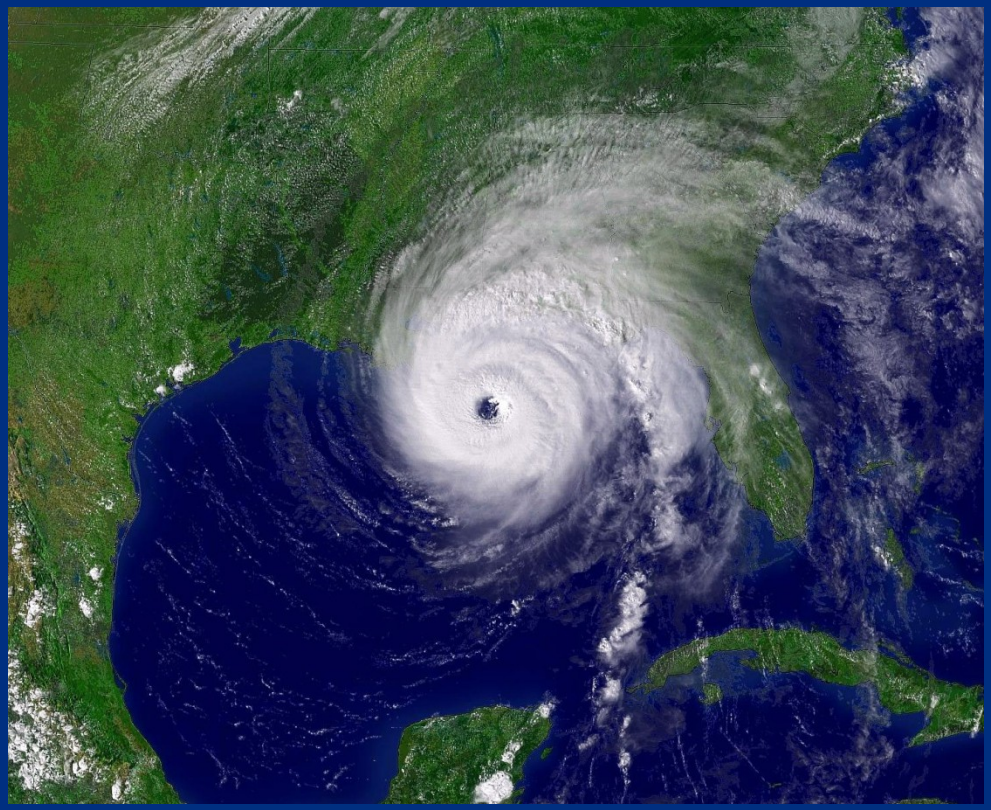
FEMA Mitigation Assessment Team Report on Hurricane Ivan

Bill Coulbourne, P.E.

(for and in memory of

Jim Delahay – LBYD, Inc.)

June 2, 2005



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Presentation Topics

Hurricane Ivan

- Introduction and Background
- Wind Effects
  - Wind Speeds
  - Key Observations
  - Conclusions and Recommendations
- Flood Effects
  - Flood Elevations
  - Key Observations
  - Conclusions and Recommendations

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Hurricane Ivan MAT

September 16, 2004

- Landfall just west of Gulf Shores, Alabama
- On September 18, 2004, FEMA HQ deploys a MAT to support Region IV response
- 10 member team includes
  - FEMA Staff
  - Architects and Engineers
  - Coastal Scientists
  - Building Officials

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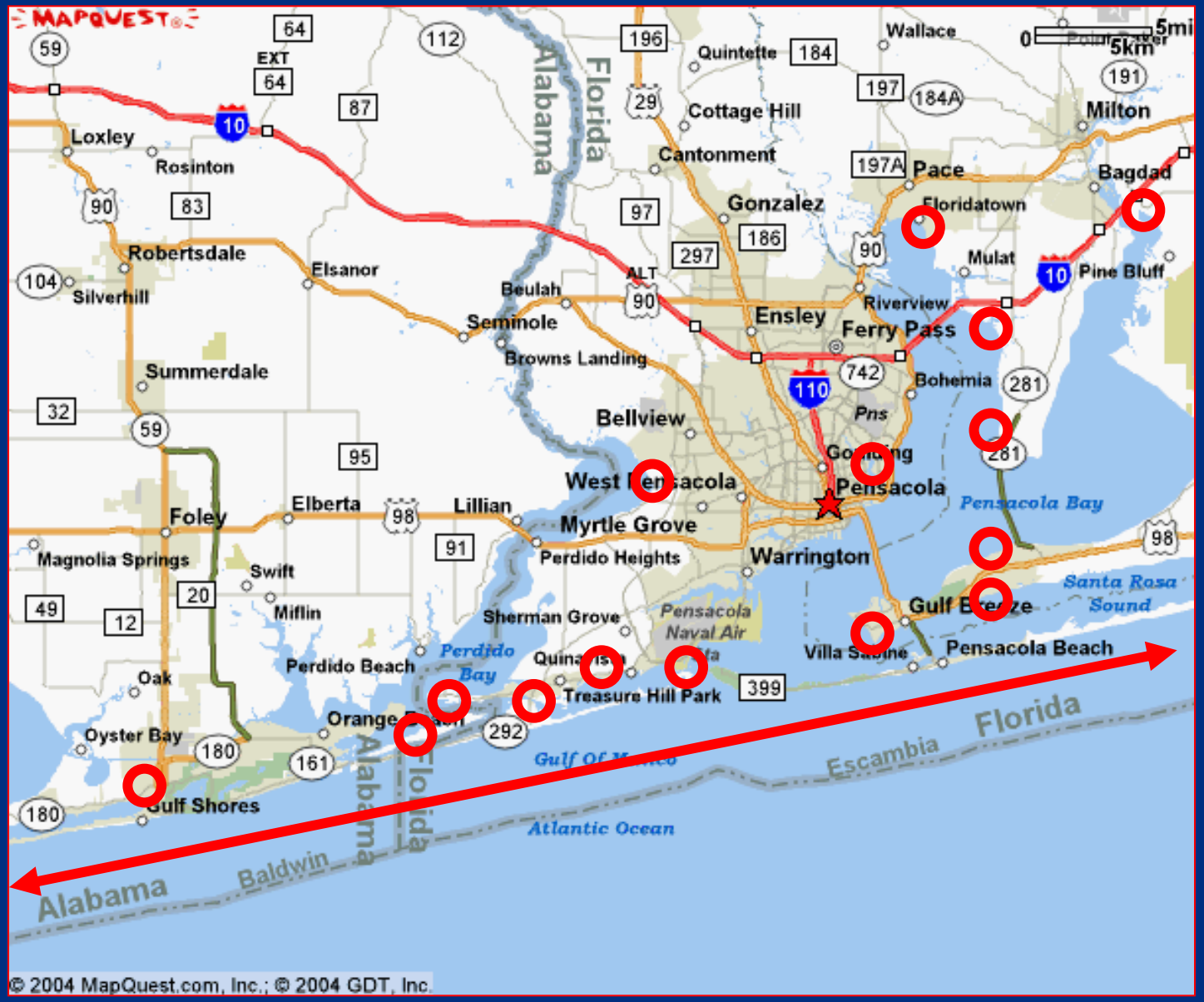
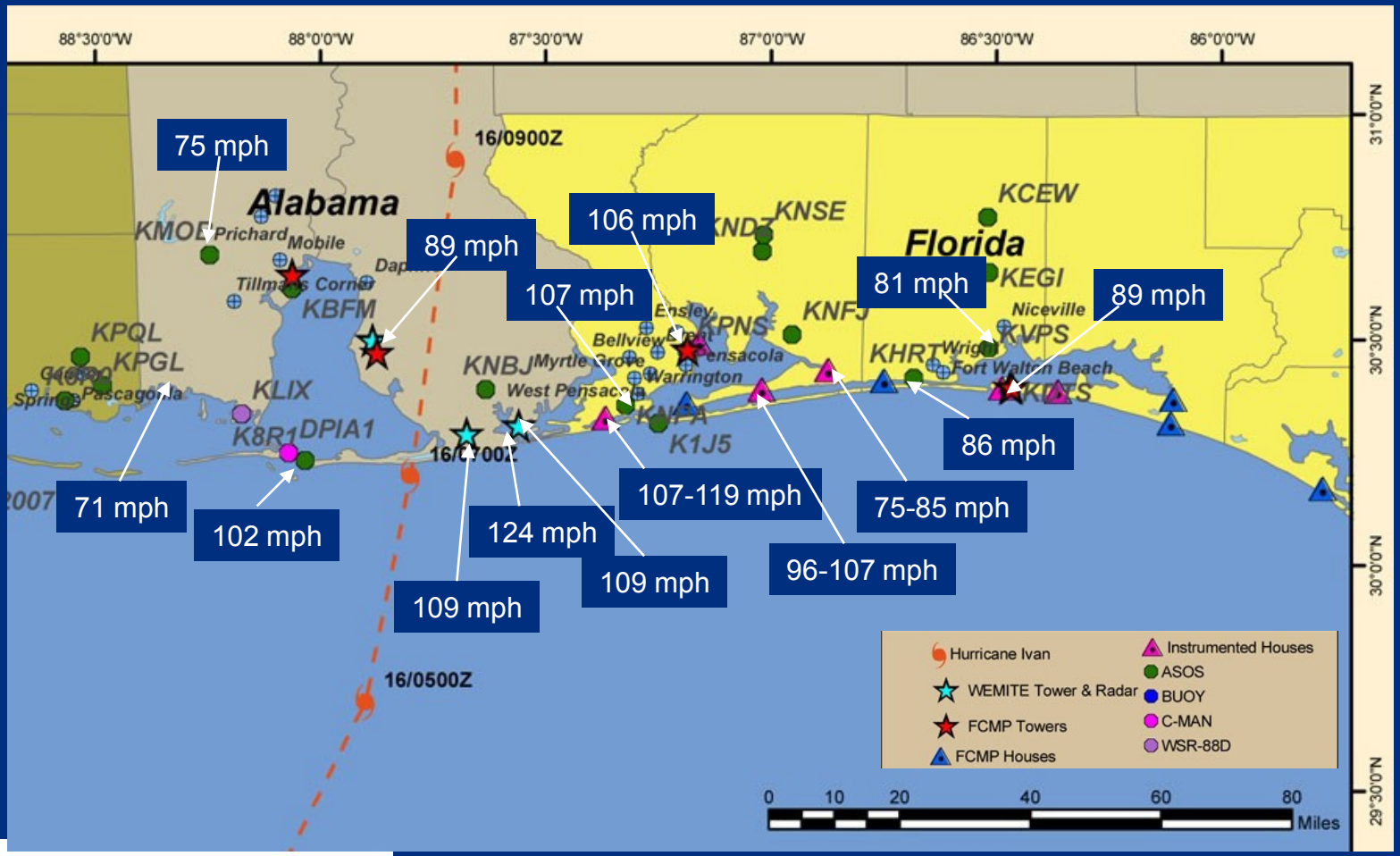
Ivan MAT Coverage Area



3-Second Gust Wind Speeds

From Actual Adjusted Measurements



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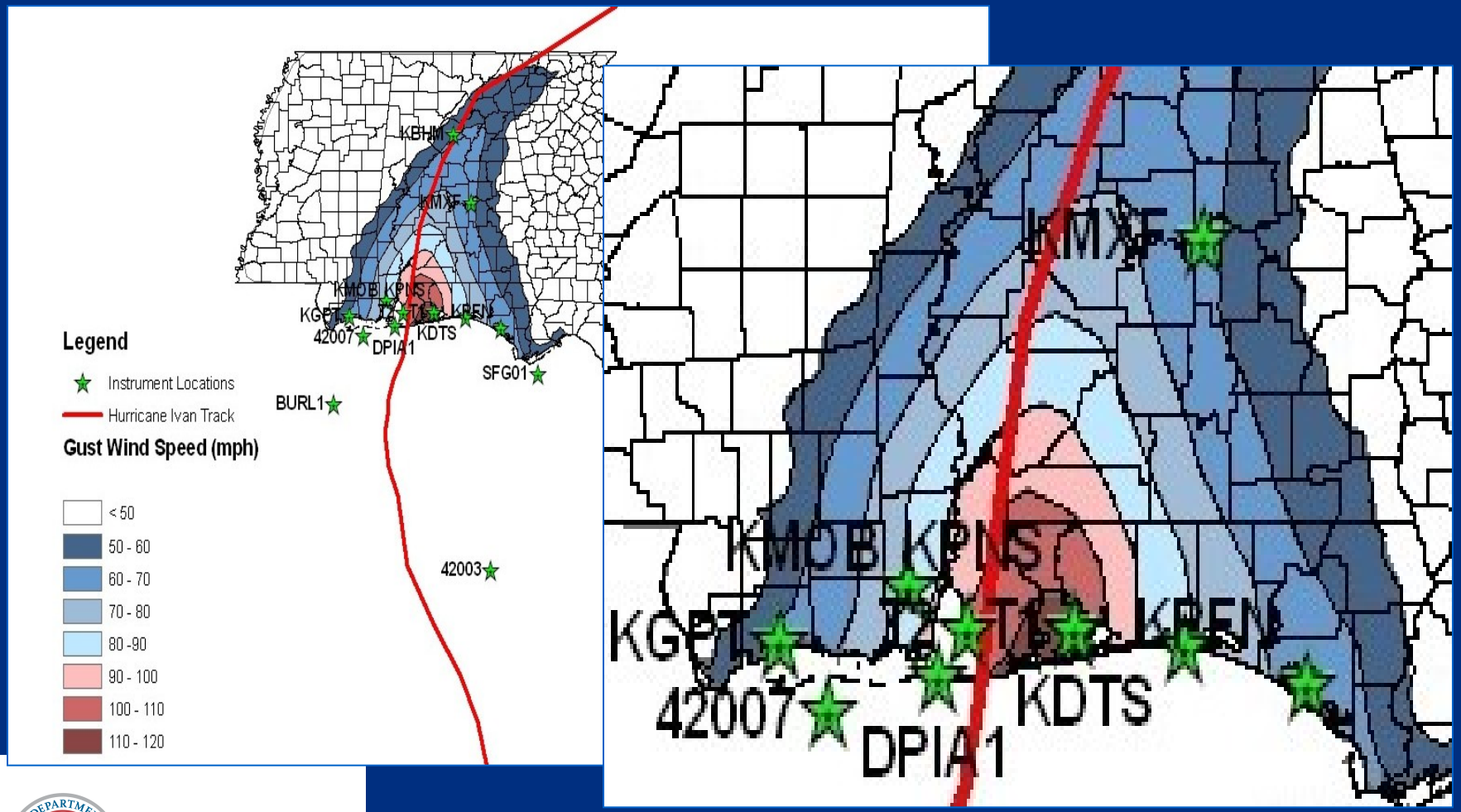
Estimated Wind Speeds

Model-based wind field data



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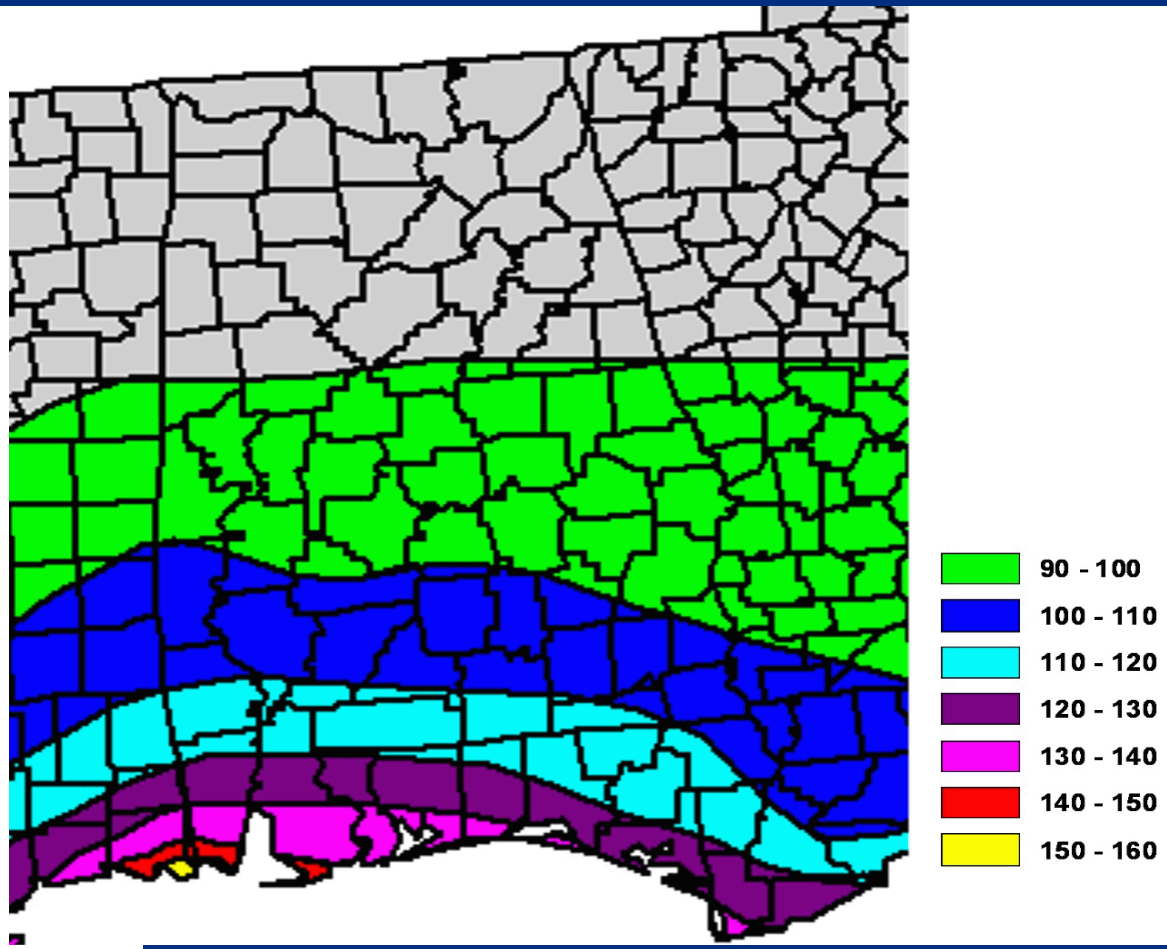
Design Wind Speeds

IBC / FBC / ASCE 7



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Design Wind Speeds

Saffir – Simpson Scale

Hurricane Category	Sustained Wind Speed (1) mph	Central Barometric Pressure inches of mercury	Storm Surge ft	Damage Potential
1	74 - 95	> 28.91	4 to 5	Minimal
2	96 - 110	28.50 - 28.91	6 to 8	Moderate
3	111 - 130	27.91 - 28.47	9 to 12	Extensive
4	131 - 155	27.17 - 27.88	13 to 18	Extreme
5	> 155	< 27.17	> 18	Catastrophic

(1) 1-minute average wind speed at 33 ft (10 m) above open water

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Design Wind Speeds

Past Building Codes – Gulf Shores, Alabama

Description	Standard Building Code 1979 Edition[1,2]	Standard Building Code 1985-97 Edition[1,2]	International Building Code 2003 Edition[1,2]	Maximum Recorded Wind Speed
Basic wind design speed (3-second gust)	126 mph	115 mph	145 mph	117 mph
Wind design pressure on exterior walls As main frame As components and cladding	 +19 psf +/- 26 psf	 +26 psf +31 / -36 psf	 +36 psf +51 / -68 psf	 +26 psf +33 / -45 psf
Wind uplift on roof, 4 in 12 slope As main frame As components and cladding	 -22 psf -22 psf	 -33 psf -64 psf	 -51 psf -99 psf	 -33 psf -64 psf

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Wind Damage - Structural

Gable End Wall Failure

Wind Damage - Structural

Wood Roof Framing Failures

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Wind Damage - Structural

Poorly Constructed New Homes

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Wind Damage - Structural

Connectors in a corrosive environment

Wind Damage - Structural

Metal Building Failures

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Wind Damage - Structural

Unreinforced Masonry Wall Failures

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Wind Damage - Structural

Wall Framing Failures

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Wind Damage - Structural

Wall Framing Failures

Wind Damage - Structural

Wall Framing Failures

Wind Damage - Structural

Roof Deck Failures

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Key Observations

- Wind damage common to roof framing and gable end walls even with wind speeds below design
- Connectors were present on new wood construction but not properly installed
- Galvanized steel connectors do not survive corrosion in a coastal environment
- Unreinforced masonry is typically not adequate in high wind zones
- Breaching of envelope can often lead to structural failures

Wind Damage - Envelope

Cladding Failures

Wind Damage - Envelope

EIFS Failures

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Wind Damage - Envelope

Roof Tile Failures – Wind-Borne Debris

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Wind Damage - Envelope

Brick Cladding Failures – Corrosion of Ties

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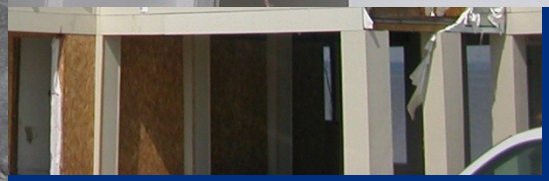
Wind Damage - Envelope

Internal Pressurization



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Success Story

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Key Observations

- Wind damage to roofing and cladding was widespread, even with wind speeds below design
- Metal roof systems clips seemed to be a problem.
- Tile roofs had attachment problems, both in mechanical and foam adhesive
- Shingles that were attached per present code performed much better
- Underlayment often saved the day

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Key Observations

- EIFS and vinyl siding generally performed poorly
- Soffits were a big problem
- Shuttering less common than South Florida, but worked were it was used
- Roof top equipment was heavily damaged
  - Debris from equipment damaged buildings
  - Displacement of equipment led to water intrusion into buildings
  - Damage led to functional downtime that was avoidable

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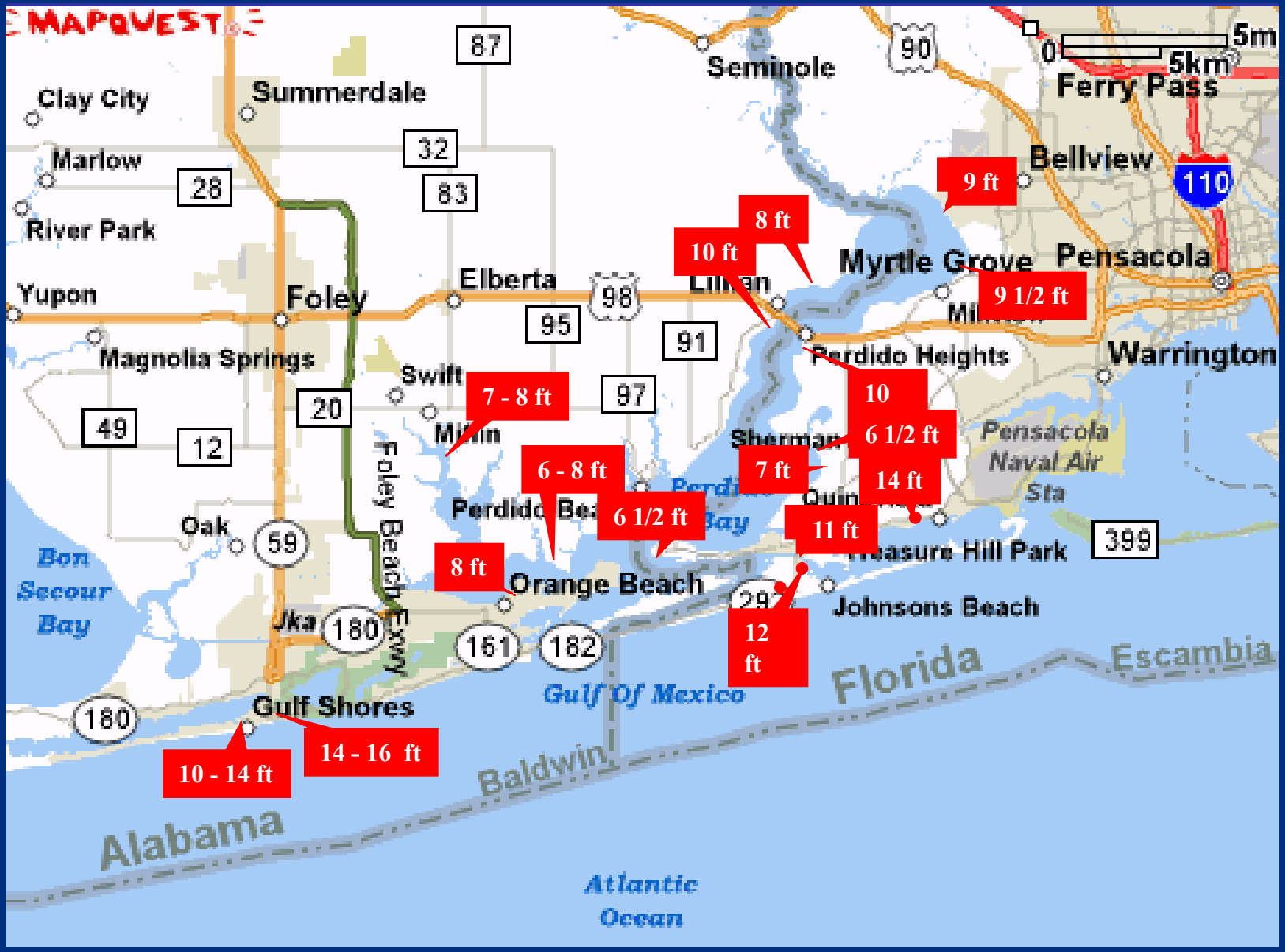
Flood Elevations – Alabama



Flood Elevations - Florida

Flood Elevations

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Flood Damage - Shallow Foundations

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Flood Damage - Shallow Foundations

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Flood Damage - Shallow Foundations

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Flood Damage - Shallow Foundations

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Orange Beach

Flood Damage - Shallow Foundations

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Flood Damage - Shallow Foundations

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Flood Damage - Shallow Foundations

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Flood Damage - Pile Foundations

Success Story

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Flood Damage – Ground Floor Condos

Widespread loss of lower units – Collapse of undermined slabs

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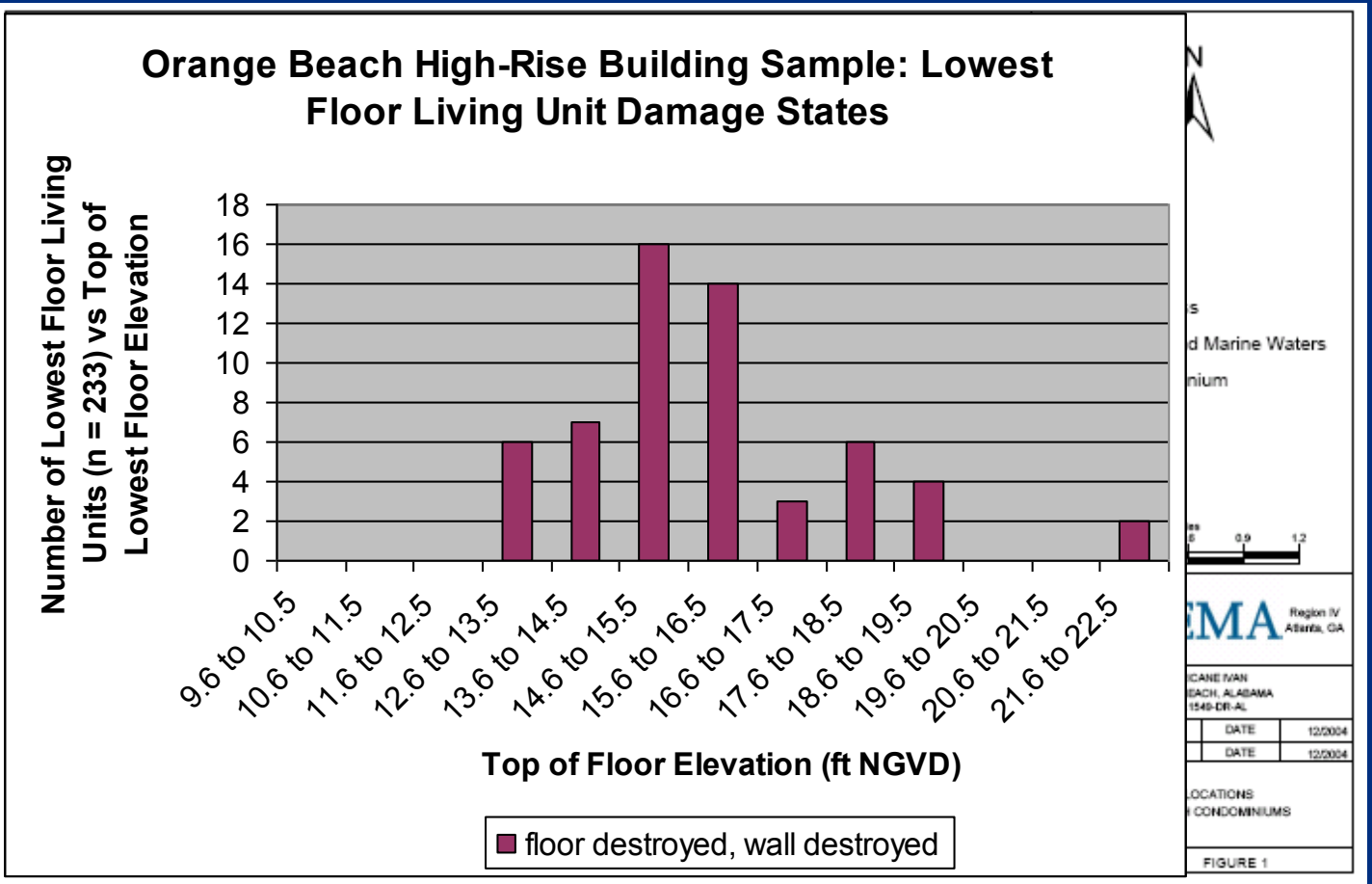
Flood Damage – Ground Floor Condos

39 of 43 high-rise buildings had ground level units



Flood Damage – Beachfront Homes

Loss of pile embedment

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Flood Damage – Beachfront Homes

Loss of pile embedment

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Flood Damage – Beachfront Homes

Framing destroyed by wave action

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Flood Damage – Beachfront Homes

Construction in the V zone

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Flood Damage – Beachfront Homes

Construction in the V zone

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Success Story

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Flood Damage – Bayfront Homes

Flood-borne debris damage
1 year old home

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Flood Damage – Bayfront Homes

Flood-borne debris damage

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Flood Damage – Bayfront Homes

Flood-borne debris damage

Flood Damage – Bayfront Homes

Flood-borne debris damage

Flood Damage – Bayfront Homes

Grand Lagoon Neighborhood

FEMA Flood Recovery Map

Grand Lagoon Neighborhood

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Flood Damage – Bayfront Homes

Flood-borne debris damage – Grand Lagoon Neighborhood
4 fatalities in neighborhood

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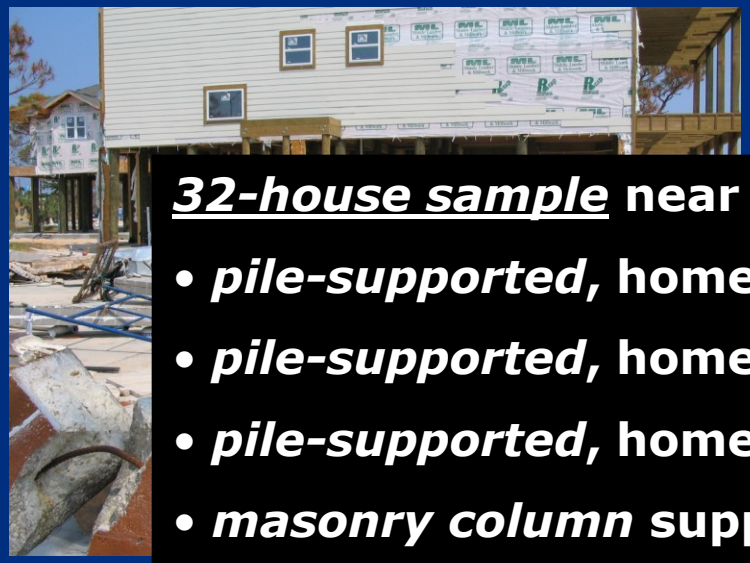
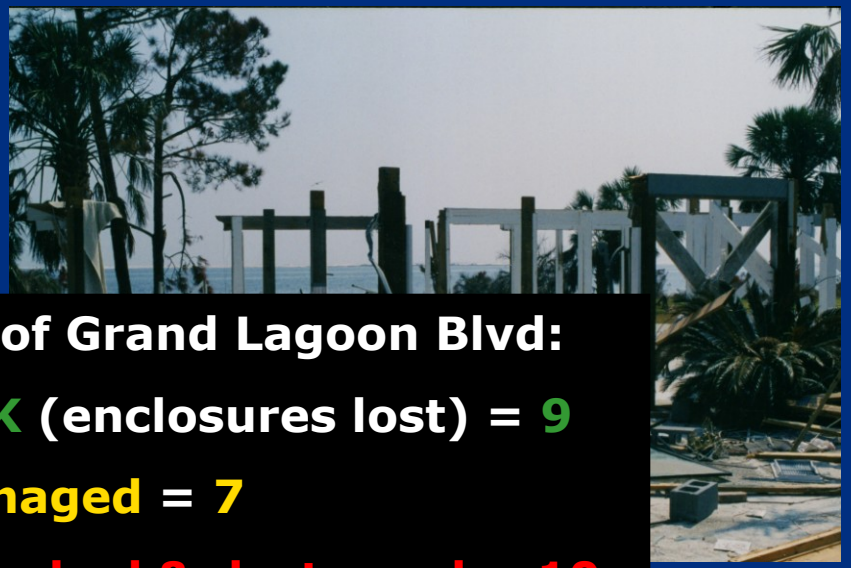
Flood Damage – Bayfront Homes

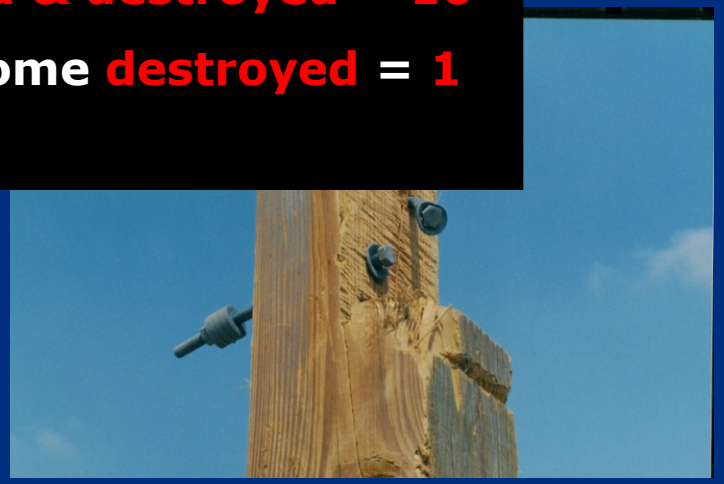
Flood-borne debris damage
Grand Lagoon Neighborhood





32-house sample **near end of Grand Lagoon Blvd:**

- ***pile-supported*****, home ~OK (enclosures lost) = 9**
- ***pile-supported*****, home damaged = 7**
- ***pile-supported*****, home detached & destroyed = 10**
- ***masonry column*** **supported, home destroyed = 1**
- ***slab*****, swept away = 5**



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Flood Damage – Bayfront Homes

Flood-borne debris damage

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Key Observations

Flood Damage

- Flooding several feet above Base Flood Elevation was widespread, especially in bays and sounds
- Floodborne debris damage was extensive
- Collapse of 3-5 story condominium buildings due to shallow foundations on beach
- Older pile foundations lost embedment due to erosion
- Pile cross bracing on older homes was destroyed by wave actions
- Very few pile failures on new buildings

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Key Observations

Flood Damage

Significant difference in wind and flood:

- We design to resist a level of wind force and the resistant has safety factors, so an slight overstress can often be absorbed

- We design to avoid flood forces, so anything above that level is catastrophic

- The difference in the 100 and 500 yr floods is about 25%

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Hurricane Ivan Summary

- Major flood event with heavy V-zone type damage in A-zones
- Major wind damage for a non-code level event
- Structural damage was usually either started from envelope or was a load path issue
- Envelope damage was common, usually due to insufficient number of connectors
- Houses built to new codes performed better than older
- Still need improvement, particularly in enforcement
- Critical facilities plagued by same problems as other construction

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