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Initial Tsunami Levels in the Negros Trench (Philippines) from 1 in 100 Year and 1 in 1000 Year Return Period Earthquakes

M A Sarker (PhD)

Technical Director, Royal HaskoningDHV, Westpoint, Peterborough Business Park, Lynch Wood, Peterborough PE2 6FZ, United Kingdom. E-mail: zaman.sarker@rhdhv.com

ABSTRACT

A major earthquake in the Negros Trench 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 Sulu Sea region. The methodology described in this paper for generating initial tsunami levels in the Negros Trench could also be applied to this type of events at other sites around the world.

Key words: Tsunami, Natural Hazards, Negros Trench, Sulu Sea, Numerical Modelling, Port Development, Royal HaskoningDHV

1. INTRODUCTION

1.1 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 The Negros Trench

The Negros Trench is situated in the north-eastern part of the Sulu Sea. The trench lies between the Manila Trench at north and the Sulu Trench at south.

1.3 Tsunamigenic Earthquakes in the Sulu Sea (Negros-Sulu Trenches)

The tsunamigenic earthquakes in the Sulu Sea (Negros-Sulu Trenches) are provided in Table 1 from Tongkul et al [4].

Table -1 Tsunamigenic earthquakes in the Sulu Sea (Negros-Sulu Trenches) from Tongkul et al [4]

No.	Date (UTC)	Magnitude (Mw)	Depth (km)	Location
1	20-09-1897	8.1	33	6.000°N, 122.000°E
2	21-09-1897	8.2	33	6.000°N, 122.000°E
3	24-01-1948	8.3	33	10.500°N, 122.00°E

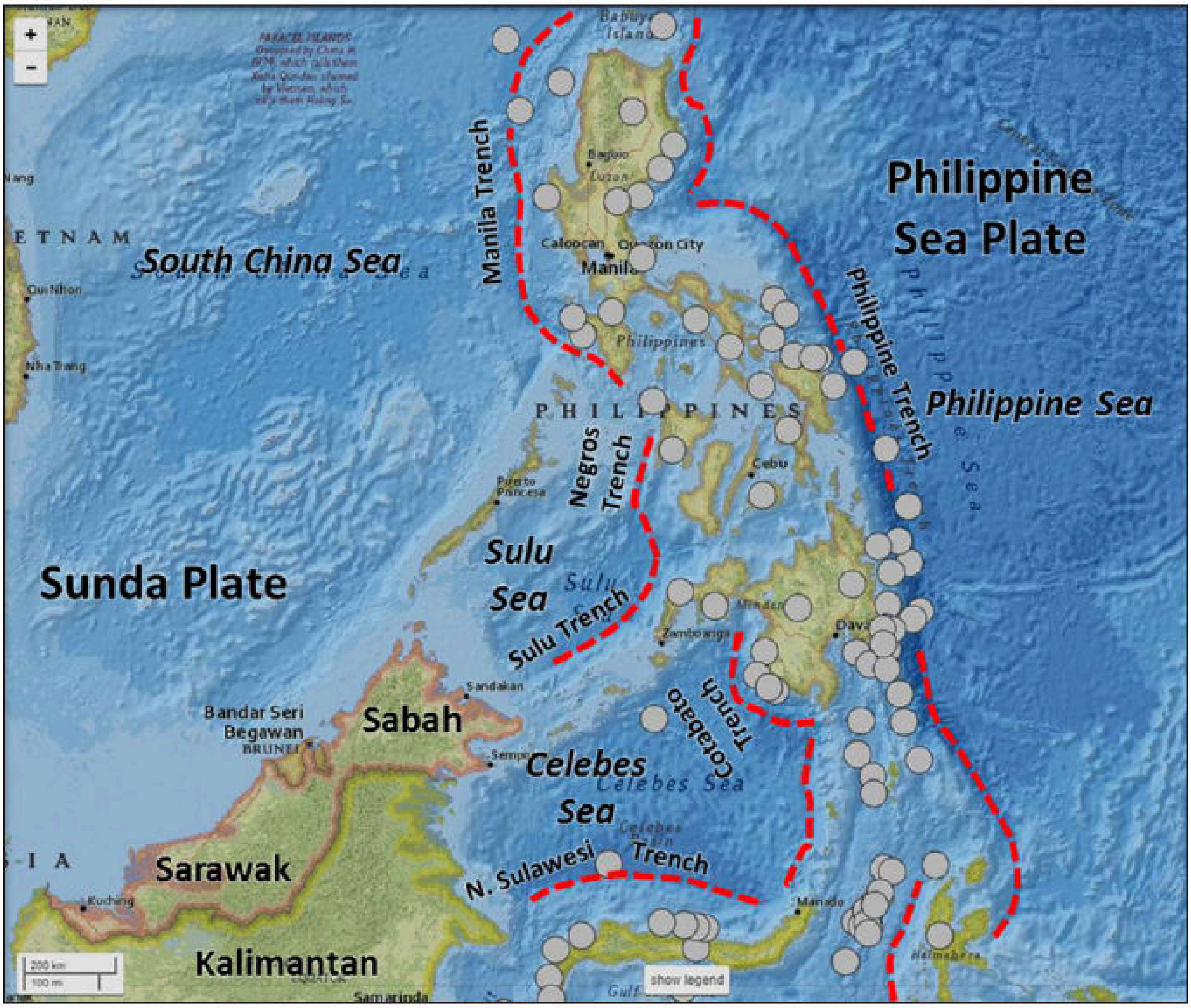

Fig. 1 Location of trenches around the Philippines [4]

1.4 Previous Studies on the Negros Trench

Salcedo [1] provided a set of earthquake source parameters for events which can occur in the 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 Negros Trench was divided into two segments (NT1 with Mw 8.2 and NT2 with Mw 8.1). 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.

Azis [5] carried out numerical modelling of tsunamis in the Sulu Sea and the Celebes Sea. Countries surrounding the Sulu Sea are affected by tsunamis in the Sulu Trench and the Negros Trench. The Negros Trench was divided into two segments (NT1 and NT2) following Salcedo [1].

1.5 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.

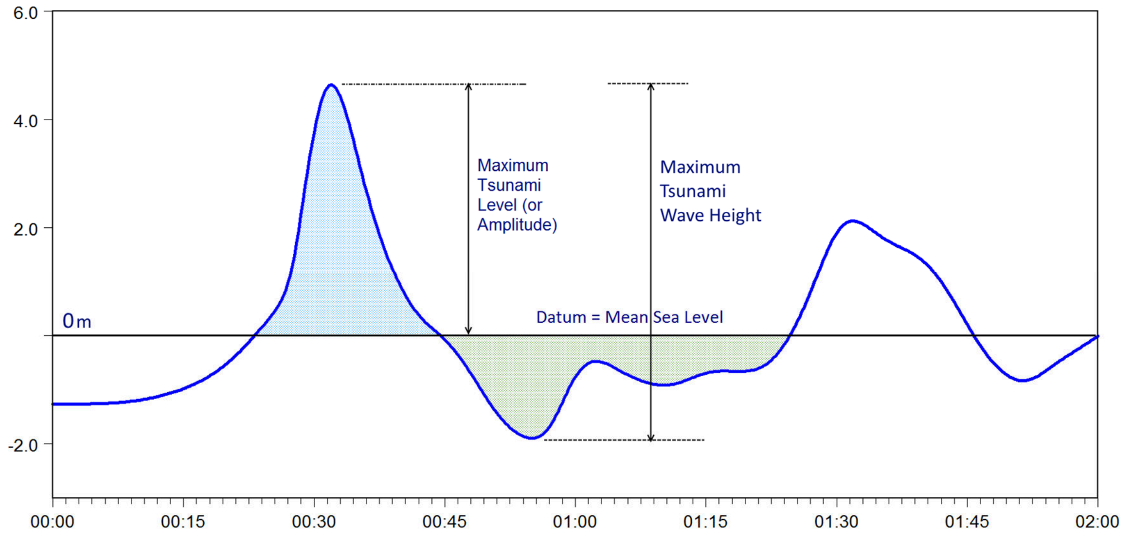

Fig. 2 General definition of tsunami level and tsunami wave height

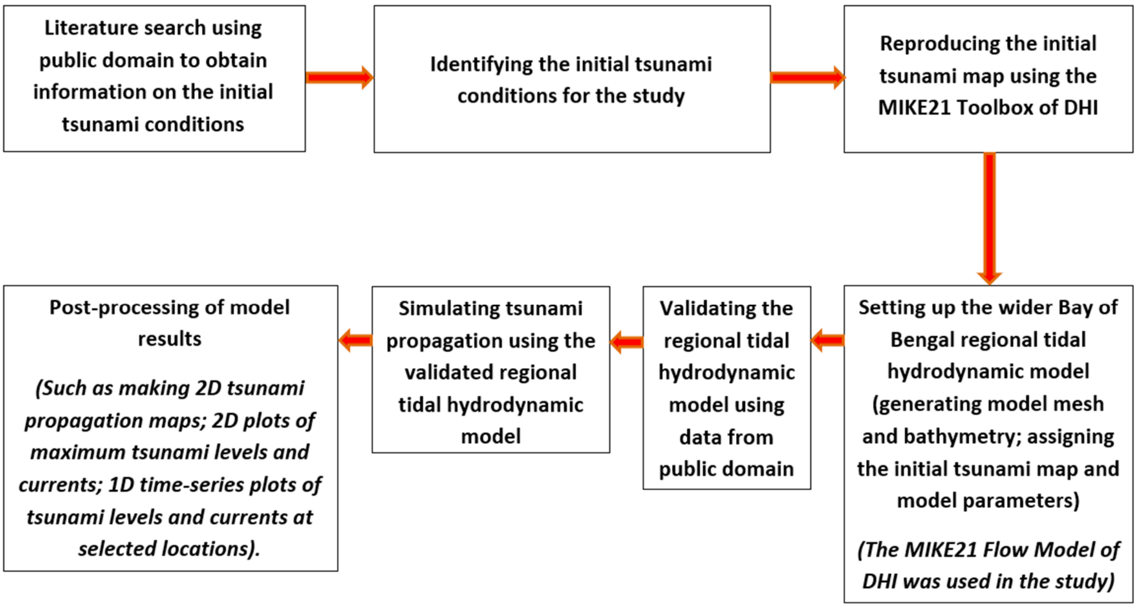

Fig. 3 Steps and software used in a typical tsunami modelling study

2. SELECTION OF EARTHQUAKE PARAMETERS

2.1 Fault parameters of the Negros Trench

The Negros Trench was divided into two segments, namely NT1 and NT2 (as in Figure 4) by Salcedo [1] following the segmentation given by Bautista and PHIVOLCS-DOST [6]. The fault parameters from Salcedo [1] are provided in Table 2. The coordinates of the corner location of the fault are shown in the table.

Table -2 Fault parameters of the Negros Trench from Salcedo [1]

Sub-faults	Mw	Latitude (°N)	Longitude (°E)	Length (km)	Width (km)	Depth (km)	Slip (m)	Strike (°N)	Dip (°)	Rake (°)
NT1	8.2	9.00	121.50	206	81.01	60	2.89	20	32	100
NT2	8.1	7.80	122.70	174	73.66	60	2.37	310	32	90

2.2 1 in 100 Year Fault Parameters of the Negros Trench (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 [7] and are provided in Table 3 and shown in Figure 5.

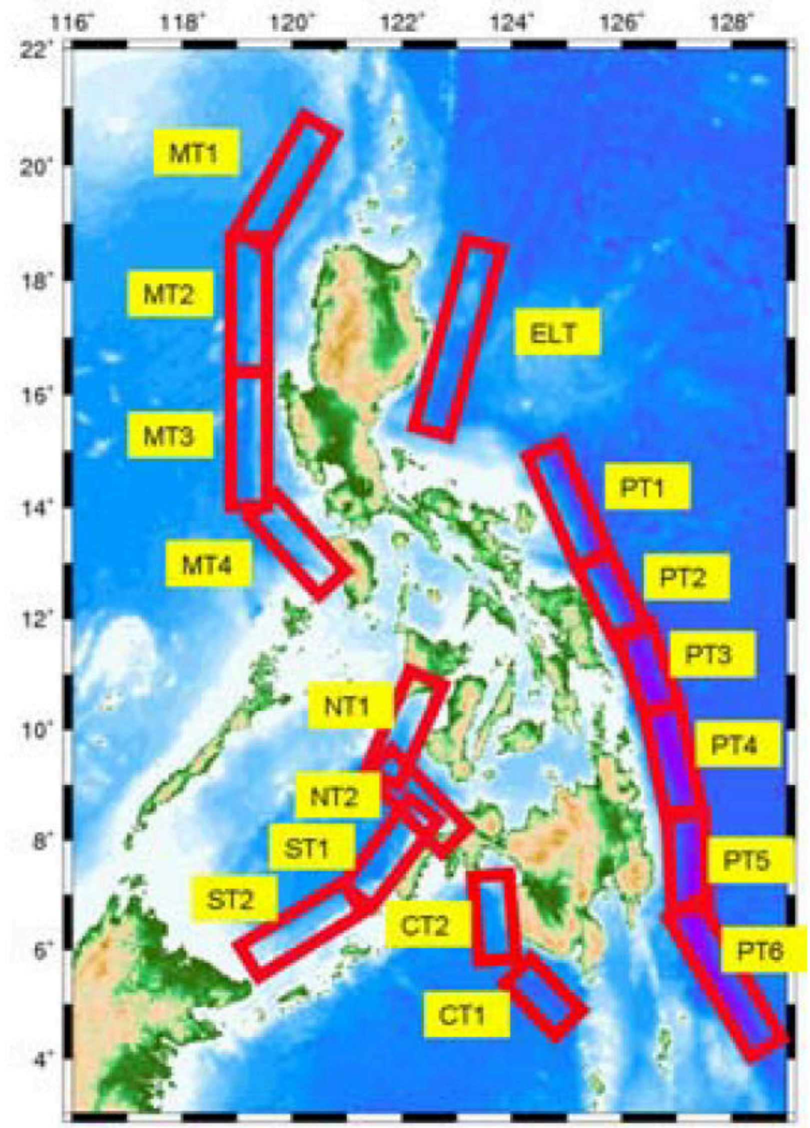

Fig. 4 Sub-fault distribution of the trenches around the Philippines from Salcedo [1]

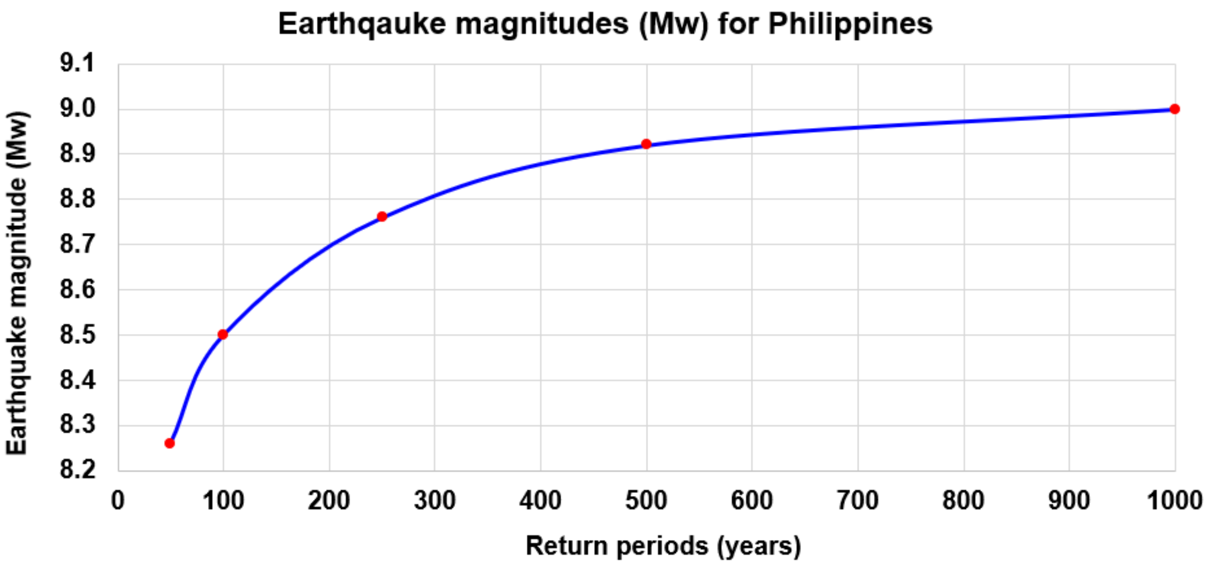

Fig. 5 Earthquake magnitudes (Mw) in Philippines for various return periods [7]

Table -3 Earthquake magnitudes for Philippines for various return periods [7]

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 2 [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 4. The resulting earthquake magnitude (as calculated by the author of this paper) is about Mw 8.5.

Table -4 Fault parameters of an 1 in 100 year earthquake (Mw 8.5) in the Negros Trench

Sub-faults	Latitude (°N)	Longitude (°E)	Length (km)	Width (km)	Depth (km)	Slip (m)	Strike (°N)	Dip (°)	Rake (°)
NT1	10.1111	122.1111	206	81.01	50	5.8	20	32	100
NT2	8.6667	122.2000	174	73.66	50	4.8	310	32	90

2.3 1 in 1000 Year Fault Parameters of the Negros Trench (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 2 [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 5. The resulting earthquake magnitude (as calculated by the author of this paper) is about Mw 9.0.

Table -5 Fault parameters of an 1 in 1000 year earthquake (Mw 9.0) in the Negros Trench

Sub-faults	Latitude (°N)	Longitude (°E)	Length (km)	Width (km)	Depth (km)	Slip (m)	Strike (°N)	Dip (°)	Rake (°)
NT1	10.1111	122.1111	206	81.01	50	33.0	20	32	100
NT2	8.6667	122.2000	174	73.66	50	27.1	310	32	90

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 2, 4 and 5 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 2. 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 6. 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 -6 Maximum initial tsunami levels in the Negros Trench

Earthquake magnitude (Mw)	Maximum initial tsunami levels (m)
8.3 (Salcedo, [1])	1.0
8.5 (1 in 100 year)	2.0
9.0 (1 in 1000 year)	11.6

4. SUMMARY AND FINDINGS

Literature search suggests that a major earthquake in the Negros Trench 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 2.0 m and 11.6 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 Sulu Sea 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.

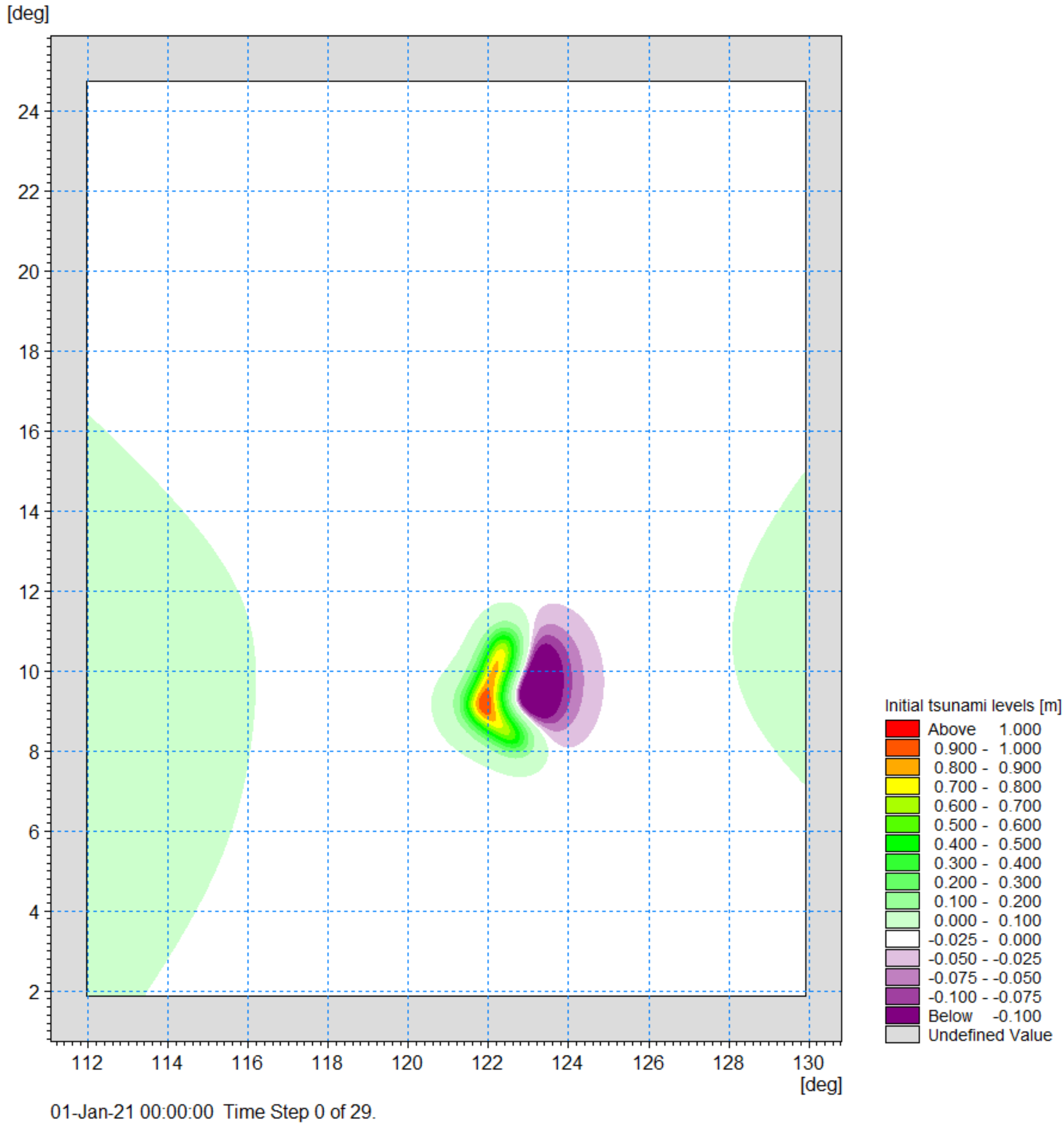

Fig. 6 Initial tsunami levels for the earthquake parameters (Mw 8.3) proposed by Salcedo [1]

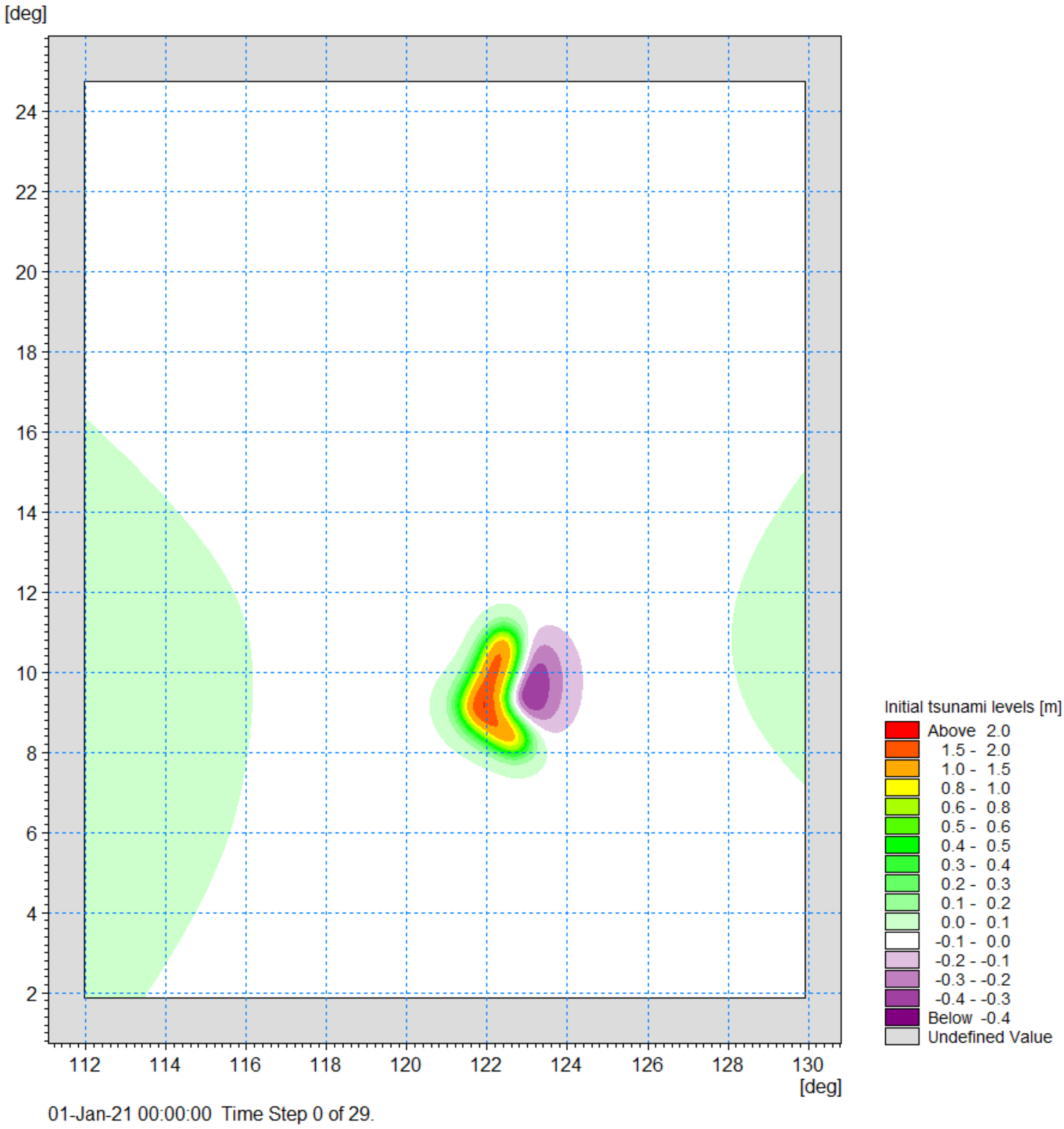

Fig. 7 Initial tsunami levels for an 1 in 100 year earthquake (Mw 8.5) in the Negros Trench generated by Royal HaskoningDHV

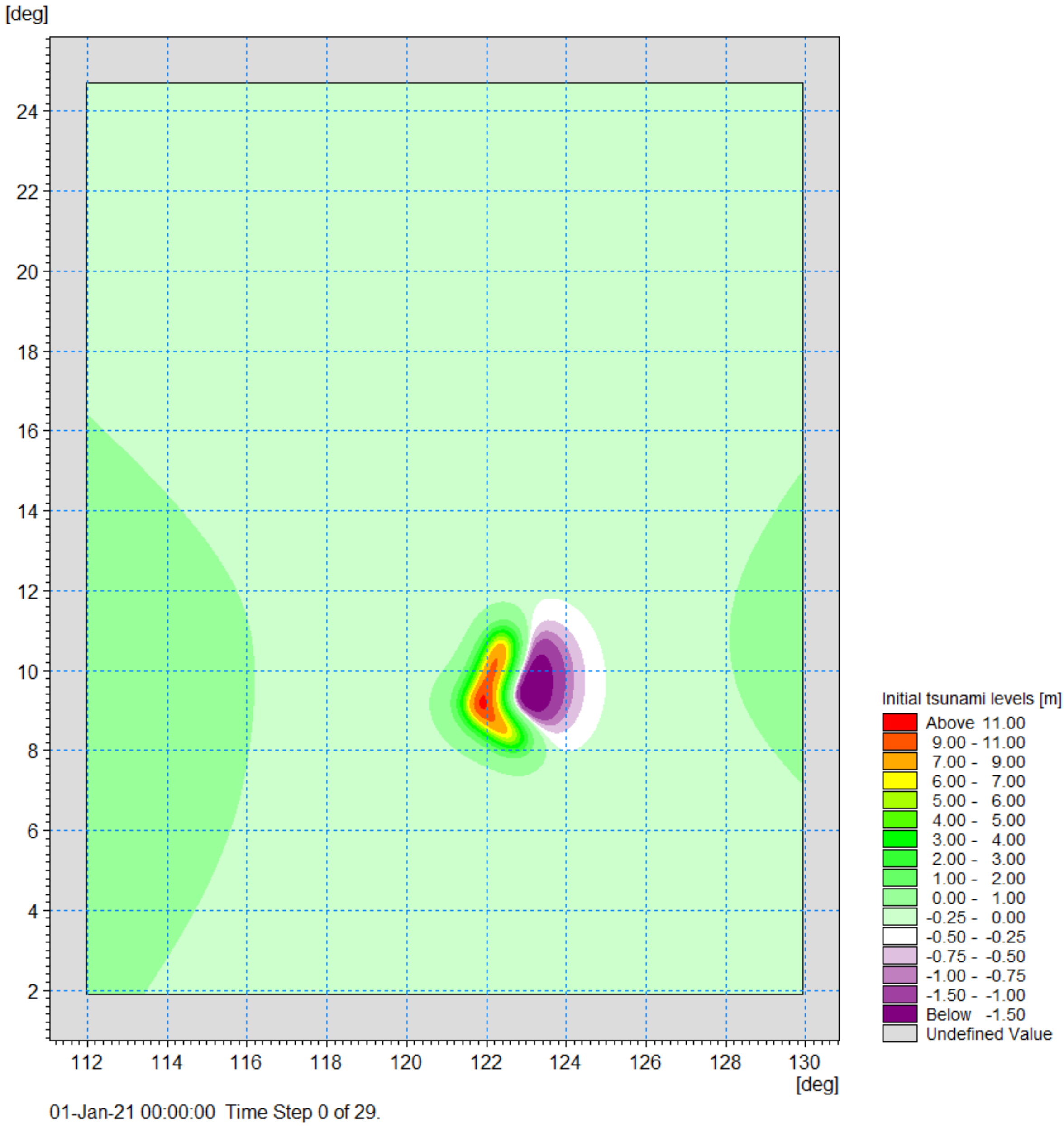

Fig. 8 Initial tsunami levels for an 1 in 1000 year earthquake (Mw 9.0) in the Negros Trench generated by Royal HaskoningDHV

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