RESPONSE OF STABLE OVERALL SLOPE GEOMETRY OF OPEN PIT COAL MINE IN WARUKIN FORMATION TO DEWATERING AND PEAK GROUND SEISMIC IN SOUTH KALIMANTAN, INDONESIA

RESPONS GEOMETRI LERENG MENYELURUH STABIL TAMBANG TERBUKA PADA FORMASI WARUKIN, AKIBAT PENYALIRAN DAN GEMPA DI KALIMANTAN SELATAN, INDONESIA

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ABSTRACT

Understanding of the response of the mine slope stability is very important regarding the safety of life and investment / productivity / environment, as anticipation of landslide prevention based on the latest research. Mine slope behavior previously discussed widely in terms of the response due to dewatering and seismic (Peak Ground Acceleration) as well through verification. This paper aims to obtain a broad dimension of design criteria that are not only unstable slopes, but the slope is stable under various conditions of the rock mass saturation (dewatering) and seismic condition. Response of slope stability per geotechnical rocks unit from different formations or any engineering formation as a result of environmental influences, for example, the same quake, will be different. This means that the geometry of the same slope in other formation will have different stability conditions (safety factor of the slope) due to the same seismic acceleration. This is also similar due to dewatering. The method used for this study is the deductive-probabilistic method with a hypothetical verification approach. The Standard statistical analysis is used to test the data normality and homogeneity, average and independent differences, as well as regression-correlation test. The research results show that dewatering activity can decrease ground water level (GWL/MAT) of the slope, so the durability of sliding along the sliding plane is reduced (increasing slope safety factor). At the same time earthquake reduces shear strength and increases driving force, so the safety factor of the slope suddenly downs. Slope stability decreased due to the earthquake, but dewatering improves slope stability. Thus, the slope in dewatering conditions will be kept stable through simulation to anticipate earthquake.

Keywords: Overall slope, Safety Factor, dewatering, Peak Ground Acceleration

ABSTRAK

Pemahaman respon dari stabilitas lereng tambang sangat penting terkait keselamatan jiwa dan investasi / produktivitas / lingkungan, sebagai antisipasi pencegahan longsor berdasarkan penelitian terbaru. Perilaku lereng tambang dibahas sebelumnya secara luas dalam hal respon karena penyaliran dan seismic serta melalui verifikasi kualitatif. Makalah ini bertujuan untuk mendapatkan dimensi yang luas kriteria desain yang tidak hanya lereng yang tidak stabil, namun lereng stabil dalam berbagai kondisi dari kejenuhan massa batuan (penyaliran) dan kondisi seismik/getaran. Respon dari stabilitas lereng per unit satuan batuan geoteknik dari formasi yang berbeda atau pembentukan keteknikan satuan batuan *sebagai akibat dari pengaruh lingkungan, misalnya, gempa yang sama, akan berbeda. Ini berarti bahwa geometri lereng yang sama dalam formasi lainnya akan memiliki kondisi stabilitas yang berbeda (faktor keamanan dari lereng) karena percepatan gempa yang sama. Ini juga mirip karena penyaliran. Penelitian ini bertujuan untuk mengetahui respons geometri lereng menyeluruh stabil tambang batubara terbuka pada Formasi Warukin di Kalimantan Selatan akibat penyaliran dan gempa. Penelitian ini menggunakan metode deduktif-probabilistik dengan pendekatan verifikasi hipotetik. Analisis kemiringan lereng dilakukan untuk mengetahui faktor keamanan lereng di daerah penelitian. Analisis statistik seperti uji korelasi regresi yang sebelumnya telah dilakukan juga uji normalitas dan homogenitas data serta menguji perbedaan rata-rata dan independen. Hasil penelitian menunjukkan bahwa aktivitas penyaliran dapat menurunkan elevasi muka air tanah (MAT) di dalam tubuh lereng, sehingga daya tahan geser di sepanjang bidang gelincir menjadi turun (faktor keamanan lereng meningkat). Gempa menurunkan gaya tahan geser sekaligus menaikkan gaya dorong geser pada saat yang bersamaan, sehingga faktor keamanan lereng turun dengan tiba-tiba. kestabilan lereng menurun akibat gempa, tetapi penyaliran meningkatkan kestabilan lereng. Dengan demikian lereng dalam kondisi* dewatering *akan dapat dijaga tetap stabil melalui simulasi untuk mengantisipasi terjadinya gempa.*

Kata kunci: *Lereng menyeluruh, faktor keamanan, dewatering, seismik dasar puncak*

INTRODUCTION

Determination of the angle of comprehensive slope (overall slope), the largest stable at a maximum depth of an open pit mine is an aspect of the geotechnical part of mine planning, so that the mining operation is capable of producing optimal cost (recovery) for mineable reserves in a safe condition (slope with no landslide). Such circumstances should always be maintained, and is a joint responsibility of all parties involved in a mining organization. Therefore management of mine to maintain the condition of safety along with the acquisition of optimal production is in accordance with the government rules of mining techniques (Good Mining Practice).

Rock formation genetically has specific physical and mechanical characteristics along with composition and variety of rock types with distinct physical characteristics, biological, and chemical, known as facies. This understanding is used as the basis for tracking the physical and mechanical characteristics in carrying out geotechnical mapping to the systematic division of geotechnical rock units. *Dearman* (1991) explained the rank of geotechnical rock units in descending order:

1. engineering types (scale 1: 5,000 or greater),
2. lithological types (scale 1; 5000-1: 10,000),
3. engineering formations (scale 1: 10000-1: 200,000),
4. engineering groups (scale 1: 200,000 or smaller).

In mining operations, which are generally large-scale geotechnical issues will involve large-scale map, so that the study of various phenomena of slope instability will focus on geotechnical rock units at the level of engineering formation until the lithological type. This research studies on all three levels of the units.

Response of slope stability per unit geotechnical rocks of different formations or any engineering formation as a result of environmental influences, for example, the same seismicvibration, will be different. It means that the geometry of the same slope made in the formation of the others will have different slope stability conditions (safety factor) though the Peak Ground Acceleration (PGA) are the same.

Similarly, due to dewatering. Both factors cause (variable /independent factor) that will be studied to what extent the effects on some important formations that have potential coal resources that are and will be mined today and in the future.

Benefits of the research is to support the efficiency and safety of mining operations warranty optimally profitable production. This study focused on the analysis of the probability of slope geometry on the open coal mine in South Kalimantan covering six study areas for the deployment of the lateral and vertical logs in Warukin Formation. The influence of PGA in Kalimantan, the effect of blasting vibration and the impact of heavy equipment are statistically considered and taken into account in determining the Safety Factor (SF).

The purpose of this research is to understand the response of stable overall slope geometry due to dewatering treatment and due to the seismic vibration (earthquake, heavy equipment or blasting). For this study, 6 cored holes have been obtained from the research area. The geology generally consists of gently folded Warukin Formation, comprising claystone, silty and sandy claystones, carbonaceous claystones and some sandstone layers alternating with several coal seams. Up to 5 m of surficial soils originating from weathered rocks of the formation are present from the Warukin Formation.

GEOLOGICAL CONDITIONS

The study area is located in the Barito Basin at the edge of the eastern sub-basin of the Barito near Meratus Mountain. Sub Barito Basin is the southern part of the Kutai basin form a vast basin and covers South and East Kalimantan during the Tertiary. Barito basin consists of four formations aged Eocene until Pleistocene namely Tanjung, Berai, Warukin and Dahor Formations (Fig.1). Warukin Formation is composed by quartz sandstone, claystone, siltstone, and conglomerates at the bottom as well as the intercalation of coal and limestone lenses. Warukin Formation is deposited in the Middle to Late Miocene on the environment of paralic up phase and delta regression (Anonymous, 2013).

The Warukin Formation (T_{mw}) is overlain unconformably by the Quaternary Dahor Formation (T_{Qd}) (Fig. 2). The Miocene Warukin Formation was deposited as shallow marine to continental sands, muds, and coals. This gentle formation is folded forming south flank of the anticlines in the study area. Warukin Formation of 1,250 meters thick consisting of alternation of fine to coarse grained quartz sanstone layers and conglomerates of 5-30 cm thick, claystones of 3-100 cm thick, sandy claystones, and coal seams of 20-50 cm thick, was deposited in the above-mentioned environment as a coal bearing formation in the study area and the vicinity. In the study area, an anticline with a southwest-northeast axis is probably cut by strike slip faults, along which Sungai Kintap Kanan and Sungai Cuka and other paralel streams going to the south coast. Sungai Rantau developing along northeast-southwest line is probably a northwest dipping reverse fault cutting the flank of the anticline. However, in the area of study, no clear indication of faults were found in either the surface layout or in the borehole cores.

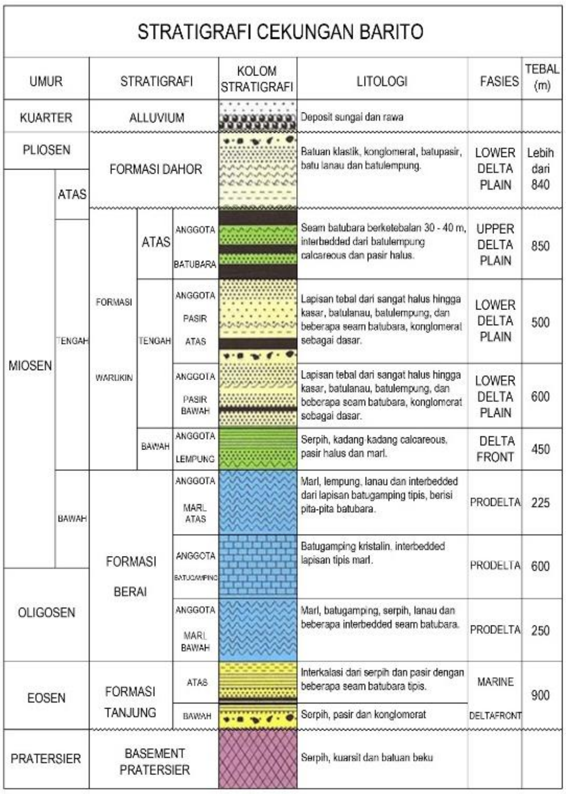


Figure 1. Barito Basin Stratigraphy (Anonymous, 2013)

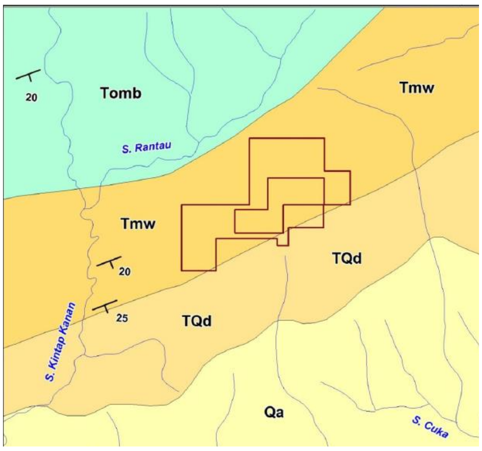


Figure 2 Geologic map of Sungai Cuka, Kintap, in Regency of Tanahlaut, South Kalimantan and the study area in Warukin Formation (Anonymous, 2013)

T_{Qd} = Dahor Formation ; T_{mw} = Warukin Formation as coal bearing formation; T_{omb} = Berai Formation; Q_a = alluvial deposits

The cores were studied for presence of fissures or jointing during geotechnical logging. The study showed that fissures and joints were frequent in the cores in the boreholes. Based on the characteristics of the borehole cores, the formation mainly consists of weathered claystones, silty and sandy claystones, and carbonaceous claystones with several intercalated coal seams. This stratified rock formation at the site is a part of south flank of a gently to moderately folded fold caused by a weak to moderate tectonic activity. The dip ranges from 20^o to 25^o to the southeast direction.

Zakaria *et al.* (2013) explained about the needs to correct the slope mass rating

(SMR) for the design of open pit coal mine due to variability of rock and soil engineering characteristics in nearby area of Sangasanga, East Kalimantan.

According to Irsyam, M., *et al.,* (2010) Indonesia is divided into 6 seismic zones giving peak horizontal ground accelerations for use in stability calculations. The accelerations in those zones vary between 0.05g to 0.30g. The axis of the central zone of highest acceleration of 0.30 g is in central Sulawesi almost parallel to the east coast of Kalimantan. Along this coast the acceleration is of 0.10 g of seismic zone 2. The Kintap area is located in seismic zone 1 of zero to 0.05g. This coefficient is generally for relatively small structures with their main axis normal to the seismic wave. This acceleration should therefore be used for local and bench failures. The analysis of slope stability in the study area is carried out being conditioned in seismic loading at α = 0.05 resulting in slightly lower safety factor values.

METHODOLOGY

Slope Stability Analyses

The stability of a slope depends on driving style and the style of the existing retaining the sliding plane in the slope. The driving force such as gravity, the force due to the acceleration of blasting and / or seismic, while the forces retaining the form of shear force, cohesion and shear strength. If the driving force is greater than the force retaining the slope unstable and landslides. But when the retaining force is greater than the driving force, then the slope is stable and will not be a landslide. If viewed from a small element that sits on a sloping sliding plane. The small element will move toward the lower left. When the driving force is composed of the heavy elements and the slope of the incline little larger than the retaining force in this case consists of the surface roughness and the slope of the sliding plane, then a small element face contact with the sliding plane can be considered as limiting balance. Furthermore, the method adopting this principle is called Limit Equilibrium Method.

If a set of small elements that form a larger mass, the stability of the masses can be analyzed based on the limit equilibrium method. At either open pit coal, minerals, or other such mass regarded as either

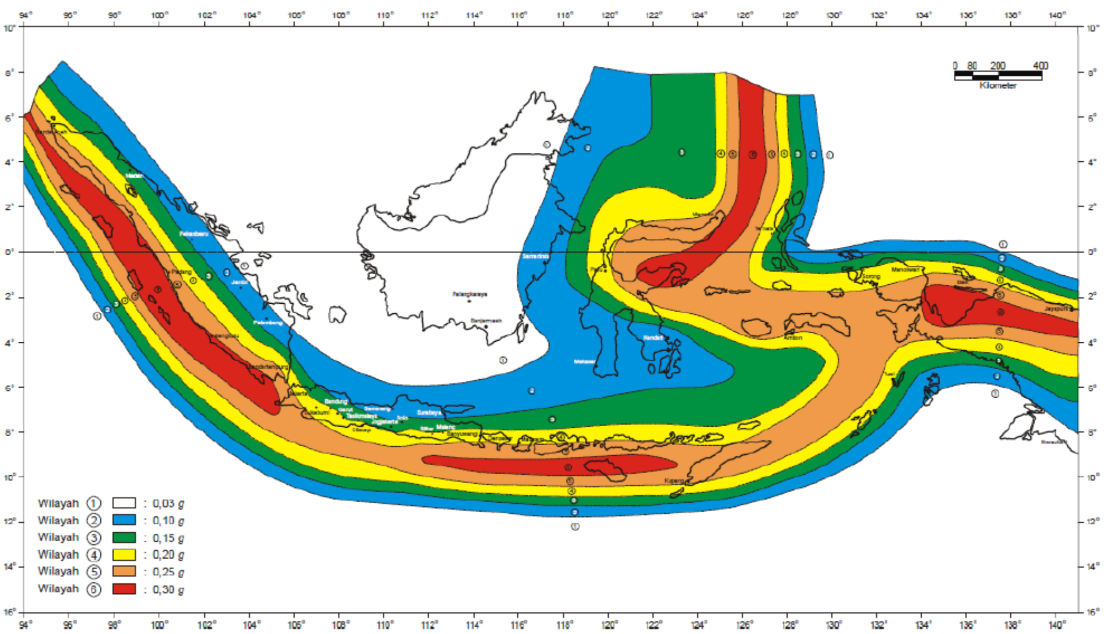


Figure 3 Seismic hazard map of Indonesia (Irsyam, *et al.,* 2010)

insitu or embankment slopes. Slope stability analysis by the limit equilibrium method only uses static equilibrium conditions, and ignore the stress-strain relationships that exist within the field of avalanche slopes and geometry must be known or determined in advance. The determination of the geometry of the landslide field greatly affect the results of the calculation of slope stability analysis. SF on the limit equilibrium method is calculated using force equilibrium or balance moments, or using both the equilibrium conditions depending on the method of calculation used. In determining SF there are some static equations are used and include:

- The sum of force in the vertical direction for each slice that is used to calculate the normal force at the base of the wedge.
- The sum of force in the horizontal direction for each slice that is used to calculate the normal force between the slices.
- The sum of moments for the whole slices resting on one point.
- The sum of force in the horizontal direction for the whole slice.

Figure 4. above describes a rock that has discontinuous field (weak field), which works normal stress and shear stress so that cracks in the rock field and a discontinuous shift. Shear stress required to fracture the rock and shift will increase in accordance with increasing normal stress. This relationship can be seen in the graph in which linearly formed a line with a slope angle of Ø to the horizontal. This angle is called the angle of friction inside. When the normal voltage is made zero and then given shear rock to rock begins to crack, then the value of shear stress needed when rocks began to crack is the value of the cohesion of the rock.The relationship between shear strength (τ) and normal stress (σ) is expressed by the following equation:

$$\tau = C + \sigma_n \tan \emptyset$$

If a mass weighing W is above an inclined plane with an area A at an angle α to the horizontal and in a state of equilibrium, then the working components of the forces as shown in Figure 4 Normal stress can be expressed as follows:

$$\sigma_n = \frac{(W \cos \alpha)}{A}$$

By subsidizing the above equation is obtained:

$$\tau = c + \frac{(w \cos \alpha)}{A} \tan \emptyset$$

Given F = τ x A, then the anchoring force Fp is:

$$F_p = c.A + (w \cos \alpha) \tan \emptyset$$

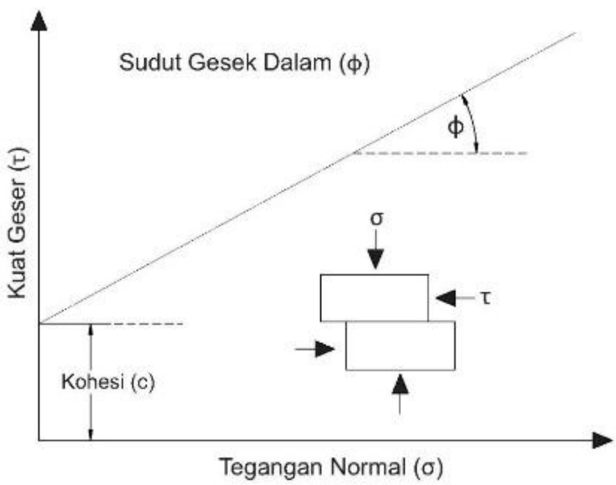


Figure 4. A description of rock that has a discontinuous field

Based on the limit equilibrium law, large retaining force is proportional to the big driving force, then:

$$w.\sin\alpha = c.A + (w\ \cos\alpha)\tan\emptyset$$

If there is no cohesive force (c = 0), which works on the basis of the beam then the equilibrium conditions can be simplified α = ∅

Analysis of Variance

The purpose of this analysis is to test whether the data follow a normal distribution or not, as a condition of a test using parametric methods. Suppose there is a random sample of observations x_1, x_2, ... x_n. Based on these observations sample to be tested whether the data is normally distributed or not. The steps of the test are as follows:

- Specify the null hypothesis, normal distribution of data, and the alternative hypothesis data is not normally distributed
- Sort data observations (x_i) data from the smallest to the largest data then calculate each raw numbers by using the following formula:

$z_i = \frac{x_i - \bar{x}}{s}$ where $\bar{x} = \frac{x_1 + x_2 + \cdots + x_n}{n}$ and $s = \sqrt{\frac{\sum(x_i - x)^2}{n-1}}$

- Calculate the odds $F(z_i)$ using the standard normal distribution list
- Calculate the proportion of z_1, z_2, …, z_n that is less than or equal to z_i. or can be calculated by:

$$S(z_i) = \frac{z_1, z_2, \cdots, z_n\ where\ \leq\ z_i}{n}$$

- Compute the difference $F(z_i)$ – $S(z_i)$ and define the absolute price
- Take the largest value (called Dmax) and then compare it with the value of Lilliefors (L) table
- Reject H_0 if $D_{max} \geq L$, received in other cases.

The research steps follow the order of the methodology as follows:

(1) For each rock formation rock geotechnical mapping studies conducted with reference based on the classification by Dearman (1991), in order to obtain geotechnical rock units according to the ranking of each in detail. Likewise, for every soil mapping with reference to the Unified Soil Classification System (USCS).

(2) On the map of the location of the prospective mine made measure section of pit the high (pit high-wall slope overalls or HW), then plotted the locations of points geotechnical drilling for geotechnical studies in the prospective opening of the mine (pit). Likewise the low overall wall slope or LW.

(3) Of the several existing geotechnical drill point at about candidates HW and LW obtained in the form of cylindrical drill core samples of rock have been drilled represent geological conditions below the surface. Each drill results are presented as log geotechnical drilling (geotechnical drilling logs).

(4) Some samples of drill core representing sent to the laboratory of soil mechanics and rock to be tested physical properties and mechanics, which will be used as data for analysis of slope stability HW and LW, also simulated to obtain the slope geometry-thorough ranging from the surface to a depth maximum (about 100 metert) stable under static conditions, dewatering, and an earthquake, but still supports the opening of the mine (pit) to stay productive but safe on slope.

(5) Then, testing the hypothesis based on the analysis of slope stability for the sample group as follows: a) slope static conditions without dewatering, b) the slope on the condition of the earthquake on the condition without dewatering, c) slope static condition and dewatering, and d) the slope on earthquake conditions and dewatering

RESULTS AND DISCUSSIONS

The research location is an area of mining and oil palm plantations. Small rivers or creeks cut sites. Stream-flow patterns are mostly intermittent, but in some places is perennial and dendritic. This indicates that the soil surface resistance to erosion varies, depending on the host rock and residual soil origin.

Kintap area is located in the Regency of Tanahlaut, which has tropical climate with wet and humid conditions and rainfall variations between 92.00 mm / month (August) to 393.00 mm / month (April) (according to the rainfall data for 1960-1990). The average monthly temperature ranged between 19.50°-33.70°C.

Data reconstruction for strike and dip of bedding planes of the formation showed that the rock layers are folded up gently to moderate as the configuration of the structural geology. Strike of the layering of several outcrops oriented toward the southwest-northeast with dips 20° to 25° to the southeast. The result of engineering geological mapping (figure 5) shows the distribution of soil types of high plasticity inorganic clay (CH) and poorly graded sand (SP).

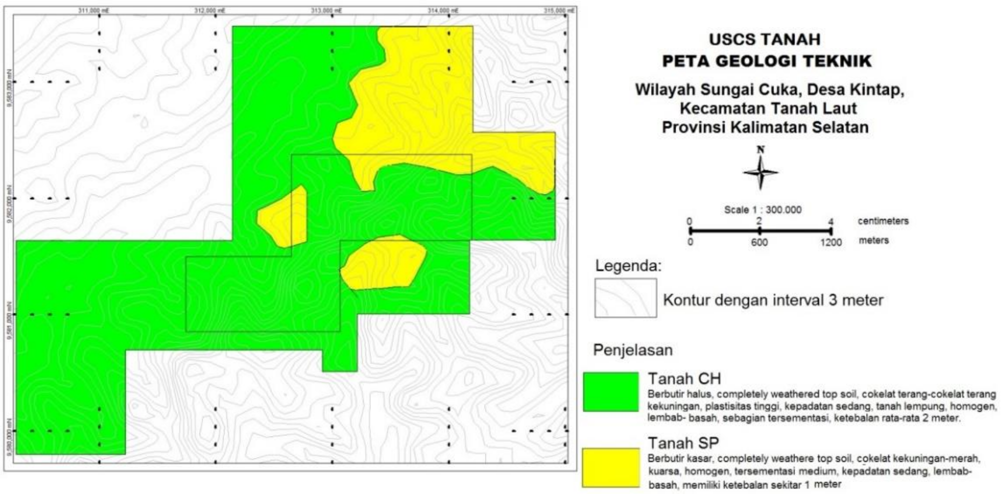


Figure 5. Engineering geological map of the study area around the study area

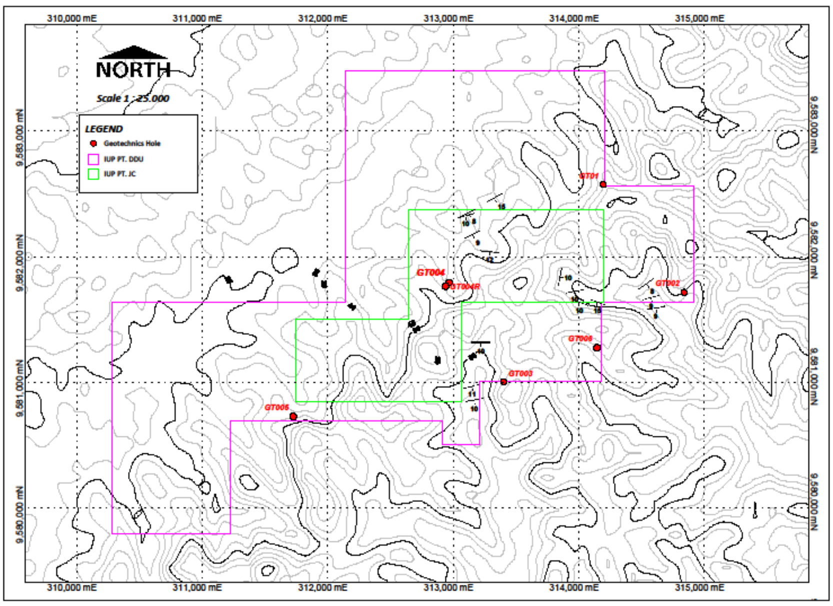


Figure 6. Geotechnical drilling holes distribution in the study area

Geotechnical drilling log (drill holes) GT.01, GT.02, GT.03., GT.04R, GT.05, and GT.06 represents the state of the subsurface geology mostly composed of intercalation between sandstone, claystone and coal seams. The geotechnical characteristics of the rocks based on the uniaxial compressive strength (UCS) values versus depth indicate that the nature of the rock mass tend to be weak. The rock mass is unstable for steep slopes. Figure 6. presents the variation of UCS value of rock along with the increasing depth in the drill hole. Classification of cohesive soil and rock by uniaxial compressive strength (modification of Hoek and Bray, 2005) were used to classify the mass of soil and rock.

Dig ability assessed by standard graph RQD (Rock Quality Designation) of the UCS. Graph rock split into five classes: two classes to fracture blast, blast up to loosen, rip and direct excavation with a value of less than 1 MPa UCS and certain RQD values of log wells, then this field can be classified in five classes that allow direct excavation without blasting or ripping.

Limit equilibrium analyses were conducted to determine the safety factor against slope failure during mining and operation of heavy mine vehicles. The analyses were conducted using available two-dimentional approach, limit equilibrium software, SLIDE. The method of slope stability analysIs used was soil slope stability because the material properties or core samples coming from 6 boreholes in research area presented by their UCS values are for soil and moderately weak rock mass. The principles underlying the method of limit equilibrium analysis of slope stability are presented below.

1. A slip mechanism of slope failure is postulated;
2. The shear resistance required to equilibrate the assumed slip mechanism is calculated by means of statics (in a state of balance, motionless);
3. The calculated shear resistance required for the equilibrium is compared with the available shear stress in terms of factor of safety FS;
4. The slip mechanism with the lowest factor of safety is determined through iteration;
5. The lowest value of FS of slope design should be larger than a critical value according to design criteria to keep the slope in a stable condition; and
6. Design criteria for the stability condition should involve rainy season (saturated soil/rock of slope) and seismic or earthquake loading at peak local acceleration. But, because local acceleration is nearly zero in Kalimantan region, the analyses of slope stability are carried out to test if the overall slopes are safe.

Factor of safety is used to account for the uncertainty and variability in the strength and pore water pressure parameters, and to limit deformation.

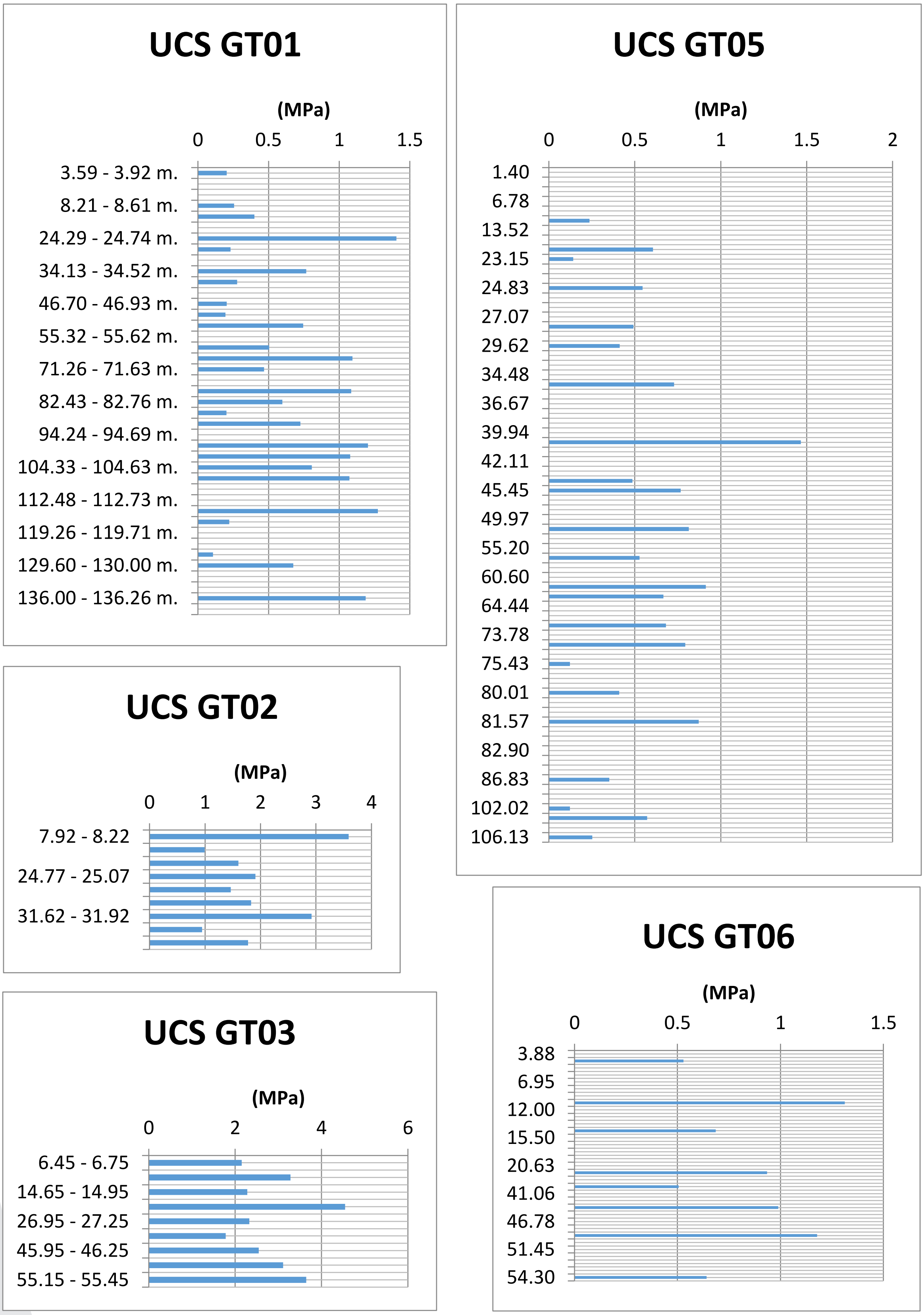


Figure 7. Values of UCS compressive strength versus depth

Slope stability analysis according to Hoek & Bray (2005) were conducted for the deepest cross sections of the open pit. The soils and rocks constructing the open-pit cut slopes were inferred, being based on the results of drilling represented by borehole logs, to be clays and silts of high plasticity, grading into alternation of soft claystones and thin bedded sandstones with coal seams intercalation. These rock mass properties act as soil mass of weak strength as mentioned earlier.

Design criteria of a stable cut overall slope should be achieved through simulation and iteration in the process of slope stability analyses. This design criteria used as a guideline in open pit mining is listed below in Table 1.

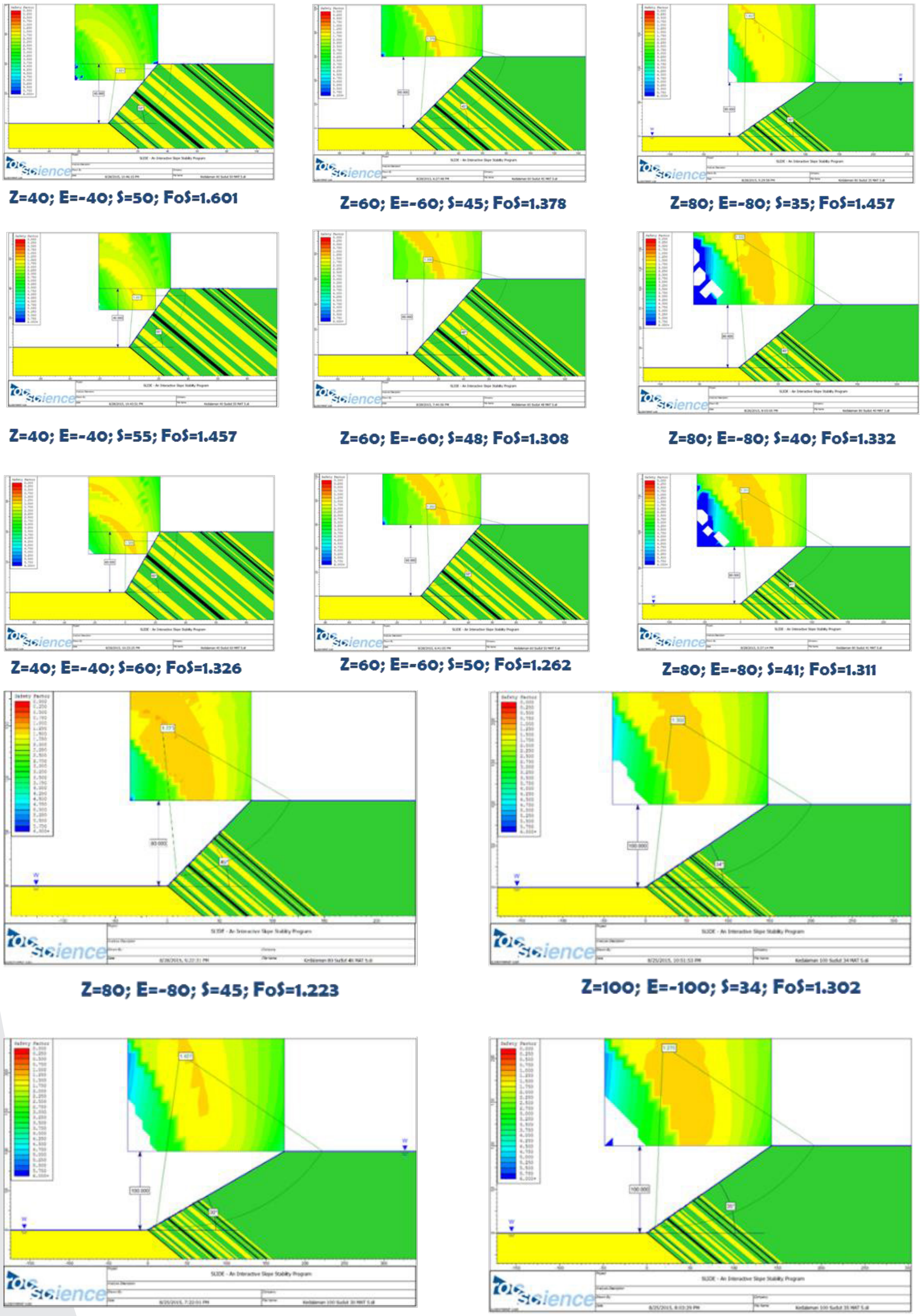
For more convenience in Figure 8 up to 11 as the results of analysis and simulation of all slope sections mentioned above variation of slope angle and height of the slope sections, both at static and pseudo static condition (at earthquake load) at α = 0.005 g (slightly larger than acceleration originated by heavy vehicles or mining equipment's), including the safety factor obtained are presented, slope stability model below (figure 8).

Based on the results of statistical tests and simulation of slope stability with static conditions, without / with dewatering, without / with the PGA (Pseudostatic condition at earthquake load). Indicates that proved the previous deduction that PGA, dewatering, and both these factors affect the overall slope safety factor-high wall open pit, as follows

- As a result of the seismic (PGA) safety factor overall slope open pit decreased;
- As a result of dewatering slope safety factor increased, more stable;
- The positive role of dewatering, although due to seismic (PGA) safety factor remained stable for overall slope.

Table 1. Design criteria for Factor of Safety (SF)

Stability Condition	Minimum Design Factor of Safety
Long Term Deep Seated Stability (static condition)	1.30
Stability at seismic loading condition (pseudo-static condition)	1.05



Z=40; E=-40; S=50; FoS=1.601

Z=60; E=-60; S=45; FoS=1.378

Z=80; E=-80; S=35; FoS=1.457

Z=40; E=-40; S=55; FoS=1.457

Z=60; E=-60; S=48; FoS=1.308

Z=80; E=-80; S=40; FoS=1.332

Z=40; E=-40; S=60; FoS=1.326

Z=60; E=-60; S=50; FoS=1.262

Z=80; E=-80; S=41; FoS=1.311

Z=80; E=-80; S=45; FoS=1.223

Z=100; E=-100; S=34; FoS=1.302

Z=100; E=-100; S=30; FoS=1.427

Z=100; E=-100; S=35; FoS=1.275

Figure 8. Static condition vs. without Dewatering

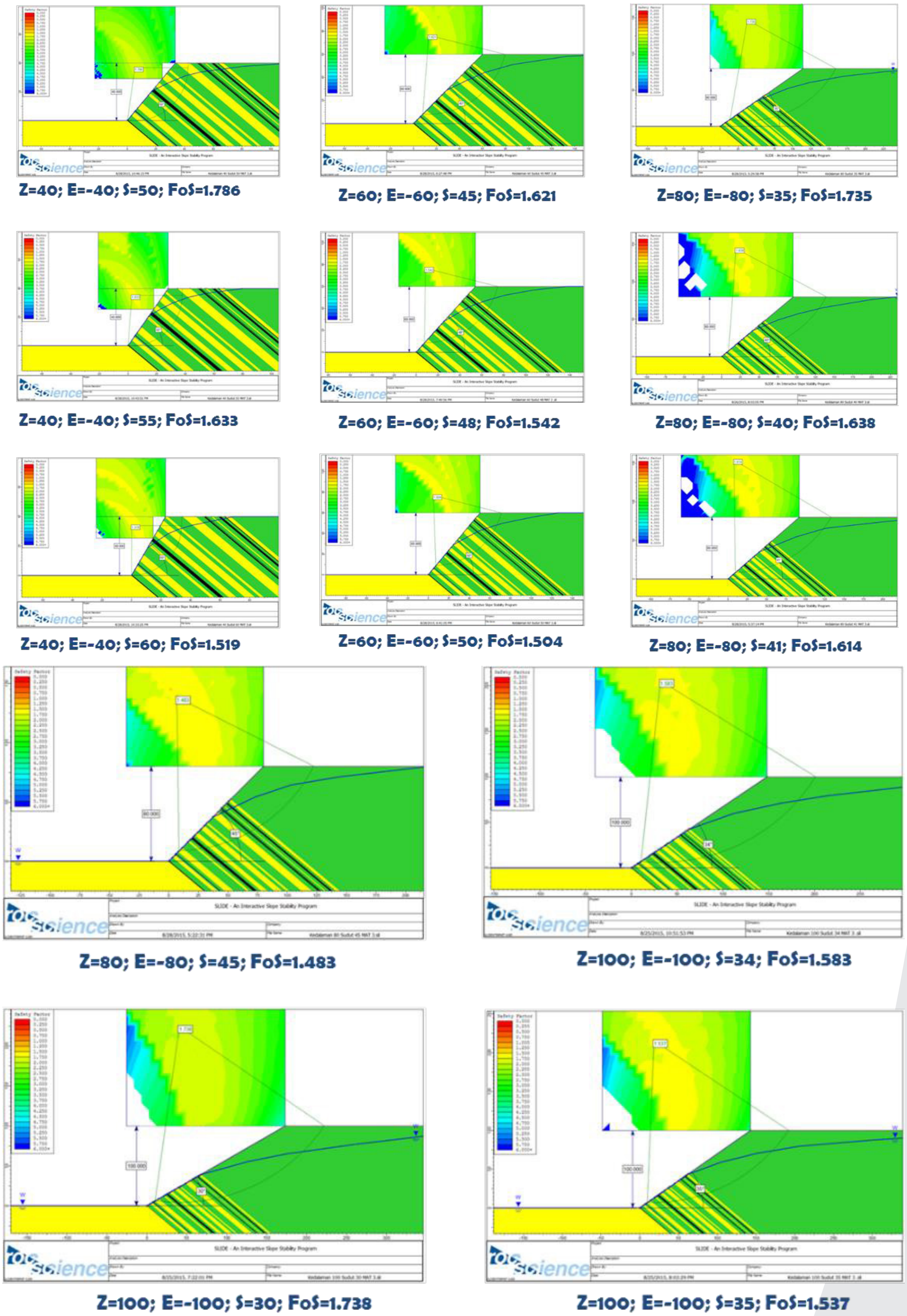


Figure 9. Static condition vs. with Dewatering

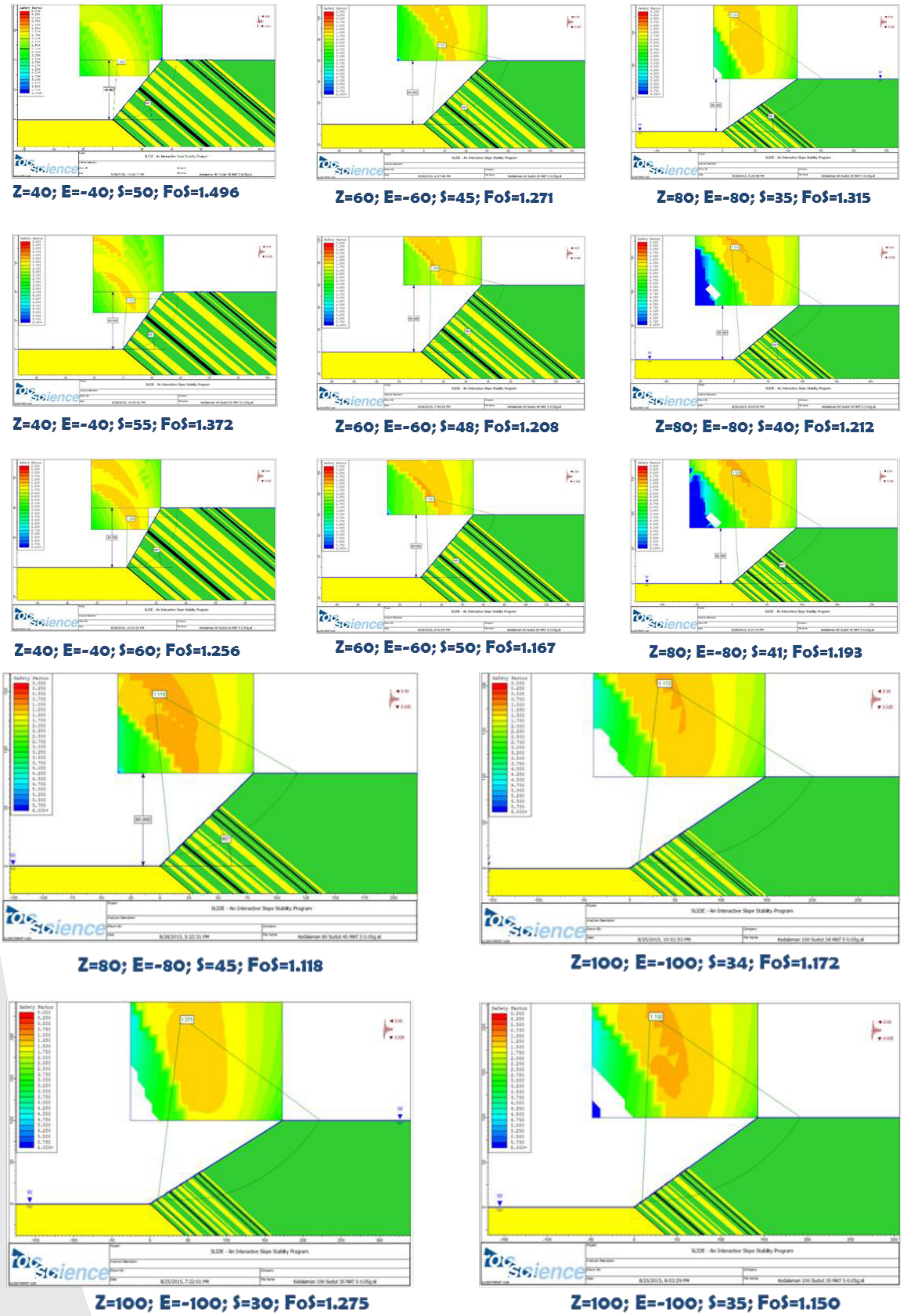
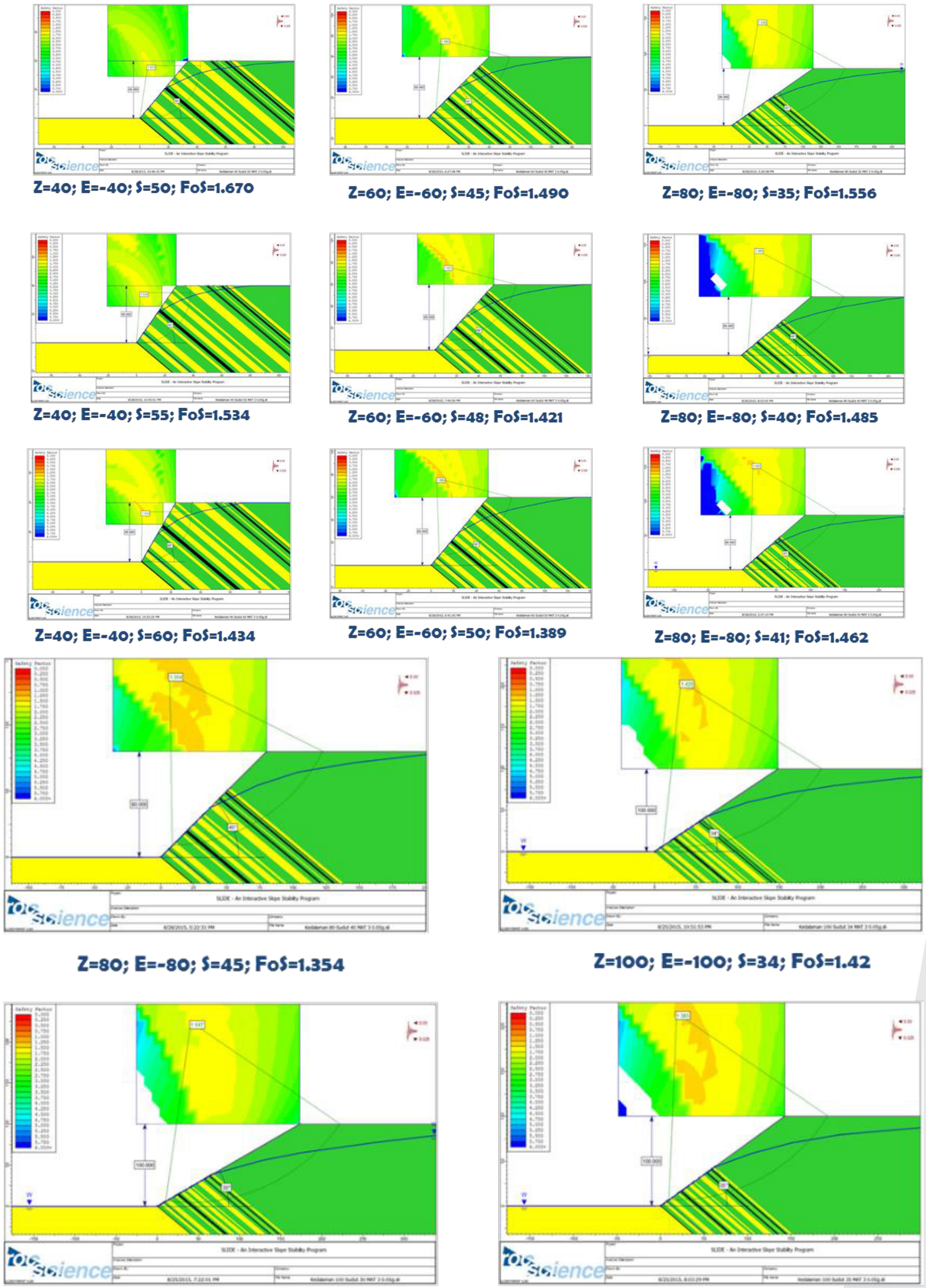


Figure 10. Pseudostatic condition (at earthquake load) vs. without Dewatering



Z=40; E=-40; S=50; FoS=1.670

Z=60; E=-60; S=45; FoS=1.490

Z=80; E=-80; S=35; FoS=1.556

Z=40; E=-40; S=55; FoS=1.534

Z=60; E=-60; S=48; FoS=1.421

Z=80; E=-80; S=40; FoS=1.485

Z=40; E=-40; S=60; FoS=1.434

Z=60; E=-60; S=50; FoS=1.389

Z=80; E=-80; S=41; FoS=1.462

Z=80; E=-80; S=45; FoS=1.354

Z=100; E=-100; S=34; FoS=1.42

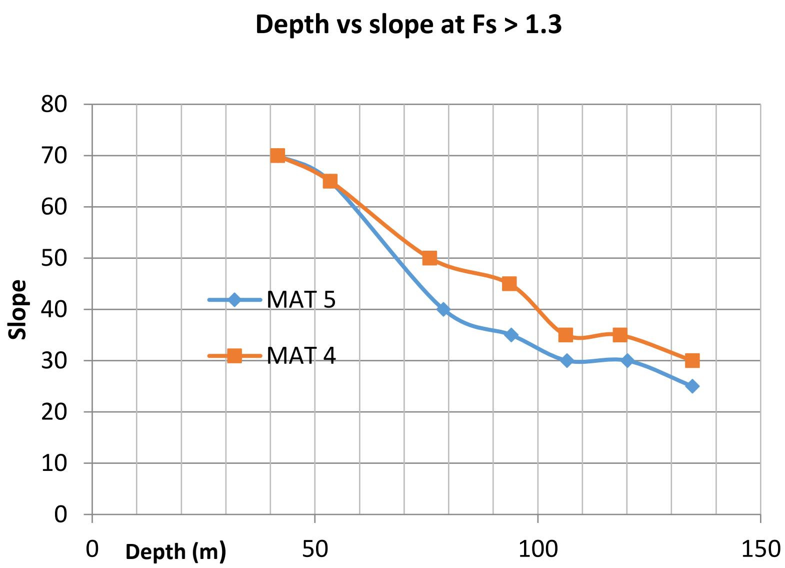
Z=100; E=-100; S=30; FoS=1.547

Z=100; E=-100; S=35; FoS=1.383

Figure 11. Pseudostatic condition (at earthquake load) vs. without Dewatering

Curves illustrating relation or correlation of depth of pit and angle of slope at stable conditions, without and with dewatering or both at groundwater level 5 and 4 (GWL/MAT 5 and GWL/MAT 4) conditions, are presented in Figure 12. below. The curves represent depth of pit from the surface (crest of highwall) up to the floor of pit at about 135 meters depth.

Curves of MAT/GWL 5 and MAT/GWL 4 in figure 12 connecting every plotted points show that depth increases with decreasing angle of slope at stable conditions. This has resulted that in this research with SF acceptable, but is still limited to representative of Warukin Formation. Continued research into a number of other open pit mines with different formations can be done to obtain a more comprehensive picture about the suitability of the criteria that have been proposed.



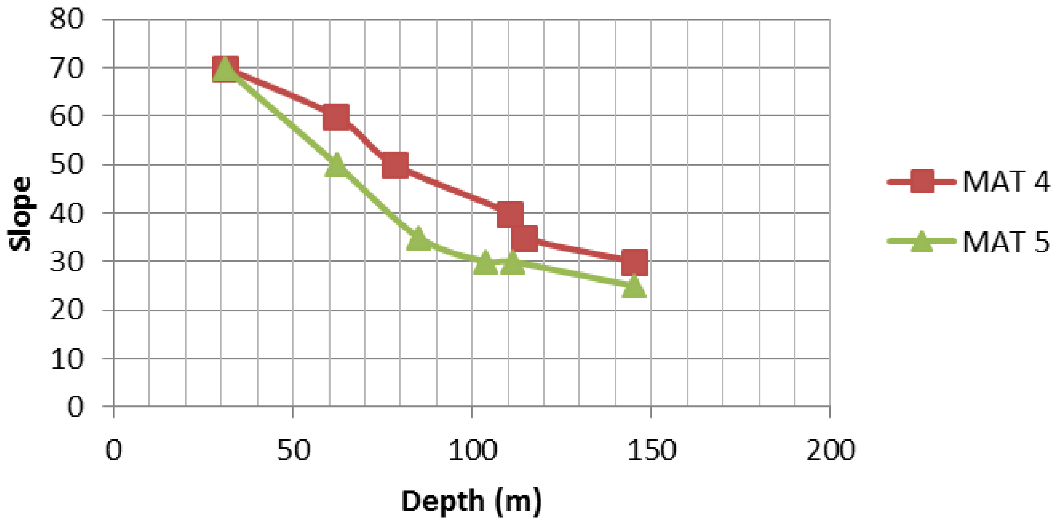


Figure 12. Cross plot of depth versus slope at stable condition or at Fs larger than 1.3 for highwall slope on section GT.04R at static condition. Curve of MAT (groundwater level) 5 is for slope without dewatering, whereas curve MAT (groundwater level) 4 is slope with dewatering

Table 2. Matrix of statistical test results:

No	Hypothesis	Test Methods	Statistical Tests	Criteria	Decision	Results
1	Seismic has no effect on Slope Safety Factor (SF). It is characterized by the absence of mean difference between the SF in static conditions with SF on seismic conditions, without dewatering	Mean Difference test, Pair samples	t_{hit}=11.830	t_{crit}=2.101	Rejected H_0	There are differences between SF in static conditions with SF on seismic conditions without dewatering
2	Dewatering has no effect on SF. It is characterized by the absence of mean difference between SF in a static condition without dewatering, with SF on the condition of the seismic in a state with the dewatering half of slope height	Mean Difference test, Independent Samples	t_{hit}=-4.218	t_{crit}=2.101	Rejected H_0	There are differences between the SF in static conditions, without dewatering, the SF in static conditions in a state with the dewatering half of slope height
3	Dewatering and seismic have no effect on the FS. It is characterized by no mean difference between FS in static condition without dewatering and the FS seismic conditions with dewatering	Mean Difference test, Independent Samples	t_{hit}=1.664	t_{crit}=2.101	Accepted H_0	There is no difference between the SF in static condition without dewatering with the SF on the seismic conditions in conditions with dewatering
4	Depth correlation with slope angle on Warukin Formation in static conditions (without dewatering)	Regression-correlation Analysis	r=-0.9635 t_{hit}=-8.0504	t_{crit}=2.5706	Rejected H_0	There is a correlation between the depth and the slope angle on Warukin Formation in static conditions (without dewatering)
5	Depth correlation with Slope Safety Factor of Warukin Formation in static conditions (without dewatering)	Regression-correlation Analysis	r=-0.3778 t_{hit}=-0.9123	t_{crit}=2.5706	Accepted H_0	There is no correlation between the depth and the Slope Safety Factor of Warukin Formation in static conditions (without dewatering)
6	Depth correlation with Slope Safety Factor of Warukin Formation on seismic conditions (without dewatering)	Regression-correlation Analysis	r=0.0551 t_{hit}=-0.1234	t_{crit}=2.7764	Accepted H_0	There is no correlation between the depth and the Slope Safety Factor Warukin Formation on seismic conditions (without dewatering)
7	Depth correlation with slope angle on Warukin Formation in static conditions (with dewatering half of the height slope)	Regression-correlation Analysis	r=-0.9688 t_{hit}=-8.7357	t_{crit}=2. 5706	Rejected H_0	There is a correlation between the depth and the slope angle of Warukin Formation, in static conditions

CONCLUSIONS

From the discussions above it can be concluded that dewatering process had lowering the groundwater level (GWL) in the slope body. GWL existence raises pore water pressure which decreases the stability of the slope or the measured slope safety factor decreased, due to the durability of sliding along the sliding plane decreases. Thus in contrary, dewatering will increase the safety factor of the slope.

The safety factor is the ratio between the minimum shear resistant force (shear strength or resisting moment) with thrust shear (shear stress or driving moment) along the sliding plane. Earthquake-resistant has lowered shear force, and simultaneously increase the thrust sliding at the same time, so the safety factor of the slope decrease suddenly.

The stability of slope decreases as a result of the earthquake, but dewatering improve slope stability. Thus the slope of the dewatering conditions will be kept stable through simulation to anticipate the earthquake.

The results of this research are also expected to be useful as a reference for geotechnical studies in various locations of Warukin Formation, as carrier of coal in Kalimantan and elsewhere.

ACKNOWLEDGEMENT

The authors would like to thank IBP for the support of this research program.

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Diterima	: 25 Februari 2016
Direvisi	: 4 April 2016
Disetujui	: 17 Mei 2016