MORPHOLOGICAL AND SEDIMENTOLOGICAL STUDY OF BEACH AT GUHAGAR DIST. RATNAGIRI MAHARASHTRA

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JUNE 2015

DECLARATION

I hereby declare that the thesis entitled "**MORPHOLOGICAL AND SEDIMENTOLOGICAL STUDY OF BEACH AT GUHAGAR DIST. RATNAGIRI, MAHARASHTRA**" **c**ompleted and written by me has not previously been formed as the basis for the award of any degree or other similar title upon me of this or any other Vidyapeeth or examining body.

(**JAGTAP SANJAY BHAGAWANRAO**)
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Place: Pune
Date: June 2015

CERTIFICATE

This is to certify that the thesis entitled **"MORPHOLOGICAL AND SEDIMENTOLOGICAL STUDY OF BEACH AT GUHAGAR DIST. RATNAGIRI, MAHARASHTRA".** Which is being submitted herewith for the award of the Degree of Vidyavachaspati (Ph.D.) in Earh Science (Geography) of Tilak Maharashtra Vidyapeeth, Pune is the result of original research work completed by **Mr. Jagtap Sanjay Bhagawanrao** under my supervision and guidance. To the best of my knowledge and this or belief the work incorporated in this thesis has not formed the basis for the award of any degree or similar title of this or any other university or examining body upon him.

(Dr. Tushar A. Shitole)
Research guide

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CHAPTER I
INTRODUCTION

1.1 The Sea Beaches

The coastal areas are transitional and complex system of the coastal environment. Headland and beaches are prominent features observed along this narrow stretch, representative of erosive power and depositional balance respectively. To portray the coastal landforms beaches play a very crucial role.

From the point of academic and research interest, beaches have always acquired greater significance for studies in physical and human Geography. It is also important to understand the geomorphic processes which tend to operate along the stretch of the beach. These processes are dynamic in nature, vary with season and are influenced by anthropogenic activities of mankind.

The beach is defined as an accumulation of unconsolidated sediment extending shoreward from the mean low tide line to some physiographic change such as a sea cliff, dune field or to the point where permanent vegetation is established (U.S. Army 1984). But according to Komar (1976) this definition has a drawback that it does not include any portion that is permanently under water, where many of the processes are responsible for changes in beach morphology.

Beach dynamics include sedimentary deposits, energy dissipation in the form of waves and tidal level change as they are influencing factors for sedimentary deposits on the beach. Climate as well as surrounding Physiography, plays a vital role in building the dynamic condition of a beach. According to Pethick (1984) the sea beaches are most unlikely of landforms to be found facing the open sea. The secret of these geomorphic existences lies in the very fact that they are made up of only loose sand and shingle manage to remain intact on the coastline. Beaches can adjust their shapes very quickly with changes in near-shore wave energy, and can dessipate the energy with minor adjustment of the position of sand and shingle grain.

Abundant supply of sand accumulates as thick wedge shaped deposits; absorb the energy of breaking waves. During a short period of storm the beach is cut back and material is carried to the offshore by the heavy wave action. However during long periods when waves are weak the sand is returned to the beach very slowly. Thus beach is easily able to maintain itself in a dynamic equilibrium due to inherent mobility of its sediment.

Theoretically, the beaches are the depositional units that are developed between low water mark and high water line. These sedimentary bodies situated at land-sea interface made up of non-cohesive particles of mainly sand, although coarser sediments like shingles are dominated in the specific settings (Bird, 1996).

From the geomorphic point of view, Friedman et. al. (1992) classify beaches as

- **Main land beaches:** these types of beaches are placed at the boundary between continent and sea.
- **Strand plains:** prograded sedimentary bodies, deposited by waves and currents at a certain distance from a coast.
- **Barrier beaches:** situated at the seaside edge of barrier islands and spits.

The specific morphology of each beach is the ‘mirror of the way in which coastal sediments react to the local wind and wave regime. Study of geomorphology and sedimentology of the beach can be understood by the predominant sedimentary processes controlling the beach.

1.2 The Beach Morphology

The development along the coastline changes occurs over centuries as well as in a matter of hour or minutes. These changes of development apply to the form of coastline like beach which may change significantly during the day and the coastal processes e.g. tidal variation seasonal fresh water discharge (Pethick, 1984).

Beaches are perhaps the most sensitive, delicately balanced mechanism of a coast. They are the most vibrant and dynamic features. Beaches adjust extensively to changes in the energy conditions of water flow (Pethick, 1984). They react rapidly to changes in sediment type or its supply rate. Beaches are not isolated systems spatial changes will be transmitted in a variety of scale along the shore line within extent of single beach as well as whole successions of beaches.

The beach interaction zone normally extends to the limit of swash action. According to Friedman et. al. (1992) the limit of beach zone is a matter of discussion over past decades, but still remain a difficult task. The landward limit of the beach is to be the maximum reach of stormy waves, generally in front of coastal dunes. While considering the seaward limit of oscillatory wave’s geomorphologists have debited four options namely, 1 low water line

2 the extent limit of oscillatory waves

3 the outer limit of breaker zone

4 fixed selected depth of water at 10 m.

Recently most coastal researchers have accepted the seaward limit, where there is interaction between waves and sediment begins (Stanica and Ungureanis, 2010). Short and Wright (1983) stated that sandy beaches are the product of the waves interacting with the sandy bed at the shore line. As a result of wave environment considerable variability's in sandy beaches occurs, as the entire beach zone consist of depositional facies formed by wave current dynamics and associated flows. According to King (1972) the beach profile extent is from low water of spring tides to the upper limit of wave action. This definition is more precise, but it is criticized as un-geomorphologic as it does not encompass the dynamic zones over which beach sediments may move. Komar's (1976) definition includes the seaward zone over which sediments may be moved by waves, is referred to as littoral zone. The stretch may be from the landward limit of wave action which is considerably higher than high tide level at water depth of 10 m to 20 m at low tide.

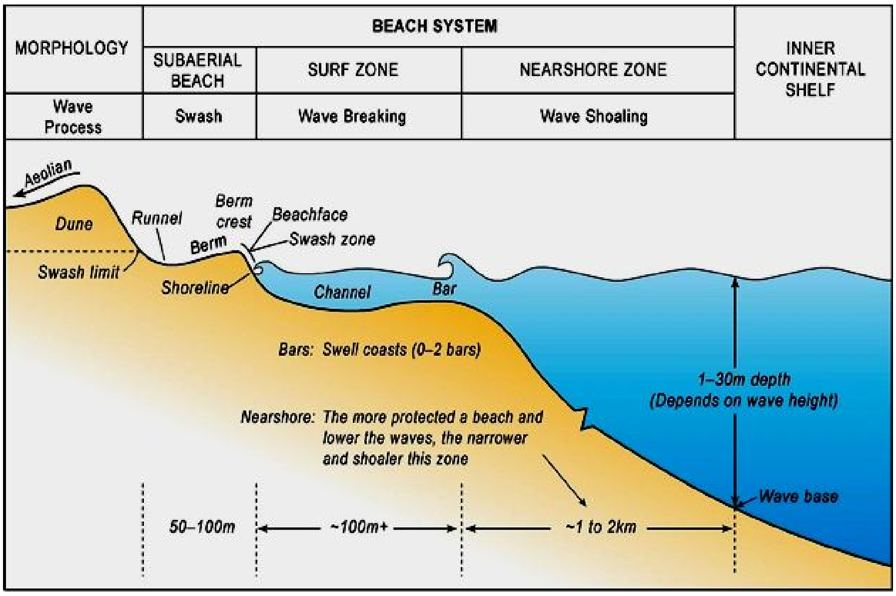
The landward and the seaward limits of beaches change constantly, both due to changes in wave characteristics and also due to tidal cycle as water depth changes the nature of beach (Pethick, 1984). According to Jago and Hardisty (1984) the beach morphology is an examination and description of overall beach profile whether it is concave upwards or otherwise the presence of longshore features such as ridge and runnels, rhythmic structure like cusps, cresentric bars, swash line, gravel line, can be studied to know the seasonal variations in beach morphology. The most important morphological feature of the beach profile is its overall gradient which is the average slope between seaward and landward limit. Beach gradient (tangent to the beach slope angle) normally varies from 11° to 0.5°. Transition of beach profile from steep to shallow gradient is marked by removal of the berm and deposition of a bar just below low tide level is the long shore bar (Karlekar, 2009).

In pre-monsoon season beaches are affected by storm waves, and most part of the beach is submerged under marine water and shoreline increases towards landward. As a result of erosion of the coastal slopes and subsequent removal of the debris by nearshore current cause the progressive recession of the shore line. In spite of this, in post monsoon season there is decreasing shoreline as well as repetitive formation of beach dynamic features. Wave energy, breaker types, sediment variability, as well as sediment transport process control profile variation.

1.2.1 Terminologies Associated With Beach and Beach Profiles

The cross section of the beach called beach profile is shown in (Figure No. 1.1). The terminologies associated with beach and beach profile are reproduced below from the shore protection manual (1984). The definitions of the terms, is in close conformity with those given by Komar (1976) and Andrian Stanica and Viorel Gheorghe Ungureanis (2010).

Figure No. 1.1 Beach System



(Education Citation: Short, A. D. (2012) Coastal Processes and Beaches. Nature Education Knowledge 3(10):15)

An idealized cross-section of a wave-dominated beach system consists of the swash zone which contains the sub aerial or 'dry' beach (runnel, berm, and beach face) and is dominated by swash processes; the energetic surf zone (bars and channels) with its breaking waves and surf zone currents; and the nearshore zone extending out to wave base where waves shoal building leads to a concave upward slope.

- **Backshore**: This zone of beach is lying between the foreshore and the landward limit of beach. The zone is acted upon by waves only during severe storm or monsoon season, especially when combined with exceptionally high water.

- **Beach face:** The sloping nearly planer section of the beach profile below the berm, which is normally exposed to the swash of the waves.
- **Bar:** A submerged or emerged embankment of sand, gravels or other unconsolidated material built on the seafloor in shallow water by waves and currents.
- **Berm:** A nearly horizontal portion of backshore formed by the deposition of sediment by wave action.
- **Berm crest:** The seaward limit of berm.
- **Beach scarp:** An almost vertical escarpment notch into the beach profile by wave action.
- **Fore shore:** The part of shore lying between the crest of the seaward berm and the ordinary low water mark, that is traversed by up-rush and back-wash of the waves as the tides rise and fall.
- **Swash zone:** The portion of beach face alternately covered by the up-rush of the wave swash and exposed by back wash.
- **Ridges and runnels:** These are broad gentle rises and depressions which are developed at the seaward side of the sandy beach and are aligned parallel to the shore line.
- **Surf zone:** The area between the outermost breaker and limit of high tide level.
- **Nearshore:** The region seaward of the shore (from approximately the step at the base of the surf zone) extending offshore to the toe of the shore face.
- **Longshore bar:** A ridge of sand running roughly parallel to the shoreline.
- **Longshore trough:** An elongated depression that extends parallel to and between the shoreline and any longshore bars that are present.
- **Breaker zone:** The portion of the near shore region in which the waves arriving from offshore become unstable and break. On a wide flat beach, secondary breaker zones may occur where reformed waves break for second time.
- **Offshore:** The comparatively flat portion of the beach profile which extends seaward from beyond the breaker zone to the edge of the continental shelf.
- **Shoreline:** This is the line of demarcation between water and the exposed beach.

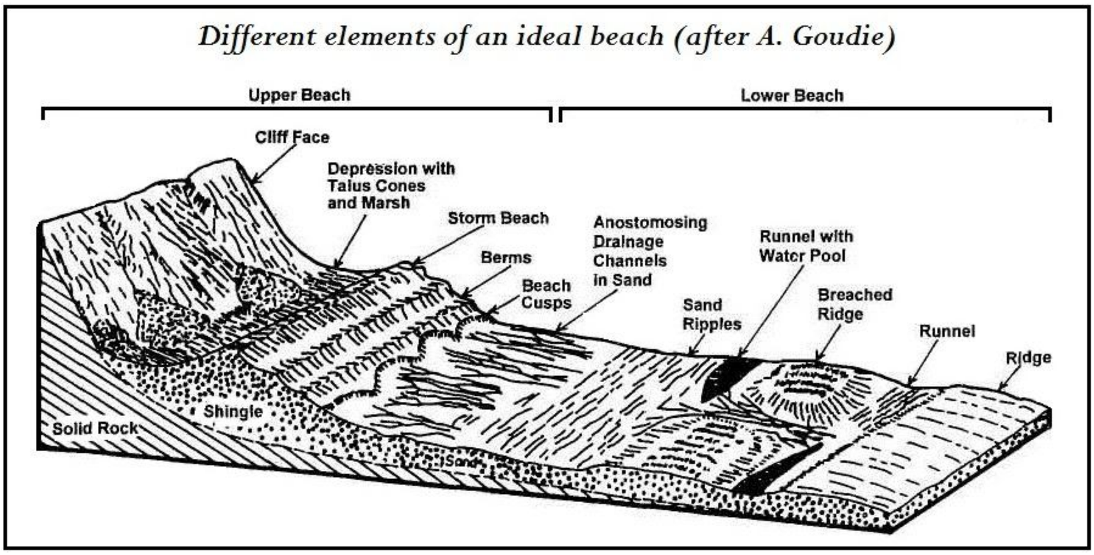
The terminologies ‘erosion’ and ‘accretion’ are used to described beach profile changes over a period of time. Whenever there is a build-up of material in a temporal frame, the beach is said to accrete. Alternately when there is loss of sediment from the beach, it is said to erode.

Another method of describing beach morphological changes is in terms of the advance or retreat of shoreline. An advance of shoreline is indicative of accretion while retreat is indicative of erosion (Thomas, 1990). Erosion and accretion or shoreline change can be both short term and long term process depending on the time scale. Along the west coast of India, seasonal erosion occurs during the south west monsoon. This eroded beach is normally rebuilt during the fair weather period resulting in no net erosion or accretion over a period of one year (Thomas, 1990).

1.2.2 Elements of Beach

Main elements of an ideal beach are Upper and Lower beach with several minor elements like storm beach, beach ridge or berm, beach cusp, small channels, ripples, ridges and runnels etc. (Figure No 1.2). The upper beach representing the landward section of the beach is composed of coarser and larger materials such as pebbles, cobbles and boulders. The slope of upper beach section ranges between 10^{o} to 20^{o}. On the other hand, the lower beach representing the seaward section of the beach is composed of sand. The slope of this section of the beach is 2^{o} or even less.

Figure No. 1.2 Ideal Beach



The storm beach is a semi permanent beach which stands well above the level of highest spring tides. The successive low ridges built by constructive waves parallel to the coast line and below the level of high spring tides are called beach ridge or berm. Beach cusps are small regular embayment and the series of headlands are composed of shingles. Sand ripples are developed on the lower beach section by wave action or by tidal currents. Ridges and runnels are broad and gentle rises and depressions which are developed at the seaward side of the sandy beach and are aligned parallel to the shoreline. These systems are formed on shallow gradient beaches due to interaction of tides, currents, sediments and beach topography.

Sand dunes are mounds or ridges of drifted sand to the inland areas. Though the process of formation of coastal dunes and inland dunes are very similar, their slopes (morphology) differ considerably. They are unique as coastal features as they are formed by air movement rather than wave action. A supply of abundant sand over a wide beach, low lying area behind the beach and dominance of onshore winds are the basic requirements for the formation of sand dune.

1.2.3 Beach Dune Interaction

The transverse profile of beach can be conveniently divided into foreshore, backshore and beach-dune zone. All these zones are narrow and merge into each other imperceptibly. According to Sherman and Baner (1993) beach and dune environment is strongly coupled and mutually adjusted. There is very close relation between beach and dune morphodynamics. Davidson-Arnott (1988) stated that beach width is important in determining fetch which is critical for determining the volume of sand delivered across the back shore and to dunes. Beach morphology is important because the greater the morphological variability, the more likely that wind velocity decelerations and variation takes place across the back shore.

Hesp (1982, 1999) showed that a wind flow across a wide, low gradient, dissipative beach displayed minimal flow variation and gradually accelerated across the backshore, thus maximizing potential aeolian transport. Reflective beaches have minimal potential for aeolian transport and intermediate beaches range from relatively high potential at the dissipative and the low potential at the reflective end.

Surveys of established foredune provide further evidence that there is strong line between surface- beach type and foredune height and volume of sand. There is no doubt that sediment supply, sea level state like (transgressive, stable and regressive) return interval, magnitude of extreme storm events and Pleistocene inheritance factors will all at times and in some places, be the controlling variable in beach – dune interaction (Shitole, 2009).

1.2.4 Wave Environment and Beach Profile

The effect of wave action acts as the most important agent shaping coastal landforms. The energy of waves is expanded primarily in the constant churning of mineral particles as wave breaks at the shore, cause erosion of shore line. The action of waves can also move sediments for long distance built beaches outward as well as form barrier islands just offshore.

With very little loss of energy waves travel across the deep open oceans, unless and until they reach the shallow water to drag of bottom, waves became slow and steeper. However the wave top maintains its forward velocity and eventually, falls down on the face of the wave, creating a breaker. Many tons of water surge forward riding up the beach slope, where soft material like regolith makes up the coastline. The force of the waves alone cuts the shoreline which is eroded rapidly.

Many field observations show the close relationship that exists between wave type and beach profile gradient. Shepord and LeFond (1940), Boscom (1954) demonstrated that the low flat swell waves during the summer period built up the berm (the beach face), forming seaward steep profile. During winter high steep storm waves erode the beach face and transport these materials of sediment towards sea, where it forms a longshore bar. The beach profile is widened and its overall gradient is reduced. The beaches are transformed into narrow beaches with steep to very steep beach face in monsoon with varying degrees of steepness and beach cuttings.

Flat beaches in Konkan are usually associated with low and spilling breakers of fair-weather and as plunging breakers with steep beaches. Sedimentary characteristics and morphodynamics of sandy beaches of Konkan are controlled mainly by specific waves and tide environment related to season and tidal range (Karlekar, 1997).

According to some researchers, specification angle of approaching waves rather than the steepness of wave result in erosion of beach and development of flat shallow profile. Beaches could only survive in their inhospitable environmental condition as they adapted dynamic equilibrium in morphology with the wave energy. Open ocean beaches and spits are subjected to large range of water condition therefore shows adaption to various stages. Wright (1979) stated that frequently there is one stage to which beach adjusts very often, some time they indicate dissipative stage and show indicative form such as longshore bars and trough.

Several studies have noted the association between waves, breakers and beach gradient. Wright (1979) note that high values of surf scaling factors are associated with flat beaches and spilling breakers while low values are associated with steep narrow beaches and surging breakers. Huntley and Bowen (1975) also note the relationship in their field experiment, found steep observation associated with plunging breakers. Such field observations have been supported by many laboratory experiments; King (1972) reports the results of her work in relating wave steepness to beach gradient which is a persuasively close one.

1.2.5. Wave Energy and Beach Profile

Wave energy is dissipated in the breaker zone. The rate of dissipation of energy depends on the type of wave breaking. Purely spilling breakers breaking on a flat low-lying beach will have a constant breaker index, throughout the breaker zone. That is the ratio of wave height to water depth will remain constant across the breaker zone. On the other hand fully plunging breakers, dessipate most of their energy at the outer breaker line.

The type of breaking waves indicates the mode of energy dessipation. In spilling breakers turbulence begins at the crest and gradually envelopes the wave front. According to Galvin (1969) spilling is a surface phenomenon continuing over a distance of up to several wave length as a result very little concentrated dispersive pressure reaches the bed. On the other hand plunging breakers is a far more violent process, so that energy dessipation is concentrated in the narrow zone. Miller (1976) has examined the generation of turbulent vortices. In spilling waves vortex generation is weak, but in plunging waves a jet is impelled into the preceding through, often penetrating the bed and causing the wave velocity so that sediment cloud emerges as a patch of foam in the lee of the breakers. However during storm considerable sediment movements may take place, where grain share becoming increasingly important and widespread (Carter, 1989).

When the wave attack is perpendicular, dissipated energy goes mainly towards sustaining a higher mean water level within the breaker zone are set up or set down, which depend on the rate at which wave energy is dissipated, which in turn dependent on breaker type and beach profile (Pethick, 1984). Thus a wave setup profile for spilling breakers on a smoothly sloping beach will follow a smooth curve where as plunging breakers will be associated with a jump in wave set up curve.

Beaches are essentially energy sinks. They act as a buffer between waves and coast. The energy of the waves is proportional to the square of its height, while the rate at which energy arrives at the coast will be related to the wave period. This means that beaches receives high energy inputs are best dissipated by a wide flat beach profile which spreads the oncoming wave energy out, so that each unit area of beach need dissipate only a small proportion of this incident energy. On the other hand the low energy inputs of flat waves are easily dissipated by a wall on which the waves founders (Pethick, 1984).

1.3. Sedimentology of the Beach

Coastal sands consist mostly of quartz grains, but comprise various litho fragments, mica, heavy minerals, oolites and other materials. Shell, shell fragment or non biotic carbonaceous fragments such as eroded limestone clastics, volcanic material, pebble and boulder size fragment may also be present and even predominate under specific circumstances (Stanica and Unqureanu, 2010). Temporary or short lived deposits of marine sediments consisting of sand, shingles, cobbles etc on the shoreline are called beaches. In fact beaches are wedge shaped sediment deposits on the sea shore. The major sources of the supply of beach materials are erosion of headlands and cliffs, sediments brought by rivers at their mouth, mass wasting and mass movements of cliffs, scouring of the offshore zone by storm waves and erosion of the pre existing beaches.

A deposit of non cohesive materials situated at the interface between dry land and the sea actively work by present day hydrodynamic processes like waves, tides and currents as well as sometimes by wind (Bird, 1996). Beaches show high spatial and temporal variability in terms of sedimentary balance and sources of sediments.

The sedimentology of beach is governed by tide and wave environment. Micro, macro and meso-tidal environment produce different type of beaches. The wave and tides induced currents of the nearshore zones also affect the sedimentology of beaches (Karlekar, 2009). At the ebb tide decrease in velocity of current results into deposition in swash zone, while in high tide and in areas of plunging breakers there is more erosion of deposits (Pethick, 1984). In the sedimentology of any beach various factors such as grain size distribution, beach slope, wave characteristics, tidal range, breaker type, long shore currents and the swash backwash sediments play a very important role.

A sandy beach is actually a prism of sediments which is subjected to reworking at different times of the year; otherwise it would have been converted in stable vegetated landform. In extreme conditions, it can be subjected to landward extension up to fore dunes which are colonized by dune plants.

According to Chapman David (1983) the reworking of sandy beaches is caused by aeolian, biological or hydraulic processes. All beaches show dynamic response to variation in natural hydraulic conditions like tides, currents and waves. The vertical cross section of beach deposits, showing surface and subsurface sediment properties generally helps to know the changes in the beach sediment over time.

1.3.1. Sediment Size and Beach Profile

Morphology and grain size characteristics of beach sediments vary significantly both spatially and temporally. The nature of topography of beach reflects the character of beach material. Beach morphological variation has been studied within different space and time interval (Reddy et. al.,1985 and Murty et. al., 1980).

Relationship between sediment size and beach gradient, are best summarized by Boscom (1951). The work emphasizes the wide range of sediment size, beach gradient and its length. Steep beaches are associated with larger shingle sized sediments whereas shallow profiles were found in the finer sand size. Shepard (1963), Bagnold (1940), quoted beach gradient of 15^{o} or more on shingle beaches with mean grain size of 16 mm. Inman and Bagnold (1963) note that gradient of beaches increase systematically towards the land and produce concave beach profiles. These concavities consist of two slopes, a low angle towards seaward associated with finer material and steep landward facet formed in coarser shingle.

Relationship between sediment size and beach profile is like a ‘black box’ in which actual mechanism is not known, but if one variable changes, the other also changes. This relationship is due to the percolation associated with the various sediment type and size. This is greatest for coarser grain sediments. Consequently as a swash moves up a shingle beach, considerable proportion of water is lost to the surface flow due to percolation. The sediment size and sediment sorting also control the percolation rates. Poor sorting results in less percolation, while well sorted sediments of the same mean grain size compare to the steeper profile and high percolation rate (Karlekar, 2009).

1.3.2. Sediment Transport and Beach Profiles

The transport of sediments on the beaches is an important process determining the overall morphology of the beach. Waves undergo transformation as they travel from open ocean to nearshore zone. At some critical point near the shore waves became unstable and break. Turbulence within the breaker zone helps sediments in suspension. Wave induced currents cause transport of beach sediments in the onshore-offshore direction. The transport of sediments through breakers is a very complex phenomenon. Initially the energy of shoaling and breaking waves is used in moving sediments. The asymmetry in shoaling waves leads to differential net sediment particles transport.

Along a wave dominated coast onshore-offshore sediment transport is more important and generally little net longshore drift is found here during erosion - accretion sequence (Silvester, 1974). Onshore offshore sediment transport alone can cause drastic changes in the beach configuration of such coasts. Thus due to suspended matter in a breaker and surf zone, development of beaches takes place. There are distinct seasonal changes in the amount of suspended matter in surf zone breakers play a vital role in building and destruction of nearby beaches.

The forces responsible for movement of sediment on beaches are provided by water and air. Velocity and viscosity of the moving water are parameters affecting the force required for sediment transport. The oscillating currents, wave energy and long shore current velocity together working on the process, result in swash and backwash of breaking waves which are responsible for shifting of the beach materials. The approach of wave front to the shore is less than a right angle, so that the burden of sand in swash rides obliquely to the beach, where the wave spends most of its energy. The flow of backwash in the most downhill direction resultant dragging of particles directly seaward up to the position of starting point. Repeated movement of beach drift becomes a very significant form of sediment transport.

In relation to the above explanation the sediment transported due to different processes in the shore zone moved with approaching waves, with shoreline at an angle to the beach. A longshore current is setup parallel to the shore in a direction away from the wind. This current is capable of carrying sand along the sea bottom only with favorable conditions of waves and winds in the process of longshore drift.

Beach drift and longshore drift acting together is called Littoral Drift. Beach erosion and accretion is one part of the larger system involving the movement of sediments. The scale effect of wave height and the relationship with grain diameter imply that sediment transport processes are of great importance and wave steepness is perhaps merely an associated variable. The study of Sonu and Vanbeek (1971) suggest that one must examine the shore normal currents and associated sediment transport movement to understand the beach profile development.

The beach is easily able to maintain itself in a dynamic equilibrium with its environment due to inherent mobility of its sediment. The concept of the cross shore equilibrium profile is generally attributed to the work of an Italian Polo Corngalia (1889), who considers the equilibrium with wave condition. He suggested a neutral line (null point) at which sediment of a particular grain size would be at equilibrium between the effects of wave asymmetry tending to move sediments offshore.

The connection between flow asymmetry and sediment transport was recognized by Cornish (1898), who suggested the hypothesis of asymmetrical sediments underwater. Cornish suggested that the higher onshore velocities with shorter duration will move small particles in the onshore direction but the lower offshore velocities will return only the finer materials. Since the offshore velocities are of larger duration there will be net offshore movement of this finer material, which will move further offshore during one wave period (Pethick, 1984).

The work performed by the water in moving of sediments will be the product of weight, a frictional resistance and a distance over which transport rates takes place. With either movement of sand upslope or down slope the work cannot be carried out with perfect efficiency. Of course there will be energy losses in both directions. During the onshore movement, energy is lost due to friction and percolation of water. Consequently the offshore movement begins with less available energy and its energy losses during the flow are proportionately less than those in the onshore direction.

Analysis done by Inman and Bagnold (1963) suggested that a fine smooth beach surface with tranquil flows and low percolation rates will become flat while a coarse grained, high percolation rate beach will steepen towards the angle of internal resistance of the sediment. The ratio between energy losses in each direction expresses these characteristics of the beach and the water movement over it.

1.3.3. Subsurface Beach Sediments

Like surface sediment on the beach the subsurface sediments at various depths is the key to the study of beach sediments. The study of subsurface sediments, the surface area of the sample and the depth of the sediment is important. A 1000 sq. cm. surface area and the depth of few centimeters are generally considered standard. On the sandy beaches substrata of the beaches is characterized homogeneous in nature. To understand the morphodynamics and sediment structure of the past of a beach system, study of subsurface sediments helps a lot. The beach habitat thus can be placed into a proper perspective.

From the nature of subsurface sediments and their internal geometry, lower beach, beach face and berm can be identified. The identification of morphodynamics beach stages, together with their temporal and spatial variability is an important prerequisite for the casual interpretation of beach profile geometry and related internal sedimentary structures on various scales.

Sets of internal sedimentary structure are produced mainly because of hydrodynamic processes. These processes are observed in different parts of the beach. A single part of the beach can be individualized by a low angle so each part of the beach shows different depositional features associated with combination of environmental conditions the result being the variability in vertical cross section of the beach. This variability in vertical cross section can be supported by textural differences in each part of the beach. Dip angle of beach layer depend upon a wave climate even if the sediments are uniform. Generally affects the filtering capacity of sea water.

1.4. Beach Morphodynamics

The beach morphodynamics includes the examination of beach morphology, beach profile, beach profile variability and beach stability including its sedimentology. The beaches respond quite sensitively to changes in environmental conditions, especially the local wave climate (Boscom, 1964). Systematic relationship was observed between the grain size of the beach and its slope as a function of exposure to wave action, beach slope in degree and grain size in phi show the higher correlation. For any given sand size a beach slope will always increase with decreasing wave energy, alternately steeper slope formed by coarser sand at similar energy. Empirical formulae for estimating beach slope as a function of grain size and wave energy.

- **Low wave energy**

  D phi = $3.17S^{-2.16}$ or S = $(3.17/\text{D phi})^{0.463}$
- **Intermediate wave energy**

  D phi = $2.72S^{-2.04}$ or S = $(2.72/\text{D phi})^{0.49}$
- **High wave energy**

  D phi = $2.25S^{-2.0}$ or S = $(2.25/\text{D phi})^{0.5}$

  Where S = beach slope in degree and D phi = mean grain size in phi

Most beach sediments are relatively well size sorted grains and major difference in grain size mostly reflects the corresponding difference in relative wave energy level. Relationship between sediment size and beach slope, established that, there is definite periodic modification with beach profiles with the changes in seasonal wave climate. A beach is thus a highly dynamic system which constantly responds to short and long term fluctuation in energy levels (Flemming and Fricke, 1983). Rise and fall of the tide is one of the shortest cycles of this nature. Guza and Inman, (1975) described, the cycle of associated surface dynamics by dissipative and reflective beaches. The classification of beaches, in two groups' mainly winter and summer profiles are synonymous with fair weather and storm profiles. This classification gives more emphasis on dynamic state of wave energy and beach profile. In the morphology of the beach profile is almost infinitely variable. Most widely used are summer and winter profile (King1972, Boscom1964), storm and normal profile (Johnson, 1949) storm and swell profile (Komar, 1976).

As the first step towards a more quantitative classification of beaches, Australian scientists significantly adapt the approach of Sonu (1973) and Guza (1975). They identified successive morphodynamics stages in the process of adjustment between the completely dissipative and totally reflective extremes, by using surf scaling parameter,

$\epsilon = a_i w^2 / g \tan^2 \beta$ Where a_i is wave amplitude near breaker point

w = 2 pai / T Where T is wave period

g = acceleration due to gravity

β = beach or inshore slope (C.F. Guza and Bowen, 1975)

For total reflectivity Є must be < 1 where as highly dissipative waves have value of Є < 33 (C.F. Wright et. al., 1979).

Morphodynamics classification of beach stage (Bs) calculated by relationship between breaker height (Hb), wave height (T) and settling velocity of mean grain size in M/sec (Ws)

Bs = Hb / WsT

According to Wright and Short (1982), reflective beaches score values < 1, whereas dissipative beaches score < 6. According to Wright and Short (1983) the morphological parameters of selected beach profile locations are sample size, length of survey, (m) = model wave height, wave period, mean grain size, mean fall velocity (cm/sec), Hb / T Ws, sub aerial beach slope, model beach state (Short and Hesp, 1982), mean beach width, standard deviation of □b (shore line mobility index), □b (backshore mobility index), mean sub aerial beach volume, standard deviation (Short and Hesps, 1982), mean sub-aerial beach volume / mean beach width.

To study the relative exposure of beaches Mclachian (1980) proposed a different field method. He rates a number of easily determined parameters such as an estimate of maximum wave height, surface width, and percentage of very fine sand, median particles diameter, depth of reducing layer and the presence and absence of stable burrows. Estimated score range 01- 20, A score of 1 represents very sheltered beach type and a score 20 would suggest a very exposed beach. This approach does not provide a rational morphodynamics classification at the same time. This approach appears to be useful for descriptive alternatives in the absence of more quantitative, process related parameters.

In the Encyclopedia of Geomorphology beaches are classified into three basic types, namely dissipative, intermediate and reflective. The intermediate type has four states making a total of six beach states. These states were described morphologically by Short (1979 b), dynamically by Wright et.al. (1979).

1.4.1. Morphodynamics Beach Classification

In a comprehensive review of wave dominated coastal environment, Heward (1981) expresses an opinion that wave dominated beaches are those where wave action causes significant sediment transport. The morphology of wave dominated coast is characterized by elongate and shore parallel sediment bodies. A plot of breaker wave height versus sand size, together with wave period, can be used to determine the approximate beach state for wave-dominated beaches. To make use of the chart, the breaker wave height, period and grain size (mm) is determined. The wave height and sand size is noted, and then it is used to determine as to where the boundary of reflective/intermediate or intermediate/dissipative beaches lies. $\Omega = 1$ along solid T lines and 6 along dashed T lines. Below the solid lines $\Omega < 1$ and the beach is reflective; above the dashed lines $\Omega > 6$ and the beach is dissipative; between the solid and dashed lines Ω is between 1 and 6 and the beach is intermediate. ($\Omega = H_b / W_s T$ and is known as the dimensionless fall velocity).

Classification of Beach Type according to various studies is given below

1 = for medium fine sand beaches only   2 = Surf scaling (Guza and Inman 1975)

3 = from Short and Hesp 1982   4 = from Wright et. al. 1982 b

5 = from Sasaki et.al. 1976

1		2	3	4	5
Beach type	Beach state	Surf scaling	Hb	$HB/TbWS^5$	sasaki
Dissipative	Dissipative	>20	>2.5m	>6	Infra gravity
Intermediate	Bar through rhythmic barand beach	20 ↓	2 - 2.5	6 ↓	instability
	Transverse bars and rip		1.5 - 2		
	Ridge and runnel		~1.5		
	Low tide terrace	2.5	1 - 1.5	1	
Reflective	Reflective	< 2.5	< 1	< 1	Edge wave

(After Short and Wright, 1983)

A dissipative beach represents the high energy end of the beach spectrum. High energy, swell and storm waves with short period and abundant supply of fine sand is the necessary environment condition for development of these types of beaches. Such beaches occur in Northwest U.S.A., Southern Africa, Southern Australia and New Zealand coast where wave must exceed 2 to 3 m. for weeks to develop full dissipative beaches. Long gradient beach face, wide surf zone, and development of two or more shore parallel bars across the surf zone are the characteristics of these beaches.

Dominance of lower frequency swash and surf zone circulation, abundant supply of pure fine sand act to produce the low gradient of beach. Wave energy dissipated, across many bars and wide surf zone on the beach. This wave energy leads to the growth in the longer period infra gravity energy which acts as strong setup and set down at the shoreline. Generating a standing wave by the interaction of incoming and outgoing waves develops two or more nodes across the surf zone with vertically circulation of surf zones.

(After Wright and Short, 1982) (Flemming and Fricke, 1983)

Beach stage	Dynamic state	Wave energy	Beach profile	Morphodynamic Beach stage
1	strongly reflective	low (H<1 m)	steep but smooth	high berm with convex beach face
2				welded bar, often with ridge and runnel systems and beach cusps
3	intermediate			transverse bars, or anvil-shaped attached crescentic bars, low-tide terraces with irregularly spaced rip channels, incipient megacusps
4				transverse bars with evenly spaced rips or unattached crescentic bars, megacusps
5				transverse to linear bars with widely spaced rips, cusps
6	strongly dissipative	high (H >3 m)	gentle but rhythmic	single or multiple parallel bars, sometimes very widely spaced rips

With the wave setup, the wave's move shoreward towards the surface of water column and with the wave set down, bed return flow tends to concentrate toward bed. By simply widening the surf zone with increasing amplitude of the standing waves dissipative beaches accommodate high and higher waves. On the other hand periods of lower waves are often too short to permit substantial onshore sediment migration.

An intermediate beach is a condition of the beach between low energy reflective and high energy dissipative. Moderate to high waves with fine to medium sand is the environmental condition for the development of these beaches. Surf zone and cellular rip circulation associated with rhythmic bar and beach topography is the most distinguishing characteristics of this type of beach.

As a resultant of a wide range of wave climate, intermediate beaches consist of four beach states ranging from the lower energy low tide terrace to the rip dominated transverse bar and rip and rhythmic bar and beach. These beaches are controlled by process related wave dissipation across the surf zone, which transfer energy from incident waves. Incoming long waves are associated with wave grouping. Increase in energy and amplitude at the shore line as wave set up and set down, crest and trough respectively. Long wave then reflects the beach by produce a standing wave leading to an interaction between incoming and outgoing waves across the surf zone. This process causes for the high degree of spatial and temporal variation in intermediate beach morphodynamics.

A Reflective beach is the combined effect of lower waves with longer periods and transport coarser sandy material. The occurrence of these beaches on open swell coasts when the average to the wave is less than 0.5 m. Sediments are composed of coarser sand material including gravels and boulders even under higher waves. Concave upward nearshore is the dominant characteristics of reflective beach.

The high degree of incident wave reflection of the beach face is responsible for explain the beach. Beach cusp and swash circulation are two dimensional beaches with no longshore variation in morphology. Sandy beaches which represent the lower energy, responding to an increase in wave height, to induce a growth in swash energy and erosion of swash zone.

1.5. Review of Literature:

Literature review is a collection of research publication, books and other related documents to the defined problem. Available literature on the present study has been categorized and reviewed under following headings:

1. Morphology of beaches
2. Sedimentology of beaches
3. Morphodynamics of beaches
4. Geomorphic features related to beach morphology
5. Methods and models

Almeida, L. P. (2010), obtained the relationship between wave height and vertical profile variations in the study of morphological changes on an exposed sandy beach. According to him wave thresholds are important for morphological changes.

Pattern of vertical variability result shows cross shore sectors like berm, sub tidal terrace and long shore bar.

Angusamy, Nimalanathan and Rajamanickan G. Victor (2006), working on sediments for analysis of textural environment. To study the depositional environment of sediments along the southern coast of Tamil Nadu, India' researchers used different methods for the textural analysis of the sediments. The sediment samples collected in the field were mechanically sieved to get the proportion of particles in different size group. From this sediment parameters like mean size, standard deviation, skewness and kurtosis were determined. They applied bi-variate plots to classify beach environment. C-M pattern and Visher diagram were used to interpret mode of deposition of the sediment. According to the researchers variation in sediment parameters is governed by fluvial input, wave dynamics and littoral transport of sediments.

Angusamy, Nimalanathan and Rajamanickam G Victor (2007), to understand the coastal processes researchers worked on grain size of beach and dune sediments. Researchers collected 108 sediment samples from beach and dune zones. Folk and Ward method was applied to study the grain size composition and textural parameter. Bivariate plots were drawn from statistical parameters. Sahu's LDF technique was applied for the multivariate analysis of beach sediments.

Apoluceno, D. Demelo et. al. (2002), carried out investigation of foreshore through high resolution shoreline cartography and topographic surveys recorded during summer. The aim of the study is, to characterize long shore and cross shore morphodynamics, of ridge and runnel system and correlate with summer hydrodynamic conditions. Concluding part of the study explains three different evolution phases linked with formation of ridge and runnel system.

Bhat, M. S. et. al. (2003), studied the morphology and sediment movements at monthly interval for one year to understand sedimentation pattern in a monsoon influenced open beach at Gangavali. Researchers observed the erosion during monsoon and accretion during fair-weather season on beach as cyclic morphological changes, also calculated loss and gain of sediments along the beach over a year.

Bhattachrya, Ashokkumar (2003), assessed coastal modification in the low lying tropical coast of Northeast India and role of natural and artificial forcing. Researcher studied the 30 km coastal area in the low lying, meso-tidal tropical coast of Bay of Bengal. Since last few decades' beaches are facing erosion due to both natural forcing as well as human activities. Suggested some conservation measures like dune maintenance, dune creation and control over coastal water pollution have been suggested in the research article.

Dora, G. Udhaba, Sunilkumar V et. al. (2012), worked on Short term observation of beach dynamics using cross shore profiles and foreshore sediments. Researchers analyzed profiles and sediments to understand an annual cycle of beach dynamics at Devbag. By a monthly interval they monitored cross shore transects for two years along with collection of sediment samples. Calculations in this change in beach volume slope of beach and sedimentary characteristics of beach sand has been studied.

Glenn s. Visher (1969), emphasized the textural analysis, based on recognizing subpopulations within individual log normal grain size distribution which may be related to a different mode of sediment transport and deposition. According to them suspension, saltation and surface creep / rolling are the three modes of transport reflected by providing a measure of their importance in the genesis of sand unit. Researcher noted the impact of currents, swash and backwash, wave, tidal channel, fallout of suspension, turbidity current, aeolian dune processes are uniquely reflected in log probability curves of grain size distribution of sand and sandstone. There are some limitations of this study that comparing sand formed under comparable conditions and obtaining an independent determination of the processes of formation of ancient sands.

Godson, Prince, Chandrasekar N. (2014), studied the seasonal variability in sediment distribution along the south west coast of Tamilnadu, India. Researchers selected eight sandy beaches from Kanyakumari coast. Grain size analysis, LDF model, C-M pattern were used to express results.

Gould, Joseph and Vermette Stephen (2005), worked on characterizing the beach morphology. Researchers survey a subset of island beaches to characterize the beach morphology. The study explores the use of simple indicators like geographic position, offshore environment; beach rock and sand grain polish to link present beach morphology to ongoing processes of beach formation.

Hanamgond, P.T. and Chavadi, V.C. (1992) emphasized on, spatial distribution of sediments. Fine to very fine sand, very well to moderate sorted and strongly coarse skewed too strongly fine skewed were the grain size characteristics of the sediments in the study area. C-M diagram in the studies suggest beach represents low energy depositional environment and sediments are deposited by the mechanism of traction currents. To study the morphology of beach daily profiling was carried out. On the basis of these profiles the cut and fill tendency of beach were noted. By the waterline migration researchers confirmed the growth of beach. As a result they noted that as the tidal range increases the width of the intertidal zone also increases.

Imhansaloeva, Titocan mark (2011), determined grain size distribution and gradation coefficients and provided purview of the numerical assessments. The analysis showed that high currents and strong wave energy are responsible for the grain size distribution of the sediments. Reportedly deposited medium sand on berm and coarse sand on waterline indicate strong wave energy and capable of imminent coastal erosion.

Jackson, Nancy (2002), reviewed low energy sandy beaches in marine and estuarine environments, identified locations where low energy beaches may occur. Researcher suggest that the about low energy locations have non storm significant wave height are < 0.25 m, significant wave height during strong onshore winds are low < 0.50 m, narrow beach face width < 20 m and morphological features are inherited from higher energy events.

Kakinoki, T. et. al. (2011), studied the morphology and sedimentology of this sheltered beach. Researcher investigates how the wave action affects the mechanism of sediment transport due to diurnal water level changes. As an effect of tidal level fluctuation on low energy beaches affect the beach profiles. To understand the morphology and sedimentology they carried out measurements of bed profiles, sediment grain size and wave condition in the field. As a result they state that sediment sorting develops horizontally and vertically with the rise and fall of the tide, therefore grain size and porosity inside the bed change accordingly.

Karlekar, Shrikant (1993), in his edited book 'Coastal Geomorphology of Konkan' accesses the impact of wide ranging factors on the shoreline development of the Konkan. Most of the articles in the book are written by researchers in Coastal Geomorphology based on actual field investigation. Research articles of surf zone dynamics, suspended sediment particles, tidal land forms, sedimentology and morphodynamics as well as depositional dynamics along beaches of Konkan are studied. Coastal sand dunes, tidal inlet, sea caves, sea level fluctuation and mangrove swamps are also dealt with.

Karlekar, Shrikant (2009), book written 'Coastal Processes and Landforms'. Discusses coastal processes operate the importance of the Konkan coast of Maharashtra. This book deals with coastal processes like waves, tides, currents, sea level, beach rock etc. along Konkan coast, land forms associated with Konkan coast such as sandy beach, mud beach, sea cliffs, shoreline terraces, shore platform; coastal dunes sand bars, coastal geo-environment and its potential and problems. According to writer, this book provides a frame work from which one can understand nature of processes and landforms especially on the rocky west coast of India.

Mclachian (1980), study the relative exposure of beaches, researcher proposed different field method. He rates a number of easily determined parameters such as an estimate of maximum wave height, surface width, and percentage of very fine sand, median particles diameter, depth of reducing layer and the presence and absence of stable burrows. Estimated score range 01- 20, A score of 1 represents very sheltered beach type and a score 20 would suggest a very exposed beach. This approach does not provide a rational morphodynamics classification at same time. This approach appears to be useful for descriptive alternatives in the absence of more quantitative, process related parameters.

Mario, Pino, Eduardo, Jaramillo (1992), considered Morphology, texture and mineralogical composition of sandy beaches. Discuss the beach ordination results and the interrelationship among the fourteen variables like orientation, slope, textural parameters, porosity etc. are discussed in relation to sediment provenance and hydrodynamic factors which form the beach.

Mujabar, P.S. and Chandrasekar, N. (2013), studied the topographical and morphological analysis of beaches along the southern coastal Tamil Nadu by beach profile surveys. Obtained data are processed by software like 'BMAP' compile by 'CERC'. Some of the beaches show the tendencies of accretion and some show erosion. Wave climate influenced the sediment characteristics and dynamics of beaches. There are some suggestions about beach filling and nourishment to save the study area from coastal erosion.

Mwakumanya, Maarifa Ali et. al. expresses how the grain size distribution and the hydrodynamic conditions on the beach affects the spatial and temporal changes in beach morphology as well as shore line instability. Researcher determined morphological parameters such as beach orientation, beach width, and beach slope. Researcher calculates wave energy by wave height, velocity of swash and backwash was measured at high tide. Beach morphology showing rapid changes with time and mostly attributed to waves and sediment characteristics. Steep sloping beaches were associated with strong wave energy and deposition of coarser sediments and they are relatively small in width, whereas gently sloping beaches associated with fine grained sediment, well sorted and less wave energy conditions.

Mycielska-Dowgiallo, Elzbieta et. al. (2011), discussed alternative interpretation of grain-size data from Quaternary deposits. Researcher's emphasis on the cumulative curves at a probability scale and frequency curve to interpret the results of granule-metric analysis of quaternary deposits. These curves help to determine the sedimentary environment. It is possible to get information about the density and dynamics of a transporting medium from the cumulative curves.

Passaga, R (1964), Interprets the method of C-M diagram for presenting the results obtained from grain-size analysis. In a diagram, values of first percentile (C) are plotted against the medium (M). The C and M values may be presented in phi units. This diagram is particularly used to study fluvial and coastal deposits as both these sediments consist of different lithofacies that can be translated into depositional sub environments.

Preoteasa, Luminita and Stroe Alfred (2010), analyzed of the beach-dune sediments and the geomorphologic significance. Researchers gave detailed insight of textural parameters and established relationship between them. Researcher collected 139 sediment samples with this regard. They used multivariate statistical analysis was used to emphasize the relationship between textural parameters with morphology and distance up to a sediment source.

Prospathopoulos, A. M. et. al. (2004), based on measurements and numerical simulation studied the cross shore profiles, researcher analysis the sediment with the help of numerical simulation model (LITPACK- VERSION 2.7). Northern coast of the study area is under the severe erosion problem due to construction of craft shelter.

Ramanathan, Al. et. al. (2009), worked on Textural characteristics of the surface sediments of a tropical mangrove Sunderban ecosystem in India. In the respective study researcher observed the marked variation in riverine stretch. Textural character pattern is highly complex as a fluctuation in the physico-chemical condition. Dominance of fine sand shows existence of low energy condition. To understand depositional environment and process they applied LDF by Sahu and C-M pattern by Pasega.

Sahu, B.K. (1964), pointed out the variation in the energy and fluidity factors shows the excellent correlation with the different processes of environment of deposition of sediment. There is strong penchant to find out the total effect of the various parameters on the grain size variation in the beaches. Sahu deciphered the process and environment of deposition by linear discriminative function Y1 (aeolian/ beach) Y2 (beach/ shallow agitated) Y3 (shallow marine/ fluvial) and Y4 (fluvial/ turbidity). Values of mean grain size, sorting index, skewness and kurtosis is used by Sahu to states the different mathematical equation for above depositions.

Sedrati, M. et. al. (2009), presented detailed hydrodynamic and morphological data of micro tidal protected beach at northern Adriatic sea which experienced intense erosion. Formation of intertidal bar depends on tide modulated swash processes. According to him it is very difficult to correlate this kind of beaches with single hydrodynamic processes.

Short, A. D. (1991), classified three types of Microtidal beaches. Group one occurs in higher sea and swell waves environment it contains steep concave profiles with cusp formation and absences of ripple and bars. Group two is the ridge and runnel system having low intertidal slope occurs in low energy environment. Group three represents a transition from beach to tidal flat which occurs in low wave system.

Andrian Stanica and Viorel Gheorghe Ungureanis (2010), stated the basic theories regarding the morphology and sediment characteristics, especially about the beaches. The definition and classification of beaches, beach morphology and main zones of beaches is given in article. The relationship between wave energy, swash dimensions and angle, dynamics of beach sediments and how the human activities have significantly interfered with natural conditions and processes is discussed.

Turner, Robert (2005), correlate evolution of beach rock morphology and its influence on beach morphodynamics' elaborate the impact of exposed beach rock on the spatial and temporal morphodynamics changes on a beach. Beach processes influenced by the extent and morphology of expose beach rock formation. Researcher was identified five distinct stages in the life cycle and morphological evolution of beach rock.

CHAPTER II

STUDY AREA AND METHODOLOGY

2.1. Konkan

The coastline of Maharashtra on the west coast of India stretches for 720 km from river Damanganga to north and river Terekhol to south. The width of this coastline is not uniform. It is wider to the north as compared to the southern region; width varies between 40- 50 km all along the region. Mumbai, Thane, Dahanu, Raigad, Ratnagiri and Sindhudurg are the administrative divisions of coastal Maharashtra. Together this region is also well known as Konkan.

According to Karlekar (2009) on the basis of certain unifying characters such as lithology, geomorphic configuration, nature of hinterland and climate, Konkan can be divided in North Konkan, Middle Konkan and South Konkan. Coastal plains, shoreline terraces, sand dunes, sandy pocket beaches, tidal inlets, creeks and estuaries are the dominant features which show a great amount of variability from North to South.

On the basis of impact of tidal range and tidal incursion in spring and neap, Konkan can be divided in to various tidal regions (Table No. 2.1).

Table No. 2.1 Coastal Divisions of Konkan

Divisions → / Characteristics ↓	**Macrotidal coast**	**Mesotidal coast**	**Microtidal coast**
Spring tide range	> 3.5 m	3.5 – 2 m	< 2 m
Neap tide range	> 2 m	2 – 1.5 m	< 1.5 m
Limit of tidal incursion in tidal rivers	40 km	25 km	20 km
Coastal stretch	Dahanu To Revas	Revas To Ratnagiri	Ratnagiri To Redi

(Karlekar, 2009)

The processes along Konkan coast change with influence of variation in intensity and frequency, approach, height and persistence in the sea and tidal waves. Considering the wind direction and velocity there are definite trend observed from north to south. In the period of pre-monsoon on middle and southern Konkan the waves are westerly and experience wind speeds up to 5 to 11 knots, and north-westerly on northern coast with wind speed varying between 3 to 8 knots. In the period of monsoon, major part of Konkan coast is covered under westerly to south westerly waves with a speed exceeding 10 knots.

June to September (monsoon), October to May (fair weather) are the two distinct seasons that can be identified on the basis of wave height. In fair-weather wave height do not exceed 2 m with 10 to 12 seconds wave period, as against this, 5 m wave height are seen along south Konkan coast in monsoon season, with decrease in wave period between 3 to 6 seconds.

Effect of regular variation of the alternating southwest and northwest monsoon affect the weather of the Konkan coast. Months of December to March with northeast wind experience dry weather and little cloud cover is a relatively cool season. April and May are hot months when winds are light and variable with sea breezes on the coast. June to September is the season of southwest monsoon with southwesterly and westerly winds on the sea, experiences general rains. Rough or very rough seas occur during southwest monsoon. Moderate to heavy swell waves also persist along the coast in this season. October and November are marked by light winds. Occasional tropical cyclones may occur on Arabian Sea in this period.

Wave climate of Konkan also varies according to season (Table No. 2.2**)**. In monsoon from June to September experience high breakers of spilling and plunging type. Low surging or collapsing waves are the characteristics of breakers in fair-weather season along the Konkan coast.

Table No. 2.2 Waves and Currents

		Revas	**Ratnagiri**	**Redi**
Significant wave height (in meters)	Fair weather	1 to 2	1 to 2	1 to 1.5
	Monsoon period	3 to 3.5	4 to 4.7	4 to 5
Wave period (in seconds)	Fair weather	10 to 12	10 to 12	< 10
	Monsoon period	4 to 6	4 to 6	3 to 6
Tidal channel velocity (cm/second)		70 to 90	10 to 20	< 10

(Karlekar, 2009)

The Konkan coast experiences semidiurnal tides with the tidal range vary from less than 2 meters to more than 3.5 meters (Table No. 2.3); gradually increase from south to north. Along the south the tidal range is very less.

Table No. 2.3 Tidal Range

		Spring tide (m)	Neap tide (m)
Dhabhol	17°35' N / 73°11'E	2.7	1.6
Jaigad	17°18' N / 73°14'E	2.7	1.5
Ratnagiri	16°59' N / 73°18'.E	2.1	1.3

(Karlekar, 2009)

Various studies on sea levels of Konkan coast suggest that the sea attained its highest level around 3000 YBP. About 6000 YBP it was more or less at the level at which it is today. Between 6000 – 2000 YBP there was arising and it attained a level of 6 m ASL (Karlekar, 2009).

According to Karlekar (1996), the present coastal features along the Konkan coast have a legacy of ancient slightly higher sea levels around 3600 YBP and a slowly rising sea level since last 1000 years. A variety of morphological features and fossil sediments on Konkan coast of Maharashtra show transgression of sea in early Holocene, followed by a regression which was possibly interrupted by minor advance of sea level.

The modern sediments, beaches and dunes of the coast are backed by old fossilized beaches and dune terraces and cliffs. The fossil deposits are calcareous, sandy and shelly in nature and occupy varying topographical positions in the area. The fossil deposits on Konkan coast are variously termed as beach rock, aeolinite and karal. Their occurrence is patchy and frequently they are concealed under the modern coastal alluvium. Fossil beach and dune ridges can be located between 20 – 700 m from high tide limit. These rarely exceed 3.5 m ASL (Karlekar, 2009).

2.2. The Beaches of Konkan

Small sandy pocket beaches are the predominant geomorphic features along the Konkan coast. Sandy beaches are dominant, with some mud beaches like Revas and shingle beaches at Shekhadi. Seasonable changing specific wave and tide environment related to tidal range controlled the sediment characteristics and the morphodynamics of these beaches.

Along the Konkan coast wave environment is a prominent factor. It plays a dominant role, for variability of sandy beaches. These depositional faces are formed by waves, wave induced currents and associated flows.

Major sediment samples are well sorted and major differences in grain size reflects differences in wave energy levels. Along the beaches on the Konkan in monsoon, north end of the beaches experience high wave energy. There is clear shift of energy conditions from monsoon to post-monsoon season. Steep breakers with short wave period and adequate supply of sediment through rivers are the quantum of sediment in waves (Karlekar, 2009). Sedimentary deposits at ebb tide currents and erosion and cutting of beach at flood tide currents. Low flat swell waves during fair weather build up the berm or beach face and high steep storm waves in monsoon cut the beach face (Karlekar, 1997).

The sedimentary deposits along Konkan beaches are subjected to reworking every year by Aeolian, biological and coastal processes. In monsoon textural parameters shows sands are poorly sorted and positively skewed, leptokurtic in nature. Along the Konkan coast the subsurface sand on beaches shows poorly to moderately sorting index. In monsoon sandy beaches show maximum slope, is as high as 7^{o} to 11^{o}. The average beach slope in fair weather is less than 2^{o} to 3^{o} (Karlekar, 2009).

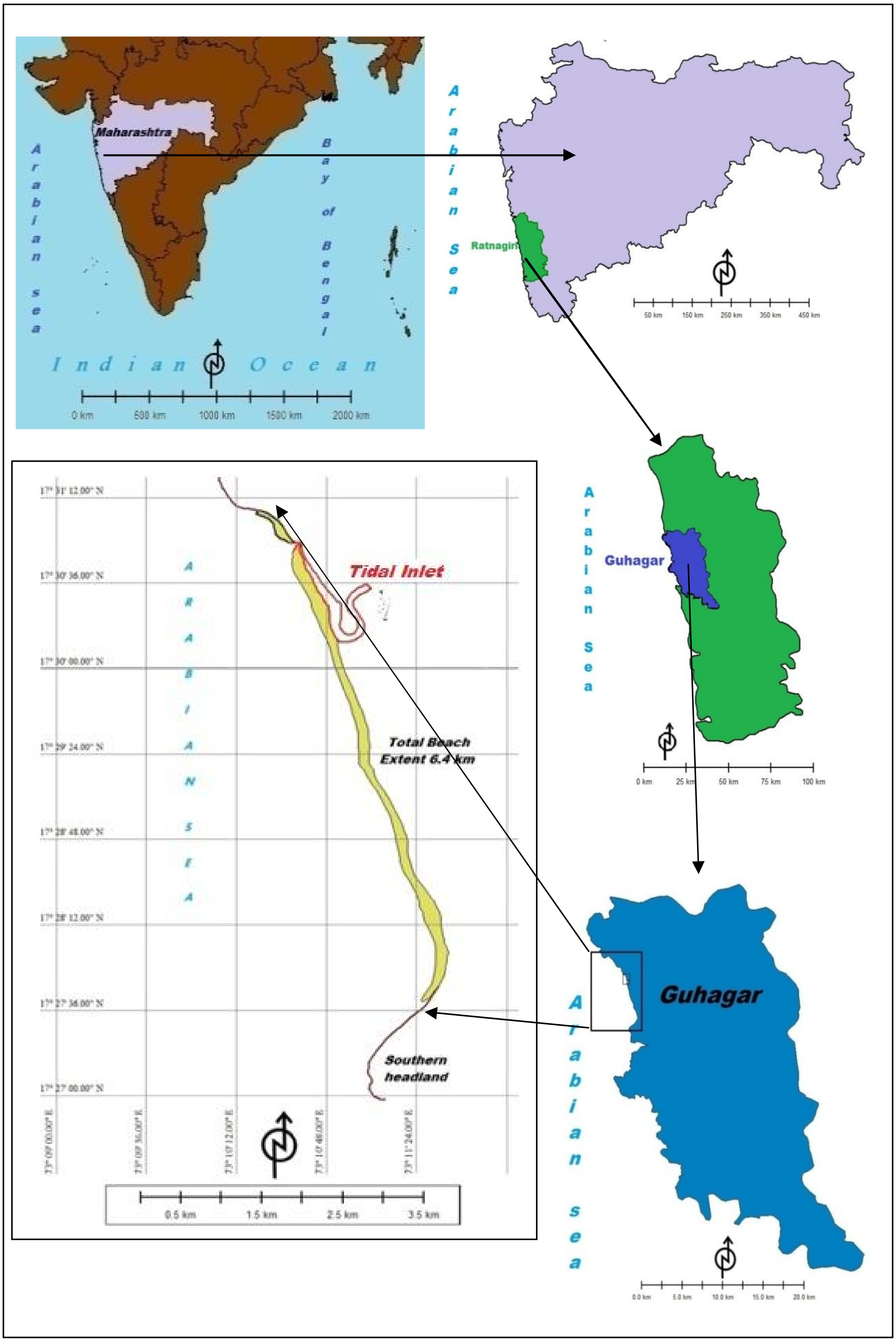
Sand dunes are a well marked and distinct feature of the coast. On the backside of many beaches primary dunes with characteristic wind ripples and parallel ridge of secondary dunes can be easily recognized. They are embryo dunes, fore dunes and back dunes. The dune zone assumes certain amount of significance only when there is formation of extensive dune system. The dune system at Diveagar, Kelshi, Mirya, Ubhadanda and Velaghar are typical examples of such formation.

2.3. Study Area

The beach at Guhagar is located on the west coast of Maharashtra in Ratnagiri district. The total length of beach is 6.44 km. The beach at Guhagar is located at 17^{o}28’48” N latitude and 73^{o}11’32” E longitude (Map No 2.1). Beach at Guhagar is a well known place of tourist attraction along the west coast of Maharashtra (Photo 1). The location of Guhagar is about 7 km south of Dhabhol. The nearest port is Jaigad about 20 km to south.

The beach at Guhagar is a pocket beach developed between two headlands. Northern headland is characterized by cliff with broad rocky platform and southern

Map No. 2.1 Location Map



Map No. 2.2 Toposheet and Google Earth Image

Toposheet 47-G/2, 47-G/3 **Google earth Image**

Scale 1: 50,000 **23rd May 2013**

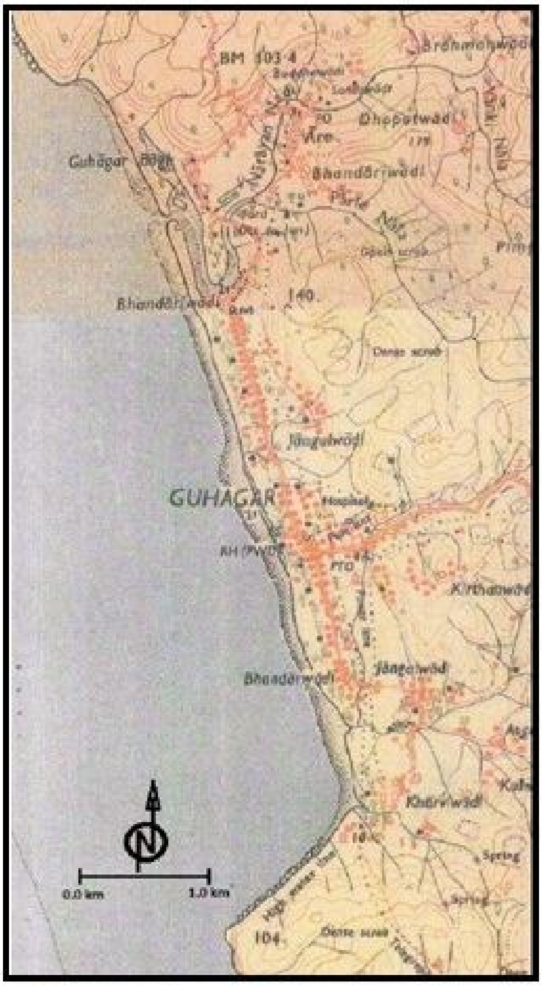
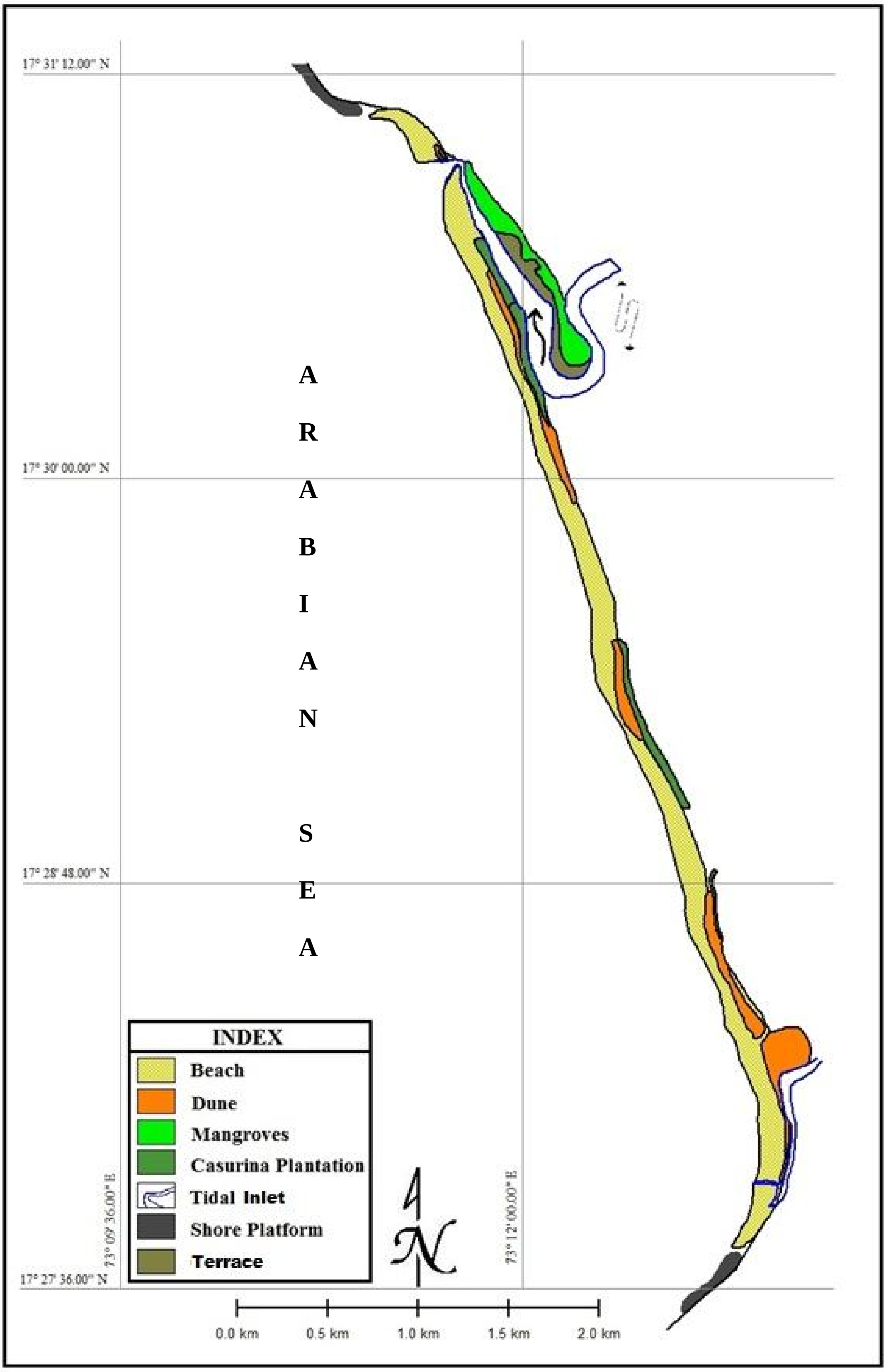


Photo 1 Aerial View of Guhagar Beach Facing North

Map No. 2.3 Geomorphic Map of the Study Area



headland with cliff and narrow rocky platforms is developed due to wave action. The beach is backed by hills which attain the height of 120 – 170 m. The alignment of beach is Northwest to Southeast. The study area is divided into two parts northern (in toposheet no. 47/G/2) and southern (in 47/G/3) (Map No. 2.2).

There is definite variation in the beach, which is clearly indicated by its width, length, micro features, beach gradient and sedimentation. The head lands on either side of the beach and the hills backing, the beach have created a water shed that drains the fresh water of the rains during the monsoon towards the sea. The water drains off into the sea through two tidal inlets, one towards the north and the other towards the south. A dominant non perennial stream drains in the northern section of Guhagar beach (total area 0.18 sq. km.). This tidal inlet runs parallel to the beach for a distance of 1.5 km (orientation south to north) demarcates the eastern limit of north section of beach. The tidal limit of this inlet is up to a distance of 2.20 km from the mouth, experiencing flooding and ebbing twice daily, with a tidal range of 2.5 m (Karlekar, 2009). Luxurious mangroves are seen along the eastern bank of tidal inlet. The mouth of tidal inlet is isolated, which separates the northern part of the beach.

At the southern end of the beach near Bhandariwadi a small shallow tidal inlet separates the southern part of the beach. A kharland bund has been recently built near the mouth of the inlet. The flow of tidal water from channel is restricted due to this bund. Anti erosion wall has been constructed to control the beach and dune erosion in the southern part of the beach.

Coastal sand dune runs parallel to the beach from northern end to southern part of the beach. The height and width of dune varies throughout the beach. Maximum height of the dune is 4.5 m in the middle part of the beach. The northern and southern parts show wider dunes as compared to the middle part of beach. Middle part is characterized by high foredune ridge parallel to the beach. (Map No. 2.3).

The study area experiences semidiurnal tides. The tidal range along the Guhagar area is 2.7 m at spring and 1.5 m – 1.6 m at neap near Jaigad and Dhabhol port respectively. The lowest tide level is only 1.3 m (recorded at Ratnagiri). South west monsoon are seasonal in the area. Storm surges are produced due to low atmospheric pressure and coincident with onshore. Seasonal change in climatic weather conditions and tidal range affects waves their intensity, frequency, approach and height. Together they influence the coastal processes along the study area. The winds are westerly and northwesterly in pre-monsoon period with the speed varying

3 – 7 knots. Monsoon is the period of westerly to southwesterly wind with a speed of 11 – 13 knots. Rough to very rough sea occurs during monsoon, moderate to heavy swell waves persist along the coast.

In the monsoon season the average wave height 1.03 m was observed with average wave period of 9.05 seconds. In post-monsoon season the average wave height 0.91 m was observed with average wave period of 12.20 seconds and in pre-monsoon the average wave height 0.93 m with average wave period of 10.63 seconds. The average maximum wave height 1.3 m was observed in the month of August and minimum 0.67 m in the month of January. The average wave period 14.1 seconds was observed in the month of February of pre-monsoon season and minimum 8.66 seconds in the month of August of monsoon season (Table No.3.22).

The prevailing winds are south westerly in monsoon and north westerly in fair weather (Karlekar, 2002). The wave height and wave period are maximum in monsoon season; shows average wave velocity 0.71 m/second. In post-monsoon season the sea is calm shows average wave velocity 0.51 m/second. In pre-monsoon the average wave velocity was 0.66 m/second was observed (Table No.3.22).

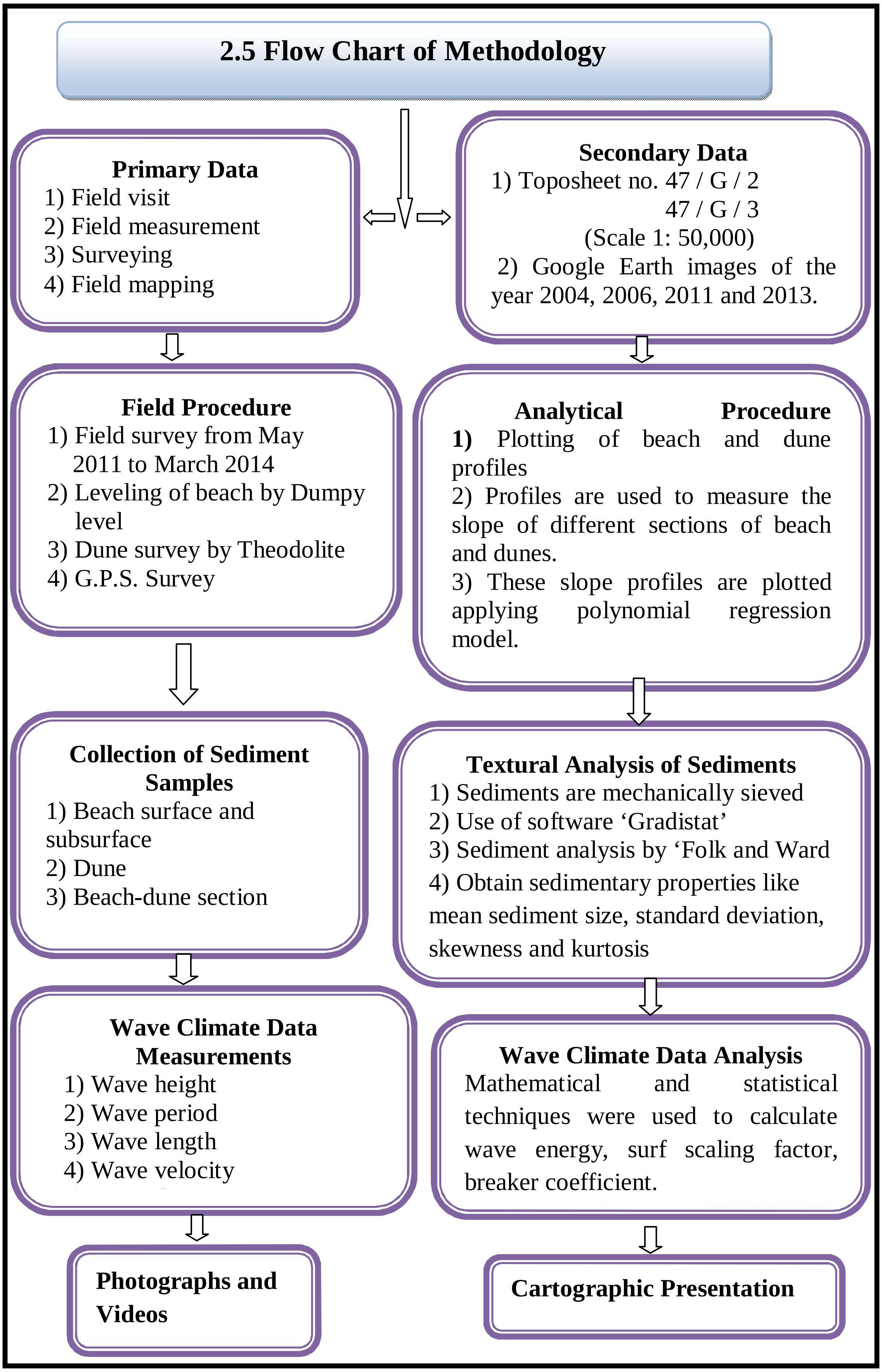
As there is no change in length of beach, the width changes seasonally. In monsoon the average width of the beach is 88 m. in post monsoon the average width of the beach is 114 m and in pre-monsoon the average width of the beach is 82 m as surveyed actually up to the line of water present at that time. In monsoon, beach at Guhagar show the average slope varying between 1.55 to 3.77 Degrees. The average slope in post-monsoon is 1.11 to 2.94 Degrees. The average slope in pre-monsoon is 1.26 to 2.80 Degrees.

In monsoon the textural parameters of surface sand shows that most of the sand is fine grained sand, moderate to moderately well sort sediment. In post monsoon sediments are fine grained, moderately to moderately well sorted sediments. In pre-monsoon season sediments are fine grained, well to moderately sorted.

2.4. Objectives of the study

The main objectives of the present study are

1. To evaluate and ascertain the spatio-temporal changes in beach morphology
2. To assess the nature and processes of sediment deposits on the beach


2.5 Flow Chart of Methodology
Primary Data
1) Field visit
2) Field measurement
3) Surveying
4) Field mapping
Secondary Data
1) Toposheet no. 47 / G / 2
47 / G / 3
(Scale 1: 50,000)
2) Google Earth images of the year 2004, 2006, 2011 and 2013.
Field Procedure
1) Field survey from May 2011 to March 2014
2) Leveling of beach by Dumpy level
3) Dune survey by Theodolite
4) G.P.S. Survey
Analytical Procedure
1) Plotting of beach and dune profiles
2) Profiles are used to measure the slope of different sections of beach and dunes.
3) These slope profiles are plotted applying polynomial regression model.
Collection of Sediment Samples
1) Beach surface and subsurface
2) Dune
3) Beach-dune section
Textural Analysis of Sediments
1) Sediments are mechanically sieved
2) Use of software 'Gradistat'
3) Sediment analysis by 'Folk and Ward
4) Obtain sedimentary properties like mean sediment size, standard deviation, skewness and kurtosis
Wave Climate Data Measurements
1) Wave height
2) Wave period
3) Wave length
4) Wave velocity
Wave Climate Data Analysis
Mathematical and statistical techniques were used to calculate wave energy, surf scaling factor, breaker coefficient.
Photographs and Videos
Cartographic Presentation

2.5 Methodology

The beaches on Konkan coast show the tendencies of cut and fill which changes seasonally. The study of morphology and sedimentology helps in understanding of such processes and factors involved in the coastal geomorphologic system. Here the area of research is a beach system located at Guhagar that is showing seasonally persistent tendency of cut and fill.

To study cut and fill tendency along Guhagar beach one needs to examine beach morphology, beach profile variability and beach stability. An attempt is made to study the spatio- temporal changes in beach morphology as well as to understand the nature and processes of sediment deposits on the beach.

The data sources used include a SOI toposheet 47G/2 and 47G/3 on scale 1: 50000 surveyed in 1952-53 and published in 1954. Google image of the year 2004, 2006, 2011 and 2013 were also used as data source. This type of study is purely geomorphic study. The major part of work comprised of field visits, field measurements, surveying and field mapping. The field and analytical procedure used in present study were selected keeping this view in mind. To study of morphological and sedimentary characteristics of beach at Guhagar a field survey was carried out regularly from May 2011 to March 2014 either in monsoon, pre-monsoon and post-monsoon season. Considering the specific environment, February to May is treated as pre-monsoon, June to September as monsoon and October to January as post-monsoon period on the coast.

The study requires actual leveling of beach profiles by using a leveling instrument like a dumpy level to understand morphological changes, and to determine the exact nature of the beach components like lower beach, upper beach, berm, and runnel and dune line. G.P.S. is used to locate way points. By considering mean sea level as 0m line, elevation at each way point was calculated.

In all twelve profiles were measured from north to south from which morphological and wave parameters were measured, along Guhagar beach perpendicular to shoreline. The whole length of the beach was studied by taking twelve profiles.

Temporary bench marks at fixed places especially on dune line was used as the horizontal control in terms of geographical location. These fixed points were referred as back sight levels for all leveling survey in each season. The relative heights were obtained along survey lines from these bench marks to the low tide level at the time of observations. These were then plotted to get the east west profiles running across the beach. The contour maps showing beach levels were prepared in the surfer environment.

The dunes were studied in detail, surveyed by tachometry method by using Theodolite. A complete survey was carried out along all twelve profiles which cover dune complex. Height from the base of the dune and inclination of the sedimentary out crop was noted. The characteristics and properties of the sections were also studied and recorded.

Beach and dune profiles of the Guhagar beach over a period of one year were used to measure the slope of different sections of beach and dunes. These slope profiles were plotted and polynomial regression model was applied. In order to understand this relationship, bivariate simple regression technique is used. Polynomial regression model at 5^{th} order is best fitted to explain the relationship. The algorithm is based on a least-squares criterion and singular value decomposition, with mean and variance standardization for improved numerical stability. R^2 is the coefficient of determination, or proportion of variance explained by the model is used in the interpretation of annual beach, dune and beach-dune profiles.

In order to study the morphology, sedimentology and Stratigraphy of the beach dune section field and analytical procedure were selected. The study therefore required instrument like measuring tape, GPS, to obtain location, elevation, width of the section. To understand the morphology of each section depth of the section was measured with measuring tape. Width of each section is measure with scale in centimeters.

A dumpy level of the cross profile along the inlet at selected site was carried out with the additional aid of GPS. A detailed mapping of the geomorphic features along the tidal inlet was undertaken which was used to prepare a Geomorphic sketch. Overlays of the toposheet, surveyed by Survey of India in the year 1952-53, and published in 1954 of the Ratnagiri district on 1:50,000 scale (Index No. 47-G/2), various Google images of inlet 2004, 2006, 2011 and 2013 respectively were used to prepare the map for comparative position of northern tidal inlet.

The boundary of shore platform is demarked by GPS locations. Different layers of cliff were observed. Cliff height and their width are measured by measuring tape. In the northern section of the beach, along the tidal channel thick mangroves are observed.

To understand the sedimentary environment and sedimentological characteristics of beach and dune and subsurface, sediment samples were collected from different locations to represent the beach by methods of hand sampling. The subsurface sediment samples were collected at the depth of 20 – 40 cm from surface. Fifteen sediment samples were collected from each horizontal layer of beach-dune section.

The sediment samples collected from beach (surface), subsurface, dune system and beach-dune section were dried and mechanically sieved, to get the proportion of particles in different size groups. Central tendencies like mean and median and parameters of the grain size distribution such as sorting index, skewness, and kurtosis were obtained using software “Gradistat”, and applying Folk and Ward method. To determine the amount of clastic and non-clastic sediments by taking 30 grams of sediment samples were reacted with concentrated hydrochloric acid. After the reaction of hydrochloric acid, the calcareous material is dissolved. The non calcareous material after reaction was washed by distilled water, dried and weighed. For understanding of sedimentary properties scatter plots, veriogram, isoline maps were prepared.

A scatter plot can suggest various kinds of correlations between variables with a certain confidence interval. Correlations may be positive (rising), negative (falling), or null (uncorrelated). If the pattern of the dots slopes from upper left to lower right it suggests the negative correlation. The line of best fit (trend line) can be drawn in order to study the correlation between the variables can be determined by established best fit procedure. For a linear correlation, the best fit procedure is known as linear regression and is guaranteed to generate a correct solution for arbitrary relationships. A scatter plot is also very useful to see how two comparable data sets agree with each other.

One of the most powerful aspects of scatter plot, however, its ability to show nonlinear relationship between variables. Furthermore if the data are represented by a mixture model of simple relationship, this relationship will be visually evident as superimpose patterns. Textural parameters of beach sediments like mean sediment size, sorting index, skewness and kurtosis are considered as variables and their relationships were tested by scatter plot.

The Variogram is the measure of how quickly things change on the average. The underlying principle is that, on an average, two observations closer together are more similar than two observations further apart. Because the underlying process of the data often has preferred orientation, values may change more quickly in one direction than another. As such Variogram is function of direction. The spatial change in textural properties of the beach sediment characteristics are analyzed by applying Variogram techniques.

The variations in the energy and fluidity factors seem to have excellent correlation with the different processes and the environment of deposition. The process and environment of deposition has been deciphered by Sahu's Linear Discriminant Functions of Y1 (aeolian, beach littoral (intertidal) environments), Y2 (Beach, shallow agitated water), Y3 (shallow marine, fluvial) and Y4 (fluvial, turbidity disturb). The said Discriminant relation can be brought out between Aeolian, beach and shallow Marine environment based on mean, standard deviation, skewness and kurtosis.

In order to study the wave climate data, wave height, wave length, wave period, wave velocity and direction of drift were covered by taking actual measurements in the breaker and surf zone. The height of waves measured with the help of 4 m graduated staff. The distance between two consecutive waves and length of the breaker zone was measured using a measuring tape.

The movement of material along the length of the beach as a result of, wave breaking at an oblique angle to the shore is longshore drift. Longshore drift was measured with the help of Flurocant Dye. The dye 'Rhodamin B' was used to measure the velocity and direction of the drift. The data obtained in the field was analyzed in the laboratory and were plotted cartographically. The mathematical and statistical techniques were used to calculate surf scaling factor, wave energy and breaker coefficient.

On the basis of data obtained during fieldwork and data of laboratory analysis were used to understand the nature of change in the morphological and sedimentological processes of Guhagar beach.

Field observations are recorded photographically.

CHAPTER III

MORPHOLOGY OF BEACH AND DUNE

3.1. Introduction

The sea beaches are most unlikely landforms to be found facing the open sea (Pethick, 1984). The morphology of the beach profile is almost infinitely variable within the spatial limits. The important morphological feature of beach profile is their overall gradient: that is average slope between seaward and landward limits. An observation of a single beach over a time period of a year shows that this gradient varies between two extremes. Profiles are either steep or shallow (Pethick 1984).

The dune system acts independently of the beach. Dunes represent sand reserves from which material can be borrowed (by erosion) under extreme conditions to reshape near shore, with return of those sand volumes during ambient conditions. Erosion and scarping of dunes by waves begin a cycle from which the dune recovers when it has achieved a stable slope and becomes vegetated (Woodroffe, 2002).

There is definite seasonal change on the beach at Guhagar; it is clearly indicated by its width and gradient. A sea beach is subject to the variety of influence acting at different scale of space and time. Beaches show dynamic response to variation in natural hydraulic conditions.

Slope is the angle of the beach gradient is h/d or tan slope. The average slope or gradient of the foreshore (mean low water to mean high water) is used to define whether the beach is either steep (11º) or shallow (5º). Beach and dune profiles of the Guhagar beach over a period of one year are used to measure the slope of different sections of the beach and dunes. These slope profiles are plotted and polynomial regression model is applied to understand the relationship between down beach distance and slope. A polynomial of upto the fifth order is fitted to the data. The algorithm is based on a least-squares criterion and singular value decomposition, with mean and variance standardization for improved numerical stability. R^2 is the coefficient of determination, or proportion of variance explained by the model is used in the interpretation of annual beach, dune and beach-dune profiles.

3.1.1. Morphological Characteristics of Beach- Dune

To study the morphological characteristics of beach- dune at Guhagar, field survey was carried throughout the year 2012 to 2013. The months of July, August, September as monsoon, October, November, December, January as post-monsoon and February, march, April, May as a pre-monsoon season. Twelve Profiles from north to south were selected along beach, perpendicular to shoreline (Figure No. 3). The horizontal control in terms of geographical co-ordinates was selected as permanent bench mark at fixed places on the dune line and used as back sight points. Vertical heights were obtained along the survey lines using dumpy level. GPS was used to locate way points. These were plotted to get East-West profiles running across the beach. Seasonal variation in beach morphology shows variation in morphological characteristics on Guhagar beach.

3.2. Morphological Characteristics of Beach

Table No. 3.1. Annual Average Beach Profiles Width (in meters)

	Northern beach	Middle beach	Southern beach	**Average width**
pre-monsoon	81.9	98.52	89.06	**89.82**
monsoon	70.5	109.92	86.25	**88.89**
post-monsoon	103.56	117.75	120.31	**113.88**
Average Width	**85.31**	**109.81**	**98.34**	

The average width of the beach in northern sector is 85.31 m. which is always less than the average width of the beach in different seasons. This indicates that the northern part of the beach shows narrow width throughout the year.

Middle and southern sectors of the beach having average width of 109.85 m. and 98.34 m. respectively shows higher width in pre-monsoon and monsoon period as compared to average width of the beach in a particular season. The average width of the beach in post monsoon season is greater than the width of the beach at middle sector (Table No. 3.1).

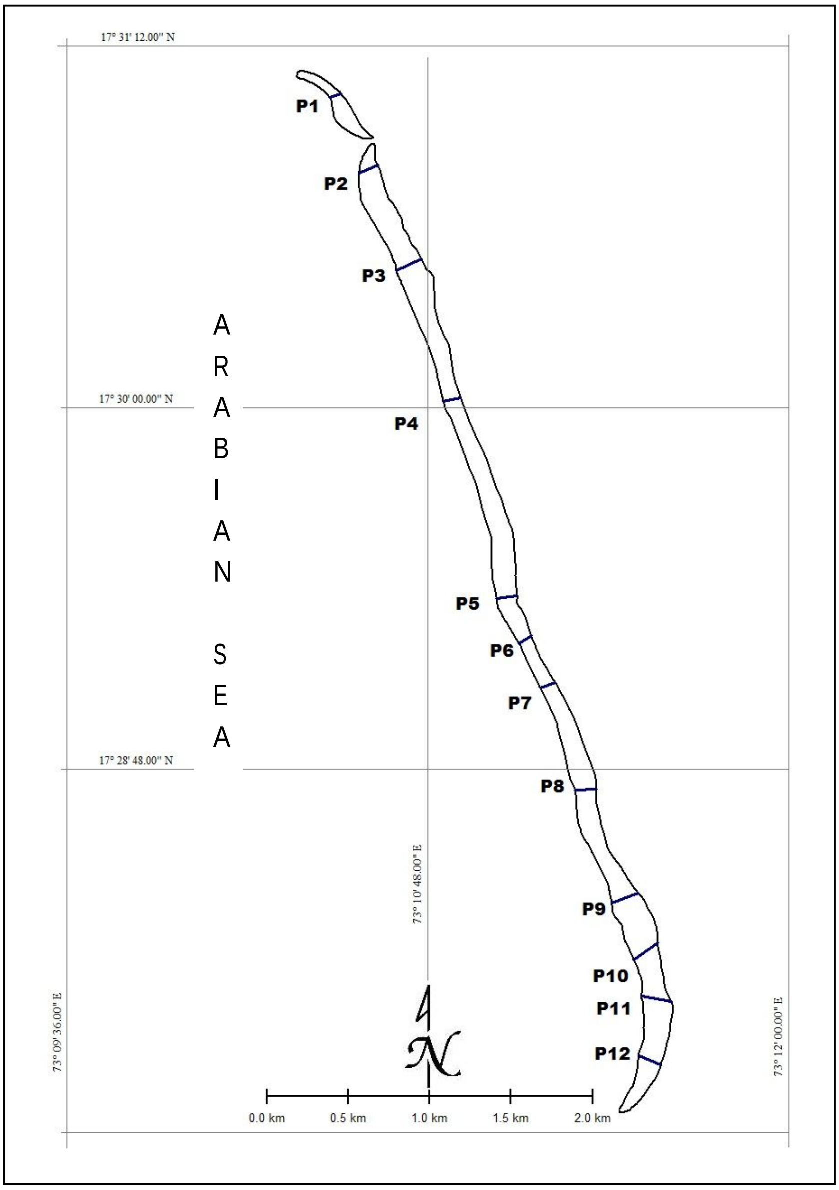
3.2.1. Beach Morphology in Monsoon

To understand the exact nature of the beach component, dumpy level survey was carried out in the month of July 2013 (Table No. 3.2 A and B), August 2013 (Table No. 3.3 A and B), and September 2013 (Table No.3.4 A and B) to understand the morphological characteristics in monsoon season.

It was tried to cover the whole beach by twelve beach sights selected from north to south. On an average the beach at Guhagar was observed to be very narrow in this season. In monsoon season the waves are forceful, heights of breakers were maximum and swash, backwash was strong. Due to the cumulative effect of wave climate the beach became narrow and concave. In monsoon beach at Guhagar show definite variation in width from north to south.

At the northern section near Guhagarbaug and at the southern section near Bhandariwadi the beach was comparatively narrow as compare to the middle section beach. On an average the width of the beach at northern section was 56 m, 54 m and 101 m in the month of July 2013, August 2013 and September 2013 respectively (Figure No. 3.1 A). The middle section shows 93 m, 98.5 m, 138 m width (Figure No. 3.1 B) and the southern section of beach shows 60 m, 86.75 m, 108 m width in the above respective months (Figure No. 3.1 C) of monsoon season. Average width of the beach in monsoon season is 88 m. As the monsoon passes, variation in width is observed along the beach at Guhagar.

Figure No. 3 Location of Profiles on the Beach at Guhagar



All the profiles on the beach, except profile no 7 shows increasing trend of width in monsoon. The average width of the beach increases by 46.33 m. Beach profiles give an idea about the morphology of the beach in monsoon season. Major part of beach is under the influence of stormy waves (Photo No.3). Especially the northern section is under direct influence of westerly shows considerable feeling in the month of August. Lowering of beach in the month of September by 1 m to 3 m was observed; indicate the tendency of erosion / cutting from profile no. 1 to profile no. 7 (Photo No. 2). Compared to the northern and middle section the southern section of beach have gentle slope as it shows the tendency of accretion / filling in all respective months of monsoon season from profile nos. 8 to profile no. 11(Figure No. 3.1 C).

The beach profiles in monsoon season are comparatively concave in nature and no distinct upper and lower beach section is observed. Beach profiles shows horizontal migration of berm to the landward side and vary from place to place.
(Figure No. 3.1.A, B).

Monthly variation in beach profiles show that, from July to August profile 1 to 4 (northern part), 7 to 11 (southern part) show filling tendencies (Photo No. 4) and profile nos. 5, 6 (middle part) and profile no. 12 (southern part) show cutting tendencies. The material transported by northern tidal inlet in monsoon is restricted in northern part of the beach. Due to strong westerly waves with maximum wave energy responsible for deposition of sediments at the northern part of the beach (profile 1 to 4). The tidal inlets from middle and southern part of the beach also carry sediments in the monsoon and are responsible for depositional tendency in southern part of the beach in August. The middle part of the beach is slightly projected seaward shows cutting tendency in August and September and shows the exposed rocks on the beach (Photo No. 5).

The overall pattern of cutting and filling of beach changes from August to September. Profile nos. 1 to 4 shows cutting tendency (Figure 3.1 A). Profile nos. 5 to 12 shows filling tendencies (Figure Nos. 3.1 B, C) as the effect of decrease in wave energy and comparatively decrease in amount of sediments from tidal inlets. Due to strong westerly monsoon winds, dune width and height is considerably decreased in the northern section. It retreats from 0.97 to 1.5 m towards landward due to strong monsoon waves.

Photo 1 High Beach Gradient in Monsoon at Northern Sector Facing South

Photo 2 Strong Wave in the Monsoon Environment

Table No. 3.2 (A) Beach Width and Height in July along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
11.2	-0.41	2.6	0.19	14	0.4	14.3	-0.35	3	-0.81	15	1.8
21.3	-0.86	4.6	0.64	32	0.43	19.7	-1.14	7.04	-2.23	20.8	1.71
37.6	-1.46	8.8	0.92	45.3	0.6	25.6	-1.77	11.64	-2.75	26.4	1.51
59.3	-2.08	14.8	1.14	54.3	1.03	31.9	-2.35	27.14	-3.65	33.2	-0.03
80.3	-2.65	25.4	1.51	59.1	1.57	41.1	-3.09	47.64	-4.23	45.7	-1.05
		39.1	1.92	62.3	1.06	51.5	-3.68	54.94	-4.6	61.5	-1.84
		43.2	1.87	68.3	0.22	63.7	-4.24	74.74	-5.15	83.3	-2.56
		52.9	1.13	76.1	-0.58	76.7	-4.29	89.14	-5.38	100.7	-2.99
		66.5	0.44	86.7	-1.28					119.6	-3.22
		81.3	-0.39	97.2	-1.78						
				108.2	-2.27						

(Continued)

Table No. 3.2 (B) Beach Width and Height in July along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
20	-0.9	8	-0.19	18.6	0.28	43.7	-0.23	6.7	-1.71	5.30	0.13
36	-1.05	12.3	0.3	33.7	0.49	83.8	0.87	11.7	-1.96	7.8	0.52
38.4	-1.1	15.2	0.09	46.2	0.73	103.8	1.47	18	-1.48	14.9	0.3
46.5	-1.72	20.2	-1.32	55.2	1.49	115.3	1.59	36.3	-1.37	43.6	-0.8
57.1	-2.3	30.7	-1.55	60	2.16	120.7	1.91	53.1	-1.36	73.8	-1.2
87.7	-3	39.1	-2.08	63.5	0.53	131	0.88	72.3	-1.53		
116	-3.5	52.8	-2.81	73.15	-0.44	139.3	0.09	91.9	-1.84		
139.9	-3.7	68.8	-3.49	86.85	-1.4	155.9	-1.11	106.1	-1.91		
		78.8	-3.73	102.65	-2.09	174.1	-1.83	137.9	-2.7		
		84.8	-3.85	117.45	-2.51	187.1	-2.01	151.2	-2.75		
				128.35	-2.71						

Table No. 3.3 (A) Beach Width and Height in August along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
5	-0.32	4.3	0.76	14.1	0.81	7.8	-0.55	8.2	-0.6	14	1.39
12.28	-0.65	7.3	1.94	26.9	0.67	13.9	-0.32	11.4	-1.26	22.4	1.45
16.98	-0.85	15.4	2.28	38.25	0.72	16.4	-0.62	13.2	-2.8	27.1	0.94
21.48	-1.03	29.5	2.58	50.15	1.16	19	-1.05	20.8	-3.3	31.4	0.15
28.38	-0.94	42.7	2.89	52.55	1.3	23.6	-1.57	31	-3.68	33.5	-0.77
35.08	-0.87	56.7	3.16	55.75	1.92	29	-2.01	42	-4.19	42.3	-1.4
44.98	-1.28	61.4	3.12	61.25	0.99	34.85	-2.32	51.2	-4.61	50.3	-1.9
52.78	-1.8	71.3	2.97	68	0.07	41.5	-2.68	67.1	-5.15	63.2	-2.55
61.48	-2.52	79.1	2.42	77.8	-0.66	49.35	-3.07	82.95	-5.46	72.7	-2.93
66.48	-3	84.6	1.87	88.4	-1.22	58.95	-3.45	97.4	-5.62	90.1	-3.32
		90.3	0.65	99	-1.81	65.75	-3.8	115.5	-5.64	107.3	-3.51
		100	0.47	116.6	-2.66	72.35	-4.08	125.8	-5.75	128.9	-3.88
		109.5	0.14								
		118.6	-0.38								

(Continued)

Table No. 3.3 (B) Beach Width and Height in August along Profiles (Profiles 7to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
21.15	-0.37	16.75	-0.52	41	0.57	59.2	1.02	15.9	-1.8	18	-1.87
26.65	-0.62	19.5	-1.32	50	0.63	77.3	1.26	19.15	-2.1	28.1	-2.6
32.05	-0.87	26.1	-1.86	53.8	1.12	94.4	1.81	21.6	-1.47	33.55	-2.79
39.35	-1.18	35.7	-2.36	59.7	2.08	112.05	2.1	36.2	-1.3	39.3	-2.81
47.8	-1.57	48.8	-2.8	61.3	1.33	117.45	2.38	47.2	-1.29	45.5	-2.51
57.8	-1.84	67.2	-3.4	62.95	0.17	127.25	1.91	63.2	-1.43	60.2	-2.5
72.3	-2.1	88.3	-3.95	70.65	-0.44	135.05	1.08	81.9	-1.8	74.4	-2.41
91.3	-2.32	110.2	-4.42	79.95	-0.85	139.85	0.42	100.1	-2.24	94.8	-2.65
		122.7	-4.47	88.35	-1.23	147.55	-0.28	116.3	-2.63	124.3	-3.05
				97	-1.64	157.65	-1.07	133.6	-2.91	133.4	-3.28
				114.2	-2.35	183.35	-1.59	148.8	-2.78		
				130.2	-2.64	195.35	-1.69	170	-3.08		
				149.6	-2.94			198.9	-4.05		
				159	-2.99						

Table No. 3.4 (A) Beach Width and Height in September along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
10	-0.02	14.25	0.31	14.25	0.31	9.7	-0.51	3.9	-0.47	13.3	1.51
14.9	0.13	30.85	0.67	30.85	0.67	13.8	-0.32	8.1	-1.76	16.3	1.44
18.2	0.09	38.05	0.76	38.05	0.76	18.7	-1.07	14.1	-3.93	20.8	1.41
23.6	-0.45	42.25	0.68	42.25	0.68	23.8	-1.74	38.7	-3.37	26	1.45
28.85	-0.88	52.05	0.56	52.05	0.56	34.1	-2.24	57.35	-5.07	28.1	0.46
46	-1.94	61.55	-0.01	61.55	-0.01	42.1	-2.73	76.45	-5.42	31.85	0.02
59	-2.33	74.95	-1.13	74.95	-1.13	60.4	-4.15	96.15	-5.58	33.85	-0.63
76.7	-2.73	95.65	-1.97	95.65	-1.97	78.1	-4.69	111.35	-5.61	38.5	-1.03
97.3	-3.26	120.75	-2.47	120.75	-2.47	98.7	-5.07	131.85	-5.64	45.4	-1.25
111.9	-3.28	140.45	-2.84	140.45	-2.84	112.2	-5.38	141.45	-5.81	55.1	-1.55
124.7	-3.41			123.1	-2.39	121.4	-5.61			64.2	-2.02
135.7	-3.49			137.5	-2.63					76.65	-2.4
				149.6	-2.89					105.4	-2.85
										121.1	-2.95
										136.9	-3.08
										142.2	-3.14
										177.35	-3.54
										198.65	-3.91

Table No. 3.4 (B) Beach Width and Height in September along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
9.5	-0.73	6.6	-0.16	15.6	0.45	30	-0.07	10.4	-1.66	11.5	-1.08
17.1	-1.04	9.6	0.08	23.95	0.07	60	0.43	19.8	-2.63	27.5	-1.27
22	-1.13	11.8	0.29	38.75	0.88	90	1.11	27.7	-3	33.9	-1.28
23.7	-1.2	17.4	-0.5	53.95	1	105	1.45	32.3	-2.88	40.25	-1.06
31.4	-1.3	24.35	-1.64	57.75	1.77	127.9	2.08	39.85	-1.84	77.95	-1.43
39.4	-1.58	43.65	-2.08	62.95	0.51	136.5	1.23	52.4	-1.49	90.35	-1.77
45.9	-1.92	51.25	-2.26	78.75	-0.43	154.1	-0.24	64.55	-1.44	101.65	-2.04
53.5	-2.24	65.3	-1.92	95.4	-0.63	168.9	-1	74.9	-1.46	115.15	-2.06
66.7	-2.49	80.65	-2.41	111.1	-1.08	202.5	-1.47	104.4	-2.12		
78	-2.68	91.05	-3.45	134.6	-2.33	223.5	-2.22	133.3	-2.73		
90.5	-2.86			150.75	-2.63	239.4	-2.42	155.2	-2.57		
107.1	-3			177.9	-2.93			186.2	-3.34		
121.9	-3.12							207	-3.01		
								223.05	-3.27		
								233.35	-3.47		
								246.65	-3.69		

Figure No. 3.1. (A) Comparative Beach Level Profiles (1 to 4) - Monsoon

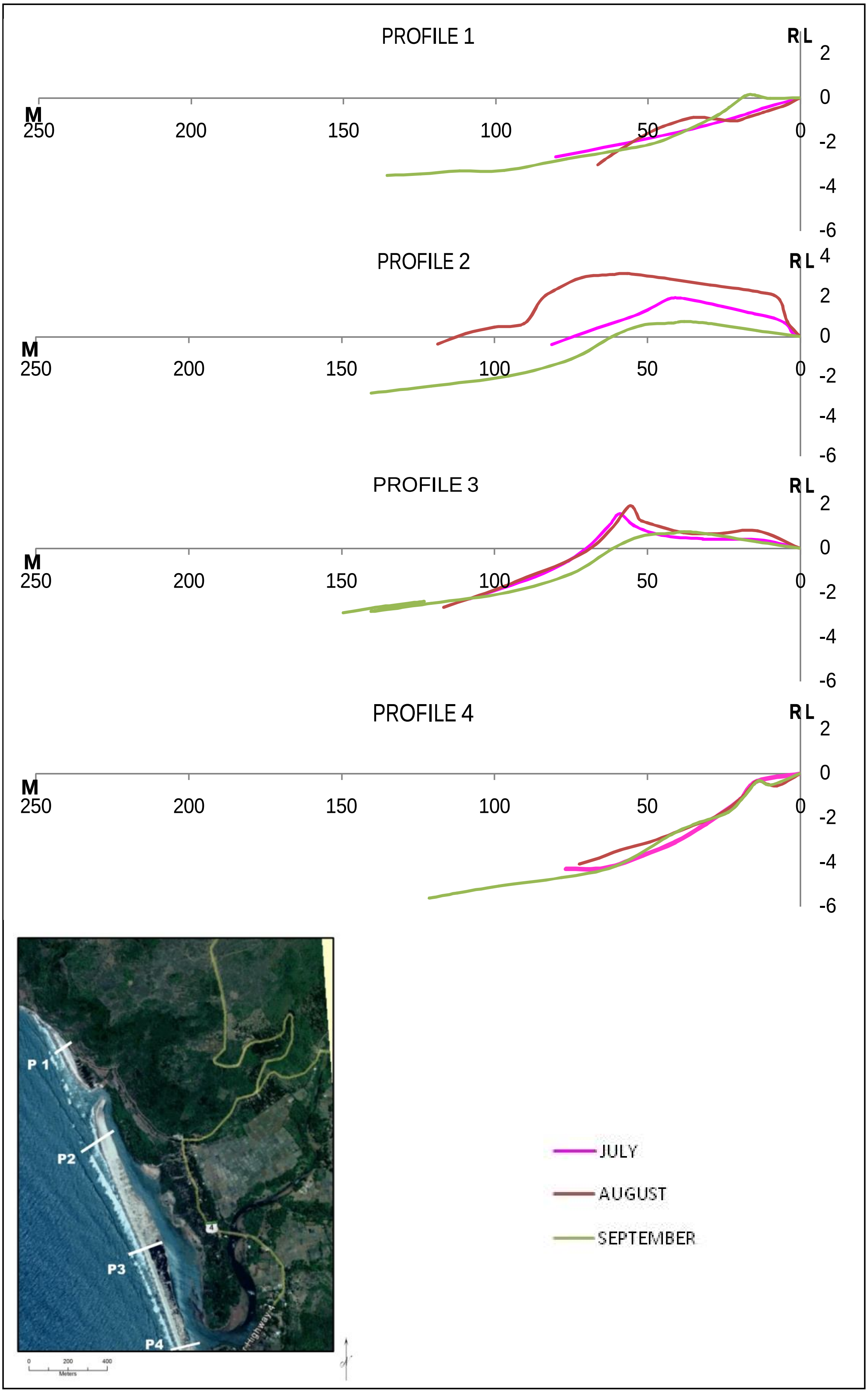


Figure No. 3.1. (B) Comparative Beach Level Profiles (5 to 8) – Monsoon

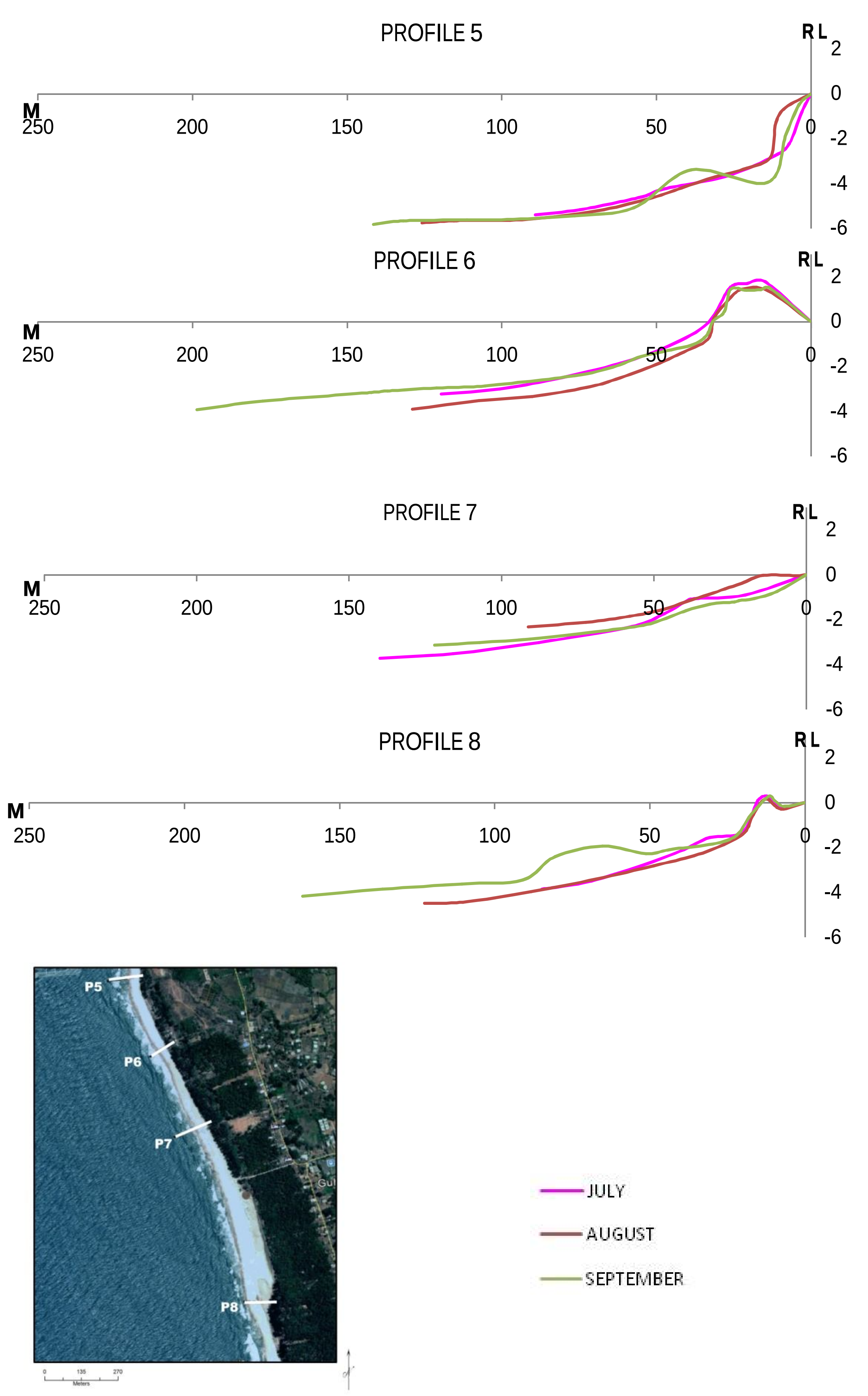


Figure No. 3.1. (C) Comparative Beach Level Profiles (9 to 12) - Monsoon

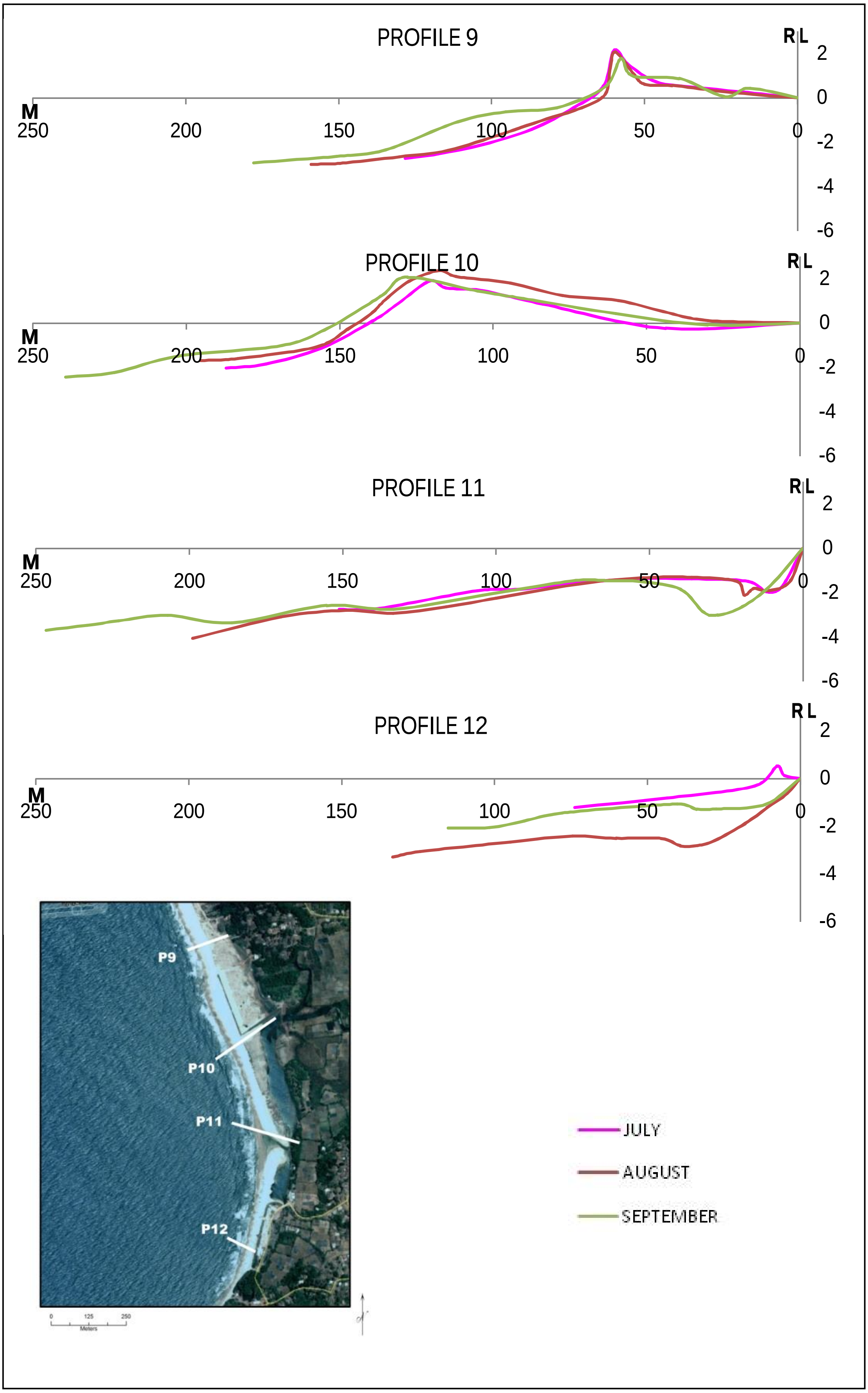


Photo 4 Narrow Beach with Waste Material

Photo 5 Rock exposures on the Beach in September at Middle Sector

3.2.2. Beach Morphology in Post-Monsoon

The beach level profiles in October 2012 (Table No. 3.5 A, B), November 2012 (Table No. 3.6 A, B), December 2012 (Table No. 3.7 A, B), and January 2013 (Table No. 3.8 A, B) shows the morphology of Guhagar beach in the post-monsoon season. This season shows a significant increase in width of the beach (Photo No. 6). On an average the northern section of beach increases by 30 m, the middle and southern section of beach by 20 m and 40 m respectively than that of the monsoon season.

In this season a definite trend was observed on beach, that in the progression of post-monsoon season the width of the beach decreasing in all three sections of beach from October to January. The average width of the beach at northern section 116 m, 92 m, 119 m, and 87 m in the month of October, November, December, and January respectively (Figure No.3.2 A). The middle section 155 m, 129 m, 101 m, 87 m (Figure No. 3.2 B) and the southern section shows 170 m, 104m, 102m, 107m width (Figure No. 3.2 C) in above respective months.

October to November beach profiles show cutting and filling tendency all over the beach but in December filling tendency is more common in each part of beach. It shows settling of post-monsoon conditions in the study area. December to January profiles again show cut and fill tendency all over the beach. Post monsoon season profiles show more dynamics in beach profile where, monthly variations are observed on upper as well as lower beach section. This season shows variation in cutting and filling tendencies on the Beach. From October to January decreasing beach width is responsible for beach and dune building processes. As the concavity of the beach is removed the profiles show the gentle slope compare to monsoon season (Figure Nos. 3.2 A, B, C), (Photo No.7). Depressions like hollows were observed on the beach at the middle part of beach (Photo No.8).

Post-monsoon season shows the definite change in wave climate condition. Decrease in wave height, increase in wave length and wave period, decrease in wave velocity and breaker zone retreat from coast line cumulative effect shows a significant decrease in effect of wave energy on the beach morphology (Table No.3.22). Due to this the beach at Guhagar in the post-monsoon gets exposed and becomes wider than the monsoon season. The features like berm, beach face, upper beach and lower beach are clearly developed and can be identified.

Photo 6 Flat Wide Beach in Post Monsoon

Photo 7 Calm Sea And Gentle Gradient of the Beach

Table No. 3.5 A Beach Width and Height in October along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
10.2	-0.01	17	0.26	14	0.76	9	-0.44	3	0.02	15	1.49
19.4	0.13	37.1	0.47	31.8	0.51	15	-0.23	6.1	-0.8	22.1	1.43
28.53	-0.57	43.3	0.35	48.5	0.98	20	-0.97	9.3	-2.63	26.25	1.4
40.83	-1.48	52.1	0.41	53.3	1.26	28	-1.65	19.5	-3.12	31.05	0.15
50.53	-1.89	62.5	-0.61	57	1.58	33.9	-1.71	31.5	-3.65	34.27	-0.77
61.73	-2.16	75.3	-1.52	62.4	0.74	45.4	-2.74	50.2	-4.18	40.97	-1.18
75.73	-2.65	93.8	-2.12	69.4	0.18	67.4	-4.07	65.8	-4.4	53.32	-1.42
87.73	-2.85	115.8	-2.5	79.85	-0.16	85.3	-4.17	86.8	-4.27	75.52	-2.76
100.73	-3.08	136.8	-2.88	99.85	-1.54	111.7	-4.55	106.8	-4.41	95.92	-2.86
129.93	-3.03	151.4	-3.15	126.45	-2.46	121	-4.72	116.8	-4.21	113.32	-2.99
150.03	-3.43	164.4	-3.35	140.55	-2.78			136.8	-4.64	135.47	-3.06
160	-3.58			152.35	-3.26			161.8	-5.66	157.37	-3.71
				164.35	-3.54			181.8	-6.05	187.37	-3.91

(Continued)

Table No. 3.5 B Beach Width and Height in October along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
12	-0.89	7.6	-0.22	25.3	0.26	60	0.34	4.9	-0.92	8.1	-0.53
24.1	-1.04	13.2	0.25	50.9	0.9	90	0.97	20.8	-1.63	15.7	-1.03
36.6	-1.29	16.9	-0.39	53.9	1.35	106	1.39	23.8	-2.36	46.5	-1.33
43.1	-1.5	24	-1.61	58.8	2	114.6	1.45	29.6	-2.53	57.9	-1.32
55.2	-2.27	36.4	-2.25	62.5	0.18	121.65	1.58	34.1	-1.59	70.9	-1
65.4	-2.31	47.1	-2.18	72.8	-0.43	127.25	1.25	48.1	-1.27	86.5	-1.11
71.2	-2.48	62.5	-1.8	82.4	-0.56	131.35	0.35	56.3	-1.24	103.7	-1.5
81.2	-2.47	72.2	-2.63	91.4	-0.58	138.65	-0.04	86.3	-1.38	119.1	-1.57
93.8	-2.54	83	-3.5	105.7	-0.79	146.65	-0.13	108	-1.42	143.2	-2
104	-2.75	97.6	-3.59	122.9	-2.12	156.25	-0.76	124	-1.69	166.9	-2.4
114.6	-2.95	117.1	-3.69	128.6	-2.17	169.05	-1.63	141.4	-2.23	188.1	-3
123.8	-3.16	142.8	-3.87	145.7	-2	177.05	-1.78	151.5	-2.34		
		168.5	-4.2	178.4	-2.36	202.05	-2.34	160.2	-2.47		
		196	-4.57	208.4	-1.87	228.95	-2.78	163.7	-2.03		
				238.4	-2.17	247.25	-3.22	182.9	-2.02		
						262.25	-3.43	210.2	-2.88		
								240.2	-3.18		
								270.2	-3.78		
								281.5	-3.93		
								291.5	-3.98		

Table No. 3.6 A Beach Width and Height in November along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
10	-0.05	8.95	1.38	12	0.4	7.7	-0.41	3.7	-0.67	13.8	1.61
32.4	0.17	32.05	2.31	18	0.69	12.87	-0.22	7.7	-2.22	21.6	1.75
50.6	-1.42	46.35	2.57	36	0.56	20.67	-1.22	19.3	-2.99	26.9	1.46
73.8	-2.17	57.95	1.53	52.35	0.9	26.07	-1.68	33.3	-3.52	32.9	0.52
103.8	-2.72	72.2	0.4	61.95	1.24	34.33	-2.44	44.9	-4.26	40.4	-0.57
113.8	-3	93.16	-0.22	73.95	0.6	64.33	-3.67	75.5	-4.63	55	-1.31
		116.8	-0.95	84.65	-0.44	84.73	-4.65	84.5	-4.31	78.2	-2.37
		146.81	-1.03	102.65	-1.55			115.1	-4.76	87.8	-2.76
		158.8	-1.48	120.65	-2.3					102.4	-2.82
				150.65	-2.55					118	-2.87
										148.6	-3.71

(Continued)

Table No. 3.6 B Beach Width and Height in November along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
12.2	-0.87	7.8	-0.21	30.6	0.5	30.6	-1.43	10.5	-1.54	13.8	-1.19
22.45	-1.42	12.1	0.29	52.2	1.11	61.2	-0.86	16.1	-2.27	21.1	-1.87
30.15	-1.38	18.7	-1.37	57.9	2.13	89.6	-0.37	36.1	-1.42	32.2	-2.38
39.15	-2.03	39.6	-1.43	60.1	2.26	115.4	0	49.6	-1.17	55.5	-2.32
69.75	-3.19	59.9	-1.94	62.7	0.26	120	0.54	61.6	-1.21	75.5	-2.99
100. 35	-3.89	74	-2.72	84.4	-0.85	129.6	-0.47	73.6	-1.47		
119.35	-4.29	93.1	-3.59	114.8	-2.17	143.6	-0.71	80.4	-2.22		
131.85	-4.08	120.2	-3.76	145.4	-2.52	167.8	-2.75	109.3	-2.53		
150.45	-4.47	147.8	-3.8	164.2	-2.48	183.9	-2.58	122.5	-1.99		
		178.4	-4.84	192.2	-3.05	214.5	-2.7	153.1	-1.9		
						245.2	-3.08	183.7	-2.67		
						262.4	-3.22	200	-3.11		

Table No. 3.7 A Beach Width and Height in December along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
12	0.03	19	1.32	52.6	1.27	13.7	-0.47	25.1	-1.58	13.8	1.45
17	0.28	42	2.53	54.4	1.83	18.7	-1.06	33.4	-1.84	21.7	1.73
27.7	-1.42	51.2	1.53	63.4	0.68	37	-2.43	43.1	-2.41	29.7	0.62
46.4	-1.92	81.8	1.02	77.1	-0.66	50.6	-2.81	64.5	-3.28	34	-0.37
72.2	-2.32	112.4	0.81	107.7	-2.91	81.2	-3.94	95	-4.02	51.5	-1.14
102.8	-2.5	143	0.72	138.3	-3.31	111.8	-4.63	116.3	-4.07	66	-1.15
		173.6	0.37	168.9	-3.51	133.7	-5.03			89.5	-2.48
		190	0.1			148.3	-5.53			113.4	-3.75

(Continued)

Table No. 3.7 B Beach Width and Height in December along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
20	-0.93	12.7	0.25	46.3	0.93	30.6	-1.35	10.5	-1.54	7.9	-0.69
36	-0.72	17.7	-0.7	60.4	1.17	61.2	-1.05	16.1	-2.17	9.7	-0.73
38.4	-0.94	19.7	-1.01	63.6	1.39	91.8	-0.43	36.1	-1.41	17	-0.92
46.5	-1.03	37.6	-1.03	83.6	-0.51	118.8	-0.15	49.6	-1.12	43.5	-1.91
57.1	-1.8	59.8	-1.05	90.7	-0.85	126.9	0.35	61.6	-1.31	74.1	-3.26
87.7	-2.4	69.9	-1.66	112.7	-0.96	143.1	-0.35	76.2	-2.58	104.1	-2.45
116	-2.8	91	-3.25	143.3	-1.61	155.9	-2.55	88.2	-2.31		
139.9	-3.2	100.9	-3.43			164.2	-2.65	103.2	-1.58		
		114.2	-3.55			194.8	-2.55	113.2	-1.29		
						225.4	-3.05	123.2	-1.31		
						240.2	-3.15	138.2	-1.61		
								148.2	-1.71		
								161.4	-1.9		
								192	-2.41		
								222.6	-2.51		
								240	-2.81		

Table No. 3.8 A Beach Width and Height in January along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
10.3	-0.11	12.9	1.6	14.7	0.96	9.2	-0.42	4.58	-0.63	8.3	0.55
19.8	-0.19	27	2.37	32.65	0.99	14.75	-0.21	7.69	-1.47	16.7	1.63
23	-0.34	39.4	2.64	52	1.99	21.98	-1.25	10.29	-2.09	24.7	1.71
27.7	-1.06	48.3	2.71	57.9	2.63	30.1	-1.78	14.39	-3.58	27.8	1.71
34.9	-2.3	60.3	2.15	64.05	1.83	40.8	-2.44	19.29	-4.03	34	0.34
43.1	-2.39	73.1	0.75	76.9	0.85	55.25	-3.08	27.19	-4	36.3	-0.25
57.3	-2.73	89.8	0.03	87.9	-0.09	72.25	-3.83	33.59	-4.09	43.1	-0.81
74.5	-3.33	119.8	-0.38	99.7	-0.99	86.65	-4.43	47.69	-4.01	55.1	-1.14
		149.8	-1.3	110.55	-1.28	105.75	-5.08	59.24	-4.41	68.5	-0.71
				126.2	-1.83	117.45	-5.4	71.14	-4.67	75.1	-0.96
				151.7	-2.63			90.44	-4.85	85.9	-1.87
										97.2	-2.46
										103.8	-2.61

(Continued)

Table No. 3.8 B Beach Width and Height in January along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
6	-0.5	7.7	-0.28	16	-0.18	60	-0.18	9.8	-1.68	5.3	-0.65
14	-0.81	12.35	0.13	26.8	0.04	90	0.21	20.6	-2.13	7.3	-0.89
22.1	-0.62	17.25	-0.7	35.2	0.27	104.6	0.5	26.8	-1.91	14.13	-0.74
27.5	-0.43	23.05	-1.62	44.2	0.46	112.3	0.38	29.6	-1.08	43.63	-1.4
31	-0.67	34.05	-2.05	52.6	1.12	116.7	0.71	56.6	-0.44	71.83	-2.15
40.4	-0.27	39.55	-2.6	55.6	1.81	120.45	0.84	72.6	-0.19	101.83	-3.24
47.8	-0.05	57.45	-2.2	60.1	2.37	124.55	0.46	95.9	-0.59	126.83	-3.52
54.2	-0.26	69.45	-2.94	63.25	0.96	130.75	-0.66	115.9	-0.76		
64.5	-0.51	87.05	-2.96	66.5	0.19	139.95	-1.19	143.1	-1.38		
75.4	-0.84	95.05	-3.16	78.4	0.38	150.05	-0.94	169.1	-1.77		
84.4	-0.87	115.55	-4	91.85	0.01	155.05	-1.37	195.8	-1.75		
115	-1.4			114.4	0.27	174.05	-2.57	219.5	-2.04		
				138.7	-0.14	188.85	-2.93	242.4	-2.12		
				168.7	-0.67	211.05	-3.64				

Figure No. 3.2.A Comparative Beach Profiles (1 to 4) – Post-monsoon

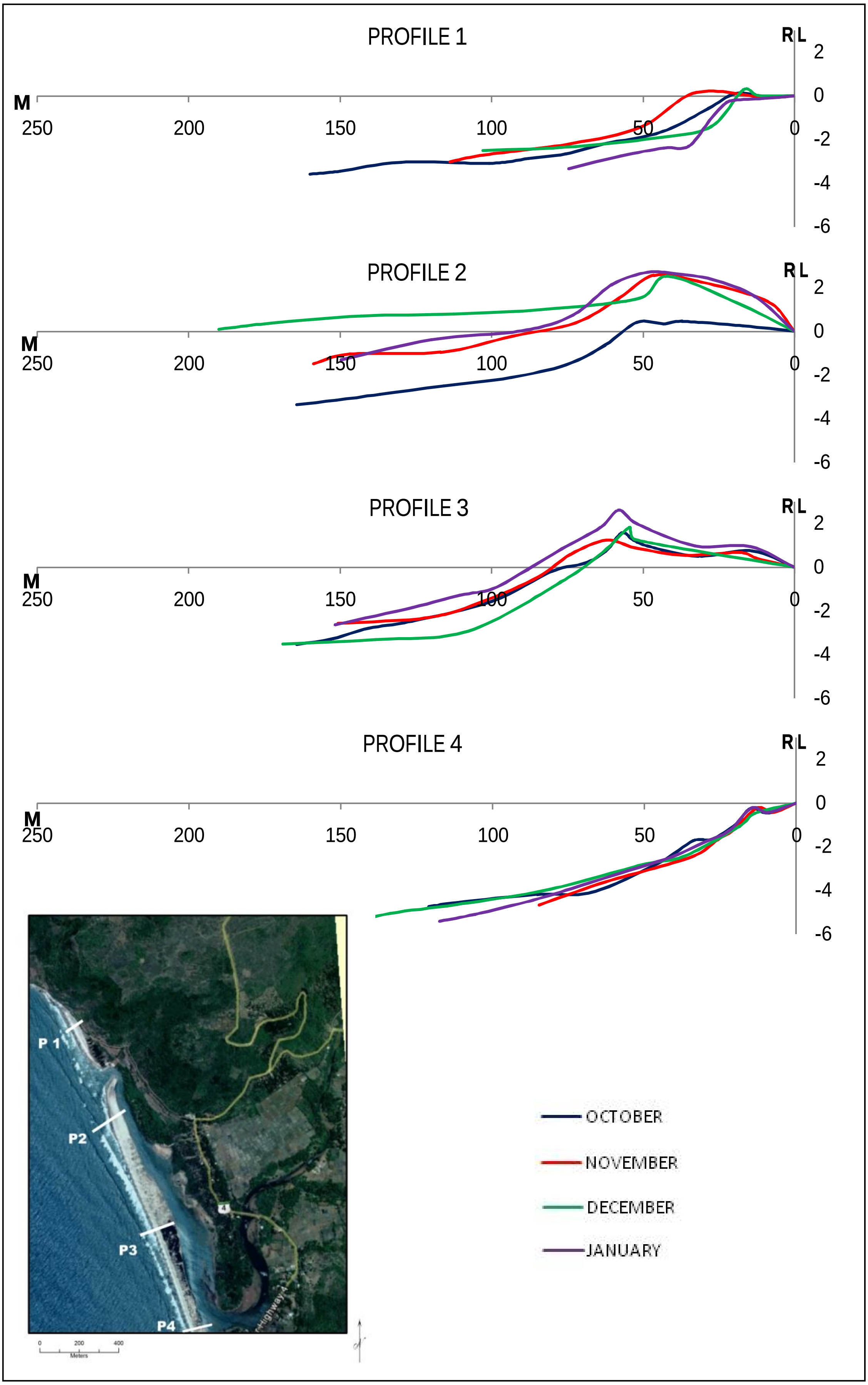


Figure No. 3.2.B Comparative Beach Profiles (5 to 8) – Post-monsoon

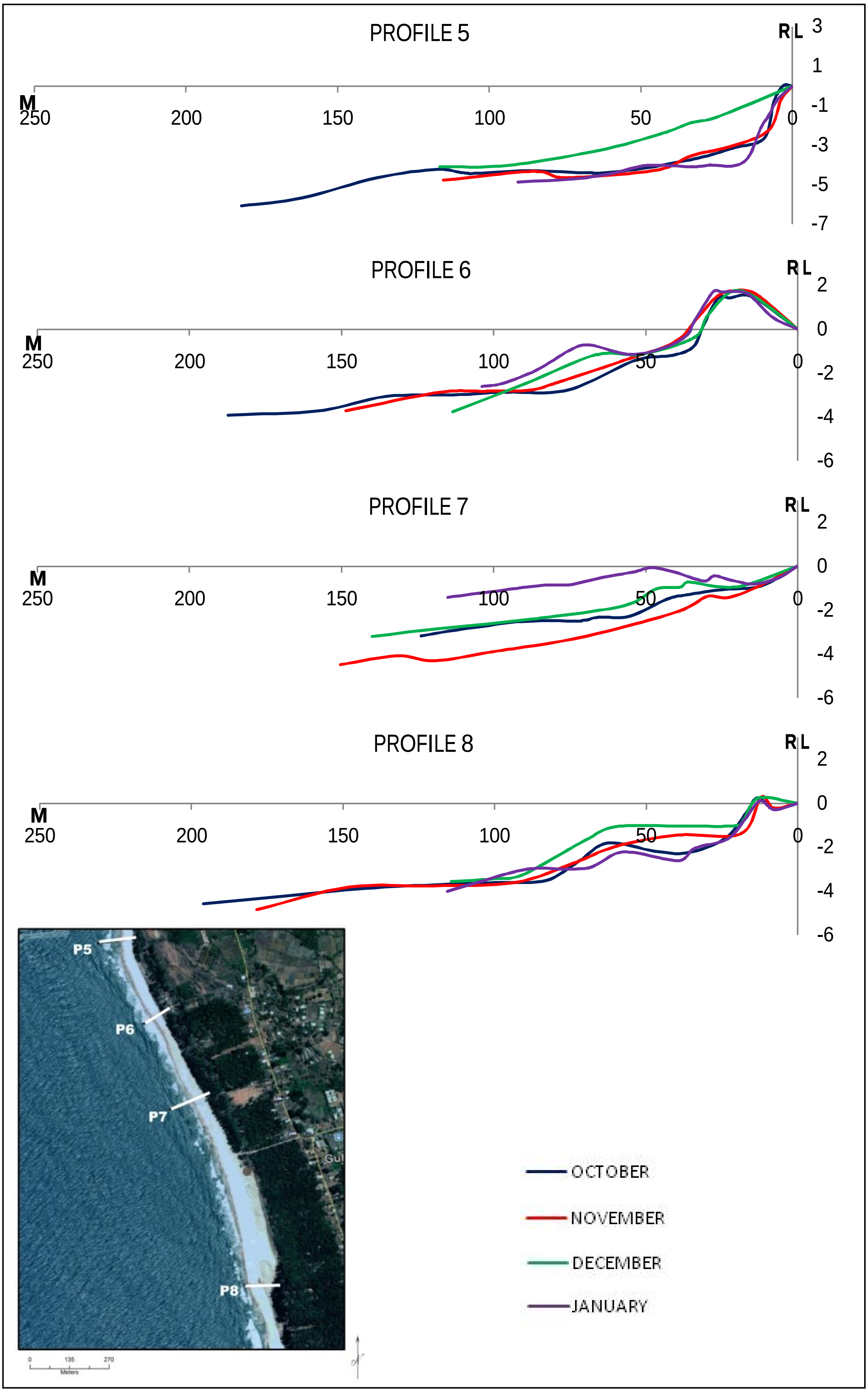


Figure No. 3.2.C Comparative Beach Profiles (9 to 12) – Post-monsoon

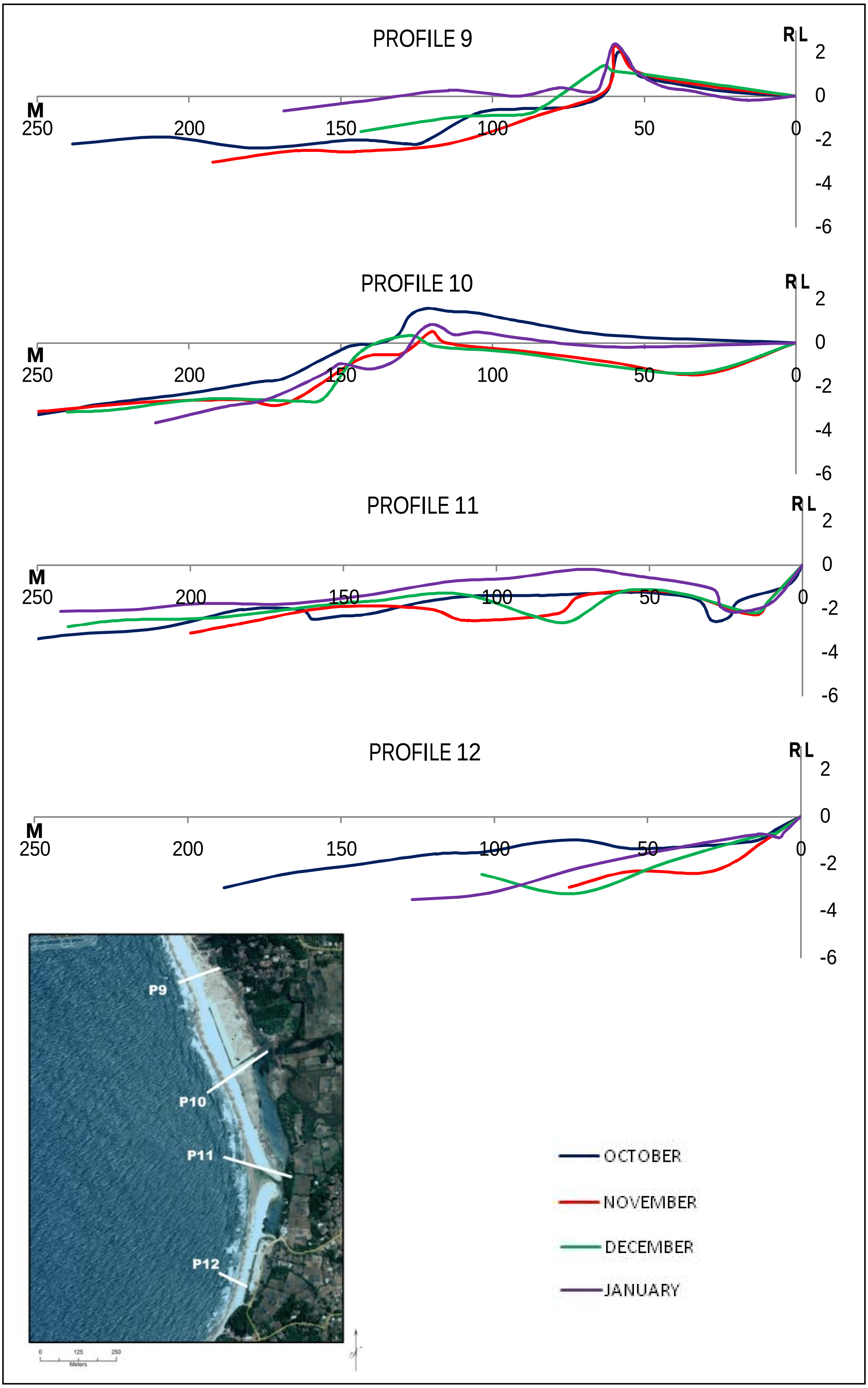


Photo 8 Swash Depression on the Beach at Middle sector

Photo 9 Cutting of Tidal Inlet Bank

3.2.3. Beach Morphology in Pre-Monsoon

The beach cross profiles leveled in February 2013 (Table No. 3.9 A, B), March 2013 (Table No. 3.10 A, B), April 2013 (Table No. 3.11 A, B), and May 2013 (Table No. 3.12 A, B) shows the morphology of Guhagar beach in pre-monsoon season. In this season beach building process reaches its extreme position has indicated by the development of beach profiles.

In the pre- monsoon season the trend was observed that the width of the beach decreases from February to May. The average width of the beach at northern section 99 m, 92 m, 81 m and 56 m in the months of February, March, April and May respectively (Figure No. 3. 3 A). The middle section show 111 m, 117 m, 98 m, 68 m (Figure No.3.3 B) and the southern section shows 101 m, 85m, 113 m, 56 m (Figure No. 3.3 C) width in the above respective months of pre-monsoon season. The middle section was wider than the northern and southern section of beach. In the month of May it observed that the width of the beach has been shortest of the year.

In this season beach building process after the monsoon season has been completed in the month February to March. So it can be estimated that beach building processes has reached its peak within the time span of five months to recover from the impact of monsoon season and again maintain itself in dynamic equilibrium (Figure No. 3.3 A, B, C). In this season from profile no. 5 to profile no. 11 dune ward slope of berm was observed (Figure No. 3.3 B, C) like post-monsoon. Pre-monsoon season shows distinct variation in upper and lower beach sections. Upper beach section show more variation in beach profiles. (Photo No.10 and 11)

The sandy material transported by winds and waves, are deposited in the middle part of the beach. The finer material further transported to dune areas as an Aeolian deposits (Photo No. 12). Upper beach shows beach and dune building processes. The foredune height is increased in this season. Lower beach shows tendency of flattening whereas upper beach varies and developed sand mounds on the beach (Photo No. 13).

Alternate sand humps and depressions almost parallel to beach are developed in to small anti-dunes like structure with a height of 0.34 m to 0.4 m, width 3.30 m to 11.7 m and length 7.4 m to 9.10 m (Photo No. 14). The orientations of these anti-dunes are NW-SE this is feature of strong NW winds. Three successive zones parallel to shore are observed. In between two anti-dunes depression hallows (Photo No. 15) are developed with coarser sand deposits. On the beach zone these feature are observed in the middle part of beach (profile no. 5 to 9) (Figure No. 3.3 B, C).

On the northern beach (profile 2 to 4) near mouth of northern inlet a distinct zone of stormy deposits mostly lateritic pebbles and coarser sand fluvial in origin with thickness of 0.14 to 0.19 m was observed in the month of March. These deposits are exposed due to strong winds (Photo No. 16).

Photo 10 Distinct Upper and Lower Beach Towards North

Photo 11 Distinct Variation in Upper and Lower Beach Sections

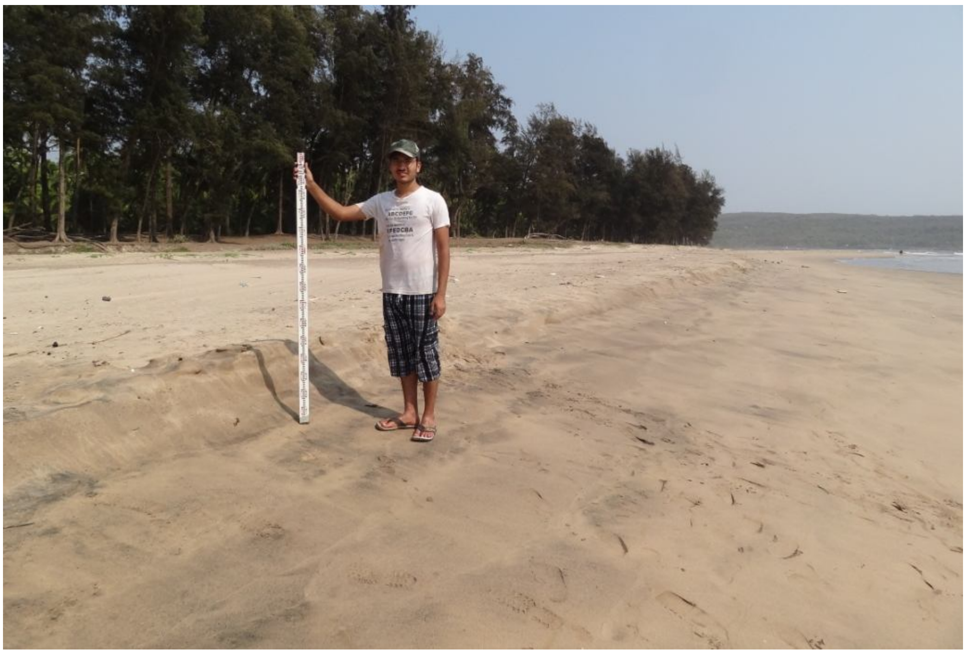


Table No. 3.9 A Beach Width and Height in February along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
9	-0.23	3	0.8	8.2	0.02	9.1	-0.61	2.8	-0.52	22.7	1.75
15.9	-0.2	9	1.43	21	0.79	14.5	-0.42	5.3	-1.23	26.9	1.39
22.5	-0.17	17.1	1.76	33.9	0.6	18.8	-1.2	8.6	-1.82	30.5	0.62
29.8	-0.83	26.9	2.05	50.5	1.07	21.7	-1.54	11.7	-3.23	33	0
42.1	-1.39	36.8	1.59	52	1.22	25.4	-1.76	16.5	-3.78	37.4	-0.77
64.7	-2.07	42.5	2.4	55.6	1.84	30.5	-1.95	21.7	-3.89	43.1	-0.93
87.7	-2.54	48.9	2.46	59	1.67	35.7	-2.2	28.2	-3.78	47.6	-0.94
105.2	-2.91	54.9	2.2	65.5	0.93	40.2	-2.42	32.7	-4.16	52.4	-1.14
111.7	-3.36	60	1.64	76.4	0.18	47.9	-2.94	42	-4.04	70	-0.82
117.7	-3.17	67.1	0.86	84.4	-0.55	55.2	-3.25	47.5	-3.89	88.7	-2.02
134.6	-3.24	76.3	0.22	94.6	-1.25	67.6	-3.63	50.7	-4.24	107.3	-2.72
158.2	-3.34	88.3	-0.25	103.6	-1.61	75.4	-3.83	56.3	-4.89	122.7	-3.12
		99.6	-0.45	111.6	-1.81	95.4	-4.01	69.9	-5.49		
		109	-0.52	141.6	-1.91	107.3	-4.2	88.3	-5.98		
		139	-0.71					109.3	-6.04		

(Continued)

Table No. 3.9 B Beach Width and Height in February along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
7.9	-0.76	8.4	-0.16	31	0.34	50	0.05	6.3	-1.6	5.2	-0.15
17.9	-1.27	12.1	0.35	53.3	1.14	100	1.32	12.7	-1.8	10.8	-0.26
26.8	-1.09	14.8	0.27	59.5	2.07	113.3	1.44	17.7	-1.67	15.2	-0.33
34.2	-1.35	18.1	-0.37	62.6	0.81	119	1.8	23.3	-1.97	22.9	-0.29
41.3	-1.21	20.4	-1.34	66.6	-0.18	128.6	0.95	28.3	-1.23	33.5	-0.63
52.3	-1.02	32.1	-1.6	75.2	-0.31	135.3	0.17	43.1	-1.09	49.2	-1.03
59.2	-1.54	39.1	-2.15	79.3	-0.23	141.5	0	50.9	-1.04	63	-1.46
71.2	-2.04	48.3	-2.03	88.5	-0.65	150	0.29	103.5	0.61	69.2	-1.62
83.9	-2.59	60.7	-1.76	101.5	-0.31	158.25	-0.21	112.5	0.15	79.2	-1.81
103.9	-3.09	71	-2.04	109.7	-0.78	173.55	-0.81	119.1	-0.16	104.2	-2.01
125.8	-3.79	81.8	-1.75	126.7	-1.4	195.05	-1.33	130.8	-0.74		
		93.5	-2.37	142.3	-1.92	218.25	-1.91	138	-0.84		
		108	-3.07	162	-2.34	238.55	-2.1	149.5	-0.86		
		131.7	-3.56	169.5	-2.46			165.3	-1.01		
		149.8	-3.76	192.5	-2.71			173.3	-1.08		

Table No. 3.10 A Beach Width and Height in March along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
9.1	-0.17	4.2	0.37	8.52	0.84	8.76	-0.6	3.46	-0.65	10.31	0.64
14.87	-0.21	8.9	1.53	18.71	0.69	14.75	-0.38	7.57	-1.8	17.31	1.74
22.59	-0.18	19.7	2.03	31.69	0.6	18.72	-0.92	10.39	-2.76	23.36	1.73
26.86	-0.56	39.3	2.69	44.94	1.09	23.66	-1.66	16.02	-3.71	27.46	1.46
32.74	-0.9	48.7	2.87	47.37	1.23	28.44	-1.71	20.99	-3.86	31.54	0.5
37.98	-1.18	58.6	2.6	50.77	2	30.75	-1.91	25.17	-3.65	33.54	0.09
47.54	-1.54	62.6	2.14	54.69	1.91	37.21	-2.33	31.86	-4.11	39.17	-0.72
61.54	-1.46	67.7	1.41	60.41	1.17	46.01	-2.9	37.7	-4.06	46.69	-0.75
81.8	-2.24	74.3	0.92	70.94	0.36	60.81	-3.59	42.81	-3.99	52.39	-0.99
111.34	-2.78	82.5	0.26	74.34	-0.04	72.83	-3.82	49.92	-4.03	61.09	-0.8
145	-3.27	87.3	0.18	79.69	-0.58	95.05	-4.15	55.24	-4.25	68.57	-0.01
		107.7	-0.25	91.14	-1.45	113.05	-4.44	66.13	-4.94	72.21	-1.22
		130.3	-0.49	103.3	-1.56			77.71	-5.49	86.25	-2.26
		156.3	-1.13	111.2	-1.75			93.51	-6.01	100.86	-2.58
								119.55	-6.14	118.72	-2.85
								142.86	-6.38	141.78	-3.39

(Continued)

Table No. 3.10 B Beach Width and Height in March along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height	Distance downbeach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
12.4	-0.77	7.4	0.78	20.9	0.18	44.5	-0.32	9.05	-1.56	4.9	-0.3
22.4	-0.73	12	1.29	43.9	0.46	75.6	0.43	21.15	-1.66	12.3	-0.19
34.43	-0.66	15	1.19	50.9	0.64	98	1.15	32.6	-1.7	21.3	-0.04
45.59	-0.56	18.1	0.46	56.4	1.89	114.5	1.38	34.8	-1.12	28.6	-0.26
55.56	-1.4	25	-0.37	60.1	2.26	121.45	1.85	54.7	-0.96	37.6	-0.72
70.22	-2.14	31.4	-0.43	63.35	0.67	125.25	1.41	75.7	-0.91	48.6	-1.17
90.15	-2.16	36.2	-0.92	68.15	-0.29	129.85	1.46	96.2	-0.44	70.4	-1.38
112.02	-3.05	39.8	-1.09	80.6	-0.27	134.15	0.57	114.8	-0.69	80.4	-1.72
123.89	-3.6	45.2	-1.07	86.9	-0.71	142.35	-0.04	135.2	-0.9		
		51.6	-0.84	94	-0.35	150.35	0.4	147.9	-1.73		
		59.4	-0.64	110.5	-0.62	156.05	0.14	156.6	-2.12		
		64.1	-0.77	119.79	-1.25	162.05	-0.13				
		67.7	-1	136.16	-1.45	170.55	-0.46				
		75.1	-0.96	151.76	-1.6	184.75	-1.22				
		80.1	-0.77	171.76	-1.72	202.65	-1.58				
		82.2	-1.43	179.26	-2						
		86	-1.59	200.26	-2.2						
		108	-1.78								
		134	-2.11								

Table No. 3.11 A Beach Width and Height in April along Profiles (Profiles 1 to 6)

Table Beach width and height in April at different locations											
PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
9.1	-0.41	9.2	0.88	14.2	1.08	10.6	-0.03	1.7	-0.5	17.31	1.6
14.87	-0.62	24.7	1.66	36.2	0.89	15.6	-0.18	3.7	-1.14	23.36	1.63
22.09	-0.82	38.8	2.03	53.8	1.9	18.1	-0.61	9.8	-2.44	25.66	1.61
26.36	-1	45.5	2.15	57.2	2.12	28.1	-1.14	19.9	-2.73	31.06	0.24
32.24	-1.3	53.9	2.18	60.2	1.76	38.7	-1.75	36.1	-3.05	36.46	-0.84
37.48	-1.6	62.8	1.24	66.3	1.19	54.6	-2.53	56.1	-3.5	50.76	-1.09
47.04	-1.85	74.5	0.22	80	0.2	68.4	-3.38	76.6	-4.5	64.06	-0.92
61.04	-2.25	84.7	-0.32	96	-1.09	84.4	-3.67	97.3	-5.3	80.26	-2.17
81.3	-2.47	91.2	-0.34	100	-1.29	99.6	-3.86			99.26	-3.36
110.84	-2.9	105.1	-0.38			114.4	-4			116.26	-3.5
144.4	-3.4	127.7	-0.68								

(Continued)

Table No. 3.11 B Beach Width and Height in April along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
17.9	-0.7	9.3	-0.08	37	1.04	40.5	-0.61	6.4	-1.61	12.2	0.16
26.8	-0.76	13.6	0.18	52.9	1.57	82.5	0.35	12.9	-1.9	22.2	0.35
41.3	-0.64	16.8	-0.37	59.9	2.64	112	0.82	25	-1.58	37.2	-0.2
59.2	-0.58	26.5	-1.46	62.9	1.68	116.45	1.02	34.1	-1.17	64.2	-0.8
71.2	-1.4	38.9	-2.12	68.7	0.36	121.75	1.56	46.9	-0.96	91.5	-1
83.9	-2.2	59.8	-1.68	88.4	-0.06	135.25	0.04	54.5	-0.88	116.5	-1.22
103.9	-2.25	66.7	-2	108.1	0.3	142.35	-0.2	73.1	-0.92		
118.4	-2.9	76.9	-1.92	127.3	-0.02	147.95	0.18	99.3	-0.44		
		91.9	-2.94	157.8	-0.2	167.95	-0.57	124.5	-0.69		
		109.4	-3.71	165.3	-0.37	199.95	-1.22	154.5	-1.75		
		135.4	-4			237.95	-1.62	184.5	-0.7		
						259.95	-2	214.5	-0.9		

Table No. 3.12 A Beach Width and Height in May along Profiles (Profiles 1 to 6)

PROFILE No.1		PROFILE No.2		PROFILE No.3		PROFILE No.4		PROFILE No.5		PROFILE No.6	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
0	0	0	0	0	0	0	0	0	0	0	0
15.6	0.02	12.9	0.86	14.7	0.96	14.3	-0.35	3	-0.79	10.7	0.79
23.7	0.06	27	1.77	32.65	0.71	19.3	-1.1	7	-2.15	20.7	1.74
74.6	-0.8	39.4	2.22	52	1.31	25.4	-1.6	11.6	-2.5	26.2	1.67
		48.3	2.12	57.9	1.94	31.7	-2.1	26.6	-3.45	29.9	0.6
		60.3	2.19	64.05	1.55	41	-3.01	41.7	-4.2	36.1	0.65
		73.1	1.12	76.9	1.01	51.5	-3.5	54.1	-4.4	39.8	-0.32
		89.8	0.17	87.9	-0.01	63.5	-4.1	74.1	-5.01	44.7	-0.44
		114.8	-0.38	99.7	-1.19	76.5	-4.2	89.1	-5.1	55.9	-0.15
										68.4	-1.55
										80	-2.52

(Continued)

Table No. 3.12 B Beach Width and Height in May along Profiles (Profiles 7 to 12)

PROFILE No.7		PROFILE No.8		PROFILE No.9		PROFILE No.10		PROFILE No.11		PROFILE No.12	
Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height	Distance down beach from B.M.	Height
(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)		(In Meters)	
		0	0	0	0	0	0	0	0	0	0
		8	-0.12	30.5	0.5	47.7	-0.44	6	-1.52	12.2	0.21
		12.8	0.34	52.2	0.91	78.2	0.1	12.9	-2.05	22.2	0.42
		16.8	-0.1	60.5	2.14	101.2	0.81	29.2	-1.68	37.2	-0.34
		20.3	-1.73	65.8	0.24	112.7	0.64	55.3	-0.96	64.2	-0.89
		45.8	-1.84	75.2	-0.18	116.5	0.59	80	-1.09	91.5	-1.14
		56.6	-2.52	90.8	0.5	119.6	1.37	100.2	-1.12	107.01	-1.37
		73.95	-2.37	101.8	-0.75	125	0.6	113.6	-1.21		
		93.4	-1.9	107.8	-1.18	135.4	0.19				
		98	-2.43			152.2	-0.17				
						159.6	-0.45				
						168.4	-1.13				

Figure No. 3.3 A Comparative Beach Level Profiles (1 to 4)- Pre-Monsoon

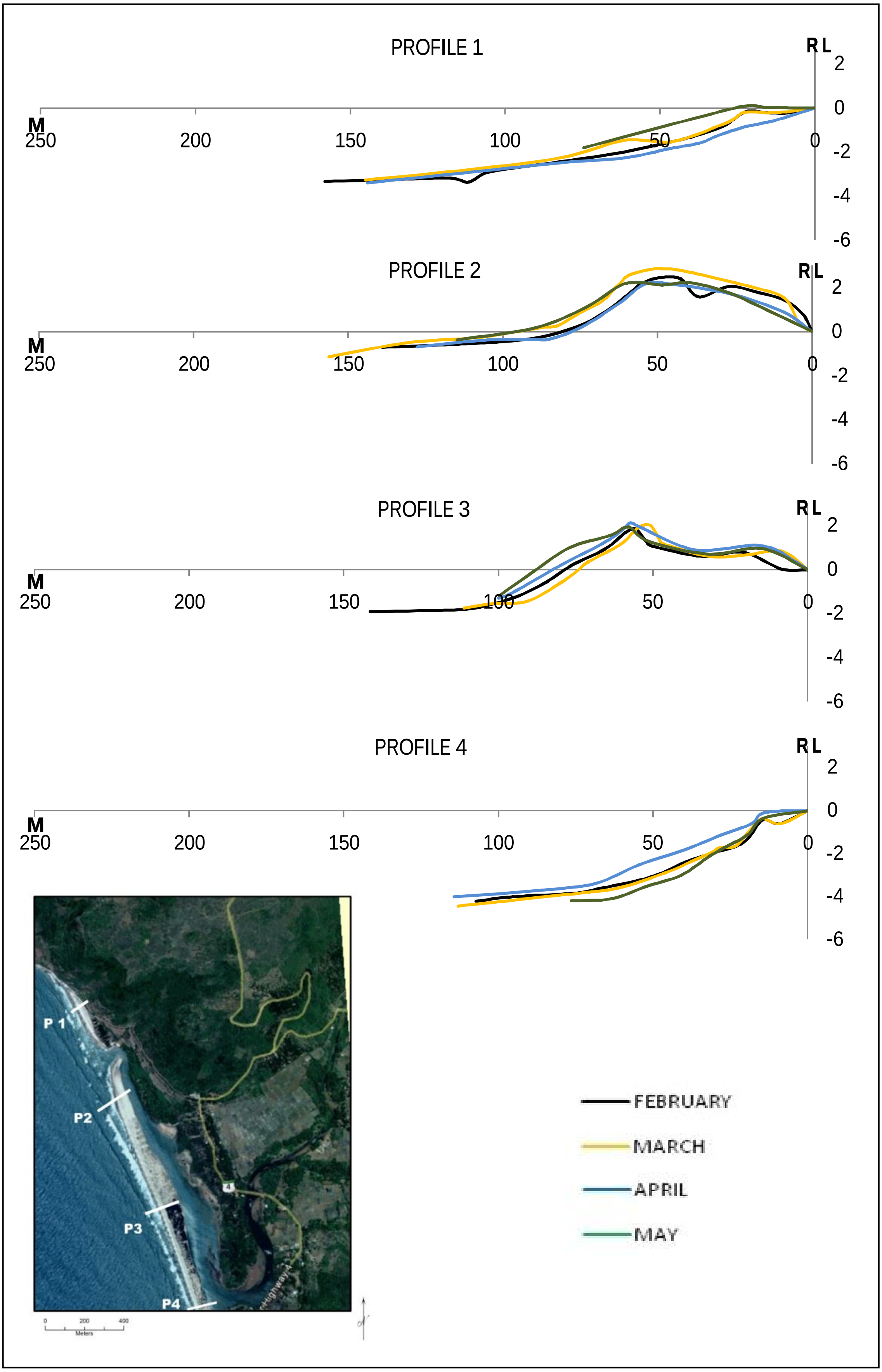


Figure No. 3.3. B Comparative Beach Level Profiles (5 to 8) -Pre-Monsoon

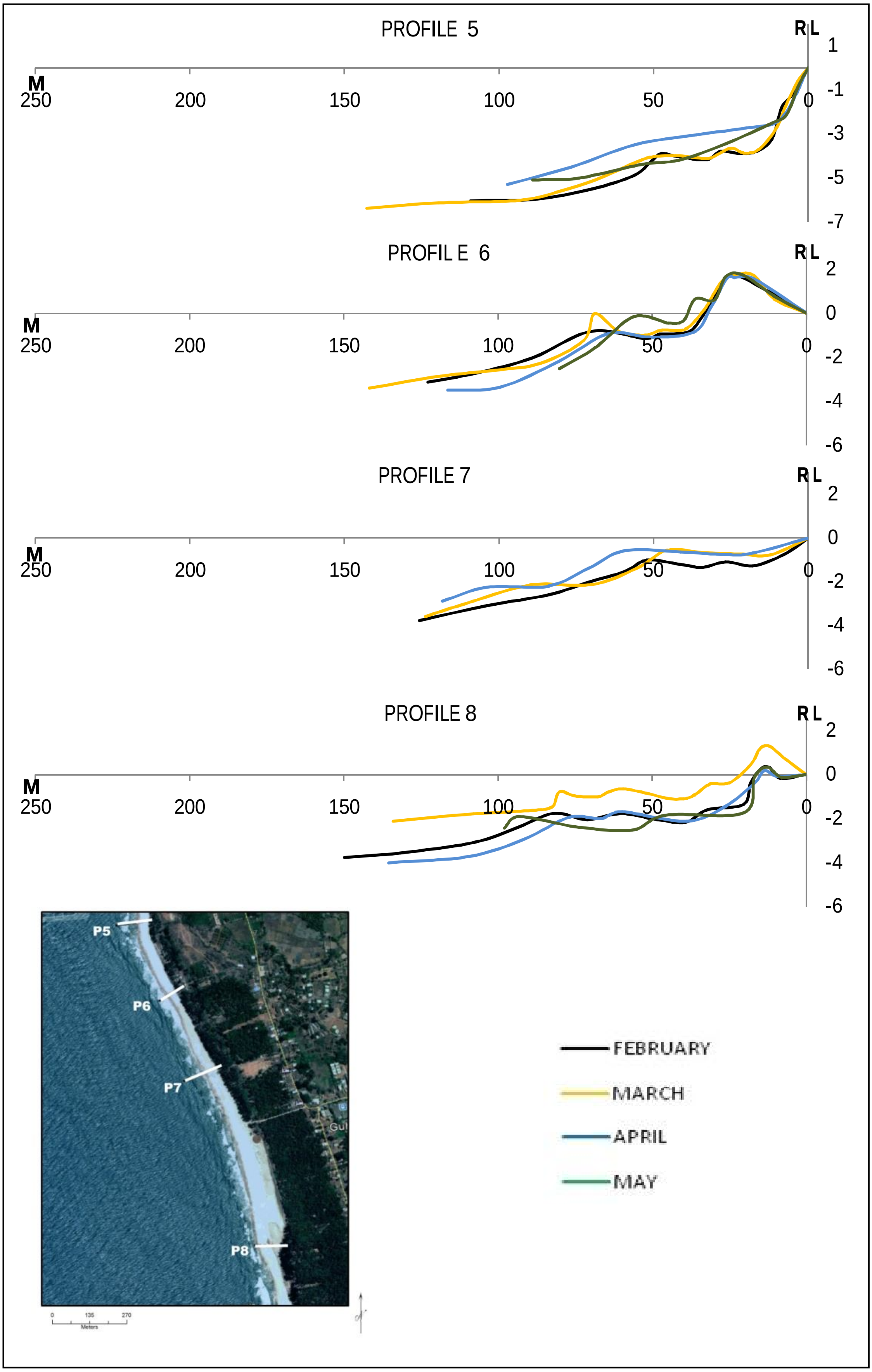


Figure No. 3.3. C Comparative Beach Level Profiles (9 to 12) -Pre-Monsoon

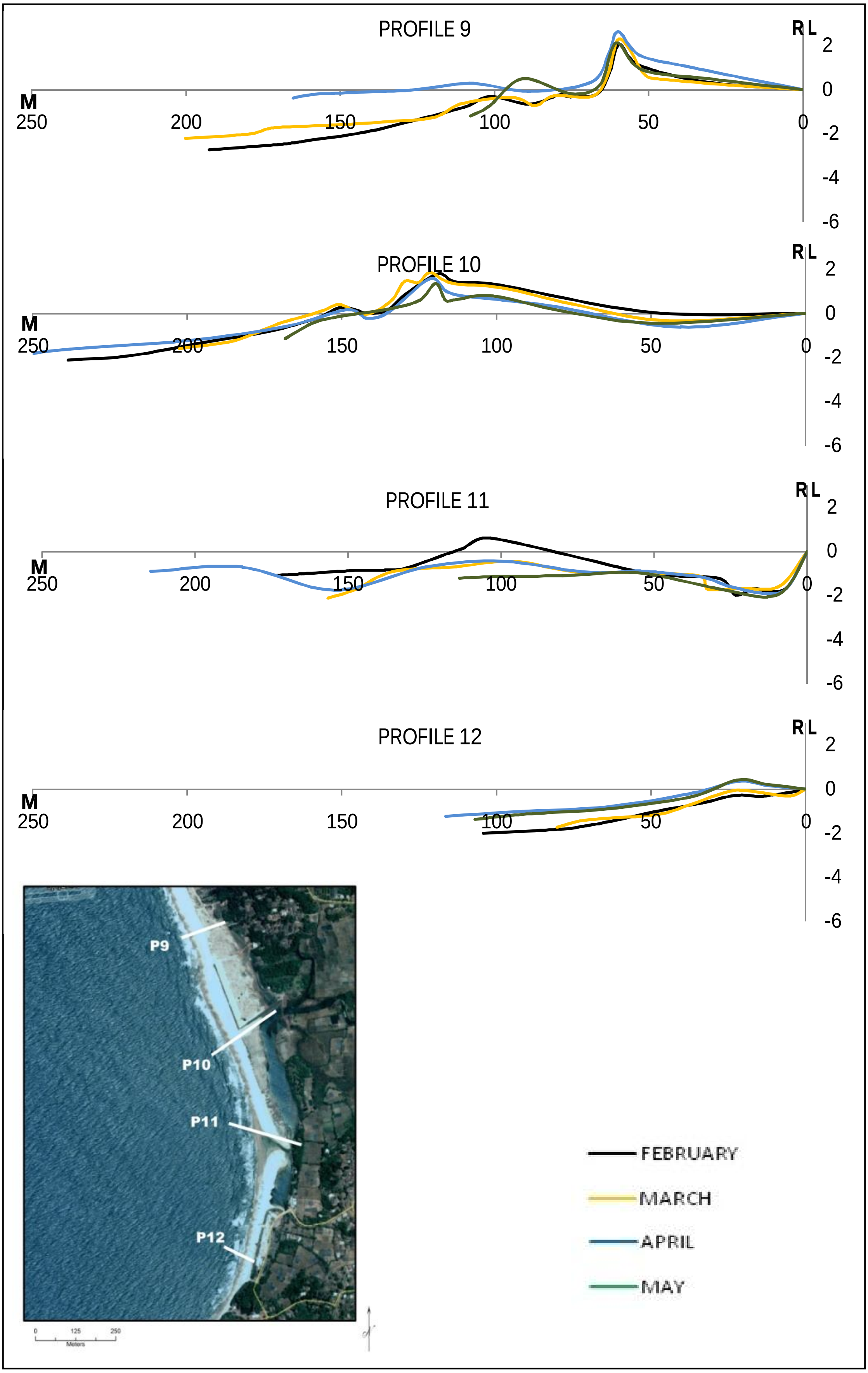


Photo 12 Development of Wind Dominated Features on the Beach

Photo 13 Sand Mounds on the Beach

Photo 14 Anti-dunes like Features Developed on Upper Beach in the Middle Sector

Photo 15 Undulated Beach Surface in April

3.3. Annual Beach, Dune and Beach-Dune Gradient

Beaches and dunes are in constant motion, continually changing their shape and shifting position in response to winds, waves, tides, relative sea level, and human activities. The most significant changes occur seasonally and following storms. During pre monsoon, beaches are generally higher and sandier than they are in monsoon. During the monsoon, the sand moves from the beach to nearshore areas to form sand bars. This happens as a result of changing wave environment due to more intense storm activity. During post monsoon, the sand at the nearshore region moves back toward the beach and eventually attaches to the beach. Once on the beach, the finer sand grains are moved by wind action to form higher, wider sand dunes. These seasonal and storm-related interactions and changes in the form, volume, and position of beaches, dunes, and nearshore areas produce what is known as 'dynamic equilibrium'.

Wave action tends to shape the beach slope as well, with high-energy waves tending to increase the steepness of the slope, and lower-energy waves resulting in flatter beach profiles. On high-energy beaches, beach profiles change seasonally.

3.3.1. Beach and Dune

While obtaining dune and beach profiles at the peak of each season is optimal, at least two are needed for comparison: one in winter and one in summer. This allows for the observation of dynamic seasonal changes in the beach and dune. Conducting a profile following significant storms is also recommended to get a sense of the dynamic response of the beach and dune to storm waves, winds, and currents. Research has revealed that beaches can recover quickly following a storm.

While conducting profiles from the same transects helps to yield both a visual and quantitative understanding of the dynamic nature of beaches and dunes, obtaining profiles from different areas revealing interesting relationships, such as slope variation based on sediment grain size. For example, cobble or coarse-grained sandy beaches are generally much steeper than fine-grained sandy beaches. Reasons for this include shape differences of the beach material and the unique interlocking characteristics of large vs. small grain sizes. Slope variation of beach and dune segment and distance down beach also show relationships.

3.3.2. Annual Beach, Dune, Beach Dune – Average Slope

Guhagar beach was divided in three sections as Northern, Middle, and Southern. The representative profiles of northern, middle and southern were plotted and there slope were calculated. In order to study the spatio - temporal variation in beach profiles, slope segments of each profile was measured (calculated).

3.4. Annual Beach Gradient

Table No. 3.13 Average Annual Beach Slope (Spatial and Temporal)

	Northern beach	Middle beach	Southern beach	**Average slope**
pre-monsoon	2.68 °	2.65 °	1.7 °	**2.34 °**
monsoon	3.19 °	1.92 °	2.27 °	**2.46 °**
post-monsoon	2.43 °	1.74 °	1.48 °	**1.88 °**
Average Slope	**2.76 °**	**2.10 °**	**1.82 °**	

Beach profile slope of pre-monsoon, monsoon and post-monsoon were compared. They show the average slope of the beach increased from pre-monsoon to monsoon and again decreased to monsoon to post-monsoon in northern and southern part of the beach. In the middle section of the beach, average slope showed decreasing trend from pre-monsoon to post-monsoon season. Maximum average slope (3.19 °) was observed in monsoon season on the northern section of the beach. Minimum average slope (1.48 °) is in post-monsoon season on the southern part of the beach. (Table No. 3.13) (Figure No. 3.4).

The average slope of the beach in northern sector was 2.76° always high than the average slope of the beach in different seasons. This indicates that the northern sector of the beach shows higher slope throughout year.

Middle sector of the beach having average slope of 2.10 ° which was less as compared to pre-monsoon and monsoon period average slope, but the average slope of the middle sector was greater than post monsoon season.

Southern sector of beach having average slope of 1.82°, show less than the average slope of the beach throughout the year (Table No. 3.13).

3.4.1. Beach Gradient in Monsoon

In the months of July 2013, August 2013 and September 2013 the average beach slope was more than post monsoon and pre-monsoon season. (Table No.3.16), In the month of July maximum average slope was observed near profile no 3 (4.56 º) and minimum average slope near profile no. 11 (1.19 º). This month show the decreasing trend of average slope towards middle section of the beach from both northern and southern section of beach except profile no. 11. (Figure No. 3.6).

In the month of August (Figure No. 3.7) the maximum slope of beach was observed towards northern section near profile no. 2 (4.70 º) and minimum average slope near profile no. 11 (1.05 º). This month shows the similar trend of slope like the month of July ie. Average slope of beach decreases towards middle section and again increases towards southern section except profile no. 11. In this month it was observed that due to filling activity the average slope of beach was reduced than that of average slope of July.

. Average slope of beach in the month of September (Figure No. 3.8) was reduced than the previous months of monsoon season. Maximum slope of beach was observed towards northern section near profile no. 4 (3º) and minimum average slope near profile no. 11 (1.15º). Average slope of beach decreases towards southern section from northern section. Due to storm surges in September, waves cross the foredune and erode the dunes. The eroded material of the dune is responsible for flattening of dune and lowering of beach slope at profile no 2 and 3. The beach slope is decreased by 2.41º and 1.92º respectively than the slope in August.

In monsoon season the waves are powerful. Strong monsoon waves, high breakers, maximum height of breakers, strong Swash and backwash results in narrow and concave beach (Photo No. 16). The average slope of beach towards northern section was 3.19º decreases towards middle section 1.92º and again increases towards southern section 2.27 º of beach.

3.4.2. Beach Gradient in Post Monsoon

The months of October, November, December and January are considered as the months of post-monsoon season. (Table No. 3.16)

The month of October (Figure No. 3.9) considered as the transitional period shows the uniformity in average beach slope. Decreasing trend of slope from northern section towards southern section of beach was observed. Maximum average slope was observed near profile no. 4 (2.53º) and minimum average slope near profile no. 11 (1.21º). This shows southward shift of average high slope.

The beach slope in the month of November (Figure No. 3.10) shows slightly increasing average slope than the month of October. Maximum average slope was observed near profile no. 4 (3.80º) and minimum average slope near profile no. 11 (1.20º). Average slope show decreasing trend from northern section towards southern section. There was no significant change in minimum average slope from October to November at profile 11.

The slope decreased considerably in December (Figure No. 3.11) from maximum average slope 3.80 º to 2.73 º in northern section and the minimum slope also decreased from 0.54 º to 1.20 º to southern section of beach because of decrease in wave energy indicate flattening of beach.

At the end of post-monsoon season in the month of January (Figure No. 3.12) average beach slope increases than that for the month of December. Maximum average slope was observed near profile no. 1 (3.28º) and minimum average slope near profile no. 11 (0.60º). Average slope show decreasing trend from northern section towards southern section.

Post-monsoon season shows gradual decrease in average slope from northern section (2.43º), middle section (1.74º) and southern section (1.48º). Northern part of beach shows high average slope than the middle and southern section of the beach.

3.4.3. Beach Gradient in Pre- Monsoon

The months of February, March, April and May are considered as the months of pre-monsoon season. (Table No. 3.16).

In the month of February (Figure No. 3.13) the average beach slope slightly increases than the month of January, especially towards the northern section of beach. Maximum average beach slope was observed near profile no. 3 (3.35º) and minimum average slope near profile no. 11 (0.48º). In the month of March (Figure No. 3.14) and April (Figure No. 3.15) maximum average beach slope was observed near profile no. 6 (4.22º) and (4.23º) at profile 3. In the above months of pre-monsoon season average beach slope seen that northern and middle section of beach shows the higher average beach slope decreasing towards southern section of beach (Photo No. 17).

The barchans like features are observed during the month of March in the middle section of the beach indicates strong aeolian impact on the beach morphology.

The month of May (Figure No. 3.16) is upcoming monsoon month. Wind direction, wind velocity change in the pre-monsoon season. Strong NW-SE winds changes to W-E during the April and May with high velocity responsible for scouring in northern section and undulated beach surface in middle section. Therefore in the month of May maximum average slope 4.83º as seen at profile 6 and minimum average slope 0.60º at profile 11. Increased wave energy and wind velocity are responsible for wind as well as wave erosion shows winnowing of beach in northern section.

The average beach slope in pre-monsoon shows maximum slope 2.68º in the northern section decreases towards middle and southern section of the beach 2.65º and 1.7º respectively.

Photo 16 Steep Beach Gradient in Monsoon at Northern Sector of the Beach Facing towards South

Photo 17 Gentle Beach Gradient in Pre- Monsoon Season Facing Towards South

3.5. Annual Dune Gradient

Table No. 3.14 Average Annual Dune Slope (Spatial and Temporal)

	Northern beach	Middle beach	Southern beach	**Average slope**
pre-monsoon	4.10 º	9.42 º	5.83 º	**6.45 º**
monsoon	3.80 º	10.58 º	5.83 º	**6.73 º**
post-monsoon	4.15 º	8.57 º	5.12 º	**5.94 º**
Average Slope	**4.02 º**	**9.52 º**	**5.59 º**	

As compared with the annual slope of beach profiles, the dune profiles are comparatively stable. Northern and Southern dune slopes are stable. The average dune slope of middle section, increase from pre-monsoon to monsoon and again decrease to post-monsoon. (Table No. 3.14).

The average slope of the northern dune sector is 4.02 ºwas always less than the average slope of the dune in different seasons. This indicates that the northern sector of dune show less slope throughout the year.

Middle sector of the dune having average slope of 9.52 º was always higher than the average slope of dune in different seasons. This indicates that the middle sector of the dune shows higher slope throughout the year.

Southern sector of the dune having average slope of 5.59 º was always less than the average slope of the dune in different season (Table No. 3.14)..

3.5.1. Average Dune Slope - Northern Sector

Dunes near the northern headland are experiencing erosion during the monsoon. Dune cutting from 0.97 m to 1.2 m is observed. The eroded material is deposited on the beach and at the mouth of northern tidal inlet.

In the northern part of the beach area is covered with embryo dunes, fore dunes, and back dunes. These dunes are backed by a tidal inlet. Dunes in this area show some patches of embryo dunes. The maximum height of these embryo dunes is 1.28 m and minimum height is 0.76 m. the width of these dune line varies from 90 m to 10 m. fore dunes are running parallel to beach and discontinues in some areas. The maximum height of fore dunes observed in this sector is 6.15 m and minimum height is 0.97 m. back dunes are not prominent

In the beginning of monsoon, average dune slope increases 2.56° to 3.88° and 3.26° to 3.43° along profiles 2 and 3 respectively. During the monsoon (July to

August) average slope of dune profile increased from 3.88° to 4.93° and 3.43° to 4.35° along profiles 2 and 3 respectively. Average dune slope near profile 4 does not show significant change as fore-dunes and back dunes in this area are stabilized and covered with casurina plantation. During August to September dunes near profile 2 and 3 are washed out due to high surge resulting in decrease of the average slope. (Table No. 3.17)

In post-monsoon season variation in average dune slope does not show significant pattern. During October to January average dune slope varies due to fluctuation in wave climate.

Average dune slope decreased during the pre-monsoon period (February to May) as NW to SE winds with high velocity are responsible for winnowing of the beach and accretion in northern dune area. (Photo No. 18).

3.5.2. Average Dune Slope - Middle Sector

Middle sector of dune area is characterized by high fore dunes stabilized by casurina plantations. These fore dunes are backed by a defunct tidal inlet, separating the back dune from the beach dune area. The back dunes are occupied by settlements of Guhagar and reclaimed for plantation. The maximum dune height of these fore dunes is 8.4 m and the minimum height is 1.3 m. The width of these dunes varies from 18.56 m. to 12.32 m. Embryo dunes are not observed in this part of dune line. Average dune slopes in monsoon increase considerably due to cutting of dune base. Strong stormy surges are responsible for dune base erosion in August. The maximum slope observed was in the month of August. These fore dunes are covered with casurina plantation, Ipomea and in some part with Spiniphix grass (Photo No.20 and 21).

During the post-monsoon (October to January) there is filling processes responsible for reduction in average dune slope (Table No. 3.17). Post-monsoon season do not show significant trends in variation as discussed earlier.

In pre-monsoon season the Aeolian activity is dominant (Photo No. 19) in the study area. Anti-dunes like structure are seen all over the middle beach. Wind velocity is maximum which results in decrease in average dune slope during March and April.

Anthropogenic activities are dominant in this sector. Newly constructed jetty, tourism activities are responsible for the change in dynamics of beach and dune.

3.5.3. Average Dune Slope - Southern Sector

Southern part of the study area is characterized by well demarked fore dunes and a complex of small dunes not more than 2.28 m in height. Dunes are covered with Ipomea and Sphiphix grass. The maximum width of this dune is 130 m, and minimum 60 m. dunes are not seen near southern head land. A break wall is constructed along the fore dune line.

In monsoon, average dune slope increases in August and decreases in September. Due to stormy waves in September average dune slope near profile no 11 is decreased from 11.97° to 5.47°. Pre-monsoon and post-monsoon do not show any trend in average slope of dune. Dune slope during this period are fluctuating (Table No. 3.17).

Photo 18 Dune Cutting in Monsoon (Northern Sector)

Photo 19 Deposition of Fresh Blown Sand on Fore Dune

Photo 20 Fore Dune Ridge Covered by Casurina Plantation

Photo 21 Ipoemea and Spinphix Grass on the Dune

3.6. Annual Beach Dune Gradient

Table no. 3.15 Annual Average Beach Dune Slope (Spatial and Temporal)

	Northern beach	Middle beach	Southern beach	**Average slope**
pre-monsoon	2.94 º	4.51 º	2.91 º	**3.45** º
monsoon	3.35 º	4.08 º	3.32 º	**3.58** º
post-monsoon	2.89 º	3.48 º	2.90 º	**3.09** º
Average Slope	**3.06** º	**4.02** º	**3.04** º	

Maximum average slope of the beach is 4.51º in pre-monsoon season at middle section and minimum average slope is 2.89º in post-monsoon season at the northern section (Table No. 3.15). It shows that there is significant increase in the average slope from pre-monsoon to monsoon season at Northern and Southern sector of the beach due to South Westerly monsoon. Average slope decreases from monsoon to post-monsoon season all over the beach. The middle section the beach shows a decrease in the average slope from pre- monsoon to post-monsoon season (Table No. 3.18), (Figure No. 3.5).

Table No. 3.16 Distance Down Beach Average Slope (Degrees)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
P 1	3.27	1.71	1.79	1.85	0.88	1.99	2.9	1.72	1.69	1.74	2.46
P 2	2.73	2.93	3.02	1.82	2.41	3.49	4.70	2.29	2	2.06	0.62
P 3	3.15	3.35	3.85	4.23	4.38	4.56	4.30	2.38	2.45	2.98	2.73
P 4	2.6	2.60	2.31	2.14	3.50	3.74	3.18	3	2.53	3.80	2.04
P 5	1.47	2.99	1.80	1.81	1.95	2.76	1.79	1.33	1.43	2.19	1.8
P 6	2.76	1.77	4.22	2.04	4.83	2.35	2.21	1.61	1.36	1.64	2.21
P 7	2.05	2.38	1.93	1.72	1.65	1.86	1.78	1.47	1.39	2.02	1.98
P 8	2.36	1.84	2.96	2.06	1.43	2.14	2	1.79	1.62	1.47	1.57
P 9	1.02	1.61	1.60	0.97	3.85	2.98	2.21	1.72	1.26	1.47	0.75
P10	2.74	1.80	3.48	1.79	2.53	3.15	4.26	2.17	1.84	1.3	0.54
P11	0.60	0.48	1.91	1.25	0.60	1.19	1.05	1.15	1.21	1.20	0.82
P12	2.92	1.2	1.85	1.03	1.27	3.5	2.86	1.38	1.44	2.99	2.31

Table No. 3.17 Distance Down Dune Average Slope (Degrees)

	Jan	Feb	Mar	Apr	May	July	Aug	Sept	Oct	Nov	Dec
***P 1**	-	-	-	-	-	-	-	-	-	-	-
P 2	2.91	4.84	4.66	2.85	2.56	3.88	4.93	1.33	1.83	3.48	4.39
P 3	4.08	3.48	4.21	3.73	3.26	3.43	4.35	3.78	4.26	2.89	8.64
P 4	4.32	5.25	5.57	3.88	4.95	4.84	4.58	4.75	4.56	4.15	4.34
P 5	14.08	15.24	13.6	15.38	12.64	17.2	18.85	14.62	15.36	15.73	13.6
P 6	6.42	9.05	6.86	6.32	6.64	5.63	9.52	8.40	7.52	5.60	7.22
***P 7**	-	-	-	-	-	-	-	-	-	-	-
P 8	6.43	8.89	6.87	5.02	9.44	6.94	8.45	5.59	6.40	7.53	6.9
P 9	7.39	9.44	8.36	8.55	7.59	6.75	10.11	5.47	9.36	10.73	2.84
P10	3.09	2.89	2.48	2.98	3.76	2.21	1.62	1.73	3	3.04	2.94
P11	7.66	5.8	6.30	5.19	6.59	7.17	11.97	5.47	8.04	1.17	2.14
***P12**	-	-	-	-	-	-	-	-	-	-	-

Table No. 3.18 Distance Down Beach Dune Average Slope (Degrees)

	Jan	Feb	Mar	Apr	May	July	Aug	Sept	Oct	Nov	Dec
***P1**	3.27	1.71	1.79	1.85	0.88	1.99	2.9	1.72	1.69	1.74	2.46
P2	2.87	3.95	3.84	2.38	2.43	3.76	4.93	1.72	1.93	3.06	2.04
P3	3.51	3.42	4.06	3.96	3.68	3.95	4.33	3.14	3.29	2.33	5.26
P4	3.01	3.17	3.4	2.66	3.86	4	4.24	3.48	3.14	3.96	2.62
P5	6.06	6.25	4.76	6.9	5.96	6.4	6.85	5.32	4.65	5.58	2.1
P6	4.45	4.81	5.21	4.18	5.56	3.81	5.26	4.25	3.78	3.44	4.72
***P7**	2.05	2.38	1.93	1.72	1.65	1.86	1.78	1.47	1.39	2.02	1.98
P8	3.85	4.19	4	3.14	5.55	4.1	4.57	3.24	2.99	3.3	3.36
P9	5.12	4.22	4.39	4.76	5.71	5.04	6.86	3.6	3.96	6.1	2.25
P10	2.94	2.3	3.08	2.38	3.37	2.59	2.86	1.93	2.35	2.17	2.07
P11	2.88	2.49	3.16	2.37	3.16	2.72	4.57	2.38	2.92	2.41	2.16
***P12**	2.92	1.2	1.85	1.03	1.27	1.5	2.86	1.38	1.44	2.99	2.31

(* these profiles do not show a distinct dune profiles)

Figure No. 3.4. Distance Down Beach Average Slope (Degrees)

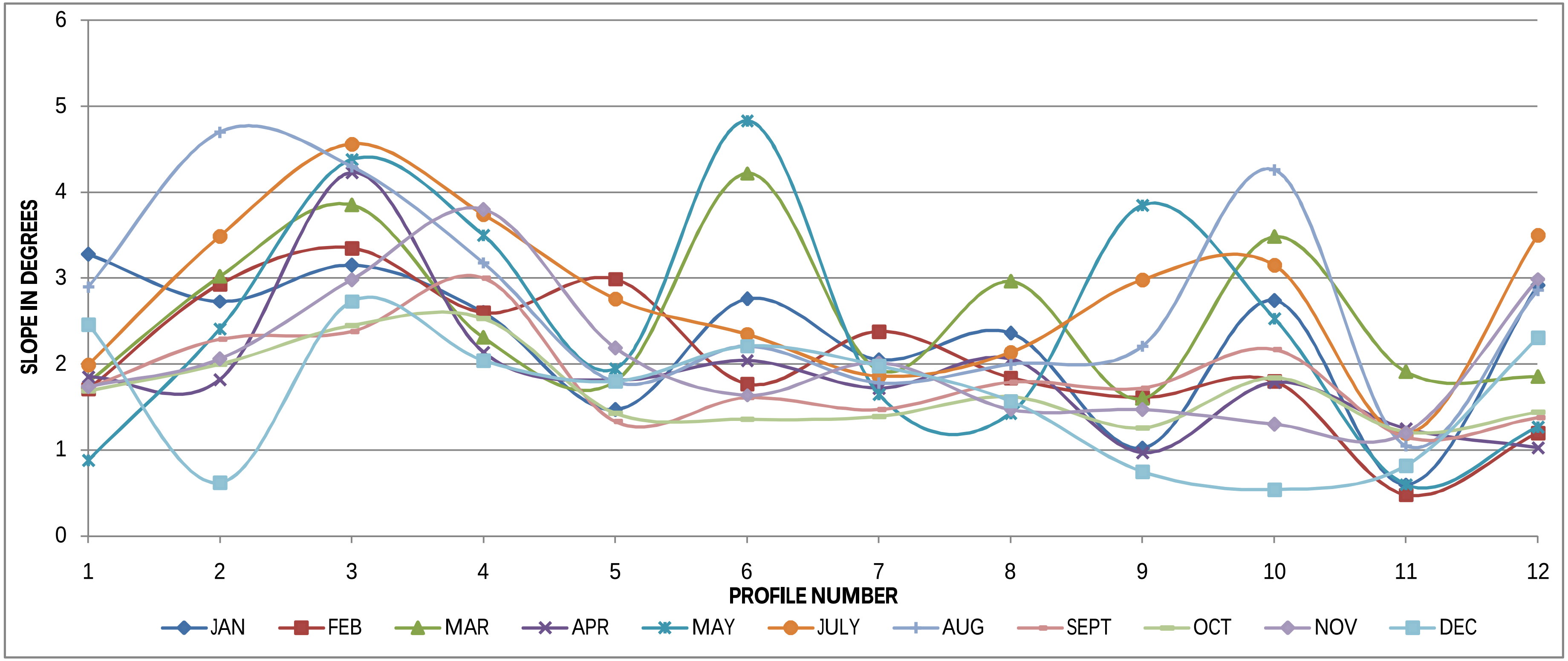


Figure No. 3.5. Distance Down Beach Dune Average Slope (Degrees)

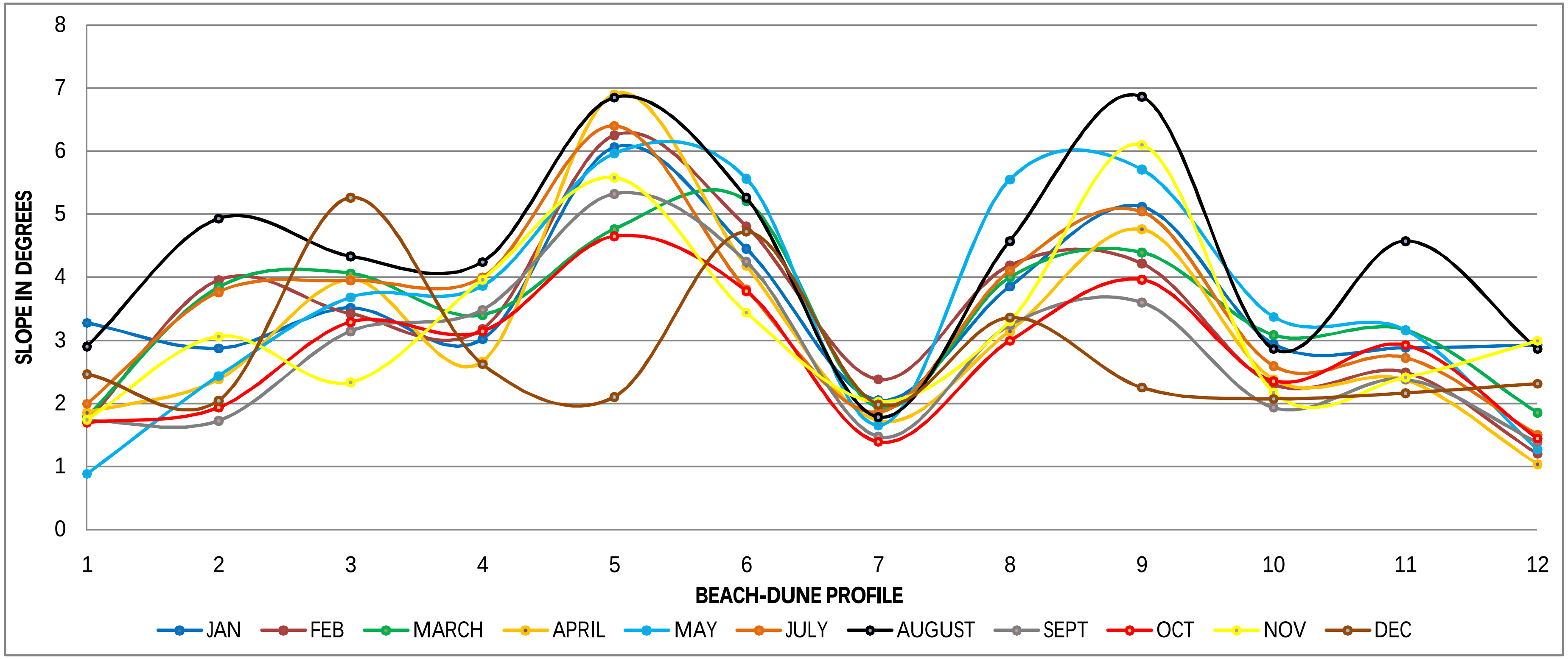
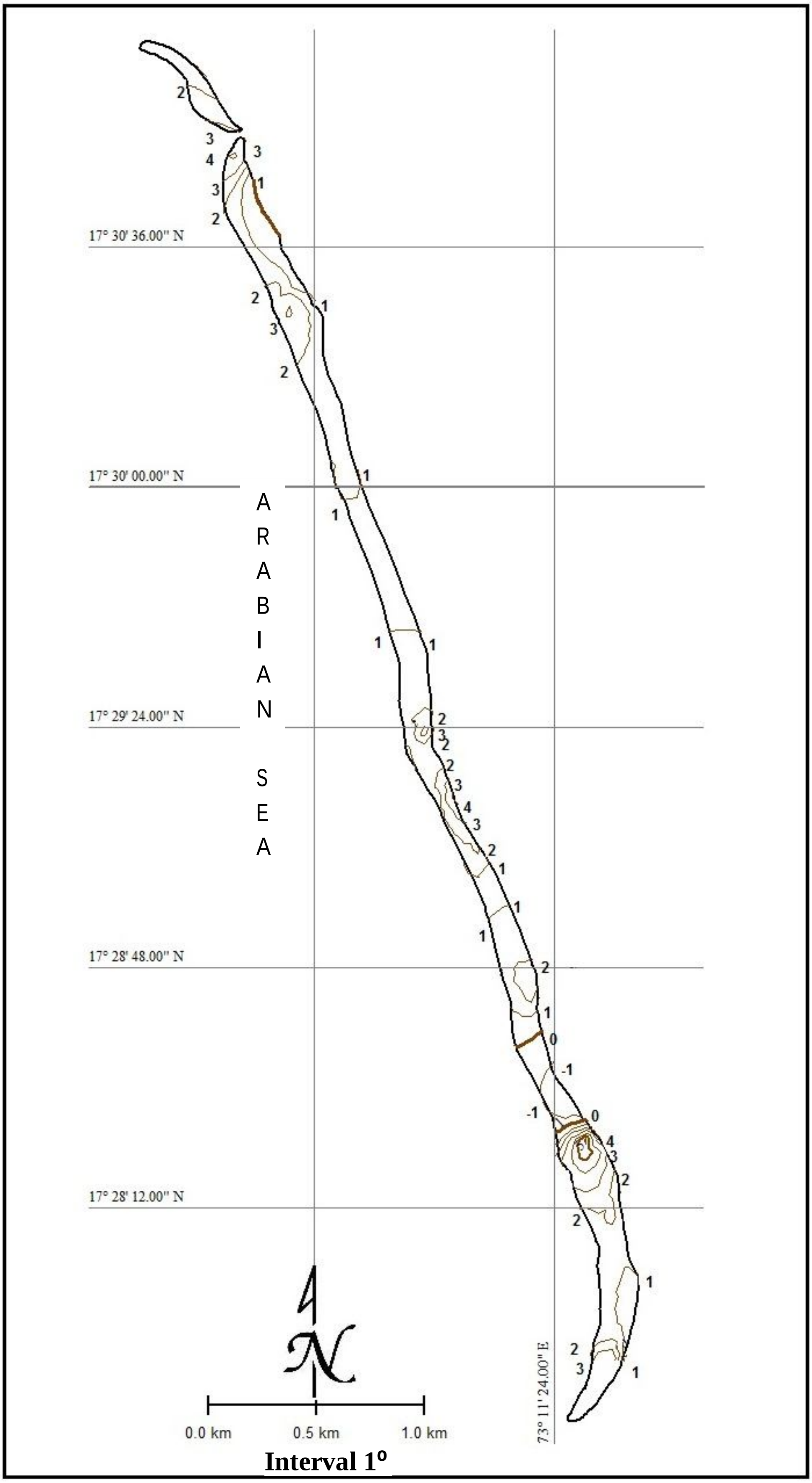


Figure No. 3.6. Isoline Map Showing Beach- Dune Average Slope (July)



Interval 1°

Figure No. 3.7. Isoline Map Showing Beach- Dune Average Slope (August)

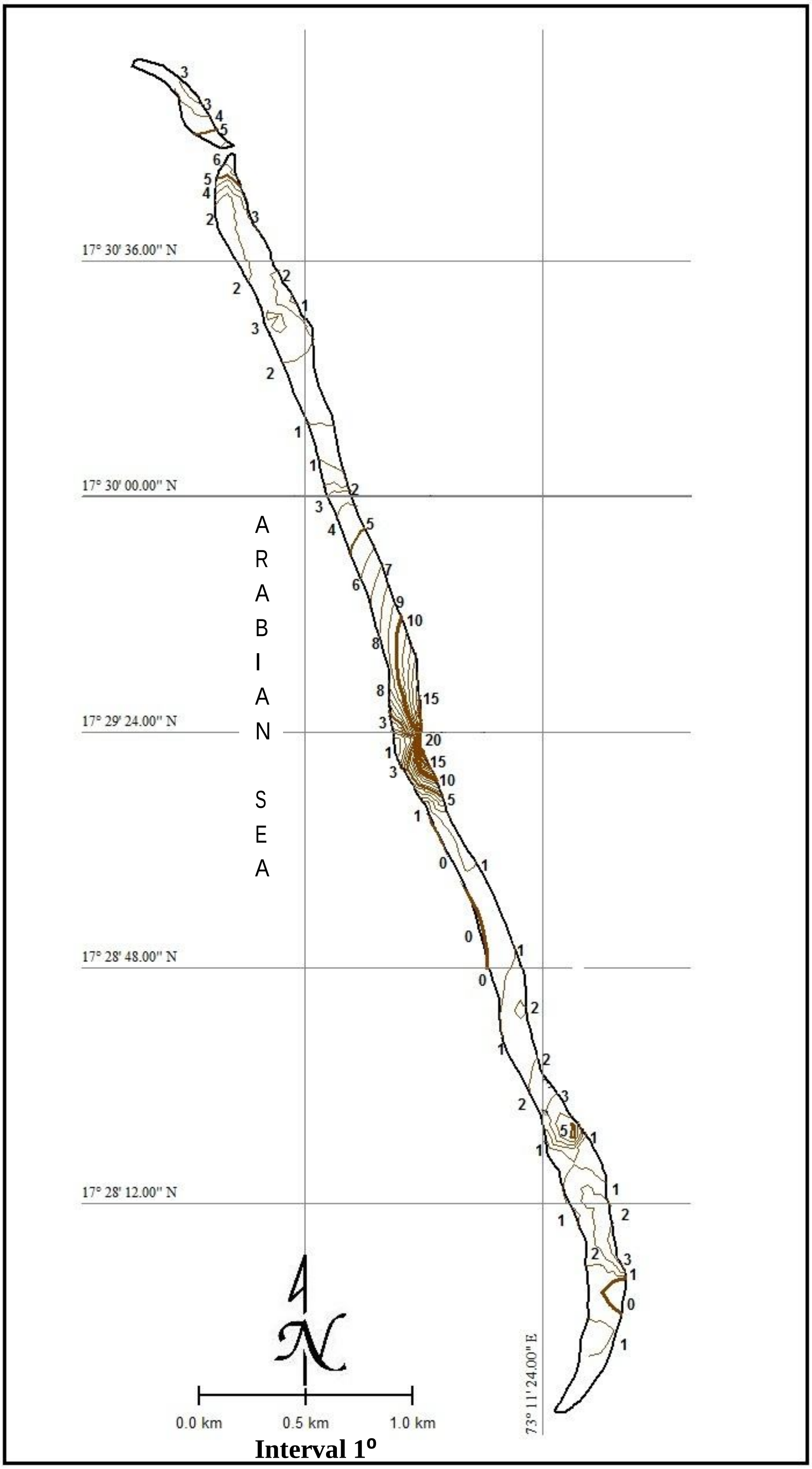


Figure No. 3.8. Isoline Map Showing Beach- Dune Average Slope (September)

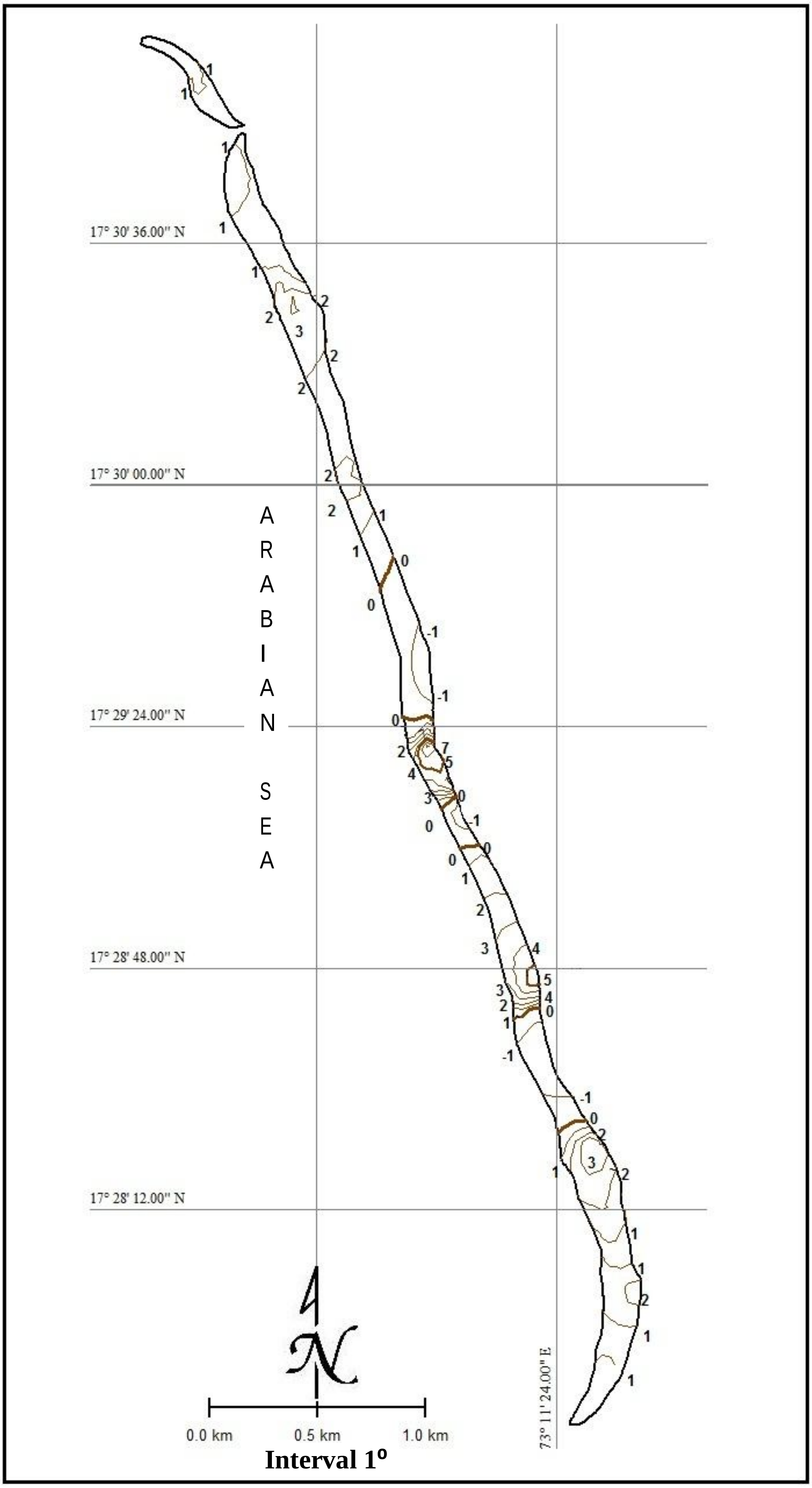


Figure No. 3.9. Isoline Map Showing Beach- Dune Average Slope (October)

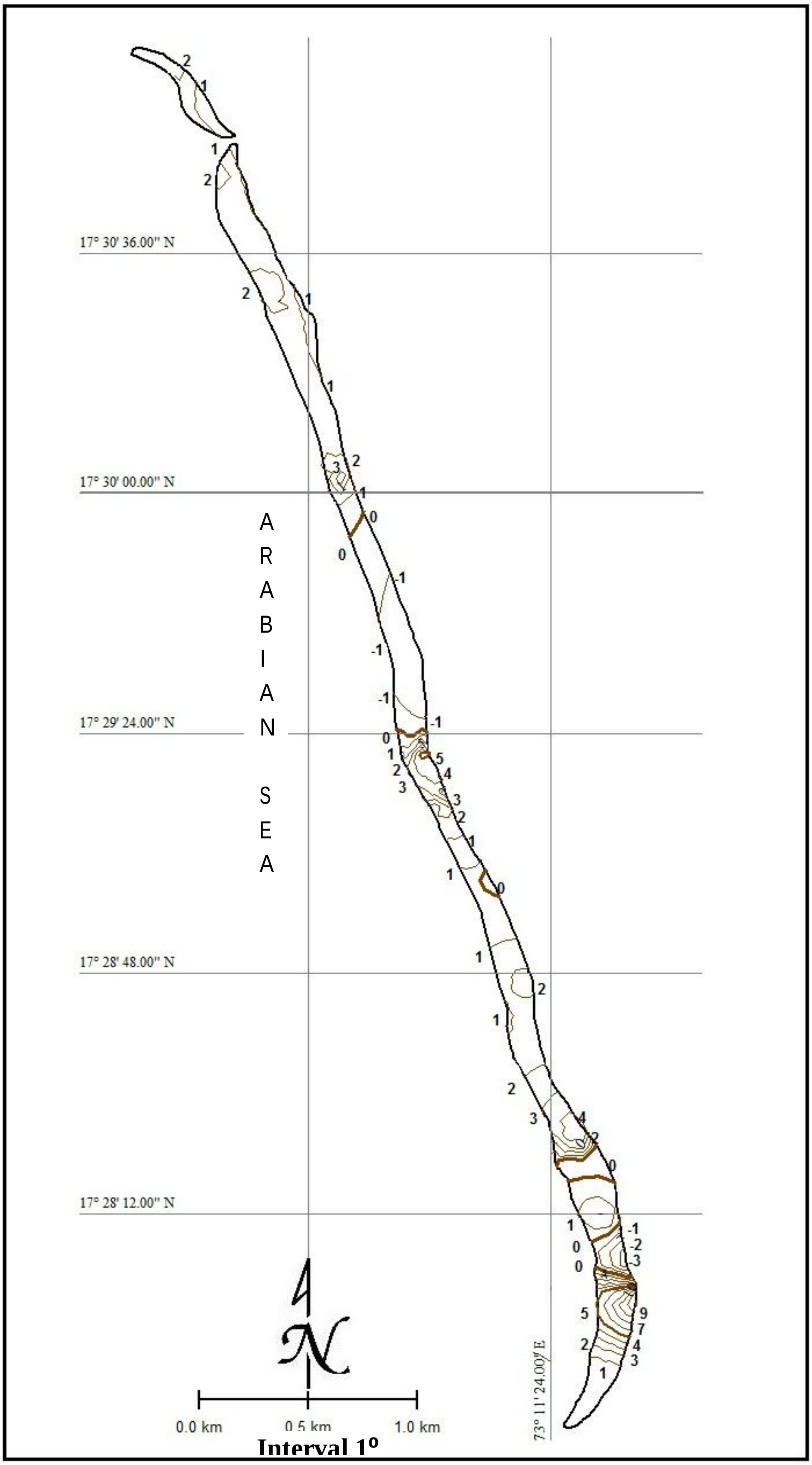


Figure No. 3.10. Isoline Map Showing Beach- Dune Average Slope (November)

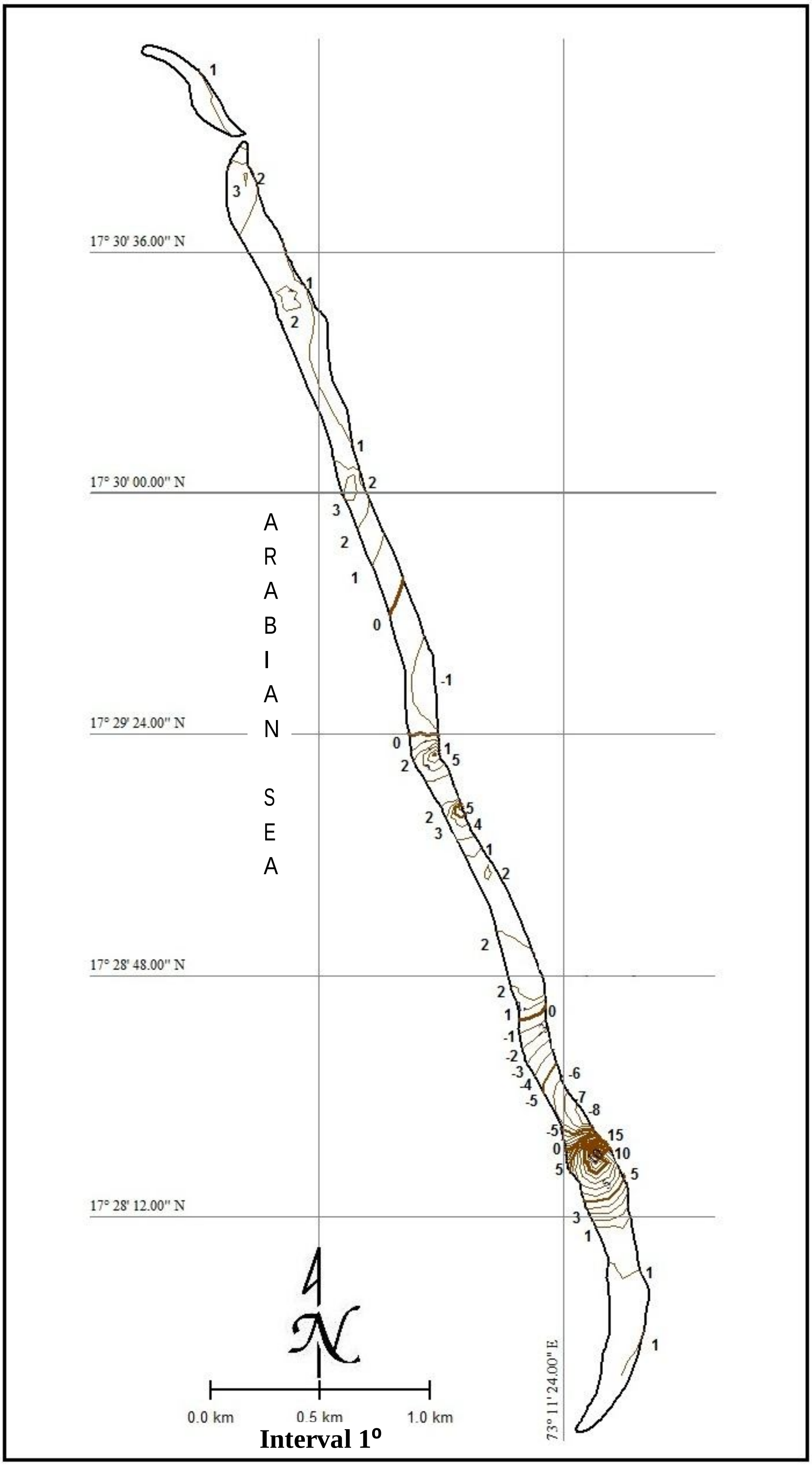


Figure No. 3.11. Isoline Map Showing Beach- Dune Average Slope (December)

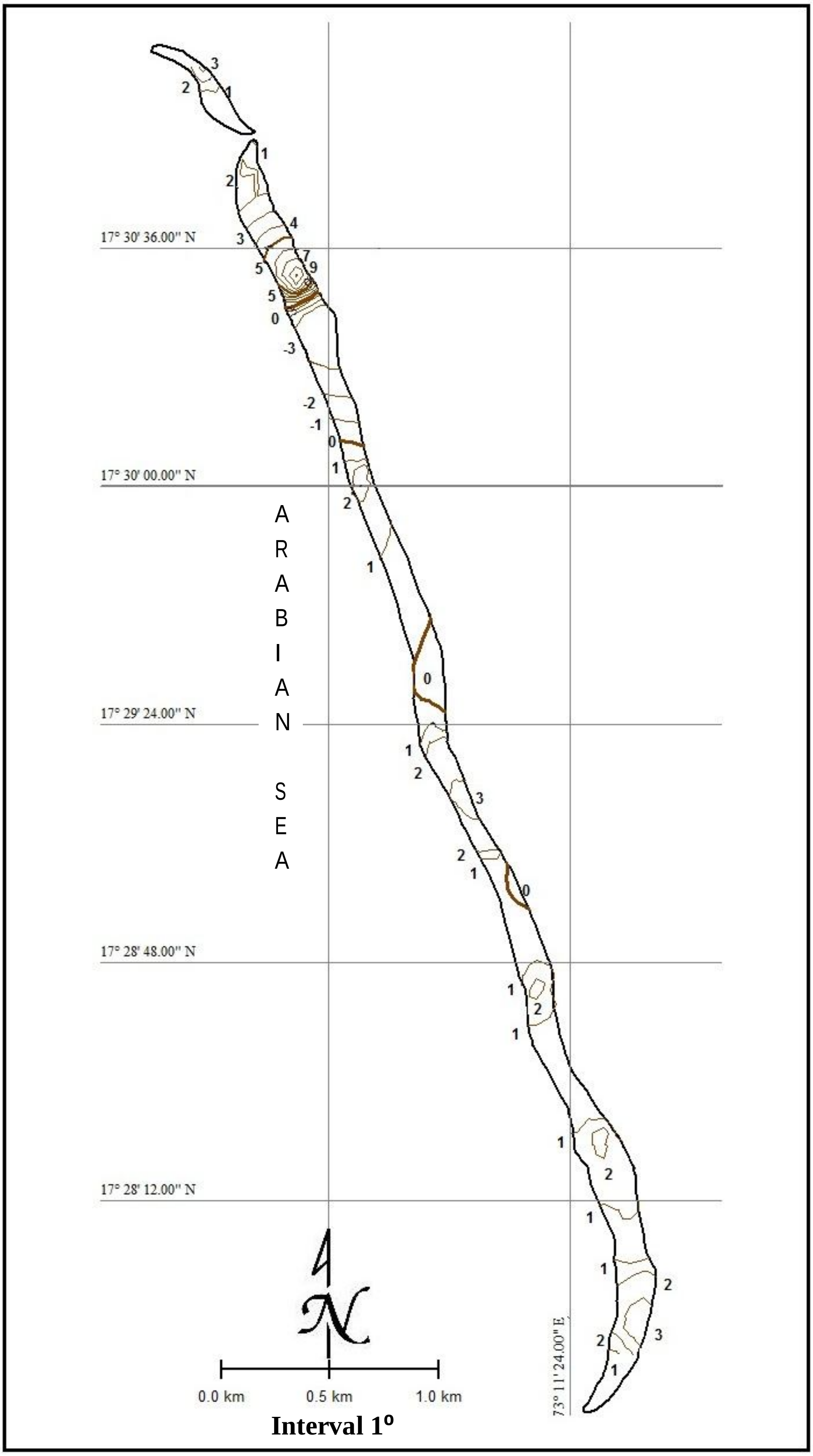
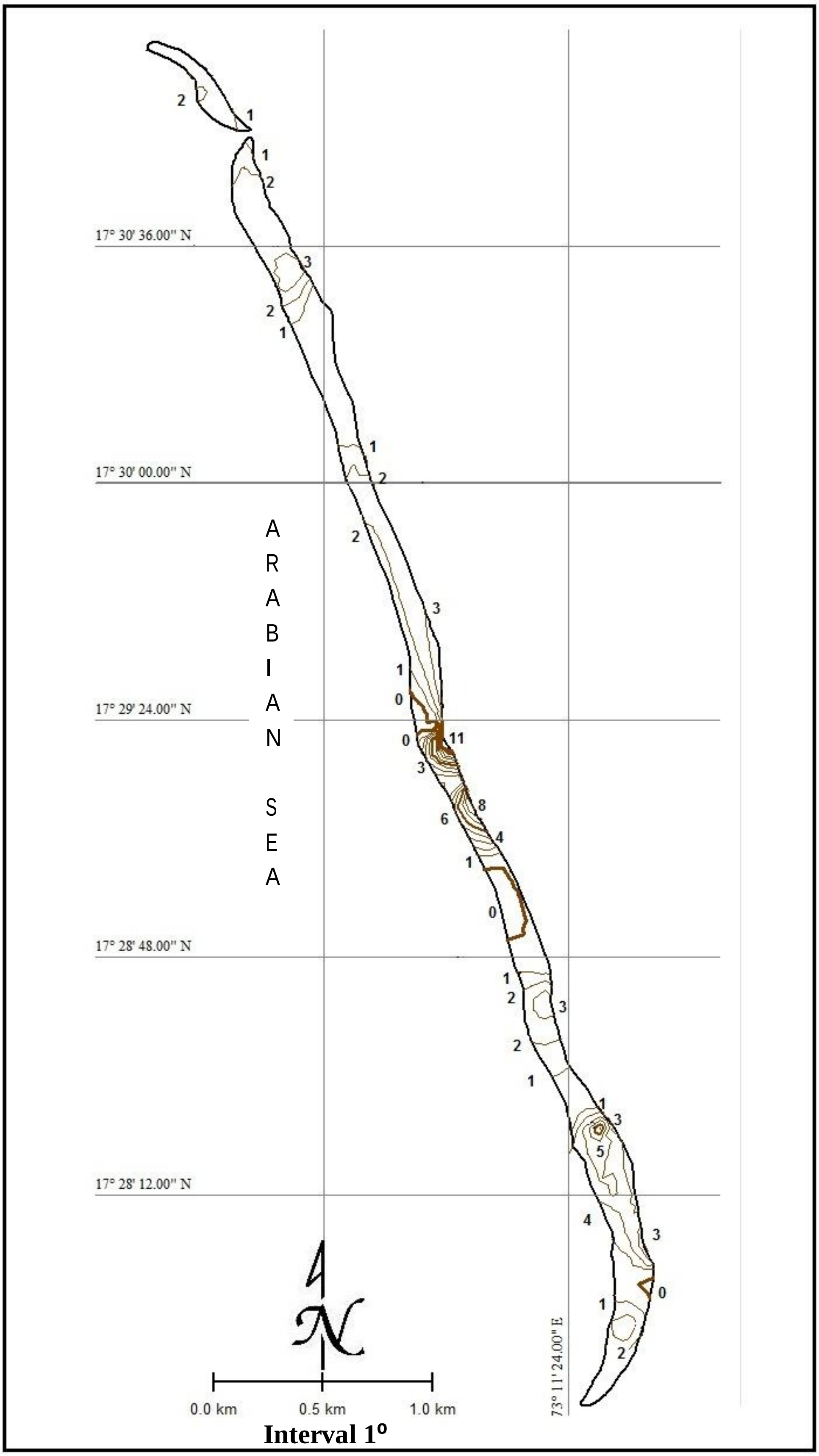


Figure No. 3.12. Isoline Map Showing Beach- Dune Average Slope (January)



Interval 1°

Figure No. 3.13. Isoline Map Showing Beach- Dune Average Slope (February)

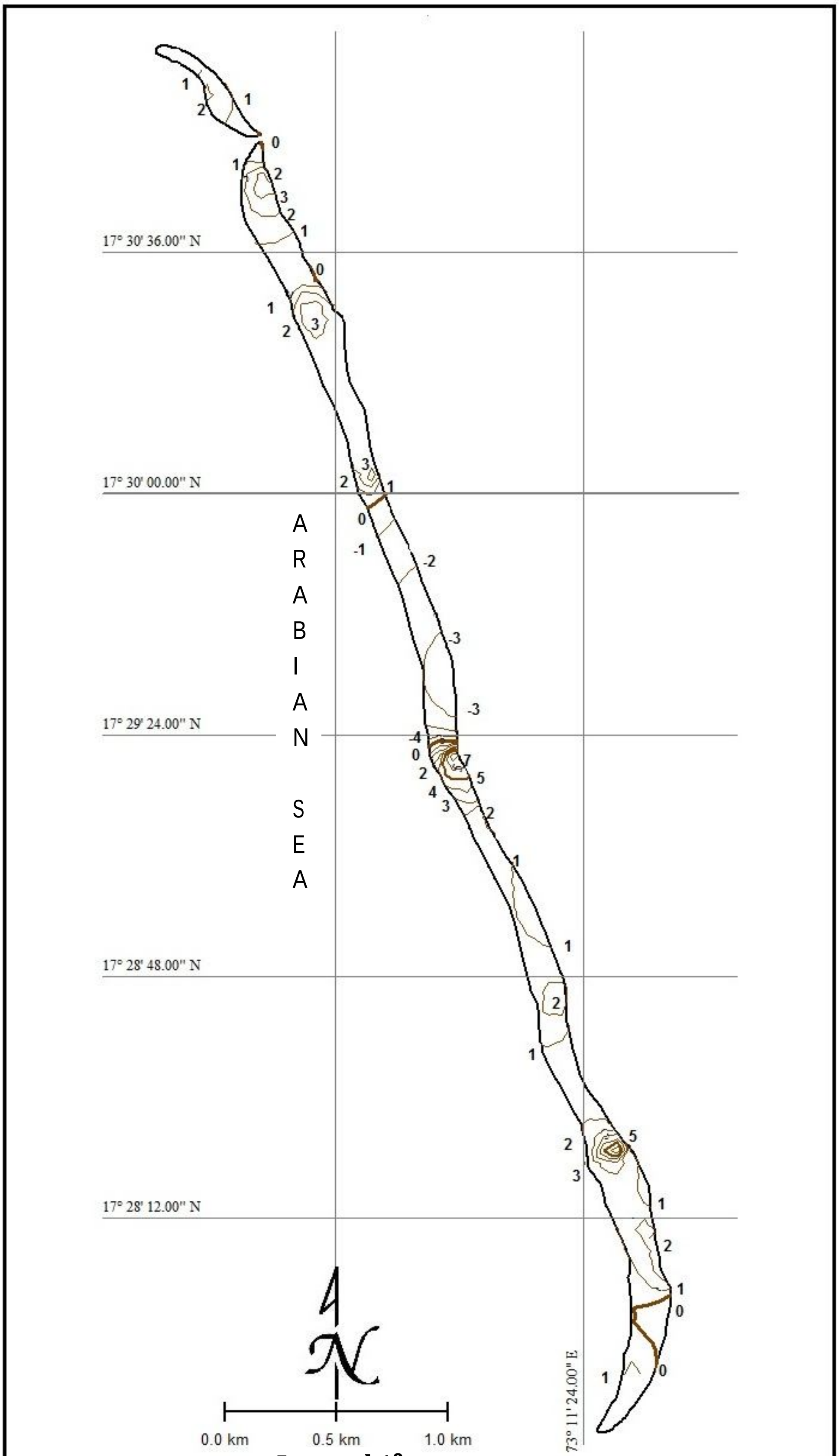
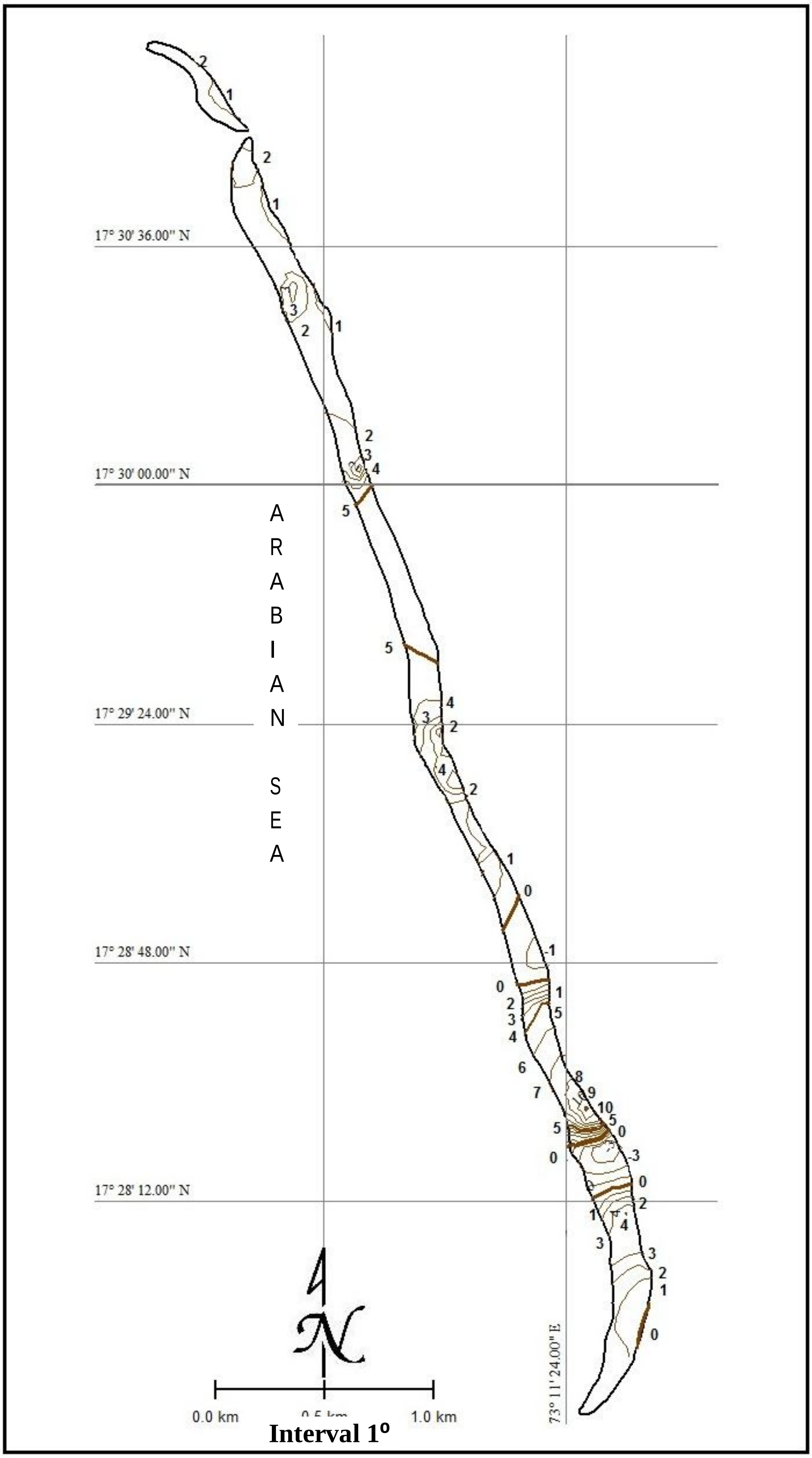


Figure No. 3.14. Isoline Map Showing Beach- Dune Average Slope (March)



Interval 1º

Figure No. 3.15. Isoline Map Showing Beach- Dune Average Slope (April)

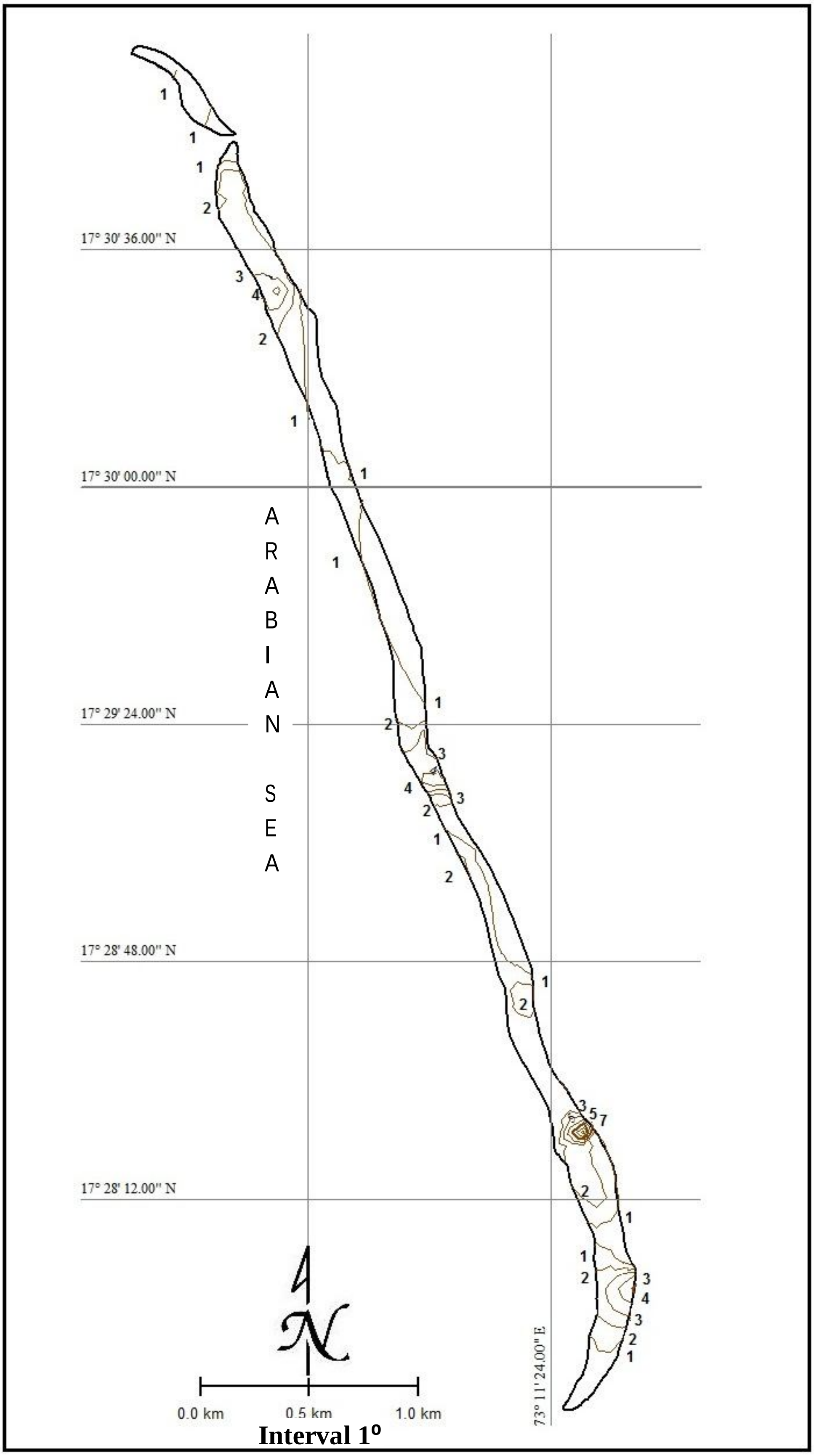
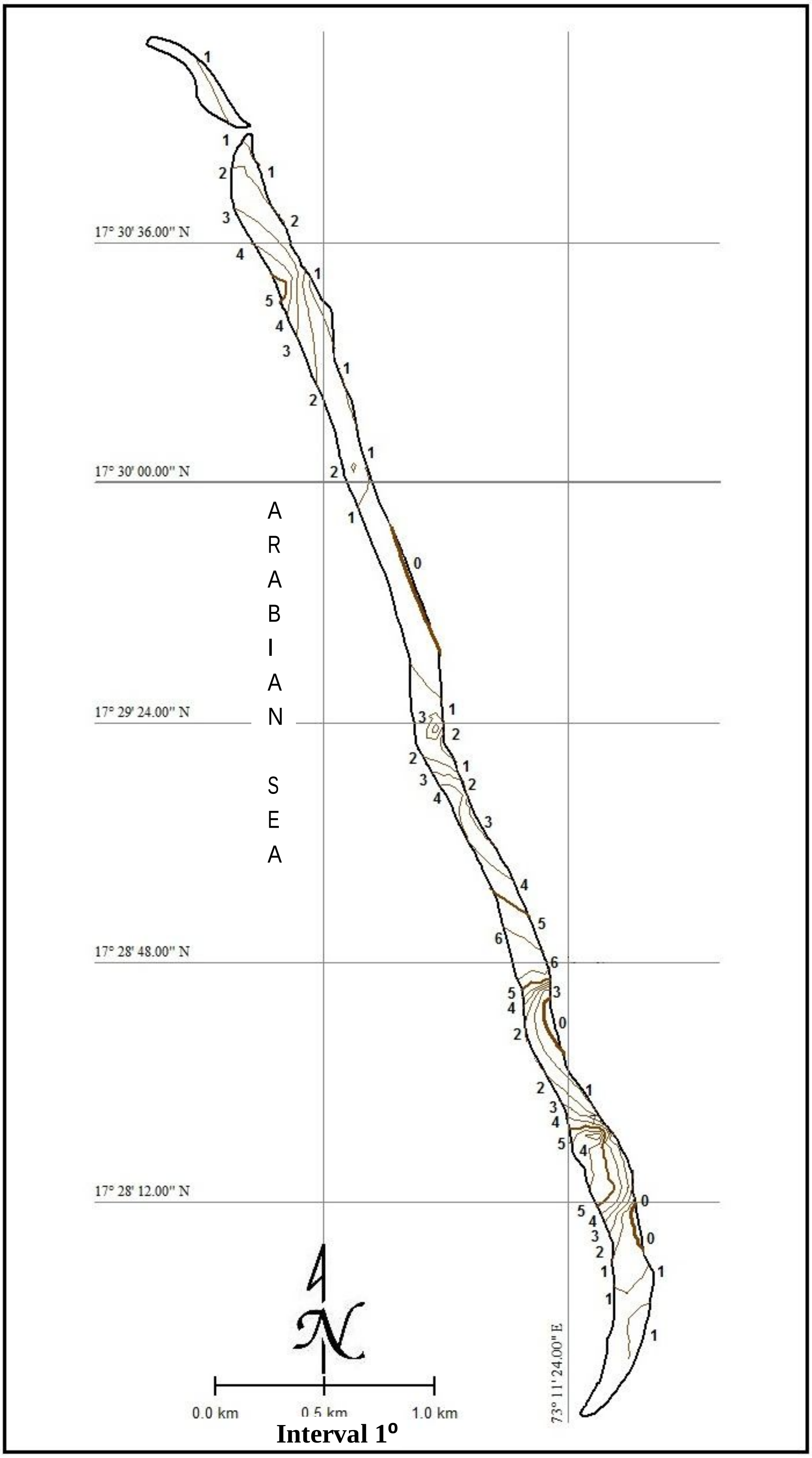


Figure No. 3.16. Isoline Map Showing Beach- Dune Average Slope (May)



3.7. Beach Slope and Down Beach Distance Relationship

Beach slope, dune slope, beach dune slope and distance down beach have certain relationship as distance is one of the major factors which affect the slope. Upper beach, lower beach, dune segments show variation in slope. Seasonal change in beach slope shows definite relationship with distance. In order to understand this relationship, bivariate simple regression technique was used.

Polynomial regression model at 5th order is best fitted to explain the relationship. The algorithm is based on a least-squares criterion and singular value decomposition, with mean and variance standardization for improved numerical stability. R^2 is the coefficient of determination, or proportion of variance explained by the model is used in the interpretation of annual beach, dune and beach-dune profiles.

Beach profiles show change in slope towards down beach direction. The model is fitted at fifth order. Beach slope and distance relationship shows 71.96% curves fitted as the polynomial best fit R^2 = 1) at 0.6 to 1.0.

In the months of monsoon, post-monsoon and pre-monsoon there was a definite spatial variation observed a long beach slope and down beach distance relationship. In the month of April and May (pre-monsoon), July and August (monsoon), November and December (post-monsoon) shows the best polynomial fit (92% to 100%). These months show very strong correlation between beach slope and distance down beach.

Along the beach at Guhagar, profiles in all three seasons, northern section shows very strong polynomial best fit (86%) than middle and southern section of beach profiles (56% and 82%) respectively. It was very interesting that at the profile no. 7 almost all profiles except in month of April and August are not significantly fit as this profile is highly disturbed by anthropogenic activities. (Figure No. 3.17 and 3.19).

3.7.1. Monsoon

The beach profiles obtained towards distance down beach direction in the month of July 2013, August 2013, September 2013 of monsoon season, beach slope and distance relationship shows 86% curves fitted as the polynomial best fit (Table No. 3.19). In the month of July 2013, (92%) profiles shows polynomial best fit. In the month of August 2013, almost all (100%) profiles show polynomial best fit. Upto

August this relationship is strongly explained by this model but during September the polynomial fit goes on decreasing up to 67%.

In the northern section 92% profiles show polynomial best fit except profile no. 4 in the month of September. In monsoon the northern section show strong relationship. The middle section of beach shows variation in relation. In the month of July all the profiles except profile no. 7 shows the polynomial best fit. In the month of August almost all profiles show the polynomial best fit. In the month of September profiles were not significantly fitted. The southern section of beach shows very strong relationship (100%) between beach slope and distance down beach in all the three months of monsoon season.

3.7.2. Post-monsoon

The beach profiles obtained along distance down beach direction in the month of October 2012, November 2012, December 2012, January 2013 of post-monsoon season, beach slope and distance down relationship shows 71% curves fitted at the polynomial best fit (Table No. 3.19).

The month of October is considered as the transitional period of the year. This is the month between monsoon and upcoming post-monsoon season. In October only (42%) profiles show polynomial best fit curves as this month shows poor relationship between beach slope and distance. The month of November and December (92%) show almost all profiles except profile no 7 shows the polynomial best fit, as the post-monsoon conditions are set during these months. Upto December this relationship is strongly explained by this model but during January the polynomial fit goes on decreasing up to 67% between beach slope and distance down beach.

The northern section of beach profiles (88%) shows polynomial best fit except at profile no. 4 in the month of October and profile no. 1 in the month of January. The northern section of beach shows a very strong relationship between slope and distance down beach than the middle and southern section of beach.

The middle section shows the variation in relation (56%). In the month of October and January the profiles show decrease in relation when compared to the profiles obtained in the months of November and December, where almost all profiles except profile no. 7 shows the polynomial best fit.

The southern section of beach also shows the variation in relation. In post-monsoon southern section of beach (75%) profiles shows polynomial best fit. The southern section of beach in the month of October and profile no. 12 in the December and January show poor polynomial best fit. In the month of November, December and January almost all profiles shows polynomial best fit curves.

3.7.3. Pre-Monsoon

The beach profiles obtained toward distance down beach direction in the month of February 2013, March 2013, April 2013 and May 2013 of pre-monsoon season, beach slope and distance down beach relationship show (67%) curves fitted (Table No. 3.19) at the polynomial best fit ($R^2 = 1$) at 0.6 to 1.0.

In the month of February and March (50% and 33% respectively) profiles show polynomial best fit. The month of April (100%) profiles shows very strong relationship and best fitted polynomial curves. The month of May which is upcoming monsoon month (83%) profiles shows polynomial best fit.

The northern section of beach in pre-monsoon season (81%) profiles show polynomial best fit. Except profile no. 1 and 4 in February and profile no. 1 in March almost all profiles shows polynomial best fit curves.

The middle section shows relation in variation. (44%) profiles shows polynomial best fit. In the month of February, March and May middle section profiles show very poor polynomial best fit.

The southern section also shows relation in variation. (75%) profiles shows polynomial best fit. The month of April and May almost all profiles in southern section show 100% polynomial best fit, as on February and March show (92% and 25%) polynomial best fit respectively.

3.8. Dune Slope and Down Dune Distance Relationship

Dune slope and distance relationship tested on polynomial regression model shows 94.94% of curves fitted at 0.6 to 1.0 (Table No. 3.20).

Profile 3 (Feb and March), profile 10 (May), profile 6 (September), and profile 11 (December) do not show significant relationship (Figure No. 3.19).

3.9. Beach Dune Slope and Down Beach Dune Distance Relationship

If we consider the beach and dune slope as a unit, polynomial regression analysis at 5th order shows very varied results. Only 28.78% of curves are fitted at 0.6 to 1.0 (Table No. 3.21) (Figure No. 3.18). In monsoon season (50%) profiles show polynomial best fit. The northern section of beach dune profiles show fairly best fit relationship than middle and southern section of beach. Compared with pre-monsoon season (21%), post-monsoon seasons (33%) shows fairly best fit relationship. In post-monsoon month of October and in pre-monsoon February and March shows very weak polynomial best fit. (Figure No. 3.19).

Table No. 3.19. Polynomial Fit r^2 (Order 5th)

Distance Down Beach vs. Beach Slope

	Jan	Feb	Mar	Apr	May	July	Aug	Sept	Oct	Nov	Dec
P 1	0.54	0.29	0.52	0.72	1	1	0.95	0.63	0.61	0.68	0.99
P 2	1	0.98	0.79	0.97	1	1	0.81	1	0.96	0.99	0.81
P 3	0.97	0.87	0.97	1	1	1	1	0.99	0.35	1	1
P 4	0.97	0.33	0.72	0.89	0.92	0.99	0.93	0.39	0.90	1	0.78
P 5	0.61	0.26	0.38	1	1	0.91	0.79	0.72	0.81	0.71	1
P 6	0.96	0.69	0.30	1	0.33	1	0.96	0.37	0.49	0.97	1
P 7	0.40	0.45	0.19	0.83	0.44	0.45	0.82	0.56	0.20	0.37	0.33
P 8	0.55	0.56	0.27	0.68	1	0.93	0.78	0.36	0.42	0.96	0.99
P 9	1	0.78	0.45	1	1	1	0.67	0.94	0.06	1	1
P10	0.64	0.91	0.52	0.93	1	1	1	1	0.48	0.64	1
P11	0.98	1	1	1	1	1	0.97	1	0.22	1	0.75
P12	0.42	0.52	0.51	0.97	0.91	1	0.66	0.63	0.67	1	0.55

Table No. 3.20. Polynomial Fit r^2 (order 5th)

Distance down Dune vs. Dune Slope

	Jan	Feb	Mar	Apr	May	July	Aug	Sept	Oct	Nov	Dec
***P1**	-	- -	-	-	-	-	-	-	-	-	-
P2	0.99	0.61	0.77	0.84	1	0.71	0.75	0.96	1	1	1
P3	1	0.55	0.42	1	1	0.99	0.86	0.92	1	0.96	1
P4	1	1	1	1	1	1	1	1	1	1	1
P5	1	1	1	1	1	1	1	1	1	1	1
P6	0.99	1	0.87	1	1	1	1	0.49	1	1	1
***P7**	-	-	-	-	-	-	-	-	-	-	-
P8	1	1	1	1	1	1	1	1	1	1	1
P9	0.76	1	0.72	1	1	0.98	0.94	0.83	1	1	1
P10	0.93	0.96	0.62	0.99	0.53	0.91	0.89	0.98	0.99	0.70	0.92
P11	1	0.94	1	1	1	1	1	1	0.88	0.99	0.43
***P12**	-	-	-	-	-	-	-	-	-	-	-

Table no. 3.21. Polynomial Fit r^2 (Order 5th) Distance vs. Beach Dune Slope

	Jan	Feb	Mar	Apr	May	July	Aug	Sept	Oct	Nov	Dec
***P1**	0.54	0.29	0.52	0.72	1	1	0.95	0.63	0.61	0.68	0.99
P2	0.59	0.25	0.23	0.59	0.74	0.42	0.45	0.71	0.47	0.37	0.79
P3	0.55	0.53	0.36	0.76	0.59	0.84	0.55	0.48	0.39	0.87	0.44
P4	0.57	0.49	0.48	0.35	0.63	0.74	0.7	0.63	0.47	0.78	0.66
P5	0.84	0.56	0.58	0.62	0.58	0.66	0.39	0.81	0.32	0.61	0.83
P6	0.28	0.47	0.22	0.31	0.18	0.37	0.37	0.27	0.33	0.53	0.63
***P7**	0.40	0.45	0.19	0.83	0.4	0.45	0.82	0.56	0.21	0.37	0.33
P8	0.66	0.39	0.32	0.54	0.45	0.4	0.58	0.7	0.46	0.49	0.54
P9	0.45	0.3	0.33	0.61	0.35	0.39	0.33	0.41	0.24	0.29	0.75
P10	0.42	0.45	0.31	0.5	0.28	0.74	0.7	0.62	0.2	0.34	0.37
P11	0.4	0.28	0.21	0.27	0.53	0.39	0.48	0.46	0.33	0.61	0.37
***P12**	0.42	0.52	0.51	0.97	0.90	1	0.66	0.63	0.67	1	0.55

(* these profiles do not show a distinct dune profile)

Figure No. 3.17. Polynomial Fit R^2 Order 5th Distance Vs Beach Slope

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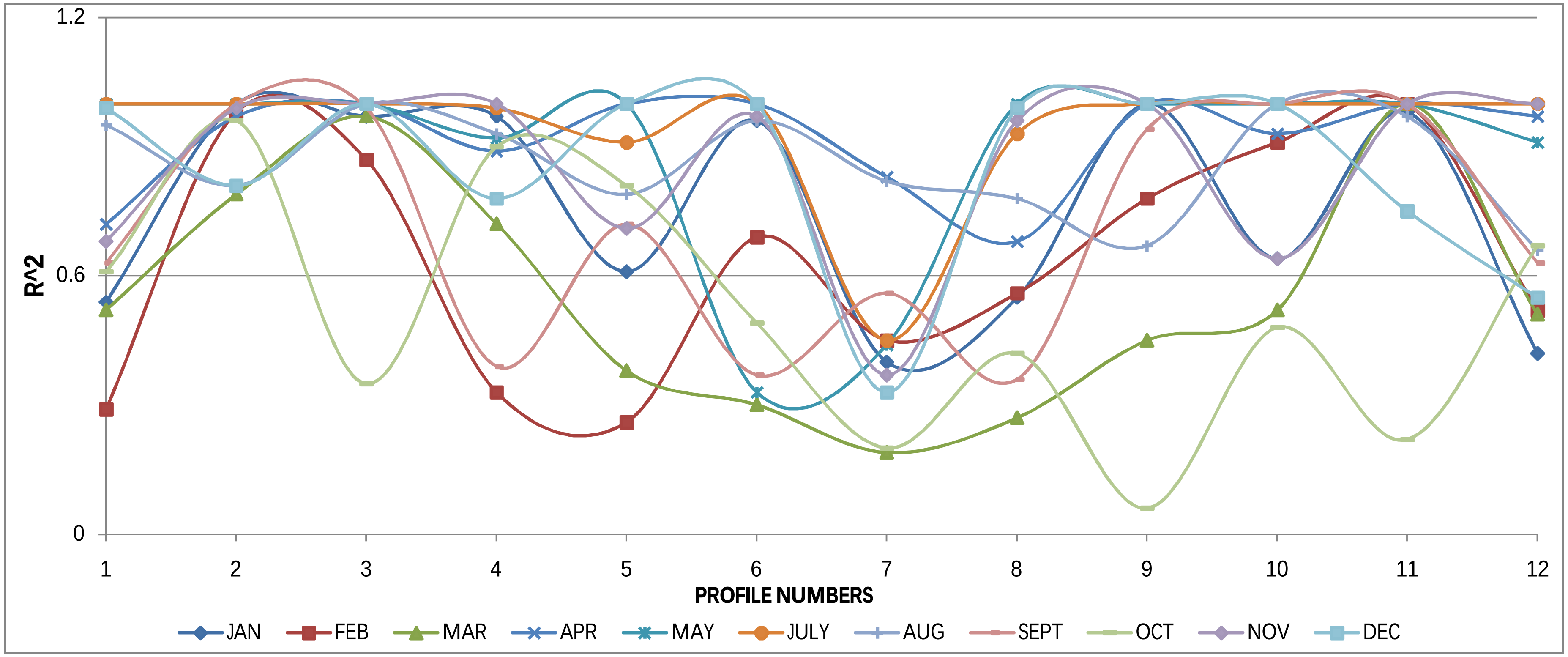


Figure No. 3.18. Polynomial Fit R^2 Order 5th Distance Vs Beach Dune Slope

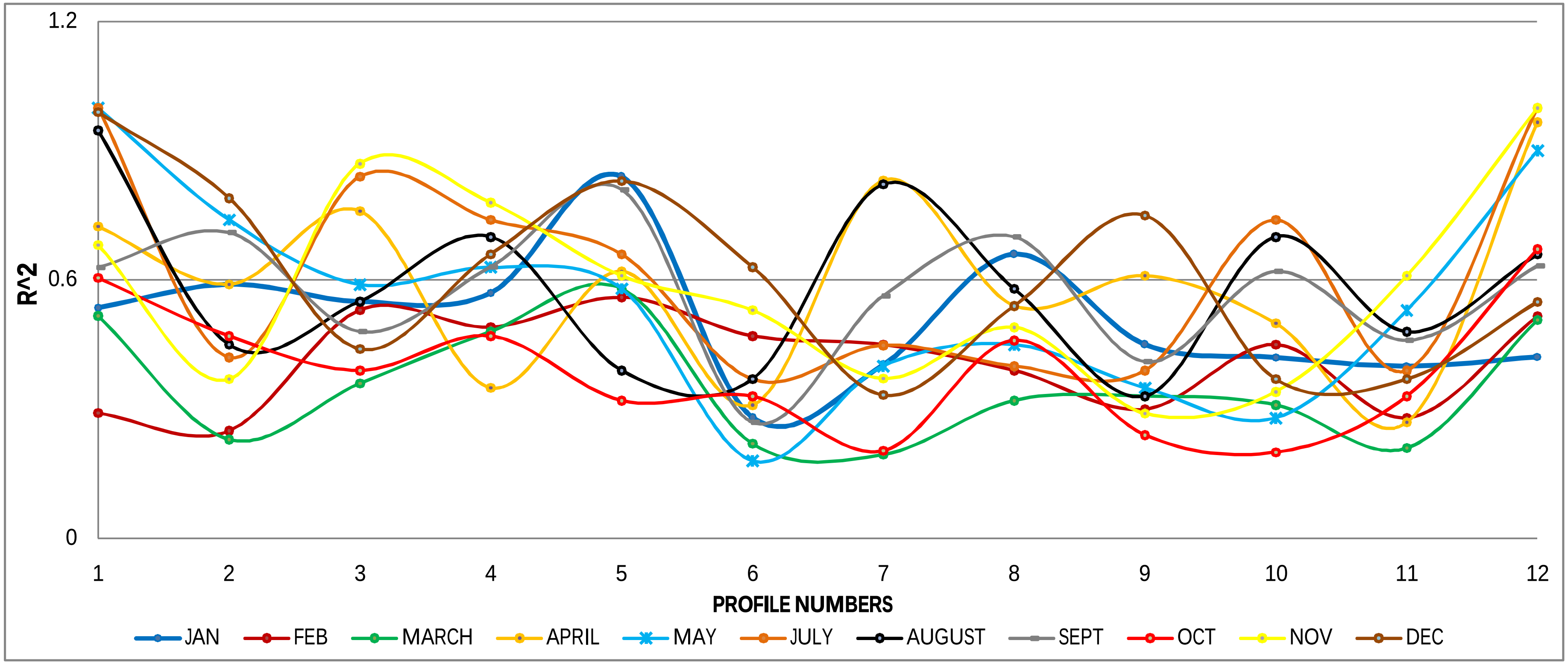


Figure No. 3.19. A Graph Showing Polynomial Fit r^2 (Order 5th) Profile 1 to 4

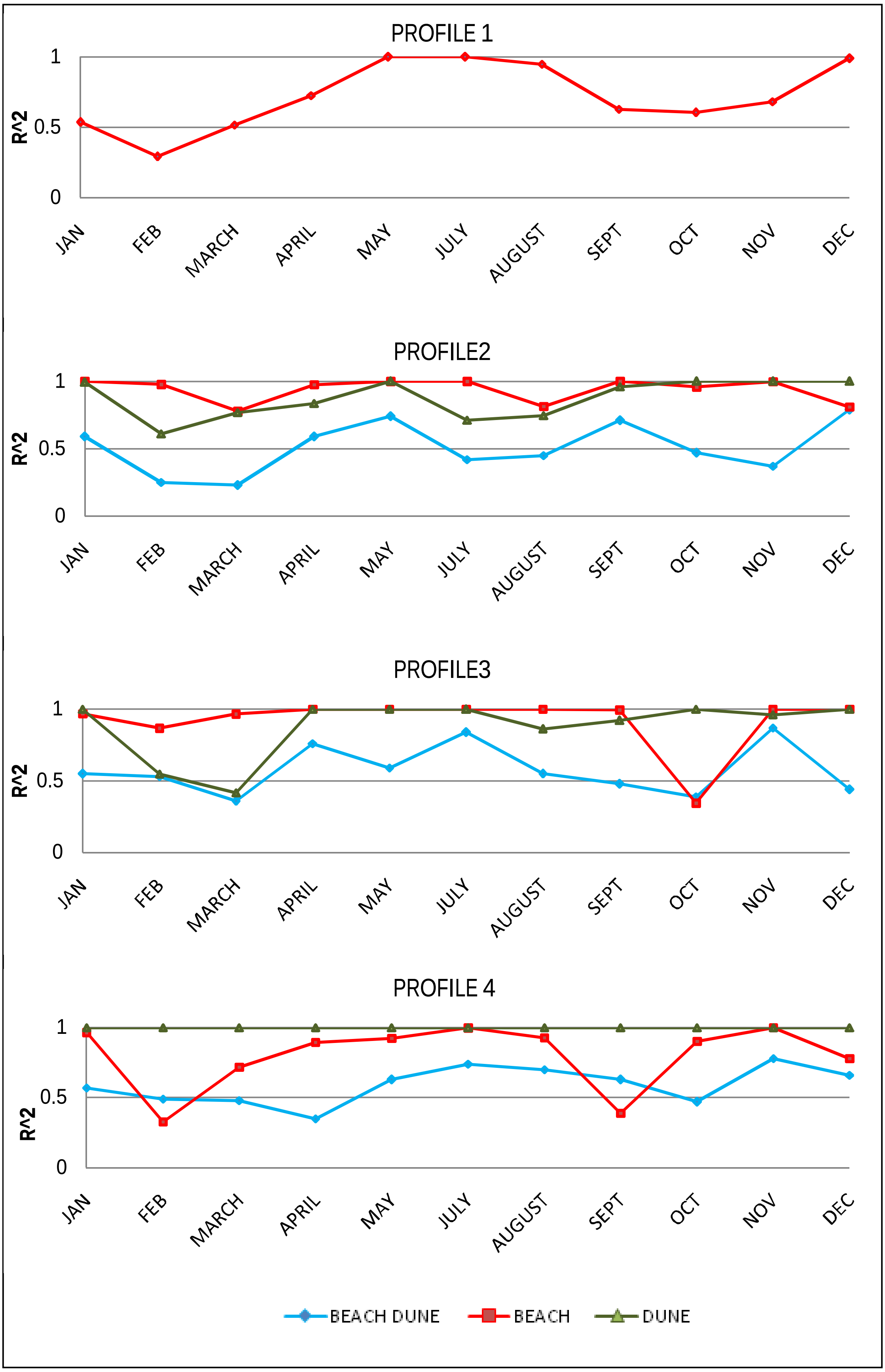


Figure No. 3.19. B Graph Showing Polynomial Fit r^2 (Order 5th) Profile 5 to 8

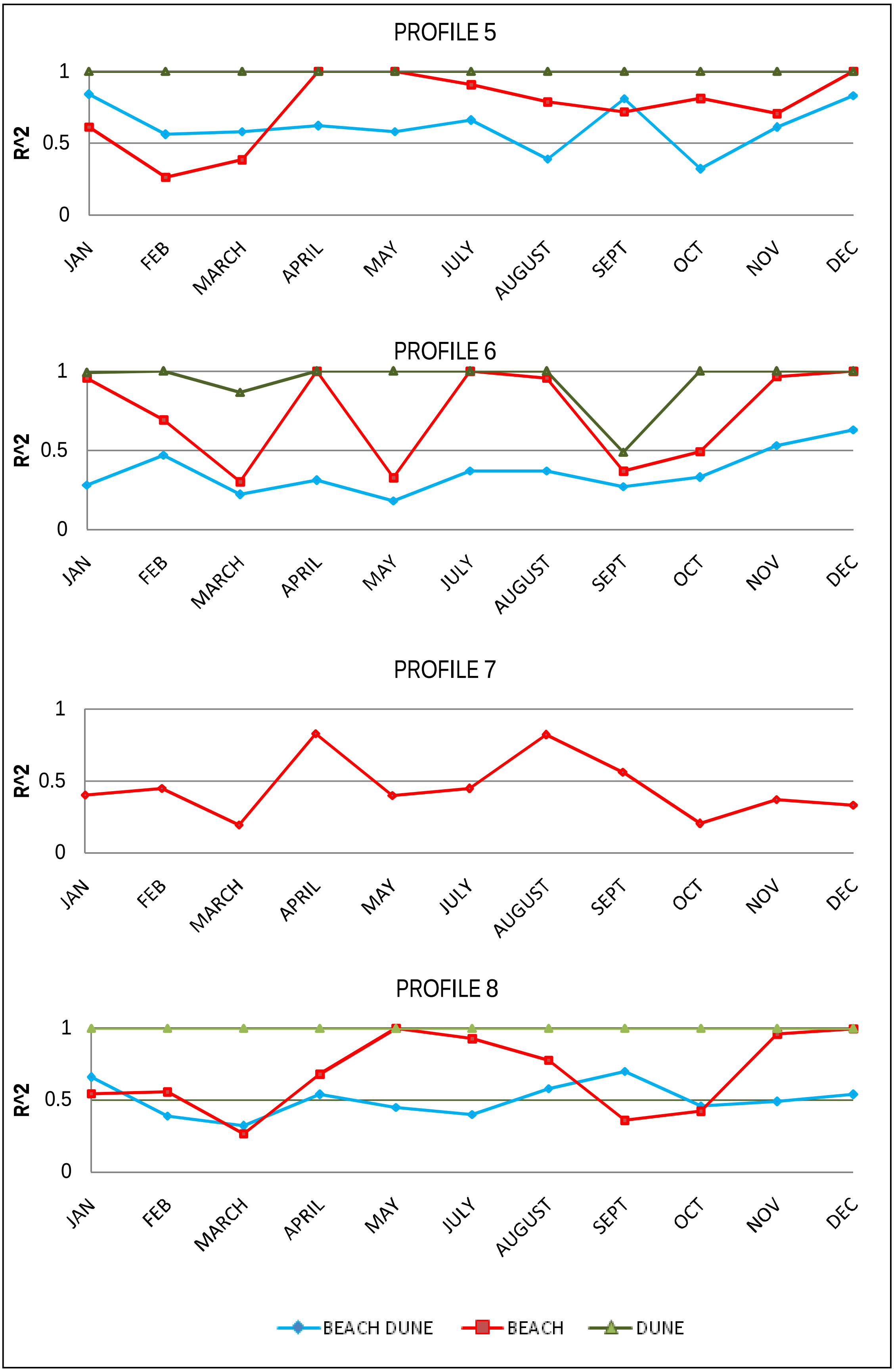
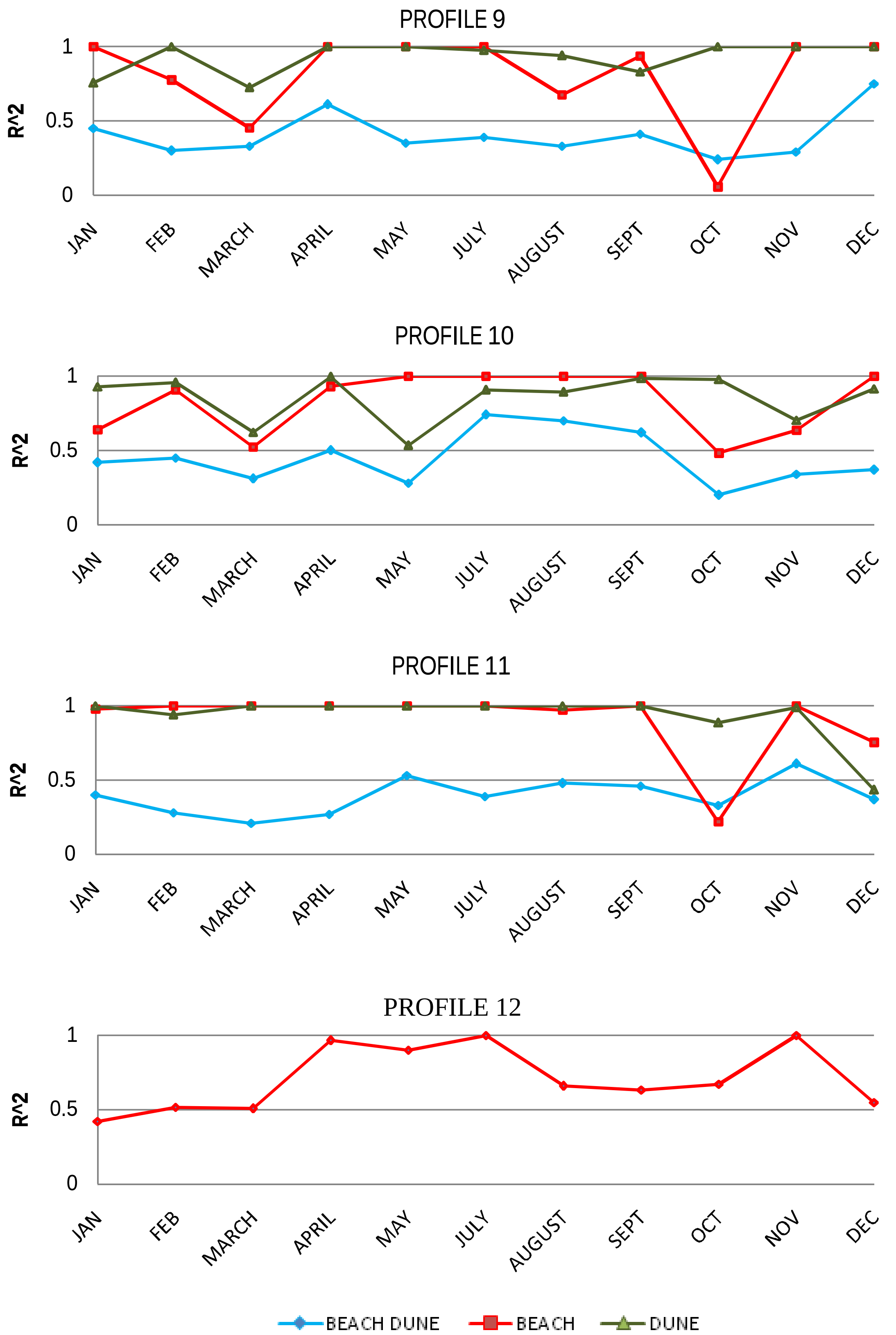


Figure No. 3.19. C Graph Showing Polynomial Fit r^2 (Order 5^{th}) Profile 9 to 12



(Profile No. 1, 7 and 12 do not show distinct dune profiles)

3.10. Morphology of Northern Tidal Inlet

Tidal inlet ranges among varieties of geomorphic processes on a small scale that are responsible for, and support the absorption and adjustment of varying energy conditions. Tidal inlets are one such similar adjustment.

There is definite change along the northern inlet of the Guhagar beach. The mouth of the tidal inlet and its shifting is dependent on the sediment size and the energy condition which can be a combination of the tidal and wave condition from the seaward side and the terrestrial fresh water flow from the landward side.

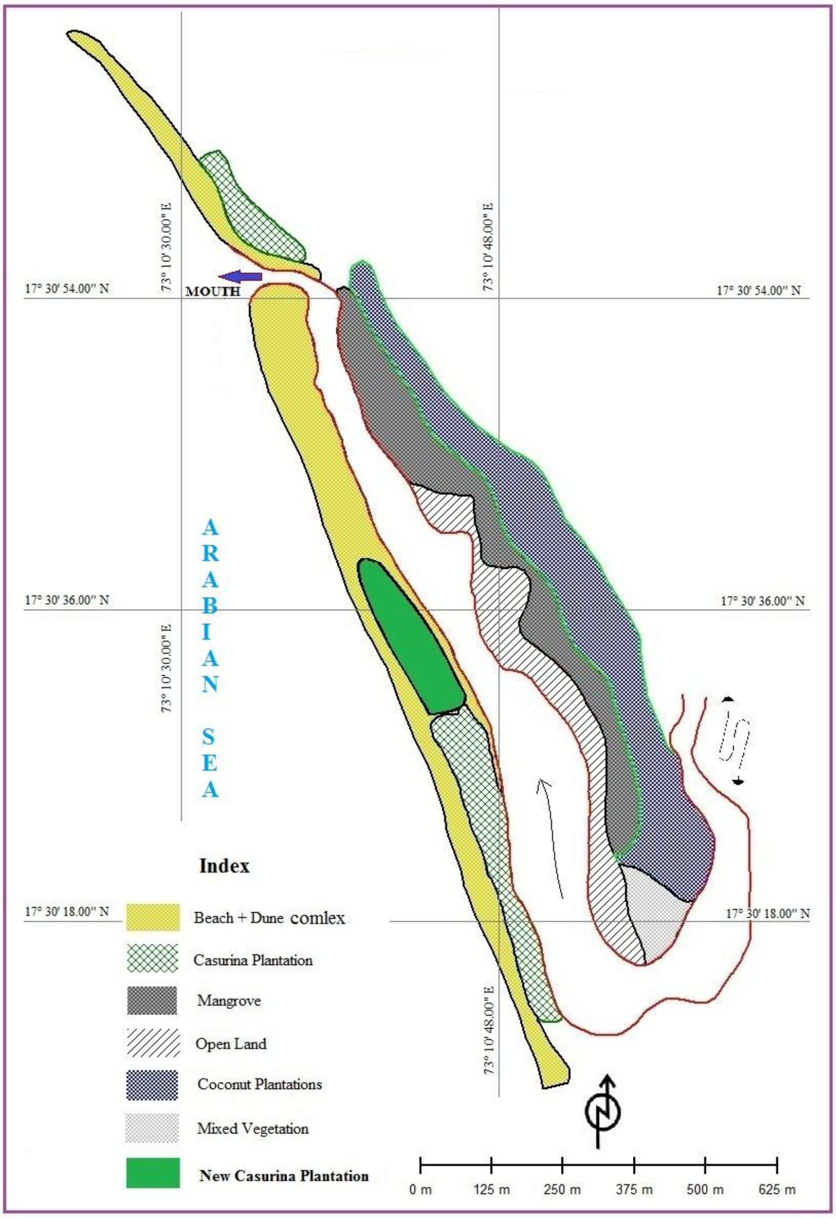
Northern tidal inlet along the Guhagar beach is located at 17 º30’56” N 17 º 30’ 11” N Latitude and 73 º 10’ 33” E to 73 º 11’ 00” E Longitude. The total area of the tidal inlet is 0.18 Sq. km. the mouth of inlet is shallow and narrow, the width of the inlet at mouth is 10 m. the width of the central portion is 110 m. and near the tidal limit portion its width is 25 m. gabions like structures have been constructed on the either side of tidal inlet to protect agricultural land from being inundated during high tide saline water (Figure No. 3.20).

The northern tidal inlet runs parallel to the beach for a distance of 1.5 kms (orientation – south to north). The tidal impact along the inlet is experienced upto a distance of 2.20 kms. Beyond the limit of tidal impact, the inlet narrows down in to a feeble stream which drains the monsoon surface flow in to the sea through the tidal inlet.

3.10.1. Shifting of Tidal Inlet

A very important morphological aspect of the northern tidal inlet is its temporal variation. The beach surveyed in 1952-53 and published in 1954 shows the different outline than surveyed in 2013-2014. The comparison of SOI toposheet, Google image shows that although there is no much more difference in the length of the inlet, the mouth of inlet shifted considerably. The total shift of mouth from 1952-53 to 2013 is 1.355 km. (1355 m). The width of the inlet is also changed, since 1954 there is decrease in width of the inlet. The dynamic shift of the mouth of the tidal inlet towards the north shows a typical pattern which can be explained through Google image 2004, 2006, 2011, 2013 (Map No. 3.21 and 3.22).

Map No. 3.20. Geomorphic map of the northern tidal inlet

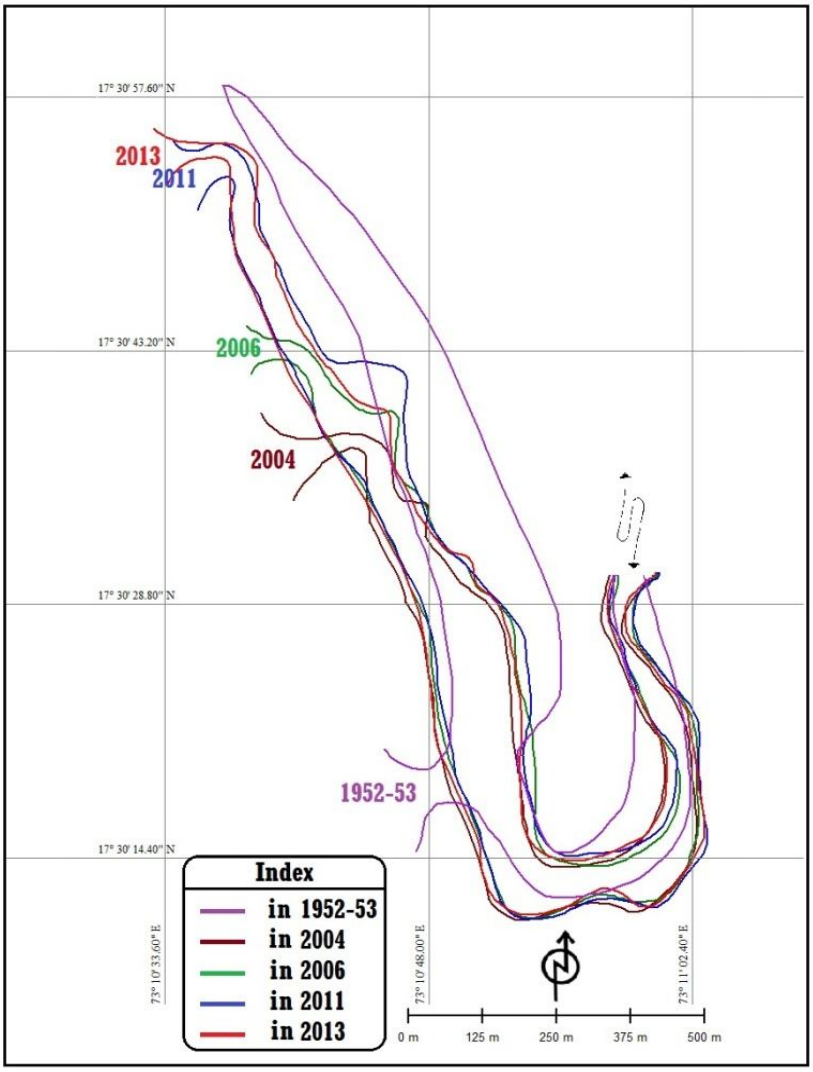


(Thorat Raviraj 2013)

The northern bank of the inlet indicates shift dynamics due to erosion and the southern bank of the inlet shift due to accretion and growth of the point bar towards north.

The alignment of the mouth of the tidal inlet changes in response to this erosion and accretion on the respective banks. It was however noted that the process of accretion towards the southern bank never exceeded the erosion of the northern bank as the mouth of tidal inlet was observed to be aligned in a west to Southwest direction in most of the images available for interpretation. At no instance was the mouth seen to be aligned to a Northwest direction.

Map No.3.21.Superimposed Map of Relative Shift at the Mouth of the Tidal Inlet

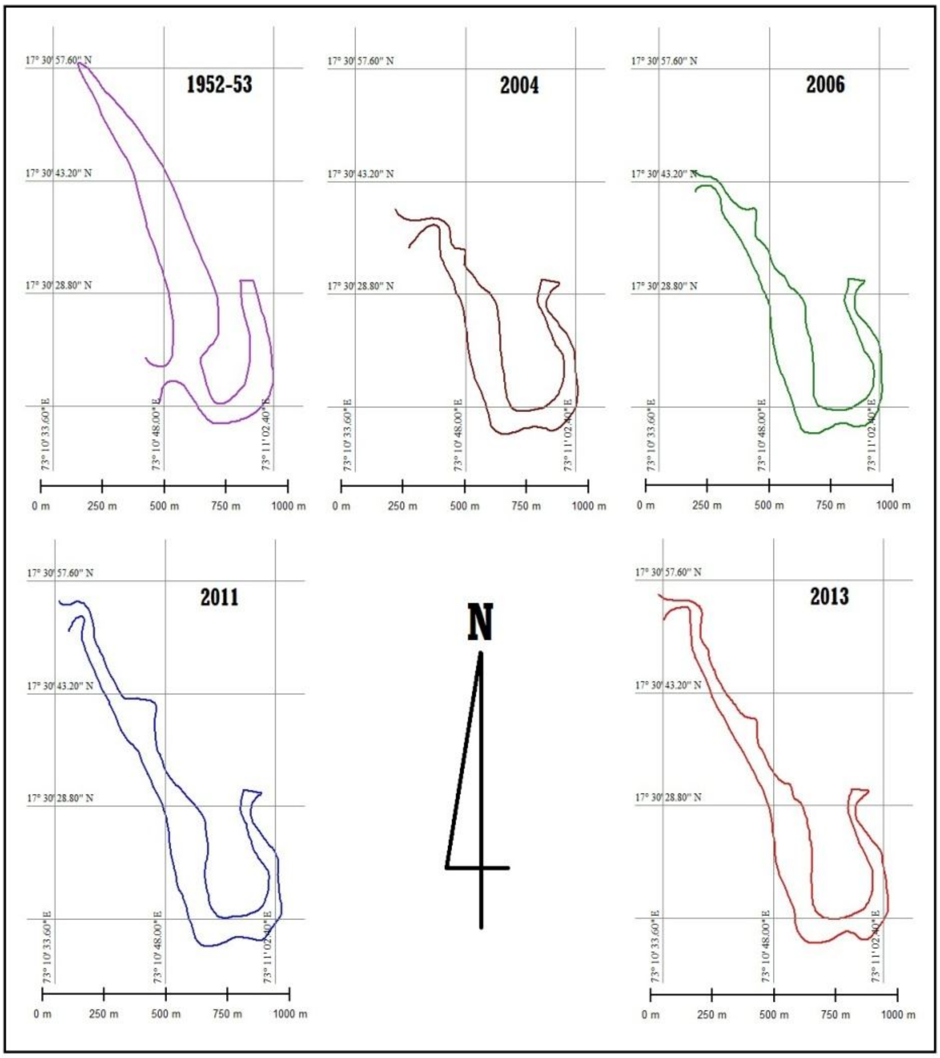


(Thorat Raviraj 2013)

The comparative position of the inlet shape shows the very dynamic change in morphology of tidal inlet. This has been interpreted with the help of Google images of year 2004, 2006, 2011, 2013 and Toposheet of 1954. All images show a continues shift in the inlet mouth, in the year of 2004 to 2006 the mouth shifted 220m, 2006 to 2011 the mouth shifted 340 m and 2011 to 2013 again shifted 25 m. 2004 to 2013 in 9 years the total shifting of the mouth was 585 m. 1335 m (1.355km) distance shifted the mouth from 1954 to 2013 towards northward direction (Map No. 3.22).

This shift extend further north in future, because the present extension and alignment of the inlet is still some meters short of the total length of the inlet observed in the toposheet. Also the uprooting of fully grown casurina trees indicates the erosion of the northern bank and confirms northward shifting of the inlet.

Map No. 3.22. Comparative Positions of Mouth of Tidal Inlet



(Thorat Raviraj 2013)

(1954 toposheet and 2004, 2006, 2011, 2013 Google images)

3.11 Wave Climate

Wave climate is also an important aspect that affects the beach. There is a definite seasonal variation in wave climate at Guhagar (Table No.3.22). In monsoon the waves are strong and effective so swash and backwash were also powerful with spilling types of breakers. In monsoon the wave energy is higher than post-monsoon and pre-monsoon seasons.

In post-monsoon and pre-monsoon there is considerable reduction in the width of breaker zone. Due to calm sea in these seasons wave period is slightly longer swash and backwash is slower than monsoon. In this season the width of surf zone and wave height is reduced.

Table No. 3.22 Wave Climate at Guhagar

Season	Month	Average Wave height (m)	Average Wave period (sec)	Average Wave velocity (m/sec)	Average Wave Energy J/Sq M
Monsoon	July	0.93	8.91	0.664	1.03
	August	1.3	8.66	0.857	2.07
	September	0.86	9.58	0.612	0.900
	AVERAGE	**1.03**	**9.05**	**0.71**	**1.33**
Post-monsoon	October	1.03	12.75	0.62	1.32
	November	1.13	11.32	0.65	1.61
	December	0.81	12.45	0.32	0.81
	January	0.67	12.27	0.45	0.56
	AVERAGE	**0.91**	**12.20**	**0.51**	**1.07**
Pre-monsoon	February	0.82	14.1	0.36	0.85
	March	1.00	8.86	0.7	1.26
	April	0.95	9.91	0.79	1.14
	May	0.97	9.64	0.77	1.30
	AVERAGE	**0.93**	**10.63**	**0.66**	**1.14**

(Source- Field Work)

Monsoon wave climate data shows that an average wave height of 1.03 m was observed with average wave period of 9.05 seconds (Photo No 22). In post-monsoon the average wave height of 0.91 m was observed with average wave period of 12.20 seconds and in pre-monsoon the average wave height 0.93 m with average wave period of 10.63 seconds was observed. The average maximum wave height of 1.3 m was observed in the month of August and minimum 0.67 m in the month of January. The average wave period 14.1 seconds was observed in the month of February i.e. pre-monsoon and minimum 8.66 seconds in the month of August of monsoon season.

According to Karlekar (2002), the prevailing winds are south westerly in monsoon and northwesterly in fair-weather. On the study area the waves are forceful shows average wave velocity 0.71 m/sec (Photo No 23). In post-monsoon season the sea is calm (Photo No.24) shows average wave velocity 0.51 M/sec, and in pre-monsoon the average wave velocity 0.66 m/sec was observed. North to north, northwest currents are stronger in October and Southeast currents are powerful in July (Karlekar, 2002).

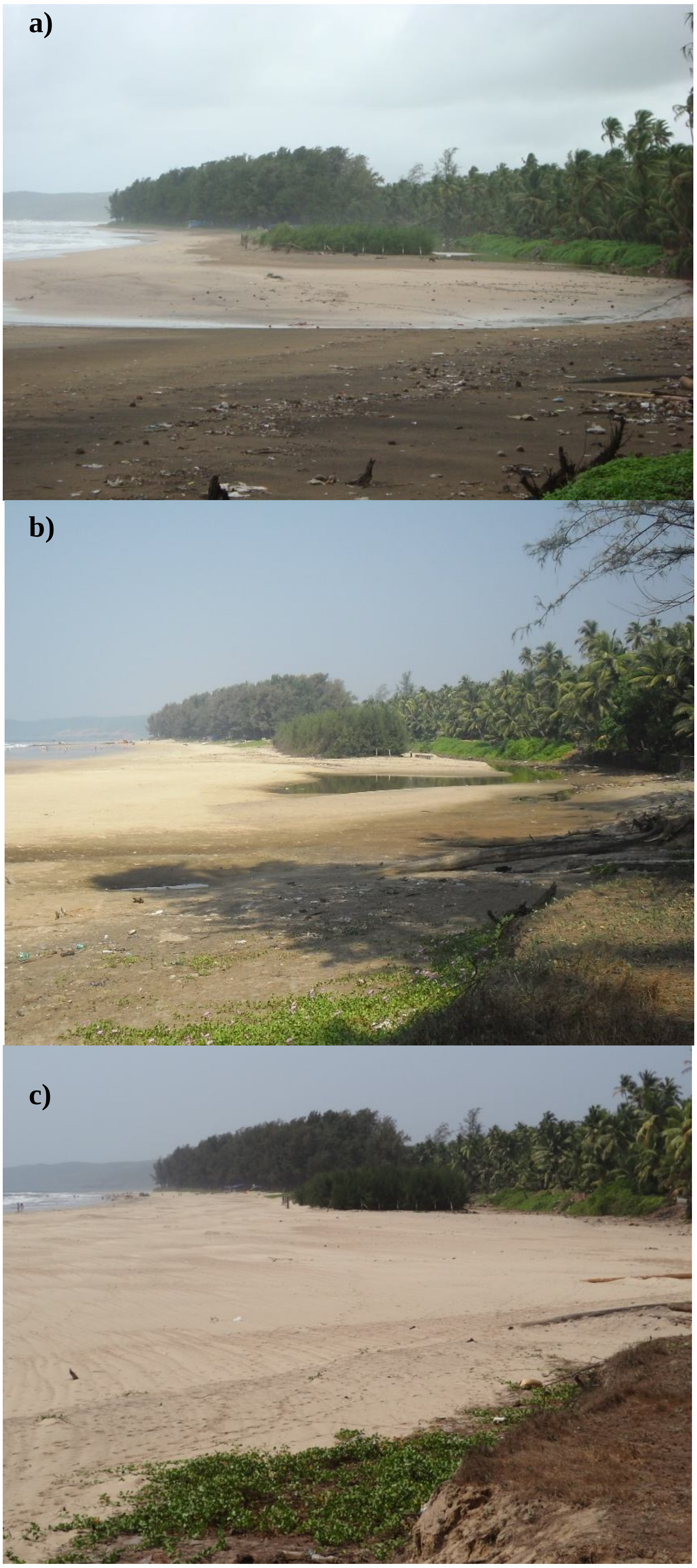
Wave energy of the breakers normally does not exceed 2.5 J/Sq M in monsoon season. The average of wave energy in monsoon was 1.33 J/Sq M. maximum wave height was observed in the month of August was 2.07 J/Sq M. Average wave energy decreases to 1.07 J/Sq M in post-monsoon season and in pre-monsoon it was slightly increasing up to 1.14 J/Sq M.

Photo 22 Strong Monsoon Surges in July

Photo 23 Wide Surf Zone and High Waves in Monsoon

Photo 24 Calm Sea Conditions in Post Monsoon

Photo 25 Morphological Changes in Tidal Inlet (Middle Sector)
a) Monsoon b) Post-monsoon c) Pre-monsoon



CHAPTER IV

TEXTURAL CHARACTERISTICS OF SEDIMENT

4.1. Introduction

Beach sediments are important aspects as; these are the materials from which beach micro features are created. The waves distribute sediments so that the beach is reshaped towards equilibrium with the waves. Beach sediment plays a vital role in documenting the depositional history of a region. They provide geomorphologic evidences of the beach. Extreme events like storms, tsunami affects very badly change the morphology of the beach and leave their record in specific sediment properties.

Textural characteristics of beach sediment is the result of complex interactions between sediment sources, wave energy and general offshore gradient upon which the beach is naturally shaped (Komar, 1998). The grain size distribution of the sediment deposits can be assessed by sieve analysis and according to Abuodha (2003) the results have been useful for the classification of sedimentary environment and can also be helpful to calculate transport dynamics (Imhansoloeva et.al., 2011).

Grain size analysis is one of the important and widely used sedimentological tools to unravel the hydrodynamic conditions of oceanic environment. Texture, the micro geometry of sediment, deals with its size and shape. Textural analysis has three objectives which include description, comparison of sediment and consequent interpretation. Several studies have been done in order to understand, grain size parameters to differentiate environments of deposition (Uden, 1914; Folk and Ward, 1957; Visher, 1969).

On the basis of shape and size frequency curves Keller (1945) has shown that dune sediments can be distinguished from beach sands. Inman (1949) has established a relationship between the dynamics involved during sedimentation and the resulting textural characteristics of the sedimentary rocks. Mason and Folk,(1958); Friedman, (1961 and 1967) have attempted to differentiate the varying environment like river, beach and dune by using textural parameter. Textural analysis is a measure of description of the grain size distribution (Mohan, 1990). Grain size sorting and skewness are the sediment textural parameters that give useful information on the origin and evolution of coastal sedimentary environment. (Carranza - Edwards, 2001). In fact grain size distribution reflects both the viscosity and energetic factors of depositional environments (Sahu, 1964).

The present day sedimentary deposits on Guhagar beach are purely clastic sediments. Very less or negligible amount of carbonate as well as biotic material is present. The sediments on the beach also show distinct variation over time. The seasonal changes occur in the sediment size properties like mean phi value and standard deviation (sorting index). The distributional properties like skewness and kurtosis also show seasonal variations or change.

The wave conditions in monsoon, post-monsoon and pre-monsoon are different considering the wave climate. According to Bryant (1982) the reason for difference in grain size distribution at different locations is due to the variation in wave energy reaching the location of sampling and the morphology of the beach.

To understand the sediment properties on Guhagar beach, one year bimonthly data was collected for sediment sample at selected locations represents that the beach sediments was predominantly sand. Result obtained from the various analyses with respect to grain size parameters of the sediments mainly mean size, standard deviation, skewness and kurtosis are presented here. (Subsurface sediments and beach-dune section samples were also analyzed).

4.2. Grain Size Parameter of the Sediment in Monsoon

The sediment samples collected in the month of July (Table No. 4.1) and September (Table No. 4.2) represents the sediment characteristics in monsoon season.

4.2.1. Mean Sediment Size

Grain size distribution and description are often used to know the nature of sedimentary environment and the seasonal changes therein. The average size of sediments which also represents entire curves of the graph is called phi mean size. The mean grain size is a measure often used to infer energy fields. The extent to which a sediment sample is sorted or composed of similar sized grains is indicated by sorting index, which is the standard deviation of the sediment size distribution. Standard deviation measures the degree of scatter, is an indicator of the spread of data about the average.

The mean sediment size range from 0.475 ø to 3.519 ø represents the monsoon conditions in **July**. Sediment ranges between very coarse grained to very fine grained sand. There is a variation in mean sediment size throughout the beach. Northern sector sediments show the range from 0.475 ø to 2.596 ø. The distribution is coarse grained to fine grained. In middle section and southern section of the beach mean sediment size ranges between 1.925 ø to 3.519 ø and 2.141 ø to 3.372 ø. The distribution is fine grained sediment (Figure No. 4.1) and (Figure No. 4.4).

The mean sediment size range from 1.19 ø to 3.674 ø represents the monsoon conditions in **September**. Sediment ranges between very coarse grained to very fine grained sand. There is a variation in mean sediment size throughout the beach. Northern sector sediments show the range from 1.219 ø to 3.674 ø. The distribution is medium grained to fine grained. In middle section of the beach mean sediment size ranges from 1.457 ø to 3.674 ø (medium grained to very fine grained) and in southern section of beach mean sediment size ranges from1.539 ø to 2.997 ø. The distribution is medium grained to fine grain (Figure No. 4.2) and (Figure No. 4.4).

On the beach in July 57% sediment samples are fine grained, 18% very fine grained and rest 25 % medium to very coarse grained sediments. In September 85% sediment samples were fine grained, 3% very fine grained and 12% medium grained sediments.

Data representing the month of July (Table no.4.3) shows the presence of sand silt and clay contents of beach sediments. Beach sediments are mainly sandy; contain 99.7 % of sand accumulation. The silt content is comparatively low, show only 0.2 %. Clay is totally absent. Coarsening is very dominant at the northern zone of beach in Guhagarbaug region (Photo No. 26 and 27). Coarser sediments restricted only to lower beach (Photo No.28) near profile no 2 and 3 at the vicinity of the mouth of the north tidal channel. Fine to very fine sand is dominant at the extreme north sector, middle sector (Photo No.29) and southern sector of the beach. On the beach in the month of September sediments are mainly sandy contain 98 to 99 % sand accumulation (Table No. 4.4). Comparatively the silt percentage increase from 0.2% to 41.2% than July.

Along the study area in the month of July beach sediments were mainly 70 % Unimodal and 30 % bimodal character. The middle and southern sector, sediment samples are Unimodal in character and northern sector where sediment samples are medium to very coarse grained show a bimodal character. Very coarse to medium grained sediments with poor sorted and fine grained sediment with moderately sorted are bimodal in character. Fine to very fine grained sediments on the beach zone with well to moderately well sorted are unimodal in character.

In the month of September beach sediments are 46 % unimodal, 49% bimodal and 6% trimodal character. It is clearly indicated that in the northern sector fine grained sediments with well sorted are unimodal and at the middle and southern sector fine grained sediments with moderately well sorted are unimodal in character.

4.2.2. Sorting Index

Sorting indicates maturity of the sediments. Sorting index can also be used to infer sediment transport pathways in case of the sediments that are moving upslope or down slope especially on a beach system.

The standard deviation value of the sediments varies from phi size 0.428 to 1.293 (well to poor sorted), 0.393 to 1.079 (well to poor sorted) in the months of July and September respectively.

In July northern sector, middle sector and southern sector, standard deviation values of sediments vary from 0.694 to 1.293 phi (moderately well to poorly sorted), 0.382 to 0.719 phi (well sorted) and 0.471 to 1.241 phi (well to moderate sorted) (Figure No. 4.1) and (Figure No. 4.5).

In the month of September standard deviation values of sediments in the northern sector, middle sector and southern sector, vary from phi size 0.393 to 1.009, 0.496 to 1.076 (both northern and middle sector shows well to poor sorted) and 0.531 to1.079 (moderately well to poor sorted) (Figure No. 4.2) and (Figure No. 4.5).

On the beach in July 13 % and 12% sediment samples are well sorted, 31 % and 46% moderately well, 31 % and 30% moderate, 26% and 12% poor sorted in the months of July and September respectively.

4.2.3. Skewness

Skewness, the measure of the degree of symmetry, describes the tendency of the data to spread preferentially to one side of the average. In the textural analysis skewness is considered as an important parameter, since it is a sensitive indicator of sub-population mixing (Mohan, 1990). Beach sediments are usually negatively skewed as there is concentration of relatively coarser sand. Dune sediments are positively skewed due to concentration of finer sand.

On the beach skewness values vary from – 0.537 to 0.374 (coarse to fine skewed), - 0.468 to 0.386 (very coarse to very fine skewed) in the respective months.

In July northern sector, sediments are coarse to very fine skewed. In the middle sector, sediments are symmetrical to very coarse skewed and the southern sector, sediments are coarse to very coarse skewed (negatively skewed distribution) (Figure No. 4.1) and (Figure No. 4.6). In September northern sector and middle sector sediments are very coarse to symmetrical skewed, whereas in southern sector sediments are coarse to symmetrical skewed (Figure No. 4.2) and (Figure No. 4.6).

On the beach zone 52% and 64% of sediment samples are very coarse to coarse skewed, 26% and 30% symmetrical and 27% and 6% fine to very fine skewed category in respective months.

4.2.4. Kurtosis

Kurtosis measures the ratio of the sorting in the extremes of the distribution compared with the sorting in the central part. Median grain size of the sand is the better indicator of wave energy on the beach. According to Doornkump (1974), the higher median grain size suggests more wave energy and the lower grain size suggest less wave energy.

The values of fourth movement kurtosis vary from 0.769 to 1.403 (platykrutic to leptokurtic), 0.668 to 1.755 (platykrutic to very leptokurtic) nature of sediments in July and September months respectively.

In July majority of sediment samples on northern sector, southern sector and the upper beach shows leptokurtic character while the middle sector and lower beach shows mesokrutic character (Figure No. 4.1) and (Figure No. 4.7). In September mesokrutic nature of sediment dominates the middle and lower beach (Figure No. 4.2) and (Figure No. 4.7).

14% and 21% sediment samples show platykrutic nature of distribution, 34% and 55% mesokrutic and 52% and 24% leptokurtic nature of distribution in respective months.

Textural analysis for both the months in monsoon season show that, in July sediments are fine grained sand, moderate to moderately well sorted sediments, that are very coarse to coarse skewed and leptokurtic in nature. In September it is fine grained sand, moderate to moderately well sorted sediments, that are coarse to symmetrical skewed and mesokrutic in nature.

The most interesting aspect on the beach at Guhagar in the month of July is that the northern and southern ends show the same textural characteristics. Almost all the samples here represent fine sand, moderate sorted sediment, that are coarse skewed and leptokurtic in nature. This is the indication of similar environment at both the ends of the beach.

4.2.5. Scatter Plots of the Sediment in Monsoon

In July the relationship between mean sediment size and sorting index shows (Figure No. 4.3 A) that fine to very fine grained sediment are well to moderate sorted, except fine grained sediment sample at profile no. 10 upper beach shows poor sorting index. Medium to coarse grained sediments restricted to northern sector of lower beach are poorly sorted. In September fine to very fine grained sediment are well to moderately sort. Medium grained sediments are moderate to poorly sorted.

The relationship between mean size, sorting index and skewness shows that (Figure No. 4.3 B and C) in monsoon season fine grained sediment with moderate to moderately well are very coarse to symmetrical skewed in nature. Very coarse to medium grained sediment with poor to moderate sorted show the symmetrical to fine skewed in nature. In September there are four sediment Samples, with moderately well sorted to poor sorted on lower beach are very coarse skewed in nature.

Monsoon skewness and kurtosis show the variation in relation (Figure No. 4.3 D). This variation is seen in leptokurtic and coarse skewed (negatively skewed) sediments as well as symmetrical to fine skewed sediments which are platykrutic to mesokrutic in nature. In September symmetrically skewed sediments show mesokrutic distribution. Negatively coarse skewed sediments show mesokrutic to leptokrutic distribution.

Photo 26 Medium and Coarser Sediment near Northern Tidal Channel

Photo 27 Lateritic Pebbles Deposited At Northern Sector In Monsoon

Photo 28 Coarse Sediments on Lower Beach and Fine Sediments on Upper Beach at Middle Sector in Monsoon

Photo 29 Fine Sediments with Waste Material on Middle Section of the Beach

Figure No.4.1.Variogram for Textural Parameter (July)

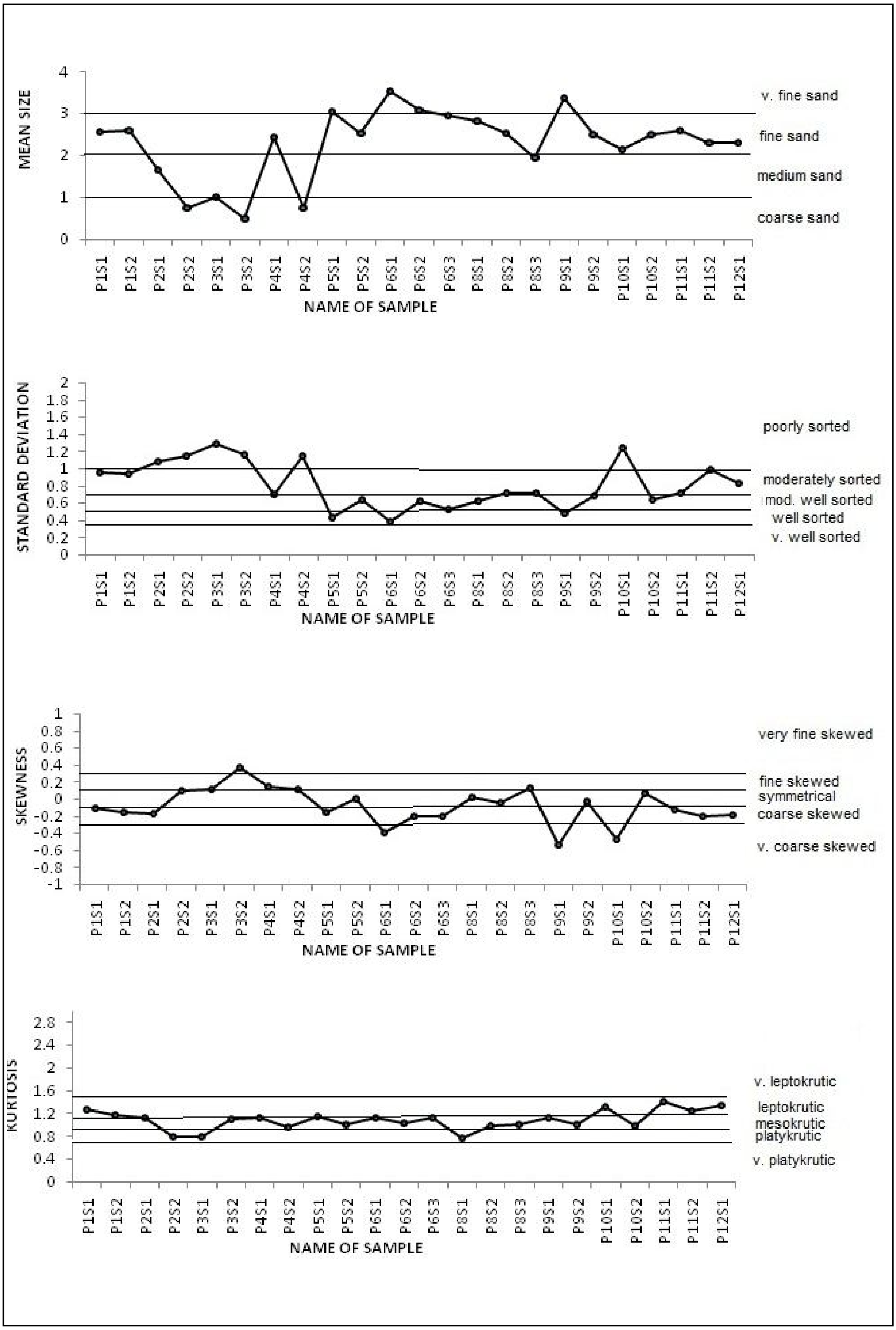


Figure No. 4.2.Variogram for Textural Parameter (September)

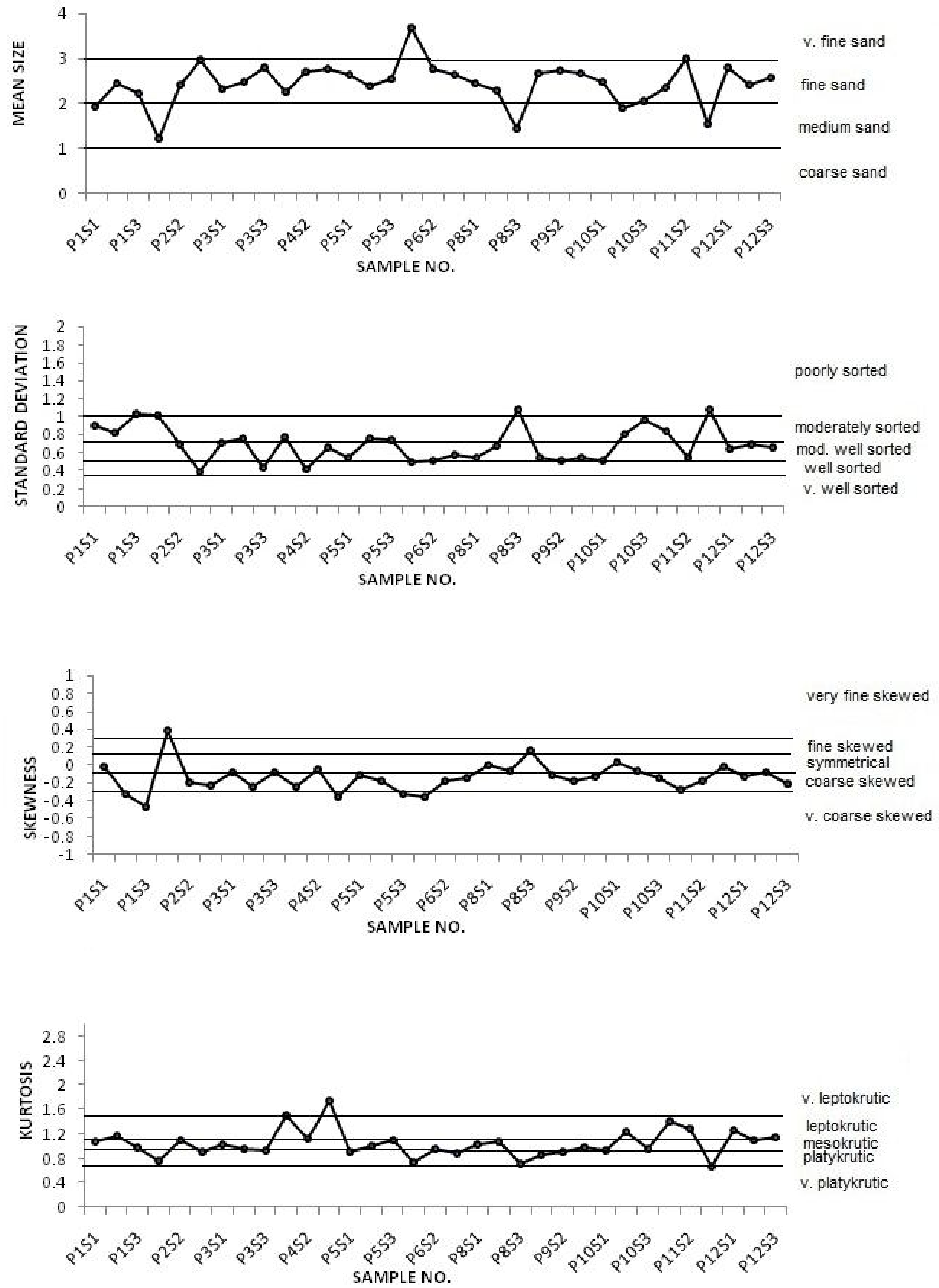


Figure No. 4.3. Scatter Plots of the Sediment in Monsoon

July **September**

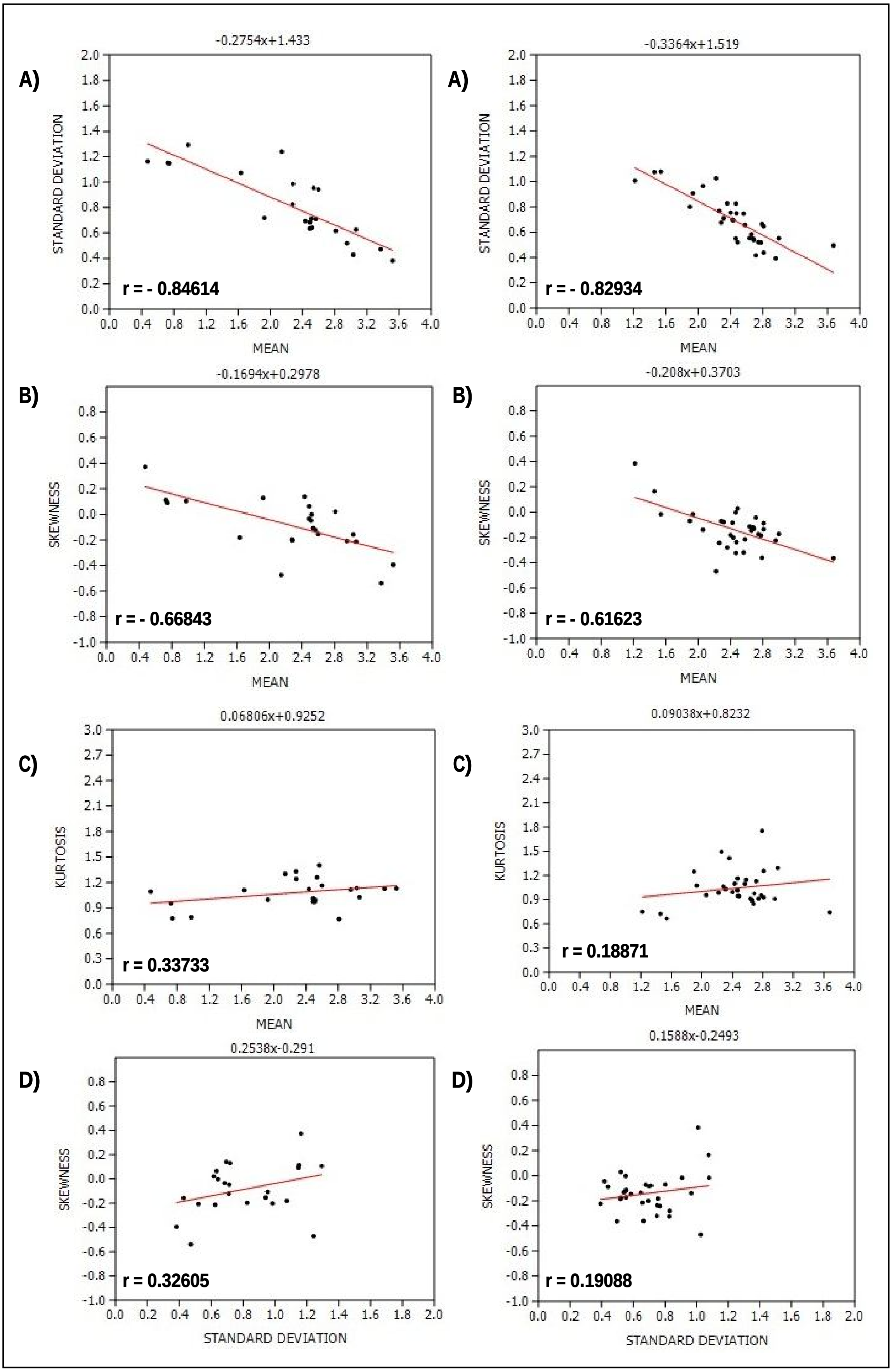


Table No.4.1.Textural Characteristics of Beach Sediments (July)

	MEAN Ø		SORTING INDEX Ø		SKEWNESS		KURTOSIS	
P1S1	2.536	FS	0.954	MS	-0.107	CS	1.264	L
P1S2	2.596	FS	0.942	MS	-0.152	CS	1.165	L
P2S1	1.634	MS	1.074	PS	-0.179	CS	1.11	L
P2S2	0.745	CS	1.148	PS	0.093	S	0.779	P
P3S1	0.977	CS	1.293	PS	0.106	FS	0.792	P
P3S2	0.475	VCS	1.163	PS	0.374	VFS	1.093	M
P4S1	2.434	FS	0.694	MWS	0.141	FS	1.123	L
P4S2	0.726	CS	1.151	PS	0.114	FS	0.957	M
P5S1	3.029	VFS	0.428	WS	-0.156	CS	1.135	L
P5S2	2.516	FS	0.642	MWS	-0.001	S	0.994	M
P6S1	3.519	VFS	0.382	WS	-0.393	VCS	1.13	L
P6S2	3.063	VFS	0.625	MWS	-0.212	CS	1.028	M
P6S3	2.952	FS	0.52	MWS	-0.206	CS	1.115	L
P8S1	2.81	FS	0.616	MWS	0.023	S	0.769	P
P8S2	2.51	FS	0.713	MS	-0.047	S	0.975	M
P8S3	1.925	MS	0.719	MS	0.131	FS	0.998	M
P9S1	3.372	VFS	0.471	WS	-0.537	VCS	1.128	L
P9S2	2.489	FS	0.684	M WS	-0.034	S	1.012	M
P10S1	2.141	FS	1.241	PS	-0.472	VCS	1.303	L
P10S2	2.489	FS	0.634	MWS	0.066	S	0.974	M
P11S1	2.564	FS	0.71	MS	-0.122	CS	1.403	L
P11S2	2.279	FS	0.985	MS	-0.201	CS	1.243	L
P12S1	2.275	FS	0.825	MS	-0.196	CS	1.332	L

Table No. 4.2. Textural Characteristics of Beach Sediments (September)

	MEAN Ø		SORTING INDEX Ø		SKEWNESS		KURTOSIS	
P1S1	1.935	MS	0.908	MS	-0.015	S	1.077	M
P1S2	2.468	FS	0.828	MS	-0.322	VCS	1.165	L
P1S3	2.222	FS	1.027	PS	-0.468	VCS	0.987	M
P2S1	1.219	MS	1.009	PS	0.386	VFS	0.753	P
P2S2	2.433	FS	0.695	MWS	-0.199	CS	1.104	M
P2S3	2.958	FS	0.393	WS	-0.222	CS	0.910	M
P3S1	2.314	FS	0.711	MS	-0.077	S	1.033	M
P3S2	2.474	FS	0.750	MS	-0.235	CS	0.947	M
P3S3	2.810	FS	0.440	WS	-0.087	S	0.928	M
P4S1	2.261	FS	0.768	MS	-0.241	CS	1.496	L
P4S2	2.713	FS	0.418	WS	-0.042	S	1.131	L
P4S3	2.790	FS	0.666	MWS	-0.359	VCS	1.755	VL
P5S1	2.636	FS	0.554	MWS	-0.113	CS	0.913	M
P5S2	2.400	FS	0.756	MS	-0.180	CS	0.996	M
P5S3	2.562	FS	0.748	MS	-0.318	VCS	1.099	M
P6S1	3.674	VFS	0.496	WS	-0.362	VCS	0.744	P
P6S2	2.777	FS	0.519	MWS	-0.183	CS	0.954	M
P6S3	2.658	FS	0.585	MWS	-0.145	CS	0.892	P
P8S1	2.466	FS	0.551	MWS	-0.001	S	1.019	M
P8S2	2.285	FS	0.678	MWS	-0.070	S	1.066	M
P8S3	1.457	MS	1.076	PS	0.166	FS	0.726	P
P9S1	2.678	FS	0.550	MWS	-0.119	CS	0.851	P
P9S2	2.744	FS	0.521	MWS	-0.173	CS	0.912	M
P9S3	2.687	FS	0.539	MWS	-0.131	CS	0.977	M
P10S1	2.488	FS	0.521	MWS	0.030	S	0.943	M
P10S2	1.898	MS	0.802	MS	-0.068	S	1.248	L
P10S3	2.060	FS	0.966	MS	-0.138	CS	0.958	M
P11S1	2.357	FS	0.830	MS	-0.279	CS	1.416	L
P11S2	2.997	FS	0.553	MWS	-0.171	CS	1.293	L
P11S3	1.539	FS	1.079	PS	-0.015	S	0.668	VP
P12S1	2.810	FS	0.648	MWS	-0.134	CS	1.256	L
P12S2	2.423	FS	0.699	MWS	-0.083	S	1.100	M
P12S3	2.579	FS	0.658	MWS	-0.214	CS	1.149	L

Table No. 4.3. Sediment Composition (July)

	GRAVEL %					SAND %					SILT %				
	VCG	CG	MG	FG	VFG	VCS	CS	MS	FS	VFS	VCS	CS	MS	FS	VFS
P1S1	0	0	0	0	0	4.5	5.8	17.3	43.3	28.8	0.3	0	0	0	0
P1S2	0	0	0	0	0	3.9	5.1	16	41.9	32.9	0.2	0	0	0	0
P2S1	0	0	0	0	0	10.2	17.6	37.2	27	8	0	0	0	0	0
P2S2	0	0	0	0	0	29.4	30.4	24.7	12.3	3.2	0	0	0	0	0
P3S1	0	0	0	0	0	25.8	27.3	21.9	18.9	6.2	0	0	0	0	0
P3S2	0	0	0	0	0	41.9	33.6	11.2	9.8	3.3	0	0	0	0	0
P4S1	0	0	0	0	0	0.2	2.5	26.9	50.5	19.7	0.2	0	0	0	0
P4S2	0	0	0	0	0	30	33.5	21	11.9	3.6	0	0	0	0	0
P5S1	0	0	0	0	0	0	0	0.1	44	55.6	0.1	0	0	0	0
P5S2	0	0	0	0	0	0.6	2.1	17.7	56.5	23.1	0	0	0	0	0
P6S1	0	0	0	0	0	0.2	0.4	0.8	12	85	1.5	0	0	0	0
P6S2	0	0	0	0	0	0.5	0.7	5.3	34.8	58	0.7	0	0	0	0
P6S3	0	0	0	0	0	0.4	0.5	3.8	43	51.9	0.3	0	0	0	0
P8S1	0	0	0	0	0	0	0.2	7.9	51.9	39.7	0.2	0	0	0	0
P8S2	0	0	0	0	0	0.2	3.2	20.7	50.2	25.4	0.2	0	0	0	0
P8S3	0	0	0	0	0	0.3	8.5	51.9	30.2	9.2	0	0	0	0	0
P9S1	0	0	0	0	0	0.1	0.3	1.2	20.3	77.8	0.3	0	0	0	0
P9S2	0	0	0	0	0	1	2.9	20.1	52.9	23	0.1	0	0	0	0
P10S1	0	0	0	0	0	9.6	9	11.1	42.3	27.9	0	0	0	0	0
P10S2	0	0	0	0	0	0.2	1.6	21	55.6	21.6	0.1	0	0	0	0
P11S1	0	0	0	0	0	3.1	2.8	9.1	61.6	23.3	0	0	0	0	0
P11S2	0	0	0	0	0	4.9	6.8	24.6	41.2	22.5	0	0	0	0	0
P12S1	0	0	0	0	0	3.5	3.6	21.8	55	16.1	0	0	0	0	0

Table No. 4.4. Sediment Composition (September)

	GRAVEL %					SAND %					SILT %				
	VC G	C G	M G	F G	V F G	VCS	CS	MS	FS	VFS	VCS	C S	M S	F S	V FS
P1S1	0	0	0	0	0	0	16.2	37	34.1	11.6	1.1	0	0	0	0
P1S2	0	0	0	0	0	0	9.8	14.5	49.3	25.5	0.8	0	0	0	0
P1S3	0	0	0	0	0	0	17	14.5	44.6	23.6	0.3	0	0	0	0
P2S1	0	0	0	0	0	0	50.7	21.7	20.6	6.3	0.7	0	0	0	0
P2S2	0	0	0	0	0	0	4.9	19.1	57.3	18	0.6	0	0	0	0
P2S3	0	0	0	0	0	0	0.6	1.7	48.2	48.8	0.7	0	0	0	0
P3S1	0	0	0	0	0	0	5.9	26	52.6	14.1	1.4	0	0	0	0
P3S2	0	0	0	0	0	0	5.5	20.7	47.8	25.2	0.8	0	0	0	0
P3S3	0	0	0	0	0	0	0.5	3.4	61.3	34.4	0.5	0	0	0	0
P4S1	0	0	0	0	0	0	10	9.6	66.9	13	0.5	0	0	0	0
P4S2	0	0	0	0	0	0	0.2	3.8	74	21.8	0.2	0	0	0	0
P4S3	0	0	0	0	0	0	6	5.1	51.7	36.8	0.4	0	0	0	0
P5S1	0	0	0	0	0	0	1	12.4	60.2	26	0.4	0	0	0	0
P5S2	0	0	0	0	0	0	7	22.8	49.5	19.8	0.9	0	0	0	0
P5S3	0	0	0	0	0	0	6.5	14.3	50	28.3	0.9	0	0	0	0
P6S1	0	0	0	0	0	0	0	0.6	8.6	49.6	41.2	0	0	0	0
P6S2	0	0	0	0	0	0	0.9	6.7	55.2	35.8	1.4	0	0	0	0
P6S3	0	0	0	0	0	0	2.2	11.7	55.4	29.3	1.3	0	0	0	0
P8S1	0	0	0	0	0	0	1.6	16.5	66.2	13.9	1.9	0	0	0	0
P8S2	0	0	0	0	0	0	5.3	26.1	56	12	0.6	0	0	0	0
P8S3	0	0	0	0	0	0	43.4	25.2	21.2	9.7	0.5	0	0	0	0
P9S1	0	0	0	0	0	0	0.4	11.1	57.3	30.5	0.7	0	0	0	0
P9S2	0	0	0	0	0	0	0.7	7.7	56.7	34.5	0.4	0	0	0	0
P9S3	0	0	0	0	0	0	1.2	9.1	61.5	27	1.2	0	0	0	0
P10S1	0	0	0	0	0	0	0.3	16.4	66.8	16.5	0.1	0	0	0	0
P10S2	0	0	0	0	0	0	14	40.4	38.5	6.6	0.5	0	0	0	0
P10S3	0	0	0	0	0	0	16.2	29.1	36.8	17.4	0.5	0	0	0	0
P11S1	0	0	0	0	0	0	11.9	12.9	57.1	17.8	0.4	0	0	0	0
P11S2	0	0	0	0	0	0	1.1	4.3	36.8	51.5	6.3	0	0	0	0
P11S3	0	0	0	0	0	0	42.6	18.1	30.5	8.4	0.5	0	0	0	0
P12S1	0	0	0	0	0	0	2.9	7.2	47.7	37.9	4.4	0	0	0	0
P12S2	0	0	0	0	0	0	4.9	19.8	55.7	18.3	1.3	0	0	0	0
P12S3	0	0	0	0	0	0	4.7	12.5	58.6	23.3	0.9	0	0	0	0

Figure No. 4.4. Isoline Map Showing Mean Sediment Size ø(July and September)

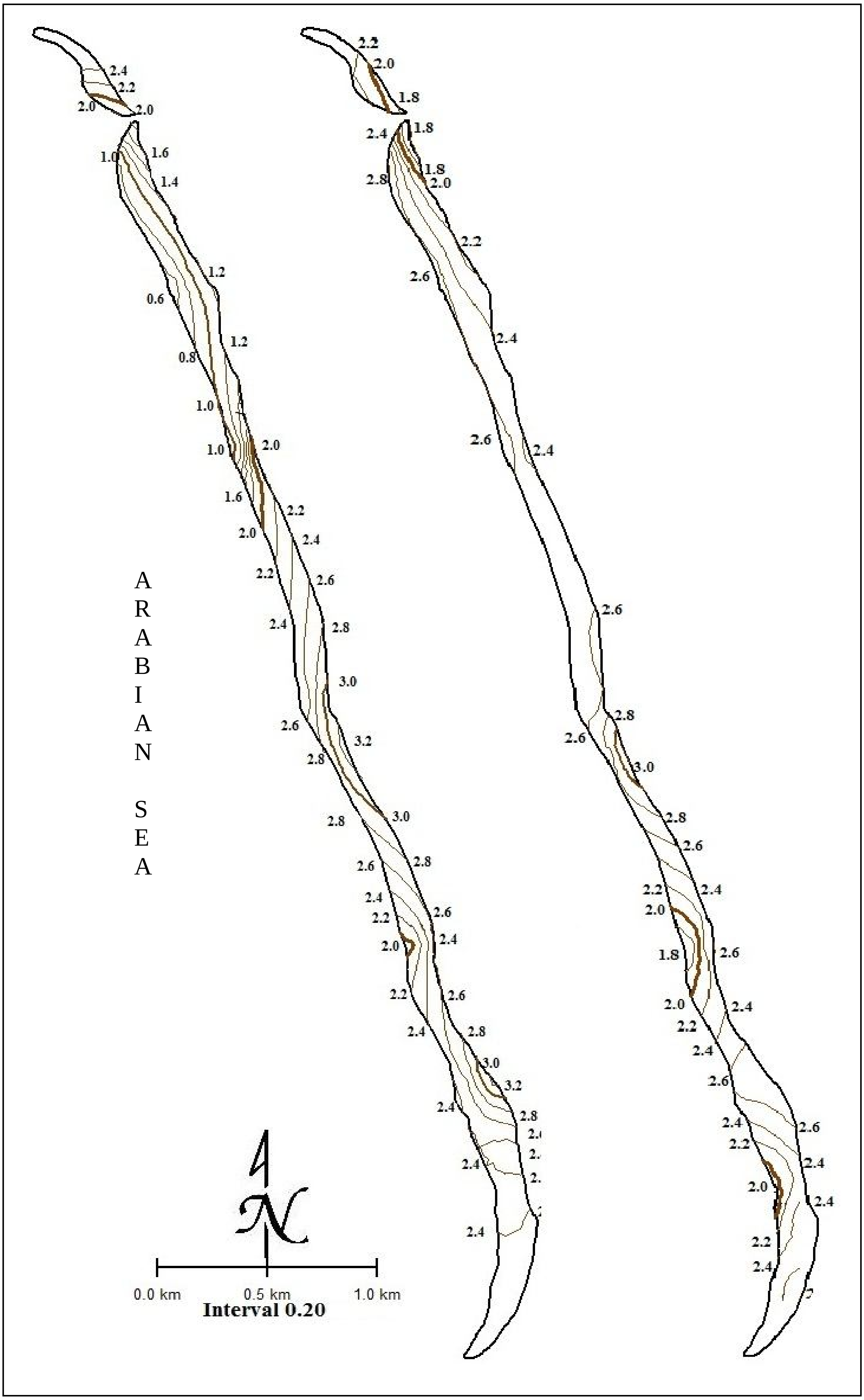


Figure No. 4.5. Isoline Map Showing Sorting Index ø (July and September)

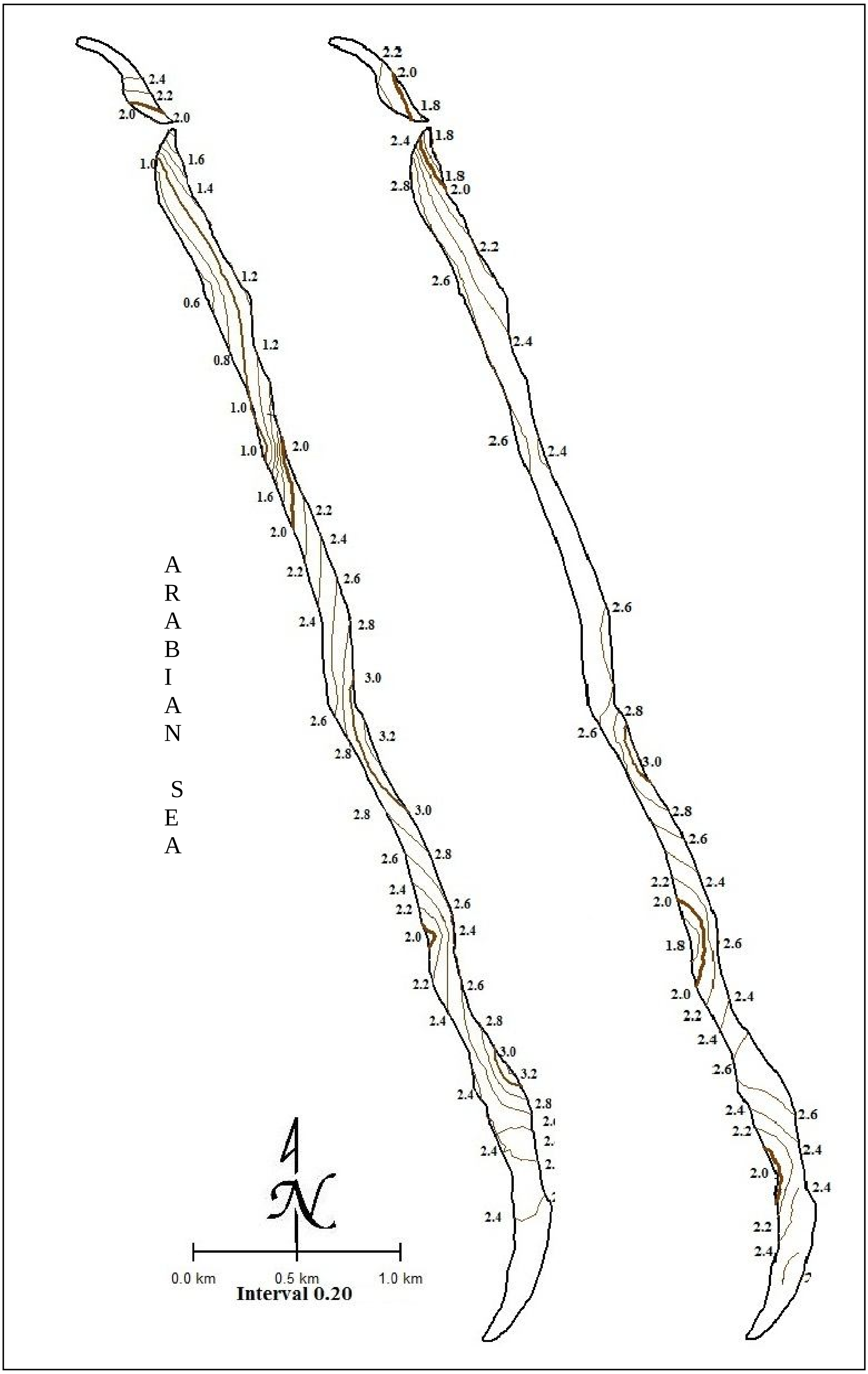


Figure No. 4.6. Isoline Map Showing Skewness Distribution (July and September)

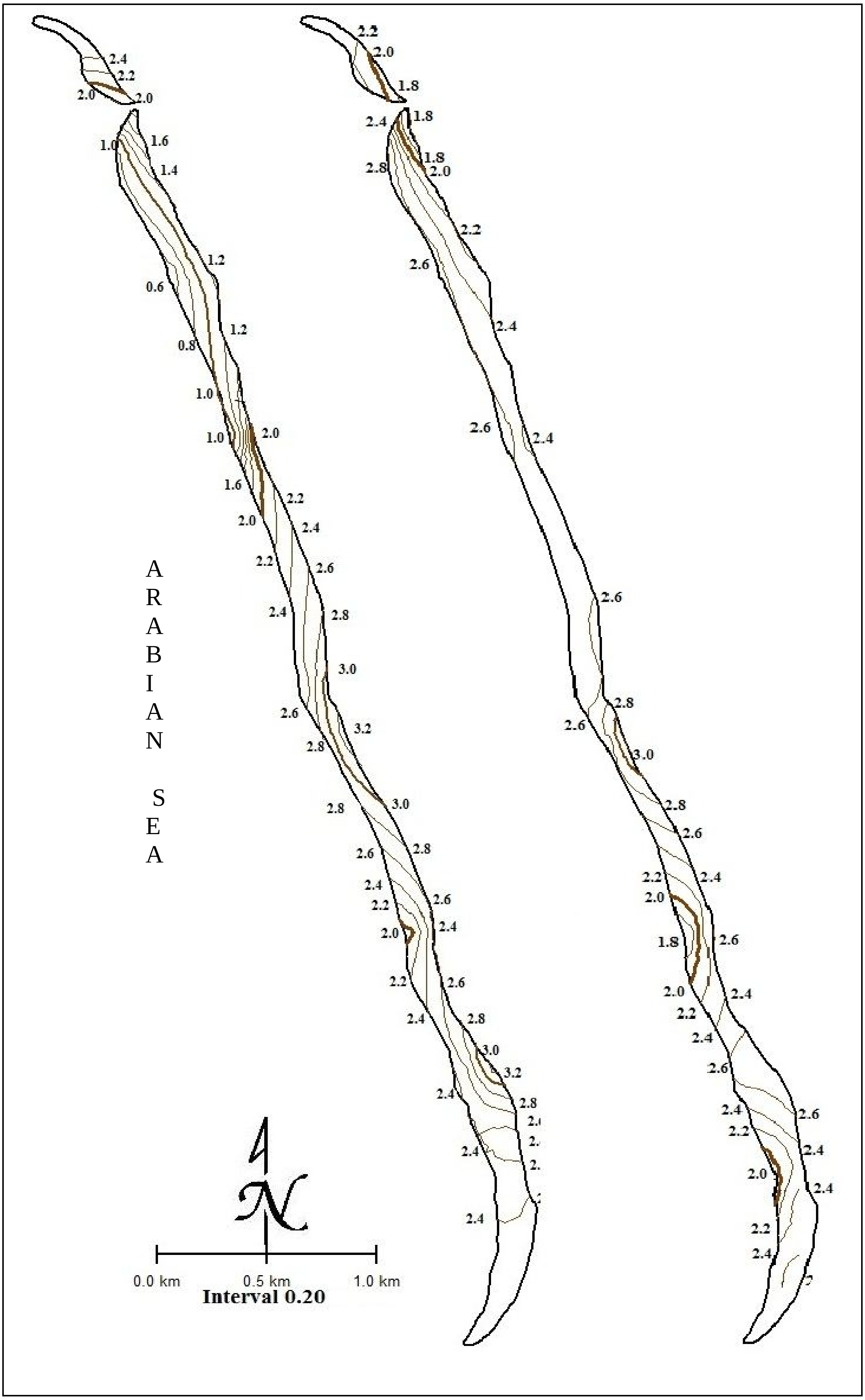
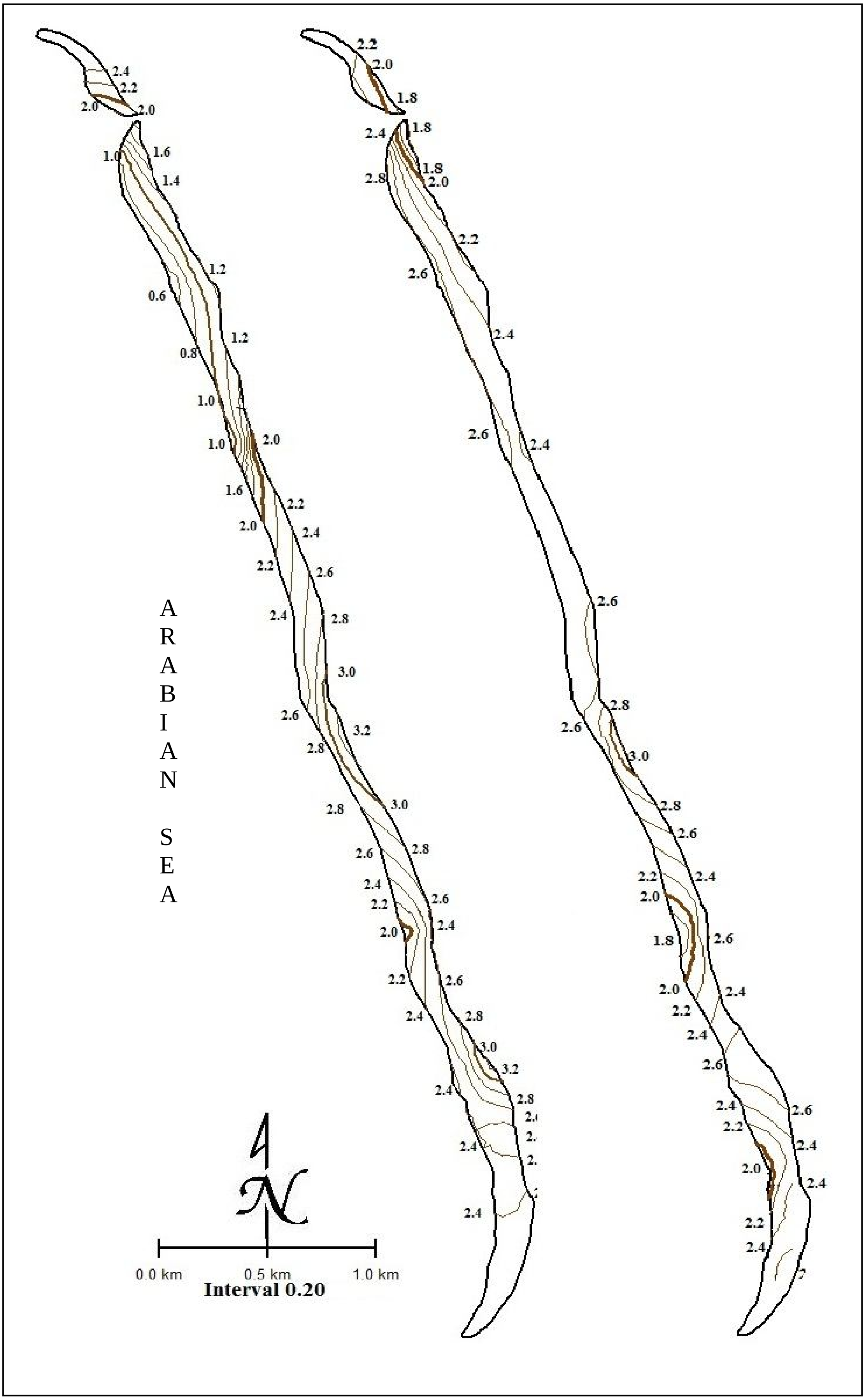


Figure No. 4.7. Isoline Map Showing Kurtosis (July and September)



4.3. Grain Size Parameter of Sediments in Post-Monsoon

To understand the post-monsoon sedimentary environment sediment samples were collected in the months of November and January (Table No. 4.5 and 4.6).

4.3.1. Mean Sediment Size

The mean sediment size range from 0.523 ø to 2.808 ø represents the post-monsoon conditions in **November**. Sediment ranges between coarse grained to fine grained sand. There is a variation in mean sediment size throughout the beach. Northern sector sediments show the range from 1.616 ø to 2.808 ø. The distribution is medium grained to fine grained sediments. In middle section of the beach mean sediment size ranges from 1.550 ø to 2.754 ø (medium grained to fine grained) sediments and in southern section of beach mean sediment size ranges from 0.523 ø to 2.786 ø. The distribution is coarse grained to fine grained sediments. Mean sediment size in the month of November shows the dominance of fine grained sediment on beach with admixture of medium grained sediment (Figure No. 4.8) and (Figure No. 4.11).

The mean sediment size range from 1.981 ø to 3.082 ø represents the post-monsoon conditions in **January**. Sediment ranges between coarse grained to very fine grained sand. There is a variation in mean sediment size throughout the beach. Northern sector sediments show the range from 1.999 ø to 3.041 ø. The distribution is medium grained to very fine grained sediments. In middle section of the beach mean sediment size ranges from 1.981 ø to 3.082 ø (medium grained to very fine grained) sediments and in southern section of beach mean sediment size ranges from 1.986 ø to 2.957 ø. The distribution is medium grained to fine grained sediments (Figure No. 4.9) and (Figure No. 4.11). Northern and middle sector of the beach, textural properties remain constant like month of November (medium grained to very fine, fine grained sediment) but along the southern sector textural properties change from coarse grained to fine grained sediment in to medium grained to fine grained sediments. The month of January shows high proportion of fine grained sediments all over the beach (Photo No.30 and 31) with admixture of very fine and medium grained sediments.

The textural composition in the month of November shows 75% sediment samples are fine grained, 20% medium grained, 5% coarse grained sediments. In

January 82% fine grained, 9% very fine grained and 9% medium grained sediments were present.

Data represented in (Table No. 4.7) and (Table No. 4.8) Illustrates the presence of sand, silt and clay contents of beach sediments. This post-monsoon period shows that the beach sediments are mainly sandy in nature contain 95% to 100% sand accumulation. The very coarse silt percentage is comparatively increasing in the January from 0.1% to 5.5% in the middle sector of beach zone.

Along the study area beach sediments are 5% uni-modal, 40% bimodal, 50% tri-modal and 5% poly-modal in character in the month of November. The January sediments are 46% uni-modal, 39% bimodal and 15% tri-modal character. It can be clearly identified that upper beach shows bi-modal and most of the sediments on middle beach show uni-modal character of sediments.

4.3.2. Sorting Index

Sorting index values vary from phi size 0.389 to 1.126 and 0.473 to 1.165 shows that sediments are well to poor sorted in November and January respectively.

In the month of November, northern, middle and southern sector of the beach sorting index values varies from 0.692 to 1.028, 0.587 to 1.014 (moderately well to poor sorted) and 0.389 to 0.850 (well to moderate sorted) respectively (Figure No. 4.8) and (Figure No. 4.12). In the month of January 0.473 to 1.165 (well to poor sorted), 0.543 to 0.992 (moderate to moderately well sorted) and 0.607 to 1.202 (moderately well to poor sorted) respectively (Figure No. 4.9) and (Figure No. 4.12).

In November 5% sediment samples are well sorted, 30% moderately well, 50% moderate sorted and 15% poor sorted. In the month of January 6% sediment samples are well sorted, 42% moderately well sorted, 39% moderate sorted and 12% poorly sorted.

4.3.3. Skewness

On the beach skewness values vary from -0.504 to 0.365 in November (Figure No. 4.8) and -0.751 to 0.184 (very coarse to fine skewed) in January (Figure No. 4.9). It is very interesting that in both the months northern, middle and southern sectors show very coarse to symmetrical, very coarse to fine and coarse to fine skewed distribution respectively (Figure No. 4.13).

25% and 12% sediment samples are very coarse skewed, 30% and 48% coarse skewed, 30% and 33% symmetrical, 10% and 6% fine to very fine skewed category in the months of November and January respectively.

4.3.4. Kurtosis

The nature of fourth movement kurtosis vary from 0.555 to 2.726 (very platykrutic to very leptokrutic) in November (Figure No. 4.8). In January kurtosis values vary from 0.585 to 1.286 (very platykrutic to leptokrutic) (Figure No. 4.9). In November a variation in kurtosis is seen. In January it is observed that most of the sediment samples on middle and the southern sector show platykrutic nature of sediments (Figure No. 4.14).

10% and 6% sediment samples on the beach show very platykrutic, 20% and 46% platykrutic, 50% and 27% mesokrutic and 10% and 21% leptokurtic in nature in the month of November and January respectively. In the month of November 10% sediment samples are very leptokurtic in nature.

Overall textural analysis in the post-monsoon season , shows the sediments are fine grained, moderately to moderately well sorted sediments that are very coarse to symmetrical skewed and mesokrutic in nature in the month of November and platykrutic in nature in the month of January.

4.3.5. Scatter Plots of the Sediment in Post Monsoon

The relationship between mean sediment size and sorting index (Figure No. 4.10 A) for both months' shows that, fine to very fine grained sediments are moderate to moderately well sort. Few fine grained types of sediment on lower beach on the northern sector within the vicinity of tidal channel mouth are poor sorted.

In post-monsoon the relationship between mean size, standard deviation and skewness values (Figure No. 4.10 B and C) shows variation. Fine grained sediments with moderate to moderately well sorted are symmetrical to very coarse skewed in nature. In the month of November Medium grained sand in the northern sector with moderately sorted are symmetrically skewed, in southern sector medium sand with moderately to poorly sorted are fine and coarse skewed. In January very fine to fine grained sediments with well to moderately sorted are symmetrical to coarse skewed. Medium grained sediments with moderately to poorly sorted are coarse to symmetrical skewed. Two sediment samples in the southern sector at profile 8 and 10 on upper beach shows fine grained with well to moderately sorted are very fine to fine skewed in nature in both the months.

Photo 30 Fine Sediment Deposits on Wide Middle Section of the Beach

Photo 31 Upper Fine and Lower Storm Deposits along Northern Tidal Inlet Bank

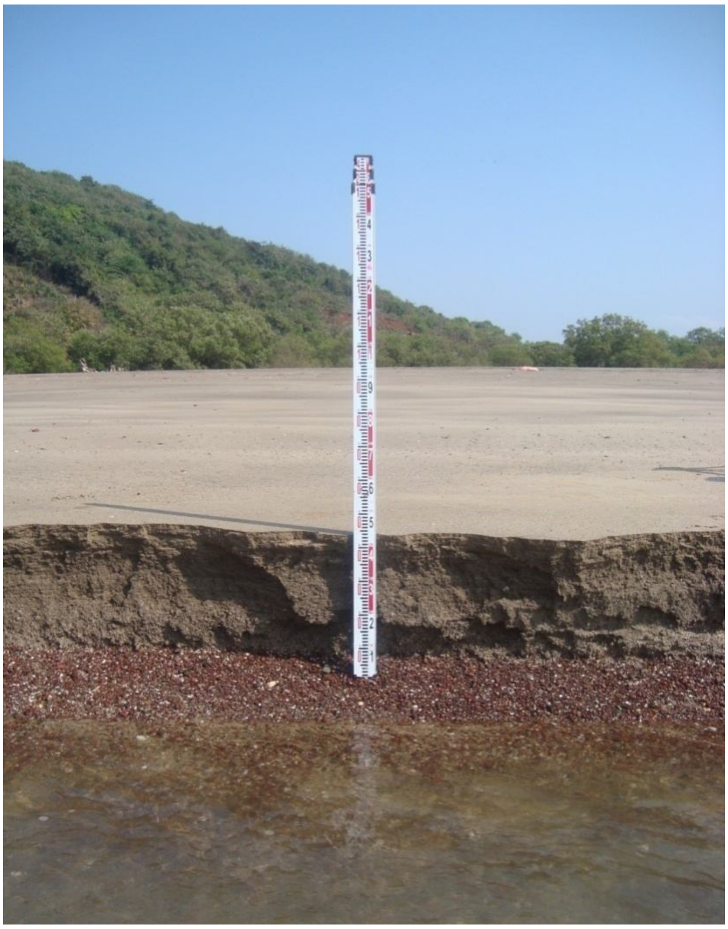


Figure No. 4.8.Variogram for Textural Parameter (November)

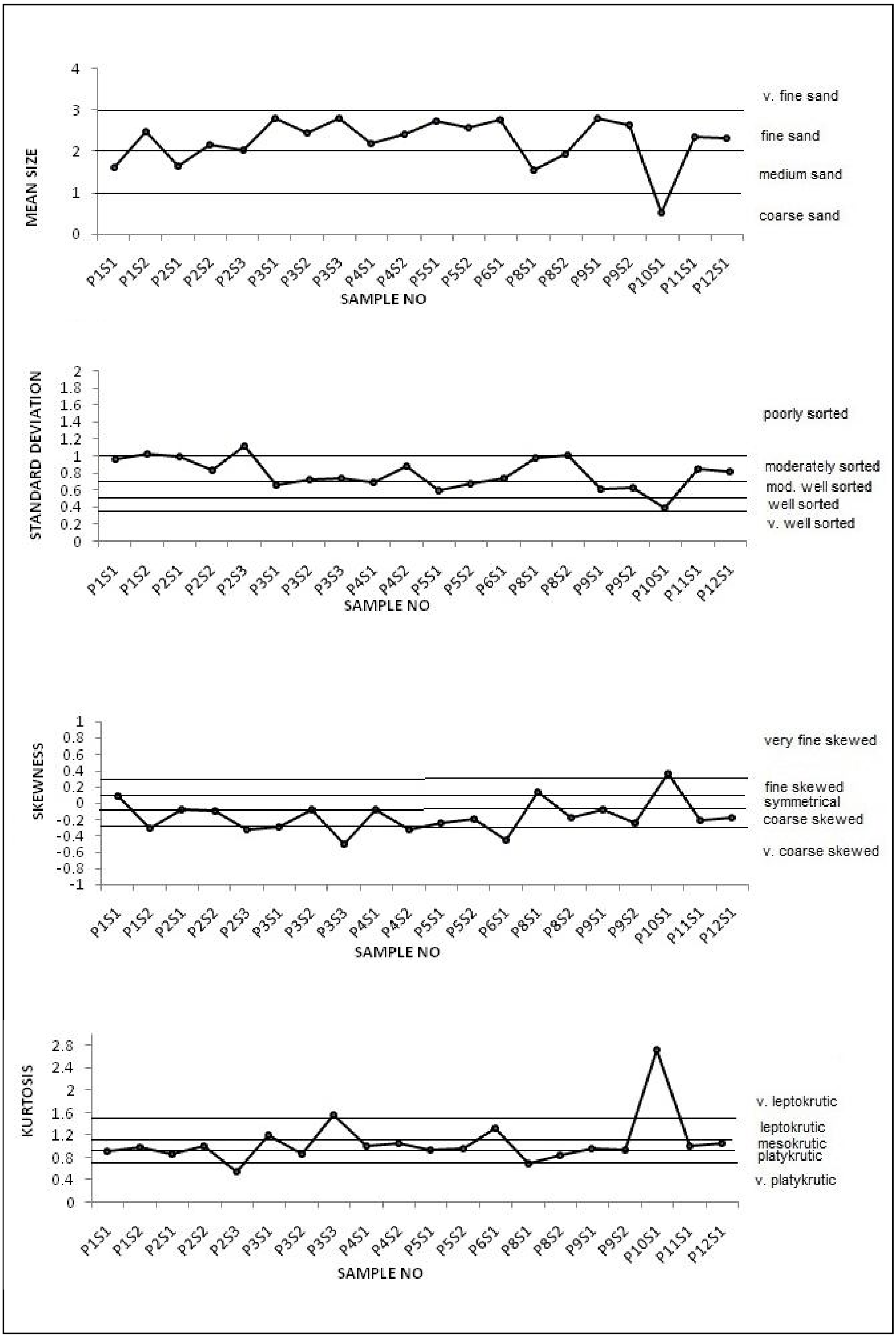


Figure No. 4.9. Variogram for Textural Parameter (January)

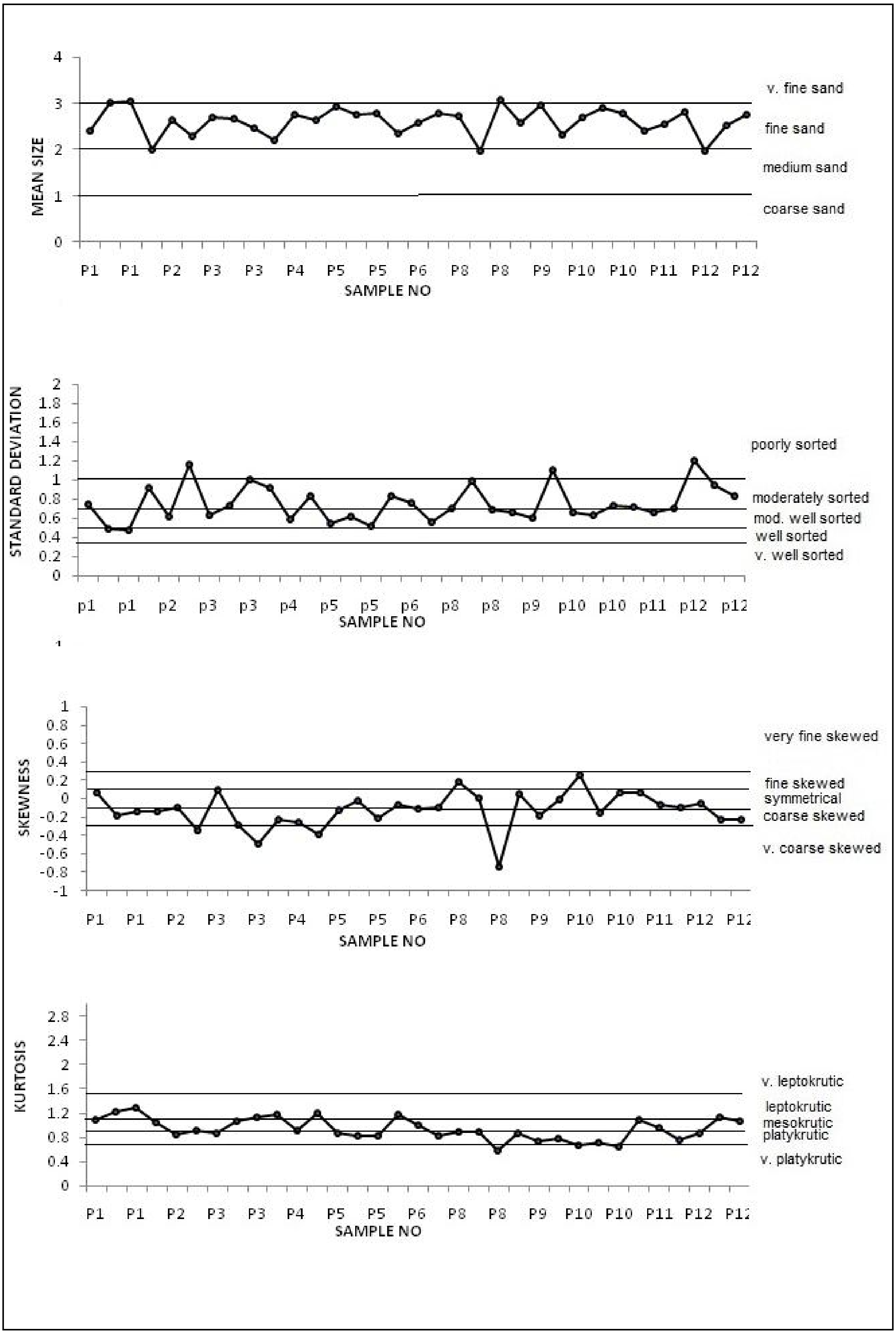


Figure no.4.10.Scatter Plots of the Sediment in Post-Monsoon

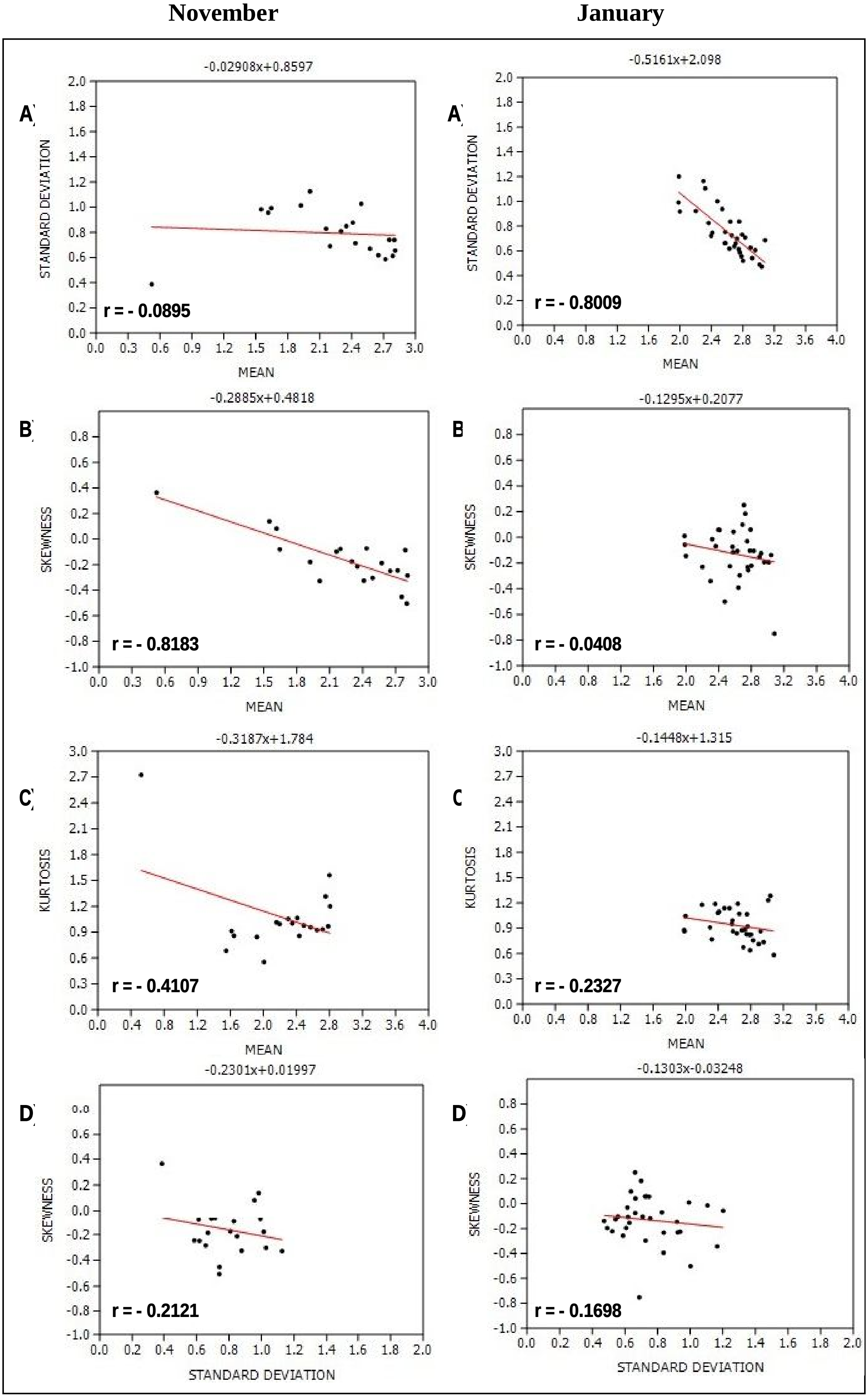


Table No. 4.5. Textural Characteristics of Beach Sediments (November)

	MEAN ø		SORTING INDEX ø		SKEWNESS		KURTOSIS	
P1S1	1.616	MS	0.957	MS	0.083	S	0.915	M
P1S2	2.490	FS	1.028	PS	-0.303	VCS	0.980	M
P2S1	1.645	MS	0.993	MS	-0.079	S	0.860	P
P2S2	2.160	FS	0.830	MS	-0.097	S	1.015	M
P2S3	2.009	FS	1.126	PS	-0.327	VCS	0.555	VP
P3S1	2.808	FS	0.657	MWS	-0.284	CS	1.202	L
P3S2	2.435	FS	0.715	MS	-0.072	S	0.859	P
P3S3	2.801	FS	0.741	MS	-0.504	VCS	1.562	V L
P4S1	2.197	FS	0.692	MWS	-0.076	S	0.996	M
P4S2	2.411	FS	0.878	MS	-0.324	VCS	1.067	M
P5S1	2.718	FS	0.587	MWS	-0.245	CS	0.932	M
P5S2	2.572	FS	0.671	MWS	-0.187	CS	0.959	M
P6S1	2.754	FS	0.742	MS	-0.451	VCS	1.317	L
P8S2	1.550	MS	0.983	MS	0.140	FS	0.686	P
P8S3	1.922	MS	1.014	PS	-0.178	CS	0.847	P
P9S1	2.786	FS	0.614	MWS	-0.084	S	0.970	M
P9S2	2.650	FS	0.619	MWS	-0.248	CS	0.926	M
P10S1	0.523	CS	0.389	WS	0.365	VFS	2.726	VL
P11S1	2.350	FS	0.850	MS	-0.213	CS	1.004	M
P12S1	2.300	FS	0.809	MS	-0.174	CS	1.055	M

Table No. 4.6. Textural Characteristics of Beach Sediments (January)

	MEAN ø		SORTING INDEX ø		SKEWNESS		KURTOSIS	
P1S1	2.411	FS	0.748	MS	0.057	S	1.098	M
P1S2	3.013	VFS	0.491	WS	-0.194	CS	1.233	L
P1S3	3.041	VFS	0.473	WS	-0.138	CS	1.286	L
P2S1	1.999	MS	0.919	MS	-0.145	CS	1.045	M
P2S2	2.629	FS	0.619	MWS	-0.106	CS	0.840	P
P2S3	2.299	FS	1.165	PS	-0.341	VCS	0.911	M
P3S1	2.691	FS	0.637	MWS	0.099	S	0.876	P
P3S2	2.657	FS	0.726	MS	-0.296	CS	1.072	M
P3S3	2.476	FS	1.002	PS	-0.501	VCS	1.140	L
P4S1	2.201	FS	0.923	MS	-0.230	CS	1.180	L
P4S2	2.761	FS	0.588	MWS	-0.256	CS	0.922	M
P4S3	2.640	FS	0.837	MS	-0.393	VCS	1.192	L
P5S1	2.919	FS	0.543	MWS	-0.125	CS	0.865	P
P5S2	2.748	FS	0.615	MWS	-0.030	S	0.830	P
P5S3	2.801	FS	0.522	MWS	-0.221	CS	0.825	P
P6S1	2.363	FS	0.826	MS	-0.069	S	1.189	L
P6S2	2.575	FS	0.754	MS	-0.117	CS	0.993	M
P6S3	2.782	FS	0.557	MWS	-0.103	CS	0.825	P
P8S1	2.726	FS	0.699	MWS	0.184	Fs	0.882	P
P8S2	1.981	MS	0.992	MS	0.011	S	0.879	P
P8S3	3.082	VFS	0.688	MWS	-0.751	VCS	0.585	V P
P9S1	2.581	FS	0.664	MWS	0.043	S	0.865	P
P9S2	2.957	FS	0.607	MWS	-0.193	CS	0.737	P
P9S3	2.321	FS	1.106	PS	-0.014	S	0.769	P
P10S1	2.708	FS	0.662	MWS	0.252	FS	0.676	P
P10S2	2.898	FS	0..627	MWS	-0.153	CS	0.714	P
P10S3	2.790	FS	0.732	MS	0.060	S	0.640	VP
P11S1	2.396	FS	0.723	MS	0.059	S	1.083	M
P11S2	2.568	FS	0.663	MWS	-0.074	S	0.952	M
P11S3	2.829	FS	0.709	MS	-0.104	CS	0.757	P
P12S1	1.986	MS	1.202	PS	-0.056	S	0.865	P
P12S2	2.538	FS	0.939	MS	-0.225	CS	1.139	L
P12S3	2.753	FS	0.838	MS	-0.232	CS	1.068	M

Table No. 4.7. Sediment Composition (November)

	GRAVEL %					SAND %					SILT %				
	VCG	CG	MG	FG	VFG	VCS	CS	MS	FS	VFS	VCS	CS	MS	FS	VFS
P1S1	0	0	0	0	0	0	22.2	40.4	28.2	9.2	0	0	0	0	0
P1S2	0	0	0	0	0	0	11.1	16.2	36.9	35.9	0	0	0	0	0
P2S1	0	0	0	0	0	0	24	37	28	11	0	0	0	0	0
P2S2	0	0	0	0	0	0	8	33	44.1	14.9	0	0	0	0	0
P2S3	0	0	0	0	0	0	27	12	37.1	23.9	0	0	0	0	0
P3S1	0	0	0	0	0	0	3	7.1	46.8	43.1	0	0	0	0	0
P3S2	0	0	0	0	0	0	1	25	49.4	24.6	0	0	0	0	0
P3S3	0	0	0	0	0	0	7.1	6.1	41.3	45.6	0	0	0	0	0
P4S1	0	0	0	0	0	0	4	30	53.1	12.9	0	0	0	0	0
P4S2	0	0	0	0	0	0	9	17	46.3	27.7	0	0	0	0	0
P5S1	0	0	0	0	0	0	1	10	54.2	34.8	0	0	0	0	0
P5S2	0	0	0	0	0	0	3	15	53	28.1	1	0	0	0	0
P6S1	0	0	0	0	0	0	6.1	8.1	44.8	41.1	0	0	0	0	0
P8S2	0	0	0	0	0	0	31	33	27	9	0	0	0	0	0
P8S3	0	0	0	0	0	0	17	30	37.6	15.4	0	0	0	0	0
P9S1	0	0	0	0	0	0	0.5	7.5	52.8	39.2	0	0	0	0	0
P9S2	0	0	0	0	0	0	2	14	52.5	31.5	0	0	0	0	0
P10S1	0	0	0	0	0	0	87	7	4.7	1.3	0	0	0	0	0
P11S1	0	0	0	0	0	0	7	23	46.8	23.2	0	0	0	0	0
P12S1	0	0	0	0	0	0	6.1	24.2	51.1	18.5	0	0	0	0	0

Table No. 4.8. Sediment Composition (January)

	GRAVEL %					SAND %					SILT %				
	VCG	CG	MG	FG	VFG	VCS	CS	MS	FS	VFS	VCS	CS	MS	FS	VFS
P1S1	0	0	0	0	0	0	7.1	29	42.9	19.5	1.5	0	0	0	0
P1S2	0	0	0	0	0	0	1.3	3	39.8	55.7	0.1	0	0	0	0
P1S3	0	0	0	0	0	0	0.3	2.9	39.9	56.9	0.1	0	0	0	0
P2S1	0	0	0	0	0	0	15.5	30	41.1	13.4	0	0	0	0	0
P2S2	0	0	0	0	0	0	1.9	15.2	51.9	30.9	0	0	0	0	0
P2S3	0	0	0	0	0	0	17.9	15	32.9	34.2	0	0	0	0	0
P3S1	0	0	0	0	0	0	0.8	12.3	53.8	32.8	0.4	0	0	0	0
P3S2	0	0	0	0	0	0	5.8	12	48.4	33.8	0	0	0	0	0
P3S3	0	0	0	0	0	0	13.6	10.4	38.6	37.4	0	0	0	0	0
P4S1	0	0	0	0	0	0	12.7	20.2	48	19.1	0	0	0	0	0
P4S2	0	0	0	0	0	0	2.5	7.4	51.9	38.2	0	0	0	0	0
P4S3	0	0	0	0	0	0	9.4	10.5	43.7	36.4	0	0	0	0	0
P5S1	0	0	0	0	0	0	0.3	2.7	48.6	48.2	0.2	0	0	0	0
P5S2	0	0	0	0	0	0	0.8	11	50.8	36.7	0.7	0	0	0	0
P5S3	0	0	0	0	0	0	1.1	5.5	53.	40.3	0	0	0	0	0
P6S1	0	0	0	0	0	0	11.4	22.9	44.8	20.9	0	0	0	0	0
P6S2	0	0	0	0	0	0	5.3	18.3	46.4	29.7	0.3	0	0	0	0
P6S3	0	0	0	0	0	0	0.1	7.1	54.2	38.3	0.3	0	0	0	0
P8S1	0	0	0	0	0	0	1.1	12.4	51.6	29.4	5.5	0	0	0	0
P8S2	0	0	0	0	0	0	18.1	33.7	31.8	16.3	0.1	0	0	0	0
P8S3	0	0	0	0	0	0	0.7	11.5	34	51	2.8	0	0	0	0
P9S1	0	0	0	0	0	0	1.5	19	51.2	28.2	0.1	0	0	0	0
P9S2	0	0	0	0	0	0	0.3	6	42.2	49.2	2.2	0	0	0	0
P9S3	0	0	0	0	0	0	13.4	26.7	30.2	29	0.7	0	0	0	0
P10S1	0	0	0	0	0	0	0.2	14.1	53.5	31.9	0.3	0	0	0	0
P10S2	0	0	0	0	0	0	1.5	7.1	44	46.9	0.6	0	0	0	0
P10S3	0	0	0	0	0	0	2	12.4	38.7	46.7	0.1	0	0	0	0
P11S1	0	0	0	0	0	0	7.1	28.9	44.1	19.9	0	0	0	0	0
P11S2	0	0	0	0	0	0	3.3	17	52.6	27.2	0	0	0	0	0
P11S3	0	0	0	0	0	0	2.7	9.1	44.8	43.4	0	0	0	0	0
P12S1	0	0	0	0	0	0	22	27	32.2	18.8	0	0	0	0	0
P12S2	0	0	0	0	0	0	11.6	12.9	42.7	32.7	0	0	0	0	0
P12S3	0	0	0	0	0	0	6.9	10	42.9	40.2	0	0	0	0	0

Figure No. 4.11. Isoline Map Showing Mean Sediment Size ø (November and January)

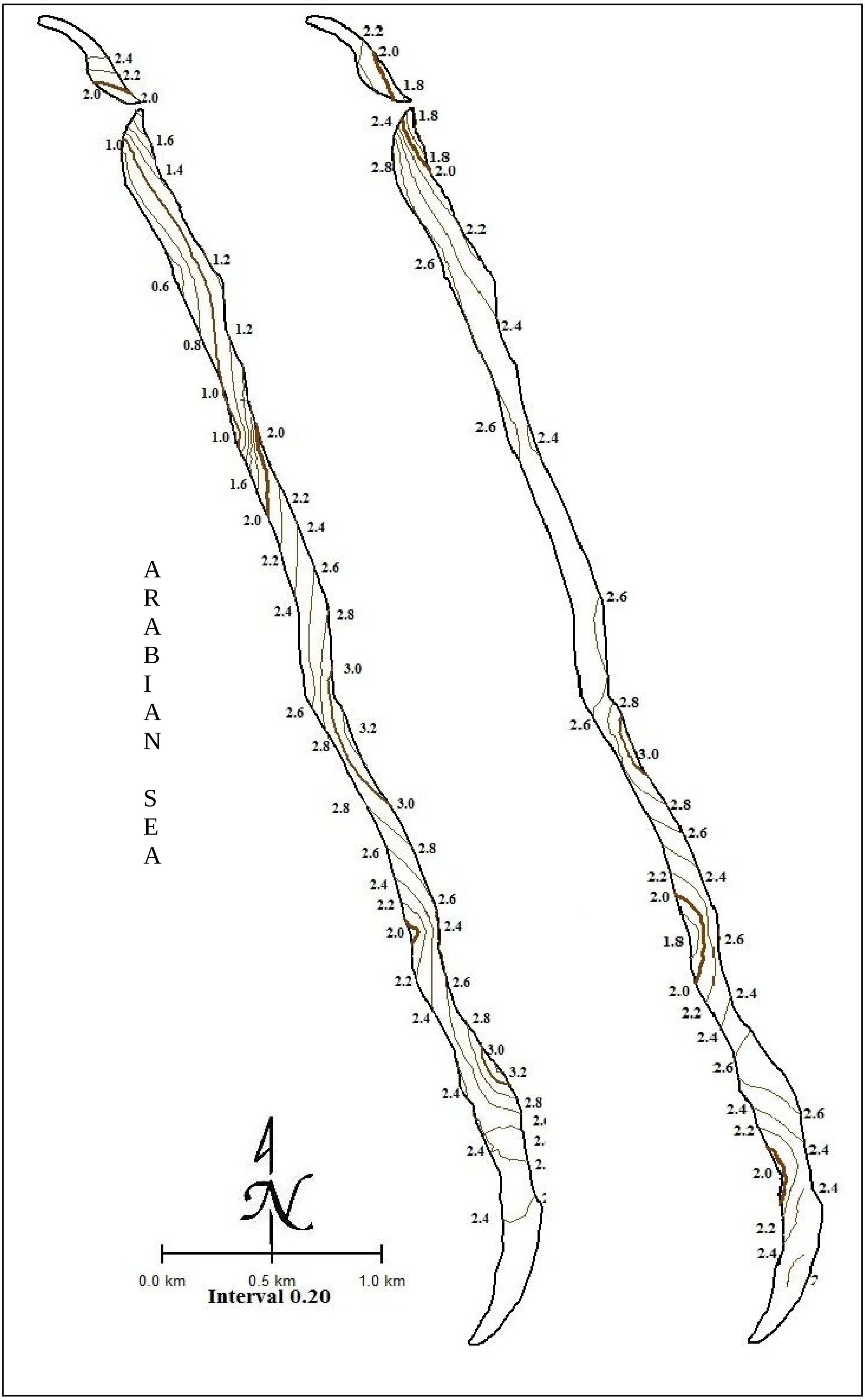


Figure No. 4.12.Isoline Map Showing Sorting Index ø (November and January)

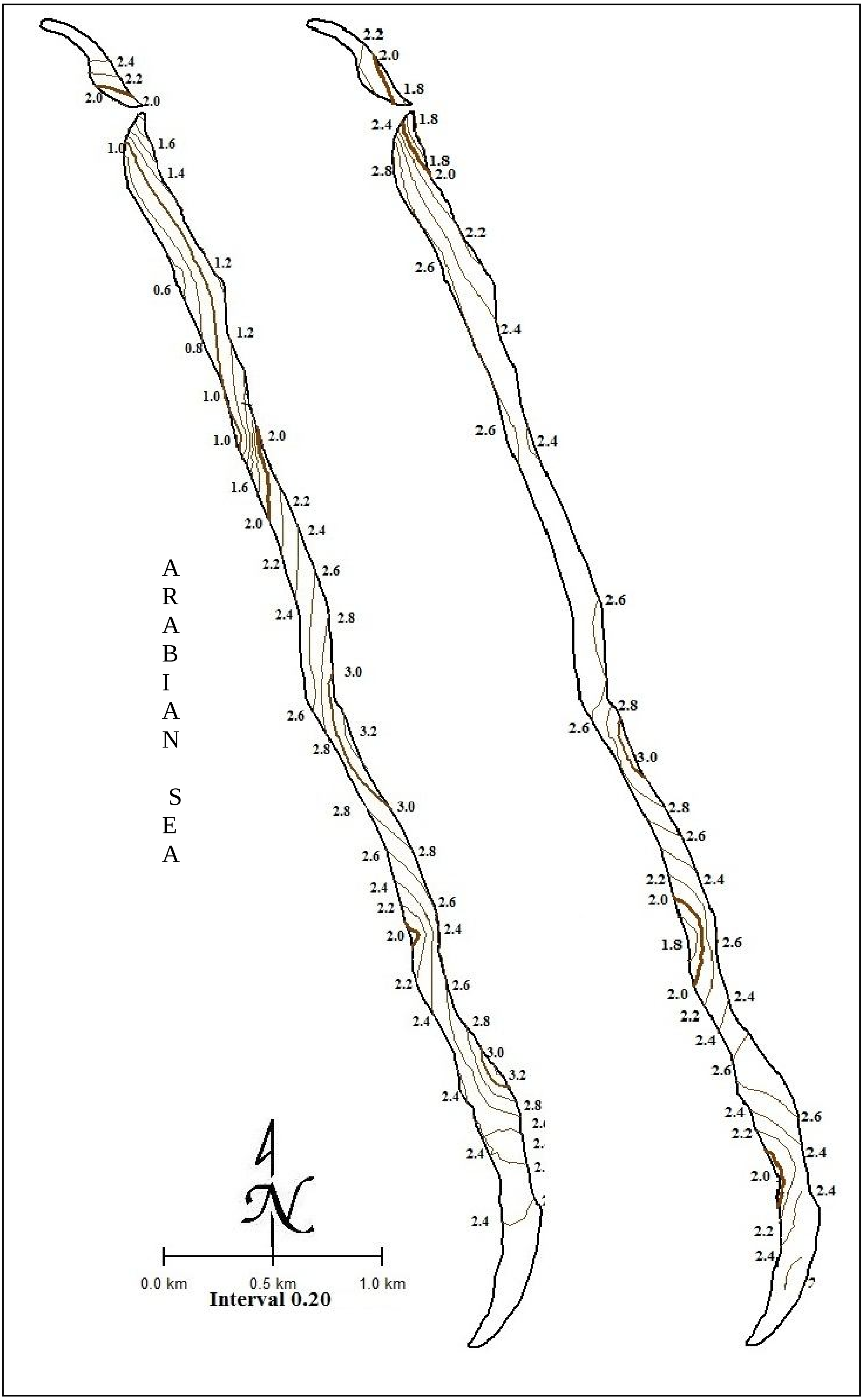


Figure No. 4.13. Isoline Map Showing Skewness (November and January)

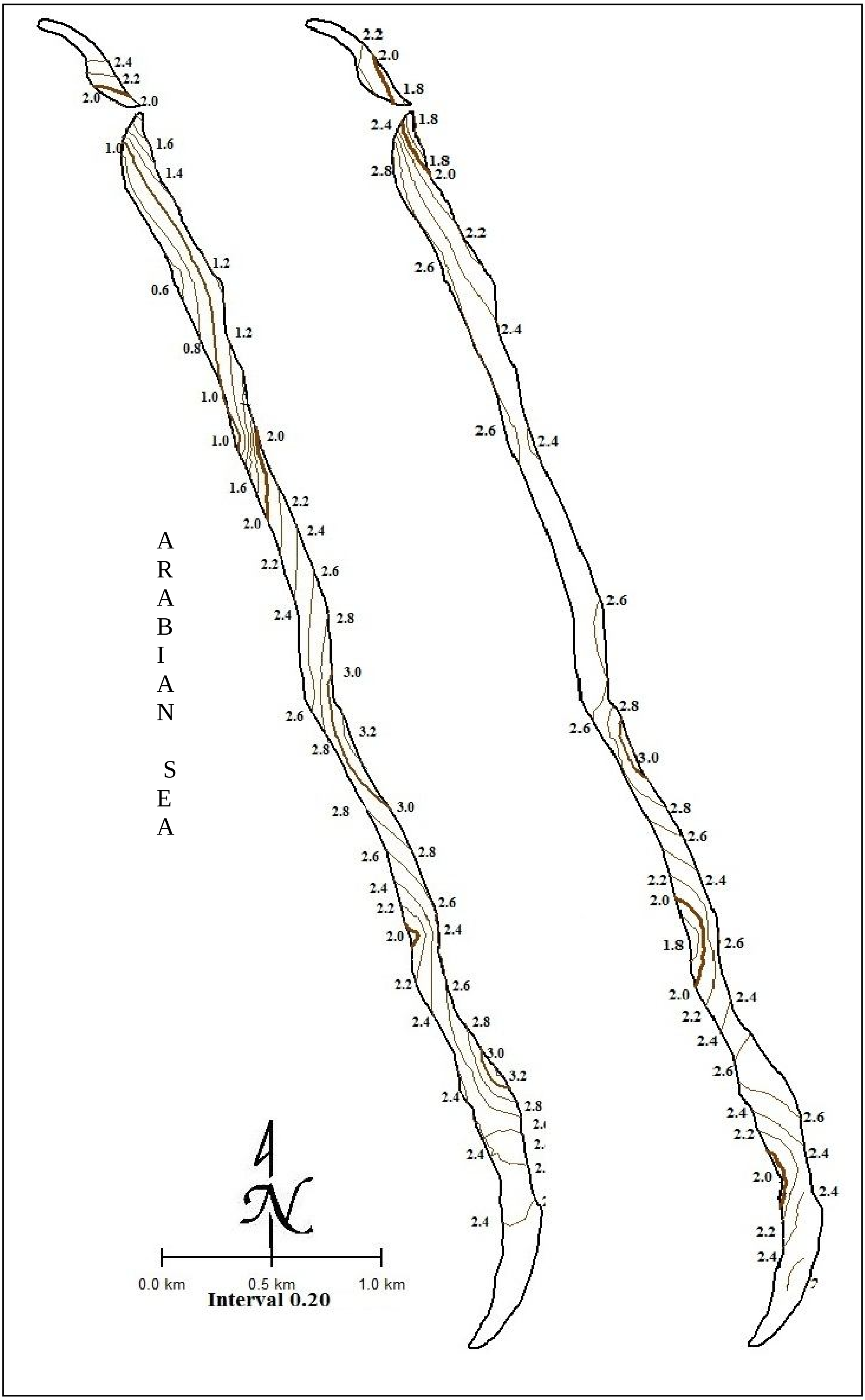
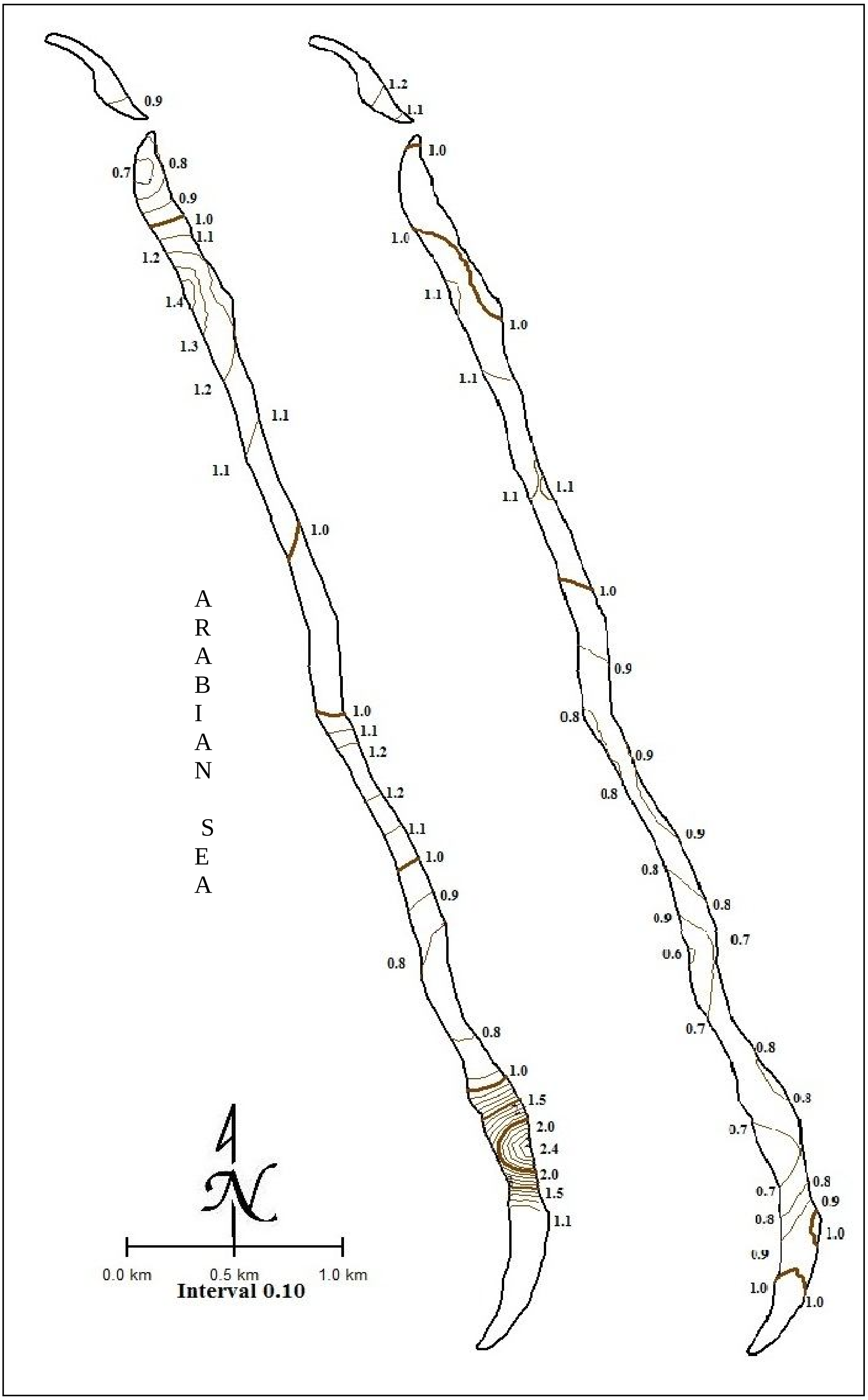


Figure No. 4.14.Isoline Map Showing kurtosis (November and January)



4.4. Grain Size Parameter of Sediments in Pre-Monsoon

To understand the pre-monsoon sedimentary environment sediment samples were collected in the months of March (Table No. 4.9) and May (Table No. 4.10).

4.4.1. Mean Sediment Size

The mean sediment size range from 1.086 ø to 3.235 ø represents the pre-monsoon conditions in **March**. Sediment ranges between medium grained to very fine grained sand. There is a variation in mean sediment size throughout the beach. Northern sector sediments show a range from 1.086 ø to 3.235 ø. The distribution is medium grained to very fine grained sediments. In middle section of the beach mean sediment size ranges from 2.462 ø to 2.939 ø (fine grained) sediments and in southern section of beach mean sediment size ranges from 2.419 ø to 3.042 ø (Figure No.4.15), The distribution is fine grained to very fine grained sediments (Photo No. 32 and 33). Almost all the beach sediments show the dominance of fine grained sediment with an admixture of very fine grained sediment. Medium sand is restricted to location P2 lower beach in the northern sector near the mouth of tidal channel (Figure No. 4.18).

The mean sediment size range from 1.081 ø to 3.298 ø represents the pre-monsoon conditions in **May**. Sediment ranges between medium grained to very fine grained sand. There is a variation in mean sediment size throughout the beach. Northern sector sediments show a range from 1.081 ø to 3.298 ø. The distribution is medium grained to very fine grained sediments. In middle section of the beach mean sediment size ranges from 2.202 ø to 3.033 ø (fine grained) sediments and in southern section of beach mean sediment size ranges from 2.500 ø to 2.660 ø (Figure No. 4.16). The distribution is medium grained to fine grained sediments. Almost all the beach sediments show a dominance of fine grained to very fine grained sediments with an admixture of medium grained sediment restricted to northern sector near the mouth of tidal channel (Figure No. 4.18).

The textural composition in month of March and May shows 86% and 77% sediment samples are fine grained, 10% and 14% very fine grained 5% and 9% medium grained sediments respectively. Data represented in (Table No. 4.11) illustrates the presence of sand, silt and clay contains of beach sediments, in the month of March beach sediments are mainly sandy with 98% to 99% of total sediment volume on beach. Middle and the southern sectors show the higher percentage of very coarse silt than the northern sector. In the month of May beach sediments are mainly sandy contain 99% of total sediment volume on beach (Table No. 4.12). It was observed that the percentage of very coarse silt is comparatively increasing than March (Photo No. 34).

In the month of March beach sediments are 67% unimodal, 29% bimodal and 5% trimodal in character. Middle and southern sector of beach shows dominance of unimodal character. In the month of May beach sediments are 18% unimodal, 46% bimodal and 36% trimodal in character of sediments.

4.4.2. Sorting Index

Sorting index values of the sediments vary from phi size 0.452 to 1.098 (well to poor sorted) and 0.472 to 1.096 (well to poor sorted) in March (Figure No. 4.15) and May (Figure No. 4.16) respectively.

In the month of March, sorting index values of sediments in the northern, middle and southern sector of beach vary from 0.558 to 1.098 (moderately well to poor sorted), 0.452 to 0.641 (well to moderately well sorted) and 0.491 to 0.645 (well to moderately well sorted). In May, standard deviation values of sediments in the northern, middle and southern sector of beach varies from 0.472 to 1.096 (well to poor sorted), 0.513 to 0.731 (moderately well to moderate sorted) show the dominance of moderately well sorted sediments and 0.650 to 0.920 (moderately well to moderate sorted) show the dominance of moderate sorted sediments (Figure No. 4.19).

In the months of March and May 24% and 9% sediment samples are well sorted, 57% and 41% moderately well sorted, 15% and 41% moderate sorted, 5% and 9% poor sorted respectively.

4.4.3. Skewness

Skewness values vary from -0.798 to 0.704 (very coarse to fine skewed) in March (Figure No. 4.15) and -0.249 to 0.699 (coarse to fine skewed) in May (Figure No. 4.16).

In March, northern, middle and southern sector, sediments are very coarse to symmetrical skewed, coarse to symmetrical skewed and very coarse to fine skewed respectively. In the month of May northern sector sediments are fine to coarse skewed, middle and the southern sector sediments are symmetrical to course skewed (Figure No. 4.20).

15% sediment samples are very coarse skewed, 24% coarse skewed, 43% symmetrical, 15% fine skewed and 5% very fine skewed category in March. In May 73% sediments are coarse skewed, 23% symmetrical and 5% fine skewed category.

4.4.4. Kurtosis

The nature of fourth movement kurtosis vary from 0.560 to 1.145 (very platykrutic to leptokurtic) in March (Figure No. 4.15) and in May (Figure No. 4.16). In March 5% sediment samples are vary platykrutic, 48% platykrutic, 43% mesokrutic and 5% leptokurtic nature of sediments. In May 9% platykrutic, 68% mesokrutic and 23% leptokurtic nature of sediments were observed.

Textural analysis for both the months in pre-monsoon season show that in the month of March, sediments are fine grained, well to moderate sorted (dominance of moderately well sorted), that are coarse to symmetrical skewed and platykrutic to mesokrutic nature of sediments. In the month of May, sediments are fine grained, moderate to moderately well sorted, that are coarse to symmetrical skewed and mesokrutic in nature.

4.4.5. Scatter Plots of the Sediment in Pre-Monsoon

In March, The relationship between mean sediment size and sorting index shows (Figure No. 4.17 A). Very fine grained sediments are moderately well sorted, fine grained sediments are well to moderately sorted and medium grained sediments are poorly sorted in nature. In the month of May, The relationship between mean sediment size and sorting index shows that very fine to fine grained sediments are moderately well to moderate sorted.

In March, the relationship between mean sediment sizes, sorting index and skewness shows variation (Figure No. 4.17 B and C). Fine grained sediment with well sorted are coarse to symmetrical skewed, fine grained sediments with moderate sorted are very coarse to symmetrical skewed, fine grained sediments with moderately well sorted are symmetrical to fine skewed. Very fine grained sediments with moderately well sorted are very coarse skewed and medium grained sediments with poor sorted are very fine skewed.

The month of May also shows relation in variation. Fine to very fine grained sediment samples with moderate to moderately well sorted are coarse to symmetrical skewed. Poor sorted are fine and coarse skewed.

Skewness values and kurtosis (Figure No. 4.17 D) do not show specific relation in the month of March. In the month of May majority of sediment samples are mesokrutic nature with admixture of platykrutic and leptokurtic nature of sediment along the beach. Symmetrical skewed sediments are mesokrutic nature, coarse skewed sediments are mesokrutic and leptokurtic nature and fine skewed sediments are platykrutic in nature.

Photo 32 Fine Sediment Deposits on Southern Section

Photo 33 Southern Tidal Inlet Mouth Blocked By Fine Sand Deposits

Photo 34 Fine Sediments with Titanium Oxide on Northern Sector of the Beach

Figure No. 4.15. Variogram for Textural Parameter (March)

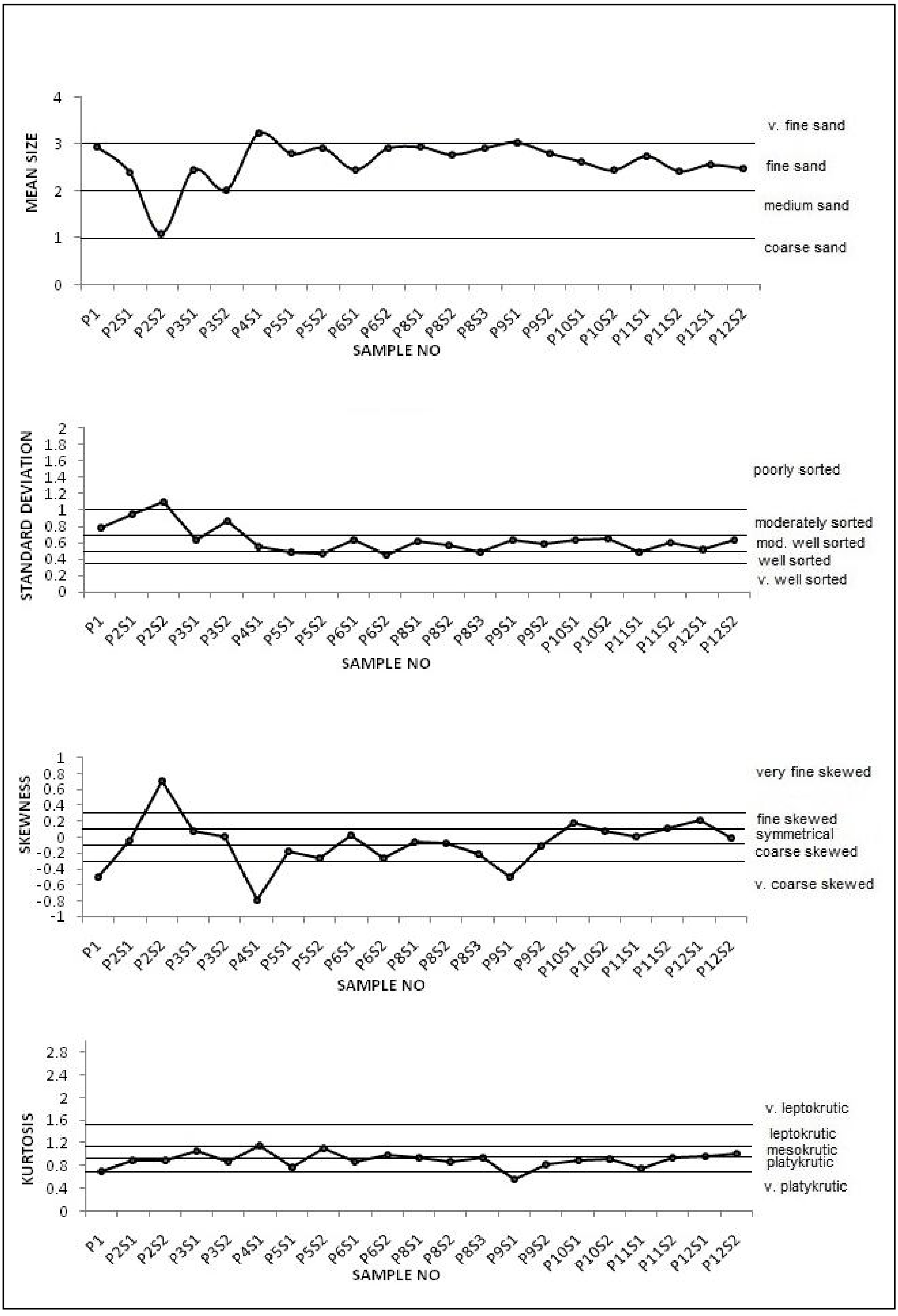


Figure No. 4.16.Variogram for Textural Parameter (May)

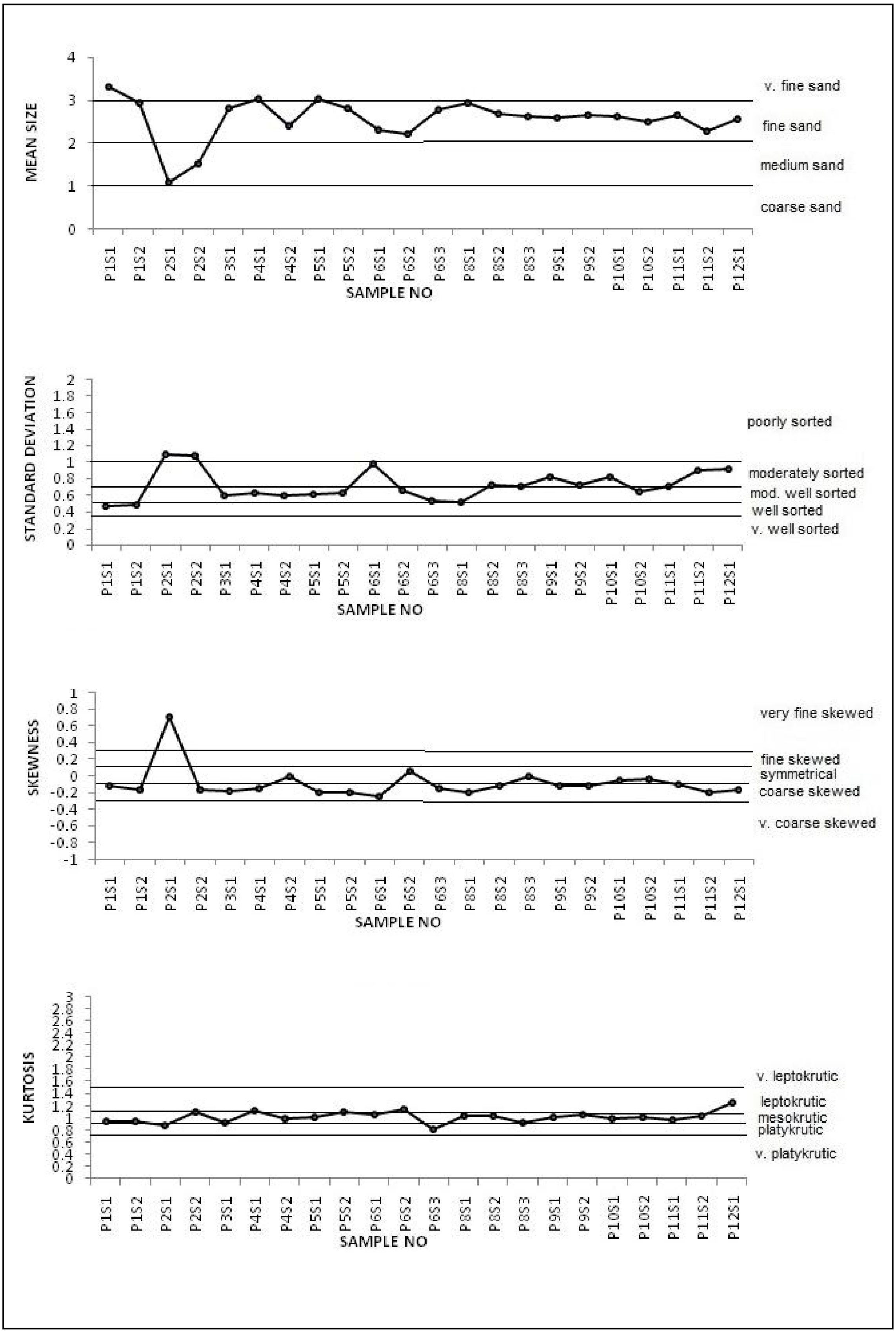


Figure no. 4.17. Scatter Plots of the Sediment in Pre-Monsoon

March **May**

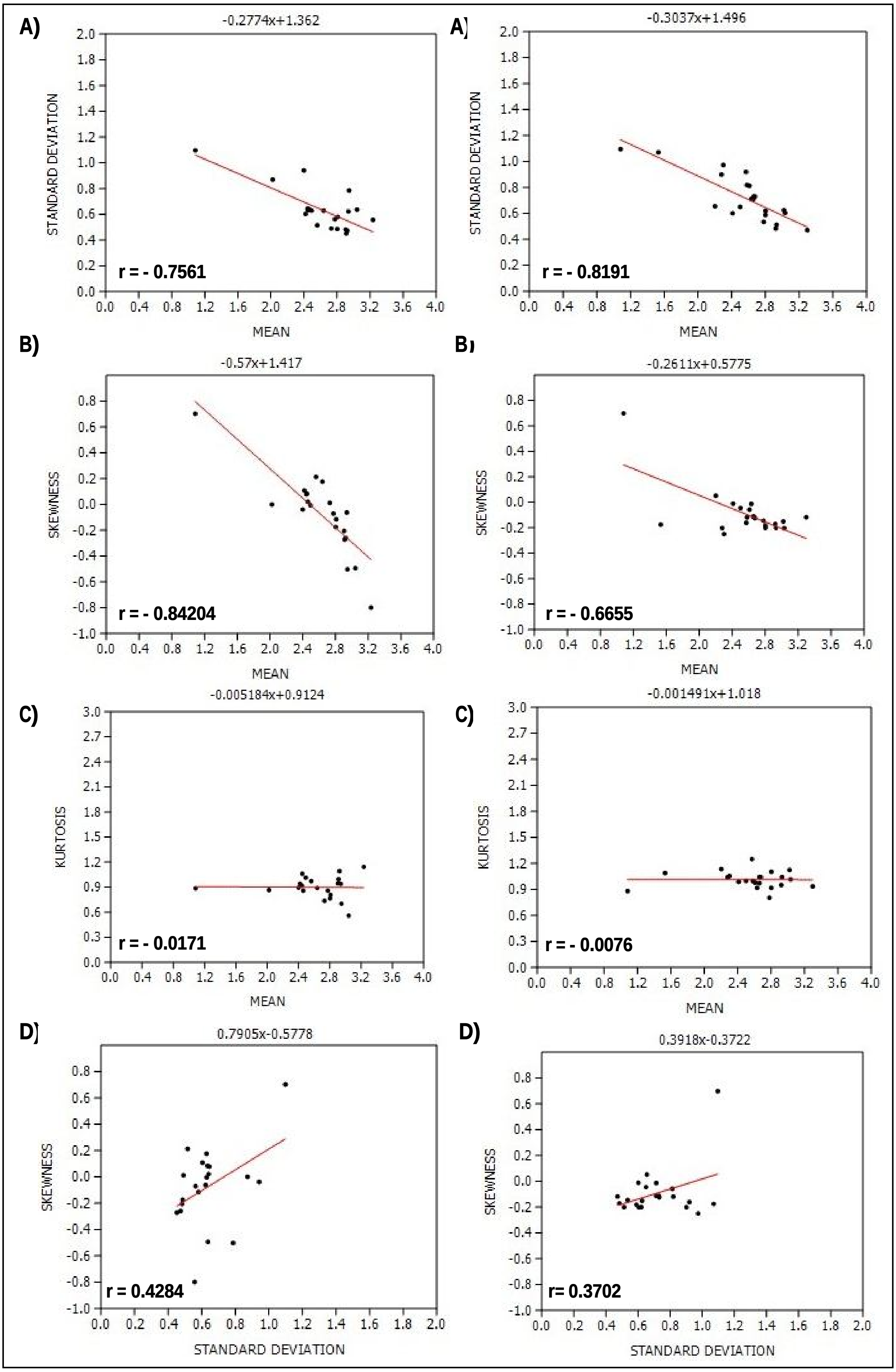


Table no. 4.9. Textural Characteristics of Beach Sediments (March)

	MEAN ø		SORTING INDEX ø		SKEWNESS		KURTOSIS	
P1S1	2.947	FS	0.787	M S	-0.502	V CS	0.704	P
P2S1	2.401	FS	0.942	M S	-0.038	S	0.895	P
P2S2	1.086	MS	1.098	PS	0.704	VFS	0.887	P
P3S1	2.449	FS	0.634	MWS	0.085	S	1.062	M
P3S2	2.023	FS	0.872	M S	0.001	S	0.867	P
P4S1	3.235	V FS	0.558	MWS	-0.798	VCS	1.145	L
P5S1	2.803	FS	0.487	WS	-0.174	CS	0.768	P
P5S2	2.923	FS	0.474	WS	-0.258	CS	1.094	M
P6S1	2.462	FS	0.641	MWS	0.022	S	0.859	P
P6S2	2.911	FS	0.452	WS	-0.271	CS	0.996	M
P8S1	2.939	FS	0.623	MWS	-0.061	S	0.942	M
P8S2	2.774	FS	0.563	MWS	-0.07	S	0.859	P
P8S3	2.905	FS	0.483	WS	-0.205	CS	0.948	M
P9S1	3.042	V FS	0.637	MWS	-0.493	VCS	0.56	VP
P9S2	2.809	FS	0.581	MWS	-0.114	CS	0.808	P
P10S1	2.639	FS	0.629	MWS	0.177	FS	0.891	P
P10S2	2.445	FS	0.645	MWS	0.08	S	0.92	M
P11S1	2.73	FS	0.491	WS	0.013	S	0.738	P
P11S2	2.419	FS	0.605	MWS	0.109	FS	0.944	M
P12S1	2.561	FS	0.516	MWS	0.214	FS	0.974	M
P12S2	2.492	FS	0.63	MWS	-0.004	S	1.015	M

Table No. 4.10. Textural Characteristics of Beach Sediments (May)

	MEAN ø		SORTING INDEX ø		SKEWNESS		KURTOSIS	
P1S1	3.298	VFS	0.472	WS	-0.117	CS	0.937	M
P1S2	2.922	FS	0.484	WS	-0.170	CS	0.953	M
P2S1	1.081	MS	1.096	PS	0.699	FS	0.883	P
P2S2	1.531	MS	1.071	PS	-0.175	CS	1.09	L
P3S1	2.801	FS	0.589	MWS	-0.180	CS	0.920	M
P4S1	3.020	V F	0.625	MWS	-0.150	CS	1.125	L
P4S2	2.410	F	0.602	MWS	-0.010	S	0.990	M
P5S1	3.033	VFS	0.605	MWS	-0.202	CS	1.018	M
P5S2	2.802	FS	0.620	MWS	-0.200	CS	1.105	L
P6S1	2.300	FS	0.974	M S	-0.249	CS	1.057	M
P6S2	2.202	FS	0.655	MWS	0.053	S	1.135	L
P6S3	2.779	FS	0.535	MWS	-0.144	CS	0.805	P
P8S1	2.931	FS	0.513	MWS	-0.200	CS	1.043	M
P8S2	2.676	FS	0.731	MS	-0.124	CS	1.043	M
P8S3	2.631	FS	0.713	MS	-0.012	S	0.920	M
P9S1	2.58	FS	0.820	MS	-0.118	CS	1.000	M
P9S2	2.660	FS	0.730	MS	-0.113	CS	1.044	M
P10S1	2.610	FS	0.813	MS	-0.057	S	0.980	M
P10S2	2.500	FS	0.650	MWS	-0.044	S	1.002	M
P11S1	2.660	FS	0.713	MS	-0.112	CS	0.974	M
P11S2	2.279	FS	0.901	MS	-0.201	CS	1.040	M
P12S1	2.570	FS	0.920	MS	-0.160	CS	1.250	L

Table No. 4.11. Sediment Properties (March)

	GRAVEL %					SAND %					SILT %				
	VCG	CG	MG	FG	VFG	VCS	CS	MS	FS	VFS	VCS	CS	MS	FS	VFS
P1S1	0	0	0	0	0	0	2.6	13.8	33.1	49.5	1	0	0	0	0
P2S1	0	0	0	0	0	0	8.7	25.3	37.9	28.1	0	0	0	0	0
P2S2	0	0	0	0	0	0	71.6	5.1	13.3	10	0	0	0	0	0
P3S1	0	0	0	0	0	0	2.4	22.5	55.7	19.3	0	0	0	0	0
P3S2	0	0	0	0	0	0	13.4	34.9	36.8	14.8	0	0	0	0	0
P4S1	0	0	0	0	0	0	0.8	2.3	21.6	74.9	0.9	0	0	0	0
P5S1	0	0	0	0	0	0	0.1	40.4	56	38.1	1.4	0	0	0	0
P5S2	0	0	0	0	0	0	0.6	8.7	45.8	49.6	0	0	0	0	0
P6S1	0	0	0	0	0	0	1.6	25.7	50.6	22.1	0.1	0	0	0	0
P6S2	0	0	0	0	0	0	0.3	0.8	48.4	47.6	1	0	0	0	0
P8S1	0	0	0	0	0	0	0.6	4.6	45.3	44.3	5.2	0	0	0	0
P8S2	0	0	0	0	0	0	1.2	5.9	55.1	35.6	2.2	0	0	0	0
P8S3	0	0	0	0	0	0	0.2	2.5	49.3	47.8	0.2	0	0	0	0
P9S1	0	0	0	0	0	0	0.4	5.1	44.1	48	2.4	0	0	0	0
P9S2	0	0	0	0	0	0	0.8	7.5	50.6	40.8	0.2	0	0	0	0
P10S1	0	0	0	0	0	0	0.1	14.3	56.4	25.9	3.2	0	0	0	0
P10S2	0	0	0	0	0	0	2.2	26.9	50.2	20.1	0.6	0	0	0	0
P11S1	0	0	0	0	0	0	0.5	3.6	62.8	32.5	0.6	0	0	0	0
P11S2	0	0	0	0	0	0	1.6	27.2	52.9	17.6	0.7	0	0	0	0
P12S1	0	0	0	0	0	0	1	9.6	68.8	20.2	0.3	0	0	0	0
P12S2	0	0	0	0	0	0	2.5	18.4	57.7	21.4	0	0	0	0	0

Table No. 4.12. Sediment Properties (May)

	GRAVEL %					SAND %					SILT %				
	VCG	CG	MG	FG	VFG	VCS	CS	MS	FS	VFS	VCS	CS	MS	FS	VFS
P1S1	0	0	0	0	0	0	0	0.6	27.6	70.6	1.2	0	0	0	0
P1S2	0	0	0	0	0	0	0	1.2	50	48.6	0.1	0	0	0	0
P2S1	0	0	0	0	0	0	18.3	35.2	31.3	15.3	0	0	0	0	0
P3S1	0	0	0	0	0	0	4.1	5	43.4	47.6	0	0	0	0	0
P4S1	0	0	0	0	0	0	0	0.1	45	54.6	0.1	0	0	0	0
P4S2	0	0	0	0	0	0.6	2.1	18.7	55.5	23.1	0	0	0	0	0
P5S1	0	0	0	0	0	0.5	0.7	5.3	33.8	57	0.7	0	0	0	0
P5S2	0	0	0	0	0	0.4	0.5	3.8	43	51.9	0.3	0	0	0	0
P6S1	0	0	0	0	0	0	9.4	21.3	42.7	25.6	0.5	0.5	0	0	0
P6S2	0	0	0	0	0	0	1.6	38.7	47.2	12.6	0	0	0	0	0
P6S3	0	0	0	0	0	0	0.1	7	54.4	38.4	0	0	0	0	0
P8S1	0	0	0	0	0	0	1.3	3	45.2	49.2	0.6	0.1	0.1	0.1	0
P8S2	0	0	0	0	0	0	3.8	12.5	49.7	33.9	0	0	0	0	0
P8S3	0	0	0	0	0	0	1.2	17.7	49.7	31.5	0	0	0	0	0
P9S1	0	0	0	0	0	0	5	22.8	40.5	31.1	0.4	0	0	0	0
P9S2	0	0	0	0	0	0	3.9	12.8	50.3	32.7	0.3	0	0	0	0
P10S1	0	0	0	0	0	0	3.5	20.4	52.2	23.4	0	0	0	0	0
P10S2	0	0	0	0	0	0.2	1.6	20	57.6	20.6	0.1	0	0	0	0
P11S1	0	0	0	0	0	2.4	3.8	8	64.7	21	0	0	0	0	0
P11S2	0	0	0	0	0	2	4.2	14	61.5	18	0.3	0	0	0	0
P12S1	0	0	0	0	0	0	3.5	25.8	58.1	13	0	0	0	0	0

Figure No. 4.18. Isoline Map Showing Mean Sediment Size ø (March and May)

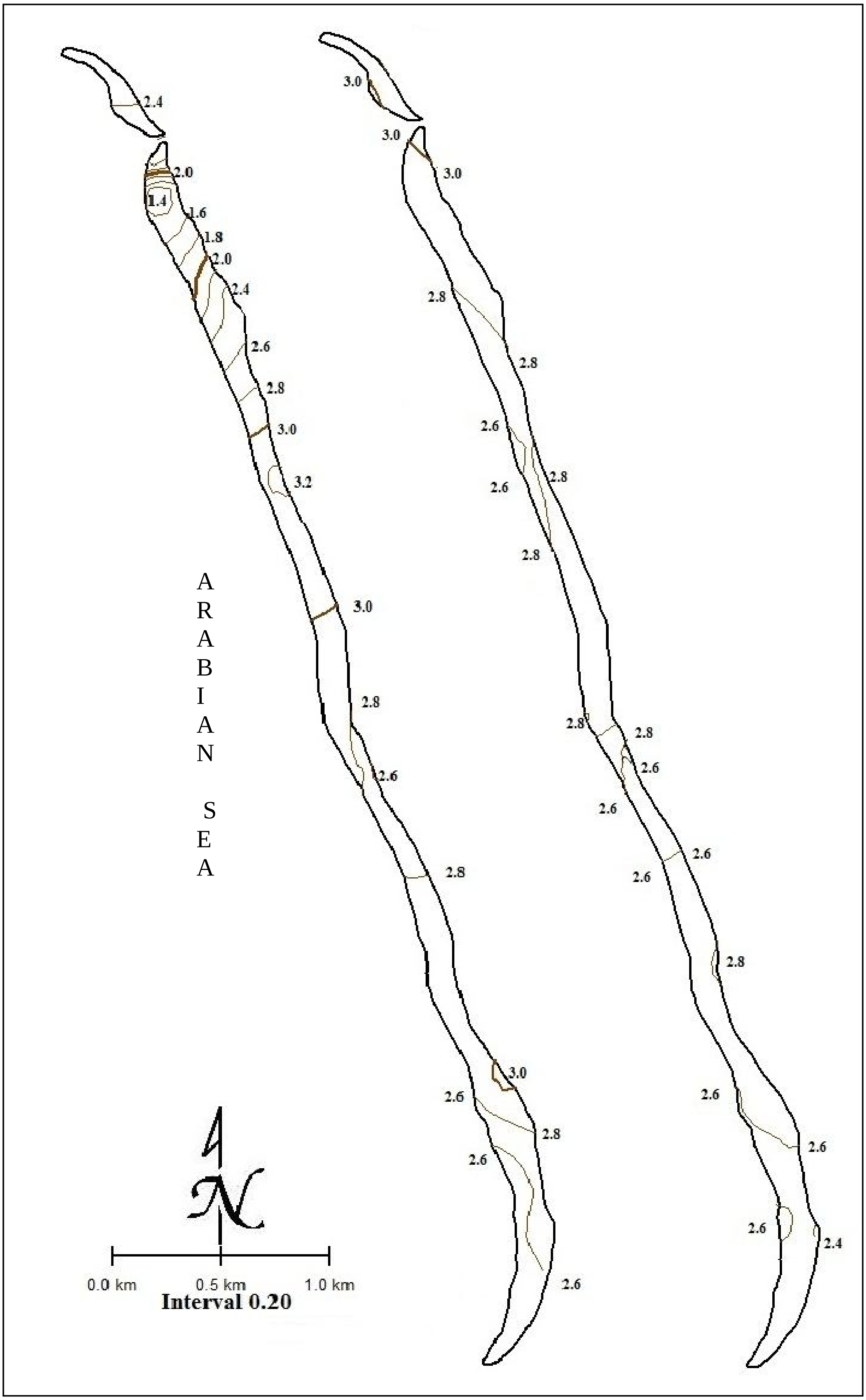


Figure No. 4.19. Isoline Map Showing Sorting Index ø (March and May)

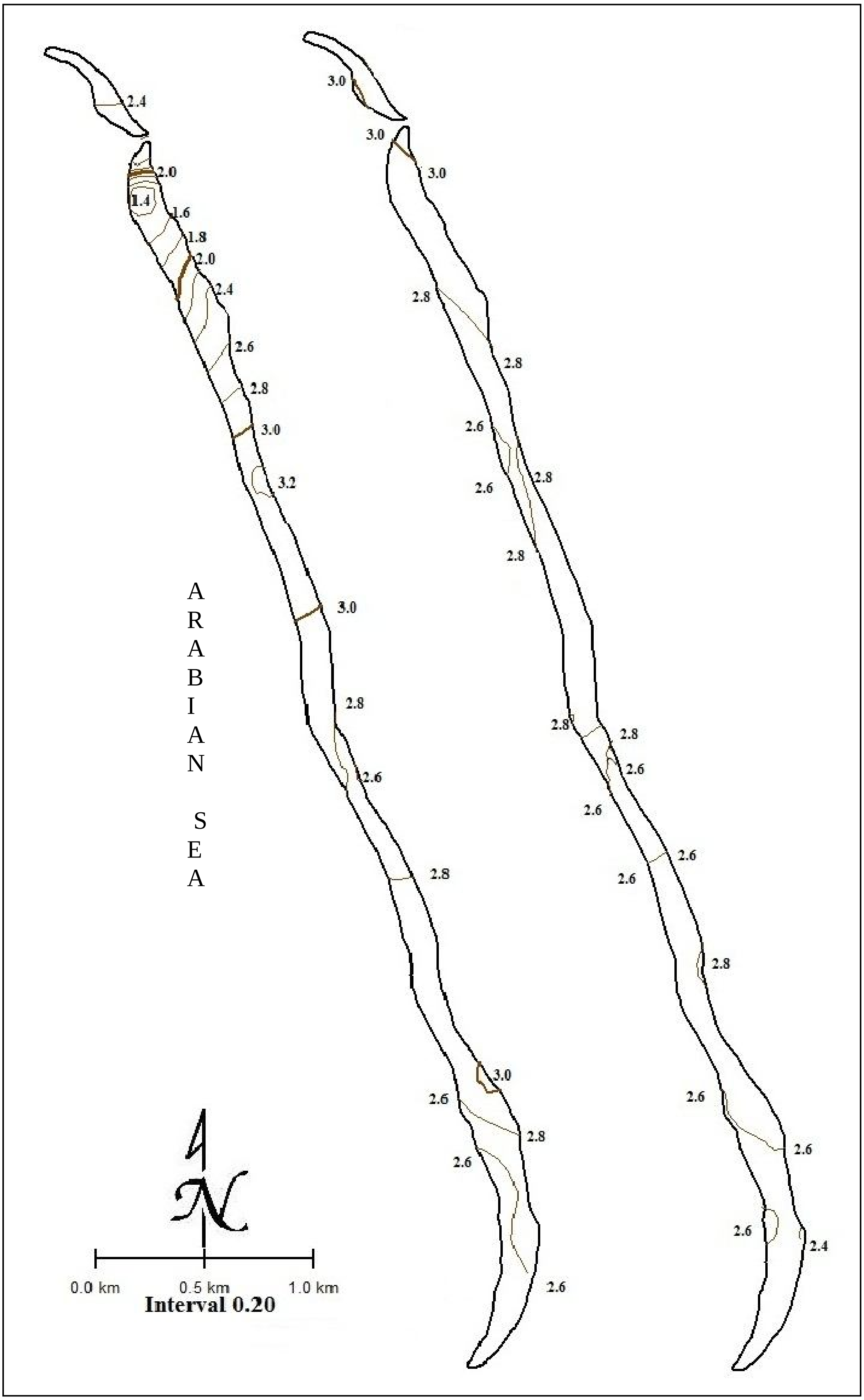


Figure No. 4.20. Isoline Map Showing Skewness Distribution (March and May)

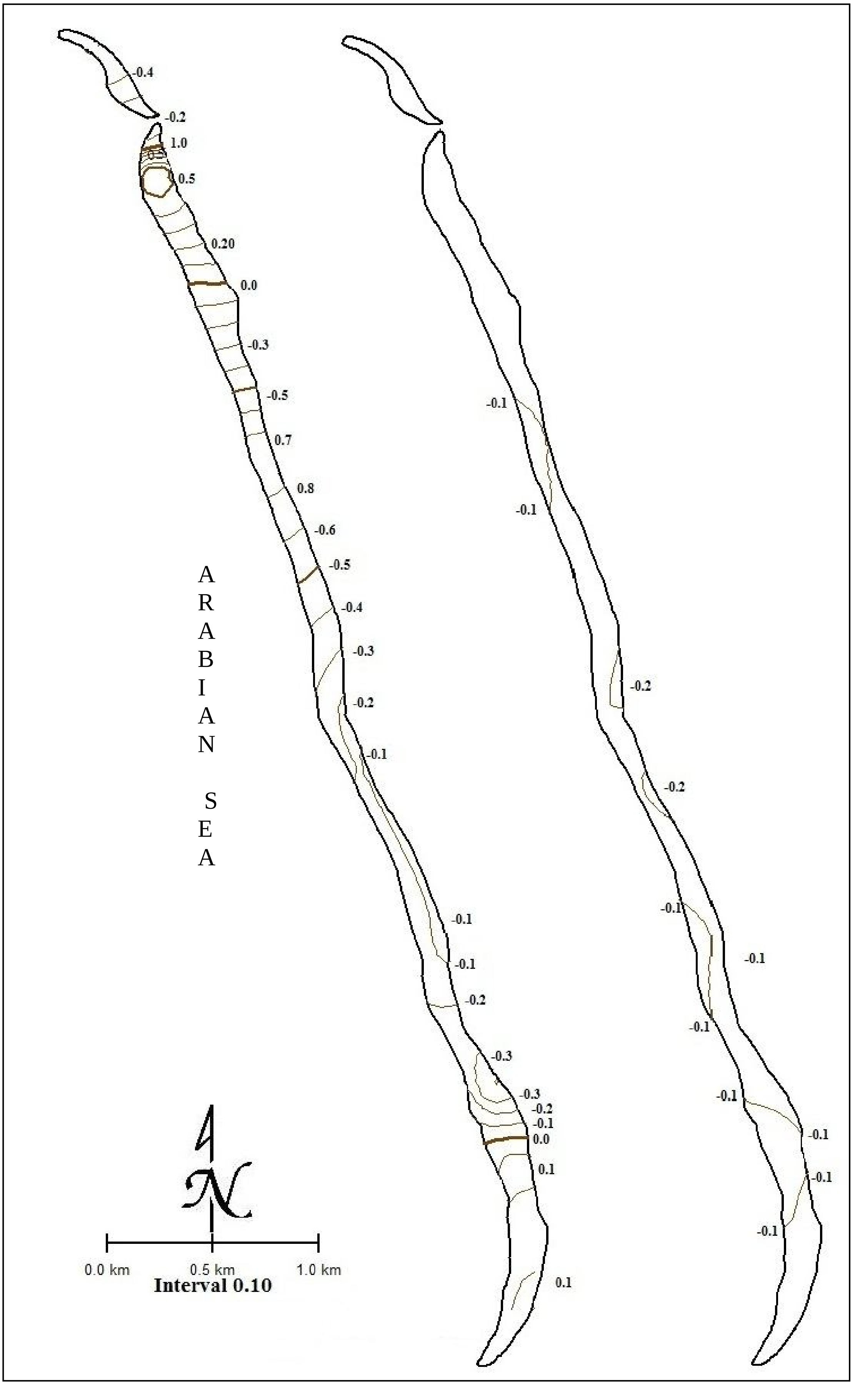
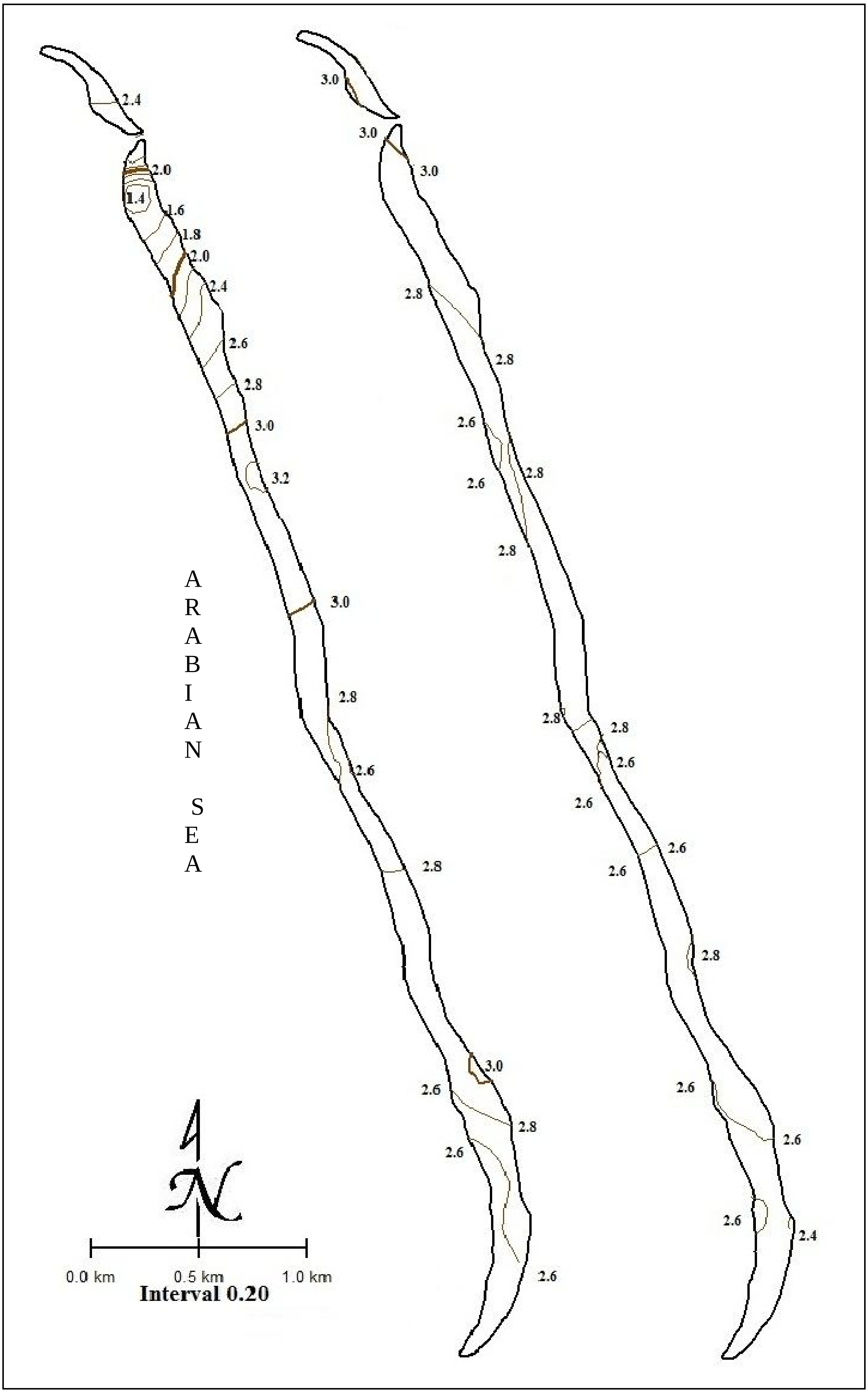


Figure No. 4.21. Isoline Map Showing Kurtosis (March and May)



4.5. Discussion

To understand the grain size parameter, Mean size, Standard deviation, Skewness, Kurtosis are most widely used. In the present study, the character of grain size distribution of beach and dune sediments have been studied to understand the energy conditions of the depositional environment of the study area.

4.5.1. Mean Sediment Size

Mean size is the average of the sediments represented by Phi mean size and mainly an index of energy conditions. The mean grain size is an important tool for interpretation of sediment data in relation to beach dynamics.

Along the Guhagar beach, sediments were medium to coarse grained to the northern section of beach in monsoon season. In post monsoon and pre monsoon, the sediments were very fine to medium with negligible percentage of coarse sand.

The variation of grain size in monsoon was a result of change in wave activity occurring along the coast. During monsoon, the waves from southwest and west directly approach the northern part of beach which results in deepening and the steep sloping of the narrow beach. Factors like the steep slope on lower beach and high wave energy, increasing wave height during July to September triggers the erosion and sediments having smaller size are winnowed away leaving the higher grain size sediments behind. The composition of sediments on this part of the beach shows high coarser fraction. In the vicinity of tidal channel at northern sector near profile no 2 and 3 shows the coarser and medium sand accumulation throughout the year.

In monsoon middle sector and southern section of beach show a comparatively moderate to gentle slope of beach than the northern section. As this stretch of beach is sheltered from south westerly wave action by the adjoining southern headland, the grain sizes increase in Phi values than northern sediments. According to Jena (1997) the temporary rise in wave activity during cyclonic weather often increase the southerly drift in the southern sector. During this southerly drift, sediment from the central section are carried by currents to the southern sector and deposited there.

During the annual cycle in pre-monsoon and post-monsoon the fine to very fine grains with admixture of medium sand were observed under low wave energy condition which prevailed with wide beach width. In this season the sea is calm, wave activity is normal, there is increasing sand volume, upper beach show the dominance of aeolian deposits resulting in decrease of grain size.

In general the spatial trend of the grain size shows increasing Phi size from north to south, i.e. Coarse to medium sand to the northern section and getting finer towards southern section. Sediment samples collected on the Guhagar beach shows dominance of fine to very fine grained sand with unimodal and bimodal distribution of sediment.

4.5.2. Sorting Index

Sorting of the sediment sample is the classification of grains according to their shape and size. According to Sahu (1964), standard deviation measures the sorting of sediments and indicates the fluctuations in the kinetic energy or velocity condition of depositing agents.

According to Chakrabarthi (1977) and Chudhari et. al. (1981), moderately sorted sands are predominant of the beaches of the east and west coast of India. The same results are observed in the study area. Throughout the year moderately well and moderate sorting sediments were dominant on Guhagar beach. In general on the beach zone at Guhagar sediments are well to poorly sort.

Inman (1962) and Friedman (1967) observed that coarse sediments tend to vary in sorting whereas fine sediments are well sorted. The influence of mean sediment size on sorting was stated by Griffiths (1951), Inman and Chamberlian (1955) and Folk and Ward (1957), observed that medium to fine sand is better sorted than very fine sediments.

There is definite correlation among the mean sediment size and standard deviation of the sediments. The analysis show that fine to very fine grained sand are well to moderately sorted, medium grained sands are moderate to poorly sorted and coarser sand are poorly sort. But some observations in the month of November and January especially in the northern section shows medium grained sand and fine grained types of sediment at few locations show poor sorting index.

Sediments along the middle and southern section of beach show an improvement in sorting with decrease in grain size. This emphasis the fact that sorting is independent of grain size and that sorting deteriorates in both coarse and fine sediments on the beach at Guhagar.

4.5.3. Skewness

Skewness measures the asymmetry of the curve of the frequency distribution and mark the position of mean with respect to median.

When the negative skewed are more, it indicates that the beach undergoes erosion and non-deposition (Duane, 1964). At the Guhagar beach the percentage of fine skewed sediments was relatively less, whereas symmetrical to course skewed were relatively more. In the post monsoon season in the month of November, January and march very course skewed samples were observed with 25%, 12% and 15% respectively.

According to Friedman (1967) present day sands on beaches show a symmetrical or negatively skewed distribution. But the predominantly fine skewed distribution indicates deposition of the fine sediments transported by littoral currents under prevailing low energy condition. The skewness characteristic of sediment distribution indicate that 57% of total sediment samples from beach were negatively skewed (very coarse to coarse skewed), 31% symmetrical and 12% positively skewed (fine skewed) in nature.

4.5.4. Kurtosis

In the month of May, July and September sediments show dominance of mesokrutic and leptokrutic nature.

In the post-monsoon season the months November and January, in pre-monsoon in the month of March sediments show dominance of very platykrutic, platykrutic, mesokrutic nature. Presence of very platykrutic nature of sediments indicates that part of the sediment achieved its sorting elsewhere in a high energy environment. The annual cycle of kurtosis indicate the changes in sediment transportation mechanism between the two sampling seasons.

4.6. Linear Discriminant Function Analysis

According to Sahu (1964), the variation in the energy and fluidity factors seem to have excellent correlation with the different processes and the environment of deposition. The process and environment of deposition has been deciphered by Sahu's Linear Discriminant Functions of Y1 (Aeolian, beach littoral (intertidal) environments,), Y2 (Beach, shallow agitated water), Y3 (shallow marine, fluvial) and Y4 (fluvial, turbidity disturb). The said Discriminant relation can be brought out between Aeolian, beach and shallow Marine environment based on mean, standard deviation, skewness and kurtosis.

To distinguish between the Aeolian and Beach environment the following equation was used

Y1 Aeolian : Beach = - 3.5688 M + 3.7016 R^2 – 2.0766 SK + 3.1135 KG

If Y1 > -2.7411 then the environment is beach and if it is Y1 < -2.7411 the environment is Aeolian environment

To confirm the environment once again the following formula was used to delineate the beach environment

Y2 Beach: Sh. Mar = 15.6534 M + 65.7091 r^2 + 18.1071 SK +18.5043 KG

Y2 > 63.3650 shallow marine/ agitated environment and Y2 < 63.3650 beach environment

To distinguish a shallow Marine environment from a Fluvial environment the following formula was used

Y3 Sh. Mar: Fluvial = 0.2852 M – 8.7604 r2 – 4.8932 SK + 0.0482 KG

Y3 > - 7.4190 shallow marine Y3 < - 7.4190 fluvial environment

To distinguish between Turbidity environment and Fluvial environment the following formula was used

Y4 Flu: Turb = 0.7215 M + 0.403 r^2 +6.7322 SK +5.2927 KG

Y4 > 10.000 turbidity environment Y4 < 10.000 fluvial environment

4.6.1. LDF Analysis of Sediment Samples in Monsoon

Table No. 4.13. LDF Analysis of Sediment Samples in July

Sample no	Y1	Aeolian & beach process	Y2	Beach & shallow environment	Y3	Shallow marine & fluvial processes	Y4	Fluvial & turbidity processes
P1S1	-1.5	Beach	120.9	Shallow Agitated	-6.6	ShallowMarine	8.1	Fluvial
P1S2	-2.0	Beach	117.7	Shallow Agitated	-6.2	ShallowMarine	7.3	Fluvial
P2S1	2.2	Beach	118.6	Shallow Agitated	-8.7	Fluvial	6.3	Fluvial
P2S2	4.4	Beach	114.3	Shallow Agitated	-11.7	Fluvial	5.8	Fluvial
P3S1	4.9	Beach	141.7	Shallow Agitated	-14.8	Fluvial	6.2	Fluvial
P3S2	5.9	Beach	123.3	Shallow Agitated	-13.4	Fluvial	9.1	Fluvial
P4S1	-3.6	Aeolian	93.0	Shallow Agitated	-4.1	ShallowMarine	8.8	Fluvial
P4S2	5.0	Beach	118.1	Shallow Agitated	-11.9	Fluvial	6.8	Fluvial
P5S1	-6.2	Aeolian	77.6	Shallow Agitated	0.1	ShallowMarine	7.2	Fluvial
P5S2	-4.3	Aeolian	84.8	Shallow Agitated	-2.8	ShallowMarine	7.2	Fluvial
P6S1	-7.6	Aeolian	78.4	Shallow Agitated	1.7	ShallowMarine	5.9	Fluvial
P6S2	-5.8	Aeolian	88.7	Shallow Agitated	-1.4	ShallowMarine	6.3	Fluvial
P6S3	-5.6	Aeolian	80.8	Shallow Agitated	-0.4	ShallowMarine	6.7	Fluvial
P8S1	-6.2	Aeolian	83.5	Shallow Agitated	-2.5	ShallowMarine	6.4	Fluvial
P8S2	-3.9	Aeolian	89.8	Shallow Agitated	-3.4	ShallowMarine	6.8	Fluvial
P8S3	-2.1	Beach	84.9	Shallow Agitated	-4.5	ShallowMarine	7.7	Fluvial
P9S1	-6.5	Aeolian	78.5	Shallow Agitated	1.7	ShallowMarine	4.8	Fluvial
P9S2	-3.9	Aeolian	87.8	Shallow Agitated	-3.1	ShallowMarine	7.1	Fluvial
P10S1	3.0	Beach	150.2	Shallow Agitated	-10.5	Fluvial	5.8	Fluvial
P10S2	-4.4	Aeolian	84.5	Shallow Agitated	-3.0	ShallowMarine	7.5	Fluvial
P11S1	-2.6	Beach	97.0	Shallow Agitated	-3.0	ShallowMarine	8.6	Fluvial
P11S2	-0.2	Beach	118.7	Shallow Agitated	-6.8	ShallowMarine	7.2	Fluvial
P12S1	-1.0	Beach	101.4	Shallow Agitated	-4.2	ShallowMarine	7.6	Fluvial

In July (Table No. 4.13) the values obtained from the differentiation of Aeolian and beach processes (Y1) show that 52% of samples came about as a results of beach environment (littoral process), where as 48% samples came about as a result of Aeolian processes. The results obtained from beach and shallow marine environment (Y2), LDF values indicate that 100% sediment samples fall within shallow marine origin. For shallow marine and fluvial processes (Y3), analysis shows that 74% of the sediment samples fall with in shallow marine processes, whereas 26% of sediment samples represent fluvial processes. The (Y4) values for fluvial and turbidity processes results show 100% sediment samples deposited by action of fluvial processes. (Figure No. 4.22)

Table No. 4.14. LDF Analysis of Sediment Samples in September

Sample no	Y1	Aeolian & beach process	Y2	Beach & shallow environment	Y3	Shallow marine & fluvial processes	Y4	Fluvial & turbidity processes
P1S1	-0.4	Beach	104.1	Shallow Agitated	-6.5	ShallowMarine	7.3	Fluvial
P1S2	-1.9	Beach	99.4	Shallow Agitated	-3.6	ShallowMarine	6.5	Fluvial
P1S3	0.0	Beach	113.8	Shallow Agitated	-6.2	ShallowMarine	4.1	Fluvial
P2S1	0.9	Beach	106.9	Shallow Agitated	-10.4	Fluvial	7.8	Fluvial
P2S2	-3.0	Aeolian	86.6	Shallow Agitated	-2.5	ShallowMarine	6.4	Fluvial
P2S3	-6.6	Aeolian	69.2	Shallow Agitated	0.6	ShallowMarine	5.5	Fluvial
P3S1	-3.0	Aeolian	87.1	Shallow Agitated	-3.3	ShallowMarine	6.8	Fluvial
P3S2	-3.3	Aeolian	88.9	Shallow Agitated	-3.0	ShallowMarine	5.4	Fluvial
P3S3	-6.2	Aeolian	72.3	Shallow Agitated	-0.4	ShallowMarine	6.4	Fluvial
P4S1	-0.7	Beach	97.4	Shallow Agitated	-3.2	ShallowMarine	8.1	Fluvial
P4S2	-5.4	Aeolian	74.1	Shallow Agitated	-0.4	ShallowMarine	7.7	Fluvial
P4S3	-2.1	Beach	98.7	Shallow Agitated	-1.2	ShallowMarine	9.0	Fluvial
P5S1	-5.1	Aeolian	76.2	Shallow Agitated	-1.3	ShallowMarine	6.0	Fluvial
P5S2	-2.9	Aeolian	90.2	Shallow Agitated	-3.3	ShallowMarine	6.0	Fluvial
P5S3	-2.9	Aeolian	91.4	Shallow Agitated	-2.5	ShallowMarine	5.7	Fluvial
P6S1	-9.1	Aeolian	80.8	Shallow Agitated	0.6	ShallowMarine	4.2	Fluvial
P6S2	-5.5	Aeolian	75.5	Shallow Agitated	-0.6	ShallowMarine	5.9	Fluvial
P6S3	-5.1	Aeolian	77.9	Shallow Agitated	-1.4	ShallowMarine	5.8	Fluvial
P8S1	-4.5	Aeolian	77.3	Shallow Agitated	-1.9	ShallowMarine	7.2	Fluvial
P8S2	-2.9	Aeolian	84.4	Shallow Agitated	-2.9	ShallowMarine	7.0	Fluvial
P8S3	1.0	Beach	115.3	Shallow Agitated	-10.5	Fluvial	6.4	Fluvial
P9S1	-5.5	Aeolian	75.3	Shallow Agitated	-1.2	ShallowMarine	5.7	Fluvial
P9S2	-5.5	Aeolian	74.5	Shallow Agitated	-0.7	ShallowMarine	5.7	Fluvial
P9S3	-5.2	Aeolian	76.8	Shallow Agitated	-1.0	ShallowMarine	6.3	Fluvial
P10S1	-5.0	Aeolian	74.7	Shallow Agitated	-1.7	ShallowMarine	7.0	Fluvial
P10S2	-0.3	Beach	93.8	Shallow Agitated	-4.7	ShallowMarine	7.7	Fluvial
P10S3	-0.6	Beach	108.7	Shallow Agitated	-6.8	ShallowMarine	6.0	Fluvial
P11S1	-0.8	Beach	103.3	Shallow Agitated	-3.9	ShallowMarine	7.5	Fluvial
P11S2	-5.1	Aeolian	87.8	Shallow Agitated	-0.9	ShallowMarine	7.9	Fluvial
P11S3	0.9	Beach	112.6	Shallow Agitated	-9.6	Fluvial	5.0	Fluvial
P12S1	-4.2	Aeolian	92.3	Shallow Agitated	-2.1	ShallowMarine	7.9	Fluvial
P12S2	-3.2	Aeolian	88.8	Shallow Agitated	-3.1	ShallowMarine	7.2	Fluvial
P12S3	-3.5	Aeolian	86.2	Shallow Agitated	-1.9	ShallowMarine	6.6	Fluvial

In September (Table No. 4.14) the values obtained from the differentiation of Aeolian and beach processes (Y1) show that 33% of samples came about as a results of beach environment (littoral process), where as 67% samples came about as a result of Aeolian processes. The results obtained from beach and shallow marine environment (Y2), LDF values indicate that 100% sediment samples fall within shallow marine origin. For shallow marine and fluvial processes (Y3), analysis shows that 91% of the sediment samples fall with in shallow marine processes, whereas 8% of sediment samples represent fluvial processes. The (Y4) values for fluvial and turbidity processes results show 100% sediment samples deposited by action of fluvial processes. (Figure No. 4.23)

Figure No. 4.22. LDF Values Plot for Samples in July

(Y1 and Y2) and (Y2 and Y3)

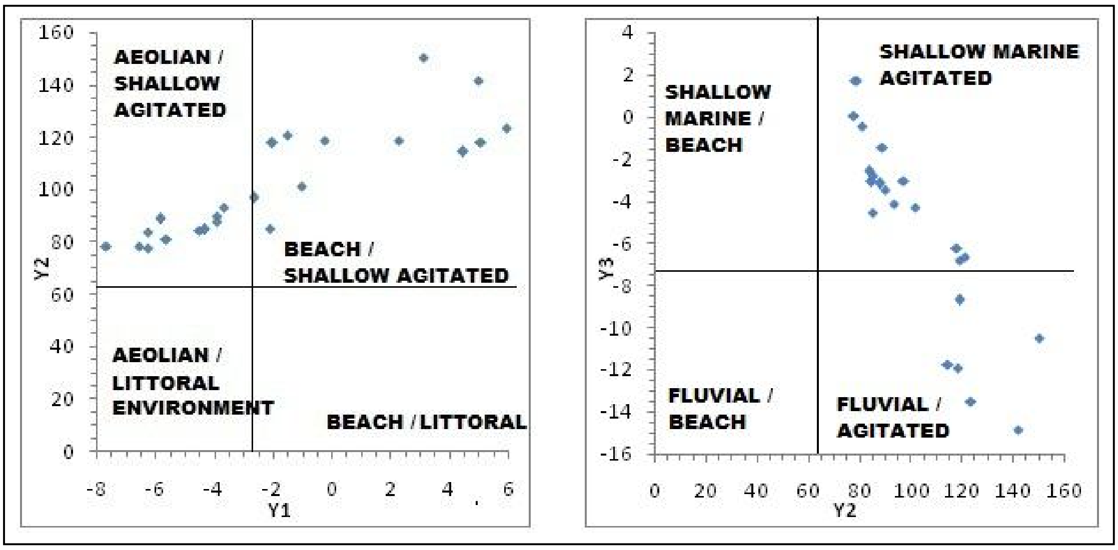
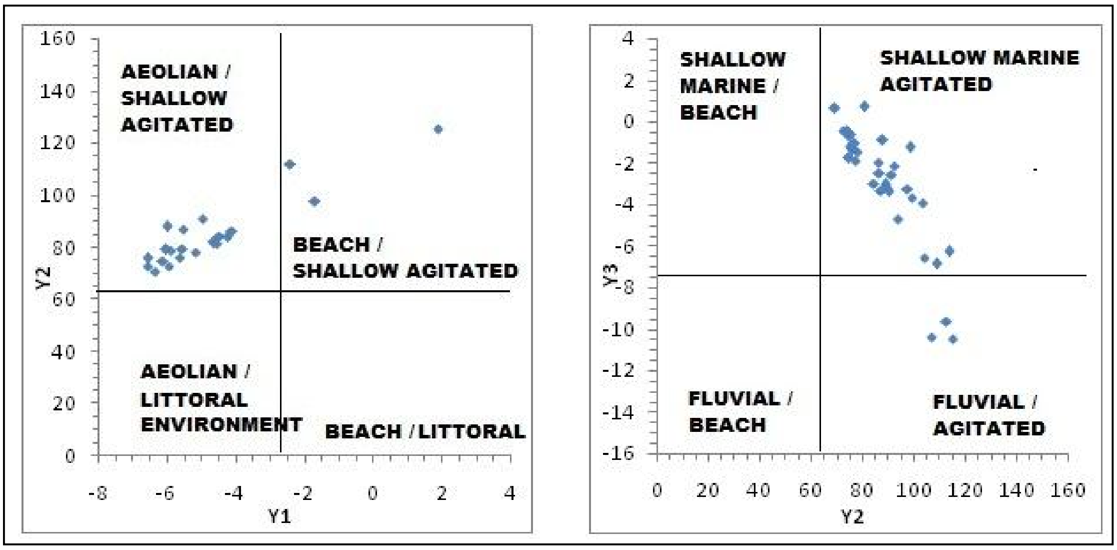


Figure No. 4.23. LDF Values Plot for Samples in September

(Y1 and Y2) and (Y2 and Y3)



4.6.2. LDF Analysis of Sediment Samples in Post-Monsoon

Table No. 4.15. LDF Analysis of Sediment Samples in November

Sample no	Y1	Aeolian & beach processes	Y2	Beach & shallow environment	Y3	Shallow marine & fluvial processes	Y4	Fluvial & turbidity processes
P1S	0.2	Beach	103.9	Shallow Agitated	-7.9	Fluvial	6.9	Fluvial
P1S2	-1.2	Beach	121.0	Shallow Agitated	-7.0	ShallowMarine	5.3	Fluvial
P2S1	0.6	Beach	105.0	Shallow Agitated	-7.7	Fluvial	5.6	Fluvial
P2S2	-1.7	Beach	96.1	Shallow Agitated	-4.8	ShallowMarine	6.5	Fluvial
P2S3	-0.1	Beach	119.1	Shallow Agitated	-8.9	Fluvial	2.6	Fluvial
P3S1	-4.0	Aeolian	89.4	Shallow Agitated	-1.5	ShallowMarine	6.6	Fluvial
P3S2	-3.9	Aeolian	86.2	Shallow Agitated	-3.3	ShallowMarine	6.0	Fluvial
P3S3	-2.0	Beach	99.7	Shallow Agitated	-1.4	ShallowMarine	7.1	Fluvial
P4S1	-2.8	Aeolian	82.9	Shallow Agitated	-3.1	ShallowMarine	6.5	Fluvial
P4S2	-1.5	Beach	102.2	Shallow Agitated	-4.4	ShallowMarine	5.5	Fluvial
P5S1	-5.0	Aeolian	77.9	Shallow Agitated	-0.9	ShallowMarine	5.3	Fluvial
P5S2	-4.1	Aeolian	84.2	Shallow Agitated	-2.2	ShallowMarine	5.8	Fluvial
P6S1	-2.	Aeolian	95.4	Shallow Agitated	-1.7	ShallowMarine	6.1	Fluvial
P8S1	-0.1	Beach	102.9	Shallow Agitated	-8.6	Fluvial	6.0	Fluvial
P8S2	-0.1	Beach	110.0	Shallow Agitated	-7.5	Fluvial	5.0	Fluvial
P9S1	-5.3	Aeolian	84.8	Shallow Agitated	-2.0	ShallowMarine	6.7	Fluvial
P9S2	-4.6	Aeolian	79.3	Shallow Agitated	-1.3	ShallowMarine	5.2	Fluvial
P10S1	6.4	Beach	75.1	Shallow Agitated	-2.8	ShallowMarine	17.3	Turbidity
P11S1	-2.1	Beach	98.9	Shallow Agitated	-4.5	ShallowMarine	5.8	Fluvial
P12S1	-2.1	Beach	95.3	Shallow Agitated	-4.1	ShallowMarine	6.3	Fluvial

In November (Table No. 4.15) the values obtained from the differentiation of Aeolian and beach processes (Y1) show that 60% of samples came about as a results of beach environment (littoral process), where as 40% samples came about as a result of Aeolian processes. The results obtained from beach and shallow marine environment (Y2), LDF values indicate that 100% sediment samples fall within shallow marine origin. For shallow marine and fluvial processes (Y3), analysis shows that 75% of the sediment samples fall with in shallow marine processes, whereas 25% of sediment samples represent fluvial processes. The (Y4) values for fluvial and turbidity processes results show 95% sediment samples deposited by action of fluvial processes and 5% sediment samples deposited by turbidity disturb. (Figure No. 4.24)

Table No. 4.16. LDF Analysis of Sediment Samples in January

Sample no	Y1	Aeolian & beach processes	Y2	Beach & shallow environment	Y3	Shallow marine & fluvial processes	Y4	Fluvial & turbidity processes
P1S1	-3.2	Aeolian	95.8	Shallow Agitated	-4.4	ShallowMarine	8.1	Fluvial
P1S2	-5.6	Aeolian	82.3	Shallow Agitated	-0.2	ShallowMarine	7.4	Fluvial
P1S3	-5.7	Aeolian	83.6	Shallow Agitated	-0.3	ShallowMarine	8.1	Fluvial
P2S1	-0.4	Beach	103.9	Shallow Agitated	-6.0	ShallowMarine	6.3	Fluvial
P2S2	-5.1	Aeolian	79.9	Shallow Agitated	-2.0	ShallowMarine	5.7	Fluvial
P2S3	0.3	Beach	135.8	Shallow Agitated	-9.5	Fluvial	4.7	Fluvial
P3S1	-5.5	Aeolian	86.7	Shallow Agitated	-3.2	ShallowMarine	7.4	Fluvial
P3S2	-3.5	Aeolian	90.7	Shallow Agitated	-2.3	ShallowMarine	5.8	Fluvial
P3S3	-0.5	Beach	116.7	Shallow Agitated	-5.5	ShallowMarine	4.8	Fluvial
P4S1	-0.5	Beach	108.1	Shallow Agitated	-5.6	ShallowMarine	6.6	Fluvial
P4S2	-5.1	Aeolian	78.3	Shallow Agitated	-0.9	ShallowMarine	5.2	Fluvial
P4S3	-2.3	Beach	102.2	Shallow Agitated	-3.4	ShallowMarine	5.8	Fluvial
P5S1	-6.3	Aeolian	78.8	Shallow Agitated	-1.0	ShallowMarine	5.9	Fluvial
P5S2	-5.7	Aeolian	82.6	Shallow Agitated	-2.3	ShallowMarine	6.3	Fluvial
P5S3	-5.9	Aeolian	73.0	Shallow Agitated	-0.4	ShallowMarine	5.0	Fluvial
P6S1	-2.0	Beach	102.5	Shallow Agitated	-4.9	ShallowMarine	7.8	Fluvial
P6S2	-3.7	Aeolian	93.9	Shallow Agitated	-3.6	ShallowMarine	6.5	Fluvial
P6S3	-5.9	Aeolian	77.3	Shallow Agitated	-1.3	ShallowMarine	5.8	Fluvial
P8S1	-5.5	Aeolian	94.4	Shallow Agitated	-4.3	ShallowMarine	8.0	Fluvial
P8S2	-0.7	Beach	112.3	Shallow Agitated	-8.0	Fluvial	6.5	Fluvial
P8S3	-5.8	Aeolian	76.5	Shallow Agitated	0.4	ShallowMarine	0.4	Fluvial
P9S1	-4.9	Aeolian	86.1	Shallow Agitated	-3.2	ShallowMarine	6.9	Fluvial
P9S2	-6.4	Aeolian	80.6	Shallow Agitated	-1.4	ShallowMarine	4.8	Fluvial
P9S3	-1.3	Beach	130.6	Shallow Agitated	-9.9	Fluvial	6.1	Fluvial
P10S1	-6.4	Aeolian	88.2	Shallow Agitated	-4.2	ShallowMarine	7.4	Fluvial
P10S2	-6.2	Beach	76.7	Shallow Agitated	-4.2	ShallowMarine	7.1	Fluvial
P10S3	-6.1	Aeolian	91.8	Shallow Agitated	-4.1	ShallowMarine	6.0	Fluvial
P11S1	-3.3	Aeolian	92.9	Shallow Agitated	-4.1	ShallowMarine	8.0	Fluvial
P11S2	-4.4	Aeolian	85.3	Shallow Agitated	-2.7	ShallowMarine	6.5	Fluvial
P11S3	-5.6	Aeolian	89.4	Shallow Agitated	-3.0	ShallowMarine	5.5	Fluvial
P12S1	1.0	Beach	141.0	Shallow Agitated	-11.7	Fluvial	6.2	Fluvial
P12S2	-1.7	Beach	114.6	Shallow Agitated	-5.8	ShallowMarine	6.7	Fluvial
P12S3	-3.4	Aeolian	104.7	Shallow Agitated	-4.1	ShallowMarine	6.3	Fluvial

In January (Table No. 4.16) the values obtained from the differentiation of Aeolian and beach processes (Y1) show that 33% of samples came about as a results of beach environment (littoral process), where as 67% samples came about as a result of Aeolian processes. The results obtained from beach and shallow marine environment (Y2), LDF values indicate that 100% sediment samples fall within shallow marine origin. For shallow marine and fluvial processes (Y3), analysis shows that 88% of the sediment samples fall with in shallow marine processes, whereas 12% of sediment samples represent fluvial processes. The (Y4) values for fluvial and turbidity processes results show 100% sediment samples deposited by action of fluvial processes.

Figure No. 4.24. LDF Values Plot for Samples in November (Y1 and Y2) and (Y2 and Y3)

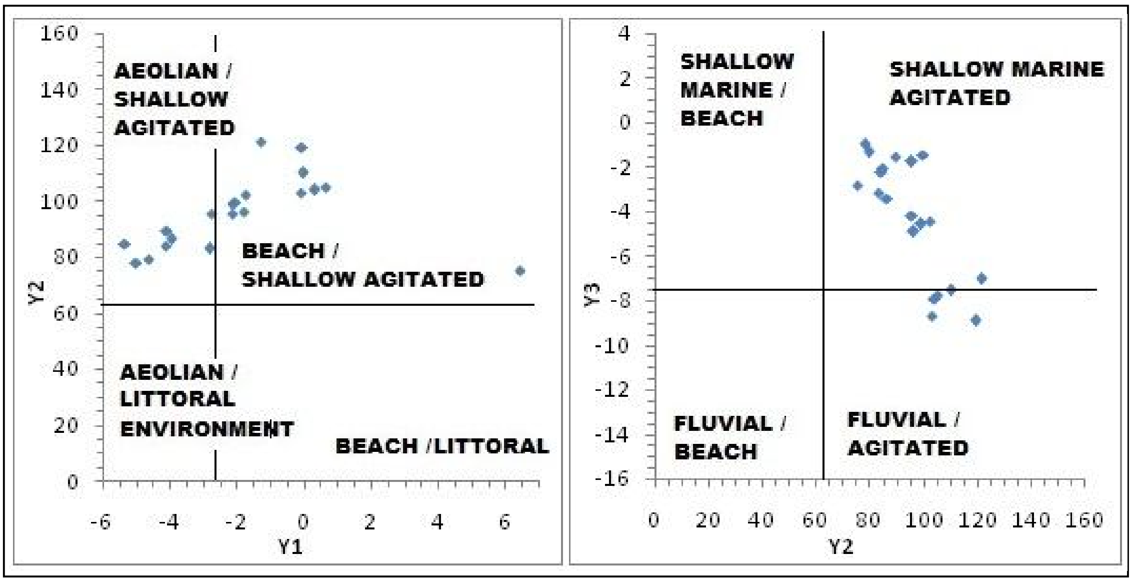
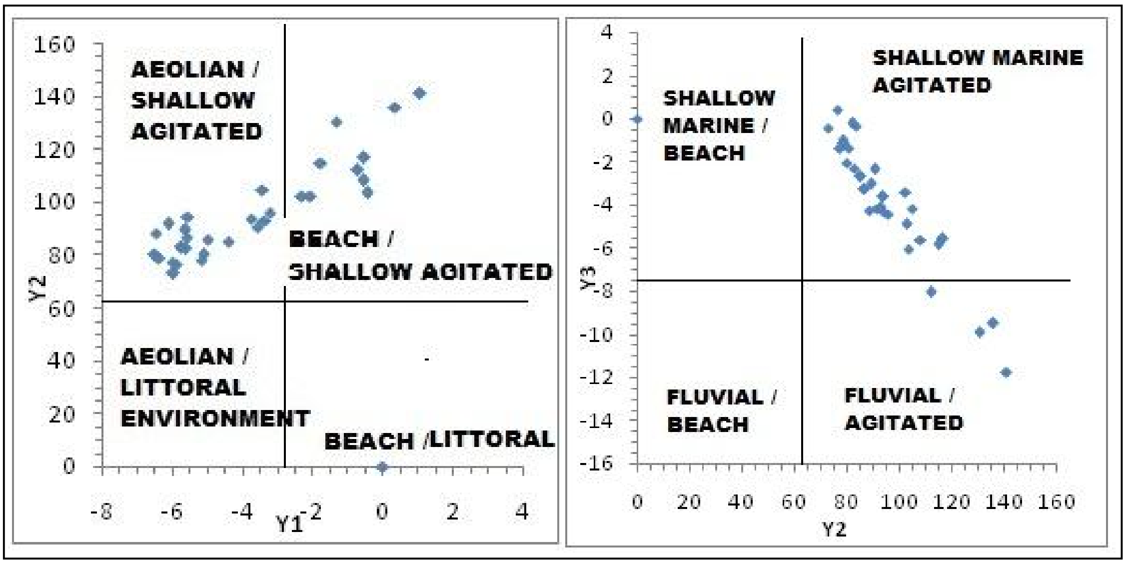


Figure No. 4.25. LDF Values Plot for Samples in January (Y1 and Y2) and (Y2 and Y3)



4.6.3. LDF Analysis of Sediment Samples in Pre-Monsoon

Table No. 4.17. LDF Analysis of Sediment Samples in March

Sample no	Y1	Aeolian & beach processes	Y2	Beach & shallow environment	Y3	Shallow marine & fluvial processes	Y4	Fluvial & turbidity processes
P1S1	-4.9	Aeolian	90.7	Shallow Agitated	-2.0	ShallowMarine	2.7	Fluvial
P2S1	-2.4	Beach	111.7	Shallow Agitated	-6.8	ShallowMarine	6.5	Fluvial
P2S2	1.8	Beach	125.3	Shallow Agitated	-13.6	Fluvial	10.7	Turbidity
P3S1	-4.1	Aeolian	85.9	Shallow Agitated	-3.1	ShallowMarine	8.1	Fluvial
P3S2	-1.7	Beach	97.6	Shallow Agitated	-6.0	ShallowMarine	6.3	Fluvial
P4S1	-5.1	Aeolian	77.8	Shallow Agitated	2.1	ShallowMarine	3.1	Fluvial
P5S1	-6.3	Aeolian	70.5	Shallow Agitated	-0.3	ShallowMarine	5.0	Fluvial
P5S2	-5.6	Aeolian	76.0	Shallow Agitated	0.1	ShallowMarine	6.2	Fluvial
P6S1	-4.6	Aeolian	81.8	Shallow Agitated	-2.9	ShallowMarine	6.6	Fluvial
P6S2	-5.9	Aeolian	72.5	Shallow Agitated	0.4	ShallowMarine	5.6	Fluvial
P8S1	-5.9	Aeolian	87.8	Shallow Agitated	-2.2	ShallowMarine	6.8	Fluvial
P8S2	-5.9	Aeolian	78.8	Shallow Agitated	-1.6	ShallowMarine	6.2	Fluvial
P8S3	-6.1	Aeolian	74.6	Shallow Agitated	-0.1	ShallowMarine	5.8	Fluvial
P9S1	-6.5	Aeolian	75.7	Shallow Agitated	-0.2	ShallowMarine	2.0	Fluvial
P9S2	-6.0	Aeolian	79.0	Shallow Agitated	-1.5	ShallowMarine	5.6	Fluvial
P10S1	-5.5	Aeolian	86.9	Shallow Agitated	-3.5	ShallowMarine	7.9	Fluvial
P10S2	-4.4	Aeolian	84.0	Shallow Agitated	-3.2	ShallowMarine	7.3	Fluvial
P11S1	-6.5	Aeolian	72.4	Shallow Agitated	-1.3	ShallowMarine	6.0	Fluvial
P11S2	-4.5	Aeolian	81.3	Shallow Agitated	-3.0	ShallowMarine	7.6	Fluvial
P12S1	-5.5	Aeolian	79.4	Shallow Agitated	-2.6	ShallowMarine	8.5	Fluvial
P12S2	-4.2	Aeolian	83.7	Shallow Agitated	-2.6	ShallowMarine	7.3	Fluvial

In March (Table No. 4.17) the values obtained from the differentiation of Aeolian and beach processes (Y1) show that 14% of samples came about as a results of beach environment (littoral process), where as 86% samples came about as a result of Aeolian processes. The results obtained from beach and shallow marine environment (Y2), LDF values indicate that 100% sediment samples fall within shallow marine origin. For shallow marine and fluvial processes (Y3), analysis shows that 95% of the sediment samples fall with in shallow marine processes, whereas 5% of sediment samples represent fluvial processes. The (Y4) values for fluvial and turbidity processes results show 95% sediment samples deposited by action of fluvial processes and 5% sediment samples deposited by turbidity disturb. (Figure No. 4.26)

Table No. 4.18. LDF Analysis of Sediment Samples in May

Sample no	Y1	Aeolian & beach process	Y2	Beach & shallow environment	Y3	Shallow marine & fluvial processes	Y4	Fluvial & turbidity processes
P1S1	-7.7	Aeolian	81.4	Shallow Agitated	-0.3	ShallowMarine	6.6	Fluvial
P1S2	-6.2	Aeolian	75.6	Shallow Agitated	-0.3	ShallowMarine	6.1	Fluvial
P2S1	1.8	Beach	124.8	Shallow Agitated	-13.5	Fluvial	10.6	Turbidity
P2S2	2.5	Beach	116.3	Shallow Agitated	-8.7	Fluvial	6.1	Fluvial
P3S1	-5.4	Aeolian	80.4	Shallow Agitated	-1.3	ShallowMarine	5.8	Fluvial
P4S1	-5.5	Aeolian	91.0	Shallow Agitated	-1.7	ShallowMarine	7.2	Fluvial
P4S2	-4.1	Aeolian	79.6	Shallow Agitated	-2.3	ShallowMarine	7.0	Fluvial
P5S1	-5.8	Aeolian	86.7	Shallow Agitated	-1.3	ShallowMarine	6.3	Fluvial
P5S2	-4.7	Aeolian	85.9	Shallow Agitated	-1.5	ShallowMarine	6.6	Fluvial
P6S1	-0.8	Beach	113.3	Shallow Agitated	-6.3	ShallowMarine	5.9	Fluvial
P6S2	-2.8	Aeolian	84.6	Shallow Agitated	-3.3	ShallowMarine	8.1	Fluvial
P6S3	-6.0	Aeolian	74.5	Shallow Agitated	-0.9	ShallowMarine	5.4	Fluvial
P8S1	-5.8	Aeolian	78.8	Shallow Agitated	-0.4	ShallowMarine	6.3	Fluvial
P8S2	-4.0	Aeolian	94.0	Shallow Agitated	-3.2	ShallowMarine	6.8	Fluvial
P8S3	-4.6	Aeolian	91.3	Shallow Agitated	-3.6	ShallowMarine	6.8	Fluvial
P9S1	-3.3	Aeolian	100.9	Shallow Agitated	-4.5	ShallowMarine	6.6	Fluvial
P9S2	-4.0	Aeolian	93.9	Shallow Agitated	-3.3	ShallowMarine	6.8	Fluvial
P10S1	-3.6	Aeolian	101.3	Shallow Agitated	-4.7	ShallowMarine	6.9	Fluvial
P10S2	-4.1	Aeolian	84.6	Shallow Agitated	-2.7	ShallowMarine	6.9	Fluvial
P11S1	-4.3	Aeolian	91.0	Shallow Agitated	-3.0	ShallowMarine	6.5	Fluvial
P11S2	-1.4	Beach	104.6	Shallow Agitated	-5.4	ShallowMarine	6.1	Fluvial
P12S1	-1.8	Beach	116.0	Shallow Agitated	-5.8	ShallowMarine	7.7	Fluvial

In May (Table No. 4.18) the values obtained from the differentiation of Aeolian and beach processes (Y1) show that 23% of samples came about as a results of beach environment (littoral process), where as 77% samples came about as a result of Aeolian processes. The results obtained from beach and shallow marine environment (Y2), LDF values indicate that 100% sediment samples fall within shallow marine origin. For shallow marine and fluvial processes (Y3), analysis shows that 91% of the samples represent fluvial processes. The (Y4) values for fluvial and turbidity processes results show 95% sediment samples deposited by action of fluvial processes and 5% sediment samples deposited by turbidity disturb (Figure No. 4.27).

Figure No. 4.26. LDF Values Plot for Samples in March (Y1 and Y2) and (Y2 and Y3)

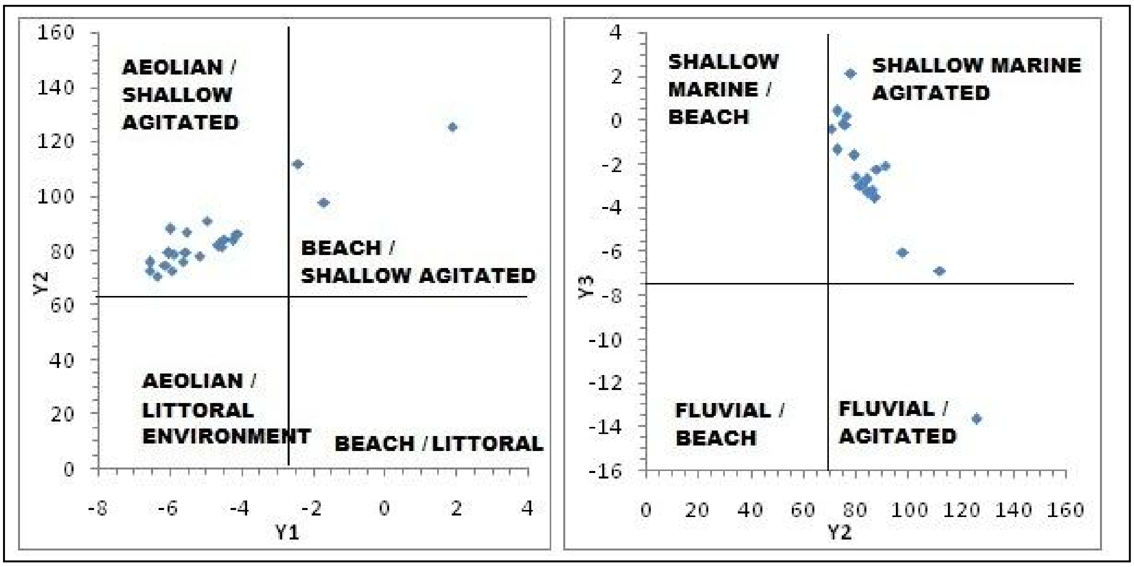
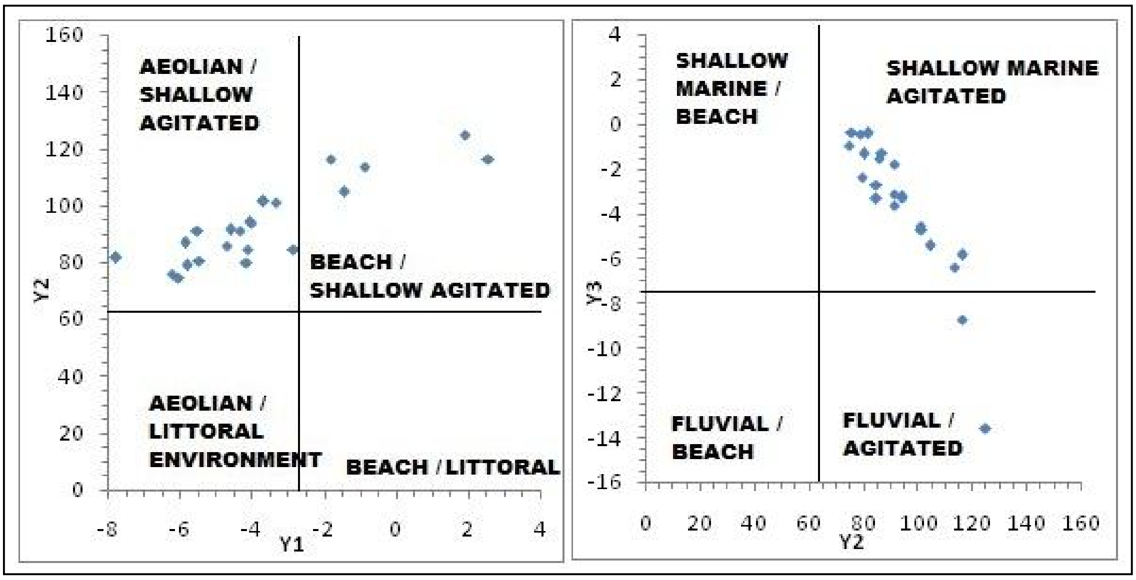


Figure No. 4.27. LDF Values Plot for Samples in May (Y1 and Y2) and (Y2 and Y3)



4.7. Textural Characteristics of Beach Subsurface Sediments

Internal sedimentary structure of beach shows depositional history of beach including the hydrodynamic condition under which they are formed. The vertical cross sections of beach deposits give subsurface (upper and lower) sediment properties help to understand changes in beach sediment deposition with a time. Generally, beach subsurface sediments are not homogeneous or not uniform in their distribution. Alternate fine to coarser sediments generally show sharp boundaries. If there is textural variation deposition of sediments, layer changes with irregular intervals varied from a few millimeters to decimeters. Even uniform sediments show little variation in there grain size.

To understand the sedimentary environment and sedimentological characteristics of subsurface sediments samples were collected from different locations to represent the beach by methods of hand sampling. The subsurface sediment samples were collected at the depth of 40 cm from surface.

4.7.1. Mean Sediment Size

The mean sediment size of the subsurface sediments ranges from 1.463 ø to 2.952 ø (Table No. 4.19). On northern, middle and southern sector of the beach, mean size of subsurface sediments from 1.463 ø to 2.771 ø, 1.711 ø to 2.816 ø (medium grained to fine grained) and 2.2 ø to 2.952 ø (fine grained) respectively (Figure No. 4.28) and (Figure No. 4.30).

Data represented in the (Table No. 4.20) illustrates the presence of sand, silt and clay contents of subsurface sediments show that subsurface sediments are sandy contain 99% sand accumulation. The amount of very coarse sediment percentage is very negligible upto 0.5%. Clay is totally absent.

The subsurface sediment samples show a dominance of fine grained sediment with admixture of medium grained sediment at different locations. Textural analysis show that 82% subsurface sediment samples are fine grained and 18% medium grained sediments.

The distributions of beach subsurface sediments are 9% unimodal, 79% bimodal and 12% trimodal in character. Upper and middle beach of northern sector, as well as, middle and southern sector shows bimodal character of sediment. Trimodal and unimodal were restricted to lower beach, in northern and southern sector respectively.

4.7.2. Sorting Index

Standard deviation values of the subsurface sediments vary from 0.303 phi to 1.282 phi indicate that sediments are very well sorted to poor sorted (Table No. 4.19). On northern, middle and southern sector of beach, standard deviation values of subsurface sediments are vary from 0.742 to 1.282 (moderate to poor sorted, 0.525 to 0.941 (moderately well to moderate sorted) and 0.303 to 0.937 (very well to moderate sorted) (Figure No. 4.28) and (Figure No. 4.31).

.The relationship between mean sediment size and standard deviation shows that fine grained sediments are moderate to moderately well sorted, medium grained are poor to moderate sorted (Figure No. 4.29 A). 15% sediment samples are poor sorted, 55% moderate sorted and 30% moderately well sorted.

4.7.3. Skewness

The subsurface beach zone, skewness values range from -0.446 to 0.206 show very coarse to fine skewed textural property (Table No. 4.19). Northern, middle and southern sector shows very coarse to fine skewed, very coarse to symmetrical and very coarse to coarse skewed nature of sediments respectively (Figure No. 4.28). The relationship between mean grain size, sorting index and skewness values show that Figure No. 4.29 B and C) Fine grained sediments with moderate to moderately well sorted are very coarse to symmetrical skewed. Medium grained sediments with poor to moderate sorted are symmetrical to fine skewed (Figure No. 4.32).

The subsurface beach zone 6% sediments samples are fine skewed, 21% symmetrical, 46% coarse skewed and 27% very coarse skewed category**.**

4.7.4. Kurtosis

The natures of fourth movement kurtosis vary from 0.53 to 2.070 (very platykrutic to very leptokurtic) sediments (Table No. 4.19). the kurtosis properties of northern sector of beach vary from very platykrutic to very leptokrutic but middle and southern sector sediments show mesokrutic to leptokrutic distribution (Figure No. 4.28) and (Figure No. 4.33**)**.

Overall beach subsurface sediments show 12% sediment samples are very platykrutic, 9% platykrutic, 43% mesokrutic, 27% leptokurtic and 9% very leptokrutic nature of sediments.

Figure No. 4.28. Variogram for Textural Parameter (Sub Surface)

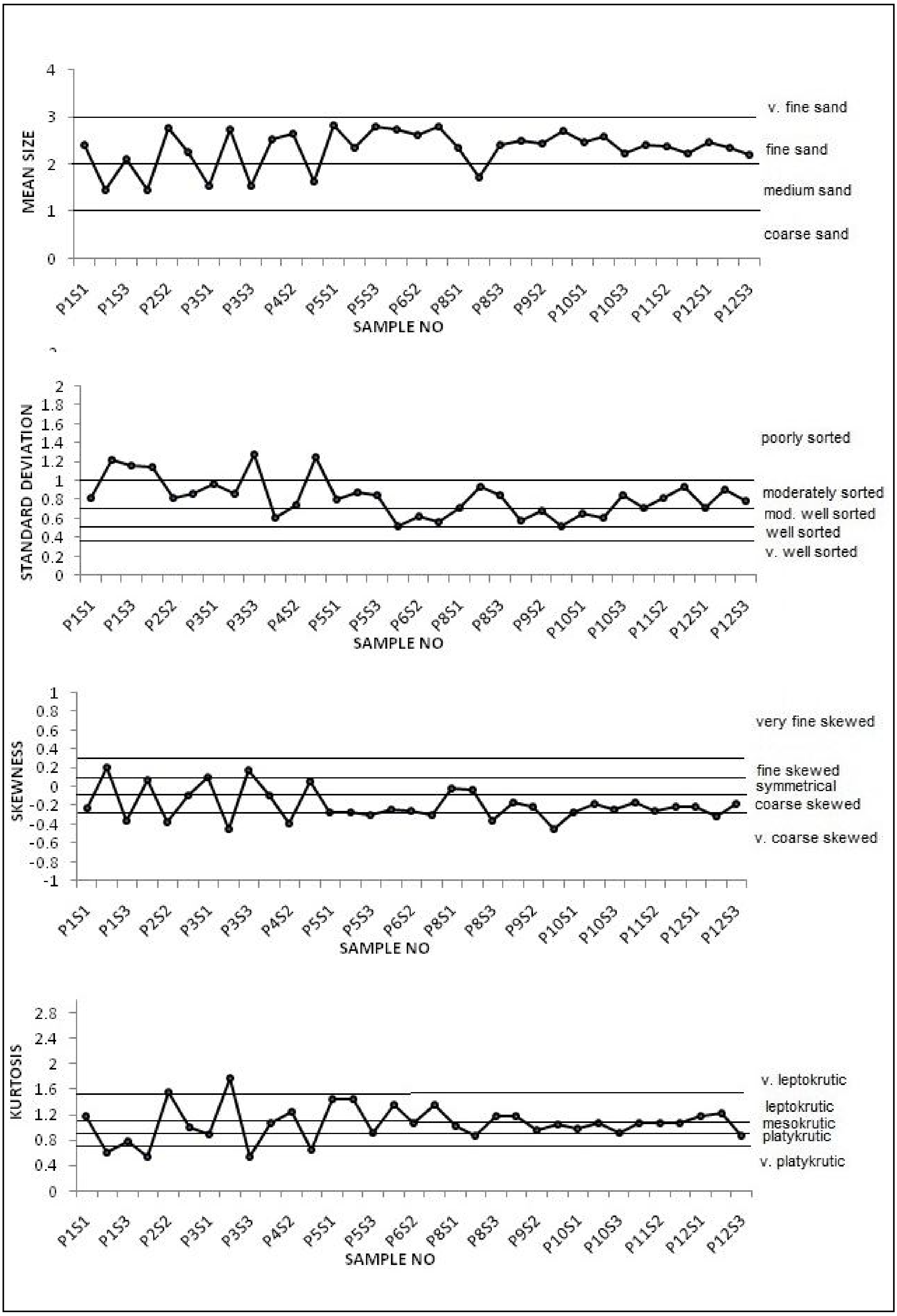


Figure No. 4.29. Scatter Plots of the Sediment (Sub Surface)

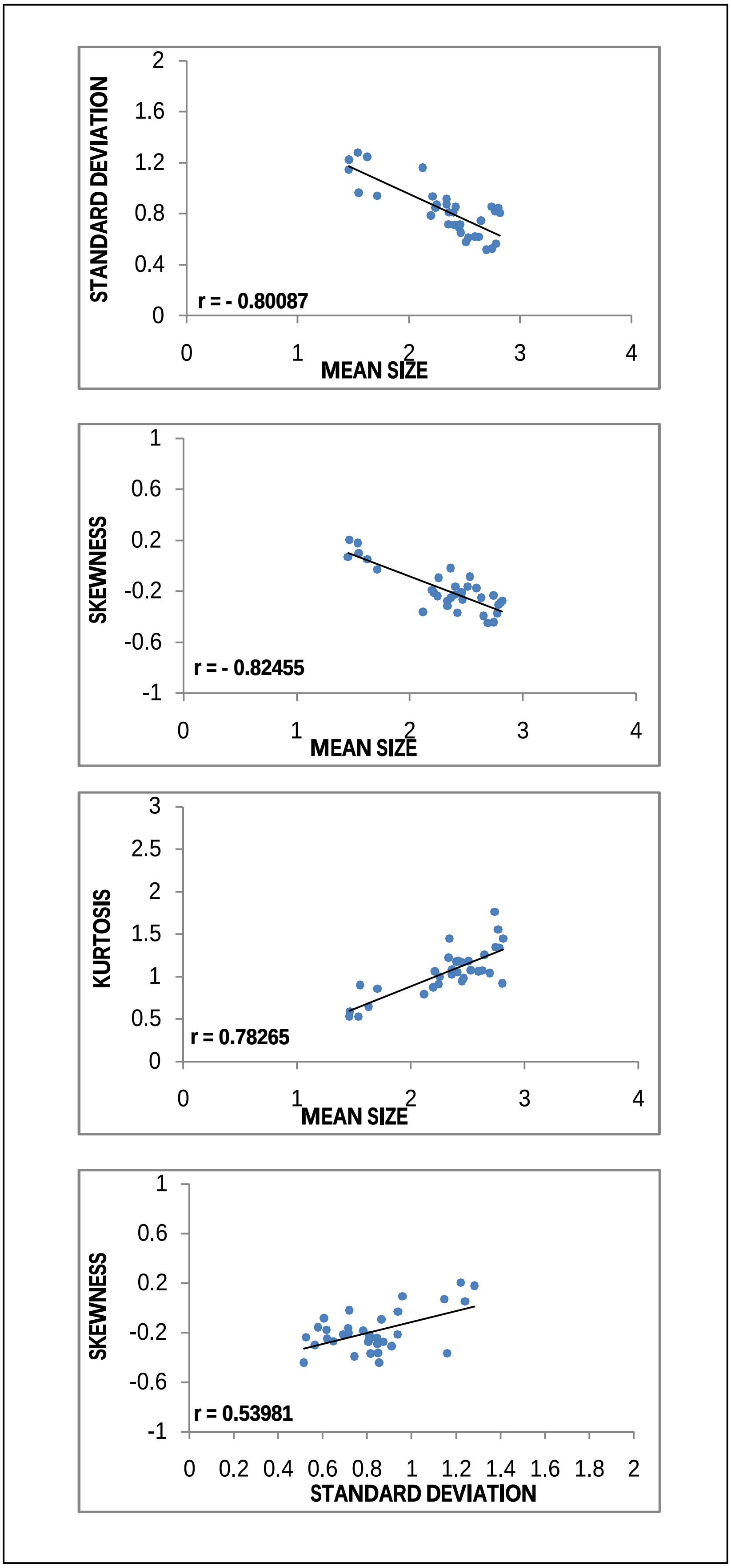


Table No. 4.19. Textural Characteristics of Beach Subsurface Sediments

SAM NO.	MEAN ø		SORTIN INDEX ø		SKEWNESS		KURTOSIS	
P1S1	2.398	FS	0.813	MS	-0.224	CS	1.173	L
P1S2	1.463	MS	1.221	PS	0.206	FS	0.595	VP
P1S3	2.121	FS	1.159	PS	-0.364	VCS	0.791	P
P2S1	1.457	MS	1.147	PS	0.072	S	0.53	VP
P2S2	2.771	FS	0.818	MS	-0.372	VCS	1.559	VL
P2S3	2.252	FS	0.867	MS	-0.096	S	1.005	M
P3S1	1.552	MS	0.961	MS	0.096	S	0.901	M
P3S2	2.741	FS	0.856	MS	-0.444	VCS	1.769	VL
P3S3	1.538	MS	1.282	PS	0.176	FS	0.533	V P
P4S1	2.53	FS	0.608	MWS	-0.087	S	1.073	M
P4S2	2.651	FS	0.742	MS	-0.395	VCS	1.255	L
P4S3	1.627	MS	1.243	PS	0.053	S	0.644	VP
P5S1	2.816	FS	0.808	MS	-0.272	CS	1.452	L
P5S2	2.337	FS	0.873	MS	-0.294	CS	0.921	M
P5S3	2.803	FS	0.849	MS	-0.224	CS	1.352	L
P6S1	2.744	FS	0.525	MWS	-0.235	CS	1.113	L
P6S2	2.629	FS	0.619	MWS	-0.253	CS	1.077	M
P6S3	2.781	FS	0.567	MWS	-0.303	VCS	1.347	L
P8S1	2.358	FS	0.719	MS	-0.021	S	1.029	M
P8S2	1.711	MS	0.941	MS	-0.028	S	0.863	P
P8S3	2.418	FS	0.851	MS	-0.367	VCS	1.183	L
P9S1	2.51	FS	0.579	MWS	-0.161	CS	0.948	M
P9S2	2.449	FS	0.691	MWS	-0.212	CS	1.081	M
P9S3	2.693	FS	0.515	MWS	-0.446	VCS	1.039	M
P10S1	2.463	FS	0.648	MWS	-0.267	CS	0.98	M
P10S2	2.592	FS	0.617	MWS	-0.177	CS	1.061	M
P10S3	2.952	FS	0.303	VWS	-0.322	VCS	2.070	V L
P11S1	2.407	FS	0.714	MS	-0.162	CS	1.059	M
P11S2	2.365	FS	0.813	MS	-0.252	CS	1.08	M
P11S3	2.216	FS	0.937	MS	-0.213	CS	1.062	M
P12S1	2.46	FS	0.718	MS	-0.206	CS	1.17	L
P12S2	2.335	FS	0.913	MS	-0.320	VCS	1.221	L
P12S3	2.2	FS	0.784	MS	-0.188	CS	0.873	P

Table No. 4.20. Proportion of Textural Class Subsurface Sample

	GRAVEL %					SAND %					SILT %				
	VCG	CG	MG	FG	VFG	VCS	CS	MS	FS	VFS	VCS	CS	MS	FS	VFS
P1S1	0	0	0	0	0	0	6.9	18.2	51.7	22.8	0.4	0	0	0	0
P1S2	0	0	0	0	0	0	40.7	20.9	24.7	13.5	0.2	0	0	0	0
P1S3	0	0	0	0	0	0	21.2	18.6	32.5	27.4	0.3	0	0	0	0
P2S1	0	0	0	0	0	0	43.0	15.8	31.7	9.6	0	0	0	0	0
P2S2	0	0	0	0	0	0	7.2	8.0	45.2	39.3	0.2	0	0	0	0
P2S3	0	0	0	0	0	0	8.6	26.8	45.6	18.7	0.3	0	0	0	0
P3S1	0	0	0	0	0	0	30.5	38.4	23.9	7.2	0.1	0	0	0	0
P3S2	0	0	0	0	0	0	9.4	6.0	45.4	38.9	0.3	0	0	0	0
P3S3	0	0	0	0	0	0	44.0	11.0	24.6	20.1	0.2	0	0	0	0
P4S1	0	0	0	0	0	0	1.6	15.3	61.3	21.6	0.1	0	0	0	0
P4S2	0	0	0	0	0	0	5.5	11.8	47.5	34.9	0.4	0	0	0	0
P4S3	0	0	0	0	0	0	35.8	20.4	25.7	17.8	0.3	0	0	0	0
P5S1	0	0	0	0	0	0	5.7	9.0	44.9	39.9	0.5	0	0	0	0
P5S2	0	0	0	0	0	0	9.4	21.2	44.5	24.8	0.2	0	0	0	0
P5S3	0	0	0	0	0	0	6.9	8.9	45.4	38.2	0.5	0	0	0	0
P6S1	0	0	0	0	0	0	0.7	6.2	58.8	34.1	0.2	0	0	0	0
P6S2	0	0	0	0	0	0	1.6	14.1	56.2	27.9	0.2	0	0	0	0
P6S3	0	0	0	0	0	0	2.1	5.1	54.3	38.1	o.4	0	0	0	0
P8S1	0	0	0	0	0	0	2.7	24.7	53.8	18.6	0.2	0	0	0	0
P8S2	0	0	0	0	0	0	25.0	35.3	31.7	7.9	0.1	0	0	0	0
P8S3	0	0	0	0	0	0	8.6	16.2	49.2	25.8	0.2	0	0	0	0
P9S1	0	0	0	0	0	0	1.4	16.5	61.0	21.0	0.1	0	0	0	0
P9S2	0	0	0	0	0	0	4.4	17.0	57.0	21.5	0.1	0	0	0	0
P9S3	0	0	0	0	0	0	2.1	7.9	60.2	29.5	0.3	0	0	0	0
P10S1	0	0	0	0	0	0	3.5	17.3	54.4	27.7	0.1	0	0	0	0
P10S2	0	0	0	0	0	0	1.8	14.5	57.8	25.9	0.1	0	0	0	0
P10S3	0	0	0	0	0	0	8.8	20.9	50.9	19.3	0.1	0	0	0	0
P11S1	0	0	0	0	0	0	4.0	20.3	55.1	20.5	0.2	0	0	0	0
P11S2	0	0	0	0	0	0	7.5	19.4	51.0	21.9	0.1	0	0	0	0
P11S3	0	0	0	0	0	0	11.2	25.5	44.9	18.2	0.2	0	0	0	0
P12S1	0	0	0	0	0	0	4.9	15.9	57.0	22.0	0.1	0	0	0	0
P12S2	0	0	0	0	0	0	10.0	18.5	50.7	20.6	0.2	0	0	0	0
P12S3	0	0	0	0	0	0	8.9	27.5	48.4	14.9	0.2	0	0	0	0

Figure No. 4.30. Isoline Map Showing Mean Sediment Size ø (Sub Surface)

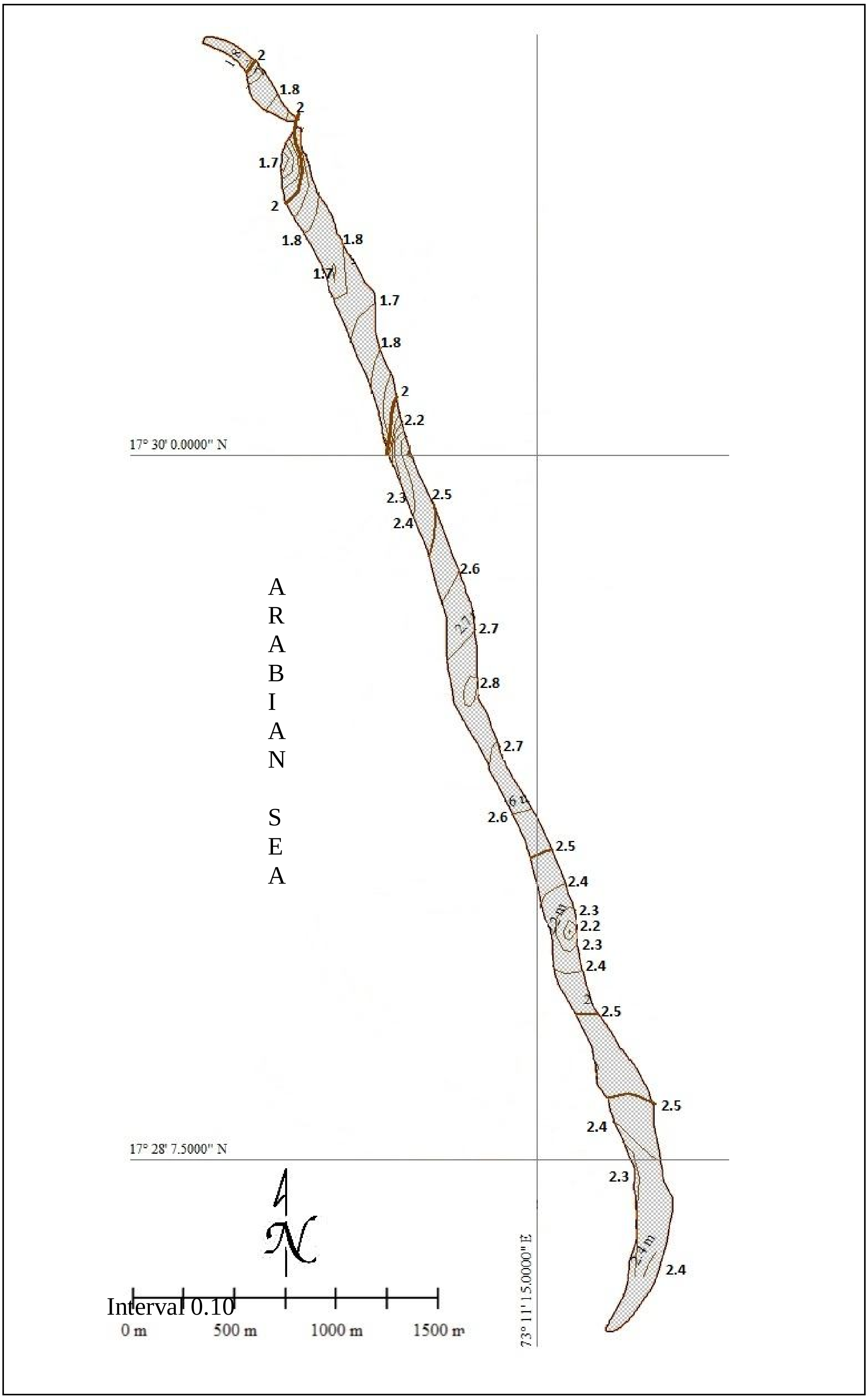


Figure No. 4.31. Isoline Map Showing Sorting Index ø (Sub Surface)

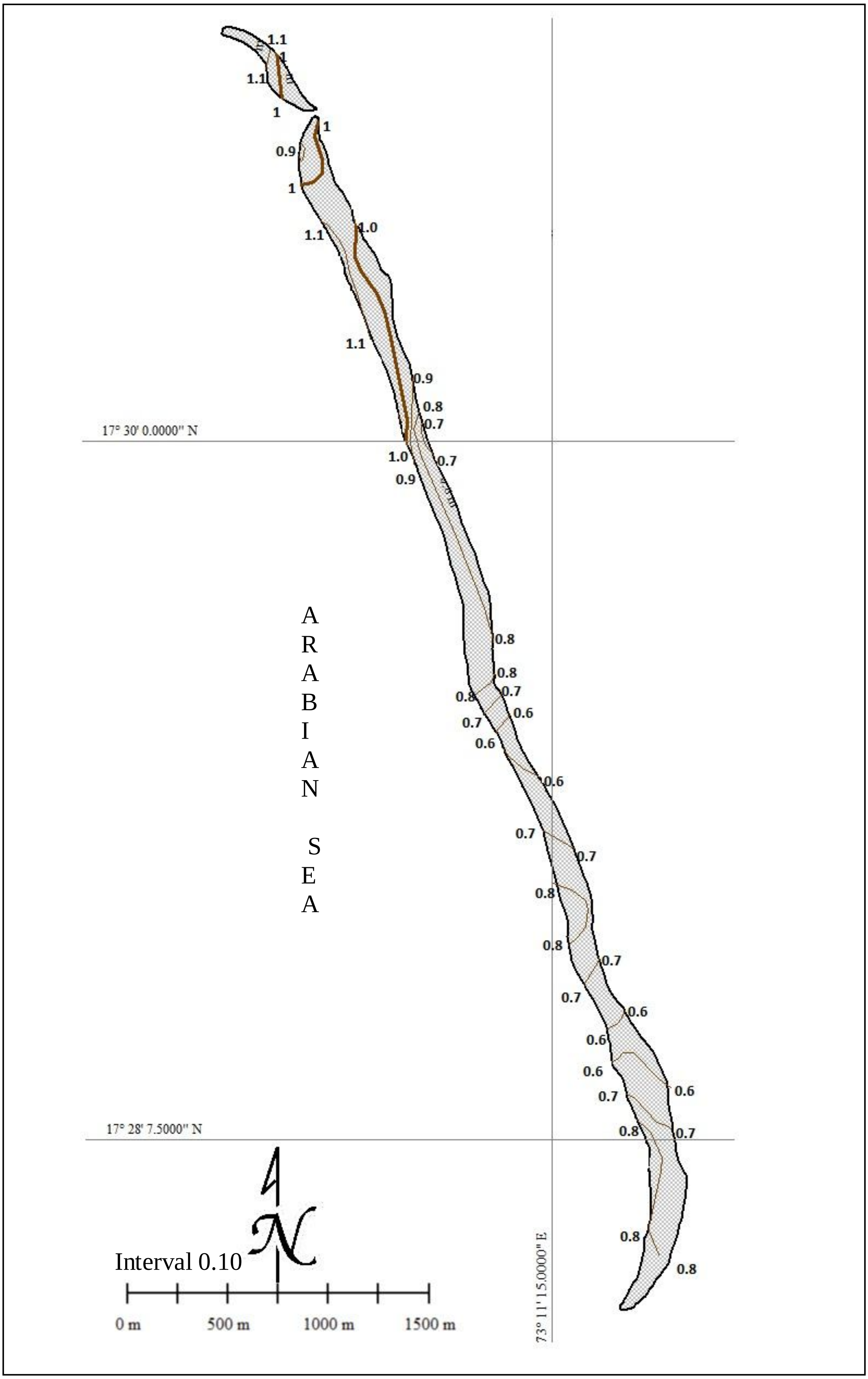


Figure No. 4.32. Isoline Map Showing Skewness (Sub Surface)

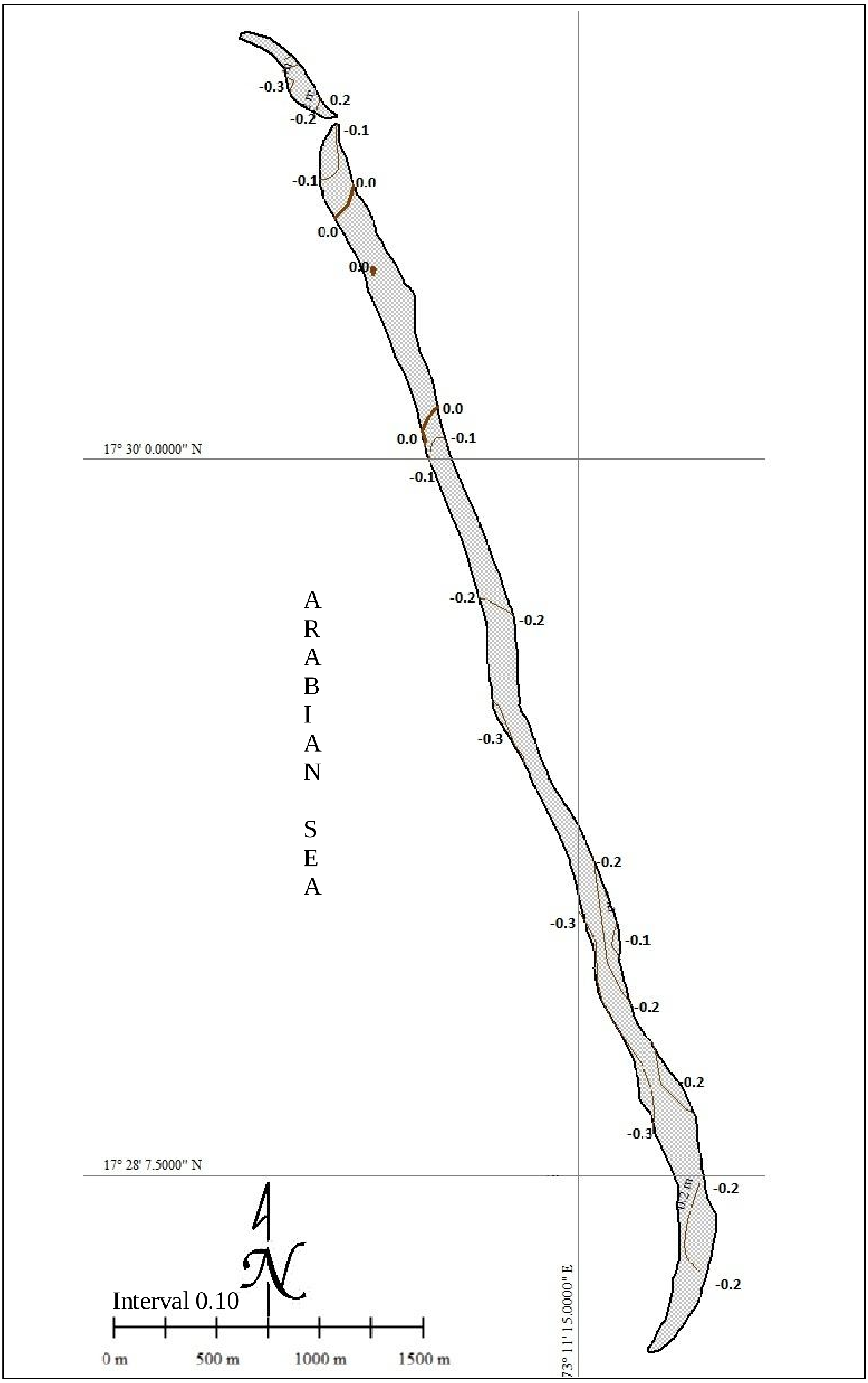
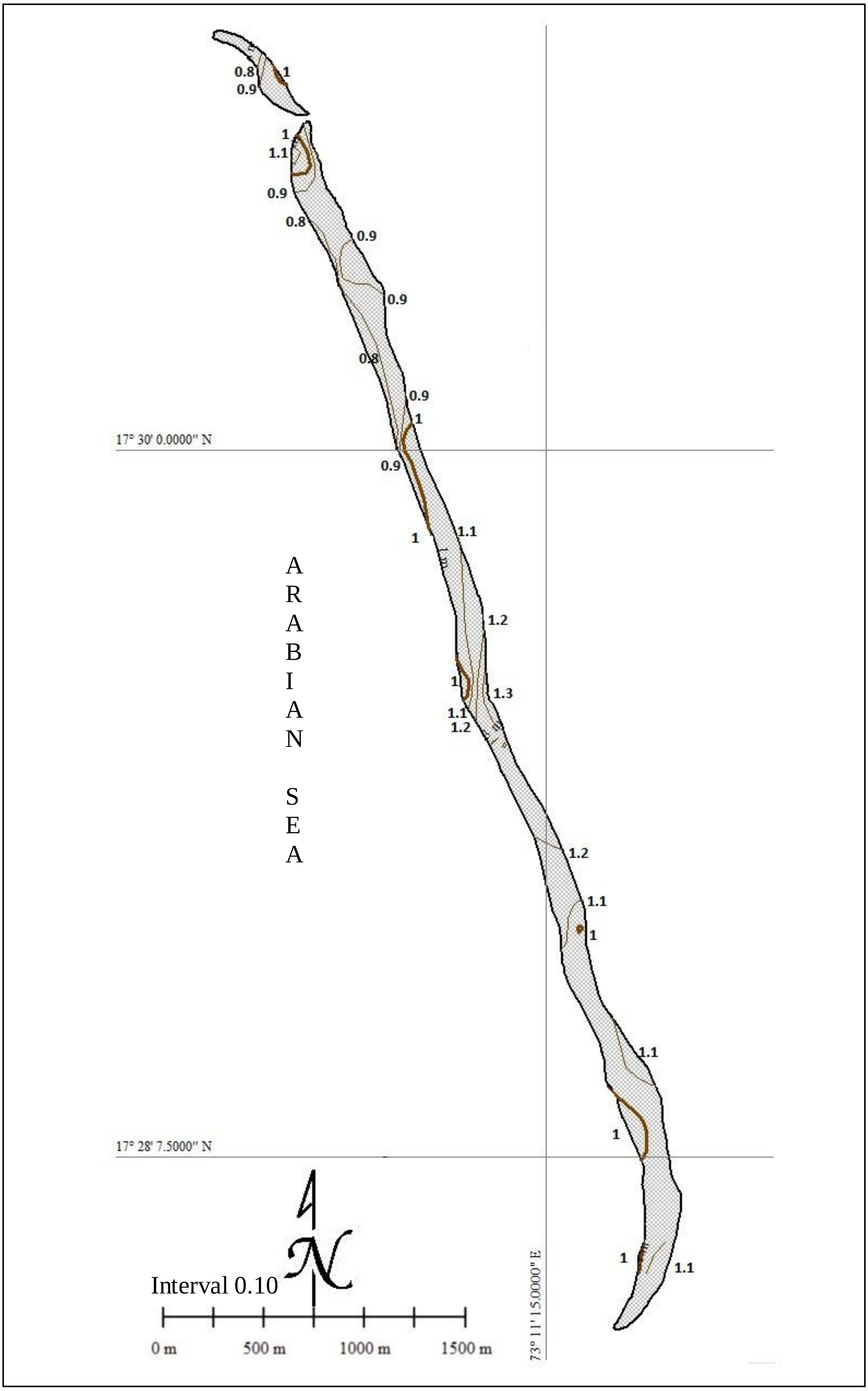


Figure No. 4.33. Isoline Map Showing Kurtosis (Sub Surface)



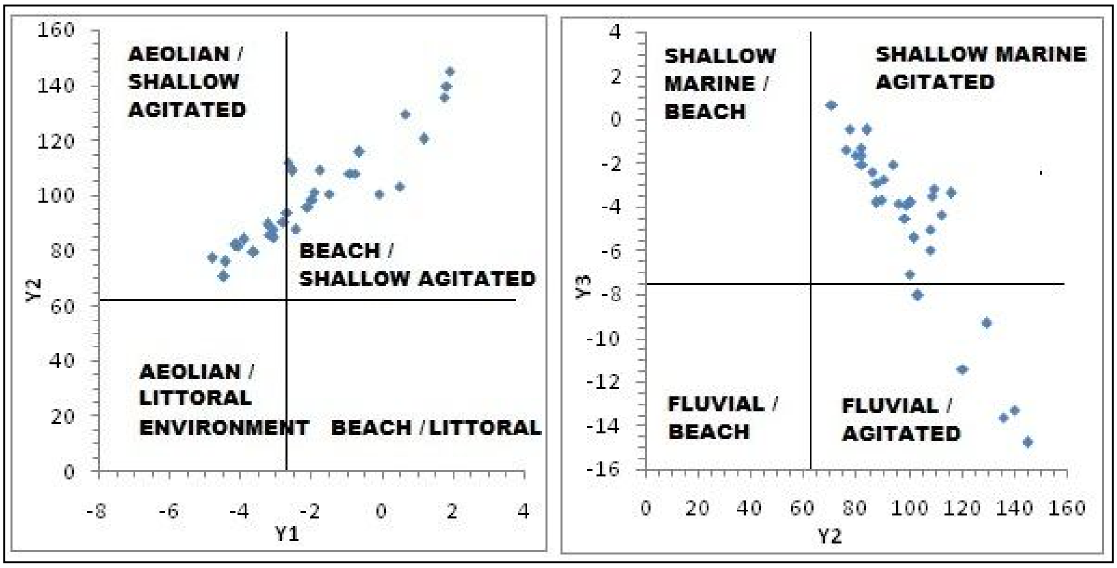
4.7.5. L D F Analysis

Table No. 4.21 L D F Analysis of Sediment Samples (Sub Surface)

Sample no	Y1	Aeolian & beach process	Y2	Beach & shallow environment	Y3	Shallow marine & fluvial processes	Y4	Fluvial & turbidity process
P1S1	-1.9	Beach	98.6	Shallow Agitated	-3.9	Shallow Marine	6.6	Fluvial
P1S2	1.7	Beach	135.6	Shallow Agitated	-13.6	Fluvial	6.1	Fluvial
P1S3	0.6	Beach	129.5	Shallow Agitated	-9.3	Fluvial	3.8	Fluvial
P2S1	1.1	Beach	120.3	Shallow Agitated	-11.4	Fluvial	4.8	Fluvial
P2S2	-1.7	Beach	109.4	Shallow Agitated	-3.1	Shallow Marine	8.1	Fluvial
P2S3	-1.9	Beach	101.5	Shallow Agitated	-5.4	Shallow Marine	6.6	Fluvial
P3S1	0.4	Beach	103.3	Shallow Agitated	-8.7	Fluvial	6.9	Fluvial
P3S2	-0.6	Beach	115.7	Shallow Agitated	-3.3	Shallow Marine	8.6	Fluvial
P3S3	1.8	Beach	145.1	Shallow Agitated	-14.7	Fluvial	5.7	Fluvial
P4S1	-4.1	Aeolian	82.1	Shallow Agitated	-2.3	Shallow Marine	7.6	Fluvial
P4S2	-2.6	Beach	93.7	Shallow Agitated	-2.7	Shallow Marine	6.1	Fluvial
P4S3	1.8	Beach	139.8	Shallow Agitated	-13.2	Fluvial	5.5	Fluvial
P5S1	-2.5	Beach	108.9	Shallow Agitated	-3.5	Shallow Marine	8.1	Fluvial
P5S2	-2.0	Beach	98.3	Shallow Agitated	-4.5	Shallow Marine	4.8	Fluvial
P5S3	-2.6	Beach	112.2	Shallow Agitated	-4.3	Shallow Marine	7.9	Fluvial
P6S1	-4.8	Aeolian	77.4	Shallow Agitated	-0.4	Shallow Marine	6.3	Fluvial
P56S2	-4.0	Aeolian	81.6	Shallow Agitated	-1.3	Shallow Marine	6.4	Fluvial
P6S3	-3.9	Aeolian	84.0	Shallow Agitated	-0.4	Shallow Marine	7.2	Fluvial
P8S1	-3.2	Aeolian	89.5	Shallow Agitated	-3.7	Shallow Marine	7.2	Fluvial
P8S2	-0.8	Beach	100.4	Shallow Agitated	-7.9	Shallow Marine	5.9	Fluvial
P8S3	-1.5	Beach	100.6	Shallow Agitated	-3.8	Shallow Marine	5.8	Fluvial
P9S1	-4.4	Aeolian	75.9	Shallow Agitated	-1.3	Shallow Marine	5.8	Fluvial
P9S2	-3.1	Aeolian	85.8	Shallow Agitated	-2.3	Shallow Marine	6.2	Fluvial
P9S3	-4.4	Aeolian	70.7	Shallow Agitated	0.6	Shallow Marine	4.5	Fluvial
P10S1	-3.6	Aeolian	79.4	Shallow Agitated	-1.6	Shallow Marine	5.3	Fluvial
P10S2	-4.1	Aeolian	82.0	Shallow Agitated	-1.6	Shallow Marine	6.4	Fluvial
P1S3	-3.1	Aeolian	84.7	Shallow Agitated	1.7	Shallow Marine	10.9	Turbidity
P11S1	-3.1	Aeolian	87.8	Shallow Agitated	-2.9	Shallow Marine	6.4	Fluvial
P11S2	-2.1	Beach	95.8	Shallow Agitated	-3.8	Shallow Marine	5.9	Fluvial
P11S3	-0.9	Beach	108.1	Shallow Agitated	-5.9	Shallow Marine	6.1	Fluvial
P12S1	-2.8	Aeolian	90.3	Shallow Agitated	-2.7	Shallow Marine	6.7	Fluvial
P12S2	-0.7	Beach	108.1	Shallow Agitated	-5.1	Shallow Marine	6.3	Fluvial
P12S3	-2.4	Beach	87.5	Shallow Agitated	-3.7	Shallow Marine	5.1	Fluvial

On the beach the sub surface sediments LDF analysis values (Table No. 4.21) obtained from the differentiation of Aeolian and beach processes (Y1) show that 61% of samples came about as a results of beach environment (littoral process), where as 39% samples came about as a result of Aeolian processes. The results obtained from beach and shallow marine environment (Y2), LDF values indicate that 100% sediment samples fall within shallow marine origin. For shallow marine and fluvial processes (Y3), analysis shows that 82% of the sediment samples fall with in shallow marine processes, whereas 18% of sediment samples represent fluvial processes. The (Y4) values for fluvial and turbidity processes results show 97% sediment samples deposited by action of fluvial processes and 3% sediment samples deposited by turbidity disturb (Figure No. 4.34**)**.

Figure No. 4.34. LDF Values Plot for Samples (Y1 and Y2) and (Y2 and Y3) (Subsurface)



4.8. Sedimentology and Stratigraphical Study of A Beach-Dune Section

On the northern section near profile 4, a 4.2 m deep beach dune cut section clearly shows 15 distinct layers of sediment deposits (Photo No. 35). To understand the subsurface Stratigraphy of beach and dune 15 sediment samples are collected and the width of each layer is measured. Sediment analysis and inclination of layers gives an idea about ancient sedimentology environment of the beach. Linear Discriminate function (LDF) technique is used to identify ancient beach environment.

Table No. 4.22. Textural Characteristics of Beach-Dune Section samples

	MEAN ø		SORTING INDEX ø		SKEWNESS		KURTOSIS	
S15	2.197	FS	0.692	MWS	-0.076	S	0.996	M
S14	2.601	FS	0.730	MS	0.402	VFS	0.955	M
S13	1.277	MS	0.944	MS	0.205	FS	0.845	P
S12	1.013	MS	1.042	PS	0.673	VFS	0.879	P
S11	1.511	MS	0.930	MS	-0.098	S	0.762	P
S10	1.140	MS	1.030	PS	0.578	VFS	0.716	P
S9	0.716	CS	0.693	MWS	0.559	VFS	1.823	VL
S8	1.084	MS	0.810	MS	0.243	FS	0.783	P
S7	1.152	MS	0.844	MS	0.195	FS	0.708	P
S6	1.212	MS	0.821	MS	0.085	S	0.756	P
S5	0.435	CS	0.467	WS	0.314	VFS	1.985	VL
S4	1.275	MS	1.026	PS	0.323	VFS	0.723	P
S3	2.124	FS	1.245	PS	-0.241	CS	0.771	P
S2	1.133	MS	0.860	MS	0.294	FS	0.738	P
S1	1.121	MS	0.809	MS	0.236	FS	0.775	P

Table No. 4.23. Proportion of Textural Class Beach-Dune Section Samples

	GRAVEL %					SAND %					SILT %				
	VCG	CG	MG	FG	VFG	VCS	CS	MS	FS	VFS	VCS	CS	MS	FS	VFS
S15	0	0	0	0	0	0						0	0	0	0
S14	0	0	0	0	0	0	1.2	24.6	50.3	23.5	0.4	0	0	0	0
S13	0	0	0	0	0	0	43.7	32.6	18.6	4.8	0.3	0	0	0	0
S12	0	0	0	0	0	0	68.3	10	15	6.3	0.4	0	0	0	0
S11	0	0	0	0	0	0	34.7	32.9	27.9	4.5	0	0	0	0	0
S10	0	0	0	0	0	0	54.4	17.8	21.1	6.7	0	0	0	0	0
S9	0	0	0	0	0	0	78.6	13.2	6.4	1.8	0	0	0	0	0
S8	0	0	0	0	0	0	50.6	35.3	10.5	2.4	1.2	0	0	0	0
S7	0	0	0	0	0	0	48.6	32.9	16.1	1.9	0.5	0	0	0	0
S6	0	0	0	0	0	0	43.5	38.3	16.4	1.8	0	0	0	0	0
S5	0	0	0	0	0	0	87.4	6.8	4.6	0.9	0.4	0	0	0	0
S4	0	0	0	0	0	0	49	21.7	22.6	6.7	0.1	0	0	0	0
S3	0	0	0	0	0	0	22.6	15.3	32.7	29.2	0.2	0	0	0	0
S2	0	0	0	0	0	0	51.1	29.7	16.5	2.6	0	0	0	0	0
S1	0	0	0	0	0	0	49.5	33.8	14.8	1.8	0	0	0	0	0

4.8.1. Mean Size Distribution

The mean size of the sediments range from 0.435 ø to 2.601 ø (coarse sand to fine graded sediment) (Table No. 4.22) and (Figure No. 4.35). Most of the layers show the dominance of medium grained sediments. Two layers at location 5 and 9 shows the coarse grained sediment while layer 3, 14 and 15 are fine grained sediments. This section shows 14% sediment samples are coarse grained, 71% medium grained and 14% fine grained sediments.

Data represent in (Table No. 4.23) illustrates the presence of sand, silt and clay contents of beach dune section. All the layers show sandy nature of sediments contains 98% to 99% sand accumulation. The proportion of coarse and medium grained sand is dominant in overall sediment samples. Except sample no 3 and 14 (29.2% and 23.5% respectively). The proportion of very fine sand is negligible and coarse silt is not more than 1.2% (Sample no.8). In sample no. 3 and 14 the maximum proportion of fine sand 32.7 and 50.3 is observed respectively.

Beach-dune cut sediments are mainly 7% unimodal, 71% bimodal and 21% trimodal character of sediments. Most of the sediments from layer 1 to 9 with coarse to medium grained sand shows bimodal and fine grained sand shows trimodal nature of sediments. sediment samples from layer 10 to 15 with medium sand shows mixture of nature of sediment from unimodal to trimodal, fine sand shows bimodal nature of sediment.

4.8.2. Sorting Index

Standard deviation values of the sediments vary from phi size 0.467 to 1.245 (well sorted to poorly sort) (Table No. 4.22) and (Figure No. 4.35). The relationship between mean sediment size and sorting index show that medium grained sediments are moderate to poorly sorted, shows dominance of moderately sorted sediments. Coarse grained sediments are well to moderately well sort and fine grained sediments are moderate to poorly sorted.

This section of sediments samples shows 7% well sorted, 7% moderately well sorted, 57% moderately sorted and 29% poorly sorted.

4.8.3. Skewness

On the beach dune section skewness values range from -0.241 to 0.578 (coarse skewed to very fine skewed) (Table No. 4.22) and (Figure No. 4.35). The relationship between sorting index and skewness show moderate sorted sediments are symmetrical to fine skewed. Poorly and well sorted sediments are very fine skewed. Two fine grained sediment samples (S3 and S4) with poorly and moderately skewed are coarse skewed and very fine skewed respectively.

In this section 7% sediment samples are coarse skewed, 14%symmetrical, 36% fine skewed and 43% very fine skewed.

4.8.4. Kurtosis

The nature of fourth movement kurtosis varies from 0.708 to 1.985 (platykrutic to very leptokrutic) natures of sediments (Table No. 4.22) and (Figure No. 4.35). Most of the sediment samples (79%) are platykrutic, 7% mesokrutic and 14% very leptokrutic nature of distribution.

Over all textural analysis of the sediments from the different strata on beach dune section show that sedimentary characters are medium grained, moderately sorted sediments that are fine to very fine skewed and platykrutic in nature.

Table No. 4.24. LDF Analysis of sediment samples (Beach Dune Section)

Sub environ ment	Y1	Y2	Y3	Y4	Aeolian & beach process	Beach & shallow environment	Shallow marine & fluvial processes	Fluvial & turbidity processes
Sample no.					Y1	Y2	Y3	Y4
S15	-2.8	82.9	-3.1	6.5	Aeolian	Shallow Agitated	Shallow Marine	Fluvial
S14	-5.1	100.4	-5.8	9.8	Aeolian	Shallow Agitated	Shallow Marine	Fluvial
S13	0.9	97.8	-8.4	7.1	Beach	Shallow Agitated	Fluvial	Fluvial
S12	1.7	115.9	-12.5	10.3	Beach	Shallow Agitated	Fluvial	Turbidity
S11	0.3	92.4	-6.5	4.8	Beach	Shallow Agitated	Shallow Marine	Fluvial
S10	0.8	111.2	-11.7	8.9	Beach	Shallow Agitated	Fluvial	Fluvial
S9	3.7	86.6	-6.6	14.1	Beach	Shallow Agitated	Shallow Marine	Turbidity
S8	0.4	79.2	-6.6	6.8	Beach	Shallow Agitated	Shallow Marine	Fluvial
S7	0.3	81.3	-6.8	6.1	Beach	Shallow Agitated	Shallow Marine	Fluvial
S6	0.3	78.5	-5.9	5.7	Beach	Shallow Agitated	Shallow Marine	Fluvial
S5	4.7	63.6	-3.2	13.0	Beach	Shallow Agitated	Shallow Marine	Turbidity
S4	0.9	108.0	-10.3	7.3	Beach	Shallow Agitated	Fluvial	Fluvial
S3	1.0	145.1	-11.7	4.6	Beach	Shallow Agitated	Fluvial	Fluvial
S2	0.3	85.3	-7.5	7	Beach	Shallow Agitated	Fluvial	Fluvial
S1	0.3	78.8	-6.4	6.7	Beach	Shallow Agitated	Shallow Marine	Fluvial

The values obtained (Table No. 4.24) from the differentiation of Aeolian and beach processes (Y1) show that the upper most two layers including dune sample represent Aeolian environment. From layer no. 1 to 13, sediment samples represent littoral (intertidal) environment. The influence of Aeolian environment in sediment sample no 14 and 15 is clearly reflected in moderate sorting with fine grained sediments. Beach environment of sediments is also reflected in dominance of moderate sorting but with medium grained sediments. On the beach dune section, 87% samples came about as a result of beach environment as the effect of littoral processes; where as 13% samples came about as a result of Aeolian processes.

The results obtained from beach and shallow marine environments (Y2), linear Discriminant function values indicate that almost all sediment samples (100%) are of shallow marine origin.

For shallow marine and fluvial processes (Y3) linear Discriminant function analysis shows that 40% of the sediment samples are consist a fluvial environment or fluvial processes, whereas 60% sediments represent shallow marine processes. The analysis shows the deposition of sediments in fluvial and shallow marine processes in alternate layers or zones. The northern tidal channel is the main source of sediments, considering the fluvial processes for supply of sediments. The sediment discharged by the northern tidal channel has been deposited in shallow environment.

For fluvial and turbidity processes (Y4) linear Discriminant function analysis shows that 80% of samples were deposited by fluvial processes or action and 20% of sediment samples by turbidity action (Figure No. 4.37).

Figure No. 4.35. LDF Values plot for sample Beach Dune Section (Y1 and Y2) and (Y2 and Y3)

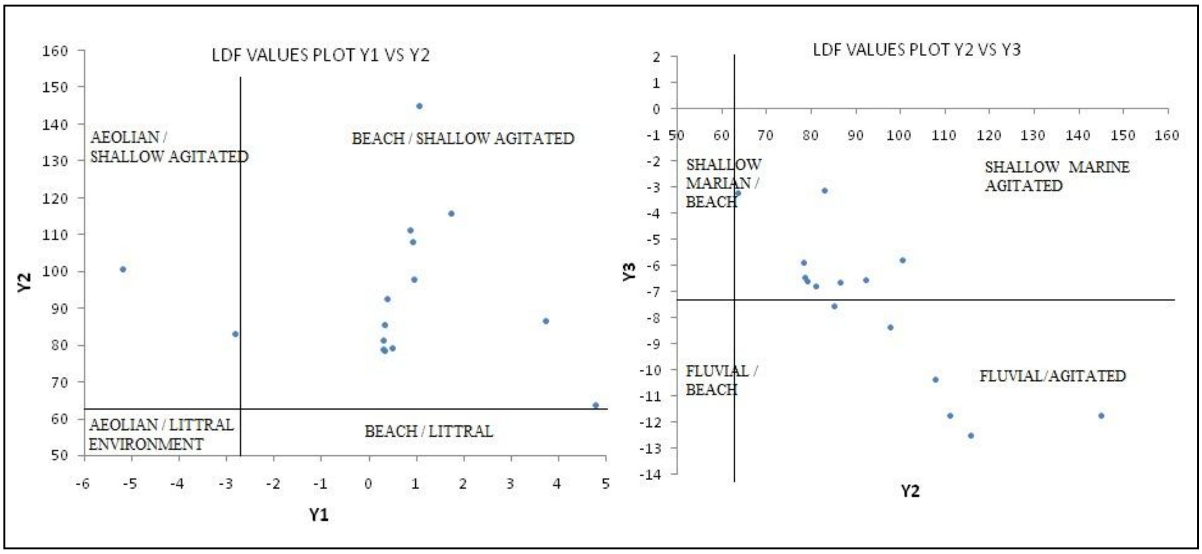


Figure No. 4.36. Variogram for Textural Parameter (Beach-Dune Section)

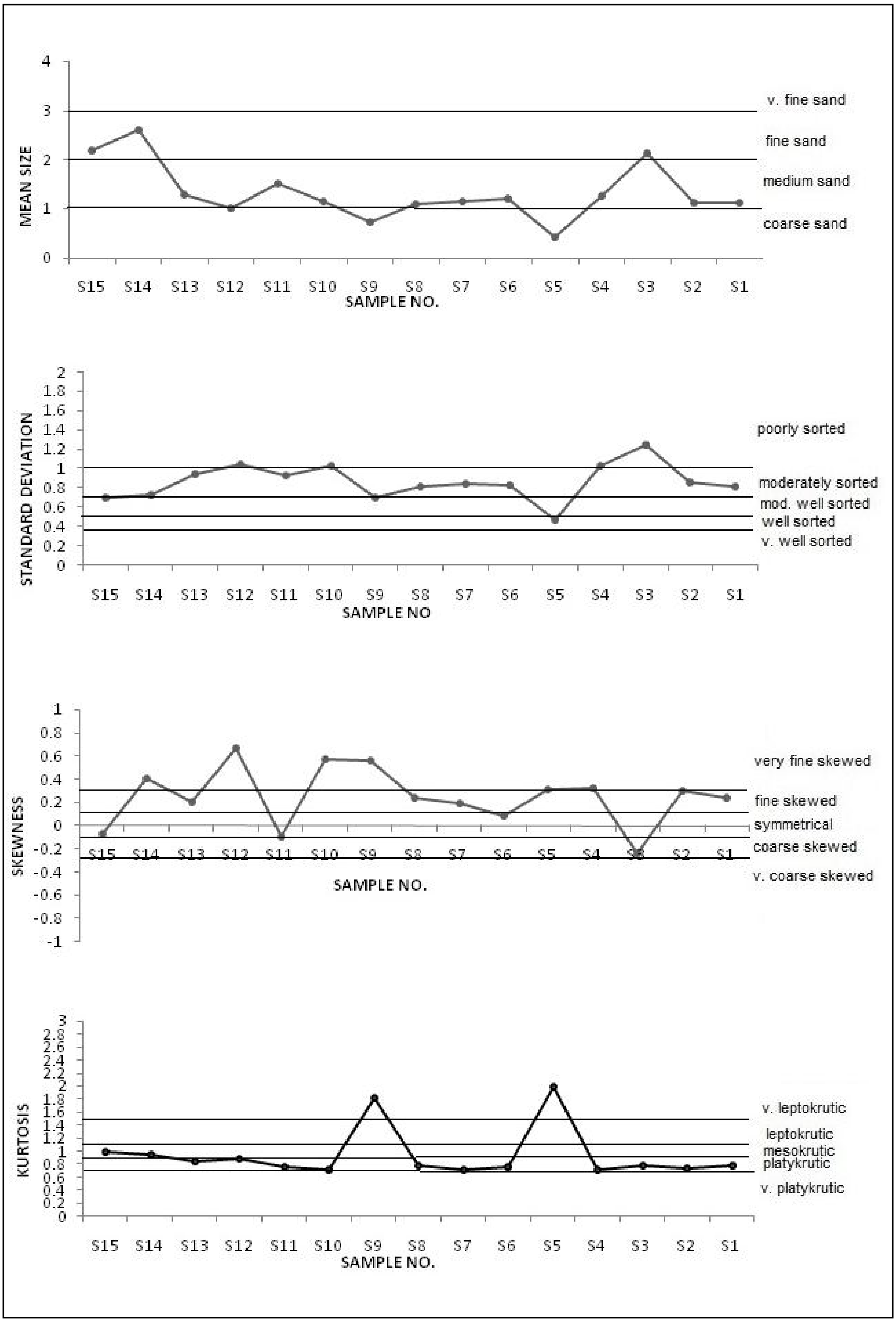


Figure No. 4.37. Stratigraphy of Beach-Dune Section

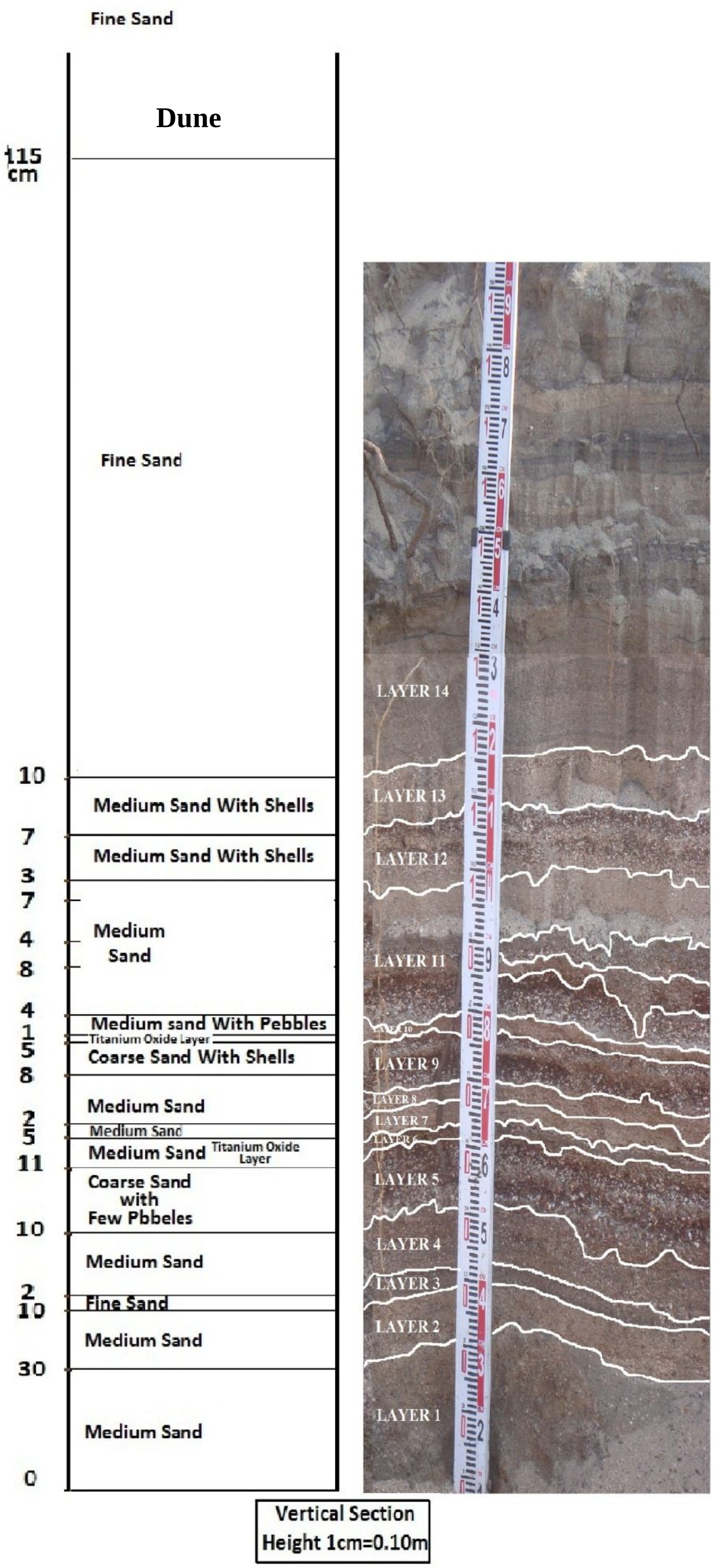
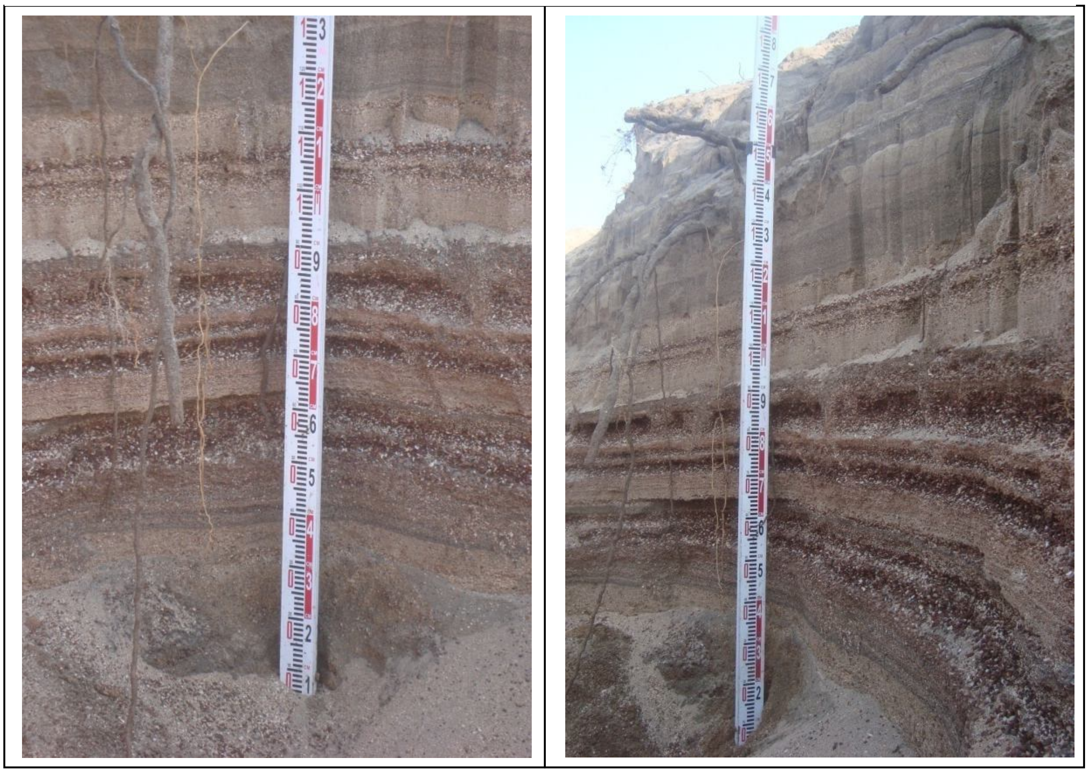


Photo 35 Sediment Layers of Beach Dune Section



4.8.5. Stratigraphy of Beach-Dune Section (Figure No. 4.36)

The S1 layer were found at the depth of 4.20 mts. Thickness of this layer varied at landward side to seaward side, it is 20 cm and 30 cm respectively. This layer contains moderately sorted medium grain sand (phi 1.121). The color of this section was gray. The proportion of clastic and non clastic sediments in this layer was 37.32 % and 62.67% respectively. (Table No. 4.25)

The S2 layer contained moderately sorted medium grain sand (phi 1.133).at landward side thickness of this layer is10 cm and at seaward side it is 6 cm. the color of this section is reddish. Clastic sediments in this layer are 40.63% and nonclastic sediments are 59.37%.

The S3 layer contained poor sort fine grained sand (phi 2.124). At landward side the thickness of this layer is 2 cm and at seaward side 14 cm. This is the zone where sand is of grey color. Sediments in this zone were open work granules and the environmental interpretation of this section was that swash zone, water edge. Sediment composition of this layer shows 65.26% clastic and 34.74% non clastic material.

The S4 layer contains poorly sorted medium grained sand (phi 1.275). This layer contains admixture of few pebbles with medium sand. The thickness of this section is 10 cm at landward side and 4 cm towards sea ward side. Environmental interpretation of this layer is swash deposits. This medium grained sand has 57.93% of clastic and 42.81% of non clastic sediments.

The S5 layer contains well sorted coarse grained sand (phi 0.435). This layer contains admixture of pebbles with medium and coarse sand. Thickness of this layer is 11 cm at landward side and only 01 cm at seaward side. Environmental interpretation of this layer is storm deposits layer, results from changing water level or high water during storm comprises the mixture of 65.74% of clastic and 34.26% of non clastic sediments.

The S6 layer contains moderately sorted medium sand (phi 1.212). Dominant titanium oxide layer were observed in this layer. The thickness of this layer is 5 cm towards landward side and 6 cm towards seaward side. This layer shows equal proportion of clastic and non clastic sediments.

The S7 layer contains moderately sorted medium sand (phi 1.152). The thickness of this layer is 2cm towards landward side and 8 cm towards seaward side. This layer is dominated by clastic sediments (62.37%) than that of non clastic sediments (37.63%)

The S8 layer contains moderately sorted medium sand (phi 1.084). The thickness of this layer is 2 cm towards landward side and 8 cm towards seaward side. The dominance of non clastic sediments (65.42%) than clastic sediment proportion (34.38%).

All the above layers from 1 to 8, the inclination of all these layers were from seaward to landward side.

The S9 layer contains moderately well sorted coarse sand (phi 0.716) this layer contains admixture of shell fragment with coarse sand. The thickness of this layer at landward side is 6 cm and 5 cm at seaward side. Sediment composition of this layer shows 59.71% clastic and 40.29% non clastic material.

The S10 layer contains poorly sorted medium sand (phi 1.140). This layer contains admixture of pebbles with sand like layer S4. The thickness of this layer is 4 cm at both sides. The maximum proportion of classic sediments i.e. 70.13% is seen in this layer.

In between the layer no 9 and 10 a dominant titanium oxide layer was found with a width of 2 cm.

The S11 layer contains moderately sorted medium sand (phi 1.511). The thickness of this layer is 22 cm at land ward side and 7 cm at seaward side. In this zone four distinct zones of coarse sand, fine sand, medium sand and fine sand found in the upward direction at various depths. This layer shows exact opposite proportion of clastic 26.4% and non clastic sediment 73.6% than underlying layer S10.

The S12 layer contains poorly sorted medium sand (phi 1.013). This layer contain admixture of shell fragments. Thickness of this layer is 7 cm at land ward side and 5 cm at seaward side. This layer shows almost equal proportion of clastic and non clastic sediments.

The S13 layer contains moderately sorted medium sand (phi 1.277). This layer also contains shell fragments. The thickness of this layer is 10 cm at landward side and 7 cm at seaward side. This layer has maximum proportion of non clastic sediments (75.98%).

The S14 layer contains moderately sorted fine sand (phi 2.601). The thickness of this layer is 115 cm at landward side and 105 cm at seaward side. This layer is the part of present day dune system. Taking into consideration about the width and zonation pattern, it is observed that for a long time there has been no drastic change in environment of beach and dune system. As this layer is a part of the dune system it was under the influence of Aeolian process rather than beach process.

The S15 layer is part of present day dune system. Above these two layers show equal proportion of clastic and non clastic sediments.

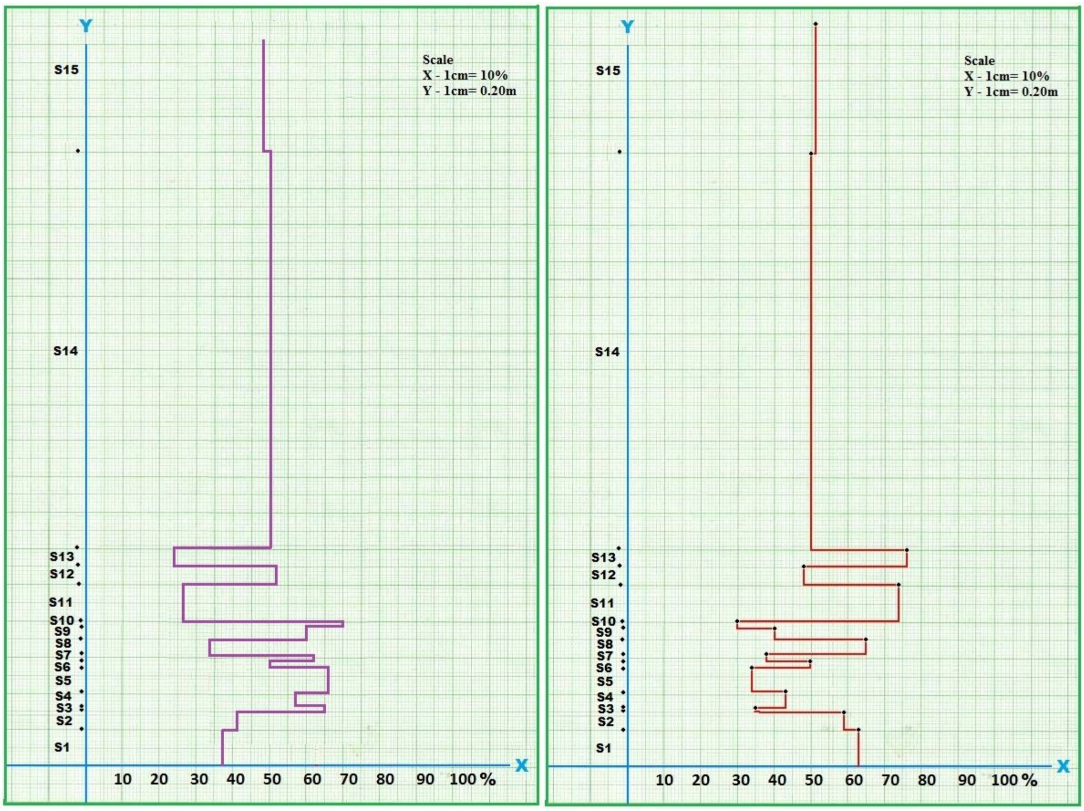
Graph (Fig. No. 4.38) showing proportion of clastic and non clastic sediments indicates the repetitive episodes of depositional history of the beach. Layer 1, 2 and 8 shows medium grained with high proportion of non clastic sediments, whereas layer 3, 5 and 7 sediments with coarse grain are well to poorly sorted with high proportion of clastic sediments.

Layer 4 and layer 9 are identical as both are having coarse grains with high percentage of clastic sediments. Layer 11 and 13 have medium sand with highest percentage of non clastic sediments may has similar depositional environment in the recent past. Layer 6, 12, 14 and15 are fine to medium grain sediments with equal proportion of clastic and non clastic sediments show similar depositional environment.

Table No. 4.25. Depositional Mechanism from the Size analysis of the Clastic and Non Clastic Sediments

Sample No	Weight Of Sample In Gram	Clastic %	Non Clastic %
S15	30	48.76	51.24
S14	30	49.69	50.31
S13	30	24.02	75.98
S12	30	51.76	48.24
S11	30	26.4	73.6
S10	30	70.13	29.87
S9	30	59.71	40.29
S8	30	34.38	65.42
S7	30	62.37	37.63
S6	30	50.02	49.98
S5	30	65.74	34.26
S4	30	57.19	42.81
S3	30	65.26	34.74
S2	30	40.63	59.37
S1	30	37.32	62.67

Figure No. 4.38. Percentage Graph Showing the Clastic and Non Clastic Sediment Proportion in Beach-Dune Section Sample



4.9. Dune Sedimentology

The prevailing wind direction does not necessarily have to be onshore for the development of coastal dunes. Winds inducing sediment transport must exist for a significant amount of time, so that an extensive dune field is created. On Konkan coast dune development is moderate to low due to continuous dampness. The development at these sites can be attributed to factors like low density of back beach vegetation, suitable sediment size, and high wind and wave energy levels.

4.9.1. Distribution of Mean Size

The mean size in phi of the dune sediment ranges from 1.718 ø to 3.05 ø. in the northern sector, middle sector and southern sector, the phi values of mean size of sediment on the dune ranges from 2.12 ø to 3.05 ø (fine grained to very fine grained), 1.71 ø to 3.02 ø (medium grained to very fine grained) and 1.99 ø to 2.96 ø (medium grained to fine grained) respectively (Table No. 4.40), (Figure No. 4.39). On the dune field 98 % to 99% sediments are mainly sandy of the total sediment volume. Percentage of very coarse silt is very negligible is 0.1% to 2.8%.

Almost all the dune sediments have shown the dominance of fine grained sediment with an admixture of medium grained and very fine grained sand. 86% sediment samples are fine grained, 9% very fine grained and only two samples with 6% are medium grained sediments.

4.9.2. Sorting Index

Standard deviation values of the dune sediments vary from phi size 0.43 to 1.29 (well to poor sorted). Standard deviation values of sediment in the northern sector, middle sector and southern sector vary from 0.45 to 0.77 (well to moderate sorted), 0.5 to 1.022 (well to poor sorted) and 0.43 to 1.291 (well to poor sorted) respectively (Figure No. 4.39).

The relationship between mean sediment size and sorting index (Figure No. 4.26 A) shows fine grained sediments are well to moderate sorted. One abnormal sediment sample with fine grained in the middle sector of dune shows poor sorted. Very fine grained sediments are well sorted and two sediment samples with middle grained sand, location on middle and southern sector are moderate and poor sorted respectively.

On the dune field 26% sediment samples are well sorted, 51% moderately well sorted, 17% moderate and only 6% poor sorted.

4.9.3. Skewness

On the dune zone skewness values vary from – 0.565 to 0.01 (very coarse to symmetrical skewed). Northern sector, middle sector and southern sector dune sediments are coarse to symmetrical, very coarse to symmetrical and very coarse to symmetrical skewed respectively. Dominance of coarse skewed sediments with admixture of symmetrical and very coarse skewed sediments was observed (Figure No. 4.39).

The relationship between sorting index and skewness shows that (Figure No. 4.26 B) moderate to moderately well sorted sediments are symmetrical to very coarse skewed. Poor sorted sediments are very coarse to coarse skewed in nature. Most of the northern sector sediments are symmetrical and middle and southern sediments are very coarse to coarse skewed in nature.

On the dune field 26% samples are symmetrically skewed, 11% very coarse skewed and 63% coarse skewed category of sediments.

4.9.4. Kurtosis

On the dune field the values of fourth movement kurtosis vary from 0.829 to 1.557 (mesokrutic to very leptokrutic) natures of sediments.

The relation between skewness and kurtosis shows, relation in variation. Most of the sediment samples are mesokrutic and leptokrutic in nature. Symmetrically skewed sediments are mesokrutic to very leptokrutic in nature. Coarse skewed sediments are mesokrutic to leptokrutic and very coarse skewed sediments are leptokrutic to very leptokrutic in nature (Figure No. 4.26 and 4.39).

6% sediment samples are platykrutic, 37% mesokrutic, 46% leptokrutic and 11% very leptokrutic nature of sediments.

Textural analysis of dune shows that, sedimentary characteristics are fine grained sand, well to moderately sorted (dominance of moderately well sorted sediments), that are coarse to symmetrical skewed and mesokrutic to leptokrutic nature of sediments.

Figure No. 4.39. Variogram for Textural Parameter (Dune Section)

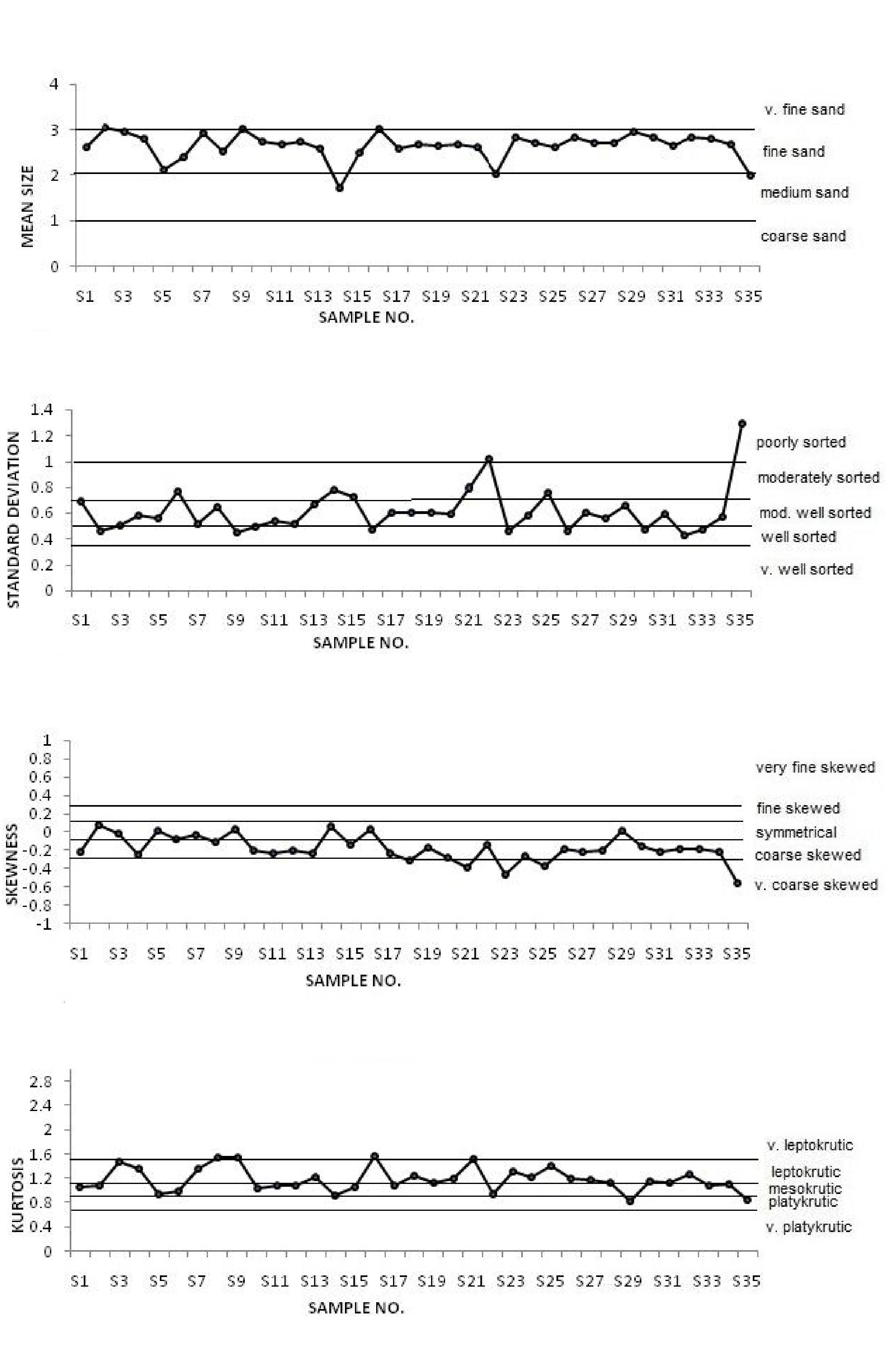


Figure No. 4.40. Scatter Plots of the Dune Sediment Section

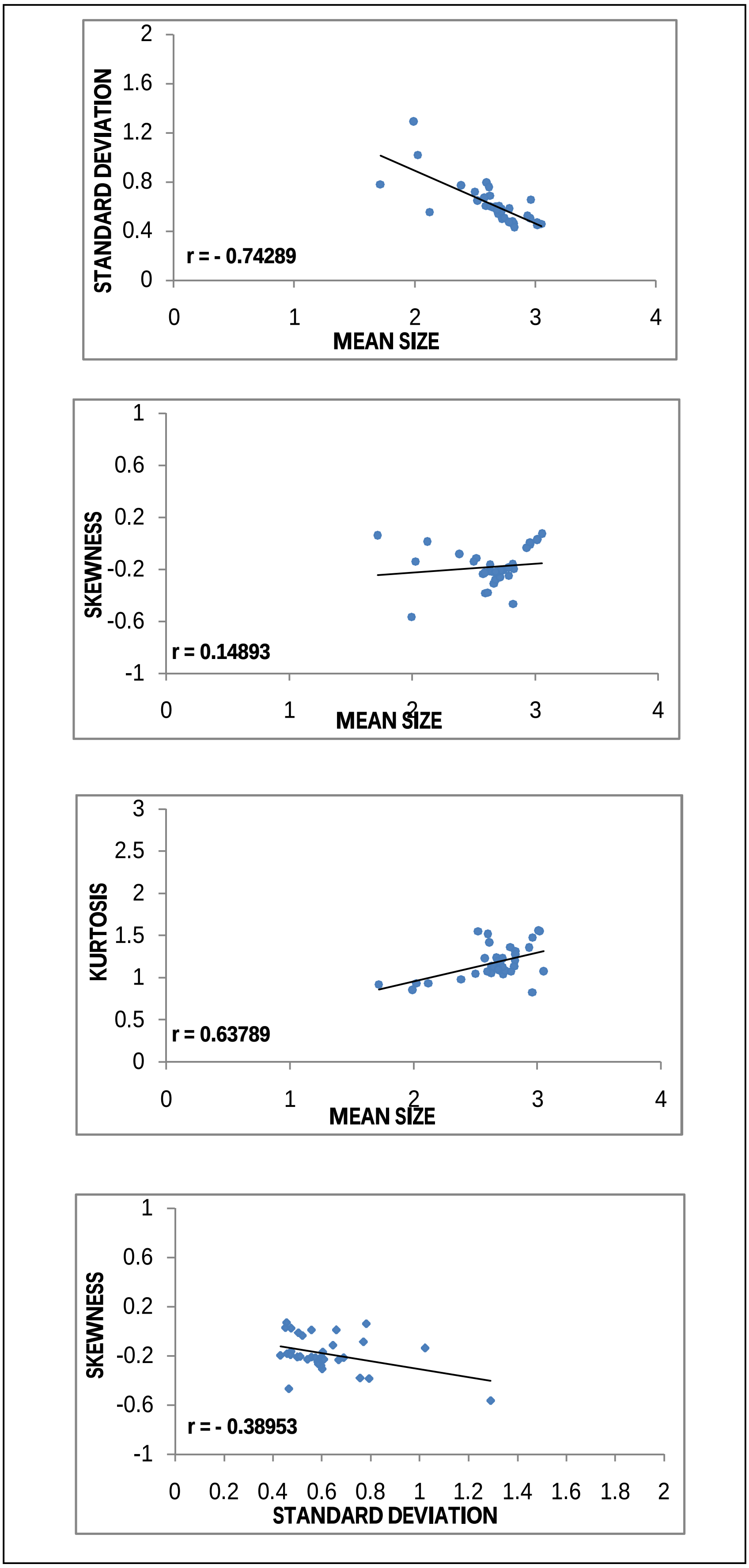


Table No. 4.26. Textural Characteristics of Dune samples

	MEAN Ø		SORTING INDEX Ø		SKEWNESS		KURTOSIS	
1	2.628	FS	0.69	MWS	-0.215	CS	1.059	M
2	3.055	VFS	0.46	WS	0.072	S	1.074	M
3	2.96	FS	0.505	MWS	-0.011	S	1.478	L
4	2.785	FS	0.583	MWS	-0.246	CS	1.367	L
5	2.122	FS	0.558	MS	0.012	S	0.937	M
6	2.388	FS	0.771	MS	-0.084	S	0.982	M
7	2.934	FS	0.522	MWS	-0.035	S	1.355	L
8	2.524	FS	0.646	MWS	-0.113	CS	1.553	VL
9	3.022	VFS	0.452	WS	0.029	S	1.551	VL
10	2.724	FS	0.5	WS	-0.21	CS	1.045	L
11	2.69	FS	0.542	MWS	-0.229	CS	1.091	L
12	2.743	FS	0.512	MWS	-0.206	CS	1.081	M
13	2.58	FS	0.669	MWS	-0.233	CS	1.228	L
14	1.718	MS	0.783	MS	0.06	S	0.922	M
15	2.499	FS	0.724	MS	-0.139	CS	1.052	M
16	3.014	VFS	0.474	WS	0.024	S	1.557	VL
17	2.594	FS	0.609	MWS	-0.228	CS	1.076	M
18	2.668	FS	0.603	MWS	-0.308	VCS	1.234	L
19	2.633	FS	0.604	MWS	-0.167	CS	1.133	L
20	2.682	FS	0.597	MWS	-0.278	CS	1.195	L
21	2.599	FS	0.795	MS	-0.382	VCS	1.516	VL
22	2.025	FS	1.022	PS	-0.138	CS	0.938	M
23	2.825	FS	0.465	WS	-0.465	CS	1.318	L
24	2.719	FS	0.585	MWS	-0.263	CS	1.229	L
25	2.616	FS	0.758	MS	-0.378	VCS	1.415	L
26	2.82	FS	0.459	WS	-0.184	CS	1.203	L
27	2.7	FS	0.602	MWS	-0.219	CS	1.167	L
28	2.721	FS	0.559	MWS	-0.21	CS	1.132	P
29	2.962	FS	0.659	MWS	0.01	S	0.829	M
30	2.816	FS	0.476	WS	-0.162	CS	1.139	M
31	2.653	FS	0.593	MWS	-0.217	CS	1.132	L
32	2.827	FS	0.43	WS	-0.195	CS	1.274	L
33	2.786	FS	0.472	WS	-0.189	CS	1.077	M
34	2.682	FS	0.575	MWS	-0.216	CS	1.104	M
35	1.993	MS	1.291	PS	-0.565	VCS	0.853	P

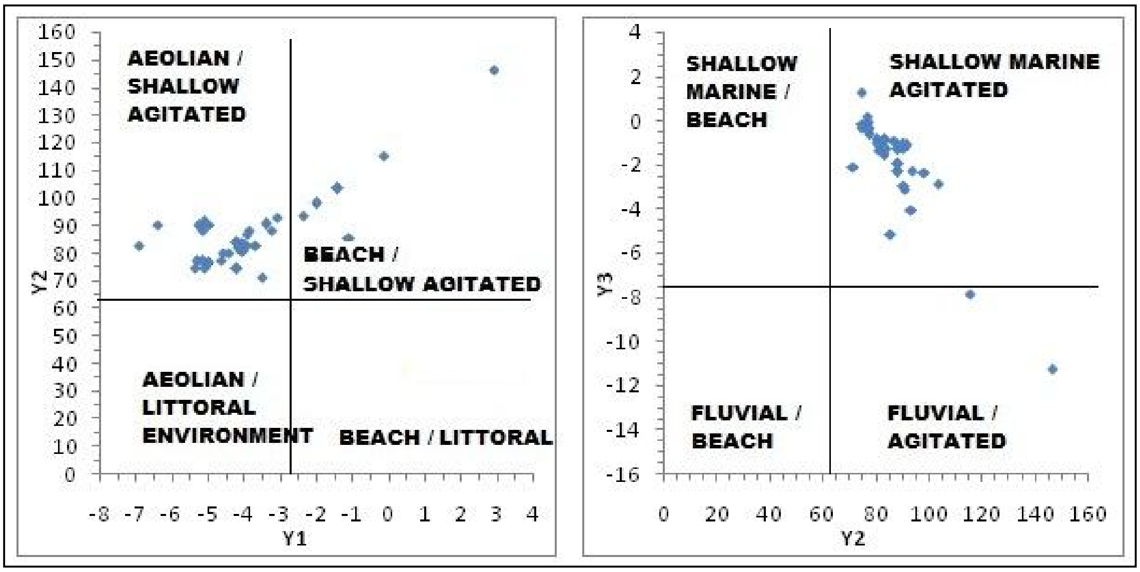
4.9.5. L D F Analysis of Dune Sediment Samples

Table No. 4.27. LDF Analysis of sediment samples (Dune Section)

Sampl e no DUNE	Y1	Aeolian & beach processes	Y2	Beach & shallow environment	Y3	Shallow marine & fluvial processes	Y4	Fluvial & turbidity processes
1	-3.87	Aeolian	88.12	Shallow Agitated	-2.31	Shallow Marine	6.24	Fluvial
2	-6.92	Aeolian	82.90	Shallow Agitated	-1.28	Shallow Marine	8.45	Fluvial
3	-4.99	Aeolian	90.24	Shallow Agitated	-1.26	Shallow Marine	9.98	Fluvial
4	-3.91	Aeolian	86.76	Shallow Agitated	-0.91	Shallow Marine	7.72	Fluvial
5	-3.52	Aeolian	71.23	Shallow Agitated	-2.13	Shallow Marine	6.69	Fluvial
6	-3.09	Aeolian	93.09	Shallow Agitated	-4.06	Shallow Marine	6.59	Fluvial
7	-5.17	Aeolian	88.27	Shallow Agitated	-1.31	Shallow Marine	9.16	Fluvial
8	-2.39	Beach	93.62	Shallow Agitated	-2.30	Shallow Marine	9.44	Fluvial
9	-5.25	Aeolian	89.95	Shallow Agitated	-0.99	Shallow Marine	10.66	Turbidity
10	-5.10	Aeolian	74.60	Shallow Agitated	-0.33	Shallow Marine	6.18	Fluvial
11	-4.64	Aeolian	77.45	Shallow Agitated	-0.63	Shallow Marine	6.29	Fluvial
12	-5.02	Aeolian	76.43	Shallow Agitated	-0.45	Shallow Marine	6.41	Fluvial
13	-3.24	Aeolian	88.29	Shallow Agitated	-1.98	Shallow Marine	6.97	Fluvial
14	-1.11	Beach	85.32	Shallow Agitated	-5.13	Shallow Marine	6.77	Fluvial
15	-3.41	Aeolian	90.51	Shallow Agitated	-3.14	Shallow Marine	6.64	Fluvial
16	-5.12	Aeolian	91.18	Shallow Agitated	-1.15	Shallow Marine	10.66	Turbidity
17	-4.06	Aeolian	80.75	Shallow Agitated	-1.34	Shallow Marine	6.18	Fluvial
18	-3.69	Aeolian	82.91	Shallow Agitated	-0.85	Shallow Marine	6.52	Fluvial
19	-4.17	Aeolian	83.12	Shallow Agitated	-1.57	Shallow Marine	6.91	Fluvial
20	-3.95	Aeolian	82.48	Shallow Agitated	-0.93	Shallow Marine	6.53	Fluvial
21	-1.42	Beach	103.3	Shallow Agitated	-2.85	Shallow Marine	7.58	Fluvial
22	-0.15	Beach	115.2	Shallow Agitated	-7.85	Fluvial	5.91	Fluvial
23	-4.21	Aeolian	74.39	Shallow Agitated	1.25	Shallow Marine	5.97	Fluvial
24	-4.06	Aeolian	83.02	Shallow Agitated	-0.87	Shallow Marine	6.83	Fluvial
25	-2.01	Beach	98.04	Shallow Agitated	-2.36	Shallow Marine	7.06	Fluvial
26	-5.15	Aeolian	76.91	Shallow Agitated	-0.08	Shallow Marine	7.24	Fluvial
27	-4.20	Aeolian	83.70	Shallow Agitated	-1.27	Shallow Marine	6.79	Fluvial
28	-4.59	Aeolian	80.27	Shallow Agitated	-0.87	Shallow Marine	6.66	Fluvial
29	-6.40	Aeolian	90.42	Shallow Agitated	-2.96	Shallow Marine	6.76	Fluvial
30	-5.32	Aeolian	77.11	Shallow Agitated	-0.33	Shallow Marine	7.06	Fluvial
31	-4.19	Aeolian	81.65	Shallow Agitated	-1.20	Shallow Marine	6.58	Fluvial
32	-5.03	Aeolian	76.44	Shallow Agitated	0.20	Shallow Marine	7.54	Fluvial
33	-5.37	Aeolian	74.75	Shallow Agitated	-0.18	Shallow Marine	6.52	Fluvial
34	-4.46	Aeolian	80.22	Shallow Agitated	-1.02	Shallow Marine	6.45	Fluvial
35	2.88	Beach	146.26	Shallow Agitated	-11.22	Shallow Marine	2.82	Fluvial

On dune the values obtained from the differentiation of Aeolian and beach processes (Y1) show that 17% of samples came about as a results of beach environment (littoral process), where as 83% samples came about as a result of Aeolian processes. The results obtained from beach and shallow marine environment (Y2), LDF values indicate that 100% sediment samples fall within shallow marine origin. For shallow marine and fluvial processes (Y3), analysis shows that 97% of the sediment samples fall with in shallow marine processes, whereas 3% of sediment samples represent fluvial processes. The (Y4) values for fluvial and turbidity processes results show 94% sediment samples deposited by action of fluvial processes rest by turbidity disturb.

Figure No. 4.41. LDF Values plot for sample Dune Section (Y1 and Y2) and (Y2 and Y3)



CHAPTER V

OBSERVATIONS AND CONCLUSION

The morphology of beach is basically a result of many factors including its sedimentology. The overall effect of seasonally changing wave environment at Guhagar beach is seen in changing nature of sandy beach at Guhagar. Beach morphology and beach morphodynamics is well understood by studying morphological characteristics of beach, various features associated with beach, seasonal variation in beach profile etc. For clear understanding of coastal processes in near shore areas the study of sediments is an important aspect of morphodynamics of a beach.

The beach at Guhagar is a sandy pocket beach located on a west coast of Maharashtra in Ratnagiri district. The total length of beach is 6.44 km. Headland with cliff and narrow rocky platforms are developed due to wave action. The beach is backed by hills which attain the height of 120 – 170 m. the alignment of beach is Northwest to Southeast.

The overall effect of seasonally changing wave climate is reflected in the changing nature of the Guhagar beach. The spatial and temporal variations in wave climatic conditions, width of breaker, height of breaker, wave energy play an important role for development on beach. The surf zone with all its force and energy decide the nature of sandy beach at Guhagar. In monsoon the waves are high energy, breakers are higher, swash and backwash is dominant. In pre and post-monsoon all these factors show reduction in intensity.

In monsoon the northern and southern section the beach were comparatively narrow as compared to the middle section of beach. The beach then, is under the influence of stormy waves. Movement of sand from beach to nearshore areas forms the features like sand bars, offshore bars. The northern section of the beach is under direct influence of westerly winds and shows considerable filling in the month of August at mouth of northern tidal inlet. The material transported by northern tidal inlet in monsoon is restricted in northern part of the beach. The middle part of the beach is slightly projected seaward shows cutting tendency in August.

Lowering of beach in the month of September indicates the tendency of erosion / cutting. As compare to the northern and middle section the southern section of beach with gentle slope show the tendency of accretion / filling as this part of the beach is sheltered by southern headland protecting the beach from strong south westerly waves.

The beach profiles in monsoon season are comparatively concave in nature and no distinct upper and lower beach section can be observed. Beach profiles show horizontal migration of berm to the landward side and vary from place to place.

The post-monsoon season show a significant increase in width of beach than monsoon season.

Definite trend was observed about width of the beach, that in post-monsoon season, the width of the beach decreases from October to January is responsible for beach and dune building processes. As the concavity of the beach is removed the profiles show a gentle slope compared to monsoon season. In December filling tendency is more common along each part of beach. It shows settling of post-monsoon conditions in study area. Post monsoon season shows more dynamics in beach profile, monthly variations are observed on upper as well as lower beach section.

Post-monsoon season shows the definite change in wave climate condition. Decrease in characteristics of wave climate shows the decrease in wave energy affecting the beach morphology. The features like berm, beach face, upper beach and lower beach are clearly developed and identified.

In pre-monsoon season beach building process reached its peak position can be indicated by the development of beach profiles. In this season the width of the beach reduce from February to May. In the month of May the width of the beach has been shortest of the year.

The beach building process after the monsoon season has been completed in the month February to March. So it can be estimated that beach building processes reached its peak within the time span of five months to recover from the impact of monsoon season and again maintain itself in dynamic equilibrium.

The upper beach section shows beach and dune building processes. Lower beach shows tendency of flattening of the beach. Alternate sand mounds and depressions developed on upper beach is almost parallel to beach further developed in to small anti-dunes like structure with a height of 0.34 m to 0.4 m, width 3.30 m to 11.7 m and length 7.4 m to 9.10 m. The orientation of these anti-dunes is NW-SE this is result of strong NW winds.

On the northern beach near mouth of northern inlet, a distinct zone of stormy deposits mostly lateritic pebbles and coarser sand fluvial in origin were observed in the month of March. These deposits are exposed due to strong winds. The sandy material transported by winds and waves, are deposited in the middle part of the beach in the form of parabolic dunes. On the beach, the finer sand grains are moved by wind action to form higher and wider sand dunes. The finer material transported to dune areas as an aeolian deposits.

Wave action tends to shape the beach slope as well, with high-energy waves tending to increase the steepness of the slope, and lower-energy waves resulting in flatter beach profiles. On high-energy beaches, beach profiles change seasonally.

Strong monsoon waves, high breakers, maximum height of breakers, strong swash and backwash results in narrow and concave beach. The average slope of beach towards northern section was (3.19º) decreases towards middle section (1.92º) and again increases towards southern section (2.27 º) of beach.

In the month of July and August average slope of the beach is maximum at northern and southern section of beach and it gradually decreases towards the middle part. Strong southwesterly winds and supply of considerable amount of sand from both northern and southern tidal channel may be responsible for increase in northern and southern slopes of the beach. In September strong waves are responsible for accretion of sediments from dune erosion results in flattening of beach near profile no. 2 and 3 at the northern section.

Post-monsoon season shows gradual decrease in average slope from northern section (2.43º), middle section (1.74º) and southern section (1.48º). Northern part of beach shows high average slope than the middle and southern section of the beach.

October, a transitional month show an uniformity in average beach slope. There is decreasing trend of average slope from northern section to southern section of beach. Maximum average slope show southward shift in this month. Average slope show slightly increasing trend in November. With decrease in wave energy in December there was considerable decrease in average slope of the beach, flattening of beach observed. At the end of post monsoon season, in January average beach slope again started increasing.

Alternate increase and decrease in beach slope observed in the post-monsoon season, this may have been a result of fluctuating wave energy. Northern section of beach show maximum average slope than southern section of the beach throughout the season.

The average beach slope in pre-monsoon (2.68º) in the northern section which, decreased towards middle and southern section of the beach (2.65º and 1.7º) respectively.

In pre-monsoon season, beach morphology change very rapidly. Aeolian impacts show dominance in changing morphology of the beach. Increase in average slopes in February and development of anti-dunes like feature in March on the middle section of beach; strongly indicate the influence of wind. Strong NW-SE wind changes to W-E during April and May with high velocity. Increase in wind velocity and wave energy was responsible for scouring in the middle section of the beach. This shows a winnowing effect of the beach in the middle section.

Recently, dune cutting in the northern section of the beach was observed during the monsoon from 0.97 m to 1.2 m. The eroded material deposited on the northern sector of beach and at mouth of the tidal inlet.

Middle and southern section of beach show variation in average slope of dunes. Middle section having well defined foredune ridge covered with casurina plantation, backed by a defunct tidal channel running parallel to the dune ridge. Back dunes are altered and Guhagar settlement is situated on these dunes. A little variation was observed in dune slope. The change in slope observed particularly at the foot of fore-dunes, especially in monsoon. Some part of the middle dune disturbed by tourism and recreational activities.

The month of July, (92%) profiles show polynomial best fit. In the month of August, almost all (100%) profiles showed polynomial best fit. Up to August this relationship strongly explained by this model but during September the percentage polynomial fit goes on decreasing up to 67%.

In October only (42%) profiles show polynomial best fit curves. The month of November and December (92%) profiles shows polynomial best fit as the post-monsoon conditions are set during these months. Upto December this relationship is strongly explained by this model but during January the percentage of polynomial fit goes on decreasing to 67% between beach slope and distance down beach.

The month of February and March (50% and 33% respectively) profiles show polynomial best fit. The month of April (100%) profiles show very strong relationship and best fitted polynomial curves. The month of May which is upcoming monsoon (83%) profiles shows polynomial best fit.

Dune slope and distance relationship tested on polynomial regression model it show 94.94% of curves fitted at 0.6 to 1.0.

If the beach and dune slope were considered as a unit, polynomial regression analysis at 5^{th} order show very different results. Only 28.78% of curves fitted at 0.6 to 1.0.

The result of polynomial analysis shows that a northern, middle and southern section of the beach has a uniform polynomial fit. However northern and the southern section of the beach show strong polynomial fit than the middle section. Considering the temporal variation in month of February, March and profile no. 7 (located near the place of tourist recreational activities and which is highly disturbed by anthropogenic activities) show very weak polynomial fit (R^2 <0.6).

Results obtained from polynomial fit for distance down beach – dune and beach – dune slope relationship curves showed a poor fit. It shows deviation on a large scale. Northern section of the beach – dune showed a fairly best polynomial fit compared to the middle and southern section

The analysis also shows a distinct seasonal polynomial curve fit to the profiles surveyed. The monsoon and post monsoon profiles show a significant fit. (R^2 > 0.6) and the pre monsoon profiles show relatively weak fit to the profiles.

Over all analysis indicate that individual beach slope and distance, dune slope and distance, relationship show a good fit but beach-dune system slope and distance relationship shows a poor fit. This is an indicator of separate functioning of beach and dune segments of the profiles since there controlling factors are different waves, tides, storms are the major factors which control the beach system while winds, storms controls the dune system.

The interface of human activities is also reflected in the weak polynomial fit to the profiles affected by such activities near Profile nos. 6, 7, and 8.

A significant shifting of the mouth of the Northern tidal inlet was observed through the Toposheet initially and subsequent Google images (Year- 2004, 2006, 2011). The uprooted trees near the mouth of the tidal inlet (Right bank) are an indicator of the ongoing shift in the mouth of the inlet. May be due to the result of high volume of water particularly during the monsoon coupled with high tides leads to breaching of the sides of the inlet and the water finds an easier way out on to the beach. Shifting of the mouth in fact is variability / imbalance in these forces. Shifting of the mouth towards the northern headland indicates dissipation of energy conditions and silting of the tidal inlet due to fast changing hinterland.

In future, the extension of the mouth of the tidal inlet may continue northwards as long as the geomorphic process allow it to grown in length and width along the course of inlet. The process may however be disturbed by the obstruction in the extension due to northern limit being reached and the maximum expansion of the width.

Beach sediments are important aspect as these are the materials from which beach micro forms are created. Textural characteristics of beach sediment are the result of complex interaction between sediment sources, wave energy and general offshore gradient upon which the beach is naturally shaped.

To understand the grain size parameter, Mean size, Standard deviation, Skewness, Kurtosis are most widely used. In the present study, the characteristic of grain size distribution of beach and dune sediments has been studied to understand the energy condition of the depositional environment of the study area.

In monsoon the amount of sand is 99.7 % and very negligible amount of silt is 0.2 % was observed and clay totally absent. Fine to very fine sand was dominant at the extreme north sector, middle sector and southern sector of the beach. Coarsening is very dominant at the northern zone of beach in Guhagarbaug region at the vicinity of the mouth of the north tidal inlet.

Scatter plot shows that fine to very fine sediments are well to moderately sort while medium and coarse sediments are poorly sorted in the months of monsoon. The relationship between mean size, sorting index and skewness shows that fine grained sediment with moderate to moderately well sort are very coarse to symmetrical skewed in nature.

Textural analysis in monsoon season shows that, in July sedimentary character are fine grained sand, moderate to moderately well sorted sediments, that are very coarse to coarse skewed and leptokurtic in nature. In September it is fine grained sand, moderate to moderately well sorted sediments, that are coarse to symmetrical skewed and mesokrutic in nature.

The most interesting aspect on the beach at Guhagar in the month of July same textural characteristics has been seen in the northern and southern ends. Almost all the samples represent fine sand, moderate sorted sediment, that are coarse skewed and leptokurtic in nature. This is an indication of uniform environment at both the ends of the beach.

The post-monsoon period shows that the beach sediments mainly sandy in nature contain 95% to 100% sand accumulation. The percentage of very coarse silt has been comparatively increasing in the January from 0.1% to 5.5% in the middle sector of beach zone.

Scatter plots shows that for both months of post-monsoon fine to very fine sediments are moderate to moderately well sort, some samples on lower beach at northern tidal channel are poor sorted.

Textural analysis in the post-monsoon season, shows that the sedimentary character are fine grained, moderately to moderately well sorted sediments that are very coarse to symmetrical skewed and mesokrutic in nature in November and platykrutic in January.

In pre-monsoon beach sediments are mainly sandy with 98% to 99%. Middle and the southern sectors show the higher percentage of very coarse silt than the northern sector. It was observed that the percentage of very coarse silt is comparatively increasing in May than in March.

Scatter plots of sediments show that very fine to fine sediments are well to moderate sorted. Medium grained sediments are poorly sorted. The relationship between sediment size, sorting index and skewness shows variation in relation.

Textural analysis for both the months in pre-monsoon season shows that in the month of March, sediments are fine grained, well to moderate sorted (dominance of moderately well sorted), that are coarse to symmetrical skewed and platykrutic to mesokrutic nature of sediments. In the month of May, sediments are fine grained, moderate to moderately well sorted, that are coarse to symmetrical skewed and mesokrutic in nature.

The variation of grain size in monsoon was the result of change in wave activity occurring along the coast. During monsoon, the waves from southwest and westerly directly approach the northern part of beach which results in deepening and the steep sloping of the narrow beach. Factors like the steep slope on lower beach and high wave energy, increasing wave height during July to September triggers the erosion and sediments having smaller size are winnowed away and leaving the higher grain size sediments behind. The composition of sediments on this part of the beach shows high coarser fraction. In the vicinity of tidal inlet at northern sector near profile no 2 and 3 shows the coarser and medium sand accumulation throughout the year.

In monsoon middle section and southern section of beach shows the comparatively moderate to gentle slope of beach than northern section. As this stretch of beach is sheltered from south westerly wave action by the adjoining southern headland, the grains increase in Phi values than northern sediments. According to Jena (1997) the temporary rise in wave activity during cyclonic weather often increase the southerly drift in the southern sector. During this southerly drift, sediment from the central section are carried by currents to the southern sector and deposited there.

During the annual cycle in pre-monsoon and post-monsoon the fine to very fine grains with admixture of medium sand were observed under low wave energy condition prevailed with wide beach width. In this season sea is calm, wave activity is normal, there is increasing beach volume, upper beach show the dominance of aeolian deposits results decrease in grain size is observed.

In general the spatial trend of the grain size shows increasing Phi size from north to south, i.e. Coarse to medium sand to the northern section and getting finer towards southern section. Sediment samples collected on the Guhagar beach show dominance of fine to very fine grained sand with unimodal and bimodal distribution of sediment indicating strong aeolian impact.

Sediments along the middle and southern section of beach show an improvement in sorting with decrease in grain size. This emphasizes the fact that sorting is independent of grain size and that sorting deteriorates in both coarse and fine sediments on the beach at Guhagar.

At the Guhagar beach the percentage of fine skewed sediments was relatively less, whereas symmetrical to course skewed were relatively more. In the post monsoon season in the month of November, January and March very course skewed samples were observed indicates the dominance of erosion process.

According to Friedman (1967) present day beach sands show a symmetrical or negatively skewed distribution. The skewness characteristic of sediment distribution show that 57% of total sediment samples from Guhagar beach were negatively skewed (very coarse to coarse skewed), 31% symmetrical and 12% positively skewed (fine skewed) in nature, predominantly fine skewed distribution indicates deposition of the fine sediments transported by littoral currents under prevailing low energy condition.

In the months November, January and March sediments show dominance of very platykrutic, platykrutic, mesokrutic nature. Presence of very platykrutic nature of sediments indicates that part of the sediment achieved its sorting elsewhere in a high energy environment. The annual cycle of kurtosis indicating the change in sediment transportation mechanism between the two sampling season.

Results of LDF analyses of all the sediment samples shows that surface sediments are deposited under shallow marine environment. The sedimentary environment is formed by Aeolian / shallow marine agitated deposits with some beach (littoral) contribution in the month of July and November. The influence of aeolian environment in sediments is clearly reflected in moderate to moderately well sorting with fine grained sediments.

The present analysis of surface sediments shows that most of the sediments are deposited under shallow marine environment. This may be the effect of the beach and fluvial processes by a near shore whirlpool agitating turbid condition of water. The northern tidal channel and the tributaries on northern headland are the main source of sediments, considering the fluvial processes for supply of sediments. The sediment discharged has been deposited in shallow environment.

The present day sedimentary deposits on Guhagar beach are purely clastic sediments. Very less or negligible amount of carbonate as well as biotic material is present, indicates the little biogenic activities on the beach. This may be the reason of rising sea level in the study area.

Changing wave climate in monsoon, post-monsoon and pre-monsoon affects variation in beach sediments over the time.

Textural analysis for subsurface sediments shows that sediments are fine grained, moderately well to moderately sorted (dominance of moderately sorted), that are coarse to very coarse skewed and mesokrutic to leptokurtic in nature.

LDF results shows that subsurface sediments are deposited under shallow marine environment. The sedimentary environment is formed by beach / shallow marine agitated deposits with some aeolian contribution. The present analysis indicates that most of the sediments are deposited under shallow marine environment.

The stratigraphic study from the section of beach dune in study area on the Guhagar beach shows 15 layers of sediments. The profile of this section was measured to be 4.20 m deep (including dune). The proportion of coarse and medium grained sand is dominant in overall sediment samples. The fraction of very fine sand and coarse silt is negligible.

Over all textural analyses of the sediments from the different strata on beach dune section show that sedimentary character are medium grained, moderately sorted sediments, that are fine to very fine skewed and platykrutic in nature.

LDF results show that sediments are deposited under beach and shallow marine as well as fluvial processes. The sedimentary environment is formed by shallow marine agitated deposition. The present study infers that most of the sediments are deposited under shallow marine environment. This may be due to the beach and fluvial processes by a near shore whirlpool agitating turbid condition.

Almost all the dune sediments have shown the dominance of fine grained sediment with an admixture of medium grained and very fine grained sand.

The scatter plots shows fine grained sediments are well to moderate sorted and very fine grained sediments are well sorted

Textural analysis of dune shows that, sedimentary characteristics are fine grained sand, well to moderately sorted (dominance of moderately well sorted sediments), that are coarse to symmetrical skewed and mesokrutic to leptokrutic in nature.

LDF results of dune sediments show that sediments are deposited under shallow marine environment. The sedimentary environment is formed by aeolian / shallow marine agitated deposits with some beach contribution.

Photo 36 Anthropogenic Activities Disturbing the Beach Dune Environment

Photo 36 a) Destruction of Dunes by JCP to Divert the Excess Water from Tidal Inlet towards Sea

Photo 36 b) Garden Developed On Back Dunes in the Middle Sector of the Beach

Photo 36 c) Construction of Staircase on Fore Dunes

Photo 36 d) Construction In Process Of Jetty for Tourist on the Middle Sector of the Beach

Photo 36 e) Jetty for Tourist Constructed On the Beach In 2014

Photo 36 f) Construction of Concrete Embankment on Tidal Channel

Photo 36 g) Artificial Beautification by Constructing Roads and Installation of Street Lamps along the Anti Erosion Wall on Dunes in Southern Sector

Photo 36 h) Fishing Boats On The Beach At Southern End.

Photo 36 i) New Casurina Plantation For Coastal Protection

In the northern sector of the beach a patch of thick casurina plantation has been cleared and dune sand is scoured and an attempt to create artificial inlet to turn the heavy flow of the water in the tidal channel in monsoon. (Photo 36 a) This may create problems of beach and dune erosion as dune vegetation plays a major role in stabilizing the fore dunes and preventing beach head erosion and inland movement of dunes. Creepers, grasses and palms provide an effective coastal defense as they trap sand particles and rainwater and enrich the surface layer of the dunes, allowing other plant species to stabilize. They also protect the berm from erosion by high winds, storm surges and subsiding flood waters.

Middle sector of beach having well stabilized foredune ridge covered with thick casurina plantation is now under construction of pedestals for tourist and temporary shelters for hotels and recreational activity (Photo 36 b). Destruction of such flora on the dunes by the use of herbicides, excessive pedestrian or vehicular traffic, may lead to erosion of the berm and dunes. While the destruction of flora may be a gradual process that is imperceptible to regular beach users, it often becomes immediately apparent after storms associated with high winds and stormy events that can rapidly move large volumes of exposed and unstable sand, depositing them further inland, or carrying them out into the permanent water forming offshore bars or increasing the area of the beach exposed at low tide.

The construction of stairs for accessing the beach for recreational purposes may cause increased erosion at the access points if measures are not taken to stabilize the beach surface above high-water mark. Middle sector of the beach is main access point of the tourist is now facilitated by constructing stairs on beach dune. This may the reason for the dangers of loss of beach front flora (Photo 36 c).

A concrete jetty about 100 m in length near profile number 7 is constructed for recreational purpose now may responsible for changing the normal flow of waves, long-shore currents, water and wind. (Photo 36 d and e)

The tidal inlet is lined by stony banks and bottom is running parallel to the beach in the middle sector. A small garden has been developed by altering the back dunes along this inlet. (Photo 36 f)

An anti erosion wall has been constructed in southern sector of the beach to protect the small dune sector; this part of the beach is also under development. Beautification of this area by pedestals and street lamps along the roads are destroying the dunes in this area. (Photo 36 g)

A fishermen settlement at the southern end of the beach is responsible for added anthropogenic activities in this area. Movement of fishing boats disturbs the natural morphological characteristics of the beach in this part. (Photo 36 h)

Although the human interference in Guhagar beach and dune system creates disturbance in natural environment, some attempts are made to protect the dunes by plantation of casurina by local authorities with the help of villagers. (Photo 36 i)

Thus local authorities responsible for managing coastal areas to restrict beach access points by physical structures or legal sanctions, and fence off fore-dunes in an effort to protect the flora. These measures are often associated with the construction of structures at these access points to allow traffic to pass over or through the dunes without causing further damage.

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ABBREVIATIONS USED

ABBREVIATION	
RL	Reduced Level
BM	Bench Mark
MS	Medium Sand
FS	Fine Sand
VFS	Very Fine Sand
CS	Coarse Sand
MS	Moderately Sorted
MWS	Moderately Well Sorted
WS	Well Sorted
VWS	Very Well Sorted
PS	Poorly Sorted
VFS	Very Fine Skewed
VCS	Very Coarse Skewed
S	Symmetrical
CS	Course Skewed
VP	Very Platykurtic
VL	Very Leptokurtic
L	Leptokurtic
P	Platykurtic
M	Mesokurtic
EL	Extremely Leptokurtic
cm	Centimeter
m	Meters
km	Kilometer
NE	North East
SE	South East
SW	South West
NW	North West