DETERMINING RISK AND UNCERTAINTY

Risk and uncertainty are intrinsic in water resources planning and design. They arise from measurement errors and the inherent variability of complex physical, social, and economic situations. All measured or estimated values in project planning and design are to various degrees inaccurate. Invariably the "true" values are different from any single, point values presently used in project formulation, evaluation, and design.

The Corps of Engineers develops best estimates of key variables, factors, parameters, and data components in the planning and design of flood damage reduction projects. These estimates are considered the "most likely" values. They are frequently based on short periods of record, small sample sizes, measurements subject to error, and innate residual variability in estimating methods. Sensitivity analysis has been the primary tool for considering uncertainty in project planning and design. Sensitivity analysis, however, frequently presumes that the appropriate range of values is identified and that all values in that range are equally likely. In addition, the results of this analysis are typically reported as a single, most likely value that is treated by some as if it were perfectly accurate.

Risk-based analyses can be advantageously applied to a variety of water resources planning and design problems. The approach captures and quantifies the extent of the risk and uncertainty in the various planning and design components of an investment project. The total effect of risk and uncertainty on the project's design and economic viability can be examined and conscious decisions made reflecting an explicit tradeoff between risks and costs. Risk-based analysis can be used to compare plans in terms of the likelihood and variability of their physical performance, economic success, and residual risks.

The Corps requires the use of risk-based analysis procedures in the formulation and evaluation of flood damage reduction measures. Risk-based analysis is used because uncertainty exists in the numerical values used to formulate and evaluate alternative measures. Risk-based analysis takes the uncertainty into account before project performance or project benefits are quantified.

The planning and design of flood damage reduction projects require establishing the relationships between flow frequency, water surface elevation, and flood damage. These relationships are determined mathematically using best estimates of key variables, factors, parameters, and other data. The resulting curves determine project performance and benefits. A level of certainty can be defined for each relationship. For instance, if there are detailed flow data and a long period of record for a given stream, the stream's flow frequency relationship will likely be well understood, and the uncertainty for that stream would be less than that for another stream with fewer or questionable data.

A Monte Carlo simulation, based on generating values of key variables through repeated random selection, is used to figure flood risk using uncertainty bounds. The simulation generates floods that result in a series of water surfaces that are compared to levee height and geotechnical strength. The simulation therefore results in a probability of levee failure, flooding, and damage. A graphic presentation of a Monte Carlo simulation is included as **Plate G-1**.

When this kind of analysis is used, the flood risk associated with a system of detention basins, channels, and levees is described in three ways: (1) the expected annual probability of alternative being exceeded (e.g., a 0.01 chance of being exceeded, also expressed as a 1-percent chance); (2) the equivalent long-term risk of exceedance over 10, 20, and 50 years; and (3) the conditional probability of nonexceedance of specified events. (e.g., a 90-percent chance of nonexceedance for a flood with a 1-in-100 chance of occurring in any year). This third way of expressing risk is called "conditional probability of design nonexceedance" but is referred to in this report as system performance. It is important to note that the probability of system exceedance and flooding in any year is not equivalent to the traditional understanding of level of protection. The phrase *level of protection* implies that the system would not fail up to a well-defined flood event that occurs at a certain frequency. In contrast, risk and uncertainty use probability to estimate flood damage reduction because there is uncertainty as to how frequently a particular flood could occur; there also is uncertainty regarding the ability of a system to contain given flood events because of the extent of unknown variables about the structure of the subject levees.