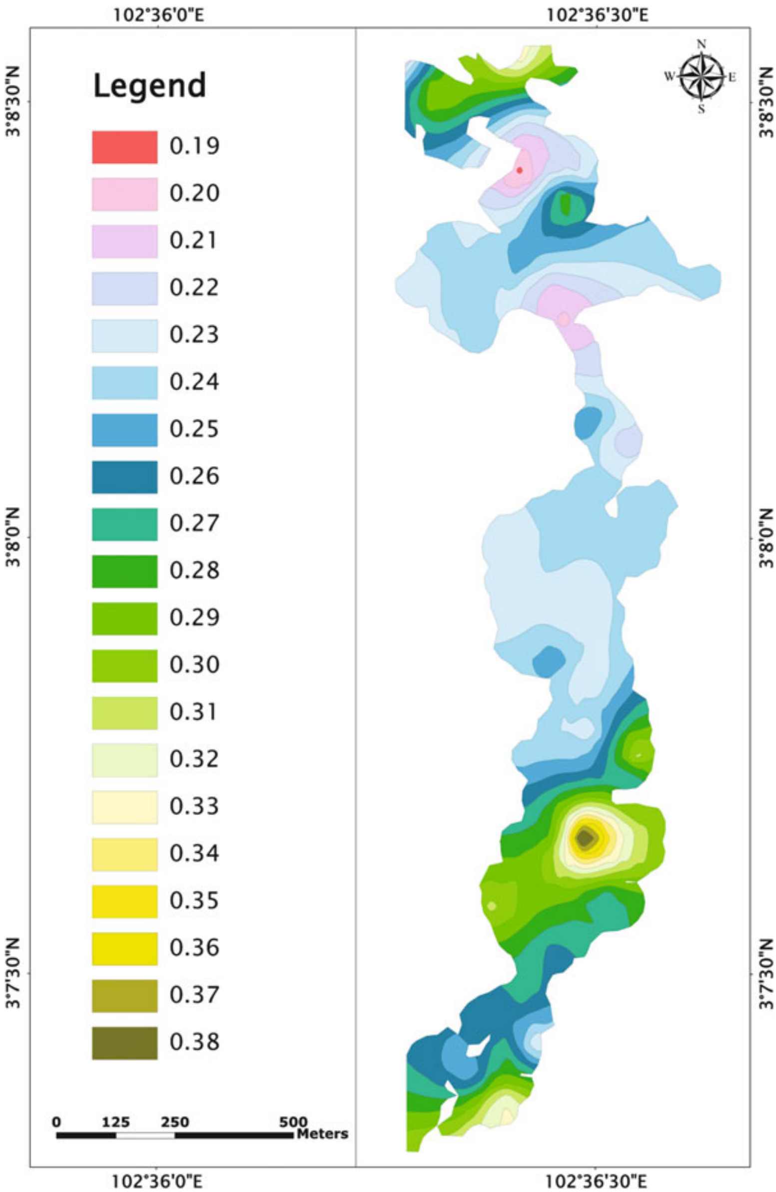

Fig. 2.36 Ammonium (mg L^{-1}) levels in Bera Lake

determine their toxicity. The lower the pH, the more toxic the metal as they are more soluble then. Solubility refers to the amount that can be dissolved in water (Chapman and Kimstach 1996).

Slightly downward increase having CV of 0.02 in water acidity is observed at Bera Lake. Distribution of acidity in Bera Lake is uniform except at the southern and northern part and at sediment entry points while slightly increased at eastern of the south of basin. A clear correlation between pH and EC was obtained at the south

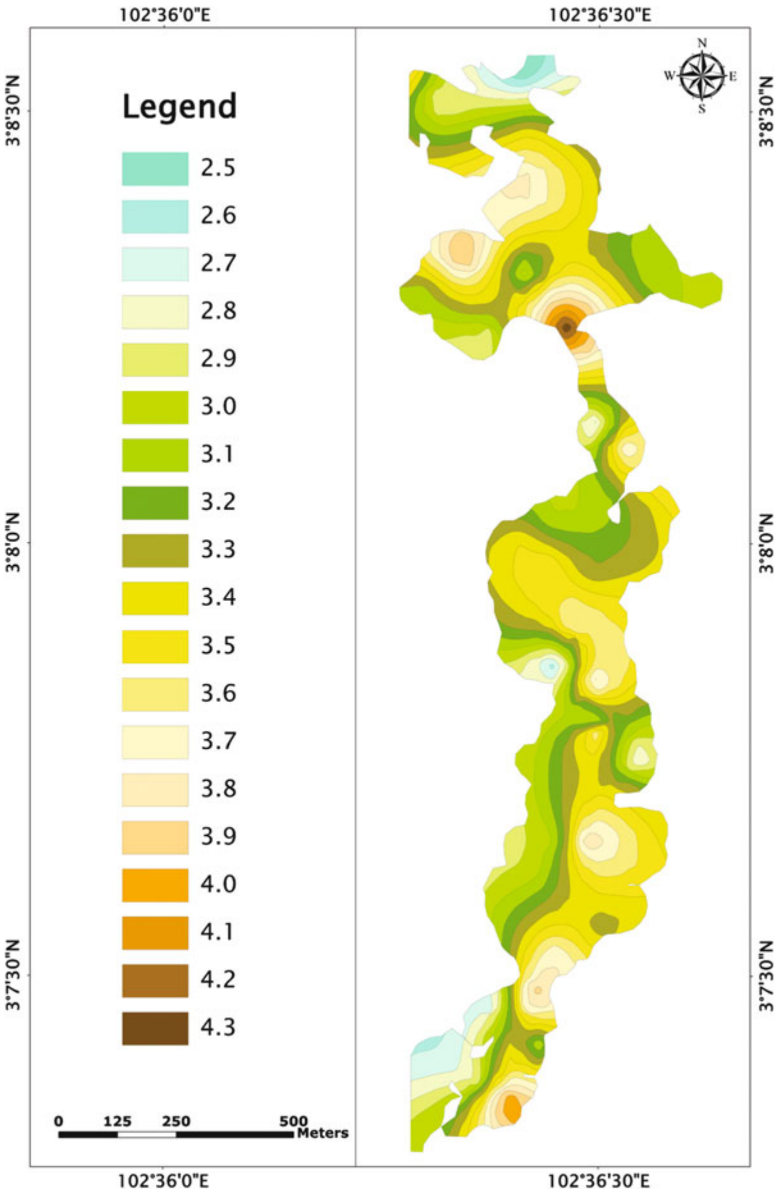

Fig. 2.37 Chloride (mg L^{-1}) levels in Bera Lake

of Bera Lake, which indicate an effluent plum or discharge into the open water. Similar to DO, increase of acidity at surface water has controlled by higher temperature and photosynbook.

Another parameter which represents Bera Lake water quality was NO_3^{2-} which is the common form of combined nitrogen found in natural waters. Natural sources of NO_3^{2-} to surface waters include igneous rocks, land drainage and plant and

Table 2.6 Bera Lake water quality that obtained based on NWQS and WQI guidelines

				Parameter					WQI	
Sampling	Salinity	TDS	pH	No_3^-	Cl^-	DO	EC	Turbidity	Brain 2010	DOE 2006
IBP1972	–	–	III	V	–	IV	–	II	39	41
Current study	I	I	IV	V	I	IV	III	IIA	Very bad	Polluted

animal debris. In lakes, concentrations of NO_3^{2-} in excess of 0.2 mg L^{-1} NO_3^{2-} tend to stimulate algal growth and indicate possible eutrophic conditions (Chapman and Kimstach 1996).

The mean average of NO_3^{2-} was obtained to be 1.49 mg L^{-1} which is indicator of a moderate eutrophication in Bera Lake. Chapman and Kimstach (1996) stated that land clearing and plough for cultivation has increased soil aeration, resulted in enhancement of nitrifying bacteria action and production of soil NO_3^{2-}. Furthermore, burning of felled tress has been released a large amount of nitrogen especially after the first heavy raining to the sink areas. Both mechanisms have happened in BLC since 1972 in which half of study area cleared, disturbed and felled tress burned. The most concentration of NO_3^{2-} was recorded at one of semi-closed open waters at northwest of Bera Lake. The rest of lake represents an acceptable range between 0.4 and 1.9 mg L^{-1}. Bera Lake water column was appeared stratified and upward increasing in NO_3^{2-} concentration is dominated. According to Chapman and Kimstach (1996) natural occurrence of ammonia in water bodies promoting from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of the nitrogen gas in water by micro-organisms and from gas exchange with the atmosphere. The mean average of ammonia was obtained to be 0.26 mg L^{-1}. Bera Lake water profile represents clear reduction downward in ammonia with a coefficient of variation 0.51 in which ammonia value deplete two times with depth. Chapman and Kimstach (1996) stated that ammonia plays an important role in creation of toxic condition for aquatic life and being detrimental for the ecological balance of open waters at certain pH levels. Higher concentration of ammonia and pH is observed at surface water in the Bera Lake. The mean average value of ammonia content is an indication of organic pollution by agriculture or industrial sewages, and fertilizer run-off at BLC area.

Chlorine enters surface waters with the atmospheric deposition of oceanic aerosols, by the weathering of some sedimentary rocks (mostly rock salt deposits) and from industrial and sewage effluents, and agricultural and road run-off (Chapman and Kimstach 1996). Minimum Cl^- value was recorded at the south water entry point and at the departure point of Bera Lake. Conversely, the highest value of Cl^- was obtained at the north open water especially at the end of connection channel. There is vivid increment downward in Cl^- concentration with coefficient of variation of 0.25. Probably downward increasing of Cl^- and NO_3^{2-} are two active ions in Bera Lake water column, which points out a significant correlation with anoxic condition and lowest DO.

2.2.4 Physical Properties of Bera Lake Sediment

Physical properties of a lake can talk properly about current and long-term physical condition of depositional system. Sediments in all sedimentary media involves signature of natural events and anthropogenic changes in source and sink areas. Bera Lake as other fresh water lakes around the world has experienced several changes in sediments physical properties over the last decades (Malmer 1990).

Grain size distribution, bulk density, moisture, soil, and porosity contents, soil and sediment classification are physical properties which have been determined in this research. Detailed physical properties of Bera Lake sediment column represented by 300 subsamples which were analyzed in depth intervals of 2 ± 0.2 cm. These samples were

Grain size distribution diagrams and calculation of statistical parameters were achieved by GRADISTAT, Version 6.0 (Blott and Pye 2001). The program is best suited to analyze data obtained from sieve or laser granulometer analysis. For this purpose, the mass or percentage of sediment retained on sieves spaced at intervals, or the percentage of sediment detected in each bin of a Laser Granulometer was transferred to GRADISTAT. The following sample statistics are then calculated using the Method of Moments: mean, mode(s), sorting (standard deviation), skewness, kurtosis, D_{10}, D_{50}, D_{90}, D_{90}/D_{10}, D_{90}-D_{10}, D_{75}/D_{25} and D_{75}-D_{25}. Grain size parameters are calculated arithmetically and geometrically (in microns) and logarithmically (using the phi scale) (Krumbein and Pettijohn 1983). Linear interpolation was also used to calculate statistical parameters by the graphical method (Folk and Ward 1957) and derive physical descriptions (such as “very coarse sand” and “moderately sorted”). The program also provides a physical description of the textural group which the sample belongs to and the sediment name (such as “fine gravelly coarse sand”) after Folk (1954). Table that gives the percentage of grains falling into each size fraction, modified from Udden (1914) is also included. In terms of graphical output, the program provides graphs of the grain size distribution and cumulative distribution of the data in both metric and phi units, and was displayed the sample grain size on triangular diagrams.

Consequently, five distinct layers were identified in the first 1 m thickness of Bera Lake sediment profile (Fig. 2.38). These layers with different thickness differentiated along all cores or at whole lake area. The identified layers have been confirmed after analysis of subsamples for grain size, bulk density, porosity, and organic matters.

Description of Bera Lake physical properties have continued by introducing of stratigraphic layers of sediment column. Core 7 recognized as master core to analyze grain size distribution in Bera Lake sediment column. Additionally, some samples from individual layers of Cores 5 and 6 were analyzed as control samples in order to verify the results of master core. Core 7 is the longest among the all collected cores which have taken from Bera Lake. Detailed grain size distribution and relevant statistical parameters for each sample presented in Fig. 2.39 and Table 2.6. Bulk density and porosity are inevitable physical

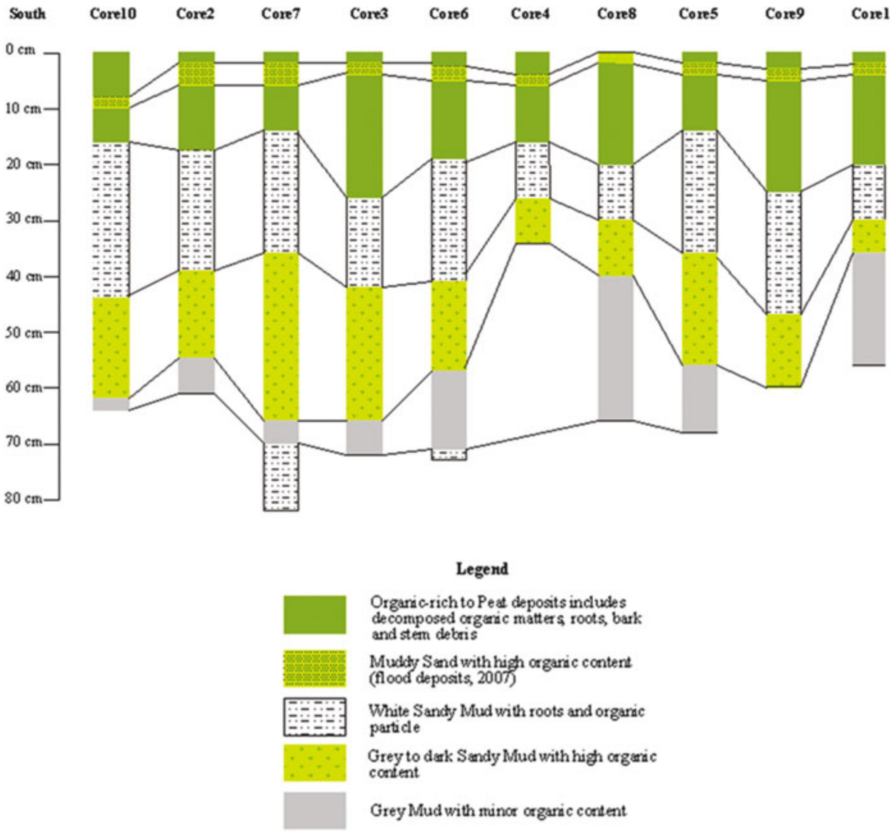

Fig. 2.38 Stratigraphic layers of Bera Lake sediment profile

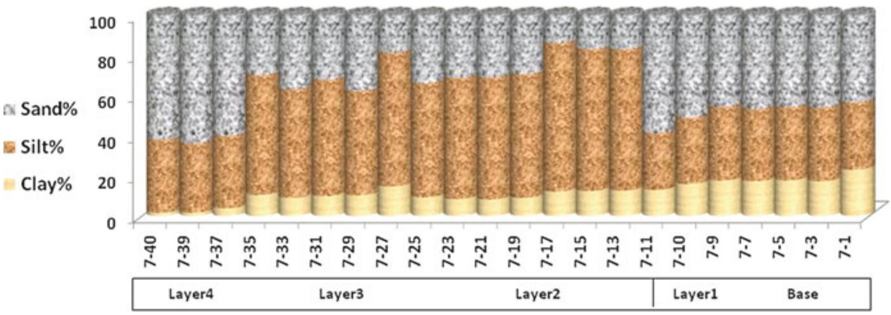

Fig. 2.39 Grain size distributions along the master core 7

properties of sediments in a sedimentological study of each basin. Bulk density is necessary for estimation of sedimentation rate using radioisotopes techniques (Appleby and Oldfield 1978).

Minerals and coarse grain particles contribute in increase of bulk density. However, fine grain size sediments, organic matters and porosity cause to decrease bulk density values. Therefore, bulk density and porosity used as indicators of environmental changes which have occurred over the past decades in BLC. Variations of bulk density and porosity values with depth have presented in Figs. 2.40 and 2.41, respectively (Table 2.8).

2.2.4.1 Sediment Layers Stratigraphy

The first layer from base in Bera Lake sediment profile is gray mud with 20 cm. Consequently, five distinct layers were identified in the first one meter thickness of Bera Lake sediment profile (Fig. 2.38). These layers with different thickness differentiated along all cores or at whole lake area. The identified layers have been confirmed after analysis of subsamples for grain size, bulk density, porosity, and organic matters.

Description of Bera Lake physical properties have continued by introducing of stratigraphic layers of sediment column. Core 7 recognized as master core to analyze grain size distribution in Bera Lake sediment column. Additionally, some samples from individual layers of Cores 5 and 6 were analyzed as control samples in order to verify the results of master core. Core 7 is the longest among the all collected cores which have taken from Bera Lake. Detailed grain size distribution and relevant statistical parameters for each sample presented in Table 2.7. Bulk density and porosity are inevitable physical properties of sediments in a sedimentological study of each basin. Bulk density is necessary for estimation of sedimentation rate using radioisotopes techniques (Appleby and Oldfield 1978).

2.2.4.1.1 Gray Mud to Sandy Mud (Layer 1)

The first layer from base in Bera Lake sediment profile is gray mud with 20-cm average thickness. Maximum thickness was recorded in Cores 1 and 8. Layer 1 overlaying white sandy mud is considered as substrate in the present study. It was recognized that muddy texture with clay, silt and sand size grains has contributed at an average of 18 ± 2.5, 35 ± 1.7, and 48 ± 2.5 %, respectively. Contribution of clay mineral in layer 1 at the middle and the north of Bera Lake sediment column decreased to 10 % while silt size grains portion has been increased to 62 %. Mean grain size represents coarse to very coarse silt with a very poorly sorted texture. Layer 1 at the south of Bera Lake is composed of polymodal sediments while it comprises unimodal sediments at the middle and the north of study area. Its cumulative curve skewed to fine grains and which illustrate its platykurtic to mesokurtic shape. Grain size description of cores indicates existence of roots, barks, and charcoals in some sub-layers. The highest lithogenic content in layer 1 caused an increase of bulk density to 2.57 g cm^{-3} in Core 10. This value calculated to be 1.58, 1.47, 1.4 g cm^{-3} in layer 1 at cores 2, 7, and 5, respectively. Porosity

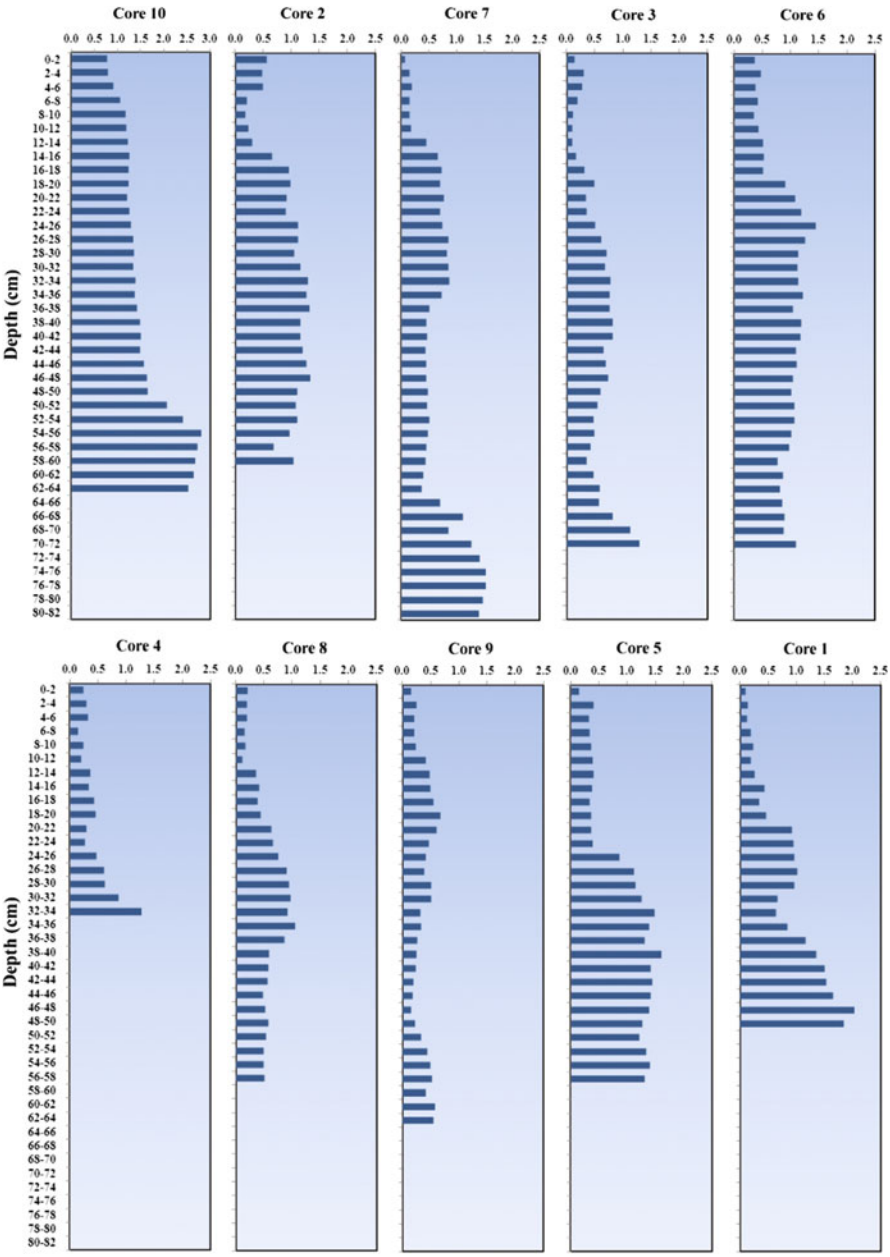

Fig. 2.40 Northward bulk density variations in Bera Lake sediment profile

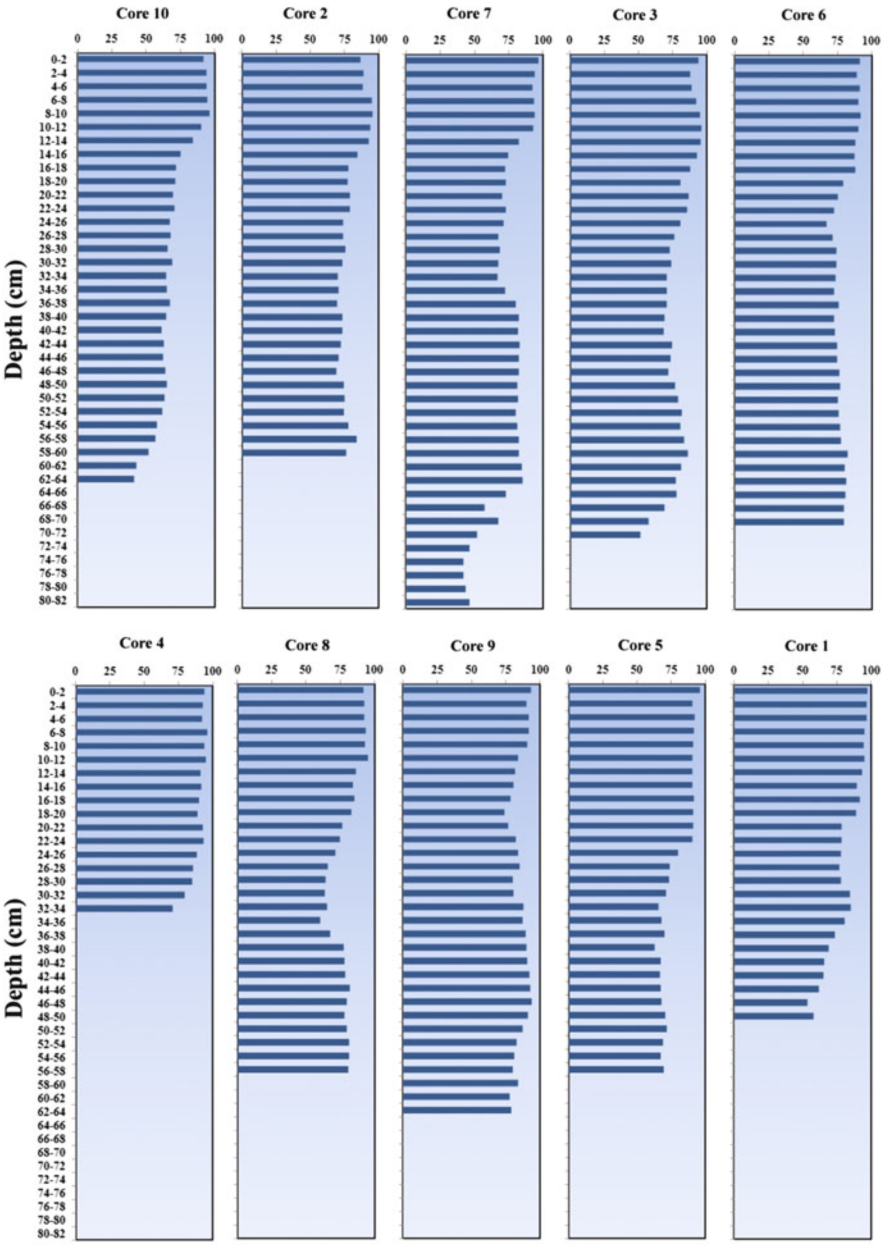

Fig. 2.41 Northward porosity variations in Bera Lake sediment profile

Table 2.7 (a)–(g) Sediment size distribution in master core 7 and statistical parameters

		7-1	7-3	7-5
(a) Sediment size distribution in master core 7 and statistical parameters				
Sample statistics parameters	Sample type:	Polymodal, very poorly sorted	Polymodal, very poorly sorted	Polymodal, very poorly sorted
	Textural group:	Sandy mud	Sandy mud	Sandy mud
	Sediment name:	Coarse sandy mud	Coarse sandy very coarse silt	Coarse sandy very coarse silt
Folk and ward method (f)	Mean ($\bar{x}_a$) :	5.392	4.946	4.965
	Sorting (σ_I):	3.956	3.589	3.612
	Skewness (Sk_I):	0.211	0.200	0.199
	Kurtosis K_G:	0.719	0.728	0.722
Folk and ward method (Description)	Mean:	Coarse silt	Very coarse silt	Very coarse silt
	Sorting:	Very poorly sorted	Very poorly sorted	Very poorly sorted
	Skewness:	Fine skewed	Fine skewed	Fine skewed
	Kurtosis:	Platykurtic	Platykurtic	Platykurtic
Mode (mm)	Mode 1 (mm):	816.5	816.5	816.5
	Mode 2 (mm):	0.985	0.985	152.176
	Mode 3 (mm):	8.359	1.558	0.985
Grain size	% Gravel:	0.0	0.0	0.0
	% SAND:	43.4	45.9	45.8
	% MUD:	56.6	54.1	54.2

		7-7	7-9	7-10
(b) Sediment size distribution in master core 7 and statistical parameters				
Sample statistics parameters	Sample type:	Polymodal, very poorly sorted	Polymodal, Very Poorly Sorted	Trimodal, very poorly sorted
	Textural group:	Sandy mud	Sandy mud	Muddy sand
	Sediment name:	Coarse sandy very coarse silt	Coarse sandy very coarse silt	Very coarse silty coarse sand
Folk and ward method (f)	Mean ($\bar{x}_a$) :	4.898	4.974	4.647
	Sorting (σ_I):	3.607	3.601	3.600
	Skewness (Sk_I):	0.217	0.200	0.301
	Kurtosis K_G:	0.726	0.732	0.771
Folk and ward method (Description)	Mean:	Very coarse silt	Very coarse silt	Very coarse silt
	Sorting:	Very poorly sorted	Very poorly sorted	Very poorly sorted
	Skewness:	Fine skewed	Fine skewed	Very fine skewed
	Kurtosis:	Platykurtic	Platykurtic	Platykurtic
Mode (mm)	Mode 1 (mm):	1.0	177.3	816.5
	Mode 2 (mm):	8.359	0.985	0.985
	Mode 3 (mm):	11.345	9.738	3.895
Grain size	% Gravel:	0.0	0.0	0.0
	% SAND:	46.7	45.6	51.0
	% MUD:	53.3	54.4	49.0

(continued)

Table 2.7 (continued)

		7-12	7-15	7-17
(c) Sediment size distribution in master core 7 and statistical parameters				
Sample statistics parameters	Sample type:	Trimodal, very poorly sorted	Unimodal, very poorly sorted	Unimodal, very poorly sorted
	Textural group:	Muddy sand	Sandy mud	Sandy mud
	Sediment name:	Very coarse silty coarse sand	Very fine sandy very coarse silt	Very fine sandy very coarse silt
Folk and ward method (f)	Mean $(\bar{x}_a)$:	4.110	6.023	6.100
	Sorting (σ_I):	3.458	2.311	2.211
	Skewness (Sk_I):	0.396	0.276	0.283
	Kurtosis K_G:	0.860	1.050	1.055
Folk and ward method (Description)	Mean:	Very coarse silt	Medium silt	Medium silt
	Sorting:	Very poorly sorted	Very poorly sorted	Very poorly sorted
	Skewness:	Very fine skewed	Fine skewed	Fine skewed
	Kurtosis:	Platykurtic	Mesokurtic	Mesokurtic
Mode (mm)	Mode 1 (mm):	816.5	44.8	38.5
	Mode 2 (mm):	0.985		
	Mode 3 (mm):	3.344		
Grain size	% Gravel:	0.0	0.0	0.0
	% SAND:	58.7	16.9	13.8
	% MUD:	41.3	83.1	86.2

		7-19	7-21	7-23
(d) Sediment size distribution in master core 7 and statistical parameters				
Sample statistics parameters	Sample type:	Unimodal, very poorly sorted	Unimodal, very poorly sorted	Unimodal, very poorly sorted
	Textural group:	Sandy mud	Sandy mud	Sandy mud
	Sediment name:	Very fine sandy very coarse silt	Very fine sandy very coarse silt	Very fine sandy very coarse silt
Folk and ward method (f)	Mean $(\bar{x}_a)$:	5.325	5.218	5.246
	Sorting (σ_I):	2.335	2.270	2.303
	Skewness (Sk_I):	0.281	0.290	0.288
	Kurtosis K_G:	1.109	1.108	1.089
Folk and ward method (Description)	Mean:	Coarse silt	Coarse silt	Coarse silt
	Sorting:	Very poorly sorted	Very poorly sorted	Very poorly sorted
	Skewness:	Fine skewed	Fine skewed	Fine skewed
	Kurtosis:	Mesokurtic	Mesokurtic	Mesokurtic
Mode (mm)	Mode 1 (mm):	44.8	52.2	52.2
	Mode 2 (mm):			
	Mode 3 (mm):			
Grain size	% Gravel:	0.0	0.0	0.0
	% SAND:	29.4	31.0	31.2
	% MUD:	70.6	69.0	68.8

(continued)

Table 2.7 (continued)

		7-25	7-27	7-29
(e) Sediment size distribution in master core 7 and statistical parameters				
Sample statistics parameters	Sample type:	Unimodal, very poorly sorted	Bimodal, very poorly sorted	Unimodal, very poorly sorted
	Textural group:	Sandy mud	Sandy mud	Sandy mud
	Sediment name:	Very fine sandy very coarse silt	Very fine sandy very coarse silt	Very fine sandy very coarse silt
Folk and ward method (f)	Mean ($\bar{x}_a$) :	5.198	6.096	5.239
	Sorting (σ_I):	2.379	2.452	2.505
	Skewness (Sk_I):	0.350	0.325	0.325
	Kurtosis K_G:	1.120	0.958	1.035
Folk and ward method (Description)	Mean:	Coarse silt	Medium silt	Coarse silt
	Sorting:	Very poorly sorted	Very poorly sorted	Very poorly sorted
	Skewness:	Very fine skewed	Very fine skewed	Very fine skewed
	Kurtosis:	Leptokurtic	Mesokurtic	Mesokurtic
Mode (mm)	Mode 1 (mm):	60.9	52.2	60.9
	Mode 2 (mm):		0.459	
	Mode 3 (mm):			
Grain size	% Gravel:	0.0	0.0	0.0
	% SAND:	33.8	18.8	34.7
	% MUD:	66.2	81.2	65.3
		7-31	7-33	7-35
(f) Sediment size distribution in master core 7 and statistical parameters				
Sample statistics parameters	Sample type:	Unimodal, very poorly sorted	Unimodal, very poorly sorted	Unimodal, very poorly sorted
	Textural group:	Sandy mud	Sandy mud	Sandy mud
	Sediment name:	Very fine sandy very coarse silt	Very fine sandy very coarse silt	Very fine sandy very coarse silt
Folk and ward method (f)	Mean ($\bar{x}_a$) :	5.309	5.087	5.437
	Sorting (σ_I):	2.436	2.386	2.422
	Skewness (Sk_I):	0.319	0.346	0.322
	Kurtosis K_G:	1.064	1.073	1.038
Folk and ward method (Description)	Mean:	Coarse silt	Coarse silt	Coarse silt
	Sorting:	Very poorly sorted	Very poorly sorted	Very poorly sorted
	Skewness:	Very fine skewed	Very fine skewed	Very fine skewed
	Kurtosis:	Mesokurtic	Mesokurtic	Mesokurtic
Mode (mm)	Mode 1 (mm):	52.2	70.9	52.2
	Mode 2 (mm):			
	Mode 3 (mm):			
Grain size	% Gravel:	0.0	0.0	0.0
	% SAND:	32.1	36.9	29.9
	% MUD:	67.9	63.1	70.1

(continued)

Table 2.7 (continued)

		7-37	7-39	7-40
(g) Sediment size distribution in master core 7 and statistical parameters				
Sample statistics parameters	Sample type:	Unimodal, poorly sorted	Unimodal, poorly sorted	Unimodal, poorly sorted
	Textural group:	Muddy sand	Muddy sand	Muddy sand
	Sediment name:	Very coarse silty fine sand	Very coarse silty fine sand	Very coarse silty fine sand
Folk and ward method (f)	Mean ($\bar{x}_a$) :	3.777	3.657	3.739
	Sorting (σ_I):	1.920	1.730	1.703
	Skewness (Sk_I):	0.321	0.371	0.346
	Kurtosis K_G:	1.123	1.046	1.051
Folk and ward method (Description)	Mean:	Very fine sand	Very fine sand	Very fine sand
	Sorting:	Poorly sorted	Poorly sorted	Poorly sorted
	Skewness:	Very fine skewed	Very fine skewed	Very fine skewed
	Kurtosis:	Leptokurtic	Mesokurtic	Mesokurtic
Mode (mm)	Mode 1 (mm):	206.5	177.3	177.3
	Mode 2 (mm):			
	Mode 3 (mm):			
Grain size	% Gravel:	0.0	0.0	0.0
	% SAND:	60.0	63.9	62.0
	% MUD:	40.0	36.1	38.0

Table 2.8 Mean bulk density (g cm^{-3}) of Bera Lake sediment layers

	Core number									
Layer no.	1	2	3	4	5	6	7	8	9	10
4	0.23	0.36	0.27	0.28	0.35	0.45	0.20	0.27	0.40	1.09
3	0.88	1.01	0.71	0.40	0.88	1.16	0.75	0.73	0.32	1.37
2	0.78	1.18	0.58	0.85	1.40	1.06	0.52	0.88	0.41	2.12
1	1.58	0.90	1.20	NR	1.40	0.87	1.47	0.53	NR	2.57
Base	NR	NR	NR	NR	NR	0.99	1.47	NR	NR	NR

NR Not recorded in collected core

values showed a downward decrease with depth especially in cores 1, 3, 4, 7, and Core 10. The lowest porosity value in Bera Lake sediment column calculated to be 42 and 41.5 % respectively in layer 1 of cores 7 and 10. The mean porosity value of layer 1 was obtained 75 ± 0.06 % in studied cores.

2.2.4.1.2 Gray to Dark Sandy Mud (Layer2)

This section of sediment profile with 25 cm average thickness, characterized by medium size matrix, abundance of partly decomposed roots, barks, stems, charcoal and organic debris, and gray to dark color. Lithology in Layer 2 gradually changed from grey to dark sandy mud and then to muddy sand deposits. Muddy matrix and clay size grain portion has decreased in Layer 2. Clay, silt and sand size grains have been contributed with an average of 11 ± 2, 61 ± 15, and 28 ± 15 %, respectively. The mean size is comparable to coarse silt, very poorly sorted texture and platykurtic shape of cumulative curve. Bulk density in the most of studied cores was reduced because of organic contamination especially in Cores 1, 3, 4, 7, 8, and 9. Minimum, maximum and average of bulk density in Layer 2 was calculated to be 0.41, 2.12, and 0.98 ± 0.5 g cm^{-3}, respectively. The minimum, maximum, and mean porosity values for layer 2 calculated to be 69.83, 79.53, and 76 ± 0.06 % respectively. The maximum porosity in Layer 2 observed in Cores 9, 4, 1, and 7 which are in positive correlation with the lowest bulk density values.

2.2.4.1.3 White Sandy Mud (Layer 3)

Erosion-induce deposits accumulated in Bera Lake as white sandy mud sediments in Layer 3 during and after maximum deforestation activities. It overlaid on Layer 2 with a sharp contact. Contribution of silt size grains was increased to 58 ± 5 % while clay and sand portions were reduced to 11 ± 2 and 32 ± 7 % on the average. Although, analyzed samples in this layer represent a mesokurtic and unimodal cumulative curve, but they are very poorly sorted sediments. The mean grain size is in the range of coarse silt and the sedimentological name is very fine sandy very coarse silt. Analyzed samples from same layer in Core 5 and 6 represented similar kind of statistic parameters. Contribution of clay, silt and sand size grains at the middle and north of study area were calculated to be 15, 68, and 17 %, respectively. A remarkable charcoal horizon was recognized at lower contact of Layer 3, signals of maximum land preparation by burning of fallen trees. This horizon has significantly reduced bulk density values to 0.5 g cm^{-3} in Cores 1, 4, and 9. Lithogenic contents in Layer 3 have contributed to increase bulk density especially in Cores 1, 3, 6, and 7. Minimum, maximum and mean bulk density values in Layer 3 calculated to be 0.32, 1.37, and 0.82 ± 0.31 g cm^{-3}, respectively. Scatter roots, barks, charcoals were found along this layer. The highest porosity of Layer 3 was observed in Cores 4, 9, 5 and 6. These cores seem to be more contaminated by organic matters than others. The maximum, minimum, and mean porosity values for white sandy mud layer calculated to be 91, 72, and 78 ± 0.07 %, respectively.

2.2.4.1.4 Organic-Rich Deposits (Layer 4)

General upward decrease in lithogenic mineral and bulk density value has been continued with deposition of organic-rich sediments at top of Bera Lake sediment column. Layer 4 was characterized by very low matrix content, abundance of partially decomposed roots, barks, stems, charcoal and organic debris, and dark color, and 25-cm thickness of average. It overlaid on white sandy mud deposits with a gradual contact. Contribution of clay and silt size grains has reduced dramatically to 2.7 and 35.5 % of the average. Coarse grains mainly composed of organic particles in different size. Therefore, this sediment represents very poorly sorted texture. Detailed organic matters include TOC and POC will present at Sect. 5.4. Minimum, maximum, and mean bulk density values in Layer 4 obtained 0.2, 1.09, and 0.39 ± 0.25 with coefficient of variation of 0.66. General upward increasing in porosity value has reach to maximum content in Layer 4. Minimum, maximum and average porosity values were calculated to be 91, 95.5, and 85 ± 0.1 %, respectively. An interruption recorded in general upward decrease in bulk density by deposition of thin layer muddy sand sediments at the depth of 0–4 cm in all parts of Bera Lake. This Layer (5) is an indicator of a hiatus event in which catchment area flooded extensively at December, 2007. This event recorded in study area after 1,200 mm continues and intense precipitation during 11 days.

References

Appleby PG, Oldfield FT (1978) The calculation of ^{210}Pb dates assuming a constant rate of supply of unsupported 210Pb to the sediment. CATENA 5:1–8

Blott SJ, Pye K (2001) GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surf Process Landf 26:1237–1248. doi:10.1002/esp.261

Brian O (2010) The water quality index, from http://www.water-research.net/watrqualindex/waterqualityindex.htm

Chapman D, Kimstach V (1996) Selection of water quality variables. In: Chapman D (ed) Water quality assessments – a guide to use of Biota, sediments and water in environmental monitoring, 2nd edn. ISBN 0 419 21590 5 (HB) 0419 21600 6 (PB) UNESCO/WHO/UNEP, p 60 http://www.who.int/water_sanitation_health/resourcesquality/wqachapter3.pdf

Chee WC, Abdulla A (1998) Country pasture/forage resource profiles, Malaysia. Ministry of Agriculture Malaysia, Kuala Lumpur

DANCED (1998) Wetland international Malaysia programme. Ministry of Science, Technology and the Environment. http://www.mst.dk/danced-uk/

DOE (2006) Department of Environment Malaysia, "Malaysia Environmental Quality Report 2006". In: River water quality, Chap 3. Sasyaz Holdings Sdn Bhd, p 24. http://elib.uum.edu.my/kip/Record/u623755

Folk RL (1954) The distinction between grain size and mineral composition in sedimentary-rock nomenclature. J Geol 62:344–359

Folk RL, Ward WC (1957) Brazos River bar: a study in the significance of grain size parameters. J Sediment Petrol 27:3–26

Gravelius I (1914) Grundrifi der gesamten Gewcisserkunde. Band I: Flufikunde (Compendium of Hydrology, vol I. Rivers, in German) Goschen, Berlin

Henson IE (1994) Environmental impacts of oil palm plantations in Malaysia, vol 33. Palm Oil Research Institute of Malaysia, Kuala Lumpur

Horton HE (1932) Drainage basin characteristics. Trans Am Geophys Union 13:350–361

Hutchison CS, Tan DNK (2009) Geology of Peninsular Malaysia. The University of Malaya and the Geological Society of Malaysia, Kuala Lumpur

IBP (1972) Research at Tasek Bera. The Malaysian IBP (PF) Subcommittee Kuala Lumpur. http://www.ilec.or.jp/database/asi/asi-15.html#top

Ismail HH, Madon M, Abu bakar ZA (2007) Sedimentology of the semantan formation (Middle–Upper Triassic) along the Karak-Kuantan Highway central Pahang. Geol Soc Malaysia Bull 55:27–34

Kirpich ZP (1940) Time of concentration in small agricultural watersheds. Civil Eng 10(6):362
Krumbein WC, Pettijohn FJ (1983) Manual of sedimentary petrography. Appleton-Century-Crofts, New York
MacDonald S (1970) Geology and Mineral Resources of the Lake Chini, Sungia Bera, Sungai Jeram area of South Central Pahang. Ministry of Lands and Mines Malaysia, Kuala Lumpur
Malmer A (2010) Phosphorus loading to tropical rain forest streams after clear-felling and burning in Sabah, Malaysia. Hydrogeochem Water Chem 32:2213–2220
MMD (2011) Malaysian Climate, http://www.met.gov.my/index.php?option=com_content&task=view&id=75&Itemid=1089&limit=1&limitstart=2
Mohamed AR (1996) Semantan formation distribution in Peninsular Malaysia. Sains Malays 25 (3):91–114
Malmer A (1990) Stream suspended load after clear-felling and different foresty treatment in tropical rainforest, Sabah, Malaysia, vol 192. International Association Hydrology Science, p 62–71
Morley RJ (1981) The palaeoecology of Tasek Bera, a lowland swamp in Pahang, West Malaysia. Singap J Trop Geogr 2(1):49–56. doi:10.1111/j.1467-9493.1981.tb00118.x
Malaysian Palm Oil Council (MPOC) (2007) Palm oil, tree of life. http://www.mpoc.org.my/pubs_view.aspx?id=7311eff0-84d9-4066-87dd-e10fa3748014
Nik AR (1988) Water yield changes after forest conversion to agricultural landuse in Peninsular Malaysia. J Trop Forest Sci 1(1):67–84
Phillips S, Bustin RM (1998) Accumulation of organic rich sediments in a dendritic fluvial/lacustrine mire system at Tasik Bera, Malaysia: implications for coal formation. Int J Coal Geol 36(1–2):31–61
Sone M, Shafeea Leman M (2000) Some Mid-Permian fossils from Felda Mayam, Central Peninsular Malaysia. Paper presented at the Annual geological conference Kuala Lumpur
Udden JA (1914) Mechanical composition of clastic sediments. Bull Geol Soc Am 25:655–744
Wüst RAJ, Bustin RM (2001) Low-ash peat deposits from a dendritic, intermontane basin in the tropics: a new model for good quality coals. Int J Coal Geol 46(2–4):179–206
Wüst RAJ, Bustin RM (2003) Opaline and Al-Si phytoliths from a tropical mire system of West Malaysia: abundance, habit, elemental composition, preservation and significance. Chem Geol 200(3–4):267–292
Wüst RAJ, Bustin RM (2004) Late Pleistocene and Holocene development of the interior peat-accumulating basin of tropical Tasek Bera, Peninsular Malaysia. Palaeogeogr Palaeoclimatol Palaeoecol 211(3–4):241–270
Wüst RAJ, Ward CR, Bustin RM, Hawke MI (2002) Characterization and quantification of inorganic constituents of tropical peats and organic-rich deposits from Tasek Bera (Peninsular Malaysia): implications for coals. Int J Coal Geol 49(4):215–249
Wüst RAJ, Bustin RM, Lavkulich LM (2003) New classification systems for tropical organic-rich deposits based on studies of the Tasek Bera Basin, Malaysia. CATENA 53(2):133–163
Wüst RAJ, Bustin RM, Ross J (2008) Neo-mineral formation during artificial coalification of low-ash mineral free-peat material from tropical Malaysia-potential explanation for low ash coals. Int J Coal Geol 74(2):114–122

Springer

http://www.springer.com/978-4-431-54979-6

Applied Limnology
Comprehensive View from Watershed to Lake
Gharibreza, M.; Ashraf, M.A.
2014, XIV, 204 p. 109 illus., 98 illus. in color., Softcover
ISBN: 978-4-431-54979-6