

PERMANENT SEA LEVEL MONITORING IN INDONESIA

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Abstract

The permanent sea level monitoring of the Indonesian archipelagic waters consists of 60 stations located in the main ports. The early implementation was started in stages by the National Coordinating Agency for Survey and Mapping (BAKOSURTANAL) in 1984 with eight tide gauges. It was initially assigned for survey and mapping purposes such as providing mean sea level height for the national height system in the main islands. A significant increase of 25 stations was carried in 1998 to support for the bathymetric mapping of exclusive economic zone and sea line passages in Indonesian waters. To provide a high quality tidal data with a fast delivery mode from the existing permanent tidal station network, most of the building stations, instrumentations, data processing and quality control should be improved.

Efforts have been made to build joint cooperation with international and inter-related government institutions and local governments in Indonesia to have the system in place. It has been agreed that all international efforts on the establishment of the Indian Ocean Tsunami Warning System is coordinated under the leadership of the Inter-governmental Oceanographic Committee (IOC)/UNESCO. Indonesia, as the most potentially badly affected country by tsunami hazards shows a high commitment on the establishment of the system. It is expected by the end of 2006, there will be at least 26 real time stations in place. Commitments for the establishment of the system are presently showed by German contribution with 10 stations, USA 10 stations and Indonesia 6 stations. BAKOSURTANAL and University of Hawaii Sea Level Centre installed the first real time station in Sibolga North Sumatra on April 22, 2005. The data transmission via Global Telecommunication System (GTS) operated under the World Meteorological Organization (WMO) is set to every 15 minutes but higher transmission in extreme conditions is possible. The data is now available online in internet with open access for scientific community. This reflects that the incoming tsunami warning system can also be part of an operational ocean observing system which provides fast and reliable sea level data which can be used for scientific research and various practical applications.

Background

Indonesia is an archipelagic country consisting of nearly 17,000 islands with a total coast line length exceeding of 81,000 km. The country borders two oceans with the sea water flows from Pacific to Indian Oceans passing the archipelago via the so called Indonesian water through flow.

Indonesia waters have large variations of tidal regime and strong tides in some parts, resulting in the demand for tidal monitoring shows a large increase in support of such as survey and mapping, navigation, marine transportation, fishery and climate research.

However, the distribution of the existing National Sea Level Monitoring Network consisting of 60 stations is considered less adequate to represent a better understanding of tidal characteristics along the country coast line. Assuming one tidal station represent for a tidal regime of about 100 km coast line length, an idealistic number of permanent tidal stations for the whole country should be simply of about 810 stations. Therefore, efforts should be made to provide a better distribution of permanent tide gauges in the country.

Considering the vast region of Indonesia and some difficulties in providing budget for covering expenses for daily operation and maintenance as well as transportation to the remote areas, this task would be hardly possible to be achieved under the responsibility of only one central government institution such as the National Coordinating Agency for Survey and Mapping (BAKOSURTANAL). This task should be shared through joint efforts amongst related institutions and local district governments. Participation from international bodies for technical assistance and development should also be encouraged.

Station Maintenance and Monitoring

As the implementation of the national program on tidal data monitoring, 54 of 60 stations were established by BAKOSURTANAL in stages and the remaining were established by the Indonesian Port Corporation (PT (Persero) Pelindo). The Indonesian Port Corporation agreed to join their active permanent sea level monitoring to be part of the national network in 2003. The early implementation of the National Network was started in 1984 with eight tide gauges located in the main harbours. A significant increase of 25 stations was carried in 1998 to support for the bathymetric mapping of exclusive economic zone and sea line passages in Indonesian waters.

The network is fully centralized under the responsibility of BAKOSURTANAL in terms of budgeting, maintenance and data processing. However, the contribution of the local port authorities is considerable by assigning at least one of their staff to daily operate the station.

The network consists of 35 analogue graphical chart and 25 digital recording instruments. Figure 1 shows the distribution of the stations of which stations located in the river estuaries cannot be seen in the figure. To provide a high quality data and to possibly achieve a full data recording

with minimum interruptions, five stations located in the busy harbours of the provincial capitals are equipped with both analogue and digital instruments. These are classified as the main stations which are capable of providing a fast and near real time delivery data. The advantage of using the digital recordings is their capability in providing a flexible data sampling rate i.e. from hourly to every minute. This would allow providing data for multi purposes mainly for offshore engineering, the study of local meteorological variability and the proposed tsunami early warning system in Indian Ocean and the internal waters of Indonesia. The on-line data communications from the central processing unit at Bakosurtanal office in Cibinong to the remote stations are via telephone line and in the future GSM mobile modem or satellite receiver communication would be used at stations where connection to the cable telephone is not available.

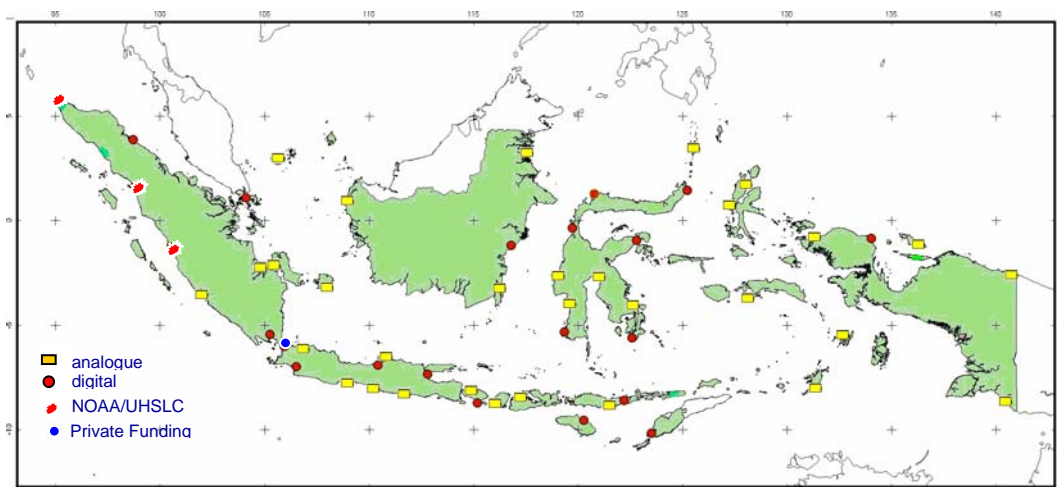


Figure 1. National Sea Level Monitoring Network of Indonesia

BAKOSURTANAL assign local operators, recruited from the local port authority office where the stations are located, to do part time jobs such as to operate and maintain the stations. The number of operator is not similar for each station of which the stations equipped with analogue graphical charts should be operated at least by two persons and that of digital by one. Hence in total, the number of operators for the national sea level monitoring network is of 85 persons.

The operators play a very significant role for maintaining the stations fully operational from day to day. This is due to recording instruments used in the network are all based on float gauge technology and the stations are mostly located in busy ports which are prone to destructions by traffic on the harbour, ships and vandalism, see Figure 2. Training workshop for the operators has been conducted since 2003 with a capacity of 10 trainees per year. The objective of the training is to improve the operators' skill on instrumentation and station maintenance and in addition basic knowledge on tidal theory and its applications were also provided.

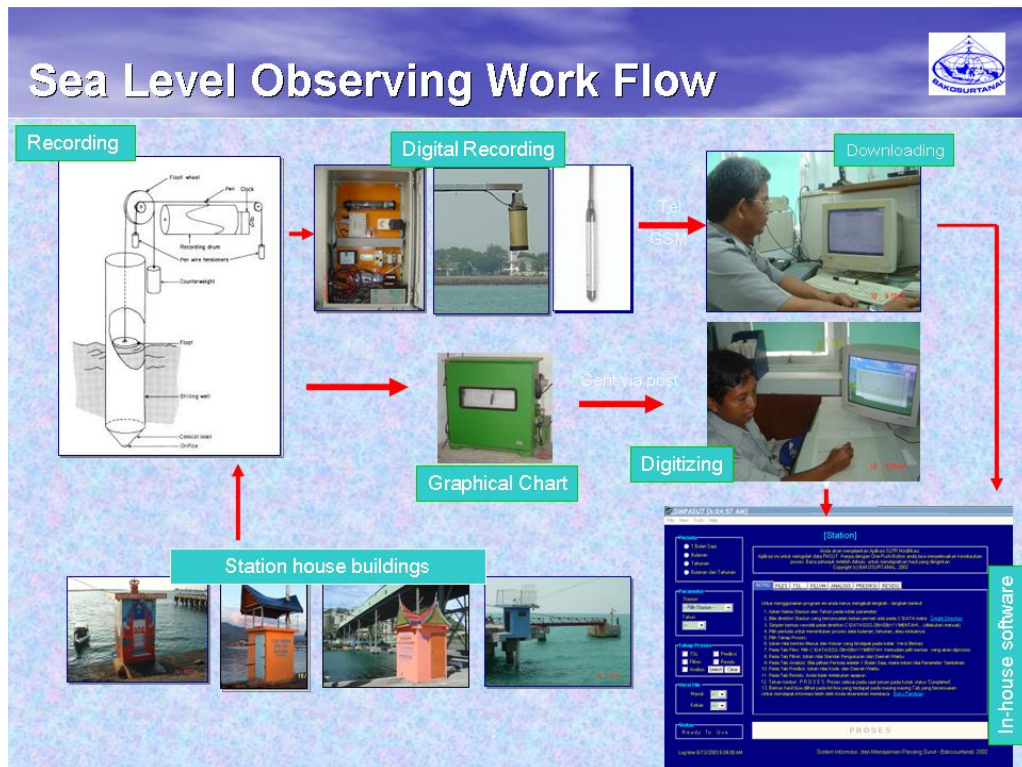


Figure 2. National Sea Level Monitoring Work Flow

The result of the training is encouraging as it is shown by a significant improvement in the statistics of operational status per year from average of 60 to 80 percents. However, to obtain a long term full operational status with a minimal interruption or near 100%, it could only be achieved through an integrated approach such as i) to build joint efforts amongst related institutions and local district governments as well as international bodies to improve the system, ii) proposing more funding for quick reconstruction of the destroyed stations, and iii) upgrading the instrumentations with the latest recording technology and less human interaction such as radar gauges.

Time and Level Synchronisations

Accurate synchronisation of time and level readings to that of UTC and tide staff level, respectively, is of importance task that should be carried out regularly by the station operators, allowing minimising drifts in the recording.

Both the analogue and digital recording tools operated in the network are of still manually synchronised and therefore the local operators are requested to provide a list of daily time and height synchronisation record, as shown in Figure 3. Time accuracy of the digital quartz clock of graphical chart recording OTT type R20 is at the level of about one second accuracy. The time reading of each graphical chart recording is

synchronised to the time of a clock owned by the local station operator. To keep the time correctly, the operators are requested to routinely performing time synchronisation of their clock to the local standard time, e.g. time broadcasted by local radio or TV. It is expected that the time accuracy would be realistically of about one minute. The level recording of each tide gauge is synchronised to that of actual sea level at tide staff with the accuracy is of about 0.5 cm.

A manual synchronisation mode, of course, should be improved to that of digital and automatic. Recording time should be automatically synchronised with a GPS receiver to UTC and the level with an auto-level switch as introduced by University of Hawaii Sea Level Centre. The real time stations in Sibolga, Padang, and Sabang which have been operational since 22 April 2005, 10 December 2005 and 20 December 2005, respectively, they are all equipped with an automatic synchronisation.

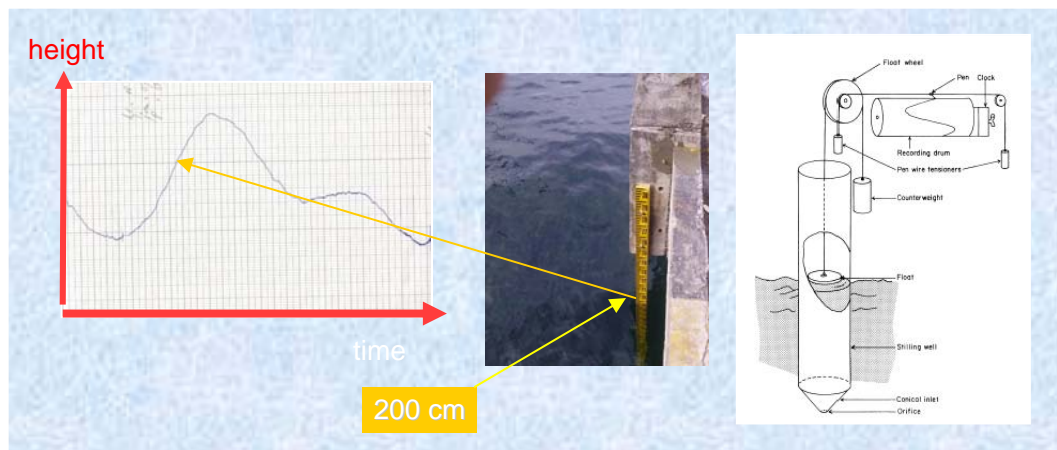


Figure 3. A manual time and level synchronisation

Height Reference

Each of the tidal stations has its own Bench Mark with standard specification similar to that of first order national levelling network. The tidal staff of each station is carefully referred to its Bench Mark by precise levelling measurements carried out regularly once in a year. The regular measurements have been carried out in the whole stations after the requirements for mean sea level rise study due to global change effects have become of increasingly importance issue nowadays.

Evaluating the mean sea level (MSL) time series of stations observed more than a decade, it was found that some stations show lack of consistency to its MSL trend. As an example, the monthly MSL of Jakarta stations as shown in Figure 4 shows a significant jump at some epochs. It is suspected that there should be an alteration of the tide staff zero setting which is not well documented leading to incorrect zero scale of the chart recording.

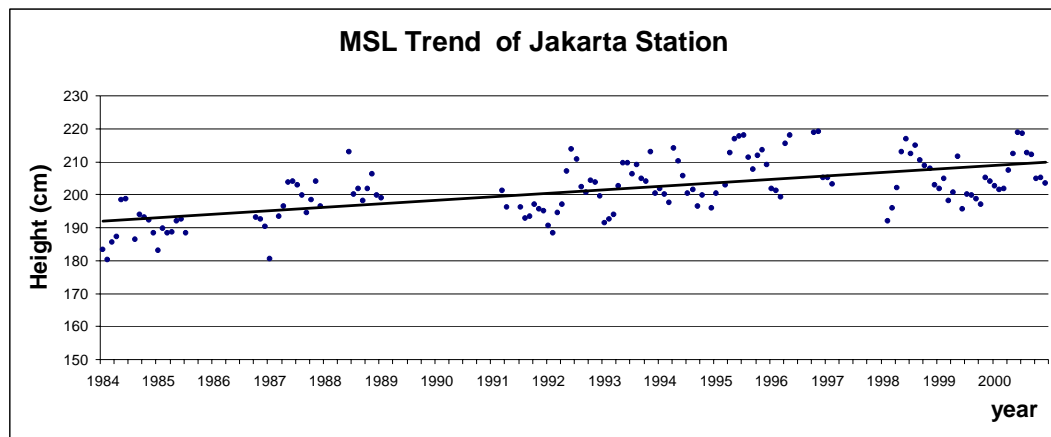


Figure 4. Monthly MSL time series of Jakarta stations

The tidal station buildings should be built in a permanent and strong structure which is capable of against destructions caused by an extreme weather and tidal wave conditions. The tide staff and BM should also be located at a highly stable platform with possible minimum local ground displacements.

Strong and Long Lasting Tide Staff

Improvement of the tide gauge staff from sheet steel to that of fibre glass bar is expected to provide high quality, and long life stable staff meter. We identified that using the vertical staff gauges of sheet steel or aluminium is one of the error sources such as discontinuity in the sea level reading time series and improper join between the sheet steels of a tide staff. Errors caused by discontinuity in sea level readings may occur when the station operators are mistakenly archived the data record of tide staff change. At least every one or two year replacement of sheet steels should be carried out since the scale readings are becoming deteriorated resulting from regular cleaning of the staff from coral and sea creatures. Improper joins between sheet steel of a tide staff are not perfectly made during the replacement. Therefore, we designed new type of tide gauge staffs made of fibre glass bar with the reading scale covered by strong and transparent resin layer, as shown in Figure 5. This staff bar with size of 5 cm x 8.5 cm x 3 meters, consecutively for thickness, width and length, it could provide high stable reading scale for more than ten years. It expected that the high resolution observations with real time data communication, precise datum and high stable tide staffs, this will contribute significant improvements in the sea level monitoring in the Indonesian Archipelago.

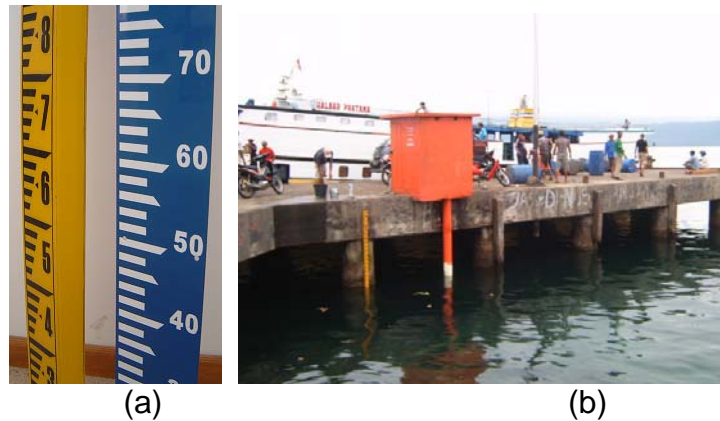


Figure 5. New designed tide staff made of fibre glass bar (yellow colour) with the reading scale covered by strong and transparent resin layer. This is better than the sheet steel type, blue colour, (a). The staff was installed at Jailolo Station in Tarnate Island Eastern of Indonesia by mid-April 2006, (b).

BAKOSURTANAL has been conducting precise GPS measurements at a selected set of BMs of the tide gauge network periodically twice in a year since year of 2002. The selected BM's were connected to the National Permanent GPS Station Network and therefore to the International Terrestrial Reference Frame. Monitoring of BMs and tide staffs with space techniques could solve the ambiguity of the computed MSL rises in many stations. Since the sea level gauges measure the relative motion between the sea surface and the land, and the records can be possibly contaminated by land vertical movements at individual tide gauges. The capability of GPS to unify local system to global reference frame, this has led to an opportunity to link a network of tide gauges to more highly accurate global reference system, resulting in a better understanding of mean sea level change. In future, the deployment of continuous GPS tracking at several tide gauges will be carried out.

Data Processing

A modification was made to convert the DOS-based TOGA software created by the University of Hawaii Sea Level Centre into Windows-based. The main purpose of performing the modification is that to make the software become more users friendly, Figure 6. There are many advantageous of windows that could be optimally utilized with the modification such as a capability of providing processing options in a pull down menu, interoperability with graphical display facilities, compatibility to windows-based commercial software used for data analysis and quality control and possible connectivity of the software to a web-based data base and processing.

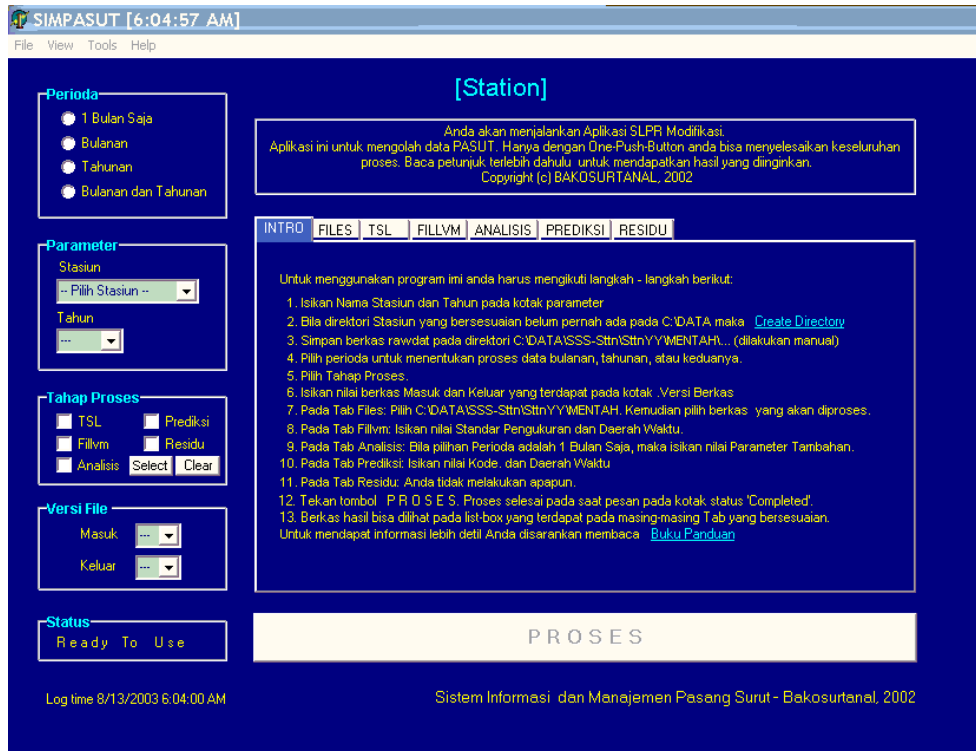


Figure 6: An in-housed windows-based tidal processing software used in BAKOSURTANAL. The software originally developed from the DOS-based TOGA tidal processing software, written by the University of Hawaii Sea Level Centre.

The content of sea level data base is mainly consists of such as meta data, raw data, monthly and yearly harmonic constants, monthly and yearly MSL trends and a description of station maintenance. Online data service via internet would be available in the near future to provide services to users with various requirements such as fast hour data and harmonic constants.

Tidal prediction of ports where the permanent sea level monitoring are located have been made to meet the present and future increase demand from users mainly from the field of survey and mapping, coastal management, fisheries, tourism and water sports. We started by publishing tidal prediction in calendar format for 5 stations in 2004. Then in 2005, we publish an annual tidal almanac book consisting of 60 standard ports where permanent stations are located and 40 temporary ports with data collected from bathymetric mapping activities.

Data Submission to International Communities

The Indonesian waters play such an important region for ocean monitoring and climate studies. It is realised that to have a better understanding on the regional climate of the region, as well as its local climate and ocean variability, global data should be incorporated in the studies. Therefore it

is of great importance to collaborate with international experts by taking part in data exchange to international communities, such as Global Observing Sea Level Monitoring (GLOSS).

Action has been made to keep the stations be fully operational and to convince decision makers at higher level to provide a consistent support to the GLOSS programme. At present, there are eight stations committed as part of the GLOSS network, namely Ambon, Benoa (Bali), Cilacap, Kupang, Bitung, Padang, Sorong, and Surabaya. All of the stations have been recording sea level for more than a decade though some intermittent inoperational conditions, mainly caused by station house destructions or instrument malfunction, may found for some days to several months at some stations.

Future Tsunami Early Warning System

A proposed upgrade and new sites for a tsunami early warning system both in Indian Ocean and Indonesia territorial waters is shown in Figure 7. This initiative was made based on the fact that people awareness on the importance of an early warning system is increasing after the recent tragedy of Indian Ocean tsunami. The tragedy was recorded be the most catastrophic in the history of tsunami, causing great loss of lives more than 120,000 people in Indonesia and more thousands over 9 countries in Asia. If an early warning system was available in the region; it should have been able to save the loss of lives. Water level stations, the main part of the early warning system, are highly sensitive in recording the earthquake signal since the propagation in the sea water is less absorbed than that of solid crust. They provide real-time information on the development of a tsunami following a seismic event, and thus are critical for guiding the issuance of tsunami warnings and for cancelling warnings when non-destructive tsunamis are observed.

Considering the tectonic setting of Indonesia region where epicentre of the earthquakes generating tsunamis are most likely take place closer to the archipelago, the distribution of the proposed early warning system in Indian Ocean should be designed capable of guiding the fast issuance of warnings. Realising the great loss in the tragedy and in addition to the early warning in Indian Ocean initiated by the United Nations, Indonesia consider to participate by allocating domestic budget for establishing national early warning system to monitor local tsunami which may happen in Indonesia internal waters. The existing digital stations should be ready for supporting an early warning. However, upgrade in data communication and power supply is still necessary.

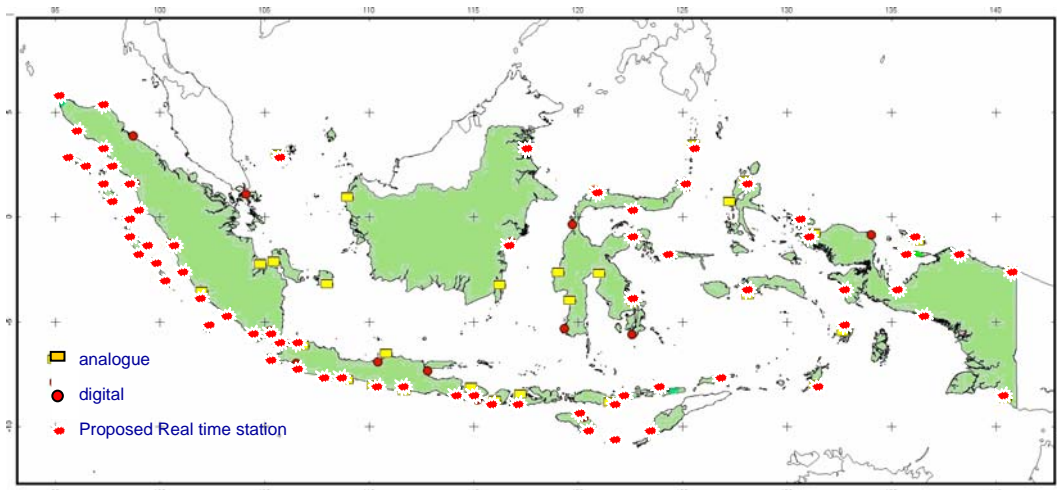


Figure 7: A proposed real time sea level monitoring stations for the tsunami early warning systems both in Indian Ocean and Indonesian internal waters.

Efforts have been made to build joint cooperation with international and inter-related government institutions and local governments in Indonesia to have the system in place. It has been agreed that all international efforts on the establishment of the Indian Ocean Tsunami Warning System is coordinated under the leadership of the Inter-governmental Oceanographic Committee (IOC)/UNESCO. Indonesia, as the most potentially badly affected country by tsunami hazards shows a high commitment on the establishment of the system. It is expected by the end of 2006, there will be at least 26 real time stations in place. Commitments for the establishment of the system are presently showed by German contribution with 10 stations, USA 10 stations and Indonesia 6 stations.

The present (April 2006) progress of the installation is encouraging. BAKOSURTANAL and University of Hawaii Sea Level Centre (UHSLC) installed the first real time station in Sibolga North Sumatra on April 22, 2005 and the remaining are in Sabang (Aceh), Padang (West Sumatra) and Benoa (Bali). The data transmission via Global Telecommunication System (GTS) operated under the World Meteorological Organization (WMO) is set to every 15 minutes but higher transmission in extreme conditions is possible. The data is now available online in internet with open access for scientific community. We recently completed installation of 2 real time stations, funded by Indonesia government. We successfully use Garuda Satellite for data communication.

Conclusions

International collaboration for establishing Indian Ocean Tsunami Warning System (IOTWS) reflects that this system can also be part of an operational ocean observing system which provides fast and reliable sea

level data which can be used for scientific research and various practical applications.

To provide a high quality tidal data with a fast delivery mode from the existing permanent tidal station network, most of the buildings and instrumentations of stations should be improved. Considering the growth of national funds allocated for maintaining the operation of the tidal network remains not significantly increasing, efforts have been made to seek for other support to improve the system. It is realised that there is also national security and cost recovery concerns which inhibit data exchange. The program on sea level monitoring should improve the operational status of national data delivery available in 'fast' mode allowing national and the international community will gain access to information at the agreed level of data exchange.

Acknowledgments

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