Evacuation and Resilience Practice and Research

Brian Wolshon
Louisiana State University

Gulf Coast Center for Evacuation and Transportation Resiliency

Making Cities Resilient Exchange

February 25, 2015
What is Disaster Resilience?

• The term "resilience" means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions*

• In the context of community resilience, the emphasis is not solely on mitigating risk, but implementing measures to ensure that the community recovers to normal, or near normal function, in a reasonable timeframe.

*As defined in Presidential Policy Directive 21.
Resilience Concept

Maintain acceptable levels of functionality during and after disruptive events

Recover full functionality within a specified period of time

Functionality

Lost Functionality

Residual Functionality

Time to Full Recovery

Adapted from Bruneau, 2003 and McDaniels, 2008
Attributes of Resilience

- Functionality – Resilience should be based on the ability of social systems to resume function within a prescribed period of time following an expected event. Buildings and infrastructure must be functional to support these social systems.

- Interdependence – Resilience must consider the interdependence of buildings and infrastructure (functionality) and the relationship of individuals and organizations with the built environment.
# Performance Levels for After-Event Evaluations

<table>
<thead>
<tr>
<th>Category</th>
<th>Infrastructure System Performance Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Resume 100% service within days</td>
</tr>
<tr>
<td>II</td>
<td>Resume 90% service within weeks and 100% within months</td>
</tr>
<tr>
<td>III</td>
<td>Resume 90% service within months and 100% within years</td>
</tr>
</tbody>
</table>
Disaster Resilience Framework 1.0

- The Disaster Resilience Framework 1.0 will focus on the role that buildings and infrastructure lifelines play in ensuring community resilience.
- The Framework will:
  - Establish types of performance goals and ways to express them
  - Identify existing standards, codes, and best practices that address resilience
  - Identify gaps that must be addressed to enhance resilience
  - Capture regional differences in perspectives on resilience
- The Disaster Resilience Framework will be informed through a series of stakeholder workshops.
Evacuation Basics

• TEMPORAL AND SPATIAL

• Hazard Characteristics
  – Scale (how “big?” -> How far to evacuate), Amount of advanced notice, Shelter-in-place options

• Evacuee Characteristics
  – Who are they? Where are they? How many? How mobile? Behavior (if/when will they leave?), What are their needs?

• Transportation Resources
  – Modes, Highway Transit, Traffic Control, Traffic Management

• Communications

• To/from, Across and between all levels, jurisdictions, agencies, and evacuees, Need for situational awareness
Evacuation by Hazard (1990–2003)

<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake</td>
<td>2</td>
</tr>
<tr>
<td>Fixed Site Hazmat Incident</td>
<td>33</td>
</tr>
<tr>
<td>Flood</td>
<td>47</td>
</tr>
<tr>
<td>Hurricane</td>
<td>22</td>
</tr>
<tr>
<td>Malevolent Act</td>
<td>13</td>
</tr>
<tr>
<td>Pipeline Rupture</td>
<td>6</td>
</tr>
<tr>
<td>Railroad Accident</td>
<td>25</td>
</tr>
<tr>
<td>Tornados</td>
<td>15</td>
</tr>
<tr>
<td>Tornados and Flooding</td>
<td>4</td>
</tr>
<tr>
<td>Transportation Accident</td>
<td>5</td>
</tr>
<tr>
<td>Tropical Storm</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
</tr>
<tr>
<td>Wildfire</td>
<td>56</td>
</tr>
</tbody>
</table>

(Source: F. Walton, Sandia National Laboratory)
Hurricane Rita Evacuation - Interstate 45 (north of Houston)

Photo Source: Lt. John Denholm
Harris Co. (TX) Sheriff's Office
Recent History in Louisiana
Recent History in Louisiana

• Prior to Hurricane Georges in 2000, there was no regional traffic management plan in LA
• No “designated” evacuation routes
• 1st plan was developed in 2000 and included contraflow in New Orleans
• Used for the first time in 2004 for Hurricane Ivan - with questionable results
• “Revised plan” was developed in 2004-2005 and implemented for the first time for Hurricane Katrina
• Evacuation was quite effective for those with the desire and means to evacuate
• Plans for the evacuation of low-mobility populations were obviously “lacking”
Primary Evacuation Routes
In the "Ivan Plan"
Normal Flow
Contraflow
Problems Identified in Ivan

- An over-reliance on the westward movement of traffic
- Confluence congestion created by the confluence of major evacuation routes in Baton Rouge, Hammond, Lafayette, Covington, and Slidell
- Inefficient loading of contraflow in New Orleans
- Inability to access up-to-date traffic information and provide timely and accurate traveler information to evacuees
New Orleans Contraflow Initiation Point
Hurricane Ivan Evacuation - Interstate 10 (west of New Orleans)
Total Traffic Volumes for Evacuation
WB I-10 at Loyola Dr
09/13/04 - 09/15/04

- Speed drops from 55 to 20 mph
- Additional capacity from Contraflow
- Normal Daily Flow
- Contraflow Started

Figure Source: LaDOTD
48-hour Traffic Volume Counts
September 14th and 15th, 2004

W.B. I-12: 73,550 veh.
W.B. US190: 54,847 veh.
W.B. I-10: 79,417 veh.
W.B. I-10: 126,241 veh.
W.B. I-10: 30,644 veh.
Total Traffic Volumes and Speeds for Evacuation
WB I-10 at Mississippi River Bridge
09/13/04 - 09/15/04

Figure Source: LaDOTD
Proposed Solutions

- Maximize the available routes out of the New Orleans area
- Improve the loading of contraflow segments in New Orleans
- Mitigate (eliminate?) the congestion in Baton Rouge
- Inability to access up-to-date traffic information and provide timely and accurate traveler information to evacuees
New Orleans Alternatives

<table>
<thead>
<tr>
<th>Scenario</th>
<th>12h volume at max. flow</th>
<th>Evacuees moved</th>
<th>Increase over no-c/f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ivan w/o contraflow</td>
<td>49,464 veh</td>
<td>123,660 people</td>
<td>-----</td>
</tr>
<tr>
<td>Ivan w/contraflow</td>
<td>67,224 veh</td>
<td>168,060 people</td>
<td>35.9%</td>
</tr>
<tr>
<td>I-10/I-610 Loading Plan</td>
<td>97,572 veh</td>
<td>243,930 people</td>
<td>97.3%</td>
</tr>
</tbody>
</table>
Baton Rouge Alternatives

<table>
<thead>
<tr>
<th>Location</th>
<th>Ivan</th>
<th>Speed</th>
<th>Flow Rate</th>
<th>w/Contraflow</th>
<th>Speed</th>
<th>Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-12 (bef. interchange)</td>
<td>16 mph</td>
<td>2,834 vph</td>
<td></td>
<td>56 mph</td>
<td>5,422 vph</td>
<td></td>
</tr>
<tr>
<td>I-10 (MS River Bridge)</td>
<td>28 mph</td>
<td>4,029 vph</td>
<td></td>
<td>22 mph</td>
<td>4,399 vph</td>
<td></td>
</tr>
<tr>
<td>I-110 (aft. interchange)</td>
<td>48 mph</td>
<td>2,067 vph</td>
<td></td>
<td>55 mph</td>
<td>3,701 vph</td>
<td></td>
</tr>
</tbody>
</table>
The Plan and Its Effects
Duration of Evacuation Volume

Data source: LA DOTD

Ave. of Prior 3 Weeks

Katrina Evacuation

Storm Landfall

Westbound (outbound) Lanes – LaPlace, Louisiana

0 500 1000 1500 2000 2500 3000

THURSDAY FRIDAY SATURDAY SUNDAY MONDAY
**Effect of Contraflow on Traffic Volume**

- **Hurricane Ivan**
  - 9/14 and 9/15, 2004

- **Hurricane Katrina**
  - 8/26 thru 8/29, 2005

**Northbound Volume in “Normal” Lanes**

**Total Northbound Volume**

(Data source: LA DOTD)
Evacuation
Traffic
Control
Examples of Control Devices

[Images of control devices]
Examples of Control Devices
Texas EVACULANE Shoulders

US 290
Houston to Hempstead

EVACULANE OPEN
WHEN FLASHING
1 MILE AHEAD

EMERGENCY USE ONLY
ALL OTHER TIMES
Examples of Control Devices
Variable Message Signs

I-10 WEST
BATON ROUGE
LEFT TWO LANES
Assisted Evacuations
“Low Mobility” Evacuees

• Individuals without personal transportation, elderly, infirm, tourists, economically disadvantaged, prisoners, homeless, etc.

• How many persons fit these description?

• Where are they located?

• Who are they and what are their needs? medicine, oxygen, dialysis, etc.

• Who is responsible for them if they are unable to take of themselves?

• Where do they go? How do they come back?

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Evacuee Categorization

1. Have
2. Ability to evacuate
3. Unwilling
4. Willingness to evacuate
5. Do not have
6. Willing

Quadrants:
- Quadrant I: Have and Willing
- Quadrant II: Have and Unwilling
- Quadrant III: Do not have and Unwilling
- Quadrant IV: Do not have and Willing
• **Existing traffic/transportation simulation systems are not created to model evacuation conditions**
  - Scale (e.g., number of vehicles)
  - Scope (e.g. duration, geographic area)

• **Existing models do not permit the modeling and simulation of multiple modes of transportation simultaneously**

• **Most models are not able to give analysts the MOE’s they’d like or decision-makers the answers to questions they pose**

• **Limited understanding and development of underlying behaviors of evacuation travel for different evacuee and mode types**
Problems of Modeling Evacuation Transportation Plans

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Recognized Limitations

- Existing traffic/transportation simulation systems are not created to model evacuation conditions
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- Limited understanding and development of underlying behaviors of evacuation travel for different evacuee and mode types
Evacuation Modeling
Evacuation Modeling Spectrum

From: “Structuring Modeling and Simulation Analyses for Evacuation Planning and Operations”

By: Hardy, Wunderlich, Bunchand, and Smith
Current Research

• Application of the TRANSIMS system
• Can be used to model very large geographical regions and large numbers of travelers
• Effort and expertise required to code and run
• Issues of verification, validation, and calibration
• Hardware and software requirements
• History, experience, and acceptance within the professional transportation community
• Not developed for the purpose of evacuation
Evacuation Traffic Simulation

• Has proven value
• Permits bottlenecks to be identified and potential solutions to be analyzed before they become problems
• Gives quantitative MOE results to decision-makers
• Allows effects of alternative strategies and adverse conditions to be assessed without consequence

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Recognized Limitations

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TRANSIMS
Project
**TRANSIMS System**

- Incorporates aspects of planning and operations
- Model large geographical regions and large numbers of travelers
- Model populations, travel activities, routing, and analyses it with a microsimulator
- Open source and available
- Effort and expertise required to code and run
- Issues of verification, validation, and calibration
- Hardware and software requirements
- History, experience, and acceptance within the professional transportation community
- Not developed for the purpose of evacuation
TRANSIMS Structure

• **Network Input**
  – *Structure and characteristics of the transportation network (control, capacity, etc.) and activity locations*

• **Population Synthesizer**
  – *Creates a disaggregate synthetic population based on aggregate census zonal information*

• **Activity Generator**
  – *Travel surveys or observation of past evacuations*

• **Router**
  – *Spatial and temporal travel behavior and route assignments*

• **Microsimulator**
  – *Tracks and compiles movements and statistics of each agent (vehicles & peds)*

• **Visualizer**
  – *3rd party developer Balfour Technologies Inc.*
**LSU Study - Approach**

- **Step 1** – Network development
- **Step 2** - “Base Model” validation and calibration based on 2005 Katrina evacuation
- **Step 3** - Code “New” New Orleans multimodal plan
- **Step 4** - “Base Model” validation and calibration based on 2005 Katrina evacuation
- **Step 5** - Code and test alternative plans and ideas

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Volume and Speed
WB I-10 in LaPlace

Network Link 58296  (DOTD Station 54 --2 miles W of US 51/I-55 Jct)
Westbound I-10 Traffic Speed
Volume and Speed
EB I-10 in Slidell
Prior to NB I-59 Contraflow Entry

Network Link 56039 (Near DOTD Station 67 -- 1 mile S of I-12, I-59 Jct)
Volume and Speed
WB US 190 in Baton Rouge

Network Link 57784 (DOTD Station 18 -- 1.1 miles E of O'Neal Ln Jct)
Conclusions

• Evidence that TRANSIMS can be an effective tool for evacuation modeling and planning

• Constituent models can be useful in whole or when used separately

• Development of the TRANSIMS model has added benefits beyond evacuation

• User interface for coding and output results was cumbersome
Assisted Evacuation Modeling
Assisted Evacuations

- Evacuation planning has historically been targeted at persons with personal vehicles.
- A substantial percentage of potential vulnerable populations do not have personal vehicles.
- Plans to evacuate “carless” populations in many locations have been created relatively recently or are currently in development.
- There have been few actual activations to gain knowledge and experience, nor tests, drills or simulations to evaluate potential weakness and needs.
Study Questions

• **Proof-of-Concept** - Can TRANSIMS be used for evacuation analysis? Are its results reasonable?

• **Develop a variety and range of hazard-response scenarios**

• **How many buses might be needed under various scenarios?** What routes should they take?

• **Potential to estimate the number of location of evacuees**

• **Examine the potential of alternate plans**
Research Methodology

• **Model Development**
  – *Spatial distribution, loading, and temporal movements* 40,000 assisted evacuees (including 10,000 tourists)

• **Scenario Development (8 cases)**
  – Routing: I-10 vs. US-61
  – Response “Urgency”: 24, 32, 36, 48 hours

• **MOE’s**
  – Total evacuation time and average travel time

• **Develop and Evaluate Alternative Management Strategies**
  – “Off-peak” movements
  – “Forced” routing
## Quantitative Results

### Total Evacuation Time (hr)

<table>
<thead>
<tr>
<th>Evacuation Scenario</th>
<th>Total Evacuation Time (hr)</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-10</td>
<td>US-61</td>
</tr>
<tr>
<td>A</td>
<td>34.95</td>
<td>32.79</td>
</tr>
<tr>
<td>B</td>
<td>47.27</td>
<td>46.44</td>
</tr>
<tr>
<td>C</td>
<td>29.89</td>
<td>25.76</td>
</tr>
<tr>
<td>D</td>
<td>41.35</td>
<td>36.49</td>
</tr>
</tbody>
</table>

### Average Travel Time (hr)

<table>
<thead>
<tr>
<th>Evacuation Scenario</th>
<th>Average Travel Time (hr)</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-10</td>
<td>US-61</td>
</tr>
<tr>
<td>A</td>
<td>4.81</td>
<td>2.55</td>
</tr>
<tr>
<td>B</td>
<td>5.03</td>
<td>2.84</td>
</tr>
<tr>
<td>C</td>
<td>4.54</td>
<td>2.20</td>
</tr>
<tr>
<td>D</td>
<td>4.80</td>
<td>2.61</td>
</tr>
</tbody>
</table>
Conclusions

• Evidence that TRANSIMS is an effective tool for multimodal evacuation modeling and planning

• Constituent models can be useful in whole or when used separately

• Quantify Process and Evaluate Alternatives

<table>
<thead>
<tr>
<th>Management Strategy</th>
<th>Total Evacuation Time</th>
<th>Average Travel Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off Peak Evacuation</td>
<td>45%</td>
<td>10%</td>
</tr>
<tr>
<td>Alternative Routing</td>
<td>14%</td>
<td>52%</td>
</tr>
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</table>
NCHRP SYNTHESIS 392

Transportation’s Role in Emergency Evacuation and Reentry

A Synthesis of Highway Practice

http://www.trb.org/
Florida Keys Evacuation Planning
Evacuation Planning in The Florida Keys: Unique Challenges and Emerging Knowledge

Brian Wolshon, Ph.D., P.E.
Louisiana State University
Discussion Topics

- **Background on the unique nature of The Florida Keys and the challenges they present to evacuation**
- **Transportation network in The Keys**
- **Social and political concerns influencing evacuation**
- **Transportation analyses and emerging knowledge**
- **Applicability to other locations**
Unique Nature of The Florida Keys

• High risk potential
• Effectively one route out
  • Susceptible to traffic and roadway incidents
  • Use of contraflow is problematic
• Approximately 80,000 resident and tourists evacuees
  • Highest concentration in the Lower Keys
• Long travel distance
• Potential effects of “mainland” traffic
(Map source: 2001 Florida Keys Hurricane Evacuation Study)
Unique Nature of The Florida Keys

• Designated as a Florida “Area of Critical State Concern”
  • Unique nature and value of the area makes The Keys important to the State as a whole
  • State, rather than local government, has authority over many key civil issues

• Evacuation
  • Must be able to undertake a full evacuation in 24 hours

• Growth and Development
  • New construction is limited by the ability to serve water, sewer, evacuation, etc.
Transportation Analysis History

- Long history of traffic analysis and modeling in The Keys

- 2001 Florida Keys Hurricane Evacuation Study (aka “The Miller Model”)
  - Linear model of link flows

- More complex models as part of the Florida Statewide Study

- The models rely on estimates of roadway capacity
General Modeling Process

- **Spatial and temporal generation of travel demand**
  - Who leaves, when do they leave, where do they come from, where do they go, what route(s) do they take?

- **What is the carrying capacity of the road network?**

- **What are the travel conditions?**
  - Speed, travel time, delay, congestion

- **Convert to a clearance time**
Model Findings 2001

- 2001 Florida Keys Hurricane Evacuation Study
  - Examined clearance time under numerous scenarios including existing road configuration and various lane and intersection capacity improvements
- Existing (no-build) condition would result in an clearance time of 25hr 58min
- Through various improvements, it was suggested that this could be lowered to just under 19 hours
  - Lane additions where expected flow were highest – Upper Keys
- FDOT implementing these improvements since

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Research Findings

• Numerous major evacuations (1999 – 2008) afforded the opportunity to collect and analyze flow patterns and characteristics

• The observed data showed consistent patterns that actual flow during events were not consistent with prior assumptions
  • They also vary at different times

• Research suggests the use of “Maximum Sustainable Evacuation Traffic Flow Rates” for modeling and analysis
The anticipated highest vehicle flow rates that can be practically sustained over an extended period of time during an evacuation.

Although Maximum Sustainable Evacuation Traffic Flow Rates are similar to the “capacity” of the road segment, they are quite different.

They vary by segment – and will also vary based on specific conditions that exist at the time of the event.
Louisiana Observations

Northbound Evacuation (2-lane) Traffic Volume - US-61 LaPlace Louisiana
Louisiana Observations

Westbound Evacuation (2-lane) Traffic Volume - US-190 (Mississippi River Bridge departure) Port Allen, Louisiana
Westbound Evacuation (2-lane) Traffic Volume - US-190 (Mississippi River Bridge departure) Port Allen, Louisiana
Louisiana Observations

Westbound Evacuation (2-lane) Traffic Volume - US-190 Port Allen Louisiana
Florida Observations

Westbound SR-528 Traffic Volume Data
Florida Observations

Eastbound SR-528 Traffic Volume Data
Florida Keys Observations

Northbound US-1 Traffic Volume Data at Cow Key Bridge
Hurricane Ivan (top) and Hurricane Frances (bottom)
# Maximum Observed Flows

<table>
<thead>
<tr>
<th>Event</th>
<th>Cow Key Bridge MM 4 (vphpl)</th>
<th>Big Pine Key MM 28 (vphpl)</th>
<th>Key Largo MM 106 (vphpl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurricane Charley</td>
<td>1,125*</td>
<td>1,100*</td>
<td>725*</td>
</tr>
<tr>
<td>Hurricane Francis</td>
<td>800*</td>
<td>595*</td>
<td>450*</td>
</tr>
<tr>
<td>Hurricane Ivan</td>
<td>600*</td>
<td>810*</td>
<td>625*</td>
</tr>
<tr>
<td>Hurricane Wilma</td>
<td>650*</td>
<td>590*</td>
<td>650*</td>
</tr>
<tr>
<td>Hurricane Dennis</td>
<td>650*</td>
<td>1,180*</td>
<td>748*</td>
</tr>
<tr>
<td>Trop. Storm Fay</td>
<td>855</td>
<td>1,030</td>
<td>874</td>
</tr>
<tr>
<td>Trop. Storm Ike</td>
<td>584</td>
<td>680</td>
<td>502</td>
</tr>
<tr>
<td>Highest Hrly Vol. of 2010</td>
<td>1,092</td>
<td>1,066</td>
<td>903</td>
</tr>
<tr>
<td>2nd Highest Hrly Vol. 2010</td>
<td>1,061</td>
<td>1,065</td>
<td>869</td>
</tr>
<tr>
<td>3rd Highest Hrly Vol. 2010</td>
<td>1,058</td>
<td>1,063</td>
<td>849</td>
</tr>
<tr>
<td>4th Highest Hrly Vol. 2010</td>
<td>1,055</td>
<td>1,059</td>
<td>824</td>
</tr>
<tr>
<td>Maximum Sustainable Evacuation Traffic Flow Rates</td>
<td>900 – 1,100</td>
<td>1,050 - 1,100</td>
<td>900 - 1,200</td>
</tr>
</tbody>
</table>

* Denotes approximate value based on graphical data.
## Maximum Sustainable Evacuation Traffic Flow Rates for Hurricane Evacuation Purposes

**US Highway 1 (Overseas Highway) and CR 905/Card Sound Road in the Florida Keys, Monroe County, Florida**

<table>
<thead>
<tr>
<th>Area</th>
<th>Milemarkers From</th>
<th>Milemarkers To</th>
<th>Location/Description</th>
<th>Year 2010 Configuration</th>
<th>Suggested Maximum Sustainable Evacuation Flow Rate per Hour per Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Keys</td>
<td>2.0</td>
<td>4.0</td>
<td>Key West to Stock Island</td>
<td>4L</td>
<td>900</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>4.0</td>
<td>9.0</td>
<td>Stock Island to Big Coppitt Key</td>
<td>4LD</td>
<td>900</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>9.0</td>
<td>17.0</td>
<td>Big Coppitt Key to Sugarloaf Key</td>
<td>2L</td>
<td>1,100</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>17.0</td>
<td>22.0</td>
<td>Sugarloaf Key to Cudjoe Key</td>
<td>2L</td>
<td>1,100</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>22.0</td>
<td>24.0</td>
<td>Cudjoe Key to Summerland Key Cove Airport</td>
<td>2L</td>
<td>1,100</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>24.0</td>
<td>25.0</td>
<td>Summerland Key Cove Airport to Summerland Key</td>
<td>3L</td>
<td>1,100</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>25.0</td>
<td>30.0</td>
<td>Summerland Key to Big Pine Key</td>
<td>2L</td>
<td>1,100</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>30.0</td>
<td>34.0</td>
<td>Big Pine Key to West Summerland Keys</td>
<td>2L</td>
<td>1,050</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>34.0</td>
<td>35.2</td>
<td>West Summerland Keys to Spanish Harbor Keys</td>
<td>2L</td>
<td>1,100</td>
</tr>
<tr>
<td>Lower Keys</td>
<td>35.2</td>
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<td>126.5</td>
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<td>2L/4L</td>
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<tr>
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<td>126.5</td>
<td>HEFT</td>
<td>Card Sound Rd to HEFT</td>
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<td>900</td>
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<tr>
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<td>Int CR 905 / CR 905 A</td>
<td>Lake Surprise to Crocodile Lake</td>
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<td>US 1</td>
<td>Crocodile Lake to South Miami-Dade</td>
<td>2L</td>
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</tr>
</tbody>
</table>

**LEGEND**

- 2L: Two-lane facility
- 2L/4L: Two lanes with short four-lane sections for passing purposes
- 3L: Three-lane facility (center lane is a two-way left-turn lane)
- 4L: Four-lane undivided facility
- 4LD: Four-lane divided facility
- 5L: Five-lane facility (center lane is a two-way left-turn lane)
Model Findings - 2010

- 2010 Statewide Regional Evacuation Study Program Models
  - More than 30 scenarios
  - Using FDOT recommended MSETFR’s
- Will be used by the State of Florida to set policy
- Enormous range of clearance times from 12 - 47 hours, based on amount of population, behavioral response, downstream traffic, etc., etc., etc.
  - Comparable assumptions to 2001 (using MSETFR’s is now about 26 hours)
Conflicting Concerns and Needs

• Improvements would be needed most in Upper Keys to serve Lower/Middle Keys populations

• Additional road capacity would bring more traffic, diminishing the quality of life and the existing nature of The Keys

• Building prohibitions would amount to government “takes” of private property, involving of hundreds of millions

• Compromise?
Current Research
Behavioral Modeling

Forecast time-dependent evacuation demand

Number of evacuations

2-hour time intervals

- Observed
- Predicted
Regional-Level Modeling and Visualization
Scenario Testing and Evaluation

Analysis of “variable” hazards and responses

- **Temporal** –
  - More/less time to evacuate
  - Implementation of phasing strategies

- **Spatial** –
  - Storm size and direction of approach
  - Network management
Future Modeling

- Police enforcement control
- MegaRegion evacuation network analysis
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