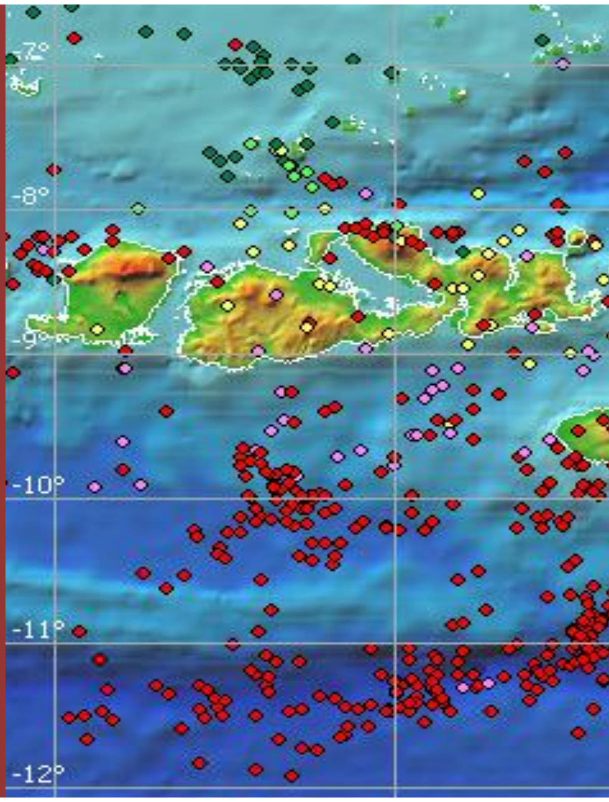

Tsunami Hazard Maps for Lombok

Technical Documentation

May 2013

IS International Services

DLR

PROTECTS

Tsunami Hazard Maps for Lombok

Technical Documentation

Multi-scenario Tsunami Hazard Maps for Lombok, 1:100.000
Multi-scenario Tsunami Hazard Maps for Kota Mataram and Gili Islands, 1:15.000

Joint publication by GIZ IS and DLR in the frame of the PROTECTS project

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Author:	Matthias Mueck (DLR)
Revision:	Harald Spahn (GIZ IS)
Indonesian language version:	Dewi Anggraeni (GIZ IS)
	Gede Sudiartha (GIZ IS)

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Tsunami Hazard Maps for Lombok

Technical Documentation

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1. Introduction

During the last decades the economy of Lombok has become highly dependent on the tourism industry. Many of Lombok's major developments, especially those related to tourism but also the urban sprawl of the islands' capital Mataram, are located directly on the shorelines facing the Indian Ocean in the south (e.g. Kuta) and the Bali Sea in the north (e.g. Gili Islands, Senggigi).

A couple of hundred kilometres south of Lombok lays one of the major tectonic collision zones of the earth, which represents a major source area of tsunamigenic earthquakes, facing especially the southern part of the island. Lombok is furthermore prone to tsunamis from the back-arc fault, facing the northern part of Lombok. The type of fault that forms on the back-arc is called a back-thrust and has a high potential to generate earthquakes and subsequent tsunamis in the direct vicinity of the coastal areas of Lombok. Bigger tsunamis in the range of the island would most probably have a severe impact on many populated coastlines. Therefore geologists and tsunami scientists consider Lombok as one of the high-risk areas for tsunami hazard in Indonesia.

Lombok experienced major earthquakes and also tsunamis in the past. Due to the island's location in the close neighbourhood of the subduction zone and its seismic history, the science community presumes that Lombok will also be impacted by tsunamis in the future – although a precise prediction is not possible. As preparedness is the clue to cope with tsunamis, the development of local preparedness strategies is essential.

Within the PROTECTS project, a step-by-step approach towards tsunami preparedness across multiple levels (Figure 1) was developed and implemented. The approach is based on the assumption that the chances to survive a near-field tsunami depend very much on the capacities of the affected people to quickly assess the situation and take the right decisions and actions based on a basic but solid knowledge of local tsunami risks and preparedness plans.

Understanding the tsunami hazard and assessing the possible impact to local communities in tsunami prone areas is a prerequisite for local decision makers and other stakeholders to anticipate future tsunami events and get prepared. Knowledge about the local tsunami hazard is necessary for risk assessments, as the risk describes the relations between the vulnerability of the people, their assets and the hazard.

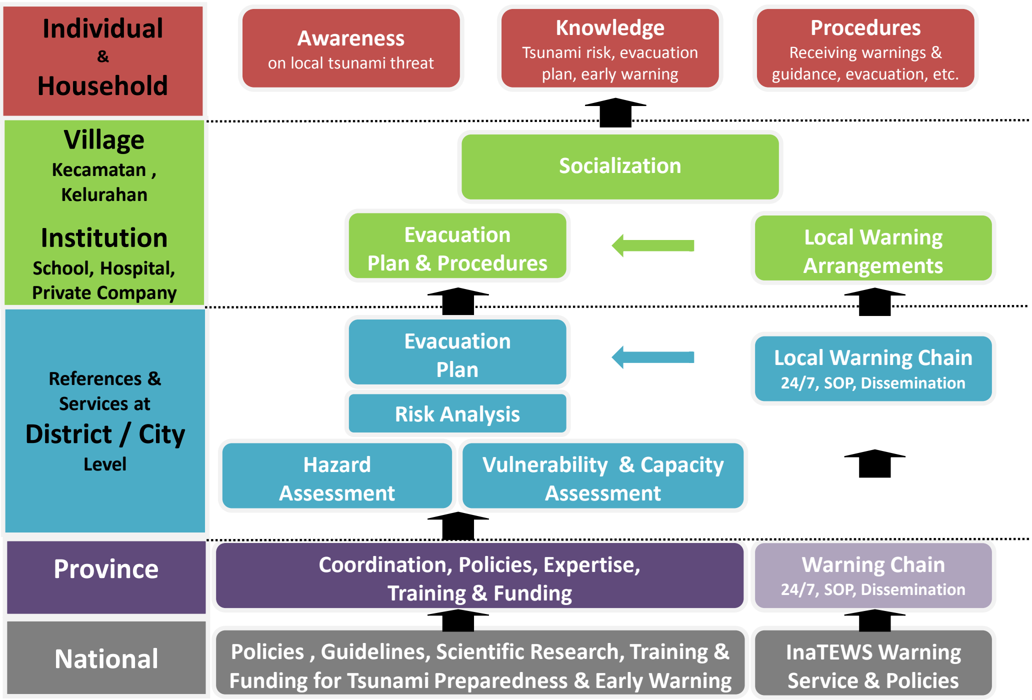


Figure 1: Multi-level approach to strengthen tsunami preparedness (GIZ IS, 2013)

The objective of this document is to provide decision makers in Lombok with background information on the tsunami hazard mapping process for the islands' coastal areas. The document (1) provides some basic information on the geological conditions and related tsunami hazard, (2) gives a short overview on the working process of the inter-institutional expert group to establish tsunami hazard maps for Lombok, (3) shows what hazard mapping products are currently available for Lombok, (4) provides background information how to read and interpret these mapping products correctly and (5) explains in detail the methodological background of the map products developed within the PROTECTS project.

A word of caution: there are different approaches to produce tsunami hazard maps, leading to maps which might significantly differ from each other. The concepts and meaning of zonings in these maps might be completely different; therefore a careful interpretation of the maps is needed. It is also necessary at this stage to point out that these maps – independent of how they were developed – can only provide an estimation of what might happen; they cannot predict exactly what will actually happen. Especially modelling results are based on many uncertainties like data quality, methodological approach and missing validation. Due to this, it is not recommended to disseminate such maps to the public in general, but use them wisely as references for planners and disaster management agencies. Nevertheless, these maps are currently the best possible orientation and reference to identify tsunami hazard zones and safe areas for evacuation planning processes and moreover an important planning tool e.g. for urban and land use planning.

2. Some background information on tsunami hazard in Lombok

According to the geological map of Indonesia (Figure 2), Lombok region is located very close to the collision zone between the Indo-Australian Plate (south) and the Eurasian Plate (north). The related subduction zone represents the main source area for tsunamis that might affect especially the southern part of the island. Just off the northern coast of Lombok, the Back Arc Fault is another source area for local tsunamis.

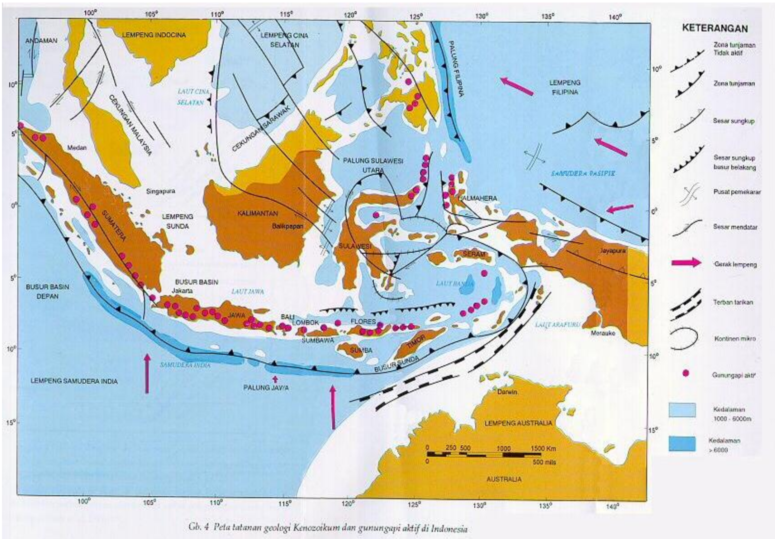


Figure 2: Geological processes and volcanic activities in Indonesia (Katili, 1994)

Shallow earthquakes in the northern part of the island arc are caused by fault activities behind the Bali Arc which is the geological structure of a reverse fault that extends to the Flores sea and Flores island (Figure 3).

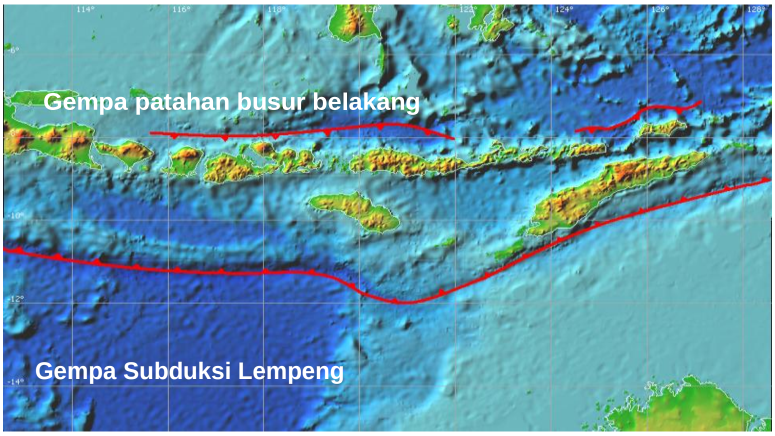


Figure 3: Tectonic setting Lombok region

The thrust zone is evident in two segments: the Flores thrust zone in the west and the Wetar thrust zone in the east. However, in this 500-km-long thrust belt, relatively short (20-30 km long) traces of individual thrusts occur, showing varying tectonic conditions and earthquake probabilities (Brink, U. et al, 2009; Sengara, W., 2002). Due to this complex conditions, only two general statements about local earthquake hazard can be made for this region: (1) There is a high frequency of large and shallow earthquakes (International Tsunami Database) and (2) the lower bound return period from seismicity in the Bali Flores Sea estimates 40 years for Mw7.8 earthquakes and 160 years for Mw 8.4 earthquakes (GFDRR, 2011). An older scientific source stating that no earthquakes that are clearly associated with the back arc thrust zone have been found deeper than 25 km (McCaffrey and Nabelek, 1987) cannot be verified as analysis of the International Tsunami Database show different results.

Figure 4 shows the historical distribution of earthquake epicentres located in the southern and northern region of NTB, respectively in the Indian Ocean and the Sea of Flores. Epicentre depth ranges from 0-99 km which includes shallow to moderate depth earthquakes.

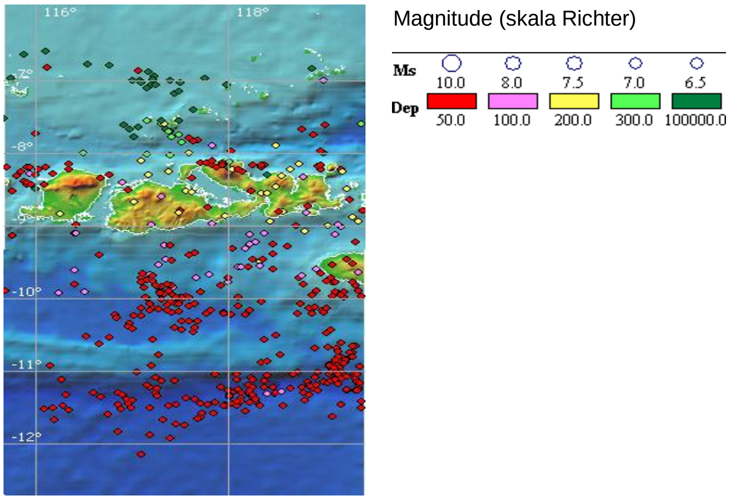


Figure 4: Distribution of large earthquakes in NTB region until 2004

(Source: International Tsunami Database)

Due to the relatively high frequency of shallow and large earthquakes in that region there is a naturally high potential risk of tsunamis affecting the southern and northern coastal areas of West Nusa Tenggara. Historical tsunami records related to the subduction zone is the Sumba (1977) tsunami, which was caused by an earthquake with epicentre in the subduction zone. The Flores Tsunami (1992) was caused by an earthquake in the back arc zone (Gempa Patahan Belakang), but did not affect Lombok.

Beside the subduction zone in the Sunda Trench and the back arc fault, two more sources of tsunami hazard have been identified: submarine landslides and volcanic activity. Submarine landslides are often associated with earthquakes. If they happen during an earthquake, they can increase the energy of a tsunami and therefore add up to the effect of uplift by tectonic movements in the subduction or back arc zone (also caused by the earthquake).

Every tsunami is different! Lombok might suffer the impact of a smaller tsunami but also the worst case might happen. Research on historical tsunami events provides important reference about possible events in the future. To understand what might be the possible impact of a tsunami in the future one can look back into the past and learn from historical experiences (as stated above) and/or can use mathematics and calculate potentially inundated areas using computerized inundation modelling tools.

A tsunami hazard map visualizes the tsunami-affected areas in a given region.

As already mentioned, there are different approaches to outline tsunami hazard zones. Simple approaches just rely on estimated maximum tsunami wave heights at coast, topographical and geomorphological information and, if available, observations of historical tsunami events which occurred in the respective area. As the impact of a tsunami is strongly influenced by the shape of the coastline, the elevation of the land surface and the seafloor topography, it is important to study these patterns and understand their influences on expected wave height and inundation areas.

Further information about simple and low-tech tsunami hazard mapping approaches is available in the “Guidebook on Tsunami Hazard Mapping for the District Level” provided in the TsunamiKit (www.gitews.org/tsunami-kit).

For a more sophisticated estimation of tsunami impacts on land, the hazard assessment is often conducted by using numerical inundation modelling results, based on a presumed geological framework. This analysis requires high resolution topography and bathymetry data (elevation data on land and underwater, respectively), and information about potential regional tsunami sources. The results of tsunami inundation modeling are presented as areas that could potentially be flooded as well as estimated water depths, current strengths, wave heights, and wave arrival times.

Numerical inundation modeling can be conducted by using a single tsunami scenario, based on one defined earthquake source and specific magnitude. Usually the chosen scenario represents either the worst case or the most credible scenario for a certain region. The resulting map then shows the inundated area of that specific scenario. Such an approach might be suitable for areas where a worst case scenario or most probable scenario has been already identified. In areas where such scenarios are not known yet, it might be more appropriate to evaluate the impacts of tsunamis coming from different source areas and magnitudes. This is called a multi-scenario approach, because it combines the inundated areas resulting from a number of different (hypothetic) tsunamis (or scenarios) in one map.

In the following, the hazard mapping process conducted in Lombok and the available map products are described in detail.

3. Tsunami hazard mapping process in Lombok

Tsunami hazard maps are a prerequisite for any initiative to develop tsunami preparedness on the local level. Therefore, as one of the first steps of the PROTECTS capacity development program for tsunami preparedness in Lombok, it was agreed to revise all existing tsunami hazard mapping products and approaches and explore the current knowledge about tsunami sources and impacts for Lombok.

During a working group meeting on tsunami hazard and risk assessment in Lombok the participants from BPBD Mataram City / Eastern and Northern Lombok, BMKG, DLR, SAR, DISTAMBEN, PMI, TNI, POLRI and BAPPEDA gathered to achieve a better understanding of tsunami hazard and the possible impacts for Lombok. The meeting was held on November 25, 2011 in Mataram, organized by West Nusa Tenggara Provincial BPBD with support from GIZ IS. During the meeting the available mapping approaches (DLR) and map products (DISTAMBEN) were presented in order to get a comprehensive overview about suitable basis information. During the workshop the working group recommended to use the multi-scenario approach from DLR (see Chapter 4.2 and 5) to provide references for subsequent evacuation planning processes.

This recommendation was based on the fact that the DISTAMBEN maps were based on a zoning concept which exclusively relied on topographical features and consequently did not consider particular effects of tsunami inundation resulting from different source areas, whereas the results from the DLR modelling provided a much more differentiated picture on the possible impacts of tsunamis in Lombok. On the other hand it was acknowledged that due to the broad scale resolution of the DLR maps, it would be appropriate to use the topography based approach of DISTAMBEN in the small bays, especially on the northern coast, as inundation areas there are relatively small and the most important feature for local evacuation strategies is the elevation of the ground close to the coast. Another advantage of the DLR maps was the fact, that they cover the entire coastal area of Lombok while the DISTAMBEN reference products (see Chapter 4.1) are only available for selected small coastal areas of Lombok.

Based on this recommendation, DLR presented first preliminary hazard maps during a working group meeting on March 6, 2012. Detailed maps with a scale of 1 : 15 000 based on precalculated tsunami scenarios from the Sunda Trench and the Back Arc Fault were developed for the City of Mataram and the Gili Islands. During the meeting it was decided to finalize the detailed maps (including further information like tsunami arrival times, hazard probabilities, etc.) and provide further coarse mapping products (with a scale of 1 : 100 000) for the entire coast of Lombok within the following months.

The final hazard maps, including soft and hardcopies of both detailed and broad scale map products, were handed over to West Nusa Tenggara Provincial BPBD at July 06, 2012.

Available map products for Lombok, including the final DLR products as well as the reference products from DISTAMBEN are presented in the following chapter.

4. Available hazard maps for Lombok

4.1. DISTAMBEN

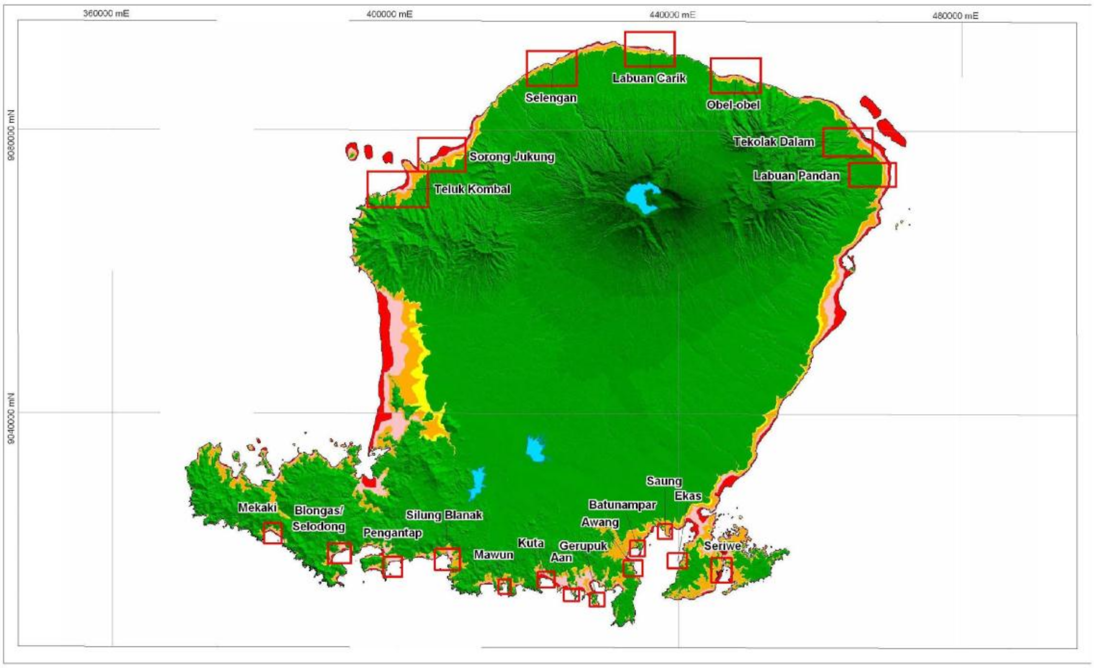


Figure 5: Overview of Lombok with areas that are historically or potentially affected by tsunamis (DISTAMBEN 2011: Potensi Gempabumi dan Tsunami di Provinsi NTB)

Maps have been developed for each of the marked areas within Figure 5. The maps are characterized by a compilation of freely available data (e.g. from BIG) and local available information showing basic topographic information, settlement areas with population data, information on infrastructure and public facilities as well as recommended evacuation areas. Figure 6 shows an example.

The map basically relies on two topographic features, which is the distance to the coast and elevation data. In all maps, this information is always set into relation to the main settlement area within the map and therefore gives a simple but good estimation about the local hazard situation (e.g. Village A is located 1 km away from the beach and 200m above sea level). Furthermore, information about the condition of infrastructure (roads, private accommodations, public facilities) and population numbers provide a good dataset of local vulnerability parameters. The data compilation also provides some useful information concerning evacuation planning (e.g. multi-storey buildings, good evacuation routes). Identified available communication infrastructure is helpful information for the set-up of local warning chains and response mechanism. Recommended evacuation routes and places provide valuable inputs for local evacuation strategies.

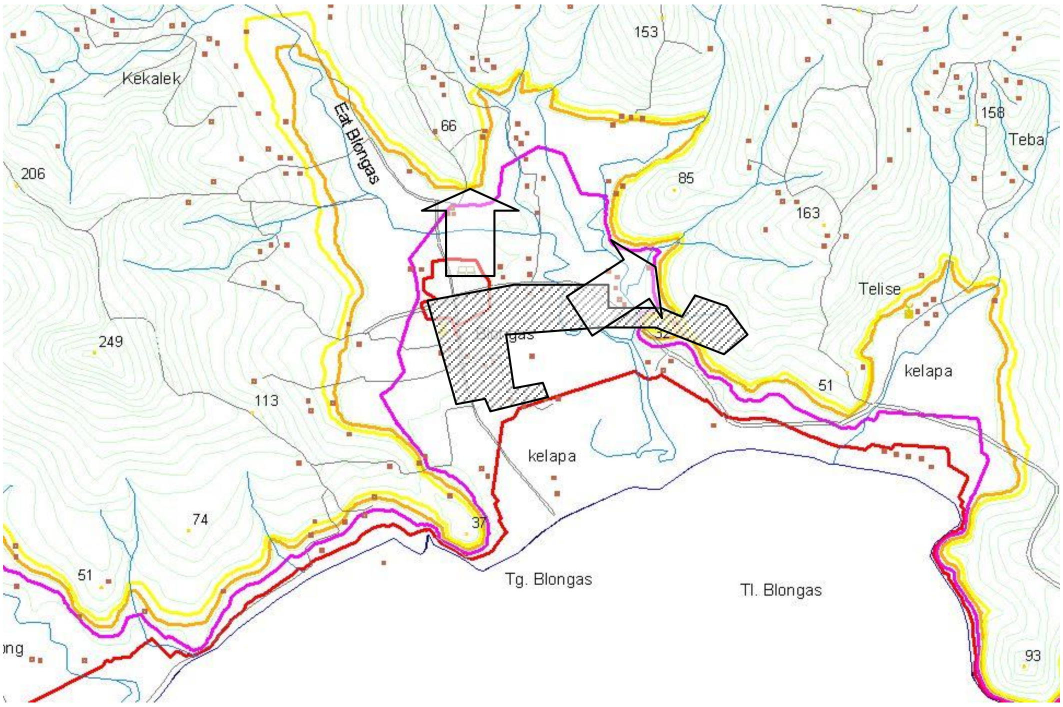


Figure 6: DISTAMBEN map product for Dusun Pengantap (Kab. Lombok Barat)

Summarized, the DISTAMBEN map products can be seen as basic risk maps based on a simple hazard zoning concept and available for selected coastal areas with an assumed tsunami threat.

4.2. PROTECTS (DLR)

Broad scale Tsunami Hazard Maps for the entire Indian Ocean coastline of Lombok are available at a scale of 1:100.000 (Figure 8).

The database for this approach consists of tsunami modelling results provided by the PROTECTS partner AWI (Alfred Wegener Institute) at epicentre locations ("source grid") for tsunami scenarios in the Sunda Arc provided by GFZ (German Research Centre for Geosciences), 2008 and AIFDR, 2010 (for epicentre locations in the Back Arc fault) . The model area covers the south coast of Sumatra, Java, Bali and Lombok and parts of the northern coast of West Nusa Tenggara. For this approach the base data are based on global coverage GEBCO data for bathymetry and global coverage SRTM data for topography. Tsunami modelling results based on these global datasets provide a level of detail usable only up to map scale of 1:100.000 or below.

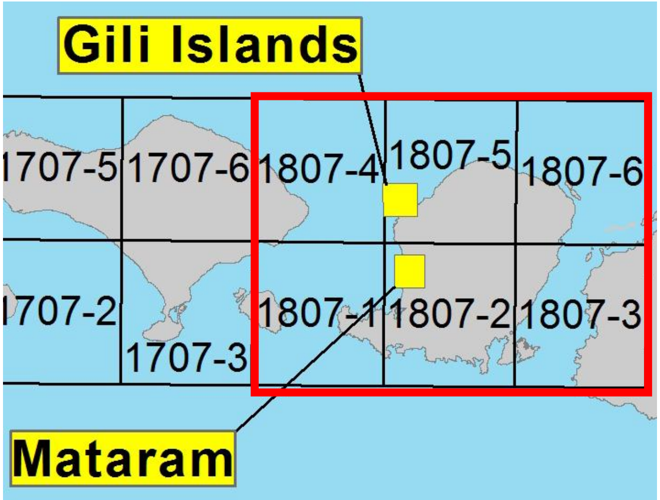


Figure 7: Available tsunami hazard maps at a scale of 1:100 000 for Lombok.

Numbers and locations of map sheets and map numbers are based on BIG (Badan Informasi Geospasial) reference system. For yellow marked areas detailed maps at a scale of 1:15 000 are available.

For the City of Mataram and the Gili Islands a detailed Tsunami Hazard Map at a scale of 1:15 000 was developed (Figure 9/10).

The methodological concept deriving the detailed hazard map (see Chapter 5.2) is the same as for the 1:100 000 hazard map series. For detailed inundation modelling the TsunAWI, Version 2010 model was used. The model uses a grid with a resolution between 7 and 200m on land and near the shore. Bathymetric data are from the GEBCO data set, augmented by bathymetry data provided by TCarta Marine (TCarta Marine's Digital Bathymetric Model (DBM)). Topographic data are derived from INTERMAP data sets.

Broad scale Tsunami Hazard Maps for Lombok at a scale of 1:100.000

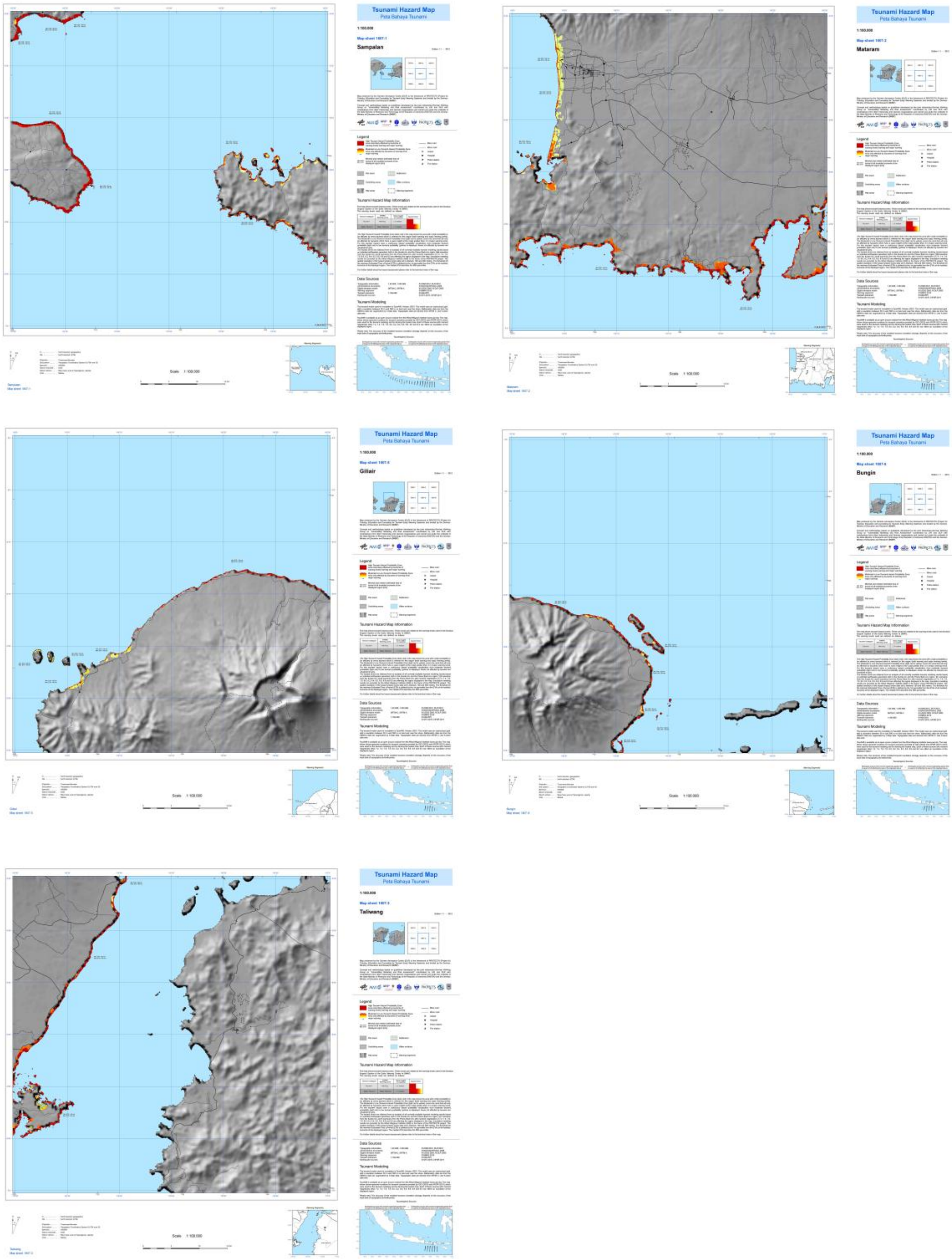
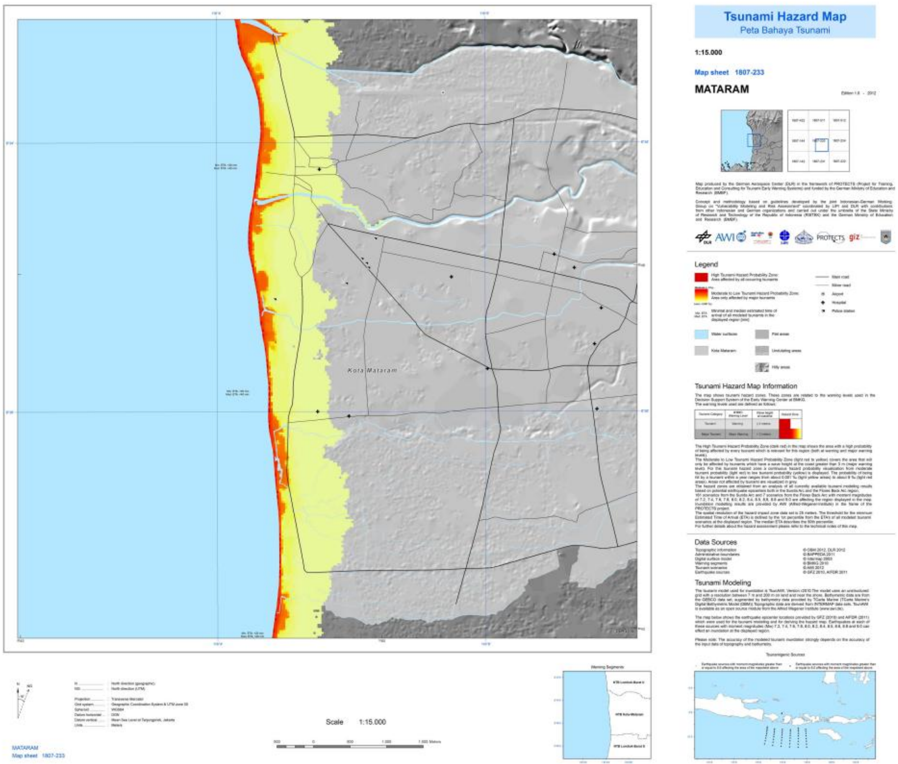


Figure 8: Available Tsunami Hazard Maps at a scale of 1:100.000 covering the entire coastal area of Lombok

Detailed Tsunami Hazard Maps at a scale of 1:15.000 for the City of Mataram and the Gili Islands



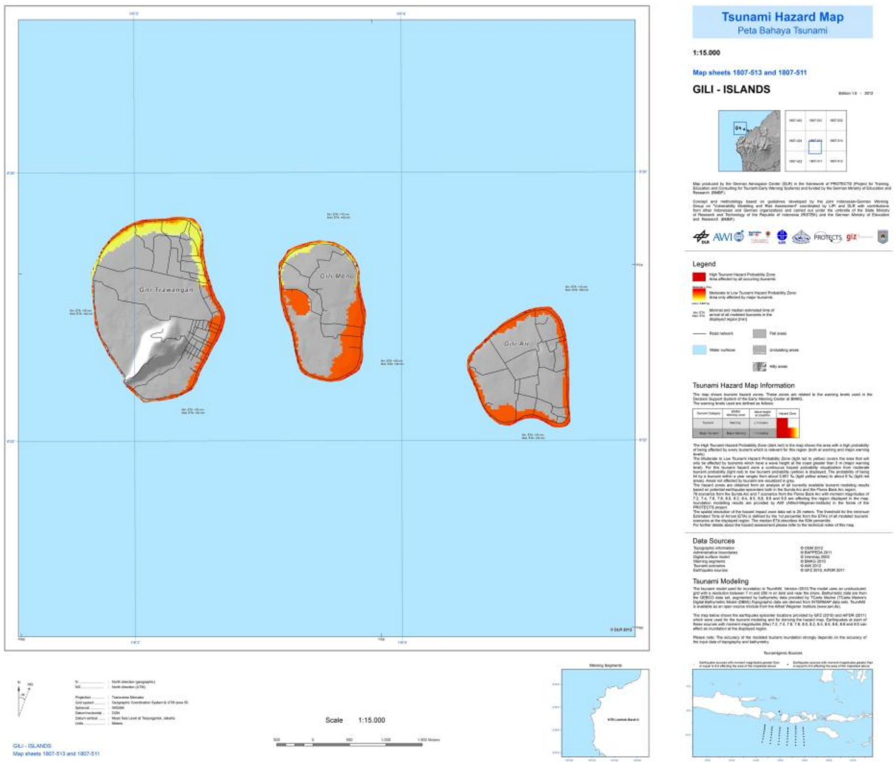
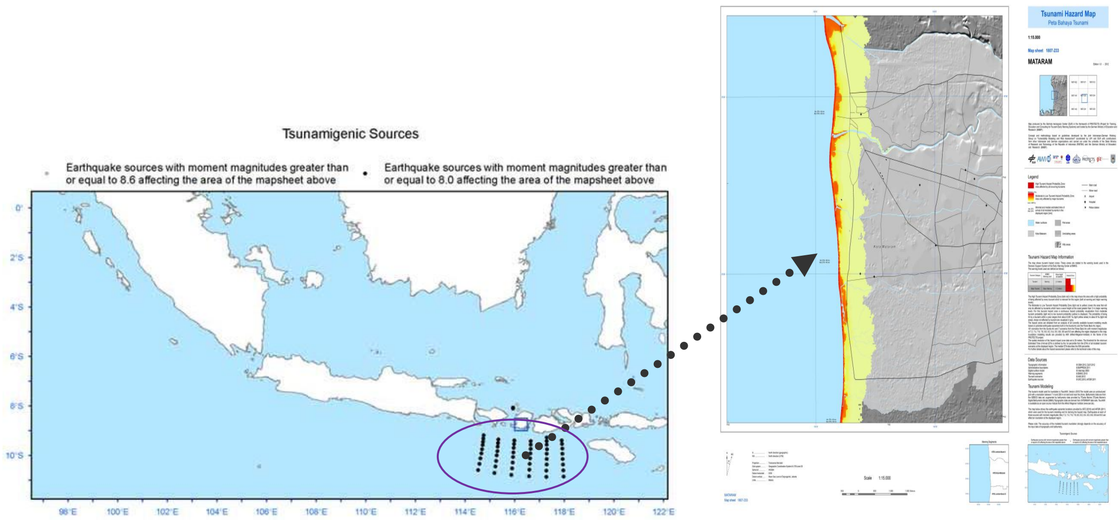


Figure 9/10: Tsunami Hazard Map for the City of Mataram (above) and the Gili Islands (below) at a scale of 1:15 000

5. Tsunami hazard mapping in the framework of PROTECTS

5.1. Map interpretation

The presented tsunami hazard maps (both the broad scale and detailed products) are multi-scenario maps. They visualize the impacts on the coastal areas of Lombok based on a big number of potential tsunamis caused by different earthquake magnitudes and originating from different locations within the subduction zone (Figure 11). It is important to note that the tsunami hazard related to the back arc fault is only considered for the detailed map products (as far as data were available until March 2012), for the broad scale products the tsunami hazard is only related to the Sunda Arc. Submarine landslides and volcanic activities are not considered in the maps. This is due to the very limited information available regarding probabilities, occurrences and possible impacts of these kinds of tsunamis.



A number of hypothetical tsunami sources with different locations and earthquake magnitudes were used in the mapping process (here exemplarily for the City of Mataram)

The red and the yellow colours show the areas affected by the calculated scenarios. Yellow areas are affected only by bigger tsunamis, while the red zone is already affected by smaller tsunamis

Figure 11: DLR Multi-scenario

The multi-scenario tsunami hazard maps provide zoning: It groups all calculated scenarios into two zones. The red zone represents the area impacted by a tsunami with a wave height at the coast between 0.5 and 3 m. The orange/ yellow zone is only impacted by major tsunamis with calculated wave heights at coast > 3 m. Both zones are directly related to the warning level of InaTEWS as indicated in Figure 12 below.

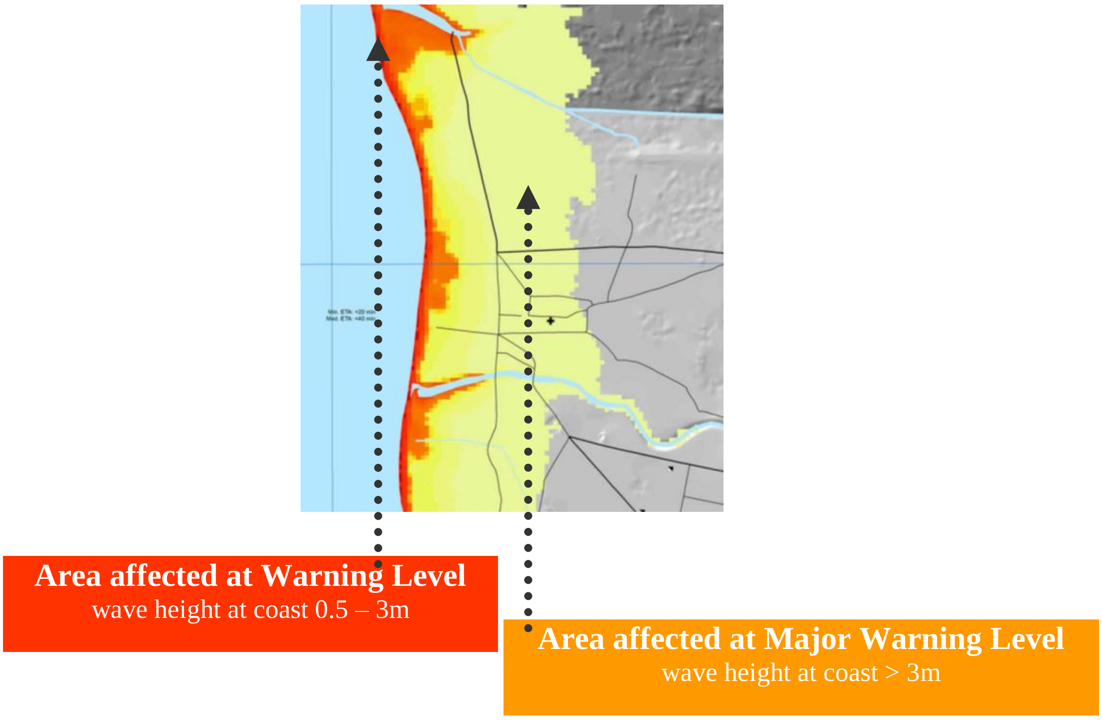


Figure 12: Zoning according to wave height and InaTEWS warning level

When assessing tsunami hazard it is essential to talk about probabilities. Tsunamis are a typical example of "low frequency – high impact" disasters; i.e. tsunamis do not occur very often but if they occur, they are very dangerous and can cause great damage. On average every two years a destructive tsunami occurs in Indonesia. At a particular coastal location, however, the recurrence interval between destructive tsunamis can vary from 30-50 to even 200-300 years. In Indonesia, most tsunamis are generated by submarine earthquakes. Tsunamis triggered by volcanic activity are much more rare events. Smaller tsunamis happen much more often than major tsunamis (and the worst case).

The <u>multi-scenario hazard maps provide information about tsunami probabilities (Figure 13)</u>. The red colour indicates the area that will be affected by all occurring tsunamis. The range of colours from orange to light yellow indicates the probability of an area to be affected by a major tsunami (with wave height at coast > 3m). Grey areas will not be affected by tsunamis (based on modelling results). Furthermore the minimum and median estimated time of arrival (ETA) of all modelled tsunamis is stated at the displayed region.

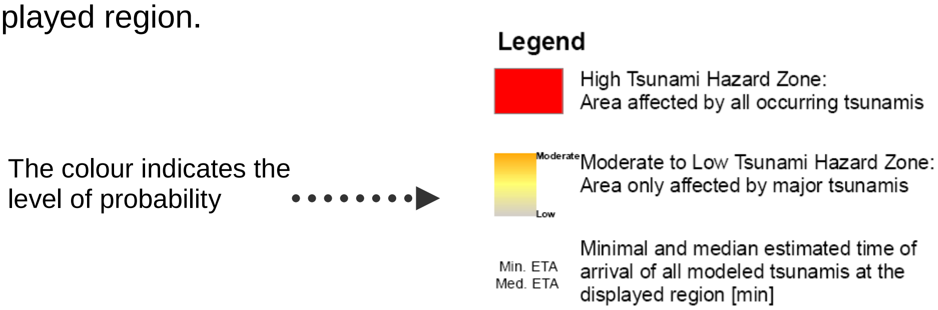


Figure 13: Tsunami probabilities and ETA's that are visualized in the map

5.2. Methodology

The approach used for the tsunami hazard map production is a combination of probabilistic analyses and multi-scenario tsunami modeling results. Along the Sunda trench (and to a small part along the Back Arc) a large number of realistic tsunami scenarios with different tsunami source locations and earthquake magnitudes have been calculated. All scenarios together cover the south coast of Sumatera, Java, Bali and Lombok. These scenarios are used as input data for the hazard maps. The approach is based on an "event tree technique" with different steps and takes into account the different warning levels which are issued from the Tsunami Warning Center. The warning levels are specified by InaTEWS (BMKG 2012) and are defined as follows (Figure 14):

Warning Level	Estimated Height of the Tsunami Wave
AWAS (Major Warning)	Wave height ≥ 3 meters
SIAGA (Warning)	Wave height between 0.5 and 3 meters
WASPADA (Advisory)	Wave height of < 0.5 meters

Figure 14: Warning levels in InaTEWS (BMKG 2012)

Tsunamis in the category of "Advisory Level" (Waspada) cause only a very small inundation area or no inundation at the coast. Hence in this hazard mapping approach the "Advisory Level" and the "Warning Level" (Siaga) are used in combination. The mapping approach for a comprehensive tsunami hazard probability map follows six steps, see below:

1. **Determine the tsunami scenarios affecting the area of interest:** As first step all the scenarios which affect the area of interest are chosen from the Tsunami Scenario Database. This is realized by a spatial data query and selects all scenarios which at least inundate one point on land of the area of interest (e.g. a map sheet). The selected scenarios represent the basis for the further assessment.

2. **Classification of the scenarios depending on the warning levels:** As second step all available scenarios are grouped into the two warning level classes. Therefore a database query "Which scenarios generating a wave height at coast over 3 m" is performed. By defining the outline of the consolidated inundation of the classes you can get a first map showing the maximum inundation areas for the warning levels (see Figure 15). For the

final hazard map product only the zone which is generated by the class "wave heights at coast smaller or equal 3 m" is displayed (red zone in Figure 15). The other zone is substituted by a calculation of continuous tsunami impact probabilities, which is described in the next steps.

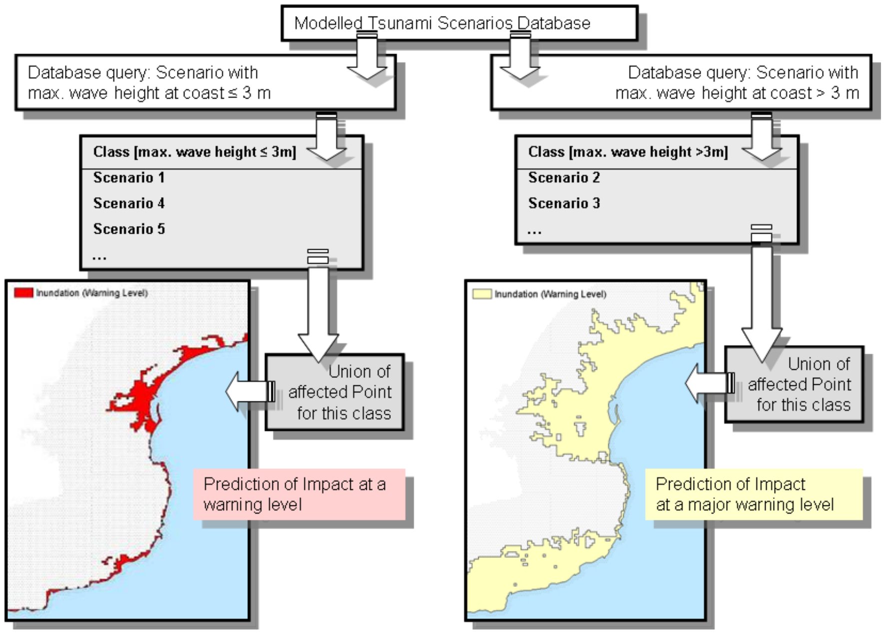


Figure 15: Grouping of tsunami modeling results depending on warning levels.

3. **Estimation of the spatial distributed probability for an earthquake with a specific magnitude along the Sunda Trench:** Because of that submarine earthquakes with high magnitudes occur more infrequent as earthquakes with lower magnitudes the scenarios with higher earthquake magnitudes (Moment magnitude: M_W) must be considered with a lower occurrence probability in the analysis. Similarly some regions along the Sunda Trench show a higher seismic activity as other regions and some spots are characterized by special geologic conditions –like a strong coupling of the plates at the subduction zone- which leads there to a higher occurrence probability for earthquakes with a high magnitude. This means that an area on land will be inundated by a tsunami caused by an earthquake with a high magnitude at a region with low seismic activity is more unlikely as by an event with lower magnitudes at an earthquake "hot spot"-area. Therefore an assessment of the earthquake occurrence probability must be done.

   This analysis is divided into two calculation steps. First the Sunda Trench region is zoned into three smaller regions which are showing different seismic activities (this is frequently published, e.g. Latief, Puspito& Imamura 2000, and can be also determined by a statistical analysis of historical earthquake data). At this zones the probability for an annually recurrence of every used Mw are estimated using the historical earthquake data (NEIC). To improve this assessment topical investigations like deterministic models are considered by a weighting of the occurrence probabilities between 1 (for determined hot spots with a high probability for an occurrence of a strong earthquake) and 0.1 (for determined more or less “inactive” spots). Figure 16 display an example for the results of a weighted earthquake occurrence probability for a specific Mw. Thus every used tsunamigenic source has an individual occurrence probability (please notice: the probability that an earthquake also generates a significant tsunami is covered by the numerical tsunami model approach).

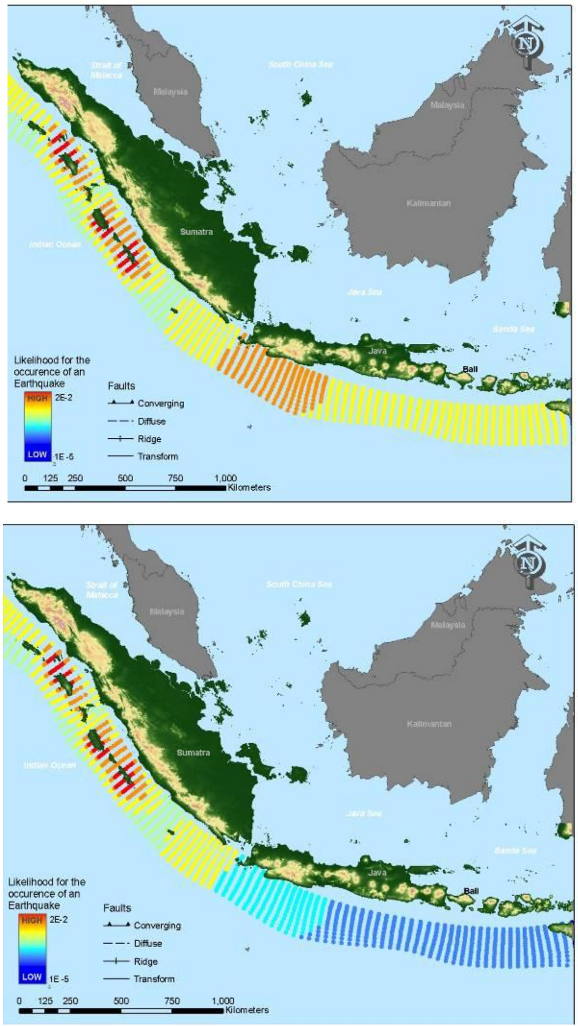


Figure 16: Assessment of the spatially differentiated likelihoods for the occurrence of an earthquake with a specific magnitude along the Sunda Trench (above: Mw 8.0, below: Mw 9.0).

4. **Determine a spatially distributed inundation probability:** In the next step a spatial differentiation for the possibility that a coastal area will be inundated is specified (spatial inundation likelihood). The results of the modelled tsunami scenarios include the impact on land, i.e. the area on

land which will be inundated from a tsunami with a specific location and magnitude. The single impact areas from the different scenarios can, of course, overlap each other (because the tsunami source locations are not so far away from each other or the location is the same and the scenarios differ only by the magnitude of the submarine earthquake). Hence every point on land can be inundated several times by different scenarios. As a general example a point near the coast will be normally more often inundated as a point far away from the coast. For the calculation of the inundation likelihood the regarded coastal area is represented by a point grid with a grid extend of about 100 m. So for every point on the grid (every 100 m inland along the whole coast) the scenarios are selected which hit this point. For these selected scenarios the occurrence probabilities of their tsunami source (estimated in step 3) are summed up and divided by the amount of used scenarios. Hence the occurrence probability represents the probability that this point will be hit by a Tsunami within a year. Figure 17 shows the query of the relevant scenarios and the total of the probabilities at one point on land. For the display in a hazard map the discrete points on land are interpolated.

Figure 18 summarize the whole demonstrated workflow to derive the continuous tsunami impact probability map with the event tree technique.

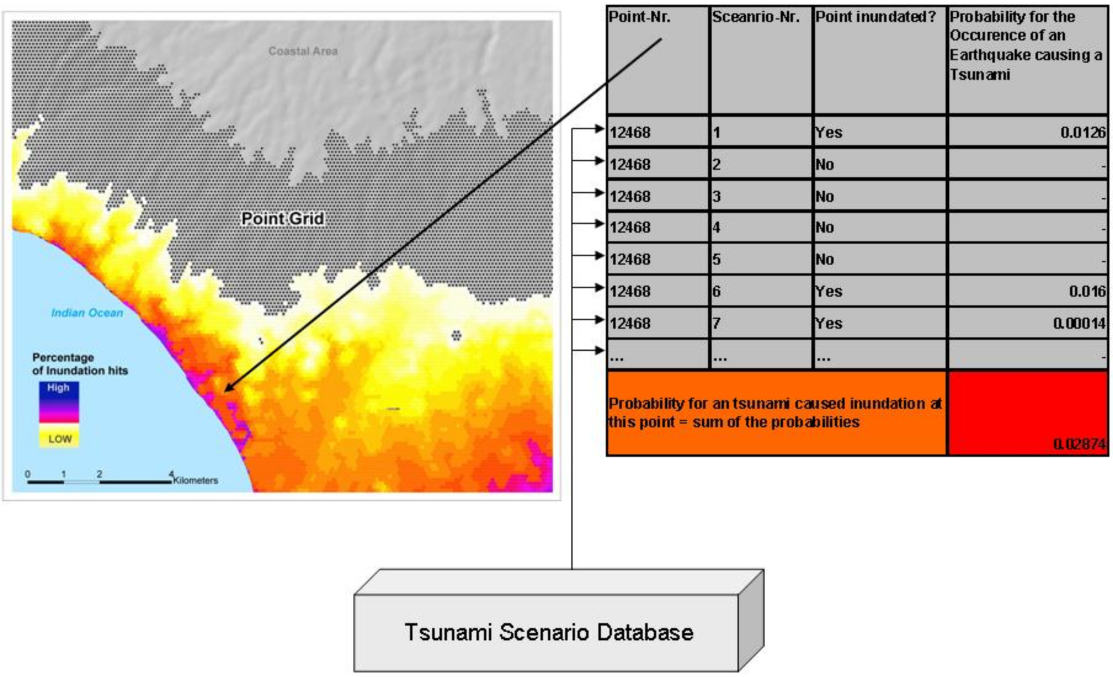


Figure 17: Example for the calculation of the inundation probability for one point on land.

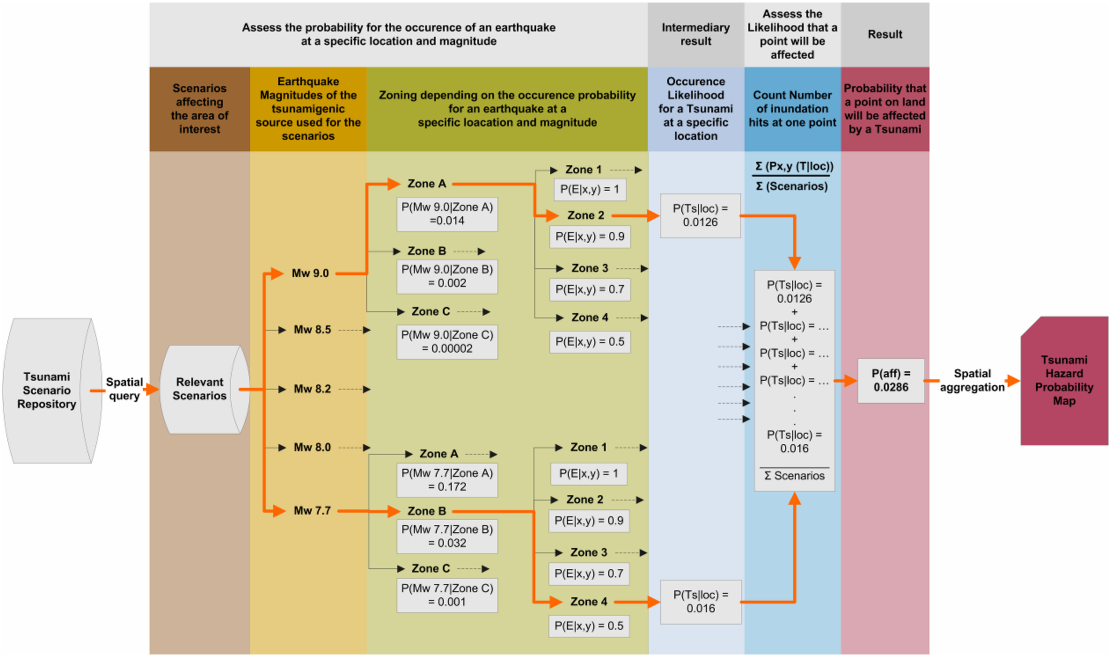


Figure 18: Overview on the workflow for processing the hazard probability maps.

Using this approach continuous hazard probability quantification is obtained. For the hazard map display we only show the probabilities for the major warning zone (moderate to low probability). The area which will be affected by a warning level situation is displayed in the hazard maps as red zone summarizing quantified tsunami probabilities to high tsunami probability. The zone is derived as described in Step 1.

5. **Combine the continuous probability with the "warning level" zone:** As last step the continuous Tsunami impact probability is overlaid by the derived "warning level" zone from step 2 in the hazard map.

6. **Adding additional parameters to the map**: Supplementary to the information about the inundation area the hazard map contains more parameters which characterize the potential tsunami danger of a coastal area. Every modelled scenario comprises an *Estimated Time of Arrival (ETA)* of the first disastrous Tsunami wave hitting the coast. The ETA can vary to a great extent for the various scenarios depending generally on the distance from the coast to the tsunamigenic source and the earthquake magnitude. To derive a valid value for the ETA from all available scenarios, two values are shown in the hazard map. The *Min. ETA* represents the minimum ETA which was found in all available scenarios. This is the worst case for the displayed point in the map. But this can be also a very rare event, so the *Med. ETA* is added to the point in the map. This value is the Median (50%-value) of the minimum ETAs of all relevant scenarios for the regarded region. These values can be taken as estimation for the time to react which is left after the earthquake event happened (see Figure 19).

Figure 19: Example for the ETA values displayed in the hazard maps

Furthermore, the relevant tsunamigenic sources for the regarded region are shown in a small display on the hazard map. It is indicated which tsunamigenic sources cause a dangerous tsunami for the region on the map. They are divided into sources with a high magnitude (which are widely dispersed along the Sunda trench) and sources with a lower magnitude (which are in general nearer to the regarded area). This illustration can be used to assess whether an earthquake will probably affect the regarded area by a tsunami (see Figure 20).

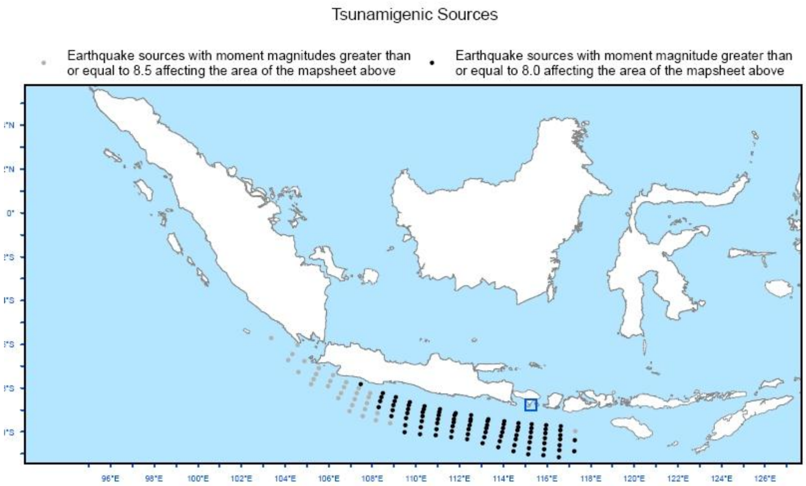


Figure 20: Example of tsunamigenic sources displayed in the map.

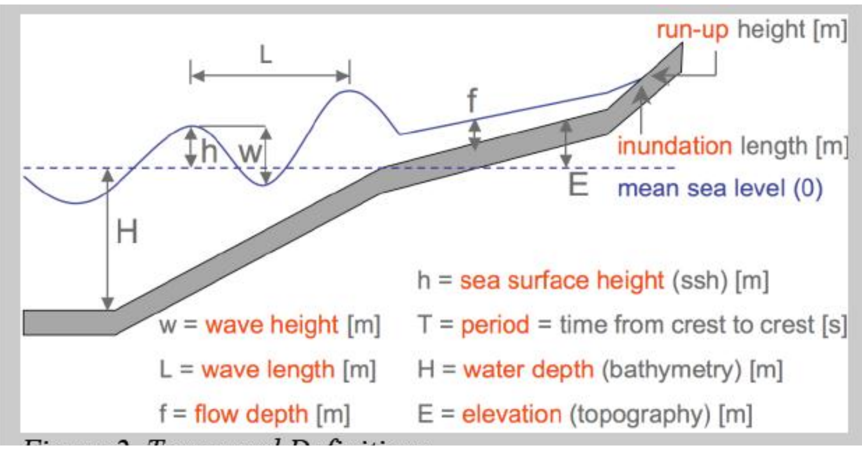
6. Definitions

In this section we introduce some of the commonly used terms and definitions, which are used throughout this document. The terms are used in correspondence with the UNESCO-IOC Tsunami Glossary. In the following some important terms are briefly summarized.

Tsunamigenic source: Source causing a Tsunami. In this context it refers to a location of a submarine earthquake with a specific magnitude.

Tsunami inundation area: Area flooded with water by the tsunami.

Estimated Time of Arrival / Tsunami Arrival Time (ETA): Time of tsunami arrival at a fixed location, as estimated from modelling based on the speed and refraction of the tsunami waves as they travel from the source. ETA is estimated with very good precision if the bathymetry and source are well known (less than a couple of minutes). The first wave is not necessarily the largest, but it is usually one of the first five waves.



Water depth (bathymetry): This is the depth of water measured from mean sea level downwards [m].

Elevation (topography): This is the land elevation above mean sea [m].

Wave height: This is the height of a wave from crest to trough in Meters [m].

7. Abbreviations

AIFDR	=	Australia–Indonesia Facility for Disaster Reduction
AWI	=	Alfred Wegener Institute
BAPPEDA	=	Badan Perencanaan Pembangunan Daerah (Local Planning Board)
BIG	=	Badan Informasi Geospasial
BMKG	=	Badan Metereologi dan Geofisika
BPBD	=	Badan Penanggulangan Bencana Daerah
DISTAMBEN	=	Dinas Pertambangan dan Energi
DLR	=	German Aerospace Center
ETA	=	Estimated Time of Arrival
GFZ	=	German Research Centre for Geosciences
GITEWS	=	German-Indonesian Tsunami Early Warning System
GIZ-IS	=	German International Cooperation – International Services
GEBCO	=	General Bathymetric Chart of the Oceans
InaTEWS	=	Indonesian Tsunami Early Warning System
NEIC	=	National Earthquake Information Center
PMI	=	Palang Merah Indonesia (Indonesian Red Cross)
POLRI	=	Kepolisian Negara Republik Indonesia
PROTECTS	=	Project for Training, Education and Consulting for Tsunami Early Warning Systems
SAR	=	Search and Rescue
SRTM	=	Shuttle Radar Topographic Mission
TNI	=	Tentara Nasional Indonesia
WH	=	Wave Height

GIZ-International Services
Menara BCA 46th Floor
Jl. M H Thamrin No.1
Jakarta 10310 –Indonesia

Tel.: +62 21 2358 7571
Fax: +62 21 2358 7570

www.giz.de
www.gitews.org/tsunami-kit

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Capacity Development in Local Communities

Federal Ministry of Education and Research