Adapting the Federal Emergency Agency’s Hazus Flood Model for Curitiba, Parana - Brazil

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Outline

- Hazus
  - Background
  - International Methodology
- Curitiba, Brazil Hazus International Methodology
  - Citywide building inventory
  - Hydrologic and Hydraulic model
  - Essential Facilities
- Future Enhancements
Hazus Risk Assessment Tool

• Earthquake, flood and hurricane wind modules
• Tsunami model coming 2017
• Developed in conjunction with the National Institute of Building Sciences
• Runs on ESRI ArcGIS 10.4
• Largest extension of ArcGIS
• Over 200 data layers – all open source
Supported Hazards

- Hurricane Wind
- Riverine and Coastal Floods
- Earthquakes
- Tsunami’s (2017)
Hazus\GIS

- Results identify specific and general vulnerabilities
- Visually displays impacts to key decision makers and the public
- Calculates scientifically-defensible damages, economic losses, and mitigation benefits
- Facilitates a risk-based approach to prioritize mitigation strategies that maximizes the return on investment
Hazus MH – Features

- Earthquake
- Flood
- Hurricane

FEMA
Hazus is Multidisciplinary

- Subject Matter Experts/User Groups
  - GIS experience
  - Engineering expertise
  - Hazard information (seismologist, geologist, meteorologists)
  - Social scientist (housing)
  - Emergency management community
  - Decision/policy makers
Brief History

- Project started back in 1992
- Replace “black box”
- Provide national capabilities
- Earthquake model functional since 1997
- 1,000’s of HAZUS users
  - Local, State, & Federal Agencies
  - Private Sector
  - Universities
HAZUS Applications

- Natural Hazards Identification
- Comprehensive Risk Assessment
- Inventory Modeling

Mitigation Strategies
- Performance Measures
- Building Code Administration
- Future Land Use Planning

Response and Recovery
- Quick Situation Assessment
- Ground Truthing

Awareness and Preparedness
- Planning and Exercise Scenarios

FEMA
Hazus International Flood Application
Curitiba, Parana: Population 1.8M
Building Inventory – US Model Data

• **Demographics** – Population, Employment, Housing
• **Building Stock** – Residential, Commercial, Industrial
• **Essential Facilities** – Hospitals, Schools, Police Stations, Fire Stations
• **Transportation** – Highways, Bridges, Railways, Tunnels, Airports, Ports and Harbors, Ferry Facilities
• **Utilities** – Waste Water, Potable Water, Oil, Gas, Electric Power, Communication Facilities
• **High Potential Loss Facilities** – Dams and Levees, Nuclear Facilities, Hazardous Material Sites, Military Installations
Building Inventory – Curitiba Model Data

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Building Inventory

- Building Points, Parcels
- Citywide inventory, over 335,000 structures

Hazus Structure Specific Attributes
Required:

- Occupancy type
- Number of stories
- First Floor Height
- Foundation Type
- Building Value, Contents (optional)
Essential Facilities
Hydrologic and Hydraulic Model

Hazus Flood Stream Delineation – Flow Direction

- Direction in which water would flow if poured at that cell onto the terrain
- 8-direction pour point model: steepest downslope neighbor
Curitiba Stream Network

- Stream network is created using Hazus H&H pour point model
- 10 meter DEM from AguasParana
- Plans to incorporate LIDAR soon
Hydraulic Analysis Options

- Select level of flood to analyze for each selected stream reach.

Analysis Options:
- Suite of return periods
- Single return period
- Single discharge
## Manning’s (n) Examples

<table>
<thead>
<tr>
<th>Manning Coefficient (n) Value</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.011 - 0.015</td>
<td>Concrete</td>
</tr>
<tr>
<td>0.025 - 0.040</td>
<td>Rock cuts</td>
</tr>
<tr>
<td>0.028 - 0.035</td>
<td>Gravel</td>
</tr>
<tr>
<td>0.040 - 0.070</td>
<td>Cobbles with large boulders</td>
</tr>
<tr>
<td>0.080 - 0.140</td>
<td>Dense brush</td>
</tr>
</tbody>
</table>

Lower value: Smoother  
Higher value: Rougher

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Discharge Values Sources – USGS

http://waterdata.usgs.gov/nwis/rt
### Curitiba Discharge Values Sources – Institute of Research and Planning (IPPUC)

**Riverine Hydraulic Analysis**

**Analysis type:** Single Discharge

**Output cell size:** 10.0089267937621

**River reaches**

<table>
<thead>
<tr>
<th>Reach ID</th>
<th>Discharge (cfs)</th>
<th>n-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>329</td>
<td>129</td>
<td>0.080</td>
</tr>
<tr>
<td>331</td>
<td>99</td>
<td>0.080</td>
</tr>
<tr>
<td>332</td>
<td>111</td>
<td>0.080</td>
</tr>
</tbody>
</table>

**Layers**

- ChosenReaches
- Reaches
- Flow_Model_100_Year_Return
- RegionDEM: Value (High: 3418.88, Low: 2783.8)
- Census Blocks: Census Blocks
- Census Tracts: Census Tracts
- Hillshade: Value (High: 254, Low: 0)
- Study Region Boundary: Study Region Boundary

**Study Region Boundary**

- Bacias_High_Resolution
- Flow_Model_10_Year_Return
- Flow_Model_100_Year_Return
- Flow_Model_25_Year_Return
- Flow_Model_50_Year_Return
Hazus Structural Flood Loss Method
Specific Occupancy Depth Damage Functions
Based on flood depth at location and flood vulnerability attributes
- Occupancy type
- Number of stories
- First Floor Height
- Foundation Type
- Building Value, Contents (optional)
# US Hazus Model Loss Estimation Outputs

<table>
<thead>
<tr>
<th>Damage Type</th>
<th>Earthquake</th>
<th>Flood</th>
<th>Hurricane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ground Shaking</td>
<td>Frequency Depth</td>
<td>Pressure</td>
</tr>
<tr>
<td>Direct Damage</td>
<td>Ground Failure</td>
<td>Discharge Velocity</td>
<td></td>
</tr>
<tr>
<td>General Building Stock</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Essential Facilities</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>High Potential Loss Facilities</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Transportation Systems</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Utility Systems</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Induced Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire Following</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Hazardous Materials Release</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Debris Generation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Direct Losses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Repair</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Income Loss</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Crop Damage</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Casualties</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Shelter Needs</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Indirect Losses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Shortages</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sales Decline</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Opportunity Costs</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Economic Loss</td>
<td>✓</td>
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Curitiba, Brazil Hazus Model Loss Estimation Outputs

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### Direct Damage
- General Building Stock
- Essential Facilities
- High Potential Loss Facilities
- Transportation Systems
- Utility Systems

### Induced Damage
- Fire Following
- Hazardous Materials Release
- Debris Generation

### Direct Losses
- Cost of Repair
- Income Loss
- Crop Damage
- Casualties
- Shelter Needs

### Indirect Losses
- Supply Shortages
- Sales Decline
- Opportunity Costs
- Economic Loss

FEMA
Flood Model Results

Legend
Structural Flood Damage
BldgDmgPct
- 0.000000 - 2.548632
- 2.548633 - 7.312988
- 7.312989 - 13.144532
- 13.144533 - 28.442380
- 28.442381 - 54.732914
Future Enhancements/Next Steps

- Review of depth damage functions for Brazil
- Review of occupancy types assigned
- Addition of building/content values for economic analysis
- Incorporation of LIDAR
- Assignment of Manning's-N values using land use/land cover data
- Development of various planning scenarios, comparison to recent large scale events for calibration
Questions?

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