CLASSIFICATION OF TSUNAMI HAZARD ALONG THE SOUTHERN COAST OF INDIA: AN INITIATIVE TO SAFEGUARD THE COASTAL ENVIRONMENT FROM SIMILAR DEBACLE

N. Chandrasekar, S. Saravanan, J. Loveson Immanuel, M. Rajamanickam
Centre for GeoTechnology, School of Technology,
Manonmaniam Sundaranar University, Tirunelveli – 627 012, India

G.V. Rajamanickam
Department of Disaster Management, School of Civil Engineering,
SASTRA Deemed University, Thanjavur – 613 402, India

Abstract

Prevention of natural disasters is not feasible but the destruction it conveys could be minimized at least to some extent by the postulation of reliable hazard management system and consistent implementation of it. With that motive, the beaches along the study area have been classified into various zones of liability based upon their response to the tsunami surge of 26 December 2004. Thereby, the beaches which are brutally affected has been identified and the beaches which are least. Based on the seawater inundation with relative to their coastal geomorphic features, we have classified the tsunami impact along the coast and the probability of the behaviour of the beaches in case of similar havoc in future. The maximum seawater inundation recorded in the study area is 750 m as in the case of Colachel and the minimum is 100 m as in the case of Kadiapatanam, Mandakadu and Vaniakudy. Beaches like Chinnamuttom, Kanyakumari, Manakudy, Pallam and Colachel are under high risk in case of similar disaster in future and the beaches like Ovari, Perumanal, Navaladi, Rajakkamangalam, Kadiapatanam, Mandakadu, Vaniakudy, Inayam and Taingapatnam are under least viability.

1. Introduction

A Tsunami is a killer wave that brings great havoc in the coastal environment. On 26th December 2004, tectonic disturbances happened in the Java Sumatra islands with an intensity of around 9.3 in the Richter scale extend to the Southern Indian Ocean basin. One such region is south west part of India facing the Bay of Bengal and Arabian Sea. Detection of Tsunami is possible only in nearshore zone where the shoaling effect can be observed. The major destructions in this area are due to the run-up height of 3m-4m leading to erosion activities changes in the beach slope variation. The first visible indication of an approaching Tsunami is a recession of water by the through preceding an advancing wave. A rise in water level is amounted to one half the amplitude of the decreasing water level. The wave moved to shore as above with churning front. In the shallow water of bay and breaker has initiated the seizing.

26th December 2004 havoc induced more damage in the southwest coast compared to southeast coast of India. It did raise the concern of scientists and emergency planners about the impact of larger earthquake/tsunami from the Java Sumatra coast. With increased awareness of the tsunami hazard, there has been confusion about areas at risk and areas of safety. Some areas of high hazard have no evacuation planning or tsunami awareness. The hazard maps produced by this study is to improve awareness of tsunami hazards and to encourage responsible emergency planning efforts by illustrating the range of possible tsunami events based on the best currently available information.

The coastal area has been subjected to tsunami which had wrought a major impact on nearshore morphology forming a risk to any vulnerable coastline. This vulnerability leads to a long term environmental impact along the shore. The tsunamis hit the obstacles that come along their path with great ferocity and the east coast (islands) was the first obstacle which the huge tidal waves encountered, causing destruction all along. All the areas remained like deserted battlefields with broken buildings, dead bodies, carcasses of animals, uprooted trees and deserted and lone houses and huts. With increased awareness of the tsunami hazard, there has been confusion about areas at risk and areas of safety. Some areas of high hazard have no evacuation planning or tsunami education efforts. Unnecessary evacuation increases exposure to other earthquake hazards. The hazard maps produced in this paper is intended for educational purposes, to improve awareness of tsunami hazards and to encourage responsible emergency planning efforts by illustrating the range of possible tsunami events based on the best currently available information.

2. Study Area

The study area (Figure. 1) lies between Latitude of N 8^0 04' to N 8^0 17' and Longitude of E 77^0 32' to 77^0 54' E at southern and western part of the Tamilnadu State, India. It encompasses the districts of Kanyakumari and Tirunelveli. The study area is bounded by Indian Ocean in the south, Arabian Sea in the west and Bay of Bengal in the east but the main part of the coast faces the Arabian Sea with mountains and undulating valleys in the north. The study area is manifested with marine terrace, sand dunes, beach ridges, estuaries, floodplains, beaches, mangroves, peneplains, uplands, sea cliff, etc., Apart from the perennial river Thamirabharani, streams like Nambiyar, Hanuman, Palaiyar, Panniyar and Valliyar forms the major drainage system along the study area with several other creeks and brooks. Most of the beaches are erosional in nature and are enriched with workable deposits of placer minerals (Angusamy and Rajamanickam, 2000). Most of the beaches are devoid of dune and habitually espouse a steep gradient in the beach face. Coconut plantation encircles most the beaches beyond the dune. Rich growth of mangrove and salt marshes has been developed in the beaches near estuary especially in Manakudy. The continental shelf along the study area extends, generally, far away from the shoreline.

3. Materials and Methods

Beach profile survey has been performed using levelling and surveying equipments following Stack and Horizon Method speculated by La Fond and Prasada Rao (1954) which was later simplified by Emery (1961). Intense field survey has been carried out to decipher the inundation extent.

The inundation distance of the seawater has been decoded by its signature in the coastal settings and from the local people's information. Digital Elevation Model (DEM) has been projected for the study area using Surfer package.

Tsunami hazard maps has been prepared using Geographic Information System (GIS) technique – ArcGIS (9.1) based on the inundation distance with respect to the nature of the coast to show the inland extend of flooding and topography of the area.

The beaches of the study area have been classified into different zones based on their relative geomorphic features and thereby the vulnerability could be decoded based on the inundation extent with respect to the coastal geomorphic features which in turn would develop a criteria to delineate the hazard area boundaries. Accordingly, the beaches of the study area have been divided into different zones based on their geomorphic features as below

Open Coast Zone

This zone is a low-lying zone in which the coast is relatively in the lower position with reference to the MSL (Mean Sea Level), say for example, submergent coast, sandy beach, etc.,

Estuary Zone

This zone includes the coasts neighbouring a river mouth/ tidal inlet/ creek and similar other coastal features.

Upland Zone

This zone includes the coasts which are comparatively elevated well above the MSL, say for example, emergent coast, rocky coast, etc.,

Tsunami hazard area boundaries are initially defined for each zone above based on elevation and inundation distance.

We emphasize numerous sources of uncertainty in hazard delineation. The size and character of faulting in a specific event may also amplify or reduce the size of the resulting tsunami. Only recently has the impact of tsunami has been recognize in contributing to tsunami hazards. The maps are intended to improve awareness of tsunami hazards.

4. Results and Discussion

The extent of inundation has also been determined by the angle of incidence of the tsunami surge as well as its velocity. Due to the presence of Sri Lanka (Figure. 2), most of the beaches along the east coast had experienced the ‘shadow waves’ but the beaches along the west coast starting from Kanyakumari had experienced the refracted waves of comparatively high rapidity. Hence, the beaches along the east coast are under least viability to any such similar hazards in future whereas high vulnerability prevails along the west coast beaches as they are devoid of any natural blockade (Narayana et al, 2005; Raval, 2005).

Figure. 3. and Table. 1. shows the coverage of the inundated seawater during the havoc along the study area. Seawater inundation had occurred to the maximum of around 750 m in Colachel and in the beaches of Kadiapatanam, Mandakadu and Vaniakudy the inundation had not exceeded 100 m. It has been inferred that maximum inundation has occurred in the coast where there is a river mouth or an estuary as in the case of Manakudy and Colachel. The inundation proved to be ineffective along the coast where rock exposures are present as in the case of Muttom and Kadiapatanam. Though there are numerous river mouths in the east coast, inundation has not claimed vast inland because of the fact that the approached waves are of low intensity due to the obstruction rendered by Sri Lanka. Despite of the fact that the west coast beaches have experienced, comparatively, high intensity tsunami surge, the fact that most of the coastal regions beyond the backshore are well vegetated with coconut plantations and other similar coastal plant life which would have discouraged the inundation to a considerable degree as attested by the beaches of Mandakadu, Taingapatnam, etc., (Barbara Keating et al, 2004; Glenda Besana et al, 2004; Koji Minoura et al, 1994)

The inundation of seawater encouraged by the tsunami waves could not proceed for longer distance in the beaches which are elevated, comparatively, from the mean sea level (MSL) as attested by the beaches of Muttom, Kadiapatanam and Mandakadu (Chandrasekar, 2005) whereas inundation has happened to its utmost coverage in the beaches where the coast is, relatively, lower than the MSL as evident from the beaches of Manakudy and Colachel (Figure. 4. a & 4.b)

The hazard map provides the bird's eye view of the impact of the tsunami surge along the study area and it has been prepared by considering the proper procedures (Chandrasekar and Loveson Immanuel, 2005; Fumihiko Imamura, 2004; Joel Bandibas et al, 2003; Timothy Walsh et al, 2000)It is well evident from Figure. 5 and Figure. 6 that west coast beaches have been brutally affected when compared with the east coast beaches. To be specific, the north eastern beaches were least affected and so is the north western beaches which may be attributed to the fact that the impact of the tsunami surge could not dominate in those coastal regions due to the variation in the intensity of the approached tsunami surge. It has been inferred that the impact of the tsunami surge was high in the southern most part of the study area as most of the high vulnerable beaches falls on that region like Chinnamuttom, Kanyakumari, Manakudy and Pallam since they are awfully very much exposed to the refracted and diverted waves from Sri Lanka.

Colachel was the only beach to suffer maximum destruction in the northwestern coast as the inundation has been encouraged by the river mouth. There were manyother beaches neighbouring river mouth but were not much affected as Colachel and Manakudy which might be due to the fact that the bathymetry of Colachel and Manakudy and their coastal configuration along with their coastal geomorphic features have favoured much inundation there. Manakudy, due to its awful location in the southern tip of the continent facing the direction of the refracted waves from Sri Lanka along with a negative feature of estuary to facilitate the inundation had suffered utmost catastrophe. The presence of a notable promontory at Muttom had been found to acted as a safeguarding feature in screening the tsunami surge diverted and refracted from Sri Lanka and then from Kanyakumari, to the beaches northwest of Muttom.

It has been inferred that the geomorphic features had also played a vital role in the partiallity in destruction (Nobuo Shuto, 2001) and hence, the geomorphic features of the beaches were also taken into account in differentiating the tsunami hazard classification along the study area (Table 2 and 3). Based on the inundation extent with relative geomorphic features, the tsunami hazard classification map has been prepared for the study area (Figure. 5, Figure. 6 and Table.4)

This paper recognizes the complexity of tsunami hazards. Despite of the fact that tsunami could strike the coast at high velocity, the fluctuating surges of water would cause infilling and draw down bays and send volume of water miles inland along large coastal rivers. The nature of the hazard and the likely inundation impact will differ in the different types of area present along the study region.

Conclusion

From the above investigation it has been inferred that the tsunami impact is more in the beaches of low lying flat topography as in the case of Manakudy, Colachel, etc., Based upon the elevation of the coast the inundation of the seawater influenced by the tsunami had varied from few meters as in the case of Mandakadu, Kadiapatanam, Vaniakudy, Inayam, Ovari etc., to around 750 meters inland as in the case of Colachel. The High lying undulating topography have less impact during the tsunami as in the case of Muttom, Kadiapatanam, etc., Furthermore, the coastal vegetation have been found to be a reliable feature in checking the seawater inundation and they had really served as a initial line of defence in controlling the inundation as in the case of Mandakadu, Taingapatanam, etc.,

It is well evident from the field observation that the river mouths and estuaries may facilitate the inundation of seawater under certain critical circumstances as attested by the beaches of Manakudy and Colachel.

The hazard map thus prepared bestow a panoramic view of the impact induced by the tsunami surge and the response of the respective beaches to the unexpected hazard. It exposes the beaches which are severely affected, thereby providing some probable clues for their destruction. The hazard map urges the need of proper coastal hazard management programme and would definitely serve as a guide to initiate the hazard management system as it shows clearly the beaches where immediate action should be taken and the beaches which need consistent disaster management measures.

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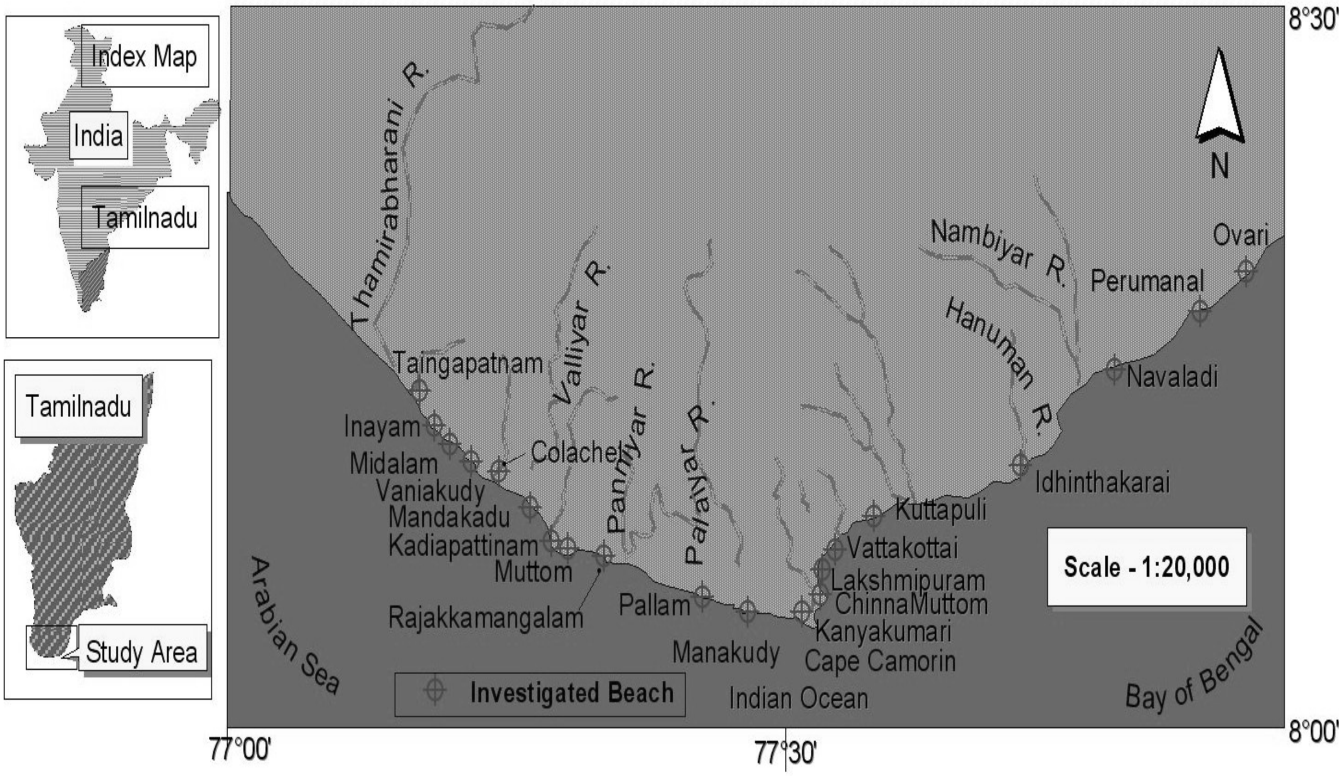

Figure. 1. Location map of the study area

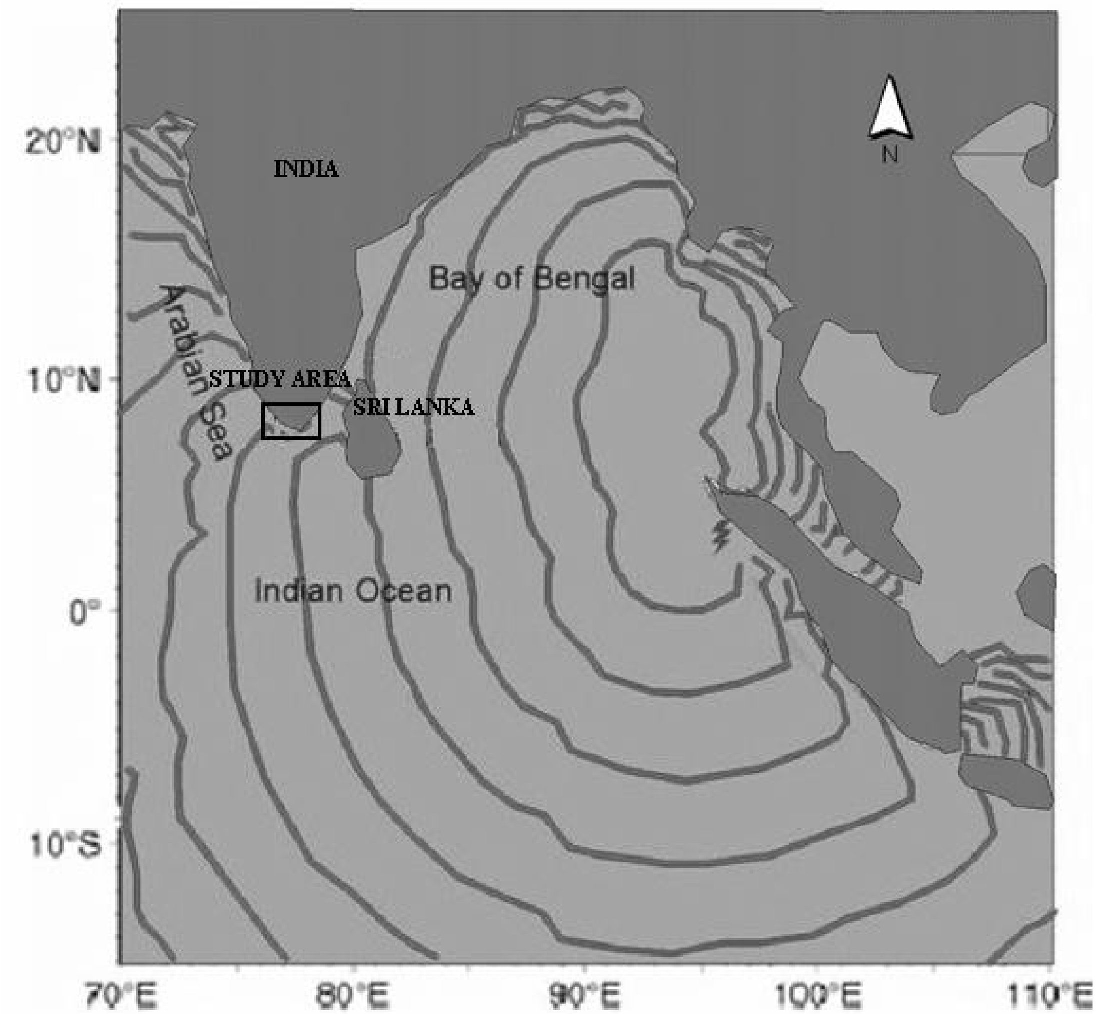

Figure. 2. Nature and Angle of Incidence of the Tsunami Surge Approached the Study Area

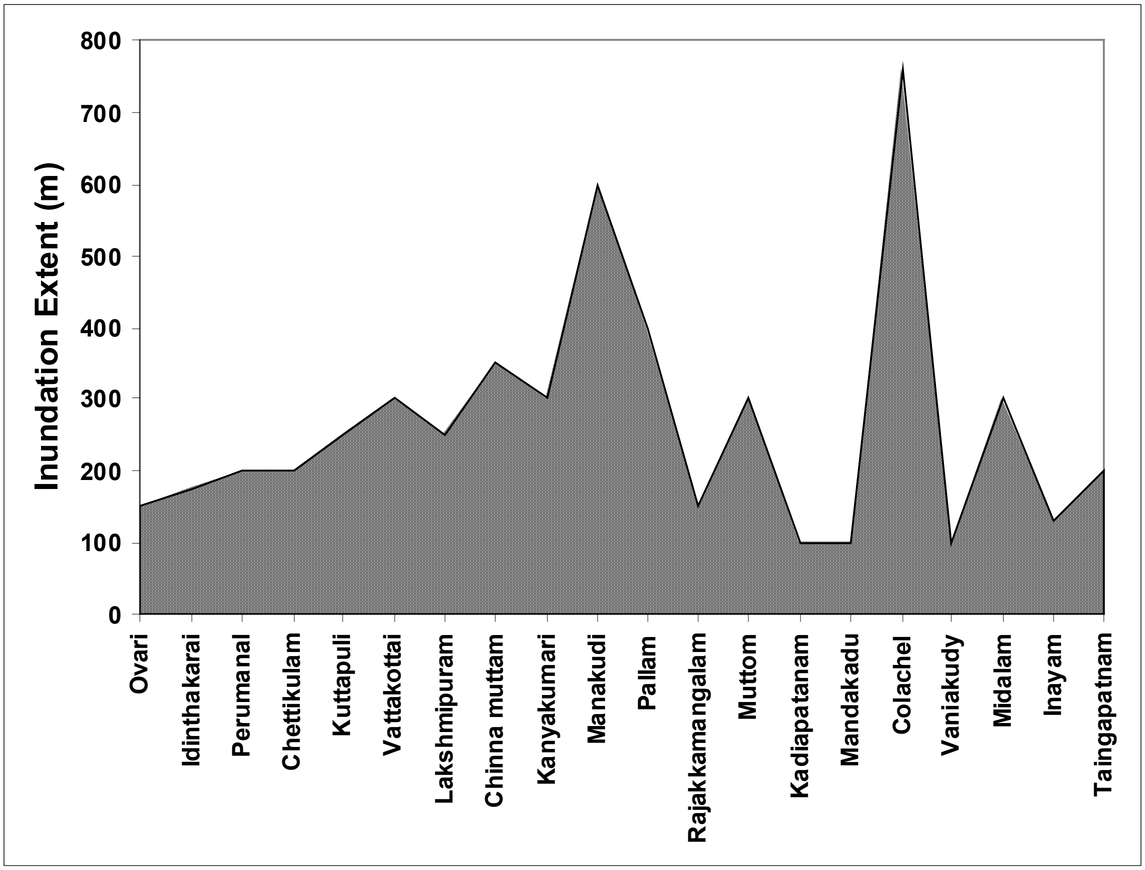

Figure. 3. Inundation Distance Limit along the Study Area

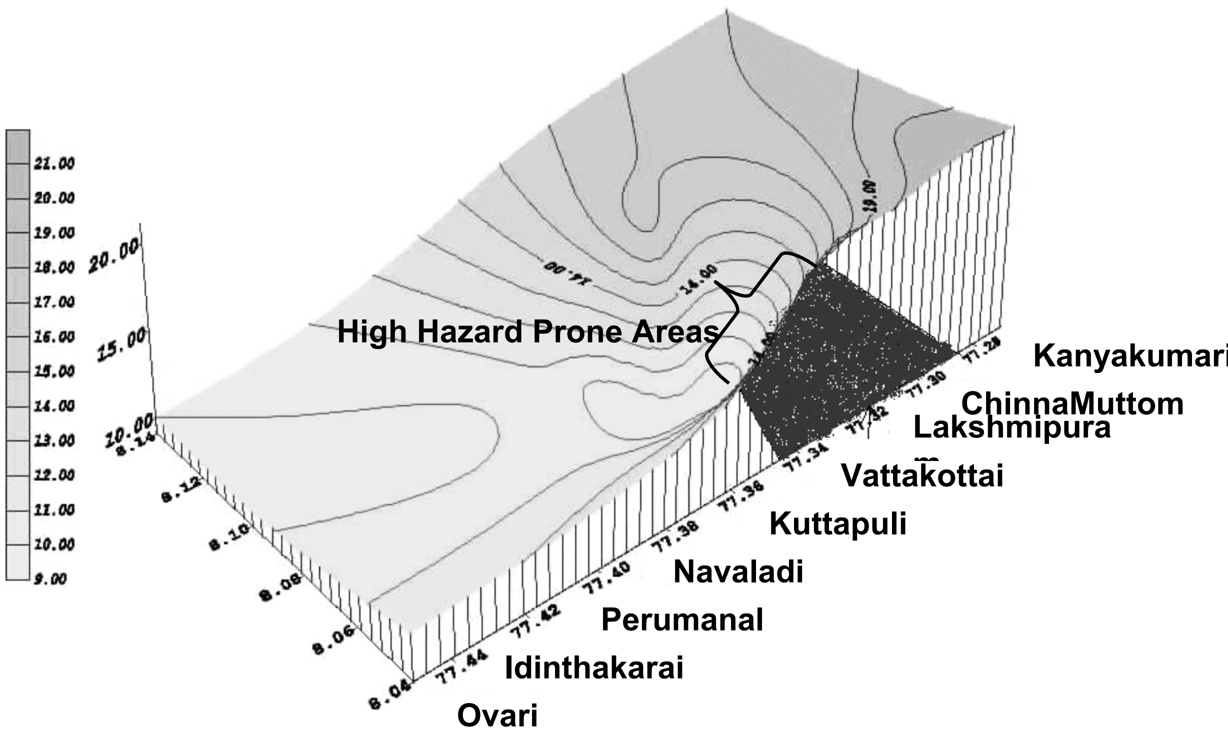

Figure. 4. a. Digital Elevation Model (DEM) from Ovari to Kanyakumari

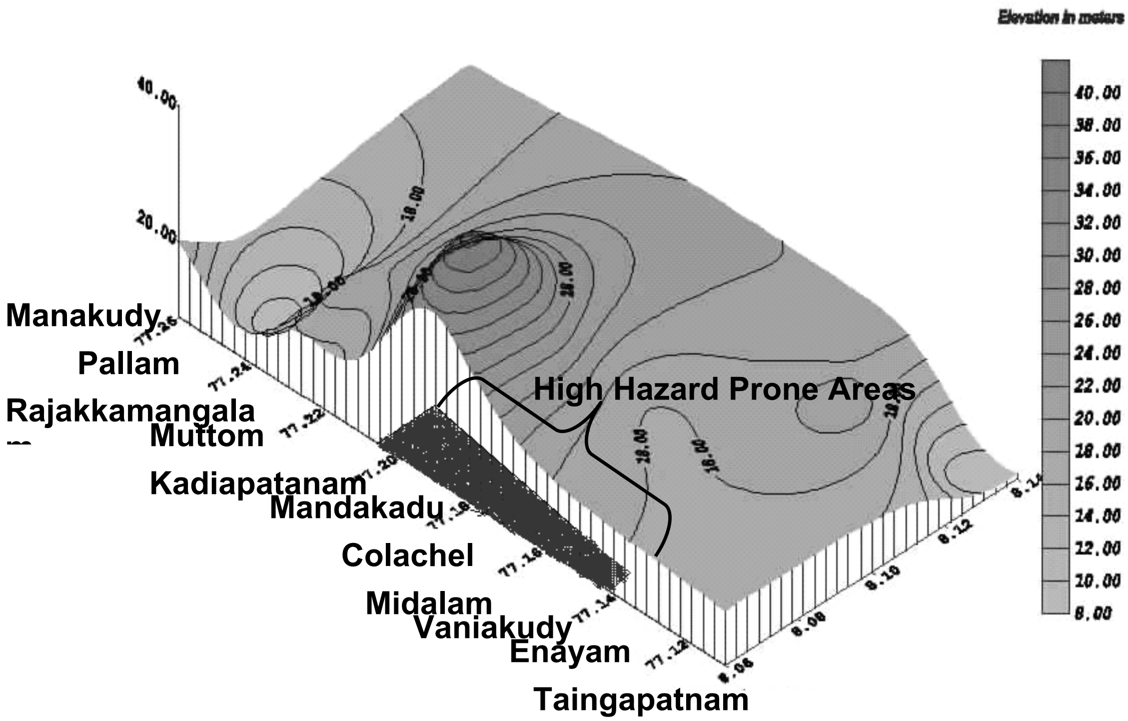

Figure. 4. b. Digital Elevation Model (DEM) from Manakudy to Taingapatnam

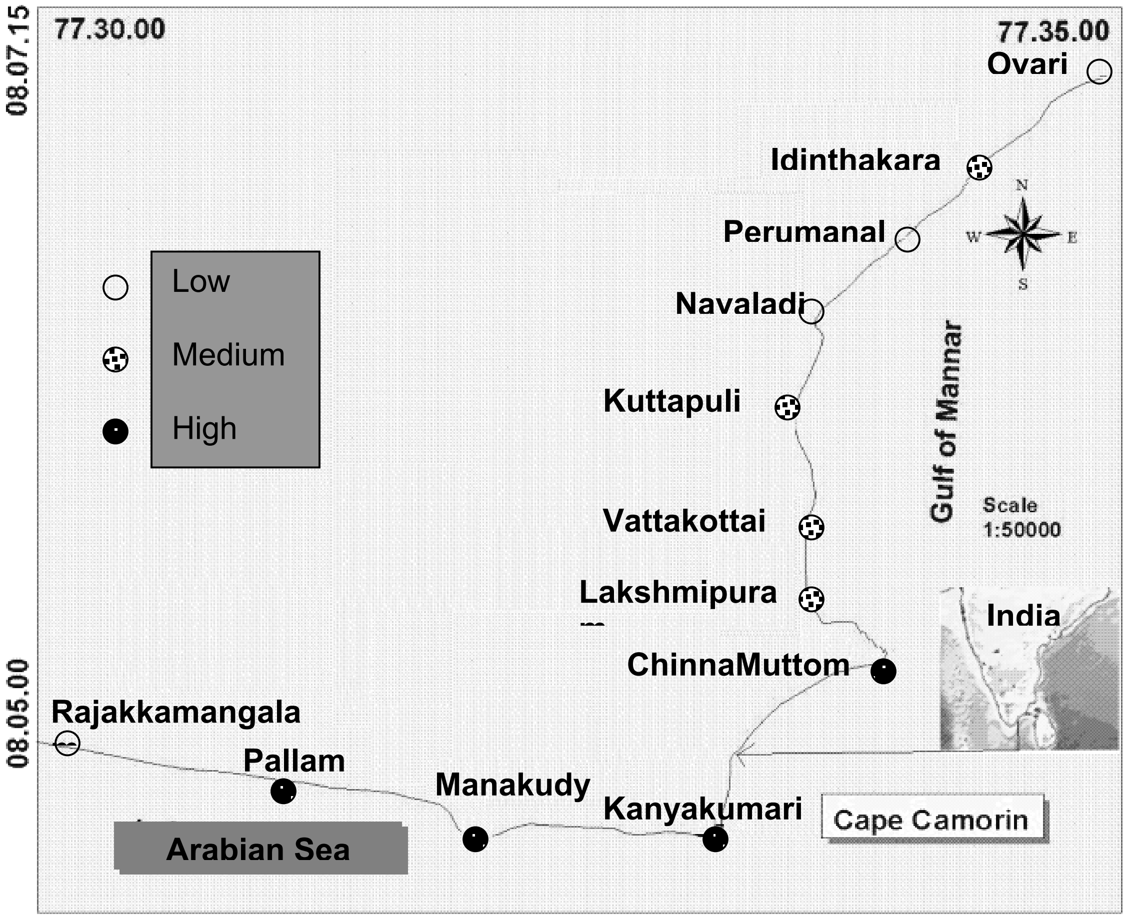

Figure.5.a. Tsunami Hazard Classification Map for Ovari to Rajakkamangalam

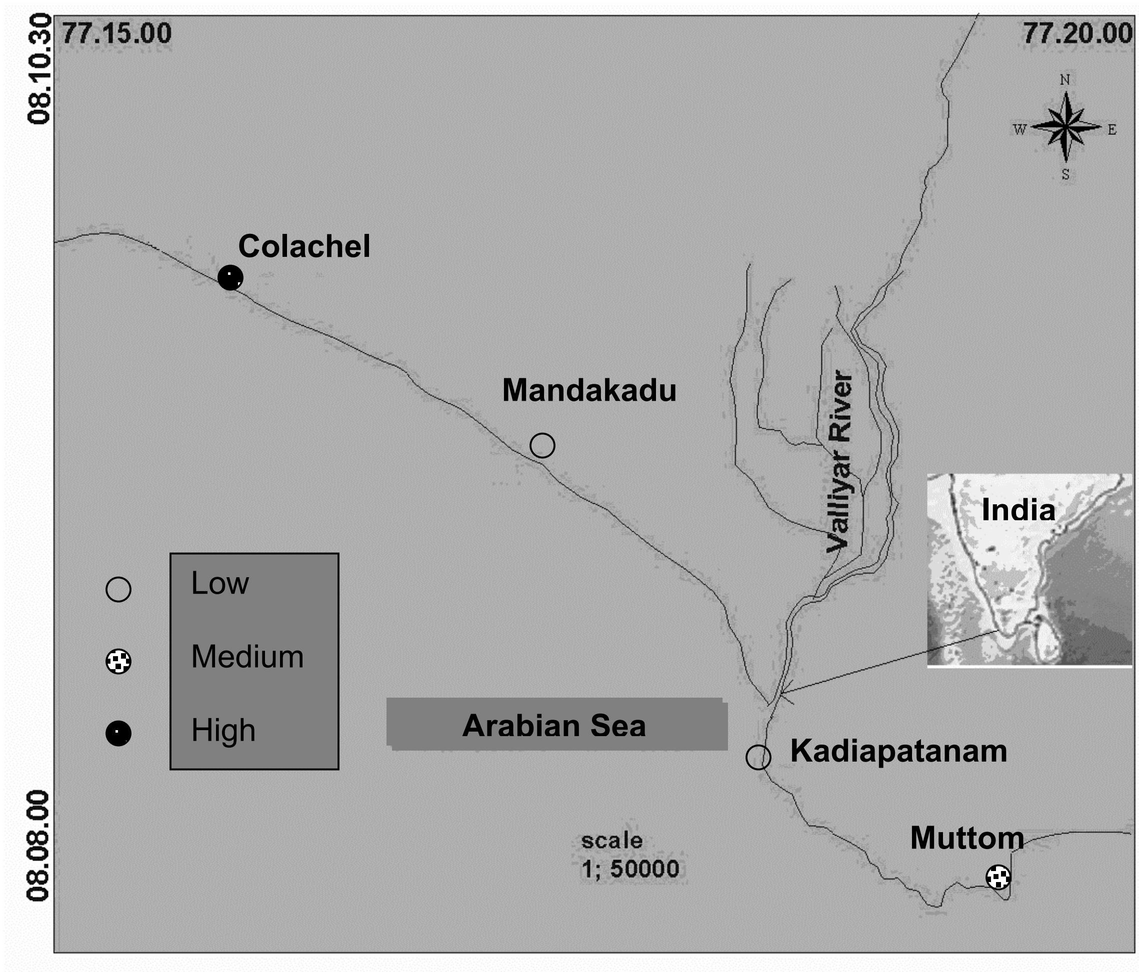

Figure.5.b. Tsunami Hazard Classification Map for Muttom to Colachel

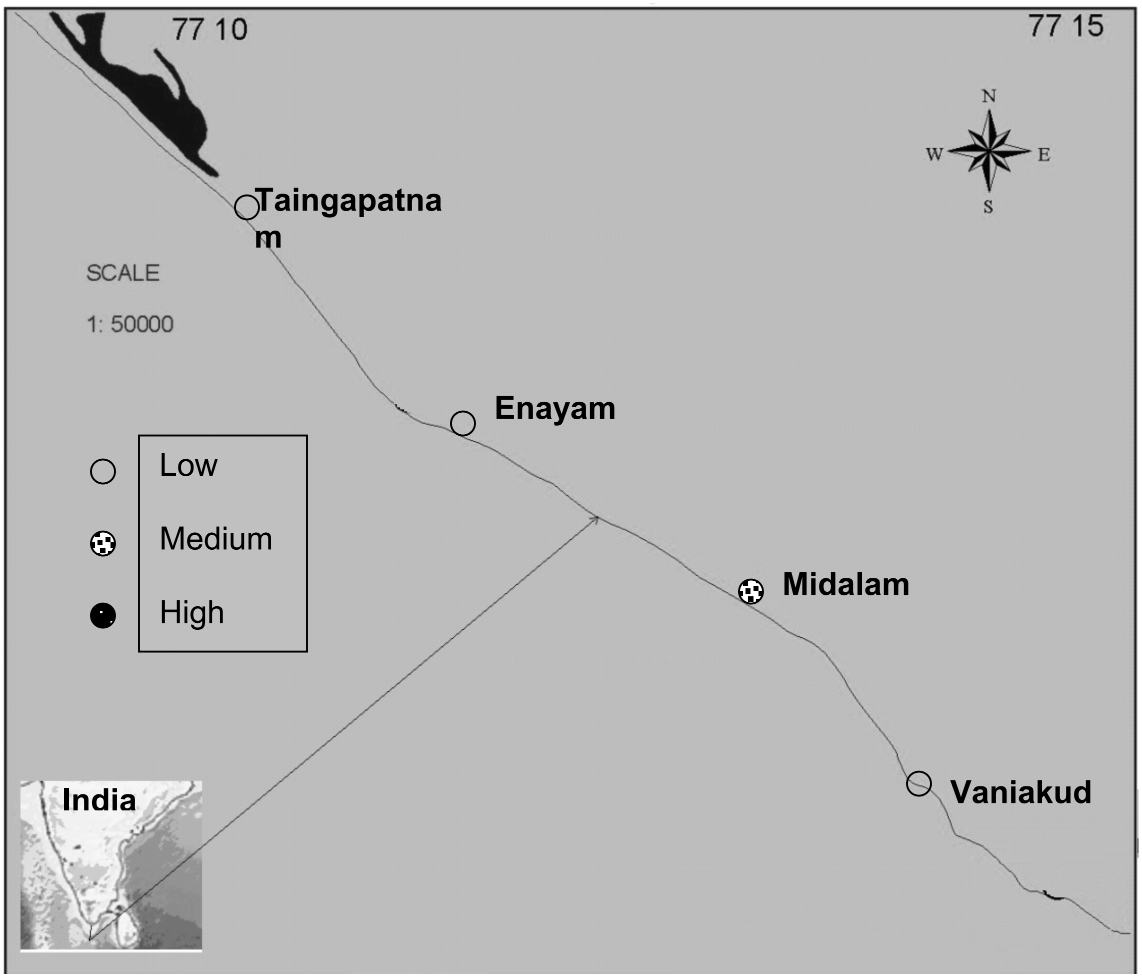

Figure.5. c. Tsunami Hazard Classification Map for Vaniakudy to Taingapatnam

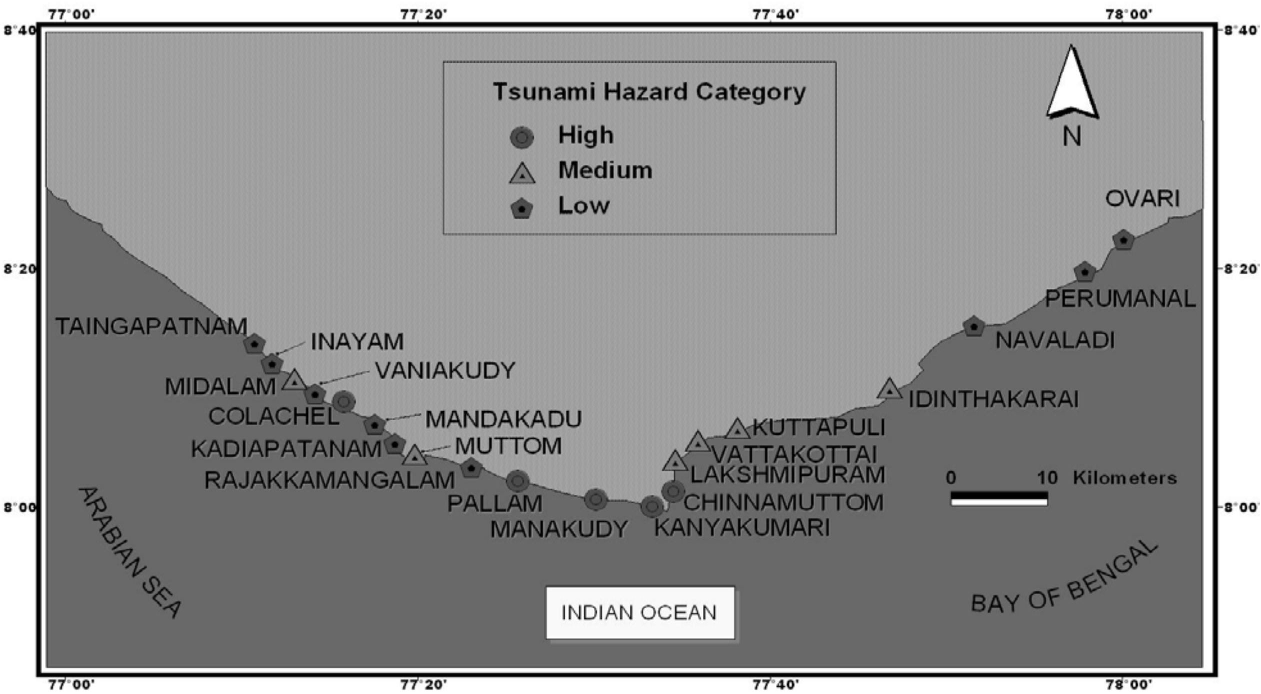

Figure.6. Integrated Tsunami Hazard Classification Map of the Study Area

Table 1. Inundation Distance Extent along the Study area

Location	Longitude	Latitude	Elevation (m)	Inundation distance (m)
Ovari	77.49	8.17	19	150
Idinthakarai	77.45	8.14	18	175
Perumanal	77.39	8.09	17	200
Navaladi	77.37	8.08	16	200
Kuttapuli	77.36	8.08	16	250
Vattakottai	77.34	8.07	15	300
Lakshmipuram	77.34	8.07	16	250
Chinna muttam	77.34	8.06	17	350
Kanyakumari	77.33	8.04	21	300
Keelamanakudi	77.29	8.05	09	600
Pallam	77.25	8.05	14	400
Rajakkamangalam	77. 22	8.06	16	150
Muttom	77.19	8.07	11	200
Kadiapatanam	77.18	8.08	14	100
Mandakadu	77.16	8.09	16	100
Colachel	77.15	8.1	12	750
Vaniakudy	77.14	8.11	16	100
Midalam	77.12	8.12	17	300
Enayam	77.09	8.13	15	130
Taingapatnam	77.1	8.14	14	200

Table. 2. Description of Beaches based on their Geomorphic features

Description	Beach
Upland Zone	Chinna Muttom, Kanyakumari, Muttom.
Open Coast Zone	Ovari, Idinthakarai, Kuttapuli, Vattakottai Lakshimipuram, Pallam, Mandaikadu, Vaniakudy, Midalam, Enayam.
Estuary zone	Perumanal, Manakudy, Rajakkamangalam, Kadiapattinam, Colachel, Taingapatnam,

Table. 3. Criteria of Tsunami Hazard Classification

Classification of Coast	Description of the Coast	Tsunami Hazard Category (Based on Inundation Extent (in M))		
		High	Medium	Low
Open Coast Zone	Relatively in the lower position with reference to the MSL	301 – 400	201 – 300	0 – 200

Estuary Zone	Coasts neighbouring a river mouth/ tidal inlet/ creek and similar other coastal features	501 – 750	251 – 500	0 - 250
Upland Zone	Coasts which are comparatively elevated well above the MSL	201 – 300	101 - 200	0 - 100

Table. 4. Tsunami Hazard Classification of the Study Area

Sl. No.	Tsunami Hazard Category	Beach Coinciding with the Respective Category
1.	Low	Ovari, Perumanal, Navaladi, Rajakkamangalam, Kadiapatanam, Mandakadu, Vaniakudy, Enayam, Taingapatnam
2	Medium	Idinthakarai, Kuttapuli, Vattakottai, Lakshmipuram, ChinnaMuttom, Midalam
3	High	Kanyakumari, Manakudy, Muttom, Pallam, Colachel

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