TSUNAMI IMPACTS ON MORPHOLOGY OF BEACHES ALONG SOUTH KERALA COAST, WEST COAST OF INDIA

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ABSTRACT

The present study is based on the post tsunami survey conducted in January 2005 along the southwest coast of India. Although tsunami affected the whole coastline of Kerala, it devastated the low-lying coastal areas of Kollam, Alleppey and Ernakulam districts leading to the loss of life and property. This paper illustrates the variation of tsunami intensity along the coasts of these districts and the consequent morphological changes occurred in the coastal area during tsunami. Topographic survey data showed that the coastal inundation was rampant along the worst affected regions where the coastal areas are like a narrow strip of land of width 100-400m, lying between the Arabian Sea and the backwaters and the down slope of the coastal area increases towards the backwater side. The data on run-up height showed a variation of 1.9 – 5 m along the study area. Post tsunami beach profiles showed erosion of the foreshore and backshore and landward transport of beach material during the run-up of waves at Puthu-Vypeen. The erosion of the backshore (berm) in several places along the coast was quite evident in the study. This has caused reduction in the elevation which may make these areas more vulnerable to breaching by the high waves, particularly during the monsoon and also during certain spring tides which is a matter of serious concern.

INTRODUCTION

On 26th December 2004, Indian subcontinent experienced the most devastating tsunami in its recorded history. The phenomenon was triggered by a submarine earthquake located at 3.4° N, 95.7° E off the coast of Sumatra (Indonesia) with an intensity of 9RSU.

Even though tsunami is a common phenomenon in the Pacific region, some destructive tsunamis have also occurred in the Indian and Atlantic Oceans (Altinok, 2000). Oceanic waves caused by the (27th August) 1883 Krakatoa volcanic explosion in Indonesia, was the earliest record of tsunami attack in India (Murty and Bapat 1999). The earthquake of magnitude 8.25 RSU occurred on 28th November 1945 near Karachi created large waves of height 11 to 11.5m in Kutch region (Pendse 1945). Most of the tsunamis are generated by the earthquake-initiated seabed displacements. Landslides (including underwater landslides), volcanic eruptions, impact of large objects (such as meteors) into the open ocean (Hills and Goda, 1998) and underwater explosions are also some triggering mechanisms for the generation of tsunami. The coastal features can determine the size and impact of tsunami waves. Kishi and Saeki (1966) identified the effect of coastal terrain roughness on wave run-up.

While tsunami approaches coast, it undergoes shallow water transformation (Synolakis, 1987). Tunami, imperceptible at deep sea, may grow to several meters when it approaches the land (Mirchina and E.N. Pelinovsky, 1982). Its speed decreases as the water depth decreases but the kinetic energy transported by the tsunami, which is dependent on both its wave speed and wave height, must remain constant. Gedik et al., (2005) carried out laboratory investigations of tsunami run-up and erosion on permeable slope beaches. Tsunamis may affect coastal areas differently, causing great damage and loss of life in one area but little in another. The destructive nature of the waves themselves act as a main cause of damage. Secondary effects include the debris which will act as projectiles and run into other objects. Just like other water waves, tsunami begins to loose energy as it rushes into the land. Some energy may get reflected and part of its energy may dissipate on the bottom.

MATERIALS AND METHODS

State of Kerala has a coastline length of 560 km and undergoes seasonal changes in the near shore processes. For the present study, the southwest coast of Kerala between Neendakara (latitude 9° 01' 17.87") and Munambam (Latitude 10° 10' 37.55") is selected (Fig. 1). The coastal plain between Cochin and Kollam consists of a series of parallel sand ridges. The coastal area is backed by Vembanad estuary, extending from Munambam to Alleppey and the large brackish water system in Kerala opens into the sea near to Valiazheekkal and heavy mineral deposits can be seen north of the Kayamkulam inlet. The Cochin port is situated at the mouth of Vembanad Lake at 9° 58' 18".

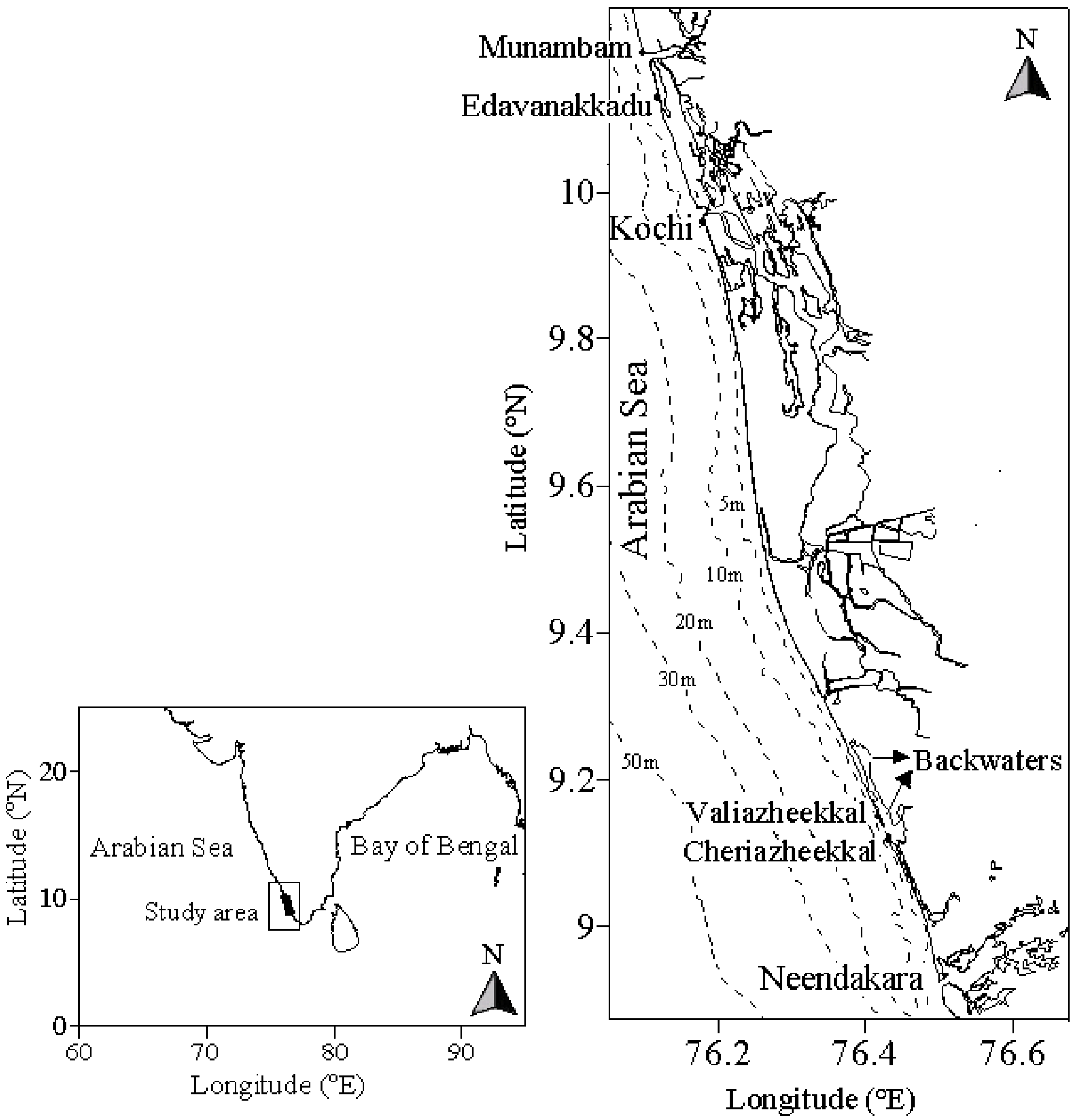

Fig.1: Study area

An extensive field survey was conducted using Differential global positioning system (DGPS), Theodolite, Dumpy level, GPS, directional compass etc., to study the impact of tsunami waves on the South west coast of India. Measurements were made of land elevation, beach slope, tsunami flow direction and distance, maximum run-up height and duration of inundation, shoreline position and status of beach vegetation. In all places, the phenomenon was also documented through systematic interviews of eyewitnesses. The Post Tsunami Survey guidelines of the Intergovernmental Oceanographic Commission (IOC, 1998) were strictly followed during the observation. The primary measurements in the field surveys were the estimation of height reached by the seawater as well as for its horizontal penetration. Information on run-up height and inundation limit are important to analyze the phenomenon (Curtis, 1982).

RESULTS AND DISCUSSION

Tsunami inundation and damage was not uniform along the coast. This may be due to the geographical orientation of the coast, geomorphology of the landmass, shallow water bathymetry and orientation of approaching waves etc. Traces left by the tsunami such as watermarks on buildings, trees and debris lines along the coast or vegetation damaged by seawater were used to identify the run up and inundation limit.

Field investigation shows variation of tsunami intensity along the study area. Maximum intensity of the tsunami was observed in Kollam district followed by Alleppey and Ernakulam. The sectors adjacent to the Kayamkulam inlet between Kollam and Alleppey districts, recorded the maximum run-up height during the flood. The run-up level recorded at the northern side of inlet (Valiazheekkal) was 4.4m. There was a drastic increase in the run-up level at Cheriazheekkal (southern side of inlet) and reached up to 5m. Figure 2 shows the post tsunami beach profile at Cheriazheekkal, where the coastal area experienced maximum inundation and run-up (zero value in the X-axis indicates the position of benchmark used for conducting the topographic survey). Here the down slope of the narrow coastal belt increases towards the backwater side. This coastal feature allows seawater to enter in to the land during high tide and strong waves which trigger panic situation among the coastal community. The devastation was quite extensive at Valiazheekkal where the width of the narrow coastal belt varies from 100m to 400m and is running parallel to the shoreline (Fig. 3). The down slope of this low-lying region increases towards the backwater side. The run up level on the coastal area between Alleppey and Cochin varied from 1.9-2.8 m. On the northern side of Cochin barmouth, the waves got intensified and maximum run up height was observed at Edavanakkadu (Fig. 4), a narrow down sloping barrier beach (Fig. 5), backed by water bodies (aquaculture farms) connected to the Cochin backwaters.

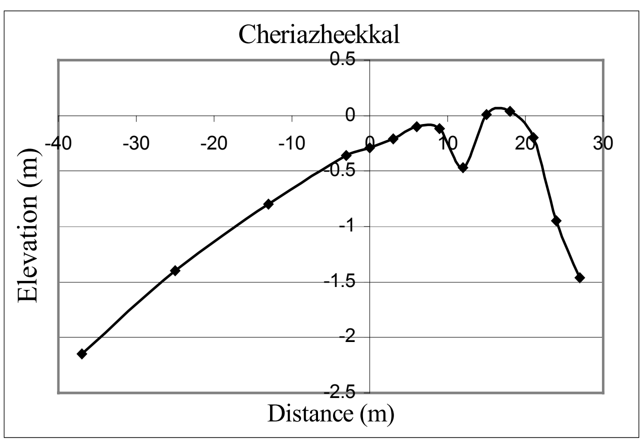

Fig. 2:
Post Tsunami beach profile at Cheriazheekkal (Kollam district)

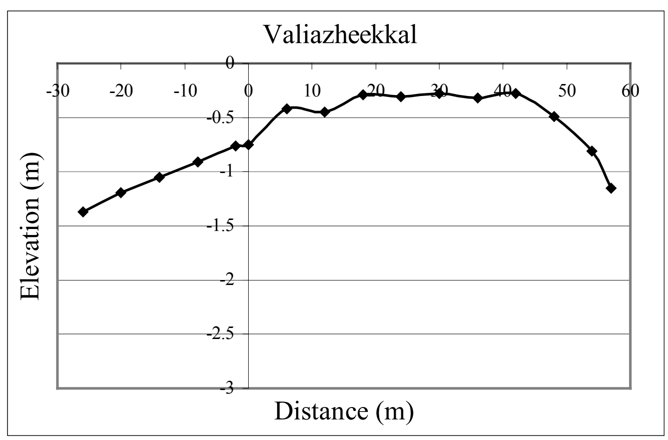

Fig. 3:
Post Tsunami beach profile at Valiazheekkal (Alleppey district)

Fig. 4:
A photograph shows the run-up height of tsunami at Edavanakkadu.

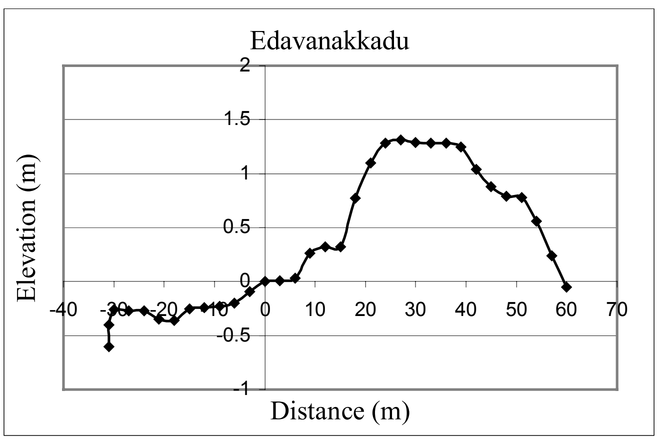

Fig. 5:
Post tsunami beach profile at Edavanakkadu (Ernakulam district)

The northern side of Cochin inlet (Puthu-Vypeen) beach is wide and having an average elevation of 1.5-2.0m. Monthly beach profile measurements have been carried out in this region as a part of an ongoing programme. Maximum inundation occurred here at 13:28 on 26th December 2004 as recorded by the digital camera from the shoreline, and covered up to 600m towards the land (Fig. 6). The post tsunami beach profiles of four stations at distance of 1km apart (Fig. 7) show the changes in beach elevation and erosion that have taken place near the seaward end. It is evident from the observation that the eroded sediments from the seaward side have been carried further inland and got deposited near the benchmark. The presence of vegetation on the beach appears to have helped to reduce the intensity and thereby decreased the erosional characteristics of the incoming waves. Most of the vegetation is seen already were wiped off during the run-up of waves, or being destroyed due to high saline conditions in the soil.

Fig. 6:
A photograph showing the tsunami inundation at Puthu-Vypeen

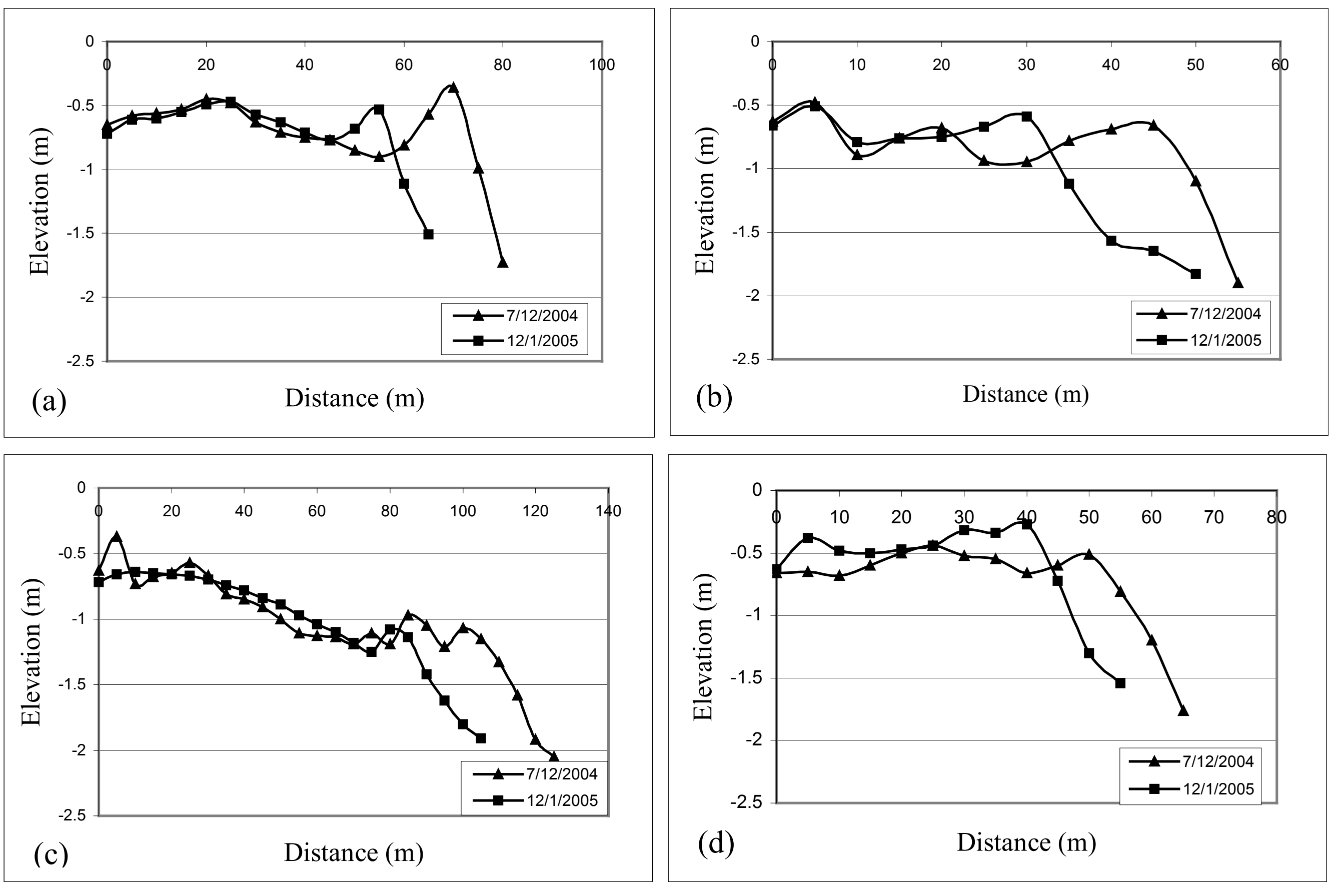

Fig. 7: Pre and post tsunami beach profiles at Puthu-Vypeen

The run-up measurements show a variation in height from 1.9 –5 m along the study area. The run-up heights and inundation limits are listed in table 1.The maximum run-up height was at Cheriazheekkal (5m) where the loss of life and property were severe.

The post tsunami beach profiles at Cheriazheekkal (Fig. 2), Valiazheekkal (Fig. 3) and Edavanakkadu (Fig. 5) reveal some basic similarities among these regions. The coastal areas are lying below the mean waterline due to its down sloping characteristic (Fig. 8). Moreover, the back water system is generally running parallel to the shoreline and the coastal areas are like a narrow strip of land (barrier Beach) lying between the backwater and sea. The inundated water had flooded into the backwaters and the force of wave has damaged most of the physical structures along the coast. It is evident that presence of seawall has played an important role in reducing the intensity of the waves along the coast, but the affected areas were not having any effective coastal defense structures (because the traditional fishermen use these places as fish landing centres). The tsunami floods at some places even destroyed the rubble-mound seawalls which got scattered along the coastline (Fig. 9).

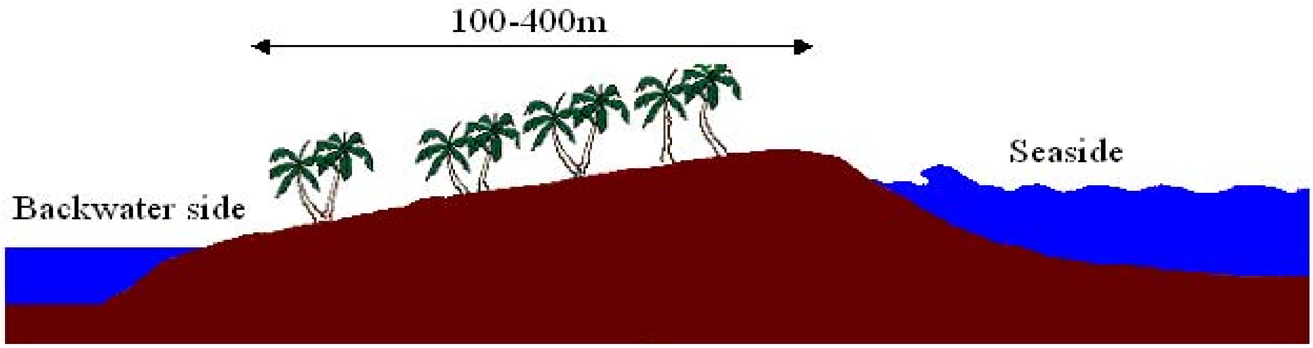

Fig. 8: Schemataic representation of the low-lying barrier beach

Fig. 9:
The destroyed and scattered seawall at Edavanakkadu

Tide gauge data provide vital information on severity of tsunami. The sea level data collected by Cochin port trust at Cochin and the hydrographic department, Government of Kerala at Neendakara provided important information on the intensity and time of occurrence of tsunami at respective places (Fig. 10). The alongshore separation between the two stations is approximately 100 km. The first hit of the tsunami took place at Neendakara at approximately 1045 hrs on 26th December, 2004 whereas in the case of Cochin, it was at 1115 hrs, suggesting a speed of 200km/hr. The sudden increase in water level at Cochin was approximately 0.65 m in 9 minutes, at the first hit. Subsequently, there were dramatic rise and drops in the water levels. In the case of Neendakara, The sudden increase in water level was approximately 0.83 m in 15 minutes. As observed in the case of Cochin, here also there were dramatic rise and drops in the sea level. The overall range of water level variability was quite high at Neendakara, as compared to Cochin. Normally, the tidal ranges are less at Neendakara as compared to Cochin, as seen in the figure. The tidal records showed the occurrence of tsunami continued till 30th

December 2004 at different intervals with varying amplitudes and diminishing progressively from 26th December.

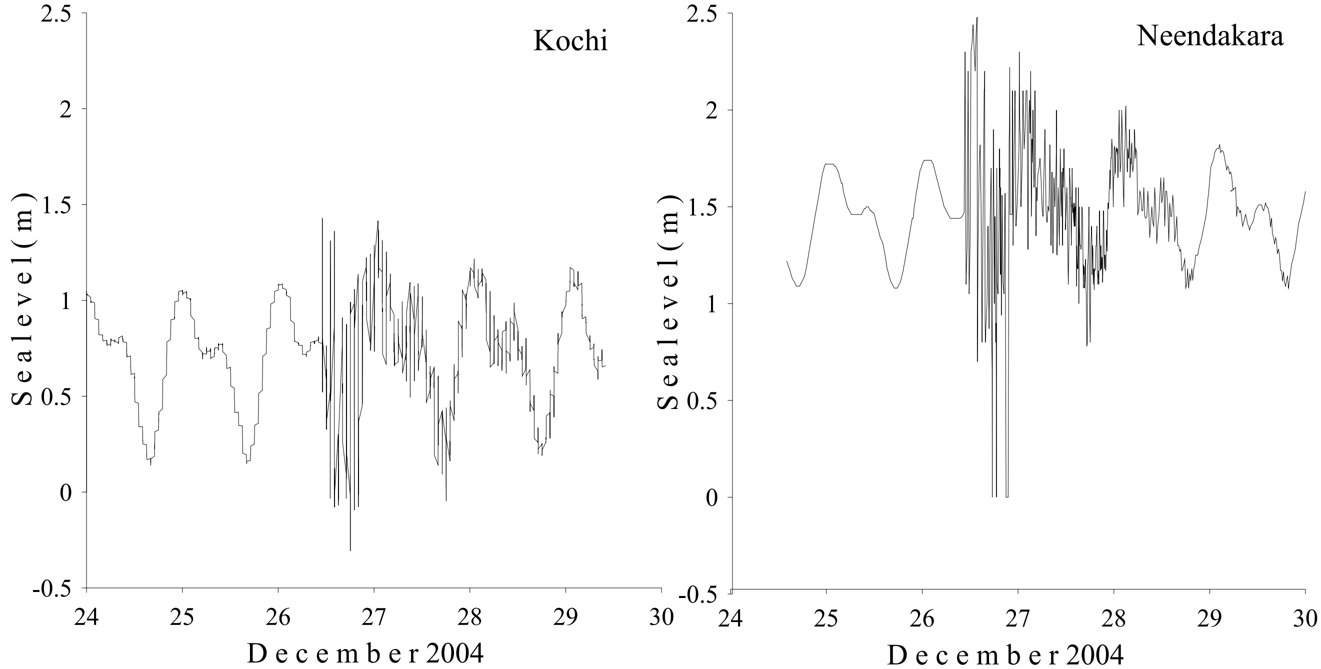

Fig. 10: Sea level variations at Cochin and Neendakara during Tsunami

Table 1. Survey results of Tsunami height

Sl No	District	Location	Latitude (°N)	Longitude (°E)	Height Measured (m)	Direction of approach (Degrees)	Inundation distance (m)	Inundation time	Maximum Inundation
1	Kollam	Neendakara	08°55' 54.1"	76°32'23.2"	2.40	220	240	1010 1210	1210
		Panikkar Kadavu	09° 02'4.5''	76°30° 8.05"	3.20	230	100 Up to Kayal	1130 1200	1200
		Cheriazheekkal	09°030'5.5"	76°30'8.3"	5.00	230-250	400 Up to Kayal	1100 1130 1200	1200
2	Alleppey	Valiazheekkal	09°08'20.3"	76°27'43.1"	4.40	220-240	600 Up to Kayal	1030 1100 1145 1230	
		Thrikkunnappuzha	09°15'29.1"	76°24'25.6"	2.77		60		
		Ambalappuzha	09°15' 30.1"	76°24' 26.6"	1.90	230-250	160	1005 1045-1100 1330-1400	
		Alleppey Beach	09°29'32.1"	76°19'04.3"	2.80	200	95	1030 1430	
3	Ernakulam	Puthu-Vypeen	09°59'53.7"	76° 13' 06.0"	2.30	250	600		13:28
		Edavanakkadu	10°05' 6.1"	76°11'36.6"	2.45	230-240	90 Up to Kayal		

CONCLUSION

Variation in run-up observed along the coastline depends on the topography of the coastline, near-shore bathymetry, beach slope, coastal orientation, direction of the arriving wave etc. Variations in the near shore bathymetry and bottom topography have to be studied in detail to understand the relationship with the amplification of the tsunami height. The Tsunami waves have penetrated inland with a greater force in areas where coastal defense structures were absent. The low-lying coastal areas with narrow strip of land between the sea and backwater at Cheriazheekkal, Valiazheekkal and Edavanakkadu, amplified the effect of waves and caused severe damage and loss of life. On the other hand, the wider beach at Puthu-Vypeen reduced the impact/damage of tsunami on life and property.

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