The Risk of Not Being Resilient

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Risk and Decision Sciences Team

Environmental Laboratory/ERDC

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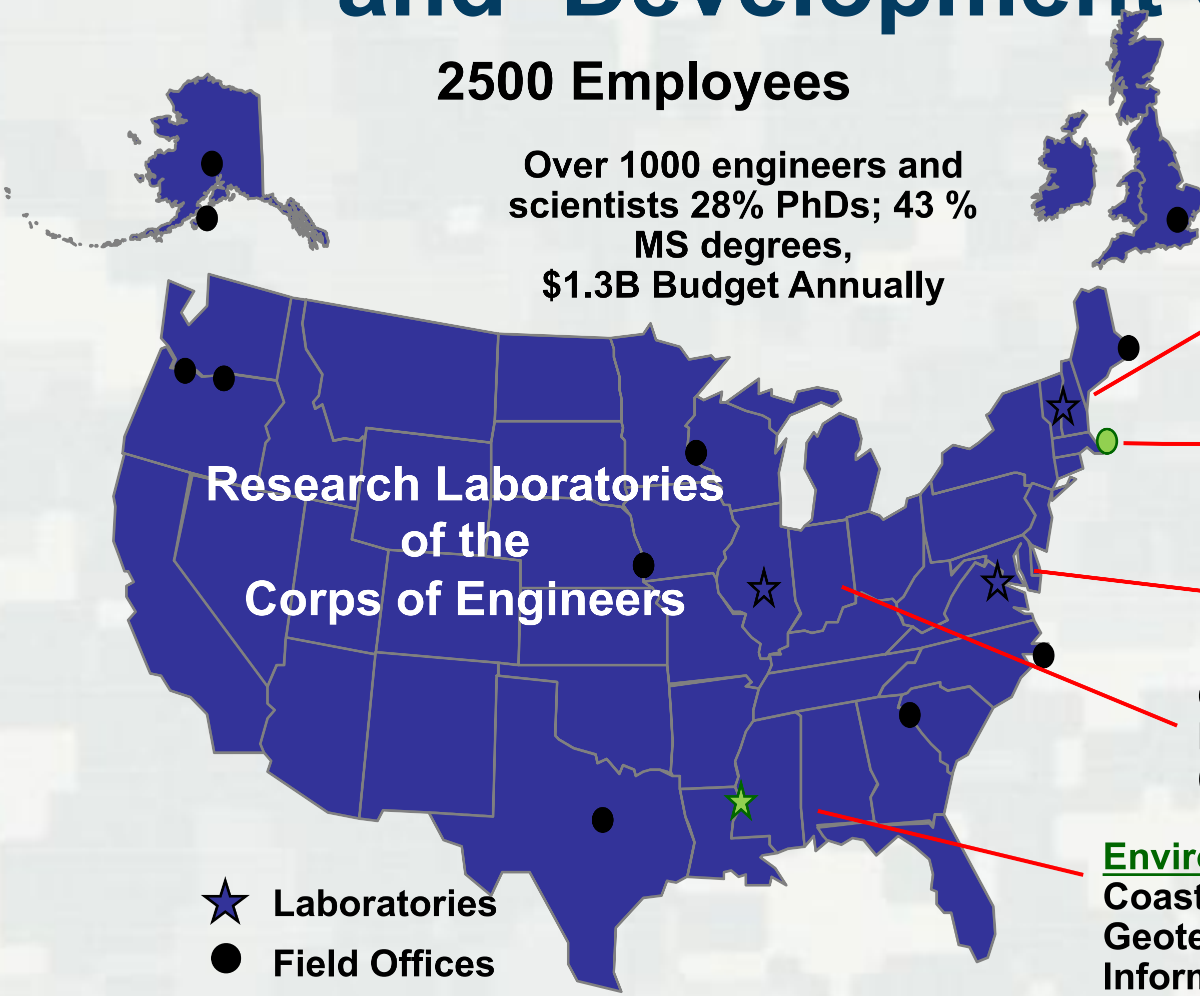
US Army Corps of Engineers®

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)

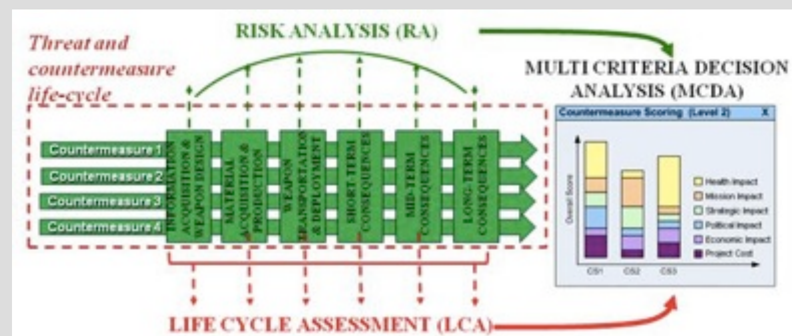
Risk and Decision Science Team

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

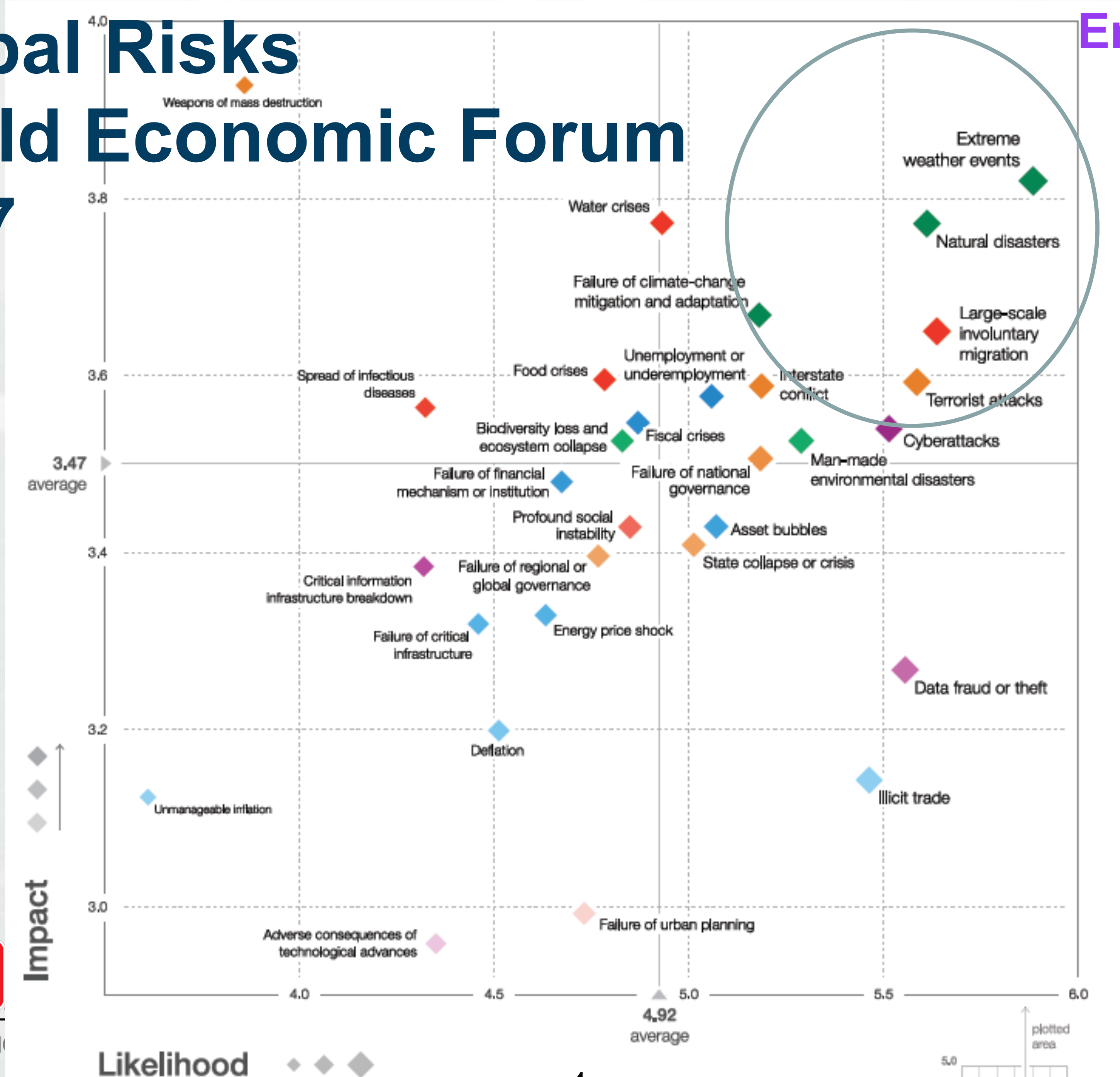
- Cutting edge R&D for DoD as well as for DHS, DOE, DHHS, EPA, CPSC and others.
- Applying Decision-Analytic tools to evaluate alternatives, bridge data-to-decision gaps, integrate stakeholder values into solution development, and prioritize research for a variety of technologies & industries.



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

Global Risks World Economic Forum 2017

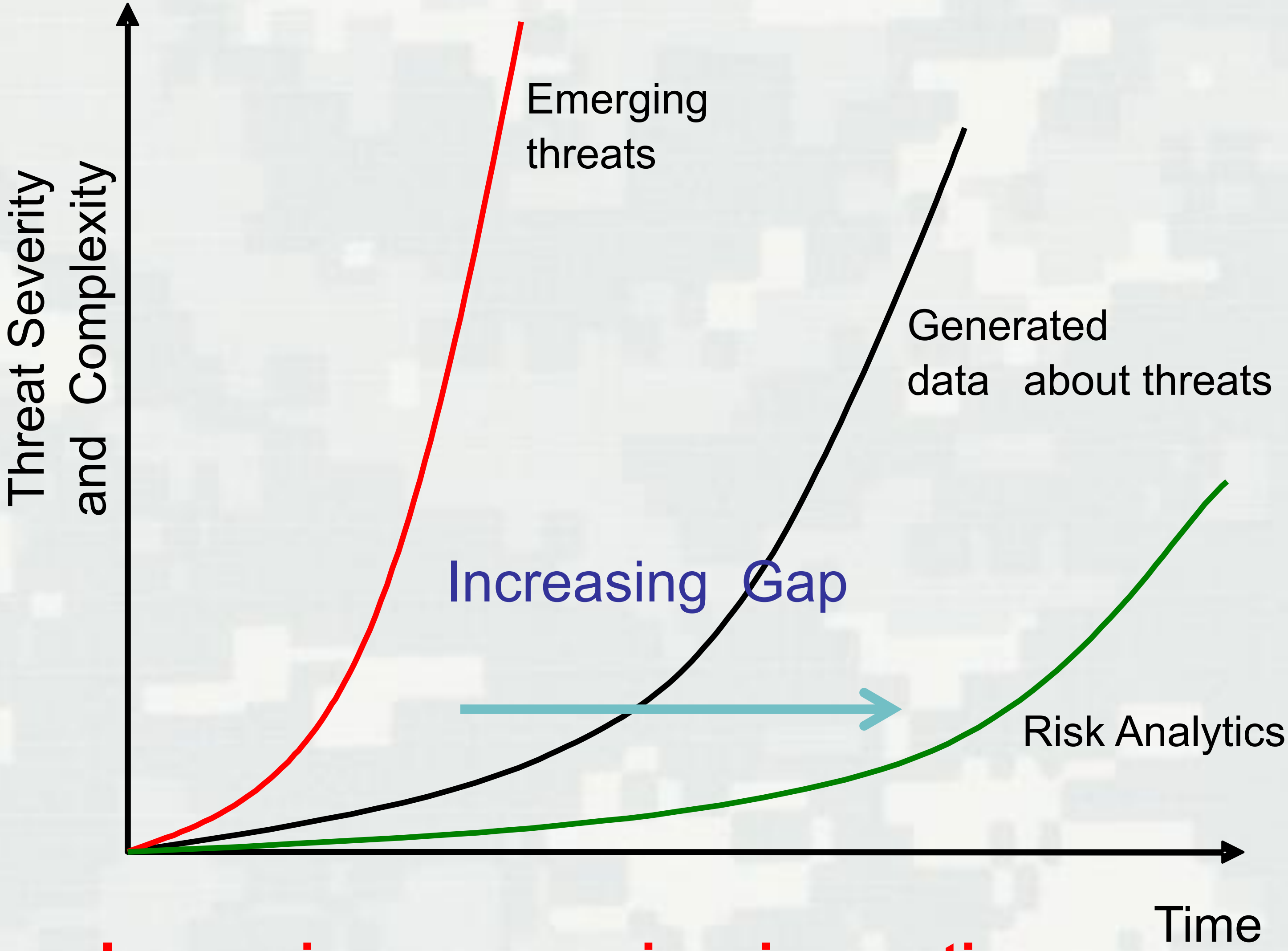
Emerging Global Risks



BUILDIN

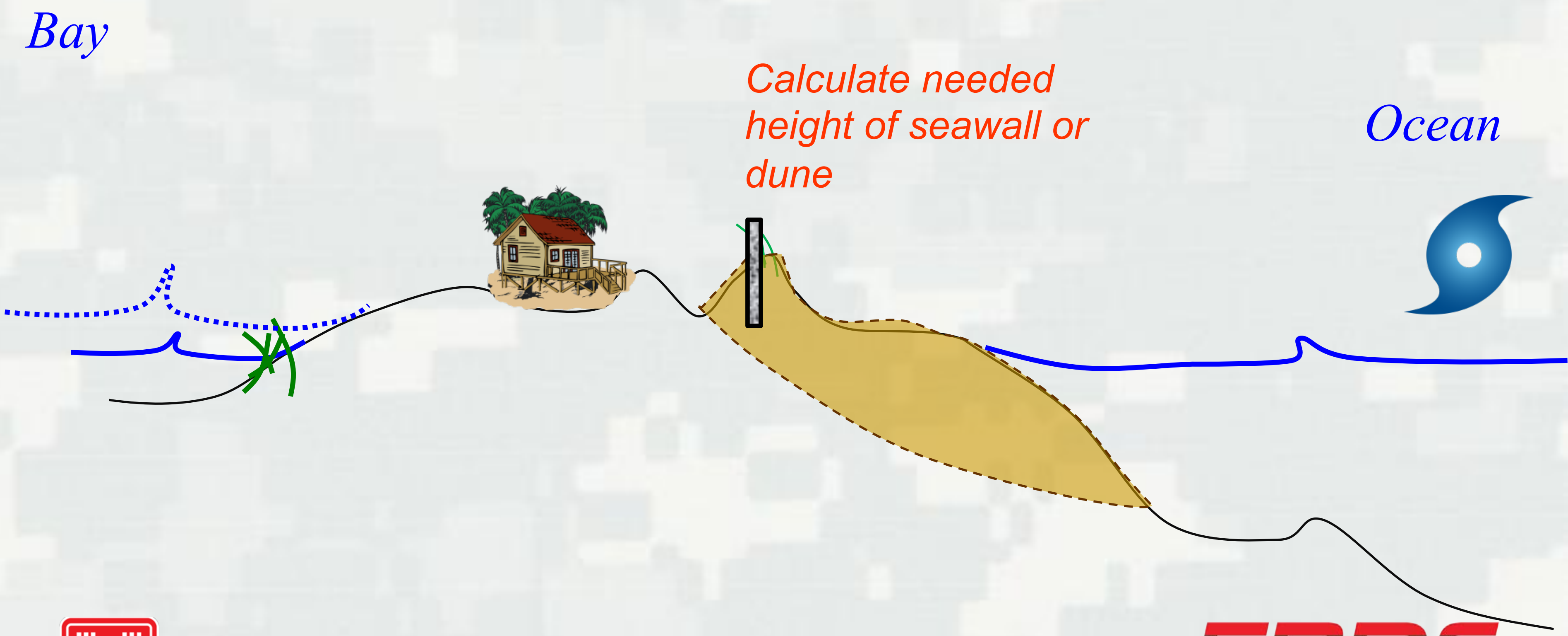
etter world

Challenge



Increasing gap requires innovative management

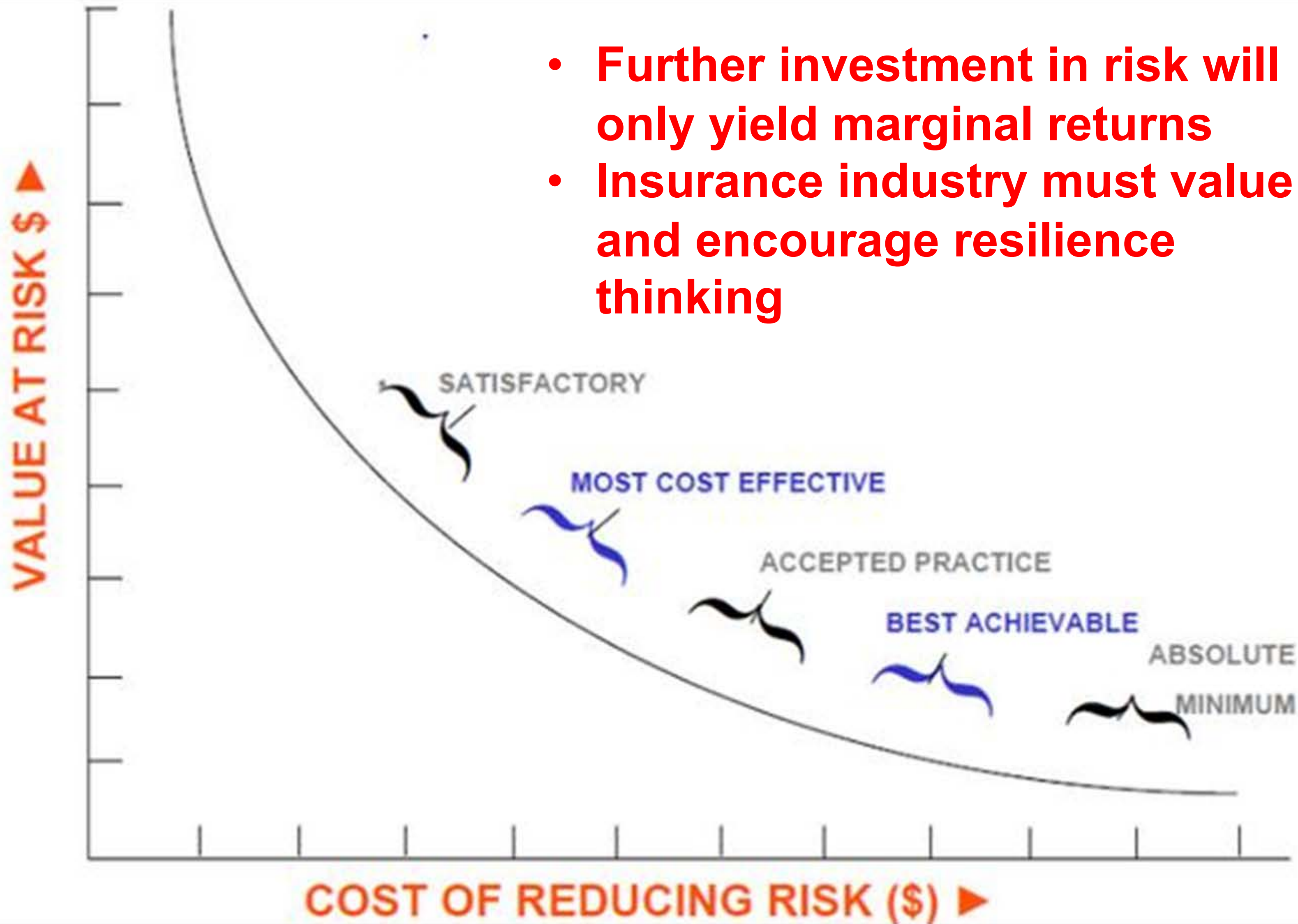
State-of-Practice in Risk Management



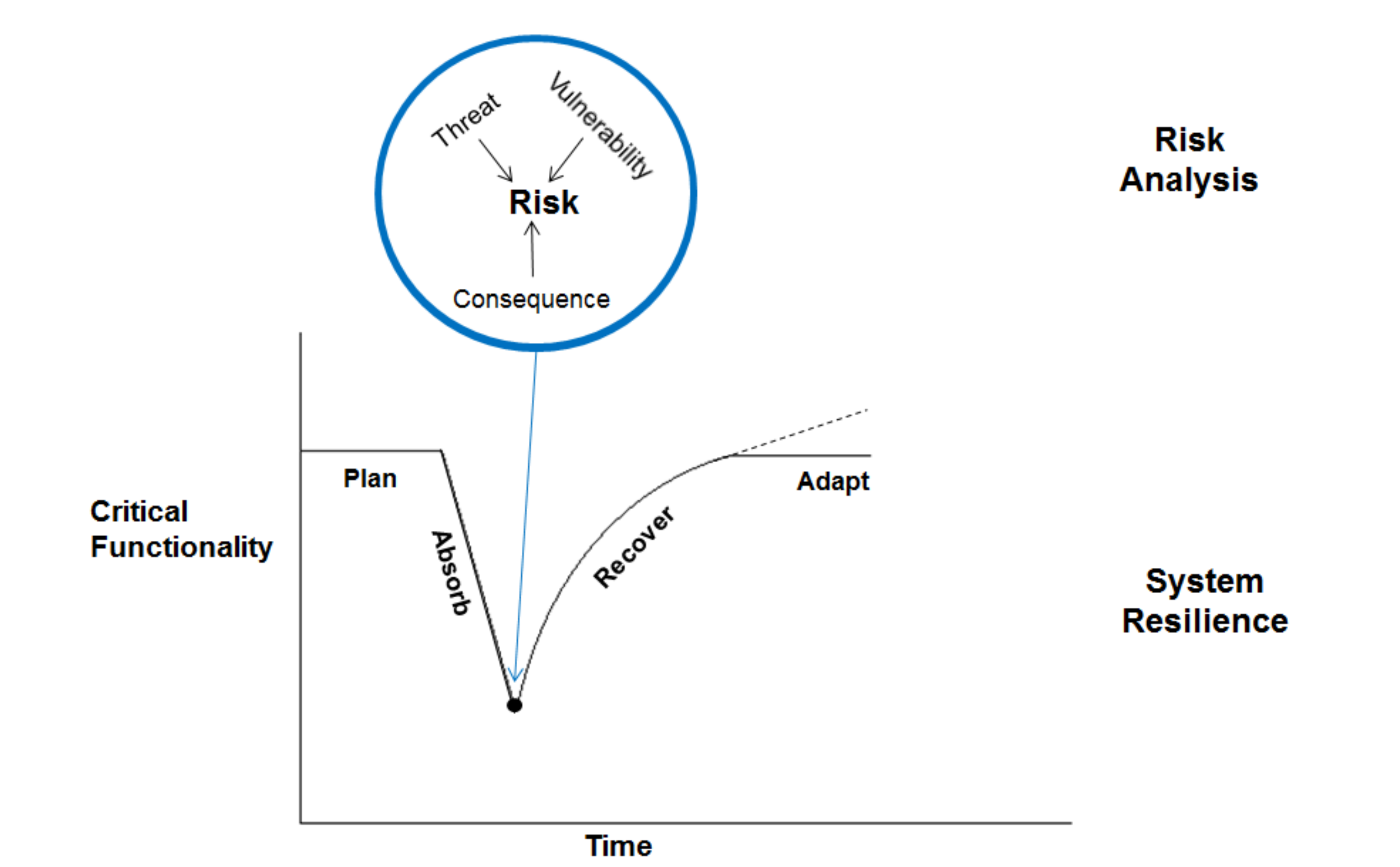
BUILDING STRONG®

Innovative solutions for a safer, better world

- **Further investment in risk will only yield marginal returns**
- **Insurance industry must value and encourage resilience thinking**

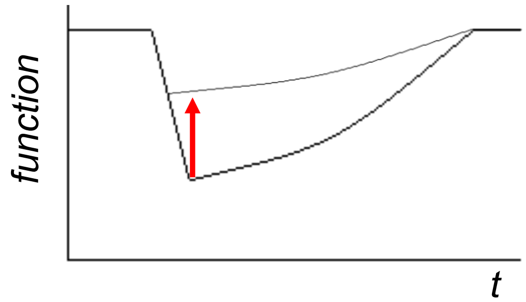


Risk and Resilience: Thresholds



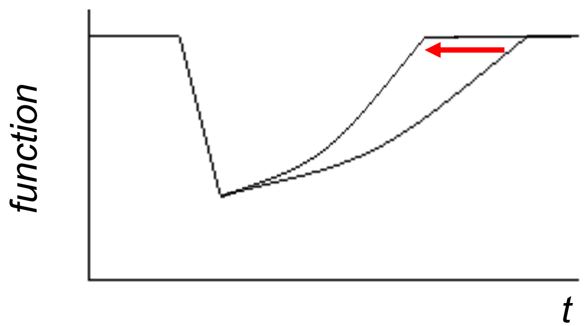
After Linkov et al, Nature Climate Change 2014

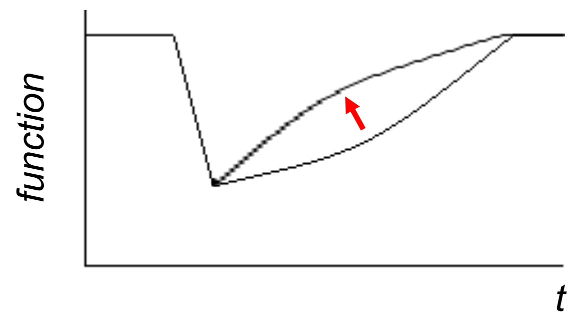
Importance of Recovery



Risk Reduction

Resilience through Recovery Enhancement





From Linkov et al, Nature Climate Change 2014

Future: Evolution of Approaches for Flood Risk Management

Live with floods

- Individuals and small communities adapt to nature's rhythm.

Use the floodplain

- Fertile land in floodplain is drained for food production.
- Permanent communities develop on the floodplain.

Control floods

- Large scale structural approaches are implemented through organized governance

Reduce flood damages

- A recognition that engineering alone has limitations.
- Effort to increase the resilience of communities should a flood occur.

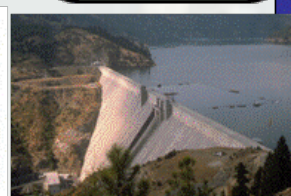
Manage risk

- Not all problems are equal.
- Risk management is an effective and efficient means to maximize the benefit of limited investment.

Manage resilience?

- •Not all problems need to be solved
- •Systems approach & integration of communities is the key

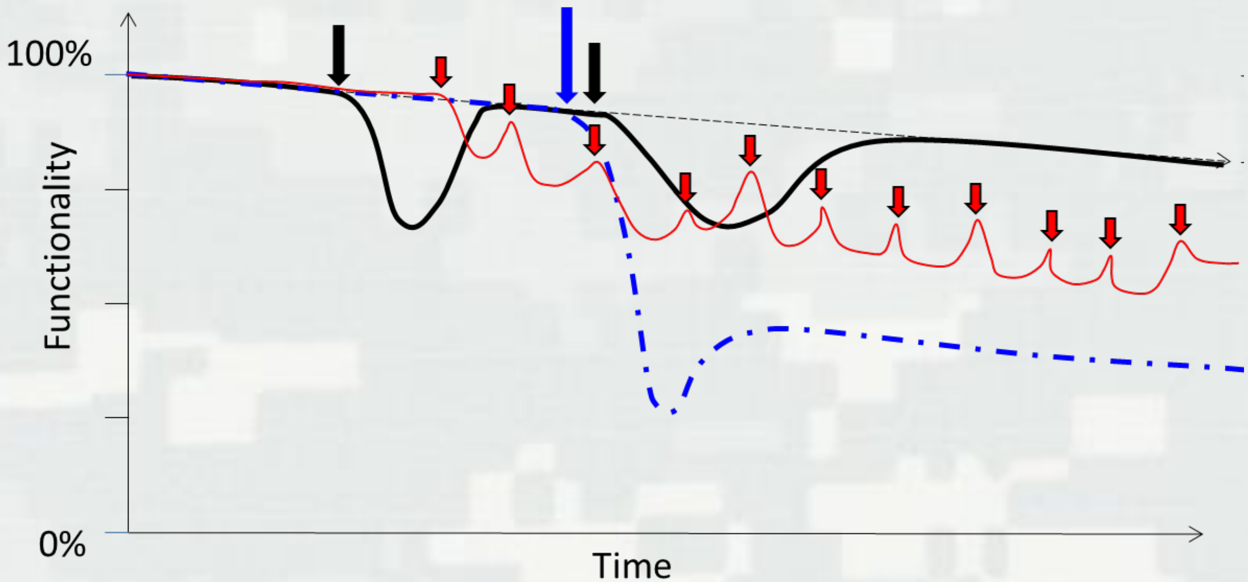




From Sayers et al , 2012

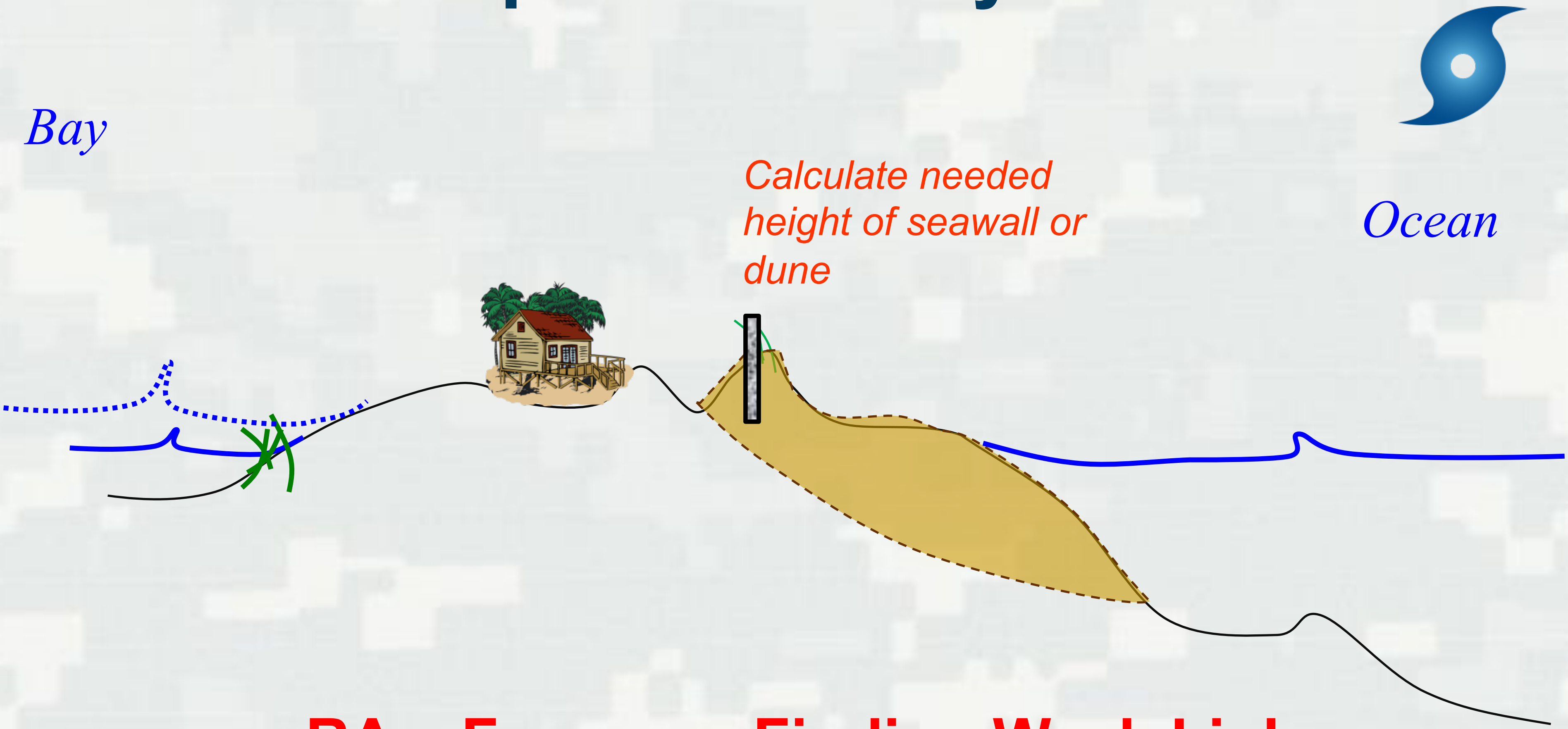
Modern View of System Functionality

- System view: Environment is part of socio-economic-technical system
- Consider both disturbances and stressors, co-occurances



Disturbance *Stressor 1* *Multiple Disturbances leading to Stressor 2*

Component vs. System



RA – Focus on Finding Weak Link:

Resilience: Political Importance and Challenge

The White House

Office of the Press Secretary

For Immediate Release Octo

Presidential Proclamation -- Critical Infrastructure Security and Resilience Month, 2013

CRITICAL INFRASTRUCTURE SECURITY AND RESILIENCE MONTH, 2013

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BY THE PRESIDENT OF THE UNITED STATES OF AMERICA

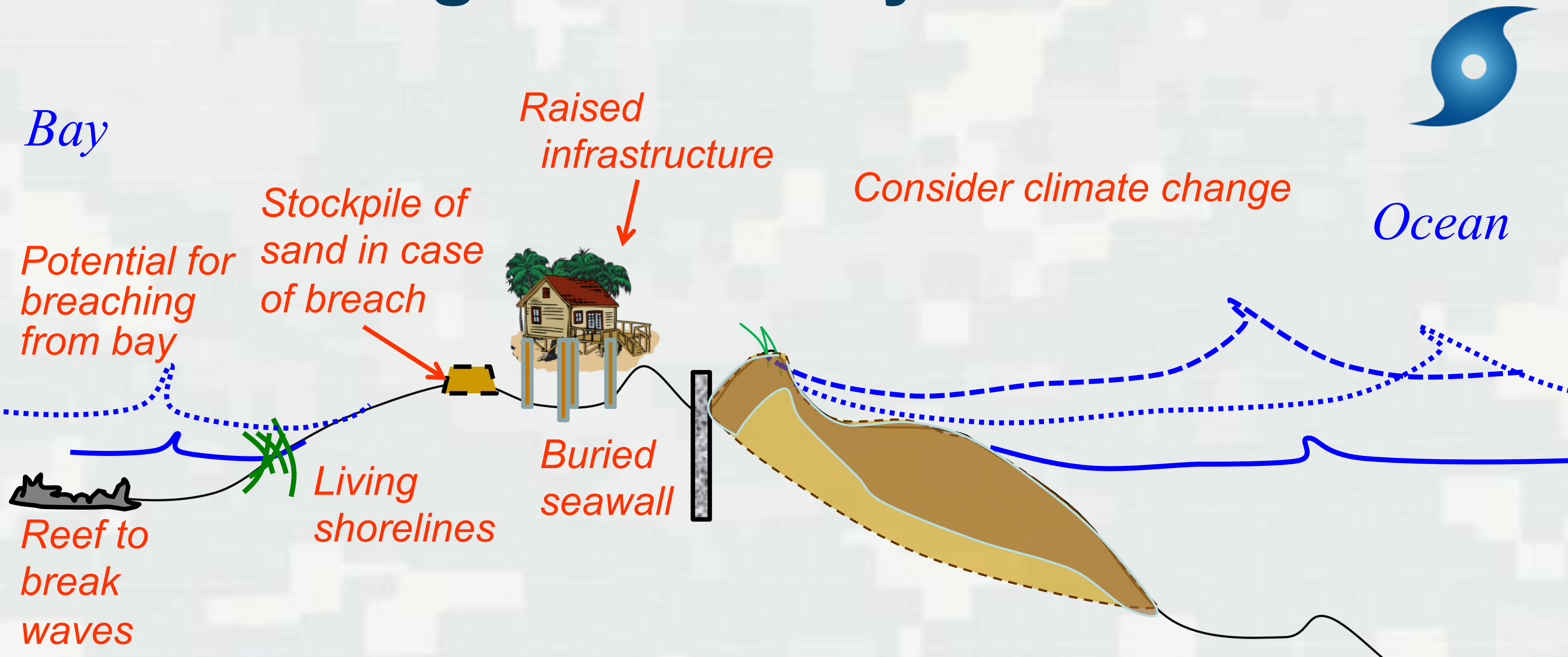
A PROCLAMATION

Over the last few decades, our Nation has grown increasingly dependent on critical infrastructure, the backbone of our national and economic security. America's critical infrastructure is complex and diverse, combining systems in both cyberspace and the physical world -- from power plants, bridges, and interstates to Federal buildings and the massive electrical grids that power our Nation. During Critical Infrastructure Security and Resilience Month, we resolve to remain vigilant against foreign and domestic threats, and work together to further secure our vital assets, systems, and networks.

Executive Order:

"resilience" means the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.

Management at System Level



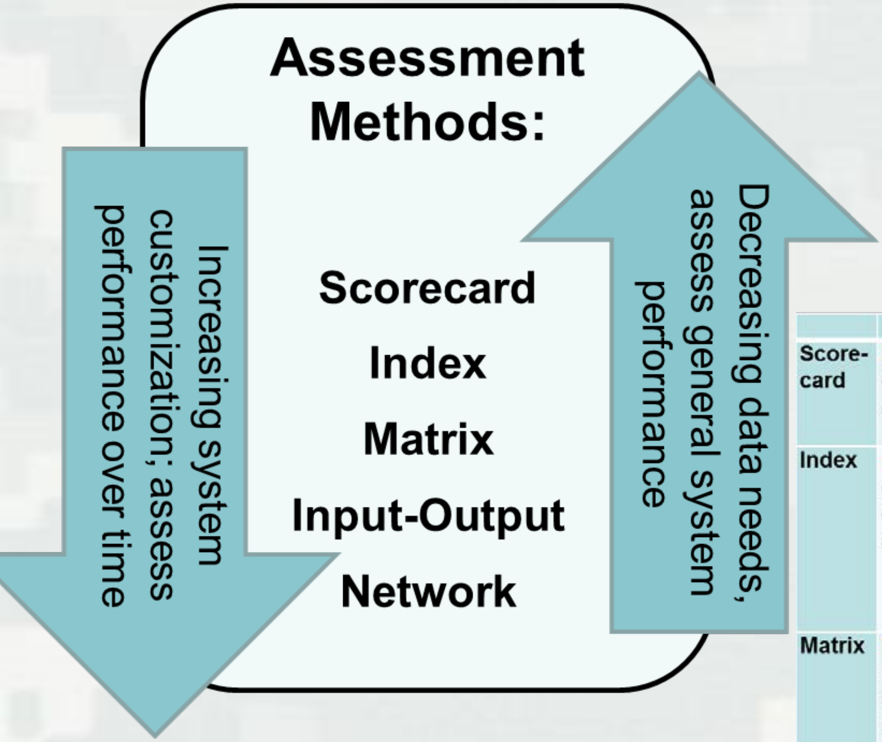
- Anticipate weak links and be ready to recover. *Ex: sand to close new inlets.*
- Provide diverse and redundant protection. *Ex: buried seawall AND beach/dune system.*
- Ensure availability of alternate networks. *Ex: multiple electrical power circuits.*
- Provide accessible information for rapid decision-making. *Ex: raised homes, evacuation routes*

Risk Management Challenges

$$Risk = Threat \times Vulnerability \times Consequence$$

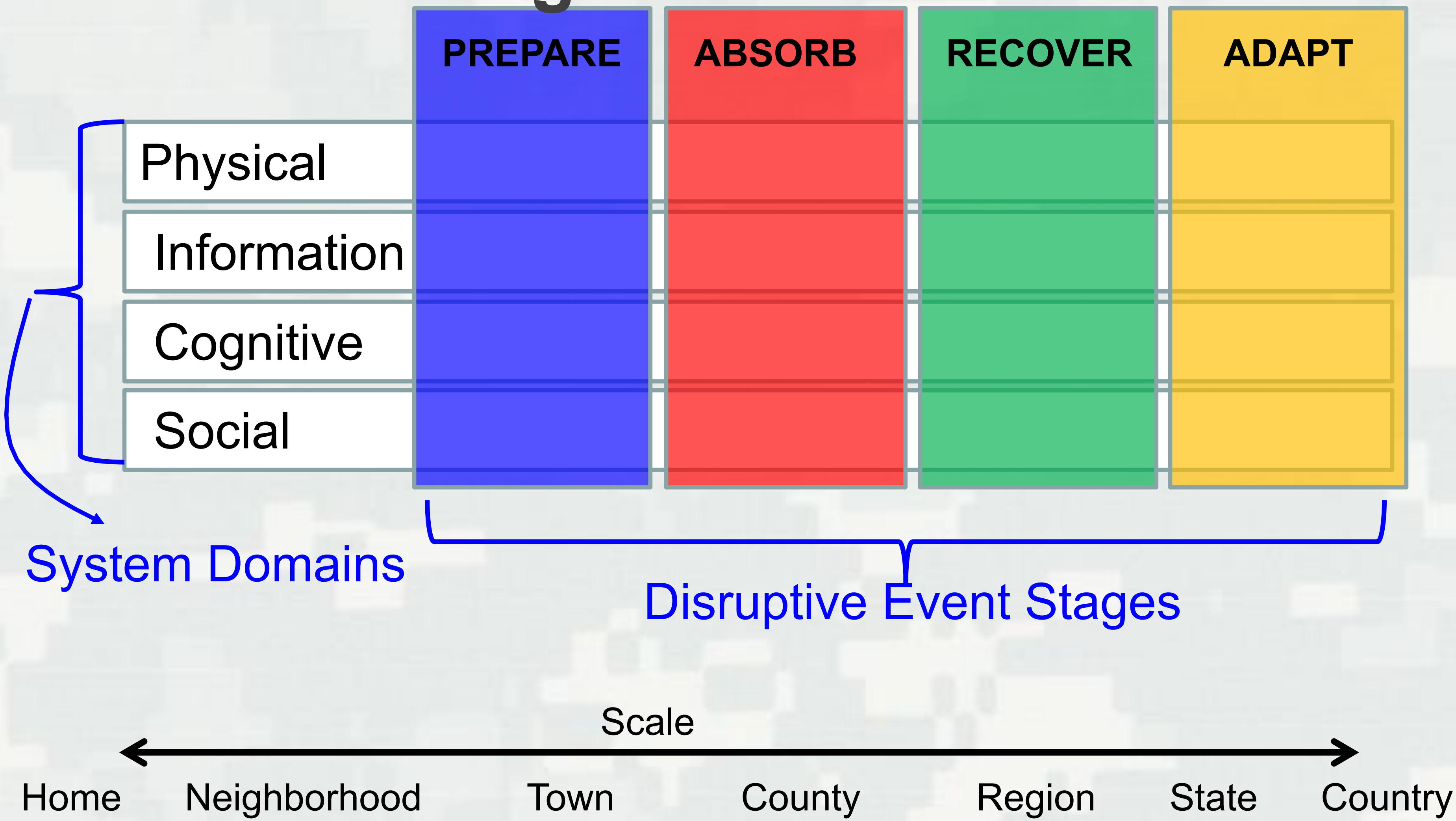
- Requires specific knowledge and quantification of all three components
- No temporal component
- Modern system complexity and threat uncertainty make risk management difficult and expensive.

Assessment Tools



	Pros	Cons	Application to MIWTS
Score-card	Rapid; promotes discussion; can include non-structural components	Only relative to previous assessment at the same site with similar rubric; utilizes expert judgement	Port Resilience Index: A Port Management Self-Assessment (Sempier 2016)
Index	Rapid assessment, quantitative, can include non-structural components, comparative across sites	Only relative to other sites (normalized); pre-defined metrics may not be equally relevant at each site; does not identify improvements	No known existing tools; Possible metrics: frequency of dredging, shoaling rate, dollar or mass of cargo per day, ships per day, rate of sea-level rise, shoreline erosion rate; some metrics are available for the U.S. (CMTS)
Matrix	Flexible framework allows metrics to be tailored to the specific site; may incorporate stages of an event cycle	Not comparable across multiple locations or even when repeated at the same site; does not identify specific improvements	Existing tools are not MITWS-specific but are flexible enough for application in this sector. E.g., Bruneau 2003, Linkov 2013, Karamouz 2014
Input-Output	System organization and dependencies; allows scenario analysis; explicitly informs improvement measures	Time consuming to create; requires intimate knowledge of the system; difficult to model non-structural components of resilience	Existing tools are not MITWS-specific but are flexible enough for application in this sector. E.g., Hollnagel 2012, JHU APL 2013
Net-work	Describes system organization and relationships; allows scenario analysis; explicitly informs improvement measures	Time consuming to create; significant data requirements; difficult to model non-structural components of resilience	MARS: Methodology for Assessing Resilience of Seaports; Achuthan 2013

cOnstructing the resilience matrix



General Form of Resilience Matrix

Adverse Event

Time →

	Previous Cycle / 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*

Assessment Process

1. Define System and Threats
2. Identify Critical Functions of the System
3. Develop Performance Indicators
4. Calculate Performance Scores
5. Identify Gaps to Prioritize Efforts

3. Performance Indicators

Experts identify indicators of performance for each cell of the matrix for each critical function.

Based on resilience properties:

- ▶ Redundancy
- ▶ Flexibility
- ▶ Modularity
- ▶ Robustness
- ▶ Resourcefulness
- ▶ Distributed
- ▶ etc.

Housing

	Prepare	Absorb	Recover	Adapt
Physical				
Information				
Cognitive				
Social				

Transportation

	Prepare	Absorb	Recover	Adapt
Physical				
Information				
Cognitive				
Social				

Wildlife Habitat

	Prepare	Absorb	Recover	Adapt
Physical				
Information				
Cognitive				
Social				

4. Performance Scores

Users score indicators or metrics (qualitative or quantitative) for the capability of the system to perform in each cell of the matrix.

Metrics can be normalized to get relative scores.

For example:

	Raw Value	Normalized Score
Participation in mobile alert system:	48%	7.5
Existing dunes/berms:	8’	6
Access to debris removal equipment:	med-low	2

Coastal Storm Resilience
Case Studies

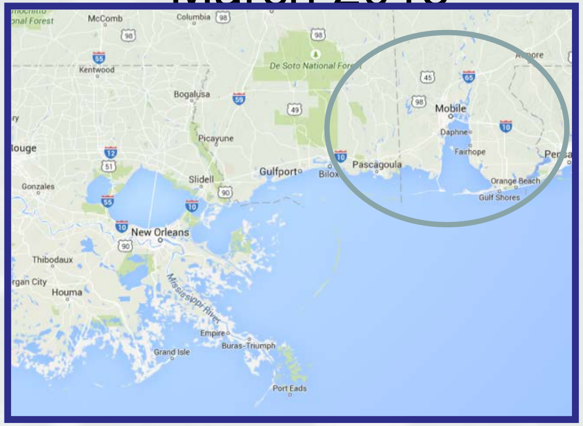
Rockaway, New York

April 2014

- Post-Sandy documentation
- Influx of recovery funds
- Specific Metrics

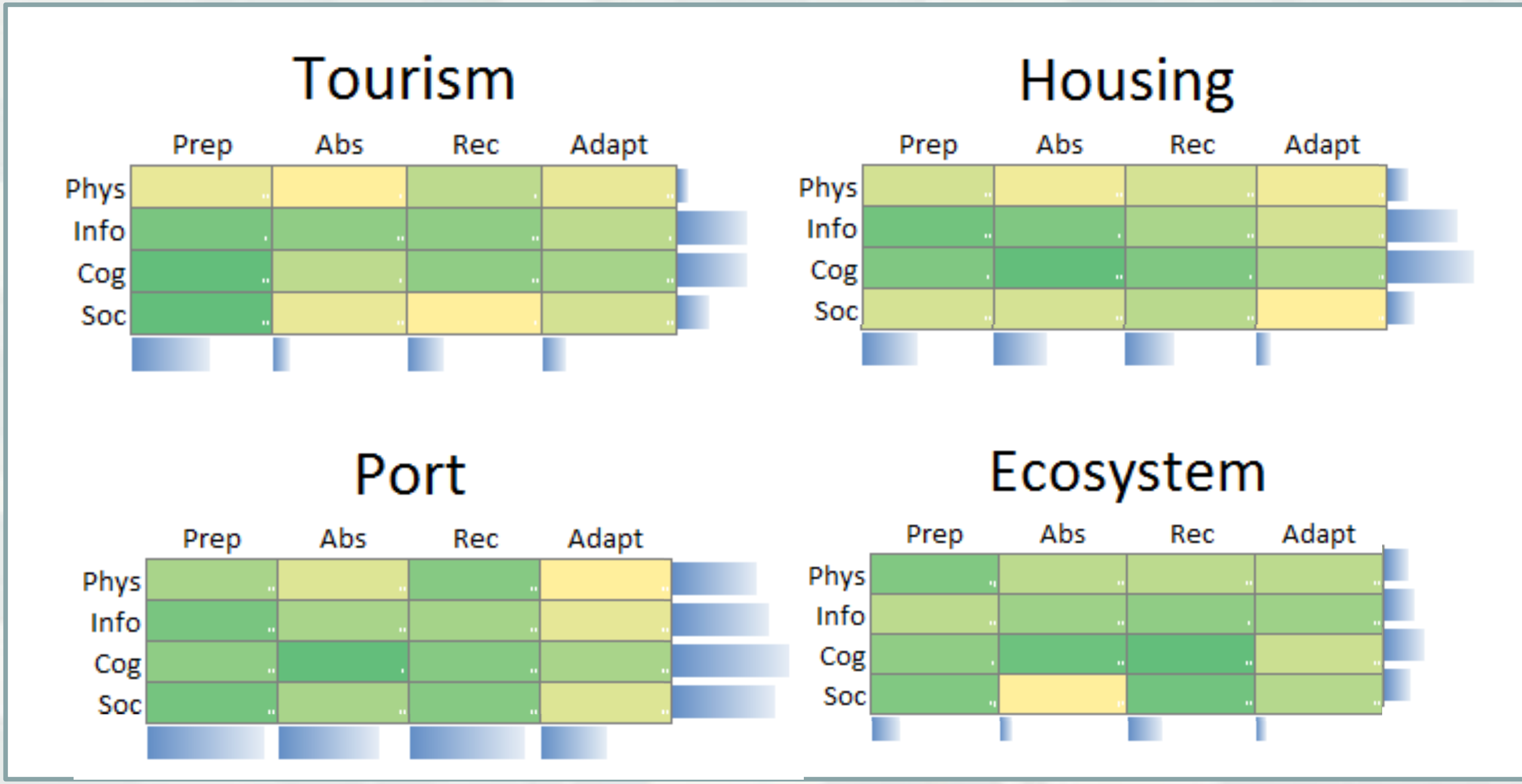
- Mobile, Alabama

March 2015



- Katrina-size threat
- Previous resilience work
- Expert / stakeholder scores

Results



Low Existing Capacity

High Existing Capacity

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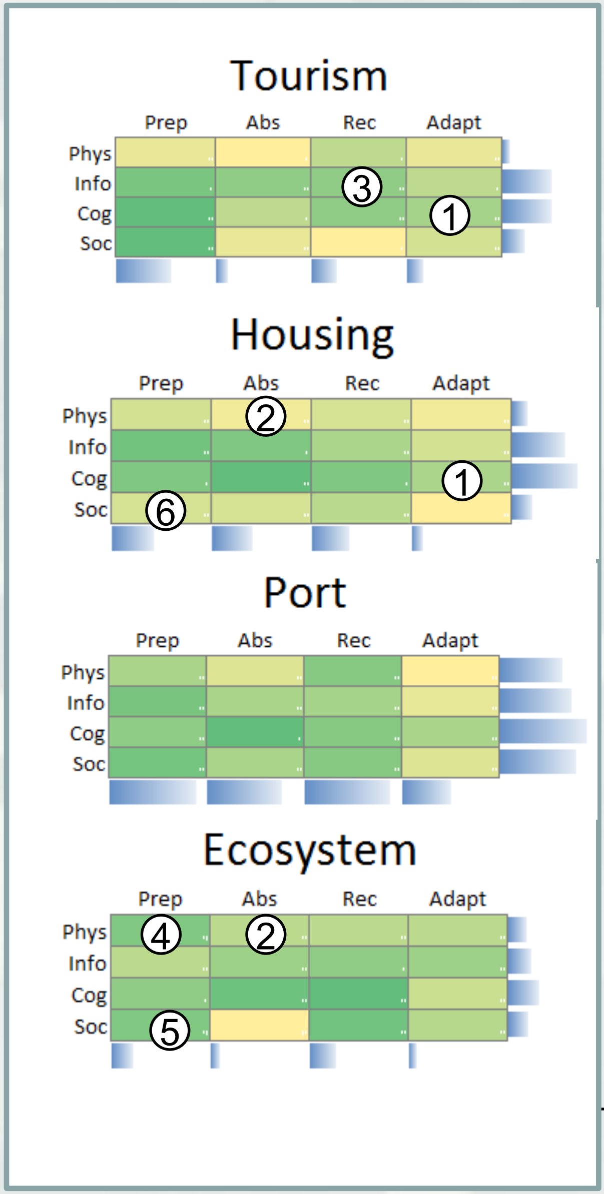
Project Evaluation

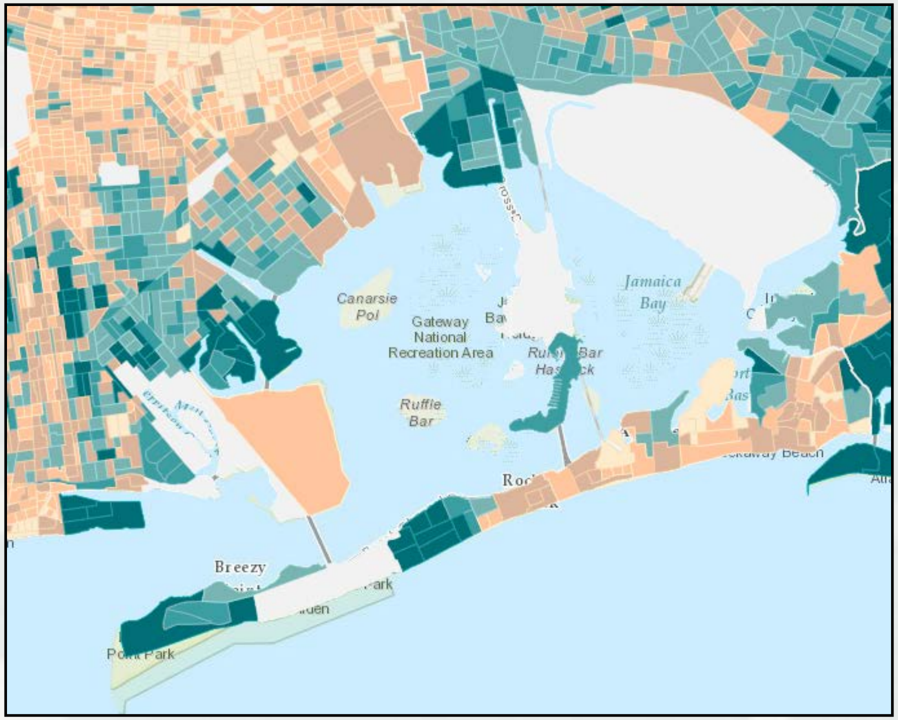


1. Building code improvements, enforcement
2. Replace bulkheads with natural revetment and living shorelines to mitigate erosion
3. Develop network of licensed contractors for businesses to access to rebuild
4. Reduce impervious surfaces in new upland developments
5. Continuing education on ecosystem services, fragility and human impact
6. Continuing education on public safety

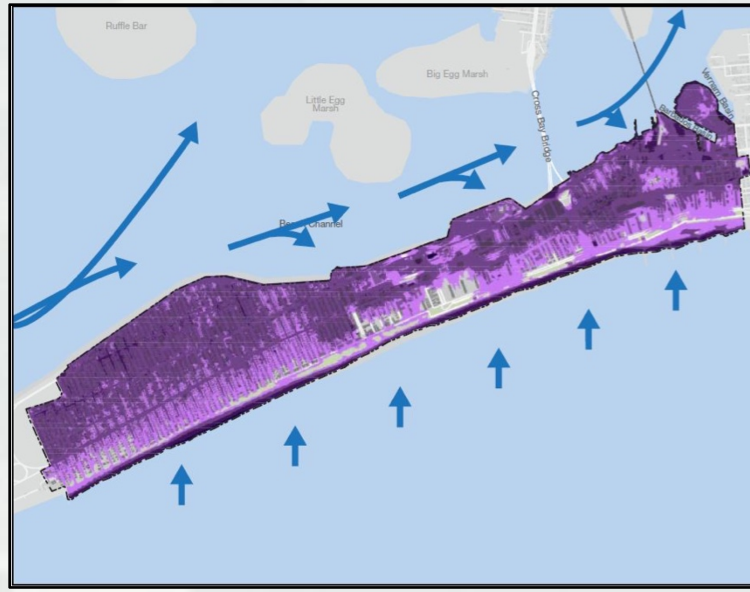
Partnerships to Address Gaps

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

Rockaway Regional Overview



- More than $82,000
- $68,001 to $82,000
- $53,001 to $68,000
- $39,001 to $53,000 (US median: $50,157)
- $24,001 to $39,000
- $24,000 or less
- No households



Superstorm Sandy Flood Depths

- < 3 ft
- 3-6 ft
- 6-12 ft
- >12 ft
- Wave Action & Water Movement

Critical Function – Stakeholder Engagement

- System has multiple functions, but not all of them are equally important
  - ▸ Stakeholder elicitation is required
  - ▸ Prioritization of project alternatives
  - ▸ Values, preferences
  - ▸ Public education

"We want to include you in this discussion without letting you affect it"

Resilience and Social Vulnerability Indexes

BRIC
The Baseline Resilience Index for Communities
Cutter, Burton, and Emrich (2010)

SoVI
Social Vulnerability Index
Cutter, Boruff, and Shirley (2010)

CDRI
Community Disaster Resilience Index
Peacock et al. (2010)

SVI
Social Vulnerability Index
Flanagan et al. (2011)

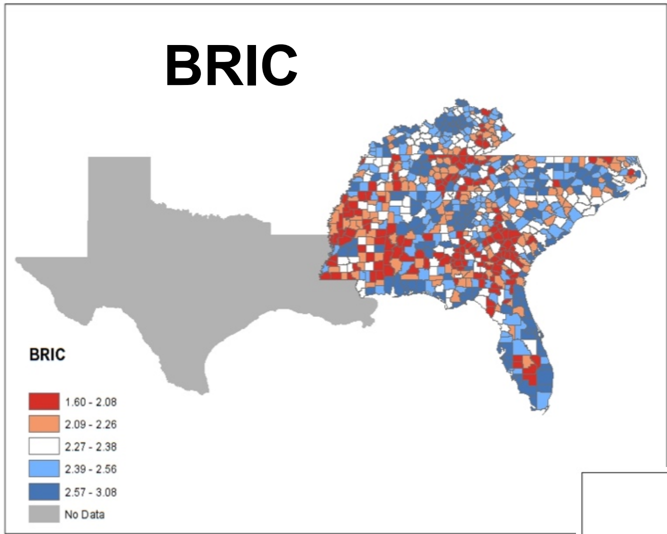
RCI
Resilience Capacity Index
Foster (2012)

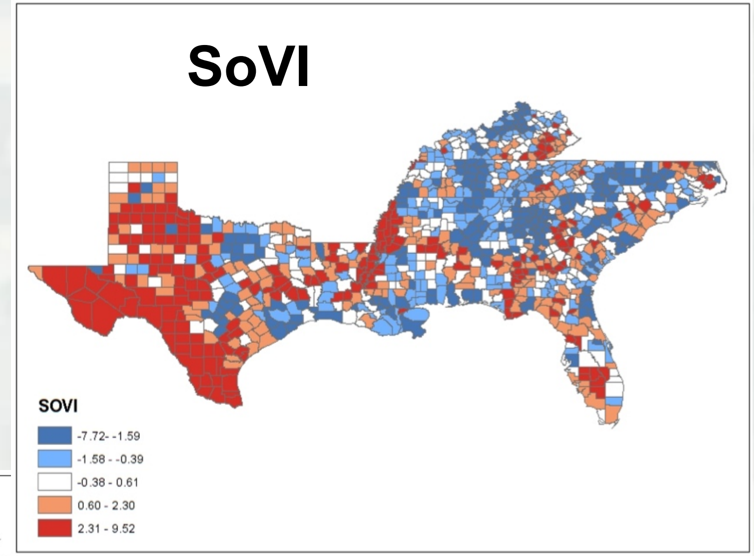
Resilience Index Goals:

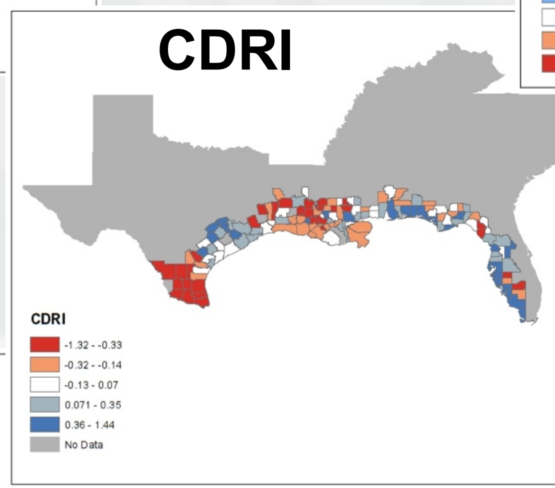
- "baseline set of conditions, from which to **measure the effectiveness** of programs… specifically designed to **improve disaster resilience**"
- "comprehensive **measure** of community **disaster resilience**"
- "resilience capacity"…"having higher capacity [implies] that the region has factors and conditions thought to position a region well for **effective post-stress resilience performance**."

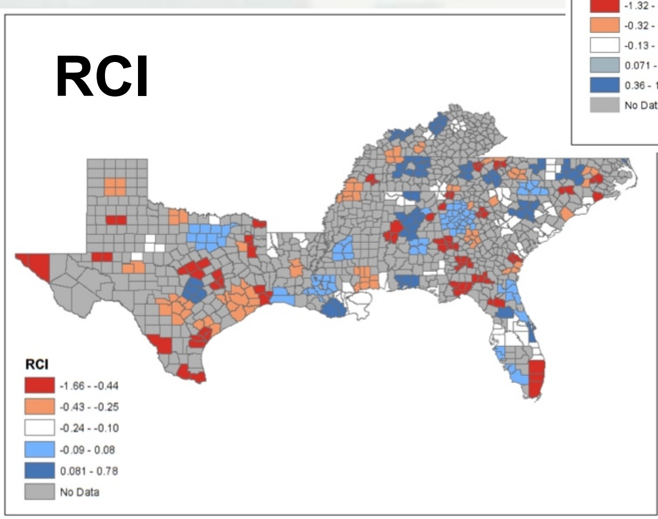
Social Vulnerability Index Goals:

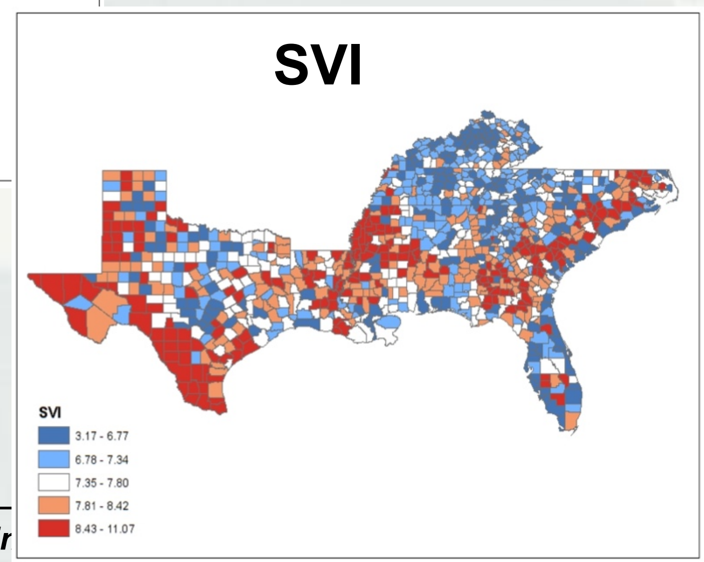
- "…tool for policy makers and practitioners [as] it shows where there is uneven capacity for preparedness and response and… is useful as an indicator in **determining differential recovery from disasters**"
- "**improving** all phases of the **disaster cycle**: mitigation, preparedness, response, and **recovery**"


BRIC
BRIC
1.60 - 2.08
2.09 - 2.26
2.27 - 2.38
2.39 - 2.56
2.57 - 3.08
No Data


SoVI
SOVI
-7.72- -1.59
-1.58 - -0.39
-0.38 - 0.61
0.60 - 2.30
2.31 - 9.52

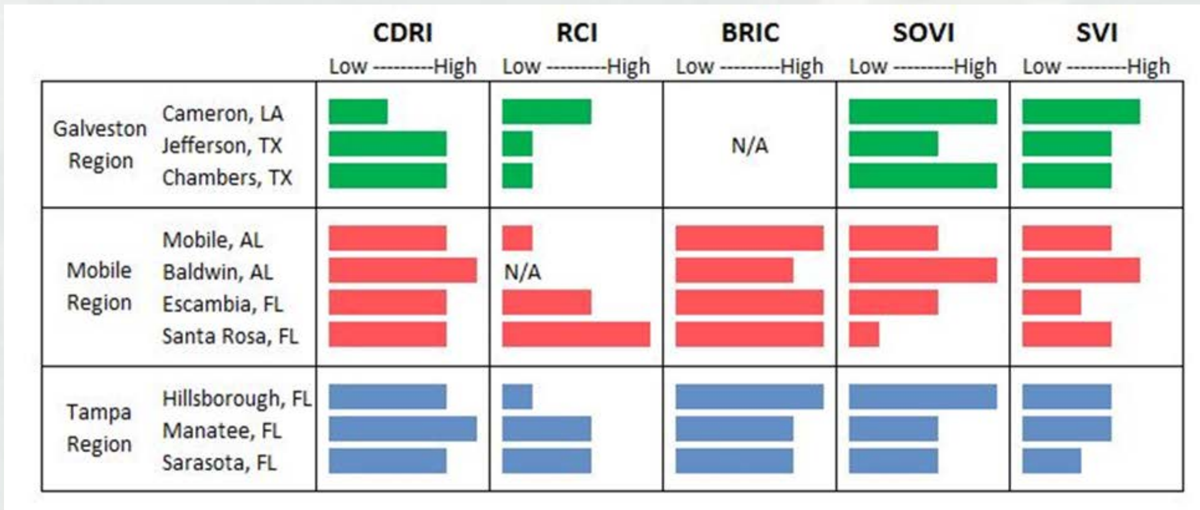

CDRI
CDRI
-1.32 - -0.33
-0.32 - -0.14
-0.13 - 0.07
0.071 - 0.35
0.36 - 1.44
No Data


RCI
RCI
-1.66 - -0.44
-0.43 - -0.25
-0.24 - -0.10
-0.09 - 0.08
0.081 - 0.78
No Data


SVI
SVI
3.17 - 6.77
6.78 - 7.34
7.35 - 7.80
7.81 - 8.42
8.43 - 11.07

Ir

Not all indices give the same result



- If city/state/federal planners are going to use an index to determine how to prioritize investments, which indices actually align with performance?

Method

- Partial validation of resilience/vulnerability score by **multivariate regression analysis**
- Test sign (+/-) and significance of index in explaining **Damages, Fatalities, and Disaster Declarations**
- Dataset: 10 southeastern US states
  - 2000 to 2012
  - 67,000 county-events
  - $170 billion in direct property losses
  - 3,394 lives lost
  - 7,625 declared county-level disasters

Summary of Results

Index	Property Damages	Fatalities	Disaster Declarations
BRIC	○		○
CDRI	●	●	
RCI	●	●	
SoVI	●		●
SVI	●	●	○

● Filled circles indicate correlation is of the expected sign and statistically significant.

○ Open circles indicate correlation is of the opposite sign and statistically significant.

No circle indicates regression results were not statistically different than zero.

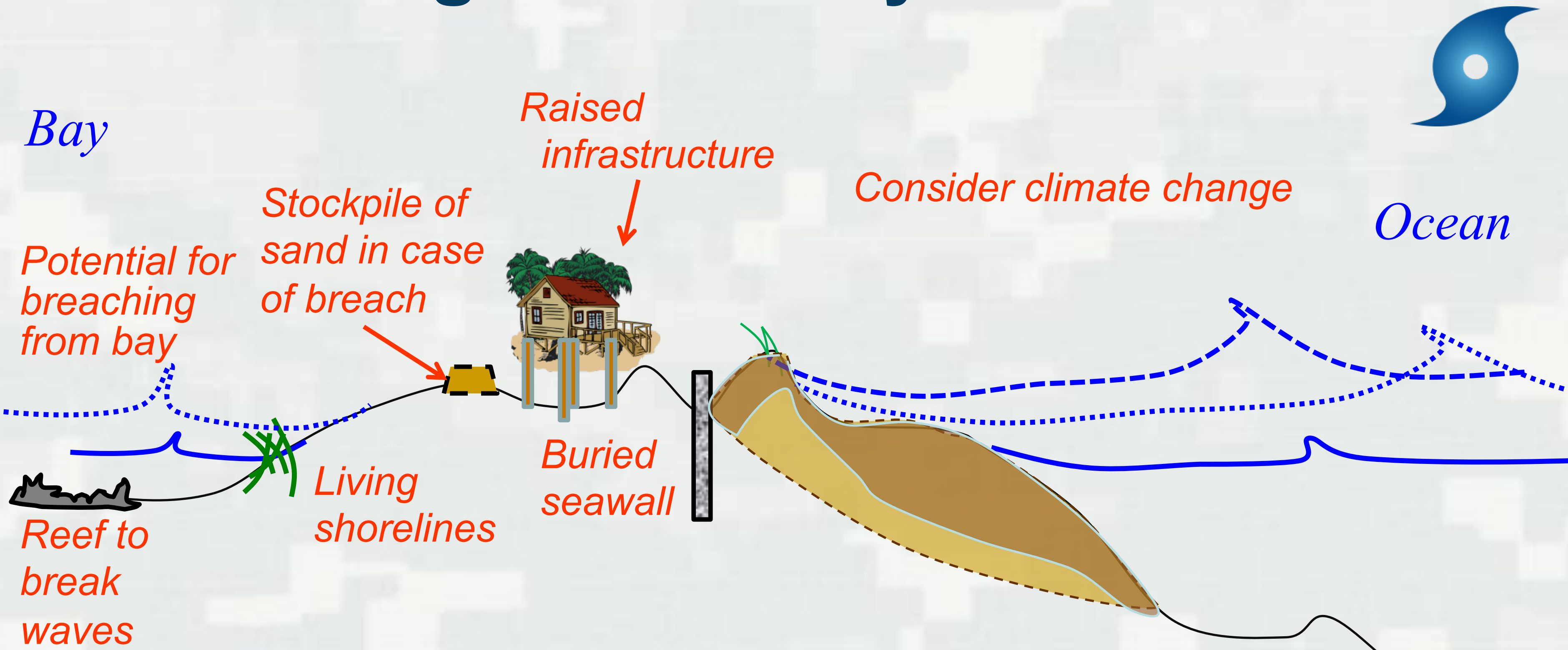
Conclusions & Next Steps

- Number of Metrics in Index
  - BRIC: 26
  - CDRI: 75
  - RCI: 12
  - SoVI: 10
  - SVI: 15

- **Users–** look at the specific underlying metrics to determine suitability for your region
- **Developers–** clearly state the community functions/ stages of resilience index targets

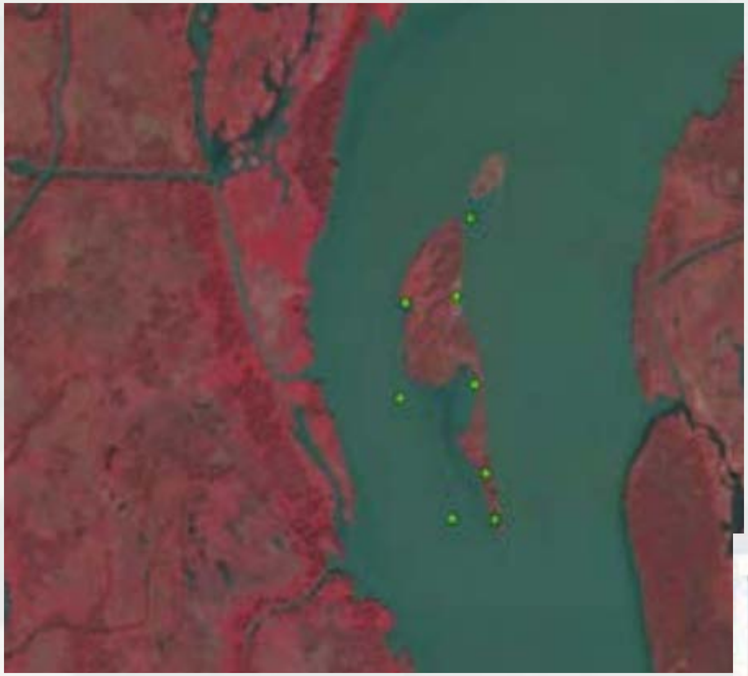
- **Next Steps**
  - Find recovery metrics to validate the
  - post-disaster performance of indices!

Management at System Level



- Anticipate weak links and be ready to recover. *Ex: sand to close new inlets.*
- Provide diverse and redundant protection. *Ex: buried seawall AND beach/dune system.*
- Ensure availability of alternate networks. *Ex: multiple electrical power circuits.*
- Provide accessible information for rapid decision-making. *Ex: raised homes, evacuation routes*

Engineering with Nature



Natural and Nature-Based Features

NATURAL AND NATURE-BASED FEATURES AT A GLANCE				
				
Dunes and Beaches	Vegetated Features (e.g., Marshes)	Oyster and Coral Reefs	Barrier Islands	Maritime Forests/Shrub Communities
Benefits/Processes Breaking of offshore waves Attenuation of wave energy Slow inland water transfer	**Benefits/Processes** Breaking of offshore waves Attenuation of wave energy Slow inland water transfer Increased infiltration	**Benefits/Processes** Breaking of offshore waves Attenuation of wave energy Slow inland water transfer	**Benefits/Processes** Wave attenuation and/or dissipation Sediment stabilization	**Benefits/Processes** Wave attenuation and/or dissipation Shoreline erosion stabilization Soil retention
Performance Factors Berm height and width Beach slope Sediment grain size and supply Dune height, crest, and width Presence of vegetation	**Performance Factors** Marsh, wetland, or SAV elevation and continuity Vegetation type and density Spatial extent	**Performance Factors** Reef width, elevation, and roughness	**Performance Factors** Island elevation, length, and width Land cover Breach susceptibility Proximity to mainland shore	**Performance Factors** Vegetation height and density Forest dimension Sediment composition Platform elevation
General coastal risk reduction performance factors include: Storm surge and wave height/period, and water levels				

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IRGC Resource Guide on Resilience

I. Linkov and M.V. Florin (eds)

- The guide is composed of **50** invited short pieces with an annotated bibliography 'for further reading'. It thus provides background information on the various perspectives and guides readers to other available literature sources.
- Papers can be searched for key words.
- They are listed by author and allocated to one type: concept, approach, illustration or case study; and one sector: engineering / infrastructure, ecological, social / community, business, cross-cutting view.
- The guide was launched on **30 August 2016**

Types: ☑ Case Studies ☑ Approaches ☑ Conceptual   Search...

File	Author(s)	Type	Sector
Introduction	Linkov		
Panarchy	Allen, Angeler, Garmestani	Conceptual	Ecological
Ecological Resilience	Allen, Angeler, Garmestani, Sundstrom	Approaches	Social / Community
Validating Resilience and Vulnerability Indices in the Context of Natural Disasters	Bakkensen, Fox-Lent, Read, Linkov	Conceptual	Engineering & infrastructure
Infrastructure Network Resilience	Barker, Ramirez-Marquez	Approaches	Engineering & infrastructure
Operationalize Data-drive Resilience in Urban Transport Systems	Bellini, Nesi	Case Studies	Engineering & infrastructure
The New Resilience Paradigm	Fiksel	Conceptual	Engineering & infrastructure
Measuring Urban Resilience As You Build It	Flax	Case Studies	Social / Community
Resilience in IRGCs Recommendations for Risk Governance	Florin	Conceptual	
Resilience to Unexpected Impacts of Emerging Risks	Florin	Conceptual	
Five Impediments to Building Societal Resilience	Flynn	Conceptual	Social / Community
Preparing Energy Systems for the Unexpected	Gössling-Reisemann	Approaches	Ecological
Resilience Engineering and Quantification	Haering et al.	Approaches	Engineering & infrastructure
A Generic Framework for Resilience Assessment	Heinimann	Approaches	Engineering & infrastructure
Managing Extraordinary Risks	Helm	Approaches	Engineering & infrastructure
A Business Continuity Perspective on Organisational Resilience	Herbane	Conceptual	Business
Resilience Engineering and Indicators of Resilience	Herrera	Conceptual	Engineering & infrastructure
Formalizing Resilience Concepts for Critical Infrastructure	Hynes et al.	Case Studies	Engineering & infrastructure
Organizational Resilience	Ilmola	Approaches	Business
Principle for Resilient Design	Jackson	Approaches	Engineering & infrastructure
Risk and Resilience Management in Social-Economic Systems	Kovalenko, Sornette	Conceptual	Social / Community
Implementation and Measurement of Strategies for the Unpredictable	Longstaff	Conceptual	Social / Community
The Quest for Enterprise Resilience	Newnham, Crask	Approaches	Business
Two Applications of Resilience Concepts and Methods	Oien	Case Studies	Engineering & infrastructure
Modern Resilience	Palma-Oliveira	Conceptual	Psychological
Ecological & Social-ecological Resilience	Quinlan, Gunderson	Conceptual	Ecological
Inclusive Resilience	Renn	Conceptual	Social / Community
Creating Value Through Resilience	Roege	Case Studies	Social / Community
Measuring Economic Resilience to Disasters	Rose	Approaches	Social / Community
Engineering Resilience in Critical Infrastructures	Sansavini	Case Studies	Engineering & infrastructure
Towards a Cross-disciplinary Understanding and Operationalisation of Resilience	Schanze	Case Studies	Engineering & infrastructure
A Multidimensional Review of Resilience	Seager et al.	Conceptual	Engineering & infrastructure
Natural Hazard Disaster Risk Reduction as an Element of Resilience	Thomas	Approaches	Social / Community
Resilience Analytics for Systems of Systems	Thorisson, Lambert	Approaches	Engineering & infrastructure
Critical Infrastructure Resilience	Vugrin	Case Studies	Engineering & infrastructure
Enhancing Community Resilience	Walsh, Madden, Purcell	Case Studies	Social / Community
UN City Disaster Resilience Scorecard	Williams, Sands	Approaches	Business
Measuring the Resilience of Infrastructure Systems	Willis	Approaches	Engineering & infrastructure
Resilience as Graceful Extensibility to Overcome Brittleness	Woods	Conceptual	Social / Community
On Resilience-based Risk Governance	Xu, Xue	Conceptual	Social / Community
Aligning Different Schools of Thought on Resilience of Complex Systems and Networks	Yu, Rao	Approaches	Engineering & infrastructure
Flood Resilience	Zevenbergen	Case Studies	Engineering & infrastructure

Questions?

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