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Initial Tsunami Levels in the East Luzon Trough (Philippines) from 1 in 100 Year and 1 in 1000 Year Return Period Earthquakes

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ABSTRACT

A major earthquake in the East Luzon Trough in Philippines cannot be ruled out. In this paper initial tsunami levels from the earthquake parameters by Salcedo [1] have been generated. The initial tsunami levels from an 1 in 100 year return period earthquake have been generated to support design of marine structures and facilities. Initial tsunami levels from an 1 in 1000 year return period earthquake have also been generated to support emergency and rescue planning and operation. The initial tsunami levels have been generated using the MIKE21 Toolbox developed by DHI [2]. These initial tsunami levels can be used to drive a tsunami propagation model to derive tsunami levels, arrival time and forward velocity at anywhere around the East Luzon Trough region. The methodology described in this paper for generating initial tsunami levels in the East Luzon Trough could also be applied to this type of events at other sites around the world.

Key words: Tsunami, Natural Hazards, East Luzon Trough, Numerical Modelling, Port Development, Royal HaskoningDHV

1. INTRODUCTION

1.1 The Trenches in Philippines

Philippines is located in an active seismic zone. Both inland and offshore earthquakes are generated in the Philippines seismic regions generating tsunamis.

Known trenches in the Philippines [3] are:

1) Manila Trench
2) East Luzon Trough
3) Philippine Trench
4) Negros Trench
5) Sulu Trench
6) Cotabato Trench

These trenches are shown in Figure 1 from Tongkul *et al* [4].

1.2 East Luzon Trough

East Luzon Trough (or East Luzon Trench) is a west-dipping subduction zone in the east of Luzon Island in Philippines. It is believed to be a part of the Philippine Trench.

1.3 Previous Studies on the East Luzon Trough

Salcedo [1] provided a set of earthquake source parameters for events which can occur in subduction zones surrounding the Philippines and cause large tsunamis and damages. Salcedo [1] identified six source regions (Manila Trench, Negros Trench, Sulu Trench, Cotabato Trench, East Luzon Trough, and the Philippine Trench) surrounding the Philippines. The East Luzon Trough was considered as one segment (ELT with Mw 8.5). The earthquake source parameters such as fault location (longitude, latitude, depth), fault length, fault width, strike angle, dip angle, rake angle and slip amount as well as the maximum plausible earthquake magnitude for each fault segmentation were provided.

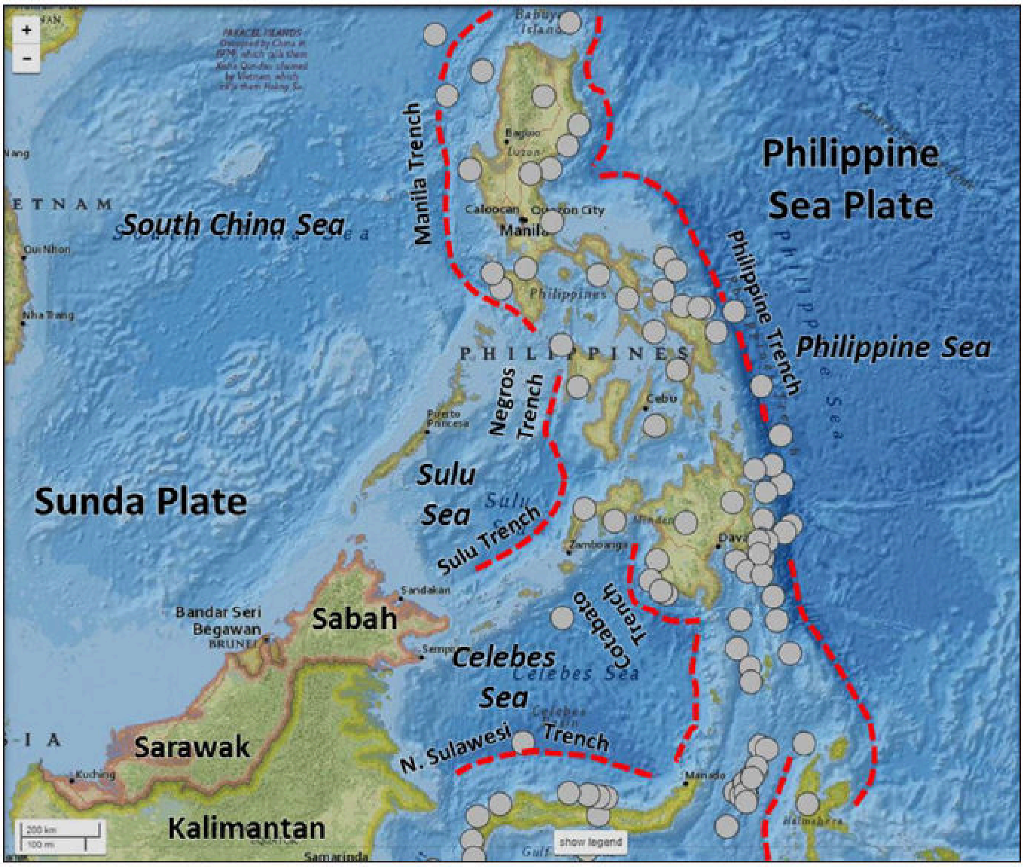

Fig. 1 Location of trenches around the Philippines [4]

1.4 The Present study

In this paper initial tsunami levels from the earthquake parameters by Salcedo [1] have been generated. The initial tsunami levels from an 1 in 100 year return period earthquake have been generated to support design of marine structures and facilities. Initial tsunami levels from an 1 in 1000 year return period earthquake have also been generated to support emergency and rescue planning and operation.

The general definition of tsunami level and tsunami wave height is illustrated in Figure 2. The flowchart in Figure 3 illustrates the steps and the software involved in a typical tsunami modelling study. The MIKE21 Toolbox was used to generate the initial tsunami levels.

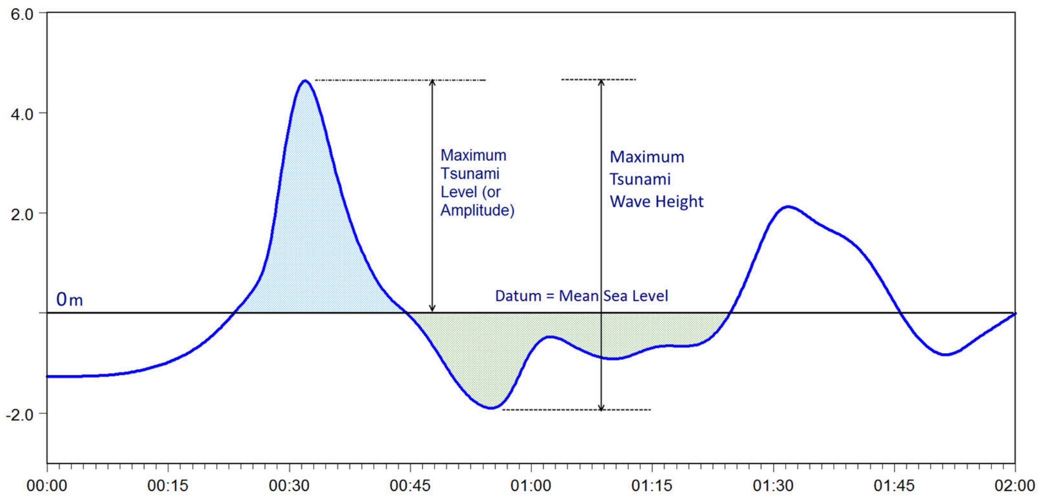

Fig. 2 General definition of tsunami level and tsunami wave height

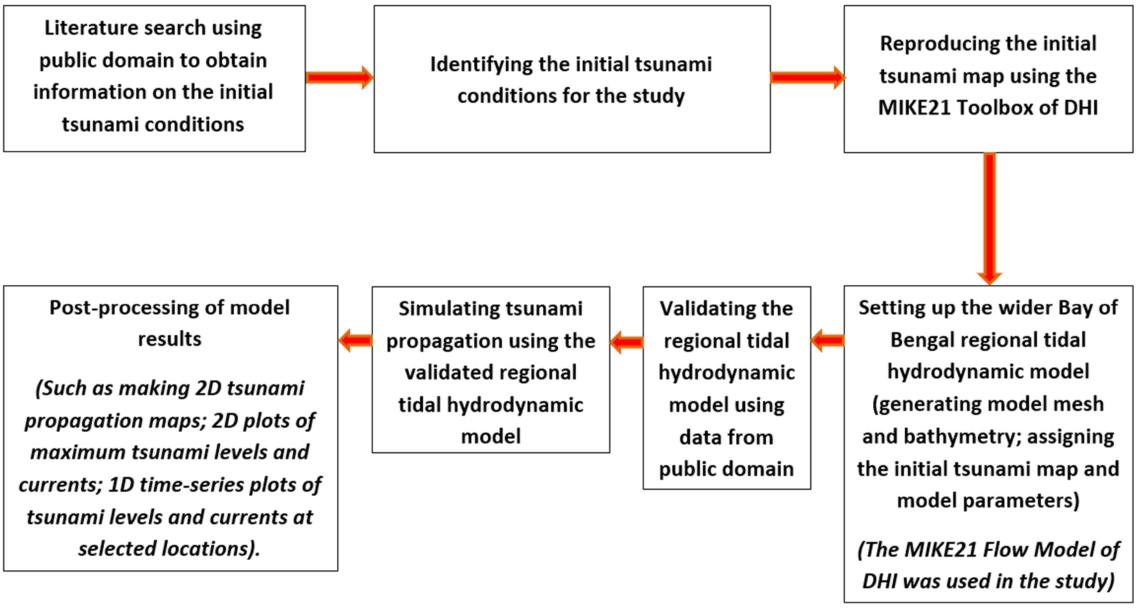

Fig. 3 Steps and software used in a typical tsunami modelling study

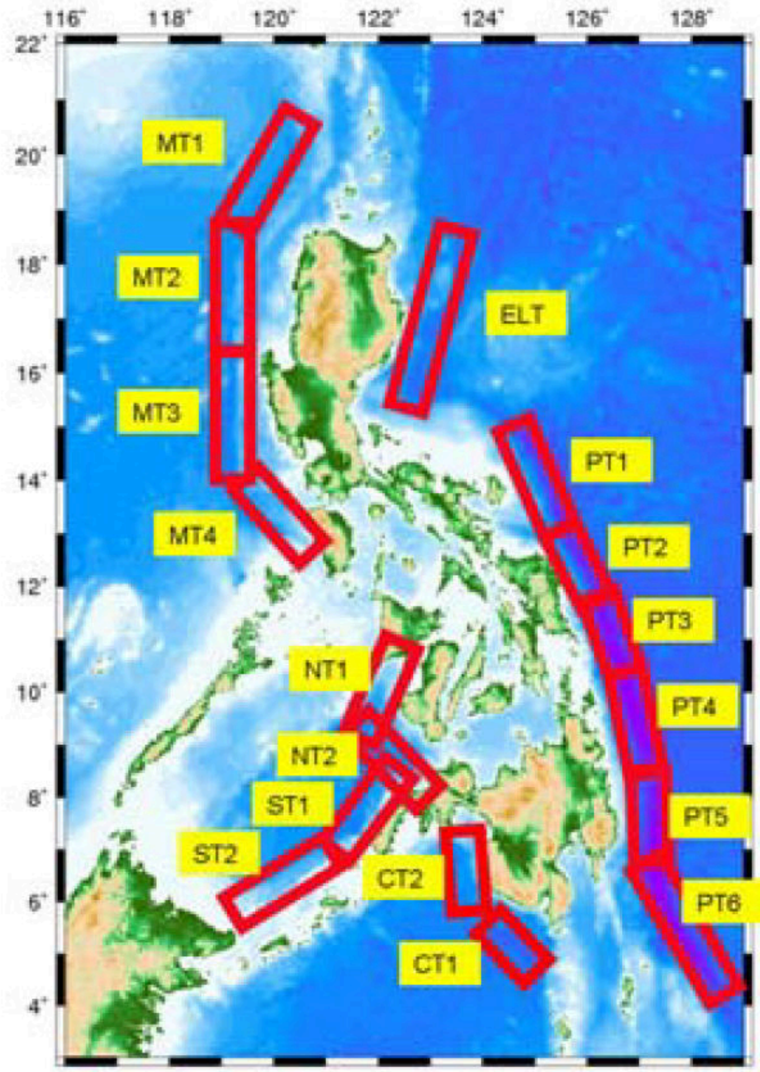

Fig. 4 Sub-fault distribution of the trenches around the Philippines from Salcedo [1]

2. SELECTION OF EARTHQUAKE PARAMETERS

2.1 Fault Parameters of the East Luzon Trough

The East Luzon Trough was considered as one segment (ELT) (as in Figure 4) by Salcedo [1] following the segmentation given by Bautista and PHIVOLCS-DOST [5]. The fault parameters from Salcedo [1] are provided in Table 1. The coordinates of the corner location of the fault are shown in the table 1.

Table -1 Fault parameters of the East Luzon Trough from Salcedo [1]

Sub-faults	Mw	Latitude (°N)	Longitude (°E)	Length (km)	Width (km)	Depth (km)	Slip (m)	Strike (°N)	Dip (°)	Rake (°)
ETL	8.5	18.2	124.2	317	100	60	4.44	200	37	89

2.2 1 in 100 Year Fault Parameters of the East Luzon Trough (Mw 8.5)

Tsunami levels and forward velocity for an 1 in 100 year return period earthquake are required for designing marine structures and facilities. Therefore, initial tsunami levels were generated for an 1 in 100 year earthquake.

The earthquake magnitude (Mw) for various return periods for Philippines were obtained from Rong et al. [6] and are provided in Table 2 and shown in Figure 5.

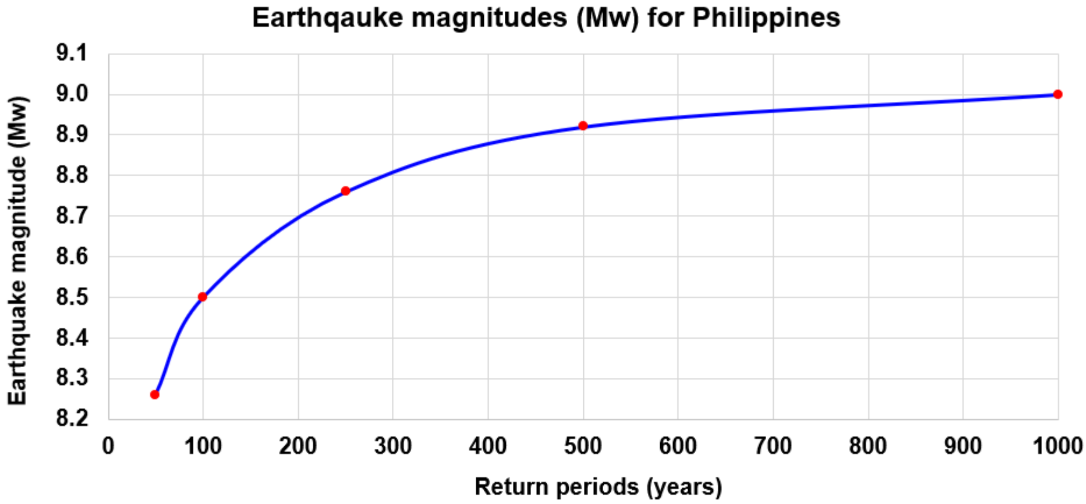

Fig. 5 Earthquake magnitudes (Mw) in Philippines for various return periods [6]

Table -2 Earthquake magnitudes for Philippines for various return periods [6]

Return periods	Earthquake magnitudes (Mw)
1 in 50 year	8.26
1 in 100 year	8.50
1 in 250 year	8.76
1 in 500 year	8.92
1 in 1000 year	9.00

All parameters (except depth and slip) were obtained from Table 1 [1]. Slip was estimated to obtain an earthquake Mw 8.5. The MIKE21 Toolbox does not accept a depth greater than 50km and, therefore, a depth of 50km was used in the study. The MIKE21 Toolbox requires the coordinates of a fault at its centroid and, therefore, the latitudes and longitudes from Salcedo [1] were modified. The final parameters for an 1 in 100 year earthquake are shown in Table 3. The resulting earthquake magnitude (as calculated by the author of this paper) is about Mw 8.5.

Table 3 – Fault parameters of an 1 in 100 year earthquake (Mw 8.5) in the East Luzon Trough

Sub-faults	Mw	Latitude (°N)	Longitude (°E)	Length (km)	Width (km)	Depth (km)	Slip (m)	Strike (°N)	Dip (°)	Rake (°)
ETL	8.5	16.9444	123.0556	317	100	50	7.5	200	37	89

2.3 1 in 1000 Year Fault Parameters of the East Luzon Trough (Mw 9.0)

Tsunami levels for an 1 in 1000 year earthquake are required to support emergency and rescue planning and operation. Therefore, initial tsunami levels were also generated for an 1 in 1000 year earthquake.

All parameters (except depth and slip) were obtained from Table 1 [1]. Slip was estimated to obtain an earthquake Mw 9.0. The MIKE21 Toolbox does not accept a depth greater than 50km and, therefore, a depth of 50km was used in the study. The MIKE21 Toolbox requires the coordinates of a fault at its centroid and, therefore, the latitudes and longitudes from Salcedo [1] were modified. The final parameters for an 1 in 1000 year earthquake are shown in Table 4. The resulting earthquake magnitude (as calculated by the author of this paper) is about Mw 9.0.

Table -4 Fault parameters of an 1 in 1000 year earthquake (Mw 9.0) in the East Luzon Trough

Sub-faults	Mw	Latitude (°N)	Longitude (°E)	Length (km)	Width (km)	Depth (km)	Slip (m)	Strike (°N)	Dip (°)	Rake (°)
ETL	9.0	16.9444	123.0556	317	100	50	42	200	37	89

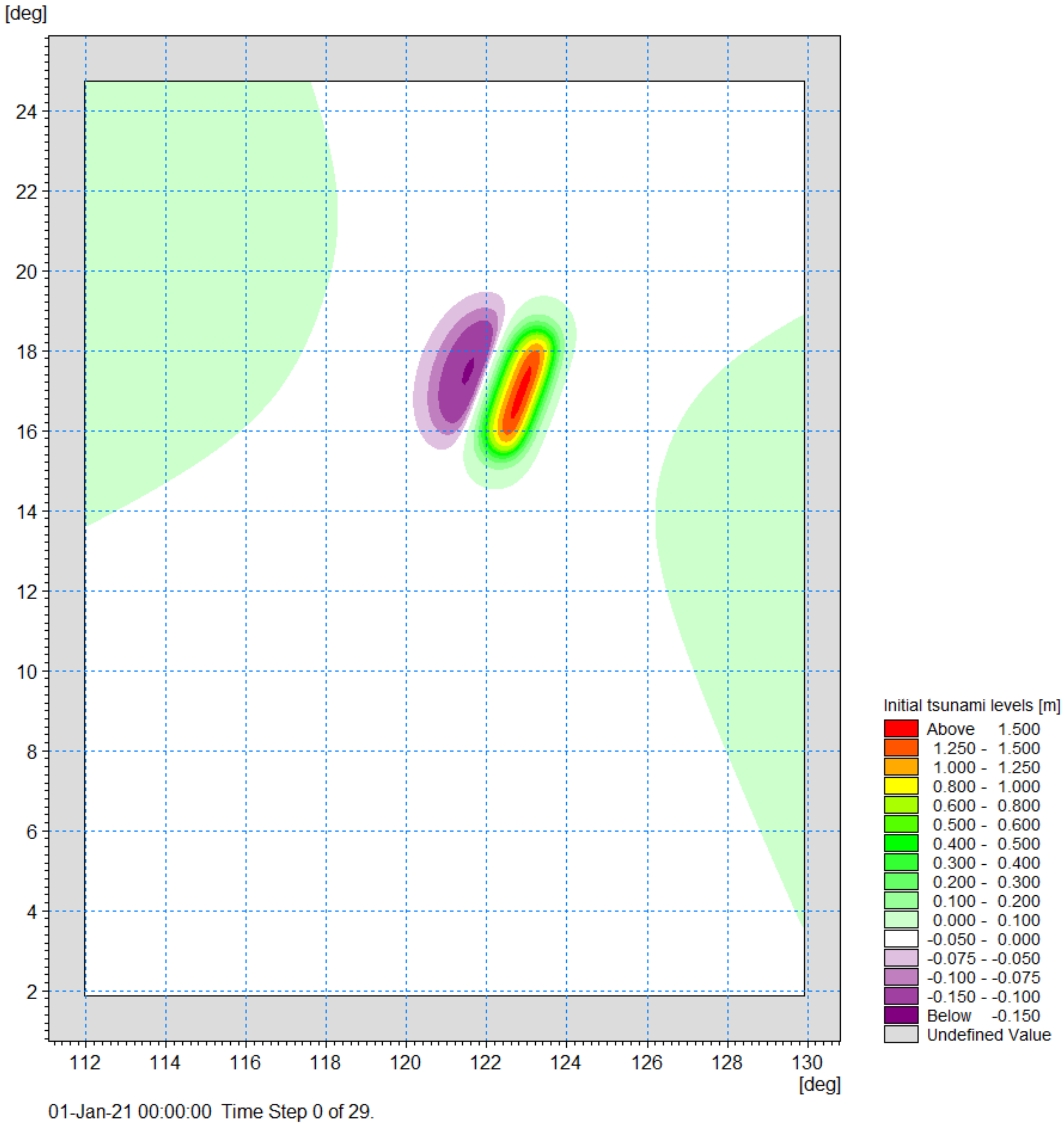

Fig. 6 Initial tsunami levels for the earthquake parameters (Mw 8.35) proposed by Salcedo [1]

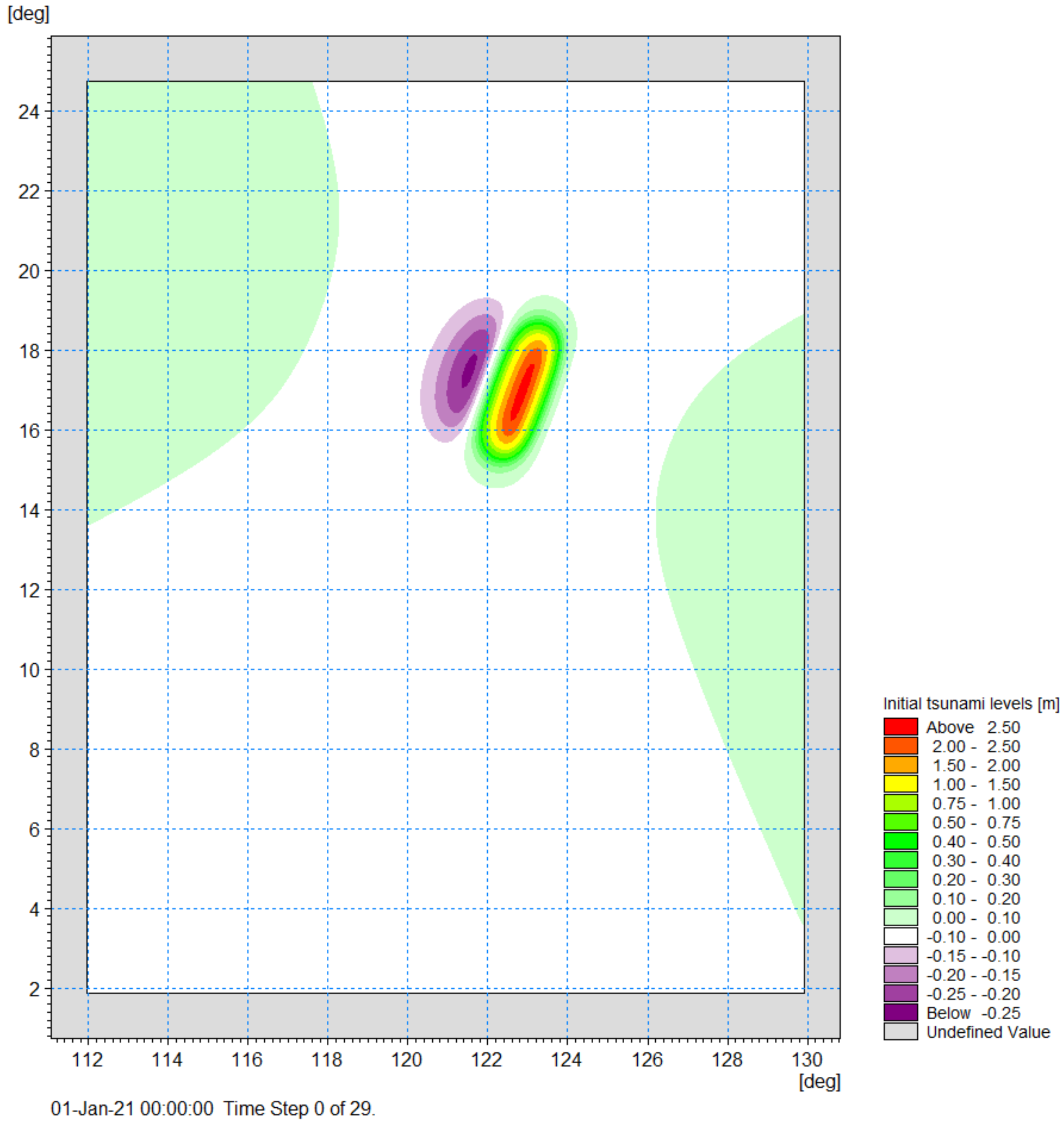

Fig. 7 Initial tsunami levels for an 1 in 100 year earthquake (Mw 8.5) in the East Luzon Trough generated by Royal HaskoningDHV

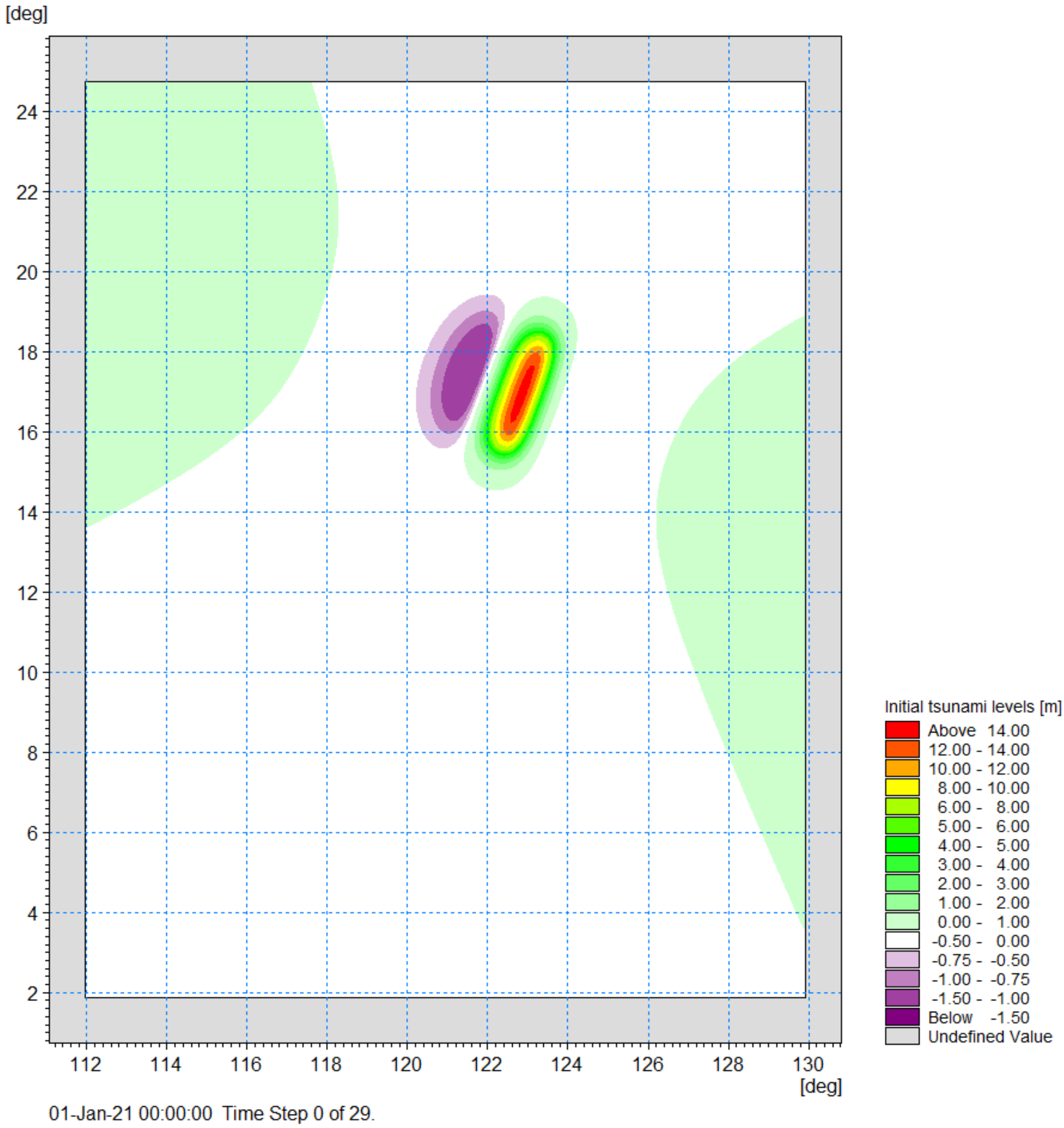

Fig. 8 Initial tsunami levels for an 1 in 1000 year earthquake (Mw 9.0) in the East Luzon Trough generated by Royal HaskoningDHV

3. Generation of Initial Tsunami Levels

It is assumed that the initial sea surface rise is the same as the final seafloor deformation after the earthquake. This is a reasonable assumption because the duration of an earthquake is generally short and the size of the rupture area is much larger than the water depth. Consequently there is not enough time for the water above the deformed seafloor to drain out. The seismic rupture is much faster than water wave propagation.

Initial tsunami levels were generated for the earthquakes parameters in Tables 1, 3 and 4 using the MIKE21 Toolbox. Square grid size of 10 km x 10 km was used for the domain to generate the initial tsunami levels. Initial tsunami levels for each sub-fault were generated separately and were then summed up to obtain the combined initial tsunami levels. Figure 6 shows the initial tsunami levels generated using earthquake parameters proposed by Salcedo [1] as in Table 1. Figures 7 and 8 show the initial tsunami levels for Mw = 8.5 (1 in 100 year) and 9.0 (1 in 1000 year) respectively. The maximum initial tsunami level for each of the conditions are provided in Table 5. It should be noted that the maximum initial tsunami level and its location for a given Mw will vary due to the distribution of the length, width and dislocation (slip) of the sub-faults.

Table -5 Maximum initial tsunami levels in the East Luzon Trough

Earthquake magnitude (Mw)	Maximum initial tsunami levels (m)
8.35 (Salcedo, [1])	1.6
8.5 (1 in 100 year)	2.7
9.0 (1 in 1000 year)	15.0

4. SUMMARY AND FINDINGS

Literature search suggests that a major earthquake in the East Luzon Trough cannot be ruled out. Initial tsunami levels for Mw 8.5 (1 in 100 year) and 9.0 (1 in 1000 year) were generated in the present study using the MIKE21 Toolbox.

Maximum initial tsunami levels of 2.7 m and 15.0 m were found from the present study for Mw 8.5 and 9.0 respectively. The initial tsunami levels generated in the present study can be used to drive a tsunami propagation model to derive tsunami levels, arrival time and forward velocity at anywhere around the East Luzon Trough region.

The maximum initial tsunami level and its location for a given Mw will vary due to the distribution of the length, width and dislocation (slip) of the sub-faults.

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