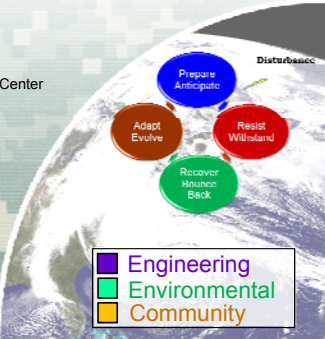



## Concepts of Resilience for Coastal Systems

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Environmental Laboratory

Engineer Research & Development Center  
US Army Corps of Engineers





■ Engineering  
■ Environmental  
■ Community

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## Overview

- Resilience Concepts
- Definitions for this Course
  - ▶ Risk, vulnerability, sustainability, and resilience
- Sectors: Engineering, Environmental, Community, Economic, etc.
- Example
- Discussion & Review


  
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## Definitions of Resilience

Study	Definition
American Society of Civil Engineers (2009) <a href="http://www.asce.org/Content.aspx?cid=4434">http://www.asce.org/Content.aspx?cid=4434</a>	"Resilience refers to the capability to mitigate against significant all-hazards risks and incidents and to expeditiously recover and reconstitute critical services with minimum damage to public safety and health, the economy, and national security."
National Disaster Recovery Framework, Strengthening Disaster Recovery for the Nation (FEMA 2011) <a href="http://www.fema.gov/downloads">http://www.fema.gov/downloads</a>	"A resilient community has ... an improved ability to withstand, respond to and recover from disasters."
The Infrastructure Security Partnership and Society of Military Engineers (ISIME), "Understanding Resilience - From the Business World to the Field" (2012) <a href="http://www.isime.org">http://www.isime.org</a>	"Disaster Resilience is... the ability to recover rapidly with limited damage."
Disaster Resilience (2012) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"Resilience is the ability to recover from and more successfully adapt to adverse events."
Hurricane San Felipe Region (2013) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"The ability to prepare for, respond to, and recover rapidly from disruptions."
Resilience in Infrastructure (2013) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"Ability to anticipate, withstand, and recover from disruption."
Coastal Risk for Army Corps of Engineers (2013) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"Ability to anticipate, respond to, and recover from disruptions."
Urban Land Use Resilience and Recovery (2013) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"The ability to recover after a disruption."
Resilience and Recovery (2013) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"The ability to anticipate, respond to, and recover from disruptions."
Community and Regional Resilience Institute (CARRI) (2013) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"Resilience means the ability to withstand, respond to, and recover from disruptions."
Resilience and Recovery (2013) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"The capacity of individuals, organizations, and communities to survive, adapt, and grow in the face of changes, even in the face of adversity."
Community and Regional Resilience Institute (CARRI) (2013) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"Community resilience is the ability to anticipate, respond to, and recover from disruptions."
U.S. Army Corps of Engineers Safety of Dams, Policy and Procedures, ER 110-2-115 (2014) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"The ability to avoid, minimize, withstand, and recover from the effects of adversity, whether natural or manmade, under all circumstances of use."
U.S. Army Corps of Engineers Safety of Dams, Policy and Procedures, ER 110-2-115 (2014) <a href="http://www.dresilience.org">http://www.dresilience.org</a>	"The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation."

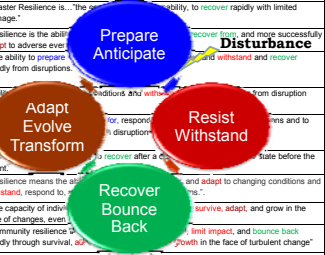
Key words:

Prepare

Resist

Recover

Adapt



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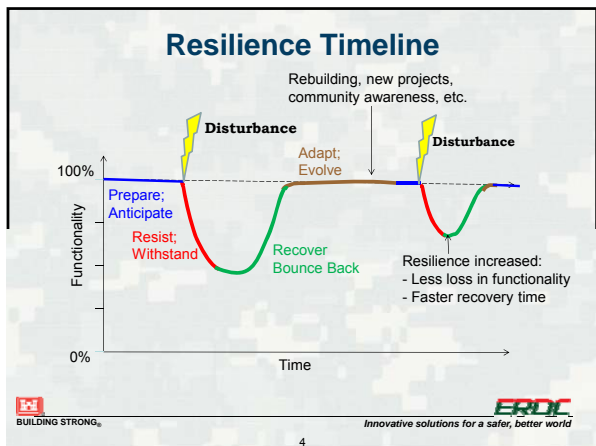
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### Resilience

**Resilience:** the ability of a **system** to **Prepare for, Resist, Recover, and Adapt** to achieve functional performance under the stress of disturbances **through time**.

Study	Definition
National Academy of Sciences (2012)	"Resilience is the ability to <b>prepare and plan for, absorb, recover from,</b> and more successfully <b>adapt</b> to adverse events."
Presidential Executive Order on Climate Change (2013)	"resilience means the ability to <b>anticipate, prepare for,</b> and <b>adapt</b> to changing conditions and <b>withstand,</b> respond to, and <b>recover</b> rapidly from disruptions."

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### Definition: Risk

**Risk is commonly referred to in two ways:**

- (1) Chance or likelihood of a potentially damaging event; *Event Risk*. *The risk of a Cat 1 storm affecting Texas is 15.2%.*
- (2) The probability of potential loss (commonly \$) over the range of potential hazards, *Consequential Risk*. *The consequential risk of all possible storms in Galveston, TX is \$x.*

▪ **Acceptable Risk:** The degree of risk that can be tolerated in the design and operation of an engineered system.

▪ **Residual Risk:** the level of risk that remains after construction of a risk-reduction system. E.g., risk of natural events that exceed the design event.

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### Definition: Vulnerability

**Vulnerability:** the degree to which a system's **attributes of concern** are susceptible to, and unable to cope with, the adverse effects of **hazards** over a period of time.



<p>▪ <b>Attributes of Concern:</b> Valued features or functions that are threatened by hazards e.g., Valued function of wetlands in Galveston Bay could be acreage of habitat and buffering of waves.</p>	<p>▪ <b>Hazards:</b> the occurrences that have the potential to cause harm to the valued functions of people or property e.g., Flooding and waves from Cat 3 Hurricane can erode and damage wetlands.</p>
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Intergovernmental Panel on Climate Change, 2007.  
Wamsley et al. 2013, Appendix S, North Atlantic Coast Comprehensive Study

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### Definition: Sustainability

**Sustainability:** *To endure without giving way or yielding*<sup>1</sup>.  
Meeting the needs of the present without compromising the ability of future generations to meet their own needs<sup>2</sup>.  
An attribute of dynamic, adaptive systems - to flourish and grow in the face of uncertainty and constant change<sup>3</sup>.  
Not an end state...it is a fundamental characteristic of a dynamic, evolving system. Long-term sustainability will result not from movement along a smooth trajectory, but rather from continuous adaptation to changing conditions<sup>3</sup>.

<sup>1</sup> Dictionary.com; <sup>2</sup> World Commission on Environment and Development, 1987, Our common future, Oxford University Press. <sup>3</sup>Ohio State University, Center for Resilience.



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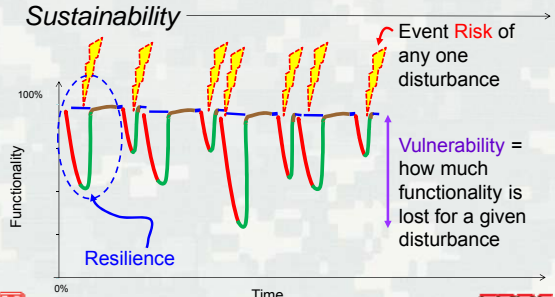
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### Risk, Vulnerability, Sustainability, and Resilience



**Sustainability** →

100%  
Functionality

0% Time

Event Risk of any one disturbance

Vulnerability = how much functionality is lost for a given disturbance

Resilience

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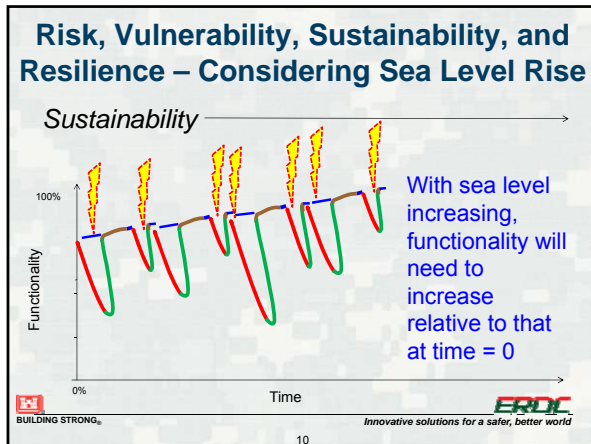
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### Engineering Resilience

prepare, resist, recover, adapt

**Engineering Resilience:**

- Reliable, predictable performance
- Range of design forcing

*Most engineered systems do not naturally adapt*

*Exception: engineered natural systems, e.g., constructed beaches, dunes, wetlands*

The ability of a **system** to **prepare for, resist, recover, and adapt** to achieve *functional performance* under the stress of disturbances **through time.**

New Orleans Storm Surge Barrier

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### Ecological Resilience

prepare, resist, recover, adapt

The capacity of a system to **absorb disturbance** and **reorganize** while **undergoing change** so as to still **retain essentially the same function, structure, identity, and feedbacks.**

**Ecological Resilience:** Ability to maintain same functioning without transitioning into a new state. In general, changes must be gradual for successful adaptation.

Walker, B., Holling, C. S., Carpenter, S. R., Kinzig, A. (2004). "Resilience, adaptability and transformability in social-ecological systems." *Ecology and Society* 9 (2): 5-14.

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### Community Resilience

prepare, resist, recover, adapt


Capability to **anticipate** risk, **limit impact**, and **bounce back** rapidly through survival, **adaptability**, **evolution**, and **growth** in the face of turbulent change.

**Community Resilience:**  
Humans have the capacity to learn and make conscious decisions to avoid future losses.





Community and Regional Resilience Institute (CARRI) (2013). "Definitions of Community Resilience: An Analysis." <http://www.resilientus.org/wp-content/uploads/2013/08/definitions-of-community-resilience.pdf>


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### Economic Resilience

prepare, resist, recover, adapt


**Both of Communities:**  
Both *Instantaneous resilience*, the ability to **limit the magnitude** of the immediate loss of income for a given amount of capital losses; and *Dynamic resilience*, the ability to **reconstruct and recover** quickly.

+

**And of Households:**  
**Distribution of direct losses** across households, the existence of basic needs, the ability to **smooth the shock** across time through savings, borrowing, insurance, and the ability to **share risks** across households through **social protection**.



Hallegatte, S. 2014. "Economic Resilience, Definition and Measurement." World Bank Climate Change Group, Office of Chief Economist, 46 p. <http://www.wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/05/02/000195349201405021337411/Rendered/PDF/WPS6882.pdf>


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### What is a resilient coastal system?

*Hypothetical Example: Galveston, TX*

Narrow portion of island; beach access may make this part of island vulnerable




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### What is a resilient coastal system?

Hypothetical Example: Galveston, TX

Bay

Potential for breaching from bay

Stockpile of sand in case of breach

Raised infrastructure

Consider climate change

Ocean

Reef to break waves

Living shorelines

Buried seawall

- Anticipate weak links and be ready to recover.
- Provide diverse and redundant protection.
- Ensure availability of alternate networks –components are independent of, and complement each other.
- Provide accessible information for rapid decision-making.

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### How do we quantify coastal resilience?

4. What is the capacity of the system to **adapt** in advance of future storms, sea level change, and human dynamics?

1. How **prepared** is the system for a storm?

2. Has the system been able to **absorb** damages and **resist** loss in functioning during storms, waves, storm surge, winds?

3. Has **recovery** been adequate to restore functioning in a desirable timeframe?

Prepare

Absorb/Resist

Recover

Adapt

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## 1 – Consider System-Scale Resilience

**Purposes**

Assess overall community system resilience to -

- Provide context for agency-specific work
- Identify locally acceptable resilience improvement plans.

**Understand**

- *Physical System* – structures, resources, manpower
- *Information* – monitoring, analyzing data, communicating
- *Cognitive* – governing structures, plans, decision making, policies
- *Social* – citizen perceptions, actions, abilities

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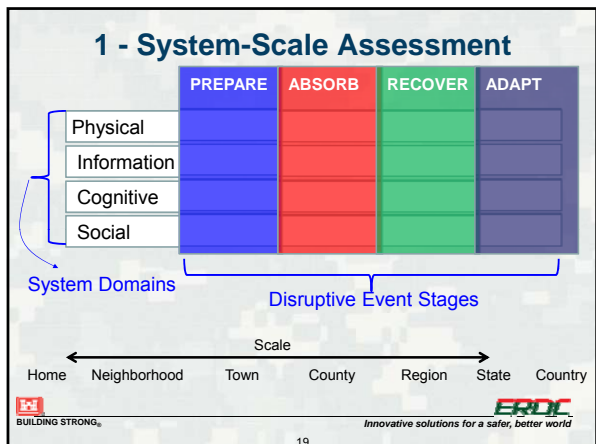
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### 1- Example of a System Scale Assessment

Critical Functions of Communities:  
Housing/Shelter, Food, Clean Water, Sanitation, Transportation, Medical, Education, Recreation, Ecosystem Services, Electricity...

	Prepare	Absorb	Recover	Adapt
Phy	Extent of coastal protection structures	Robustness of coastal structures, existence of secondary protection	Time to rebuild coastal structures	Flexibility and modularity of coastal structures to allow change
Info	Tracking of threats and community vulnerability	Hazard monitoring and communication	Monitoring recovery needs; communicating rebuilding requirements	Modeling local climate change impacts
Cog	Emergency management lead agency and plans	Agency effectiveness at shelter emergency management	Agency effectiveness in supporting recovery	Decision making authority for future climate scenarios
Risk	Understanding of Risk	Ability and willingness to evacuate	Community neighbor support	Financial and cultural barriers to change

Legend: Good, High (Green); Medium (Yellow); Poor, Low (Red)

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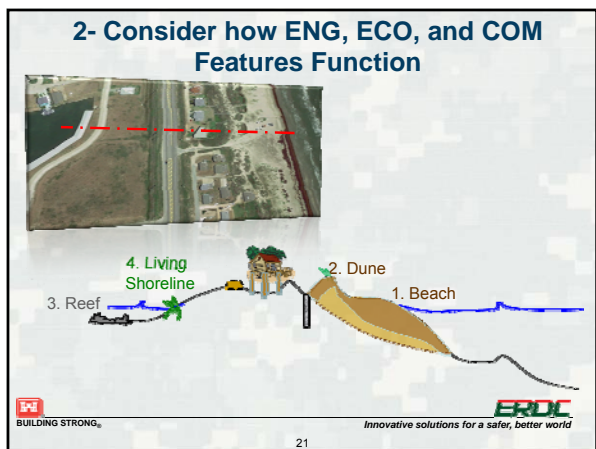
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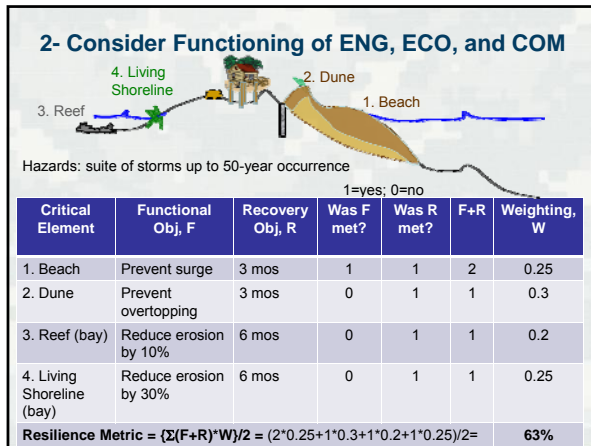
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### Summary

- Many definitions of resilience
  - Key words: **prepare**, **resist**, **recover**, **adapt**
- Risk, Vulnerability, Resilience, and Sustainability are distinct but interrelated
- Methods to estimate resilience can be:
  - Qualitative, based on expert judgment
  - Quantitative, based on past functional performance
  - Qualitative and quantitative, based on hypothetical future functioning and numerical modeling calculations
- Consider resilience of the SYSTEM, including weakest links and potential for cascading failures

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