RISK ANALYSIS
For Water Resources Investments
NEWSLETTTER

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Institute for Water Resources
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Risk Analysis Program Developments

News from the Program Manager

Issues related to risk analysis arise from time to time. I would like to briefly address one of these in this newsletter; the confusion about what is risk analysis and uncertainty's role. I frequently see the term "risk and uncertainty" and hear people say they are doing "risk and uncertainty analysis" as if they are one thing. The P&G states and the new ER 1105-2-100 restates that "planners shall characterize, to the extent possible, the different degrees of **risk and uncertainty**." No doubt some of the risk analysis R&D products have helped continue this confusing blending of two concepts. Generally, we in the Corps seem to be inexact in defining what should be a precisely defined activity.

Within the professional risk analysis community, there is a recognition that the language of risk analysis is messy resulting in confusion. The term risk now tends to be applied exclusively to situations dealing with the likelihood or chance of unwanted or adverse consequences.

Situations of uncertainty tend to be less narrowly defined and the term uncertainty is used to encompass a wider variety of usage. For instance, uncertainty is applied to situations of statistical variability, subjective judgment, inherent randomness, disagreement, or even imprecise words. Notice that none of these situations necessarily deal with unwanted or adverse consequences. Just the same, probabilities and statistical methods are frequently applied to many types of uncertainties. This may be one of the reasons for the blending of risk with uncertainty into "risk and uncertainty."

The foregoing suggests that uncertainty is inherent in everything done within Civil Works but that risk is not. Therefore, considering uncertainty and describing uncertainty should be how any analysis is done and how all results are presented. There is no reason to call special attention to uncertainty; it was always there.

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New Dam Safety Risk Regulation Forthcoming

A new regulation providing guidance for incorporating risk in the Dam Safety Assurance Program is slated to be issued later this year. The regulation will be prepared as part of the ongoing Dam Safety R & D program, and will eventually result in a revised ER 1110-2-1155.

The new regulation will be a product of the Dam Safety Risk Assessment research and development work unit which has two primary purposes: to develop analytic frameworks for conducting both site specific and portfolio level risk assessment, and; to develop a risk assessment toolbox of procedures, models, and software to be used in the Dam Safety Assurance Program. The goal of these efforts is to effectively target dam safety investments to achieve the greatest reduction in risk to life and property.

The work unit began with two case studies to demonstrate how RA can be applied to Dam Safety analyses in the Corps. The site level case study for the Alamo Dam in Los Angeles District has been completed (see Newsletter #3, page 7), and a portfolio assessment of the dams in the Baltimore District is well underway.

Based in part on knowledge gained from the case studies and from examining other approaches worldwide, the forthcoming regulation will provide guidance and procedures concerning the use of risk assessment in preparing studies and reports within the Dam Safety Assurance Program. The guidance will provide preliminary procedures for determining project risk to downstream life and property. The regulation will be developed iteratively over a period of years until a revised ER 1110-2-1155 is issued which fully incorporates advances in risk assessment concepts and procedures being developed in the research and development program.

Incorporating risk assessment into the DSAP will introduce several fundamental changes to current approaches required under ER 1110-2-1155. Foremost among the changes is that all potential initiating events (flood, earthquake, internal failure, and others) will be considered within a unified framework, and all will be considered on a probabilistic basis rather than with reference to performance standards. Similarly, downstream economic, life loss, and environmental consequences of potential dam failures will be described probabilistically. In the absence of performance standards as criteria, residual dam safety risks under various alternatives will be compared to other societal risks to determine their relative acceptability or lack thereof.

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Risk Analysis for Dam Safety R&D Program

The Corps of Engineers expanded R&D in risk analysis to dam safety in FY99. This new program focuses exclusively on dam safety issues. One of the ultimate objectives of the program is to develop a single, scientifically based risk analysis methodology to be used for all dam safety improvements. To achieve this goal, a central feature of the program develops the basic risk assessment and risk management procedures and requirements. These will include guidelines for choosing from among dam safety improvement alternatives ranging from "do nothing" to "decommissioning."

Assessing dam safety risks requires quantifying loading events, system responses, and consequences of dam failure. Work on hydrologic and hydraulic, structural, and geotechnical engineering aspects provides an enhanced scientific basis for quantifying these quantities. To test risk assessment methods and risk management guidelines, the R&D program includes demonstration applications to Corps dams. The first demonstration was initiated at Hills Creek dam in cooperation with the Portland District. This

demonstration will be concluded in early FY01.

In addition to developing site specific risk analysis methods and procedures, the R&D program is investigating the use of portfolio risk assessment (PRA). In a PRA, all dams in the portfolio are evaluated and ranked in terms of existing risk and the cost effectiveness of risk reducing investments. The goal is to determine the most efficient allocation of investments in dam safety improvements for a group of dams. Two levels of PRA are being investigated. One is a screening level that relies on knowledgeable individuals to assess a dam in terms of several criteria. It is anticipated that the screening level can be applied to the entire Corps portfolio with systematic updating from supplemental assessments provided during the periodic inspection of the project. The second level is more like a streamlined site specific risk assessment. It uses the same approach but relies more on expert knowledge and less on detailed engineering and economic studies. Probably more applicable to a single district portfolio, it can identify projects that warrant more detailed studies. Each of the PRA methods are being demonstrated on a single district portfolio. The first demonstration with the fifteen dams of the Baltimore District.

For more details on the Risk Analysis for Dam Safety R&D program visit the program's website:

http://www.wes.army.mil/ITL/damsafe

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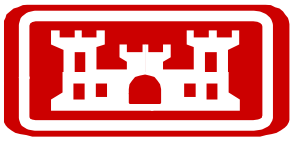

"Risk analysis for Dam Safety – Evaluating Spillway Adequacy"

A methodology is being developed for estimating the probability of large inflows that potentially cause dam failures due to spillway inadequacy. The methodology is being developed as part of the Corps current R&D effort to develop an overall dam safety risk assessment methodology.

The probable maximum flood (PMF) has traditionally been used as the upper bound flood for either assessing the adequacy of an existing spillway or for design of new structures. No occurrence probability has been assigned to this flood. In a risk assessment procedure, the likelihood of all factors that may impact on dam safety need to be addressed to estimate risks to the structure and the benefits versus costs of mitigating the structure's inadequacies. Estimating the risks posed by PMF magnitude floods requires developing new methods because the magnitude of these floods is well outside the range covered by traditional flood frequency analysis. Typically, the flood frequency curve is extended to estimate annual flood occurrence probabilities as small as (1/100) to (1/500). However, traditional estimation techniques cannot be used to extend the flood frequency to the smaller probabilities corresponding to the likely occurrence of floods approaching PMF magnitude l

The approach being taken to extend the frequency curve to these smaller probabilities is to combine information from precipitation-watershed models, and bounding information available from paleoflood and PMF estimates (see figure 1). Currently, the focus the of research is on applications of a statistical precipitation storm model and watershed model to simulate large floods useful for extending the frequency curve. The advantages of the approach stem from the long periods available in gage records and the ability of watershed models to simulate flood runoff dynamics. The long periods available in gage records reduces the sampling error in the parameters of the statistical precipitation models. The watershed model is used to simulate the statistical storms obtained from the precipitation model to estimate

the occurrence probability of floods approaching PMF magnitude. The frequency curve extended with these floods is possibly more realistic because it reflects the precipitation-runoff dynamics captured in simulating the floods with the watershed model.

The statistical precipitation-watershed model methodology is being applied in a case study of Folsom Dam on the American River near Sacramento, California. MGS Engineering Consultants, Inc has been contracted to develop the statistical precipitation model. The precipitation depth-duration frequency analysis of the precipitation gages needed to obtain the annual statistics for developing appropriate traces of maximum annual storms has been completed. The temporal characteristics (or hyetograph patterns) have also been developed. Work is now proceeding on developing the appropriate precipitation depth-area relationships, and storm spatial distribution characteristics for the statistical precipitation model.

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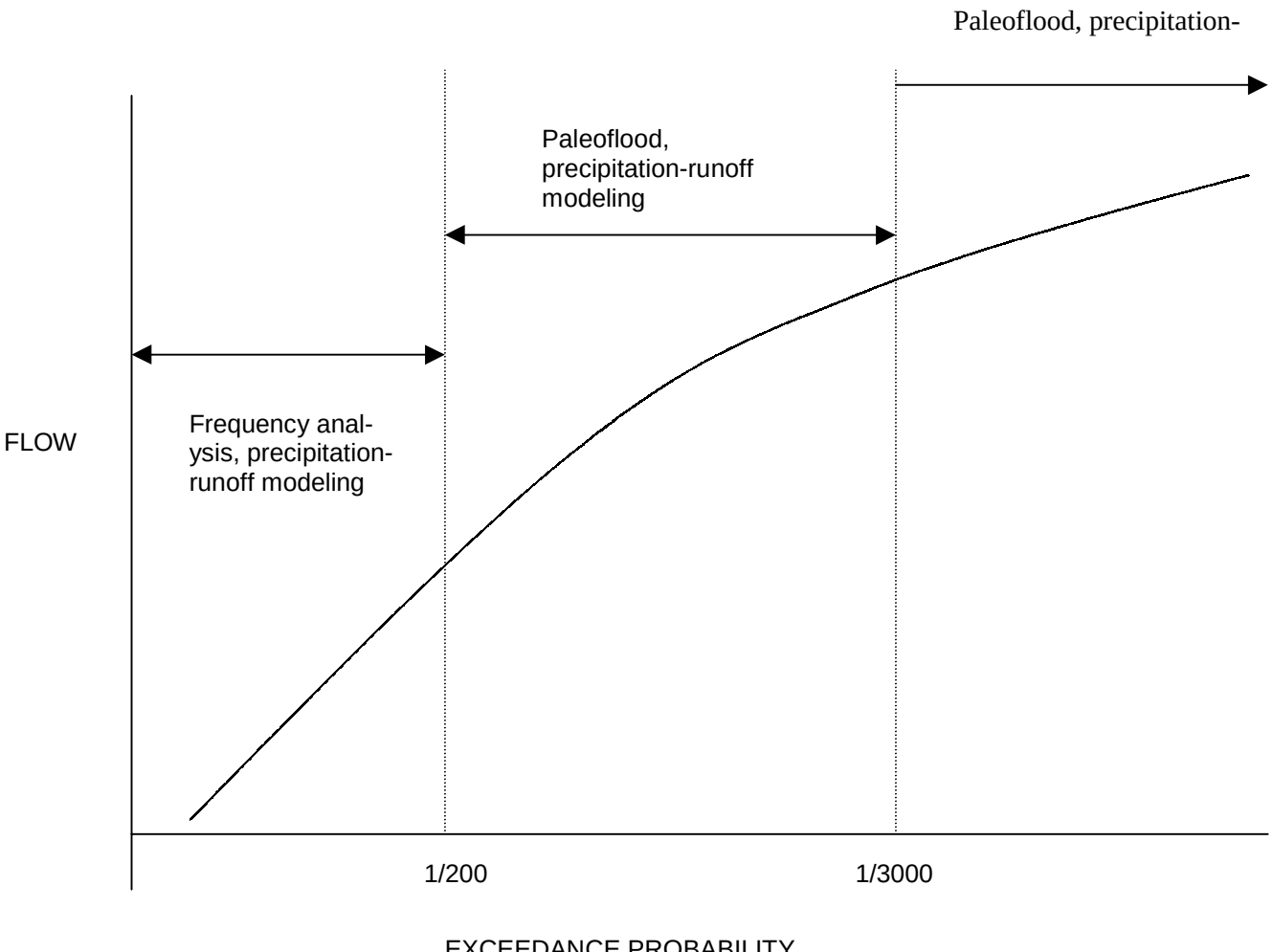
Risk and Uncertainty for Environmental Investments

The Technical Analysis and Research Division of the Institute for Water Resources (IWR), in cooperation with the Coastal and Hydraulics Laboratory (CHL) and the Hydrologic Engineering Center (HEC) is conducting an investigation into the analysis of risk and uncertainty for environmental investments. This research work unit builds on the techniques developed under the Evaluation of Environmental

SOURCES OF INFORMATION FOR ESTIMATING FLOOD FREQUENCY CURVE



Investments Research Program (EEIRP). CHL is investigating risk and uncertainty in environmental models. HEC is evaluating the affects of H&H uncertainty on environmental outputs. IWR is researching the uncertainty in cost estimating and guidelines for combining these areas of uncertainty into the planning process. The guidelines will include an evaluation framework to tie the separate research, techniques, and procedures together as well as to incorporate risk-based information into the decision criteria for environmental restoration project decision-making.

As part of the research effort, the research team has conducted two workshops with field and HQ personnel. The workshops served to educate the research team on the practical problems faced by study teams. The second workshop included discussion papers written by field practitioner describing their experience and by the principal investigators relating the findings and status of the individual research work units. These papers are available upon request.

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Risk Analysis Applications to Project Cost Estimation

The Uncertainty of Financial Cost Estimates.

Cost estimation is one of the most common and important tasks in the conduct of the Corps' mission. Cost estimation is a prediction with varying degrees of uncertainty. Approaches to cost estimation vary; some may develop a more conservative estimate to avoid overruns, while others prefer lower estimates to encourage project participation.

The initial focus of this research was to examine cost estimating procedures with an emphasis on the role of "cost contingencies." Cost contingencies are upward allowances in the cost estimate for unexpected developments in project costs during construction that are specifically unaccounted for in the cost estimate due to a lack of precise information on quantities of work required from the natural uniqueness of a Civil Works project. Typically, cost contingencies take the form of a percent, say 5%, 10%, 15% of the estimate, that are then added onto the cost estimate at certain intervals, to the final estimate, or to both in the calculation of a final cost estimate. After examining the cost estimation process, it became quite clear that the process could be improved by demonstrating to cost engineers how risk and uncertainty techniques can be employed in their cost estimating process.

The focus of this research demonstrates the employment of risk and uncertainty techniques to the generation of a cost estimate on a Corps project with particular focus on how such procedures can replace "rule of thumb" cost contingencies, and how such analysis can provide valuable information in terms of determining what the "cost contingency" should be based on desired levels of confidence in the estimate itself.

The final report details the conceptual basis for using risk and uncertainty techniques in the Corps cost estimating process. A specific case study illustrates application of these techniques to generate a risk-based cost estimate while using the expert judgement of District personnel. Lastly, the report describes procedures for interpreting results in the planning process to facilitate more informed decision-making.

This report will soon be available at the IWR web site: http://www.wrsc.usace.army.mil.

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Risk Analysis Applications to Ecosystem Restoration Costs

The Uncertainty of Ecosystem Restoration Costs

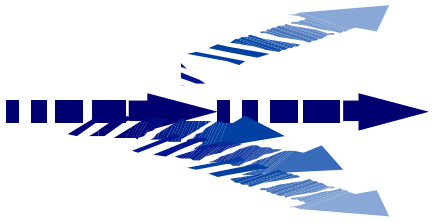
Under the Corps Risk Analysis of Water Resources Investments Research Program, managed by the Institute for Water Resources, researchers are addressing the uncertainty in costs associated with Ecosystem Restoration Projects. Various types of engineering techniques and management measures used in ecosystem restoration and watershed studies will be reviewed to identify components contributing most greatly to uncertainty.

Risk and uncertainty-based analytical tools and methods will be identified to address engineering input cost uncertainties. Once these methodologies are field tested, practical procedural methods will be developed to address quantifying engineering feature and input cost uncertainties.

A review of engineering techniques and management measures of various ecosystem projects has been conducted. Findings from this review are summarized in a preliminary effort to examine the factors that contribute to the differences between projected costs and actual expenditures for ecosystem projects.

Also identified are ways to reduce the uncertainty associated with the costs of habitat restoration projects. These findings are presented in the report *Analyzing Uncertainty in the Costs of Ecosystem Restoration (*Battelle, Seattle Research Center and Battelle Marine Sciences Laboratory), **IWR Report 00-R-3.** This report will soon be available at the IWR web site: http://www.wrsc.usace.army.mil.

A survey was conducted, and data from a total of 47 Corps and Non-Corps projects was interpreted. These 47 projects, which represented a broad geographic spectrum, were divided almost evenly between wetlands and river/lake projects.



Overall, for 14 of the 47 projects, or roughly 30% of the sample, actual expenditures exceeded projected costs by more than 20% of the original estimate. A similar pattern was found for projects with actual expenditures less than projected costs by more than 20% of the original estimate. Approximately 57% of the projects involved in this sample involved significant overruns or underruns.

Among the Corps projects, differences between estimated costs and actual expenditures were most common among the larger, integrated restoration efforts. Large cost differences were also found among the projects involving channel improvements. There was also some indication that differences were more frequent in the river/lake projects. However, cost differences have been decreasing with increased experience in project implementation.

Project managers surveyed working in different areas on a variety of different projects, cite the following issues pertaining to uncertainty of ecosystem restoration costs:

- **Incomplete site surveys** – unexpectedly difficult working conditions increase project costs.
- **Insufficiently detailed planning** – the need to redesign projects during construction can lead to significant cost overruns.
- **General project experience** – project managers, local agency staff, and private contractors have been gaining experience with restoration projects.
- **Construction window constraints** –scheduling can have a large impact on total project costs.
- **Difficulties with land acquisition** – hard to estimate land values and conflicts with individual

property owners over appropriate compensation can delay project implementation.

- **Weather conditions** – extreme conditions such as storms and prolonged flooding can dramatically alter schedules and increase costs.

The next step of this research effort is to identify risk and uncertainty-based tools, such as sensitivity analysis, decision criteria, simulation modeling and field tested on the engineering techniques to address the uncertainty attendant in them. These results from the field tests will be documented and generic procedural methods will be developed for application in ecosystem restoration planning throughout the Corps and possibly other agencies.

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Development of Risk-Based Decision Framework for Deep Draft Navigation

Considerable uncertainty often exists in the analysis and planning of navigable waterway systems. Such uncertainties extend to the projection waterway activities including vessel fleet or service composition, cargo flow or throughput, and vessel or terminal operating practices. Uncertainty also often exists concerning environmental issues, engineering and construction, and future or on-going obligations for maintenance and operation. Failure to incorporate potential variances in costs and time can lead to erroneous estimation of costs and benefits.

The primary purposes of research for development of a risk-based framework for deep-draft navigation are to develop processes and procedures to facilitate the identification of various sources of uncertainty and to determine the relative level of significance of such factors.

Significance will most likely depend on site specific characteristics and, therefore, vary from project to project. The goal of this effort is to identify the risk variables and to document procedures guidelines that will assist the practitioner in identifying significance.

Supporting research elements of the framework will involve the formulation of general methodologies for quantitatively analyzing or measuring the potential influence of factors determined to be significant during the study process. Application of such procedures will facilitate adequate measurement of engineering and economic performance for existing and proposed navigation features.

The risk-based framework will extend existing or accepted methods for quantifying risk to include consideration of deep draft navigation variables. The framework will be applied to a case study for model evaluation and refinement. The framework will serve as the basis for the development of a procedures manual and, eventually, project guidance.

To date, interviews with many District-level analysts have been conducted and a case-study example has been selected for application of the draft framework upon completion. Activities for the end of this fiscal year and coming fiscal year (i.e. FY 2001) include data compilation for the case study, a coordination meeting with USACE navigation study practitioners, and initial development of the conceptual framework. Analysts within USACE are invited and encouraged to express views and insights and to forward any information for considerations, such as criteria which they believe should be integrated into the development of the risk-based decision framework for deep-draft navigation.

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Information on the Net

The Institute for Water Resources

(IWR) World Wide Web (WWW)

home page address is as follows:

http:/www.wrc-ndc.usace.army.mil/iwr/index.htm

At this location reports, newsletters, working papers, and other types of IWR research products may be downloaded in a format identical to the original hardcopy publication. Such products on the IWR home page cover a wide spectrum of research topics as there are products representing work from each of IWR's divisions:

- Research and Technical Analysis Division,
- Navigation Division,
- Policy and Special Studies Division, and
- Program Analysis Division.

Some of the products are also the result of inter-divisional cooperation. The myriad of topics include: wetland mitigation banking reports, alternative dispute resolution case studies, national drought study reports, navigation news, environmental evaluation investment program reports, and information and reports of the risk program.

Newsletter Communication

To comment on the newsletter. Suggest topics, or to submit an article, please contact Darlene Guinto at:

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Articles and/or Case studies describing or summarizing the process of applying developed risk and uncertainty principles and guidance to a project in planning or construction are welcomed.