APN

ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

REAL TIME FLOOD MODELING FOR IMPROVED COMMUNITY RESILIENCY IN SOUTHEAST ASIA (RT-FLOOD-CORE)

CRRP2022-07MY-Basri

Project Reference Number: CRRP2022-07MY-Basri

Project Duration: 3 years

Funding Awarded: 22 July 2022

Grant DOI:

Date of Publication:

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Recommended Citation:

Basri, H., Mohd Sidek, L., Chua, L., Irvine, K. N., Sahavacharin, A., Likitswat, F., Wan Abdul Majid, W. H. A., Moh Khambali, M. H., Abu Ujum, E., Teang, L., Chitwatkulsiri, D., Hazrin, N. A., Zulkefli, M. A., Omar, Z. J., Ahmad Mazuki, M. Y., Azmi, N. A., & Azhar, S. S. A. (2025). Real-Time Flood Modeling for Improved Community Resiliency in Southeast Asia (RT-FLOOD-CORE). Project Final Report. Asia-Pacific Network for Global Change Research.

1. Summary

This project enhances flood resilience in Malaysia and Thailand through real-time flood simulation and stakeholder collaboration. It focuses on developing early warning systems via cross-disciplinary research and improving stakeholder disaster preparedness through effective communication and informed policy. With nearly a quarter of Malaysia's population in flood-prone areas and the 2011 Thailand flood causing over 800 deaths and $46.5 billion USD in damages, improved flood response is crucial. Real-time modeling can strengthen early warning systems, but high computational demands pose challenges. Leveraging cloud computing with models like PCSWMM can optimize efficiency and reduce processing time, making disaster response more effective. As an element of enhanced stakeholder preparedness, the project consulted with a range of government agencies but also sought participation from diverse communities to assess their understanding regarding flood risk. The study focuses on two key areas: Batu Dam in Gombak, Selangor, Malaysia, and Pathum Thani, Thailand.

The project involves collaboration between researchers from Malaysia, Australia, and Thailand, focusing on a multi-dimensional approach to flood resilience. The methodology includes:

1. **Development of Flood Models** – Using a coupled 1D-2D hydrological and hydraulic modeling approach with PCSWMM, the project analysed floods resulting from dam failures in Malaysia and extreme rainfall events in Thailand. These models were validated against historical flood data.
2. **Real-time Implementation** – The models integrated real time-time data nowcasts and Numerical Weather Prediction rainfall data forecasts. In Malaysia, these data were used to simulate dam failures under adverse weather conditions, while in Thailand, rainfall predictions leveraged C-band radar data. The flood forecast data and results were ported to VPS Malaysia cloud platforms aiming to provide real-time reservoir water level and flood forecast and increasing prediction lead time. The model can be accessed through the NaRIF website: https://narif.dam-safety.uniten.edu.my/ .
3. **Climate Change Scenarios** – Using Representative Concentration Pathways (RCP4.5 and RCP8.5), the models were used to assess future flood risks under changing climatic conditions.
4. **Community Resilience Assessment** – Design-thinking principles and resilience tools were employed to better understand flood resilience at the community level. The UNDP CoBRA resilience tool, currently used in Thailand, was expanded for use in Malaysia and urban areas of Pathum Thani.
5. **Government and Community Engagement** – A series of workshops were held to engage stakeholders, including government agencies and local communities. The workshops included introductory information-sharing sessions and active engagement activities, culminating in final deliberative retreats involving representatives from Indonesia and Vietnam.

This project aligns with multiple policy frameworks, including Malaysia's National Policy on Climate Change, Thailand's Disaster Management Plan 2015, and global initiatives like the Sendai Framework for Disaster Risk Reduction and the Paris Agreement. It contributes to scientific capacity development by fostering collaboration between early-career researchers, postgraduate students, senior academics, and government officials.

By integrating scientific innovation with community-driven approaches, this project aims to provide a scalable and transferable flood resilience framework. The outcomes will support better flood risk assessment, informed policy-making, and improved disaster preparedness across multiple APN member economies.

2. Objectives

The overall aim of this project is to mitigate flood risk and suggest climate change adaptation measures. The research questions focus on level of community vulnerability to flood and how real-time flood forecasting can improve community resilience to flood. The objectives of this project are:

i. Develop a real-time flood forecast and adaptation model consisting of a cloud-based early warning flood modeling package, adopting weather radar nowcast and rainfall forecasts and climate change scenarios.
ii. Assess community resilience using a collaborative, participatory workshop approach that included a diversity of community demographics.
iii. Capacity building and training – Our team consists of 3 ECRs, from Malaysia and Thailand. They will work alongside and be mentored by senior colleagues. A multi-stakeholder engagement program conducted through workshops will provide key information to and from agency decision makers. The workshops will also open up opportunities for the establishment of advisory committees from a range of groups and agencies.

3. Outputs, Outcomes and Impacts

Outputs	Outcomes	Impacts
Development of Cloud-Based Flood Models and Resilience Adaptation Tools for Malaysia and Thailand - The models will implement numerical weather prediction rainfall forecast data to produce reservoir water level forecast and spatio-temporal flood simulations in real-time.	The models will implement numerical weather prediction rainfall forecast data and forecasts to produce spatio-temporal flood simulations in real- time. The real- time flood model development can be accessed via NaRIF website: https://narif.dam-safety.uniten.edu.my/	The development of real-time flood models and resilience adaptation tools is expected to significantly enhance disaster preparedness and response capabilities in Malaysia and Thailand. By leveraging rainfall forecasts data, these models enable spatio-temporal flood simulations that support timely decision-making. This technological advancement strengthens early warning systems, improves risk communication, and facilitates targeted mitigation strategies—ultimately reducing the potential loss of lives, damage to infrastructure, and socio-economic disruptions caused by flooding. The integration of these tools lays the foundation for climate-resilient communities and promotes regional cooperation in addressing transboundary flood risks.
Supervision of Junior Researchers and Students – Two post-graduate and three early career research staff will work on this project. The students and early career research staff will be supervised by senior researchers from Australia, Malaysia, and Thailand who will	2 postgraduate students from Malaysia and Thailand worked on this project. Meanwhile, early career research staff from Malaysia and Thailand were supervised by senior researchers on flood modeling, weather radar, real-time system integration and community engagement	This project made important contributions to capacity building and knowledge transfer in the field of flood resilience and community-based disaster risk management across Australia, Malaysia, and Thailand. Through the structured supervision of two

also be co-supervisors for the students' theses.	specialization. Additionally, one final year project student worked on extraction of building footprint data for Batu Dam downstream area while 6 young researchers from engineering and social backgrounds were trained to assist with community engagement workshops and CoBRA programmes. 1 young engineer is being trained on the flood modeling using PCSWMM.	postgraduate students and three early career researchers, the initiative fostered cross-country collaboration and mentorship by experienced researchers specializing in flood modeling, weather radar applications, real-time system integration, and community engagement. The involvement of a final year student in extracting building footprints for the Batu Dam downstream area strengthened technical skill development at the undergraduate level. Furthermore, the 6 young researchers from both engineering and social science backgrounds were equipped with the practical tools and methodologies necessary to conduct effective community engagement through workshops and the CoBRA approach. One young engineer received specialized training in flood modeling using PCSWMM, enhancing their technical expertise in hydrological simulations. Through these workshops and collaborative activities, a new generation of professionals has gained practical skills and confidence to address real-world challenges in disaster risk reduction and community resilience. The workshop in

		Thailand became a key platform for regional exchange, leading to collaboration with the Vietnam team under the CLARE project. This connection has since evolved into sustained cooperation between the Malaysian and Thai teams, who continue to share knowledge and build institutional capacity under CLARE. Together, these partnerships are strengthening regional expertise, supporting innovation in resilience research, and creating long-term opportunities for policy and capacity development.
Training of Government Agency Personnel – Collaborate with state and national government agencies in the application of real-time modeling and adaptation and provide regional capacity building with state-of-the-art water resource management tools.	Active collaboration via meetings between project members and workshops continued throughout the project. PCSWMM training was also provided to engineers involved in flood modeling & flood forecasting.	The initiative has significantly strengthened institutional capacity in flood modeling and forecasting across key government agencies. The Department of Irrigation and Drainage (DID), as the owner and operator of Batu Dam, plays a central role in managing reservoir operations, flood control, and drainage systems. Meanwhile, the National Disaster Management Agency (NADMA) serves as the national coordinating body for disaster preparedness and emergency response, ensuring that flood forecasts are translated into timely actions to protect communities at risk. By fostering active collaboration through workshops and project meetings, the program has

		enhanced knowledge sharing and coordination among key stakeholders. The hands-on PCSWMM training provided to engineers has not only increased technical proficiency in using real-time hydrological models but has also promoted the integration of adaptive water resource management practices in decision-making processes. This has led to more informed, data-driven responses to flood risks, contributing to improved community resilience and long-term water resource sustainability.
Develop Procedures and Framework - to include participatory planning and community consultation as part of a resiliency assessment and enhancement effort.	As part of the initiative to develop procedures and a framework that integrated participatory planning and consultation in communities having diverse demographics, both Malaysia and Thailand successfully conducted a series of workshops in three phases—Introductory, Active, and Final Workshops—tailored to each project region. These workshops served as a platform for inclusive engagement and knowledge co-creation, applying the CoBRA (Community-Based Resilience Analysis) Framework to assess and enhance local resilience. A total of 90 participants, including students, local community members, and key stakeholders, actively took part	The development and implementation of procedures and a framework rooted in participatory planning and knowledge co-creation have strengthened community resilience in the targeted regions of Malaysia and Thailand. By embedding community consultation into every phase of the resilience assessment process, the initiative fostered a culture of inclusivity, empowerment, and shared responsibility. The CoBRA Framework served as a vital tool for facilitating informed dialogue and co-creation among diverse stakeholders, leading to heightened community awareness, enhanced local capacities, and stronger

	in the workshops—58 from Malaysia and 32 from Thailand. The structured, phased workshop approach ensured progressive learning, deepened stakeholder understanding, and fostered collaboration. This participatory model not only built local ownership of the resilience planning process but also generated valuable community insights to inform the development of actionable and context-specific resilience strategies.	partnerships. The active participation of 90 individuals—spanning students, local leaders, and relevant stakeholders—demonstrated a tangible shift towards locally driven resilience planning. This approach not only produced context-sensitive strategies but also laid the groundwork for sustainable, community-led disaster risk reduction efforts, which can be replicated and scaled in similar settings.
Enhance Research Output- Senior professors in the project will mentor early career researchers in research and manuscript preparation and disseminate project results through Scopus-indexed, peer-reviewed journals and professional conferences.	The following manuscripts have been published, submitted, or are planned. Full details are provided in section 7 of the report: ● 1 Paper has been published in ICDSME2023 conference proceedings. ● 1 Journal Paper has been published as a research article on PLOS One. ● 1 paper has been revised and resubmitted (minor revisions required) for the International Research in Geographical & Environmental Education journal. ● 1 paper on PCSWMM modeling focusing on land use change and climate change for Pathum Thani area has been published on climate journal. ● 1 Paper has been accepted in ICDSME2025 conference	The project has contributed to advancing research in disaster preparedness, hydrological modeling, and community resilience. By fostering a collaborative research environment, senior professors have successfully mentored early career researchers, enhancing their capacity in academic writing and research dissemination. Building on this momentum, the team has submitted or is preparing five additional manuscripts to be submitted to high-impact journals, including IRGEE, with research focusing on serious games for disaster education, PCSWMM modeling under climate and land use change scenarios, real-time flood modeling, and community resilience assessments using the CoBRA framework.

	proceedings. ● 1 Paper on CoBRA community resilience assessment for Thailand has been published on Land journal. ● 1 Guidelines on Dam Break Flood Hazard Map .	In total, the project is set to deliver seven high-quality research outputs, demonstrating a robust academic contribution and practical insights into disaster risk reduction and climate-resilient water management. These outputs are not only shaping scholarly discourse but also supporting evidence-based decision-making in disaster risk management practices across diverse regions.
Stakeholder Communication - make results accessible to stakeholders and general public by translating into non-technical explanations and holding workshops, posting on social media platforms and coverage by mainstream media.	The National Reservoir Inflow Forecasting System (NaRIF) has been successfully developed and implemented as a predictive tool for enhancing dam safety and flood risk management in Malaysia. By integrating rainfall forecast data from MetMalaysia with water level simulation models and early warning applications, NaRIF enables the prediction of reservoir water levels up to seven days in advance. This capability allows for timely alerts to at-risk residents, providing them with sufficient time to prepare and mitigate potential flood damages. Initially deployed as a pilot project at Batu Dam and Bekok Dam, NaRIF has demonstrated its effectiveness in proactive decision-making and community preparedness. The system's success has laid the	The successful implementation of the National Reservoir Inflow Forecasting System (NaRIF) has greatly enhanced Malaysia's capacity for flood risk management and dam safety. Through strategic stakeholder communication—such as public workshops, social media outreach, and mainstream media coverage—the system's technical capabilities have been translated into practical knowledge that is easily understood by the general public and key stakeholders. This inclusive communication strategy has strengthened trust, increased public awareness, and empowered communities living downstream of dams to take timely action during potential flood events. The tangible benefits observed at Batu Dam

	groundwork for its expansion to other dams managed by the Department of Irrigation and Drainage (DID) and other agencies across Malaysia, promising long-term benefits for national flood risk management and disaster resilience. In addition, the workshops held in Malaysia (with Indonesian participants) and in Thailand (with Vietnamese participants) provided valuable opportunities for regional dissemination of results. These cross-country engagements have further strengthened collaboration among UNITEN, Thammasat University, Kasetsart University, and Vietnam National University (VNU) under the Climate Adaptation and Resilience (CLARE)–ASEAN program, fostering a sustained regional partnership in climate and disaster resilience.	and Bekok Dam have catalyzed national interest, positioning NaRIF as a model for scalable, technology-driven disaster preparedness. As the system continues to be rolled out nationwide, it is expected to reduce flood-related damages, protect lives and livelihoods, and foster a more resilient society in the face of climate uncertainties.

4. Key facts/figures

4.1 Technical Findings/Results

1. Development of PCSWMM Model

1.1 Batu Dam, Malaysia

The hydrological and hydraulic models encompass an area of approximately 6,941 ha, which is subdivided into 43 sub-catchments. Figure 1 shows the example of the integrated modeling in PCSWMM for Batu Dam. Of these, 6 sub-catchments directly contribute runoff to the Batu Dam reservoir, making them particularly critical for understanding and managing inflows to the reservoir. The Sungai Batu, which forms the primary downstream channel, has a total length of 8.74 km. Table 1 summarizes the key properties of the Batu Dam, reservoir, and catchment that were incorporated into the modeling framework.

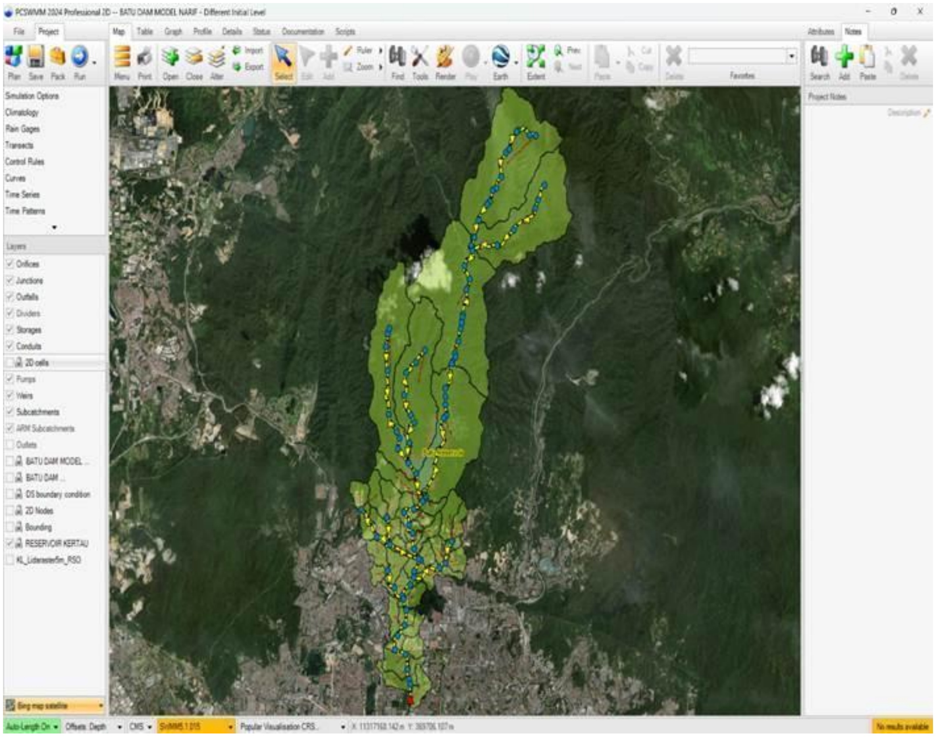

Figure 1 Overview of hydraulic model setup for Batu Dam catchment.

Table 1 Batu Dam, reservoir and catchment properties used in the model.

Name of Dam	Batu Dam
Type of Dam	Zoned Earthfill Embankment Dam
Purpose	Flood Control and Water Supply
Year Completed	1987
Dam Height (m)	44
Dam Crest Level (m LSD)	109.0 m LSD
Dam Crest Length (m)	550
Dam Crest Width (m)	10 m
Avg. Upstream Embankment Slope	3H:1V

Avg. Downstream Embankment Slope	2.5H:1V
Spill Level	104.85 m LSD
Downstream River	Sg. Batu and Sg Tua
Spillway Type	Ungated Side channel (Inlet Ogee Crested)
Spillway Crest Length (m)	21.5 m
Spillway Discharge Capacity (m3/s)	198
Surface Area (sq. km)	2.5
Storage Capacity (MCM)	36.6
Active Storage (MCM)	27.5
Max. Top Water Level	107.3 m LSD
Full Supply Level	104.85 m LSD
Min. Operating Level	102.7 m LSD
Total Area	6941 ha
Sub-catchments Upstream of Batu Dam	6
Total Sub-catchments	43

Figure 2 illustrates the examples of transect input showing cross -section survey of Sungai Batu downstream of Batu Dam.

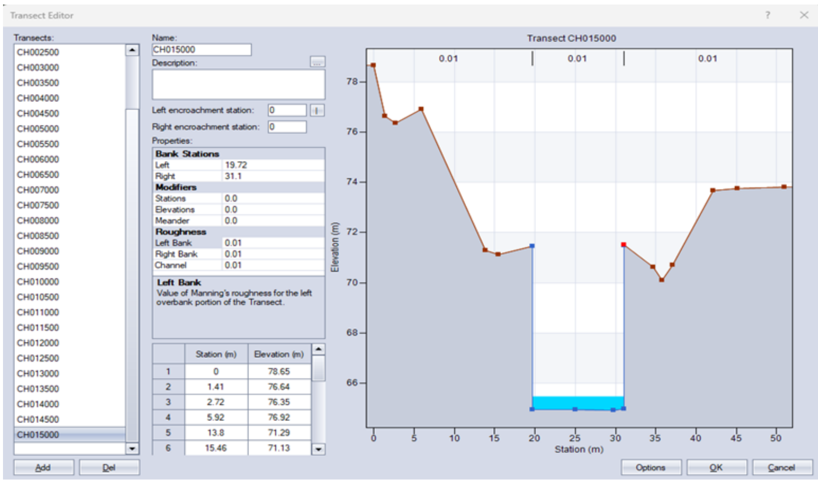

Figure 2 Examples of transect Input showing cross -section survey of Sungai Batu downstream of Batu Dam.

The model was calibrated for three events using Batu Reservoir water level data and results are shown in Figure 3, together with the NSE goodness-of-fit statistics. The NSE values range between 0.535 and 0.789. The NSE is a commonly used performance indicator, although the upper benchmark for acceptable performance seems to vary from as low as 0.5 up to 0.75 (Lin et al. 2017; Seibert et al. 2018; Lane et al. 2019). Shamsi and Koran (2017) recommended that an NSE value in the range 0.5–1.0 could be considered an excellent calibration result and as such, the model could be used for planning, preliminary designs, and final designs. Our NSE results indicate the model could satisfactorily represent water level dynamics for the Batu Reservoir. The events identified in dam authorities' records, occurred in July 2006, March 2009, and December 2021.

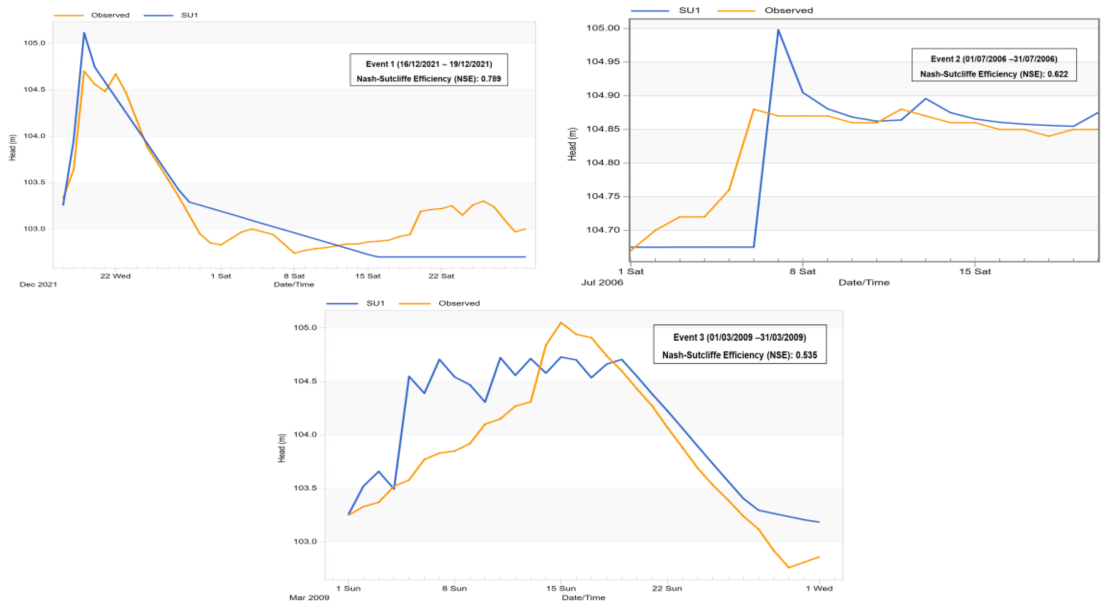

Figure 3 Model performance for three flood events

Table 2 presents the results of inundated area and range flood depth for different design rainfall, climate and dam break scenarios.

Table 2 Inundated area and range flood depth for different scenarios.

Design Rainfall/ Scenarios	Inundated Area (km^2)	Flood Depth Range (m)
2 ARI	2.19	0.010 – 0.682
2 ARI + CCF	2.37	0.010 – 0.707
5 ARI	2.63	0.013 – 0.753
5 ARI + CCF	2.88	0.013 – 0.858
10 ARI	2.89	0.013 – 0.817
10 ARI + CCF	3.13	0.013 – 0.932
20 ARI	2.93	0.013 – 0.891
20 ARI + CCF	3.66	0.021 – 1.070
50 ARI	3.57	0.018 – 0.988
50 ARI + CCF	4.03	0.021 – 1.189
100 ARI	3.77	0.021 – 1.103
100 ARI + CCF	4.27	0.025 – 1.251
200 ARI	3.98	0.021 – 1.179
200 ARI + CCF	4.62	0.028 – 1.289
CDF Failure	25.94	1.892 – 4.717
PMF Failure	28.91	1.991 – 4.760
RCP 4.5 (Early Century)	6.61	1.223 – 5.207
RCP 4.5 (Mid Century)	5.986	1.093 – 4.451
RCP 8.5 (Late Century)	6.611	1.223 – 5.207

Remark: The flood hazard map is confidential and not available for public but will be provided separately for APN.

1.2 Pathum Thai, Thailand

Rangsit, Pathum Thani, is a peri-urban area located approximately 55 kilometers north of Bangkok and lies within the lower Chao Phraya River Basin. The study area covers 77,881 hectares and is characterized by a complex hydrological network of canals and drainage channels that originally were constructed between 1869 and 1900 for agricultural irrigation purposes. These canals, which form a north-south grid approximately 2.5 km apart and bounded by main east-west canals, are referred to locally as "khlongs," and now function as irrigation and urban drainage infrastructure. The area's topography predominantly is flat, with elevations ranging from 0.5 to 2.0 meters above mean sea level. This low-lying terrain makes Rangsit particularly susceptible to surface water accumulation during intense or prolonged rainfall events, especially in areas that lack engineered drainage systems.

The modeling framework incorporates detailed spatial data, hydraulic infrastructure layouts, and calibrated rainfall-runoff relationships throughout the Rangsit study area. PCSWMM's watershed delineation tool was employed to initially define the boundaries of 1,094 subcatchments using a 30-meter resolution Digital Elevation Model (DEM) sourced from the Royal Thai Survey Department. This delineation subsequently was refined through site investigation and visualization with Google Earth Imagery in ArcGIS. The delineated subcatchments range in size from approximately 5 to 60 hectares, contingent upon topography and land use heterogeneity. Drainage pathways were accurately mapped to reflect the actual routing of stormwater across urban and peri-urban surfaces (Figure 4).

The hydraulic model encompasses 1,557 canal segments corresponding to the region's primary and secondary khlongs (canals) (Figure 4). These segments are characterized by 41 surveyed cross-sections representing at least one for each khlong and their hydraulic properties including channel width, slope, and Manning's roughness coefficient have been assigned based on field data obtained from the Royal Irrigation Department (RID). The model also includes 47 hydraulic structures (e.g., weirs, sluice gates), 13 downstream outlets, and two active pumping stations.

In general, the runoff from the subcatchment areas is drained directly into the adjacent khlong, but we also represented three urbanized areas in more detail, including their subsurface pipe network and pump operations. These sites were selected as case studies to investigate urban flooding in more detail, specifically the broad runoff and flooding trends expected for each type of development. The three sites include a new single family residential estate (moo baan) on Khlong 4, a mixed, mature, industrial/residential estate (Nava Nakorn), and the older, established community of Ratanakosin Village, Rangsit.

Boundary conditions were defined by the inflow from upstream river systems, which include contributions from the Pasak River and adjacent catchments. Meetings with the Royal Irrigation and Drainage Department (RID) indicated that their target rainy season inflow conditions of 140 m^3/s from the Pasak River should be used to define the upstream boundary conditions and this target was used in the preliminary model runs. However, this approach provided an unsatisfactory fit to the observed flow data for the individual khlongs. After further discussions with RID, we obtained observed inflow values to the study area for the Pasak River and observed values can be quite different from the target inflow conditions of 140 m^3/s. The 2022 peak inflow rates from the Pasak River, for example, were more than 4 times greater than the target value. Figure 4 Drainage network for PCSWMM simulation. Weirs are located at the head of each khlong but also can be noted as the khlong gates in Figure 5. Urbanized areas highlighted by red borders are Nava Nakorn industrial estate (northern polygon), Ratanakosin Village, Rangsit (southern polygon), and moo baan (eastern polygon).

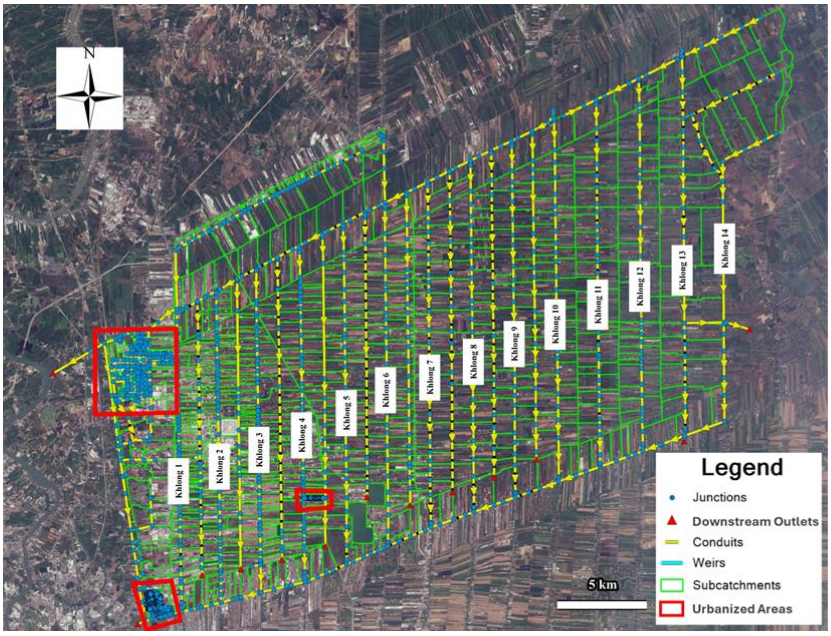

Figure 4 Drainage network for PCSWMM simulation.

Figure 5 Drainage system components visualized in PCSWMM for selected urbanized areas, moo baan (left); Nava Nakorn industrial estate (middle); and Ratanakosin Village, Rangsit (right).

PCSWMM was run in continuous mode using 3-hour rainfall data to provide an initial assessment for current conditions and the build-out scenario at a finer temporal resolution. Subsequently, the model was run at daily time steps for the current conditions, build-out, and climate change scenarios to ensure appropriate temporal comparison, particularly with respect to peak rainfall intensity.

The PCSWMM model was calibrated for the period 10 Oct 2021 to 10 Oct 2022, which represents parts of two wet seasons and an intervening dry season. Bangkok experienced some of the heaviest rainfall in 20 years during August 2022 and up-stream Ayutthaya also experienced heavy flooding. By selecting this period of record, we conservatively focus on a potentially more damaging wet period. Peak flow entering the study area in 2022 was at least 400 m^3/s greater than peak flow for the benchmark 2011 flood. Model validation was done for the period October 2016 to October 2017. To assess model goodness-of-fit, we used the Nash Sutcliffe Efficiency (NSE) statistic, the Integral Square Error (ISE), and the Pearson Product-Moment Correlation Coefficient (r).

Hydraulic calibration entailed the adjustment of conduit and node parameters, gate opening levels, and channel connectivity. The gate operations, in particular, were challenging to represent, as there are gates at the head and outlet of each of the north-south running khlongs, as well as on the main east-west khlongs and based on assessment of the historical water level records, as well as daily field observation of Khlong 4, gates are adjusted through RID interventions from the standard plan, considering incoming flow at the upstream boundary, as well as rainfall forecasts (whereby levels may be lowered in anticipation of a future large event). As such, the timing and extent of gate openings was adjusted through PCSWMM Control Curve scripting as part of the calibration process.

The calibration results for 10 October 2021 to 10 October 2022 are presented in Figure 6 and the goodness-of-fit statistics are summarized in Table 3. The calibration results indicate that PCSWMM is able to accurately reflect the dynamics of the water levels within the system.

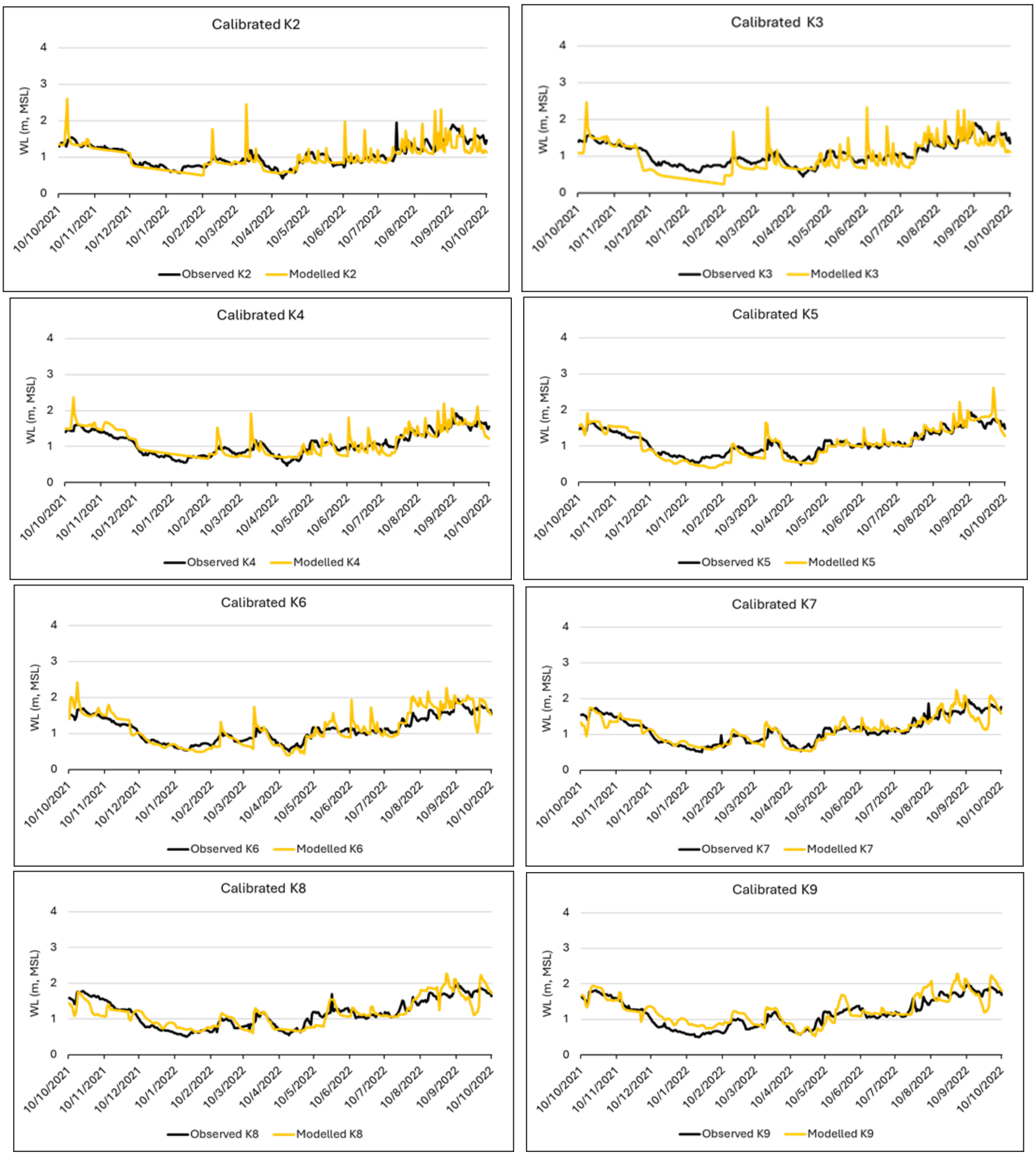

Figure 6 Comparison of simulated and observed water levels for PCSWMM calibration.

Table 3 Goodness-of-fit statistics for PCSWMM calibration 10 Oct 2021 to 10 Oct 2022.

	K2	K3	K4	K5	K6	K7	K8	K9
ISE rating	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
ISE	1.03	1.29	0.867	0.776	0.937	0.783	0.93	0.986
NSE	0.538	0.292	0.695	0.77	0.682	0.792	0.726	0.706
r	0.795	0.836	0.878	0.944	0.926	0.896	0.86	0.871

Because of the variable gate operations through the year that are strongly influenced by the incoming flow at the upstream boundary to the system, it is a challenge to establish a set of standard gate operation procedures that reflect current practice. As such, the gate operations used in the calibration for the wet period of 10 October 2021 to 10 October 2022 are not expected to provide a highly accurate reflection of system conditions under a drier period. Nonetheless, we explored this dynamic system situation as part of a validation exercise using the period October 2016 to October 2017, encompassing both pre-monsoon and post-monsoon events. This period was considerably drier than the 2021-2022 calibration period, with peak flow being about half of the wetter calibration period. Example validation results for this period are shown in Figure 7. The validation run approximated the general temporal trend for the period, but as expected, the peak depths are less accurately captured due to the system dynamics. However, because we are comparing relative changes in runoff patterns with different land use and climate change scenarios in this study, it is an acceptable compromise to use the calibrated gate operations for a particularly wet period.

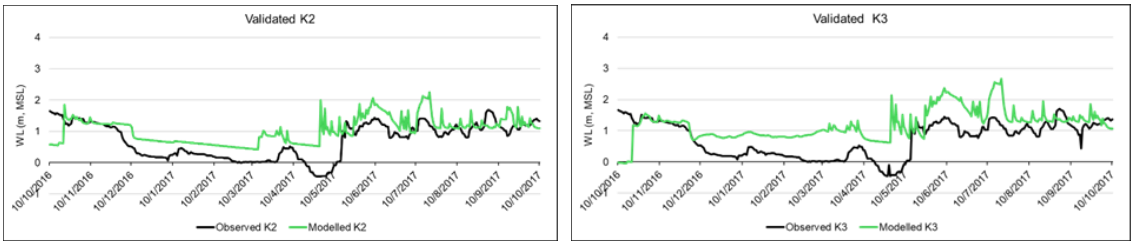

Figure 9 Comparison of simulated and observed water levels for PCSWMM validation.

Potential flooding conditions under the future build-out scenario were modeled using the same rainfall time series as was used for the calibration results, 10 Oct 2021 to 10 Oct 2022. The proportion of non-urban areas decreased to 24% under the future build-out scenario. The future build-out scenario produced a total runoff volume that was 2.7 times higher than under the current land use scenario. This extra runoff produced a 78% increase in flood volume as well as an increase in the spatial extent of flooding under the future build-out scenario (Figure 10).

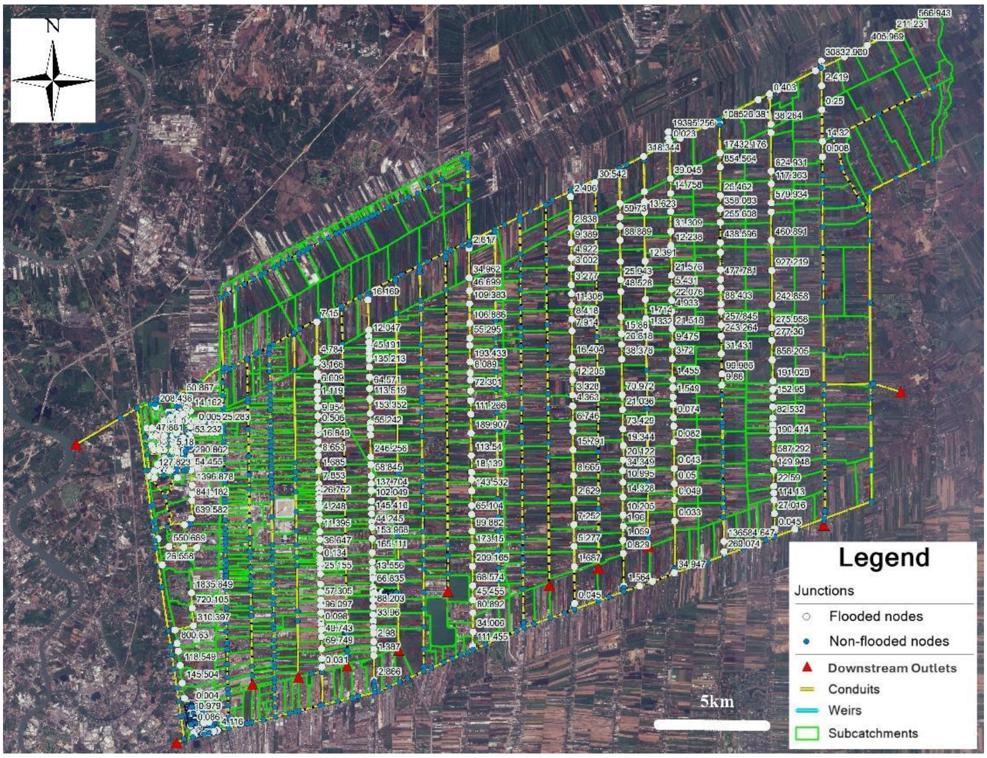

Figure 10 Model nodes flooding under current conditions for the calibration year 10 Oct 2021 to 10 Oct 2022

For appropriate comparative purposes current conditions, build-out conditions, and climate change scenarios (RCP4.5 and RCP8.5) were run using daily rainfall. Furthermore, in the interest of computational time, the climate change scenarios were run for the October through October annual period, 2061/2062 and 2091/2092, covering parts of two rainy seasons that can be compared to current conditions 2021/2022. This comparison enabled us to divide the climate change scenario into thirds under which we can examine mid- and end-century conditions.

Results of the modeled runoff for the different scenarios are summarized in Table 4, along with the annual rainfall data for the modeled time period. As shown in Table 4, total annual rainfall was higher under the RCP8.5 scenario compared to RCP4.5. Notably, both climate scenarios show increasing precipitation between 2062 and 2092. Interestingly, total rainfall in the calibrated year 2022 was comparable to that of the RCP8.5 scenario in 2092. By calibrating current conditions using a wet year, we effectively incorporated the uncertainty associated with projected increases in rainfall due to climate change into our baseline scenario.

Table 4 Comparison of runoff volume under current and future climate and scenarios.

Scenario	Total Rainfall mm	Runoff (m^3)	
		Current Land Use	Future
Calibrated Year (2022)	1,724	159,305 $\times 10^3$	463,808 $\times 10^3$
SSP2-4.5 (2062)	1,129	41,899 $\times 10^3$	145,479 $\times 10^3$
SSP5-8.5 (2062)	1,607	63,993 $\times 10^3$	224,748 $\times 10^3$
SSP2-4.5 (2092)	1,496	56,400 $\times 10^3$	198,163 $\times 10^3$
SSP5-8.5 (2092)	1,718	79,810 $\times 10^3$	276,475 $\times 10^3$

As illustrated in Table 4, land use changes driven by ongoing and anticipated urban development may exert a stronger influence on runoff than climate change alone. For instance, under the RCP8.5 scenario, the combined effects of future build-out and climate change produce runoff levels 3.4 times greater than those under current land use with climate change. This underscores the important role of urban expansion in shaping future flood risk.

2.0 Community Based Resilience Analysis (CoBRA)

2.1 Malaysia

Three Community-Based Resilience Analysis (CoBRA) workshops were held under the RT-FLOOD-CORE project to assess community and institutional resilience to dam-related hazards in Malaysia. Table 5 presents the CoBRA Workshops conducted in Malaysia alongside with dates, participants and focus groups.

Table 5 CoBRA Workshops conducted in Malaysia.

Workshop	Date	Participants	Focus
UNITEN Students Trial Exercise	8 October 2023	16 local & international UNITEN students	Youth awareness & behavioral perception
Batu Dam Community Exercise	2 December 2023	21 village representatives residing near Batu Dam	Downstream dam community preparedness & hazard prioritization
Stakeholders Exercise	8 May 2024	21 officers from Department of Irrigation & Drainage Malaysia (Dam & Design Division, Batu Dam Personnels & Bekok Dam Personnels) and National Disaster Management Agency	Institutional coordination

2.1.1 UNITEN Students Trial Exercise

This pilot session engaged 16 students in simulated flood and dam-failure scenarios to evaluate awareness and preparedness. The workshop aimed to test the CoBRA framework's effectiveness in enhancing understanding of dam-related risks among youth. Figure 11 shows the participants of UNITEN students for Trial Exercise workshop.

Figure 11 UNITEN students for Trial Exercise.

Activity 1: Imagination Game

Students imagined a sudden Batu Dam failure after heavy rainfall and had five minutes to choose three items to take. Table 3 presents the top 3 items selected by UNITEN students groups during imagination game.

Table 6 Top 3 items selected by UNITEN students groups during Imagination Game.

Group	Top 3 Items	Other Items Mentioned
1	Wallet (IC, cash); Fire starter; Medical kit bag	Water, food, smartphone, documents
2	First-aid kit; Food & water; Life jacket	Survival kit, phone, birth certificate, flashlight
3	Clean water; Rope; Battery/crank radio	Packed food, documents, whistle, torchlight

The activity demonstrated the students' ability to connect physical survival needs with longer-term continuity needs (communication, identity). It also underscored the importance of having personal evacuation checklists and household emergency plans.

Activity 2: Stop Disasters Game

Students engaged in the UNDRR "Stop Disasters" simulation. All groups explored solutions such as early-warning systems, relocation, and retaining walls. Only one group improved its secondround score, emphasizing the value of iteration and teamwork in decision-making. Students were divided into three groups and tasked with completing the "Flood Management" scenario, which requires players to balance economic growth, safety investment, and time under limited budgets.

Learning Objectives:

1. Apply theoretical concepts of disaster-risk reduction to a real-time decision-making environment.
2. Understand trade-offs between infrastructure spending, community protection, and preparedness education.
3. Experience time-pressure dynamics that mirror actual emergency-management situations.

Figure 12 Students engaged in the UNDRR "Stop Disasters" simulation.

Results:

Table 7 The results of Activity 2 for different groups.

Group	Strategy Adopted	Key Interventions Implemented	Score Improvement	Observations
1	Prioritized structural defenses	Constructed levees and retaining walls; partial relocation of high-risk housing	+4 %	Reduced fatalities but exhausted budget early.
2	Balanced structural + non-structural measures	Built floodwalls, invested in early-warning system,	+11 %	Achieved best overall resilience; casualties reduced by ~60 %.

		launched awareness campaign		
3	Emphasized community preparedness	Focused on public education, evacuation drills, and green-belt zoning	+6 %	Lower property loss but slower recovery due to limited physical protection.

Behavioral and Analytical Findings:

- Systems Thinking: Students realized that no single intervention guarantees safety; success requires integrated structural and social strategies.
- Prioritization under Constraints: Participants acknowledged the need to invest in *prevention* rather than post-disaster reconstruction.
- Awareness of EWS Role: All groups highlighted the importance of early-warning systems and communication chains between authorities and the public.
- Budget Optimization Skills: The exercise revealed how even limited financial resources can be leveraged effectively through informed decision-making.
- Team Dynamics: Collaborative decision-making improved in Round 2, with clearer role assignments and consensus building.

Qualitative Reflections (Post-Game Discussion):

- *"We learned that education and drills can be as powerful as building walls."*
- *"Losing points taught us that ignoring early warnings or delaying action is costly."*
- *"Balancing budgets felt like real-world policymaking—every decision has trade-offs."*

Activity 3: CoBRA

The UNITEN Students Trial Exercise demonstrated that experiential learning can substantially raise disaster literacy. Students recognized the importance of early warnings, teamwork, and pre-emptive household planning. Post-workshop data confirmed measurable increases in awareness and engagement (+28.6% EWS recognition, +35.8% site awareness).

Figure 13 Students identified and lists main crises.

Table 8 Results and Interpretation for CoBRA questions.

CoBRA Question	Description / Scale	Results (Workshop Findings)	Interpretation
Q1–Q2	Identify and rank main crises/hazards.	Air pollution → Food security → Financial crisis	Students associated resilience not only with floods but also environmental and economic stressors.
Q3–Q4	List and rank characteristics of a resilient community.	1. Access to clean water 2. Savings/credit availability 3. Community cooperation and preparedness training	Emphasized social capital and basic resource security.
Q5	Assess change in resilience over past 5 years (1–5 scale): 1 = Significantly worse, 5 = Significantly better.	Average = 4 ('Slightly better than before')	Students perceived steady improvement in disaster awareness and preparedness.
Q6	Score current status (0–10 scale): 0 = Not achieved, 10 = Fully achieved. Compared 'Current' vs 'Crisis'.	Awareness 6→8; Preparedness 5→7; EWS knowledge 5.1→6.6	Clear gains in knowledge and intended preparedness actions after the workshop.

Activity 4: Survey Findings

- Awareness of EWS existence increased by 28.6%
- Knowledge of EWS installation locations increased by 35.8%
- Understanding of negligence and structural risks increased by ~30%
- Willingness to store documents and contacts for emergencies improved significantly

2.1.2 Batu Dam Community Exercise

Held on 2 December 2023 with 21 residents living near Batu Dam, this workshop focused on assessing local perceptions of hazards, community preparedness, and resilience characteristics through participatory exercises.

Figure 14 Batu Dam Community Exercise.

Activity 1: Imagination Game
Participants selected items they would take in a sudden dam-break evacuation. The most cited were important documents, medicines, food, and emergency bags. Reflections revealed attention to family safety, elderly care, and psychological readiness during crises.

Table 9 Top 3 selected items for different groups.

Group	Top 3 Items Selected	Supporting Reasoning (as expressed by participants)
1	Identity documents; Cash; First-aid kit	Documents prove ownership and identity for recovery after disaster. Cash used for urgent needs.
2	Food & water; Medicines; Mobile phone	Survival priority and maintaining contact with family members.

3	Emergency bag; Life jacket; Torchlight	Safety during evacuation and visibility at night.
4	Documents; Family photos; Clothing	Emotional attachment and proof of life events; preparedness for displacement.

Activity 2: Mapping Game

Residents marked their home locations and flood levels on maps showing historical flood zones and dam-break scenarios. The activity increased awareness of spatial vulnerability, particularly in medium-risk areas downstream, and prompted discussion on poor drainage maintenance and illegal waste dumping.

Figure 15 Residents marked their home locations and flood levels on maps.

Activity 3: CoBRA

The Batu Dam results highlight a dual pattern of strong grassroots awareness but limited institutional capacity. Community-driven campaigns perform reliably during floods, yet enforcement and waste management require formal institutional reinforcement. These findings validate CoBRA's sensitivity in capturing both behavioral and systemic resilience dimensions.

Figure 16 One of the communities presented their group results.

Table 10 Results and Interpretation for CoBRA questions.

CoBRA Question	Description / Scale	Results (Workshop Findings)	Interpretation
Q1–Q2	Identify and rank main crises or hazards affecting daily life.	1. Improper garbage disposal 2. Overpopulation/undocumented settlers 3. Flash floods and clogged drains	Environmental cleanliness and social issues dominate local resilience concerns.
Q3–Q4	List and rank resilience characteristics desired by the community.	1. Public education & environmental awareness 2. Spring-cleaning/ awareness campaigns 3. Waste system reliability	Residents prioritize social behavior change and community cooperation over

		4. Villager–agency cooperation 5. Enforcement & governance	infrastructural solutions.
Q5	Change over past 5 years (1–5 scale): 1 = Significantly worse, 5 = Significantly better.	Range = 1–4.5; highest = Spring-cleaning (4.5), lowest = Budget approval (1).	Social mobilization has improved, but enforcement and infrastructure budgets lag behind.
Q6	Current vs Crisis (0–10 scale): 0 = Not achieved, 10 = Fully achieved.	Public education 8/8; Spring-cleaning 6/7; Waste system 6/2; Enforcement 4/3; Budget approval 8/6.	Awareness initiatives remain stable; service delivery and enforcement collapse under crisis stress.

2.1.3 Stakeholders Exercise

Conducted on 8 May 2024 at UNITEN, this workshop engaged 21 representatives from DID and NADMA. The objective was to evaluate institutional coordination and align operational frameworks with community-based findings.

Figure 17 Stakeholders Exercise workshop.

Activity 1: Stop Disasters Game

The purpose was to explore how institutional decisions under resource constraints affect both infrastructure resilience and community safety, while testing inter-agency coordination dynamics.

Figure 18 Stakeholders engaged in the UNDRR "Stop Disasters" simulation.

Table 11 The summary results of Activity 1 for different groups.

Group	Strategic Approach	Main Interventions	Simulation Outcome	Observations
A	Infrastructure-first approach	Strengthened dam structure, built levees, upgraded telemetry	Moderate success – physical losses reduced by 40%, but communication gaps delayed evacuations	Showed technical expertise but limited cross-agency interaction
B	Balanced risk reduction	Combined infrastructure repair, early-warning upgrades, and community training	Best performance – 70% risk reduction, rapid information dissemination, improved evacuation outcomes	Reflected integrated thinking and effective inter-agency coordination
C	Response-focused approach	Prioritized emergency response teams, logistics, and relief after flood	High casualties and economic loss despite efficient post-disaster aid	Reactive planning exposed lack of proactive mitigation mindset

Analytical Findings

1. Decision-Making under Constraints: The exercise revealed that agencies tend to default to their organizational mandates when pressured (e.g., engineers focus on dam safety infrastructure; NADMA prioritizes relief logistics). However, the integrated approach in Group B demonstrated that strategic budget allocation across multiple sectors yields higher resilience dividends.
2. Information Flow and Coordination: During the simulation, Group B introduced an ad hoc "information liaison" role (mirroring a command-center coordination officer) which significantly improved real-time communication. This simple adaptation resulted in faster community alerts and fewer simulated casualties, confirming the critical value of dedicated communication roles in EAP activation.
3. Proactive vs. Reactive Planning: The comparison of Group A (preventive) and Group C (reactive) strategies reinforced a key CoBRA insight: preventive investment in early-warning systems and training is more cost-effective than post-disaster spending on relief. This aligns with the NaRIF framework's emphasis on forecast-informed operations.
4. Institutional Learning and Cooperation: Participants acknowledged that inter-agency collaboration during the game mirrored real emergency coordination challenges. NADMA representatives noted that the simulation clarified overlaps in information-sharing responsibilities, while JPS participants recognized the need to make NaRIF outputs more accessible to local authorities during crisis activation.

Qualitative Reflections (Post-Exercise Debrief)

During the debrief, participants shared reflections that illustrated institutional learning:

> *"We now see the importance of embedding early warnings into every phase of dam operation—not just during floods."* – DID Officer
>
> *"Having a clear liaison officer reduced confusion. This should be replicated in our real EAP drills."* – NADMA Representative
>
> *"It's not just about the dam structure; the community's trust in the warning system matters equally."* – BRE Participant

Activity 3: CoBRA

The Stakeholder workshop validated that CoBRA can be scaled upward to assess institutional resilience. It revealed that while Malaysia's dam-safety infrastructure and modeling systems (NaRIF) are robust, crisis-phase communication and coordination protocols require refinement. The outcomes guided joint actions including simulation calendars, EAP–NaRIF integration, and inclusion of CoBRA metrics in future DID guidelines.

Figure 19 The Stakeholders identified and listed crises based on CoBRA question.

Table 12 Results and Interpretation for CoBRA questions.

CoBRA Question	Description / Scale	Results (Aggregated Scores)	Interpretation
Q1–Q2	Identify and rank institutional crises or gaps.	1. Inter-agency communication bottlenecks 2. Role ambiguity in warnings 3. Telemetry data inconsistency 4. Weak community linkages	Communication and coordination remain the weakest institutional components.
Q3–Q4	Identify and rank key resilience characteristics.	1. Efficient information flow 2. Clear command structure 3. System redundancy 4. Policy alignment & community interface	Technical capacity high, but policy and communication integration need strengthening.
Q5	*Institutional progress over past 5 years (1–5 scale):* 1 = Significantly	Average = 4 (“Slightly better than before”).	Reflects incremental policy alignment progress and adoption of

	worse, 5 = Significantly better.		NaRIF-based protocols.
Q6	*Normal vs Crisis (0–10 scale):* 0 = Not achieved, 10 = Fully achieved.	Communication 9→6; Coordination 8→5; Technical 9→8; Policy 8→6; Community interface 7→5.	Resilience drops significantly under crisis conditions; coordination and communication priority areas for reform.

2.2 Thailand

A total of 3 workshops were run: i) 25 Jun 2023 with local rice farming community; ii) 25 Jan 2024 with Thammasat University Landscape Architecture and Urban Design students; and iii) 28 May 2024 with local residents from different housing developments.

2.2.1. Local Rice Farming Community

A total of 15 rice farm head of households attended the workshop, with 8 being female and 7 being male. The average age the workshop attendees was 59, with a range of 47 to 72 (Figure 20).

Figure 20 Resilience workshop 1 with rice farming community.

Key Findings

Main crises or hazards

The set of main crises or hazards were ranked by each group through a voting process. The primary concerns of rice farming communities in peri-urban areas, as identified in this study, revolve around two critical issues: production costs and flooding (table 1). Input cost crisis in agriculture is the economic difficulty faced by farmers due to the high expenses associated with essential agricultural inputs such as pesticides and fertilizers. These challenges are interconnected and have significant implications for the economic viability and overall sustainability of rice farming in these regions.

Flood events emerge as a significant environmental challenge faced by peri-urban rice farming communities. The data indicates a high occurrence of flooding, highlighting the vulnerability of these areas to adverse weather conditions. Flooding not only poses an immediate threat to crop yields but also has broader implications for infrastructure, transportation, and community well-being.

The listed issues might be grouped into 3 categories: 1) economic challenges (expensive pesticides and fertilizers, rice price drop, oil crisis, and no money, 2) environmental and climate-related challenges (flood, leachate water, drought, and hot temperature/climate change) and 3) health and safety concerns (drugs, rice diseases and pests, theft, COVID-19, PM 2.5, and mental illness). These three categories represent the primary areas of concern, with environmental and climate-related challenges taking precedence. This indicates a substantial impact of these issues on peri-urban rice farming communities. This finding suggests that the environmental and climatic factors are significant determinants affecting the sustainability and resilience of rice farming in these areas.

Table 13 Main crises or hazards affecting the community.

	group 1	group 2	group 3	group 4	total
environmental and climate-related challenges					**28**
flood	2	2	9		13
leachate water	8				8
drought		3	1		4
hot temperature/ climate change				3	3
rice diseases and pests	2	2	1		5
theft	3				3
economic challenges					**21**
expensive pesticides and fertilizers	2	3	5	4	14
rice price drop		2	7		9
oil crisis		3	2		5
no money		3			3
health and safety concerns					**18**

Community resilience characteristics

In the CoBRA analysis framework, the subsequent phase involved the formulation of outcome statements delineating resilience for all households within the rice farming community. Following this, the four teams reconvened to individually generate a list of outcome statements, which was subsequently refined to eight key statements through collaborative group discussions and a ranking process. Understanding the factors contributing to community resilience is essential for effective development planning. This result presents a detailed analysis of outcome statements derived from the peri-urban rice farming community, highlighting key characteristics that define their resilience. The identified features encompass a range of domains, including agriculture, finance, knowledge, and community cooperation.

The top 3 characteristics of a resilient community identified by participants include community self-production inputs, financial security, and supplement income or alternative crops (Table 14). The community places a high value on self-sufficiency in agricultural inputs, emphasizing sustainable farming practices. The production of biological fertilizer, compost, and biopesticides not only promotes environmental sustainability but also enhances agricultural resilience by reducing dependence on external inputs.

Financial stability emerged as a cornerstone of resilience for the Pandan community. Recognizing the importance of economic security, the community prioritizes measures to ensure stability in the face of economic uncertainties, reinforcing their ability to withstand shocks and adversities.

Cultivating alternative crops or diversifying income sources by exploring various agricultural avenues. Diversifying income sources through alternative crops signifies adaptability and flexibility. The community's focus on supplementing income through various agricultural avenues showcases a forward-thinking approach, mitigating risks associated with market fluctuations or challenges specific to particular crops.

Table 14 Outcome statements that describe resilience in the community.

Characteristics of a resilient community	group 1	group 2	group 3	group 4	total
Producing their own biological fertilizer, compost, and biopesticides	9	1	3	6	**19**
Having financial security		5	9	3	**17**
Supplement income/ alternative crops	5	3	6		**14**
Integrated agriculture	3	1		2	**6**
Having knowledge			5		**5**
Government policy/ law/ regulation		4			**4**
Having your own seed bank	4				**4**
Having land ownership	3				**3**
Support/cooperate within the community			2		**2**
Reduce labor costs/ agricultural machines		1			**1**

Community's progress

The methodology involved soliciting individual assessments from workshop participants regarding the changes in resilience statements/characteristics presented in Table 15 over the past 5 years. Each participant was asked to provide a subjective rating for each resilience statement based on their perception of the observed changes. The ratings were on a scale of 1 to 5, where: 5: Significantly better than before, 4: Slightly better than before, 3: Same as before, 2: Slightly worse than before, 1: Significantly worse than before. This comprehensive approach allowed for a nuanced understanding of the perceived changes in each resilience statement and provided a holistic assessment of the community's overall progress in achieving resilience outcomes. The methodology aimed to capture diverse perspectives from workshop participants, contributing to a comprehensive and participant-driven evaluation of community resilience.

These scores reflect a positive trend in various resilience characteristics, with notable improvements in land ownership, community support, integrated agriculture, and financial security. However, challenges are observed in areas related to labor costs and satisfaction with government policies. This nuanced understanding can guide future interventions and policy adjustments to further enhance community resilience.

Table 15 Assess change in the Resilience statements/characteristics, over the past 5 years.

Characteristics of a resilient community	score
Having land ownership	4.7
Support/cooperate within the community	4.5
Integrated agriculture	4.5
Having financial security	4.4
Supplement income/ alternative crops	4.3
Producing their own biological fertilizer, compost, and biopesticides	4.1
Having knowledge of adaptation	4.0
Having your own seed bank	4.0
Reduce labor costs/ agricultural machines	3.6
Government policy/ law/ regulation	3.0

2.2.2. University Student and Local Resident Workshops (Moo Baan)

A total of 17 students participated in Workshop 2, 25 Jan 2024 and 15 people participated in Workshop 3 held on 28 May 2024, both at Thammasat University Faculty of Architecture and Planning. For convenience, and also to access a diversity of residential experiences, the 15 Moo Baan participants were faculty and staff with homes in this area.

As an icebreaking activity, participants were divided into 3 (moo baan participants) or 4 (students) groups and they played the UNDRR Stop Disasters online flood management game (Figures 21 and 22). As the final step of the workshop, the participant groups discussed and completed the CoBRA resilience assessment tool, following the same procedures that were used for Workshop 1 (Rice farming community). The main crises identified within the three workshops is summarized in Table 8. The top ranked crisis was different for each group (expensive production costs for the farming community; PM2.5 for the university students; flooding for the Moo Baan participants). Although there were differences in the top-ranked crisis, it is interesting that some common themes appear for all workshop groups, including flood, drought, PM2.5, and Covid 19.

Figure 21 Thammasat student resilience workshop, 25 Jan 2024

Figure 22 Moo Baan participants play the UNDRR Stop Disasters online flood management game as part of the resilience workshop 3.

Table 16 Main crises or hazards identified in each workshop.

Workshop I: **Rice farmers**	total
Expensive pesticides and fertilizers (economic crisis)	**14**
Flood	**12**
Rice price drop	**10**
Leachate water	8
Rice diseases and pests	7
Drugs	6
Drought	4
Hot temperature/ climate change	3
Theft	3
Oil crisis	3
No money	3
Covid19	3
PM 2.5	1
Mental illness	1

Workshop II: **University students**	total
PM 2.5	**37**
Flood	**19**
Drought	**11**
Covid19	10
Land subsidence	8
Oil crisis	6
Traffic jam	6
Chemical plant explosion	5

Workshop III: **Gated community**	total
Flood	**34**
Covid19	**20**
PM2.5	**15**
Road construction	7
Drought	4
Pollution	4
Fire	3
economic crisis	2
Typhoon	1

The statements identified in each workshop as best characterizing resilience for their main crisis and community progress in achieving resilience goals, (a) over the past 5 years; and (b) before and during the main crisis period, are summarized for Workshop 2 in Figure 23 and Workshop 3 in Figure 24.

Characteristics of a resilient community	score
Accessibility to hospital	**4.10**
Work from home/ Close to workplace	**3.80**
Lots of green space	**3.50**
Supportive community	**3.50**
Innovative devices	**3.40**
Eco community/ Self-sufficiency community	3.40
Good infrastructure	3.40
High income	3.10
Stay in rural area	2.60
Far from the pollution sources	1.90

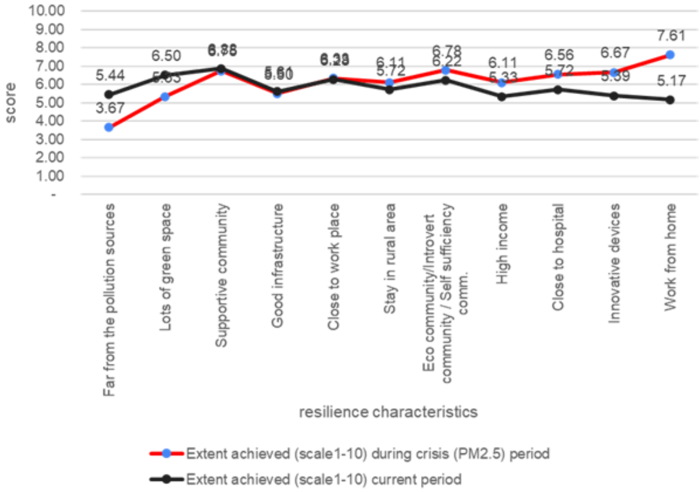

Figure 23 Workshop 2 – progress towards resilience over the past 5 years (scale 1-5), left; and progress towards resilience before and during the most recent PM2.5 crisis.

Characteristics of a resilient community	score
Elevated land/ flood protection structure	**4.50**
Stilt house, elevated house	**4.00**
Agriculture community	**4.00**
High land	**4.00**
Have crop diversity	**3.75**
Flood free location	**3.75**
Have retention area/pond	3.50
Nearby elevated road	3.25
Floating house	2.75
Good drainage system	2.50

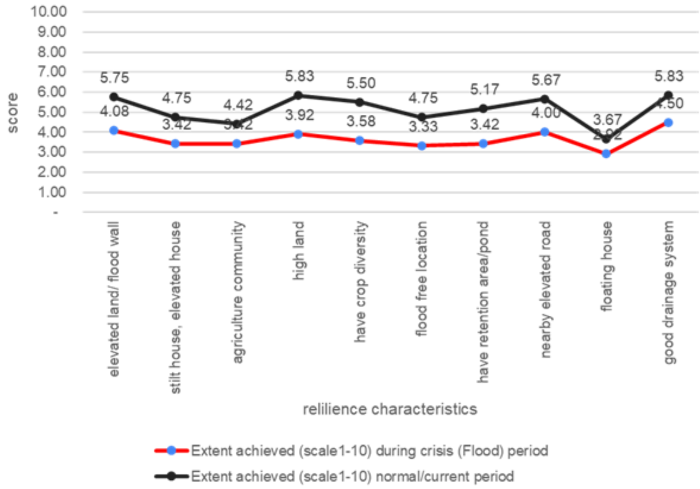

Figure 24 Workshop 3 – progress towards resilience over the past 5 years (scale 1-5), left; and progress towards resilience before and during the 2011 flood crisis.

Briefly, we can conclude:

- The priorities and crises faced by agricultural and urban-residential communities vary depending on their specific situations or environments. This highlights the importance of understanding the unique challenges and needs of each group to address their pathway to resilience effectively.
- While CoBRA provides in-depth local insights, it may be challenging to scale the approach for broader regional or national assessments without losing detail. And ensuring consistency in methodology and data collection across different communities / country/ culture can be challenge.

3.0 National Reservoir Inflow Forecasting System (NaRIF)

The National Reservoir Inflow Forecasting System (NaRIF) is a national platform developed to provide early forecasts of water inflows into Malaysia's major reservoirs. It helps dam operators and government agencies manage water resources more effectively, prepare for floods, and ensure dam safety. NaRIF brings together rainfall, river flow, radar, and weather prediction data into one system. Using hydrological models, it produces short- to medium-term inflow forecasts that can be accessed through an online dashboard. This allows quicker decision-making for reservoir operations, flood warnings, and water supply planning. For the pilot project, NaRIF was implemented at the Batu Dam and Bekok Dam for Malaysia, and Pathum Thai, Thailand. Figure 25 illustrates the architecture of the NaRIF system.

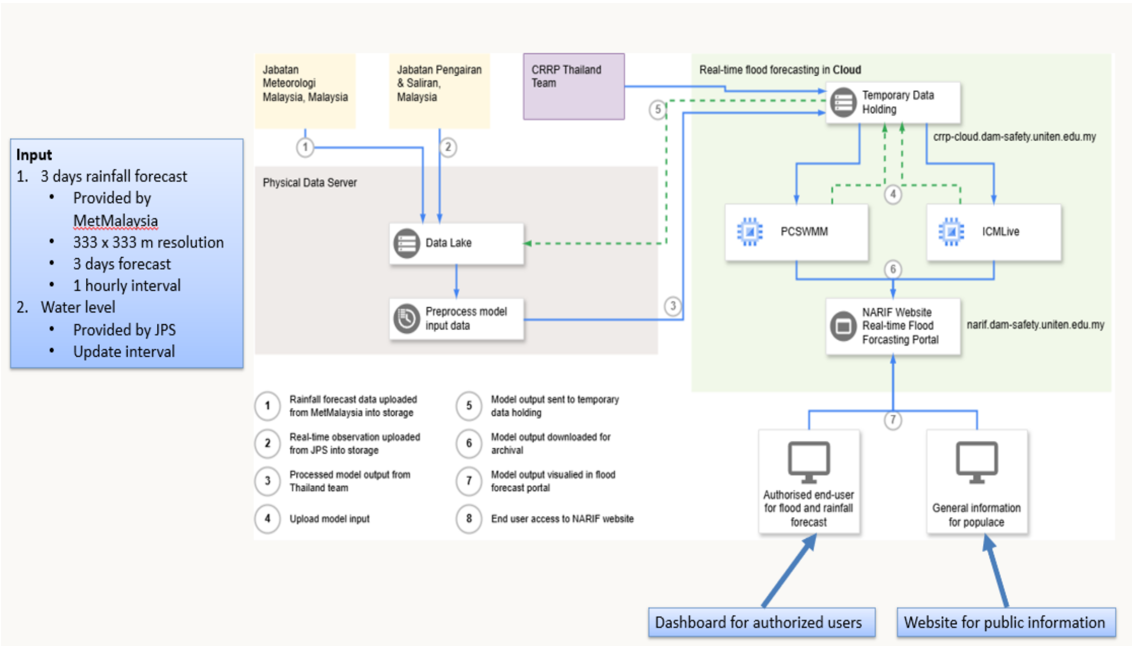

Figure 25 Overview of the architecture system.

Figure 26 present the NaRIF dashboard login interface and after login interface. For the login interface shows the water level & rainfall forecast, flood hazard maps and current water level. For Malaysia only Batu Dam is clickable.

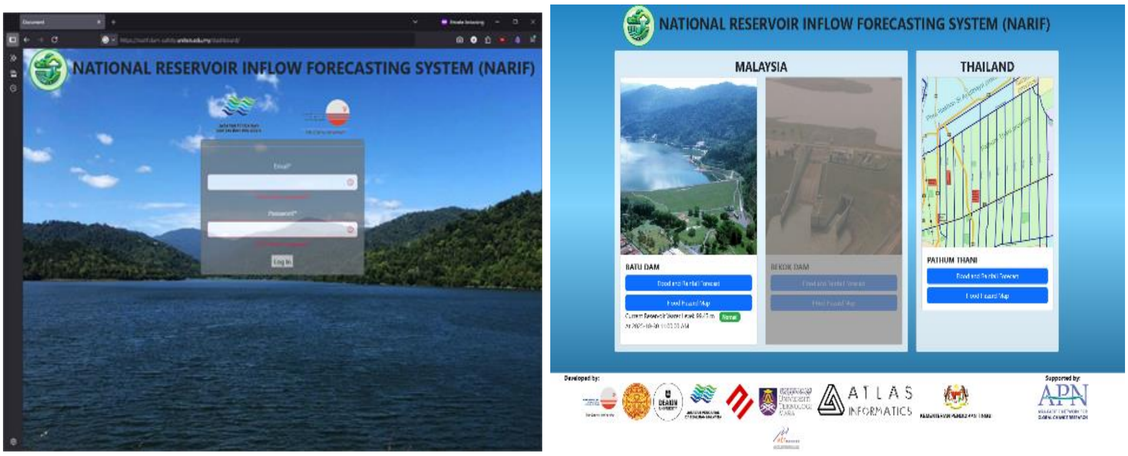

Figure 26 NaRIF authorized dashboard (left); NaRIF login interface (right).

Figure 27 shows the NaRIF dashboard interface for BATU DAM for Rainfall Forecast, with time slider at the bottom and legends of the rainfall intensity.

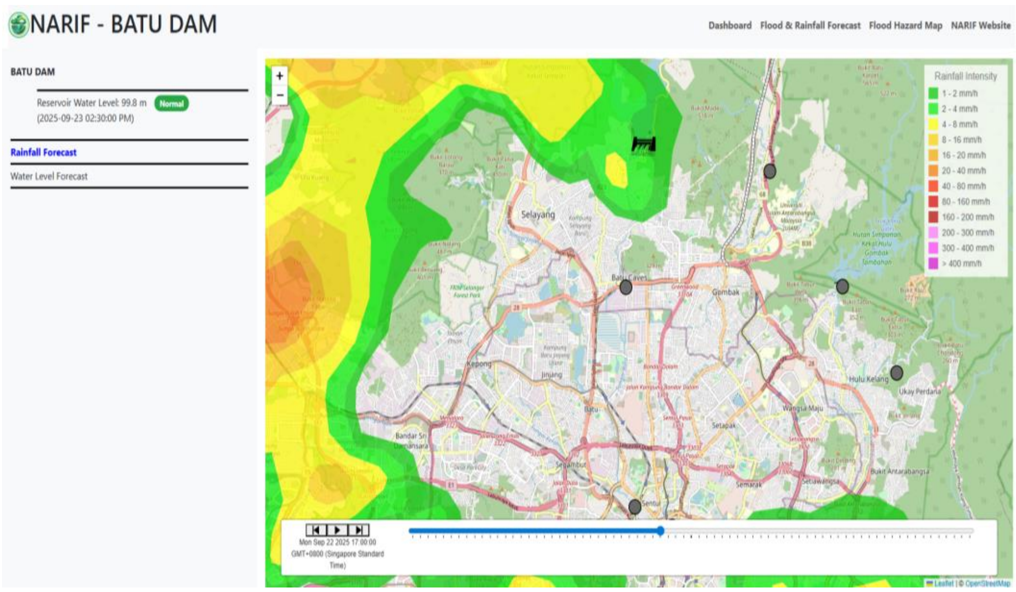

Figure 27 Dashboard interface for BATU DAM for rainfall forecast.

Figure 28 shows the dashboard interface for water level forecast. The triangle symbol represents water level for a specific river (left). Figure 28 illustrates the example result of water level forecast at one of the triangle symbols i.e Sg. Gombak di Batu 10 (right).

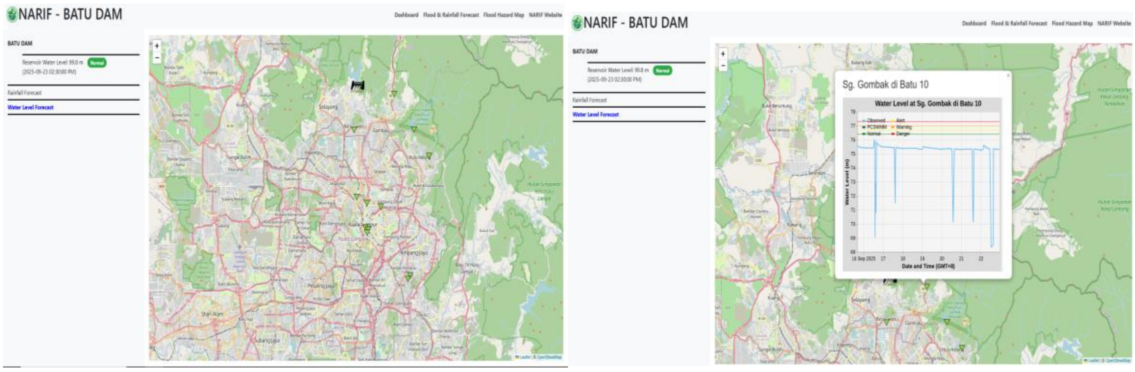

Figure 28 Dashboard interface for water level forecast (left); The results of water level forecast at Sg. Gombak Batu 10 (right)

Figure 29 illustrates the Mock NaRIF dashboard for Pathum Thai. The left figure is the main dashboard of Pathum Thai, while the right figure present the results of water level forecast at Pasak Chonlasit Dam.

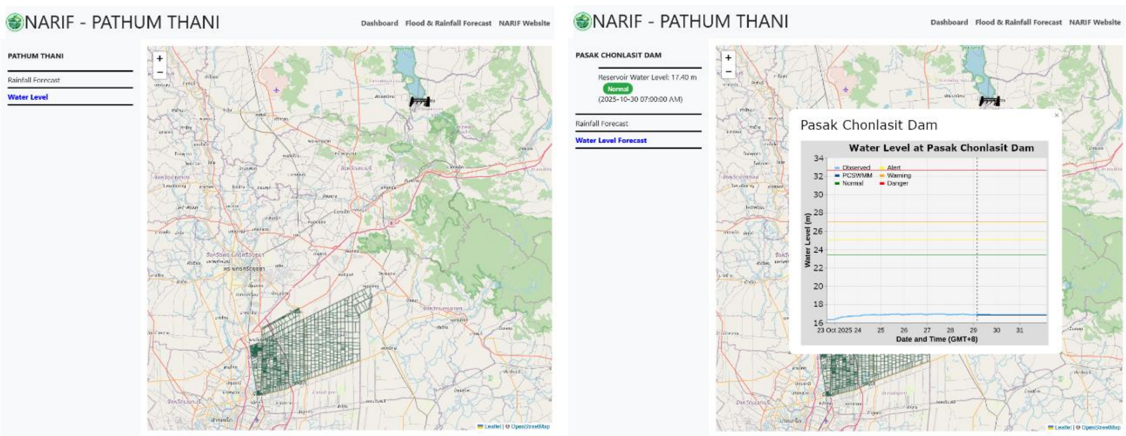

Figure 29 Dashboard interface for water level forecast (left); The results of water level forecast at Pasak Chonlasit Dam (right)

The dashboard flood hazard map interface is confidential and not available for the public. More information is available at https://www.narif-system.org. The user guidelines for this system are provided in Appendix 3.

4.0 The Guidelines for Dam Break Analysis and Flood Hazard Mapping

The Guidelines for Dam Break Analysis and Flood Hazard Mapping is a national reference designed to standardize how Malaysia assesses the risks of dam failures and develops flood hazard maps. Its purpose is to strengthen dam safety, improve public protection, and support disaster preparedness through consistent technical practices. The document combines international best practices with Malaysia's local hydrological, regulatory, and institutional contexts, ensuring both global credibility and national relevance. The guidelines are structured into seven main chapters:

- Chapter 1: Introduction – Provides the background and objectives of the guidelines, explains their importance for disaster risk reduction, identifies key users (such as DID, NADMA, consultants, dam operators), and benchmarks Malaysia's framework against international standards.
- Chapter 2: Flood Risk Associated with Dams – Explains the different types of dams, their classification systems, hazard ratings, and typical failure modes. It also introduces dam break scenarios, including failures under normal conditions (Clear Day Failure) and during extreme floods (PMF Break).
- Chapter 3: Data Preparation – Outlines the types of essential data needed for analysis, including topographical (LiDAR, DEMs), hydrological (rainfall, discharge, water levels), dam and river structure data, catchment characteristics, and building footprints to estimate population and infrastructure at risk.
- Chapter 4: Hydrological Analysis and Modeling – Details how to analyze rainfall and runoff, calculate Inflow Design Floods (IDF), estimate Probable Maximum Precipitation (PMP) and Probable Maximum Flood (PMF), and apply rainfall–runoff models. These provide the baseline inputs for dam break simulations.
- Chapter 5: Dam Break Modeling – Focuses on breach parameters (width, depth, formation time), prediction methods (empirical, semi-physical, physical), and hydrodynamic modeling. It explains the use of 1D, 2D, and 3D models and lists common software like HEC-RAS, MIKE, and PCSWMM.
- Chapter 6: Flood Hazard Map – Provides guidance on producing clear, accurate, and user-friendly maps. It covers coordinate systems, essential map elements, GIS integration, and design principles to ensure maps are easy to interpret and actionable for stakeholders.
- Chapter 7: Flood Hazard – Explains how hazard ratings are used to evaluate risks to people, buildings, and infrastructure. It also addresses evacuation routes, shelters, emergency planning zones, and community response strategies, linking technical outputs to disaster management needs.

Together, these chapters form a comprehensive workflow from data collection through modeling to decision-making. The guidelines serve not only engineers and consultants in carrying out technical studies, but also government agencies, urban planners, and emergency responders who rely on hazard maps for evacuation planning, land use decisions, and early warning systems.

By adopting these guidelines, Malaysia strengthens its ability to protect downstream communities, reduce disaster impacts, and build resilience in the face of climate change and extreme weather events. Figure 30 illustrates the cover front page of the guidelines.

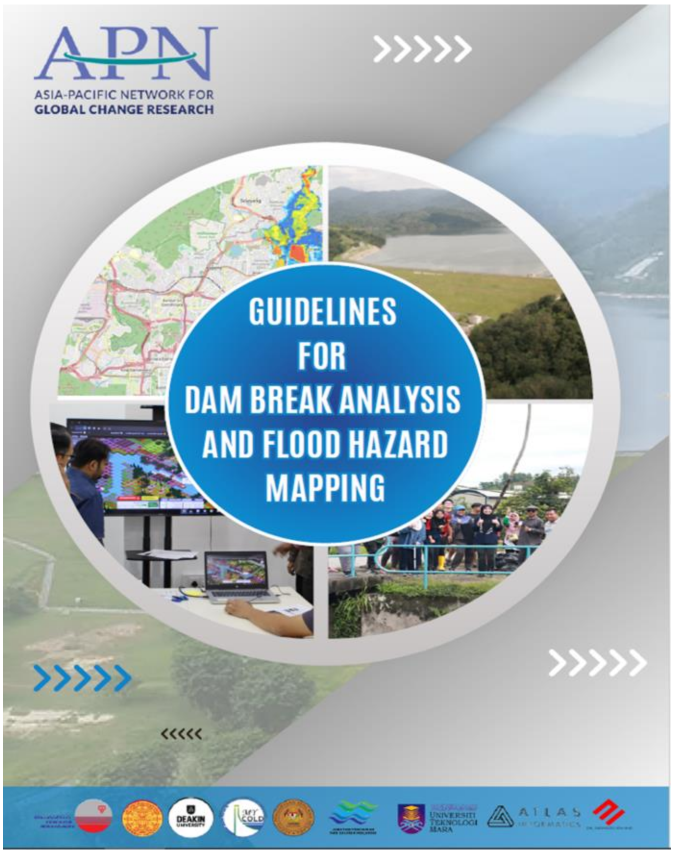

Figure 30 Cover front page of the guidelines

Its plan to be launch on 5 November 2025 at 3rd International Conference on Dam Safety Management and Engineering (ICDSME2025) in Kuching, Sarawak.

5.0 Stakeholders Engagement Workshops

The RT-FLOOD-CORE project has been structured around a series of carefully designed workshops held in Malaysia and Thailand, complemented by cross-country capacity-building initiatives with partners from Indonesia and Vietnam. These activities are aimed at strengthening regional flood resilience through multi-stakeholder collaboration, technical knowledge sharing, and practical engagement exercises.

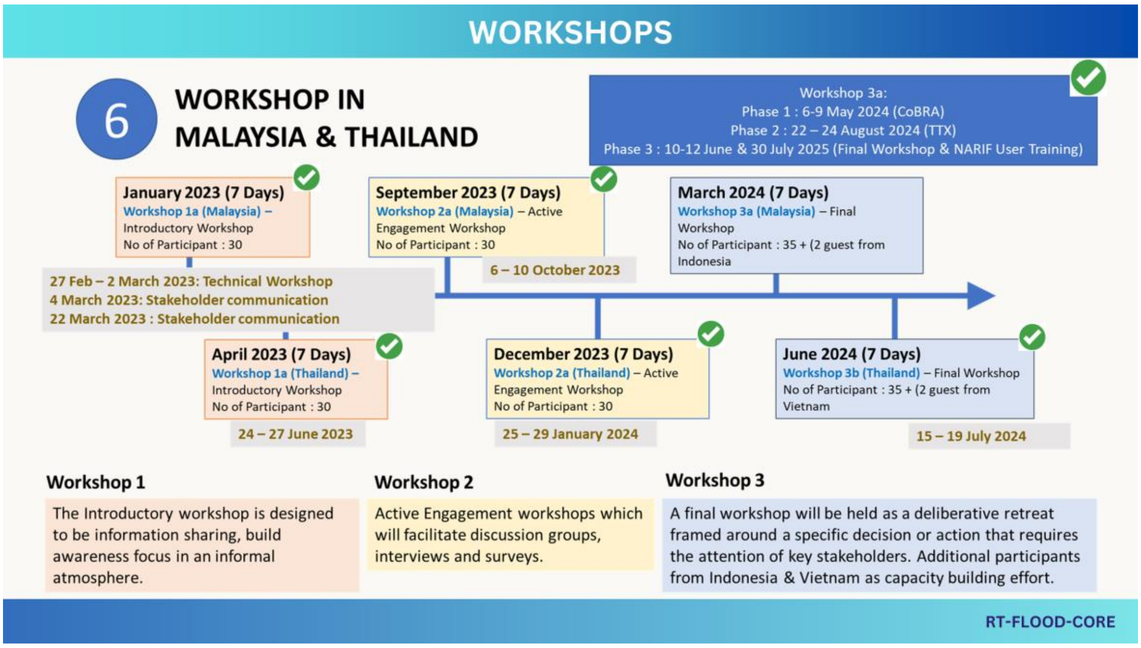

Figure 31 Workshop Overview

The program was divided into three main phases:

- **Workshop 1 (Introductory Workshops):** These sessions focused on information sharing and building a common understanding among stakeholders in an open and informal environment.
- **Workshop 2 (Active Engagement Workshops):** Conducted in both Malaysia and Thailand, these workshops facilitated interactive group discussions, interviews, and surveys to capture stakeholder perspectives and co-develop solutions.
- **Workshop 3 (Final Workshops):** Designed as deliberative retreats, the final workshops brought together key experts, decision-makers, and community representatives to reflect on outcomes, refine strategies, and strengthen regional cooperation. Additional participants from Indonesia and Vietnam are invited to broaden the knowledge exchange and build regional capacity.

Through these interconnected activities, the project ensures progressive knowledge transfer (from introductory learning to active engagement, and finally to collective decision-making) ultimately supporting a stronger, more resilient flood forecasting and disaster preparedness framework in Southeast Asia.

Workshop 1A: Public Safety Program Around the Dam with Sg. Kertas Community

Date: 4 March 2023
Location: Gombak, Batu Dam Area
Participants: 80 Volunteers

1. Community Involved

- **Sg. Kertas Community, Gombak**
- Engagement focused on ***Kesedaran Bencana Empangan*** **(Dam Disaster Awareness)** to strengthen local preparedness and resilience.

2. Program Objectives

- Increase awareness of dam-related safety and disaster preparedness.
- Provide knowledge on precautionary steps before, during, and after disasters.
- Encourage active community involvement in ensuring public safety around the dam.

3. Activities Conducted

- **Awareness Briefing:** Education on Batu Dam functions, risks, and community responsibilities.
- **Gotong-royong (Clean-up):** Volunteers cleaned riverbanks, roadside areas, and drains to reduce environmental and flood risks.
- **Preparedness Exercises:** Sharing of practical steps for disaster readiness and emergency response.
- **Community Engagement:** Group activities to strengthen collaboration and local responsibility.

4. Outcomes (CoBRA Framework)

- Enhanced community knowledge on dam risks, safety procedures, and early preparedness.
- Demonstrated positive actions: active participation in cleaning, listening to safety briefings, and teamwork.
- Mobilisation of 80 volunteers, with support from local authorities and organizers, created a strong resource network.
- Implemented concrete measures: clean-up activities, hazard awareness talks, and preparedness planning for future emergencies.


Figure 32 Workshop 1A Public Safety Program Around the Dam (PEKASE) with the Sg Kertas community

Workshop 1B: Flooding and Resilience Awareness and Practices in Rice Farming Communities and Water Resource Management Agencies in Pathum Thani Province, Thailand

1. **Community/Agencies Involved**

- A total of 15 rice farm head of households attended the workshop, with 8 being female and 7 being male. The average age the workshop attendees was 59, with a range of 47 to 72 (Figure 3.3).
- UNITEN study team.
- Royal Irrigation Department, Pathum Thani Office
- Nava Nakorn Industrial Estate

2. **Program Objectives**

- Introduce the UNITEN team to the Thailand study site and key stakeholders.
- Provide observation opportunity to the UNITEN team with application of the CoBRA resilience assessment tool.

3. **Activities Conducted:**

- 24 June 2023: Tour of the study area (Figure 3.4).
- 25 June 2023: CoBRA community workshop in Khlong Sam area (rice farmers).
- 26 June 2023: Team meeting to discuss real-time modeling; meeting with Royal Irrigation Department, Pathum Thani office and Nava Nakorn Industrial Estate management team (Figures 3.5).

4. **Outcomes**

- Understand rice farming community resilience to flood and concerns regarding other disrupting events through the CoBRA framework.
- Coordinate modeling efforts between Malaysia and Thailand with respect to model development approach and real-time model development.
- Meeting of Malaysia and Thailand water resources government agencies.
- Understand the impacts and resilience of a large industrial estate stakeholder to flood resilience.

Figure 33 WORKSHOP Workshop 1B COBRA Community Workshop in Khlong Sam Area

Figure 34 Workshop 1B Tour of Study Area (Khlongs 2-9; Nava Nakorn & Rattanakosin Village Rangsit

Figure 35 Workshop 1B Progress meeting with collaborator Thailand (lefttop) and Meeting with Royal Irrigation Department (RID), Thailand (center and rightbottom left) and Nava Nakorn Industrial Estate Management (bottom right)

Workshop 2A: Batu Dam Emergency Action Plan (EAP) & CoBRA Simulation

1. Community Involved

- 30 participants of Batu Dam Downstream Community.
- Engagement with UNITEN students and local residents.
- Supported by Batu Dam Operator, JPS, APM, NADMA, and government agencies.

2. Activities Conducted:

- 7 October 2023: Site visit to downstream Batu Dam area.
- 8 October 2023: CoBRA simulation with UNITEN students.
- Phase 1 (10 October 2023):
    - Batu Dam EAP Drill Exercise – staff training, testing communication channels, and system response.
- Phase 2 (2 December 2023):
    - CoBRA Simulation Workshop with Batu Dam community – role-play simulation, community preparedness drills, and evaluation of coordination among stakeholders.

3. Outcomes (CoBRA Framework)

- Improved knowledge of Batu Dam EAP procedures.
- Strengthened capacity of both staff and community through simulation and drills.
- Active participation of community and students in role-play exercises.
- Adoption of proactive disaster preparedness attitudes.
- Mobilisation of dam operator staff, government agencies (NADMA, JPS, APM), and community volunteers.
- Effective use of simulation tools and EAP resources.
- Conducted full-scale drill and simulation.
- Established clearer communication and coordination protocols among agencies and community stakeholders.

Figure 36 Workshop 2A Site visit to downstream Batu Dam area (left) and COBRA Simulation Workshop with UNITEN Students (right).

Figure 37 Workshop 2A (Phase 1) Batu Dam EAP Drill Exercise

Figure 38 Workshop 2A (Phase 2) CoBRA Workshop with Batu Dam Community

Workshop 2B Project Partner Coordination and CoBRA Workshop Delivery

1. Community / Agencies Involved:

- UNITEN, JPS, Thammasat University, Kasetsart University, moo baan residents.

2. Participants:

- The CoBRA workshops were administered to Thammasat University Landscape Architecture undergraduate students (Thailand Workshop 2) and separately to residents of gated communities (locally known as moo baan or muban) from the study area (Thailand Workshop 3).
- 17 students participated in Workshop 2, 25 January, 2024.
- 15 people participated in Workshop 3 held on 28 May 2024.

3. Activities:

- **Phase 1 (25-27 January 2024):**
  - Review CoBRA results with communities in Malaysia and Thailand to date.
  - Review PCSWMM model results to date (Figure 3.9).
  - Finalize plans for real-time model implementation.

  - CoBRA workshop with Thammasat Landscape Architecture and Urban Design students, including trialing the serious game, community flood disaster simulation (Figure 3.10).
- **Phase 2 (28 May 2024):**
  - CoBRA workshop with moo baan residents, including use of the serious game, community flood simulation (Figure 3.10).

4. Outcome:

- Model effort is on track. Some issues with model calibration were resolved.
- Path forward for real-time modeling is confirmed.
- CoBRA worshop successfully implemented with Thammasat and Moo Baan communities. The serious game delivered a richer, more motivating opportunity to discuss, explore, and evaluate elements of flood management to enhance community resilience, despite the diverse stakeholder groups. The large majority of participants clearly enjoyed the game and the lively interactions with others. The game reinforced and expanded elements of participant declarative knowledge both in addressing challenges and opportunities for flood management,

Figure 39 Workshop 2B Review on PCSWMM model

Figure 40 Workshop 2B, Thammasat University student CoBRA workshop

Workshop 3A

1. Community / Agencies Involved:

- Batu Dam & Bekok Dam personnel
- BRE, PLSK, JPS Daerah Gombak, NADMA
- Guest collaborators from Indonesia (INACOLD)

2. Participants:

- Dam operators, technical staff, government agencies, and academic representatives (exact count not listed, but multi-agency participation noted).

3. Activities:

- **Phase 1 (6–9 May 2024):**
  - Project progress discussions & CoBRA workshop findings.
  - Real-time model configuration & PCSWMM introduction to INACOLD.
  - CoBRA Workshop with Batu Dam & Bekok Dam personnel, including dam safety sharing session by INACOLD.
- **Phase 2 (21–23 August 2024):**
  - **EAP Table-Top Exercise (TTX)** for Batu Dam and Klang Gates Dam.
  - Risk assessment discussions, strengthening inter-agency cooperation, and decision-making simulations.
- **Phase 3 (10-12 June & 30 July 2025):**
  - **NaRIF user training session** (National Reservoir Inflow Forecasting system).

4. Outcome (Results – CoBRA):

- Enhanced technical knowledge in CoBRA, PCSWMM modeling, and dam safety practices.
- Strengthened collaboration among dam operators, agencies, and international partners.
- Engagement of multi-agency expertise (JPS, NADMA, INACOLD, dam operators).
- Conducted CoBRA simulations, TTX exercises, and prepared for NaRIF implementation to improve real-time dam safety decision-making.

Figure 41 Workshop 3A (Phase 1) Project progress discussions, CoBRA workshop preparations (left). Overview the real-time model configuration and Introduction Project and PCSWWM to Guest Collaborator from Indonesia (INACOLD) (center), CoBRA sessions with Batu & Bekok Dam personnel, BRE, PLSK, JPS Gombak, and NADMA, followed by a knowledge-sharing session on dam safety practices by INACOLD (right)

Figure 42 Workshop 3A (Phase 2) Table Top Exercise (TTX) Batu Dam and Klang Gates Dam Year 2024

Figure 43 Workshop 3A (Phase 3) Engagement session with stakeholders on project findings and training of NaRIF System

Workshop 3B

1. Community / Agencies Involved:

- UNITEN, Thammasat University, Kasetsart University
- Guest collaborators from Vietnam National University (International Campus), Asian Institute of Technology, and Nanyang Technological University, Singapore

- Electricity Generating Authority of Thailand (EGAT)

2. Participants:

- 15 faculty and graduate students from the participating universities noted above made presentations related to flooding, flood resilience, and water resources management.
- 4 staff from Electricity Generating Authority of Thailand (EGAT) Srinagarind Dam.

3. Activities:

- **Guest Collaborator Presentations (15 July 2024)**

Figure 44 Workshop presentations from Malaysia (top), Thailand (bottom left), and Vietnam (bottom right)

- **Visit to Benjakitti Forest Park (16 July 2024):** Located in downtown Bangkok, close to Lumphini Park and One Bangkok, and adjacent to the Queen Sirikit Convention Centre, the most recent phase of Benjakitti Park opened in 2022 and represents a 42 ha NbS green/blue space that formerly was a tobacco manufacturing facility. The park design includes preservation of existing trees and new plantings of a number of native tree species, such as Cork tree/ลำพู (Sonneratia caseolaris), Lumpan/ลำแพน (Sonneratia ovate), Cassod tree/ขี้เหล็ก (Senna siamea), Neem tree/สะเดา (Azadirachta indica), Bodhi or sacred figs/ โพธิ์ (Ficus religiosa), Banyan trees, Yangna/ ไทร (Dipterocarpus alatus), and Iron wood/ ตะเคียน (Hopea odorata). The constructed wetland systems contain a series of 4 connected cells that can help treat water diverted from the local khlong system, Khlong Phai Singto (up to 1,600 m^3 per day) and has a design capacity to store 128,000 cubic meters of stormwater runoff. The distinctive, Chinese-inspired ponds and mounds necklace design can be viewed from an extensive overhead boardwalk system that also provides an inviting exercise platform (Figure 45). The site visit will include a review of our IoT water quality platforms in wetland cell 1 and discussion of aesthetic, community well-being, and environmental value of the park.

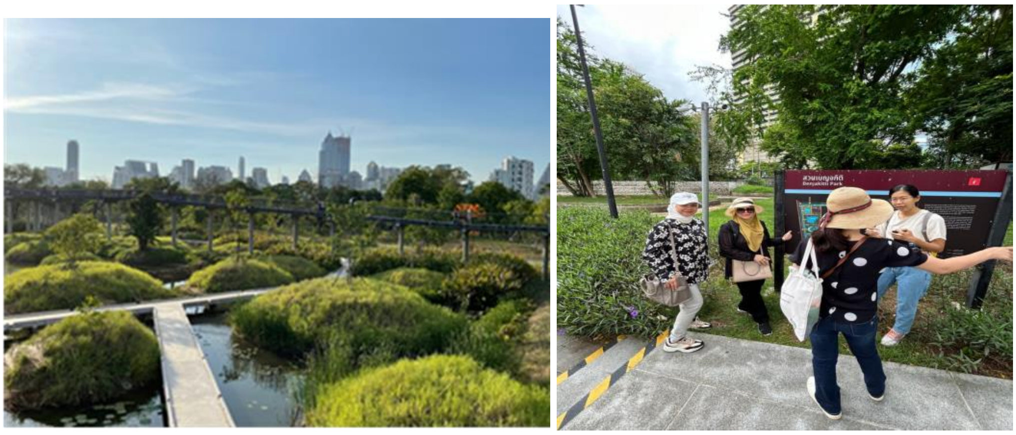

Figure 45 Benjakitti Forest Park wetlands and boardwalk system

- **Visit to EGAT's the Srinagarind Dam (17 July 2024):** Located in Kanchanaburi Province, approximately 3 hours west of Bangkok, the Srinagarind Dam is 140 metres tall and 610 metres long embankment dam. It contains a reservoir with a capacity of 17,745 million cubic metres. The dam's power station has an installed capacity of 720 MW. The facility has pumped-storage capability and that generates electricity during peak hours. In off-peak hours, the pump turbines return water from the lower reservoir back into the upper reservoir (Figure 46).

Figure 46 Visit to EGAT's Srinagarind Dam

4. Outcomes:

- At the Srinagarind Dam, Malaysia, and Thailand project participants were able to exchange ideas on dam safety practices, community resilience, and community engagement and outreach.
- Partners from Thailand, Malaysia, and Vietnam explored future collaborative possibilities. This resulted in the successful award for the proposal *NbCLARE (Nature-based Climate Adaptation and Resilience): A Framework to Enhance Design and Implementation of Nature-based Solutions through Integration of Evidence-Based Practices and Policies*, funded by the UK's Foreign, Commonwealth and Development Office (FCDO-UK) and the International Development Research Centre (IDRC-Canada), under their CLARE-ASEAN program at a level of 9.2 million THB ($285,500 USD) for 16 months.

6.0 Impacts

The development process followed the APN collaborative research-to-practice model, combining scientific modeling, stakeholder engagement, and participatory risk communication.

Impact Domain	Key Achievements
Operational	Delivered a fully functional NaRIF web portal (http://narif.dam-safety.uniten.edu.my), providing 7-day inflow forecasts and 1-day early flood warnings for Batu Dam.
Institutional Collaboration	Strengthened coordination among DID Malaysia, NADMA, METMalaysia, and dam owners through TTX exercises and information-sharing protocols.
Technological Advancement	Introduced a cloud-based automation workflow combining PCSWMM simulations with MetMalaysia radar forecasts and near real-time inflow predictions.
Capacity Building	Over 100 participants trained across Malaysia and Thailand, including government engineers, early-career researchers, and dam operators.
Policy Integration	NaRIF forms the technical basis for Malaysia's proposed Dam Break Flood Hazard Mapping (DBFHM) Guideline, co-endorsed by DG NADMA and DG JPS.
Recognition	Awarded Top-10 Innovation Award under Pertandingan Horizon Baharu Kumpulan Inovatif dan Kreatif (HBKIK) JPS Malaysia 2024, under the *Hang Nadim* team of BRE.
International Exposure	Presented "Community Resilience through CoBRA" at ICOLD 2024 COPAE Technical Community Meeting, and selected for the ICOLD 2025 COPAE Workshop – "Resilient Dams for Safe Communities" (17 May 2025, Chengdu, China).
Societal and Educational Impact	Beyond technical modeling, NaRIF is integrated with the Community-Based Resilience (CoBRA) framework. Through participatory mapping and UNDRR "Stop Disasters!" games, Batu Dam communities and UNITEN students learned to interpret early warnings, read hazard maps, and plan local preparedness actions. This combined technical and social

	approach supports APN's goal of turning research into real community action.
Expansion Potential	The NaRIF framework has high scalability potential: To be Expanded for implementation at other dams in Peninsular Malaysia, Thailand and Southeast Asia

Key Highlights

- Cross-disciplinary approach: Combined *hydrological–hydraulic modeling*, *cloud-based forecast systems*, and *participatory community engagement* across Malaysia and Thailand.
- Case studies: Batu Dam (Malaysia) and Pathum Thani (Thailand) served as demonstration sites for applying climate-change scenarios (RCP4.5 and 8.5) in real-time flood forecasting.
- Community involvement: Multi-level CoBRA workshops involving students, local residents, and dam safety stakeholders used *design-thinking* to identify resilience gaps and co-create action plans.
- Policy alignment: The framework supports Malaysia's Dam Break Flood Hazard Mapping (DBFHM) Guideline and NaRIF early-warning system, both developed as CRRP outcomes.

Knowledge Transfer Outcomes

Impact Area	Key Achievements
Operational Integration	CoBRA adapted as a qualitative module within MyIBF for assessing vulnerability and preparedness of targeted districts.
Capacity Building	Introduced CoBRA methodology to PRABN officers and consultants as a participatory engagement tool supporting IBF calibration.
Policy Uptake	Enhanced understanding among national and state-level agencies of how community resilience factors can inform impact-based thresholds.
Scientific Contribution	Extended CRRP methodologies into Malaysia's national forecasting framework, creating a continuous link between research innovation and operational application.

The incorporation of CoBRA into the MyIBF Project demonstrates the successful translation of CRRP research into operational practice. It operationalizes resilience assessment as part of Malaysia's Impact-Based Forecasting (IBF) workflow, ensuring that flood forecasts are contextualized by community capacity and real-world impact. This knowledge transfer initiative reinforces APN's objectives of building institutional capability, mainstreaming transdisciplinary science, and promoting resilience-informed early warning systems across Southeast Asia.

CoBRA Integration into the Transnational Project

As part of the CRRP Project's knowledge-sharing efforts, the Community-Based Resilience Analysis (CoBRA) method was successfully adapted for a new initiative: the Transnational Project on Erosion and Sediment Control for Highland Agriculture (ESCP-CH). Led by UNITEN's Dam Safety & Sustainability Intelligence (DSSI) group and partners in Malaysia and Thailand, this marked a major step in applying CRRP tools beyond flood forecasting—now helping highland farming communities build resilience.

Objective and Rationale

The project aimed to apply CRRP's participatory resilience assessment to climate-sensitive farming and land management. CoBRA was embedded into ESCP training to help farmers in Cameron Highlands and Thailand's upper catchments:

- Identify risks like erosion, landslides, and drought
- Assess their capacity to adapt
- Co-design Best Management Practices (BMPs) for sustainable farming and slope stability.

Implementation Framework

Using CoBRA's six-question framework (from Batu Dam and Pathum Thani), the project focused on:

1. Local hazards affecting farms
2. Traits of resilient communities (e.g., water access, soil knowledge, financial readiness)
3. Changes in resilience before and after ESCP, rated on a 0–10 scale
4. BMP effectiveness through group discussions and puzzle-based learning

Interactive tools like map pinning, bean-voting, and games helped engage participants and collect data.

Capacity Building and Knowledge Sharing

Workshops and focus groups brought together farmers, officials, and technical experts from both countries to assess land use impacts. This led to:

- Using CoBRA as a tool for agricultural resilience
- Sharing methods between flood and land management sectors
- Repeating successful CRRP formats (e.g., scoring tables, stakeholder maps)
- Better understanding of how upstream erosion affects downstream flooding

Final assessments showed improved adaptive capacity after ESCP interventions.

Outcomes and Regional Impact

Impact Area	Key Achievements
Knowledge Transfer	CoBRA framework from CRRP adapted for transnational ESCP implementation, linking dam safety resilience with agricultural watershed management.
Capacity Building	Trained local facilitators and farmers to conduct participatory resilience assessments and interpret results within their ESCP practices.
Cross-Sectoral Application	Demonstrated CoBRA's versatility beyond flood forecasting—now applicable to slope stability, soil conservation, and land-use resilience.
Transnational Collaboration	Strengthened Malaysia–Thailand partnerships under CRRP's extended network through joint workshops, farmer engagement, and technical exchange.
Monitoring and Evaluation	Established baseline and post-intervention resilience scores (0–10 scale) as part of ESCP performance monitoring.

The integration of CoBRA into the Transnational ESCP Project exemplifies the knowledge transfer pathway envisioned under CRRP—transforming a flood-resilience assessment framework into a broader tool for climate-resilient agriculture and catchment management. By extending CoBRA's participatory principles across national boundaries and disciplinary domains, the project strengthened regional collaboration, local empowerment, and adaptive learning, reinforcing APN's mission to operationalize science for resilience and sustainable development across Southeast Asia.

5. Publications

Paper Title: Conceptual Frameworks of Real Time Flood Modelling for Improved Community Resilience
Authors: Muhammad Fayed Burhanuddin, Hidayah Basri, Lariyah Mohd Sidek, Siti Aisyah Zulkarnain, Lloyd Chua, Kim Neil Irvine, Wardah Tahir, Mohd Hazri Moh Khambali, Wan Hazdy Azad Wan Abdul Majid, Ephrance Abu Ujum
Conference: International Conference on Dam Safety Management and Engineering (ICDSME2023), 16 – 17 March 2023 in Kuala Lumpur, Malaysia
Reference: Burhanuddin, M. F., Basri, H., Mohd Sidek, L., & Zulkhurnain, S. A. (2024). Conceptual frameworks of real-time flood modelling for improved community resilience. In *Proceedings of the 2nd International Conference on Dam Safety Management and Engineering* (pp. 827–836). Springer.
DOI: https://doi.org/10.1007/978-981-99-3708-0_57

Paper Title: Overtopping risk of high-hazard embankment dam under climate change condition

Authors: Wan Noorul Hafilah Wan Ariffin, Lariyah Mohd Sidek, Hidayah Basri, Noorhayati Idros, M. Torres Adrian, Noor Hisham Abd Ghani, Hazri Mohd Khambali, Siti Mariam Allias Omar, Muhammad Izzat Azhar Khebir, Ali Najah Ahmed

Reference: Hafilah, W. N., Ariffin, W., Mohd Sidek, L., Basri, H., Idros, N., Torres Adrian, M., Hisham, N., Ghani, A., Khambali, H. M., Mariam, S., Omar, A., Izzat, M., Khebir, A., & Ahmedid, A. N. (2025). Overtopping risk of high-hazard embankment dam under climate change condition. *PLOS ONE, 20*(2), e0311181.

DOI: https://doi.org/10.1371/journal.pone.0311181

Proposed Paper Title: The National Reservoir Inflow Forecasting System (NaRIF) in Malaysia: Real-Time Flood Forecasting System

Authors: Hidayah Basri, Lariyah Mohd Sidek, Muhammad Yunus Ahmad Mazuki, Wan Hazdy Azad Wan Abdul Majid, Mohd Hazri Mohd Khambali, Mohamad Amiruddin Zulkefli, Nur Alyaa Hazrin, Siti Syairah Atiqah Azhar, Prof. Kim Irvine, Prof. Lloyd Chua

Conferences: International Conference on Dam Safety Management and Engineering (ICDSME2025), 4 – 7 November 2025 in Kuching, Sarawak

References: Basri, H., Sidek, L. M., Ahmad Mazuki, M. Y., Wan Abdul Majid, W. H. A., Mohd Khambali, M. H., Zulkefli, M. A., Hazrin, N. A., Azhar, S. S. A., Irvine, K., & Chua, L. (2025). In *Proceedings of the 3rd International Conference on Dam Safety Management and Engineering.*

Paper Title: Serious gaming as an educational support approach to examine flood management with diverse stakeholder groups.

Authors: Irvine, K.N., F. Likitswat, A. Sahavacharin, L. Teang, Hidayah Basri, Lariyah Mohd Sidek, A. Hazrin, D. Chitwatkulsiri and L.H.C. Chua.

Reference: Rvine, K. N., Likitswat, F., Sahavacharin, A., Teang, L., Basri, H., Mohd Sidek, L., Hazrin, A., Chitwatkulsiri, D., & Chua, L. H. C. (in press). Serious gaming as an educational support approach to examine flood management with diverse stakeholder groups. *International Research in Geographical and Environmental Education*.

Paper Title: Assessing Urban Resilience Through Physically Based Hydrodynamic Modeling Under Future Development and Climate Scenarios: A Case Study of Northern Rangsit Area, Thailand

Authors: Detchphol Chitwatkulsiri, Kim Neil Irvine, Lloyd Hock Chye Chua, Lihoun Teang, Ratchaphon Charoenpanuchart, Fa Likitswat and Alisa Sahavacharin

Reference: Chitwatkulsiri, D.; Irvine, K.N.; Chua, L.H.C.; Teang, L.; Charoenpanuchart, R.; Likitswat, F.; Sahavacharin, A. Assessing Urban Resilience Through Physically Based Hydrodynamic Modeling Under Future Development and Climate Scenarios: A Case Study of Northern Rangsit Area, Thailand. Climate 2025, 13, 200.

Link: https://doi.org/10.3390/cli13100200

Paper Title: Community-based resilience analysis (CoBRA) to hazard disruption: Case study of a peri-urban agricultural community in Thailand

Authors: Sahavacharin, A., Likitswat, F., Irvine, K. N., & Teang, L.
Reference: Sahavacharin, A., Likitswat, F., Irvine, K. N., & Teang, L. (2024). Community-based resilience analysis (CoBRA) to hazard disruption: Case study of a peri-urban agricultural community in Thailand. Land, 13(9), 1363. https://doi.org/10.3390/land13091363

Guideline Title: Guidelines for Dam Break Analysis and Flood Hazard Mapping.
Collaborators: Universiti Tenaga Nasional (UNITEN), the Department of Irrigation and Drainage Malaysia (JPS), Atlas Informatics Sdn. Bhd., Universiti Teknologi MARA (UiTM), Deakin University (Australia), Thammasat University (Thailand), ZHL Engineers Sdn. Bhd., and the Malaysian National Committee on Large Dams (MYCOLD).

6. Media reports, videos and other digital content

Website: http://narif.dam-safety.uniten.edu.my

7. Pull quotes

Datin Prof. Ir. Dr. Lariyah Mohd Sidek Co-President Malaysian National Committee on Large Dams & Professor, Institute of Energy Infrastructure, Universiti Tenaga Nasional	Dam safety is not only about sound engineering — it is about people. Strengthening technical expertise must go hand-in-hand with empowering communities to understand, prepare, and act. When both sides come together, we create resilience that protects lives and sustains trust in our dams
Prof. Kim Neil Irvine Associate Professor, Faculty of Architecture and Planning, Thammasat University	This project represents a novel multidisciplinary and transdisciplinary approach in linking policy, engineering, and community engagement to enhance flood resilience under a changing climate and urbanization pressures. Early career and mature engineers and landscape architects teamed effectively to produce lasting collaborations that already have been leveraged into new projects.
Prof. Lloyd Chua Associate Professor, School of Engineering, Deakin University	The project provides valuable interaction between experts from engineering, social science and industry; this coming together of experts has been the highlight and I believe an important step in solving many of the problems we are facing today.
Mohd Hazri Mohd Khambali Deputy Director Design & Dam Division DID Malaysia	This initiative reflects the true spirit of collaboration — bringing together dam owners, government agencies, academia, and NGOs to advance a shared vision of dam

	safety. By integrating science, policy, and practice, we are building a stronger and safer future for all.
Ir. Dr. Hidayah Basri Project Leader & Senior Lecturer Institute of Energy Infrastructure, Universiti Tenaga Nasional	"Through real-time flood modeling, regional collaboration, and grassroots engagement, this project delivers scalable, data-driven solutions for disaster resilience. By investing in local capacity and cross-border partnerships, we're creating lasting impact that empowers communities and institutions to face future flood risks with confidence."

8. Acknowledgments

This study was funded by Asia-Pacific Network (APN) via Collaborative Regional Research Programme (Project Code: CRRP2022-07MY-Basri) and supported by the Ministry of Higher Education (MoHE), Malaysia, through the Trans Disciplinary Research Grant Scheme (Project Code of TRGS/1/2020/UNITEN/01/1/1). The authors would like to express their sincere appreciation to Resilient Water-Energy & Dam Intelligence (REDI-Lab), Institute of Energy Infrastructure (IEI), Universiti Tenaga Nasional (UNITEN), Department of Irrigation and Drainage Malaysia (DID) especially to Design and Dam Division, Pejabat Lembangan Sg. Klang (PLSK), DID Gombak, Malaysian National Committee on Large Dam (MYCOLD), ZHL Engineers Sdn. Bhd., National Disaster Management Agency (NADMA), ATLAS Informatics, Universiti Teknologi MARA (UiTM), and Pengurusan Air Selangor Sdn Bhd (Air Selangor).

9. Appendices

Appendix 1: Guidelines Dam Break Flood Hazard Maps

Appendix 2: Paper publications

Appendix 3: User Guidelines National Reservoir Inflow Forecast (NaRIF) System: Functional Overview

10. References

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