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Monroe County Hurricane Evacuation Clearance Time—Final Report

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1. Hurricane Evacuation Modeling Generally

The federal government, under FEMA, mandates that all states have comprehensive emergency operations plans for such disasters as hurricanes. The majority of states have a two-tiered approach to emergency planning and response. Evacuation planning, response, and recovery activities are done at the local level (either county or city) while the state is responsible for coordinating local emergency management activities and state-level law enforcement and transportation. The state emergency management agency in Florida plays a larger role in managing and developing evacuation plans than other states since the state of Florida is highly susceptible to hurricanes.

Evacuation models are used to estimate clearance time. Clearance time is the total time it will take to evacuate all anticipated evacuees from the vulnerable area following an evacuation order. Clearance time is calculated by adding the amount of time it takes residents of an area to prepare for an evacuation (mobilization response time) and the amount of time it takes them to leave the area (evacuation time).

Hurricane evacuation clearance times are used as emergency management tools throughout the state of Florida. However, in Monroe County only, estimated hurricane evacuation clearance times are also used for regulatory and growth management purposes. Specifically, since 1992, Monroe County has used clearance times to control the rate of growth in the county, with State of Florida oversight.

In 2005, the Monroe County Year 2010 Comprehensive Plan was amended to establish a three-phase evacuation process, as follows:

Policy 216.1.8 In the event of a pending major hurricane (category 3-5) Monroe County shall implement the following staged/phased evacuation procedures to achieve and maintain an overall 24-hour hurricane evacuation clearance time for the resident population.

1. Approximately 48 hours in advance of tropical storm winds, a mandatory evacuation of non-residents, visitors, recreational vehicles (RV's), travel trailers, live-aboards

(transient and non-transient), and military personnel from the Keys shall be initiated. State parks and campgrounds should be closed at this time or sooner and entry into the Florida Keys by non-residents should be strictly limited.

2. Approximately 36 hours in advance of tropical storm winds, a mandatory evacuation of mobile home residents, special needs residents, and hospital and nursing home patients from the Keys shall be initiated.

3. Approximately 30 hours in advance of tropical storm winds, a mandatory phased evacuation of permanent residents by evacuation zone (described below) shall be initiated. Existing evacuation zones are as follows:

a) Zone 1 – Key West, Stock Island and Key Haven to Boca Chica Bridge (MM 1-6)

b) Zone 2 – Boca Chica Bridge to West end of 7-mile Bridge (MM 6-40)

c) Zone 3 – West end of 7-Mile Bridge to West end of Long Boat Key Bridge (MM 40-63)

d) Zone 4 – West end of Long Boat Key Bridge to CR 905 and CR 905A intersection (MM 63-106.5)

e) Zone 5 – 905A to, and including Ocean Reef (MM 106.5–126.5)

The actual sequence of the evacuation by zones will vary depending on the individual storm.. The concepts embodied in this staged evacuation procedures should be embodied in the appropriate County operational Emergency Management Plans.

The evacuation plan shall be monitored and updated on an annual basis to reflect increases, decreases and or shifts in population; particularly the resident and non-resident populations. [9J-5.012(3)(c)4]

Objective 101.2 of the Comprehensive Plan requires Monroe County to reduce hurricane clearance time to 24 hours by 2010. The Miller Model, developed specifically to estimate clearance time for the Florida Keys, has yet to be tested with a phased evacuation scenario to see if Monroe County meets this objective.

Our charge is to conduct such a test, while updating the model based on 2000 U.S. Census data, recent building permit data, the best available tourist data, all available hurricane survey results, realistic roadway link capacities, and other data that have become available since the last test. This report estimates clearance time under three-phase evacuation for a worst case Category 5 hurricane.

Clearly, estimated clearance time will vary with the assumptions made in the Miller Model update. The matrix in the Appendix at the end of this report sets forth the assumptions proposed by different agencies. This update is based on the assumptions in the Ewing column, which the author views as most realistic.

Conventional Evacuation Models

Conventional hurricane models make use of traditional urban transportation models, the same models used in long-range transportation planning. There are more than 30 transportation

modeling tools that have been used for evacuation modeling. In addition, there are also several specialized transportation planning models that were developed specifically for hurricane evacuation events, including ETIS, HEADSUP, and HURREVAC. These three models are described in more detail below.

There are three basic ways to model a traffic network: macro, micro and meso. The three models differ in terms of scale (geographic area) and the level of detail (how precise the analysis is). Therefore, "[u]nderstanding the potential of transportation modeling to support decision-making for evacuations hinges on identifying those decisions in the process that best lend themselves to the strengths of a particular modeling approach."[1]

Macro models are able to represent a large geographic area such as an entire metropolitan area; however, these models cannot represent individual vehicles or people on the road network. A sub-category of macro models that are time sensitive, real-time decision support tools, are becoming increasingly popular.

Micro models represent only a portion of a road such as milemarkers along an interstate. These models are helpful in modeling smaller sections of a network such as a specific roadway corridor and are able to calculate precise results since individual vehicles are tracked on the network for a small segment of time (normally $1/10^{th}$ of a second).

A third type of model, meso models, are able to represent larger geographic areas than micro models and at the same time are able to allow for more precise results than macro models. In addition, these models are able to represent individual roadway links and vehicles on a network; however, they are not able to represent individual lanes on each roadway segment.

HURREVAC is a macro model designed by the U.S. Army Corps of Engineers for FEMA to assess hurricane evacuation scenarios. The model estimates the amount of time it will take to evacuate an area and can be used to determine the best time to begin an evacuation. The model uses information from the National Hurricane Center, flood estimates from the SLOSH model, and information on the utility of all shelters in the area.

PBS&J developed the ETIS model following Hurricane Floyd. This is a macro-level modeling and analysis system which is primarily comprised of an Internet travel demand forecasting system. The system is able to predict congestion from evacuation traffic as well as traffic flows between states. It allows emergency officials to input the category of storm, the estimated participation rate, tourist occupancy rate, and destination percentages for the counties of concern. With such data, the model is able to output the level of congestion on major highways as well as tables of anticipated vehicle volumes.

The Florida HEADSUP program is used to manage traffic proactively during an evacuation. Although HEADSUP uses the same information as ETIS, the program is more detailed and complete. The program is able to automatically process real-time traffic data from 27 strategically located traffic counters throughout Florida in order to analyze evacuation conditions and assist in emergency management decisions. The program is also able to run hourly dynamic travel demand forecasts, impact analyses of contraflow lanes, socio-economic

[1] Hardy, Matthrew and Wunderlich, Karl. (2007). Evacuation Management Operations (EMO) Modeling Assessment: Transportation Modeling Inventory. Pg. 19.

statistics on evacuees, a map-based user interface, a traffic model that gradually loads evacuees onto the roadway network, and an archival capability which records when key events occurred during a hurricane evacuation.

The Florida Keys Hurricane Evacuation Model, widely known as the Miller Model, is a deterministic model that supplies a specific model output – clearance time – based on such inputs as the number of dwelling units and capacity of roadway links. Miller Consulting developed this hurricane evacuation model in 2000 to measure and analyze the unique characteristics of the Florida Keys and to determine the clearance time required to evacuate the Florida Keys up to Florida City, based on existing US 1 conditions.

The Miller Model was designed to model the behavior of residents and tourists in responding to a mandatory hurricane evacuation order in the Florida Keys and is able to test various scenarios in order to determine the clearance time for each scenario.

State-of-the-Art Evacuation Models

Traditional urban transportation models are static. They do not take into account the dynamic changes that occur in travel behavior during the evacuation process. The static models assume stable conditions both in demand variables and traffic flows.

Haoqiang Fu and Chester Wilmot have developed a sequential logit dynamic travel demand model for hurricane evacuation. The model considers the evacuation order as a time-dependent variable rather than a static variable and thereby analyzes both the impact of the type and timing of evacuation orders. The model divides evacuation time into discrete intervals; the probability of a household evacuating in a particular interval is the product of the probability of evacuating in that time period and the product of the probability of not evacuating in all earlier time intervals. The model is also designed to test phased evacuation.

Fu and Wilmot used a small dataset from Southeast Louisiana from Hurricane Andrew to develop their dynamic model. Due to the limitations with the size of this dataset, Fu and Wilmot then estimated a similar sequential logit model using a larger dataset from South Carolina collected after Hurricane Floyd.

This model is considered state-of-the-art because it is able to analyze the impact of the type and timing of evacuation orders. Fu and Wilmot used the model to better understand household evacuation behavior under different evacuation order conditions. The model can also be used to study the impact of a variety of factors such as the type and location of the residence, and storm-specific characteristics such as wind speed, forward speed, and the path of the hurricane.

Monroe County could benefit from developing a dynamic model for future hurricane evacuation updates. It would provide a more accurate measure of clearance time than the currently used evacuation response curves.

2. The 2001 Study

While other modeling options exist and may be pursued in the future, time and budget limitations under our contract led to a decision to update a conventional model developed in the *2001 Keys Hurricane Evacuation Study* (the 2001 Study). The conventional model is widely referred to as the Miller Model. The model is a spreadsheet-based program executed in Microsoft Excel. The model is comprised of 39 Excel spreadsheets, 31 of which relate to individual roadway segments. The 31 roadway segments are defined by roadway cross-section, capacity, and mile markers. The model is deterministic, predicting evacuation movement link-by-link, in 2-minute increments, assuming a 30 mph average driving speed.

Clearance Time

There are different definitions of clearance time, depending on the hurricane model that is utilized. The 2001 Study definition is:

> "…the time required to clear the roadways of all vehicles evacuating in response to a hurricane situation. Clearance time begins when the first evacuating vehicle enters the road network and ends when the last evacuating vehicle reaches its destination."

This definition had to be modified to account for the phasing of evacuation and the tendency of some residents to evacuate spontaneously before an evacuation order is issued. "Clearance time" begins 36 hours prior to tropical force winds when mobile home residents are ordered to evacuate (at the beginning of Phase 2), and it ends when the last evacuating vehicle exits, or passes by the northbound entrance to Florida's Turnpike on US 1 in Florida City. For purposes of determining total time to safety for evacuating vehicles, the 2001 Study added Dade County travel time to Monroe County clearance time to reflect an approximate time to get from Florida City to the evacuation shelter at Florida International University (FIU). This additional time was assumed to be 30 minutes for Category 1-2 hurricanes, and 52 minutes for Category 3-5 hurricanes reflecting addition congestion under the worst case. As we are only interested in time to evacuate to Florida City, this update does not include this additional travel time.

Zone Structure

When the 2001 Study was in process, a decision was made to delineate seven evacuation zones, as that was what the Monroe County's Emergency Management Division was using at the time. The Monroe County's Emergency Management Division has since transitioned to five hurricane evacuation zones. Moreover, the South Florida Regional Planning Council has opted to base the zone structure of its evacuation model on census geography, which simplifies model updates.

For this application, we held to the seven-zone structure of the 2001 Study. The seven zones are defined by mile makers:

Table 1. Mile Marker Limits for each Evacuation Zone

	Evacuation Zone	Mile Marker
Lower Keys	1	0-13
	2	13-46

Middle Keys	3	46-64
Upper Keys	4	64-84
	5	84-95
	6	95-113
	7	106-ICWW

To update inputs to the Miller Model based on the 2000 Census, it was necessary to determine how census geography relates to the seven 2001 Study evacuation zones. We used a combination of maps provided in the *2001 Keys Hurricane Evacuation Study* and descriptions of the zonal boundaries to produce the following correspondence table (Table 2).

Table 2. Zone Structure for Updated Miller Model (2008)

Zone	Census Tract	Block Group	Percentage of Block Group in Zone
Zone 1 (Key West to Saddle Bunch Channel Bridge - mm 0-13)	9726	All block groups	100%
	9725	All block groups	100%
	9724	All block groups	100%
	9723	All block groups	100%
	9722	All block groups	100%
	9721	All block groups	100%
	9720	All block groups	100%
	9719	All block groups	100%
	9718	All block groups	100%
	9717	All block groups	100%
Zone 2 (Saddle Bunch Bridge to Knight Key Channel - mm 13-46)	9716	All block groups	100%
	9715	All block groups	100%
	9714	All block groups	100%
Zone 3 (Knight Key Channel to Long Key Viaduct - mm 46-64)	9713	All block groups	100%
	9712	All block groups	100%
	9711	All block groups	100%
	9710	2	100%
	9710	3	100%
Zone 4 (Long Key Viaduct to Whale Harbor Channel - mm 64-84)	9710	1	100%
	9709	1	40%
	9709	2	45%

	9709	3	100%
	9709	4	100%
	9709	5	100%
Zone 5 (Whale Harbor Channel to Milemarker 95 - mm 84-95)	9709	1	60%
	9709	2	55%
	9708	All block groups	100%
	9707	All block groups	100%
	9706	3	100%
Zone 6 (along U.S. 1 - mm 95-113)	9706	1	100%
	9706	2	100%
	9705	All block groups	100%
	9704	All block groups	100%
	9703	All block groups	100%
	9702	1	40%
	9702	3	60%
Zone 7 (along CR 905 - mm 106-ICWW)	9702	1	60%
	9702	2	100%
	9702	3	40%
	9701	All block groups	100%

Inputs

The Miller Model requires the following inputs related to housing, evacuee behaviors, and road network performance.

- How many dwelling and tourist units exist in the evacuation area;
- What fraction of the dwelling and tourist units will be occupied at the time of evacuation;
- How many people will leave their dwellings to go someplace safer (i.e., evacuation rate or evacuation participation rate);
- When evacuees will leave, with respect to when evacuation orders are issued;
- What effect a policy of phased evacuation will have;
- Where the evacuees will go, in terms of ultimate destinations inside or outside the county;
- How many vehicles will be used in the evacuation;
- Where evacuating traffic will load onto the road network;

- How much background traffic will be using the road network at the same time;
- How much traffic can be handled by critical links in the road network;

The following chapter outlines sources of data, methods of estimation, and values for each of the above used in our update of the 2001 Study.

3. Update of the 2001 Study

Numbers of Dwellings and Tourist Units

2001 Study

Evacuating population comes from three types of units: 1) permanent dwelling units, 2) mobile home units, and 3) tourist units. The 2001 Study began with the official number of dwelling units as of 1990 from the U.S. Census. Monroe County Planning Department then provided numbers of new units based on certificates of occupancy (CO) issued each year. The number of COs was summed, cumulatively, from 1990 to 1999. After 1999, the methodology followed by the County shifted to the potential number of dwelling units available under the permitting guidelines of the Rate of Growth Ordinance (ROGO).

Update

The number of permanent dwelling units and mobile homes was determined from the 2000 U.S. Census, updated to reflect new dwellings occupied between 2000 and 2008 (see Tables 3 and 4). Permanent dwellings in 2000 included all census categories of permanent structures from single-family detached to multifamily with 50 or more units. Mobile homes included census categories of "mobile home" and "RV, boat, van, etc." The decision to include the latter with the former was prompted by belief that permanent residents living in RVs (many in mobile home parks), boats, vans, etc. would behave more like mobile home residents than tourists in an evacuation.

Permit data for new residential units issued from 2000 through 2008 were provided by the Monroe County Building Department and the equivalent departments of the five incorporated cities in Monroe County—Key West, Islamorada, Key Colony Beach, Layton, and Marathon. Post-2000 unit counts were added to 2000 unit counts to obtain current estimates of dwelling units by evacuation zone.

Tourist unit data was collected from the Department of Profession and Business Regulation. This department licenses hotels, motels, bed and breakfasts, timeshares and vacation rental units – all of which were included in the update. The data from DPBR were geocoded by Bryan Davisson, the GIS Planner in Monroe County's Growth Management Department.

Table 3. Permanent Dwelling Units in 2000, constructed and occupied between 2000-08, and total in 2008

Zone	2000	2000-08 Key West	2000-08 Islamorada	2000-08 Marathon	2000-08 Key Colony Beach	2000-08 Layton	2000-08 County	2008 Total
1	14,509	319					280	15,108
2	6,143						360	6,503
3	6,972			124	170		47	7,313
4	1,880					21	3	1,904
5	5,095		169				42	5,306
6	5,093						242	5,335
7	1,310						0	1,310
Total	41,002	319	169	124	170	21	974	42,779

Table 4. Mobile Home Units in 2000, permitted between 2000 and 2008, and in 2008

Zone	2000	2000-08	2008
1	2,496		2,496
2	1,751		1,751
3	1,940		1,940
4	720	2	722
5	1,219	1	1,220
6	2,459	1	2,460
7	8		8
	10,593	4	10,597

Table 5. Tourist Units in 2008

Zone	2008 lodging	2008 vacation rental	2008 timeshare	2008 Total
1	8,148	0	0	8,148
2	491	23	0	514
3	2,997	29	19	3,045
4	1,734	2	1	1,737
5	576	0	0	576
6	1,960	3	14	1,977
7	36	0	19	55
	15,942	57	53	16,052

Occupancy Rates

2001 Study

The Project Steering Committee (PSC) identified "% Occupancy of Dwelling Units" as a critical variable. The PSC used 1990 Census data to determine the occupancy rates during the month of April (when the Census data are collected).

For tourists, the occupancy rate utilized was from the 1991 Hurricane Evacuation Analysis of the Monroe County Comprehensive Plan and the 1995 update, both prepared by PBS&J. The occupancy was estimated as 45% on the low end and 75% on the upper end. The Project Steering Committee studied these numbers and decided to estimate the occupancy rate by subregion of the Keys. Actual rates, based on specific knowledge of the Project Steering Committee members, were used whenever available. For example, an occupancy rate of 72% was used for Key West since members knew that overall occupancy rate here was higher than the rest of the county.

Update

Occupancy rates for permanent dwellings were determined by zone from the 2000 Census (see Table 6). Occupancy rates for the county as a whole appear to have declined by about 20 percent between the 2000 Census and the 2008 American Community Survey. We therefore produced a second set of occupancy rates, prorating 2000 occupancy rates by zone to account for this decline (see Table 6).

Table 6. Occupancy Rates for Permanent Dwellings and Mobile Homes (2000 and 2008 estimate)

Zone	Percent Occupied Housing Units – 2000 Census	Percent Occupied Housing Units – Adjusted for 2008 American Community Survey
1	84%	67%
2	67%	54%
3	59%	47%
4	44%	35%
5	58%	46%
6	65%	52%
7	34%	27%

To update tourist occupancy rates, we referred to Smith Travel Research's latest Trend Report, submitted annually to Monroe County's Tourist Development Council. Occupancy rates have remained relatively constant over the years. During the hurricane season (June 1 through November 30), July is the highest occupancy month, while September is the lowest. We used July 2008 values (see Table 7). This is a worst-case assumption, since the peak of Atlantic hurricane activity is in September, the month with the lowest occupancy.

Table 7. Occupancy Rates for Tourist Units (July 2008)

Zone	Percentage Occupied Units
1 (Key West)	82%
2	71%
3	71%
4	71%
5	71%
6 (Key Largo)	77%
7	71%

Evacuation Participation Rates

2001 Study

To estimate evacuation participation rates, the 2001 Study relied heavily on a survey conducted by Dr. Carnot Nelson in 1989. The assumed evacuation participation rates are shown in Tables 7

and 8. All are taken from Dr. Nelson's behavioral analysis, except participation rates for tourist units which were assumed to be 100%. Dr. Nelson had suggested lower numbers.

Nelson's survey was done before Hurricane Andrew, and it simply asked people what they intended to do in response to a number of hypothetical hurricane threats. Intended-response data may be unreliable predictors of actual evacuation behavior.

Much more information has become available since Nelson's pre-Andrew survey (Baker 2000):

- A University of Florida group conducted a survey following Andrew, not only asking what people did in Andrew, but also using the very same intended-response questions previously used by Nelson.
- James Mattson conducted a survey following Andrew, dealing with Andrew response and intended response in future storms.
- Dr. Earl Baker did a survey following Andrew for the National Science Foundation that documented response in Andrew, perceptions of vulnerability, confidence in construction, and intended responses in future threats.
- Following Georges, FIU conducted a survey documenting response to Georges as well as asking about certain subjects that could have a bearing on future response.
- Also following Georges, the Monroe County School Board had public school students take home a questionnaire asking what their households did in Georges.
- Dr. Earl Baker conducted interviews in the Lower Keys as part of a post-Georges survey for the Corps of Engineers and FEMA. It dealt with response to Georges as well as vulnerability perception, concerns about traffic congestion, and future response.
- Dr. Earl Baker conducted an additional survey in the Lower Keys, dealing with response to Georges but also posing several hypothetical threat scenarios and evaluating the effect on intended response of roadway improvements and having refuges of last resort in Key West.
- Following Hurricane Ivan, a Post-Ivan Behavioral Analysis was prepared for the Federal Emergency Management Agency and the U.S. Army Corps of Engineers in September 2005. A total of 200 interviews were conducted in Monroe County. The questionnaire asked questions regarding evacuation decisions and behavior, home mitigation and/or preparation, household circumstances, economic impacts, and household information needs.
- The South Florida Behavioral Survey was conducted in 2007-2008 as part of Statewide Regional Evacuation Study Program. The primary aim of the survey was to provide data to assist in deriving evacuation behavioral assumptions for transportation and shelter analyses. In each non-coastal county of the state 150 interviews were conducted randomly by telephone. In each coastal county of the state, 400 interviews were conducted.

Baker Study

Based on actual and intended responses to hurricanes, from several surveys after Hurricanes Georges, Andrew, and Irene, Professor Earl Baker at Florida State University derived most probable evacuation participation rates for a number of hurricane threat scenarios. Earl "Jay" Baker is an associate professor of geography and an expert in the field of hurricane evacuation. His research is focused on how people respond to warning and evacuation orders and how emergency managers are able to use forecasts to implement evacuation plans. He has studied peoples' vulnerability perceptions and hurricane preparedness in most areas of the Gulf of Mexico and Atlantic coasts.

Table 8 provides Baker's best estimates of participation rates for Category 5 storms approaching the Keys from the south, posing a greater risk to the Lower Keys. Table 8 also provides his best estimates of participation rates for storms at latitudes similar to Andrew, posing a greater risk to the Upper Keys. The table assumes mandatory evacuation orders and aggressive actions by public officials to educate the public about appropriate responses.

Table 8. Evacuation participation rate assumptions for Category 5 hurricanes approaching from different latitudes, aggressive mandatory evacuation ordered and improved public education regarding vulnerability (Baker 2000)

	from latitudes south of Key West	from latitudes similar to Andrew
Lower Keys	90	35
Middle Keys	95	95
Upper Keys	95	100

South Florida Behavioral Survey

The 2008 South Florida Behavioral Survey asked whether respondents intended to evacuate their homes for some place safer if mandatory evacuation notices were issued due to potential flooding (see Table 9). The question was asked for both Category 3 and 5 hurricanes. Results weren't presented for Category 4 hurricanes. The Category 5 results are most relevant to this worst-case analysis.

Table 9. Would Leave Home if Mandatory Evacuation Notice is Given for a Category 5 Hurricane

	N	Yes	No	Don't know/depends	Yes plus Don't know/depends
Monroe	400	88%	8%	4%	92%
Key West	100	89%	9%	3%	92%
Lower Keys	100	91%	6%	3%	94%

Middle Keys	100	90%	7%	3%	93%
Upper Keys	100	84%	8%	8%	92%

Perhaps a better predictor of evacuation participation than intended response to hurricanes is perceived vulnerability to both wind and water in hurricanes of different intensities. Table 10 reports Monroe County responses to the question of whether respondents would remain safe in a Category 4 hurricane (Category 5 results weren't released).

Table 10. Safe from Wind and Water in a Category 4 Hurricane

	N	Yes	No	Don't know/depends
Monroe	400	15%	80%	5%
Key West	100	19%	76%	4%
Lower Keys	100	11%	81%	7%
Middle Keys	100	15%	83%	1%
Upper Keys	100	13%	79%	8%

Monroe County residents were also asked if they left home during Hurricanes Georges (a Category 2), Ivan (a tropical depression as it approached Florida), and Wilma (a Category 2 hurricane in Monroe County). Hurricane Georges prompted 38% of households in the Monroe County region to evacuate, with the Middle Keys reporting the highest participation (50%). Hurricane Ivan caused 28% of households in Monroe County region to evacuate, with the Upper Keys reporting the highest participation (34%). Hurricane Wilma caused 32% of households in Monroe County to evacuate, with the Lower Keys reporting the highest participation (37%). These results are for low-intensity hurricanes; no Category 4-5 hurricanes have hit the Keys in recent years.

Update

The worst case is a Category 5 hurricane that approaches from latitudes below Key West, with aggressive mandatory evacuation ordered and improved public education regarding vulnerability (see Table 11). Baker suggests that 90-95% of residents might evacuate under such circumstances. While no clear geographic pattern of evacuation compliance emerges from the various surveys, we will go an upper bound evacuation participation rate equal to Baker's recommended rates. In this worse case, a 100% evacuation rate will be assumed for mobile home and tourist units.

Actual evacuation rates during past hurricanes have reportedly been much lower than this worst case. True, these were less intense hurricanes than posited here, but it seems likely that respondents overstate their willingness to evacuate when asked to speculate in surveys. We will therefore conduct a sensitivity test of clearance time, assuming a lower bound evacuation participation rate of 70-75% for permanent dwellings in response to a more typical hurricane.

Table 11. Category 5 Storm Evacuation Participation Rates

	Mobile Homes	Tourist Units	Other Units
Lower Keys (Zones 1 & 2)	100%	100%	70-90%
Middle Keys (Zone 3)	100%	100%	75-95%
Upper Keys (Zones 4, 5, 6 & 7)	100%	100%	75-95%

Evacuation Timing

Evacuation timing refers to when evacuees depart their residences. While some spontaneous evacuation occurs, it is unusual for more than 15% of the eventual evacuees to have departed before officials issue evacuation orders. Departures then occur depending upon the urgency perceived by evacuees.

2001 Study

The 2001 Study uses tables to represent the rate at which evacuating traffic enters U.S. 1. The exact number of hours over which the traffic is loaded is not terribly important. The main thing is that the scenarios reflect a range of plausible response distributions, based on the timing of evacuation orders prior to landfall, to assess the sensitivity of clearance times to those variations.

The 2001 response curves don't reflect the fact that some evacuees will leave before an evacuation order is issued. That is clearly wrong. Dr. Baker calls 10% spontaneous evacuation a conservative figure.

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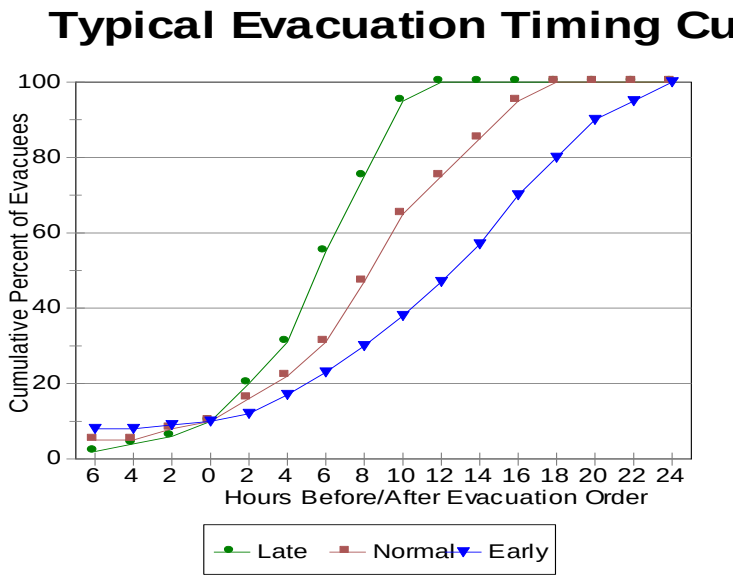
Baker Study

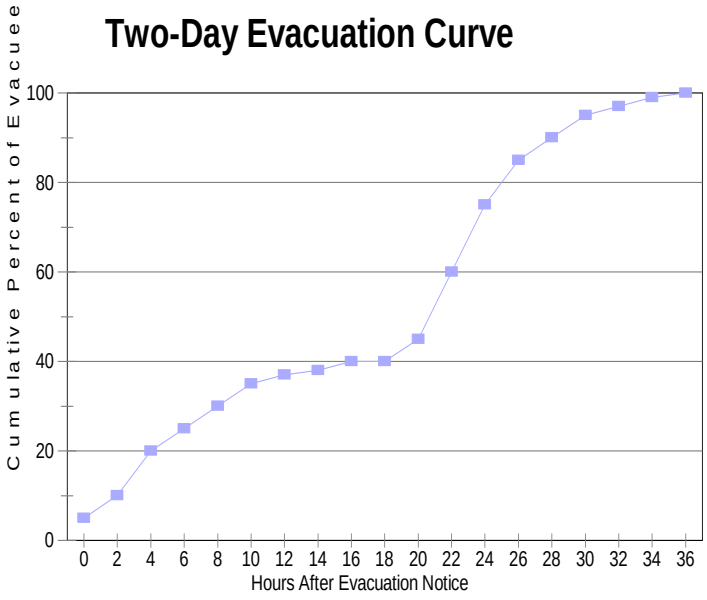
Dr. Baker developed the curves in Figure 1. They indicate how promptly evacuees depart when evacuation orders are issued under three scenarios of urgency. "Late, normal, and early" refer to when evacuation orders were issued relative to expected arrival of a hurricane. These curves assume 10% spontaneous evacuation even before the evacuation order is issued.

Figure 1. Early, normal, and late evacuation timing curves



Based on evacuation response to Hurricanes George and Andrew, Baker developed the two-day curve in Figure 2. This response curve accounts for early evacuees even before evacuation orders are issued. At least for strong hurricanes, Baker concluded that such a curve could apply to Monroe County.

Figure 2. Two-day evacuation timing response curve



Update

The three Baker curves in Figure 1 seem most applicable to evacuation scenarios for Monroe County, where a mandatory evacuation order is issued early, at a normal time, or late. The fact that Baker provides three different curves allows us to perform sensitivity tests on evacuation timing assumptions.

One anomaly associated with the Baker curves is that the clearance time cannot be less than 24 hours when an evacuation order is issued early, which is arguably the scenario which involves the least risk to the public. Therefore, in assessing clearance time, primary emphasis will be placed on the late response scenario.

Effect of Phased Evacuation

2001 Study

In the 2001 Study, all residents and tourists were assumed evacuate at the same time.

Update

In 2005, Monroe County adopted a mandatory phased evacuation policy as part of the update of its comprehensive plan. This phased evacuation requires that all tourists, recreational vehicles, military and live aboard vessels begin to evacuate from the county 48 hours in advance of tropical force winds. Next, mobile homes and special needs residents will receive the order to evacuate 36 hours in advance of tropical force winds. Last, the residents living in permanent dwelling units will receive the order to leave 30 hours in advance of these winds.

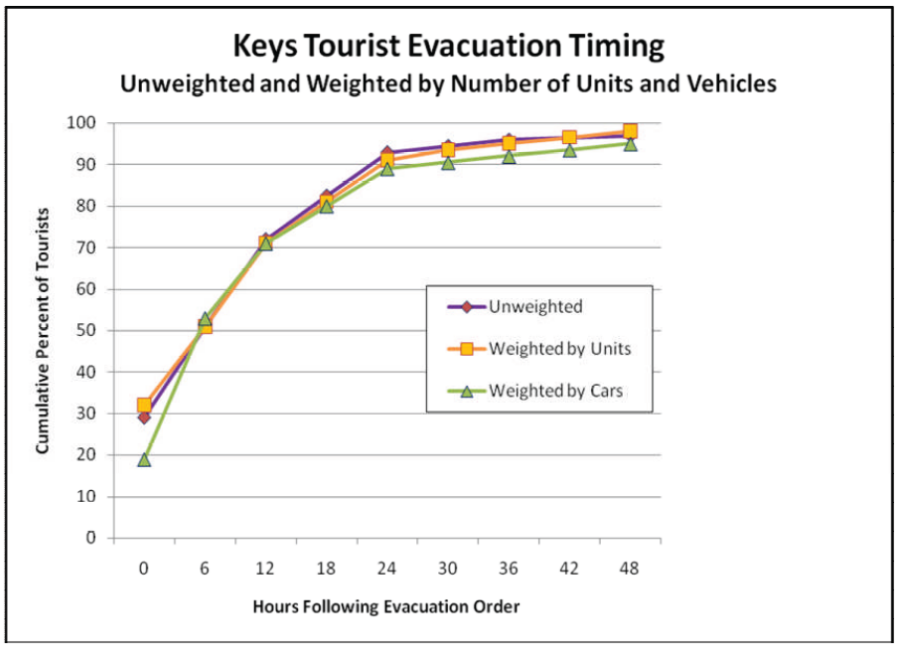
The Miller Model had not been used to test phased evacuations before and therefore needed to be adapted. This was done by having separate response curves and trip tables for mobile home residents and permanent dwelling unit residents, with a six hour lag between the former and the latter. The two groups of evacuees are added together where their response curves and trip tables overlapped. The Miller Model had to be significantly modified to represent a phased evacuation.

Both groups of residents were assumed to evacuate according to Dr. Baker's late response curve in Figure 1, with overlap between the two groups starting at 30 hours prior to tropical force winds. Essentially, since the late response curves show evacuees leaving home over approximately a 12 hour period, there is six hours of overlap in departures between the groups. Of course, after that, they are on the road together for the remainder of the evacuation trip.

Handling tourist evacuees involved a judgment call. Under phased evacuation, the tourist evacuation order will be issued 48 hours before tropical force winds, or 12 hours before the evacuation order for mobile home residents. Dr. Baker's most recent report, based on 2009 surveys of hotels, motels, resorts, bed and breakfasts, seasonal housing rentals, and recreational vehicle parks, suggests that 30 percent of tourists evacuate spontaneously before the order is issued, and another 40 percent of tourists evacuate in the first 12 hours after the order (see Figure 3). This leaves 30 percent of tourists to evacuate at the same time as the mobile home

park residents. To simplify the model calculations, this 30 percent of tourists was simply added to the mobile home park total and assumed to evacuate following the same response curve.

Figure 3. Tourist Evacuation Timing



Source: Earl J. Baker, Behavioral Assumptions for Hurricane Evacuation Planning in Monroe County, prepared for the Department of Community Affairs, September 2009, p. 4.

Destinations

2001 Study

Based on Dr. Nelson's research, the 2001 Study had four possible destinations for the resident evacuees: 1) Monroe County public shelter, 2) Monroe County motel, 3) Monroe County friend or relative, and 4) Out of Monroe County.

Baker Study

Based on several surveys of actual and intended behavior after Hurricanes Georges and Andrew, the Baker 2000 report indicates the most likely percentage of evacuees from the three different areas of the Keys who will go to destinations outside of Monroe County for different categories of storm intensity (see Table 12).

Table 12. Planning assumptions for percent of evacuees leaving Monroe County, aggressive mandatory evacuation ordered throughout Monroe County for all categories

	Cat 3-4	Cat 5
Lower Keys	80	90
Middle Keys	90	95
Upper Keys	95	100

South Florida Behavioral Survey

The 2008 survey asked respondents where they would go if they evacuated for hurricanes of different intensities. Results for Category 5 hurricanes are shown in Table 13.

Table 13. Evacuation Destination (Category 5)

	N	Own neighborhood	Own county	Someplace else in Florida	Someplace outside Florida	Don't know
Monroe	304	3%	7%	65%	17%	8%
Key West	72	7%	13%	52%	14%	14%
Lower Keys	79	2%	7%	69%	19%	3%
Middle Keys	77	1%	1%	71%	21%	6%
Upper Keys	76	2%	6%	68%	15%	8%

Data are available on the destinations of evacuees during three previous hurricanes (Tables 14-16). The great majority of evacuees leave the county. Residents of Key West are most likely to leave the county, while residents of the Upper Keys are least likely to leave the county (though a majority still do).

Table 14. Destinations of Evacuees (Hurricane Georges)

	N	Own neighborhood	Own county	Someplace else in Florida	Someplace outside Florida	Don't know
Monroe	80	3%	15%	75%	6%	1%
Key West	20	2%	5%	91%	1%	0%
Lower Keys	18	0%	2%	68%	25%	5%
Middle Keys	26	1%	19%	79%	1%	0%
Upper Keys	16	8%	37%	46%	8%	0%

Table 15. Destinations of Evacuees (Hurricane Ivan)

	N	Own neighborhood	Own county	Someplace else in Florida	Someplace outside Florida	Don't know
Monroe	84	1%	10%	76%	12%	2%
Key West	22	0%	3%	93%	4%	0%
Lower Keys	25	5%	1%	75%	9%	10%
Middle Keys	17	0%	8%	79%	12%	0%
Upper Keys	20	0%	24%	56%	20%	0%

Table 16. Destinations of Evacuees (Hurricane Wilma)

	N	Own neighborhood	Own county	Someplace else in Florida	Someplace outside Florida	Don't know
Monroe	82	1%	11%	81%	5%	0%
Key West	20	4%	4%	91%	1%	0%
Lower Keys	27	0%	3%	84%	11%	2%
Middle Keys	13	0%	11%	89%	0%	0%
Upper Keys	22	0%	30%	62%	8%	0%

Update

The survey data indicate that the majority of evacuees from Monroe County would leave the county and evacuate to another county within the state of Florida. Beyond this generalization, the data are difficult to interpret.

The intended response and actual response questions point in different directions, with the percentages intending to leave the county increasing as you move north from the Lower Keys to Middle Keys to Upper Keys. But the percentages actually leaving during past hurricanes decrease as you move north. Most likely the small numbers of evacuees during past hurricanes are atypical of the larger populations. We will assume that 90% of evacuating residents from Lower Keys (Zones 1 and 2) will leave the county, that 95% of evacuating residents from the Middle Keys (Zone 3) will leave the county, and that 100% of evacuating residents from the Upper Keys (Zones 4 through 7) will leave the county. These assumptions are in line with Dr. Baker's recommendations and the original Miller model. 100% of tourists are assumed to leave the county.

Vehicle Use

Not all vehicles available to households are used in evacuations. Vehicle use is predicted well by hypothetical response data.

2001 Study

The source of the vehicle usage rates used in the 2001 Study is not specified. It was assumed that 69 to 71% of available vehicles would be used.

Baker Study

Dr. Baker states that the normal range for vehicle usage is 65% to 75%. Based on behavior during Hurricane Georges, the Baker 2000 report recommended that for planning purposes, it be assumed that 70% of the vehicles available to evacuating households will be used, and 10% of those households will pull a camper, trailer, or boat or take a motor home.

South Florida Behavioral Survey

The 2008 survey asked how many vehicles would be available to a household that could be used to evacuate, and how many vehicles would a household take if they evacuated? As can be seen from Table 30, the percent of available vehicles that would be used in an evacuation varies from a low of 72% in the Lower Keys to a high of 91% in Key West.

Table 30. Vehicle Availability and Use During an Evacuation

	N	Available vehicles	Vehicles used in evacuation	% of available vehicles used in evacuation	% of households with no vehicle
Monroe	400	1.9	1.4	81%	5%
Key West	100	1.5	1.5	91%	10%
Lower Keys	100	2.6	1.3	72%	2%
Middle Keys	100	1.8	1.3	79%	2%
Upper Keys	100	1.8	1.4	80%	3%

Update

The South Florida survey data are the most recent, and we believe the most accurate data available. The one exception is the very high vehicle usage rate for residents of Key West, out of line with all the other data available. Baker reports that residents of Key West used 1.11 vehicles per evacuating household during Hurricane Georges. That amounts to about 80% of the vehicles owned by households in Key West. We therefore assumed the following vehicle usage rates for residents: 80% vehicle usage for Key West (Zone 1); 72% vehicle usage for the

rest of the Lower Keys (Zone 2); 79% vehicle usage for the Middle Keys (Zone 3); and 80% vehicle usage for the Upper Keys (Zones 4-7). We assumed 100% vehicle usage rates for tourists.

Background Traffic

Background traffic is the measure of vehicles using the roadways for reasons other than hurricane evacuation. The 2001 Study defines background traffic as including: out-of-County traffic (business trips and recreational trips), non-evacuating vehicles conducting hurricane preparation trips, typical day commuting trips, etc. In sum, this traffic is comprised of non-evacuating vehicles on the road.

Background traffic increases the level of traffic on the roadway system and therefore, has a direct effect on clearance time. This traffic is comprised of non-evacuating traffic and includes trips to run errands and buy hurricane supplies.

2001 Study

The 2001 Study used approximations of background traffic based on recorded traffic volumes. This background traffic affects processing time through each of the 31 links and, eventually, this background traffic declines as the evacuation occurs and decreases to zero background vehicles at the end of the evacuation. For example, if a 12 hour response curve is selected for modeling purposes, the background traffic is 100% of the actual recorded count at hour one of the evacuation and zero at hour 12. A uniform distribution is assumed for the rate of decline of the background traffic.

Update

We have no basis for refinement of the 2001 Study background traffic assumptions.

Number and Capacity of Critical Links

2001 Study

The Miller Model has 31 outbound evacuating links. It relies on the critical link concept. This concept means that the evacuation time is mainly affected by the link with the highest demand to service volume ratio. This link experiences the longest delay due to the overload of evacuating vehicles. This link, the critical link, is not static and can shift due to either demand changing by link or from capacity improvements to a link.

A critical variable in the determination of evacuation time is the assumed capacity of roadway links. The Miller Model takes the capacity of uninterrupted flow highways (essentially freeway quality roads) and makes downward adjustments to account for driveways and intersections. There are two potential problems with this procedure. First, U.S. 1 isn't an uninterrupted flow facility but rather a state signalized arterial, whose capacity is determined using different

formulas. Second, the downward adjustments are essentially arbitrary as opposed to empirically based.

Update

The Florida Department of Transportation (FDOT) has recommended updates to the 2001 Study to reflect the addition of auxiliary lanes and evacuation shoulders. These additions include:

a. Completed projects from Table 18 of the 2001 Keys Evacuation Study

b. Projects under construction from Table 18 of the 2001 Study

c. Projects funded in the current work program from Table 18 in the 2001 Study

Table 31 compares the number of functional evacuation lanes in the original Miller model to and the number in the FDOT update. There will be substantial functional capacity added to critical links by 2015.

Based on the concept of "maximum sustainable evacuation traffic flow rates," FDOT has recommended a reduction the 2001 Study flow rates for several links. The recommended rates take into account site-specific capacity studies, observational studies of actual hurricane evacuations, and traffic simulation runs. The FDOT rates are the best available. Values are compared in Table 31.

Table 31. Maximum Sustainable Flow Rates per Hour

Link Name	Milemarkers		2001 Functional Evacuation Lanes	2015 Functional Evacuation Lanes	2001 Flow Rates		2010 FDOT Flow Rates	
	From	To			Per Lane	Total	Per Lane	Total
A1	2.0	4.0	2	2	900	1,800	900	1,800
A2	4.0	9.0	2	2	900	1,800	900	1,800
B	9.0	17.0	1	1	1,350	1,350	1,100	1,100
C	17.0	22.0	1	1	1,350	1,350	1,100	1,100
D1	22.0	24.0	1	1	1,350	1,350	1,100	1,100
D2	24.0	25.0	1	1	1,350	1,350	1,100	1,100
D3	25.0	30.0	1	1	1,350	1,350	1,100	1,100
E	30.0	34.0	1	2	1,050	1,050	1,050	2,100
F1	34.0	35.2	1	1	1,350	1,350	1,100	1,100
F2	35.2	36.5	2	2	1,350	2,700	1,100	2,200
F3	36.5	37.5	1	1	1,350	1,350	1,100	1,100
G	37.5	47.0	1	1	1,500	1,500	1,200	1,200
H1	47.0	48.0	1	2	1,350	1,350	1,100	2,200
H2	48.0	50.2	2	2	900	1,800	900	1,800
I1	50.2	50.8	2	2	900	1,800	900	1,800
I2	50.8	54.0	2	2	900	1,800	900	1,800
J1	54.0	54.5	2	2	900	1,800	900	1,800
J2	54.5	58.0	1	2	1,350	1,350	1,100	2,200

Link Name	Milemarkers		2001 Functional Evacuation Lanes	2015 Functional Evacuation Lanes	2001 Flow Rates		2010 FDOT Flow Rates	
	From	To			Per Lane	Total	Per Lane	Total
K	58.0	74.0	1	2	1,350	1,350	1,100	2,200
L	74.0	80.0	1	2	1,350	1,350	1,100	2,200
M1	80.0	83.5	1	2	1,350	1,350	1,100	2,200
M2	83.5	85.6	1	2	1,350	1,350	1,100	2,200
N	85.6	90.0	1	2	1,350	1,350	1,100	2,200
O	90.0	100.0	2	3	900	1,800	900	2,700
P	100.0	105.0	2	3	900	1,800	900	2,700
Q	105.0	106.3	2	3	900	1,800	900	2,700
R1	106.3	126.5	1	2	1,500	1,500	1,200	2,400
R2	126.5	HEFT	2	3	900	1,800	900	2,700
S	106.3	Int CR 905 / CR 905 A	1	1	1,350	1,350	1,100	1,100
T	Ocean Reef	Int CR 905 / CR 905 A	1	1	1,350	1,350	1,100	1,100
U	Int CR 905 / CR 905 A	US 1	1	1	1,350	1,350	1,100	1,100

Additional Clearance Time to Reach Shelter

Miller Model

The Miller Model added a fixed 30 minutes (category 1 or 2) and fixed 52 minutes (category 3-5) to the clearance time for the trip from Florida City to the public shelter at FIU. One of the weaknesses of the Miller Model is that it assumes a fixed time for all vehicles to travel to the FIU shelter and it does not include the effects of traffic from Miami-Dade County. The South Florida Regional Planning Council was charged with creating a model to address this deficiency. However, that model is not available at the time of this writing.

Updated Miller Model

Following an administrative law judge's opinion, where an opposing counsel challenged the end point of evacuation, the end point for hurricane evacuation clearance time estimates is the beginning of the Florida Turnpike in Florida City. The Department of Community Affairs concurs with this end point for Hurricane Evacuation Clearance Time modeling. Therefore the final clearance time estimates do not include the 30/52 minutes to travel from Florida City to FIU.

Clearance Time Estimates

Table 32 provides clearance times for 12 different scenarios. The 2000 occupancies are those in the first column of Table 6. They reflect occupancies at the time of the 2000 Census. The 2008 occupancies reflect a downward adjustment in occupancies county-wide according to the 2008 American Community Survey.

The low participation rates are the suggested lower bound rates for permanent dwelling units in a Category 5 hurricane coming from the southeast (70-75%). The high participation rates are the suggested upper bound rates for the same scenario (90-95%).

The three maximum flow assumptions are those associated with the original Miller Model (2001 lane configuration with Miller maximum flow rates), a combination of Miller and FDOT assumptions (2001 lane configuration with FDOT maximum flow rates), and the FDOT update (2015 lane configuration with FDOT maximum flow rates).

Clearance time is measured from the time of the evacuation order for permanent dwelling unit residents until the last evacuating vehicle reaches Florida City. The updated Miller Model puts time zero at 36 hours before tropical force winds, when the evacuation order is issued for mobile home residents. Therefore, we subtracted six hours from the Miller Model clearance time outputs to arrive at clearance times relative to the evacuation order for permanent dwelling residents.

The longest clearance times are, of course, associated with the 2001 lane configuration and the lower FDOT maximum flow rates. The shortest are associated with the 2015 lane configuration, which includes additional lanes compared to 2001, and the FDOT maximum flow rates. Clearance times associated with the 2001 lane configuration and Miller's higher flow rates are intermediate.

The difference between these clearance time estimates and those in my report of September 17, 2010 are due entirely to the exclusion of travel time from Florida City to the FIU shelter in these most recent estimates. The earlier report erroneously said that a fixed 52 minutes had been added to the Miller Model's clearance time estimates to account for this last leg of the evacuation. In fact, 52 minutes were added to the clearance time for the "High Participation" scenario but only 30 minutes were added to the clearance time for the "Low Participation" scenario, in keeping with the reduced traffic volumes. My apologies for this erroneous statement.

The reader will note that using a simple model like the Miller Model, based on fixed capacities and speeds on the different links, clearance time is not sensitive to the assumed participation rate because there is ample capacity to handle the additional traffic with the additional lanes

constructed or planned by FDOT. The clearance time reflects unimpeded travel by the last evacuating vehicle from Key West to Florida City.

Table 32. Clearance Times (relative to the permanent unit evacuation order)

	Low Occupancies		High Occupancies	
	Low Participation	High Participation	Low Participation	High Participation
2001 Lanes/Miller Flow Rates	16 hours 16 minutes	18 hours 50 minutes	18 hours 32 minutes	22 hours 6 minutes
2001 Lanes/FDOT Flow Rates	18 hours 58 minutes	22 hours 28 minutes	22 hours 8 minutes	27 hours 2 minutes
2015 Lanes/FDOT Flow Rates	16 hours 16 minutes	16 hours 16 minutes	16 hours 16 minutes	18 hours 52 minutes

Appendix

	PBS&J Hurricane Evacuation Analysis Dec. 1991 (1990 Census)	2000 Miller Model (1990 Census & PSC) Final Report in 2001	2004 Miller Update (2000 Census)	2008 Statewide Regional Evacuation Study Program South Florida Behavioral Survey Report		Ken Metcalf Miller Model Analysis - Summary of 2000 Census	Reid Ewing Recommendations Report
	Same behavioral parameters of 1989 ACOE study			Sample size (n=400)			
	7 evac zones	7 evac zones	7 evac zones			7 evac zones	
Number of People per M.H. Unit	Zone 1 - 2.44 2 - 2.31 3 - 2.25 4 - 1.97 5 - 2.27 6 - 2.27 7 - 2.11	Zone 1 - 2.44 2 - 2.31 3 - 2.25 4 - 1.97 5 - 2.27 6 - 2.27 7 - 2.11	Zone 1 - 2.44 2 - 2.31 3 - 2.25 4 - 1.97 5 - 2.27 6 - 2.27 7 - 2.11				Zone 1 - 2.35 2 - 2.21 3 - 2.18 4 - 2.08 5 - 2.27 6 - 2.27 7 - 1.74
Number of People per Permanent Unit	Zone 1 - 2.44 2 - 2.31 3 - 2.25 4 - 1.97 5 - 2.27 6 - 2.27 7 - 2.11	Zone 1 - 2.44 2 - 2.31 3 - 2.25 4 - 1.97 5 - 2.27 6 - 2.27 7 - 2.11	Zone 1 - 2.44 2 - 2.31 3 - 2.25 4 - 1.97 5 - 2.27 6 - 2.27 7 - 2.11				Zone 1 - 2.35 2 - 2.21 3 - 2.18 4 - 2.08 5 - 2.27 6 - 2.27 7 - 1.74
Number of People per Tourist Unit	Zone 1 - 2.90 2 - 3.76 3 - 2.75 4 - 2.53 5 - 12.80 6 - 12.90 7 - 12.90	Zone 1 - 2.90 2 - 3.76 3 - 2.75 4 - 2.53 5 - 3.00 6 - 3.00 7 - 3.00	Zone 1 - 2.90 2 - 3.76 3 - 2.75 4 - 2.53 5 - 3.00 6 - 3.00 7 - 3.00				Zone 1 - 2.90 2 - 3.76 3 - 2.75 4 - 2.53 5 - 3.00 6 - 3.00 7 - 3.00
Number of Vehicles per Unit	Zone 1 - 1.80 2 - 1.80 3 - 1.82 4 - 2.00 5 - 2.00 6 - 2.00 7 - 2.00	1 - 1.35 2 - 1.76 3 – 1.39 4 – 1.65 5 – 1.76 6 – 1.61 7 - 1.58	1 - 1.36 2 - 1.74 3 – 1.56 4 – 1.65 5 – 1.71 6 – 1.83 7 - 1.43	Key West 1.5 Lower 2.6 Middle 1.8 Upper 1.8 (available vehicles - page 65)	Key West 1.5 Lower 1.3 Middle 1.3 Upper 1.4 (vehicles used in evacuation - page 65)	**Vehicle/occupied unit** Zone 1 - 1.36 2 - 1.73 3 - 1.56 4 - 1.63 5 - 1.69 6 - 1.83 7 - 1.43	1 - 1.36 2 - 1.73 3 – 1.60 4 – 1.34 5 – 1.75 6 – 1.83 7 - 1.44
Number of Vehicles per Tourist Unit	Zone 1 - 1.04 2 - 1.04 3 - 1.05 4 - 1.10 5 - 1.10 6 - 1.10 7 - 1.10	1 - 1.04 2 - 1.04 3 - 1.05 4 - 1.10 5 - 1.10 6 - 1.10 7 - 1.10	Zone 1 - 1.04 2 - 1.04 3 - 1.05 4 - 1.10 5 - 1.10 6 - 1.10 7 - 1.10				Zone 1 - 0.83 2 - 1.23 3 - 1.23 4 - 1.13 5 - 1.13 6 - 1.55 7 - 1.55

	PBS&J Hurricane Evacuation Analysis Dec. 1991 (1990 Census)	2000 Miller Model (1990 Census &	2004 Miller Update (2000 Census)	2008 Statewide Regional Evacuation Study Program South Florida Behavioral		Ken Metcalf Miller Model Analysis -	Reid Ewing Recommendations Report
% Participation of M.H. Units	95%	95%	95%				100%
% Participation of Other Units	60% lower keys (1 &2) 80% middle keys (3) 85% upper keys (4-7)	Zone 1 - 60% 2 - 60% 3 - 80% 4 - 85% 5 - 85% 6 - 85% 7 - 85%	Zone 1 - 60% 2 - 60% 3 - 80% 4 - 85% 5 - 85% 6 - 85% 7 - 85%	Would leave if mandatory evacuation notice is given for a **Cat 3** Hurricane (page 36) Key West 77% Lower 69% Middle 74% Upper 71%	Would leave if mandatory evacuation notice is given for a **Cat 5** Hurricane (page 36) Key West 89% Lower 91% Middle 90% Upper 84%		Zone 1 - 70-90% 2 - 70-90% 3 - 75-95% 4 - 75-95% 5 - 75-95% 6 - 75-95% 7 - 75-95% Category 5 Storm
% Occupancy of Dwelling Units		Zone 1 - 86% 2 - 71% 3 - 69% 4 - 57% 5 - 66% 6 - 65% 7 - 42%	Zone 1 - 84.10% 2 - 66.85% 3 - 58.95% 4 - 45.43% 5 - 57.99% 6 - 66.37% 7 - 32.84%			Zone 1 - 83.5% 2 - 69.8% 3 - 56.6% 4 - 47.9% 5 - 60.2% 6 - 67.6% 7 - 33.3%	Zone 1 - 67% 2 - 54% 3 - 47% 4 - 35% 5 - 46% 6 - 52% 7 - 27% 2008 Estimate
% Participation by Tourists Units at Risk	95%	100%	100%				83% 17% downward adjustment for evacuating by air
% Occupancy of Tourist Units	45 % low occupancy 75% high occupancy	Zone 1 - 72% 2 - 64% 3 - 64% 4 - 70% 5 - 70% 6 - 70% 7 - 70%	45% low occupancy			**63.77%** - average Keys occupancy 2003-2007 **73-78%** June-July (peak summer months) **45-57%** Sept - October (lowest) **70.38%** average Key West occupancy 2003-2007	July 2008 Smith Travel Research Zone 1 - 82% 2 - 71% 3 - 71% 4 - 71% 5 - 71% 6 - 77% 7 - 71%
Vehicle Usage %	Zone 1 - 69% 2 - 69% 3 - 70% 4 - 71% 5 - 71% 6 - 71% 7 - 71%	Zone 1 - 69% 2 - 69% 3 - 70% 4 - 71% 5 - 71% 6 - 71% 7 - 71%	Zone 1 - 69% 2 - 69% 3 - 70% 4 - 71% 5 - 71% 6 - 71% 7 - 71%	Key West 91% Lower 72% Middle 79% Upper 80% (% of available vehicles used in evacuation - page 65)			Zone 1 - 80% 2 - 72% 3 - 79% 4 - 80% 5 - 80% 6 - 80% 7 - 80%

	PBS&J Hurricane Evacuation Analysis Dec. 1991 (1990 Census)	2000 Miller Model (1990 Census &	2004 Miller Update (2000 Census)	2008 Statewide Regional Evacuation Study Program South Florida Behavioral	Ken Metcalf Miller Model Analysis -	Reid Ewing Recommendations Report
Tourist Vehicle Usage %		100%	100%			100%
% Distribution Public Shelters (Residents)		Zones 1 to 7 = 0%	Zones 1 to 7 = 0%			**Out of County** Zone 1 - 90% 2 - 90% 3 - 95% 4 - 100% 5 - 100% 6 - 100% 7 - 100%
(Perm. Residents) Friend/Relative		Zones 1 to 3 = 5% Zones 4-7 = 0%	Zones 1 to 3 = 5% Zones 4-7 = 0%			
Hotel/Motel		Zones 1 to 7 = 0%	Zones 1 to 7 = 0%			
Out of County		Zones 1 to 3 = 95% Zones 4-7 = 100%	Zones 1 to 3 = 95% Zones 4-7 = 100%			