SIMULATION OF PLAUSIBLE HAZARD SCENARIOS ASSOCIATED WITH DAM FAILURES: CASE STUDY ON KANTALE DAM, SRI LANKA

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Abstract: Dams serve as critical infrastructure for water supply, irrigation, flood control, and power generation, but their failure can lead to catastrophic consequences, including loss of life, property damage, and environmental degradation. This study aims to simulate potential breach scenarios of the Kantale Dam using hydraulic modeling to assess flood impacts and enhance disaster risk management strategies. The research employs hydraulic modeling and simulation techniques, specifically HEC-RAS (Hydrologic Engineering Center's River Analysis System), to predict flood scenarios resulting from dam breaches. Digital Elevation Models (DEMs) and GIS data are used to model the reservoir's geometry and simulate the flood propagation, providing detailed insights into flood behavior and affected areas. The analysis explores multiple breach scenarios, highlighting their impact on downstream communities, particularly the town of Kantale. The study's findings demonstrate how simulation-based approaches can enhance early warning systems, improve emergency preparedness, and inform land-use planning to mitigate disaster risks. By developing a predictive model, research provides a valuable tool for policymakers, engineers, and disaster risk managers to optimize disaster management strategies and minimize the socio-economic impacts of potential dam failures. The study contributes to the broader field of disaster risk management by advocating for the integration of advanced simulation techniques in dam safety assessments, thereby promoting sustainable disaster preparedness and resilient infrastructure planning.

Keywords: *Dams, Dam Failures, Disaster Risk Management, Digital Elevation Models*

1. Introduction

Dams play a critical role in ensuring a sustainable water supply, especially in the face of increasing population demands and environmental challenges (Luo et al., 2020). They are essential infrastructure components that support various societal needs, including irrigation, water supply, flood control, and power generation (Tariq et al., 2021). However, while the benefits of dams are significant, the potential risks associated with their failure cannot be overlooked (Alvi & Alvi, 2023). Dam failures can lead to catastrophic events, causing extensive property damage, loss of life, and long-term environmental degradation (Ge et al., 2024). This is especially critical in the case of major dams such as the Kantale Dam in Sri Lanka, where any failure could have devastating socio-economic impacts on nearby communities.

The Kantale Dam is an earthen embankment dam in the Trincomalee District of Sri Lanka that has served to be quite critical for water management in the region. Constructed during the 1950s, the facility supports irrigation into agricultural areas, domestic supply, and local flood control (Lutter et al., 2024). Among various types of dams, earthen dams, such as Kantale dam are widely used due to their adaptability to different foundations, ease of construction, and cost-effectiveness (Hamza et al., 2022). Despite all this importance, a failure of the dam was indeed recorded in 1986, resulting in great loss of life and property (Perera & North, 2021). This event exposed a loophole in the management of dams and emphasized the impacts that would be witnessed should an incident occur. The region below the dam, including the town of Kantale, is still highly at risk in terms of severe flooding in the event of another dam failure.

The failure of such dams often results in the sudden release of large volumes of water, generating flood waves that can cause severe downstream damage (Ferrari et al., 2023). This highlights the importance of comprehensive dam break analysis as a vital component of disaster risk management (Carmo et al., 2017).

Improvements in hydraulic modelling and Geographic Information System (GIS) tools have made possible powerful simulation and analysis capabilities of dam breach scenarios. The integration of simulation techniques into dam break analysis allows for more accurate predictions of flood scenarios, enabling decision-makers to develop effective land use and emergency response plans (Peramuna et al., 2024). These plans are crucial for mitigating the catastrophic impacts of dam failures on both human safety and the environment. By utilizing tools such as HEC-RAS, researchers and engineers can create detailed inundation maps that guide the development of strategies to protect vulnerable communities and infrastructure (Bharath, Shivapur, et al., 2021; Phyo et al., 2023).

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DOI: https://doi.org/10.31705/FARU.2024.42

In Sri Lanka, such futuristic simulation techniques incorporated into risk assessments would be necessary as disaster preparedness and mitigation are becoming dynamic (Senarathne et al., 2023). This resonates well with global trends in emphasizing the incorporation of predictive modelling to help better manage disasters, reduce socio-economic impacts, and ensure sustainability of critical infrastructure systems (Gaagai et al., 2022). In this regard, this study aims to simulate potential breach scenarios of the Kantale Dam using hydraulic modelling to assess flood impacts and enhance disaster risk management strategies. The paper presents the literature review on integrating simulation techniques into sustainable disaster management practices to minimise the socio-economic impacts of dam failures. The research methodology adopted for this paper is then presented followed by the key findings. Finally, the conclusions and the way forward are presented.

2. Literature Review

This section reviews key literature on dam safety, disaster risk management, and the socio-economic impacts of dam failures. Dams are crucial for water supply, irrigation, and flood control, but their failure can lead to severe consequences. The review focuses on the historical dam failure events, role of simulation techniques, such as hydraulic modelling, GIS, and agent-based modelling, in predicting dam failures and aiding risk management. It also examines the socio-economic effects of dam failures, including loss of life, economic disruption, and environmental damage. The insights from this review lay the groundwork for applying these techniques to assess potential dam failures at Kantale Dam in Sri Lanka.

2.1. CAUSES OF DAM FAILURE

The failures of dams have so many causes and are often interrelated, involving structural deficiencies, geotechnical challenges, hydrological extremes, operational lapses, and environmental factors. The common cause of structural failures includes poor design, inferior quality of materials, or deterioration over time, which ultimately leads to cracks, seepage, or instability under pressure (Adamo et al., 2020). Aging infrastructure is more vulnerable where maintenance is inadequate or has been deferred, causing small problems to become catastrophic failures (Hoque et al., 2022).

Hydrological causes, such as overtopping, occur when water levels are more than the storage capacity of the dam, usually due to heavy rainfalls or flooding (Schapper & Urban, 2021). This may cause erosion of the dam crest, which might lead to the beginning of a breach if the spillways are not well designed or are poorly maintained. Climate change has intensified these risks by increasing the frequency and unpredictability of extreme weather events (Sun et al., 2022).

Further there are geotechnical causes of dam failure such as instability in the foundation, soil erosion, or liquefaction during seismic activity undermines the structural integrity of the dam (Angelakis et al., 2024). The landslides, sediment accumulation, or changes in the surrounding geology can add unexpected stresses, while the rapid drawdown of reservoir levels may destabilize the dam embankment. Other environmental and natural forces that can further strain the dam structure include upstream debris flow (Silva & Eleutério, 2023).

These vulnerabilities can be further compounded by operational failures, including human error, mismanagement of water levels, and poor emergency procedures (Cerveny et al., 2022). Often, the lack of proper monitoring systems and late response to warning signs, such as unusual seepage or deformation, further compounds the risk. Often, these causes are further aggravated by a lack of updated risk assessments and emergency action plans where the dams are not prepared for possible failure (Lucas-Borja et al., 2021).

Such realization of the causes of dam failure can trigger devastating socio-economic impacts, including loss of life, displacement of communities, destruction of critical infrastructure, and livelihood disruptions, and massive environmental degradation that, in combination, pose long-lasting challenges for affected regions(Samsuddin et al., 2024).

2.2. SOCIO-ECONOMIC IMPACTS OF DAM FAILURES

Socio-economic consequences of dam failures are overarching and lead to disaster in the social and economic systems of societies (Piciullo et al., 2022). Perhaps the most drastic of these effects is the economic one which is disrupted almost immediately (Bhatti et al., 2019). A failure of a dam leads to loss of lives and property, destruction of infrastructures and agricultural land which have severe economic consequences (Abdullah & Rahman, 2021). The cost of recovery and reconstruction can be very high, and this calls for a lot of capital which is very costly, and can greatly affect the economy of the area, especially the less developed areas(Perera & North, 2021). Companies may have their property and people damaged or killed, and the infrastructure, including roads and bridges, on which businesses depend for transport of goods and/or delivery of services may be destroyed, aggravating economic difficulties (Vogel, 2013).

Another significant consequence of dam failures is thus social displacement. People living through the downstream of a dam are often affected by floods whereby their homes, farms, and even neighbourhoods are flooded and are therefore at the risk of being evicted (Perera & North, 2021). Relocation is again forced, arbitrary and abrupt and as such breaks the natural social fabric, alters support structures that are critical when they are in the process of recovering (Bhatti et al., 2019). In this context, displacement also disrupts the people's means of living because many of them rely on the farming businesses for instance, and due to flooding they lose their properties, and sources of income (Abdullah & Rahman, 2021). Displacement alters the social fabric and signature of living and cause psychological and health issues that are difficult for the affected populations to overcome and reconstruct their lives (Wilk-Woźniak et al., 2021).

Overall, the socio-economic impacts of dam failures are extensive and multifaceted. Economically, they can cripple local and regional economies, leading to long-term financial instability (Lyu et al., 2019). Socially, they cause displacement, disrupt livelihoods, and fracture communities (Seneviratne et al., 2020). Environmentally, they wreak havoc on ecosystems and biodiversity, further exacerbating the challenges of recovery.

Accordingly, Figure 1 framework illustrates the main causes of dam failures and the potential socio-economic impacts, both long term and short term, arise from these dam failures. This paper focuses on dam structure, triggering mechanism and external factors to develop a predictive model to simulate these events, aiming to better predict, prevent, and manage the consequences associated with dam failures. The impacts due to dam structure are presented in terms of materials, design, age, maintenance and integrity of the dam, the natural events, human activities and operational failures have been identified as the potential causes for the impacts due to external factors, and seismic activity, overflow and structural weakness are identified as the key triggering mechanisms that lead to dam failure. These diverse and far-reaching consequences highlight the critical need for robust dam safety management, proactive risk assessment, and preparedness strategies to mitigate the potential impacts of dam failures (Perera & North, 2021). Improving early warning systems, implementing community training, and developing disaster resilience strategies are essential steps to reducing the harm caused by such catastrophes (Scoble et al., 2010). Therefore, as a result to minimize such socio-economic impacts identified; this paper takes the initial steps in developing a predictive model using hydraulic modelling and flood simulation techniques.

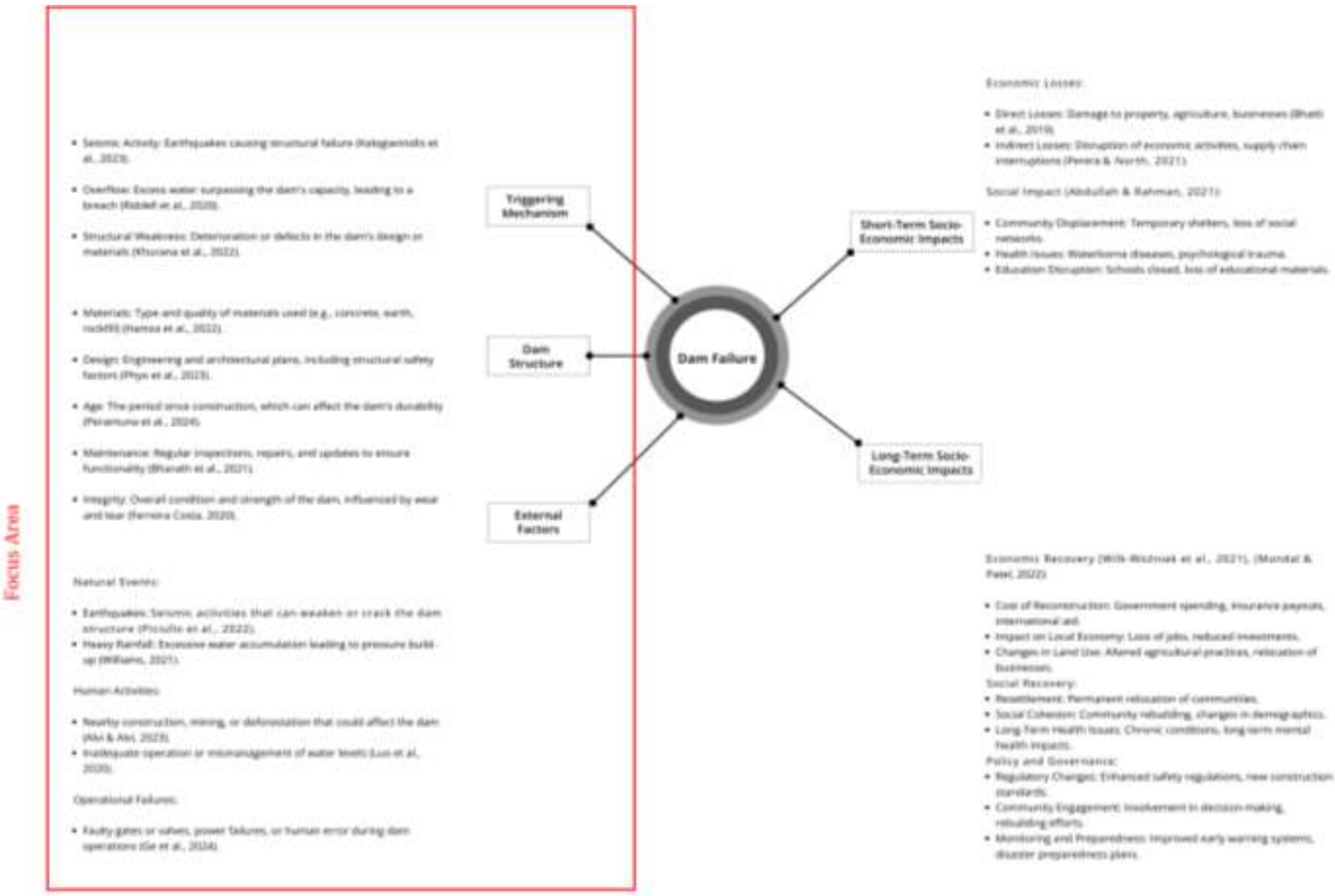

Figure 1: Conceptual framework on the potential socio-economic impact

2.3. SIMULATION TECHNIQUES IN DISASTER RISK MANAGEMENT

Disaster risk simulation exercises are crucial and a must-have instrument at the present time, while various disaster situations can be modelled with high accuracy (Khan et al., 2023). Such methods offer useful information on how various variables interconnect to contribute to the incidence of disasters and the ways by which those risks can be prevented (Cvetković et al., 2024). Hydrological and hydraulic modelling is one of the approaches that are directed to analysing the flow and occurrence of water in the reservoirs of dams (Tavakoly et al., 2021). Using these simulations, specialists should identify tendencies for failure and flood occurrence at different situations, for instance, high water levels or damages to the structure of the dam (Ribas et al., 2021). This is important for the interaction modelling between environmental parameters and dam security and subsequently risk management and assessment with prescription of specific countermeasures (Cvetković et al., 2024).

Another important simulation technique is Geographical Information Systems (GIS) and evaluations of remotely sensed data to determine effects of disasters on geography and human settlements (Islam et al., 2022). Thus, geospatial analysis facilitates the identification of areas most susceptible to specific calamities and helps enhance the approach to the strategies and funds allocation (Wang et al., 2021). In turn, this approach assists decision-makers in defining or evaluating the most requisite locations for intervention, planning the paths for people's evacuation, or designing structures that would be able to resist or reduce influences of disasters (Feizizadeh et al., 2023). Further, geospatial analysis gives a map view of disaster likely impacts which is useful when trying to bring it into the attention of people of interest or the public (Li et al., 2022).

Agent-based modelling, in contrast, models the behaviour of the people in the individual cases in front of the disaster (Palomo-Briones et al., 2022). This approach provides a view on the human conduct and action in incidences of disasters that are unexpected and could greatly affect the response measures to such incidences (Ghaffarian et al., 2021). Because it specifies how people may behave in certain ways such as how much information they have, or what risks they are aware of, or checklist of evacuation routes, it assists in determining how suitable evacuation strategies and emergency responses are (Zhang et al., 2024). This technique is particularly useful in planning concerning circumstances where human element is of essence e.g., in evacuation crises or distribution of relief stuffs (Ghaffarian et al., 2021).

Altogether, each of these simulation techniques constitutes a complete arsenal of tools for disaster risk management and help to make more precise, plan and respond adequately to the probable disasters. Hydrological and hydraulic modelling, GIS and Agent based modelling can be used in concert with disaster management professionals to formulate not only risk and disaster reduction plans but also the durability of communities and structures in future disasters.

2.4. INTEGRATING SIMULATION TECHNIQUES INTO SUSTAINABLE DISASTER MANAGEMENT PRACTICES

Simulation-based approaches play a crucial role in enhancing disaster preparedness, particularly in the development and improvement of early warning systems (Shaktawat & Vadhera, 2021). Using simulation data, thereby making more effective early warning systems allowing the authorities and the communities involved to obtain timely warnings (Nayak & Shukla, 2023). These alerts are important in ensuring that action and evacuation is promptly taken, in cases where they must be taken, to minimize loss of lives and the level of damage that may be occasioned by the failure of dams (Silva & Eleutério, 2023). As a result of the predictive capabilities of the simulation models, the precedent to disasters is possible so that warnings are given beforehand, affording the people enough time to acquire safety and safeguard their property (Naeem et al., 2023).

In addition to early warnings, simulation methods are particularly valuable in risk analysis and management. When integrated into risk evaluation frameworks, these models allow for the identification of specific threats to infrastructure, communities, and ecosystems (Lumbroso et al., 2021). When the outcomes of modelling are integrated into the schemes of risk evaluation, leaders can define the precise threats in a certain area or society (Ge et al., 2020). It is from such a detailed knowledge of areas of potential risks that more specific approaches to disaster prevention and mitigation can be formulated (Silva & Eleutério, 2023). For example, the simulation can tell which of the infrastructure components are most likely to fail; that information can then be used to plan performance maintenance and enhancement (Chen et al., 2020). Furthermore, the use of simulation-based risk assessments helps the planners to develop efficient evacuation plans, shelter and other response mechanisms tied to the predicted scenarios and hence enhancing the efficiency of disaster response plans (Wang et al., 2022).

Simulation data also enhances community engagement and training in disaster risk management(Chang et al., 2024). To raise awareness among the communities, Disaster Risk Management practitioners should be presenting the people with authentic situations derived from simulation data and explaining what they are likely to face and what they should do in the absence of a dam (Wang & Jia, 2021). This way, it promotes the development of cultures of contingencies and proactivity because people and communities become more conscious of certain obstacles that they are likely to face and are therefore empowered to offer correct responses (Coun et al., 2022). Another benefit is that training programmes which use simulation activities may also be useful in rehearsing the general tactics of the local authorities and the emergency services in order that they stand ready to respond rapidly and effectively if disaster strikes (Gwynne et al., 2020).

3. Research Methodology

The methodology adopted for the Kantale Dam break analysis involved a comprehensive approach using hydraulic modeling and flood simulation techniques. Dam break analysis involves predicting the breach outflow hydrograph and generating inundation maps that are crucial for emergency planning and response (Phyo et al., 2023). The primary tasks in such analysis include estimating breach parameters, such as breach width, depth, and formation time, and modelling the flood wave propagation along the downstream valley (Peramuna et al., 2024). Hydraulic models such as HEC-RAS are commonly used for this purpose due to their reliability and ability to simulate complex channel geometries and bed discontinuities (Bharath, Shivapur, et al., 2021). These models help predict the shape, magnitude, and timing of flood waves, which are essential for evacuation planning and minimizing the impact of potential dam failures (Bharath, Shivapur, et al., 2021; Ferrari et al., 2023).

First, geometric data was collected through Digital Elevation Model (DEM) files from the USGS Earth Explorer, which were processed using QGIS software to extract the reservoir's geometry (Bharath, Shivapur, et al., 2021). This information was essential for building the hydraulic model. The dam breach parameters, including the final breach width, bottom elevation, and breach formation time, were estimated using regression equations based on the dam's physical attributes, such as height, construction material, water elevation, and storage volume. The hydraulic modeling was conducted using HEC-RAS, where the dam was modeled as an inline structure with cross-sections to enable full dynamic wave routing, providing a detailed representation of how water would behave during a breach. Boundary conditions, such as the probable maximum flood (PMF) hydrograph, were incorporated to simulate the inflow, while gate operations were defined to reflect actual scenarios during the event of a dam failure. Finally, the simulation was executed in HEC-RAS, providing floodplain mapping and allowing the assessment of the downstream flood behavior and its potential socio-economic impacts. This methodology leverages modern technologies to simulate dam breach events effectively, offering insights into mitigation and risk management strategies.

3.1. PROFILE OF THE CASE STUDY - KANTALE DAM IN SRI LANKA

The Kantale Dam is a significant embankment dam located in Kantale, in the Trincomalee District of Sri Lanka. This historic dam plays a crucial role in the region's irrigation infrastructure, impounding the Per Aru River, a small watercourse that eventually discharges into Koddiyar Bay at Trincomalee Harbour. The Kantale Dam is one of the largest embankment dams in Sri Lanka, stretching 14,000 feet (4,267 meters) in length and standing over 50 feet (15 meters) high. The dam was originally constructed centuries ago, reflecting the ancient engineering skills of the region. It was built to capture and store water from the Per Aru River, providing a critical source of water for irrigation to the surrounding agricultural lands. The reservoir created by the dam, known as the Kantale Reservoir or Kantale Tank, has been vital for the agricultural economy of the area, supporting the irrigation of thousands of hectares of paddy fields and other crops. The reservoir's water is distributed through an extensive canal network, ensuring a reliable water supply for farmers, especially during dry seasons. On the morning of April 20, 1986, at approximately 3:00 AM, the Kantale Dam experienced a catastrophic breach, resulting in one of the most devastating dam failures in Sri Lanka's history. The breach unleashed a massive wall of water that surged downstream, inundating villages and agricultural lands.

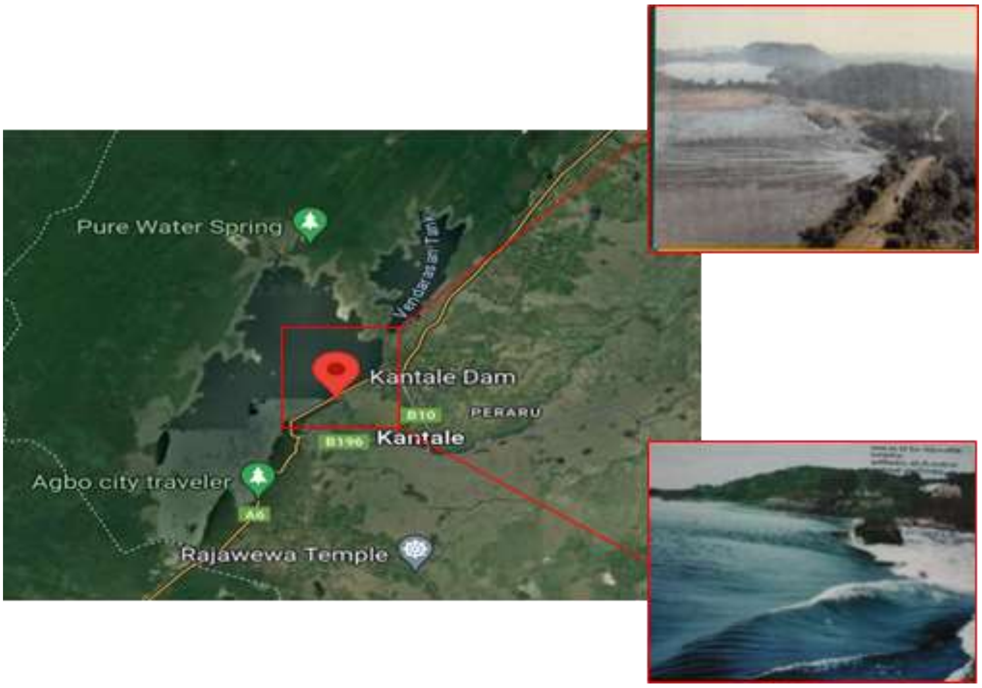

Figure 2: Location of the Dam

3.2. RESEARCH PROCESS

The research process that involves a sequence of steps essential for the successful execution of research is illustrated in Figure 3.

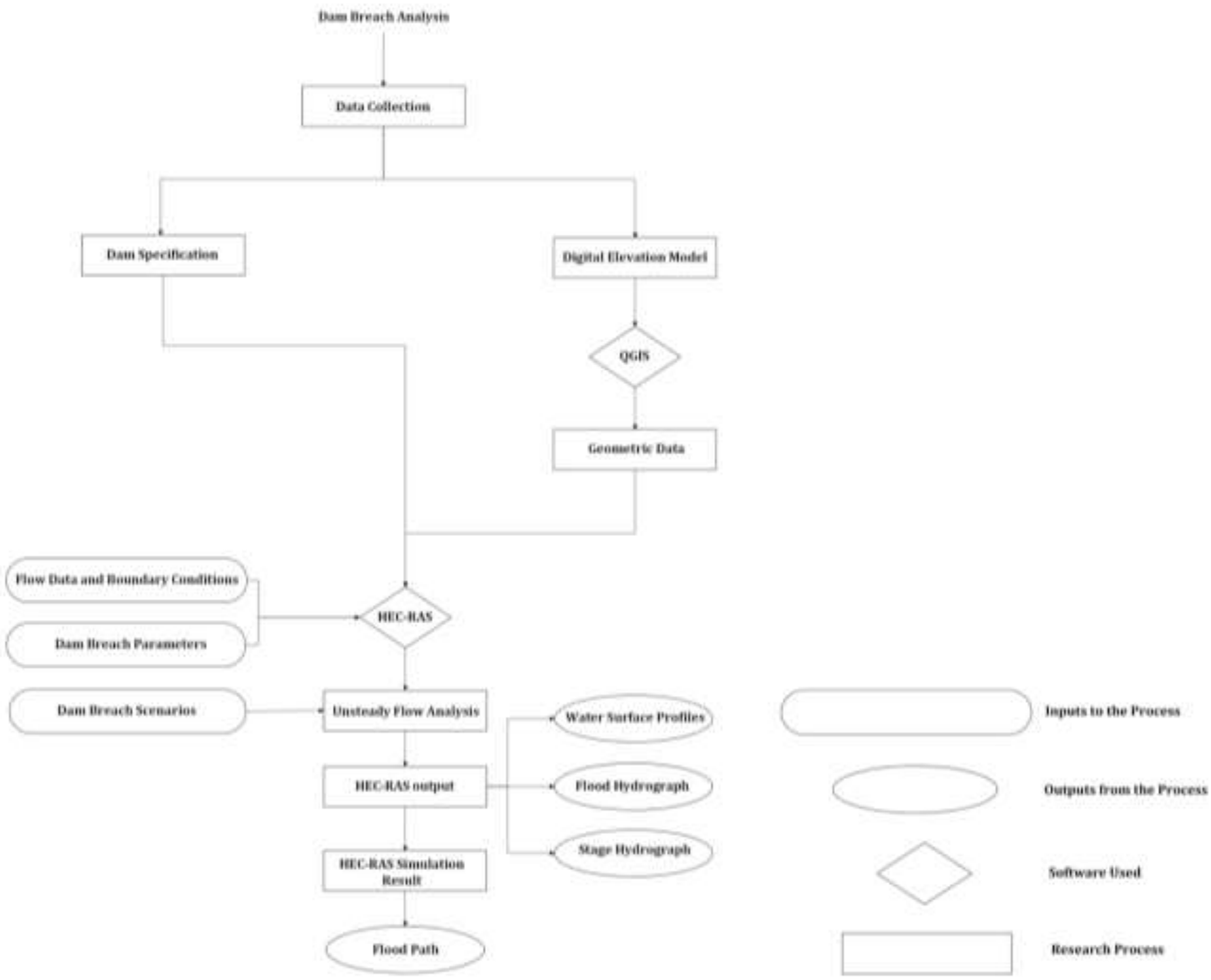

Figure 3: Research Process

The steps followed in the research process are explained below.

3.2.1. Step 1: Digital Elevation Model

Geometric data

For hydraulic modelling, obtaining river geometry is essential. This data can be gathered through field surveys or by using remote sensing techniques. While traditional survey methods yield precise river geometry, they are labour-intensive and time-consuming, especially for large areas. On the other hand, remote sensing offers a quicker and more cost-effective alternative, which is why its use in hydraulic modelling has grown significantly (Annis et al., 2020; Bharath, Kumar, et al., 2021; Sodango et al., 2021)

In this study, the Digital Elevation Model (DEM) was sourced from the USGS Earth Explorer and subsequently processed using QGIS software to convert it into a Tagged Image File Format (TIF) for extracting reservoir geometry data. In HEC-RAS, reservoirs can be modelled in two ways: first, as a storage reservoir pool with a storage-elevation relationship, resulting in level pool routing; and second, using 1D cross-sections throughout the reservoir pool, which allows for dynamic flood routing. Long, narrow reservoirs typically exhibit a more pronounced water surface slope upstream of the dam compared to wide, short reservoirs (USACE, 2016). Consequently, full dynamic wave (unsteady flow) routing is the most accurate method for modelling pool elevations and outflow in long, narrow reservoirs. This can be achieved by modelling the pool with 1D cross-sections for full dynamic wave routing in HEC-RAS.

Fig. 4 highlights the cross-sections of the reservoir obtained from the HEC-GeoRAS tool using TIF data prepared from DEM. Manning's roughness coefficients were selected based on land use and land cover through visual inspection of the site using web imagery. A grid size of **50 meters** in both directions has allowed for sufficient detail in capturing the flow dynamics of the floodwaters while avoiding excessively fine grids that would increase computational load and time This spacing ensures that the simulation captures key hydraulic features such as changes in water depth, flow velocities, and the extent of flooding, especially over a large area like the downstream floodplain. At the same time, it maintains a manageable number of computation points, allowing for a practical simulation runtime and reasonable data handling.

Figure 4: Cross-sections of the reservoir obtained from the HEC-GeoRAS

3.2.2. Step 2: Dam Specification

Dam Breach Data
For dam break analysis, several breach parameters are necessary, including the final bottom breach width, the final elevation of the breach bottom, the side slope of the breach, the breach formation time, and the initial reservoir elevation at the time of breach initiation. Estimating these breach parameters using regression equations involves factors such as the dam height, the material used in construction, the water surface elevation, and the storage volume.

3.2.3. Step 3 – Unsteady Flow Analysis

Model Simulation
In HEC-RAS, a dam is modeled as an inline structure with at least two cross-sections specified upstream. The dam's geometry, material properties, and discharge outlets are all defined within the model. Reservoir storage is modeled using cross-sections, enabling full dynamic wave routing, which allows for a sloping water surface upstream of the dam during a failure.

Afterwards, by using HEC-RAS unsteady flow analysis, simulation time window was specified (start and end date/time of the dam failure). The computation interval was set to 5 seconds and the mapping output interval was set to 30 seconds. Finally, the following processers were allowed to run.

- Geometry Preprocessor
- Unsteady Flow Simulation
- Post Processor
- Floodplain Mapping

As the result, there were three HEC-RAS outputs developed such as,
- Water Surface Profiles
- Flood Hydrograph
- Stage Hydrograph

Finally, through the results option in the RAS Mapper in the HEC-RAS software the flood path from the dam failure was simulated. The outputs from simulation are discussed in the following result section.

4. HEC-RAS Simulation Results
This section presents the results of the dam failure simulation, specifically focusing on the flood hydrograph and stage hydrograph, which outline the flood water's path and its impact on surrounding areas. The simulations illustrate multiple breach scenarios, including failures from the center and corners of the dam. These scenarios highlight the areas affected by floodwaters, with significant implications for Kantale town in Sri Lanka.

The results are presented to visually and analytically assess the flood path and to determine which areas would be impacted, fulfilling the paper's objective to develop a predictive model using hydraulic modeling and simulation techniques. This approach aids in assessing the potential socio-economic impacts of dam failures, with a focus on enhancing disaster preparedness and planning. By identifying the regions vulnerable to floodwaters, these simulations provide valuable insights into minimizing socio-economic risks and preventing future developments in high-risk zones, directly supporting the study's goal of promoting sustainable disaster management practices.

4.1 FLOW DATA AND BOUNDARY CONDITIONS

Boundary conditions are a crucial input in flood modeling, as they greatly influence the behavior of downstream floodwaters. These conditions must be selected carefully to accurately reflect the actual site conditions. In this analysis, the upstream boundary condition is represented by an inflow hydrograph, specifically the probable maximum flood (PMF) hydrograph provided by the dam authority (see Fig. 5). At the inline structure, the boundary condition is defined by the time series of gate operations: the spillway gate is kept open at 0.1 m throughout the simulation period, while the sluice gate remains completely closed.

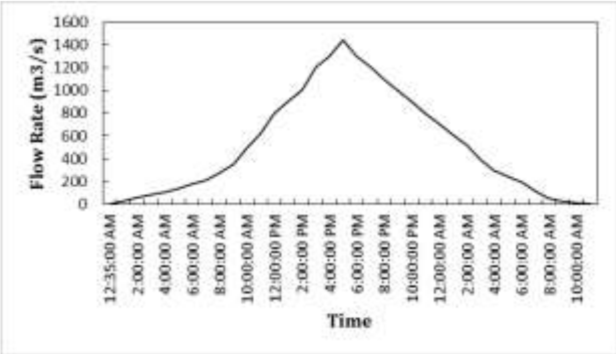

Figure 5: Flood Hydrograph

4.2. FLOOD HYDROGRAPH AND STAGE HYDROGRAPH

Figure 6 represents the dam profile after the simulation. The figure highlights the breach formed in the dam section and depleted water surface level at the end of the simulation.

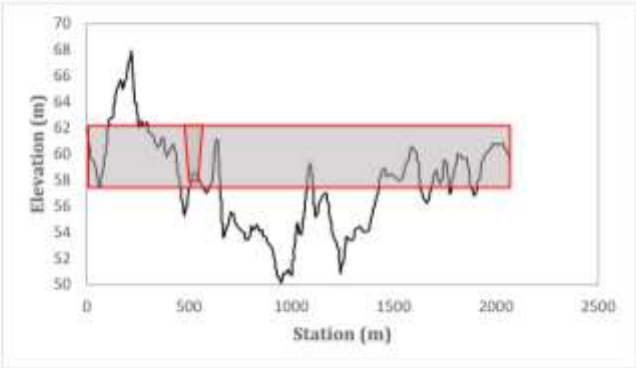

Figure 6: Dam profile after the simulation

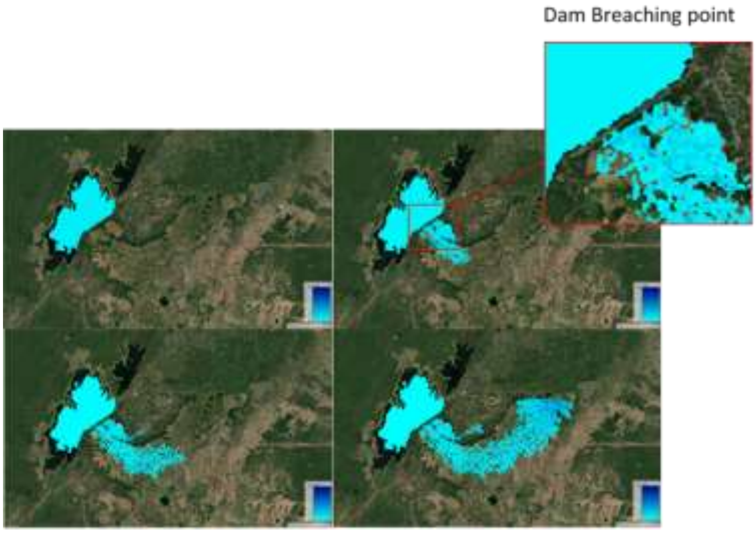

Figure 7: Flood path as a result from a dam breach at center point

Figure 7 illustrates the path of the flood water if the dam fails from the center of the dam. It clearly shows the area that is affected by the flood. These simulation techniques offer a novel approach for preplanning to mitigate such disasters from occurring. Especially to identify the affected areas and to prevent any development around those areas.

4.3 CAUSES OF THE BREACH

The primary cause of the breach was attributed to the structural failure of the dam, which had been compromised by various factors. One significant contributing factor was the stress caused by the passage of extra-heavy vehicles over the dam. The repeated and unregulated movement of these vehicles, particularly large trucks and construction machinery, weakened the dam's structure over time. The dam's earthen embankment, which was not designed to withstand such heavy loads, eventually gave way under the strain.

Additionally, inadequate maintenance and monitoring of the dam's condition were also cited as contributing factors. The failure to detect and address signs of structural weakness in the dam, such as cracks or seepage, allowed the situation to deteriorate to the point of failure.

4.4 ALTERNATIVE SCENARIOS

Figure 8 illustrates the path of the flood water if the dam fails from one corner of the dam. It clearly shows the area that is affected by the flood. The flood water path is similar to the previous scenario, where a small water flow is impacting the Kantale town.

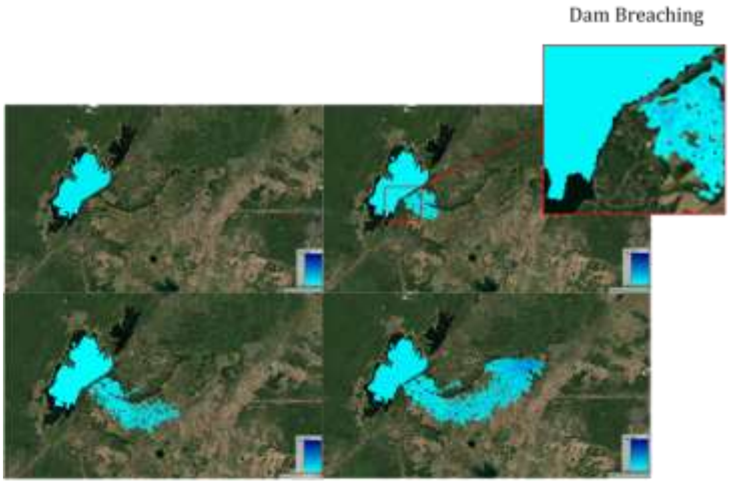

Figure 8: Flood path as a result from a dam breach at one corner point

Figure 9 illustrates the path of the flood water if the dam fails from a corner of the dam. It clearly shows the area that is affected by the flood. In the previous two cases there was a small water flow impacting Kantale town whereas, now it can be seen that there is significant impact to the Kantale town as there is a water path going through the town.

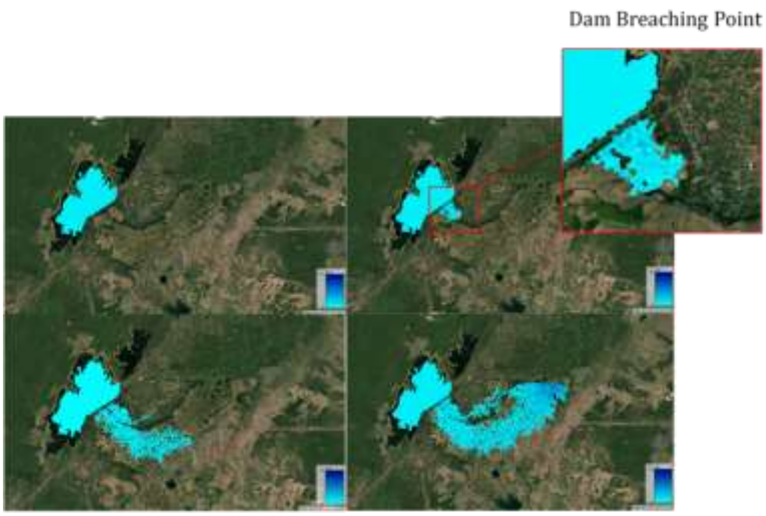

Figure 9: Flood path as a result from a dam breach at the other corner point

The simulation model for dam break analysis is a valuable tool in disaster risk management, offering predictive accuracy, comprehensive risk assessments, and the ability to analyze multiple scenarios. It aids in emergency preparedness, supports sustainable disaster risk management, and enhances community awareness.

However, the model has limitations, including sensitivity to data quality, complexity in setup, uncertainty in breach parameters, and challenges in scalability. Additionally, the sociopolitical, economic, and environmental implications of implementing the model's findings may affect its practical application. Addressing these challenges is essential to maximizing the model's effectiveness in reducing disaster risks.

5. Conclusions and way forward

This research investigates the application of simulation techniques, particularly hydraulic modelling and Digital Elevation Models (DEM), to assess the socio-economic impacts of dam failures, using the Kantale Dam in Sri Lanka as a case study. By simulating flood conditions and dam break scenarios, the study demonstrates how these models can improve disaster preparedness and early warning systems, helping to mitigate the risks of dam failures. The findings emphasize the role of predictive modelling in identifying vulnerable areas, guiding land use planning, and informing emergency response strategies. Moving forward, the study advocates for the broader integration of systematic simulation models in flood management to enhance disaster resilience, protect vulnerable communities, and minimize environmental and economic damage from potential dam failures.

6. Acknowledgement

Authors greatly acknowledge the financial support provided by the Senate Research Committee (SRC) of University of Moratuwa under the Grant SRC/ST/2024/18.

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