WORKSHOP ON

REMOTE SENSING AND GIS

FOR DISASTER MANAGEMENT AND MITIGATION

9TH MARCH 2005

Sponsored by

CENTRE WITH POTENTIAL FOR EXCELLENCE

IN ENVIRONMENTAL SCIENCE

ANNA UNIVERSITY

CHENNAI – 600 025

Organized by

INSTITUTE OF REMOTE SENSING

ANNA UNIVERSITY, CHENNAI – 600 025

Supported By

INDIAN SOCIETY OF GEOMATICS (ISG)

CHENNAI CHAPTER

CONTENTS

DECISION SUPPORT CENTRE FOR DISASTER MANAGEMENT

M V KRISHNA RAO

Head, Crop Inventory & Drought Assessment Division (CI&DAD)
Project Director, Decision Support Centre (DMSP)
National Remote Sensing Agency, Dept. of Space
Hyderabad – 500 037, India

Abstract

Decision Support Centre (DSC) is an operational service provider exploring the synergy and convergence of space and contemporary technologies in pre-disaster, during disaster and post-disaster phases. DSC will respond to the disaster situation depending upon the nature of the disaster in providing timely information. In order to realize this stupendous task, the DSC, at its core will have data and its application servers with several clients connected. The important components of the DSC includes

- Satellite/ Aerial data acquisition strategy
- Output generation in user required formats
- Dissemination of information generated to the users through network
- Supportive functions such as digital database, hazard zonation, network modelling, query shells, etc.

It is envisaged that the DSC will be connected to National Emergency Operation Centre (NEOC), State Emergency Operation Centres (NEOCs), selected knowledge institutions and Shadnagar Earth station through Satellite based Virtual Private Network (VPN). Thus, DSC will have online interface with these agencies to effectively use the ground observations and the data in conjunction with the space data to derive updated information on disaster events and provides decision support. DSC is also represented as an active member in National Core Groups on various natural disasters.

1. Introduction

The Department of Space (DOS), Government of India, has successfully demonstrated the capabilities of space systems to support disaster management activities of the country. In the process, the DOS has recognized the strong need to evolve and execute a programme for integrating operationally the space technology inputs and services on a reliable and timely basis for strengthening country's resolve towards disaster management. Thus, the Disaster Management Support has been identified as one of the major activities of the DOS.

The framework of Disaster Management Support, as conceived by DOS, has also taken into account (i) the experience & lessons learnt especially during Malpa Landslides, Orissa Super-cyclone, Gujarat Earthquake and the recent droughts in the country, (ii) operational needs of the disaster management authorities at various levels, (iii) the recommendations of the High Powered Committee on Disaster Management constituted by Government of India, and (iv) recent developments in Space, Information and Modelling technologies. Towards enabling the operational services as cited above, it has been proposed to establish a Decision Support Centre (DSC) at National Remote Sensing Agency, Hyderabad.

The Decision Support Centre (DSC) is envisioned as a single window operational service provider exploring the synergy and convergence of space and contemporary technologies striving towards effective disaster management. DSC will serve as (i) a centre to discharge its functions, (ii) as a mechanism to pave way for improved management capabilities of disasters, and (iii) as a network node to communicate in a two-way mode with the line departments and prominent working centres engaged in disaster management. In order to realize this stupendous task, the DSC, at its core will have data and its application servers with several clients connected. The important components of the DSC include satellite/ aerial data acquisition, output generation, user required information and formats, dissemination of information generated to the users through networking and supportive functions such as digital database, hazard zonation, network modelling, query shells, etc.

In the backdrop of the national commitments towards disaster management and the proactive role planned by the DOS, the DSC at NRSA defined its functioning to provide the space generated deliverables in a timely and effective manner.

2. Operations of DSC

DSC, being a single window service provider addressing all the operational needs of disaster management, generates up to date information using satellite data on disasters at the disaster foot print level, assess the risk and damage and monitor the disasters to provide value added information to suit users' needs. The organisational structure of the DSC within the DMSP of the DOS is presented in fig. 1. Various components of the DSC to address its functionality are given below.

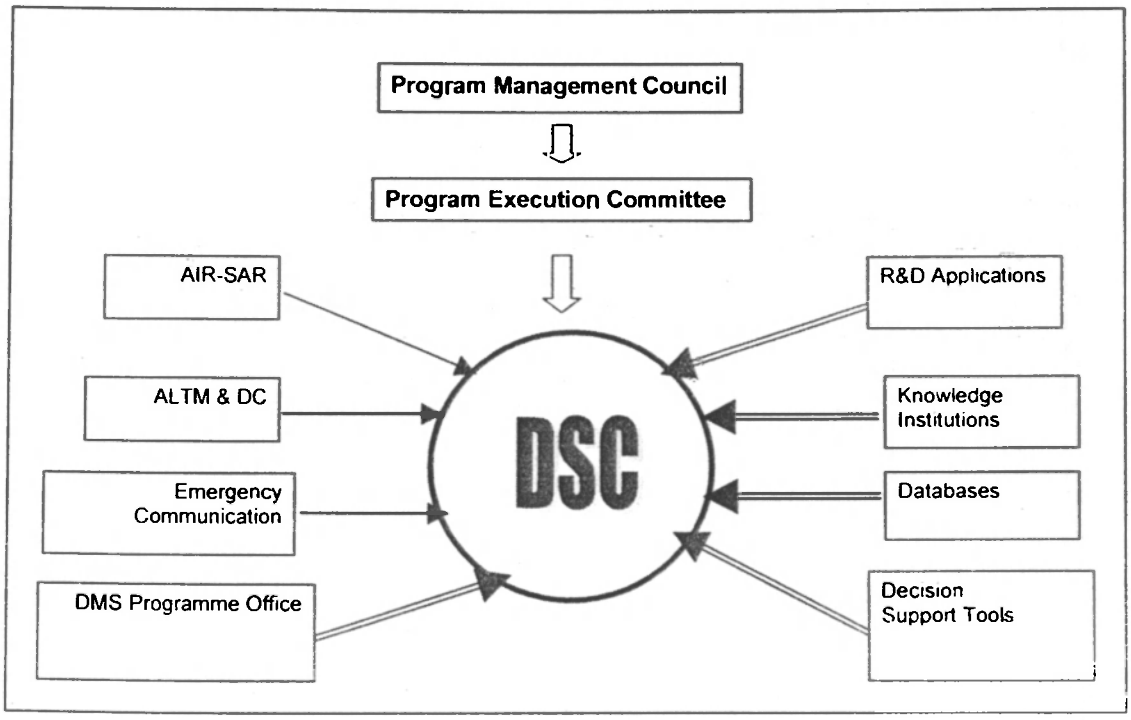


Fig.1 Organisational Structure for DSC within DOS

3. Activities of DSC

The DSC will discharge its functions within the framework of the DMSP in order to provide the deliverables to the line departments related to the disaster management in a timely and effective manner. Continuous efforts will be put to improve the functioning keeping pace with the technological developments.

Functioning of the DSC is designed to generate and disseminate the disaster related information in the required turn around time in the most effective manner and strives to augment the resources and capabilities of DSC with a feedback mechanism. The functions enumerated above have been presented in detail in the following sections. In order to address various issues related to the DSC, three supporting activities viz., applications, database and decision support tools development were identified. In addition, the DSC will have close liaison with various centres for ground data and feedback. In this regard, DSC will have close liaison with various centres for acquisition, processing and analyses of data, generation and transmission of information, R&D support and capacity building. Concerted efforts will be put by the DSC, involving all the concerned DOS and non-DOS centres in order to carry out these tasks towards preparedness and assessment of the disasters for mitigation and management. Different activities of the DSC are planned to be carried out under the auspices of the DMSP are presented in fig. 2.

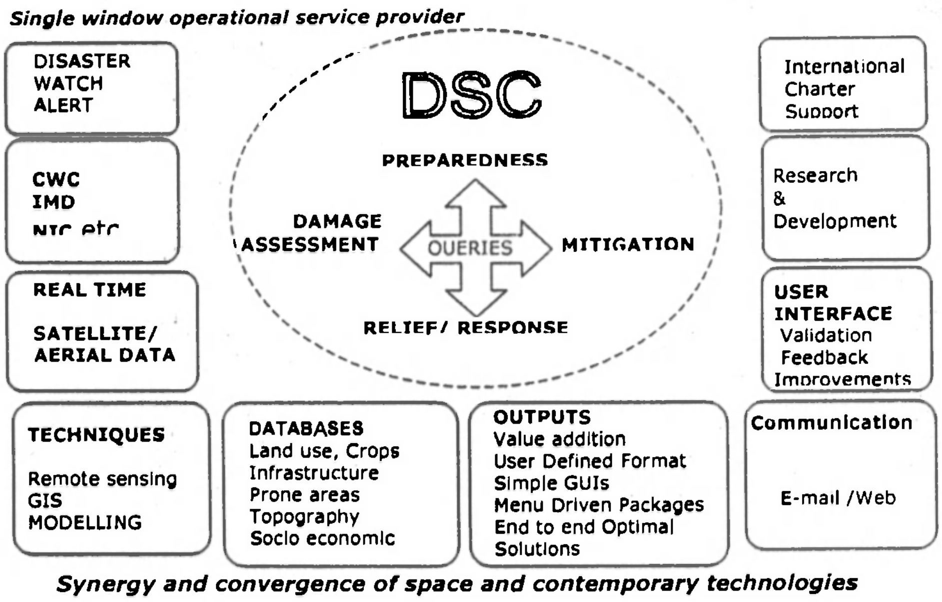


Fig. 2 Activities of DSC

3.1 Disaster Watch and Data acquisition

The DSC will come to know of the occurrence of an event through the local administrative bodies and / or by mail. Information will also collected and compiled from TV-news media and disaster web-sites like www.imd.ernet.in, www.cwc.nic.in, www.ndmindia.nic.in, etc. Further, DSC will have its own mechanism for ascertaining the information at its earliest occurrence.

The disaster management authorities must be provided information to affect a quick response. The driving need in this context is the capability to produce output products with the information, which enables the assessment of damaged areas. Resolution, visibility and the turn around time are the key elements in the planning for satellite / aerial data. A schematic representation of the satellite / aerial data acquisition is presented in fig.3.

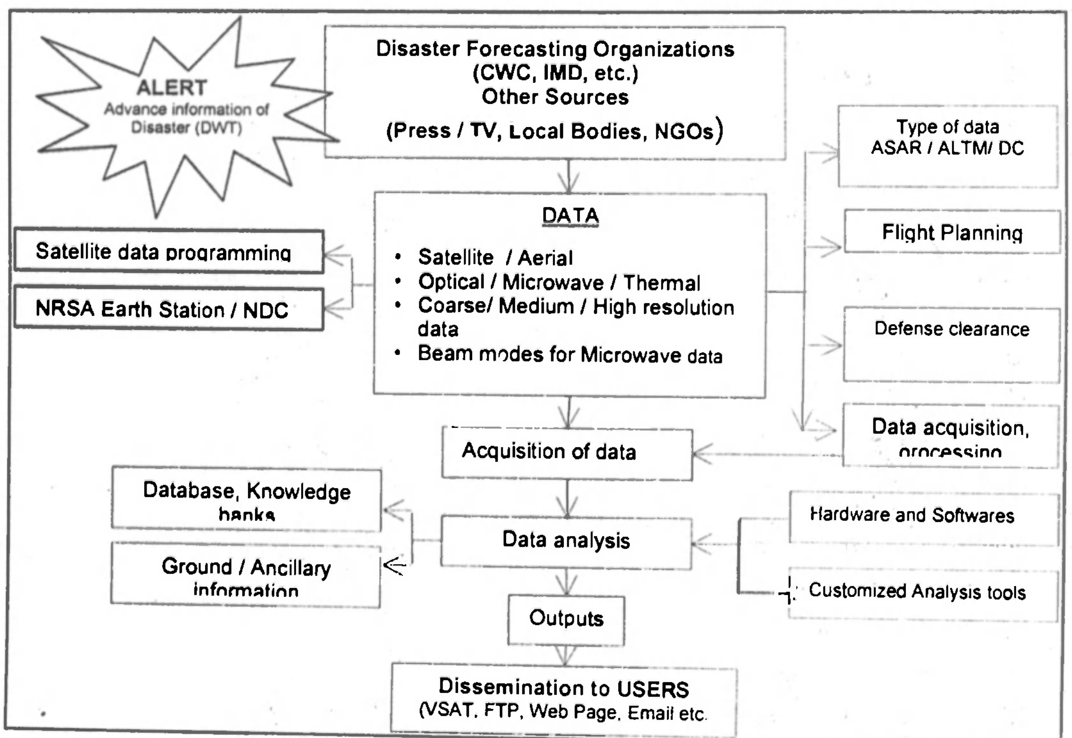


Fig 3. Data Acquisition Plan

Currently, the satellite data of IRS-1C, 1D and P6 and NOAA are acquired at the Earth Station of NRSA located at Shadnagar and the NOAA data is acquired at Balanagar Campus itself. The IRS data is physically transferred to Balanagar Campus for further processing and made available for generation of the satellite deliverables. In order to reduce the time lag for the application group to receive the data, it is contemplated to transfer the data electronically from the Earth Station with a leased communication network. Radarsat data, being used in flood disaster studies, is ordered through NDC to Radarsat Inc., and the data is being supplied electronically.

3.2 Digital database

Database is the most essential element towards generating the information required by users at the Central and State levels. The database consisting of various thematic layers such as land use / land cover, topography, hydro-geomorphology etc. needs to be created which can be used to overlay disaster related information from satellite/aerial data and assess the extent and impact of disasters. In addition, disaster management requires information on weather, infrastructure, demography, etc and precision GIS / digital maps of all states, districts and Urban centres with spatial and aspatial data at appropriate scales.

Standards defined by the NRIS will be reviewed for its direct utility in providing disaster related information. Digital database comprising of comprehensive geospatial datasets on the disaster prone areas, disaster occurrence, infrastructure, natural resources, socio-economic structure, etc. are immensely useful in understanding the nature of the disaster preparedness, mitigation and management practices.

The areas to be covered for database creation consist of several priority districts in the country that are prone to various disasters. ISRO has initiated the work on creation of digital database for selected disaster-prone districts in 5 States (Orissa, Andhra Pradesh, Bihar, West Bengal and Assam). The database created will contain information in the spatial domain in the form of thematic layers and non-spatial domain to socio-economic infrastructure data and resource attribute parameters.

3.3 Query shell development

The query shell development is needed so as to reach the data and information in a user-friendly format to the end-users. Automation of various steps involved in the process of generation of disaster information will save considerable time and enables the availability of outputs / services timely to the users These query shells will be developed to generate maps of vulnerability and hazard zonation. User friendly and menu-driven packages have to be developed to generate outputs in the user-defined formats.

3.4. Hazard Zonation using Aerial Data Support

DSC also envisages tapping the potential of the aerial data. The air-borne SAR data is advantageous to circumvent the cloud problem during the disaster phase. The LiDAR techniques can provide information to generate close contour information. Studies on airborne SAR Developments will be carried out at SAC, Ahmedabad. ALTM surveys will be carried out by the NRSA. DSC maintains a close liaison with the teams of these two activities to meet the requirements of DSC in generating the deliverables.

3.5 Airborne SAR for all-weather mapping

Taking into account the improved turn-around time to the extent of T + 12 hrs, it is necessary to have air-borne SAR for all weather mapping and also to fill the gaps due to inadequate repetitivity of EO satellites, including microwave missions (where T is the time of occurrence of the reporting of disaster). Airborne and space borne systems will conjunctively be used to meet the near real time information delivery needs. Considering the information and survey needs, the systems need to be configured catering to a wide range of resolutions and swaths

3.6 Close-contour information

Contour information is essential for spatial analysis and also for planning mitigation measures. Accurate elevation information is required for estimating areas that will be inundated by floods, cyclones. This would assist in evacuating people from inundating areas and in the identification of encroachments etc. Currently available contour data (at 20 m resolution) is inadequate to carry out such analysis. This type of applications needs 0.5m contour maps.The integrated Airborne Laser Terrain Mapping ALTM also consists of Differential GPS (GPS onboard the aircraft and GPS operated on ground simultaneously) to create reference frame of the aircraft, and Inertial Reference Unit (IRU) to record attitude variations (pitch, roll and yaw) of the platform.

3.7 Mechanism of Information Dissemination

Broadly, there are three different ways of dissemination the disaster information : (a) Conventional – sending directly to the user either by speed post or courier or personally handing over, (b) Digital way - sending directly through Internet by e-mail to the user departments and (c) Web-hosting- Placing directly on the customized web site so that authorized users can access the information from their end. The web application can have many users than a conventional, non-www application and in the event of disaster, it is more appropriate to use website for data dissemination. Website for DSC delivers multiple benefits for communication and information dissemination among DSC nodes

3.8 Timeline of the deliverables

Disaster related information is required at the earliest possible time towards planning for disaster mitigation and thus the timely availability of information greatly reduces the damages. Satellite data provides information at different stages of disaster – pre, during and post event. Information on vulnerability and hazard zonation leads to preparedness, while the information during and posteriori to disasters enable planning and execution of relief operations and assess the damage. In order to provide the information timely in a reliable manner, a systematic planning of various activities leading to generation of disaster information are required.

The time line activities of disaster are grouped into two categories based on the rapidity with which these disasters cause damage. Floods, cyclones, forest fires, earthquakes and landslides are rapid and require information at the earliest possible time after the event. Amongst these rapid disasters also, the area being affected by floods need continuous monitoring. Detailed schemes have been worked out for different natural disasters. Drought, being a slow disaster needs to be monitored regularly all through the crop growth cycle. The information of agricultural situation, using the time composited satellite data, is generated at monthly intervals during June to October, corresponding to the south west monsoon period of India. The first report is generated by the end of August, and monthly updates thereon upto October are disseminated to the administrative machinery for taking up appropriate strategies to mitigate the drought.

4. Summary

Space technology provides critical and timely information on various disasters, which will play a vital role in disaster management. The Decision Support Centre (DSC) is envisioned as a single window operational service provider exploring the synergy and convergence of space and contemporary technologies striving towards effective disaster management.

DSC addresses all the operational needs of disaster management, generates up to date information using satellite data on disasters at the disaster foot print level, assess the risk and damage and monitor the disasters to provide value added information to suit users' needs. In this regard, DSC will have close liaison with various centres for acquisition, processing and analyses of data, generation and transmission of information, R&D support and capacity building. Concerted efforts will be put by the DSC, involving all the concerned DOS and non-DOS centres in order to carry out these tasks towards preparedness and assessment of the disasters for mitigation and management. DSC is also fulfilling the mandate of the International Charter on Space and Major Disasters by providing support to the activities of the Charter in the global arena.

NATURAL DISASTERS SCENARIO OF SOUTH INDIA

Dr. SM. Ramasamy
Prof. & Head/Director
Centre for Remote Sensing
Bharathidasan University, Khajamalai campus
Tiruchirappalli
e-mail: smrsamy@yahoo-co.in

The southern part of the Indian peninsular has been thought as a stable shield area, and hence inert to younger earth movements, related seismicities and other connected natural disasters. But, in addition to the most devastating earthquakes in Killari, Japalpur and Gujarat, the recently carried out remote sensing based geological investigations have convincingly proved that the southern part of the Indian peninsular is tectonically alert and prone for chains of tectonically induced natural disasters. These disasters can be broadly classified into two groups:

1. Active tectonics induced natural disasters (seismicities, landslides, flooding, tsunami etc.)
2. Active tectonics induced chains of environmental disasters (soil erosion, sediment dump into ocean, modifications in the fluvial dynamics, eco degradation along the coasts, modifications of the hydrological systems etc.

The mantle convection currents which were instrumental in drifting the different plates/ continents have pushed the Indian plate towards north northeasterly and as a result, the Indian plate has moved over 6000 km at least during the last 60 million years, collided with Eurasian plate in the north and caused the rise of huge Himalayan chains of mountains. Though the said north northeasterly force is still active, India is not able to move northerly because of the obstruction provided by the Himalayas. Hence, the whole India is whirling like a worm from Cape Comorin in the south to Himalaya in the north. In parts of the South India alone, the land is arching up along two major axes, one along Mangalore-Chennai in the north and the other along Cochin-Rameswaram in the south. These two arches are intervened by a complementary ongoing land subsidence along Ponnani-Palghat-Manamelkudi and Kambam-Pondicherry. Consequent to such post collision buckling, spectrum of NS faults are opening up like lenses, NE-SW faults are moving left handedly (sinistral) and the NW-SE faults are moving right handedly (dextral). This vibrant tectonic process seems to be the basic stimuli for various natural disasters in South India.

The correlative analysis between these active faults and the historical seismic data (though less than 3 in magnitude) shows that the ENE-WSW to NE-SW trending sinistral faults are more seismogenic, that too in zones where these intersect at 45^0 to 75^0 angles. The landslides of South India, though have been demonstrated to be due to pore pressure increase, the active tectonics again seems to be the basic tutoring factor. The Nilgiri massif is sinistrally rotating along two sinistral bounding faults occurring both on the south and on the north The same rotation has caused fractures facilitating the water entry and to ultimately cause landslides. The other landslides inducing parameters seem act as further triggering parameters. On the basis of these observations, certain new types of mitigation measures were evolved using Remote Sensing and GIS.

Though the flooding is leastly observed in South India, the flash floods observed in different parts of Tamil Nadu and the recurring flood in Cauvery in Tiruchirappalli in a time frame of every 5-7 years indicate that the ongoing Holocene grabening in between Pondicherry in the north east and Kambam valley in the south west seems to control the flooding especially in Tiruchy urban area. Models have also been brought out to mitigate flooding in Tiruchy. Similarly, though the December 26^{th} Sumatra tsunami, is proved to have been induced by the subduction of the Indian plate below the Burmis micro plate. However, the tsunami vulnerability of Tamil Nadu coast seems to be overall controlled by active tectonics and the induced development of various geomorphology features.

For example, the concave Pondicherry coast should have been affected more when compared to the convex Chennai coast, because of the ongoing tectonic emergence in Chennai and subsidence in Pondicherry. But vice-versa has happened due to some of the tectonically induced coastal dynamics. In addition, various tectonic, fluvial, fluvio marine and marine geomorphic features seem to have acted as facilitators/carriers/absorbers/barriers etc. of the tsunami energy. Critical geo system based models are being evolved for tsunami mitigation.

Similarly, such ongoing tectonic movements related to the post collision phenomena seem to control chains of disasters such as soil erosion, massive sediment dumping into the Ocean, modifications of fluvial dynamics, modifications of land-Ocean interactions along coasts, variations in the hydrological systems etc.

The paper thus provides an over view on the Earth System Dynamics and the related natural disasters scenario of South India.

DAMAGE ASSESSMENT IN TSUNAMI AFFECTED AREAS USING REMOTE SENSING AND GIS

Dr.M.RAMALINGAM
Institute of Remote Sensing
Anna University, Chennai – 600 025.

ABSTRACT

Tsunami is a Japanese world with the English translation **"harbor wave".** Tsunamis are a series of very long waves generated by any rapid, large – scale disturbance of the sea. The Tsunami may occurs due to under see earthquake. Submarine landslide, underwater volcanic eruptions and large meteorites plunging in to the sea. A Tsunami can exceed 500 mph in the deep ocean but slows to 20 or 30 mph in the shallow water near land. A number of countries incurred loss of life from the Tsunami including Bangaladesh, Indonesia, Kenya, Malaysia, Maldives, Myanmar, Seychelles, Somalia, Srilanka, Thailand etc., The December 26th 2004 Tsunami triggered by a massive under sea earthquake off Sumatra in Indonesia left over more than 1.50 lakh people dead and tens of thousands of people found homeless in India, Srilanka and South east Asia. In India more than 9.500 people were killed in Tamilnadu, Pondichery, Andhrapradesh, Kerala and Andhaman and Nicobar islands. In Tamilnadu more than 362 villages covering 6.9 lakhs population have been affected. A number of dwelling units and roads have been damaged. In Tamil Nadu the worst affected areas are Nagapattinam, Cuddalore, Chennai and Kanyakumari. In order to assess the damage a project has been undertaken using the aerial and satellite data.

The main objective of the project is to assess the damages occurred in the selected stretches of coastal zone by studying the condition of the coastal stretch prior to and after the occurrence of Tsunami and also enumerate the damages caused to the individual properties. For pre disaster scenario it is proposed to use IKONOS data with 1m spatial resolution to map the condition that have prevailed before the devastation and for the post disaster scenario proposed to use aerial photographs immediately taken after the occurrence of the Tsunami. This study has been proposed to be taken up in all the four stretches covering Chennai, Cuddalore, Nagapattinam and Kanyakumari. IRS will be responsible for Chennai area. It is also proposed to carryout the details of damages occurred to the properties by conducting detailed field surveys using GPS. In this aspect number of field parties will be identified to collect the extent of damage to the individual properties by visiting the sites and checking the properties with the help of the maps generated using IKONOS imagery and aerial photographs. An information system with the above data will be developed for the disaster mitigation.

DROUGHT ANALYSIS IN PALAR RIVER BASIN

* DR. V. SUKUMAR, M.E.,P.HD. **THIRU. K. SANTHANAM, M.SC., MIRS.

Preamble

Drought is a normal, recurrent feature of climate although many erroneously consider it a rare and random event. It forms one extreme end of the hydrologic cycle. Drought represents a period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance and connotations of a moisture deficiency with respect to various uses. The study of drought is an extremely relevant and essential aspect for the overall planning and management of water resources in order to meet the increasing demands on available water for different uses. In periods of distress, direct losses due to droughts result form reduced crop yields, pasture deterioration and livestock deaths which include reduced returns of most agricultural products. Financial losses result from transport of emergency water supplies.

In India, drought is frequent hazard striking in some part or the other. The worst drought affected States in general are Karnataka, Tamil Nadu, Gujarat, Rajasthan, Andrapradesh and Maharashtra. During the seventies, about 80% of the Worlds victims affected by Drought lived in India. National commission on Agriculture 1976 revealed that one third of the geographical area of India i.e. 107 million hectare spread over 99 districts in 13 states is affected by droughts. Tamil Nadu state experiences recurring droughts. 50% of the districts in the state are drought prone due to severe water deficit in Southwest Monsoon period and in summer months.

Institute for water studies, WRO, PWD is entrusted with the task of assessing water potential (Surface & Ground water), deciding sectoral demands and arriving at the balance for future utilization, Regional drought analysis and monitoring have to be done for each river basin.

Remote sensing is capable of furnishing data periodically covering large areas which are required for macro level studies, Geographical Information System furnished

* Chief Engineer & Director, WRO, PWD
**G.I.S. Specialist, IWS.

scientific environment to handle and analyse such kind of data needed for assessing drought.

The year 1987 witnessed a succession of drought, which affected Tamil Nadu in 1986. The Continuous drought was severe in its impact until the northeast monsoon brought in the much needed respite. Briefly, the strategies adopted by the departments are indicated as follows:-

- Due to the poor storage in the reservoirs, the cropping pattern was changed to make the best of the situation. The Kuruvai was lost. In paddy area, short-term samba crop was promoted and the broadcast method of sowing was advocated to the farmers, as the levels in the reservoirs were low. Subsidy to the small and marginal farmers was given and deferment of loan repayment was allowed;
- Drinking water schemes were augmented by various programmes taken up urgently. The Tamil Nadu Water Supply and Drainage (TWAD) Board was given the responsibility of sinking bore wells and completing comprehensive water supply schemes that would augment the water supply to the people;
- The Rural Development, Municipal and Town Panchayat Departments took up execution of schemes such as open wells, ring wells, deepening of wells. Funds were given for strengthening water supply feeder-lines to the Electricity Board to be taken up in Municipal and Town Panchayat area;
- Agriculture labourers were given employment by PWD (I), PWD (MI), Rural Development and Agriculture Engineering Departments. Works of labour intensive nature were taken up. The aim was to give labour work locally and to take up such works as would recharge ground water and serve as a drought proofing measure;
- Afforestation and labour oriented works were taken up in the forest area by the Chief Conservator of Forests. He also catered to drinking water needs of the tribal population and resident forest staff. Water and soil conservation measures in the forest area were taken up. Water points for wild animals were created. The labour schemes were taken up by the local tribal population living in forest area who were out of employment during the drought period and when neglected abetted poaching and destruction of forests. A special feature

of the drought programme by the Forest Department was the creation of forest ecology farms in each district; and

- Wherever the sources dried up or the water turned brackish, transportation of water through lorries and carts was resorted to.

I.W.S. and Centre for Water Resources Anna University conducted detailed study about droughts in Palar river basin (for which Government of Tamilnadu, recently established River Basin Board, Basin Management committee and Technical Secretariat)

Details of Study

In order to develop a drought information system (DIS) in GIS environment, studies were taken. The aim of the study is

- To generate a water related data base
- To carryout meteorological drought analysis
- To carryout hydrological drought analysis from water availability data
- To carryout agricultural drought analysis using remote sensing data, to identify drought risk using remote sensing data, to identify drought risk areas using G.I.S.

Palar is located in the North Eastern part in of Tamil Nadu.

The tributaries of Palar are Kavandinya, Malattar, Agaramar, Poiney, Cheyyar and Killiyar. Total geographical area of Palar basin in Tamil Nadu is 10911 sq.km. Agricultural land occupies 79% of the area. Palar originates in Karnataka, passes through Andhra and reaches Tamilnadu near Pullur. This river has surface water flow only for a few days in a year. Aquifer thickness is more in the main river and tributaries.

Methodology:

Spatial and Temporal data was collected from various sources. Administrative, irrigation system, rainfall stations locations, landuse maps have been generated by using GIS techniques. Geology, geomorphology, landuse, drainage maps were derived based as Remote Sensing. 30 years monthly water, land and rainfall data were collected. From the water level fluctuation, mean seasonal groundwater fluctuation values were calculated and analysed for the Panchayat unions of the two river basins.

Meteorological Drought:

By utilizing Indian Meteorological Department method meteorological drought of any year can be classified into 4 classes –1. No. drought 2. Mild drought 3. Moderate drought and 4. Severe drought. Drought severity was assessed for all the Panchayat unions from 1971-1999. This meteorological drought analysis will be helpful in predicting agricultural drought by IMD method.

$$D1(\text{Drought}) = \frac{P1(\text{Annual Rainfall in the year}) - \overline{P}(\text{long-term annual mean rainfall})}{\overline{P}}$$

Classification of Drought

Ranging of D1	
> 0	(No drought (m 0)
0 to -25	Mild drought (m1)
-25 to –50	Moderate drought (m 2)
>-50	Severe drought

Hydrological drought analysis:

By utilizing Herbst method, hydrological drought assessment was made. Monthly utilization in various storage structures (Anicuts) for the period from 1971 to 2000 was taken. Hydrological drought is associated with the effects of periods of rainfall shortfalls as surface or groundwater supply.

30 years data of monthly utilization at various anicuts of the 2 river basins were considered for surface flow drought assessment. The drought analysis based on irrigation release data reflects incorrect hydrological drought assessment. Ground water data for the 3 decades 1971-2000 was used for this study. In this study the utilization of water is referred to as the irrigation release to the crops.

Agricultural drought assessment:

Meteorological and hydrological droughts are concerned with supply-oriented components like rainfall, surface and groundwater, but agricultural drought is concerned with availability of water to meet crop water requirements. The irrigated-crop–drought assessment is based on supply-demand analysis. The irrigation release is the supply and crop water requirement is the demand.

In rainfall dry crop drought assessment, the supply is the effective rainfall for the crop season and demand is the crop evapo-transpiration values for the crop seasons.

Remote Sensing based Agricultural drought analysis:

NADAMS – National Agricultural Drought Assessment and Monitoring System is based on crop condition. NADAMS provides accurate information on agricultural drought conditions.

After satellite data generation of NDVI, images was done, The NDVI based Agri-drought assessment was made. Based on ranges of NDVI % values, the crop condition is divided into 5 classes.

If NDVI is >10 crop condition is excess. In between -10 to +10 it is normal. If NDVI % is in between –10 and –20 it is mild. Crop condition is moderate if the NDVI %is in between -20 and –40. if the NDVI % is > -40, Crop condition is severe.

Crop condition NDVI range was reclassified to obtain Panchayat union wise agricultural drought assessment. Weightage for each condition was arrived in order to arrive a suitable value for each Panchayat union, the area falling under each crop condition was multiplied by the corresponding weightages and the sum was divided by the total area of block. Based on the values of each block, reclassification was made.

<u>Reclassification of drought severity</u>

Reclassification	Drought severity
1 to 1.5	Excess
1.5 to 2.5	Normal
2.5 to 3.5	Mild drought
3.5 to 4.5	Moderate drought
4.5 to 5	Severe drought

ASSESSMENT OF DROUGHT IN PALAR RIVER BASIN

For assessment of drought in Palar basin, river system details, soil types, cropping pattern, landuse classification, rainfall pattern and water level fluctuation etc were collected.

1. Palar Basin System

Palar is one of the 17 major river basins of Tamilnadu. It originates in Karnataka, passes through Andhrarpradesh, reached Tamilnadu near Pullur in Vellore district. Out of the total geographical area of 18,300 sq.km, the area fall in Tamilnadu is 10910 sq.km. Length of the basin is 350 km and width ranges between 37 to 135 km. Tributaries of Palar basin are Cheyyar, Poiney, Kavaundinya, Malattar and Killiyar.

Geologically westernpart is underlain by Archaen hard rocks and eastern part is occupied by sedimentary formations. The thickness of alluvium is focused to be in the more confluency points of tributaries. Even though, surface flow is for few days, it acts as a good ground water reservoir. There are 47 Panchayat unions belonging to Vellore, Kancheepuram and Thiruvannamalai districts. Riverbed aquifer is the main source of drinking water supply to municipalities, major town panchayats and villages. Palar basin area in Vellore district is 4710.58 sq.km, in Thiruvannamalai it is 4012.19 sq.km and in Kancheepuram district it is 2187.90 sq.km.

2. Anicuts:

There are 7 anicuts viz., Palar, Poiney, Alyabed, Cheyyar, Uthiramerur, Kamandala Naganadhi and Thandarai. Catchment areas are 10293, 1725, 8699,1841,3889,751 and 1161 sq.km. respectively. Palar anicut system has 4 channels which provide irrigation to 32796 ha of ayacuts. There are 324 Tanks in river system. Poiney anicut has 2 head sluices which irrigate 6883 hectares of ayacut 129 tanks are lying in this system. Aliyabad anicut irrigate 1038 ha and it has 16 systems.

3. Soils

Inceptisol, Alfisol, Entisol & Vertisol soils occur in this basin. These soils are suited for commonly grown crops.

4. Landuse

Out of the total geographical area of 10910 sq.km, 80.21% area is under agricultural land, 18.57 % area is under forest and 1.22 % area is under wasteland.

Data Collected

Data required for drought assessment is divided into 2 categories (Spatial and attributes) spatial data was collected in the form of satellites & maps. Attributes of meteorological, hydrological & agricultural data were also collected.

Meteorological Data:

From 35 Rainguage stations, 1971 to 2000, monthly rainfall data were collected. Temperature, humidity, sunshine etc were collected from Kilnatchipattu and Tiruttani stations.

Hydrological data:

Stream flow data were collected from 8 anicuts of Palar river basin and 4 gauging stations maintained by Central Water Commission. Hydraulic data on watershed area capacity and ayacut area of system and non-system tanks and water level fluctuation of 120 shallow observation wells were also collected.

Agricultural data:

Land utilization, crop pattern crop area and crop yield were collected. Block wise agricultural data were also collected.

Maps collection:

Basin, administrative, land use, hydrogeology and geomorphology maps were obtained. Geology, geomorphology and landuse maps were derived based on Remote sensing interpretation for 1998, 1999, IRS 1C & 1D Wifs scenes were procured. Blocks under drought area programme are 44 blocks in the 3 districts.

Rainfall patterns:

Monthly mean rainfall for all Rainguage stations were calculated. Average annual rainfall, seasonal (NE & SW) rainfall were also calculated.

During both monsoon periods basin receives good amount of rainfall. Northeast monsoon rainfall analysis reveals that eastern part of basin (7 full blocks, 9 part blocks) received substantial amount Western part (14 full blocks) received poor rainfall. During southwest monsoon, Kancheepuram, Walaja, Chengalpet, Anani, Cheyyar, Walaja received good rainfall main crops season is (April –August) Navarai and samba (August –January). During average annual rainfall is 778 mm and in Navarai season, it is 143 mm. In sornavai season, rainfall is observed as 382mm.

Groundwater Status:

Groundwater fluctuation is very high in Jolanpettai, Pullur Vellore,Chetpet, Kukuppam, Thurinjapuram, Walaja, Cheyyar anicut, Anani, Pernampet, Uthiramerur, Kalasapakkam and Chithamur block. This may be due to over exploitation.

Meteorological drought assessment:

Drought assessment has been carried out for all 35 stations and presented in the following section in the form of drought severity such as No (M0), Mild (M1), Moderate (M2) & Severe (M3) droughts.

Year	*Severely affected*	*Moderate*	*Mild*
1980	9 blocks	15 blocks	22 blocks
1981	6 blocks	17 blocks	23 blocks
1982	1 block	17 blocks	
1992	4 blocks	12 blocks	
1997 to 1999	Almost most of the area are severely affected.		

Natrampally, Alangayam, Padappai, Katankolathur, Thirupattur, Sriperumpudur, Lathur, Chithamur.

Hydrological drought assessment:

Meteorological drought analysis is important for rainfed agriculture. In, Palar, irrigation is practiced throughout the year Sornavani (April to August) Samba (September- January) and Navarai (December to April) are 3 main crop seasons. As Surface water & groundwater are utilized, for drought assessment, these two factors are essential.

By using HERBST method, analysis in covered out the onset termination and duration of the drought and intensity were obtained from HERBST method by executing a programme in C languages.

Surface Water:

Long-term monthly irrigation releases from 1970 to 2000 for 7 anicuts were analysed by HERBST method. Palar anicut area had 9 drought spells with intensity ranging from 0.06 to 0.78. Poiney anicut also had 9 drought shells (0.04 to 0.51). For Aliyabad anicut intensity varies from 0.03 to 1.57. In Cheyyar anicut there were 13 spells and in Thandarai anicut area there were 7 spells.

Groundwater

Ayacut area under groundwater irrigation is 120445 ha. Due to over draft, decline in groundwater levels is experienced. Long term monthly water levels of 80 wells were analysed to find out dry spells using Herbst method. The deviation of the monthly groundwater level from the mean monthly value was qualified as drought intensity by this method. The temporal occurrence of dry spells are seen for 7 times with drought intensity ranging from 0.49 to 1.77. Water level fluctuations from 10.5 to 17.8 m is observerd during the period of 1975-1988. In Thiruvannamalai district there was long dry spells for 57 months. During drought spell of February 1987 to November 1991 water level fluctuated from 9.5 m to 14.7 m. The lower level of water table is due to the impact of drought. Hydrological drought severity in Kancheepuram district was analysed. The drought severity was very high during February 1987 to November 1991. Many blocks of this basin have moderate and severe droughts. Tail end blocks were also severely affected with intensity ranging from 2 to 4. Especially Lathur and Thirukalunkundnam blocks were severly affected. Walajapet, Katpadi, Kaniyambadi, Timivi, Arani, Kancheepuram, Walajabad, Sviperumpudur, Jolarpettai, Thirupattur and Pernambut were least affected. Moderate drought has occurred in Gudiyatham, Pernambut, Kancheepuram, Cheyyar, Cembakkam and Walajabad.

Remote Sensing Based Agricultural Drought Assessment

By using IRS WIFS Satellite data, Agricultural drought severity maps were generated by developing NDVI statistics. It was attempted to estimate the aerial extent of identified major crops and to find the reduction of crop areas in 1999 compared to that of 1988

Normalizing Rainfall Data :

Remote Sensing based, Agri drought assessment is based as comparative analysis between normal and deficit years. The year can be declared as normal or excess or deficit based on the following conditions

Normal years - + (or) - 18% of the long term basin average

Excess years - > + 18% of the long term basin average

Deficit Year - < -18 % of the long term basin average

Mean Annual Rainfall was calculating for 30 years for 35 Rain gauge Stations. Rainfall analysis was done for the period 1995 to 1999

Rainfall in 1995,1997 & 1998 –Normal

1996 - Excess

1999 - Deficit

Hence 1998(Normal and 1999(drought) years were chosen for study. Analysis revealed that in the year 1998. A part of eastern part of Palar basin experienced less rainfall while in the year 1999 almost entire eastern and westerns parts were effected by rainfall deficiency

Landuse:

Landuse map reveals that out of total geographical area of 1091683 hectares, 29% is under intensively irrigated area, 13% is under sparsely irrigated area 25% is under dry crop area 25% is under forest 2% is under plantation 1% is under grooves 1% is under wasteland 2 % is under river and 1% is under tanks.

Crop Condition Assessment:

The crop condition assessment was made by comparing NDVI values of the year 1999 with that of 1998. The crop condition image for Samba season and Navarai seasons were generated

Agricultural Drought Assessment:

The reclassification of 1998 &1999 crop condition NDVI images, has been completed.

Samba Season:

During 1999, out of 44 blocks, 3 were under normal, 23 under mild drought, 18 under moderate drought, 2 under severe drought conditions

Navarai Season:

In 1999, out of 44 blocks, 7 blocks were under mild drought, 23 blocks were under moderate drought, 14 were under severe drought.

Ground truth data and imagery data were compared variation is ranging from 6.27 to 8.01%.

It is observed that in Samba season in blocks like Jolarpet, Arcot and kancheepuram change in paddy area is up to 70% and it is 90% in Walajabad and Sriperumpudur block. In Navarai season, the change in paddy area in most of the blocks is 100% metrological drought risk mapping (Surface and Ground water risks) supply oriented drought risk mapping Integrated agricultural drought risk mapping were completed. Based on above works Drought prone areas in Palar basin were identified.

Conclusion:

Out of 44 Blocks of Palar basin, 7 blocks are prone to very mild (Walajabad, Timiri, Nemeli, Vembakkam, Arni, Walajapet, and Arniwest) .

12 blocks are prone to mild drought (Vellore, Kaniyambadi, Katpadi, Arcot, Kaveripakkam, Thellar, Turinjapuram, Anakkayur, Kalarapakkam, Chetpet, Thirukalugundram and Kancheepuram. 16 Blocks are prone to moderate drought (Jolarpet, K.V.kuppam, Gudhiyattam, Pernampet, Wandavasi, Pernamallur, Cheyyar, Chengam, Pudupalayam, Pollur, Javadi, Kattankulathur, Tiruporur, Acharapakkam, Padappai and Sriperumpudur.

9 Blocks are prone to severe drought Anaicut, Thirupattur, Natrampalli, Madhavur, Alangayam, Uthiramerur, Lathur, Chitamur and Madurantangam.

Remote Sensing & GIS FOR DISASTER MANAGEMENT

Dr. Asis Bhattacharya
Former Deputy Director (RS & GIS),
NRSA, Hyderabad

Each year natural disasters exert a heavy toll on human life and property. The United Nations estimates that, in the past 20 years, nearly three million lives have been lost to natural disasters, and some 800 million people have been affected despite technological advances in forecasting, early warning and disaster management services. Floods, Cyclones, Droughts, Landslides, Volcanoes, Forest Fires, Earthquakes and Oil Spills are the common forms of natural disasters that affect human population.

India is one among the disaster prone geographical zones of the world and suffers losses worth more than Rs. 1000 crores as a result of damages due to different types of disasters annually.

Remote sensing techniques are invaluable for collecting the data rapidly and mapping the affected areas extensively, particularly in developing countries for which conventional resource mapping sources are limited. Mapping the disaster areas would help in the management of rescue and rehabilitation operations.

In order to plan the relief operations and also for long term flood mitigations, flood information, specifically in the form of a flood map is essential. Remote Sensing can effectively be used for mapping the flood damaged areas. However, ancillary information has to be used alongwith remotely sensed data for better assessment. One direct method to estimate the flood damages is to procure satellite data before, during and after the event and analyse them together for change detection. From the satellite images prior to the flood and pre-flood situation can be mapped. The satellite images during flood reveal the flood inundation extent. The post-flood satellite data shows the residual effects of the damaged area.

Cyclone is a disaster resulting from nature's fury and is beyond human control. It causes damage to agriculture, human lives, livestock, infrastructure and communication facilities. The crucial part here is the information collection, mapping and its dissemination. The real-time operation of satellite remote sensing has demonstrated the translation of information derived from space technology to ground reality, e.g. Orissa cyclone study through Remote Sensing techniques.

Drought is the single most important weather – related natural disaster often aggravated by human action. Drought may start any time, last indefinitely and attain many degrees of severity. It affects very large areas for months and years and thus has a serious impact on regional food production, often reducing

life expectancy, huge economic losses, destruction of ecological resources, food shortages and starvation of millions of people. Remote sensing techniques make it possible to generate information rapidly over large areas by means of sensors operating in several spectral bands, mounted on aircraft or satellites. The bands used by these sensors cover the whole range between visible and microwaves. Unlike in the conventional methods, where the crop condition is indirectly assessed through rainfall, evapotranspiration etc., in the Remote sensing methodology, the crop condition is assessed based on spectral characteristics of vegetation, which indicates the condition of the crop directly and finally relating to the drought situation.

Identification of small landslide on imagery is rather difficult, but larger landslide can be identified directly due to the scale factor. However, satellite data may be helpful in providing necessary information on the susceptibility of terrain for landslides indirectly by studying the regional terrain conditions. As an advantage of repetitive coverage, seasonal changes in vegetative cover and moisture level (indicated by tonal changes) can be mapped and evaluated to increase the accuracy of interpretation of terrain conditions. Landslide Hazard Zonation (LHZ) maps of Himalayas have been prepared using large scale satellite data.

One of the most useful aspects of remote sensing in a tropical volcanic region is the ability of the visible and infrared radiation to discriminate between fresh rock and vegetated surfaces. The geomorphological changes can be effectively mapped with all the visible sensors in the orbits. Barren Island volcano situated in the Andaman Sea of Bay of Bengal is the only known active volcano in the country. This volcano erupted in March, 1991 and again in January, 1995 after a prolonged period of quiescence. The area is remote and inaccessible and hence there is limited opportunity to collect field data. Remote Sensing data was extensively used for barren Island volcano monitoring.

Every year millions of hectares of the world's forests are consumed by fire, which results in enormous economic losses because of burnt timber, degraded sites, high costs of suppression, damage to environmental, recreational and amenity values and loss of life. Forest fires in India are generally ground fires. About 35 million ha of forest area is affected by fire annually. A survey conducted by Forestry Survey of India in 1995 found that fires affect around 55 per cent of the forest area annually. Using data from satellites orbiting the earth, it is possible to map the forest situation over large areas, to monitor the emergency, identify risks, detect fires and assess the damage. Different satellites have proved to be useful in achieving this. Remote Sensing of fires, smoke and even burn scars allows for improved detection of fire characteristics and thereby helps in mapping the affected forest areas.

Remote Sensing plays an important role in earthquake studies, but limited to mapping the active faults, lineament density and liquefaction zones, and suggesting safer sites for locating the villages. Area-wise damage assessment is also possible using satellite data. Of late, a new technique called "Radar Interferometry" is emerging as a powerful tool, which is useful in detecting and mapping the surface deformations or morphological changes in the order of few centimeters, caused due to earthquakes. However, its applicability for forecasting the earthquakes is still to be evaluated.

Coastal zones receive considerable amount of oil from shipping which includes dumping of bilge, accidental discharge of oil from tankers, exhaust discharge from small crafts, runoff of oil via sewage, land waste and industrial effluents. Present day knowledge on the oil spill information is primarily based on the visual observations as reported by ships. Hence, remote sensing becomes a vital tool not only to detect the oil spills but also collect information about the oil spills for mapping and computation of their extent /relative thickness.

With the availability of high spatial resolution data from different satellites such as IRS-1C/1D, IKONOS and QUICK BIRD, the mapping of disaster affected areas on larger scale, e.g. 1:10,000 scale, has become possible. The high spectral and spatial resolution data, likely to be available from different space missions in future, will add a new dimension in understanding the physical processes and phenomena for mapping various types of disasters leading to the effective management programmes.

TSUNAMI - GENERATION, PROPAGATION AND EFFECTS

Prof. V. Sundar and Dr. S.A. Sannasiraj
Department of Ocean Engineering, IITMadras

1. INTRODUCTION

A tsunami is a series of waves traveling across the ocean with extremely long wavelengths (up to hundreds of kilometers between wave crests in the deep ocean). When such a wave approach the shore, its speed decreases as it begins to "feel" the sea bottom. It is at this time that the height of the wave drastically increases. As the waves strike the shore they may inundate low-lying coastal areas resulting in mass destruction and in many instances loss of life. Other terms for "tsunami" found in the literature include: seismic sea wave and incorrectly, tidal wave. The term "tidal wave" is frequently used in the older literature and in popular accounts, but is now considered incorrect. Tidal waves are simply the periodic movement of water associated with the rise and fall of the tides produced by the gravitational attraction of the sun and moon. Tsunamis have connection neither with the weather nor with the tides. "*Tsunami*" is a Japanese word which translates as "harbor wave".

2. ORIGIN OF A TSUNAMI

A tsunami can be generated by ANY disturbance that displaces a large water mass in the ocean from its equilibrium position. Oceanographers often refer 'tsunamis' as seismic sea waves as they are usually the result of a sudden rise or fall of a section of the earth's crust under or near the ocean. A seismic disturbance (such as an earthquake) can displace the water column, creating a rise or fall in the level of the ocean above. This rise or fall in sea floor level is the initial formation of a tsunami wave. Tsunami waves can also be created by volcanic activity and landslides occurring above or below the sea surface. These types of activity produce tsunamis with much less energy than those produced by submarine faulting (earthquakes). During a submarine landslide, the equilibrium sea level is altered by sediment moving along the sea floor. Similarly, a violent marine volcanic eruption can create an impulsive force that displaces the water column and generates a tsunami. Above water landslides and space born objects can disturb the water from above the surface. The falling debris displaces the water from its equilibrium position and produces a tsunami. Gravitational forces then propagate the tsunami given the initial perturbation of the sea level. The size and energy of these tsunamis dissipates rapidly with increasing distance from the source, thus resulting in more local devastation. Unlike ocean-wide tsunamis caused by some earthquakes, tsunamis generated by non-seismic mechanisms usually dissipate quickly and rarely affect coastlines far from the source area.

3. APPEARANCE OF A TSUNAMI WAVE

The image most people have of a tsunami is a large, steep wave breaking on the shore. This image is hardly if ever the case. Most tsunamis appear as an advancing tide without having a developed wave face, resulting in rapid flooding of low-lying coastal areas. Sometimes, a bore can form during which an abrupt front of whitewater will rapidly advance inland much similar to the tidal bore formed at the mouth of large rivers.

4. TSUNAMI CHARACTERISTICS

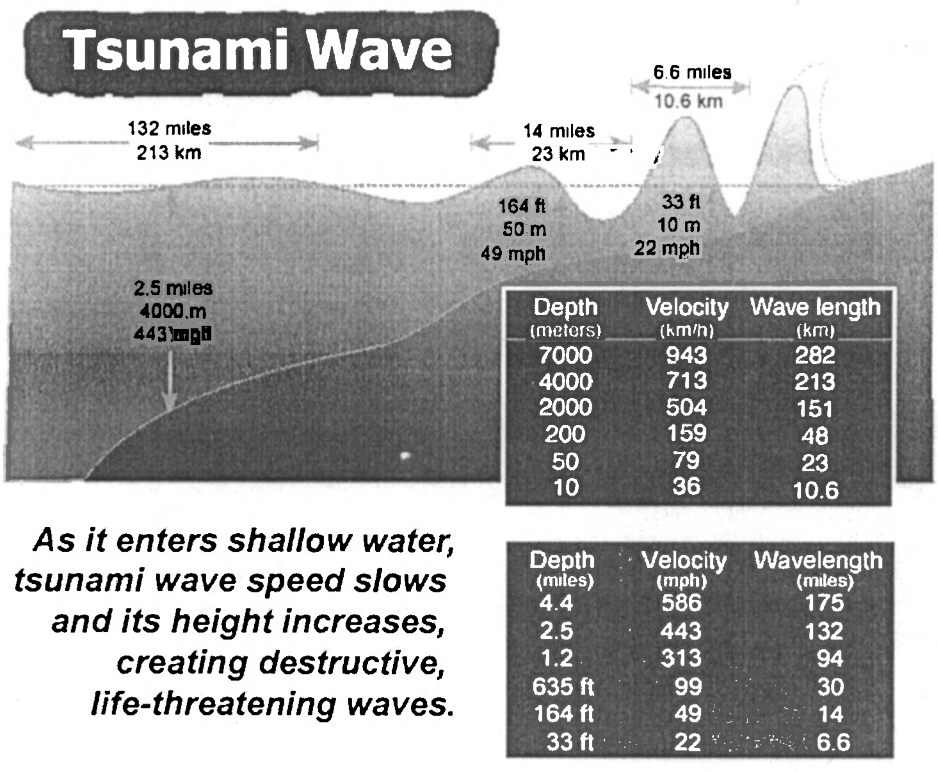
Tsunamis are characterized as shallow-water waves. These shallow-water waves are different from wind-generated waves. Wind-generated waves usually have period (time between two success ional waves) of five to twenty seconds and a wavelength (distance between two successive waves) of about 100 to 200 meters. A tsunami can have a period in the range of ten minutes to two hours and a wavelength in excess of 500 km. It is because of their long wavelengths that tsunamis behave as shallow-water waves. A wave is characterized as a shallow-water wave when the ratio between the water depth (d) and its wavelength (L) gets very small ($d/L < 0.5$). The speed (C) of a shallow-water wave is equal to the square root of the product of the acceleration of gravity (g) and the depth of the water.

$$C = \sqrt{gd}$$

One can note that the speed of a tsunami wave thus does not depend on the wave length or its energy level. The rate at which a wave loses its energy is inversely related to its wavelength. Since a tsunami has a very large wavelength, it will lose little energy as it propagates. Hence in very deep water, a tsunami will travel at high speeds and travel great transoceanic distances with limited energy loss. For example, when the ocean is 6000 m deep, unnoticed tsunami travel about 870 km/hr, the speed of a jet airplane.

5. PROPAGATION TO COASTAL AREAS

As a tsunami leaves the deep water of the open sea and propagates into the more shallow waters near the coast, it undergoes a transformation (**Fig. 1**). Since the speed of the tsunami is related to the water depth, as the depth of the water decreases, the speed of the tsunami diminishes. However, the total energy of the tsunami remains constant. Therefore, the speed of the tsunami decreases as it enters shallower water, and the height of the wave grows. Because of this "shoaling" effect, a tsunami that was imperceptible in deep water may grow to be several meters or more in height near the coast.



Depth (meters)	Velocity (km/h)	Wave length (km)
7000	943	282
4000	713	213
2000	504	151
200	159	48
50	79	23
10	36	10.6

Depth (miles)	Velocity (mph)	Wavelength (miles)
4.4	586	175
2.5	443	132
1.2	313	94
635 ft	99	30
164 ft	49	14
33 ft	22	6.6

Fig. 1. Propagation of a tsunami wave

When a tsunami finally reaches the shore, it may appear as a rapidly rising or falling tide, a series of breaking waves, or even a bore. When tsunami waves approach land, their appearance and behavior depend on the topography of the seafloor, the actual shape of the shoreline, reefs, bays, river entrances and the slope of the beach. Tsunamis rarely become great, towering breaking waves. Sometimes the tsunami may break far offshore. Or it may form into a bore: a step-like wave with a steep breaking front. A bore can happen if the tsunami moves from deep water into a shallow bay or river. The water level on shore can rise many meters. In extreme cases, water level can rise to more than 15 m for tsunamis of distant origin and over 30 m for tsunami generated near the earthquake's epicenter. Wave heights can also be increased when concentrated on headlands or when traveling into bays having wide entrances that become progressively narrower. The presence of an offshore coral reef can dissipate the energy of a tsunami, decreasing the impact on the shoreline. Normal wind swell may ride atop of a tsunami wave thereby increasing wave height.

A tsunami generally consists of a series of waves, often referred to as the tsunami wave train. The amount of time between successive waves (wave period) is only a few minutes to over an hour apart. Many people have lost their lives after returning home in between the waves of a tsunami, thinking that the waves had stopped coming. The first wave may not be the largest in the series of waves. The initial withdrawal of the water is actually the trough of the tsunami reaching shore. One coastal area may see no damaging wave activity while in another area destructive waves can be large and violent. The flooding of an area can extend inland by 300m or more, covering large expanses of land with water and debris. Flooding tsunami waves tend to carry loose objects and people out to sea when they retreat. The maximum vertical height to which the water is observed with reference to sea level is referred to as run-up. The maximum horizontal distance that is reached by a tsunami is referred to as inundation. Tsunamis may reach a maximum vertical height onshore above sea level, called a run up height (H), of 30 meters.

"Runup" is the maximum height of the water observed above a reference sea level. Two other terms may be determined from the runup value are, (1) tsunami magnitude (m), which is defined (Iida and others, 1967) as

$$m = \log_2 H$$

and, (2) tsunami intensity (I), which is defined (Soloviev and Go, 1974) as

$$I = \log_2(2^{1/2} * H)$$

Another rare event that may result from a tsunami is a standing wave or seiche. A seiche occurs in bodies of water that are partially or completely enclosed, such as a harbor basin, creating a standing wave that continually sloshes back and forth. When a seiche is generated by a tsunami, subsequent tsunami waves may arrive in unison with a seiche resulting in an increase in the drawdown in sea level and a dramatic increase in wave height. Seiche waves may continue several days after a tsunami.

6. OCCURRENCE OF TSUNAMIS

Tsunamis have been recorded to occur in all the major oceans of the world. However, this phenomenon is mainly restricted to the Pacific basin, an area surrounded by volcanic island arcs, mountain chains and subduction zones, as it is the most geologically active area on the planet. The amount of activity in this region makes it much more susceptible to submarine faulting and subsequent tsunami events, whereas the Indian and Atlantic oceans are far less geologically active, with some exceptions, and therefore the occurrence of tsunamis is rare. The statistics on the worldwide tsunamis until 2000 is reported in **Fig.2**. 90 tsunamis recorded in the pacific since 1900 [major is once a decade, (Alaska in Mar 1964 & Chile in 1960 traveled 17000km and 200 died in Japan)].Tsunamis are not entirely unknown in Sri Lanka. For example, the Tsunami in 1883 generated by the Volcanoes at Krakatoa led to a surge of at least 1 m in Sri Lanka. The damage was much less then. Table.1 shows the details of tsunami occurrences in India.

Table 1. Tsunamis recorded in India

Date	Cause	Impact
August 1883	Explosion of the Krakatoa Volcano in Indonesia	East coast of India was affected; 2m tsunamis were recorded at Chennai.
26 June 1941	A 8.1 Richter scale earthquake in the Andaman archipelago.	East coast of India was affected but no estimates of height of the tsunami is available
27 November 1945	A 8.5 Richter scale earthquake at a distance of about 100km south of Karachi	West coast of India from north to Karwar was affected; 12m tsunami was felt at Kandla.

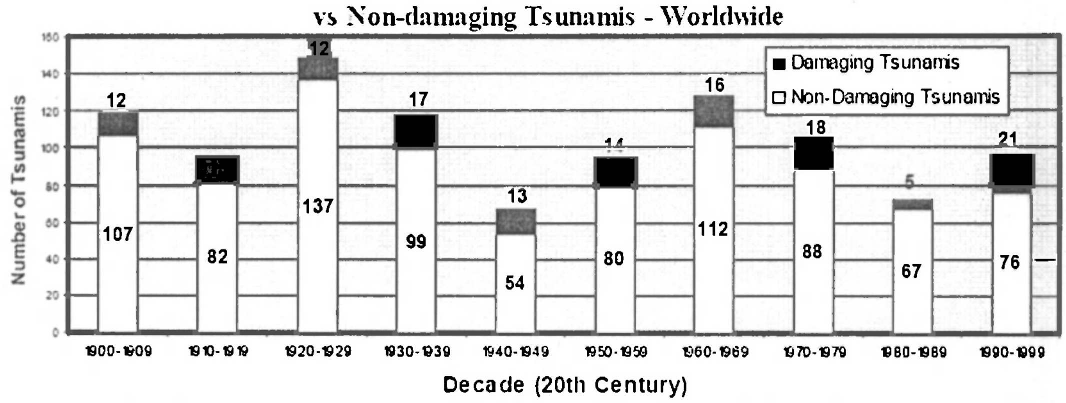
Initial warning

Typically, before a tsunami, the sea will recede from the coast, exposing part of the seabed. If the slope is shallow, this recession can exceed 800 m. People unaware of the danger may stay at the shore, due to curiosity, but this may be a warning sign of a coming tsunami.

7. FACTORS OF DESTRUCTION FROM TSUNAMIS

There are three: inundation, wave impact on structures, and erosion. Strong, tsunami-induced currents lead to the erosion of foundations and the collapse of bridges and seawalls. Flotation and drag forces move houses and overturn railroad cars. Considerable damage is caused by the resultant floating debris, including boats and cars that become dangerous projectiles that may crash into buildings, break power lines, and may start fires. Fires from damaged ships in ports or from ruptured coastal oil storage tanks and refinery facilities, can cause damage greater than that inflicted directly by the tsunami. Of increasing concern is the potential effect of tsunami draw down, when receding waters uncover cooling water intakes of nuclear power plants.

Damaging Tsunamis
vs Non-damaging Tsunamis - Worldwide



Most Damaging Tsunamis Worldwide

Fig. 2. Most damaging Tsunamis worldwide upto 2000

8. TSUNAMI WARNING SYSTEM

The lack of a warning during the 1946 tsunami that devastated many coastal areas in Hawaii, led scientists and governmental agencies to establish the Pacific Tsunami Warning System (PTWS), for the Hawaiian Islands and United States territories in the Pacific by 1948. The main objectives of this system are: To detect and locate the existence all possible tsunami causing earthquakes by the use of properly monitored seismographs; to ensure that a tsunami actually exists by measuring water level changes at tide-gauging stations located throughout the Pacific; and finally, to determine the time of arrival of the tsunami and to provide an adequate warning for evacuation procedures.

The only permanent tsunami warning system in operation at the present time is that operated for the entire Pacific basin by the United States National Weather Service, based at the Tsunami Warning Center in Honolulu, Hawaii. Since 1965, it has operated under the auspices of the Intergovernmental Oceanographic Commission, which in 1966 set up an "International Coordination Group for the Tsunami Warning System in the Pacific."

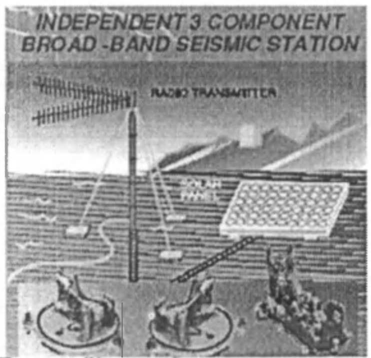
However, despite the development of the ocean-wide warning system, which uses the most advanced techniques of detection, measurement and communication, in many countries there are still obstacles to the rapid diffusion of warnings in thinly-populated areas or in regions where modern communication networks do not yet exist. In such areas, it is essential that the local population be informed about tsunamis. The population must be educated to recognize the signs that portend an approaching tsunami and to take appropriate action on their own initiative. The following "Tsunami Safety Rules," issued by the United States Department of Commerce, provide an example of information that is useful in such situations:

- All earthquakes do not cause tsunamis, but many do. When you hear that an earthquake has occurred, stand by for a tsunami emergency.
- An earthquake in your area is a natural tsunami warning. Do not stay in low-lying coastal areas after a local earthquake.
- A tsunami is not a single wave but a series of waves. Stay out of danger areas until an "all-clear" is issued by competent authority.
- Approaching tsunamis are sometimes heralded by a noticeable rise or fall of coastal water. This is nature's tsunami warning and should be heeded.
- A small tsunami at one beach can be a giant a few kilometers away. Don't let the modest size of one make you lose respect for all.
- The Tsunami Warning Center does not issue false alarms. When a warning is issued, a tsunami exists. The tsunami of May 1960 killed 61 in Hilo, Hawaii, who thought it was "just another false alarm."

- All tsunamis--like hurricanes--are potentially dangerous, even though they may not damage every coastline they strike.
- Never go down to the beach to watch for a tsunami. When you can see the wave, you are too close to escape it.
- Sooner or later, tsunamis visit every coastline in the Pacific. Warnings apply to you if you live in any Pacific coastal area.
- During a tsunami emergency, your local civil defense, police and other emergency organizations will try to save your life. Give them your fullest cooperation.
- In general, the tsunamis of distant origin, potential danger areas are those less than 15 meters above sea level and within one-and-half kilometers of the coast and the tsunamis of local origin, potential danger areas are those less than 30 meters above sea level and within one-and-half kilometers of the coast. Prior to the installation of the tsunami warning system it is extremely important to create a public awareness among the public residing close to the sea coast. This may be achieved by conducting a number of programs in local language through radio, newspapers, magazines and media. **The public should also be trained in the use of walkie Talkies, mobile phones, Public address Systems and also with Hand held Global positioning system.**

TSUNAMI WARNING

1949 in the Pacific & in 1965 made International
(Hawaii & Alaska) 26 member countries
National Oceanic & Atmospheric Administration (NOAA)



Deep-Ocean Assessment & Reporting of
DART Mooring System

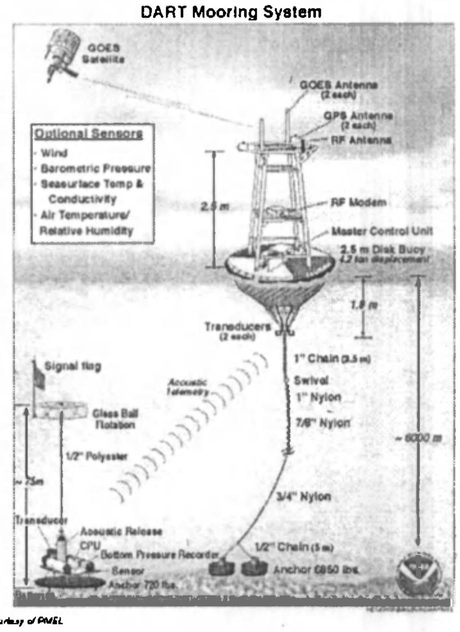


Fig. 3. DART Mooring system (NOAA)

9. DISASTER MITIGATION

The most systematic measures to protect coastal areas against tsunamis have been taken in Japan, the country in which the largest number of people lives in areas liable to tsunami attack. **The measures have consisted of the seawall construction along low-lying coastal stretches, breakwater construction at the entrances to bays and harbors, and the planting of pine tree belts.** Although the trees do not afford protection against flooding, belts of pine trees can play in important role by ridding the tsunami of some of its energy and by acting as a filter for solid objects carried by the tsunami, thus reducing its destructive power. To be effective they must be at least 200 meters broad (perpendicular to the coast). **They should be planted with dense undergrowth in addition to the trees themselves.**

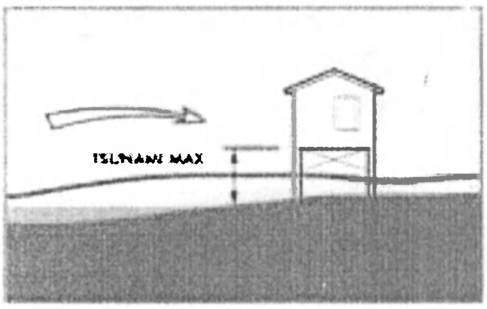
There are four basic site planning techniques that can be applied to projects to reduce tsunami risk (Fig. 4):

1) Avoid inundation areas

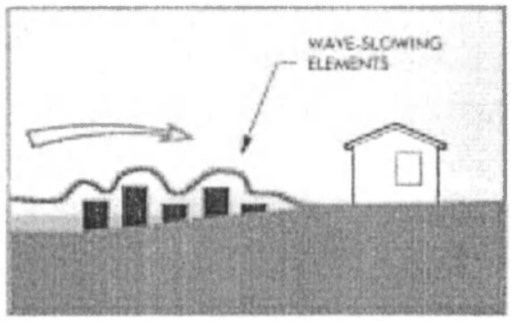
2) Slow water currents

3) Steer water forces

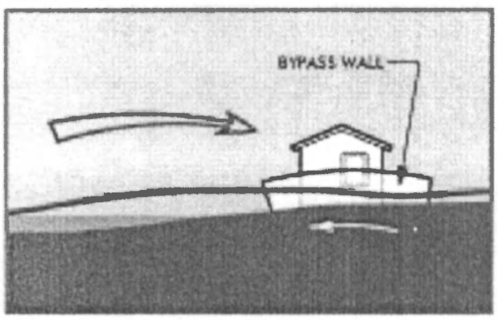
4) Block water forces



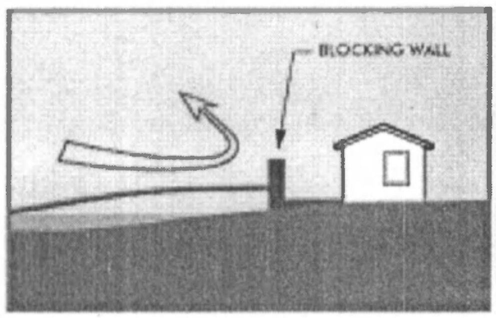
a. Avoiding



b. Slowing



c. Steering



d. Blocking

Fig. 4. Basic strategies to reduce Tsunami risk

These basic strategies can be used separately or be combined into a broader strategy. The methods can be used in passive ways to allow tsunamis to pass through an area without causing major damage, or they can be used to harden structures and sites to withstand the force of a tsunami. The efficacy of these techniques depends on the intensity of the tsunami event. If the tsunami hazard is underestimated, development in the area may still be vulnerable to a larger event.

Strategy 1: Avoiding

Avoiding a tsunami hazard area is, of course, the most effective mitigation method. At the site planning level, this can include siting buildings and infrastructure on the high side of a lot or raising structures above tsunami inundation levels on piers or hardened podiums.

Strategy 2: Slowing

Slowing techniques involve creating friction that reduces the destructive power of waves. Specially designed forests, ditches, slopes, and berms can slow and strain debris from waves. To work effectively, these techniques are dependent on correctly estimating the inundation that could occur.

Strategy 3: Steering

Steering techniques guide the force of tsunamis away from vulnerable structures and people by strategically spacing structures, using angled walls and ditches, and using paved surfaces that create a low-friction path for water to follow.

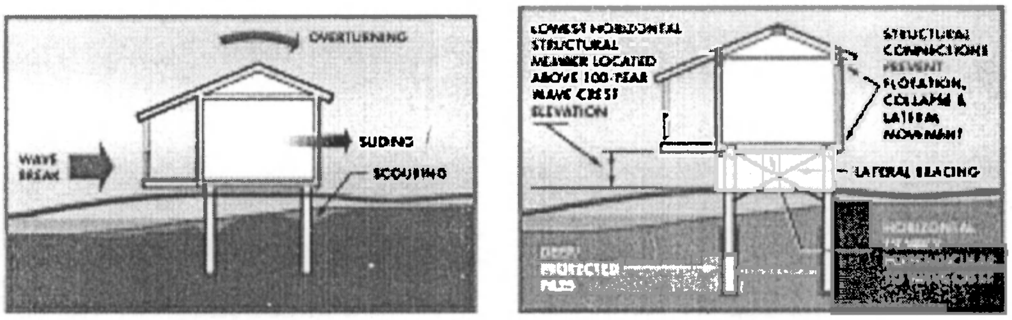
Strategy 4: Blocking

Hardened structures such as walls, compacted terraces and berms, parking structures, and other rigid construction can block the force of waves. Blocking, however, may result in amplifying wave height in reflection or in redirecting wave energy to other areas.

The town of Yoshihima, Japan, which was completely destroyed by a tsunami in 1896, is now protected by a sea-wall some 800 meters long and thirty six meters high. This proved effective against the Chilean tsunami of May 1960 which, being of distant origin, produced waves of long period, but there is some doubt as to whether it would provide complete protection against a tsunami of local origin.

It is obvious that large engineering works are extremely costly. They can be undertaken only when the value of the property to be protected and the frequency of occurrence of tsunamis are sufficiently high to justify them on economic grounds. In most exposed coastal areas, there is little hope of providing effective protection to property. All that can be done is to ensure that loss of life is reduced to a minimum by the timely evacuation of people from areas liable to flooding by tsunamis. Civil defense authorities must therefore prepare detailed plans for the rapid evacuation of people to high ground, or far enough inland to be out of danger. This requires the ready cooperation of the population. It is obvious that timely and reliable warnings of approaching tsunamis are an indispensable element of any such evacuation procedures.

The forces on structures located near the coast that may be subjected to the action of tsunamis is shown in Fig. 5a. The probable methodologies that could be adopted in the design practice to minimize the damages to structures due to the tsunami are illustrated in Fig. 5b.



a. Forces on structures **b. Design concepts**

Fig. 5. Forces on structures created by tsunami and probable design solutions

10. TSUNAMI DISASTER OVERVIEW

Environmental Effects:

High sea waves; inundation of water Flooding and impact damage to buildings and crops; High winds scour land; salinate wells and standing water

Patterns of Injury and Surgical Needs in Disasters:

Deaths exceed injuries. Low surgical needs the first 72 hours.

Patterns of Disease Resulting from Disasters

Actual Epidemiological Threat Secondary Epidemiological Threat None Waterborne diseases (except cholera), vectorborne diseases

Immediate Social and Economic Consequences of Disasters:

Loss of housing Loss of industrial production Loss of business production Loss of crops damage to infrastructure Disruption of communications

Effects of Natural Hazards:

On Land, damage to structures, agriculture trees due to flooding resulting in loss of buildings, bridges, crops; contamination of underground water and cultivating land.

Response to Natural Hazards (Ideal):

Initial Response:

Search and rescue; medical treatment; cash assistance, disaster assessment of roads; re-establishing communications.

Secondary Response:

Repair and reconstruction of housing, infrastructure; Assistance to agriculture, small business institutions and fishermen.

Appropriate Aid in terms of cash and short-term feeding (normal foods) loans or credit for agricultural.

10. SUGGESTED STEPS FOR EFFECTIVE MANAGEMENT AFTER TSUNAMI WITH PARTICULAR REFERENCE TO COASTAL EROSION

- Enforcement of CRZ guidelines. Should penetrate through grass root level
- Relocate habitation from low lying coastal areas to higher levels landward
- Assess the damages to the coast due to Tsunami & perennial problem of erosion
- Vertical walls could be only for certain locations where the land property is extremely important. Further, in the case of vertical walls, although the wave run-up may be less, there are other problems like enhancement of scour leading to uncertainty in their stability. The forces exerted by waves and tsunami are high if they are directly exposed. The toes in such case of walls have to be properly protected.
- Sloping walls on the other hand will gradually dissipate the incident wave energy. Against tsunami, it is suggested to provide crown walls (vertical or other shapes) at landward end of such walls.
- Identify the locations along the coast where casuarinas or mangroves (bio-shields) can be planted and efforts to be taken for their preservation (Long term solution) [Soft Measure]
- At locations, where beach width is narrower, artificial beach nourishment (pumping in sand from location of sand deposition like sand dunes & bars to

the eroding areas) along the coast. This is however is not possible always [Soft Measure]

- Only in case, any of the above two cannot be implemented, need arises for Measures with structures [hard measure]
- Hard measures are construction of seawalls (with or without a berm, preferably the second option), groin field or offshore detached breakwaters. The last option is comparatively costly and difficult to construct. Only after careful assessment of the coast, the final remedial measure needs to be considered. At location of densely populated stretches of the coast that has suffered damages due to tsunami, immediate steps as a crisis management need to be taken up

11. INDIAN OCEAN TSUNAMI OF 26 DECEMBER, 2004

The **2004 Indian Ocean Earthquake** was an undersea megathrust earthquake of moment magnitude 9.0 that struck the Indian Ocean off the western coast of northern Sumatra, Indonesia on December 26, 2004 at 00:58:49 UTC (07:58:49 local time in Jakarta and Bangkok). It was the largest earthquake on Earth since the 9.2-magnitude Good Friday Earthquake which struck Alaska, USA, on March 27, 1964, and the fourth largest since 1900. The hypocenter was at 3.298°N, 95.779°E (Fig. 6), some 160 km west of Sumatra, at a depth of 10 km underwater, within the "Ring of Fire" zone of frequent earthquakes. The quake itself (apart from the tsunamis) was felt as far away as Bangladesh, India, Malaysia, Myanmar, Singapore, Thailand and the Maldives (Fig. 7). The earthquake was unusually large in geographical extent. An estimated 1,200 km of faultline slipped 15 m (50 ft) along the subduction zone where the India Plate dives under the Burma Plate. This formed a shock wave in the Indian Ocean, creating tsunamis that traveled at up to 800 km/h. Tens of thousands were killed by the resulting tsunamis, which were as high as 10 m and struck between 15 minutes and 3 hours after the quake, causing one of the most cataclysmic disasters in modern history.

The multiple tsunamis struck and ravaged coastal regions all over the Indian Ocean, devastating regions including the Indonesian province of Aceh, the coast of Sri Lanka, coastal areas of the Indian state of Tamil Nadu, the resort island of Phuket, Thailand, and even as far away as Somalia and several other countries in Africa, 4,500 km (2,800 mi) or more west of the epicenter.

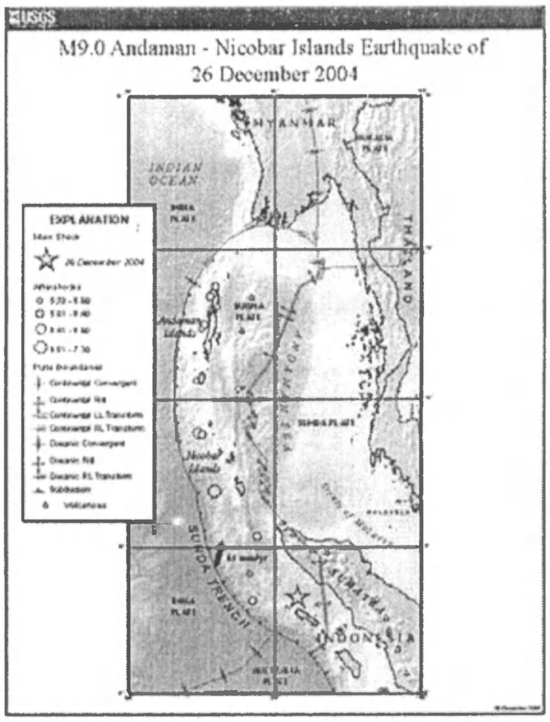


Fig. 6. Tectonic plates at epicenter

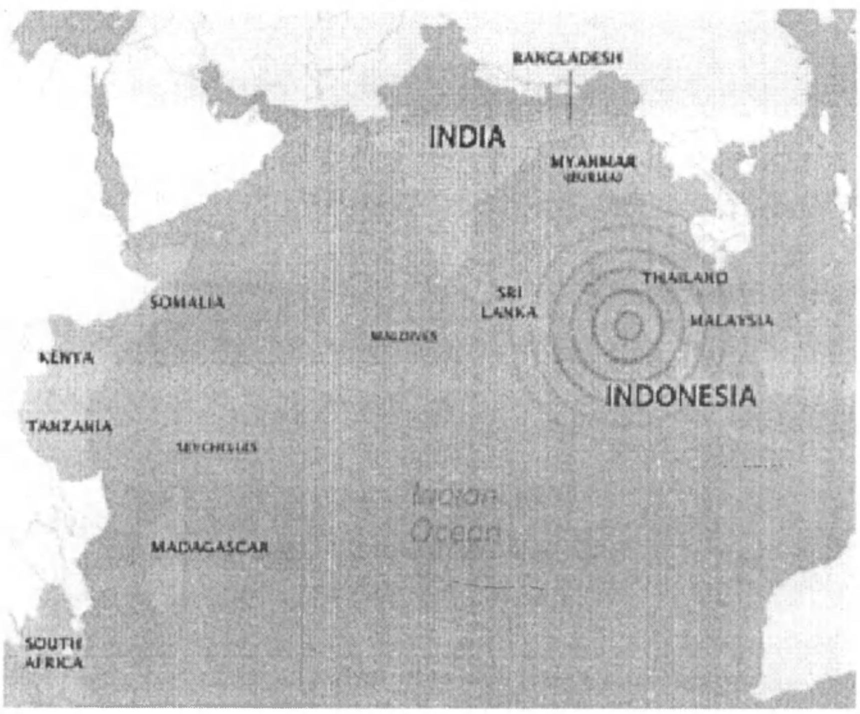


Fig. 7. Countries most affected by December 26 Indian Ocean tsunami

The survey of India has installed tide gauges all along our Indian coasts (Fig. 8). Som Using the mass-energy equivalence formula $E = mc^2$, this amount of energy is equivalent to a mass of about 100 kg (much more than is actually converted to energy in a nuclear explosion), or enough to boil 5000 litres of water for every person on Earth.

Based on one seismic model, some of the smaller islands southwest of Sumatra have moved southwest up to 20 m (66 ft). The northern tip of Sumatra, which is on the Burma Plate (the southern regions are on the Sunda Plate), may also have moved southwest up to 36 m. Other models suggest that most of the movement would have been vertical rather than lateral.e of the tide gauges which recorded December 26th tsunami event is presented in Fig.9.

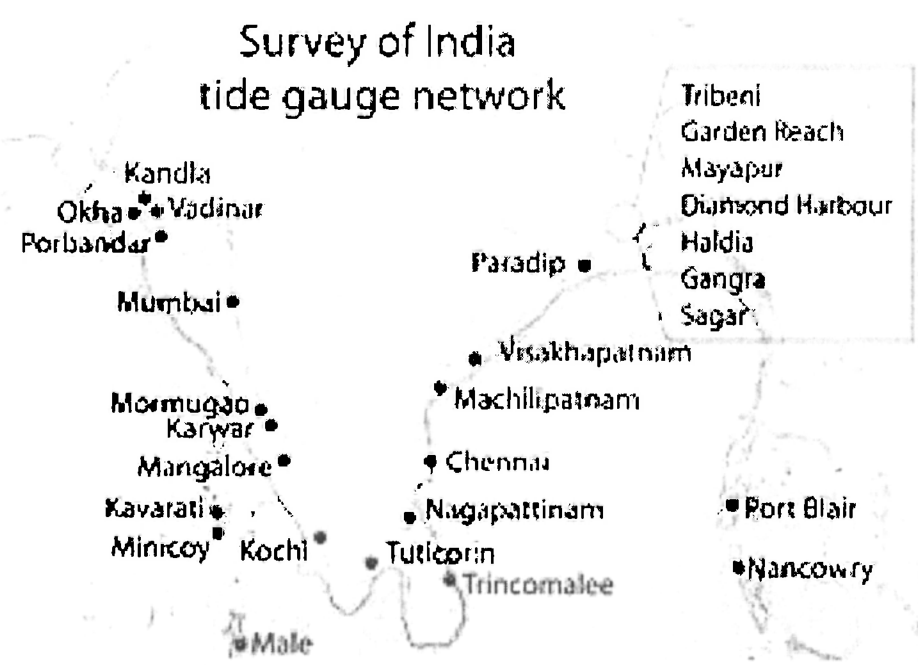
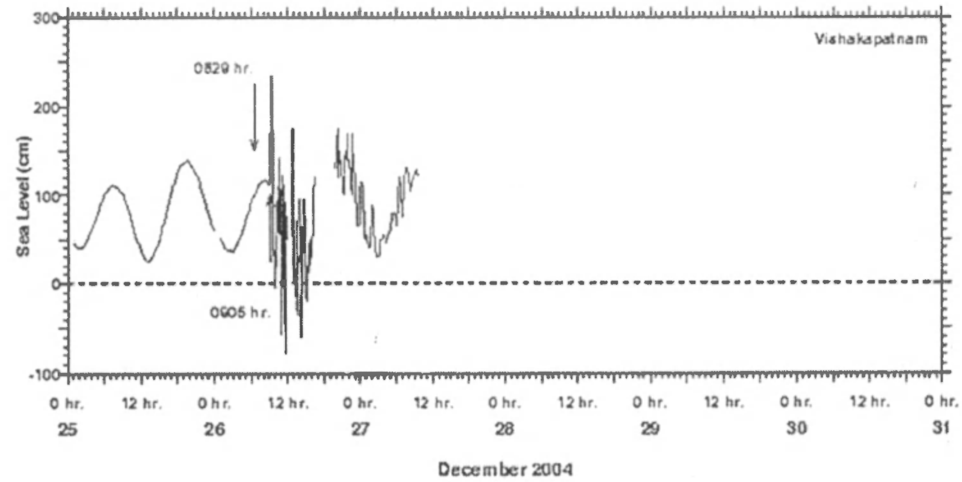
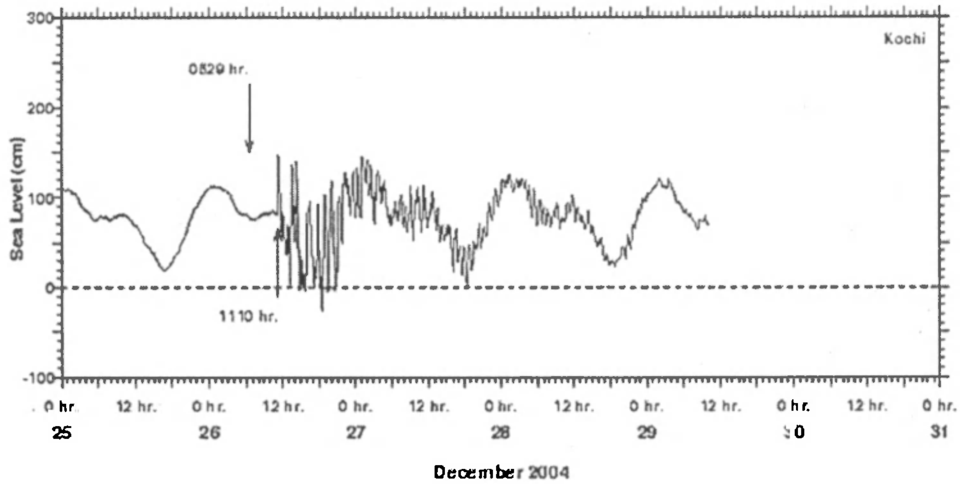
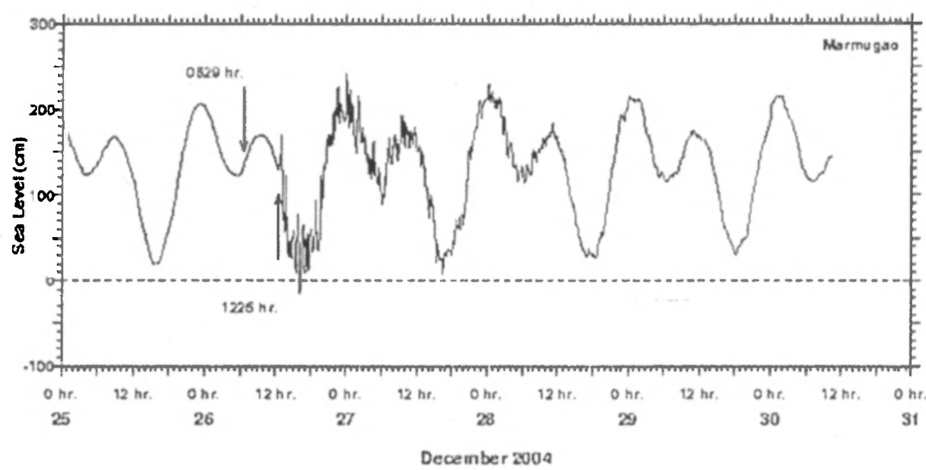


Fig. 8. Survey of India Tidal gauge locations


Vishakapatnam
0829 hr.
0605 hr.
Sea Level (cm)
December 2004


Kochi
0829 hr.
1110 hr.
Sea Level (cm)
December 2004


Marmugao
0829 hr.
1226 hr.
Sea Level (cm)
December 2004

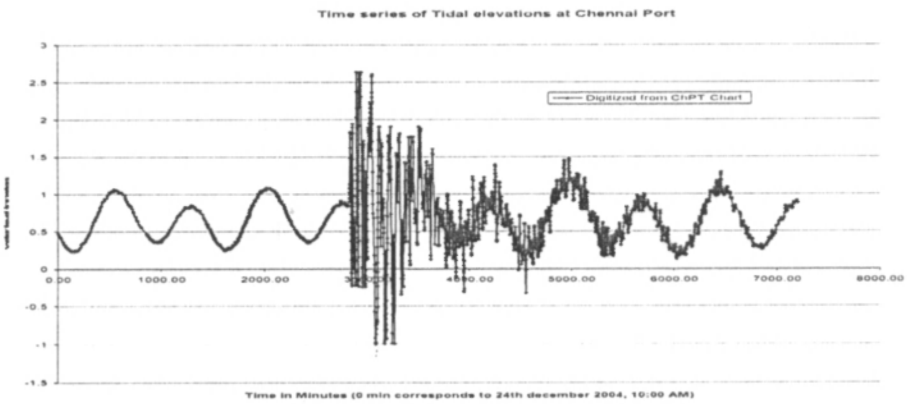


Fig. 9. Tidal records from various ports during December 26

12. CONCLUSION

The impact of tsunamis is very limited geographically, affecting only land mass at the edge of some of the world's oceans. However, where they do strike they can be with a destructive force greater than the other types of disasters. Protecting lives and property from such losses begins with good land planning, placing high economic investments out of reach of a potential tsunami and implementing a warning/evacuation system that will maximize the safety of persons living and working near the coastlines.

BIBLIOGRAPHY

Various Internet resources including NOAA, survey of India, N.I.O

LANDSLIDE DISASTER MANAGEMENT AND PLANNING –

A GIS BASED APPROACH

Dr.S.S.Ramakrishnan** . V.Sanjeevi Kumar*
Institute of Remote Sensing,
Anna University,Chennai-600 025
Tamilnadu, INDIA.
Ph: 91-44-2352189,Fax: 91-44-2352166
Email: sanjeevee_varadhan@hotmail.com,
***Professor * Research Scholar.*

Keywords: Aerial photograph, Geographical Information System, Landslide Disaster, Zonation

Abstract

Landslides disasters are one of the most common natural disasters next to earthquake causing, loss to life, property and natural resources. Landslide hazard zonation helps in identifying strategical points and geographically critical areas prone to landslides. Use of high-resolution satellite data will also play an important role in landslide disaster mitigation and management.

In this study, a methodology has been developed to identify landslide prone areas using high-resolution images with 3D GIS.

A small area in the Kothagiri taluk of The Nilgiris district has been selected for this study. It is geographically located between 76° 14' 00" and 77° 02' 00" E longitude and 11° 10' 00" and 11° 42' 00" N latitude. The Nilgiris district comprises of complex hilly terrain with steep slopes, thus making way for frequent landslides as a natural phenomenon. These phenomena have a great potential to destroy terrain, properties, and lives. The landslide in most of the study area occurs, due to changes in landuse/landcover and indiscriminate deforestation in the forest area.

The data used for the study is obtained from aerial photograph on 1: 8000 scale. By the virtue of Photogrammetry, orthophoto map was generated by ORTHOCOMP from aerial photograph. The advantage of the high-resolution data helps in deriving 2m contour, which is ideal to get the elevation and slope values of the terrain.3D GIS software can be a viable solution for delineating landslide prone areas.

Digital Elevation Models are derived to refer to any digital representation of a topographic surface. The ideal structure for DEMs depends on the intended use of the data and how it might relate to the structure of a model. The products derived from DEMs are contour maps (2m interval), slope maps, aspect maps, shaded relief maps and three dimensional perspective views.

The orthophoto map, topographic map, landuse/landcover map, drainage, slope map, soil map, transportation network and relative relief map have been utilized to generate various thematic data layers in GIS environment. In order to get the landslide prone areas the criteria should be assigned to each map layers. Depending on the threat posed by each category the Landslide Susceptibility Index, i.e.weightages were assigned. A landslide hazard zonation map was prepared by integrating the effect of various triggering factors. The data layers have been integrated in GIS environment by overlay analysis. Multi-temporal data was used to identify old, active and potential landslides areas. The zonation map divides the study area into five zones of landslide vulnerability viz., very high, high, moderate, moderate to low and low. Arc view – 3D analyst was used especially for generating 3Dview and getting slope and aspect information. It can be used for land use planning so that landslide can be avoided.

High-resolution data are useful in implementing landslide hazard planning and mitigation measures. Aerial photogrammetry technique is expensive and has some operation difficulty in obtaining photographs in time. Nowadays satellite remote sensing data provide high-resolution images (Cartosat and IKONOS). The methodology adopted in the study can be used effectively and becomes economical, if such high-resolution data is made available.

Mitigation of damage due to coastal natural disasters – A Scientific approach in Planning

B.R.Subramanian

Integrated Coastal and Marine Area Management (ICMAM) Project Directorate
Department of Ocean Development, Chennai

1. Introduction

Among the coast based natural disasters, storm surges arising during cyclones, abnormal waves during tsunamis are the most prominent ones. The Bay of Bengal being a cyclogenic area, generates cyclones every year. The cyclonic storms, which cross the coastal regions cause sudden abnormal rise of sea water, called surges and this is the primary cause for coastal flooding in the adjoining land. This rapid sea level rise in the near shore region, known as the storm surge and the high waves induced by storms destroy coastal marshes, erode the shore line, flood the low lying areas and increase the salinity of estuaries, bays and aquifers along the coast. Most of the damages caused to life and property in the coastal region during a storm are mainly due to the storm surge flooding the populated low-lying areas along the coast. Similar event occurs when tsunami waves hit the coast.

2. Cyclones

The Bay of Bengal is one of the favoured ocean basins for the transformation of regions of low-pressure in the atmosphere into cyclonic storms. Due to this, storms and surges are frequent along the coastal regions surrounding this bay. Between the years 1891 and 1977 the Bay of Bengal has generated about 400 cyclonic storms with different degrees of intensity. The effects of these storms are more pronounced in the states located on the East Coast of India, namely West Bengal, Orissa, Andhra Pradesh and Tamil Nadu. A list of storms that have crossed the Indian coast and the extent of damages caused by them since 1582 AD have been compiled by Jayanthi and Sen Sarma (IMD Scientific report, 1986). Sometimes, the surges along the coast accompanying these storms are abnormally high and form the most destructive component of this coupled ocean-atmosphere phenomenon. The surge during the

Andhra cyclone of November 1977 has been one of the most devastating surges in the past along the East Coast of India. More than 10,000 inhabitants of the coastal region were reported to have been killed by this surge flooding the coastal areas near Machilipatnam.

3. Tsunamis

Earthquakes measuring intensity of more than Ms 7.0, with the epicentre located in the seabed, generate tsunamis. Such earthquakes could be called as "Tsunamigenic earthquakes". Tsunamis generate deep ocean waves. They are different from normal sea waves generated by winds. The tsunami waves have larger wavelengths, greater amplitude, period and velocity compared to normal waves. A typical tsunami wave has about 10-20 m height, 200 km of wave length and travel at a speed of 750-900 km per hour. These waves have tremendous energy and propagate in the deep sea. These high energy waves generated in several numbers (which depend on earthquake rupture parameters) travel long distance say 3000 km. When they come across shallow waters of islands and land mass undergo transformation. Since the velocity of the tsunami is also related to the water depth, as the depth of the water decreases, the velocity of the tsunami decreases. The change of total energy of the tsunami, however, remains constant. Furthermore, the period of the wave remains the same and thus more water is forced between the wave crests (peaks) causing the height of the wave to increase. Because of these shoaling effect, a tsunami that was imperceptible to deep water may grow to have wave heights of several meters or more. When the trough of the wave reaches the shore first, it draws down the water exposing the sea bed a few meters to kilometers and is followed by the crest, which causes rise in sea level. As the successive waves hit the coast, the seawater penetrates the coast with high speed and causes extensive inundation, which is called run-up **(Figure 1).** Run-up is usually expressed in meters above normal tide or Mean Sea Level. Run-ups from the same tsunami can be variable because of the influence of the geomorphology (shape) of the coastline. Run-up values can be used for determining the extent of vulnerability of human settlement in a coastal village or town and therefore useful in coastal land use planning. In one coastal area destructive waves can be large and violent with large damaging activity, while in another area without being violent cause extensive flooding with rise in water level to a few meters. The inundation of the area can be upto 2 to 5 km inland especially at locations where estuaries have good depth profile. While retreating, the waves with considerable velocity tend to carry loose objects and people out to sea. The extent of damage depends on extent of run up height, velocity of the water, local topography and land utility pattern (say settlement, agriculture, forestry etc). The loss of human life in a single tsunami could be as much as 100000 and damage to properties to several millions of dollars.

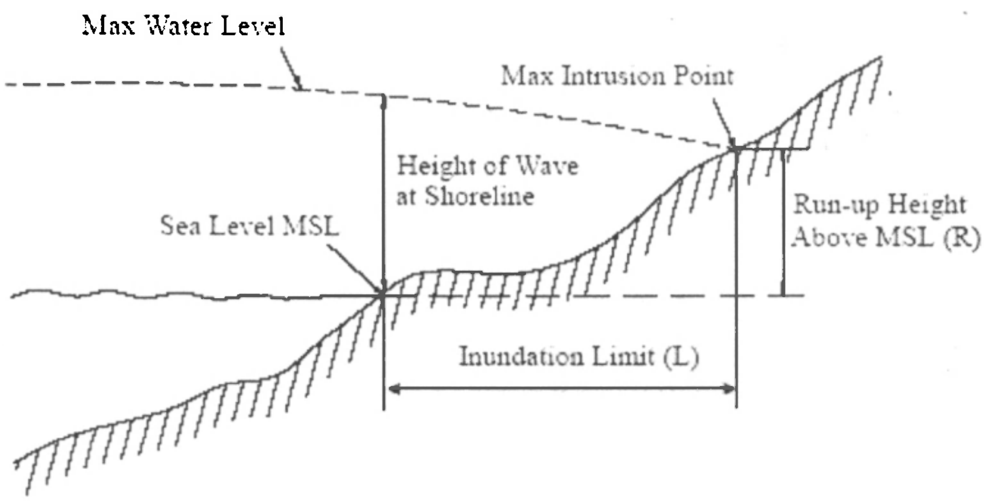


Figure 1 Schematic diagram showing measurement of Run-up height

3.1. Occurrence of Tsunami in the world and extent of inundation

Tsunamis occur mostly in the Pacific Ocean. According to the Tsunami Laboratory in Novosibirsk during the 101-year period from 1900 to 2001, 796 tsunamis were observed or recorded. 117 caused casualties and damage most near the source only. At least nine caused widespread destruction throughout the Pacific. The greatest number of tsunamis during any 1 year was 19 in 1938, but all were minor and caused no damage. There was no single year of the period that was free of tsunamis.

Tsunamis seldom occur in the Indian Ocean region and is reported in the 300 years only 6 tsunamis have occurred. One incident having maximum run up of 13 m was noticed along the coast of Pakistan in the year 1945 with the source zone of earthquake in the Arabian sea. The earthquake was recorded at a magnitude of Ms 8.2 and tsunami resulted in death of 4000 people. In the Andaman and Nicobar and Tamilnadu region only 3 tsunamis (1868, 1881 & 1941) have been recorded in the last 300 years. While details of location of epicentre, death/damage caused etc. are not known, data on run-up levels indicate to the extent of 4 m in Port Blair, 0.76 in Car Nicobar and 1.22 m in Nagapattinam. The earthquake in these years had magnitudes of MW 7.5 to 7.9. (**Data Source : National Geophysical Data Centre, USA).**

The history of run up levels registered/observed during 185 tsunami incidences in Pacific area and Indian ocean that occurred between 1940 and 2004, reveals that the run-up levels of 5-10m were predominant followed by the run-up levels from 10-15m. There were only three incidents of run-up level recorded above 30m.

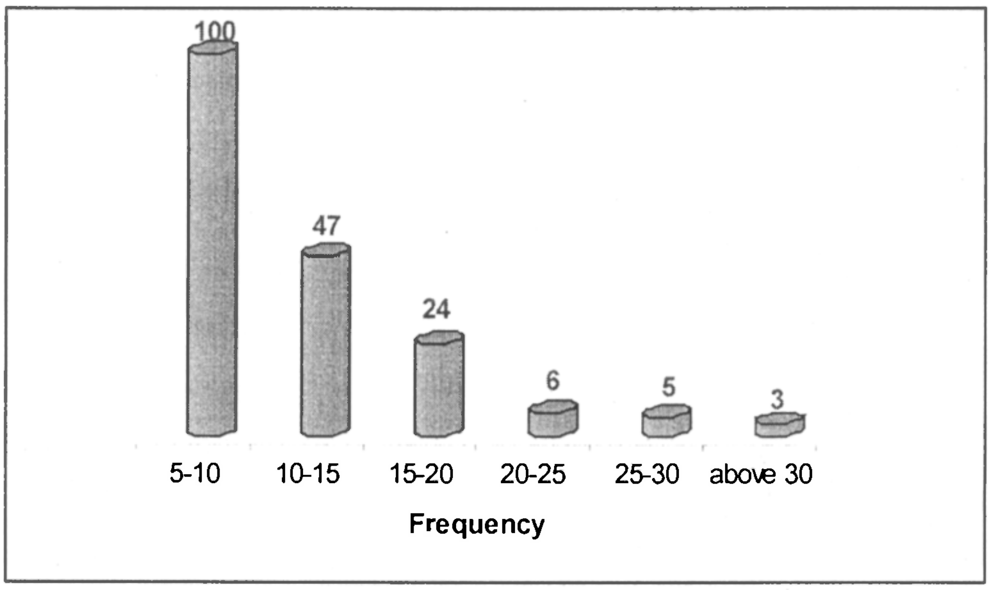


Figure .2 : Frequency diagram of run-up levels (in metres) observed during 185 tsunamis between 1940 and 2004 in the Pacific and Indian Ocean
Data Source: National Geophysical Data Centre, USA

4. Scientific approach to Disaster mitigation

The major components of the problem of management of disasters associated with inundation of coastal areas are:

- Observance/prediction of sea level and surges caused by storms and tsunamis
- Estimation of inundation of seawater in coastal land areas
- Preventive measures, preparedness and Mitigation

Among the above components, prediction of surges and estimation of inundation of coastal areas play vital roles in preventive measures. These include, non-locating of settlement in inundation prone areas, improvement of infrastructure like roads in existing vulnerable areas etc. for quick evacuation of people, avoiding vital establishments like power plants in these areas etc.

4.1. Storm surges – their prediction and mapping of inundation using GIS

The National Institute of Ocean Technology (NIOT), has gained expertise in developing storm surge models for cyclones and mapping of inundation areas. The work carried out by them in one of the low lying and cyclone prone areas of the country namely Nellore to Machilipatnam is given in detail below:

4.1.1. Surge Prediction Model

The general approach for the prediction of storm surges is to solve numerically the vertically integrated form of the hydrodynamic equations governing the shallow water flow field in ocean shelves, subjected to wind stresses associated with the cyclonic wind field at the ocean free surface. The numerical method of solving the basic hydrodynamic equations involves discretization of the study area and the governing equations over space using either finite difference or finite element method and integration of the resulting equations over time using a suitable time stepping procedure.

In recent years, the Finite Element Method (FEM) is being increasingly used in shallow water flow simulations. In the finite element method the flow domain is divided into a large number of subdomains called elements and in each of these elements, the flow variables are approximated by piecewise continuous polynomials. This method is highly flexible and more suitable for flow simulation over regions surrounded by irregular boundaries and complex topographies. Further this method is capable of accommodating fine grids over areas where the model or the flow parameters are expected to have large gradients. At NIOT an operational level model for surge prediction using the finite element method has been developed and benchmarked using MIKE21 software.

Model Calibration

The depth contours from the hydrographic charts, along the east coast of Sri Lanka and India are digitized and the finite element mesh created with this bathymetry is used for simulation of surges. Surge simulations are carried out using the cyclone data for 11 past cyclones and the model is calibrated.

Coastal Boundary & Coastal Flooding

In most of the studies on simulation of surges along the Indian coast the coastal boundary is assumed as a fixed impermeable vertical wall located at the water-land interface. Then the extent of flooding of the low lying coastal areas is estimated by assuming that the flooding takes place up to the contour of height equal to the estimated surge height at the coast.

But some investigators have observed that in surge simulation models, the impermeable vertical wall assumption, at the water-land interface which actually moves inland when the surge floods the low lying coastal regions, is likely to lead to errors in the estimates of surges along the coast. They used a rectangular grid over the study region and allowed the boundary to move with the advancing water front, by turning the finite-difference cells at the boundary on and off, according to a prescribed criterion on wet and dry point selection. But the wet and dry method (WDM) requires fine grids over areas where the flooding due to surges are likely to occur. They applied this moving boundary model, assuming a uniform slope for the coastal terrain along the East Coast of India. But this approach is limited to flow simulations in regions with geometries that could be transformed into rectangular regions using simple algebraic functions.

Recently Shi *et al.* (1997) used a generalized curvilinear grid and WDM method for surge simulation over a continuously deforming analysis area. They reported a difference of 0.12m between the maximum surges predicted using their moving and fixed boundary models at a coastal station in the Huanghe Delta in North China, for the storm of 7th April 1994. This difference in the surge estimates is very small and it could be due to the different spatial resolution of the grid systems used in their fixed and the moving boundary models. It may not be due to the unrealistic piling of water at the impermeable coastal boundary in the fixed boundary model as reported by Shi *et al.* (1997).

In view of these varying observations on the influence of coastal flooding on surges at the coast, the nature of the over land flow that could be anticipated in the coastal region during a storm is qualitatively examined. When a cyclonic storm approaches the coast, the sea level on the northern side of the cyclone track increases. This increase in the sea level at the coast leads to a reduction in the water surface gradients in the natural drainage channels, which control the capacities of these channels to drain the floodwater into the sea. As storms are always accompanied by heavy rain in the coastal region, these channels get flooded with rainwater and they over flow the banks because of their reduced capacity during storms to drain the floodwater into the sea. This intensifies the flooding initially in the coastal regions. When the sea level at the coast rises abnormally high, the seawater also directly floods the low-lying areas in the coastal region. Under these conditions, it is difficult to quantify the individual contributions from the sea and the run-off from the natural drainage systems, to coastal flooding. But all moving boundary models essentially assume that during cyclonic storms, exclusively the seawater overflowing the coast onto the land causes the coastal flooding.

Further, this abnormal sea level rise due to a surge takes place only over a short stretch of the coastline on the northern side of the landfall point and the consequent flooding will also be only local. The consequent flooding will also be confined to the area adjacent to this stretch of the coast, and the volume of seawater required for flooding the coastal region will be relatively small compared to the volume of water involved in the storm induced flow field in the adjacent shelf. The extent of this coastal flooding depends on the topography of the region affected by surges and it is a site-specific problem. The topography of the coastal region is highly corrugated with cultivated lands, wastelands, coastal forests, shallow coastal water bodies, human settlements etc. Consequently, the land elevation contours in these regions are also highly irregular, and the flow simulation over such regions requires spatial grids with very fine resolution. Hence, the existing moving boundary models are not suitable for simulating flow fields in such highly irregular regions. From this qualitative review on the nature of flooding that is likely to occur over the highly corrugated coastal region during a storm and the occurrence of high surges over short stretches of the coast, it is concluded that the coastal inundation can be estimated by using the predicted surge heights along the cyclone hit area, the local topography and the river run off.

4.1.2. Estimation of inundation of seawater using GIS

The estimation of coastal flooding using GIS, with surge heights as the input, is demonstrated here.

The coastal topography maps for the region from Nellore to Machilipatnam along the Andhra Coast, of the scale 1:25000 have been obtained from Survey of India. The maps are of very fine contours with in 0.5m contour intervals and have been digitized using Arcinfo in GIS. The topography in GIS consists of different layers for coastline, roads, railways, settlements, vegetation, water bodies, canals, mud etc. The cyclone that crossed Kavali in 1979 is considered and the surges along the coast due to the cyclone have been predicted using the finite element model (Fig.3). Peak surge occurred near Ongole and the surge heights at different points along this stretch is used as the input to GIS to estimate the flooded area. Based on the surges as input to the topography in GIS the flooded area is estimated (Fig. 4). The estimated area of inundation is approximately 1207 km^2. In the real time forecasting scenario, since the NIOT surge model is an operational level model, once the cyclone track is identified, surges can be computed. Then using GIS, risk assessment (likely area to be inundated) can be made and mitigation strategies can be formulated to minimize the damages. It is to be mentioned here that, for accurate estimation of area of flooding, the hydrology and rain fall data need to be available. Due to non-availability of data this estimation is given based on available topography and this is only an approximate estimation of the flooded area.

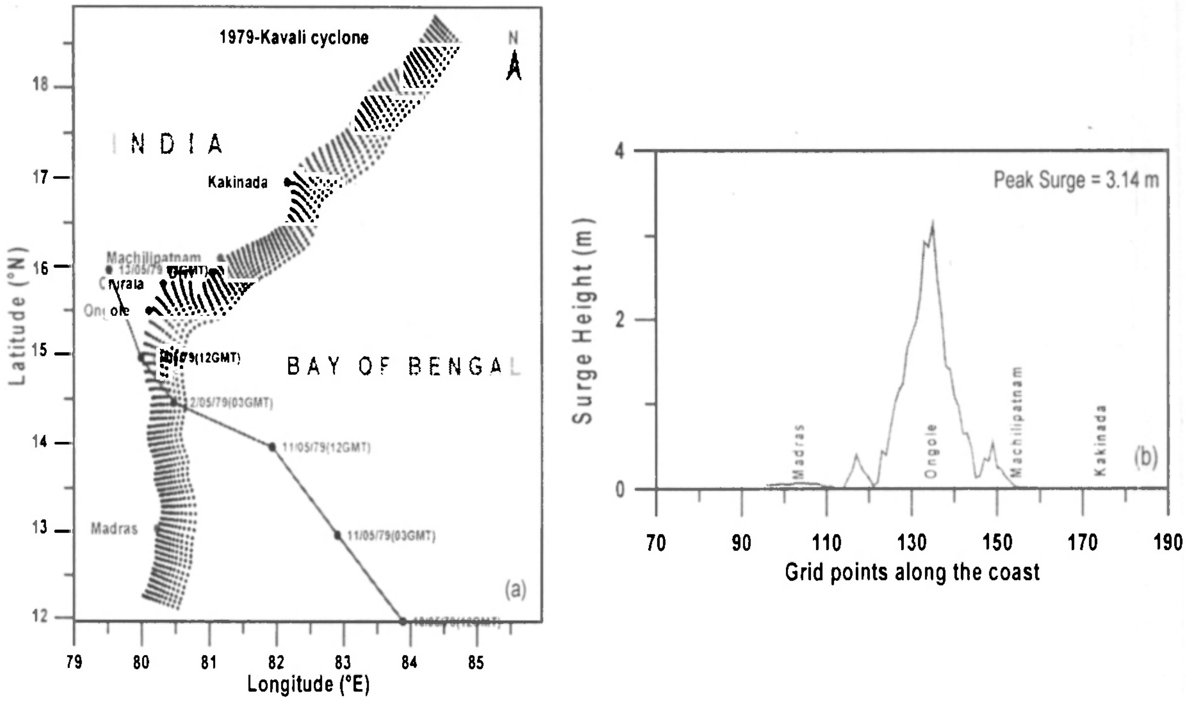
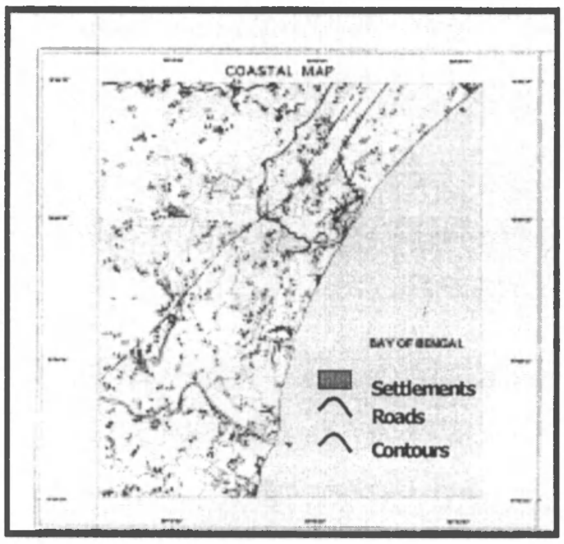
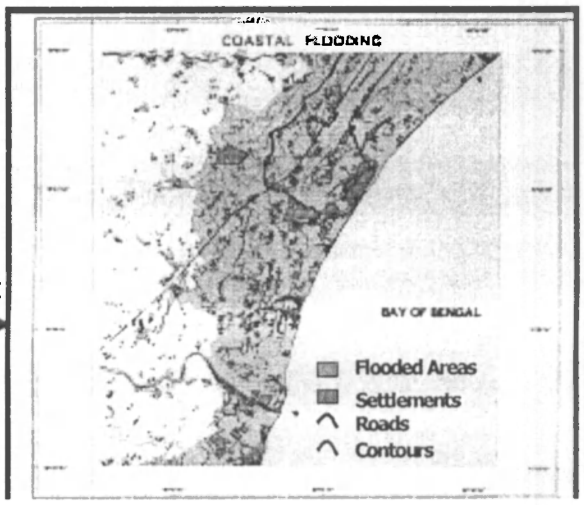


Fig.3. Cyclone track and surge envelop



Coastal Landuse
Nellore to Machalipatnam



Flooding of low lying areas in the event of storm and flooding

Fig. 4. Extent of inundation of seawater due to storm surge in Nellore to Machilipatnam – Estimated area 1207 sq.km

4.2. Tsunamis and Inundation of coastal areas

As stated above, tsunami waves can rise suddenly and inundate the coastal land areas. Extent of inundation of seawater at the time of tsunamis, is made through measurement of run-up levels (Fig.1). Run-up values can be used for determining the extent of vulnerability of human settlement in a coastal village or town and therefore useful in coastal land use planning. The propagation of tsunami wave on land depends on its height at shoreline/ direction of approach and topography of the land. The ICMAM Project Directorate conducted run up measurements at different sites in A & N islands and at certain locations of Tamilnadu coast using Realtime Kinematic Global Positioning System (RTKGPS). Transect runs from sea water upto maximum inundation point was identified from 1) deposition of washed materials and/or 2) degraded grass/vegetation or 3) seawater level mark on external walls of the buildings. These transects were drawn at each location representing characteristics of open coast with built up and transect adjacent to inlet/ backwater. All the levels taken along the transects connected to GTS bench mark wherever it was available and other places the sea level was taken as reference. All run up measurement levels were corrected to tide and reduced to Mean Sea Level. The water point was measured in backwater/ bay/ inlet to minimise error in measuring the Sea Level. The highest point of inundation was also mapped along the identified signature using ARCPAD Differential Global Positioning System, where the inundation points were tracked using "Polyline" feature, at an interval of 2 m. For preparation of inundation map, 10 to 15 Ground Control Points (GCP) were collected using DGPS, evenly distributed in the area of interest. Image was rectified to geographical location using GCP (projection Geoscientific Lat/Long and datum WGS 84). Few locations, where run-up level measurements were made are indicated in **Figures 5 & 6.**

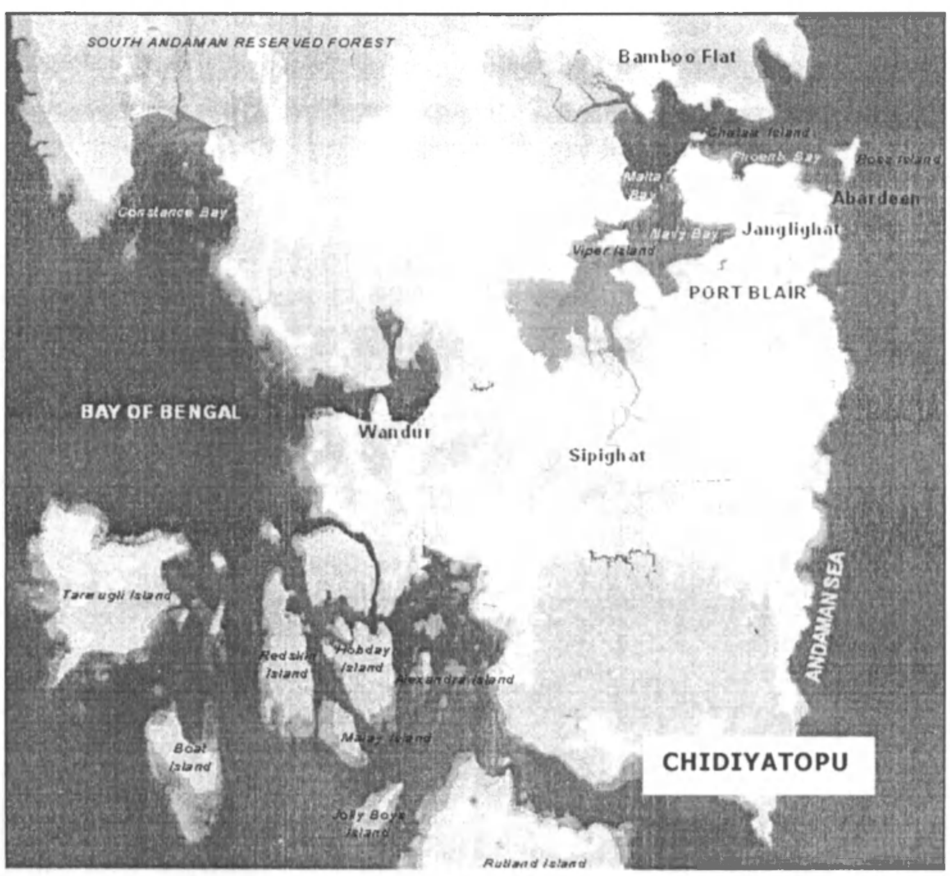


Figure 5 : Few locations of run up measurements in and around Port Blair

Fig. 6 Map indicating Location of run up level measurements (●)along Tamilnadu coast

The inundation of seawater into the land with high velocity and their retreat with same or higher velocity cause extensive damage to human life and property. The extent of vertical run-up of seawater depends on geographical location, nearshore bathymetry, beach profile, land topography and velocity of tsunami waves and their frequency. Due to these parametric variations in Andaman and Nicobar islands and Tamilnadu coasts, the run-up level and landward penetration characteristics of seawater were location specific and varied within a location and even in an island (Table 1). In the case of A & N, the North and South Andaman group islands the run up levels varied from 1.5 m to 4.5 m with distance upto, which the seawater penetrated from the coast ranged from 100 to 250m (Table 1). The little Andaman recorded a run up of 5 m with the distance of penetration as 1200m. In the two Nicobar islands, the run up levels varied from 3 to 7 m with distance of penetration having a range of 50 to 1000m with higher run up levels and longer penetration noted in Car Nicobar (Table 1). The wide variation in Andaman and Nicobar islands was primarily due to geographical location of the islands, variation in land topography apart from the other probable key parameters like bathymetry, beach width and its profile, direction of propagation of tsunami wave and its velocity. Variation within the island like South Andaman and Great Nicobar is also attributed to the above factors. The data indicates penetration of seawater to a short distance in Andaman islands (except Little Andaman) compared to the Nicobar group, which was primarily due to presence of elevated areas within the short distance from the coast. The little Andaman and the Nicobar group that had relatively gentle slope along the coast compared to South Andaman islands experienced farthest penetration of seawater. The slope value of 1 in 32 for Chidyatopu in South Andaman compared to slope values of 1 in 325 for Little Andaman and 1 in 167 for Car Nicobar support this interpretation (Table 2). This clearly indicates the vulnerability of low lying areas with gentle beach/land slope for inundation of seawater during storms, tsunamis etc. The low lying areas adjoining to creeks that facilitates travel of tsunami waves far inland, are too vulnerable as indicated by the landward penetration of seawater upto 2 km from the creek in Sippighat area of Port Blair (Table 1 and Figure 5).

Table 1. Run-up level of sea water during tsunami in Andaman & Nicobar Islands and at selected locations along Tamilnadu coasts

Location	Max, run up level (m)	Distance upto which seawater inundated inland (m)
ANDAMAN & NICOBAR ISLANDS		
South Andaman (Port Blair)		
JNRM College, Aberdeen	2.9	130
Bamboo Flat	3.5	250
New Wandoor	3.7	215
Wandoor	3.9	215
Chidiyatopu	4.5	130
Sippighat (Creek)	2.0	2000
North Andaman		
Diglipur	1.5	100
Rangat	1.5	200
Little Andaman		
Hut Bay	5.0	1200
Car Nicobar		
Malacca	7.0	1000
Great Nicobar		
Campbell Bay (central)	3.0	300
Campbell Bay (North)	6.0	50
TAMIL NADU COAST		
Chennai (Besant Nagar)	2.8	200
Nagapattinam (Light House)	3.9	750

The run up levels along Tamilnadu coast, showed almost similar trend as noted in A & N islands. The worst affected Nagapattinam showed longer penetration of seawater (750m) upto an elevation of 3.9 m due to gentle slope of coastal land combined with the effect of tsunami wave diffraction caused by northern tip of Sri Lanka (**Figure 7).** Presence of creeks like Vedaranyam canal in Nagapattinam facilitated the seawater inundation upto 2.2 km inland. The Chennai areas showed less landward penetration of seawater (45 to 200m) due to prevalence of wider elevated beach (2.8m), which acted as buffers. The slope value of 1 in 227 for Nagapattinam compared to 1 in 39 at Chennai showing gentleness in Nagapattinam further supports this interpretation (Table 2). The presence of offshore shoals along the Ennore coast (4 – 7 km from coast) and the wider beaches subdued the effect of tsunami waves, saving the villages of Kattupalli and Kalanji that had penetration of seawater only upto 45 m.

Figure 7 – Satellite image of Nagapatinam showing inundation of seawater during tsunami

Table 2. Coastal land slope values of various locations in Andaman and Nicobar Islands and Tamilnadu

Location	Distance upto which seawater penetrated (in metres)	Slope
Chidyatopu (South Andaman)	130	1 in 32
Hut Bay (Little Andaman)	1200	1 in 325
Malacca (Car Nicobar)	1000	1 in 167
Campell Bay (Great Nicobar)	300	1 in 89
Nagapattinam (Tamil Nadu)	755	1 in 227
Chennai-Besant Nagar (Tamil Nadu)	200	1 in 39

The Nicobar group of islands namely Great Nicobar, Katchall, Terressa, Trinkat, Car Nicobar etc., were severely affected by tsunami waves as they are closer to the epicenter and also smaller in nature surrounded by the sea all around. The Satellite based data indicate that in terms of inundation of seawater, Great Nicobar, Trinkat, Camorta and Katchall were the worst affected (NRSA satellite data- NRSA web site). The impact on North and South Andaman group of islands were less, since the settlement in South Andaman islands is largely confined in elevated sheltered areas like bays and they are little away from the coast except Chidiyatopu area (**Figure 5**). In case of Chidiyatopu the run-up level of 4.5 m is mainly due to its geographical location i.e. a tip of South Andaman facing tsunami wave direction in the Andaman sea. There were almost no loss of life, but damage to properties especially to fishing vessels was considerable. Video observations also indicated that inundation of seawater in Port Blair area was without much fury of tsunami waves.

Another major reason for inundation of seawater in South Andaman and Nicobar islands is land subsidence, the degree of which is yet to be confirmed. Location specific observations made by ICMAM PD indicate 0.8m around Port Blair and 1.3 m in Great Nicobar. Such a land subsidence is evident from the high tide water entering into the paddy fields of Sippighat area that registered penetration of seawater upto 2 km during tsunami. Inundation of inland low lying areas during the high tide has become a cause of concern for inhabited population as their houses are marooned with seawater. The concern is likely to increase during the monsoon months when the rain water antagonizes movement of high tide water. The net effect would depend on the velocity of rain water flowing from low lying areas through sluice gates to the adjoining bay. If the tidal water dominates, the rain water tends to accumulate in all low lying areas and both the freshwater and sea water would increase the height of water level and likely to spread to the neighboring elevated areas too. However, these needs further investigation through modeling studies.

5. Preventive measures against Disasters– Pre Planning of Settlement areas

The above described storm surge modelling and prediction of possible inundation areas and run up levels of seawater during tsunami, postulates the need to adopt these scientific predictions/observations in the disaster mitigation strategies. The most appropriate adoption would be at the stage of planning of settlements in the Local Area Master Plan itself. The prediction of storm surge upto 3 m height in Ongole area, and the prevalence of the run up level of 7m in Car Nicobar and 3.9m in Nagapattinam and at the distance of 1.1 km and 750m respectively where large settlements occur indicate the need to consider elevation based setback line in human settlement planning along the coastal areas of the country. Both the sites along with the others like Katchall island had huge loss of human life due to presence of settlement close to the coastline. For e.g., in Nagapattinam, there are dense households from the coast and upto 1.5 Km **(Figure 7)**. Tsunami has devastated the Nagapattinam area with a death toll of 6065 people and damaging as much as 40000 houses (Data Source : TN Govt. website 14

Feb.2005) In fact, it is well known that Nagapattinam is one of the low lying coastal areas of the country and experienced several times fury of storm surges as it is one of the possible landfall points for cyclones. It is clearly evident that even the 200m setback line prescribed under CRZ III category under the Coastal Regulation Zone notification is far insufficient. The safe elevations for human settlement especially in low lying areas recorded in the present study need further refinement through modeling studies, as the present elevation observed is only with respect to the present tsunami which originated at a distant location such as Indonesia. Model outputs taking into account other future probabilistics such as occurrence of epicenter of tsunamigenic earthquake close to A & N islands, anticipated sea level rise due to global warming, loss of beaches due to coastal erosion , be used, to determine safe elevation based setback line or vulnerability line for human settlement along the coastal areas. These setback or vulnerability lines need to be notified under the Town and Country Planning Acts or other pertinent Acts of the States, Centre/UTs. to give effect for adoption of location specific elevation plus distance based human settlement planning along the coastal areas of the country. Provision also need to be made to protect the vacant area between the High Water Line and the set back line by declaring them as No Development Zone or as protected areas. The observations of protection offered to human settlement by wide and elevated beaches, sand dunes, plantation etc along the coastal stretches clearly indicate the need to protect the existing beaches from threat of erosion and destruction of sand dunes and plantation due to human intervention through appropriate schemes, strategies and awareness programmes.

Tsunami - Effect on Coastal Systems

Ramesh, R., Nirmal Rajkumar, A and Purvaja, R
Institute for Ocean Management, Anna University, Chennai 600 025
Email: rramesh_au@hotmail.com

Introduction

Any event, which causes a significant displacement of the sea floor, also causes the displacement of an equivalent volume of water. This is the basic mechanism behind which tsunamis are generated. Although most tsunamis are produced from earthquakes, they can also be caused by volcanic activity, submarine landslides, slumps, and meteor impacts and occasionally by human activity. The primary cause of wave generation is the release of energy and associated crustal deformation resulting from the earthquake. Thus, any earthquake, which produces a tsunami, is known as a tsunamigenic earthquake. The magnitude of the earthquake does not dictate whether or not a tsunami will be produced or its size; it is decided by the type of fault from which the earthquake is generated. For example, the San Andreas Fault in California is characterized by a horizontal, i.e., strike-slip, motion. There is no vertical displacement of the sea floor; therefore no tsunami was generated by the great 1906 earthquake of the area. By contrast, when the sea floor undergoes vertical deformation, it acts like a huge paddle, pushing huge volumes of displaced water outward from the zone of deformation.

December 26, 2004 Tsunami in South Asia

The magnitude 9.0 earthquake that occurred on December 26, 2004, created massive tidal waves that spread out in all directions across the Indian Ocean. The major thrust of the waves was east-west, and minor thrust was north-south. Waves radiating from the epicenter northward and southward did significantly less damage than those moving east-west. This earthquake was caused by a large segment of the India plate being subducted beneath the Burma plate along a thrust fault that stretches more than 1200km north-south along the coast of Sumatra and the Andaman and Nicobar Islands (USGS, 2004). The India plate is moving northward at approximately 6cm year^{-1}, placing huge stresses on the Burma micro-plate, which includes the island of Sumatra. These stresses were released when approximately 35m of the India plate slid beneath the Burma plate, releasing the energy in the form of a massive earthquake. The Burma plate has risen approximately six meters during the earthquake. This violent uplift is what generated the massive tsunamis that spread out east and west at speeds approaching 900km h^{-1}. There is no accurate count of the number of primary tsunami waves generated, but several locations report from five to six waves striking shore. The tsunami waves were approximately 10m in height in many locations. The first area struck was the west coast of Sumatra, where waves arrived approximately 20 minutes after the earthquake. The entire northern coastline of Sumatra has been seriously affected.

India's southeastern coast suffered heavily from the tsunami. A number of towns from Pondicherry down to the village of Agasyampalli sustained moderate to severe damage, with loss of large numbers of buildings, damage to breakwaters and harbors, flooding and erosion. The hardest hit were the towns of Agasyampalli, Karaikal, Tarangambadi, Chennai and Nagapattinam. Much of the infrastructure along the east coast was damaged or destroyed, including a number of major bridges, miles of road and rail lines, and several ports. Erosion and flooding have caused significant loss of agricultural land, at least for now (Table 1).

Table 1: Area of coastal stretch affected in South India and the Andaman and Nicobar Islands

Details	Tamil Nadu	A&N Islands	Pondicherry	Kerala	Andhra Pradesh	Total
Coastal length affected in km	1000	NR	25	250	985	2260
Penetration of water into mainland in km	1-1.5	NR	0.3-3.0	1-2	0.5-2.0	
Average height of tidal wave in meters	7-10	NR	10	3-5	5	
Number of villages affected	376	30 Islands	33	187	301	927
Cropped Area (hectares)	10245	NR	506	NR	790	11827
Boats damaged	45920	NR	6678	10065	1362	64025

The Hazard

Human suffering during tsunami flooding can be enormous; people are swept along with other debris in the tsunami-induced currents at speeds up to 60 km hr^{-1}, resulting in drowning due to multiple injuries like broken bones, lacerations, abrasions, punctures, and crushed body cavities. Since 1850, tsunamis in the Pacific have caused the death of over 120,000 coastal residents. Tsunamis are a major hazard to coastal residents in earthquake-prone regions. The Indian Ocean has also been severely affected by tsunamis in the past and the major events are detailed in Table 2 below, apart from the December 26, 2004 event.

Table 2: Major tsunamis recorded during the past 115 years in the Indian Ocean Region

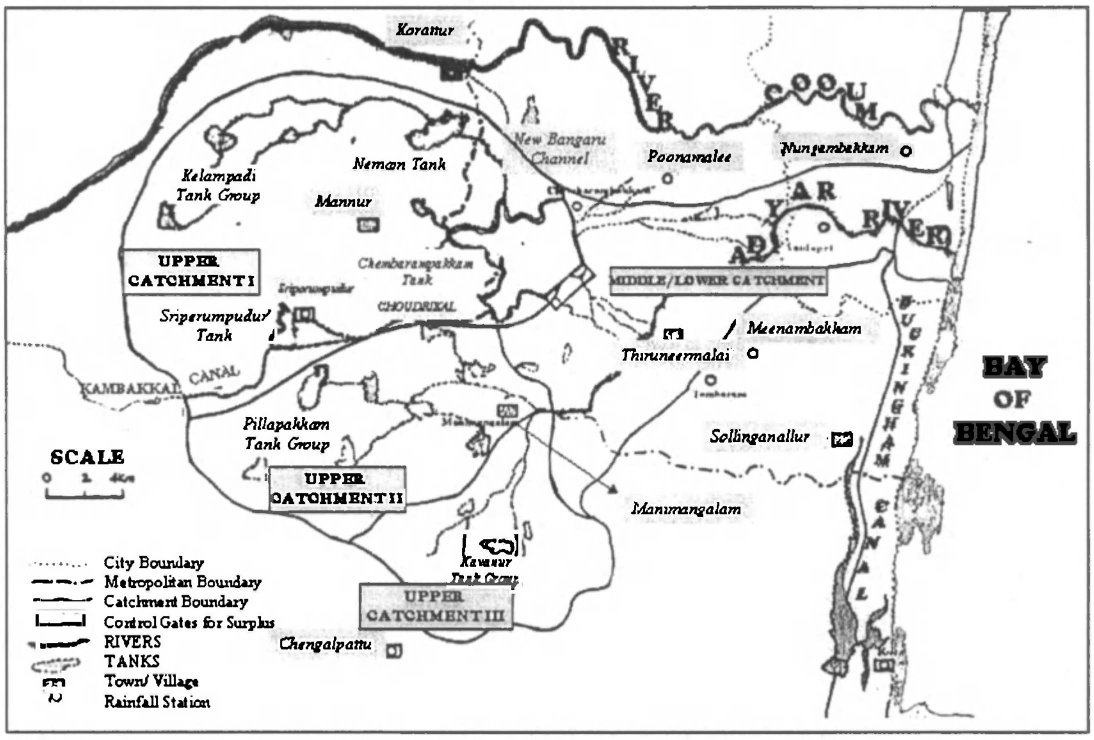
Date	Cause	Impact
31 Dec 1881 (Source: Prof Roger Bilham)	A 7.9 Richter scale earthquake beneath Car Nicobar	Entire east coast of India and Andaman & Nicobar Islands; 1m tsunamis were recorded at Chennai.
August 1883 (Source: Dr. Arun Bapat)	Explosion of the Krakatoa Volcano in Indonesia	East coast of India was affected; 2m tsunamis were recorded at Chennai.
26 June 1941 (Source: Dr. Arun Bapat)	A 8.1 Richter scale earthquake in the Andaman archipelago.	East coast of India was affected but no estimates of height of the tsunami is available
27 November 1945 (Source: Dr. Arun Bapat)	A 8.5 Richter scale earthquake at a distance of about 100km south of Karachi	West coast of India from north to Karwar was affected; 12m tsunami was felt at Kandla

With this background, we studied the extent of landward intrusion of seawater into the Chennai coast, (Adyar estuary) and the associated changes in surface water and sediment characteristics.

Study Area

The study area covers the entire stretch along the Adyar River (Fig. 1), between 12°55' N – 13°02'N latitudes and 80°00'E – 80°17'E longitudes. The River Adyar traverses the Southern area of Chennai city and enters into the Bay of Bengal.

Fig. 1: The River Adyar, Chennai, India



The Adyar River is seasonal with an average flow of 89.43 MCM yr^{-1}. The course of the Adyar River from the source to the sea extends to a distance of approximately 40 km. The river originates from three main tank groups: Kallampadu, Pillapakkam and Kavanur. The river drains a catchment area of 810 km^2, which includes three major tanks viz., Chembarambakkam, Sriperampudur and Pillapakkam and over 100 minor tanks. The upper catchments comprise about 75% of the basin and hence important in terms of generating floods. Approximately 40% of the basin is controlled by Chembarambakkam tank. The discharge of the river is estimated to be approximately $114 \times 10^6\ m^3$. The study area is a low-lying, flat, slightly undulating terrain with a general slope of 3°-5° toward E-ENE direction. The elevation of the area generally ranges between 30m in the west and the sea level in the east. The Madras basin has tropical climate with high temperature and humidity. The basin falls under semi- arid tropic with hottest climate between April and June and cold climate between December and February. The wet period covers seven months (June- December) and the dry period for five months (January – May). The area receives an average annual precipitation of 1200mm from Southwest (SW) and intense Northeast (NE) monsoons. The average annual temperature ranges from 25° to 40°C. It receives an average rainfall of 422mm from SW monsoon, and 598mm from NE monsoon, which are 37% and 53% of the annual average rainfall.

Environmental Status

Adyar River is used as a carrier of wastewater and poses significant public health hazard. Increasing population and encroachment on the banks has caused continued degradation of this riverine environment. Besides functioning as flood discharge channels during the brief north-east monsoon period, the waterways are recipients of a considerable quantity of refuse, including builders' rubble, vegetable matter and synthetic and metallic wastes of containers. The sediments in waterways are derived from variety of sources like, alluvium from underlying alluvial basin, sediment transported from further upstream, run-off from the city, solids in suspension from direct discharges and direct disposal of solid wastes.

Materials and Methods

The tidal range and the surface water quality from the Adyar River and its estuary were studied for the purpose of assessing the changes in tidal incursion due to tsunami. Poles of 6 m height were installed in the middle of the Adyar estuary and hourly variation in water height was monitored for a period of 12 hours in a tidal cycle. At the same time, surface water samples from the river were also collected to study the changing water characteristics. Water samples were also collected to quantify the dissolved trace gases such as CH_4 and N_2O, and nutrients, the results of which are not discussed in this paper.

Results

Satellite Imagery

At first, satellite pictures showing (Fig. 2) the effect of tsunami at the confluence of Adyar River were compared. The bar mouth, which remained closed even during monsoon (November – December) was breached and the extent of landward migration of seawater was estimated to be over 3 km. The beachfront area seems to have doubled in width, and all buildings and vegetation about 30m inland are gone. Several of the islands in the river are significantly smaller than they were previously, and the amount of silt visible appears to almost block the waterway around and between these islands. There is damage to the southern peninsula, and to the coast road shown in the imagery. There is some damage to the road around the crescent of buildings on the inland side of the river, and some damage to the islands further up the river channel, but none of it appears to be substantial. There is flooding in several open areas around the northern portion of the city, indicating that the surge traveled well inland in some areas.

Moderate damage noted throughout the beachfront areas of the city, and damage to the harbor itself. The breakwater around the harbor have been heavily struck by tsunami waves, but remained undamaged. There is significant evidence of erosion and minor to moderate damage to the main wharf. There is evidence that the local fishing fleet has sustained moderate damage, with a number of boats on the piers at the south end of the dock, and several others appear to be overturned. There are several boats that were washed ashore at the south end of the harbor. The entire beach area north of the harbor was heavily hit, but the coastal highway appears to be intact. There is also evidence of light to moderate damage to the houses on the western side of the main coast highway in the northern portion of the city. South of the harbor, the grassy area below the harbor has been denuded of vegetation. There is evidence of erosion in several places. There are two large warehouses south of the harbor that do not show signs of physical damage, but activity around both indicate that items stored inside may have been soaked by the waves.

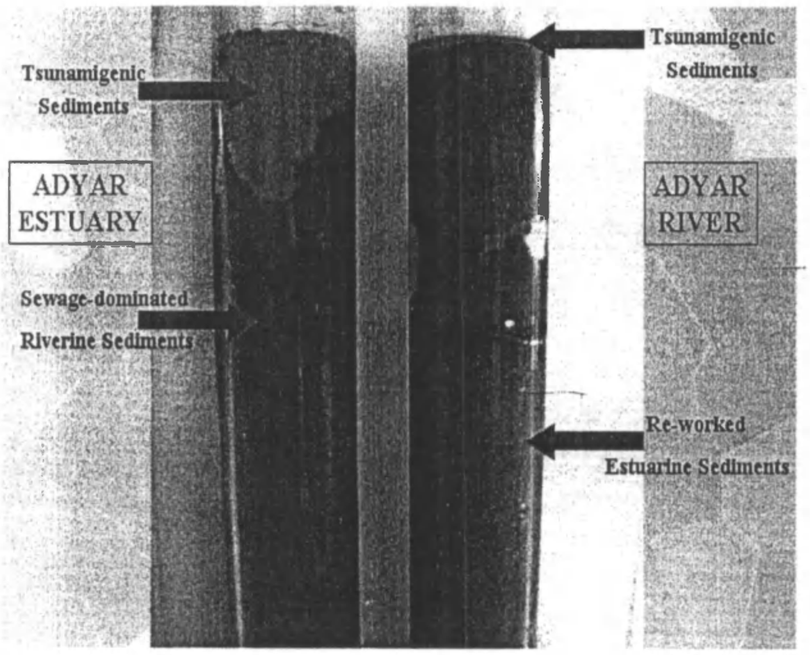
Fig. 2: 'Before' and 'after' satellite imageries of Adyar River Confluence with Bay of Bengal (Source: NRSA, 2004)

a) Before Tsunami *b) After Tsunami*

Study on Sediment Characteristics and its Importance

When sediment is deposited by a tsunami and preserved, a geologic record of that tsunami is created. By looking at the sedimentary record in an area, we will be able to identify such deposits and infer the occurrence of past tsunamis. The recognition of deposits from past tsunamis allows geologists to extend the relatively short or non-existent historical record of tsunamis in an area. Because scientists cannot yet predict when a tsunami will occur, obtaining a geologic record of past events may be one of the only means to assess future risk as clearly seen in the picture of cores taken from the Adyar estuary below (Fig. 3).

Fig. 3: Deposition of tsunamigenic sediments and reworking in the Adyar River and Estuary



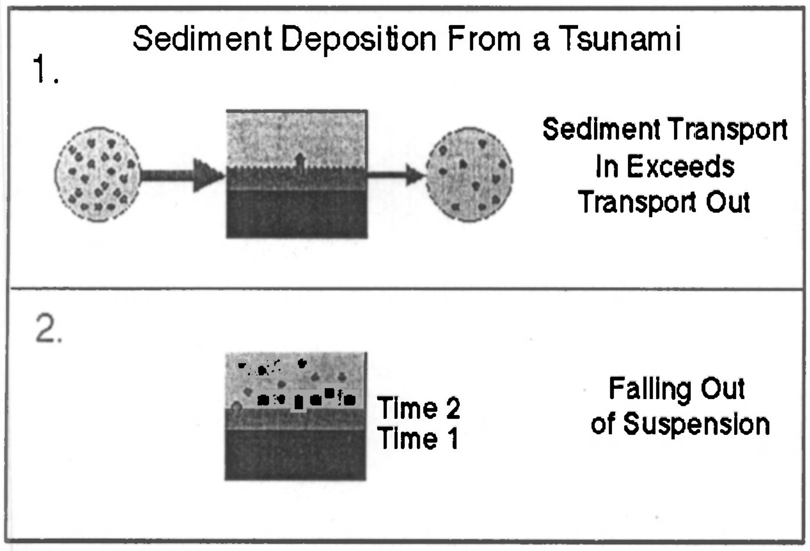
We measured tsunami sediment thickness, run-up and inundation distance for two shore-normal transects along 5 km of coastline in the Adyar River and Estuary. More than 20 samples were collected for laboratory analyses for grain size distribution, mineralogy, and chemistry. Sedimentary characteristics of the tsunami deposits and underlying material were logged and photo-documented (Fig. 4).

Box cores and sediment peels were taken at several sites to preserve the stratigraphy of the sediments. Erosion, flow-direction indicators, watermarks on buildings, and damage to structures were also documented. Local residents were interviewed for their observations of the tsunami and local conditions before and after the tsunami. Tsunamis often leave a layer of sediments that may be preserved in the geologic record. The geologic record may then be used to help assess tsunami hazard. In some cases, this record may be the only evidence that a region may be at risk from a tsunami. Where more than one tsunami deposit is preserved in a stratigraphic sequence, the record may help determine how often a tsunami is likely to occur. Tsunami sediments may also record important information about the wave that deposited them (Fig. 4).

Identifying Tsunami Deposits

A tsunami deposit is usually identified by sedimentary context (e.g. deposited on soil associated with coseismic subsidence), larger grain size than surrounding sediments indicating higher-energy depositional conditions, spatial distribution of the deposit, and by ruling out other high-energy depositional modes (e.g. storm surges or floods). Paleotsunami deposits are identified as being anomalous sand layers in low energy marsh or lacustrine environments (Peters et al. 2001, Atwater 1987, Clague et al. 2000). Additional information that indicates a seaward source of sediments, such as microfossils (Hemphil-Haley 1995) or geochemical signature (Schlichting 2000), is also useful for determining that a deposit was formed by a tsunami. Identification of deposits in Papua New Guinea used the "anomalous sand layer" criteria. The other criteria used were the thickness and spatial distribution of the sand layer (as thick as 16 cm), mud rip-up clasts mixed with the sand, an erosive base, upward fining, shells in the deposit indicating a marine source of the sediment, and a general landward fining indicating landward transport of sediment from the ocean.

Fig. 4: Sediment deposition from a Tsunami



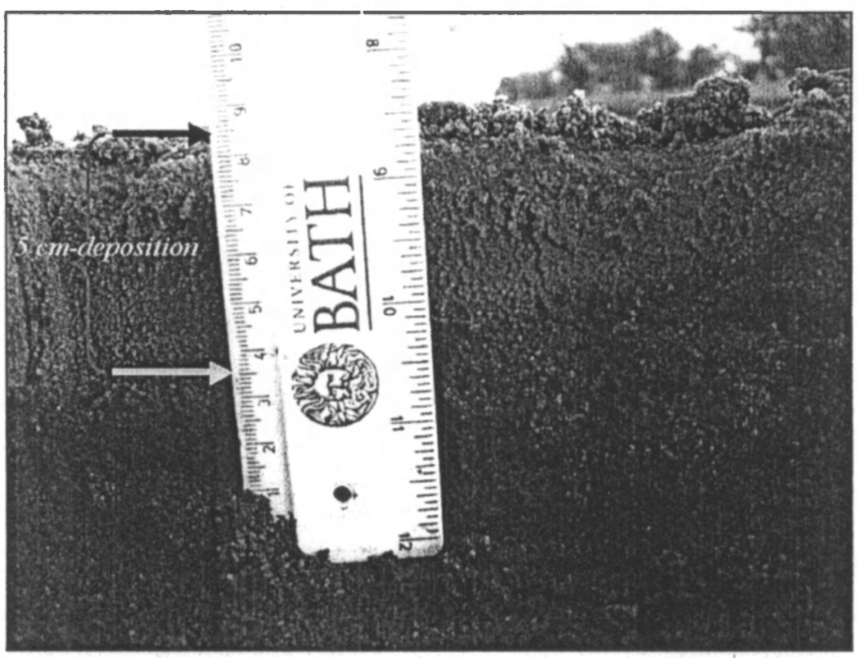
By examining the thickness and grain size distribution of tsunami deposits, we may be able to deduce the wave height and flow velocity of the wave. Wave height and flow velocity are among the most important properties of a tsunami that determine how destructive the wave is. By studying sediments from recent tsunamis, we may be better able identify and interpret tsunami sediments in the geologic record.

In the recent tsunami, two basic processes have occurred. In the first process, deposition had occurred through gradients in transport (more sediment goes into an area than comes out). Deposition also occurs by sediment falling out of suspension and it would be important to analyze the tsunami sedimentary deposits to determine which process is dominant. This will aid in the development of sediment transport models.

Tsunami Sand Deposits

The tsunami in South India in places such as Kalpakkam, Cuddalore etc., sand was carried from the beach and ocean floor and were deposited them on buildings, on top of boulders, and on the ground. Tsunami sand deposits were found at all sites along the Tamil Nadu coast. Although tsunamis are capable of eroding the land, erosion was often concentrated in a relatively narrow zone near the coast. The sand eroded was transported both onshore and landwards as observed for the Adyar River Basin in Chennai. The sand transported onshore formed a recognizable tsunami sand deposit. Tsunami sand deposits at Chennai started about 50 meters inland, and decreased in thickness from about 10 centimeter (average 5 cm) total thickness to about 2 cm thickness at about 150 meters inland (Fig. 5). In other locations where the tsunami was larger, both the width of the erosion zone and the tsunami deposit were larger. The tsunami sand deposits often contained two or more layers. These layers were formed by different tsunami waves and by variations in flow within a wave.

Fig. 5: Tsunamigenic sediment deposits (in layers) in the Adyar River and Estuary, South India



The sand deposited by the recent tsunami is light colored and overlies a pre-tsunami darker sandy soil (see Fig. 5) This tsunami deposit is approximately 5 cm thick and composed of three thick layers defined by darker areas and sub-layers that are visible near the surface. Data from analysis of grain size will be used to determine whether the deposit was formed by two or more waves. Thickness and grain size tend to decrease with distance from the ocean. However, in the middle of the transect there is a region where the variability is low indicating spatial gradients in transport were not significant in forming the deposit. The characteristics of the deposits reflect hydrodynamics of the tsunami that created them and can be interpreted to learn information about the tsunami magnitude.

While no single characteristic may universally be used to distinguish a tsunami deposit, the combination of several characteristics are often used to rule out other processes and leave little or no doubt as to a tsunami origin for the deposit. Tsunami deposits may be distinguished from river deposits by distinct biological markers, spatial distribution, sediment characteristics and geochemistry. The presence of marine or brackish water macro- and microfossils is used to infer a marine rather than river source for the deposit (Hemphill-Haley, 1995). Thinning and fining of the deposit landward are often used to suggest a marine surge rather than a river source for the deposit (Atwater, 1987; Benson et al., 1997). Flop-overs, which consist of the leaves and stems of herbaceous plants bent over by the flow, preserve information about flow direction and may indicate a landward-directed flow, suggesting a marine source (Atwater and Hemphill-Haley, 1997). The composition and texture of the sand grains has been used to differentiate between a coastal or upriver source (Darienzo and Peterson, 1990; Peterson and Darienzo, 1996). Geochemical indicators, such as bromine enrichment, have also been used to indicate a marine source for the deposit (Schlichting, 2000).

Differentiating Tsunamis from Storm Surges

Storm surge deposits are more difficult to distinguish from tsunami deposits because, similar to tsunami deposits, they also contain marine or brackish water macro- and microfossils, have saltwater chemistry, and thin and fine landward (Nelson et al., 1996). Some studies use distance inland to indicate a tsunami source, arguing that it is not likely that storm waves or a storm surge could deposit sand inland to the extent of the deposit (Clague et al., 2000). Reinhart (1991) argues that in protected tidal channels, storms are unlikely to suspend the volume of sediment necessary to produce the deposits observed. When layers are present, their number and thickness are sometimes used to differentiate between a tsunami and storm deposit (Williams and Hutchinson, 2000). Tsunami deposits tend to have several relatively thick normally graded beds, suggesting deposition from suspension by successive waves in the tsunami wave train, while storm deposits may be expected to have thinner and more numerous laminations from higher frequency but lower energy storm waves (Nelson et al., 1996). Abramson (1998) uses the presence of rip-up clasts in the deposit to indicate the higher energy deposition of a tsunami. Our main observations were that:

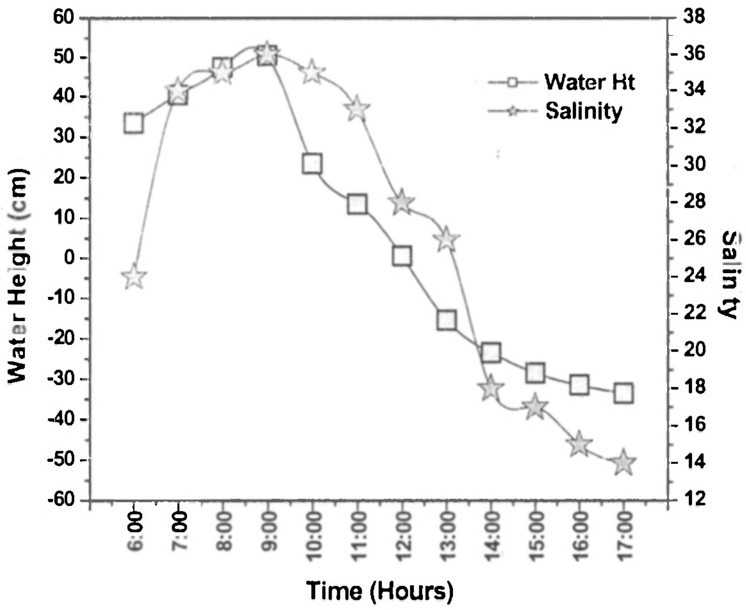
- Sediment deposits were found at all sites;
- Sediment deposit thickness was variable, effected by distance from the shoreline, local topography, and change in slope;
- Only a few sites had easily identifiable deposits;
- Some deposits were normally graded, some were inversely graded, and some had no visible grading and
- Flow indicators suggest significant onshore flow and weaker, but significant offshore flow.

The deposits from the tsunami exhibited a wide variety of forms throughout the study area. Thickness varied both with distance inland and with site. The thickest deposits measured in the estuarine region (Fig. 3). While sedimentary structures were usually absent, many deposits contained 2-4 internal layers. Each layer is believed to represent deposition from a single wave within the tsunami wave train. Eyewitness accounts report that the tsunami consisted of 3-4 waves, with the first and second waves being the largest. The greatest run-up measured was between 10 and 12 meters. The greatest inundation distance measured was up to 1 km at some locations (Fig 7).

Tidal Variations

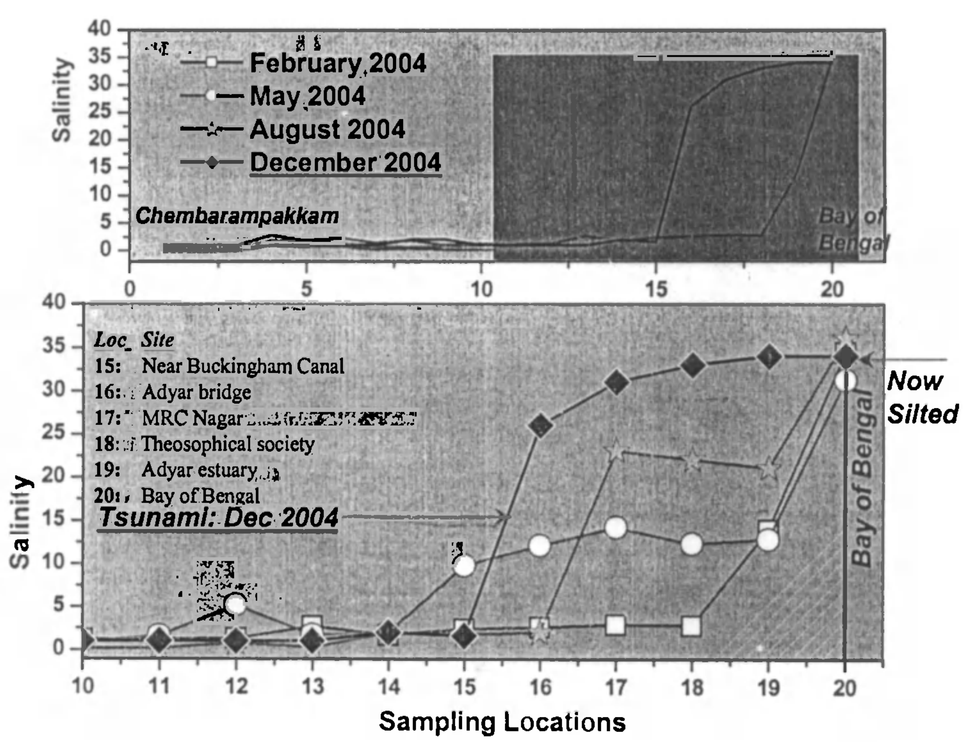
Salinity, dissolved O_2, CH_4 and N_2O concentrations and nutrients were measured from surface water collected at the Adyar Estuary, over a partial tidal cycle (12 hours) after tsunami (January 2005). The tidal (Fig. 5) and seasonal (Fig. 6) variation in salinity prior to tsunami show significant increase inundation limits. However, only salinity variations and extent of landward migration of seawater has been discussed here.

Fig. 5: Post-tsunami tidal variations in salinity in the Adyar River and Estuary



Two dominant processes have occurred in the Adyar estuary as a result of tsunami: i) erosion of the bar mouth at the confluence and ii) reworking and re-deposition of estuarine sediments to the riverine areas, which were previously inundated with river and sewage mixed sludge. Thus, the sediments that were removed by the force of the tsunami at the confluence have been redistributed and deposited in the riverine reaches close to the estuary. This has caused a lowering of salinity in the northern side of the Adyar River (Foreshore Estate).

Fig. 6: Seasonal (pre and post tsunami) variation in salinity in the Adyar River and Estuary (Sampling locations from Chembarampakkam [origin] to the Bay of Bengal [confluence] has been depicted in the x-axis covering a total distance of 40 km)



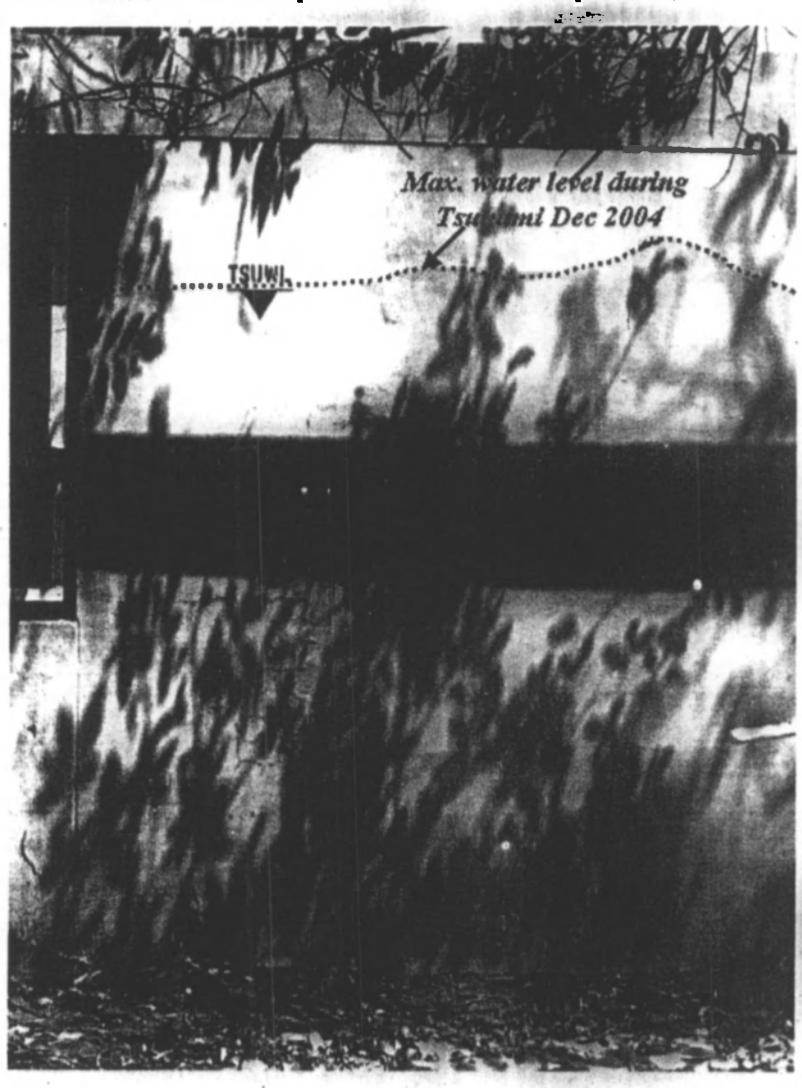
Measurement of Inundation Distances and Run-up Elevations

The power of the tsunami in Chennai and Kalpakkam were documented by measuring inundation distances and run-up elevations.

Inundation distance—the distance from the shoreline to the limit of tsunami penetration

Inundation distance measured varied from less than 50 meters to more than 1 kilometer. In general, inundation distance increased towards the South, while deposition was dominant in the North of Chennai. Tsunami inundation was greatest in the embayments such as in the Adyar and Cooum Estuaries and at Kalpakkam (Fig. 7).

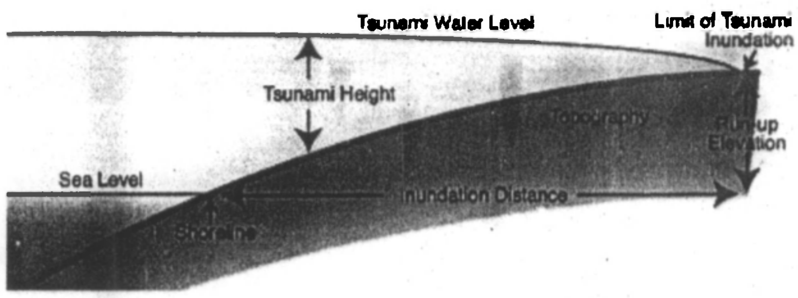
Fig. 7: Tsunami inundation and run-up characteristics at Kalpakkam, South India



Run-up elevation—the elevation above sea level of a tsunami at the limit of penetration

Run-up elevation measured varied from less than 3 meters to more than 12 meters. In general, run-up elevation increased towards the South. There was, however, considerable variability caused by a number of factors, including slope of the land (lower run-up elevations in flatter areas), underwater topography, and orientation of the coastline as shown in Fig. 8.

Fig. 8: Tsunami inundation and run-up characteristics



Potential Future Research

- Compare with deposits of other modern tsunamis; use results to interpret paleo-tsunami deposits in Tamil Nadu and other locations such as the Andaman and Nicobar Islands
- Use Tsunami deposits to further develop and test models to calculate flow properties from sediment deposits
- Collect bathymetric data for flow modeling
- Collect sediment samples offshore to determine source of sediment in tsunami deposits
- Conduct geophysical surveys offshore to map subsurface structure and surficial offsets caused by recent faulting

New Technologies for Tsunami Hazard Mitigation

New technologies were applied to the tsunami hazard mitigation during this decade in some countries of the Pacific region. Similar technologies could be developed in India including:

- Development of a real time, deep ocean tsunami detection system that uses pressure transducers, acoustic modems, and satellite communications,
- A new generation of numerical models for estimating tsunami inundation,
- Internet-based communications to share results from numerical experiments and field surveys rapidly with a world-wide audience,
- Global Positioning System, that increased the accuracy of tsunami inundation surveys and the bathymetric and topographic imaging used in numerical models,
- Multibeam bathymetric survey tools to increase the resolution of underwater surveys revealing scars from past slumps,
- Remotely operated underwater vehicles that can examine evidence for underwater landslides or slumps, and
- Increasingly sophisticated dating technology in paleotsunami research to estimate recurrence intervals.

Conclusions

Tsunami research in the past decade has taken on a momentum-fueled by events and technologies-that can only serve to push the boundaries even further toward the scientific goal of understanding the physics of tsunamis and the practical goal of the maximum preservation of lives and property. The data gathering efforts will be combined with increasingly detailed bathymetric and topographic surveys, numerical simulation techniques, and laboratory measurement techniques to greatly increase our understanding of the tsunami phenomenon on all space and time scales.

Acknowledgements

The authors thank Prof. V. Rajamani, SES, JNU, for his valuable suggestions in the conduct this study and Dr. M. Prithviraj, Department of Science and Technology (DST), Government of India for supporting this work. R. Purvaja thanks the DST for financial assistance (Grant #: SR/FTP/ES-59/2001). Dr. V. Kannan, Head, Environment Survey Laboratory, Bhabha Atomic Research Centre, Kalpakkam; M. Ahmed and other research students of IOM, Anna University are thanked for their technical and field support during this study.

References

Abramson, H.F., 1998, Evidence for tsunamis and earthquakes during the last 3500 years from Lagoon Creek, a coastal freshwater marsh, northern California: M.S. thesis, Humboldt State University, 76 p.

Atwater, B., 1987, Evidence for great Holocene earthquakes along the outer coast of Washington state: Science, v.236, p.942-944.

Atwater, B., and Hemphil-Haley, E., 1997, Recurrence intervals for great earthquakes of the past 3500 years at northeastern Willapa Bay, Washington: U.S. Geological Survey Professional Paper 1576, 108 p.

Benson, B. E., Grimm, K. A., and Clague, J. J., 1997, Tsunami deposits beneath tidal marshes on northwestern Vancouver Island, British Columbia: Quaternary Research, v. 48, p. 192-204.

Clague, J.J., Bobrowski, P.T., and Hutchinson, I., 2000, A review of Geological records of large tsunamis at Vancouver Island, British Columbia, and implications for hazard: Quaternary Science Reviews, v.19, p. 849-863.

Darienzo, M.E. and Peterson, C.D., 1990, Episodic tectonic subsidence of late Holocene salt marshes, northern Oregon central Cascadia margin: Tectonics, v. 9, n. 1, p. 1-22.

Hemphill-Haley, E. 1995. Diatom Evidence for earthquake-induced subsidence andtsunami 300 yr ago in southern coastal Washington. Geological Society of America Bulletin, 107(3), 367-378.

Nelson, A.R. and Peronius, S.F., 1996, Great earthquake potential in Oregon and Washington - an overview of recent coastal geologic studies and their bearing on segmentation of Holocene ruptures, central Cascadia Subduction zone: in Assessing Earthquake Hazards and Reducing Risk in the Pacific Northwest, Rogers, A. M., Walsh, T. J., Kockelman, W. J., and Priest, G. R., eds., USGS Professional Paper 1560, p. 91-114.

Peters, B., Jaffe, B. E., Peterson, C., Gelfenbaum, G., and Kelsey, H. 2001. An Overview of Tsunami Deposits Along the Cascadia Margin. Proceedings of the International Tsunami Symposium, 2001, 479-490.

Peterson, C. D. and Darienzo, M. E., 1996, Discrimination of climatic, oceanic, and tectonic mechanisms of cyclic marsh burial: in Assessing Earthquake Hazards and Reducing Risk in the Pacific Northwest, Rogers, A. M., Walsh, T. J., Kockelman, W. J., and Priest, G. R., eds., USGS Professional Paper 1560, p. 115-146.

Reinhart, M.A. , 1991, Sedimentological analysis of postulated tsunami-generated deposits from Cascadia great-subduction earthquakes along southern coastal Washington: Unpublished M.S. project, University of Washington Department of Geological Sciences, 83 p.

Schlichting, R.B, 2000, Establishing the inundation distance and overtopping height of paleotsunami from the late-Holocene geologic record at open coastal wetland sites, central Cascadia margin: Masters Thesis, Portland State University, 166 p.

Williams, H. and Hutchinson, I., 2000, Stratigraphic and microfossil evidence for late Holocene Tsunamis at Swantown Marsh, Whidbey Island, Washington: Quaternary Research, v. 54, p. 218-227.

Possible Impact of the recent Tsunami on the Marine Living Resources of the Indian Seas

Dr. V. Sampath
Director
Department of Ocean Development
NIOT Campus, Chennai-601302

Introduction

On 26th December, 2004, a team of Scientists of National Institute of Ocean Technology (NIOT) located at A & N Islands was on board MV Dering, at Hut Bay, ready to leave for Port Blair, when the strong earthquake hit the Hut Bay around 06 40 am, followed by the tsunamis around 7.15 am. Severe jolting was observed in the jetty and breakwater for approximately 30 to 40 seconds leading to damage of light mast and jetty, (approximate length of jetty 125m) and the breakwater (length ~500m). Then water receded rapidly to a distance of approximately 100m from shore and it started raising menacingly, inundating the entire coastline adjoining Hut Bay. The breakwater collapsed and sunk after the earthquake and the tsunamis that followed.

A team of scientists from ICMAM-PD visited Besant Nagar Beach in Chennai, Tamil Nadu to monitor the water level fluctuation from 10.00 a.m. to 6.00 p.m. on 26.12.2004 and to analyse the impact of tsunamis.

The ICMAM Scientists carried out extensive studies on the shoreline changes and coastal inundation studies to assess the impact of tsunamis along the Tamil Nadu and Andhra Coasts and Andaman and Nicobar islands during January and February 2005.

Seiches i.e., harbour oscillations induced by Tsunami have been recorded by the Acoustic Tide Gauges (ATGs) developed and installed by NIOT, at Port Blair and at Chennai Port. At Port Blair the surge was up to 3.48 m and at Chennai the amplitude of the surge was more than 3m (in the port). The time of occurrence of Tsunami as recorded by ATG at Port Blair was 7.14 hrs and at Chennai was 09.06 hrs.

Scientists around the world including the Marine Biologists and Oceanographers in India are currently trying to collect data to get an idea of the amount of damage, caused to marine life in the Bay of Bengal and it will take a few more months or a year before we could make a realistic assessment of the damage. The research vessels of the various Institutes in India have been deployed on cruises in the Bay of Bengal to assess the impact of tsunami. The 4 research vessels of the Department of Ocean Development (DOD) viz., ORV Sagar Kanya, Sagar Sampada and the two coastal research vessels Sagar Purvi and Sagar Paschimi were deployed on cruises along the track of tsunami for collecting first hand information and data on the impact of 9.3 high magnitude earthquake in the South Andaman Sea and the resultant tsunamis on the east and west coast of India. The cruises were started in the first week of January 2005 and completed their first phase of studies and returned in the 3rd week of February 2005. The preliminary results of the observations made by the dedicated scientists and oceanographers of this country have revealed a number of surprises on the nature of earthquakes and the impact of the earthquake and tsunamis on the marine environment and its resources. It might take some more time for us to analyse the large quantum of samples and data collected from the tsunami affected areas, to arrive at a conclusion on the impact of these natural calamities on the marine environment and its resources. The DOD has taken up the initiative of establishing a tsunami and storm surge warning and mitigation system for the Indian Ocean region, with a view to safe guarding the life and property of millions of people. These aspects are highlighted in this report.

The major question presently asked by scientists and researchers all over the globe is what would have been he impact of this tsunami on the myriad life in sea, particularly the phyto and zooplankton which are free swimming surface organisms, the coral reefs and associated flora and fauna, the microscopic and macroscopic benthic organisms, which are sensitive to sedimentation by the debris brought and deposited on them by the furious tsunamis, the shell-fish and fin-fish species which are the source of bread and butter for the coastal fishermen.

Likely impact of tsunamis on the coral reefs

Coral reefs occur along shallow, tropical coastlines where the marine waters are clean, clear and warm. Many of today's coral reefs have been built up gradually over the last 5000 to 8000 years, often on the remains of far more ancient corals, which may date back to over 400 million years. They are one of the most productive ecosystems in the world. Even though coral reefs occupy ¼ of 1% of the surface area of the oceans, about 25% of the World's fish species are, in some way, dependent on coral reefs for their survival. They contribute to fisheries, as approximately one third of world's fish species are reported to be living on coral reefs. In many a countries, they support booming tourist industries. They serve as natural protective barriers, deterring beach erosion, retarding storm surges and allowing mangroves to grow.

Both the coral atoll and the fringing coral reefs are of utmost significance in Indian waters. Coral reefs are found in the Palk Bay, Gulf of Mannar, Gulf of Kachchh, central West Coast of India, Lakshadweep and Andaman & Nicobar Islands. From the Indian coast 342 species of corals belonging to 76 genera have been reported, with the maximum number reported from Palk Bay and Gulf of Mannar, followed by Andaman waters and Lakshadweep Islands.

Corals provide food and habitat to countless marine organisms, and damage to reefs can have direct effects on the intricate web of marine life that depends on the health of the reefs for survival. The destruction of coral reefs can result in drastic changes in the fish populations associated with these ecosystems, leading to a drastic reduction in the catches of local fishers, with a loss of food security and an increase of poverty.

A joint assessment mission conducted by the World Bank and the Food and Agricultural Organisation (FAO), and the United Nations Development Programme (UNDP) during the first week of January, 2005 in the Phuket area, has found that heavy debris were subjecting the corals to tremendous stress and that, on average, about 5% of the coral reefs along the southern coastline and around the main tsunami-affected islands had been damaged.

Likely impact on near shore marine ecosystems

A major indirect impact of the tsunami on near shore marine ecosystems includes sedimentation from runoff and the churning up of coastal silt, sand and organic matter. Some ecosystems could have been buried by sediments flushed into shallow near-shore environments. For areas normally exposed to high wave energy or strong currents, this sedimentation will probably be washed away over several weeks or months, depending on degree of sedimentation. When debris of this type is caught up in strong nearshore waves and current, it can easily 'bulldoze' corals and other benthic substrates (i.e., ocean bottom). In more protected areas (not typically exposed to significant wave energy or currents), it could take years or decades for the ecosystem to recover.

The heaps of debris that have entered the ocean by the tsunami would pose a risk to marine life. Excessive amounts of debris, including building materials, vehicles, boats, refrigerators, large, non-buoyant objects flushed out to sea could have contained toxic chemicals, oils, paints, etc., which could be deposited causing stress to near shore marine ecosystems. These could cause disease in marine organisms. Fishing gear from sunken and damaged boats or which might have been dragged into the Bay of Bengal could pose a threat to many-a-species of fish, turtles and marine mammals by entangling them in the net leading to "Ghost Fishing". Because fishing gear is often composed of plastic and/or other non-biodegradable materials, it can last in the marine environment for years.

Fish stocks and young fishes might probably have been affected and hence in the next couple years fish yield may go down. The other possibility is that due to upwelling the cold nutrient rich bottom sea water which rises to the sea surface might trigger the primary production to abnormal levels on sea surface leading to increase in productivity or production of both wanted and unwanted (toxic) algal blooms. These impacts could be long-lived and might not be apparent to researchers for months or even years. Time is needed to study these events and come out with a firm answer on these assumptions.

Cruise of ORV Sagar Kanya

A multidisciplinary cruise of ORV Sagar Kanya in tsunami affected areas was carried out from 3rd January 2005 to 21st February, 2005, involving the participation of scientists of NCAOR and NIO. The vessel sailed from Goa on 3rd January 2005 and observations were carried out along the affected coastal areas of Malabar coast and Nagapattinam, Cuddalore, Pondicherry and Chennai on the Coramandal coast. The vessel reached Chennai on 15th January 2005 and sailed for a cruise in Bay of Bengal, Andaman & Nicobar region, immediately, thereafter. The vessel returned to Chennai on 21st February ' 05 after completing the 37-day post-tsunami cruise. The multi-disciplinary and multi-parameter data collection was so planned as to reoccupy some of the areas where earlier data were available and also to collect new data in some areas, which were not covered earlier.

The data generated during the cruise included:

- Time series environmental data (such as temperature, salinity, current, water quality, etc), which would help to study the impact of the earthquake and the tsunamis on coastal and deep-sea marine environment.
- Underway-geophysical data (swath bathymetry, gravity, sub-bottom profiling, etc,) which might help in demarcating the physiographic and tectonic changes in the track of the fracture and tsunamis.
- Gravity and spade cores over the Andaman and Nicobar Trench axis, Andaman basin and Bengal Fan to study the probable variations in the sediment structure of the upper column.
- Creation of new database in these regions, as well as re-occupation of some of the areas, where earlier oceanographic data are available.
- Biological species data in the coastal waters of Andaman and Nicobar Islands and Andaman Basin to study the changes in their distribution pattern following the tsunami surge.

Preliminary Observations:

Sea surface temperature increased from 27°C off Chennai to 28°C at 92°40′ E.

Mixed layer depth, varied from 50 to 100m between 80° 52′ to 87°E and thereafter it decreased to 70m towards Andaman.

A temperature maximum was observed at 84°E at ~80m.

Along the west-east section the near-surface salinity varied from 32.8 to 33.9 psu, with low salinity water (31.7psu) identified near the Andaman Islands. A conspicuous feature identified in the vertical profiles is the occurrence of high salinity core (35.2 psu) at 100 m between 83° and 84°E; in the same region the temperature maximum (~29°C) was also encountered. In general, surface freshening occurred near Andaman region.

Chemical and biological parameters as well as sediment cores collected during the expedition would be taken up for analysis at the shore-based laboratories.

Study on possible effects of Tsunami on the coastal Marine Living Resources

Apprehensions have been raised by leading scientists and media with regard to the impact of tsunami on the fishery resources also. A team of scientists from Cochin University of Science & Technology, NIO-RC, Kochi, Annamalai University and Centre for Marine Living Resources and Ecology, Kochi sailed out from Kochi onboard FORV Sagar Sampada on 5.1.2005 to carry out detailed investigations on the impacts of the tsunami on the benthic communities, water chemistry and productivity patterns of the coastal waters covering the Kerala, Tamil Nadu and Andhra coasts.

Impact assessment was made through comparison of the results with previous data collected from these areas by the earlier cruises. Concurrent measurements on the near coastal waters i.e. up to 30 m depth were also undertaken. On completion of this cruise, studies were conducted in the Andaman sea, for which the participants were drawn from NIO-RC, Kochi, CMFRI and CMLRE, Kochi.

The observations made in the Kochi – Chennai track during 05.01.2005 to 19/01/05, are as under:

- Sea surface temperature (SST) varied between 26.62° and 27.25° C. Mixed Layer Depth (MLD) ranged from 58 m to 82 m.
- Except for silicate and phosphate values, all other chemical parameters viz. salinity, dissolved oxygen, pH were normal. Normal surface values of silicate were below 1.5µM. High phosphate values (up to 7.27µM) were observed at 30m and 50m stations off Nagapattinam. Normal values are below 3.0µ M.
- Benthic organisms were recorded from all the stations. Study of major groups from samples collected from 30 m and 100 m depth and the comparison with data earlier recorded indicate that the major groups of benthos are not significantly affected.

- A significant variation of clay particles in the east and west coast at 30 and 100 m depths was recorded. The data indicate a substantial increase in the finer particles at 30 m depth at Kollam, Thiruvananthapuram and Kozhikode in the west coast and Chennai and Krishnampattinam in the east coast. At 100 m depth also an increase in finer particles was recorded off Kollam, Kochi and Kozhikode and in the east coast off Karaikal and Krishnampattinam. Statistically total sediment character change was significant at 30 and 100 m depth both in the east and west coasts.

- In the demersal fishery catches nothing unusual was observed. Neither algal blooms were observed, nor was abnormal swarming of zooplanktons noticed.

In the track of the tsunami from Andaman to Chennai (23/01/05 to 16/02/05) a number of observations were made.

- In the northeastern region, the coastal area is not much affected as evidenced by the status of corals in the near shore waters. Corals, gorgonids and coral reef associated fauna are alive and in good condition in this region, which indicates the stability of the bottom.
- Even though the surface salinity and temperature didn't show much variation in the middle Andaman, coral and associated fauna were heavily damaged in the Wandoor and Jolly boys region. This could be due to sedimentation and deposition of the debris over the coral reef beds by heavy force of tsunami waves and beach erosion.
- Comparatively high values of nutrients concomitant with high dissolved oxygen promote the phytoplankton production in the near shore waters of Viper Island and Minnie Bay, where the intensity of tsunami waves was high.
- In the fishing ground of northeast region, benthic organisms including sponges, gorgonids, echinoderms, etc., were alive and abundant, while in the southern region it was less but a large number of nautilus of various sizes was observed.
- The areas having thick mangrove vegetation are least affected. In such areas beach erosion is very much reduced. This may be due to the reduction of intensity of waves by mangrove vegetation.

Studies by CAS in MB, Annamalai University on Tamil Nadu & Andhra Coasts

In general after the tsunamis the mouths of the estuaries and backwaters all along the coastline have widened, resulting in free exchange of tidal waters. Equally 5 - 10 km of the offshore waters were also found to show a lot of variation in the physico-chemical and biological properties.

Cooum waters in Chennai city recorded the maximum total nitrogen in the water column and the observed value of TN was 164.83 µmol/l, whereas in the earlier observations before tsunami the value was only 90.6 µmol/l.

Coastal stretches at 10 km were also found to record higher level especially at Cheyyur and the recorded values were 47.20 µmol/l of nitrate and 52.22 µmol/l of total nitrogen. During the earlier observations in the pre-tsunami scenario, the nitrate value recorded in this area was only 44.32 µmol/l.

Nagapattinam, Cuddalore and Parangipettai waters showed higher levels of nutrients at 0.5 and 1 km stretch of coastal waters. In general, the Karaikal coastal water was found to record fairly lower levels of nutrients compared to other areas.

Microbial population was found to have only marginal differences between sediment and water column after tsunami. However, the sediment was found to show higher values in all the investigated areas compared to the water column. Salmonella like organism was found to be present only in Nagapattinam and Chennai coastal stretches up to 10 km in the water, a unique feature after tsunami. Most of the forms, which were found to be predominantly represented in the 0.5 - 1 km stretch, were now found even in the 5 - 10 km stretch.

An interesting observation was the blooming of phytoplankton *Lauderia borealis* (1, 05,000/3,22,993 No./l) recorded only in Chennai (Ennore, Cooum, Chennai harbour, Muttukadu) coastal waters. However, it was not found in other areas.

Occurrence of *Lucifer* all along Tamil Nadu and Pondicherry coast instead of its restricted distribution earlier, is another interesting observation.

Zooplankton *Oikopleura* sp. was found to be represented by 35,000/95,000 no./m^3 in the Tamil Nadu & Pondicherry coastal waters, instead of restricted distribution in harbour waters observed earlier.

Very low numbers of benthic fauna (1-9/0.08 m^2) and species (15) were recorded from Chennai to Nagapattinam coastal areas after tsunamis. However, higher number (~ 146/0.08 m^2) and diversity (35 species) were recorded at Cooum (0.5 km). Besides, *Polyodontes melanonotes* ~ 2500 / 0.08 m^2 (polychaete) was recorded only in Pondicherry hot spot area for the first time.

Conclusion & lessons learnt

Only time can tell us the extent of damage the living resources of our seas has suffered, how will our coastal community, particularly the fisherfolk who are dependent on the sea and its resources, which is shattered physically and mentally, overcome these sufferings and resume their normal life.

Reports point to the fact that the places that had healthy coral reefs and intact mangroves were far less badly hit than places where the reefs had been damaged and the mangroves ripped out and replaced by beachfront residential and industrial complexes, hotels, etc. The impact of tsunami was not felt in the Sunderbans mangrove forest area in West Bengal and Pichavaram mangroves south of Cuddalore in Tamil Nadu, India. Long-term environmental lessons must be drawn from this tsunami disaster, especially the consequences of wiping out mangroves and destroying coral reefs that help in protecting the coasts from natural calamities such as storm surges, tsunamis, etc.

MANAGEMENT OF COASTAL AQUIFERS IN TAMILNADU

By

Dr.M.Sriman Narayan

Introduction:

Tamilnadu coast is endowed with a 1076 km. length of coastline. The coastal areas have heterogeneous conditions in terms of soil, land uses, ground water potential, ground water quality etc. While there are fertile lands, the agricultural activity is hampered by lack of water; and in places where fresh water aquifers exist; the soil is saline and unsuitable for any activity. In certain flat terrain inundation occurs due to water logging due to heavy floods, poor drainage system, etc.,

These issues show up their severity in times like floods, cyclones, and recent events like tidal upsurge due to earthquake. In order to put the entire coastal stretches to best use, a comprehensive study of the multi various fields such as water, soil, agriculture, industry these coastal stretches is the need of the hour.

2. Hydrogeology of Tamilnadu coast:

Hydrogeology of the deltaic coasts is by far the most fascinating Palaeohydrology and Paleo depositional history has determined the occurrence and distribution of coastal aquifers. As distinct from the inland aquifers, coastal areas have a typical association of fresh water and salt-water aquifers. Some of the factors that control the fresh water – saline water distribution are land slope, rainfall, geological set up, tectonic history, marine transgression and regression, sea level changes, tidal activities, and changes in the river courses and flow pattern. Under natural conditions, fresh water and salt water are under dynamic equilibrium.

Almost the whole length of Tamilnadu coast, except parts of Kancheepuram district and Kanyakumari district, has recent alluvial deposits underlain by the older formations like Tertiary, Cretaceous and Gondwanas overlying the Archaean basement. The alluvial formations have a wide range of thickness of 60-70 m. in the northern most part of the state to about a few hundreds metres in southern districts. Especially in Ramanathapurm, these alluvial deposits extend very deep to 400 to 450 m. In spite of the vast stretches of alluvium, they do not form potential aquifers in all places. The most prominent alluvial aquifers are in the Araniyar Koratalayar Basin where the well fields are identified and are being exploited to a largest extent for water supply to Chennai city. In other areas, these alluvial formations have alternate layers of sand and clay in discontinuous stretches, thus making them marginally productive. In several cases the sand dunes act as reservoirs of ground water due to the composition of permeable sand with scope for direct percolation of rainfall. In the coastal areas where the rainfall is plenty, compared to inland, these sand dunes with shallow water table conditions are valuable sources of ground water.

Among the other sedimentary formation, the Miocene and Pliocene aquifers of Tertiary age are the most prolific aquifers. They occur in parts of the districts of Villupuram, Cuddalore, Thiruvarur, Nagapattinam, Thiruvarur, Tiruchi, Thanjavur, Pudukottai, Sivagangai and Ramanathapuram. In some places these aquifers extend deep in land. In several places in Cuddalore, Tiruchi, Thanjavur and Pudukottai and Sivagangai districts these aquifers occur under artesian conditions with pizometric heads much above ground level. In course of over two decades period, the flowing conditions however ceased to exist. The other aquifers of lesser ground water potential are the Cretaceous and Gondwana formations with more clay content and consequent less permeability.

In the southern districts of Tuticorin and Tirunelveli, the limited thickness of alluvial formation is underlain by calcareous sand stone, which forms moderate aquifers. However they suffer from poorer quality of water. In the southern most part of the state in Kanyakumari district, the formations are consolidated ones unlike in the rest of the state. In this district hard rocks underlie a thin soil cover. They form moderate aquifers whenever there is considerable thickness of weathered zone. Due to high rainfall conditions, the water levels in these unconsolidated aquifers are shallow.

3.Water quality issues:

The alluvial aquifers present in the coast are in contact with the sea. Under normal circumstances, the equilibrium between fresh water in the aquifer and seawater is maintained as long as a pressure head is maintained in the form of water table above mean sea level. An interface in the form of a wedge is created between the fresh water and seawater. As the head of seawater or fresh water changes, the position of the interface also changes. However, the interface between fresh and salt water is never a sharp one, but a zone of diffusion. In a multi layered aquifer system, the penetration of saline water wedge depends upon how the piezometric head of fresh water body counter balances the saline water head at its outlets. Hence the penetration varies in different layers.

The saline water bodies along the coast owe their origin from various sources like, entrapped sea water, sea water ingress in to aquifers, tidal effects etc. The various situations met with in coastal areas in general and also in Tamilnadu coast is:

1. Saline water overlying fresh water bodies.
2. Fresh water bodies overlying saline waters.
3. Fresh water and Saline water bodies alternating.

Notwithstanding the thin sand layer in the top near the coast, the situation mentioned in the first category is more common in many parts of the state where the alluvial aquifers are saline in quality and these are overlying the confined aquifers containing fresh water. This category of aquifers is formed under marine environment.

The second category aquifers occur in very limited places in the state. These aquifers have the risk of turning saline with the fresh water – saltwater interface moving landward and or simultaneously rising up to ground level. This phenomenon is caused by large scale pumping from the fresh water aquifer. A classic example of such an aquifer and the possible damage caused to the aquifer by over use is Minjur well field located at a distance of about 15 km. from coast in the Araniar Koratalayar basin and located at a distance of about 30 km. north of Chennai. The thin shallow aquifers located in Chennai and its southern suburbs like Thiruvanmiyur and Besant Nagar and down south to Muttukadu to a distance of 15 to 18 km. also fall in this category. While the aquifers in Chennai city and Besant Nagar have been affected by lateral movement of seawater as well as up coning from the saline hard rock zones, the aquifer located between Thiruvanmiyur and Muttukadu has just been maintaining the equilibrium and is highly susceptible for damage depending on the quantum of rainfall and groundwater extraction in this aquifer. There is an urgent need to protect this fragile aquifer.

The third category also exist in Tamilnadu where the sand dunes of limited thickness containing fresh water over lie the alluvial aquifers with poor quality water and these in turn are underlain by fresh water bearing confined aquifers.

A major cause for the salinity in the alluvial aquifers is the depositional nature of these sediments. Paleohydrology plays a major role in such case. Occurrence of strandlines far inland in river deltas, show marine influences on sediments in the entire stretch between the present coast and strand line. As the sea regressed, the seawater of sediments was flushed out. But in case of sediments with finer clastic nature, the rate of flushing is sluggish and salt water in the sediments get trapped. Sometimes marine sediments may cover a fresh water layer. As the sea regressed, the upper layer is flushed out, while the salt water percolates to the more porous underlying formation making it saline.

4.Ground Water Monitoring:

The Ground Water Wing of PWD has been monitoring the groundwater in terms of water level and water quality in 1746 shallow observation wells spread all over the State. Considering the larger part of the State as hard rock area, most of these wells are located in hard rock portion. Besides the shallow observation wells, 852 Nos. of piezometers were constructed under Hydrology project and are under observation for their piezometric levels for the past four years. As a part of special attention to the coastal areas ground water levels and ground water quality are being monitored in 146 structures both shallow dug wells and a few medium depth borewells. On the basis of the observations made from these monitoring structures several areas are found to have saline ground waters due to the depositional environment like marine transgression and regression or back waters or tidal effected zones. In a few places like Chennai city and south in Besant Nagar, parts of Cuddalore district, a few coastal areas in Nagapattinam district near Thirumullaivasal, certain parts of Tirunelveli district near Udangudi and Chettikulam area are affected by seawater ingress. The interface between salt water and fresh water in these areas varied from 0.5 to 2.5 kms. In Minjur aquifer located north of Chennai at a distance of about 30 kms. there is a progressive inland movement of saline waters due to the impact of sea over the past 25 years and the present interface between fresh water and contaminated water is identified at a distance of 15 kms. from the coast. Due to the contamination of groundwater in the production wells, some of them supplying water for city needs had to be abandoned.

5. Impact of extraordinary disasters:

Certain extraordinary situations like severe cyclones causing high tidal effects for long periods, unusual and rare phenomenon like Tsunami may have an adverse impact on the coastal aquifer, especially the shallow water table aquifers. While the intrusion of seawater into the inland aquifers due to the high velocity waves is a rare possibility, a direct impact by way of overflowing tidal water into the groundwater extraction structures will damage the groundwater especially in the open wells.

A brief study was conducted on the possible effects of Tsunami waves that occurred on 26th December 2005 on groundwater. Water levels and on the spot Electrical Conductivity values were measured in 146 structures, both open wells and shallow and deep borewells. These data were compared with pre Tsunami data and it was found that there is rise in water levels and salinity in 38 wells. The district wise break up is 12 wells in Tiruvallur district, 6 in Chennai, 12 wells in Nagapattinam 5 wells in Thanjavur. However, in the districts of Cuddalore, Pudukkotai, Ramanathapuram, Tuticorn and Kanyakumari there is no simultaneous rise in water level and salinity. The following tentative inferences are drawn on the basis of these data.

1. The simultaneous rise in water levels and salinity in a Post monsoon period only in certain number of wells is attributable to the impact of Tidal waves.

2. The absence of any simultaneous rise in water level in the districts of Pudukottai, Ramanathapuram, and Tuticorn probably explains the lesser impact of the Tsunami in these districts by the shielding effect of Srilanka island

3. Kanyakumari district, which reported severity of Tsunami on the ground has registered no impact on groundwater.This is attributable to the haru rock nature of the subsurface geology with low permeability compared to alluvial aquifers.

4. The post Tsunami data from the observation well at Tirumullaivasal in Nagapattinam district showed Ca/Mg ratio as **0.25** Cl/Co3+Hco3 as **94**, TA/TH as **.02** indicating the possibility of influence of Tsunami. The pre event values are **0.8, 2.2, 0.7**respectively. This site was already pronounced as affected by Sea water Intrusion.

6. Protection and management of aquifers:

Various steps involved in the management of the precious coastal aquifers are as below:

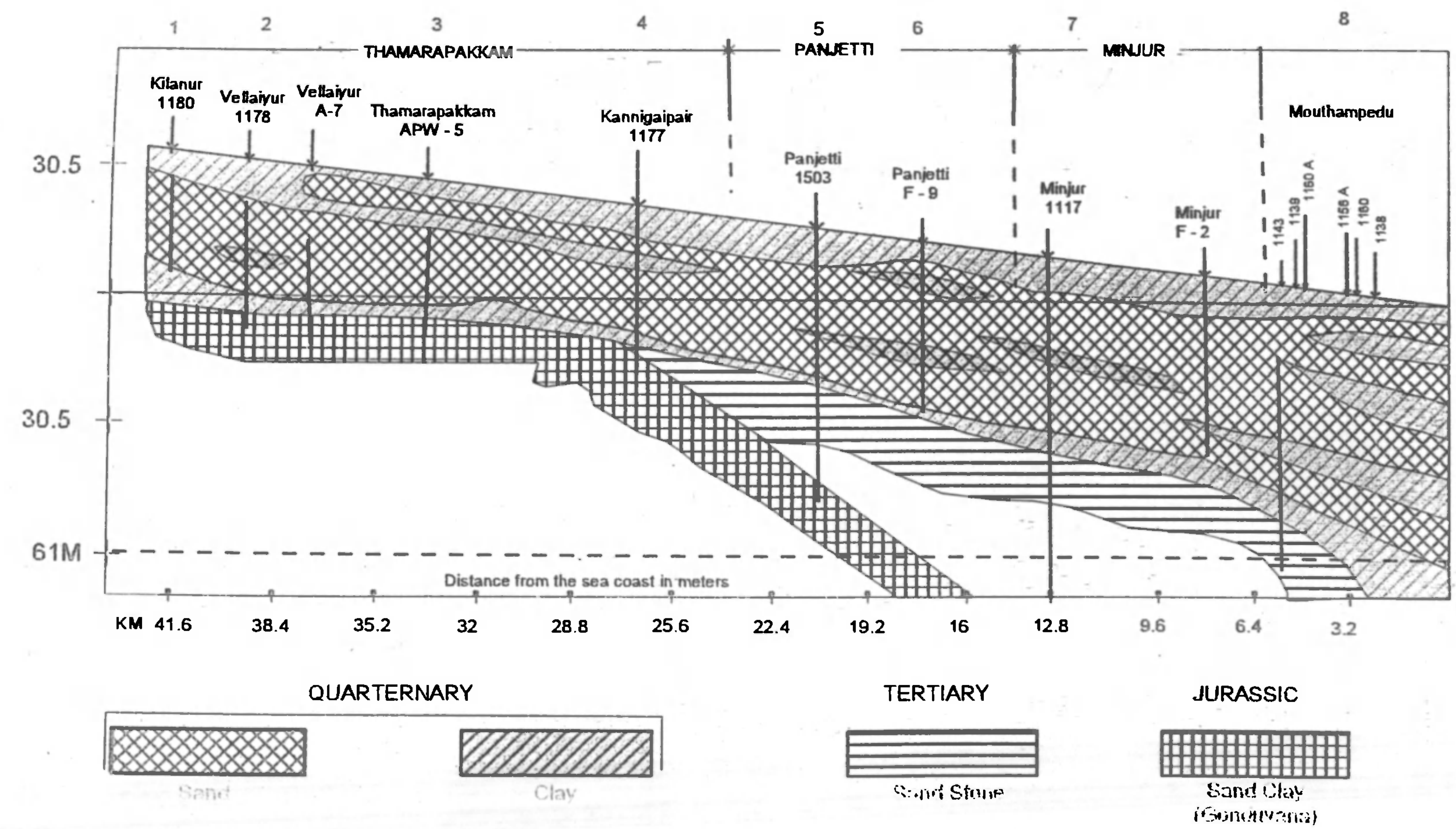
1. Periodical Assessment of Groundwater potential and quality of water in the coastal aquifers which should include the multiple aquifer system wherever it exists.
2. Close monitoring of the aquifers for their performance like water levels, piezometric head, yields, drawdown, water quality etc. by installing a network of shallow and deep ground water structures for various aquifers.
3. Stabilising the ground water potential by artificial recharge means which include the creation of additional reservoirs, construction of check dams, diversion of flood flows, conjunctive use of surface and ground water, well injection methods etc.
4. Seawater intrusion in coastal areas where large-scale extraction of ground water in the alluvial aquifers of shallow depth exists just adjacent to the coast can be arrested by reduction of pumping or construction of sub surface barriers. One possible example of such case is the aquifers located south of Chennai City extending to a length of 18 km. along the coast with 1 to 1.5 km.

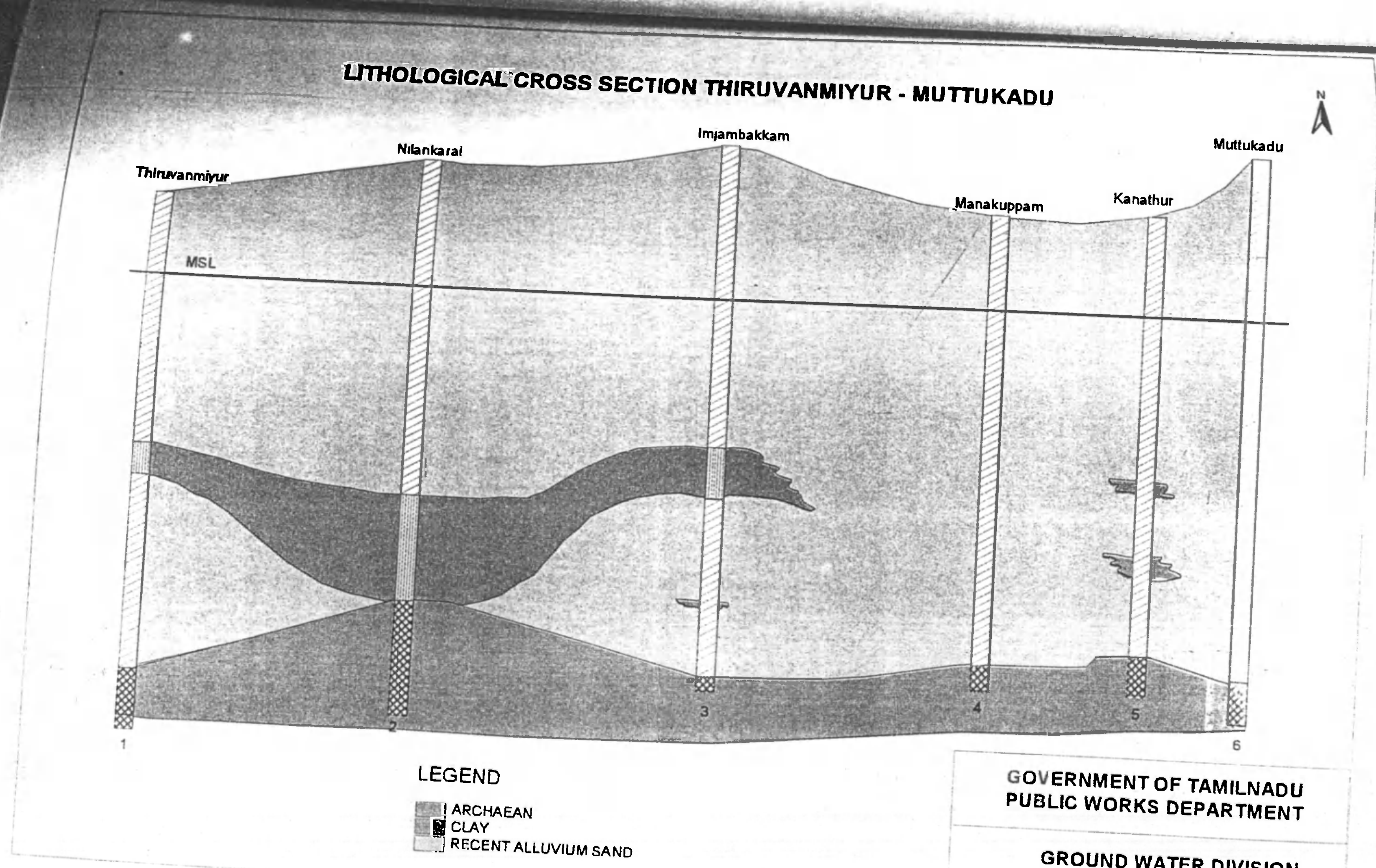
5. Making shutter arrangements near river mouths where tidal water enters the river to a long distance inland and consequently damage the surface quality and in turn the groundwater quality.
6. Provide top cover for all the open wells lying close to the coast in order to avoid over flow of sea water into the wells directly in times of high rise Tsunami waves
7. Undertake special studies to identify sources of salinity of ground water like, seawater intrusion, effect of backwaters, depositional nature of the sediments, and leakage from overlying saline aquifers etc. in order to plan for appropriate remedial measures.
8. Ground water modeling studies for various coastal aquifers for prediction of aquifer behaviour, planning for their development, and for taking up restoration cum amending measures in case of possible damage to the aquifers.

7. Conclusions:

Various aspects of geohydrology and hydro chemistry discussed in the earlier paragraphs indicated that the precious and fragile aquifers existing along the Tamilnadu coast are facing threat either by mane made events like over extraction or by natural phenomenon like marine depositional nature. It is also possible that these aquifers come under the influence of grave disasters like severe cyclones and Tidal waves of Tsunami. Hence there is an urgent need to take up various measures like scientific assessment of the aquifers, planning for their development and protection of these aquifers

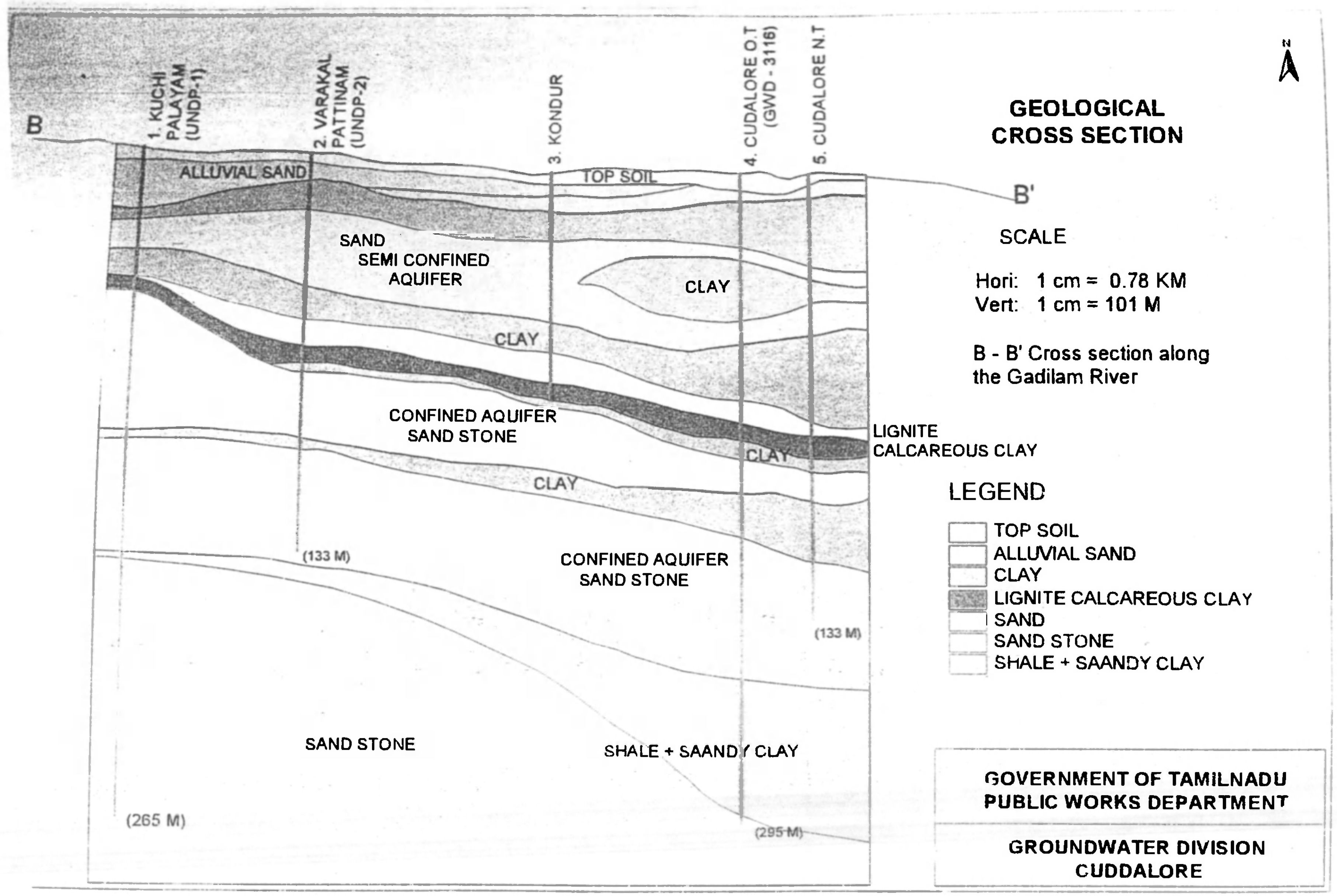
HYDROGEOLOGICAL SECTION ALONG KORATTALAIYAR ALLUVIUM - THIRUVALLUR DISTRICT
MINJUR, PANJETTI AND TAMARAIPAKKAM WELL FIELDS



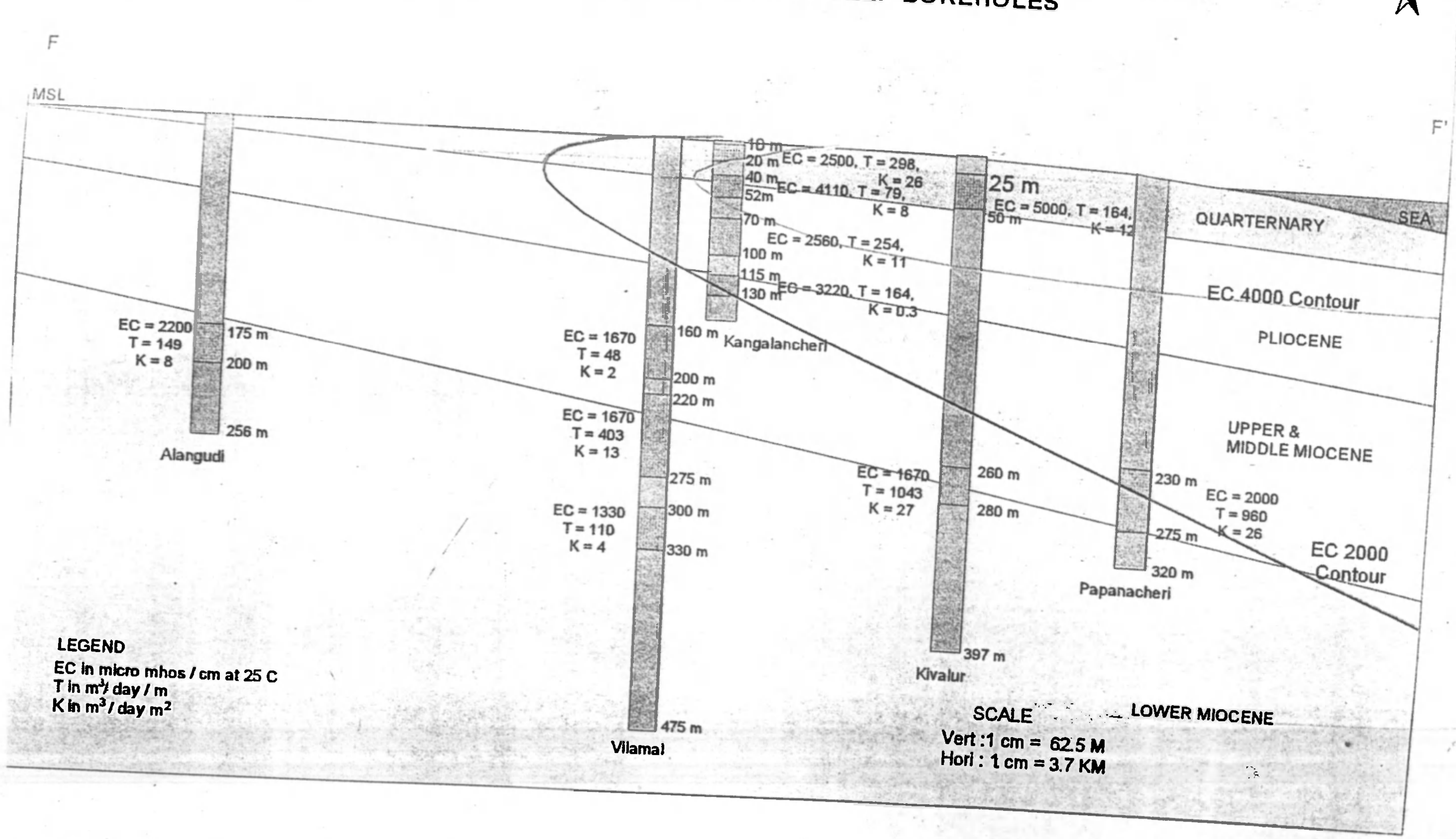


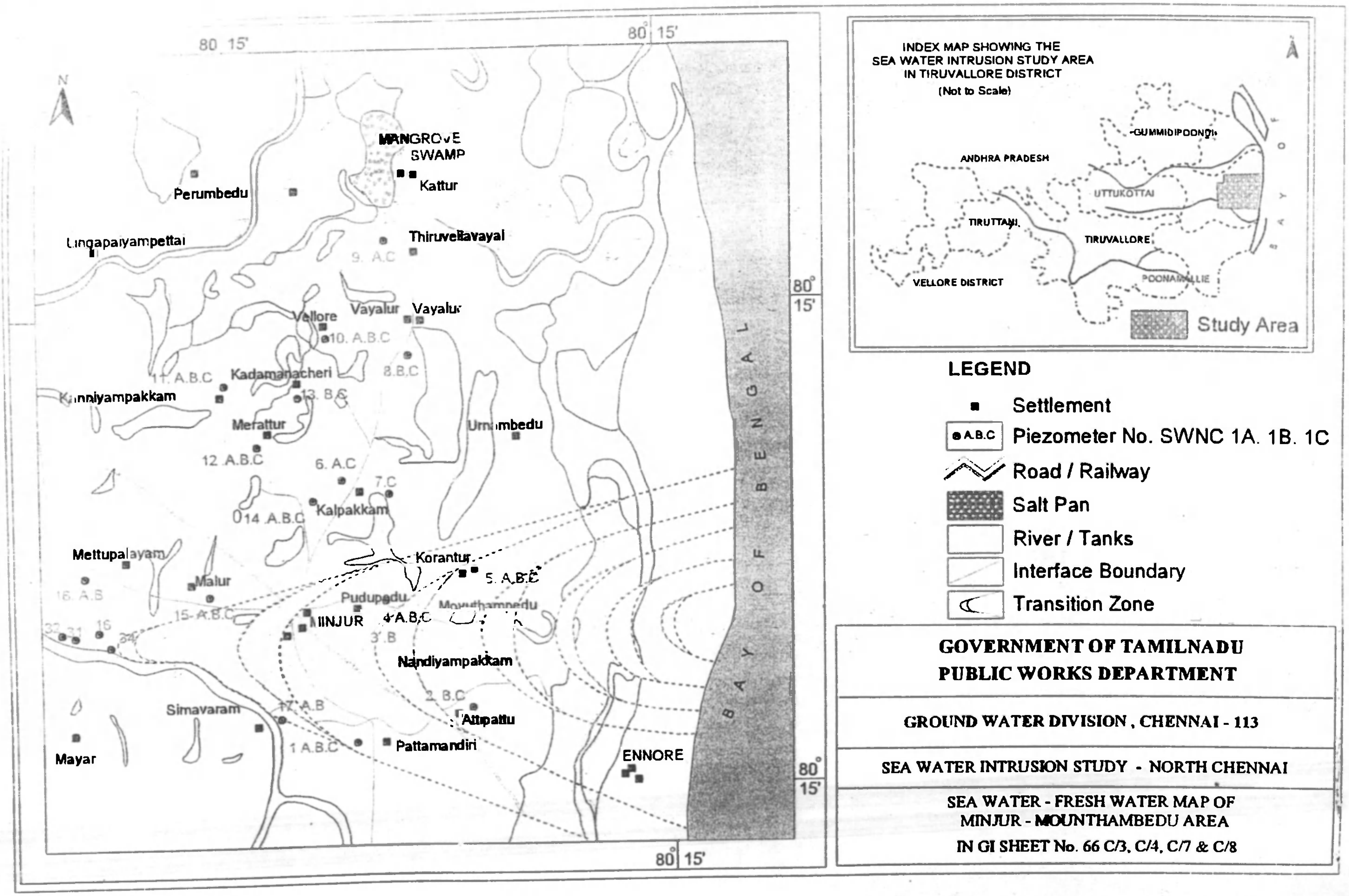
GOVERNMENT OF TAMILNADU
PUBLIC WORKS DEPARTMENT

GROUND WATER DIVISION
CHENNAI - 113

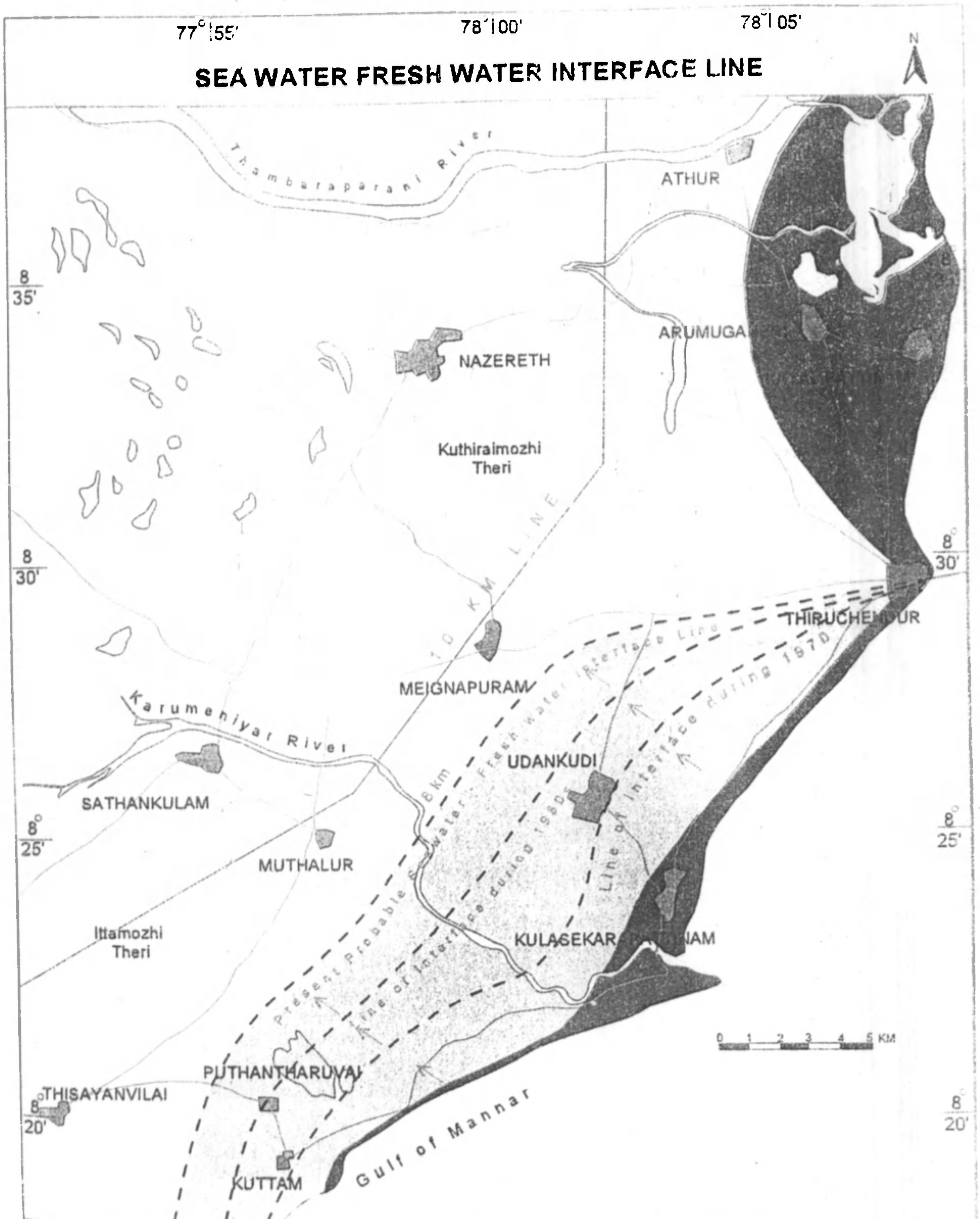

B
1. KUCHI PALAYAM (UNDP-1)
2. VARAKAL PATTINAM (UNDP-2)
3. KONDUR
4. CUDALORE O.T (GWD - 3116)
5. CUDALORE N.T
B'
ALLUVIAL SAND
TOP SOIL
SAND SEMI CONFINED AQUIFER
CLAY
CLAY
CONFINED AQUIFER SAND STONE
CLAY
CLAY
LIGNITE CALCAREOUS CLAY
(133 M)
CONFINED AQUIFER SAND STONE
(133 M)
SAND STONE
SHALE + SAANDY CLAY
(265 M)
(295 M)
GEOLOGICAL CROSS SECTION
SCALE
Hori: 1 cm = 0.78 KM
Vert: 1 cm = 101 M
B - B' Cross section along the Gadilam River
LEGEND
TOP SOIL
ALLUVIAL SAND
CLAY
LIGNITE CALCAREOUS CLAY
SAND
SAND STONE
SHALE + SAANDY CLAY
GOVERNMENT OF TAMILNADU
PUBLIC WORKS DEPARTMENT
GROUNDWATER DIVISION
CUDDALORE

LITHOLOGICAL CROSS SECTION OF DEEP BOREHOLES





INDEX MAP SHOWING THE SEA WATER INTRUSION STUDY AREA IN TIRUVALLORE DISTRICT
(Not to Scale)
ANDHRA PRADESH
GUMMIDIPOONDI
UTTUKOTTAI
TIRUTTANI
TIRUVALLORE
POONAMALLIE
VELLORE DISTRICT
Study Area
LEGEND
Settlement
Piezometer No. SWNC 1A. 1B. 1C
Road / Railway
Salt Pan
River / Tanks
Interface Boundary
Transition Zone
MANGROVE SWAMP
Kattur
Perumbedu
Lingapalyampettai
Thiruvellavayal
Vellore
Vayalur
Kadamanacheri
Kanniyampakkam
Merattur
Urnambedu
Kalpakkam
Mettupalayam
Malur
Korantur
Pudupedu
MINJUR
Nandiyampakkam
Simavaram
Attipattu
Pattamandiri
Mayar
ENNORE
BAY OF BENGAL
80° 15'
GOVERNMENT OF TAMILNADU
PUBLIC WORKS DEPARTMENT
GROUND WATER DIVISION, CHENNAI - 113
SEA WATER INTRUSION STUDY - NORTH CHENNAI
SEA WATER - FRESH WATER MAP OF MINJUR - MOUNTHAMBEDU AREA
IN GI SHEET No. 66 C/3, C/4, C/7 & C/8



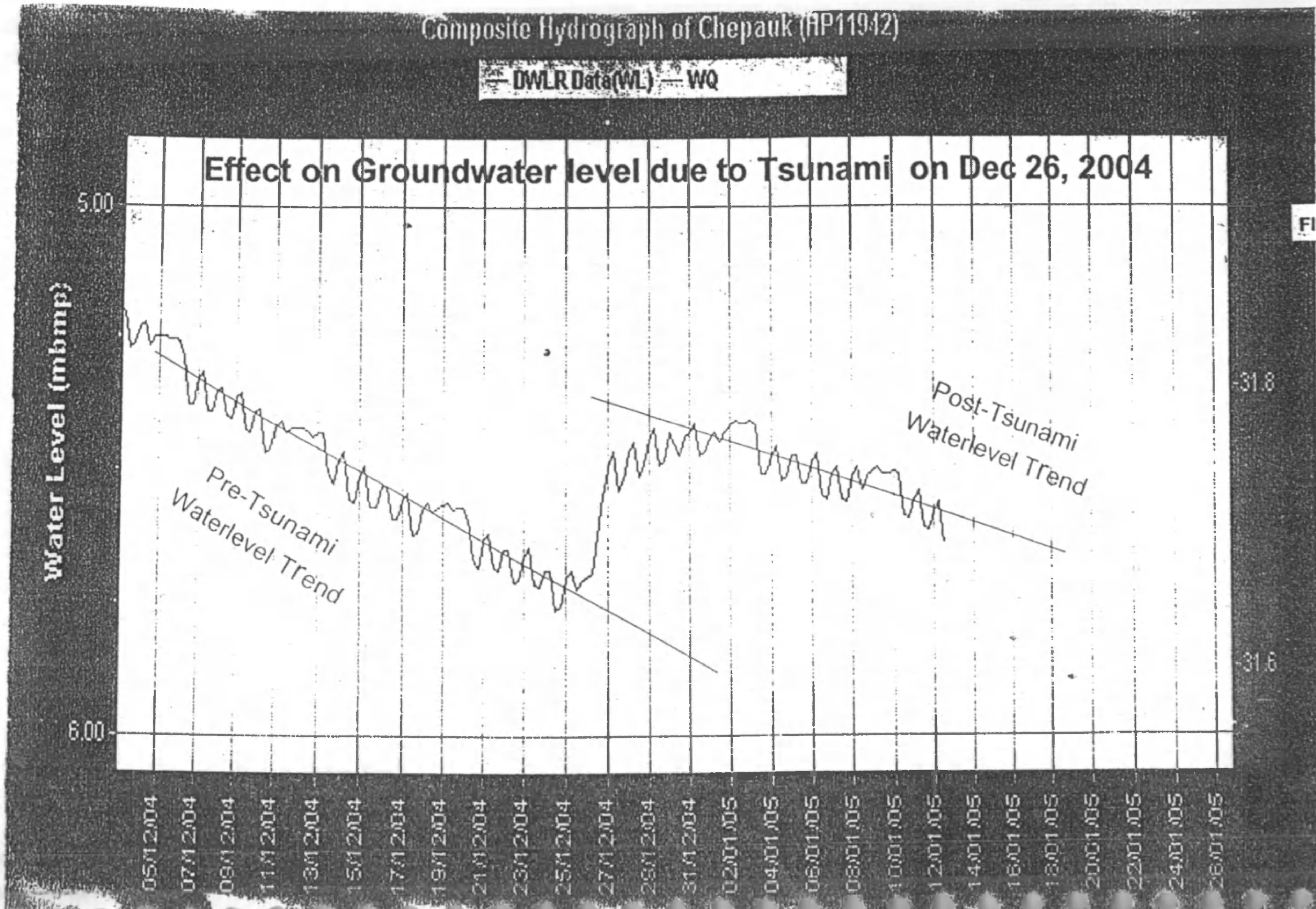
Area Affected by Marine Formations

Area Affected By Sea Water Intrusion

GOVERNMENT OF TAMILNADU
PUBLIC WORKS DEPARTMENT

GROUND WATER DIVISION
THIRUNELVELI

SEA WATER INTRUSION
THIRUCHENDUR
THOOTHUKUDI DISTRICT



Composite Hydrograph of Chepauk (HP11942)
DWLR Data(WL)
WQ
Effect on Groundwater level due to Tsunami on Dec 26, 2004
Water Level (mbmp)
5.00
6.00
-31.8
-31.6
Pre-Tsunami Waterlevel TRend
Post-Tsunami Waterlevel TRend
05/12/04
07/12/04
09/12/04
11/12/04
13/12/04
15/12/04
17/12/04
19/12/04
21/12/04
23/12/04
25/12/04
27/12/04
29/12/04
31/12/04
02/01/05
04/01/05
06/01/05
08/01/05
10/01/05
12/01/05
14/01/05
16/01/05
18/01/05
20/01/05
22/01/05
24/01/05
26/01/05

FIGURE-10

EFFECT OF TSUNAMI ON COASTAL SEDIMENTS OF TAMIL NADU.

S.SRINIVASALU, R.NAGENDRA AND HEMA ACHYUTHAN
Department of Geology, Anna University, Chennai – 600 025

EXTENDED ABSTRACT

The 26th December 2004 tsunami event devastated several major coastlines in South Asia including Tamil Nadu coast. The tsunami event caused destruction to both human life and property in a very short span. It has also left this event's signature along the coastline. A thorough investigation of these signatures is necessary for better understanding the effect, extent and impact on coastal habitats. Field mapping of tsunami-affected areas was carried to record its geological signatures. The observations reveal that this event has left significantly recognizable sediment deposits in patchy areas in beaches, marshes, mangrove swamps and paddy fields of Tamil Nadu coast. The sediment deposits record tsunami inundation for more than 1 km in open coastal settings and up to 4 kms in rivers and backwaters. This short-lived catastrophic saltwater inundation due to tsunami has also resulted in the deposition of a sand layer fining upward and thinning landwards to clay lenses. The integrated field geological data and laboratory sediment core and surface samples data were used for document the degree of effect of recent tsunami in Tamil Nadu coast. The tsunami sediments were identified by its unique nature in its colour, grain size and organic content compared to surrounding and underlying sediments. The water inundation were mapped using water marks in walls and trees, trail of twigs and leaves, alien Sediment coating, dried plants due to tsunami waters, ripple marks and alignment of plant roots and erosion of settlements. The tsunami sand deposits often contained two or more layers. These layers were formed by different tsunami waves and its intensity. Repeated field studies after December 26th 2004 were made to assess the sediment inundation and its impact on coastal environment. Along the Tamil Nadu coast the maximum sediment inundation were noticed in Nagappattinam District. This is due to the various river channels which has acted as pathway for the sediment inundation to the near by lands. The sediment inundation can be classified into three categories.

i. Sediment inundation in coastal beaches

ii. Sediment inundation in the agricultural fields and river mouths.

iii. Sediment inundation in human settlements.

The tsunami sediment inundations in coastal beaches are present along the Tamil Nadu coast with varying thickness from few cm to 1.5m. The sediment inundation is more in agricultural fields and river mouths than the beaches. Sediments were also deposited in the tsunami affected human settlements. The characteristics of the tsunami sediments depend on the nature of the shelf sediments of the area. In Nagappattinam region the tsunami deposits are very fine grained in nature and gradually grain size increases towards north direction. In the northern districts the tsunami sediments are coarse sand, where as Kalpakkam, Karaikal, and Tharangambadi heavy minerals enrich areas. The tsunami clay deposits are rich in nutrients.

GIS IN DISASTER PLANNING AND MANAGEMENT

Dr. S. Ramaseshan, Visiting Professor, IRS, Anna University, Chennai, TN India

Disasters may be natural or man made and they create havoc with the lives, infrastructures and economy of humanity. Very often disasters can not be predicted. Hence it is necessary to plan and prepare for disasters before they arrive; identify the nature and magnitude of disasters as and when they occur; respond to the disaster to control its ill effects and save people and resources; mitigate the disaster consequences; and initiate recovery activities over short and long times.

The disasters have a significant geographic presence and the planning and management activities need large amount of spatial and attribute information. GIS is a computational environment for analysis, design and control of real physical and engineered systems that contains easily retrievable spatial and attribute information about a large variety of details concerning the several components of the men, materials, resources and information. Thus GIS is a very essential and useful tool in related activities.

The use of GIS in disaster planning, preparedness, identification, response, relief and recovery or control are illustrated with a number of examples including September 9 attack on Manhattan, Asian Tsunami, Columbia disintegration, land slides, fire, oil spill, chemical vapours, Bhuj and other Earth quakes, avalanches, fire, oil spill, chemical plumes and floods. The potential for GIS, not only in Disaster planning, but also in real time relief, recovery and control are enormous. It is hence necessary to develop and use these technologies in India.