Geomorphic and Sedimentological Changes in the East Coast of Tamilnadu by Indian Ocean Tsunami-2004

S.R.Singarasubramanian, M.V.Mukesh and K.Sujatha

***Abstract*—The coastal zone of Tamilnadu was worst affected by the December, 2004 Tsunami. Most of the east coast of Tamilnadu was affected by the tsunami waves. Except the region between Point Calimere and Thoothukudi were very meagerly affected. The rest of entire coastal region was affected along with the coastal communities. In some regions erosion was prominent with a large scale inundation and deposition was prominent in some places. The coastal dunes and river systems were completely altered.**

***Index Terms*——Coastal morphology, Tsunami, Inundation.**

I. Introduction

The coastal zone of Tamilnadu is endowed with varied landscape such as sandy beaches, beach ridges, backwaters, estuaries, intertidal mud and sand flats, dunes, cliffs, beach rocks, deltas, lagoons, mangrove forests and coral reef ecosystems. The coast has been constantly undergoing physical changes in the geological past and at present. Many rivers bring considerable sediments, which affect shore processes significantly.

The coast between Chennai and Pondicherry through Muttukadu, Mammallapuram and Marakkanam is a narrow sandy belt. The major geomorphic features include tidal flats, estuary, beaches, dunes and beach ridges. The dunes are stable at their base and mobile on their crest. The coastal dune field, which is stabilized by vegetation, occurs in a very high-energy wind regime. Linear dunes along the shoreline, which are stabilized to a large extent, represent the major geomorphic features.

The coastal area between Pondicharry and Nagapattinam is occupied by various geomorphic features. The varying geomorphic features like beach ridges, swales, sand dunes, deltaic plain, chenniers, palaeo-tidal flats, palaeo-lagoons, salt marshes, palaeo-channel and lagoon are seen in the area (Anbarasu and Rajamanickam 1997). The coastal features in and around Point Calimere include beaches, beach ridges, swales, dunes, tidal flats, palaeo tidal flat, barrier islands, alluvial plain, chenier, palaeo lagoons, flood plains, mud flats salt pan, mangrove etc.(Shanthi Devi and Rajamanickam, 2000).

The coastal landforms between Devipattinam and Mandapam were classified into depositional, erosional features and others (Chockalingam et. al. 2000). Rocky beaches are characteristic of Mandapam to Rameswaram. The important features in these areas include spits, swales, sand dunes, shoals, deltaic plains, sand sheets, mud flats, chenier plains, cliffs, beach rocks, sea caves, sea cliffs and marine terraces.

Apart from the coastal geomorphic features, the Tamilnadu coast is protected with coral ecosystem in the Gulf of Mannar region. Coral reefs act as a barrier against wave action and prevent coastal erosion. There are 21 islands, situated at an average distance of about 8 km from the coast and running parallel to the coastline. Along these coastline both erosion and accretion takes place. Island erosion and accretion are caused mainly by the action of waves, wave induced currents and long shore currents along the shore.

On 26th December, 2004, the deadliest tsunami a new word in the Indian history triggered by a massive earthquake of magnitude 9.0, at 6.29 IST was the largest recorded worldwide in 40 years. The earthquake epicenter lies at Lat.3° 7'N and Long. 95° 7'E in the Indian Ocean off the west coast of Sumatra islands, Indonesia.

II. Study Area

Study area forms the tsunami affected east coast of Tamilnadu extends from Vellar River to Thoothukudi. Coastal geomorphic features were studied by field survey, using toposheets and satellite pictures. The sedimentation changes were studied by means of digging pits and analyzing the samples at 2 or 5 cm interval. The inundation was noted with the remnant water marks and by transported debris during the tsunami. Original dune height was measured from the eroded parts and uprooted vegetation.

III. Discussion

The coastal area between Vellar estuary and Muzhukkuthurai was occupied by prominent 4 to 6 m stable sand dunes with lot of vegetation, ridges are prominent. These dunes run parallel to the coast. In the study area M.G.R.Tittu, Muzhukkuthurai, Karaikal, Nagapattinam and Velankanni were the major coastal regions destructed by the tsunami waves.

There was a long sand dune of 3m height protecting the Tittu running parallel to the coast. Apart from this major sand dune there was lot of stable dunes with vegetation. Run-up height in M.G.R. Tittu was more than 3m and completely inundated the island. Inundation in inland area in Muzhukkuthurai was 1000 to 1200m (Table-1) from the coast and run-up height was 1.2m in the inland.

Manuscript received March 9, 2011.

S.R.Singarasubramanian*, M.V. Mukesh and K.Sujatha, Department of Earth Sciences, Annamalai University, Annamalainagar-608 002, Tamilnadu, India,Corresponding author: email: laksrs@yahoo.com

TABLE 1 INUNDATION AND RUN UP HEIGHTS OF THE TSUNAMI WAVES IN SOME LOCATIONS

S.No.	Place	Maximum Inundation (m)
1.	Muzhukkuthurai	1200
2.	Parangipettai	1700
3.	Nagapattinam	1100
4.	Akaraipettai	3000
5.	Vedharanyam	1400
6.	Kodiakkarai	1500
7.	Point Calimere	1000
8.	Melmanakudi	1500
9.	Keezhamanakudi	1000
10.	Thoothukudi	75
11.	Thondi	30
12.	Vellapatty	75
13.	Colachal	1500
14.	Melmanakudi	1500
15.	Keezhamanakudi	1000

Fig 1. A- Deposition and alteration of coast near Vellar; B- Erosion of stale dune at M.G.R.Tittu; C-Erosional water bodies at Vedharanyam; D-Erosion of 2m high stable dune at Point Calimere; E- Parallel bedding with basal erosional contact with Pre tsunami sediments at Kodiampalayam; F-Erosion base and deposition of sediments with erosional structures near Poompuhar.

In most of the coastal regions the sand dunes protecting the coast was completely eroded by the waves (Fig 1. B). The tsunami waves not only alter the geomorphic features but also bring voluminous sediments from the shelf. The stable palaeo dunes were breached by the tsunami waves. Development of sand bars perpendicular to the coast was noticed in the south near M.G.R.Tittu (Singarasubramanian, et.al. 2009). This evidenced the change in coastal morphology and wave direction after tsunami. Small uplands could be seen in near the mouth of Vellar (Fig 1. A) immediately after tsunami, but slowly they became flat and merged.

A prominent spit is occurring near Thoothukudi, running few kilometers in length. It joins with main land and forming Tombolo. Beach ridges are found to be discontinuous. Sand dunes are formed at interface between sea and land. They bordered the high tide mark and extend inland upto 2 to 5 km. They run parallel to the shoreline separated from each other by marked troughs. The crests are flat and range in height from 0.5 to 2m. They are stabilized by the vegetation. After the mega tsunami event the sand dunes were breached in many places and the coastal geomorphology has changed. In many places the channels were diverted or filled with sediments or new formations of erosional structures were observed. Most of the coastal regions become steep in some places and shallow in some places due to the differential erosion and accretion of sediments by tsunami waves.

In Kodiakarai the sediment and water inundation was upto 1500m (Table-1) from the shore. Parallel to the shoreline in the beach, erosion is prominent and filled with water bodies. The stable dunes in these areas were breached at places or eroded (Fig 1. C). Point Calimere has encountered a wide spread sedimentation and formation of eroded channels due to tsunami. The entire stable 2m high dunes was eroded (Fig 1. D). The newly created channel was about 120cm deep near the shore and extends upto 1km inland. Here the beach was eroded and occupied by sea for about 20m after tsunami.

In areas like Mallipattinam, Manora, Kalamangudi, Manthiripattinam, Prathabharamapattinam, Adhipattinam, Palakudi, R.Pudupattinam and Vattanam encountered sedimentation in the fishing harbors. The recent sediments brought down by the tsunami waves were spread in inland. In some areas like Prathabharamapattinam and Manora, the coastal fishing areas become clayey. In all these areas the beaches are shallow and wave domination is less.

In Thondi, Mullimanal, Tiruppalakudi, Devipattinam and Uchipuli regions the tsunami waves entered upto 25 to 30m inland. In Thondi, the waves entered up to 30m (Table-1) inland and the sedimentation was not observed in inland, only water inundation was observed. From Thondi up to Uchipuli, less inundation of sediments was observed. This may be due to the shallow beaches and their locations.

Vaippar, the projected coast encountered erosion normally was not affected by much sedimentation by tsunami. Taruvakulam, Vellapatty, Pulavali and Thoothukudi Harbor guest house were affected by tsunami waves. In Taruvakulam the shoreline was filled with sediments to an extent of about 120cm thick with 150m length and 20m width along the coast. Coastal morphology was completely altered. Thick sedimentation in the northern part of Taruvakulam leads to the extent of beach towards the sea. Vellapatty, near Thoothukudi was also affected by the sedimentation due to the tsunami waves. The inundation is up to 75m inland (Table-1). The sediments were deposited over the normal coarser beach sediments as thin layers. Behind the Harbor Guest House in Thoothukudi, the sedimentation was up to 500m inland from the shore (Singarsubramanian, et. al. 2006).

In the southern sector of the study area includes Palayakayal, Punnakayal, Kayalpattinam,Virapandipattinam and Tiruchendur. The estuaries of Tamiraparani River enter the sea in Palayakayal and Punnakayal. The estuary is wide spread. The erosion due to tsunami waves was prominent in the back water channels. Tsunami waves enter up to 2100m inland through the channels. In Virapandipattinam, the tsunami waves erode 20 to 25m of beach from the shore. Due to the erosion the beach becomes steep. The entire

stable vegetated dunes at Colachal (Fig 1. F) was devastated along with the roads aside. The geomorphology of the Van coral Island was altered by erosion at one end and deposition at other end by changing the shape of the island.

The most of the sedimentation along the coast were altered. The sequences register a fining upwards and thinning towards inland character. Due to backwash the tsunami wave signatures were not preserved. The base of each layer was characterized by darker sand with abundant heavy minerals. The base of the deposits exhibits cramped or loaded structures due to erosion and deposition (Fig 1..; E & F). The heavy mineral slag deposited in the scoured regions gives raise to loaded structures (Fig 1. E). Very fresh and no clear surface texture of quartz grains in the deposits indicates that they might have undergone abrasion during transportation. The strong grooves in the quartz indicate a mechanical abrasion and a high energy deposition. The thickness of the tsunami deposits vary from 2 cm to 50 cm. the pre and post tsunami deposits show uniform textural characteristics, showing finer sediments than tsunamigenic sediments. In the east coast of Tamilnadu, India the coarser fractions deposited by the tidal cycle might been carried back by the high energy tsunami waves in the northern and central part of the coast (Singarasubramanian, et. al. 2005 & 2006).

Depending upon the available source along the coast or offshore, tsunami waves either enhance the heavy mineral concentration or totally erode them. The deposits have more etched, angular or pitted heavy minerals with overgrowth texture along the coast.

IV. CONCLUSION:

In general, the study area encountered good sedimentation in some locations depending upon their geomorphologic setup. Inundation due to tsunami waves ranged from 20 to 2000m and led to changes in coastal geomorphology and heavy sedimentation in estuaries, canals and waterways. From the study, it was observed that the tsunami wave propagation was almost from south east and flowed to North West. These waves are diffracted since the region is located in and near the shadows of Sri Lanka. The wave velocity is also less due to the shallow nature of the coasts. The Islands were also affected but less inundation takes place due to their location and the effect of waves. There were three waves struck the Tamilnadu coast and deposited the sediments in different time interval. The thickness of tsunamigenic sediments vary depending upon the morphological features of the coast. The south-central part was shadowed by Sri Lanka and hence the diffracted waves hit the shore and sedimentation was very less.

Rivers acted as carriers of tsunami waves and deposition of marine sediments on their retreat. The waves also led to deposition of continental shelf sediments along the river beds and floodplains changing the river morphology and damaging agricultural lands. The sediments were deposited with debris and broken fragments over the older clay or fine sized sediments. A rise in the percentage of silt and clay (2.34-6.70%) after tsunami was observed in some coastal transects. Clay was observed as older sequences in many places. The sediments were medium to fine in nature. Sediments were fresh and light coloured, where as the older are dark coloured Tsunami waves propagated in E-NE direction.

ACKNOWLEDGMENT:

Author acknowledges the Department of Science and Technology (DST) and Council for Scientific and Industrial Research(CSIR) for providing financial support to carryout the research programme. Also thanks Shri.K.Manoharan, Dept. of Earth Sciences, Annamalai University Prof. P.Seralathan, CUSAT, Cochin for their valuable support.

REFERENCES:

[1] Anbarasu, K. and Rajamanickam, G. V. (1997) Abandoned channels of rivers- An evidence for neotectonism. *Indian Journal of Geomorphology*.(2):.209-217

[2] Chockalingam, M. Suresh Gandhi, M and Rajamanickam, G. V. (2000) A study on the evolution of coastal landforms between Mandapam and Devipattinam, East coast of India. *Indian Journal of Geomorphologists*.(5) 1&2, 81-90

[3] Shanthi Devi,R. and Rajamanickam.G.V. (2000) Distribution of coastal landforms between the coast of Adirampattinam and Nagapattinam, Tamil Nadu. *Journal of Indian Journal of Geomorphology*.(5):.1&5:137-160.

[4] Singarasubramanian, S. R., Mukesh, M. V. and Manoharan, K. (2005) A preliminary report on coastal sediment characteristics after M 9 tsunami event along the central Tamil Nadu, east coast of India. In Book: Sumatra Tsunami on 26th December 2004, *Proc.of the Special Asia Tsunami Session at APAC, 2005 Korea, Ed* .Byung Ho Choi and F. Imamura, Hanrimwon Pub. Co. pp209-221

[5] Singarasubramanian. S. R., Mukesh. M .V, Manoharan. K. Murugan. S, Bakkiaraj. D. John Peter. A, and Seralathan, P**.** (2006): Sediment characteristics of the M 9 tsunami event between Rameswaram and Thoothukudi, Gulf of Mannar, Southeast coast of India. *Journal of Science of Tsunami Hazards*.(25):3:160-173.

[6] Singarasubramanian.S.R., Mukesh.M.V., Manoharan.K., Seralathan.P., Sujatha.K. and Bakkiaraj.D.(2009) Geomorphological and Sedimentological changes during and after the December-2004 Indian Ocean Tsunami near the Vellar river and the M.G.R. island area of the central Tamilnadu coast. International Jour. of science of Tsunami hazards. V.28 No.1. pp.67-74.