Reply to Anonymous Referee #2:

We would like to thank the Referee for the thoughtful reviews and comments.

The authors would like to thank that the Referee sympathizes with the topic of the manuscript. The organization of the manuscript will be modified and rearranged in the revised version.

1. Introduction: The contents of introduction have been rearranged and revised as shown in the appendix.
2. In Figure 9, the correlation coefficient is small because there are different types of rainfall i.e. pre-peak, post-peak and medium-peak, and each of them have different run-off effects. In addition, the data observed before and after the catchpits construction are put together, therefore the catchpits may have the effects of groundwater drawdown. After amendment, as shown in the revised figures 9(a) to 9(c), each rainfall type is distinguished respectively, and the data of before and after catchpits construction are illustrated in different symbols. The data indicate that for each rainfall type, before the catch pits were constructed, the correlation coefficient varies from 0.692 to 0.8226, and after the catch pits were constructed, the correlation coefficient varies from 0.643 to 0.5519. Furthermore, the time lag of response for the groundwater level to rise after the catchpits construction seems larger than that before the catchpits were constructed, especially for the pre-peak and medium-peak rainfall type (when the peak rainfall value is higher than 20 mm). That is because the catchpits draws down the groundwater and increases the time of groundwater level to rise. Further, by comparing the Figures 9(a), 9(b), and 9(c), it shows that the time lag value for the pre-peak type rainfall is observed higher compared to the other two types of rainfall. It is possibly due to the fact that in the pre-peak type of rainfall, most of the surface runoff from rainfall, before it seeps into the ground and raise the groundwater level. On the contrary, for the post-peak type of rainfall, before the rainfall amount reaches the peak value, the infiltrated rainfall may have gradually caused the upper soil to become wet or saturated, so that when the subsequent peak rainfall arrives, the groundwater level will easily rise. All the figures and discussions mentioned above will be added in the revised manuscript.

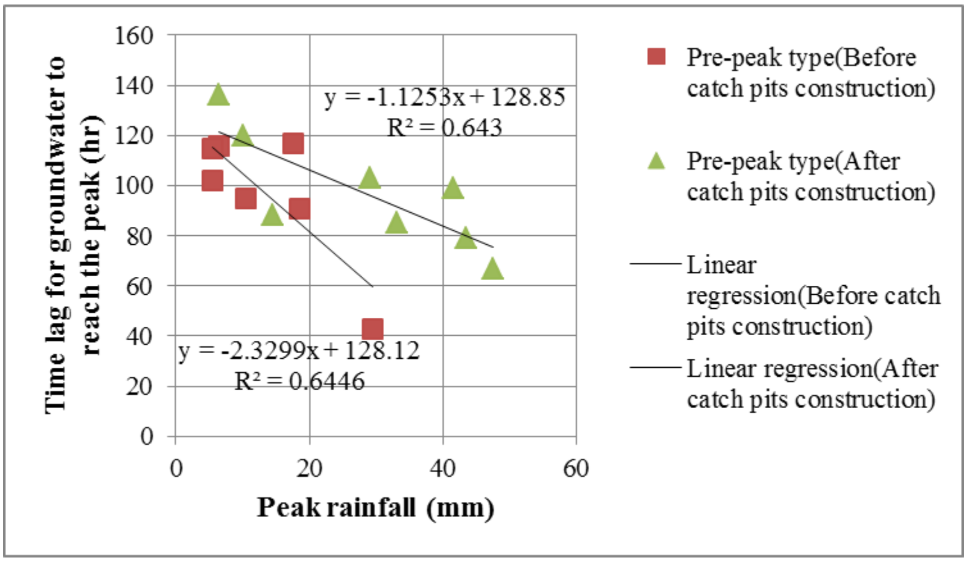


Figure 9(a): Groundwater level and time lag of rainfall peak diagram for pre-peak type rainfall.

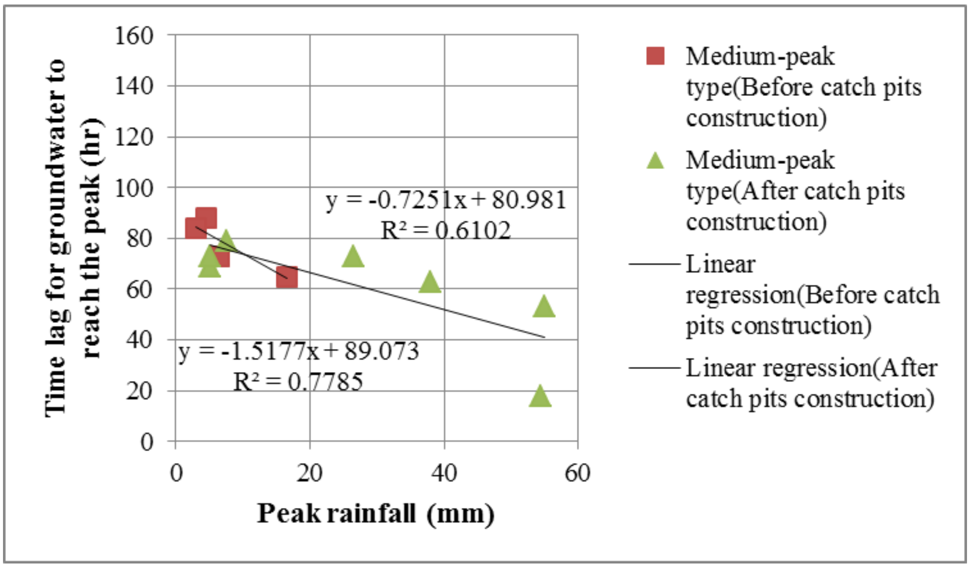


Figure 9(b): Groundwater level and time lag of rainfall peak diagram for medium-peak type rainfall.

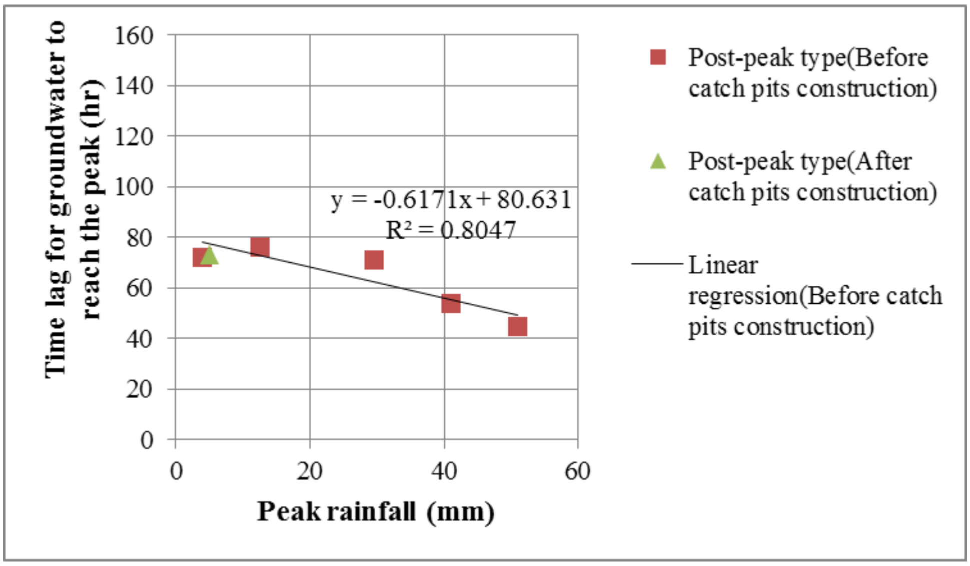
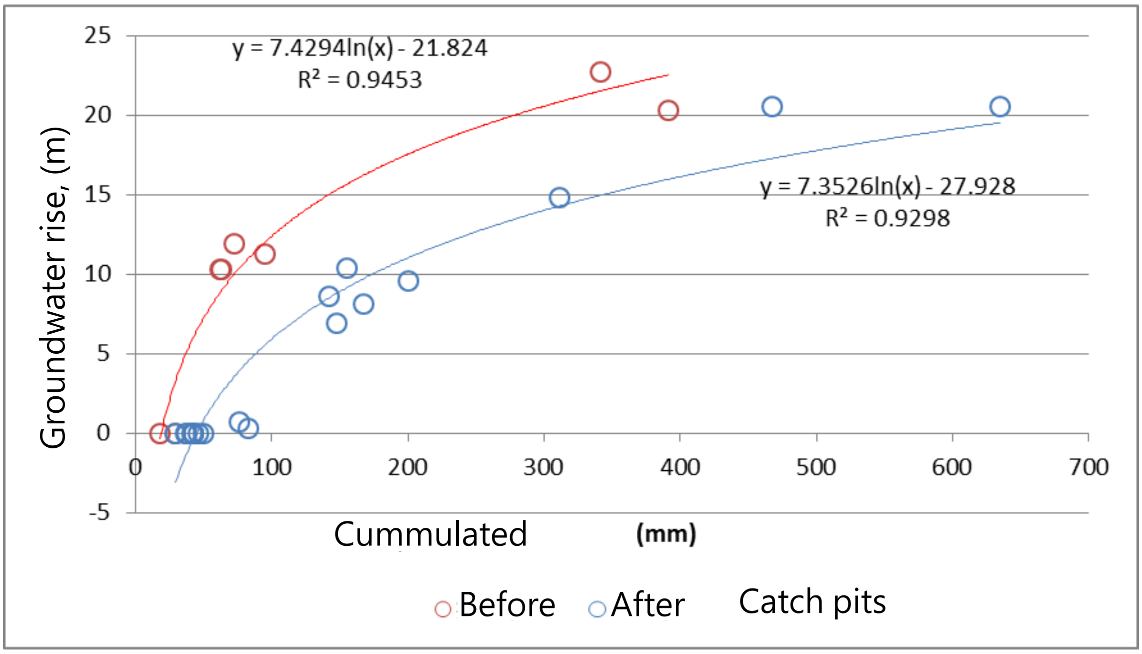


Figure 9(c): Groundwater level and time lag of rainfall peak diagram for post-peak type rainfall.

The results shown in Figure 10 and Figure 11 have been redrawn and discussed based on the catchpits construction effect, similar to the description for Figure 9, and shall be amended in the revised manuscript. The new figure shown as below is the relation curves of groundwater rise value vs. cumulated rainfall before and after the catchpits construction.



3. Fig. 15 is the same as Fig. 14, which is a mistake. The corrected Fig. 15 is shown as follows, and it will be also amended in the revised manuscript.

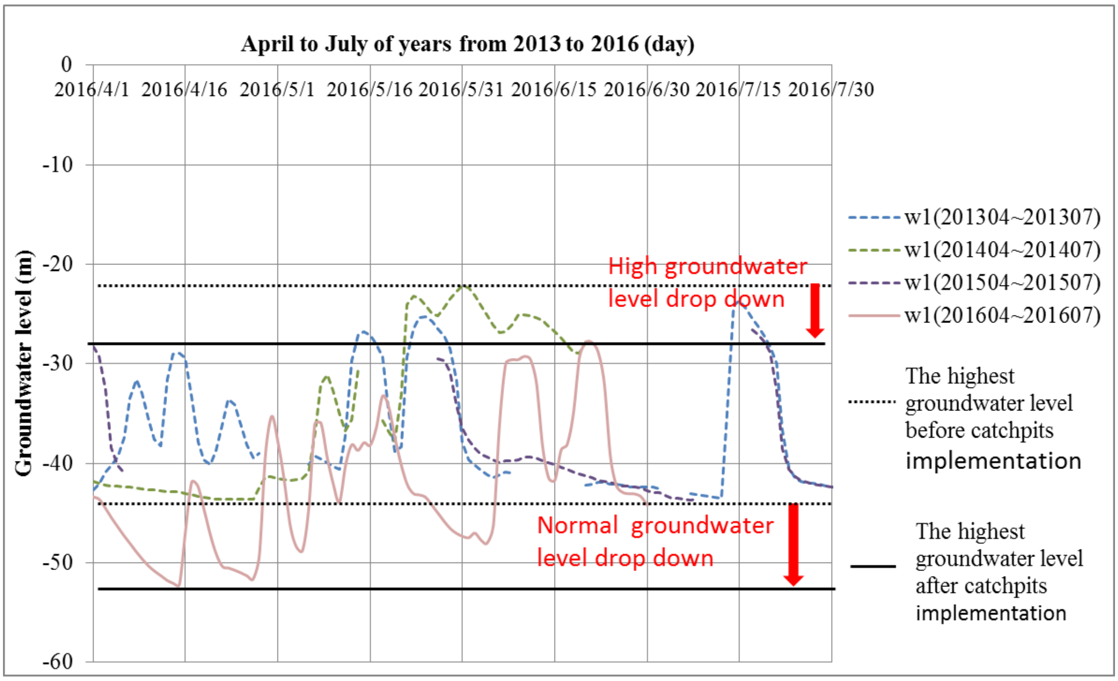


Figure 15: Comparison of groundwater level before and after catchpits implementation.

In the revised manuscript, the analyses of the simulation work will be revised for better clarity and to point out the quantitative relationship between typhoon rainfall, slop groundwater level and the displacement of the slope.

4. The conclusions will be revised based on the details mentioned above and amended in the revised manuscript.

APPENDIX:

1 INTRODUCTION

In general, slope displacement can be distinguished into various stages, in which the three particular stages are: “initial displacement,” “constant velocity displacement,” and “accelerated incremental displacement.” Xu (2011) pointed out obvious characteristics of each stage for the gradual evolution of slope movement. To classify slope movement into the three stages, the s-t curve for the relationship between displacement and time can be converted into a T-t curve. The curve obtained following the conversion has a unique and deterministic tangent angle (α). Normally, the tangent angle of the curve is greater than 45 degrees when it enters the acceleration stage. Detailed demonstration of each deformation stage is shown in Figure 1(a) and Figure 1(b).

Jesus et al. (2018) dealt with the constrains and triggering factors of landslides and mentioned that in addition to gravity, groundwater level is the most important factor in slope stability as it can affect slope stability in different ways, such as reducing the strength, changing the density and generating the pore water pressures. Furthermore, the study indicates that deep-seated landslides are also triggered by high groundwater levels; however; conditions for their occurrence are not so widely spread. Taib et al. (2017) implemented a sand slope model for testing its stability under rising groundwater condition. They found that the slope with the highest density has a higher safety factor, but results in faster slope failure due to rapid development of the pore pressure ratio. Prokešová et al., (2013) studied the monitored data, and their observations suggest that groundwater level (i.e. GWL) response to precipitation differs considerably with respect to both overall hydrological conditions and GWL mean depth. Further, they found that slightly above-the-average rainy season following the prolonged wet period can be far more responsible for the accelerated movement in deep-seated landslides, compared with the single season of extreme precipitation following a longer dry period.

The Japan Association for Slope Disaster Management (JASDiM) recommended the threshold values of slope displacement for different sliding stages, which were used to define three ranges. However, the displacement data recorded by the inclinometers used in the study were retrieved once a month, and the displacement and subsidence of the slope by the observation points on the ground were observed every six months. Therefore, the instantaneous changes of each typhoon rainstorm event could not be captured. An additional groundwater level gauge was installed in the study area, and two Shape Acceleration Arrays (SAA) were installed within the inclinometer casings, which were used to observe depths of sliding surfaces. These monitoring systems have enabled to obtain the continuous changes of groundwater level and slope displacement during typhoon rainfall. Slope stability was also analyzed during the period.

This research focuses on the dip slope area at the Huafan University in northeastern Taiwan. The campus is located on a geological dip slope toward the southwest in the Ta-Lun Shan area with an elevation range of 450 m to 550 m, as shown in Figure 2. For risk management and research on slope stability, monitoring systems were set up in 2001, which has collected geographical data since then. The monitoring systems included inclinometers, tiltmeters, crack gauges, groundwater level observation wells, settlement and displacement monitoring marks, rebar strain gauges, concrete strain gauges, and rain gauges.

Jeng and Sue (2016) analyzed the monitoring data collected from more than 300 settlement and displacement observation marks on this site, and compared them with the displacement recorded by the inclinometers, thereby finding a preliminary relationship between the displacement of the slope and daily rainfall at the campus. The software STABL based on the limit equilibrium method was applied for analysis, concluding that a rise in the groundwater level caused by typhoons is the most critical factor in slope stability. Therefore, several countermeasures, including catchpits with horizontal drainage pipes, were recommended, and threshold-value curves of the slope displacement based on rainfall intensity and cumulative rainfall were established. Those curves were derived from the rainfall records of numerous typhoon events over the past ten years, along with the corresponding slope displacement increment recorded by the ground surface marks.

Considering the project budget, two catchpits were implemented within the study area in the present stage. The study provides valuable monitoring information and experience of continuous observation over years. The study also offers a comprehensive survey of the slope behavior during rainfall exposure. It includes the highest groundwater level measured within the slope, the time lag of response of groundwater variations, the influence of rainfall types and the amount, the relationship curve of rainfall amount and groundwater level, and a review of the effectiveness after the two catchpits were constructed. The displacement curve measured by the inclinometers was used for comparing feedback, and numerical analysis and simulation were performed to validate the changes in the behavior and mechanism. Subsequently, according to the characteristics of the slope, including the allowable displacement alert and action values, the data analyses revealed a corresponding relationship rainfall curve. The results will help to assess possible changes in groundwater level within the slope, possible slope displacement, and safety and stability factors, from the estimated rainfall before a disaster occurs.