Study of Control Well to Prevent Landslides Risk During Construction of Cisumdawu Toll Road

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ABSTRACT

Landslides often occur in the Cisumdawu toll road area. The reason is that the toll road section is located in a basin surrounded by three volcanic mountains, namely Mount Tampomas, Manglayang, and Patuha, so that it has geographical conditions in the form of ravines and cliffs that have steep slopes. The purpose of this research is to study the control well planning as a short term/temporary solution (during the construction period of 3-5 years) that can be carried out in the construction of the Cisumdawu Toll Road project section 1 phase 3 at STA 0+975 in order to be safe from hydrological disasters which are expected to modeled on other toll road construction projects in need. The research phase begins with the primary data collection phase through soil sampling, soil laboratory testing, and documentation of existing conditions. Secondary data in the form of rainfall data, contour maps, postal maps of rainfall, and drilling log data. Furthermore, the data processing stage begins with geotechnical analysis in the form of taking soil samples which are then tested in the laboratory, as well as slope stability analysis using the finite element method, namely Plaxis 2D software in three conditions, namely before excavation, after excavation without load and after excavation with traffic loads to determine groundwater level at safe conditions (SF > 1.25). The second stage is a hydrological analysis to calculate the intensity of rainfall with a return period, calculate the infiltration discharge and end with the planning of control wells. Control wells are planned to keep the groundwater level from exceeding the critical water level, which can cause landslides. From the research, the planned control well has a diameter of 1 m which is dug as deep as 10 m, with the choice of a centrifugal pump which has a diameter of 12 inches, a total head of 10 m, and a discharge of 14 m^3/ min and equipped Water Level Control (WLC) as sensors.

***Keywords**: Control Well, Landslides, Plaxis 2D, Infiltration Discharge.*

1. INTRODUCTION

Landslides often occur in the Cisumdawu toll road area because the toll road section is in a basin, so that it has geographical conditions in the form of ravines and cliffs that have a steep slope. The development of a very rapid and dense population and the rain that falls at certain periods causes excess water in this area [1]. Coupled with unstable soil conditions and large vehicle loads, this area is prone to landslides [2]. Landslide on a slope is the movement of soil rock mass in an upright, horizontal or inclined direction from the initial position, resulting from the slope's inability to withstand the shearing force acting on the boundary between the moving mass and the stable mass [3]. According to the news, many houses in four hamlets in Sinarmulya, North Sumedang District, Sumedang Regency are threatened with landslides due to the Cisumdawu Toll Road construction project. The reason is because the project location is located right on the edge of a residential area and causes vibrations on the ground surface. Seeing the problems that occur, it is necessary to carry out further studies in hydrological analysis calculations and geotechnical analysis on existing conditions by examining the possibility of hydrological disasters during toll road construction. Control wells are expected to provide an overview of toll road protection solutions to be safe from the risk of landslides which are expected to be applied to other similar project road works.

2. RESEARCH METHODS

The implementation methodology can be seen in the figure below. The flowchart of this research methodology describes the stages in completing the research to produce the expected output.

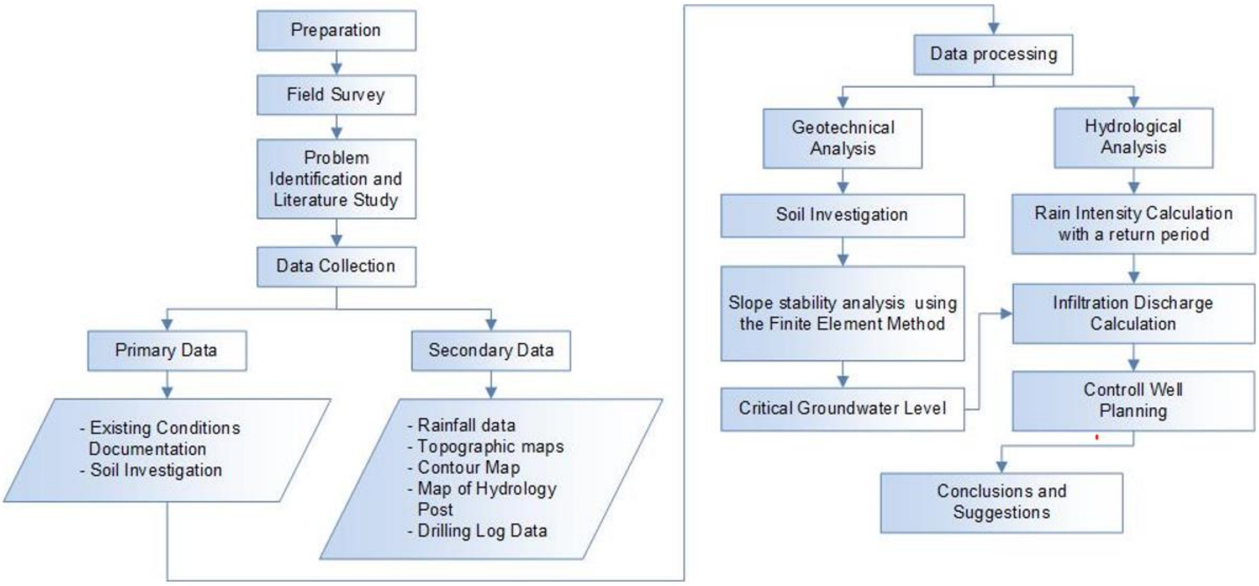

Figure 1. Final Project Research Location

2.1. Study Area

Cisumdawu is an abbreviation of Cileunyi – Sumedang – Dawuan, which is currently one of the national strategic projects that aim to improve the economy of West Java Province. The 60 kilometer long toll road part of the Trans Java Toll Road in West Java connects the Cileunyi – Sumedang – Dawuan or Padaleunyi Toll Roads with the Palimanan – Kanci Toll Road with a total area of 825 ha. In addition, this toll road will be one of the alternatives connecting Bandung, Dawuan, and Subang. The Cisumdawu toll road will support the transfer of the functions of Husein Sastranegara Airport in Bandung to Kertajati Airport in Majalengka. The Cisumdawu toll road is targeted for completion in 2021, but with the acceleration of the operation of West Java Kertajati International Airport, the construction of this toll road will be accelerated to the end of 2020 to increase traffic movement to the airport. The research is carried out on the main road of STA 0 + 975 in Phase 3 of Cileunyi, as shown in the figure below.

Figure 2. Final Project Research Location
Source: Google Earth

2.2 Soil Investigation

Soil investigation begins with taking soil samples at the research site by drilling to a depth of 22.5 m so that the type of each soil layer is known [4]. The soil samples were then taken to the laboratory for testing. It begins with testing the soil's physical properties, which aims to determine the properties related to the elements of the composition of the existing soil mass [5], consisting of testing the soil's water content and bulk density. It is followed by testing the soil's mechanical properties, which aims to determine the nature/behavior of the soil mass structure subjected to a force or pressure described by mechanical engineering [6], consisting of permeability testing and triaxial Unconsolidated undrained (UU). Data from laboratory tests are used for slope stability parameters using Plaxis 2D.

2.3 Slope Stability Analysis

Slope stability analysis must be based on accurate data regarding the condition of subsurface materials, groundwater conditions, and the loading that may act on the slope [7]. In this study, the analysis uses the finite element method, which is a method that provides an overview of the great potential to deal with geotechnical problems because of its ability to model nonlinear soil stress behavior [8]. Plaxis 2D modeling is used specifically to carry out deformation and stability analysis in the geotechnical field, making it easier to quickly create geometric and elemental models based on cross-sections of the slope conditions to be analyzed [9]. Parameters used in the software are obtained from the results of soil testing in the laboratory[10]. The output of this analysis is the critical groundwater level which can cause the risk of landslides. The minimum safety factor used is SF > 1.25. provided that [11]:

SF > 1.25 = Slope in a safe condition.

SF < 1.07 = Slope in an unsafe condition.

SF 1.07 > 1.25 = Slope is in critical condition.

2.4 Rainfall Intensity

The calculation of rainfall intensity begins with determining the rainfall station containing rainfall data for the past 10 years. The rainfall design needs to be calculated for the frequency distribution used to analyze the data, statistical parameters to get the design of rainfall, and which method meets the requirements. [12]. It is followed by a distribution method fittest to determine whether the probability distribution equation used can represent the statistical distribution of the analyzed data for both the vertical and the horizontal data deviation. [13]. The calculation of rain intensity uses the mononobe formula, where it is assumed that the duration of the rain is the same as the previously obtained value of the time of concentration. The resulting output is a relationship of rainfall intensity for each duration. [14]. The method used in this research is Mononobe which has the following general formula.

$$I = \left[\frac{R_{24}}{24}\right]\left[\frac{24}{t}\right]^{2/3} \quad (1)$$

Where:
I = rain intensity (mm/hour)
t = rainfall time (hour)
R_{24} = maximum rainfall in 24 hours (mm)

2.5 Infiltration Discharge

Calculation of infiltration discharge is used to determine the amount of rain discharge inundated and absorbed into the soil. Starting with the calculation of the Catchment Area sourced from the contour map downloaded from the Seamless Digital Elevation Model (DEM) and National Bathymetry [15]**.** Furthermore, for the area and determination of land use, it is obtained by using Software ArcGISand obtained by Google Earth Pro. Furthermore, the determination of the value of C based on land use, calculation of Cr (Coefficient of flow), and Qin (Infiltration Debit). The following equation calculates the infiltration discharge.

$$Qi = O{,}278 \times (1 - C) \times l \times A \quad (2)$$

Where:
Qi = infiltration discharge (m3/s).
(1 – C) = infiltration coefficient (without dimensions).
A = area of drainage ((Km2).
I = rainfall intensity (mm/h).

2.6 Control Well planning

After analyzing the slope stability using plaxis 2D, the critical groundwater level was obtained. The critical groundwater level is the height of the groundwater level that can cause the risk of landslides, as indicated by the value of the safety factor SF < 1.25. The control wells are planned to keep the groundwater level from exceeding the critical water level, which can cause landslides. The principle of calculation is using the tank model method with 1 tank layer). In tank models, the amount of runoff and infiltration is a function of the amount of water stored in the soil or subsurface water reservoirs [16]. The safety pump will operate before the GWL height reaches a critical condition and stop when the GWL reaches a safe height. The safety pump discharge is determined based on the catchment area and the infiltration discharge resulting from the simulation of the tank model. The evapotranspiration data used are climate parameters influenced by solar radiation, air temperature, humidity, and wind speed [17]. However, this data is not used because the research was conducted during the construction period, and it is assumed that the rainwater had not evaporated at that time. The control well is expected to be an alternative solution for slope failure during the construction period [18].

3. RESULTS AND DISCUSSION

3.1 Soil Investigation

After taking soil samples in the field, laboratory tests were carried out in the form of testing the physical properties consisting of testing the water content and bulk density of the soil and mechanical properties consisting of permeability testing and triaxial Unconsolidated undrained (UU), which is presented in Figure 3 - Figure 5 below.

Figure 3 Taking soil samples at the research site

Figure 4 Soil physical properties test

Figure 5 Soil mechanical properties test

3.2 Slope Stability Analysis

After taking soil samples in the field, laboratory tests were carried out to test the soil's physical properties and mechanical properties. The test results are then used as soil parameters for slope stability analysis using the finite element method, namely Plaxis 2D. The software analysis was carried out in three conditions: before excavation, after excavation without load, and after excavation with load with variations in groundwater level (0 m, -6 m, -7 m, and – 10 m). The software's output was in the form of safety factor and displacement values and to get what GWL was in safe conditions (SF > 1.25). The first condition was before the excavation was carried out, as described in the image below [19].

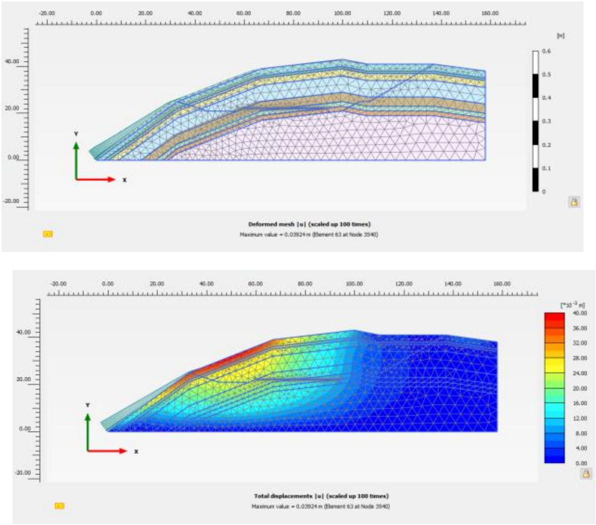

Figure 6 Displacement On The Slope before the excavation

Furthermore, software analysis was carried out in the second condition, described in the image below, after excavation without external load.

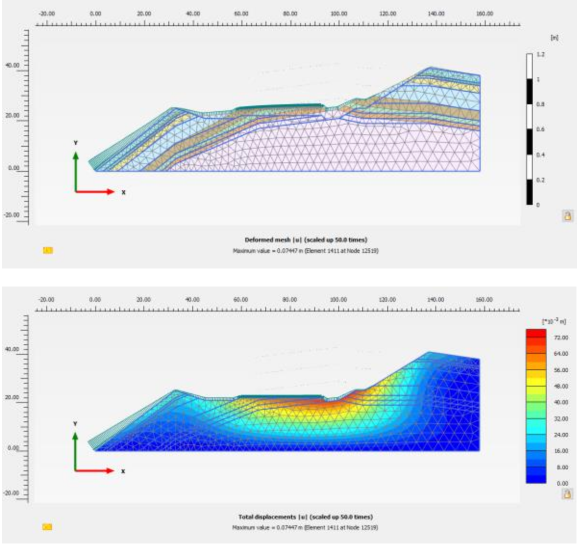

Figure 7 Displacement On The Slope after excavation without load

Furthermore, software analysis was carried out in the third condition, after excavation with an external load of 35 kN, as depicted in the image below.

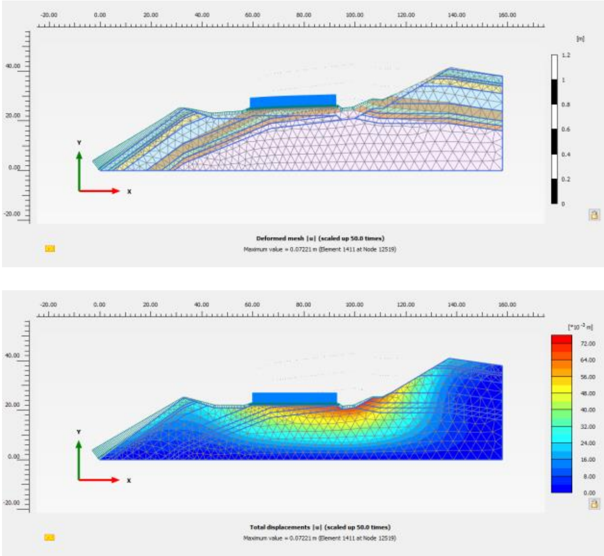

Figure 8. Displacement On The Slope after excavation with traffic load

Resume of values *displacement* slope at three conditions, namely before excavation, after excavation without load, and after excavation with load using variations in groundwater level on is presented in the table below.

Table 1. Recapitulation of Slope Displacement Value

GWL (m)	Displacement (m)		
	Before excavation	After excavation without traffic load	After excavation with traffic load
0	0.034	0.065	0.062
-6	0.035	0.069	0.067
-7	0.039	0.074	0.072
-10	0.045	0.085	0.084

Next, resume the value *Safety Factor* slope with three conditions is presented in the table below.

Table 2. Recapitulation of Slope Safety Factor Value

GWL (m)	Safety Factor		
	Before excavation	After excavation without traffic load	After excavation with traffic load
0	1.398	1.295	1.102
-6	1.461	1.362	1.238
-7	1.473	1.384	1.253
-10	1.496	1.401	1.271

The tables above show that the slope conditions after excavation with external loads on the GWL – 7 m have an SF value of 1.253, which means – 7 m is the GWL limit. The slope is in a safe condition because it has an SF value > 1.25. The value of GWL – 7 m is then used as a reference in planning the depth of the control well.

3.4 Rainfall Intensity Calculation

The rainfall data used comes from one station, namely Cileunyi station, with 10 years of data from 2011-2020. Maximum daily rainfall data for the last ten years obtained from BMKG can be seen in the following table.

Table 3. Maximum Daily Rainfall Data

No	Year	Maximum Daily Rainfall (mm)
		St. Cileunyi
1	2011	94
2	2012	100.2
3	2013	83.5
4	2014	95
5	2015	95
6	2016	90.5
7	2017	70
8	2018	122
9	2019	79
10	2020	138
Total (mm)		967.2
Average (mm)		96.72

Rainfall intensity is calculated over a 5-year return period using the method of Dr. Mononobe can be seen in the following table.

Table 4. Rainfall Intensity with Mononobe Method.

Time (t)	Rainfall Intensity (I)	
	R2	R5
	93,320	111,354
[hour]	[mm]	[mm]
1	32,352	38,604
2	20,381	24,319
3	15,553	18,559
4	12,839	15,320
5	11,064	13,202
6	9,798	11,691
7	8,841	10,550
8	8,088	9,651
9	7,477	8,922
10	6,970	8,317
11	6,541	7,805
12	6,172	7,365
13	5,852	6,982
14	5,570	6,646
15	5,319	6,347
16	5,095	6,080
17	4,893	5,839
18	4,710	5,621
19	4,544	5,422
20	4,391	5,239
21	4,250	5,072
22	4,121	4,917
23	4,000	4,773
24	3,888	4,640

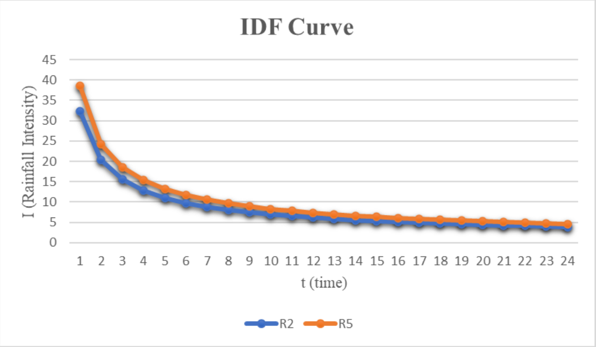

Figure 9 IDF Curve

Based on Figure 9**,** it can be seen that the value of the highest rainfall intensity is in the 1st hour, and the value decreases until the 24th hour. In addition, it can also be seen that there is an increase in the intensity of rainfall in each period of time.

3.5 Infiltration Discharge

The calculation of infiltration discharge was used to determine the pump discharge in the control well planning, which begins with calculating the catchment area. The catchment area in the thesis research was sourced from contour maps downloaded from the Seamless Digital Elevation Model (DEM) and the National Bathymetry. Furthermore, for the area and determination of land use, it was obtained using Software ArcGISand obtained by Software Google Earth Pro. The Catchment Area was divided into 2 following the placement of control wells. Those that enter the control well area 1 and control well 2 can be seen in the figure below.

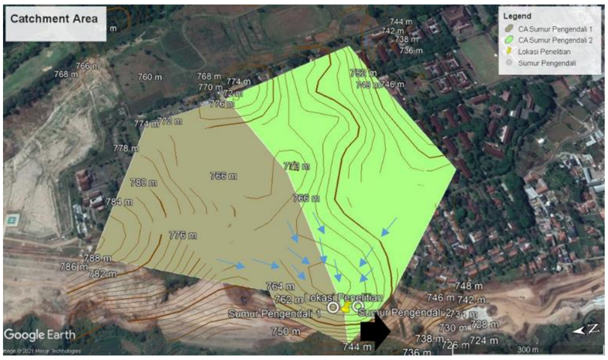

Figure 10 Catchment Area

Flash/sudden flood is a flood that occurs only in less than 5 hours after heavy rain began to fall. So the calculation of infiltration discharge in this study used rain intensity data at the 4th hour for a 5-year return period on the grounds that in the field. The trigger for the landslide phenomenon due to high rainfall intensity occurs after 4 hours, and at that hour is the maximum water flow discharge that seep into the soil through the soil surface. The calculation is presented in Table 5 - Table 6.

Table 5. Infiltration Discharge of Control Well 1

Land Use	Area (m2)	Runoff Coefficient	Infiltration Coefficient.	Infiltration Coefficient x Area	Infiltration Discharge (m3/s)
		(C)	(Cla)		
Grass	20473	0.55	0.45	0.00921	0.0475
Green space	52821	0.60	0.40	0.02113	0.1090
Building	79532	0.85	0.15	0.01193	0.0616
Total	152826				0.2181

Table 6. Infiltration Discharge of Control Well 2

Land Use	Area (m2)	Runoff Coefficient	Infiltration Coefficient.	Infiltration Coefficient x Area	Infiltration Discharge (m3/s)
		(C)	(Cla)		
Grass	31892	0.55	0.45	0.01435	0.0740
Green space	49561	0.60	0.40	0.01982	0.1023
Building	71693	0.85	0.15	0.01075	0.0555
Total	153146				0.2318

The type of well used was a dug well that used concrete, so it did not require a casing or screen pipe. As for the placement of the control well, it was 10 m from the edge of the right slope because it was temporary security, not the reinforcement usually placed on the left side of the road. The well has a depth of 10 m and a diameter of 1 m according to the concrete used, which has a diameter of 1 m. The image is presented in the 100-meter long slope review area shown in Figure 11 - Figure 12 as follows:

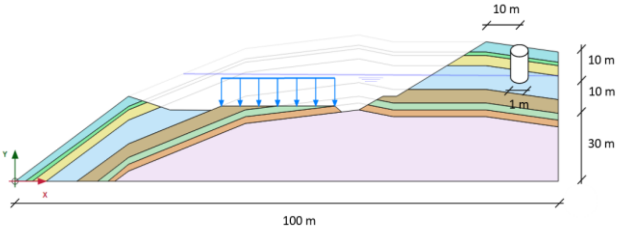

Figure 11 Cross Section Placement of Control Wells 100 m Slope Overview Area

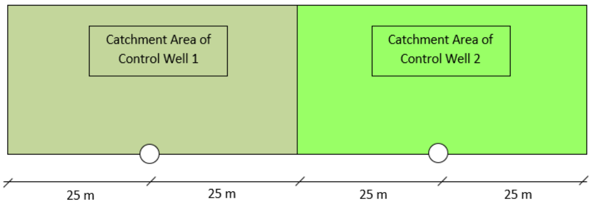

Figure 12 Top View Placement of Control Well for Slope Overview Area 100 m

Furthermore, the parts in the control well are depicted in the figure below.

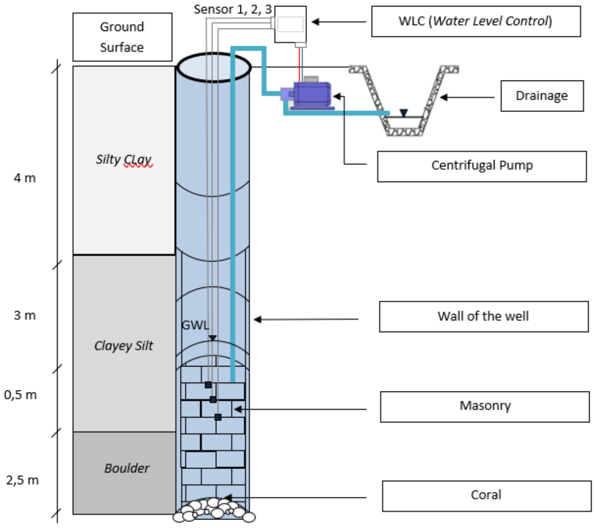

Figure 13 Control Well

The pumps were used in the planning of control wells which centrifugal pump with the consideration that the pump was used for wells with low depth, discharge pumps used adapted to discharge a pre-calculated infiltration was 0.2181 m^3/ s equivalent of 13.086 m^3/ min for control wells 1 and 0.2318 m^3/ s equivalent of 13.908 m^3/ min for control wells 2, so that the selected pump discharge that was 14 m^3/ min. The suction diameter of the pump is 12 inches, and the total head is 10 m. Furthermore, the well capacity is selected after calculating the infiltration discharge, as shown in the figure below.

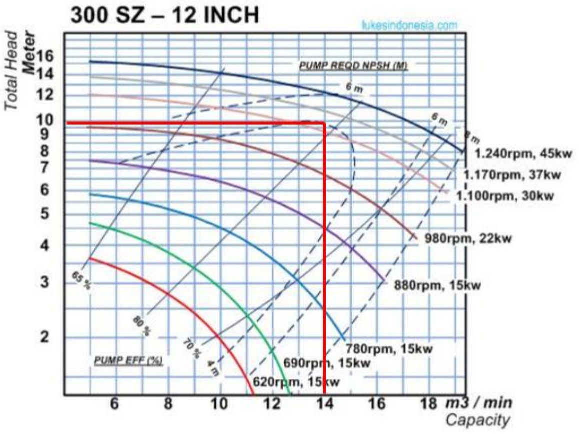

Figure 14 Selection of Wells based on Discharge Capacity

Water Level Control (WLC) works by using three sensors, namely sensor 3, which is useful as a voltage trigger channeled to sensor 2 and sensor 1. Sensor 2 serves to deliver voltage as a controller of Transistor 2 (Q2). Sensor 3 serves to deliver voltage as controller SCR which will later be useful for regulating the work of the circuit WLC.

4. CONCLUSION

Based on the results of the control well planning as a short-term/temporary solution (during the construction period of 3-5 years) that can be carried out on toll road construction to be safe from hydrological disasters, it can be concluded several things, as follows:

1. Analysis of slope stability using PLAXIS 2D found that a depth of – 7 m is the GWL limit of the slope in a safe condition which is used as a reference in planning control wells.
2. The infiltration discharge into the control well area 1 is equal to Q inf = 0.2181 m^3/ sec, and control well area 2 is equal to Q inf = 0.2318 m^3/ sec.
3. The control well is planned to be dug as deep as 10 m with a diameter of 1 m, selecting the type of centrifugal pump with a suction diameter of 12 inches, a total head of 10 m, and a discharge of 14 m3/minute and equipped with WLC (Water Level Control) as a sensor.

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