Disaster Risk Assessment of Tsunami on the Indian Coast Line and plan for Mitigation

A THESIS

Submitted by

V.K.Sri Rangarajan

R107213018

In partial fulfilment for the award of the degree of

MASTER OF TECHNOLOGY IN

Disaster Management

DEPARTMENT OF HEALTH, SAFETY & ENVIRONMENT

UNIVERISITY OF PETROLEUM & ENERGY STUDIES

DEHRADUN

APRIL 2015

BONAFIDE CERTIFICATE

Certified that this Thesis titled "**Disaster Risk Assessment of Tsunami on the Indian Coast Line and plan for Mitigation"** is the bonafide work of **Mr. V.K.Sri Rangarajan (Roll No. R107213018)** who carried out the work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

Dr.Nihal Anwar Siddiqui

Head of Department

Department of HSE

UPES, Dehradun

Mr.Dharani Kumar

Assistant Professor

Department of HSE

UPES, Dehradun

ACKNOWLEDGEMENT

I feel very pleased to acknowledge that I have completed my Project Work from **IIRS-ISRO.** I am very thankful to the Assistant Professor of Health and Safety Department of University of Petroleum and Energy Studies, **Mr.Dharani Kumar** for providing me support & guidance throughout the project work.

I was with IIRS for the past 3 months and this project work was an opportunity to observe the organization more closely. It was a great pleasure to be with the organization & learn about its culture, practices, people, processes & safety activities.

I would like to extend my indebtedness to **Miss. Manu Mehta**, for providing me with the support to do project at IIRS.

I really feel very pleased to take this opportunity to thank **Miss Manu Mehta** my Project head/guide, for provided me with the wonderful and stimulating environment to work in and devoting his valuable time in helping me and guiding me. His suggestions helped me in adding new dimensions to my knowledge and have always inspired me for the successful completion of the project.

In the end I would like to thank all the employees of IIRS and all my friends, for their friendly gestures and for giving me the valuable assets of their knowledge and experience. Without their presence I would not have been able to successfully complete my training in such an esteemed organization.

Date: **14th JULY 2014** Roll No. R107213018

V.K.Sri RangaRajan Sem-IV

ABSTRACT

Satellite data can be used to assess the disaster extent and plan relief operations during disaster and plan mitigation operations to prevent future catastrophes. Tsunami is a special category wave which is very dangerous and devastating to the coastal. It is difficult to predict the tsunami occurrence and its return period along with the earth quakes that produces it. Hence it is necessary to be prepared for the worst case scenario in highly hazardous zones for a peninsula like India the hazard for tsunami is always present. The stud[y focuses on how the Indian coast line should be mitigated to prevent catastrophes from tsunamis. The study focuses on an earthquake occurrence in "Indian plate" region and hazard assessment is performed based on the factors like cities, power plant, ports & rescue capability unlike traditional methods. The study incorporates the data of major ports, cities, power plants etc. and their location. Assessment of risk and rescue capabilities is performed based on the rescue capability of a region and the hazards that are present .Highly hazards areas are identified and mitigation measures are calculated based on the requirement. A special care is taken to deceive mitigation project as a matter of attraction.

KEYWORDS: Disaster, Tsunami, Mitigation, Indian coast lines, Remote sensing

Table of Contents

List of Tables

1 INTRODUCTION

India is a unique country with multi-cultural heritage. It's also highly vulnerable to disasters costing about 2% of GDP on an average, when compared to the total area of the land [1]. Table 1 illustrates the risk of disasters in India and Table 2 lists the disasters that occurred in India in past decade.

Table 1.1: Risk of Disaster in India

Type of Disaster	Area Prone	Percentage of area
Earth quakes	-	58.6
Floods	40 million hectors	12
Cyclones & Tsunami	5,700 km	75% coast line
Drought	-	68% of Cultivable land

Table 1.2: Disasters in India during past decade

S.No.	Name of Event	Year	State & Area
1.	Sikkim Earthquake	2011	North Eastern India with epicenter near Nepal Border and Sikkim
2.	Cloudburst	2010	Leh, Ladakh in J&K
3.	Drought	2009	252 Districts in 10 States
4.	Floods	2009	Andhra Pradesh, Karnataka, Orissa, Kerala, Delhi, Maharashtra
5.	Kosi Floods	2008	North Bihar
6.	Cyclone Nisha	2008	Tamil Nadu
7.	Maharashtra Floods	2005	Maharashtra State
8.	Kashmir	2005	Mostly Pakistan, Partially Kashmir
9.	Tsunami	2004	Coastline of Tamil Nadu, Kerala, Andhra Pradesh, Pondicherry and Andaman and Nicobar Islands of India

Remote sensing data can offer great help for disaster assessment & its mitigation. The satellite data can provide accurate information of pre and post disaster scenarios that can help in rescue and relief operations as well as capacity building for planning. Even during the planning stage, the remote sensing data can be utilized to issue warning for slow onset disaster and calculate the impact level for disasters like drought using agricultural index and issue cyclone warning and predict its landfall time in an area.

After 2004 Tsunami many studies are performed for tsunami risk assessment using traditional methods like Scenario-based Tsunami Hazard Analysis (STHA) and Probabilistic Tsunami Hazard Analysis (PTHA) The risk assessment are performed by various agencies and organization for some parts of India. The major gap in the field of disaster management is the update of knowledge and application of newer methodologies. The return period of tsunami is uncertain and the earth quake that produces tsunamis are difficult to identify. Hence many plans are based on the two methods which checks the probability of an incident may fail to identify the hazards that are actually present in it. The beast example to quote is Fukushima-Daichi incident where the tsunami counter measures are done in 1960 [3]. Unlike the traditional methods the study focuses a new method of assessing the risk of a given area. It doesn't consider the probability of a disaster but assumes the worst case scenario if the ingredients for a disaster is present. Later the risk is calculated based on population, ports, power plants etc. along with the rescue capability for an area. By this method we can be sure to survive a disaster no matter when it occurs.

1.1 Common Type of Disasters in India:-

High Power Committee on Disaster Management identified 31 types of disasters. Tsunami has been added in 2005 in this list.

Table 1.3 :List of various disasters

Water and Climate related disasters	a) Floods and drainage management b) Cyclones c) Tornadoes and Hurricanes d) Hailstorms e) Cloud burst f) Heat wave and Cold wave g) Snow avalanches h) Droughts i) Sea erosion j) Thunder and lighting k) Tsunami
Geological related disasters	Landslides and mudflows Earthquakes Dam failure/Dam bursts Mine disasters
Chemical, industrial	a) Chemical and industrial disasters

and nuclear related disasters	b) Nuclear disasters
Accident related disasters	Forest fires Urban fires Mine flooding Oil spills Major building collapse Serial bomb blasts Festival related disasters Electrical disasters and fires Air, road and rail accidents Boat Capsizing Village fire
Biological related disasters	a) Biological disasters and epidemics b) Pest attacks c) Cattle epidemics d) Food poisoning

1.2 Tsunami

A tsunami (in Japanese „tsu" means harbor and „nami" means wave) is a series of water waves caused by the displacement of a large volume of a body of water, usually an ocean. In the

Tamil language it is known as "Aazhi Peralai". Seismicity generated tsunamis are result of abrupt deformation of sea floor resulting vertical displacement of the overlying water. Earthquakes occurring beneath the sea level, the water above the reformed area is displaced from its equilibrium position. The release of energy produces tsunami waves which have small amplitude but a very long wavelength (often hundreds of kilometer long). It may be caused by non-seismic event also such as a landslide or impact of a meteor.

1.3 Historical Tsunamis in India

Tsunami Sources for India

For a tsunami to hit Indian coast, it is necessary that earthquake of magnitude > 7 should occur.

Two such possible zones are

- Andaman-Sumatra
- Makran

Historical Tsunamis in India

- 12 Apr, 1762 (Earthquake in Bay of Bengal)
- 31 Dec, 1881 (Car Nicobar Earthquake)
- 27 Aug, 1883 (Eruption of Karkatoa volcano (Sunda Strait) Indonesia)
- 26 Jun, 1941 (Andaman Earthquake)
- 27 Nov, 1945 (Makran Earthquake)
- 26 Dec, 2004 (Sumatra Earthquake)

December 2004: Tsunami in Indian Ocean

The Tsunami of 26th December 2004 caused extensive damage to life and property in the states of Tamil Nadu, Kerala, Andhra Pradesh, UTs of Puducherry and Andman & Nicobar Islands (A & NI). The Tsunami disaster had badly affected the fishermen community who not only lost their near and dear ones but also lost their means of livelihood. A population of 26.63 lakhs in 1396 villages in five states and UTs was affected by this disaster. Almost 9395 people lost their lives and 3964 people were reported missing and feared dead. Most of the missing persons were from Andaman & Nicobar Islands.

1.4 State Profiles

Gujarath

Area	**1,96,024 sq km**
Coastal Area	Over 1600 kms. One third of the coastal length of India.
Population	Gandhinagar

Maharastra

Area	3,07,713 sq. km
Coastal Area	720 kilometers.
Population	11.24 crore

Karnataka

Area	1,91,791 sq.km
Coastal Area	322 kms
Population	611 lakhs

Kerala

Area	38,863 sq. km.
Coastal Area	580 kms
Population	3,34,06,061

Tamilnadu

Area	1,30,058 sq km
Coastal Area	1000 Km
Population	72138958

Andhra Pradesh

Area	2,76,754 sq.km
Coastal Area	972 km
Population	762.1 lakhs

Odisha

Area	155,707
Coastal Area	480km
Population	4,19,47,358

2 AIM OF THE PROJECT

The aim of the project is to identify the risk of tsunami in the Indian coast line.

Mapping of all the coast line based in risk assessment and identify new methodology in assessing the risk.

Identifying different mitigation measures and evaluation the same.

2.1 Motivation

The main reason for this project is that till 2004 December there is no tsunami hazard in India but after2004 India faces a new threat in the form of tsunami even after a decade India is still lacking in mitigation of tsunami.

As a disaster management professional I am interested in this topic and took it to create a new approach to mitigation

3 Tsunami Hazard in India

3.1 Some Historical Tsunamis

Prior to the Tsunami of 26 December 2004, the most destructive Pacific-wide Tsunami of recent history was generated along the coast of Chile on May 22, 1960. No accurate assessment of the damage and deaths attributable to this Tsunami along the coast of Chile can be given; however, all coastal towns between the 36th and 44th S (latitude) parallels either were destroyed or heavily damaged by the action of the waves and the quake. The combined Tsunami and earthquake toll included 2,000 killed, 3000 injured 2,000,000 homeless and $550 million damages. Off Corral, the waves were estimated to be 20.4 meters (67 feet) high. The Tsunami caused 61 deaths in Hawaii, 20 in the Philippines, and 100 or more in Japan. Estimated damages were $50 million in Japan, $24 million Hawaii and several millions along the west coast of the United States and Canada. Wave heights varied from slight oscillations in some areas to range of 12.2 meters (40 feet) at Pitcairn Islands; 10.7 meters (35 feet) at Hilo, Hawaii and 6.1 meters (20 feet) at various places in Japan.

The hydrographic survey in Japan after the great Kwato earthquake of September 1, 1923 showed that vertical displacements of the order of 100 meters had occurred over a large area of sea floor. Tsunamis are very common in the Pacific Ocean because it is surrounded on all sides by a seismically active belt. In the Hawain Islands, Tsunamis approach from all directions, namely, from Japan, the Aleutian Islands and from South America.

3.2 Tsunamis in India

The Indian coastal belt has not recorded many severe tsunamis in the past. Waves accompanying earthquake activity have been reported over the North Bay of Bengal. During an earthquake in 1881 which had its epicenter near the Andamans in the Bay of Bengal, tsunamis were reported. The earthquake of 1941 in Bay of Bengal caused some damage in Andaman region. This was unusual because most Tsunamis are generated by shocks which occur at or near the flanks of continental slopes. During the earthquakes of 1819 and 1845 near the Rann of Kutch, there were rapid movements of water into the sea. There is no mention of waves resulting from these earthquakes along the coast adjacent to the Arabian sea, and it is unlikely that Tsunamis were generated. Further west, in the Persian Gulf, the 1945 Mekran earthquake (magnitude 8.1) generated Tsunami of 12 to 15 metres height. This caused a huge deluge, with considerable loss of life and property at Ormara and Pasi. The estimated height of Tsunami at Gulf of Kutchch was 15m but no report of damage is available. The estimated height of waves was about 2 metres at Mumbai, where boats were taken away from their moorings and casualties occurred. A list showing the Tsunami that affected Indian coast in the past is given in Table-3.2. The information given in the Table for the first three events is sketchy and authenticity cannot be confirmed except the Tsunami of 26th December 2004.

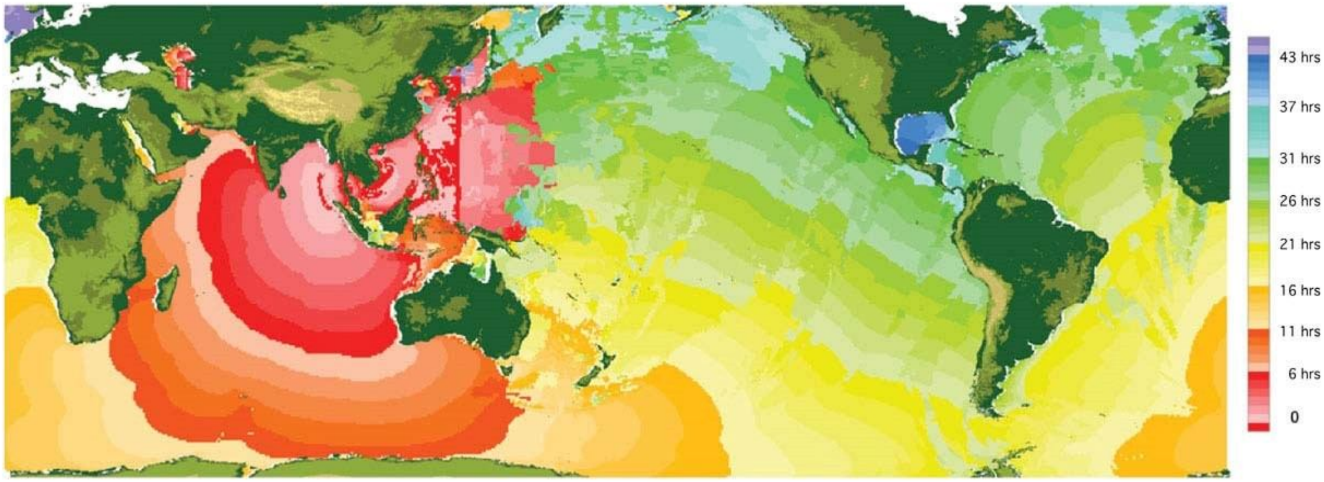
Above facts indicate the coastal region of Gujarat is vulnerable to Tsunamis from great earthquakes in Mekran coast. Earthquake of magnitude 7 or more may be dangerous. It may be noted that all earthquake do not generate Tsunami. Research is still being undertaken in this field. For the Indian region, two potential sources have been identified, namely Mekran coast and Andaman to Sumatra region.

Model generated Travel time of 26th December Tsunami is shown in Fig 3.1. Fig. 3.2 indicates the wave heights generated by the model which show the wave heights in Indian coast could have been between 2-4 meter. (Actual on some coasts was observed more than 4m)

Table -3.1 A Global List of Some Historical Tsunami Deaths

Year	**Place**	**Number of Lives lost**
1692	Port Royal, Jamaica	3000
1703	Tsunamis in Honshu, Japan following a large earthquake	5000
1707	38 foot Tsunami, Japan	30,000
1741	Following Volcanic eruptions 30 feet wave in Japan	1400
1753	Combine effect of an earthquake and Tsunami in Lisbon,	50,000

	Portugal	
1783	A Tsunami in Italy	30,000
1868	Tsunami Chile and Hawaii	More than 25000
1883	Krakatoa Volcanic explosion and Tsunami Indonesia	36,000
1896	Tsunami Sanrika , Japan	27,000
1933	Tsunami, Sanrika Japan	3000
1946	32 foot high waves in Hilo, Hawaii	159
22 May, 1960	Along the coast of Chille	Approx. 2000 (+ 3000 person missing).
1946	Honsu, Japan Earthquake Spawan Tsunami	2000
1964	195 foot waves engulf Kodiak, Alaska after the Good Friday Earthquake	131
17 Aug. 1976	Philippines	8000
19 Aug. 1977	Indonesia	189
18 July 1979	Indonesia	540
12 Sept. 1979	New Guinea	100
12 Dec. 1979	Columbia	500
26 May 1983	Sea of Japan	Approx. 100
1998	Papua New Guinea	



Tsunami Research Program
NOAA OAR Pacific Marine Environmental Laboratory
Seattle, Washington (Credit NOAA)

Fig.3.1:- Arrival time of first waves (sec) – 2004 12 26 Indian Ocean Tsunami Simulation

Table 3.2 List of Tsunami that Affected India

S.No	Date	Remarks
1	April 12, 1762	Eq. in the Bay of Bengal generated tsunami wave of 1.8 m in coastal Bangladesh
2	August 19, 1868	Earthquake Mw 7.5 in the Bay of Bangal. Tsunami wave run-up level at Port Blair, Andaman Island 4.0 m.
3	December 31, 1881	Earthquake of magnitude Ms 7.9 in the Bay of Bangal, reported tsunami run-up level of 0.76m at Car Nicobar, 0.3m at Dublat , 0.3 m at Nagapattinam and 1.22 m at Port Blair in Andaman Island
4	1883	Karakatau, volcanic explosion in Indonessia. 1.5 m tsunami at Chennai, 0.6 m at Nagapattinam.
5	1884	Earthquake in the western part of the Bay of Bengal. Tsnamis at Port Blair & mouth of Hoogly River
6	June 26, 1941	Earthquake of magnitude MW 8.1 in the Andaman Sea at 12.9^0 N,92.5^o E. Tsunamis on the east coast of India with amplitudes from 0.75 to 1.25 m. Some damage from East Coast was reported.
7	November 27, 1945	Mekran Earthquake (Magnitude Ms 8.3). 12 to 15 M wave height in Ormara, 13 m at Pasni, and 1.37 m at Karachi (Pakistan) . In Gulf off Cambay of Gujarat wave heights of 11.0 m was estimated, and 2 m at Mumbai, where boats were taken away from their moorings.

8	December 26, 2004	An earthquake of rear Magnitude (M_W9.3) generated giant tsunami waves in North Indian Ocean. Tsunmai made extensive damage to many coastal areas of Indonesia, India, Malaysia, Maldives, Srilanka and Thailand. A trans-oceanic tsunami, observed over areas beyond the Ocean limit of origin. More than 2,00,000 people lost their lives in above countries which is a record.

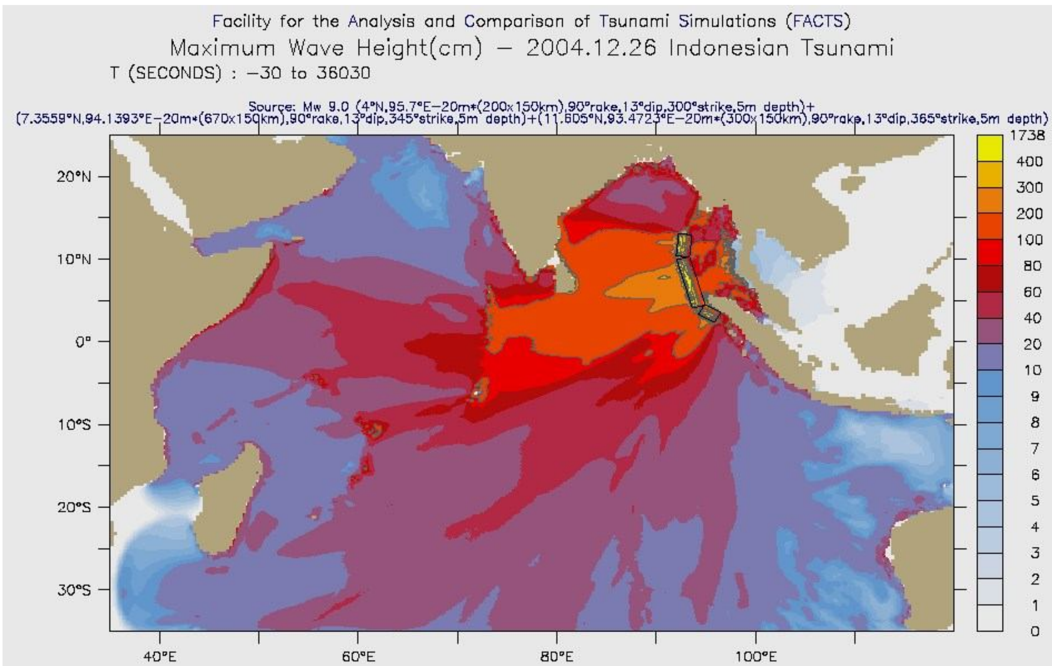


Fig 3.2: Maximum Wave Height (cm) – 2004.12.26, Indonesian Tsunami

3.3 Tsunami risk

It will be assessed by a deterministic approach according to the following:

TSUNAMI RISK = TSUNAMI HAZARD **.** EXPOSURE **.** VULNERABILITY.

(a) For the Tsunami Hazard assessment:

- Preparation of data-base of historical and archival information (newspapers, archives, anecdotal information, literature survey) of relevant Indian Tsunamis, with the emphasis clearly on the December 26, 2004 event.
- Supplement the data from computer based simulations.
- Analyses of these data, to

-define the scenario Tsunamis from various earthquake sources -prepare the Tsunami hazard map.

(b) For the Exposure

- List all habitations below 10 m contour level and locate on a map.

- List and locate all vital installations below 10 m contour level (Ports, Harbours, Schools, Hospitals, Power Plants, Bridges, etc.)

(c) For the VULNERABILITY assessment:

- Based on the earthquake vulnerability assessment, define the vulnerability of various exposed elements on the coastal, island and reef environments and in the Ports and Harbours

- Prepare vulnerability maps (based on Remote Sensing, Geographical information system and other data related to various hazards). *(d) For the RISK assessment:*

- Integrate these hazard and exposure data with vulnerability assessments to obtain the risk assessment.

3.4 ***Scenario Tsunami*** The following parameters will need to be defined:

- *Tsunami source region:*

- *Mode of generation:*

- *Potential wave heights*

- *Maximum Run-up* (maximum height of the water onshore observed/inferred above the mean sea level. Usually measured at the horizontal inundation limit)

- *Tsunami intensity* I=0.5 log 2H (Pelinovsky, 1996) with H = average maximum run-up height >3 m. Imax = 2.5

3.5 Tsunami Hazard Map

The Tsunami hazard map may be empirically defined using a deterministic approach, based upon potential maximum wave heights for the scenario tsunamis. Where found applicable, Remote Sensing and Geographical Information system may be used. The definition of the tsunami hazard zones, as preliminary estimates, is given in Table 3.3. For the terrestrial environment the hazard may be presented as inundation levels, in terms of run-up heights at specified land contours. For the marine environment ("ON WATER") Harbour, Bay and Reefs – hazard may be given in terms of potential maximum wave heights.

CHARACTERISTIC	TSUNAMI HAZARD ZONE		
	HI	MED	LO
ON LAND INUNDATION LEVEL-MAXIMUM (m CONTOUR)	>5	3-5	1-3
RUN-UP HEIGHT –AVERAGE (m)	>3	1-3	0-1
TSUNAMI INTENSITY (I)	>2	1-2	0
LIKLIHOOD OF TSUNAMI	Yes	Yes	Possible
DAMAGE OBSERVED IN EARLIER TSUNAMI	Severe	Minor	None
COAST ADJACENT TO TSUNAMI GENIC SOURCE	Yes	Yes	No
ON WATER WAVE HEIGHTS (m)	>2	1-2	<1
REEF DAMAGE	Severe	Minor	None

Table 3.3: Tsunami Hazard Zones Definition (Preliminary)

3.6 Tsunami Vulnerability Assessment

The exposure inventory with vulnerability to tsunami impact for both the built and natural environments will need to be developed for shores and Harbours. Potential damage is related to the hydrological controls of wave action (surging), flooding and debris deposition, and consequent geotechnical controls to damage by liquefaction, cracking and slumping. These result in structural damage to buildings, water damage to contents, flooding damage to infrastructure (roads, bridges, water supply, sewerage, wharves, sea-walls), damage to navigational aids and reef damage. There is the potential for "seiching" in the shallow harbour areas where, alternately (from the tsunami waves), water is drained from the harbour and then flooded to depths greater than high tide levels. This has the potential for threat to human life (death and injury) from people collecting fish from the harbour seafloor. In the Harbour, waves are a threat to shipping (sinking, striking wharves) and fishermen (drownings).

The vulnerability assessment is expressed as details of elements of the built, natural and human environments vulnerable to potential tsunami-related damage. These need to be considered in terms of the Tsunami Hazard Zones for the terrestrial environments around the shores and the marine environments.

3.7 Tsunami Risk Assessment

By integrating the hazard and vulnerability assessments, the tsunami risk assessment is to be developed in terms of zonation and inundation maps and associated affects.

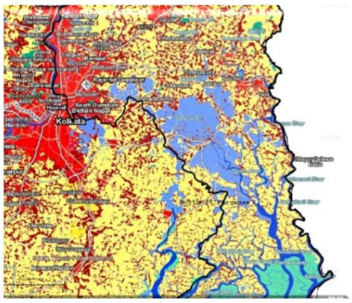
3.8 Practical Applications

The key factors to reduce potential losses due to tsunami are AWARENESS and PREPAREDNESS. The practical applications of this tsunami risk assessment, in both quantitative and qualitative terms, for implementation into mitigation strategies for the terrestrial and marine environments include:

1	Building Codes	(potential damage due to wave action and flooding)
2.	GIS Mapping	
3.	Land-Use Planning	(taking note of wave action & flooding)
4.	Disaster Planning	(in identified hazard zones)
5.	Emergency Management	
6.	Emergency Personnel Training	(necessary aspects relevant to marine situations)
7.	Rescue and Response (marine situations related to shipping)	(cargo, tourist, inter-islands fishing community, recreational boating)
8.	Insurance Needs	
9.	Community Education	
10.	Simulated Tsunami Exercises	

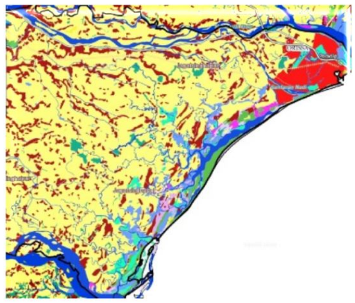
4 Data Used

4.1 Thematic data from Bhuvan



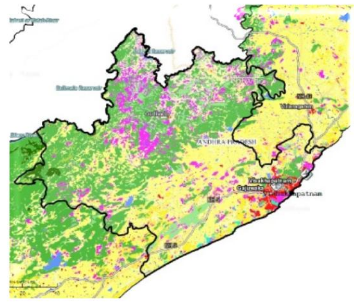
North 24

West Bengal



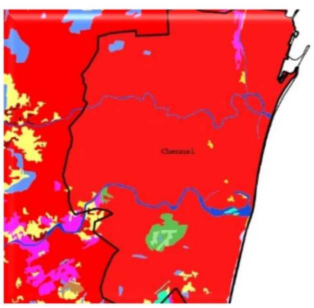
jagatsinghpur

Odissa



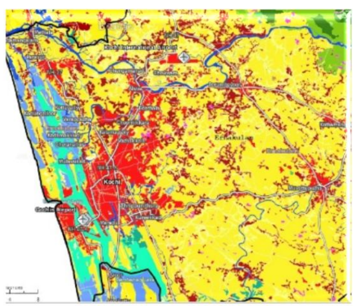
Visakapatnam

Andhra Pradesh



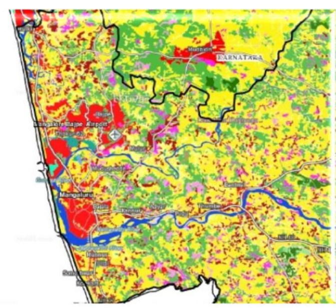
Chennai

Tamil Nadu



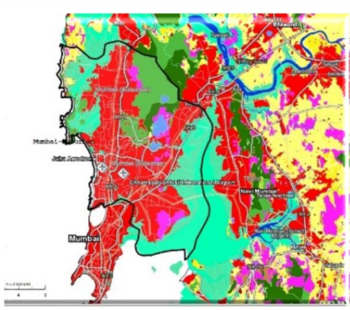
Ernakulam

Kerala



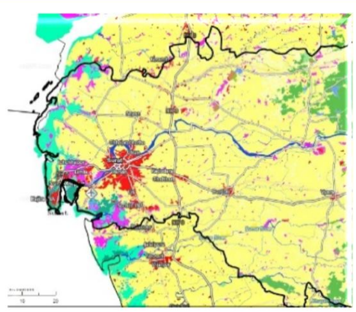
Daksin kanada

Karnataka



Mumbai

Maharashtra



Surat

Gujarath

Classes	Classes
Built Up	**Grass / Grazing**
Urban	Grass/Grazing
Rural	**Barren / Waste Lands**
Mining	Salt Affected Land
Agricultural Land	Gullied/Ravinous Land
Crop Land	Scrub Land
Agricultural Plantation	Sandy Area
Fallow Land	Barren Rocky
Current Shifting Cultivation	Rann
Forest	**Wetlands / Water bodies**
Evergreen/ Semi Evergreen	Water bodies
Deciduous	Rivers/Streams/Canals
Forest Plantation	Inland Wetland
Scrub Forest	Coastal Wetland
Swamp/ Mangroves	**Snow and Glaciers**
	Snow/Glaciers

Bhuvan, a software application which allows users to explore a 2D/3D representation of the surface of the Earth has been used in the study. The browser is specifically tailored to view India, offering the highest resolution in this region and providing content in four local languages

It consists of all the statistical data of evert indian disatric and thematic version of maps is also present which is utilized to identify the urbanized and populated area along the shores.

4.2 Transport Maps

The risk assessment for this project is performed in a new methodology which is based on the rescue efficiency of a region.

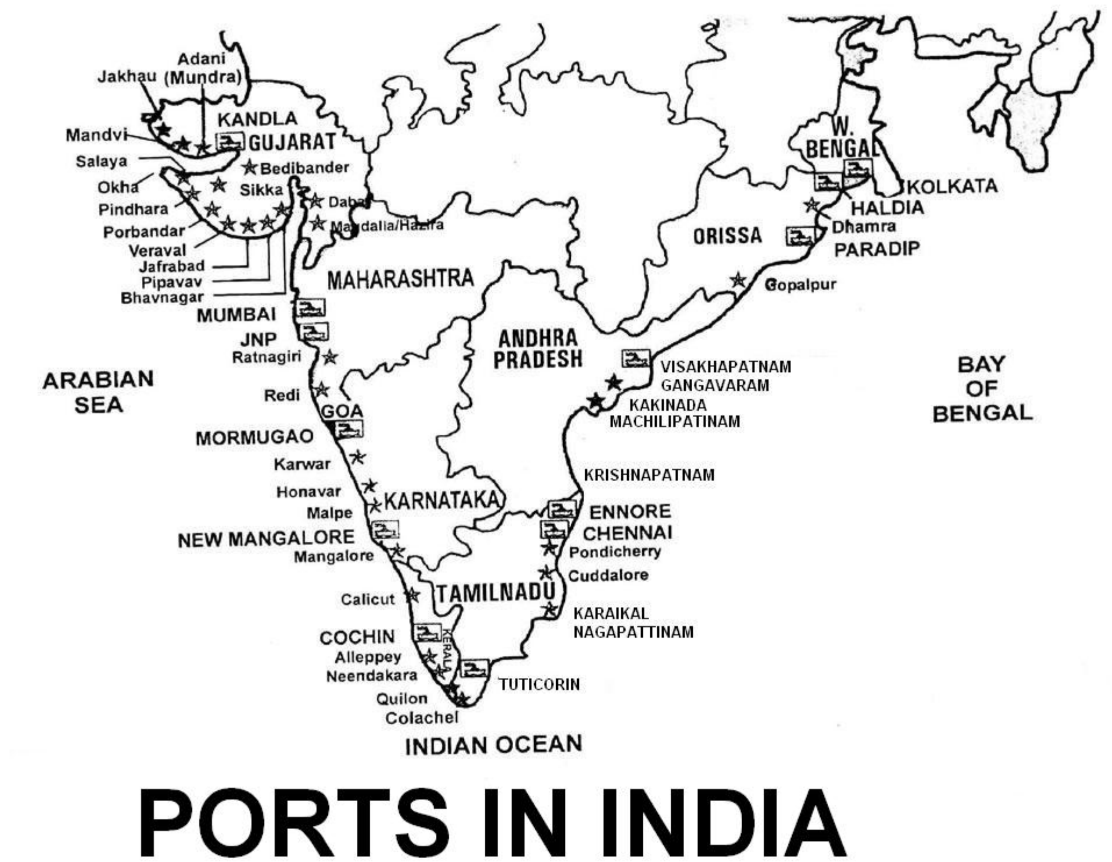
Road and Railway maps are used to determine the rescue efficiency and then to determine the rescue inefficiency.

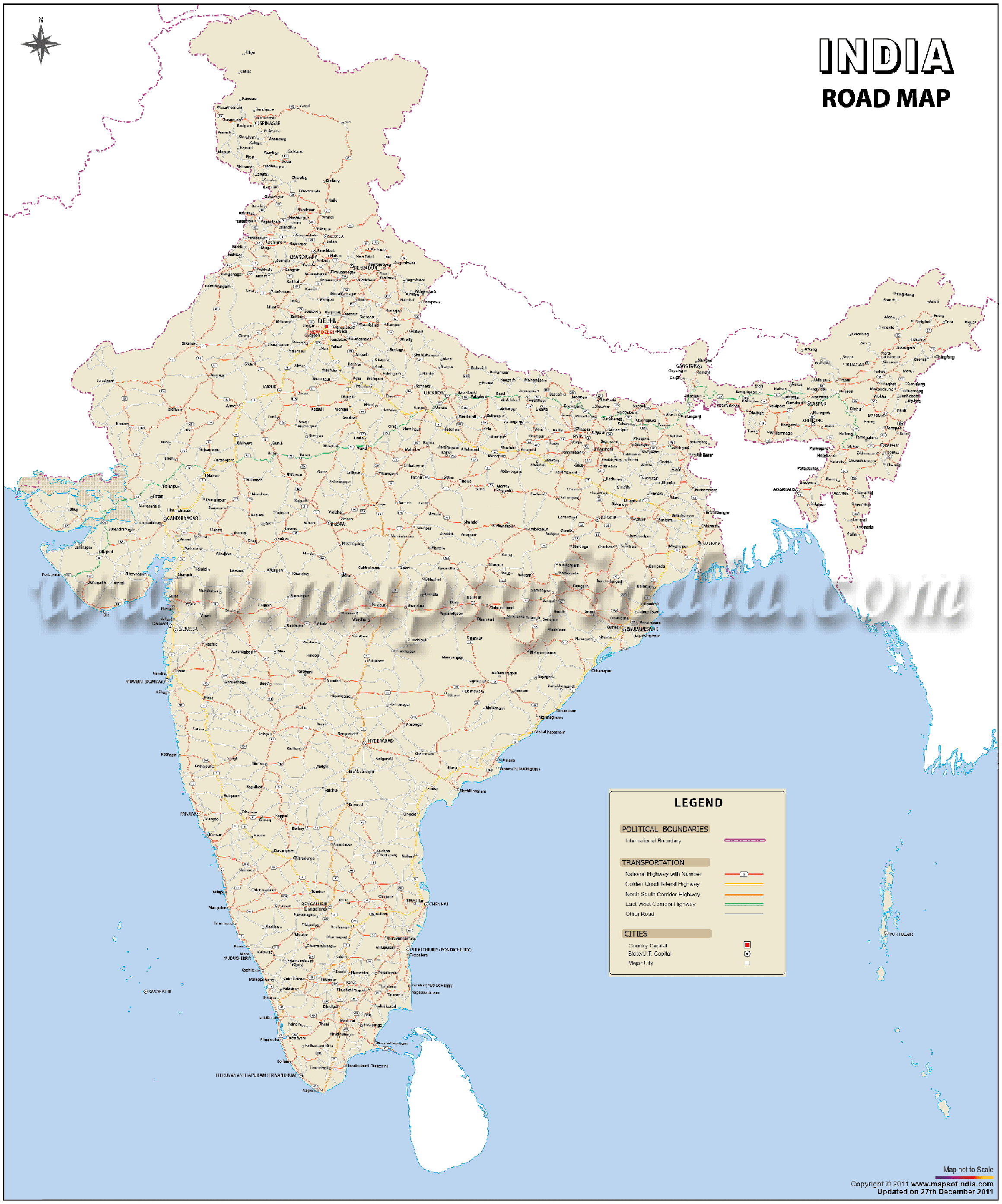
4.3 Ports Map

Ports are the region that causes trouble in the event of a tsunami as they are very vulnerable and high chance of debris is also present in it. Hence ports are considered as high hazard area and measures are taken to reduce it.

MAPS USED	SOURCE
Railway Map	http://www.mapsofindia.com/maps/india/india-railway-map.htm
Road map	http://www.mapsofindia.com/roads/wall-map.html
Airports & Sea ports	http://www.worldofmaps.net/en/asia/map-india/map-india-airports-seaports.htm
City Maps Of Coastal regions	Bhuvan Portal

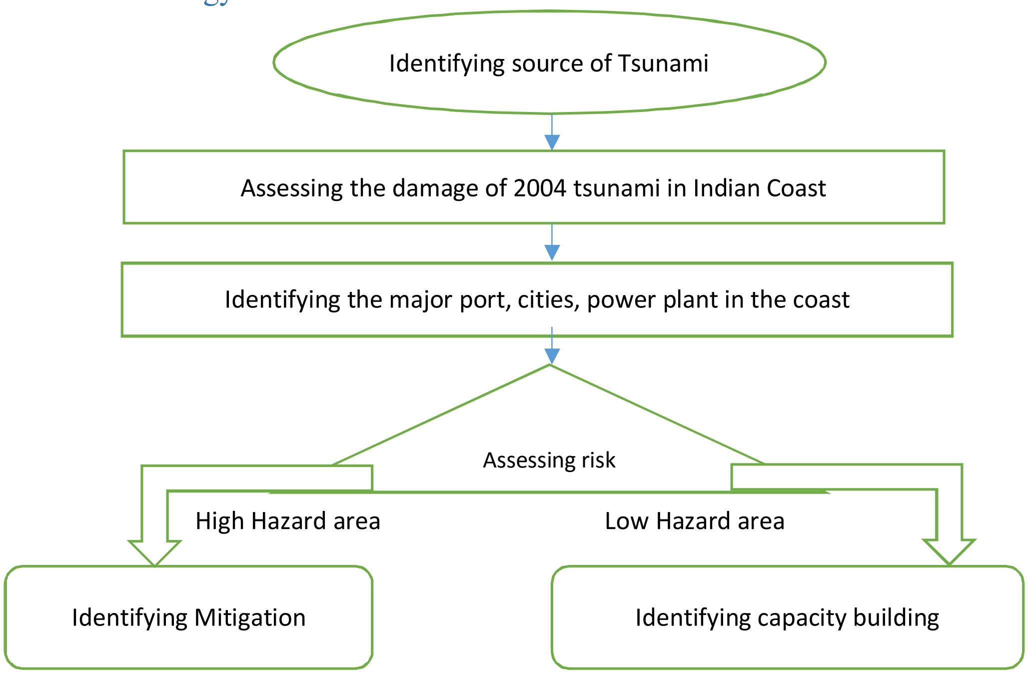
Table 4.1 : Data Used and source




N
INDIA
ROAD MAP
DELHI
www.mapsofindia.com
LEGEND
POLITICAL BOUNDARIES
International Boundary
TRANSPORTATION
National Highway with Number
Golden Quadrilateral Highway
North South Corridor Highway
East West Corridor Highway
Other Road
CITIES
Country Capital
State/U.T. Capital
Major City
Map not to Scale
Copyright © 2011 www.mapsofindia.com
Updated on 27th December 2011


N
INDIA
RAILWAY MAP
Srinagar
Jammu Tawi
Amritsar
Jalandhar City
Shimla
Ludhiana
Chandigarh
Ambala Cantt.
Dehradun
Bathinda
Sri Ganga Nagar City
Kurukshetra
Panipat
Rohtak
Moradabad
New Delhi
Bareilly
Bikaner
Mathura
Shahjahanpur
Phalodi
Bharatpur
Agra Cantt
Tundla
Farrukhabad
Lucknow
Narkatiaganj
Gangtok
Siliguri
New Jalpaiguri
Naharlagun
Itanagar
Dekargaon
Dispur
Amguri
Haibargaon
Lumding
Silchar
Agartala
Jaipur
Ajmer
Jodhpur
Kanpur
Sultanpur
Siwan
Sawai Madhopur
Jhansi
Allahabad
Patna
Katihar
Kota
Varanasi
Mughalsarai
Mokama
Bhagalpur
Chittaurgarh
Guna
Chunar
Gaya
Azimganj
Palanpur
Bina
Satna
Garwa Rd.
Madhupur
Katni
Bokaro
Sitarampur
New Bhuj
Gandhinagar
Ratlam
Bhopal
Jabalpur
Ranchi
Barddhaman
Ahmedabad
Ujjain
Tatanagar
Calcutta
Rajkot
Vadodara
Indore
Itarsi
Nainpur
Rourkela
Kharagpur
Bharuch
Khandwa
Amla
Bilaspur
Raigarh
Jharsuguda
Rupsa
Udhna
Jalgaon
Tumsar Rd
Raipur
Nagpur
Durg
Jakhapura
Bhubaneshwar
Titlagarh
Puri
Mumbai
Kalyan
Manikgarh
Singapur Rd.
Parbhani
Mudkhed
Pune
Koraput
Naupada
Nizamabad
Kurduwadi
Kazipet
Vizianagaram
Kothavalasa
Miraj
Wadi
Hyderabad
Dornakal
Samalkot
Vijayawada
Belgaum
Guntur
Gudivada
Vasco-da-gama
Hubli
Guntakal
Cuddapah
Renigunta
Chennai (Madras)
Mangalore
Hassan
Bangalore
Jolarpettai
Mysore
Villupuram
Salem
Kozhikode
Coimbatore
Vriddhachalam
Shoranur
Karur
Tiruchchirappalli
Thrissur
Dindigul
Ernakulam
Madurai
Virudhunagar
Kayankulam
Tenkasi
Rameswaram
Thiruvananthapuram
Tirunelveli
Nagercoil
Kanyakumari
Important Broad Gauge Line
Other Broad Gauge Line
Metre Gauge
Narrow Gauge Line
Under Gauge Conversion
Under Process
Major Railway Junction
Other Stations
Map not to Scale
Copyright © 2014 www.mapsofindia.com
(Updated on 30th October 2014)

5 Methodology



Step-1: The first step is to identify all the sources of tsunami which include

- Volcano
- Earth quakes
- Lansdslides

For this project the Indian Plate is considered for a possible source of tsunami

Step-2: In this step the effects of 2004 tsunami is assessed and same impact is to be considered for east and west coast.

Step-3: Tsunami affected regions are port and cities hence all the urban areas in the coast is identified and mapped (fig- 3)

Step-4: The risk is assed using the table -6.1 and calculated using the formula
Risk level = Hazard rating * Rescue in efficiency
Rescue Efficiency = 5-[(sum of the rescue efficiency rating)/6]

Step-5: Final step is to mitigate the region as required

6 Risk Ratings

Table 6.1 : Hazard Assessment

HAZARDS PRESENT	HAZARDS RATING	RESCUE EFFICIENCY	RESCUE EFFICIENCY RATING
Sea Port	5	Airport	5
Nuclear Power Station	5	National Highways	4
Major City	4	Minor roads	3
City	3	Railways and rail availability	4 (5 trains) 3 (3-4 trains) 2 (1-2 trains)
Villages	2	Disaster cell efficiency	1
Agricultural Land	1		

6.1 Rescue In-efficiency Calculation

It is the failure to evacuate the people in case of a tsunami from hazardous region.

It is calculated using the formula

Rescue efficiency = $\sum Rescue\ rating/5$
Rescue Inefficiency = 5 - $\sum Rescue\ rating/5$

Colour colding is given and rating is rated as depicted below

Rescue Inefficiency Rating	Colour Code	Considered Rating
1-2		2
2-3		3
3-4		4

Table 6.2 : Color coding of Rescue Inefficiency

6.2 Hazard Assessment

Hazard is assessed based on the facilities available in a particular region. The hazards are listed in the above table.

Based on this the hazard rating is calculated with the following formulae

$$\text{Hazard rating} = \sum Hazrd\ rating/5$$

The color coding is then given as per the table below

Color Coding	Hazard Rating	Hazard Level
(red)	4	Very High
(orange)	3	High
(yellow)	2	Modelrate
(green)	1	Low

Table 6.3 : Hazard Assessment Color Coding

6.3 Risk Matrix

The risk matrix is the matrix that determines the risk level in a region. It is the product of hazard rating and Rescue Inefficiency in this case.

The table determines the risk level in a region.

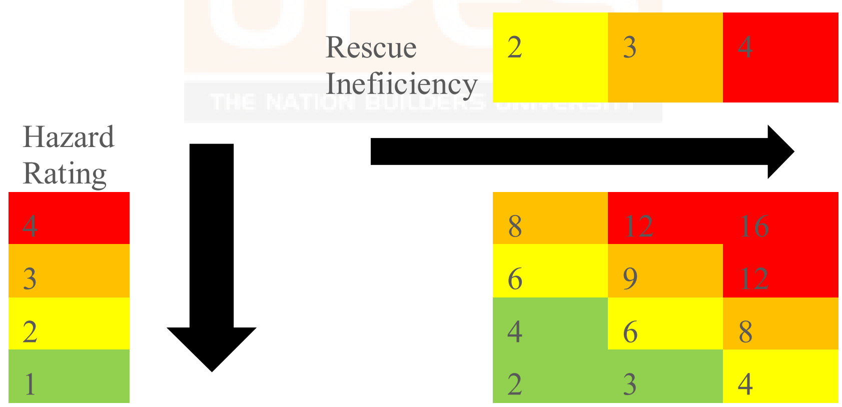


Table 6.4 : Risk Matrix

6.4 Mapping

The hazard assessment is mapped in a map of each state and analysed. Two maps are created one for each district and other for regions.

7 Results & Discussion

7.1 Risk Matrix

The risk matrix of different coastal states are calculated and is listed below

State & District	Hazard In the Region						Hazard assessment	Rescue facilities					Rescue Rating	Rescue Ineffeciency rating	Colour Coding	Risk Rating
	Sea Port	Nuclear Plant	Major City	City	Village	sea mitigation req		Airport	National Highways	Minor roads	Railways and rail availabili	Disaster cell efficienc				
Kerala																
kasaragod	0.5	0	0	1	1	1	3	0	4	3	3	3	2.6	2.4	3	9
kannur	0	0	0	1	1	1	3	0	4	3	3	3	2.6	2.4	3	9
kozhikode	0	0	0	1	1	1	4	0	4	3	3	3	2.6	2.4	3	12
malappuram	0	0	0	0	0	0	1	0	0	0	0	0	0	0		
thrissur	0	0	0	0	1	0	1	0	0	0	0	0	0	0		
Ernakulam	0	0	0	1	0	0	2	0	4	3	2	3	2.4	2.6	3	6
alappuzha	0	0	0	1	1	1	2	0	4	3	3	3	2.6	2.4	3	6
Kollam	1	0	0	1		0	4	0	0	0	0	0	0	0		
thiruvananthapuram	1	0	1	0	1	1	4	5	4	3	4	3	3.8	1.2	2	8
Maharastra																
Thane	0	1	0	1	0	1	4	0	0	3	4	3	2	3	4	16
Mumbai	0	0	1	1	0	1	3	5	4	3	4	3	3.8	1.2	2	6
rajgad	0	0	0	0	0	0		0	0	0		0	0			
ratnagiri	0	0	0	0	0	0		0	0	0	0	0	0			

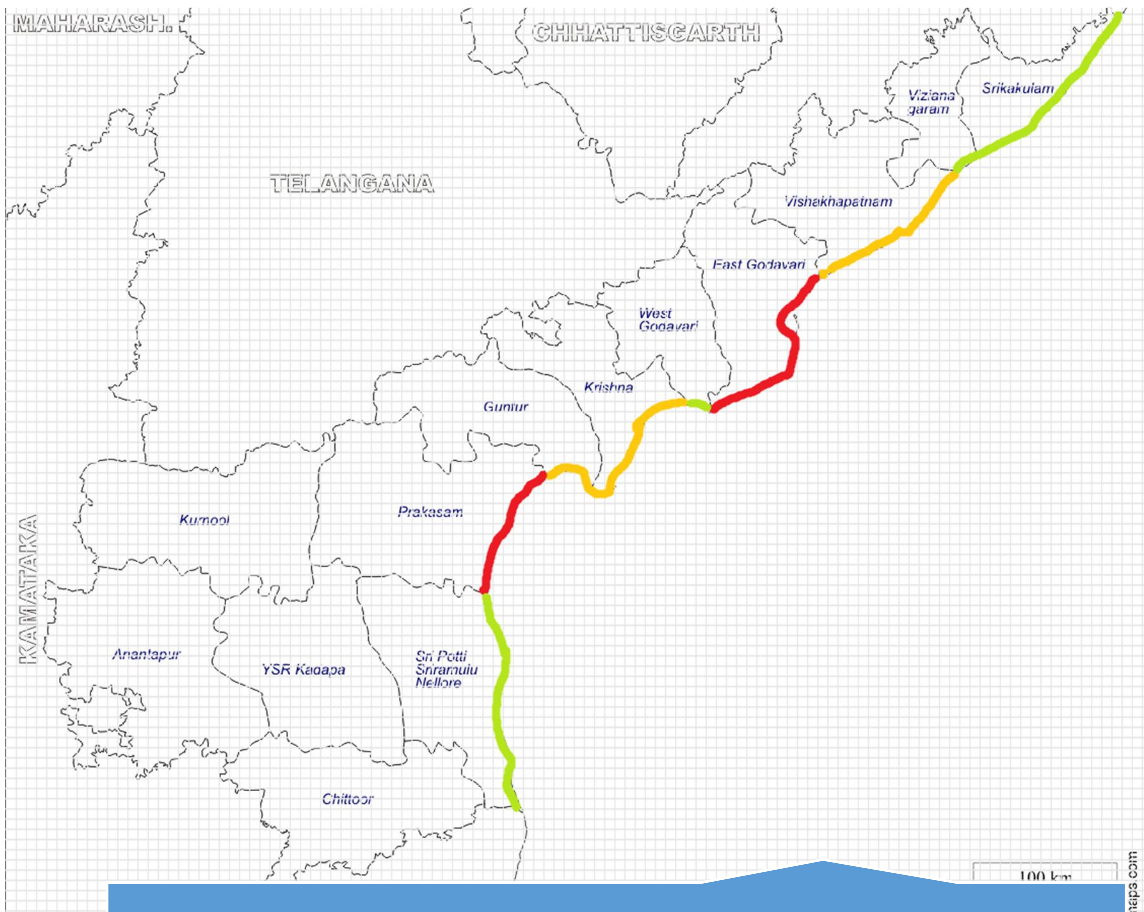
State & District	Hazard In the Region						Hazard assessment	Rescue facilities					Rescue Rating	Rescue Ineffieciency rating	Colour Coding	Risk Rating
	Sea Port	Nuclear Plant	Major City	City	Village	sea mitigation req		Airport	National Highways	Minor roads	Railways and rail availabili	Disaster cell efficienc				
Gujarath																
Jamnagar	0.5	0	0	0	0	0		0	0	0	0	0	0	0		
porbandar	0.5	0	0	1	0	1	2	5	4	3	3	3	3.6	1.4	2	4
junagadh	0.5	0	0	1	0	1	2	0	4	3	4	3	2.8	2.2	3	6
amreli	0.5	0	0	1	0	0	2	0	0	0	0	0	0	0		
Bhavnagar	0.5	0	0	1	0	1	2	5	4	3	3	3	3.6	1.4	2	4
Anand	0.5	0	0	1	0	1	2	0	0	3	2	3	1.6	3.4	4	8
Bharuch	0.5	0	0	1	0	0	2	0	0	0	0	0	0	0		
Surat	0.5	0	0	1	1	1	3	5	4	3	4	3	3.8	1.2	2	6
Karnataka																
Uttar Kannada	0.5	0	0	1		1	2	0	4	3	4	3	2.8	2.2	3	6
Udupi	0.5	0	1	1	1	1	4	0	4	3	4	3	2.8	2.2	3	12
Dakshina kannada	1		1	1	1	1	4	5	4	3	4	3	3.8	1.2	2	8

State & District	Hazard In the Region						Hazard assessment	Rescue facilities					Rescue Rating	Rescue Inefficiency rating	Colour Coding	Risk Rating
	Sea Port	Nuclear Plant	Major City	City	Village	sea mitigation req		Airport	National Highways	Minor roads	Railways and rail availability	Disaster cell efficiency				
Andhra Pradesh																
SriKakulam	0.5	1	0	0	0	0		0	0	0	0	0	0			
Vizayanagaram	1	0	1	0	0	0	4	0	0	0	0	0	0			
Visakapatnam	1	0	1	0	0	1	4	5	4	3	4	3	3.8	1.2	2	8
East godavari	0.5	0	0	0	1	1	2	0	0	3	2	3	1.6	3.4	4	12
West Godavari	0.5	0	0	0	1	0	2	0	0		0	0	0			
Krishna	0.5	0	0	1	1	1	3	0	4	3	2	3	2.4	2.6	3	9
Guntur	0.5	0	0	0	1	1	2	0	4	3	0	3	2	3	4	8
Prakasam	0.5	0	0	1	1	1	3	0	0	3	0	3	1.2	3.8	4	12
Nellore	0.5	0	0	0	0	0	1	0	0	0	0	0	0			
Tamil Nadu																
Thiruvallur	0.5	0	0	1	1	1	3	0	0	3	2	3	1.6	3.4	4	12
Chennai	1	1	1	0	0	1	4	5	4	3	4	3	3.8	1.2	2	8
Kanchipuram	0.5	0	0	1	1	1	3	5		3	2	3	2.6	2.4	3	9
cuddalore	0.5	0	0	1	1	1	3	0	4	3	3	3	2.6	2.4	3	9
Nagapatanam	0.5	0	0	1	1	1	4	0	0	3	2	3	1.6	3.4	4	16
Kanya kumari	1	1	0	1	1	1	4	0	0	3	2	3	1.6	3.4	4	16

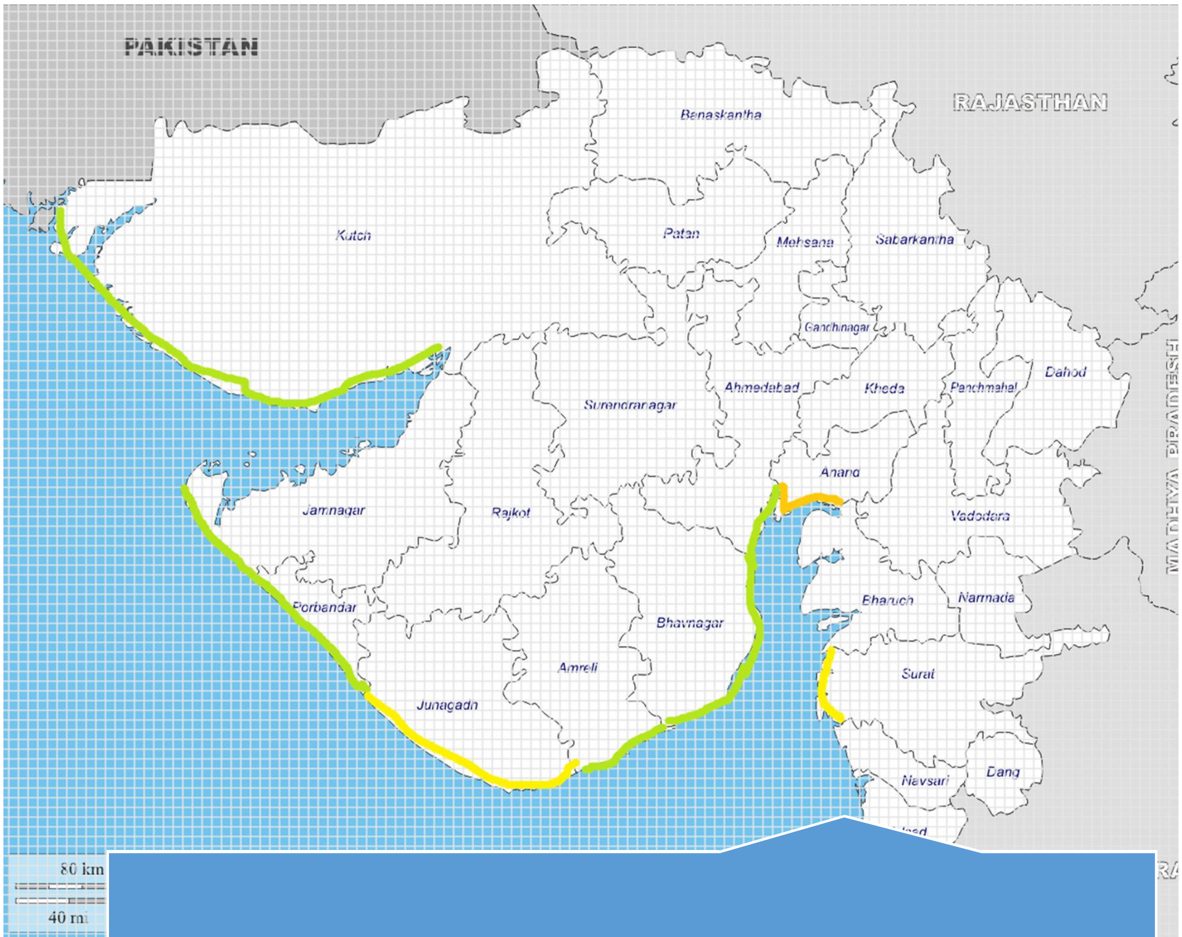
State & District	Hazard In the Region						Hazard assessment	Rescue facilities					Average Rescue Rating	Rescue Inefficiency rating	Colour Coding	Risk Rating
	Sea Port	Nuclear Plant	Major City	City	Village	sea mitigation req		Airport	National Highways	Minor roads	Railways and rail availability	Disaster cell efficiency				
Odisha																
baleshwar	0	0	0	0	1	1	2	0	0	3	0	3	1.2	3.8	4	8
bhadrak	0	0	0	0	0	0		0	0	0	0	0	0			
kondrapara	0	0		0	0	0		0	0	0	0	0	0			
jagatsinghpur	1	0	0	0	0	0	4	0	0	0	0	0	0			
puri	0	0	0	1	1	1	1	0	4	3	0	3	2	2	3	3
ganjam	1	1	0	1	1	1	4	0	0	3	2	3	1.6	3.4	4	16

7.2 Mapping

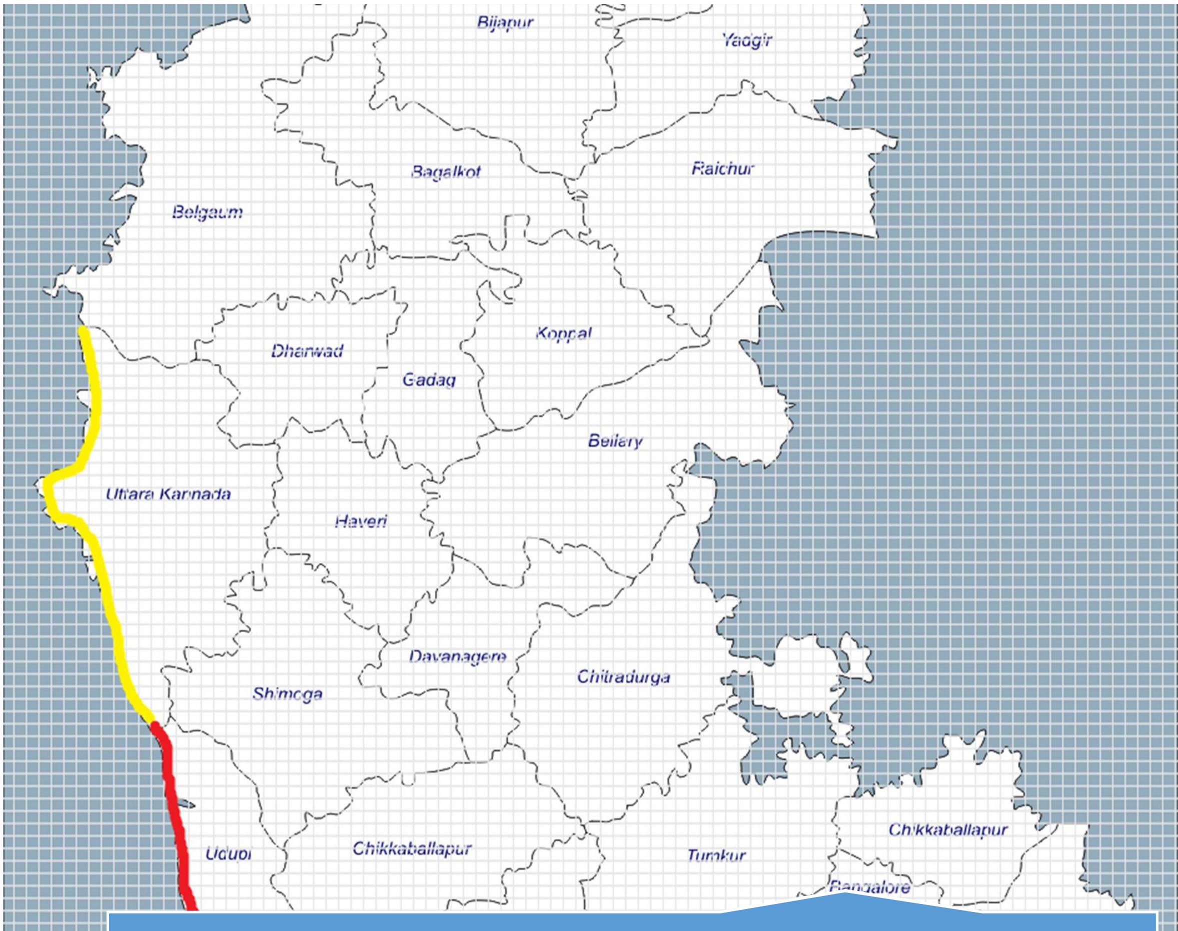
In the next stage of the project the mapping of the region is done in the state map according to the locality of the people



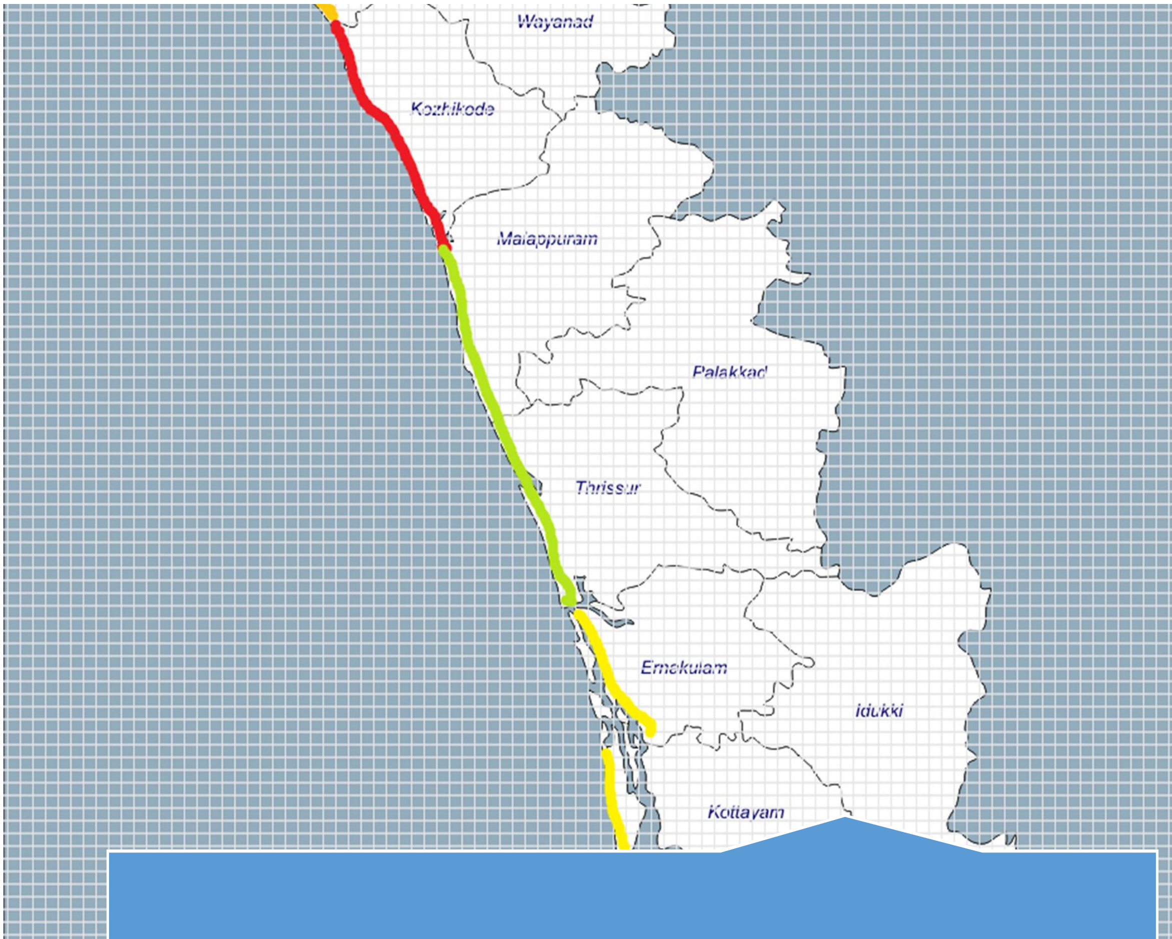
Andhra Pradesh


PAKISTAN
RAJASTHAN
MADHYA PRADESH
Banaskantha
Kutch
Patan
Mehsana
Sabarkantha
Gandhinagar
Ahmedabad
Kheda
Panchmahal
Dahod
Surendranagar
Anand
Jamnagar
Rajkot
Vadodara
Bharuch
Narmada
Porbandar
Bhavnagar
Amreli
Surat
Junagadh
Navsari
Dang
80 km
40 mi

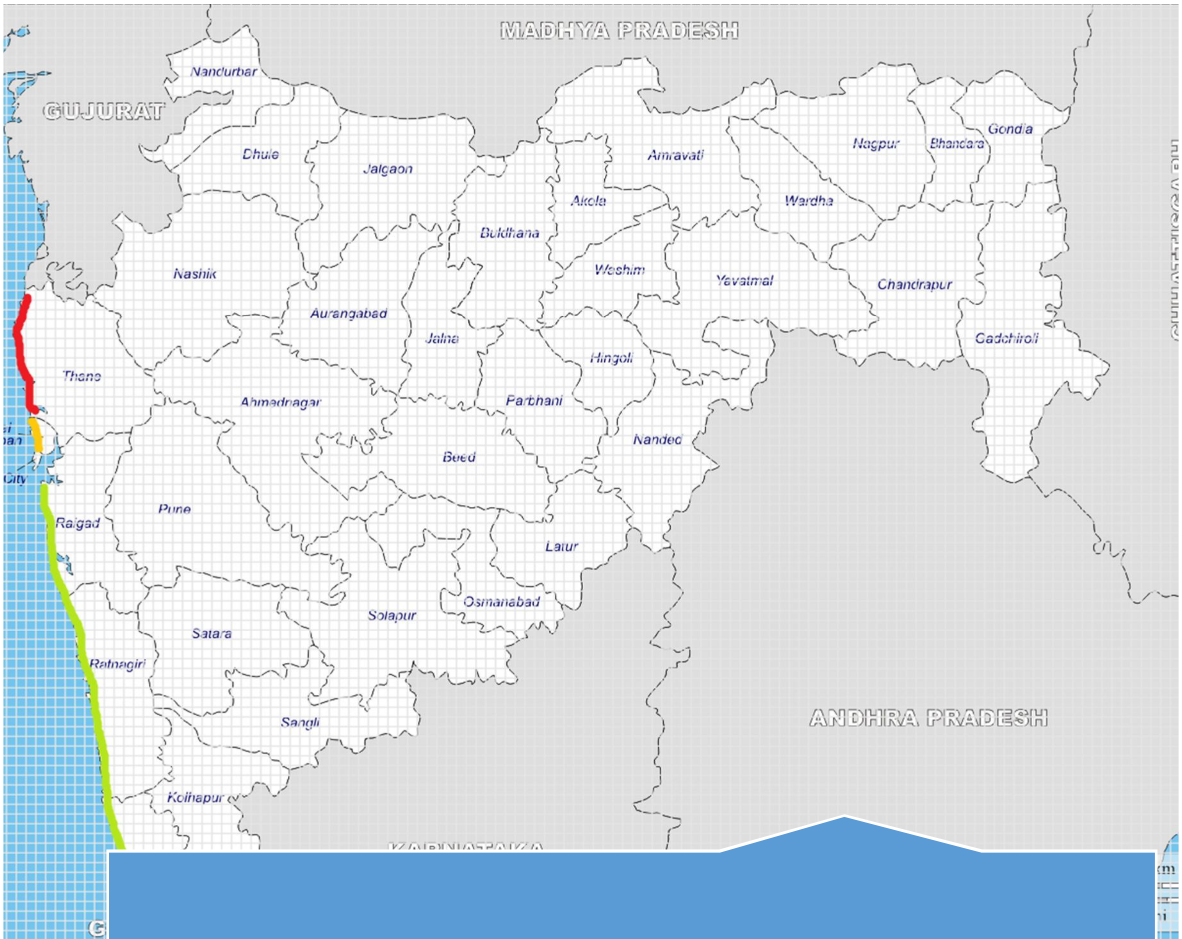
Gujarath


Bijapur
Yadgir
Bagalkot
Raichur
Belgaum
Koppal
Dharwad
Gadag
Bellary
Uttara Kannada
Haveri
Davanagere
Chitradurga
Shimoga
Chikkaballapur
Udupi
Chikkaballapur
Tumkur
Bangalore

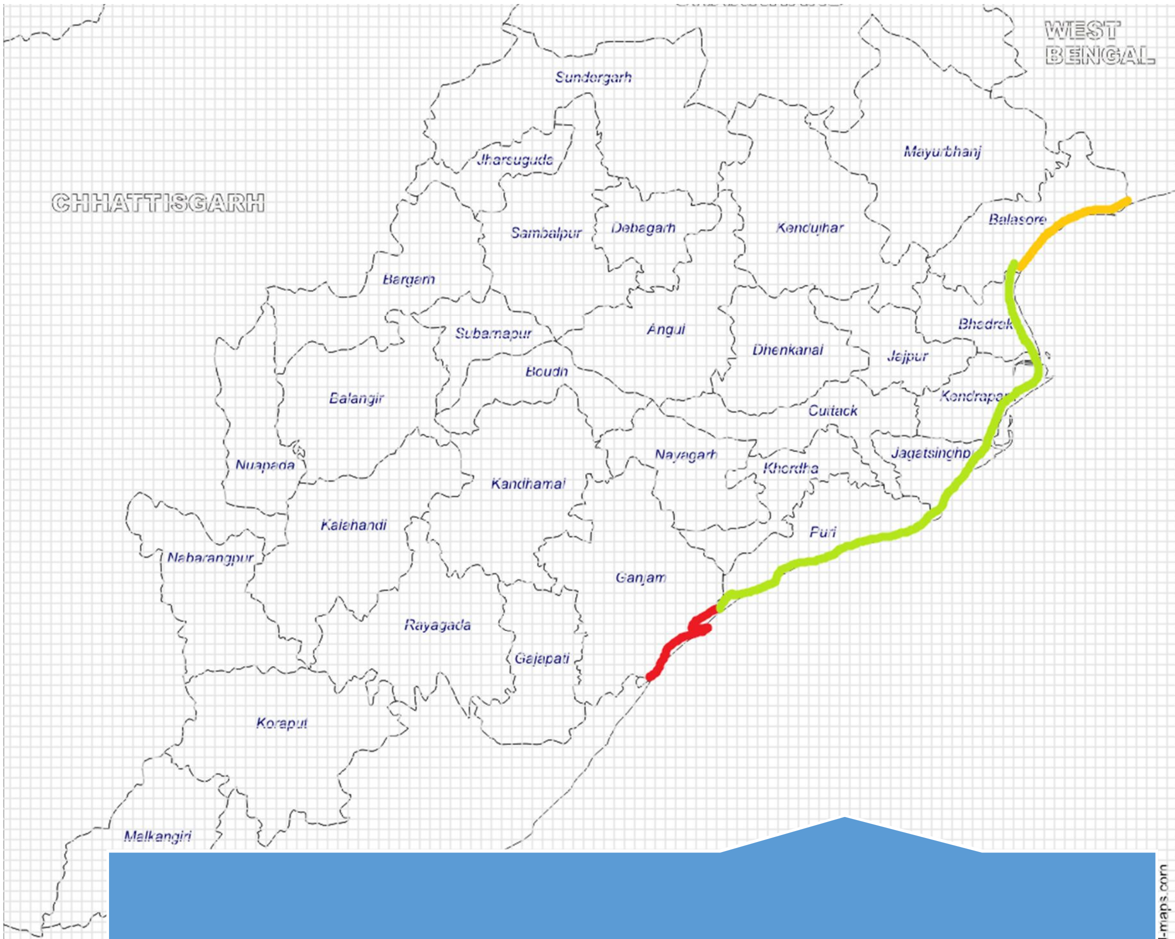
Karnataka


Wayanad
Kozhikode
Malappuram
Palakkad
Thrissur
Ernakulam
Idukki
Kottayam

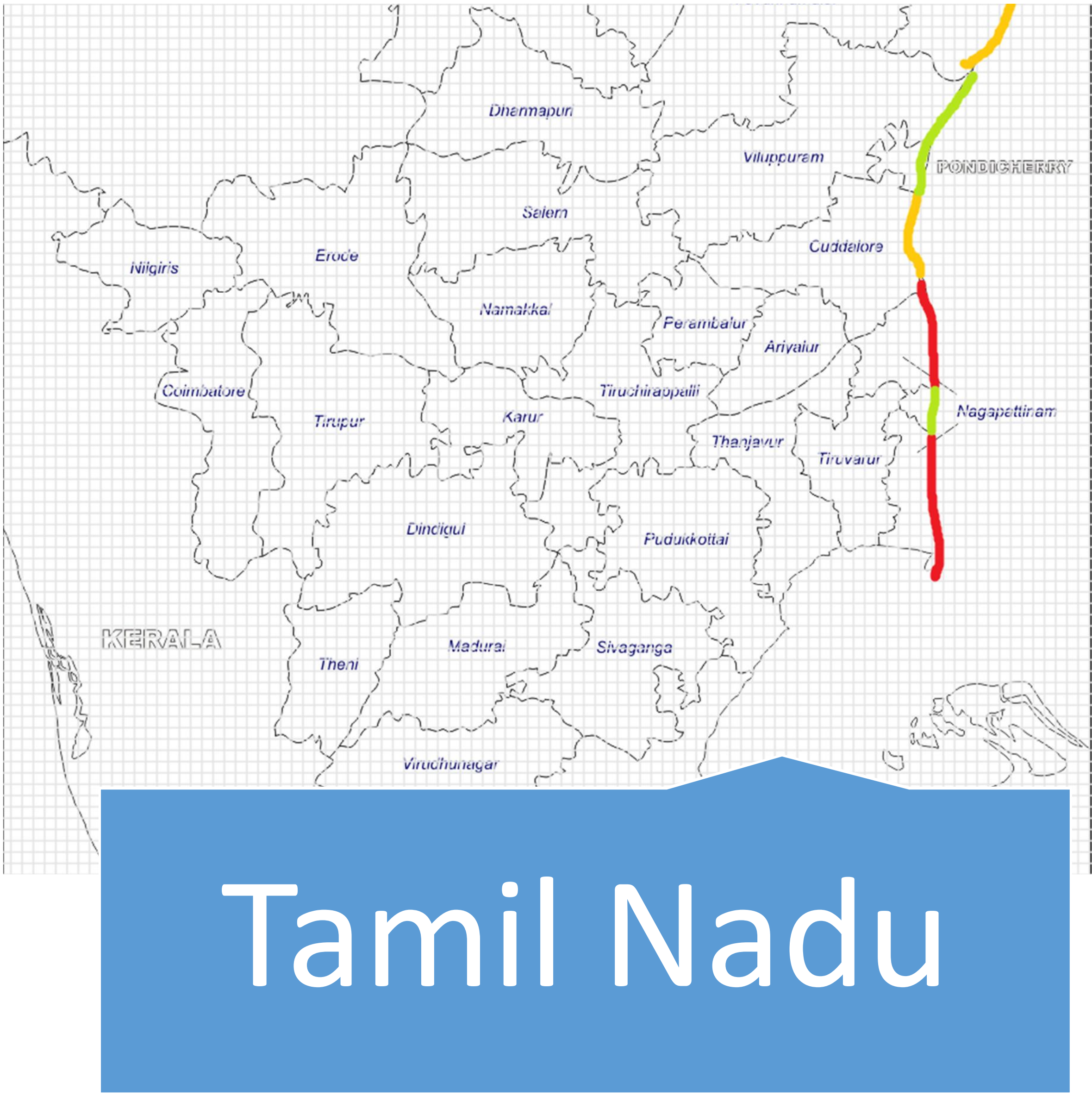
Kerala


MADHYA PRADESH
GUJURAT
Nandurbar
Dhule
Jalgaon
Amravati
Nagpur
Bhandara
Gondia
Akola
Wardha
Buldhana
Washim
Yavatmal
Chandrapur
Nashik
Aurangabad
Jalna
Hingoli
Gadchiroli
Thane
Ahmednagar
Parbhani
Nanded
Beed
Raigad
Pune
Latur
Osmanabad
Solapur
Satara
Ratnagiri
Sangli
ANDHRA PRADESH
Kolhapur

Maharastra

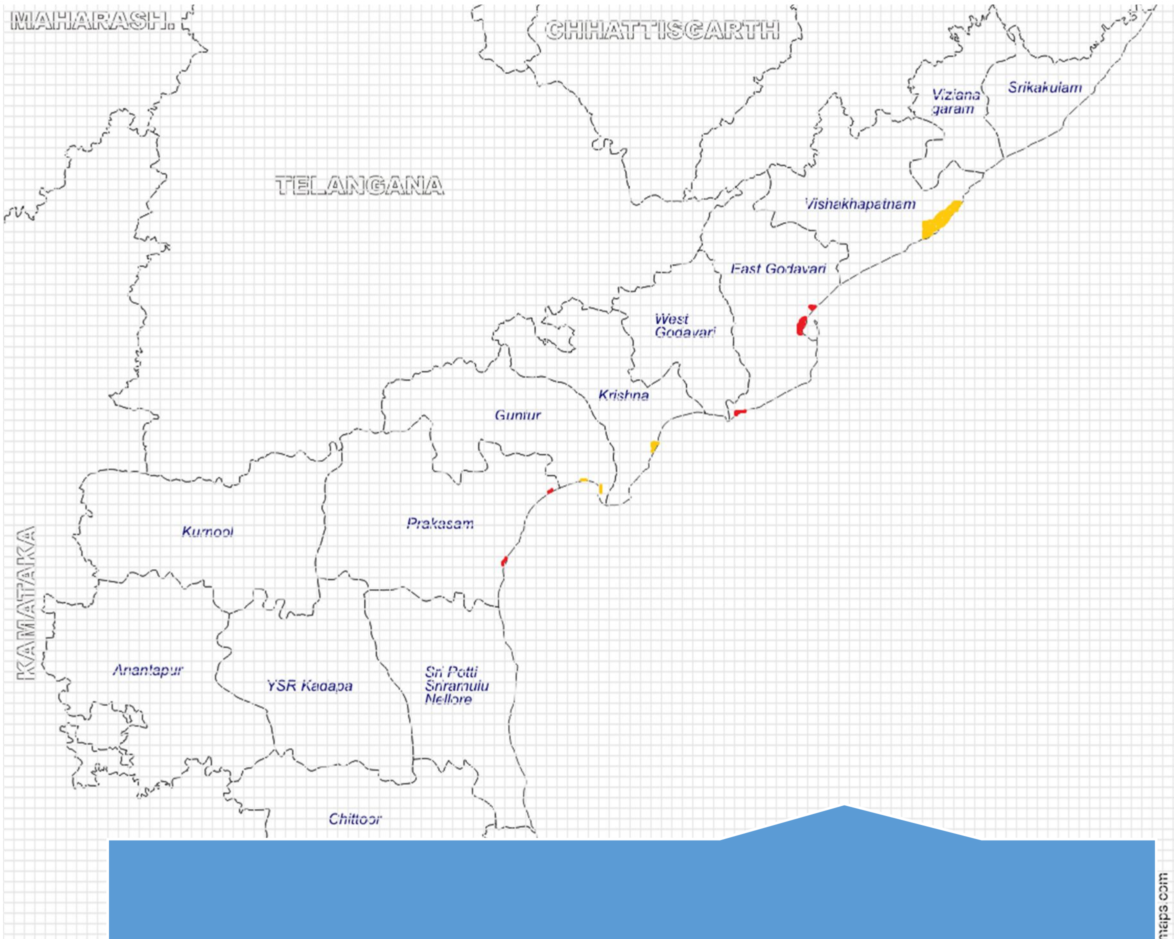

WEST BENGAL
CHHATTISGARH
Sundergarh
Jharsuguda
Mayurbhanj
Balasore
Sambalpur
Debagarh
Kendujhar
Bargarh
Subarnapur
Angul
Dhenkanal
Jajpur
Boudh
Balangir
Cuttack
Nayagarh
Khordha
Nuapada
Kandhamal
Kalahandi
Puri
Nabarangpur
Ganjam
Rayagada
Gajapati
Koraput
Malkangiri
d-maps.com

Odissa

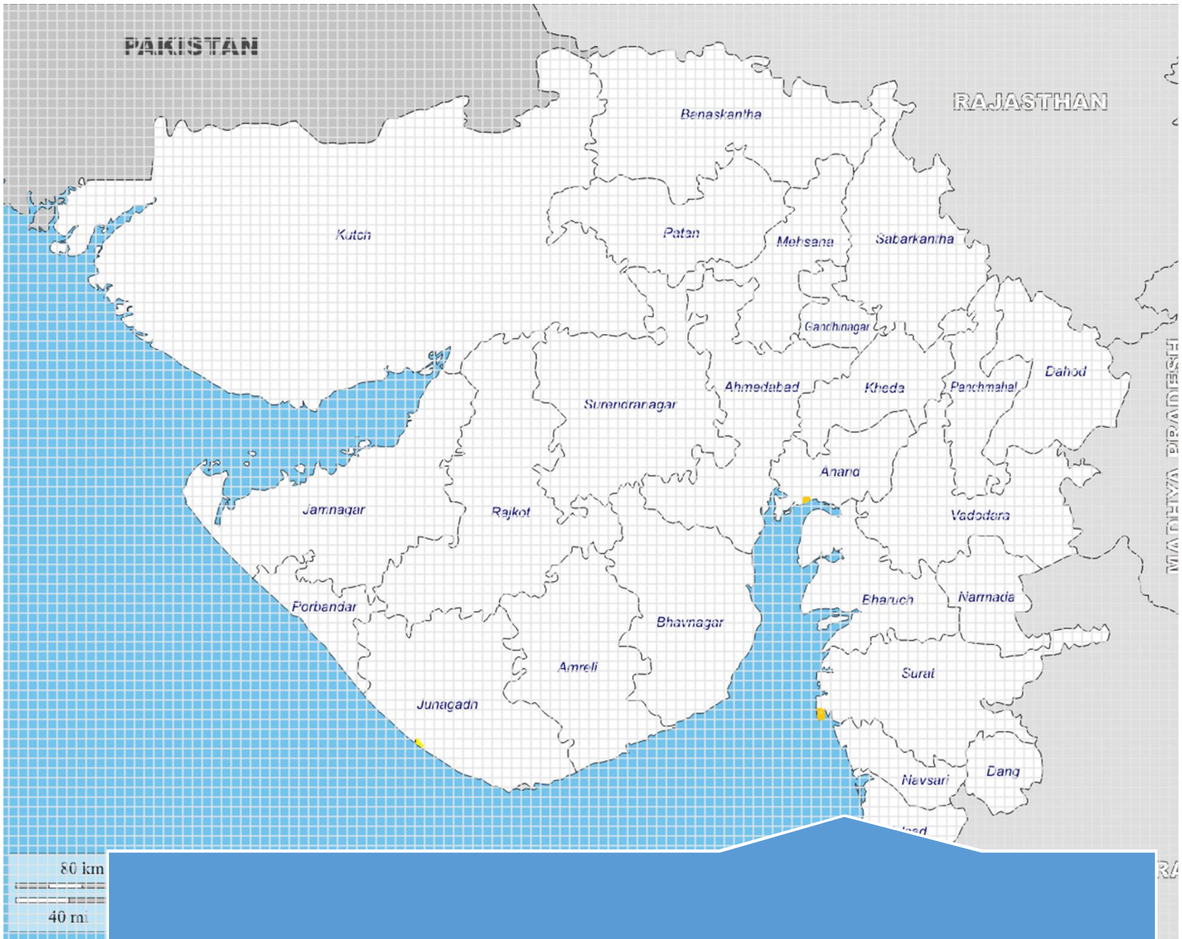


The above maps are the maps of each district which determines the overall risk . This risk assessment is based on the facilities and powerplant of the region rather than individual urbanized regions.

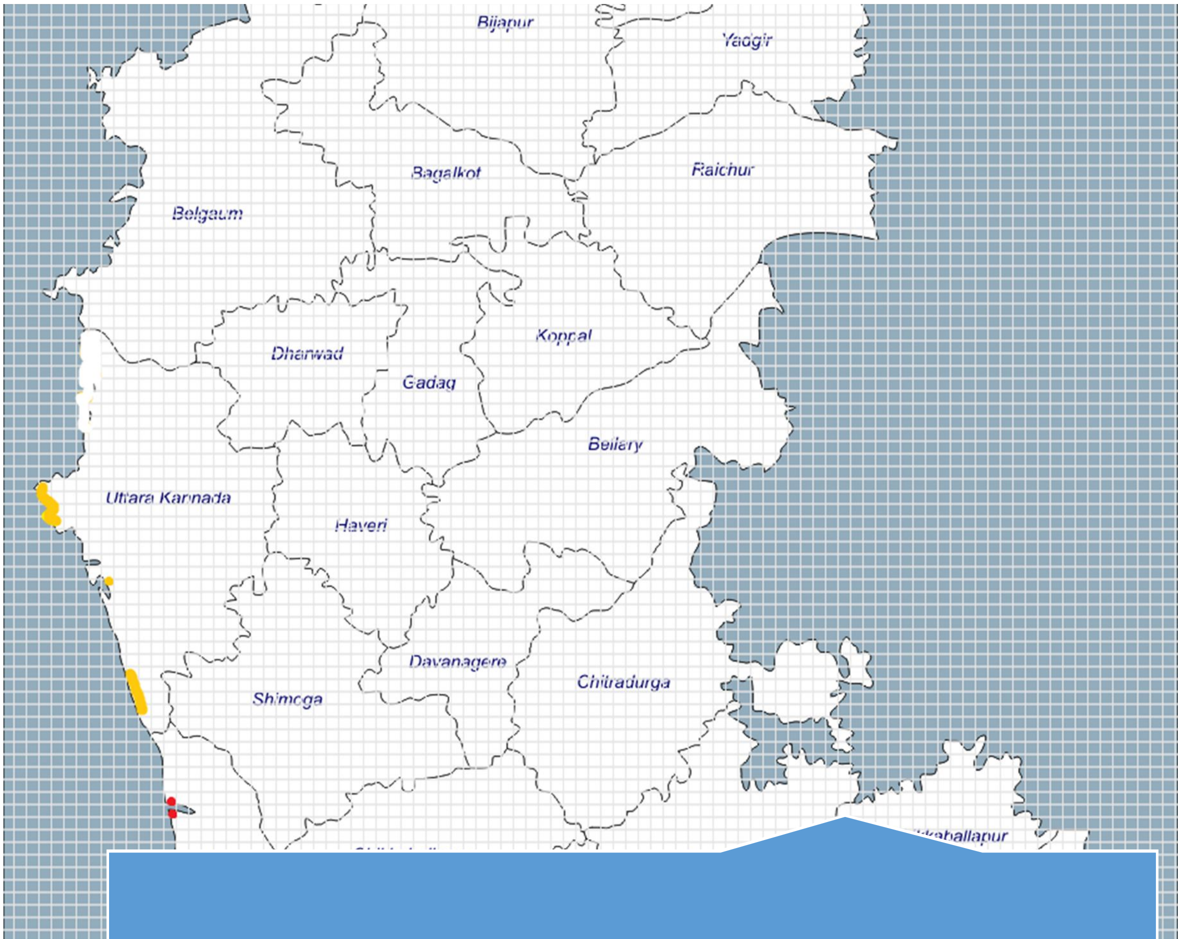
Next set of maps are the maps that is mapped for a specified location. Urbanization or ruralization of .5 km from coast line is considered for this mapping.



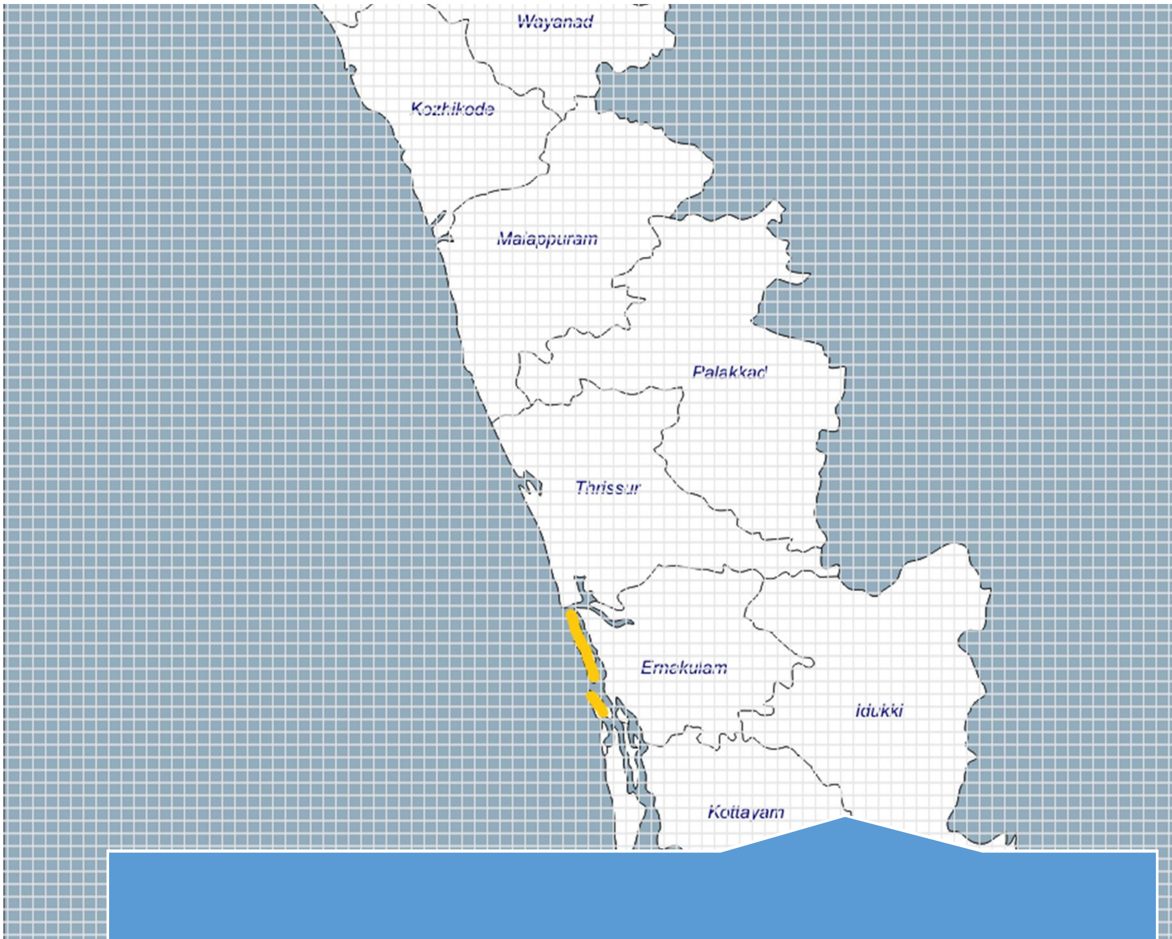
Andhra Pradesh


PAKISTAN
RAJASTHAN
MADHYA PRADESH
Banaskantha
Kutch
Patan
Mehsana
Sabarkantha
Gandhinagar
Dahod
Ahmedabad
Kheda
Panchmahal
Surendranagar
Anand
Jamnagar
Rajkot
Vadodara
Porbandar
Bharuch
Narmada
Bhavnagar
Surat
Amreli
Junagadh
Navsari
Dang
80 km
40 mi

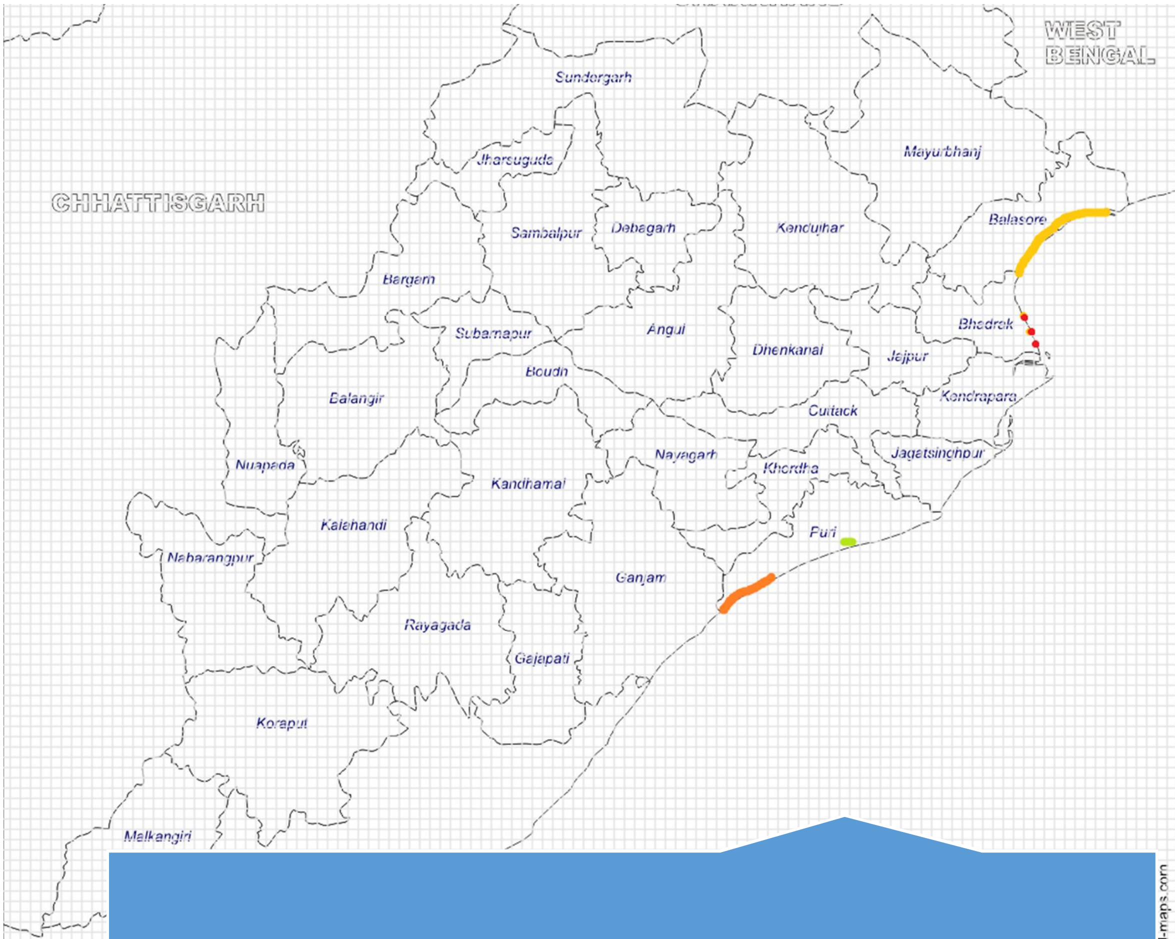
Gujarath


Bijapur
Yadgir
Bagalkot
Raichur
Belgaum
Dharwad
Koppal
Gadag
Bellary
Uttara Kannada
Haveri
Davanagere
Chitradurga
Shimoga

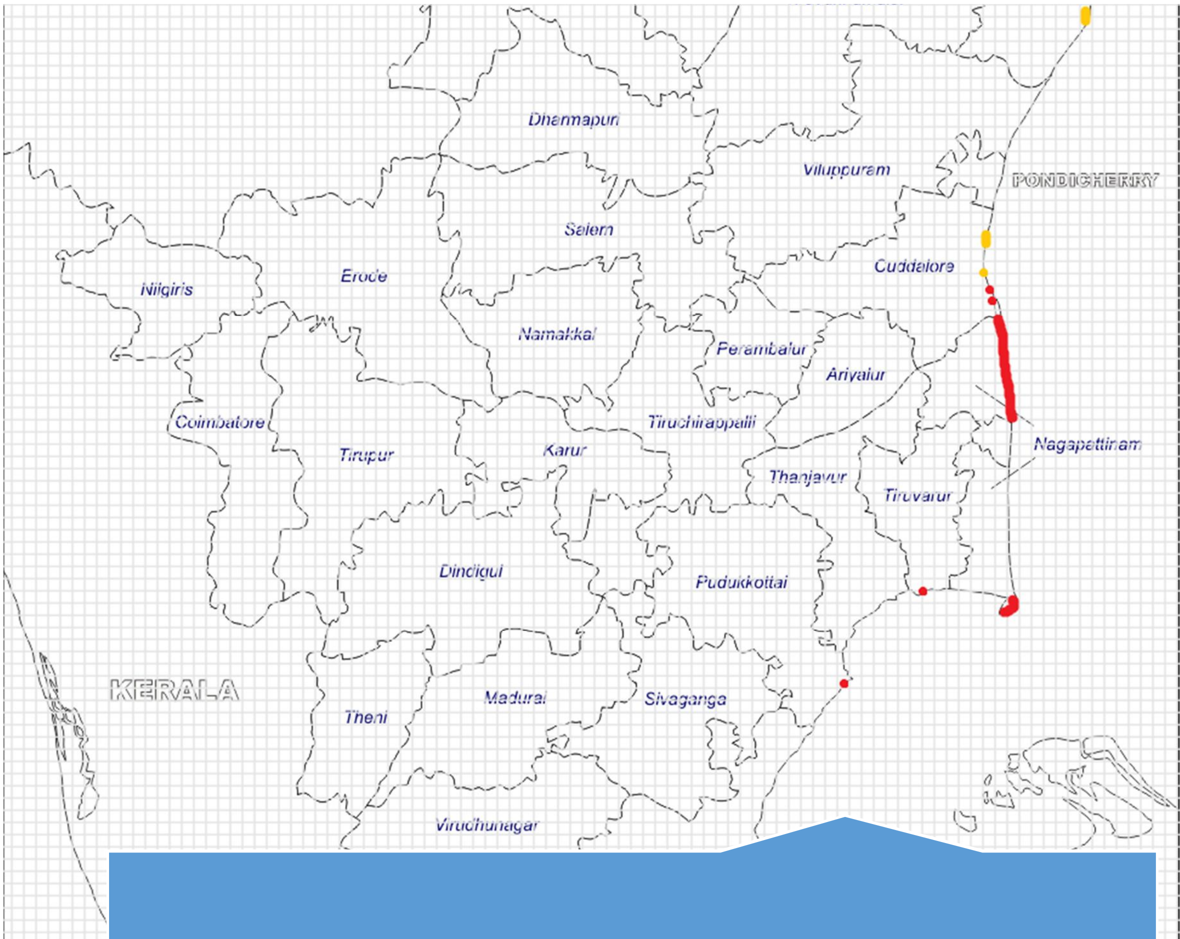
Karnataka


Wayanad
Kozhikode
Malappuram
Palakkad
Thrissur
Ernakulam
Idukki
Kottayam

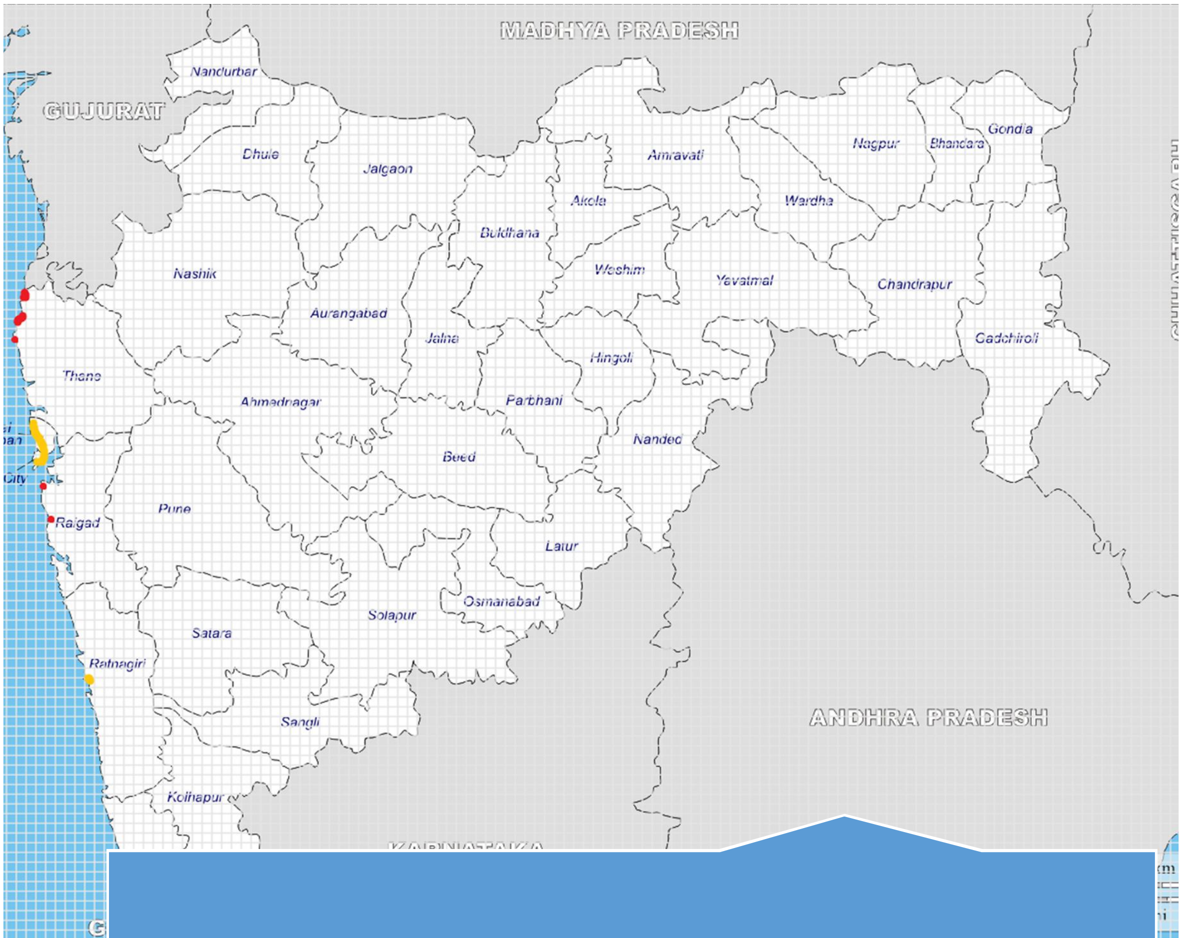
Kerala


WEST BENGAL
Sundergarh
Jharsuguda
Mayurbhanj
CHHATTISGARH
Sambalpur
Debagarh
Kendujhar
Balasore
Bargarh
Bhadrak
Subarnapur
Angul
Dhenkanal
Jajpur
Boudh
Balangir
Kendrapara
Cuttack
Nayagarh
Jagatsinghpur
Nuapada
Kandhamal
Khordha
Kalahandi
Puri
Nabarangpur
Ganjam
Rayagada
Gajapati
Koraput
Malkangiri
d-maps.com

Odissa


Dharmapuri
Viluppuram
PONDICHERRY
Salem
Cuddalore
Erode
Nilgiris
Namakkal
Perambalur
Ariyalur
Coimbatore
Tiruchirappalli
Nagapattinam
Tirupur
Karur
Thanjavur
Tiruvarur
Dindigul
Pudukkottai
KERALA
Madurai
Sivaganga
Theni
Virudhunagar

Tamil Nadu


MADHYA PRADESH
GUJURAT
Nandurbar
Dhule
Jalgaon
Amravati
Nagpur
Bhandara
Gondia
Akola
Wardha
Buldhana
Washim
Yavatmal
Chandrapur
Nashik
Aurangabad
Jalna
Hingoli
Gadchiroli
Thane
Ahmednagar
Parbhani
Nanded
Beed
Pune
Raigad
Latur
Osmanabad
Solapur
Satara
Ratnagiri
Sangli
Kolhapur
ANDHRA PRADESH

Maharastra

8 Mitigation Activities

Region	Mitigation plan	Region	Mitigation plan
East godavari Prakasam Thiruvallur Nagapatanam Kanya kumari Udupi kozhikode Thane ganjam	Barricade, Early Warning System,Evacuation Routes.	junagadh Surat Uttar Kannada Ernakulam alappuzha Mumbai	Community planning,Evacuation routes, Tsunami preparation kits
baleshwar kasaragod kannur thiruvananthapuram Anand Dakshina kannada Visakapatnam Krishna Guntur Chennai Kanchipuram cuddalore	Early warning system, Evacuation routes,community planning, tsunami preparation kits.		

The mitigation of general zone is given accourding to the colour zone and for each hazard level various tsunami mitigation is given in general

Nuclear Stations: In Places Nea Nuclear Stations its important to have Tsunami walls that protect the region from tsunami induction.

Sea Ports : For Sea port a special type of technology is reqired which is used in a super tructure in dubai.

This Mechanism reduces the wave energy there by reducing the

9 Conclusion

Altough India has a vast coast line people subjected to tsunami hazard is very less. Very few regions has population with in .5 km of coast line hence I conclude that there is no need for major mitigation planning as of now and no advance mitigstion is required.

10 Reference

1. http://www.in.undp.org/content/india/en/home/library/crisis_prevention_and_recovery/disaster-management-in-india.html
2. http://www.ndma.gov.in/en/vulnerability-profile.html
3. http://www.ndma.gov.in/en/disaster-data-statistics.html
4. http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Fukus hima-Accident/
5. **Tsunami** Risk Assessment And Mitigation For The Indian Ocean by UNESCO, June 2009
6. Modeling and Mapping of Tsunami along Indian coast as a part of the early tsunami and storm surge warning system by MINISTRY OF EARTH SCIENCE , March 2009
7. Proposed strategy for building resilience to tsunamis in the Indian Ocean 2006-2008, UN/ISDR.
8. Tsunami - The Great Waves. IOC Brochure 2006-2, UNESCO, 2006