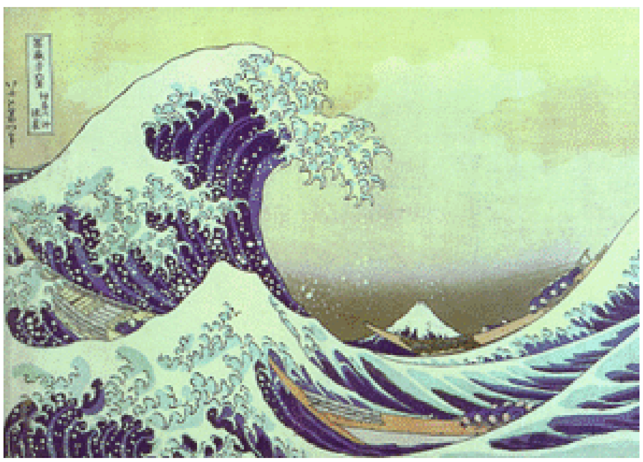
Tsunami Hazard Assessment in the Northern Bay of Bengal

Final Report

March 2011



Institute of Water and Flood Management,
Bangladesh University of Engineering and Technology

Institute of Water Modelling

In Collaboration with:

Bangladesh Water Development Board

Geological Survey of Bangladesh

Department of Geology, University of Dhaka

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RESAERCH TEAM

Institute of Water and Flood Management (IWFM),
Bangladesh University of Engineering and Technology (BUET)

Dr. M. Shah Alam Khan, Professor
Dr. Anisul Haque, Professor
Dr. Md. Asad Hussain, Assistant Professor

Institute of Water Modelling (IWM)

Mr. Zahirul Haque Khan, Director, Coast, Port & Estuary Management Division
Mr. Manjur Murshed Zahid Ahmed, Senior Specialist

Bangladesh Water Development Board (BWDB)

Mr. Jalaluddin M. Abdul Hye, Chief Engineer (Hydrology)

Geological Survey of Bangladesh (GSB)

Mr. Reshad Md. Ekram Ali, Deputy Director

University of Dhaka

Dr. Mahmood Alam, Professor, Department of Geology

Jadavpur University, Kolkata, India

Dr. Gupinath Bhandari, Sr. Lecturer, School of Oceanographic Studies

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ABBREVIATIONS AND ACRONYMS

BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
GSB	Geological Survey of Bangladesh
IWFM	Institute of Water and Flood Management
IWM	Institute of Water Modelling
MHWS	Mean High Water Surface
MoU	Memorandum of Understanding

EXECUTIVE SUMMARY

Tsunamis gained world-wide attention after the devastating tsunami of December 26, 2004 that originated off the coast of Sumatra and resulted in death of approximately 310,000 people and widespread damages in several countries around the Bay of Bengal and Indian Ocean including Indonesia, Thailand, Sri Lanka, Eastern India and Myanmar. The damage caused by this event to Bangladesh coast was limited. There were reports of 2 deaths and several capsized fishing trawlers resulting from 5 to 6-ft high waves in the coastal areas of Bangladesh. There were also reports that the shore waterline receded by about 50 meters in Saint Martin's island, and the water level fluctuated for about 3 hours, which are usual signs of a tsunami. The coastal fisheries were affected since the coastal water was very rough for a long time. Direct damage to fish habitat and ships in the Bangladesh coast was unknown.

Since damages to the northern Bay of Bengal and Bangladesh coast were very limited from the Sumatra tsunami, a popular hypothesis was that the northern Bay of Bengal coast was protected from tsunamis by the relatively long and shallow continental shelf. It was supported by the fact that the most wave energy from the nearly North-South aligned India-Burma plate subduction faultline would be released in the East-West direction, and relatively less wave energy would affect the northern Bay of Bengal coasts. However, historical accounts indicate that tsunamis have hit Bangladesh and adjoining coasts in the past, including a major tsunami that originated in the Arakan coast (Myanmar) in 1762 and inflicted significant damages. Therefore it was felt necessary that the threats of tsunami be investigated through a scientific research.

This collaborative research project was initiated under an MoU between Institute of Water and Flood Management (IWFM) of Bangladesh University of Engineering and Technology (BUET) and Institute of Water Modelling (IWM). Other partners - Bangladesh Water Development Board (BWDB), Geological Survey of Bangladesh (GSB), Department of Geology, University of Dhaka, and Jadavpur University, Kolkata, India, were later invited to join the collaboration. The main objectives of this research were to: (i) devise scenarios, in terms of origin of tsunami, sea-level displacement and energy release orientation, which may have significant impact on the coasts around the northern Bay of Bengal; and (ii) estimate the wave height and inland intrusion extent of tsunami water in Bangladesh coast under different scenarios using numerical models.

Possible origins of tsunami along the India-Burma Plate faultline and along the edge of the continental shelf were identified from secondary information. Possible maximum vertical displacements of the sea-floor at these locations were also estimated from secondary information. Numerical models were employed to estimate the tsunami height and intrusion extent at the coast. Four potential tsunamigenic fault-sources were identified from geophysical and geological data. Subsequently, four scenarios for tsunami modeling were developed from the information on fault source parameters such as rupture length, slip offset, dip angle, slip angle, strike angle and the moment magnitude.

Two numerical models were employed in this study. In the first model, a 3D hydrodynamic model simulates 'tsunami generation' and provides initial water surface as an input to a 2D 'tsunami propagation' model that simulates wave propagation. We sincerely appreciate the cooperation of Professor Shinji Sato of the University of Tokyo for allowing us to use the 2D propagation model for the present research. The propagation model was calibrated and validated for the 'Sumatra' tsunami of December 2004 at the Sri Lankan coast by Welhena (2006). This model has been also applied to calculate tsunami propagation at the Cox's Bazar coast of Bangladesh by Hussain et. al. (2008). The widely used ETOPO 2 global data by NOAA (2005) were used to generate the model bathymetry.

The second tsunami model was developed using MIKE 21 modeling tool, and comprises four nested levels. The regional model covers the Indian ocean, the Arabian sea, the Bay of Bengal and the Bangladesh coast. The fine grid model covers the coastal region of Bangladesh. Initial surface maps for all four scenarios were generated using 'QuakeGen', a geological model, and MIKE 21 modeling system. Then tsunamis were simulated with respective initial surface and the maximum inundation map for each scenario was generated based on the simulation results.

The flow module of this model is a two-dimensional hydrodynamic simulation program which calculates non-steady flow resulting from tidal and meteorological forcing on rectilinear grid. The model solves the non-linear shallow water equations on a dynamically coupled system of nested grid using a finite difference numerical scheme. It simulates unsteady two-dimensional flows taking into account density variations, bathymetry and external forcing such as metrology, tidal elevations, currents and other hydrographical conditions.

Numerical experiments were conducted with the 3D hydrodynamic model to investigate the effects of the origin of tsunami generation, amplitude and length of subduction, orientation of subduction, and proximity of the tsunami origin to the coast. Travel times of tsunamis to reach Bangladesh coast in the four cases were computed from the 2D propagation model results. In addition to these four cases, a fifth case was considered to analyze the impact of the continental shelf on tsunami attenuation. The travel time is the minimum in Case FS 1 for Cox's Bazar, whereas it is the maximum in Case FS 3 for the Borguna coast and Meghna estuary. The travel time is almost the same for the entire coast in Cases FS 3 and FS 4. Travel time for Case FS 4' indicates that if there were no continental shelf, the tsunami waves from Sumatra would reach the Bangladesh coast 20 to 40 minutes earlier.

Maximum wave heights along four transects from the shoreline in the five cases indicate that in most cases shoaling occurs at the continental shelf margin, which is also supported by MIKE 21 model results. Maximum wave heights vary in different cases and also at different locations along the coast. The maximum wave height at the shoreline would occur in Cox's Bazar for Case FS 1. Comparison of wave heights and travel time for different cases indicates that a tsunami originating at the Myanmar coast would be the highest and would arrive the earliest. For Case FS 1, a tsunami having a maximum wave height of 0.98 m would arrive Cox's Bazar 10 min after originating at the Myanmar coast.

In the MIKE 21 model, the Regional grid model was calibrated with the observed wave height of December 2004 tsunami, which originated at the West coast of Sumatra. Manning number (M), reciprocal of Manning's roughness coefficient (n), is the main calibration parameter for this model. M was selected based on the values suggested by Aida (1977), Kotani et al. (1998), CERP (2000a), and Ozara and Ibe (1999). Model results indicate that wave transformation takes place as a tsunami propagates across the continental shelf. Wave height increases because of shoaling and wave speed decreases as the waves approach the shoreline. Waves start to break after they hit the continental shelf, and the broken waves propagate toward the shore. Model outputs also indicate wave breaking at the edge of the continental shelf. Wave speed decreases from approximately 31 m/s at the edge of the continental shelf to 9-19 m/s along the shoreline.

Maximum inundation maps for the coastal region of Bangladesh under MHWS condition show that the maximum inundation takes place in the Sundarbans area, Nijhum Dwip, Shonadia island, Bauphal upazila of Patuakhali district and small islands in the Meghna Estuary. The maximum inundation is found at Nijhum Dwip in the range of 3-4 m, and in the Sundarbans area, Moheskhali and Cox's Bazar coast in the range of 1-3 m. Small islands and part of the Manpura island in the Meghna Estuary get inundated by 1-3 m. Tsunami level at Nijhum Dwip varies from 4.15 to 5.0 m PWD with a minimum travel time of 1 hour 45 minutes for scenario FS 1. Tsunami level at Sandwip varies from 3.65 to 4.5 m PWD with a minimum travel time of 20 minutes for scenario FS 1. The Teknaf beach is likely to be inundated by a maximum depth of 4.5 m.

This study identifies the major tsunamigenic fault sources in the Bay of Bengal and presents tsunami inundation maps under different scenarios. This study also presents two numerical models that would be useful to predict tsunami hazard under different conditions along the coast. The models may be used in a tsunami warning system in future, and in further detailed hazard mapping and risk analysis. Findings of this study will be useful for planning disaster risk reduction measures in the coastal zone.