

公路土壤邊坡與擋土支撐監測系統精進及預警系統測試

Improvements of IoT Monitoring for Highway Slopes with Retaining Systems Incorporating with Warning System

主管單位：交通部運輸研究所
 合作單位：財團法人成大研究發展基金會

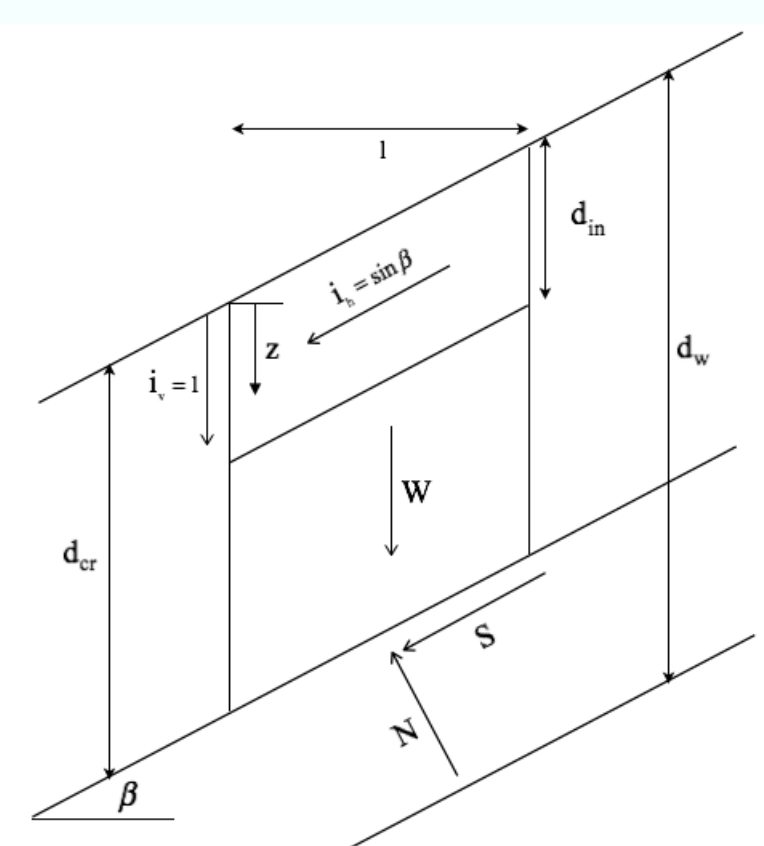
計畫主持人：蔡立宏、賴瑞應、曾文傑
 計畫主持人：黃安斌、張文忠

整體目標 Overall objective

本計畫針對公路土壤邊坡可能遭遇之土層滑動破壞，進行水力力學耦合解析法分析並搭配無線土層反應監測模組，測試發展適用於具擋土支撐系統公路邊坡之依時預警模式，用以互補現有以雨量監測為指標之經驗法預警模式，作為相關防災作為啟動之參據。

A coupled analytical framework, incorporating IoT wireless sensing module for soil and retaining system responses, is developed and tested to provide time-dependent warning for highway slope failures in soil layers. The long-term goal of the project is to provide site-dependent warning system for soil slope failures as an effective alternative or improvement of current rainfall-based warning for critical highway slope.

水力力學耦合邊坡穩定分析 Coupled hydro-mechanical slope stability analysis



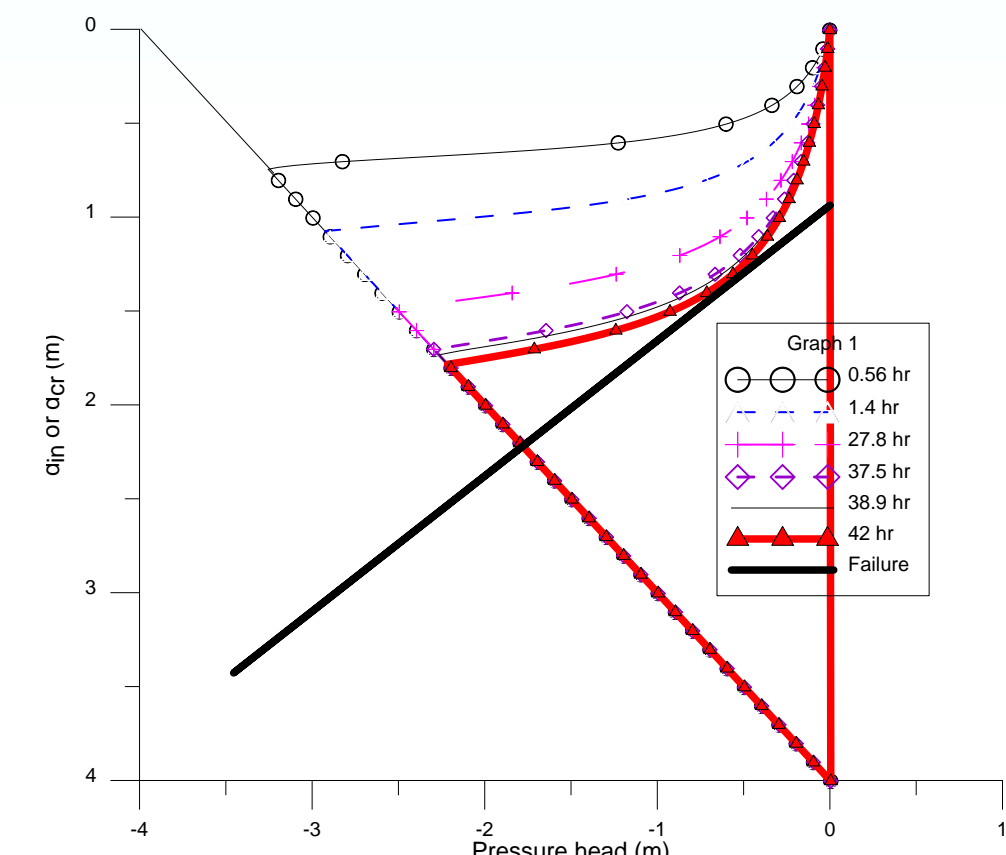
淺層臨界滑動深度 d_{cr}
 (Critical depth, d_{cr})

$$d_{cr} = \frac{c' + \gamma_w \cdot h_c(z) \tan \phi^b}{\gamma_t \cdot \cos^2 \beta (\tan \beta - \tan \phi')}$$

深層滑動安全係數
 (FS of deep-seated slide)

$$FS = \frac{c'}{\gamma_{sat} d_{cr} \sin \beta \cos \beta} + \left(\frac{\gamma_{sat} - \gamma_w r_u}{\gamma_{sat}} \right) \frac{\tan \phi'}{\tan \beta}$$

依時性無限邊坡破壞預測模式
 Time-dependent failure prediction



土層無線監測模組 IoT Slope monitoring modulus

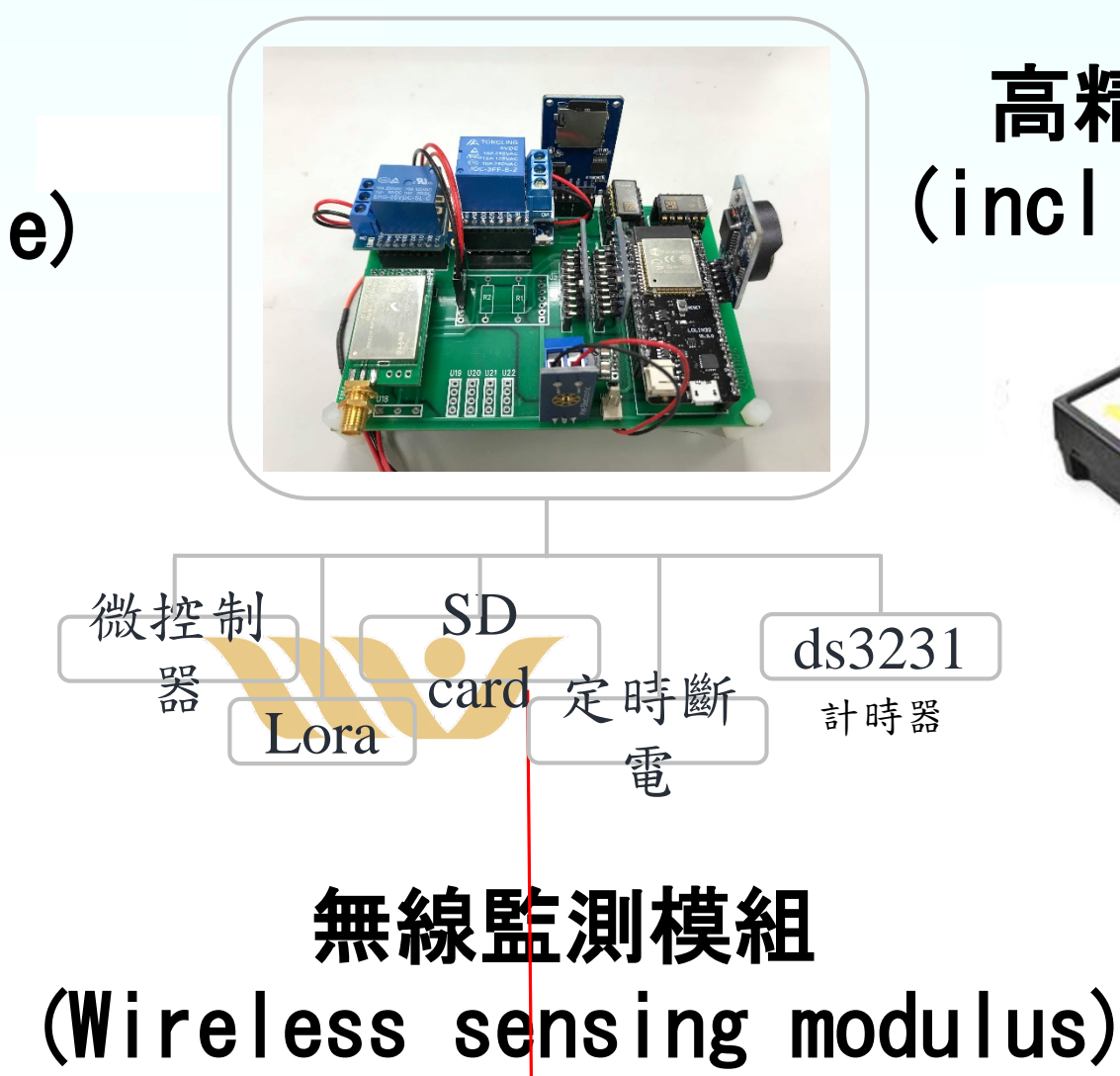
太陽能供電模組
 (Solar power module)



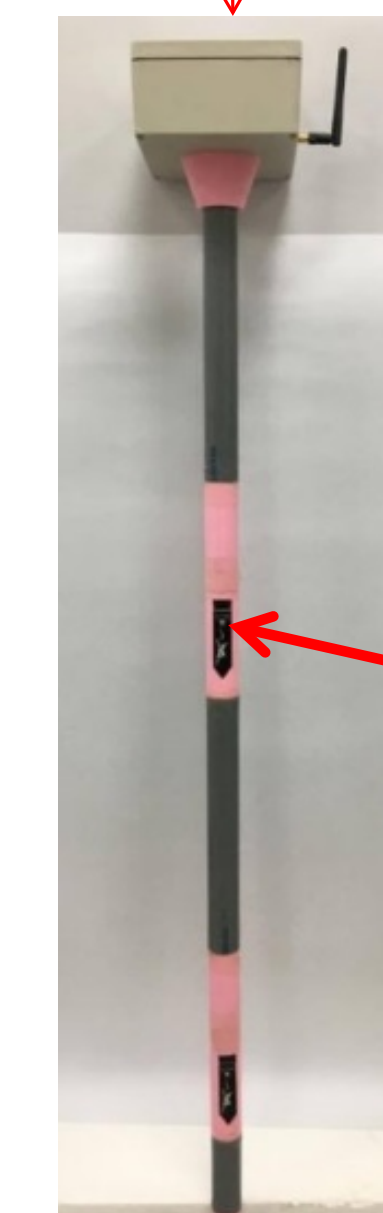
高精度傾斜儀
 (inclinometer)



傾斗式雨量計
 (Tipping Bucket Rain Gauge)



無線監測模組
 (Wireless sensing modulus)



液位計
 (Liquid level meter)



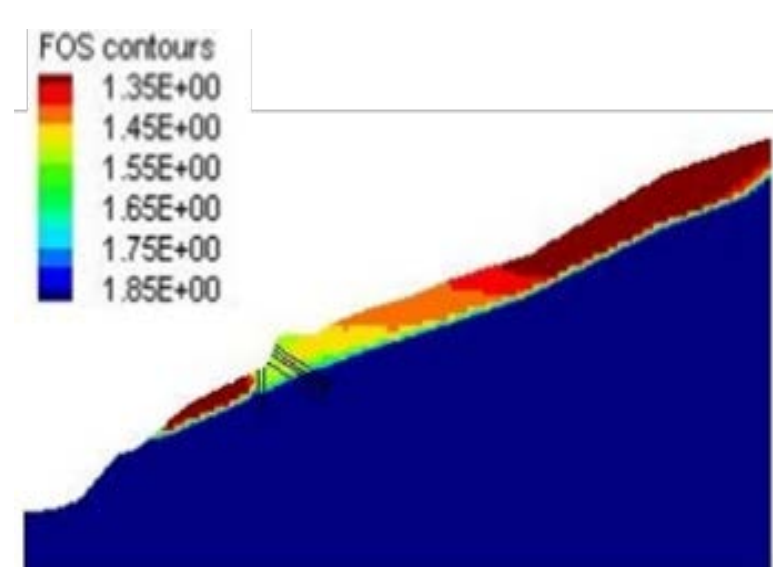
電容含水量計
 (Capacitance moisture probe)



4G網路版本
 (4G Gateway)

研究成果 Current progress

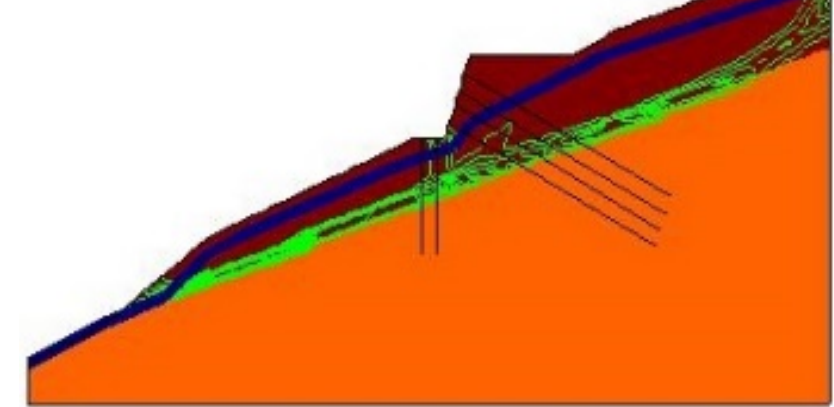
二維水力力學耦合邊坡分析
 2D coupled hydro-mechanical slope stability analysis



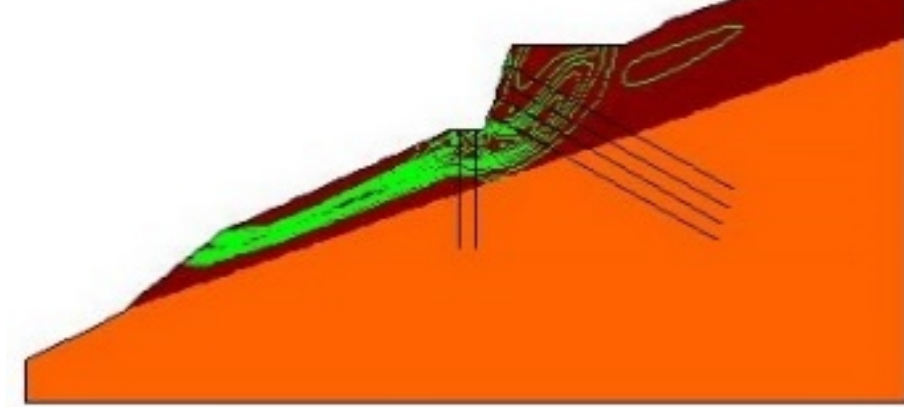
總體滑動分析

(overall stability analysis)

地下水位分析

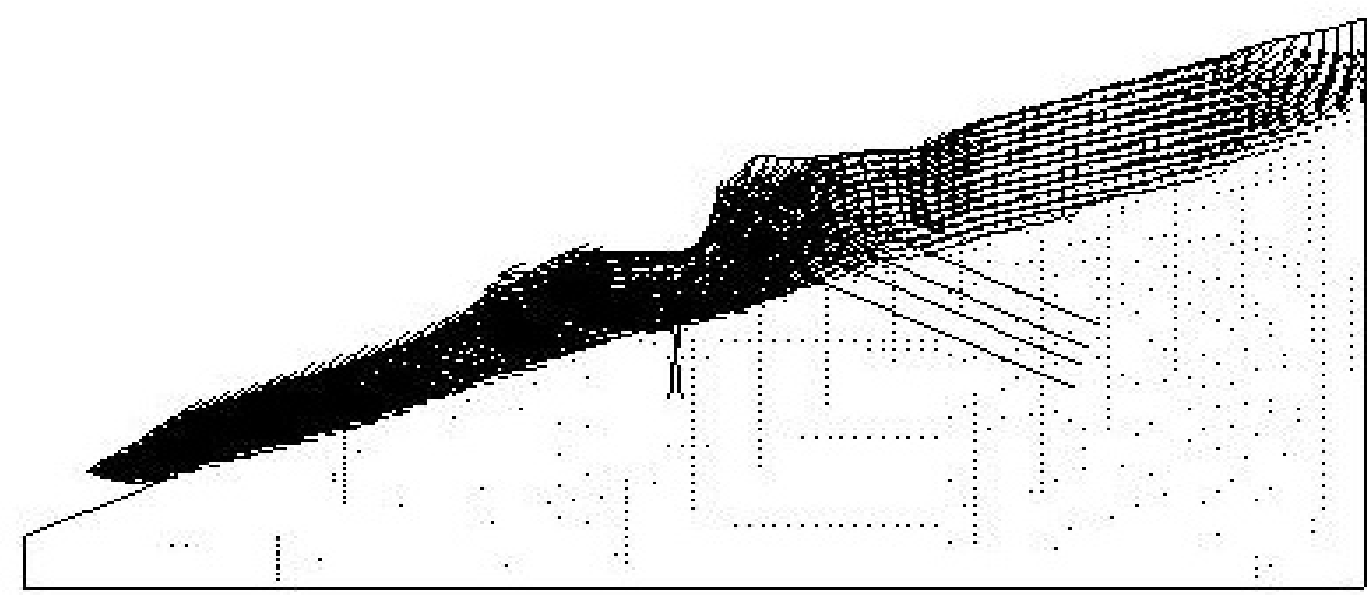


入滲分析



局部擋土系統分析

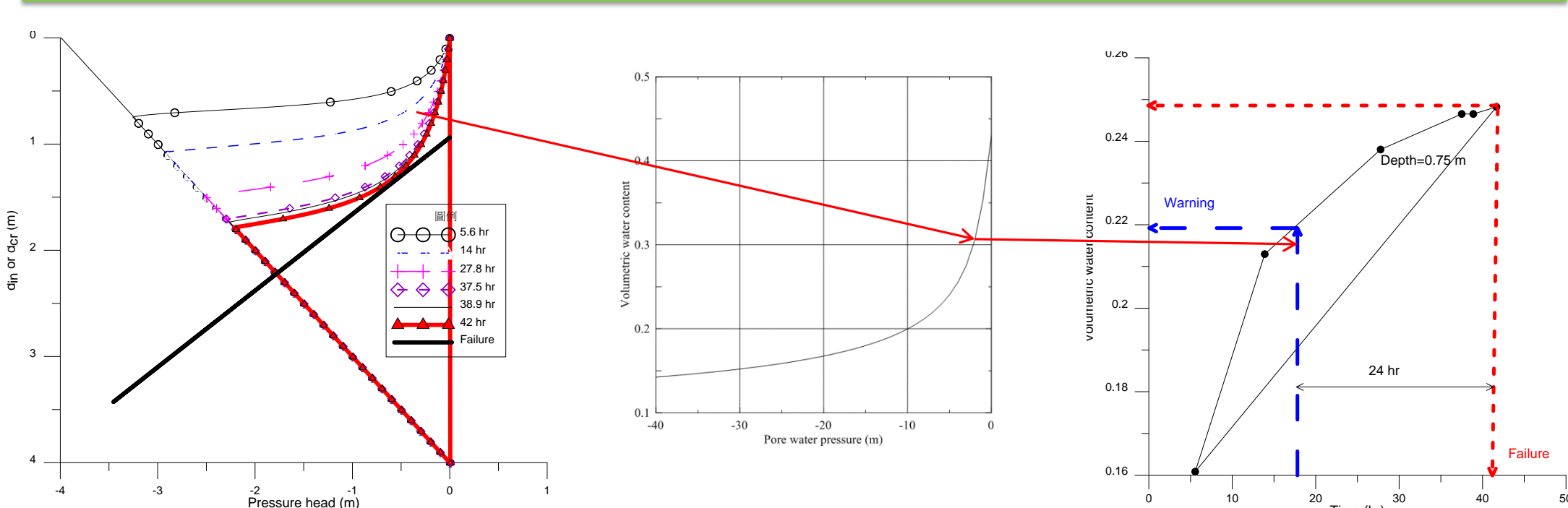
(local retaining stability analysis)



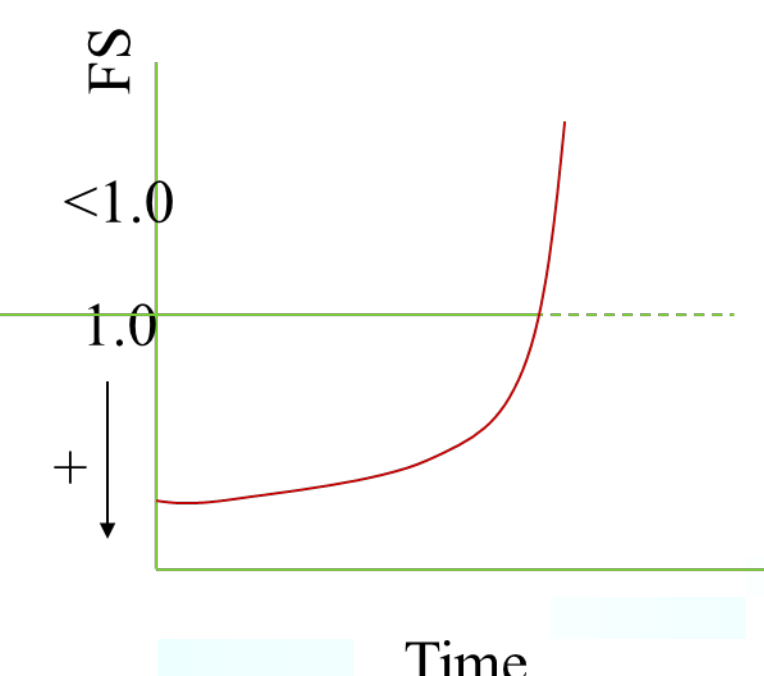
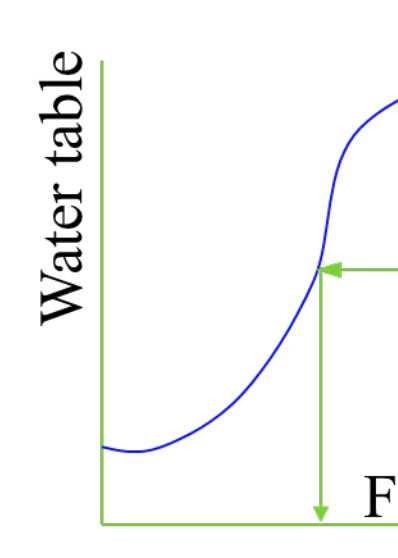
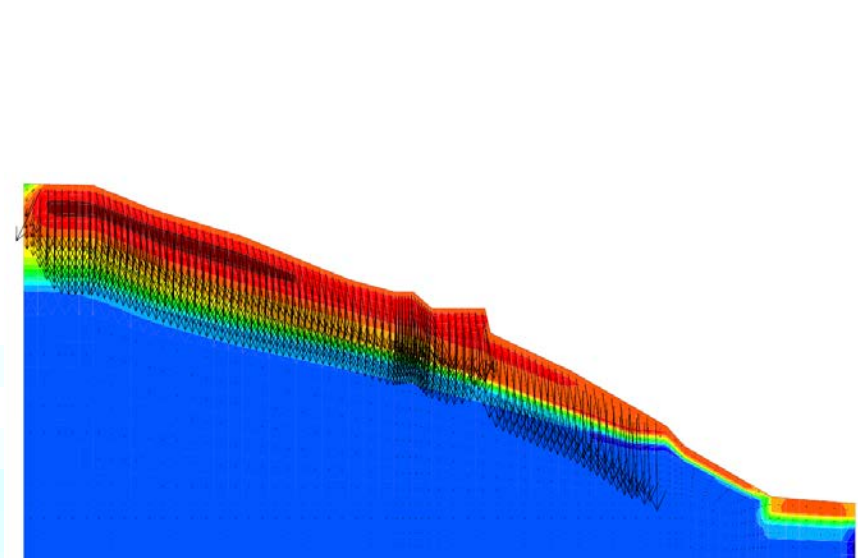
破壞位移圖

(displacement of slope failure)

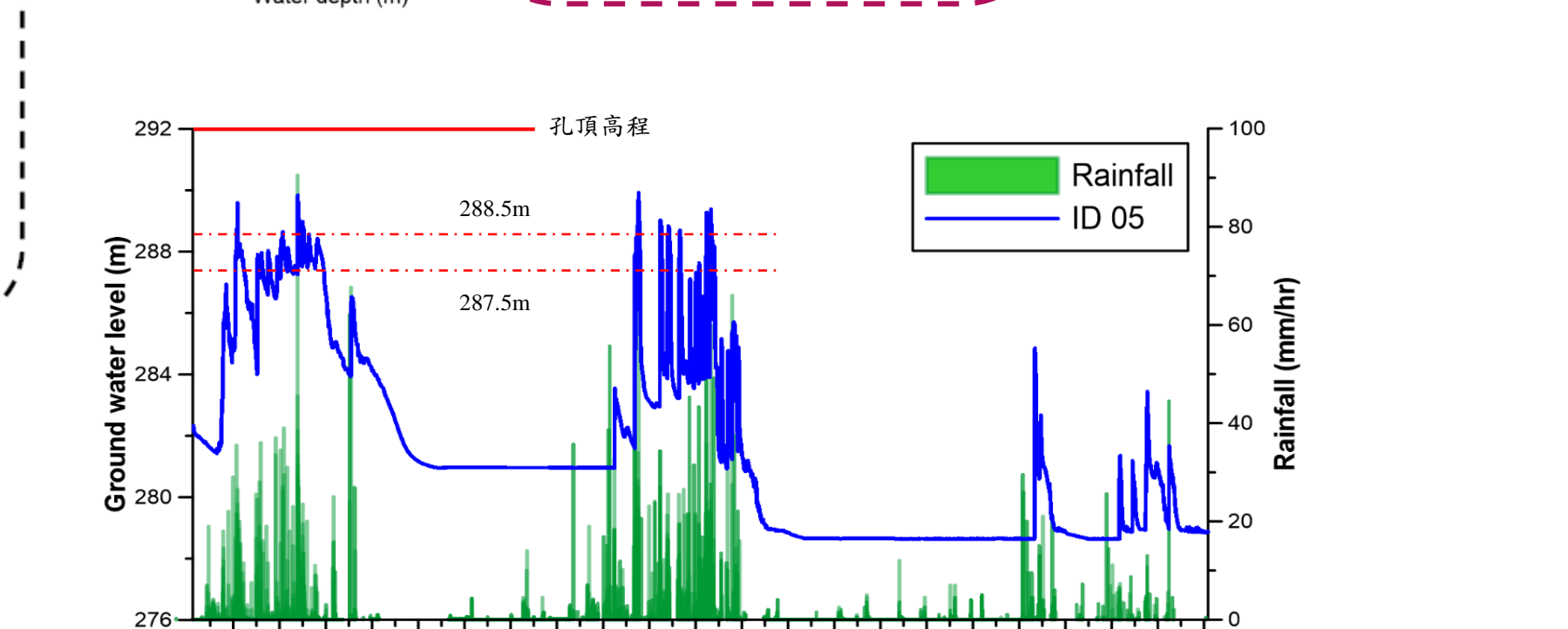
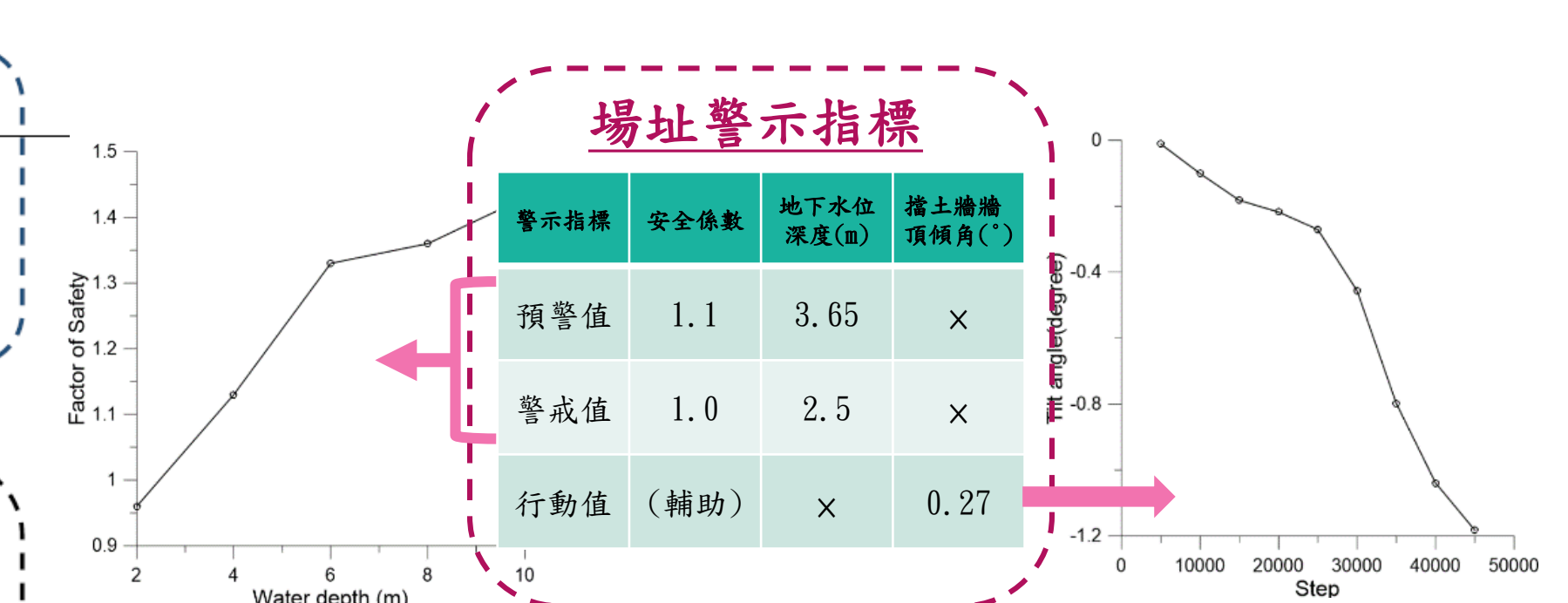
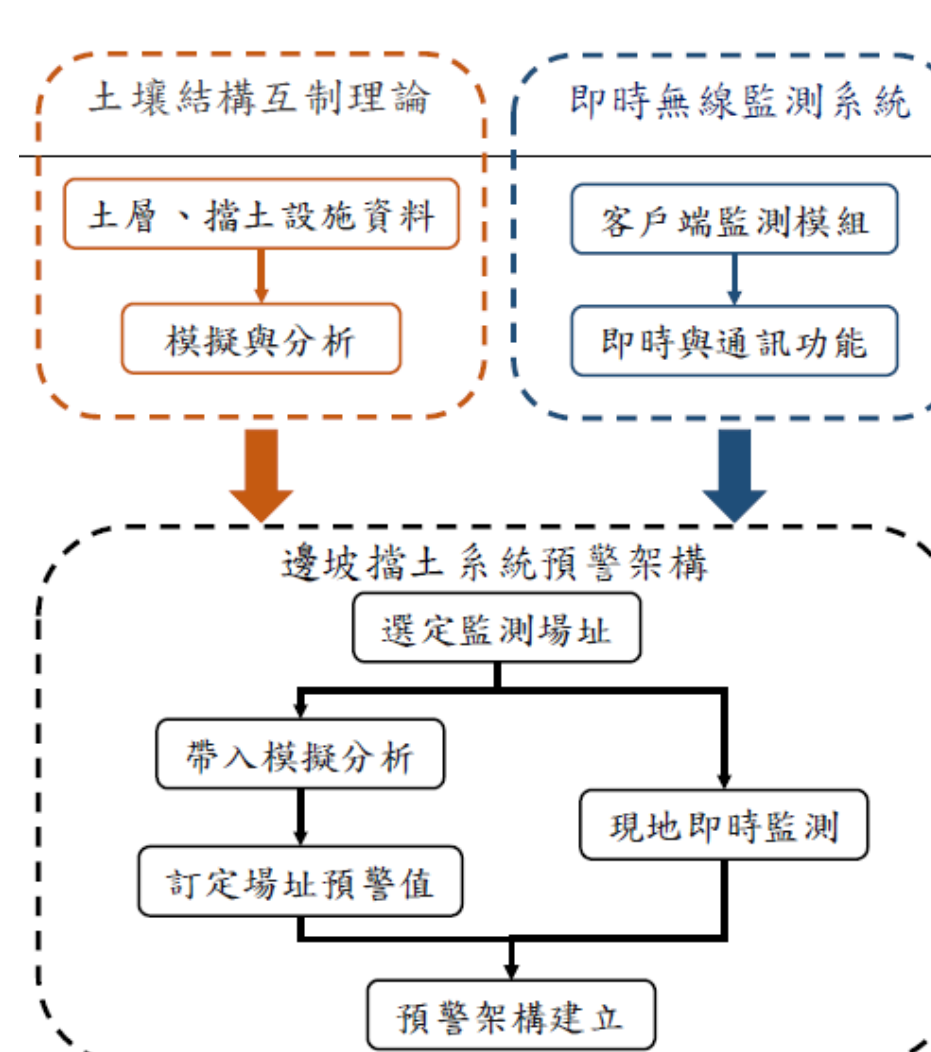
依時預警模式 (Time-dependent warning concept)



無限邊坡淺層滑動含水量預警
 (water-content-based warning)



擋土系統變位預警架構
 Warning system for slope retaining systems



雲端整合平台
 Cloud integration platform

