

ANALYSIS OF THE BEACH MATERIALS AT THE KUAKATA COAST

BY

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of Master of Engineering (Water Resources)

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DHAKA



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CERTIFICATE

This is to certify that this project work has been done by me and neither this project nor part thereof has been submitted elsewhere for the award of any degree or diploma

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We hereby recommend that the project presented by Mr. Md. Matiur Rahman entitled "ANALYSIS OF THE BEACH MATERIALS AT THE KUAKATA COAST" be accepted as fulfilling the part of the requirements for award of Master of Engineering in Water Resources Engineering

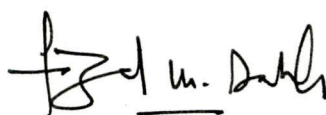
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Finally, the author wishes to give thanks to those who provided their best assistance and cooperation during the field survey and he laboratory analysis.

ABSTRACT

The Kuakata beach is about 19.5 km long and lies between the latitudes $21^{\circ}45'N$ and $21^{\circ}55'N$ and longitudes $90^{\circ}E$ and $90^{\circ}15'E$. The beach extends between the Nilgonj river confluence at the extreme west and the dead portion of Gangamati khal confluence at the east. The coast is covered mostly by dense plantation to the northward whereas to the south it is directly exposed to the Bay of Bengal.

A reconnaissance survey was made and eleven nos. of stations at an interval of 2.0 km along the length were selected for collecting beach material samples from the surface, at 0.6m and 1.0m depth. The locations of the stations were fixed by a Nav 1000 Pro Global Position Survey (GPS). Bed and bank samples from Nilgonj river and Gangamati khal were also collected. Total one hundred five samples, each 2 kg in weight were collected by hand scrapping and were preserved in the plastic bags and carried to Hydraulics and River Engineering Laboratory in BUET for necessary analysis.

The 1st field trip for survey works of this study started on 8th June 1999 and continued till 13th June 1999. A team consisting of four members equipped with GPS receiver, levelling instrument etc. worked to do the necessary levelling works across the beach at different stations. Preliminary analysis of the data collection were then done and it was felt necessary to collect few more field data to close the gap in the earlier data collection programme. A 2nd field trip was therefore made between 25th and 29th September 1999.

The Kuakata beach has no definite trend of shape. The beach surface elevation increases @ 1:10,900 from Nilgonj confluence (ch. 0.00 km) at the west upto 8.00 km at the east. The beach elevation then decreases @ 1:3,400 upto chainage 10.00 km at station 6. The part between ch. 12.00 km and ch. 16.00 km is more or less the same and the profile takes the form of a trough shaped between ch. 16.00 km and ch. 19.50 (Dead portion of Gangamati khal confluence at the east).

The Kuakata Coast is wider and the beach slope lies between 1:19 and 1:66 (vertical to horizontal). The beach slope within the foreshore zone has minimum value (1:66) at station 11 (ch. 19.50 km) where the beach is flattest and maximum value (1:19) at station 4 (ch. 6.00 km). The beach slopes at stations 1 and 2 (ch. 0.00 km and ch. 2.00 km) are the same and also at stations 3 and 6 (ch. 4.00 km and ch. 10.00 km) are more or less the same.

The grain size distribution curves were plotted and the sorting characteristics of the sand were studied both along and across the beach. The beach sands are dominated by fine sand with a trace of medium sand and fine-grained materials (silt and clay). Coarse sand is absent from the whole beach. There is no trend of variation of surface particle sizes across the beach profile and the mean diameter (d_{50}) can be considered around 0.20mm all throughout the beach. The trend is same both at 0.6m and 1.0m depth from the surface. However, a trend of decrease of particle size, it is noticeable that the particle size in the western side is slightly coarser than the eastern side.

A comparison of the result has been made with the earlier studies of the Cox's Bazar-Teknaf Coast. It has been found that the mean diameter (d_{50}) of the beach materials of Kuakata Coast has the similarity with those of 10 km coastline portion at the extreme south at Teknaf along the Cox's Bazar-Teknaf Coast. But Cox's Bazar-Teknaf beach sand is finer than the Kuakata beach sand. An interesting similarity was also found in the wave breaking phenomena for both the coasts, which is of spilling type.

Finally, recommendations have been made for further studies.

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CHAPTER 1

INTRODUCITON



1.1 BACKGROUND AND IMPORTANCE OF THE STUDY

The coastline of Bangladesh can be described under two major groups resulting from different geological processes. The first group having a near east-west orientation, extends from Haribanga channel along Indo-Bangladesh border in the west to the Sandwip channel in the east and covers a coastline of about 380 km (Figure 1.1). The second group is the entire 275 km coastline of Chittagong, which has a north-south orientation (Figure 1.2). The total coastline is thus 655 km long which is very irregular and mainly consists of mud and mangroves. Out of this total 655 km long coastline only coast at Kuakata and coast between Cox's Bazar and Teknaf are formed of sand and have distinguished beach length and width. The sandy beach between Cox's Bazar and Teknaf is approximately 160 km long and have been studied by Matin (1995) from civil engineering point of view. The Kuakata beach, which is a patch of sand of about 19.5 km long and was not known very much before. Only recently its importance as a tourist place has been explored.

The Kuakata coast lies between the latitudes $21^{\circ}45'$ and $21^{\circ}55'$ North and longitudes 90° and $90^{\circ}15'$ East. The coastline is interrupted by the one major river namely Nilganj River and one major khal Gangabati Khal as shown in Figure 1.3. Large concentration of heavy minerals has been discovered in 1986 in the sand of Kuakata beach (Biswas). But from civil engineering and coastal engineering point of view no work has been done before. The proposed topic will cover an analysis of beach materials of about 19.5 km long coastline at Kuakata along the east-west orientation coastline. Of greatest interest are those physical properties of beach materials that control their response to wind, wave and current action and are important to civil and coastal engineers.

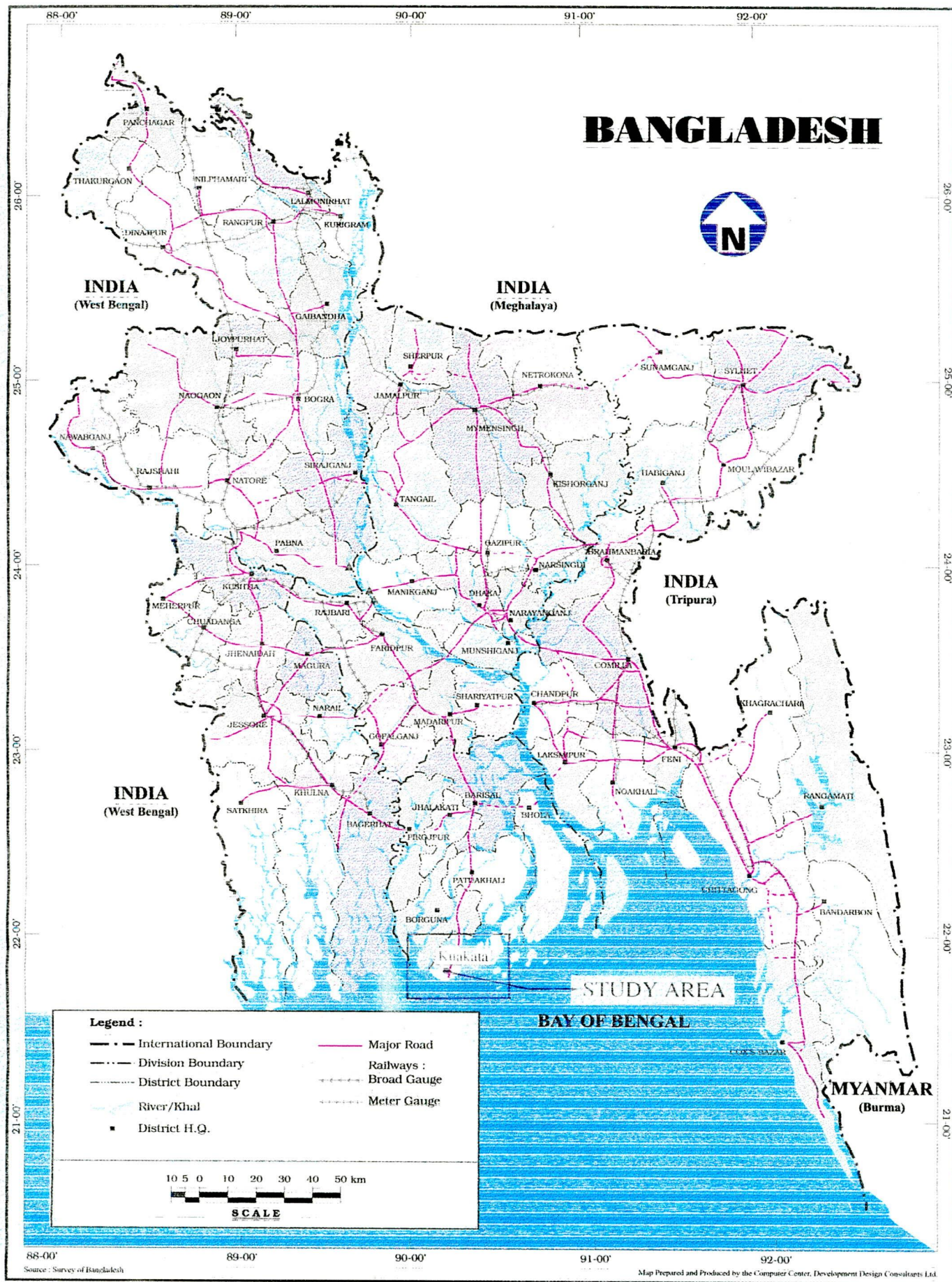
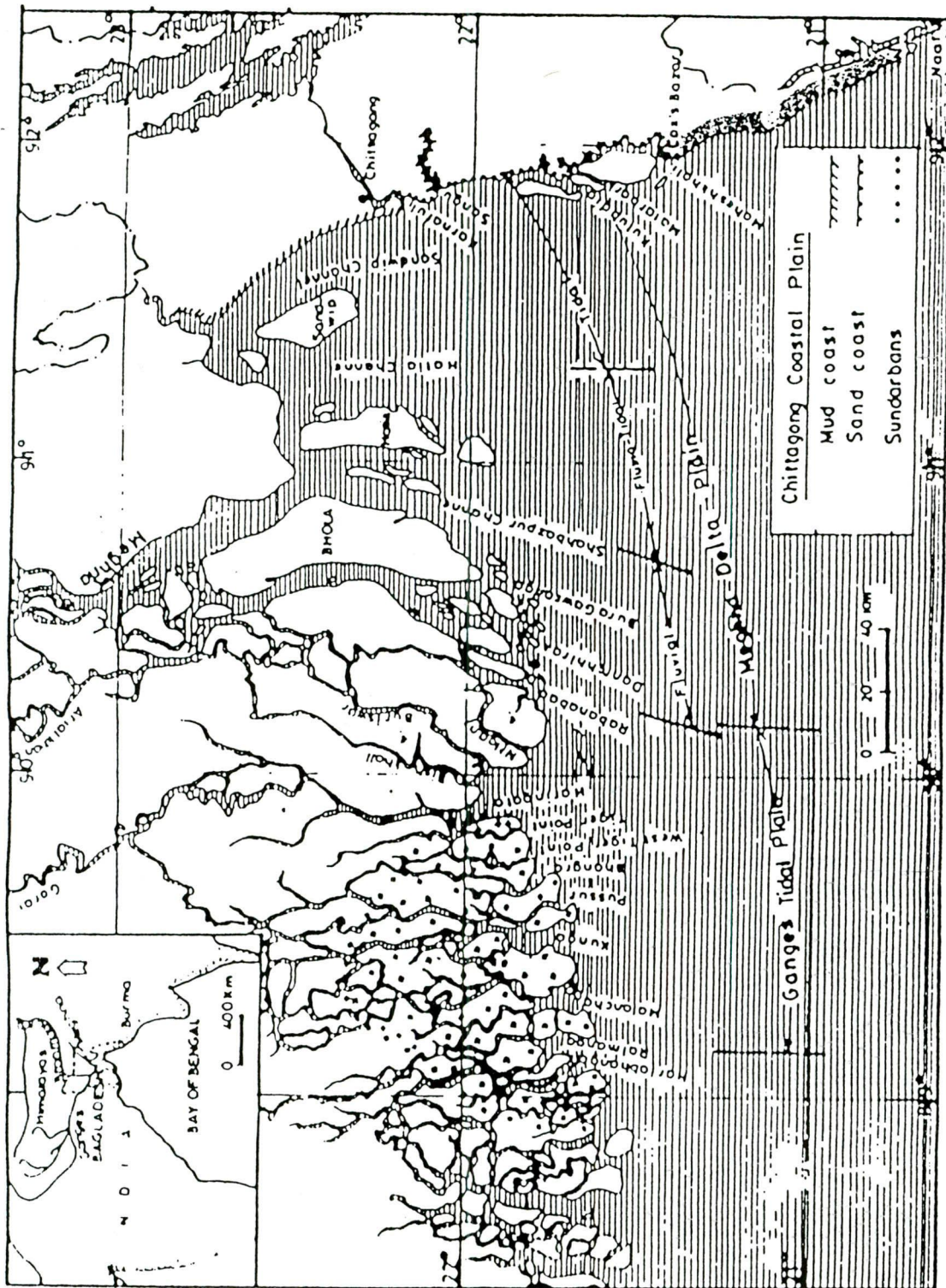


Figure 1.1 Location Map of Kuakata Beach



(after Barua, 1991)

Figure: 1.2 → → → Coastline of Bangladesh.



MAUZA NAME	J.L.No.	Geo-Code	No.
LATACHAPLI UNION	34	592	47
MITHAGANJ UNION	18	59	296
Choua Balaiali	19	571	21
Lemupara	21	677	30
Mithaganj	30	084	31
Bara Balaiali	31	169	38
Choua Balaiali	38	867	21
Sonapara	43	910	2
Tegachhia	44	613	18
Madhukhali	45	254	46
Char Nazib	46	211	17
Char Ershad	47	232	42
Char Habib	42	529	5
NILGANJ UNION	5	740	22
Nilganj	22	973	23
Umedpur	23	889	24
Sonatala	24	423	40
Hazipur	40	698	41
Nabipur	41	952	5
Tungibaria	42	529	5
Kumirmara	42	529	5

MAUZA NAME	J.L.No.	Geo-Code	No.
DHANKHALI UNION	64	700	65
Maschukhali	65	823	66
Patua	66	135	67
Binamkatadia	67	651	68
Karishnapur	68	466	69
Golabania	69	343	70
Dabpur	70	171	71
Chalitabunia	71	749	72
Panchajina	72	356	73
Dhankhali	73	687	23
Londa	23	804	25
KHAPRABHANGA UNION	25	846	26
Nizampur	26	994	27
Sibbaria	27	656	28
Ichhabpur	28	317	29
Haradrapur	29	486	35
LALUA UNION	35	783	11
Nisanbaria	11	635	12
Madhupara	12	402	13
Golbunia	13	550	14
Lalua	14	063	15
Banaitipara	15	719	16
Nayakata	16	148	17
Chandupara	17	275	48
Char Nisanbaria	48	275	48

Note: The number outside the parenthesis indicates J.L. No. and within it indicates Geo-Code No. J.L. No. refers to the Jurisdiction List number numerically identifying Mauzas for cadastral, revenue and administrative purposes within a Thana. Geo-code number refers to Geographic Area Code number as a digital expression of administrative units for recording statistical data with reference to spatial areas.

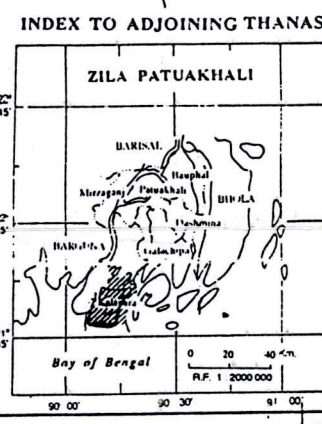


Figure 1-3 Kalapara Thana Base Map

LEGEND

- Boundaries**
 - International
 - District
 - Thana
 - Union
 - Mauza
 - Municipality / Pourashava
- Head Quarters**
 - District
 - Thana
 - Union
 - Police Station
- Natural Features**
 - River with Char area

- Khal / Canal**
 - Water bodies, Beel / Haor / Baor
 - Tank / Pond
 - Forest
 - Hill / Hillock
- Physical Infrastructures**
 - National, Regional Highway
 - Feeder Road (Type A)
 - Feeder Road (Type B) Pucca
 - Feeder Road (Type B) Katcha
 - Pourashava / Local / Rural Pucca Road (R-1, R-2, R-3)
 - Pourashava / Local / Rural Katcha Road (R-1, R-2, R-3)
 - Railway with station, Broad / Metre gauge
 - Launch / Steamer route
 - Telecommunication

- Transmission Line**
 - Bus Stop / Passenger Shed
 - Bridge / Culvert
 - Ferry, Launch, Steamer Ghat
 - Sea port, Airport, Helipad
- Agricultural Infrastructures**
 - Embankment
 - Head cum Embankment
 - Deep / Shallow Tubewell / L.L.P
 - Sluice / Regulator
- Socio-Economic Infrastructures**
 - Growth Centre
 - Haat / Bazar / Trading Centre
 - Hospital / Thana Health Complex
 - Family Planning Centre
 - Mill / Factory (Large Scale)

- Bank**
 - Food Godown
 - Post Office / Telephone / Telegraph Office
 - Historical Place / Parjaton-Kendra
 - University
 - College / Technical & Vocational Institute
 - High School
 - Primary School
 - Madrasa
 - Mosque/Eidgah/Tomb/Church/Temple/Chhatra
 - Graveyard / Cemetery / Burning Ghat
 - Cyclone / Flood Shelter
 - Settlement Area

Compiled from : SPOT Image 1989-90, Aerial Photograph 1983-84, Topographic Maps, Thana Maps, B.B.S. and field Check
Projection : Lambert's Conformal Conic
LOCAL GOVERNMENT ENGINEERING DEPARTMENT
UNDP/ILO PROJECT BGD/89/041

1.2 OBJECTIVES

The objectives of the present study have thus been set as follows :

- i) to determine the grain size and distribution of the beach materials at Kuakata coastline.
- ii) to compare the variations of the grain size distribution of the beach materials of the study area with that of the beach materials between Chittagong and Teknaf coast.
- iii) to find out the cross-slope of the beach at an interval of 2.0 km along the length.
- iv) to make an analysis of wave-breaking phenomena at the beach.
- v) To compare the results obtained in i), iii) and iv) with that of the Chittagong-Teknaf coast as studied by Matin (1995).

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The Kuakata Beach is one of the attractive tourist destinations and a perfect place for holiday makers and sun-seekers because both the sun-rise and sun-set in the sea are visible from this place. It is under Lata Chapli Union and Kalapara Police Station. Recently Kuakata has been taken up by the Bangladesh Parjatan Corporation for major development as a tourist place.

2.2 BRIEF HISTORY OF KUAKATA

More than two hundred & fifty years ago the Rakhains (Buddhists) at Myanmar (Burma) were turned out from Myanmar and migrated to Kuakata and settled there. During that period there was lack of potable water in the area. They had to sink wells known as "Kuas" (Photo 1) in the area in order to get fresh water. That is why the area has been named as Kuakata. Now a days other communities have also settled there and majority of the Rakhains have returned back. Few of them who are still residing their tribal customs, costumes, traditions and culture. Their pagado-shaped house, their dialect and mode of living and social institutions, temples etc. are a source of fascinating study to the tourists and anthropologists. The Rakhains today are engaged in agriculture as well as in handicraft and cottage industries such as hand woven cloths. Other people in the area are mostly engaged in fish catching and also in agriculture.

During field visits it was reported from the local elderly people who were eye witness of the 1970 storm surge condition that the whole beach area was bordered by natural sand dunes of about 12m to 15m high. The sea was about 10 km away to the south from the present position and the sandy beach was about 2 km to 3 km wide with about 7 km to 8 km wide plantation behind it. Since last two decades the sea is at the present position. However, the navigation route for bigger ships is still 5 km away from the present coastline.

2.3 STUDIES BY BANGLADESH ATOMIC ENERGY COMMISSION

A survey of the available literature shows that systematic study on beach materials of Kuakata coast is very sparse and rare. Only during 1960, Bangladesh Atomic Energy Commission took the pioneer study of this coast in search of heavy minerals with the assistance from the Australian Mineral Development Laboratory (AMDEL), an agency engaged by the Australian Government. Actual study began in 1968 and continued till 1985 (BAEC, 1991).

The main objectives of these studies were: i) to determine the area of high and low mineral content; ii) to delineate the economic margins of the deposits; and iii) to establish the grades and estimate the ore reserves of the deposits. The study discovered heavy mineral deposits along the Kuakata coast. Six other deposits were also reported along the main coast at Badarmokkam, Sabrang, Teknaf,

Silkhali, Inany, Cox's Bazar and ten deposits in the offshore islands of Moheshkhali (7 deposits), Matarbari (1 deposit), Kutubdia (1 deposit) and Nijhum Dwip (1 deposit). The summary of the reserve of economic heavy minerals in the beach sand of Bangladesh are shown in Table 2.1 as adopted from the report published by Bangladesh Atomic Energy Commission in June 1991.



Photo 1: Kuakata's Kua for which the area has been named as Kuakata

Table 2.1
SUMMARY OF THE RESERVE OF ECONOMIC HEAVY MINERALS AT KUAKATA AND OTHER PLACES ALONG THE COAST

(In Tons)

Deposit	Crude Sand	Heavy Minerals	Zircon	Rutile	Ilmenite	Leucoxene	Magnetite	Monazite	Kyanite	Garnet
Kuakata	2872486	831668	9647	3911	76015	9647	4325	83.2	16800	52229
Badarmokkam	1765000	411000	4932	3288	94530	18002	10275	4932	*	*
Sabrang	347558	68582	4184	1372	19614	3470	1001	206	727	3018
Teknaf	1939580	442291	28306	13230	163170	20124	7209	3045	14728	22424
Silkhali	2756828	489714	33300	10774	173360	10970	3085	3918	4407	39422
Inani	729286	175476	10880	4036	53170	439	5545	965	1404	12810
Cox's Bazar	5119000	920000	23000	6440	161000	10488	33212	2024	*	50600
Moheskhal Island	4114230	784210	37122	24596	242963	20682	7604	2044	47496	35958
Matarbari Island	69030	15215	794	295	4962	374	575	20	*	*
Nijhum Dwip	379337	96348	2052	424	12978	77	4384	19.3	2592	*
Kutubdia Island	404646	120000	3900	1908	23796	2436	3384	96	2592	6300
Total	20496981	4354504	158117	70274	1025558	96709	80599	17352.5	90746	222761

(Source : Bangladesh Atomic Energy Commission, June 1991)

* - Not estimated

2.4 STUDIES BY BISWAS

Biswas (1986) separately analyzed the sand samples from the 12-mile long Kuakata Beach.

Sand samples were taken generally at an interval of 500 ft along the 12-mile long sea beach. Total 139 nos of sand samples were collected from 117 points on the upper foreshore above the high-tide line as shown in Figure 2.1. Sample collection was made with the help of hand auger which penetrated into the beach to an average depth of 0.76m. An initial sample mass of about 2 kg. was collected from each sample point. In the laboratory this sample was divided on a riffle and 100 gm of material was removed for mechanical sieving. The samples were washed, dried and sieved following the technique suggested by Folk. Using this sieve data the statistical parameter such as mean, standard deviation, skewness, kurtosis, first percentile and median diameter were determined by Folk's graphical method. The heavy minerals were separated from all samples by using bromoform.

Analysis of sand samples show that the grain size distribution in all the 139 samples are unimodal as shown in Figure 2.2 of which in 132 samples the modal peaks lie between 2.5-3.0 phi ($d_{50}=0.177-0.125\text{mm}$) interval. The material of this size range makes 47.14% (by weight) of the total sand, while material coarser than 2.50 phi ($d_{50}=0.177\text{mm}$) and finer than 4.00 phi ($d_{50}=0.0625\text{mm}$) constitutes only 2.77 and 1.59% respectively. The clay content in the sand is 2.18%.

The sand is characteristically fine to very fine grained, well sorted, fine skewed and mesokurtic.

Heavy mineral contents vary within a wide range from 3 to 75% (by weight). A majority of the samples (80%), however, contains heavy minerals from 15 to 60%. The average value for all samples is 36.64%.

Concentration of heavy minerals in the sands is strongly related with their grain size distribution characteristics. With the increase in the contents of heavy minerals of the sand the concentrations of material having size range 3.00-3.50 phi ($d_{50}=0.125-0.088\text{mm}$) and 3.50-4.00 phi ($d_{50}=0.088-0.0625\text{mm}$) in the sand increase from 27.34 to 34.84% and from 16.12 to 21.19% respectively, while the percentages of material with size grade coarser than 3.00 phi ($d_{50}=0.125\text{mm}$) and clay in the sand decrease from 53.83 to 41.83 and 2.08 to 1.00 respectively. The concentration of material in the fraction finer than 4.00 phi ($d_{50}=0.0625\text{mm}$), however, remains constant.

Statistical parameters of the sand are, to some extent, related with the heavy mineral contents. The wider variations in the values of statistical parameters are the characteristics of sands having lower concentration of heavy minerals. The optimum values of mean size and sorting of the sands for heavy mineral concentration are, however, 2.70-2.90 phi ($d_{50}=0.154-0.134\text{mm}$) and 0.30-0.40 phi ($d_{50}=0.812-0.758\text{mm}$) respectively. No such values for skewness and kurtosis could be established.

From the nature and pattern of grain size distribution he concluded that the sand was deposited under relatively calm and low energy conditions of the depositional type of beach environment where some role was also played by aeolian and shallow agitated marine processes.

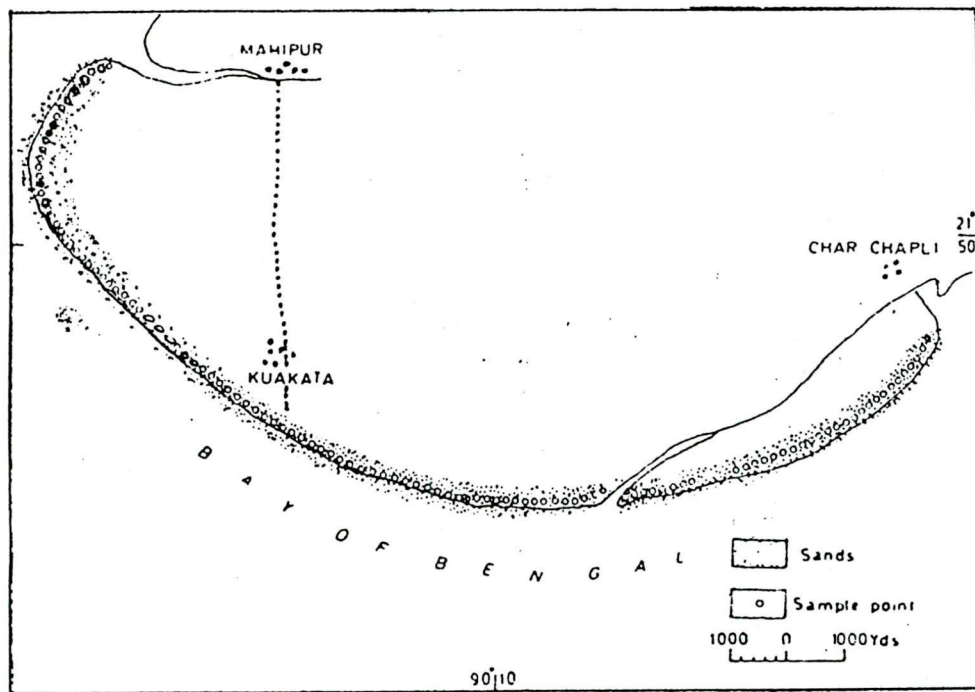


Figure No. 2.1 Index map showing location of study area and sample collecting points.

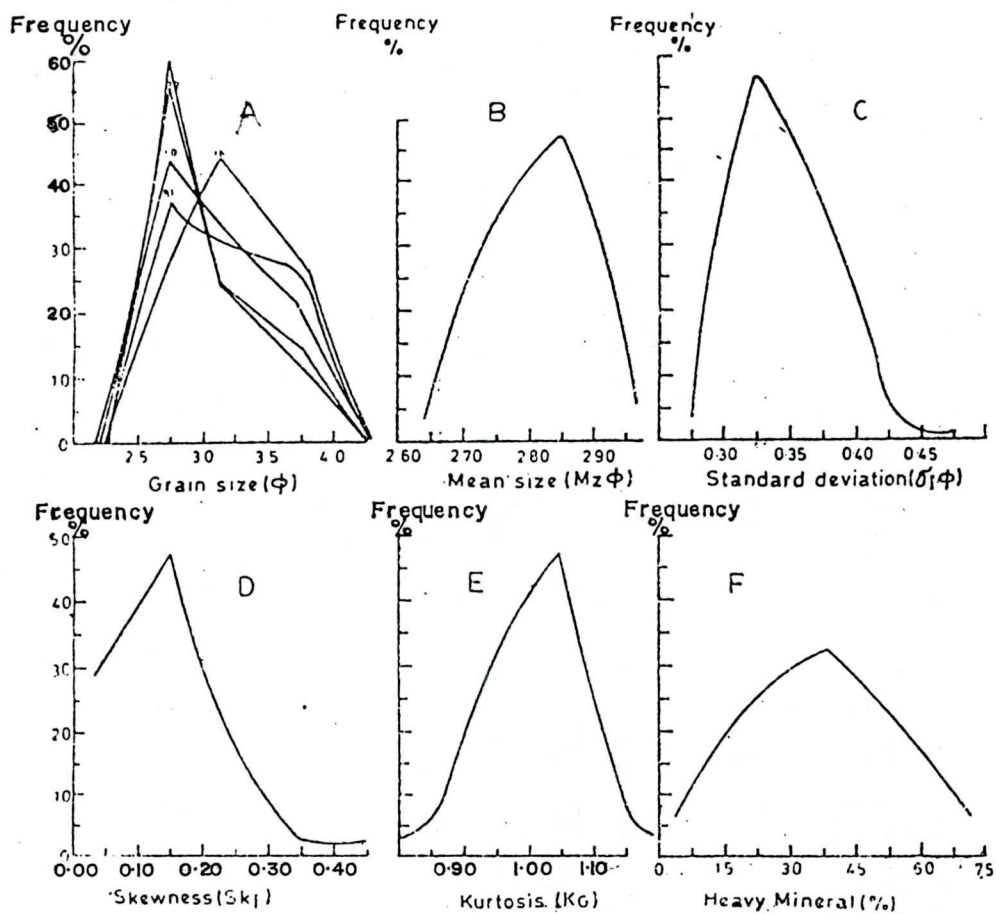


Figure No. 2.2 Frequency curves showing distribution of : A-grain size distribution of some representative sand samples (* sample number) ; B, C, D & E-different statistical parameters of sand samples (139) ; and F-heavy mineral contents of sand samples.

CHAPTER 3

DATA COLLECTION AND LABORATORY ANALYSIS

3.1 INTRODUCTION

The first field trip for survey works of this study started on 8th June 1999 and continued till 13th June 1999. A team of four members, consisting of surveyors, technicians was engaged for the work.

Before the start of actual data collection, a full reconnaissance of the 19.5 km long Kuakata beach was necessary for the tentative selection of the stations. The work took about 10 hours from morning till evening on 8th June 1999. A second field trip was necessary to close the gap in the data. Preliminary analysis of the data collected were then done and it was felt necessary to collect few more field data to close the gap in the earlier data collection programme. This was done between 25th and 29th September 1999 after two days after the full moon when the high tide is at highest level and the low tide is at the lowest level. This was very much necessary for field observation of wave breaking phenomena especially.

The study area is not fully accessible by the usual vehicle. The main interruptions are due to about 230m wide Gangamati khal and a nos. of small tidal creeks (khals) and dense mixed forest areas around the 19.5 km long Kuakata coast. The bed level of the Gangamati khal is (-) 0.45m PWD. However, the beach is accessible by vehicle through the coastal embankment around the coast to the northward direction. During low tide it is possible for the vehicle to cross the smaller khals. So ultimately it was possible to move the whole 19.5km long Kuakata beach from west to east. The chainage 0.00 km for this study was chosen at the extreme western point of the beach where the Nilgonj River meets with the sea (Photo 2). The last station (chainage 19.5km) thus ends at the east where the dead portion of Gangamati Khal at Kawarchar meets with the sea (Photo 3).

3.2 PHYSICAL DESCRIPTIONS OF THE STUDY AREA

The 19.5 km long coast is covered mostly by dense mixed forest areas to the northward (Photo 4 & 5). Figure 3.1 shows the Global Position of the Kuakata beach. To the south it is directly exposed to the Bay of Bengal.

3.3 HYDROLOGICAL CONDITIONS

Tides in the investigated area are semi-diurnal and vary approximately from 3 to 5m in height. From March to October the wind blows over the investigated area from south with an average velocity of 12.68 km/hr. From November to January the wind blows from the north with an average velocity of 9.37 km/hr. Average annual rainfall over the area is 2639 mm, temperature is around 25.8°C and humidity of the air varies from 36 to 88% (Dependable Meteorological Office at Khepupara).



Photo 2: Nilgonj River confluence with the sea at Chainage 0.00 km during low tide



Photo 3: Gangamati Dead Channel confluence with the sea at Kawarchar at Chainage 19.50 km during low tide (Land side facing)



Photo 4: Khajura Forest Area near Station 1 at Chainage 0.00 km during low tide (Land side facing)



Photo 5: Nakuripara Forest Area near Station 2 at Chainage 2.00 km during high tide

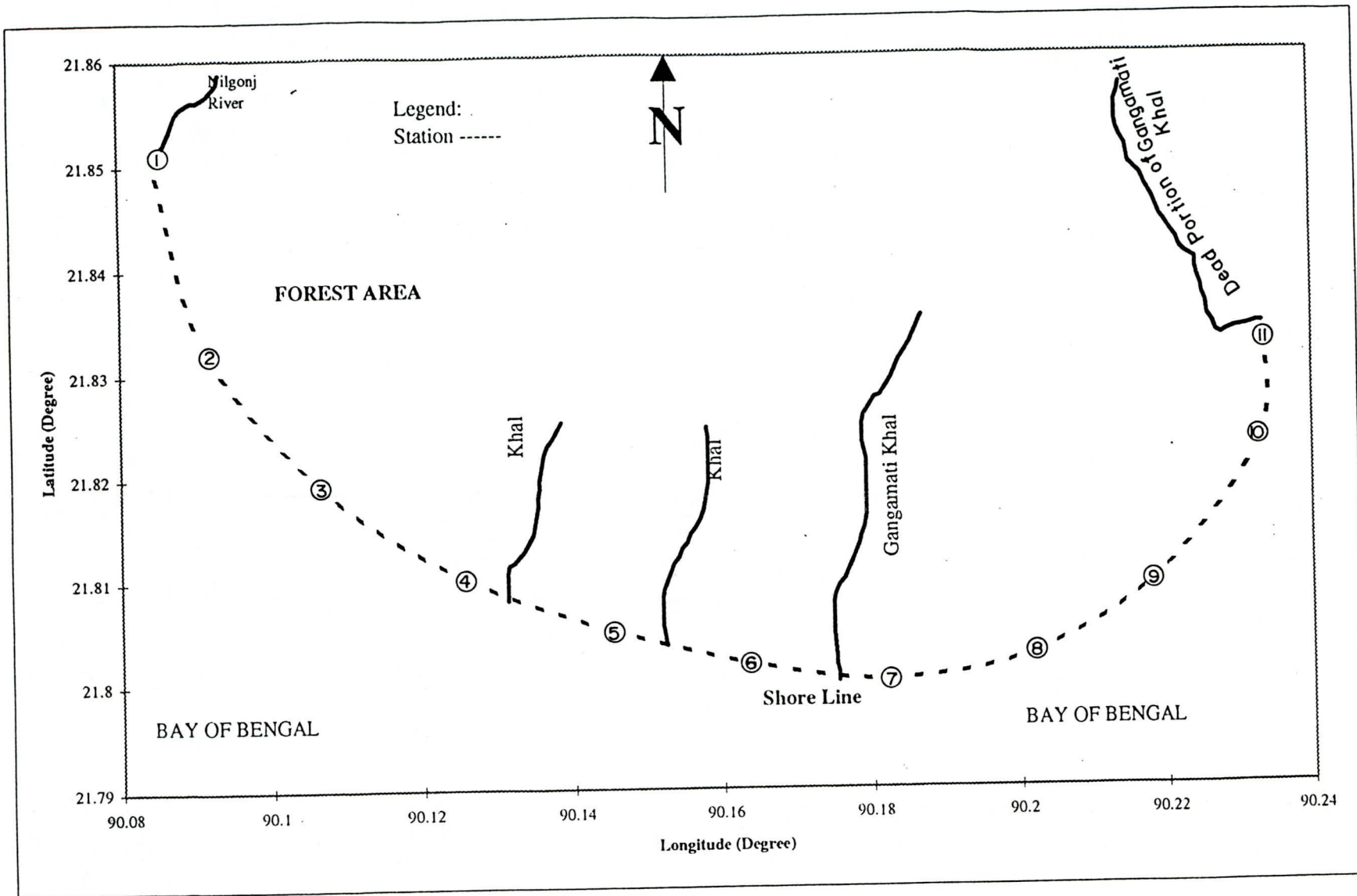


Figure 3.1 : Global Position of the Kuakata Sea Beach

Waves in high tide is quite high and is about 4m to 5m high and hits the coast with tremendous erosive force. In recent year (July 1999) a severe breach (Photo 6) occurred in the retired embankment which is about 6m high. However, there is plantation in front of the present embankment which is quite effective in disseminating wave energy.

The coastline is interrupted by one major river known as Nilgonj River in the west and one major khal named as Gangamati khal in the east. Few nos. of tidal creeks also cross the beach (Photo 7).

The beach has got flat slope as well as steep slope. The width of the foreshore zone (Horizontal distance between low and high water levels) varies from place to place along the beach.

An approximate 18.0 km long Coastal Embankment termed as Polder No. 48 (Figure 3.2) was constructed in June 1967 and runs parallel to the beach. The top level of the embankment is set at 6.1 m PWD and is used as road for vehicles.

Natural dunes (Photo 8 & 9) with an approximate width of 3.0m and 1 to 1.5m high and about 10-15 m long is seen lying scattered ways throughout the beach within the backshore zone. In some of the places, temporary storage of water within the backshore zone (Photo 10) could be observed during high tides.

3.4 STATION SELECTIONS

The total 19.5 km length of the Kuakata beach was divided into 11 (eleven) segment at an interval of 2.0 km as shown in Figure 3.3. These are called as "Stations" and the Locations (Latitudes and longitudes) of these stations were determined by the Global Positioning Survey (GPS) receiver (Nav 1000 Pro, Photo 11) and is shown in Table 3.1. These stations were selected on the basis of (i) accessibility, (ii) in conformity with the earlier information of Biswas (1986) and (iii) maintaining uniformity in space distribution. A brief description of the stations are as follows:

1. Station no. 1: Station no. 1 is at **Khajura** forest area and lies to the extreme west to the south of the confluence of the river Nilgonj to the Bay of Bengal. It was taken as Reference Starting Station with chainage 0.00 km for our study. The CEP Polder 48 (Photo 12) is at the south of the station. The latitude and longitude of the station is 21°50.99'N and 90°5.10'E respectively.
2. Station no. 2: It is 2 km away to the south from Station no. 1 and the local name of the area is **Nakuripara**. It is covered with dense mixed reserved forest areas. The latitude and longitude of the station is 21°49.95'N and 90°5.49'E respectively.
3. Station no. 3: Its chainage is 4.00 km to the south-east from the Reference Station no. 1 at **Khajura** and lies at about 0.50 km to the south west of main approach of the Kuakata beach. The latitude and longitude of the station is 21°49.14'N and 90°6.41'E respectively.
4. Station no. 4: It is about 1.5 km to the east from Kuakata Central part and is covered with dense mixed reserved forest. A small tidal creek (khal) of about 10.0m width crosses through the beach and lies 700m away to the east of the station. A Coconut Garden locally known as Afaz Miah's Narikel Bagan (Photo 13) is just at the north of the station. The latitude and longitude of the station is 21°48.65'N and 90°7.57'E respectively.



Photo 6: Breach point of old retired embankment near Station 3 at Chainage 4.00 km during low tide (Land side facing)



Photo 7: Small Tidal Creek (Khal) at Chainage 8.50 km during low tide (East side facing of the beach)



Photo 8: Scattered Sand dunes at Kuakata Coast near Station 8 at Chainage 14.00 km during low tide (Land side facing)



Photo 9: Grass and bushes on the Sand dunes near Station 9 at Chainage 16.00 km during low tide (Land side facing)



Photo 10: Temporary storage of water within the Backshore zone during full tide (Sea side facing)



Photo 11: Global Positioning Survey (GPS) receiver operation



Photo 12: Coastal Embankment (Polder No. 48) at Kuakata (Land side facing)



Photo 13: Afaz Miah's Narikel Bagan at Kuakata Coast near Station 4 at chainage 6.00 km (Land side facing)

90°-00'E

90°-05'E

90°-10'E

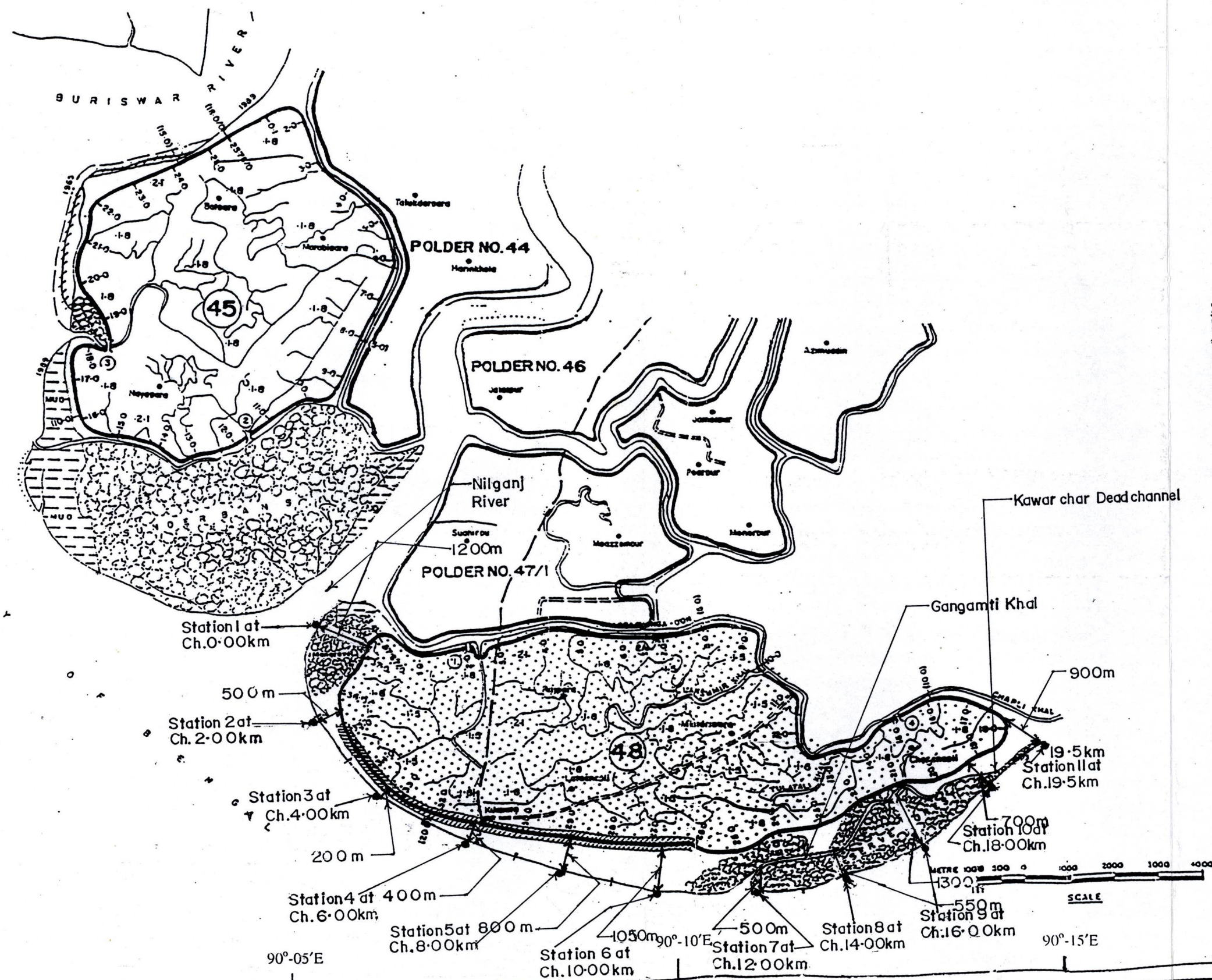
90°-15'E

22°-00'N

21°-55'N

21°-50'N

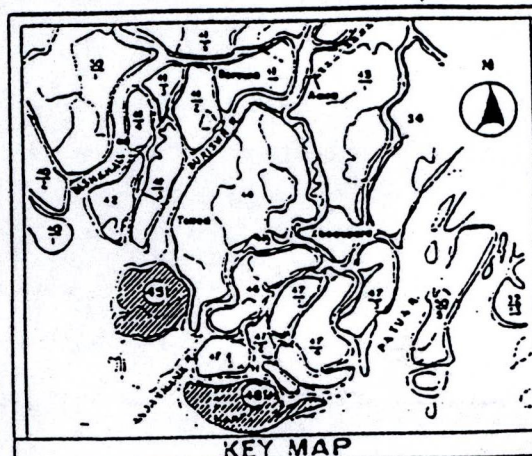
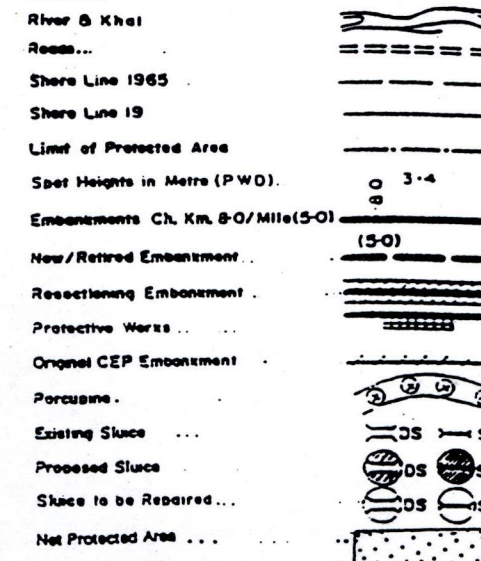
90°-00'E



POLDER NO.

48

LEGEND



PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION, WATER DEVELOPMENT
AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

CYCLONE PROTECTION PROJECT II

MID TERM PROGRAMME-
PHASE 2
PROPOSED WORKS

POLDER 48

Design: Recomm. Appr.:

DATE: 01-02-92

KAMPSAX INTERNATIONAL A/S, BCOH
and DANISH HYDRAULIC INSTITUTE
in association with
DEVELOPMENT DESIGN CONSULTANTS
LTD.
23, New Eskaton Road, Dhaka-
1000, Tel. 405477,
Fax 880 02 832951

SCALE:
1:100 000

DRAWING
NO.:

Figure No. 3.2 Polder No. 48

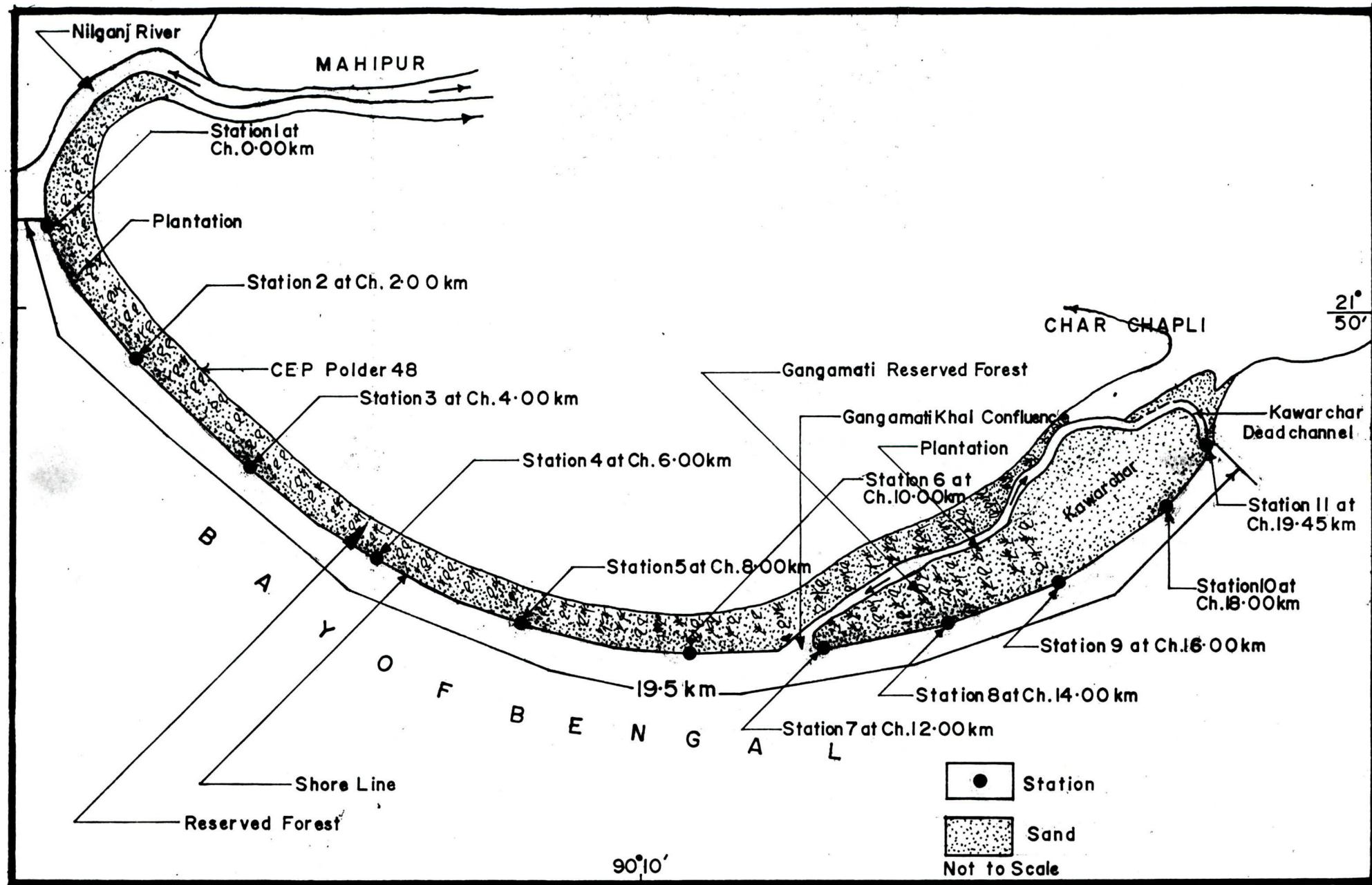


Figure 3.3 Index Map showing locations of study area and sample collecting stations

5. Station no. 5: Its chainage is 8.00 km to the south-east from Reference Station. Station no. 5 is also surrounded by dense mixed forest areas. A small tidal creek (khal) crosses the beach 500 m away to the east of the station. The latitude and longitude of the station is $21^{\circ}48.31'N$ and $90^{\circ}8.70'E$ respectively.
6. Station no. 6: It is under **Gangamati** reserved forest areas at chainage 10.00 km. The Gangamati river confluence is about 1.14 km to the east of the station and makes division as major two parts of the Kuakata beach. The latitude and longitude of the station is $21^{\circ}48.09'N$ and $90^{\circ}9.90'E$ respectively.
7. Station no. 7: It is located in the **Gangamati** reserved forest areas at chainage 12.00 km and is situated near the left bank of the Gangamati Khal (Photo 14). Scattered sand dunes parallel to the coast are found visible near the station. The latitude and longitude of the station is $21^{\circ}47.98'N$ and $90^{\circ}11.00'E$ respectively.
8. Station no. 8: It is also under **Gangamati** reserved forest areas at chainage 14.00 km. Sand dunes parallel to the coast in scattered ways are also found near the station. The latitude and longitude of the station is $21^{\circ}48.15'N$ and $90^{\circ}12.15'E$ respectively.
9. Station no. 9: The local name of the station area is **Kawarchar**. There is no plantation in the area and sand dunes with height varying between 1.0m and 1.5m are found lying in a scattered way. The latitude and longitude of the station is $21^{\circ}48.62'N$ and $90^{\circ}13.17'E$ respectively.
10. Station no. 10: It is also under **Kawarchar** area at chainage 18.00 km. This station is also featured with scattered sand dunes. There is no plantation in the area. The latitude and longitude of the station is $21^{\circ}49.35'N$ and $90^{\circ}14.00'E$ respectively.
11. Station no. 11: It is the last station at the end point of Kuakata beach at chainage 19.45 km where the dead portion of Gangamati Khal at **Kawarchar** meets with the sea. The station is also featured with scattered sand dunes. The latitude and longitude of the station is $21^{\circ}49.97'N$ and $90^{\circ}14.59'E$ respectively.



Photo 14: Gangamati Khal confluence with the sea at Chainage 11.50 km during low tide (West side facing of the beach)

Table 3.1**LATITUDES AND LONGITUDES OF SAMPLING STATIONS**

Sl. No.	Station No.	Chainage along the coast (Km)	Latitudes	Longitudes	Time and Date of GPS Survey
1	1	0.00	21°50.99'N	90°5.10'E	12-00 AM; 9-6-99
2	2	2.00	21°49.95'N	90°5.49'E	02-25 PM; 9-6-99
3	3	4.00	21°49.14'N	90°6.41'E	04-30 PM; 9-6-99
4	4	6.00	21°48.65'N	90°7.57'E	08-45 AM; 11-6-99
5	5	8.00	21°48.31'N	90°8.70'E	11-25 AM; 11-6-99
6	6	10.00	21°48.09'N	90°9.90'E	01-10 PM; 11-6-99
7	7	12.00	21°47.98'N	90°11.00'E	11-35 AM; 12-6-99
8	8	14.00	21°48.15'N	90°12.15'E	12-55 PM; 12-6-99
9	9	16.00	21°48.62'N	90°13.17'E	02-05 PM; 12-6-99
10	10	18.00	21°49.35'N	90°14.00'E	03-30 PM; 12-6-99
11	11	19.45	21°49.97'N	90°14.59'E	04-35 PM; 12-6-99

3.5 DATA COLLECTION

The actual data collection was done between 9 and 12 June 1999. As mentioned earlier the usual transport was found not useful during the survey work. Locally available four wheel drive vehicle (Photo 15) was necessary for data collection along the stations. During 2nd field trip between 25th and 29th September 1999 few more soil samples from bed and bank of confluences were also collected and the wave phenomena was observed specifically.

Types of Data

The data collected from the eleven (11) nos. of stations included:

- a) cross-sectional survey of the sea beach at each stations;
- b) collection of soil sample at each station from the surface, from 0.6m depth and from 1.0m depth within the backshore and foreshore zone; and;
- c) collection of water sample from the near shore zone at each station

The data collection also included bed and bank samples (6 nos.) from Nilgonj River and Gangamati Khal.

Instruments Used

The instruments used to conduct the field works were:

- a) a Nav 1000 Pro Global Position Survey (GPS) receiver,
- b) level and staff,
- c) tape,
- d) spade,
- e) steel plate,
- f) iron grid (specially fabricated for the purpose),
- g) 6" dia. Open box,
- h) polythene bags, water sampling bottle.

Possible Instrumental Error:

The Nav 1000 Pro Global Position Survey (GPS) receiver has a possible error of ($\pm$) 30m and the staff has a possible error of (+/-) 10%.

3.5.1 Cross-sectional Survey of the Stations

T.B.M. Carrying

The T.B.M.(Temporary Bench Mark) (RL=5.363m PWD) established by BWDB at Zilla Parishad Dakbangla, Kuakata was carried for the survey works (Photo 16). This T.B.M. station is usually utilized in the BWDB Coastal Embankment Rehabilitation Project at Kuakata.



Photo 15: Vehicle for Field Investigation



Photo 16: T.B.M. (Temporary Bench Mark) carrying through the Coastal Embankment (Polder No. 48)

Cross-sectional Survey

The cross-sectional survey of each station was done by direct levelling (Photo 17 & 18). The readings were taken with the help of a staff and the distances were measured with the tape. It was not possible to continue the survey work throughout the day because of high tides and waves. The survey readings were recorded in a level book and the reduced levels were calculated with respect to the T.B.M. (RL=5.363m PWD) established by BWDB at Zilla Parishad Dakbangla. The calculated reduced levels are presented in the tables 3.2 through 3.7. The bed level of the khals were also surveyed and are shown with the Table 3.7.



Photo 17: Cross-sectional Survey works across the Beach



Photo 18: Staff positioning for Cross-sectional survey works across the Beach

Table 3.2
Cross-Sectional Survey of the Sea Beach (Sheet-1)

Station No : 1

Date : 09/6/99
Name : Khajura, Kuakata
Chainage : 0.00 Km
Location : Longitude : 90°5.10'
Latitude : 21°50.99'
W.L : 0.36m PWD
Time : 12-00 AM
Tide : Low

Dist. (m)	RL (mPWD)	Remarks
0.00	2.98	
5.00	2.73	
13.00	2.64	3 rd Sample location
20.00	2.51	
30.00	2.27	
42.00	1.98	2 nd Sample location
50.00	1.82	
60.00	1.62	
70.00	1.32	
80.00	1.10	
90.00	0.99	
100.00	0.92	
110.00	0.84	
120.00	0.74	
130.00	0.58	
140.00	0.47	
145.00	0.45	1 st Sample location
150.00	0.36	Water level
160.00	0.02	
172.00	(-) 0.11	
180.00	(-) 0.21	

Station No : 2

Date : 09/6/99
Name : Nakuripara, Kuakata
Chainage : 2.00 Km
Location : Longitude : 90°5.49'
Latitude : 21°49.95'
W.L : 0.84m PWD
Time : 02-20 PM
Tide : High

Dist. (m)	RL (mPWD)	Remarks
0.00	2.94	
8.00	2.65	
12.50	2.45	3 rd Sample location
20.00	2.14	
25.00	2.02	
35.00	1.50	2 nd Sample location
50.00	1.33	
60.00	1.28	
70.00	1.26	
77.00	1.20	
85.00	0.90	1 st Sample location
90.00	0.84	Water level
100.00	0.76	
110.00	0.74	
120.00	0.44	
130.00	0.34	
140.00	0.25	
155.00	0.06	
160.00	(-) 0.06	
165.00	(-) 0.22	

Table 3.3
Cross-Sectional Survey of the Sea Beach (Sheet-2)

Station No : 3

Date : 09/6/99
Name : Kuakata
Chainage : 4.00 Km
Location : Longitude : 90°6.41'
Latitude : 21°49.14'
W.L : 1.40mPWD
Time : 04-25 PM
Tide : High

Dist. (m)	RL (mPWD)	Remarks
0.00	3.07	
5.00	2.94	
9.00	2.76	3 rd Sample location
15.00	2.42	
20.00	2.22	2 nd Sample location
25.00	2.06	
30.00	1.92	
35.00	1.67	1 st Sample location
42.00	1.40	Water level
50.00	1.17	
60.00	0.98	
70.00	0.67	
80.00	0.47	
90.00	0.32	
100.00	0.19	
110.00	(-) 0.04	
115.00	(-) 0.14	

Station No : 4

Date : 11/6/99
Name : Kuakata
Chainage : 6.00 Km
Location : Longitude : 90°7.57'
Latitude : 21°48.65'
W.L : 1.17m PWD
Time : 08-45 AM
Tide : High

Dist. (m)	RL (mPWD)	Remarks
0.00	3.06	
5.00	3.09	
10.00	3.23	
15.00	3.34	3 rd Sample location
20.00	2.80	
27.00	2.28	2 nd Sample location
35.00	2.12	
40.00	1.84	
50.00	1.43	1 st Sample location
55.00	1.17	Water level
60.00	0.87	
65.00	0.62	
70.00	0.30	
75.00	0.06	
80.00	(-) 0.10	
85.00	(-) 0.29	

Table 3.4
Cross-Sectional Survey of the Sea Beach (Sheet-3)

Station No : 5

Date : 11/6/99
Name : Kuakata
Chainage : 8.00 Km
Location : Longitude : 90°8.70'
Latitude : 21°48.31'
W.L : 1.26 mPWD
Time : 11.20 AM
Tide : Low

Dist. (m)	RL (mPWD)	Remarks
0.00	3.04	
5.00	3.11	
10.00	3.35	
15.00	3.66	3 rd Sample location
20.00	3.87	
25.00	3.81	
30.00	3.28	2 nd Sample location
35.00	2.83	
40.00	2.55	
45.00	2.30	
50.00	2.11	1 st Sample location
55.00	1.93	
60.00	1.79	
65.00	1.63	
70.00	1.51	
75.00	1.40	
80.00	1.26	Water level
85.00	1.18	
90.00	1.10	
95.00	0.99	
100.00	0.87	
110.00	0.65	

Station No : 6

Date : 11/6/99
Name : Gangamati, Kuakata
Chainage : 10.00 Km
Location : Longitude : 90°9.90'
Latitude : 21°48.09'
W.L : 0.32m PWD
Time : 01-05 PM
Tide : Low

Dist. (m)	RL (mPWD)	Remarks
0.00	3.32	
5.00	3.34	
10.00	3.73	
16.00	3.00	3 rd Sample location
20.00	2.65	
25.00	2.42	
30.00	2.16	
35.00	1.99	
40.00	1.83	
45.00	1.68	
50.00	1.48	2 nd Sample location
55.00	1.33	
60.00	1.19	
65.00	1.02	
70.00	0.93	
75.00	0.89	
80.00	0.83	
85.00	0.74	
90.00	0.53	1 st Sample location
98.00	0.32	Water level
105.00	0.24	
110.00	0.13	
115.00	(-) 0.02	

Table 3.6
Cross-Sectional Survey of the Sea Beach (Sheet-5)

Station No : 9

Date : 12/6/99
Name : Kawarchar, Kuakata
Chainage : 16.00 Km
Location : Longitude : 90°13.17'
Latitude : 21°48.62'
W.L : (-) 0.21 PWD
Time : 02-00 PM
Tide : Low

Dist. (m)	RL (mPWD)	Remarks
0.00	3.34	
10.00	3.34	
20.00	3.29	
30.00	3.19	
40.00	3.62	3 rd Sample location
50.00	3.87	
60.00	3.25	
65.00	2.95	
70.00	2.66	
75.00	2.39	
80.00	2.14	
85.00	1.93	
90.00	1.78	
95.00	1.63	
100.00	1.49	
105.00	1.39	2 nd Sample location
110.00	1.29	
115.00	1.17	
120.00	1.07	
125.00	0.97	
130.00	0.89	
135.00	0.78	
140.00	0.67	
145.00	0.57	
150.00	0.51	
155.00	0.31	1 st Sample location
160.00	0.15	
165.00	(-) 0.01	
173.00	(-) 0.21	Water level
180.00	(-) 0.41	
190.00	(-) 0.71	

Station No : 10

Date : 12/6/99
Name : Kawarchar, Kuakata
Chainage : 18.00 Km
Location : Longitude : 90°14.00'
Latitude : 21°49.35'
W.L : (-) 0.30m PWD
Time : 03-30 PM
Tide : High

Dist. (m)	RL (mPWD)	Remarks
0.00	3.39	
10.00	3.06	
20.00	2.98	
30.00	3.05	
40.00	2.89	
50.00	2.95	
58.00	2.65	3 rd Sample location
70.00	2.24	
80.00	1.89	
90.00	1.69	
100.00	1.52	
110.00	1.38	
120.00	1.24	
130.00	1.05	2 nd Sample location
140.00	0.91	
150.00	0.73	
160.00	0.56	
170.00	0.33	
180.00	0.01	1 st Sample location
190.00	(-) 0.30	Water level
200.00	(-) 0.62	
210.00	(-) 0.78	
220.00	(-) 0.98	

Table 3.7

Cross-Sectional Survey of the Sea Beach (Sheet-6)

Station No : 11

Date : 12/6/99
 Name : Kawarchar, Kuakata
 Chainage : 19.45 Km
 Location : Longitude : 90°14.59'
 Latitude : 21°49.97'
 W.L : (-) 0.32m PWD
 Time : 04-30 PM
 Tide : Low

Dist. (m)	RL (mPWD)	Remarks
0.00	2.95	
10.00	3.05	
20.00	2.56	3 rd Sample location
30.00	2.32	
40.00	2.13	
50.00	2.21	
60.00	2.19	
70.00	2.13	
80.00	1.94	
90.00	1.81	
100.00	1.65	
110.00	1.49	
120.00	1.39	
130.00	1.28	2 nd Sample location
140.00	1.15	
150.00	1.03	
160.00	0.92	
170.00	0.74	
180.00	0.46	
190.00	0.11	1 st Sample location
200.00	(-) 0.12	
210.00	(-) 0.25	
220.00	(-) 0.32	Water level
225.00	(-) 0.51	
230.00	(-) 0.66	
240.00	(-) 0.78	

Bed level of the River/Khal

Name	Chainage (Km)	Elevation (m PWD)
Nilgonj River	0.00	(-) 6.93
Smaller Khal	6.70	0.631
Smaller Khal	8.50	1.044
Gangamati Khal	11.46	(-) 0.45
Kawarchar Thota dead channel	19.45	-

3.5.2 Collection of Soil Samples

Three locations were selected for each station as explained in Figure 3.4. These locations were: one within the foreshore zone adjacent to the water level; one from the limit of normal wave up-rush (approximately selected by inquiry from the local people) near the backshore zone and one approximately at the middle of the two. Foreshore is the part of the shore, lying between the crest of the seaward berm (or, upper limit of wave wash at high tide) and the ordinary low-water mark, that is ordinarily traversed by the up-rush and back rush of the waves as the tides rise and fall as defined by US. Army Coastal Engineering Research Center, Department of the Army Corps of Engineers (Figure 3.5). Backshore is that zone of the shore or beach lying between the foreshore and the coastline comprising the Berm or Berms and acted upon by waves only during severe storms especially when combined with exceptionally high water as defined by US. Army Coastal Engineering Research Center, Department of the Army Corps of Engineers (Figure 3.5). The distance between the locations were measured with the tape. At every locations, three samples were collected; one from the surface; one at 0.6m depth below the surface; and one at 1.0m depth below the surface. Thus nine soil samples were collected for each station and all together total ninety nine nos. of soil samples were collected from the eleven nos. of stations during the first field trip.

The samples from the surface were collected by hand scrapping and the samples at 0.6m depth and 1.0m depth were excavated by the spade in a test pit and were collected by the hand (Photo 19).

Approximately 2 kilogram of soil was stored in the plastic bag for each sample. These were properly marked stating the Station no., Location no. and the Sample no. as explained in Figure no. 3.4. For example, Sample no. S3-3-1 means surface soil sample from Station no. 3 and at location no. 3, Sample no. S3-3-2 means soil sample at 0.6m depth from Station no. 3 and at location no. 3 and Sample no. S3-3-3 means soil sample at 1.0m depth from Station no. 3 and at location no. 3 (Figure 3.4). A schematic diagram showing the profile for sample collection is also shown in Figure 3.5.

During second field trip additional soil samples (6 nos.) from the bed and bank of Nilgonj river and Gangamati khal were also collected.



Photo 19: Collection of Soil Samples by hand scrapping at Station no. 1 (Chainage 0.00 Km)

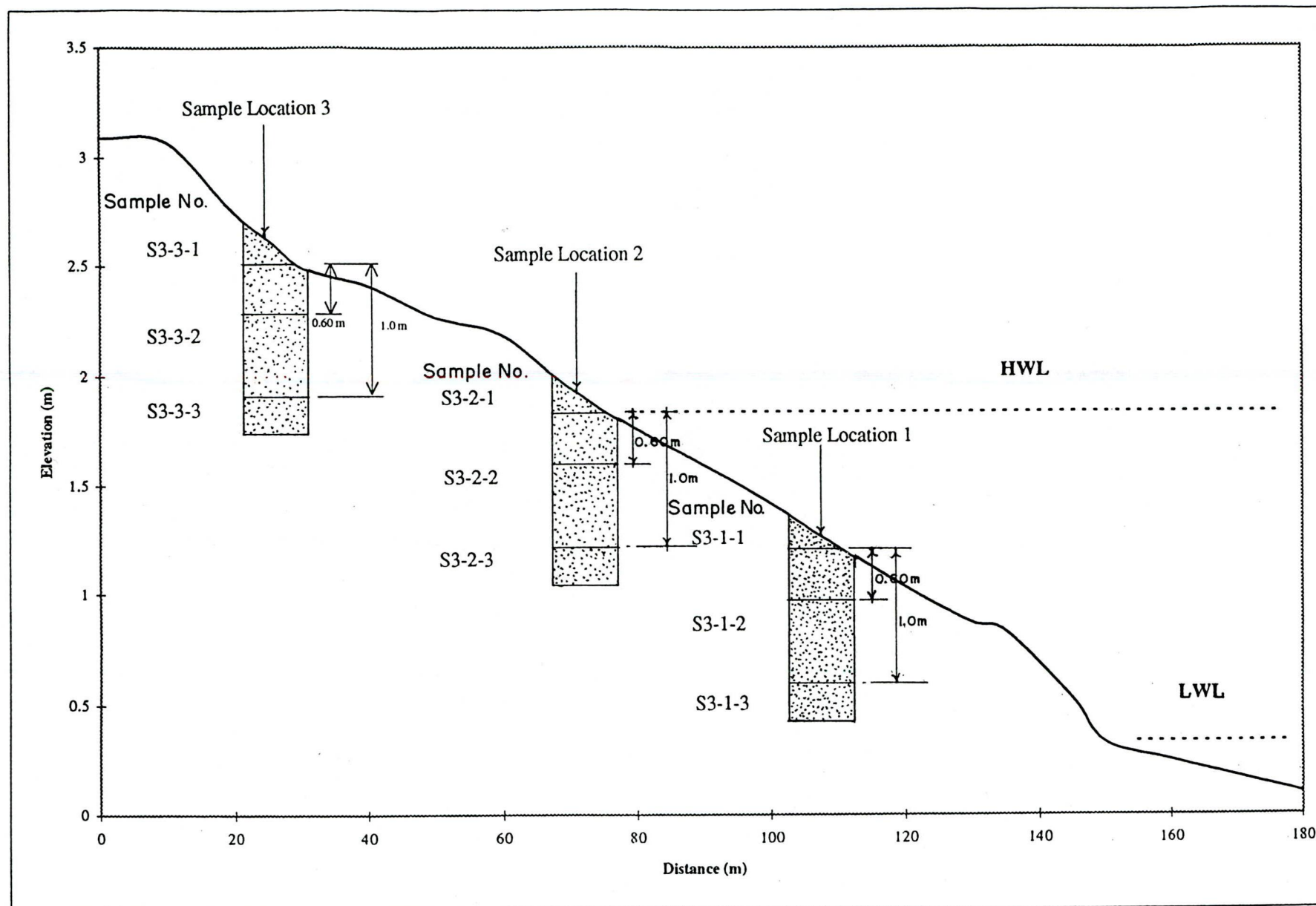
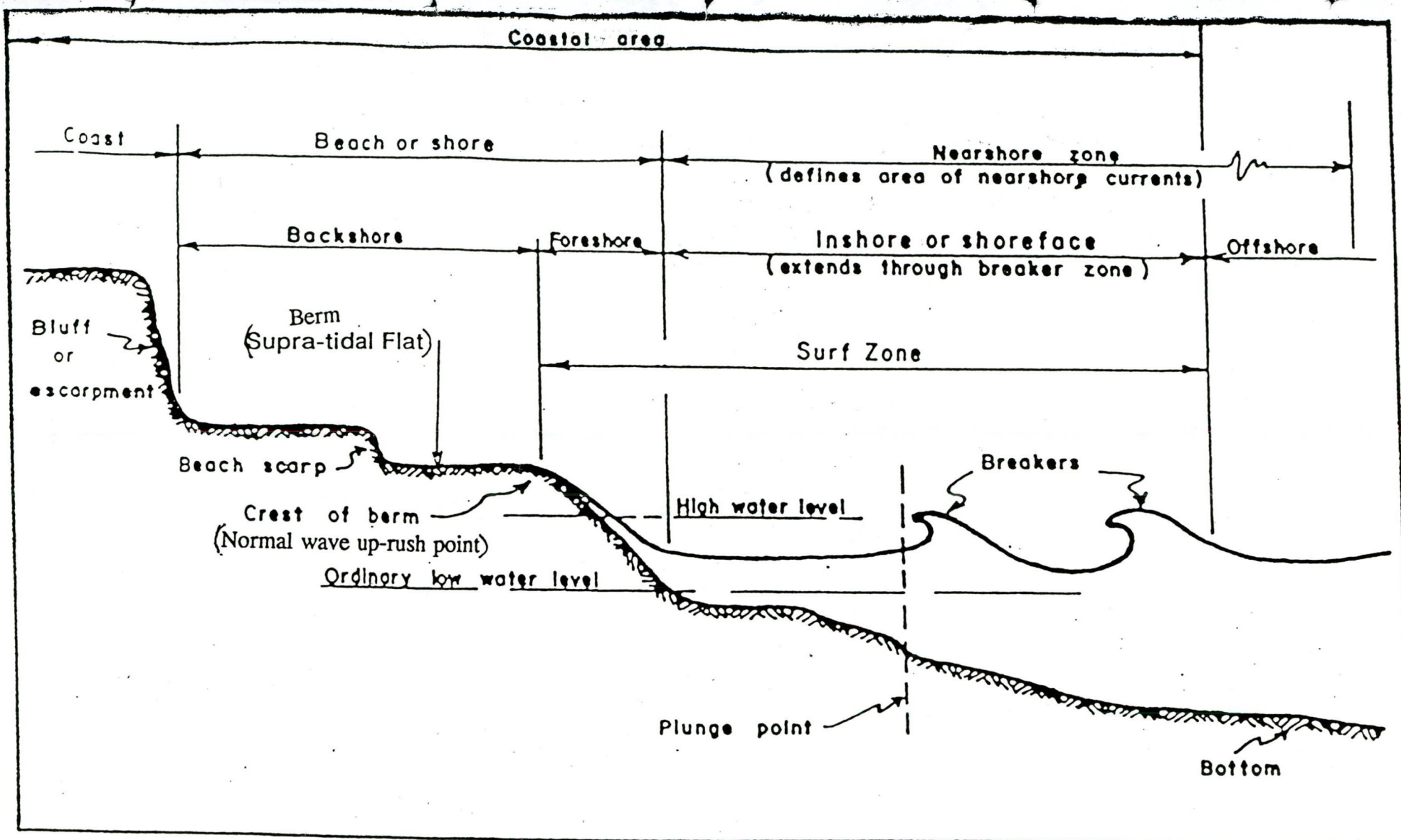


Figure 3.4 : Locations of Soil Sampling across the Beach (Station 3) and Sampling Nomenclature



(after Shore Protection Manual, Volume II, 1977)

Figure 3.5 Schematic Diagram Showing Sea Beach Profile.

3.6 LABORATORY TESTING OF SOIL SAMPLES

Laboratory testing of the soil samples were done in the Hydraulics and River Engineering Laboratory of the Bangladesh University of Engineering and Technology, Dhaka. The tests were done by using the U.S. standard sieve number 16, 30, 50, 100 and 200 (sieve opening 1.18mm, 0.60mm, 0.30mm, 0.15mm and 0.075mm) and by the British Standard (BST) method. The results were plotted in a semi-logarithmic graph paper. The percentage finer was plotted as the ordinate to a natural scale, and the corresponding particle diameter (sieve opening) was plotted as the abscissa to a logarithmic scale. The curve thus plotted was the gradation curve as shown in the figures between Figure no. 3.6 through 3.40. The hydrometer analysis of the samples were not required as the presence of fine grained materials were very less (maximum 5%).

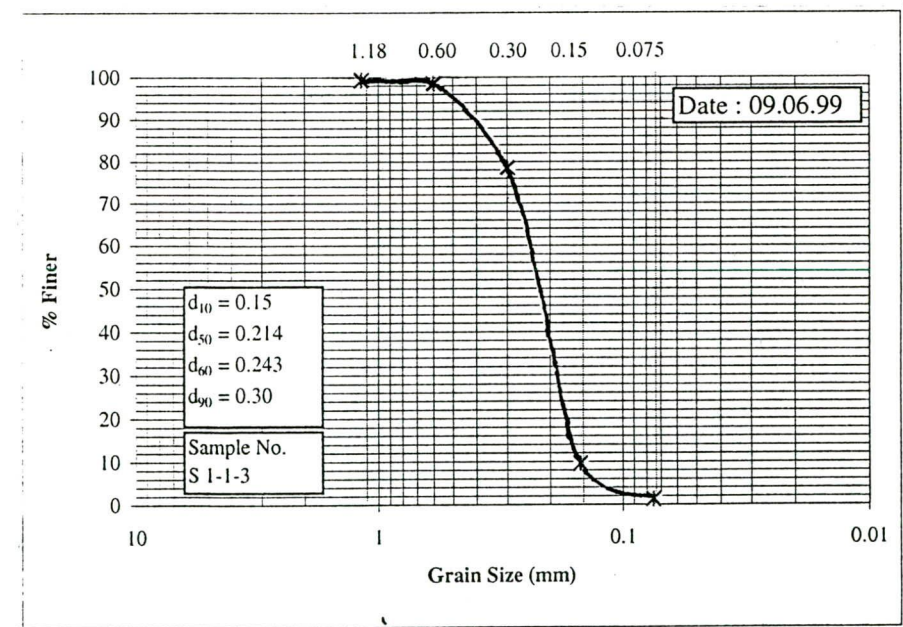
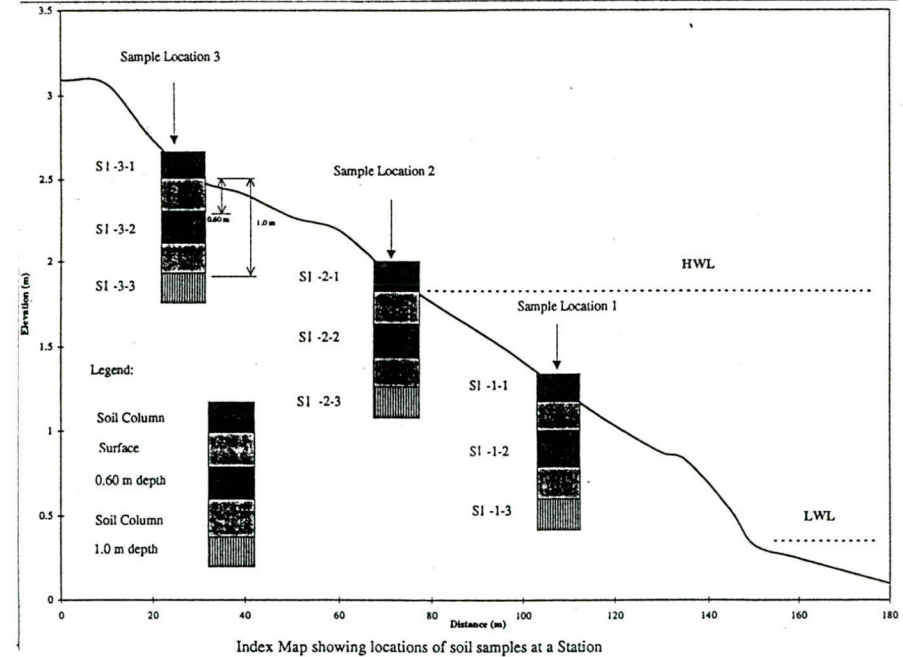
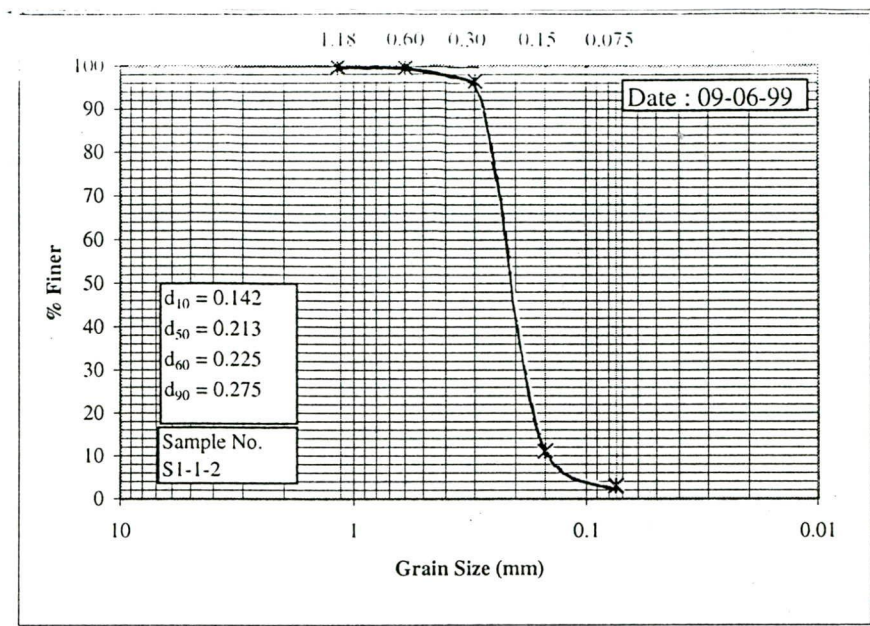
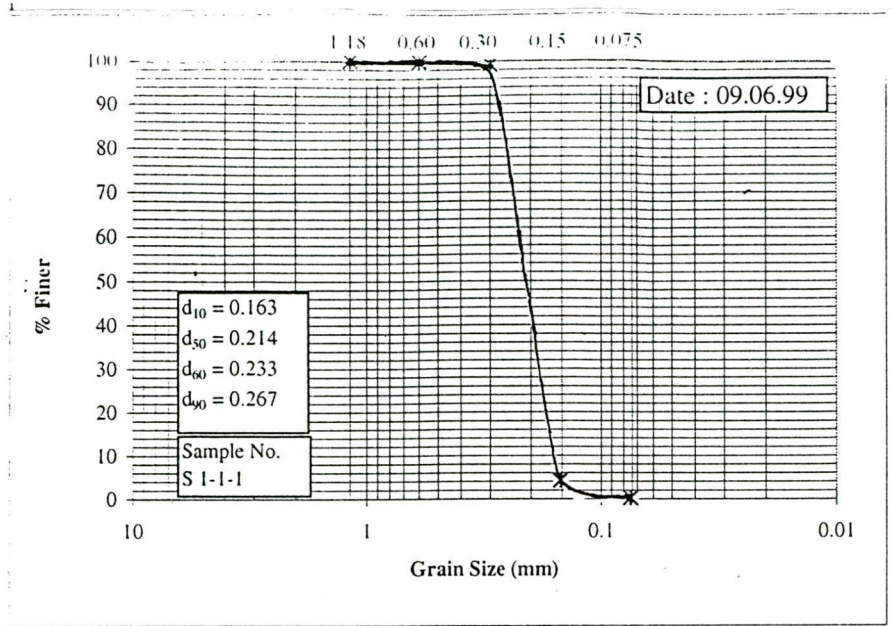


Figure 3.6 : Grain Size Distribution Curve for Station 1

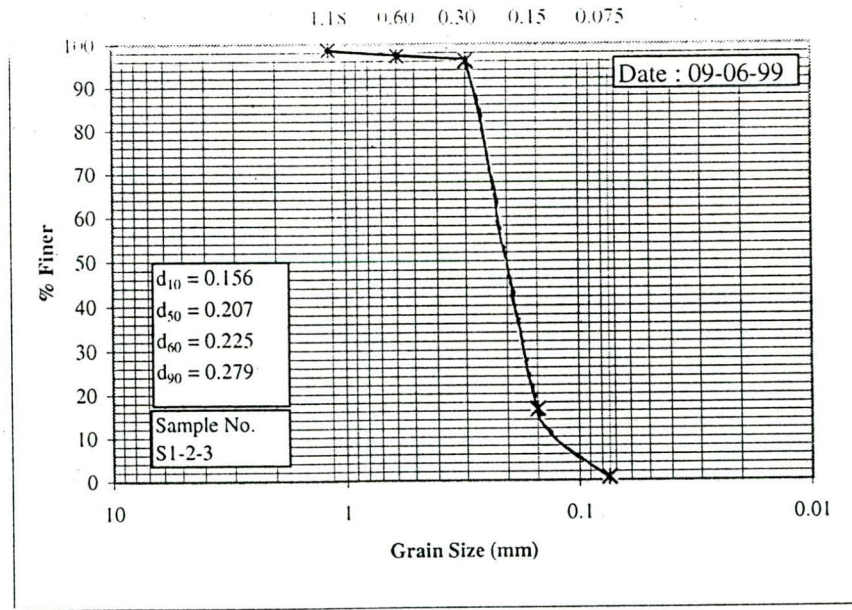
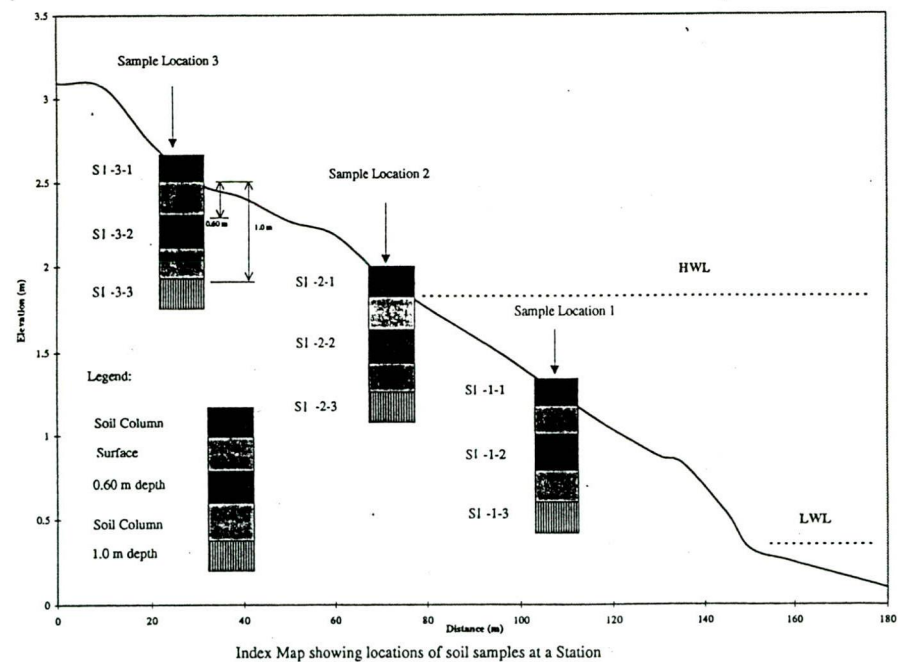
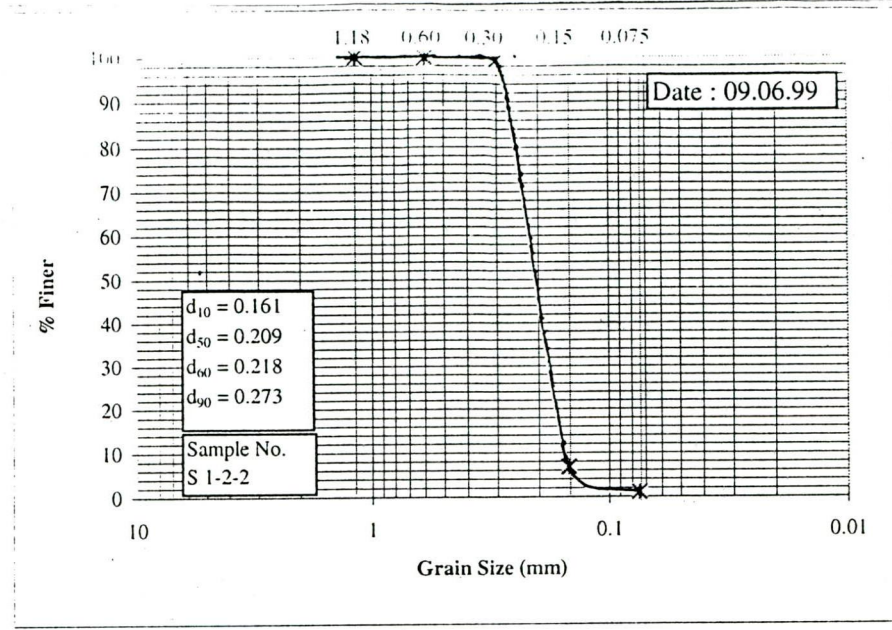
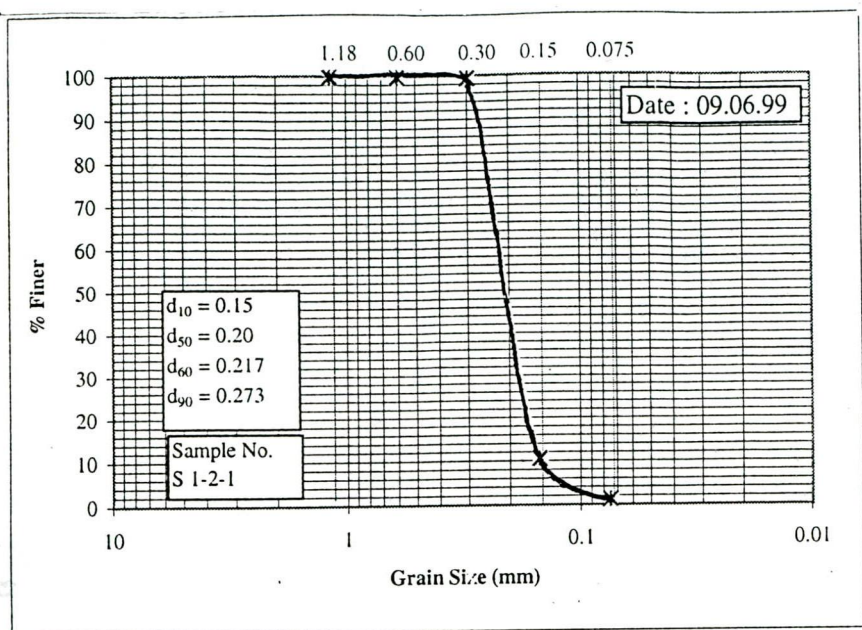


Figure 3.7 : Grain Size Distribution Curve for Station 1

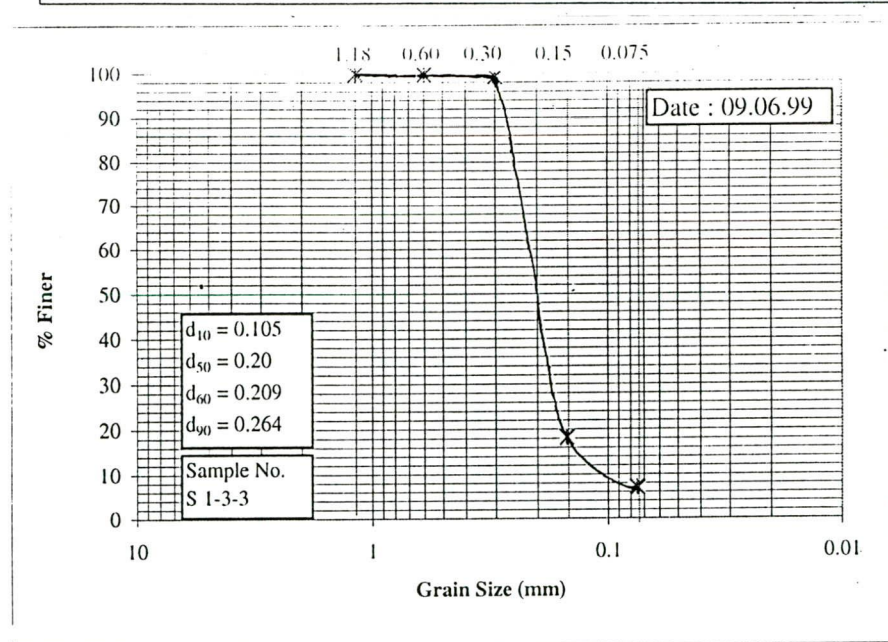
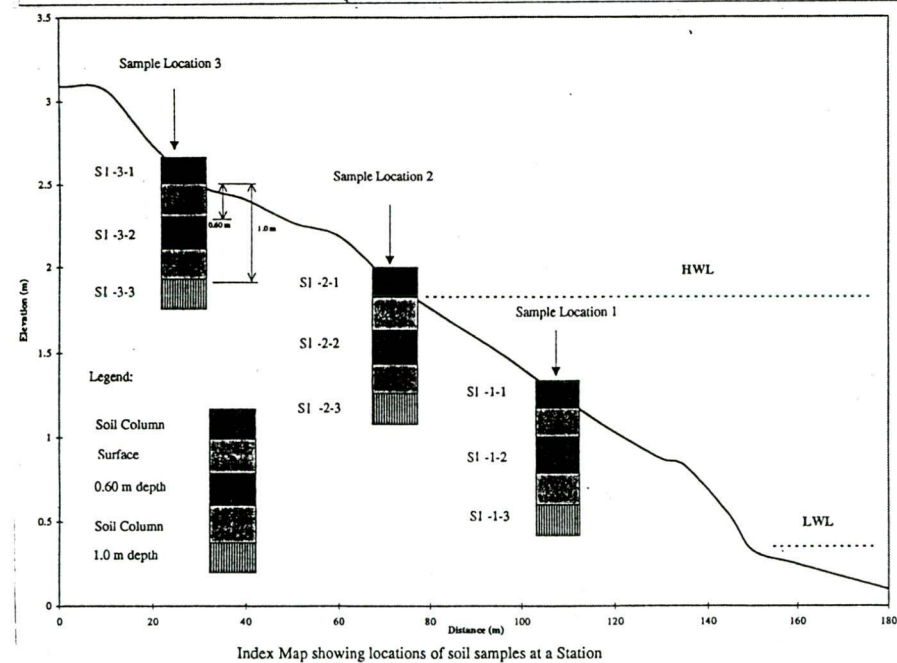
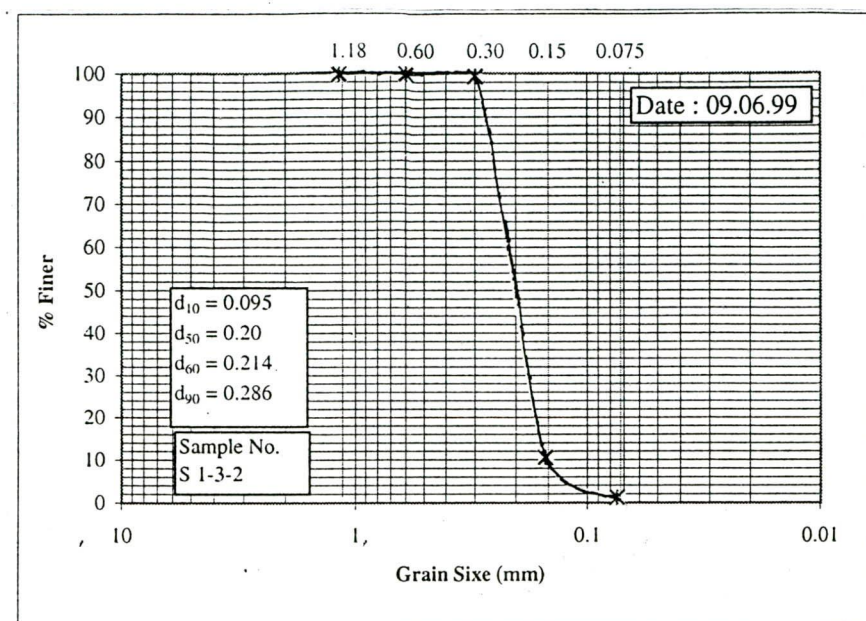
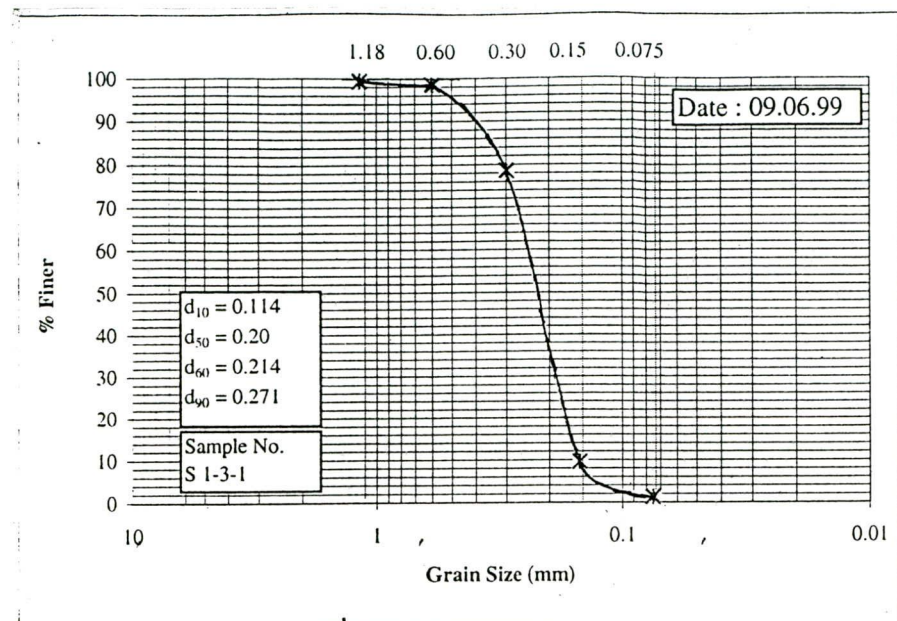


Figure 3.8 : Grain Size Distribution Curve for Station 1

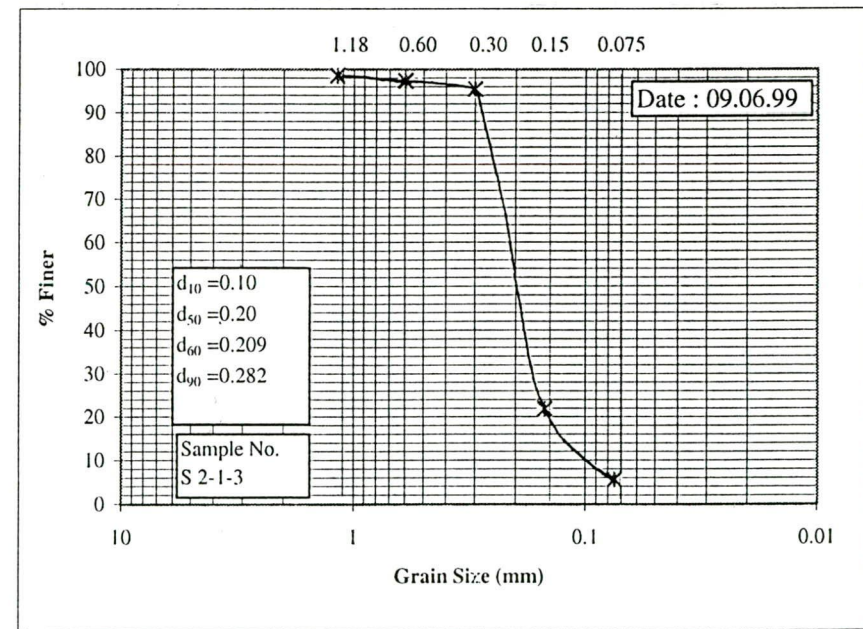
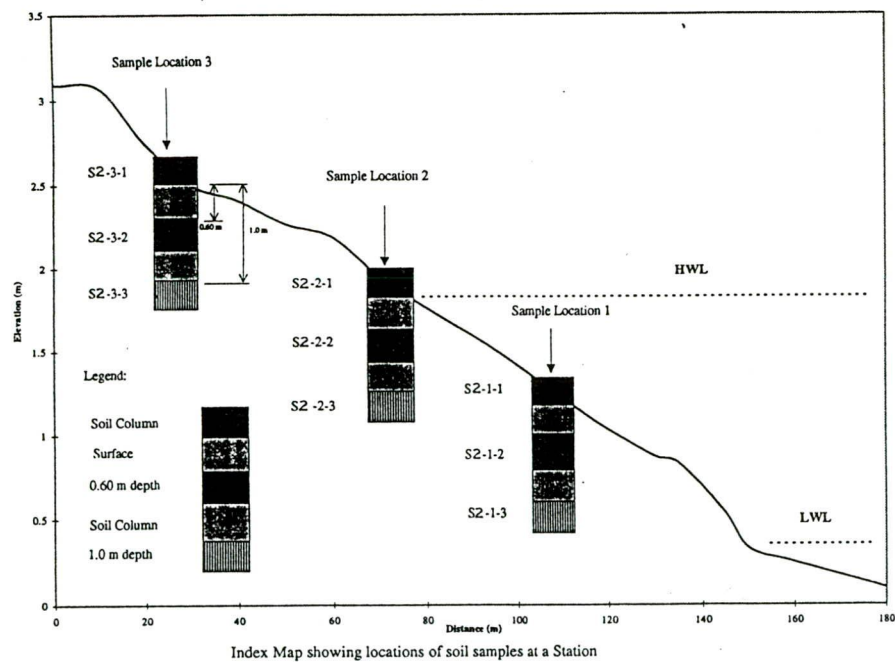
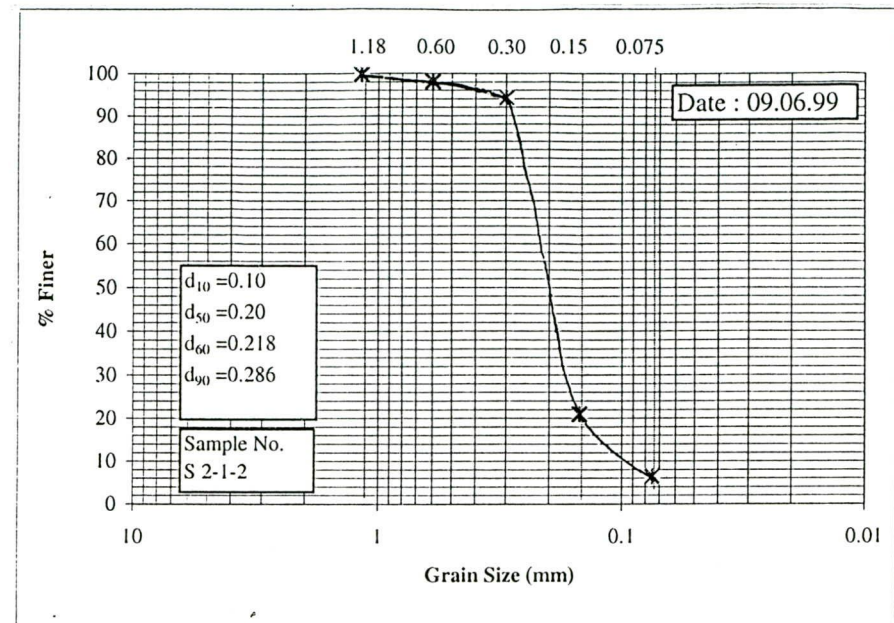
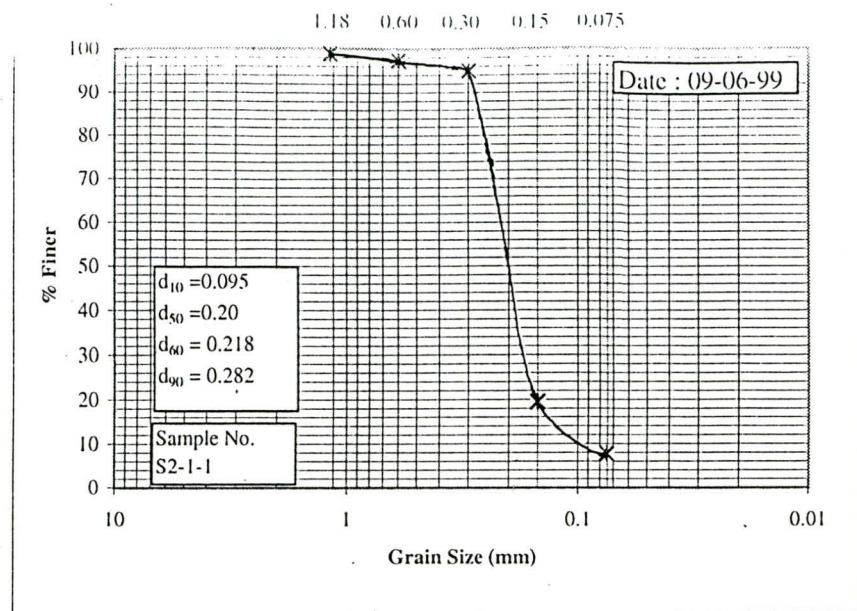


Figure 3.9 : Grain Size Distribution Curve for Station 2

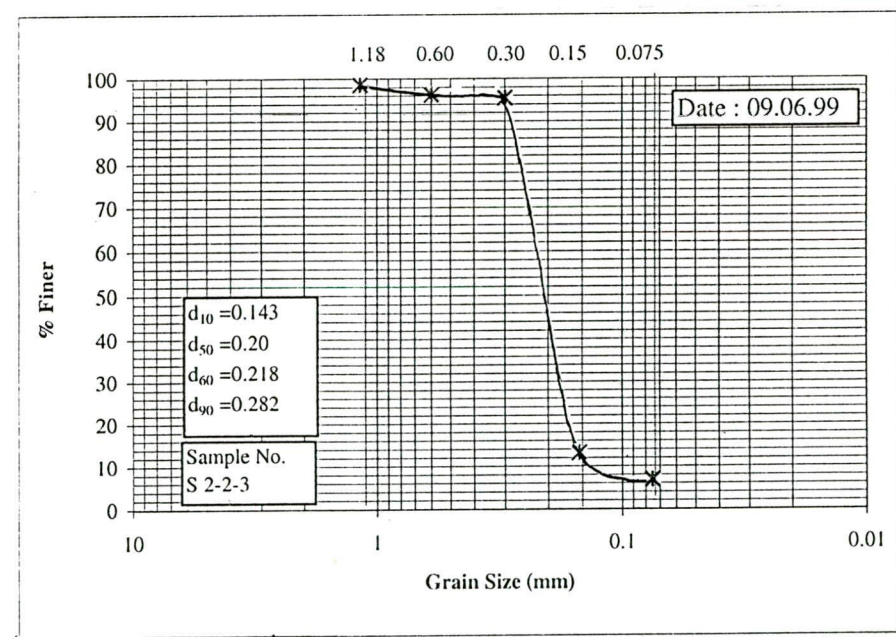
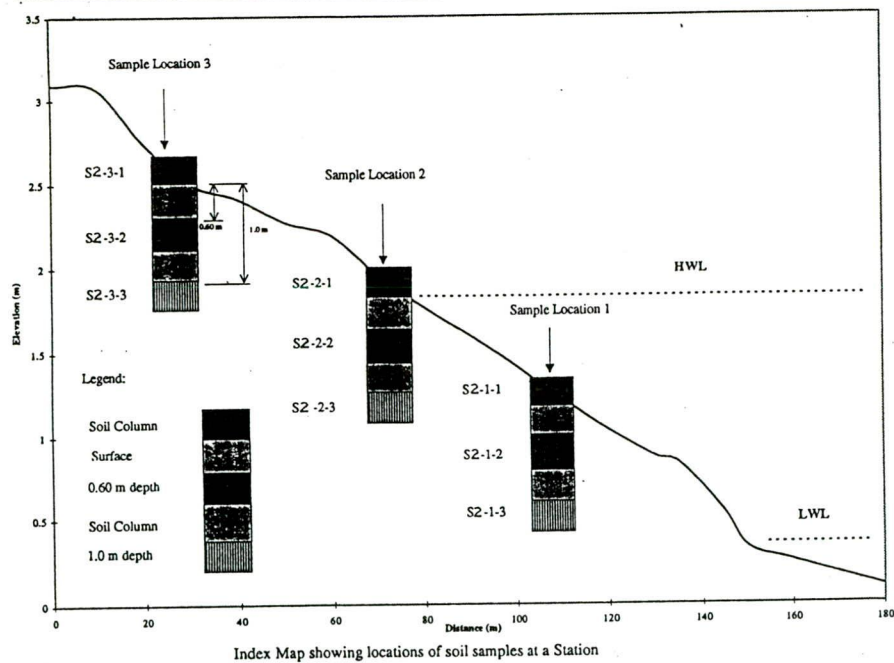
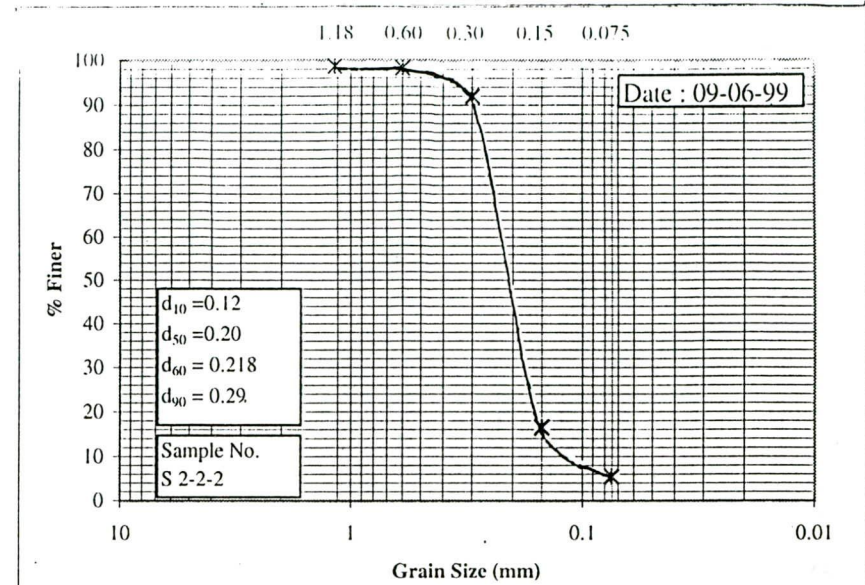
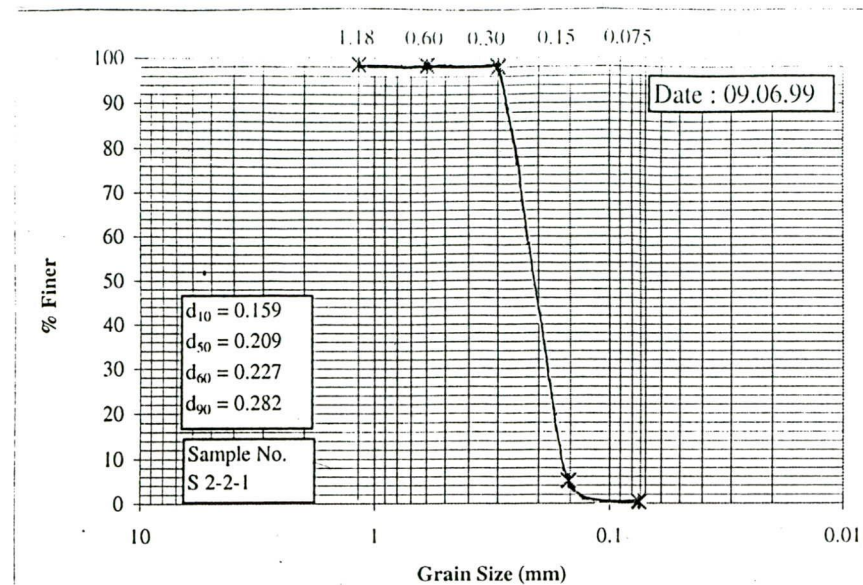


Figure 3.10 : Grain Size Distribution Curve for Station 2

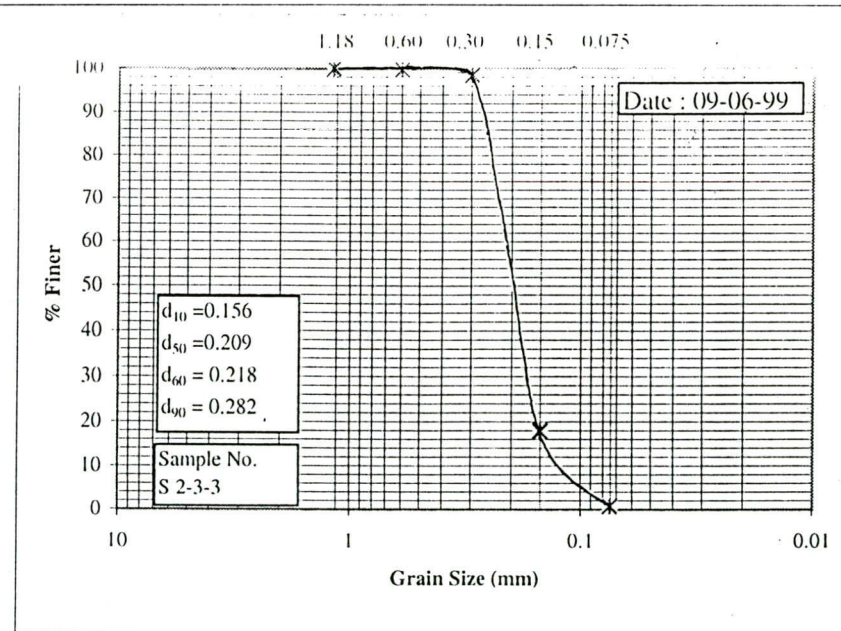
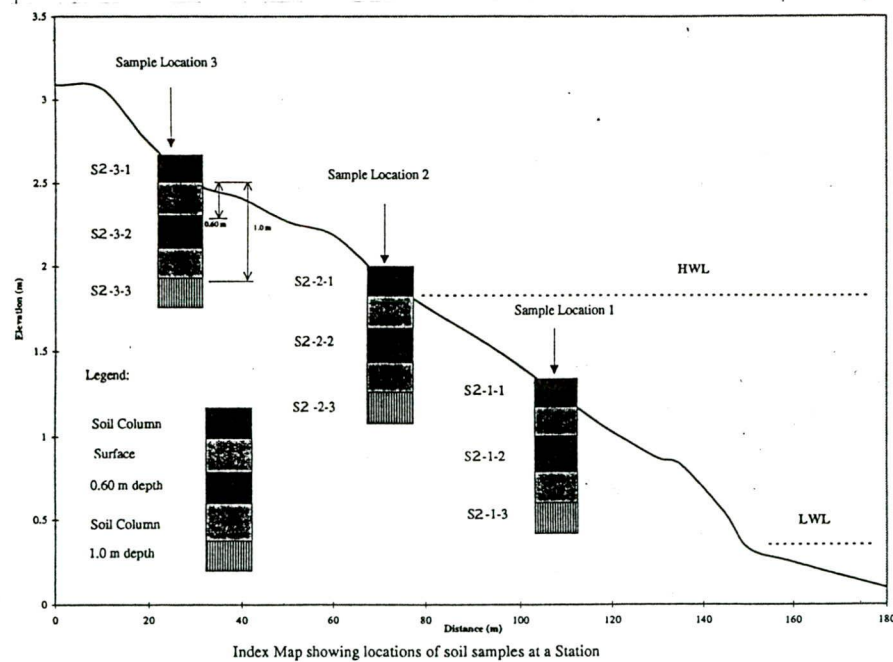
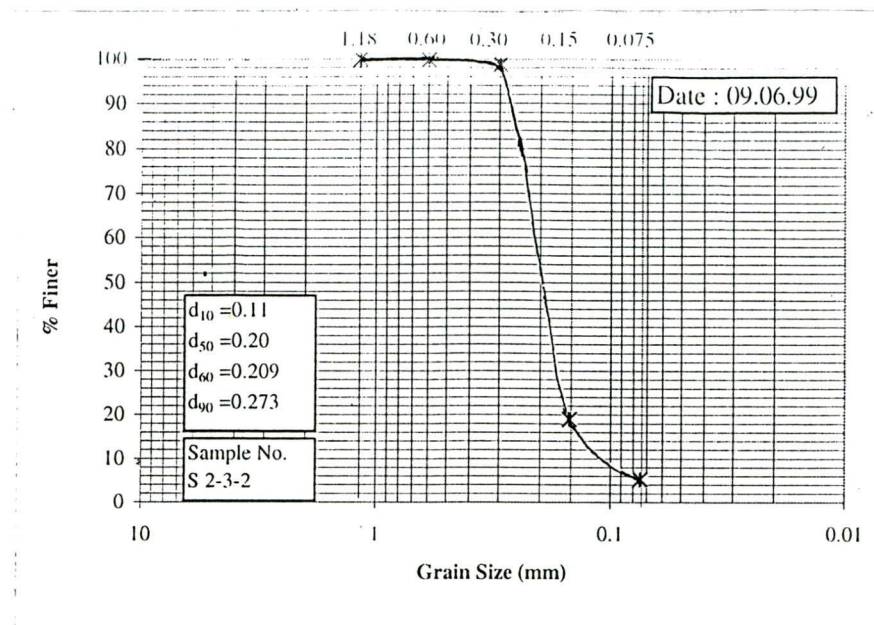
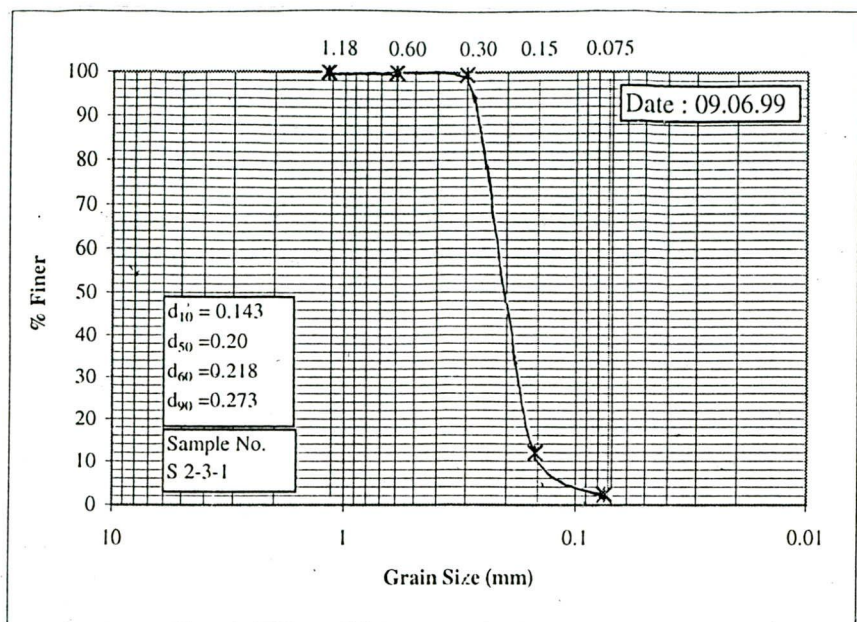


Figure 3.11 : Grain Size Distribution Curve for Station 2

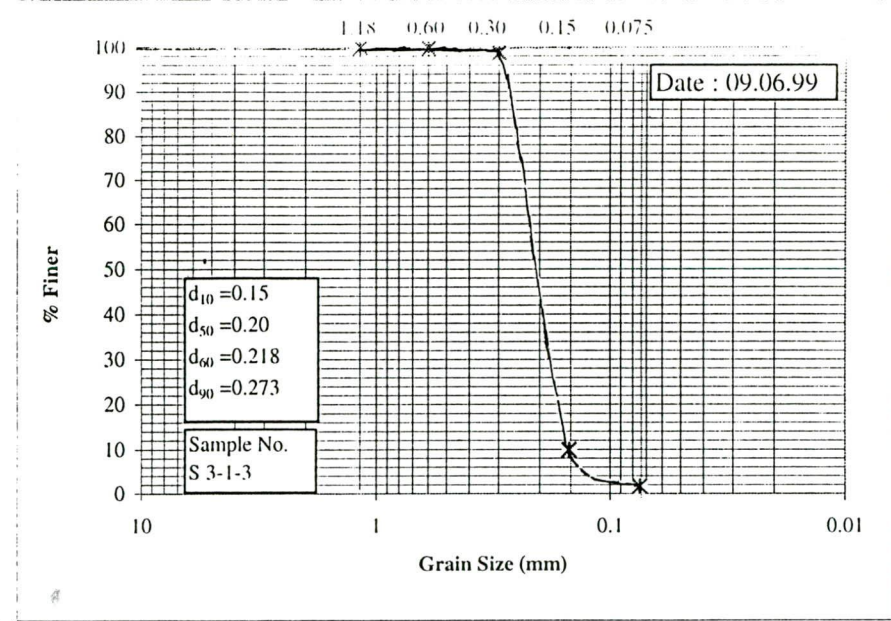
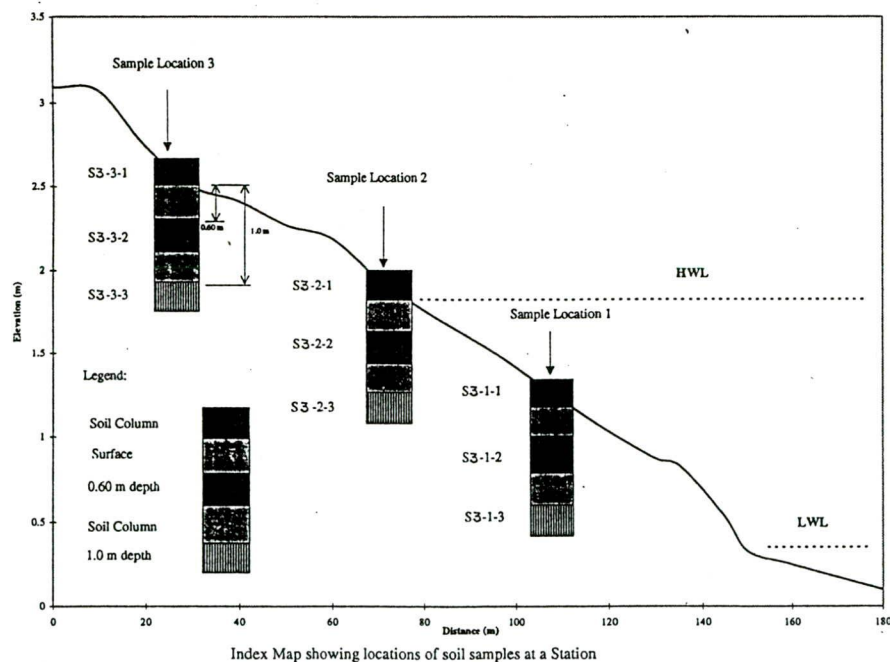
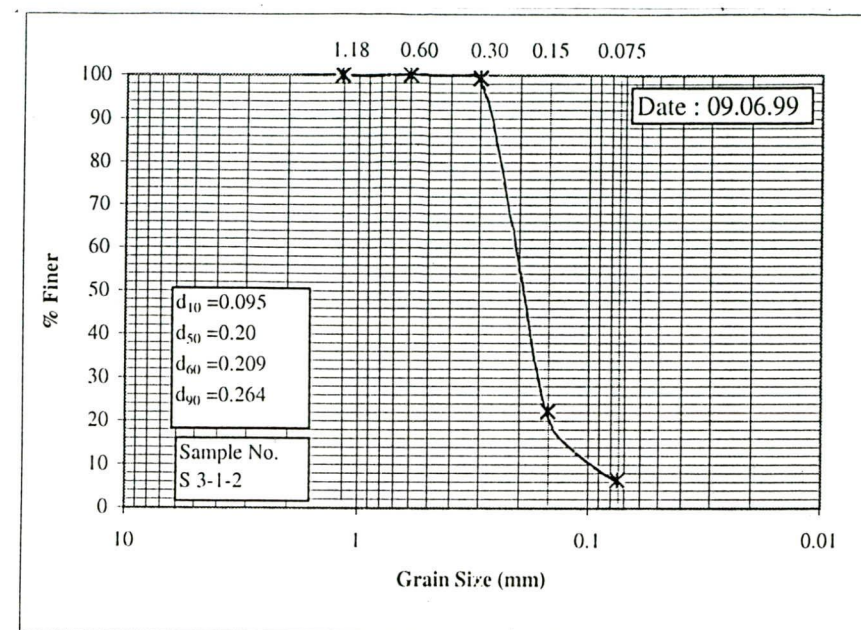
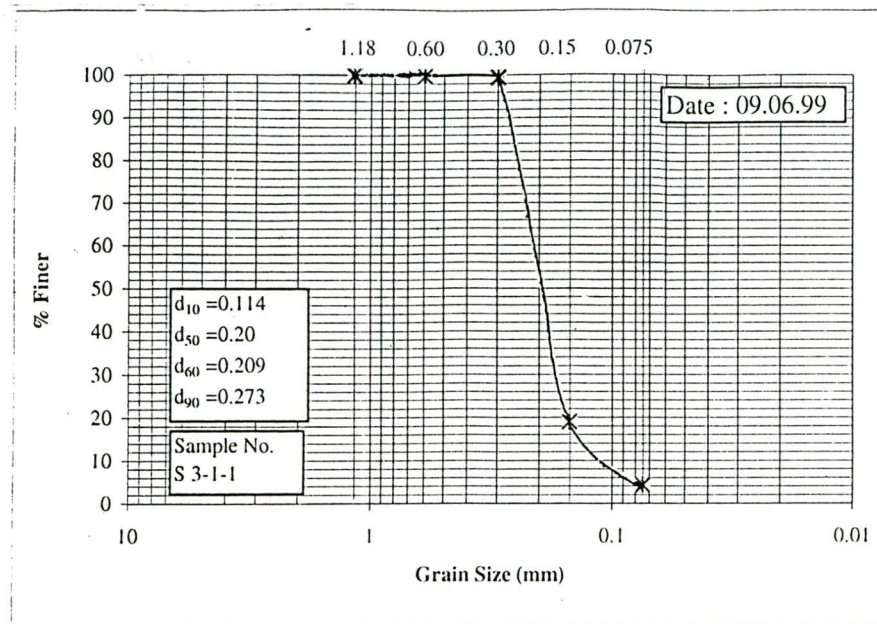


Figure 3.12 : Grain Size Distribution Curve for Station 3

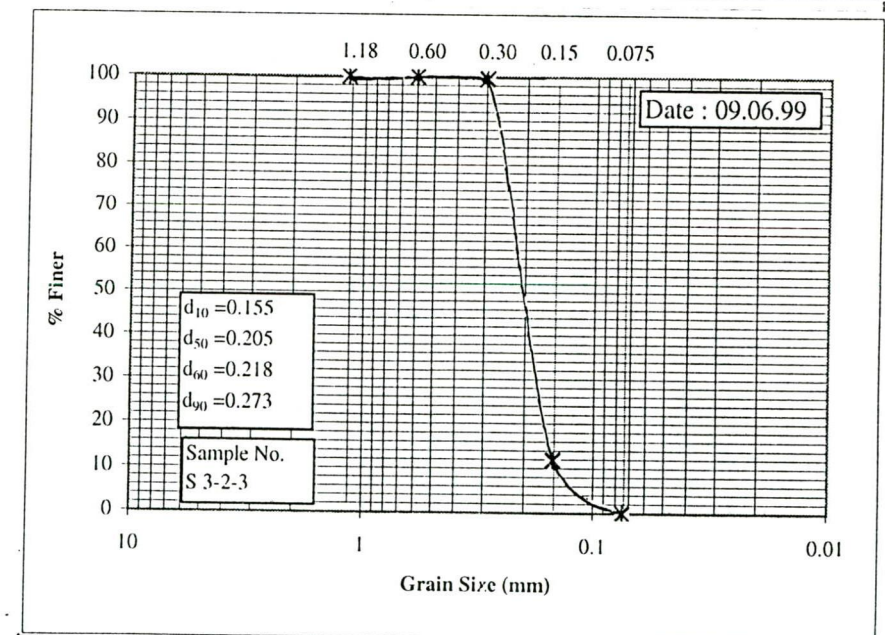
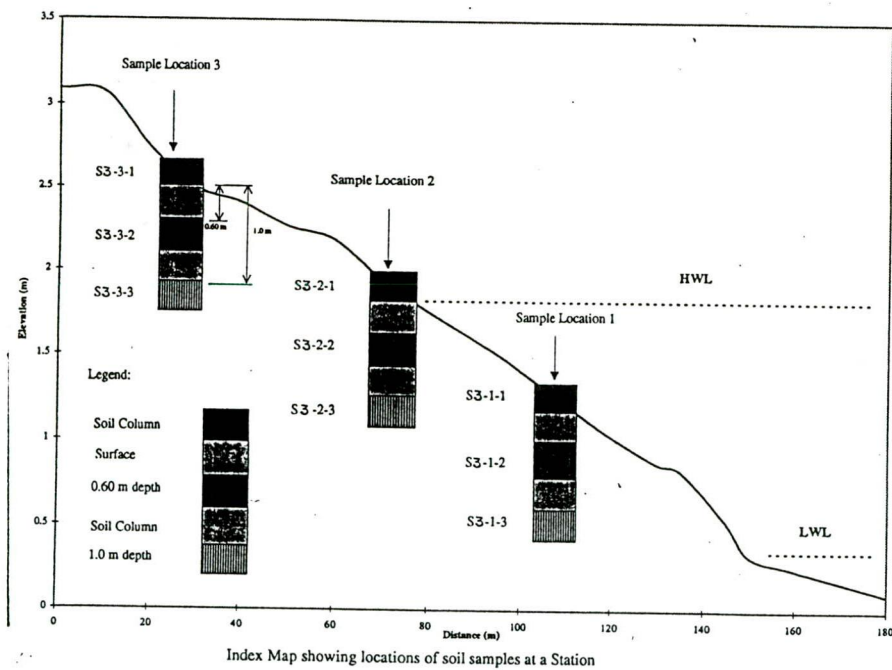
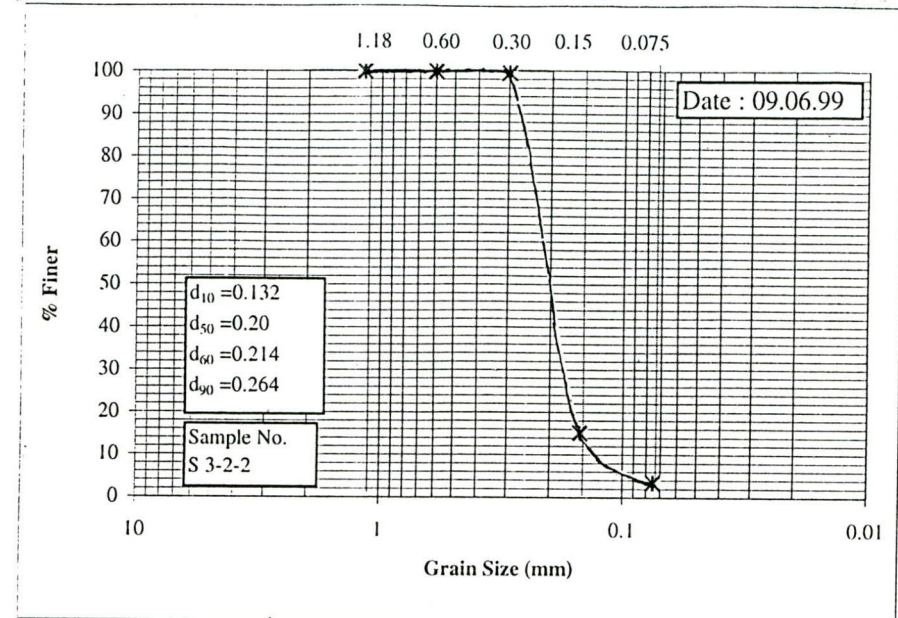
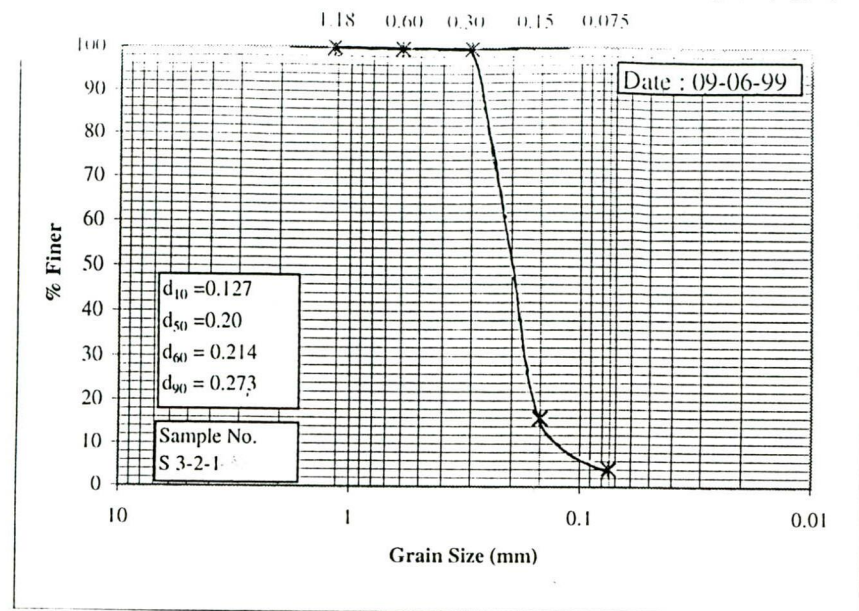


Figure 3.13 : Grain Size Distribution Curve for Station 3

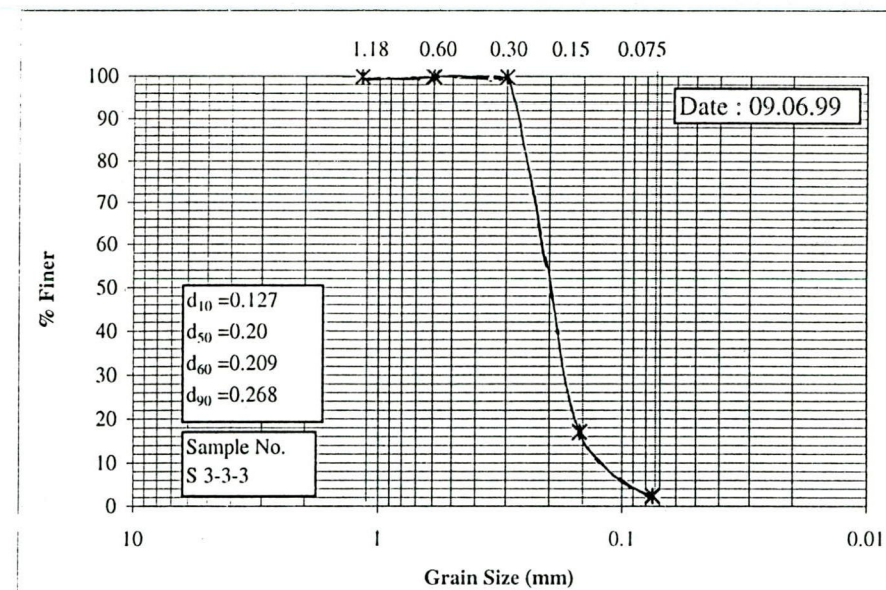
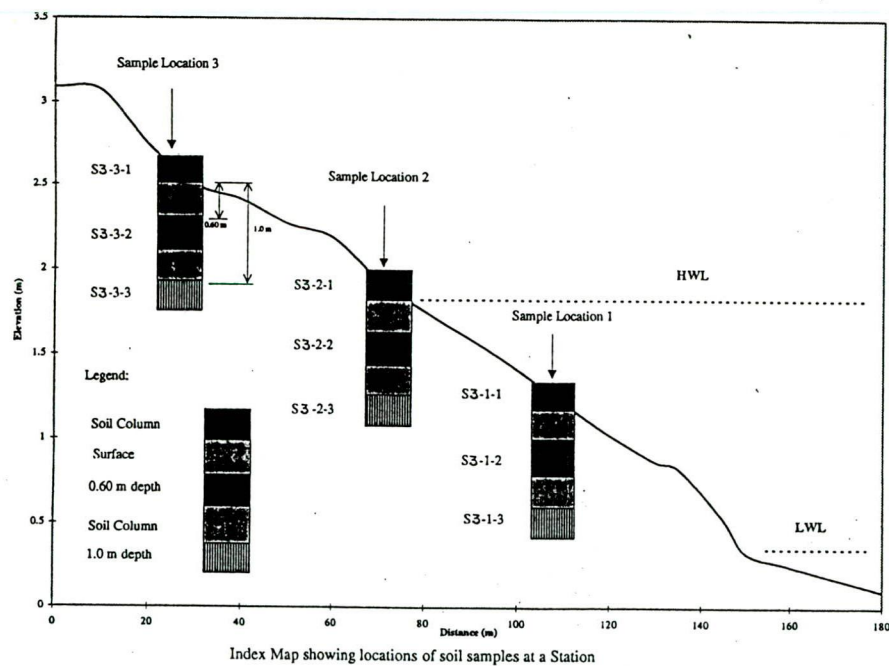
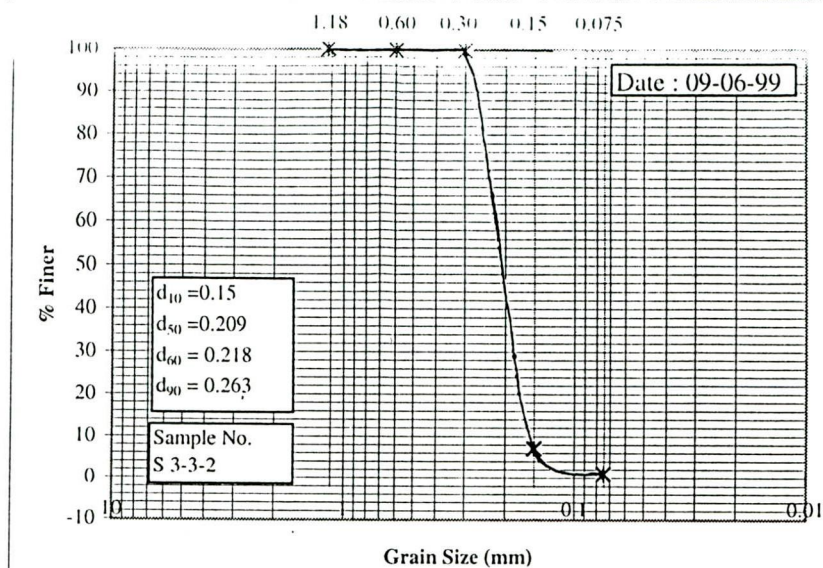
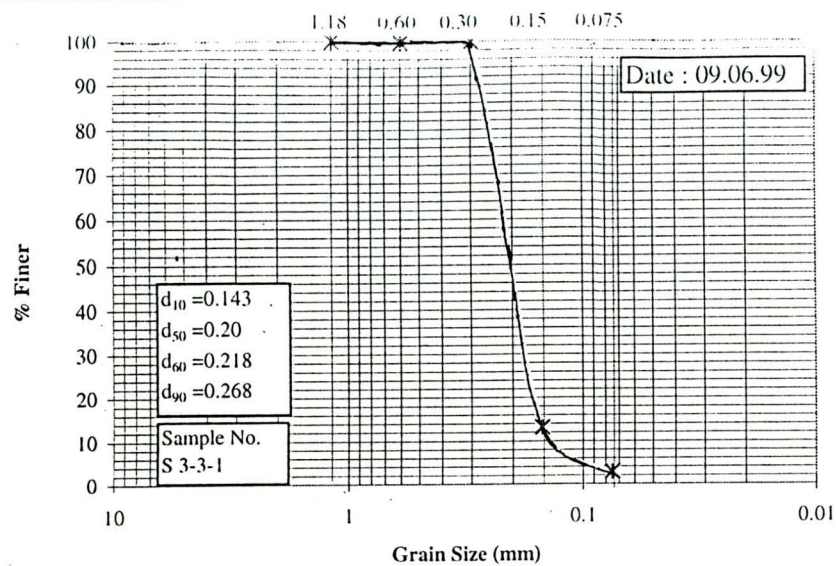


Figure 3.14 : Grain Size Distribution Curve for Station 3

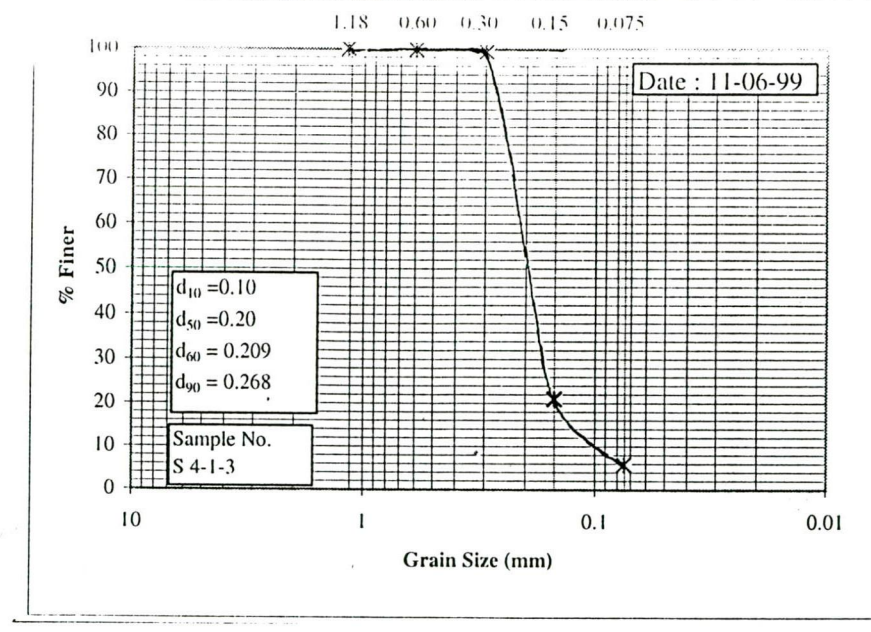
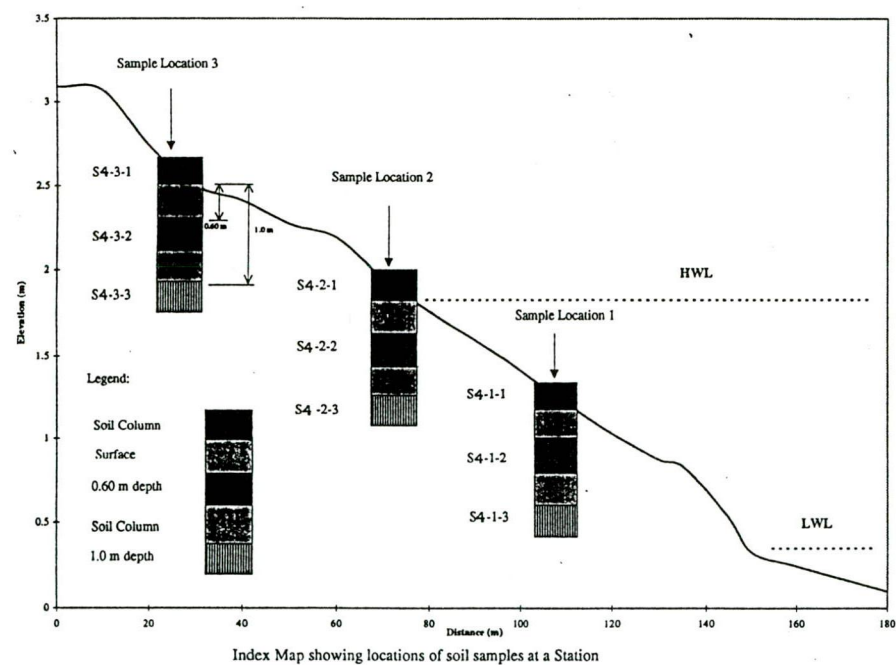
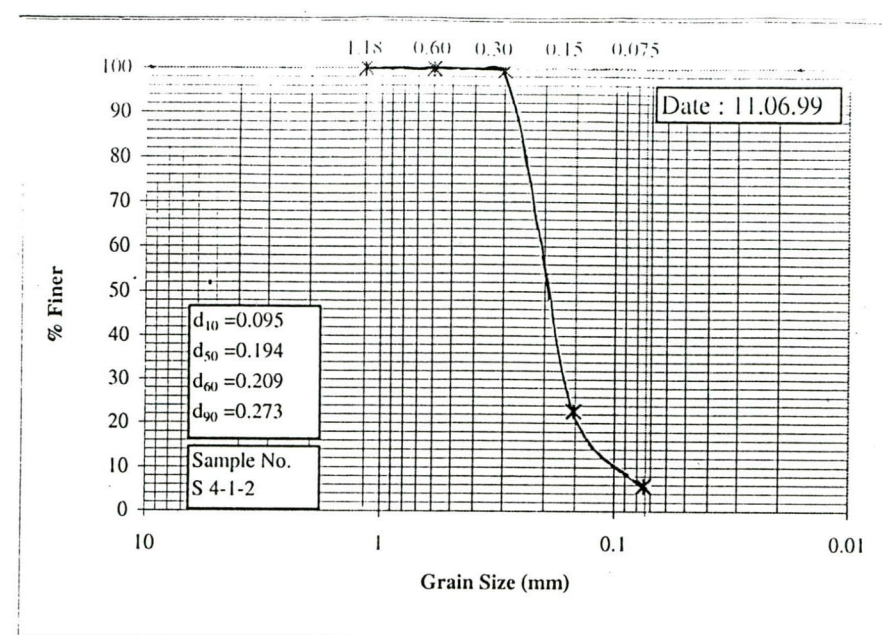
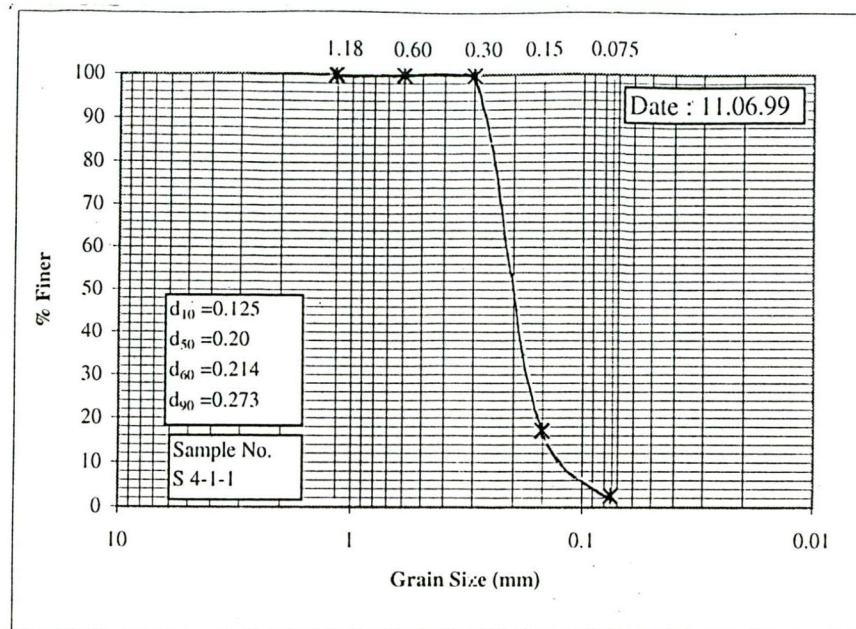


Figure 3.15 : Grain Size Distribution Curve for Station 4

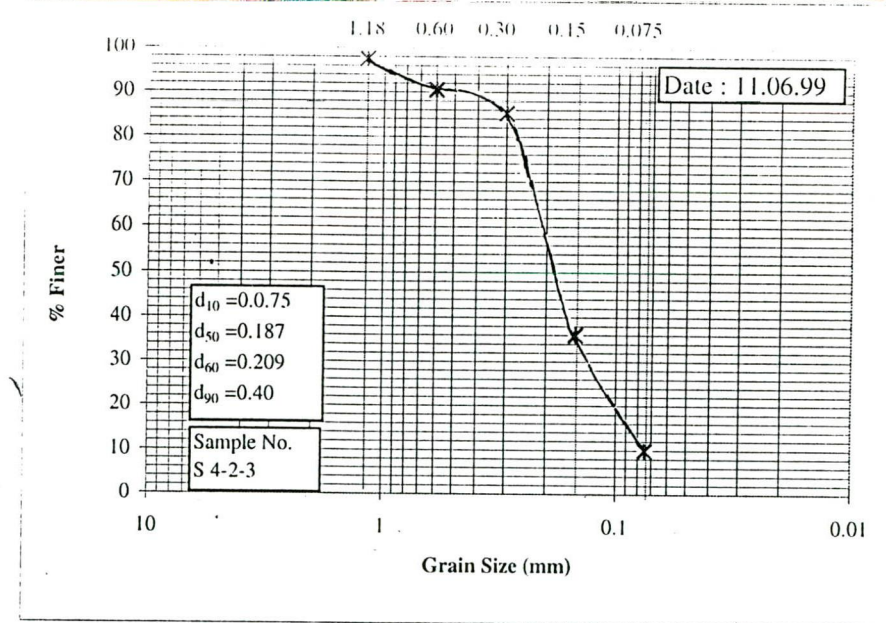
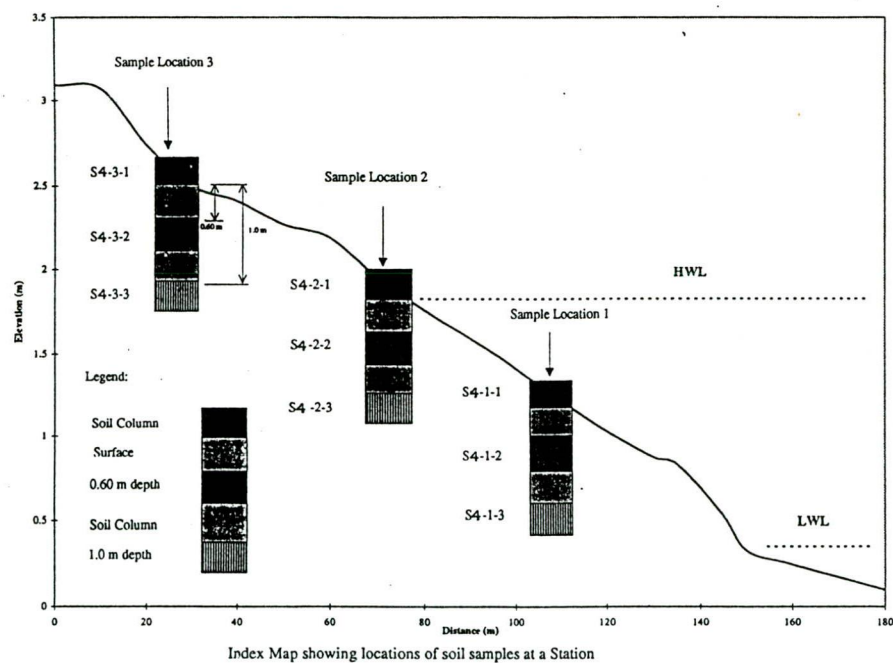
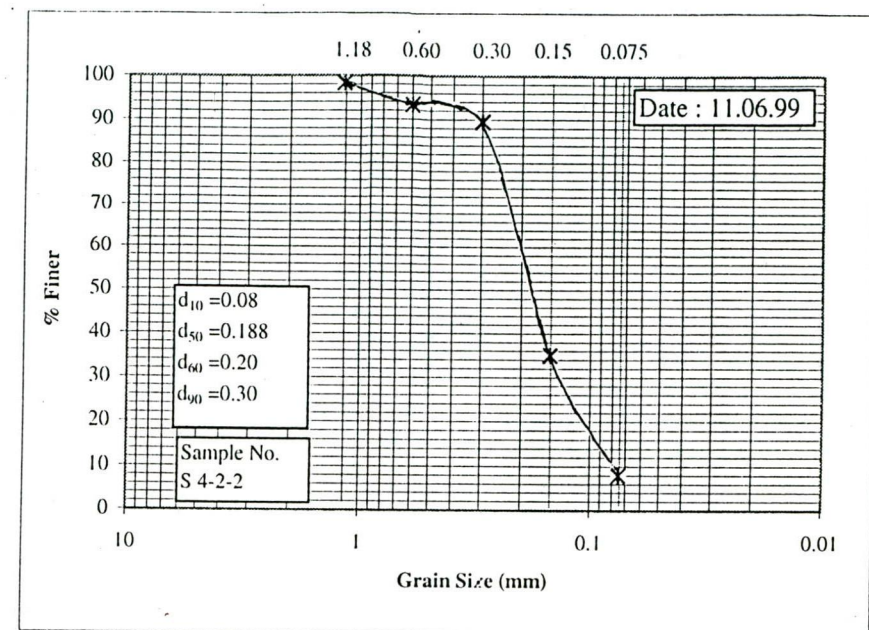
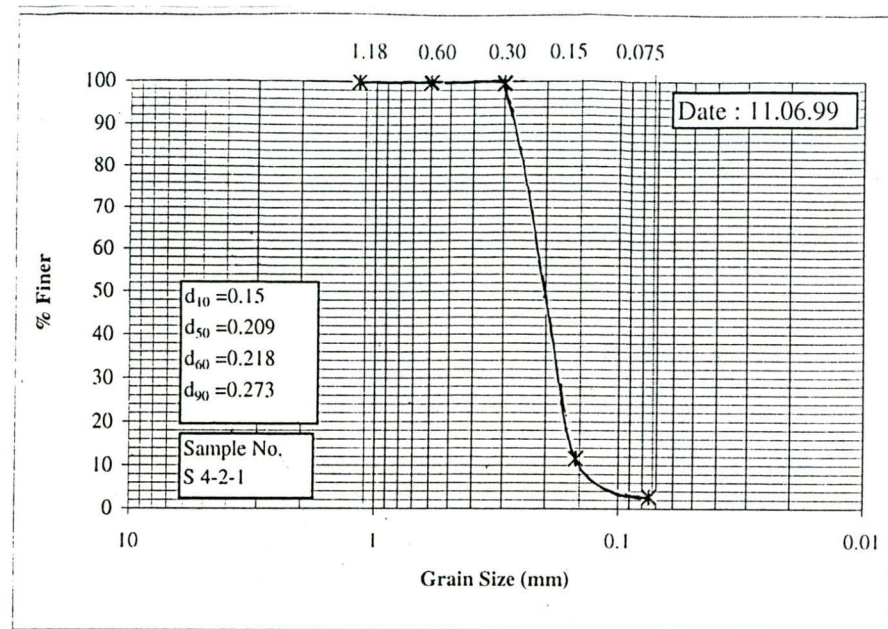


Figure 3.16 : Grain Size Distribution Curve for Station 4

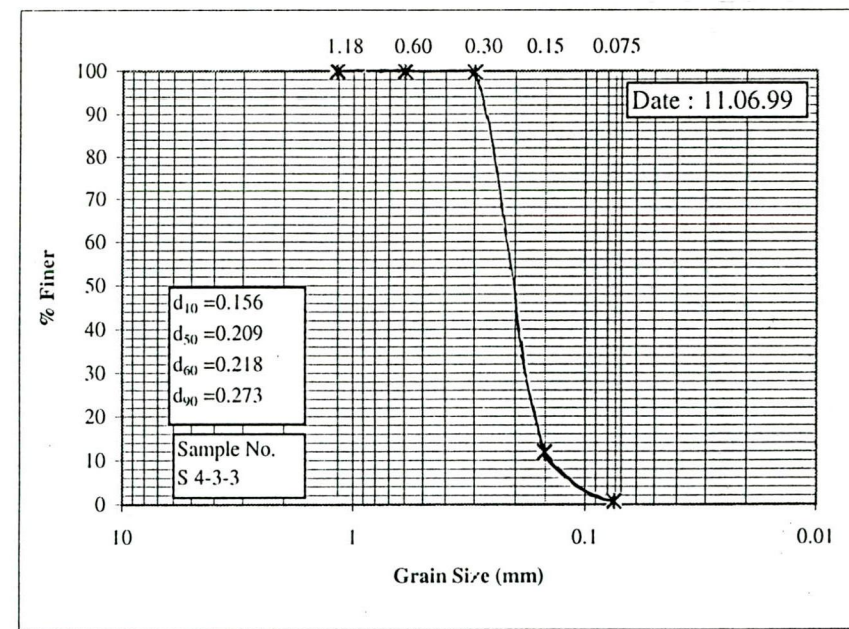
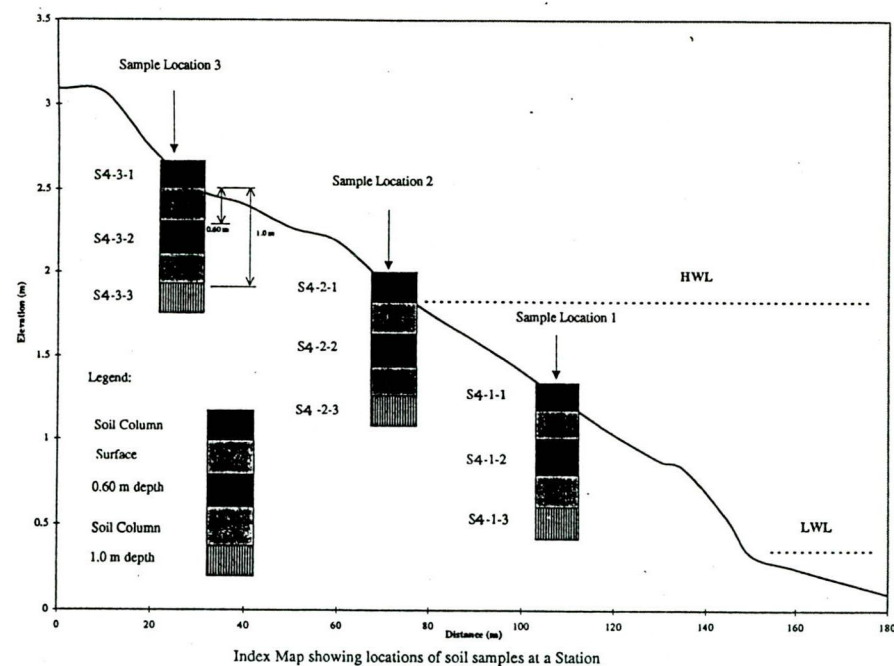
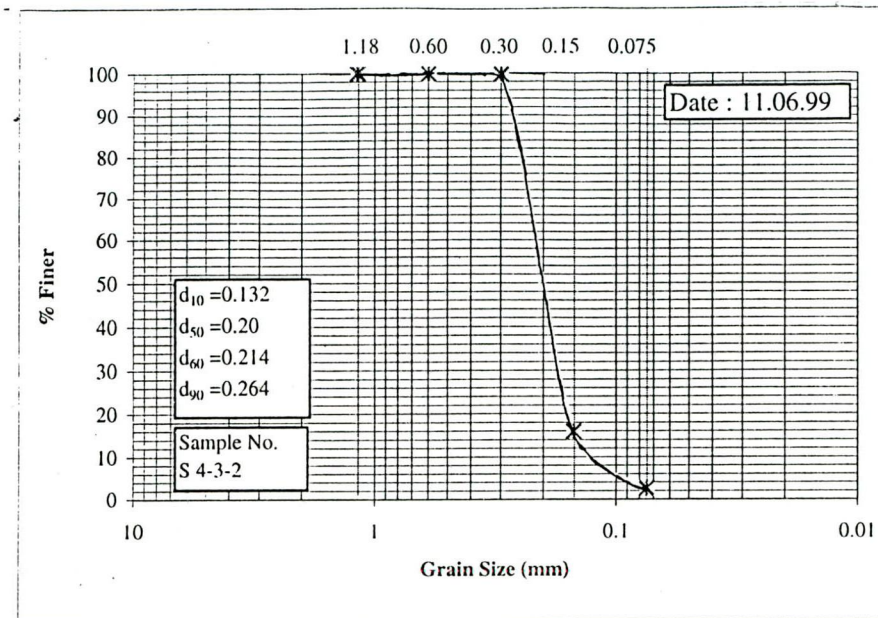
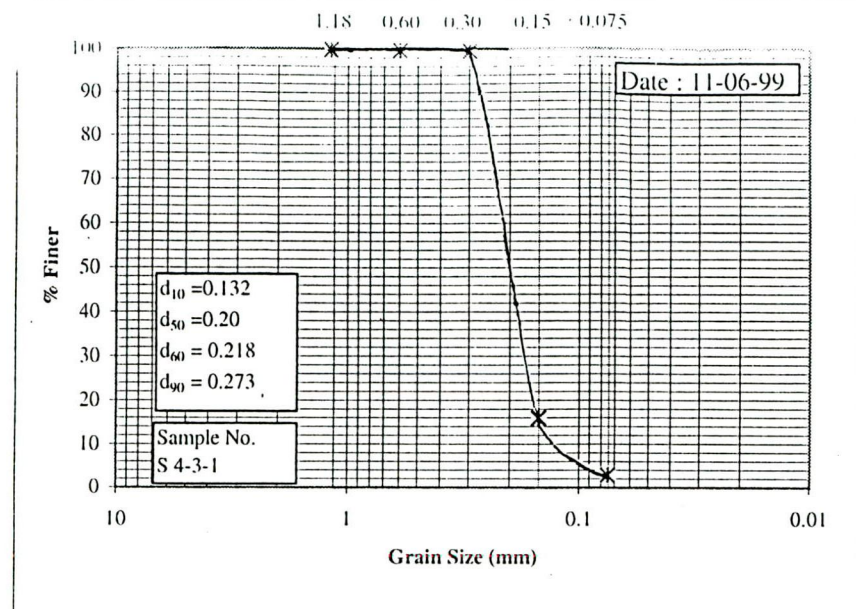


Figure 3.17 : Grain Size Distribution Curve for Station 4

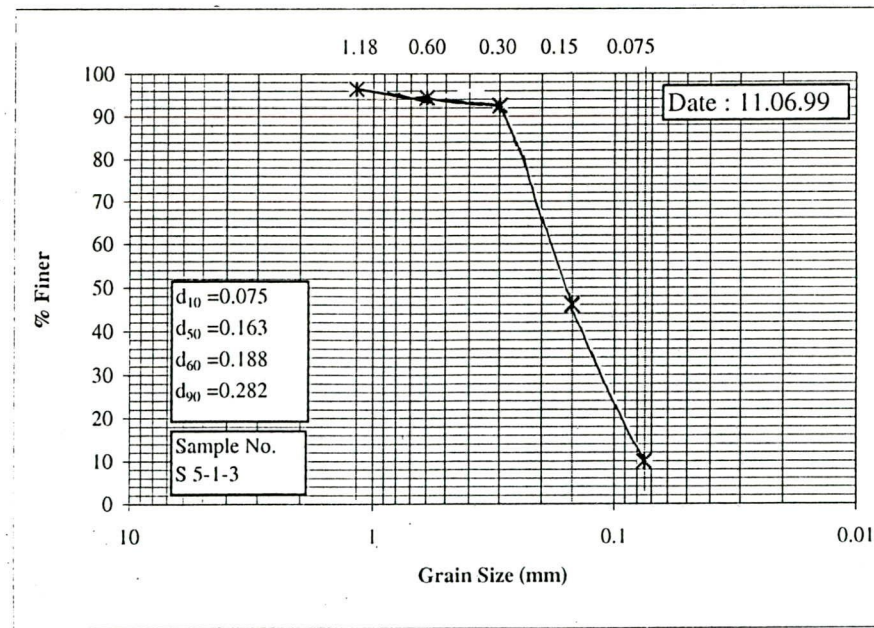
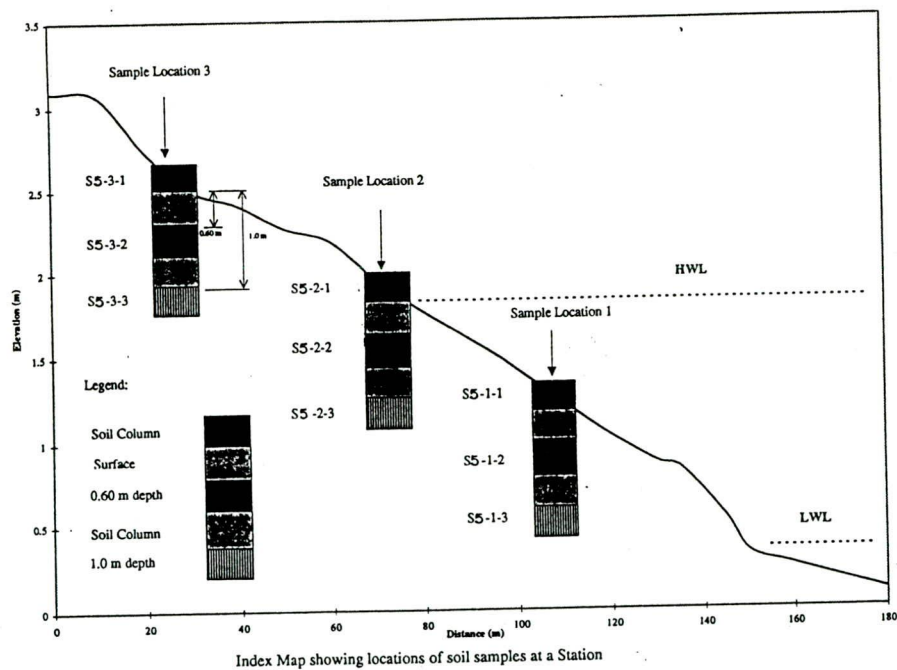
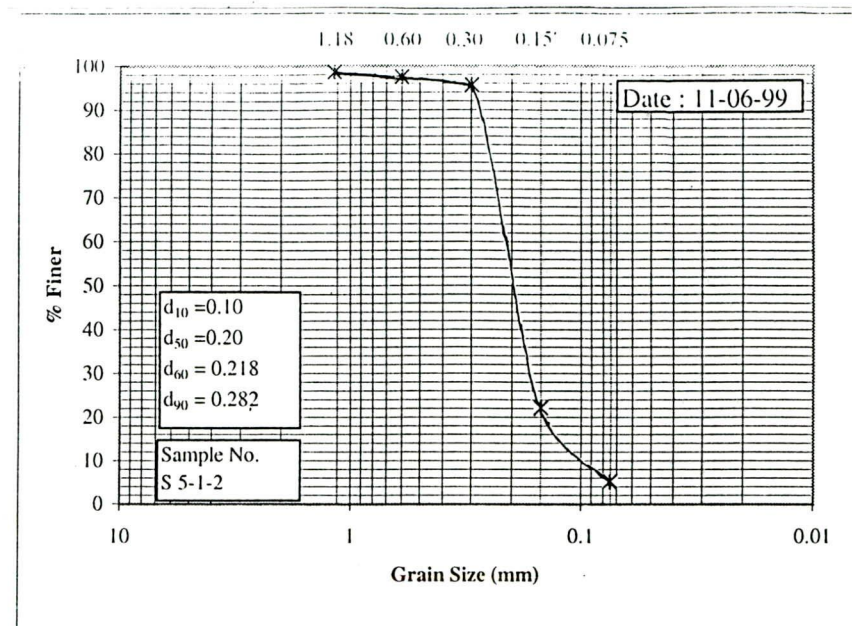
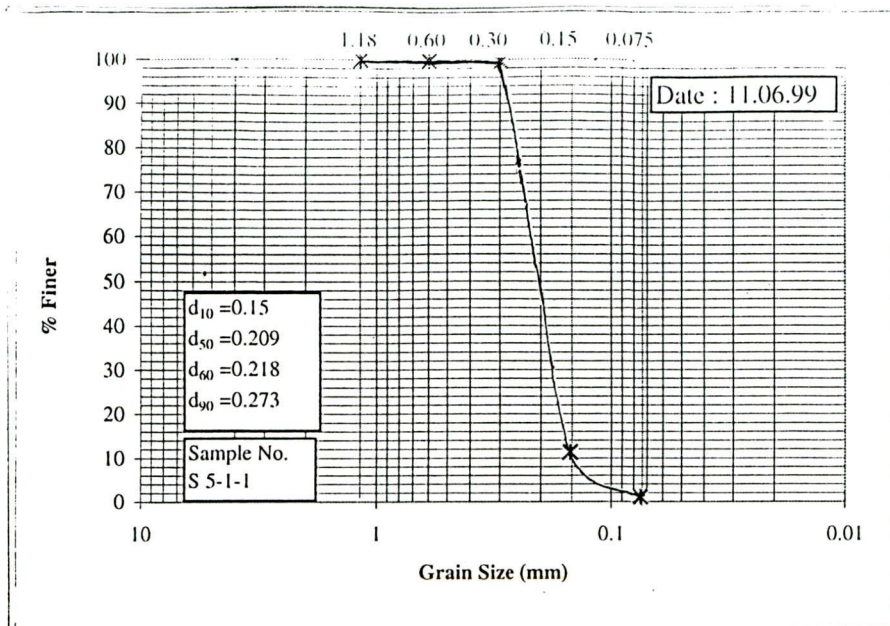


Figure 3.18 : Grain Size Distribution Curve for Station 5

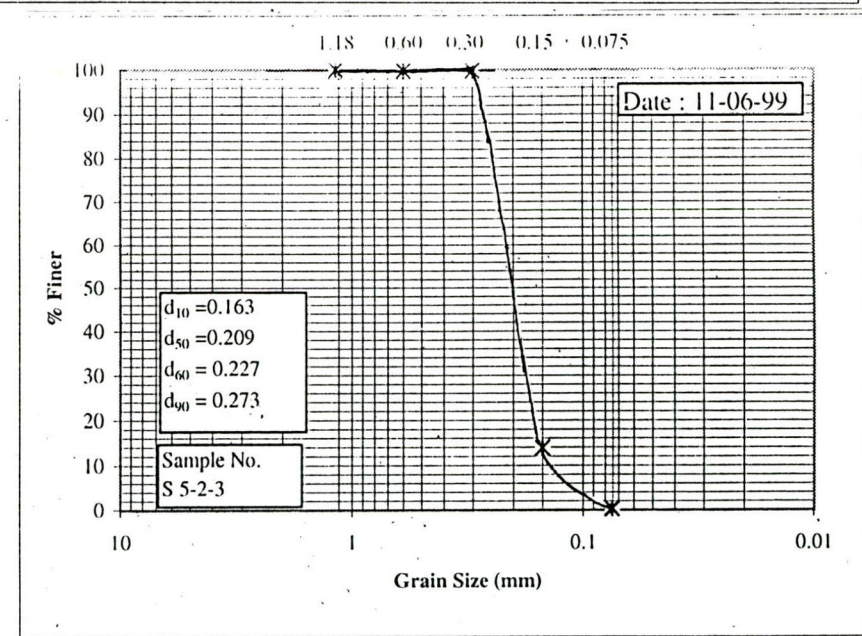
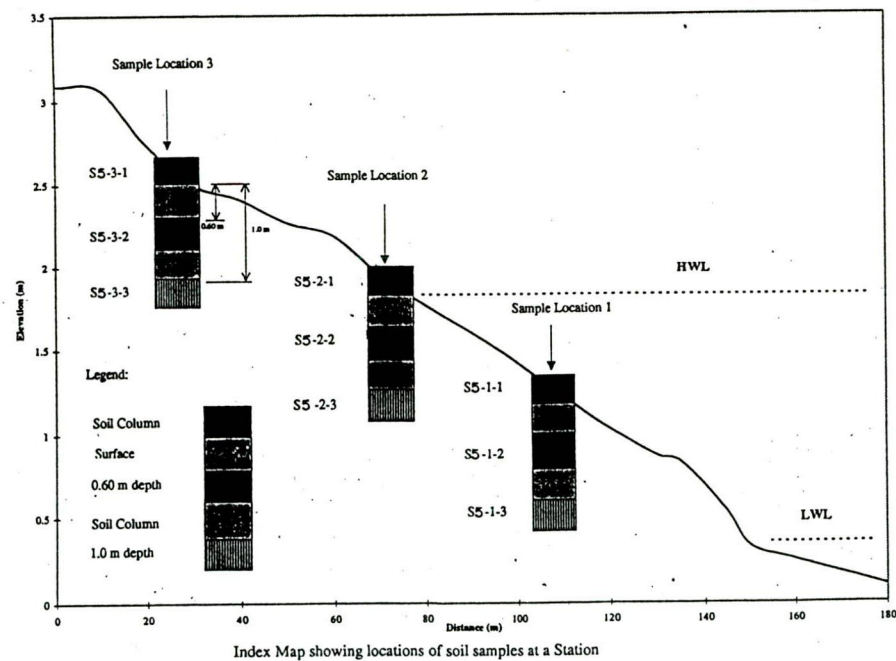
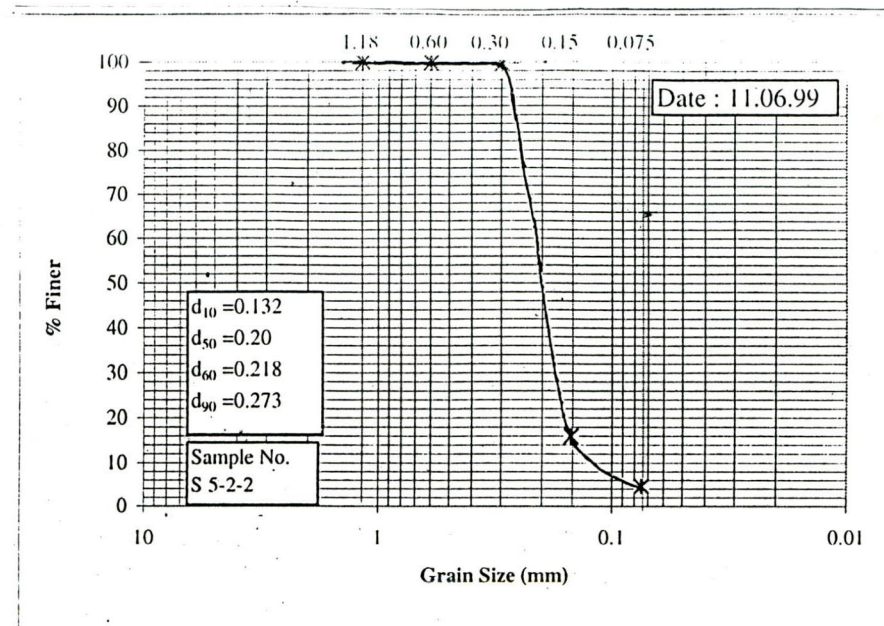
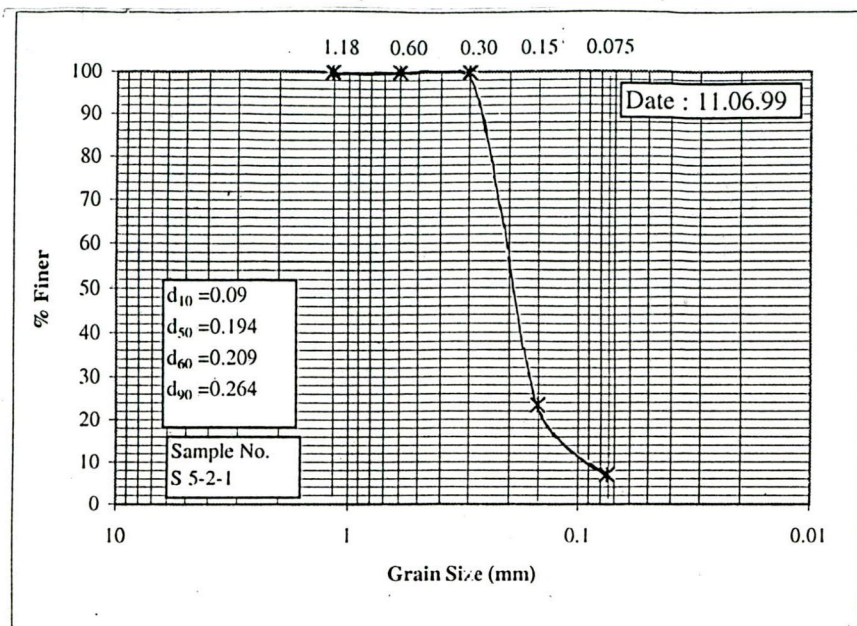


Figure 3.19 : Grain Size Distribution Curve for Station 5

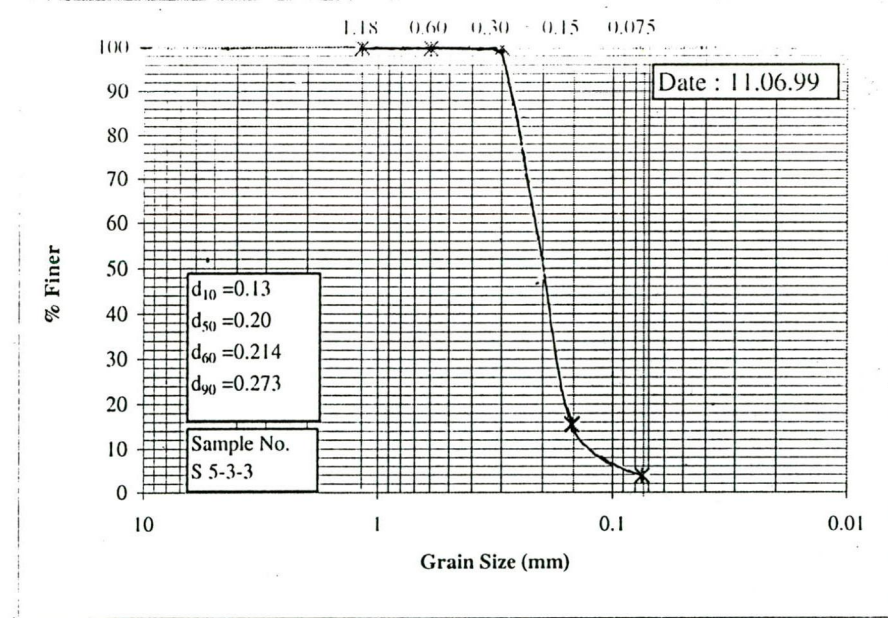
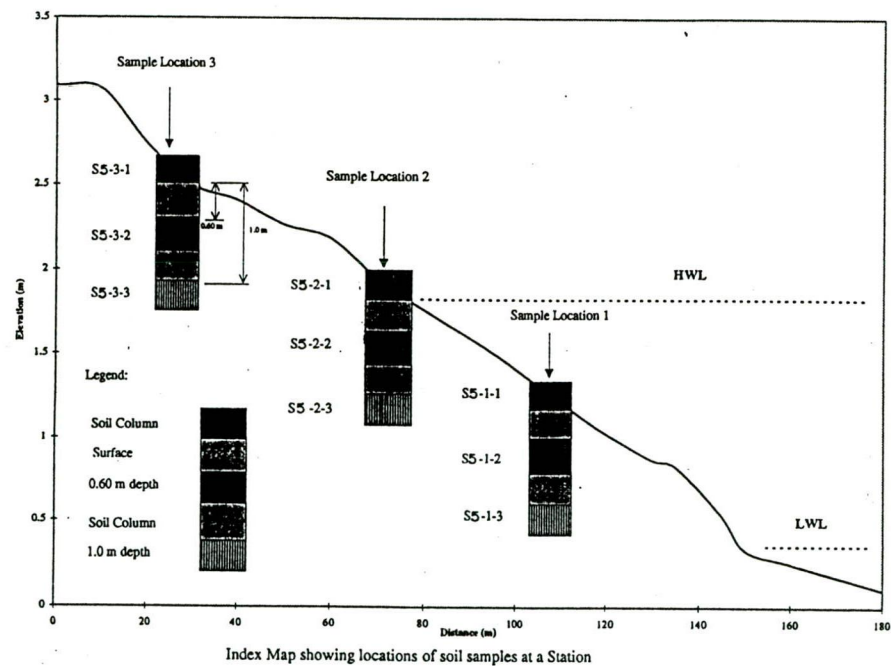
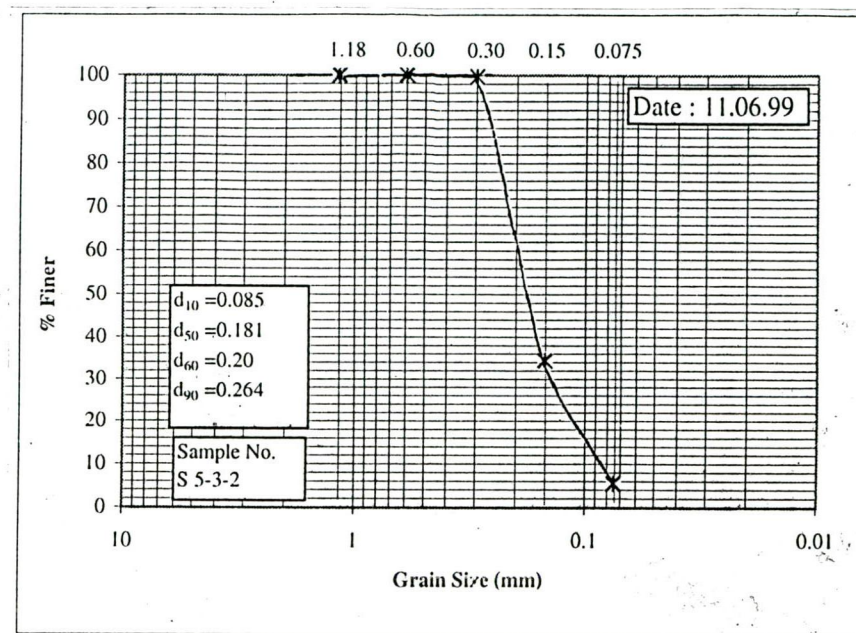
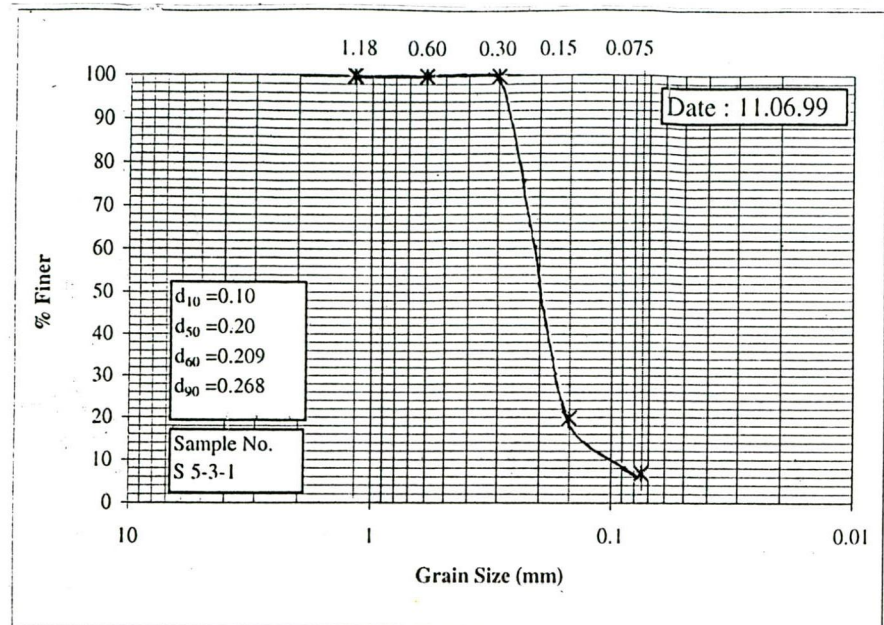


Figure 3.20 : Grain Size Distribution Curve for Station 5

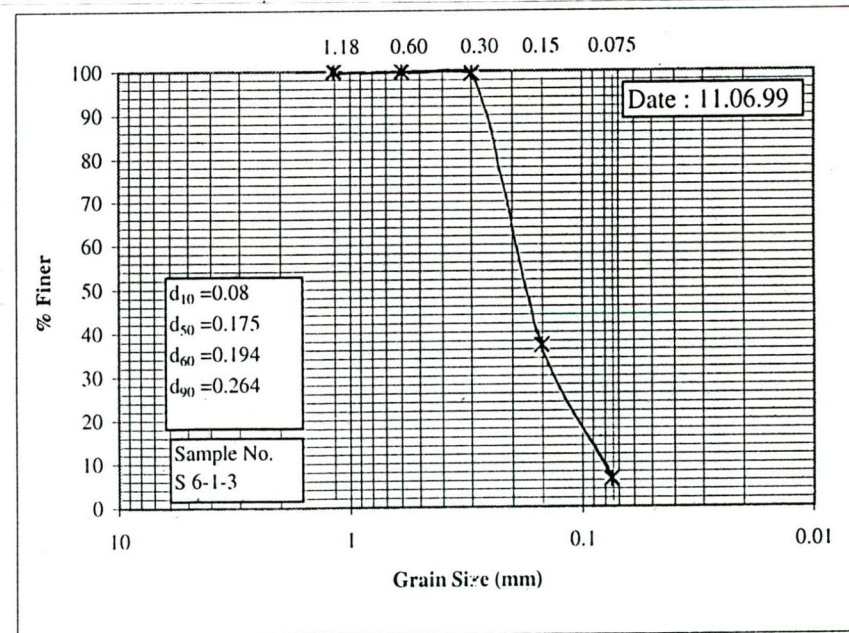
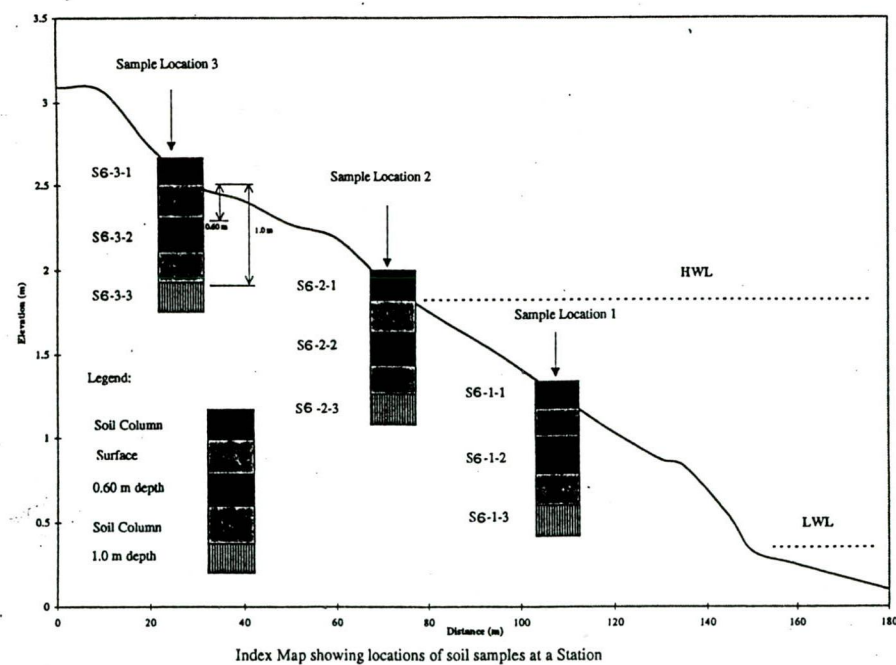
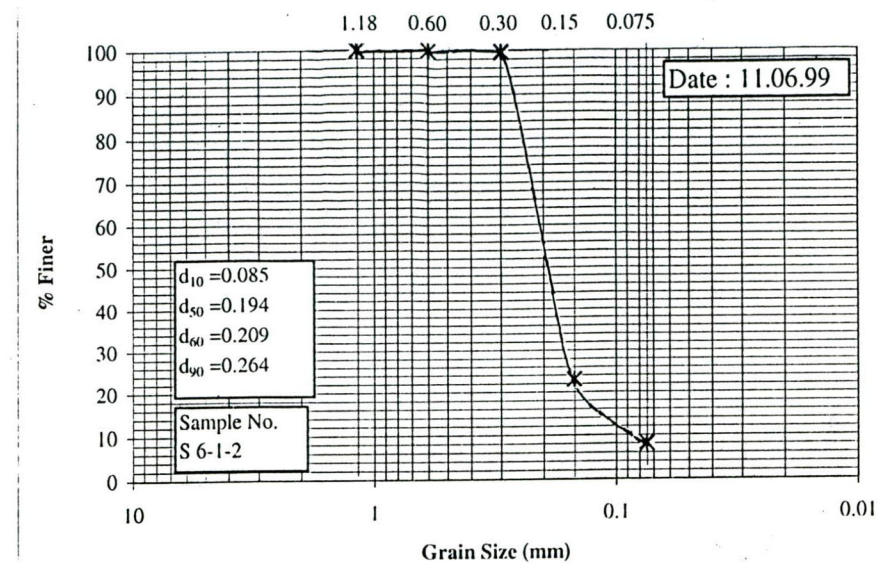
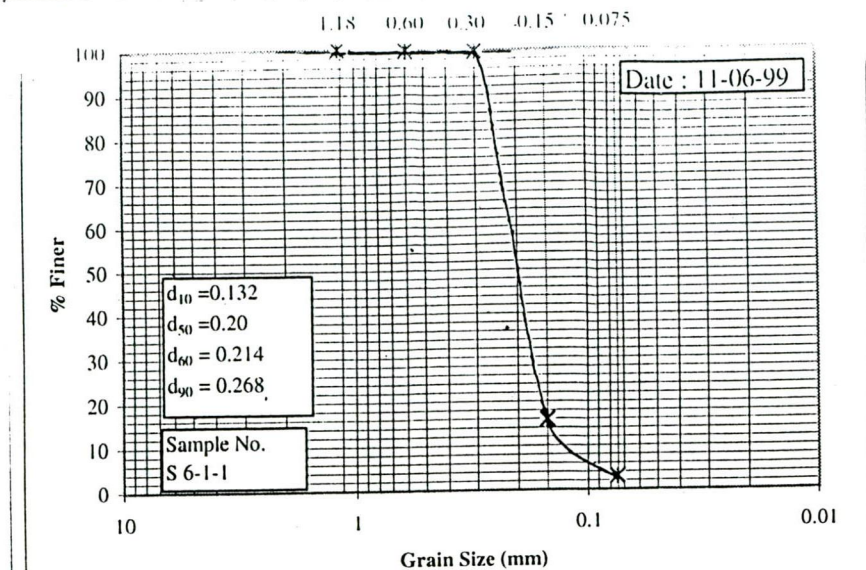


Figure 3.21 : Grain Size Distribution Curve for Station 6

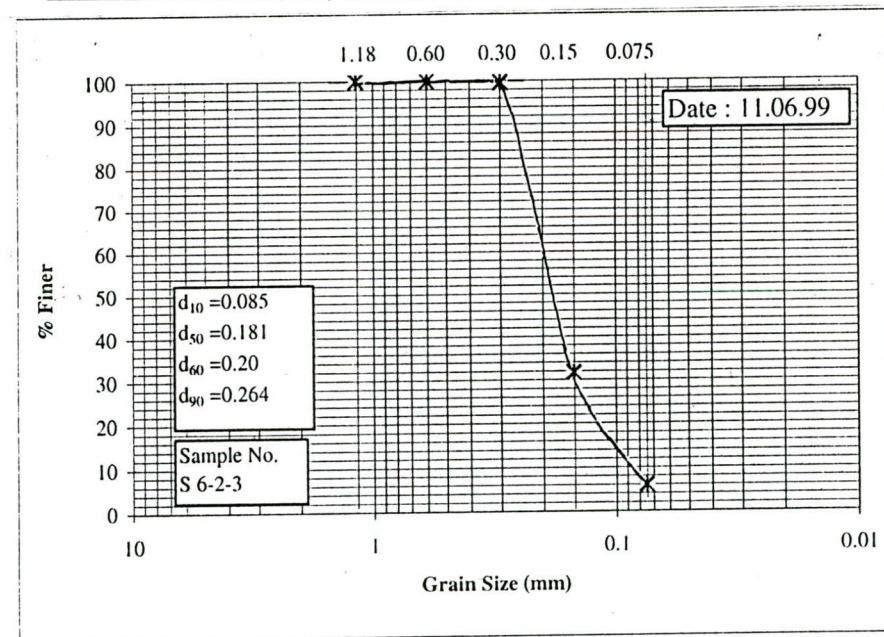
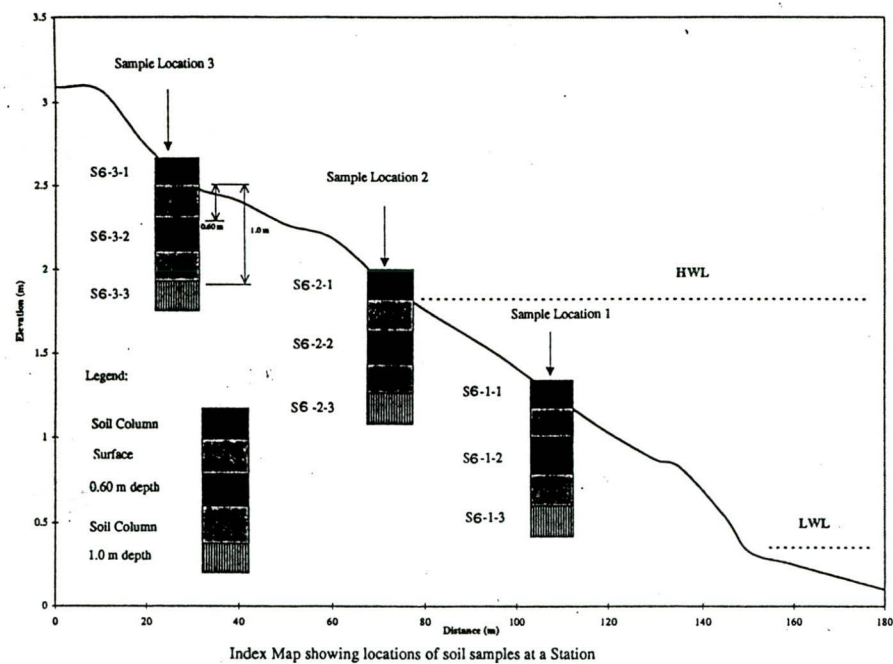
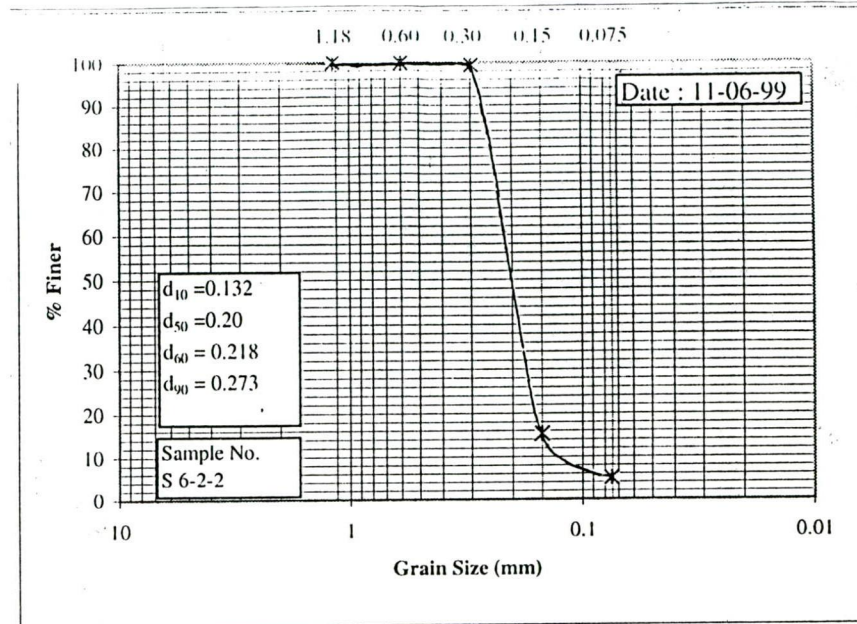
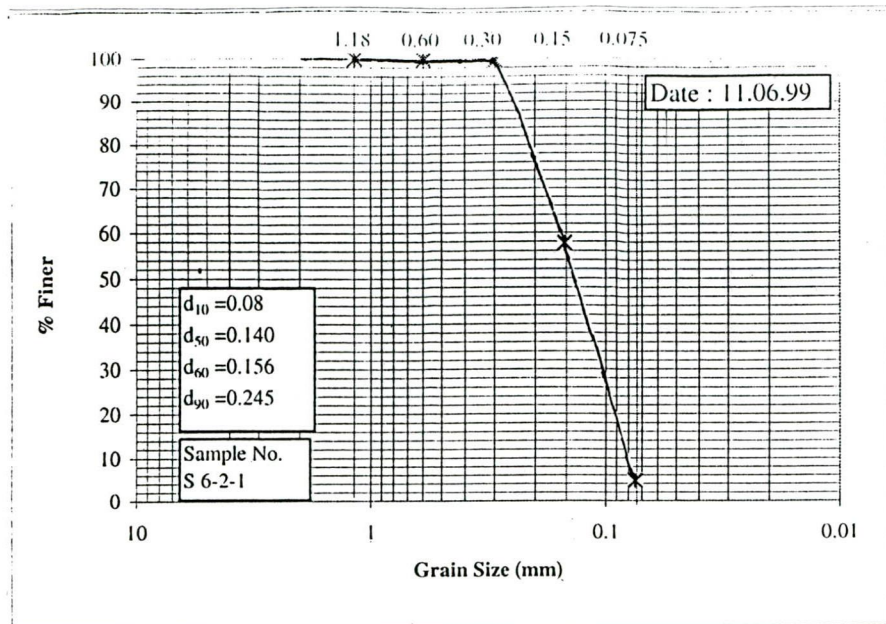


Figure 3.22 : Grain Size Distribution Curve for Station 6

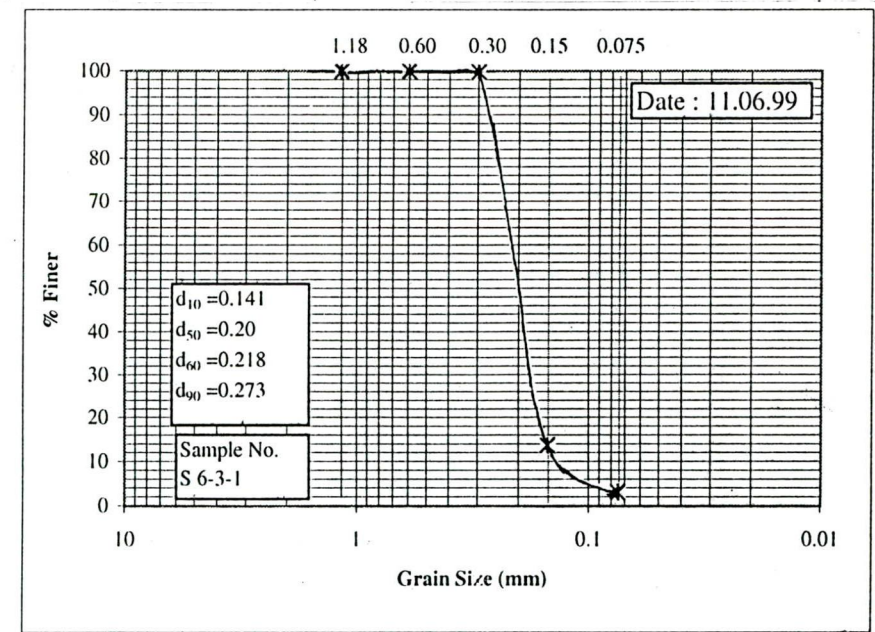
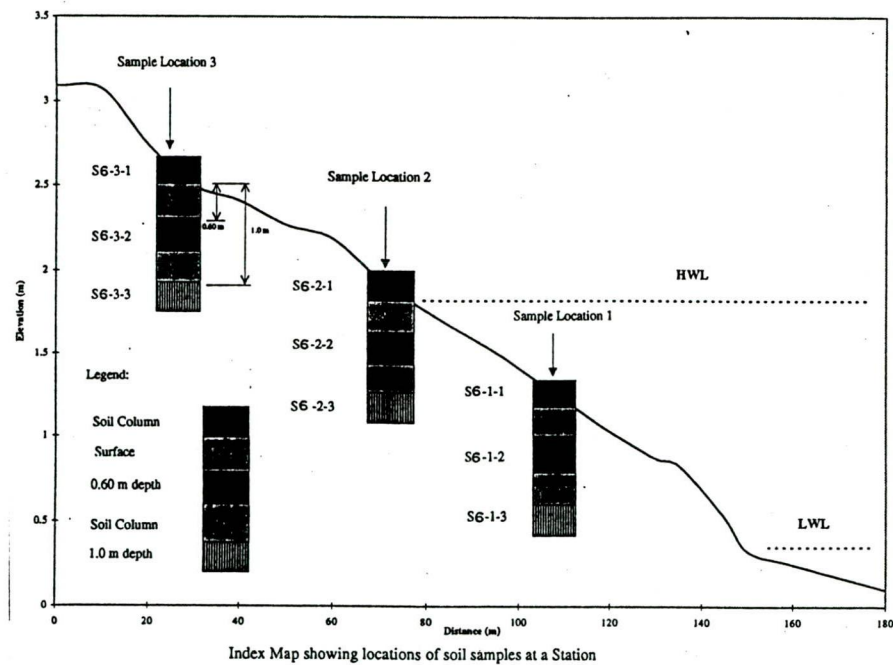
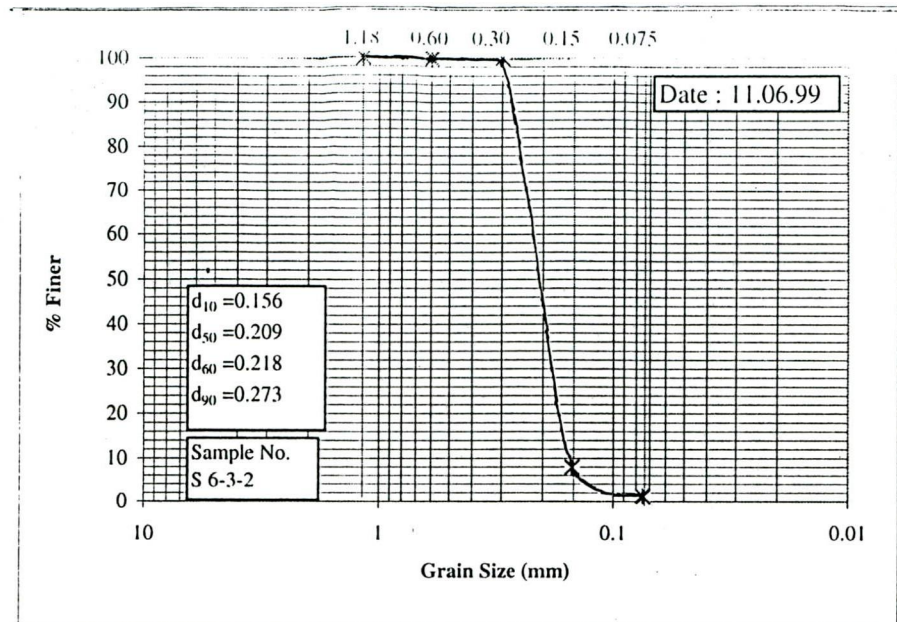
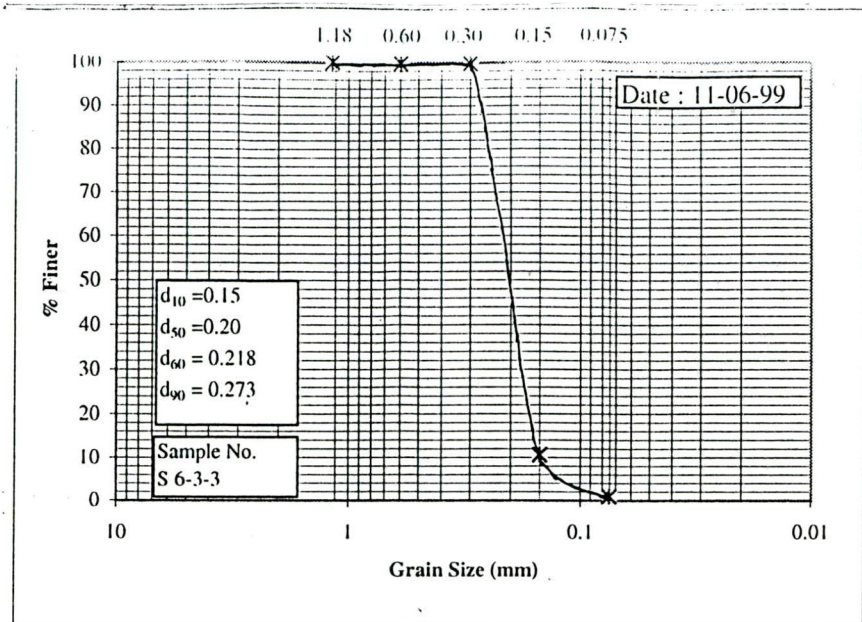


Figure 3.23 : Grain Size Distribution Curve for Station 6

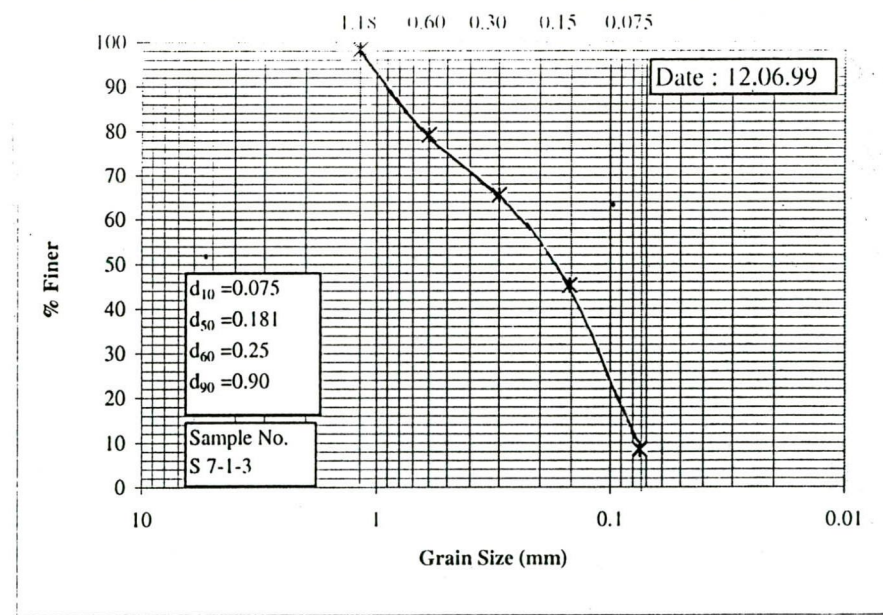
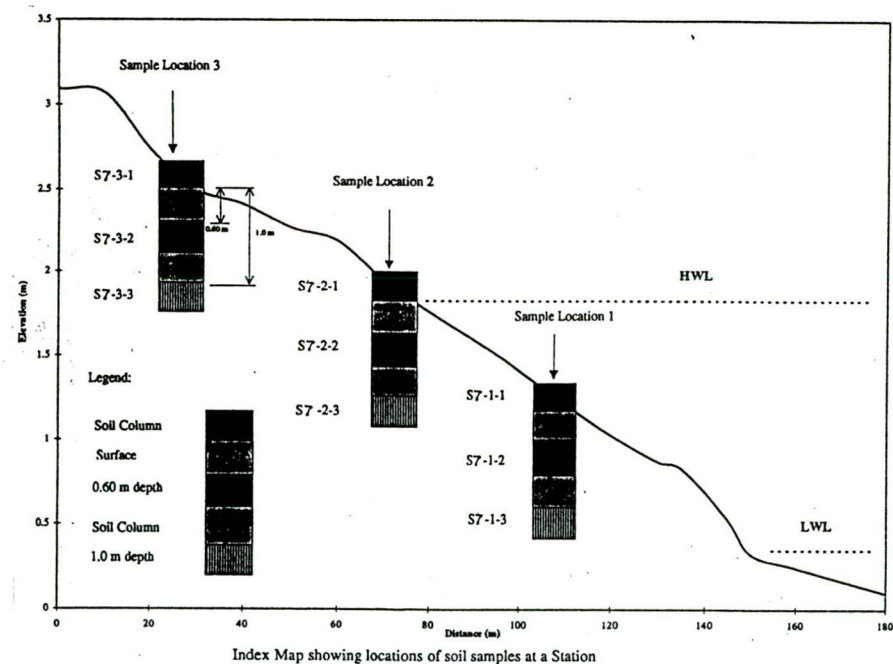
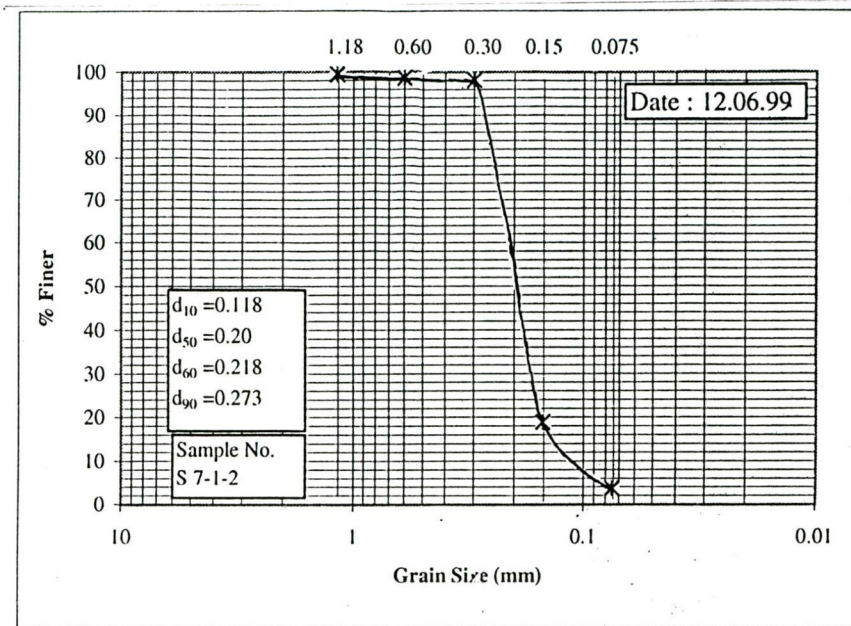
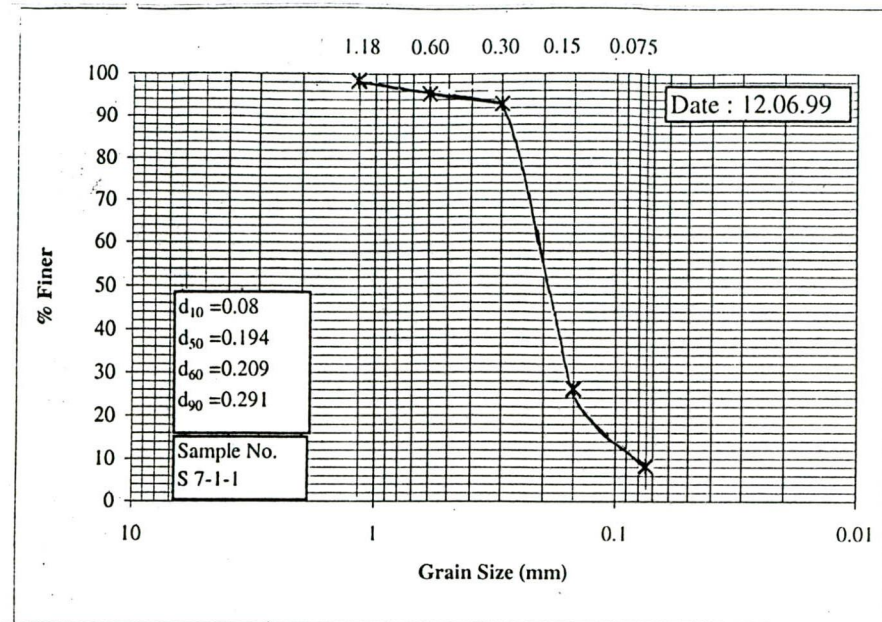


Figure 3.24 : Grain Size Distribution Curve for Station 7

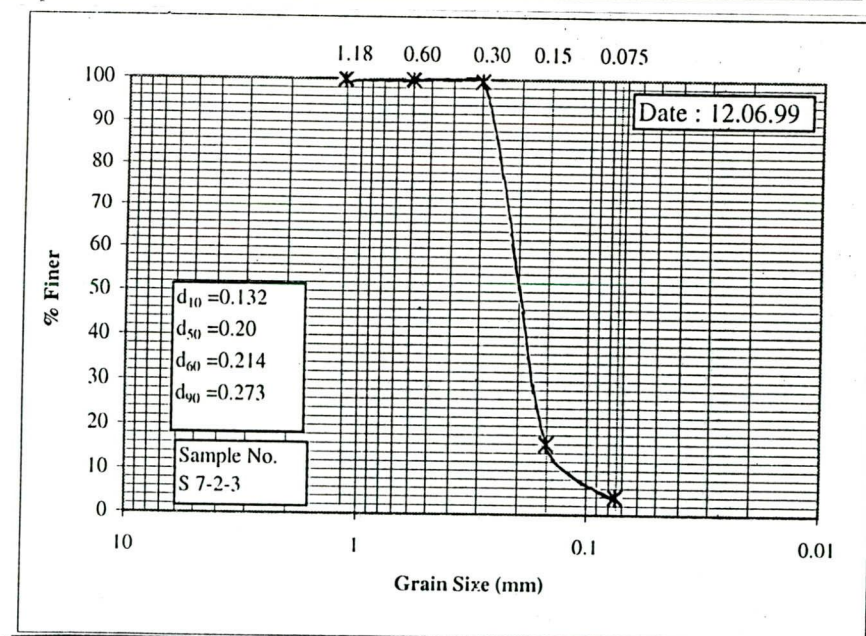
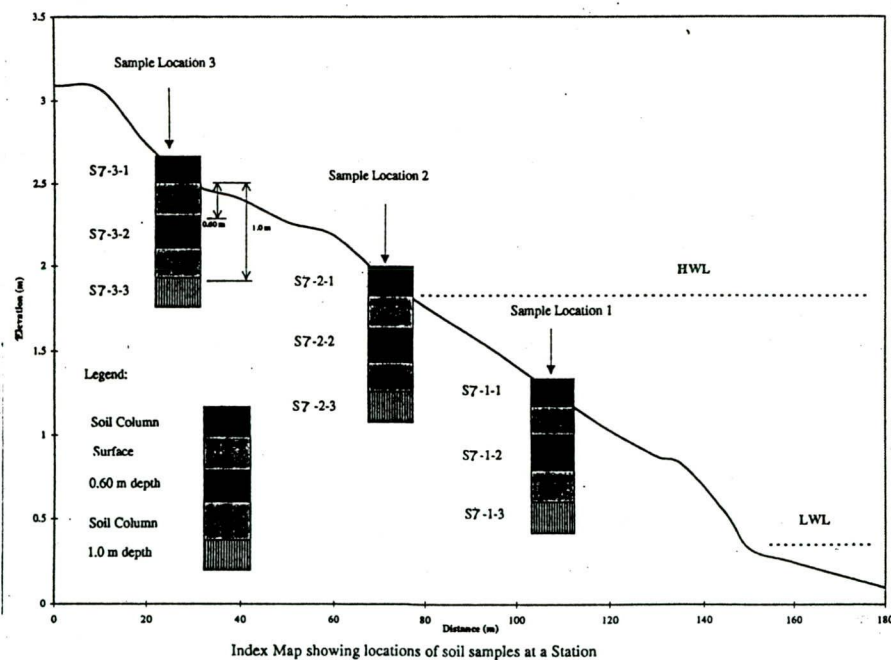
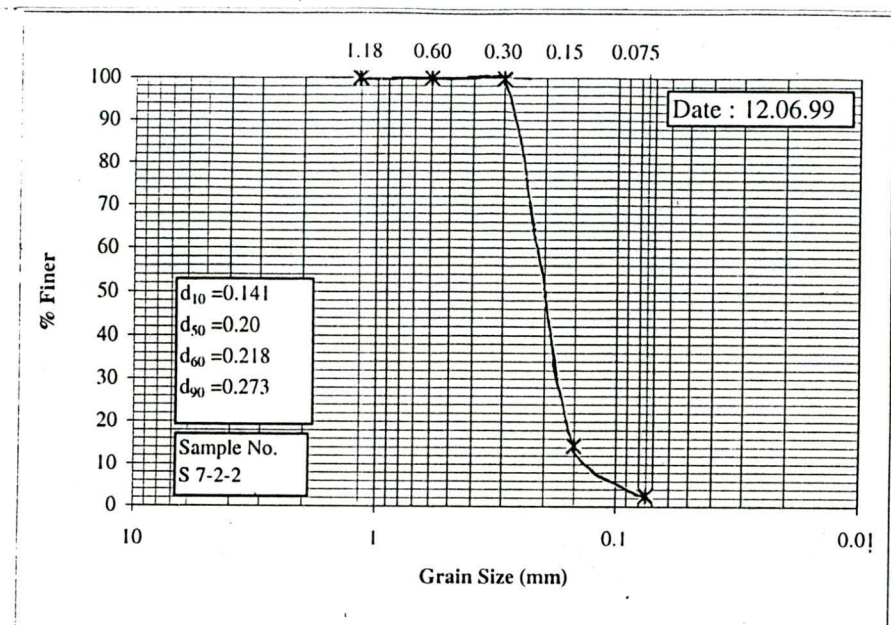
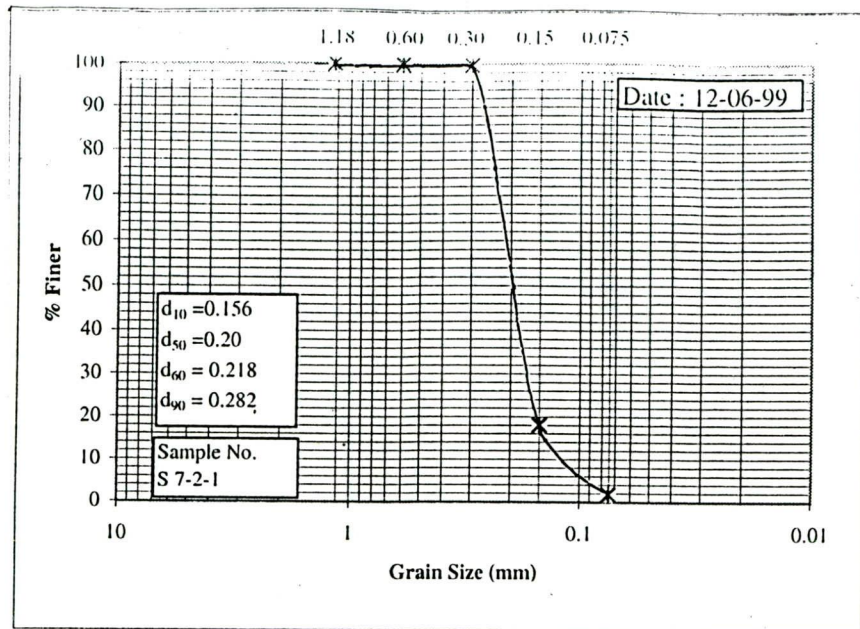


Figure 3.25 : Grain Size Distribution Curve for Station 7

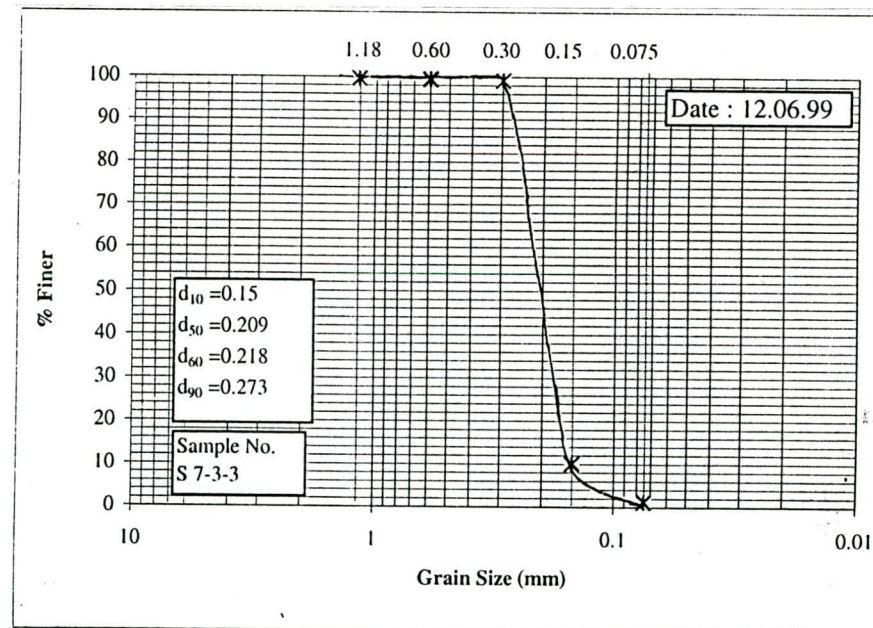
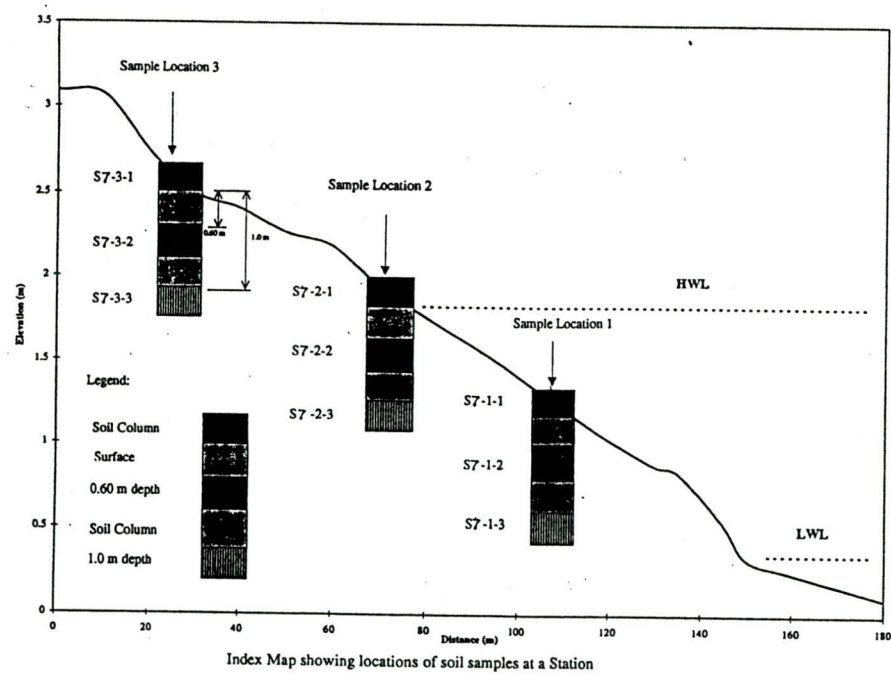
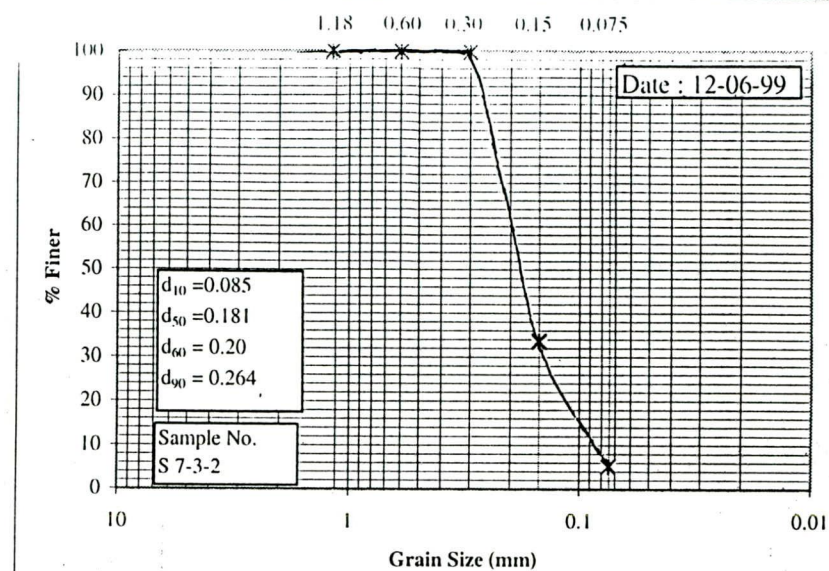
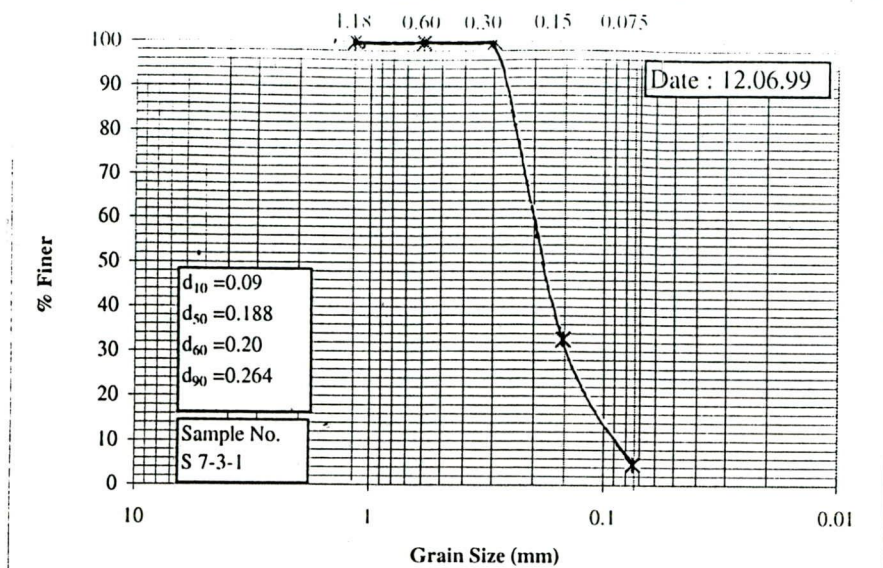


Figure 3.26 : Grain Size Distribution Curve for Station 7

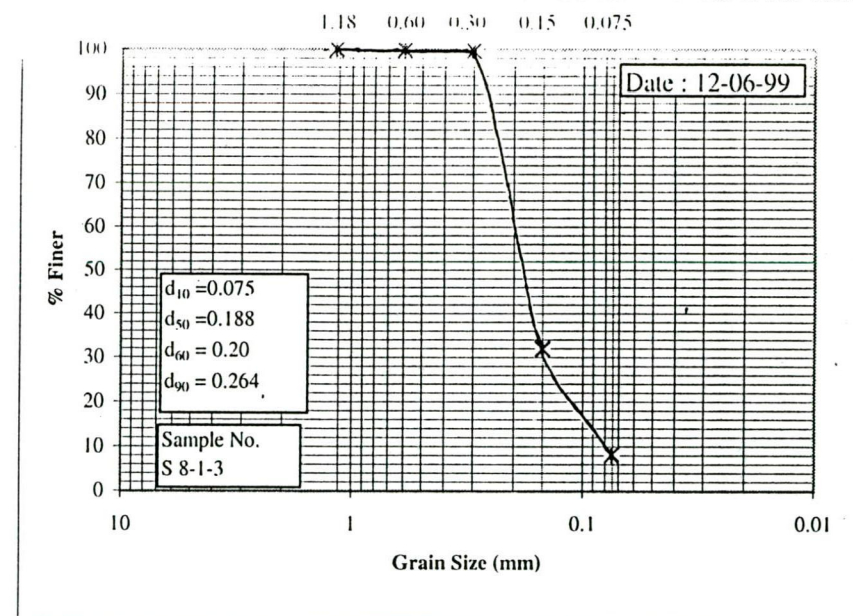
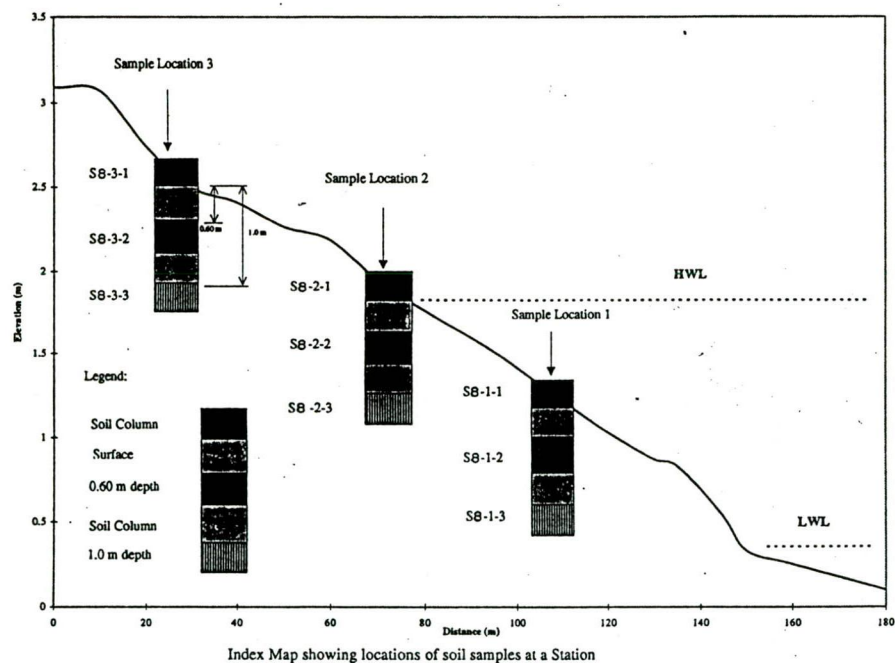
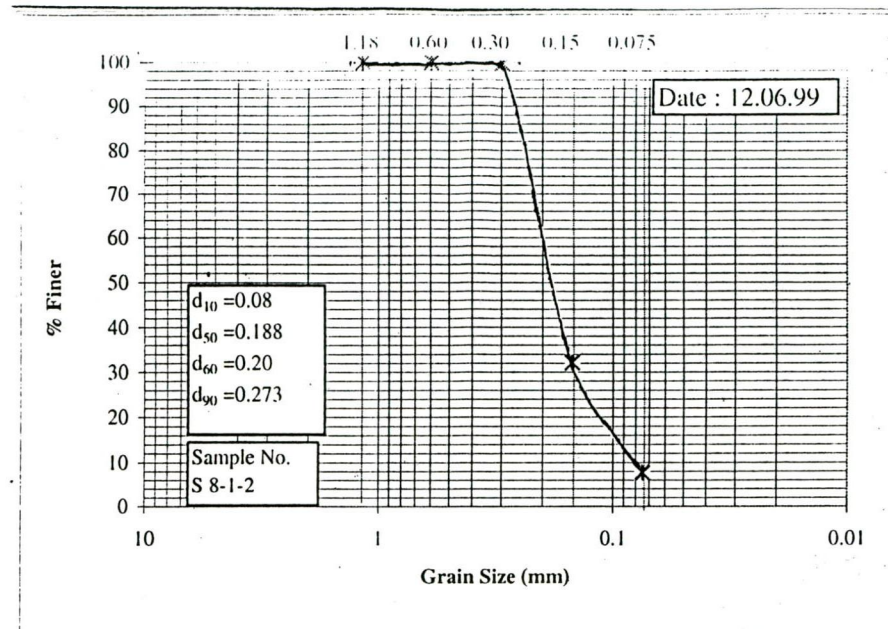
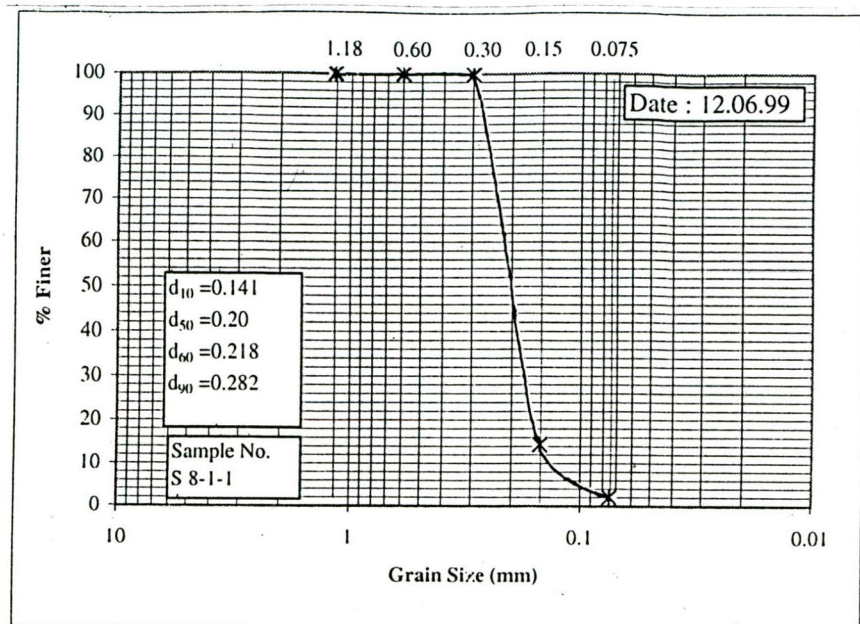


Figure 3.27 : Grain Size Distribution Curve for Station 8

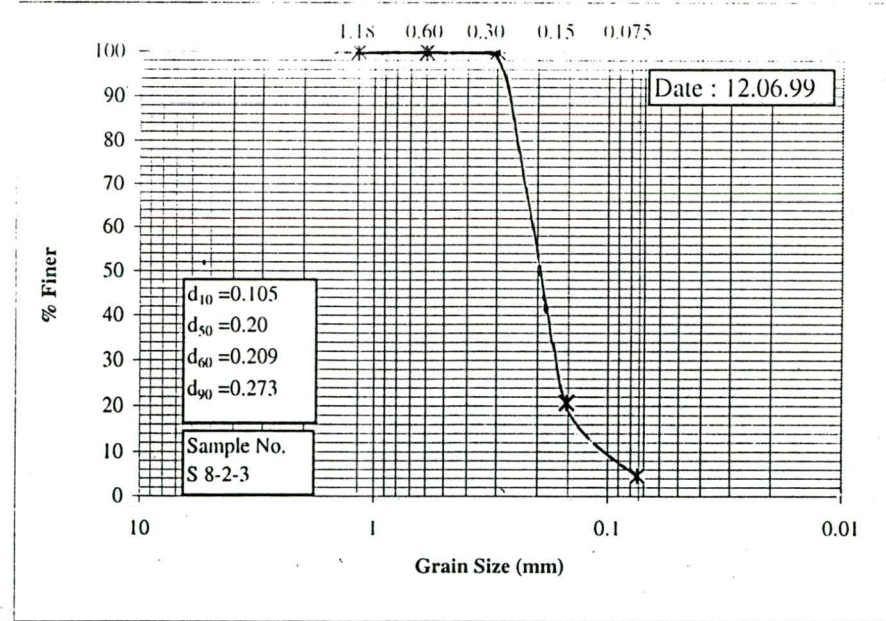
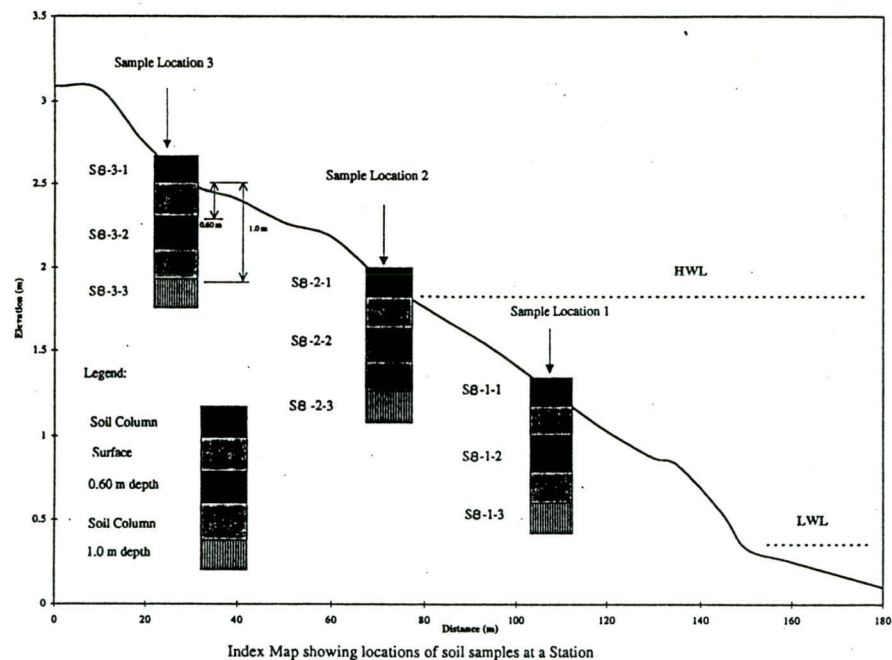
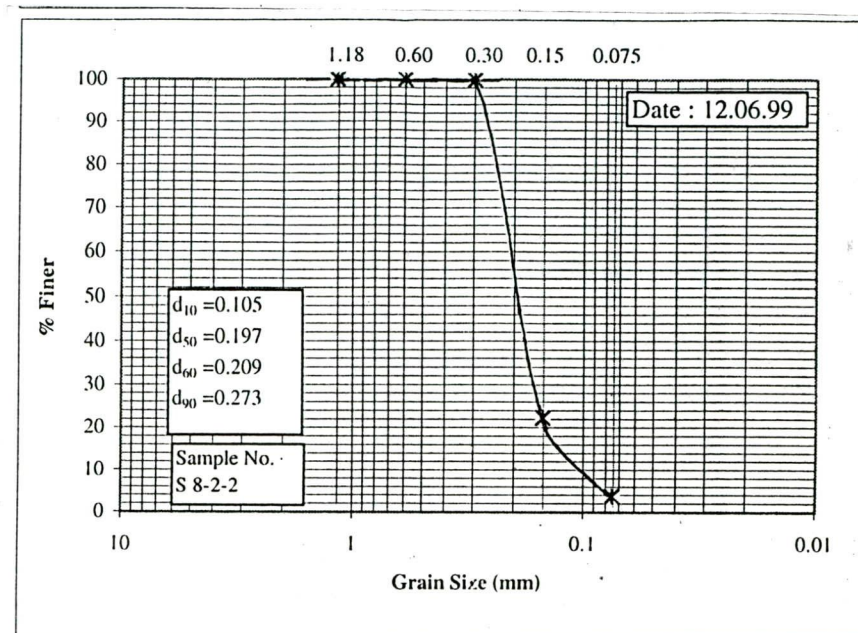
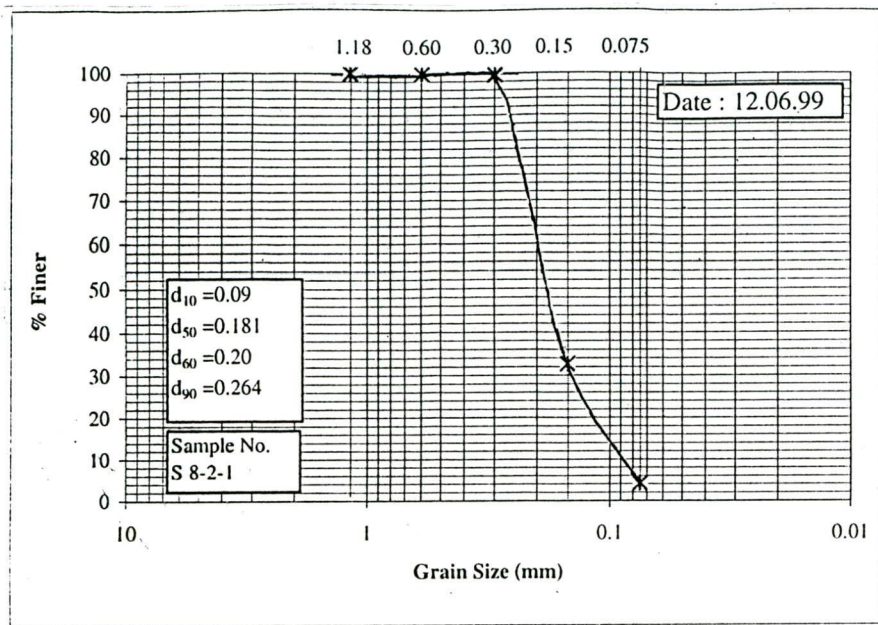


Figure 3.28 : Grain Size Distribution Curve for Station 8

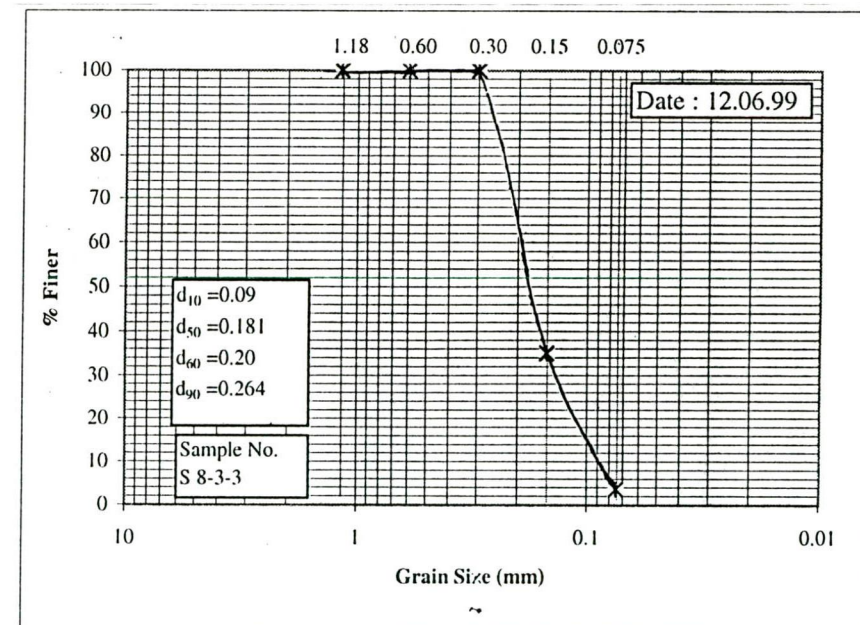
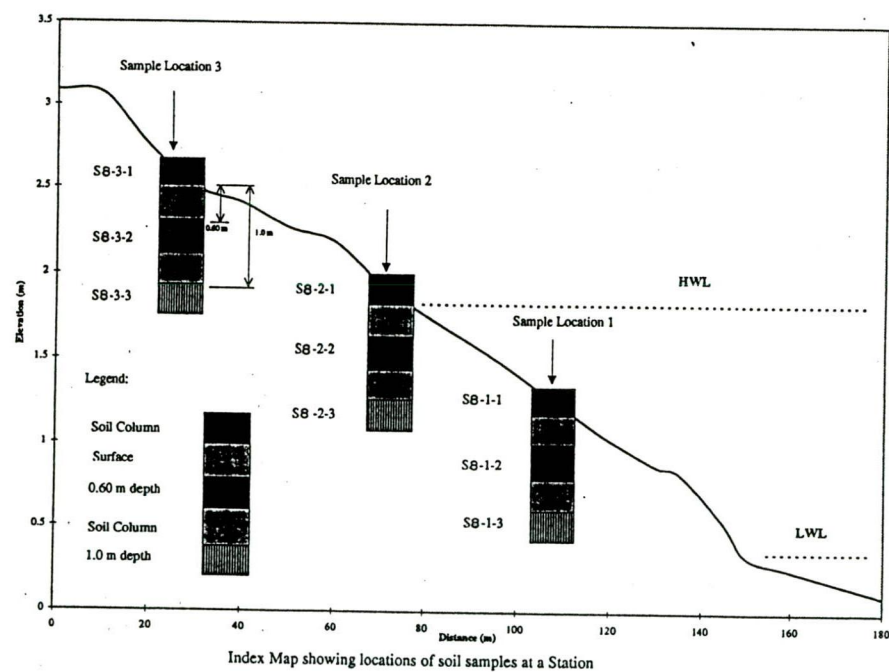
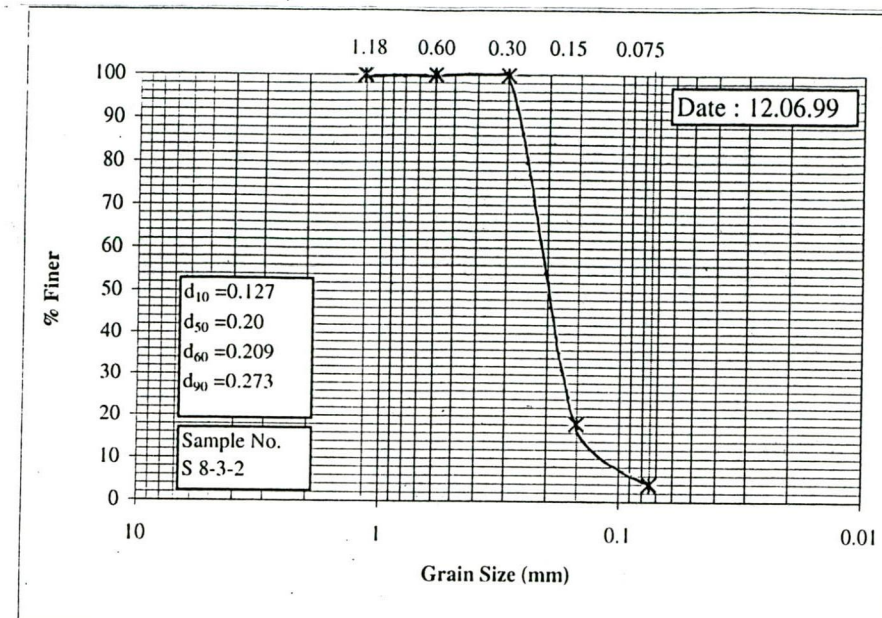
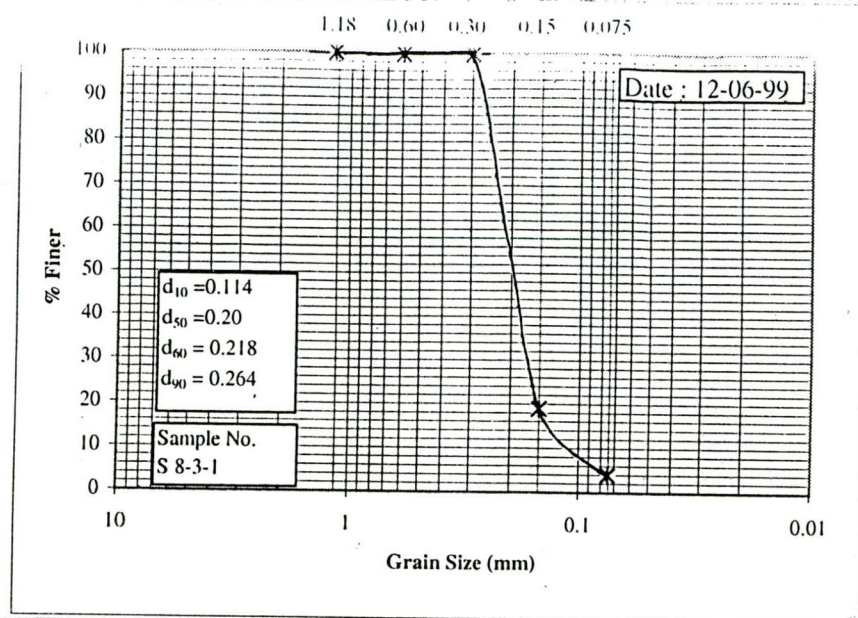


Figure 3.29 : Grain Size Distribution Curve for Station 8

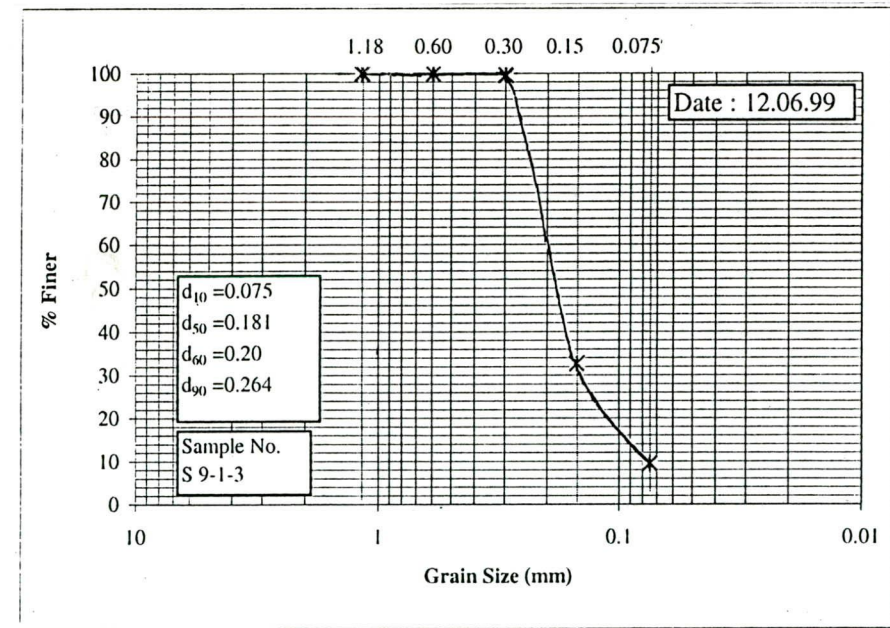
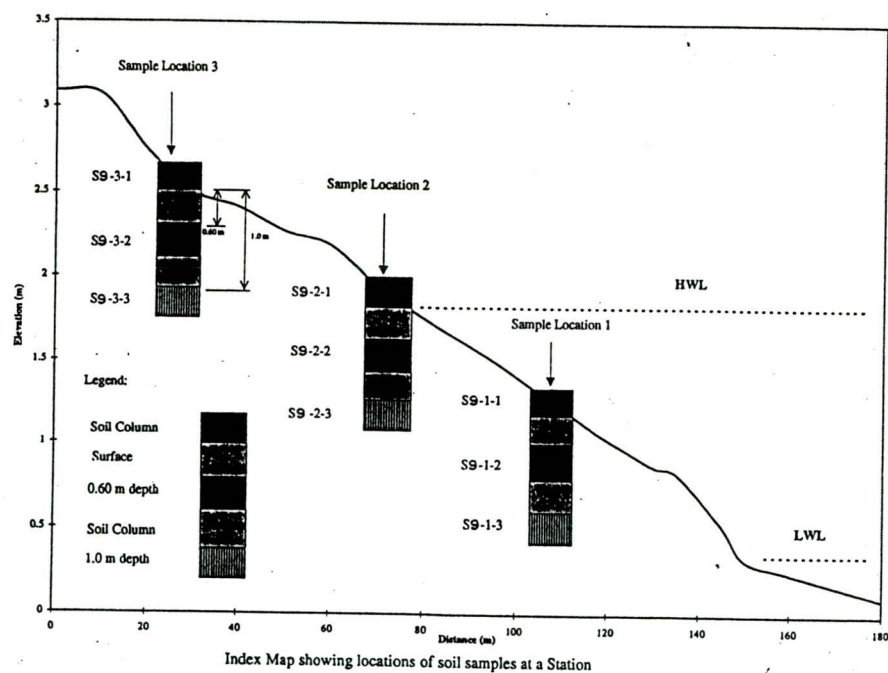
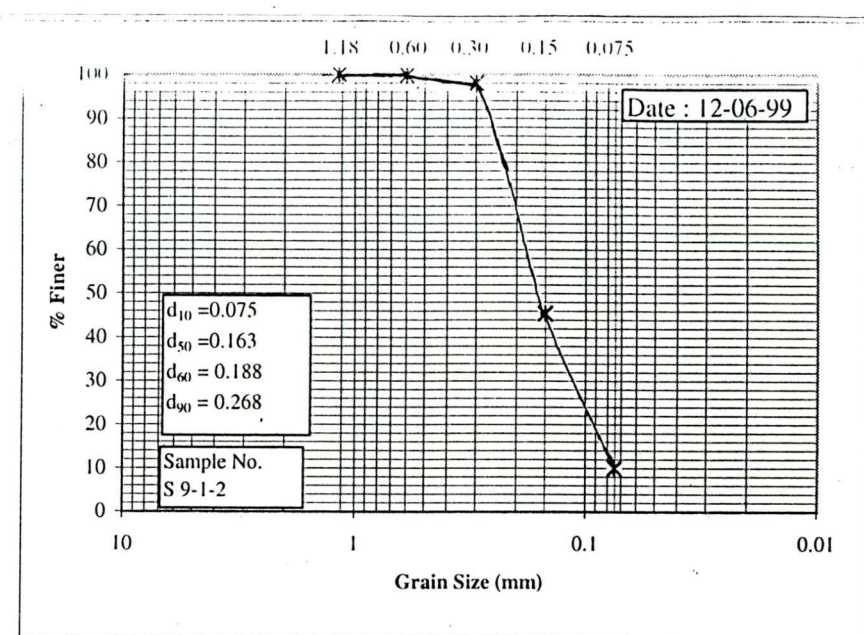
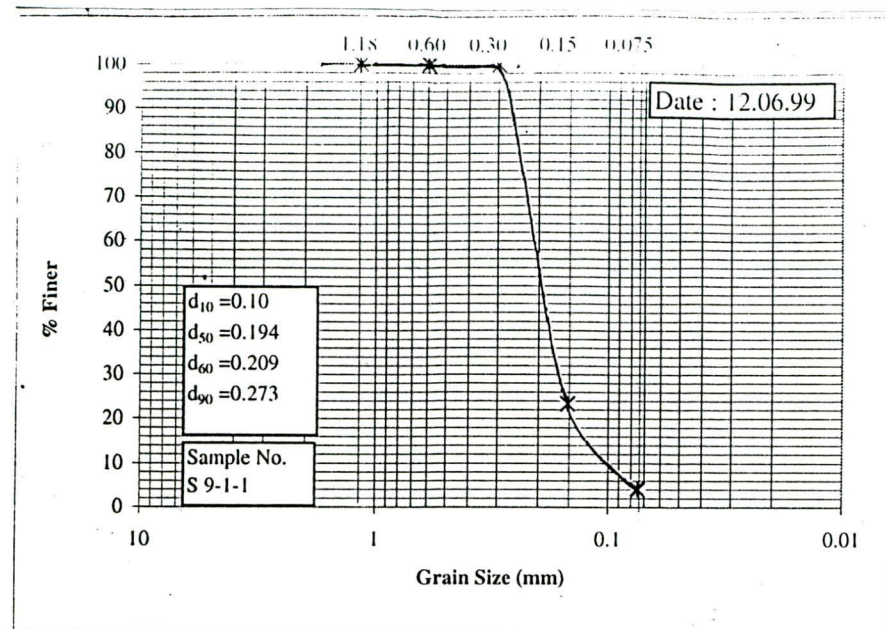


Figure 3.30 : Grain Size Distribution Curve for Station 9

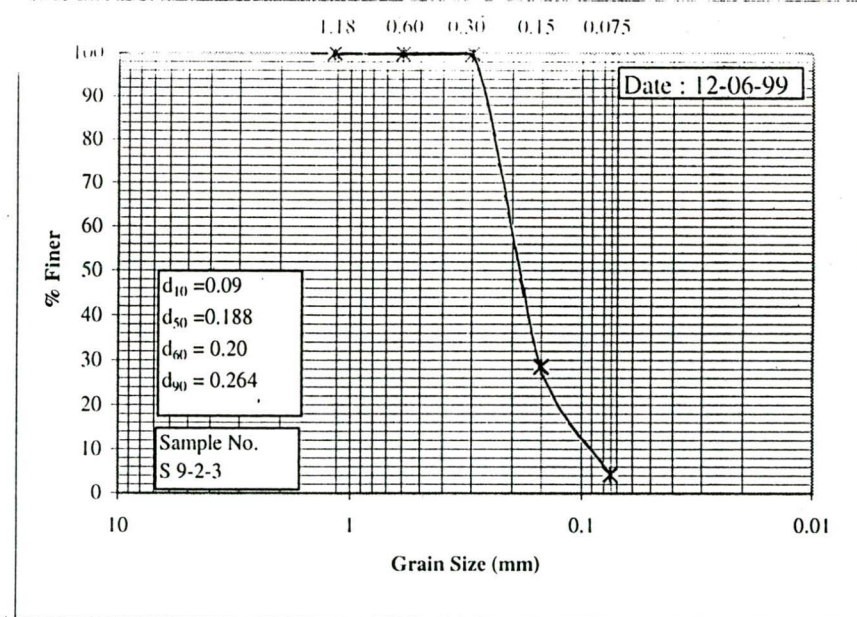
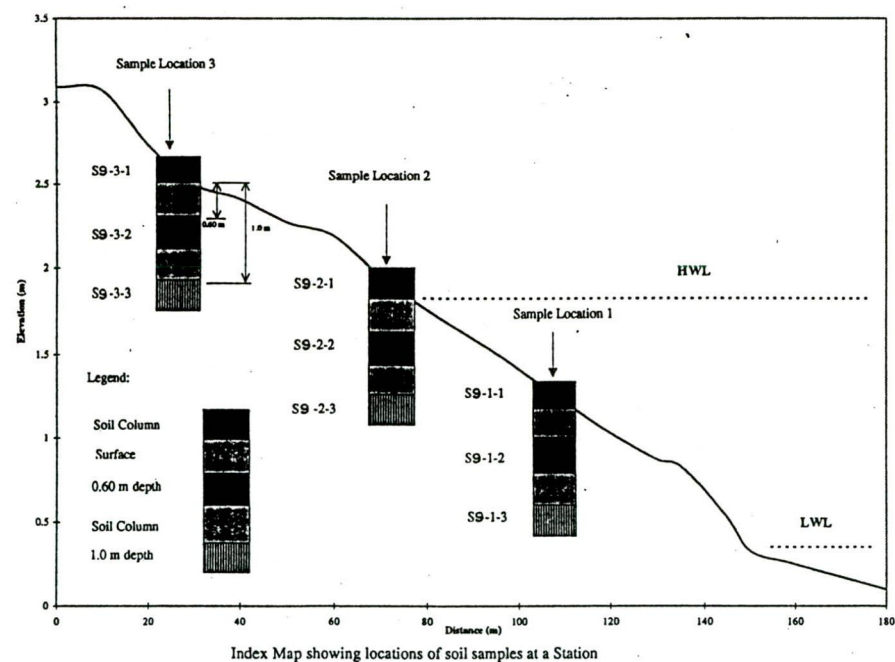
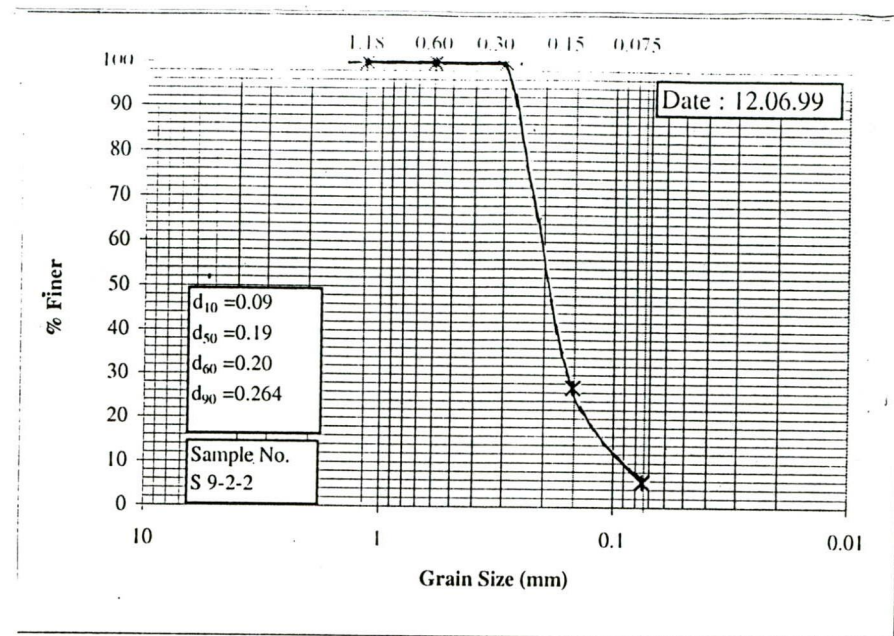
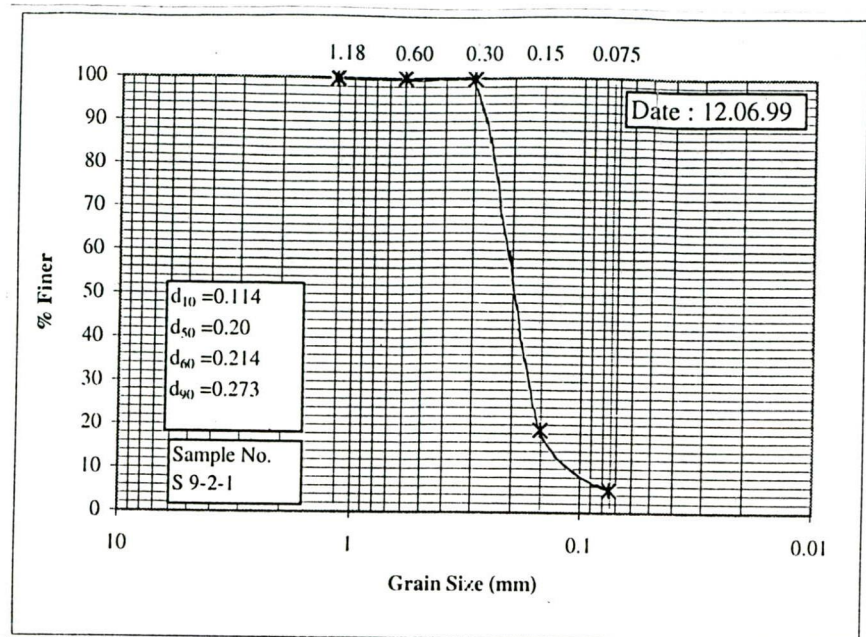


Figure 3.31 : Grain Size Distribution Curve for Station 9

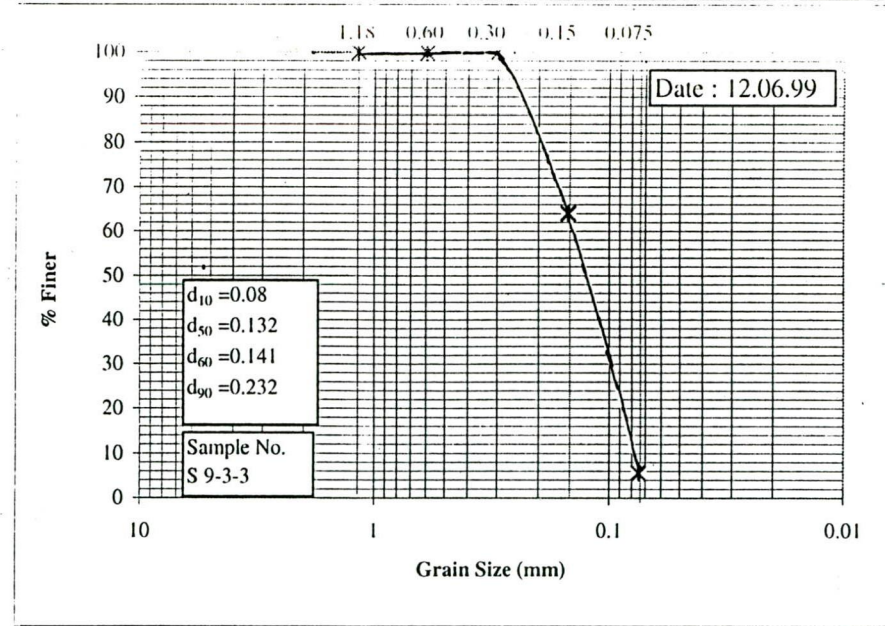
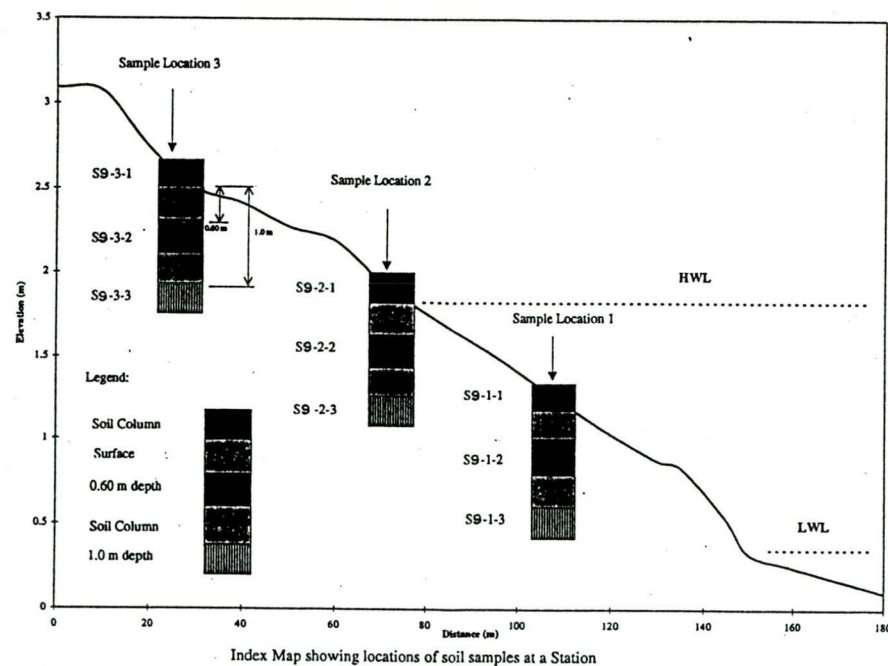
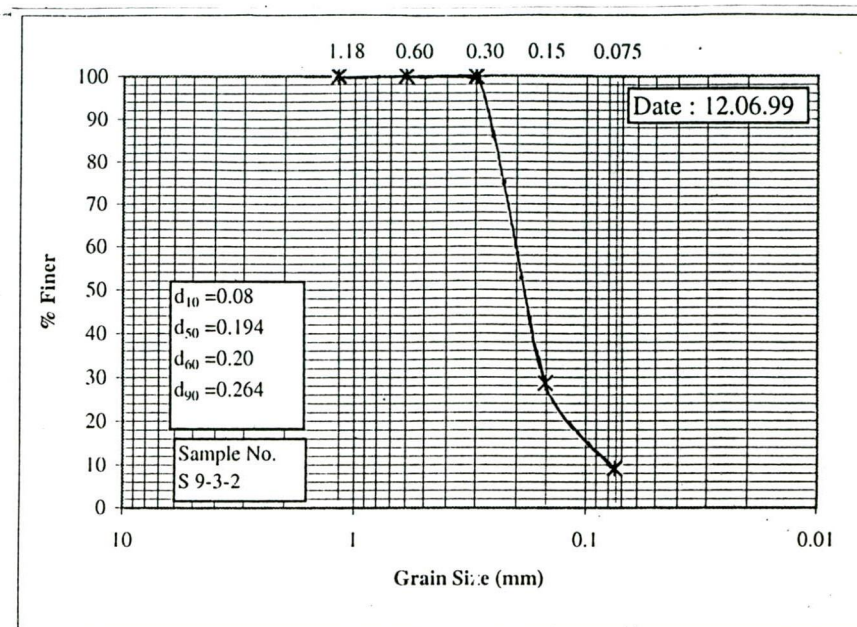
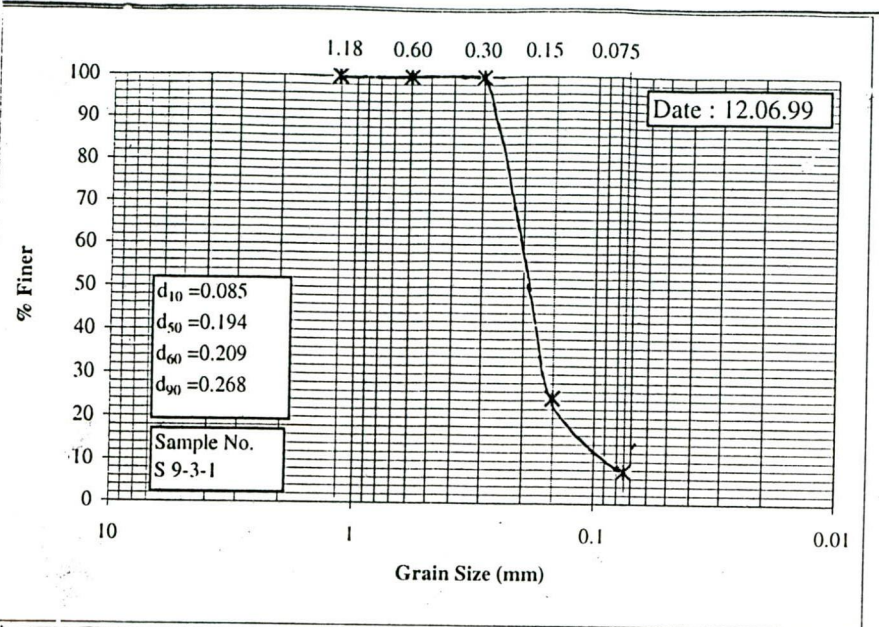


Figure 3.32 : Grain Size Distribution Curve for Station 9

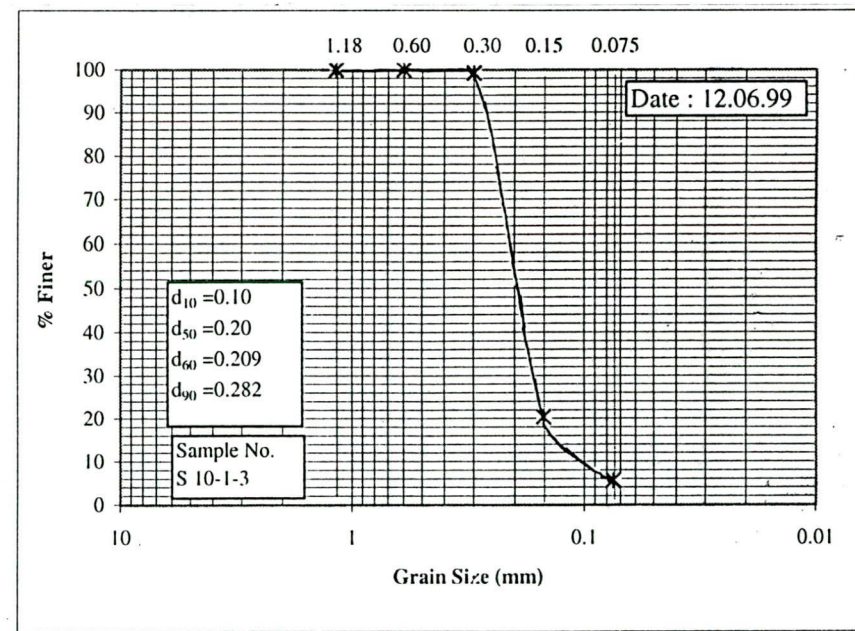
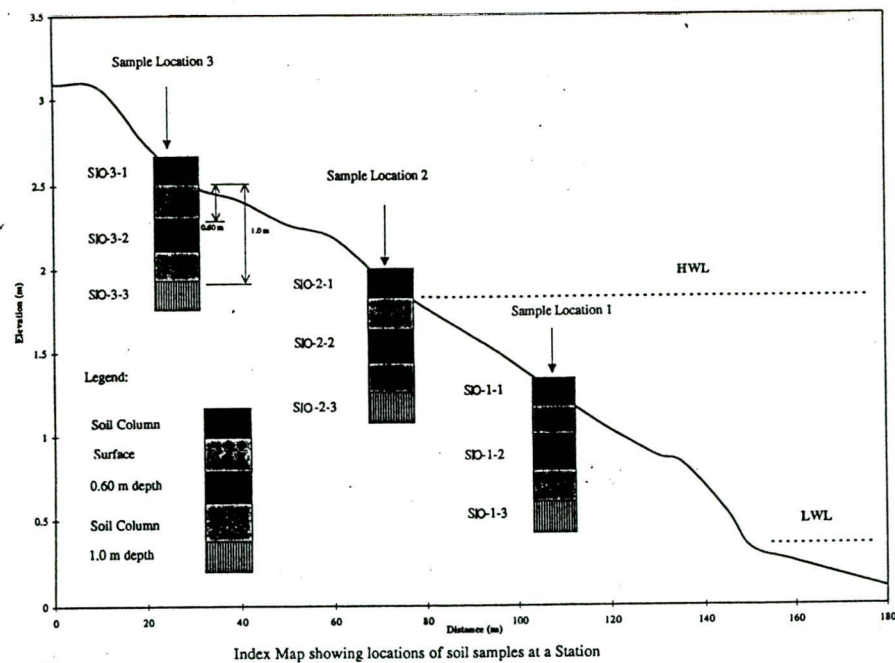
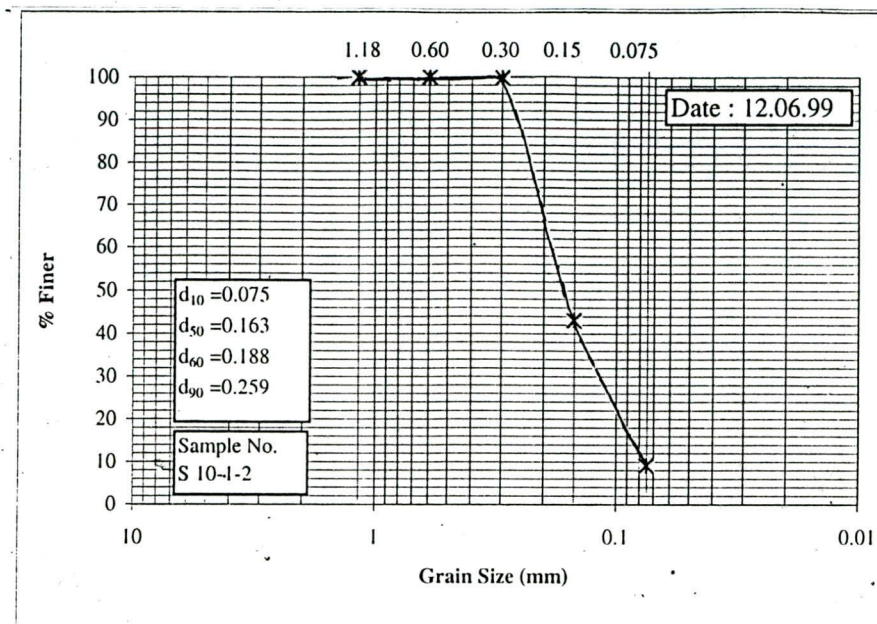
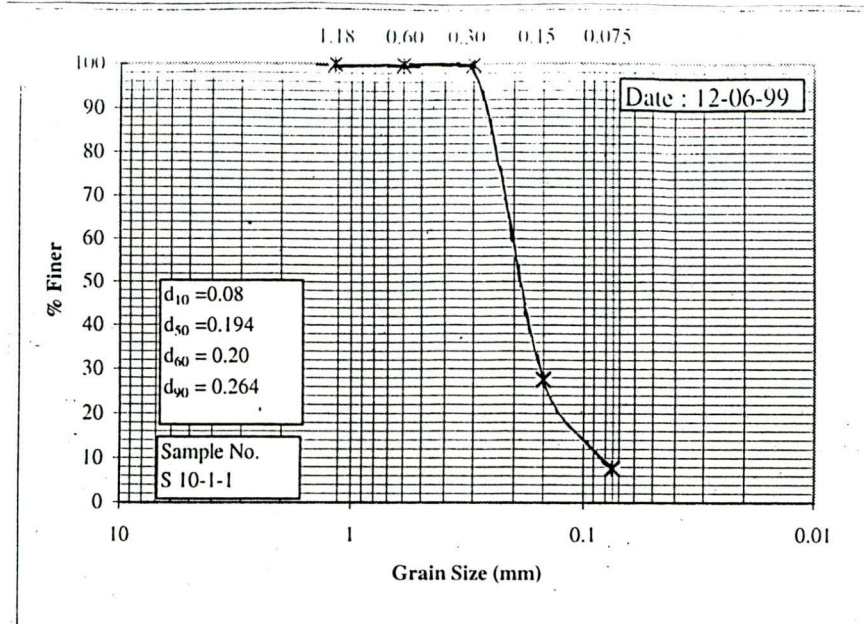


Figure 3.33 : Grain Size Distribution Curve for Station 10

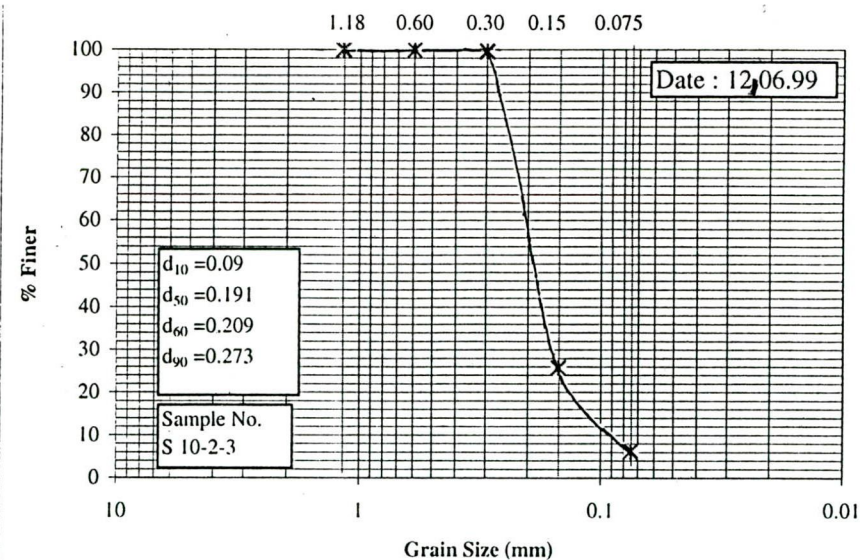
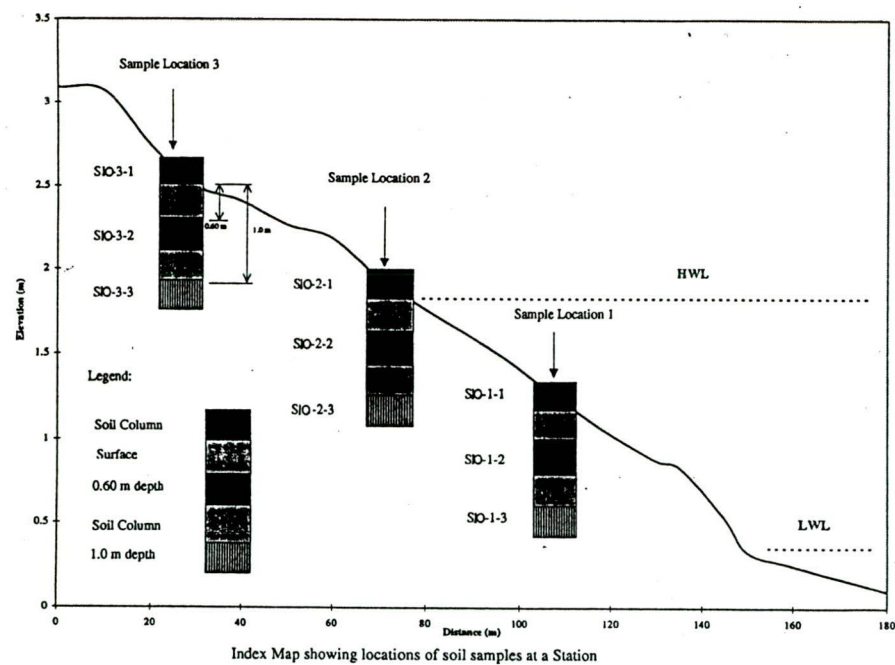
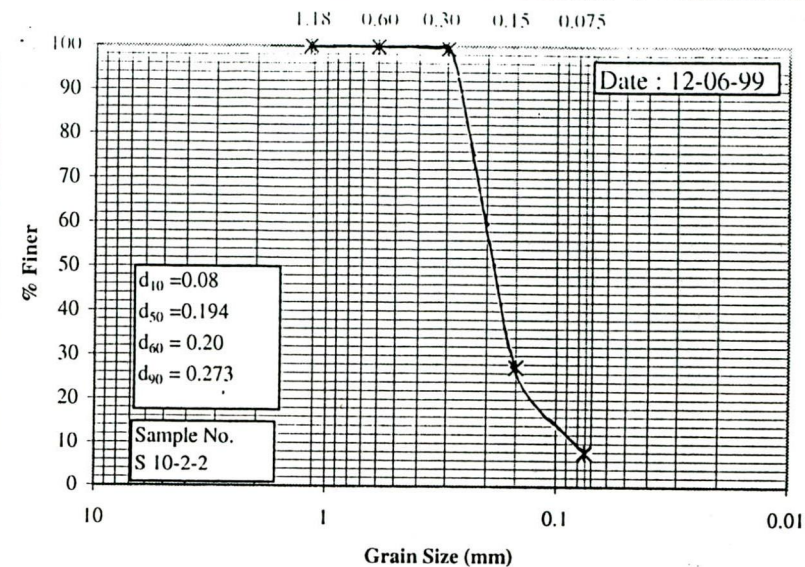
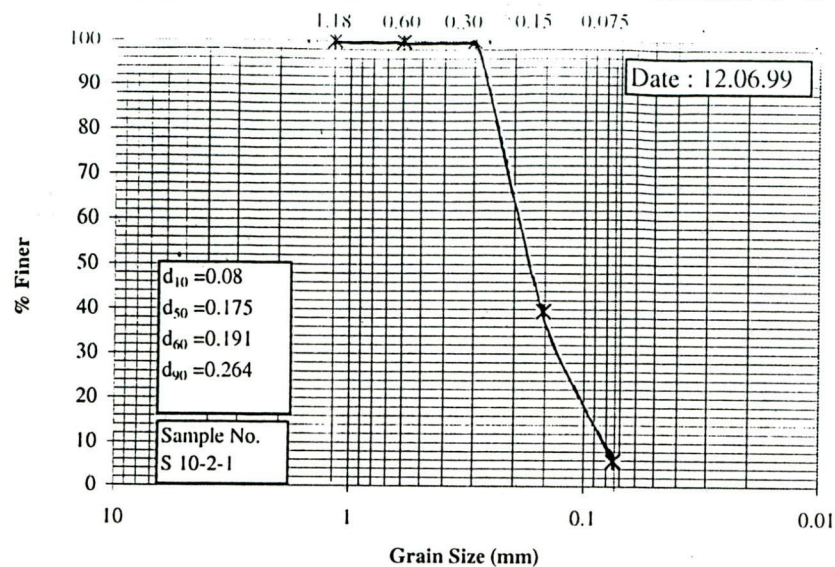


Figure 3.34 : Grain Size Distribution Curve for Station 10

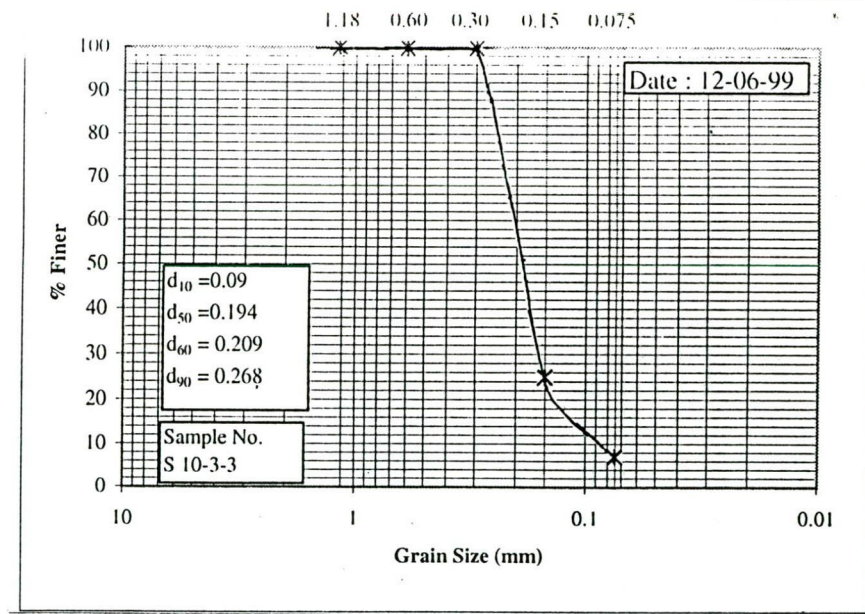
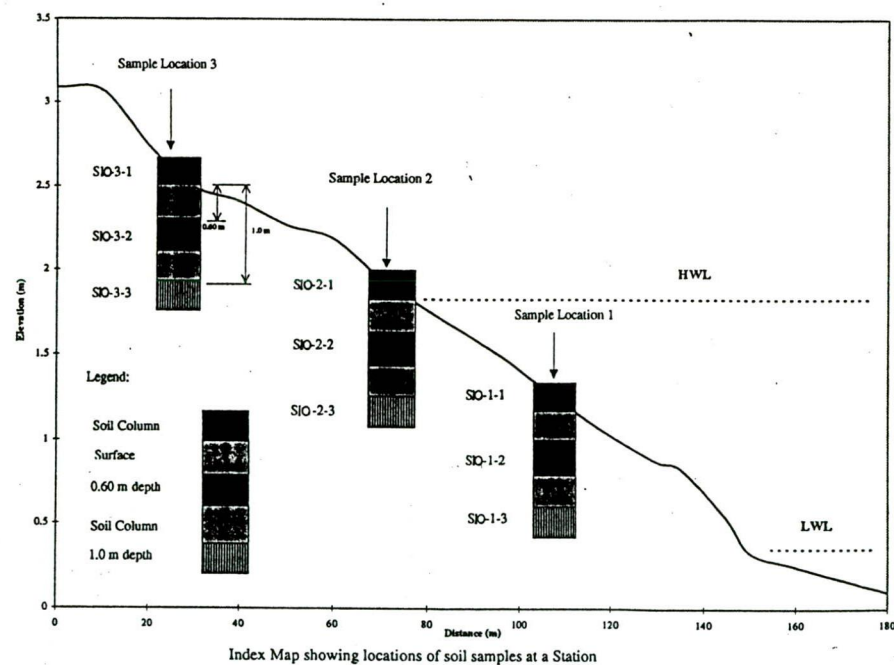
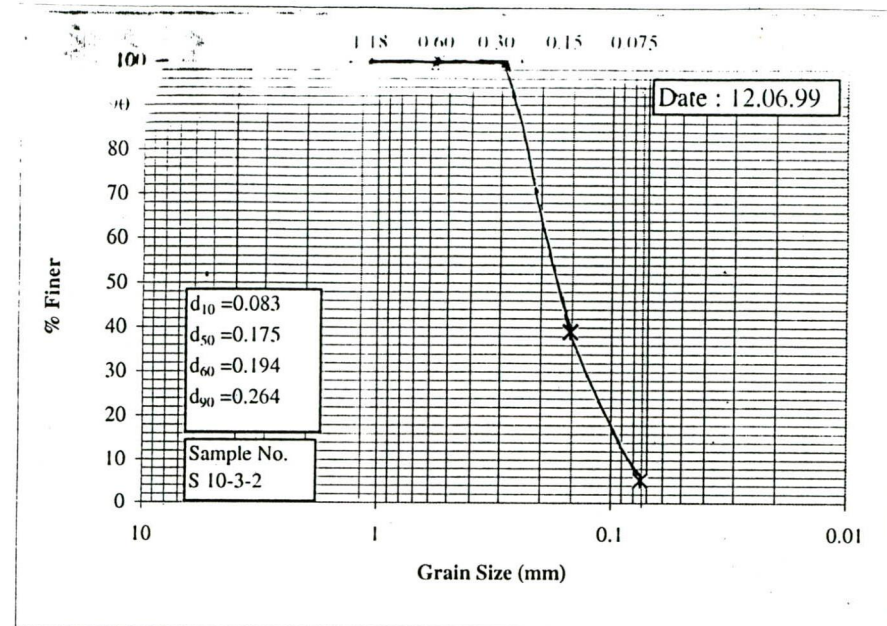
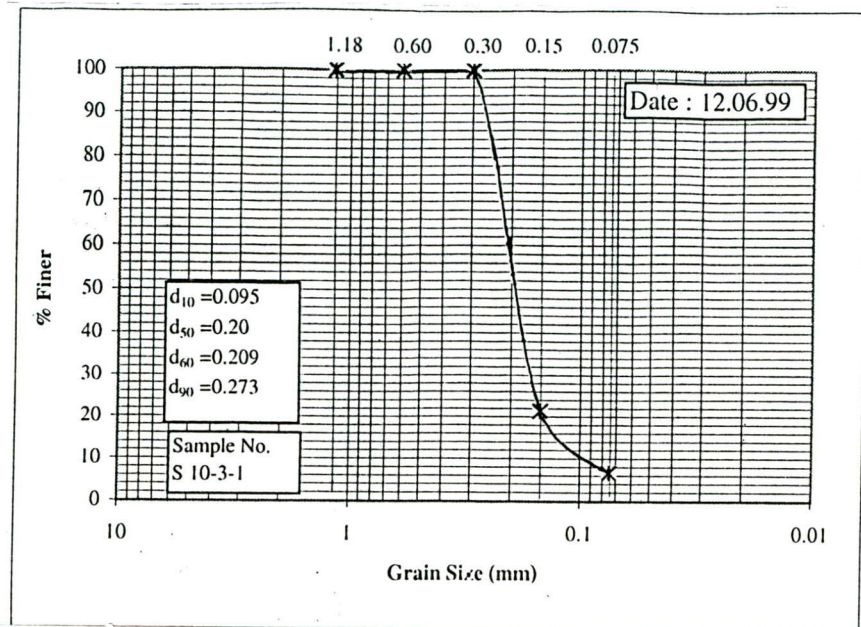


Figure 3.35 : Grain Size Distribution Curve for Station 10

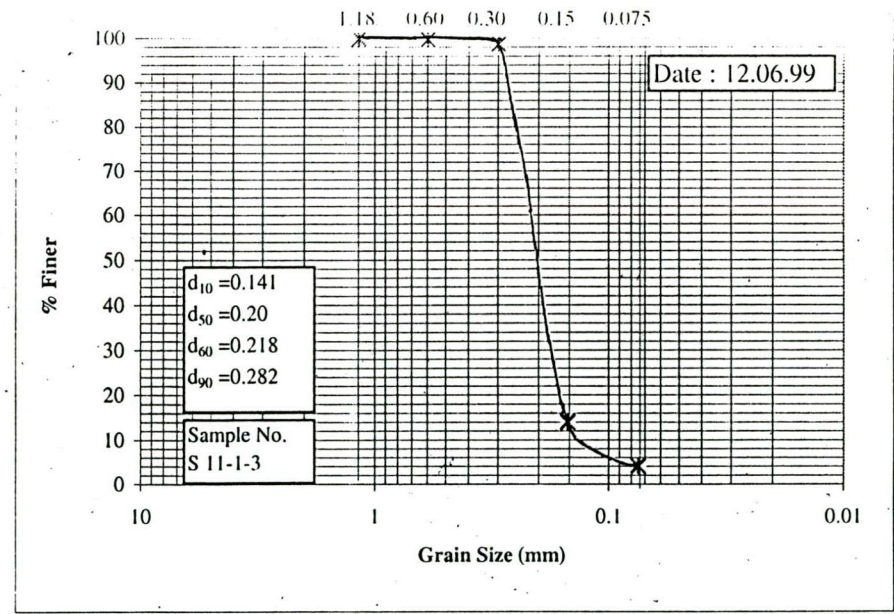
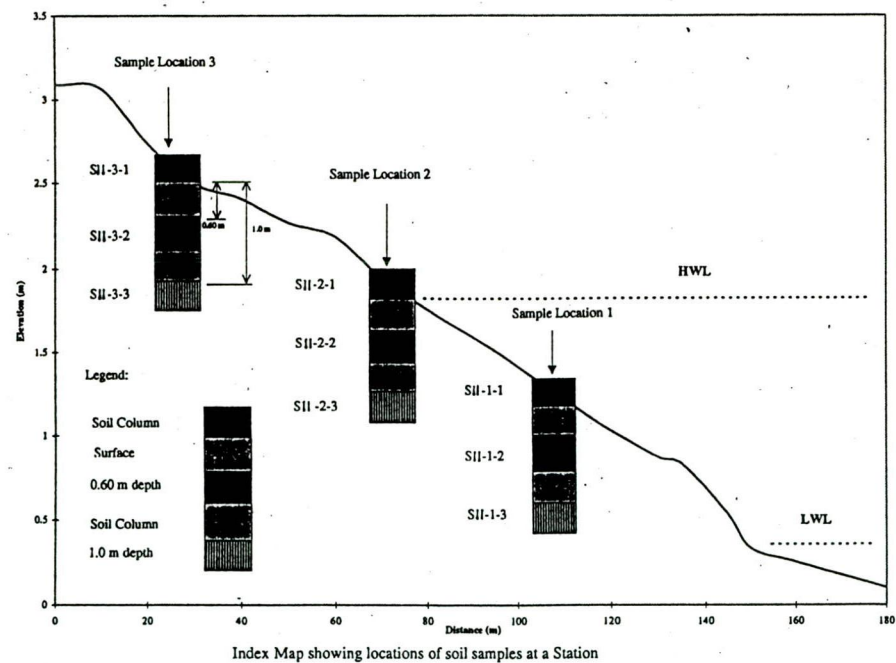
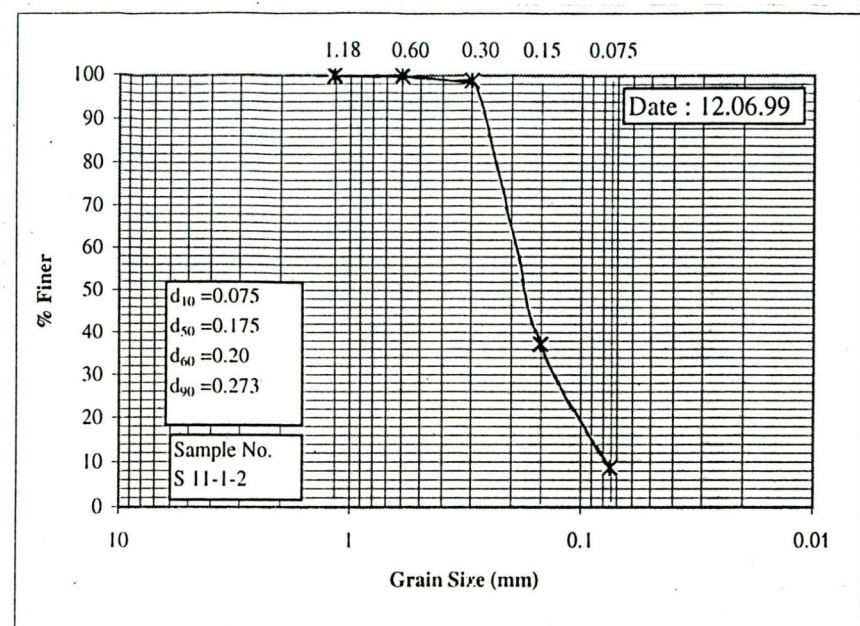
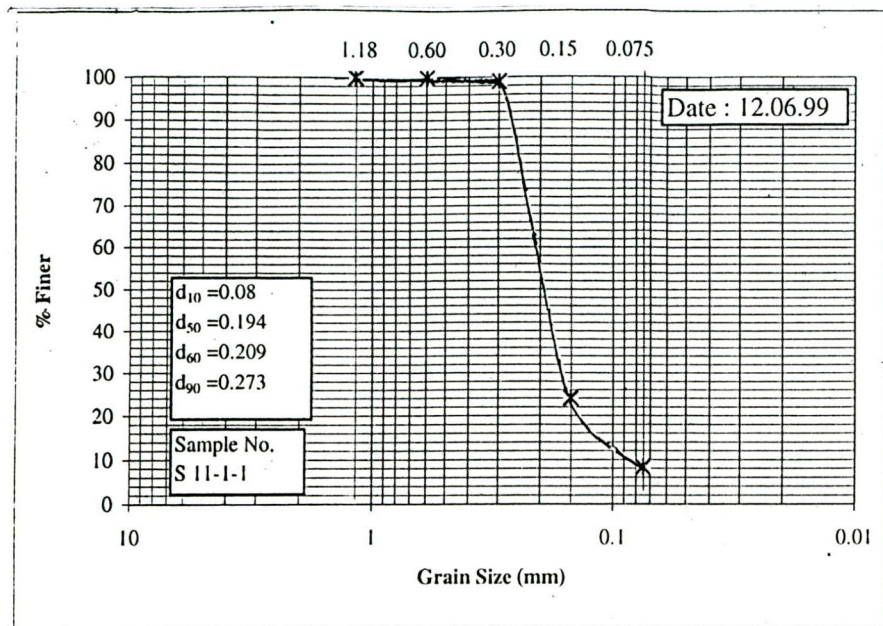


Figure 3.36 : Grain Size Distribution Curve for Station 11

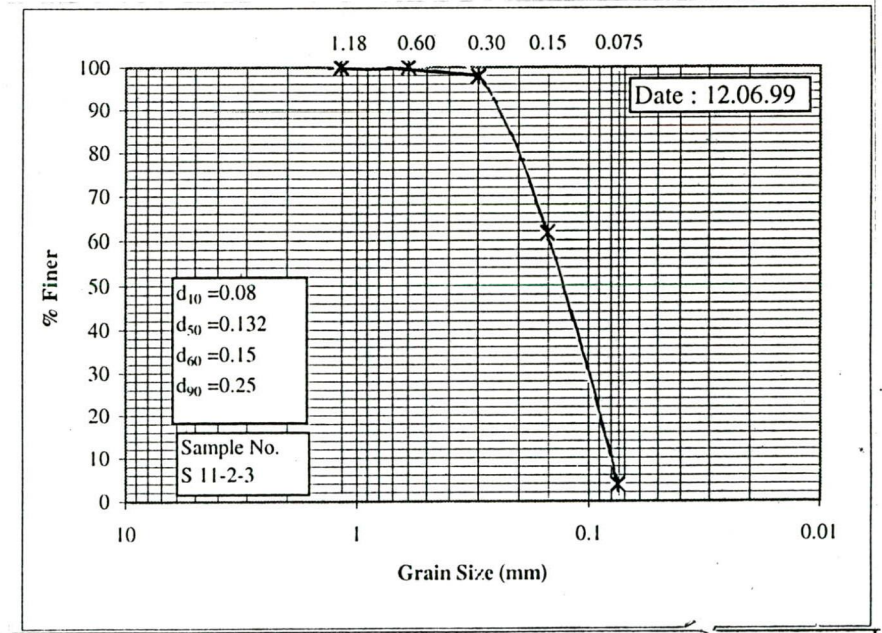
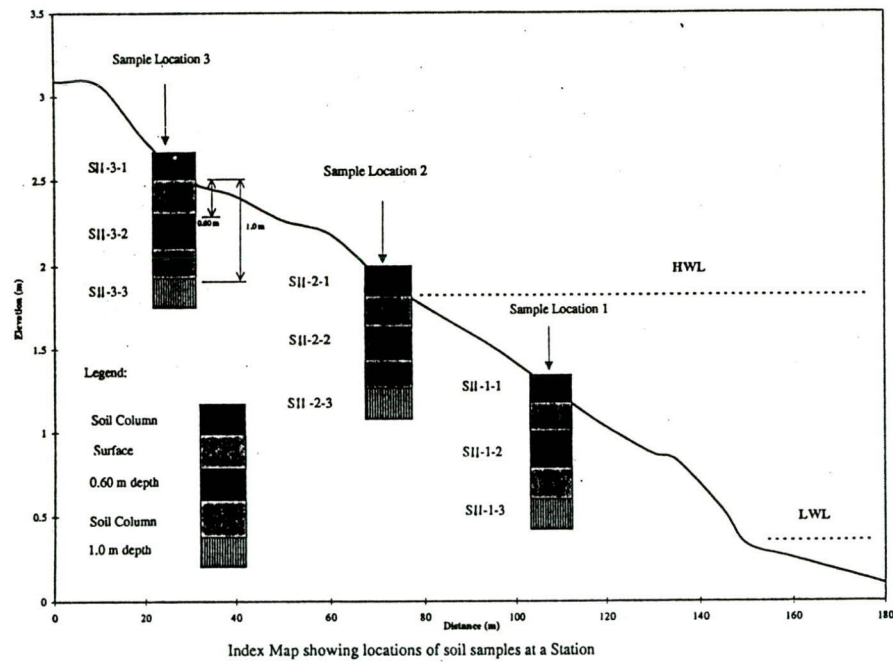
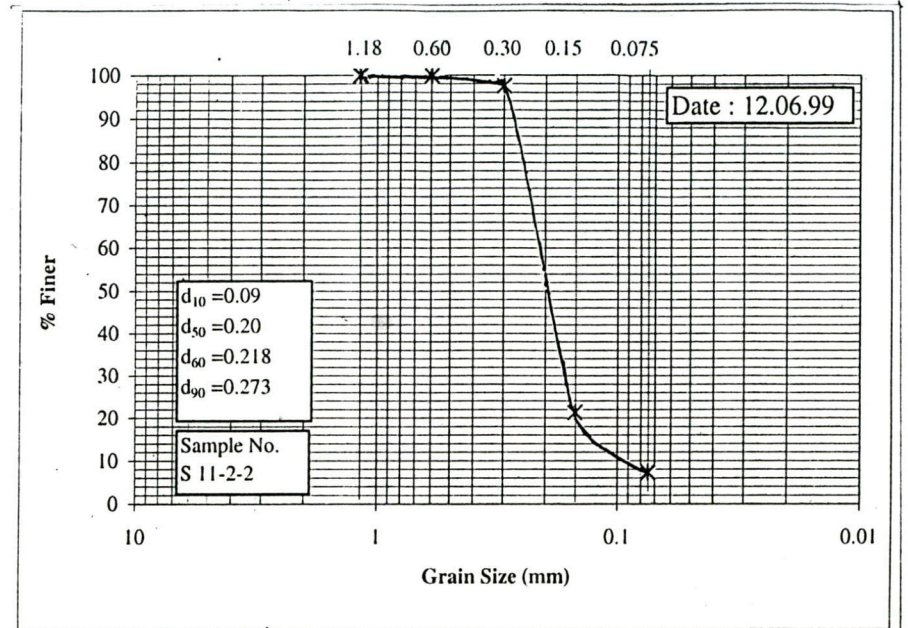
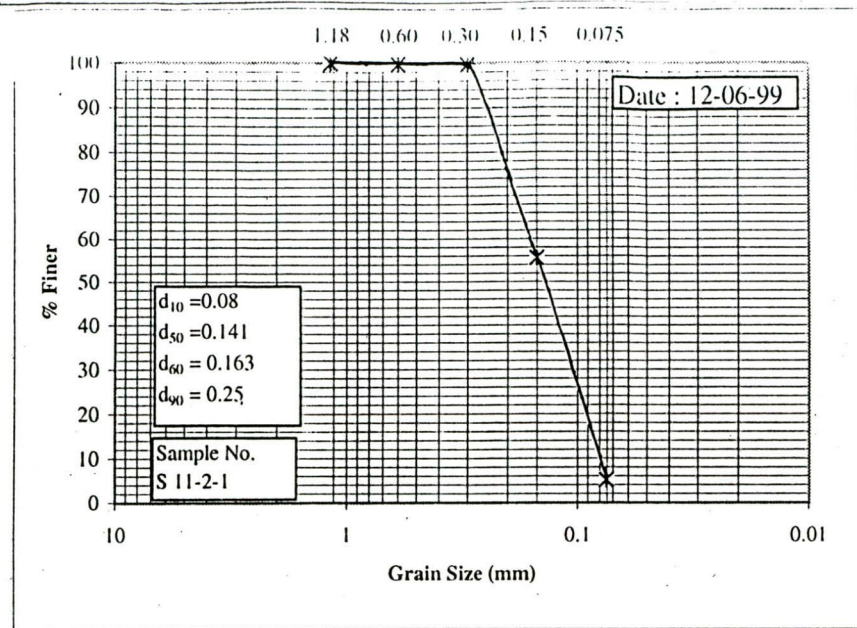


Figure 3.37 : Grain Size Distribution Curve for Station 11

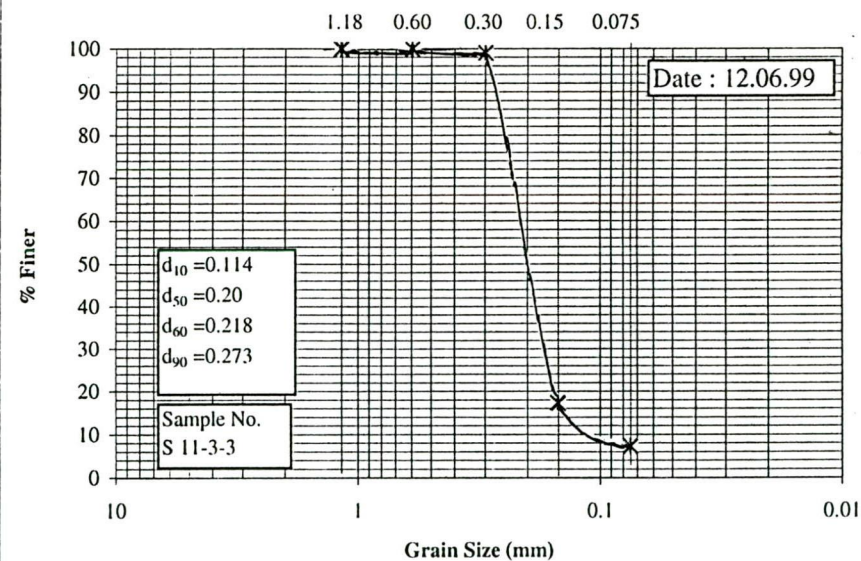
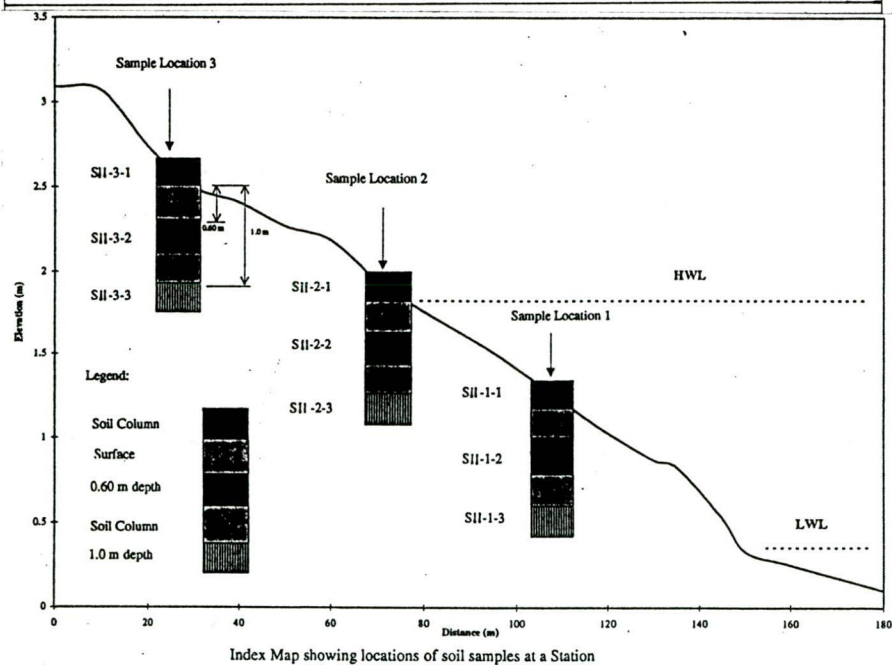
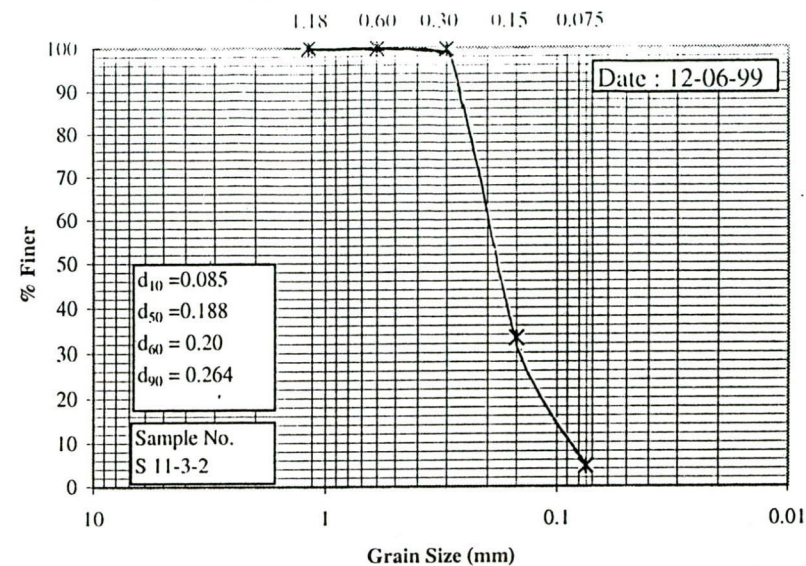
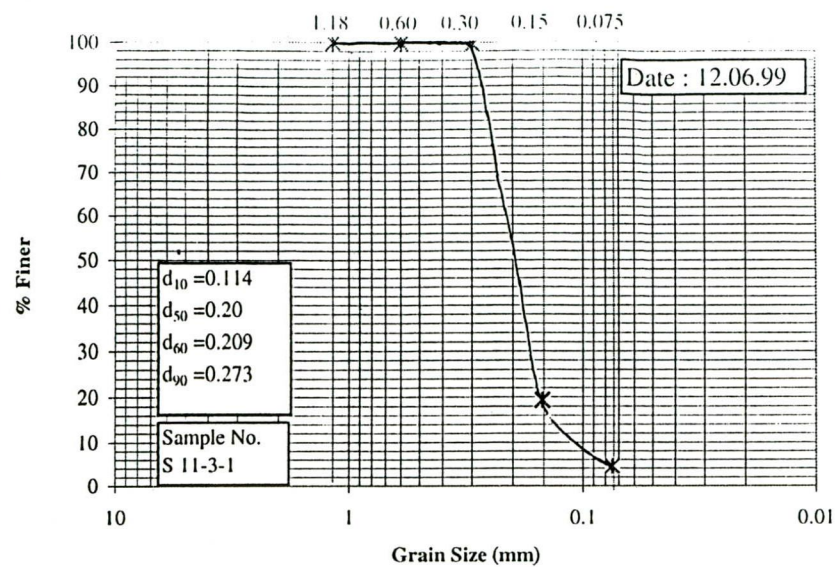
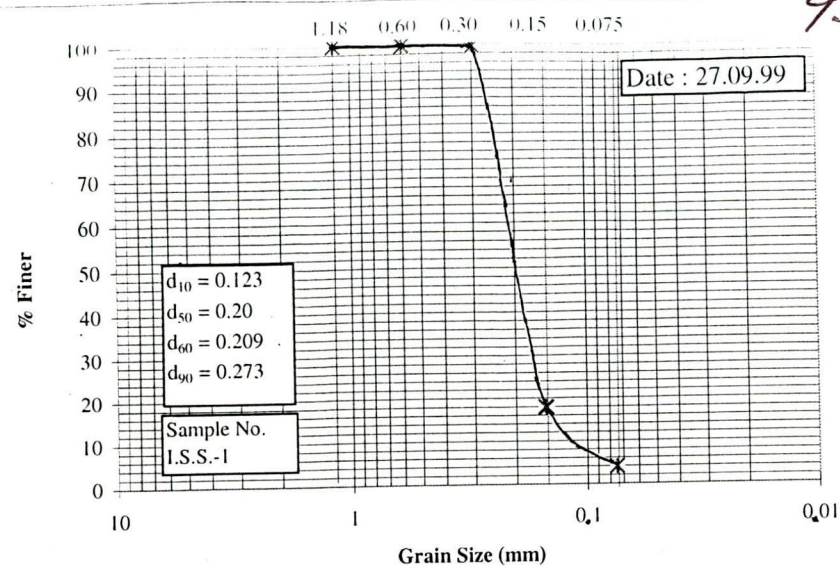
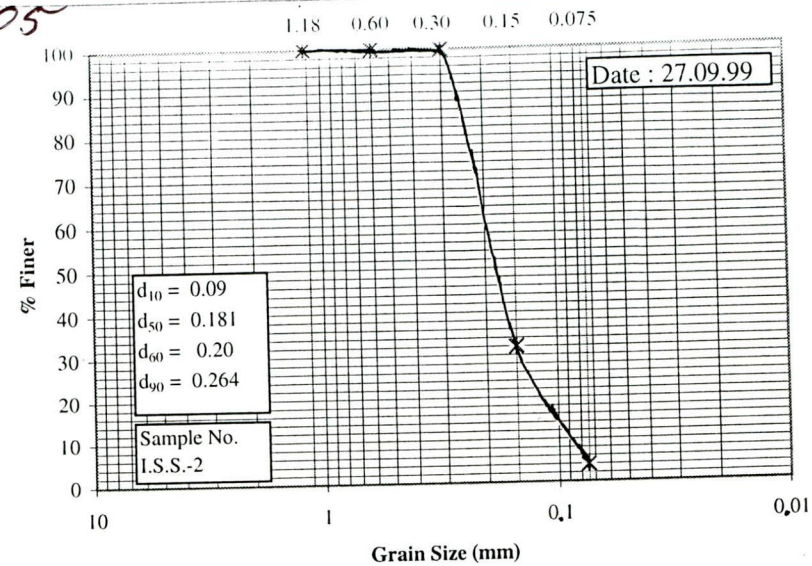


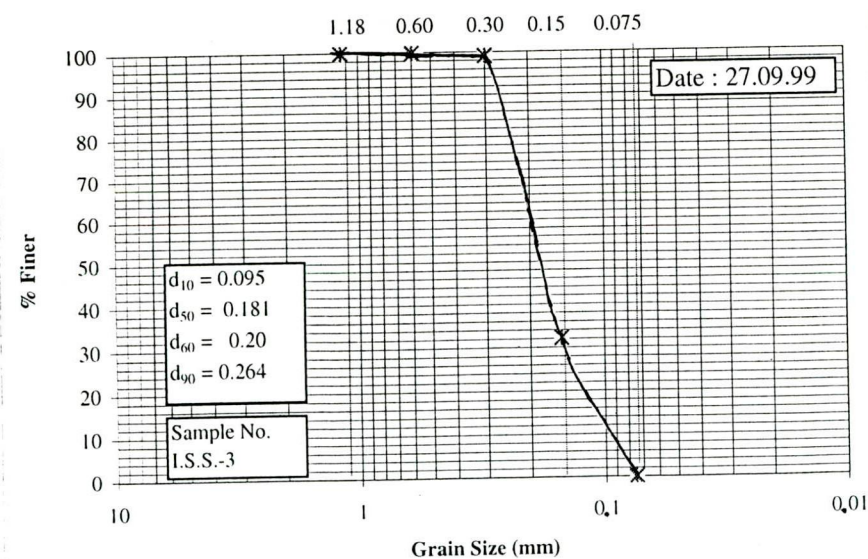
Figure 3.38 : Grain Size Distribution Curve for Station 11



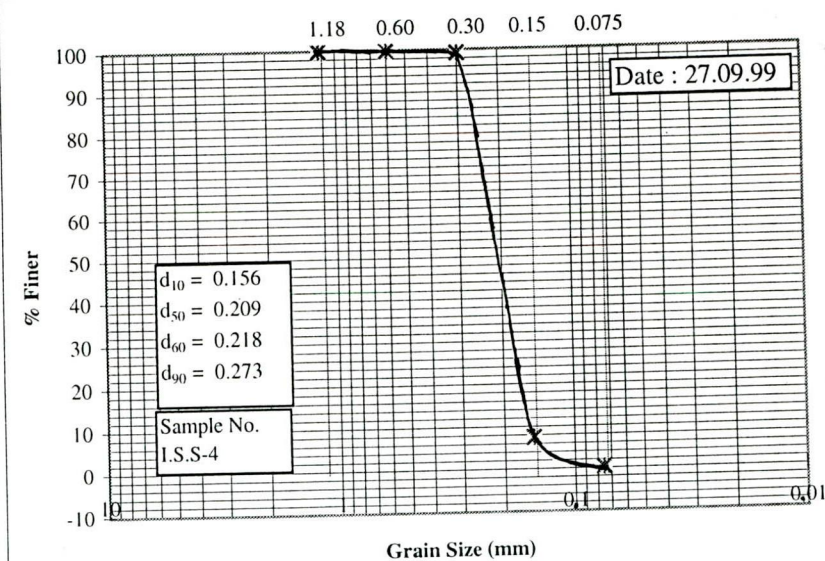
a. Bed Sample from Nilgonj River near confluence



b. Sample from L/B of Nilgonj River near confluence



c. Bed Sample from Nilgonj River confluence (500 m to the North)



d. Sample from L/B of Nilgonj River near confluence (500 m to the north)

Figure 3.39 : Grain Size Distribution Curve for Bed and Bank Samples of Nilgonj River

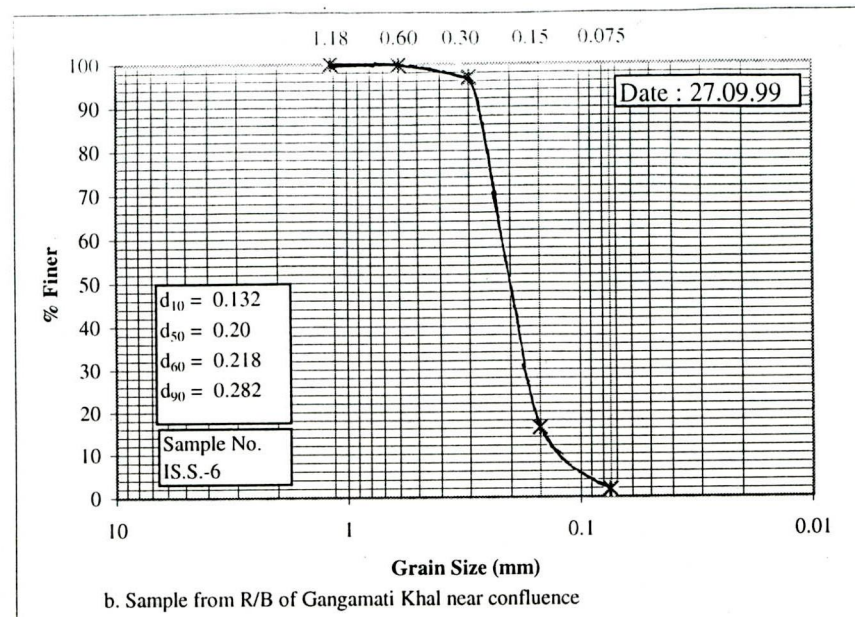
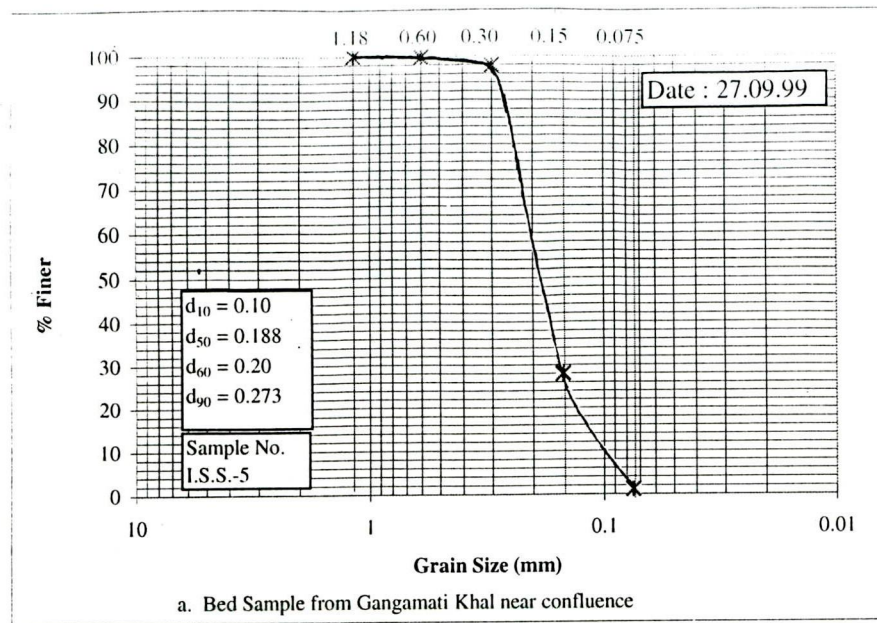


Figure 3.40 : Grain Size Distribution Curve for Bed and Bank Samples of Gangamati Khal

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

The distances between the stations were measured by tape. To get the width of the beach (foreshore zone) at a station the distance along the slope of the beach in between high and low water levels was measured by tape and was extended upto the normal up-rush point of wave run up. To get the profile of the beach the R.L. at different points of the cross profiles have been used. For finding actual widths (foreshore zone) of the beach the Chart Datum (Lowest Low Water Level) with respect to PWD was considered as reference line for safety factor. The PWD Zero Level is 1.96 m higher than the Chart Datum (CD). The Highest Astronomical Tide Level at Khepupara (BIWTA, Bangladesh Tide Tables, 1999, Page 161) was also considered for locating wave run-up point. Highest Astronomical Tide (H.A.T.) is the highest tidal level under average meteorological conditions and under any combination of astronomical conditions as defined by Oza (1976). It should be mentioned here that the approximate wave up-rush point has been found out from the inquiry of local people. The width of the foreshore zone was then calculated from the profile (Table 4.1).

The cross-sectional profiles of the beach at various stations thus drawn (Figures 4.1 through 4.11) show the backshore zone (partially) and the foreshore zone. It was, however, not possible to show the foreshore zone at Station no 5 in full because of discontinuation of the survey work due to high tides and waves. The actual width of the tidal flat plain was also not surveyed as it was beyond the scope of the study.

4.2 LONGITUDINAL PROFILE OF KUAKATA BEACH

The variation of elevation along the foreshore zone is shown in Figure 4.12. In drawing the plot the average of the spot levels of a station within the foreshore zone has been considered. The bed levels of the khals crossing the beach were not considered while calculating the average elevation.

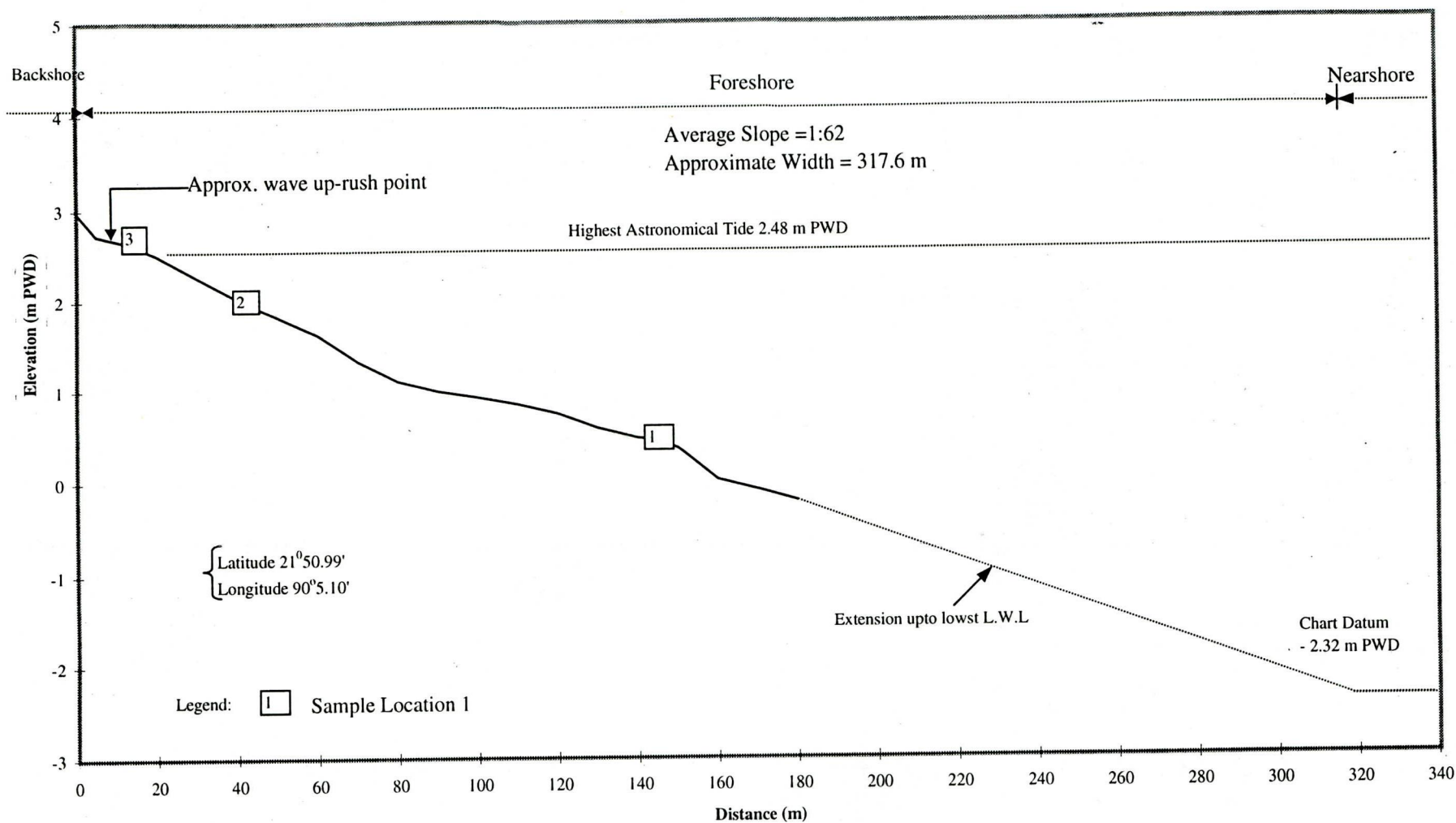


Figure 4.1 : Cross-sectional Profile of Station No. 1

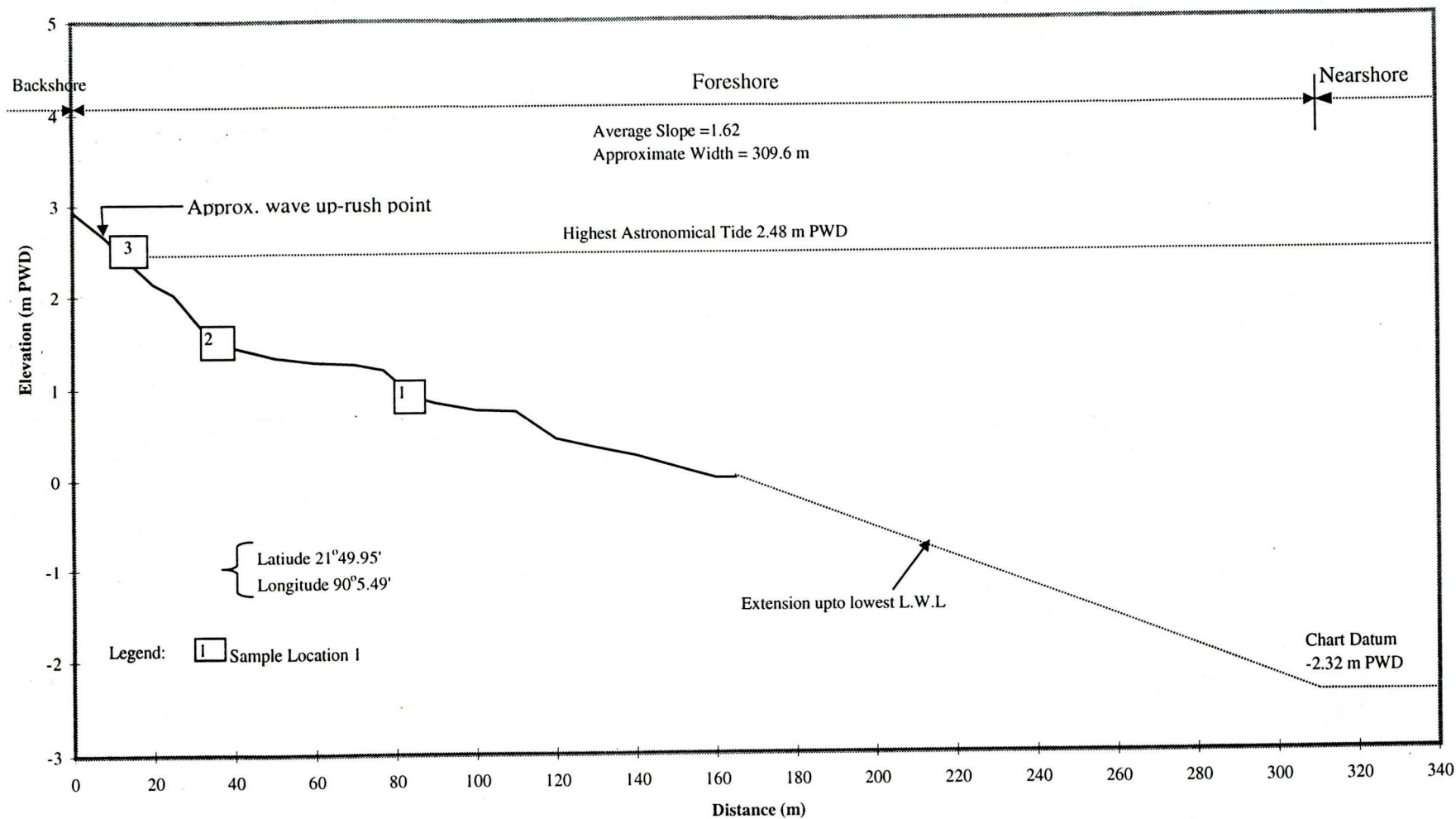


Figure 4.2 : Cross-sectional Profile of Station No. 2

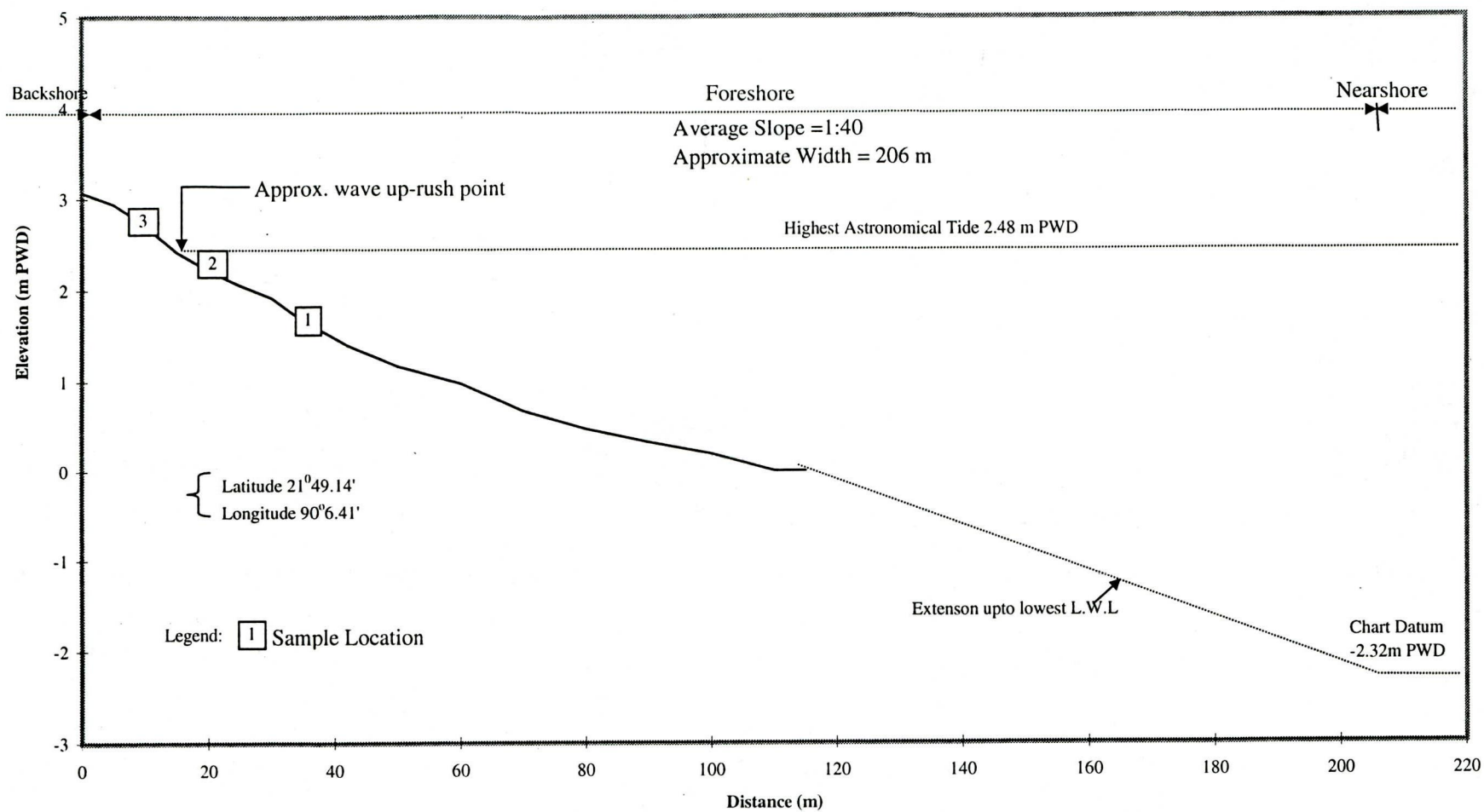


Figure 4.3 : Cross-sectional Profile of Station No. 3

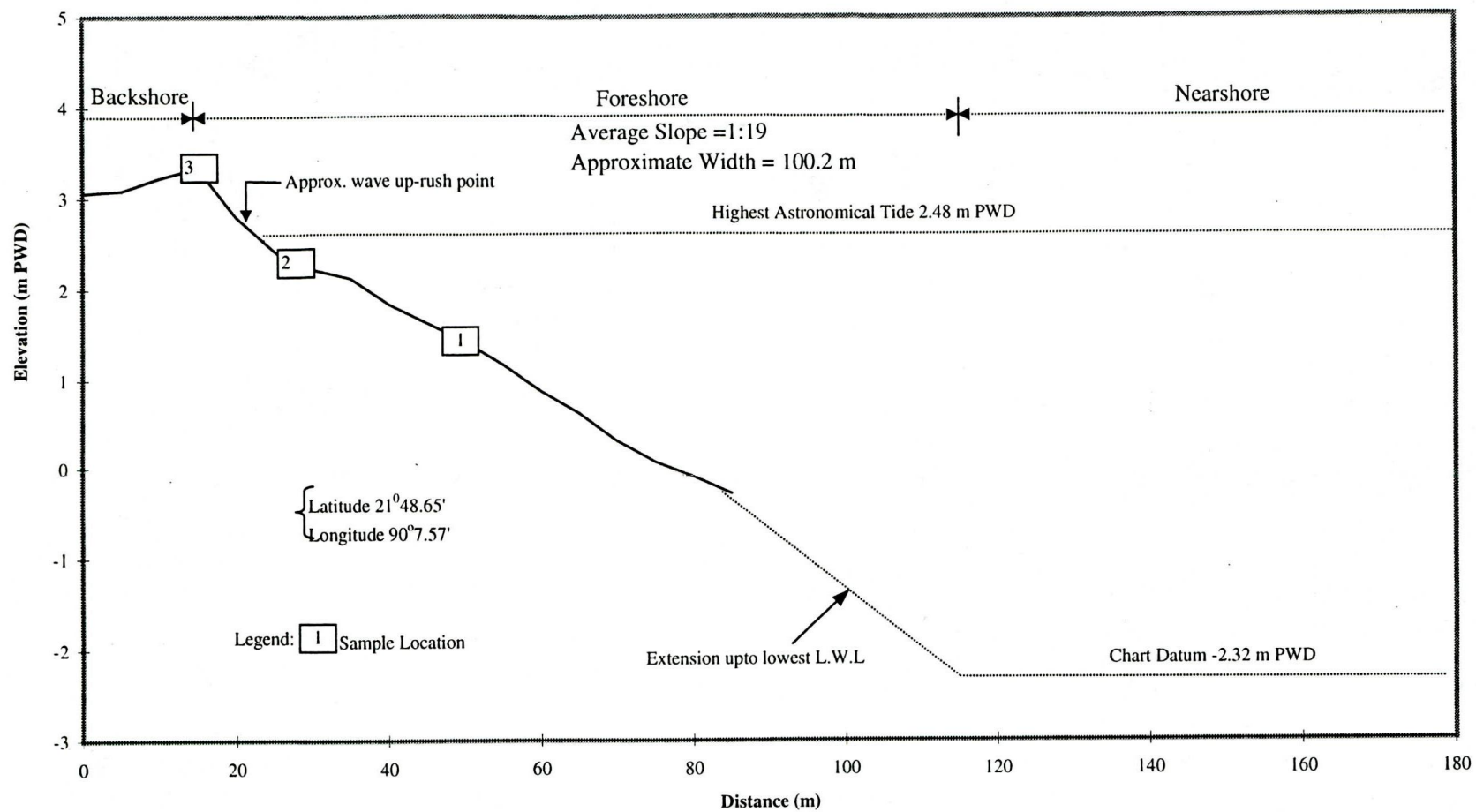


Figure 4.4 : Cross-sectional Profile of Station No. 4

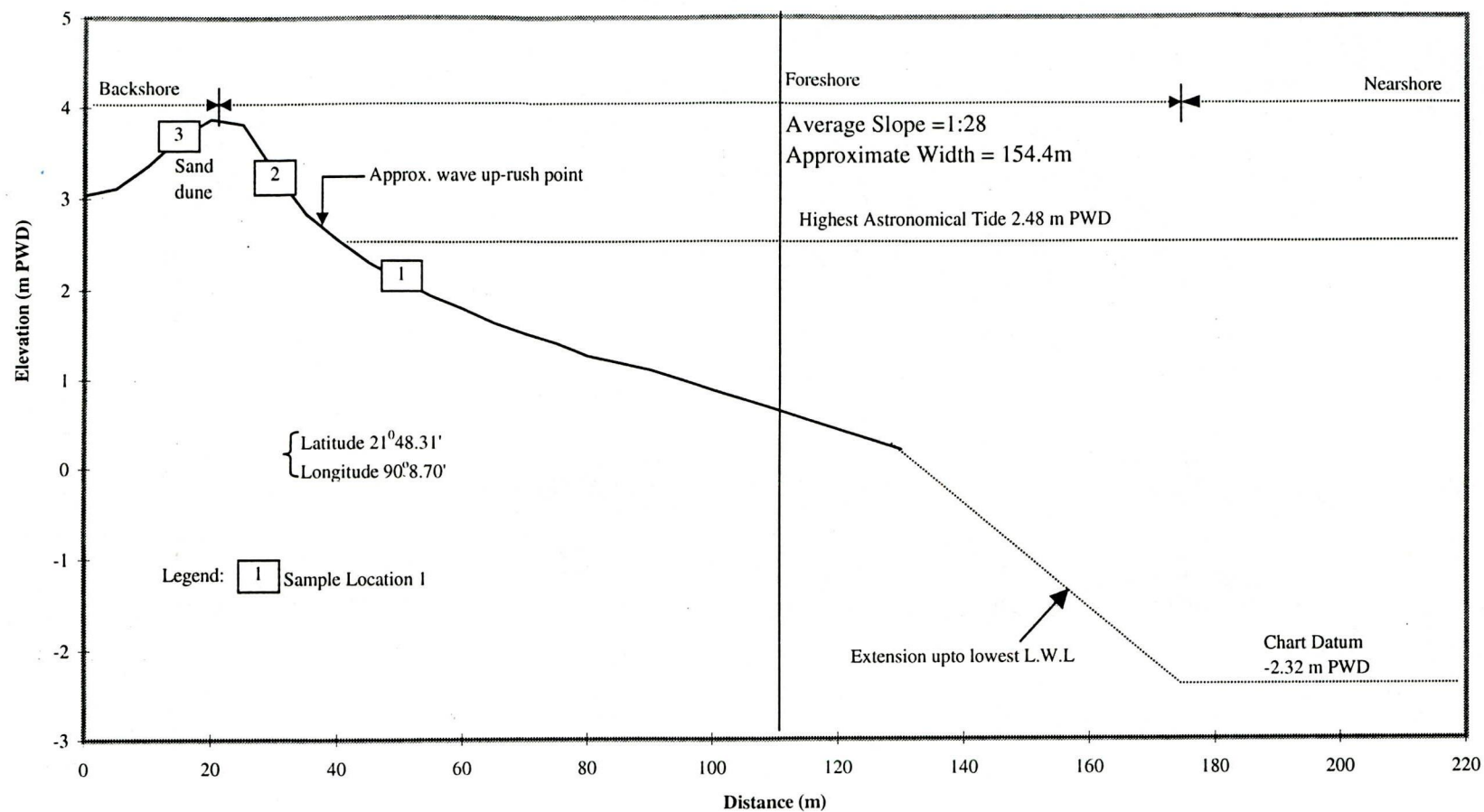


Figure 4.5 : Cross-sectional Profile of Station No. 5

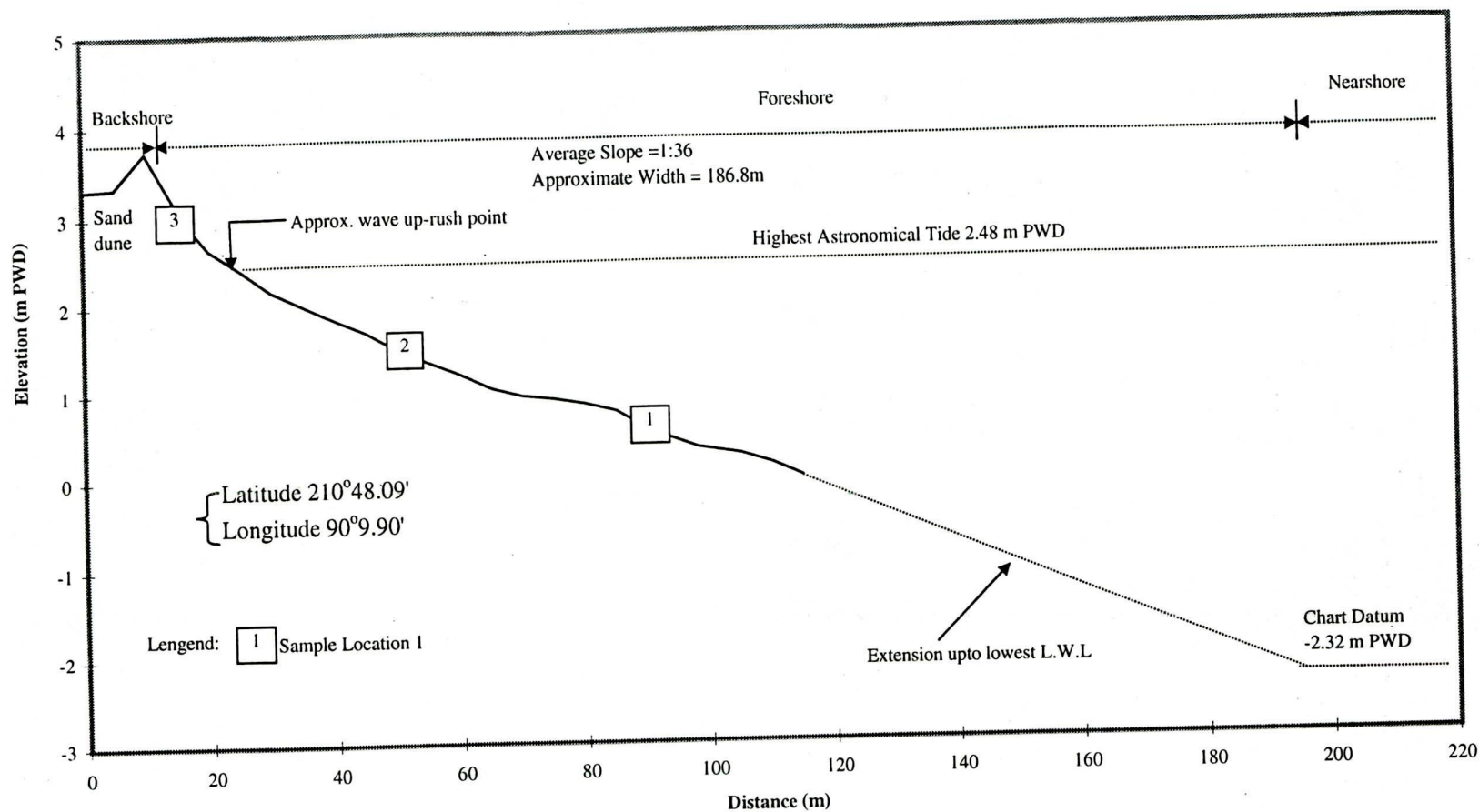


Figure 4.6 : Cross-sectional Profile of Station No. 6

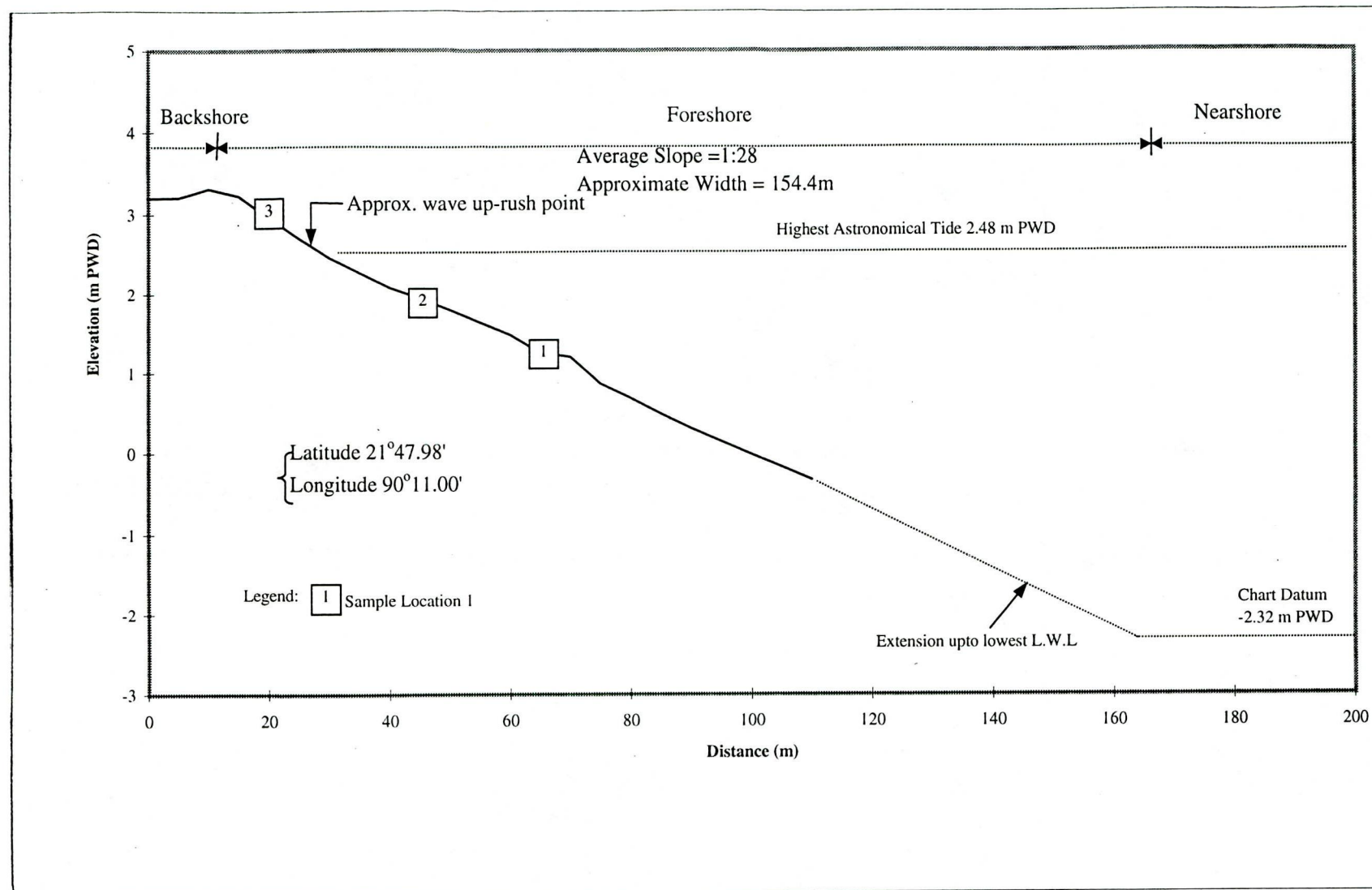


Figure 4.7 : Cross-sectional Profile of Station No. 7

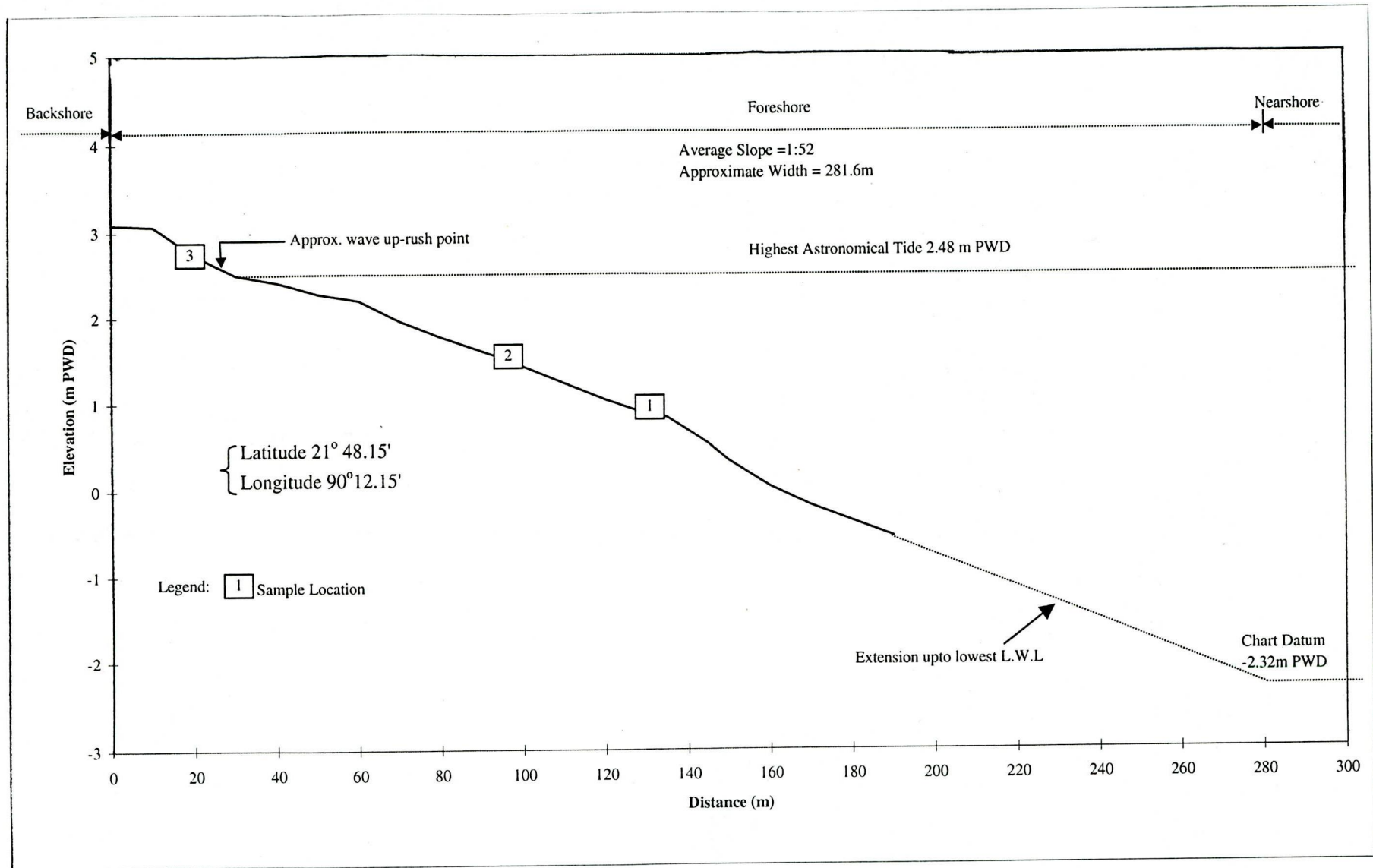


Figure 4.8 : Cross-sectional Profile of Station No. 8

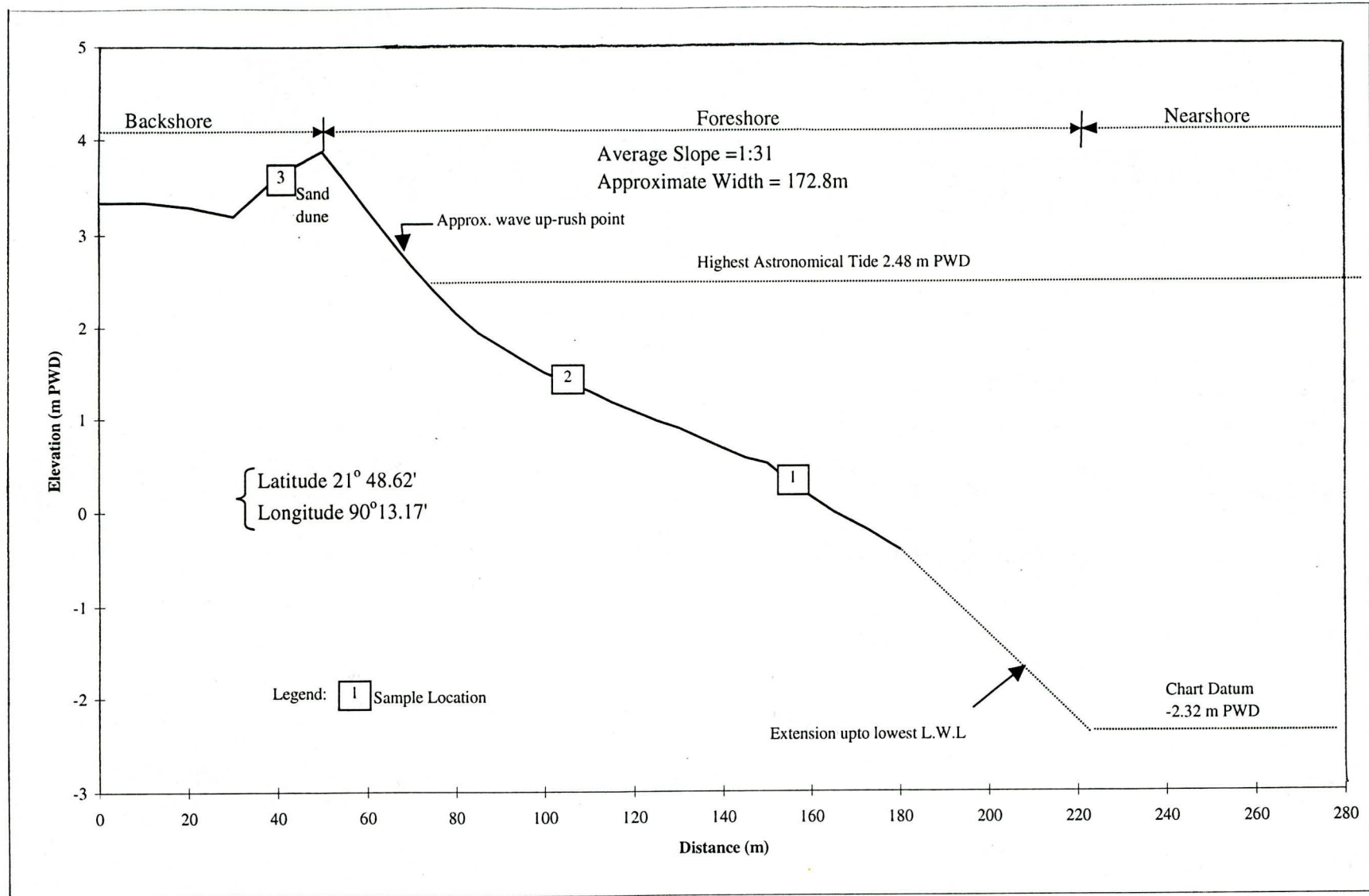


Figure 4.9 : Cross-sectional Profile of Station No. 9

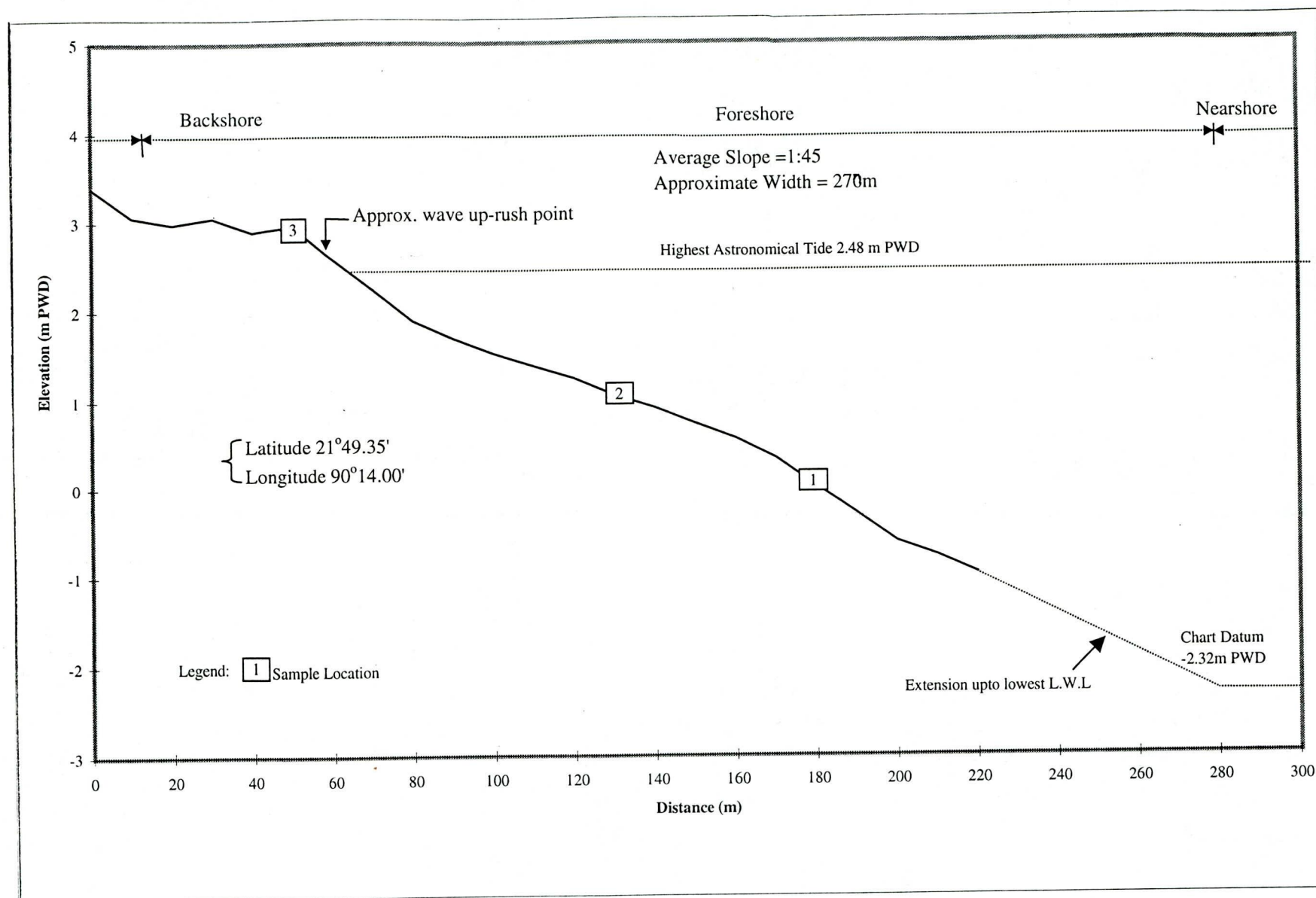


Figure 4.10 : Cross-sectional Profile of Station No. 10

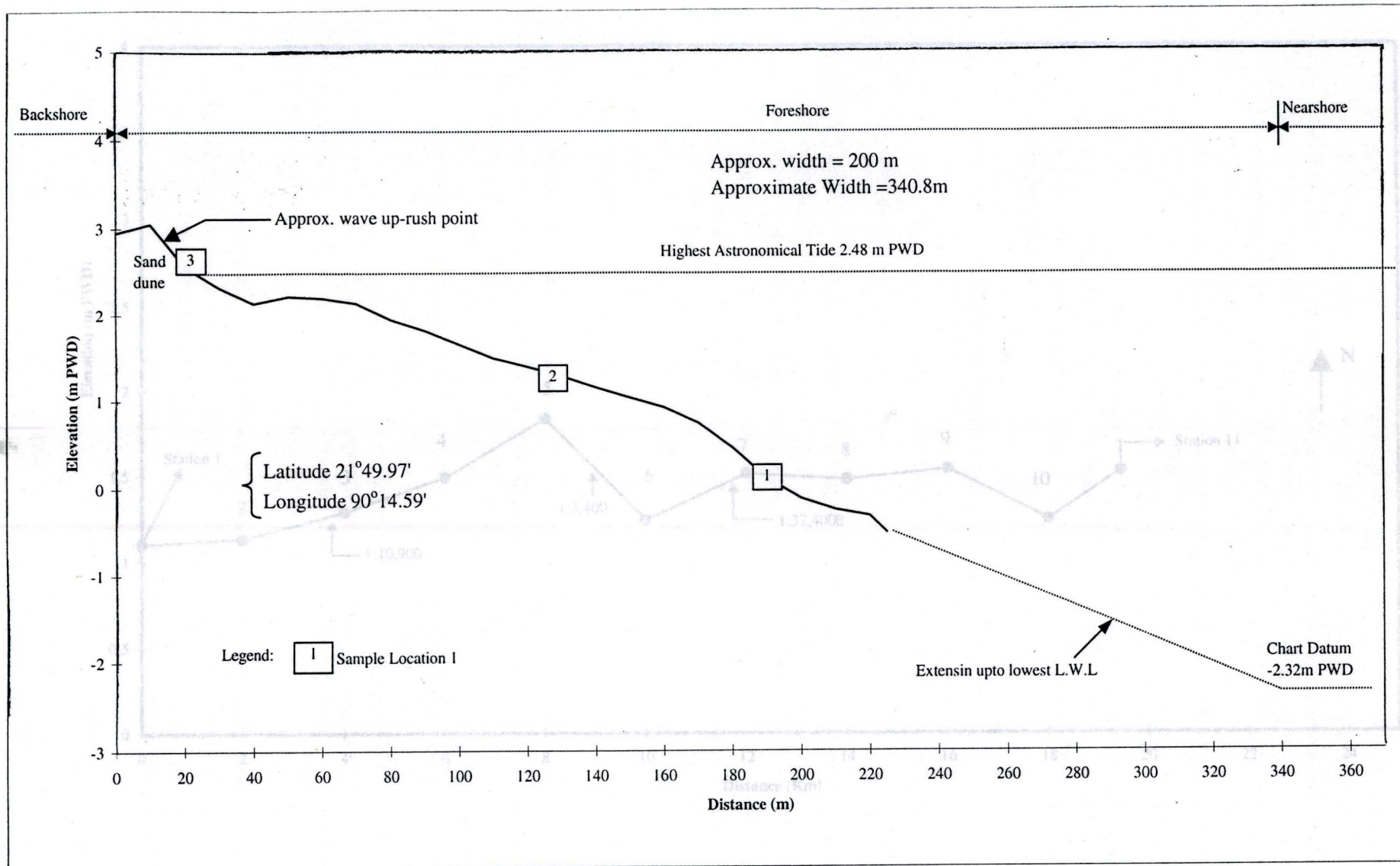


Figure 4.11 : Cross-sectional Profile of Station No. 11

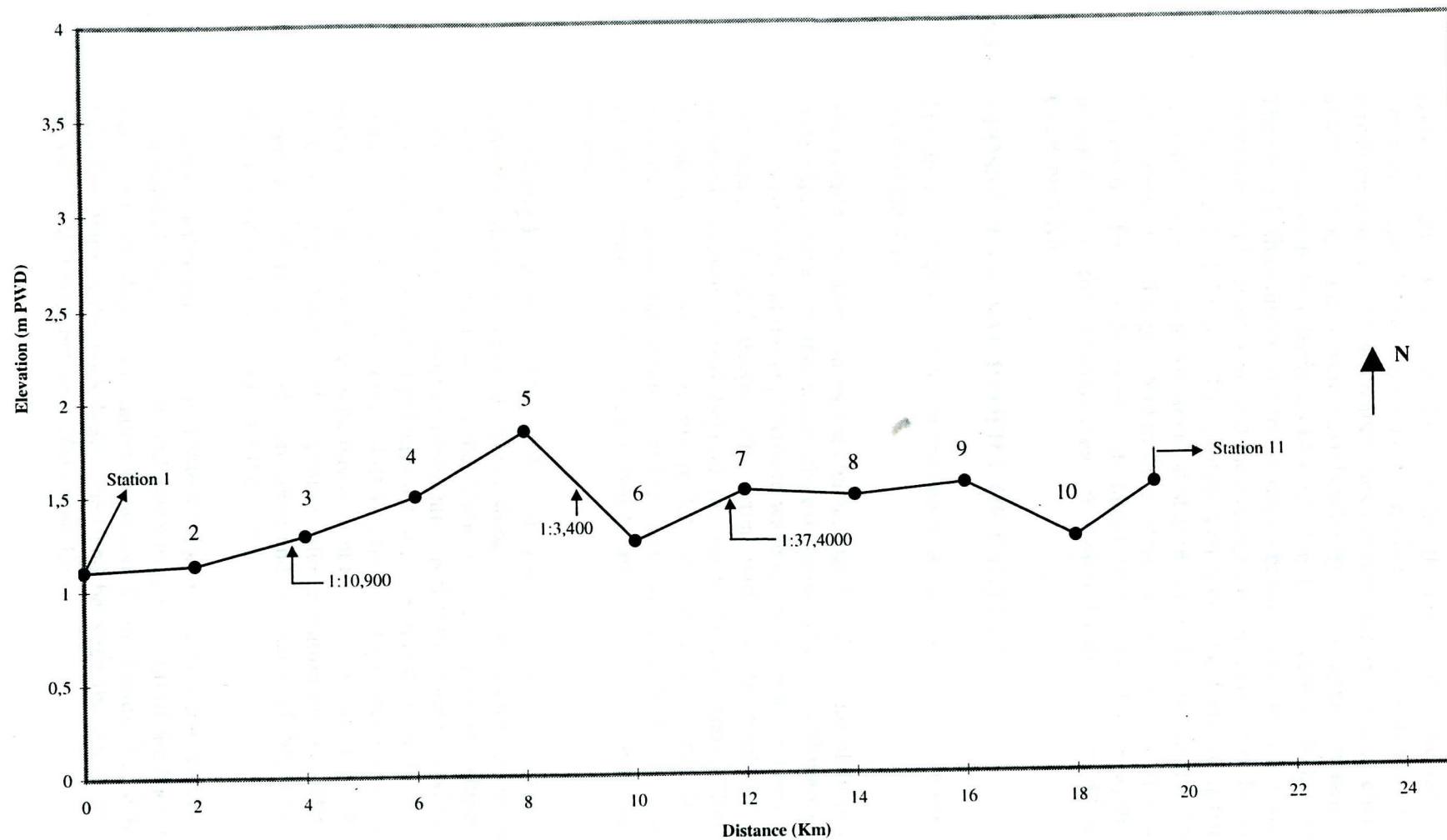


Figure 4.12 : Longitudinal Slope (Variation of Beach Elevation) along the Foreshore zone

Looking Figure 4.12, it can be said that the beach long profile has no definite trend of shape. From station no. 1 at chainage 0.00 km, the elevation of the foreshore zone of the beach increases towards station no. 5 at chainage 8.00 km and the average rate of increase of beach elevation is approximately 1:10,900. The beach elevation then decreases @ 1:3,400 upto chainage 10.00 km at station no. 6. The slope is then almost flat in the region between stations no. 6 and 9 (chainage 10.00 km to ch. 16.00 km) and the average rate of increase of beach elevation is approximately 1:37,400. The profile then takes the form of a trough between stations 9 and 11. The low level at station 6 may be due to the development of tidal creek at chainage 8.50 km by eroding beach materials from the areas near station 6. The low level also at station 10 may be due to wash out of beach materials from the adjacent areas at station 10 through the Dead Channel of Gangamati Khal.

4.3 CROSS-SECTIONAL PROFILE OF THE BEACH

The cross-sectional profiles of the beach at various stations are shown in Figures 4.1 through 4.11.

The profiles in many places are characterized by tidal flat plain in the backshore zone (land between the wave up-rush point and embankment). It should be mentioned here that the approximate wave up-rush point has been found out from the inquiry of local people. The actual width of the tidal flat plain was not surveyed because it was beyond the scope of the study. The width of the backshore zone is shown in Figure 3.2 but was not measured directly. This was done by plotting the widening of the foreshore zone. In LGED map (Figure 1.3) all the features in the sandy beach are not shown and the map is not representative.

Examining Figures 4.1 through 4.11, it is seen that at most of the stations there exists two distinct slopes, a steeper slope in the backshore zone and a relatively flatter slope in the foreshore zone (Table 4.1). The foreshore slopes vary between 1:19 and 1:66. The important observation is that the foreshore slopes are flatter at stations no. 1, 2, 8 and 11 (Figures 4.1, 4.2, 4.8 and 4.11) and relatively steeper at stations no. 4, 5 and 7 (Figures 4.4, 4.5 and 4.7). Comparative study (Figure 4.13) shows that the foreshore slope has minimum value at station no. 11 (1:66) where the beach is the flattest and maximum value at station no. 4 (1:19). The foreshore slopes at stations no. 3 and 6 are more or less same (Table 4.1). The foreshore slopes at stations no. 1 and 2 are the same.

Figures 4.1 through 4.11 and Table 4.1 also reveal that the width of the foreshore zone varies between 100.2 m and 340.8 m. The width of the backshore zone also varies considerably from station to station. From Figure 3.2, it reveals that the tidal flat plain in the backshore zone (land between the wave up-rush point and embankment) varies between 200 m and 1300 m.

Table 4.1
Summary of the Cross Profiles and Widths of the Kuakata Beach

Station No.	Station Name	Lat/Long	Beach Slope (Foreshore)	Width (m)		Remarks
				Foreshore	Backshore	
				Distance between wave run-up point and chart datum	Distance between wave run-up point and embankment	
1	Khajura	21°50.99'E/ 90°5.10'N	1:62	317.6	1200	Nilgonj River confluence
2	Nakuripara	21°49.95'E/ 90°5.49'N	1:62	309.6	500	Dense Plantation
3	Kuakata	21°49.14'E/ 90°6.41'N	1:40	206	200	Near LGED Rest House
4	Kuakata	21°48.65'E/ 90°7.57'N	1:19	100.2	400	Steep slope exists
5	Kuakata	21°48.31'E/ 90°8.70'N	1:28	154.4	800	Dense Plantation
6	Gangamati	21°48.09'E/ 90°9.90'N	1:36	186.8	1050	Dense Plantation
7	Gangamati	21°47.98'E/ 90°11.00'N	1:28	154.4	500	Near confluence of Gangamati Khal
8	Gangamati	21°48.15'E/ 90°12.15'N	1:52	281.6	550	Dense Plantation
9	Kawarchar	21°48.62'E/ 90°13.17'N	1:31	172.8	1300	No plantation exist
10	Kawarchar	21°49.35'E/ 90°14.00'N	1:45	270	700	No plantation exist
11	Kawarchar	21°49.97'E/ 90°14.59'N	1:66	340.8	900	Dead portion of Gangamati Khal confluence with sea

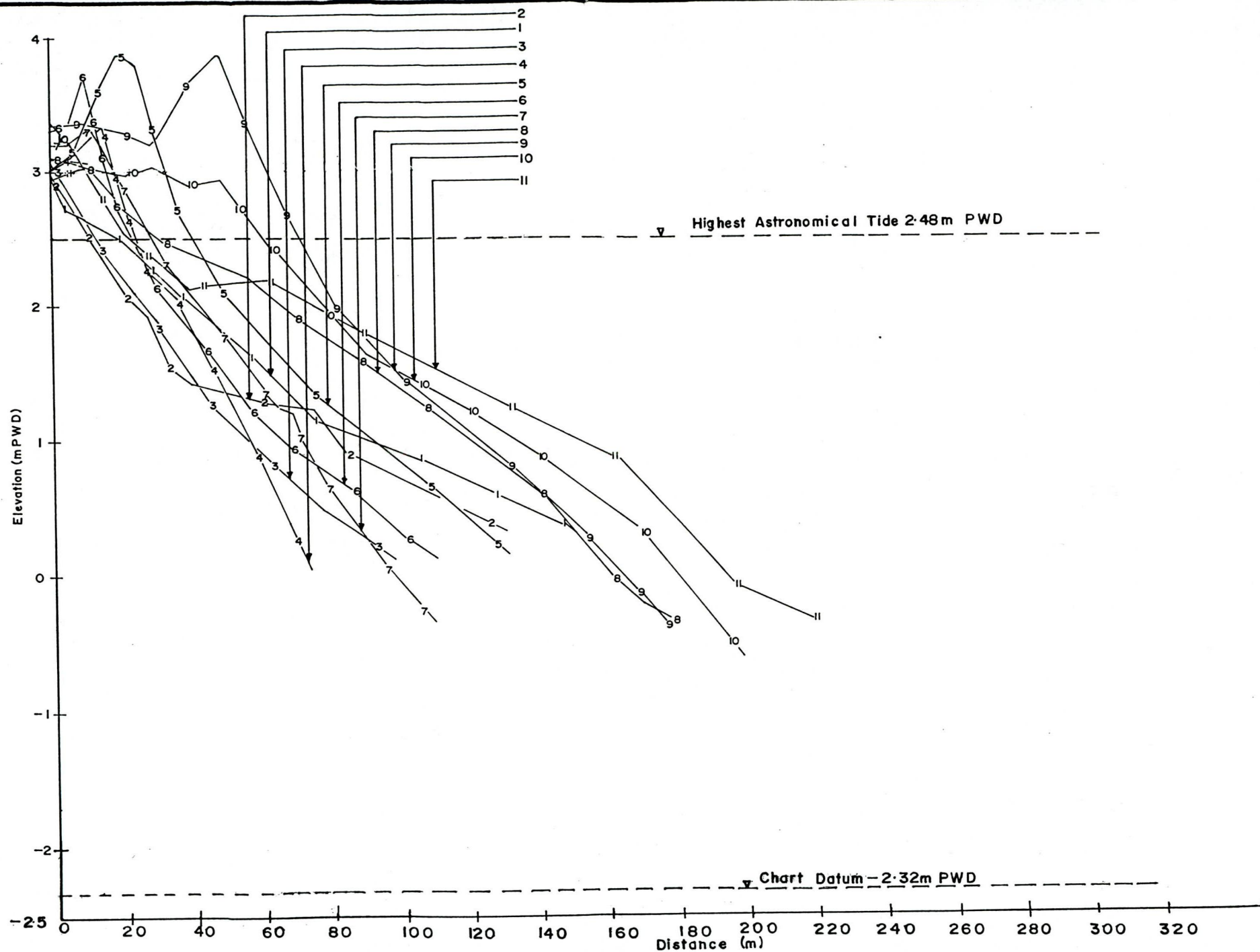


Figure 4-13 Combined Diagram of the Cross-Profiles of the Sampling Stations

As found in the analysis of Longitudinal profile in Figure 4.12, the elevation of the beach is the highest at Station no. 5 at ch. 8.00 km, whereas the beach is at the lowest elevation at Station no. 1 (ch. 0.00 km), Station no. 2 at ch. 2.00 km has the second lowest elevation.

4.4 PARTICLE SIZE DISTRIBUTION : OVERALL VARIATION

Figures no. 3.6 through 3.40 presented in Chapter 3, show the gradation curves (particle size distribution) of the collected soil samples. Table 4.2 and 4.3 have been prepared from those curves to show d_{10} , d_{30} , d_{50} , d_{60} and d_{90} (% finer) sizes of the samples. From Table 4.2 it can be seen that the mean particle sizes (d_{50}) of the beach sand at the surface varies between 0.14 mm and 0.214 mm (2.84 phi and 2.22 phi), at 0.6 m depth varies between 0.163 mm and 0.213 mm (2.62 phi and 2.23 phi) and at 1.0 m depth between 0.132 mm and 0.214 mm (2.92 phi and 2.22 phi). The average particle mean diameter (d_{50}) at the surface, at 0.6 m depth and at 1.0 m depth all through the whole beach can be considered around 0.20 mm (Figures 4.14 through 4.16). The particle diameters at 10% finer varies between 0.075 mm and 0.163 mm, at 30% finer between 0.10 mm and 0.188 mm, at 60% finer between 0.141 mm and 0.25 mm and at 90% finer between 0.232 mm and 0.90 mm as shown in Table 4.3. Table 4.3 also presents the uniformity coefficient of the soil samples which varies between 1.40 and 2.61 for the surface samples, between 1.35 and 2.67 for the samples at 0.6 m depth and between 1.39 and 3.33 for the samples at 1.0 m depth. The beach sands, therefore, are poorly graded with uniformity coefficient (d_{60}/d_{10}) varying between 1.35 and 3.33.

Table 4.4 shows the percentage of silt, clay, fine sand, medium sand, coarse sand and snails at different stations. From this table it is seen that the percentage of medium sand (0.425 mm to 2.00 mm) varies between 0.25 and 28.0 percent through the whole study area. Medium sands are almost absent at Stations no. 6 & 10 (ch. 10.00 km & ch. 18.00 km). Fine sands (0.075 mm to 0.425 mm) are mostly abundant in the study area and varies between 63.38% to 99.73%.

A percentage of silt and clay (<0.075 mm), varying between 0.02 to 10 percent are present in the soil samples of the beach. No shingles and gravels are found throughout the beach.

The variation of particle mean diameter (d_{50}) at the surface, at 0.6m depth and at 1.0m depth across the beach at different stations are shown in Figure 4.17.

$$\begin{aligned} 1 \text{ Phi units} &= -\text{Log}_2 d \text{ (mm)} \\ &= -\text{Log}_2 e \times \log_e d \\ &= -1/(\text{Log}_e 2) \times \log_e d \end{aligned}$$

For example, $d_{50} = 0.14$ mm

$$\therefore \text{Phi units} = -1/(\text{Log}_e 2) \times \log_e(0.14) = (-1.442) \times (-1.966) = 2.84$$

Table 4.2
PARTICLE SIZE DIAMETER OF DIFFERENT SAMPLES

Station No.	Lat/Long	Location	Mean Particle Size. Diameter in mm and phi units								
			Surface Sample			0.6m below Surface			1.0m below Surface		
			d ₅₀	Dia (phi)	Sam. No.	d ₅₀	Dia (phi)	Sam. No.	d ₅₀	Dia (phi)	Sam. No.
1	21°50.99'E/ 90°5.10'N	Location 3	0.20	2.32	S1-3-1	0.20	2.32	S1-3-2	0.20	2.32	S1-3-3
		Location 2	0.20	2.32	S1-2-1	0.209	2.26	S1-2-2	0.207	2.27	S1-2-3
		Location 1	0.214	2.22	S1-1-1	0.213	2.23	S1-1-2	0.214	2.22	S1-1-3
2	21°49.95'E/ 90°5.49'N	Location 3	0.20	2.32	S2-3-1	0.20	2.32	S2-3-2	0.209	2.26	S2-3-3
		Location 2	0.209	2.26	S2-2-1	0.20	2.32	S2-2-2	0.20	2.32	S2-2-3
		Location 1	0.20	2.32	S2-1-1	0.20	2.32	S2-1-2	0.20	2.32	S2-1-3
3	21°49.14'E/ 90°6.41'N	Location 3	0.20	2.32	S3-3-1	0.209	2.26	S3-3-2	0.20	2.32	S3-3-3
		Location 2	0.20	2.32	S3-2-1	0.20	2.32	S3-2-2	0.205	2.29	S3-2-3
		Location 1	0.20	2.32	S3-1-1	0.20	2.32	S3-1-2	0.20	2.32	S3-1-3
4	21°48.65'E/ 90°7.57'N	Location 3	0.20	2.32	S4-3-1	0.20	2.32	S4-3-2	0.209	2.26	S4-3-3
		Location 2	0.209	2.26	S4-2-1	0.188	2.41	S4-2-2	0.187	2.42	S4-2-3
		Location 1	0.20	2.32	S4-1-1	0.194	2.37	S4-1-2	0.20	2.32	S4-1-3
5	21°48.31'E/ 90°8.70'N	Location 3	0.20	2.32	S5-3-1	0.181	2.47	S5-3-2	0.20	2.32	S5-3-3
		Location 2	0.194	2.37	S5-2-1	0.20	2.32	S5-2-2	0.209	2.26	S5-2-3
		Location 1	0.209	2.26	S5-1-1	0.20	2.32	S5-1-2	0.163	2.62	S5-1-3
6	21°48.09'E/ 90°9.90'N	Location 3	0.20	2.32	S6-3-1	0.209	2.26	S6-3-2	0.20	2.32	S6-3-3
		Location 2	0.14	2.84	S6-2-1	0.20	2.32	S6-2-2	0.181	2.47	S6-2-3
		Location 1	0.20	2.32	S6-1-1	0.194	2.37	S6-1-2	0.175	2.51	S6-1-3
7	21°47.98'E/ 90°11.00'N	Location 3	0.188	2.41	S7-3-1	0.181	2.47	S7-3-2	0.209	2.26	S7-3-3
		Location 2	0.20	2.32	S7-2-1	0.20	2.32	S7-2-2	0.20	2.32	S7-2-3
		Location 1	0.194	2.37	S7-1-1	0.20	2.32	S7-1-2	0.181	2.47	S7-1-3
8	21°48.15'E/ 90°12.15'N	Location 3	0.20	2.32	S8-3-1	0.20	2.32	S8-3-2	0.181	2.47	S8-3-3
		Location 2	0.181	2.47	S8-2-1	0.197	2.34	S8-2-2	0.20	2.32	S8-2-3
		Location 1	0.20	2.32	S8-1-1	0.188	2.41	S8-1-2	0.188	2.41	S8-1-3
9	21°48.62'E/ 90°13.17'N	Location 3	0.194	2.37	S9-3-1	0.194	2.37	S9-3-2	0.132	2.92	S9-3-3
		Location 2	0.20	2.32	S9-2-1	0.19	2.40	S9-2-2	0.188	2.41	S9-2-3
		Location 1	0.194	2.37	S9-1-1	0.163	2.62	S9-1-2	0.181	2.47	S9-1-3
10	21°49.35'E/ 90°14.00'N	Location 3	0.20	2.32	S10-3-1	0.175	2.51	S10-3-2	0.194	2.37	S10-3-3
		Location 2	0.175	2.51	S10-2-1	0.194	2.37	S10-2-2	0.191	2.39	S10-2-3
		Location 1	0.194	2.37	S10-1-1	0.163	2.62	S10-1-3	0.20	2.32	S10-1-3
11	21°49.97'E/ 90°14.59'N	Location 3	0.20	2.32	S11-3-1	0.188	2.41	S11-3-2	0.20	2.32	S11-3-3
		Location 2	0.141	2.83	S11-2-1	0.20	2.32	S11-2-2	0.132	2.92	S11-2-3
		Location 1	0.194	2.37	S11-1-1	0.175	2.51	S11-1-2	0.20	2.32	S11-1-3

Table 4.2 (Contd.)
Bed and Bank Samples at River Confluences

Sample No.	Mean dia (phi units)	Mean dia (mm)	Remarks
I.S.S.-1	2.32	0.20	Bed sample from Nilgonj River near confluence
I.S.S.-2	2.47	0.181	Sample form Left Bank of Nilgonj river near confluence
I.S.S.-3	2.47	0.181	Bed sample from Nilgonj River 500m away to the north of confluence
I.S.S.-4	2.26	0.209	Sample from Left Bank of Nilgonj River 500m away to the north of confluence
I.S.S.-5	2.41	0.188	Bed sample from Gangamati Khal near confluence
I.S.S.-6	2.32	0.20	Sample from Right Bank of Gangamati Khal near confluence

Table 4.3
GRADING PARAMETERS

Sample Location	Station No.	Sample No.	D10	D30	D50	D60	D90	Cu
Surface Sample	1	S1-1-1	0.163	0.188	0.214	0.233	0.267	1.43
		S1-2-1	0.15	0.181	0.20	0.217	0.273	1.45
		S1-3-1	0.114	0.169	0.20	0.214	0.271	1.88
	2	S2-1-1	0.095	0.169	0.20	0.218	0.282	2.29
		S2-2-1	0.159	0.188	0.209	0.227	0.282	1.43
		S2-3-1	0.143	0.181	0.20	0.218	0.273	1.52
	3	S3-1-1	0.114	0.169	0.20	0.209	0.273	1.83
		S3-2-1	0.127	0.175	0.20	0.214	0.273	1.69
		S3-3-1	0.143	0.181	0.20	0.218	0.268	1.52
	4	S4-1-1	0.125	0.175	0.20	0.214	0.273	1.71
		S4-2-1	0.15	0.181	0.209	0.218	0.273	1.45
		S4-3-1	0.132	0.175	0.20	0.218	0.273	1.65
	5	S5-1-1	0.15	0.181	0.209	0.218	0.273	1.45
		S5-2-1	0.09	0.163	0.194	0.209	0.264	2.32
		S5-3-1	0.10	0.169	0.20	0.209	0.268	2.09
	6	S6-1-1	0.132	0.175	0.20	0.214	0.268	1.62
		S6-2-1	0.08	0.105	0.14	0.156	0.245	1.95
		S6-3-1	0.141	0.175	0.20	0.218	0.273	1.55
	7	S7-1-1	0.08	0.163	0.194	0.209	0.291	2.61
		S7-2-1	0.156	0.188	0.20	0.218	0.282	1.40
		S7-3-1	0.085	0.15	0.181	0.20	0.264	2.35
	8	S8-1-1	0.141	0.181	0.20	0.218	0.282	1.55
		S8-2-1	0.09	0.15	0.181	0.20	0.264	2.22
		S8-3-1	0.114	0.169	0.20	0.218	0.264	1.91
	9	S9-1-1	0.10	0.163	0.194	0.209	0.273	2.09
		S9-2-1	0.114	0.169	0.20	0.214	0.273	1.88
		S9-3-1	0.085	0.163	0.194	0.209	0.268	2.46
	10	S10-1-1	0.08	0.15	0.194	0.20	0.264	2.50
		S10-2-1	0.08	0.132	0.175	0.191	0.264	2.39
		S10-3-1	0.095	0.169	0.20	0.209	0.273	2.20
	11	S11-1-1	0.08	0.163	0.194	0.209	0.273	2.61
		S11-2-1	0.08	0.105	0.141	0.163	0.25	2.04
		S11-3-1	0.114	0.172	0.20	0.209	0.273	1.83

D10 – Particle diameter at 10% Finer

D30 – Particle diameter at 30% Finer

D50 – Particle diameter at 50% Finer

D60 – Particle diameter at 60% Finer

Cu = Uniformity Co-efficient = D_{60}/D_{10}

**Table 4.3 (Contd.)
GRADING PARAMETERS**

Sample Location	Station No.	Sample at Depth (0.6m)						Sample No.	D10	D30	D50	D60	D90	Cu
1	2	S2-1-2	0.10	0.169	0.20	0.218	0.286	2.18						
		S2-2-2	0.12	0.175	0.20	0.218	0.29	1.82						
		S2-3-2	0.11	0.175	0.20	0.209	0.273	1.90						
	3	S3-1-2	0.095	0.163	0.20	0.209	0.264	2.20						
		S3-2-2	0.132	0.175	0.20	0.214	0.264	1.62						
		S3-3-2	0.15	0.188	0.209	0.218	0.263	1.45						
	4	S4-1-2	0.095	0.163	0.194	0.209	0.273	1.28						
		S4-2-2	0.08	0.136	0.188	0.20	0.30	2.50						
		S4-3-2	0.132	0.175	0.20	0.214	0.264	1.62						
	5	S5-1-2	0.10	0.163	0.20	0.218	0.282	2.18						
		S5-2-2	0.132	0.175	0.20	0.218	0.273	1.65						
		S5-3-2	0.085	0.141	0.181	0.20	0.264	2.35						
6	6	S6-1-2	0.085	0.163	0.194	0.209	0.264	2.46						
		S6-2-2	0.132	0.175	0.20	0.218	0.273	1.65						
		S6-3-2	0.156	0.188	0.209	0.218	0.273	1.40						
	7	S7-1-2	0.118	0.169	0.20	0.218	0.273	1.85						
		S7-2-2	0.141	0.175	0.20	0.218	0.273	1.55						
		S7-3-2	0.085	0.143	0.181	0.20	0.264	2.35						
	8	S8-1-2	0.08	0.15	0.188	0.20	0.273	2.50						
		S8-2-2	0.105	0.163	0.197	0.209	0.273	1.99						
		S8-3-2	0.127	0.169	0.20	0.209	0.273	1.65						
	9	S9-1-2	0.075	0.114	0.163	0.188	0.268	2.51						
		S9-2-2	0.09	0.156	0.190	0.20	0.264	2.22						
		S9-3-2	0.08	0.15	0.194	0.20	0.264	2.50						
10	10	S10-1-2	0.075	0.123	0.163	0.188	0.259	2.51						
		S10-2-2	0.08	0.15	0.194	0.20	0.273	2.50						
		S10-3-2	0.083	0.132	0.175	0.194	0.264	2.34						
	11	S11-1-2	0.075	0.136	0.175	0.20	0.273	2.67						
		S11-2-2	0.09	0.166	0.20	0.218	0.273	2.42						
		S11-3-2	0.085	0.145	0.188	0.20	0.264	2.35						

D10 - Particle diameter at 10% Finer
D30 - Particle diameter at 30% Finer
D50 - Particle diameter at 50% Finer
D60 - Particle diameter at 60% Finer

Cu = Uniformity Co-efficient = D60/D10

Table 4.3 (Contd.)
GRADING PARAMETERS

Sample Location	Station No.	Sample No.	D10	D30	D50	D60	D90	Cu
Sample at 1.0m Depth	1	S1-1-3	0.15	0.188	0.214	0.243	0.30	1.62
		S1-2-3	0.156	0.188	0.207	0.225	0.279	1.44
		S1-3-3	0.105	0.175	0.20	0.209	0.264	1.99
	2	S2-1-3	0.10	0.169	0.20	0.209	0.282	2.09
		S2-2-3	0.143	0.181	0.20	0.218	0.282	1.52
		S2-3-3	0.156	0.188	0.20	0.218	0.282	1.40
	3	S3-1-3	0.15	0.181	0.20	0.218	0.273	1.45
		S3-2-3	0.155	0.188	0.205	0.218	0.273	1.41
		S3-3-3	0.127	0.175	0.20	0.209	0.268	1.65
	4	S4-1-3	0.10	0.169	0.20	0.209	0.268	2.09
		S4-2-3	0.075	0.132	0.187	0.209	0.40	2.79
		S4-3-3	0.156	0.181	0.209	0.218	0.273	1.40
	5	S5-1-3	0.075	0.114	0.163	0.188	0.282	2.51
		S5-2-3	0.163	0.188	0.209	0.227	0.273	1.39
		S5-3-3	0.13	0.114	0.20	0.214	0.273	1.65
	6	S6-1-3	0.08	0.175	0.175	0.194	0.264	2.43
		S6-2-3	0.085	0.15	0.181	0.20	0.264	2.35
		S6-3-3	0.15	0.181	0.20	0.218	0.273	1.45
	7	S7-1-3	0.075	0.114	0.181	0.25	0.90	3.33
		S7-2-3	0.132	0.175	0.20	0.214	0.273	1.62
		S7-3-3	0.15	0.181	0.209	0.218	0.273	1.45
	8	S8-1-3	0.075	0.15	0.188	0.20	0.264	2.67
		S8-2-3	0.105	0.169	0.20	0.209	0.273	1.99
		S8-3-3	0.09	0.141	0.181	0.20	0.264	2.22
	9	S9-1-3	0.075	0.15	0.181	0.20	0.264	2.67
		S9-2-3	0.09	0.15	0.188	0.20	0.264	2.22
		S9-3-3	0.08	0.15	0.132	0.141	0.232	1.76
	10	S10-1-3	0.10	0.169	0.20	0.209	0.282	2.09
		S10-2-3	0.09	0.159	0.191	0.209	0.273	2.32
		S10-3-3	0.09	0.163	0.194	0.209	0.268	2.32
	11	S11-1-3	0.141	0.181	0.20	0.218	0.282	1.55
		S11-2-3	0.08	0.10	0.132	0.15	0.25	1.88
		S11-3-3	0.114	0.175	0.20	0.218	0.273	1.91
River bed and bank soil samples		LS.S.-1	0.123	0.175	0.20	0.209	0.273	1.70
		LS.S.-2	0.09	0.145	0.181	0.15	0.264	2.22
		LS.S.-3	0.095	0.15	0.181	0.20	0.264	2.10
		LS.S.-4	0.56	0.188	0.209	0.218	0.273	1.40
		LS.S.-5	0.10	0.156	0.188	0.20	0.273	2.00
		LS.S.-6	0.132	0.175	0.20	0.218	0.282	1.65

D10 - Particle diameter at 10% Finer
 D30 - Particle diameter at 30% Finer
 D50 - Particle diameter at 50% Finer
 D60 - Particle diameter at 60% Finer
 Cu - Uniformity Co-efficient = D60/D10

Table 4.4
ASTM CLASSIFICATION OF SOIL

Sieve no.	>> 4	10	40	200	200 <<	
Dia in mm	>> 4.75	2	0.425	0.075	0.075 <<	
Classification	Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines (Silt & Clay)	
Station No.	Sample No.	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines (Silt & Clay)	% Snails
1	S1-1-1	0	0.25	99.53	0.22	0
	S1-1-2	0	1.75	95.31	2.94	0
	S1-1-3	0	8	90.74	1.26	0
	S1-2-1	0	0.5	98.3	1.2	0
	S1-2-2	0	0.25	98.65	1.1	0
	S1-2-3	0	3	96.36	0.64	0
	S1-3-1	0	0	94.24	5.76	0
	S1-3-2	0	4.5	87.78	7.72	0
2	S2-1-1	0	4	88.2	7.8	0
	S2-1-2	0	3.5	90	6.5	0
	S2-1-3	0	4	90.35	5.65	0
	S2-2-1	0	0.75	98.81	0.44	0
	S2-2-2	0	3	91.5	5.5	0
	S2-2-3	0	4	89.04	6.96	0
	S2-3-1	0	0.25	97.33	2.42	0
	S2-3-2	0	0.5	94.24	5.26	0
3	S3-1-1	0	0.25	95.41	4.34	0
	S3-1-2	0	0	93.5	6.5	0
	S3-1-3	0	0	98.3	1.7	0
	S3-2-1	0	0	95.86	4.14	0
	S3-2-2	0	0.25	96.33	3.42	0
	S3-2-3	0	0.25	99.73	0.02	0
	S3-3-1	0	0	97.16	2.84	0
	S3-3-2	0	0	98.98	1.02	0
4	S4-1-1	0	0	97.48	2.52	0
	S4-1-2	0	0	94.2	5.8	0
	S4-1-3	0	0	94.12	5.88	0
	S4-2-1	0	0.25	97.05	2.7	0
	S4-2-2	0	7	85	8	0
	S4-2-3	0	10	80	10	0
	S4-3-1	0	0.35	96.79	2.86	0
	S4-3-2	0	0.25	97.15	2.6	0
5	S5-1-1	0	0.25	98.59	1.16	0
	S5-1-2	0	3	91.7	5.3	0
	S5-1-3	0	6	84	10	0
	S5-2-1	0	0	92.96	7.04	0
	S5-2-2	0	0	95.3	4.7	0
	S5-2-3	0	0	99.68	0.32	0
	S5-3-1	0	0	93.1	6.9	0
	S5-3-2	0	0	94.48	5.52	0
6	S6-1-1	0	0	96.98	3.02	0
	S6-1-2	0	0	91.82	8.18	0
	S6-1-3	0	0	93.62	6.38	0
	S6-2-1	0	0	95.26	4.74	0
	S6-2-2	0	0	94.94	5.06	0
	S6-2-3	0	0	93.98	6.02	0
	S6-3-1	0	0	96.88	3.12	0
	S6-3-2	0	0	98.74	1.26	0

Sieve no.	>> 4	10	40	200	200 <<
Dia in mm	>> 4.75	2	0.425	0.075	0.075 <<
Classification	Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines (Silt & Clay)

Station No.	Sample No.	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines (Silt & Clay)	% Snails
7	S7-1-1	0	5	86.7	8.3	0
	S7-1-2	0	1.75	94.51	3.74	0
	S7-1-3	0	28	63.38	8.62	0
	S7-2-1	0	0	98.2	1.8	0
	S7-2-2	0	0	97.46	2.54	0
	S7-2-3	0	0.25	95.75	4	0
	S7-3-1	0	0	95.22	4.78	0
	S7-3-2	0	0	94.76	5.24	0
	S7-3-3	0	0.75	98.03	1.22	0
8	S8-1-1	0	0	97.92	2.08	0
	S8-1-2	0	0	92.22	7.78	0
	S8-1-3	0	0	91.76	8.24	0
	S8-2-1	0	0.25	95.51	4.24	0
	S8-2-2	0	0	96.18	3.82	0
	S8-2-3	0	0	95.34	4.66	0
	S8-3-1	0	0	96	4	0
	S8-3-2	0	0	95.96	4.04	0
	S8-3-3	0	0	96.34	3.66	0
9	S9-1-1	0	0	95.8	4.2	0
	S9-1-2	0	1	89	10	0
	S9-1-3	0	0	90.5	9.5	0
	S9-2-1	0	0	94.8	5.2	0
	S9-2-2	0	0	94.3	5.7	0
	S9-2-3	0	0	95.76	4.24	0
	S9-3-1	0	0	92.28	7.72	0
	S9-3-2	0	0	90.8	9.2	0
	S9-3-3	0	0	94.34	5.66	0
10	S10-1-1	0	0	92.3	7.7	0
	S10-1-2	0	0	90.84	9.16	0
	S10-1-3	0	0	94.36	5.64	0
	S10-2-1	0	0	94.1	5.9	0
	S10-2-2	0	0	92.12	7.88	0
	S10-2-3	0	0	93.72	6.28	0
	S10-3-1	0	0	93.26	6.74	0
	S10-3-2	0	0	94.68	5.32	0
	S10-3-3	0	0	92.94	7.06	0
11	S11-1-1	0	0.5	91.12	8.38	0
	S11-1-2	0	0.5	90.72	8.78	0
	S11-1-3	0	0.5	95.32	4.18	0
	S11-2-1	0	0.25	94.53	5.22	0
	S11-2-2	0	2	90.66	7.34	0
	S11-2-3	0	1.5	94.66	3.84	0
	S11-3-1	0	0	95.42	4.58	0
	S11-3-2	0	0	95.34	4.66	0
	S11-3-3	0	0.5	94.84	4.66	0
River bed and bank soil samples	I.S.S.-1	0	0	95.94	4.06	0
	I.S.S.-2	0	0	96.12	3.88	0
	I.S.S.-3	0	0.06	99.94	0	0
	I.S.S.-4	0	0.4	99.26	0.34	0
	I.S.S.-5	0	0.08	98.78	1.14	0
	I.S.S.-6	0	0.16	98.06	1.78	0

Ref: Ralph B. Peck, Walter E. Hanson, Thomas H. Thornburn, 1973. "Foundation Engineering, 2nd Edition, Table 1.1".

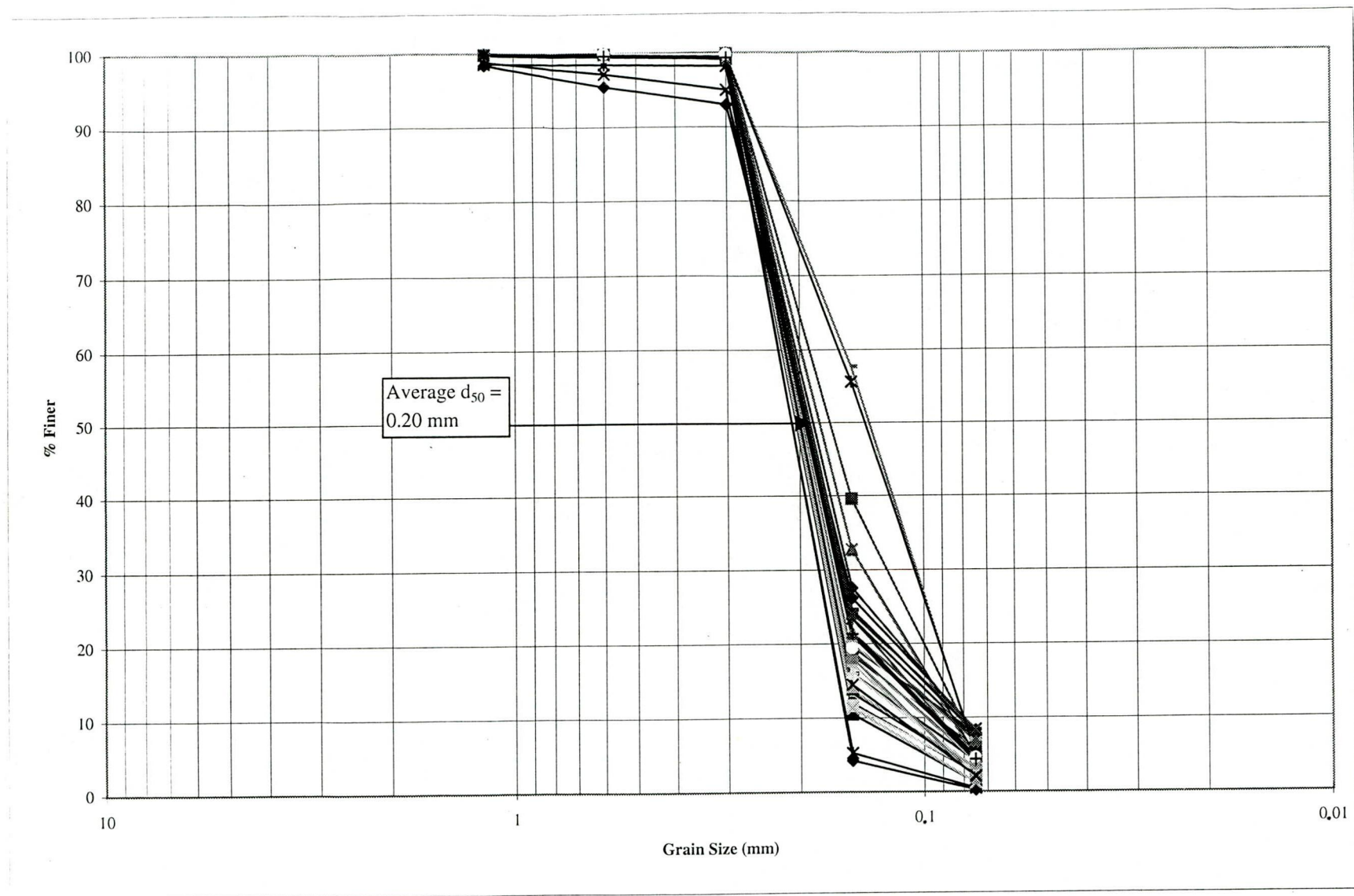


Figure 4.14 : Combined Grain Size Distribution Curve for Surface Samples

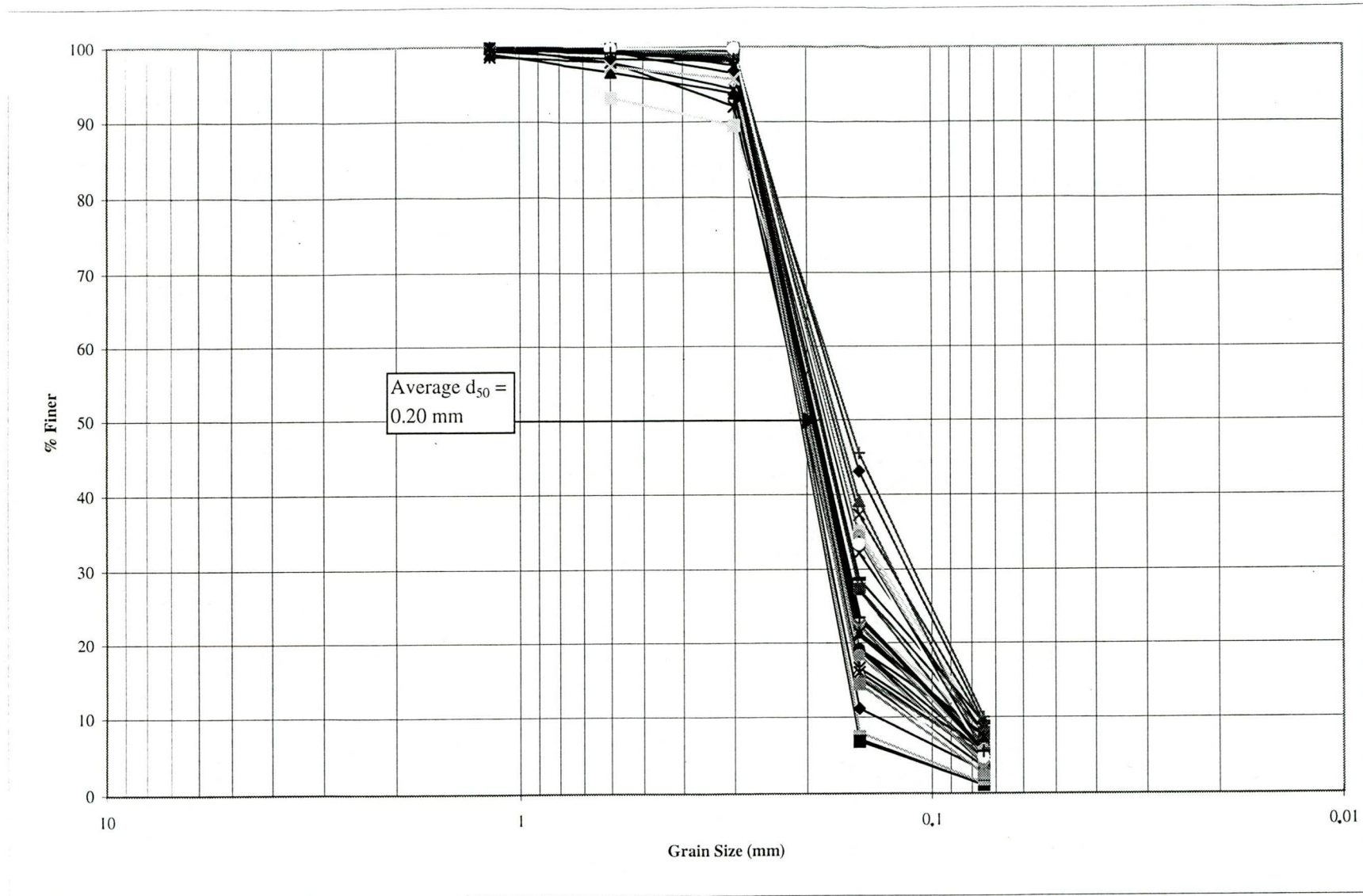


Figure 4.15 : Combined Grain Size Distribution Curve for Samples at Depth 0.6 m from the Surface

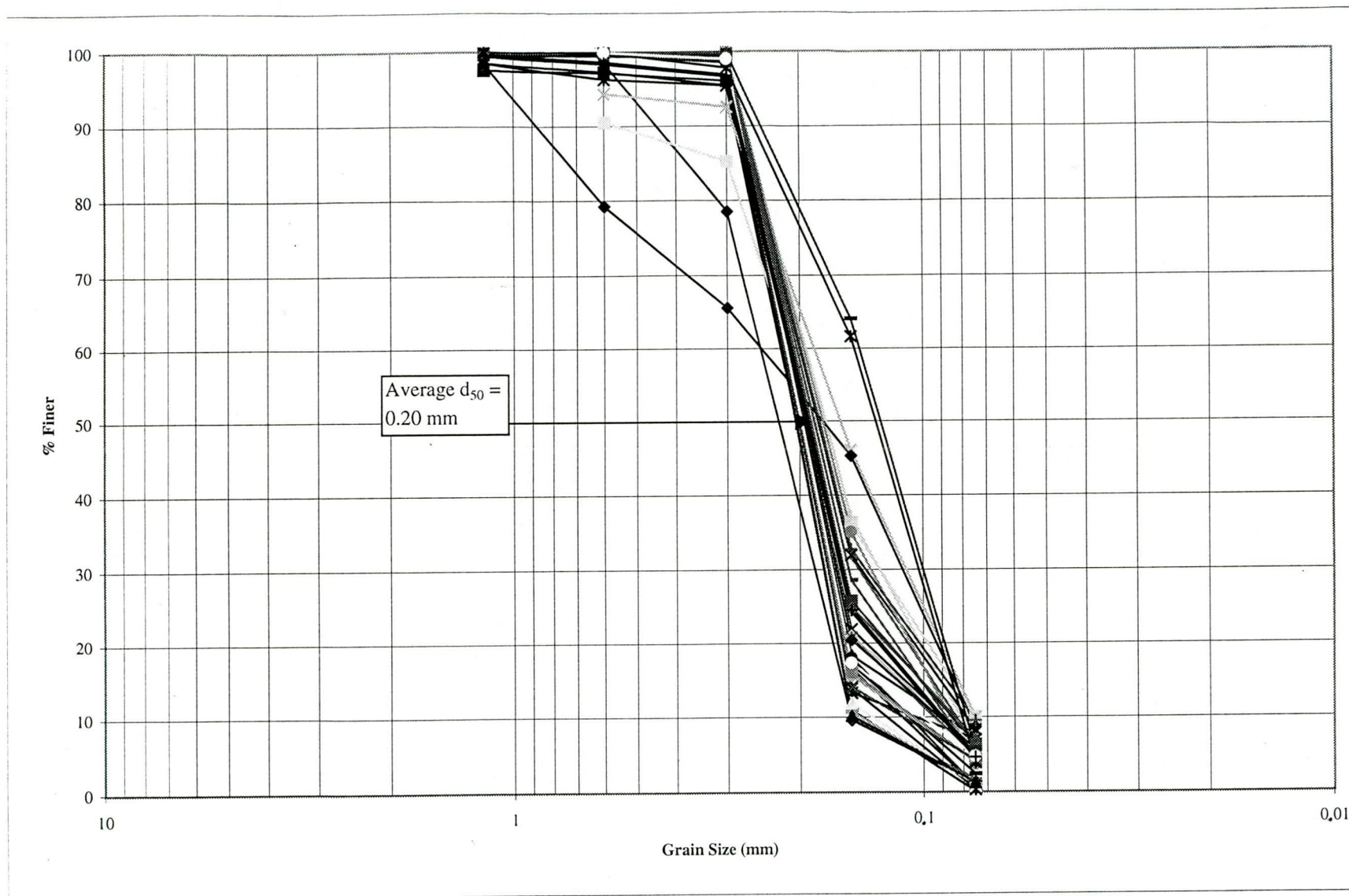


Figure 4.16 : Combined Grain Size Distribution Curve for Samples at Depth 1.0 m from the Surface

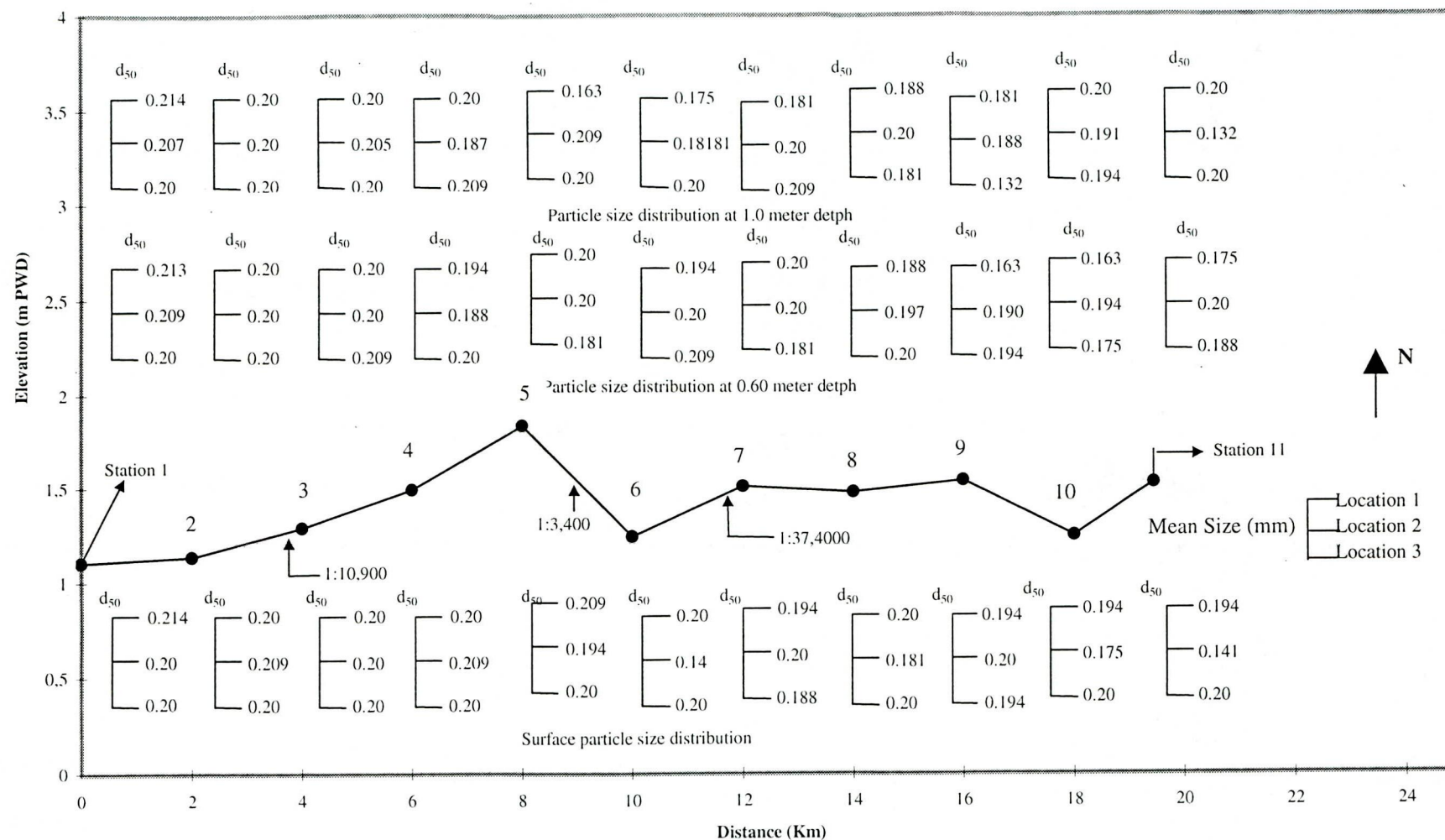


Figure 4.17 : Variation of Mean Diameter across the Beach at different stations

4.4.1 Particle size distribution at the bed and bank samples of the Nilgonj River and Gangamati Khal

The particle mean diameter (d_{50}) of the bed sample at the out-fall (confluence) of Nilgonj River is 0.20 mm whereas the particle mean diameter (d_{50}) of bank material is about 0.181 mm. At about 500m upstream from the confluence these values are 0.181 mm and 0.209 mm respectively as shown in Figure 4.18. The particle mean diameter of the bed and bank samples at the out fall (confluence) of Gangamati Khal is 0.188mm and 0.20mm respectively.

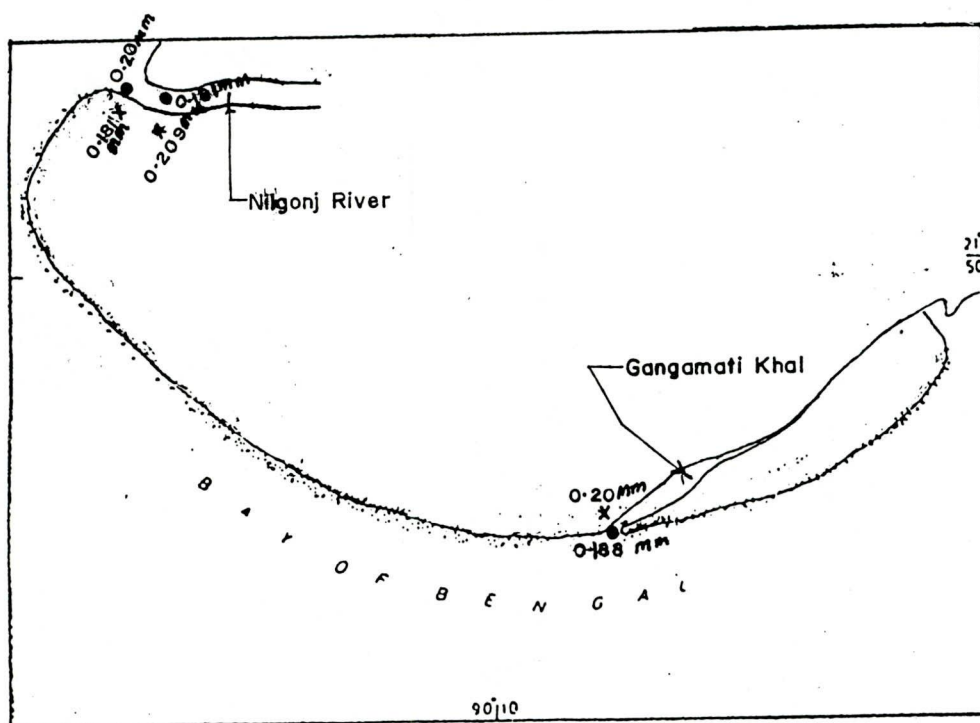


Figure 4.18 Mean Diameter of Soil Samples from the Bed and Bank of Nilgonj River and Gangamati Khal confluences

4.5 PARTICLE SIZE DISTRIBUTION ALONG THE FORESHORE

4.5.1 Surface particle size distribution

From Figure 4.19 it is seen that the surface particle mean diameter (d_{50}) in between Stations 1 and 5 (Ch. 0.00 km to Ch. 8.00 km) varies between 0.20 mm and 0.205 mm i.e. almost the same. But it abruptly decreases from 0.202 mm to 0.18 mm at Station 6 (Ch. 10.00 km). Then it increases from 0.18 mm to 0.194 mm at Station 7 (Ch. 12.00 km) and in between Stations 7 and 10 (Ch. 12.00 km to Ch. 18.00 km) it remains more or less the same (0.19 mm to 0.197 mm). But at station 11 (Ch. 19.45 km) it decreases from 0.19 mm to 0.178 mm. So the surface particle mean diameter is highest at station 1 (0.205 mm) and lowest at station 11 (0.178 mm).

4.5.2 Particle size distribution at 0.6m depth

Figure 4.19 shows the variation of the particle mean diameter (d_{50}) at 0.6m depth in the foreshore zone along the beach. The figure shows that the particle mean diameter varies between Stations 1 and 8 (Chainage 0.00 km to Ch. 14.00 km) between 0.194 mm and 0.207 mm in which it remains the same at Stations 2 and 5 (0.20 mm) and at stations 4 and 7 (0.194 mm). At Station 9 it decreases from 0.195 mm to 0.177 mm and it remains the same at station 10. At station 11 it increases from 0.177 mm to 0.188 mm. So the particle mean diameter (d_{50}) is highest at station 1 (0.207 mm) and lowest at stations 9 and 10 (0.177 mm).

4.5.3 Particle size distribution at 1.0m depth

Figure 4.19 shows the variation of the particle mean diameter (d_{50}) at 1.0m depth in the foreshore zone along the beach. The figure shows that the particle mean diameter varies between Stations 1 and 4 (Ch. 0.00 km to Ch. 6.00 km) between 0.199 mm and 0.207 mm. At Station 5 it decreases from 0.199 mm to 0.186 mm and at Station 6 it is more or less the same (0.185 mm). In between Stations 6 and 11 it varies between 0.177 mm and 0.197 mm. The particle mean diameter is highest at Station 1 and lowest at Station 11 like surface particle distribution.

4.6 PARTICLE SIZE DISTRIBUTION ACROSS THE BEACH

Close look to Table 4.2 and Figure 4.17 shows that there is no trend of variation of surface particle sizes across the beach profile and the mean diameter (d_{50}) can be considered around 0.20 mm all through the beach. The trend is same both at 0.6m and 1.0m depth from the surface. However, a trend of decrease of particle size from western side towards eastern side is noticeable, i.e. in the western side, the particle size is slightly coarser than the eastern side. This may be due to supply of fine sand from sea by wind action from south-west direction.

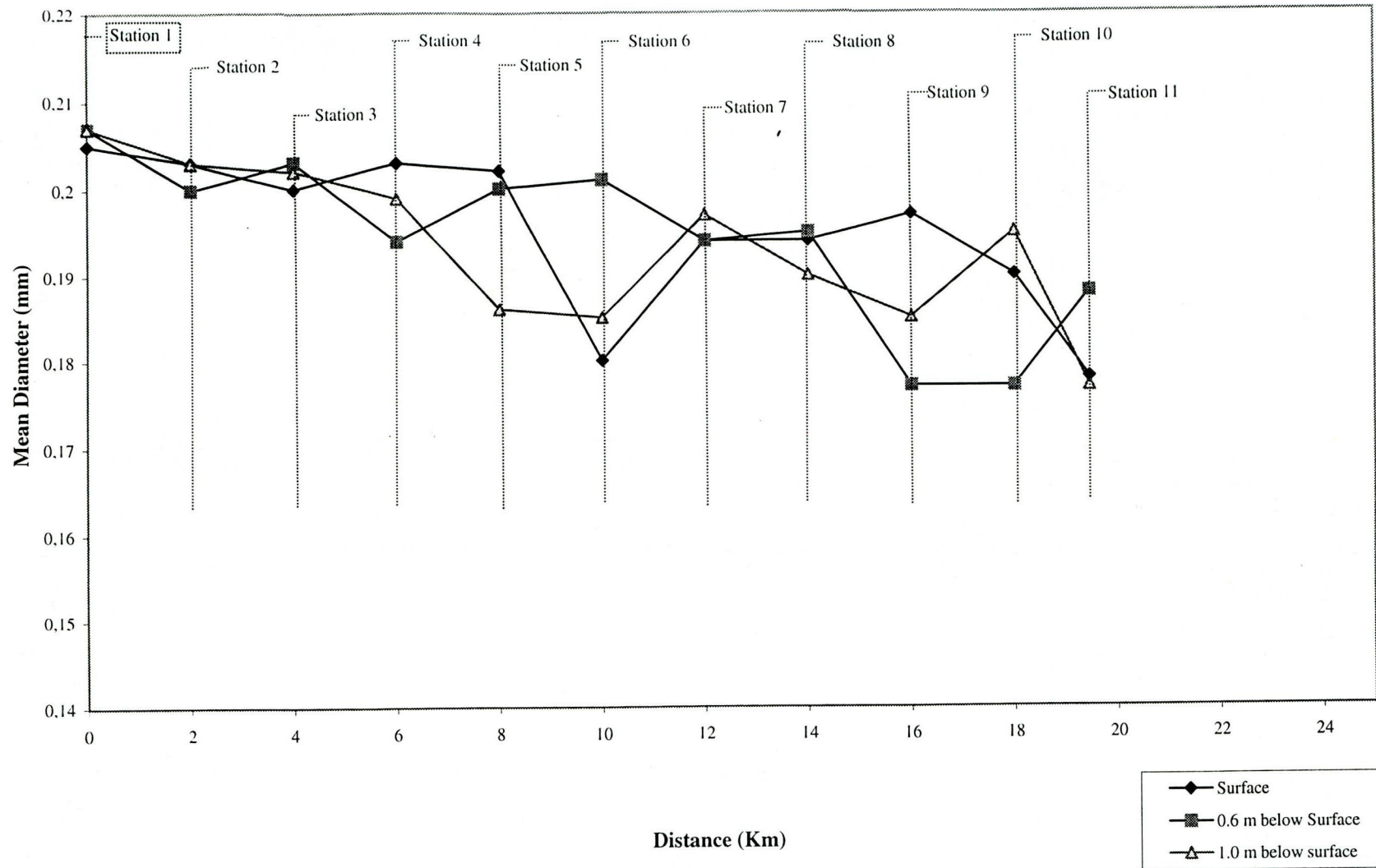


Figure 4.19 : Variation of Particle Mean Diameter along the Foreshore Zone of the Beach

4.7 WAVE BREAKING PHENOMENON AT THE SHORE LINE

1st field observations and data collection programme revealed that waves are almost non existing at low tide condition. The waves start growing during rising tide and attains maximum height at extreme high tide. Since the 1st field visit was made during neap tide condition of the sea, the 2nd field visit and data collection programme was made between 25th and 29th September 1999 two days after moon when the sea was at extreme spring tide condition to get an idea of the representative of maximum wave condition. It attains its maximum height at a distance very close to the shore (approximately 100m away from water line). It then breaks with foam developing at the crest. The layer of foam of the breaking waves then move about 50m towards shore before reflecting back to the sea side i.e the run-up is about 50 m along the beach. Most of the wave energy are dissipated during its up-rush towards the beach and very little reflection of momentum back towards the sea.

During this second time investigation the visual observation of wave conditions were made for a full tide cycle. Since measurement of wave parameters are very costly and also beyond the scope of the study, visual observation and photographic techniques were adopted to have an preliminary idea of the wave breaking phenomena. To get an approximate idea of wave height graduated bamboo pool was used just prior to wave breaking by manual method. Photographs 20, 21, 22, 23, 24 and 25 show wave phenomena at various stages of the tide cycle.

Based on above technique the maximum wave height was guessed around 4m during high tide condition. The wind during that period was blowing at normal condition, speed varying below 9 km/hr. These waves were approaching the coast at an interval of approximately 15 seconds to 20 seconds.

The wave braking phenomenon have then been analyzed by the method suggested by Battjes (1974), WW Massie (1986) and Galvin (1972) are shown in Appendix. The analysis shows that the wave breaking phenomenon is of spilling type. Figure 4.20 shows the general character of Spilling Breakers.



Photo 20: Wave breaking during high tide in between Stations 1 and 2



Photo 21: Wave breaking during high tide in between Stations 3 and 4



Photo 22: Wave breaking during rising tide near Station 4 at Chainage 6.00 km



Photo 23: Wave breaking and wave run-up during rising tide near Station 3 at Chainage 4.00 km



Photo 24: Wave breaking during high tide near Stations 3 at Chainage 4.00 km



Photo 25: Wave breaking and wave run-up during rising tide near LGED Rest House at Kuakata (Chainage 4.50 km)

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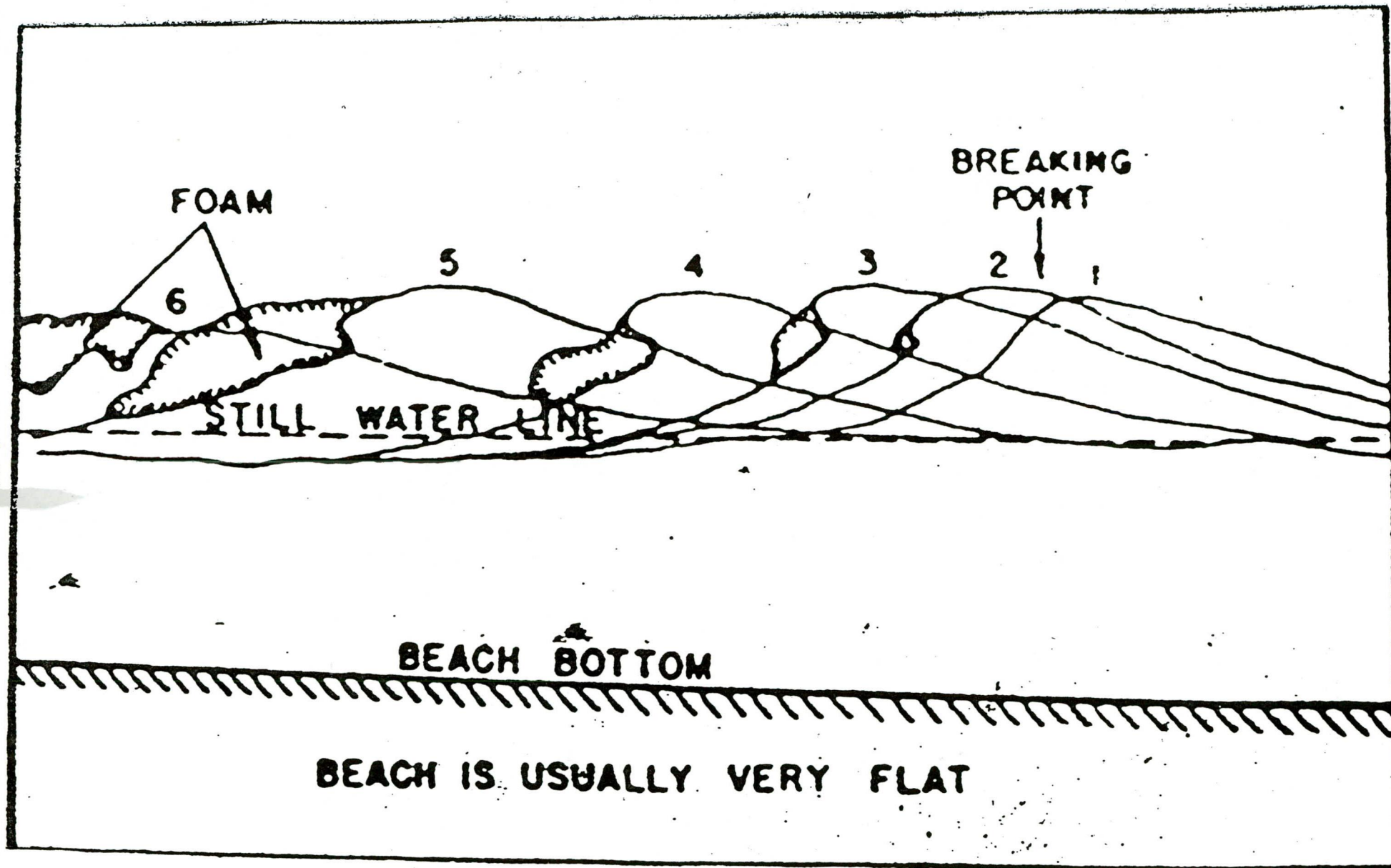


Figure 4-20 General Character of Spilling Breakers.

(after Wiegel, 1953)

4.8 COX'S BAZAR-TEKNAF COAST AND KUAKATA COAST

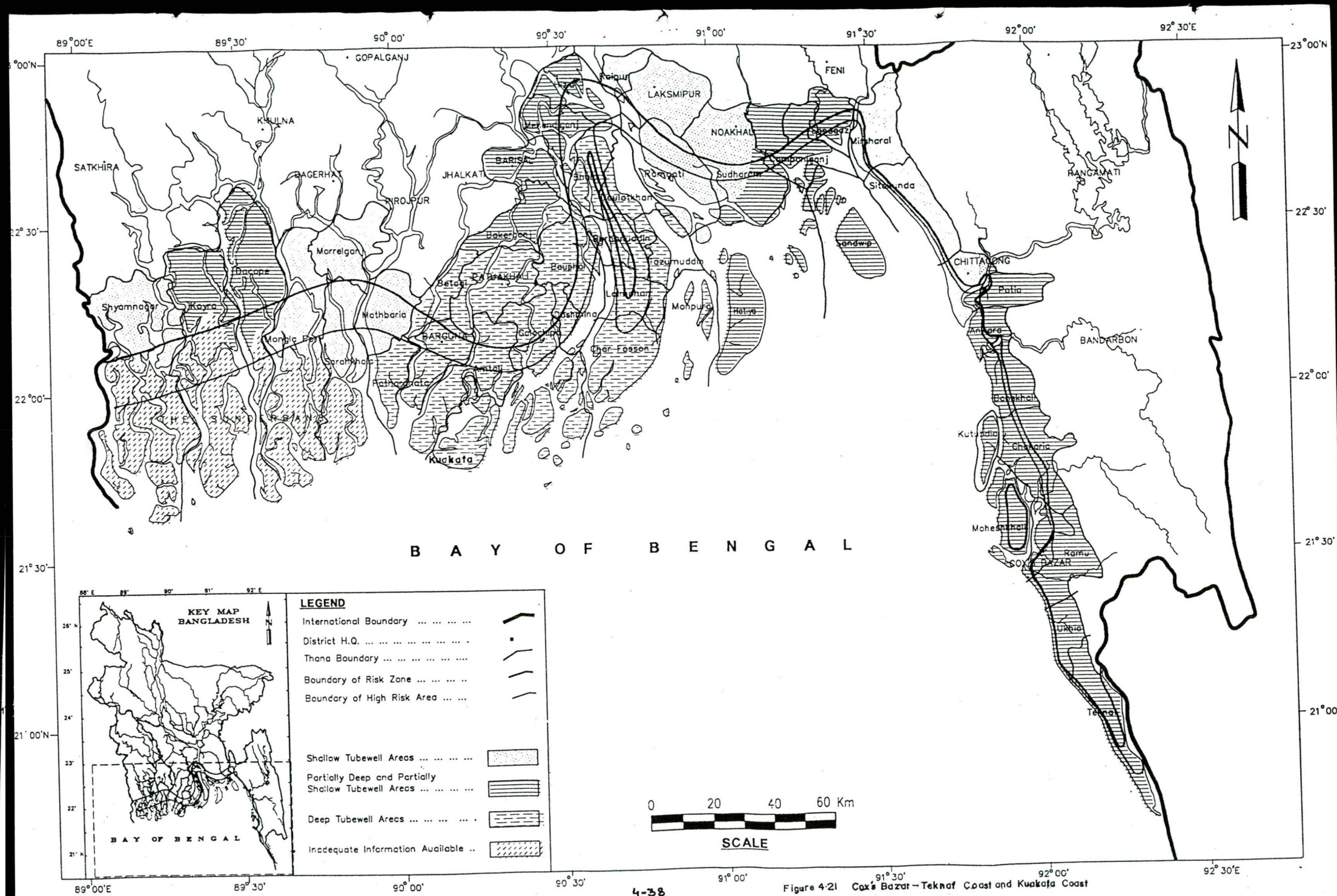
The Kuakata Coast lies between the latitudes $21^{\circ}45'$ and $21^{\circ}55'$ north and longitudes 90° and $90^{\circ}15'$ east whereas the Cox's Bazar-Teknaf Coast (Figure 4.21) lies between the latitudes $21^{\circ}30'$ and $20^{\circ}50'$ north and longitudes $92^{\circ}20.12'$ and $91^{\circ}57.88'$ east. The Kuakata coast is, thus in the north-west of Cox's Bazar-Teknaf coast. The backshore portion of the Cox's Bazar is bordered by hills whereas the backshore zone of Kuakata coast is bounded by coastal embankment of about 6.0m height. Kuakata coast has no distinct shape whereas the Cox's Bazar-Teknaf coast is humped shaped.

The mean diameter (d_{50}) of the beach materials of Kuakata Coast lies between 0.177 mm and 0.207 mm and the average mean diameter (d_{50}) all through the whole beach is around 0.20 mm. In case of Cox's Bazar-Teknaf Coast it varies between 0.11 mm and 0.23 mm. There is a similarity in the mean diameter (d_{50}) of beach materials between the 1st 10.00 km portion of Teknaf Coast ($d_{50} = 0.19$ mm-0.215mm) and Kuakata Coast. But the Cox's Bazar-Teknaf beach sand is comparatively finer than the Kuakata beach sand. The percentage of fine sand of Kuakata Coast varies between 63.38% to 99.73% and that of Cox's Bazar-Teknaf Coast varies between 94% to 99%. The Kuakata beach sand is more and less uniform in the particle mean diameter (d_{50}).

The widths of the Kuakata beach (foreshore zone) vary between 100.2 m and 340.8 m whereas those of Cox's Bazar-Teknaf Coast vary between 110 m and 170m. The beach slope of Kuakata Coast lies between 1:19 and 1:66 (vertical to horizontal) whereas the Cox's Bazar-Teknaf Coast has flatter slope and lies between 1:65 and 1:120. Hence on an average the Kuakata coast is wider and has steeper beach cross-slope than the Cox's Bazar-Teknaf Coast.

For Kuakata coast, there is no trend of variation of surface particle mean diameter (d_{50}) across the beach profile and the trend is also same both at 0.6m and 1.0m depth from the surface. But in case of Cox's Bazar-Teknaf Coast the particle mean diameter (d_{50}) decreases from the sea side towards landward side across the beach.

An interesting similarity can be seen in the wave breaking phenomenon (spilling type) for both the coasts of Cox's Bazar-Teknaf Coast and Kuakata Coast.



4.9 DISCUSSION

The sorting pattern, i.e., the sand particle distribution along the beach (foreshore zone) shows that the Kuakata beach is characterized by coarser portions of the fine sand group (0.075mm to 0.425mm). The particle mean diameter is highest (0.207 mm) at the extreme western point (Khajura forest area) of the beach (Station 1 with chainage 0.00 km) where the Nilgonj river meets with the sea and is lowest (0.177 mm) at the east (last station at chainage 19.45 km) at Gangamati dead channel confluence at Kawarchar. A trend of decrease of particle size shows that the western side is composed of slightly coarser sand than the eastern side.

The particle mean diameter (d_{50}) of the surface samples vary between 0.178 mm and 0.205mm (2.49 phi and 2.29 phi) within the foreshore zone whereas from the findings of Biswas (1986), it was shown that the particle mean diameter (d_{50}) varied between 0.125 mm and 0.177 mm (3.0 phi and 2.5 phi) in the upper foreshore zone. Biswas's sampling points differ from this study and Biswas's methodology of sampling analysis has not been described.

Particle size distribution of bed and bank samples from Nilgonj river and Gangamati khal confirms that the soil samples at the out-fall (confluence) of the Nilgonj river and Gangamati khal is more or less the same (0.181 mm to 0.209 mm). It, therefore, appears that the supply of sand comes from sea but is not known at this stage whether the sand source is from eastern side i.e. Meghna Estuary or from the erosion of islands on the western side.

The Kuakata coast is exposed to the sea at the south. The waves move from south to the north. Wave during rising tide is quite high and is about 4m to 5m high and hits the coast with tremendous erosive force. In recent year (July 1999) a severe breach occurred in the retired embankment which is about 6m high. The plantation (ch. 0.00 km to ch. 16.00 km) in front of the present embankment however, plays an effective role in disseminating wave energy. This study could not find systematic trend of sand deposition from east to west side. A large land has been accreted to the eastern part of Kuakata beach at Kawarchar area near the confluence of Gangamati dead channel with the Bay of Bengal. This accreted land is full of sand deposition. Further investigation is necessary to confirm the source of sand of this land.

Considering the cross-wise surface particle distribution at the stations, it can be said that there is no trend of variation of surface particle sizes across the beach profile and the mean diameter (d_{50}) can be considered around 0.20 mm. The trend is same both at 0.6m and 1.0m depth from the surface.

The beach long profile has no definite trend of shape. From station 1 at chainage 0.00 km the elevation of the foreshore zone of the beach increases at @ of 1:10,900 towards station no. 5 at chainage 8.00 km. The beach elevation, then decreases @ of 1:3,400 upto chainage 10.00 km at station no. 6. The slope is almost flat in the region between stations 6 and 9 (chainage 10.00 km to chainage 16.00 km). The profile then takes the form of a trough between stations 9 and 11.

The Kuakata beach slope lies between 1:19 and 1:66 (vertical to horizontal). The coast has got flatter slopes at the western and eastern sides and relatively steeper slopes in the middle part.

This study under field investigation could not find any trend of beach erosion or loss of beach materials. The width of the beach appears to be reasonable dimension (Table 4.1), not being too short, nor too long, and convenient to pleasure maker and sight seeing lovers.

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS FOR FUTURE STUDY

CONCLUSIONS

From the present study the following can be concluded:

- i) There is no definite trend of shape of the Kuakata beach. The beach surface elevation increases from 1.10 m PWD to 1.83 m PWD from Nilgonj confluence (ch. 0.00 km) at the west to a distance upto 8.00 km in the east. The beach elevation then decreases upto chainage 10.00 km at Station no. 6. The part between ch. 12.00 km and ch. 16.00 km has more or less the same elevation. The profile takes the form of a trough shaped between ch. 16.00 km and ch. 19.50 km;
- ii) The widths of the beach (foreshore zone) vary between 100.2 and 340.8 m;
- iii) The beach slopes vary between 1:19 and 1:66 (vertical to horizontal). The beach is relatively flatter at both western and eastern ends and the middle part has got steep slopes;
- iv) The waves in the beach approaches from the sea and the wave breaking phenomenon is of spilling type;
- v) The particle mean diameter (d_{50}) of the surface samples vary between 0.178 mm and 0.205mm (2.49 phi and 2.29 phi) within the foreshore zone whereas from the findings of Biswas (1986), it was shown that the particle mean diameter (d_{50}) varied between 0.125 mm and 0.177 mm (3.0 phi and 2.5 phi) in the upper foreshore zone. Biswas's sampling points differ from this study and Biswas's methodology of sampling analysis has not been described. Hence any more conclusion on both the results has not been made;
- vi) There is no trend of variation of surface particle sizes across the beach profile and the mean diameter (d_{50}) can be considered around 0.20mm. The trend is same both at 0.6m and 1.0m depth from the surface. However, a trend of decrease of particle size from western side towards eastern side shows that the western side is composed of slightly coarser sand than the eastern side;
- vii) Particle size distribution of bed and bank samples from Nilgonj river and Gangamati khal confirms that the soil samples at the out-fall (confluence) of the Nilgonj river and Gangamati khal is more and less the same. From this it can be said that the supply of sand comes from sea but it is not known at this stage whether the sand source is from eastern side i.e Meghna Estuary or from the erosion of islands on the western side;
- viii) The beach materials of Kuakata Coast (0.177 mm-0.207 mm) can be considered to be almost similar to the beach materials of 1st 10 km coast line portion at Teknaf (d_{50} =0.19 mm-0.215 mm). But the Cox's Bazar-Teknaf beach sand is comparatively

finer than the Kuakata beach sand. The Kuakata beach sand is more and less uniform in the particle mean diameter (d_{50}). An interesting similarity also exists in the wave breaking phenomenon which is spilling type for both the cases. Hence on an average the Kuakata coast is wider and has steeper beach cross-slope than the Cox's Bazar-Teknaf Coast.

SUGGESTIONS FOR FUTURE STUDY

- i) This study was done during summer (June 1999). It is about 8 years after severe storm surges in April 1991. Since the coast is often attacked by the storm surges, investigations immediately after any storm surges in the future will be worthwhile for useful comparison.
- ii) A quantitative study on waves phenomenon and long shore transport will also be worthwhile from morphological point of view.
- iii) A water level and wave recording station is desirable for conducting studies on coastal phenomena in the area.

APPENDIX

A. BATTJES 1974, Breaking Types as a function of ξ

Battjes described the following criteria for breaking phenomenon:

$$\xi = \tan a / (H_s/L_0)^{1/2}$$

when $\xi > 5$ wave breaking will be Surging type,
when $3.3 < \xi < 5$ wave breaking will be Collapsing type,
when $0.5 < \xi < 3.3$ wave breaking will be Plunging type,
when $\xi < 0.5$ wave breaking will be Spilling type,

where $\tan a$ = Beach cross slope at foreshore,
 H_s = Significant Shallow Water Wave Height
 L_0 = Deep Water Wave Length = $5.22 T^2$, where T is deep water wave period in sec.

Now, in our case $\tan a = 1:19$ to $1:66$ (Table 4.1)
 $H_s = 4 \text{ m} = 13.12 \text{ ft}$ (actual)
 $T = 15 \text{ sec.}$ (considered)
 $L_0 = 5.22 T^2 = 5.22 \times 15^2 = 1174.5 \text{ ft.} = 358.08 \text{ m.}$

Case 1: considering the slope as the steepest, i.e, $\tan a = 1:19 = 0.052$

$$\xi = 0.052 / (13.12/1174.5)^{1/2} = 0.49$$

Case 2: considering the slope as the flattest, i.e, $\tan a = 1:66 = 0.015$

$$\xi = 0.015 / (13.12/1174.5)^{1/2} = 0.14$$

So, it is seen that in both the cases the value of ξ is less than 0.5 and as such the wave breaking phenomenon is of spilling type.

B. W W MASSIE 1986, Breaking Types as a function of $H_0 / (L_0 m^2)$

Massie described the following criteria for breaking phenomenon:

when $0.0 > H_0 / (L_0 m^2) < 0.09$ wave breaking will be surging type,
when $0.09 > H_0 / (L_0 m^2) < 4.8$ wave breaking will be plunging type,
when $4.8 > H_0 / (L_0 m^2) < \infty$ wave breaking will be spilling type,

where H_0 = Deep water wave height
 L_0 = Deep water wave length
 m = Beach cross slope at Foreshore

Now, in our case L_0 = 1174.5 ft (as before)
 m = 1:19 to 1:66 (Table 4.1)
 d = 19.58 ft = 6 m (Ref. FAP-7)
 H_s = 4 m = 13.12 ft (as before)

Now, using Table C-I of the Shore Protection Manual (Vol. II):

$d/L_0 = 19.68/1174.5 = 0.017$, corresponding value of $H_s/H_0 = 1.27$

So, $H_0 = H_s/1.27 = 10.33$ ft.

Case 1: considering the slope as the steepest, i.e, $m = 1:19 = 0.052$

$$H_0 / (L_0 m^2) = 10.33 / (1174.5 \times 0.052^2) = 3.25$$

So, it is seen that the wave breaking will be plunging type and close to spilling type
i.e the wave breaking will be spilling type during high tide.

Case 2: considering the slope as the flattest, i.e, $\tan a = 1:66 = 0.015$

$$H_0 / (L_0 m^2) = 10.33 / (1174.5 \times 0.015^2) = 39.09$$

So, it is seen that the value is within the range of $4.8 > H_0 / (L_0 m^2) < \infty$; the wave breaking will be spilling type.

C. Wave Breaker Type Transition Points (Galvin, 1972)

Galvin described the following transition points for breaking phenomenon:

Parameter	Spilling/Plunging	Plunging/Collapsing-Surging
$H_o/(L_o m^2)$	4.8	0.09
$H_b/(gmT^2)$	0.068	0.003

Where m is the beach slope and H_b is the wave height at breaking. It should be emphasized that these transitions are gradual and the stated transition points are strongly dependent on the judgement of the observer.

Case 1: considering the slope as the steepest, i.e, $m = 1:19 = 0.052$

$$H_b / (gmT^2) = 13.12 / (32.2 \times 0.052 \times 15^2) = 0.034$$

So, the wave breaking is of plunging type.

Case 2: considering the slope as the flattest, i.e, $m = 1:66 = 0.015$

$$H_b / (gmT^2) = 13.12 / (32.2 \times 0.015 \times 15^2) = 0.119$$

So, the wave breaking is of spilling type.

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