A Blueprint for Modern Floodplain Management: System Requirements and Architecture for AI-Ready Platforms

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Abstract
Floodplain managers play a critical role in mitigating flood risks and ensuring compliance with federal, state, and local regulations. Their daily work often depends on a patchwork of standalone tools, manual processes, and legacy systems that have evolved over time to meet regulatory and community needs. To establish a foundation for next-generation technological solutions, we synthesized insights from a multi-tiered requirements elicitation process involving the analysis of continental U.S. local ordinances, professional consultations, and iterative community validation at targeted domain venues. This domain survey revealed five recurring themes spanning data use, workflow efficiency, communication challenges, regulatory complexity, and openness to technological innovation. The domain input identified a heavy reliance on FEMA maps with limited integration capabilities, widespread manual documentation, and significant barriers to public engagement and cross-jurisdictional tool adoption. It also identified opportunities for improvement, including enhanced GIS overlays, streamlined permit automation, scenario-based modeling, real-time alerts, and elevation verification tools. Drawing on these insights, we propose design principles for intelligent, user-centered platforms that integrate local workflows, regulatory requirements, and citizen engagement. This work establishes a highly practical, forward-thinking blueprint for democratizing AI-ready hydrology tools across resource-constrained local governments.

Keywords: Floodplain Management, Decision Support Systems, Requirements Engineering, Local MLOps, Client-Side Execution

1. Introduction

Floodplain managers (FPM) serve as critical intermediaries between complex hydrological scenarios and community resilience, tasked with the multifaceted challenge of mitigating flood risks while balancing engineering solutions, regulatory compliance, and stakeholder engagement (Bostick et al., 2017; Emiroglu et al., 2025). These professionals operate at the intersection of data analysis, policy implementation, and community outreach, utilizing federal guidelines such as FEMA flood maps while adapting strategies to meet local conditions and needs (Pursnani et al., 2024; Tyler et al., 2021). In a broad perspective, the responsibility of an FPM includes interpreting hydrological phenomena through analysis and models, along with ensuring regulatory compliance in the implementation of both structural and non-structural mitigation measures that accommodate natural river processes while protecting community assets (Freitag, 2012; Yevjevich, 1995).

The role of floodplain managers has evolved significantly from traditional federal regulation towards localized land use planning approaches, requiring integration of engineering solutions with community-specific policies to optimize social, economic, and environmental outcomes (National Research Council et al., 2012). The transition has been accompanied by increasing reliance on advances in numerical models (Neal et al., 2012; Agliamzanov et al., 2020) and benchmark datasets (Xu et al., 2025; Ebert-Uphoff et al., 2017) to predict flood behavior and guide land use decisions, particularly with the continuous readjustment loop between hydrological processes and urban development (Smith et al., 2016; Bagheri & Liu, 2024). However, the applicable procedures of these professionals vary considerably based on location, experience, training, and available resources, highlighting the need for enhanced capabilities and tools to support their decision-making processes (Levy, 2005; Siebeneck et al., 2022; Burby, 2001).

Despite their critical role, a floodplain manager's daily tasks present challenges that complicate effective flood risk management and regulatory implementation (Sayer et al., 2015). Urbanization pressures continue to increase exposure of population and infrastructure to flood risks, particularly as industrial and business development in floodplains elevates the potential for environmental contamination during flood events (Glosinska, 2014; Varma et al., 2021). The tension between immediate flood protection needs and long-term ecological considerations creates additional complexity, as floodplain managers must navigate competing priorities between stakeholders advocating for traditional engineering solutions and those promoting nature-based approaches such as wetland restoration (Christopher et al., 2024; Kiedrzyska et al., 2015).

Organizational barriers present equally significant obstacles, with poor inter-agency cooperation, political interference, and inconsistent policy implementation hindering effective flood management across jurisdictions (SHOLA & Rollason, 2024). These challenges are amplified by capacity constraints, as local floodplain administrators often lack adequate training and resources, with their effectiveness varying significantly based on location, experience, and available support systems (Siebeneck et al., 2022; Scholte, 2005). In arid and semi-arid regions, these struggles are further complicated by unique hydrological and climatic conditions that require specialized strategies often absent from standardized management approaches (Nabinejad & Schüttrumpf, 2023; El Kenawy, 2024).

In response to these persistent challenges, floodplain management has increasingly integrated land use planning, engineering solutions, and nature-based approaches to optimize outcomes across social, economic, and environmental dimensions (Christopher et al., 2024; Soz et al., 2016). Contemporary floodplain management increasingly emphasizes the integration of land use planning with engineering solutions, employing optimization models to determine effective combinations of flood control measures and development policies that account for economic trade-offs and local contexts (Chakraborty, 2021; Freitag et al., 2012). Geographic Information Systems (GIS) have become critical in this integration, providing accurate flood risk assessments and facilitating emergency response and post-storm evaluations in urban environments at a level easily digestible to the public (Cova, 1999; Amatebelle et al., 2025; Alabbad et al., 2024).

However, the effectiveness of these solutions remains constrained by institutional and financial barriers, limited community engagement, and the ongoing challenge of adapting approaches to diverse local contexts while managing competing objectives (Christopher et al., 2024; Wells et al., 2020). As climate change continues to intensify flood risks and increase the complexity of floodplain management decisions, there is growing recognition that traditional tools and manual processes may be insufficient to support the need for complex analysis, real-time decision-making (Kadiyala et al., 2025), and stakeholder coordination required for effective flood risk governance (Xiang & Demir, 2022). This recognition has sparked interest in leveraging advanced computational approaches to augment human decision-making capabilities in floodplain management (Ahmad & Simonovic, 2006; Karanjit, 2023).

The application of artificial intelligence in environmental and regulatory domains has demonstrated significant potential for addressing complex, data-intensive challenges similar to those faced in floodplain management (Nishant et al., 2020; Alotaibi & Nassif, 2024). AI models including neural networks and IoT-enabled adaptive techniques have proven effective in flood prediction and real-time monitoring (Khan, 2024; Wilson et al., 2023; Prabhanjana et al., 2025), with geospatial AI (Rezvani et al., 2024; Mukarram et al., 2025) and remote sensing technologies (Wang & Xie, 2018; Li et al., 2023) further enhancing flood prediction models and providing valuable insights for policymakers and emergency responders across diverse geographic contexts (Gonzales-Inca et al., 2022; Liao et al., 2023). Machine learning approaches have shown particular promise in coastal flooding prediction where traditional monitoring systems are limited (Maheswari et al., 2024; Sang-Jin & Dong-Kun, 2020).

With the advances of large language models, there is potential to support hydrological knowledge tasks relevant to flood management, with benchmark studies revealing both capabilities and limitations of AI-driven tools in understanding specialized water-related content (Gacu et al., 2025; Kizilkaya et al., 2025a), and domain-specific language models being developed to further advance this capacity (Xu et al., 2025; Kizilkaya et al., 2025b). Building on this foundation, domain-specific embedding models have been developed to enhance semantic retrieval and question-answering in hydrological contexts, with fine-tuned models demonstrating improved performance over general-purpose embeddings in retrieval-augmented generation (RAG) systems (Arslan, 2026; Sajja et al., 2025a). Practical applications have further shown AI's potential in supporting hydrological workflows (Eythorsson et al., 2025; Ramirez et al., 2022), with LLM-enhanced platforms successfully assisting researchers in navigating complex hydrological models and documentation while generating code and providing ready-set execution environments for specialized analysis tasks (Tudaji et al., 2026; Demir et al., 2018).

Building on these broader applications, AI is beginning to transform floodplain management specifically through targeted tools and systems designed to address the unique challenges faced by floodplain managers. The development of AI-driven virtual assistants, such as the Floodplain Manager AI, demonstrates the potential for location-specific guidance and automated interpretation of complex regulatory documents like FEMA flood maps, enhancing decision-making by simplifying access to critical floodplain management resources (Pursnani et al., 2025). Educational applications have emerged through AI-assisted tools that support professional certification processes, offering personalized learning experiences and real-time feedback to improve training outcomes for aspiring floodplain managers (Sajja et al., 2025b). Operational systems, including smart flood control automation that utilizes deep learning for water level management, illustrate how AI can provide prompt, data-driven responses to flood disasters (He at al., 2025; Chang et al., 2025; Grudenić, 2026).

Despite the growing body of AI applications in flood-related domains, a critical gap persists between technological capability and practical deployment in floodplain management workflows. Existing AI tools have been developed largely in isolation from the lived realities of floodplain managers, focusing on flood prediction accuracy, map generation, or isolated regulatory Q&A, without accounting for the heterogeneous, jurisdiction-specific, and deeply human-centered nature of day-to-day floodplain management practice (Martelo et al., 2024; Kadiyala et al., 2024). To the best of our knowledge, no study to date has systematically examined how floodplain managers across multiple U.S. jurisdictions function within the context of the development and use of AI-based technologies: what documents they use, how they coordinate with stakeholders, where manual processes create bottlenecks, and what computational augmentation would be both feasible and trusted in professional contexts.

This study addresses that gap through a domain needs assessment and requirements elicitation to inform AI-assisted platform design. Our contributions are threefold: (1) a characterization of systemic operational bottlenecks in floodplain management derived from a multi-tiered elicitation of U.S. local ordinances, professional consultations, and iterative community validation; (2) a conceptual system architecture for an integrated platform featuring local Machine Learning Operations (MLOps) and cross-cutting governance to ensure strict data privacy; and (3) a framework for deploying place-based, domain-specific AI tools that can bypass prohibitive cloud computing fees through on-premise and client-side execution. The novelty of this work lies not in developing a new AI algorithm, but in establishing the empirical and design foundation that such algorithms require to be useful, trusted, and adopted in the complex sociotechnical environment of floodplain management.

The rest of the paper is structured as follows: Section 2 describes our multi-tiered domain needs assessment and requirements elicitation approach; Section 3 details the identified operational bottlenecks alongside the conceptual architecture designed to resolve them; Section 4 discusses the implications of deploying this architecture, with a focus on local MLOps and client-side execution; and Section 5 concludes with future directions for intelligent floodplain governance.

2. Methodology

This project employed a multi-tiered requirements elicitation approach to characterize the current state of floodplain management practice and identify opportunities for technological enhancement. To ensure the resulting architecture was grounded in nationwide realities rather than isolated jurisdictions, we synthesized insights from three core streams: (1) systematic retrieval and analysis of publicly available floodplain management guidelines and local ordinances across applicable counties in the continental United States; (2) professional engagements and virtual consultations with floodplain management professionals across multiple U.S. jurisdictions; and (3) iterative community validation of proposed architectural concepts at targeted domain venues, including the 2026 ASFPM Conference and GulfCon 2026. This triangulated process was designed to capture both common patterns emerging across the field and context-specific operational considerations that could inform the development of more effective, user-centered tools for floodplain governance.

2.1. Domain Engagement Strategy

To understand the current workflows, tools, and challenges faced by floodplain managers in their day-to-day operations, we conducted a requirements elicitation process through professional consultations, conference discussions, virtual meetings, and follow-up conversations with practicing floodplain management professionals across multiple U.S. jurisdictions. This process was intended to capture operational requirements and workflow considerations that could inform the design of technological solutions aligned with real-world floodplain management practices.

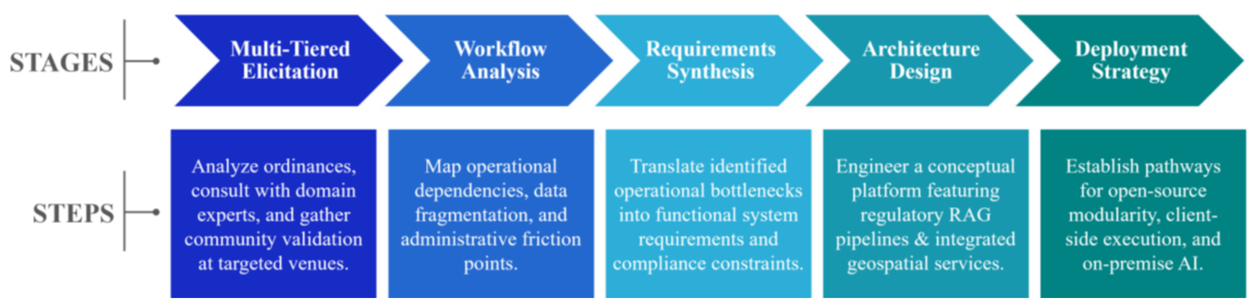

Figure 1. Systems engineering lifecycle including stages and steps for deployment strategy.

This approach was well suited given the complex, context-dependent nature of floodplain management work, which varies significantly across different geographic regions, regulatory environments, and organizational structures. Structured consultations and professional discussions enabled the identification of both common workflow patterns and jurisdiction-specific operational considerations while maintaining consistency in the topics explored across engagements. Figure 1 shows the systems engineering lifecycle, illustrating the progression from multi-tiered requirements elicitation and workflow analysis to the synthesis of the conceptual architecture and deployment strategy.

2.2. System Requirements and Design Goals

The elicitation process was guided by several key objectives that emerged from gaps identified in existing literature and preliminary observations of floodplain management practice. We sought to understand the current state of tool usage and data sources in floodplain management, examining what tools and data sources practitioners rely on in their daily work and how these tools integrate with each other to support different aspects of their responsibilities. This inquiry was essential given the limited existing research on the operational realities of how floodplain managers use technology in practice.

We also aimed to identify workflow challenges and pain points that characterize current floodplain management practice, exploring where manual processes create inefficiencies or barriers to effective work. Understanding these friction points was crucial for identifying opportunities where technological innovation might genuinely improve rather than complicate existing workflows.

Communication and stakeholder engagement represented as another critical area of investigation, as we examined how floodplain managers communicate complex technical information to diverse stakeholders and what challenges exist in public engagement and community education around flood risk. This reflected the inherently collaborative nature of floodplain management work that extends beyond technical analysis to include community interaction.

The engagement process also explored regulatory complexity and jurisdictional variation, investigating how state and local regulatory differences impact tool adoption and workflow standardization, and what implications this complexity has for developing technological solutions that can work across different jurisdictions. This objective was particularly important given the federated nature of floodplain management in the United States.

Finally, we examined technology adoption and innovation readiness among floodplain management professionals, exploring their attitudes toward new technologies, including artificial intelligence and automation, and where they see opportunities for technological enhancement versus areas where human expertise remains essential. This research scope was critical for understanding how emerging technologies might be successfully integrated into floodplain management practice. These design goals guided our domain consultations and subsequent analysis, allowing us to explore the multifaceted nature of floodplain management practice while remaining open to themes that emerged organically from the engagements with domain professionals.

2.3. Requirement Elicitation via Competency Questions

Domain engagement was conducted through collaboration with floodplain management professionals from multiple U.S. jurisdictions. Professional consultations were held with practitioners representing Iowa, Massachusetts, Colorado, Montana, Vermont, Minnesota, Illinois, and Washington, D.C., providing exposure to a broad range of regulatory environments, organizational structures, and operational workflows. Additional discussions with specialized personnel, including directors from Johnson County, Iowa, contributed further domain-specific expertise.

Because floodplain management in the United States is implemented through a federated system of federal, state, and local agencies, consulting professionals from multiple jurisdictions provided insight into both common operational workflows and jurisdiction-specific practices. The diversity of organizational contexts, regional regulations, and operational practices informed the identification of system requirements and the development of the proposed integrated floodplain management tool.

The professional consultations focused on three primary areas: current floodplain management workflows and day-to-day responsibilities, the software tools and data sources used to support these activities, and opportunities where an integrated software platform could improve existing practices. A consistent set of discussion topics was used throughout the consultations to ensure that comparable information was gathered across jurisdictions while allowing conversations to naturally adapt to each professional's operational responsibilities and areas of expertise.

Table 1 summarizes the competency domains, guiding questions, and representative operational topics that structured the domain engagement process. Rather than serving as a rigid questionnaire, these competency questions provided a consistent framework for discussing existing workflows, software tools, regulatory practices, documentation requirements, and organizational challenges while allowing conversations to adapt to the responsibilities and expertise of each professional.

During the consultations, notes were taken to document existing workflows, recurring operational challenges, commonly used software and datasets, and suggested capabilities for future software tools. These observations were subsequently synthesized to identify common patterns, recurring design needs, and jurisdiction-specific considerations that informed the proposed system architecture. This process provided both a broad understanding of shared operational requirements across floodplain management organizations and insight into variations introduced by differing regulatory and organizational contexts.

Table 1: Competency domains, questions, and representative operational topics explored during domain engagement.

Competency Domain	Competency Questions	Representative Operational Topics

Role and context	What operational responsibilities and decision-making authority define the role?	Jurisdiction scope, staffing, permits, coordination, reporting
Tools and data	Which software systems, maps, and datasets are required to support operational decisions?	FEMA maps, GIS, terrain/elevation, hydrologic models, parcel data
Workflow realities	What are the major stages of a permit review from intake through final approval?	Intake, elevation checks, floodway/no-rise checks, documentation, approvals
Documentation and reporting	What information must be documented and reported throughout the workflow?	Activity logs, CRS/NFIP reporting, training/outreach tracking, file retention
Communication and engagement	How is flood risk information communicated to stakeholders?	Public-facing maps, property-specific questions, post-event communication
Cross-jurisdictional differences	Which operational requirements differ across jurisdictions?	Definitions/thresholds, local ordinances, CRS nuances, overlapping authorities
AI and automation	Which activities are suitable for automation, and which require human oversight?	Candidate use cases, trust/accuracy needs, explainability, liability
Desired capabilities	Which capabilities would provide the greatest operational benefit?	Priority features, integrations, quick wins vs. long-term

3. Results

While the domain engagements were guided by the predefined competency questions (Table 1), the resulting observations and operational considerations were synthesized across these domains to identify common workflows, recurring challenges, and system requirements. By examining the intersections of professionals' workflows, tool usage, and regulatory challenges, we identified recurring patterns across professional workflows, software usage, and regulatory practices. This cross-cutting analysis revealed five major emergent topics that characterize the current state, challenges, and technological opportunities in floodplain management practice. As summarized in Table 2, the synthesized observations across each competency domain reveal both the complexity of current floodplain management practices and the corresponding design implications for AI-enhanced tools. These synthesized observations were organized into five overarching themes, which form the basis of the proposed system architecture and core system modules.

Table 2: Summary of synthesized observations and corresponding design implications.

Domain	Synthesized Insights	Implications for AI-enhanced Tools
Role and context	Practice varies by scale; time split between permits, coordination, and reporting	Configurable workflows; dashboards reflecting local scale; role-based views
Tools and data in use	Heavy FEMA reliance; limited integration across sources; manual cross-referencing	Unified map overlays; connectors/APIs; data provenance and versioning
Workflow realities	Manual steps dominate; ad hoc elevation verification; inconsistent documentation	Digital permit intake; validation rules; elevation verification helpers; audit trails
Documentation and reporting	Reporting is time-consuming, manual, and dispersed	Automated activity logging; report generators with export templates; KPIs
Communication and engagement	Map literacy is a barrier; desire for plain-language property-level summaries	Property reports in plain language; risk visualizations; notification/alert features
Cross-jurisdictional differences	Variation complicates standard tools; one-size-fits-all solutions underperform	Configurable rulesets; jurisdiction profiles; localized checklists and citations
Attitudes toward tech and AI	Openness to targeted automation; strong emphasis on accuracy and human oversight	Human-in-the-loop design; confidence thresholds; explanations with citations
Desired capabilities	Consistent asks: integrated overlays, digital permits, auto reporting, alerts	Prioritized roadmap; modular architecture; pilotable feature bundles

3.1. Identified Operational Bottlenecks

The multi-tiered requirements elicitation process revealed five primary operational bottlenecks that currently hinder the efficiency, scalability, and modernization of day-to-day floodplain management workflows.

3.1.1. Fragmentation of FEMA Maps and Limited Data Integration

FEMA floodplain maps emerged as the primary geospatial resource used across all participating jurisdictions. While these maps provide essential baseline information for floodplain management, they are rarely sufficient as a standalone source and typically require supplementation with local datasets, jurisdiction-specific mapping resources, and professional interpretation to support permitting and regulatory decisions. Although some jurisdictions have adopted platforms that integrate FEMA layers with additional mapping resources and flood models, such capabilities remain uncommon. Where available, integrated systems were viewed as significantly more effective than relying on standalone FEMA maps because they reduce manual cross-referencing across multiple data sources. In most jurisdictions, however, professionals continue to rely on disconnected software tools and manually reconcile information from FEMA maps, local datasets, and other geospatial resources.

The consultations also revealed a persistent disconnect between the information available to floodplain professionals and the information accessible to the public. While practitioners often have access to specialized state mapping tools and flood corridor datasets, community members frequently struggle to locate and interpret floodplain information. Public inquiries commonly focus on property-specific flood insurance requirements, yet obtaining current and understandable information often requires direct communication with floodplain administrators, who frequently rely on paper documents or manually compiled reference materials during these interactions.

3.1.2. Dependency on Manual, Paper-Based Workflows

Despite the availability of digital tools, many core floodplain management workflows remain dominated by manual processes and paper-based documentation. This is particularly evident in permitting, where paper application forms, handwritten notes, and informal documentation practices continue to play a central role in day-to-day operations.

Determining critical elevation information remains especially challenging because supporting documentation frequently arrives in informal formats, including hand-drawn sketches and applicant-prepared materials. In addition, many jurisdictions maintain incomplete historical records due to relatively low permitting volumes, making it difficult to establish comprehensive digital archives or standardized data collection practices. These limitations reduce data consistency and complicate both regulatory review and long-term record management.

Manual reporting requirements also emerged as a significant administrative burden. Tracking outreach activities, training sessions, community engagement, and other program metrics often requires staff to compile information manually from multiple sources before preparing reports for different reporting periods. As a result, substantial staff effort is devoted to administrative recordkeeping rather than core floodplain management responsibilities, highlighting the need for integrated workflow management, automated activity tracking, and report generation capabilities.

3.1.3. Structural Barriers to Public Risk Communication

Communicating floodplain information to community members and stakeholders remains a persistent challenge across floodplain management. This challenge extends beyond permit applications to public education, community outreach, and post-disaster response, where technical information must be communicated accurately while remaining accessible to non-specialist audiences.

Current FEMA floodplain maps provide authoritative information but are often difficult for the general public to interpret because of their technical detail and complexity. As a result, there is a need for tools that translate floodplain regulations, risk information, and property-specific requirements into clear, accessible language without sacrificing regulatory accuracy. Improving the communication of floodplain information has the potential to significantly strengthen public understanding and community engagement with flood risk management.

The consultations also highlighted the need for improved visualization tools that enable residents to better understand flood risks and determine whether individual properties are located within regulated floodplain areas. Beyond traditional mapping interfaces, opportunities were identified for more engaging communication approaches, including systems capable of incorporating community experiences with past flooding to provide more relatable and context-rich risk communication.

Communication challenges also extend to the planning process itself. Property owners and developers may overlook floodplain requirements during the early stages of project planning, resulting in compliance issues that become significantly more difficult and costly to address later. Automated notification and alert systems could help mitigate these oversights by proactively informing stakeholders of applicable floodplain regulations and permitting requirements before critical planning decisions are made.

3.1.4. State and Local Regulatory Variations

Although many floodplain management challenges are shared across jurisdictions, substantial variation in state and local regulations complicates the development and adoption of generalized technological solutions, particularly AI-assisted systems. Regulatory differences extend beyond implementation details and often involve distinct definitions, mapping practices, and administrative procedures that directly influence how floodplain regulations are interpreted and applied.

Approaches to mapping and defining floodplain boundaries vary considerably across states, creating challenges for technologies intended to operate across multiple jurisdictions. Differences in terminology, regulatory concepts, and implementation practices make it difficult for AI systems to accurately interpret and apply regulations without jurisdiction-specific knowledge. In addition to federal FEMA requirements, many jurisdictions enforce state-specific regulations that introduce additional compliance obligations. Local ordinances frequently add further requirements that differ from both state and federal standards, creating multiple layers of regulation that complicate efforts to provide standardized summaries or automated regulatory guidance.

These regulatory variations highlight the need for technology platforms that are configurable rather than universally standardized. While general-purpose tools may offer broad functionality, effective AI-assisted floodplain management systems must accommodate jurisdiction-specific regulations, localized workflows, and customizable rule sets to support the diverse operational requirements of different states and municipalities.

3.1.5. Professional Liability and AI Explainability Constraints

The consultations revealed a balanced perspective toward AI and automation. While there was broad interest in technologies that improve efficiency and reduce administrative burden, there was also a strong emphasis on maintaining professional standards, regulatory accuracy, and human oversight. Rather than replacing expert judgment, AI was viewed as most valuable when supporting well-defined tasks within existing workflows.

Several opportunities for automation were consistently identified, including online permitting systems, automated floodplain status notifications, and administrative workflow support. AI was also viewed as having potential for predictive applications, particularly in analyzing stormwater data to improve flood forecasting. Existing engineering and hydrologic modeling tools, including EPA-Net, HEC-RAS, and SWMM, were repeatedly identified as foundational components of current practice. Any AI-assisted system was expected to complement these established tools rather than replace them, with effective deployment requiring access to extensive historical datasets and validated engineering models.

At the same time, significant reservations were expressed regarding the use of AI in regulatory interpretation and public-facing communications. Because floodplain management decisions carry legal, financial, and public safety implications, professionals emphasized that any AI-generated recommendations must satisfy stringent standards for accuracy, transparency, and accountability. Established workflows have evolved over many years to ensure regulatory compliance, and introducing new technologies should strengthen these processes rather than disrupt them.

The consultations also highlighted limitations of current AI technologies for interpreting jurisdiction-specific regulations. While software vendors are beginning to integrate AI capabilities into floodplain management platforms, successful adoption will depend on systems that provide reliable, explainable, and verifiable outputs aligned with professional practice. These observations suggest that effective AI integration should prioritize human oversight, traceable decision support, and seamless integration with existing engineering workflows instead of attempting to replace established professional processes.

3.2. Proposed System Architecture

To resolve the systemic workflow constraints identified during the domain needs assessment, we propose a modular, AI-ready conceptual architecture designed to bridge the gap between fragmented data sources and localized regulatory compliance.

3.2.1. Architectural Overview

Based on our findings from discussions with floodplain managers across multiple jurisdictions, we propose the development of an integrated web-based platform that addresses the key challenges identified in current floodplain management workflows. This recommendation will focus on creating a centralized platform that adapts to different state requirements while maintaining accessibility for both floodplain management professionals and community members. Throughout this approach, the platform will respond to the ongoing challenges highlighted within the consultations, meanwhile accommodating the regulatory complexity and jurisdictional variations that create barriers to adopting generalized technological solutions. Furthermore, rather than treating compliance as a localized feature, the architecture implements a cross-cutting global governance and security framework, encompassing role-based access control (RBAC), immutable audit logs, and Freedom of Information Act (FOIA) ready exports, that securely oversees all operations from the infrastructure level up to the user experience layer.

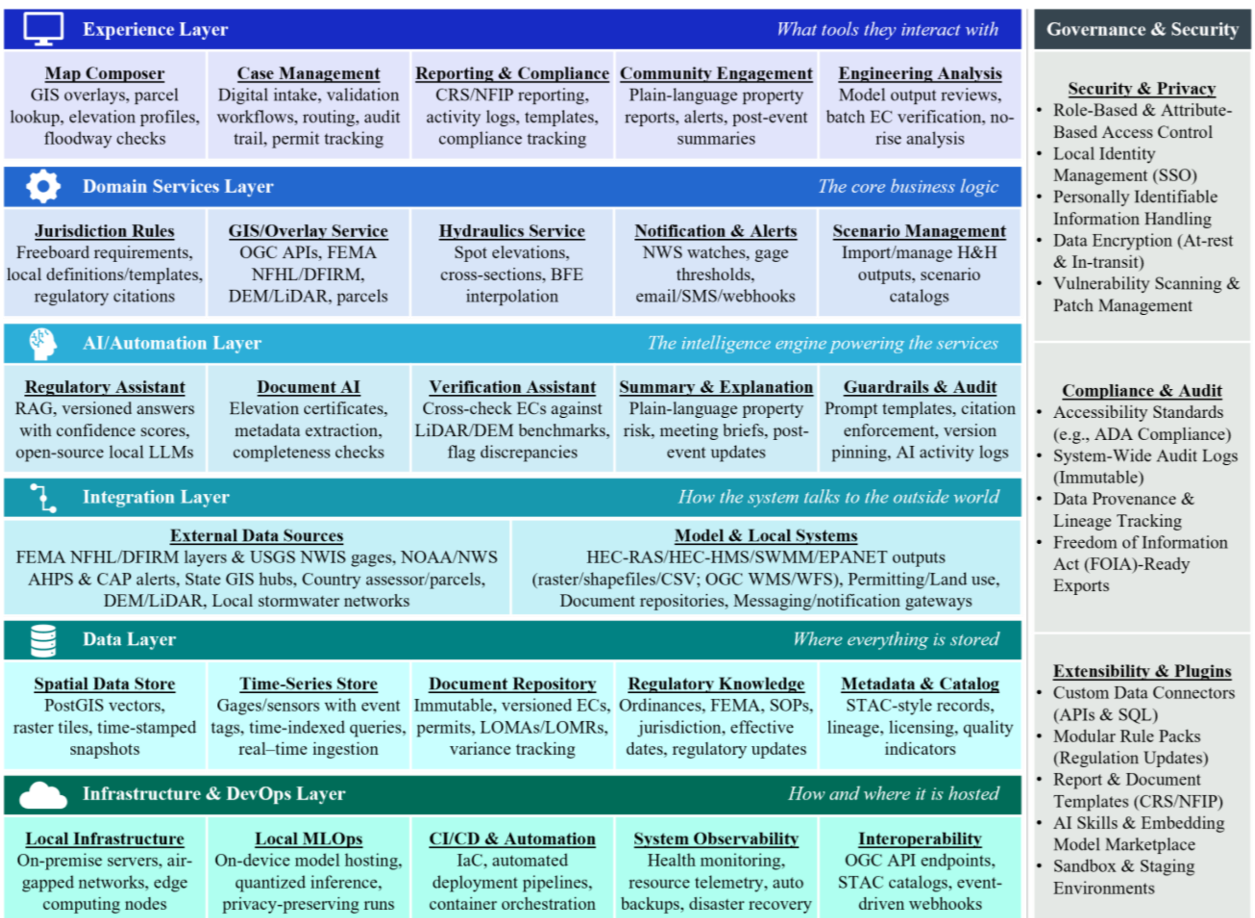

Figure 2. Conceptual architecture of the proposed floodplain management platform

The proposed architecture is designed to serve two distinct user profiles with interconnected stakes in the floodplain management ecosystem. The first group comprises public stakeholders, including residents, property developers, realtors, and local officials, who require highly accessible, plain-language interfaces to understand property-specific flood risks, insurance obligations, and initial zoning compliance. For these users, the system acts as an educational and risk-communication gateway. The second group consists of domain professionals, such as floodplain administrators, civil engineers, Community Rating System (CRS) coordinators, and emergency managers. These users rely on the system's advanced professional consoles to conduct complex elevation verifications, manage regulatory permitting workflows, audit municipal compliance, and execute technical hydrologic analyses. The architecture that is described in Figure 2 ensures that both public inquiries and professional tasks can be processed securely from the same underlying regulatory data structures.

3.2.2. Core System Modules

The platform should maintain a centralized architecture that can dynamically adapt to different state regulations, mapping standards, and local requirements. As discussed in Section 3.1, regulatory complexity and state-specific requirements present significant barriers to generalized technological solutions. The proposed architecture addresses these challenges by combining integrated FEMA map access with configurable jurisdiction-specific components. A shared core infrastructure provides common functionality, while state-specific modules accommodate regulatory differences, local mapping preferences, and jurisdiction-specific workflows. This modular approach allows jurisdictions to benefit from shared development resources and a consistent user experience while remaining compliant with local requirements, as illustrated in Figure 2.

A central feature of the platform is a state-specific Regulatory Assistant powered by open-source language models that can be adapted using state regulations, FEMA guidance, and local ordinances. Consistent with the needs identified during the domain engagement, this assistant provides location-specific guidance for both floodplain management professionals and community members while maintaining transparency regarding its capabilities and limitations. Human oversight is incorporated by directing users to qualified professionals whenever queries exceed the system's confidence or scope, ensuring that AI functions as decision support rather than a replacement for professional judgment.

The platform integrates data dashboards that combine FEMA floodplain maps with state and local datasets through a unified interface. These dashboards support key floodplain management workflows, including permit review, elevation verification, and community risk communication, while reducing the need for manual reconciliation across disconnected data sources. Interfaces should prioritize clarity and accessibility, incorporating features such as elevation verification, flood risk visualization, and property-specific information that effectively serve both technical users and the general public.

Automated reporting and documentation capabilities should be integrated throughout the platform to reduce the administrative burden associated with manual reporting processes. The platform should support activity tracking, report generation, and documentation tailored to the reporting requirements of different governmental agencies. Automated summaries generated from user activities and platform interactions can streamline compliance reporting while improving consistency and reducing repetitive administrative tasks.

Community engagement should be supported through dedicated communication tools that simplify the presentation of floodplain information. Plain-language property reports, intuitive map interfaces, risk visualizations, and educational resources can improve public understanding while preserving regulatory accuracy. Interactive visualizations, narrative explanations of flood risks, and property-specific guidance further enhance accessibility for users without technical expertise and strengthen communication between floodplain managers and their communities.

Digital permit processing capabilities should streamline existing permitting workflows by incorporating automated elevation verification, regulatory compliance checking, and application status tracking while integrating with existing local systems. Rather than replacing established workflows, these capabilities are intended to augment current practices through optional automation that organizations can adopt gradually according to their operational needs and readiness.

The platform should be built using open-source models and software components to promote transparency, customizability, and cost-effectiveness for resource-constrained jurisdictions. Accessibility should remain a core design principle, ensuring that community members without specialized knowledge can navigate floodplain information through plain language, intuitive interfaces, and clear visualizations. This dual-purpose design supports both professional decision-making and effective public engagement while addressing the communication challenges identified during the needs assessment.

Implementation should proceed through close collaboration with floodplain management practitioners to ensure that technological capabilities remain aligned with operational requirements and established professional practices. Pilot deployments across representative jurisdictions can provide valuable feedback for refining the platform before broader implementation, supporting iterative development while accommodating the regulatory diversity and workflow complexity that characterize floodplain management in the United States.

4. Discussion and Future Directions

This study provides comprehensive requirements elicitation and conceptual architecture to tackle the operational bottlenecks in modern floodplain management. A multi-tiered domain assessment was conducted through the analysis of continental U.S. local ordinances, professional consultations, and iterative community validation. Based on the synthesis of these insights, it was empirically observed that the daily operations of floodplain managers are heavily hindered by disjointed mapping tools, manual documentation processes, and highly localized regulatory complexities.

Key issues and challenges that may constitute setbacks and hindrances to the principled adoption of artificial intelligence in local government have been identified and reported, accompanied by the design of a four-tiered conceptual architecture to persevere in spite of the logistical, computational, expertise-related, and data-related challenges to its adoption. Based on the extent of this needs assessment and the broad spectrum of operational demands, we anticipate municipal governments will continue to incorporate automated compliance and intelligent support tools at an accelerating rate, and AI will play a key role in the future of floodplain governance.

AI-ready platforms and modular architectures open a plethora of application and deployment opportunities to revolutionize floodplain management and workflow. In a bird's eye view fashion, key areas of innovation for future research include:

a) *On-Premise AI Deployment*: As this needs assessment outlined, the integration of artificial intelligence into municipal workflows must address strict data privacy mandates and restricted budgets. In the future, efforts can be coordinated between software developers and local governments to collaboratively prioritize local, on-premise AI model hosting solutions over cloud-based instances. Deploying fine-tuned, localized models on-premise entirely eliminates recurring external cloud computational fees while ensuring that sensitive resident and infrastructure data remain strictly within the jurisdiction's secure environment. This approach will constitute the future of privacy-preserving municipal decision-making systems.

b) *Client-Side Execution*: The lack of accessible, lightweight tools for resource-constrained local governments was stressed in the previous sections. The main problem caused by centralized, monolithic software is that it requires heavy infrastructure maintenance and limits broad public engagement. As a solution, shifting computational execution to the client side offers a new perspective. By prioritizing open-source software practices and client-side computational deployment, municipalities can distribute interactive, web-native platforms for public engagement and classroom education more effectively.

c) *Machine-Readable Regulatory Datasets*: The lack of AI-ready datasets within the floodplain management field poses a significant barrier. The main problem caused by this absence is that the research community and local governments do not build upon previous work in terms of constructing better compliance architectures, often forcing jurisdictions to manually interpret text-heavy PDFs. This absence implicitly causes redundancy in the field. We believe if more studies focus on creating open, benchmark datasets of localized regulations for RAG pipelines (Lewis et al., 2020), both the cumulativeness of the science would be satisfied, and AI-powered regulatory modeling would go further in terms of generic applicability across state lines.

d) *Intelligent Assistants*: The massive amount of technical and regulatory data makes it challenging to efficiently and effectively extract required knowledge in a timely manner. Manual efforts are often needed to cross-reference FEMA layers with local freeboard requirements for permitting purposes. As a solution, intelligent regulatory assistants serve as localized knowledge engines that can interpret a natural language question regarding complex ordinances, apply human-like reasoning via RAG architecture, and extract the desired factual response out of curated local data. These assistants can be integrated into public-facing portals and professional consoles to facilitate rapid permit review, public inquiry resolution, and emergency preparedness.

e) *Inter-Agency Interoperability*: The main propeller in the creation of smart municipal applications is consistent and unified data flux. However, as the diversity of local zoning codes and federal mapping resources expands, a fragmented approach simply may not be viable. Furthermore, poor inter-agency cooperation complicates standard tool adoption. Future research should focus on developing generalized web frameworks that can readily provide the means to connect disparate systems (e.g., local GIS, FEMA NFHL, hydrologic models) through APIs and Platform-as-a-Service (PaaS) designs. These systems hold great potential for the floodplain community as they allow local governments to connect predefined modules with local datasets to create unified mapping overlays.

5. Conclusion

This study provides critical insights into the day-to-day realities of floodplain management practice through a multi-tiered assessment of continental U.S. local ordinances, domain engagements with professionals, and community validation. The findings reveal five key themes that characterize current practice including universal reliance on FEMA maps with limited integration capabilities, manual paper-based processes dominating workflows, significant communication barriers with communities, regulatory complexity creating tool adoption barriers, and selective openness to AI coupled with professional concerns. Based on the latter, there is a clear need for technological solutions that are sophisticated enough to address complex challenges while remaining flexible enough to accommodate diverse regulatory and operational contexts.

The domain engagement presented in this work was conducted within the project timeline and reflects consultations with floodplain management professionals who were available during that period. Additional interest from professionals across the United States emerged after the consultation phase had concluded, highlighting opportunities for broader engagement in future work. As the proposed platform is developed and evaluated, future validation will incorporate practitioners from a wider range of jurisdictions, particularly regions that experience more frequent flooding, to assess the generalizability of the proposed architecture and refine jurisdiction-specific capabilities.

Our research fills a critical gap by examining how floodplain management professionals actually use technology in practice, moving beyond technical capabilities to understand human factors and contextual complexities that shape technology adoption. The findings demonstrate that successful AI innovation in floodplain management must carefully consider integration with existing workflows, accommodation of regulatory variations, and the dual need to serve both professional users and community members. Based on these insights, we propose an integrated web-based platform featuring state-specific chatbots, integrated data dashboards, automated reporting tools, and community engagement features built on open-source architecture with accessibility as a core design principle.

As climate change continues to intensify flood risks, the need for intelligent, user-facing tools becomes increasingly urgent. However, the adoption of these technologies in municipal governance requires architectures that respect strict data privacy mandates and restricted budgets. This work demonstrates that by prioritizing open-source software practices, client-side computational deployment, and local AI model hosting, we can effectively mitigate prohibitive cloud computing costs. Future research will focus on the deployment of these privacy-preserving modules into pilot jurisdictions, further advancing the transition toward secure and intelligent floodplain governance.

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8. Author Contributions

Dilara Kizilkaya: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Visualization, Data Curation and Writing - Original Draft. **Yusuf Sermet**: Conceptualization, Methodology, Visualization, Writing - Review & Editing, Investigation, Supervision. **Ibrahim Demir**: Conceptualization, Writing - Review & Editing, Project administration, Funding acquisition, and Resources.

9. Declaration of Generative AI and AI-Assisted Technologies

During the preparation of this manuscript, the authors used ChatGPT and Gemini to improve the flow of the text, correct grammatical errors, and enhance the clarity of the writing. The language model was not used to generate content, citations, or verify facts. After using this tool, the authors thoroughly reviewed and edited the content to ensure accuracy, validity, and originality, and take full responsibility for the final version of the manuscript.

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