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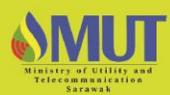
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ABSTRACT BOOK

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A Holistic Approach to Assessing Feasibility of Pumped Hydro Energy Storage and Conventional Hydropower; Prioritising Maximum Long-Term Value

Amanda Ashworth

Abstract

The global drive for decarbonisation and rapid growth of wind and solar energy has intensified the need for energy storage and firming. Pumped hydro energy storage (PHES) is a re-emerging solution, currently capable of longer duration storage than batteries. To determine whether PHES is the optimal solution, a truly holistic PHES feasibility study must carefully consider context, strategy, power market conditions, environmental and social impacts, and long-term value. PHES is not impact-free, nor inherently more sustainable than conventional hydropower. Comprehensive site screening including multicriteria analysis, as developed by Entura and applied in Australia and India, can guide appropriate site selection by identifying lower impact opportunities, including repurposing degraded landscapes such as mine pits. Potential alternatives should also be considered, including the relative value of conventional hydropower, with its significant water storage. Life-extension of existing hydropower schemes, redevelopment for greater capacity or operational adjustments for flexibility, may increase the value achieved from the historical impacts incurred. Hydropower and dams professionals should strive to achieve the greatest long-term social, environmental and economic value from a dam or power scheme, which can be maximised by enabling multiple purposes, such as water storage, flood protection, climate resilience, energy generation, and support for agriculture and the environment – alleviating pressure on the water-energy-food nexus. To maximise long-term value, dams must be expertly designed, constructed, monitored and maintained. Good stewardship of dam assets also requires ongoing knowledge transfer and capacity building in dam safety management for maximum benefit to future generations.

Keywords: Renewable Energy, Hydropower, Pumped Hydropower, Energy Storage, Sustainability, Refurbishment, Multi-Purpose Water Storage, Dam Safety Management.

Floating Photovoltaic Applications in Hydropower Dams (Hydro-Solar)

Lloyd Hock Chye Chua, Kim Neil Irvine, Detchphol Chitwatkul Siri

Abstract

Floating photovoltaic (FPV) applications have been increasing rapidly for the past decade. Based on a 2023 review carried out by the Solar Energy Research Institute of Singapore (SERIS), 1,086 FPV systems have been installed, with a total energy production of 6 GWp. This is a factor of 4.6 times increase over the previous Floating Solar Market Report conducted in 2019 by the World Bank and SERIS. Wikipedia reports a 2023 Bloomberg article which estimates a potential technical capacity of 4,000 GW, if only 10% of sites that are deemed suitable for FPV implementation are utilized. The role FPV in hydropower dams (hydro-solar) has also been discussed where it was generally recognized that advantages of such a hybrid system include increased clean energy production, co-utilization of energy infrastructure, reduced evaporation losses, increased panel efficiency due to lower operating temperatures, improved water quality due to limitations on algal growth, provision of energy for pumped storage operations. The placement of FPVs on a lake surface necessitates proper environmental assessments as this can affect ecological and hydrodynamic behaviour, although the requirements for a hydropower application may be less stringent compared to more sensitive waterbodies such as drinking water reservoirs. Although there has been a sharp increase in FPV applications, the focus has largely been centered on power generation with less attention on environmental assessment. Furthermore, reservoir response in temperate and tropical regions are different, necessitating assessments to be conducted in target climate regions. Two case studies involving tropical reservoirs are discussed. The first was conducted by the first and second authors and showed that FPV panel temperatures and algal concentrations in the waterbody shielded by the panels decreased, potentially giving rise to higher panel efficiency and improved water quality. The second study is a proposed hydro-solar application for the Sirindhorn Hydropower Reservoir, which also serves as a water supply for irrigation and supports tourism activities. The reservoir is in north-east Thailand and has a surface area of approximately 290km². The study applies a numerical model to quantify the impacts of FPV placement in the reservoir under multiple design and operational scenarios, with calibration and validation based on in-situ monitoring. Integration with Internet of Things (IoT) sensor networks further enhances spatiotemporal resolution of water quality observations. The results will provide a quantitative assessment to optimize hydro-solar systems.

Keywords: Floating Photovoltaic; Environmental Assessment; Pumped Storage; Energy Generation.

Application of Geosynthetics in Dam Engineering

Vivek P. Kapadia

Abstract

Food security is of utmost importance for the world; and, therefore, the dams, too. Agriculture is the backbone of economy for several countries of the world and hence the irrigation is very crucial for them. In order to make proper water resource management including flood control and hydropower generations, many countries have built large dams long ago. As a tolerant infrastructure, a dam might withstand several challenges without any sign of distress manifested; but would certainly require repairs over a period. As the life of the dam is long, maybe at the time of repairs, the materials that were in practice at the point of time it was built are not much in vogue and so could be the design and construction practices. With the pace of time, different but better materials and design practices have evolved and hence the full utilization of the design life of a dam has become a promising phenomenon. In some cases, the advancements have made it feasible to even enhance the storage potential of a dam. Dam repairs is a challenging job because of several aspects. It requires interdisciplinary knowledgebase and skill sets for making diagnosis and designing solutions. In recent times, efforts are made to resort to non-invasive restoration techniques. Many types of Geosynthetics in the present times have potential to provide innovative solution techniques for addressing several issues related to the aging dams. Many case studies across the world have proven utilitarian value of such advanced materials. This talk would include some innovative solutions with actual case studies so as to shed light on out-of-the-box approaches towards dam repairs.

Keywords: Dam, Design life, Food security, Geosynthetics, Repair.

Piano Key Weirs; Advancements and Future Research

Zulfaquer Ahmad

Abstract

An overflow section in the form of a spillway is provided in the dam to pass surplus flow downstream. An efficient spillway passes high discharge at relatively low head above the crest. Generally, spillways of linear crest are provided which are having limited discharging capacity. However, a non-linear spillway/weir passes higher discharge at low head. Piano Key (PK) weir is an improved version of labyrinth non-linear weir, which are generally installed on low head dams to enhance the discharging capacity. PK weirs are preferred over the other spillways when there is a limited length available for the construction of the spillway and high discharge is to be passed at low head to avoid flood inundation upstream. With an increase in PMF of the dam under climate change, it has become necessary to adopt a high discharging capacity weir like PK weir. PKW is a novel weir having various configurations based on the inlet and outlet key's shape. They are classified into four types based on the upstream and downstream overhangs. In the present era, PKWs are built widely across the globe. In India, two PKWs are constructed in recent period. The biggest PKWs built at Van Phong barrage and Dakrong dam are having design discharge of 8700 m³/s and 6550 m³/s respectively. Several investigations have been conducted to study the discharge characteristics, design guidelines and flow characteristics on different types of PKWs. Energy dissipation, scour downstream of the weir, and aeration of flow over the PK weir have been extensively investigated. Modification in the shape of the PK weirs, such as shape of the inlet and outlet keys, parapet wall, etc. have been carried out to enhance the discharging capacity of the PK weir. Recent study reveals that it can also be used as side weir to enhance the diverted discharge.

Keywords: Spillway, Labyrinth weir, Piano Key Weir, Discharge, Aeration, Scour.

Sustainable Sediment Management and Preservation of Ringlet Lake, Cameron Highlands: A Collaborative Corporate Social Responsibility (CSR) Initiative

Syahida Farhan Azha, Lariyah Mohd Sidek, Hidayah Basri, Nor Syafiqah Kamal, Sa'aidan Abu Hasan, Mohd Saifuddin Zakria, Wan Haryati Wan Abdullah

Abstract

This manuscript introduces a comprehensive Corporate Social Responsibility (CSR) project aimed at addressing the urgent issue of sedimentation in Ringlet Lake, a picturesque location nestled in the heart of Cameron Highlands, Malaysia. The project's multifaceted objectives encompass a range of initiatives, including extensive public awareness campaigns, the implementation of erosion and sediment control measures guided by the Erosion and Sediment Control Plan (ESCP), fostering behavioral change, educational outreach, and active community engagement. By adopting this holistic approach, the project seeks to cultivate a profound sense of environmental responsibility and foster a spirit of community ownership. Central to our efforts is the ESCP program, which is instrumental in mitigating soil erosion and sedimentation, thus safeguarding the ecological balance of Ringlet Lake. This program serves as a cornerstone, providing practical guidance to farmers and stakeholders on sustainable land management practices in hilly areas. Moreover, the project has a vital role in enhancing the safety and resilience of Sultan Abu Bakar Dam, given Ringlet Lake's pivotal role as its primary reservoir. Through collaborative endeavors, we are dedicated to addressing sedimentation challenges, preserving the pristine ecosystem surrounding Ringlet Lake, and fortifying the dam's infrastructure. This CSR initiative exemplifies our commitment to environmental sustainability and community well-being, underscoring the importance of collective action in preserving this invaluable natural resource.

Keywords: Ringlet Lake, Sedimentation, Communities, Hydropower Dam, Cameron Highlands, TNB, CSR Project.

Water Availability and Water Yield Analysis for Kenyir Dam Catchment

Mohd Rashid Radzi, Nor Aima Syazwani, Meldi Suhatri, Muhammad Khairi A.Wahab

Abstract

The Kenyir Reservoir, a major man-made lake covering 421.26 km² and holding up to 7,400 million cubic meters (MCM) of live storage at Full Supply Level (FSL), serves as a critical water source for power generation at the Sultan Mahmud Hydroelectric Power Station operated, which is run under Tenaga Nasional Berhad (TNB). Given the large reservoir volume, extensive catchment area, and increasing concerns regarding downstream safety and operational efficiency, accurate long-term hydrological forecasting is essential for effective reservoir management, particularly in light of the proposed 40-year extension of the plant's operational lifespan. This study presents a comprehensive hydrological modeling analysis for simulating future inflows into the Kenyir Dam catchment under climate change scenarios. Future climate data, including rainfall and temperature, were derived from the statistically downscaled outputs of the Coupled Model Intercomparison Project Phase 5 (CMIP5), specifically using the Canadian Earth System Model (CanESM2). The projections are based on the Special Report on Emissions Scenarios (SRES) developed by the Intergovernmental Panel on Climate Change (IPCC), with climate data downscaled for the period 2025–2085. Analysis of the projected climate data, supported by findings from national sources such as NAHRIM, indicates a slight decline in total annual rainfall due to global warming effects. The mean annual rainfall is projected to be 3,397 mm under RCP 4.5 and 3,369 mm under RCP 8.5—both are approximately 4% lower than the baseline historical value of 3,520 mm. Lower magnitude of rainfall coupling with the higher PE for future climate change scenario has caused the lower inflow under the future climate change.

Keywords: Hydrological Modeling, Climate Change, Rainfall-Runoff Simulation.

Performance Evaluation of Dam Monitoring Systems Following the Landslide Event: A Case Study of Kenyir Dam

Ismail Faruq Serip Mohamad, Hafizul Fahmi Roslan, Darul Hisham Saman, Mohd Hafiz Rosni

Abstract

Following the significant landslide event on 27 February 2022 at Kenyir Dam, a performance evaluation of the dam's monitoring systems was carried out. Several instruments were damaged by the landslide therefore, the preliminary analysis was based only on data from instruments that remained operable. This study presents the preliminary analysis of seepage, pore pressure and groundwater levels data to evaluate the dam's performance after the landslide event. Despite the extreme rainfall and slope instability around the dam, the data showed that the dam structure remained stable and performed within normal operational parameters. This paper integrates data from operable instruments, field inspections, and findings from a special site assessment to evaluate seepage, pore pressures, and structural impacts. From 130 dam monitoring instrument previously existing, only 90 instruments remained working after the landslide event. Using this remaining instruments, the hydraulic pore pressure and seepage data were gathered, and analysis was done to evaluate the dam integrity and health condition. The findings were discussed in this paper where the dam was found to be structurally stable, through erosion, spillway damage, while abutment integrity requires immediate attention. Mitigation strategies, instrumentation restoration, and monitoring enhancements are discussed to improve future dam resilience. It was recommended that damaged instruments be repaired quickly and that monitoring be improved, especially in weak areas.

Keywords: Dam Monitoring, Dam Safety, Dam Instrumentations, Landslide.

Strengthening Disaster Risk Governance: Insights from Malaysia's Approach to Dam Safety Management

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Abstract

This paper explores the frameworks that govern disaster risk reduction (DRR) in Malaysia, specifically focusing on institutional, legislative, and policy frameworks governing DRR, with a specific focus on dam-related disasters. Although Malaysia is relatively protected from seismic hazards, it is still highly vulnerable to hydrological events, such as floods and landslides, especially in areas near dams. The paper traces the evolution of national disaster policies, including Directive MKN 20, and discusses the role of the National Disaster Management Agency (NADMA). It also evaluates the effectiveness of community-based preparedness strategies. A case study of Dam vicinity in Cameron Highlands has been selected for a Focus Group Discussion (FGD) involving various stakeholders was held to assess local knowledge, early warning systems, emergency response plans, and safe evacuation locations. The findings emphasize the necessity of coordinated efforts between agencies and communities for improvements in dam DRR Program, and the importance of consistent emergency drills. This case study highlights significant progress in the implementation of DRR and identifies key areas for enhancing policy integration, community engagement, and dam disaster governance.

Keywords: Disaster Management, Disaster Risk Reduction (DRR), Dam Safety, Early Warning Systems (EWS), Community Preparedness.

Tunnel Integrity Inspection Under Site Constraints and Complex Inspection Challenges: A Case Study of Menglang Tunnel, Cameron Highlands-Batang Padang Hydroelectric Scheme

Mohd Hafiz Rosni, Hafizul Fahmi Roslan, Ismail Faruq Serip Mohamad, Darul Hisham Saman, Muhammad Mustaqim Omar

Abstract

Tunnel inspections in hydropower schemes are essential for ensuring long-term asset integrity, yet in tropical mountainous regions they are often constrained by adverse weather, limited access, and high-risk environments. Despite their importance, systematic studies on inspection under such conditions remain scarce, with most literature focusing only on structural defects. This paper addresses this gap by presenting a risk-based case study of the Menglang Tunnel, a 14.2 km low-pressure conveyance tunnel in the Cameron Highlands–Batang Padang Hydroelectric Scheme. The inspection, conducted during a planned outage in September 2023, encountered multiple challenges, including hazardous abseiling, landslides, wildlife encounters, heavy rainfall, and communication blackouts. A Hazard Identification, Risk Assessment and Risk Control (HIRARC) framework was applied to systematically evaluate these risks and implement mitigation measures. Two major structural defects were identified, leading to immediate rehabilitation actions. The study contributes by framing tunnel inspection not only as a technical activity but as an integrated risk management process, advancing current practice in dam and tunnel safety. Findings provide practical lessons for inspection planning in tropical, remote environments and extend knowledge on inspection risk management frameworks for hydropower infrastructure.

Keywords: Hydropower Infrastructure, Inspection Planning, Risk Management Framework.

Implementation Of the Early Warning System Web-Based Application for The Cirata Dam Break Flood Emergency Connected to The Android System

Bambang Wahyu Jatmiko, Rendy Pratna, Haris Pradipta Putra

Abstract

Cirata Hydroelectric Power Plant (HEPP) is a HEPP in Indonesia that produces an average of 1,428 Giga Watts hour (GWh) of electrical energy per year, which contributes electricity through the Java-Madura-Bali interconnection. The Cirata HEPP has a Cirata Dam as main construction building. Cirata Dam is a large dam with Concrete Faced Rockfill Dam (CFRD) type. In the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 27/PRT/M/2015 Concerning Dams, in article 2 it is stated that one of the 3 (three) pillars of the dam safety concept is emergency preparedness. Using our android smartphone that installed Cirata EWS Application, we know our exact position in relation to disaster-prone areas. Then we can conduct independent evacuation away from vulnerable areas at any time if a disaster occurs through a safe route and to the nearest evacuation location according to the instructions detected through each installed Cirata EWS App. By using technology that has been developed, through the application that innovated by PLN Nusantara Power, it can further minimize the occurrence of loss of life and property, and also being able to assist in the implementation of an early warning system for flooding caused by the discharge of water from reservoirs caused by overflow through spillway or even by dam collapse. With this application, it can assist the Dam Operation and Maintenance Officer in increasing dam safety and reliability. And help disaster management officer to evacuate residents effectively.

Keywords: Dam Application, Cirata Dam, Emergency Action Plan.

Impact of Climate Change on Power Generation Facilities in Peninsular Malaysia based on the Standard Precipitation Evapotranspiration Index (SPEI)

Nur Alyaa Hazrin, Muhammad Yunus Ahmad Mazuki, Lariyah Mohd Sidek, Hidayah Basri

Abstract

In the 21st century, climate change has intensified, largely due to increased fossil fuel use since the Industrial Revolution. This has resulted in a significant rise in carbon dioxide levels, from 280 ppm in the 1800s to 400 ppm in 2013, leading to a projected global temperature increase of over 1.5°C by the end of the century. These climatic shifts are altering global water cycles and precipitation patterns, impacting water management systems, especially those reliant on specific hydrological conditions. Thermal power plants (TPPs) in Peninsular Malaysia are particularly susceptible to these changes, as they depend heavily on water for cooling. The potential consequences include water shortages, elevated water temperatures, and heightened flood risks, all of which can damage infrastructure and decrease operational efficiency. This study seeks to analyse both historical and projected climate data, with a focus on extreme rainfall events and temperature fluctuations using Standard Precipitation Evapotranspiration Index (SPEI). The methodology involves screening TPPs for vulnerability to climate change and assessing the impacts of relevant extreme events. The resulting insights will guide stakeholders in developing effective mitigation strategies, including climate resilience measures and planning guidelines to address flood risks to TPP infrastructure. These measures will support Malaysia's energy transition goals as outlined in the National Energy Policy (NEP) 2022-2040 and the Malaysia Renewable Energy Roadmap (MyRER), aiming to mitigate the future impact of global warming on stakeholders' facilities and operations.

Keywords: Climate Change Impact, Thermal Power Plants, Standard Precipitation Evapotranspiration (SPEI), Hydrological Conditions, Global Warming.

Comprehensive Failure Mode Identification for Risk-Informed Decision Making in Dam Safety Management: A Case Study of Sultan Abu Bakar Dam

Lariyah Mohd Sidek, Siti Mariam Alias Omar, Hidayah Basri, Sarbani Anjang Ahmad, Darul Hisham Saman, Noryusuhariq Mohd Yusof, Adrian Morales Torres

Abstract

As the largest electricity distributor in Malaysia, TNB Power Generation (Genco) recognizes its vital responsibility in dam safety management. Genco is the first dam owner in the country to implement Risk-Informed Decision Making (RIDM) in its safety protocols, guided by international standards from the International Commission on Large Dams (ICOLD), the United States Army Corps of Engineers (USACE), the United States Bureau of Reclamation (USBR), as well as relevant organizations in Spain and India. This progressive approach allows for the holistic integration of diverse dam safety data, which are often examined separately in multiple reports, thereby strengthening the effectiveness of risk analysis as a decision-making instrument. The Identification of Failure Modes (FMI) is a central element of risk-based methods, reflecting its long-standing importance in engineering. A failure mode can be described as a particular chain of events that has the potential to cause dam failure, with the possibility of generating serious socio-economic consequences. Recognizing these modes is crucial in risk assessment, as it provides the link between engineering expertise and numerical risk evaluation. Therefore, excluding any relevant failure mode during FMI may lead to its omission from the overall risk model, reducing the accuracy of the assessment. To ensure the robustness and quality of the FMI outcomes, a panel of experts critically evaluated the failure mode classification results. This paper delineates the framework developed for failure mode identification, specifically applied to the concrete hollow buttress design of the Sultan Abu Bakar (SAB) Dam. The FMI process revealed eight (8) potential failure modes associated with this dam type. Importantly, only Class B failure modes proceed to full Quantitative Risk Analysis (QRA), while Classes A, C, and D are managed through other actions, resulting in not all identified failure modes being included in the QRA.

Keywords: RIDM, Risk Assessment, Qualitative risk assessment, Hydropower, Consequences, Failure Modes.

Flood Inundation and Dam Break Analysis for Emergency Response Plan: Case Study of Kenyir Hydroelectric Dam

Nur Farazuien Md Said, Lariyah Mohd Sidek, Hidayah Basri, Sarbani Ahmad Anjang,
Noryusahasriq Mohd Yusof, Mohd Ruzaimi Bin Yalit

Abstract

This paper presents a comprehensive dam break study for the Kenyir Hydroelectric Dam, aligning with Malaysia Dam Safety Management Guidelines (MyDAMS). The study aims to enhance dam safety by developing an Emergency Response Plan (ERP) for extreme events, focusing on hydrological analysis, dam break modeling, and socio-economic impact assessment. The methodology involves conducting a Probable Maximum Precipitation (PMP) review to determine the Probable Maximum Flood (PMF) and assessing spillway adequacy. The MIKE FLOOD hydrodynamic dam-break model is utilized to analyze flood routing under various scenarios, calculating hydraulic elements of dam failure like flood depth, flood velocity, flood arrival time and inundated area. Integration with a digital elevation model allows mapping of potential affected areas downstream. The study evaluates flood impacts on population at risk, potential loss of life, and property damage based on flood characteristics. A 1km² grid is used to estimate the severity of flooding uniformly, aiding in decision-making for Emergency Response Plans and Dam Break Evacuation strategies. This comprehensive approach ensures effective risk assessment and supports informed decision-making for dam safety and emergency preparedness.

Keywords: Emergency Response Plan, Dam Break Analysis, Dam Safety, Kenyir Hydroelectric Power Station.

Evaluating Climate Resilience of Kenyir Hydroelectric Scheme Using Integrated RVI and SPEI Models

Mohd Edzham Fareez Othman, Lariyah Mohd Sidek, Hidayah Basri, Ahmed El-Shafie, Ali Najah Ahmed

Abstract

Climate variability presents growing risks to hydropower operations, particularly in tropical regions where extreme weather events are becoming more frequent. This study assesses the climate resilience of the Kenyir Hydroelectric Scheme by examining hydrological variability using the Rainfall Variability Index (RVI) and the Standardized Precipitation-Evapotranspiration Index (SPEI). Historical rainfall data (1999–2023), combined with climate projections under RCP2.6 and RCP8.5, were analyzed to evaluate shifts in rainfall patterns and the frequency of extreme wet and drought events across multiple timescales (1, 3, 6, and 12 months). The findings reveal significant variability in water availability, with RCP8.5 projecting an increase in both the frequency and intensity of extreme wet events, particularly towards the end of the century. In contrast, RCP2.6 shows more moderate changes, indicating less severe shifts in hydrological conditions compared to RCP8.5. These results provide critical insights into climate-related risks, highlighting the need for adaptive management strategies to address future challenges in hydropower systems. While RVI and SPEI offer valuable tools for evaluating climate variability and understanding potential risks, further detailed studies are necessary to develop comprehensive strategies for addressing and mitigating these risks in hydropower systems. The results emphasize the importance of ongoing research to ensure the long-term resilience and sustainability of the Kenyir Hydroelectric Scheme in the face of evolving climate conditions.

Keywords: Hydropower, Climate Resilience, RVI, SPEI.

Sustainable Development and Analysis of Check Dam Systems for Ulu Jelai Hydroelectric Scheme Focusing on Hydraulic and Stability Aspects

Mohd Edzham Fareez Othman, Jansen Luis Luis Alexander, Muhammad Mustaqim Omar,
Lariyah Mohd Sidek, Hidayah Basri

Abstract

The Ulu Jelai Hydroelectric Scheme is a critical component of Malaysia's renewable energy infrastructure, with check dams playing a pivotal role in sediment management and reservoir capacity maintenance. Accelerated land use changes in the Cameron Highlands, including deforestation and agricultural expansion, have exacerbated soil erosion, leading to substantial sediment deposition in the Susu Reservoir. This study focuses on the hydraulic and stability analysis of a proposed check dam system, particularly Check Dam 1 with a 3m high ogee weir, designed to intercept sediment-laden runoff from Sg. Bertam. Through detailed hydrodynamic and sediment transport modelling, the study evaluated the flow characteristics, energy dissipation, and sediment trapping efficiency of the system. The results indicate that the Check Dam 1 achieves a sediment trapping efficiency of 42%, effectively managing larger particles while requiring further optimization for fine sediment capture. Stability analysis confirmed the dam's ability to resist hydrostatic pressure, sliding forces, uplift, and piping risks, ensuring long-term structural integrity. Despite these findings, the relatively low efficiency in trapping fine particles suggests the need for design enhancements, such as expanding the sediment basin or increasing the weir height. Overall, this study provides critical insights into improving sediment management strategies, ensuring the long-term sustainability of the Susu Reservoir.

Keywords: Check Dam Systems, Hydraulic Analysis, Stability Analysis, Sustainability.

Enhancing Dam Safety Through Strategic Risk Evaluation: The Screening Tools Approach at Batu Dam

Lariyah Mohd Sidek, Muhammad Izzat AzharKhebir, Ir. Dr. Hidayah Basri, Siti Mariam Allias Omar, Norziana Jamil, Zeittey Karmilla Kaman, Mohd Hazri bin Moh Khambali

Abstract

This paper discusses the Screening Tools technique for risk evaluation, using Batu Dam as a pilot project. Batu Dam was chosen because of the large population living downstream. This method is becoming popular in the dam safety field as it helps prioritize actions for reducing risks and guides further assessments based on initial findings. To evaluate risks, the team collects technical data about normal operations and technical records from the dam operator and related agencies. The risk screening method assesses the dam using several factors: hydrological hazards, seismic hazards, design vulnerabilities, operations and surveillance, emergency management, and social impacts. Each factor is given a score, resulting in Risk Sub-Indexes for specific aspects and an overall score known as the Global Risk Index. The results provide a preliminary assessment that helps the dam operator target the most critical issues. The findings show that Batu Dam has a medium risk index with low uncertainty, indicating that no further studies are needed at this time.

Keywords: Screening Tools, Batu Dam, Risk Analysis, Analytical Hierarchy Process (AHP).

Evaluating Seepage Water Quality Parameters in Embankment Dam Systems

Nurshahira Mohd Noh, Syahida Farhan Azha, Lariyah Mohd Sidek, Zakiyyah Muhammad,
Sheikh Ahmad Farhan Hazari

Abstract

This study focuses on the structural challenges and environmental impacts of different types of dams in Malaysia, particularly embankment dams, which are the most common. These dams, constructed from locally sourced materials, are prone to issues such as seepage and internal erosion, which can compromise their integrity and have serious consequences for downstream populations. Seepage can negatively affect water quality by changing pH levels and increasing turbidity due to suspended solids. Despite serving critical functions like water supply, hydropower, recreation, and flood control, some dams are specifically designed to manage mining tailings. The study aims to determine the water quality parameters of the seepage at the selected dam location and reservoir receiving the mining residue. The water quality analysis conducted for this study indicates that seepage significantly pollutes water bodies by carrying away minerals, salts, and other natural chemicals from the surrounding soil and rock. The highest concentrations of TSS, BOD, COD, AN, As, and Fe were found in the sample from WQR3 (seepage) location, indicating that the seepage is more concentrated compared to samples taken from other locations upstream and downstream of the dam. The study will also identify potential sources of pollution in the area to verify the presence of heavy metals. By identifying seepage as a critical issue, the study highlights how this phenomenon not only compromises dam integrity but also significantly degrades water quality. These findings can inform dam management practices, guide water quality monitoring, and help develop mitigation strategies to protect downstream populations and the environment.

Keywords: Water Quality Analysis, Seepage, Embankment Dam, Heavy Metals, Water Quality Index.

Flood Risk Analysis from Hypothetical Dam Break of Batu Dam Using Open-Source Hydrodynamic Modelling Approach

Azazkhan I. Pathan, Lariyah Mohd Sidek, Hidayah Basri, Harsh Shah, Mohd Hazri bin Mohd Khambali, Muhammad Izzat Azhar Bin Khebir

Abstract

Dam breach events, though rare, can lead to catastrophic significances for human life, infrastructure, and the environment. This study conducts a hypothetical dam break analysis of Batu Dam in Malaysia using the open-source hydrodynamic modeling software HEC-RAS 2D. The analysis considers four scenarios i.e., spillway-crest breach (100-year ARI), overtopping-induced breach (100-year ARI), PMF with failure, and PMF without failure. A detailed hydrodynamic simulation was carried out to evaluate downstream flood propagation in terms of flood depth, velocity, and arrival time. Hydrodynamic simulations of Batu Dam under various scenarios show that downstream flood extents range from 74 km² for the 100-year ARI scenario to approximately 92 km² under the PMF with failure, while the PMF without failure affects only L1, L6, L7, L8, and L14. Maximum flood depths occur at L1, varying from 7.42 m to 12.3 m depending on the scenario, whereas minimum depths are observed at L2, ranging from 0.32 m to 0.63 m. Flow velocities are highest immediately downstream of the dam, reaching up to 9.7 m/s, with L1 recording the peak velocity (1.1–5.67 m/s) and L12 the lowest (0.72–0.79 m/s). Flood arrival times at locations L1, L2, L5–L9 are under 3 hours, indicating high vulnerability to rapid dam-break flooding. These findings underscore the importance of incorporating spatially distributed flood parameters into Emergency Action Plans (EAPs). The ability to predict arrival times and flood intensities at specific locations provides crucial inputs for timely evacuations, rescue logistics, and prioritization of response efforts. This work demonstrates the utility of open-source 2D hydraulic modeling in simulating hypothetical complex dam failure scenarios and provides a practical framework for improving flood resilience and community safety in dam-influenced catchments.

Keywords: Dam Break Analysis, HEC-RAS 2D, Overtopping, Flood Hazard Mapping.

Machine Learning-Based Prediction of Water Levels from Rainfall Data: A Case Study of Batu Dam, Malaysia

Azazkhan I. Pathan, Lariyah Mohd Sidek, Hidayah Basri, Harsh Shah, Mohd Hazri bin Mohd Khambali, Muhammad Izzat Azhar Bin Khebir

Abstract

Machine learning (ML) techniques are gaining traction in modeling complex hydrological systems. This study investigates and compares the performance of four ML algorithms Extreme Gradient Boosting (XGBoost), Multi-Layer Perceptron (MLP), and Support Vector Regression (SVR) for predicting water levels using rainfall data at Batu Dam, located approximately 16 km from Kuala Lumpur, Malaysia. Batu Dam is vital for both flood control and water supply. The predictive models were evaluated using statistical indicators such as Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and the Coefficient of Determination (R^2). Among all models tested, MLP consistently demonstrated superior performance, especially under scenarios with extended lag intervals. Notably, the MLP model with a 3-day lag (MLP-3) yielded the best results, achieving a MAE of 0.005, an RMSE of 0.0072, and R^2 of 0.9972. Its predictions closely aligned with observed water levels, indicating excellent model fit. Conversely, the SVR model with a 30-day lag (SVR-30) underperformed with an R^2 of 0.83 and scattered predictions. Three input scenarios were formulated based on correlation analysis. Overall, the MLP model emerged as the most effective in capturing temporal variations in dam water levels. These findings suggest MLP's potential as a robust tool for improving early warning systems and supporting flood risk mitigation strategies in similar hydrological contexts.

Keywords: Machine Learning, Batu Dam, Water Level Prediction.

The Risk Informed Decision Making (RIDM) for TNB Genco Dam Safety Program – Case Study for Temengor Dam

Nurmalisa Fazrina Binti Ismail, Noryusuhasriq Bin Mohd Yusof, Shamsul Amri Sulaiman, Darul Hisham Saman, Hidayah Basri, Lariyah Mohd Sidek

Abstract

TNB Genco has implemented a Risk-Informed Decision Making (RIDM) method to improve its Dam Safety Program (DSP), reflecting its dedication to dam safety and operational excellence. The DSP is a structured framework of preventive measures, technical assessments, and emergency preparedness protocols designed to maintain the integrity of dam structures while protecting people, property, and the environment. In acknowledgment of the deteriorating infrastructure of dams and the increasing threats posed by climate variability and catchment disturbances, TNB Genco launched RIDM as a proactive, data-driven approach to enhance its current non-structural measures, especially for dams that do not meet Probable Maximum Flood (PMF) standards. This paper presents the implementation of RIDM in the context of the Temengor Dam, a major hydroelectric asset in TNB Genco's portfolio. The RIDM framework consolidates dam safety documentation, site evaluations, and both qualitative and quantitative risk assessments with specialized tools such as iPresas and RIDM-DaMS. A comprehensive screening process was performed to assess Global Risk and Uncertainty Indices, thereby leading to the identification of potential failure mechanisms and an in-depth quantitative risk assessment. Findings revealed that although Temengor Dam functions under a generally acceptable risk threshold, particular vulnerabilities, including overtopping threats and deficiencies in monitoring instruments, necessitate focused mitigation efforts. The study concludes with a prioritized array of mitigation strategies established using expert assessment and optimization algorithms to support effective decision-making. The RIDM initiative not only bolsters dam safety but, more importantly, improves TNB Genco's capacity for reliable power generation, ensures compliance with emerging requirements, and strengthens public trust in the resilience of dam infrastructure.

Keywords: Dam Safety Program (DSP), Risk Informed Decision Making (RIDM), Quantitative Risk Assessment (QRA), Temengor Dam, Failures Modes Analysis.

Rehabilitation of Exposed Geomembrane in RCC Dams: Case of Susu Dam with Global Best Practices

'Ammar Taqi Borhan, Shamsul Amri Sulaiman, Wan Amirul Wan Hussin, Mohd Fauzi Abdullah, Mohd Zul-azri Zaimi

Abstract

Exposed PVC geomembrane system is commonly used in roller-compacted concrete (RCC) dams because of their resilience, quick deployment and economical. Nevertheless, their durability is affected by UV degradation, mechanical impacts, and operational damage. This paper presents the case at Susu Dam, Malaysia that has been experienced abnormal increase seepage reading due to puncture in its SIBELON® CNT 4400 membrane. The emergency repair procedure, root cause investigation, and system response are discussed. Similar issue has cropped up at Punt dal Gall in Switzerland, Santa Luzia in Portugal, and the Yele RCC Dam in China; comparing notes with those sites proved enlightening. In the end, the exercise boiled down to sharper inspection intervals, smarter patch materials, and design improvements that would be beneficial for upcoming hydropower projects including pumped storage

Keywords: Geomembrane Waterproofing, RCC Dam Rehabilitation, Dam Safety Management.

Assessment and Rehabilitation Work for Puah Headrace Tunnel U2, Hulu Terengganu Hydroelectric Scheme

Muhamad Fairuz Nadzmie Badrul Azman, Md Yuzeiry Md Yasin¹, Azizul Hassani Abd Rahman, Mohd Faizal Musa, Muhammad Mustaqim Omar

Abstract

The Puah Hydroelectric Power Station features two headrace tunnels with vertical shafts, each designed to deliver water for power generation at 125 MW per unit. A comprehensive structural inspection of Headrace Tunnel U2 was conducted to assess its integrity and identify defects. The evaluation revealed significant water leakage along the tunnel invert and right wall near Chainage (CH) 11, primarily at construction joints. Additional defects included concrete spalling, scouring, cracks, and water jetting along the tunnel lining. A Ground Radar Penetration (GPR) test was conducted to further check the leakage conditions and shows the water ponding started at approximately at CH 10 to CH 30. This was corroborated by visible dark blue staining at the initial chainage and active water splashing along the tunnel's right. Rehabilitation work has been undertaken to address the tunnel deterioration. The heavily seepage construction joint is treated using OPC Grouting with non-shrink additive followed by polyurethane (PU) injection which conducted when the leakage stopped. Moreover, concrete spalling and scouring defects with a minimum 10-20mm saw cut is conducted and application of Sika Bonding Agent Monotop 910 N and Sika Monotop 412 MY. All the structural cracks, either wet or dry, are repaired using epoxy grouting. All defects, including the leakage zones, were successfully remediated within the scheduled plant outage period, restoring the tunnel's operational reliability.

Keywords: Headrace Tunnel, Tunnel Inspection, Ground Radar Penetration, Tunnel Rehabilitation.

Case Studies of Rehabilitation of Dams with Geomembrane Liners Installed in the Dry and Underwater

John Cowland, Jonghao Su

Abstract

Energy and water securities are crucial in the 21st century to combat climate change and rising demand of renewable energy. Ageing of existing dams is undeniably becoming an issue as a lot of dams are reaching an age threshold of 50 or 100 years. Maintaining the functionality of old dams so that they can operate safely is essential to meet future demands. In dams and in their appurtenant structures, one of the aspects of ageing is the loss of watertightness; depending on the type and condition of the dam, persisting leakage can lead to increasing water content in the dam body, increasing uplift, instability of slopes and internal erosion which ultimately could trigger a safety issue. Restoring watertightness by rudimentary repairs is generally not a long-lasting solution, may become expensive and sometimes requires lowering the reservoir's level. Refacing the upstream water barrier with a durable flexible geomembrane, to seal cracks, fissures and joints, caused by settlements and differential displacements, is a reliable and safe option that has gained popularity. In rehabilitation carried out in the dry, geomembranes have been used on all types of dams and appurtenant structures. Since the 1990s geomembrane systems have been developed to be installed underwater, regardless of the depth, providing a means to dam owners and operators to rehabilitate the structure without emptying the reservoir and losing both water and energy generation. This paper will present six case histories on both dry and underwater rehabilitation projects carried out globally including four Asian projects.

Keywords: Geomembrane, Rehabilitation, Underwater.

Geomembrane Lining for Rockfill Dams in Hydropower and Pumped Storage Schemes

Jonghao Su, John Cowland

Abstract

Rockfill dams with a concrete facing (CFRD) or a bituminous concrete facing (AFRD) have been constructed since the 1920s. With the increasing height of these dams inducing higher water pressures on the face, and larger dam settlement, the facing can suffer from deformation, leading to cracking and spalling, which can cause leakage problems. This has led to repairs of the concrete face with PVC geomembranes since the 1990s, due to their flexibility and elongation capability, allowing them to resist settlement, differential movements, and earthquakes that would damage stiff concrete slabs. The excellent waterproofing performance and fast installation times of PVC geomembranes has led to the development of geomembrane faced rockfill dams (GFRD), substituting the concrete facing as the waterproofing layer for the dam. In recent years, countries rapidly transitioning to cleaner energy have focused their attention on pumped storage schemes for long duration storage of excess electricity and stability of the grid. In these schemes, rockfill dams are a common structure used to construct the reservoirs of pumped storage schemes. Given the advantages of GFRD over concrete facing, an increasing number of designers are considering GFRDs. With a GFRD, proper anchorage to resist daily water pumping cycles and high wind uplift needs to be designed to allow the geomembrane system to stay stable even in the most critical condition. Two recent GFRD projects will be outlined: Nam Ou VI dam for hydropower production in Laos, and the Pinnapuram project for pumped storage in India.

Keywords: GFRD, Geomembrane, Pumped Storage Schemes.

Contribution Quantitative Risk Analysis of Internal Erosion Vulnerabilities in Temengor for Dam Sustainability

Lariyah Mohd Sidek, Ahmad Fauzan Abdul Hamid, Hidayah Basri, Siti Mariam Allias Omar, Nur Farazuien Md Said, Muhammad Izzat Azhar Khebir, Sarbani Anjang Ahmad, Darul Hisham Saman, Noryusuhariq Mohd Yusof

Abstract

Quantitative Risk Analysis (QRA) is a crucial process for determining the tolerability of existing risks, the adequacy of current risk control measures, and the justification for potential alternative measures. By incorporating both risk analysis and evaluation phases, QRA provides a systematic approach to risk management. This QRA examines the internal erosion risks of the Temengor dam, which are key structures in hydropower management systems. The abstract highlights the crucial role of embankment dams and stresses the urgent need to address potential internal erosion risks. The study's main objectives include identifying failure mechanisms, quantifying failure probabilities, and evaluating potential consequences. The QRA framework combines geotechnical assessments, hydraulic profiling, and advanced probabilistic modelling techniques to thoroughly assess risk exposure. Key input data sets encompass geotechnical parameters, hydrological patterns, dam geometries, and historical operational data. The anticipated outcomes include the development of a detailed and nuanced risk assessment matrix. This matrix will identify critical risk zones and provide comprehensive recommendations for optimal risk mitigation strategies and enhance the overall risk management approach for the hydropower dams. In conclusion, the importance of these infrastructures to the country's hydropower system cannot be overstated, as any failure could lead to significant repercussions. This emphasizes the need for continuous monitoring and robust risk management strategies, including a strong emphasis on emergency preparedness and cooperation with downstream communities.

Keywords: Hydropower Dam, Energy, Quantitative Risk Analysis, Risk Factor, Risk Reduction, Social and Economic Consequences.

Dam Safety Assessment- Spillway Structure Computational Modelling for Damage Assessment: Case Study Temengor Spillway, Sg. Perak Hydroelectric Scheme

Jansen Luis Luis Alexander, Muhammad Mustaqim Omar, Mohd Edzham Fareez Othman,
Shamsul Amri Sulaiman

Abstract

In most hydropower projects the main civil structures would be dam, tunnel, spillway and outlet work. The spillway is a hydraulic structure that transfers exceeding flows safely out from dam without overtopping and damaging the structure. Designing and constructing a spillway is a complex task that requires careful consideration of the engineering parameters which includes hydrologic, geology, geotechnical, hydraulic, structural, and environmental aspects. In the past, spillway structures have spilled on several occasion during extreme rainfall events in Malaysia. The continuous high flows could cause significant damage to the structure which requires long period of time to repair under worst conditions and extreme site challenges. One case study on Temengor spillway is discussed. In the case study, the analysis and investigation conducted can be used to improve knowledge on different situations that led to the failure mechanism. Since most spillways are concrete lined, they tend to have vulnerability due to long life span and exposed to environmental conditions. The paper aims to discuss some of the findings on the spillway which was damaged in the past during extreme spilling events. The Temengor spillway which had one section of the concrete invert block uplifted due to joint failure. This case study are aimed to share the knowledge on the recommendations adopted and can help operators and dam owner to safely operate their structure and to avoid failures and to improve the emergency response plan during an incident.

Keywords: Spillway Failure Analysis, Hydropower Infrastructure, Dam Safety and Emergency Response.

Emergency Action Plan: Leveraging Experience for Future Application in Dam Safety

Nor Syafiqah Kamal, Hidayah Basri, Lariyah Mohd Sidek, Nur Farazuien Md. Said, Zakiyyah Muhammad, Mohd Hazri Moh Khambali, Engku Ahmad Khalil Azhar Engku Mohamed, Sheikh Ahmad Farhan Kamal Hazari

Abstract

Dams are strategically located around the world to fulfill essential roles such as water storage, flood control, irrigation, and hydroelectric power generation. In Malaysia, there are 104 dams, with 83 situated in Peninsular Malaysia and 21 in East Malaysia. These dams serve diverse functions, including providing water during dry periods, generating electricity using turbines, and mitigating downstream flood risks during heavy rainfall. One notable dam serving flood control and water supply purposes is Batu Dam, located in Mukim Batu of Gombak District, capable of storing up to 36.6 million cubic meters of water. Despite the significant benefits provided by these dams, there has been a rise in dam-related incidents in recent years, leading to multiple casualties and substantial losses for downstream communities. Dam failure can arise from various factors such as extreme weather events, aging infrastructure, seismic activity, insufficient maintenance, and deliberate sabotage. Consequently, the development of an emergency action plan (EAP) has become essential to assist dam owners and stakeholders in effectively managing dam-related risks. An EAP is a formal document outlining procedures and actions to be taken in response to dam-related emergencies. In an Emergency Action Plan (EAP) document, crucial components encompass a notification flowchart, emergency level classification, emergency response actions, delineation of roles and responsibilities for each agency, flood inundation maps, and evacuation zoning. Recognizing its importance, the Batu Dam operator has formulated an emergency action plan, which will be presented in this paper, outlining the guidelines followed in its development and the structure of the Batu Dam emergency action plans.

Keywords: Dam Safety, Emergency Action, Emergency Preparedness.

Assurance for Dam Safety and Resiliency under Climate Change: Ulu Padas Hydroelectric Dam, Sabah

Rosidha Febriana, Muhamad Rusdi Bhaharuddin

Abstract

The rising electricity demand in Sabah, East Malaysia, is closely tied to the region's rapid population and economic growth. To address this, the Ulu Padas Hydroelectric Project (UPHEP) has been proposed, with the potential to generate an average of 1,052 GWh of electricity annually. Given the challenges posed by global climate change, it is essential to assess the dam's safety and performance under extreme hydrological conditions. This study evaluates the resilience of the UPHEP dam and its ancillary structures, focusing on their ability to withstand extreme floods and maintain downstream flow during droughts. The dam's role in flood mitigation is also examined. Findings indicate that the approximately 125 m high roller-compacted concrete (RCC) dam, founded on bedrock and equipped with a robust spillway, is capable of sustaining a probable maximum flood of up to 9,638 m³/s and attenuating peak flows associated with a 10,000-year return period flood of 4,544 m³/s under climate change scenarios. Furthermore, it ensures a minimum environmental flow of 7.5 m³/s during dry seasons, supporting ecological sustainability downstream. These results demonstrate that the UPHEP is well-adapted to future climate variability and can contribute to both energy security and water resource resilience in Sabah.

Keywords: Hydropower, Dam Safety, Climate Resilience, Flood Mitigation, Environmental Flow, RCC Dam, Sabah.

Geospatial Analysis on Identification of Suitable Land for Construction of Solar Power Plant Interconnection Facility (SPPIF) in Hydro Power Station

Muhammad Ammar bin Jakrin, Mohd Rashid bin Mohd Radzi

Abstract

The integration of a floating solar photovoltaic (FPV) power plant into the Temenggor Hydropower Plant requires the construction of a new Solar Power Plant Interconnection Facility (SPPIF) to enable grid connectivity. Advanced geospatial analysis is used to identify the optimal SPPIF location. Airborne LiDAR scanning was conducted across the proposed area to capture high-resolution topographic data, and the resultant point clouds were processed in ArcGIS Pro to generate digital elevation models (DEMs) and perform comprehensive terrain analyses, including slope gradient classification and hydrological modeling which includes flow accumulation and flow direction. These analyses provide critical insights into susceptibility to landslides and flooding under varying climatic conditions. By synthesizing slope stability metrics and hydrological risk factors, this data-driven approach facilitates the selection of a site that minimizes exposure to geohazards and decreases future maintenance cost that comes from it. This systematic framework demonstrates the value of integrated geospatial technologies in supporting sustainable energy infrastructure planning in complex terrains.

Keywords: Geospatial Dam Planning, LiDAR Dam Analysis.

Advancing Sustainable Hydropower in Malaysia: A Comprehensive Review of Tenaga Nasional Berhad's Hydro Life Extension Program (HLEP)

Roshidi Bin Khamis, Sarunan Letchmanan

Abstract

Malaysia's commitment to achieving net zero carbon emissions by 2050 has accelerated its energy transition agenda, with hydropower playing a central role due to its low-carbon, reliable, and flexible nature. Tenaga Nasional Berhad (TNB), through its subsidiary TNB Power Generation (TNB Genco), has launched the Hydro Life Extension Program (HLEP), a strategic initiative to modernize and extend the life of major hydropower assets across Peninsular Malaysia. The program covers the Sungai Perak (650.75 MW), Cameron Highlands (250 MW), and Kenyir (400 MW) hydroelectric schemes, aiming to extend operational lifespans by 30–40 years, enhance system efficiency, and integrate digital innovations such as SCADA and digital twins. Key challenges include aging infrastructure, environmental impacts, and climate-driven variability, all addressed through robust contingency planning. The HLEP supports national frameworks like the NETR and MyRER, while contributing to multiple UN Sustainable Development Goals (SDGs), particularly in clean energy, climate action, and infrastructure. With a huge investment and a cumulative capacity exceeding 2,661 MW, TNB's approach offers a replicable model for emerging economies aiming to decarbonize while leveraging existing infrastructure. The HLEP reinforces Malaysia's position as a regional leader in hydropower and sustainable energy development.

Keywords: Hydropower Modernization, Renewable Energy Optimization, Rehabilitation, Climate Resilience, Sustainable Energy Transition.

Check Dams as a Mitigation Strategy for Sedimentation in Hydropower Reservoirs: A Case Study of Ulu Jelai, Cameron Highlands

Ahmad Fadhli Mamat, Rahsidi Sabri Muda, Mohamad Amirul Hafiz Abd Hamid

Abstract

Reservoir sedimentation poses a significant threat to the sustainability of hydropower infrastructure, especially in highland regions undergoing rapid land use changes. The Ulu Jelai Hydroelectric Power Project in Cameron Highlands, Malaysia, is currently experiencing an estimated annual sedimentation rate of 350,000 m³, primarily driven by agricultural expansion and tourism development. This paper evaluates the effectiveness of check dams as a sediment mitigation strategy, focusing on a real-world application within the project. Through GIS-based modelling, field reconnaissance, and hydraulic simulation, three priority locations were identified for additional check dam installations, projected to intercept up to 60% of the annual sediment load. The findings highlight the feasibility and cost-efficiency of check dams in extending reservoir lifespan, minimizing maintenance costs, and enhancing operational resilience. This study emphasizes the importance of integrated sediment management for safeguarding hydropower assets in vulnerable tropical catchments.

Keywords: Reservoir Sedimentation, Sustainable Hydropower, Check Dam.

Floating Solar Technology and Its Potential Synergizing with Hydropower Infrastructure for Renewable Energy Optimization

Muhammad Mustaqim Omar, Jansen Luis Luis Alexander, Shamsul Amri

Abstract

The integration of floating solar photovoltaic (FSPV) systems with existing hydropower infrastructure presents a promising pathway for enhancing renewable energy output, land-use efficiency, and climate resilience. This hybrid approach leverages the complementary generation profiles of solar and hydro sources, enabling more stable and optimized power delivery while minimizing additional land acquisition. Malaysia, with its extensive network of hydropower reservoirs, holds substantial potential for such synergistic applications. This paper examines the technological components of FSPV systems, outlines viable integration models with hydropower assets, and evaluates both the operational and environmental benefits and the challenges of the hybridization system. Case studies from Asia countries are referenced to contextualize the feasibility and scalability of hybrid systems. Key challenges including anchoring solutions, grid interfacing, and regulatory readiness are also discussed. The paper concludes by proposing a strategic framework to guide future FSPV-hydro deployments aligned with Malaysia's National Energy Transition Roadmap and global netzero ambitions.

Keywords: Floating Solar, Renewable Energy, Hybrid Floating Solar.

Evaluation of Dam Safety Challenges in the Climate Change Era: A Southeast Asian Regional Perspective

Nugraha, Setyadi Hartomo

Abstract

Climate change has significantly increased the frequency and intensity of extreme weather events, posing serious challenges to the safety and sustainability of dams in Southeast Asia. This study aims to evaluate the vulnerability of dams in the region under changing climate conditions and to assess the level of preparedness and modernization of safety systems. The research employs a qualitative and comparative approach, drawing on data from international organizations (ICOLD, IPCC), government reports, and case studies from Indonesia and Malaysia. The evaluation framework considers the number of dams, types of monitoring systems in place, and policy responses at the national level. The findings indicate that modernization of dam monitoring remains uneven across Southeast Asia, with Malaysia and Vietnam showing stronger progress compared to Indonesia and the Philippines. Case studies, such as the Situ Gintung Dam failure in Indonesia and the Bakun Dam in Malaysia, highlight the risks of inadequate systems and the benefits of technological adaptation. The discussion emphasizes the importance of digital monitoring, early warning systems, and policy integration to address climate-induced risks. The study concludes that regional collaboration, policy reforms, and the adoption of advanced monitoring technologies are crucial to ensure dam safety and resilience. These findings provide actionable insights for policymakers, engineers, and stakeholders in shaping adaptive strategies for sustainable dam management in the climate change era.

Keywords: Dam Safety, Climate Change, Southeast Asia, Monitoring, Resilience.

Site Selection for Pumped Hydro Energy Storage Project

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Abstract

Site selection process for the development of a pumped hydro energy storage project involved a multi-disciplinary approach to assess various aspects of the site ensuring both sustainability and efficiency of the proposed hydroelectric plant. In order to identify and define the best possible Pump Storage Project scheme in the area. The screening area includes three large existing lakes, namely Lake A, Lake B and Lake C which shall be considered as upper and/or lower reservoirs of the pump storage project scheme. From sixty-three (63) identified PHES to three (3) best options, which are Site 3, Site 4 and Site 7 were selected based on multicriteria assessment. Site 3 offers the highest head but requires long access roads while Site 4 has existing reservoirs and good access but a smaller head. Site 7 provides a high head with proximity to roads and transmission lines, but challenging access to the upper reservoir.

Keywords: Site Selection, Pumped Hydro Energy Storage Project, Upper Reservoirs, Lower Reservoirs.

Sedimentation Analysis of Susu Reservoir and Formulation of Mitigation Strategies

Azwin Zailti Abdul Razad, Wan Haryati Wan Abdullah, Norhidayah Selamat, Roshidi Kamis, Shamsul Amri Sulaiman, Wan Amirul, Saifuddin Zakaria, Hidayah Basri, Lariyah Mohd Sidek, Mazura Nor Zulkifli, Nik Muaz Kamel

Abstract

Reservoir sedimentation is one the main issue faced by dam and reservoir operator, often resulted from rapid land use change within the catchment. To develop the suitable mitigation measures, annual sedimentation rate must be established. Bathymetry survey is most accurate but high cost to be done frequently. In the emerging technological advancement, sediment yield model using RUSLE offers faster estimation, allowing comparison between past and future potential sedimentation rate based on the land use maps. This paper discusses comparison between these methods and how they are used to prepare sediment management framework for Susu Reservoir, in Ulu Jelai Hydroelectric Scheme in Cameron Highlands.

Keywords: RUSLE, Hydropower, Reservoir Sedimentation, Bathymetry Survey.

Adaptive Mechanical Systems for Safe Dam Operations

Nur Aqilah Nadiah Azley Ariff

Abstract

As global climate patterns shift and renewable energy integration accelerates, the demands on dam structure have become more dynamic and complex. Mechanical systems play one of the crucial roles in maintaining dam safety and operational reliability. These systems include gates, valves, hoists, turbines, cooling systems, and other hydromechanical components that regulate water flow, control pressure, and support emergency operations. Proper design, operation, and maintenance of these systems ensure the dam can respond effectively to varying water levels, extreme weather events, and energy demands. Malfunction or failure of even a single mechanical component such as a spillway gate or pressure relief valve can compromise the safety of the entire structure. Therefore, integrating adaptive and automated mechanical systems, supported by real-time monitoring and predictive maintenance technologies, is essential to enhance dam resilience and performance in today's changing climate and energy landscape. This paper explores the role of adaptive mechanical systems in ensuring the safe and efficient operation of dams under evolving environmental and operational conditions.

Keywords: Adaptive Mechanical Systems, Real-Time Monitoring, Dam Safety, IoT Sensors, Hydraulic Materials.

Complete Feature for Dam Safety, Operation Reliability and Environmental Sustainability in Merangin HEPP 350 MW

Jumadil Syam, Sulistianto, Faruq Assegaf, Alimuddin Sewang, Aries F. Firman

Abstract

Merangin HEPP 350 MW located in Jambi Province, Sumatera, Indonesia, with 418 m gross head, 100 m³/s rated discharge capacity and 1.280 GWh/years energy production from Merangin River. The power plant operates under a scheme of 5 hours of peaking operation and 19 hours of base load operation. Kerinci Dam is one of the main structures in Merangin HEPP 350 MW. The dam is construct as a concrete gravity 65,3 m high, with two unit of radial gate spillways 14x16 m, Low Level Outlet (LLO), Debris Flushing, and Environmental Release Flow facility integrated Minihydro 3,2 MW and Fish Trap and Lift facility. LLO is the main dam safety feature which have release capacity around 600 m³/s and under emergency condition, it can be utilized to evacuate the storage from EL. +745,00 down to EL. +705,00 within just 12,66 hours. A total of 178 instrumentation devices have been installed within the dam body and its surrounding areas to facilitate comprehensive dam safety monitoring. To optimize the reliability of hydropower plant operations and flood controls, Regulating Weir structure was constructed at 29,6 km upstream of dam precisely on the outlet of Kerinci Lake. Water passage facility using headrace tunnel with fully concrete lining for low pressure area and steel lining for high pressure area. Surface Air Cushion Surge Chamber (ACSC) in the headrace tunnel and Pressure Relief Valve (PRV) in the powerhouse is an important safety feature for pressure rise control during load rejection of power plant.

Keyword: Dam Safety, Hydropower, Reliability, Sustainability.

Evaluation of the Adequacy of the Riprap Dimensions of the Sutami Dam Due to Reservoir Wave Loads

Satria Wahyu Oetomo, Kamsiyah Windianita, Arief Budiyanono, Sugik Edy Sartono, Fahmi Hidayat

Abstract

This study aims to evaluate the adequacy of the riprap dimensions at Sutami Dam in facing wave loads that occur in the reservoir and can be a reference in the management and maintenance of protective structures at Sutami Dam with a practical and applicable approach. Waves in the reservoir can cause significant hydrodynamic forces on the riprap protective structure, so an accurate analysis is needed to ensure the stability and protective function of the riprap against erosion and damage. Riprap dimension analysis is carried out based on wave height using the Correction Wind Method, Old Method VPMH Design Wind, New Method VPMH Design Wind, and USBR Method. The required data include wind data for the last 10 years, fetch data, and riprap data for Sutami Dam. From the wave height analysis, the significant wave height (H_s) of the Correction Wind Method is 0.413 m, the Old Method VPMH Design Wind Method is 0.313 m, and the New Method VPMH Design Wind Method is 0.243 m. Based on the results of the riprap dimension analysis, the average riprap size (D_{50}) of the riprap using the average significant wave height data is 0.311 m and 0.582 m when using 100 year return period significant wave height data, and when compared to the existing riprap D_{50} , which has an average diameter of 0.79 m, the existing riprap D_{50} exceeds the calculated D_{50} , therefore it can be concluded that, in general, the riprap condition of the Sutami Dam is safe against the effects of the reservoir wave action.

Keywords: Riprap, Fetch, Wave Load.

Construction of 125 m High Concrete Gravity Dam in Subansiri Lower Hydro Electric Project (2000MW)-India-A Case Study

Rao Mushraf Ali Khan

Abstract

Subansiri Lower HE project is one of the largest hydroelectric project in advance stage of completion and likely to be commissioned shortly. Safety of the dam and its satisfactory performance is utmost important for the safety of the downstream population. High seismicity and other foundation related aspects are of high importance while ensuring the safety of the dam and its foundation and abutment. During the construction, challenges faced from diversion of huge discharge of Subansiri river which is a tributary of Brahmaputra River. 5 no. 9.5 di. Diversion tunnels were constructed for passing the diversion discharge of the river during lean season of 4550 cumecs. In monsoon season, discharge passed partly from the diversion tunnel and balance from overtopping of the partly constructed dam. Another important challenge was to provide a dedicated seepage barrier in the dam foundation. Due to low grout intake of the sandstone rock foundation, Seepage from the dam foundation was to be controlled and concrete cut-off wall in the rock foundation was chosen under all the blocks. Cut-off wall construction was carried out from the specially designed large size cut-off wall galleries and access galleries in the dam concrete. It was planned to have dam concrete unhindered in above cut-off wall galleries to raise the dam blocks and parallelly the cut-off wall construction is continued to have optimum utilization of the time and schedule. First time in India, 50 m deep concrete cut-off wall has been constructed beneath the dam foundation of concrete gravity dam Construction of the cutoff wall from specially constructed access galleries (7m x 7m D-shape) in the dam body and tunnels / open excavation in both abutments was a challenge due to limited space for working and to have unhindered construction of the dam. Concrete cut-off wall with conventional concrete was chosen from other alternatives like curtain grouting to have a continuous, dedicated seepage barrier without any windows. Bank to bank construction of cut-off wall mainly in steep slopes was very challenging to perform the operations from various elevations by constructing galleries, overlapping tunnels and open excavation and their combinations to have it up to dam top level. Additionally, downstream cut-off wall has been provided below the plunge pool scour level to provide more seepage control and exit gradient also to mitigate the retrogression of the scour downstream of the dam. Cut-off wall galleries and access galleries, overlapping tunnels were backfilled with concrete after completion the cutoff wall construction to avoid any stress concentration at later stage during the reservoir filling. Another important challenge was to have monolithicity of the already constructed dam and new extended part by providing suitable joint treatment measures due to substantial increase in the base width of the spillway blocks. For concrete placement, Rotec conveyor belt system was employed so that the required rate of placement is achieved. The dam comprised around overall 20 lac m³ of mass concrete and reinforced concrete. The dam also comprised very high head spillway radial gates comprising of size 11.5 m x14 m height under head of 60 m. for high head and velocity in the glacis and spillway portion, aerator arrangements were introduced to avoid cavitation damage. The PMF for the dam is 37500 cumecs. This technical paper insights the challenges faced in handling the high diversion discharge and monsoon discharge for having progress in limited working season.

Keywords: Concrete Dam, Cut-Off Wall, Instrumentation, Methodology.

Analysis of Potential Megathrust Earthquake on Tsunami Disasters in Pangandaran, West Java

Fransiskus Sean Tanlie, Evi Anggraheni, Benazir

Abstract

Indonesia is located in the 'Ring of Fire' and 'Megathrust' zone, where such geological conditions make the country prone to frequent earthquakes. Surrounded by four major tectonic plates—Indo-Australian, Eurasian, Philippine Sea, and Pacific—Indonesia has a high potential for large-magnitude earthquakes that can trigger tsunami disasters. The tsunami disaster of July 17, 2006 stands as a significant example, with particularly severe impacts in Pangandaran, West Java, a region situated along the island's southern coast. The simulation was conducted using the Cornell Multi-grid Coupled Tsunami Model (COMCOT) software, which is based on the shallow water equations (SWE) solved using the finite difference method. Earthquake parameters, topographic data, bathymetric data, and coastal Manning's coefficient were used as the main input variables for the model. This study aims to analyze the tsunami hazard potential caused by megathrust earthquakes in Pangandaran, West Java. The model is created by calibrating simulation models using historical scenarios and field observation data. Model validation based on the historical tsunami scenario of the Mw 7.8 earthquake on July 17, 2006, shows a wave arrival time of 45.77 minutes, a maximum wave height of 5.98 meters, and an inundation area of 289.54 hectares. Meanwhile, the potential tsunami scenario for an Mw 8.8 earthquake results in a wave arrival time of approximately 40.18 minutes, a maximum wave height of 8.55 meters, and an inundation area of 950.75 hectares.

Keywords: COMCOT, Inundation Area, Megathrust Earthquake, Tsunami Impact, Tsunami Simulation, Wave Height.

Dam Safety Assessment Using Back-Analysis: A Case Study of Karkheh Dam

Mohammad Salehinik, Ahmadreza Tabibnejad

Abstract

Karkheh Dam with a height of 127m is a large earthfill dam with clay core located in Khūzestān, Iran. The dam reservoir is the largest in the country with a capacity of 5.9 MCM. After about 17 years from impounding, In April 2019, for the first time, the reservoir not only reached its normal operating level but also exceeded it by nearly 5 meters. This extreme event raised concerns regarding the long-term stability of the dam under sustained high-water conditions. In this regard, a comprehensive safety evaluation program including instrumentation data processing, numerical modeling and back-analysis of the dam body was carried out. During the back-analysis the material parameters was changed on a trial and error basis, until the model output became close to the instrumentation measurements. Initial calibration of material parameters was based on the dam behavior, mainly deformations and pore water pressures, at the end of construction. Using these validated parameters, the dam's response was subsequently evaluated under loading conditions that has not been experienced yet. The study also involved a full reassessment of both static and dynamic stability after 25 years of operation. The numerical dynamic analysis was performed by means of a nonlinear finite difference approach that incorporated updated, site-specific earthquake records.

Keywords: Dam Safety, Back-Analysis, Numerical Modeling, Instrumentation, Karkheh Dam.

Sediment Flushing of Sengguruh Reservoir: Key to Reservoir Capacity Recovery and Renewable Energy Optimization

Kamsiyah Windianita Arief Budiyanono, Sugik Edy Sartono, Fahmi Hidayat

Abstract

Sediment flushing of the Sengguruh Reservoir is a crucial sedimentation management effort in maintaining the reservoir's storage capacity and supporting the hydrological and operational functions of the reservoir, particularly as a water supply for hydroelectric power plants (HEPP). The sediment flushing program successfully removed accumulated sediment by flushing through the spillway gate in a planned and structured manner. This activity not only restored the reservoir's storage capacity but also increased the efficiency of water flow, contributing to increased electricity production at the hydroelectric power plant with an installed capacity of 2 x 14.5 MW. Sediment flushing was carried out with cross-agency coordination and thorough technical support, making it an effective method in mitigating sedimentation in the Sengguruh Reservoir. Sustainable sediment flushing is essential to ensure the reservoir's continued function in flood control, raw water supply, irrigation, and optimizing electricity generation in the Brantas River Basin.

Keywords: Flushing Sediment, HEPP, Reservoir.

Projected Inflow and Outflow Extremes under Climate Change in Kenyir Catchment and Implications for Dam Safety

Mohd Edzham Fareez Othman, Lariyah Mohd Sidek, Hidayah Basri, Ahmed El-Shafie, Ali Najah Ahmed, Jansen Luis Luis Alexander, Muhammad Mustaqim Omar, Shamsul Amri Sulaiman

Abstract

Projected hydrological extremes under climate change present growing challenges to dam safety in tropical catchments. This study evaluates peak inflow and peak outflow responses at the Kenyir Hydroelectric Scheme in Malaysia through a combination of percentile-based rainfall analysis and hydrological simulation using HEC-HMS. Future rainfall projections were sourced from four Representative Concentration Pathway (RCP) scenarios RCP2.6, RCP4.5, RCP6.0, and RCP8.5 across three future periods 2020–2046, 2047–2073, and 2074–2100. Gumbel-distributed rainfall depths for 100year Annual Recurrence Interval (ARI) events were applied across durations of 24 to 168 hours to simulate runoff generation and reservoir response. Among all scenarios, RCP6.0 produced the highest peak outflow during 2020–2046, reaching 1,483.8 m³/s at 133 hours following a 120hour storm. Reservoir elevation rose to 147.9 m, exceeding the spill threshold by 2.9 m but remaining within structural limits. A transition in dominant scenario was observed in the far-future period, with RCP4.5 generating the highest discharge, though all values remained below the 6,500 m³/s design capacity. Across all periods, peak outflows were predominantly driven by long-duration events, particularly 120 to 168 hours, indicating increased sensitivity to cumulative rainfall inputs. Findings support the adoption of adaptive operational strategies to improve response under changing rainfall regimes. Incorporation of upper-percentile rainfall estimates into planning enables more robust anticipation of extreme scenarios. Results underscore the need to reconfigure reservoir routing protocols, introduce forecast-informed regulation, and apply dynamic rule curves to enhance dam reliability and flood risk mitigation in evolving climate conditions.

Keywords: Climate Change, Dam Safety, HEC-HMS, Hydropower.

Active Fault Zone as Renewable Energy Potential Source (Small Hydroelectric Power Plant and Geothermal Power Plant) And Geological Hazard Risk (Earthquake and Landslide) Potential Source

Asmaruddin Surya Ariyanto

Abstract

Some Renewable Energy Power Plant potential (Hydroelectric Power and Geothermal Power Plant) and geological hazard risk in Lampung Province are in tectonic and Sumatra Active Fault Zone with special geological condition. Geological condition in Lampung is influenced by some fault active (Great Sumatera Fault Zone) from Ranau Lake, Liwa Valley to Semangko Bay. Kumering Fault is an active fault located around Ranau Lake. Semangko fault is an active fault found near Suoh Valley and Semangko Bay. Meanwhile, Liwa Fault is found in Liwa City. This study is used for identification some impacts from faults around Lampung especially Sumatra Faults Zone for presence of Renewable Energy Power Plant and geological hazard risk. For Renewable Energy Power Plant, there are some Hydroelectric Power Plants and Geothermal Power Plant areas are in Sumatra Fault zone, especially between Ranau Lake, Lembah Suoh, and Semangko Bay. Meanwhile, Sumatra Fault zone is also identified caused some geological hazard event in Western part of Lampung Province. They are tectonic earthquake and landslide risk areas. Some damage earthquakes events have already happened at Liwa Regency in 1908, 1933, and 1994. Meanwhile, several geological hazard areas are located between Ranau Lake to Suoh Valley and Semangko Bay with some events have already happened in some Hydroelectric Power Plant.

Keywords: Geological hazard, Renewable energy, Hydroelectric, Power Plant, Sumatra Fault Zone.

Atmospheric Carbon Removal: The Role of DAC in Climate Mitigation

Mohammad Sherjeel Javed Khan, Lariyah Mohd Sidek, Sadiq Abdullah Abdo Alkhadher,
Hidayah Basri

Abstract

Rising atmospheric CO₂ levels primarily caused by over a century of fossil fuel combustion have become a central driver of climate change. While conventional carbon capture technologies such as pre- and post-combustion systems help limit ongoing emissions from industrial sources, they cannot reduce the already accumulated CO₂ in the atmosphere. Direct Air Capture (DAC) presents a promising solution, offering the ability to remove CO₂ directly from ambient air and operate independently of emission sources. Over the last two decades, significant advances have been made in DAC materials, including supported amines, ammonium-based compounds, ionic liquids, and metal-organic frameworks (MOFs). These sorbents demonstrate strong CO₂ interactions and operate through reversible sorption-desorption cycles. Additionally, emerging materials such as graphene-based adsorbents show superior performance compared to traditional options like zeolites and activated carbon. However, high energy requirements such as the 3.5 GJ/ton CO₂ for monoethanolamine regeneration pose a major barrier to commercial deployment. To address this, innovative approaches like modulated amine blends and integration with existing infrastructure (e.g., HVAC systems) are being explored to reduce energy demands. Long-term CO₂ storage options, such as geo sequestration in geological formations, provide large-scale potential, though CO₂ utilization remains limited to niche applications. For DAC to become a viable climate solution, research must prioritize designing cost-effective sorbents, enhancing material stability, and conducting thorough techno-economic assessments. Integrating DAC with renewable energy sources like geothermal power will be essential for scalable, sustainable carbon removal, helping to offset residual emissions and mitigate the global climate crisis.

Keywords: CO₂ Capturing, Direct Air Capture, Fossil Fuel, Mofs, Zeolites.

Hydropower-Floating Solar Photovoltaic Hybrid Systems Operational Benefits

Muhammad Najmi bin Hamzah

Abstract

Hydropower and solar photovoltaic (PV) systems are among the most sustainable energy generation technologies. By utilizing the combined effect between the two renewable sources, hybrid systems optimize energy output while offsetting fossil fuel usage, significantly reducing carbon emissions. The floating solar photovoltaic (FPV) multiple benefits and the potential offered by existing hydropower reservoirs are aligned with the Malaysia's goals for net zero emissions under the National Energy Transition Plan (NETR) initiatives. This paper explores the integration of FPV system with existing hydropower infrastructure, focusing on some potential operational benefits from the hybrid systems. The detail operational benefits that this hybrid systems may provide could be quantified in future modelling and/or analysis of existing or planned solar FPV-hydropower plant hybrid systems.

Keywords: Hydropower Plan, Floating Solar Photovoltaic (FPV), Hybrid Systems, Operational Benefits Potential.

Application of Electrical Resistivity Tomography (ERT) in Enhancing the Accuracy of Phreatic Surface Evaluation for Dam Stability Assessment

Hendra Jitno, Henny D Purnamasari, Ibadurrahman A Dzikro, Abdul Salam

Abstract

A slope stability analysis of the dam was conducted using the Limit Equilibrium Method (LEM), based on a phreatic surface estimated from a seepage model. The calculated factor of safety was below the required limit, raising concerns about the dam's stability. This prompted a review of the seepage model, focusing on the accuracy of the phreatic surface, which significantly affects pore pressure and the shear strength of dam materials. To improve accuracy, a field investigation using Electrical Resistivity Tomography (ERT) was carried out. ERT is a non-invasive method that maps moisture levels underground by measuring electrical resistivity, offering a more detailed and reliable view of the phreatic surface than modelling alone. The ERT-derived phreatic surface was cross-checked with piezometer readings in the dam and also compared with previous seepage model results. This helped validate the new profile and provided a clearer understanding of groundwater flow within the dam. Using the updated phreatic surface, a revised slope stability analysis was conducted with both LEM and the Finite Element Method with Strength Reduction (FEM-SRM). The same soil parameters were used to isolate the impact of the improved phreatic surface. The new analysis showed a higher safety factor, meeting design requirements. This highlights the importance of accurately defining the phreatic surface and the value of combining geophysical methods, such as ERT, with traditional geotechnical analysis in dam safety assessments.

Keywords: Slope Stability, ERT, Phreatic Level.

Strength and Deformation Characteristics of Asphaltic Concrete Core Embankment Dams Built in the Tropical Region

Hendra Jitno, Aris Rinaldi, Slamet Lestari, Aries Firman

Abstract

Asphaltic concrete (AC) cores are increasingly utilised in embankment dams due to their superior impermeability, flexibility, and resistance to cracking under settlement or seismic loading. In Indonesia, where embankment dams are often subjected to extreme hydroclimatic conditions—characterised by high rainfall, prolonged wet seasons, and elevated ambient temperatures—the application of AC cores presents both opportunities and challenges. This study presents a comprehensive evaluation of the in situ strength and deformation characteristics of asphaltic concrete cores extracted from Sidan dam in Indonesia. Field investigations involved core drilling, sampling, and laboratory testing, including triaxial compression and modulus of elasticity calculation. The results reveal that the mechanical performance of in situ AC cores is influenced significantly by void content, compaction quality, and confining pressures. This study addresses the gap in published data from tropical regions and highlights the need for performance monitoring under high-temperature and high-moisture conditions. The findings provide valuable benchmarks for the design, construction, and maintenance of asphalt-core dams in similar tropical and seismically active settings.

Keywords: Asphalt Concrete Dam, Deformation Characteristics, Tropical Region.

Water Stress, Risk Analysis Assessment on Lombok Island, Indonesia

Rizki Aulia Putra, Evi Anggraheni

Abstract

Water stress is an increasing environmental concern in Indonesia, particularly on Lombok Island, which often faces drought and unstable water availability. This study aims to assess the water stress risk assessment model, following the guidelines of the Indonesian National Disaster Management Authority (BNPB RI). The hazard component that analyzed consist of drought, flood, volcanic activity, and landslide. Vulnerability is measured through indicators such as population density, Gross Regional Domestic Product (PDRB), and housing infrastructure. Capacity is evaluated based on the availability of water infrastructure on its and dams. The risk assessment analyzed through geospatial techniques utilizing climate data spanning from 2000 to 2023. Results show that drought is the most frequent and impactful hazard, especially in central, eastern, and southern areas. High vulnerability is linked to dense populations and economic activity, while capacity remains low due to uneven infrastructure distribution. The integrated risk map identifies areas with high hazard, vulnerability, and low capacity as being at greatest risk. This research highlights the need for targeted interventions, such as infrastructure development, improved water governance, and climate resilience planning, to reduce water stress in Lombok and similar regions.

Keywords: Water Stress, Risk Assessment, Drought, Vulnerability, Capacity, Lombok Island, Water Related Infrastructure, Spatial Analysis.

Site-Specific Geological and Seismic Characterization for Klang Gates Dam

Ahmad Fakhri Bin Ishak, Meldi Bin Suhatriil

Abstract

This study presents the findings of a seismic site characterization conducted at the Klang Gates Dam, focusing on shear-wave velocity (V_s) profiling of subsurface materials using both field and laboratory methods. Field investigations included the Multichannel Analysis of Surface Waves (MASW) and seismic downhole surveys, while laboratory analysis involved ultrasonic wave velocity tests on metasandstone core samples. A significant disparity was observed between the V_s values obtained from field and laboratory methods. MASW yielded average V_s values between 300–450 m/s, while the downhole survey recorded values ranging from 250–750 m/s. In contrast, ultrasonic tests produced substantially higher V_s values, ranging from 460 to 2700 m/s. Special attention was given to the metasandstone rock layers, as these are critical to seismic hazard analysis. Considering the variability due to natural joints in the rock mass, a conservative shear-wave velocity of 1,500 m/s was adopted for the dam foundation. This value aligns with the NEHRP site classification system for rock, providing a standardized basis for seismic input in further hazard modeling. The results from this investigation serve as a foundational input for subsequent seismic hazard assessments and structural response studies for Klang Gates Dam.

Keywords: Klang Gates Dam, Seismic, MASW.

Seismotectonic Modelling and Source Characterization for Seismic Hazard Analysis at Klang Gates Dam

Ahmad Fakhri Bin Ishak, Meldi Bin Suhatri

Abstract

This paper presents a comprehensive seismicity assessment for the Klang Gates Dam, emphasizing the importance of understanding regional tectonics and local seismic behavior in evaluating infrastructure safety. By analyzing historical earthquake records, active fault systems, and tectonic configurations, the study delineates three main seismic source zones: the Sumatra Subduction Zone (SSZ), the Sumatra Fault Zone (SFZ), and background seismicity. These zones reflect the dynamic tectonic environment formed by the interaction between the Indo-Australian and Eurasian plates, which poses seismic risks to Peninsular Malaysia, including the Klang Valley region. Seismic design parameters such as peak ground acceleration (PGA) and magnitude-distance relationships were determined to support structural and hazard analyses. Additionally, the study integrates risk assessment considerations to evaluate the potential impact of regional seismic activity on the dam. The findings contribute critical data for input into deterministic and probabilistic seismic hazard modeling and underscore the need for localized seismic assessments for high-risk structures. The approach reinforces the importance of integrating regional seismotectonic insights with site-specific evaluations to support resilient infrastructure planning and emergency response strategies.

Keywords: Seismic, Klang Gates Dam, Seismotectonic.

Seismic Hazard Assessment of Klang Gates Dam Using Deterministic and Probabilistic Approaches

Ahmad Fakhri Bin Ishak, Meldi Bin Suhatriil

Abstract

This study presents a comprehensive seismic hazard assessment of Klang Gates Dam using both Deterministic Seismic Hazard Analysis (DSHA) and Probabilistic Seismic Hazard Analysis (PSHA) approaches. The DSHA method evaluates the maximum expected ground motion by considering the most critical nearby seismic sources, independent of occurrence probabilities. Results show that the controlling earthquake scenario originates from local faults, with computed Peak Ground Accelerations (PGA) of 0.173g and 0.309g at the 50th and 84th percentiles, respectively. These conservative values provide essential input for structural safety evaluation and design. Conversely, the PSHA approach incorporates uncertainty in seismic source parameters through the use of logic trees and provides PGA values over a range of return periods. The analysis yielded PGAs of 0.103g to 0.287g for return periods between 145 and 10,000 years, enabling a risk-informed framework for performance-based engineering and long-term planning. Comparison of both methods reveals that DSHA offers an upper-bound scenario, while PSHA facilitates nuanced risk assessments aligned with regulatory and international standards. Together, the results reinforce the importance of integrating both deterministic and probabilistic methodologies for comprehensive dam safety management, ensuring resilience against seismic events while optimizing design and mitigation strategies.

Keywords: Klang Gates Dam, DSHA, PSHA.

Evaluation of Risk Management Impact on Project Schedule Performance: Case Study of Jlantah and Temef Dam Package 4 Construction Using Schedule Performance Index and Schedule Deviation

Muhammad Asyqar Raasyaad, Alfin Septya Nugroho, Eko Suyono, Nugraha

Abstract

Delays in construction project execution remain one of the primary challenges in Indonesia's construction industry, often resulting in cost overruns, extended timelines, and reduced efficiency and credibility of project implementers. These issues are generally attributed to inadequate initial planning and the lack of an integrated risk management approach during the early project phases. This study aims to evaluate the effectiveness of risk management strategies on project time performance, employing the Schedule Performance Index (SPI) and schedule deviation as key indicators. The research focuses on two case studies: Temef Dam Package 4 and Jlantah Dam, utilizing document analysis of project scheduling and risk management documentation. Findings reveal that although both projects recorded SPI values greater than one and positive schedule deviations, these outcomes do not necessarily indicate the success of their risk management systems. Instead, the performance was largely influenced by the high number of schedule addendums issued in response to unforeseen obstacles. Furthermore, the evaluation of risk documentation quality in both projects indicates suboptimal standards. This study recommends enhancing the preparation and active utilization of risk management plans, as well as integrating SPI and schedule deviation measurements into routine evaluations to improve project preparedness in mitigating future delay risks.

Keywords: Risk Management, Schedule Deviation, Schedule Performance Index.

Decarbonization of The Cibeet Dam Project: Comparative Carbon Emission Assessment of RCC and Earthfill Construction Methods Through Fly Ash Optimization

Phelix Ghibran, Alfin Septya Nugroho, Aqua Budinata, Riyanto Wibowo, Ahmad Sidik

Abstract

The development of dam infrastructure in Indonesia, particularly through the Roller Compacted Concrete (RCC) method, plays a vital role in the national strategy toward low-carbon development. However, infrastructure construction faces a major challenge in the form of high greenhouse gas (GHG) emissions, largely resulting from energy consumption and the use of carbon-intensive materials such as cement. This study aims to quantify carbon emissions from the construction of RCC and earthfill dams as a basis for selecting more environmentally friendly design alternatives. The primary focus is on reducing energy consumption and GHG emissions through the utilization of fly ash as a partial substitute for cement. The analysis adopts a quantitative approach based on embodied energy and emission factors, covering three major emission sources: materials, transportation, and construction processes. The results show that the RCC method generated a total of 78 million kg CO₂-eq, which is lower than the earthfill method at 89.9 million kg CO₂-eq. Material production was identified as the largest emission contributor, with cement accounting for 85.82% of the total emissions in the RCC method, while fly ash contributed only 2.73%. The use of fly ash to partially replace cement has the potential to reduce carbon emissions by approximately 25% of the total mix applied. These findings suggest that employing RCC concrete with an optimal proportion of fly ash can serve as an effective strategy for decarbonizing the construction sector. Furthermore, this approach supports sustainable development practices in water resources infrastructure projects in Indonesia.

Keywords: Dam Construction, Greenhouse Gas Emissions, Fly Ash, RCC, Earthfill, Decarbonization.

Analysis Of Bamboo Fiber Reinforced Concrete (FRC) To Reduce Thermal Crack Potential in the Leuwikeris Dam Construction

Ilham Putra Pratama, Alfin Septya Nugroho, Elly Yuliasari, Fariz Kurnia Aziz

Abstract

Mass concrete casting is prone to thermal cracking due to the rise in hydration temperature. This cracking is primarily caused by the temperature differential between the concrete core and its surface, which can exceed safe limits especially in tropical climates such as Indonesia. This study analyzes the potential use of Bamboo Fiber Reinforced Concrete (FRC) as a solution to reduce the risk of thermal cracking in the spillway wall of the Leuwikeris Dam. The study was conducted quantitatively through thermal model simulations based on adiabatic parameters and hydration temperature calculations for two types of concrete: conventional K-225 and Bamboo FRC. The calculation results show that K-225 concrete can reach a core temperature of up to 53.1 °C with an average temperature difference (ΔT) of 21.1 °C, whereas Bamboo FRC reaches only 46.77 °C with a ΔT of 14.77 °C. The ΔT reduction of approximately 30% indicates that Bamboo FRC can lower peak temperature and provide a more uniform heat distribution. From the standpoint of material availability, the bamboo required for this project accounts for only 0.0185% of the total annual national production, making it a feasible and environmentally friendly option. Therefore, Bamboo FRC proves to be an effective alternative material in mass concrete construction for enhancing thermal stability and improving casting efficiency.

Keywords: Mass Concrete, Thermal Cracking, Bamboo FRC, Hydration Temperature, Dam Spillway.

Economic–Environmental Analysis of Dam Failure Losses with Emphasis on Public Health Consequences in Iran: A SWOT-Based Approach

Ehsan Farhadi, Hossein Sadeghi Saghdel, Lotfali Agheli, Samira Motaghi

Abstract

Dam failures represent a multifaceted threat to sustainable development, particularly in arid and semi-arid countries such as Iran, where water resource management, food security, and public health are highly dependent on the safety and reliability of dam infrastructure. While much attention has been paid to the technical and economic dimensions of dam safety, the broader economic, environmental, and public health consequences of dam failures remain underexplored in Iranian policy and research. This study employs a mixed-method approach, combining systematic literature review, expert interviews, and a structured survey of 135 professionals in water management, environment, and public health, to identify and prioritize the key internal and external factors shaping Iran’s preparedness for dam failure events. The research applies the SWOT (Strengths, Weaknesses, Opportunities, Threats) framework to provide a holistic analysis, with quantitative prioritization of indicators and the formulation of actionable strategies. The findings reveal that internal weaknesses—such as underfunded dam maintenance, insufficient early warning and crisis management systems, inadequate inter-agency coordination, and a lack of integrated health impact planning—significantly outweigh existing technical strengths. Externally, Iran faces escalating threats from climate change, extreme weather events, economic sanctions, and regional hydropolitical tensions, all of which hinder effective disaster risk reduction. Although there are opportunities to leverage international cooperation, technological advances, and growing public awareness, the current convergence of internal vulnerabilities and external pressures positions Iran in the defensive (WT) quadrant of the strategic SWOT matrix. This suggests that risk reduction and institutional resilience should be prioritized over ambitious transformation. The study concludes with targeted policy recommendations, emphasizing incremental capacity-building, enhanced coordination among key sectors, investment in early warning and public health systems, and the integration of health and environmental considerations into dam safety policy. The model and results offer a roadmap for more holistic and effective disaster risk management in Iran and similar contexts.

Keywords: Dam Failure, Economic Impact, Environmental Risk, Public Health, Disaster Risk Management, SWOT Analysis.

Insitu Balancing, Vibration Measurement and Analysis on 50 MW Francis Turbine Hydro Power Station

Zahir Fikri bin Zulkifli Jasmin, Mohd Rashid bin Mohd Radzi, Mohd Aswad bin Abdol Rani, Ismail bin Roslan

Abstract

Unit 3 SJ Sultan Idris II, Woh has undergone planned turbine and generator major overhaul. During post commissioning activity the unit experience high vibration on generator upper guide bearing. TNB Genco Mechanical Diagnostic, Test and Diagnostic Unit was requested to perform vibration measurement and analysis on the unit. After analyzing vibration data from external proximity vibration probes which was then extracted from Bently Nevada Adre 408 Data Signal Processing analyzer, In-situ balancing activity was done to reduce vibration on the machine by adding additional balancing weight on the generator upper fan. Overall, in-situ balancing purpose were successfully achieved as vibration level manage to reduce to acceptable limit. SJ Woh Unit 3 falls under Zone A as per ISO 7919-5:1997(E) where it stated that vibration within this zone is normally considered as new machine condition. The unit is considered safe and healthy for normal operation condition.

Keywords: Turbine, Generator, Vibration Measurement and Analysis, In-situ Balancing.

Integrated Water Resources Management Towards Sustainability Water in Selangor

Haslina Amer, Nor Zamri Sondor, Siti Haida Ramli

Abstract

Selangor, as Malaysia's most populous and industrialized state, is increasingly challenged by the need to secure sufficient and sustainable water resources amid rapid urbanization, climate variability, and industrial expansion. Lembaga Urus Air Selangor (LUAS) is the pioneering agency that is accorded with legislative and enforcement authority through the Lembaga Urus Air Selangor Enactment 1999. LUAS plays a central role in ensuring the sufficiency, sustainability and quality of water resources in the state. LUAS is responsible to manage water resources in the State of Selangor through in managing and safeguarding the state's water resources within an integrated water resources management (IWRM) framework. Established under the LUAS Enactment 1999, the agency is vested with comprehensive authority to regulate, monitor, and coordinate all water-related activities across river basins and coastal areas in Selangor. It's a responsibility for LUAS to assure that the Selangor's water resources are available at all situations to cater current and future demand of water. Hence, through LUAS, the Selangor State Government identifies strategies and methods in better managing the needs for water resources by its continuous availability and quality. The findings affirm that LUAS has established a robust, data-driven, and enforcement-oriented governance model for water resource management. The paper concludes with policy recommendations, including the expansion of real-time monitoring networks, the incorporation of alternative water sources such as groundwater and scaling of ecological restoration initiatives. These measures are essential for enhancing water resilience and ensuring long-term water security in Selangor.

Keywords: Sufficient Water Resources, Water Resources Management.

Reservoir Sedimentation: Causes, Impacts, and Sustainable Management Strategies for Hydropower Operations in Malaysia — A Case Study of Susu Reservoir

Sadeq Abdullah Abdo Alkhadher, Lariyah Mohd Sidek, Mohammad Sherjeel Javed Khan, Syahida Farhan Azha, Hidayah Basria

Abstract

The long-term ecological health and sustainable use of the Susu Reservoir are fundamentally linked to the complex dynamics of sediment loading and distribution within its aquatic environment. These sediment deposits, a product of soil erosion and in-situ biological processes, act as a critical medium for the transport, uptake, storage, and release of numerous contaminants. As such, the characterization of bottom sediments is paramount to understanding the broader water quality status of the reservoir. Soil erosion and mining drive sediment inputs, not only threatening the structural integrity and operational efficiency of the dam infrastructure but also contributing to a substantial degradation of water quality, impacting the entire ecosystem. This study delves into the current understanding of sediment distribution, composition, causes, and effects within the Susu Reservoir. By drawing upon existing studies and examining prevailing methodologies for sediment analysis, we seek to assess the ramifications of sediment deposition on various facets of the reservoir system – from operational efficiency and sedimentation patterns to the broader impacts on water quality and the ecosystem. The substantial volumes of sediment that have accumulated in the reservoir pose considerable challenges to effective management, necessitating a multi-faceted approach. Ultimately, we conclude that strategically planned and implemented targeted sediment dredging is an essential measure for mitigating maintenance requirements and addressing critical environmental concerns related to water and sediment quality in the Susu Reservoir. This underscores the need for comprehensive sediment management strategies to safeguard this vital water resource's long-term health and functionality.

Keywords: Sediment, Water, Distribution, Energy, Climate Change, Susu Reservoir.

Utilization of the Sutami Reservoir for the Development of Floating Solar Power Plants

Sugik Edy Sartono, Adi Bowo Kusumo, Nugroho Hari Anggoro Suyono, Muhammad Adnan Maulana, Fahmi Hidayat, Hamim Ghufroni, Abdul Razaq

Abstract

Sutami Reservoir, located in Malang Regency, is one of the water resource infrastructures utilized for multiple purposes, including flood control, irrigation, hydroelectric power generation, raw water supply, fisheries, and tourism. However, intensive fish farming activities particularly through floating net cages (keramba jarring apung - KJA) have led to the degradation of water quality, indicated by increased organic pollutant load, eutrophication, and the potential for mass fish deaths. This study aims to evaluate water quality conditions of Sutami Reservoir, reduce the number of KJA units and fish barriers, and analyze the feasibility of developing floating solar photovoltaic systems with capacity 100 MW, especially for placing floating solar panels within utilization zones and buffer zones in the Sutami Reservoir. The assessment covers parameters of physical, chemical, and biological, as well as technical aspects such as bathymetry, wind, solar irradiance, and environmental carrying capacity. The findings indicate that Sutami Reservoir is experiencing moderate to severe pollution, dominated by eutrophic phytoplankton and zooplankton, with a total waste load far exceeding its assimilative capacity. Furthermore, the proposed development of the floating solar power plant planned to occupy 1.36 km² of the reservoir surface (11% of the total inundated area) requires the removal of 1,023 KJA units and 55 barriers, covering a total area of 14.44 hectares. The reduction of KJA units and barriers is expected to gradually restore the water quality of the Sutami Reservoir.

Keywords: Sutami Reservoir, Water Quality, Floating Solar Power Plant.

Rapid Risk Indexing: A Tool for Risk-Informed Dam Safety Prioritization

C. Richard Donnelly, P.A. Zielinsky, E. Halpin, J. Quebbeman, C.R. Singh, Z.M. Ziegelhoefer

Abstract

Risk-informed decision-making approaches are increasingly becoming best practices for many jurisdictions and dam owners around the world. However, despite these advances in dam safety management there have been a number of recent examples of dam safety incidents. Attempting to address this crisis through the application of comprehensive risk-informed methodologies is problematic since true risk analysis can be a highly challenging and sometimes opaque process that requires calculating a probability distribution over the range of possible consequences. This paper describes a risk screening tool that can be used to prioritize dam safety remedial interventions using a simplified, but effective risk informed screening approach.

Keywords: Risk Informed Decision Making, Dam Safety, Dam Safety Remedial Work Prioritization.

Impact of Bakun Hydroelectric Plant (HEP) Dam on Water Quality Parameters in the Rajang River

Nor Azalina Rosli, Inawati Othman, Ahmad Kueh Beng Hong, Muhammad Kamal Rusyaidi Mohtar, Ahmad Adzhar Khairulzaim, Nuqman Nadeem Sharkawi

Abstract

Bakun Hydroelectric Plant (HEP) dam is one of the Southeast Asia's largest dams. Besides its main role to generate electricity, Bakun HEP dam also provides water security for downstream usage by balancing upstream and downstream flow. However, the environmental implications, particularly on downstream water quality, have raised substantial concerns. Thus, the objectives of this study were to investigate the effects of the Bakun HEP dam operations on water quality parameters in the Rajang River. Physicochemical parameters data including pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS), were obtained NREB and DOE monitoring stations with some gaps. The statistical differences in water quality parameters before and after the Bakun Dam construction was investigated using descriptive analysis, followed by t-test or Mann-Whitney U test based on normality assessments (Anderson-Darling and Levene's tests). The findings show that, for post-construction data most of the parameters' quality is significantly improving. For instance, TSS showed a notable improvement, from >580 mg/L (Class IV/V) to <90 mg/L (Class IIA/IIB). On the other hand, controlled release data also showed good improvement of most of the parameters across the monitoring stations as compared to without controlled release. Overall, the findings suggest that the dam's operation has contributed a positive impact, especially to sediment control and oxygenation. However, continued monitoring is essential to assess long-term trends and ensure sustainable water quality management.

Keywords: Bakun Dam, Rajang River, Controlled Release Operation, Water Quality, Statistical Analysis.

Assessment of Rainfall and Water Level at Rajang River Pre- and Post-Bakun Hydroelectric Plant Construction

Rosmina A Bustami, Marjorie M L Moses, Norazlina Bateni, Darrien Y S Mah, Charles H J Bong

Abstract

This paper explores the hydrological changes within the Rajang River Basin, specifically on the variation in rainfall and water level pre- and post- Bakun Hydroelectric Plant (HEP) construction. Statistical analysis of data from rainfall and water level stations along the Rajang River reveals significant hydrological changes. Although rainfall has generally increased over time, the construction of Bakun HEP has allowed for storing excess water during heavy rain and gradual controlled release, thus contributing to the reduction of risk and severity of flooding downstream. Minimised fluctuations of water level along the Rajang River were observed albeit the changes in minimum and maximum water level. Bakun HEP was also observed in alleviating local water shortages and post construction, peak flood levels decreased, with no pronounced impact in downstream Sibuh.

Keywords: Rajang River, Rainfall, Water Level.

Development of Dam Safety Index (DSI) for Five Major Dams of Pakistan to Evaluate Dam Safety, Ensure Better Maintenance and Timely Preventive Measures

Zahid Majeed, Zia ur RehmanM, Ian Waqar Ali Shah

Abstract

Dams are critical structures which should be monitored and maintained properly to ensure their safety and efficient operation. Water and Power Development Authority (WAPDA) constructed mega dams in 1960s on major rivers of Pakistan and is also responsible for their operation and maintenance. In order to ensure safety and efficiency of the dams, Dams Safety Organization (DSO) was set up in 1973 by WAPDA. Since its inception, the DSO has been carrying out regular annual, periodic and on request inspections followed by inspection reports which are communicated to the relevant dam authorities. These inspections are carried out by a team of professionals which include engineers, geologists, seismologists and research officers. This study has been carried out for five mega dams of national importance that are Tarbela, Mangla, Warsak, Khanpur and Simly for evaluation of safety conditions using statistical weightage. Dam Safety Index (DSI) has been developed considering five fundamental parameters such as structural integrity of key components, hydraulic performance / hydrological safety, operational factors, hazard capacity and emergency action plan. Weightages were assigned to each criterion based on annual inspection reports and the knowledge / experience of professionals of DSO. Upon analysis, it has been observed that Tarbela and Mangla have secured "Good", Khanpur and Simly have secured "Satisfactory" and Warsak has secured "Poor" classification based on DSI score. This study will help the managers to formulate a better maintenance program and provide knowledge to prioritize the key areas prone to hazards.

Keywords: Dams Safety Index, Dams Safety Organization, Statistical Weightage.

Premium Advantage of a Calibrated Finite Element Model for a Dam Under Operation

S. P. Banihashemi, M.M Zakeri

Abstract

Concrete arch dams transfer most of the applied loads to the abutments due to special geometry. On the other hand, the geomechanical parameters of rock mass in the operation period will differ significantly with respect to the ones in dam design process. Knowing the characteristics of rock mass is necessary as long as evaluating the stability of dam body or even every study in which dam body is an essential element during the operating period is targeted. Performing in situ tests during operation is notoriously difficult and extremely expensive. One solution is defining rock mass geomechanical parameters based on the results of instruments. Calibrated instruments could be considered as a reference for acquiring required parameters for finite element model. In this regard a series of sensitivity analyses should be carried out in order to obtain an FEM model in which a rather well compatibility in comparison with instruments could be achieved. Dez concrete arch dam with a height of more than 200m located in south west of Iran was constructed in 1962. It has been under operation up to now. It is a vitally important structure and has a significant role in the economy of Khuzestan province. The dam possesses an innovative design so that a reinforced saddle dubbed pulvino is located all over the abutments. In order to calibrate the FEM model, a thorough model was constructed. In the model pulvino as well as contraction joints are included. In this paper the process of calibrating the Dez FEM model with the results of instruments will be presented. Dam behavior was compared with pendulum results for one year and a good compatibility was achieved.

Keywords: Dez Dam, Finite Elements Method, Model calibration, Dam Instrumentation.

Development and Analysis of Intensity-Duration-Frequency (IDF) Curves with Climate Change for Energy Facilities in Peninsular Malaysia

Nur Zafirah Zainudin, Hidayah Basri, Lariyah Mohd Sidek, Sarbani Anjang Ahmad, Noryusuhariq Mohd Yusof

Abstract

This paper presents a comprehensive analysis of Intensity-Duration-Frequency (IDF) curves for energy infrastructures in Peninsular Malaysia (PM), using the latest data from the Department of Irrigation and Drainage (DID) 2021. The study aims to establish IDF relationships that are crucial for the design and planning of energy facilities, particularly considering potential climate change impacts. IDF curves were developed for ten different durations, ranging from 0.25 to 120 hours, and for seven return periods, spanning 2 to 200 years. The analysis incorporates Climate Change Factors (CCF) based on NAHRIM's Technical Guide, which helps estimate future rainfall intensities under various climate change scenarios. The results reveal projected increases in rainfall intensity of 11% to 26% across different return periods, highlighting the necessity for updated hydrological models to adapt to evolving climate conditions. Studies have shown that rising global temperatures lead to increased water vapor in the atmosphere, intensifying precipitation and, consequently, the likelihood of flooding. Therefore, this study serves as a crucial reference for future energy infrastructure developments across Peninsular Malaysia, aiming to mitigate the risks of power cut-offs during major flooding or extreme wet seasons.

Keywords: Climate Change, Rainfall, Design Rainstorm, IDF Curves.

Floating Solar Photovoltaic Systems on Dam Reservoirs: Potential and Challenge Toward National Energy Transition Roadmap (NETR)

Mohd Aswad bin Abdol Rani, Kamaruddin Bin Abd Aziz, Mohd Rashid bin Mohd Radzi, Ismail bin Roslan

Abstract

Floating solar photovoltaic (FSPV) systems present a strategic opportunity to expand Malaysia's renewable energy portfolio by utilizing water surfaces such as hydropower reservoirs, ex-mining lakes, water supply dams, and flood retention ponds. Unlike ground-mounted PV systems, FSPV offers benefits such as reduced land-use conflict, enhanced system performance due to natural cooling, and synergy with existing hydropower and utility infrastructure. In Southeast Asia, several countries including Thailand, Singapore, and Indonesia have implemented large-scale FSPV projects. Malaysia has also made notable progress, with operational projects at Danau Tok Uban, Rawang, and Batang Ai, and upcoming initiatives under the Large-Scale Solar (LSS) and Corporate Green Power Program (CGPP). This paper reviews the current status, technical considerations, environmental implications, and policy alignment of FSPV deployment in Malaysia. The analysis highlights the untapped potential of Malaysia's water reservoirs and recommends strategic actions for optimizing FSPV adoption to support the National Energy Transition Roadmap (NETR) goal of achieving a 70% renewable energy mix by 2050.

Keywords: Floating solar photovoltaic, Malaysia's Reservoir, NETR.

Prediction of Water Level using Machine Learning Techniques: Batu Dam as Case Study

Saad Sh. Sammen, Lariyah M. Sidek, Nisreen Jawad Rasheed

Abstract

The main objective of this research is to assess the performance of machine learning methods in predicting the reservoir water level at Batu Dam, which is located at Gombak, Selangor in Malaysia. Two different machine learning techniques have been used, including Artificial Neural Network (ANN) and Random Forest (RF). Hydrological data, including water level and rainfall data for the period from 2000 to 2021, are used to develop the machine learning models. According to different input combinations, four machine learning models are developed, including ANN1 and RF1, which use lagged water level data as input, while the other models, ANN2 and RF2, use lagged water level and rainfall data as inputs. Performance evaluation of the developed models was conducted using different statistical indices such as RMSE, R², MSE, IOD, and KGE. The results indicate that the best performance has been obtained by the ANN2 model, with a highest value of R² of 0.978 and a lower value of RMSE of 0.339. The worst result was obtained when the RF1 model is used. In summary, this research proves the ability of ANN models for water level estimation and it could be used for other hydrological applications.

Keywords: Water level, Machine Learning, Batu Dam, Artificial Neural Network, Rainfall.

Development of Emergency Action Plan for Paya Peda Dam Using IR4.0 Technologies

H.S. Cheok, O.C.L. Aaron, Zakiyyah Muhammad, Mohd Hazri Moh Khambali, Asmadi Ahmad, Wan Hazdy Azad, Abdul Halim Abdul Aziz, Aliya Mhd Zahir

Abstract

The primary objective of this study was to develop a comprehensive and innovative Emergency Action Plan (EAP) for the Paya Peda Dam, aimed at mitigating critical risks to downstream communities. This was achieved by generating detailed flood inundation simulations and a thorough impact assessment on population and infrastructure, leveraging advanced digital technologies such as a geospatial data management system (GIS) and a sophisticated catchment-wide 1D/2D hydrodynamic model. Based on these findings, an innovative EAP was developed in accordance with national guidelines, introducing the concept of assembly points to supplement the insufficient capacity of conventional evacuation centers. The project culminated in stakeholder workshops and a tabletop exercise. These integrated engagements were instrumental in raising the awareness and preparedness of various agencies, providing a robust framework for disaster management and ultimately contributing to the enhanced safety of the public.

Keywords: Emergency Action Plan, Catchment-Wide Hydrology and Hydrodynamic Modelling, IR4.0 Technologies.

NucleaRace: A STEM Outreach Initiative Promoting Radiation Awareness Near Hydro Dams

Nuraslinda Anuar, Ang Wei Eng, Rogemah Ramli, Mohd Syukri Yahya

Abstract

There is limited empirical evidence on how game-based STEM outreach can influence nuclear energy awareness in rural and semi-rural communities near hydro dams, despite the strategic importance of promoting clean energy literacy in Malaysia. This study evaluates NucleaRace, an interactive, checkpoint-based competition designed under the Ministry of Higher Education (MOHE) Translational Community Grant to empower youth, bridge knowledge gaps, and strengthen STEM skills. The program was delivered to students from SMK Kampung Raja and SMK Sultan Ahmad Shah, each completing a ten-statement post-activity Likert-scale survey. Responses were analyzed using filtered respondents and pairwise deletion methods, with descriptive statistics, Cronbach's alpha, and Welch's t-tests assessing internal reliability and inter-school differences. Results revealed consistently high mean ratings (>4.0) for most statements, indicating strong engagement and learning impact across both schools. Significant differences emerged for three items—perceived interactivity, change in perception of nuclear radiation, and awareness of nuclear safety—where SMK Kampung Raja reported higher scores. Cronbach's alpha indicated strong internal consistency for SMK Kampung Raja with $\alpha = 0.794$. The lower internal reliability with $\alpha = 0.687$ for SMK Sultan Ahmad Shah suggests opportunities for improvement in future program implementation. Overall, the findings confirm the effectiveness of NucleaRace as a tool to promote nuclear energy understanding and STEM engagement, while highlighting areas for targeted program refinement to ensure equitable impact across diverse educational contexts.

Keywords: Nuclear Literacy, Hydro Dam Community, STEM Outreach.

Challenging Decision of Base Soil Selection from Variable Earthfill Materials in Alluvial Flood Plain – Implications to Dam Safety

Aqsa Bukhari, Zaheer Muhammad Malik

Abstract

Pakistan is facing unprecedented problems of water management amid the climate change crisis. This article proposes a state-of-the-art solution in terms of creating inland reservoirs along the alluvial flood plains of the Indus and Chenab rivers. The present dyke's infrastructure in Pakistan is already facing problems due to geotechnical design discrepancies. This necessitates the selection of materials that not only provide adequate protection against failure but are also easily available during the construction process. In view of this aspect, this case study indicates the availability of appropriate construction materials at three different locations within the proposed project vicinity, i.e., across the river and along the right and left banks in the flood plain of the Chenab. A preliminary scrutiny revealed the presence of clayey silt and silty sand as the two principal base soil materials available in the borrow areas, which may be used for the construction of the main body of the embankment. Since filter design in the embankment is sensitive to the selected base soil, the following three options for the filter design were analyzed using the latest provisions of USBR, considering a) individual gradation envelopes of clayey silt as base soil, b) individual gradation envelopes of silty sand as base soil, c) grouping the gradation plots of clayey silt and silty sand into a single base soil envelope. The studies and evaluations have grossly indicated that the filter gradation developed for all three cases does not show significant variation, thus putting weightage on the actual filter design over the base soil classification. Therefore, the available base soils have been bracketed into a single category for the design of a filter for the embankment. This paper also discusses the background studies, the reasons adopted for this approach in detail, and recommends using the average gradation curve of the base soil for filter design in such design scenarios.

Keywords: Filter Design, Base Soil, Dykes, Embankments.

Seepage Problems in Downstream Face of Earthfill Embankment Dams, Causes and Proposed Solutions

Sheikh Ahmad Fahan bin Kamal Hazari, Zulkefli bin Mustaffa, Lariyah binti Mohd Sidek

Abstract

Excessive seepage through earthfill embankment dams can lead to internal erosion (piping) and instability if not adequately controlled. This paper presents a combined technical review and case study examining seepage mechanisms, failure modes, and mitigation strategies in embankment dams. The review identifies key causes of problematic seepage, including cracking in an impermeable core, defects in seepage barriers (e.g. cutoff walls or liners), and deficiencies in drainage and filter design. Such factors create preferential leakage paths or elevate the phreatic surface, increasing the risk of erosion and slope failure. Effective seepage control measures – notably properly graded filter zones (chimney and blanket drains, toe drains, filter diaphragms) and impermeable barriers – are discussed in terms of their function in allowing safe seepage discharge while retaining soil. Filter and drainage design issues (like clogging or incompatibility) are highlighted as critical considerations, as inadequate drainage can raise pore pressures to unsafe levels. The paper's case study of the Semenyih Dam in Selangor, Malaysia, exemplifies these concepts. Inspection of this dam's downstream face revealed persistent wet spots and cracking indicative of uncontrolled seepage, prompting remediation. An engineering intervention was proposed: replacing the deteriorated slope protection with a weighted rockfill filter (graded riprap underlain by geotextile) to permit free seepage exit and relieve pressure. This combined study underlines the importance of robust, integrated filter-and-drain systems and early detection of seepage signs to safeguard embankment dam integrity.

Keywords: Seepage, Earthfill Embankment Dam, Downstream Face.

Integrated Water Resources Management in Sarawak's Hydropower Catchments: Insights from the Murum, Bakun, and Batang Ai Hydropower Plants

Joan Alicia Joseph Blandoi, Joyce Janggu

Abstract

Integrated Water Resources Management (IWRM) is a globally recognised framework promoting for sustainable and coordinate water governance, particularly in complex multi-user river basins. In Sarawak, the state's increasing demand of energy has been predominantly supported by renewable energy (RE) from large-scale hydropower development evident by the Batang Ai, Bakun and Murum Hydroelectric Plants currently in operation. With the upcoming Boleh Hydroelectric Project and Sarawak's latest policy to develop smaller-scale cascading power sources (CPS), the integration of IWRM principles into hydropower catchment management becomes both timely and essential. This paper examines the application of IWRM principle, specifically Pillar A (Enabling Environment) and Pillar C (Management Instruments), within the context of Sarawak's major hydropower catchments. Adopting a qualitative, case-based approach, the paper draws on Sarawak Energy's operational experience to assess relevant policies, legal frameworks, and institutional arrangements. The paper further identifies practical challenges related to land use governance, environmental flow regulation, inter-agency coordination, and data management. By benchmarking local practices against regional and international examples (e.g., Mekong and Zambezi River basins), the paper provides insights into opportunities for improving integrated catchment governance. The findings aim to support informed policy direction and planning efforts, aligning hydropower development with long-term sustainability objectives for tropical river systems.

Keywords: Integrated Water Resources Management (IWRM), Hydropower, Catchment, Water Governance.

Dam Safety Management – Instrumentation System Monitoring at Bakun Hydroelectric Plant in Sarawak, Malaysia

Jonathan Kung Yew Tiong, Tiew Whong Ting

Abstract

Bakun dam is part of Bakun Hydroelectric Plant, which is a monumental hydroelectric project in Malaysia and representing a crucial pillar of the nation's energy infrastructure. To ensure robustness and integrity, the performance of Bakun dam is examined through a comprehensive analysis of instrumentation systems. This includes geotechnical sensors, structural health monitoring devices, and hydrological instrumentation. This paper will focus specifically on the instrumental techniques employed to monitor its structural integrity, discussing their efficacy in providing informative data on dam behaviours, foundation stability, and reservoir dynamics. The findings will provide comprehensive insights into the Bakun dam's operational performance and resilience, facilitating the implementation of proactive strategies to strengthen the structure. The results of this analysis contribute meaningfully to dam safety performance management and impart valuable guidance for the sustainable operation of large-scale hydroelectric infrastructure globally.

Keywords: Performance Of Bakun Dam, Instrumental Techniques, Dam Behaviours, Foundation Stability, Reservoir Dynamics.

Machine Learning-Based Short-Term Multi-Step Forecasting of Reservoir Water Levels at Batang Ai HEP Using XGBoost with Operational Input

Chris Aaron Anak Winston

Abstract

Accurate short-term reservoir water level forecasting is critical for the efficient operation of hydropower plants. This study applies a machine learning approach – Extreme Gradient Boosting (XGBoost) – to forecast daily reservoir water levels for 1 to 7 days ahead specifically on the Batang Ai Hydroelectric Project (HEP) in Sarawak, Malaysia. The model utilises autoregressive lag features of water level and inflow from the past seven days, along with known hydropower generation values for the upcoming seven days as predictors. Historical data from 2004 to 2020 was used for training, while the model was tested on data from 2021 to 2024 using a rolling weekly forecast method. Results show consistently high forecasting performance, with R^2 values exceeding 0.98 for all horizons and increasing forecast error with lead time. Forecast performance was evaluated across multiple weeks, indicating model stability and sensitivity to hydrological conditions. The study highlights the practical potential of machine learning for short-term reservoir forecasting at Batang Ai HEP and supports its integration into generation planning and hydropower decision-making.

Keywords: Batang Ai HEP, Reservoir Water Level, Hydrology, Forecasting, Xgboost, Machine Learning, Artificial Intelligence.

Seismic Vulnerability of Murum Dam: Analyzing Spillway and Penstock Performance under Earthquake Loads

Imtiyaz Akbar Najar, Raudhah Ahmadi, Rosmina Ahmad Bustami, Mohd Shazwan Bin Mohamad Aziz, Bilal Ahmad Najar, Dayang Siti Afiqah Abang Kamarud-din, Azira Taip

Abstract

The seismic performance of critical dam structures, such as spillways and penstocks, is vital for ensuring the safety and functionality of hydropower infrastructure, particularly in earthquake-prone regions. This study investigates the seismic response of the Murum Dam's spillway and penstock in Malaysia using a 3D nonlinear finite element method in ABAQUS software. The analysis incorporates three levels of Peak Ground Acceleration (PGA) 0.05g, 0.15g, and 0.25g, based on Cekmece earthquake data to evaluate structural behavior under seismic loads. Results reveal that higher PGA levels significantly increase displacement, stress, and strain responses, with the penstock experiencing a maximum displacement of 670.895 mm and stress reaching 2984.140 MPa at 0.25g. Similarly, the spillway shows heightened vulnerability, with displacement peaking at 654.305 mm under the same conditions. The findings indicate that both structures are prone to failure at PGAs exceeding 0.1g, emphasizing the need for enhanced seismic design considerations. The study underscores the importance of precise modeling, including material properties and reinforcement details, to improve accuracy in future assessments. These insights contribute to the broader understanding of dam resilience in seismically active regions and provide actionable recommendations for mitigating catastrophic failures in critical hydropower infrastructure.

Keywords: Dam, Earthquake, Penstock, Seismic, Spillway.

Beyond the Crest: Assessing Bakun Dam's Resilience to Future 1-in-50 and 1-in-100 AEP Events

Jerry Betie Chin Timothy Asson

Abstract

Climate change is exacerbating extreme rainfall events in tropical regions, including Sarawak, Malaysia, which raises concerns regarding the sufficiency of dam safety infrastructure. This study evaluates the adequacy of freeboard and the capacity of the spillway for the Bakun Dam, the tallest dam in Malaysia at 205 metres, under climate-adjusted storm events with 1-in-50 and 1-in-100 Annual Exceedance Probability (AEP). Rainfall projections from CMIP5 climate models under RCP 4.5 and RCP 8.5 scenarios were utilised, and statistical analyses using Log-Pearson Type III distributions were conducted to estimate future peak rainfall. The estimates were utilised in RORB runoff routing and GeoHECRAS flood routing models to ascertain inflow hydrographs, peak discharge, and maximum reservoir levels. The results demonstrate that peak rainfall and discharge are expected to rise by as much as 27% and 31%, respectively, by the conclusion of the 21st century. However, Bakun Dam upholds a conservative freeboard of 6.92–6.96 metres across all scenarios, significantly exceeding the thresholds advised by ICOLD, ANCOLD, and MYDAMS. Simulated peak spillway discharges are consistently below 1.5% of the design capacity (15,000m³/s), validating the spillway's significant surplus capacity. The findings highlight Bakun's structural resilience while suggesting further analysis of Probable Maximum Precipitation (PMP) and Probable Maximum Flood (PMF) scenarios to improve future preparedness. This study provides essential insights for Sarawak Energy Berhad and the Sarawak State Disaster Management Committee. It emphasises the necessity for regular climate-informed dam safety reassessments to maintain long-term infrastructure integrity and mitigate downstream risks.

Keywords: Climate Change, Extreme Rainfall, Dam Safety, Bakun Dam, Sarawak.

Operation, Maintenance and Emergency Management at Sultan Ismail Petra Pergau Power Station: A review

Ganesh Rao, Shamsul Amri Sulaiman

Abstract

The Kuala Yong Dam, located on the Pergau River in Kelantan, Malaysia, is one of the nation's largest hydropower assets, supplying up to 600 MW through the Sultan Ismail Petra Pergau Power Station. The dam's gross storage capacity of 53.5 million m³ at full supply level (636 m) is sustained by dual inflows: approximately 69% from a 24 km aqueduct tunnel fed by the Terang Pump Station and six tributary intakes, and 31% from the Sungai Pergau catchment. Water is transported from the reservoir via a high-pressure headrace tunnel system to an underground powerhouse housing four 150 MW Francis turbines, prior to discharge to a reregulation pond for controlled downstream release. This paper explores the operational framework, maintenance strategies, and emergency management systems that ensure sustained performance, structural integrity, and public safety. Maintenance practices, aligned with the Malaysia Dam Safety Management Guidelines (MyDAMS), encompass comprehensive inspections, instrumentation monitoring, and preventive rehabilitation works for key components, including the dam embankment, powerhouse, aqueduct tunnel, and ancillary structures. Case studies, such as the rehabilitation of the aqueduct tunnel and seepage control in the powerhouse cavern, illustrate proactive asset management. The station's Dam Safety Emergency Response Plan (DSERP) integrates hazard detection, alert protocols, and inter-agency coordination to mitigate risks from hydrological fluctuations, with a detailed account of a 2023 flood-level fluctuation event provided. These findings highlight the importance of integrating robust engineering design with adaptive operation, rigorous surveillance, and effective emergency preparedness to ensure long-term safety, efficiency, and sustainability of large-scale hydropower infrastructure.

Keywords: Kuala Yong Dam, Pergau Hydropower, Operation and Maintenance, Dam Safety, Emergency Management, Malaysia.

Fine Content Effects on the Stability and Compaction Behavior of Hydraulic Fills in Sustainable Dam Engineering

Khairul Bashar Khan, Lariyah Mohd Sidek, Hidayah Basri, Mohamed Ahmed Hafez Ahmed

Abstract

Hydraulic fill materials are increasingly used in the construction, rehabilitation, and maintenance of earth dams and embankments, where compaction performance and material stability are critical to long-term structural integrity. Among the governing factors, the influence of fine content on the density and compaction behavior of hydraulic fills remains insufficiently quantified, especially in the context of dam safety. This study investigates the impact of varying fine content on the density characteristics of sand-based hydraulic fills through a series of controlled laboratory experiments. Sand samples from Sylhet (coarse) and Munshiganj (fine), blended with clay fines from Dhaka, were prepared with fines content ranging from 0% to 25%. Simulated hydraulic placement using a deposition tank and controlled drainage was employed to replicate field-like conditions. Results reveal a dual behavioral pattern: moderate fines (up to ~10%) enhance packing and compaction, while excessive fines promote bulking and reduce relative density, potentially compromising fill stability. These findings provide actionable insights for optimizing fill composition in dam embankment design, with implications for reducing internal erosion, improving slope stability, and supporting sustainable dam infrastructure under variable climatic and sedimentary conditions.

Keywords: Hydraulic Fill, Fine Content, Relative Density, Dam Embankment, Compaction Behavior, Sustainable Dam Engineering.

A Comparative Review of Statistical and Machine Learning Models in Dam Behavior Evaluation and Monitoring

Nur Aliesya Binti Mohd Azmi, Lariyah Mohd Sidek, Hidayah Basri, Syahida Farhan Azha, Nur Farazuien Md Said

Abstract

Dam safety is a critical component of infrastructure management, requiring continuous monitoring to prevent catastrophic failures. This review explores the application of statistical and machine learning models in evaluating and monitoring dam behavior with a focus on seepage and deformation. Statistical models provide foundational insights through trend analysis and parameter relationships, while machine learning models excel in predictive accuracy and handling complex and non-linear data. By comparing these approaches, this paper highlights their strength, limitation and potential synergies providing a roadmap for researchers and practitioners to enhance dam safety.

Keywords: Dam Safety, Statistical Model, Machine Learning Model.

Assessing Biodiversity Offset in Malaysian Hydropower: A Conceptual Indicator Framework for Dam Projects

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Abstract

Hydropower projects pose significant risks to biodiversity through habitat loss, river fragmentation, and altered flow regimes. While such projects are central to Malaysia's renewable energy ambitions, they can undermine ecological integrity if not carefully managed. Biodiversity offsets, when properly designed and implemented, offer a last-resort mechanism to achieve No Net Loss (NNL) or even Net Gain (NG) of ecological values. In Malaysia, the National Policy on Biological Diversity 2016–2025 explicitly endorses NNL, but offset mechanisms, particularly in the hydropower sector, remain underdeveloped and lack consistent monitoring standards. International frameworks such as the International Finance Corporation (IFC) Performance Standard 6 and the Business and Biodiversity Offsets Program (BBOP) highlight the importance of clear indicators for measuring offset effectiveness. However, Malaysia's Environmental Impact Assessment (EIA) practice still relies heavily on descriptive reporting rather than measurable outcomes. This concept paper reviews existing international and domestic indicator systems, identifies critical gaps in their application to dam development, and proposes a comprehensive set of potential indicators across ecological, design, governance, and social domains. The proposed framework provides a roadmap for researchers, regulators, and project developers, enabling future empirical testing and integration into Malaysia's EIA governance to strengthen accountability and enhance ecological credibility of offsets.

Keywords: Biodiversity Offsets, No Net Loss, Hydropower Dams, Governance.

Tourism Prospects for Large Dam Farming Communities in Cameron Highlands, Malaysia

Zuraidah Ali, Izzaamirah Ishak, Lariyah Mohd Sidek, Nursyahida Farhan, Hidayah Basri, Nur Farah Shazana Rashidi

Abstract

This study examines the prospects of farm tourism among farming communities in Cameron Highlands, Malaysia, where large dams support both hydropower and intensive agriculture. A structured survey was conducted to assess farmer readiness and willingness to integrate tourism-related activities into their livelihoods. Exploratory factor analysis confirmed the validity of four attitudinal constructs namely perception of tourism, general attitudes toward tourists, destination image, and perceived benefits that supported by acceptable KMO values (.694–.769) and high internal reliability ($\alpha = .729-.883$). Descriptive findings indicate a discrepancy between positive attitudes and behavioral intentions, with 77% of farmers unwilling to host visitors despite 83% recognizing farm tourism potential. Correlational analysis revealed a significant positive association ($r = .367, p < .05$) between farming experience and willingness to participate. These results suggest latent opportunities for agro-educational tourism but highlight infrastructural and sustainability constraints. The study recommends targeted interventions for farm tourism among the farming community for more sustainable livelihood and tourism diversity in the highland attraction.

Keywords: Dam Communities, Farm Tourism, Cameron Highlands.

Geo-Resistivity Monitoring and FLAC2D Modelling for Landslide Risk Management in Slope-Prone Terrains

Nur Salina Rosli, Rohayu Che Omar, Nor Hazwani, Nor Khalid, Amina Hanna Zainal Abidin, Warishah Abdul Wahab, Azizul Hasani Abd. Rahman, Rasidi Yamin, Yin Jeh Ngui, Marcus Dobbs

Abstract

This paper presents the application of the PROactive Infrastructure Monitoring and Evaluation (PRIME) system for real-time subsurface profiling and landslide risk management at the Sultan Mahmud Power Station, Kenyir, Terengganu, a site characterized by steep granitic slopes prone to recurrent failures. Borehole investigations identified a stratified soil–rock profile consisting loose sandy silt and medium stiff sandy silt overlying weathered granite, underlain by intact granite at depth. PRIME resistivity monitoring, supported by ResIPY inversion, delineated low-resistivity zones linked to moisture accumulation in weak soils and highly weathered granite. These anomalies correlated with FLAC2D numerical modelling, which predicted displacement and Factor of Safety (FoS) reduction along the soil–weathered granite transition and highlighted the slope toe as a critical stress zone. The integrated results confirm that slope instability is governed by subsurface heterogeneity and rainfall-driven moisture infiltration, with the soil–granite interface acting as the dominant slip surface. The convergence of field data, geophysical imaging, and numerical simulations provides a strong basis for slope health assessment and predictive analysis. Engineering implications emphasize the need for drainage and toe reinforcement, while continuous PRIME monitoring enhances early-warning capability by tracking subsurface conditions against simulated thresholds. This study demonstrates that coupling geophysical monitoring with numerical modelling offers a robust framework for early warning, proactive risk management, and hydropower infrastructure resilience. Future work will involve calibrating rainfall thresholds and extending the workflow to debris flow simulations, moving towards real-time, risk-informed slope management in landslide-prone terrains.

Keywords: Geophysical Monitoring, Landslide Risk Management, Hydropower Infrastructure.

Bio-VeGeGrout: A Biocement-Based Enhancer for Soil Strength Improvement

Wan Aisyah Fadilah Wae AbdulKadir, Rohayu Che Omar, Farah 'Atiqah Abdul Azam

Abstract

This paper investigates the feasibility of utilizing vegetable waste, termed Bio-VeGeGrout (BVG), as a sustainable material for bio-cementation. Bio-cementation has been proposed as an eco-friendly ground improvement technique that enhances soil stability, mitigates erosion, and encapsulates waste, providing a greener alternative to conventional chemical stabilizers. In this study, BVG was prepared with different fermentation period and applied to soil collected from Simpang Pulai to evaluate its potential for soil strength improvement. Unconfined compressive strength (UCS) tests showed marked differences among soils treated with 20% BVG. The soil using 30 days fermentation period of BVG exhibited the highest improvement, reaching 15.63 MPa, compared with raw, 21 days and 35 days, which recorded only 0.00 MPa, 7.32 MPa and 7.24 MPa, respectively. Scanning electron microscope (SEM) analysis showed the characteristic morphological changes in BVG-treated soils. These results suggest that BVG offers significant promise as a bio-based, sustainable solution for strengthening problematic soils, with broader implications for environmental and geotechnical engineering.

Keywords: Vegetable Waste, Bio-Cementation, Soil Strength.

Enhancing Social Awareness and Resilience of Dam- Adjacent Communities in Cameron Highlands through Disaster Interactive Games (DIG)

Izyan Fadillah Che Malid, Rohayu Che Omar, Farah 'Atiqah Abdul Azam, Wan Aisyah Fadillah, Warishah Abdul Wahab, Zakaria Mohammed

Abstract

Dam-adjacent communities in Cameron Highlands face cascading hazards, including dam-break floods, rainfall-induced landslides, and flash floods. These risks are intensified by steep topography, high rainfall, and expanding settlements, leaving local populations highly vulnerable. Conventional awareness strategies as pamphlets, talks, siren alerts, and occasional drills often fail to sustain engagement or build the decision-making capacity required for sudden-onset emergencies. This study introduces Disaster Interactive Games (DIG) as an innovative approach to strengthen disaster awareness and resilience in dam break prone areas. Grounded in gamification principles, DIG integrates participatory mapping, scenario-based learning, role-play, and risk visualization to transform technical hazard information into interactive, community-centered experiences. A pilot was conducted near the Sultan Abu Bakar (SAB) Dam, engaging farmers, residents, students, and disaster management volunteers from Ringlet, Habu, and Kg Raja. Evaluation involved pre- and post-game surveys and focus group discussions to measure engagement, knowledge retention, and preparedness intent. DIG achieved strong community engagement, with more than 85% of participants rating the games as more engaging than conventional methods. Post-game surveys revealed an 80% improvement in knowledge retention, especially in recalling evacuation routes, hazard zones, and warning signals. Community feedback underscored the importance of localized scenarios, such as landslides blocking access roads or sudden dam releases affecting farms, which participants described as relatable and trustworthy. DIG strengthens community resilience by linking hazard knowledge with practical drills, supporting Malaysia's Disaster Risk Reduction Policy and the Sendai Framework as a scalable, participatory, and replicable tool for disaster preparedness.

Keywords: Disaster Interactive Games (DIG), Gamification, Dam Safety, Community Resilience, Disaster Risk Reduction (DRR).

Landslide Threat Assessment of Transmission Towers in Hilly Terrain

W. A. Wahab, R. C. Omar, K. K. Joo, N. S. Rosli, N. A. Zarime

Abstract

Transmission towers situated in hilly terrain are highly vulnerable to landslides, which pose significant risks to power infrastructure and energy security. This study assessed the susceptibility and risk of 28 transmission towers located within a landslide-prone corridor in Malaysia. A combined approach integrating landslide susceptibility mapping, hazard classification, vulnerability analysis, and exposure assessment was employed using geographic information systems (GIS). Landslide susceptibility was derived from terrain parameters, geological conditions, and rainfall intensity, and subsequently classified into hazard levels ranging from very low to very high. Each transmission tower leg was spatially intersected with these hazard zones to determine exposure. Vulnerability was defined using a binary framework: towers were considered fully vulnerable if at least one leg intersected hazard classes ≥ 4 , and non-vulnerable if all legs were located within hazard classes ≤ 3 . Final risk classification revealed that 18 towers (64.3%) were categorized as No Loss, while 10 towers (35.7%) were classified as Total Loss. The findings emphasize the importance of susceptibility-based monitoring for risk-informed management of energy infrastructure.

Keywords: Landslide threat assessment, Transmission towers, Susceptibility and hazard mapping, Vulnerability analysis, Slope instability.

Integrated IMRS- Geophysics- Modelling Approach for Resilient Slope Management and Disaster Risk Reduction

Amina Hanna, Rohayu Che Omar, Badariah Solemon, Nor Hazwani Nor Khalid, Rasyikin Roslan.

Abstract

This study advances slope health assessment by integrating the Innovative Monitoring Rating System (IMRS) with geophysical surveys, geotechnical investigations, and numerical stability modelling. Three representative slopes, Slope 6, Slope 10, and Slope 32 along the Segari - Ayer Tawar transmission corridor in Perak, Malaysia, were selected as case studies. Although each was categorized as “moderate potential” by IMRS, detailed analyses revealed contrasting instability mechanisms and risk levels. Slope 6 reflects a historically unstable but partially managed slope. Resistivity (110 - 2800 Ω m) and seismic velocities (220 - 800 m/s) indicated sandy clay over weathered granite with shallow groundwater (~5 m). Geotechnical tests confirmed low shear strength ($c' = 0 - 5.25$ kN/m²; $\phi' = 21^\circ - 23^\circ$), with Factors of Safety (FOS) of 1.1 - 1.25, indicating marginal stability despite remedial works. Slope 10 represents a critically unstable slope, with fractured granite, clogged drains, and negligible cohesion ($c' \approx 0$) yielding an extremely low FOS of 0.358. Field evidence of a 26 - 36 m² plane failure directly impacting tower foundations confirms urgent structural risk. Slope 32 demonstrates latent instability, where gravelly clay soils of poor strength ($c' = 0 - 10$ kN/m²; $\phi' = 18^\circ - 21^\circ$), perched groundwater, and very low resistivity (3 - 143 Ω m) produced an FOS of 0.634. Tension cracks and shallow slumping suggest incipient circular failure. The findings highlight IMRS as an effective first-tier screening tool but emphasize the necessity of integrating geophysics and modelling to differentiate managed, progressive, and latent instability. Globally, this integrated approach aligns with the Sendai Framework (2015 - 2030) and SDGs 9, 11, and 13, providing a replicable model for resilient infrastructure management. Enhance drainage and monitoring at Slope 6, implement urgent stabilization at Slope 10, and apply preventive measures at Slope 32. Embedding such integrated methods into transmission corridor policies ensures proactive risk reduction and climate-resilient asset management.

Keywords: Disaster Risk Reduction, Infrastructure Resilience, Geophysics, Factors Of Safety, Preventive Slope Management.

Bio-Vege-Grout Card Game – Protect Slopes, Safe Community

Muhammad Shukri Mohamed Shariff, Rohayu Che Omar, Farah 'Atiqah Abdul Azam, Nor Hazwani Nor Khali, Warishah Abdul Wahab

Abstract

This paper presents the Bio-Vege-Grout Card Game – Protect Slopes, Safe Community, developed under the CERUN HEROES initiative as an innovative participatory platform for enhancing slope awareness, geohazard preparedness, and sustainable community-based learning. Designed by the Institute of Energy Infrastructure (IEI), Universiti Tenaga Nasional, the game transforms complex geotechnical and bioengineering concepts into an engaging, visual, and interactive educational tool. It integrates three foundational principles engineering simplification, nature-based learning, and participatory awareness to promote intuitive understanding of slope stability, hydrological behavior, and eco-engineering practices. The methodology is implemented through four structured phases: observation, planning, hazard test, and reflection. Participants use engineering, nature based, awareness, hazard, and impact cards to design and evaluate slope stabilization strategies under simulated environmental conditions. The field application at Gunung Jerai, Kedah, involved ten community groups representing local stakeholders. Performance evaluation based on four parameters stability, sustainability, cost efficiency, and community involvement produced total scores ranging from 12 to 19, with an average of 15.3 out of 20, reflecting moderate-to-high community integrated resilience. Results showed that teams combining engineering and ecological strategies achieved the highest performance, displaying enhanced slope literacy, adaptability, and collaboration. Participants demonstrated stronger comprehension of slope processes, ecosystem-based management, and sustainable maintenance approaches. Overall, the Bio-Vege-Grout Card Game - Protect Slopes, Safe Community successfully bridges scientific knowledge with community action, offering a replicable and scalable model for disaster risk reduction (DRR), climate resilience, and sustainable slope management in Malaysia's high-risk terrain.

Keywords: Card Game, Slope Management, Nature-Based Solutions, Disaster Risk Reduction, Community Resilience, Sustainable Engineering Education.

Numerical Assessment of Slope Instability Adjacent to Tidal Gate Structures in the Northern Region of Peninsular Malaysia under Transient Seepage Conditions

Ahmad Luqman bin Mohd Salehuddin, Zulkefli bin Mustafa, Lariyah binti Moh Sidek

Abstract

Riverbank and slope stability adjacent to hydraulic structures remains a critical factor in safeguarding their long-term performance, particularly in tropical environments where rainfall intensity, tidal fluctuations, and soil heterogeneity converge to create highly variable loading conditions. This paper documents field observations of slope and riverbank damage at a tidal gate structure located in an alluvial channel. The damage was manifested as bank erosion, localized slope failures, and progressive loss of fill material, all of which threatened the integrity of the ancillary channel as well as operational efficiency of the hydraulic structure. The root causes were identified as a combination of hydraulic and geotechnical mechanisms: (i) toe erosion and scour due to high-velocity flows and tidal currents, (ii) reduction in soil shear strength resulting from repeated saturation of compacted fill, and (iii) internal erosion pathways arising from poorly graded material and insufficient filter protection. These factors were exacerbated by the absence of subsoil drainage and inadequate slope geometry relative to the shear strength of the existing fill. To address these challenges, an integrated protection system was proposed. The design combined hydraulic countermeasures, including riprap toe aprons and gabion mattresses for scour resistance, with geotechnical enhancements such as properly graded filters, subsoil drains, and geogrid reinforcement of compacted fill. Vegetative surface protection was introduced in low-energy zones to achieve long-term stability with ecological benefits. The proposed measures are discussed in terms of design principles, constructability, and long-term monitoring strategies. Lessons learned from this study are transferable to other tidal and riverine hydraulic structures where ancillary slope instability could compromise primary safety functions.

Keywords: Slope instability, Riverbank, Tidal Gate.

An Integrated Multi-Sensor Approach for Slope Monitoring and Its Application to Dam Safety

N.H.N. Khalid, R.C. Omar, F.Usman, B.Solemon

Abstract

This paper presents the application of an integrated multi-sensor monitoring system implemented at the high-risk slopes located in Cameron Highlands, Malaysia. The method combines geophysical, geological, and Internet-of-Things (IoT) to provide continuous, real-time monitoring and early warning of potential slope instabilities (landslides). Subsurface characterization was first conducted using electrical resistivity and seismic profiling to identify weak zones and groundwater pathways. The identified areas were then installed with triaxial tilt sensors, soil moisture probes, and rain gauges, and then linked to a server via 4G gateways. The server received real-time data every 30 minutes, which is integrated with threshold values to automatically send an alert if the slope reaches the threshold, especially during critical rainfall events. The field monitoring results demonstrated a strong correlation between rainfall intensity and tilt movement, confirming the system's sensitivity in detecting slope movement. Within 10 months of continuous monitoring, a slope movement was detected, the affected area was successfully identified, and the management was promptly informed of the condition. This proves the operational reliability of IoT-based monitoring compared to conventional manual inspections for monitoring slopes around dam reservoirs.

Keywords: Landslide, Slope Movement, Real-Time Monitoring, Slope Sensor.

What's Up with this Contractor?

Darren George Protulipac

Abstract

Selecting the right contractor should remain a critical factor in planning for the successful execution of a dam construction or dam upgrade project. Greenfield and brownfield dam sites can sometimes exude a surprise or two, with new sites often presenting foundation challenges, while upgrades of existing dams often suffering with incomplete as-built records, or a non-existent project completion report, thereby revealing their own surprises. So be aware - remain on guard when preparing to select a contractor, e.g., watch for strengths and weaknesses and their capacity to address a surprise or two. This paper explores contractor selection strategies through the lens of personal experience, focusing on some key decision-making criteria such as technical capability, safety culture, communication, and past performance. Drawing from real-world dam construction and safety projects, the paper highlights lessons learned, common pitfalls, and best practices that can (hopefully) guide project owners and engineers in choosing reliable contractors. Items discussed include procurement methods, bid evaluation, stakeholder engagement, and quality assurance. By sharing practical insights, this paper aims to contribute to safer, more efficient dam infrastructure development, while at the same time it tries to reduce risk (of cost overruns).

Keywords: Procurement, Contractors, Risks, Project Delivery, Contract Form.

CFD-Based Investigation of Flow Dynamics of Pergau Dam Spillway

N. H. Hassan, M. H. Zawawi, M. R. M. Radzi, M. A. Abas, M. R. R. M. A. Zainol, Hayana Dullah

Abstract

Dams play a vital role in water resources management, hydropower generation and flood control. Among their critical components, spillways ensure the safe release of excess water during flood events, thereby protecting the dam structure and downstream communities. This study focuses on the hydraulic and structural performance of the Pergau Dam spillway, a chute-type structure located in Kelantan, Malaysia. The main objective is to evaluate the flow behavior, pressure distribution and structural response of the spillway under varying reservoir levels using integrated numerical modeling. A three-dimensional computational fluid dynamics (CFD) model was developed to simulate water flow characteristics at two reservoir levels which are 638 m and 641 m representing normal and near-maximum operating conditions. The numerical model employed the volume of fluid (VOF) method to capture the air and water interface, while the $k-\epsilon$ turbulence model was used to simulate turbulent flow conditions. A mesh independence test was performed to ensure numerical reliability and stability. The CFD results indicated a well-distributed pressure profile along the spillway chute walls, with localized high-velocity zones and turbulence detected near the stilling basin at higher water levels. The study concludes that the Pergau Dam spillway operates efficiently under the analyzed conditions but recommends future research to include validation with physical model data, extreme flood scenarios and cavitation analysis for enhanced reliability and design optimization.

Keywords: Computational Fluid Dynamics (CFD), Spillway Analysis, Dam Safety Assessment.

Integrated Approach of Universal Soil Loss Equation (USLE) and Geographical Information System (GIS) for Soil Loss Risk Assessment in Reservoir Management

Lariyah Mohd Sidek, Dzahir Rashidi Mohd Dzaki, Nor Azura Ishak, Norlida Binti Md. Dom, Amirah Hanim Mohd Puad, Norashidah Md Din, Siti Noratiqah Mohd Deros, Hidayah Bte Basri

Abstract

Changes in land use and land cover are one of the most significant challenges that alter the relationships among natural processes, such as soil productivity, animal diversity, climatic conditions, and biogeochemical and hydrological cycles. Moreover, land use is one of the important factors that affect the quality and quantity of water. The Universal Soil Loss Equation (USLE) is the most widely used model to quantify soil loss. In this research the Universal Soil Loss Equation (USLE) empirical model technique with integration of Geo-graphic Information System (GIS) was developed to forecast the source of soil erosion and sedimentation rate at Johor River basin. Spaceborne IFSAR with an accuracy of +/-20m was used to generate a Digital Elevation Model (DEM) for terrain and elevation profile. Rainfall Erosivity (R), Soil Erodibility (K), Topographic land surface (LS), Cover Management factor (C), Support Practice factor (P) are the factors needed for the USLE's formula. Land use maps comprising historical landuse data in 2020 and projected landuse data for 2025 have been used to calculate the C factor and P factor. The result of probable soil loss rate data was predicted to increase by 1.68 % between 2020 and 2025. Soil loss rate from the agriculture area is relatively increase as it change to cleared bare land and land opening for construction in future 2025 which implies the role of various human activities on accelerated soil erosion particularly in development of built up areas which covers residential, infrastructure, amenities, industrial, commercial and transportation. Thus, the development USLE can help to design landuse management practices for that particular area.

Keywords: USLE, Soil Loss, Landuse.

Linking Wastewater Treatment Life Cycle Assessment to Integrated Water Resources Management: Insights from Global Trends and Relevance for Malaysia

Nurul Hani Mardi, Hayana Dullah, Mohd Hafiz Zawawi, Ali Najah Ahmed, Nur'atiah Zaini, Marlinda Abd Malek

Abstract

This paper presents a comprehensive review of Life Cycle Assessment (LCA) applications in wastewater treatment plants (WWTPs) and explores their integration into Integrated Water Resources Management (IWRM). Covering 29 case studies published between 2016 and 2025, the review identifies evolving methodological trends, key environmental hotspots, and alignment with IWRM principles. Most studies adopted a functional unit of 1 m³ of treated wastewater, with only 12 extending analyses to endpoint categories such as Human Health (HH), Ecosystem Quality (EQ), and Resource Depletion (RD). The majority applied CML and ReCiPe methods, with Global Warming Potential (GWP), Eutrophication Potential (EP), and Acidification Potential (AP) emerging as dominant midpoint categories. Findings highlight electricity consumption in aeration, sludge treatment, and nutrient discharges as major impact contributors, while recent studies emphasize biogas recovery, water reuse, and nutrient valorization to reduce overall burdens. The progression from operational to cradle-to-gate boundaries demonstrates increasing methodological maturity and alignment with circular economy concepts. In the Malaysian context, the review underscores the potential of integrating LCA into IWRM to support data-driven decision-making, optimize energy–water–emission trade-offs, and guide sustainable investment planning. By synthesizing global insights, this review provides a structured understanding of how LCA outcomes can operationalize the pillars of efficiency, equity, and sustainability within IWRM frameworks, strengthening the scientific basis for circular and low-carbon water sector transformation in Malaysia.

Keywords: Life Cycle Assessment, Wastewater Treatment, Integrated Water Resources Management, Circular Economy, Malaysia.

Integrated Slope Stability and Debris Flow Modelling Using Slope/W, RAMMS, and FLO-2D for Rainfall-Induced Hazards

Nur Salina Rosli, Rohayu Che Omar, Nor Hazwani Nor Khalid, Warishah Abdul Wahab, Azizul Hasani Abd. Rahman, Rasidi Yamin, Yin Jeh Ngui, Marcus Dobbs

Abstract

Rainfall-induced slope failures are a recurring hazard in the Hulu Terengganu region of Malaysia, posing severe threats to hydropower infrastructure, transmission networks, and surrounding communities. This study develops an integrated modelling framework that combines static slope stability analysis using Slope/W with dynamic debris flow simulations in RAMMS and FLO-2D, to evaluate the complete rainfall slope flow interaction under tropical conditions. Long-term rainfall data identified critical hydrological thresholds exceeding 200 mm/day and 900 mm/month, which correspond to observed failure events. The Slope/W analysis demonstrated a progressive reduction in slope stability, with the Factor of Safety (FoS) decreasing from approximately 3.3 under dry conditions to 1.2 under full saturation. These results indicate that rainfall infiltration and pore pressure buildup are key triggers for instability. Dynamic modelling using RAMMS showed that fine-grained soils, particularly clayey gravels, produced high mobility runouts extending up to 950 m, while FLO-2D simulations revealed associated inundation depths exceeding 3 m in depositional zones. In contrast, coarse sandy gravels maintained greater stability (FoS > 1.5), resulting in shorter runouts (<500 m) and shallow inundation (<1 m). The coupled framework demonstrates a strong hydromechanical relationship between rainfall intensity, soil rheology, and debris flow mobility. The study provides a validated, physics based methodology for forecasting debris-flow hazards, enhancing early warning thresholds, and improving slope management and disaster resilience in tropical high-rainfall terrains such as Hulu Terengganu.

Keywords: Rainfall threshold, Slope stability, Debris flow, Numerical modelling, Hulu Terengganu.

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

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, Kim Irvine, Lloyd Chua

Abstract

Malaysia is a country that is frequently affected by recurrent floods, with approximately 21% of its population living in areas prone to this risk. While dams play an important role in water irrigation, supply, and hydropower generation, they also pose a potential risk of flooding, especially in the event of dam failure. To address this concern, the National Reservoir Inflow Forecasting System (NaRIF) has been developed as an important forecasting tool. Through the RT-FLOOD-CORE project, NaRIF produces near-real-time flood forecasts for the catchment areas controlled by dams. The system uses three-day rainfall forecasts obtained from the Malaysian Meteorological Department (MetMalaysia) and current reservoir level information, then runs hydrodynamic simulations using PCSWMM software to produce flood maps. The entire workflow including data acquisition, processing, simulation and output generation is fully automated using Apache Airflow, enabling daily updates without the need for manual intervention. The output is delivered via a public website and a dedicated security dashboard for operators, which displays information such as reservoir inflow, water level hydrographs, and hazard maps based on various scenarios (e.g.: 100-year flood, maximum flood probability, and climate-adapted design). In a pilot application at the Batu Dam, the NaRIF system successfully provided early warning times of up to 72 hours before peak flooding, demonstrating its potential in reservoir management and early warning. By combining modern IT technology and hydrological modeling, NaRIF strengthens operational flood forecasting capabilities and can more effectively improve emergency preparedness and community resilience.

Keywords: Real-Time Flood Forecasting System, PCSWMM, Southeast Asia, Batu Dam, Malaysia, Reservoir Inflows.

A Web-Based System for Landslide Insurance Premium Estimation by Integrating COPE and Hazard Scores

Nazrul Chowdhury, Badariah Solemon

Abstract

Landslides pose an increasing threat in Malaysia, particularly in rapidly developing and hilly regions. However, current insurance premium structures do not adequately reflect localized landslide risk. This study introduces a COPE (Construction, Occupancy, Protection, Exposure) based model for estimating landslide insurance premiums in a more accurate and equitable manner. The model combines the COPE underwriting with Malaysia's Revised Fire Tariff (RFT), which provides standardized insurance rates based on building classification. To incorporate environmental hazard, the model uses landslide risk scores derived from geographic information system (GIS) data presented in prior research. These hazard scores are integrated with vulnerability and exposure values to estimate the expected loss. Loading factors are then applied to account for administrative costs, profit margins, and protection discounts. The resulting estimated premium based on site-specific geohazard exposure, promoting more risk-sensitive and resilient insurance practices for landslide-prone properties. The proposed model has been implemented as a web-based insurance quotation system that collects user input and generates risk-adjusted estimated premium.

Keywords: Landslide Risk, Insurance Premium, Risk-Based Pricing, Infrastructure, Hazard Score, Web System.

Range-dependent Threshold of Transportation Network and Infrastructure for Impact-based Flood Forecasting for Extreme Weather

Siti Noratiqah Mohammad Deros, Lariyah Mohd Sidek, Norashidah Md Din, Nor Azura Ishak, Sazali Osman, Fazli Ali Hassan, Mohamad Hafiz Hassan

Abstract

Floods represent a major natural hazard in Malaysia, predominantly triggered by monsoonal rains, flash floods, and tidal surges. Their impacts extend beyond loss of life and damage to property, with significant disruption to socio-economic systems. Transportation infrastructure, particularly road and rail networks, is critical to sustaining economic activity and emergency response. However, these infrastructures highly vulnerable to flooding, which increases economic liabilities and reduces operational reliability. Existing methodologies for assessing flood impacts on transportation infrastructure frequently neglect the interaction between rainfall intensity and infrastructure thresholds. This study addresses this limitation by establishing the dependency of threshold ranges on rainfall intensity to improve the accuracy of flood risk classification. The approach was demonstrated in the Sungai Kelantan basin through the generation of colour-coded risk maps, enabling spatial visualization of varying impact levels. The principal contribution of this work lies in advancing threshold-based techniques to capture rainfall–infrastructure interactions with greater precision. Results indicate that flood risk is strongly dependent on accurate threshold determination in relation to rainfall likelihood. High-risk zones correspond to densely populated regions with intensive development and substantial infrastructure investment, whereas areas classified as low or very low risk require minimal protective measures. Validation against observed flood events confirmed a high degree of consistency between Flood Risk Matrix (FRM) derived from threshold-based analysis and actual impacts. The findings underscore the value of integrating threshold-sensitive models into Impact-Based Forecasting (IBF) and early warning systems. This contributes to enhancing preparedness, supporting decision-making, and damage to critical infrastructure mitigation while safeguarding lives.

Keywords: Impact-Based Forecasting, River Basin, Flood Risk Matrix, Road and Railway, Transportation Infrastructure.

Hydrodynamic Modeling of Kenyir Dam for Flood Risk Assessment and Disaster Resilience in Sungai Terengganu

Lariyah Mohd Sidek, Hidayah Basri, Wan Zafida Wan Ghazali, Ir.Dr. Norlida Mohd Dom, Ir. Dr. Mohd Zaharifudin Muhamad Ali, Nur Farazuien Md. Said, Syahida Farhan Azha, Ruzaimie Yalit

Abstract

The paper aims to comprehensively analyze the release flow discharges over Kenyir Dam spillway, examining various flood scenarios to assess potential flood inundation and impacts on Sungai Terengganu and downstream rivers. The methodology involves hydrodynamic modeling to study the discharge behaviors of the overflow spillway towards the river downstream of the dam. Multiple simulations are conducted, considering different Annual Recurrence Intervals (ARIs) including 10-year, 50-year, and 100-year events, as well as Clear Day Failure (CDF) and Probable Maximum Flood (PMF) scenarios. The study employs InfoWorks ICM, a sophisticated software integrating 1-D and 2-D simulations for above-ground river networks, enabling comprehensive hydrological and hydraulic analyses in a single run, including flood extent delineation. Data acquisition involves utilizing hydrological information (rainfall, discharge, water level) from JPS combined with dam operation records. The analysis encompasses survey cross-sections of the river, including bridges and structures, to provide valuable insights into potential dam failure risks, improve disaster preparedness, and enhance the resilience of the region against catastrophic flooding events, safeguarding life, property, and the local economy.

Keywords: Kenyir Dam, Hydrodynamic Modeling, Potential Dam Failure Risk, Disaster Preparedness.

Risk Assessment and Mitigation Measures of DID Hydraulic Structures in Central Region of Peninsular Malaysia

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Abstract

The Central Region of Peninsular Malaysia, encompassing Selangor, the Federal Territories of Kuala Lumpur and Putrajaya, and Negeri Sembilan, contains numerous hydraulic structures—barrages, tidal control gates, headworks, pump stations, and access bridges—that are critical for flood mitigation, irrigation, and coastal protection. Many of these Department of Irrigation and Drainage (DID) assets, exceeding 25 years in service, show progressive deterioration due to material aging, environmental exposure, and operational stresses. This study presents a comprehensive structural integrity and risk assessment of 345 hydraulic structures using a framework integrating visual inspection, non-destructive testing and a semi-quantitative risk-matrix approach in accordance with AS/NZS 4360. The results indicate that 0.87%, 5.50%, 50.73%, and 42.90% of the structures fall within extreme, high, moderate, and low risk categories, respectively. Based on rehabilitation needs, barrages exhibited the highest (8.3%), followed by tidal control gates (6.8%), headworks (3.9%), pump houses (3.5%), and bridges (0%). Common distress mechanisms included concrete cracking, spalling, reinforcement corrosion, differential settlement, and erosion linked to aging materials and geotechnical instability. Recommended mitigation measures include preventive maintenance, protective coatings, foundation stabilization, and drainage and erosion control improvements. The study contributes to enhanced risk management and long-term resilience of hydraulic infrastructure, aligning with the United Nations Sustainable Development Goals (SDG) 9 and SDG 11 on resilient infrastructure and sustainable cities.

Keywords: Risk Assessment, Risk Mitigation, Disaster Risk Reduction, Resilient infrastructure, SDG 9, SDG 11.

The Development of Physically Based Dam Breach Model of a Rockfill Dam using EMBREA: A Case Study of Kenyir Dam

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Abstract

Quantifying the risks associated with dam failure demands a detailed assessment of breach dynamics. The Kenyir Dam, a major rockfill structure in eastern Peninsular Malaysia, impounds a large reservoir in a region of high rainfall, posing considerable downstream hazards in the event of a breach. Such failure could lead to catastrophic consequences, including loss of life, economic disruption, and environmental degradation. Therefore, this study employs the physically based Embankment Breach (EMBREA) model to improve breach behavior prediction and mitigate associated risks. Hydrological, geotechnical, and historical datasets were integrated to establish realistic breach parameters representative of a rockfill dam. Multiple hydrological scenarios were simulated to assess corresponding inflow conditions and breach responses. Breach parameters were analyzed, showing that at a 500-year Average Recurrence Interval (ARI), the width reached about 720 m, while under the Probable Maximum Flood (PMF), it expanded to approximately 726 m. The variation between simulated and empirical estimates by Froehlich (2008) remained within 7%, indicating comparable and strong model consistency. It highlights the influence of inflow magnitude on breach development and reaffirms the value of physically based modeling for accurately evaluating breach mechanisms under different hydrological conditions. Findings emphasize the importance of physically based modeling, early warning systems, real-time monitoring, and adaptive operations to support risk-informed decision-making.

Keywords: Dam Breach, EMBREA, Rockfill Dam, Breach Parameters, Probable Maximum Flood.

Advancing Sustainable Rural Electrification through ESG-Driven Micro Hydro System Development in Pos Lenjang, Lipis, Pahang, Malaysia

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Abstract

This paper presents the Environmental, Social and Governance (ESG) considerations applied in developing four off-grid micro hydro systems that supply electricity to 10 remote rural villages in Pos Lenjang, Lipis, Pahang. Located approximately 25 km from the main access road, the area faces logistical and cost challenges for conventional grid extension. The adopted run-of-river micro hydro approach offers a sustainable, low maintenance, low operation cost and community-owned alternative aligned with ESG principles. Micro hydro system design began with identifying local load demand. Next, the site selection and hydrological assessment was conducted using 20 years streamflow data and Flow Duration Curve (FDC) approach. A design flow corresponding to more than 90% flow exceedance was selected to ensure reliable generation across seasonal variations while maintaining riparian flow. For maintenance and operation, due to accessibility limitations, the micro-hydro systems are designed to be owned, operated, and maintained by the local community. To ensure long-term sustainability, the system was purposely designed to be highly automated, requiring minimal human intervention and low maintenance. In parallel, local socioeconomic activities were developed to generate supplementary income, enabling the community to self-fund the operation and maintenance. Appointed operators were selected from among the local community and will undergo structured training to build operational capability. The Pos Lenjang micro hydro project demonstrates how an ESG driven engineering approach can deliver stable and clean energy in remote area while promoting environmental preservation, community empowerment and progress towards sustainable community governance.

Keywords: Micro-hydro, ESG, Off-grid, Rural electrification, Sustainability.

Flood Resilience and Climate Adaptation for Asset Protection in the Energy Supply Industry Using Flood Mitigation Software (FaMouS)

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Abstract

In response to the significant threat of floods in Malaysia, Universiti Tenaga Nasional has developed FaMouS (Flood Mitigation Software) to address flood risks and minimize economic losses. FaMouS serves as an integrated database system aimed at prioritizing flood-vulnerable assets, optimizing mitigation costs, and aiding stakeholders in risk management and compliance efforts. The software was rigorously tested using TNB's Thermal Power Plants (TTP), featuring modules such as Asset Inventory Database, Flood Risk Exposure, Flood Mitigation Measures, and Cost-Benefit Analysis with Net Present Value (NPV) calculations. By incorporating Eleven (11) TTPs, including gas-fired and coal-fired plants, and utilizing flood risk maps for detailed analysis based on flood depth, FaMouS provides critical insights into asset risk. Additionally, the software integrates a Climate Change Factor (CCF) to account for climate change effects on rainfall intensity and sea level rise (SLR), ensuring its adaptability to changing environmental conditions. FaMouS facilitates real-time communication and data sharing, enabling informed decision-making through economic impact assessments, thereby enhancing asset protection and community resilience. This innovative software contributes to sustainable flood management, improves quality of life, and lays the foundation for energy supply industries focused on disaster risk reduction tools.

Keywords: Climate Change Impacts, Sustainable Flood Management, Flood Mitigation Software, Thermal Power Plants, Integrated Database System.

Flood Hazard Mapping Downstream of Kenyir Dam in the Terengganu River Basin Utilizing Advanced Machine Learning Techniques

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Abstract

Identifying flood-prone areas is crucial for applications in engineering, risk reduction, and research. Traditional flood hazard maps (FHM) are generated using hydrodynamic modelling, which combines hydrological and hydraulic techniques but often incurs significant computational costs. To overcome these challenges, this study employs machine learning approaches to produce FHMs under various rainfall scenarios, enhancing early warning systems and disaster management. Specifically, we utilized three algorithms: Decision Tree Classifier (DTC), Random Forest (RF), and K-Nearest Neighbours (KNN), to generate FHMs for the Terengganu River Basin. A comparative analysis of the models revealed that the DTC-based model outperformed the others, achieving an AUC-ROC score of 0.82, followed by RF at 0.763 and KNN at 0.675. These predictive results will be applied to forecast flood impacts downstream of the Kenyir Dam using the Impact-Based Forecasting technique, ultimately contributing to risk reduction efforts.

Keywords: Flood hazard Map; Machine Learning; Classification; Impact-based Forecasting, Disaster Risk Reduction.

Development of Impact-Based Forecasting Consequences for Dam Failure Flood Hazards Downstream of Kenyir Dam

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Abstract

Traditional flood prediction methods rely on historical data and hydrometeorological models, often failing to provide timely warnings. To improve disaster preparedness, this paper explores impact-based forecasting (IBF), which focuses on the consequences of flooding on communities and infrastructure. This study focussed to forecast the impact of dam failure flood hazards in the downstream area of the Kenyir Dam in the Terengganu River Basin, assessing eight receptors: agriculture, commercial properties, industrial sectors, infrastructure and utilities, population, public facilities, residential areas, and transportation. The impacts are classified into low, very low, medium, and high categories. Results indicate that total economic damages could exceed RM 369 million in extreme rainfall scenarios. Notably, agricultural impact damages decline from 27.11% to 13.65%, while residential impact damage rises from 8.85% to 15.63%. These findings highlight the need for comprehensive flood risk management strategies and proactive community resilience measures. Ultimately, the insights gained can inform risk assessments and contribute to developing an effective early warning system, assisting policymakers and stakeholders in protecting both the economy and the well-being of residents.

Keywords: Flood Hazard, Impact Based Forecasting, Impact Matrix, Impact Damage.

Water Level Forecasting using LSTM Deep Learning Algorithm in Muar River Basin

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Abstract

Water level forecasting plays a vital role in managing water resources and mitigating risks associated with floods and other extreme hydrological events. Traditional hydrological models, while effective, often struggle with the nonlinear and dynamic nature of water systems. Recent advancements in artificial intelligence, particularly the use of Long Short-Term Memory (LSTM) deep learning algorithm, have shown promise in improving forecasting accuracy. LSTM, a type of recurrent neural network, excels in modeling time series data due to its ability to capture long-term dependencies and handle complex, nonlinear relationships. This paper demonstrates the application of LSTM models in water level forecasting at station Jambatan Konkrit in Pekan Rompin, located along the Muar River Basin, Malaysia. Extremely strong autocorrelation relationship has been observed in the water level time series while the cross correlation between the rainfall and water level time series was not as strong as observed in the water level time series. The water level at present time step was most strongly cross correlated to the rainfall at previous 24-time steps. The trained LSTM models in this study have produced highly accurate water level predictions with low RMSE and high NSE values during model validation in the testing period. Furthermore, the forecasted water level obtained from the best-trained models consistently matched the observed one. Therefore, utilizing deep learning forecasting models can significantly enhance early flood warning and monitoring systems by providing quick and reliable forecasts.

Keywords: Long Short-Term Memory (LSTM), Deep Learning, Recurrent Neural Network (RNN), Water Level Forecasting, Muar River Basin, NSE.

Determination of Rainfall Thresholds for Flood Onset in Southern Region-Zone 2B under the Development of the National Flood Forecasting and Warning System (NaFFWS)

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Abstract

Flood triggering rainfall amount refers to the volume or intensity of rainfall that exceeds the land's natural or engineered capacity to absorb, drain, or store water, leading to surface runoff and subsequent flooding. This threshold varies widely depending on several factors, including catchment characteristics, soil saturation, land use, vegetation cover, and the presence of drainage infrastructure. In general, heavy or prolonged rainfall can saturate soils and overwhelm rivers, reservoirs, and urban drainage systems. Once the infiltration capacity of the soil is exceeded, additional rainfall becomes runoff, rapidly increasing water levels in rivers and low-lying areas. The critical rainfall amount needed to trigger a flood is not fixed and can be much lower in already saturated catchments or in areas with impervious surfaces, such as urban regions. Estimation of rainfall thresholds for flood triggering has been carried out for 3 river basins (Sg Skudai, Sg. Muar, and Sg. Batu Pahat) in southern region-zone 2B under the development of National Flood Forecasting and Warning System (NaFFWS). In this study, peak rainfall intensities, total storm accumulation, and average intensities extracted from each river basin has been used to plot the "peak rainfall intensity versus duration" graphs for investigation of correlation between specific rainfall conditions and flood triggering in the river basins. It is concluded that the overall rainfall threshold estimated in the study area for duration of 1-hr, 3-hr, 6-hr, 12-hr, and 24-hr is about 63 mm, 79 mm, 90 mm, 103 mm, and 118 mm respectively. Besides, it is observed that about 80% of the estimated average rainfall threshold are associating to the return period of 2-years ARI and about 90% of the estimated average rainfall threshold are corresponding to the return period of less than 3-years ARI.

Keywords: Rainfall Threshold, Flood Triggering, Flood Forecasting and Warning, NaFFWS, Peak Rainfall Intensities.



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