Levee Layouts and Design Optimization in Protection of Flood Areas

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Abstract: This paper addresses a possible decrease in flood damages by using structural methods and determines proper locations (layout) to construct protective levees and height of levees (design of levees) in high-risk areas. Because of discontinuity of the objective function and a large number of decision variables, the optimization uses the genetic algorithm (GA). The simulation of the region is carried out with the Hydrologic Engineering Center's River Analysis System (HEC-RAS) model. The GA is employed to maximize the benefit of flood control and also to minimize the cost of protective levees' construction. Thus, the fitness function of the algorithm maximizes the net benefit of the project. After a sensitivity analysis, mutation and crossover probability are assumed to be 0.03 and 0.7, respectively. Thus, 1,000 generations and 98 chromosomes for each run are considered. The optimization model is run 5 times for floods with return periods of 50 and 100 years. Furthermore, the algorithm is used to evaluate flood damages in the Sarm and Khoor Abad River, located in the Qom province of Iran. Project net benefits resulting from the optimization model for rivers using 100-year flood exceed those for a 50-year flood. Results indicate that construction of protective levees reduces the rate of damages up to 99% in comparison with a nonconstruction of levees scenario. By taking into account the construction cost of levees, net benefits decrease by 0.97% and 1.1% for floods with 50-year and 100-year return periods, respectively. **DOI: 10.1061/(ASCE)IR.1943-4774.0000864.**

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Introduction

Investigations of natural factors that underlie floods show that human intervention in the cycle of nature increases the likelihood of flooding in various regions. These interventions are through vegetation destruction, inappropriate land use, and so forth. In recent decades, significant measures have been taken toward developing flood control measures in rivers with flood risk. These measures include structural methods of flood control, among which were the construction of protective levees in places (layout of levees) that have suffered damages during floods; however, these measures require considerable time for construction and implementation of structures. Other measures for flood control are nonstructural methods. In these methods, instead of removing flood waters, techniques such as crisis management are employed to reduce flood damages. Flood diversion, watershed management, change in cropping pattern, and cultivation on iso-height lines are considered to be nonstructural flood control methods.

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Effective measures for floodplain management as well as investigations for flood risk zoning have been reported by several investigators. Pramojanee et al. (1997) investigated zoning of flood risk in southern Thailand using a geographic information system (GIS). In the study, the degree of risk was determined by weighting a number of factors. However, only the approaches that were used for mapping flood hazard and risk areas in one of the two provinces were assessed.

Oslen et al. (2000) presented a dynamic model for floodplain management in nonstationary conditions. The model was formulated as a Markov decision process and linear programming. Also, a single-floodplain, single-objective, stationary model was extended to include multi-floodplains, nonstationarity, and multiple objectives. Two cases of nonstationarity were investigated: (1) future bridge construction, and (2) future hydrologic changes. For nonstationary conditions, results showed that buy-out of property owners following levee overtopping was an optimal policy because increased future flooding reduced the expected benefits of structural flood measures. Also, results indicated that optimal policies included construction of larger levees and increase of floodplain development.

Plate (2002) investigated flood risk and management on three levels: operational level, project planning level, and project design level. Results showed that decisions for change depend on changes in alternatives available for managing a flood situation, as well as on changes in risk perception and attitudes towards risk. On the third level, actual costs of design were assessed and compared with benefits determined from the planned project. The residual risk was considered at this level.

Billa et al. (2004) examined a flood early warning system development for the Langat river basin in Malaysia through the coupling of remote sensing for quantitative precipitation forecasting (QPF) and GIS hydrodynamic modeling. Digital hydrological and cadastre data maps were used to generate digital elevation model (DEM) and river geometry in ArcView GIS and MIKE 11 hydrodynamic models for the runoff hydraulic modeling and flooding