Risk-Based Project Management Approach for Large-Scale Civil Engineering Projects

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USACE Risk-Based Management Enterprise

BUILDING STRONG – USACE Supports the Army and the Nation

Homeland Security
- Critical Infrastructure
- Anti Terrorism Plans
- Intelligence
- Facility Security Partnership

Military Programs
- Military Construction
- COCOM Support, Overseas Contingency Operations (OCO)
- Installation Support, Environmental, Energy & Sustainability

Geospatial Support
- Support to Military Programs
- Support to Civil Works Program
- Common Operating Picture/Environment
- Support to Emergency & Contingency Ops

Civil Works
- Navigation, Hydropower
- Flood Control, Shore Protection
- Water Supply, Regulatory
- Recreation, Disaster Response
- Environmental Restoration

Research & Development
- Installations & Energy
- Environment
- War fighter
- Water Resources

Real Estate
- Acquire, Manage & Dispose
- DoD Recruiting Facilities
- Contingency Operations

Interagency Support
- Federal
- State
- Local
- International

USACE Has a Diverse Mission Set Driven by Diverse Customers

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The single official repository for official U.S. Army Corps of Engineers (USACE) Engineering Regulations (ERs), Engineering Circulars (ECs), Engineering Manuals (EMs) and other official public documents originating from Headquarters USACE.

https://www.publications.usace.army.mil/
Why worry about risk? On the geotech (earthen embankment, read: levees) side:

HURRICANE KATRINA
On the structural side:

Runaway barges, concrete and steel fatigue, flooding damage, etc.
RISK IS NOT JUST ABOUT LOSSES

Risk and the risk framework apply when desired gains are uncertain (and/or potential losses are anticipated). A lot of what USACE does is about getting a return or a gain, i.e. wetlands restored, flood damages reduced, transportation cost savings realized, etc. The term is “opportunity risk”.
The fact that the Congress approves the project budget piecemeal (annually) adds to uncertainty and increases funding risk. If/when a project is not funded (or funded partially) for any given fiscal year, all (some of) construction work stops.
At the organizational level, the USACE has made a decision to establish an enterprise-wide guidance for applying risk analysis, a systematic application of assessment, communication and management of risk and uncertainty in decision-making, as a part of Civil Works Project Risk Management practices.

Perhaps the most important objective here is to facilitate the effective communication of information to employees at all levels in the organization, and to establish a culture where each individual is empowered to identify, evaluate and act on risks and opportunities within and beyond a project.

Risk management - (in business) the forecasting and evaluation of financial risks together with the identification of procedures to avoid or minimize their impact.
The objectives are to:

- Support execution of USACE Military, Civil Works and International and Interagency Support (IIS) missions;
- Integrate existing risk management practices across functional silos;
- Improve strategic planning and decision-making;
- Improve the flow of risk information to decision makers;
- Include diverse viewpoints while driving towards consensus;
- Establish early warning systems and escalation policies;
- Identify, prioritize, and proactively manage risks;
- Identify opportunities;
- Support budget decisions and performance management;
- Establish forums to discuss risks across functional silos;
- Promote accountability and integrity of the USACE’s work; and
- Use a common approach to evaluating risks within the USACE.
The USACE Risk-Based Management Enterprise focuses on DAM & Levee SAFETY. The old program focused on individual projects needing to meet safety standards such as PMF and MCE (probable maximum flow and maximum credible earthquake). The new program focuses on Risk Management of the entire portfolio by applying the concept of tolerability of risk.

The diagram illustrates the relationship between HAZARD, PERFORMANCE, Exposures, Vulnerability, and Consequence, leading to Flood Risk. Each step in the process of risk assessment involves asking questions about the potential harm, the system's reaction, who and what can be harmed, how susceptible they are, and the severity of the consequences.

- **HAZARD**: What can cause harm?
- **PERFORMANCE**: How will the system react?
- **Exposure**: Who and what can be harmed?
- **Vulnerability**: How susceptible to harm?
- **Consequence**: How much harm?

Flood Risk is influenced by the likelihood and severity of adverse consequences.
Risk utility or risk tolerability is the amount of satisfaction or pleasure received from a potential payoff

- Utility rises at a decreasing rate for people who are risk-averse
- Those who are risk-seeking have a higher tolerance for risk and their satisfaction increases when more payoff is at stake
- The risk-neutral approach achieves a balance between risk and payoff.
TOLERABILITY OF RISK

UNACCEPTABLE REGION
Risk cannot be justified except in extraordinary circumstances.

TOLERABLE RISK REGION
People and society are prepared to accept risk in order to secure benefits.

BROADLY ACCEPTABLE REGION
Risk regarded as negligible with no effort to review, control or reduce the risk.

Increasing individual risks and societal concerns.
A dictionary definition of risk is “the possibility of loss or injury (physical, financial, etc.)”

**Negative risk** then involves understanding potential problems that might occur in the project and how they might impede project success.

Negative risk management is like a form of insurance; it is an investment.
Risk Can Be Positive

Positive risks are risks that result in good things happening; sometimes called opportunities.

A general definition of project risk is an uncertainty that can have a negative or positive effect on meeting project objectives.

The goal of project risk management is to minimize potential negative risks while maximizing potential positive risks.
Other possible risks to be tracked are:

- Lands & Damages (Real Estate Acquisition Status, Right-of-Way, etc.)
- Regulatory and Environmental (water quality, endangered species, cultural artifacts, etc.)
- Construction (contractor inefficiency, materials availability, differing site conditions, etc.)
- Estimate & Schedule (priority conflicts, local costs and delivery, etc.)
- External Risks (sponsor’s share of costs, objections from local communities, late stakeholder changes, etc.)

A case history:

East Branch Dam Safety Modifications
USACE Risk-Based Management Enterprise

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USACE-LRP
OTEC-2018

East Branch dam safety modification

184 feet high, 1725 feet long earthen embankment dam repairs
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East Branch Dam:

Congress-Authorized Purposes:

- Flood Control
- Water Quality
- Recreation
**Problem**: Dam is DSAC-II classified, meaning likely to fail (a risk designation), with leakage / seepage through the base (rock foundation) and embankment.

**Solution**: embankment grouting and cut-off wall

Easy enough, right? What can possibly go wrong?
<table>
<thead>
<tr>
<th>Dam Safety Action Class (DSAC)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Urgent and Compelling (Unsafe)</td>
</tr>
<tr>
<td></td>
<td>Critically near failure or Extreme high risk</td>
</tr>
<tr>
<td>II</td>
<td>Urgent (Unsafe or Potentially Unsafe)</td>
</tr>
<tr>
<td></td>
<td>Failure initiation foreseen or very high risk</td>
</tr>
<tr>
<td>III</td>
<td>High Priority (Conditionally Unsafe)</td>
</tr>
<tr>
<td></td>
<td>Significantly inadequate or moderate to high risk</td>
</tr>
<tr>
<td>IV</td>
<td>Priority (Marginally Safe)</td>
</tr>
<tr>
<td></td>
<td>Inadequate with low risk.</td>
</tr>
<tr>
<td>V</td>
<td>Normal (Adequately Safe)</td>
</tr>
<tr>
<td></td>
<td>Residual risk considered tolerable.</td>
</tr>
</tbody>
</table>
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SPRA Conducted in May 2006 – 8 Hr Effort

**Results:**
- Emb Erosion, Toe-Surf-Cr PI @ Extreme
- Emb – Abutment S&P PI @ Un; I @ Extreme
- Emb – Stability I @ Un & Extreme

**Recommendations:**
- Update EAP; Monitor Seepage; Initiate studies leading to more positive cut-off/grout curtain
Review Existing Project Data & Evaluate Potential Failure Modes

Risk Team Identified Potential Failure Modes (17 for EBr)
Screened & Consolidated list to identify most plausible modes of failure.
Identified Factors that made each mode of failure more or less likely.

<table>
<thead>
<tr>
<th>More Likely Factors</th>
<th>Less Likely Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piezometers at 8+30 show high pressures upstream of centerline in embankment overburden and respond immediately (with little head loss) to reservoir</td>
<td>Remediation stopped developing erosion in 1957 (Plugged up some part of seepage path)</td>
</tr>
<tr>
<td>Grouting may have concentrated seepage path (dam within dam)</td>
<td>No reoccurrence of internal erosion since 1957</td>
</tr>
<tr>
<td>Grouting created anomaly in dam</td>
<td>Maximum RWS of 1685.55 in 1972 showed no seepage issues</td>
</tr>
<tr>
<td>1981 drilling showed undesirable soft materials adjacent to cavity</td>
<td>High potential that unusual seepage would be observed and intervention would occur</td>
</tr>
<tr>
<td>Grouting limited to 180 ft. upstream and to 15 ft. depth in rock</td>
<td>Flows at Weir 6 have been consistent for last 50 years</td>
</tr>
<tr>
<td>Grout remediation now 50 years old</td>
<td>37 feet of storage above top of normal high summer pool</td>
</tr>
</tbody>
</table>
EAST BRANCH
f – N  Plot

Annual Probability
of Failure (f)

- VS -

Loss of Life (N)

Perform Qualitative Risk Analysis

Develop Event Trees for each Failure Mode

Estimate Conditional Probabilities at each node

Use @Risk (or other engine) to calculate Probability of Failure

Plot Probability of Failure vs LoL on f – N chart
Building Event Trees for Major Issues and Findings

USBR found Seepage and Piping to be most plausible failure mode

- Static Pool Level
- Hydrologic Loading (PMF)

**EVENT TREE FORMAT**

Initiation Occurs?  
Flaw Exists?  
Erosion starts?  
Unfiltered or inadequate filtered exit?  
Progression - Roof forms to support pipe?  
Progression - Upstream zones do not fill crack?  
Intervention Fails?  
Dam Breaches?  
Consequences occur?
The main features of the contract work include construction of a seepage cutoff wall at the East Branch Dam, consisting of a minimum 18 inch wide continuous vertical concrete cutoff wall and permanent foundation grouting at locations shown on the contract drawings. If a slurry system is used for excavation support, slurry control grouting shall be required in accordance with these specifications to prevent slurry loss during construction. Exploratory borings shall be required at locations shown on the drawings prior to cutoff wall excavation activities. A data management system shall be required to collect real time data and store historical and all construction related monitoring and documentation. Monitoring of Existing Instrumentation and Installation and Monitoring of New Instrumentation shall be required as part of the contract work and as outlined in the Joint Instrumentation and Monitoring Plan. A temporary work platform shall be constructed for performance of the cutoff wall construction. The work platform may incorporate the embankment for the final dam crest road. The temporary work platform shall be removed after completion of cutoff wall construction activities, except for permanent embankment for the final dam crest road. The final dam crest widening and access road shall be constructed in accordance with the plans and specifications. Inclined drains shall also be drilled in the right abutment and shall exit into a new weir located near the outlet tunnel.

Proposed Alternative
EAST BRANCH DAM SAFETY MODIFICATIONS

Overall Project Scope

East Branch Dam Rehab Plan S3 includes construction of a concrete cutoff wall through the embankment/overburdened and into rock. Current designs are for a one meter wide, 2,300 foot long concrete cutoff wall through embankment and overburdened of various depths from zero to 100 feet, and into rock 50 to 150 feet thick and at a maximum depth of 250 feet (approx EL 1450) below the crest of the dam (approx EL 1700). Construction activities involved with construction of the cutoff wall include:

1. Site development and Access road improvement,
2. Investigative drilling,
3. Construction of a 75 foot wide work platform on the dam crest,
4. Instrumentation installation,
5. Containment and Pre-grouting,
6. Construction of a 1m wide 2100 LF cutoff wall,
7. Site remediation.
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Risk Management Process Flowchart (USACE Draft – Work in Progress!)

- Establish the context
  - The strategic context
  - MDSAP context
  - The risk management context
  - Develop criteria
  - Decide the structure

- Identify risks
  - Source of risk
  - What are the risks?
  - How do they arise?
  - How can it happen?

- Analyze risks
  - Determine existing controls
    - Determine likelihood
    - Determine consequences

- Estimate level of risk
Risk Management Process Flowchart cont..

1. Evaluate risks
   - Compare against criteria
   - Decide ranking
   - Select risk priorities

2. Accept risks

3. Treat risks
   - Identify treatment options
   - Evaluate treatment options
   - Plan treatment measures
   - Assess secondary risks
   - Allocate responsibilities
   - Prepare and Implement plans

4. Update plans

5. Review objectives, decisions and assumptions

How important are they?

What should be done about them?
Planning risk management: Deciding how to approach and plan the risk management activities for the project

Identifying risks: Determining which risks are likely to affect a project and documenting the characteristics of each

Performing qualitative risk analysis: Prioritizing risks based on their probability and impact of occurrence
Performing quantitative risk analysis: Numerically estimating the effects of risks on project objectives

Planning risk responses: Taking steps to enhance opportunities and reduce threats to meeting project objectives

Controlling risk: Monitoring identified and residual risks, identifying new risks, carrying out risk response plans, and evaluating the effectiveness of risk strategies throughout the life of the project
The main output of this process is a risk management plan—a plan that documents the procedures for managing risk throughout a project.

The project team should review project documents and understand the organization’s and the sponsor’s approaches to risk. The level of detail will vary with the needs of the project.
Topics Addressed in a Risk Management Plan:

- Methodology
- Roles and responsibilities
- Budget and schedule
- Risk categories
- Risk probability and impact
- Revised stakeholders’ tolerances
- Tracking
- Risk documentation
Contingency and Fallback Plans, Contingency Reserves

Contingency plans are predefined actions that the project team will take if an identified risk event occurs.

Fallback plans are developed for risks that have a high impact on meeting project objectives, and are put into effect if attempts to reduce the risk are not effective.

Contingency reserves or allowances are provisions held by the project sponsor or organization to reduce the risk of cost or schedule overruns to an acceptable level; management reserves are funds held for unknown risks that are NOT part of the cost baseline but ARE part of the budget and funding requirements.
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Common Sources of PM Risk on Construction Projects

- Schedule Delays
- Inaccurate Estimates
- Ineffective Cost Controls
- Contractor delays
- many more…
The main output of the risk identification process is a list of identified risks and other information needed to begin creating a **risk register**.

**A risk register is:**
- A document that contains the results of various risk management processes and that is often displayed in a table or spreadsheet format
- A tool for documenting potential risk events and related information

**Risk events** refer to specific, uncertain events that may occur to the detriment or enhancement of the project
Risk Register Contents

- An identification number for each risk event
- A rank for each risk event (based on probability of occurrence and impact)
- The name of each risk event
- A description of each risk event
- The category under which each risk event falls
- The root cause of each risk
- Potential budget/schedule impact
- Risk management strategy
- Triggers for each risk; **triggers** are indicators or symptoms of actual risk events
- Potential responses to each risk
- The **risk owner** or person who will own or take responsibility for each risk
- The probability and impact of each risk occurring (linked to risk ranking).
- The status of each risk
The project RR also tracks construction risks, estimate & schedule risks, lands & damages, environmental & regulatory risks, etc. (seventeen 11x17 sheets in total).
The project also tracks construction risks, estimate & schedule risks, lands & damages, environmental & regulatory risks, etc. (seventeen sheets in total).

<table>
<thead>
<tr>
<th>Risk No.</th>
<th>Project Cost</th>
<th>Project Schedule</th>
<th>Correlation to Others</th>
<th>Responsible POC</th>
<th>Affected Project Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPM-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PPM-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CA-1</td>
<td></td>
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<td></td>
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<tr>
<td>TL-01</td>
<td></td>
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<tr>
<td>TL-02</td>
<td></td>
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</tbody>
</table>
After identifying and quantifying risks, we must decide how to respond to them.

Four main response strategies for negative risks:

- Risk avoidance
- Risk acceptance
- Risk transference
- Risk mitigation
1. A Risk Register (RR) has been created and, as a living document, is constantly maintained / updated / revised.

2. The PDT has developed and “bought into” the RR.

3. Risk owners have been ID’d for each risk.

4. The risk management strategies were developed for each risk.

5. Risk horizon (predicted schedule of occurrence / realization) has been determined.

6. Potential $$ impact determined.
### Impact and Probability Ratings Definitions:

**USACE General Guidance for Mega-Projects:**

<table>
<thead>
<tr>
<th>Rating --&gt;</th>
<th>Very Low</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost Impact of Threat (CO + COS)</strong></td>
<td>Insignificant cost increase</td>
<td>&lt;5% cost increase</td>
<td>5-10% cost increase</td>
<td>10-20% cost increase</td>
<td>&gt;20% cost increase</td>
</tr>
<tr>
<td><strong>Cost Impact of Opportunity (CO + COS)</strong></td>
<td>Insignificant cost reduction</td>
<td>&lt;1% cost decrease</td>
<td>1-3% cost decrease</td>
<td>3-5% cost decrease</td>
<td>&gt;5% cost decrease</td>
</tr>
<tr>
<td><strong>Schedule Impact of Threat</strong></td>
<td>Insignificant slippage</td>
<td>&lt;1 month slippage</td>
<td>1-3 months slippage</td>
<td>3-6 months slippage</td>
<td>&gt;6 months slippage</td>
</tr>
<tr>
<td><strong>Schedule Impact of Opportunity</strong></td>
<td>Insignificant improvement</td>
<td>&lt;1 month improvement</td>
<td>1-2 months improvement</td>
<td>2-3 months improvement</td>
<td>&gt;3 months improvement</td>
</tr>
<tr>
<td><strong>Probability</strong></td>
<td>1–9%</td>
<td>10–19%</td>
<td>20–39%</td>
<td>40–59%</td>
<td>60–99%</td>
</tr>
</tbody>
</table>
Impact and Probability Ratings Definitions, cont...:

**Cost Impacts**


**Schedule Impacts**

Negligible: 0 to 2 Months, Marginal: 2 to 6 Months, Significant: 6 to 10 Months, Critical: 10 to 18 Months, Crisis: 18 Months and up.
Some of the risks on the East Branch Rehab Risk register:

- PM turnover (the project is on its 3rd PM in 3 years);
- Grout quantities and modifications (exceeding the original estimate);
- Adequate cleaning of panel joints;
- Unforeseen obstructions during the COW (cut-off wall) installation;
- Slurry loss / reservoir contamination;
- NPDES permits renewal;
- Seasonal construction restrictions;
- Contractor efficiency.
- Etc.
**East Branch Stakeholder Project Risk Management Best Practices:**

- Institute weekly PDT project progress meetings;
- Institute monthly project risk look-ahead updates;
- Institute monthly stakeholder (KTR, USACE / external consultants design team, construction QA, PM) project progress meetings;
- Institute monthly KTR / USACE RR sharing;
- Institute annual facilitated partnering meetings for all the stakeholders;
- Institute monthly PRB (project review board) meetings w/ USACE district upper management – present / discuss active risks status
The USACE is currently implementing the risk-based project management approach to all of its megaprojects. The next step would be to expand this onto all projects. Stay tuned – To be continued.
Questions?

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