EBC Climate Change Program Series – Part Four

Adaptation and Resiliency Programs at Institutions
Welcome

Daniel K. Moon

President and Executive Director
Environmental Business Council
Program Introduction and Overview

Michael Macrae

Energy Analytics Manager
Harvard University
Planning for a Resilient MIT: Collaborating Across Scales, Systems, and Teams

Laura L. Tenny, ASLA, MIT

&

Brian Goldberg, LEED AP BD+C, AICP, MIT
Planning for a Resilient MIT: Collaborating Across Scales, Systems, and Teams

Laura Tenny, Senior Campus Planner, MIT Office of Campus Planning
Brian Goldberg, Sustainability Project Manager, MIT Office of Sustainability
How can the campus prepare for the next 100 years:

• MIT has begun a major capital renewal program to enable the next 100 years
• Capital Renewal program focus is on systems
• Getting buy-in to consider Site as another “system” – a living infrastructure – takes work!
• Climate change will bring new challenges, how does systems renewal respond?
• On a 100-year-old urban, highly developed campus, needs present complex challenges:
  • For stormwater – how to consider the whole campus as a system when so many pressing building needs have priority – who “owns” the site?
  • For climate resiliency – how to plan and prepare now in the face of uncertain future conditions?
Organizational and Physical Challenges

Large institutions share common organizational challenges:
• Operational silos
• Projects have strictly defined site limits/scope
• Considering site as another system, like infrastructure, burdens project finances
• Complexity of applying climate science to planning
• Regulatory compliance vs going above & beyond
• Urban constraints – limited land for development above and below ground; limited infiltration capacity
• Incomplete archival records for existing infrastructure
• Challenging to articulate and quantify co-benefits
• Limited staff time/resources to strategize about interdisciplinary, system-wide approaches
The Opportunity to Integrate Stormwater and Climate Resiliency Planning

• Complex challenges benefit from collaboration of expertise across sectors – build teams!
• Similar science and planning applications
• Both share similar physical assets (i.e. “site” and “infrastructure systems”)
• Ability to build shared capacity of staff
• Institutions privileged to take long-term view with regard to system-wide infrastructure
• Our integrated approach is helping us to prepare for new challenges coming

Sustainable Stormwater & Landscape Ecology Plan 2017
Climate Vulnerability Study 2017
How We Started Integrating

• Governance – cross-section of technical specialties and perspectives
  ➢ Stormwater and Land Working Group
  ➢ Sustainable Stormwater Core Team
  ➢ Resiliency Site Systems sub-group

• Capacity building – past 2+ years, broadened group as topics develop

• Data and mapping / creating a baseline of existing infrastructure

• Forecasting / modelling – joint drainage modeling

• Applied outcomes – Project Toolkit, mapping, visualizations
The urban campus has altered the natural water balance. Impervious surfaces prohibit infiltration and increase runoff that cause localized flooding. Accumulated pollutants are discharged from urban storm drains and impair the Charles River. This plan will re-establish the natural water balance using a landscape-integrated stormwater system.
Existing urban watershed development conditions and the projected impacts of climate change combine to put MIT’s urban campus at risk. The capacity of MIT’s century-old stormwater system can become overburdened by current storms; future weather patterns will further strain the system. Anticipated regulatory requirements may require retroactive measures in order to comply with water quality and quantity standards.

According to climate change projections, MIT may experience unprecedented disruptions from flooding and chronic heat stress on campus that is >65% impervious, along with financial burdens from regulatory fees, damage to the physical campus, and rising costs to maintain its aging infrastructure.
Why Act Now? MIT's Physical Assets are Vulnerable to Climate Change

As MIT invests $$$ over decades to renew its buildings and systems, these assets are increasingly vulnerable to:

• **Increased flood risk**
  - Aging infrastructure near capacity
  - Precipitation events more frequent and intense
  - Property damage
  - Human safety
  - Disruptions to research and campus life

• **Rising temperatures**
  - Increased energy costs and demand
  - Increased water costs
  - Loss of mitigating landscape
  - Human safety and comfort

Images: City of Cambridge Climate Change Vulnerability Assessment
Context for the Plan: A Campus at Capacity

Historic Conditions
An extraordinary location developed from tidal marshes but limited by its geographic boundaries.

Current Constraints
A dense urban campus with excellent facilities but limited expansion possibilities.

Future Opportunities
A progressive urban campus with planned renewal & development, where every space and surface serves a vision.

MIT’s New Approach must Protect Historic and Future Assets
Gray infrastructure will exceed its capacity with climate change and larger storm events.

Landscape is not considered part of the stormwater management approach.

MIT’s Approach Today: A Single Benefit Stormwater Approach

Stormwater runs off paved and compacted unpaved surfaces, discharging unmitigated and untreated stormwater runoff to Charles River.
Stormwater from paved and compacted surfaces is absorbed and cleansed by landscape and soils.

Reliance on gray infrastructure is relieved.

Landscape and soils provide capacity to address stormwater.

MIT’s Proposed Approach Tomorrow: A Multi-benefit Stormwater System
Excessive pavement and widespread soil compaction thwart implementation of Best Management Practices.

Currently landscape is not considered as part of the stormwater management approach.
One Healthy Tree

- Slows rainwater 15-30%
- Cools urban areas 6-19°F
- Per rain event absorbs 100 gallons H₂O
- Reduces building energy use 10-30%
- 40% reduced runoff over impervious surface
- Absorbs 48 lbs CO₂/yr

5’ of Healthy Soil

- Stores 1.1-2” water/ft for plants per rain event
- Infiltrates 2.5” water/ft
- Low heat flux
- Reduces urban heat island
- Stores more carbon than atmosphere or trees over pervious surface
- Absorbs phosphorus from stormwater

Planning for a Resilient MIT: Collaborating Across Scales, Systems, and Teams
The Vision: “The Commons” Enhances Resiliency to Climate Change and Contributes to the Experience of the Campus
Planning for a Resilient MIT: Collaborating Across Scales, Systems, and Teams

Impact across scales: Project to Site - Project Toolkit

Site is understood as a campus-wide system, but projects can enable gradual implementation toward a larger goal. Proposed “Toolkit” approach incorporates resiliency planning combined with landscape-based stormwater strategies on large and small projects, at the earliest phases of project planning.

Example: draft documents

The Project Performance Standards for MIT ProjectsSites will be used to determine if individual projects support the larger campus sustainability goals identified by the Sustainable Stormwater and Landscape Ecology Plan (currently under development). The key goals established by the Plan are intended to address the following campus and regional issues:

The Project Performance Standards for MIT ProjectsSites will be used to determine if individual projects support the larger campus sustainability goals identified by the Sustainable Stormwater and Landscape Ecology Plan (currently under development). The key goals established by the Plan are intended to address the following campus and regional issues:

The recommended Project Performance Standards will be reviewed and considered by individual projects on MIT’s campus as part of the planning and design process as directed by MIT. Priority credits have been identified with the priority icon.
Tactics of Integration: Stormwater and Resiliency Planning

- Governance / organizing people to attack the problem
- Aligning systems of analysis
- Capacity building
- Co-benefits
- Jointly generating base data / base mapping
- Forecasting / modelling
- Applied outcomes
An MIT campus capable of fulfilling its mission in the face of intensifying climate risks.
MIT Resiliency Approach: Building on a strong baseline
MIT Resiliency Approach: Getting the right people in the room

1. RESEARCH + DATA

2. OPERATIONS + GOVERNANCE

- Community Systems
- Buildings/Systems
- Infrastructure/Utility Systems
- Site Systems

- Faculty
- Facilities
- Repair & Maint.
- Campus Planning
- Emergency Mgmt
- Business Continuity
- Utilities
- Systems Engineer.
- MIT Medical
- MITIMCo
- EH&S
- Insurance
- Students
- Risk Management
- Student Life
- Sustainability
- Housing
- Dining
MIT Resiliency Approach: Aligning systems / layers of resilience

- Community
- Buildings / Equipment
- Infrastructure / Utilities
- Site
1. Climate
   - Global climate is changing
   - Boston area climate has shifted
   - Hurricane Sandy

2. Campus
   - MIT campus history as filled wetland
   - 100 years of physical assets and constraints
   - Stormwater management system and BMPs
Climate risk projection: Heat Stress – Co-benefit with stormwater

- Historic heat index: 85 deg
- 2030s heat index: 96 deg
- 2070s heat index: 115 deg
Climate risk projection: Storm surge / sea level rise flooding

Cambridge Climate Vulnerability Assessment, 2017, based on WHG MassDOT Boston Harbor Flood Risk Model
Climate risk projection: Precipitation–driven flooding, co-benefit stormwater

- Current 100 yr (1% prob) rain: 8.9 inches
- 2070 100 yr (1% prob) rain: 11.7 inches
• 5000 Storms over Cambridge
• 5 Global Circulation Models
• Distribution of probable rainfall totals
MIT Flood Vulnerability: Base mapping and forecasting

Sample localized modelling output

2070 Manhole flooding MWH, Riverine flooding VHB
Cambridge Climate Vulnerability Assessment, 2015
Launch Resiliency Sub group: Site Systems (aka Stormwater Core Team)

1. IDENTIFY VULNERABILITIES TO CLIMATE RISKS

2. PRIORITIZE PHYSICAL CONSTRAINTS AND OPPORTUNITIES

3. MAKE RECOMMENDATIONS

Most critical constraints
Tactics of Integration: Stormwater and Resiliency Planning

- Governance / organizing people to attack the problem
- Aligning systems of analysis
- Capacity building
- Co-benefits
- Jointly generating base data / base mapping
- Forecasting / modelling
- Applied outcomes
Concluding Thoughts: Lessons Learned

• Long-term view
• Shared complexity
• Shared processes and tactics
• Define “resiliency”
• Grapple with uncertainty
• Opportunity for beyond campus collaborations
• Visualize potential risks
Next Steps: Climate resilient MIT

• Prioritize vulnerabilities across systems
• Integrate physical and community system priorities
• Determine standards and design guidance
• Tackle heat stress – co-benefits for resiliency and stormwater
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CIRCA’s Municipal Grant Program for Resiliency and Storm Resilience Modeling for the Eversource-Connecticut Inland Substations and Power Grid

Emmanouil Anagnostou

University of Connecticut, Eversource Energy Center, and Connecticut Institute for Resilience & Climate Adaptation (CIRCA)
Storm Resilience Modeling for the Eversource-Connecticut Inland Substations and Power Grid

Emmanouil Anagnostou
Director, Eversource Energy Center
Applied Research Director, Connecticut Institute for Resilience & Climate Adaptation

EBC Climate Change Program Series – June 23 2017
Outline

I. Current Research on Power Grid Resilience
   I. Storm Outage Modeling for Electric Distribution Networks
   II. Investigate Remote Sensing and Other Advanced Data
   III. Developing Tools to Support Outage Restoration Modeling
   IV. Evaluation of Power Grid Vulnerability to Future Climate Hazards

II. Flood Vulnerability Analysis Framework
   I. High resolution multi-year (35-76 years) hydrologic reanalysis
   II. Flood frequency analysis and hydraulic structure modeling
   III. Mapping inundation with RS data
Historic Storms and Impacts

IRENE OUTAGES (2011)

- >16,000 outages repaired over 9 days
- Estimated 128,000 crew hours of restoration work
- Most significant damage experienced south of the I-84 corridor

OCTOBER NOR’EASTER OUTAGES (2011)

- >25,500 outages (nearly 60% greater than Irene) repaired over 11 days
- Estimated 205,000 crew hours of restoration work
- Most significant damage experienced in north-central portion of state
OPM System Architecture

Weather Forecasts:
- WRF 3.4.1
- ICLAMS
- WRF 3.8.1

Event trigger
- emailed weather forecasts
- or manual trigger

NWP forecast products
- parameter file

Input:
- Current storm

Static Data
- land use, LAI, infrastructure data

UConnOPM

Output:
- Outage predictions

Update with Actual Outage Data

Historical training data

Webpage displays
Cross-validations performed with different weather forecasts

Operational WRF 3.4.1

NAM based WRF 3.8.1

ICLAMS
Leveraging the Power of LiDAR
- Has the potential to be among the most important inputs into the OPM, requires regular updates to reflect maintenance activities.
Figure: Comparison of grid cells across Eversource CT service territory. Grid cells with color represent that trimming occurred (does not reflect how intense the trimming was, just that some form of intervention took place).
**Partial Dependence (Resilience)**

**Figure:** Partial dependence plots related to vegetation management, circuit and wire type.
Vulnerability to Future Hazards

**Figure:** Current and Future Sandy storm tracks. Colored lines correspond to individual WRF simulations, the grey line indicates the ensemble mean track (ENS), and the dashed black line represents the National Hurricane Center (NHC) “best track” for Current Sandy.
Wind Gust

We see comparatively reasonable differences in wind variables

**Figure:** Cumulative distributions of maximum wind at 10m height for current (grey) and future (blue) Sandy simulations for the sub-region of the model domain enclosing the State of Connecticut.
Accumulated Precipitation

We see enormous differences in precipitation variables.

**Figure:** Cumulative distributions of total accumulated precipitation for current (grey) and future (blue) Sandy simulations for the sub-region of the model domain enclosing the State of Connecticut.
Future Sandy (Predicted Outage Map)

Figure: Distribution of predicted outages for Future Sandy by simulation and machine learning models for the full model forcing (wind and precipitation variables).

42 – 64% increase in predicted outages from ensemble mean (ENS), depending on model forcing.
Flood Vulnerability Analysis Framework

Reanalysis data driven (36/68 yrs) hydrological simulations of hourly flow rates

50, 100, 200, 500-yr return period flood peak magnitudes

Hydraulic Structure Modeling

Overtopping & structural ROF

Inundation mapping

Inundation Modeling

1m DEM (LIDAR)

Profile

Remote Sensing Data on Water Surface Areas

Cal/Val

Inflow

Outflow
Hydrograph of Flood Events

-100
0
100
200
300
400
500

Date
2006/01/16:23
2006/06/24:07
2006/07/04:08
2006/07/14:09
2006/08/03:11
2007/04/15:02
2007/05/07:19
2008/03/05:04
2008/12/25:08
2009/05/05:02
2010/01/21:21
2010/12/22:18
2011/01/21:21
2011/05/22:15
2011/09/21:21
2011/11/15:07
2012/01/01:16
2012/12/22:21
2013/05/26:11
2013/06/05:12
2013/07/05:15
2013/06/14:07
2014/03/31:16

NSCE=0.6997
CC=0.85
Bias=-6.3%

-100
0
100
200
300
400
500

R_Obs
R

Eversource Energy Center
Flood Frequency Analysis

Adjusted flood frequency from the Inlet of the Thomaston dam

Flow contribution from downstream area alone
Flooding scenario: 200 years return flood + two reservoir operation scenarios

Downstream hydrograph

Depth time series at the transformer
Demo of 200 year Inundation Scenario of the Freight St. Substation
Mapping Inundation with Remote Sensing Data

SAR data

Probability Map (30-yr TM)

DEM

Land Cover
Mapping Inundation by SAR data

Water body Identification based on Statistical Distribution

Input Datasets
- Single/dual/fully polarized SAR data
- Probability map (30yr TM)

Target
Generate Initial water mask

Morphologic Processing

Input Datasets:
- Initial water Mask
- Probability map
- CLEAR Land cover (TM based)

Target
Remove artificial water body to form noise contained water bodies

Machine Learning

Input Datasets
- Noise contained water bodies
- High Res DEM,
- Probability Map
- River network

Target
eliminate speckle noise and artifacts by strong scatterers in water bodies
Conclusions

I. Power Grid Resilience
   I. Strive towards working with regional or global datasets to drive the scalability of the outage model, and account for the (new) processes that contribute to outages.
   II. Crew allocation, grid restoration, resilience assessment and economic analysis

II. Flood Vulnerability Analysis Framework
   I. Derive distributed flood frequencies and inundations
   II. Use of RS data to derive flood maps
Improving Climate Resiliency at Harvard’s Allston Campus

Michael Flood, AICP

Special Projects Lead
WSP / Parsons Brinckerhoff
Improving Campus Resiliency
Presentation Outline

• Overview of Climate Assessment
• Outline of Recommended Design Practices
• Conclusion
Analyzing Building Resiliency

Climate Risk Assessment Approach

What are projected future conditions?

Define Potential Future Hazard Exposure

- Storm Surge
- Temperature
- Precipitation

What are the water levels or temperature levels that could damage building components?

Define Building Sensitivity

- Building Elevations
- Internal Electrical / Mechanical Systems
- Other Utility Systems

For Assets Where Exposure and Sensitivity Coincide

- What are the assumptions behind projected future conditions?
- How often are impactful events expected to occur in future years?
- What scenarios for future climate are to be used for analysis?
- What is the timeframe of impacts from future hazards?
- Refine Exposure Assumptions

- Which components are of higher or lower risk tolerance for impact due to their relative importance to operations?
- If damaged, what would be the cost of repairs and how long would the building be out of service?
- How much would it cost to alter designs to add resiliency and what impact reduction would be associated with the design?
- Refine Cost and Response Assumptions
Considerations of Risk

Risk Tolerance vs. Asset Value

- Traditional Practice
  - 100 Year Storm

- Risk Based Design
  - Broader Costs
Long Term Vision for Campus
## Climate Impact Risk Assessment

### Gradual Impact:
- Sea level rise, increased precipitation, higher average temperature, water table rise

### Extreme Events:
- Storm surge, heavy downpour, heat wave, high winds

<table>
<thead>
<tr>
<th>HAZARD</th>
<th>TODAY</th>
<th>2020s</th>
<th>2050s</th>
<th>COMMENTS</th>
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</thead>
<tbody>
<tr>
<td><strong>Gradual</strong></td>
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<tr>
<td>Sea Level Rise</td>
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<td></td>
<td>Increasing numbers of buildings will face weekly and daily flooding</td>
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<tr>
<td>Increased Precipitation</td>
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<td>Localized flooding</td>
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<tr>
<td>Higher Average Temperature</td>
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<td>Heat island effect due to large spans of impervious surfaces</td>
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<tr>
<td><strong>Extreme Events</strong></td>
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<tr>
<td>Storm Surge</td>
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<td>Large and growing number of buildings would likely face significant flooding risk</td>
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<tr>
<td>Heavy Downpour</td>
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<td>Localized flooding</td>
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<tr>
<td>Heat Wave</td>
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<td></td>
<td>Indirect impact primarily relating to increased risk of power outages</td>
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<tr>
<td>High Winds</td>
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<td></td>
<td>Building codes need to be calibrated to anticipated wind speeds though in-place stock and equipment may be vulnerable</td>
</tr>
</tbody>
</table>
Climate Impact
Existing Models
Climate Impact
Existing Models
Climate Impact
Future Models
Climate Impact
Future Models

Near End of Century
100 Year (1% Annual) Event

Near End of Century
500 Year (.02% Annual) Event
Comparison
Climate Models

**FEMA - Does not include sea level rise or other climate change related effects**

- Flood levels are referenced in local and national building codes
- Campus is outside 100 year flood plain

**MassDOT - Flood level analysis including climate change effects on sea levels and storm tracks**

- Detailed assessment of combined surge and river discharge
- Parts of campus are identified in future 100, 500 and 1000 year flood plains
Climate Impact
Facility Risk Assessment

Health and Safety Risk
• Loss of Life
• Injury
• Contamination

Asset Risk
• Asset Loss
• Equipment Failure
• Water and Mold Damage
• Finishes and Furnishings

Structure Risk
• Water Pressure
• Erosion
• Roof Damage

Operational Risk
• Loss of Use
• MEP Failure
• System Overload
Protecting Critical Infrastructure
Research on Best Practices
Combined Stormwater / Open Space Design
Climate Resiliency Best Practices
Gradual Impact

Sea Level Rise
• Elevated Structures
• Higher Design Flood Elevation
• Water-tight Construction

Increased Precipitation
• On-site retention
• Pervious pavement
• Use underground storage tanks
• Site grading to slow run-off and enhance filtration
• Perform regular drainage improvements and maintenance
• Build infiltration galleries and French drains
• Use bio-swales and other vegetated on-site water capture systems
Climate Resiliency Best Practices
Gradual Impact

Higher Average Temperature
• Natural ventilation
• Use woody trees and shrubs for grading
• Use vegetated permeable pavements
• Cool roofing techniques
• Added insulation
• Use advanced wall framing techniques to reduce energy loss
• Use thermal mass or building materials that absorb heat energy
• Passive cooling
• Insulate water systems
• Consider thermal energy storage
• Roof mounted heating, ventilation and air conditioning units
Climate Resiliency Best Practices
Extreme Events

Storm Surge
- Dry flood proofing
- Wet flood proofing
- Elevated structures
- Use of flood damage resistant materials
- Water-tight window and door barriers
- Sealed electrical, telephone and fuel line access
Contact Information

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Partners HealthCare’s Response to Climate Resilience

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MGH, Partners Healthcare, Harvard T.H. Chan School of Public Health
Partners HealthCare’s Response to Climate Resilience

Paul D. Biddinger, MD FACEP
Medical Director for Emergency Preparedness
Partners HealthCare
Climate-Related Disaster Patterns are Changing

Historical Data No Longer Sufficient for Good Planning

Massachusetts Historic Snowfall, 2015
Sgt. Michael Broughey, MA National Guard/Wikimedia
https://www.dvidshub.net/image/1782093

Louisiana Floods, 2016
Patrick Dennis/The Advocate via AP
Climate Change and Health

Climate Change and Healthcare

• Increased threats to health mean greater demand for healthcare services

• During a disaster, health care facilities:
  • Care for the newly sick and injured
  • Must continue routine health care services
  • Sometimes serve as a place of refuge for those needing water or electricity

• Hospitals must strive to become more resilient given the impending threats of climate change
  • However, all rely on community infrastructure to some degree
  • Cannot become resilient alone

• According to the US Department of Health and Human Services’ 2014 report: there are several important planning considerations for healthcare with respect to climate change resilience:
  • Health care facilities and services cannot rely on community infrastructure
  • Hardening health care facilities, including hospitals and sub-acute facilities is vital
  • Resiliency includes planning for staffing and supplies in addition to physical structures
  • Green design serves a dual purpose
  • Protecting research must be part of the plan

Climate Change and Healthcare

Sustainable and Climate-Resilient Health Care Facilities Toolkit

This toolkit includes a best practices document, a framework describing affordable measures that can help make health care facilities more resilient, and additional resources for responding to challenges associated with the impacts of climate change.

Tools: Sustainable and Climate-Resilient Health Care Facilities Toolkit

Webpage:
Sustainable and Climate Resilient Health Care Facilities Toolkit

Regions:
Northeast > Infrastructure and the Built Environment

Topics:
Built Environment > Buildings and Structures

Health > Extreme Heat—NIHGIS

Health > Extreme Events

Health > Increased Levels of Air Pollutants

Health > Food- and Water-
Obstacles to Change

Skepticism about climate projections

Difficult to quantify consequential damage from broad data range

Long term cost-benefit analysis competing with short-term essentials

Making the Case

Confirm data sources, establish range of maximum/minimum projections

Assemble comparable case studies with financial quantification, business interruption, etc.

Prioritize critical items vs. medium-term actions integrated in regular budgetary cycle
**Initial Influences**

- Superstorm Sandy’s near-miss to Boston
- Nearby Boston and Cambridge, MA municipal climate assessments

**Initial Goals**

- Identify climate risks
- Identify vulnerabilities
- Review and refine operational protocols
- Prioritize remedial action
Key to Gaining Buy In #1: Phased Approach

PHASE 1
Climate Scenarios Hazard Assessment

- Climate analysis
- Hazard priorities
  - SLR / Storm Surge
  - Precipitation
  - Temperature
  - Wind
  - Seismic

PHASE 2
Vulnerability Assessment

- Critical Facilities and Operations
- Checklist for Risk Assessment
- Prioritize Needs Across System

PHASE 3
Implementation

- Facility Resilience
- Operations Enhancement
- Community Engagement
- Capital Prioritization
- Long-term Adaptation
- Arrange and Align Insurance as needed
Key to Gaining Buy In #2: Dual-Time Horizons

Climate analysis projections

*Value of long view vs. quality of data*

Year: 2000, 2015, 2045, 2055, 2085, 2100

**Near-term strategies**
- Enhance operations
- Deferred maintenance upgrades

**Long-term strategies**
- Comprehensive capital planning
- High performance resilient buildings

Lifespan of typical institutional building 75 years

**Risk = Probability x Consequence**

Where to place the emphasis?

**Probability based**
- Informs capital investment cycle
- 10 year: 10%
- 100 year: 1%
- 500 year: 0.2%
- 1000 year: 0.1%

**Consequence based**
- ‘Worst case scenario’ for emergency operations management. Based on 5 storm models.

- 1% probability of an event occurring in any one year
- = 26% in 30 years
- = 39% in 50 years
Key to Gaining Buy In #3: Multi-Disciplinary Approach

• Real Estate, Facilities, and Engineering
  – Long-term capital planning
  – Energy planning

• Emergency Preparedness/Emergency Management
  – Operational enhancements and business continuity planning
  – Hazard Vulnerability Analysis (HVA) data demonstrated high risk associated with climate disasters

• Risk and Insurance Management
  – Informs, arranges, and aligns insurance coverage as needed
  – Opportunity to identify financial incentives to become more resilient
Identifying Interventions

### Discussing the threats

<table>
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<th>Facility Operations</th>
<th>Infrastructure Vulnerability</th>
<th>Continuity Considerations</th>
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<tbody>
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<td>• Ambulatory Care</td>
<td>• Power – main grid</td>
<td>• Patient transfers</td>
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<tr>
<td>• Ambulatory – Surgical/Procedural</td>
<td>• Power – emergency</td>
<td>• Staff availability/ accommodations</td>
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<tr>
<td>• Emergency Care</td>
<td>• Natural gas</td>
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<td>• Administration</td>
<td>• Water – potable/non</td>
<td>• Hospital as community anchor</td>
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<td>• Storm water</td>
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<td>• Medical waste</td>
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<td>• IT/Communications</td>
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<td>• Transportation</td>
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Future Actions

- Monitoring and improving our patients’ health in the face of climate change
- Advocacy at all levels to combat climate change
- Enhanced enterprise emergency planning
- Medium to long-term capital renovations
  - Consider energy redundancy/independence
- Future construction anticipating change
Conclusions

• Strive to achieve multiple goals through a single project/investment
  – Capital planning
  – Operational enhancements
  – Sustainability
  – Insurance coverage and risk management assumptions

• Challenge long-held assumptions by grounding all phases of the project in data
  – Assumptions may be held by executives, facilities managers, emergency managers, others
Institutional Barriers to Coastal Resilience

Porter Hoagland, Ph.D.

Senior Research Specialist
Wood's Hole Oceanographic Institution
INSTITUTIONAL BARRIERS TO COASTAL RESILIENCE

Porter Hoagland

Marine Policy Center
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EBC Climate Change Program Series
Part Four: Adaptation and Resiliency Programs at Institutions
Take-Away Points

• Coastal resilience is about “bouncing back” from a natural hazard (flooding, erosion, property loss)

• A measure(s) of coastal resilience should be chosen and observed

• (Only then can we know what might lead to it!)

• The coastal environment has been built-out (but it’s still expanding)

• Economic incentives are aligned (and policies have been designed) to protect coastal properties, not to abandon-and-retreat

• Coastal communities have been observed to “bounce back,” but are there net benefits from protection?

Plum Island
Newbury, MA
(March 2013)
• What is “resilience”?
• Why is it needed?
• How can it be measured?
• How can it be achieved?
• Are there obstacles?
What is resilience?

Coastal resilience means building the ability of a community to "bounce back" after hazardous events such as hurricanes, coastal storms, and flooding – rather than simply reacting to impacts.

Communities across the country are increasingly vulnerable.

Resilience is important everywhere because all communities face hazard threats such as droughts and flooding. Coastal areas have additional hazard risk from storms such as hurricanes and increased population pressures, making resilience particularly important.
Vulnerability and Resilience

Resilience metric over time.

- There is a lack of … performance measures for assessing resilience
- Our understanding of the factors that make a natural or social system resilient is limited
- Most communities have had little experience in managing explicitly for resilience
- These issues will need to be overcome before effective resilience-based management can be implemented
Evaluation of Existing Indicators and Indexes

<table>
<thead>
<tr>
<th>INDICATOR OR INDEX</th>
<th>ORIGINS</th>
<th>THEORETICAL GROUNDING</th>
<th>DATA AVAILABILITY</th>
<th>SIMPLICITY</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
<th>OVERALL FEASIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Development Index (HDI)</td>
<td>Introduced in 1990 by the United Nations Development Programme (UNDP) in the first-ever Human Development Report (HDR)</td>
<td>Created to enable social scientists to evaluate development along more than just economic lines, the HDI combines health, education, and income indicators. The American HDI is based on the same dimensions but utilizes more “American” indicators.</td>
<td>HDI – National level; AHDI – Metropolitan, county, and state levels</td>
<td>Medium – Three characteristics are measured and combined.</td>
<td>Scope – The HDI examines more than just income, including two other components of well-being, health and education. Mutability – In 2010, the HDI was modified to account for economic inequality, measured using the UNDP’s Coefficient of Human Inequality. The existence of the AHDI also demonstrates the HDI’s adaptability.</td>
<td>Lack of environmental indicator – Despite its efforts to include additional dimensions of development, the HDI fails to factor in the health of the natural world.</td>
<td>Medium</td>
</tr>
</tbody>
</table>

- Per Capita Personal Income
- Gini Coefficient
- Gross Domestic Product
- Happy Planet Index
- NOAA Coastal Resilience Index
- Resilience Capacity Index
- Social Vulnerability Index
- Hurricane Disaster Risk Index
The “Portland Gale”
(27-28 November 1898)

Humarock’s “Shingle Dyke” breached between Scituate’s Third and Fourth Cliffs
Growth of Coastal Housing on Humarock Beach, Scituate, MA (1880-2016)

George H. Walker Co., *Atlas of Plymouth County, Massachusetts* (1879)
Scituate has ~150 NFIP “repetitive loss properties” (40% of Massachusetts)
Coastal Property Owner’s Decision Problem

- Yohe et al. decision rule

- Socially optimal timing:
  - Delay
  - Protect
  - Abandon

Massachusetts Coast
Massachusetts Coastal Protection \( (n = 3,767) \)

- Seawalls
- Revetments
- Groynes, Jetties
- Bulkheads
- Gabions
- Dune reconstructions
- Beach replenishments

Coastal Structures in Massachusetts
3,767 structures
Data from Massachusetts Office of Coastal Zone Management
Plum Island
(Inlet-associated beach)
Strong Incentives for Property Owners to Protect

<table>
<thead>
<tr>
<th>Environmental/Costal Risk Factor</th>
<th>Effect on Property Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Soft Structure on the Oceanfront*</td>
<td>35%</td>
</tr>
<tr>
<td>Oceanfront</td>
<td>21%</td>
</tr>
<tr>
<td>Private Hard Structure on Basin*</td>
<td>19%</td>
</tr>
<tr>
<td>Basin</td>
<td>16%</td>
</tr>
<tr>
<td>Back-barrier</td>
<td>13%</td>
</tr>
<tr>
<td>Elevation on Pilings**</td>
<td>6%</td>
</tr>
<tr>
<td>Marsh</td>
<td>5%</td>
</tr>
</tbody>
</table>

*Resistance
**Redundancy Contingency
Muir-Wood (2016)
Strong Incentives for Communities to Protect

- Municipal property tax assessments
- Public infrastructure investments (roads, sewer, water)
- Historical tradition of community

Leading to:

- Political pressures (local to state)
- Threats of litigation

Photo: Christin Walth
Are there Net Benefits of Protection?

- **Benefits**
  - Aesthetic views
  - Place to live
  - Beach amenities
  - Recreation
  - Community traditions

- **Costs**
  - Losses of property
  - Risks to human health
  - Protective structures
  - Disaster responses
Should “abandon-and-retreat” be part of the discussion?
Acknowledgements

• Di Jin (WHOI/MPC)
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• Andy Solow (WHOI/MPC)

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• Northeast Regional Sea Grant Consortium Award No. 2014-R/P-NERR-14-1-REG
Casting a Wide Net – Connecticut State Colleges & Universities’ Approach to Hazard Resiliency

Mary House

Senior Principal
Woodard & Curran
Casting a Wide Net
Connecticut State Colleges & Universities’ Approach to Hazard Resiliency

Mary E. House, Senior Principal, Woodard & Curran
Christopher M. Dupuis, P.E. Director of Capital Projects, Connecticut State Colleges & Universities
CSCU

- 17 campuses and System Office located in 15 communities
- Campus-level and system-level leadership
- 85,000 students enrolled, 15,000 degrees awarded annually
- 7,181 FTE faculty and staff
- 13,500,000 GSF, 250+ buildings
- Geographically diverse within the state
- Several coastal campuses
What Do We Mean by the Term ‘Hazard’

- Avalanche
- Earthquake
- High winds
- Hurricanes
- Tornadoes
- Urban Fire
- Floods
- Extreme Heat/Cold
- Drought
- Winter storm
- Ice storm
- Hailstorm
- Tsunami
- Thunder/Lightning
Project Funding

- CSCU took advantage of FEMA’s Hazard Mitigation Grant Program to apply for planning funding to develop a Multi-Campus Hazard Mitigation Plan.
- The State was excited about CSCU’s interest in embarking on hazard mitigation planning due to the large state footprint and valuable assets that could be at risk.
- Plan will help identify cost effective mitigation measures to reduce or eliminate long-term risk to life and property from hazards.
- Allows the campuses to be eligible to receive non-emergency disaster assistance, including state and federal funding for mitigation and recovery projects pre-identified in the hazard mitigation plan.
Hazard Mitigation Planning Process

- The CSCU planning process closely followed FEMA’s recommended four-stage approach.
- Initial and ongoing community support is critical to the planning process.

1. Organize Resources
2. Assess Risks
3. Develop a Mitigation Plan
4. Implement Plan and Monitor Progress
Project Organizational Structure

CSCU Project Manager

Project Steering Committee
- 4 State Universities: Point Person from each
- 12 Community Colleges: Point Person from representative campuses
- Charter Oak State College: Point Person
  Woodard & Curran

Each State University
Hazard Mitigation Planning Committee

Several Community Colleges
Hazard Mitigation Planning Committee

Several Community Colleges
Hazard Mitigation Planning Committee

Charter Oak State College
Hazard Mitigation Planning Committee
Project Team

For a Multi-Campus Plan, it was important to identify:

- Overall CSCU Project Manager and point of contact
- Steering Committee member and primary point of contact at each campus – the selected individual needed to be in a position to assemble a campus-specific team and gather information necessary for plan development.
- Campus Planning Team for each campus, comprised of individuals who represent a cross-section of campus departments and services.
- Other stakeholders from campus and communities – good to work through existing community departments and organizations if possible (e.g. regional planning groups).
**Stakeholder Engagement**

- Leadership and dedicated resources provided at the System level
- Planning teams at the System and campus levels
- Cross section of campus personnel including senior administration, facilities, EH&S, IT, public relations, students, faculty and staff
- Seven formal opportunities for engagement including interviews, topic based meetings, public meetings
- Reached beyond campuses to community emergency management personnel and administration
- Held a total of 10 public meetings, 40 campus meetings, 18 steering committee meetings
- Project team relied on the knowledge and experience of stakeholders to contribute to the hazard rankings and development of mitigation strategies.
Documentation

- CSCU developed and followed a standard documentation protocol for all mitigation planning meetings, presentations and interviews.
- Sign-in sheets, agendas, handouts and Power Point presentations (when appropriate) were prepared for each and every meeting, whether formal or informal.
- Meeting documentation was maintained and included as a Mitigation Plan Appendix. These materials accompanied a meeting summary table within the Plan that demonstrates stakeholder engagement.
Long Project Timeline with Stakeholder Turnover

- Project Timeline
- Project Planning/Data Gathering – April – June 2014
- Campus Kick-Off Meetings – June 2014
- Campus Workshops & 1st Public Meeting – Sept-Nov. 2014
- Mitigation Projects Workshop – Jan/Feb. 2015
- Present Draft Plan to CSCU & 2nd Public Meeting – June-Sept. 2015
- Review and Finalize Plan – Fall 2015
- Submit Draft to State/FEMA – February 2016
- Obtain Approval and Complete Final Presentations – February 2017

Changes in CSCU Personnel

- One Senior Administrator
- One CSCU project manager
- Three DEHMS project managers
- Seven Steering Committee members
Strategy for New Team Members

- Immediate outreach and project orientation
- Collective review of existing project materials
- Planned additional review and interaction time
- Specific campus visit/meeting if necessary
- Supplement campus team with added resources
Communication Strategies

- Multiple communication pathways
- Project web site
- Tag team voice mail and e-mail communications
- Outreach to Superiors if necessary
- Customized approach to stakeholder engagement
- Hands on with face to face interactions
- Staffing of public meetings
- Provided detailed examples – public meeting advertising, data templates
- Took on important tasks – vetting insured values, in-kind labor tracking
Facilitated Campus Specific Discussions

<table>
<thead>
<tr>
<th>Natural Hazard</th>
<th>Frequency</th>
<th>Duration</th>
<th>Severity</th>
<th>Intensity</th>
<th>Probability</th>
<th>Consequence</th>
<th>Total</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Storm/Nor'easter</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1.07</td>
<td>30</td>
<td>2.47</td>
<td>M</td>
</tr>
<tr>
<td>Dam Failure</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>L</td>
</tr>
<tr>
<td>Drought</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1.00</td>
<td>2.00</td>
<td>1.00</td>
<td>L</td>
</tr>
<tr>
<td>Earthquake</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1.07</td>
<td>3.00</td>
<td>3.07</td>
<td>M</td>
</tr>
<tr>
<td>Flood</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1.07</td>
<td>2.00</td>
<td>1.07</td>
<td>L</td>
</tr>
<tr>
<td>Hurricane</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>2.07</td>
<td>5.00</td>
<td>4.07</td>
<td>S</td>
</tr>
<tr>
<td>Thunderstorm/Lightning</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.07</td>
<td>1.00</td>
<td>1.07</td>
<td>L</td>
</tr>
<tr>
<td>Tornado</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1.07</td>
<td>3.00</td>
<td>2.47</td>
<td>M</td>
</tr>
<tr>
<td>Wildfire</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1.07</td>
<td>2.00</td>
<td>1.07</td>
<td>L</td>
</tr>
<tr>
<td>Windstorm</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2.00</td>
<td>3.00</td>
<td>2.00</td>
<td>M</td>
</tr>
<tr>
<td>Winter Related Hazards</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3.00</td>
<td>4.00</td>
<td>3.00</td>
<td>H</td>
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</tbody>
</table>

Existing Buildings  | Date Construction Completed | Gross Square Feet | Building Criticality Value | Factored Square Footage | Building/Total Campus Square Footage | Per Day Loss of Function Cost | Estimated Hazard Specific Loss of Function Days | Loss of Function Cost Per Hazard |
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Student Center</td>
<td>1984</td>
<td>155,582</td>
<td>3</td>
<td>466,746</td>
<td>1.62</td>
<td>$155,545</td>
<td>7</td>
<td>$1,088,817</td>
</tr>
<tr>
<td>Dining Hall</td>
<td>2002</td>
<td>132,600</td>
<td>5</td>
<td>663,000</td>
<td>2.30</td>
<td>$220,948</td>
<td>7</td>
<td>$1,546,635</td>
</tr>
</tbody>
</table>

Criticality Ranking

- **Level 5**: Buildings critical to campus operations and likely to shelter students/faculty:
  - Dining Area/Food Service
  - Dormitories
  - Laboratories and animal research facilities
  - Critical Infrastructure (including IT)

- **Level 4**: Buildings that are less critical but serve a support function:
  - Records/document locations
  - Archives
  - Non-critical but important infrastructure

- **Level 3**: Buildings that are administrative, academic or multi-use.

- **Level 2**: Buildings used for recreational purposes such as Campus Centers.

- **Level 1**: Buildings that are non-essential such as maintenance buildings, storage sheds, etc.
Mitigation Activities & Action Plan

- Identified both Preparedness and Mitigation Projects
- STAPLEE Rankings
- Potential Funding Sources
- Capabilities Assessment
- Fiscal Resources

**Best Management Practice** – Utilized multi-disciplinary team to identify mitigation projects including campus stakeholders, scientists, planners, and engineers
Mitigation Projects with Assigned Responsible Party

STAPLEE Mitigation Projects

<table>
<thead>
<tr>
<th>Hazard Addressed</th>
<th>Project Description</th>
<th>Responsible Party</th>
<th>Objectives Addressed</th>
<th>Estimated Cost</th>
<th>Cost Effectiveness of Activity</th>
<th>Sociably Acceptable</th>
<th>Technically Feasible</th>
<th>Project Benefit Environment</th>
<th>Legal</th>
<th>Economic Benefit</th>
<th>Project Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Expand emergency generator capacity.</td>
<td>Administration</td>
<td>2B, 3B, 5B</td>
<td>$200,000</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Flood</td>
<td>Implement drainage improvements to Administration &amp; Data Center Building</td>
<td>Administration</td>
<td>1B, 5A, 6B</td>
<td>$40,000</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>All</td>
<td>Develop campus GIS to map hazard areas, at-risk structures, and associated hazards to assess high-risk areas.</td>
<td>Administration</td>
<td>1C, 1D, 2C</td>
<td>$15,000</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Mitigation projects aid in **reducing or eliminating risks** prior to a hazard. Preparedness aids a campus in emergency **response** once an event occurs.

Preparedness Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Responsible Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase redundancy in communications systems.</td>
<td>Administration</td>
</tr>
<tr>
<td>Install outdoor public address system.</td>
<td>Administration</td>
</tr>
</tbody>
</table>
Project Benefits

- Project goals accomplished
- Tremendous value in campuses working together
- Uncovered important information - technology vulnerabilities
- Credibility and education about System level support achieved
- Expanded perspective on risk management
- Achieved a more proactive awareness/mindset
Other Benefits

- Developed a complete and accurate list of campus and system assets used for this and subsequent energy master plan
- Improved upon existing information on building insured values
- Developed a working GIS and system wide mapping
- Relationship building and peer to peer connections
- Perspective on value engineering decisions
THANK YOU!

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