Corps Risk Analysis Gateway Training Module

Introduction to Risk Analysis

Series:
Corps Risk Analysis Online Training Modules

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US Army Corps of Engineers

Contents

Introduction to Risk Analysis

This module was originally developed as a web-based training on the Corps Risk Analysis Gateway. The content has been modified to fit this format. Additional modules are available for download on the IWR website.

The purpose of this training module is to acquaint you with the basic concepts of:

- risk analysis
- assessment
- communication
- management

You are encouraged to read through all of the examples provided in this module, which look at specific concepts in more depth.

This training is approximately one hour.

This course includes a self-assessment; it's recommended that you be able to achieve 70% for successful course completion.

Chapter 1 - Why Risk Analysis?

1.0 WHY RISK ANALYSIS?

Why should we perform risk analysis?

Risk analysis is a system for dealing with uncertainty. And uncertainty is a part of the day-to-day job for everyone in the Corps. Therefore, risk analysis is the responsibility of every Corps employee.

Figure 1. Risk assessment, risk management, and risk communication make up the risk analysis framework.

1.1 WHY RISK ANALYSIS

Why should we do Risk Analysis?

The answer, in short, is to counter "uncertainty."

When we are not sure, for any reason, we are uncertain. The future is uncertain. We make decisions in the present based on information from the past that are intended to affect the future. We can't be sure how those decisions will turn out in an uncertain future. Risk analysis is a framework developed to aid decision-making under such conditions of uncertainty.

More Reasons for Risk Analysis...

- Traditional standards based approaches are no longer enough–problems persist
- Identifies uncertainties to be monitored and managed
- Risk analysis is a way of approaching problems that integrates science and social values
- The global community is embracing risk analysis

Figure 2. Reasons for Risk Analysis

1.2 Risk is a Factor in all of our Jobs

Whatever our day-to-day assignments in the Corps, all of us face uncertainty in our jobs. Consider the following questions:

- When and where will the next major flood occur? How many hurricanes will reach landfall in the US this season? What communities will be affected? Will the levees be overtopped? How many people will be exposed to flooding? How many will die?
- How many work-related injuries can we expect on this job?
- Will bids come in under the government estimate? Will the project cost more or less than the government cost estimate? Can we count on a budget that will provide a consistent commitment to a project?
- Will our infrastructure perform as designed? Will the levees hold back the floodwaters? How much longer will that lock chamber pump operate?
- Will improvements in water quality be sufficient to realize maximum benefits at the Everglades Restoration project sites? Will the restoration benefits be realized? How many people will return to New Orleans and Galveston?
- When will the channel need to be dredged again? What is the quality of the material to be dredged? Where is maintenance dredging most needed? Will new channels lead to greater commerce? Will transportation cost savings be realized? Where will the Nation's marine casualties occur?

We just do not and cannot know the answers to many, if not most, of the questions encountered in the Corps' performance of its mission. Risk analysis can help address this uncertainty. Risk analysis is the responsibility of every Corps employee. It is an effective way of thinking about and organizing to solve problems on the job and to counter uncertainty.

Chapter 2 - Risks

2.0 RISKS

Risk is the possibility of a situation producing undesirable outcomes. It is a measure of uncertain future events that can be present throughout a project's life cycle. To combat risk, the Corps employs a diverse range of risk analysis programs, tools and protocols for a variety of real world applications.

2.1 WHAT IS RISK?

Risk is the chance of an undesirable outcome in any given situation. It is a measure of the probability and consequence of uncertain future events and it includes:

- Potential for gain (opportunities)
- Exposure to losses (hazards)

Hazards

There is uncertainty associated with hazards that include natural disasters, like the wind and hurricane susceptible regions shown below.

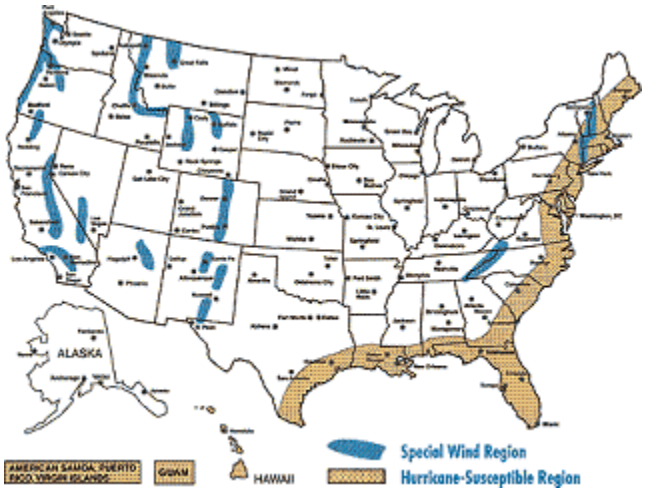


Figure 3. Hazard map

Opportunities

Our opportunities for gain, e.g., restored ecosystem function, improved water quality and reduced transportation costs, can also be subject to substantial uncertainty.

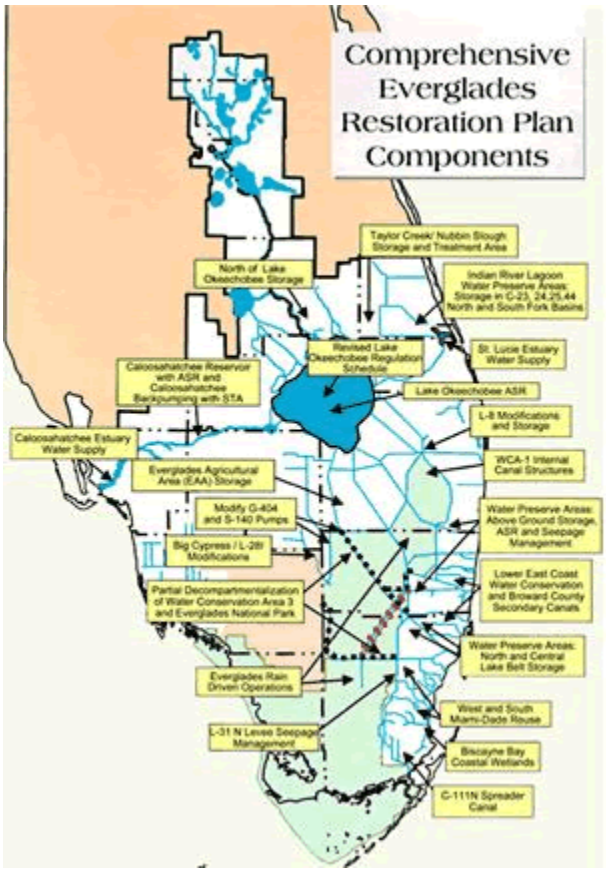


Figure 4. Comprehensive Everglades Restoration Plan Components

2.2 Uncertainty in a Project's Life Cycle

Uncertainty can and does exist throughout a project's life cycle. Consider the following example related to a construction project.

- **Planning.** Will this plan solve the problems and realize the opportunities? How much do we over- or under-estimate costs? Will project benefits be realized?
- **Design.** Are there issues with the site? Will the funds be available when needed?
- **Construction.** Will weather or labor unrest affect the work? What is the risk of injury during construction?

- **Operations.** How long will components last before failure? Will the project be maintained properly?

2.3 Corps Use of Risk Analysis

The Corps already has many successful risk analysis initiatives, so it makes sense to build on this success and expand the use of risk analysis throughout the organization. Some examples of past and current successes include:

- Expected annual damages
- Major rehabilitation
- Establishment of design levels
- Risk-informed cost estimation
- Dam safety program
- Levee safety program
- Establishment of product safety standards, performance standards and specifications
- Risk-based software tool
- Scenario planning
- Scientific sampling protocols

2.4 Examples of Risk in the Real World

The following are some instances of where risk has come into play in Corps projects:

- Will the Levee Hold?
- Will they come?
- Will service be available?
- Will we have water?

Will the Levee Hold?

The Corps project in Sunbury, PA in Figures 5 and 6 contained Tropical Storm Agnes flood flows with not an inch to spare, earning the thanks of a grateful city.

Figure 5. Floodwater

Figure 6. "We love you wall"

Will they come?

If the quantity, quality and timing of water in the Florida Everglades is changed, will new habitats result? Will species thrive and survive in them?

Figure 7. Alligator

Will service be available?

John Day Dam lock was damaged by a barge during a lockage. Traffic on the Columbia River was disrupted during the repairs.

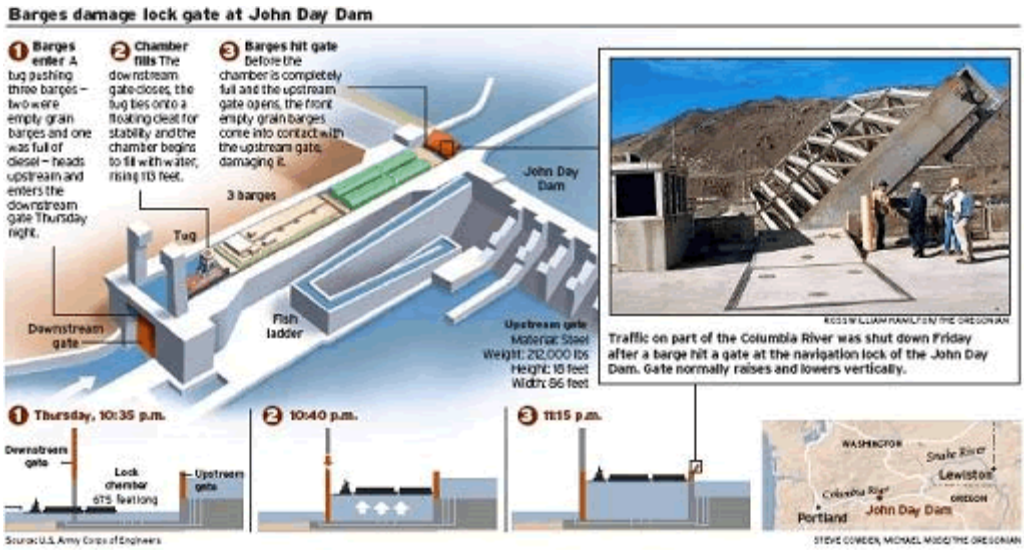


Figure 8. Barges damage lock gate at John Day Dam

Will we have water?

Will water be available in the quantity and quality required at the time and place it is needed?

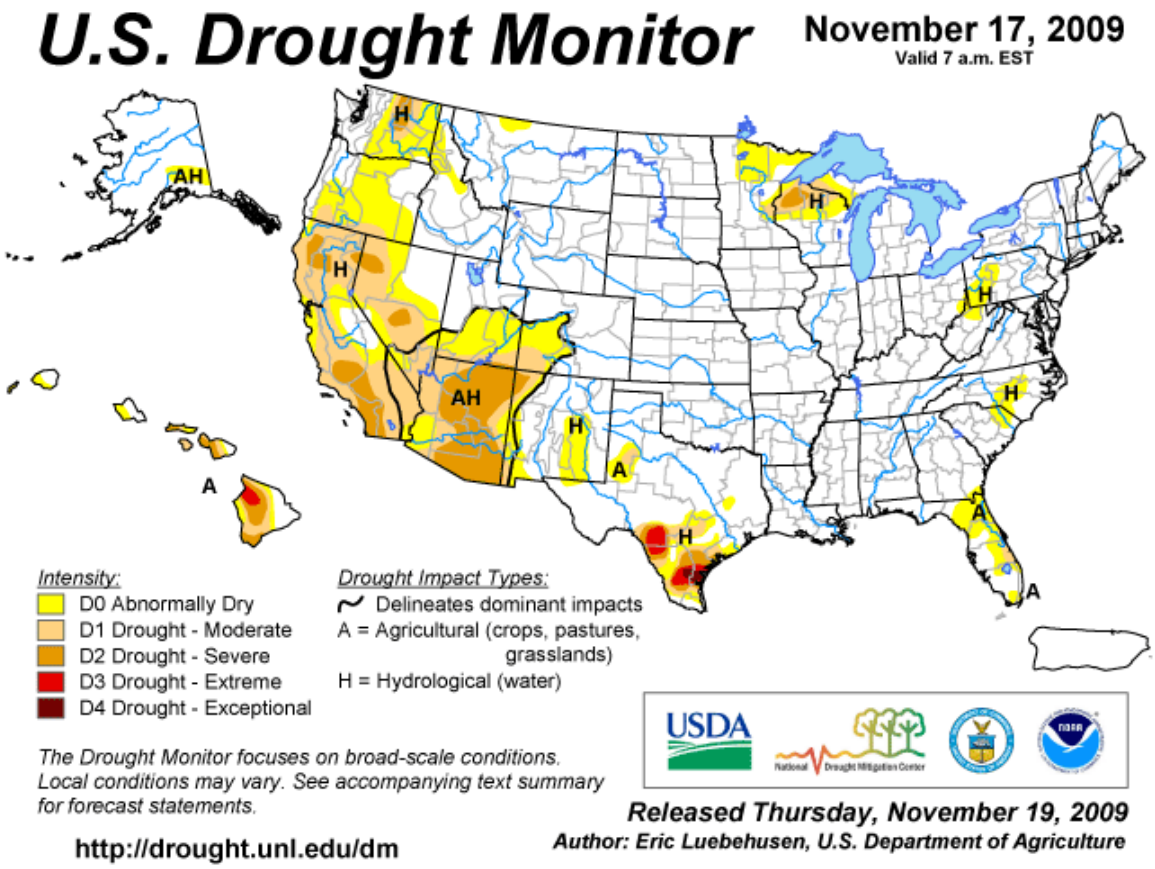


Figure 9. U.S. Drought Monitor from November 17, 2009

Chapter 3 - Risk Analysis

3.0 Risk Analysis

Risk analysis is a system for making decisions in the face of uncertainty. It is a way of thinking and organizing in order to solve problems. Risk analysis is commonly thought to consist of three tasks: risk management, risk assessment, and risk communication.

3.1 What is Risk Analysis?

Risk analysis is a framework for making decisions when we are uncertain. Risk analysis is designed to evaluate the level of risk if no action is taken and the costs and benefits of reducing risks when making decisions. It is designed to address the risks discussed earlier in the course and it is often considered to consist of three tasks:

- Risk management
- Risk assessment
- Risk communication

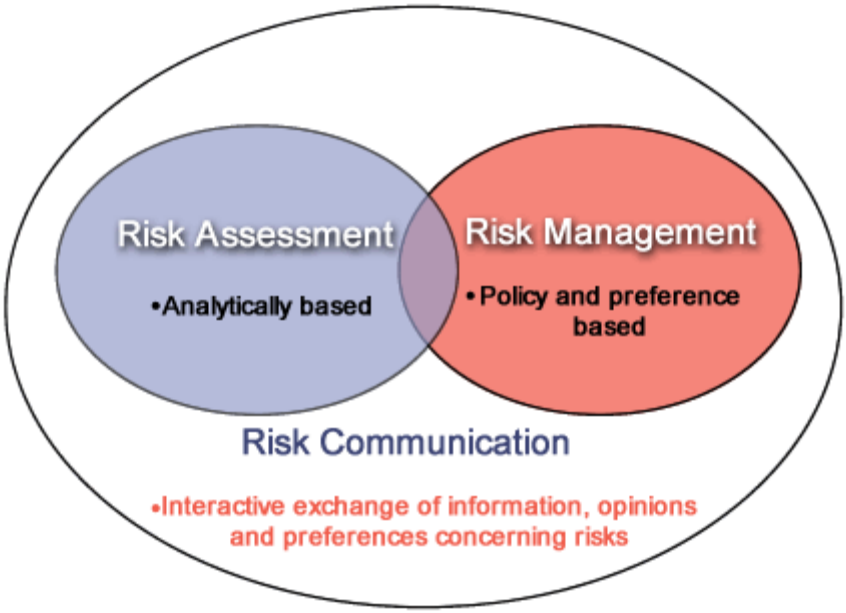


Figure 10. Risk assessment, risk management, and risk communication make up the risk analysis framework.

Risk analysis is not simply a tool or technique. Rather, it is a way of thinking about and organizing to solve problems. It is science-based but it is not pure science. Risk analysis provides

a link between science and social values. Many of us are already doing this process without formally calling it "risk analysis."

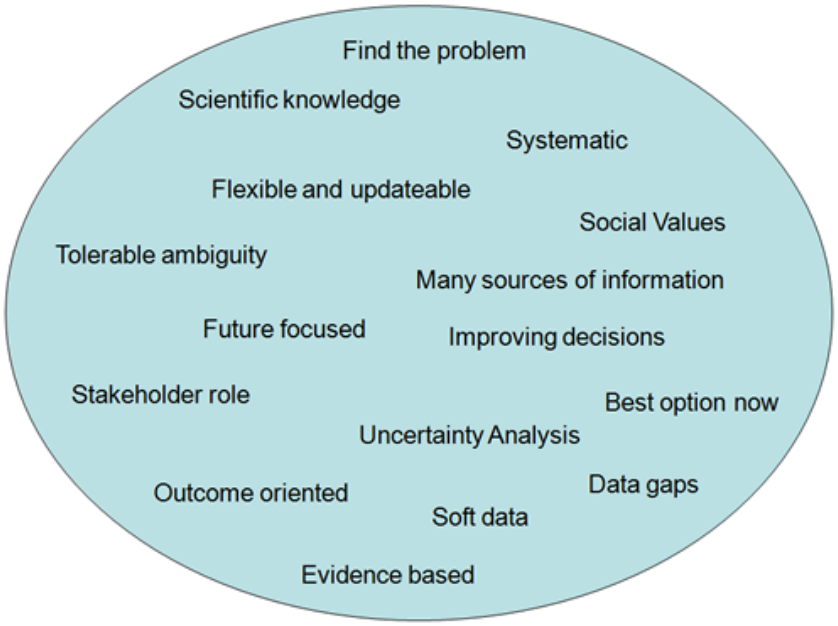


Figure 11. Risk Analysis Paradigm Attributes

Take the Harvard Center for Risk Analysis' risk quiz (http://www.hsph.harvard.edu/hcra/).

Then have a look at some related statistics that put risk in perspective (http://riskometer.org/).

Finally, the New York Times puts risk in a broader perspective (http://www.nytimes.com/2008/07/08/health/research/08stat.html?fta=y).

3.2 CORPS RISK GUIDANCE

For more detailed look at how the Corps uses risk analysis, please review the following guidance documents:

- Economic And Environmental Principles And Guidelines For Water And Related Land Resources Implementation Studies (ftp://ftp-fc.sc.egov.usda.gov/Economics/priceindexes/Data/PrinciplesAndGuidelinesLocalSite.pdf)
- WRDA 2007, Sections 2021, 2022, and 2024
- Planning Guidance Notebook (ER 1105-2-100) (http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1105-2-100.pdf)

- Risk Analysis for Flood Damage Reduction Studies (ER-1105-2-101) (http://planning.usace.army.mil/toolbox/library/ERs/er1105-2-101.pdf)
- Updated Principles for Risk Analysis (Executive Office Memo M-07-24)

Learn more about risk analysis by:

- Taking the Risk Quiz (http://www.hsph.harvard.edu/hcra/) developed by the Harvard Center for Risk Analysis
- Reviewing statistics that put risk in perspective (http://riskometer.org/)
- Reading a New York Times article that gives a broader view of risk (http://www.nytimes.com/2008/07/08/health/research/08stat.html?fta=y)

You also may want to visit:

- Society for Risk Analysis (http://sra.org/)
- Riskworld (http://www.riskworld.com/)
- Risk Analysis: An International Journal (http://sra.org/sra-journal)
- Journal of Flood Risk Management (http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1753-318X)
- RISKANAL Discussion Group
- Process for Risk Analysis for Flood Control Project (http://www.hec.usace.army.mil/publications/ProjectReports/PR-71.pdf)
- EPA's Risk Thesaurus (http://www.epa.gov/waterscience/criteria/humanhealth/microbial/thesaurus/)

Chapter 4 - When to Do Risk Analysis

4.0 When to Do Risk Analysis

Not all tasks are created equally. Likewise, not all tasks require risk analysis. It's important to know when to take the time to apply risk analysis and when it is not warranted.

The two main things to consider when deciding if risk analysis is required are:

- The level of uncertainty in the decision
- The consequences of being wrong

If there is little uncertainty and the consequences of being wrong are minor, such as filling out a travel voucher, risk analysis is not necessary. On the other hand, if there is much uncertainty and the consequences of being wrong are high, it is essential to perform an extensive risk analysis. This chart is helpful in determining when and to what degree to perform risk management.

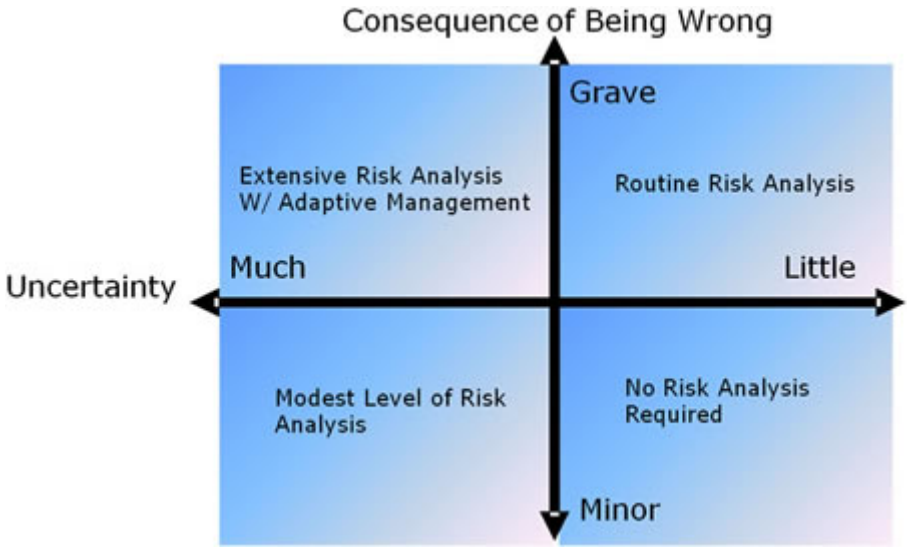


Figure 12. When to do risk analysis

Chapter 5 - Risk Management Defined

5.0 Risk Management Defined

Risk management is the foundation of the risk analysis process. It includes identifying problems, assessing risks and evaluating options, and implementing and monitoring risk management decisions. Although the Corps has its own definition, risk management has been defined in many different ways to meet the needs of many different organizations and applications.

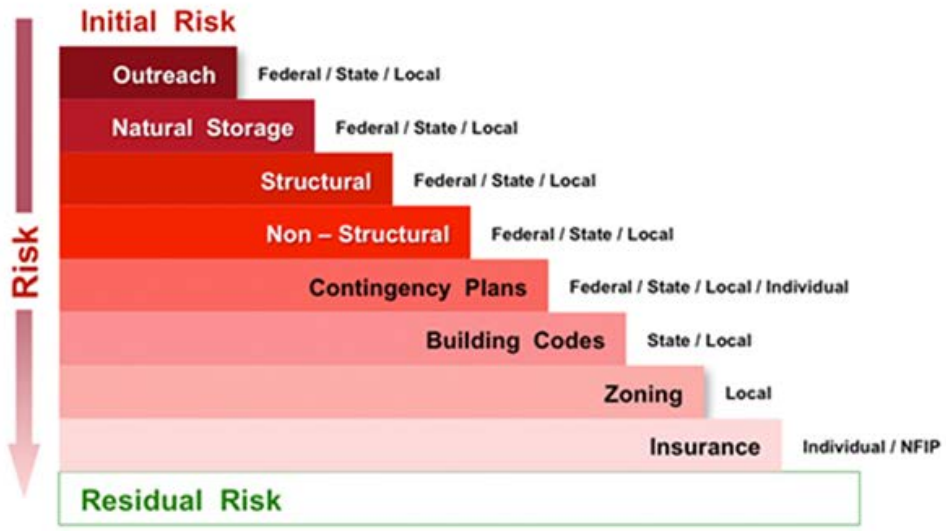


Figure 13. Effective flood risk management is a shared responsibility.

5.1 Defining Risk Management

Risk management is the keystone activity in the risk analysis process. It starts with identifying problems and decisions to be made. The next step is to begin efforts to identify and assess risks, which includes evaluating risk management options and selecting the best one from among them. It is also a risk management responsibility to implement and monitor the selected risk management activity and to modify those decisions when necessary.

Although there are risk managers within the Corps, risk management is really the responsibility of every person in the organization and it is intended to be an integral part of Corps culture. This does mark a change in the way the Corps approaches its responsibilities.

Risk management has been defined in many different ways to meet the needs of many different organizations and applications. Common to many of these definitions are the following informal questions:

- What is the problem?
- What question(s) do we want risk assessment to answer?
- What can be done to reduce the impact of the risk described?
- What can be done to reduce the likelihood of the risk described?
- What are the trade-offs of the available options?
- What is the best way to address the described risk?
- Is it working?

Answer these questions and you are doing risk management.

In *Transforming the Corps into a Risk Managing Organization* (series) risk management is defined as:
"The process of problem finding and initiating action to identify, evaluate, select, implement, monitor and modify actions taken to alter levels of risk, as compared to taking no action. The purpose of risk management is to choose those technically sound integrated actions to reduce risks after consideration of the costs of each increment of risk reduction. Environmental, social, cultural, ethical, political and legal considerations all factor into the decision made on how much cost will be incurred for each increment of risk reduction (how safe is safe enough?"

5.2 Adaptive Management

One method of risk management is known as adaptive management, which responds to uncertainty through a series of steps:

- Identify known uncertainties at the time a decision is made
- Include design features in an action as experiments that can be used to test hypotheses about the known uncertainties
- Measure and monitor results of the experiments to test the identified hypotheses
- Modify predictive models based on what is learned
- Use the revised models to identify adjustments to the actions over time to increase the likelihood that management objectives will be attained

Adaptive management means that actions are taken to both change the system and at the same time learn about the system.

Chapter 6 - Corps Risk Management Model

6.0 Corps Risk Management Model

The Corps model for managing risk focuses on a multi-part risk assessment process supported through ongoing communication and consultation and regular monitoring and evaluation.

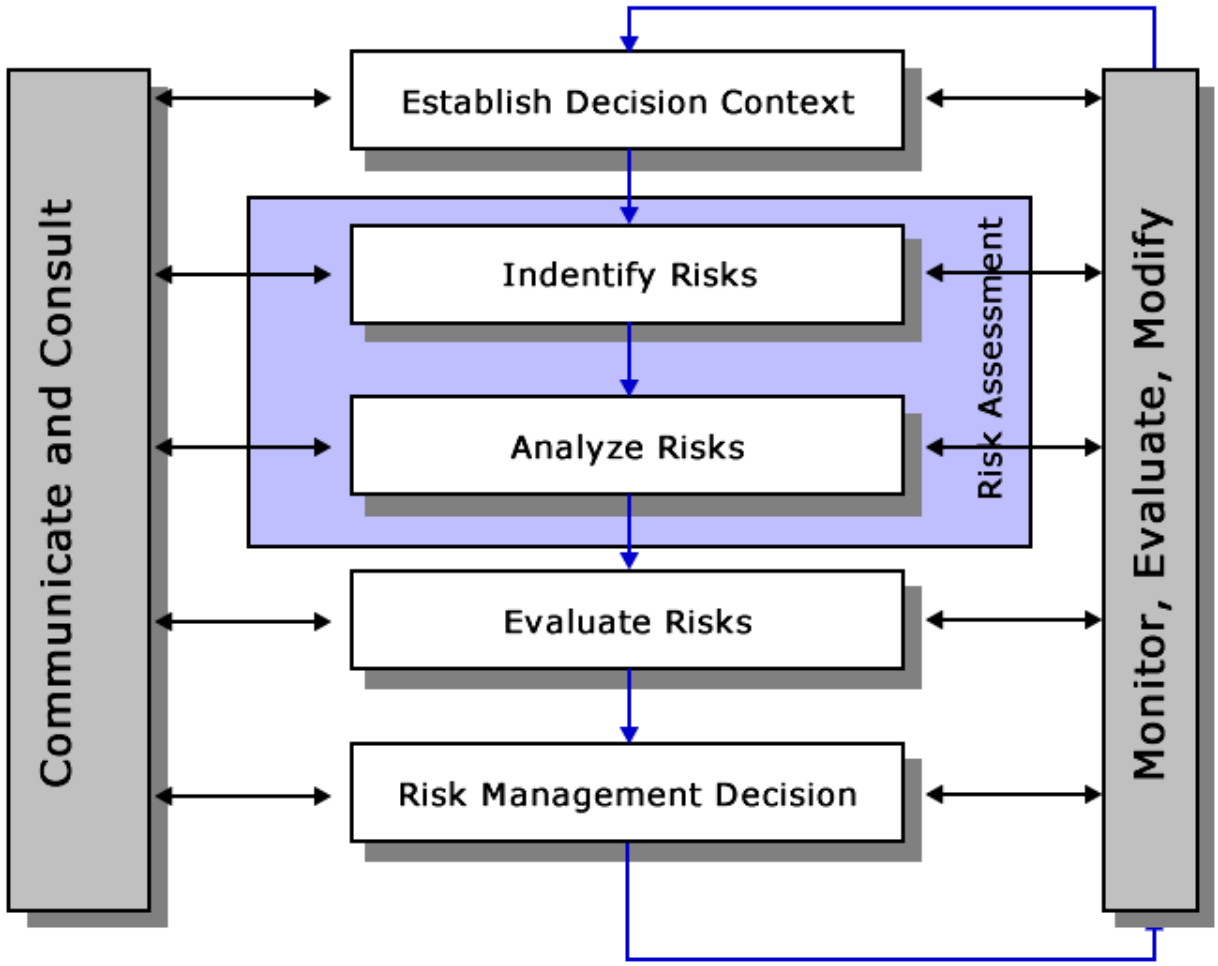


Figure 14. USACE Risk-informed decision making model

Establish decision context. The goal of establishing decision context is to define the problem; to identify the goals, objectives, strategies and scope of the activity being assessed; and to establish the areas of uncertainty and the criteria for making decisions. This should result in a written:

- Problem statement
- Statement of the activity's objectives
- List of management information questions

- List of the decision criteria
- List of key uncertainties

Identify Risks. Identify the risks relevant to the decision context. This means identifying but not yet quantifying the consequences (positive or negative) and likelihoods and how they will be expressed. This process should result in a narrative description of the risks or significant uncertainties of concern to the risk management activity and a decision on whether or not to pursue a risk assessment.

Analyze Risk. Estimate the consequences and likelihoods of the identified risks. This estimation addresses key uncertainties. The consequence and likelihood for each risk may be combined to produce an estimated level of risk. Alternative mitigation strategies (ways to reduce or limit risk) are analyzed at this point. Together, Identifying risks and analyzing risks comprise the risk assessment task when such a task is required. In some decision contexts, a complete risk assessment may not be needed. Analyzing risk should result in written answers to relevant uncertainties, formulated alternative risk mitigation strategies, characterization of each significant risk with a focus on relevant uncertainties, and a formal risk assessment if required.

Evaluate Risks. Alternatives to reduce or limit risk are evaluated and compared in order to identify the best solution. The evaluation of risks should lead to an effective summary of the most relevant uncertainties and the varying contributions of risk management options to the risk management objective and other social values considered in the decision process.

Risk Management Decision. Develop a risk management strategy, including desired and measurable outcomes. To the extent there is significant analytical uncertainty, the risk management strategy will include an adaptive management plan to reduce such uncertainties. The process of developing the risk management strategy should lead to a determination of a tolerable level of risk, the best risk management option, measurable desired outcomes to monitor the option's success, and an implementation plan.

Communicate & Consult

Throughout the risk management process it is critical to actively **communicate and consult** with internal and external stakeholders. Review the Corps Risk Analysis Gateway risk communication page for more information and resources about this part of the process. It also is important to **monitor and evaluate** results and to modify approaches in response to what is learned.

Monitor, Evaluate, Modify

Post implementation monitoring:

- measures progress toward achieving the desired outcomes of the risk mitigation strategy

- reduces analytical uncertainties identified in the initial planning process as part of an adaptive management plan
- scans the overall setting of the activity to identify hazards or changes in socioeconomic preference or conditions maybe not recognized during the initial risk analysis process, or that may have changed in their significance

In all cases the risk mitigation strategy may be modified in accordance with what is learned.

Risk Management Activities

Virtually every risk management model includes some version of the following tasks.

- Problem Recognition
- Deciding to Act
- Risk Estimation
- Risk Evaluation
- Risk Control

Figure 15. Risk management tasks

Chapter 7 - Risk Assessment Defined

7.0 Risk Assessment Defined

Risk assessment is the step in the risk management process where risks are identified, evaluated and categorized. The purpose of risk assessment is to gather the information and do the analytical work required to provide risk managers with the information they need to make decisions and solve problems.

The Corps defines risk assessment as follows:

"Risk assessment is a systematic, evidence-based approach for quantifying and describing the nature, likelihood and magnitude of risk associated with the current condition and the same values resulting from a changed condition due to some action."

Think about the work that you are doing for the Corps right now. It does not matter where you work or what you are working on, risk assessment is the work you need to do to answer the following questions:

- What can go wrong?
- How can it happen?
- How likely is it?
- What are the consequences?

Ask and answer these questions and you are doing risk assessment.

Risk Assessment

Risk assessment is defined differently by virtually every organization that uses it. Although the words may vary the four key questions outlined to the right are common to almost all of them. (See http://www.google.com/search?hl=en&rls=com.microsoft:*:IE-SearchBox&rlz=1I7SUNA&defl=en&q=define:Risk+assessment&ei=peSZSf_KMqKBtwfbiciwCw&sa=X&oi=glossary_definition&ct=title)

White Paper

Risk analysis, risk assessment and other terminology used in this course are defined in their Corps context in the White Paper *Transforming the Corps into a Risk Managing Organization (series)*.

Chapter 8 - Risk Assessment Steps

8.0 Risk Assessment Steps

The Corps risk assessment process consists of four different steps. The first step is looking for hazards and opportunities. The next step is assessing possible consequences. The following step is assessing the likelihood of those consequences. And the final step is to characterize the risk.

8.1 Accomplishing Risk Assessment

It is convenient to think of risk assessment as practiced by the Corps as a process involving four distinct steps:

Step 1: Look for hazards or opportunities

Step 2: Assess consequence

Step 3: Assess Likelihood

Step 4: Characterize risk

Notice in the definitions that follow, the importance of recognizing and addressing the uncertainty encountered in the analytical process.

Other Views

Risk assessment is practiced by many people in a variety of contexts. There are as many different risk assessment models as there are different applications of our informal (four questions) definition of risk assessment. A few examples are offered below.

- A United Kingdom 5-step model for health and safetyEPA's Superfund offers an 8-step model (http://archive.epa.gov/reg5sfun/ecology/web/html/8stepera.html)

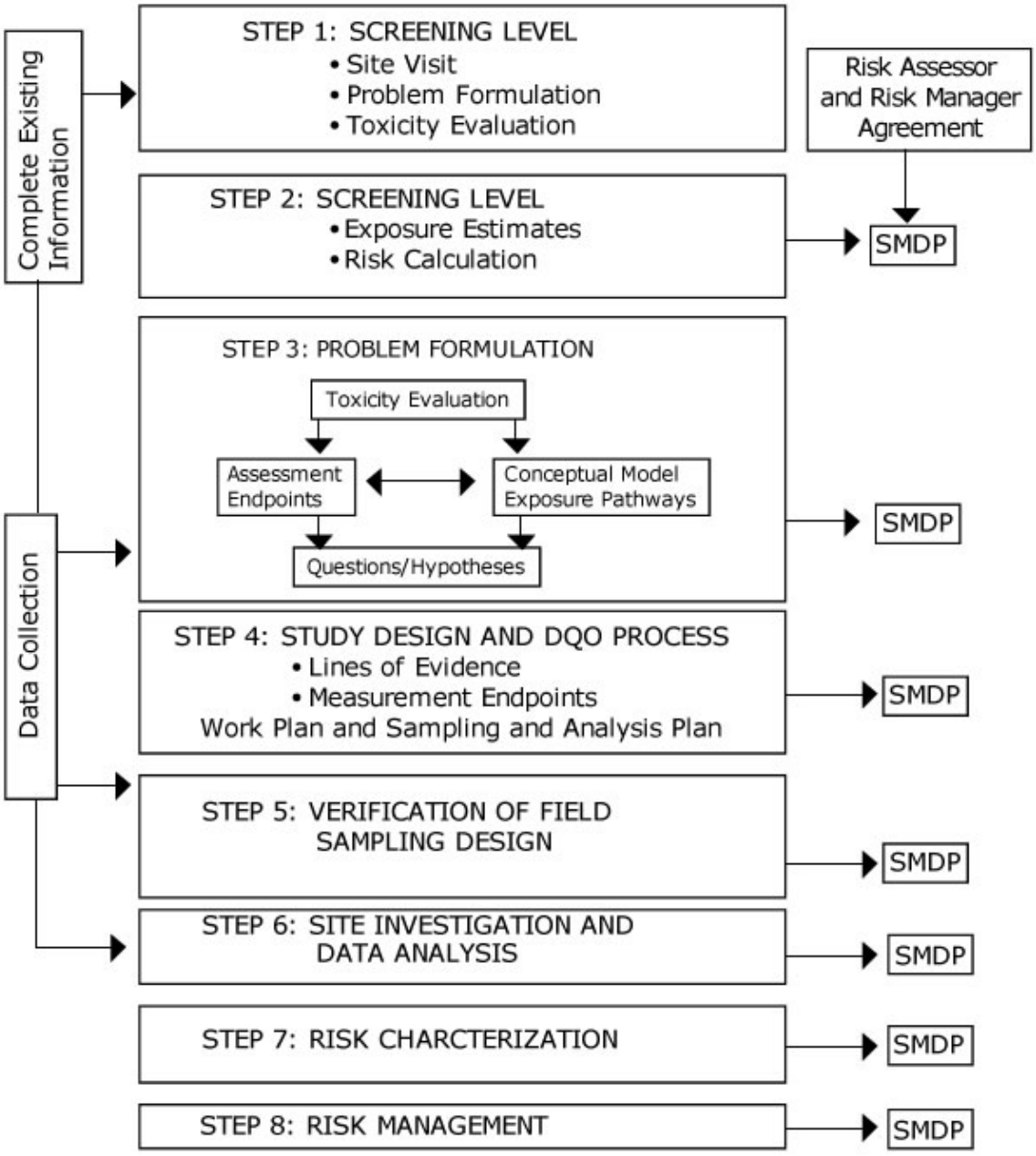


Figure 16. EPA Superfund 8-Step Risk Assessment Model

- GAO's information security risk assessment (http://www.gao.gov/special.pubs/ai00033.pdf) *(pdf, 183KB)*

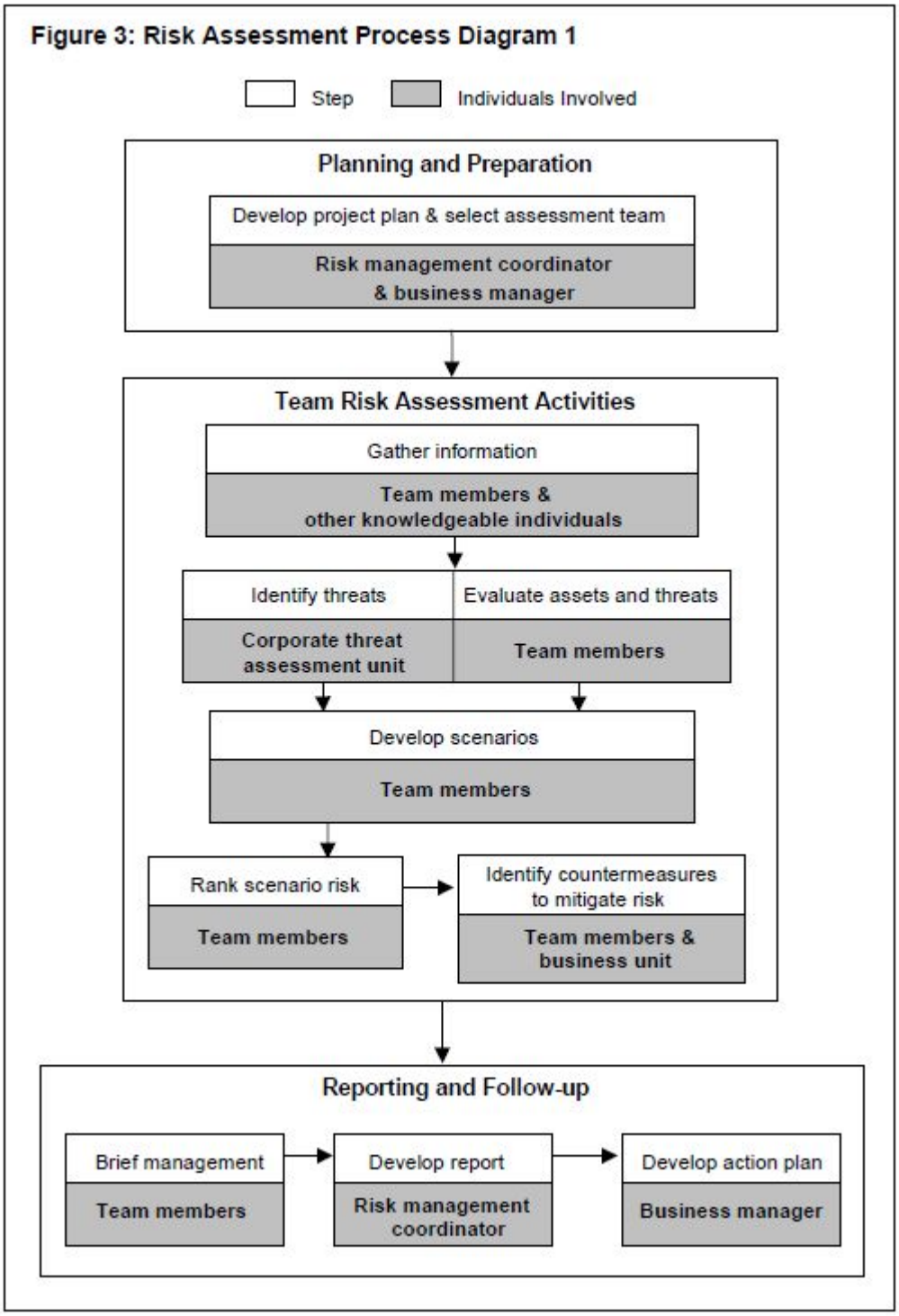


Figure 17. Risk Assessment Process Diagram

The take-away point is to feel free to adapt and change the risk assessment model you use. It is less important how many steps you have and what you call them than that we answer those four informal questions.

8.2 STEP 1: LOOK FOR HAZARDS/OPPORTUNITIES

This step is focused on identifying the hazards that can cause harm or the opportunities for gain that are uncertain.

Example

Flood risk managers try to assess a wide variety of harmful hazards or opportunities for gain including:

- Flood flows
- Property damages
- Loss of life
- Infrastructure failures
- Cost overruns
- Unpredictable budgets
- Environmental impacts
- Ecosystem restoration benefits
- Economic (re)development

In evaluating these factors flood risk managers are addressing the first two questions of risk analysis: What can go wrong and how can it happen?

8.3 STEP 2: CONSEQUENCE ASSESSMENT

In this step we decide who or what may be harmed or benefited and in what ways. We gather and analyze the relevant data and characterize the consequences qualitatively or quantitatively.

Example

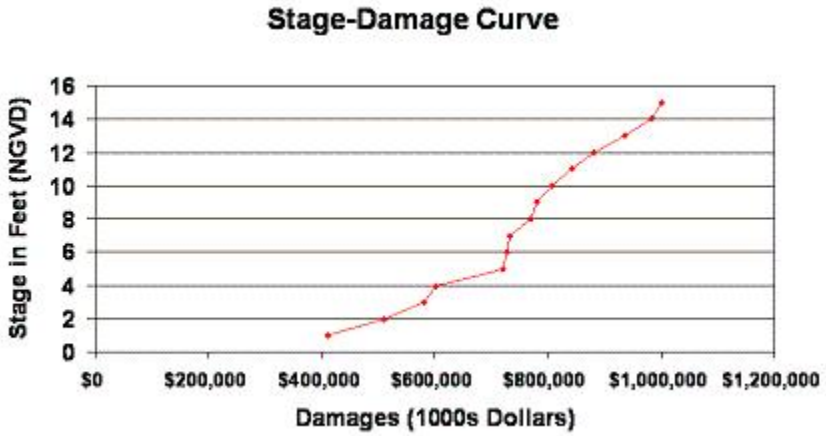


Figure 18. Stage-Damage Curve

When Corps economists conduct a stage damage survey for a flood risk management study, they are conducting a consequence assessment. This step continues to address "how can it happen" while adding a focus on the "what are the consequences" question with respect to flood damage to property.

8.4 STEP 3: ASSESS LIKELIHOOD

In this step we assess the likelihood of the various good and bad consequences and begin to characterize these likelihoods qualitatively or quantitatively.

Example

When Corps hydrologists develop a frequency curve, they are contributing to the likelihood assessment. This step continues to address "how can it happen" while adding a focus on the "how likely is it" question of our informal definition of risk assessment.

8.5 STEP 4: CHARACTERIZE RISK

In this step we estimate the probability of occurrence, the severity of negative consequences, and the magnitude of potential gains, including attendant uncertainties, of the hazards and opportunities identified based on the evidence in the preceding steps. Characterize the risk qualitatively or quantitatively with appropriate attention to baseline and residual risks, risk reductions, transformations and transfers.

Example

The Corps calculation of expected annual damages (EAD) is an example of a risk characterization. It combines knowledge of the hazard, assessment of the consequences if flood flows of varying heights occur and an assessment of the likelihood of such flows into a single risk estimate, EAD.

Chapter 9 - Characterizing Flood Risk

9.0 Characterizing Flood Risk

The characterization of flood risk has evolved over the years, with a greater emphasis on all the kinds of risk involved. Elements of a flood risk characterization include a risk estimate, a risk description, and evaluations of risk management options.

9.1 Case Study: Characterizing Flood Risk

In 1936 the National Flood Control Program was initiated. Since that time the changing name of the program, Flood Control, Flood Protection, Flood Damage Reduction, and now Flood Risk Management has reflected the evolving realization of the nature of this issue.

The U.S. Army Corps of Engineers has effectively reduced property damages from floods in the United States. During the 10-year period from 1991 through 2000, the United States would have suffered an estimated $253 billion in property damage from floods. The Corps flood damage reduction measures prevented 82% of that damage ($208 billion).

Despite this impressive record of performance, significant flood and storm damages persist. Losses in that decade amounted to $45 billion. There were $5.5 billion in flood damages in 2000 alone. (*Source*: U.S. Army Corps of Engineers) Storm damages in the last few years are well over $100 billion. One estimate of Hurricane Katrina damages alone topped $125 billion (AP Wire, 2005).

Many experts believe it is time to move away from using old notions like level of protection (LOP) to describe the effect of a project in favor of more risk-informed terminology, like tolerable level of risk (TLR) and residual risk. Level of protection was used to emphasize the strides taken to reduce a risk of flooding. What LOP does not reveal, however, is the residual risk of flooding. Hurricanes Rita and Katrina and floods on the Upper Mississippi River-all vivid examples of residual risk- have made the vulnerability of so-called protected areas a front page concern.

9.2 Elements of a Flood Risk Characterization

A **risk estimate** is an assessment of the likelihood and potential severity of the negative effects of flooding, with attendant uncertainties, for a given potential event or flood at a specified location over a given time frame. Examples of risk estimates include the probability of flooding, damages associated with specific events, expected annual damage estimates, population at risk, flood depths and so on.

A **risk description** is the story of a community's flood problem. It includes a narration that bounds and defines a risk for decision-making purposes. It may include the qualitative or

quantitative estimates of the risk. This narrative should reflect the values that are important to a community. This should include an effective description of the community's social vulnerability in addition to its economic vulnerability. These values can only be identified by effectively engaging with and involving the public in their identification.

Evaluations of risk management options include measures of baseline and residual risks, public perception of the hazard, inequities of distributions of benefits and risks, and the effects of transformed and transferred risks and other values important to decision makers and the public. Specific estimates of expected risk reductions and residual risks under alternative mitigation strategies are required for decision making. The monetary and other social costs of reducing risks and of residual risks under alternative mitigation strategies must also be considered. This cannot be done without effective public involvement.

9.3 Tolerable Levels of Risk

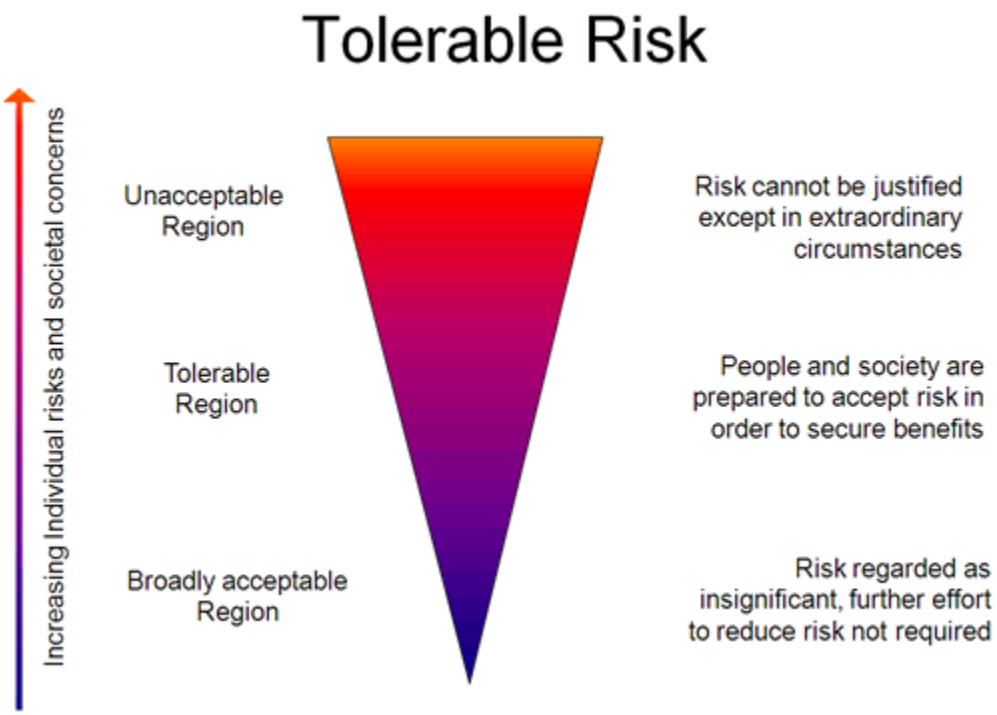


Figure 19. Tolerable levels of risk

The London Hazards Centre Fact Sheet puts tolerable risk in another perspective as seen in Table 1 below.

Table 1 A single risk-level estimator

Likelihood	Slightly harmful	Harmful	Extremely harmful
Highly unlikely	Trivial Risk	Tolerable Risk	Moderate Risk
Unlikely	Tolerable Risk	Moderate Risk	Substantial Risk
Likely	Moderate Risk	Substantial Risk	Intolerable Risk

9.4 Flood Problems Access the Nature

The US Geologic Survey Kansas Water Center (Perry, 2000 (http://pubs.usgs.gov/fs/2000/0024/report.pdf)) provides a vivid summary of the scope of the Nation's remaining flood problems. This map summarizes some of the major floods experienced in the last century. It illustrates the severity of the flood risks across the Nation. While some of these risks have been mitigated over time, the number of events causing billions of dollars in damage since the 1990s provide convincing evidence of serious ongoing flood risks.

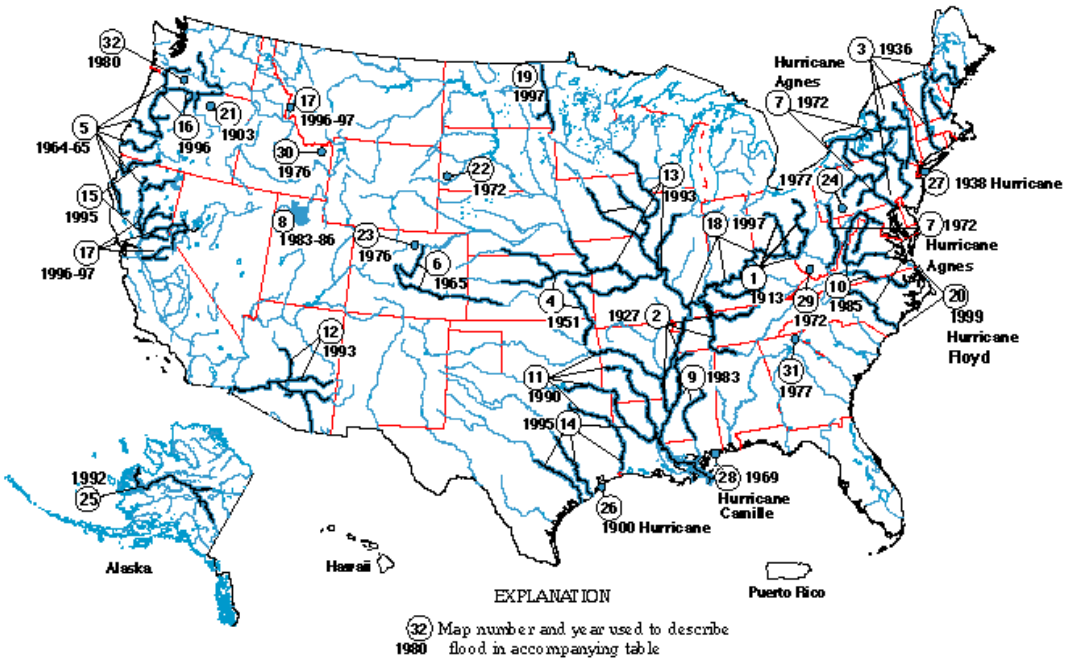


Figure 20. Flood map

9.5 What You May Not Know About Flood

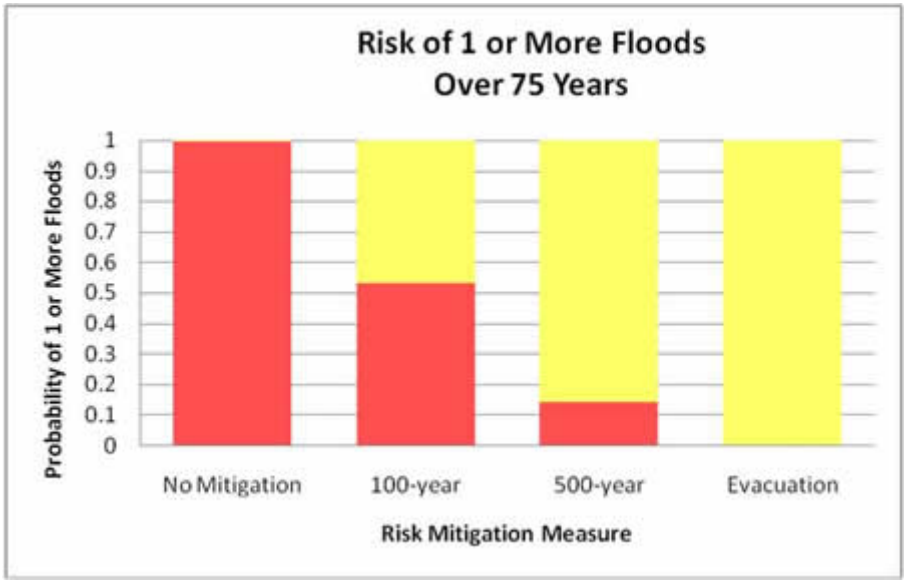


Figure 21. Risk of 1 or More Floods Over 75 Years

Playing Russian Roulette with a six shooter yields a 16.7% chance of losing. No right-minded person would take such a risk. Yet many Corps flood "protection" projects have left people with risks close to and usually much greater than that.

Consider a house in the 10-year floodplain. The figure above shows the cumulative probability of being flooded one or more times (pink) if a person spends a 75-year lifetime in that location. With no flood risk mitigation the likelihood of one or more floods is so close to 100% as to be regarded as a virtual certainty.

In the past, a flood study might have spoken of 100-year protection. This could be a wall or levee built to hold back floodwaters with an exceedence frequency of 0.01 annually. Many people would consider this to be a high degree of protection. In the past the Corps focused on safety and levels of protection, perhaps leaving residents with a false sense of security. Even with so-called 100-year protection, there is a 52.94% chance a person will be flooded one or more times in a 75-year lifetime.

Bump that level of protection up to 500-year protection and there is still a 13.94% chance of being flooded one or more times in 75 years at that location.

Is that a level of risk a person or community can tolerate? It is only slightly better than Russian Roulette. If we are going to manage risk, we have to characterize it and communicate it effectively.

Chapter 10 - Assessment of Management Measures

10.0 Assessment of Management Measures

Risk managers assessing risk must decide between accepting risk if it is tolerable, or mitigating risk if it is not tolerable. Risk management measures are intended to mitigate risk through methods including precautionary and discursive strategies. Effective risk management deals with various types of risks including residual risk, transformed risk, and transferred risk.

10.1 Assessing What to Do About Risk

Once a risk is identified, an obvious decision is whether to accept and assume the risk, if it is judged tolerable, or to mitigate (try to lessen the impact) if it is not tolerable. Risk management measures are intended to mitigate risk. In flood risk management, risks are often reduced via structural and nonstructural means. Risks of any type may be mitigated in any of the following ways.

- Risk-based management measures/relies on risk assessment and decision science
    - Avoidance
    - Reduction
    - Transfer
    - Retention/acceptance
- Precautionary strategies
    - Containment
    - Constant monitoring
    - Continuous research
    - Development of substitutes
    - Increasing resilience/resistance and robustness to surprises
    - Precautionary principle
- Discursive strategies
    - Build confidence and trustworthiness
    - Reduce uncertainties
    - Clarify facts
    - Involve affected people
    - Deliberation
    - Accountability

EXPLORE

Test your own risk intuition. Imagine that you live in a home located in the 10-year floodplain, i.e., a flow with an annual exceedence frequency of 0.1 or less will flood you.

- What is the probability you will be flooded this year?
- If you live there for 10 years what is the probability you will be flooded one or more times?
- If you live there for 30 years (the duration of a common mortgage) what is the probability you will be flooded one or more times?
- If you live there for 75 years what is the probability you will be flooded one or more times?

10.2 THE REST OF THE RISK STORY

Estimating existing and future risks is an easy focus for most risk assessment. It can be equally important, though, at times to look at other aspects of risk including:

- Residual risk
- Transformed risk
- Transferred risk

Although the discussion that follows centers around flood risk, the concepts are applicable to all kinds of risks.

In following sections we will discuss risk communication. If the Corps is to involve the public effectively in making flood risk management decisions, it must find effective and meaningful estimates and descriptions of existing, residual, transformed and transferred risks associated with a flood risk mitigation strategy.

Residual Risk

This is the risk remaining after mitigation strategies have been implemented. Residual risk has often been overlooked in the past to the possible detriment of flood-prone communities that did not understand the limits of their protection. Residual risk can be described quantitatively but qualitative, descriptive narratives may be useful to the public.

Transformed Risk

When the fundamental nature of a hazard and a population's exposure to that hazard are changed, we call that a transformed risk. For example, when a community without flood risk measures in place is exposed to flooding it has a certain kind of risk. Once a levee is built, however, the nature of the risk changes. The community is no longer subject to the lower levels

of flooding it once sustained but new risks arise. There is a risk of infrastructure failure (the vulnerability of the community is altered) as experienced in New Orleans during Hurricane Katrina, for example. There is also the risk of overtopping, as experienced in several communities during the upper Mississippi River floods of 2008. Protective measures can create new hazards or significantly alter existing ones, thereby transforming the risk. The public is not likely to be familiar with the nature of a transformed risk and extra care must be taken to assure that it is well understood.

Transferred Risk

Some risk mitigation measures, like channels, levees and walls, can reduce the risk in one location only to increase it at another. This is often the result of induced flooding. Protective measures can change hydrographs and flood profiles. Channels may alter the speed with which water is transported and walls can alter the height of a flow in adjacent or downstream communities thereby exacerbating existing flood problems. So in this situation the risk reduction measure in one community can increase the risk in another. This is a risk transfer. Affected publics need to be fully informed about the nature of these risks.

Chapter 11 - Risk Assessor's Toolbox

11.0 Risk Assessor's Toolbox

There are two general types of risk assessment: qualitative and quantitative risk assessment. Risk assessment tools used in qualitative assessments rely on descriptive expressions of risk. Tools used in quantitative assessments rely on numerical expressions of risk. There are also tools that can be used in either qualitative or quantitative risk assessments.

11.1 Risk Assessor's Toolbox

Addressing the uncertainty in the universe, while meeting decision makers' information needs, is the greatest challenge for risk assessors. Risk assessment can be divided broadly into qualitative and quantitative risk assessment. Some of these tools are primarily for one or the other of these types of risk assessment, while others are used for both.

Qualitative

Qualitative tools tend not to rely on numerical expressions of risk. Qualitative tools include:

- Narratives
- Ordering Techniques
- Enhanced Criteria Ranking
- Evaluation Framework
- Sensitivity Analysis
- Scenario Planning

Quantitative

Quantitative tools rely on numerical expressions of risk. Quantitative tools include:

- Deterministic scenario analysis
- Probabilistic scenario analysis

Flexible Assessment Tools

There are also several tools that can be used with either qualitative or quantitative risk assessments.

- Adaptive Management
- Premise Sets
- Multi-Criteria Decision Analysis
- Corps Software Tools
- Other Techniques

11.2 QUALITATIVE ASSESSMENT TOOLS

Qualitative tools tend not to rely on numerical expressions of risk. Qualitative tools include:

Narratives

The most basic way to address risk is via a narrative. This qualitative technique is simply telling the story of the risk, its key uncertainties and their significance to the decision outcomes. This is the absolute bare minimum requirement for risk assessment. It answers the four questions:

- What can go wrong?
- How can it happen?
- How likely is it?
- What are the consequences?

Although very simple and qualitative, the importance of this technique should not be overlooked as a starting point for risk assessment. In fact, an effective narrative needs to accompany every risk estimate. Not everyone will need to understand the details of the risk assessment. But all stakeholders and decision makers need to know the significance of the risk to decision making.

Ordering Techniques

Screening, rating and ranking are useful ordering techniques that require increasing levels of detail and information. These techniques are used to identify hazards, risk potential, pathways, mitigation measures and the like that are of interest to decision makers.

Screening

This is a process of separating elements into categories of interest and no interest through systematic elimination. It requires:

1. Items to be screened
2. Carefully defined categories (yes/no)
3. Criteria for screening
4. Evidence for the criteria
5. An algorithm for using the criteria to separate the items into the desired categories

Some common screening algorithms include:

1. Domination procedures (better/worse on all criteria)
2. Conjunctive procedures (meets all criteria thresholds)
3. Disjunctive procedures (meets a least one criterion threshold)
4. Elimination by aspects (set cut-off value for most important criterion and eliminate, then set cut-off value for next most important criterion, etc.)
5. Lexicographic rules (rank against all criteria then rank alternatives)

Rating

This is a systematic process of separating elements into multiple categories of varying degrees of interest. Individual items may be rated high, medium, low or no risk, for example. it requires:

1. Items to be rated
2. Carefully defined categories (non-ordinal is okay)
3. Criteria for rating
4. Evidence for the categories
5. An algorithm for using the criteria to separate the items into the desired categories

Ranking

This is a systematic process used to put items in a numerical sequence, thus rated items can be ranked. Ranking may rely on ordinal ranked categories or an ordinal ranking of each individual item. Ranking is simple when objective measures of a risk or other characteristic of interest are available. It requires:

1. Items to be ranked (alternatives)
2. Carefully defined evidence-based criteria for ranking
3. Evidence of each item's measurement or rating for each criterion
4. Differential weights for criteria when appropriate
5. A synthesis algorithm

Enhanced Criteria Based Ranking

This technique was developed and used by the U.S. Department of Agriculture. Its steps are:

- Criteria
- Ratings
- All Possible Combinations of Ratings
- Ranking
- Evaluate Reasonableness of Ranking
- Add Criteria
- New Combinations of Ratings
- New Ranking

For a demonstration of this technique download the Power Point file and then download the audio file.

Evaluation Framework

This is a risk evaluation technique which identifies how experts evaluate current scientific evidence on a chosen topic for the purpose of identifying the conclusions they reach regarding a risk potential. It reveals the evidence and arguments they use to justify conclusions and surfaces the consensus and disagreement that exist as well as the uncertainties that remain. The core elements of an evidence framework seen in the template (left) are:

- Evidence base or data
- Pro and con arguments (the warrants)
- Includes respective supporting or opposing arguments
- Conclusions of claim about existence of a hazard with remaining uncertainties

See examples of evidence maps developed by the inventors of this technique and presented in the presentation "Risk evaluation of the health effects of mobile phone communication. Results of a scientific dialogue." by Peter M. Wiedemann, Holger Schütz, and Albena Spangenberg of Forschungszentrum Jülich GmbH in October 2005 .

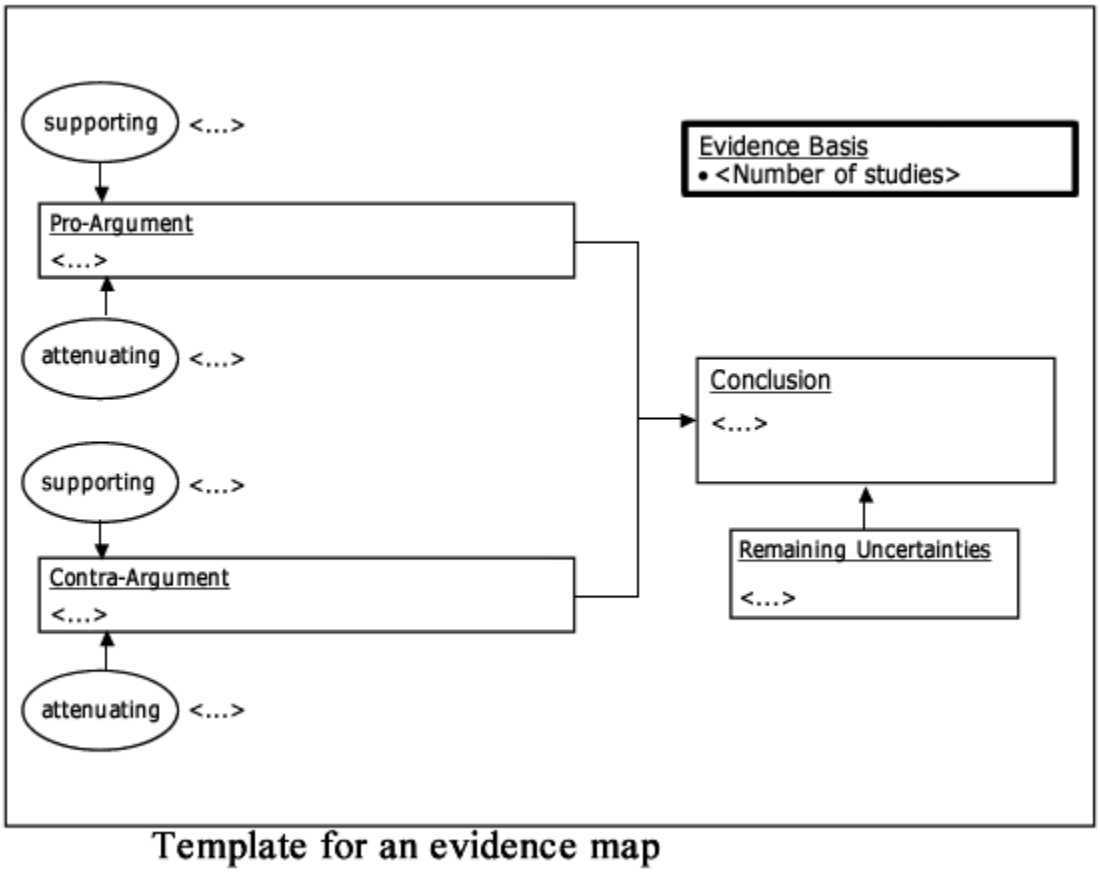


Figure 22. Template for an evidence map

Sensitivity Analysis

The most common tool used to explore the significance of uncertainty in a risk assessment is sensitivity analysis. It can be either qualitative or quantitative. Some project outcomes and decisions are sensitive to minor changes in assumptions and input values. Thorough, rational decision making requires an explicit examination of such sensitivities. It is not always immediately obvious which assumptions and uncertainties may affect our outputs, conclusions and decisions most. The purpose of sensitivity analysis is to systematically make this determination. Sensitivity analysis is a systematic investigation of model parameters, model inputs, assumptions and model functional forms. Challenging (and changing) assumptions along with parametric variation of input variable/parameter values to examine these effects on project outputs are the cornerstones of sensitivity analysis.

Sensitivity analysis is used to increase confidence in risk assessments and the decisions based on them. It provides an understanding of how model outputs respond to changes in inputs, i.e., the data used, model structures and other factors. Some sensitivity analysis tools include:

- Vary assumptions
- Deterministic one-at-a-time analysis of each factor
- Deterministic joint analysis
- Subjective estimates of significant threshold values
- Parametric analysis (using a range of values)
- Probabilistic analysis to support importance analysis

Scenario Planning

Scenario planning (Ralston and Wilson, 2006 (http://www.amazon.co.uk/Scenario-Planning-Handbook-Developing-Strategies/dp/0324312857)) is an appropriate response when there are relatively few but important knowledge uncertainties where the consequences of being wrong are great. Scenarios, in this context, are narrative descriptions of markedly different plausible alternative futures. Scenario planning allows analysts to consider a range of without or with project conditions, each of which is dramatically different from the other and from the current operating environment. Rather than rely on a single "most likely" forecast, analysts can compare and contrast alternative opinions on how the future may evolve.

Multi-Criteria Decision Analysis

Multi-Criteria Decision Analysis (MCDA) (http://www.mcdmsociety.org/) is the study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process. The risk manager contemplates a choice of action in an uncertain environment and MCDA helps the manager choose from among a set of pre-specified alternatives. Decision making relies on information about these alternatives. The quality of information can be anything from scientifically-derived hard data to subjective interpretations. The outcomes of decisions may be certain (deterministic information) or uncertain and represented by probabilities and fuzzy numbers. MCDA can assist in information processing and may lead to better decisions.

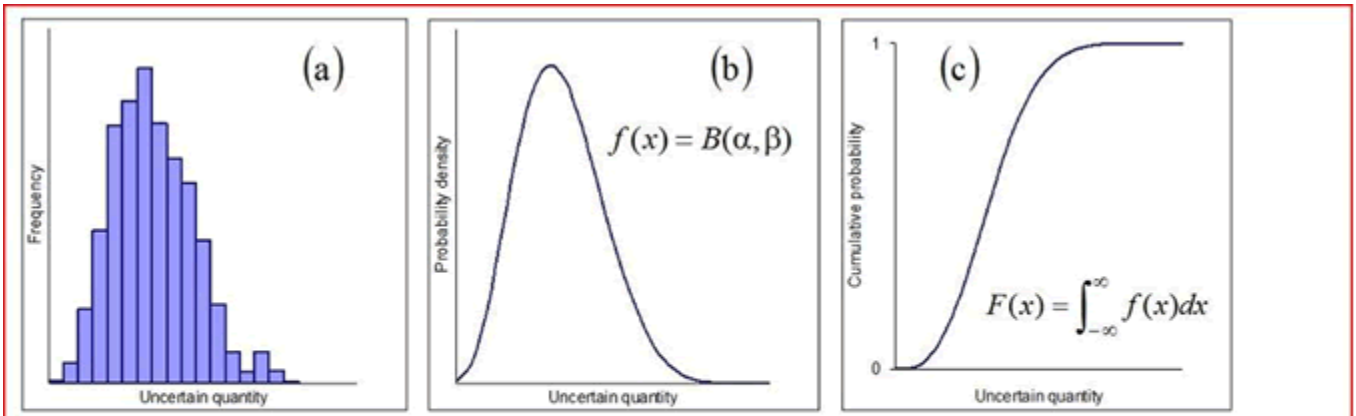
11.3 Quantitative Assessment Tools

Quantitative tools rely on numerical expressions of risk. Scenario analysis is the primary tool used by the Corps in quantitative risk assessment. In this context, scenarios are the stories we tell about problems, plans and their effects. There are two major types of scenario analysis:

Deterministic scenario analysis examines specific scenarios used to explore the range of effects uncertainty can have on decision criteria. Some common scenarios include worst case, best case, most likely, locally preferred, nonstructural and no action scenarios.

Probabilistic scenario analysis is one of the most common and powerful quantitative responses to uncertainty. Because of the presence of variability and uncertainty in so many analytical problems there are often an infinite number of possible future scenarios. It is not possible to

describe them all but some of them may be important to the decision process. Probability is the language of variability and uncertainty and it can be incorporated into scenario analysis using such techniques as the Monte Carlo process, interval analysis (http://www.cs.utep.edu/interval-comp/main.html) , fuzzy set theory (http://www.doc.ic.ac.uk/%7End/surprise_96/journal/vol4/sbaa/report.fuzzysets.html), possibility theory (http://www.scholarpedia.org/article/Talk:Possibility_theory), evidence theory (Dempster-Shafer), and imprecise probability theory (http://en.wikipedia.org/wiki/Imprecise_probability). Most of these theories are in an early stage of development relative to classical probability theory (i.e., Monte Carlo processes and Bayesian estimation). Uncertain quantities can be represented as random variables. Random variables can be described using frequency distributions, statistical variances, confidence intervals, and probability distributions.



Three ways to describe uncertainty in a random variable. Panel (a) presents a histogram, Panel (b) presents a probability density function (PDF) and Panel (c) presents a cumulative distribution function.

Figure 23. Three ways to describe uncertainty in a random variable

11.4 Flexible Assessment Tools

There are also several tools that can be used with either qualitative or quantitative risk assessments.

Adaptive Management

Many might consider this a risk management tool. It is included here as an effective means for dealing with uncertainty; it can include adaptive learning as well as management.

Uncertainty analysis gives rise to the development of adaptive management strategies. Adaptive management is a limited idea related to learning to reduce uncertainties about how to achieve a target, by reducing knowledge uncertainties that are recognized at the time the action is taken. Adaptive management can follow a prescribed sequence of steps:

- Define target outcomes
- Develop models to predict — with epistemic error estimates - success of actions intended to secure the desired outcomes
- Develop alternatives that are directionally correct in securing the outcome, are reversible and that include provision for learning over time through monitoring, experimentation, implementation
- Based on what is learned revise models
- Make new predictions
- Revise the original set of actions.

Premise Sets

Premise sets were used by the Corps to address significant uncertainties encountered in the aftermath of the Mount Saint Helen's eruption. Analysts identify the range of possible outcomes as well the assumptions and other things one must believe for each outcome to be realized. Decision makers then identify their view of the uncertain future by choosing from these several sets of premises and their consequences prepared by analysts the set they consider most likely in the future.

Corps Software Tools

Corps software tools include:

- HEC FDA (http://www.hec.usace.army.mil/software/hec-fda/)
- HEC Software Tools (http://www.hec.usace.army.mil/software/)
- IWR Plan (http://crbweb01.cdm.com/IWRPlan/default.htm)
- Beach-fx (http://hera.cdmsmith.com/beachfx/default.aspx)
- Harbor Sym (https://www.iwr.usace.army.mil/Missions/Economics/Container-Model-Suite-of-Tools-CMST-/HarborSym/)

Other Techniques

Other flexible assessment techniques include:

- **Uncertainty rankings** which can be used to rank benefit estimates from the least to the most uncertain. Confidence rankings enable analysts to express their degree of confidence about their analysis. Qualitative scales, defined by the analyst, such as very certain, reasonably certain, moderately certain, moderately uncertain, reasonably

uncertain and very uncertain can be used to place the analysis in a context for decision makers to consider.

- The **minimax regret criterion approach** (http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/92r1.pdf) estimates the opportunity cost (regret) associated with each possible course of action. The decision-maker selects the activity that has the least regret, or loss. Regret is measured as the difference between the best and worst possible payoff for each option.

Chapter 12 - Risk Communication

12.0 Risk Communication

Risk communication is an open, two-way exchange of information between risk managers and stakeholders. It is an ongoing process throughout the different risk management procedures. Proper risk communication leads to better understanding and better risk management decisions.

Risk communication is a multidirectional communication process (see Figure 24).

Figure 24. Risk communication cycle

12.1 Risk Communication Defined

The Corps defined risk communication in its White Paper **Transforming the Corps into a Risk Managing Organization** (series) (as follows.

"Risk communication is the open, two-way exchange of information and opinion about hazards and risks leading to a better understanding of the risks and better risk management decisions.

Risk communication is integrated into the assessment and management processes. It is not a task that occurs only after decisions have been made. Risk communication ensures that the decision makers, other stakeholders and affected parties understand and appreciate the process of risk assessment and in so doing can be fully engaged in and responsible for risk management."

12.2 What Risk Communication Is and Is Not

Risk communication has been defined in varying ways by various groups. All definitions seem to include some version of an open, two-way exchange of information and opinion about risk leading to better understanding and better risk management decisions.

A 1996 IWR report *Applied Risk Communication Within the Corps of Engineers* (http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/96r14.pdf) provides background on the thinking about risk communication a decade ago. Risk communication has progressed considerably in the years since that report was written and we would like to acknowledge the National Center for Food Protection & Defense Risk Communicator Training (http://www.foodinsight.org/National_Center_for_Food_Protection_and_Defense_International_Food_Information_Council_Risk_Communication) for the bulk of the material in this section of the course.

There is an internal risk communication task that involves effective communication and interaction between the risk managers and the risk assessors. The focus of this course, though, is on the external risk communication task, which involves that two-way exchange of information and opinion. We begin with three specific goals for risk communication:

- Tailor communication so it takes into account the emotional response to an event
- Empower stakeholders and public to make informed decisions
- Prevent negative behavior and/or encourage constructive responses to crisis or danger

12.3 Risk Communication Examples

Example 1:

Consider the Center for Disease Control warning message shown here.

- How does this statement take into account the public's emotional response?
- What constructive behavior is encouraged?
- How does the statement empower audiences to make informed decision-making?

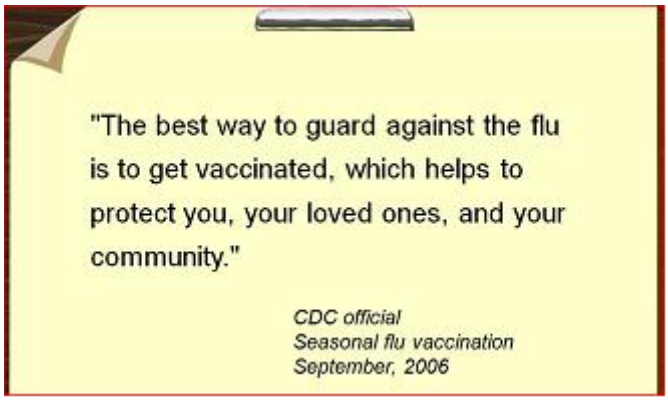


Figure 25. CDC memo

Example 2:

Now consider the warning message issued as Hurricane Ike approached Galveston, Texas.

- How does this statement take into account the public's emotional response?
- What constructive behavior is encouraged?
- How does the statement empower audiences to make informed decision-making?

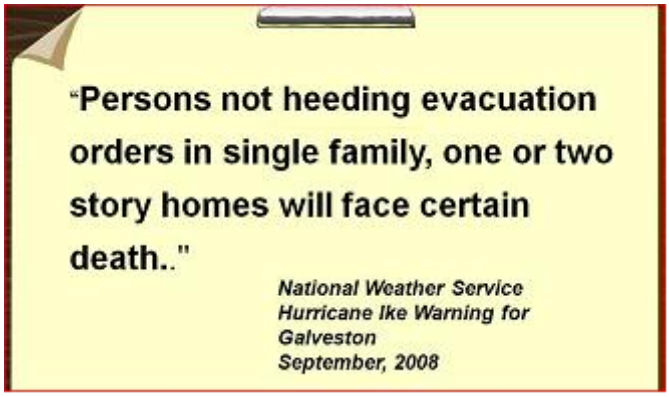


Figure 26. National Weather Service memo

12.4 ELEMENTS OF RISK COMMUNICATION

Figure 27. The Elements of Risk Communication

- Audience assessment — *know the public*
- Audience involvement — *involve the public as partners*
- Message — *information content*
- Logistics — *how you get the content, how you get it to the audience, how you get their response back*
- Listening — *for audience response*
- Metamessaging — *the larger, holistic meaning of a message, the attitude communicated by the message sender, how you say it, reflects how communicator and audience feel about event*
- Self-assessment — *on-going*
- Evaluation — *lessons learned*

Chapter 13 - Risk Perceptions

13.0 Risk Perceptions

When communicating risk, we must take into account people's perceptions of risk. Risk perception is influenced by both objective and subjective factors. Good risk communication addresses both the objective and subjective aspects of risk perception.

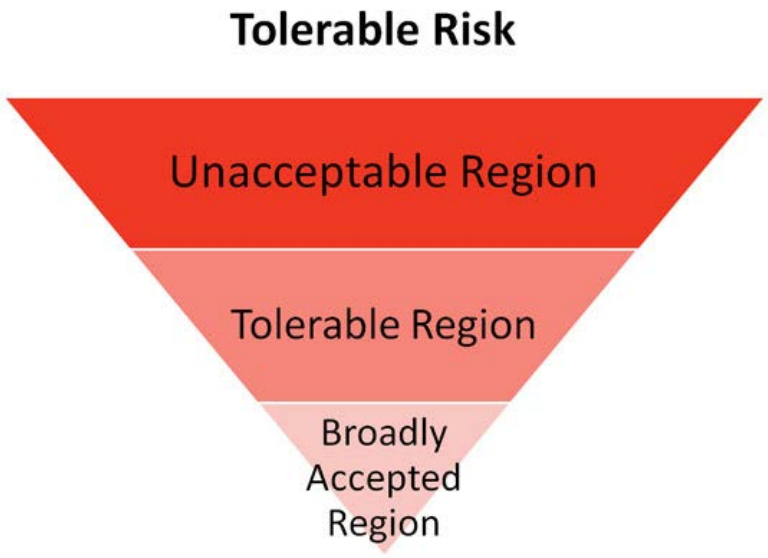


Figure 28. The levels of tolerable risk

The tolerability of risk is an often subjective factor that influences the public's perception of risk.

13.1 Risk Perceptions

Figure 29. Caution: This Sign Has SHARP EDGES

Communicating about risk is difficult because of the way people interpret risk. There is a scientific or factual dimension to risk but there is also a social dimension or context. This difference introduces competing views of risk, objective vs. subjective.

What shapes our perceptions of risk? Consider the following attributes of a risk:

- Hazard — something that can go wrong
- Probability — likelihood of it happening
- Consequences — implications of the hazard
- Value — subjective evaluation of the relative importance of what might be lost (or gained)

Risk = Hazard + Outrage

Figure 30. Risk = Hazard + Outrage

The first two of these attributes rely on our "thinking" (logic). They focus on the objective hazard (danger) and its probability (likelihood or chance) of occurring. The last two attributes involve our subjective feelings. They involve fear, anger and other emotions that are evoked when we consider the potential consequences and the value of what may be lost (or gained).

The researcher **Dr. Peter M. Sandman** (http://www.psandman.com/index-intro.htm) has suggested there is very little correlation between a risk's hazard (think of this as the objective nature of risk) and its outrage (its subjective nature). He goes on to say:

- When hazard is high and outrage is low, the task is **"precaution advocacy"** — alerting insufficiently upset people to serious risks. **"Watch out!"**

- When hazard is low and outrage is high, the task is **"outrage management"** — reassuring excessively upset people about small risks. **"Calm down."**
- When hazard is high and outrage is also high, the task is **"crisis communication"** — helping appropriately upset people cope with serious risks. **"We'll get through this together."**
- When hazard and outrage are both intermediate, you're in the **"sweet spot"** — dialoguing with interested people about a significant but not urgent risk. **"And what do *you* think?**

13.2 Goal of Precaution

The goal of precaution advocacy, as would be appropriate for floodplain occupants, is to increase awareness of and concern for the actual hazard. Note that the outrage or subjective perception of the hazard is low when the actual hazard may be great.

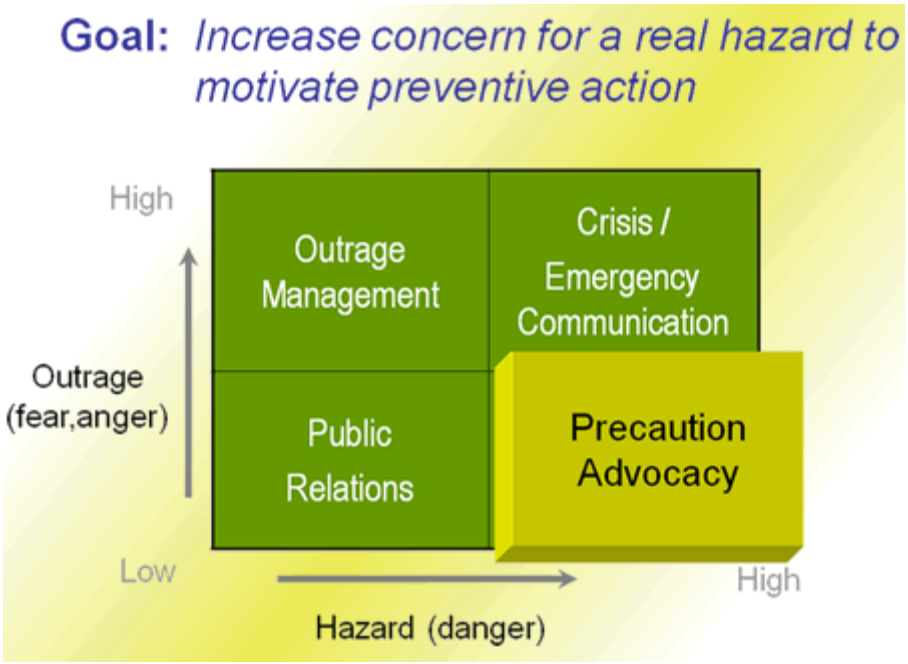


Figure 31. The goal of precaution advocacy

When outrage is high and the actual hazard is low, the communication goal is to reduce the outrage. An example may be when a community on the bank opposite a newly protected community expects induced flooding effects that will not occur.

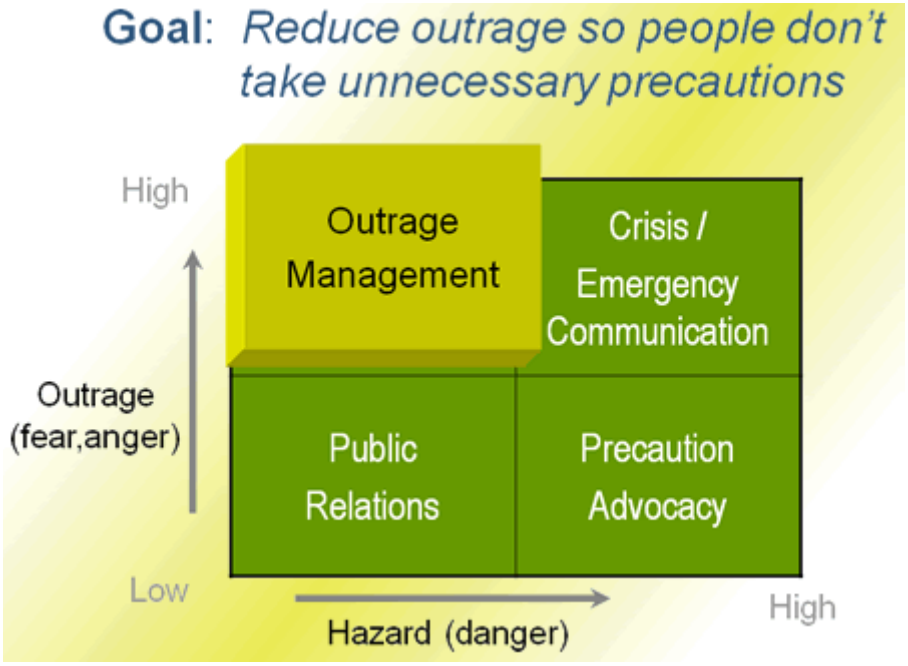


Figure 32. The goal of outrage management

When both the hazard and outrage are high, as was the case with Upper Mississippi River flooding in June 2008, the goal is to acknowledge the hazard, validate people's concerns and give people information that empowers them to act.

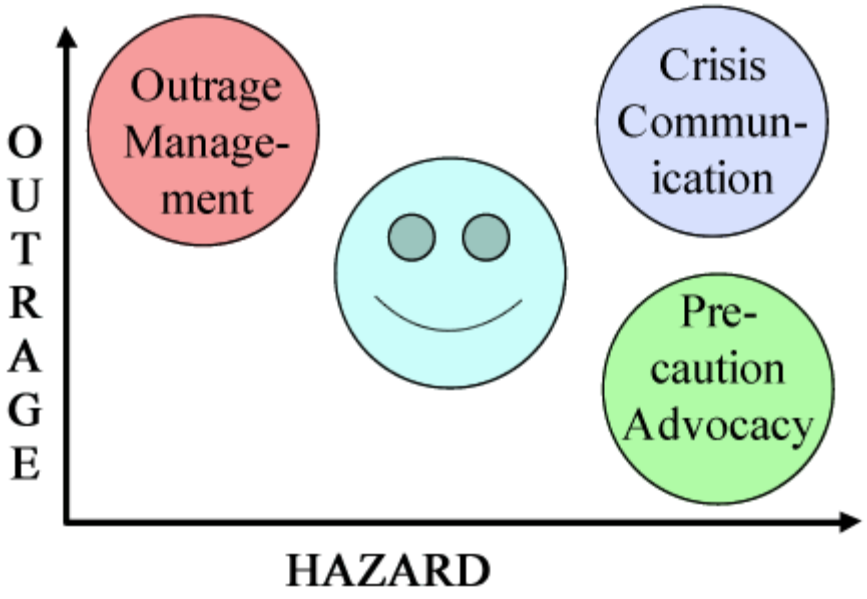


Figure 33. Outrage Management, Crisis Communication, Precaution Advocacy

Chapter 14 - Desired Outcomes

14.0 Desired Outcomes

Effective risk communication will require a different approach from one situation to another. The goal of risk communication is not always the same and will vary from situation to situation. Likewise, the technical expertise needed to communicate risk will vary from situation to situation. It is important for risk communicators to understand their audience.

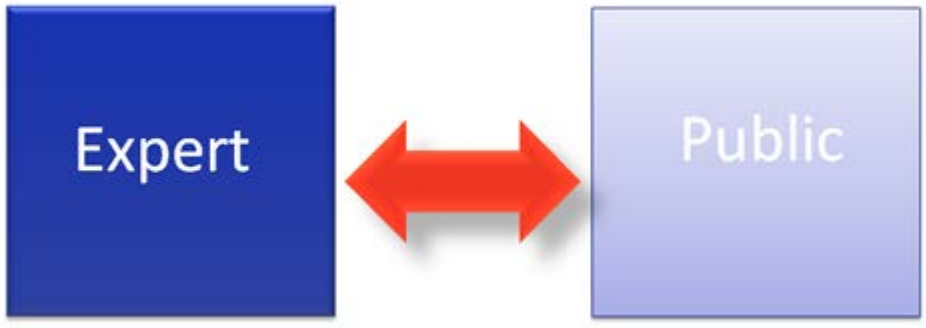


Figure 34. Expert vs public perception

14.1 Risk Communication Outcome

Figure 35. What is not an intended risk communication outcome?

To understand the desired outcomes for risk communication, it may be helpful to first consider what is NOT an intended risk communication outcome. For example, it is commonly thought that risk communication is supposed to make people feel safe and less anxious to avoid panic. Likewise, many think risk communication is supposed to assure public that their fear is unwarranted. This is not the case.

It is not spin, damage control or public relations. Risk communication is not how to write a press release or how to give a media interview. Risk communication is only as good as its effectiveness to help implement a plan. A case in point is the Katrina evacuation. Risk communication left much to be desired as did the implementation of an evacuation plan.

Desired Outcomes:
Risk communication outcomes will vary with the circumstances of the risk management activity. Some commonly anticipated outcomes include:

- Decrease illness, injury and deaths
- Reduce property and economic losses
- Build support for a response plan
- Assist in executing a response plan
- Prevent wasting of resources
- Keep decision-makers well informed
- Counter or correct rumors
- Foster informed decision-making concerning risk

14.2 RISK COMMUNICATION IN A TEAM

Risk communication has evolved from a number of contributing disciplines and is now trans-disciplinary (cutting across professions) in nature. For instance, communicating about complex issues like Love Canal and Three Mile Island required technical expertise. The EPA sought help bridging the gap between "expert" and "lay" perceptions of physical hazards. Psychologists answered this call by studying perceptions of hazards. Philosophical and sociological work focused on the culturally shaped meanings of risk. Political science looked at decision-making based on risk. Media, technology and communications experts have studied the ways in which people communicate about risks and have engaged in message design research.

The Corps is involved with a wide range of risk issues and a broad range of audiences. The audience for budget and cost risk messages will be vastly different from the audiences for flood warnings. This means the Corps risk communication will not only involve multiple disciplines but those disciplines must be integrated well enough to form a coherent message that reflects all relevant aspects of a problem. You can expect the Corps' risk communication to rely on the following sciences:

- Environmental Sciences
- Social Psychology
- Philosophy
- Political Science
- Communication
- Engineering
- Economics
- Public Health
- Natural Sciences