

前進 馬太鞍溪堰塞湖

SCIENTISTS AT THE MATAI'AN CREEK BARRIER LAKE

文／顏廷恩 · 圖／林業及自然保育署花蓮分署提供、林志平教授提供、趙韋安副教授提供、楊昇學研究員提供、黃奕傑提供、秘書處

By Ting En Yen

Image courtesy of the FANCA Hualien Branch, Professor Chih-Ping Lin, Associate Professor Wei-An Chao, Research Fellow Sheng Hsueh Yang, I Chieh Huang, and the Secretariat

Matai'an Creek Barrier Lake

馬太鞍溪堰塞湖

科學家出動了

在學校裡，有一群科學家，他們是防災與水環境研究中心（防災中心）的成員。去年一個看似平凡的七月傍晚，中心實驗室裡的螢幕突然跳出警示，顯示花蓮馬太鞍溪上游的山坡正在崩塌。

土木工程學系趙韋安副教授的即時崩塌監測系統偵測到這處山坡異常的震動，發現一座兩百公尺高的天然壩正在山谷間堆積成形，隨著時間在無人深

Scientists respond

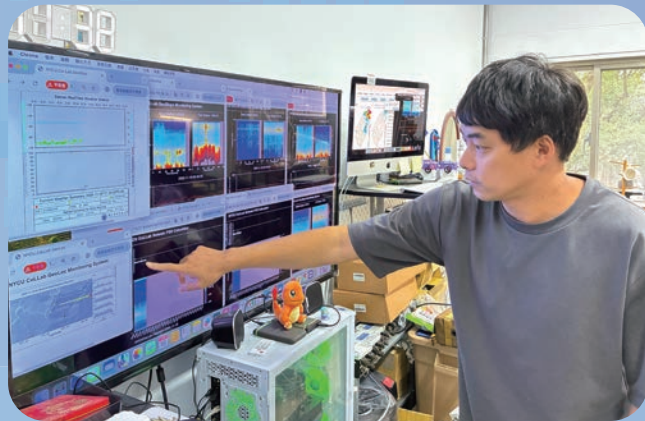
At NYCU, there is a group of scientists from the Disaster Prevention and Water Environment Research Center (DPWE). Last year, on what seemed like an ordinary July evening, an alert popped up on screens in the center's lab, showing that a slope upstream of Hualien's Matai'an Creek was collapsing.

Associate Professor Wei-An Chao from the Department of Civil Engineering detected unusual vibrations on the slope using his real-time landslide monitoring system and discovered that a 200-meter-high natural dam was forming in the valley. This made the DPWE the first team to discover the Matai'an Creek barrier lake.

圖／林業及自然保育署花蓮分署提供



DPWE Chief Director Chih-Ping Lin
防災中心林志平主任



Associate Professor Wei-An Chao
趙韋安副教授



Assistant Research Fellow Kuo-wei Li
李國維助理研究員



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山中形成一座蓄水量達九千萬立方公尺、充滿變數的巨大堰塞湖。防災中心也成為第一個發現馬太鞍溪堰塞湖的團隊。隔天，應林業及自然保育署（林保署）的緊急委託，這群科學家開始監測、調查與追蹤這座馬太鞍溪堰塞湖的變化。

他們如何協作？

「堰塞湖最麻煩的，就是你根本不知道它形成了。過去通常要等巡山員、登山客發現，或下游水位偵測到水位驟降才會知道有堰塞湖形成，但這時往往已經過了數小時甚至數天，」趙老師說明。

而在防災工作中，越早發現異狀，越可爭取更多時間應對。趙老師形容即時崩塌監測系統像「崩塌獵人」，這套系統偵測到了馬太鞍溪堰塞湖的形成，

Over time, it created a massive barrier lake deep in the uninhabited mountains, with a capacity of about 90 million cubic meters and many uncertainties. The day after detecting the unusual vibrations, the DPWE responded to an emergency request from the Forestry and Nature Conservation Agency (FANCA) by monitoring, investigating, and tracking changes in the Matai'an Creek barrier lake.

Working together

"The tricky thing about barrier lakes is that you have no idea when they have formed. In the past, we typically had to wait until mountain rangers or hikers spotted the lakes, or we could find that lakes had formed when downstream water level monitors detected a sudden drop in water level. By that point, hours or even days had already passed," Prof. Chao explains.

In disaster prevention work, the earlier you detect something unusual, the more time you have to respond. Prof. Chao describes the real-time landslide monitoring system as a "landslide hunter." This is the system that detected the formation of the Matai'an Creek barrier lake. It works by capturing vibration signals from

可捕捉山崩、土石流或水流產生的震動訊號，在堰塞湖形成的第一時間就發出警訊通知相關單位。

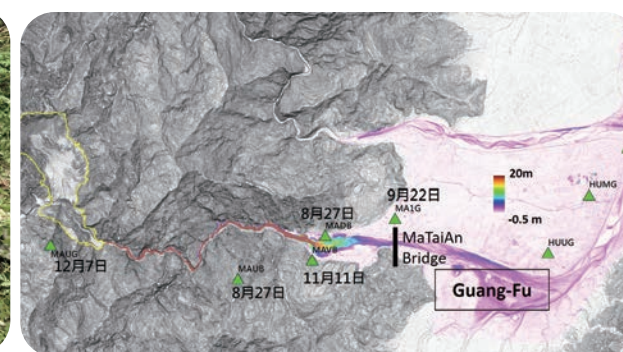
由於洪水流動同時會產生震動，團隊沿著河道兩岸架設微地動洪水預警系統。趙老師說明，洪水一秒約走三到五公尺，但震動訊號傳遞極快，利用兩者的速度差，這套系統能提前約二十分鐘，將預警傳給十幾公里外的下游居民。這二十分鐘可讓居民有時間移動車輛、關閉門窗或垂直避難。如果沒有這套預警系統，下游居民往往在洪水到達的那一刻才知道發生了什麼。

那麼發現馬太鞍溪堰塞湖形成後，接下來要做什么？在林保署委託後，防災中心李國維助理研究員擔任計畫主持人，協調相關單位投入調查與監測工作。衛星影像證實了堰塞湖的位置與規模後，他形容這座天然壩體的形成就像大型溜滑梯一樣，土石

landslides, debris flows, or water flow, and sends out alerts to relevant agencies the moment a barrier lake forms.

Since floodwater movement generates vibrations, the team has set up a flood early warning system based on microseismic signals along both sides of the river. Prof. Chao explains that floodwaters travel at about three to five meters per second, while vibration signals travel much faster. By taking advantage of the difference in speed, the system can issue warnings about 20 minutes in advance to residents living more than 10 kilometers downstream. These 20 minutes give residents time to move their vehicles, close doors and windows, or evacuate to higher ground. Without this early warning system, downstream residents often only realize what is happening when the floodwaters actually arrive.

After discovering the Matai'an Creek barrier lake had formed, FANCA sent the investigation request to DPWE. Assistant Research Fellow Kuo-wei Li from DPWE served as the principal investigator, coordinating relevant agencies to undertake investigation and monitoring work. Satellite imagery confirmed the barrier lake's location and scale, and Dr. Li describes the formation of this natural dam as being like a giant slide. Earth and rocks collapsed from a mountaintop a kilometer high, sliding



The team set up monitoring stations along both sides of Matai'an Creek.
團隊沿著馬太鞍溪兩岸架設測站

從一公里高的山頭崩塌而下，滑行兩公里後在溪中堆疊起一座阻斷水流的巨牆。這種土石形成的壩體結構往往極為鬆散，溪水會像穿過指縫一樣滲透，甚至可能掏空內部。

李博士定期操作無人機、以及透過分析林保署航測及遙測分署拍攝的航照與光達資料，掌握壩體的裂縫與滲水量變化。這些資料可以用來分析壩體是否穩定、有沒有立即破壞的跡象。李博士也協調中華電信在荒煙蔓草的山區拉起專用光纖，讓堰塞湖與壩體的影像可以在 Youtube 上公開直播。

馬太鞍溪堰塞湖在去年九月因樺加沙颱風帶來的豪雨潰決後，附近又陸續形成了第二、第三座堰塞湖。李博士解釋，只要邊坡持續崩塌、土石再次阻斷河道，新的堰塞湖就會不斷形成，這種情況可能持續數年，因此防災中心團隊仍需要持續監測馬太鞍溪堰塞湖的後續發展。

堰塞湖形成後，下一個關鍵問題是這座湖到底有多大。防災中心楊昇學研究員的任務，是把現場空拍影像變成可分析數據。在剛知道馬太鞍溪堰塞湖形成時，楊博士面對的是一連串未知數。因為現場沒有道路通往堰塞湖，當時只能使用遙測影像與相片，一點一點拼湊出堰塞湖的真實樣貌。

Dr. Yang and his team visited the Matai'an Creek site after the typhoon to inspect temporary engineering works and compare field conditions with their earlier analysis.

楊博士與團隊災後前往馬太鞍溪現場，查看臨時工程狀況，並比對是否與前期分析結果相符

two kilometers before piling up into a massive wall in the creek, which blocked the water flow. This type of dam structure formed from earth and rocks is often extremely loose. Creek water seeps through it like water through a sieve and might even hollow out the interior.

Dr. Li regularly operates drones and analyzes aerial imagery and LiDAR data captured by the Aerial Survey and Remote Sensing Branch of the FANCA to monitor changes in the dam's cracks and seepage. These data can help to reveal whether the dam is stable and if there are any signs of imminent failure. Dr. Li also arranged for Chunghwa Telecom to install dedicated fiber optic cables in the overgrown mountain area so that images of the barrier lake and dam could be livestreamed publicly on YouTube.

After the Matai'an Creek barrier lake burst in September last year due to heavy rain from Typhoon Ragasa, a second and third barrier lake formed one after another nearby. Dr. Li explains that as long as slopes continue to collapse and the earth and rocks block the river channel again, new barrier lakes will keep forming. This situation could last for several years, so the DPWE team needs to remain vigilant about monitoring the situation at Matai'an Creek.

After a barrier lake forms, the next critical question is just how big this lake actually is. Research Fellow Sheng Hsueh Yang from DPWE was tasked with turning aerial footage from the site into analyzable data. When Dr. Yang first learned the Matai'an Creek barrier lake had formed, he faced a series of unknowns. Because there were no roads leading to the barrier lake site, he could only use remote sensing images and photos at the time, piecing together the true appearance of the barrier lake bit by bit.

Dr. Yang tells us this is a process that evolves over time, as the data become clearer and clearer. From rainfall amount and watershed

楊博士告訴我們，這是個隨著時間演進、資料會越來越明確的過程。從降雨量、集水區面積，到壩體高度與庫容，每一個參數都得反覆校正，最終計算出這座堰塞湖能蓄多少水、何時會滿。

確定堰塞湖何時會滿只是第一步，更關鍵的是評估潰決時會有多大的水量衝到下游來、可能淹水到哪裡。楊博士解釋，如果天氣平靜，水會慢慢一層層流下來；但如果碰上颱風豪雨，水不斷灌進來、不斷沖刷壩體，兩種情境的破壞力天差地別。楊博士針對不同情境進行水理模擬，推估可能的淹水範圍與水位變化。

作為計畫主持人，李博士彙整團隊的調查資料、監測數據與分析結果，轉化為災害風險評估報告，提供給林保署及相關單位作為警戒發布與疏散決策的依據。在這整個防災流程中，防災中心團隊的職責是監測與科學判讀，至於疏散規劃與現場應變執行，則由政府負責。

與大自然共處

為了在馬太鞍溪上游架設洪水預警系統測站，趙老師和團隊搭了好幾個小時的車到花蓮，再改搭發財車進入林道。那是颱風來臨的前一個夜晚，發財車在泥濘中顛簸前行，耳邊不斷傳來馬太鞍溪的水聲。團隊趕在颱風來臨前，在黑暗中挖洞、埋設儀器、架設太陽能板。回程時，他們看見一條百步蛇橫臥在路中央。

「百步蛇被當地視為山神，連原住民都不容易遇到，」趙老師驚嘆的說。那條百步蛇盤在路中央，看了他們一會兒，然後緩緩讓開。趙老師回憶說，在野外工作這麼多年第一次遇見百步蛇。那晚沒下雨，測站順利安裝完成，回程還遇見了山神。

李博士駐點東部，去年九月樺加沙颱風來襲後，團隊展開高強度的馬太鞍溪堰塞湖後續監測工作。

area to dam height and storage capacity, every parameter has to be calibrated repeatedly to ultimately calculate how much water the barrier lake can hold and when it will fill up.

Figuring out when the barrier lake will be filled is just the first step. What's even more important is to assess how much water will rush downstream when it breaches and which areas may be flooded as a result. Dr. Yang explains that if the weather stays calm, water will slowly overflow in stages. But if a typhoon hits with heavy rain, water keeps pouring in and keeps scouring the dam. The destructive power of these two scenarios is worlds apart. Dr. Yang conducts hydraulic modeling for different scenarios to estimate possible flood zones and water level changes.

As principal investigator, Dr. Li compiles the team's investigation data, monitoring information, and analysis results, transforming the raw data into disaster risk assessment reports. These reports are provided to FANCA and relevant agencies as the basis for issuing warnings and making evacuation decisions. Throughout the entire disaster prevention process, the DPWE team is responsible for monitoring and interpreting the data, while evacuation planning and on-site emergency response are handled by the government.

Living with nature

To install flood early warning system monitoring stations upstream of Matai'an Creek, Prof. Chao and his team drove for several hours to Hualien. Then, they switched vehicles and drove a pickup truck onto a forest road. It was the night before a typhoon hit. The truck bounced along through the mud, with the constant sound of Matai'an Creek rushing in their ears. Racing against the typhoon's arrival, the team dug holes in the darkness, buried instruments, and set up solar panels. On the way back, they saw a hundred-pace viper lying across the middle of the road.

"The hundred-pace viper is considered a mountain deity by locals. Even indigenous residents, who know the mountains well, don't encounter them easily," Prof. Chao says in amazement. The snake was coiled in the middle of the road and watched the team for a while. Then, it slowly moved aside. Prof. Chao recalls that in all his years of fieldwork, this was the first time he had encountered a hundred-pace viper. It didn't rain that night. The monitoring station was successfully installed, and on the way back, they had even met the mountain deity.

Dr. Li is stationed in eastern Taiwan. After Typhoon Ragasa hit last September, the team launched high-intensity follow-up monitoring work on the Matai'an Creek barrier lake. When

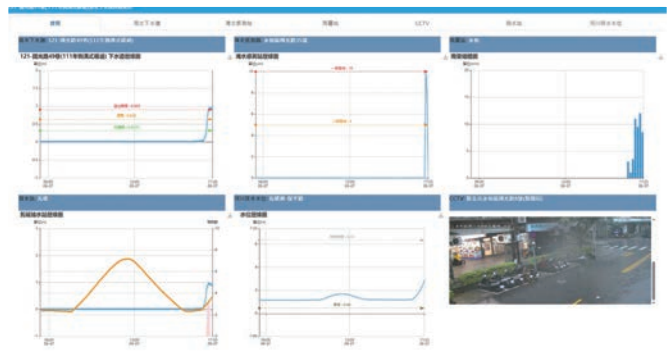
談起那段時間一件讓他印象深刻的事，中秋節那天他在北部開完災害應變會議，開車帶著家人返回東部途中，因連日工作累積的疲勞突然失去意識，醒來時車子一半掉進路旁山溝，安全氣囊都爆開了，所幸一家人都平安。

防災中心的工作遍及全台各地，趙老師的監測系統即時推播崩塌預警給第一線應變人員。李博士有豐富的山林調查經驗，曾為調查八通關古道安全性連續走了八天七夜的山路，楊博士的智慧防汛平台整合新北市八十四座抽水站，用 AI 預判淹水風險。



asked about that period, he shared a harrowing story. On the day of Mid-Autumn Festival, he had finished a disaster response meeting in northern Taiwan and drove back east with his family. The fatigue from working day after day suddenly caught up with him and he lost consciousness. When he woke up, the car had careened halfway into a ditch beside the road, and all the airbags had deployed. Fortunately, the whole family was safe.

DPWE's work extends across Taiwan. Prof. Chao's monitoring system sends real-time landslide alerts to frontline emergency responders. Dr. Li has extensive mountain survey experience and once trekked mountain trails for eight days and seven nights to investigate the safety of the Batongguan Historic Trail. Meanwhile, Dr. Yang's smart flood prevention platform integrates 84 pumping stations across New Taipei City, using AI to predict flood risks.



Dr. Yang's smart flood prevention platform integrates 84 pumping stations across New Taipei City. The platform uses AI to predict flooding risks and automatically assess flooding conditions. Flood prevention efforts in New Taipei City have long faced key challenges: information was scattered across different agencies, pumping stations could only respond passively to flooding, and surveillance footage required manual review camera by camera.

By consolidating flood prevention data into a single interface, the platform delivers real-time situational awareness and early warnings through AI and image recognition. Districts with varying terrain, including Sanchong, Luzhou, Zhonghe, and Xindian, can now monitor conditions and respond proactively.

楊博士的智慧防汛平台整合新北市八十四座抽水站，用 AI 預判淹水風險並自動判讀積水狀況。新北市防汛過去的困境是資訊分散在不同單位、抽水站只能被動反應、監視器需人工逐一檢視。此平台將防汛資訊整合到單一介面，透過 AI 與影像辨識提前預警，讓三重、蘆洲、中和、新店等不同地形的區域都能即時掌握防汛情況、提前應變

災害很少照預期的方式發生。「面對不確定性，就是防災工作的日常，」防災中心林志平主任告訴我們。正因如此，防災工作者需要的除了技術，還要有跨領域整合、韌性思維，以及接受不確定性的心理準備。「我們不是去控制大自然，而是與大自然共處。」林主任說，「重要的是即時監測、動態決策，讓我們能在災害發生時減少損失、快速恢復。」

從堰塞湖到颱風，從地震到土石流，每一場災害都考驗著人與自然共處的能力。而面對這些不確定性，讓預警資訊真正發揮作用、建構韌性的社會體系，是這群科學家持續努力的方向。那些深夜傳回的監測數據、現場來回的身影，都在實踐著這個目標。

Disasters rarely happen the way we expect. "Dealing with uncertainty is just part of everyday disaster prevention work," Chief Director Chih-Ping Lin of the DPWE tells us. Because of this, disaster prevention workers need more than just technical skills. They also need cross-disciplinary collaboration, a resilience mindset, and the ability to work with uncertainty. "We are not trying to control nature. We are trying to live alongside it," Prof. Lin says. "What matters is real-time monitoring and dynamic decision-making that allows us to minimize losses and recover quickly when disasters strike."

From barrier lakes to typhoons and earthquakes to debris flows, every disaster tests our ability to coexist with nature. To face these uncertainties, the scientists are dedicated to providing early warning systems that are truly effective and building a resilient social system. Keys to their success include the monitoring data sent back late at night and the researchers traveling back and forth to field sites.



Disaster prevention involves dealing with many uncertainties. Ensuring that early warning systems are truly effective and building a more resilient society are goals these scientists continue to pursue.

防災工作需要面對許多不確定性，因此讓預警資訊真正發揮作用、建構韌性的社會體系，是這群科學家持續努力的方向

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