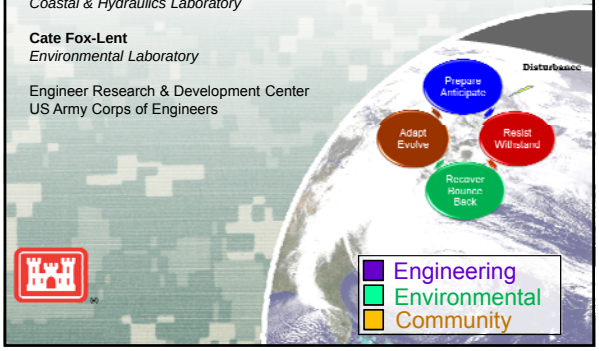
Concepts of Resilience for Coastal Systems

Julie Dean Rosati
Coastal & Hydraulics Laboratory

Cate Fox-Lent
Environmental Laboratory

Engineer Research & Development Center
US Army Corps of Engineers

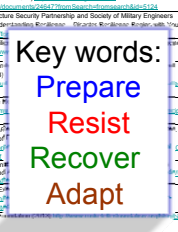


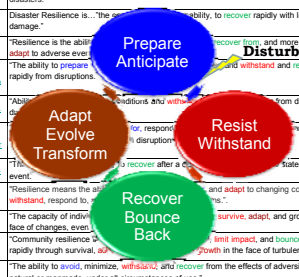
Overview

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

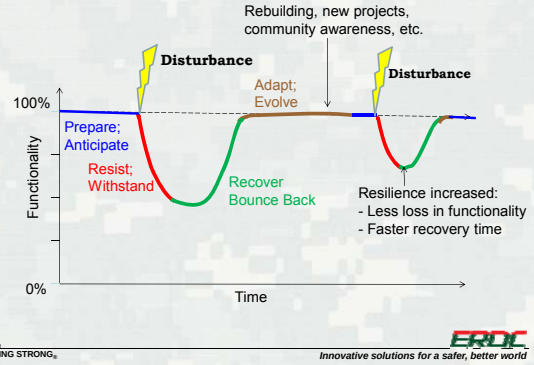
Definitions of Resilience

Study	Definition
American Society of Civil Engineers (2008) http://www.asce.org/Content.aspx?id=8478	"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) http://www.fema.gov/media-library/assets/documents/24647?fromSearch=fromsearch&id=5124	A resilient community has … "an improved ability to withstand, respond to and recover from disasters."
The Infrastructure Security Partnership and Society of Military Engineers (SAME), "Understanding Resilience: Charting Resilience Ranks with You" (2012) http://t	Disaster Resilience is…"the c ability, to recover rapidly with limited damage."
Disaster Resilie 2012) http://ww	"Resilience is the abili recover from, and more successfully adapt to adverse ever Disturbance
Hurricane San Region (2013) http://portal.hs .pdf	"The ability to prepare and withstand and recover rapidly from disruptions."
Infrastructure R http://coastalrisk .pdf	"Abili conditions and withs from disruption d
Coastal Risk R Army Corps of F http://www.cor R_2013_5.pdf	US for, respond ns and to disruption
Urban Land Inst Resilience and http://www.uli. Documents/ULI	"Th to recover after a d state before the event."
Presidential Exe http://www.whi executive-ord	"Resilience means the ab and adapt to changing conditions and withstand, respond to, ns.".
Rockefeller Fo creative/	"The capacity of indivi survive, adapt, and grow in the face of changes, even
Community and Regional Resilience Institute (CARRI) (2013) http://www.resilientus.org/wp-content/uploads/2013/03/Definition-of-Community-Resilience.pdf	"Community resilience limit impact, and bounce back rapidly through survival, ad growth in the face of turbulent change"
U.S. Army Corps of Engineers Safety of Dams, Policy and Procedures, ER 1110-2-1156 (2014) http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1156.pdf	"The ability to avoid, minimize, withstand, and recover from the effects of adversity, whether natural or manmade, under all circumstances of use."
Intergovernmental Panel on Climate Change Fifth Assessment Report, "Climate Change 2014: Impacts, Adaptation, and Vulnerability" (2014) http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Glossary_FGD.pdf	"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"





Resilience Timeline



BUILDING STRONG® Innovative solutions for a safer, better world

4

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 **prepare and plan for**, **absorb**, **recover from**, and more successfully **adapt** to adverse events."
Presidential Executive Order on Climate Change (2013)	"resilience means the ability to **anticipate, prepare for,** and **adapt** to changing conditions and **withstand,** respond to, and **recover** rapidly from disruptions.".

BUILDING STRONG® Innovative solutions for a safer, better world

5

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.

6

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.

- **Attributes of Concern:** 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.

- **Hazards:** 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.

Intergovernmental Panel on Climate Change, 2007.
Wamsley et al. 2013, Appendix S, North Atlantic Coast Comprehensive Study

Definition: Sustainability

Sustainability: *To endure without giving way or yielding*[1]**.**

Meeting the needs of the present without compromising the ability of future generations to meet their own needs[2].

An attribute of dynamic, adaptive systems - to flourish and grow in the face of uncertainty and constant change[3].

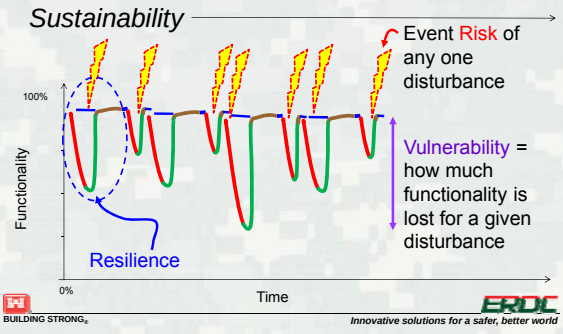
Not an end state…it is a fundamental characteristic of a dynamic, evolving system. Long-term sustainability will result not from movement along a smooth trajectory, but rather from continuous adaptation to changing conditions[3].

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

BUILDING STRONG® *Innovative solutions*

8

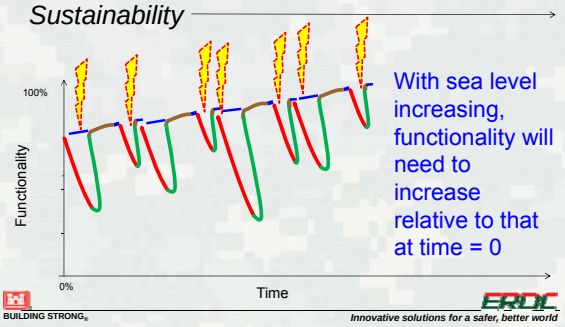
Risk, Vulnerability, Sustainability, and Resilience



BUILDING STRONG® *Innovative solutions for a safer, better world*

9

Risk, Vulnerability, Sustainability, and Resilience – Considering Sea Level Rise



With sea level increasing, functionality will need to increase relative to that at time = 0

BUILDING STRONG®

Innovative solutions for a safer, better world

10

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

BUILDING STRONG®

Innovative solutions for a safer, better world

11

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.

Innovative solutions for a safer, better world

12

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

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.

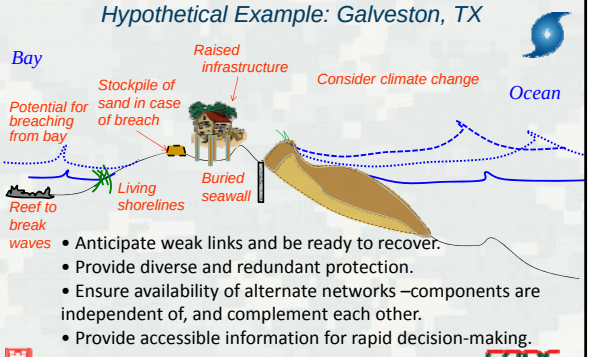
Hallegatte, S. 2014. "Economic Resilience, Definition and Measurement," World Bank Climate Change Group, Office of Chief Economist, 46 p. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/05/02/000158349_20140502133741/Rendered/PDF/WPS6852.pdf

What is a resilient coastal system?

Hypothetical Example: Galveston, TX

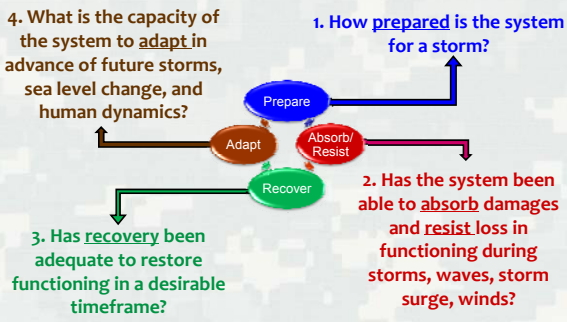
What is a resilient coastal system?

Hypothetical Example: Galveston, TX



- 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.

How do we quantify coastal resilience?



1 – Consider System-Scale Resilience

Purposes

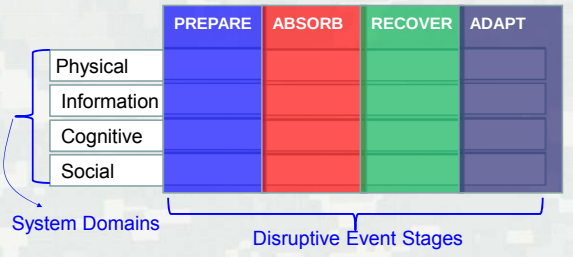
Assess overall community system resilience to -

- 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

1 - System-Scale Assessment



Scale

Home | Neighborhood | Town | County | Region | State | Country

BUILDING STRONG®

Innovative solutions for a safer, better world

19

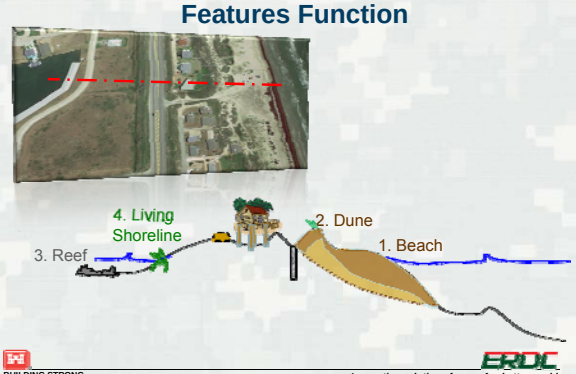
1- Example of a System Scale Assessment

Good, High
Medium
Poor, Low

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
BUILD	Understanding of Risk	Ability and willingness to evacuate	Community neighbor support	Financial and cultural barriers to change

2- Consider how ENG, ECO, and COM Features Function

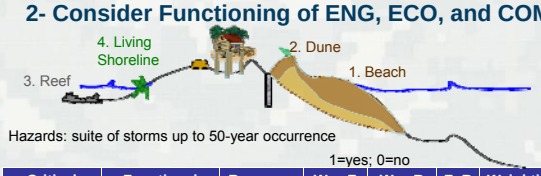


BUILDING STRONG®

Innovative solutions for a safer, better world

21

2- Consider Functioning of ENG, ECO, and COM



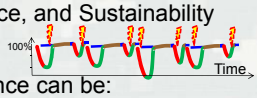
Hazards: suite of storms up to 50-year occurrence

1=yes; 0=no

Critical Element	Functional Obj, F	Recovery Obj, R	Was F met?	Was R met?	F+R	Weighting, W
1. Beach	Prevent surge	3 mos	1	1	2	0.25
2. Dune	Prevent overtopping	3 mos	0	1	1	0.3
3. Reef (bay)	Reduce erosion by 10%	6 mos	0	1	1	0.2
4. Living Shoreline (bay)	Reduce erosion by 30%	6 mos	0	1	1	0.25
Resilience Metric = {Σ(F+R)*W}/2 = (2*0.25+1*0.3+1*0.2+1*0.25)/2=						**63%**

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

BUILDING STRONG®

ERDC

Innovative solutions for a safer, better world

23