Institute for Water Resources

RISK ANALYSIS FOR WATER RESOURCES INVESTMENTS

NEWSLETTER

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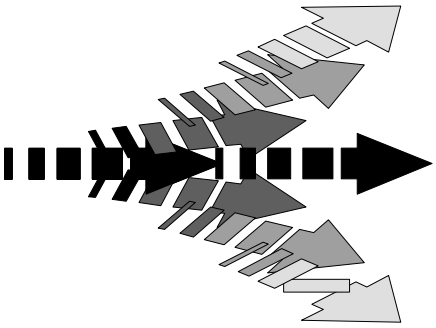

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NEWS FROM THE PROGRAM MANAGER

First, thank you for all your comments, complements, and suggestions on the first newsletter. The publication of the first newsletter was highly successful, judging from the messages from readers and the demand for additional copies. Federal agencies, academia, and the private sector have all shown considerable interest in the risk analysis activities within the Corps.

Risk analysis within the Corps is expanding. The primary applications continue to be in flood damage reduction and major rehabilitation. Developme in these and other areas are reviewed later in this newsletter. Many practitioners within the Corps are starting to become more confident in applying risk analysis tools in these areas. This can be attributable to at least four causes. First, the Corps pioneered the use of risk analysis in these areas. Second, products of the research program and increased training have made using risk analysis simpler, more understandable and, simultaneously, more credible. Third, Corps technical experts have engaged in R&D in a cooperative and focused effort. Lastly, the Risk Analysis for Water Resources Investments research program has provided a focal point to transfer proven risk analysis methods from one problem area to others. That is, the program has not only served in the development of risk analysis methods, but also in the application of such methods to differing problems.

The Risk Analysis for Water Resources investments research program will be changing starting in FY98, corresponding with the restructuring of all Corps R&D areas and programs. It is not yet clear what the changes will bring. One proposal is to encourage research in risk and reliability quantification in each of the separate Research Areas. The existing program would then be limited only to problems that cut across these areas such as general methodologies and models. Presumably by the next newsletter, the direction of risk analysis within the Corps will become clearer to us all.

David A. Moser

THE WHO, WHAT, AND WHERE OF ON GOING RESEARCH IN THE RISK PROGRAM?

Currently, the on-going research under the Risk Analysis For Water Resources Investments Program is performed primarily at the three following Corps offices:

- The Institute For Water Resources CEWRC-IWR,
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  POC: David Moser

- The Hydrologic Engineering Center CEHEC,
  609 Second Street,
  Davis, CA 95616-4687
  POC: Mike Burnham

- The Waterways Experiment Station CEWES,
  3909 Halls Ferry Road,
  Vicksburg, MS 39180-6199
  POC: Mary Ann Leggett

Generally, each of these offices have established niches for themselves by specializing. This specialization generally conforms to the areas of technical expertise historically associated with each office. WES, for example, has focused on the reliability of physical structures, or how engineered structures perform with respect to time. IWR generally has developed methodologies for incorporating risk and uncertainty into the planning procedures of various project outputs. The research at IWR has also developed procedures explicitly linking engineering and planning variables within risk analysis. HEC has concentrated its efforts on various engineering and software development applications to flood damage reduction. Methods for quantifying uncertainty in hydrology have been extended, and software to combine uncertain engineering and economic data have been developed.

A major product of all of these offices, regardless of their respective specialization, has been the establishment of procedural guidance for their area of expertise. The development of a methodology or standard that has been approved by Headquarters and presented to the field in the form of: ETL's, EM's, ER's, and EC's.

RISK ANALYSIS RESEARCH AT IWR

Deep Draft Navigation.

The objective of this work effort is to characterize and quantify sources of risk and uncertainty in deep draft navigation projects which integrate planning, engineering and operational aspects. These uncertainties will be combined into overall measures of engineering and economic performance of deep draft navigation projects. The goal is to develop methodologies which will derive distributions of project benefits and costs for planning and operations decisions. The Research and Development work unit under which this effort was to be conducted was originally scheduled to start in FY96. However, due to budgetary limitations it was zeroed out of the fiscal year budget. It is now scheduled to be started as a FY 97 R&D work effort.

Some preliminary research has been initiated in spite of current budgetary constraints. A draft literature review has been developed, as well as, a survey of all Corps of Engineers District offices which have deep draft navigation responsibilities. This survey was designed to identify the techniques and procedures currently being used by field offices to measure the risk and uncertainty of proposed projects and the key variables used in their analyses. Additional work is being pursued to identify risk and uncertainty methodologies associated with commodity and fleet forecasts in an attempt to develop a model which could be used by Corps field offices. The model would take current fleet specifications for a given port, historical growth, assumptions regarding the future movement of commodities, and produce a forecast of future fleet specifications while incorporating risk and uncertainty in the estimates. The principle investigator for this work effort is Phillip J. Thorpe of the Navigation Analysis Division of IWR. Mr. Thorpe may be contacted at:

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Inland Navigation.

Risk and Uncertainty is being incorporated into Inland Navigation Studies. Inland Navigation is the most difficult project purpose to apply risk and uncertainty techniques into the analysis because of the systems approach necessary to identify project benefits. Within the system there are literally hundreds of alternative events which can affect the performance of the system. Incorporating each of these events into the feasibility analysis can be a daunting task.

The proposed guidance for Inland Navigation risk and uncertainty recognizes this complexity by refraining from mandating specific "how to" criteria. Rather, it identifies certain variables, such as commodity flows and delay costs, which must be considered in the risk and uncertainty analysis. The district decides how to incorporate this uncertainty into their analysis. The proposed guidance for Inland Navigation risk and uncertainty is being circulated for comment. If you have not received a copy of the proposed guidance and would like to provide comment, contact Brad Fowler, CECW-PD at 202 761 8571.

IWR has contracted with Planning and Management Consultants Ltd. (PMCL) to develop a forecasting with risk and uncertainty manual. This manual will focus on methods to identify and incorporate risk and uncertainty into the four commodity forecasting methods most often used by Corps districts. The first draft of this manual is due in the middle of

September. If you would like a copy of this draft, to provide comments on this work, or to discuss topics concerning this research contact the principal investigator for this work, Keith Hofseth of the Research and Technical Analysis Division of IWR. Mr. Hofseth may be contacted at:

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Dredging.

The scheduling and costs of maintenance dredging have come under increased scrutiny in recent years. The complexity of dredging decisions as well as budgetary constraints require that these decisions be made with less margin for error and greater understanding of cost and reliability tradeoffs. The uncertain and variable nature of dredging costs and navigation benefits from channel maintenance encourage the use of risk analysis techniques which are being applied to engineering problems elsewhere within the Corps. Two prototype decision support models have been developed by IWR which apply risk-based analysis to maintenance dredging problems.

Real-Time Dredging Decision Support System

Working with Operations personnel from New Orleans District, a prototype PC-based Dredging Decision Support System (DSS) software was developed to help District managers anticipate maintenance dredging requirements and plan dredging schedules over a 30-day horizon. This approach to dredging management combines submodels that estimate such physical parameters as channel depths from real-time river stage and hydrographic data; such operational variables as the cost and productivity of dredging operations; and such economic factors as the likely range of navigation costs borne by shippers attributable to restrictions in channel depths. A central feature of the Dredging DSS is the ability to consider alternative maintenance dredging decisions and deployments by testing various "What if?" scenarios and to investigate the associated tradeoffs between dredging costs and economic benefits. The Dredging DSS thus represents an additional decision-making tool that can be used by Corps operations personnel to evaluate the probable effects and costs of dredging decisions.

A trial operation of the Dredging DSS software on the Lower Mississippi River was conducted at New Orleans District in the summer of 1996. An assessment of the software's accuracy in predicting controlling depths and dredging schedules will be included in the forthcoming IWR report, *Development and Application of a Risk-Based Dredging Decision Support System.* The report also contains a user manual for the software.

Long Term Cost Estimation and Scheduling Model

Interactive PC-based computer software was also developed to aid Corps managers in longer-term planning and budgeting of maintenance dredging. This software uses the Reliability-Based Dynamic Dredging Decision (RBD^3) Model, an optimization model that incorporates uncertain information about predicted navigation channel dimensions and dredging requirements, dredge costs and characteristics, and project dimensions to estimate a least cost dredging schedule to meet specified channel reliability levels. In addition to a least cost dredging schedule, the model can also be used to estimate solutions that maximize the channel reliability level for a specified or constrained budget; that minimize costs for a range of channel reliability levels, producing a cost-reliability tradeoff curve. The analysis thus demonstrates the impacts of varying dredge productivity on costs, reliability, and scheduling. Such analysis should be useful for estimating the maintenance dredging costs associated with, for example, new work, complying with environmental regulations, and changes in dredging technology and dredge availability.

A workshop on the RBD^3 model at the New Orleans District in the summer of 1995 was attended by planning, operations, and engineering personnel from throughout the Corps. Modifications to the IWR-RBD^3 software were made based on recommendations from workshop participants. A description of the RBD^3 model and a software users guide are presented in the forthcoming IWR reports, *Development and Application of the Reliability-Based Dynamic Dredging Decision Model (RBD^3) Volume I -Main Report* and *Volume II -The IWR-RBD^3 Software Program User Manual.* The draft report, *Sedimentation and Control Depth Uncertainty: Quantification for Risk Analysis of Maintenance Dredging,* summarizes some of the associated issues related to estimating sedimentation and dredging requirements under uncertainty.

For more information on these models or the application of risk analysis to dredging problems, please contact L. Leigh Skaggs, the principal investigator for the risk-based analysis of maintenance dredging work effort at IWR. Mr. Skaggs may be contact at:

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Major Rehabilitation.

Risk-Based Economic Programs for the Evaluation of Investments in Rehabilitation (REPAIR) Software Tools

Building on early spreadsheet models, the Institute for Water Resources is developing software tools for risk-based economic analysis of major rehabilitation proposals for hydroelectric power and navigation projects. While the spreadsheet models were hard to understand, inflexible, and required hours to run, the new REPAIR software tools are easier to understand, use, and run

time has been reduced from hours to a matter of minutes.

The REPAIR software tools are object-oriented programs developed in the C++ programming language, with a Windows-based graphical user interface. The baseline and alternative rehabilitation proposals are described in terms of familiar 'objects' and associated attributes via a graphical editor. Risk parameters are also entered into the REPAIR tools. The heart of the REPAIR tools is a Monte Carlo simulation module that assesses the risk- based cost and benefits associated with the baseline and alternative plans for rehabilitation. The relative benefits and costs of each alternative proposal can be evaluated against the baseline to determine the best course of action given the economic risk.

Rehabilitation projects within the Corps of Engineers fall broadly into two general types: hydropower and navigation. Initial research efforts were devoted towards development of a single model that would handle both kinds of problems, but a deeper understanding of the issues has led to the evolution of two separate models, one for hydropower and one for navigation. At present, the hydropower model, known as Hydropower REPAIR Version 1.0, is available to evaluate hydropower rehabilitation proposals. Work continues to improve the software. REPAIR version 2.0 should be available by the end of 1996.

Navigation REPAIR is designed to evaluate the risk-based economics of lock rehabilitation and is under development, with an initial prototype complete. IWR is working together with the Huntington District to complete the initial version of Navigation REPAIR.

The principal investigator for this effort at IWR is Michael R. Walsh. Mr. Walsh can be reached at:

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Flood Damage Reduction

Risk-based analysis for flood damage reduction procedures were pioneered in a joint effort by IWR, HEC, and WES. Work at IWR initially entailed coordinating the development of the draft EC on risk-based procedures for flood damage reduction projects (EC 1105-2-205) that became the current guidance, ER 1105-2-101. In the development of the technical procedures, IWR developed procedures for combining the uncertain variables that comprise the stage-damage relationship. Additionally, IWR has quantified the uncertainties of the residential depth-percent damage functions from the FIA flood claims data and provided approaches for quantifying the uncertainty in other relevant variables which influencing the uncertainty in the stage-damage relationship.

Recent efforts have provided technical input and support for the economic analysis component of the HEC-FDA computer software package (See Risk Analysis Research at HEC). This includes specifications for data input hierarchy, variable uncertain relationships, and details of computations for quantifying stage-damage uncertainty. Continuing work will specify the statistical computations required for using sample and grouped data within the economic component of HEC-FDA. The principal investigator for this effort is David Moser of IWR. Dr. Moser can be reached at:

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RISK ANALYSIS RESEARCH AT HEC

Flood Damage Analysis.

The Corps of Engineers requires the use of risk-based analysis procedures for formulating and evaluating flood damage reduction measures (ER 1105-2-101). Procedures developed and defined in EM 1110-2-1619 are now applied to ongoing Corps studies. They quantify uncertainty in discharge-exceedance probability, stage-discharge, and stage-damage functions and incorporate these uncertainties into economic and engineering performance analyses of alternatives. The process applies Monte Carlo simulation, a numerical-analysis technique that computes the expected value of damage reduced while explicitly accounting for the uncertainty in the basic functions.

The Flood Damage Analysis program (HEC-FDA) was developed by the Hydrologic Engineering Center. It is designed to expedite the plan formulation and evaluation technical analysis for flood damage reduction studies. It includes risk-based analysis methodologies. HEC-FDA operates on multiple Windows 3.1x, NT, and 95 operating systems, and Sun Solaris platforms. The program has a modern user interface, enhanced risk calculations, and graphical output consistent with federal and Corps policy and technical regulations.

HEC-FDA streamlines the plan formulation and evaluation process, following functional elements of a study involving coordinated study layout, hydrologic engineering analysis, economic analysis, and plan formulation and evaluation. The program may be used continuously throughout the planning process as the study evolves from the base without-project conditions analysis through the analysis of alternative plans for reducing flood damage using risk-based analysis methods. Plans are evaluated as the expected annual damage associated with a given analysis year or the equivalent annual damage over the project life of the plan. Information on the flood risk performance and expected annual damage reduced is included in the results. Output includes tabular and selected graphics of information by plan, analysis year, stream, and damage reach for the plan.

HEC-FDA is presently being beta tested by several Corps offices. It replaces the existing HEC Lotus/@Risk and IWR damage-uncertainty spreadsheet capabilities. The general release of Version 1.0 of HEC-FDA is scheduled for the end of this fiscal year. The Institute for Water Resources contributed significantly in the design and testing of the program.

Recently, training classes have been held at HEC introducing the HEC-FDA software package to Corps project managers, economists, and H&H engineers. In these classes the programs capabilities are demonstrated in close concert with instruction on statistical techniques, traditional analysis, and Corps guidance and procedures on risk and uncertainty analysis. The principal investigator for this effort is Mike Burnham of HEC. Mr. Burnham can be reached at:

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RISK ANALYSIS RESEARCH AT WES

Engineering Reliability Assessment of Corps Structures.

Many Corps structures have exceeded their design life and/or their capacity, resulting in an increased need for replacement funds. Major Rehabilitation funds can be used to extend this design life and/or capacity, thereby decreasing new construction costs. To qualify for Major Rehabilitation funding, districts are currently required to prepare a report demonstrating the need for reliability or efficiency improvement (USACE 1995). When this requirement was first issued, USACE districts cited a lack of criteria for assessing the reliability of structural performance in these two areas.

WES's work units in the Risk Analysis For Water Resources Investments Program are to develop reliability procedures and methods in the context of examples and case studies to enhance their usefulness to USACE districts. These work units have focused on reliability in the following areas:

- timber and steel pile foundations including deep-seating stability, loss of support, and system reliability,
- gravity structures both with and without anchors including geotechnical strength parameters,
- coastal structures, and
- stability evaluation of levees.

Computer procedures have been developed to apply this guidance to reliability assessment. Currently, reliability assessment procedures are being added to two CASE (formerly, CORPS) programs: CSLIDE and CPGA. The reliability versions, RCSLIDE and RCPGA, operate in the Windows 3.1x environment with a windows user interface, enhanced graphical input/output, and utilize advanced reliability calculation procedures. RCSLIDE is currently available and a test version of RCPGA should be available soon.

Since the risk analysis economic model was extremely sensitive to the input value for a structure's degradation with regard to time, an additional work unit was established to develop time-dependent reliability analysis procedures. These procedures should consider the initial strength of the component, degradation characteristics of construction materials, rate of occurrence or stress history of loads, and magnitude of stress variations. Current time-dependent models have been developed to formulate a hazard function, and these models are continually being refined.

Using the procedures and guidance developed and refined in these R&D work units, along with the risk analysis economic model developed under a separate work unit by IWR, several Major Rehabilitation projects have received budgetary approval and funding. Reference: USACE. "Guidance for Major Rehabilitation Projects for Fiscal Year 1998". Memorandum CECW-OM-O dated 29 September 1995.

Mary Anne Leggett is the principal investigator for this research at WES. Ms. Leggett may be contacted at:

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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,
- Policy and Special Studies Division,
- Navigation Division, and
- Programs Analysis Division.

The myriad of topics include: wetland mitigation banking reports, alternative dispute resolution case studies, national drought study reports, navigation news, environmental evaluation investment research program reports, and information on the risk program.

NEWSLETTER COMMUNICATION

To comment on the newsletter, suggest topics, or to submit an article, please contact Mr. David Hill at:

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Articles describing and summarizing the process of applying developed risk and uncertainty principles and guidance to a project are welcomed.