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Morphological Analysis of Runnel of Digha Coastal Beach, West Bengal, India

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Abstract

A flow of water streaming on the beach in respect of the beach slope is called Runnel. Runnel is an important part of coastal geomorphology. This research work deals with the expedition to search for the runnel and Digha coastal beach is a part of this search. Types of runnel, their formation, their lifeline and also their impact (may be positive or negative) are the main concerning matter of the paper.

Introduction

Coastal geomorphology is a branch of geomorphology in which the focus is on the area influenced by large bodies of water, including seas and oceans and a large lake (Davidson Arnott 2005, p.10). A coastal beach is the most dynamic field in the world. The coastline is the interaction line between land and sea. And also, the line has been changed from time to time in a cyclic way. Beach is the interaction zone between land and ocean water. Being the transition zone between land and sea, the beach is a coastal landform facing the open sea and it is a gently sloping flat plain between low water line of spring tide to the upper limit of wave action (Dey and Shukla March 2019). It could be defined as a sloppy sand platform towards the sea with several features sand dune, runnel, ripple mark, beach cusp, etc landforms or features occur due to the influence of wave energy, sediment grain size, wind and also morphological setup. Thus, the profile describes the littoral zone that may stretch from the landward limit of wave action (considerably higher than high tide level) to water depths of 10m to 20m at low tide (Komar, 1976). Runnel is an important landform of the coastal beach. The term 'runnel', is applied here sensu strictto describe the morphological highs and intervening lows across the intertidal zone of certain low-gradient sandy foreshores (King and Williams 1949). Runnel is a stream of water, which flows from the land towards the sea according to the beach slope. The development of this type of beach morphology is limited geographically due to its association with very specific conditions of fetch (and hence wave spectra), beach slope, tidal range and sediment size (Mulrennan 1992). Runnel is to be defined as a multiple swash bar cut by drainage channels.

The Study Area

Digha is an important tourist destination of West Bengal. It comes under Contai or Kanthi sub-division, Purba Medinipur District, West Bengal. Geographically, it is a part of Kanthi coast that is about 45 km long stretching from the mouth of Subarnarekha River in the west to the mouth of RasulpurRiver in the east (Dey and Shukla March 2019). The sedimentary geology of the great Bengal basin has been totally controlled by regional tectonic activities, quaternary as well as Holocene sea-level fluctuation and sedimentation history (Banerji 1984; Hutchison 1989; Achharyya et al. 2000; Goodbred and Kuehl 2000; Morley 2002; Alam et al. 2003; Sikder et al. 2003; Mukharjee, et al. 2009; Jana, et al. 2018, Dey and Shukla

February 2019).About 7 km long, the Digha coast sketches from the mouth of the tidal river Champa in the east to Udaipur (West Bengal Odisha Border). Digha coastal beach is also divided into 15 beaches, viz. from west, beaches are Udaypur (80.32m), Jatranala (1632.9m), Police Holiday Home (304.73m), Larika (656.42m), Hospital (368.90m), Jagannath Temple (170.00m), Aparajita Cottage (342.00m), Blue View (161.60m), 1st Gate (260.30m), Saikatabas (154.51m), Hotel (362.57), Breack (260.00m), Digha Mohana (1662.60m) (Dey and Shukla 2017; Mondal and Dey 2018).

Objective

The main objective of the research paper is to study beach runnel system, type, formation, associated characteristics and also its impact on the beach of Digha coast.

Methodology

The research work has been done through the field survey. Both primary and secondary data is used. A conventional instrument as like Dumpy level, Abney level, etc have been used to collect the primary data. Wave data has been collected by holding a staff. To classify the collected sediment samples into different grain size, ASTM sieves have been used. In addition, secondary data has been collected from books, journal, a map from Survey of India, Kolkata and NATMO, Kolkata, embankment data collected from Digha Shankarpur Development Authorities (DSDA), Tidal data collected from Kolkata Port Trust web portal, etc. The general statistical method has been used to analyze. Tidal range after Davies (1964), Short (1991); Breaking coefficient of onshore wave by Galvin (1968); Relative Tidal Range by Hayes (1979), Davis and Hayes (1984); dimensionless fall velocity of Sonu (1973), Wright and Short (1984), Sunamurs (1989); Lippmann and Holman (1990), conceptual beach model by Clarke et al. (1984), Wright et al. (1986, 1987); Masselink and Short (1993), Mean grain size after Inman (1952), Folk and Ward (1957) Standard Deviation after Krumbein (1938), Otto (1939), Folk and Ward (1957) are used to study and evacuate the said concern.

Beach Morphology and Morphodynamics

A sandy beach can be defined as a sand-lain deposit along the shoreline, which is known as a land-sea interaction zone. This interaction becomes more complex with additional processes, such as tide and wind, and boundary conditions such as antecedent morphology, geology, sediments characteristics and biota (Short and Jackson 2013). Beach is considered as a zone which extends from the low tide line to storm tide line and also consists of primarily sand-sized material. Sandy beach is the most dynamic zone in the world and is regularly affected by surf zone processes. Sandy beaches are generally associated with coastal dunes and are confined to about 20% of the world's coast. On all-natural beaches, processes and morphology are predominantly influenced by waves and tide (Masselink and Short, 1993). In addition, wind and sediments are the main influencers of the sandy beach.

Sandy beaches are characterized by i) beaches consisting of sandy sediments, ii) beaches are the interaction zone of land and water, iii) consist due to the action of gravity waves. Beach sediment textual distributions and waves control beach profile and shape and, ultimately, it's dynamic behavior (Trindade et al., 2009).

The fundamental concept of geomorphology is developed on the basis of temporal and spatial scale. The landforms are the basic elements in any landscape and it is defined by Howard and Spock (1940) as “any element of the landscape, characterized by a distinctive surface expression, internal structure or both and sufficiently conspicuous to be included in a physiographic description” (Hashimy, 1989). Coastal beach is the area of land and sea interaction zone which is rich in various morphodynamics features. Coastal zone is a transition area between land and water where the terrestrial environment influences the marine environment and vice-versa© arter, 1989). To analyze the sandy beach, the temporal and spatial scales are very important.

Beach morphodynamics refers to the dynamic interactions between wave shoaling and breaking processes and bed response across a range of time-space scales (Short and Jackson 2013). Sandy beach has various types of landforms that are also categorized into different sections such as micro morphology, secondary morphological features and primary beach profile (Fig.2). Micro morphology is characterized by a temporal scale of minutes and a spatial scale of less than 1m. Ripple mark, runnel, etc is the example of it. Perturbations to secondary morphological features are characterized by a temporal scale of days and spatial scale of up to 1m to 100m. Berm, beach cusps, mega ripples, and mega runnels are the example of it (Figure No. 2). Primary beach profile is characterized by a temporal scale of days to years or decades and spatial scale of 100m to 1km. Bar morphology, low tide terrace, the upper part of the profile, fore-dune, backshore dune are the examples of it. In addition, the whole beach profile is also demarcated as a feature under the primary beach profile.

Tidal ranges have been classified by Davies (1964) as being micro- (< 2 m), meso- (2 4 m or macro-tidal (> 6 m) (Masselink and Short, 1993). The tidal range of Digha beach is about 3.4 m. Thus, it is a meso tidal beach. The average width of the Digha coastal beach varies between 190 - 210 m. Maximum section, about 5286.78 meters of the coastline of Digha has concrete embankment. The longitudinal beach profile of Digha coast is divided into two parts (Fig. 3):one is sand lying tract, the average width is 150 - 170 meter and,2) the other is concrete dam portion, the average width is 30 - 40 meter. Width of the beach between low tide and high tide line is 180 meter. The steep seaward section of the swash bar is called beachface (Fig.3) or berm or bar. These bars develop under a wide range of hydrodynamic conditions and their morphology assumes a variety of configurations in which the form, size, and numbers can differ significantly in space and time (King and Williams, 1949; Orford and Wright, 1978; Greenwood and Devidson-Arnott, 1979; Aagaard et al., 1998; Wijnberg and Kroon, 2002; Sedrati et al. 2009). It may also develop due to the weld of the sediment, which is transported by runnel from the upper beach. Beach face is played a role to form a different type of runnel in a different section of coastal beach (Fig. 3).

Runnels

The term 'runnel' was introduced by King and Williams in 1949. Ridge and runnel both are interlinked. For Hayes and Boothroyd

(1969), ridge and runnel systems are the result of nearshore topography readjustment of excess sediment to wave conditions (Apoluceno et al. 2002). Runnel is a flow of water according to the slope towards the sea. They are present in the intermittently wet and dry zone of the beach profile where fluctuating water levels and waves constantly reshape their appearance (Figlus et al. 2012). It is generally developed in the zone between low tide and high tide line. Runnels represent a process of gradient adjustment and can play a significant role in beach recovery after storms (Figlus et al. 2012). On the basis of their formation, three different categories have been identified as follows:

Runnel Type I

These form due to the sub-surface flow intrusion of seawater, which is controlled by the wave energy power or front power of the wave. Generally, it is developed at the edge of the concrete dam, because the sub-surface flow of seawater has been choked and it moves upward like an artesian well and creates a stream towards the sea. Offshore flow over the ridge occurs if the runnel is full (Figlus et al. 2012).

The average length of such runnels is 40 to 45m. Width of runnel increases with the increase of length (Fig. 6). Width of the runnel at source is 0.20 - 0.35 m and near mouth 7.1 - 7.5 m. Beach gradient and slope both influence the runnel width. Beach gradient acts positively to runnel width (Fig. 5). But beach slope acts out the negative role to runnel width. Depth of runnel decreases with the increase of runnel length (Fig. 7).

It has been observed that the relation between runnel width and runnel depth is negative (Fig. 8). Beach slope and gradient also controls the runnel's depth (Fig.9). Beach gradient and also beach slope has a negative impact on runnel depth. Beach gradient and slope control the morphological structure of runnel. The characteristic slip-face at the seaward end of the runnel steepened up to a slope of 1/5 in LR17 mainly due to the strong influence of the offshore flow out of the runnel which limited deposition at the landward end of the runnel (Figlus et al. 2012). In addition, wavefront power, sediment grain size, Seawater intrusion as sub-surface flow volume controls the morphology of the aforesaid runnel type. Generally, the aforesaid runnel type occurs at the foot of the concrete dam and extends up to the beach face.

Runnel Type II

These are formed due to the formation of depression storage (ponded) of seawater in the middle beach or high middle beach. This type of depression occurs in middle beach or high middle beach due to the dumping of big rock or boulder for the purpose of dam construction (Fig.10). At the ebb time, when the seawater retreats, then a stream of water occurs on shoreward and this type of runnel is formed. Generally, this type of runnel extends from depression storage to beach face. The average length of the runnel is 30 - 35 m long. Depth of the source of runnel is 40 - 60 cm. Dumped Boulder, backwash effect, beach slope, and beach gradient are the main factors that influence the formation of these runnels.

Runnel Type III

These are formed between mega ripple marks and are closely related to the 'ridge and runnel concept' (King and Williams (1949). These are multiple swash bars cut by drainage channels (Apoluceno and et al., 2002). Sometimes, during the seawater retreatment, a very low amount of water is stored between two ripple marks (Fig.11), thereby forming such runnels. The average length varies between 0.25 - 0.35m. Depth and width of the runnel are very negligible. Ripple index (which has been calculated from ripple length and ripple wave height) is controlled by the morphological structure of this type of runnel. These are found in the lower beach and the lifeline is very small, making it a micro morphological feature.

Sediment Transportation and Beach Morphodynamics

Grain size is one of the most significant physical property of sediment and commonly used parameter for understanding the processes involved in transportation and deposition of sediments (Inman 1952; Folk and Ward 1957; Mason and Folk 1958; Friedman 1961; Krumbein and Sloss 1963; Nordstrom 1977; Parthasarathy et al., 2016). The texture of beach sediment and waves control beach profile and shape and ultimately, it's dynamic behavior (Trindade et al., 2009). Ponded water acts as a small settling basin for sediment transported over the ridge crest (Figlus et al. 2012). Sediment transportation rate is 4.82 gm/ 100ml/ minute through the offshore flow (runnel) at Digha coast.

It has been observed (Fig.12, 13) that, due to sediment transportation, sedimentary textural distribution is changed of beach face into a well-sorted tract. This transport asymmetry promotes landward ridge migration (Figlus et al. 2012). Wave breaker type is more surging than plunging in Digha coast. Based on the ratio between RTR and dimensionless fall velocity, the Digha coastal beach is considered as 'low tide bar/rip intermediate' type (Dey and Shukla March 2019). Thus, the beach system reacts as a reflective beach during high tide.

Conclusion

Length of runnel is an important indicator for a beach's sustainability because runnel streams medium to the low quantity of sand. Due to the low streaming velocity, small-sized sediments are transported (below 150 μm) towards the sea. Slowly and gradually, it transforms the beach into an Erosional beach (Fig.14) which may occur a threatening condition for Digha coastal zone. The concave beach profile of the aforesaid coast proves this concern. In addition, it has been observed that concrete dam which resists the entry of the seawater into the land, plays a positive role to influence the development of 1st and 2nd type of runnel indirectly.

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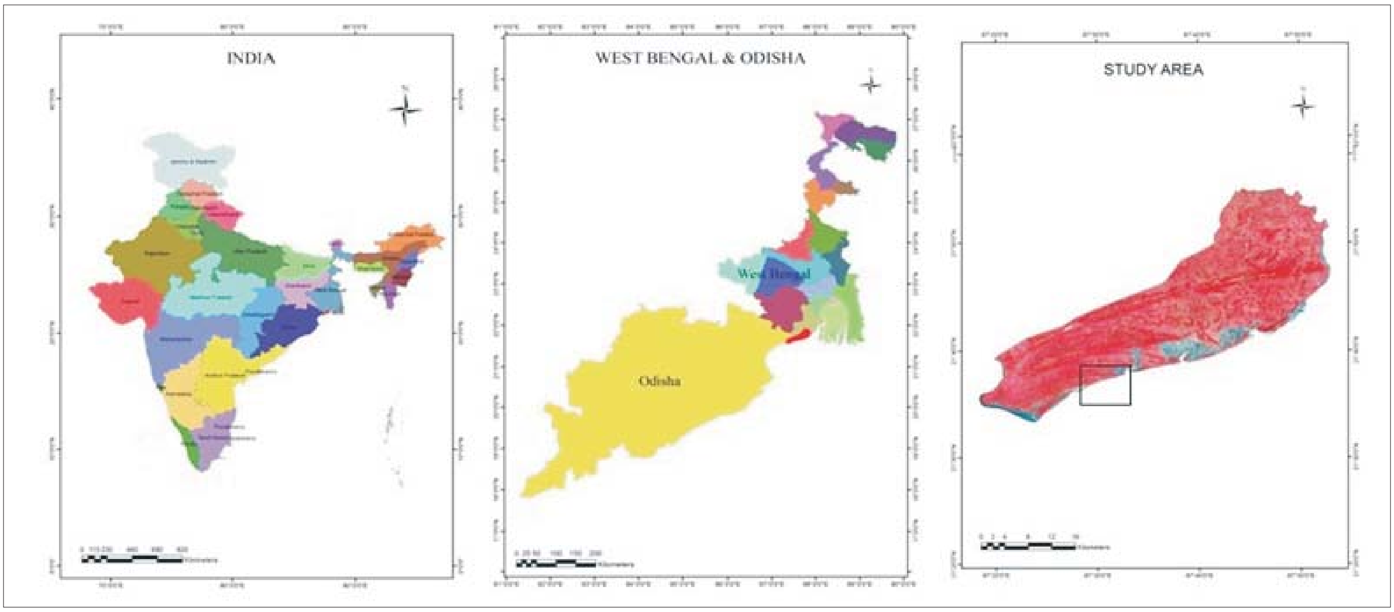

Fig.1: Location of the Study Area

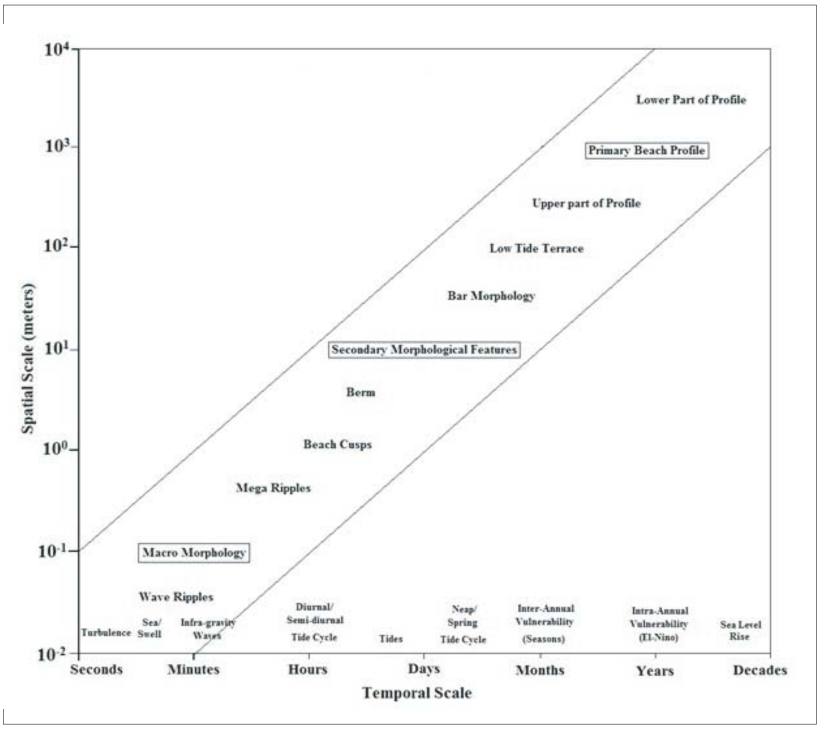

Fig. 2: Relation between Spatial and Temporal Scales of Morphological Features and Fluid Motions associated with Sandy Beaches (*After Masselink and Kroon)*

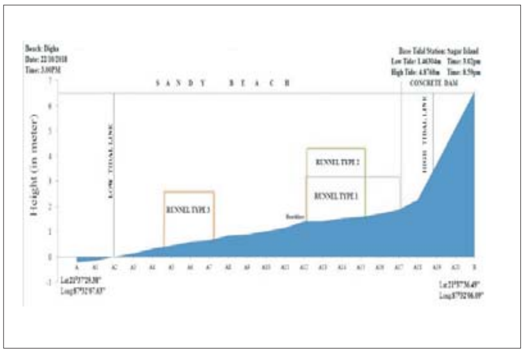

Fig. 3 Longitudinal Beach Profile of the Digha Coast

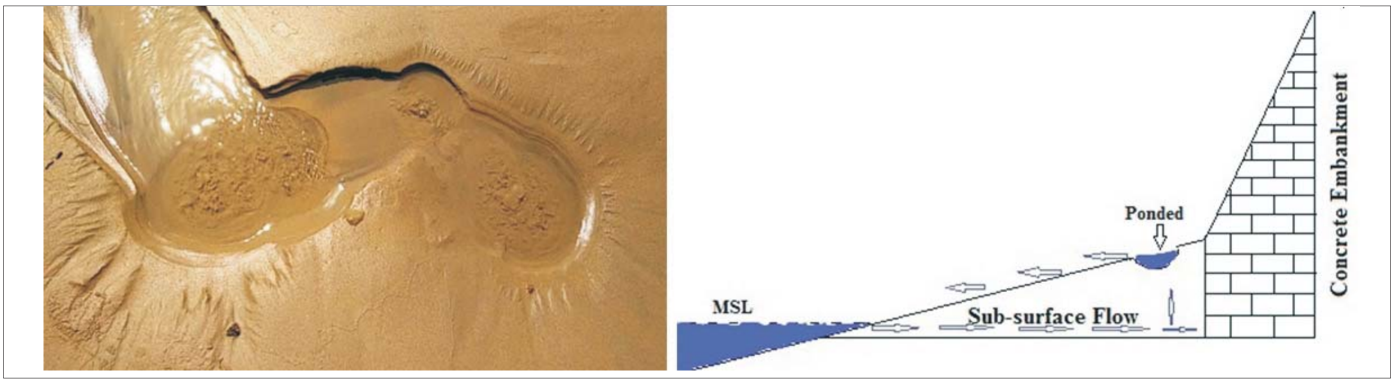

Fig. 4: Runnel Type I in Digha Coast

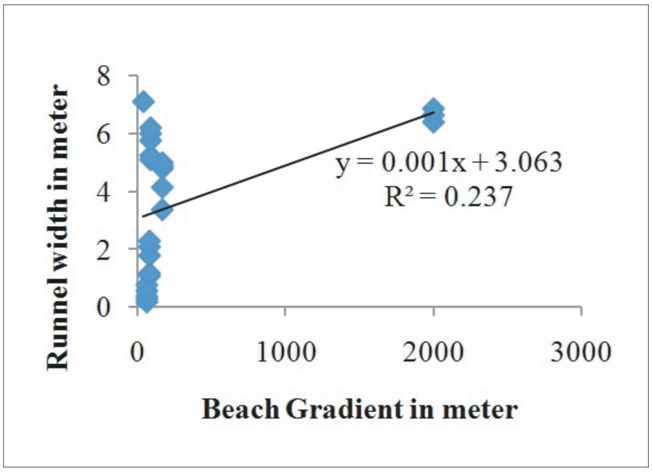

Fig. 5: Relation between Runnel Width and Beach Gradient

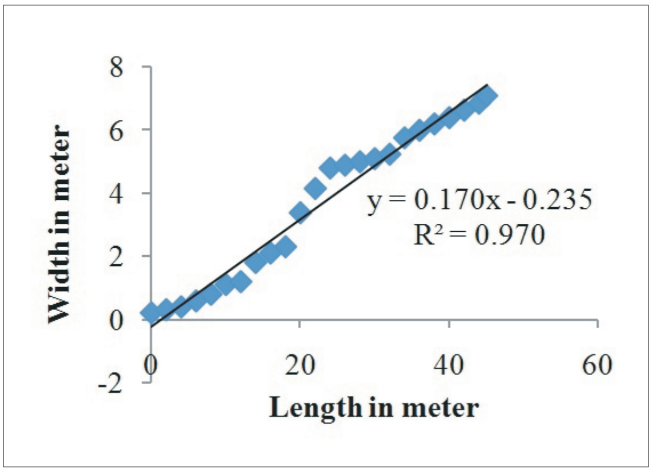

Fig. 6: Relation between Runnel Width and Runnel Length

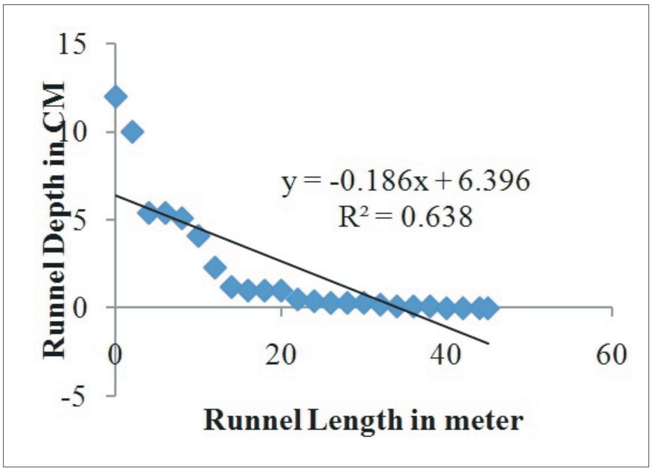

Fig. 7: Relation between Runnel Depth and Runnel Length

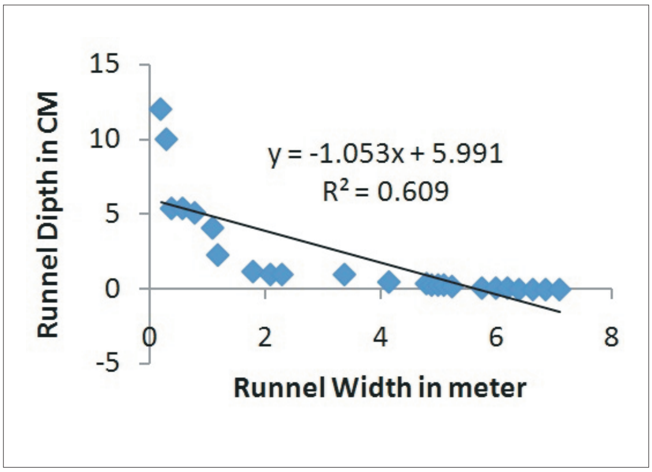

Fig. 8: Relation between Runnel Width and Runnel Depth

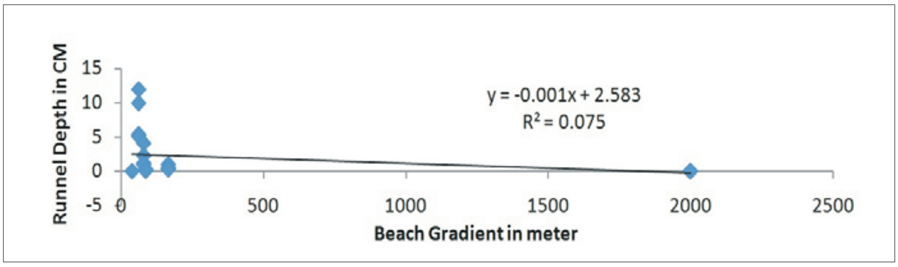

Fig. 9: Relation between Runnel Depth and Beach Gradient

Fig. 10:Runnel Type II in Digha Coast

Fig. 11 Runnel Type III in Digha Coast

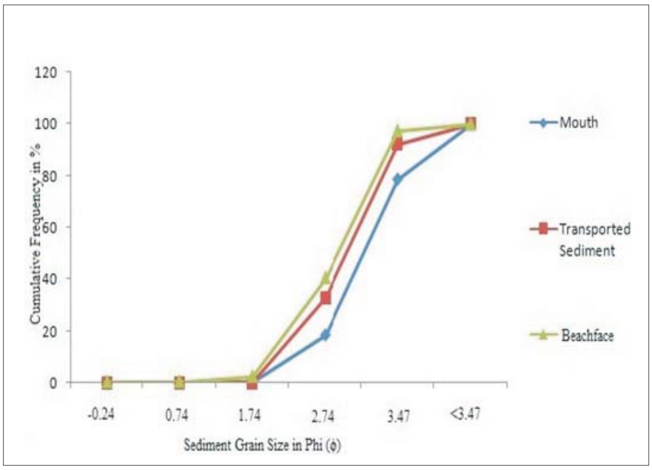

Fig. 12 (for explanation see Text)

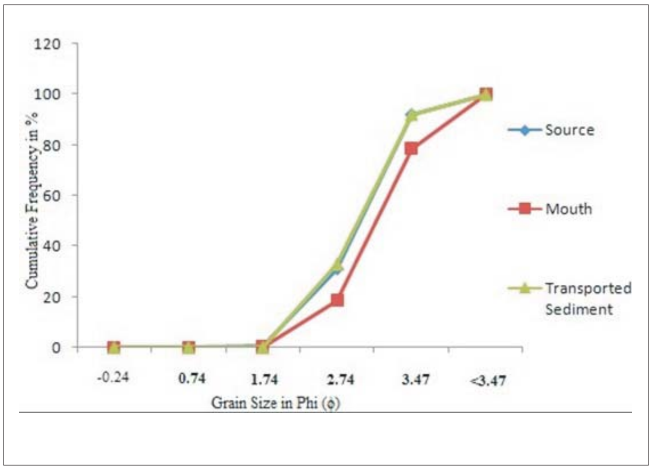

Fig. 13 (for explanation see Text)

Fig. 14:Erosion through beach Runnel in Digha Coast

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