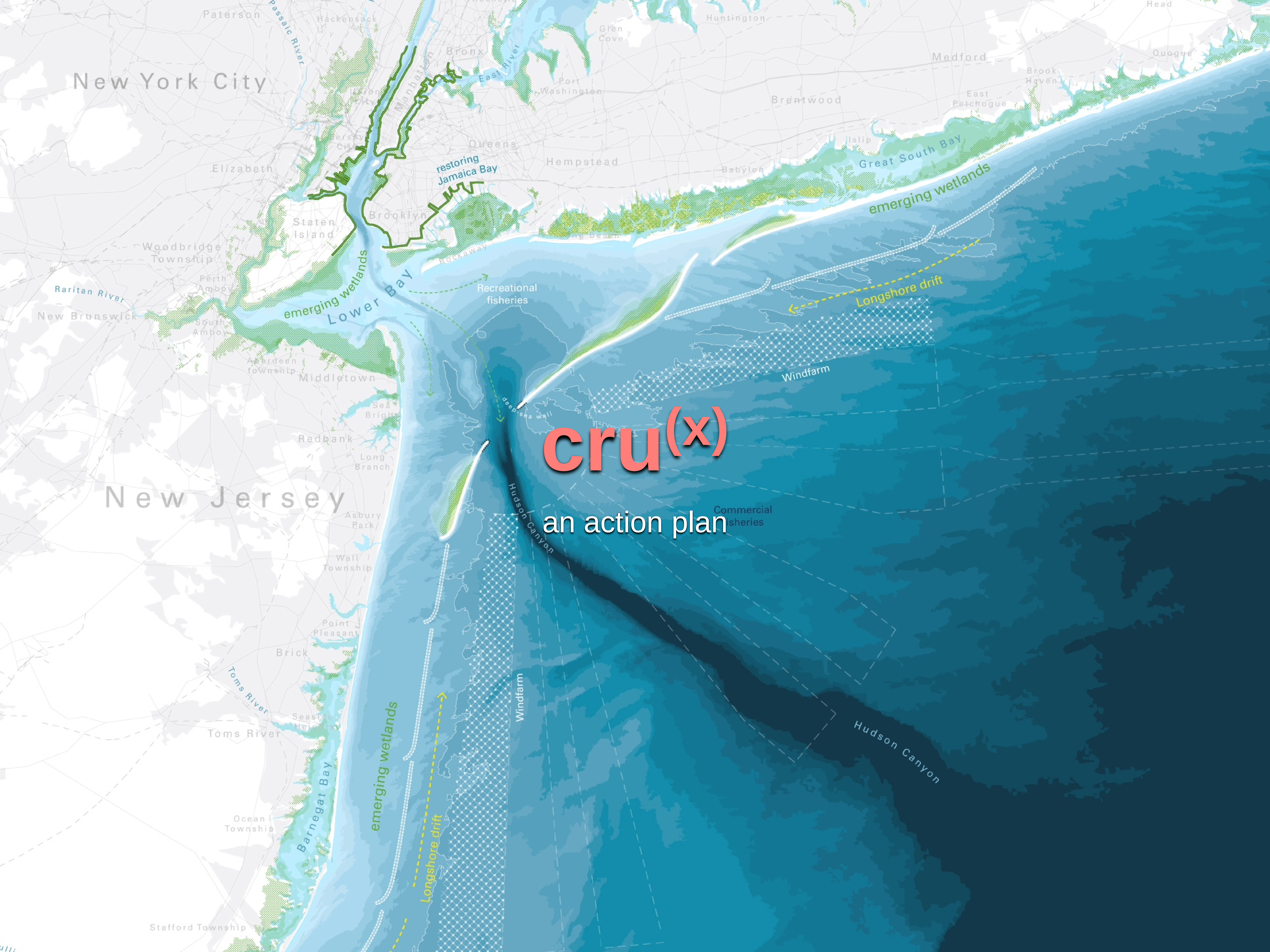

cru(x)
an action plan
New York City
New Jersey
Paterson
Hackensack
Passaic River
Bronx
Manhattan
East River
Union City
Jersey City
Queens
Elizabeth
restoring Jamaica Bay
Brooklyn
Staten Island
Woodbridge Township
Perth Amboy
Raritan River
New Brunswick
South Amboy
emerging wetlands
Lower Bay
Rockaway
Recreational fisheries
Aberdeen township
Middletown
Sea Bright
Redbank
Long Branch
Asbury Park
Wall Township
Point Pleasant
Brick
Toms River
Seaside Heights
Barnegat Bay
Ocean Township
Stafford Township
Glen Cove
Huntington
Port Washington
Hempstead
Babylon
Islip
Brentwood
Medford
Brook Haven
East Patchogue
Quogue
Great South Bay
emerging wetlands
Longshore drift
Windfarm
deep-sea wall
Hudson Canyon
Commercial fisheries
Windfarm
emerging wetlands
Longshore drift
Hudson Canyon

cru$^{(x)}$ is a research and education center dedicated to the proposition that coastal cities can increase their resilience to climate change while simultaneously improving their quality of life.

STEVENS INSTITUTE OF TECHNOLOGY

CRUX DISCIPLINES

CRUX believes that resilience and quality of life can best be achieved in coastal cities by combining three disciplines:

Hydrodynamics: Understanding the force of the water

Urban Design: Understanding the force of the city

Complex Systems: Understanding population response

The Nature of Urban Design

a New York perspective on resilience

Alexandros Washburn

RISK EQUATION

Lower Manhattan blackout after Hurricane Sandy. *(Credit: David Shankbone)*

as Wall Street. As long as you are coastal, in zone A, you are supposed to leave. That's more than 350,000 people. My neighborhood is Red Hook, in Brooklyn, about a mile from downtown Manhattan where the East River meets upper New York Harbor. They used to make ships in Red Hook, and you could say ships used to make Red Hook, too. Much of the neighborhood is built on cobblestone fill brought over as ballast in the nineteenth century. The neighborhood was covered in factories and warehouses, all brick, now occupied by artisans and grocers. When not flooded, it is a beautiful neighborhood, with views of

lights are flickering, the wind is really picking up, and as I write this, I know I should probably move away from the windows in case they shatter. The guy on the first floor evacuated a long time ago. I comfort myself with the thought that I'm on the second floor. Even if the storm surge is the full eleven feet, I'm at twelve feet. Right? It's the cocktail hour, and I am having my customary martini. No sense in curtailing my routine. High tide will be at 8 p.m., which unfortunately coincides with landfall for the hurricane, which unfortunately coincides with the full moon. So the storm surge is amplified by an ex-

I can check the Internet. A crane is in danger of collapsing in Manhattan, one thousand feet above Midtown. The first fatality is reported in Queens. And there's a blog post about Red Hook, about how the water is seeping up Van Brunt Street.

I look outside and see a trickle of water in the gutter. Nothing unusual, except that the water is flowing *out* of the gutter, and the trickle is turning rapidly into a stream. I put on my rubber boots and go downstairs. I open the door and water rushes in, dark water covered in the golden leaves of autumn. I step out into the street but realize that I'd better

Now it's all darkness, not black
brown, and whatever light there is
water, which keeps on rising. My
pretty badly now, but because I defi
tion order, I can put buckets under th
can stop a rain shower easily, but whe
by high winds, it goes horizontal, a
gets in.

I love New York, I love Red Hook
than anxious now. The waters outsid
ther and moving faster. I go upstairs t
the roof. The wind is too strong to go

Global risk equation

cesses if nothing happens. Both have different units of m
processes of measure, the former hypothetical, the latter s
they are related is through the notion of risk.

Risk = probability x consequence

New York City has a higher hurricane risk than New
the probability of a hurricane strike is lower, the conseq
we are a larger city, are higher. Ecometrics would use the
set up a decision-making relationship between mitigat
tion. Mitigation can be understood to affect probability:
index of greenhouse gases in the atmosphere and thereby
reduce the energy in the weather system and decrease
future extreme weather events. Adaptation can be unde
consequences: a seawall might protect a city from a give
my neighborhood had had a fourteen-foot–high seawall, t
been very few consequences from Sandy's storm surge. O
creasing greenhouse gases, the likelihood of the next st
higher than fourteen feet is greater. Therefore, adaptatio
are linked. The shorthand equation might read:

Risk = (probability – mitigation) x (consequence –

So if we want to manage climate risk, everything we
signed to either lower probability or lower consequences.
there is no mitigation today, any adaptation will be over

@washburNYC

Sustainable risk

they are related is through the notion of risk.

$$\text{Risk} = \text{probability} \times \text{consequence}$$

New York City has a higher hurricane risk than New Orleans. Thoug the probability of a hurricane strike is lower, the consequences, becau we are a larger city, are higher. Ecometrics would use the risk equation set up a decision-making relationship between mitigation and adapt tion. Mitigation can be understood to affect probability: it can lower th index of greenhouse gases in the atmosphere and thereby eventually he reduce the energy in the weather system and decrease the likelihood future extreme weather events. Adaptation can be understood to affe consequences: a seawall might protect a city from a given storm surge. my neighborhood had had a fourteen-foot–high seawall, there would hav been very few consequences from Sandy's storm surge. Of course with i creasing greenhouse gases, the likelihood of the next storm surge bein higher than fourteen feet is greater. Therefore, adaptation and mitigatio are linked. The shorthand equation might read:

$$\text{Risk} = (\text{probability} - \text{mitigation}) \times (\text{consequence} - \text{adaptation})$$

So if we want to manage climate risk, everything we do should be d signed to either lower probability or lower consequences. In other words, there is no mitigation today, any adaptation will be overwhelmed tomo row. But by writing equations, I don't want to imply that a mathematic system of ecometrics currently exists; it does not.

@washburNYC

they are related is through the notion of risk.

$$\text{Risk} = \text{probability} \times \text{consequence}$$

New York City has a higher hurricane risk than New Orleans. Thoug the probability of a hurricane strike is lower, the consequences, becau we are a larger city, are higher. Ecometrics would use the risk equation set up a decision-making relationship between mitigation and adapt tion. Mitigation can be understood to affect probability: it can lower th index of greenhouse gases in the atmosphere and thereby eventually he reduce the energy in the weather system and decrease the likelihood future extreme weather events. Adaptation can be understood to affe consequences: a seawall might protect a city from a given storm surge. my neighborhood had had a fourteen-foot–high seawall, there would hav been very few consequences from Sandy's storm surge. Of course with i creasing greenhouse gases, the likelihood of the next storm surge bei higher than fourteen feet is greater. Therefore, adaptation and mitigatio are linked. The shorthand equation might read:

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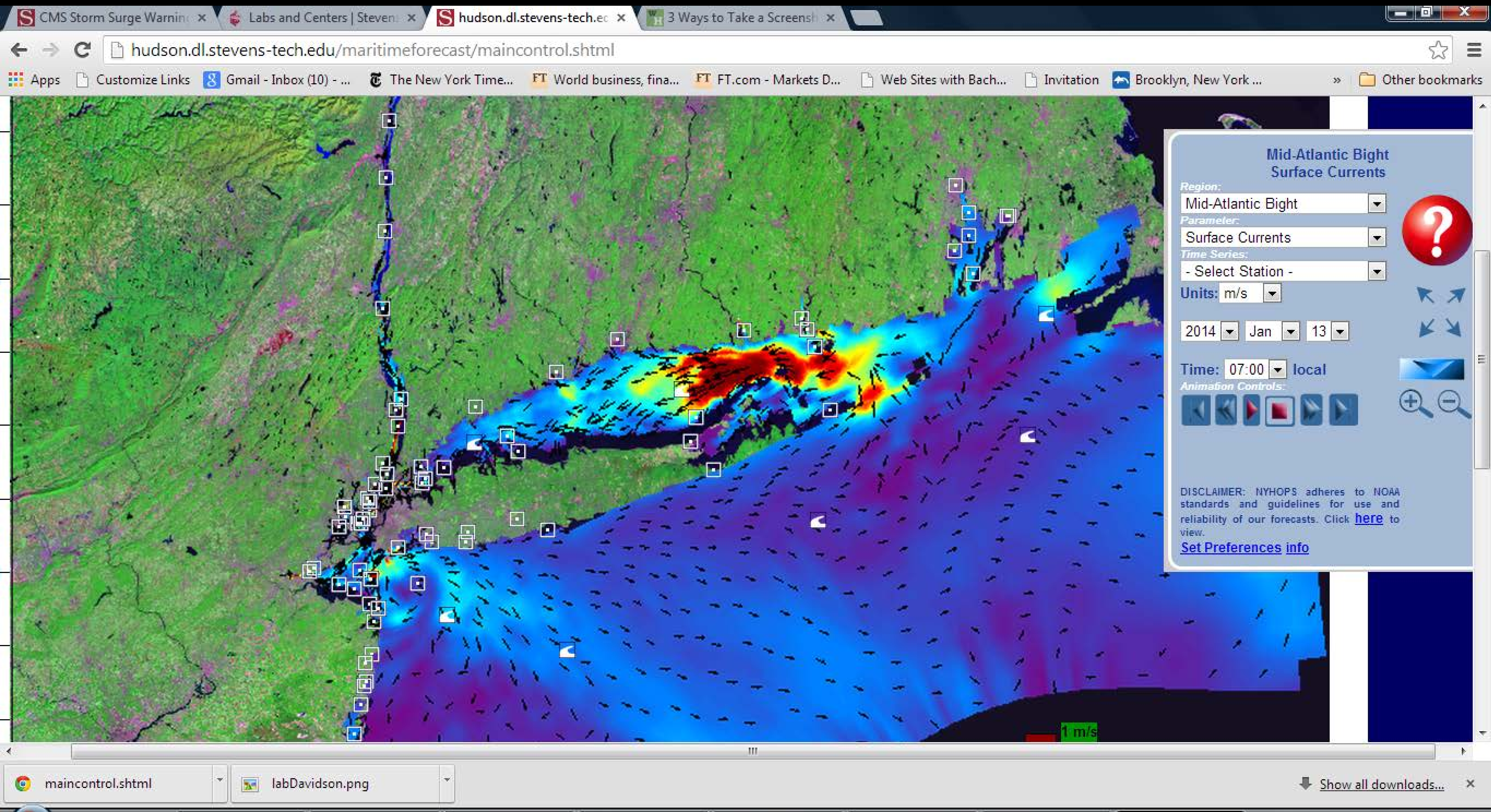
Resilience

Social cohesion
Emergency planning
Economic diversity
Fortification
Resistance
Retreat

DATA AND INDEXING

MEASURE



While early research efforts have been devoted to the protection (or hardening) of systems against disruptive events, be they malevolent attacks, man-made accidents, or natural disasters, recent attention has been placed on preparedness, response, and recovery (PR^2) from these events. This is particularly true for the nation's critical infrastructure and key resources (CIKR), as DHS (2009) recently stated that "CIKR resilience may be more important than CIKR hardening."

Resilience research has been an emerging research area for the last decade, though no standard definition or quantitative technique for the paradigm of system resilience has emerged. One approach, illustrated in Fig. 1 as described in Henry and Ramirez-Marquez (2012), describes resilience as the ability to restore a system from disrupted state, S_d, to a stable recovered state, S_f. Resilience is thus defined as the time dependent ratio of recovery over maximum loss in Eq. (1).

$$\text{я}(t) = \text{Recovery}(t)/\text{Maximum Loss}(t_d) \qquad (1)$$

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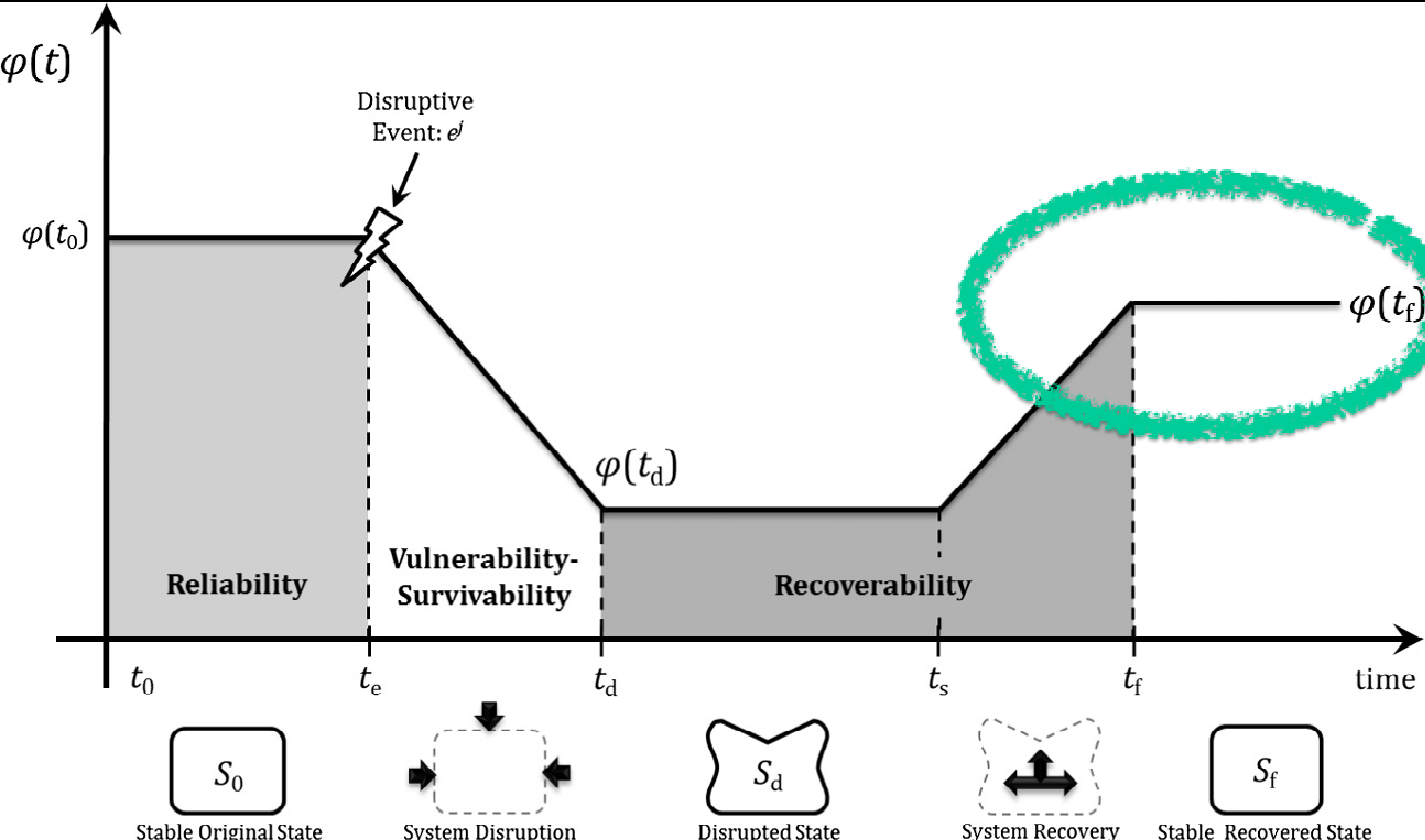
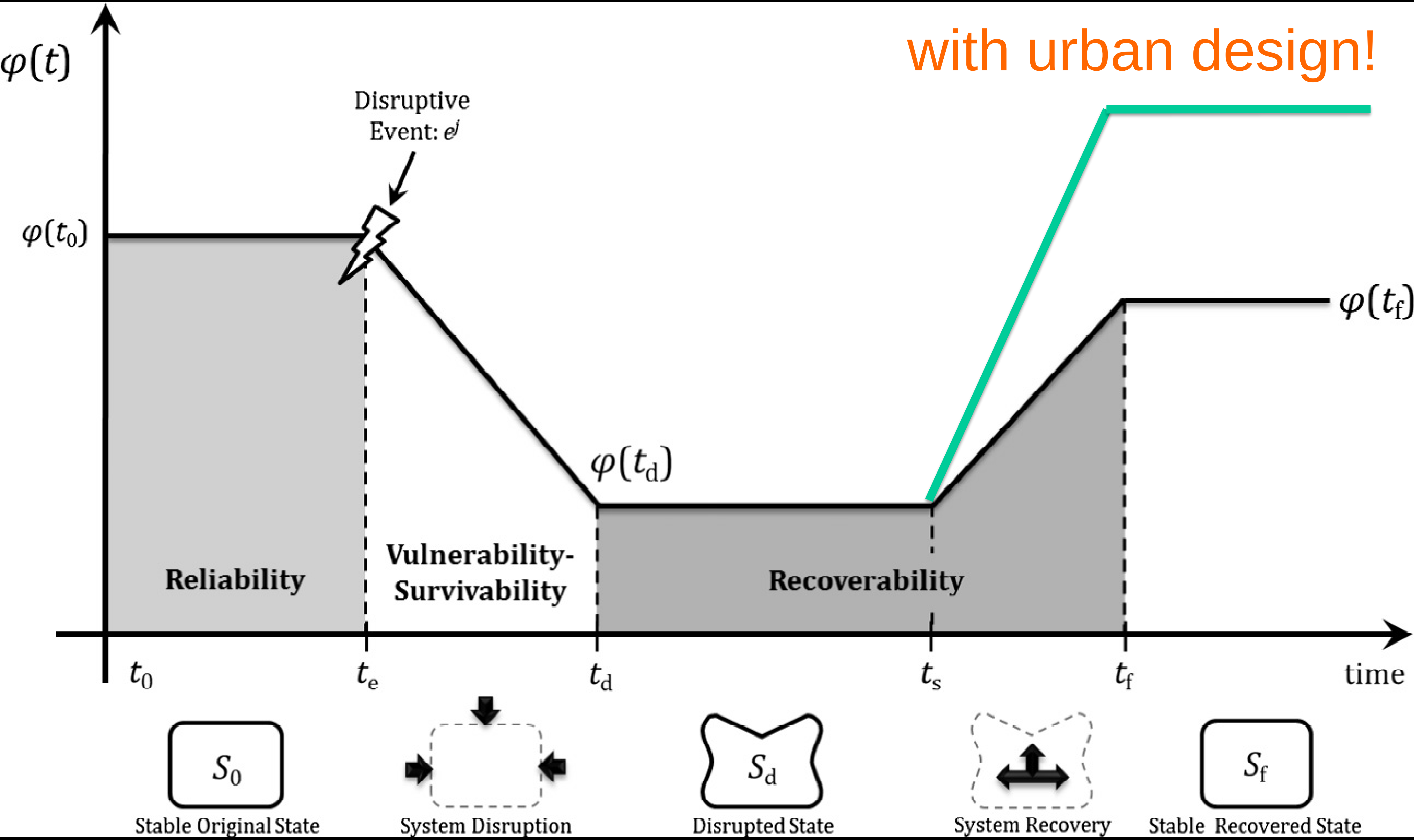
http://dx.doi.org/10.1016/j.cie.2014.01.017

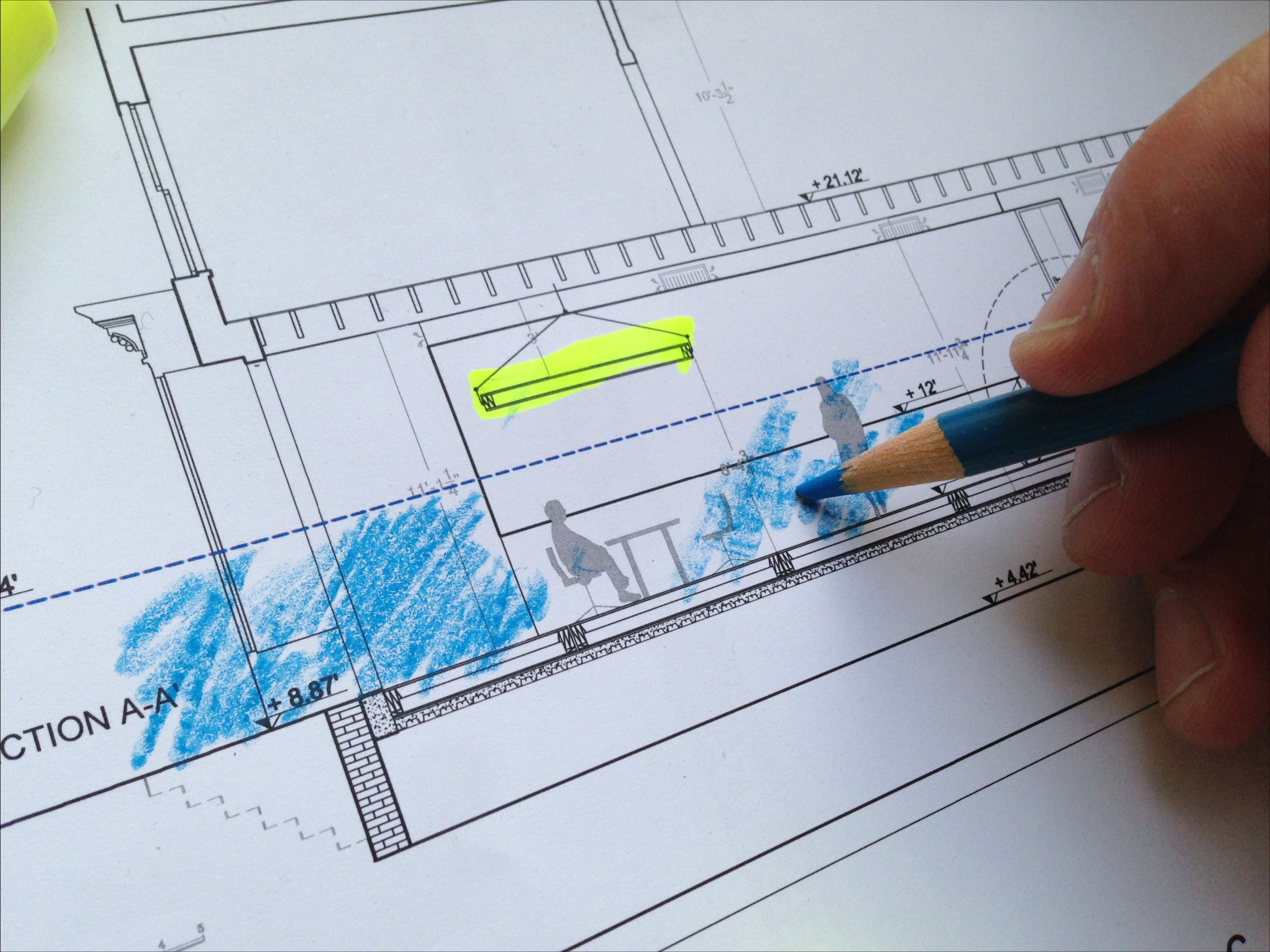
transportation s
flows across mu
actual disruptiv
clude the colla
in Oklahoma re
nearly 2 month
I-35W bridge c
which required
Liu, & Harder, 2

As a result o
tive events cou
ties such as ra
inland ports. Cr
waterway ports
modity flows (
…ri, 2009; Sima
o… the same ri
…eveloped risk
MacKenzie, Bar
in North Amer
(Rodrigue, Deb
Zeng, 2008). Th



$\varphi(t)$
Disruptive Event: e^j
$\varphi(t_0)$
$\varphi(t_d)$
$\varphi(t_f)$
Reliability
Vulnerability-Survivability
Recoverability
t_0
t_e
t_d
t_s
t_f
time
S_0
Stable Original State
System Disruption
S_d
Disrupted State
System Recovery
S_f
Stable Recovered State

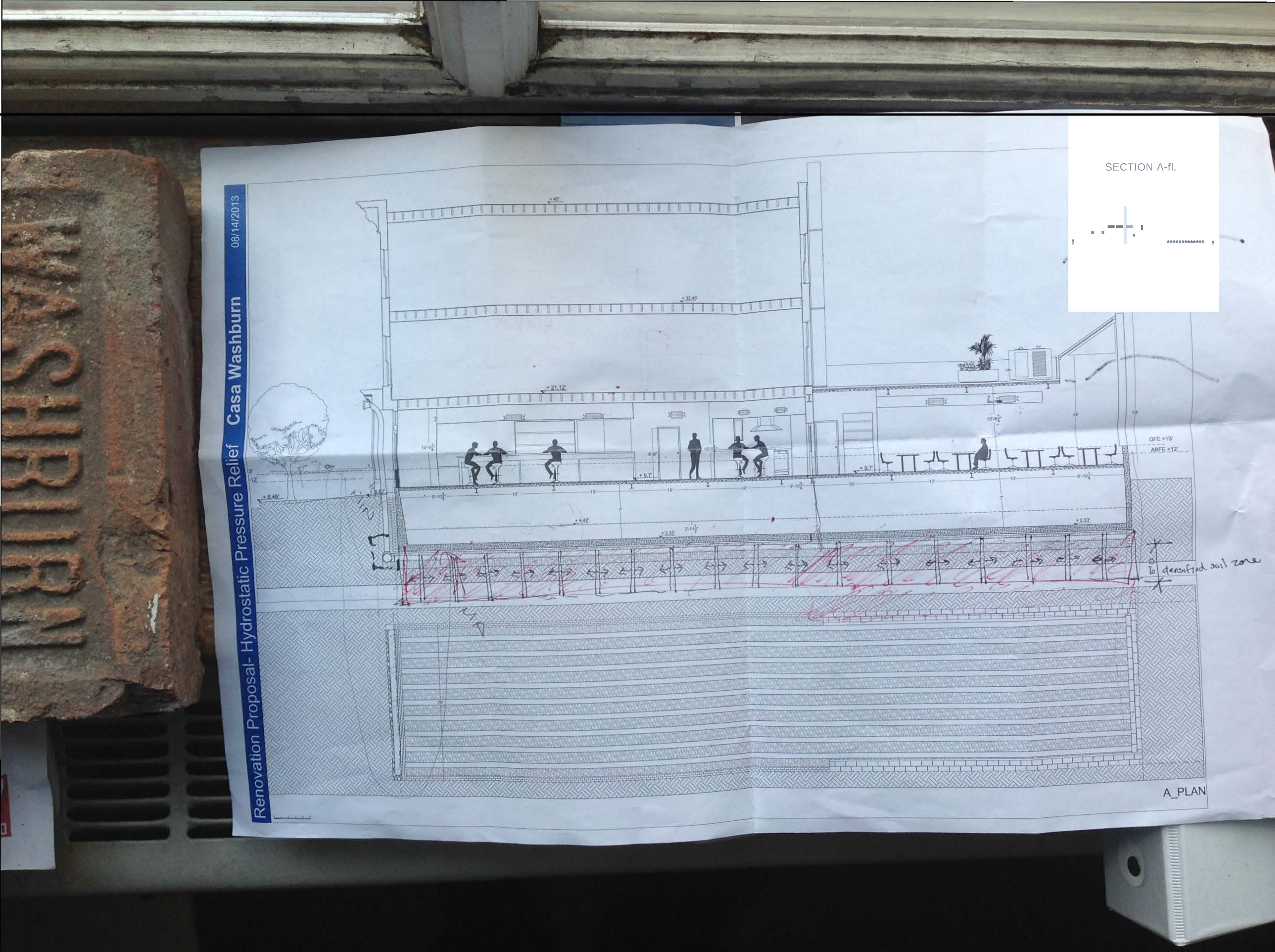

with urban design!
φ(t)
Disruptive
Event: e^j
φ(t0)
φ(td)
φ(tf)
Reliability
Vulnerability-
Survivability
Recoverability
t0
te
td
ts
tf
time
S0
Stable Original State
System Disruption
Sd
Disrupted State
System Recovery
Sf
Stable Recovered State



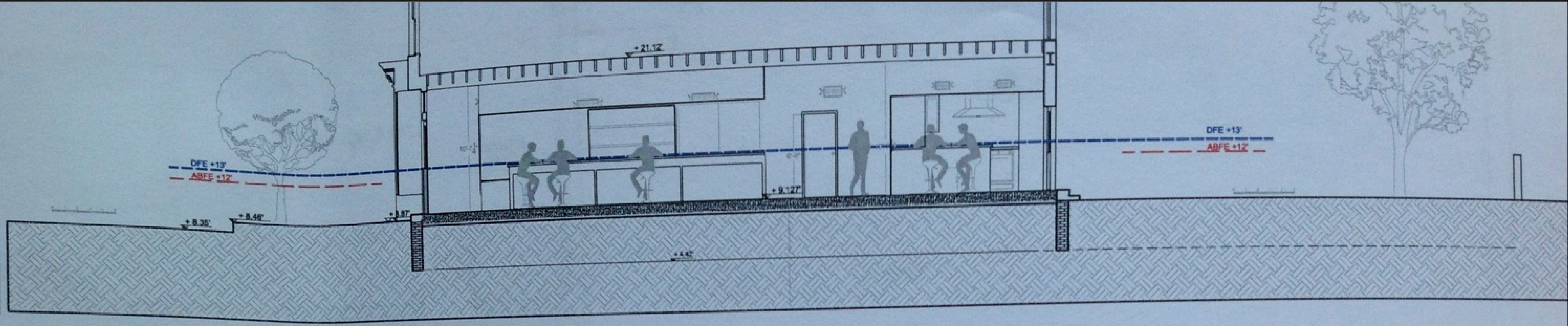
+ 21.12'
10'-3 1/2"
+ 12'
11'-11 3/4"
11'-1 1/4"
+ 4.42'
+ 8.87'
CTION A-A'

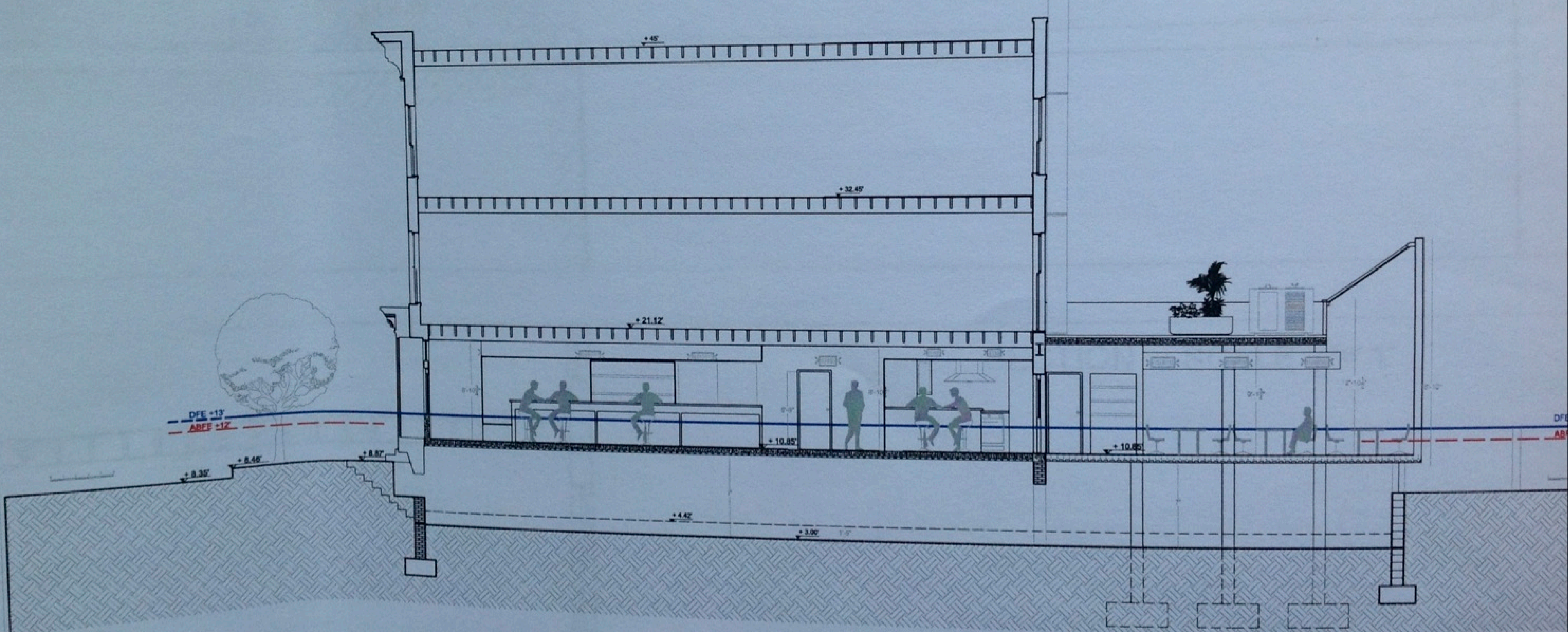
WHAT ABOUT
MY STREET?

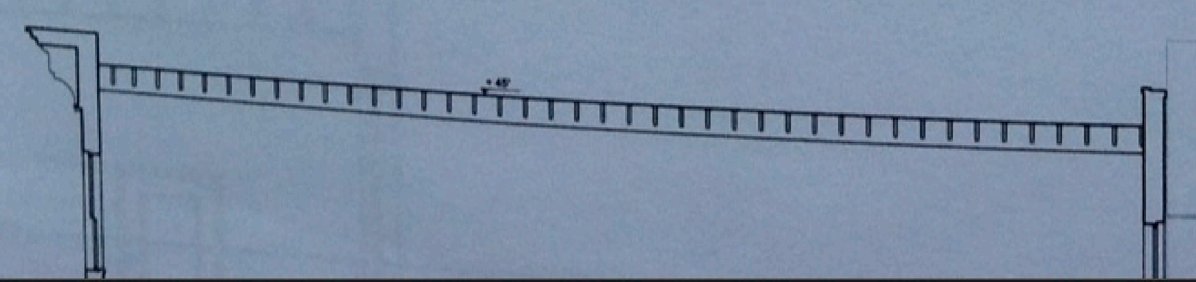
Resilience



SECTION A-fl.
Casa Washburn
08/14/2013
Renovation Proposal- Hydrostatic Pressure Relief
densified soil zone
A_PLAN
WASHBURN


+ 21.12'
DFE +13'
ABFE +12'
DFE +13'
ABFE +12'
+ 9.127'
+ 8.35'
+ 8.46'
+ 8.87'
+ 4.42'


+ 45'
+ 32.45'
+ 21.12'
DFE +13'
ABFE +12'
+ 10.85'
+ 8.87'
+ 8.46'
+ 8.35'
+ 4.42'
+ 3.00'


+ 45'

VALUES TO IMPROVE URBAN QUALITY OF LIFE
TECHNOLOGY TO ACHIEVE COASTAL RESILIENCE

RESILIENCE

OUTCOME