Technical Documentation

Tsunami Hazard Maps for Kabupaten Cilacap

Multi-scenario Tsunami Hazard Map for Kabupaten Cilacap, 1:100,000

Multi-scenario Tsunami Hazard Map for the City of Cilacap, 1:30,000

with zoning based on wave height at coast (in line with the InaTEWS warning levels) as well as probability of areas being affected by a tsunami.

Presented by

Cilacap Working Group for Tsunami Hazard Mapping

compiled by

DLR / GTZ

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1. Executive Summary

Cilacap district (Kabupaten) is considered as one of the high risk areas regarding tsunami hazard in Indonesia because a large tsunami within range of Cilacap would have a severe impact on its densely populated coastlines. Many of Cilacap's major development areas and especially the oil-mining industry is located directly on the shorelines facing the Indian Ocean. Below the same ocean, a couple of hundred kilometres south of Cilacap, lies one of the Earth's major tectonic collision zones, which is a major source of tsunamigenic earthquakes. Thus, geologists and tsunami scientists consider Cilacap a high risk tsunami area.

Cilacap has experienced major earthquakes and tsunamis in the past. Due to the area's proximity to the subduction zone and its seismic history, the science community presumes that tsunamis will affect Cilacap again in the future, although a precise prediction is not possible. As preparedness is the key to cope with tsunamis, development of local preparedness strategies is essential. This requires a good understanding of the hazard. An **official tsunami hazard map** provides all stakeholders with a crucial reference for development of preparedness strategies.

An official tsunami hazard map is needed as the basic reference and most important planning tool for developing evacuation strategies and maps for Cilacap district. The hazard map is also relevant for land use planning and development of mid-term measures to mitigate possible impacts of tsunamis. Publication of an official tsunami hazard map at district level **is the responsibility of local governments**.

This paper is a **technical document** that describes the process and the underlying technical concepts of hazard assessment and the mapping process. The maps have been developed in the framework of the establishment of the Indonesian Tsunami Early Warning System (InaTEWS).

The purpose of this document is to provide decision-makers in Cilacap with background information on the tsunami hazard mapping process. This information will support further discussions and help to initiate the legalization process of the maps. The maps described here are:

- A multi-scenario Tsunami Hazard Map for Kabupaten Cilacap, 1:100,000
- A detailed multi-scenario Tsunami Hazard Map for the City of Cilacap, 1:30,000

The maps show <u>two zones</u> based on wave height at coast (in line with the two warning levels of InaTEWS), the <u>probability</u> of areas being affected by a tsunami, and <u>estimated arrival times.</u>

The maps are the product of a multi-institutional effort including Cilacap government institutions, Indonesian science institutions and partners from the GITEWS (German-Indonesian Cooperation for a Tsunami Early Warning System) project. The institutions involved agreed on the mapping approach and methodology. The maps were produced by DLR (German Aerospace Centre). DLR and the German Technical Cooperation (GTZ) drafted the technical document. The Cilacap Working Group for Tsunami Hazard Mapping reviewed the document in August 2010. The document was updated to incorporate results from detailed inundation simulations in September 2010.

2. Background Information on the Tsunami Hazard Map for Kabupaten Cilacap

Tsunami occurrences in the southern coast of Java where Cilacap is located can be categorized as very frequent since the region of the plate boundary between the Australia plate and Sunda plate has a high seismic activity. The related subduction zone represents the main **source area for tsunamis** that might affect Cilacap. It should be expected that tsunami waves from this area will need only 50 to 100 minutes to reach the coast.

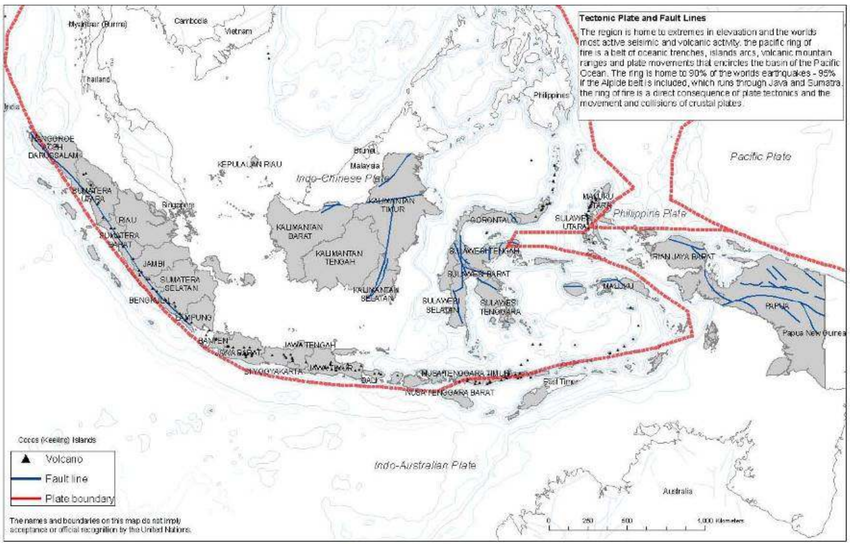


Figure 1: Source areas of tsunamis

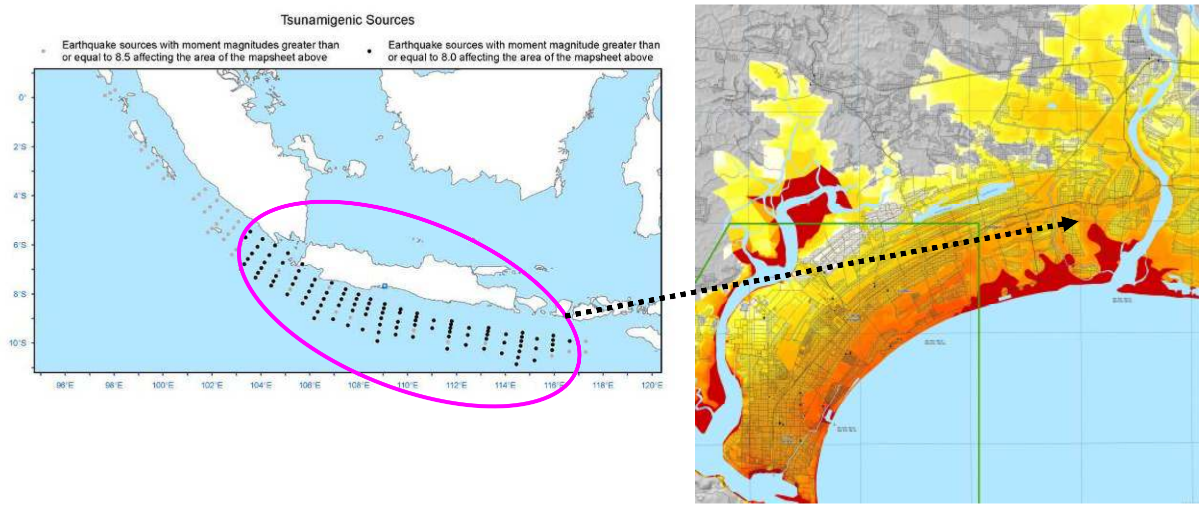
One of the biggest tsunami events in the recent past was the so-called Pangandaran tsunami after the destructive earthquake on 17 July 2006 with a moment magnitude of 7.7. The earthquake occurred as a result of thrust-faulting on the boundary between these plates and generated subsequent three to five meter high tsunami waves (Cousins et al., 2006) which struck the south coast of Java Island, Indonesia.

Beside the trust- faulting in the Sunda Trench, also submarine landslides could cause tsunami hazards in Southern Java. They are often associated with earthquakes and have then the potential to increase the energy of a tsunami. It is suspected, for example, that the extreme run-up of 20m at Permisan during the 2006 Central Java tsunami was caused by a landslide (Brune et al., 2010).

Every tsunami is different! Cilacap might suffer the impact of a smaller tsunami; but also the worst case might happen. Research on historical tsunami events provides important information 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** (USGS, 2006) and/ or can use mathematics to calculate potentially inundated areas using computerized **inundation modeling** tools.

A tsunami hazard map generally visualizes **tsunami- affected areas** in a given region. There are different types of hazard maps. In some cases, the maps show only the inundated areas of a tsunami that is considered as the **most probable scenario**. Other maps show the affected areas resulting from a number of (hypothetic) tsunami events. This is called a **multi-scenario approach** because it combines the inundated areas of a variety of tsunamis (or scenarios) in one map.

The tsunami hazard map presented here is a multi-scenario map based on tsunami modeling. It visualizes the impacts on the coastline of Cilacap of a large number of potential tsunamis caused by earthquakes of various magnitudes and originating from various locations within the subduction zone. It is important to note that the map does not take into account tsunami hazards related to submarine landslides and to volcanic activity as information regarding probabilities, occurrences and possible impacts of these kinds of tsunamis are very limited.



A number of hypothetical tsunami sources with different locations and earthquake magnitude were used process

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

Figure 2: Multi-scenario approach

This <u>tsunami hazard map is also zoned</u>; it groups all calculated scenarios into two zones. The red zone represents the area impacted by tsunamis with wave heights at coast between 0.5 m and 3 m. The orange and yellow zone represents areas impacted only by major tsunamis with a calculated wave height at coast of more than 3 m. This zone is displayed with a continuous color gradient representing decreasing probabilities (from orange to yellow) that a location will be inundated. Both zones are directly linked to the InaTEWS warning levels, as shown below:

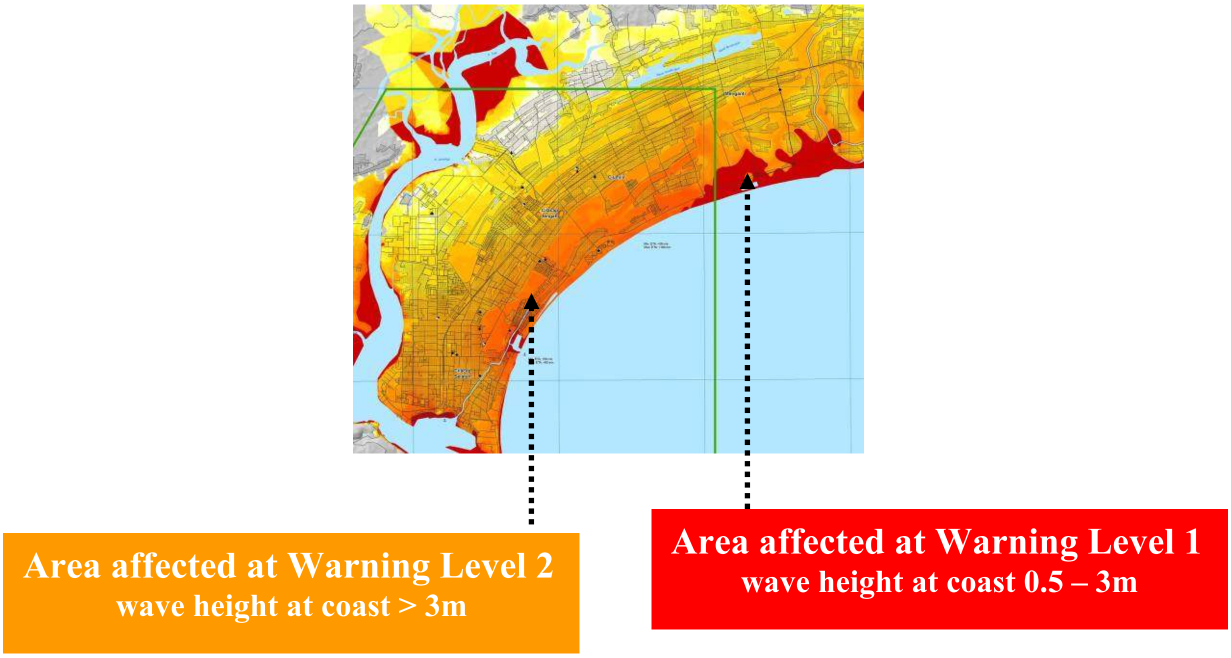


Figure 3: Zoning according to wave height and warning level

When assessing the tsunami hazard it is essential to talk about **probabilities**. Tsunamis are a typical example of **“low frequency, high impact”** disasters. In other words, 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 of destructive tsunamis can vary from 30-50 years or even 200-300 years. In Indonesia, most tsunamis are generated by seaquakes. Tsunamis triggered by volcanic activity are much rarer events. Smaller tsunamis happen more frequently than major tsunamis (and worst case tsunamis).

The multi-scenario hazard map provides information about tsunami probabilities. Red indicates the area that will be affected by tsunamis with a wave height between 0.5 m and 3 m. The range of colours from orange to light yellow indicates the probability of an area being affected by a major tsunami.

The colour gradient indicates the level of probability

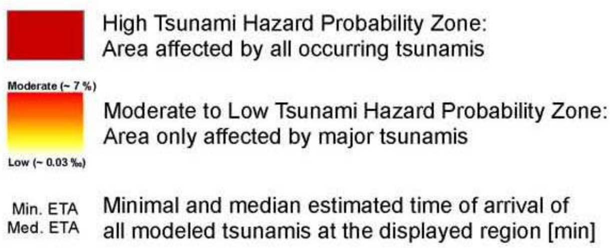


Figure 4: Visualization of probabilities on the map

The question of probabilities leads directly to discussion about acceptable risk. Due to the infrequent occurrence of tsunamis information about their possible impact, occurrence and run up heights is uncertain. It must be assumed that no action can take into account all possible risks, and that some degree of risk must be accepted due to economic reasons. The determination of an acceptable risk requires decisions that are often very difficult to make because they involve choices, trade-offs and uncertainties.

3. Background Information on the Mapping Process

3.1. German-Indonesian Cooperation in the Framework of InaTEWS

The German government supports the implementation of a tsunami early warning system in the Indian Ocean – especially in Indonesia – through the GITEWS project (German-Indonesian Cooperation for a Tsunami Early Warning System). Funded by the German Ministry of Education and Research (BMBF) GITEWS is part of a bilateral cooperation between the governments of Indonesia and Germany, based on a joint agreement between BMBF and the Indonesian State Ministry of Research and Technology (RISTEK). The warning concept which was developed under the guidance of the Potsdam Geo Research Centre (GFZ) and in cooperation with national and international partners will significantly reduce warning times by making use of real-time data transfer, predetermined flooding scenarios in coastal regions, and direct warning reports. The two-year operational phase of German support for InaTEWS began in November 2008.

The scope of this cooperation covers not only the technical aspects of the early warning system, but also hazard, vulnerability and risk assessment, production of maps for the project area, and capacity building. The German cooperation partner for hazard, vulnerability and risk assessments is the German Aerospace Centre (DLR). The cooperation is coordinated and developed within the framework of the Indonesian-German Working Group on Vulnerability Modelling and Risk Assessment (see section 3.2.).

Within the framework of local capacity building for tsunami early warning the German Technical Cooperation-International Services (GTZ IS) has been supporting the district government since early 2007 in the development of tsunami early warning procedures and mechanisms, clarification of roles in receiving and issuing warnings, and in overall preparedness planning. This cooperation is based on agreements with the district government.

3.2. Indonesian-German Working Group on Vulnerability Modelling and Risk Assessment

Risk and vulnerability assessment is an important component of an effective tsunami early warning system, and contributes significantly to disaster risk reduction. Knowledge of exposed communities, their vulnerabilities, and coping and adaptation mechanisms, is a precondition for the development of people-centred warning structures, local evacuation planning and recovery planning. In the past, the vulnerability was quantified based on economic damage assessments. However, based on the three pillars of sustainable development, this working group applied indicators for physical and social, as well as economic, dimensions of vulnerability.

The approach has been developed within the framework of the joint Indonesian-German Working Group on Vulnerability Modelling and Risk Assessment which is coordinated by the Indonesian Institute of Science (LIPI) and the German Aerospace Centre (DLR) with contributions from Indonesian, German and international organizations, such as LAPAN, BAKOSURTANAL, BPPT, DKP, AWI, GKSS and UNU-EHS. Its goal is to develop indicators to assess the vulnerability of coastal areas of Sumatra, Java and Bali exposed to tsunami hazard on a broad scale; and on a more detailed scale of three pilot areas of Padang, Cilacap and Kuta. The major task is to conduct hazard assessments, physical and socioeconomic vulnerability assessments, and to produce risk and vulnerability maps and guidelines for decision makers on how to monitor risks and carry out continuous risk assessment, for effective early warning and disaster mitigation strategies.

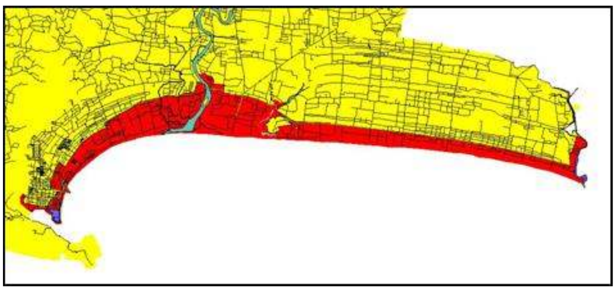
3.3. Tsunami Hazard Mapping within the Framework of GITEWS

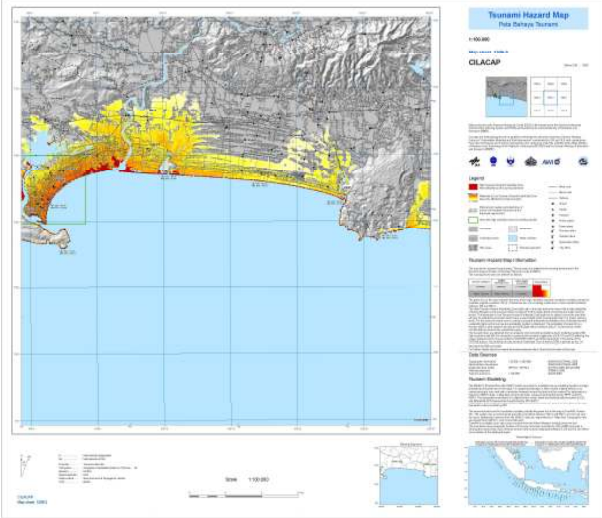
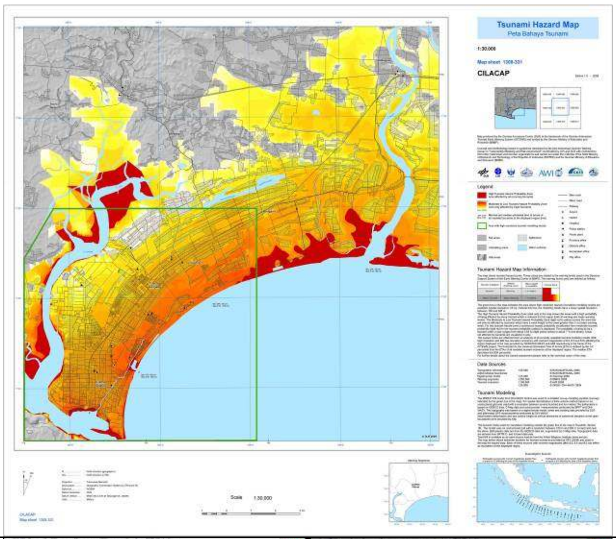
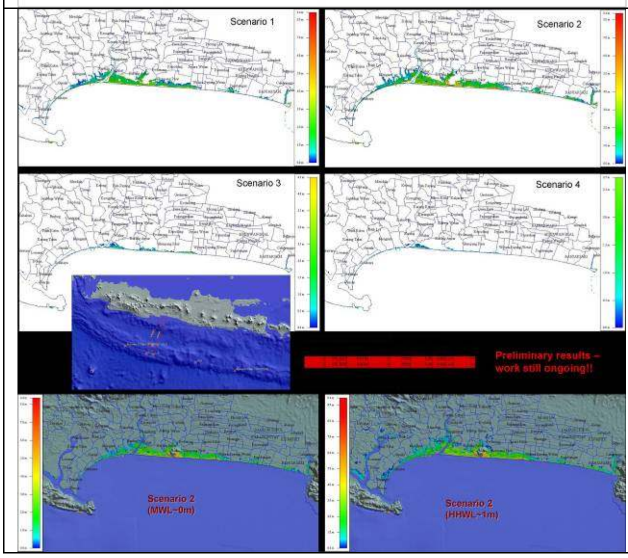
Within the framework of the GITEWS project, small-scale hazard maps (1:100,000) are produced, covering the whole west and south coast of Sumatra as well as the south coasts of Java and Bali. Additionally, detailed hazard maps (1:25,000 – 1:30,000) are produced for the three pilot areas of Padang, Cilacap and Kuta. During three workshops conducted in Indonesia, with participants from national and local government and research groups from various institutes, the layout and the content of the hazard and risk maps were discussed and agreed.

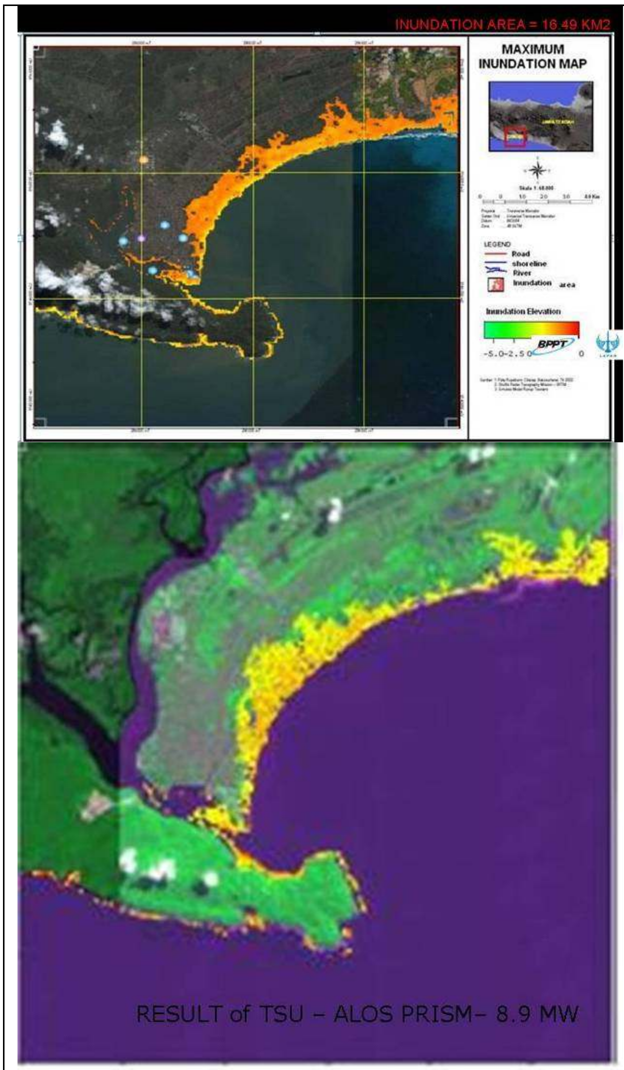
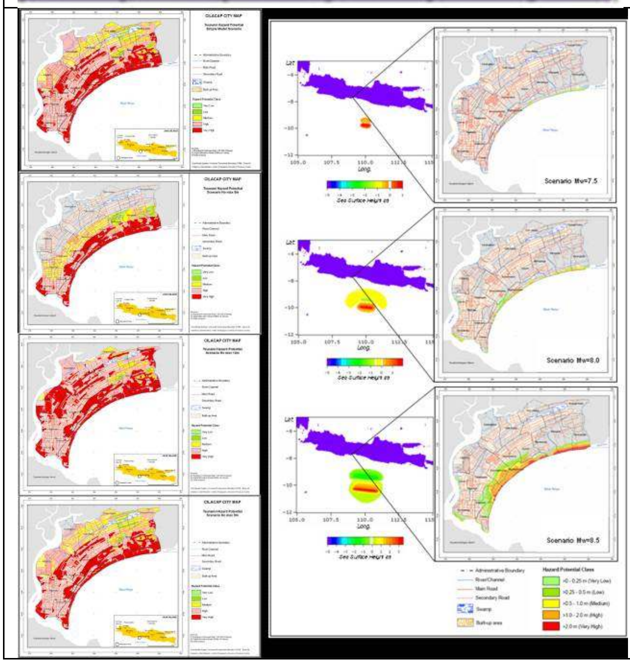
3.4. The Tsunami Hazard Mapping Process in Cilacap

Tsunami hazard information for Cilacap addresses specific planning needs within disaster management as it is a precondition for e.g. evacuation and spatial planning. Many national and international institutions worked on the hazard assessment for Cilacap within the last years. The outcomes of these efforts are various mapping products based on different approaches and covering different areas (see Table 5).

Table 1: Hazard assessment results presented and discussed during workshop

 	**Tsunami Hazard map – Cilacap Working Group** • Hazard mapping based on “low-tech” method. • Takes geomorphological features, elevation and distance to the coast relations into account • No tsunami modelling results included • Zones (red and yellow) areas correspond to BMKG warning level • Technical documentation available

  	**Tsunami Hazard maps – GITEWS** • Two scales: broad-scale 1 : 100 000 and detailed scale 1 : 30 000 • Shows the probability of tsunami occurrence and the endangered area on land. • Shows the estimated time of tsunami arrival in minutes • Hazard zones related to early warning information issued and defined by BMKG • Technical documentation available
 	**Tsunami Hazard map – BPPT** • Based on tsunami modelling • Shows 4 different scenario results representing different source locations with Mw 8.0. • Preliminary result - will be updated (as in December 2009).

	**Tsunami Hazard maps - LAPAN** • Based on single modelled tsunami scenario produced by BPPT • 8.9 Mw Earthquake as worst case scenario • Modelling results shown on top based on SRTM elevation data, result shown below based on elevation data generated from ALOS data (better spatial resolution)
	**Tsunami Hazard maps – UGM** • <u>Left side:</u> Based on geomorphological features and anticipated inundation for wave heights of 5, 9, 12 meter • <u>Right side:</u> Results based on tsunami modelling. Single scenario results for Mw 7.5, 8.0 and 8.5 on same source location

From 30.11 – 02.12.2009, a workshop took place in Cilacap. The workshop was a joint activity involving Indonesian and German research institutions and universities. It was the 7th workshop conducted in the frame of the joint Indonesian-German working group on risk modelling and vulnerability assessment. The workshop was opened by his Excellency Vice Bubati H. Tatto Suwarto Pamuji and Head of BPBD Dangir Mulyadi, S. Sos, M. Si stating the strong need to use Tsunami Risk Assessment for disaster management purposes.

A main topic of this workshop was to compare and discuss the hazard assessment results from the different institutions (see table 5) with the aim to harmonize results to be used for further planning by local authorities and to suggest an official hazard map for Cilacap district.

During the workshop, the involved Indonesian and German institutions recommended the GITEWS multi-scenario product as the official tsunami hazard map for Cilacap. This recommendation was based on the fact that current scientific knowledge is unable to identify the most probable scenario. A multi-scenario approach combines the impacts of a large number of calculated tsunami scenarios (generated by numeric modelling) on one map giving the probability that a specific point on land is actually affected by a future tsunami. A further decisive factor for this recommendation was the fact that the GITEWS map incorporates all scenarios modeled by the various institutions which are mainly based on single worst case scenarios. Additionally, this multi-scenario map also includes two hazard zones corresponding to the BMKG warning levels. But it was asserted that an official hazard map for Cilacap has to cover the whole Kabupaten Cilacap in order to enable further planning based on the hazard map for the whole district.
In April 2010 a further meeting between representatives of the Cilacap Working Group, DLR and GTZ-IS took place. The intention of this meeting was to finally discuss specific requirements for the hazard map, documentation issues and further steps regarding the official legalization process. During the meeting the GITEWS hazard map was finally suggested as official hazard map for Cilacap, provided that

- the tsunami hazard map will cover the entire Kabupaten Cilacap
- the map will be updated with new available tsunami scenarios (if any)

- a detailed technical documentation for the hazard map will be available

Finally it was concerted to conduct a seminar as soon as possible to share the suggested GITEWS hazard map to the relevant local stakeholders prior to the legalization of the map.

4. Methodology

The approach used for developing the tsunami hazard map is a combination of the results of probability analyses and multi-scenario tsunami modelling. A large number of realistic tsunami scenarios, using various tsunami source locations and earthquake magnitudes along the Sunda Trench, have been calculated. Together, these scenarios cover the entire Indian Ocean coast of Sumatra, Java and Bali. These scenarios were used as input data for the hazard maps. The approach is based on an “logic tree technique”, which takes into account the various warning levels that are issued from the Tsunami Warning Centre. The warning levels defined in the InaTEWS (BMKG 2008) are as follows:

Tsunami Category	Warning Level	Wave height (WH) Range [m]
<none>	<none>	0.0 = WH < 0.1
Minor Tsunami	Advisory	0.1 = WH < 0.5
Tsunami	Warning	0.5 = WH < 3.0
Major Tsunami	Major Warning	WH ≥ 3.0

Figure 5: InaTEWS warning levels (BMKG 2008)

A minor tsunami of the Advisory warning level causes little or no inundation at the coast. Hence, in this hazard mapping approach, the “advisory” and “warning” warning levels are combined. The approach used to produce a comprehensive tsunami hazard probability map involves six steps:

1. Determine the tsunami scenarios that are relevant to the target area:

As a first step, all the scenarios that are relevant to the target area are selected from the tsunami scenario database. This involves running a spatial data query and selecting all scenarios that result in inundation of at least one point on land in the target area (e.g. using a map). The selected scenarios provide the basis for the further assessment.

2. Group the scenarios by warning level:

The second step is to group all selected scenarios into two categories of warning level. A database query asking "Which scenarios generate a wave height at coast over 3 m?" is performed. Defining the outline of the consolidated inundation of the classes produces a first map showing maximum inundation areas for each of the warning levels (Figure 6). On the final hazard map, only the zone generated by the class "wave heights at coast ≤ 3 m" is displayed (red zone in Figure 7). The other zone is substituted by a calculation of continuous tsunami impact probabilities which is described in the steps below.

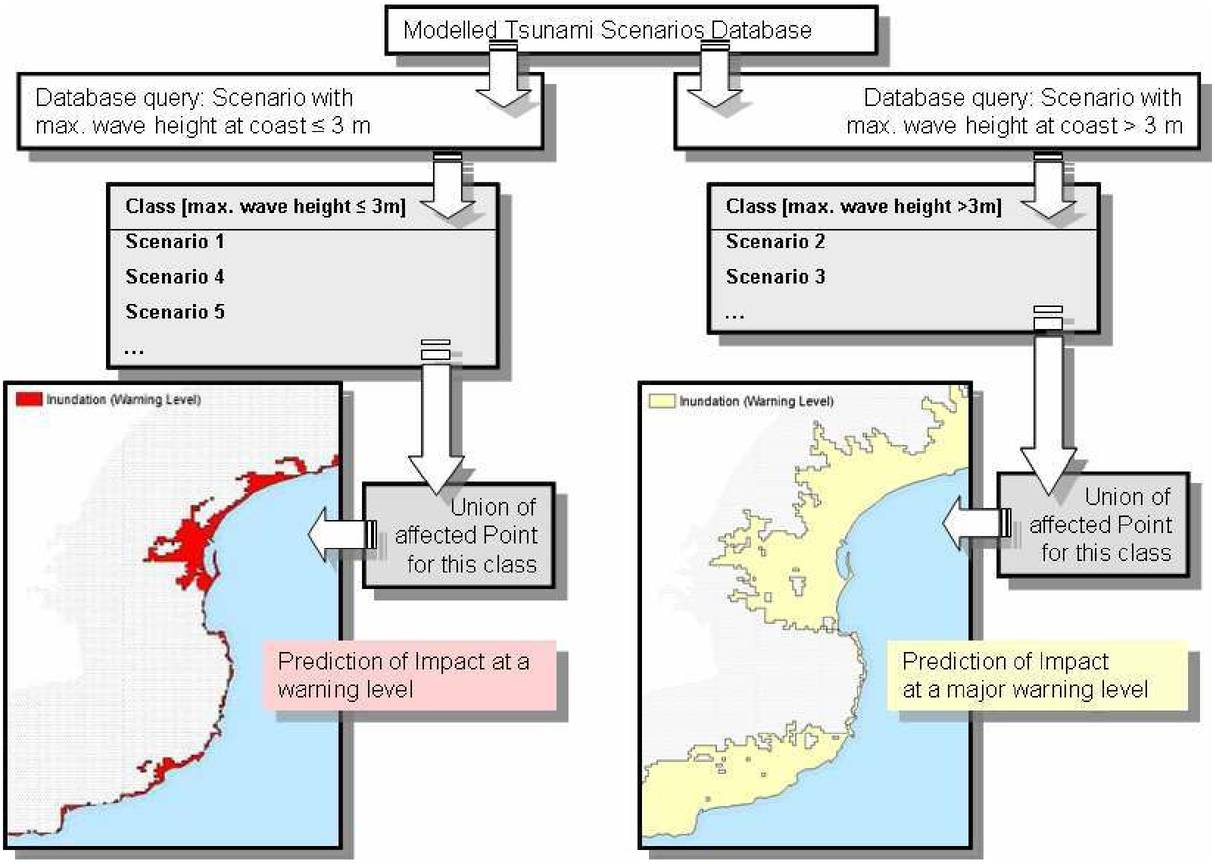


Figure 6: Grouping of tsunami modelling results by warning level

3. Estimate the spatially distributed probability of earthquakes of specific magnitudes along the Sunda Trench:

Due to the fact that submarine earthquakes of high magnitudes occur far less frequently than earthquakes of lower magnitudes, scenarios with higher earthquake magnitudes (moment magnitude M_w) must given a lower weighting in the analysis, since the probability of a higher magnitude earthquake occurring is lower. Similarly some regions along the Sunda Trench show higher seismic activity than other regions, and some spots are characterized by special geologic conditions such as a strong coupling of the plates in the subduction zone which means there is a higher probability of the occurrence of high magnitude earthquakes. This means that inundation by a tsunami event caused by an earthquake with a high magnitude at a region with low seismic activity is less likely than a tsunami event caused by a lower magnitude earthquake in an earthquake hot spot. Therefore, a probability analysis of earthquake occurrence must be performed.

This analysis involves two steps. First, the Sunda Trench region is divided into three smaller zones, by seismic activity (these have been widely published, e.g. Latief, Puspito & Imamura 2000, and can be also determined by a statistical analysis of historical earthquake data). The probability of an annual recurrence of an earthquake of each Mw is estimated using historical earthquake data (NEIC). To improve the analysis, topical investigations such as deterministic models are considered by weighting the occurrence probabilities between 1 (for a known hot spot where the probability of the occurrence of an earthquake of high magnitude is high) and 0.1 (for unidentified or “inactive” spots). Figure 8 presents an example of the results of weighted earthquake occurrence probability for a specific Mw. Thus, each tsunamigenic source has an individual occurrence probability (Note that the probability of an earthquake also generating a significant tsunami is included in the numerical tsunami model approach).

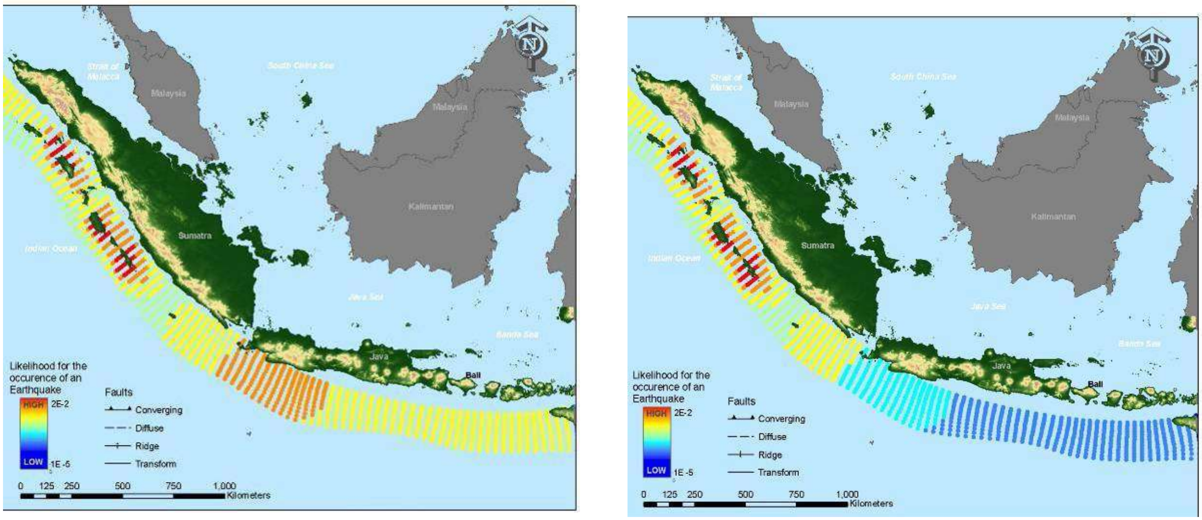


Figure 7: Analysis of the spatially differentiated probabilities of the occurrence of an earthquake of a specific magnitude along the Sunda Trench (left figure: Mw 8.0, right figure: Mw 9.0)

4. Determine the spatially differentiated inundation probability:

This step involves determining a spatial differentiation for the probability of a point on land being inundated (spatial inundation probability). The results of the modelled tsunami scenarios include their impacts on land, i.e. the area on land that will be inundated as a result of a tsunami originating from specific location and of a specific magnitude. The impacted areas of the various scenarios may, of course, overlap each other (either because the tsunami source locations are close in proximity or because they originate from same location and the scenarios differ only in terms of the magnitude of the submarine earthquake). Hence every point on land may be inundated several times in different scenarios. As a general example, a point near the coast is more likely to be frequently inundated than a point far away from the coast. Calculation of the inundation probability in a coastal area is represented by points on a grid, about 100 m apart. So, for each point on the grid (every 100 m point inland along the whole coast), the number of scenarios that hit that point is calculated. For these selected scenarios the occurrence probabilities of their tsunami source (estimated in step 3) are summed up and divided by the amount of scenarios. Hence, the occurrence probability represents the probability that this point will be hit by a tsunami within a year. Figure 8 shows the query for the relevant scenarios and the total of the probabilities at one point on land. For display on a hazard map, the discrete points on land are interpolated.

Figure 9 summarises the workflow for producing tsunami impact probability maps using the event tree technique.

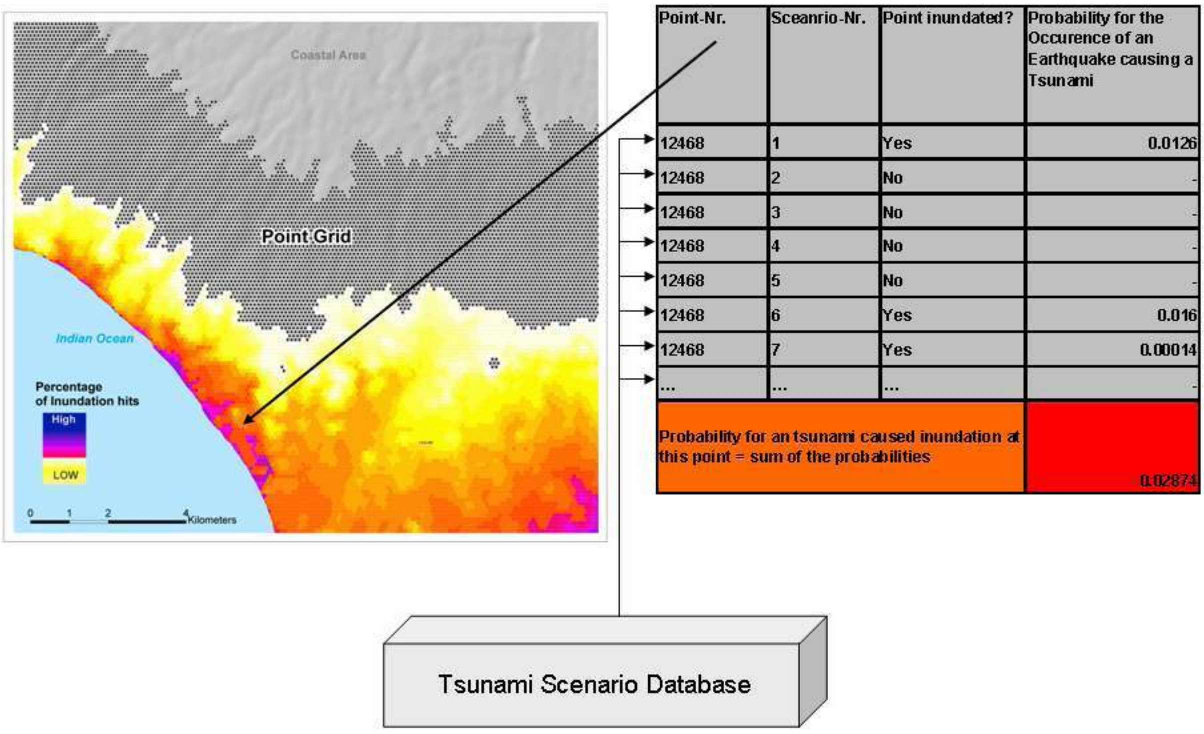


Figure 8: Example of the calculation of the inundation probability for one point on land

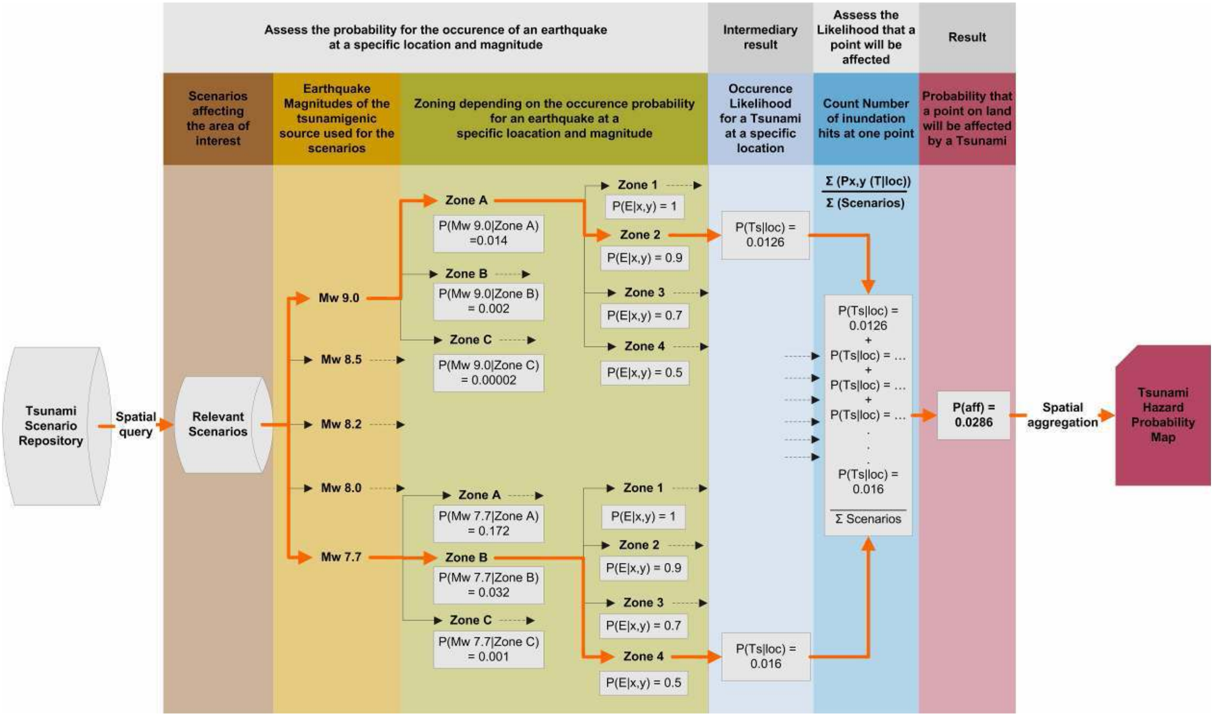


Figure 9: Overview of the workflow for processing the hazard probability maps

Using this approach, continuous hazard probabilities are obtained. The hazard maps show only the probabilities for the major warning zones (moderate to low probability). The areas that will be affected in a 'warning level' situation are displayed on the hazard maps as red zones. The zone is derived as described in Step 1.

5. Combine the continuous probability with the "warning level" zone:

In this step, the "warning level" zone derived in step 2 is overlaid on the continuous tsunami impact probability on the hazard map.

6. Add additional parameters to the map:

To supplement the information on the inundation areas, additional parameters are incorporated into the hazard map that characterize the potential tsunami danger of a coastal area. Each modelled scenario includes the estimated time of arrival (ETA) of the first tsunami wave hitting the coast. The ETA can vary to a great extent, depending, in general, on the distance from the coast to the tsunamigenic source and the magnitude of the earthquake. To provide a valid value for the ETA from all possible scenarios, two values are shown on the hazard map. "Min. ETA" represents the minimum ETA from all possible scenarios. This is the worst case for that specific coastal location on the map. But as this can be a very rare event, “med. ETA” is also stated on the map. This value is the median of the minimum ETAs of the scenarios for that area. These values can be taken as an estimate of the available time to respond after the earthquake event happened (see Figure 10).

Figure 10: Example of the ETA values displayed on the hazard maps.

The tsunamigenic sources relevant to the area are also displayed on the hazard map. They are divided into sources of high magnitude earthquakes (which are widely dispersed along the Sunda trench) and sources of lower magnitude earthquakes (which are generally closer to the region in focus). This information can be used to assess whether an earthquake will likely result in a tsunami affecting the area on the map (see Figure 11).

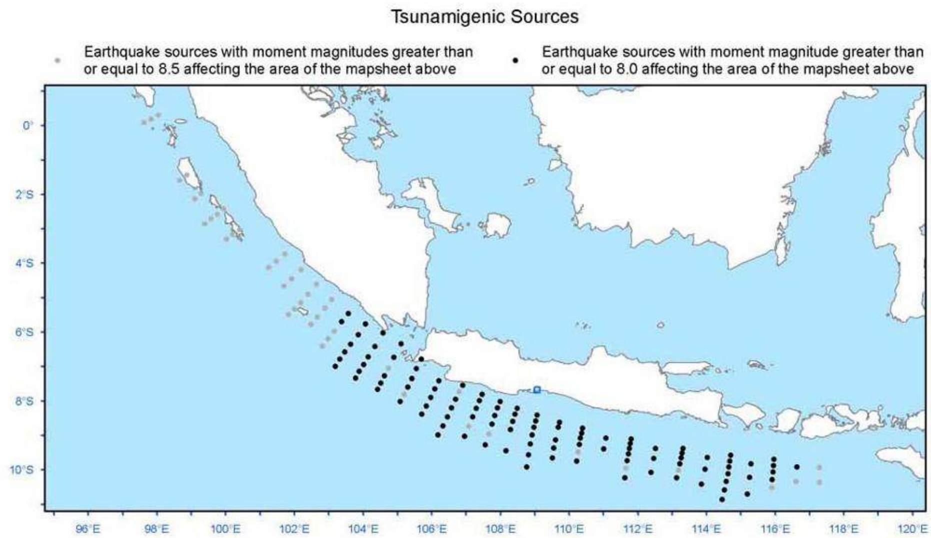
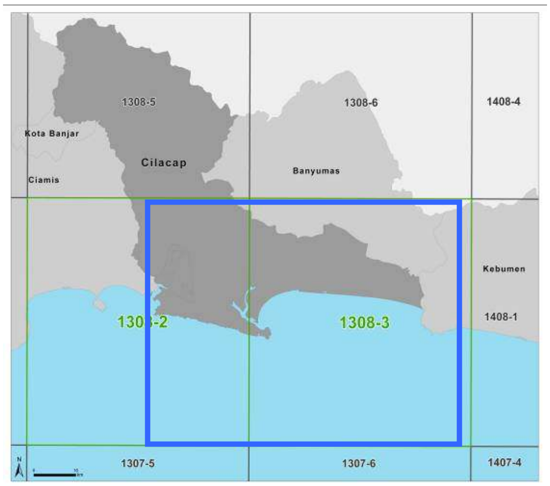


Figure 11: Example of tsunamigenic sources displayed on the map.

5. The Maps

A Small Scale Tsunami Hazard Map (1:100,000) is available for the entire coastline of Cilacap district. The database for this approach consists of the results of the tsunami modelling performed by GITEWS partner AWI (Alfred Wegener Institute) at epicentre locations (source grid) for tsunami scenarios provided by GFZ (German Research Centre for Geosciences, 2008). The area modelled covers the south coasts of Sumatra, Java and Bali and considers earthquakes with moment magnitudes of 7.5, 7.7, 8.0, 8.2, 8.5 and 9.0. The datasets used are global coverage GEBCO data (bathymetry data) and global coverage SRTM data (topography data). The results of the tsunami modelling based on these global datasets provide a level of detail usable only for maps of a scale of 1:100,000 or below which are suitable to provide tsunami hazard information at district level. It must be made clear that the hazard assessment results based on these input data only provide coarse information on potentially inundated areas in Cilacap district. Therefore the large-scale tsunami hazard map is intended to be an indication for areas potentially affected by a tsunami and is not recommended as a detailed planning basis for disaster management.



Available tsunami hazard map at a scale of 1 : 100 000 for Cilacap district (Kabupaten). Numbers and locations of map sheets and map numbers are based on National Coordinating Body for Survey and Mapping reference system (BAKOSURTANAL)

Available tsunami hazard map at a scale of 1 : 30 000 for the City of Cilacap.

Figure 12: Available tsunami hazard maps for Cilacap in different scales

For the City of Cilacap a **detailed Tsunami Hazard Map** of a scale of 1:30 000 was produced.

The method used to produce this hazard map is the same as for the 1:100 000 hazard map series. For detailed inundation modelling the MIKE21 FM model from DHI-WASY GmbH was used, and run-up modelling was performed by GKSS and DHI-WASY. Initial bottom deformation and sea surface height as well as time series of water level elevation at the open boundaries were provided by AWI and GFZ in the frame of the GITEWS project. Spatial resolution used in modelling is between several hundreds of meters to ten meters, allowing for representation at a map scale of 1 : 30,000. The number of tsunami inundation scenarios used was 300 with moment magnitudes of 8.0, 8.5 and 9.0. The bathymetry is based on GEBCO data, C-Map data and echosounder measurements performed by BPPT and DHI-WASY. The topography is based on digital surface model, street and building data, provided by DLR, and differential GPS measurements performed by DHI-WASY.

Both for the large-scale and the detailed scale tsunami hazard map, it has to be pointed out that the provided hazard information **are based on modelling results** which naturally disclose forecast uncertainties. Hence, the hazard maps have only to be seen as best available reference information for the development of local specific disaster preparedness, adaptation and mitigation strategies, **always considering that modelling results will differ from reality.**

The Large Scale Tsunami Hazard Map (1:100,000)

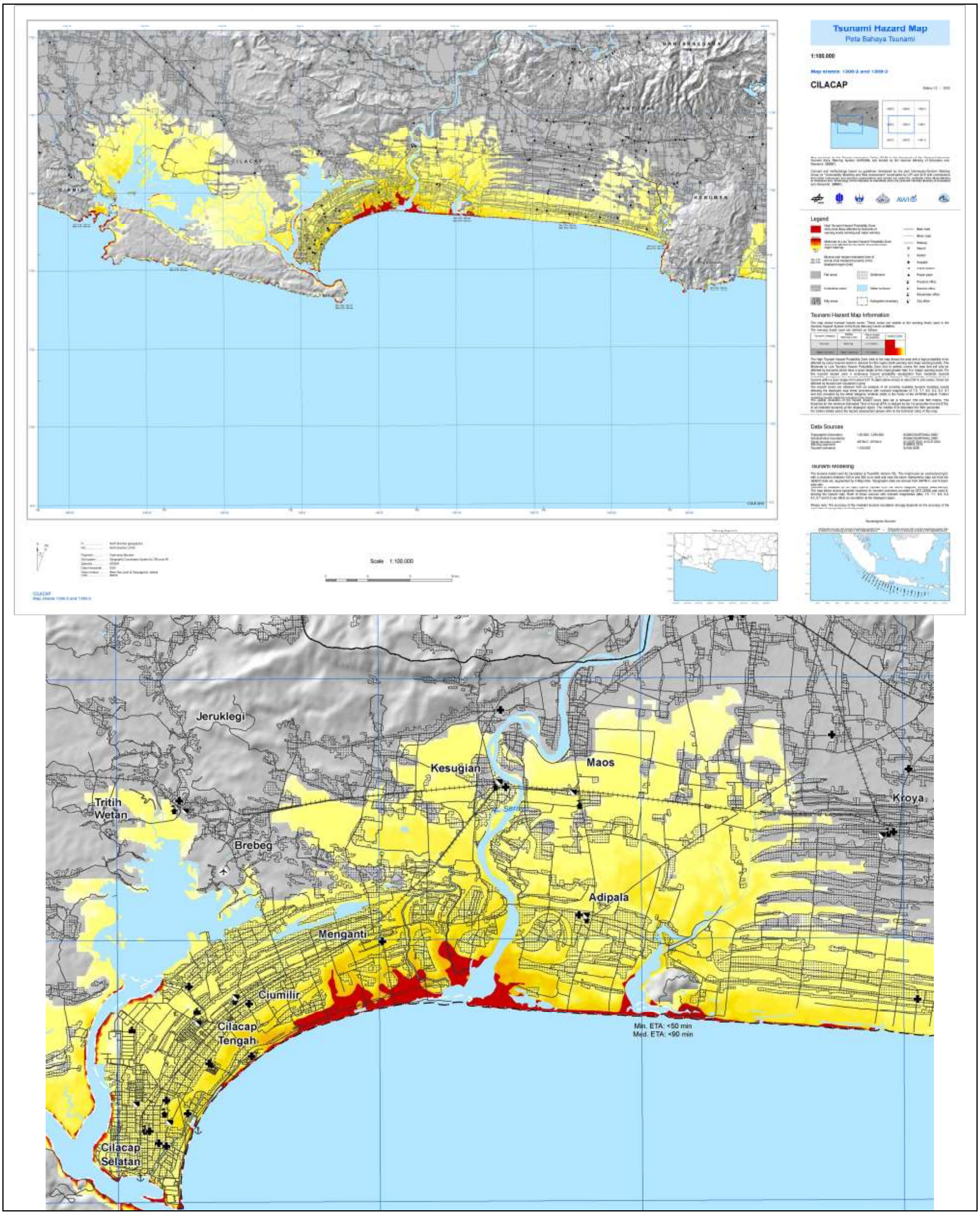


Figure 13: Tsunami Hazard Map of a 1 : 100 000 scale

(Only tsunamis from Subduction Zone source area!)

The Detailed Tsunami Hazard Map (1:30,000) City of Cilacap

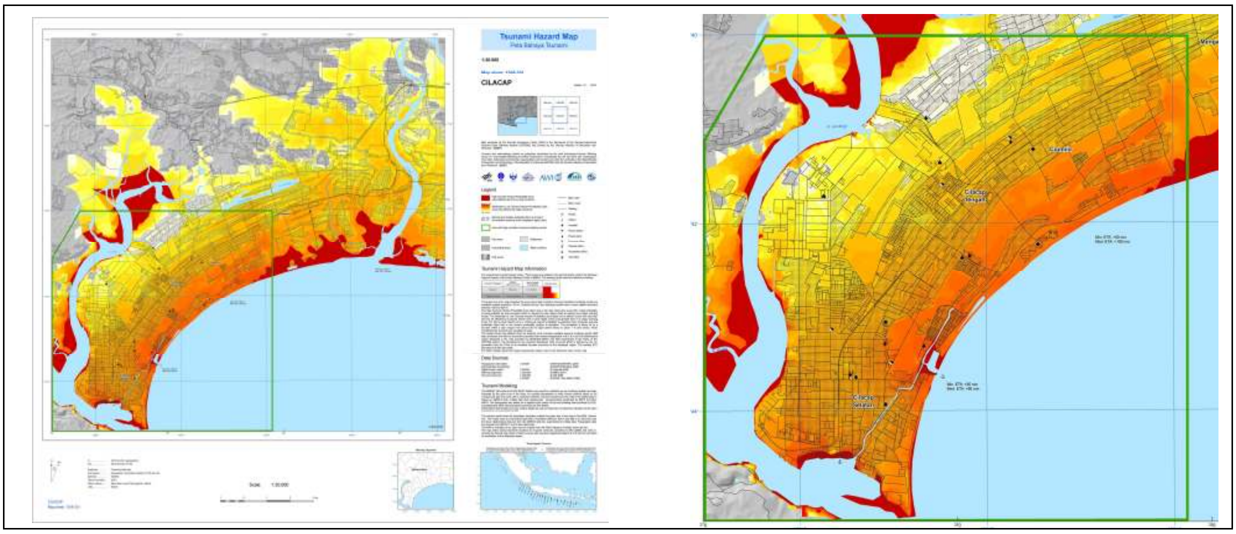


Figure 14: Hazard map of a 1:30,000 scale, based on detailed topographic and bathymetric data (only in the green box)

(Only tsunamis from Subduction Zone source area!)

6. Definitions

This section presents commonly used terms and definitions that are used throughout this document. The terms correspond with those in the UNESCO-IOC Tsunami Glossary.

Tsunamigenic source: Source causing a tsunami. In this context, a location of a submarine earthquake of a specific magnitude.

Tsunami inundation area: Area flooded with water by a tsunami

Estimated Time of Arrival / Tsunami Arrival Time (ETA): Time taken for a tsunami to arrive at a specific fixed location, estimated by modelling the speed and refraction of the tsunami waves as they travel from the source. ETA can be estimated with very good precision (+/- 2 minutes) if the bathymetry and source are well known. The first wave is not necessarily the largest, but one of the first five waves usually is.

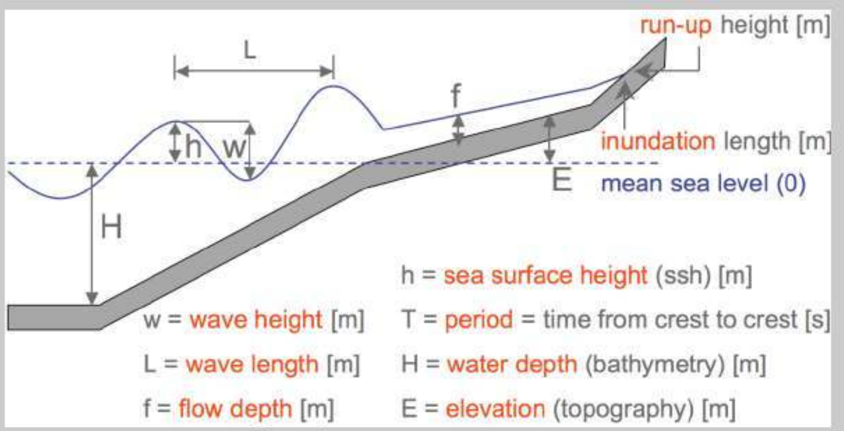


Figure 2. Terms and Definitions

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

Elevation (topography): The land elevation above mean sea [m].

Flow depth: The water depth above land surface in case of inundation, and is a time dependent value, given in meters [m].

Wave height: The height of a wave from crest to trough in meters [m].

Inundation length (inundation distance): The distance from shore inundated by water, given in meters [m]. Inundation is usually defined as at least 10 cm flow depth.

Run-up height: The height above mean sea level at the line of inundation, given in meters [m].

7. Abbreviations

AWI	= Alfred Wegener Institute
BAKORSURTANAL	= Badan Koordinasi Survei dan Pemetaan Nasional (National Coordinating Body for Survey and Mapping)
BAPPEDA	= Badan Perencanaan Pembangunan Daerah (Local Planning Board)
BMBF	= German Ministry of Education and Research
BMKG	= Badan Metereologi dan Geofisika (National Agency for Meteorlogy, Klimatology, and Geophysics)
DHI	= DHI-WASY GmbH
DKP	= Departemen Kelautan dan Perikanan (Department for Marine and Fisheries)
DLR	= German Aerospace Center
ETA	= Estimated Time of Arrival
GFZ	= German Research Centre for Geosciences
GKSS	= Research Center Geesthacht
GITEWS	= German-Indonesian Tsunami Early Warning System
GTZ	= German Technical Cooperation
GEBCO	= General Bathymetric Chart of the Oceans
KESBANGPOLLINMAS	= Kesatuan Bangsa, Politik, dan Perlindungan Masyarakat (Civil Defence)
InaTEWS	= Indonesian Tsunami Early Warning System

LAPAN	= Lembaga Penerbangan dan Antariksa Nasional (National Aeronautics and Space Institute)
LIPI	= Lembaga Ilmu Pengetahuan Indonesia (Indonesian Institute of Sciences)
PMI	= Palang Merah Indonesia (Indonesian Red Cross)
PU	= Pekerjaan Umum (Public Works)
RISTEK	= Kementrian Negara Riset dan Teknologi (State Minister of Research and Technology)
SRTM	= Shuttle Radar Topographic Mission
SR	= Skala Richter (Richter Scale)
TNI	= Tentara Nasional Indonesia
UNU-EHS	= United Nations University –Environment and Human Security

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