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論文題目	Comprehensive Assessment of Cascading Reservoir Systems and Advanced Optimization Techniques for Flood Risk Reduction and Dam Management (洪水リスク軽減とダム管理のための連続貯水池システムの包括的評価および高度な最適化手法の適用)		
(Summary of the Thesis) Vietnam’s Vu Gia–Thu Bon (VGTB) River Basin faces intensifying flood risk driven by climate change, hydropower expansion (19 major plants by 2020), upstream deforestation, rapid LULC change, and fast urbanization of low-lying plains. This thesis (i) quantifies how cascading reservoirs alter streamflow and water levels; (ii) assesses downstream flood-inundation responses under alternative operating configurations and urbanization; and (iii) forecasts-aware operating rules for a key storage dam (Song Tranh 2). A calibrated/validated HYPE model represents basin hydrology and, via strategically placed Virtual Stations, isolates operational signals from confounders (e.g., inter-basin transfers). Validated HYPE outputs drive HEC-RAS 1D/2D to map flood depths/extents under multiple scenarios using updated geometry/topography (2018, 2021). For optimization, RTC-Tools is coupled with SCE-UA (global search) and MPC (dynamic control) and applied to 18 flood events ($Q_{in} > 500 \text{ m}^3/\text{s}$) from 2016 to 2020. Findings show systematic flow redistribution between rivers (with Dak Mi 4 a pivotal driver), storage reservoirs that reduce flood depths and delay waves, run-of-river schemes that track natural regimes, and optimized operations that lower peaks (e.g., 17.04% at Song Tranh 3 in 2020) while restoring post-event storage at runtimes suitable for real-time use. Overall, the thesis delivers a decision-ready, transferable framework for reconciling flood-risk reduction with hydropower reliability under evolving climate and land-use pressures. This thesis consists of six chapters. Chapter 1 presents the problem context, research questions, and objectives in the context of escalating flood hazards in the VGTB. It frames the compound drivers (climate variability, hydropower build-out, deforestation, LULC change, and urban growth). It articulates the dual need to (a) isolate reservoir-operation impacts on basin hydrology and flooding and (b) optimize operations to co-deliver flood mitigation and energy services. The chapter also outlines the end-to-end workflow (HYPE → HEC-RAS → RTC-Tools/MPC). Chapter 2 investigates the VGTB’s physical, hydrological, and socio-economic setting, reviews the state-of-the-art on upstream operations and downstream impacts, and identifies key gaps: limited ability to separate operation effects from hydraulic artifacts (e.g., diversions), sparse/heterogeneous observations (flood masks, operations logs, gauges), and a lack of forecast-aware optimization for Vietnamese cascades. These gaps motivate the Virtual Stations concept and the integrated modeling–optimization pipeline used in the thesis. Chapter 3 evaluates the cumulative impacts of cascading reservoirs on streamflow and water levels using the calibrated/validated HYPE model and the Virtual Stations network to avoid confounding by inter-basin transfers (notably via the Quang Hue Channel). Results show clear operational signals: at Virtual Station 1 (Vu Gia), reservoir operations significantly reduce both water level and discharge; at Virtual Station 2 (Thu Bon), water levels increase during			

flood and dry seasons, while the maximum flood level decreases by 4.69% (≈ 0.5 m). The Dak Mi 4 diversion emerges as decisive—reducing Vu Gia flows and increasing Thu Bon flows by shifting water between basins—whereas run-of-river schemes exhibit minimal deviations from natural regimes. These results establish the primacy of storage capacity and inter-basin transfer rules in shaping seasonal and event-scale hydrology.

Chapter 4 investigates downstream flood-inundation responses to alternative reservoir-group operations and to urbanization using HEC-RAS 1D/2D driven by HYPE outputs. Simulations (calibrated at major gauges; geometry/topography from 2018/2021 surveys) show that upstream reservoirs reduce flood extent and depth and delay wave propagation. Scenarios using storage reservoirs only perform similarly to full-group operations, confirming storage dams as the main regulatory lever. A comparative analysis with/without Dak Mi 4 inter-basin transfer demonstrates that removing transfer markedly raises Vu Gia levels and lowers Thu Bon levels, underscoring its restructuring effect on floodplain hydraulics. The chapter also quantifies urbanization impacts via DEM scenarios (2014 vs 2020): in newly developed areas (e.g., Hoa Xuan, Co Co), flood depths decrease due to land elevation/raised construction, improving local protection; however, altered micro-topography, reduced drainage capacity, and major roads across floodplains impede flow, redistribute water, and increase depths in adjacent low-lying zones. Overall, urban development can shift risk downstream or laterally, highlighting the need to co-manage land use and reservoir releases.

Chapter 5 presents the optimal reservoir-operation framework for Song Tranh 2, integrating RTC-Tools with SCE-UA and MPC over 18 significant flood events (2016–2020; $Q_{in} > 500$ m³/s). The dual objectives are: (1) minimize downstream peak discharge and (2) restore post-event storage for hydropower and dry-season supply. In the 2020 event, optimized releases reduced peak flow at the Song Tranh 3 control point by up to 17.04% (from 2688 to 2230.6 m³/s) while refilling to the normal level. The results demonstrate that a forecast-aware MPC with global-search seeding can deliver meaningful attenuation without sacrificing storage objectives.

Chapter 6 synthesizes cross-cutting conclusions and operational implications. Reservoir-group operations materially restructure basin hydrology and flood response; storage capacity is the dominant lever for regional flood mitigation; inter-basin transfers (e.g., Dak Mi 4) must be explicitly managed to balance risks between sub-basins; and optimization-based, forecast-aware operation can reconcile flood-risk reduction with energy production under time-varying conditions. Limitations include data sparsity, simplified urban drainage representation, and model assumptions. The thesis recommends (i) tighter forecast assimilation within MPC, (ii) operator-in-the-loop pilots across additional reservoirs, and (iii) finer-resolution hydrodynamics to resolve urban hotspots and road-induced blockages.

(Summary of the thesis review results)

The thesis makes an important contribution to basin-scale flood-risk mitigation and reservoir operations in the VGTB by combining a calibrated HYPE–HEC-RAS modeling chain with a novel “Virtual Stations” assessment strategy and an optimization framework (RTC-Tools + SCE-UA + MPC) demonstrated on Song Tranh 2. The study rigorously separates upstream operational effects from downstream hydraulic confounders, providing quantitative evidence of inter-basin flow redistribution and changes in flood extent under alternative scenarios. It shows that real-time, optimization-based releases can meaningfully attenuate peaks while safeguarding storage for hydropower and dry-season supply. The results of this study are as follows:

- 1) Quantifying Reservoir-Driven Flow Redistribution: A new “Virtual Stations” approach isolates operational impacts from local hydraulic artifacts (e.g., transfer channels). Analyses reveal systematic alterations in seasonal and annual streamflow in both rivers. In the Vu Gia, annual, dry-season, and flood-season flows decrease by 16.07%, 16.14%, and 16.03%, respectively. In the Thu Bon, they increase by 14.41%, 23.89%, and 22.35%, respectively. The Dak Mi 4 system is pivotal, reducing Vu Gia's annual flow by 15.94% while increasing Thu Bon's by 14.63%, consistent with its inter-basin transfer role.
- 2) Downstream Flood Mitigation by Storage Reservoirs: HEC-RAS inundation mapping driven by validated HYPE outputs shows that upstream reservoirs reduce downstream flood depths by 0.51–2.84 m (5.7–46.2%) and delay wave arrival. Scenarios with storage reservoirs only perform comparably to full group operations, highlighting the primacy of storage capacity in regulation. In contrast, run-of-river schemes yield depths close to natural conditions, indicating limited flood-control efficacy. Urbanization exerts a mixed influence—reducing depths by 0.5–2 m in some areas due to altered elevations/drainage, while intensifying localized flooding elsewhere—underscoring the need to co-manage land use with operations.
- 3) Optimization-Based Operations (RTC-Tools) Reduce Peaks While Protecting Storage: For 20 flood events (2016–2020) at Song Tranh 2, the RTC-Tools framework with SCE-UA + MPC meets dual objectives: peak reduction and post-event storage recovery. In the 2020 event, optimized releases lowered peak outflow by ~39% while achieving the target final water level; in a 2016 case, downstream peak at Hiep Duc was reduced by approximately 50% (from 2,000 to 1,000 m³/s). Computation completes in minutes per scenario, enabling practical real-time decision support.

- 4) Operational Implications and Data Priorities: The findings emphasize the value of real-time forecasting and monitoring in supporting adaptive releases, especially in rapidly urbanizing floodplains where vulnerability is increasing. Future work should further refine the balance between hydropower revenue and flood risk reduction, enhance forecast assimilation into the MPC, and expand cross-reservoir coordination across the 19-plant cascade.

The committee judges this dissertation to be methodologically rigorous, quantitatively robust, and practically impactful. It advances integrated reservoir operation science for the VGTB by: (i) introducing a defensible assessment framework (Virtual Stations) for isolating operational impacts; (ii) coupling calibrated hydro-hydraulic models to map flood-extent responses under realistic scenarios; and (iii) demonstrating an efficient optimization controller capable of materially reducing flood peaks while respecting storage objectives. The work offers actionable evidence and tools for operators and policymakers and is suitable for extension to other Vietnamese basins and comparable monsoon-affected systems. Accordingly, the thesis meets the standards for the doctoral degree.

On July 18, 2025, an examination was conducted to assess the thesis content and related matters. It was confirmed that the applicant met the criteria necessary for obtaining a doctoral degree and successfully passed the examination. This thesis complies with Article 14, Paragraph 2 of the Kyoto University Degree Regulations. The period of publication for the abstract (i.e., the period until the full text becomes available) is September 31, 2026.

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