INDONESIA TSUNAMI EARLY WARNING SYSTEM (InaTEWS): CONCEPT AND IMPLEMENTATION

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Abstract
Located in the very active seismic area, establishment of early warning system for tsunami is crucial for the coastal areas of Indonesia. This paper explains seismicity and tsunami record, information on tsunami occurrences and concept of InaTEWS, multi institutional tasks arrangement, multi national involvement, seismic network, tide gauge network, buoys, telecommunications system, dissemination sistem, and tsunami modeling.

1. Background
1.1. Seismicity and Tsunami Record

Indonesia is located in a seismic active area due to the triple junction of three mega tectonic plates, namely: Eurasia plate, Indian Ocean–Australia plate and Pacific Ocean plate. Thousand of earthquakes are detected annually at which most of them are only by seismograph, some are strong and can be felt (70) and some are destructive (3). Some big submarine earthquakes generate tsunamis every 2 years.
The earthquake of 26 December 2004 with a magnitude of 9.3 generated a gigantic tsunami and killed more than 200,000 people in 9 countries. In Aceh province, Indonesia more than 160,000 lives were lost.

Figure 2. Seismicity map of Indonesia 1973-2007

This tragedy was so painful that it was felt not only by the Indonesian people but also by most of the people around the world. Assistance came from all over the world to the affected countries, and alerted governments and scientists to consider the necessity of establishing tsunami early warning systems: IOTWS (Indian Ocean Tsunami Warning and Mitigation System). Once the IOTWS is established then the warning will alert people in the potentially affected areas to evacuate and move to higher ground to avoid tsunami waves. The Government of Indonesia supported by other countries especially Germany, France, China, Japan USA and international organization; UNESCO have committed to Establish InaTEWS (Indonesia Tsunami Early Warning System).
Figure 3. Site distribution of destructive earthquakes and tsunami in the 1991-2007 period

1.2. Information on Tsunami Occurrences

Indonesia has had a lot of tsunami experiences, if we just look since 1992, there have been nine destructive tsunami events. Beginning with Flores tsunami in December 1992 the total casualties reached 2000 people killed, followed by east Java tsunami 1994, Biak 1996, Sulawesi 1998, North Maluku 2000, gigantic tsunami Dec 2004 Aceh, Nias 2005, Buru island 2006, West-Central Java July 2006 and Bengkulu September 2007. With this record we can say that almost every 2 years Indonesia suffers from tsunamis generated by earthquakes. It can be noted that the severity of the tsunami is not always proportional to the magnitude of the earthquake, even though most of the earthquake source mechanisms showed thrusting fault.

The last earthquake generated tsunami was Bengkulu earthquake with magnitude 8.0 on the Richter Scale (RS). This earthquake generated a tsunami with heights reached 4 metres on the Bengkulu coast. The tsunami was also recorded at Padang tide gauges 45 minutes after the earthquake occurrence with maximum high of 0.8 m. This earthquake was the first one located by InaTEWS after upgrading the processing system which enables BMG to measure magnitudes up to 7.9 RS and the modification of issuing the warning from automatic processing to interactive processing. The work was done within 5 minutes of the earthquake’s origin time.
2. Concept of InaTEWS

The basic concept of the InaTEWS is based on the model proposed by the International Tsunami Information Centre (ITIC), which consists of 3 components namely: Operational, Capacity Building and Emergency Response and Mitigation. This concept is presented in the form of triangle.

![Figure 4. Devastation of one Aceh area due to tsunami of 26 December 2004](image)

![Source: Tsunami mailing list]

![Figure 5. The three integral components of tsunami warning and mitigation system](image)

![Source: Int'l Tsunami Information Center; March 2005]
The Operational component involves monitoring, data collection, processing, analyzing, preparing warning, issuing, and dissemination.

Capacity Building involves modeling, research and development, training, education, engineering.

Emergency response and mitigation involves public education, improvement of preparedness and awareness, emergency response, shelter and logistic preparation, drill etc.

![Diagram of Institutions involved in the tsunami warning and mitigation system](image)

**Figure 6. Institutions involved in the tsunami warning and mitigation system**

**2.1. Multi institutional tasks arrangement**

The establishment of InaTEWS is a national program and implemented under the coordination of the State Ministry of Research and Technology and involving 16 national institutions: State Ministry of Research and Technology (Ristek), Ministry of National Development Planning (Bappenas), Ministry of Energy and Mineral Resources (ESDM), Ministry of Marine and Fishery Affairs (DKP), Ministry of Environment (LH), National Police (Polri), Meteorological and Geophysical Agency (BMG), National Coordinating Agency for Survey and Mapping (Bakosurtanal), Agency for Assessment and Application of Technology (BPPT), Indonesia Institute for Sciences (LIPI), National Institute for Space Aviation (LAPAN), Bandung Institute of Technology (ITB), Ministry of Communications and Information Technology (Kominfo), Ministry of Home Affairs (Depdagri), Ministry of Foreign Affairs (Deplu), National Coordinating Board for Disaster Management (BAKORNAS PB).
The key ministries/institutions are:

Ministry of Research and Technology (Ristek): InaTEWS is full with the application of high technology, started from high sensitive and reliable sensors up to the need of ICT for data and information transmission and processing system, human resources development and technology transfer. It is one of the roles of Ristek to adopt the technology of InaTEWS into the Indonesian culture.

Meteorological and Geophysical Agency (BMG):

BMG is responsible for the Seismic monitoring system, before the December 2004 event, BMG has already been operating 30 geophysical stations stand alone and 5 regional centres equipped with 27 remote seismic sensor.

To accelerate the installations of broadband seismic sensors BMG set up most of the seismic sensors in BMG stations facilities, with basic consideration that tsunami will only be generated by strong earthquakes, for the first step most of seismic sensors are located in the meteorological and geophysical stations which are normally in the site not quiet enough for seismic sensors deployment, we will analyse the quality and it is possible that if the station quality under minimum requirement then it will be relocated accordingly. BMG is the Agency responsible for hosting the Operational Centre, which collects and process all seismic data, determines the earthquake locations, analyzes whether the earthquake is tsunamigenic, issues the earthquake information and tsunami warning, integrates other observation data for confirmation or cancellation of the warning.

Figure 7. Multi-institutional task arrangements of the InaTEWS
National Coordinating Agency for Survey and Mapping (Bakosurtanal) is responsible for installing and operating tide gauges and GPS networks. Before the December 2004 event, Bakosurtanal already operated 60 tide gauges stations (35 analogue and 25 digital) and a GPS network of 9 stations. The stations were not transferring data on real time. Both tide gauges and GPS data will now be sent to BMG on near real time base to enhance the accuracy of the warning.

Agency for the Assessment and Application of Technology (BPPT) is responsible for the deployment and operational of buoys at which the data are transmitted to BMG and to BPPT. This Agency operates research vessels Baruna Jaya, which enable it to install, maintain, and relocate the buoys. BPPT is also responsible for run up tsunami modelling.

Indonesian Institute of Sciences (LIPI) is responsible for preparing modules for public awareness and preparedness. LIPI has conducted field work to inform local government and the community of the danger of impending earthquake generated tsunamis. This institute is also responsible to conduct research of the geo-science as well as the nature of tsunami.

Ministry of Communication and Information Technology is responsible for all mass media and telecommunications providers, so its role is very important for the sending out warnings.

Ministry of Home Affairs coordinates local governments’ program for public education; public awareness and preparedness.

Institute Technology Bandung (ITB is responsible for preparing the tsunami data base that will be installed at the Situation Centre in BMG. As a university ITB will also responsible for the preparation and enhancement of the human resources.

Operational Components of InaTEWS

A. Monitoring System
   • Land Monitoring
     - Seismic (160 bbs, 500 acc)
     - GPS (40)
   • Sea Surface Monitoring
     - Buoys (22)
     - Tide Gauges (80)

B. Processing System
   - Seismic 10 RC, 1 NC
   - Other: 1 Tide Gauges Center, 1 Buoys Center, 1 GPS Center

C. Telecommunication
   - Upstream (Data Collection)
   - Down stream (Dissemination)
2.2. Multi National Involvement

The establishment of InaTEWS is carried out by the government of Indonesia and supported strongly by donor countries, international organizations and NGOs. Assistance comes from among others:

- Germany, through the GITEWS project, involves in developing part of all kind of monitoring system, situation centres, telecommunications, capacity building (human resources, research, local and institutional)
- China through ICDN, involves part of seismic monitoring system, situation centre, telecommunications, capacity building
- Japan, through real time JISNET, involves in part of seismic monitoring system. And through JICA involves in situation centre and capacity building
- France, upgrading the existing seismic network and Tremors
- USA, USAID through multi institutions involves in sea level monitoring, capacity building, conducting local, national and international workshop and visit.
- USTDA in the form of Technical Assistance.
UNESCO, IOC, ITIC supports for infrastructure, Capacity Building, Technical Assistance.

IFRC, capacity building.

2.3. Seismic Network

When an earthquake occurs, a seismic signal will be transmitted and recorded by the network of seismometers. The signal is then sent via VSAT to the centres and is processed and analyzed by an on duty seismologist to produce earthquake source information. When the earthquake parameter fulfils the criteria to generate a tsunami, the tsunami warning will be issued. The signal detected by buoys arrives shortly afterwards, which can be used to confirm or cancel the warning.

Seismic Network was designed consisting of 160 broadband seismometers, 500 accelerometers and will be group into 10 Regional Centers. The distance between sensors is in the order of 100 km so that in the first 3 minutes the earthquake’s source can be located after its occurrence in Indonesian territory.
2.4. Tide Gauge Network (Bakosurtanal)

Bakosurtanal plans to install 80 Tide Gauges for the InaTEWS, up to present 9 tide gauges are already installed and the data transmitted near real time via GTS. The data that are already received in BMG Operational Center are 4 of 9 with 15 minutes delay. List of commitment from contributor appears at the table below.

The 30 stations supported by the Government of Indonesia will be installed in 2007 using VSAT IP communications, which means the data will be available in real time to Bakosurtanal. The data will be sent to InaTEWS Centre in BMG using VPN and will be back up with VSAT. It is expected that the installation can be carried out as scheduled. The map of the network appears at the previous page under the Sea level network.
2.5. Buoys (BPPT)

Beginning 2006 BPPT has already reengineered buoy instruments. The buoys were tested as a dummy system and deployed in December at Sunda Strait. The system specification of the equipment, the operation mode and time schedule for operation appears below.

The data will be sent to BPPT Center using Imarsat communications and will be sent directly to BMG using VPN and back up with VSAT IP. With this kind of communication it is expected that time delay will be negligible.

The activities carried out in 2007 included the design and construction and installation of 3 Indonesian buoys, deployment of Dart buoys assisted by NOAA, redeployment of 2 German buoys and deployment of 2 German buoys.

![Buoy Array 2008](source: BPPT)

Figure 12. Buoy Array 2008

![Indonesia tsunami early warning system](source: BPPT)

Figure 13. Indonesia tsunami early warning system
3. **Telecommunications System**

The basic communication system for data collection is satellite base using VSAT system. For seismic data the communication system uses 3 type of VSAT, namely:

1. LIBRA system, Canadian Technology for 180
2. Reftec system, American technology for 37
3. CSM system, we just rent from CSM provider 15

Some of tide gauges and GPS stations will use VSAT communication as well, but buoys will use other type of satellite base communication.

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*Figure 14. Telecommunication system for data collection.*

*Figure 15. The front view of the operational building*
4. Situation Center

The Tsunami Warning Center (InaTWC) hosted by BMG will occupy a new building that was completed at the end of 2007. The building will host the InaTWC.

![Figure 16. Layout of control room](source: GITEWS)

The BMG Operational Center has installed a number of processing facilities from Germany, China, Japan (NIED), and France. The operational system for InaTEWS is German System SiscomP, since its real time automatic processing is providing satisfactory results. The system has just been updated which enables the Centre to calculate earthquake magnitude comparable to moment magnitude that is appropriate for tsunami warning. This system upgrade has already been tested during the last Earthquake generated tsunami (southern Sumatra close to Bengkulu). The magnitude issued for the warning was 7.9 which was same magnitude issued by PTWC and JMA few minutes later.

At the Centre the so-called Decision Support System DSS will be installed. This system will integrate all monitoring information coming from seismic, GPS, buoys and tide gauges as well as the simulation system taken from the tsunami data base and geospatial data. The system will give recommendations to the manager on duty of the level of warning and the time that should be issued. DSS will be ready by end of 2008.
Figure 17. Logical overview of decision support system

The Decision Support System DSS is a tool for the manager in preparing the Tsunami Warning. The DSS is provided with the earthquake info, observation signal (seismic, buoys, tide gauge, GPS and the animation).

The decision is in the hand of the manager, having considered information from the observation and simulation.

Logical overview of DSS

- At this time decision of earthquake generates tsunami only pursuant to earthquake magnitude and location.
- The decision common so that require be assisting and detailing with various information, tsunami simulation and related data in a DSS system.
- DSS consist of information receiver system; data and information received become a decision bargain and at the same time will deliver its product to dissemination network.
- Visualizing all information at data and map assist operator to choose what news for certain area.
Figure 18. The decision support system of graphic user interface

**DSS-GUI (Graphic User Interface) with 4 screens**

1. Perspective Situation;
   - Earthquake Parameter
   - Advising situation in disaster area before delivering warning to the area
   - Overview Modeling tsunami
   - Expectation from sea data monitoring

2. Perspective Observation;
   - Real Time data from GPS, Tide Gauge, Buoy and seismic
   - Expectation information of deformation crustal, and tsunameter

3. Perspective Decision;
   - Offer type of warning created by the system to be evaluated by the officer before sending it out.

4. Perspective Product;
   - Sound text warning of message and clarification
   - Confirmation and dissemination

**Situation Perspective**

- Less than 5 minute after earthquake, DSS map earthquake location along with tsunami simulation.
- Dynamic timeline make a move according to time at under panel. Present time shown with red line and dynamic red contour also. Deadline 5 minute after earthquake given with special signs.

![Figure 19. Situation perspective after earthquake generated tsunami](image)

**Observation Perspective**
- With GUI, operator can see time real data which enter, GPS, Tide Gauge, Buoy or seismic.
- As according to situation there, hence displayed the condition of observation to determine action hereinafter, start from warning up to end of warning.

**Decision Perspective**
- Product from tsunami modelling in the form of is high of tsunami mapped according to impact which possibly will experience.
- Standard wearied to determine warning type:
  - High of tsunami > 3 meter represent major tsunami
  - High of tsunami 3 meter represent warning
  - High of tsunami <1 meter represent advisory
- Each monitoring parameter (GPS, Tide Gauge, Buoy) giving situation information at left panel with color symbol.
Figure 20. Observation perspective

Figure 21. Decision perspective
5. Dissemination System

The current system of dissemination based on several ways, the earliest one and so far the most effective is still via sms through two main national provider namely Telkomsel and Indosat. The earthquake information sent out via specific number given by the providers and also long number of cellular phones to reach the addresses using other than the two mention providers.

The five in one system of information which means that the receiving addresses that are having servers can act as the server in the InaTEWS center meaning that it can trigger alarm to warn the operator, send out the information via sms, automatic facsimile, website, and to convert the text message into voice message (the last mention is not yet in operation)

This five and one system is sent out from BMG by several telecommunications system such as: VPN-MPLS, internet, RANET, leased channel, VSAT.

Up to present the five in one system has been installed in 29 locations.
Figure 23. Five in one information dissemination

The distribution of five in one was extensive due to the donation of NOAA USA i.e 150 Ranet receivers and 50 servers. The installation of 159 RANET system has been done up to early 2008.

Figure 24. RANET distribution

Up to present 18 sirens had been installed and other 25 will be integrated to the existing. In short future more than 100 sirens will also be set up Indonesia wide following the existing BTS tower of GSM provider (Telkomsel).
6. Tsunami Modelling

Modelling for tsunami both for the need of quantitative database required for tsunami forecast and run up have been done for several areas. The total seismic sources are grouped into 14 regions which appear at the map below. Tsunami modeling has been done mainly on the areas south of Java Island, while the run up model especially for Bali Island.