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The Role of Construction Management in Flood Risk Identification and Land Use Planning: A Case Study of Shalman City, Iran

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Abstract

Urban flooding represents one of the most significant natural hazards affecting cities worldwide, with impacts intensifying due to climate change and rapid urbanization. This study investigates the role of construction management in identifying flood-prone areas along river corridors and determining appropriate land use for urban development projects. Using Shalman City in Gilan Province, Iran, as a case study, the research integrates hydraulic modeling Hydrologic Engineering Center–River Analysis System (HEC-RAS) with Geographic Information Systems (GIS) to delineate flood zones and assess management strategies. The findings demonstrate that an integrated construction management approach, combining structural measures (gabion construction) with non-structural strategies (reservoir operation and land use planning), can significantly reduce flood impacts. Results indicate that implementing detention reservoirs can reduce peak discharge from 600 m³/s to 300 m³/s, decreasing required gabion height from 8.0 m to 6.6 m and achieving cost savings of approximately 20.8 billion IRR (≈\$500,000 USD) while storing 25.93 million m³ of water for beneficial use. This research highlights the necessity of integrating construction management principles—including risk management, crisis management, and time management—into comprehensive urban flood management frameworks.

Keywords: Construction management, Flood zoning, Hydrologic engineering center–river analysis system, Geographic information systems, Land use planning, Urban flood risk.

1 | Introduction

Civil engineering encompasses the design, construction, and maintenance of the physical and naturally built environment [1]. Within this discipline, construction management plays a pivotal role in coordinating resources, time, and expertise to deliver infrastructure projects effectively. Urban flooding represents one of the most pressing challenges facing civil engineers today, with 13.3% of the U.S. population—over 40 million

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people—exposed to 100-year flood risks [2], while global losses from extreme hydrometeorological events average \$136.7 billion annually [3].

Flood risk is amplified by the interaction of climate extremes and urbanization at the city-river interface. Research demonstrates that impervious surfaces increase runoff by reducing infiltration, while engineered infrastructure creates drainage bottlenecks that impede flow toward major waterways [2]. These challenges are particularly acute in rapidly urbanizing regions where land use changes have outpaced infrastructure development.

Construction management provides a framework for addressing flood risks through integrated approaches that combine structural measures (levees, floodwalls, detention basins) with non-structural strategies (land use zoning, early warning systems, insurance) [4]. The role of construction management extends beyond project execution to encompass risk assessment, resource optimization, and stakeholder coordination [5].

Shalman City, located in Gilan Province, Iran, experiences recurrent flooding due to its geographic position along the Shalman River corridor. The river originates from the Natesh Kuh mountains in the Alborz range and flows through the city before emptying into the Caspian Sea [6]. The 2011 flood event caused substantial damage to agricultural lands, residential areas, and infrastructure, highlighting the need for comprehensive flood management strategies.

This study aims to:

- I. Identify flood-prone zones along the Shalman River using Hydrologic Engineering Center–River Analysis System (HEC-RAS) hydraulic modeling integrated with Geographic Information Systems (GIS).
- II. Evaluate the role of construction management in flood risk reduction.
- III. Assess the effectiveness of combined structural and non-structural management strategies.
- IV. Determine appropriate land use planning based on flood risk zones.

2 | Literature Review

2.1 | Flood Risk and Urbanization

Urban development fundamentally alters natural hydrological cycles. The conversion of pervious surfaces to impervious areas increases runoff coefficients from 10-20% in natural conditions to 70-95% in urbanized areas [7]. This transformation, combined with climate change intensifying extreme precipitation events, creates conditions for more frequent and severe urban flooding [2].

Recent research by Ballesteros Cánovas et al. [8] demonstrated that understanding social perceptions and community preparedness is essential for effective flood management. Similarly, Wickes et al. [9] found that community resilience to flooding depends on social capital and institutional trust, emphasizing the importance of public participation in flood risk management.

2.2 | Construction Management in Flood Mitigation

Construction management contributes to flood mitigation through several mechanisms. Kellens et al. [10] highlighted the importance of early warning systems and public awareness campaigns as components of comprehensive flood management. Verkade and Werner [11] demonstrated that probabilistic forecasting significantly improves flood warning effectiveness, enabling more timely and appropriate responses.

Cost-benefit analysis is essential for prioritizing flood management investments. Yin et al. [12] developed frameworks for evaluating the economic impacts of urban flooding, emphasizing the need for integrated assessment approaches. The concept of "build back better" has gained prominence, advocating for reconstruction that improves resilience to future flood events [4].

2.3|Geographic Information Systems and Hydraulic Modeling in Flood Zoning

GIS provide powerful tools for analyzing spatial data and supporting flood risk assessment. GIS enables the integration of topographic, land use, and infrastructure data to identify areas vulnerable to flooding [13]. The combination of GIS with hydraulic models has revolutionized flood zone mapping. HEC-RAS (River Analysis System) developed by the U.S. Army Corps of Engineers is the most widely used hydraulic modeling software for flood studies [14]. It computes water surface profiles for steady and unsteady flow conditions, enabling the delineation of flood extents for various return periods. Tate [15] demonstrated the successful integration of HEC-RAS with ArcView GIS for floodplain analysis, establishing a methodology that has been widely adopted.

2.4|Previous Studies in Iran

Ghahroudi Tali [16] applied integrated urban flood models in northern Tehran, demonstrating the importance of data integration for flood prediction. Roshan et al. [17] used HEC-RAS within a GIS environment to simulate hydraulic behavior of the Beshar River, confirming the model's reliability for flood zoning applications. Tajdari et al. [18] simulated flood zones along the Siahrood River in Rasht City, identifying critical points where urban drainage systems could become obstructed. These studies provide methodological precedents for the current research. The literature reveals gaps in understanding the specific role of construction management—as distinct from general flood management—in coordinating flood mitigation efforts. This study addresses this gap by examining construction management's contribution to integrated flood risk reduction in Shalman City.

3|Methodology

3.1|Study Area

Shalman City is located in Gilan Province, northern Iran, with a population of 5,651 people (1,716 households) according to the 2006 census. The Shalman River flows through the city, dividing it into eastern and western sections. Agricultural activities, particularly rice cultivation, dominate the local economy. The region experiences heavy rainfall, particularly in late summer and early autumn, creating conditions conducive to flooding.

3.2|Data Collection

Data sources included:

- I. Topographic maps and cross-sections of the Shalman River (1500 m urban corridor).
- II. Hydrometric station data from Shalman station (1974-2014).
- III. Meteorological satellite imagery (NOAA, www.esrl.noaa.gov).
- IV. Reservoir (Ab-bandans) characteristics in the watershed.
- V. Cost data (Irrigation and Drainage Price List, 2017).

3.3|Hydraulic Modeling

The HEC-RAS model was used to simulate hydraulic conditions for various return period floods. The model input included:

- I. River geometry (cross-sections, channel alignment).
- II. Manning's roughness coefficients ($n=0.035$ for main channel, $n=0.047$ for floodplains).
- III. Boundary conditions (normal depth with slope 0.0004).

IV. Design discharge (25-year return period = 600 m³/s).

The HEC-GeoRAS extension facilitated integration between HEC-RAS and ArcGIS, enabling extraction of geometric data and visualization of flood extents.

3.4| Flood Management Strategies

Two management approaches were evaluated:

Structural approach: Gabion construction along 3,000 m of riverbank (1,500 m on each side) was designed based on required heights for various discharge scenarios. Non-structural approach: Reservoir operation was proposed to reduce peak flows. Existing Ab-bandans (traditional reservoirs) covering 1,307 hectares with 1.2 m average depth were assessed for expansion potential (93 additional hectares) and operational improvements.

3.5| Cost-Benefit Analysis

Construction costs were calculated using 2017 unit prices (14,200,000 IRR/m³ for gabion construction). The cost of gabion construction was compared for scenarios with and without reservoir detention.

4| Results

4.1| Hydraulic Modeling Results

The HEC-RAS model successfully simulated flood conditions for various discharges (100-600 m³/s). *Table 1* presents the relationship between discharge, water surface elevation, and required gabion height.

Table 1. Hydraulic modeling results for gabion height requirements.

Discharge (m³/s)	Water Surface Elevation (m)	Required Gabion Height (m)
100	-18.19	4.81
200	-17.17	5.83
300	-16.41	6.59
400	-15.81	7.20
500	-15.35	7.65
600	-14.97	8.00

The 25-year return period discharge of 600 m³/s would require an 8.0 m gabion wall along 3,000 m of riverbank, representing a significant engineering intervention.

4.2| Flood Zone Identification

Analysis of the HEC-RAS output revealed that flood inundation becomes critical at kilometer 17 of the river reach (*Fig. 1*). At this location, the river channel narrows and the floodplain elevation decreases, increasing the risk of overbank flow. Cross-section analysis at stations 129 and 131 confirmed that floodwaters would extend beyond channel capacity at 600 m³/s discharge, threatening adjacent land uses including residential areas and agricultural lands.

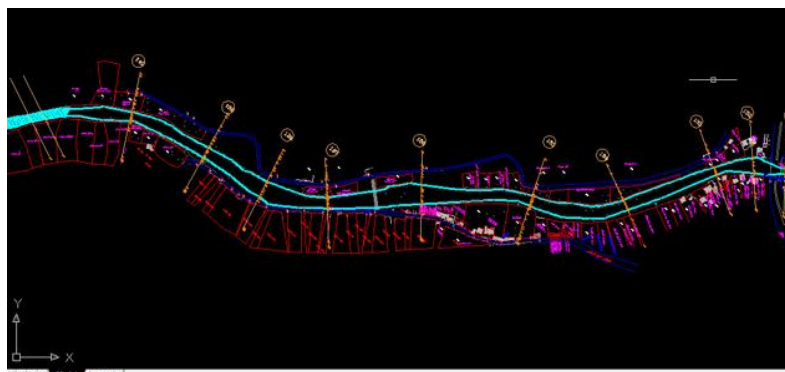


Fig. 1. Plan view of flood extent at 25-year return period (600 m³/s).

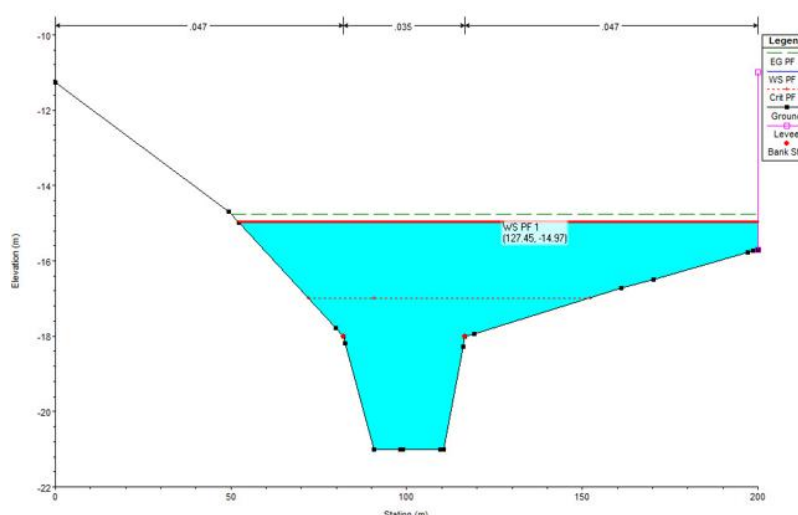


Fig. 2. Cross-section showing flood levels at 600 m³/s.

4.3 | Reservoir Operation Benefits

Analysis of existing reservoirs (Ab-bandans) in the watershed demonstrated substantial detention potential. With the proposed expansion from 1,307 to 1,400 hectares and increasing average depth from 1.2 m to 3.0 m, total storage capacity would reach 42 million m³.

Table 2. Cost analysis of gabion construction with and without reservoir operation.

Scenario	Peak Discharge (m ³ /s)	24-hour Volume (m ³)	Required Gabion Height (m)	Gabion Volume (m ³)	Total Cost (IRR)
Without reservoir	600	51,840,000	8.00	64,500	91,590,000,000
With reservoir	300	25,920,000	6.59	49,800	70,716,000,000

The reservoir operation scenario reduced peak discharge by 50% (from 600 to 300 m³/s), decreasing required gabion height from 8.0 m to 6.6 m and achieving cost savings of 20,874,000,000 IRR (≈\$500,000 USD). Additionally, 25.93 million m³ of water would be stored for beneficial uses including agriculture, industry, and tourism.

4.4 | Land Use Implications

Flood zone mapping enabled the classification of land uses based on flood risk exposure. Areas within the 25-year floodplain were identified as requiring either flood protection measures or land use restrictions. The

research demonstrates that integrated management approaches protect existing land uses while enabling the rational allocation of new development.

5 | Discussion

5.1 | The Role of Construction Management

Construction management provides the coordinating framework for implementing flood mitigation strategies. The case study illustrates several key roles:

Risk management: Construction management involves systematic risk assessment, identifying vulnerabilities and prioritizing interventions. In Shalman, the identification of critical flood zones enabled targeted investment in gabion construction and reservoir improvement.

Time management: Effective flood management requires temporal coordination—pre-flood preparation, during-flood emergency response, and post-flood recovery. Construction management principles ensure that activities are sequenced appropriately and completed within required timeframes.

Resource optimization: The cost analysis demonstrates that construction management enables resource optimization. By investing in non-structural measures (reservoir improvement), structural requirements (gabion height) can be reduced, achieving significant cost savings while storing water for beneficial use.

Stakeholder coordination: As highlighted by Rouillard et al. [19], public participation and stakeholder coordination are essential for effective flood management. Construction management facilitates coordination among government agencies, private sector entities, and communities.

5.2 | Integration of Structural and Non-Structural Measures

The research confirms that integrated approaches combining structural and non-structural measures are more effective than either approach alone. Structural measures (gabions) provide protection against flood inundation, while non-structural measures (reservoir operation) reduce flood peaks. This finding aligns with the integrated flood management paradigm promoted by international organizations [4].

5.3 | Implications for Urban Planning

Flood zoning provides essential information for land use planning. The identification of flood-prone areas enables municipalities to implement appropriate land use controls, restricting development in high-risk zones while permitting appropriate uses in lower-risk areas. As noted by Zerger and Smith [20], impediments to GIS use in real-time disaster decision support often relate to institutional rather than technical factors, emphasizing the need for institutional capacity building.

5.4 | Comparison with International Studies

The findings of this study align with international research. Ghazi Mahaleh Mehrvaz et al. [21] and Gul et al. [22] reported that detention reservoirs reduce peak flood discharges by 40-83%, consistent with the 50% reduction achieved in this study. The methodology combining HEC-RAS and GIS has been validated in numerous international contexts [15], [23].

6 | Conclusion

This study demonstrates the essential role of construction management in urban flood risk reduction through the case study of Shalman City, Iran. Key conclusions include:

- I. Flood zone identification using HEC-RAS and GIS enables targeted flood management interventions by identifying critical areas requiring protection.
- II. Integrated management approaches combining structural measures (gabion construction) and non-structural measures (reservoir operation) are more effective and cost-efficient than either approach alone.
- III. Construction management provides the coordinating framework for risk assessment, resource optimization, time management, and stakeholder coordination essential for effective flood management.
- IV. Reservoir detention can reduce peak discharges by 50%, decreasing required gabion height and achieving substantial cost savings while storing water for beneficial uses.
- V. Land use planning informed by flood zoning can reduce exposure to flood risks by directing development away from high-risk areas.

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Author Contributions

A. D.; Conceptualization, investigation, and writing—original draft. E. A.; Supervision, methodology, and writing—review and editing. Both authors reviewed and approved the final manuscript.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this article.

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