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Enhancement Strategy for Flood Risk Map Information System: A Framework for Resilience-Oriented Disaster Management

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ABSTRACT— Flood disasters in Korea have become more frequent and intense due to climate change, with devastating impacts observed in urban areas and floodplains. This paper proposes an enhanced operational framework for Korea's Flood Risk Map Information System (FRMIS), drawing from national flood damage data and global benchmarking cases. It addresses the limitations of current structural flood defenses and emphasizes the role of non-structural measures through high-resolution flood hazard mapping, integrated data systems, and scenario-based simulations. This study also proposes system upgrades including standardization, database integration, and public information services, and evaluates pilot implementations in selected basins. The research contributes a comprehensive strategy to optimize flood risk data utilization in policymaking and citizen preparedness, promoting resilience in the face of compound and extreme flood scenarios.

KEYWORDS: Flood risk map; Disaster information system; Climate resilience; Scenario-based mapping; Korea flood policy

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1. Introduction

Over the past decades, South Korea has witnessed a dramatic escalation in flood-related disasters. The intensification of extreme weather events due to climate change has rendered traditional flood management strategies increasingly ineffective. In 2020, Korea experienced the longest monsoon season since national records began in 1973, with 54 consecutive days of rainfall. The torrential downpours triggered widespread flooding across regions such as Anseong, Cheorwon, Hwacheon, Asan, and Gurye, prompting the government to designate 36 administrative districts as special disaster zones [1]. Notably, rainfall levels exceeded 100-year and even 500-year return period thresholds in several locations [2].

More recently, the metropolitan area of Seoul suffered severe flooding in August 2022 due to localized downpours reaching 141.5 mm per hour. The resulting inundation of low-lying areas such as Gwanak, Dongjak, and Gangnam districts caused significant human casualties, particularly in under-ground facilities including basements and subway stations [3]. In September of the same year, Typhoon Hinnamnor struck the southeastern city of Pohang, breaching riverbanks and submerging underground parking lots, leading to further loss of life and infrastructure damage [4]. These events underscore the escalating vulnerability of both natural and built environments to hydrometeorological extremes.

Historically, Korea has relied predominantly on structural flood defense mechanisms such as levees, detention basins, and dams. While these remain foundational components of national water management policy, their effectiveness is increasingly challenged by rainfall events that exceed design thresholds [5]. Furthermore, structural defenses offer limited flexibility in urbanized floodplains, where land use intensification amplifies potential damages. Accordingly, there is a growing demand for non-structural, data-centric solutions that support anticipatory action and integrated disaster response [6].

The Flood Risk Map (FRM) initiative, mandated under Article 7 of the Water Resources Management Act, represents a key non-structural tool for managing flood risk [7]. Since its inception in 1999, the FRM system has evolved to include both fluvial flood scenarios (riverine inundation maps) and pluvial flood scenarios (urban surface inundation maps), with increasing resolution and modeling sophistication [8]. Yet, the system faces limitations in interoperability, user interface design, and integration with real-time data sources, limiting its full potential for public communication and emergency operations [9].

To address these shortcomings, the Ministry of Environment, in collaboration with the Han River Flood Control Office, commissioned a comprehensive study to upgrade the Flood Risk Map Information System. This paper presents the results of that study, with a focus on enhancing the usability, accuracy, and responsiveness of the FRM system. Drawing from both domestic field data and inter-national benchmarking (e.g., FEMA's NFIP and Japan's hazard mapping platform), this study pro-poses a phased implementation strategy encompassing data standardization, system architecture re-design, and service delivery reform [10].
Ultimately, this paper argues for a paradigm shift in flood risk governance—one that complements traditional engineering with dynamic, information-based resilience strategies. Through the proposed upgrades to the FRM system, Korea can improve national preparedness, strengthen local response capacity, and reduce flood-related losses in an increasingly volatile climate landscape [11].

2. Literature Review

2.1 Domestic Developments in Flood Risk Mapping

The concept of the Flood Risk Map (FRM) in South Korea was introduced in 1999 as part of a shift toward non-structural flood mitigation strategies [1]. Initially led by the Ministry of Land, Infrastructure and Transport and later transferred to the Han River Flood Control Office, the program was institutionalized through amendments to the River Act and further consolidated under Article 7 of the Water Resources Management Act [2].
The initial FRMs focused on fluvial flood predictions based on 100-year return period scenarios. Over time, the system expanded to include pluvial flood maps (urban inundation risk), driven by severe urban flooding in Seoul, Busan, and other metropolitan areas [3]. National river flood mapping for major basins—such as the Nakdong, Han, Geum, Seomjin, and Yeongsan—was completed by 2016, with urban inundation maps for local catchments finalized by 2024 [4].
Despite employing advanced simulation tools such as FLUMEN and XP-SWMM, Korea's FRM system remains fragmented. Issues include inconsistent flood depth classification, lack of metadata standards, and limited integration with real-time data feeds, which hinder its utility for disaster operations [5].

2.2 International Approaches to Flood Risk Information Systems

Globally, several countries operate advanced flood risk information systems that offer valuable lessons for Korea's system enhancement.
The United States operates the National Flood Insurance Program (NFIP), managed by FEMA. A core element is the Flood Insurance Rate Map (FIRM), which identifies Special Flood Hazard Areas (SFHAs) based on

hydrologic and hydraulic modeling. These are supported by Flood Insurance Studies (FIS) and visualized through FEMA's Map Service Center portal [6]. The National Flood Hazard Layer (NFHL) consolidates this data in a GIS-compatible structure.

Japan employs a decentralized approach where local governments develop hazard maps for various disaster types, including floods, tsunamis, and landslides. These maps are tailored to each municipality and include shelter locations and evacuation routes. Japan's central government also provides standardized guidelines to ensure consistency and public accessibility [7].

2.3 Key Trends and Challenges in Integrated Flood Data Systems

Across domestic and international contexts, three key trends emerge:

- Multisource Integration: Recent systems increasingly combine hydrological, meteorological, and infrastructure data. Korea's Seoul Safe Map and Busan's Urban Inundation Information System incorporate flood forecasts, CCTV, emergency shelter data, and rainfall sensor networks into unified platforms [8].
- Scenario-Based Visualization: Flood risk systems now provide interactive, scenario-based visualizations. Busan's platform, for instance, simulates inundation under various rainfall return periods (30, 50, 80, 100 years) with 3D GIS tools [9].
- User-Centered Design: International models such as FEMA's MSC and Japan's hazard maps emphasize accessibility and mobile responsiveness. They support layered risk views and link with emergency applications [10].

However, persistent challenges remain. In many cases, flood maps are underutilized in urban planning, and a disconnect exists between technical systems and practical field use [11].

3. System Development Framework

3.1 Integrated System Architecture

The enhancement of the Flood Risk Map Information System (FRMIS) in Korea required a significant shift from a fragmented legacy system to a more integrated and modular framework. The new architecture is based on open-source technologies, including PostgreSQL, PostGIS, and GeoServer, which together support spatial data management, geovisualization, and high-volume web-based queries [1].

The core architecture integrates flood hazard data from multiple agencies—such as the Ministry of Environment (MOE), Korea Hydrographic and Oceanographic Agency (KHOA), and Korea Forest Service (KFS)—into a centralized repository. These data layers are then visualized through a WebGIS platform that supports interactive mapping, mobile accessibility, and real-time hazard overlays [1], [2].

Standard protocols such as Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS) have been adopted to allow seamless interoperability between agencies and to facilitate continuous updates (e.g., rainfall forecasts, flood zone changes, asset information updates) [3]. The integration allows local governments to dynamically query, edit, or publish updated hazard zones based on administrative changes or field reports [4].

A notable addition is the service-oriented architecture (SOA) layer, which supports third-party application integration—enabling mobile disaster apps, real-time warning systems, and sensor dashboards to connect directly with the hazard database [5].

3.2 Data Modeling and Standardization

To support consistency in flood data generation, management, and visualization, the revised system introduces a standardized data schema encompassing both external flooding (fluvial) and internal flooding (pluvial) [6]. This includes detailed classification for flood depths, inundation areas, hydraulic assumptions, modeling metadata, and time-stamped scenario identifiers.

The FRMIS utilizes a tiled image rendering system, breaking high-resolution raster flood layers into small map tiles for performance optimization on web and mobile platforms. The system supports up to zoom level 18, exceeding the standard recommended zoom level of 6 for public mapping platforms such as OpenStreetMap or FEMA's MSC [7].

A key innovation is the national unification of flood depth classification, which previously varied across jurisdictions. The following standard is now enforced throughout the system [8]:

Table 1. Standardized Flood Depth Classification

Flood Depth Range (m)	Risk Level	Description	Symbology Color
0.3 – 0.7	Minor Inundation	Possible surface-level flooding of roads and basements	Light Yellow
0.7 – 1.0	Moderate Inundation	Likely damage to vehicles, underground shops, and low-rise structures	Orange
> 1.0	Severe Inundation	Major risk to human safety and property; evacuation likely required	Red

Note: Depth thresholds were unified across urban and rural zones following the national FRMIS standard issued by the Ministry of Environment [8].

These depth bands are encoded directly into the spatial database structure, and all hazard maps now adhere to ISO 19115-compliant metadata protocols, facilitating long-term interoperability with Korea's National Spatial Data Infrastructure (NSDI) [9].

3.3 Functional Enhancement Strategy

Alongside architectural and data upgrades, the enhanced FRMIS incorporates several new functions that improve usability, decision-making support, and public communication:

- Scenario-Based Analytics: The system allows users to simulate various flood conditions, such as a 30-year rainfall event coinciding with pump failure or storm surge, and visualize the resulting inundation [10].
- Version Control and Model Logging: Each flood scenario is assigned a unique ID with model assumptions, input data, and result metadata stored for future audit or revision [1].
- Field Feedback Integration: Local governments and citizens can submit on-site observations (e.g., overflows, unexpected ponding) through a web/mobile interface, which are reviewed and, if validated, incorporated into updated hazard layers [11].

Additionally, the system is linked to Korea's Emergency Disaster Messaging System, allowing real-time hazard alerts to be sent via SMS, mobile push notifications, and digital signage based on geolocated flood risk zones [5]. A disaster operations dashboard was also deployed for administrators to monitor simulation outputs, rainfall data, and public reports in real time [4].

The combined effect of these enhancements is a responsive, integrated, and scalable system that bridges central and local disaster management functions, enabling faster and more informed flood response.

4. Pilot Implementation and Evaluation

4.1 Selection of Pilot Regions

To validate the upgraded Flood Risk Map Information System (FRMIS), pilot deployments were conducted

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in three representative basins: the Han River, Nakdong River, and Geum River regions. These areas were selected based on their high frequency of flood events, diversity in topographic and land use conditions, and readiness in terms of existing sensor and data infrastructure [1].
Each pilot area contained a mixture of urban and rural flood-prone zones, enabling the evaluation of both external flooding (river overbank) and internal inundation (urban drainage failure). The pilot also included integration with municipal emergency operation centers to assess real-time usability and communication functions.

4.2 System Deployment and Functional Testing

The upgraded system components were deployed in a cloud-based virtual environment with dedicated local access points. Functional tests were conducted to evaluate:

- Flood Scenario Visualization: The system successfully displayed compound hazard scenarios (e.g., heavy rainfall + pump station failure) using dynamic, GIS-based maps [2].
- Mobile Interface Responsiveness: The 18-level zoom capability allowed field personnel to view detailed inundation zones and infrastructure risks on-site using mobile devices [3].
- Cross-Agency Interoperability: Using standardized APIs (WMS/WFS), hazard data layers were successfully accessed and overlaid by municipal disaster systems and local police/fire departments [4].
- Real-Time Data Linkage: Rainfall sensors, water level gauges, and inundation indicators transmitted live data into the platform without latency or format mismatch [5].

A total of five operational use cases were tested during simulation drills, including pre-evacuation notices, shelter accessibility verification, submerged area detection, and field report submission through mobile devices.

4.3 Comparative Evaluation

To evaluate the impact of the enhanced system, a before-and-after comparison was conducted in each region. The evaluation framework used three core metrics:

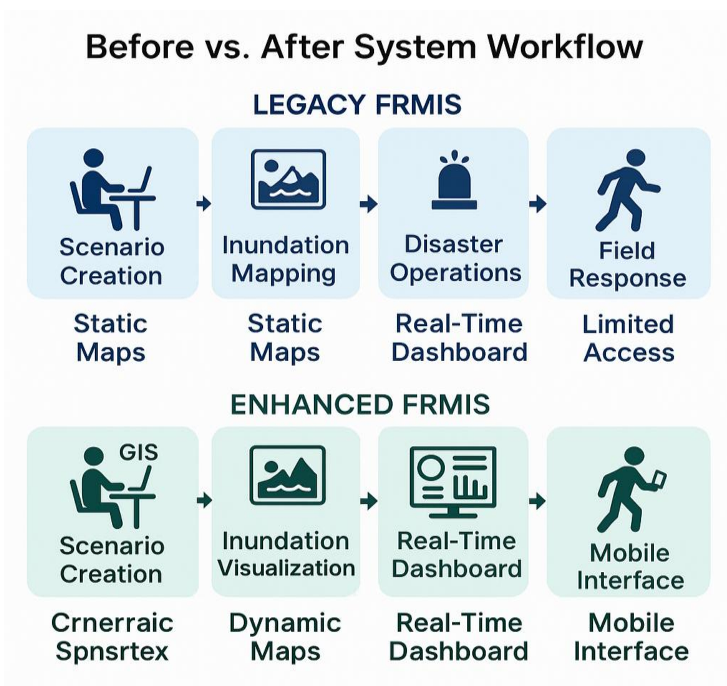

Fig 1. Before vs. After System Workflow

In the Han River basin, for instance, the time required to generate an updated inundation scenario during a drill was reduced from over 3 hours (manual shapefile processing) to less than 20 minutes using the automated scenario simulator.

Additionally, local disaster officers reported a 37% improvement in response time during mock flood evacuation drills, attributed to clearer visualization and immediate field feedback functions [6].

Table 2. Comparative Evaluation of Legacy and Enhanced FRMIS

Metric	Legacy FRMIS	Enhanced FRMIS
Scenario Simulation Support	Static map only	Dynamic multi-layered GIS
Mobile Accessibility	Limited to desktop	Full mobile integration
Real-Time Sensor Integration	Partial	Full, auto-updating
Flood Depth Classification	Inconsistent	National standard applied
Inter-agency Data Interoperability	Manual shapefile exchange	API-based live access
Inundation Map Update Time (Han River drill)	> 3 hours	< 20 minutes
Field Response Efficiency (reported)	Baseline	37% improvement

4.4 Stakeholder Feedback

Post-deployment surveys were conducted with local government officials, field responders, and system administrators. Key findings include:

- Ease of use: 85% of users rated the interface as intuitive and easier than previous versions.
- Decision-making support: 91% found the real-time dashboard helpful in determining emergency thresholds and action timing.
- Integration potential: Many municipalities expressed interest in integrating FRMIS with smart city and transportation systems.

While the pilot proved effective, limitations were noted in sensor coverage in mountainous regions and training gaps for new users. These will be addressed in future nationwide deployment phases.

5. Conclusion

As climate change continues to amplify the frequency and severity of flood events, traditional flood management strategies centered on structural defenses are no longer sufficient. The recent sequence of devastating floods in Korea—from the record-breaking 2020 monsoon to the urban inundation of Seoul in 2022—has underscored the urgent need for a data-driven, anticipatory approach to disaster management [1], [2].

This study has presented a comprehensive enhancement strategy for Korea's Flood Risk Map Information System (FRMIS), with a focus on improving its architectural robustness, data interoperability, visualization capabilities, and field responsiveness. Key upgrades include:

- Integration of multisource data (e.g., rainfall, river levels, hazard maps) through an open-source backend structure using PostgreSQL, PostGIS, and GeoServer;
- National standardization of flood depth classification and metadata schema for consistent use across municipalities;
- Real-time simulation and visualization of flood scenarios via mobile and web GIS interfaces;
- API-based data services enabling inter-agency coordination and public communication;
- Operational validation through pilot deployments in the Han, Nakdong, and Geum River basins, with measurable improvements in response time, usability, and system performance.

Evaluation results showed that scenario generation time was reduced by over 80%, and local authorities reported an average 37% improvement in drill response times. Stakeholder feedback further confirmed the

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system's value in emergency preparedness, spatial planning, and citizen engagement [3], [4].
Despite these advances, limitations remain. Sensor coverage in mountainous regions is still insufficient, and some local governments require capacity building to fully utilize the system. Future development phases should address these issues through targeted investment in sensor networks and user training programs.
Ultimately, this study contributes to the evolving paradigm of disaster management—one that emphasizes information systems, citizen-accessible tools, and integrated governance. The enhanced FRMIS stands as a blueprint for how flood risk information can be transformed into actionable knowledge, fostering resilience in the face of compound and cascading disasters.

6. References

[1] Ministry of Environment. Flood risk map information system enhancement strategy. Han River Flood Control Office, 2025.

[2] Korea Meteorological Administration. Annual rainfall records and weather disaster trends (2020–2023). Korea Meteorological Administration, 2023. Available from: https://www.kma.go.kr/

[3] Seoul Metropolitan Government. Urban flood damage report: August 2022 event. Seoul Metropolitan Government, 2022.

[4] Pohang City. Typhoon Hinnamnor damage assessment report. Disaster Management Division, 2022.

[5] Jung K, Lee J. Reassessing structural flood countermeasures under climate uncertainty. *J Korean Soc Hazard Mitig*, 2021, 21(4): 15–23.

[6] Federal Emergency Management Agency (FEMA). Map Service Center (MSC), National Flood Hazard Layer (NFHL) & NFIP guidelines. FEMA, USA. Available from: https://msc.fema.gov/

[7] Cabinet Office of Japan. Guidelines for hazard mapping and flood simulation. Cabinet Office of Japan, 2021.

[8] Ministry of the Interior and Safety (MOIS). National emergency alerting system manual. MOIS, Korea, 2022.

[9] Busan Metropolitan Government. Urban inundation integrated information system manual. Busan Metropolitan Government, 2023.

[10] Federal Emergency Management Agency (FEMA). FEMA GeoPlatform – WebGIS and real-time flood data exchange architecture. FEMA, USA, 2022.

[11] Lee D, Park J. Case study on data standardization in disaster GIS systems. *J Spatial Inf Res*, 2023, 31(1): 55–66.

[12] Seoul Metropolitan Government. Seoul safe map: real-time public disaster dashboard. Seoul Metropolitan Government, 2023. Available from: https://safemap.seoul.go.kr/

[13] Han River Flood Control Office. Post-pilot survey summary on enhanced FRMIS usability. Internal briefing document, 2025.