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# Matrix Approach to Stormwater Management for a Resilient Built Environment

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Engineer Research and Development Center
Environmental Laboratory
Risk and Decision Science Team

ERDC
Engineer Research and Development Center



US Army Corps of Engineers.

U.S.ARMY

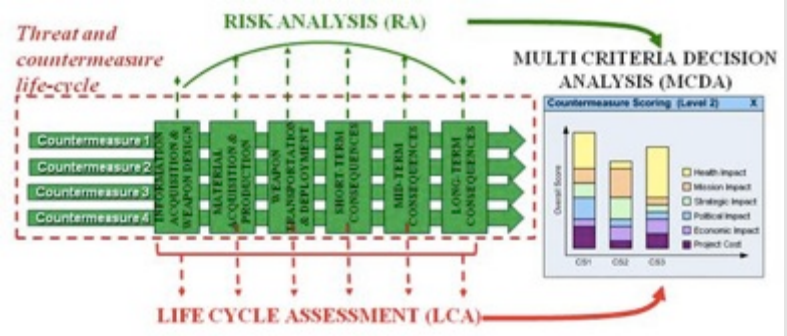
# Risk and Decision Science Team

**Capabilities**

- Over 15 risk/decision analysts, scientists, & engineers developing solutions that support decisions across broad gov't needs.
- State-of-the-science models and tools for structuring and conducting risk assessment, stakeholder engagement, resource prioritization, planning, and other emerging issues relevant to USACE, DoD, and Nation.

**Current Programs**

- Cutting edge R&D for DoD as well as for DHS, DOE, DHHS, EPA, CPSC and others.
- Applying Decision-Analytic tools to evaluate alternatives, bridge data-to-decision gaps, integrate stakeholder values into solution development, and prioritize research for a variety of technologies & industries.

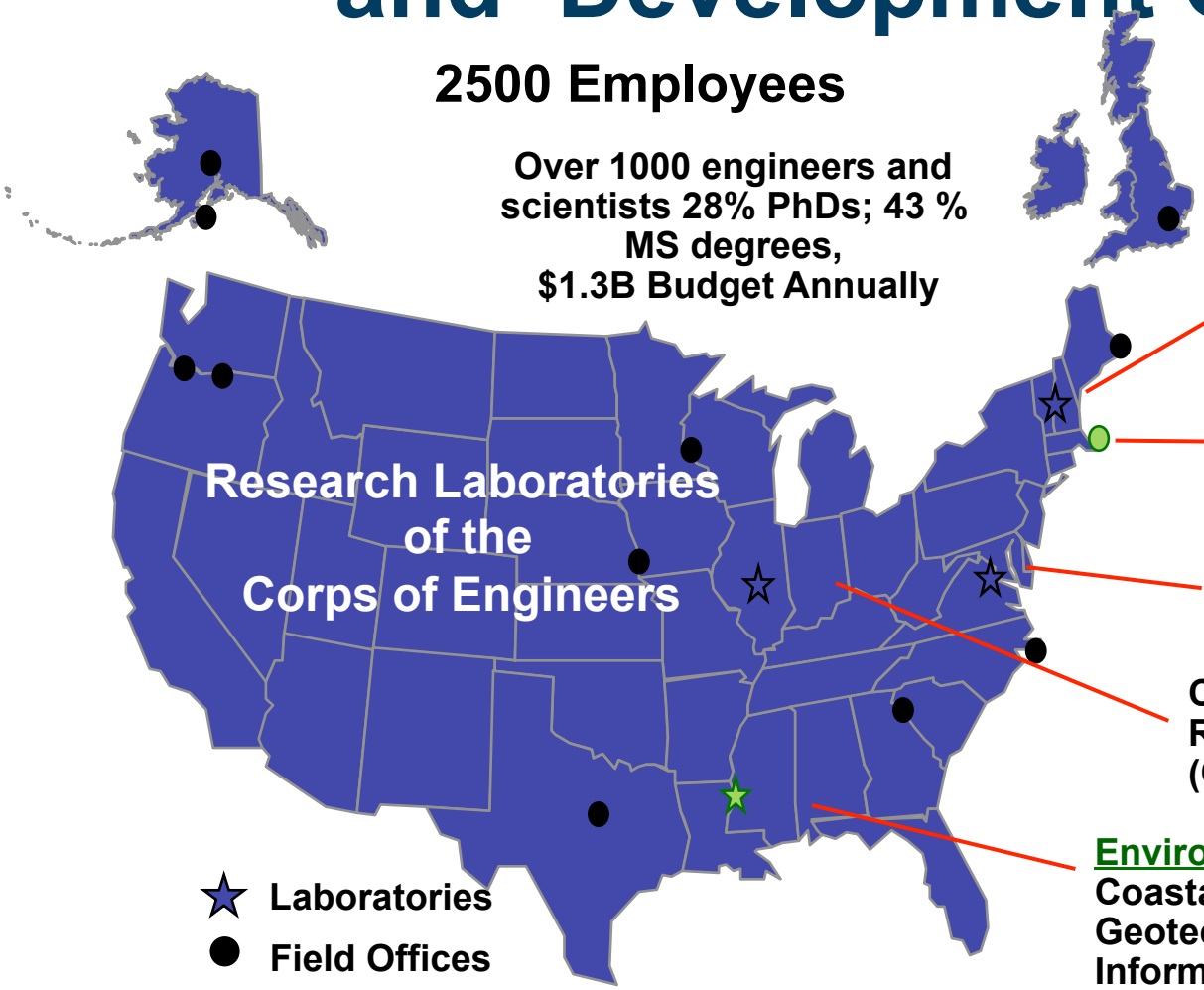



*Integrating Risk Analysis, Life Cycle Assessment, and Multi-Criteria Decision Analysis models for the assessment of emerging materials & risks.*

# US Army Engineer Research and Development Center

## 2500 Employees

Over 1000 engineers and scientists 28% PhDs; 43 % MS degrees,
$1.3B Budget Annually




Cold Regions Research Engineering Laboratory (Hanover, NH)

Risk and Decision Science Team Boston, MA)

Topographic Engineering Center (Alexandria, VA)

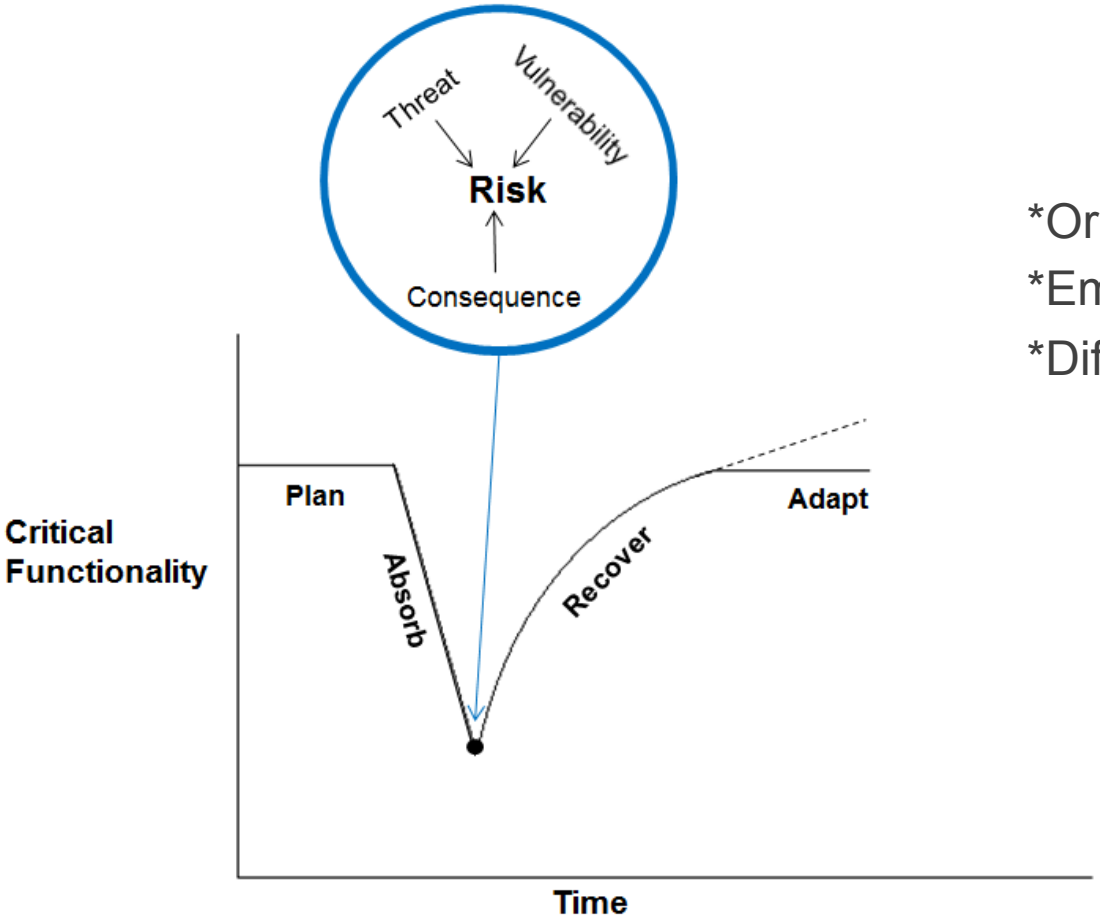
Construction Engineering Research Laboratory (Champaign, IL)

Environmental Laboratory
Coastal & Hydraulics Laboratory
Geotechnical & Structures Laboratory
Information Technology Laboratory
Headquarters (Vicksburg, MS)

# Risk and Decision Science Approach

ERDC | RISK AND DECISION SCIENCE TEAM

# Risk and Decision Science Approach



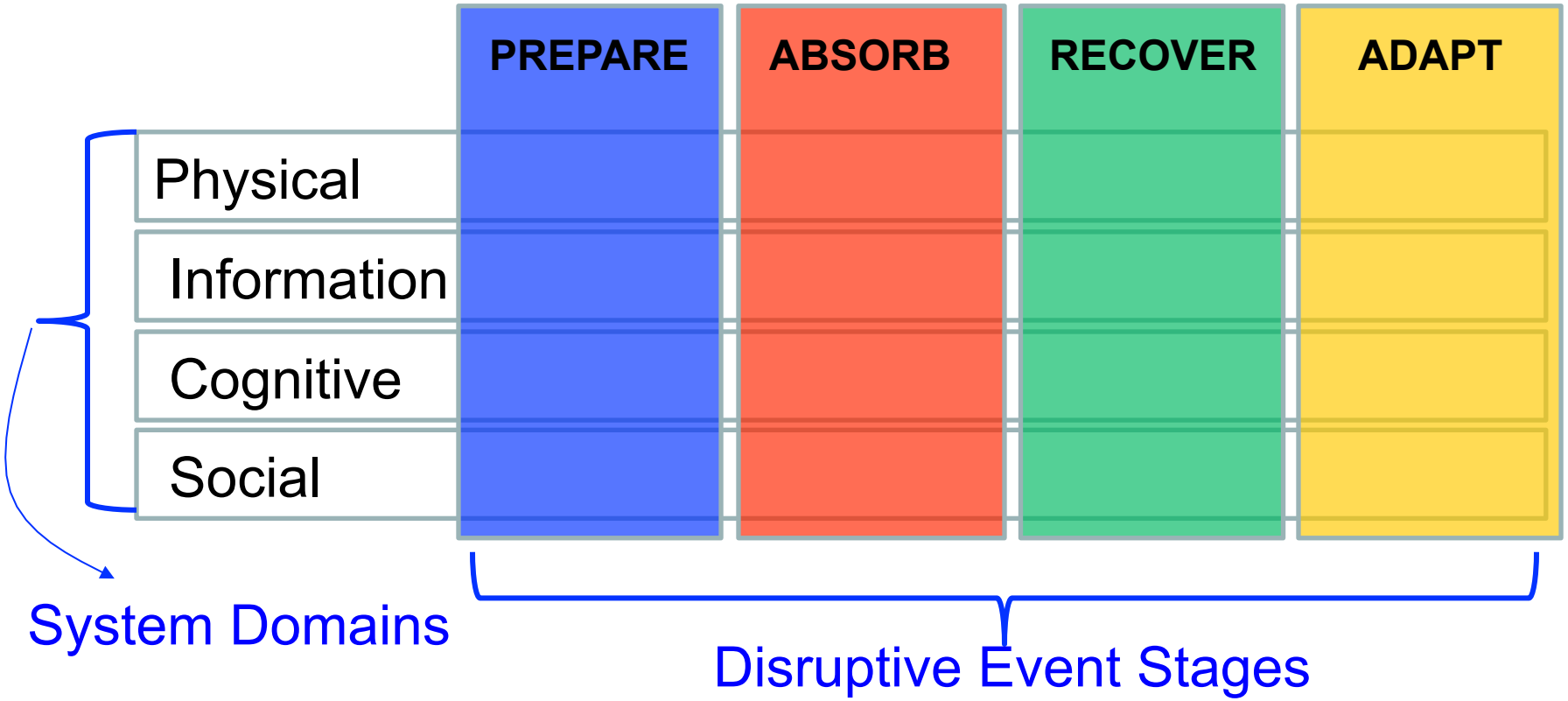

Linkov et al., Nature Climate Change 2014

*Oriented toward a “critical function”

*Emergent property of a system

*Different than risk assessment

# Developing a Framework and Methodology




Scale

Home Neighborhood Town County Region State Country

# General Form of Resilience Matrix

Adverse Event

Time

Previous Cycle | Plan/Prepare | Absorb | Recover | Adapt

| | Plan/Prepare | Absorb | Recover | Adapt |
|---|---|---|---|---|
| ***Physical*** | State and capability of equipment and personnel, network structure | Event recognition and system performance to maintain function | System changes to recover previous functionality | Changes to improve system resilience |
| ***Information*** | Data preparation, presentation, analysis, and storage | Real-time assessment of functionality, anticipation of cascading losses and event closure | Data use to track recovery progress and anticipate recovery scenarios | Creation and improvement of data storage and use protocols |
| ***Cognitive*** | System design and operation decisions, with anticipation of adverse events | Contingency protocols and proactive event management | Recovery decision-making and communication | Design of new system configurations, objectives, and decision criteria |
| ***Social*** | Social network, social capital, institutional and cultural norms, and training | Resourceful and accessible personnel and social institutions for event response | Teamwork and knowledge sharing to enhance system recovery | Addition of or changes to institutions, policies, training programs, and culture |

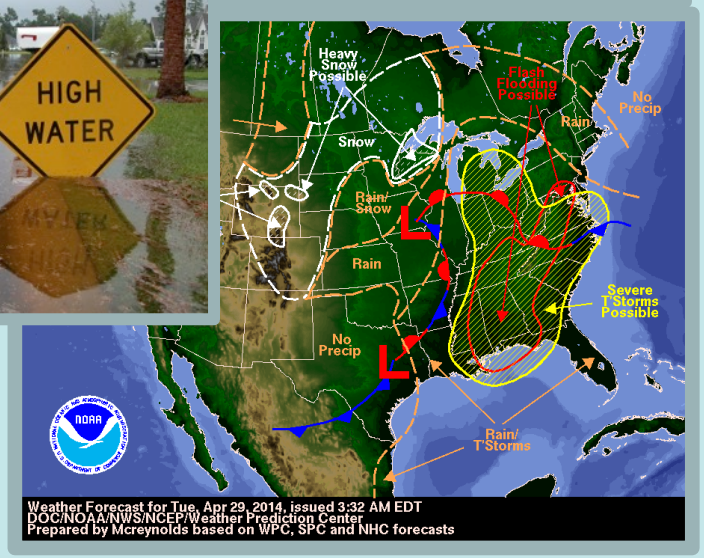
From: *Linkov et al, Env. Sci. & Tech., 2013*

# RM Applications to Stormwater Management

- Define System and Threats
- Identify Critical Functions of the System
- Develop Performance Indicators (domain-phase)
- Score Performance of System Capabilities
- Identify Gaps to Prioritize Efforts

# Stressors & Shocks

Rain!


# (Multi-Objective) = Critical Function(s)

- Water Quality
- Infrastructure

ERDC

*Innovative solutions for a safer, better world*

# RM Applications to Stormwater Management

Some facts for framing the problem:

- SWM systems are inherently multi-objective
- Vary in how active or passive they are
- Experience stressors and shocks
- Multiple responsible parties
- Experience concurrent and cascading failures

## How does stormwater management contribute to the resilience of [some] critical function to a storm event?

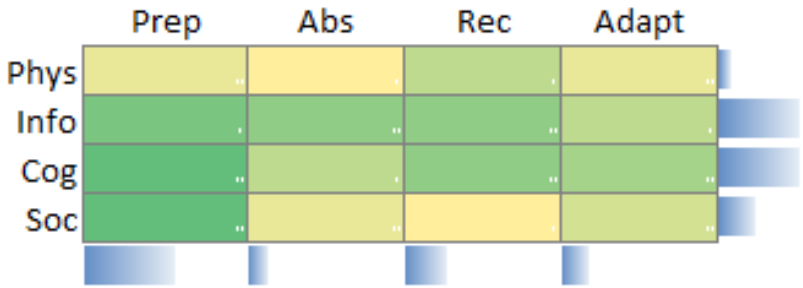
Water Quality

| | PREPARE | ABSORB | RECOVER | ADAPT |
|---|---|---|---|---|
| Physical | Grey & Green Infrastructure | | Cleanup/ Repair | Change Infrastructure |
| Information | Monitor & Model | Monitor & Model | Monitor & Model | ☆ |
| Cognitive | Rulemaking | Implement Plans | Mobilize | Lessons-Learned |
| Social | Individual Behavior | | Place-Based Experience | |

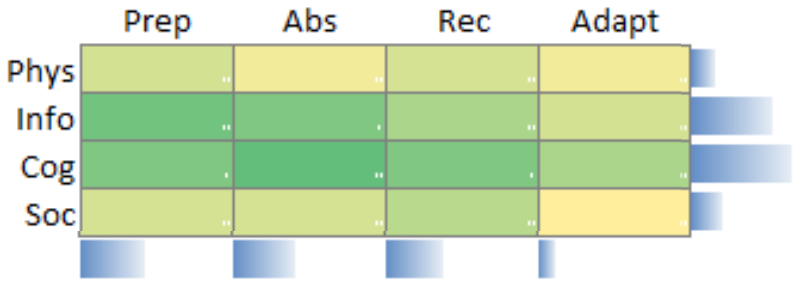
# Metrics and Scoring Performance

Low Existing Capacity — High Existing Capacity

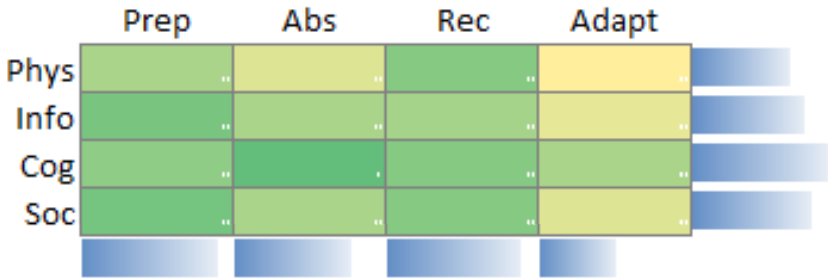
## Tourism



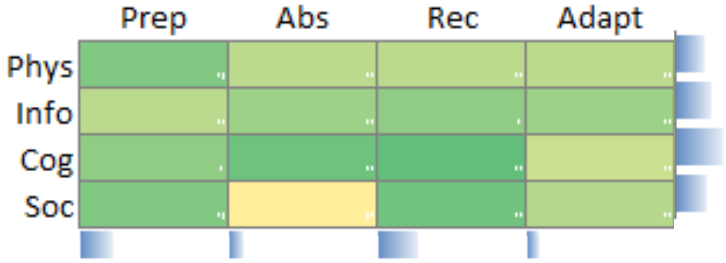

## Housing




## Port




## Ecosystem



# Mapping Responsibilities and Capabilities

## E.g., City DPWs, MWRA, BWSC, USACE, Federal Highway Admin, DEP, EPA, A/E firms, others?

| | Prepare | Absorb | Recover | Adapt |
|---|---|---|---|---|
| **Physical** | USACE | USACE | USACE<br>FEMA | USACE |
| **Information** | NOAA<br>USACE | Mayor's Office<br>FEMA | FEMA<br>NYC OEM | NYC Planning |
| **Cognitive** | NYC Planning | NYC OEM<br>FEMA | FEMA<br>NYC | USACE<br>NYC |
| **Social** | NYC OEM | NYC OEM<br>FEMA | NGO/Non-Profit<br>HUD | NGO/Non-Profit |

# Resources

Igor.Linkov@usace.army.mil, Team Lead

Fox-Lent, C. and Linkov, I. (2018). Resilience Matrix for Comprehensive Urban Resilience Planning, *in* Resilience-Oriented Urban Planning, Ed. Y. Yamagata and A. Sharifi. Springer.

# Video Credit

Written by Risk and Decision Science Team

Narrated by Ben Trump

Produced by George Siharulidze

With help from EssenceCartoon and Fernando Suarez