Future Proofing Our Floodplains

A Holistic Approach to Maximizing Community Resilience in Changing Climate

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Long Beach, CA

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Hurricane Matthew

- Maximums approx. 16 in across North Carolina on 10/9
Substantial Impacts

FEMA Individual Assistance Claims

During Storm and Immediately After

<table>
<thead>
<tr>
<th>Location</th>
<th>Within 500 year floodplain with damage</th>
<th>Outside 500 year floodplain with damage</th>
<th>Within 100 year floodplain with damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Structural Damage</td>
<td>$19,379,600.00</td>
<td>$18,569,098.00</td>
<td>$12,969,708.00</td>
</tr>
<tr>
<td>Total Content Damage</td>
<td>$19,144,475.00</td>
<td>$9,446,593.00</td>
<td>$14,301,828.00</td>
</tr>
<tr>
<td>Total Damage</td>
<td>$38,524,075.00</td>
<td>$28,015,691.00</td>
<td>$27,271,536.00</td>
</tr>
</tbody>
</table>

Long Term

Fayetteville, NC – Dam Breach damaged homes downstream and reduced value of 70 lake front homes.
How can Communities become more Resilient?
Many Solutions Available...at varying cost.

Limited Resources

Must **Quantify Resilience** to Make Decisions

Maximize Return on Investment
The Importance of Scope

To forecast this,
You have to model this…

https://www.wunderground.com/hurricane/atlantic/2017/hurricane-irma
The Scope of Resilience

https://www.wunderground.com/hurricane/atlantic/2017/hurricane-irma
Natural disasters are simulated at the size and frequency resulting from climate change. Natural disasters result in little drop in prosperity due to preparedness. Recovery is fast. Resumes high rate of improvement quickly. Natural disasters result in large drop in prosperity. Lack of preparedness makes it difficult to recover. Sometimes the situation worsens after the disaster.
Quantifying Resilience Requires Stress Testing

In Stress Testing, we analyze the city over a long planning horizon during business-as-usual and disaster times.

To produce this forecast, must have a City Simulation that:

- Captures **interacting systems** (Economy, People, Infrastructure, Natural)
- Includes **business-as-usual as well as disasters**
- Includes disasters that are **representative of climate change** effects
- Allows for addition of **proposed strategies** and measures their effect
- Includes a long enough time line to measure **return on investment**

25 September 2017
Future Proofing City Simulator
City Simulator Modeling Process

A nested loop to capture city growth and response to hazards

Carbon footprint evaluated from daily travel, city wide power usage, other factors.

Gradually changing threats like rising sea level 3mm per year.

Impacts to ecosystem evaluated.

Percentage growth in economy year over year.

Yearly Loop (2017-2050)

Urbanization impact to floodplains is evaluated.

New commercial buildings are added based on growth rate.

Roads, utilities, schools, churches, are added to fulfill new populations’ needs.

Buildings receive an array of businesses with an array of jobs; new jobs are filled by immigrants or population entering workforce.

New workers receive housing, spouses, children.

Carbon System Changes

Economics

New Places of Work

Workers

New Infrastructure

Families

New Housing

Structures Recover

Disaster?

Structures Affected

Commerce

Work

Daily Loop

Gradually changing threats like rising sea level 3mm per year.

Percentage growth in economy year over year.

New commercial buildings are added based on growth rate.

Buildings receive an array of businesses with an array of jobs; new jobs are filled by immigrants or population entering workforce.

New workers receive housing, spouses, children.
City Simulator Modeling Process

A nested loop to capture city growth and response to hazards

Citizens conduct commerce throughout the day (grocery shopping, etc). This is also tracked.

For workers whose place of work and residence are not in recovery, the commute and daily work activities are tracked.

In each day of the year, a GCM-driven forecast determines if a disaster occurs.

Structures affected by the disaster are identified through flood models, storm surge models, earthquake risk models, etc.

Damage to structures is estimated using damage curves that equate severity of disaster to cost of damage.

If a structure is affected, a recovery curve is established that governs whether the structure is productive or not in the future.
City Simulator Tests Proposed Improvement Scenarios

Policy and planning
- Enforce building buffers along rivers and coast
- Tax incentives for electric cars
- Campaigns to build awareness
- Encouraging living centers
- Mitigation banking
- Mixed use zoning
- Climate-change aware master planning
- Reduction regulations
- Tax incentives for LEED certified buildings

General infrastructure improvement
- Fiber optic network
- Potable water plant
- Residential solar feeding the grid
- Light rail
- Wind farms
- Wastewater collection system
- LID/Green infrastructure

Physical counter measures
- Stormwater storing parking garages
- Raising building
- Natural levees
- Sea walls
- Raising roads
- Injection wells
Case Study:
Las Terrenas, Dominican Republic

- Pop.n – 19,000
- Economy:
  - Tourism
  - Fisheries
  - Agriculture
- 300% growth since 1990
- High immigration
- High unemployment/Poverty
- Large % under 20
- High traffic congestion
- Poor Health
Case Study:
Las Terrenas, Dominican Republic

Total Econ Loss due to Storms - $329M
Case Study:
Las Terrenas, Dominican Republic

Scenario for City Simulator

- **Improve Stormwater system** to handle storms up to 50 year storm (majority of city in floodplain)
- **Add fiber optic telecoms** for city-wide internet access to encourage teleworking/education
- Design new workplaces with **Well Briefing** – User-focused design to improve wellness.
Case Study: Las Terrenas, Dominican Republic

Total Econ Loss due to Storms - $249M
Case Study:
Las Terrenas, Dominican Republic

Fiber Optic Network

City Revenues
$2M

Traffic Congestion
↓27%

Teleworkers
↑700%

Capital Expenditures
↑$0.6M
For 5 years

Operating Expenditures
↑$0.5M

Average Annual City Productivity
$8M

Carbon Footprint
↓250 Tonnes

Sick Days
↓15%

Operating Expenditures
↑$0.5M

Capital Expenditures
↑$2M
For 5 years

Damage from Storms
↓15%

Capital Expenditures
↑$2M
For 5 years

City Revenues
$2M

Operational Expenditures
$0.5M
Case Study:
Cumberland County, NC; Hurricane Matthew Response

Population:

<table>
<thead>
<tr>
<th>Cumberland County, North Carolina / Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>325,871 (2013)</td>
</tr>
</tbody>
</table>

General Statistics (used for model calibration)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Current Population</td>
<td>327127</td>
</tr>
<tr>
<td>Current Num Jobs</td>
<td>92537</td>
</tr>
<tr>
<td>Current Employer Establishments</td>
<td>5689</td>
</tr>
<tr>
<td>Non-Employer Establishments</td>
<td>17167</td>
</tr>
<tr>
<td>All Firms</td>
<td>21117</td>
</tr>
<tr>
<td>Current Total Payroll</td>
<td>$3,079,679</td>
</tr>
</tbody>
</table>
Case Study:
Cumberland County, NC; Hurricane Matthew Response

- 33 Years
- $429B Earned
- 3.9B Work days
- 32M Sick Days
- 7.8T Commutes
- 2 Large Hurricanes (average per forecast ensemble)
Case Study:
Cumberland County, NC; Hurricane Matthew Response

**Scenario 1**

- Acquire All properties in 500 year Floodplain that were damaged in Matthew
- Reconstruct Dams with Hardened Dam Tech ($1M per reconstruction) – implies no damage for Matthew-sized storms and lower.

**Scenario 1 vs. Base**

*Lower Cost* - Acquire damaged properties and use hardened dams

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25 September 2017
Case Study: Cumberland County, NC; Hurricane Matthew Response

**Scenario 2**

- Acquire All properties in 500 year Floodplain
- Reconstruct Dam with Earth Dam Tech ($500K per reconstruction)

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**Scenario 2 vs. Base**

**Expensive** – Acquire all properties, replace dams with same earth/fill construction

- Land Acquisition
  - CapEx $315.4M
  - OpEx $0.0M
  - Flood Loss Avoided +$8.6M /yr
  - Building Recovery Days -43 days /yr

- Reconstruct Existing Dam
  - CapEx $4.5M
  - OpEx $0.0M
  - Real Estate Value Loss Avoided +$4.2M /yr
  - Tax Revenue +2% /yr

- City Productivity +$9.3M /yr
Case Study: Cumberland County, NC; Hurricane Matthew Response

Conclusions:

1. With 1/6\textsuperscript{th} of budget of acquiring all properties in 500 year floodplain can achieve high percentage reduction in flood damage and building recovery days.

2. Costs less to harden dams than to continue re-building as earth dams over long run.

3. Either approach for dams costs less than real estate value lost from losing lake front properties.

4. Overall city productivity gain is about 10\% of total capital expenditure – recouped in 10 years.
Next Steps

• **Continued Development**
  - Improved Climate Change-based Forecasts
  - Improved Uncertainty Analysis
  - Different Disaster Types (Heat Wave, Fire, Earthquake)
  - Expanded Economic and Social Analysis
  - Transportation Analysis – including SMART City elements
  - Expand 3D presentation capabilities for stakeholder communication

• **Used in National FEMA Tools**

• **Cornerstone of Atkins Resiliency Planning Process**
Questions and Discussion