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Mapping the Level of Earthquake Risk of Holtekamp Bridge at Jayapura Region Based on Earthquake Data and Microtremor Measurement

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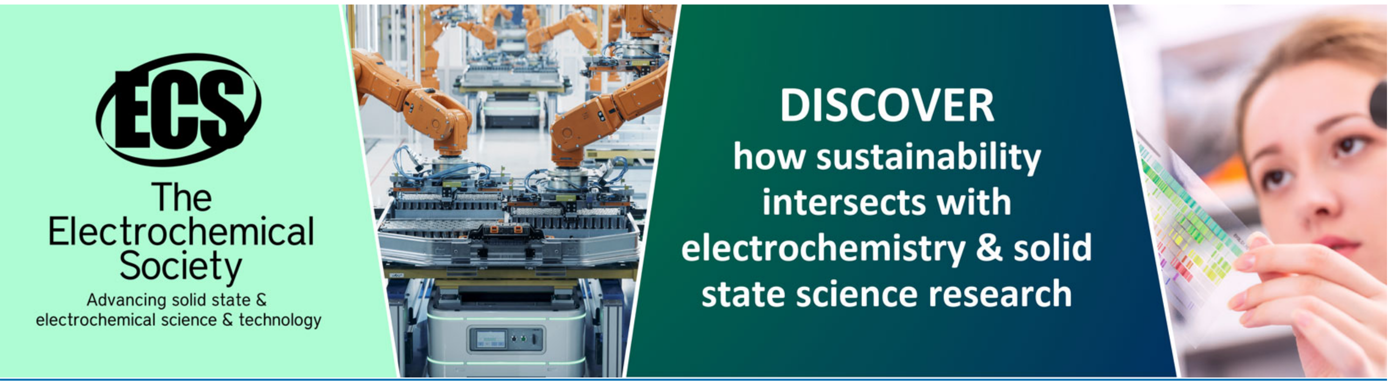

Mapping the Level of Earthquake Risk of Holtekamp Bridge at Jayapura Region Based on Earthquake Data and Microtremor Measurement

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Abstract. Holtekamp bridge which is located in Jayapura region between Hamadi and Holtekamp Village in the Northern part of Papua Island. The region constitutes an active earthquake zone with the recurrence frequency and magnitude of the earthquake are relatively high. The region is located on an active fault zone. The seismotectonic setting in the region is directly implied to the calculations of the seismic design for engineering and design purposes on building and non-building structures including Holtekamp bridge in Jayapura city. To recognize a characteristic of the earthquake at the site of interest, the historical earthquakes (background) data surrounding the study area. Local microtremor measurements data are analyzed by means of a probabilistic seismic hazard analysis (PSHA). Deterministic seismic hazard analysis (DSHA) using some ground-motion models in attenuation relationship equations. In resulting of seismic hazard parameter as represented by peak ground acceleration (PGA), values in earthquake scenario at operating basis earthquake (OBE), maximum design earthquake (MDE), and maximum credible earthquake (MCE) conditions. These values are used as a reference to evaluate the compliance of the current technical aspects with the new required design facing the updated seismicity parameters.
Keywords: Seismic Hazard Analysis, Peak Ground Acceleration, Jayapura, Hamadi, Holtekamp.

1. Introduction

Holtekamp bridge which is located in Jayapura region between Hamadi and Holtekamp village in the Northern part of Papua island. The region constitutes an active seismic region that is having a high earthquake intensity in term of the frequency and magnitude parameters. Earthquake sources that threaten the region located in the sea and on land due to subduction and faults activity (Suwarna, et al, 1995) [1] (Fig. 1). The potential seismic hazard in the region had been observed widely by national researchers such as Irsyam, et al. (2010) [2] and 2017 [3], and Cipta, et al. (2016) [4] as the parameter is represented by a peak ground acceleration (PGA) value. Since earthquake occurrence always occurs repeatedly, required analysis of earthquake hazard to estimate the events that will occur in the future. An important requirement in

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earthquake disaster mitigation is to do an accurate assessment of seismic hazard, so the potential damage from earthquakes can be predicted.

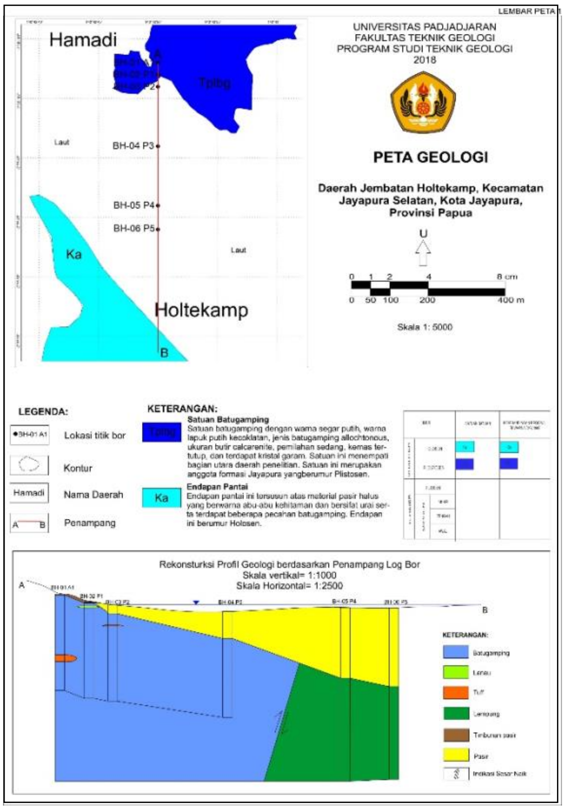

Figure 1. Geological Map around the Holtekamp Bridge of Jayapura Region

2. Methodology

The strength parameters of the earthquake in one place can be seen through ground acceleration (Peak Ground Acceleration). Ideally, these parameters are measured by accelerograph installed permanently. However, due to limitations of the equipment, then the value of the ground acceleration can be estimated through the empirical approach, i.e. by converting the earthquake parameters (locations and magnitude) into the parameters of acceleration in a particular place.

The seismicity setting of the research area can be assessed by the meaning of probabilistic seismic hazard analysis (PSHA) and/or deterministic seismic hazard analysis (DSHA) approach by considering the availability of earthquake data, geological information, and soil/rock properties at the site-specific. This method aims to analyze the probability of exceeding a given level of ground shaking that caused by earthquakes by considering all possible earthquakes that could occur in a region in a given period. This probabilistic method has accounted for the uncertain factor in the seismicity and also the possibility of earthquake events that exceed the ground motion design (worst scenario) (Fig. 2). All parameters used in the deterministic method have been included in this probabilistic method. This method assumes the earthquake magnitude M and distance R as continuous independent random variables, the peak ground acceleration (PGA) can be derived by following some published ground-motion models in attenuation relationship equations for a shallow crustal earthquake. In general, the theory of total probability can be expressed in the equation by Douglas (1964-2010) [5] as follows:

$$H(a) = \sum vi\ P[A > a\ m, r]\ fMi\ (m)\ fRi\ Mi\ (r,m) drdm \quad (1)$$

Where vi is the annual rate (with a magnitude higher than the limit value of Moi) on the source of the earthquake I, fMi (m) and $fRi\ Mi$ (r,m), respectively, the probability density function of magnitude and distance. $P[A > a\ m,\ r]$ is the probability of an earthquake with a magnitude m at a distance r that gives the maximum acceleration A at the site that is higher than a.

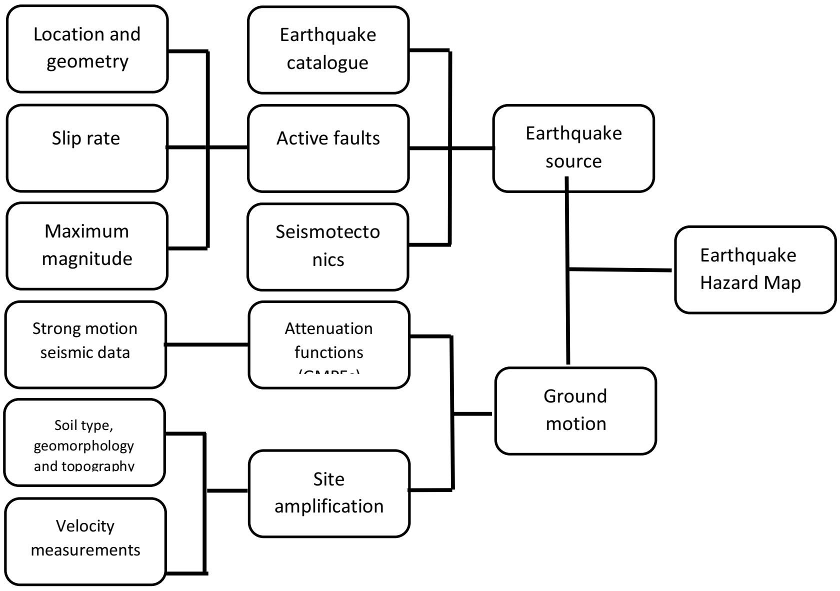

Figure 2. Flowchart of earthquake hazard calculations using PSHA method

Earthquake source models used in the calculation derived from sources which are located around the area of investigation would be possible to give effect to the area. Earthquake sources are used usually have a maximum range of about 400 km from the study area (Figure 3).

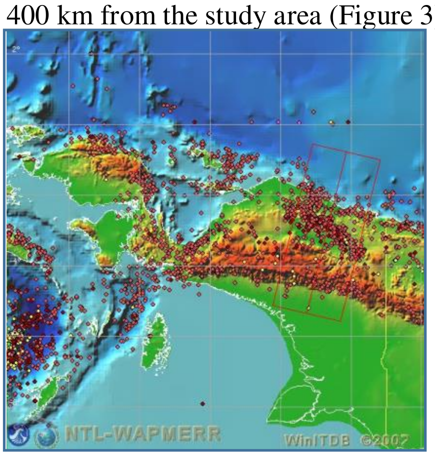

Figure 3. Earthquake catalog for Jayapura and surrounding areas during 1964 to 2011

To obtain characteristic of soils or rocks at the site of interest, a microtremor measurement is undertaken using a portable digital seismometer (short period, 3 elements) type TDL-303 for sensitive velocity sensor with sampling frequency until 100 Hz, equipped by data cable, digitizer, solar panel, GPS, and software for data acquisition and analyzing the HVSR (horizontal to vertical spectral ratio). A published software namely GEOPSY is also used to acquire and analyze the HVSR values.

A procedure for processing of the microtremor data is by the meaning of the horizontal to the vertical seismic ratio (HSVR) following the equation below (Nakamura, 1989) [6]:

$$HVSR = \frac{S_{HS}}{S_{VS}} \tag{2}$$

$HVSR$ = spectural value ratio of H/V
S_{HS} = spectural horizontal element at rock layer
S_{VS} = spectural vertical element at rock layer

The peak value of HVSR spectral is Amplification (A_0), while the frequency value (f_0) at HVSR spectral is a predominant frequency referred to as a resonance frequency of the rock at the surface. It can be influenced by the physical properties of the rock, for instance, the old rocks are commonly more massive, compact, and tends to have a higher value of predominant frequency than the other.

The value of a seismic vulnerability index (K_g) is derived from the following equation:

$$K_g = \frac{A_0{}^2}{f_0} \tag{3}$$

K_g = seismic vulnerability index
A_0 = peak amplitude of microtremor
f_0 = resonance frequency

After resulting value of resonance frequency (f_0) and seismic vulnerability index (K_g) of each measurement point the data are plotted to figuring out region spatial based on the f_0, A_0, and K_g accordingly.

The value of a predominant period of the ground (T_G) is obtained from the following equation:

$$T_G = \frac{1}{f_0} \tag{4}$$

T_G = predominant period of ground
F_0 = resonance frequency

Refer to Equation (4) above, the peak ground acceleration (PGA) values according to Kanai 1966 (in Douglas, 2010) [5] attenuation relationship is obtained.

Furthermore, to acquire a mean of the PGA values, a logic tree is introduced to justify weighting factors according to author's level of confidence by considering the site characterization, geological structures, and tectonic setting as well. The logic tree is shown in the following (Fig. 4).

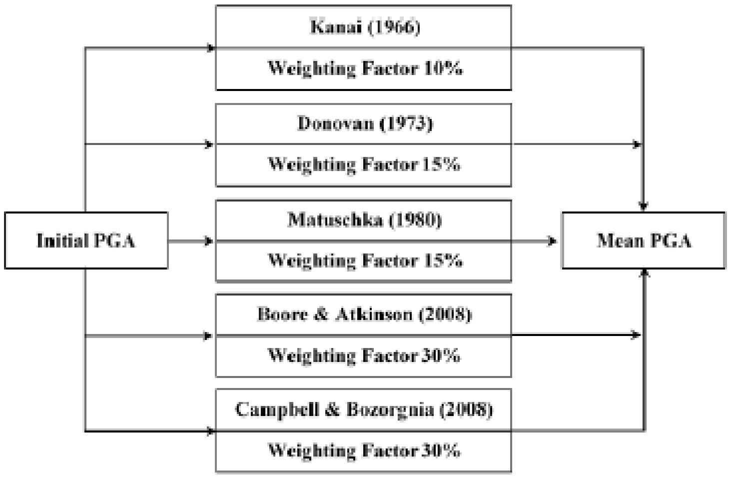

Figure 4. logic tree

Therefore, the PGA values of respective conditions are classified referring to the classification of the earthquake risk level (Fauzi, et al., 2005 in Lunga, et al., 2015) [7] as follows;

Table 1. The classification of earthquake risk level (modified Fauzi, *et al*., 2005 in Lunga, et al., 2015) [7]

Risk Level	Column A (*t*)	Column B (*t*)
Very low risk	< 0.025	<VI
Low risk	0.025 – 0.051	VI – VII
Medium risk 1	0.051 – 0.076	VII – VIII
Medium risk 2	0.076 – 0.102	VII – VIII
Medium risk 3	0.102 – 0.127	VII – VIII
High risk 1	0.127 – 0.153	VIII – IX
High risk 2	0.153 – 0.204	VIII – IX
High risk 3	0.024 – 0.306	VIII – IX
Very high risk 1	0.306 – 0.612	IX – X
Very high risk 2	> 0.612	> 6

3. Result and Discussion

Seismic data obtained from ISC earthquake catalog from 1964 to 2011 [8], is used to identify the figure a and b (Fig.6). Value based on the Gutenberg-Richer equation as background earthquake source parameters. In this model, it is assumed that earthquake can occur anywhere with equal probability.

Earthquake source models using three types of source models are subduction model; comes from the New Guinea Trench subduction zone (North Papuan Thrust), fault models; derived from Yapen fault, Tarera Aiduna, Wamena, Mamberamo, Waipoga, Jayapura, and Jayawijaya, dan background models to accommodate unknown earthquake (Suwarna, et al, 1995) [1] (Fig. 6).

a b

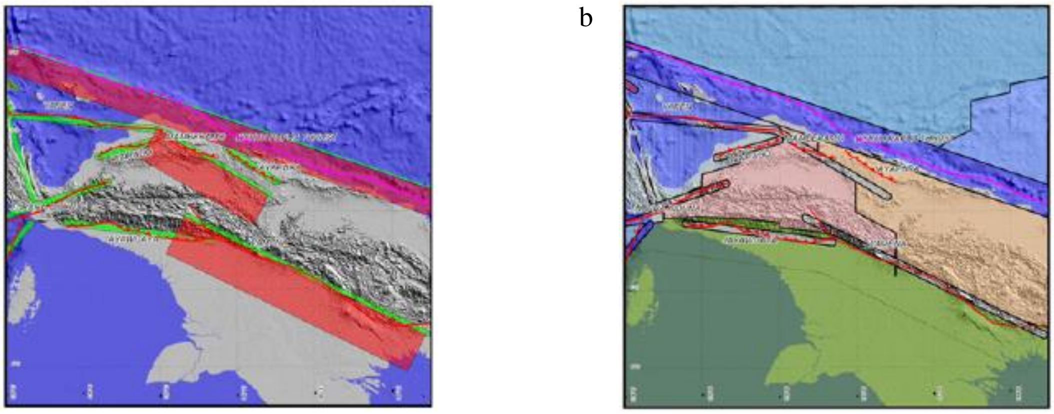

Figure 5. Earthquake source models to calculate probabilistic seismic hazard at Jayapura

(a) source models of faults and subduction, (b) background source model

Frequency and magnitude of the earthquake are relatively high. Within the last 14 years, from 2000 to 2014 there were 607 earthquake events with magnitude 4 to 6,5 Richter scale. (Fig.7).

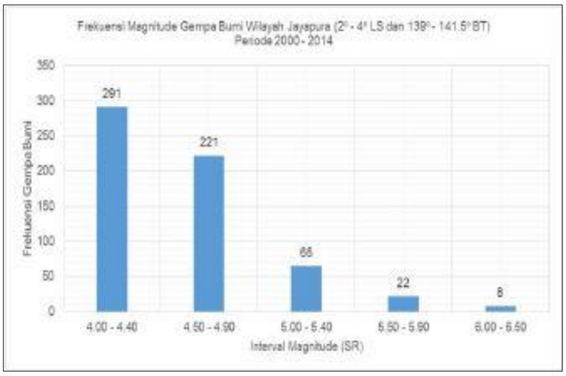

Figure 6. Frequency and magnitude of the earthquake in Jayapura region

Modeling and mathematical calculations are done by using Earthquake Risk Model (EQRM) software, developed by Geoscience Australia (GA). Results were used for analysis of earthquake hazards around Holtekamp Bridge area is the distribution of earthquake acceleration value (PGA) with probability exceeded 10% for a period of 500 years. PSHA calculations performed for the peak ground acceleration (PGA), spectra 0.2, and 1.0 seconds on bedrock (Fig. 8) (Booreand, et al, 2008) [9] and (Campbelland et al, 2008) [10] and at the surface. (Fig. 9).

Based on earthquake hazard map above, that Jayapura regions have quite a high earthquake hazard. Areas high hazard are generally a residential area and the center of community activity. Areas that are at high disaster prone are low-lying areas around the coast an area with a dense population, such as Koya, Abepura, Kotaraja, Entrop, Hamadi, and Holtekamp as a construction site for Holtekamp bridge. While areas that have relatively lower hazard only a small part in the highland area located in Gurabesi and Polimak Circle.

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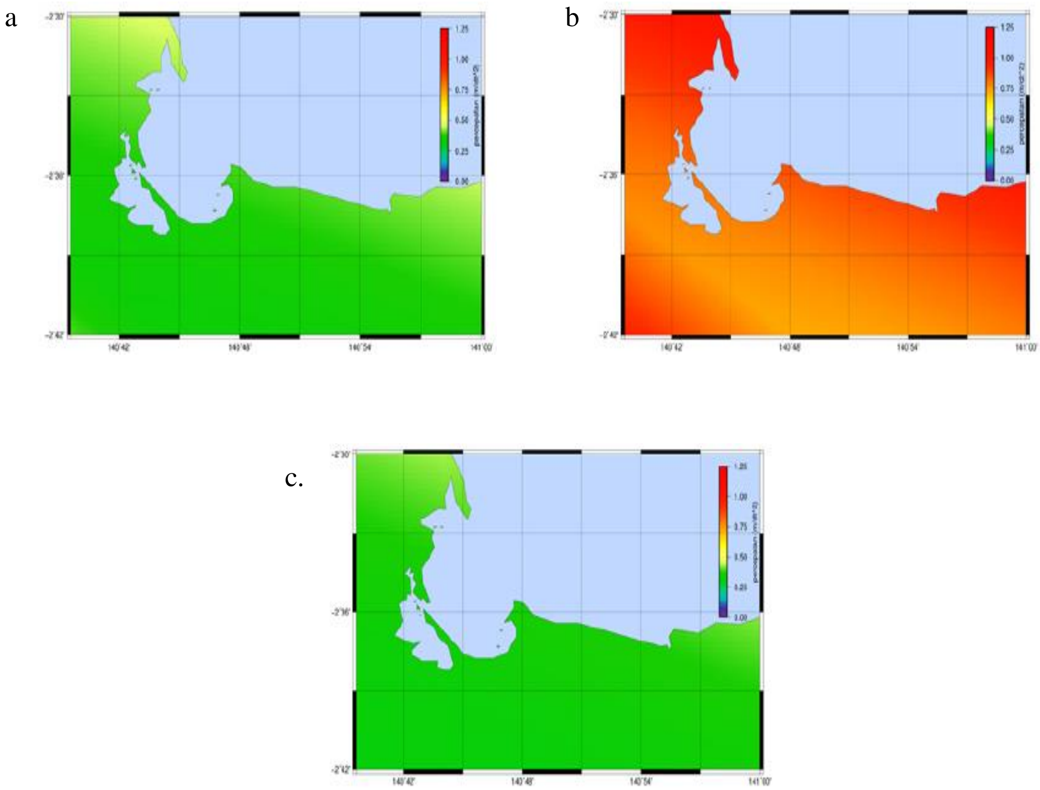

Figure 7. (a) Earthquake hazard maps around the holtekamp bridge on bedrock for the peak ground acceleration (PGA); (b) spectra 0.2; and (c) 1.0 second.

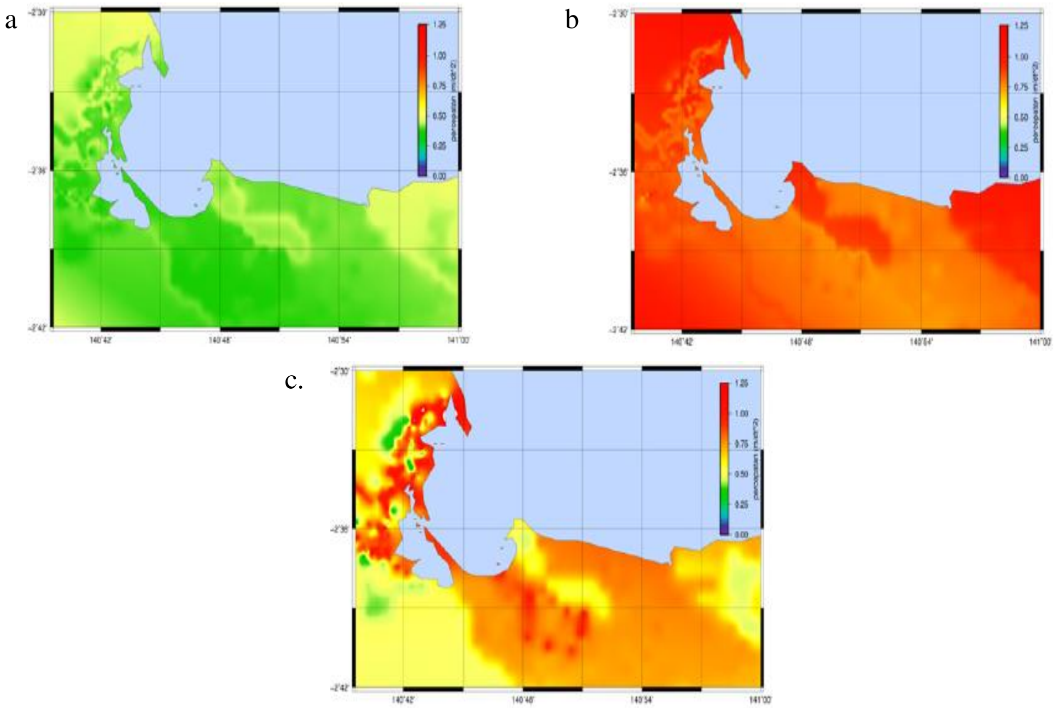

Figure 8. (a) Earthquake hazard maps around the holtekamp bridge at the surface for the peak ground acceleration (PGA); (b) spectra 0.2; and (c) 1.0 seconds.

The residual map above shows the difference values between the results of measurements to the geomorphology and topographic slope approach. A negative value means the region is relatively more stable than they should so that amplifications becomes smaller and the PGA can be smaller too, it means there is under-estimating to the earthquake hazard. Based on a comparison of the residual value which is then select the approach that is used to complete the amplification value in Jayapura (Fig.10).

Using the NEHRP system to classify site class from Vs30 value distribution, soil layer of Jayapura region can be classified into class B, C, D, and E (Fig. 11).

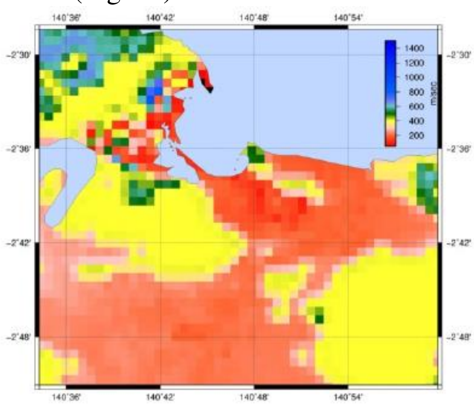

Figure 9. Vs30 map from microtremor measurement result and geomorphological approach

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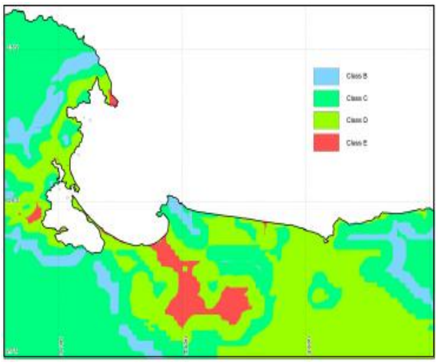

Figure 10. Site class classification around the Holtekamp Bridge

4. Conclusion

The area around the Holtekamp bridge has a high earthquake hazard level. Amplification factor in the region greatly affects the increase in the level of earthquake shaking. Required good preparation of earthquake hazard mitigation strategies to minimize casualties and loses causes by the earthquake in the future. The result shows that Peak Ground Acceleration (PGA) around Holtekamp Bridge have values from 32,74-207 gal with VI-IX Modified Mercalli Intensity (MMI). Based on the risk level classification of the earthquake of these data can be concluded that around Holtekamp Bridge vulnerable of the earthquake, which has the risk level is from the low risk up to the third highest risk.

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