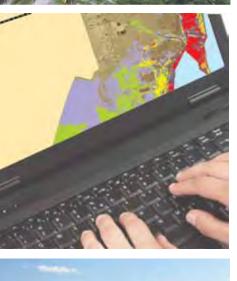


FLORIDA STATEWIDE REGIONAL EVACUATION STUDY PROGRAM



DEPTH ANALYSIS ATLAS

MONROE COUNTY

Volume 9-11 Book 3D of 3

CATEGORY 4

FLORIDA DIVISION OF EMERGENCY MANAGEMENT

SOUTH FLORIDA REGIONAL PLANNING COUNCIL

SOUTH FLORIDA REGION







SOUTH FLORIDA DEPTH ANALYSIS ATLAS

Volume 9-11 Book 3D (Category 4) Monroe County

This Book is part of Volume 9 of the *Statewide Regional Evacuation Study Program* (SRESP), and one of three county books in the *South Florida Depth Analysis Atlas* series. Book 1 covers Broward County; Book 2 covers Miami-Dade County; and Book 3 covers Monroe County. The Atlas maps identify those areas subject to potential surge flooding from the five categories of hurricane on the Saffir-Simpson Hurricane Wind Scale, as determined by the National Oceanic and Atmospheric Administration (NOAA) numerical storm surge model, Sea, Lake and Overland Surges from Hurricanes (SLOSH), updated in 2009.

The *Storm Tide Atlas* (Volume 7-11) and the *Depth Analysis Atlas* together form the foundation of the hazards analysis from surge and represent key components of the SRESP. The *Technical Data Report* (Volume 1-11) builds upon this analysis and includes the revised evacuation zones and population estimates, results of the evacuation behavioral data, shelter analysis and evacuation transportation analyses. The study, which provides vital information to state and local emergency management, forms the basis for county evacuation plans. The final documents with summary information are available on the Internet at www.sfrpc.com/sresp.htm.

This Atlas was prepared and published by the South Florida Regional Planning Council with funding from the Florida Legislature and the Federal Emergency Management Agency, through the Florida Division of Emergency Management.



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VOLUME 9-11 SOUTH FLORIDA

DEPTH ANALYSIS ATLAS

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A. Introduction

A comprehensive emergency management program requires attention to four key inter-related components: preparedness, response, recovery and mitigation. Preparing and avoiding or reducing potential loss of life and property damage – **preparedness and mitigation** – requires accurate and precise hazard and vulnerability analyses. These analyses are the foundation for evacuation and disaster response planning, as well as the development of local mitigation strategies designed to reduce the community's overall risk to disasters. This Atlas series provides information to state, county and local emergency management officials and planners for use in hurricane preparedness and coastal management in the South Florida Region, including Broward, Miami-Dade and Monroe Counties (Figure 1). It is part of a statewide effort to enhance our ability to respond to a hurricane threat, facilitate the evacuation of vulnerable residents to a point of relative safety and mitigate our vulnerability in the future. The **Statewide Regional Evacuation Study Program** provides a consistent, coordinated and improved approach to addressing the state and regional vulnerability to the hurricane threat.

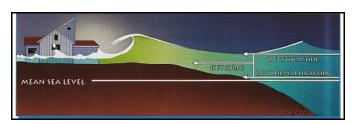
The specific purpose of this Atlas is to provide maps that depict storm surge flood depth from hurricanes of five different intensities in the South Florida area. The Atlas was prepared by the South Florida Regional Planning Council as part of the *Statewide Regional Evacuation Study Program*. The Study is a cooperative effort of the Florida Department of Economic Opportunity, the Florida Division of Emergency Management, the Florida Regional Planning Councils and the county emergency management agencies.



Figure 1 The South Florida Region

B. The SLOSH Model

The principal tool utilized in this study for analyzing the expected hazards from potential hurricanes affecting the study area is the Sea, Lake and Overland Surges from Hurricanes (**SLOSH**) numerical storm surge prediction model. The SLOSH computerized model predicts the storm tide heights that result from hypothetical hurricanes with selected various combinations of pressure, size, forward



speed, track and winds. Originally developed for use by the National Hurricane Center (NHC) as a tool to give geographically specific warnings of expected surge heights during the approach of hurricanes, the SLOSH model is utilized in regional studies for several key hazard and vulnerability analyses.

The SLOSH modeling system consists of the model source code and the model basin or grid. SLOSH model grids must be developed for each specific geographic coastal area, individually incorporating the unique local bay and river configuration, water depths, bridges, roads and other physical features. In addition to open coastline heights, one of the most valuable outputs of the SLOSH model for evacuation planning is its predictions of surge heights over land into inland areas.

The Tampa Bay SLOSH model basin completed in 1979 represented the first application of SLOSH storm surge dynamics to a major coastal area of the United States. The model was developed by the Techniques Development Lab of the National Oceanic and Atmospheric Administration (NOAA), under the direction of the late Dr. Chester P. Jelesnianski. In December 1990 the National Hurricane Center updated the SLOSH model. A major improvement to the model was the incorporation of wind speed degradation overland as the simulated storms moved inland. This duplicated the pressure "filling" and increases in the radii of maximum winds (RMW) as the hurricanes weaken after making landfall. The grid configuration also provided more detail and additional information.

The newest generation of the SLOSH model basin incorporated in the 2010 Statewide Regional Evacuation Study Program reflects major improvements, including higher resolution basin data and grid configurations. Faster computer speeds allowed additional hypothetical storms to be run for creation of the MOMs¹ or the maximum potential storm tide values for each category of storm.

1. Hypothetical Storm Simulations

Surge height depends strongly on the specifics of a given storm including, forward speed, angle of approach, intensity or maximum wind speed, storm size, storm shape, and landfall location. The SLOSH model was used to develop data for various combinations of hurricane strength, wind speed, and direction of movement. Storm strength was modeled using the central pressure (defined as the difference between the ambient sea level pressure and the minimum value in the storm's center), the storm eye size and the radius of maximum winds using the five categories of hurricane intensity as depicted in the Saffir-Simpson Hurricane Wind Scale (see Table 1).

Category	Wind Speeds	Potential Damage
Category 1	Sustained winds 74-95 mph	Very dangerous winds will produce some damage
Category 2	Sustained winds 96-110 mph	Extremely dangerous winds will cause extensive damage
Category 3	Sustained winds 111-130 mph	Devastating damage will occur
Category 4	Sustained winds 131-155 mph	Catastrophic damage will occur
Category 5	Sustained winds of 156 mph and above	Catastrophic damage will occur

Table 1 Saffir-Simpson Hurricane Wind Scale

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¹ Maximum of MEOWs or Maximum of Maximums

The modeling for each tropical storm/hurricane category was conducted using the mid-range pressure difference ($\triangle p$, millibars) for that category. The model also simulates the storm filling (weakening upon landfall) and radius of maximum winds (RMW) increase.

Ten storm track headings (E, ENE, NE, NNE, N, NNW, NW, WNW, W, and WSW) were selected as being representative of storm behavior in the South Florida region, based on observations by forecasters at the National Hurricane Center. And for each set of tracks in a specific direction storms were run at forward speeds of 5, 15 and 25 mph. And, for each direction, at each speed, storms were run at two different sizes (30 statute miles radius of maximum winds and 45 statute miles radius of maximum winds). Finally, each scenario was run at both mean tide and high tide. Both tide levels are now referenced to North American Vertical Datum of 1988 (NAVD88) as opposed to the National Geodetic Vertical Datum of 1929 (NGVD29) used in previous studies.

A total of 13,620 runs were made, consisting of the different parameters shown in Table 2.

Table 2 Florida Bay Basin Hypothetical Storm Parameters

Directions, speeds, sizes, (Saffir/Simpson) intensities, number of tracks and the number of runs.

Direction	Speeds (mph)	Size (Radius of Maximum Winds)	Intensity	Tides	Tracks	Runs
E	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	21	1,260
ENE	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	21	1,260
NE	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	24	1,440
NNE	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	27	1,620
N	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	28	1,680
NNW	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	24	1,440
NW	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	22	1,320
WNW	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	21	1,260
W	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	21	1,260
WSW	5, 15, 25 mph	30 statute miles, 45 statute miles	1 through 5	Mean/High	18	1,080
TOTAL				_		13,620

2. The Grid for the Florida Bay SLOSH Model

Figure 2 illustrates the area covered by the grid for the Florida Bay SLOSH Model. To determine the surge values the SLOSH model uses a telescoping elliptical grid as its unit of analysis with

124 arc lengths (1 < I < 124) and 189 radials (1 < J < 189). Use of the grid configuration allows for individual calculations per grid square, which is beneficial in two ways: (1) it provides increased resolution of the storm surge at the coastline and inside the harbors, bays and rivers, while decreasing the resolution in the deep water where detail is not as important; and (2) it allows economy in computation.

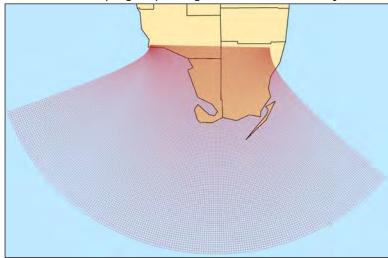


Figure 2 Florida Bay Basin Grid

The grid size for the Florida Bay Model varies from approximately 0.03 square mile or 19 acres closest to the pole (i = 1) to the grids on the outer edges where each grid is approximately 2.85 square miles.

3. Storm Scenario Determinations

As indicated, the SLOSH model is the basis for the "hazard analysis" portion of coastal hurricane evacuation plans. Thousands of hypothetical hurricanes are simulated with various Saffir-Simpson Wind categories, forward speeds, landfall directions, and landfall locations. An envelope of high water containing the maximum value a grid cell attains is generated at the end of each model run. These envelopes are combined by the NHC into various composites which depict the possible flooding. One useful composite is the MEOW (Maximum Envelopes of Water), which incorporates all the envelopes for a particular category, speed, and landfall direction. Once surge heights have been determined for the appropriate grids, the maximum surge heights are plotted by storm track and tropical storm/hurricane category.

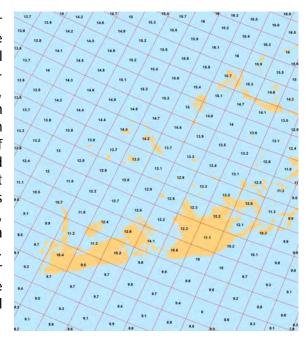


Figure 3 SLOSH Grid with Surge Values

These plots of maximum surge heights for a given storm category and track are referred to as Maximum Envelopes of Water (MEOWs). The MEOWs, or Reference Hurricanes, can be used in evacuation decision-making when and if sufficient forecast information is available to project storm track or type of storm (different landfalling, paralleling, or exiting storms).

The MEOWs provide information to the emergency managers in evacuation decision-making. However, in order to determine a scenario which may confront the county in a hurricane threat 24-48 hours before a storm is expected, a further compositing of the MEOWs into Maximums of the Maximums (MOMs) is usually required.

The MOM (Maximum of the MEOWs) combines all the MEOWs of a particular category. The MOMs represent the maximum surge expected to occur at any given location, regardless of the <u>specific</u> storm track/direction of the hurricane. The only variable is the intensity of the hurricane represented by category strength (Category 1-5).

The MOM surge heights, which were furnished by the National Hurricane Center, have 2 values, mean tide and high tide. Mean tide has 0' tide correction. High tide has a 1' tide correction added to it. The Storm Tide limits include the adjustment for mean high tide. All elevations are now referenced to the NAVD88 datum.

These surge heights were provided within the SLOSH grid system as illustrated on Figure 2. The range of maximum surge heights (low to high) for each scenario is provided for each category of storm (MOM) in Table 3. It should be noted again that these surge heights represent the maximum surge height recorded in the county from the storm tide analysis, including inland and back bay areas where the surge can be magnified dependent upon storm parameters.

Table 3 Potential Storm Tide Heights by County (In feet above NAVD88)

*Storm Strength	Broward	Miami-Dade	Monroe		
Category 1	Up to 3.1'	Up to 5.0'	Up to 7.9'		
Category 2	Up to 4.7'	Up to 8.2'	Up to 12.2'		
Category 3	Up to 6.2'	Up to 11.4'	Up to 16.4'		
Category 4	Up to 8.3'	Up to 14.2'	Up to 20.0'		
Category 5	Up to 9.5'	Up to 16.5'	Up to 23.3'		

^{*} Based on the category of storm on the Saffir-Simpson Hurricane Wind Scale

^{**} Surge heights represent the maximum values from SLOSH MOMs.

C. Creation of the Surge Depth Zones

The maps in this atlas depict SLOSH-modeled surge depth and extent of flood inundation for hurricanes of five different intensities. As indicate above, the surge depth was modeled using the Maximum of Maximums (MOMs) representing the potential flooding from the five categories of storm intensity of the Saffir-Simpson Hurricane Wind Scale.

1. Determining Storm Tide Height and Flooding Depth

SLOSH and SLOSH-related products reference storm tide heights relative to the model vertical datum, NAVD88. In order to determine the inundation depth of surge flooding at a particular location the ground elevation (relative to NAVD88) at that location must be subtracted from the potential surge height.²

Surge elevation, or water height, is the output of the SLOSH model. At each <u>SLOSH grid point</u>, the maximum surge height is computed at that point.

Within the SLOSH model an average elevation is assumed within each grid square. Height of water above terrain was not calculated using the SLOSH average grid elevation because terrain height may vary significantly within a SLOSH grid square. For example, the altitude of a 1-mile grid square may be assigned a value of 1.8 meters (6 feet), but this value represents an average of land heights that may include values ranging from 0.9 to 2.7 meters (3 to 9 feet).

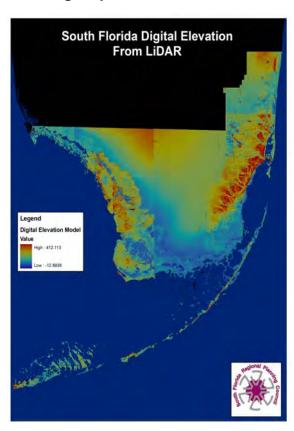


Figure 4 Digital Elevation from LIDAR

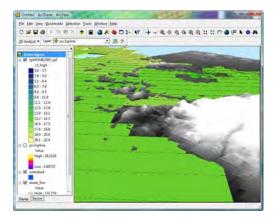
In this case, a surge value of 2.5 meters (8 feet) in this square would imply a 0.7 meters (2 feet) average depth of water over the grid's terrain. However, in reality within the grid area portion of the grid would be "dry" and other parts could experience as much as 1.5 meters (5 feet) of inundation. Therefore, in order to determine the storm tide limits, the depth of surge flooding above terrain at a specific site in the grid square is the result of subtracting the terrain height determined by remote sensing from the model-generated storm tide height in that grid square.³

² It is important to note that one must use a consistent vertical datum when post-processing SLOSH storm surge values.

³ Note: This represents the regional post-processing procedure. When users view SLOSH output within the SLOSH Display Program, the system uses average grid cell height when subtracting land.

2. Storm Tide Post-Processing

The Atlas was created using a Toolset wrapped into ESRI's ArcGIS mapping application, ArcMap. The surge tool was developed for the Statewide Regional Evacuation Study Program by the Tampa Bay Regional Planning Council, which had used a similar tool for the previous Evacuation Study Update (2006). This tool enabled all regions within the state of Florida to process the SLOSH and elevation data with a consistent methodology.



The tool basically performs the operation of translating the lower resolution SLOSH grid data into a smooth surface resembling actual storm tide and terrain, processing it with the high resolution elevation data derived from LiDAR. The image on the left represents how the data would look as it appears directly from SLOSH Model output.

Processing all the data in the raster realm, the tool is able to digest large amounts of data and output detailed representations of surge inundation.

Figure 5 SLOSH Display

The program first interpolates the SLOSH height values for each category into a raster surface using spline interpolation. This type of interpolation is best for smooth surfaces, such as water and slow changing terrain. The result is a raster surface representing the surge height for a category that can be processed against the raster Digital Elevation Model from the LIDAR. The "dry" values (represented as 99.9 in the SLOSH Model) are replaced by an average of the inundated grids surrounding the current processed grid. An algorithm performs this action

utilizing the range of values in the current category of

storm being processed.

Using this methodology, once the elevation is subtracted from the projected storm tide, the storm tide limits are determined. The output of the tool is a merged polygon file holding all the maximum inundation zones for Category 1 through Category 5. The output depicted in this Storm Tide Atlas is determined consistent with the coastal areas throughout the state. Figure 7 presents a compilation of the Storm Tide Atlas for the region.

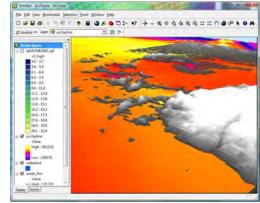
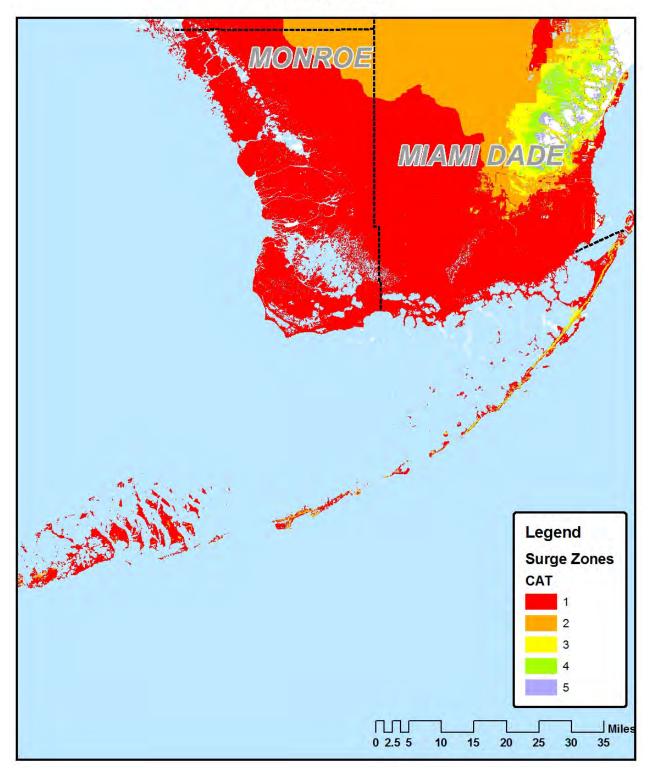


Figure 6 SLOSH Display Post-Processing

Figure 7 Storm Tide Limits for the South Florida Region Florida Bay Basin



D. Variations to Consider

Variations between modeled versus actual measured storm tide elevations are typical of current technology in coastal storm surge modeling. In interpreting the data emergency planners should recognize the uncertainties characteristic of mathematical models and severe weather systems such as hurricanes. The surge depths developed for this study and presented in the *Depth Analysis Atlas* should be used as guideline information for planning purposes.

1. Storm Tide and Wave Height



Regarding interpretation of the data, it is important to understand that the configuration and depth (bathymetry) of the Ocean or Gulf bottom will have a bearing on surge and wave heights. A narrow shelf, or one that drops steeply from the shoreline and subsequently

produces deep water in close proximity to the shoreline tends to produce a lower surge but a higher and more powerful wave. Those regions that have a gently sloping shelf and shallower normal water depths, can expect a higher surge but smaller waves. The reason this occurs is because a surge in deeper water can be dispersed down and out away from the hurricane. However, once that surge reaches a shallow, gently sloping shelf it can no longer be dispersed away from the hurricane; consequently water "piles up" as it is driven ashore by the wind stresses of the hurricane. Wave height is NOT calculated by the SLOSH model and is not reflected within the surge depth delineations.

2. Forward Speed

Under actual storm conditions it may be expected that a hurricane moving at a slower speed could have higher coastal storm tides than those depicted from model results. At the same time, a fast moving hurricane would have less time to move storm surge water up river courses to more inland areas. For example, a minimal hurricane or a storm further off the coast, such as Hurricane Elena (1985), which stalled 90 miles off the Tampa Bay coast for several tidal cycles, could cause extensive beach erosion and move large quantities of water into interior lowland areas. In the newest version of the SLOSH model, for each set of tracks in a specific direction, storms were run at forward speeds of 5, 15 and 25 mph.

3. Radius of Maximum Winds

As indicated previously, the size of the storm or radius of maximum winds (RMW) can have a significant impact on storm surge especially in bay areas and along the Gulf of Mexico. All of the hypothetical storms were run at two different sizes, 20 nautical mile radius of maximum winds and 35 nautical mile radius of maximum winds.

4. Astronomical Tides

Surge heights were provided by NOAA for both mean tide and high tide. Both tide levels are referenced to North American Vertical Datum of 1988. The surge depths reflect high tide in the region.

5. Accuracy

As part of the Statewide Regional Evacuation Study, all coastal areas, as well as areas surrounding Lake Okeechobee, were mapped using remote-sensing laser terrain mapping (LiDAR⁴) providing the most comprehensive, accurate and precise topographic data for this analysis. As a general rule, the vertical accuracy of the laser mapping is within a 15 centimeter tolerance. However, it should be noted that the accuracy of these elevations is limited to the precision and tolerance in which the horizontal accuracy for any given point is recorded. Other factors such as artifact removal algorithms (that remove buildings and trees) can affect the recorded elevation in a particular location. For the purposes of this study, the horizontal accuracy cannot be assumed to be greater than that of a standard USGS 7.5-minute quadrangle map, or a scale of 1:24,000.

E. Points of Reference

County emergency management agencies selected reference points, which include key facilities or locations critical for emergency operations. The table below includes the map identification number, descriptions of the selected points, and the elevation of the site. The elevation is based on the digital elevation data provided by the LiDAR. It should be noted that if the site is large, elevations may vary significantly. The table also provides the storm tide value from the SLOSH value and the depth of inundation (storm tide value minus the ground elevation) at the site.

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⁴ Light Imaging Detection and Ranging

Table 4 Selected Points of Reference – Monroe County

								,					
Marker ID#	Elevation	C1 DEPTH⁵	C2 DEPTH	C3 DEPTH	C4 DEPTH	C5 DEPTH	C1 SURGE ⁶	C2 SURGE	C3 SURGE	C4 SURGE	C5 SURGE		
0	10.059	0.000	0.000	0.000	0.000	0.000	2.519	5.203	7.402	8.337	10.043		
1	4.741	0.000	0.634	3.248	3.983	5.363	2.803	5.375	7.989	8.724	10.104		
2	2.607	0.434	3.662	6.524	7.169	7.942	3.041	6.269	9.131	9.776	10.549		
3	2.691	0.488	3.555	6.286	7.655	8.753	3.179	6.246	8.977	10.346	11.444		
4	3.393	0.000	2.083	4.584	6.827	8.370	3.123	5.476	7.977	10.220	11.763		
5	5.975	0.000	0.000	3.678	5.702	7.559	3.011	4.246	9.653	11.677	13.534		
6	13.506	0.000	0.000	0.000	0.000	0.000	3.103	4.677	8.637	10.591	12.655		
7	2.655	0.246	2.716	4.749	7.072	9.699	2.901	5.371	7.404	9.727	12.354		
8	12.702	0.000	0.000	0.000	0.000	0.000	3.247	5.942	8.400	10.133	12.094		
9	3.638	0.000	2.521	5.053	7.394	8.684	2.925	6.159	8.691	11.032	12.322		
10	2.980	0.000	3.184	6.197	8.151	9.671	2.901	6.164	9.177	11.131	12.651		
11	5.285	0.000	0.902	3.424	4.979	6.906	3.067	6.187	8.709	10.264	12.191		
12	6.036	0.000	0.318	1.222	2.748	5.376	3.764	6.354	7.258	8.784	11.412		
13	5.086	0.000	1.313	2.739	3.939	5.872	3.506	6.399	7.825	9.025	10.958		
14	2.966	0.305	3.495	5.330	6.483	8.163	3.271	6.461	8.296	9.449	11.129		
15	8.073	0.000	0.000	0.000	2.260	3.378	4.033	6.710	7.894	10.333	11.451		
16	6.064	0.000	0.866	2.694	4.513	5.251	4.112	6.930	8.758	10.577	11.315		
17	4.566	0.000	2.327	4.283	6.025	6.714	4.067	6.893	8.849	10.591	11.280		
18	3.041	1.003	4.054	5.840	7.811	8.493	4.044	7.095	8.881	10.852	11.534		
19	4.073	0.000	2.538	4.497	6.453	7.734	3.548	6.611	8.570	10.526	11.807		
20	4.288	0.000	1.956	4.378	6.098	7.592	3.840	6.244	8.666	10.386	11.880		
21	3.867	0.000	2.341	4.654	6.225	7.899	3.765	6.208	8.521	10.092	11.766		
22	4.332	0.000	1.863	3.863	5.574	7.235	3.894	6.195	8.195	9.906	11.567		
23	1.573	2.515	4.405	6.240	8.150	9.638	4.088	5.978	7.813	9.723	11.211		
24	6.646	0.000	0.000	1.129	2.868	4.374	4.229	5.818	7.775	9.514	11.020		
25	1.752	2.512	4.449	6.091	7.443	8.780	4.264	6.201	7.843	9.195	10.532		
26	0.000	4.340	6.221	7.932	9.567	10.378	4.340	6.221	7.932	9.567	10.378		
27	4.061	0.000	1.512	3.407	5.302	6.332	3.994	5.573	7.468	9.363	10.393		
28	0.000	4.143	5.189	6.788	9.676	10.780	4.143	5.189	6.788	9.676	10.780		

DEPTH refers to the depth of inundation at the site (storm surge value minus the ground elevation)
 SURGE refers to the storm surge value from the SLOSH Model

Marker	Floretien	04 DEDTU5	C2	C3	C4	C5	O4 CHROE	00 0400	00 CHB0=	04.04.00	OF CLIPPOF
ID#	Elevation 6.994	C1 DEPTH ⁵	DEPTH	DEPTH	DEPTH 2.270	DEPTH 4 E 40	C1 SURGE ⁶	C2 SURGE	C3 SURGE	C4 SURGE	C5 SURGE
29		0.000	0.000 1.314	0.000	3.270	4.548	4.047	5.097	6.870	10.264	11.542
30 31	4.007 6.036	0.016 0.000	0.000	3.386 1.399	6.560 4.055	7.545	4.023 3.693	5.321 5.224	7.393 7.435	10.567 10.091	11.552 10.855
32	4.613	0.000	0.000	2.317	4.055 4.883	4.819 5.962	3.093 3.161	5.224 4.919	6.930	9.496	10.855
33	0.000	2.864	4.701	2.317 6.477	4.883 7.972	10.030	2.864	4.919 4.701	6.477	9.496 7.972	10.575
33 34	6.963	0.000	0.000	0.000	7.972 1.261	2.747	2.864 2.914	4.701 4.770	6.571	7.972 8.224	9.710
34 35	12.071	0.000	0.000	0.000	0.000	0.000	2.899	4.770	6.880	8.857	9.710
35 36	0.000	2.829	4.731	6.677	8.578	10.897	2.899	4.899 4.731	6.677	8.857 8.578	9.005 10.897
36 37	5.020	0.000	0.000	1.284	2.868	6.318	2.829	4.731	6.304	7.888	11.338
			0.000								9.696
38 39	4.760 0.000	0.000 2.645	4.423	1.528 6.327	3.065 7.960	4.936 9.723	2.804 2.645	4.493 4.423	6.288 6.327	7.825 7.960	9.090 9.723
39 40	14.615	0.000	0.000	0.000	0.000	0.000	2.620	4.423 4.255	6.056	7.960 7.812	9.723 9.537
40	0.000	2.628	4.122	5.780	7.354	8.925	2.628	4.233 4.122	5.780	7.012	9.557 8.925
41	0.000	2.525	4.122	5.639	7.354 7.262	8.868	2.545	4.122	5.760	7.354 7.262	8.868
42	0.000	2.343	4.036 3.914	5.494	7.202 7.106	8.813	2.343	4.036 3.914	5.494	7.202 7.106	8.813
43	0.000	2.433	3.742	5.315	6.791	8.615	2.433	3.742	5.474	6.791	8.615
45	0.000	2.424	3.630	5.450	6.789	8.698	2.424	3.742	5.450	6.789	8.698
46	0.000	2.289	3.855	5.637	7.178	8.909	2.289	3.855	5.637	7.178	8.909
47	8.060	0.000	0.000	0.000	0.000	1.433	2.445	4.327	6.390	7.176	9.493
48	3.277	0.000	1.680	3.514	5.112	6.665	2.443	4.957	6.791	8.389	9.942
49	4.370	0.000	1.592	3.107	4.516	6.094	2.436	5.962	7.477	8.886	10.464
50	3.905	0.000	2.300	3.985	5.123	6.488	2.739	6.205	7.477	9.028	10.404
50 51	4.269	0.000	1.811	3.412	4.796	6.085	2.739	6.080	7.681	9.065	10.354
52	4.207	0.000	2.194	3.699	5.530	6.982	2.727	6.286	7.001	9.622	11.074
53	5.112	0.000	1.136	3.095	4.873	5.967	2.972	6.248	8.207	9.985	11.074
54	4.713	0.000	1.666	3.836	5.428	6.773	3.461	6.379	8.549	10.141	11.486
55	5.707	0.000	1.241	2.923	4.217	6.075	3.650	6.948	8.630	9.924	11.782
56	2.932	0.602	3.713	5.897	7.344	8.529	3.534	6.645	8.829	10.276	11.461
57	3.096	0.142	2.729	4.818	6.160	7.830	3.238	5.825	7.914	9.256	10.926
58	2.645	0.539	2.628	4.866	6.280	8.404	3.184	5.273	7.514	8.925	11.049
59	3.660	0.000	1.006	4.184	5.872	8.733	3.321	4.666	7.844	9.532	12.393
60	5.364	0.000	0.000	1.689	3.546	5.501	2.935	5.204	7.053	8.910	10.865
61	3.563	0.000	0.164	2.570	5.782	7.504	2.204	3.727	6.133	9.345	11.067
62	7.959	0.000	0.000	0.000	0.114	1.910	2.434	4.080	6.012	8.073	9.869
UZ	1.757	0.000	0.000	0.000	0.114	1.710	۷.۶۵۶	4.000	0.012	0.073	7.007

Marker ID#	Elevation	C1 DEPTH⁵	C2 DEPTH	C3 DEPTH	C4 DEPTH	C5 DEPTH	C1 SURGE ⁶	C2 SURGE	C3 SURGE	C4 SURGE	C5 SURGE
63	9.015	0.000	0.000	0.000	0.000	0.197	2.290	3.697	5.335	7.240	9.212
64	0.000	2.271	3.560	5.270	6.880	8.664	2.271	3.560	5.270	6.880	8.664
65	0.000	2.167	3.536	5.227	7.024	8.590	2.167	3.536	5.227	7.024	8.590
66	2.525	0.000	1.100	2.867	4.780	6.316	2.162	3.625	5.392	7.305	8.841
67	2.574	0.000	1.511	3.050	4.707	6.170	2.470	4.085	5.624	7.281	8.744
68	3.456	0.000	0.889	2.685	4.208	6.076	2.572	4.345	6.141	7.664	9.532
69	2.297	0.402	2.135	4.440	6.438	8.618	2.699	4.432	6.737	8.735	10.915
70	5.317	0.000	0.000	1.239	3.379	5.709	2.526	4.469	6.556	8.696	11.026
71	0.000	2.453	4.329	6.147	8.661	10.474	2.453	4.329	6.147	8.661	10.474
72	8.367	0.000	0.000	0.000	0.000	1.011	2.596	4.320	5.936	7.626	9.378
73	0.000	2.590	4.205	5.579	7.102	8.521	2.590	4.205	5.579	7.102	8.521
74	2.194	0.501	2.413	3.860	5.228	6.588	2.695	4.607	6.054	7.422	8.782
75	2.451	0.306	2.243	3.557	4.617	6.013	2.757	4.694	6.008	7.068	8.464
76	2.876	0.000	1.962	3.178	4.552	6.435	2.869	4.838	6.054	7.428	9.311
77	3.667	0.000	1.105	2.466	3.872	5.800	2.923	4.772	6.133	7.539	9.467
78	0.000	2.669	4.400	6.034	7.747	9.745	2.669	4.400	6.034	7.747	9.745
79	3.546	0.000	1.111	2.942	5.094	7.152	2.774	4.657	6.488	8.640	10.698
80	4.008	0.000	0.672	2.432	4.961	6.873	2.746	4.680	6.440	8.969	10.881
81	7.454	0.000	0.000	0.000	3.259	4.940	2.902	5.077	7.064	10.713	12.394
82	8.102	0.000	0.000	0.000	2.405	4.808	2.839	5.254	7.222	10.507	12.910
83	6.194	0.000	0.000	1.642	3.839	6.770	2.772	5.987	7.836	10.033	12.964
84	0.000	2.944	5.024	6.740	8.513	12.526	2.944	5.024	6.740	8.513	12.526
85	4.906	0.000	1.155	3.215	4.906	7.326	3.439	6.061	8.121	9.812	12.232
86	8.167	0.000	0.000	0.028	1.612	3.662	2.558	6.193	8.195	9.779	11.829
87	8.171	0.000	0.000	0.000	2.114	5.186	3.157	5.278	6.991	10.285	13.357
88	7.211	0.000	0.000	0.000	4.958	7.244	3.311	5.732	5.932	12.169	14.455
89	6.315	0.000	0.464	2.494	5.948	8.133	3.858	6.779	8.809	12.263	14.448
90	4.857	0.000	1.960	3.903	9.453	12.183	3.981	6.817	8.760	14.310	17.040
91	5.902	0.000	0.000	0.987	6.624	8.904	3.215	5.625	6.889	12.526	14.806
92	7.074	0.000	0.000	0.426	3.680	5.538	3.363	5.873	7.500	10.754	12.612
93	2.251	1.419	5.625	8.098	11.099	12.118	3.670	7.876	10.349	13.350	14.369
94	7.940	0.000	0.000	2.416	3.486	5.677	4.308	7.595	10.356	11.426	13.617
95	4.314	0.157	3.204	5.945	6.378	10.601	4.471	7.518	10.259	10.692	14.915
96	8.715	0.000	0.000	0.000	0.643	5.469	3.618	6.892	8.436	9.358	14.184

Marker ID#	Elevation	C1 DEPTH⁵	C2 DEPTH	C3 DEPTH	C4 DEPTH	C5 DEPTH	C1 SURGE ⁶	C2 SURGE	C3 SURGE	C4 SURGE	C5 SURGE
97	9.549	0.000	0.000	1.065	2.417	4.432	3.306	7.601	10.614	11.966	13.981
98	9.138	0.000	0.000	2.619	3.741	5.227	3.407	8.390	11.757	12.879	14.365
99	9.345	0.000	0.000	3.014	3.588	4.893	3.093	8.483	12.359	12.933	14.238
100	8.373	0.000	0.005	4.252	5.042	5.824	3.582	8.378	12.625	13.415	14.197
101	10.942	0.000	0.000	1.307	2.416	3.042	3.639	8.140	12.249	13.358	13.984
102	11.087	0.000	0.000	0.000	1.202	2.359	4.165	7.413	10.951	12.289	13.446
103	11.512	0.000	0.000	0.000	0.000	1.043	3.659	6.421	8.985	10.707	12.555
104	11.428	0.000	0.000	0.000	1.330	2.049	3.488	6.683	11.223	12.758	13.477
105	9.875	0.000	0.000	1.348	2.982	3.988	3.276	7.325	11.223	12.857	13.863
106	10.171	0.000	0.000	0.891	2.368	3.442	3.554	7.136	11.062	12.539	13.613
107	0.000	3.709	8.604	12.630	13.678	14.199	3.709	8.604	12.630	13.678	14.199
108	0.000	4.205	8.169	11.665	13.183	14.233	4.205	8.169	11.665	13.183	14.233
109	-1.343	5.505	9.115	12.692	14.654	15.883	4.162	7.772	11.349	13.311	14.540
110	0.000	4.065	7.462	11.079	13.303	14.719	4.065	7.462	11.079	13.303	14.719
111	0.000	4.140	7.215	10.812	13.248	14.893	4.140	7.215	10.812	13.248	14.893
112	0.000	4.156	7.090	10.425	13.063	14.875	4.156	7.090	10.425	13.063	14.875

F. Depth Analysis Atlas

The surge depth ranges (MOM surge heights minus the ground elevations) are provided as GIS shape files and graphically displayed on maps in the hurricane *Depth Analysis Atlas* for the South Florida Region. The *Atlas* was prepared by the South Florida Regional Planning Council under contract to the State of Florida, Division of Emergency Management, as part of this study effort. The maps prepared for the *Atlas* consist of base maps (1:24000) including topographic, hydrographic and highway files (updated using 2008 county and state highway data). Detailed shoreline and surge depth ranges for each category of storm were determined using the region's geographic information system (GIS).

The purpose of the maps contained in this Atlas is to reflect a "worst probable" scenario of the hurricane storm tide inundation and to provide a basis for the hurricane evacuation zones and study analyses. While the surge depth ranges include the addition of an astronomical mean high tide and tidal anomaly, it should be noted that the data reflects only stillwater saltwater flooding. Local processes such as waves, rainfall and flooding, are usually included in observations of storm tide height, but are not surge and are not calculated by the SLOSH model. It is incumbent upon local emergency management officials and planners to estimate the degree and extent of freshwater flooding, as well as to determine the magnitude of the waves that will accompany the surge.

Figure 8 provides an index of the map series for Monroe County. Please note that, for each category of storm, only the map sheets where surge is present were included in the Atlas. Therefore, the number of plates included in the Atlas varies with the storm category, depending on the extent of surge associated with the category of storm.

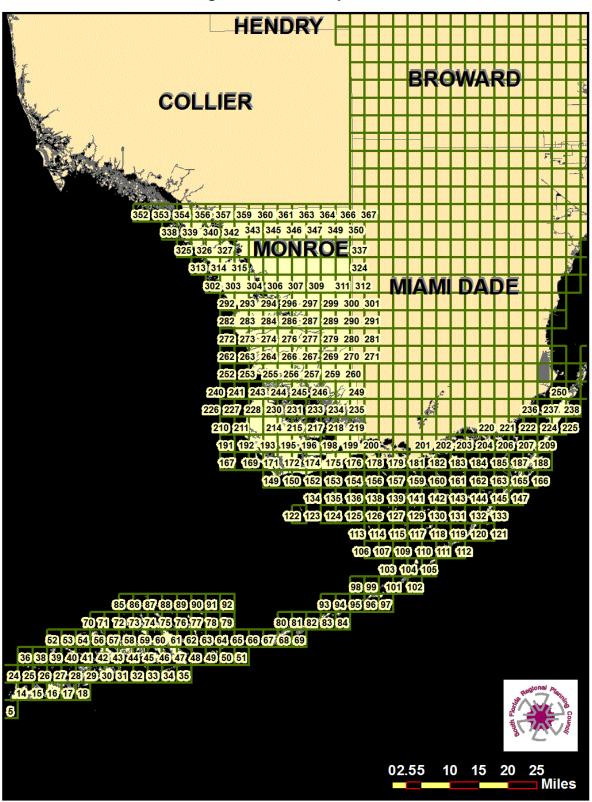
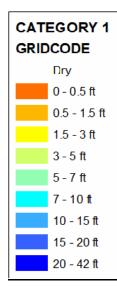


Figure 8 Atlas Map Index

G. Notes on Surge Depth Ranges

Historically, the SLOSH storm surge analysis had focused on "average" storm parameters (size and forward speed), although the intensity and angle of approach was modeled to include direct strikes and catastrophic intensity. In the 2010 Regional Evacuation Study for the Florida Bay Basin, 13,620 hypothetical hurricanes were included in the SLOSH suite of storms modeled varying forward speeds and the radii of maximum winds to include the large storm events and different forward speeds. This allowed for the development of a truer picture of the storm surge vulnerability in the region. The five categories of hurricane reflect a "worst probable" surge extent for hurricanes, holding the wind speed constant (consistent with the Saffir-Simpson Hurricane Wind Scale) while varying storm parameters including size, forward speed, and angle of approach.

This has led to some confusion regarding evacuation decision-making, since hurricane evacuations are based primarily on storm surge vulnerability. The National Oceanic and Atmospheric Administration (NOAA) is working to enhance the analysis and prediction of storm surge. Direct estimates of inundation are being communicated in the NHC's Public Advisories and in the Weather Forecast Office's (WFO) Hurricane Local Statements. NHC's probabilistic storm surge product, which provides the likelihood of a specific range of storm surge values, became operational in 2009, and the National Weather Service (NWS) Meteorological Development Laboratory provided experimental, probabilistic storm surge products for 2010. In addition, coastal weather forecast offices provided experimental Tropical Cyclone Impacts Graphics in 2010; these include a qualitative graphic on the expected storm surge impacts. Finally, the NWS is exploring the possibility of issuing explicit Storm Surge Warnings, which could be implemented in the next couple of years. In all of these efforts, the NWS is working to provide specific and quantitative information to support decision-making at the local level⁷. NOAA continues to emphasize that the hurricane forecasts are not 100% accurate and dependent upon many factors.

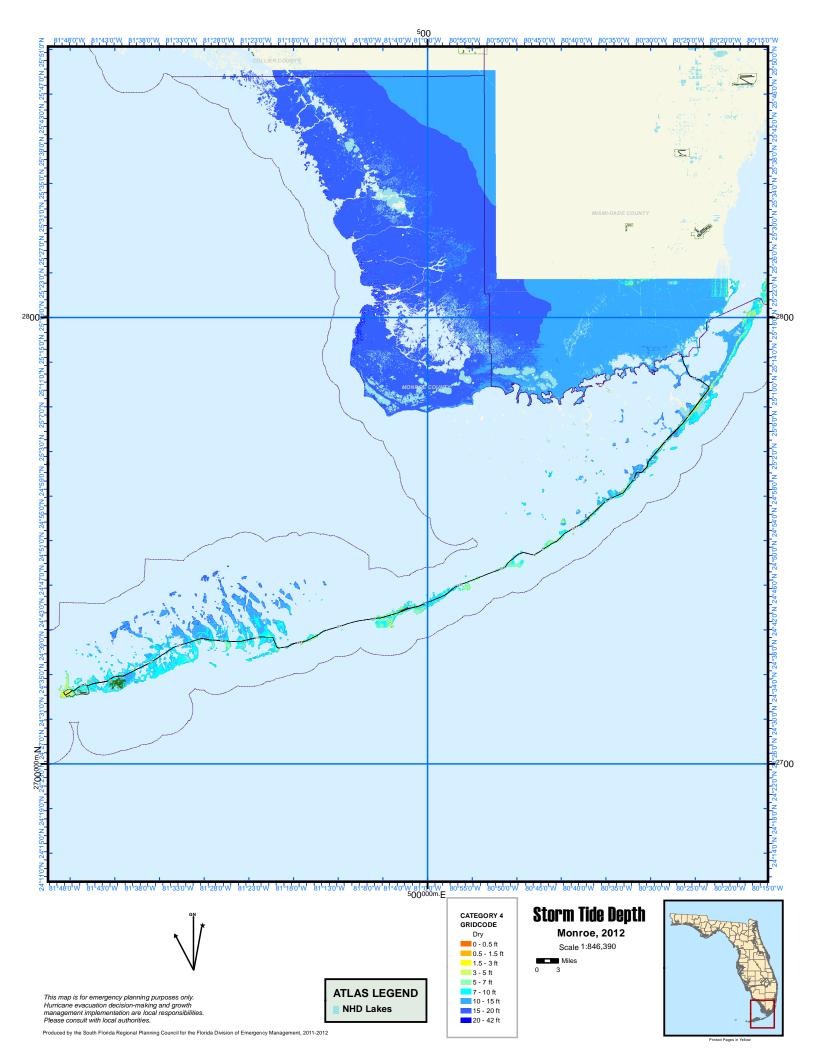


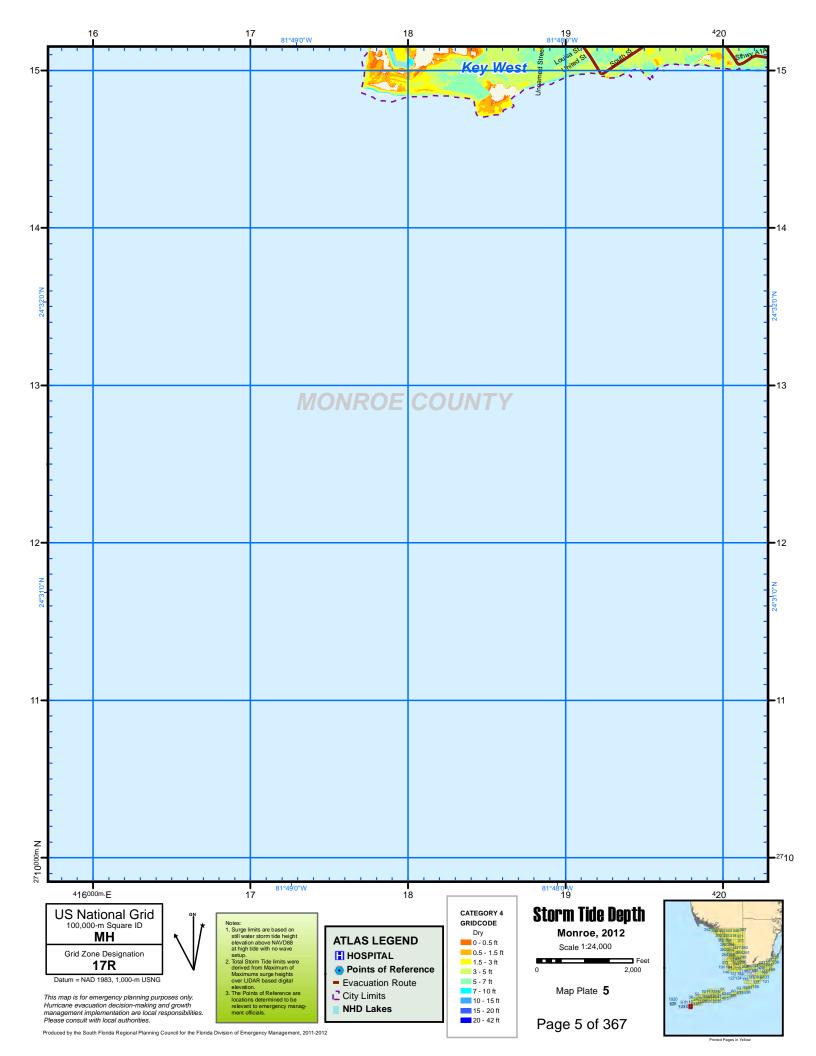
To the left are the Surge Depth ranges identified for Monroe County under the five (5) categories of hurricane on the Saffir-Simpson Hurricane Wind Scale. It is important to recognize the following:

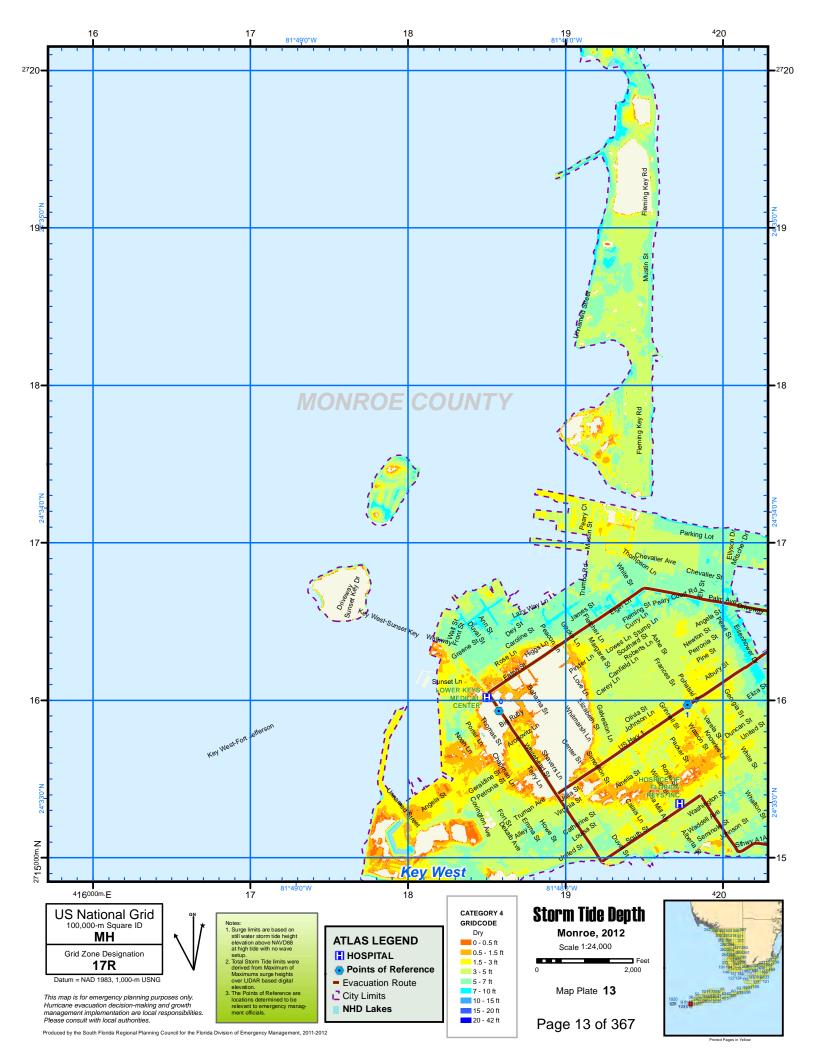
- The surge depth values are based on the highest surge height elevation above a standard datum (NAVD88) predicted by the model in the entire county and will only be appropriate for selected areas.
- Typically the highest surge depth values are NOT the surge depths predicted at the coast. The highest surge depth values are typically experienced inside bays and up rivers and inlets (water above ground).
- Surge depth ranges by category of storm are presented in Table 3 on page 5 of this document.
- For surge heights at specific locations, please refer to Table 4 on page 11, which provides the expected storm surge depth at points of reference with the actual inundation (water depth) at that site.

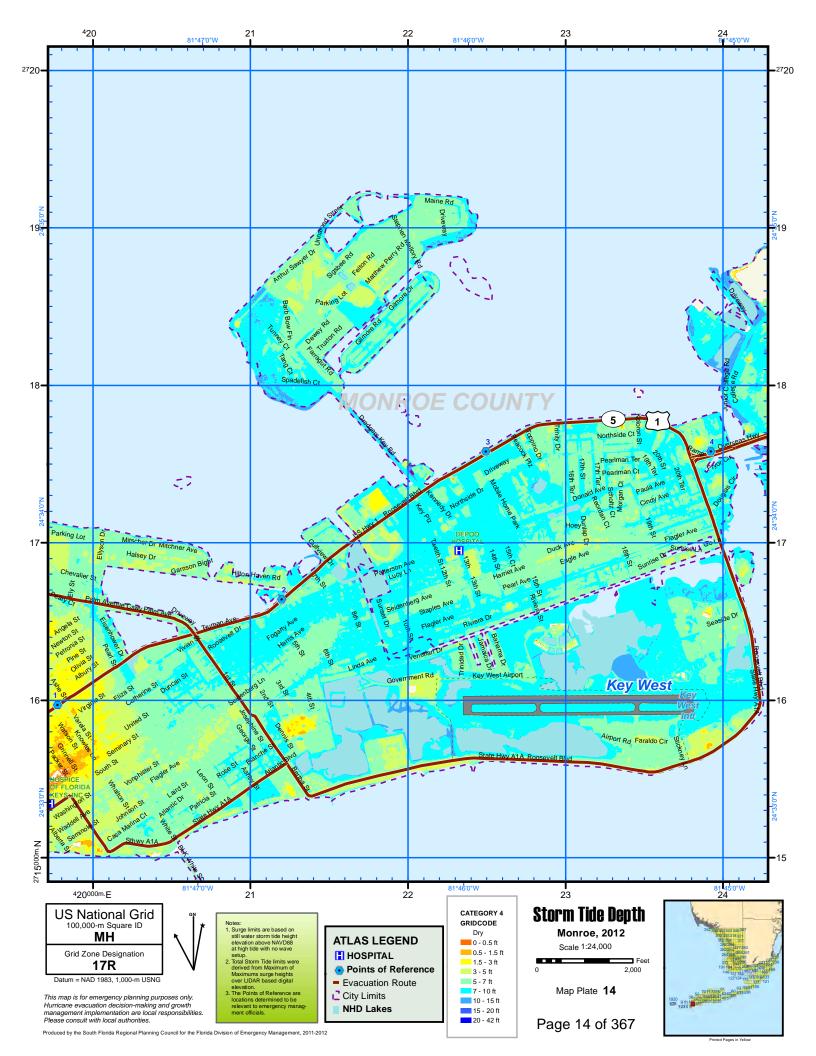
⁷ www.nhc.noaa.gov/sshws_statement.shtml

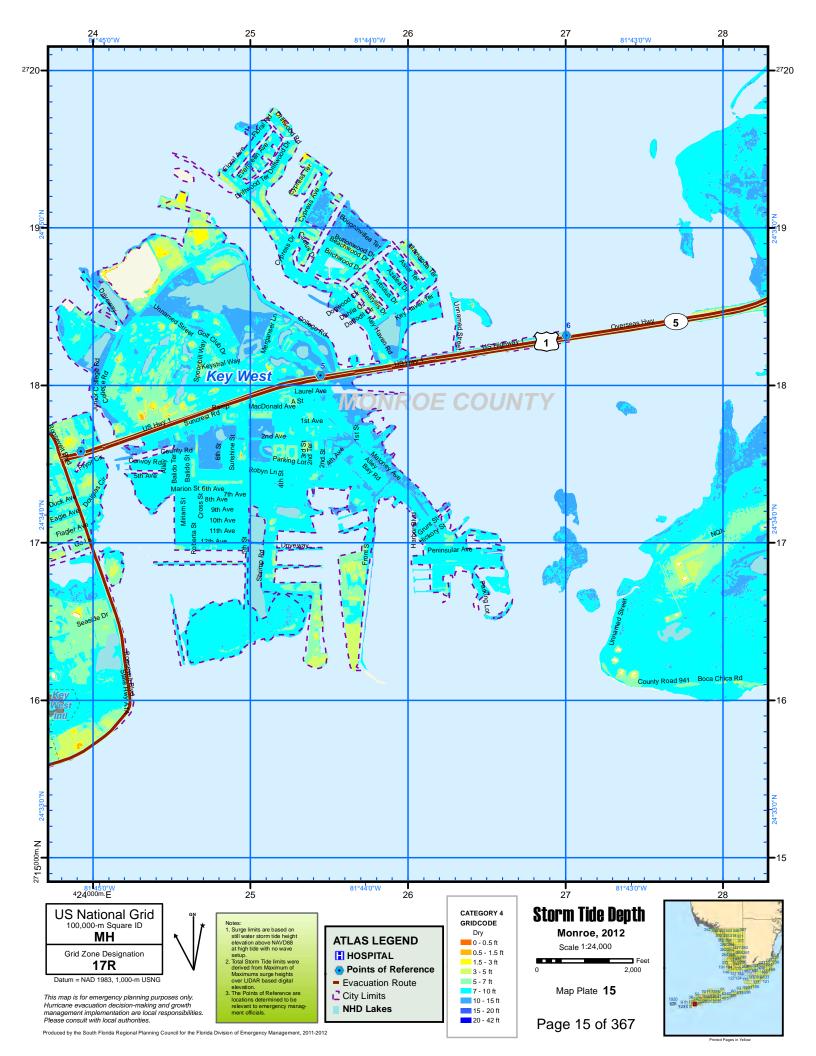
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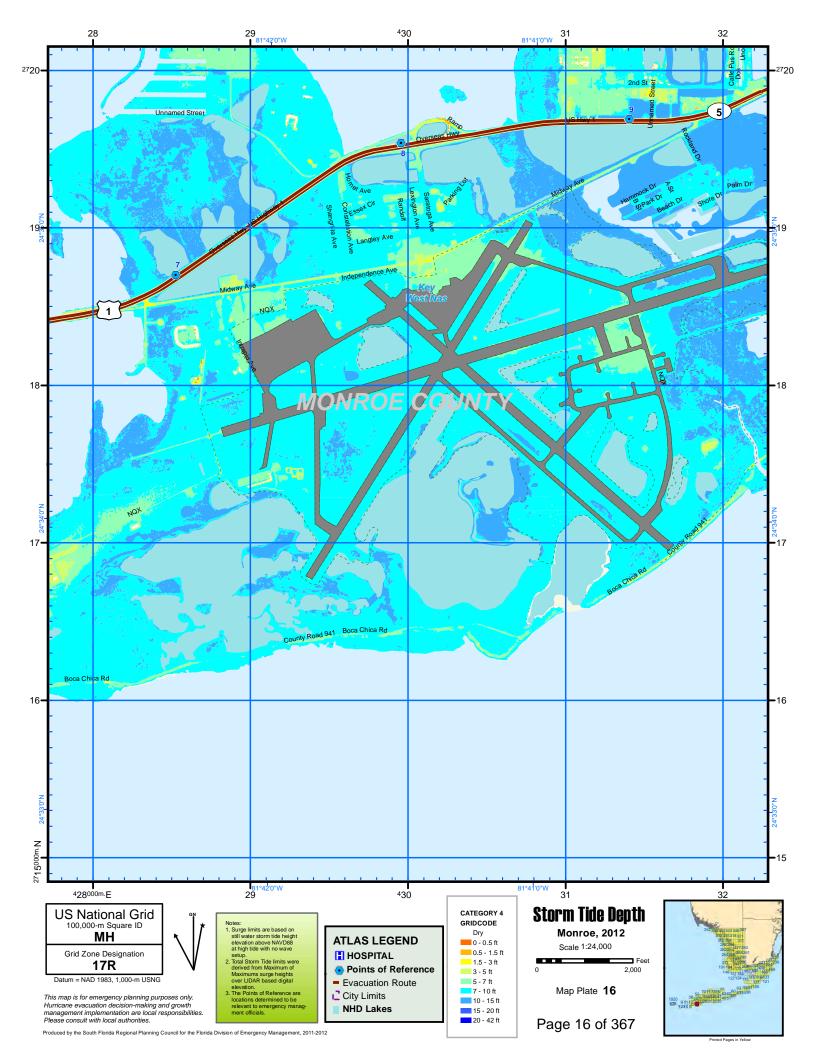


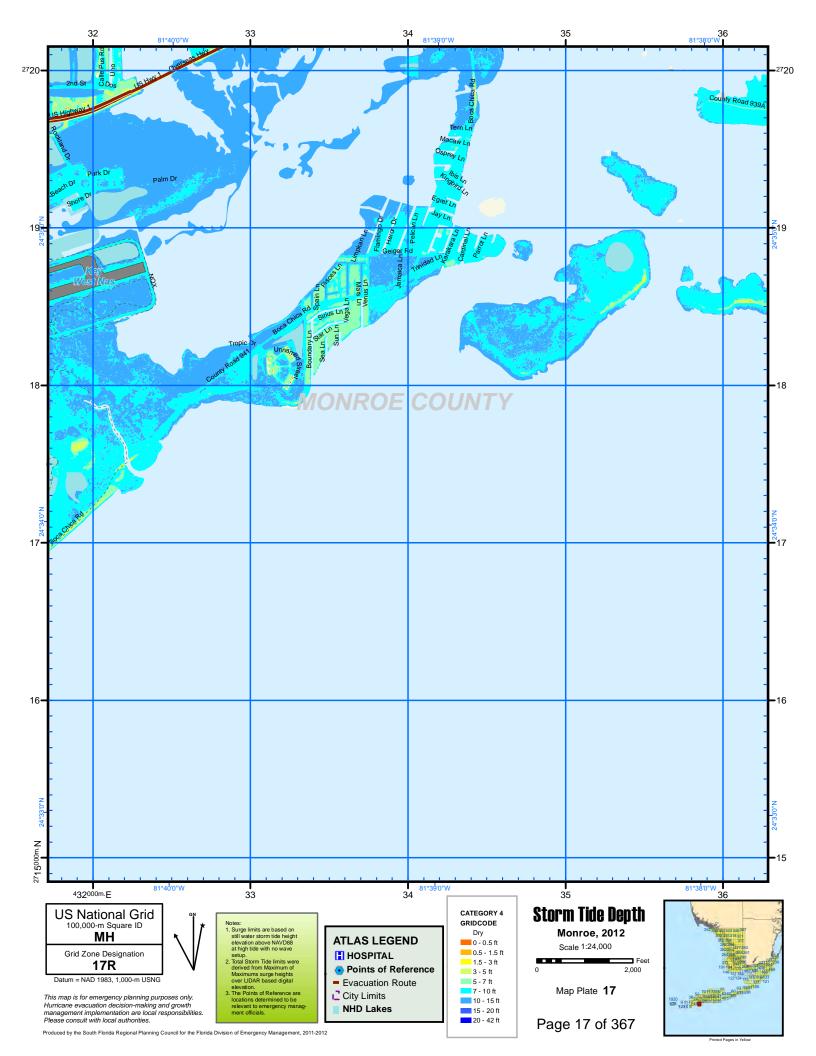


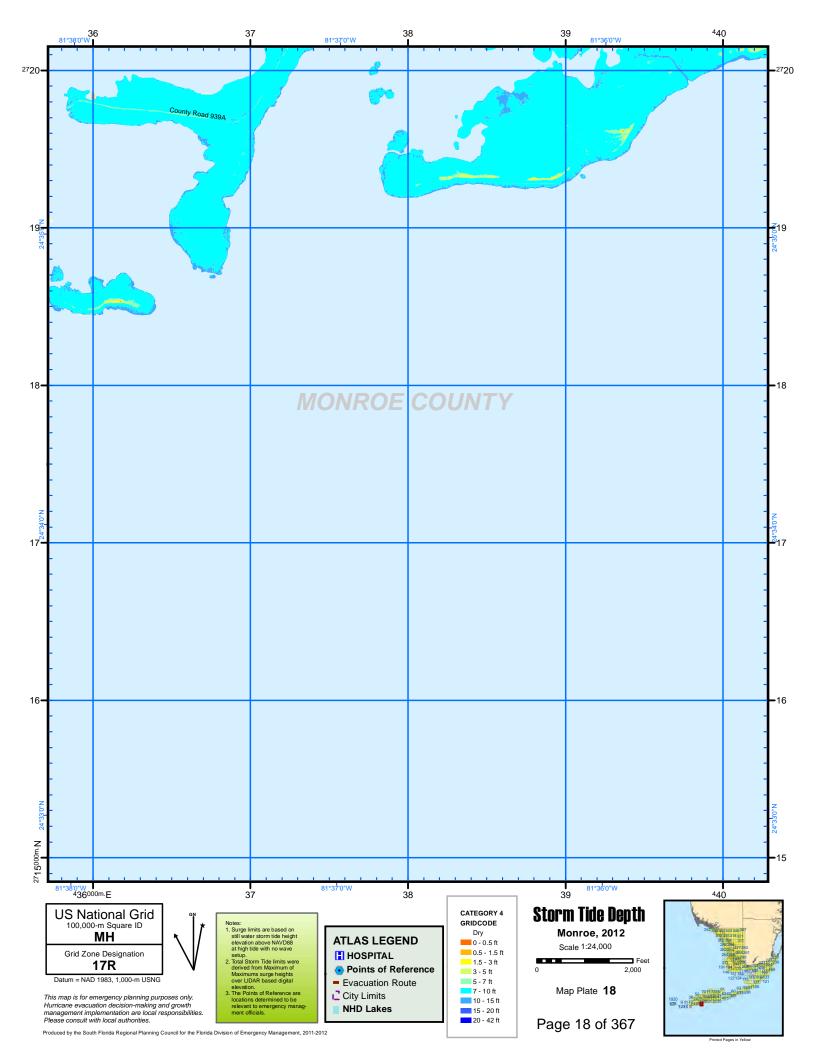


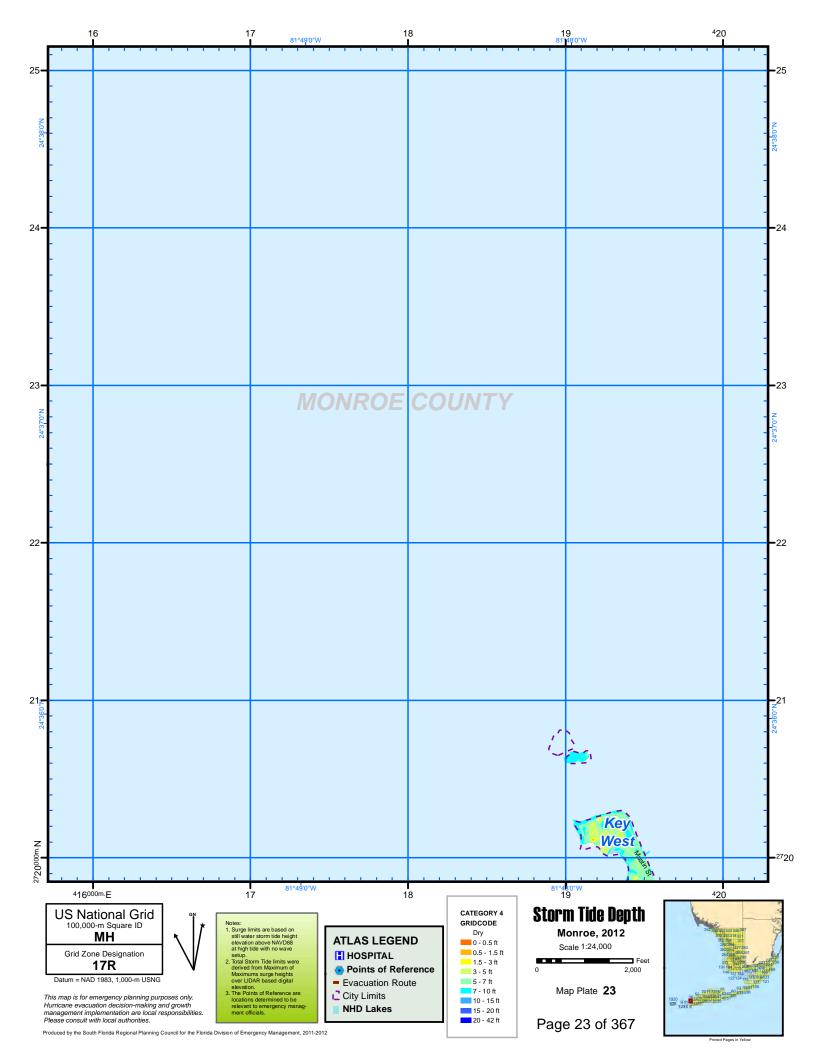


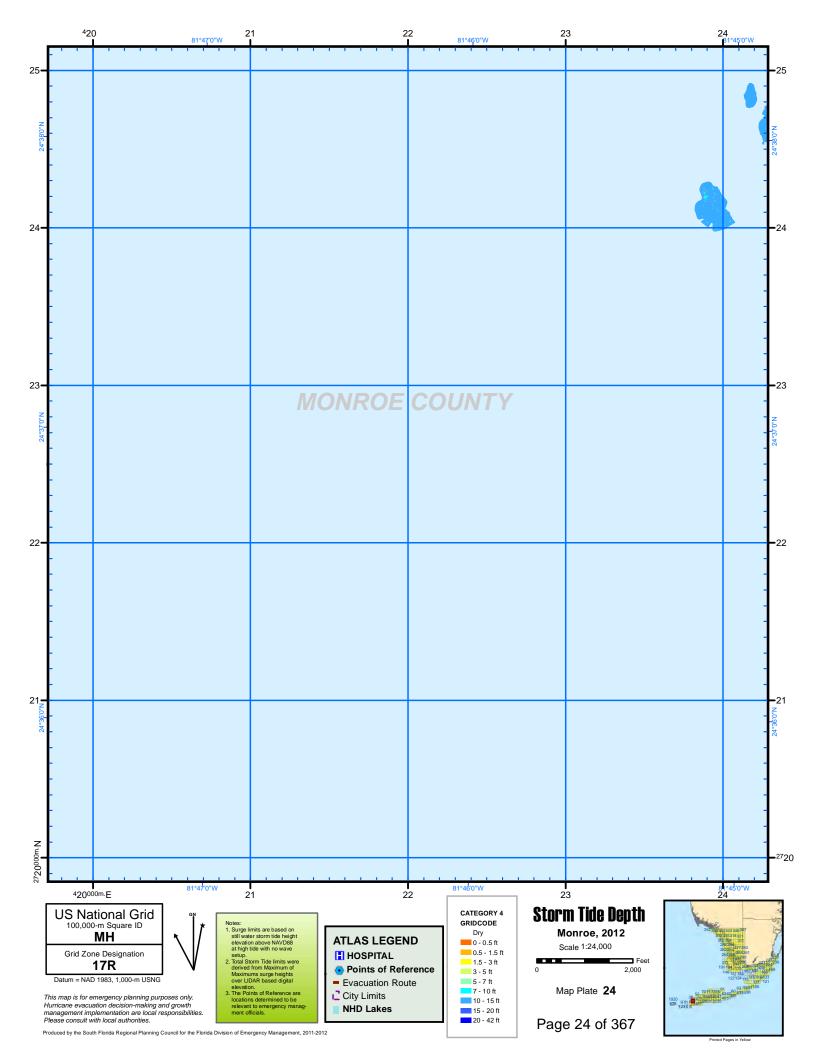


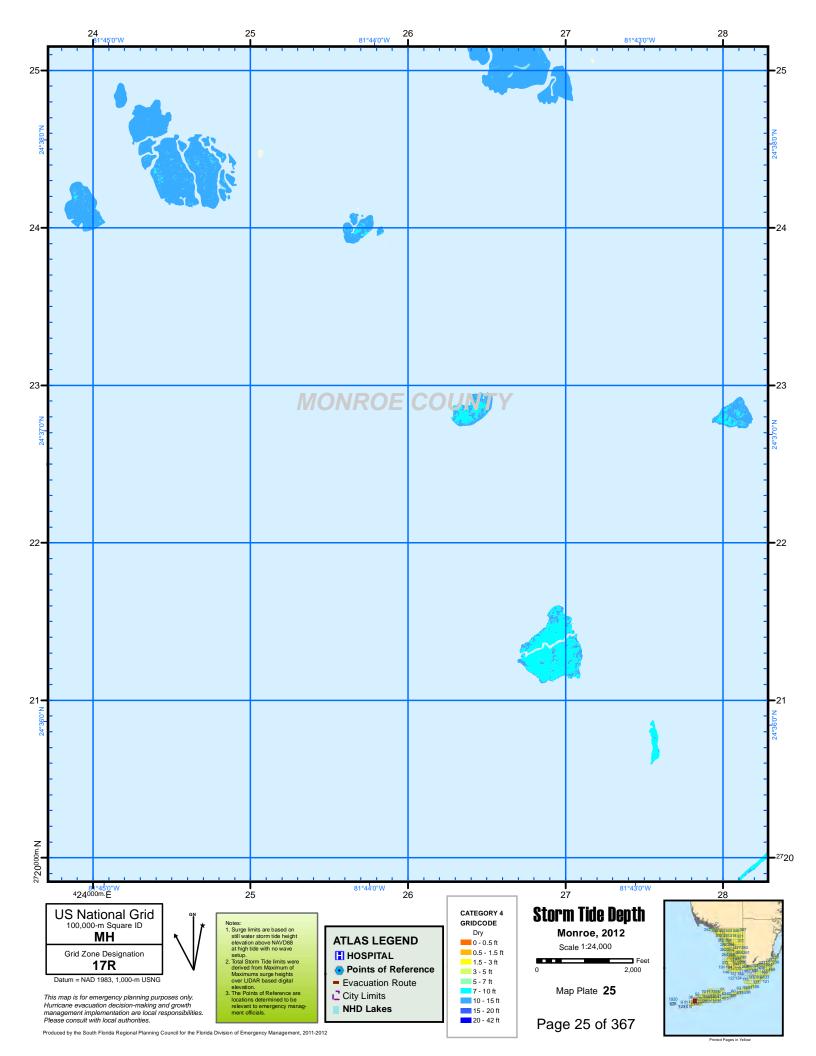


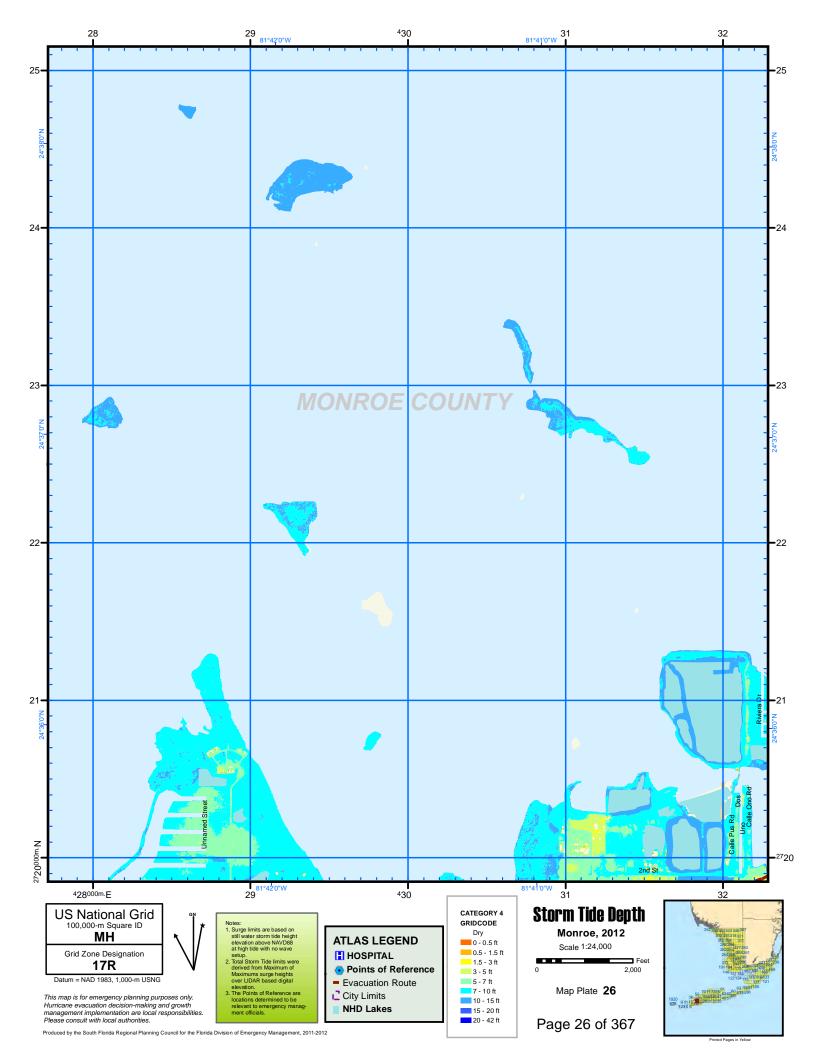


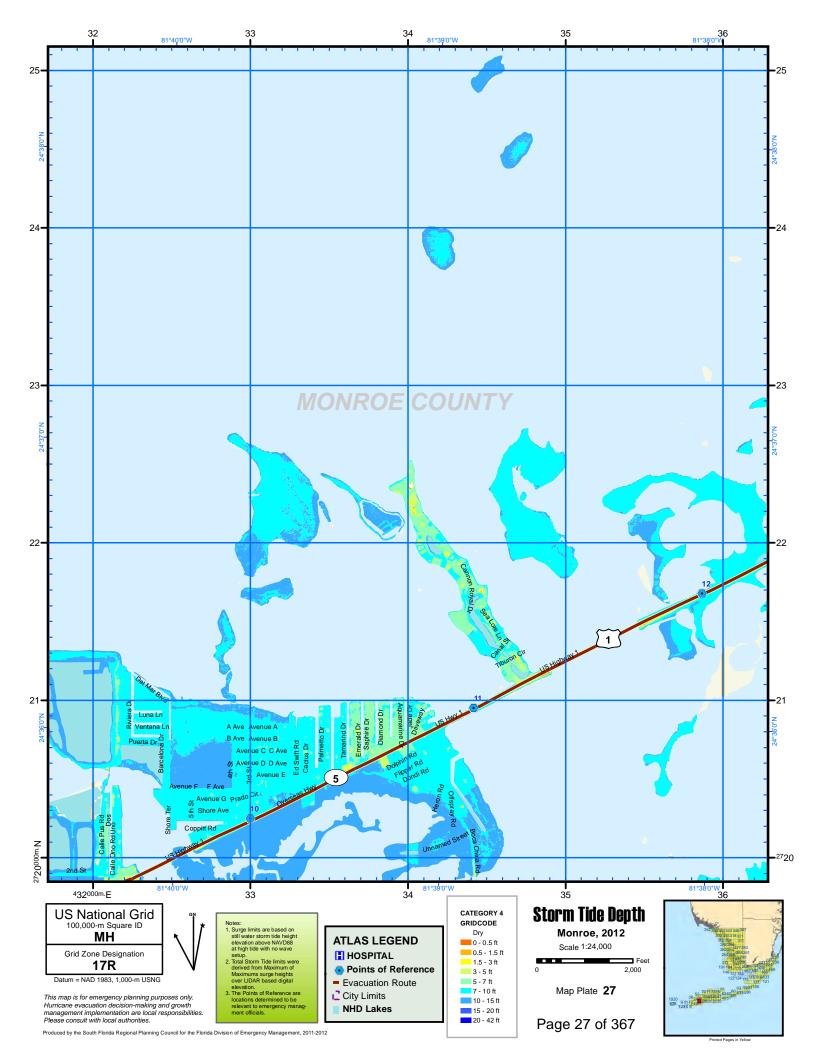


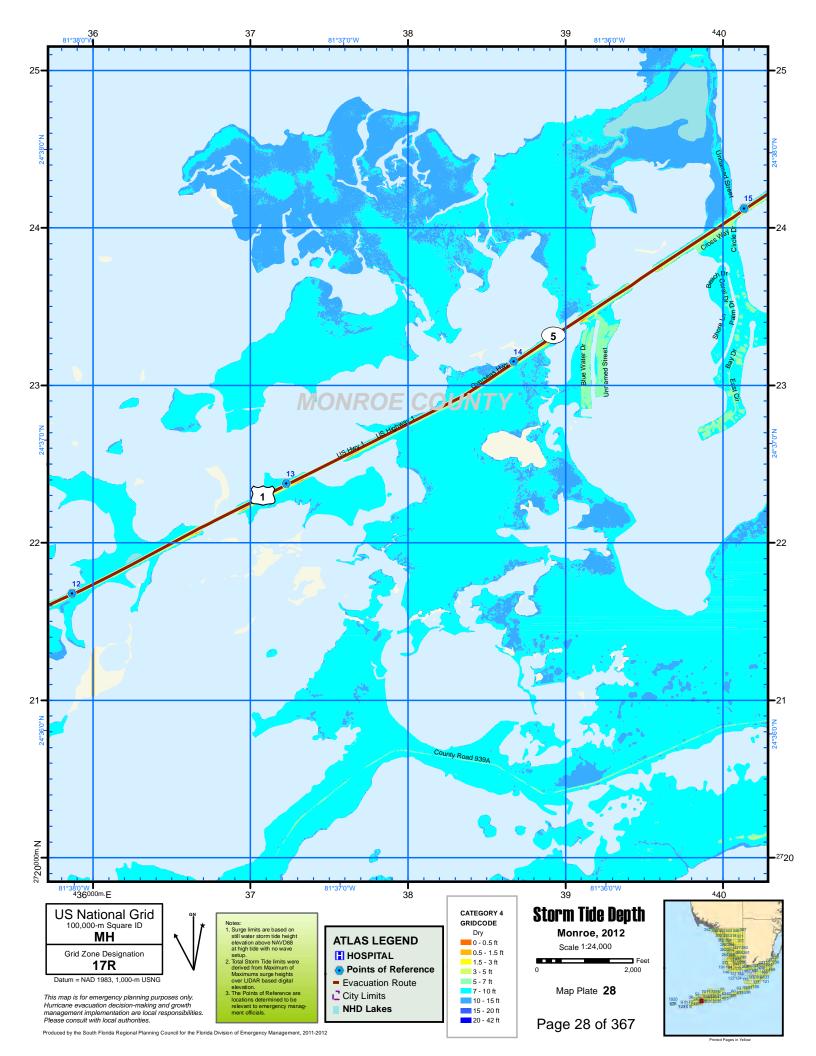


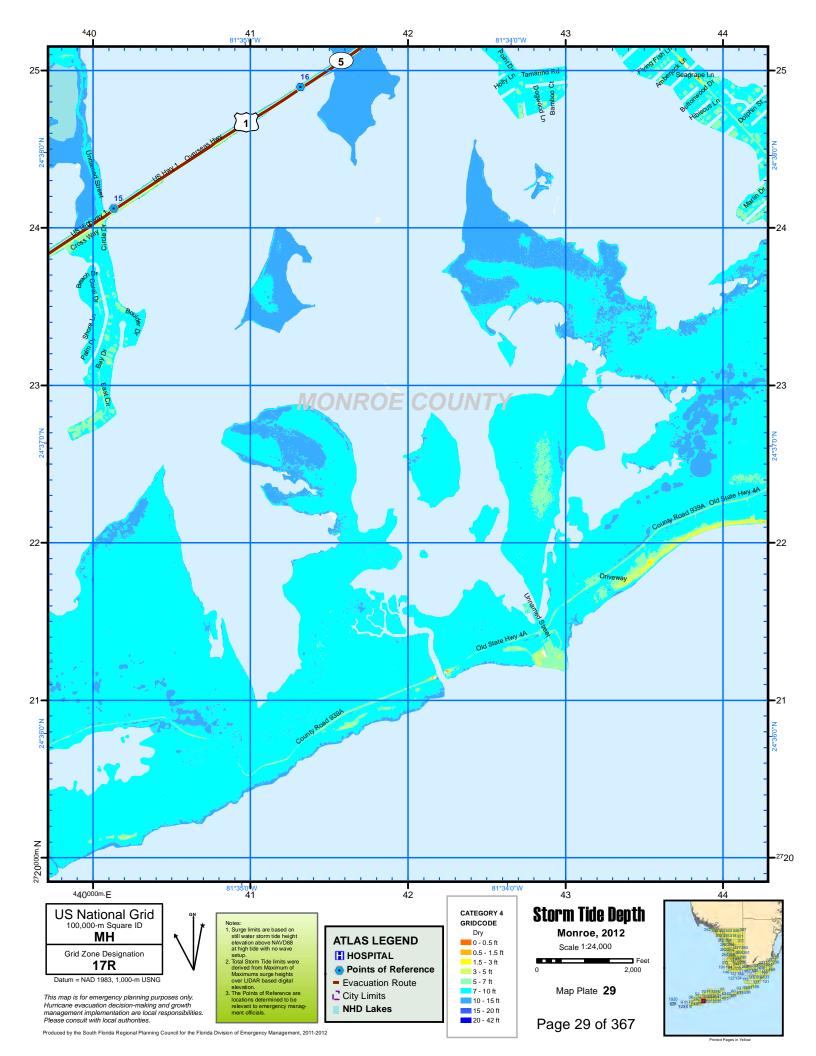


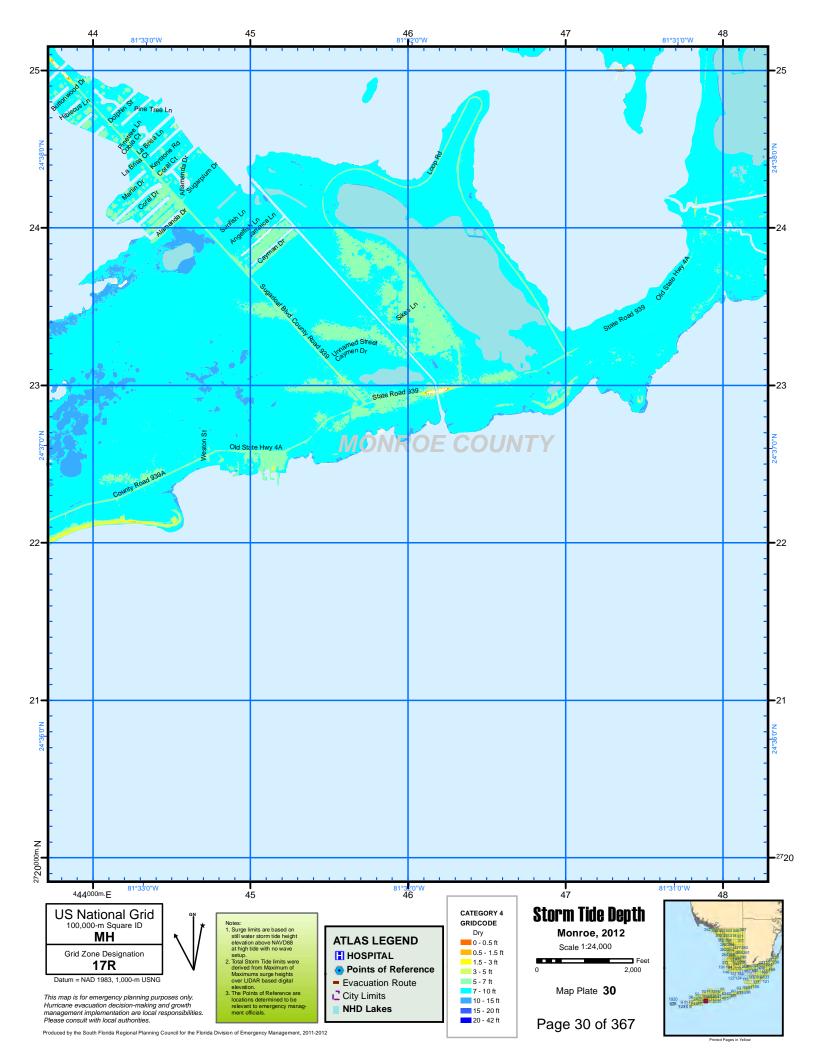


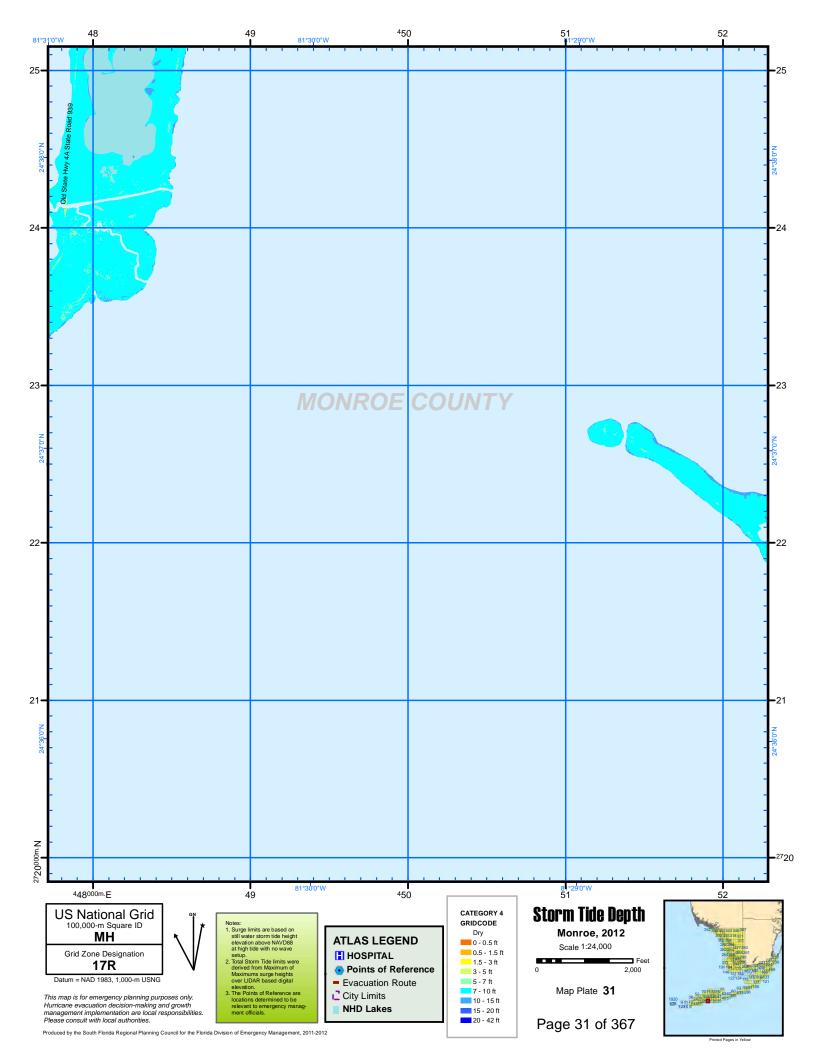


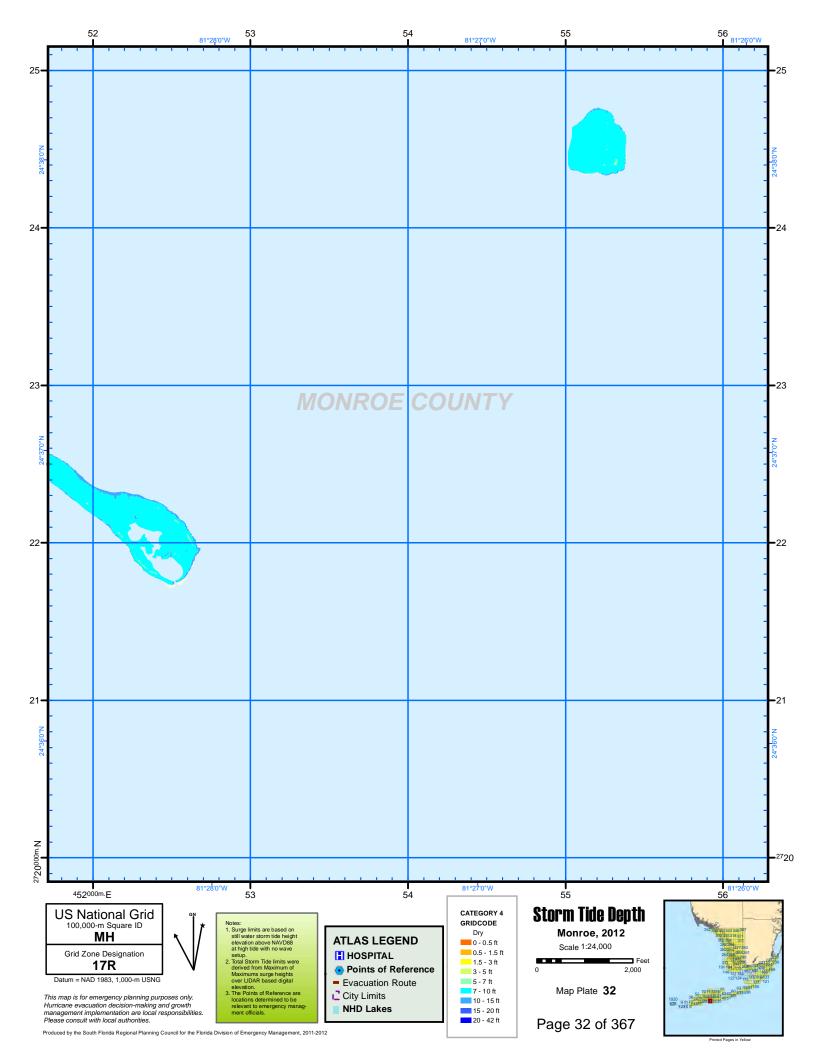


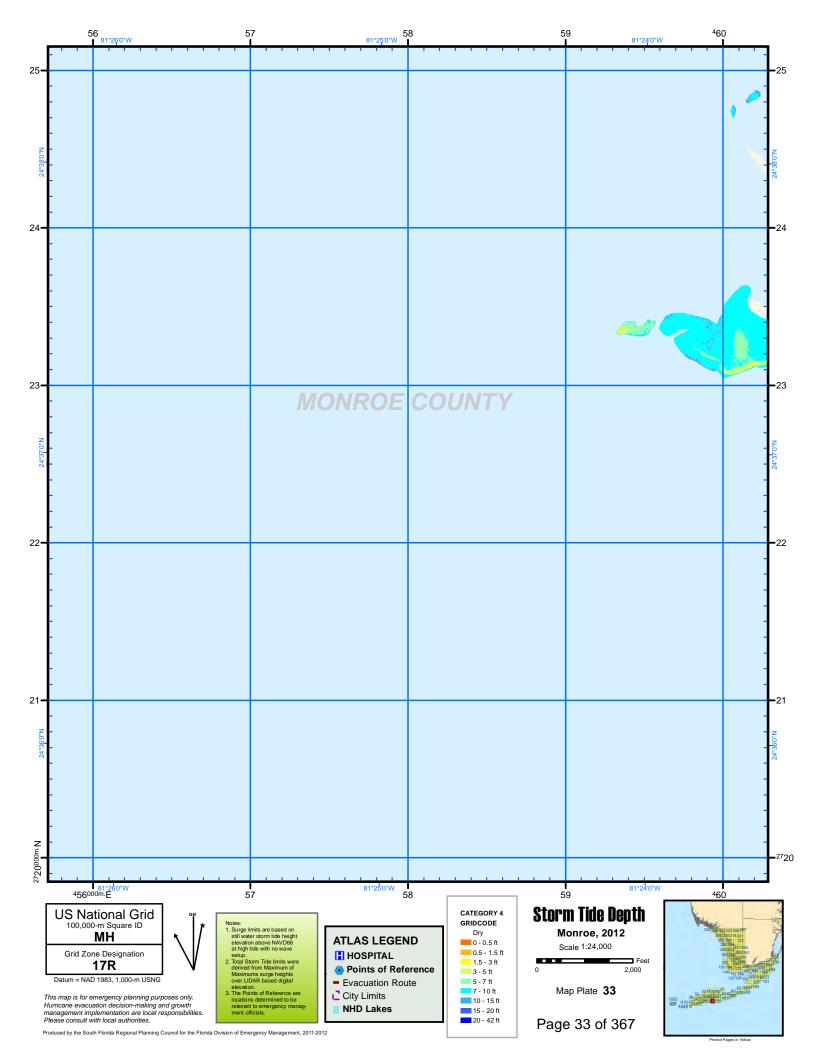


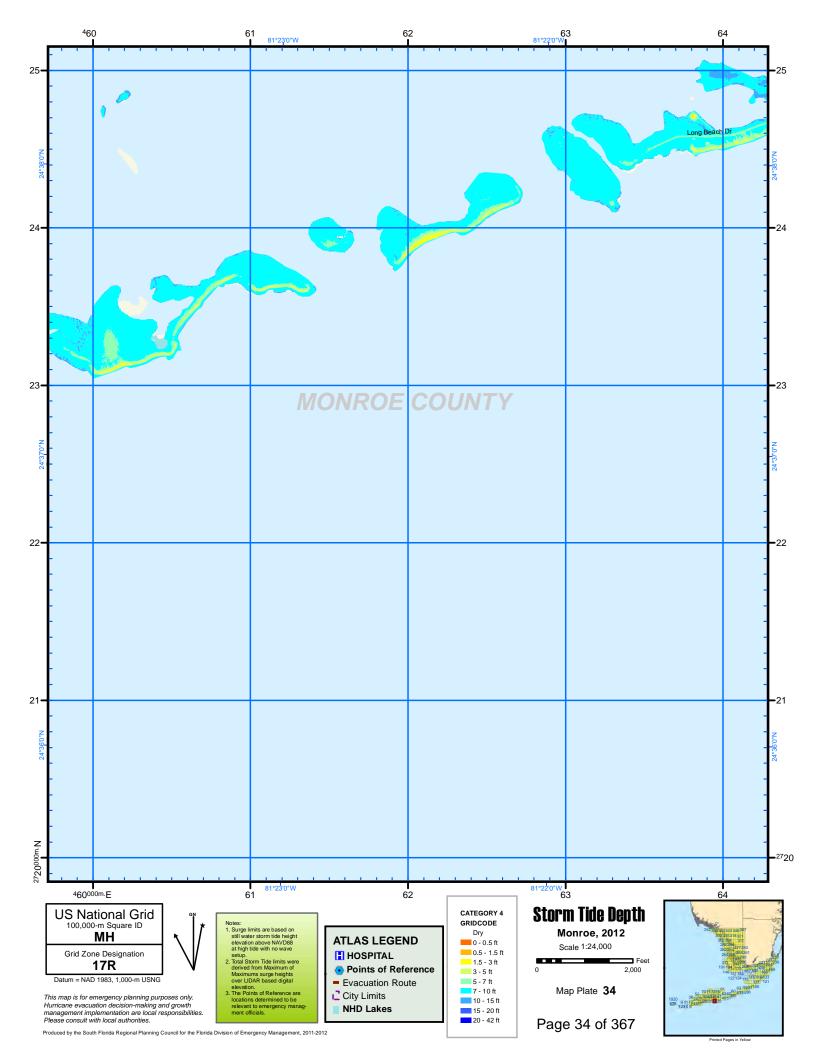


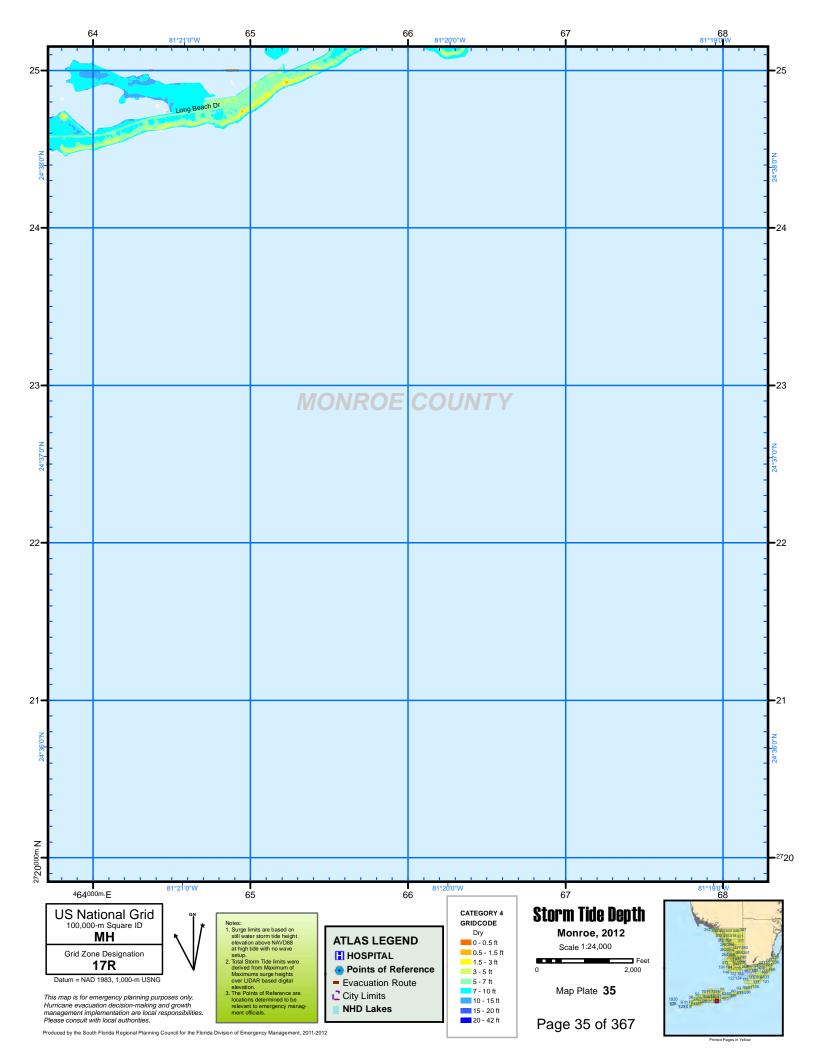


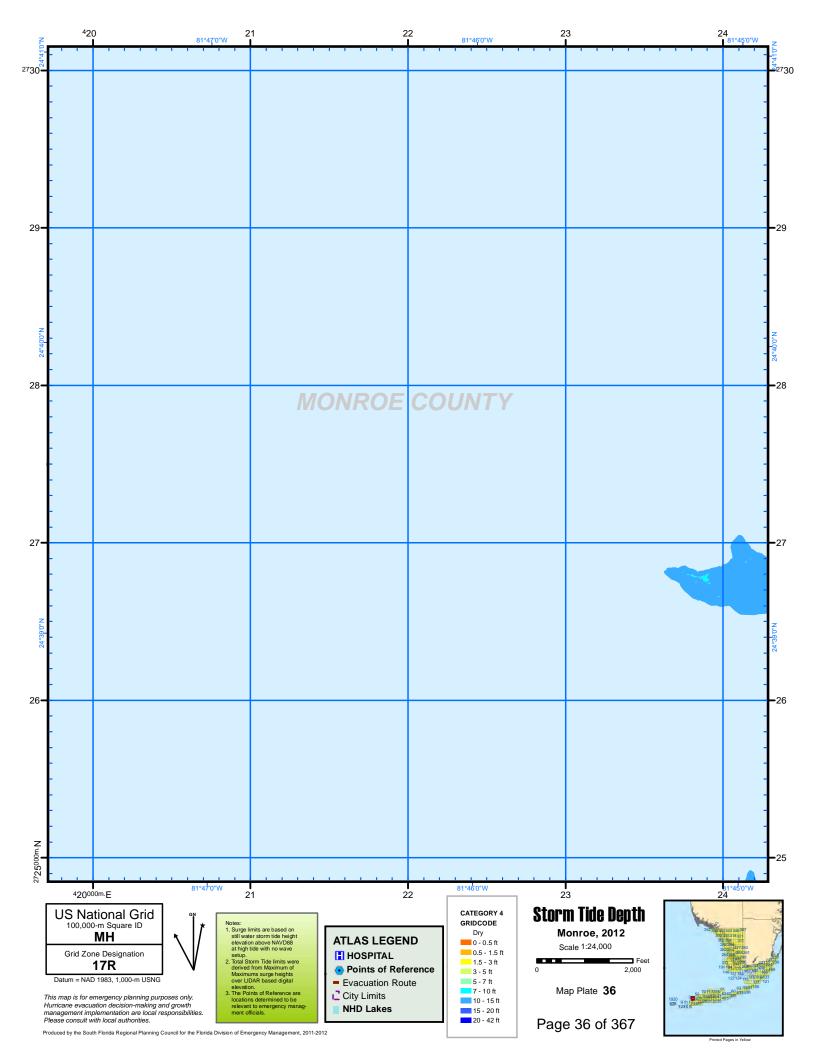


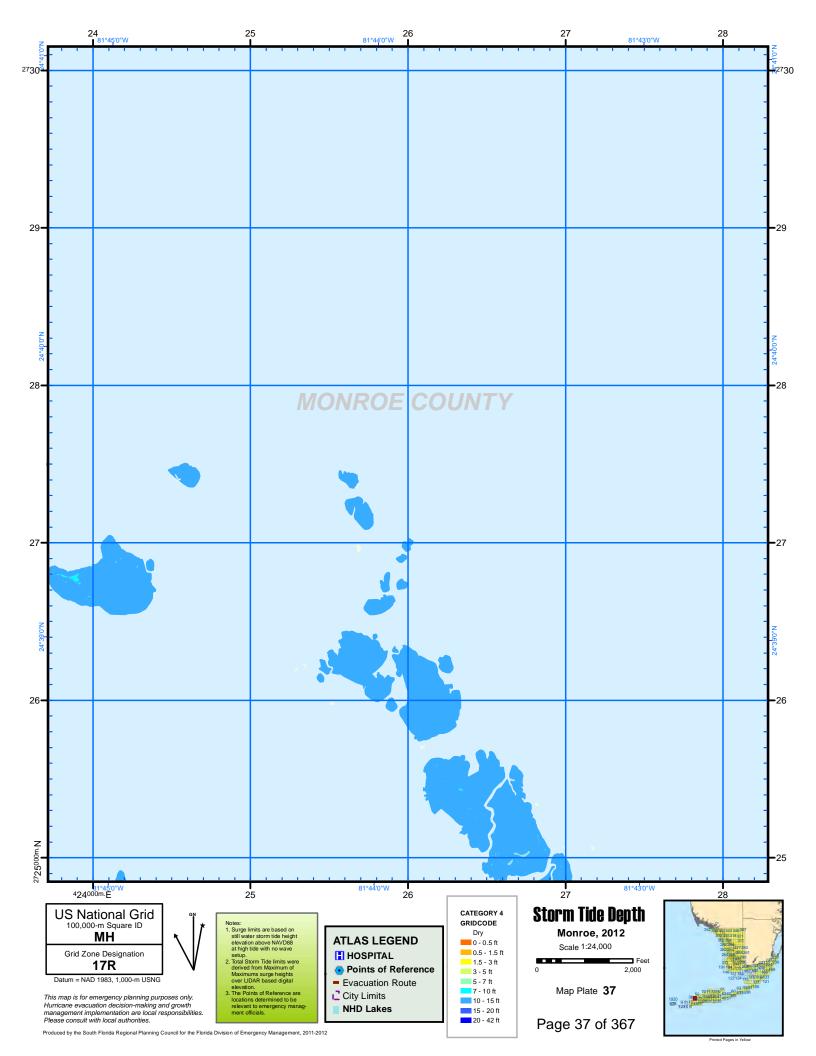


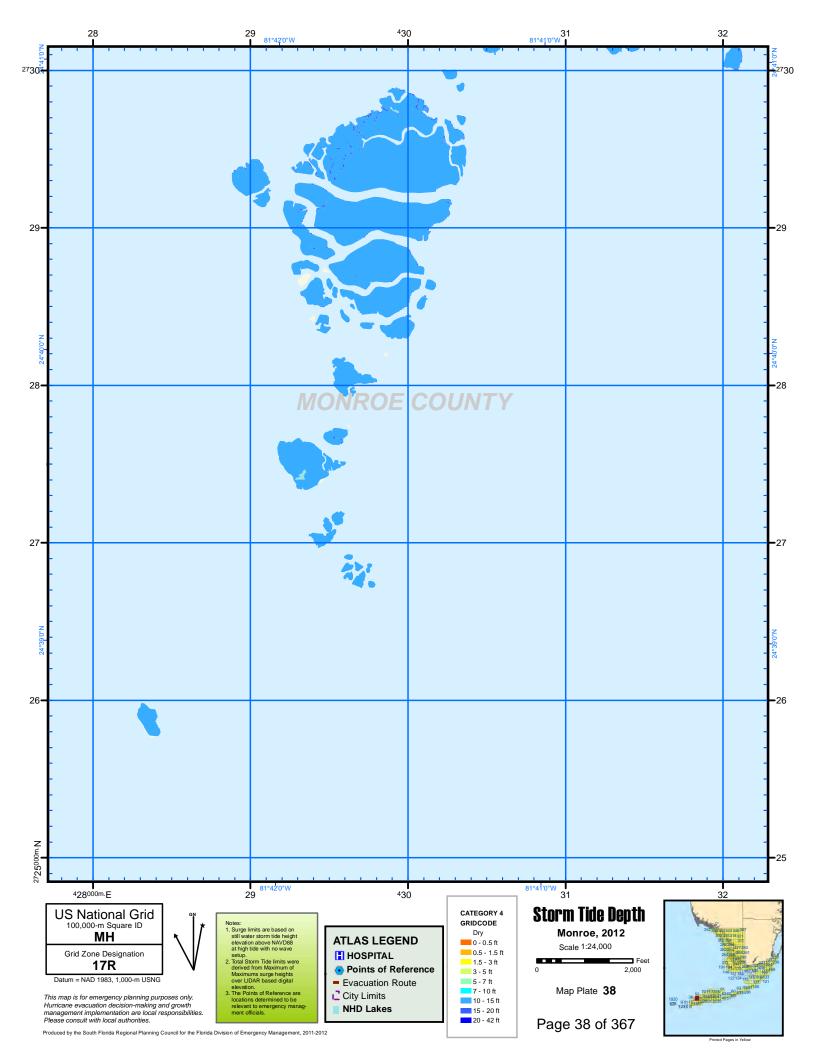


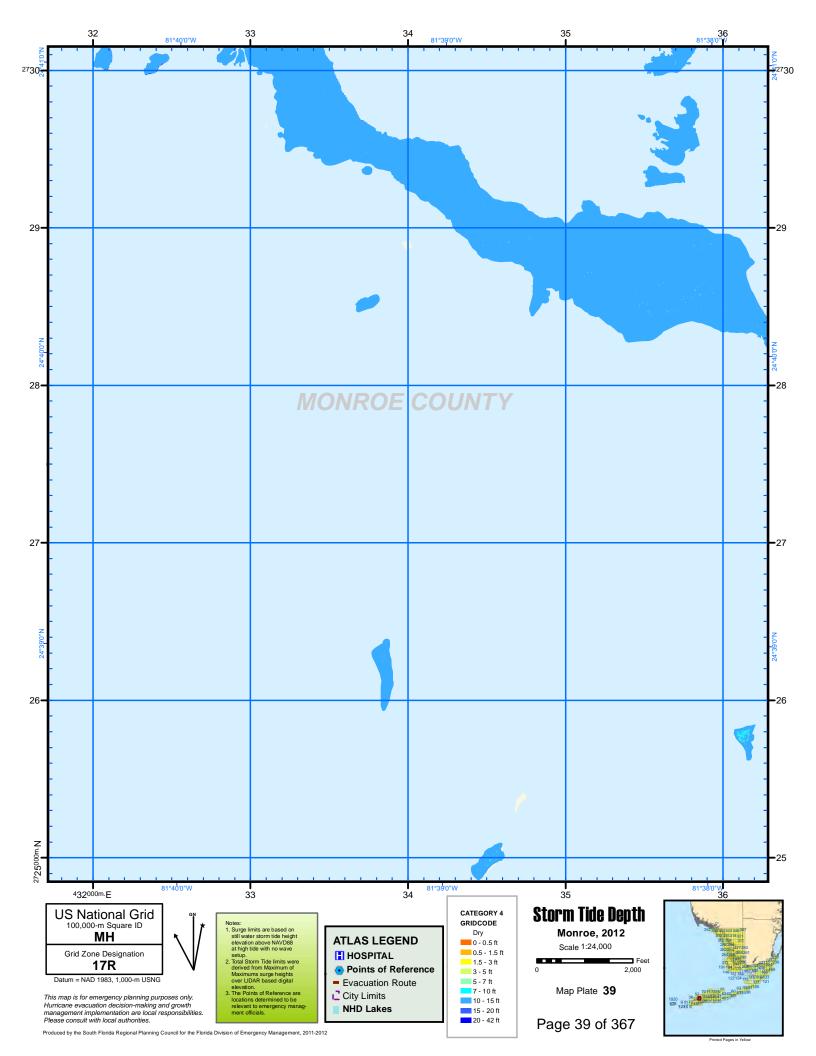


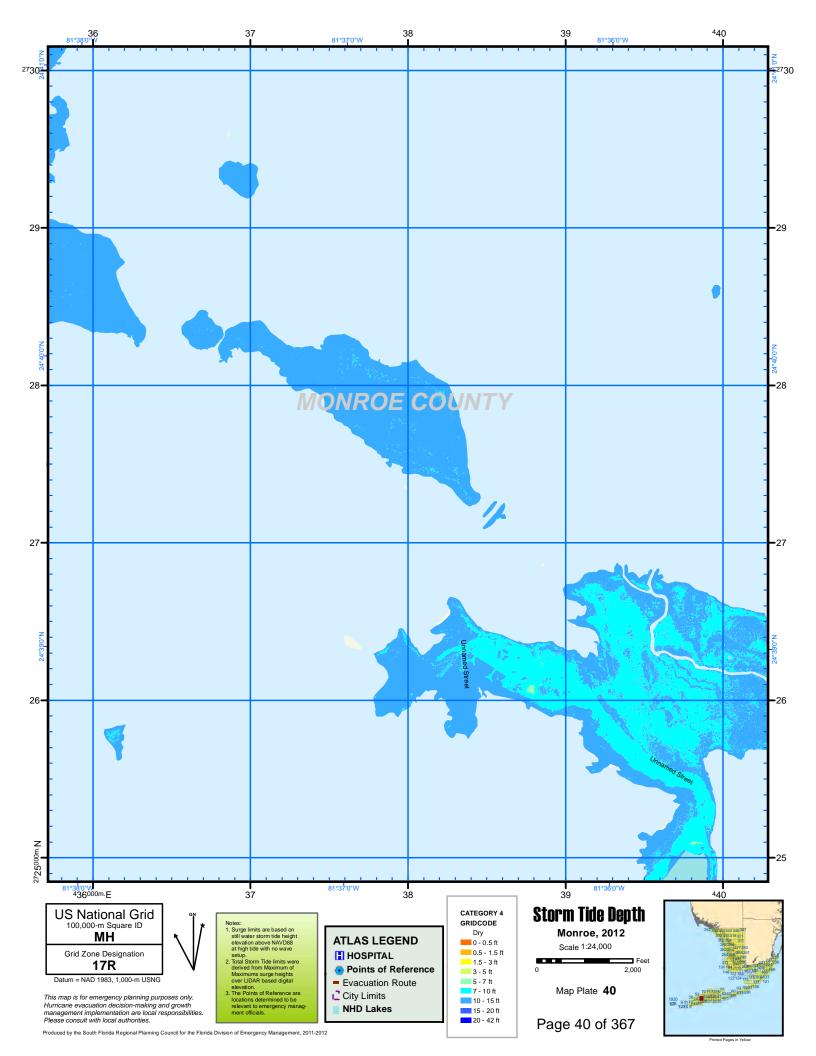


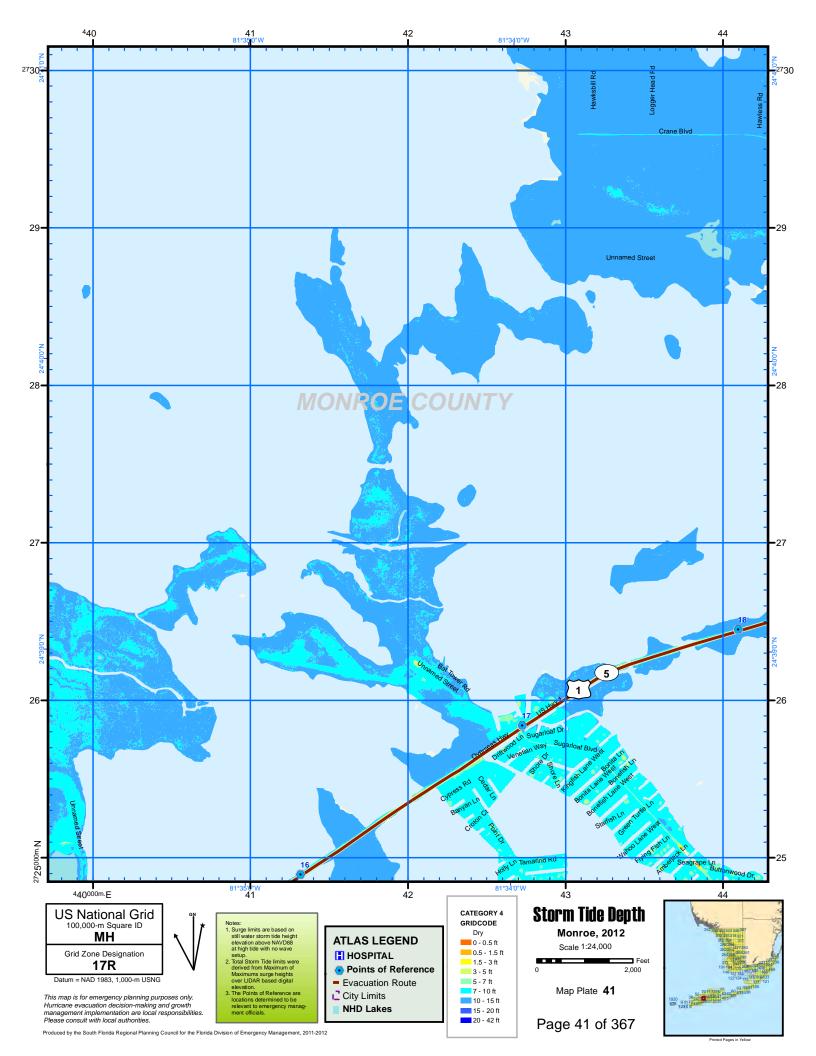


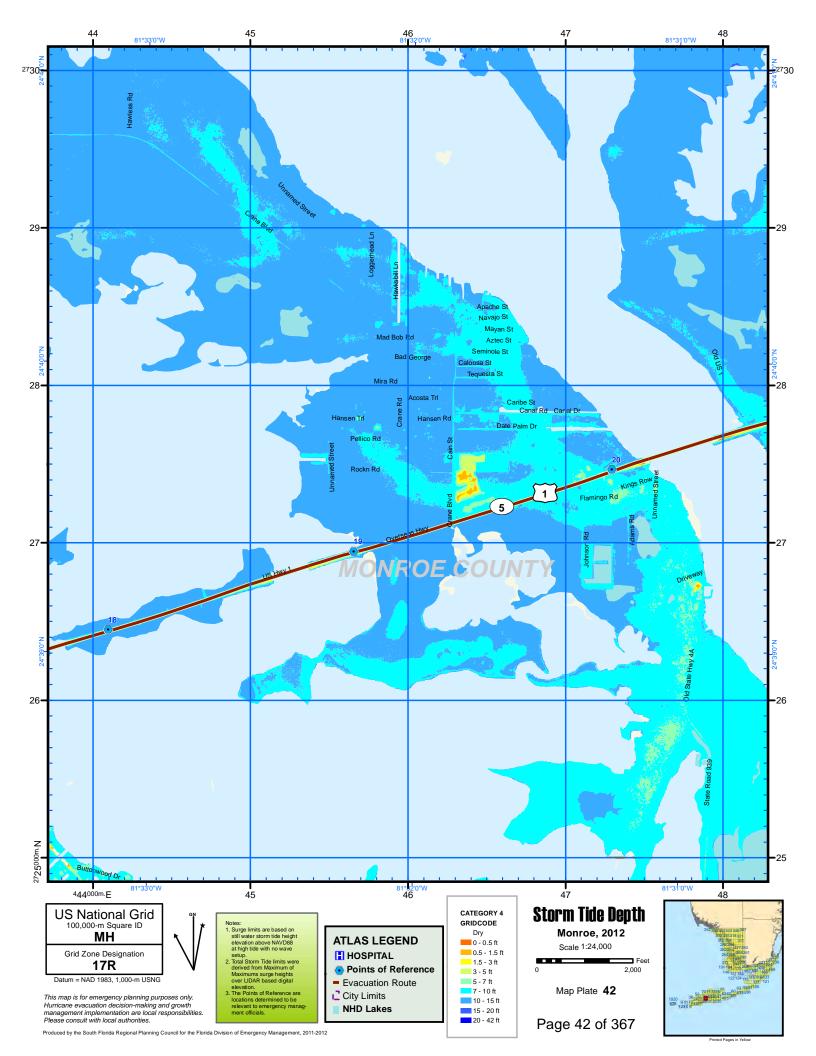


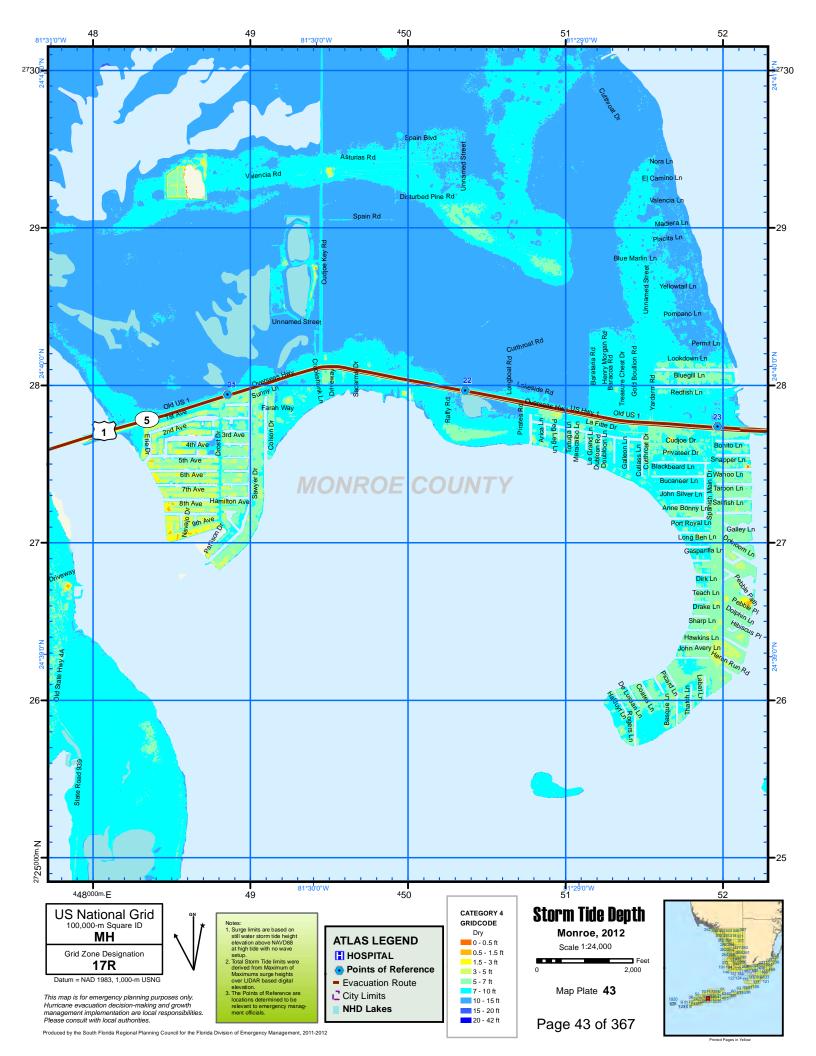


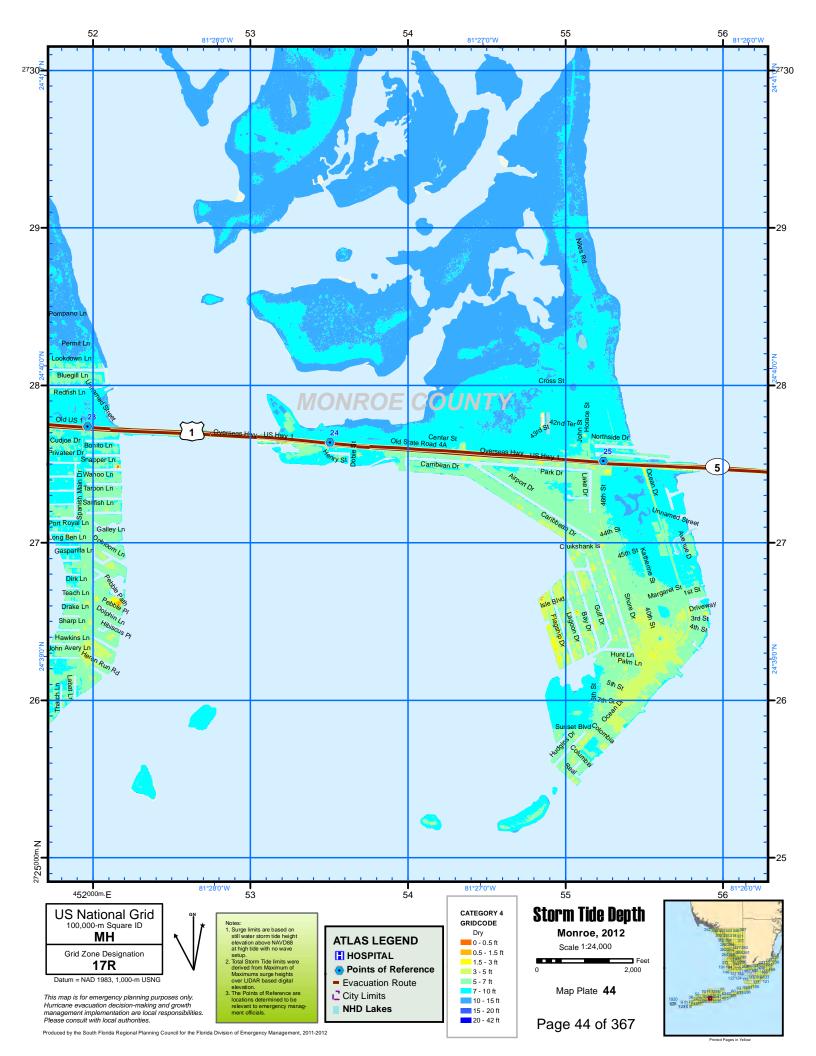


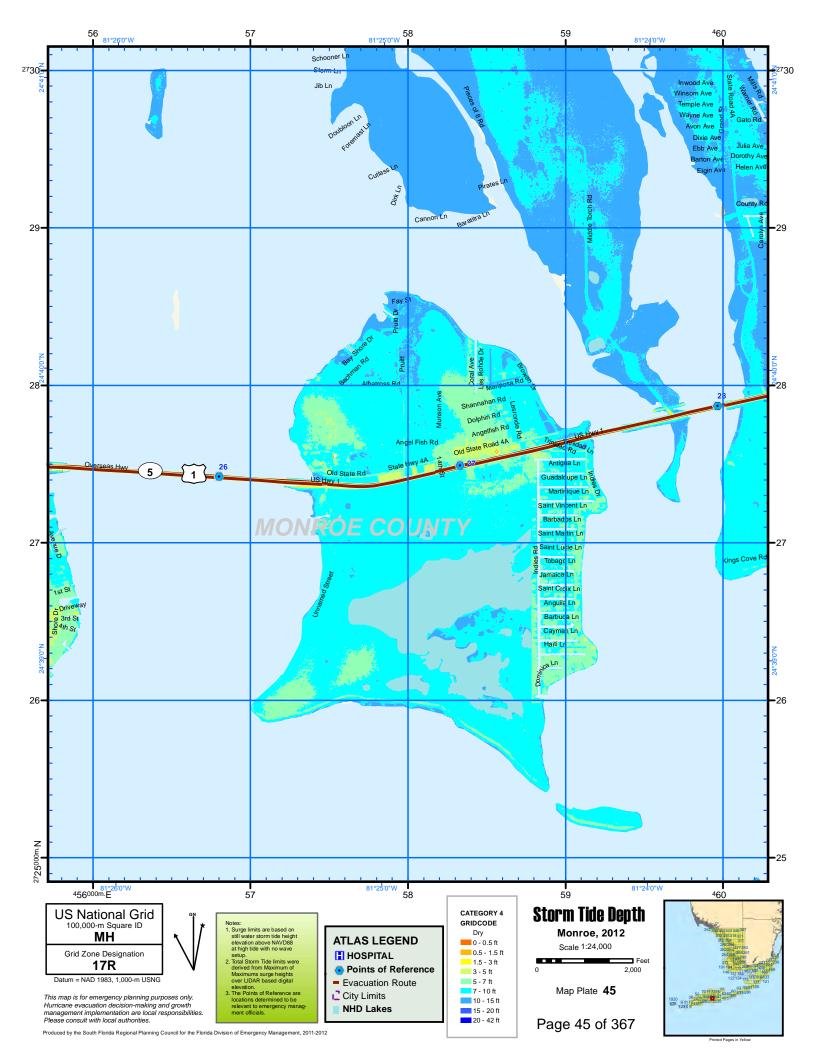


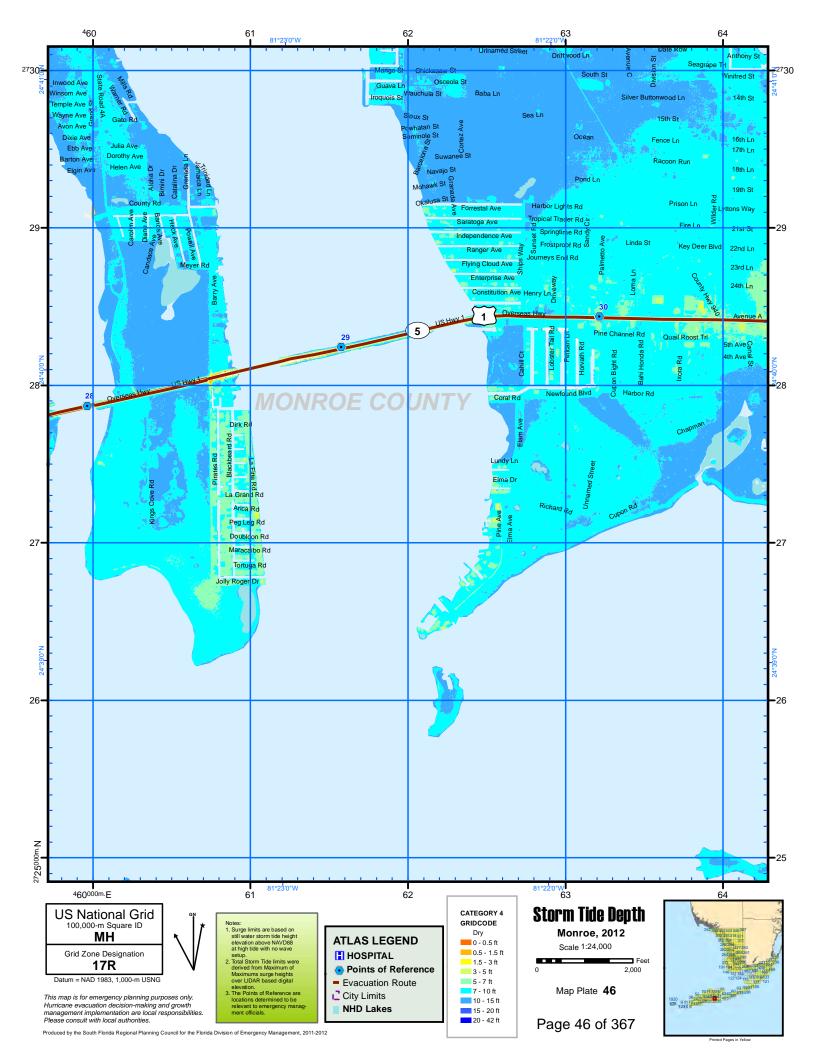


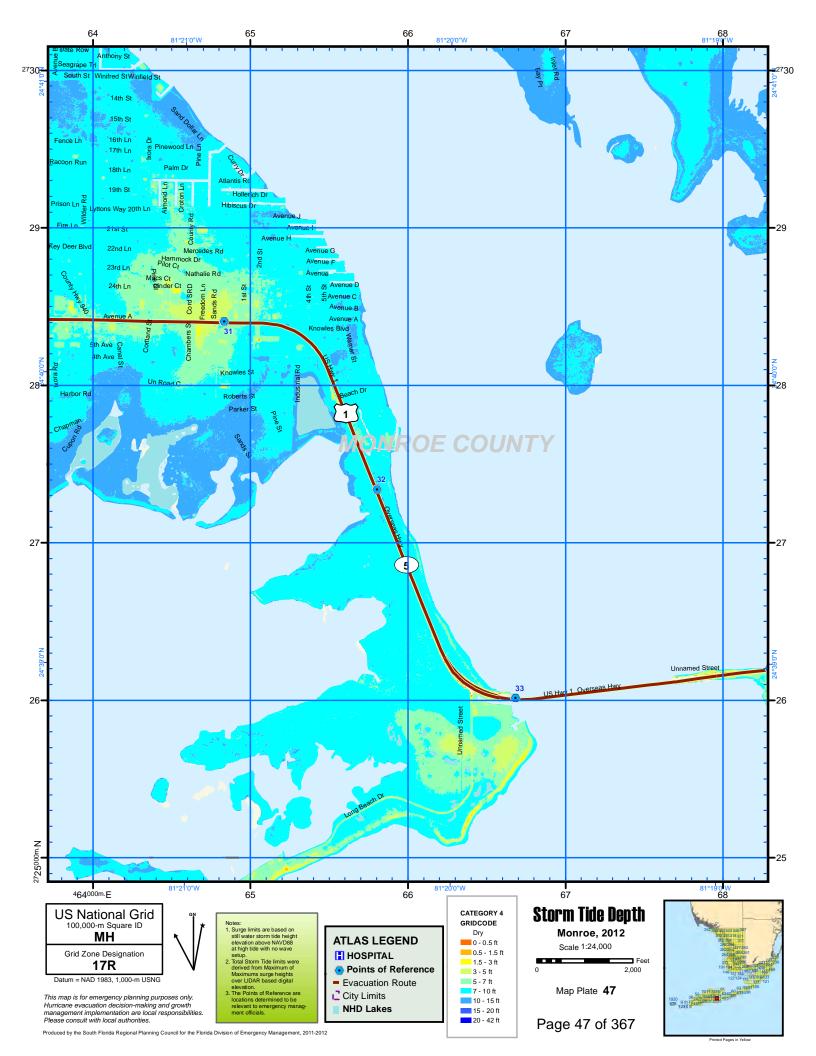


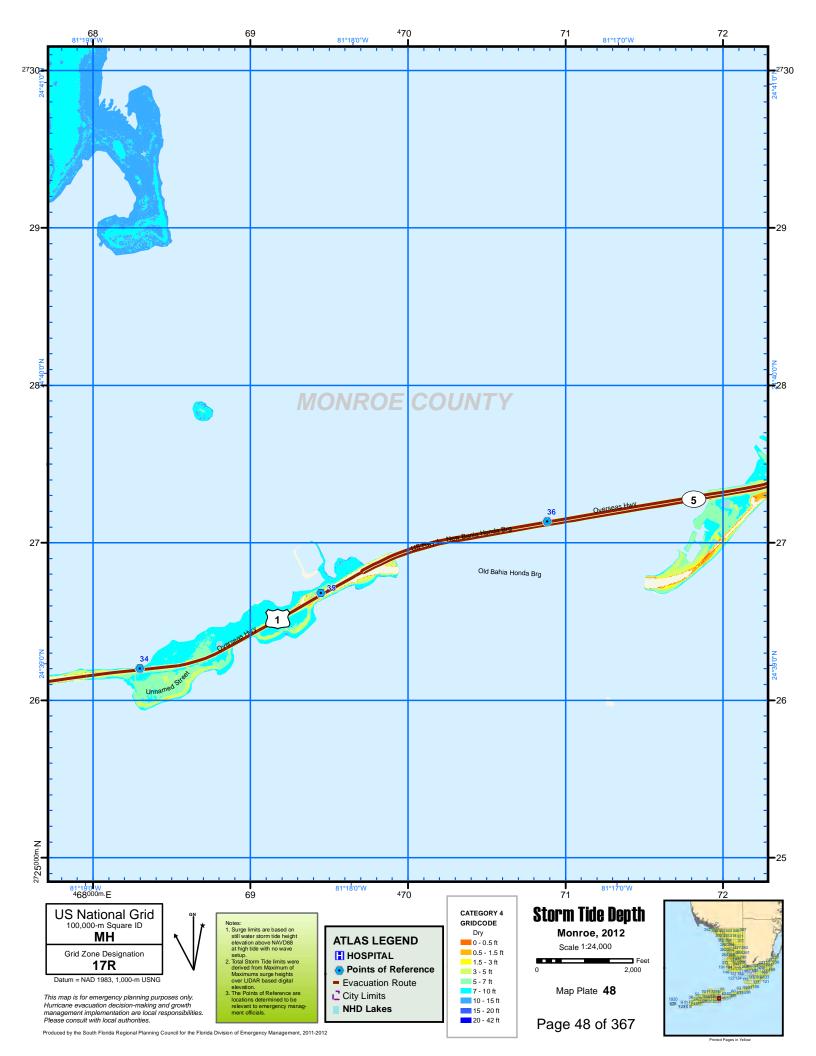


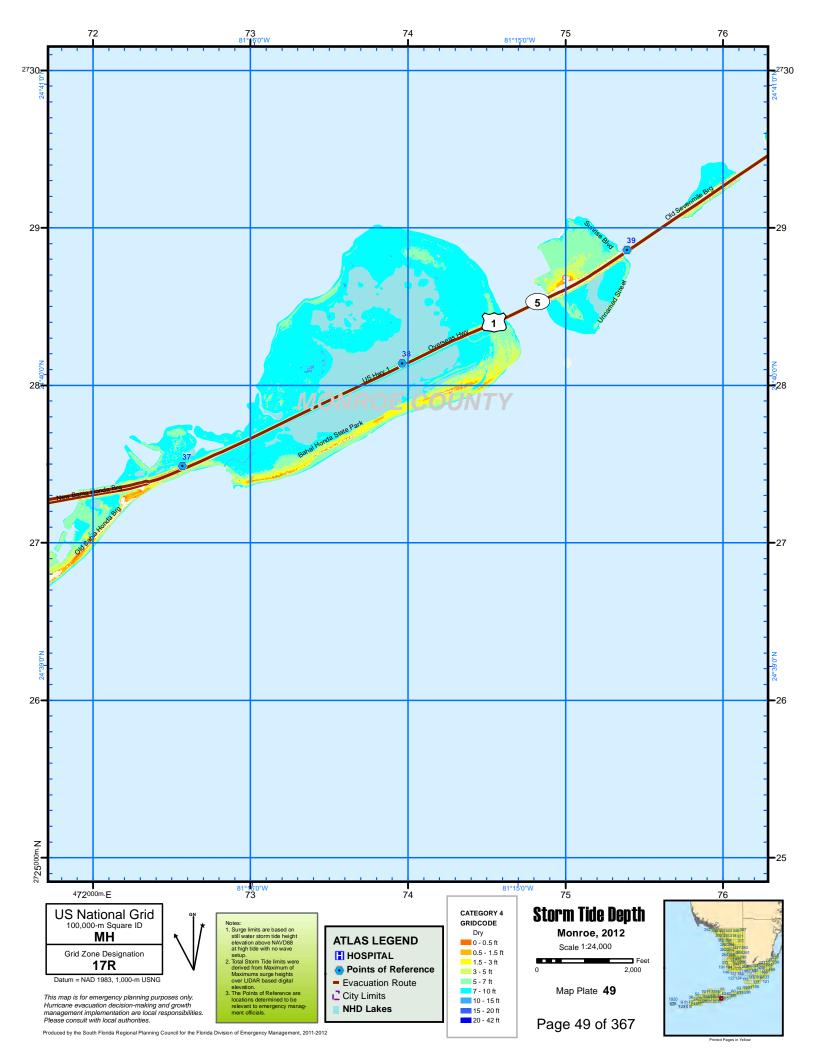


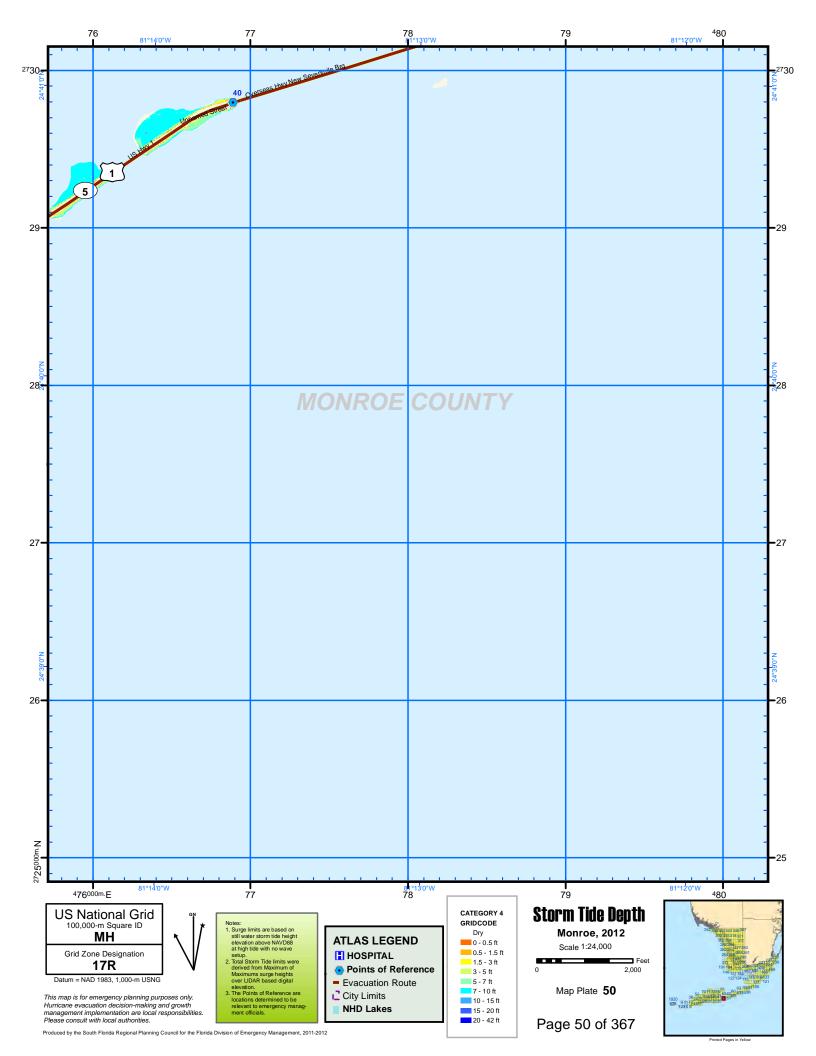


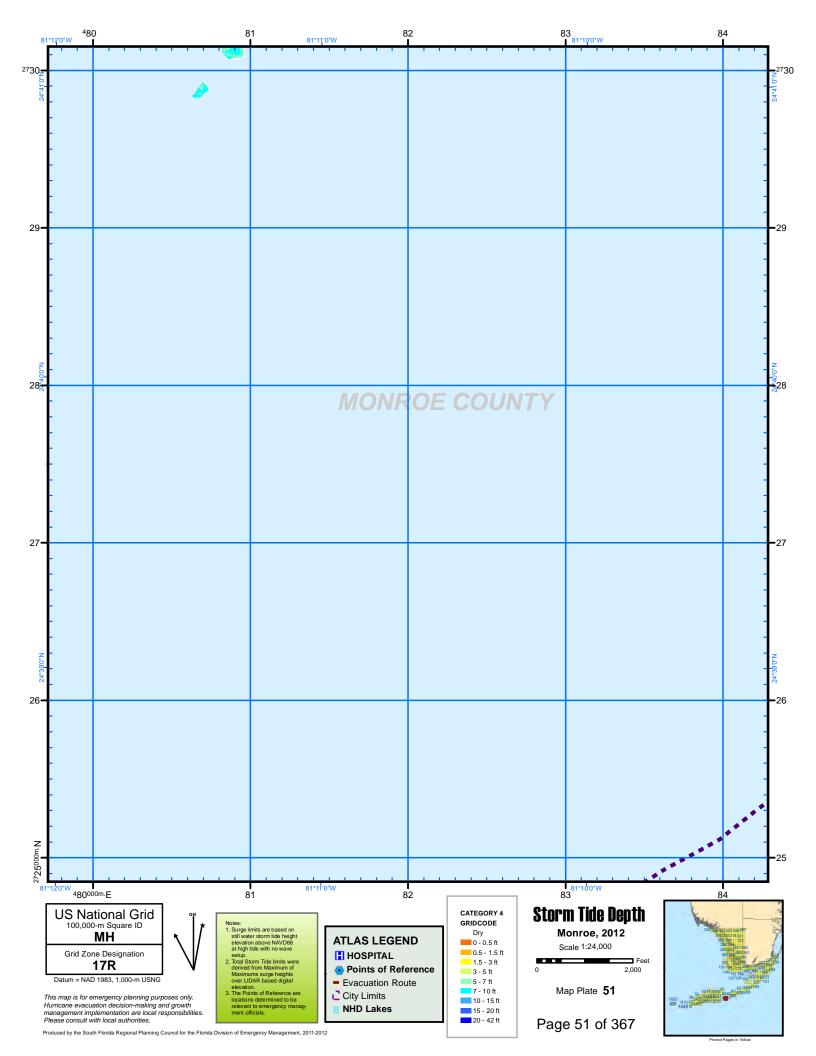


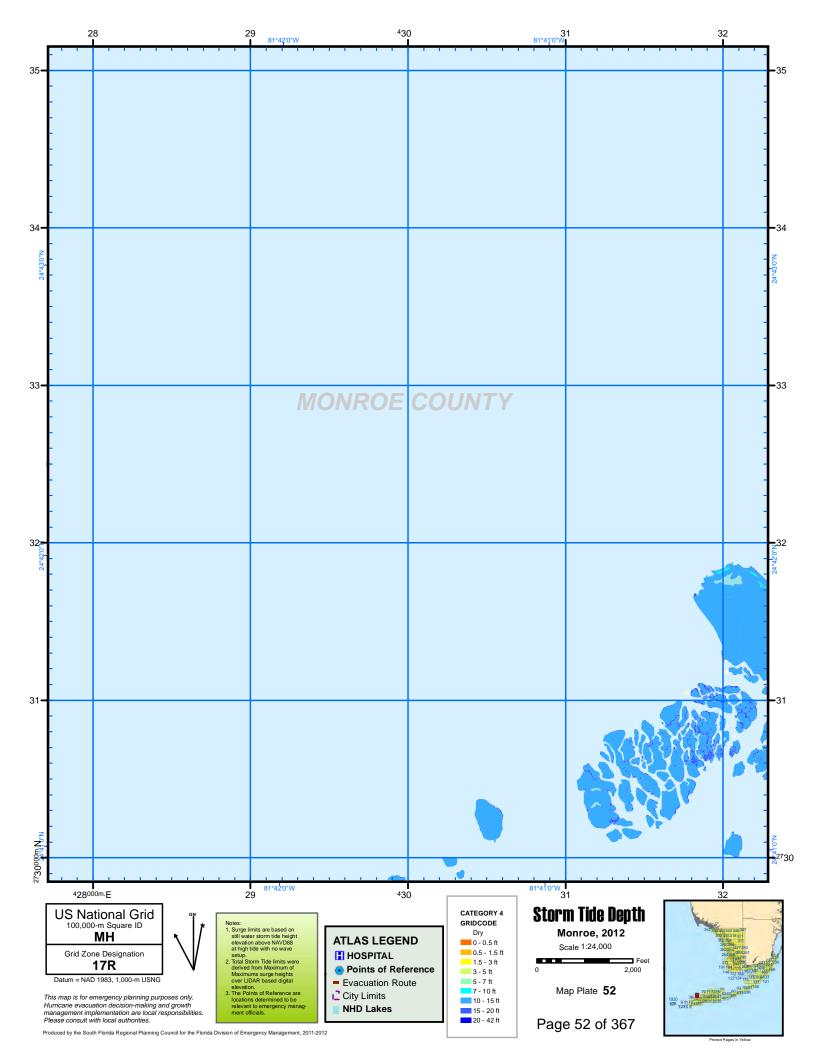


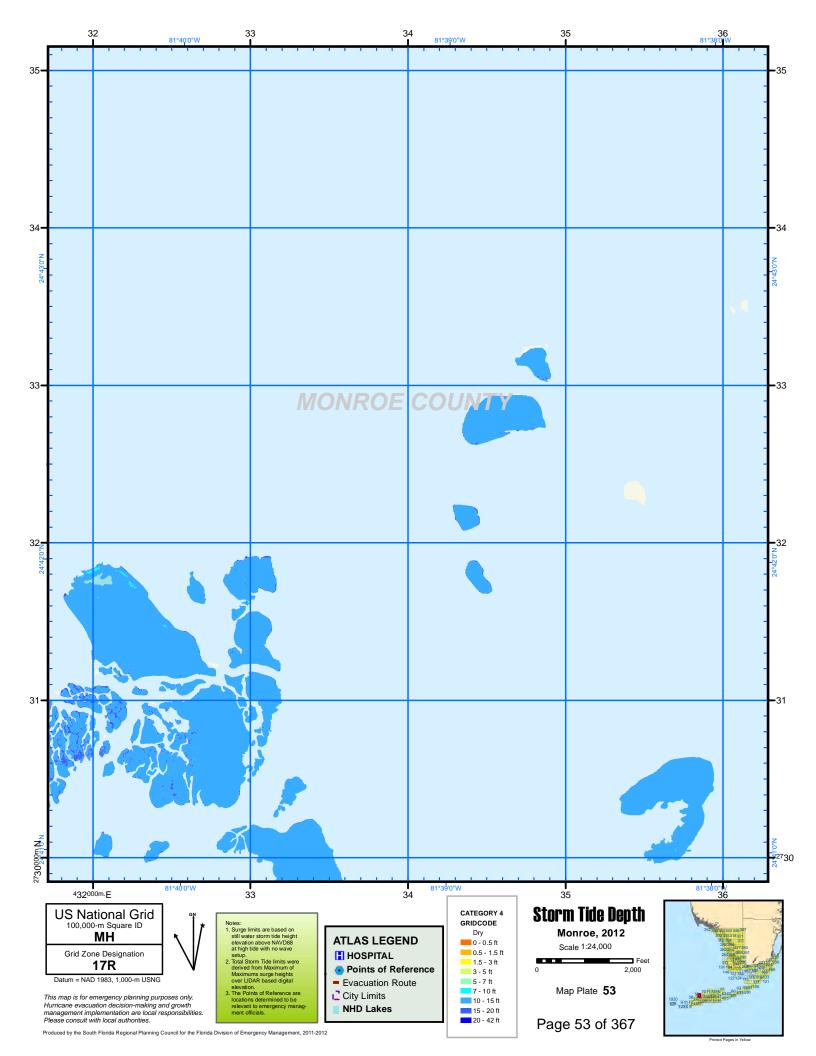


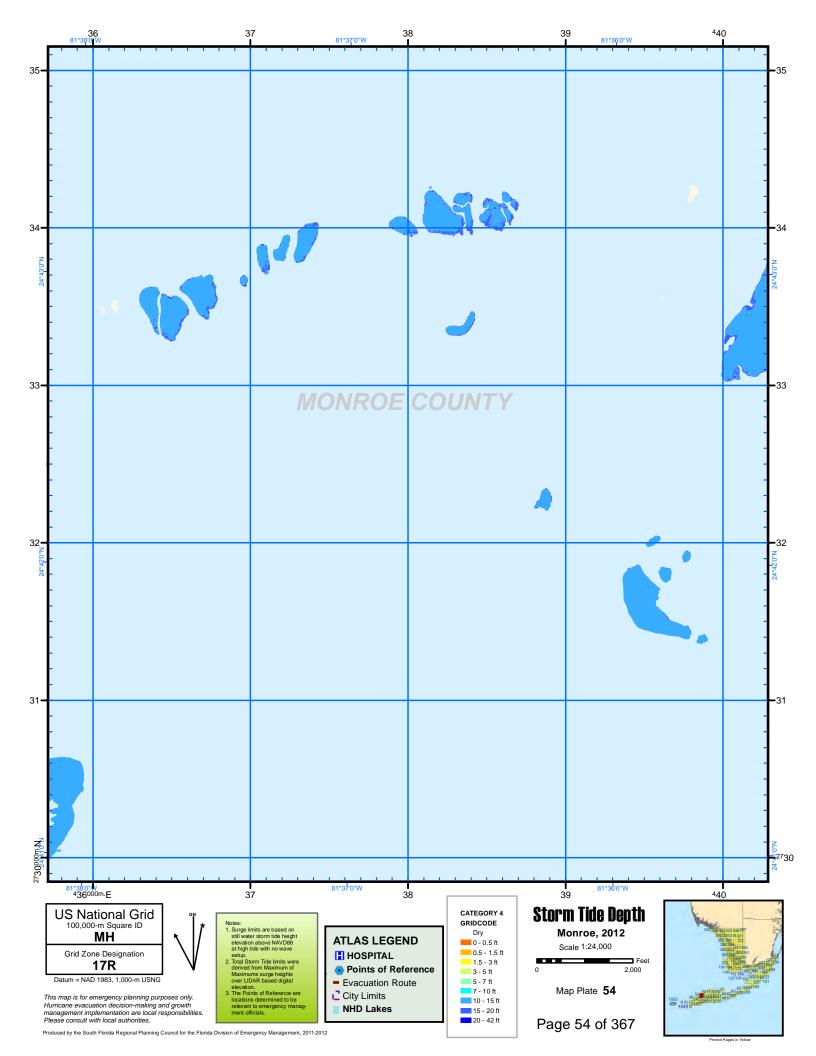


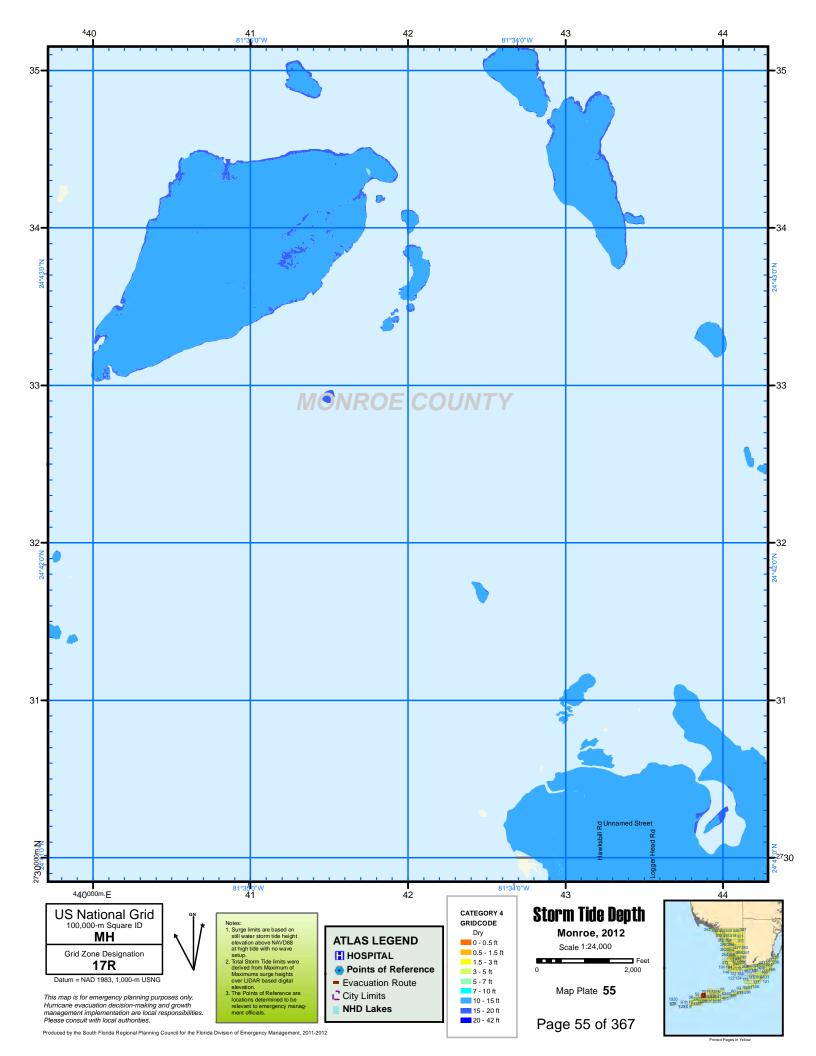


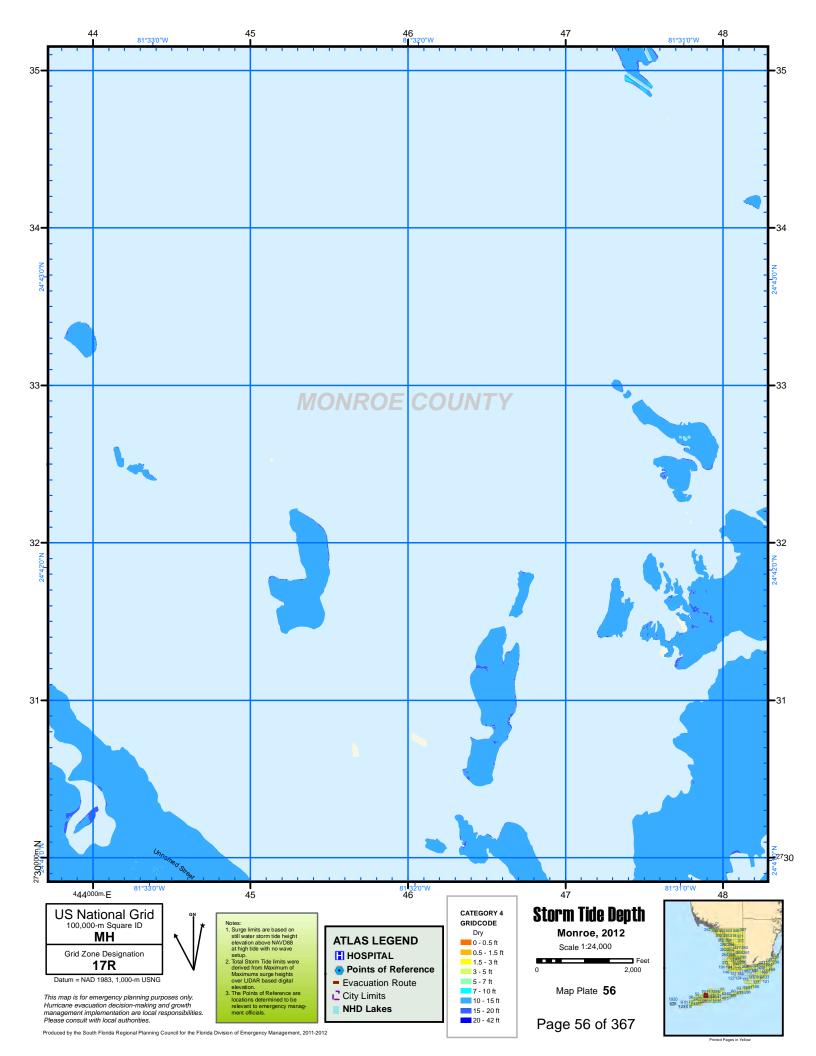


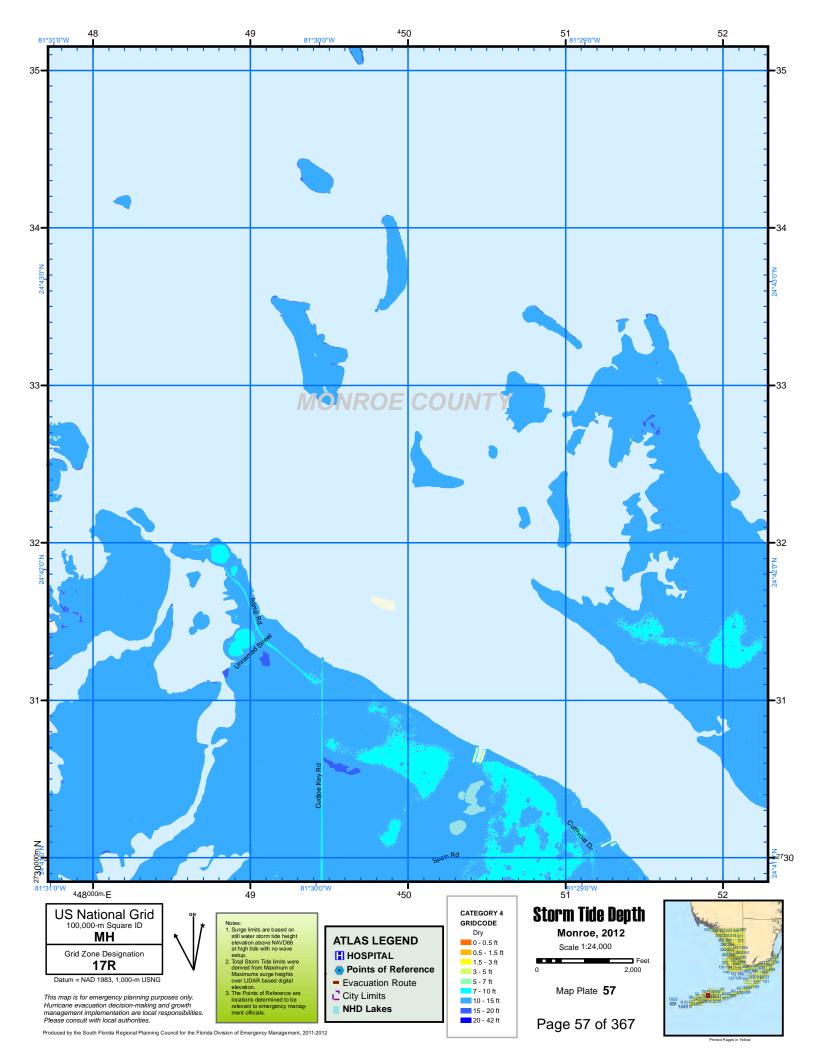


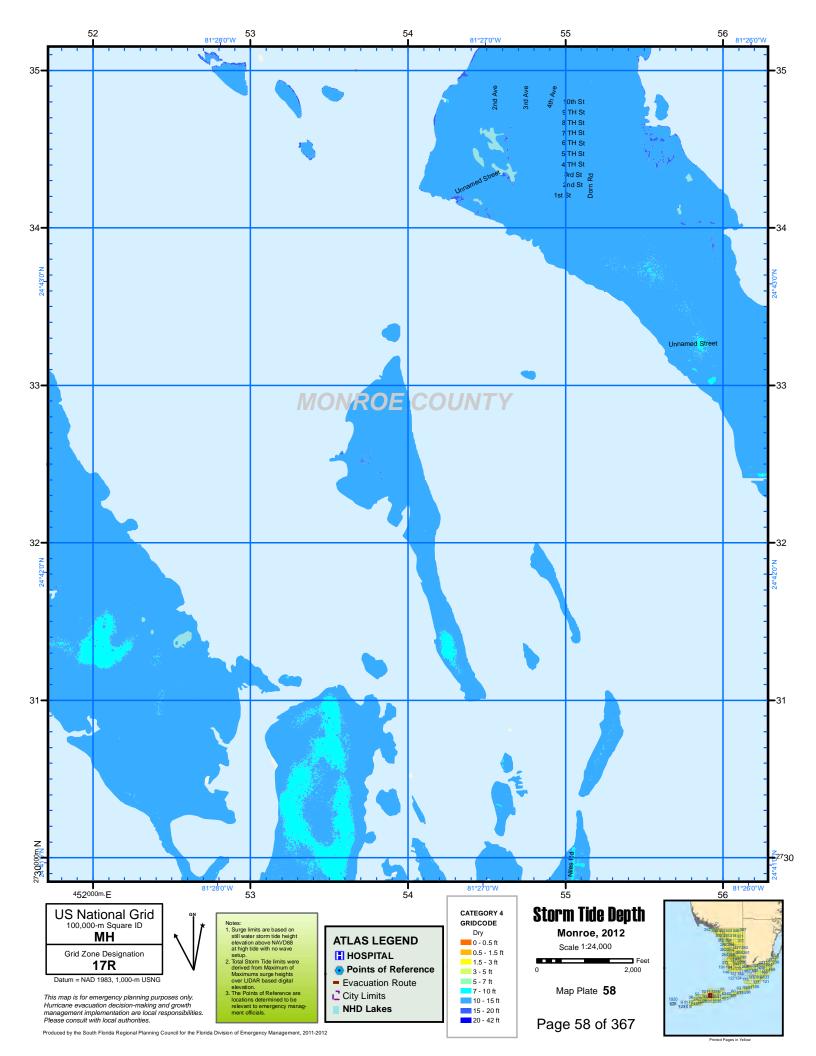


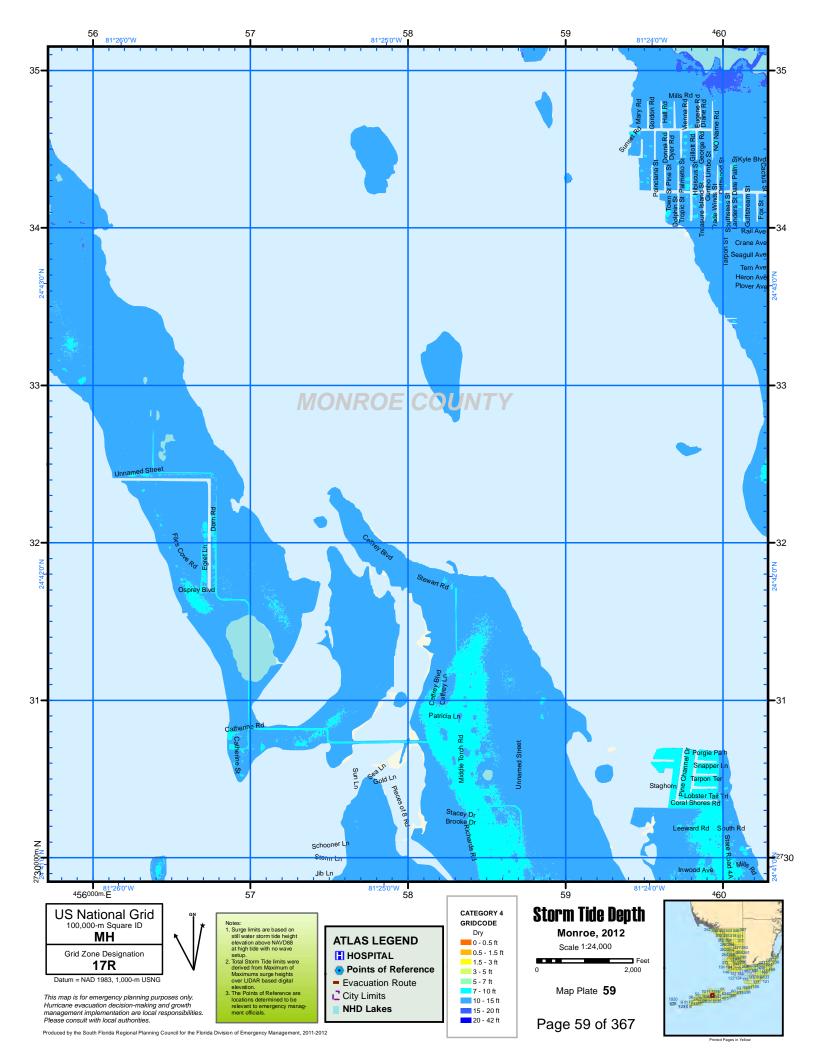


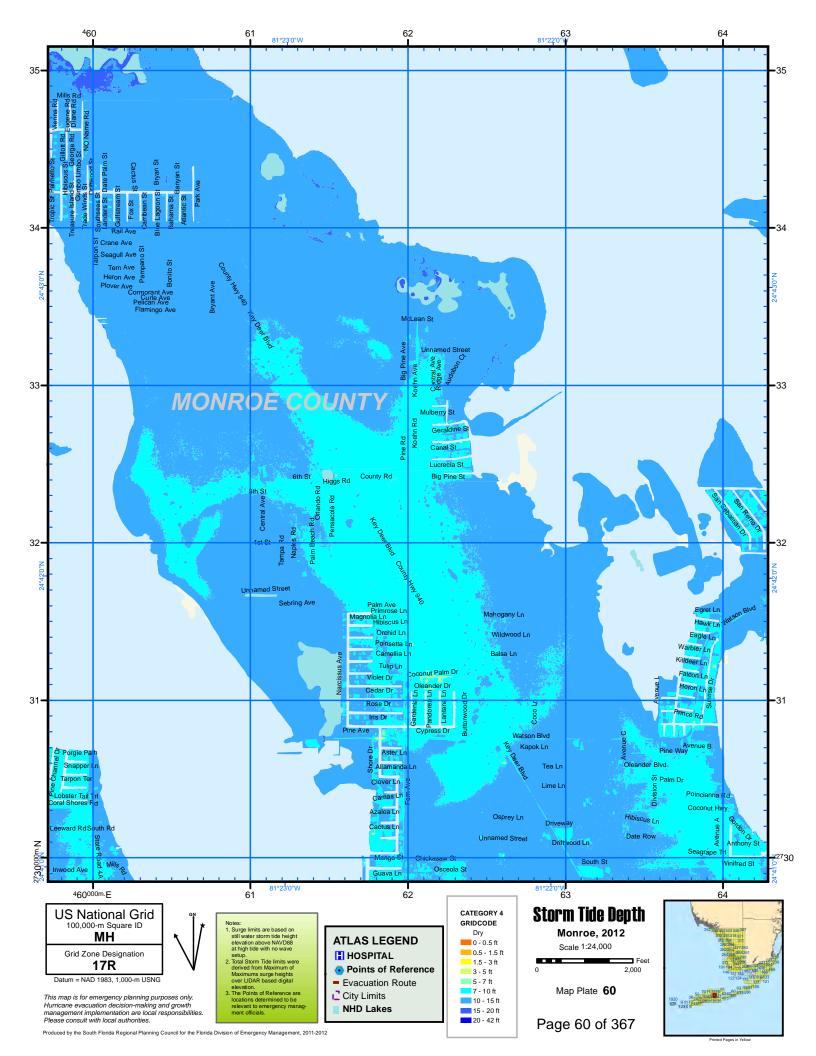


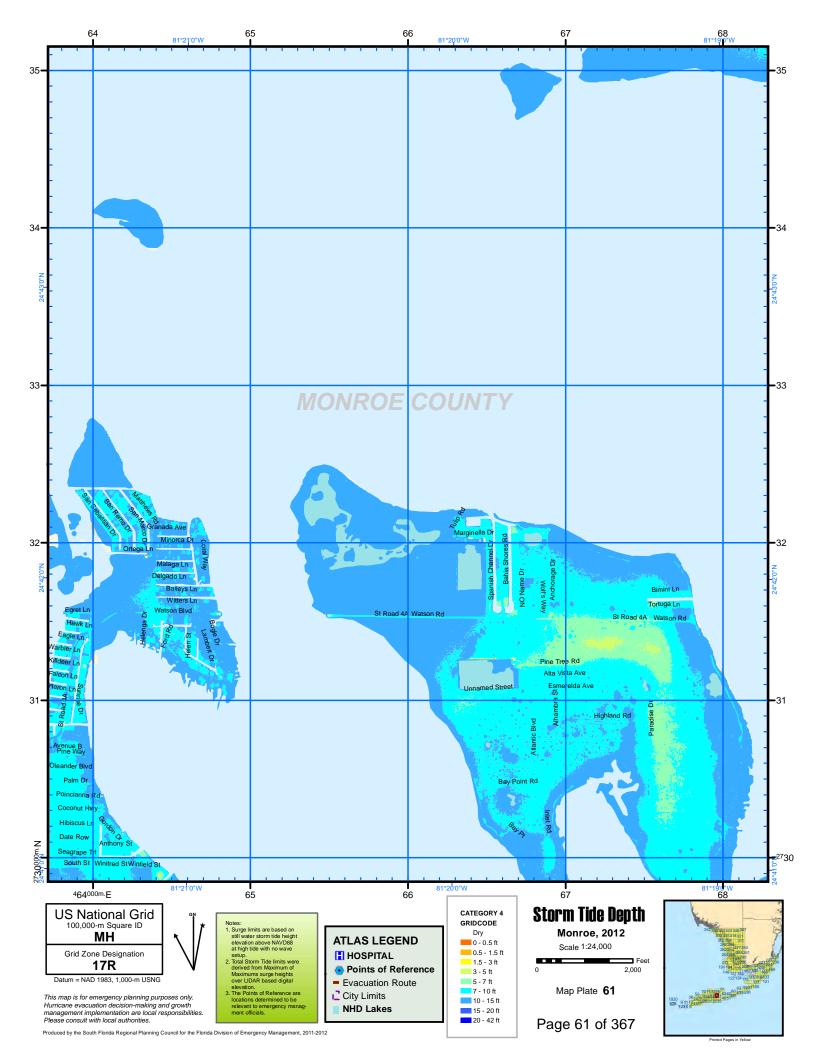


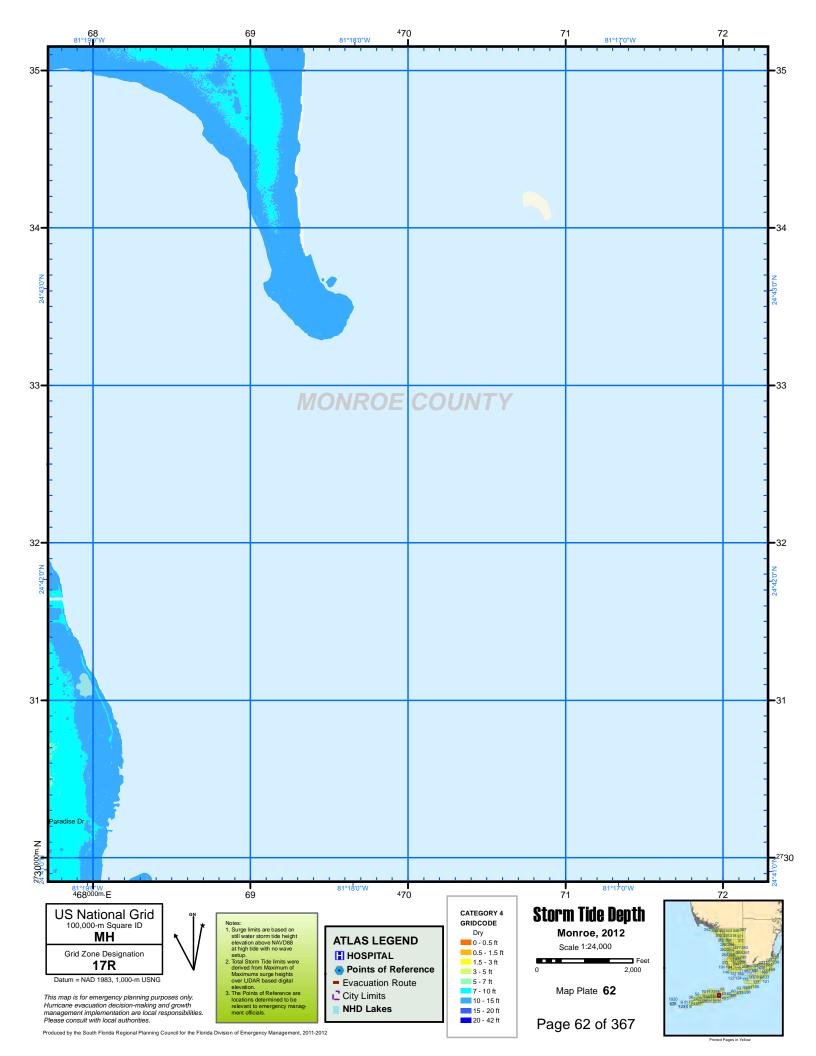


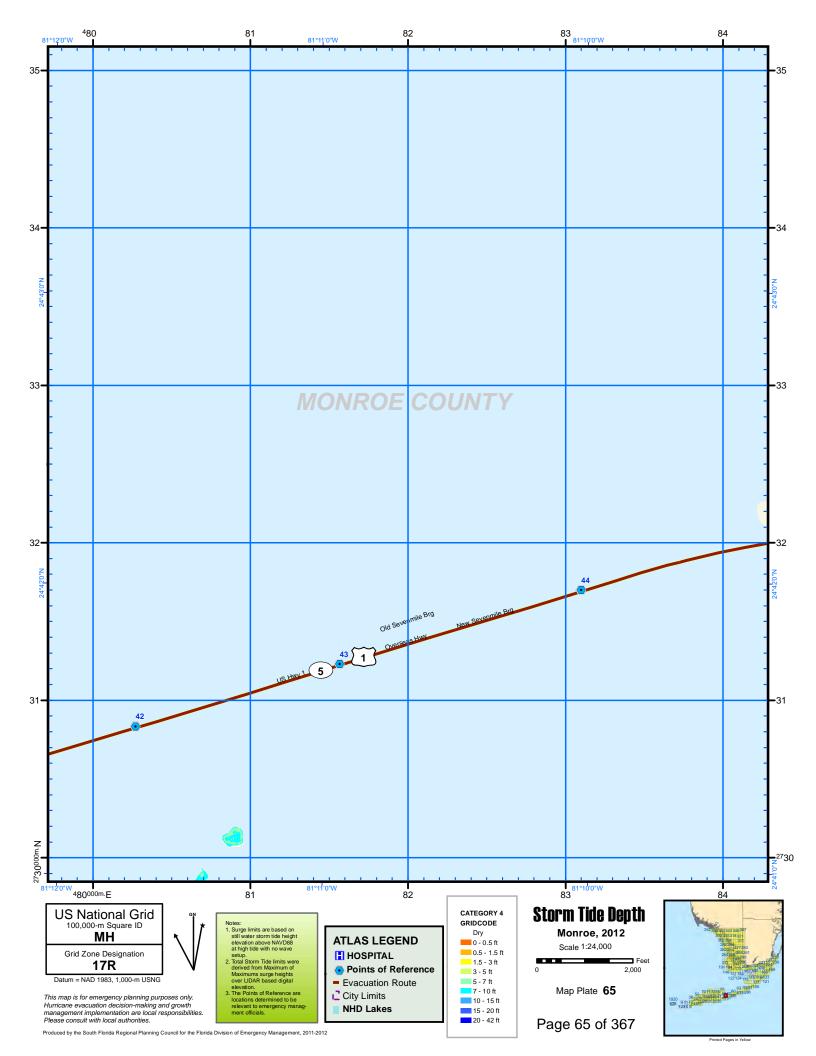


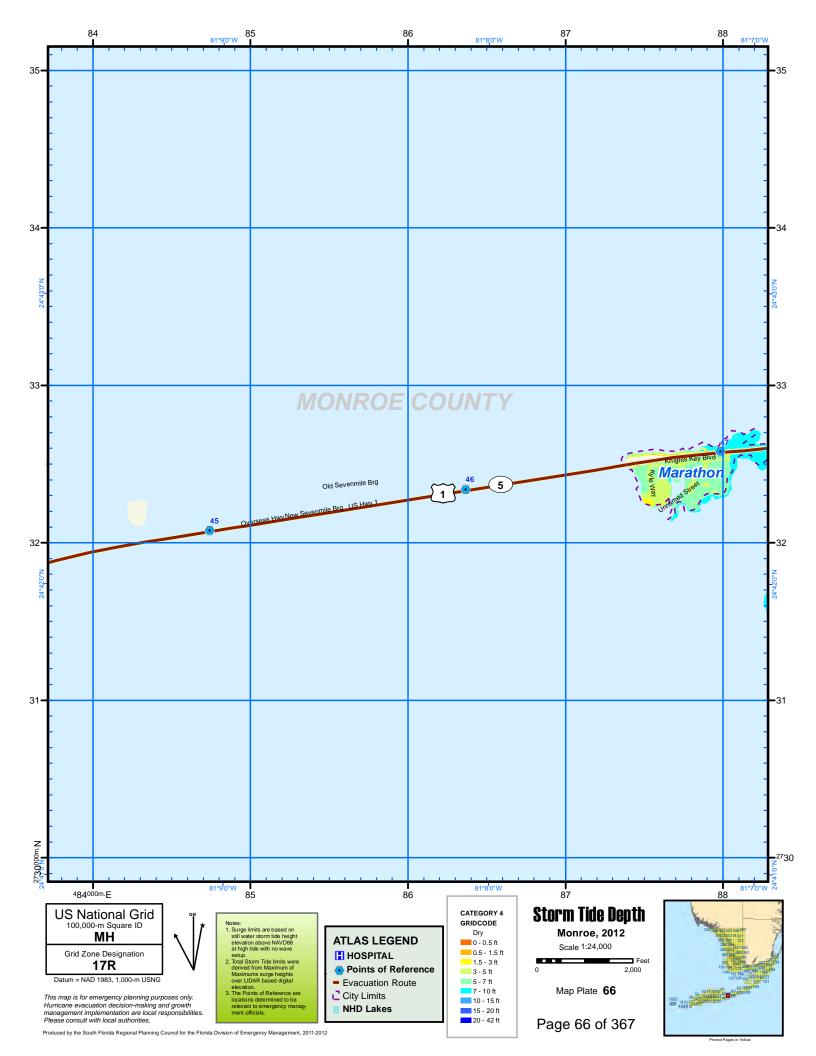


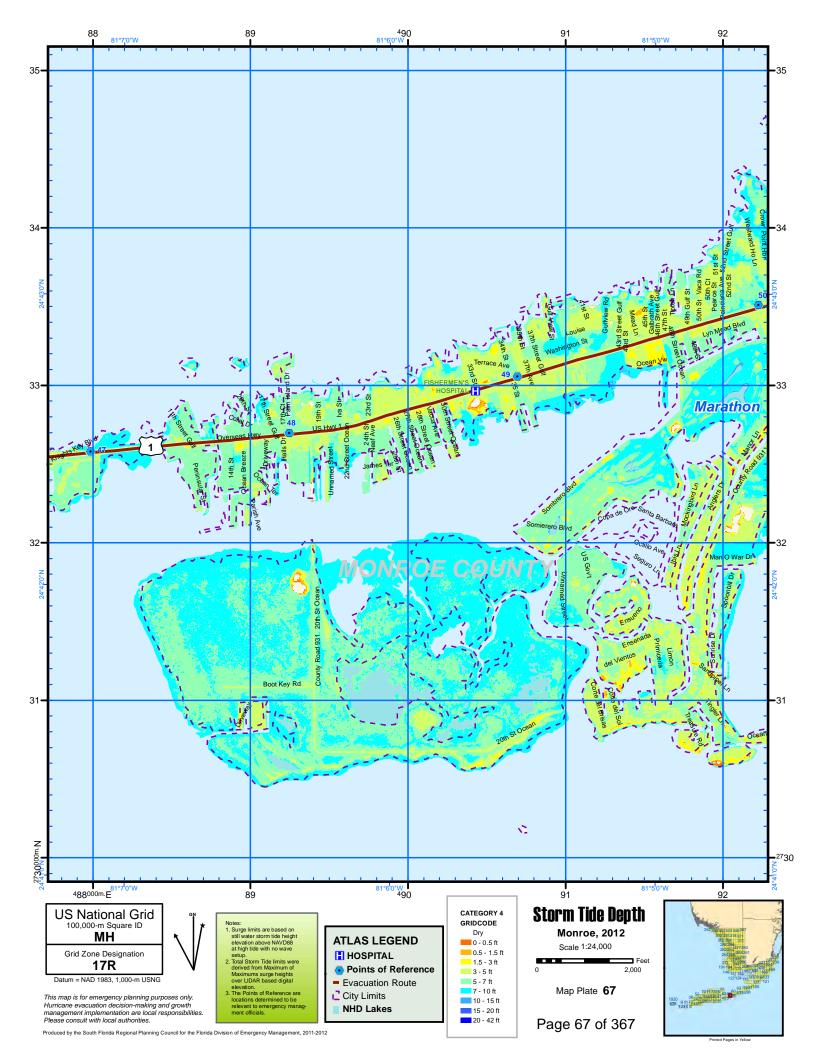


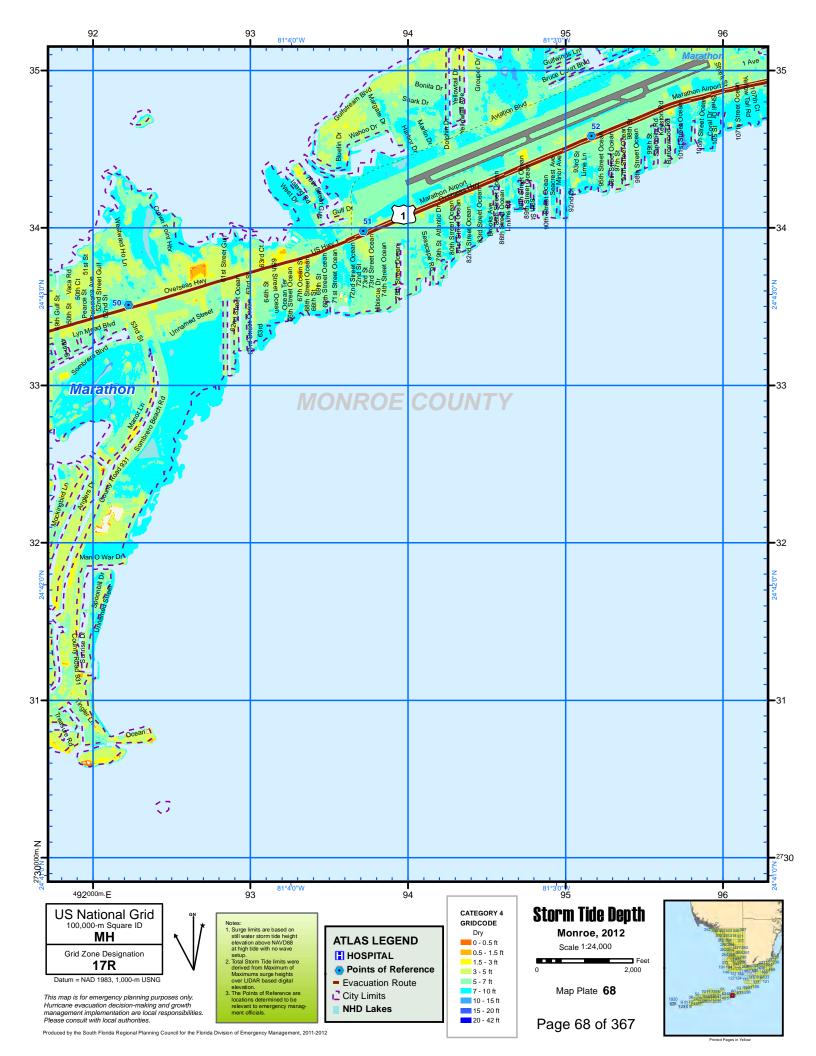


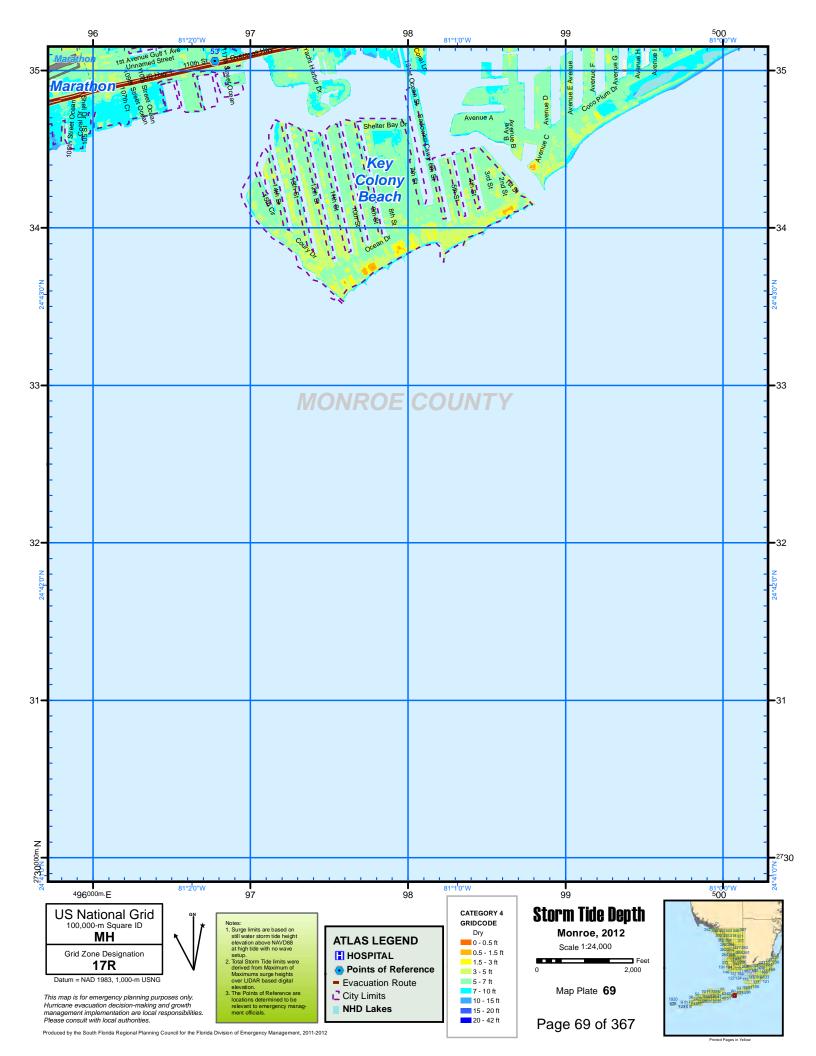


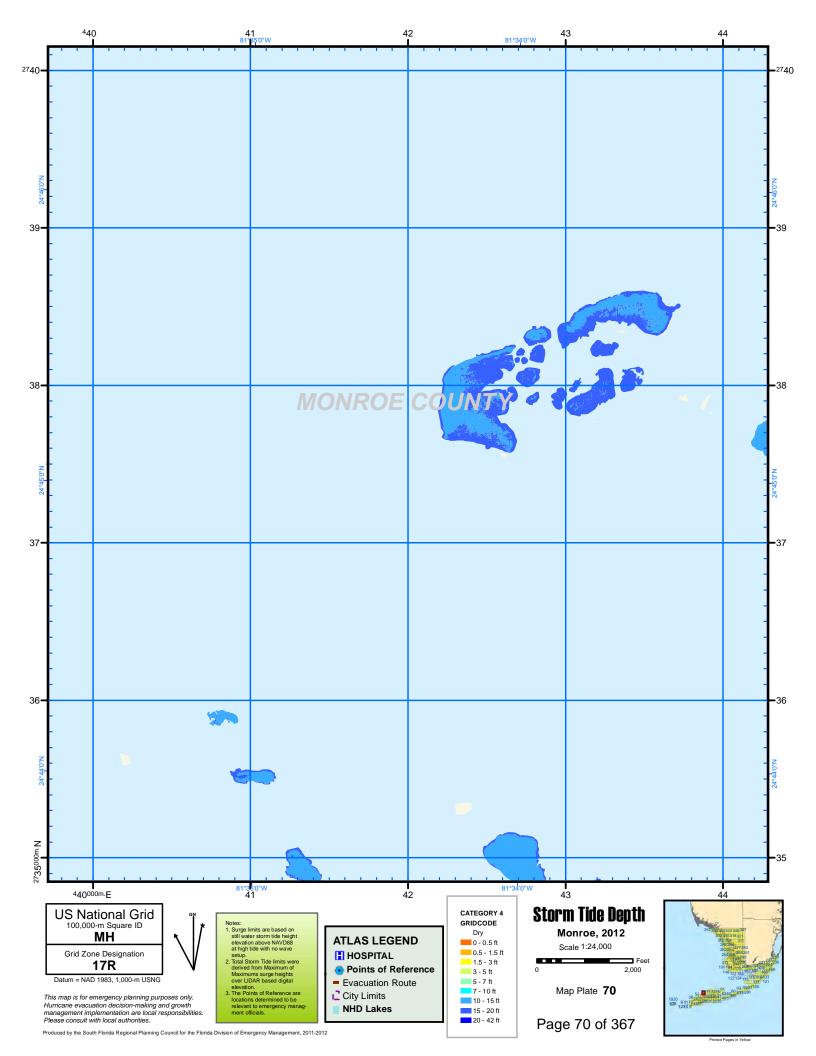


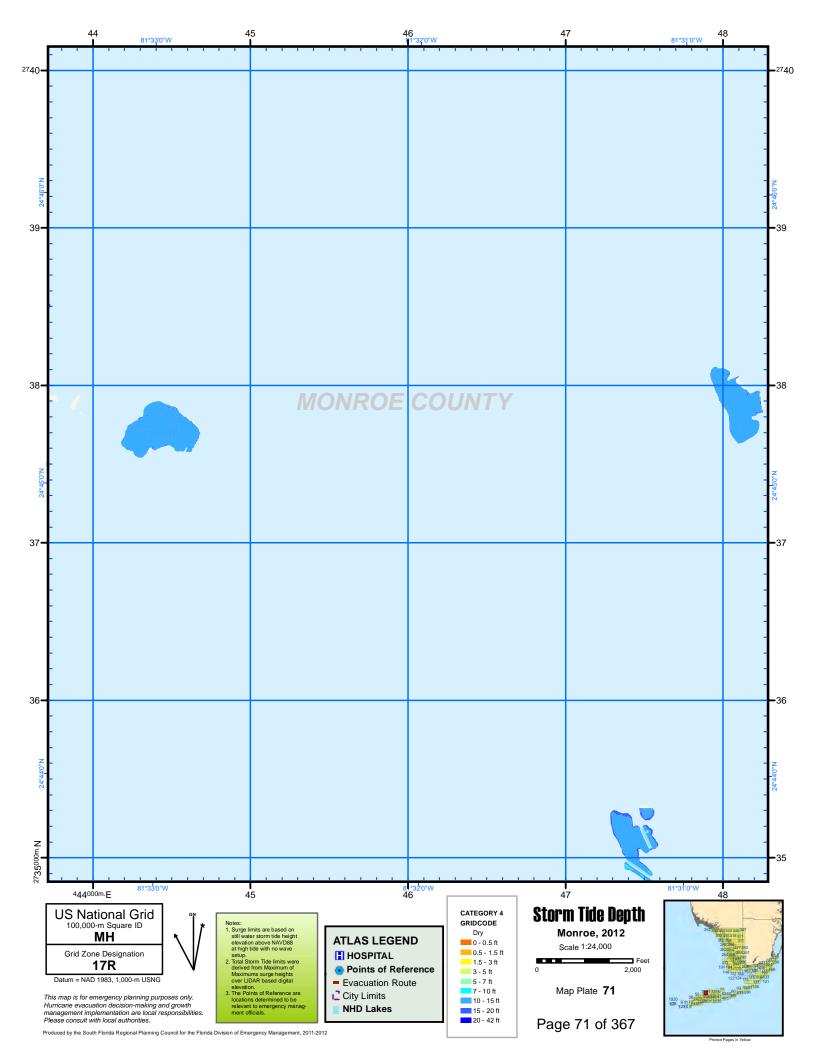


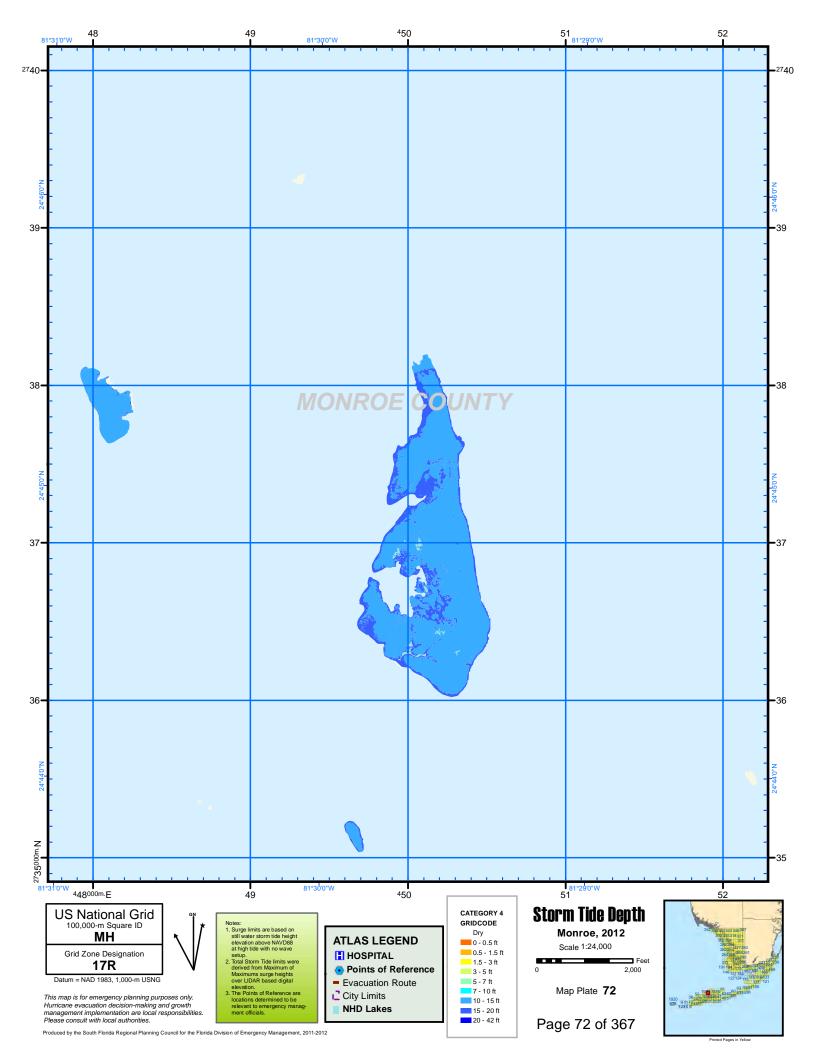


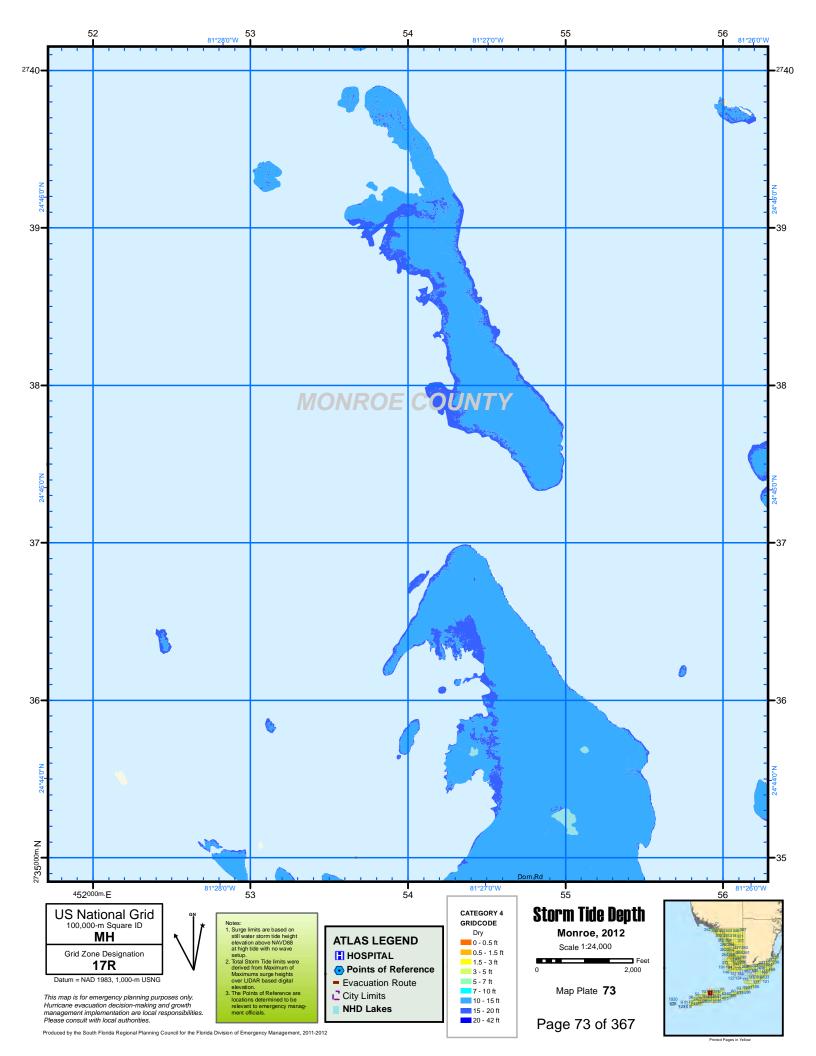


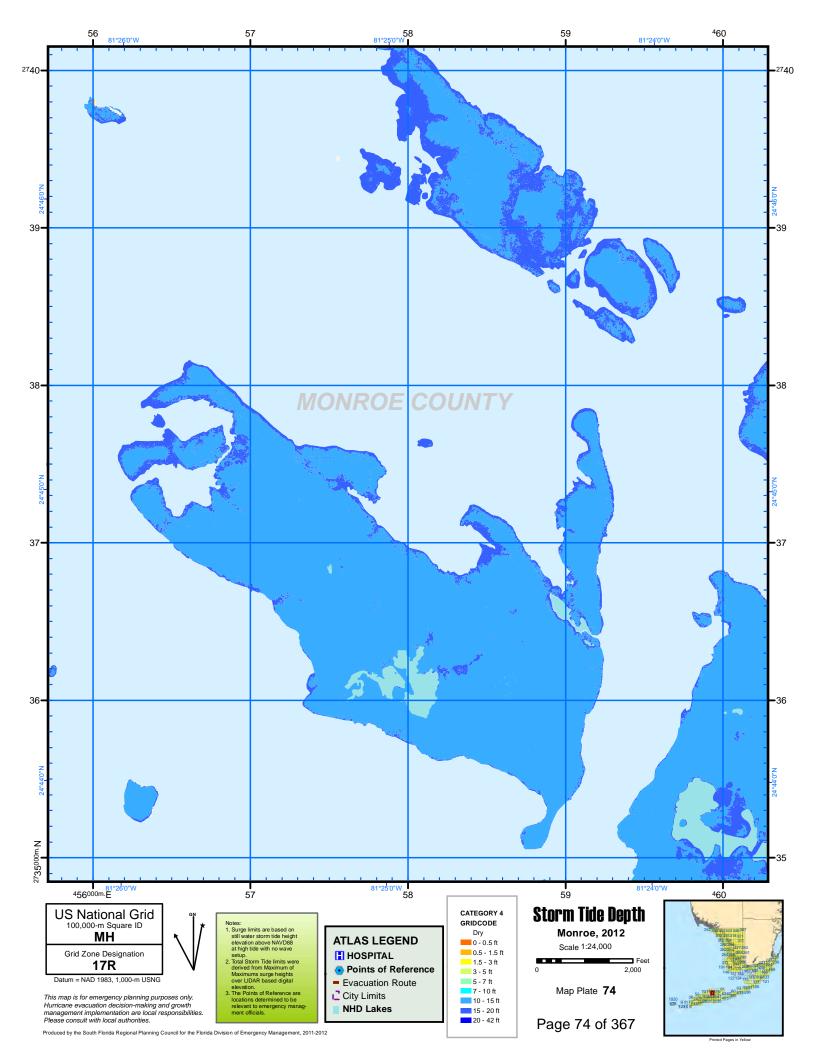


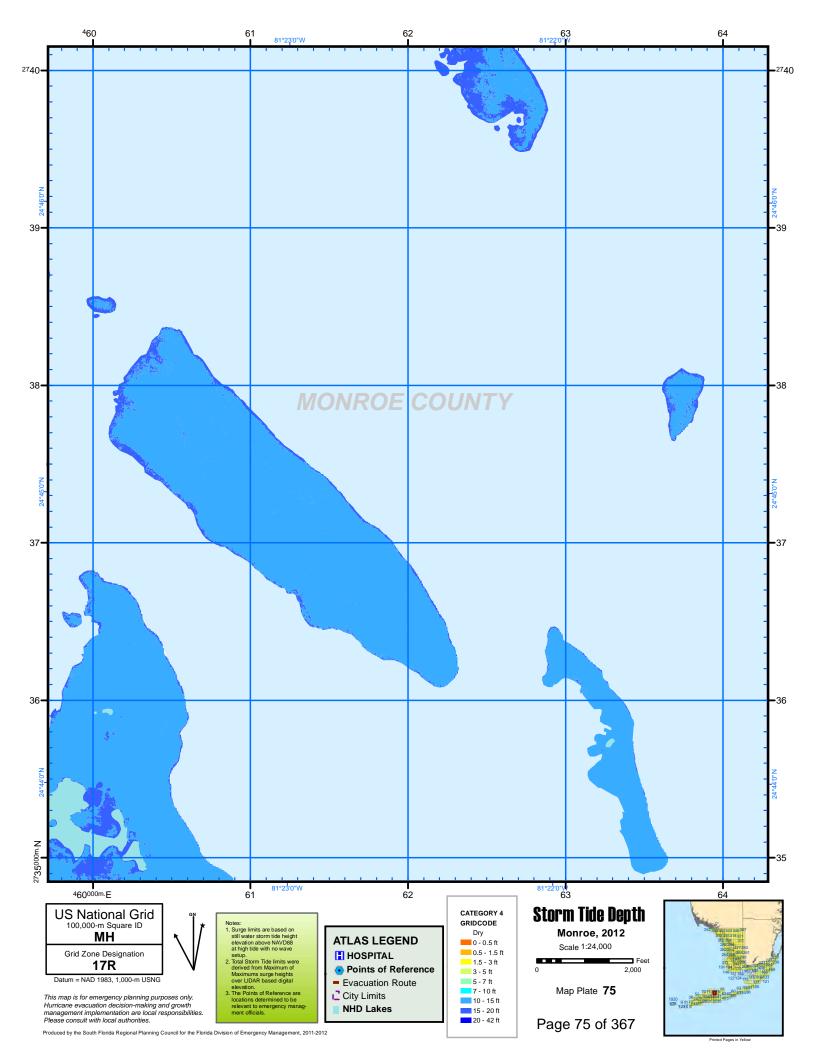


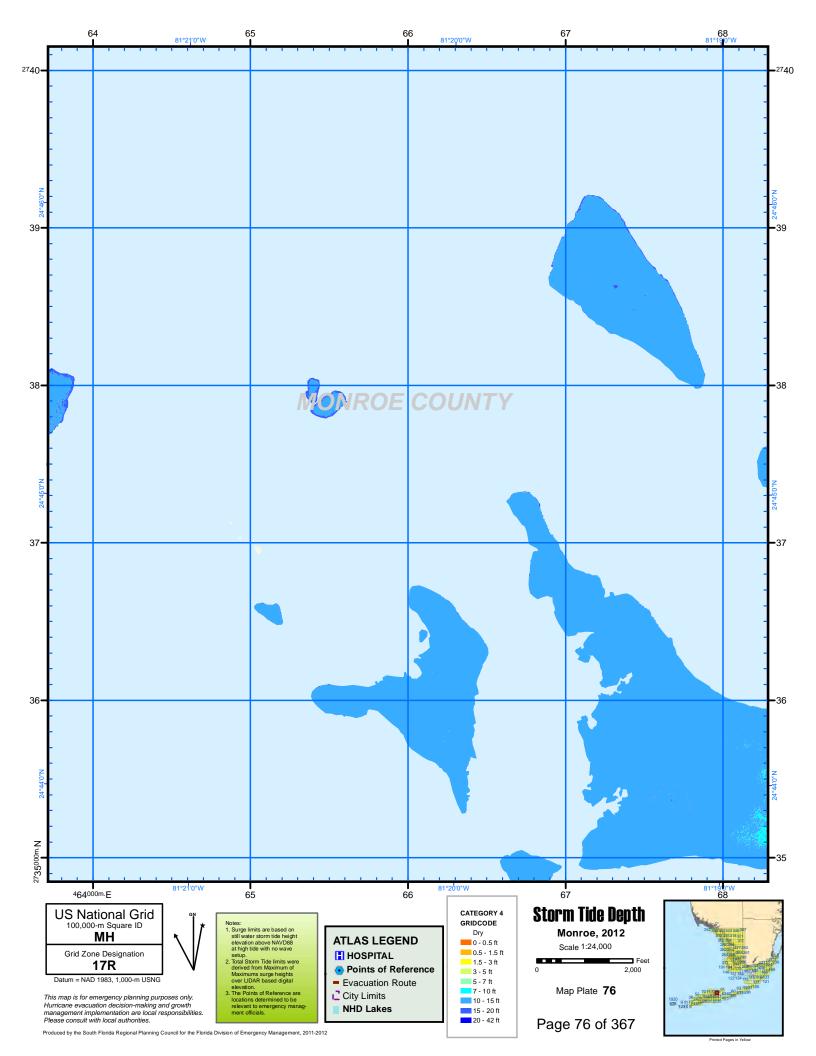


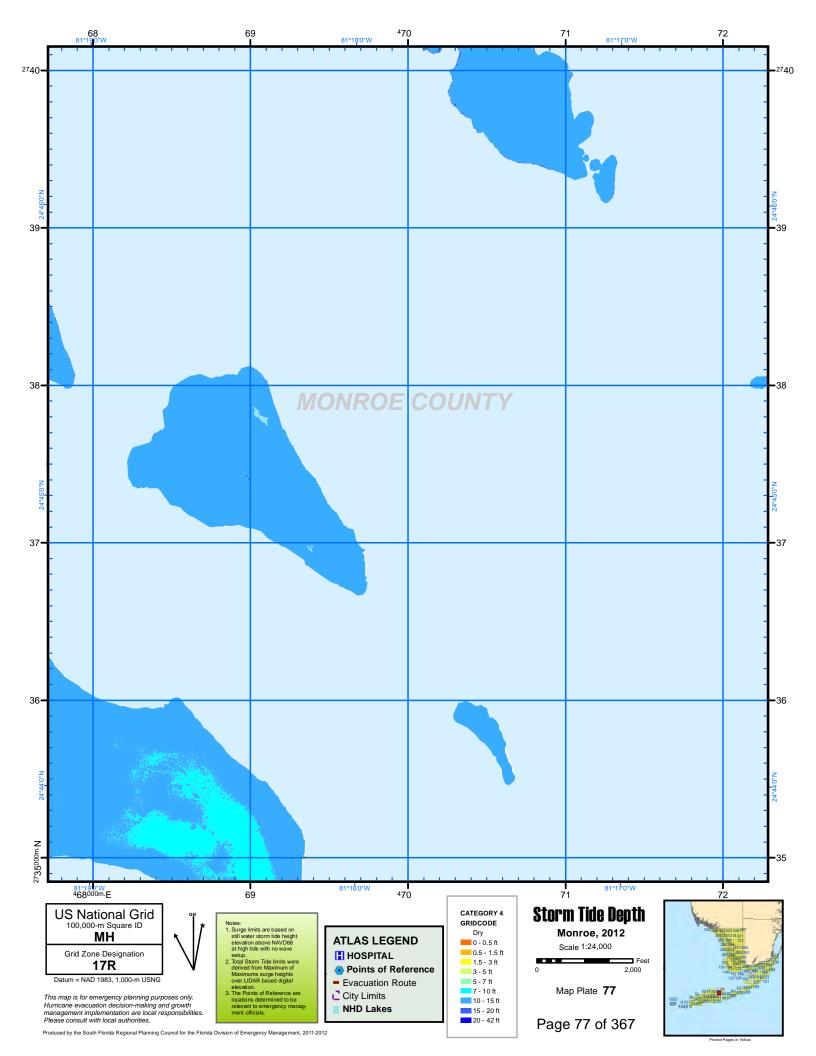


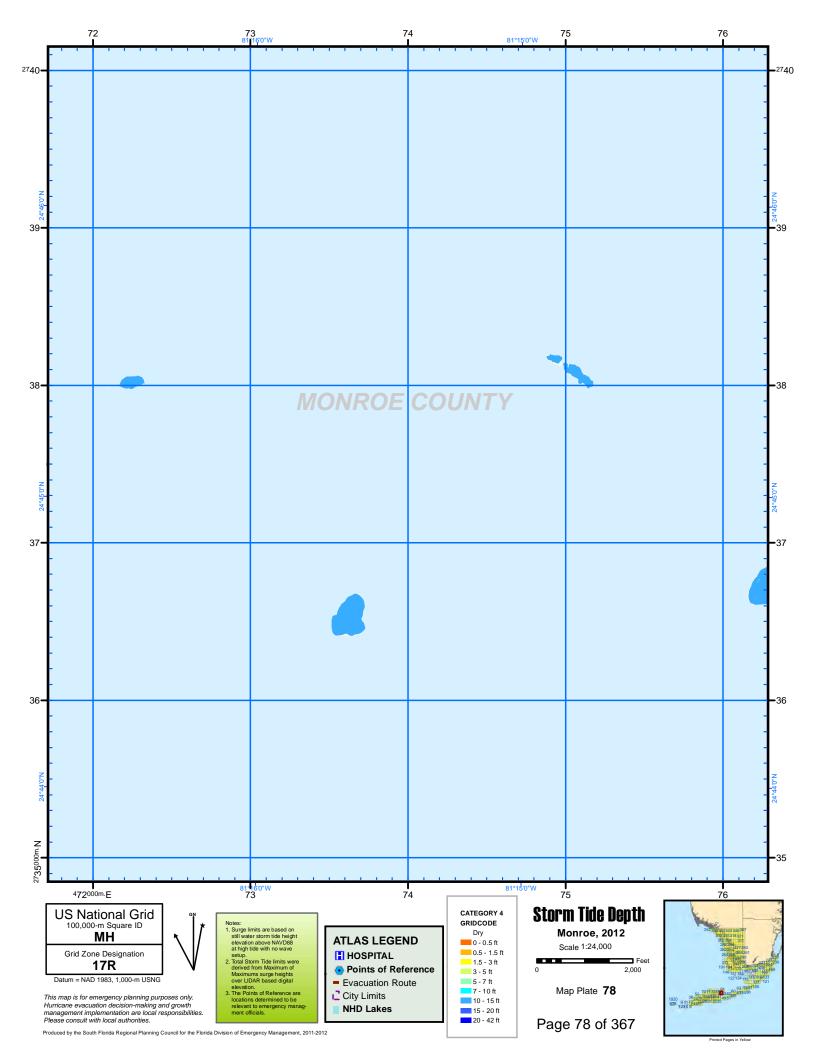


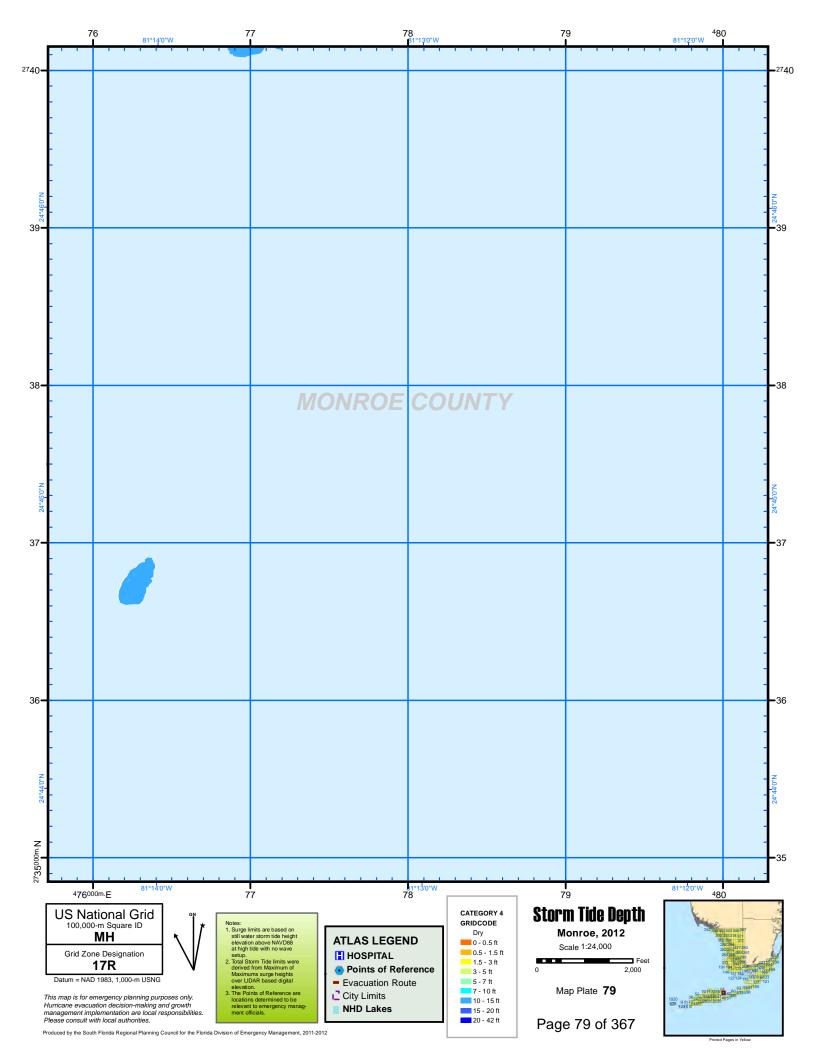


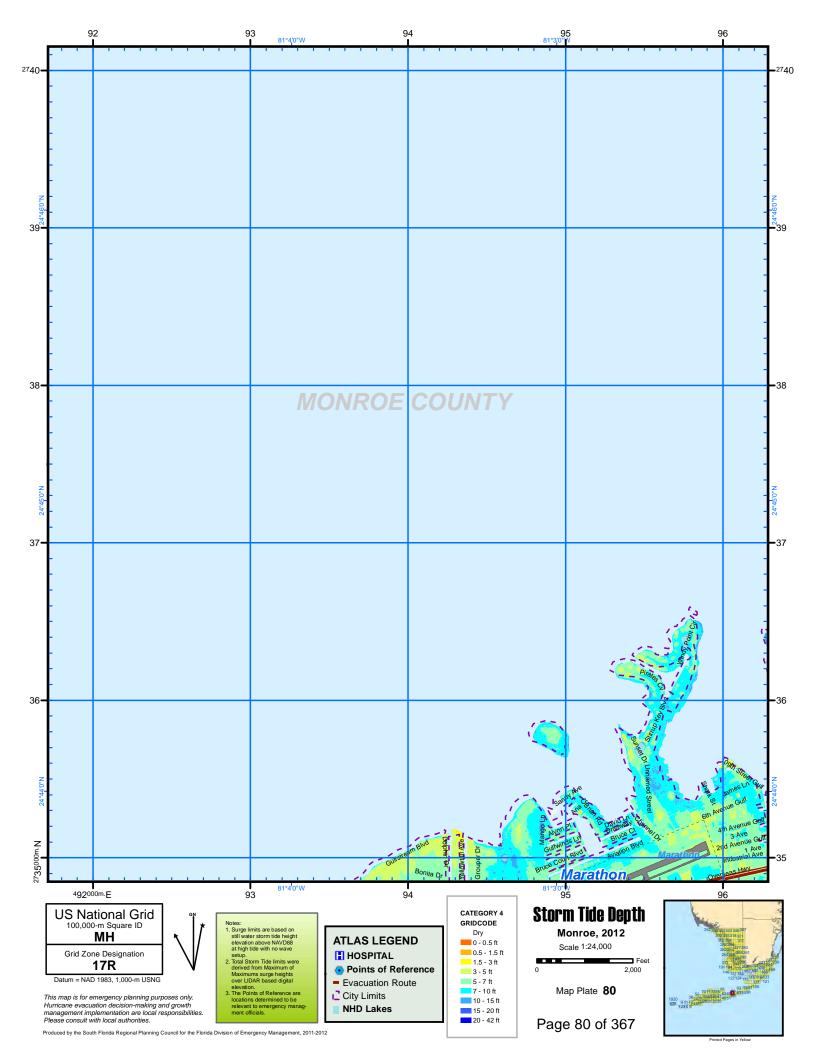


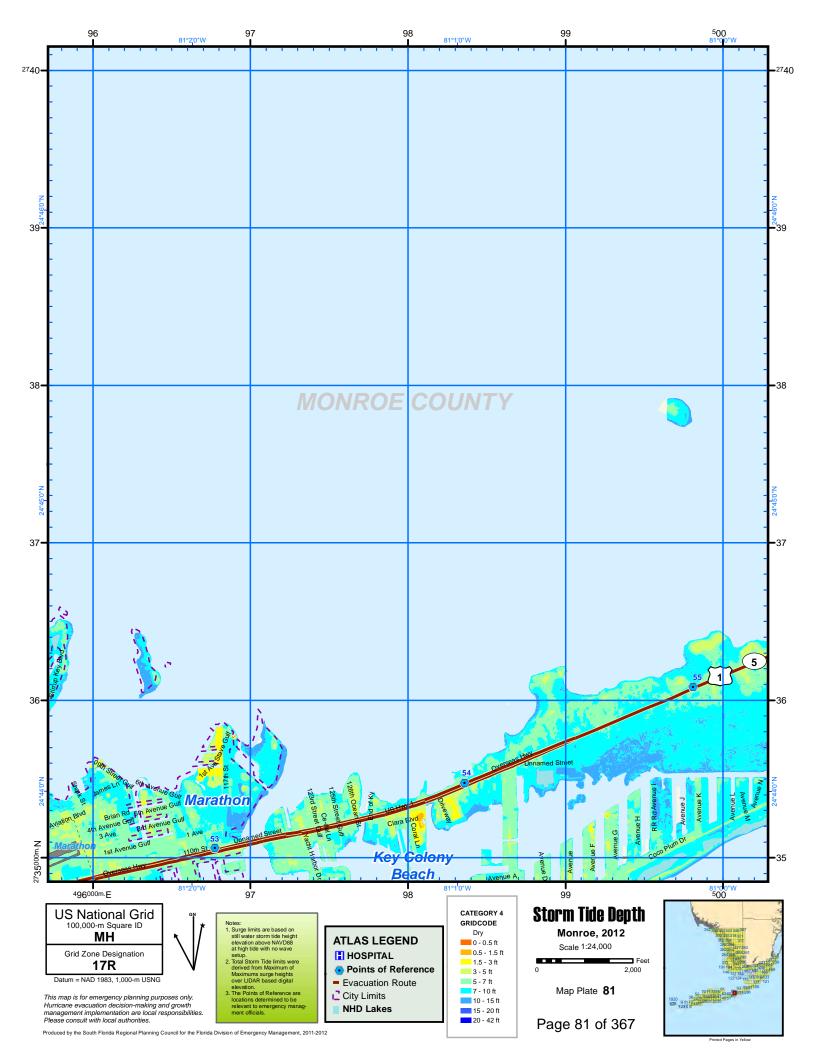


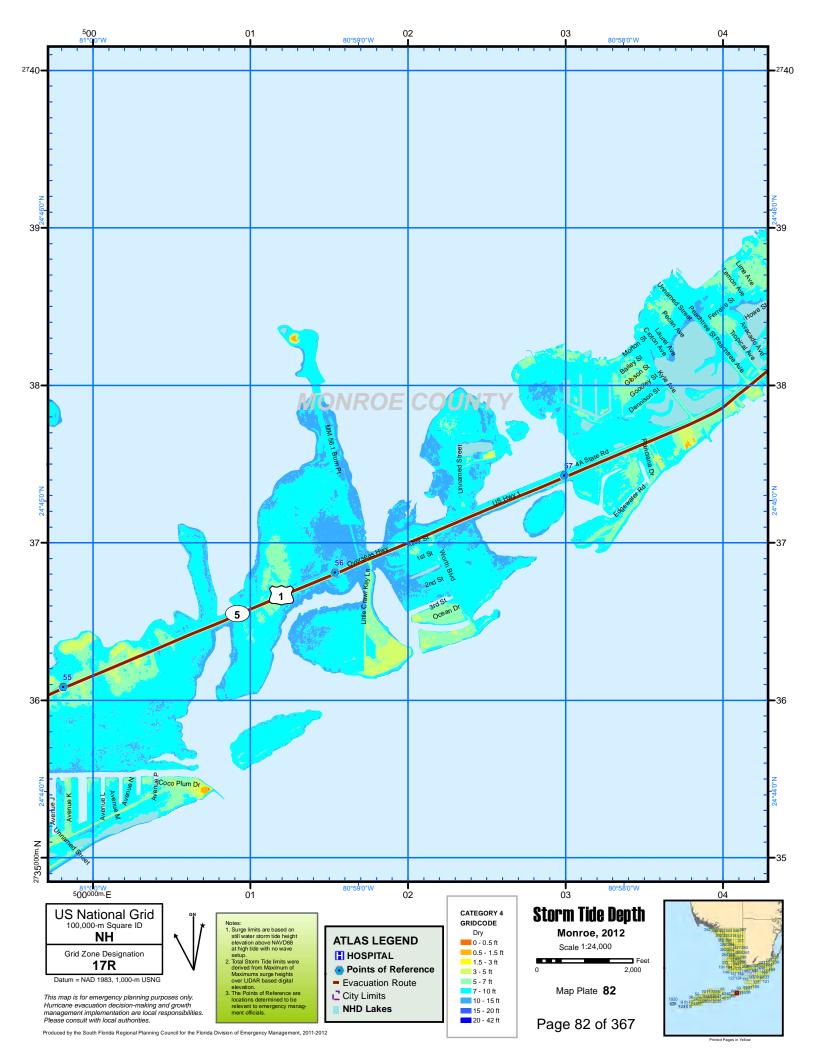


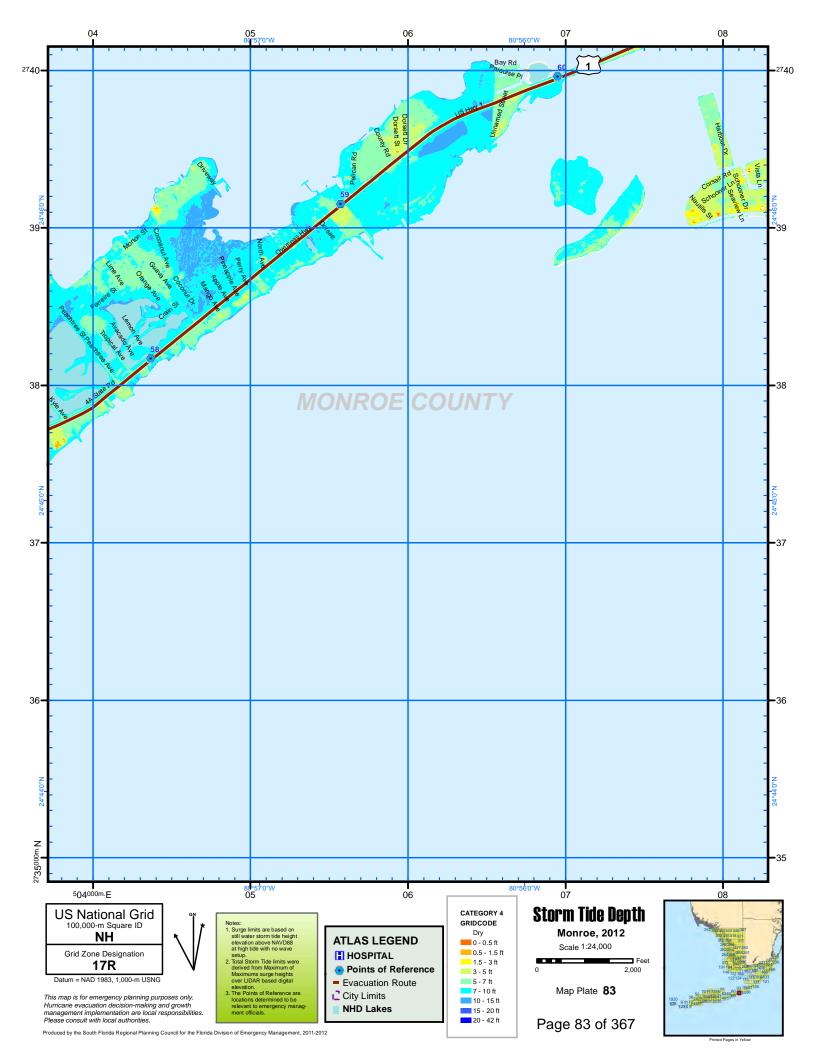


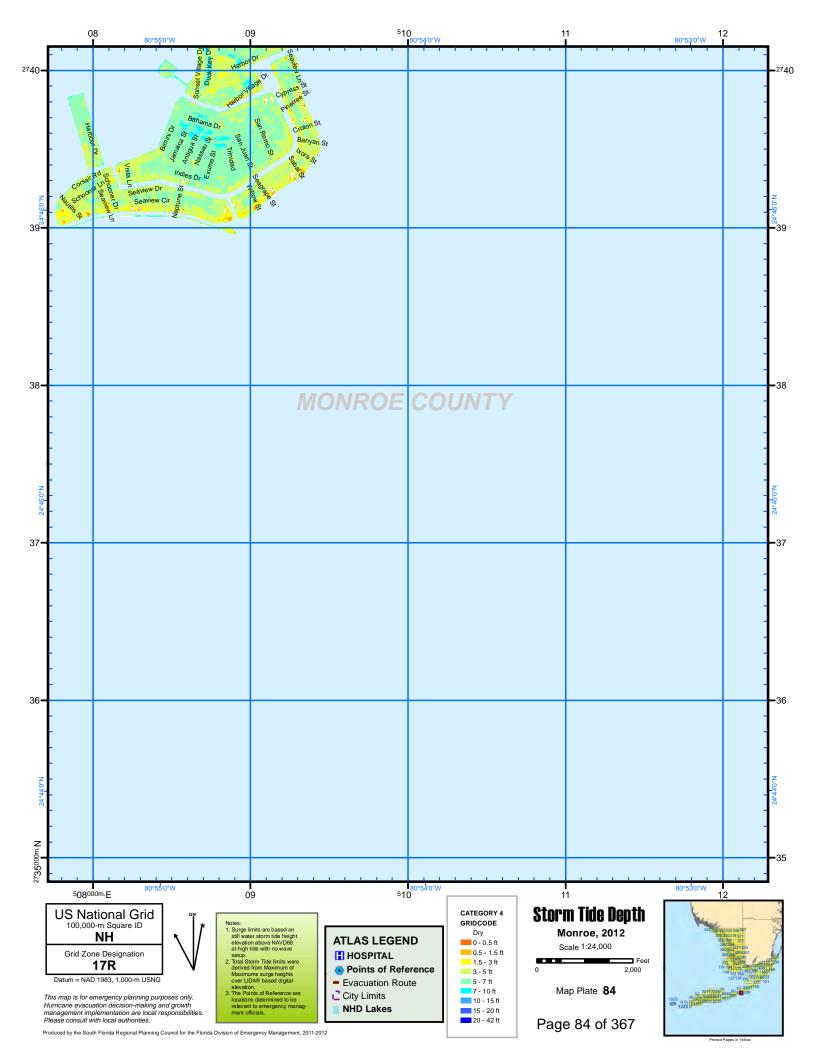


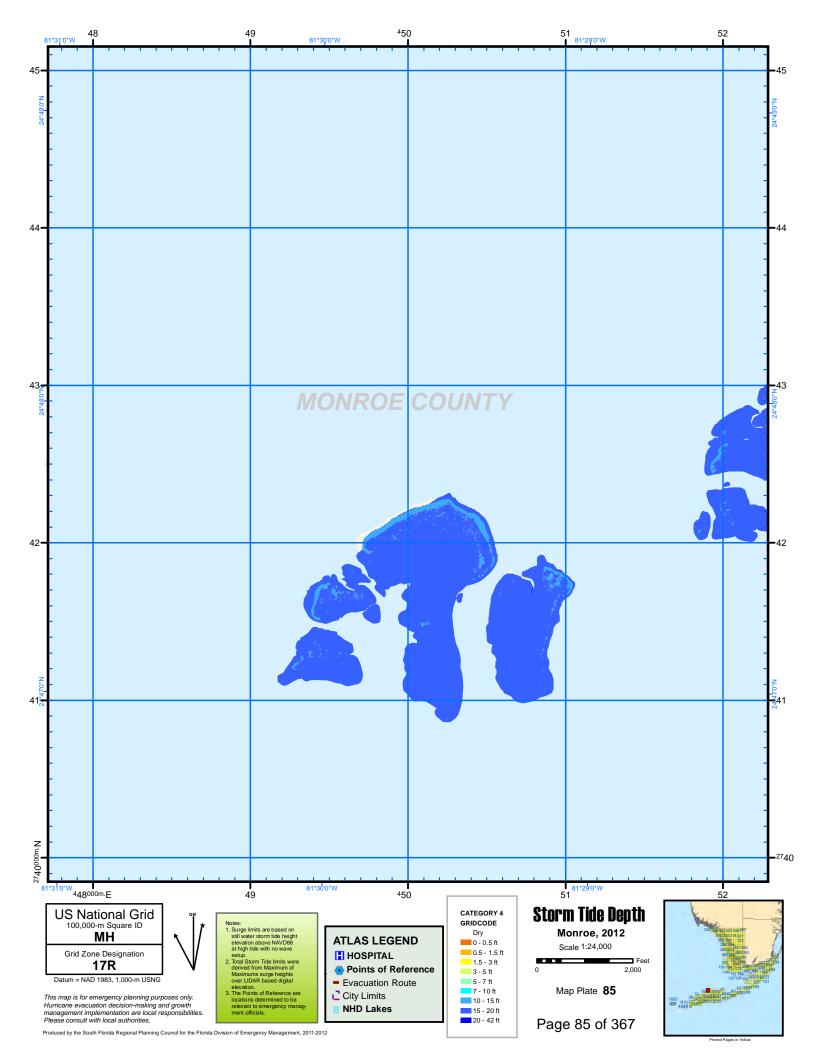


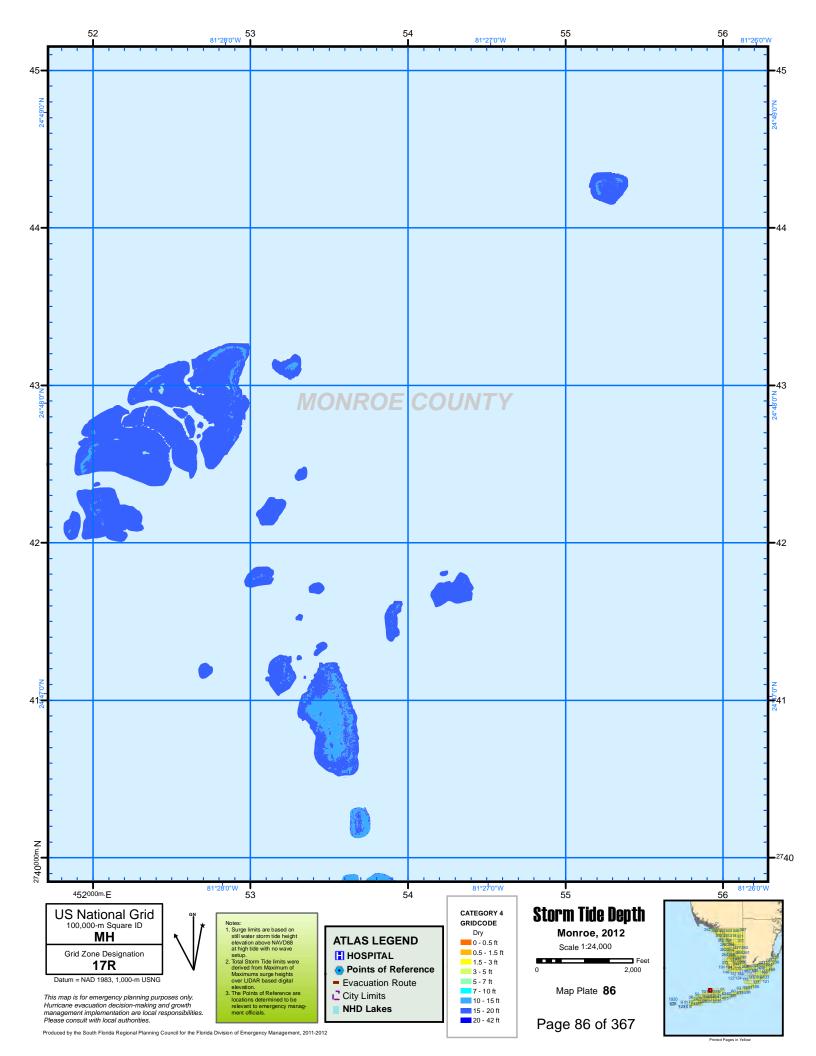


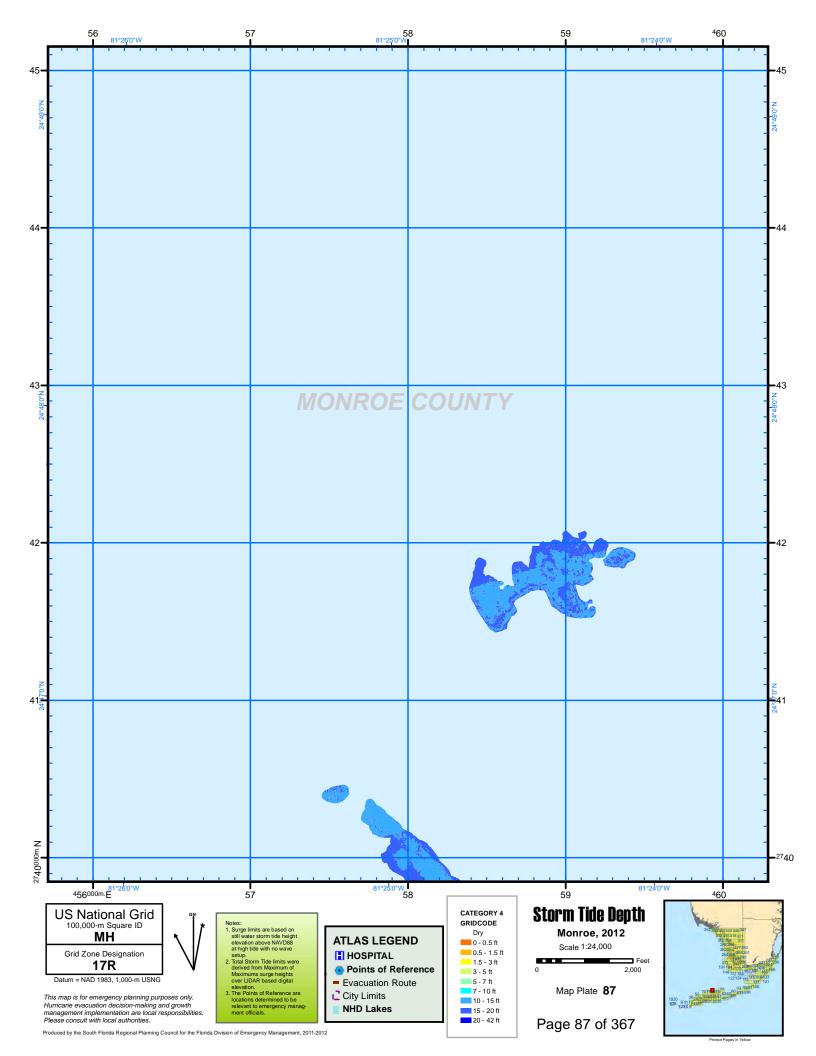


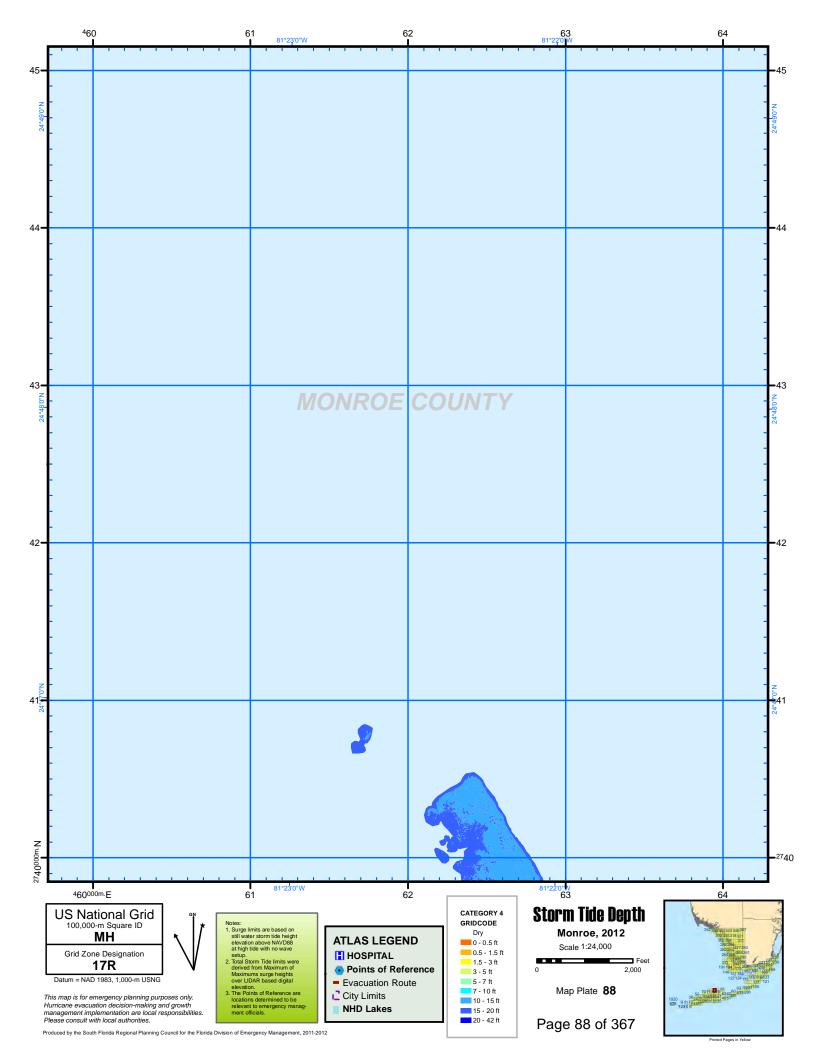


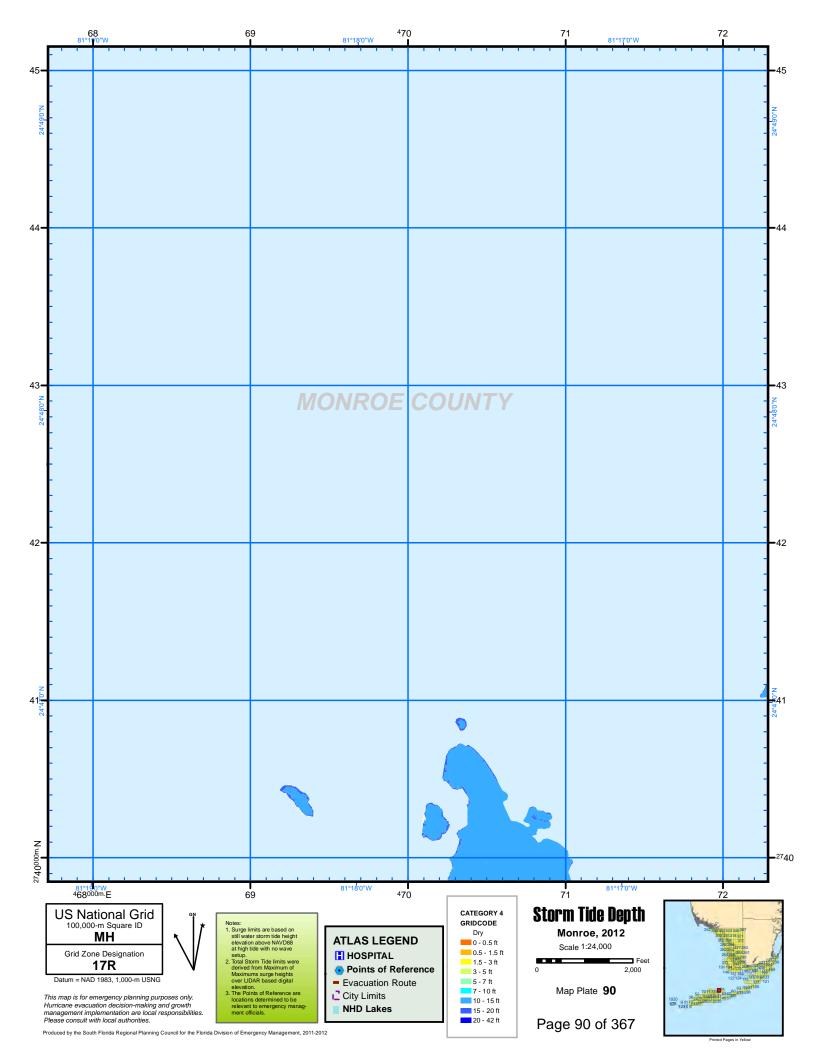


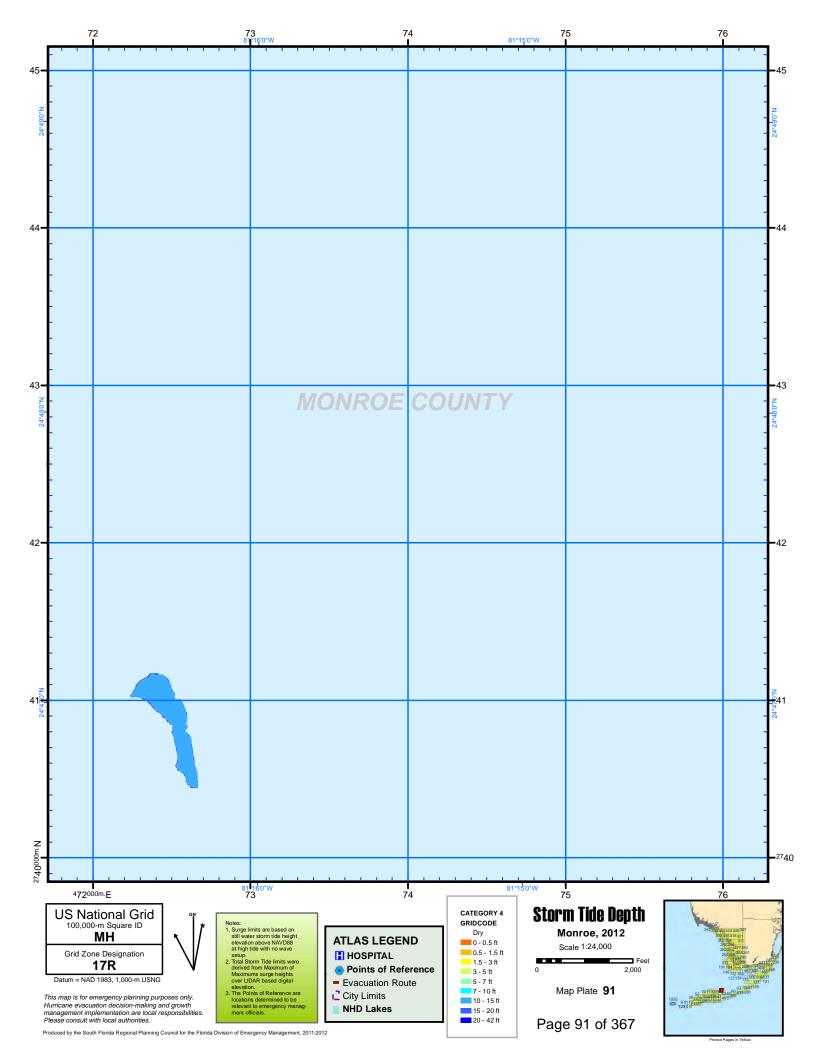


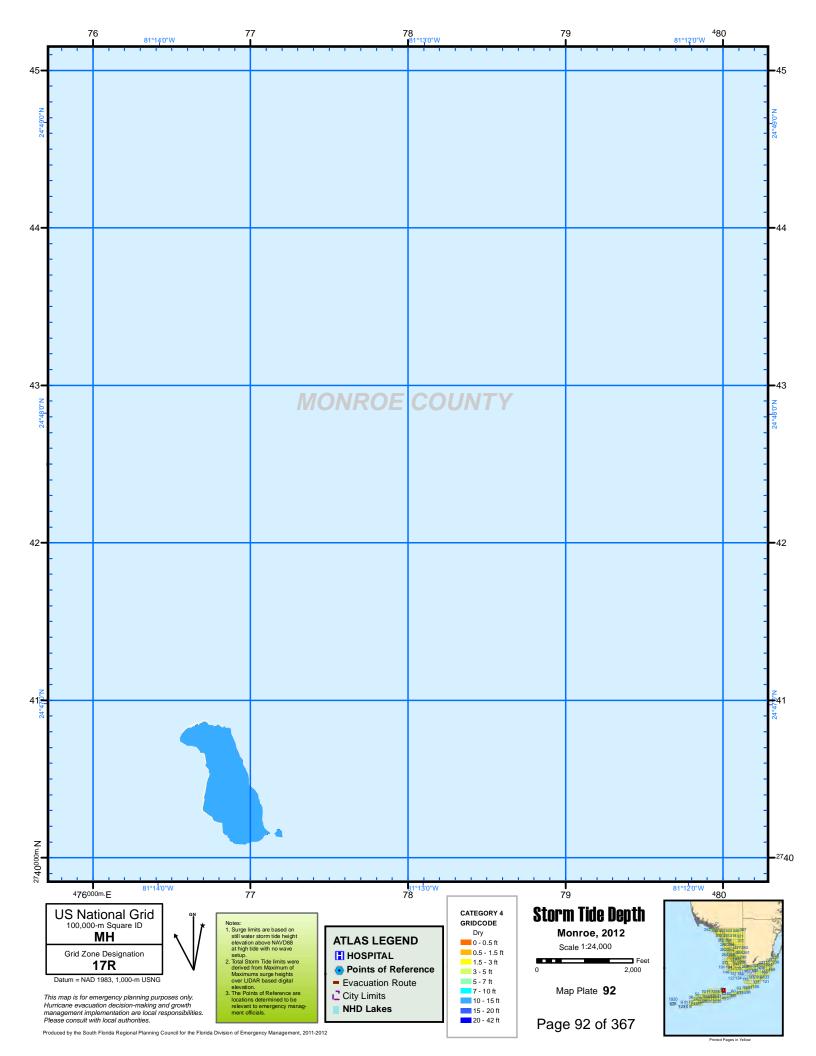


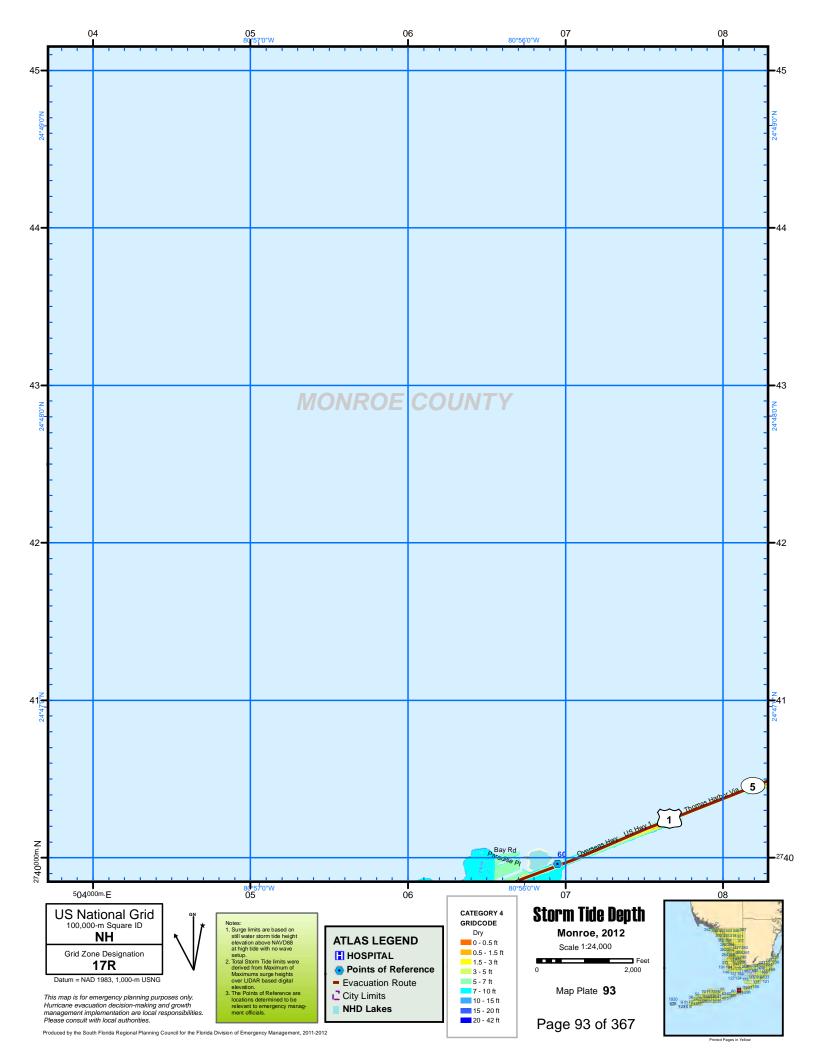


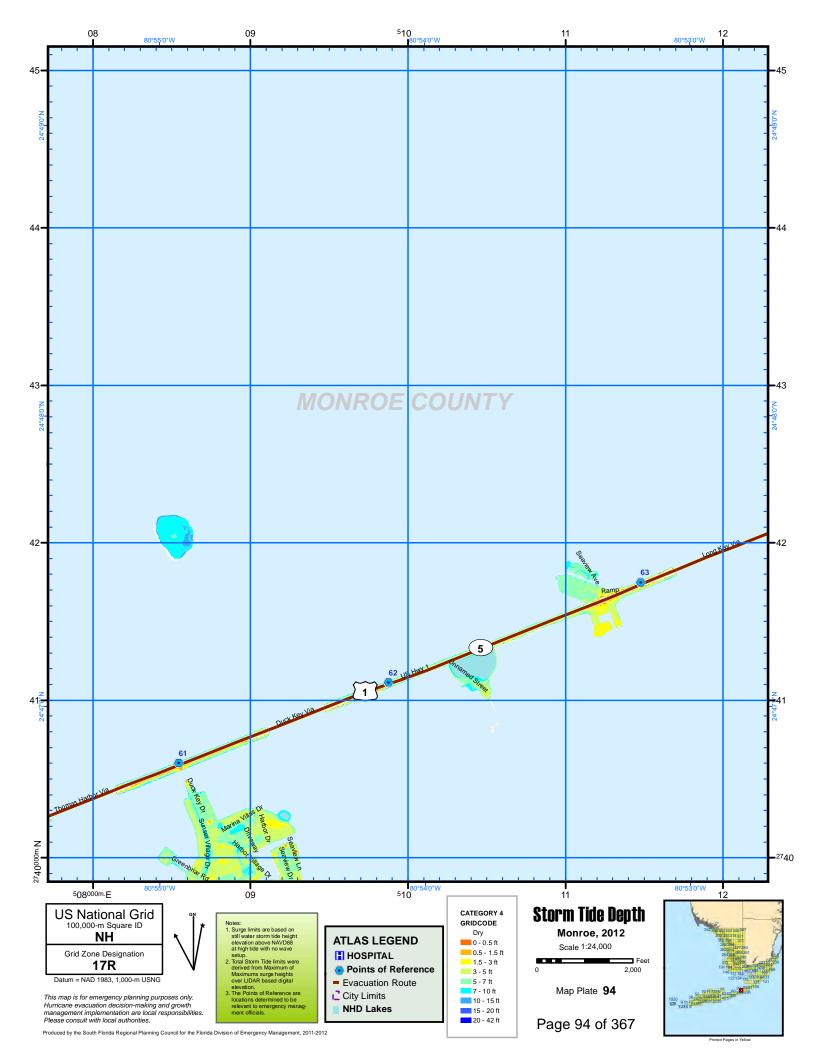


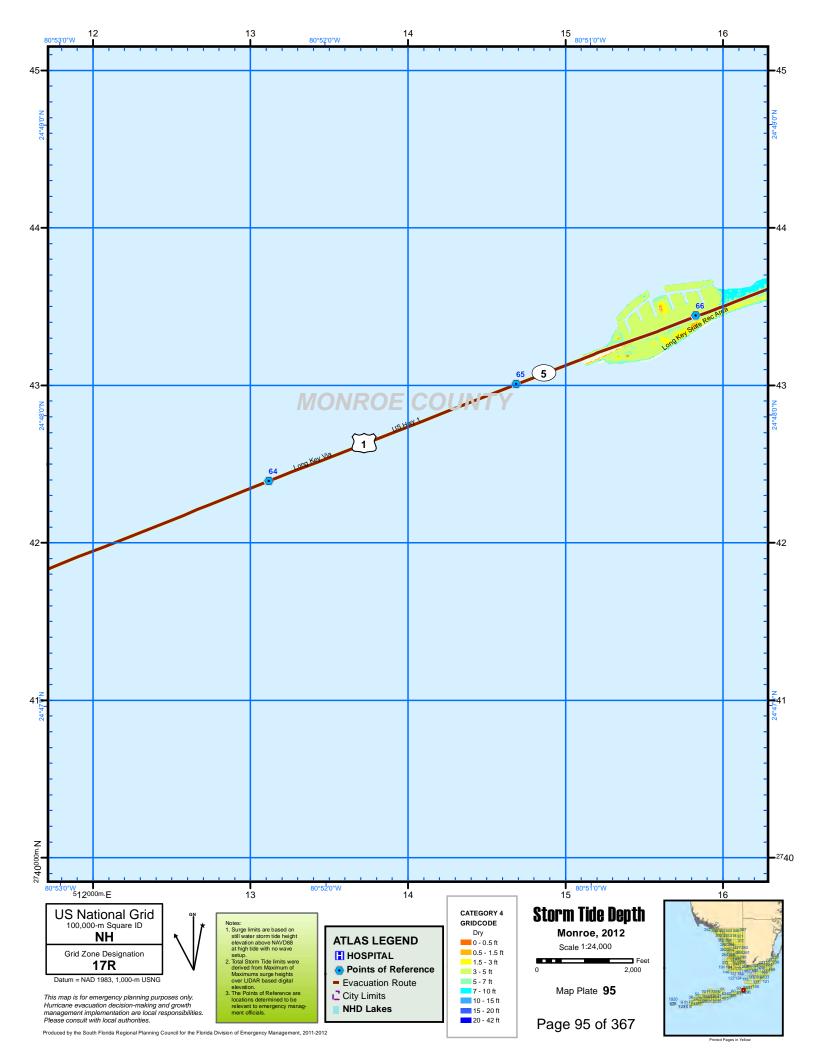


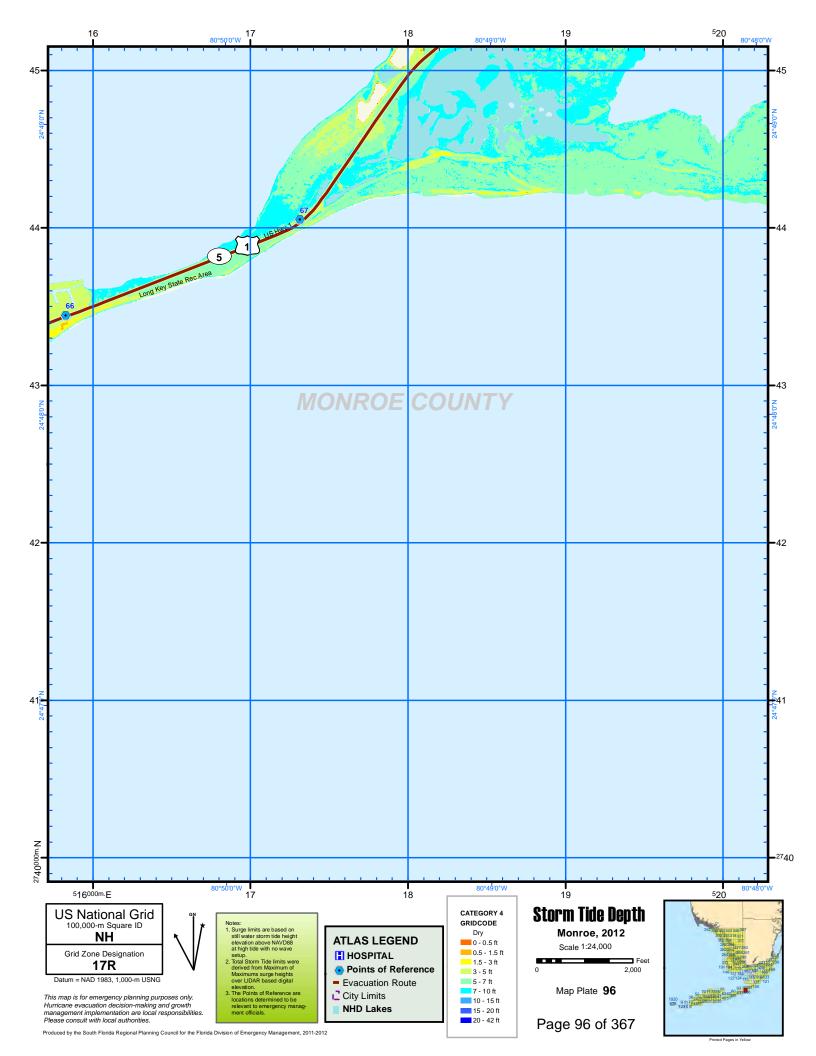


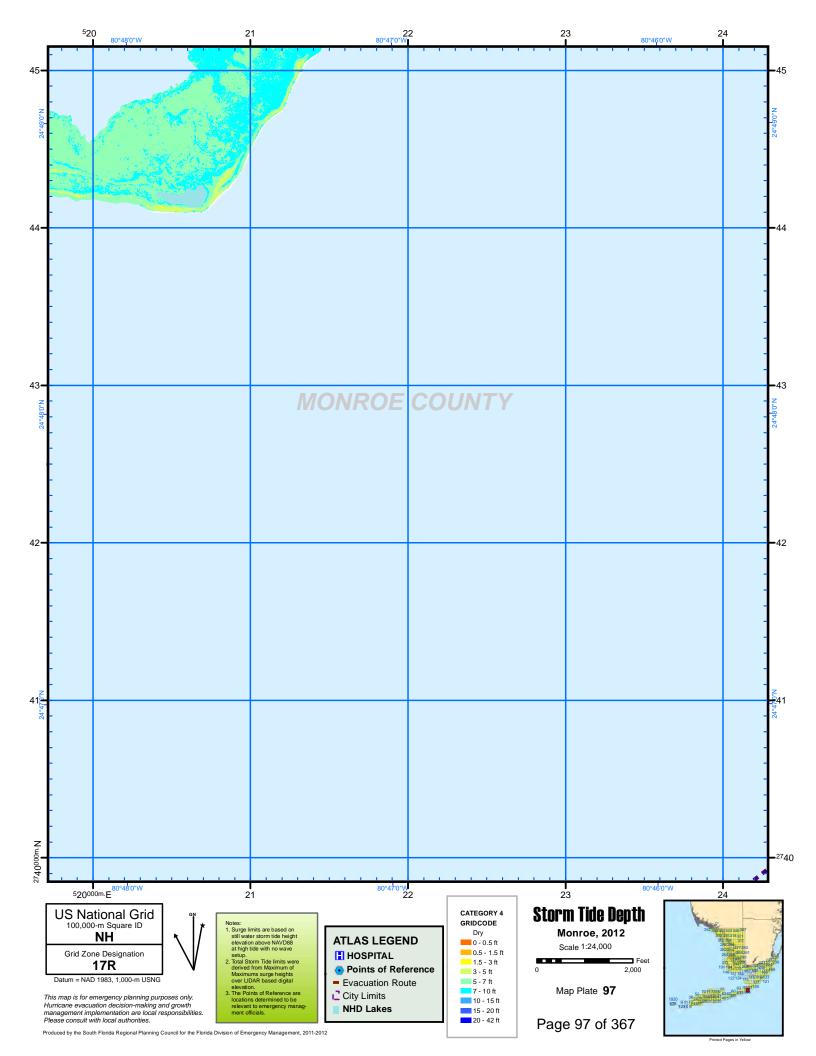


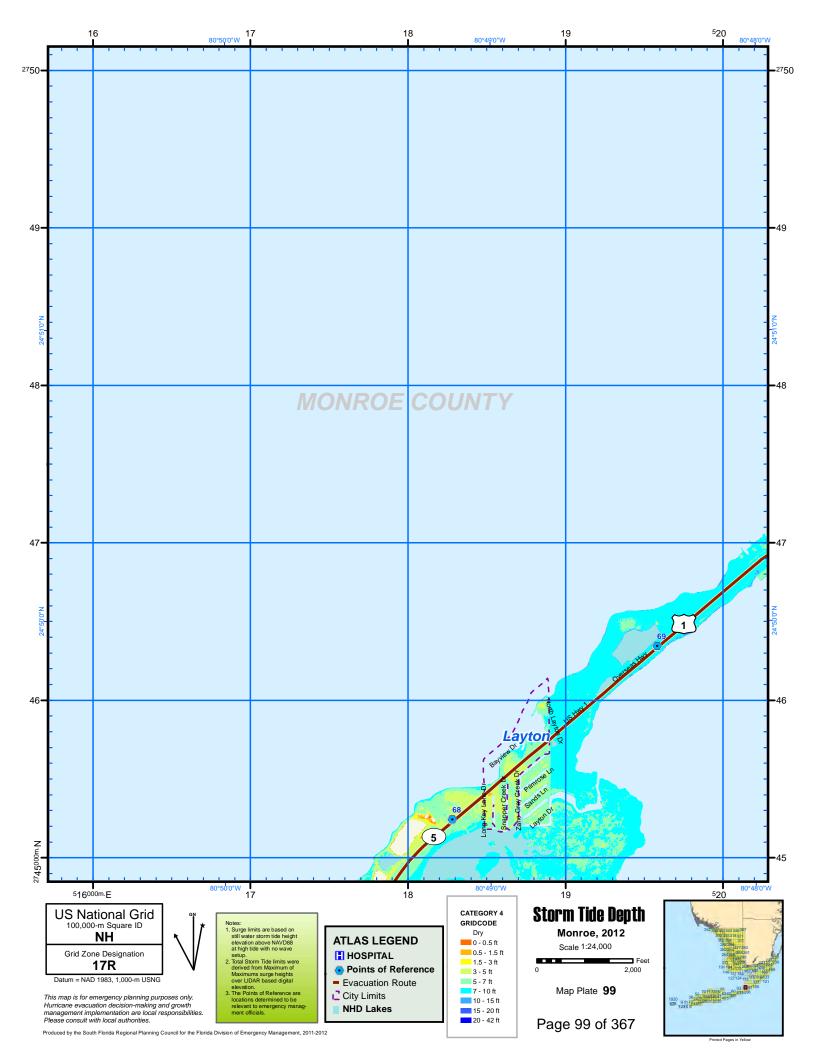


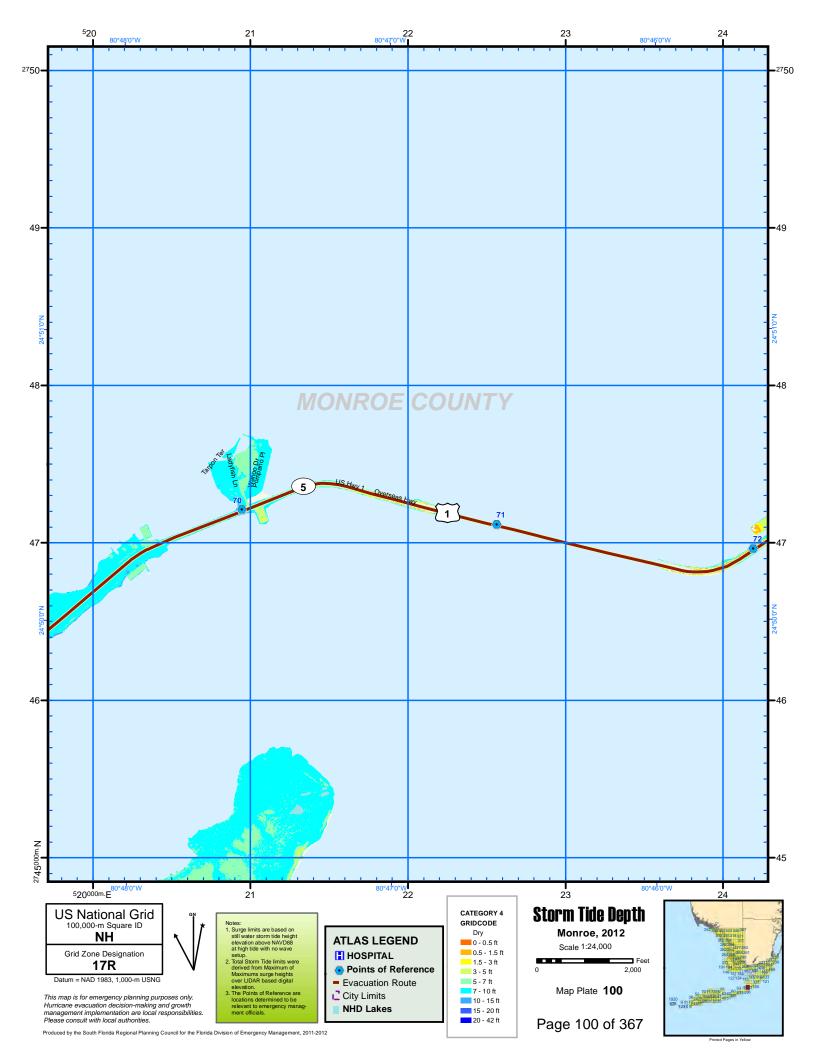


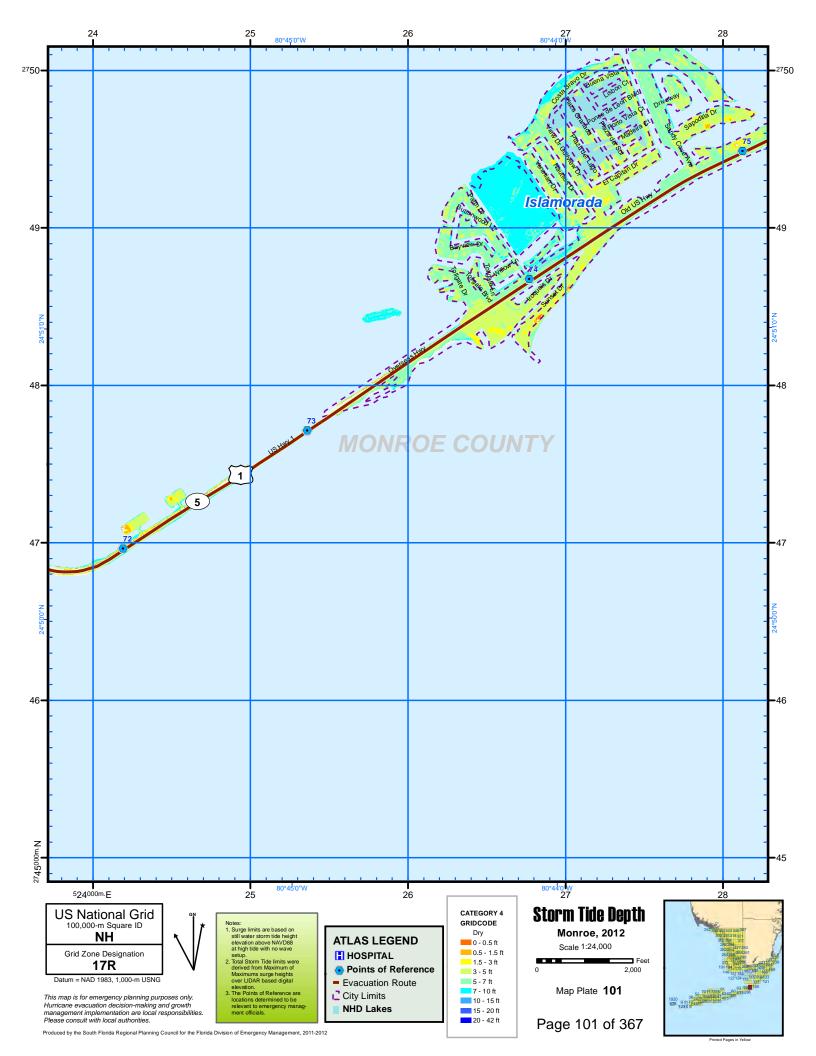


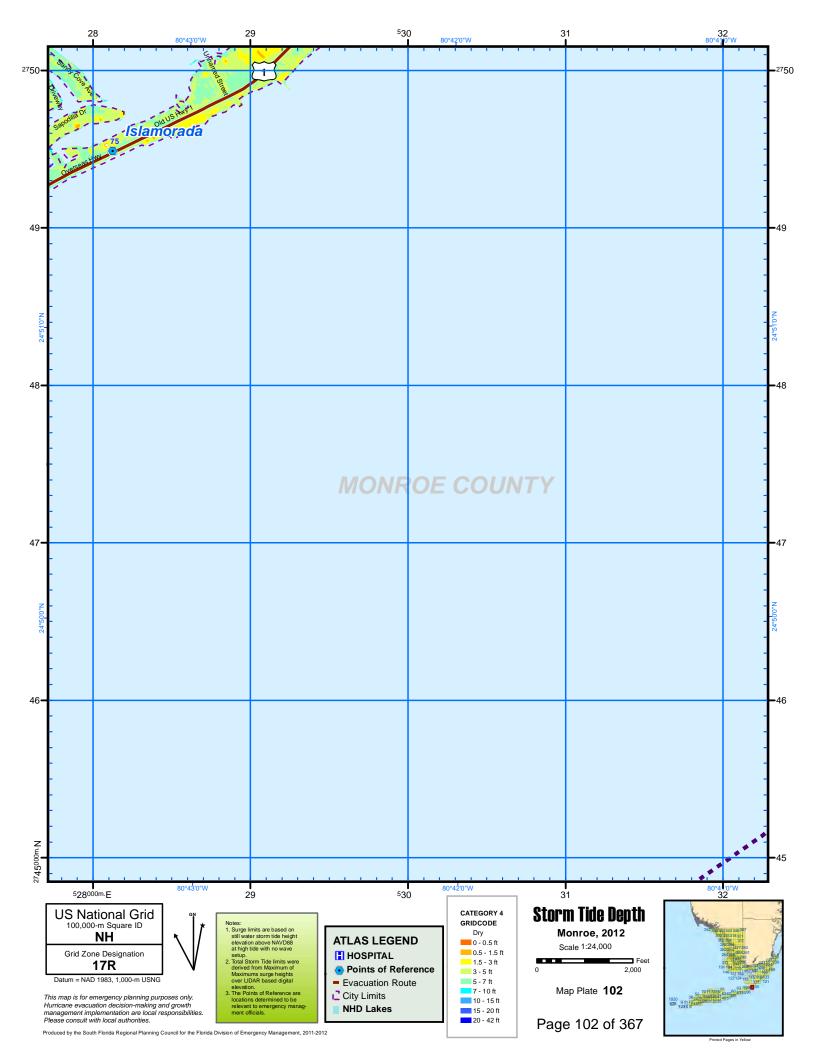


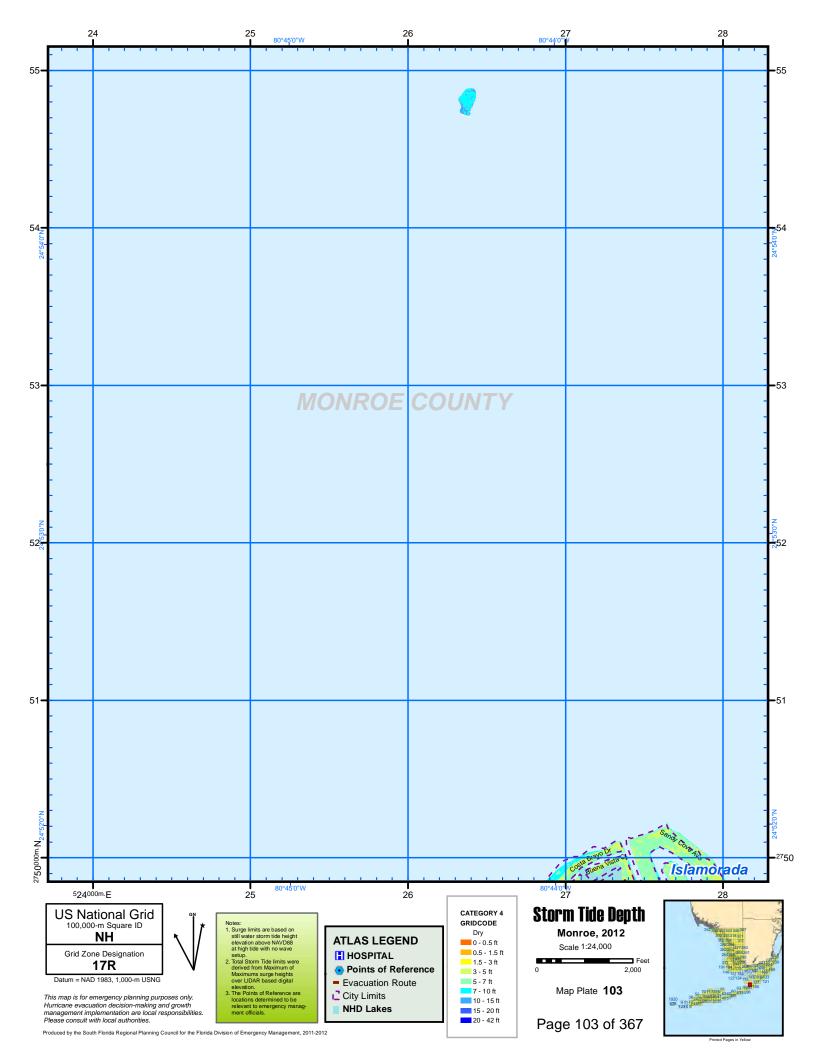


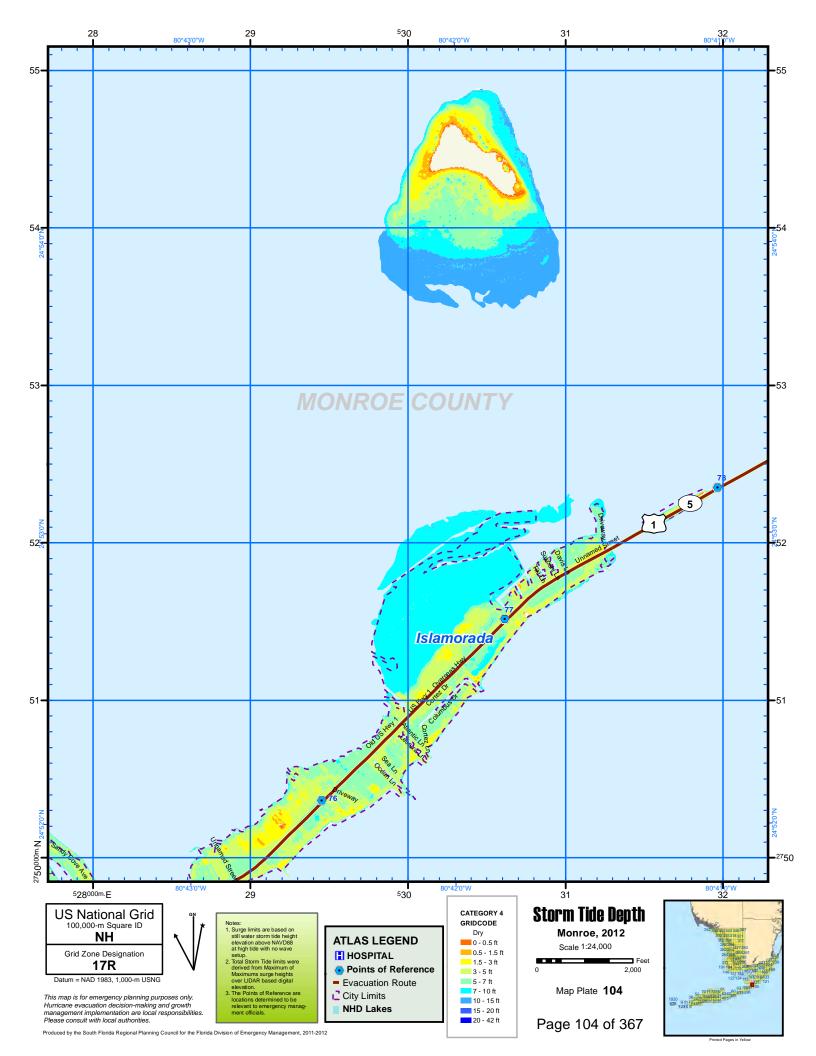


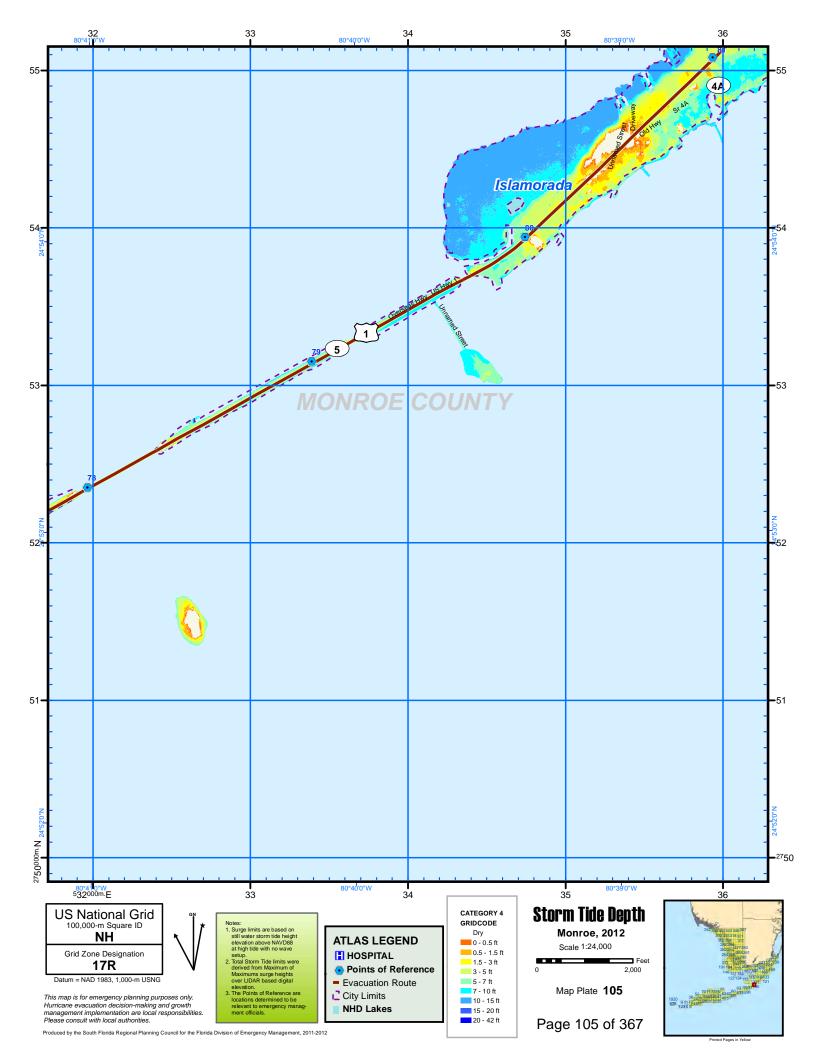


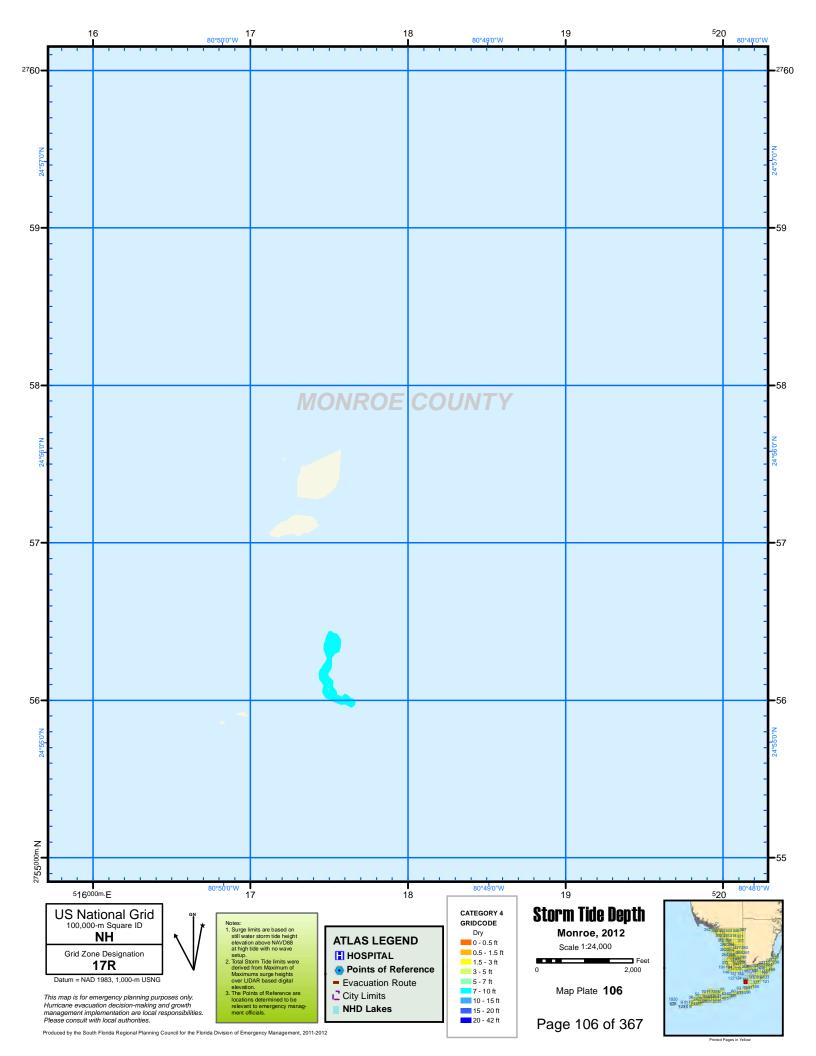


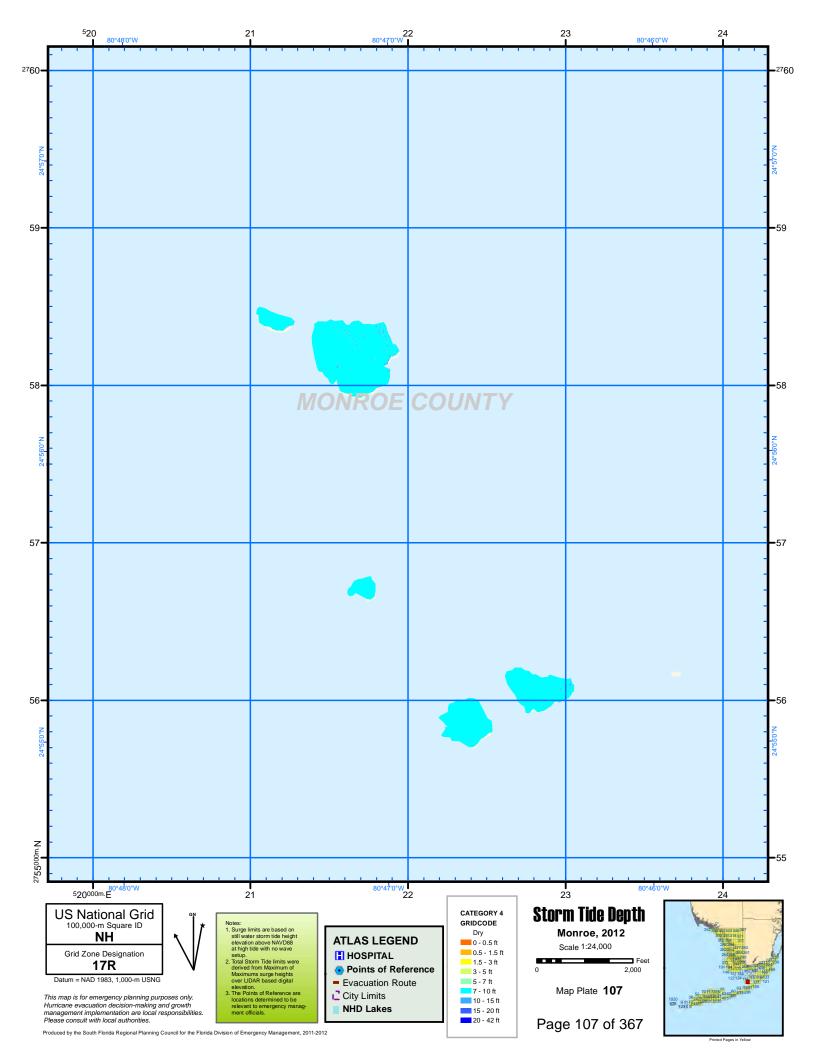


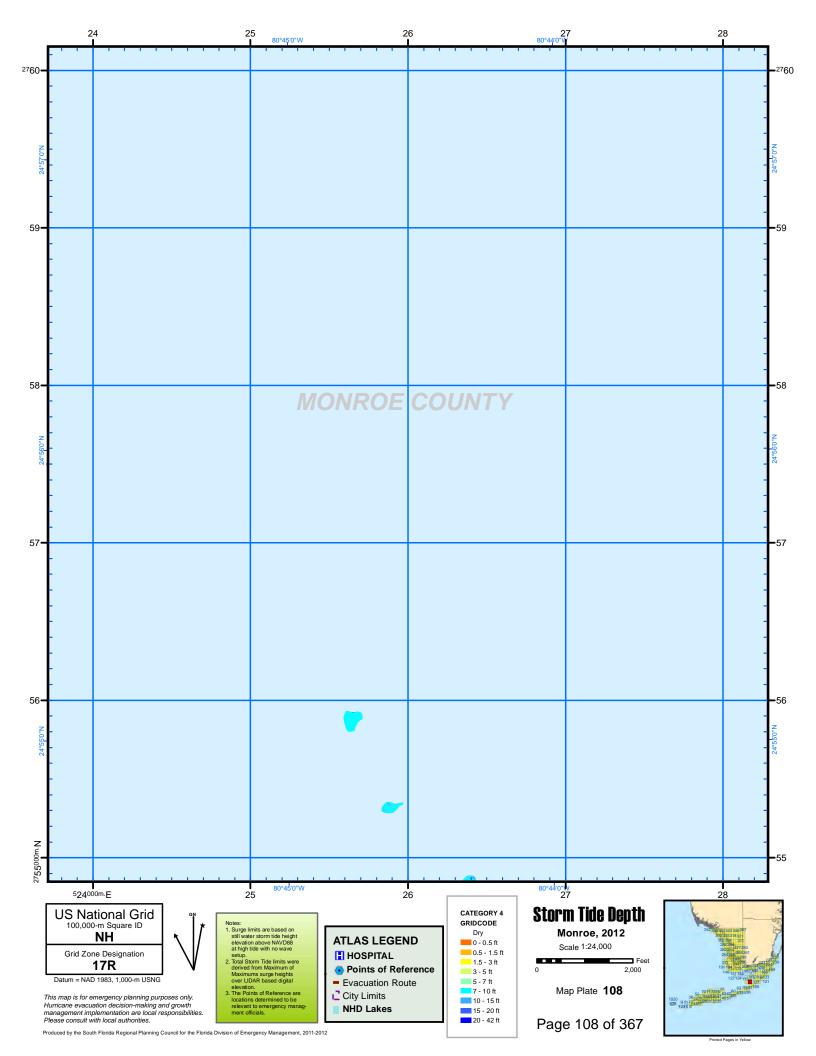


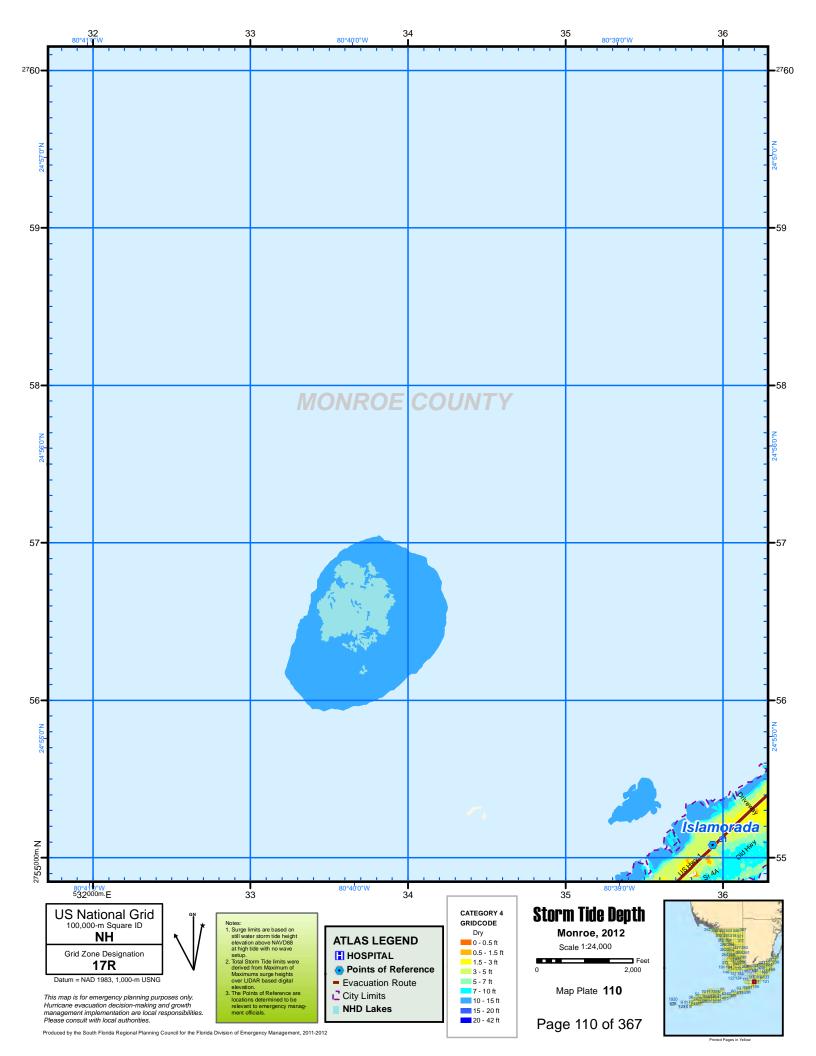


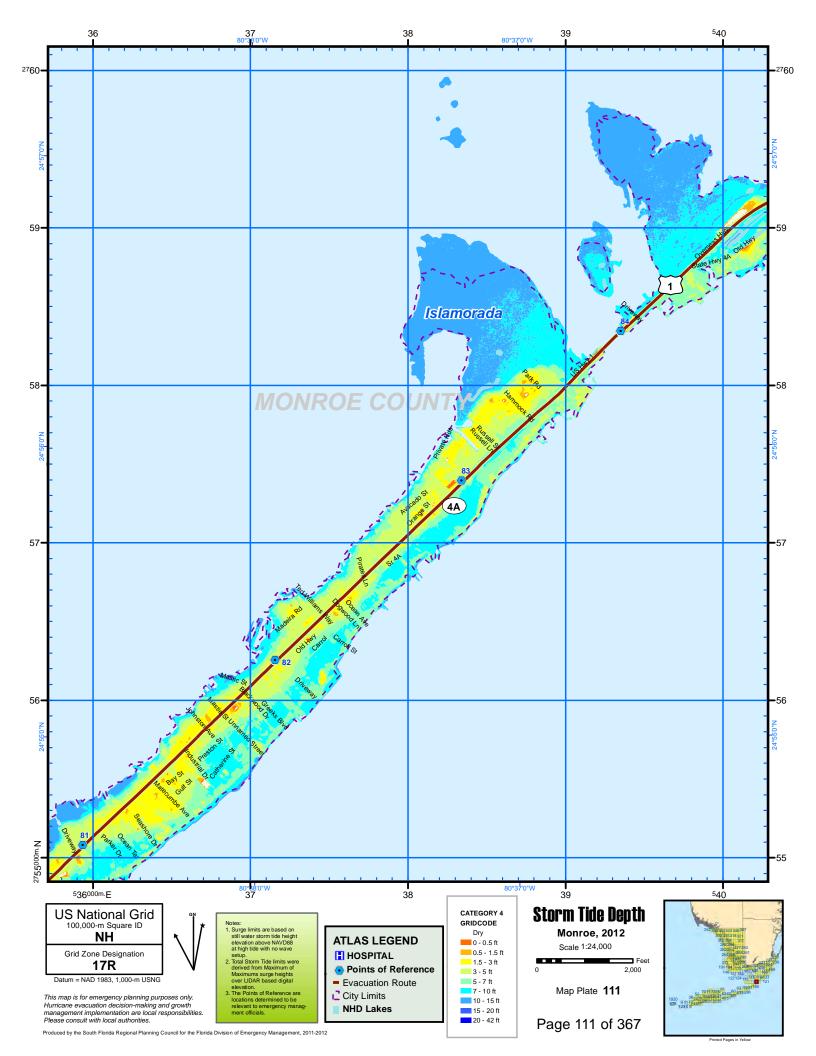


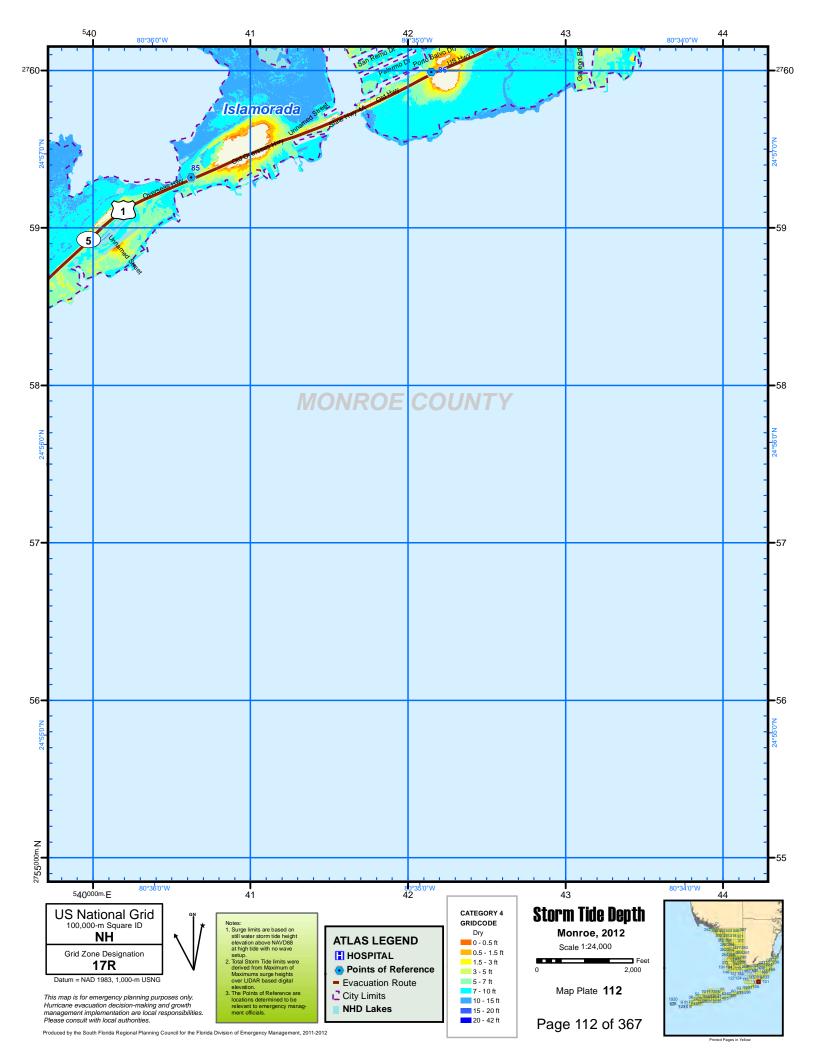


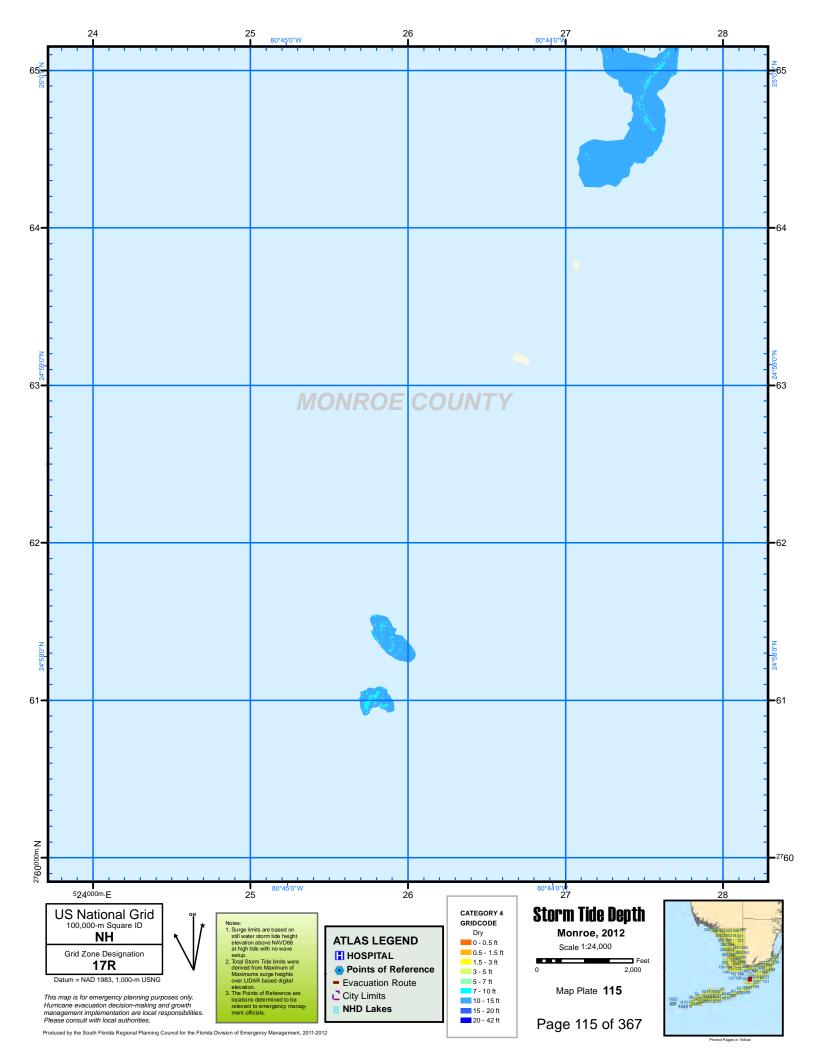


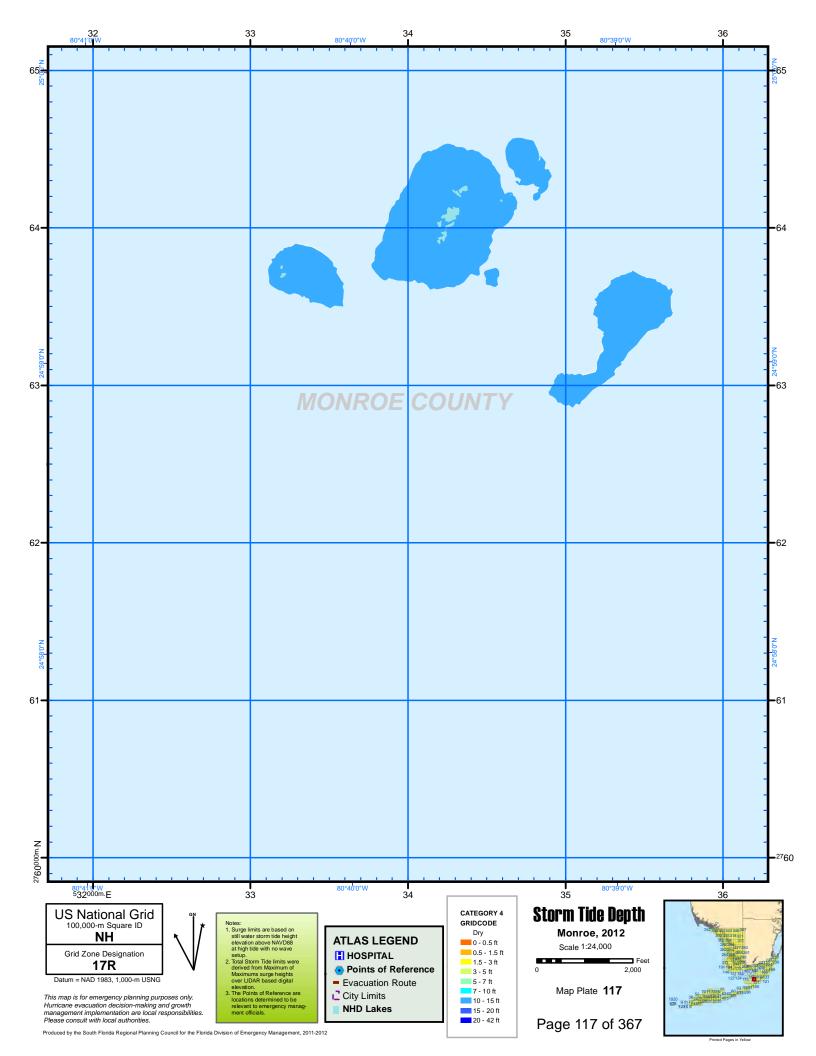


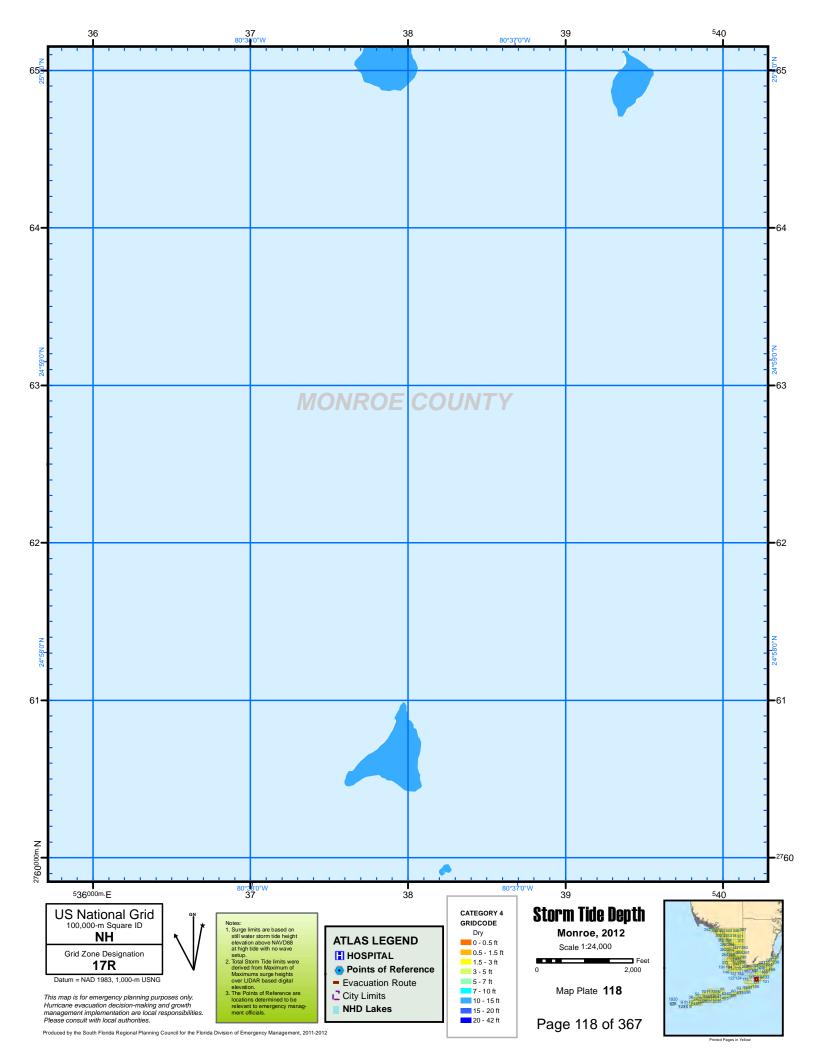


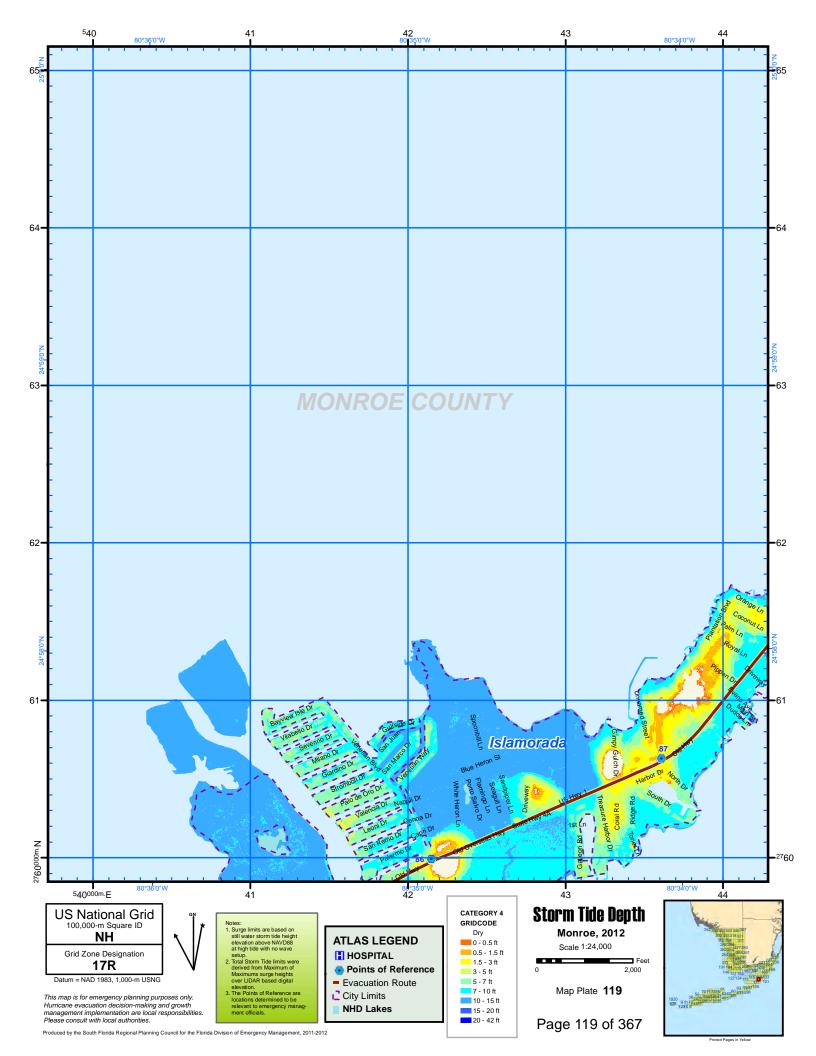


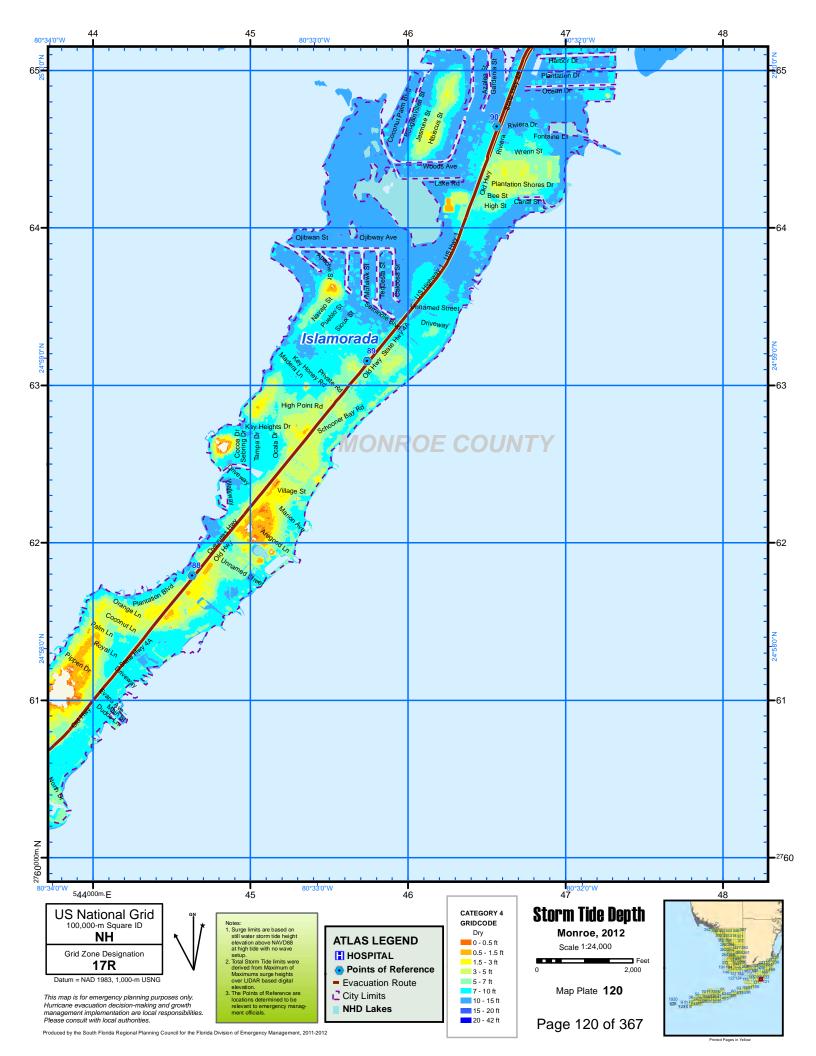


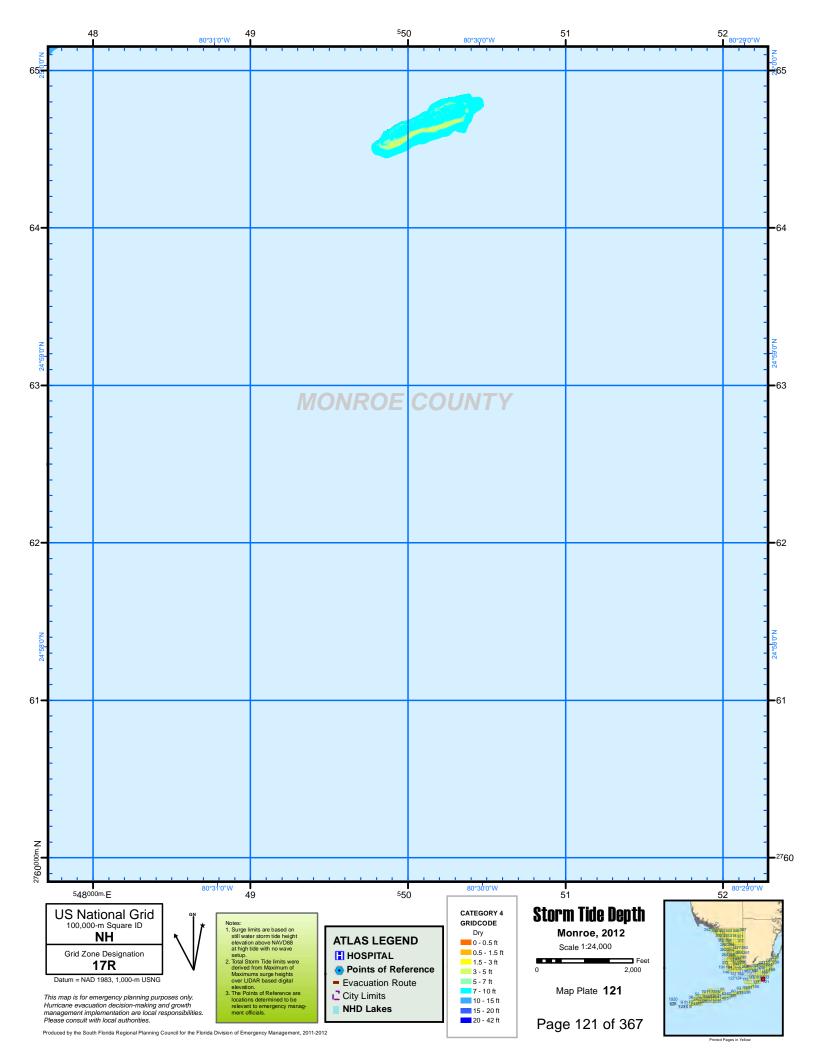


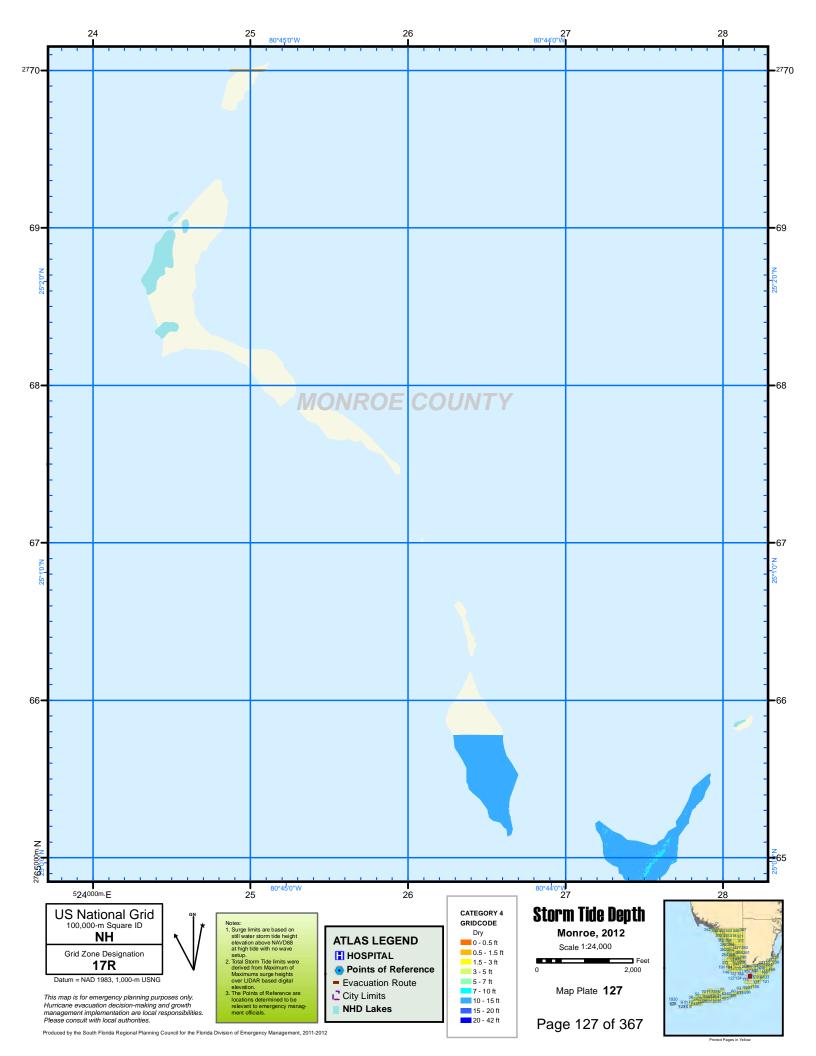


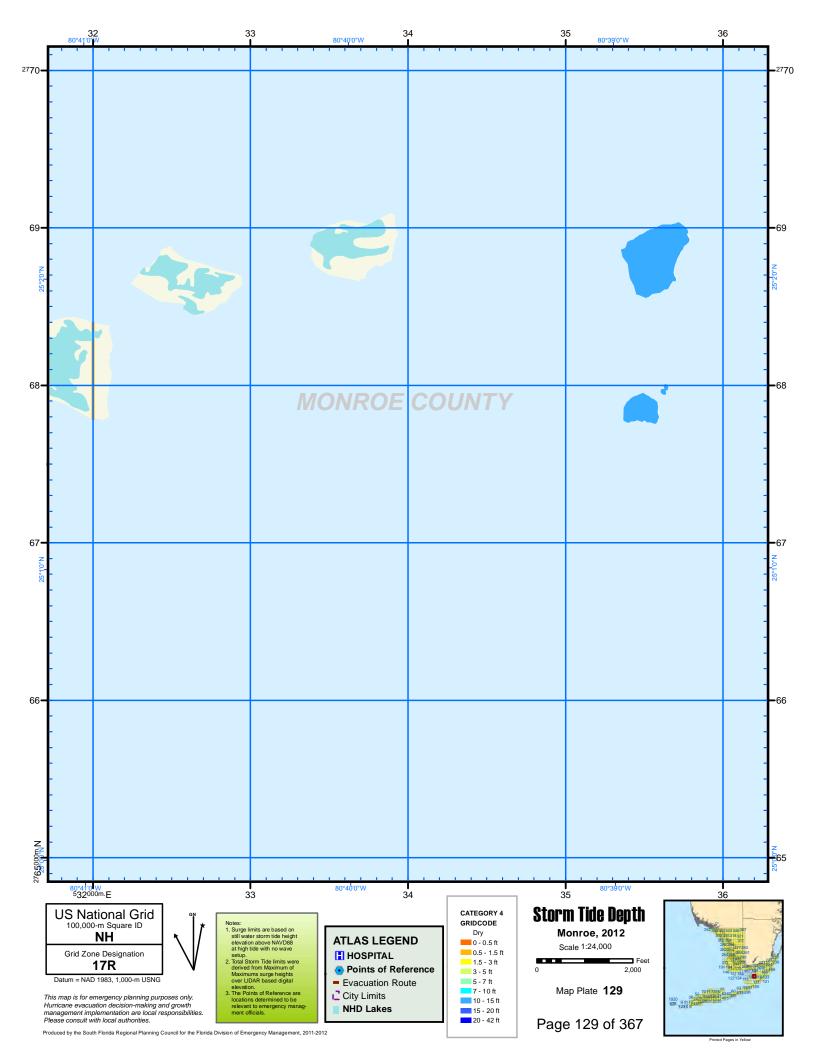


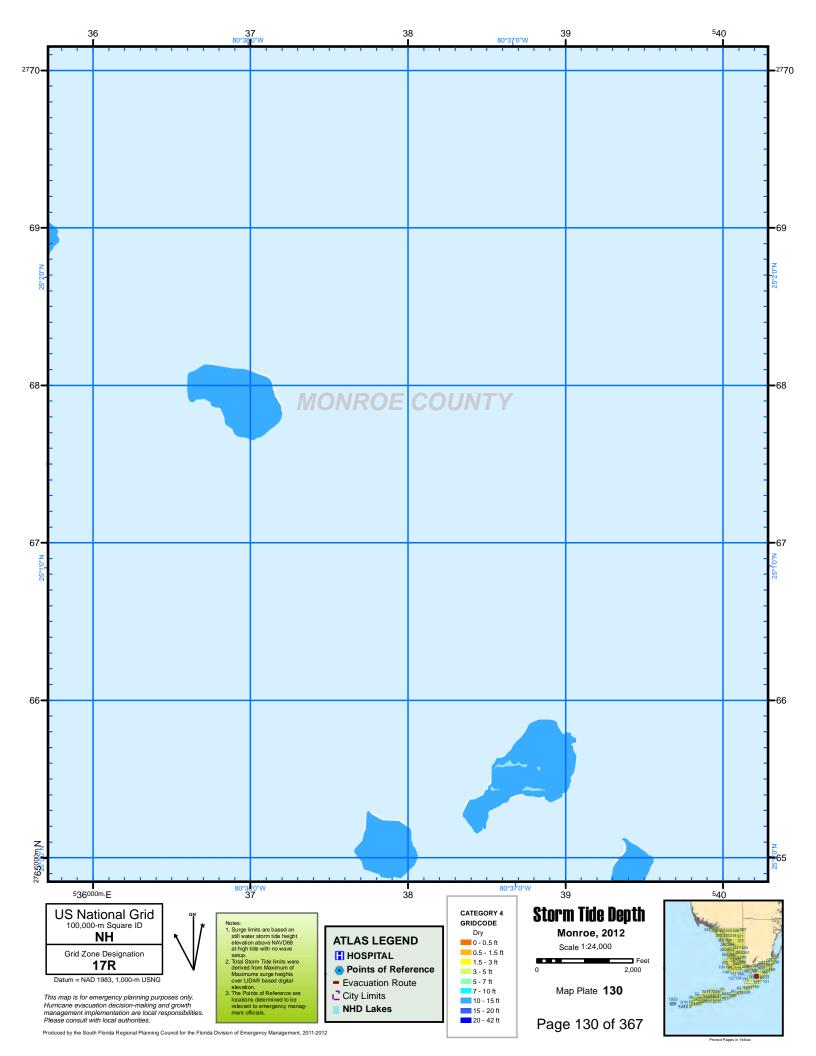


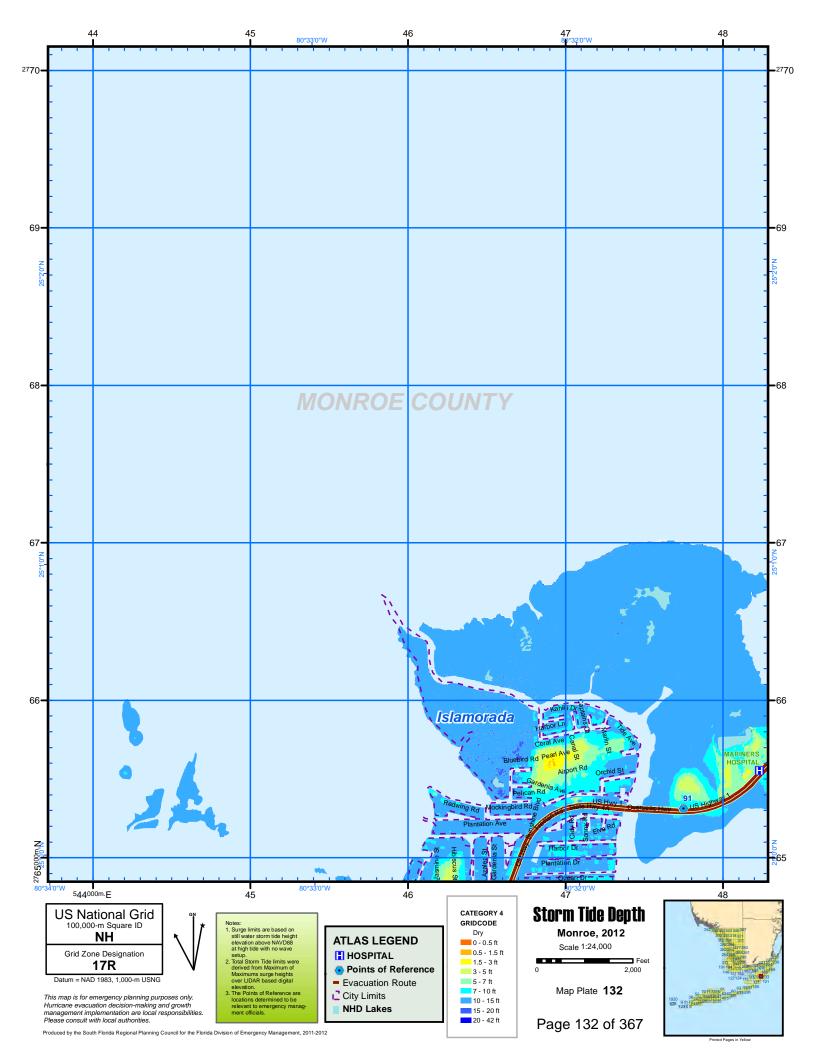


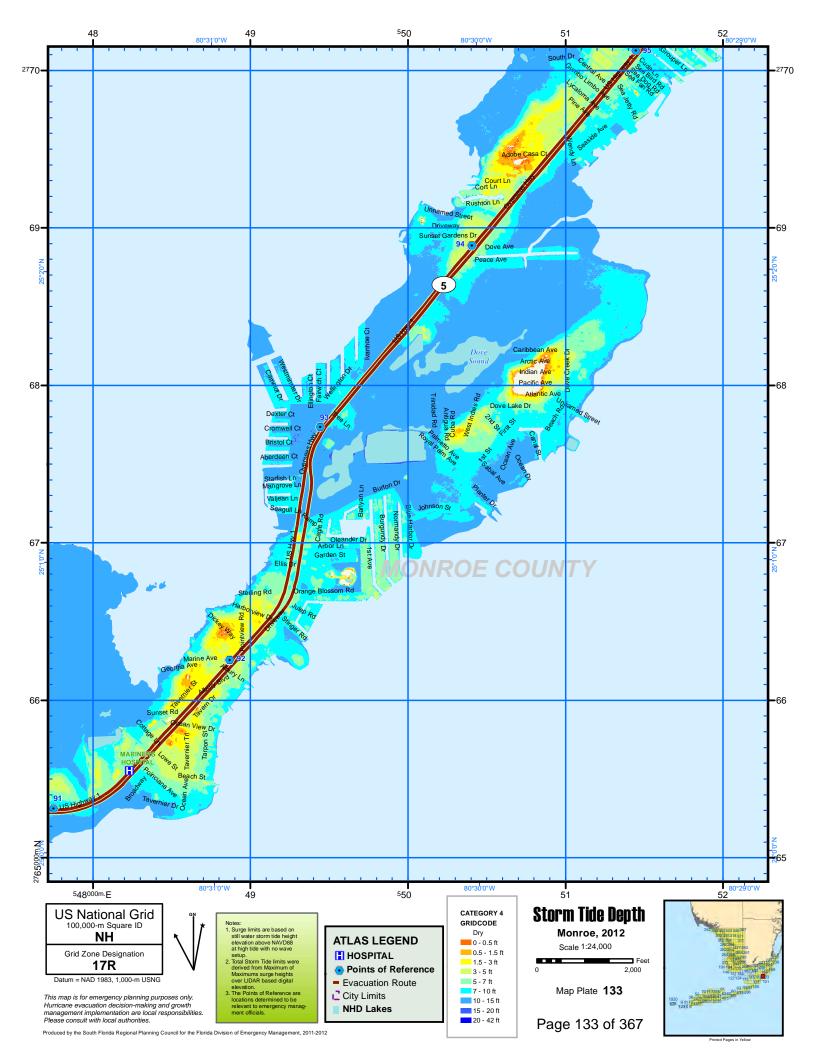


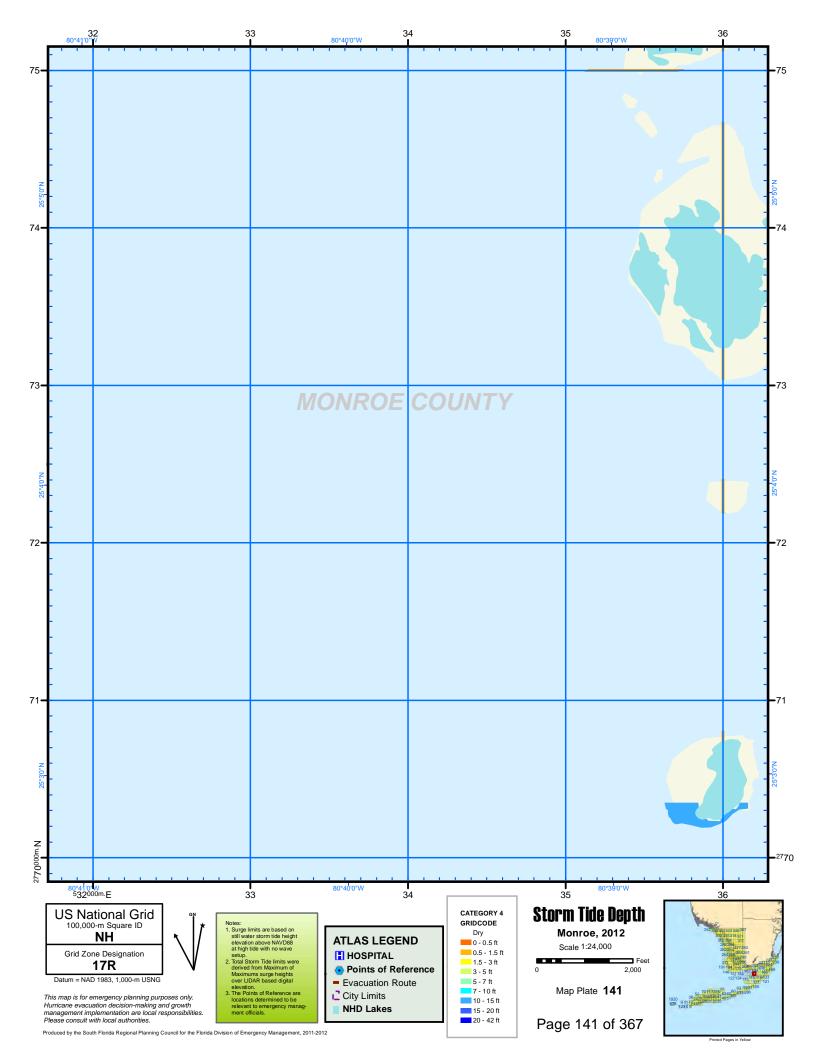


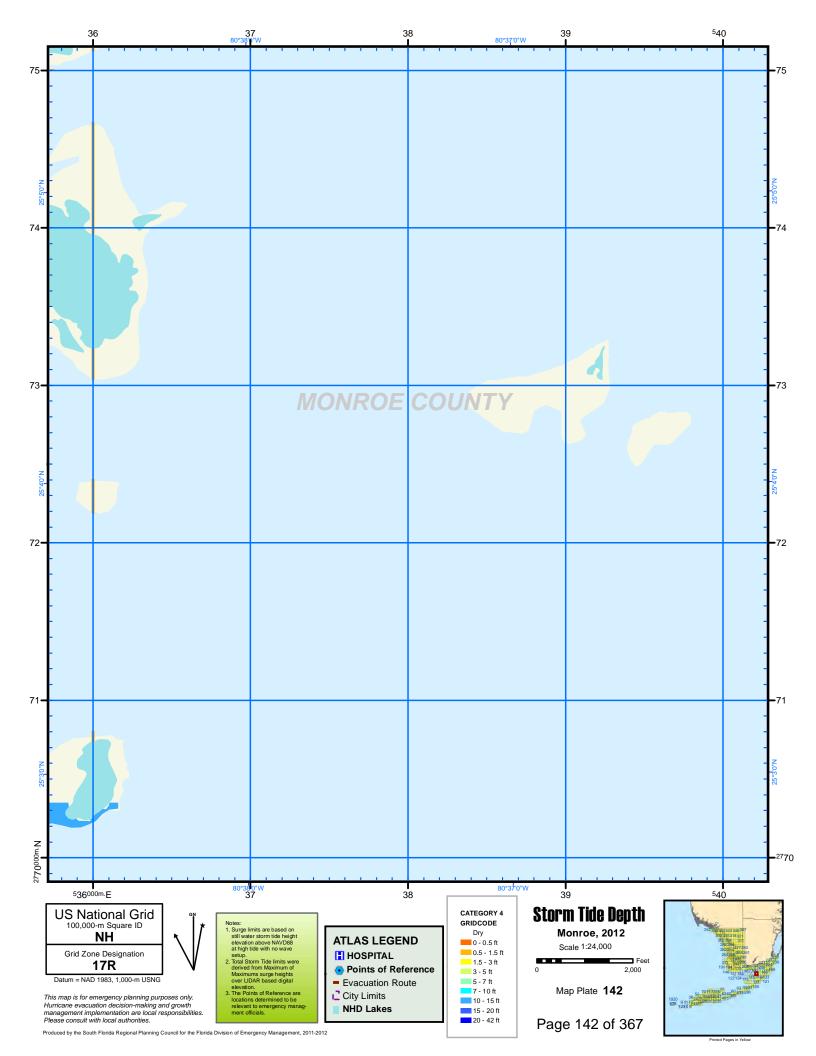


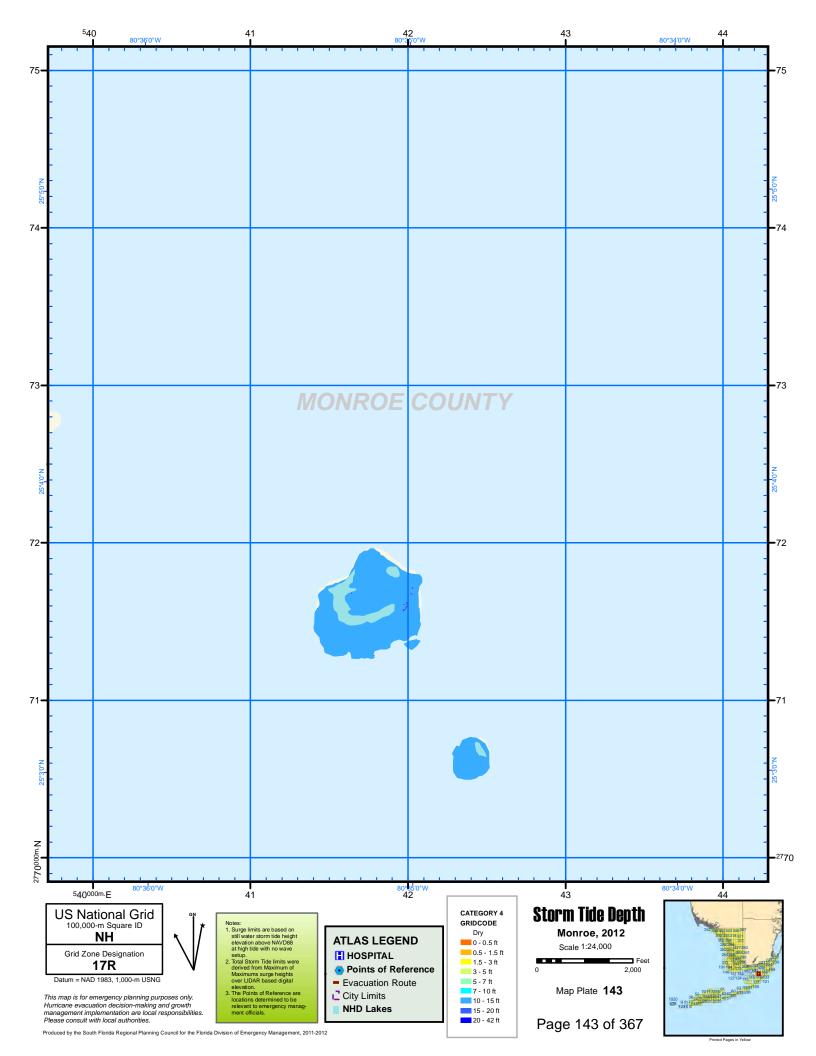


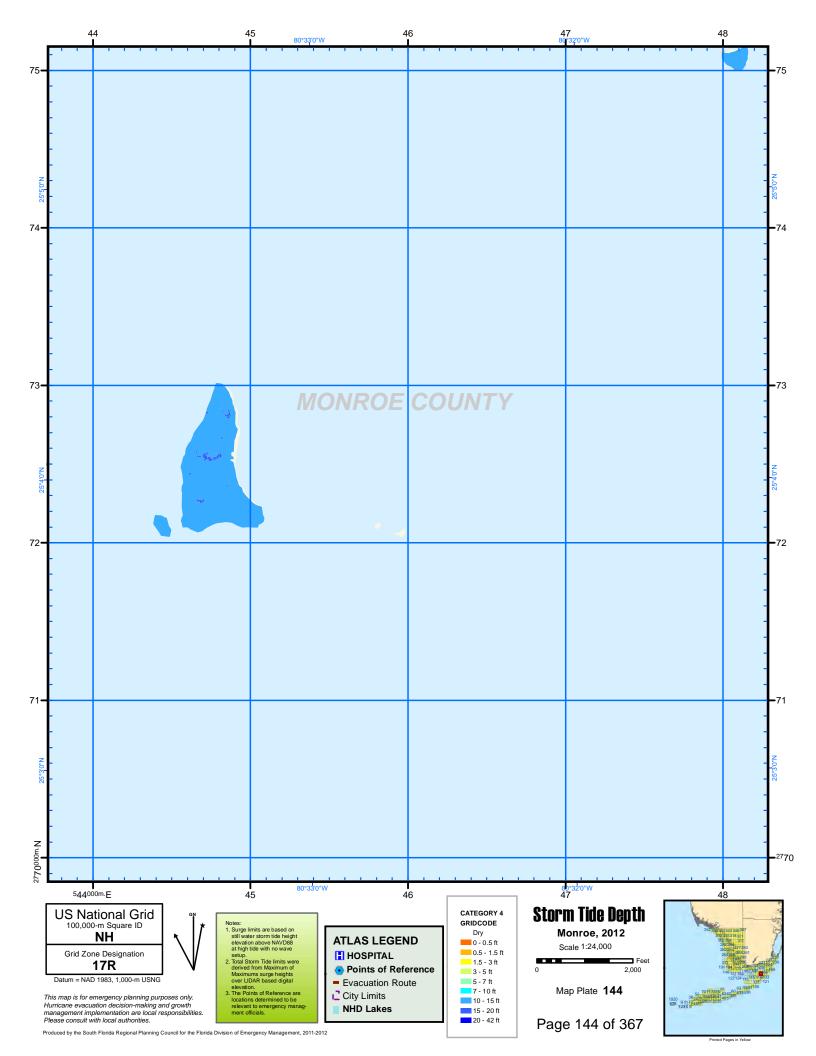


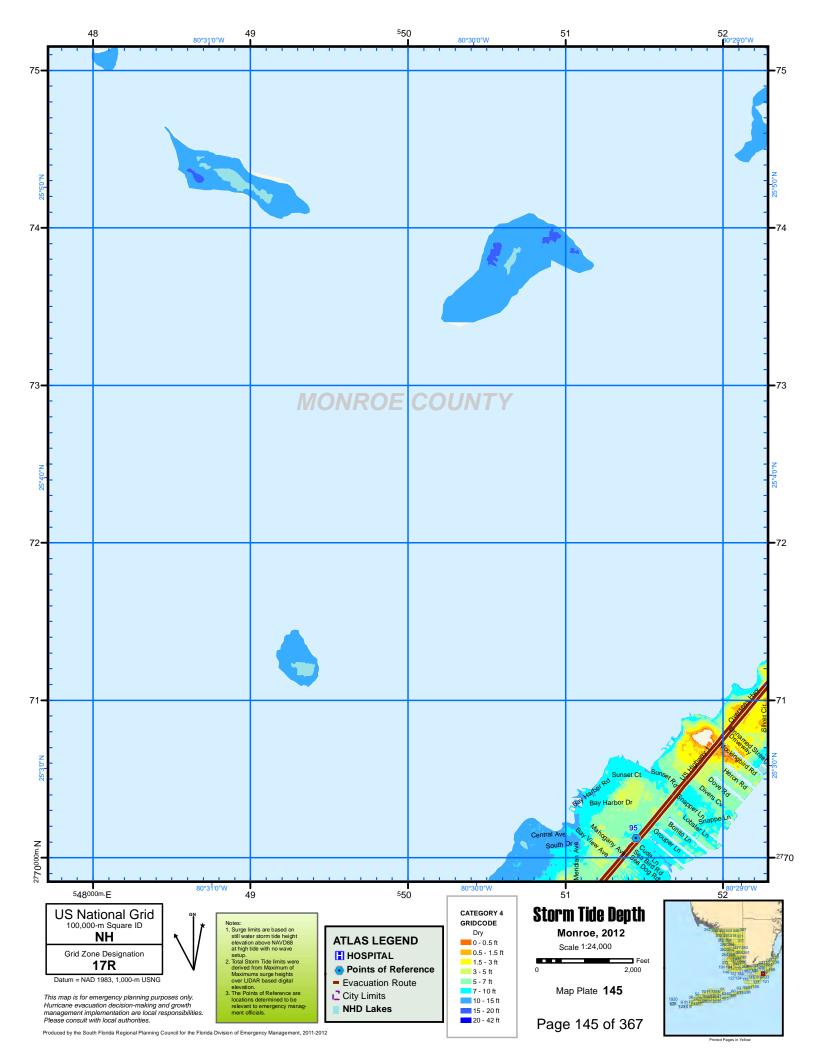


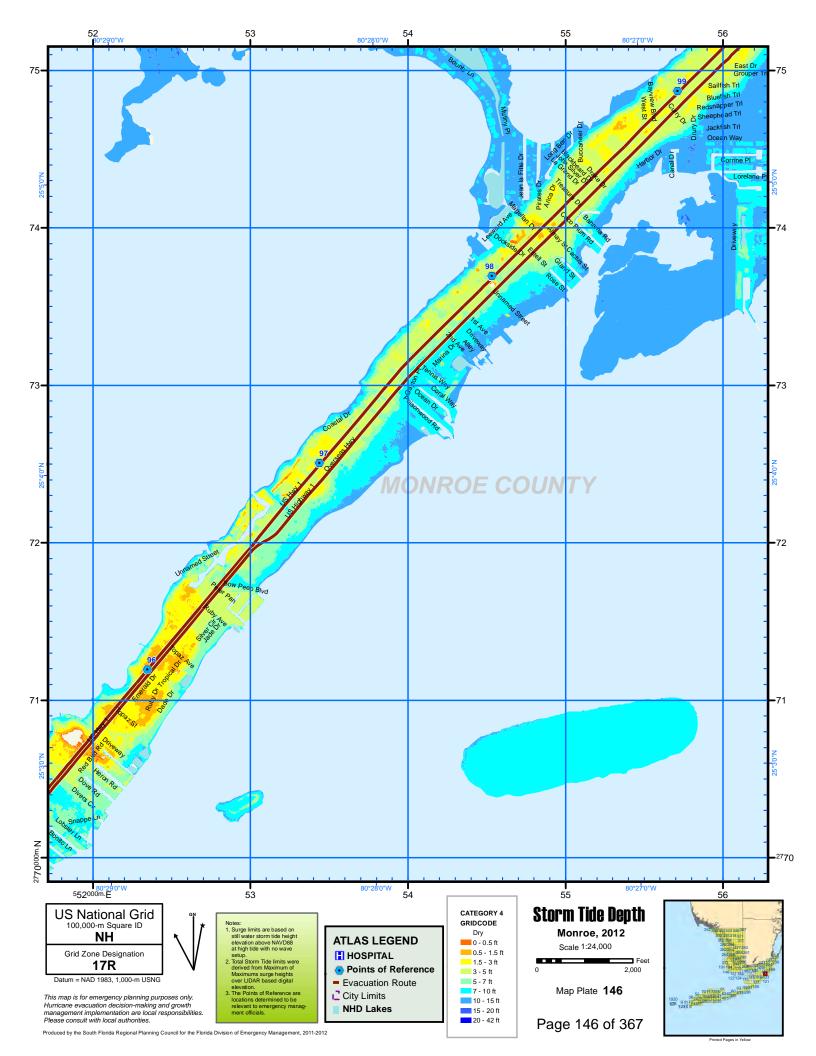


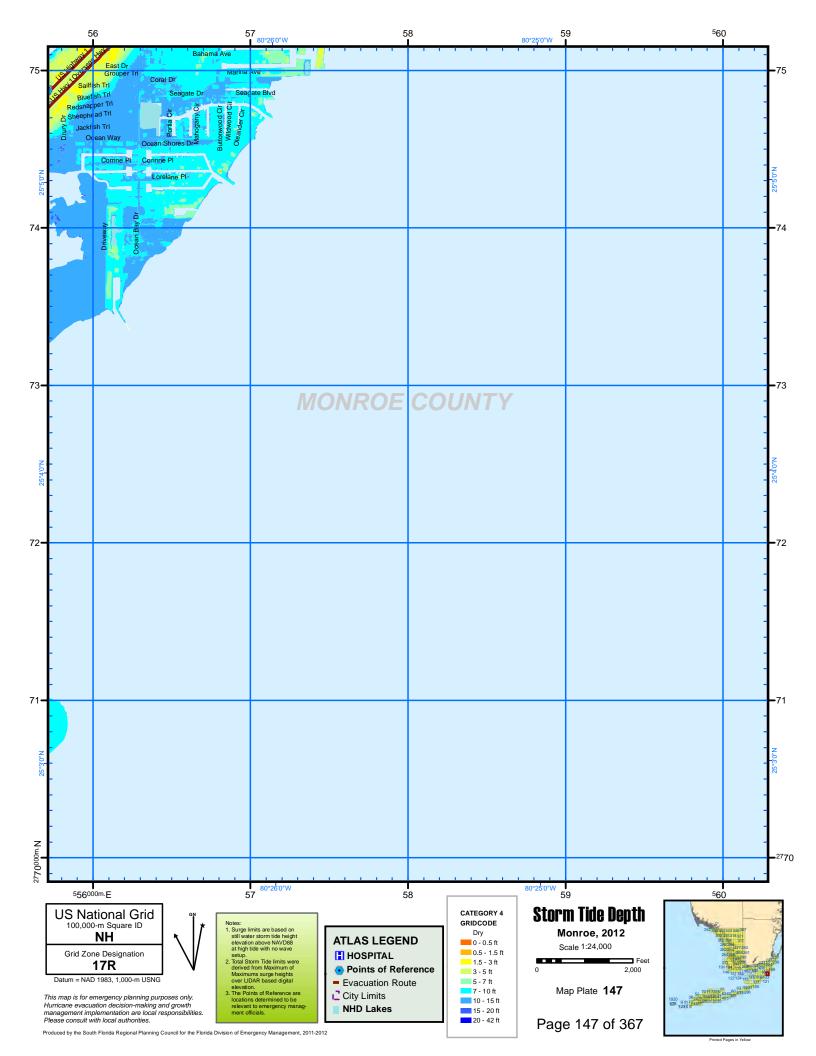


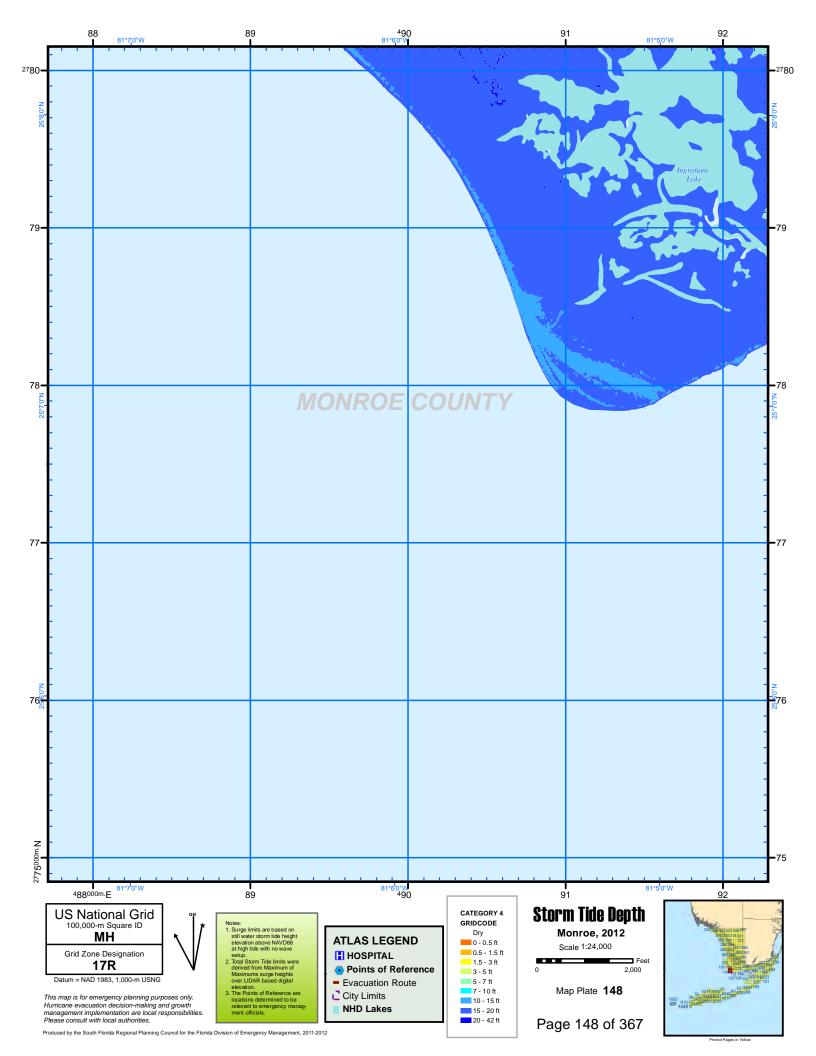


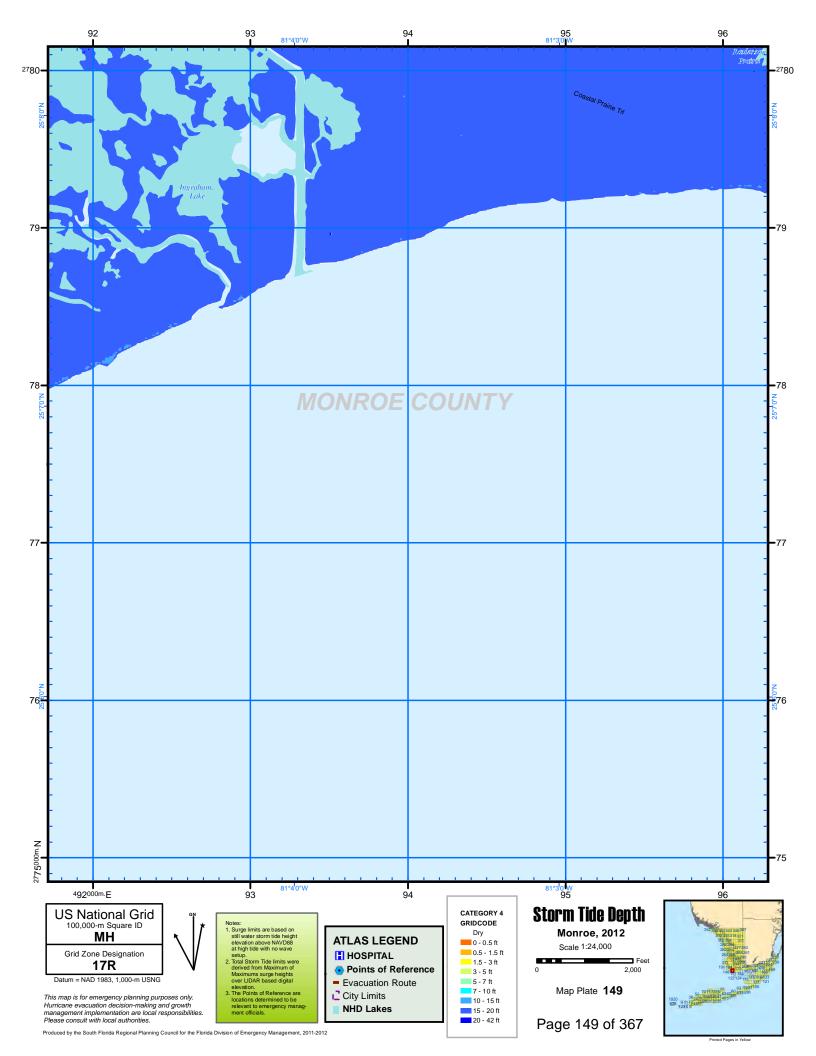


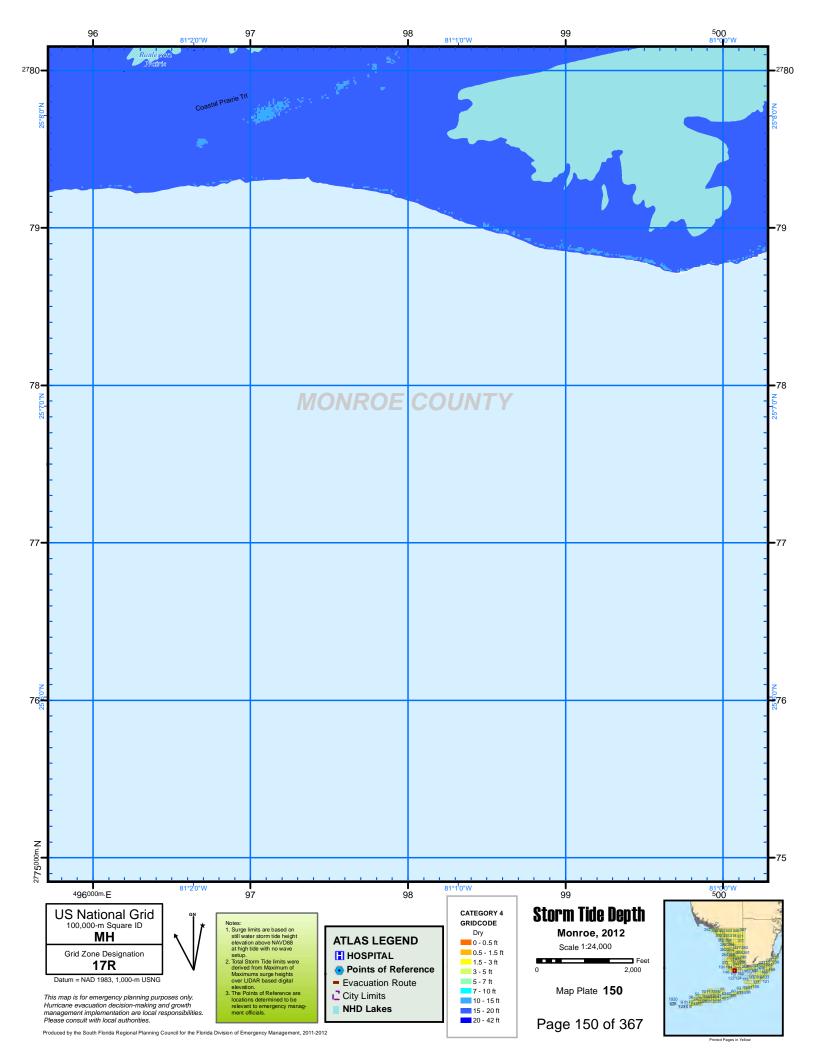


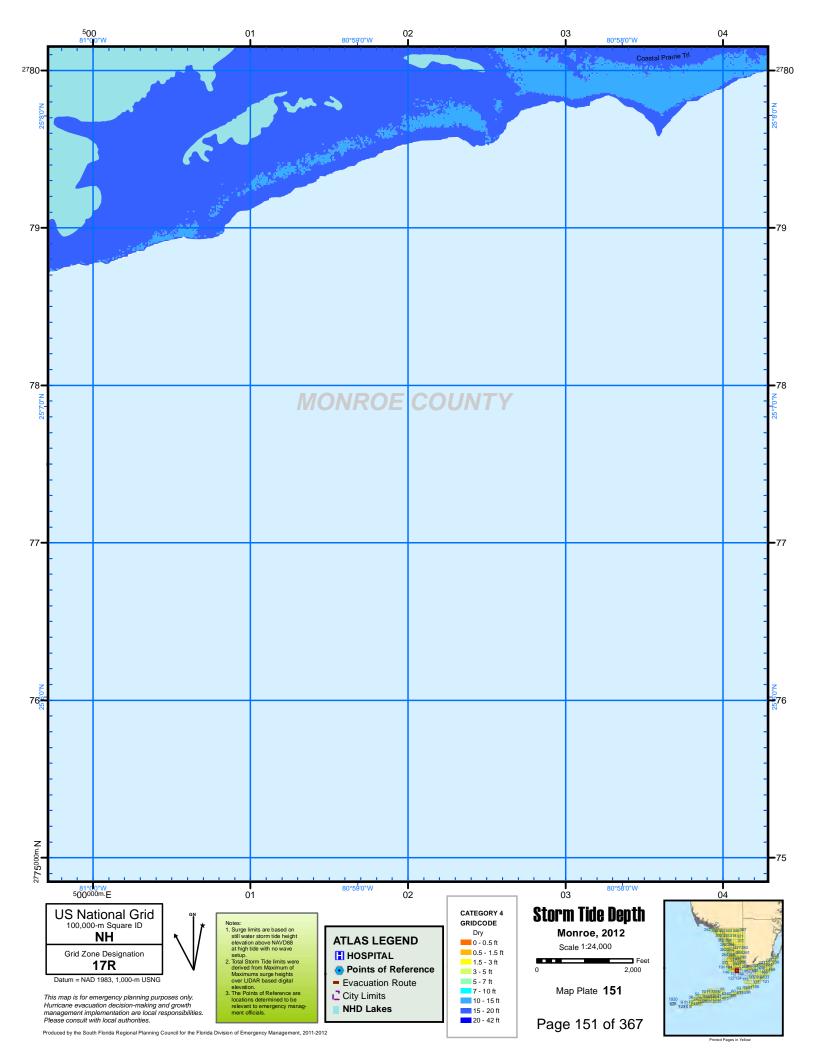


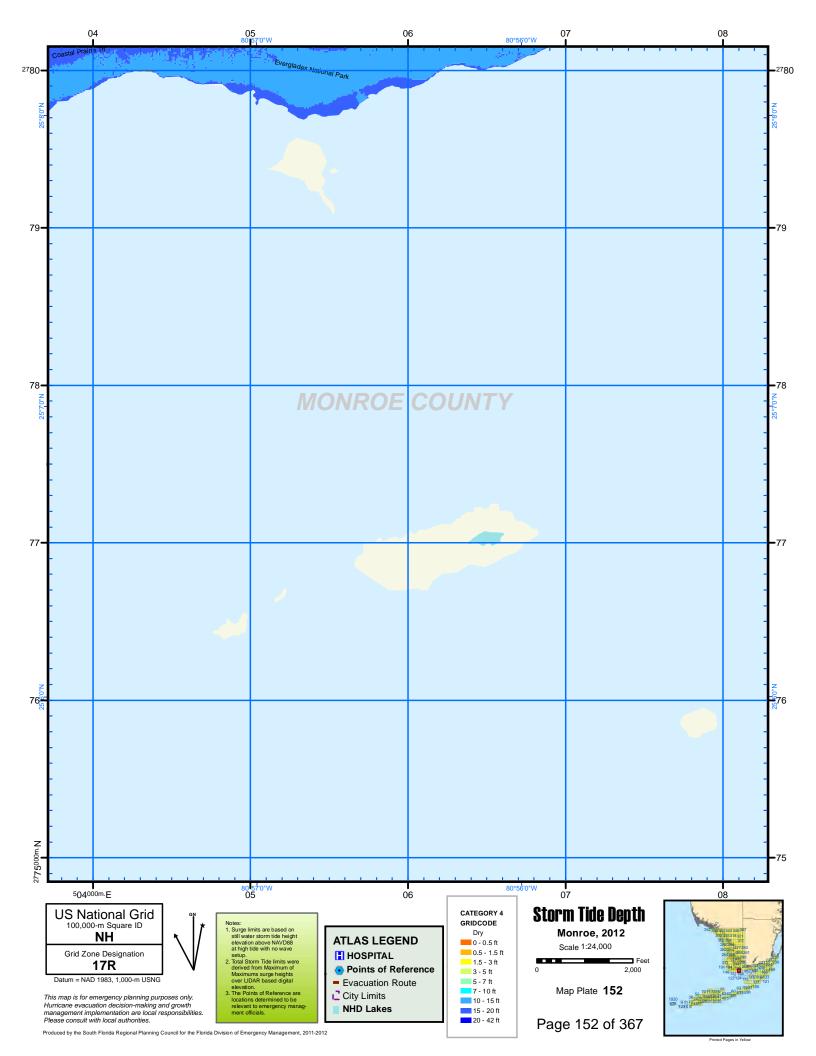


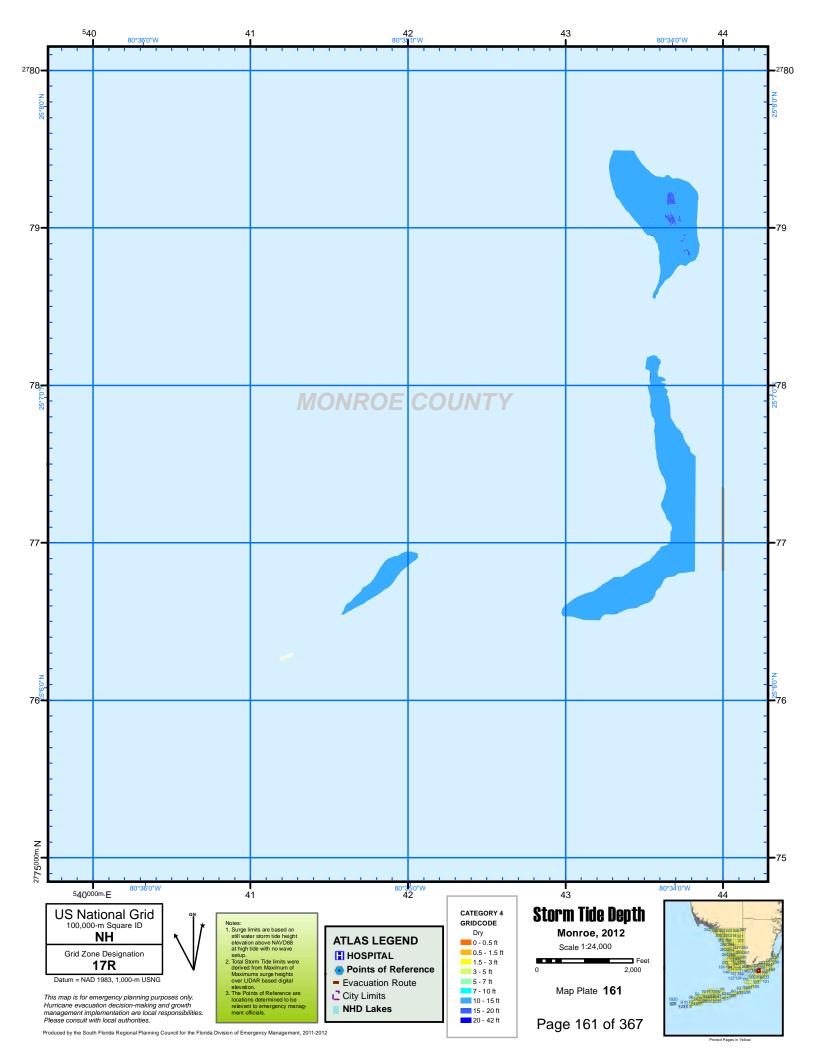


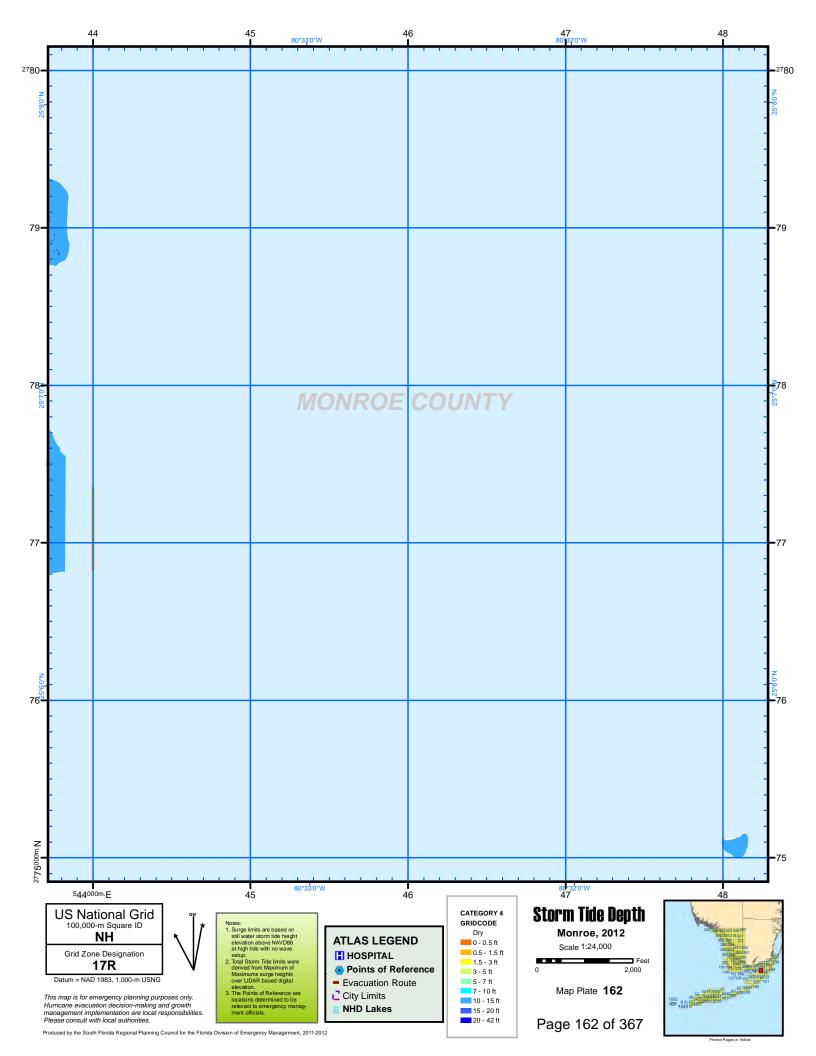


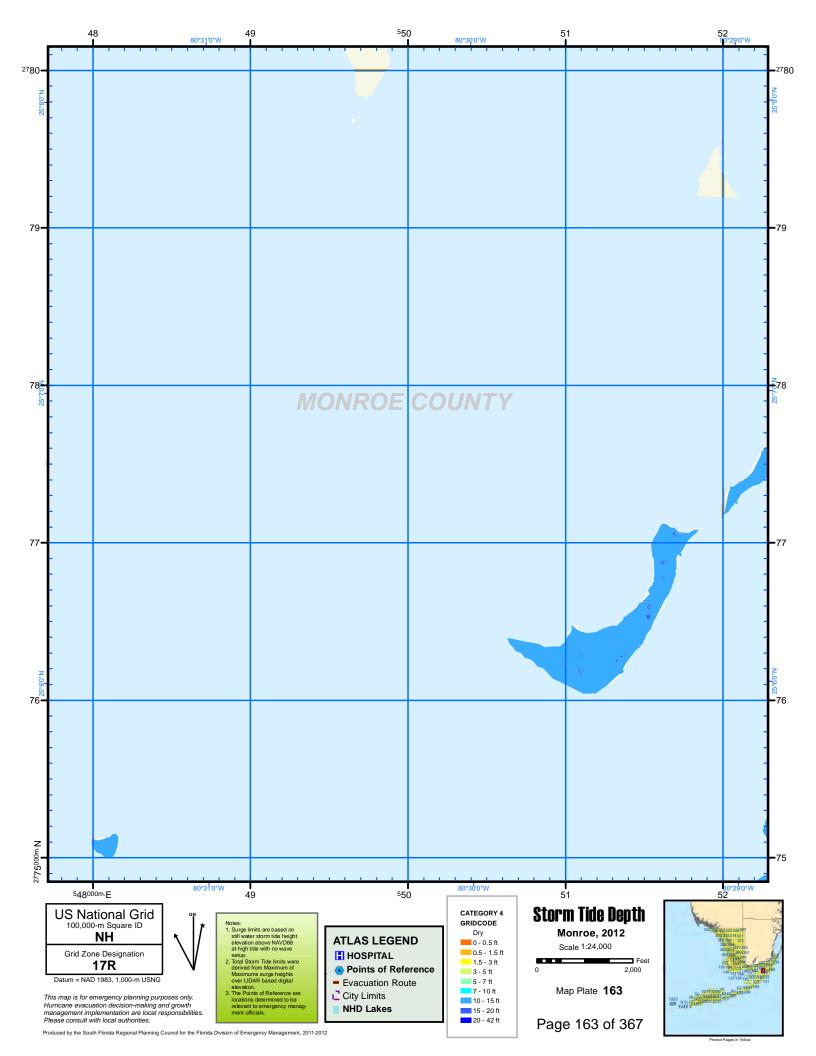


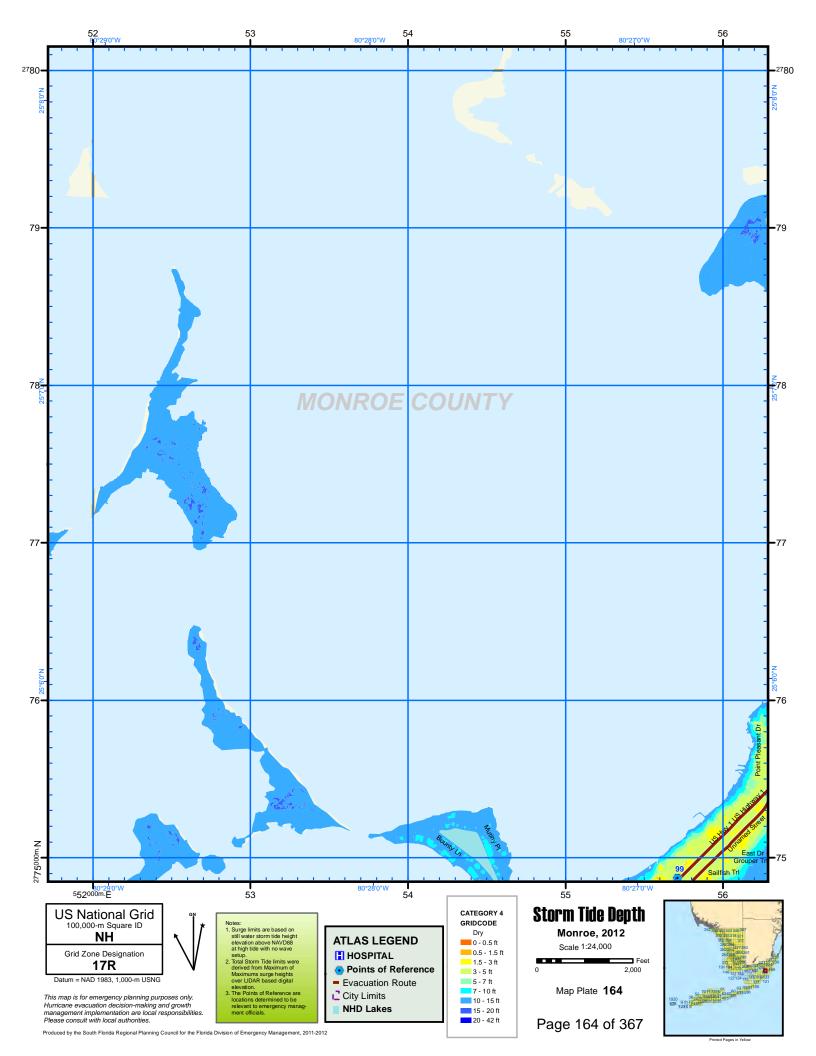


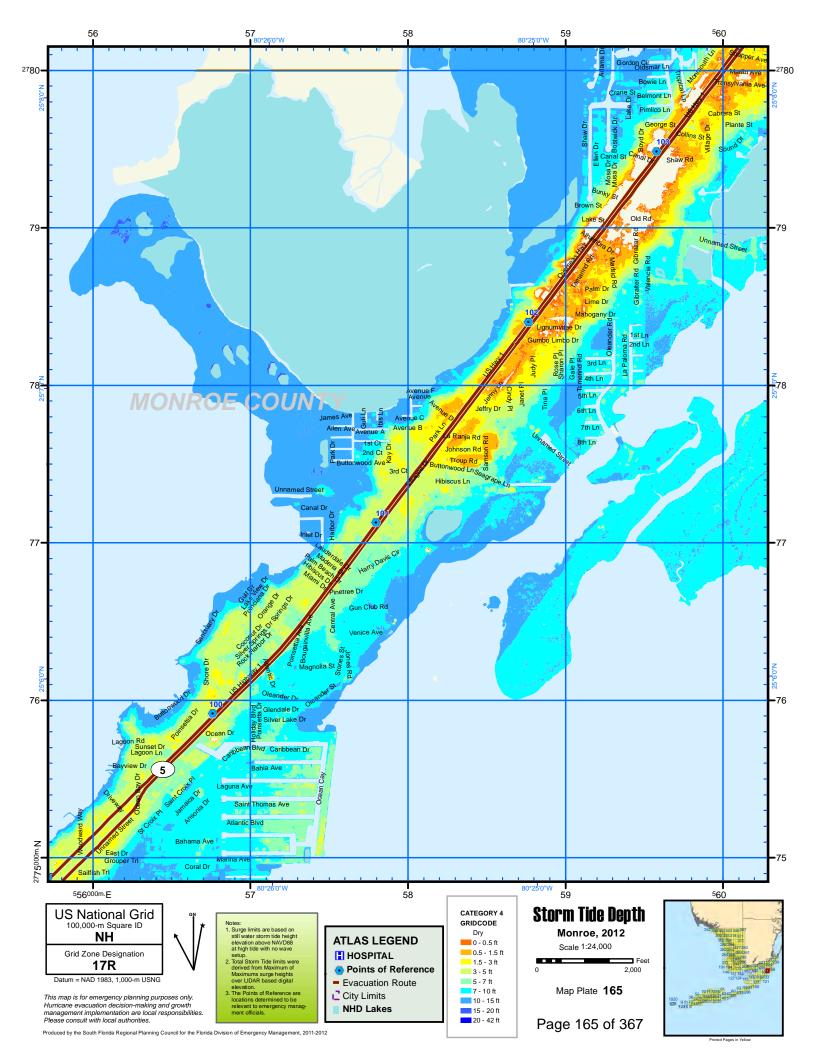


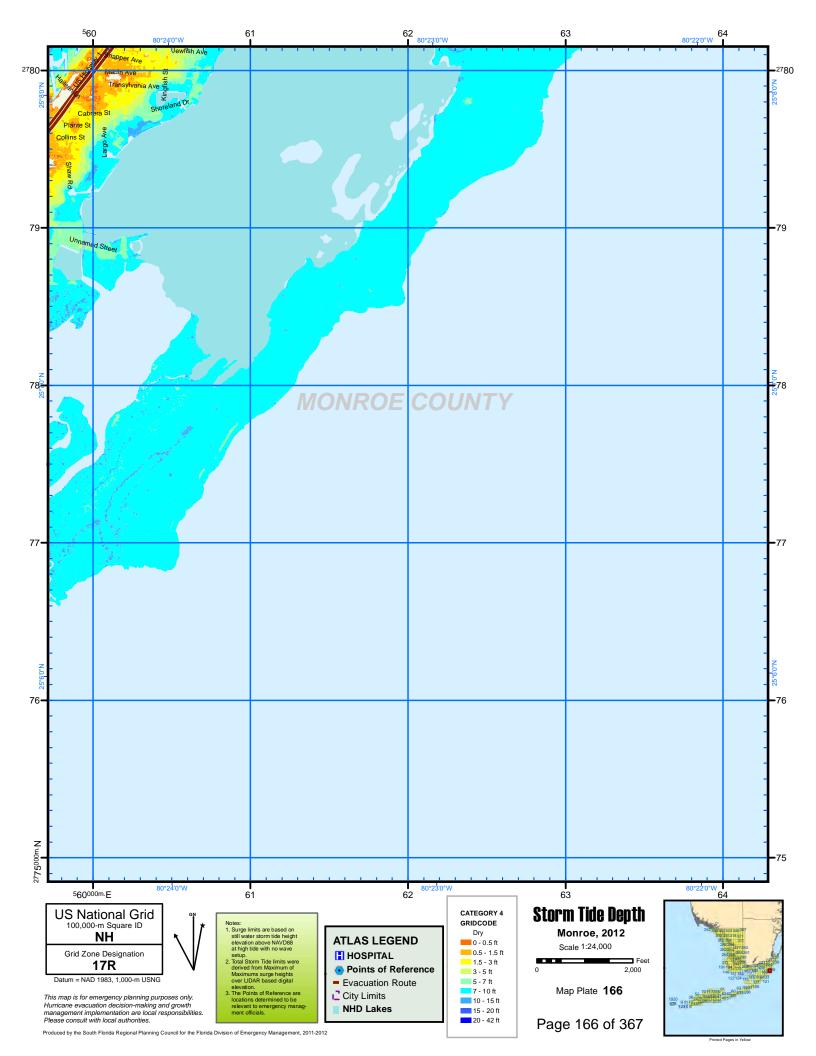


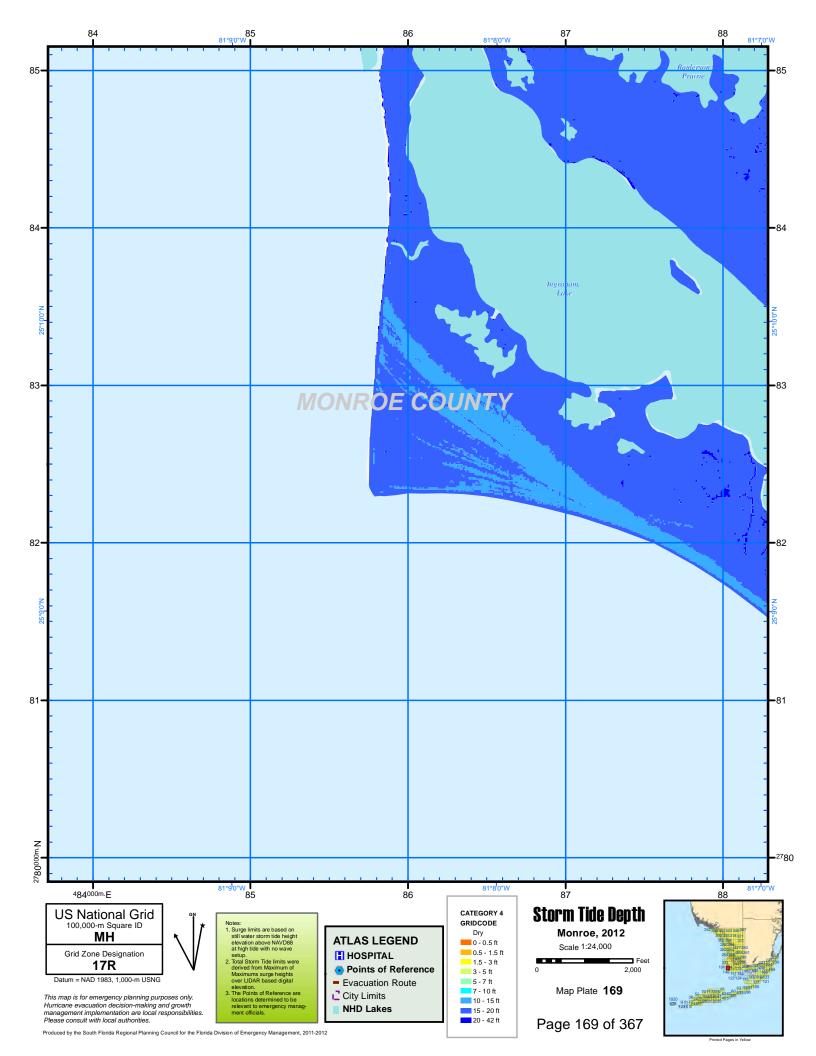


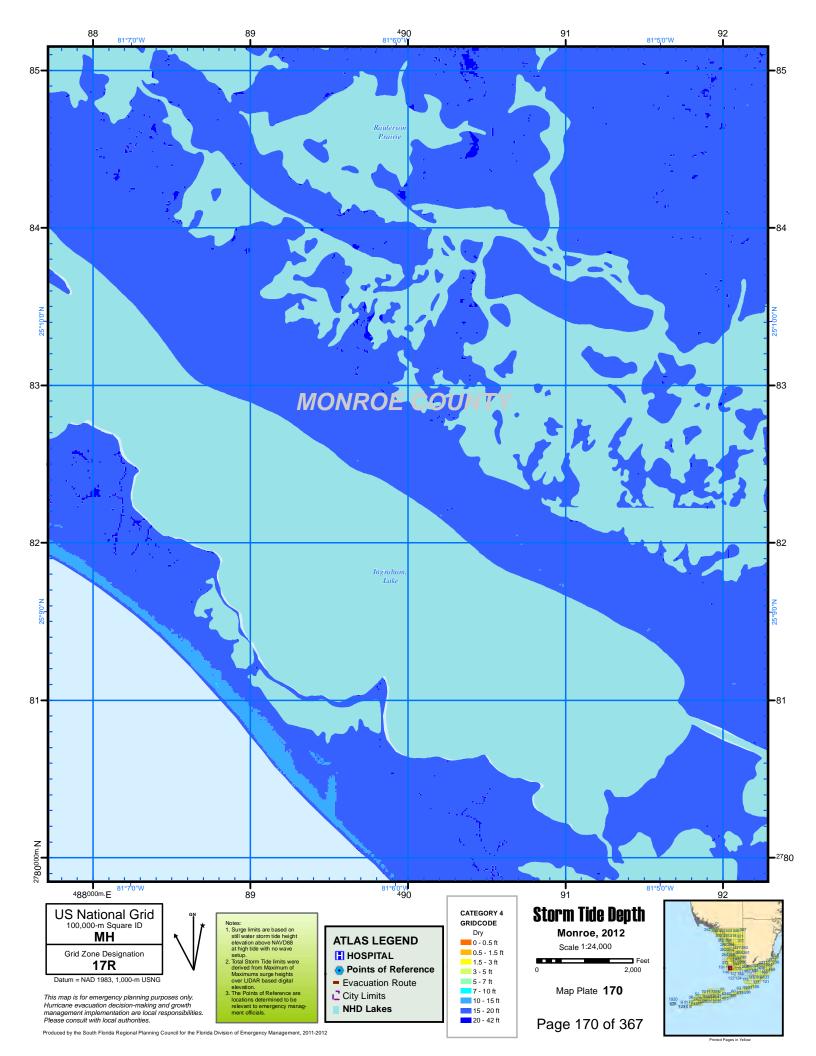


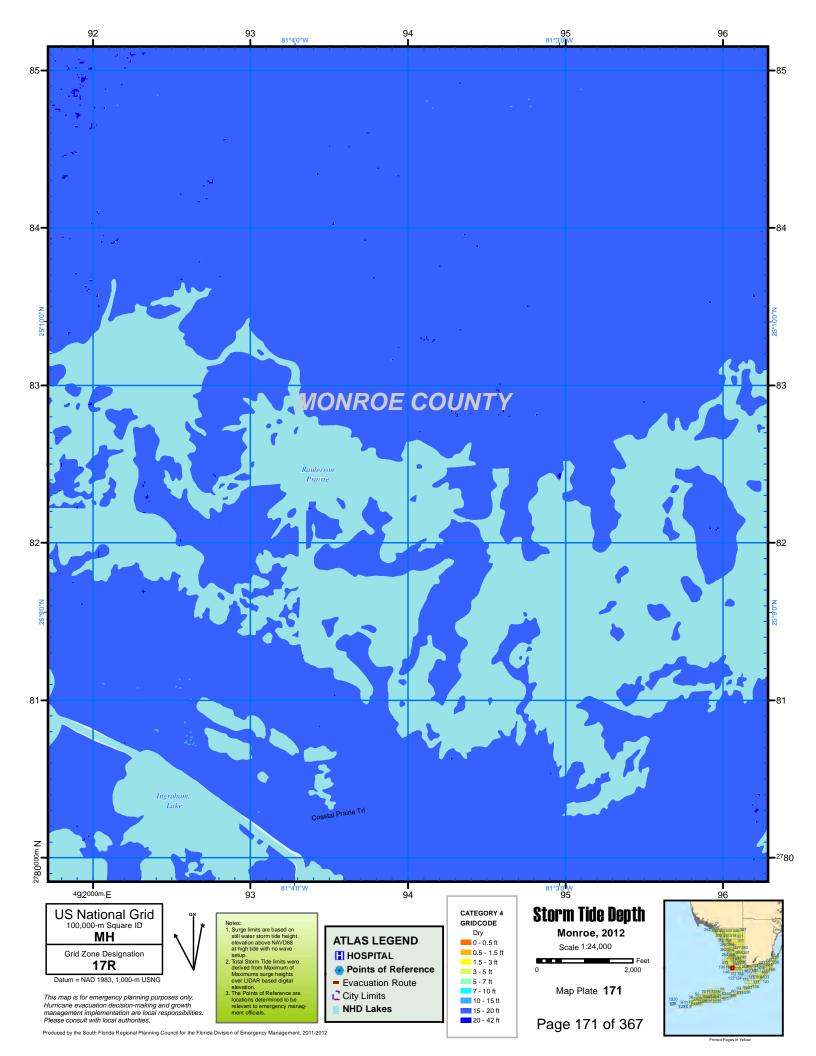


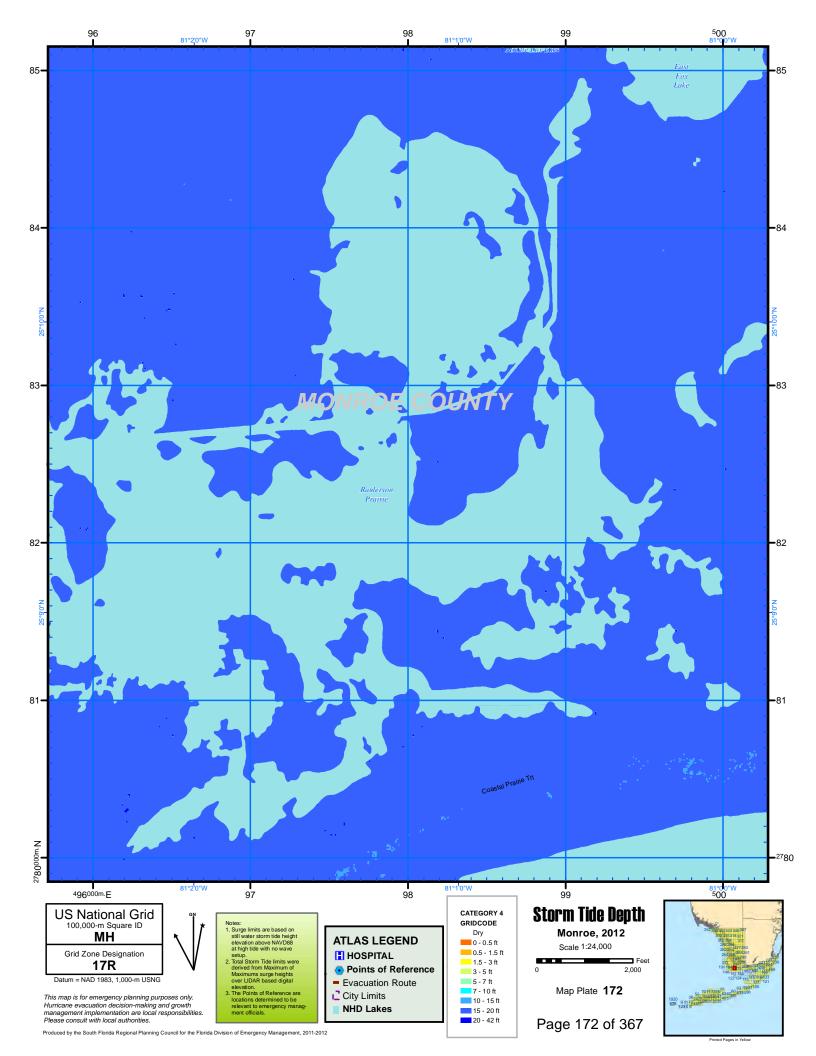


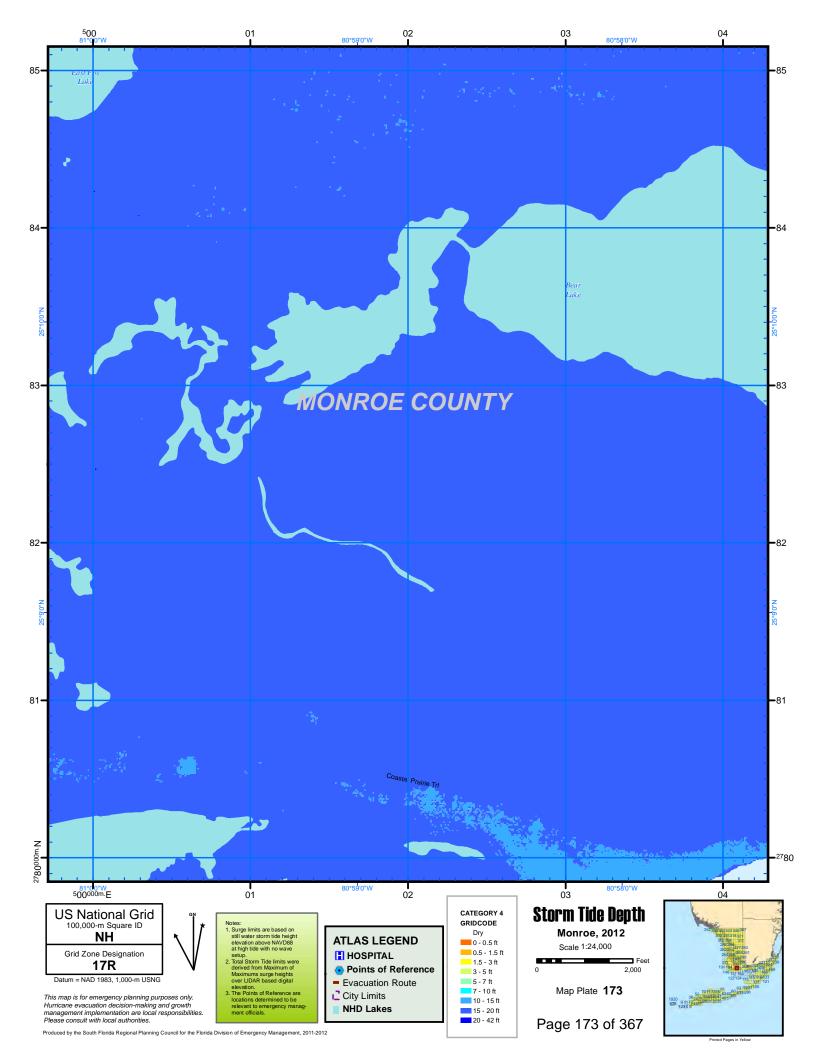


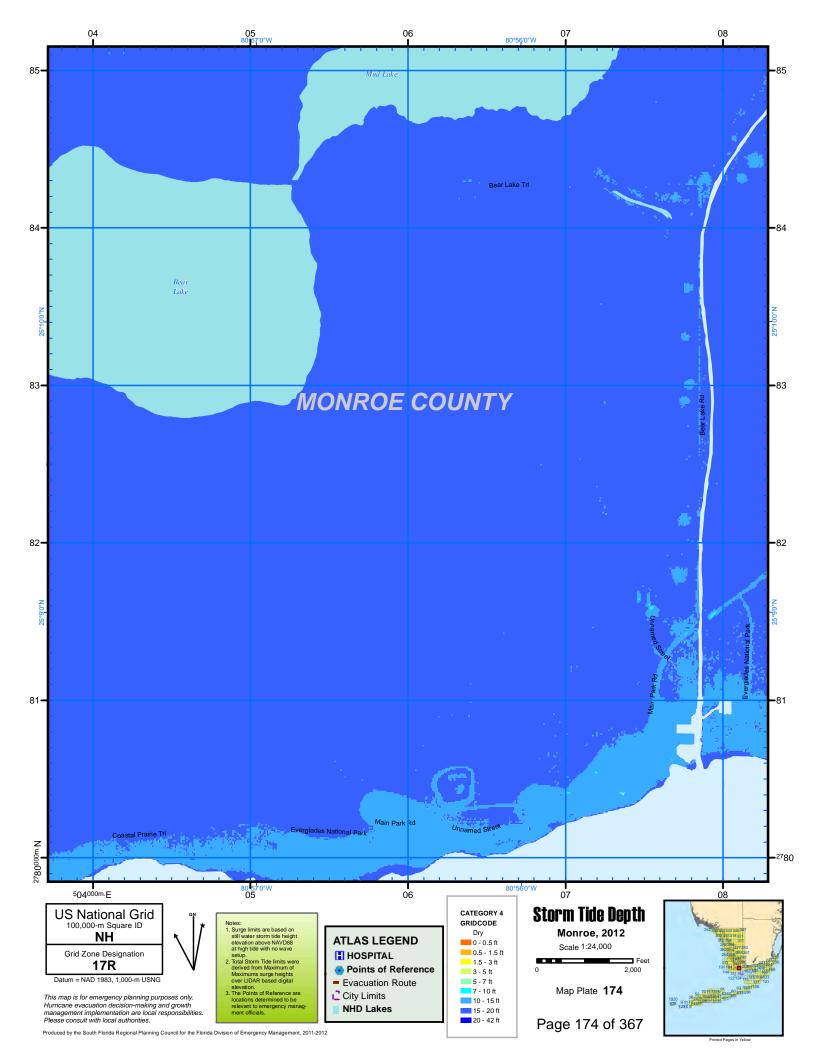


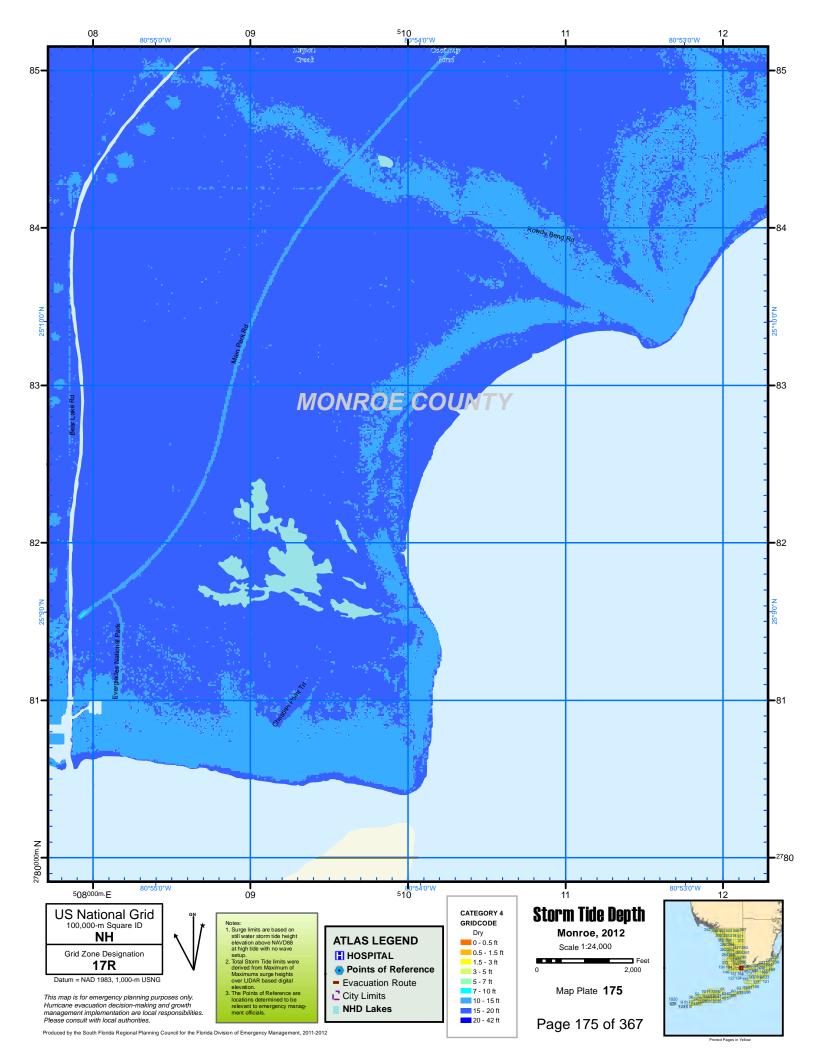


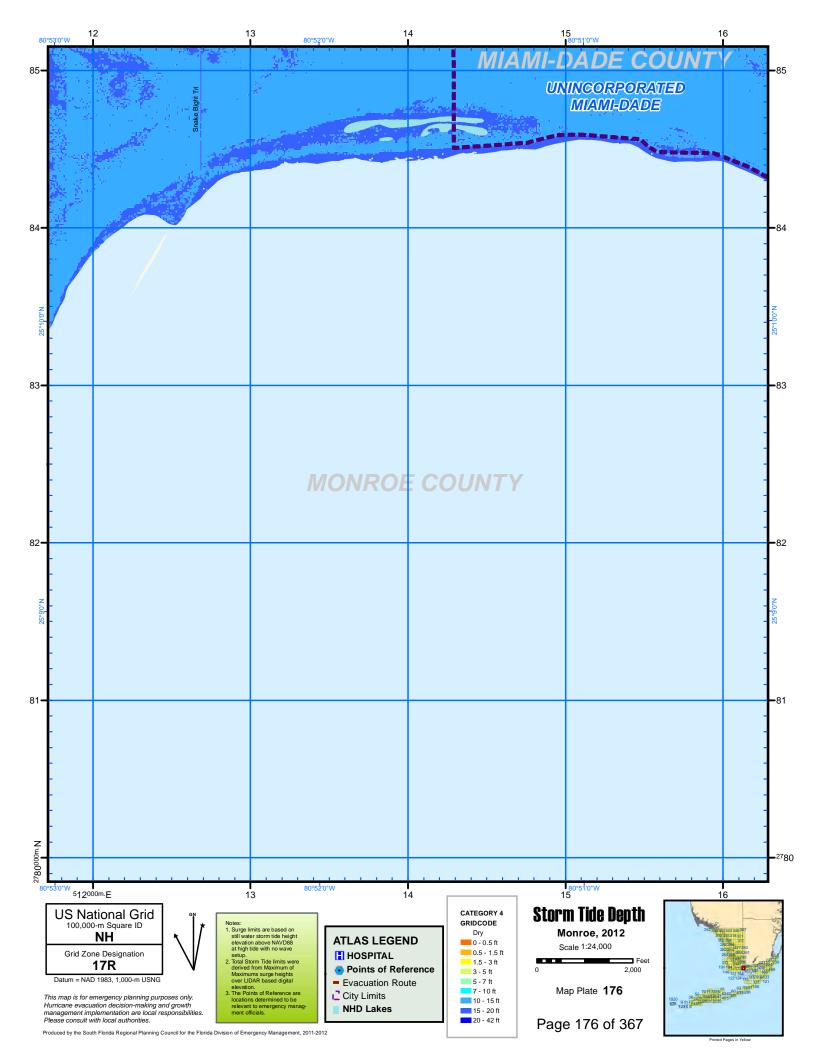


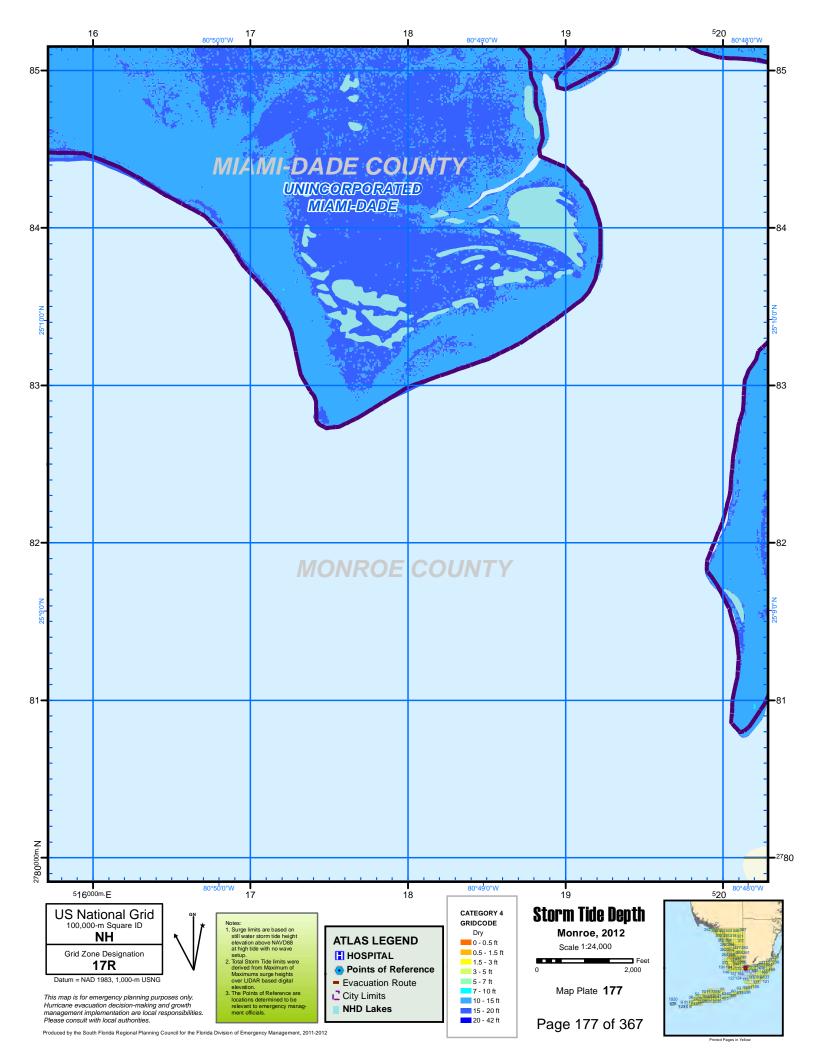


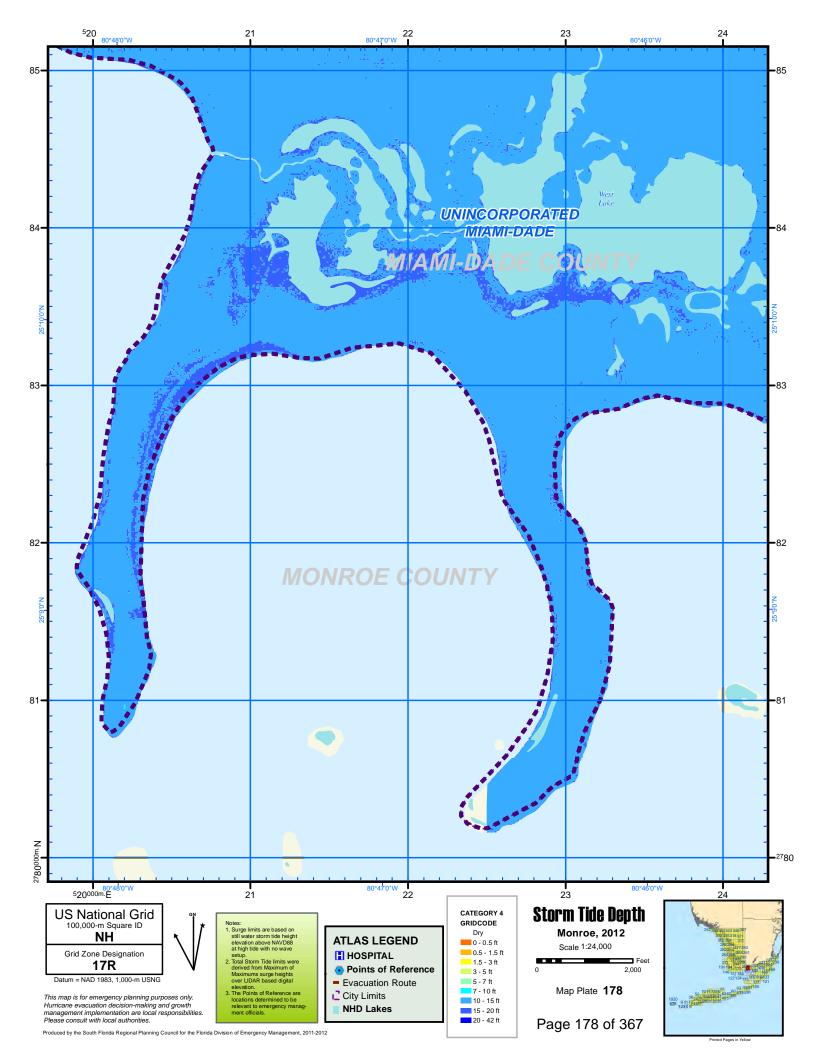


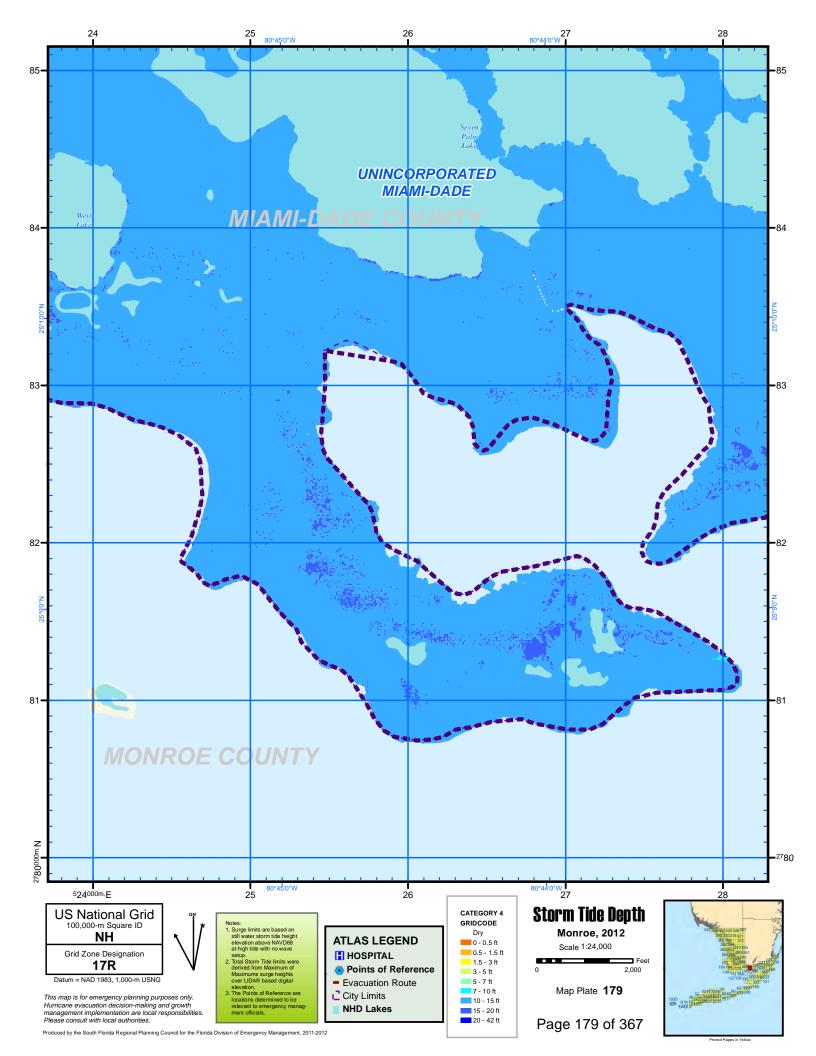


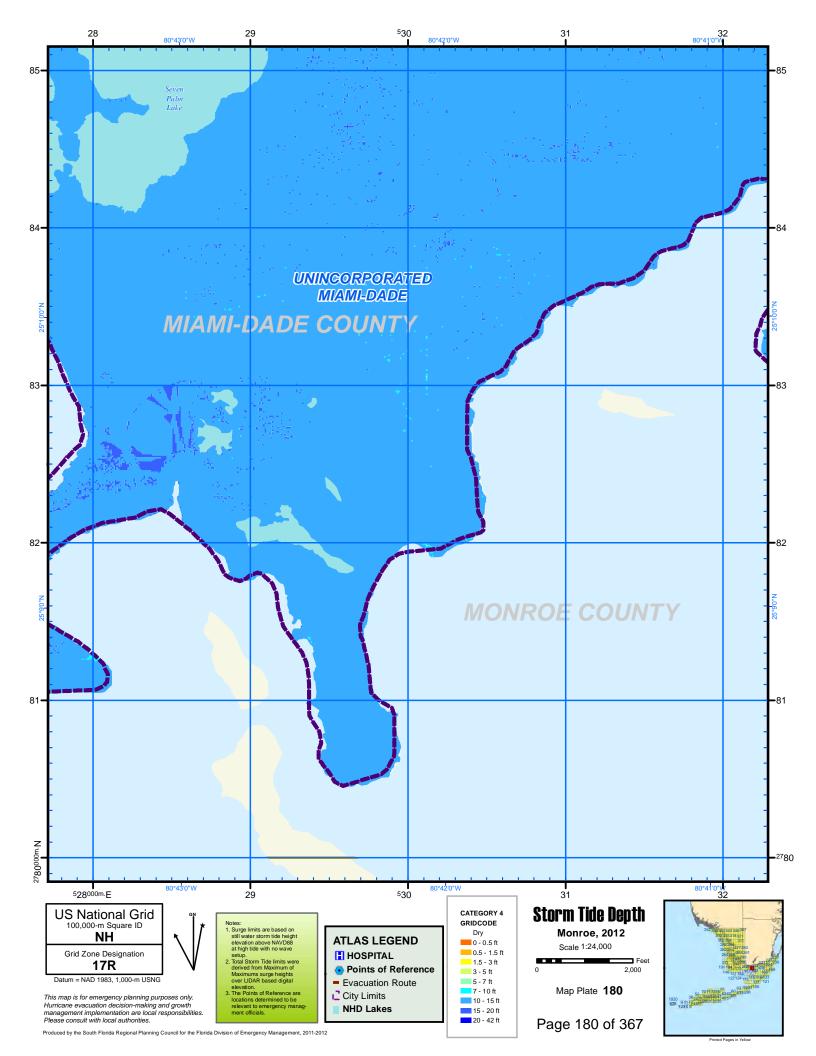


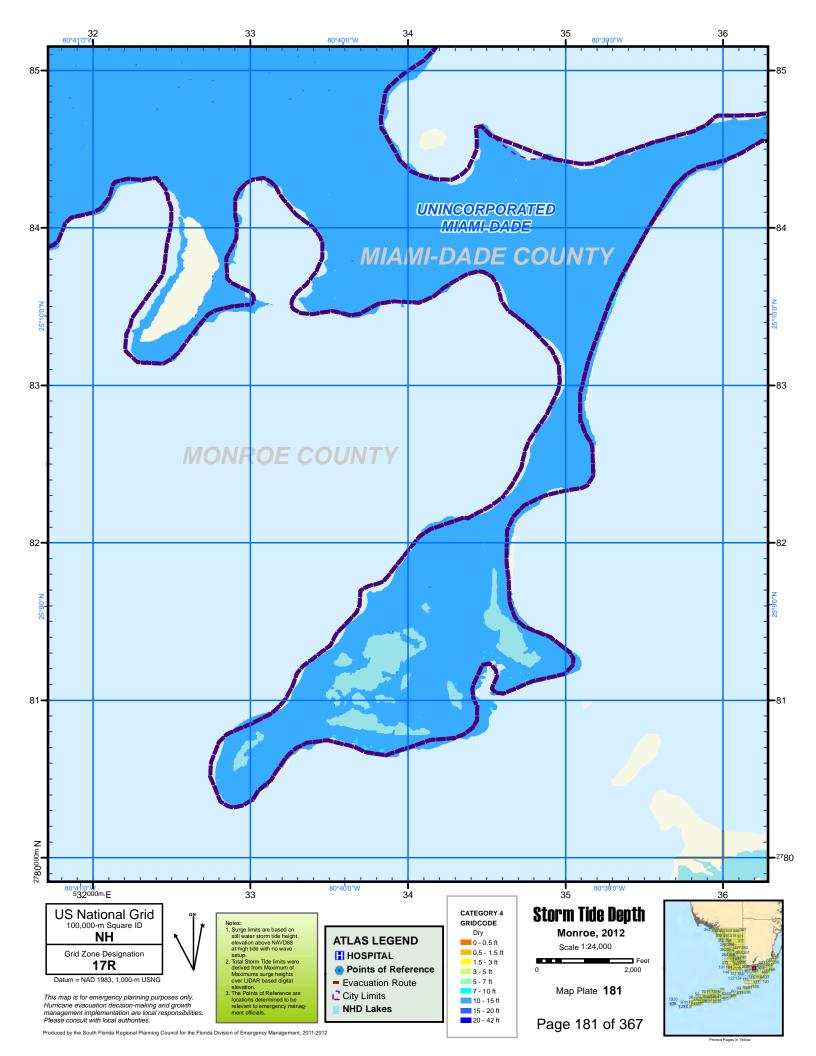


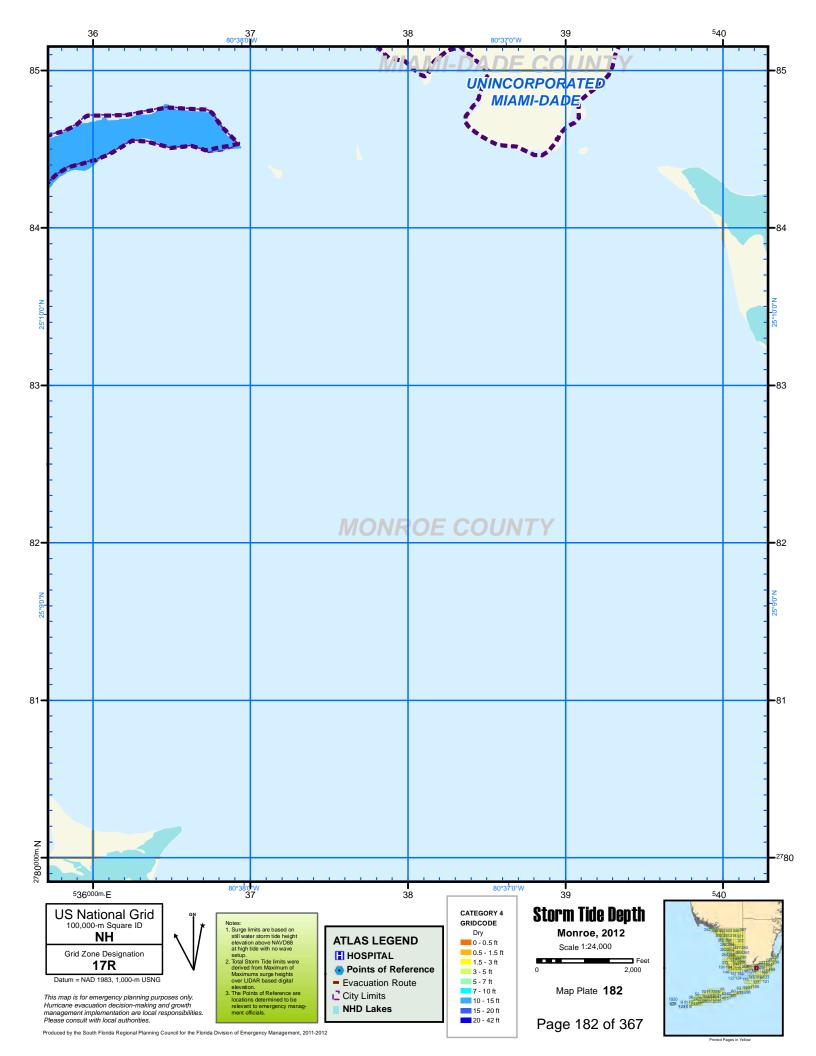


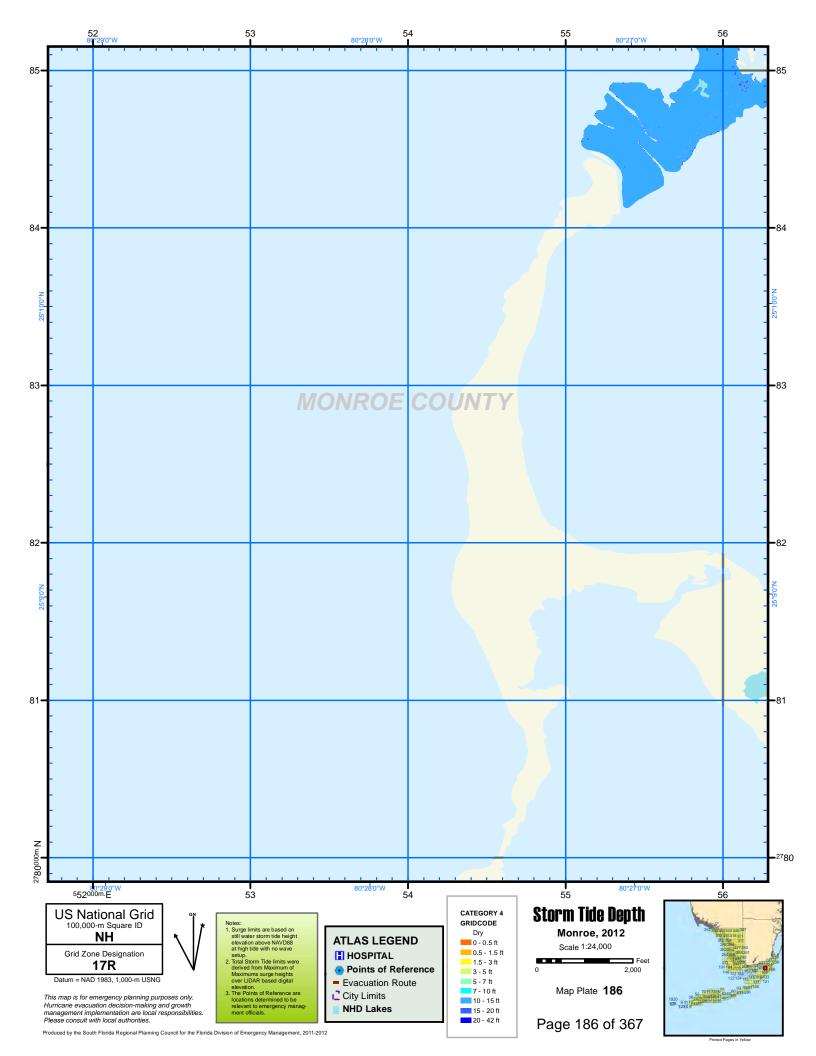


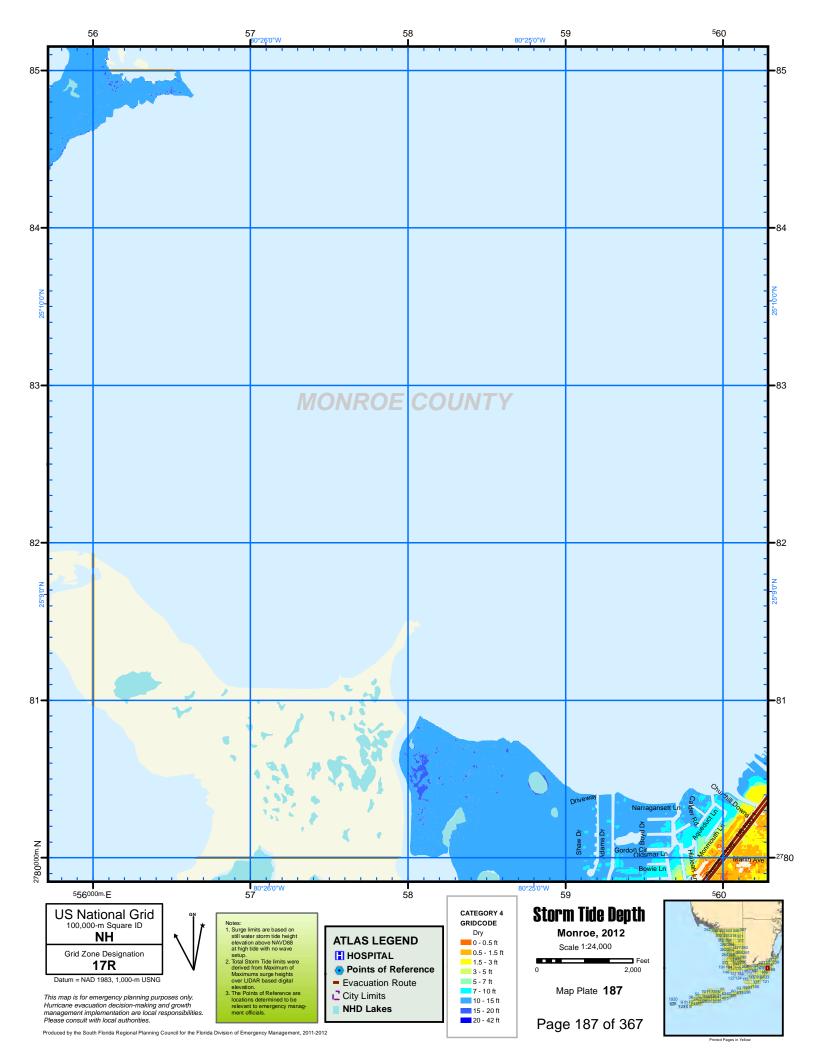


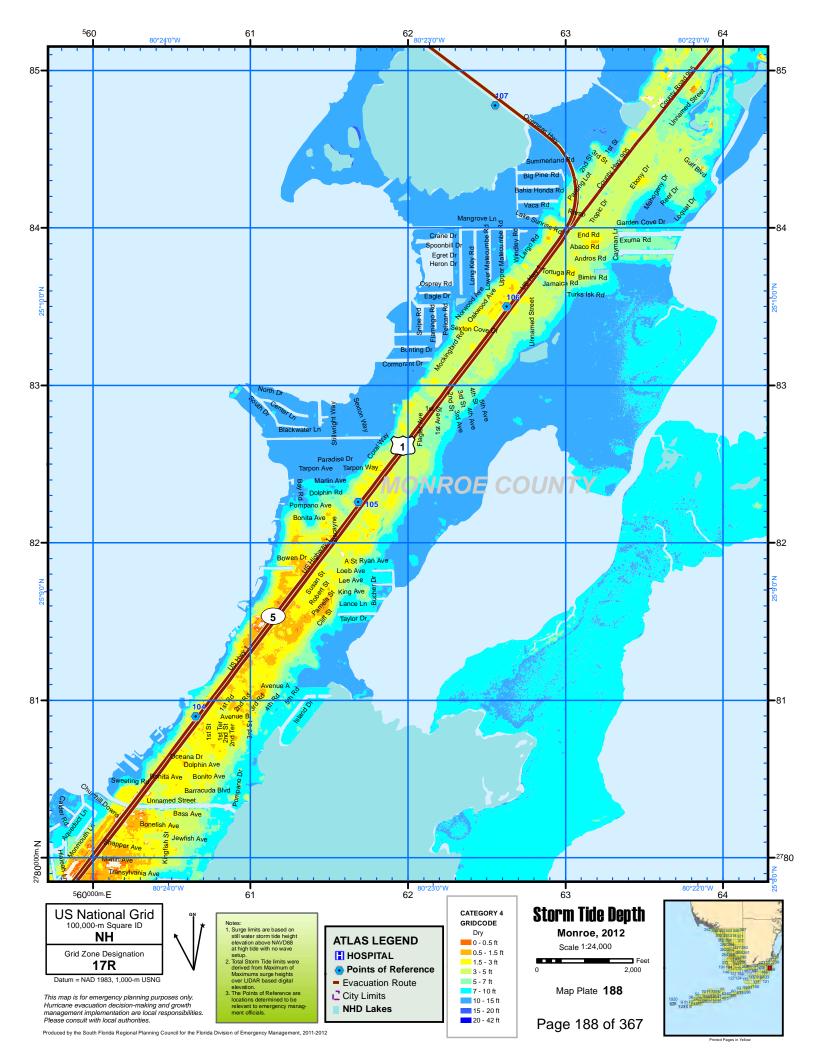


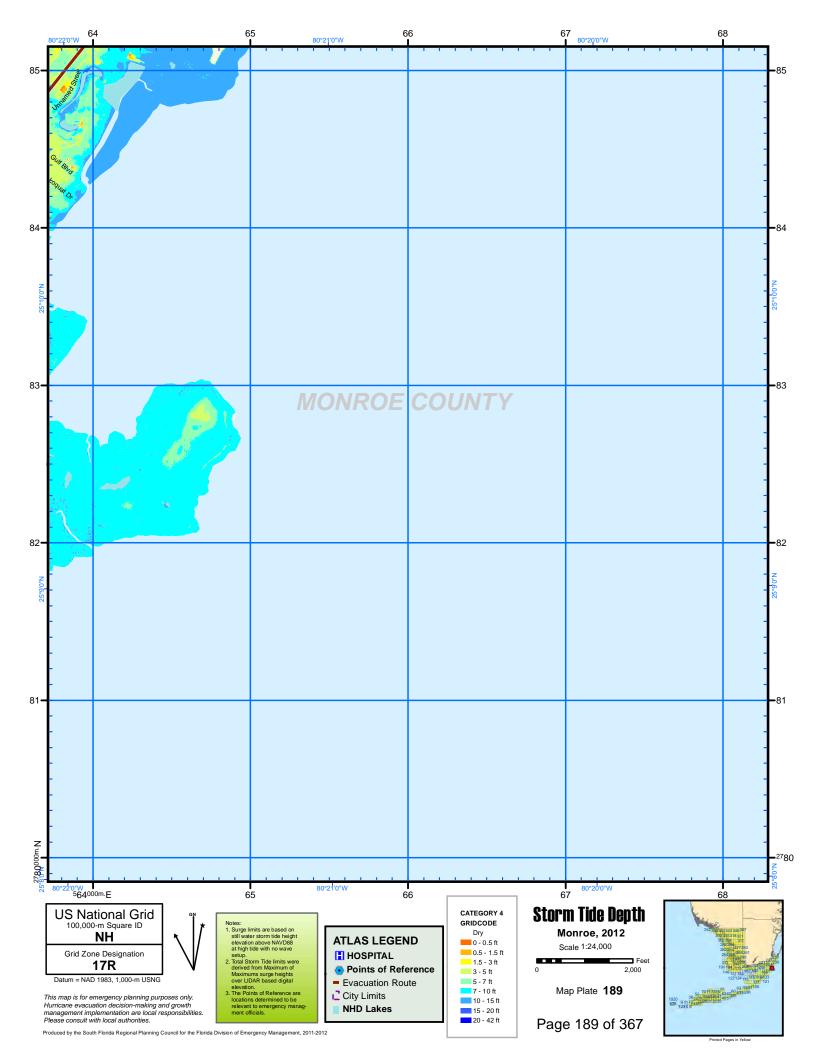


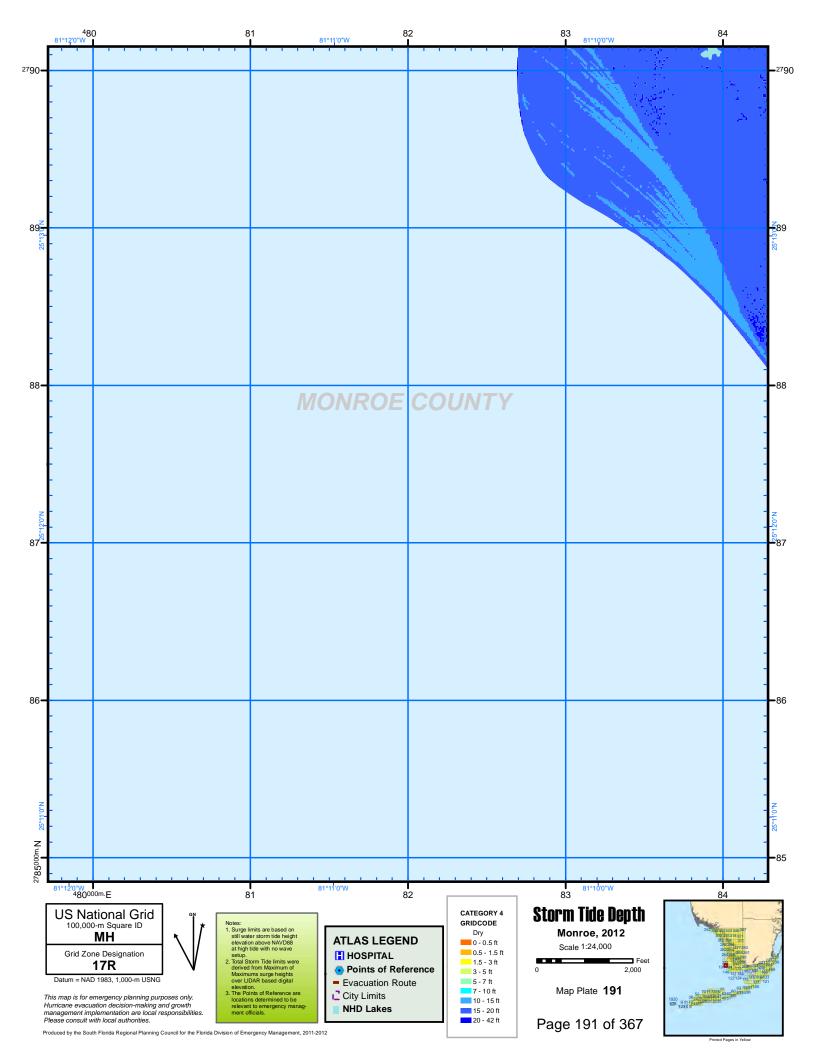


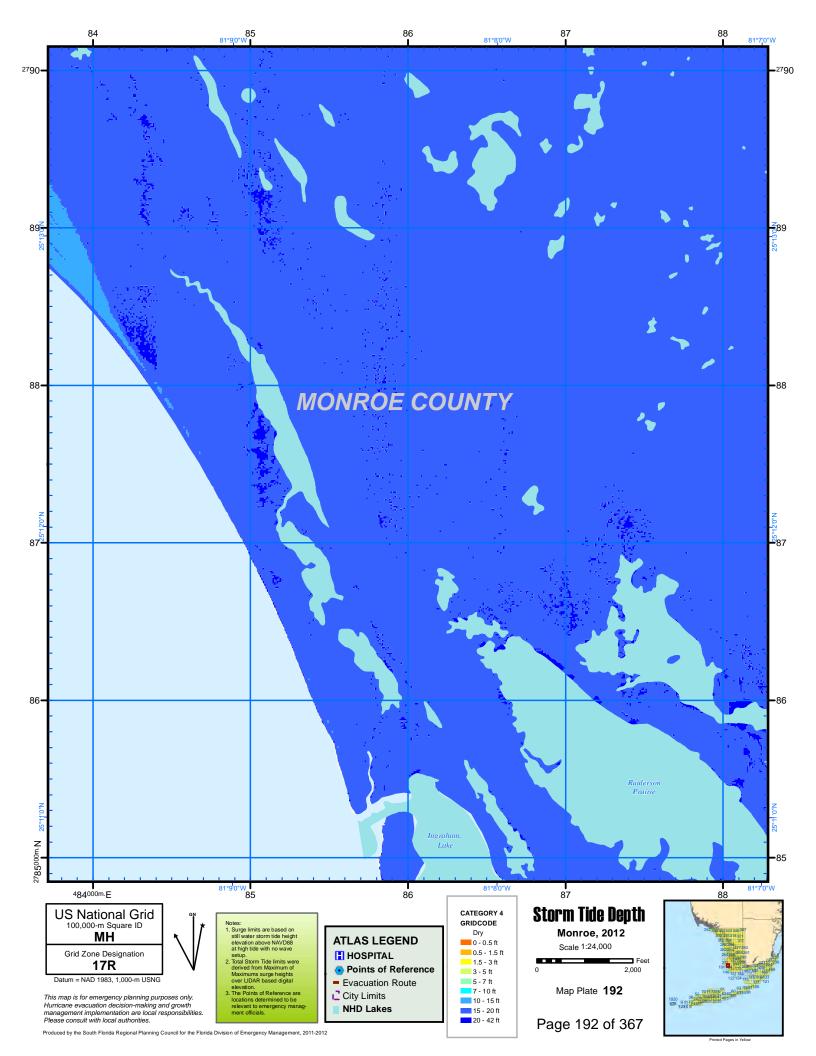


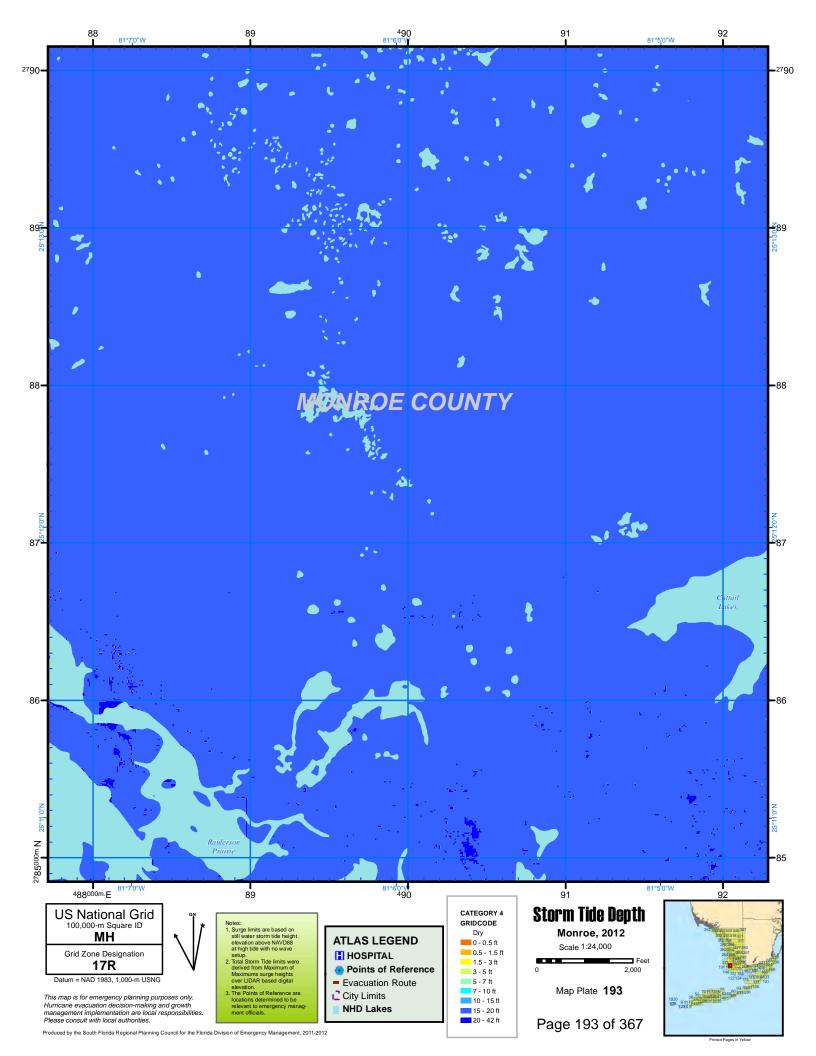


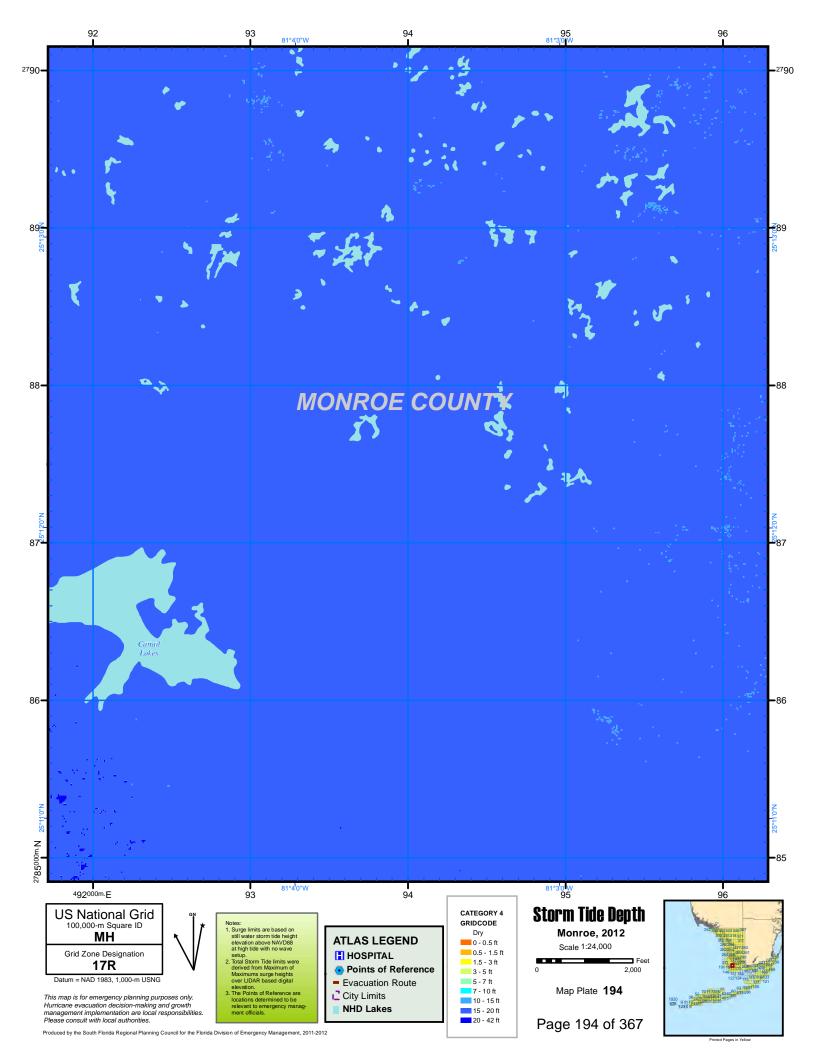


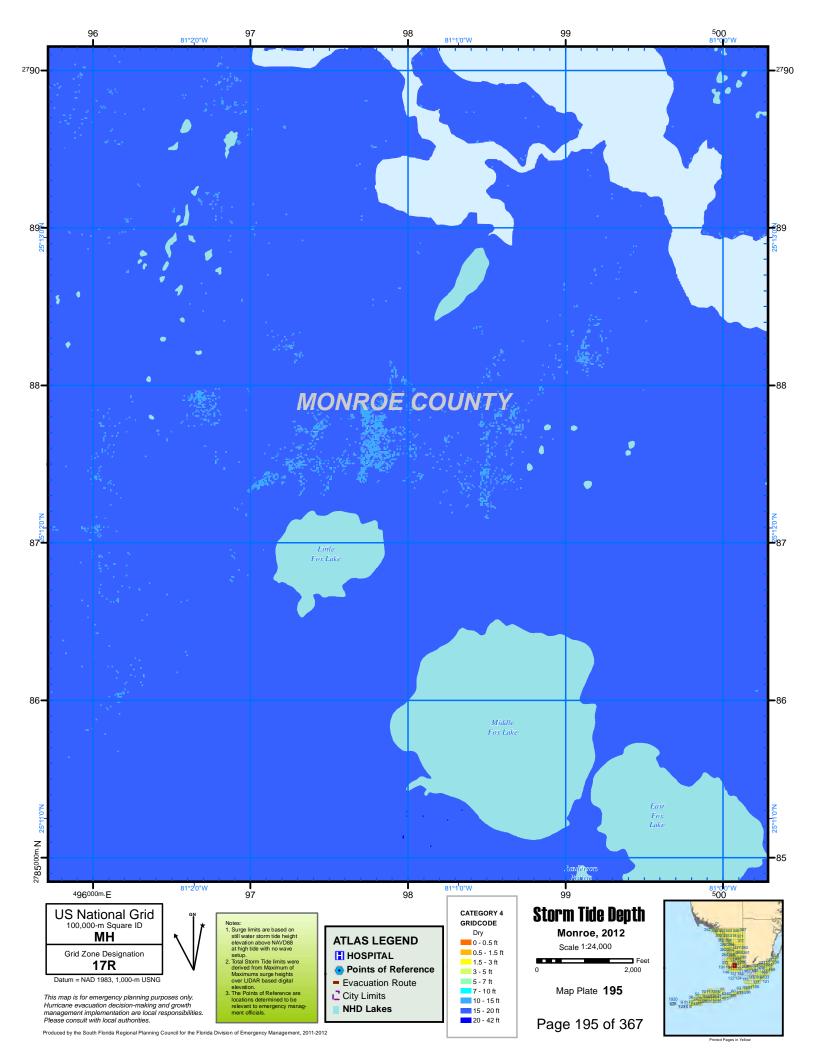


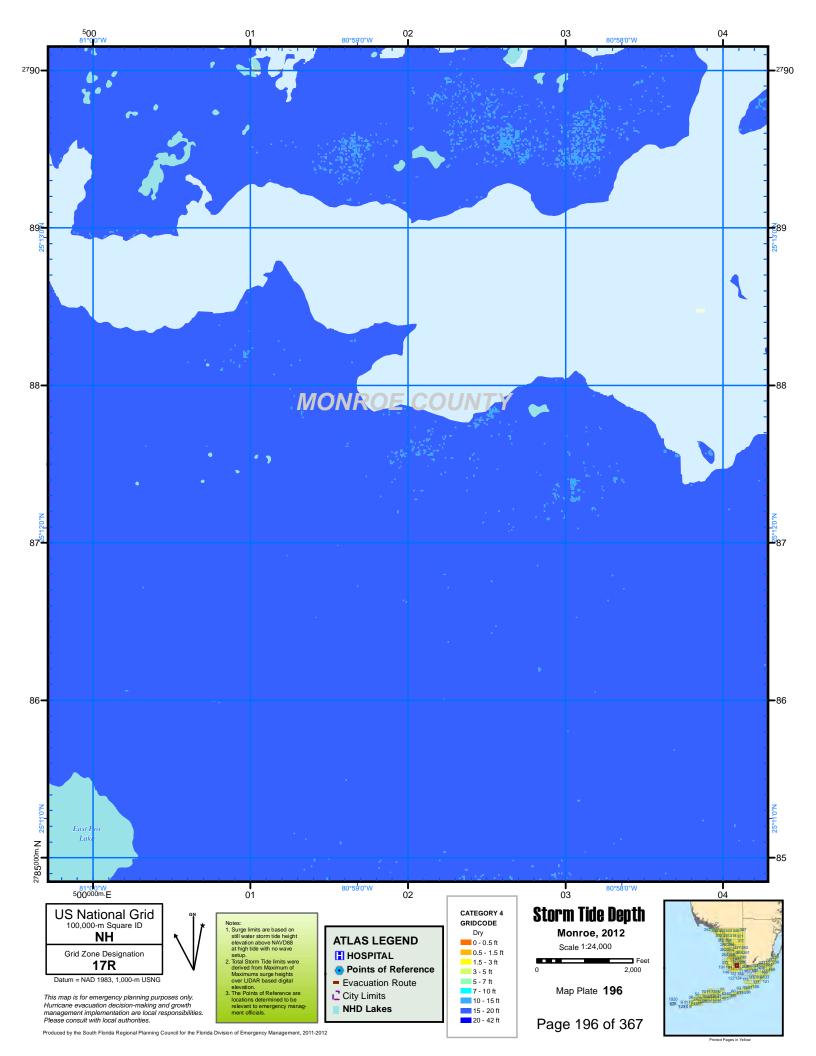


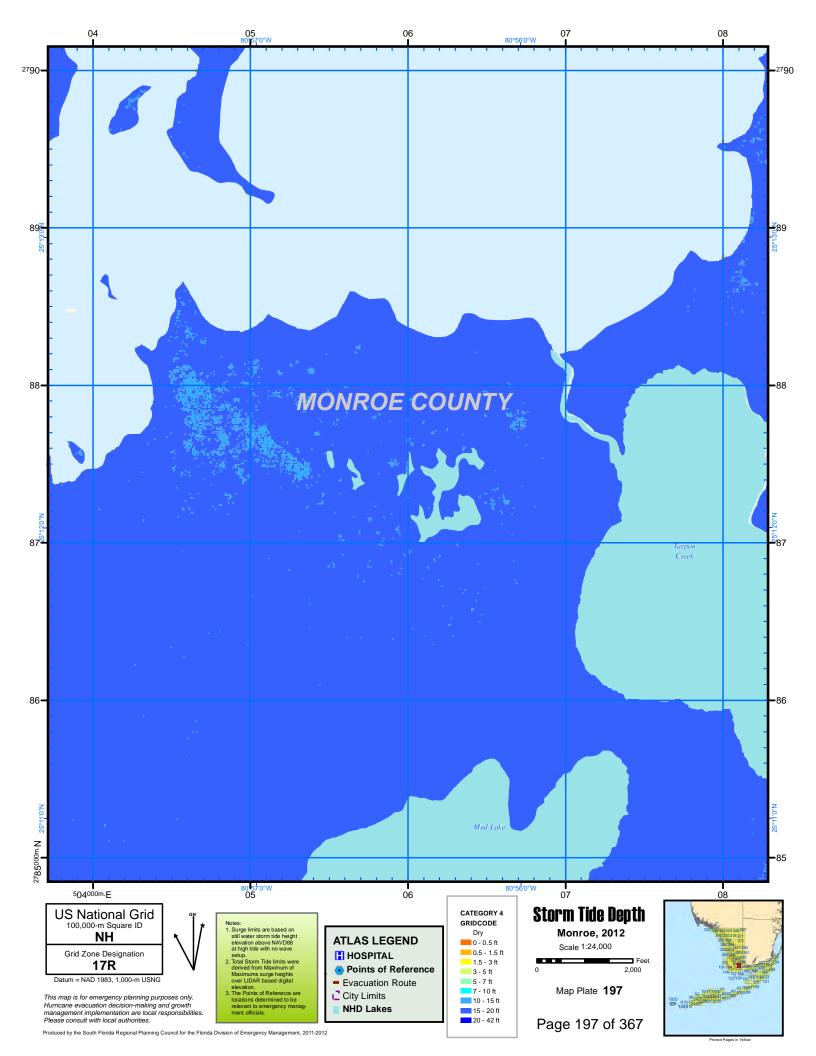


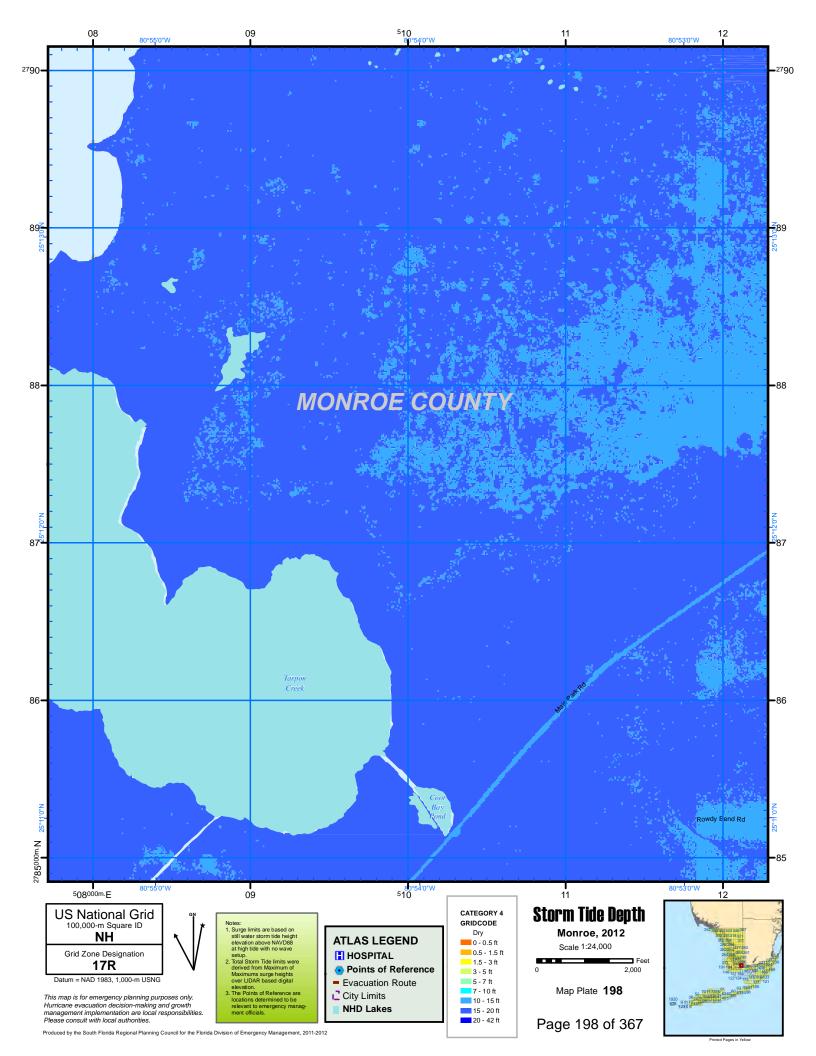


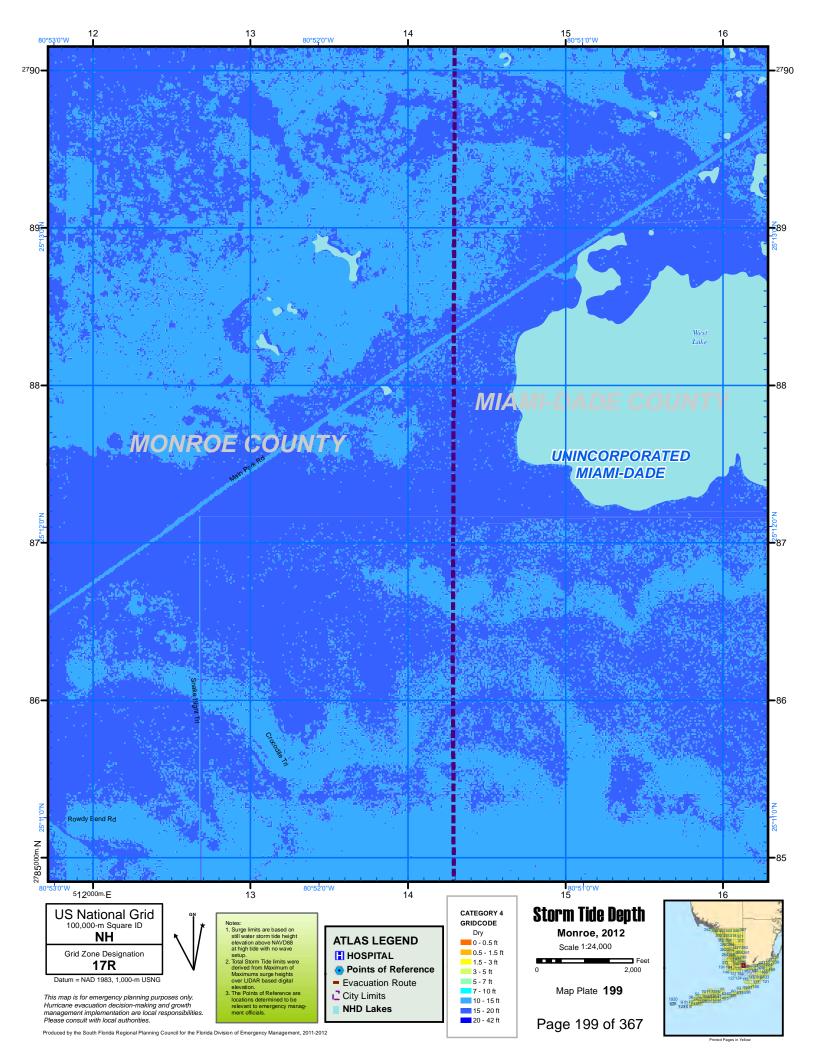


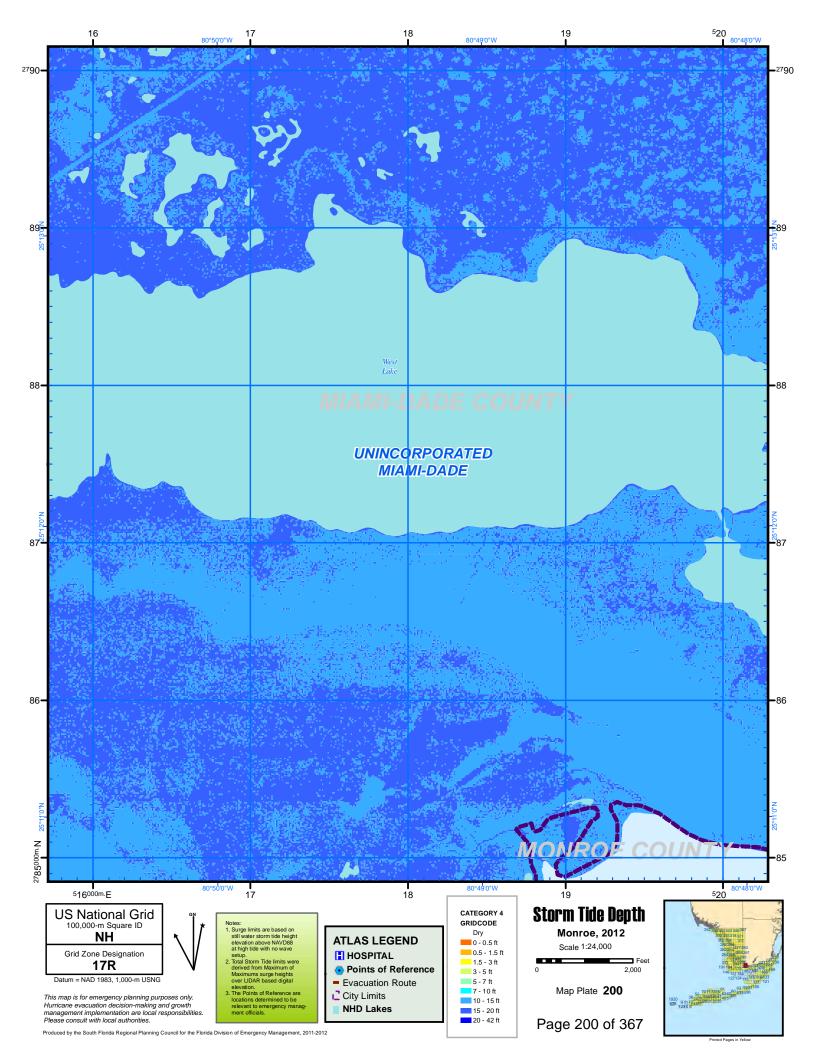


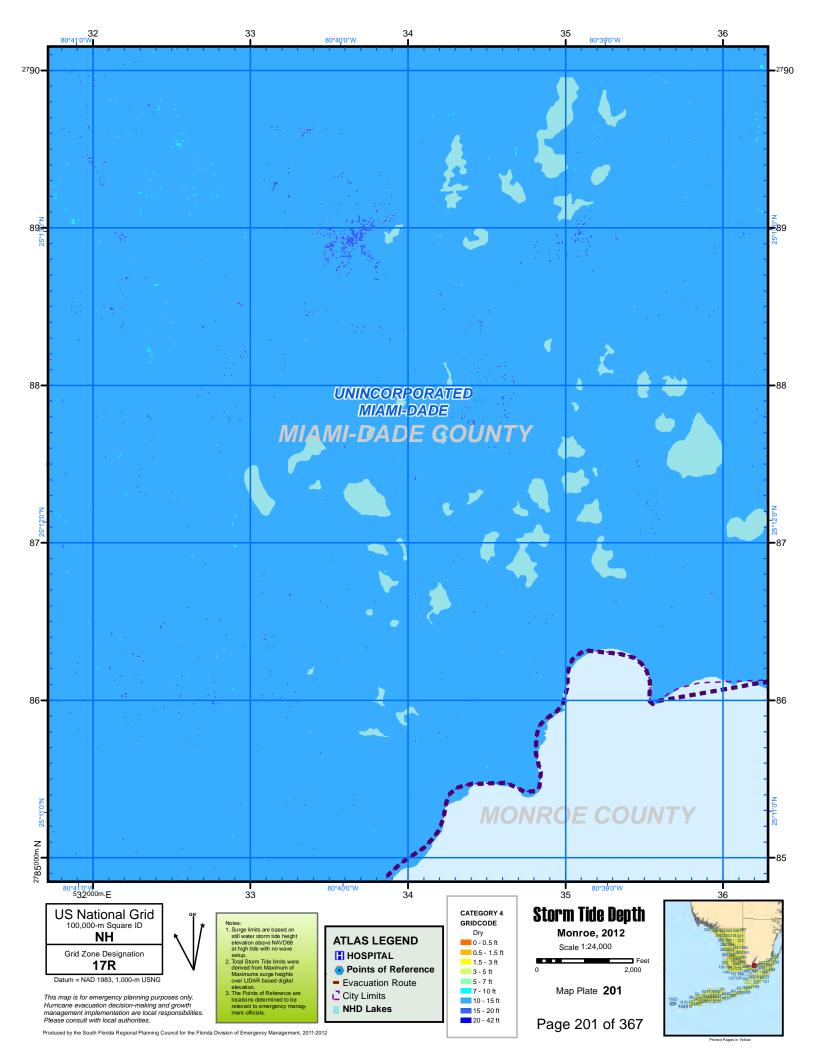


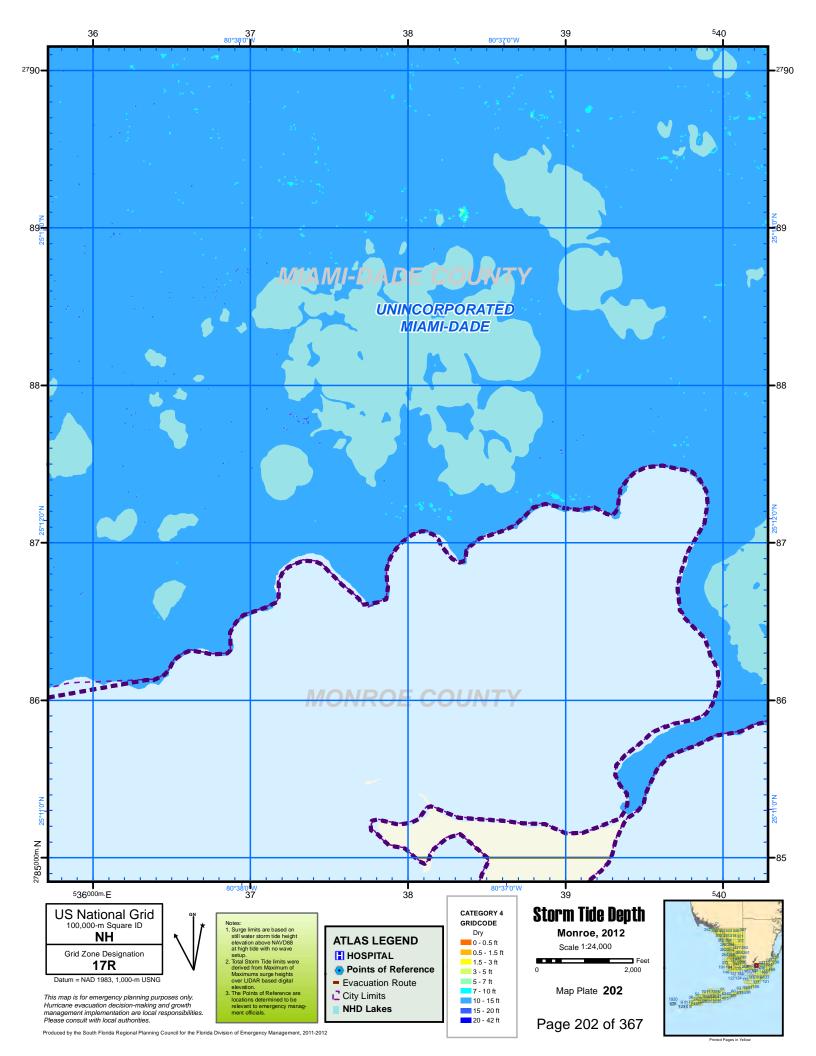


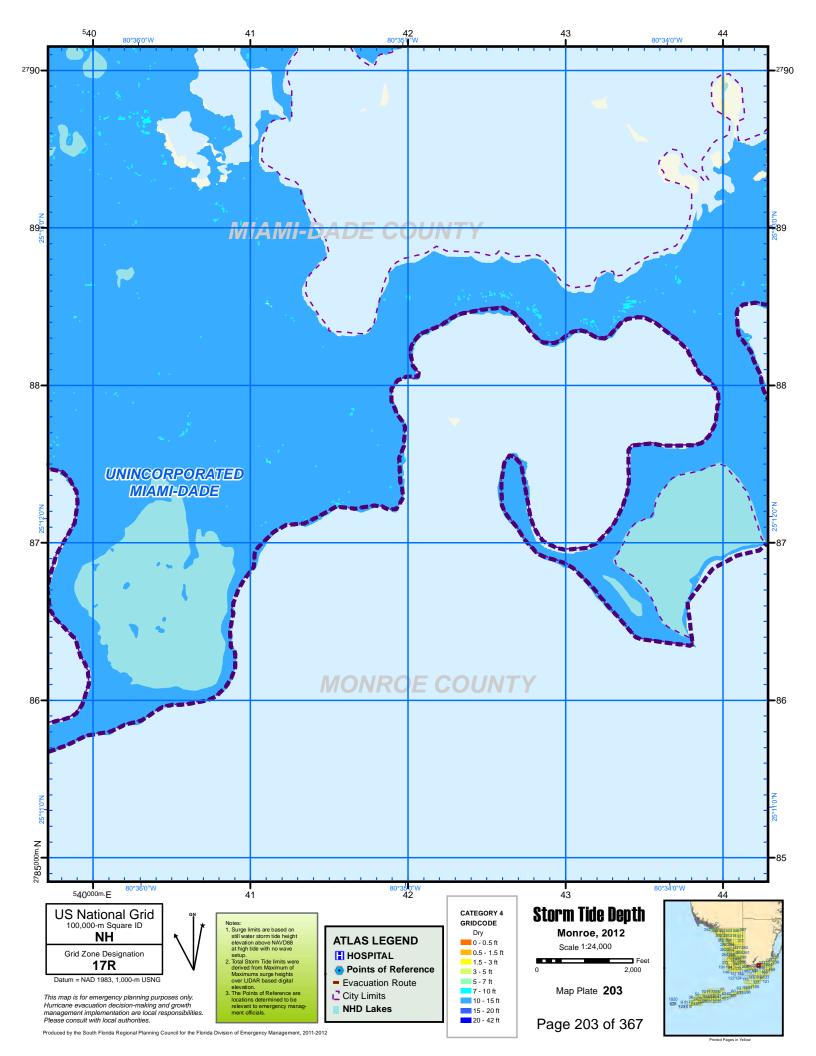


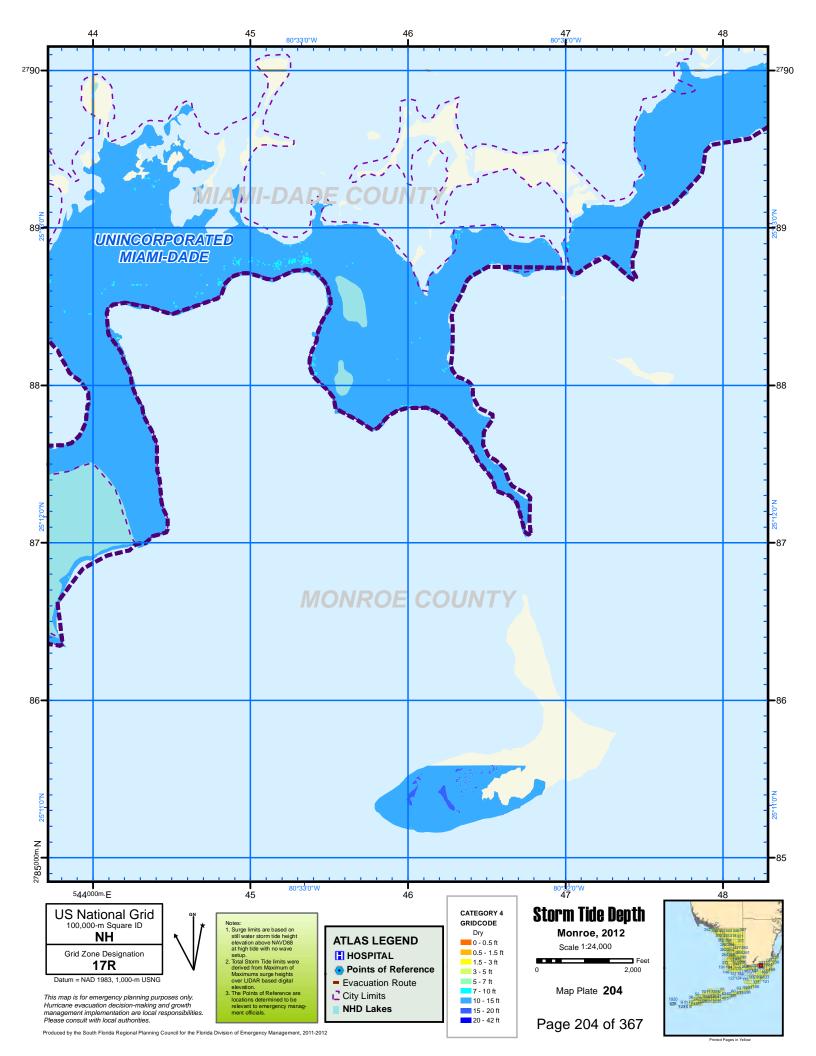


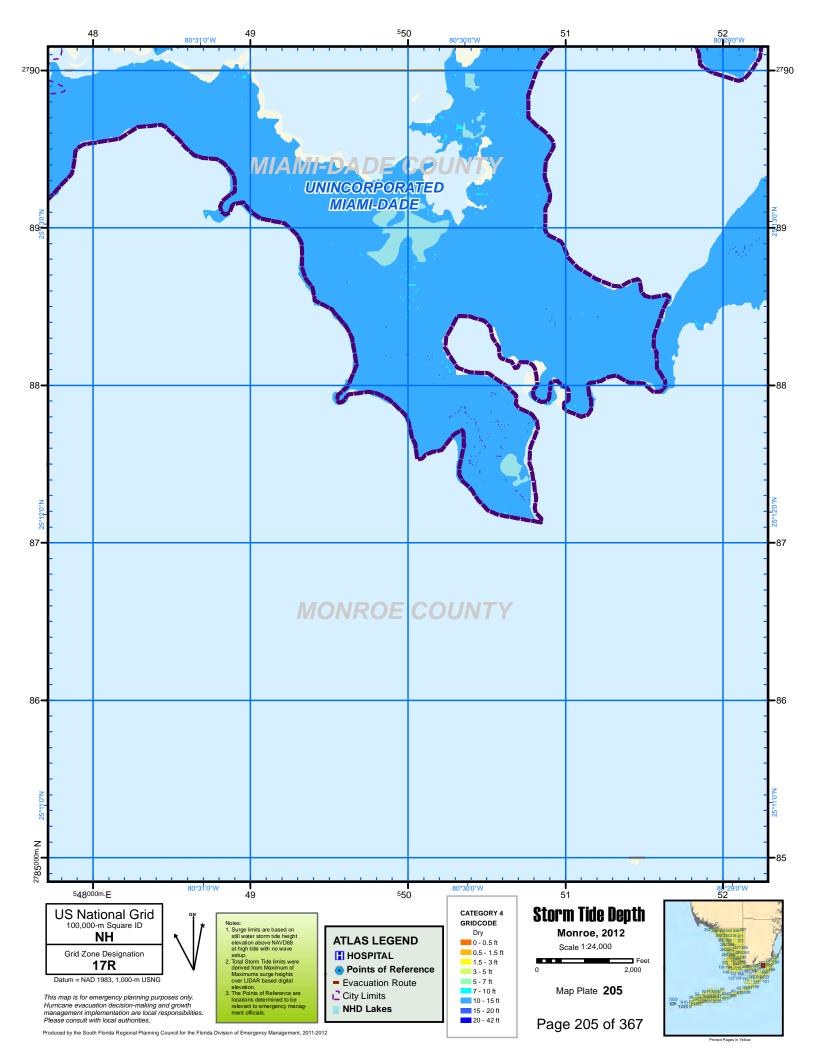


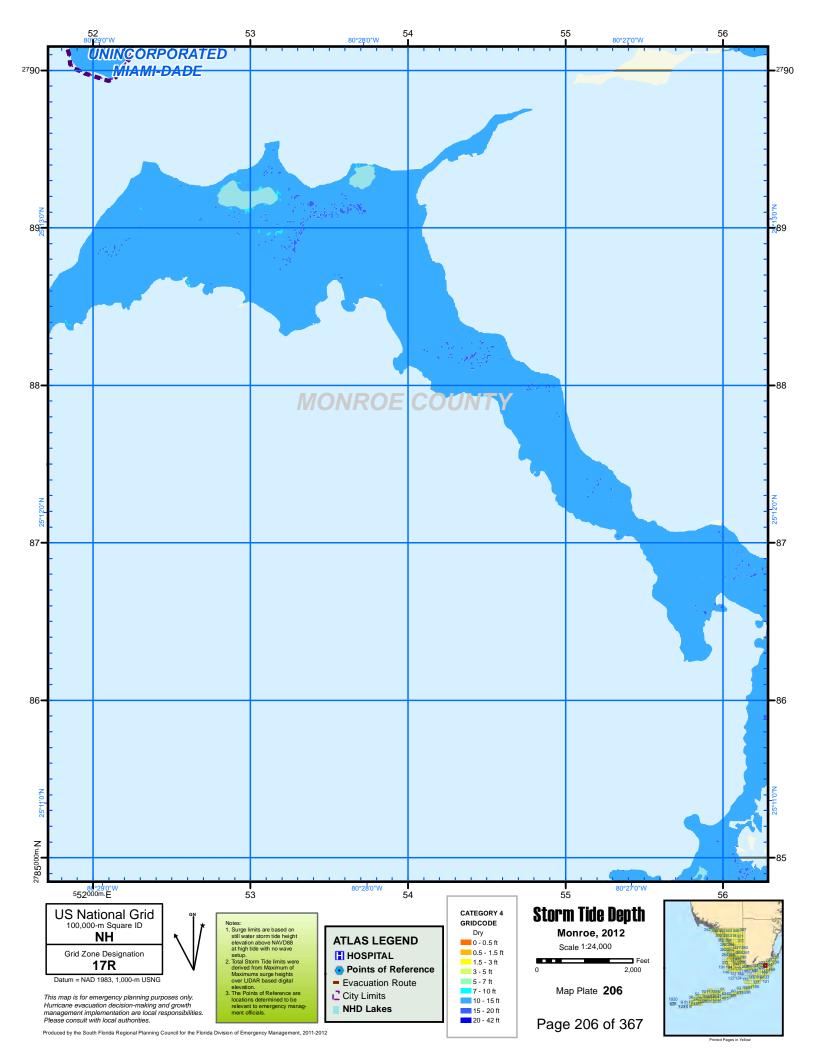


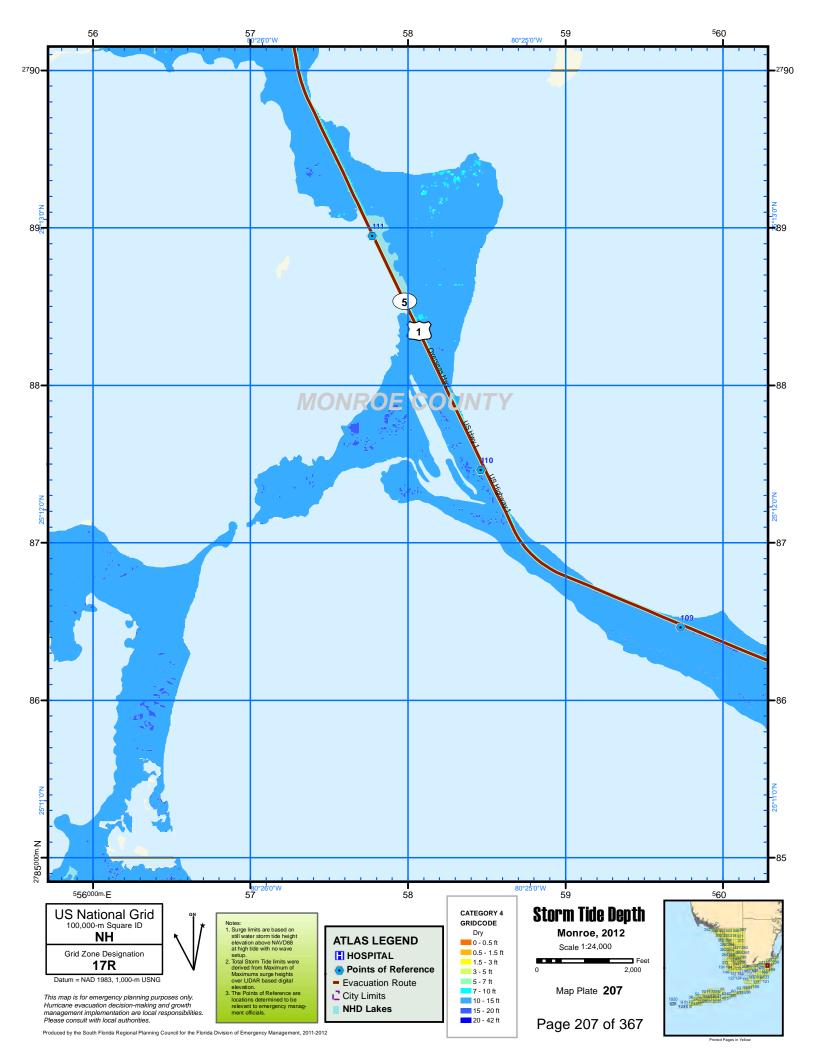


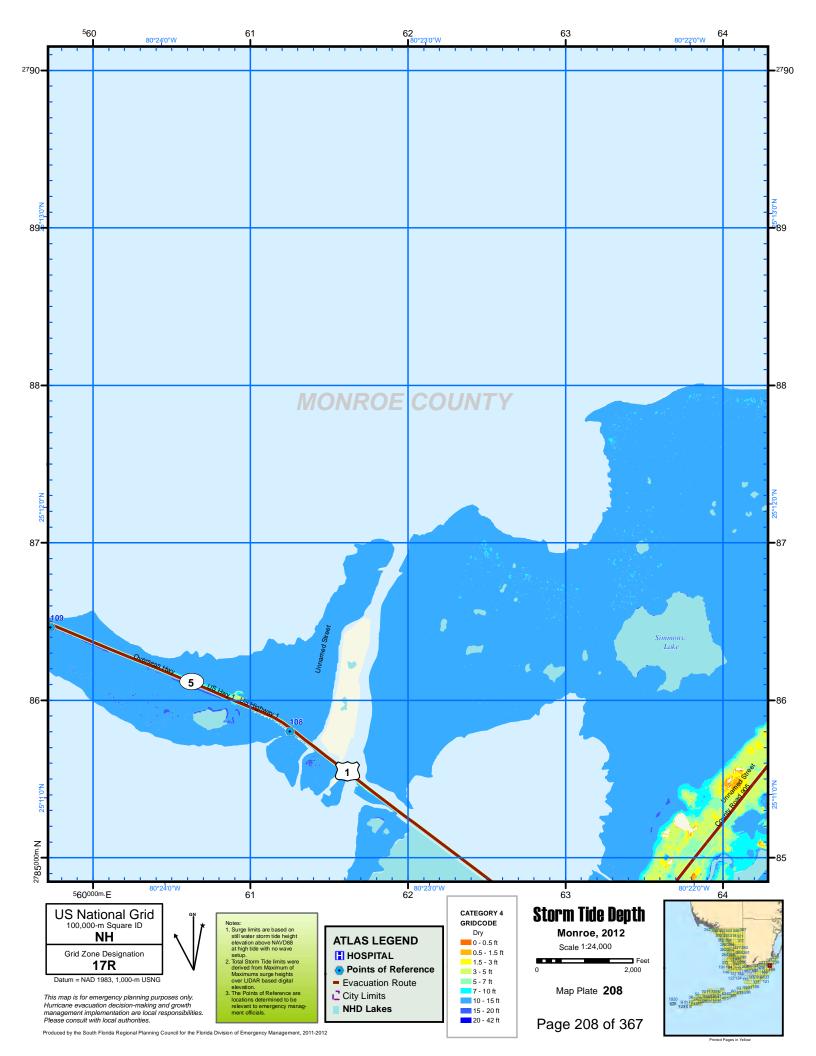


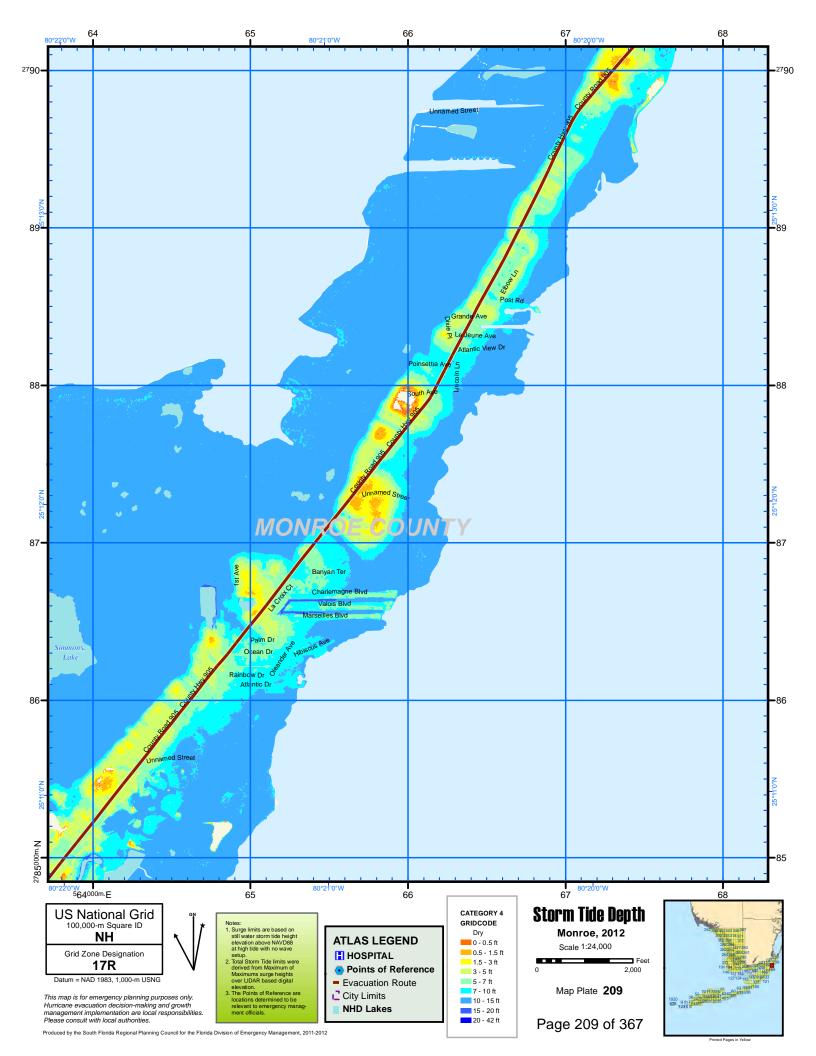


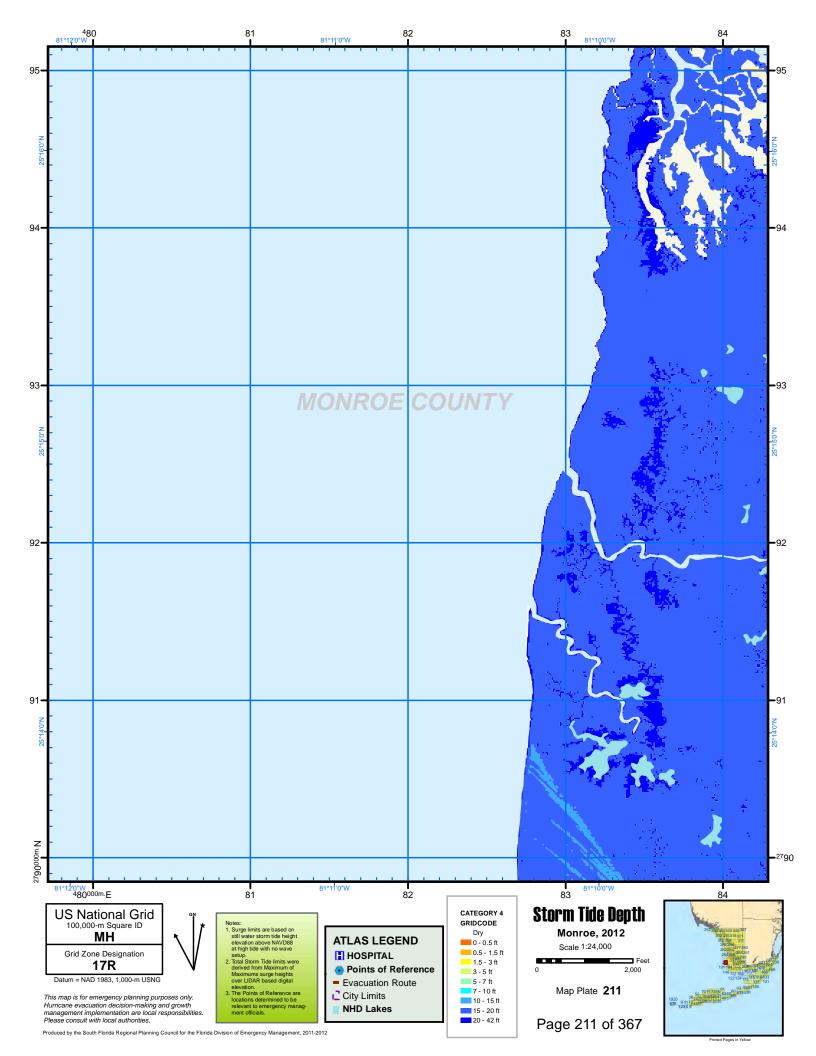


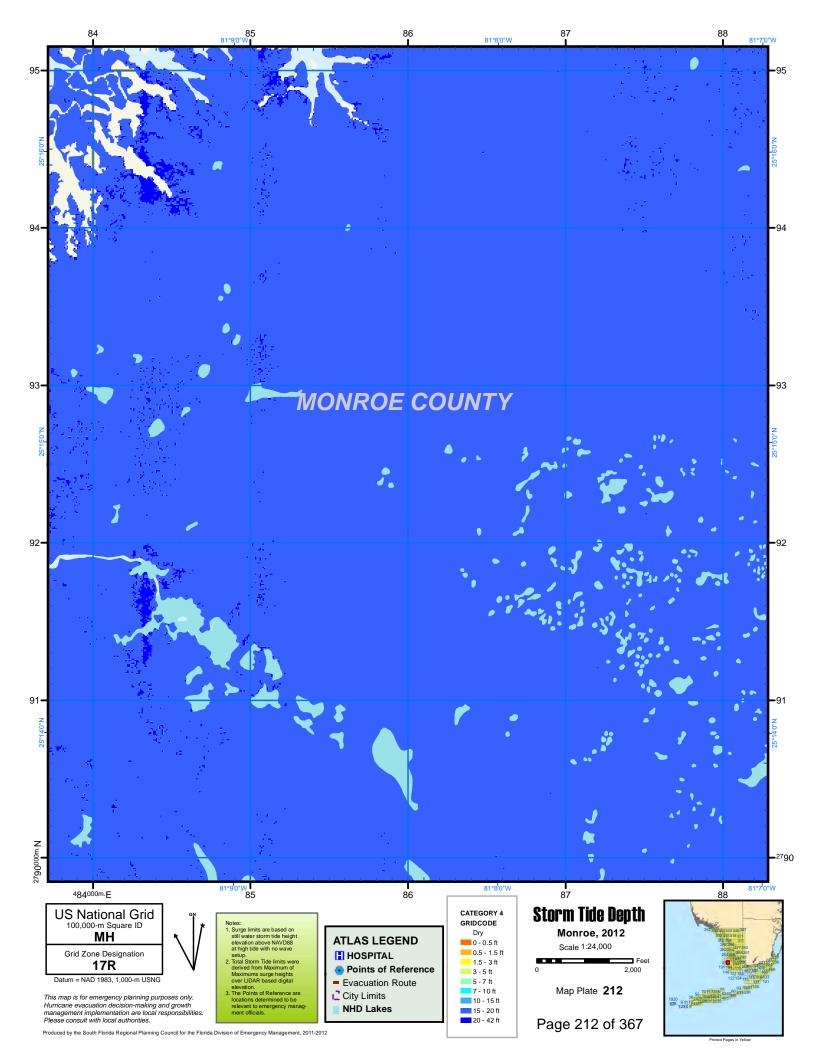


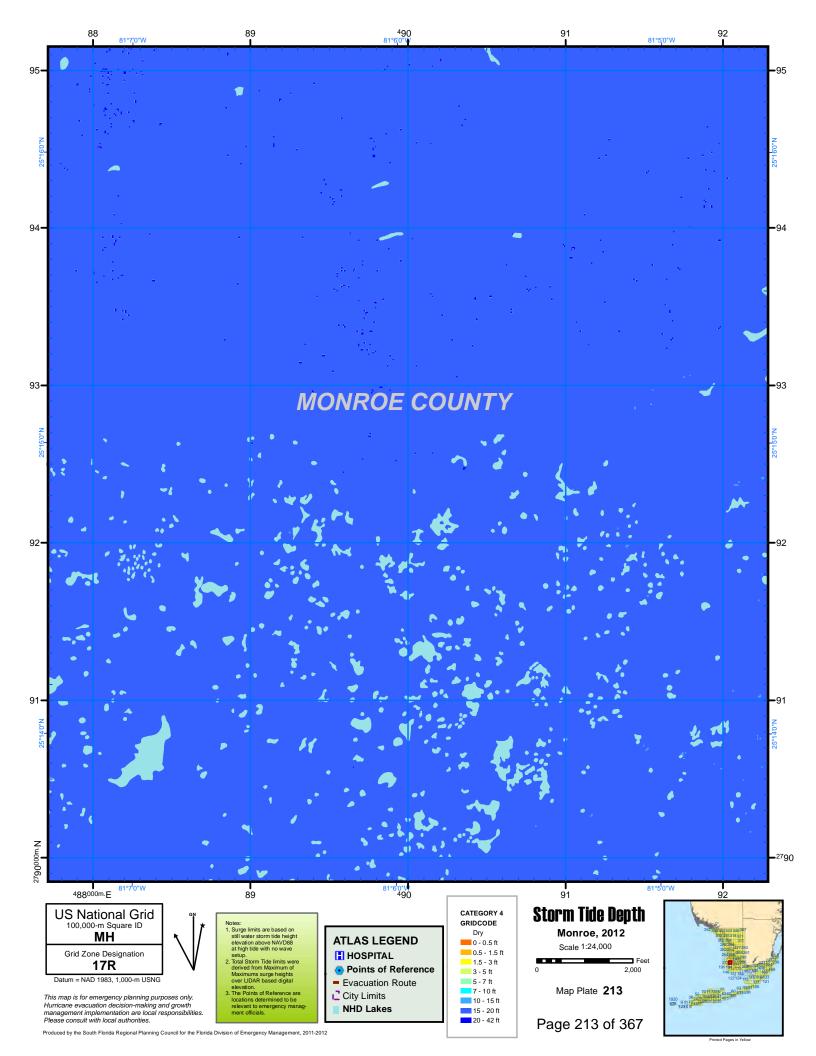


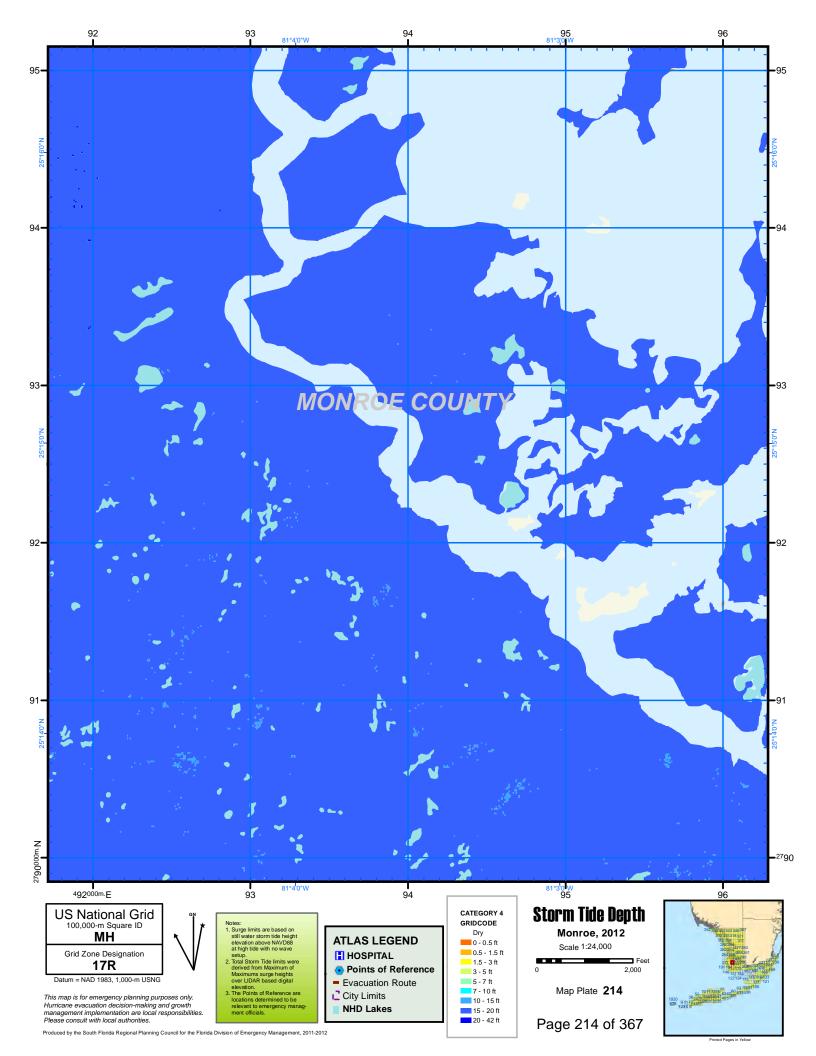


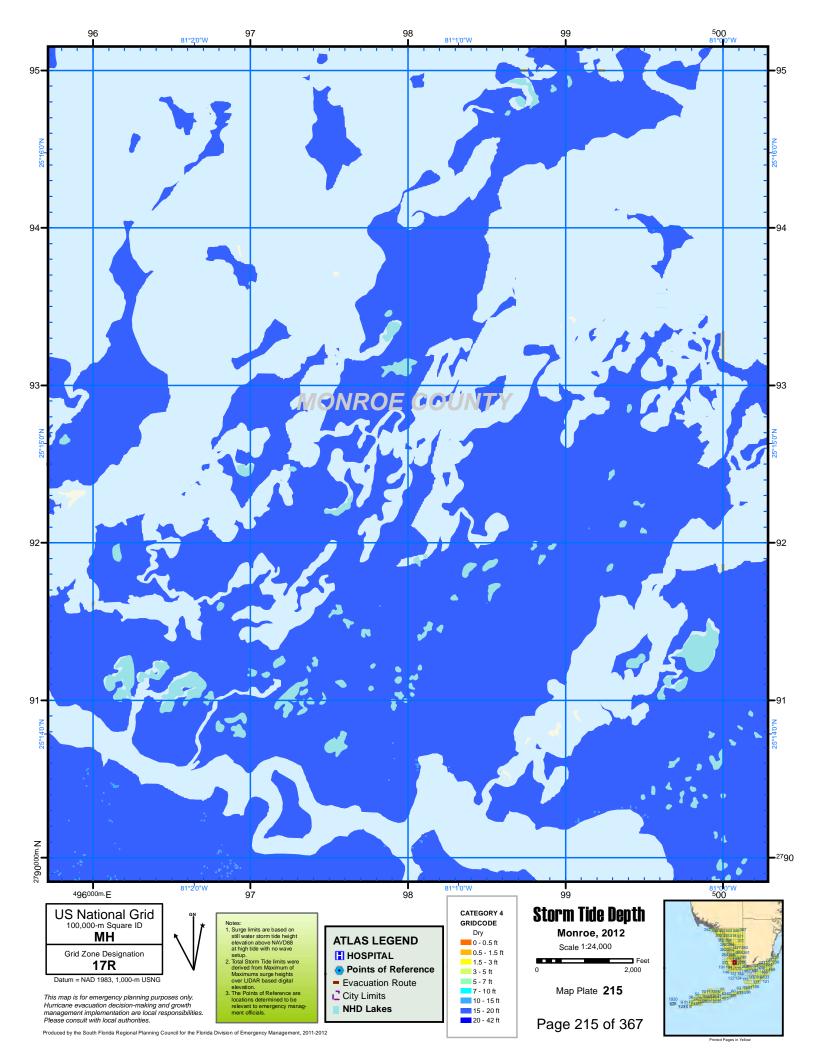


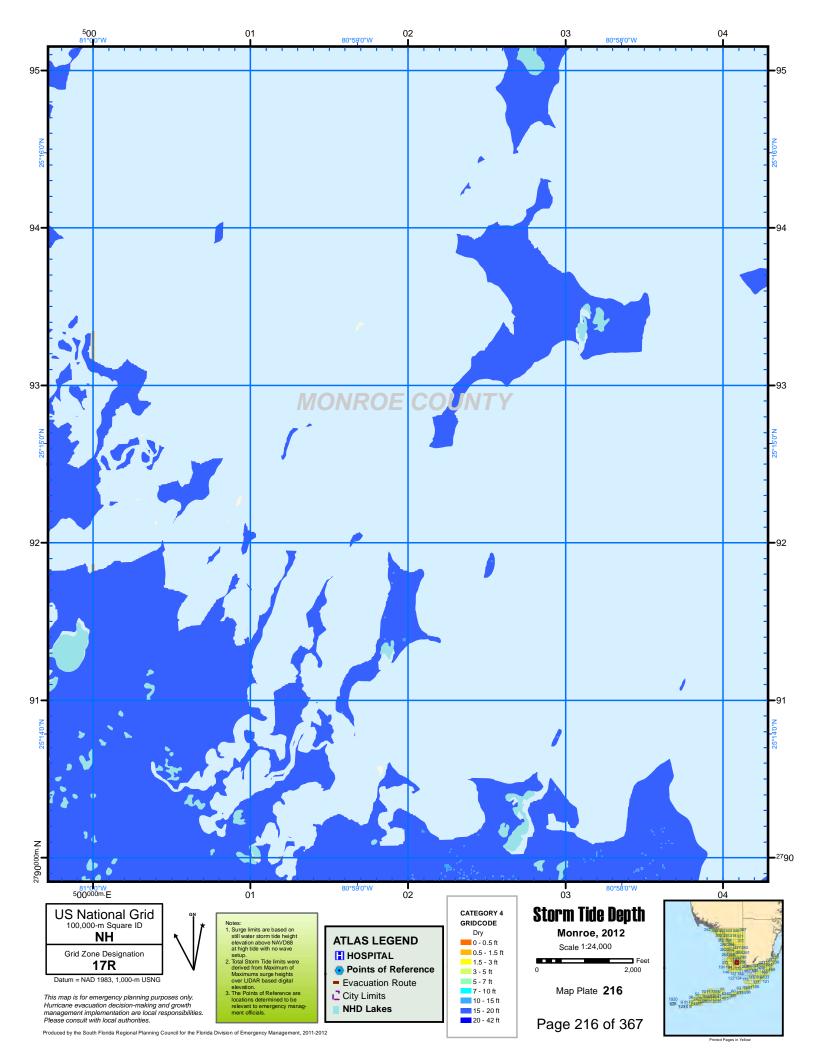


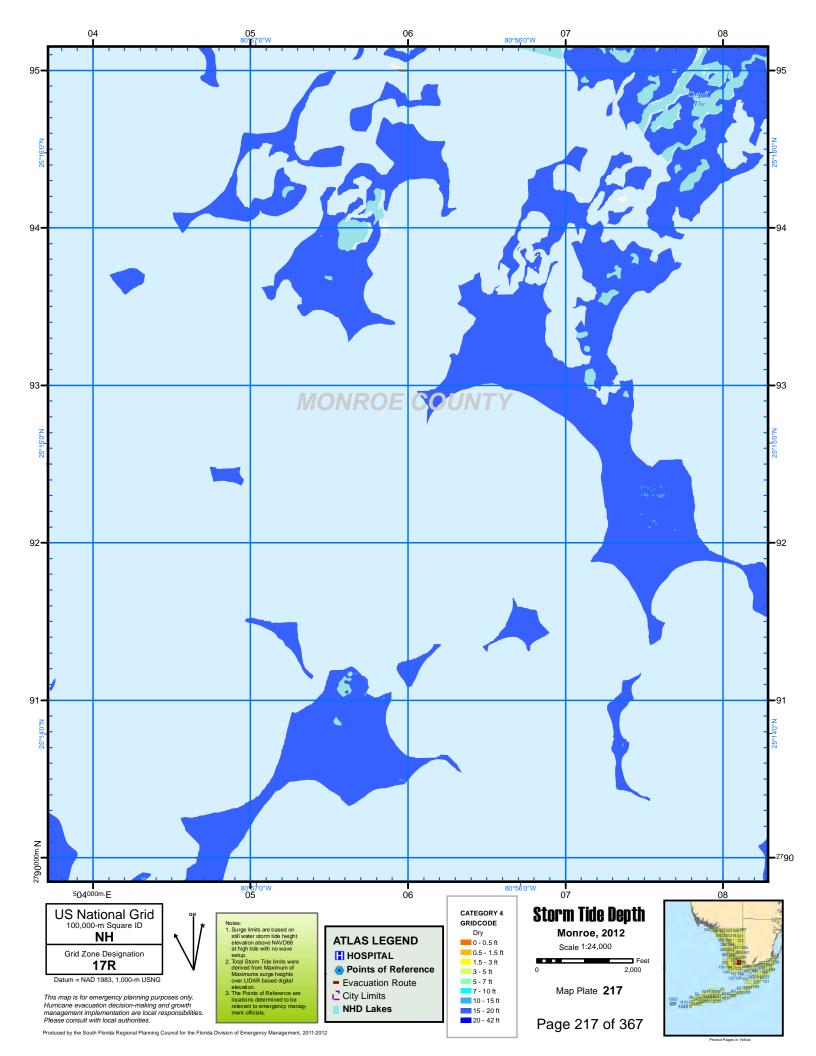


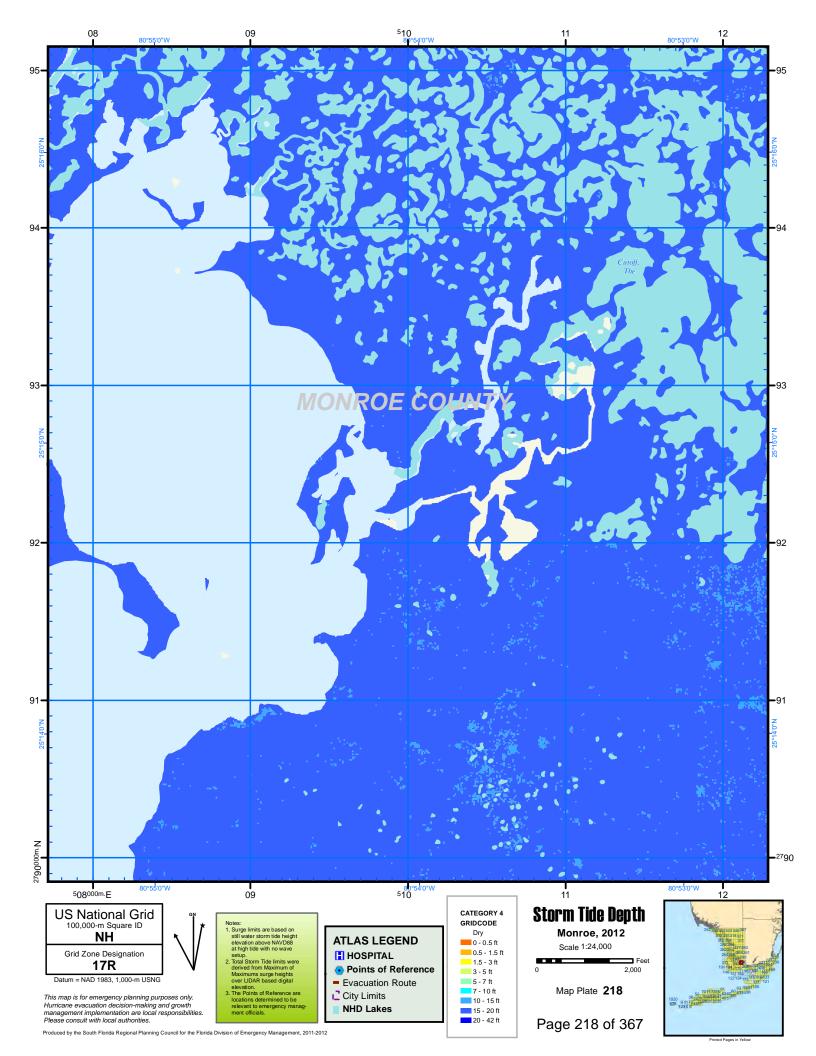


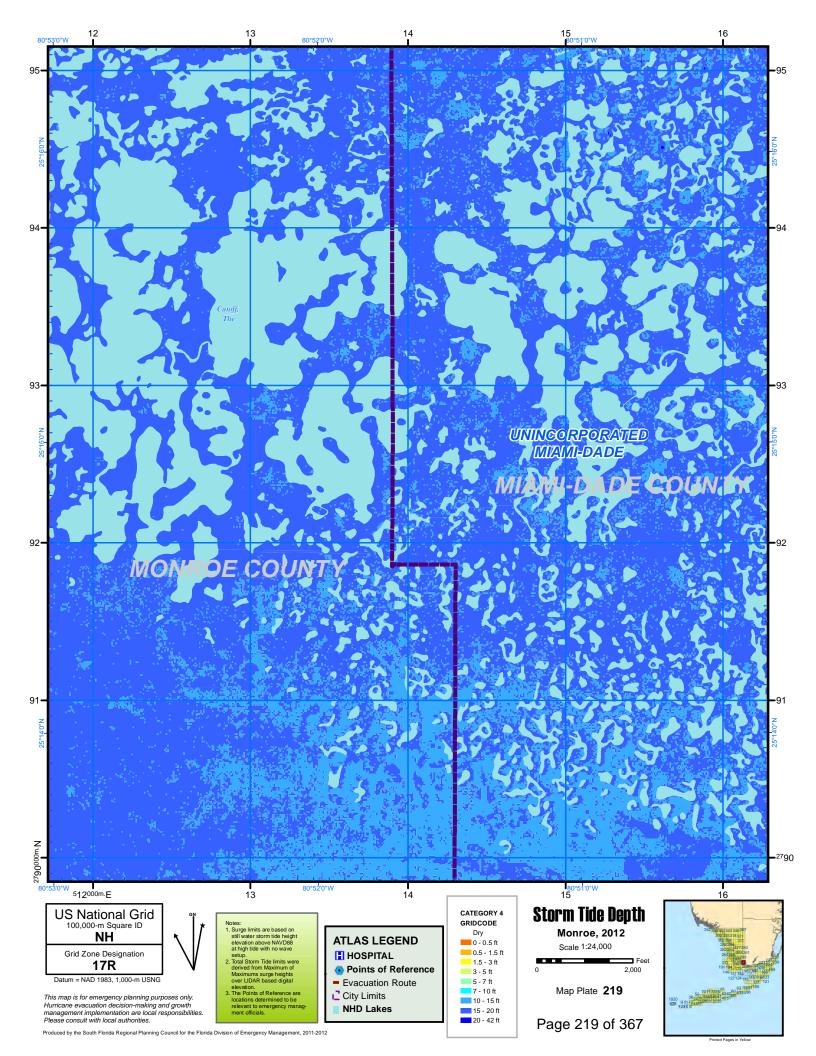


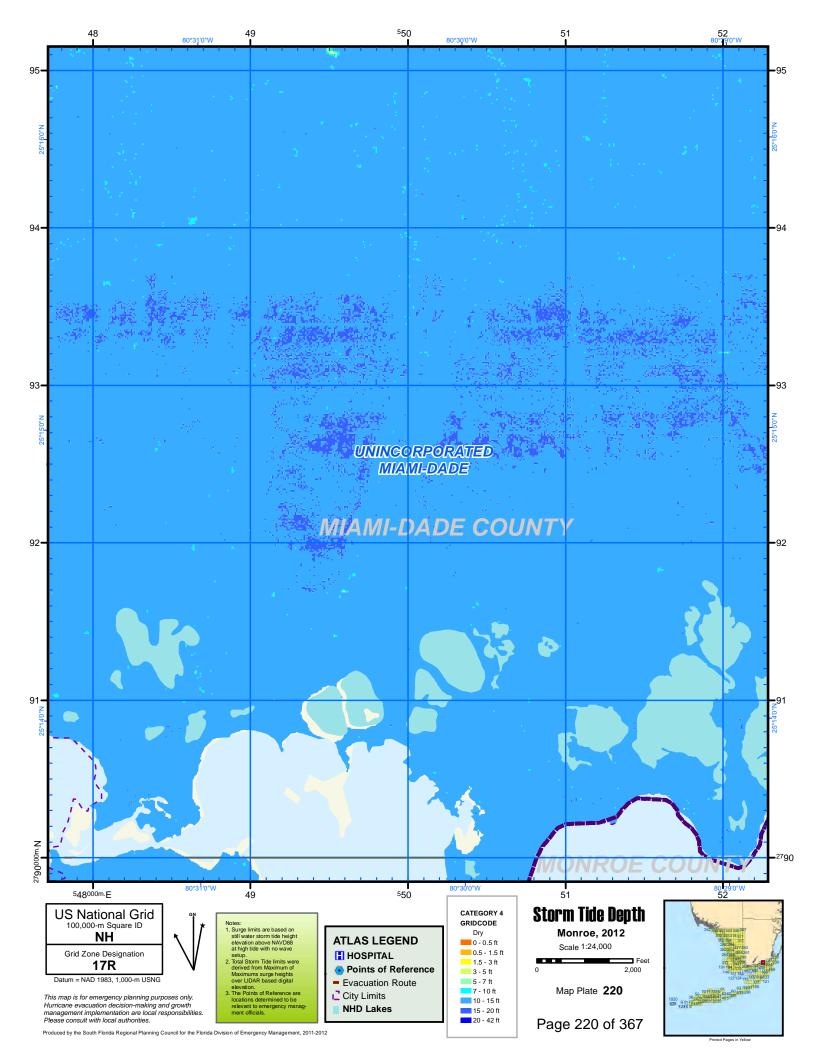


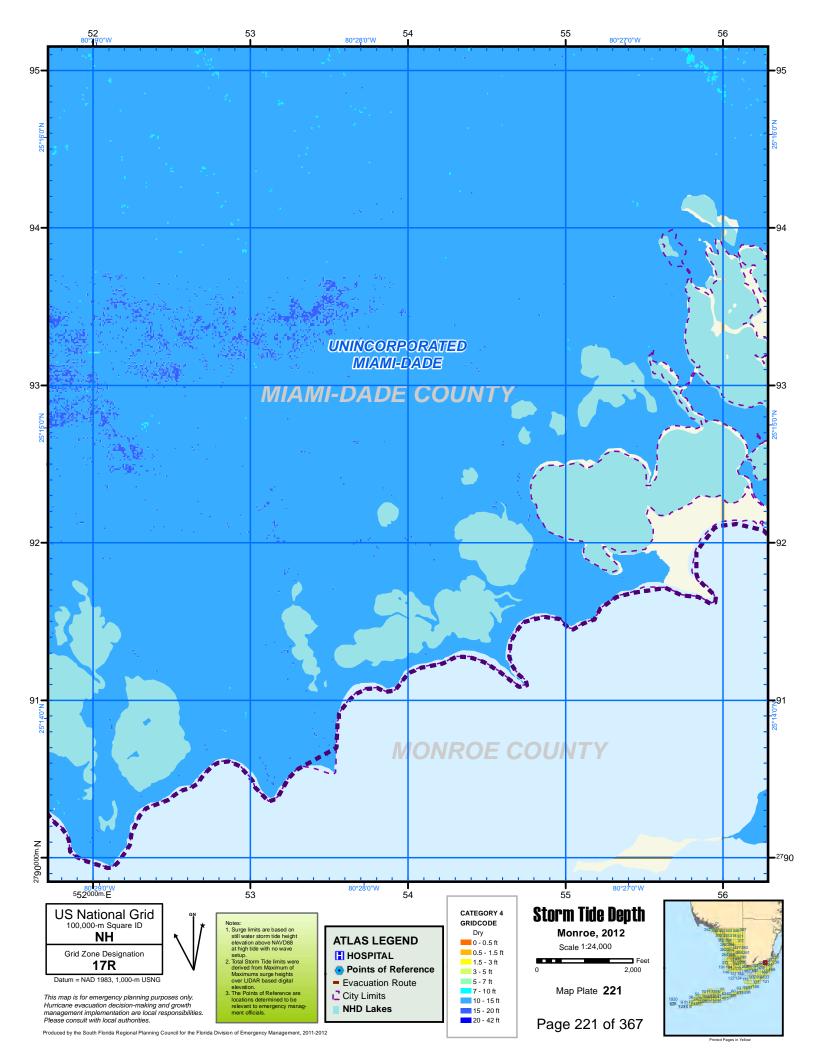


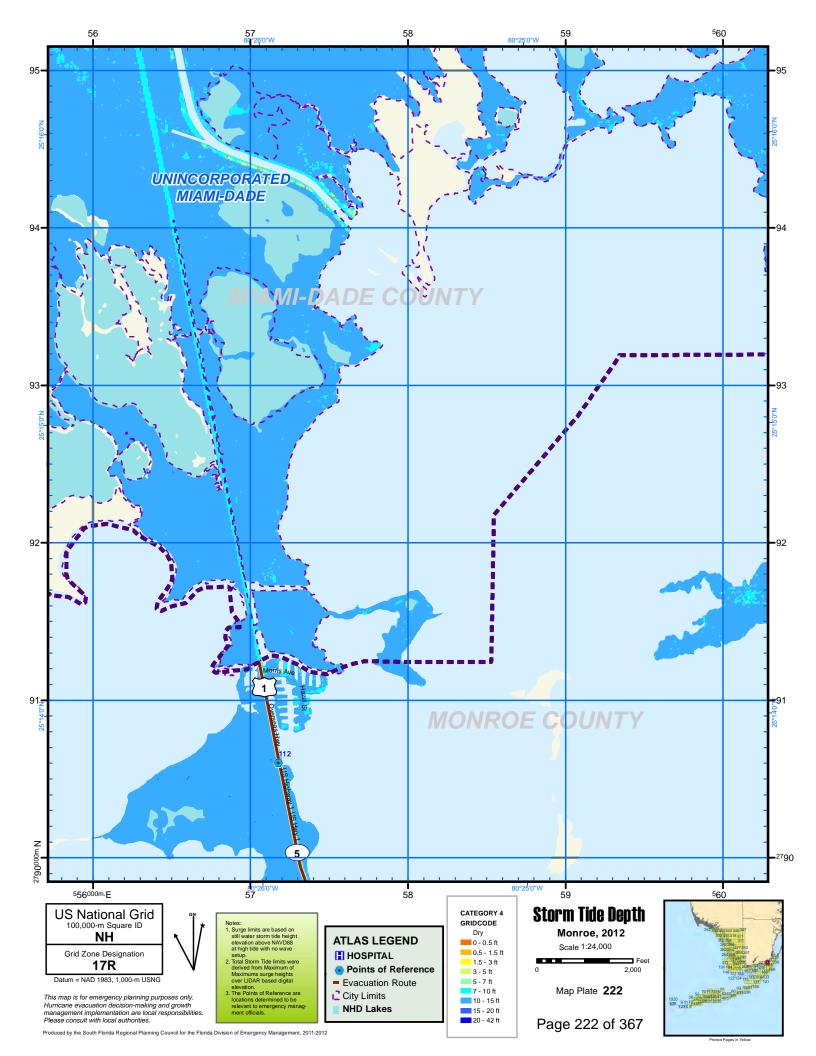


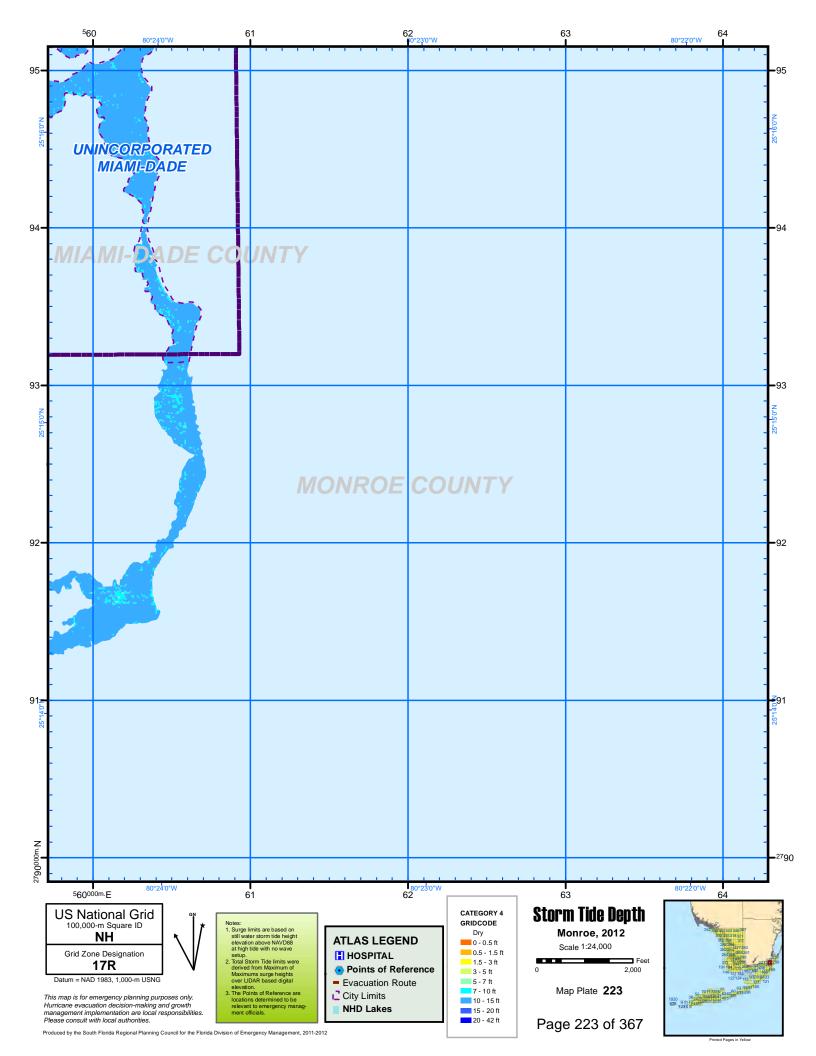


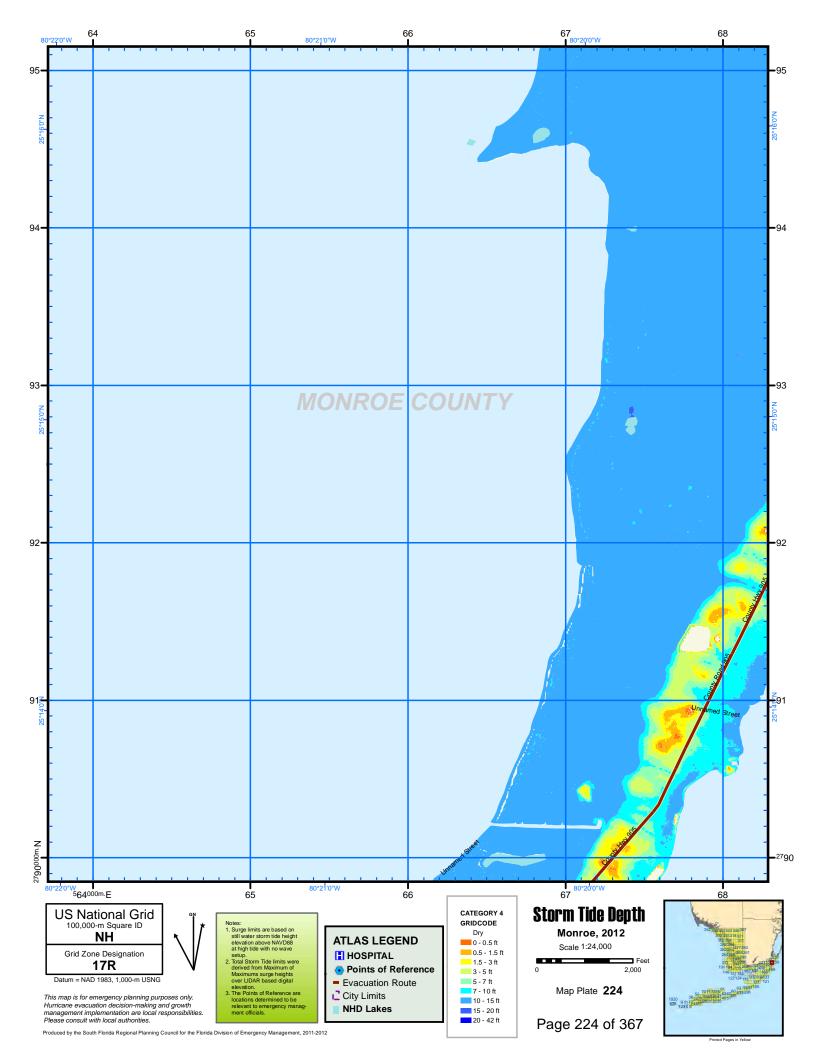


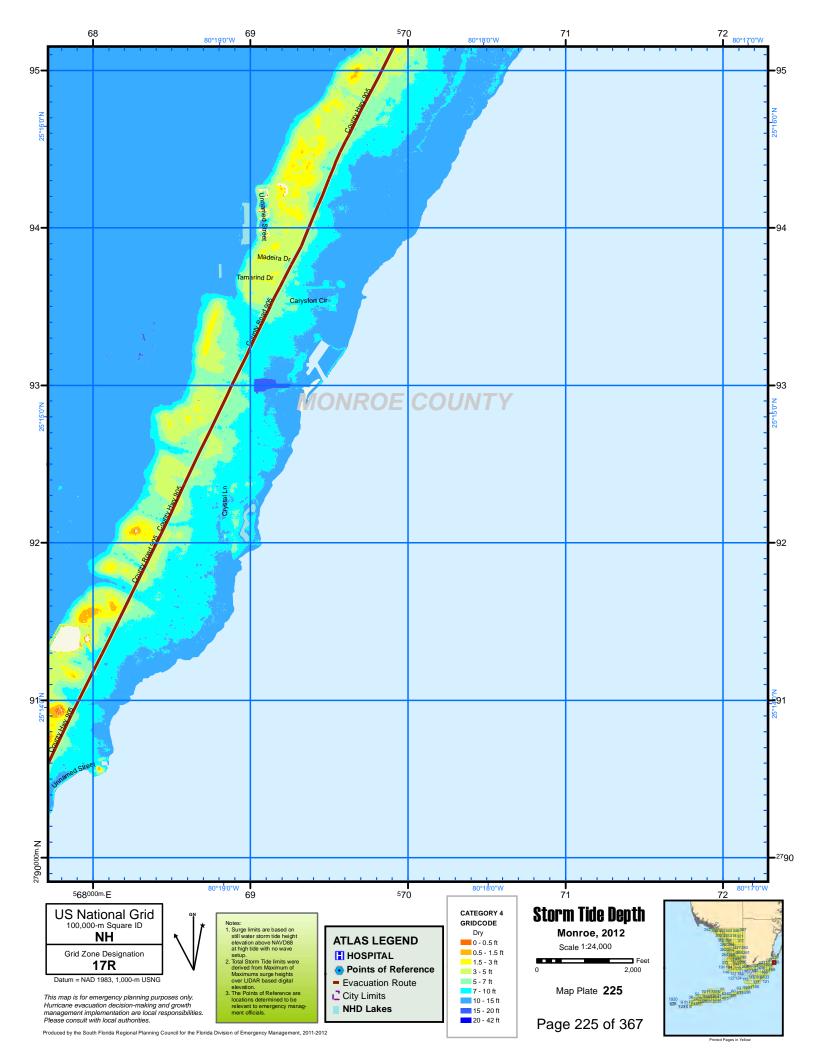


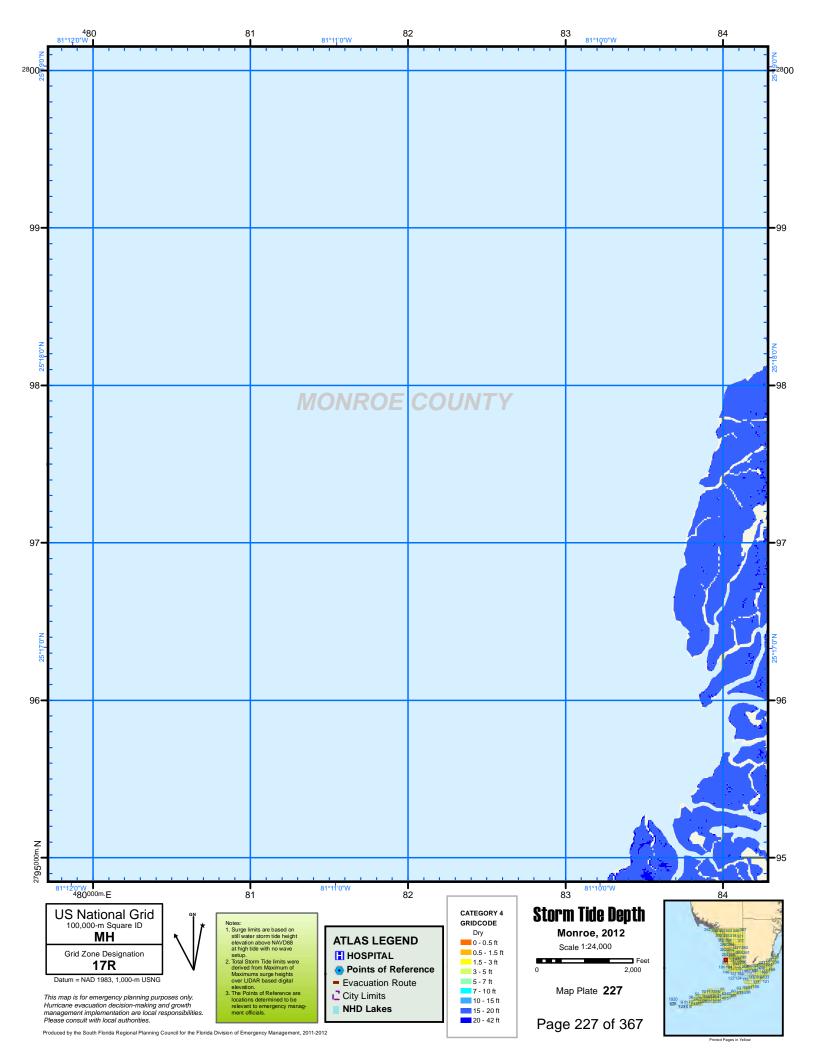


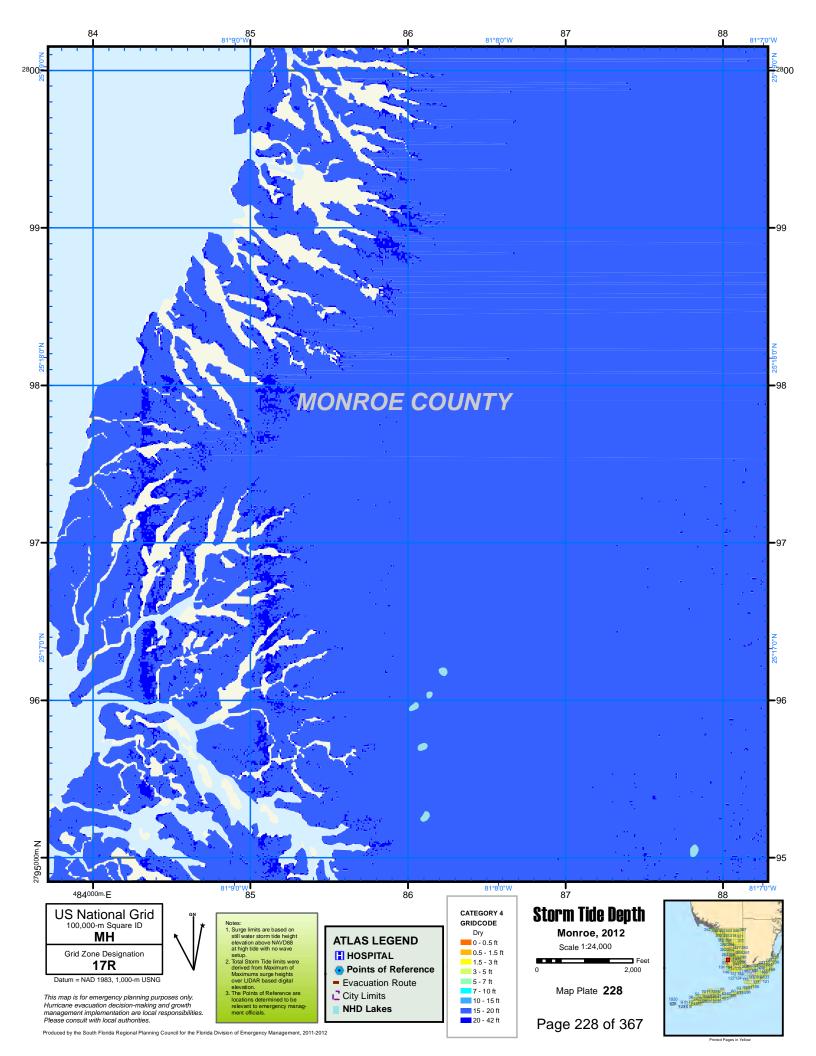


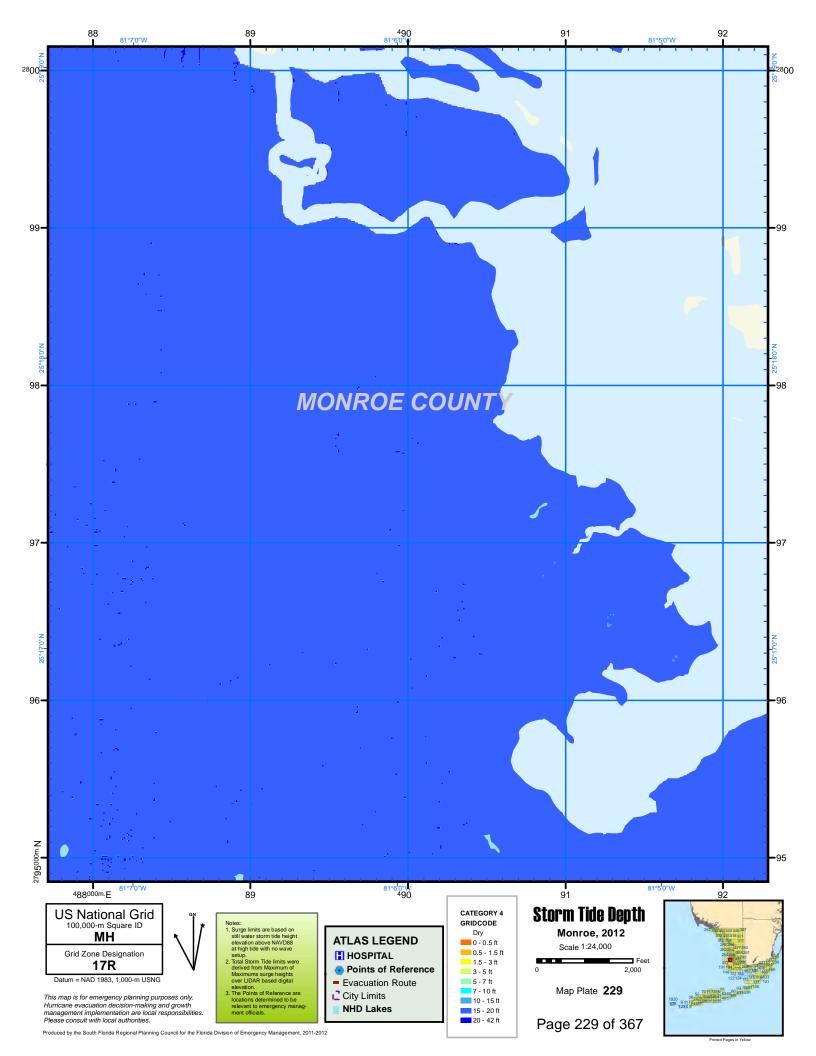


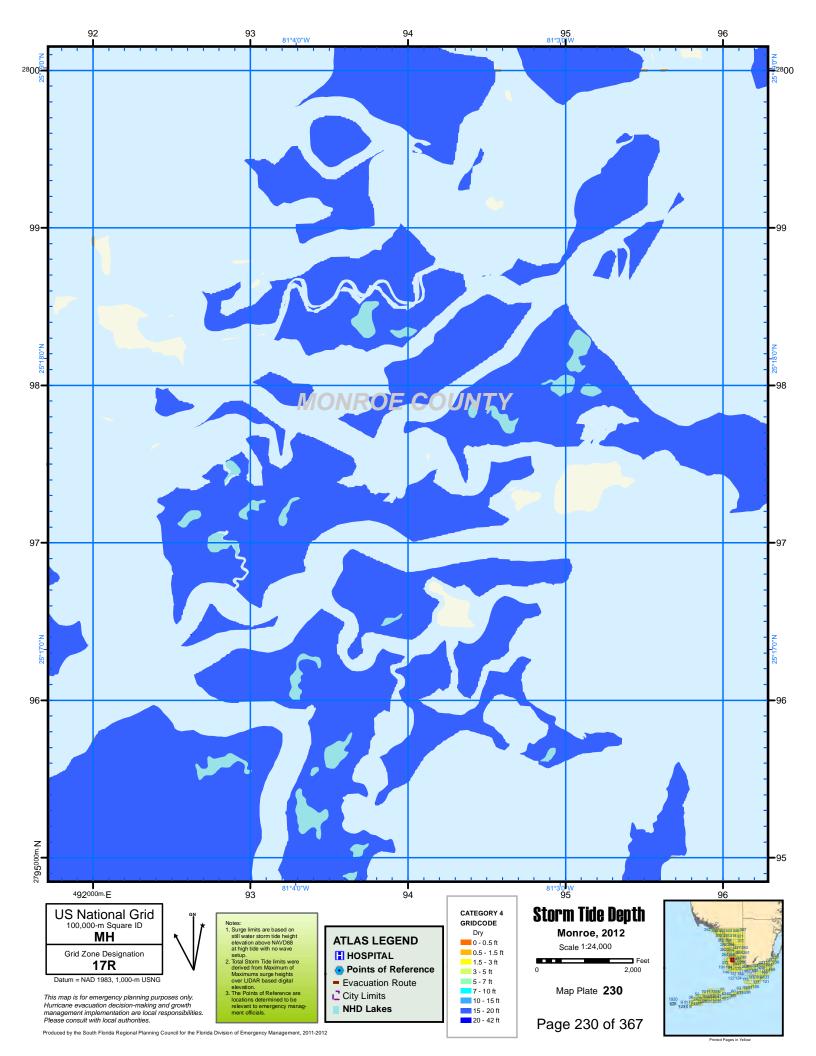


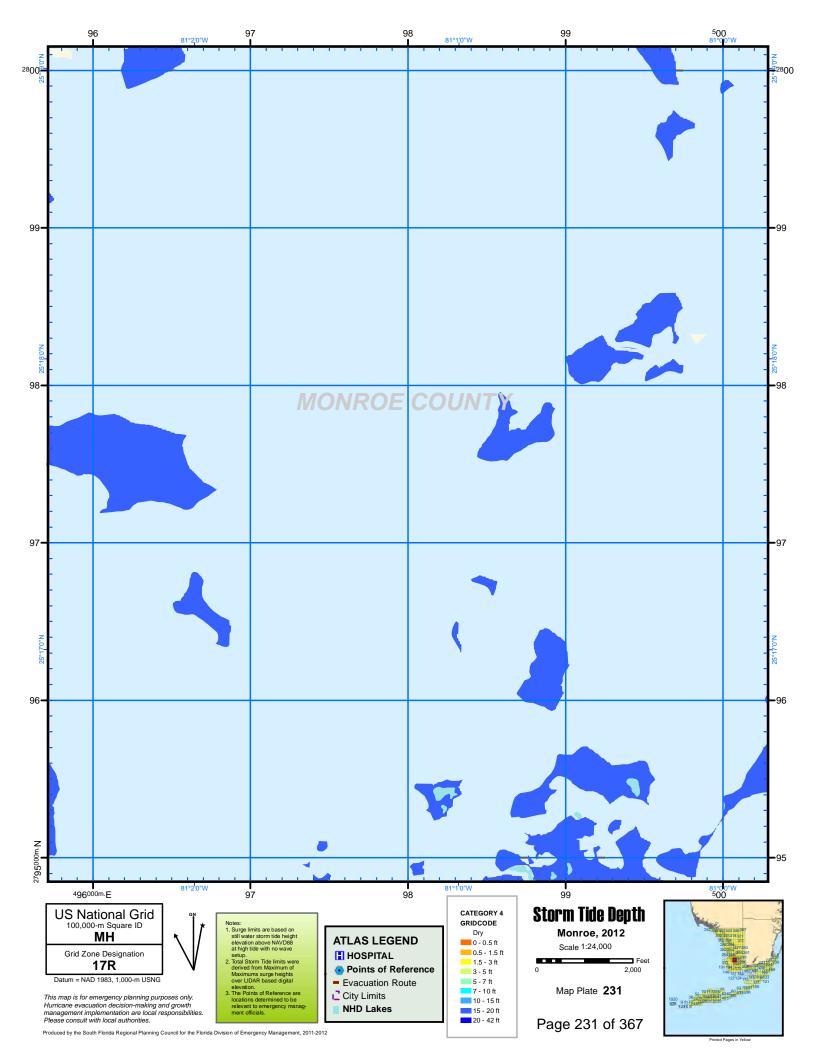


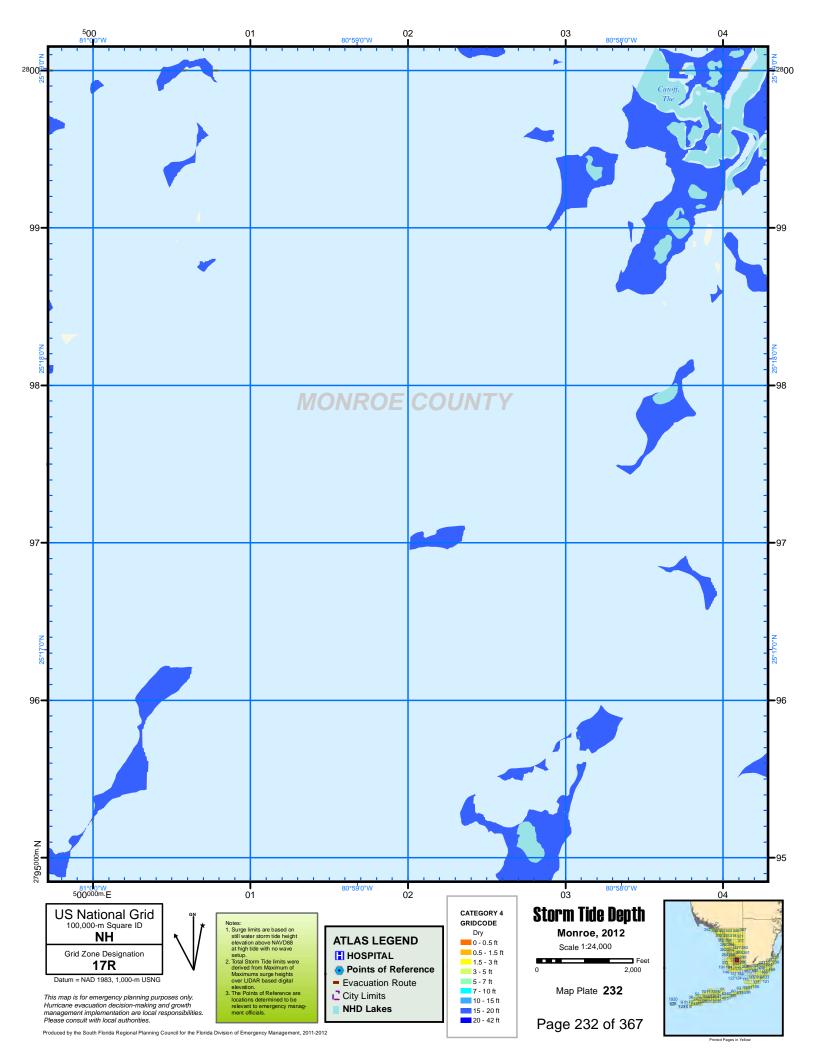


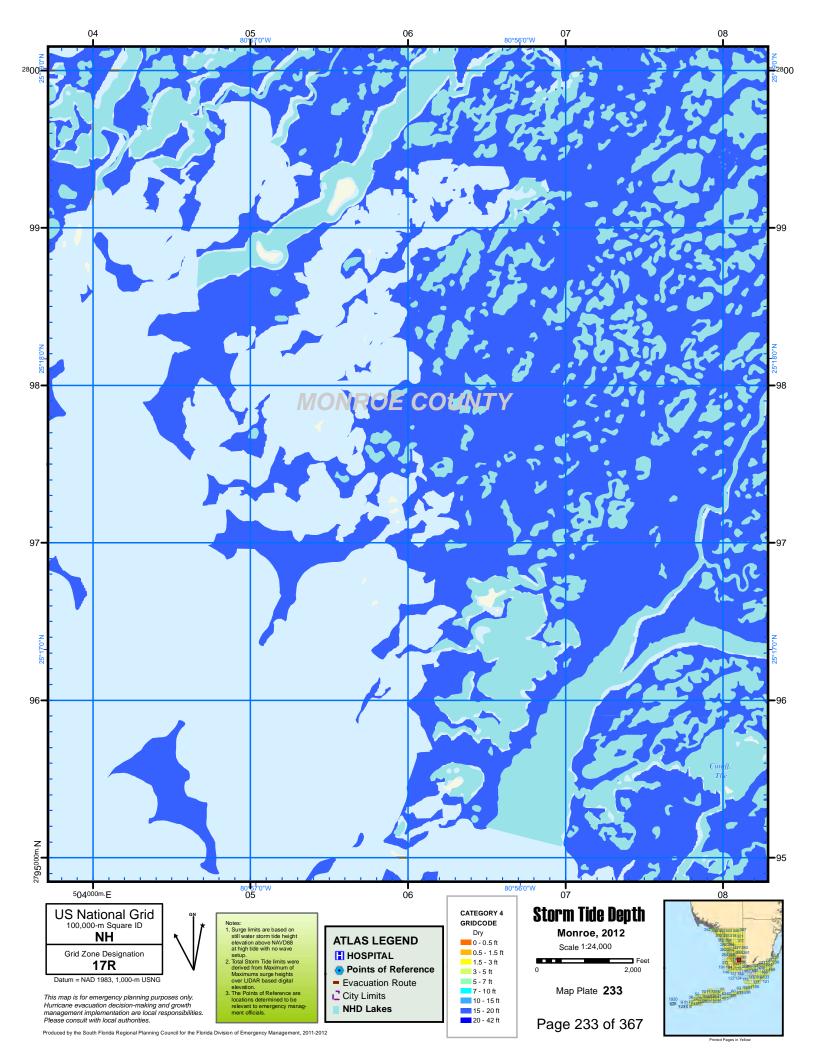


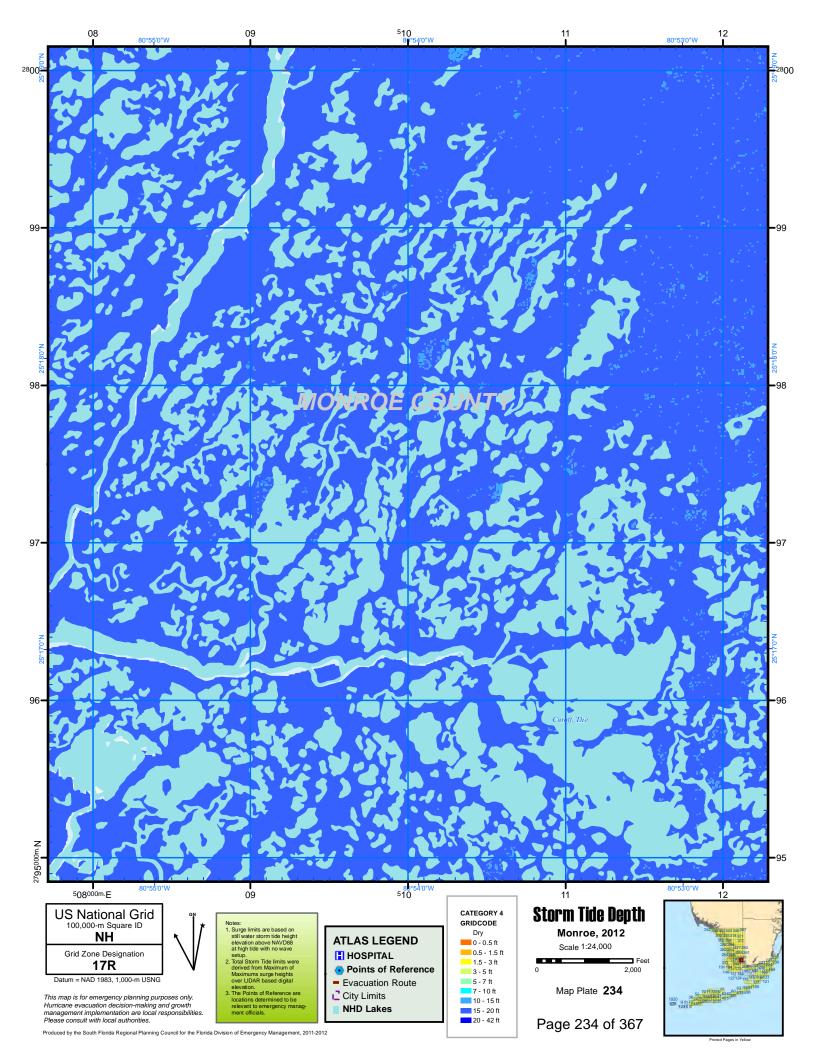


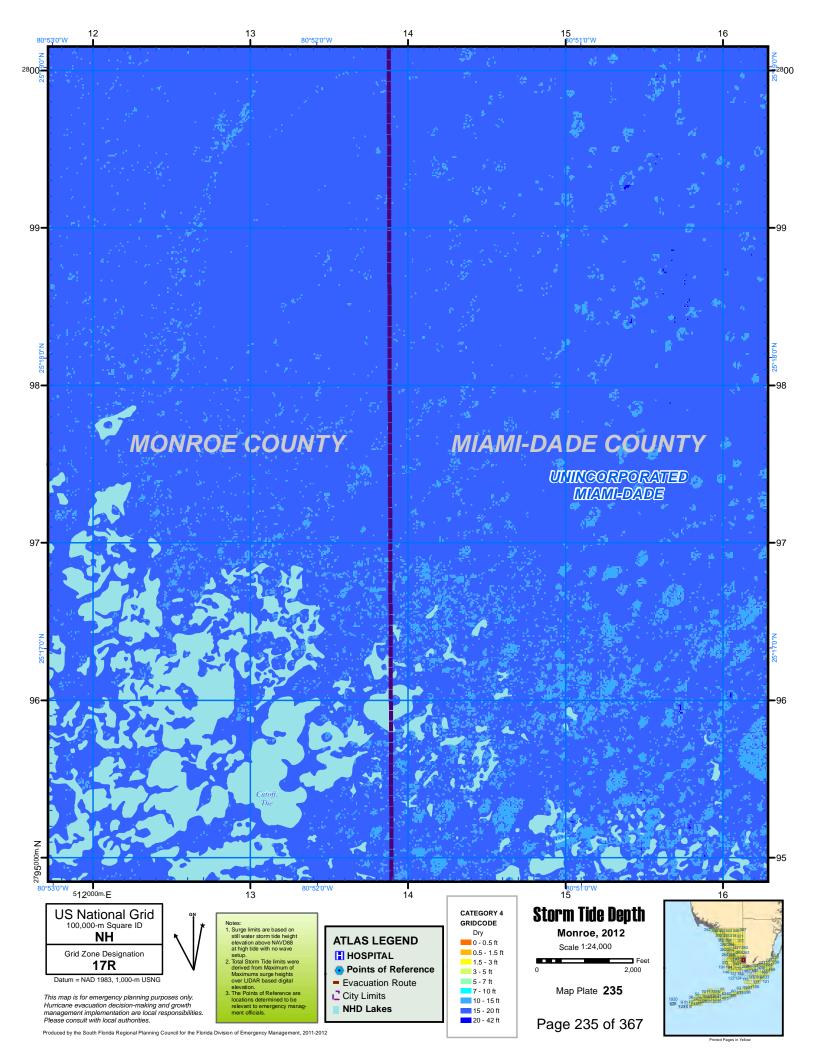


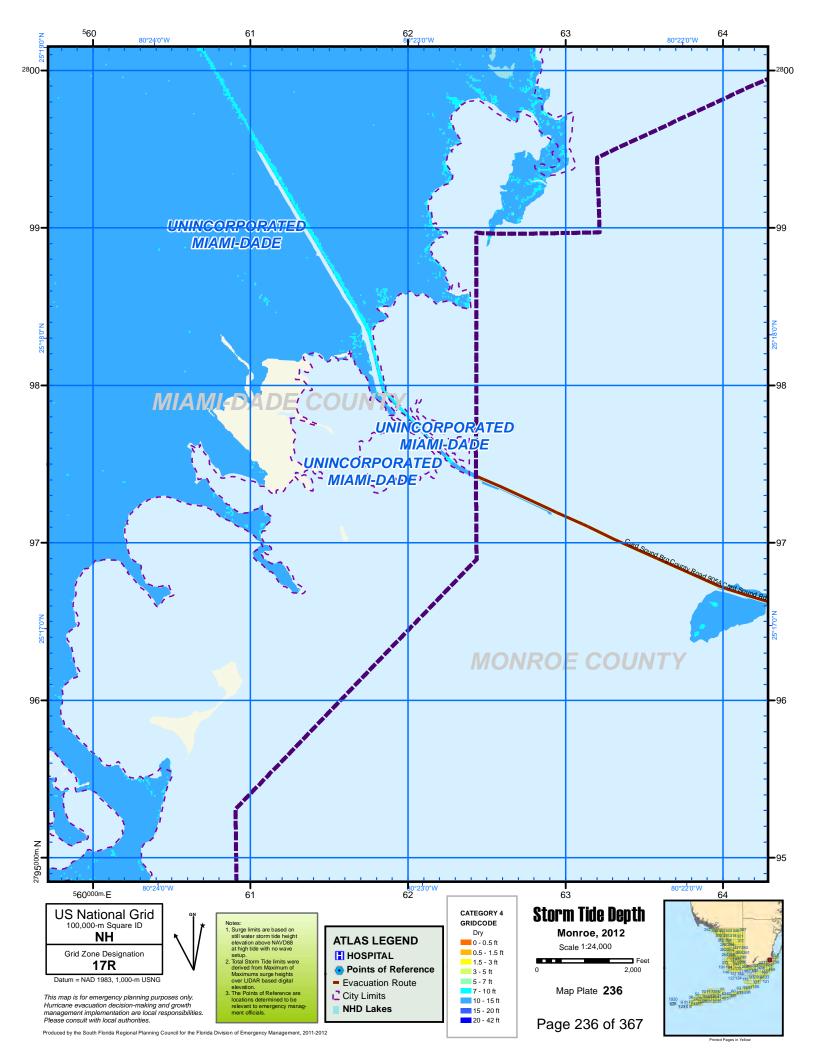


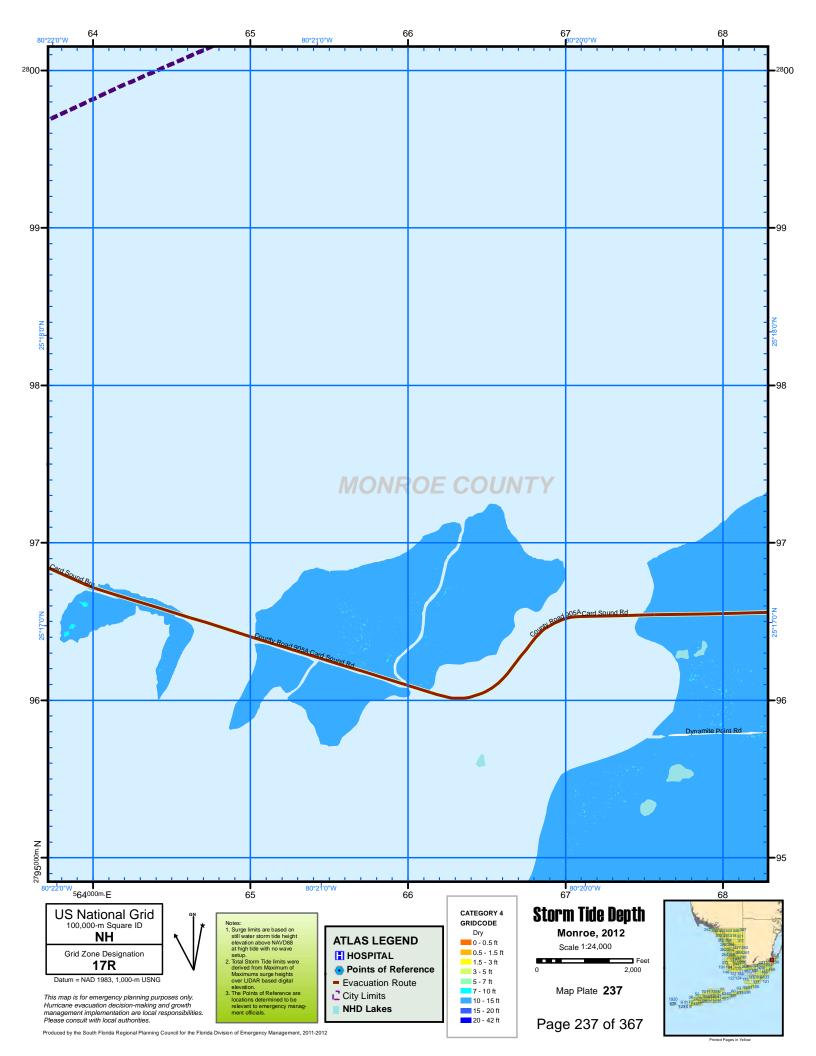


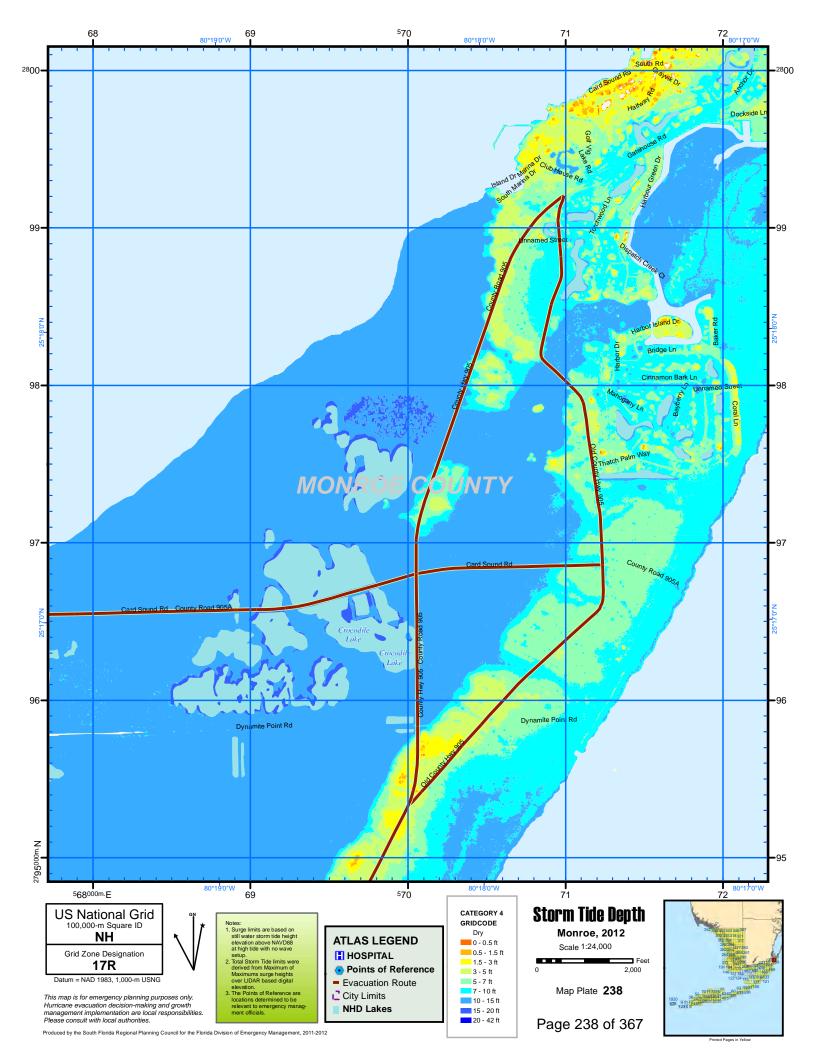


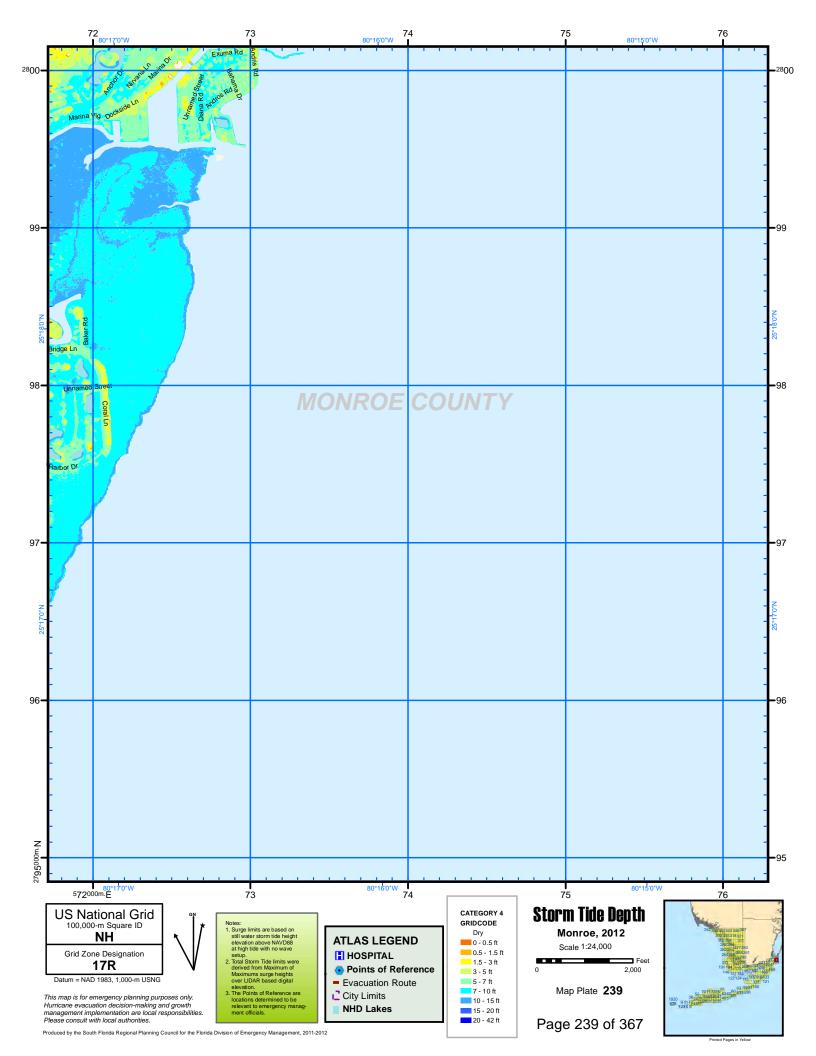


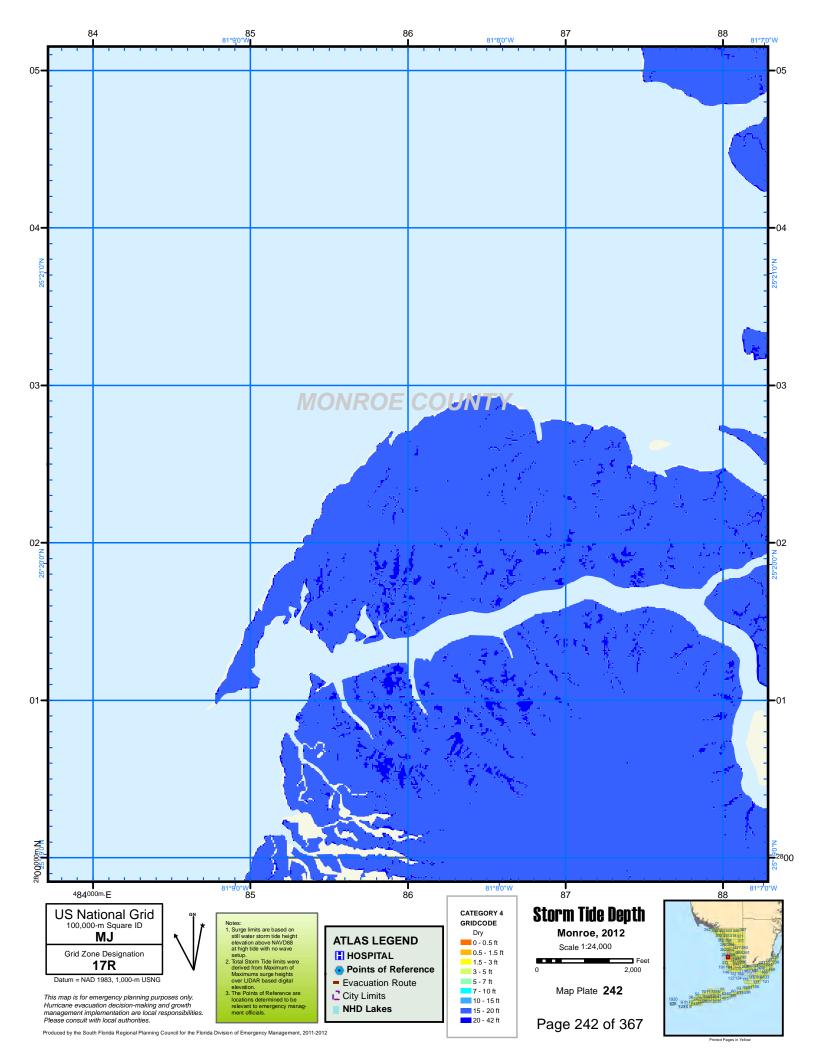


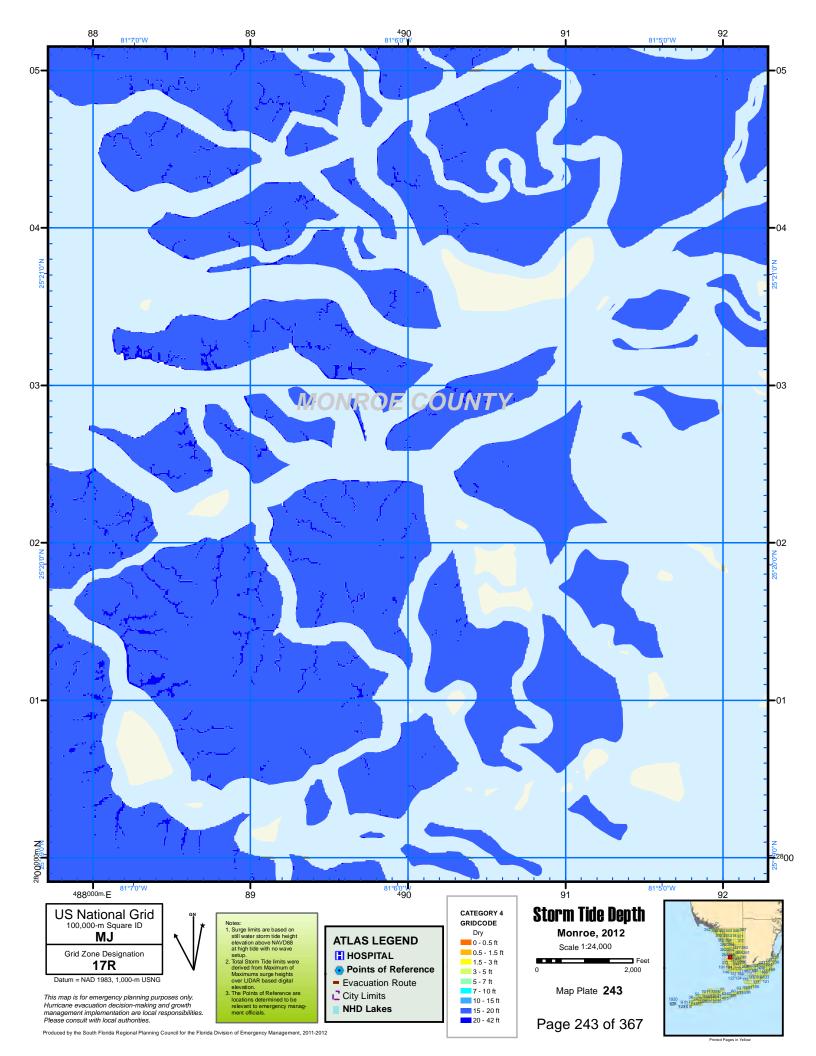


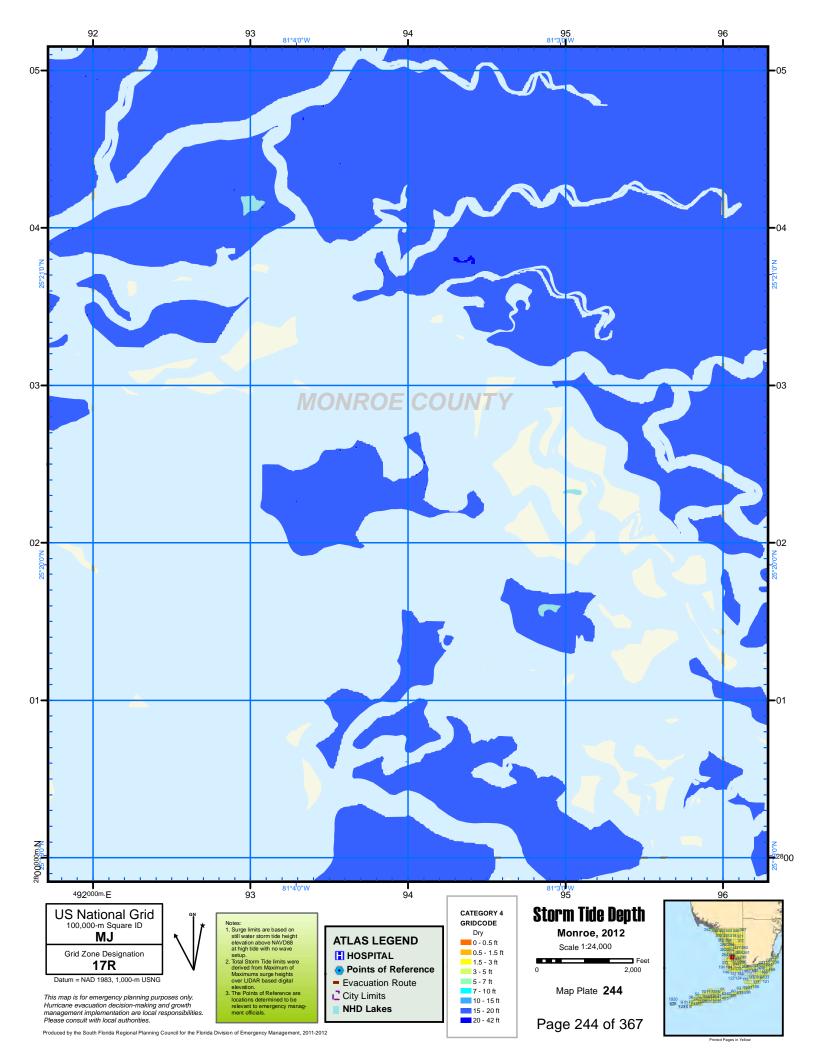


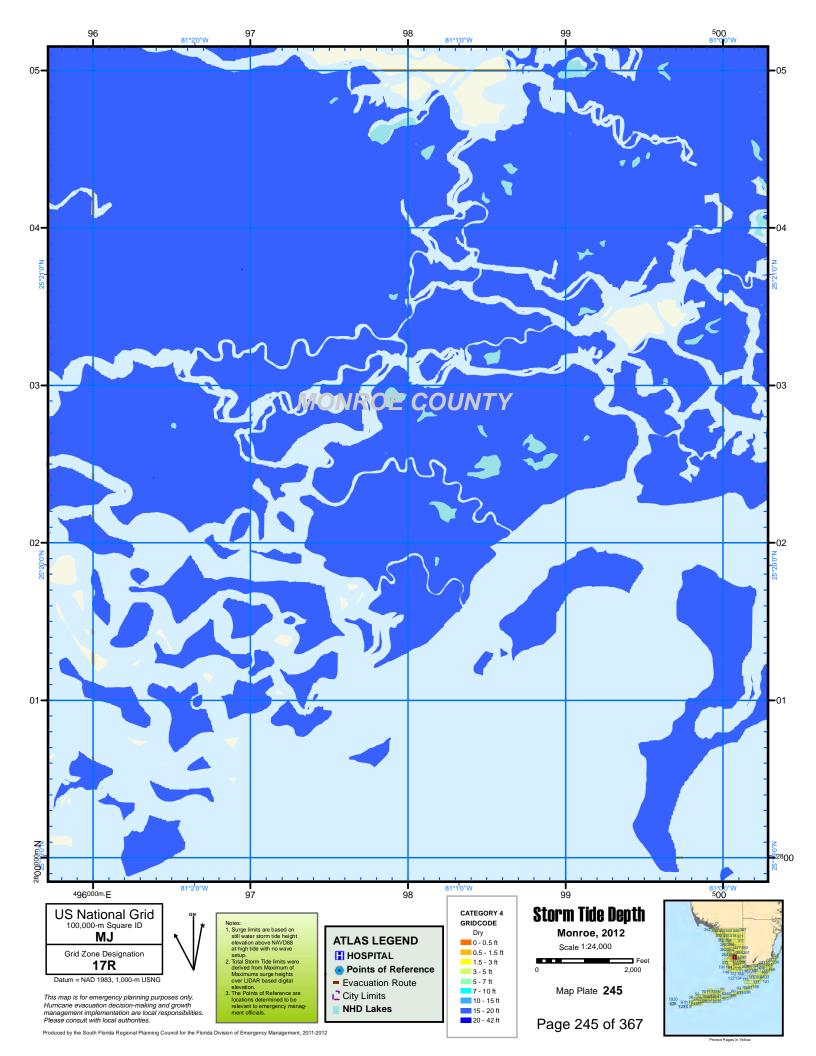


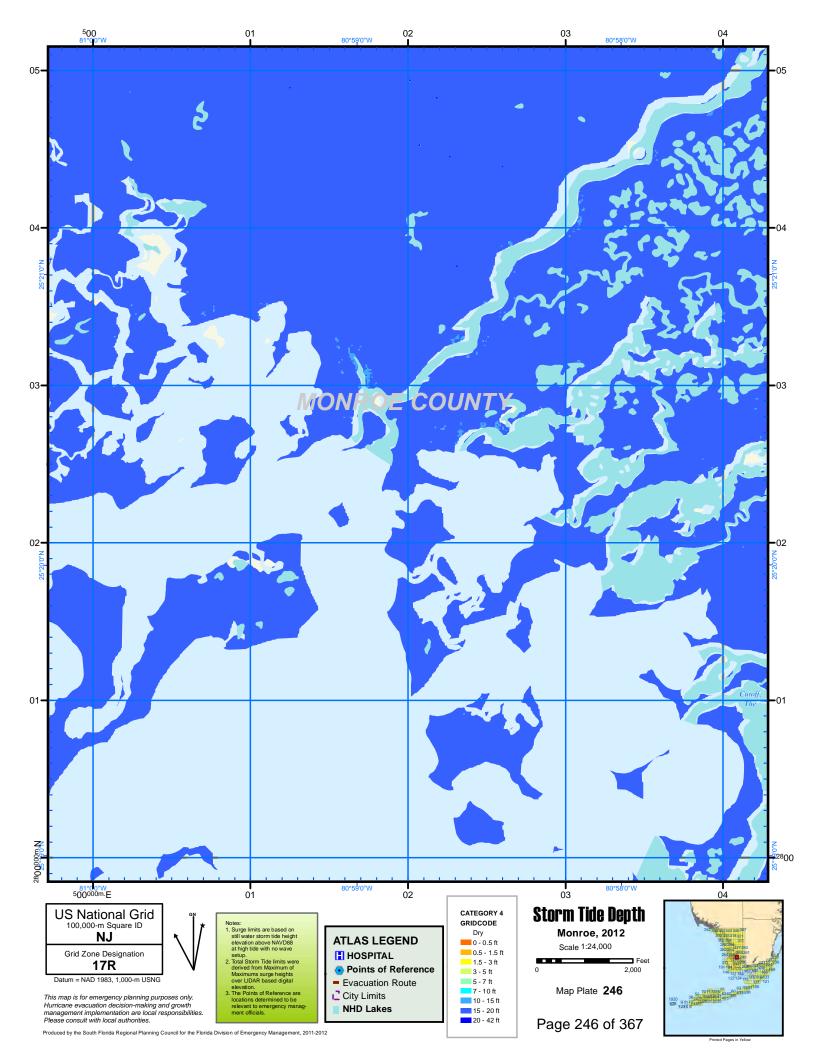


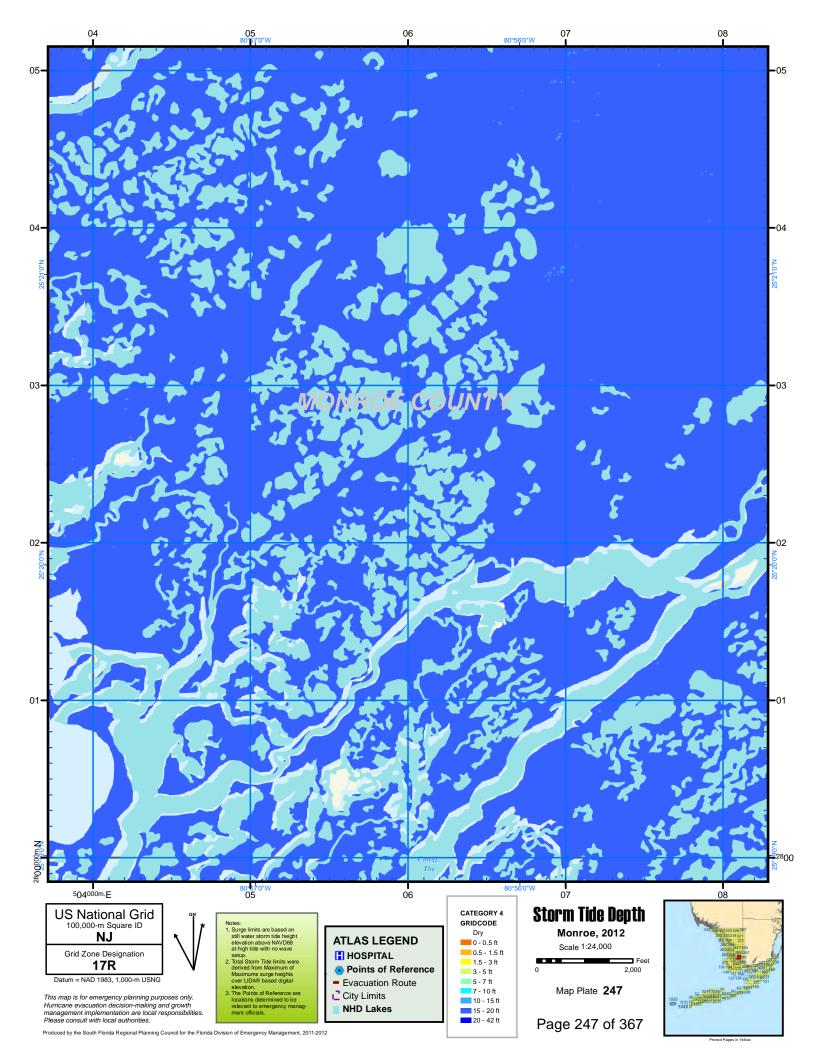


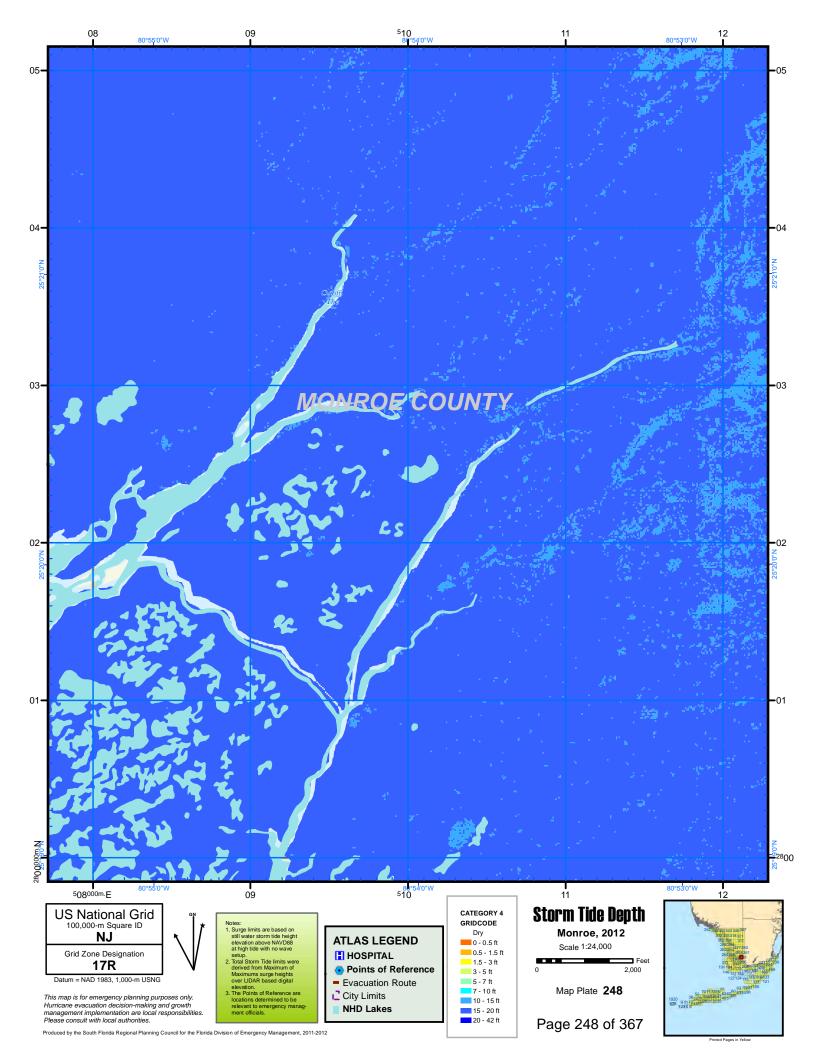


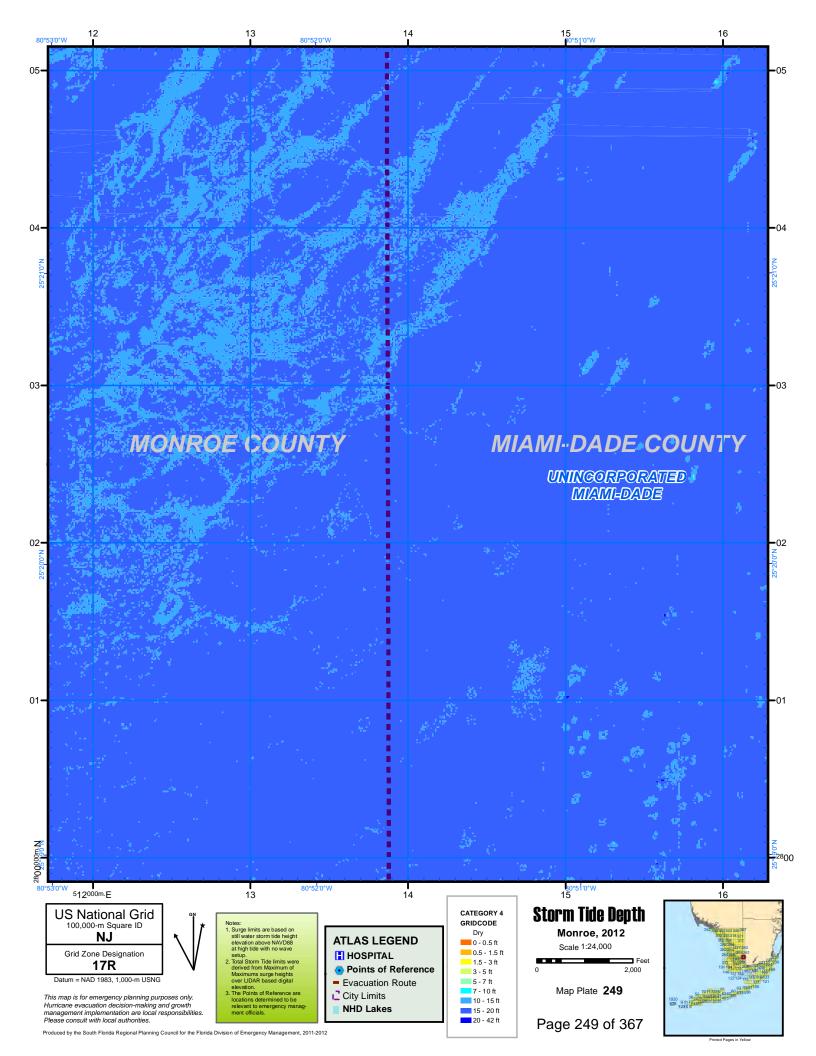


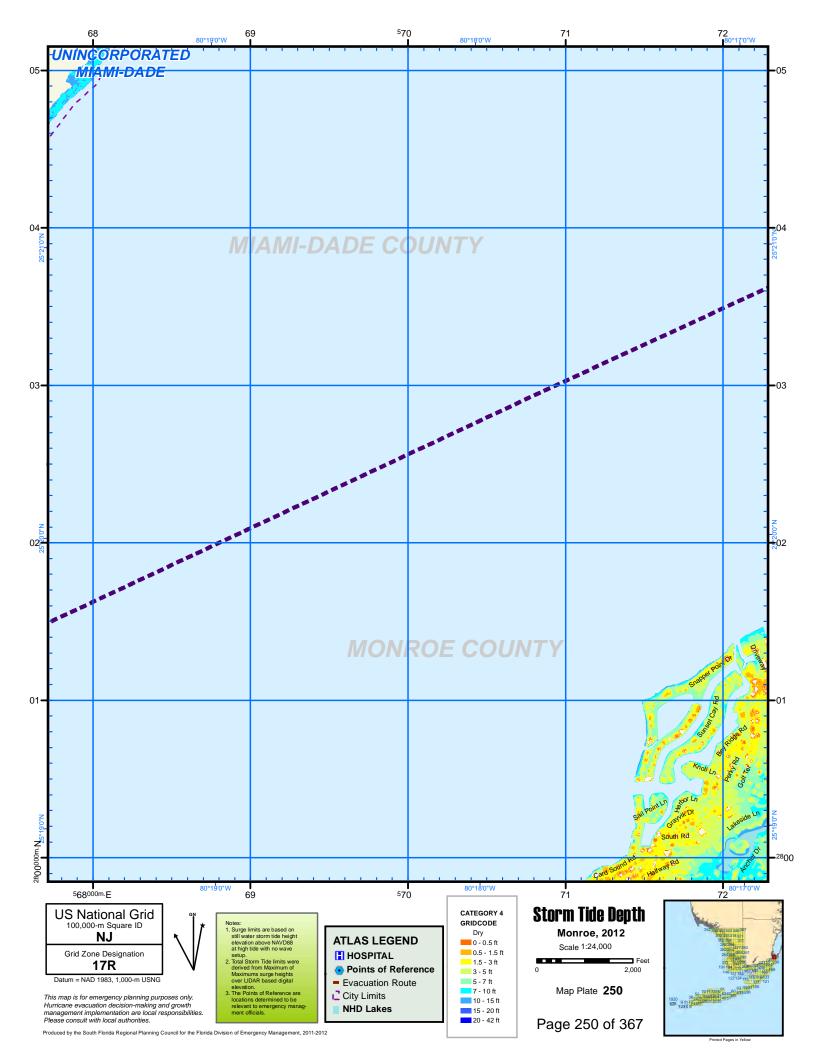


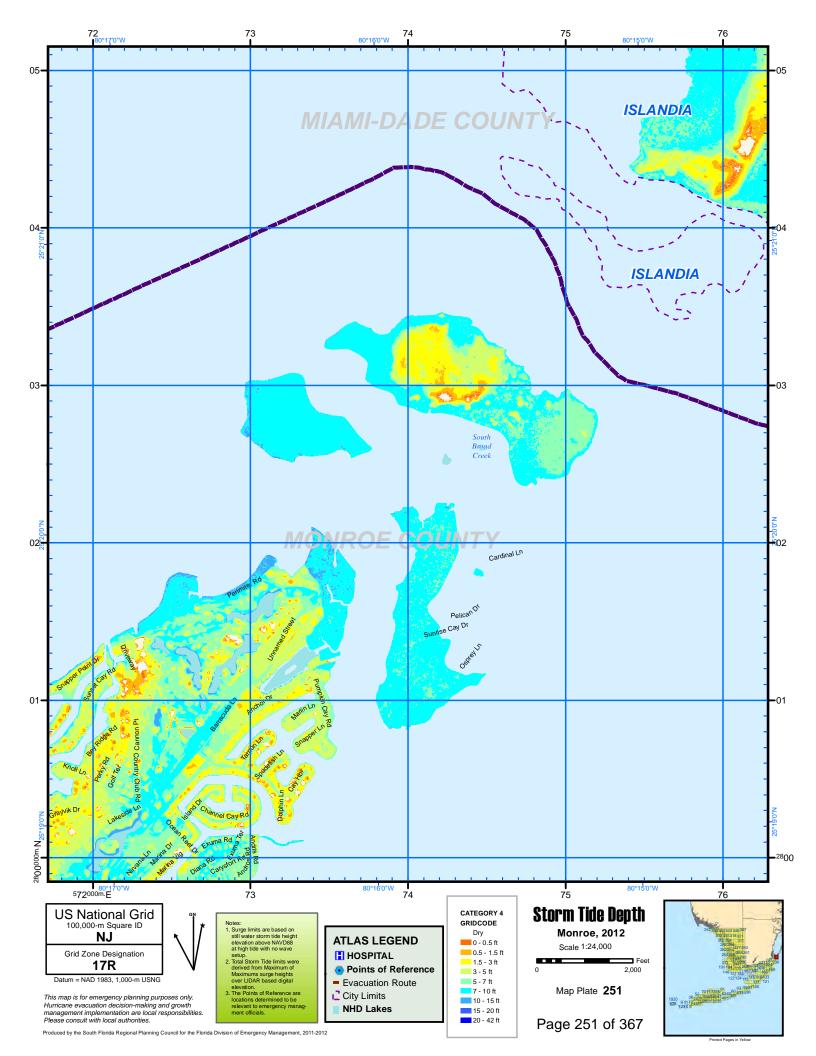


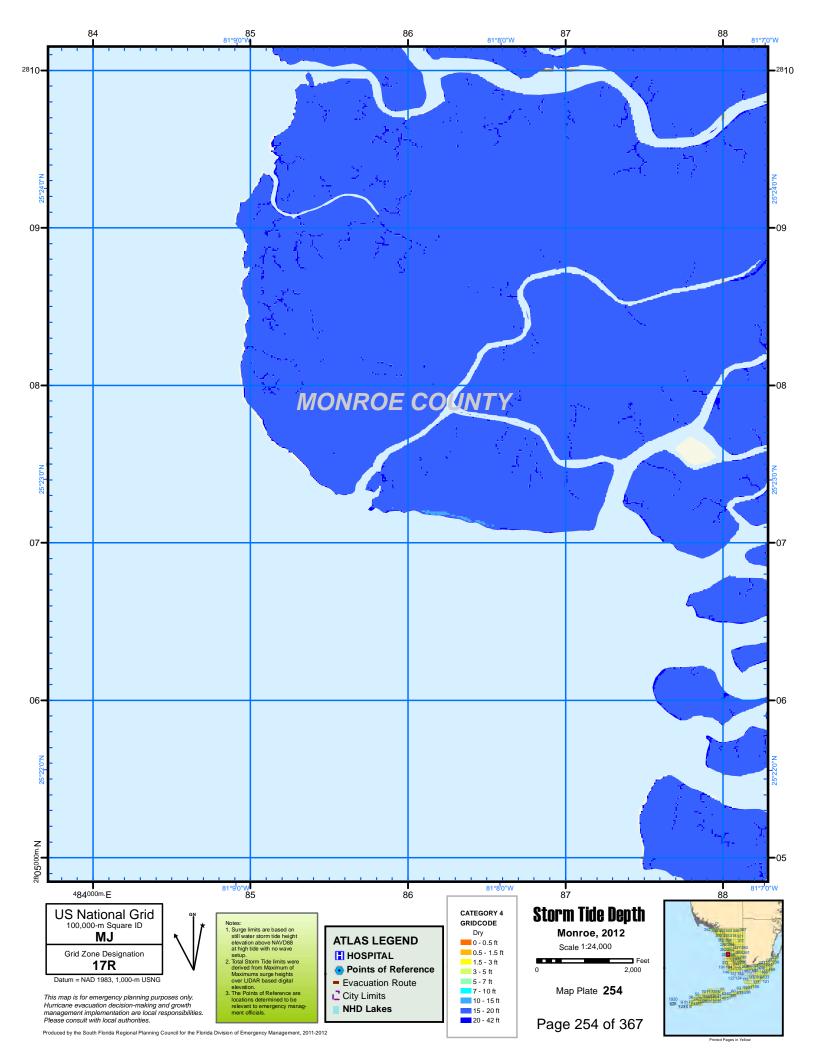


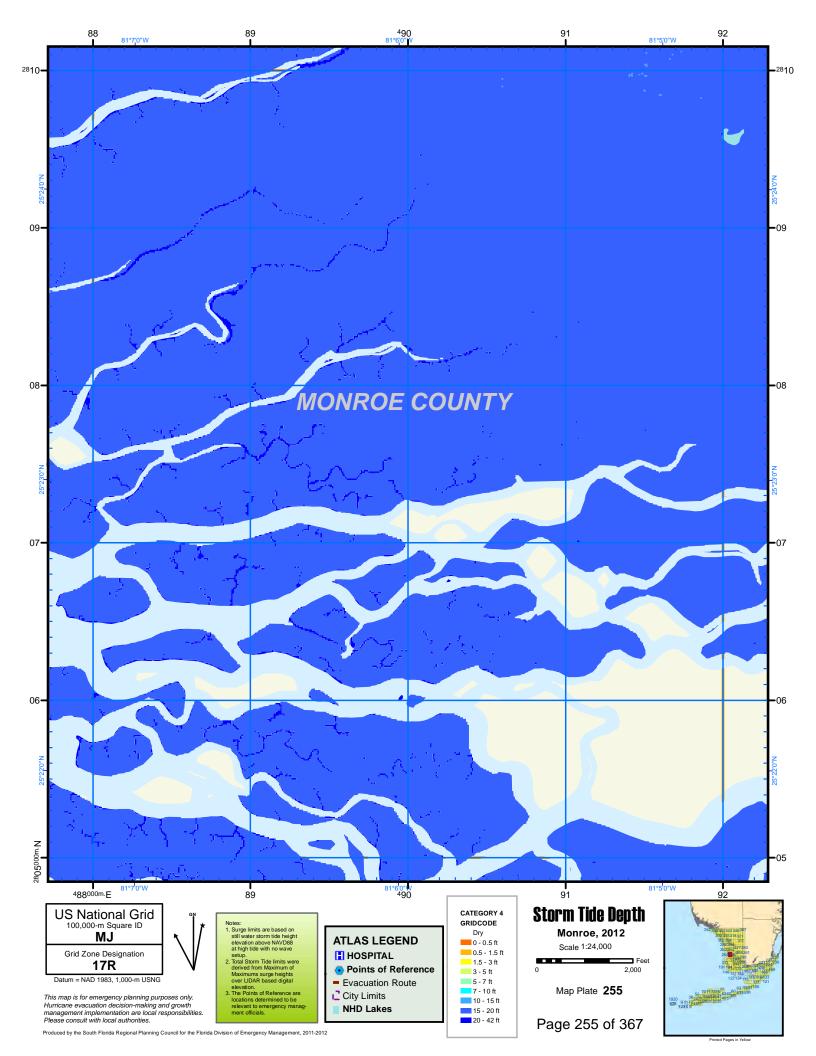


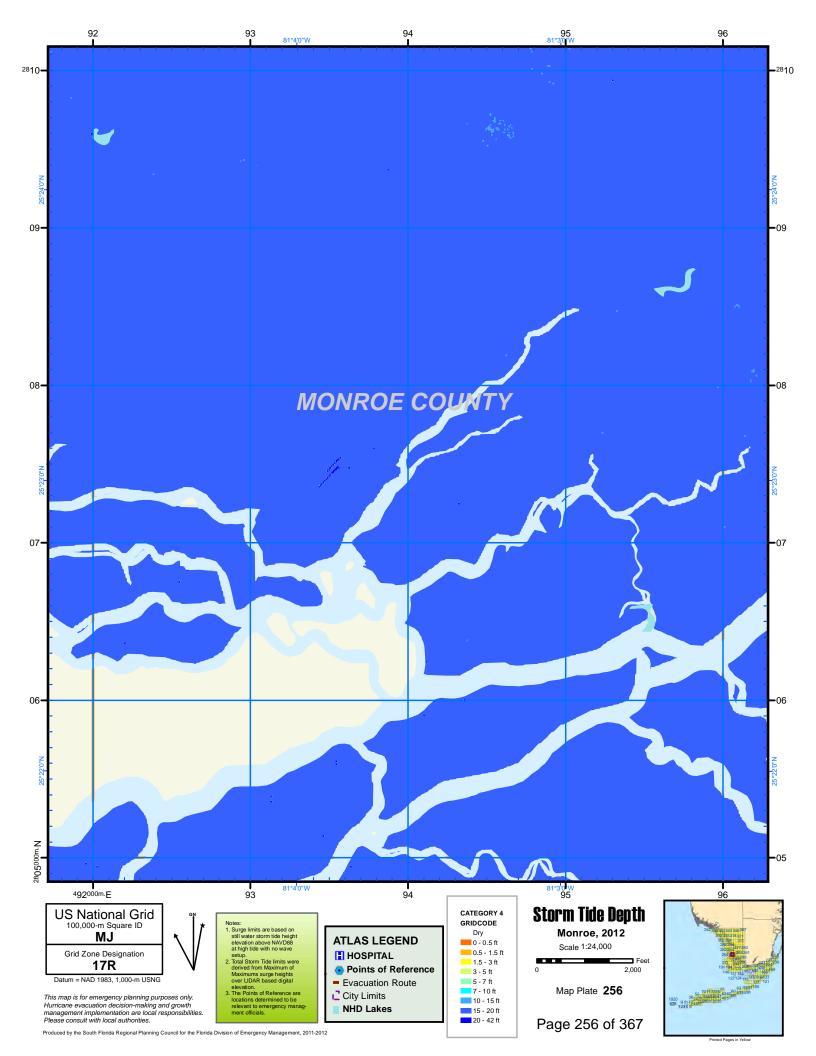


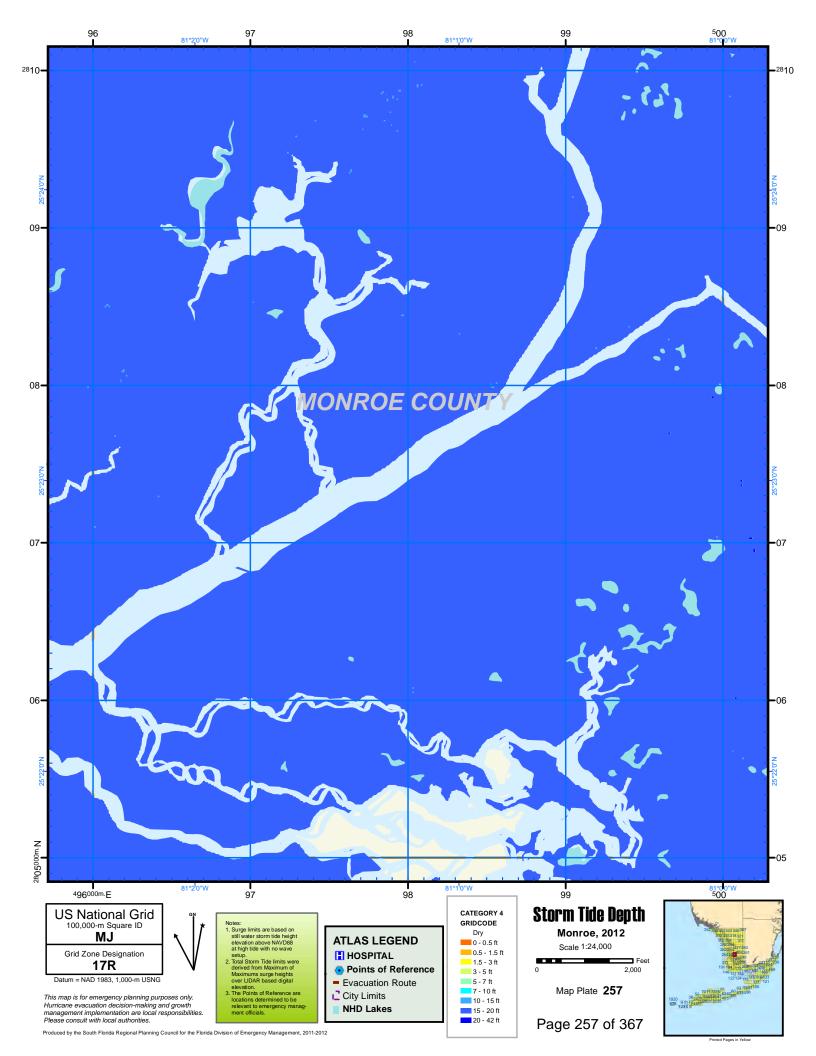


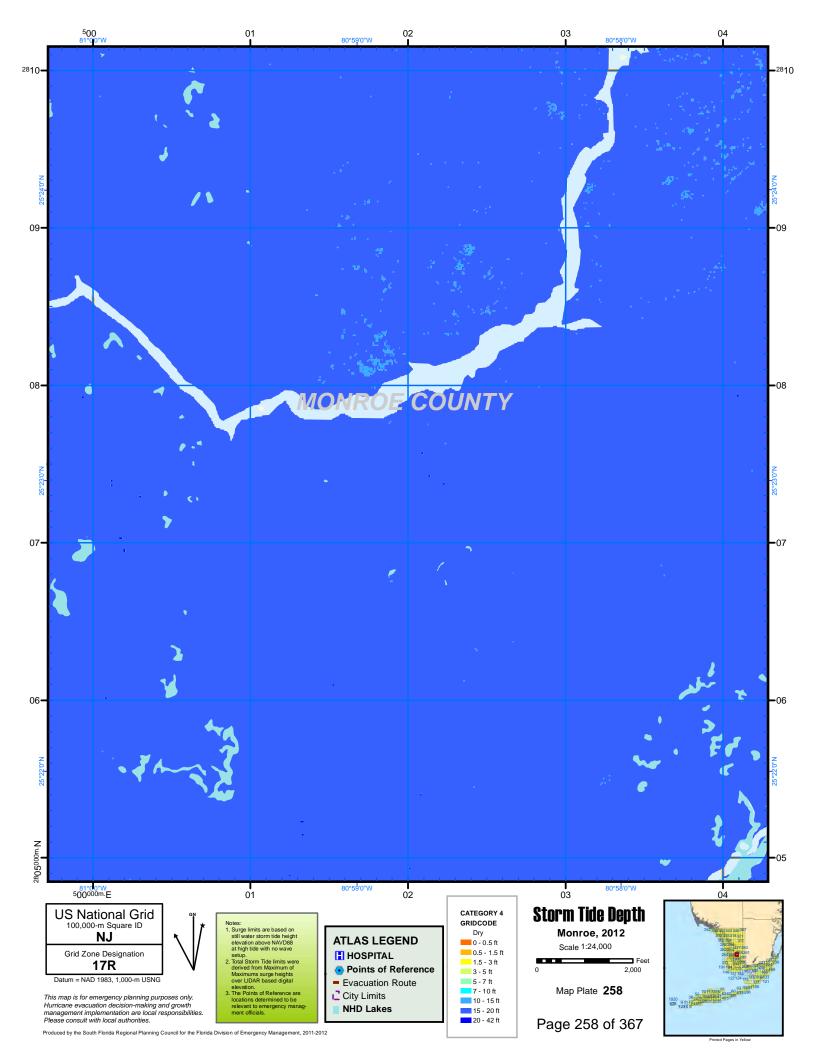


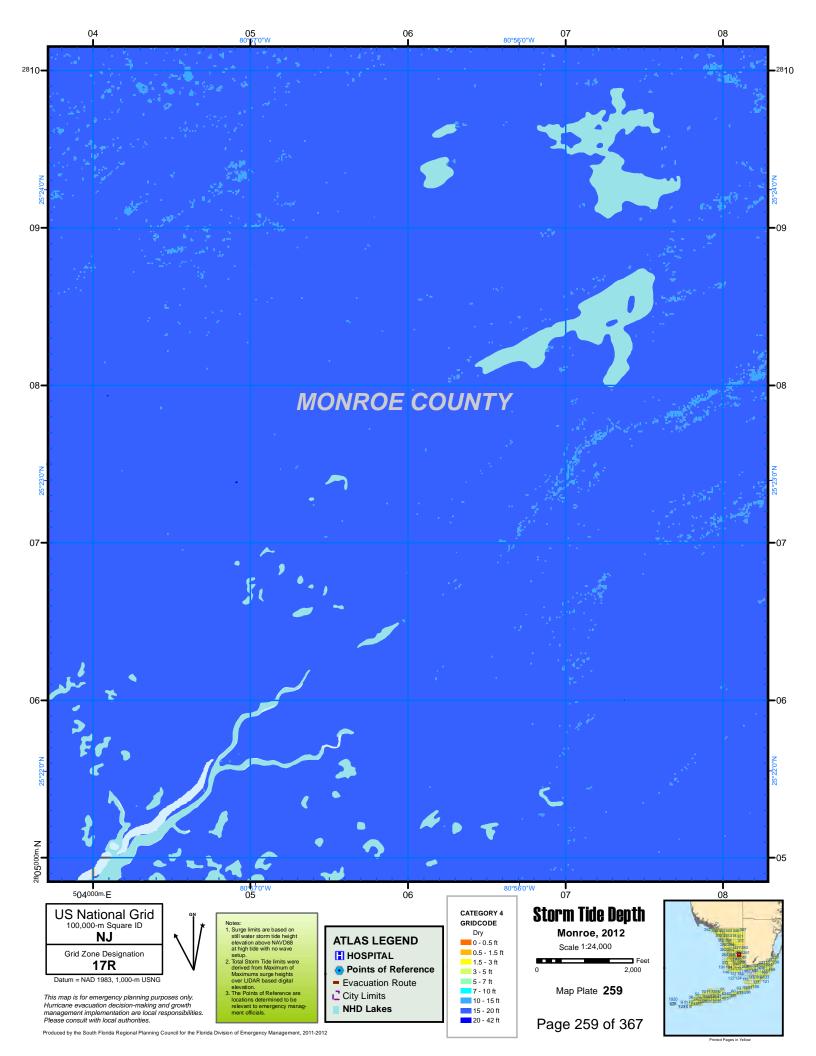


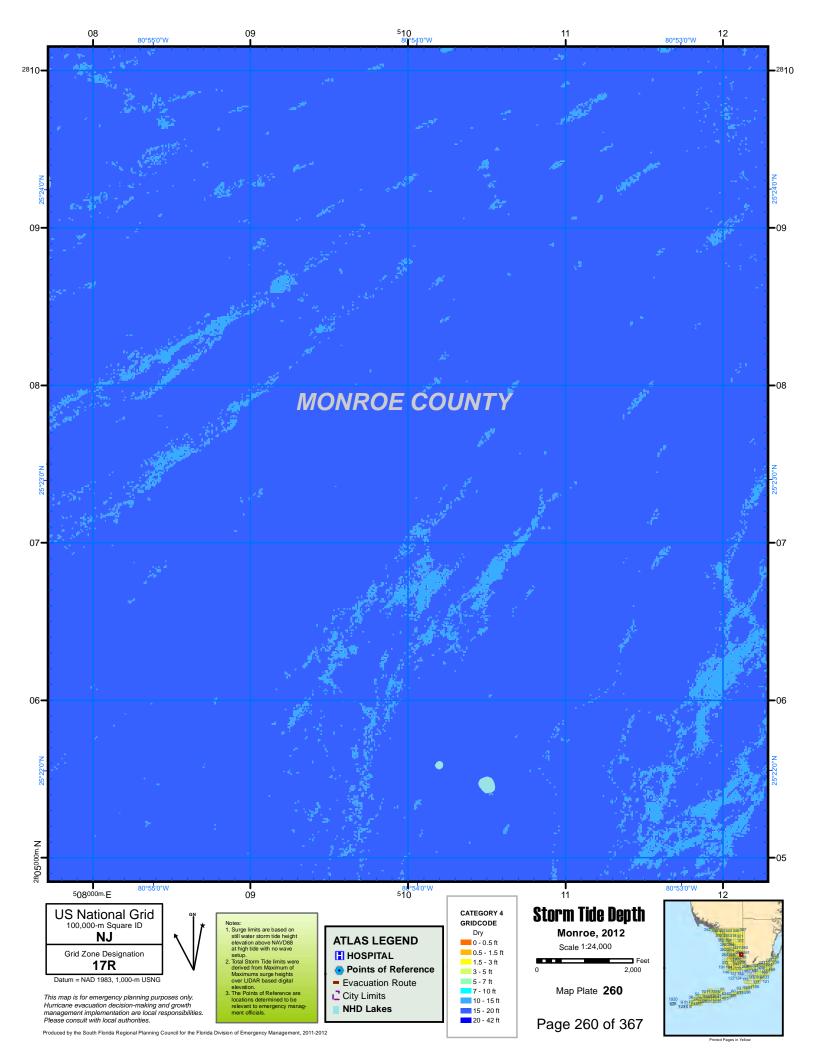


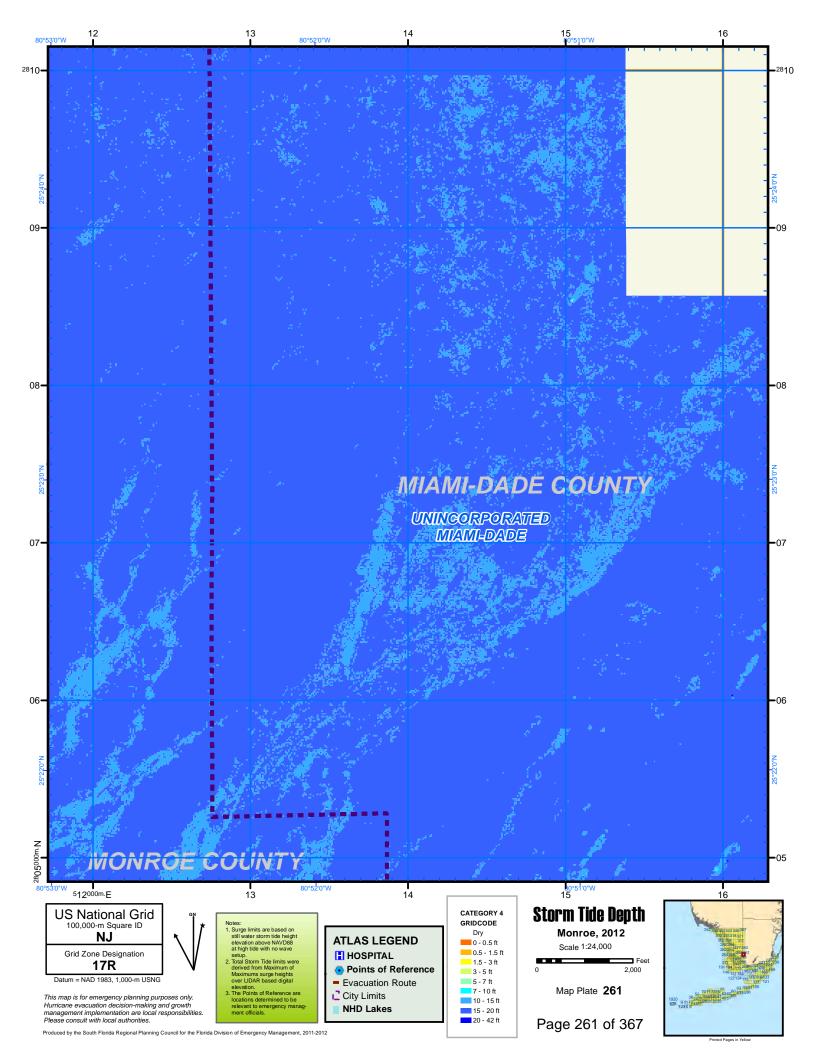


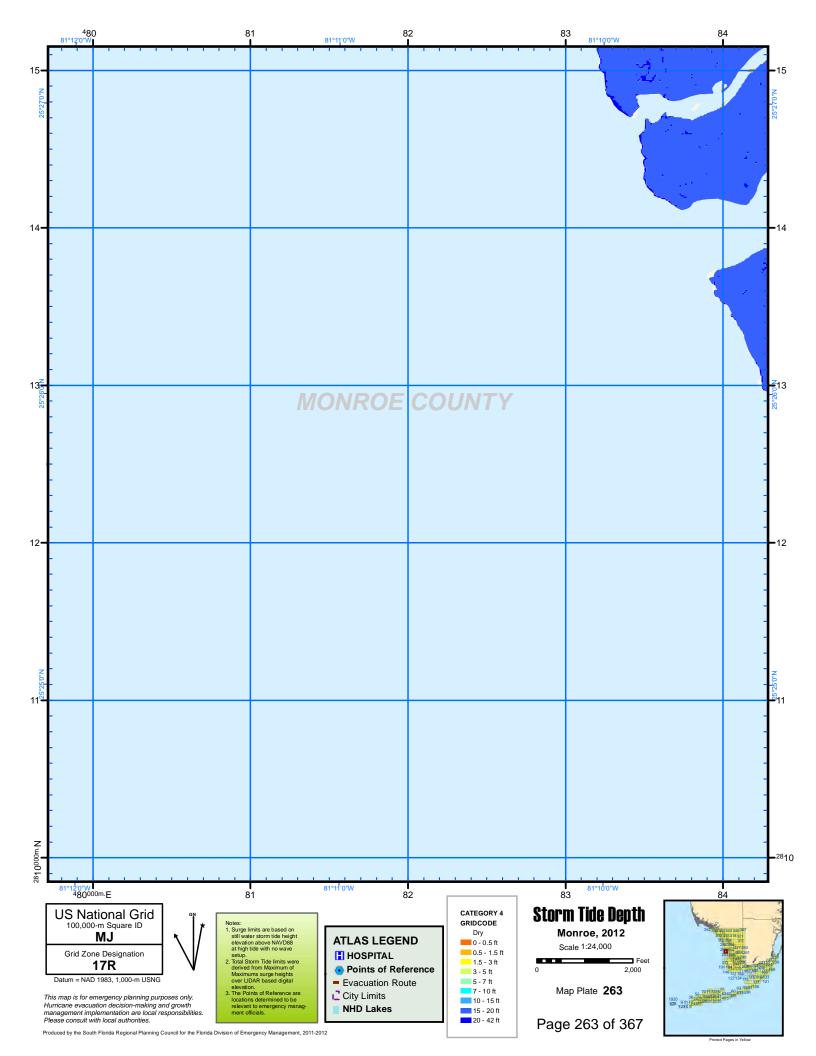


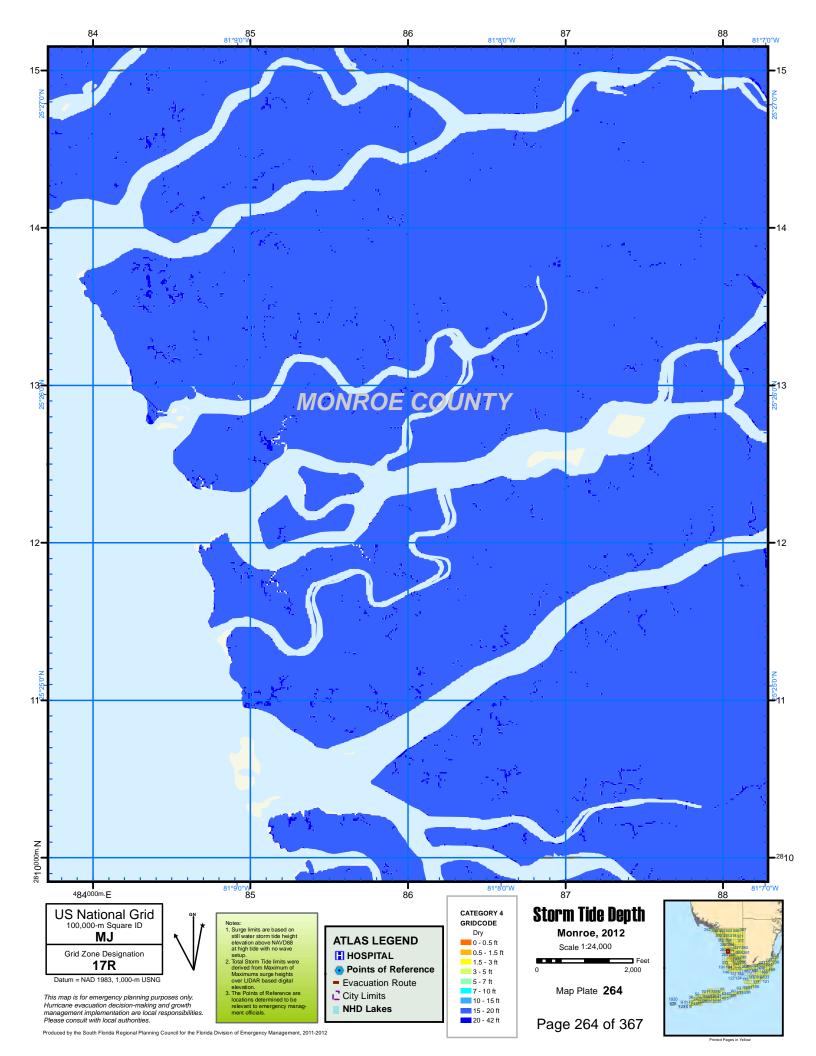


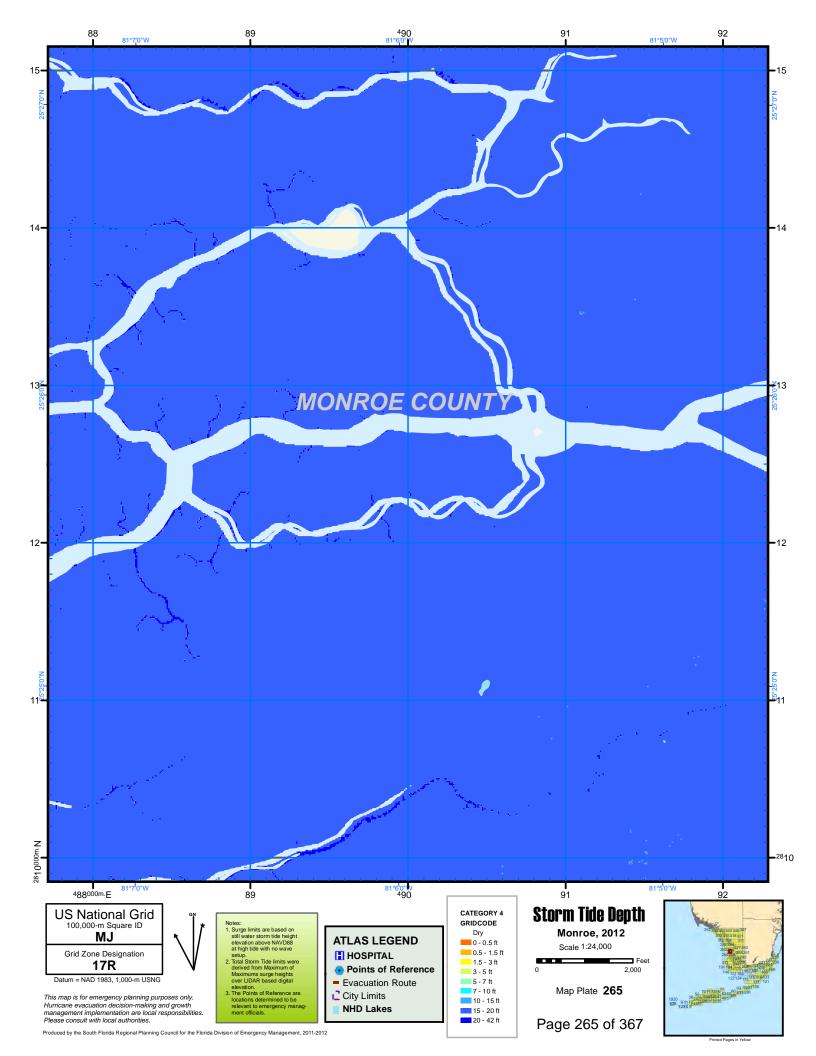


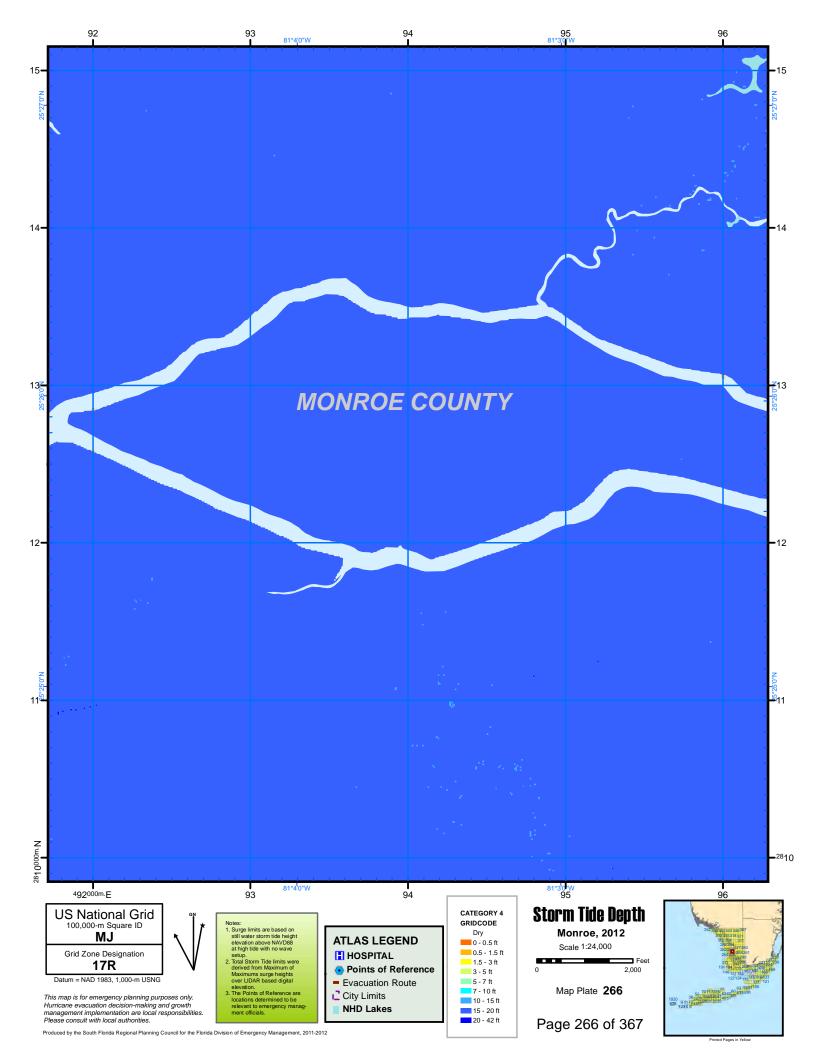


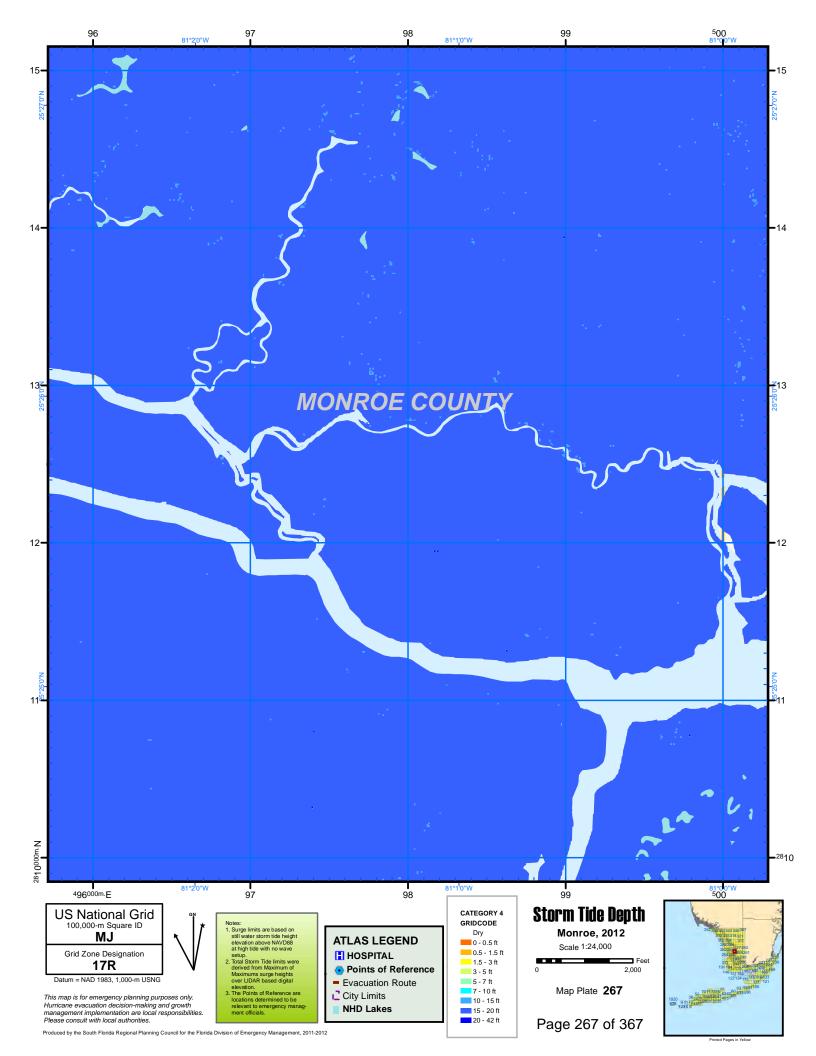


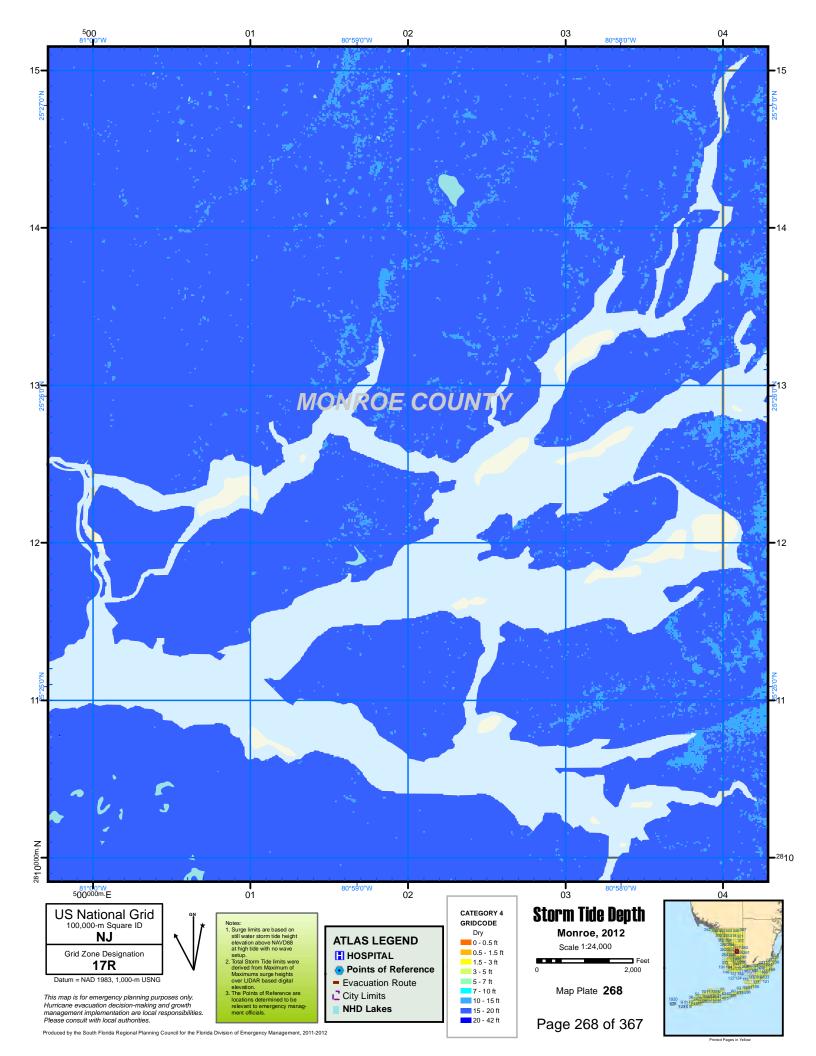


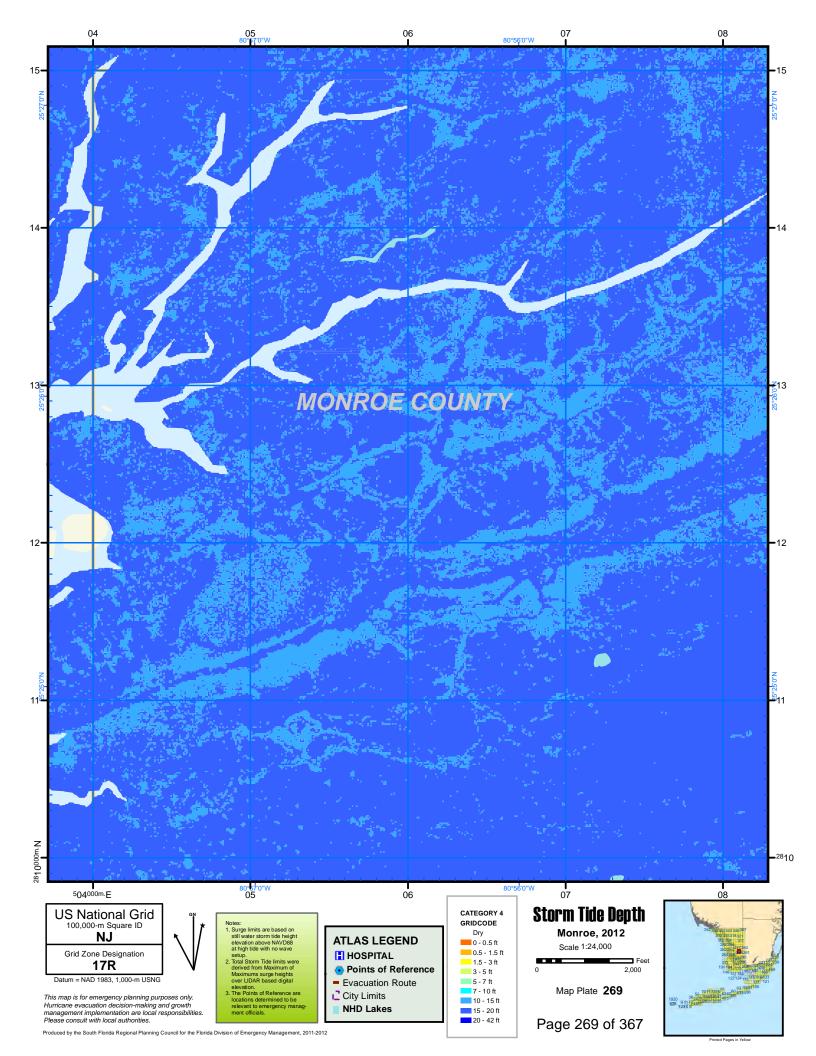


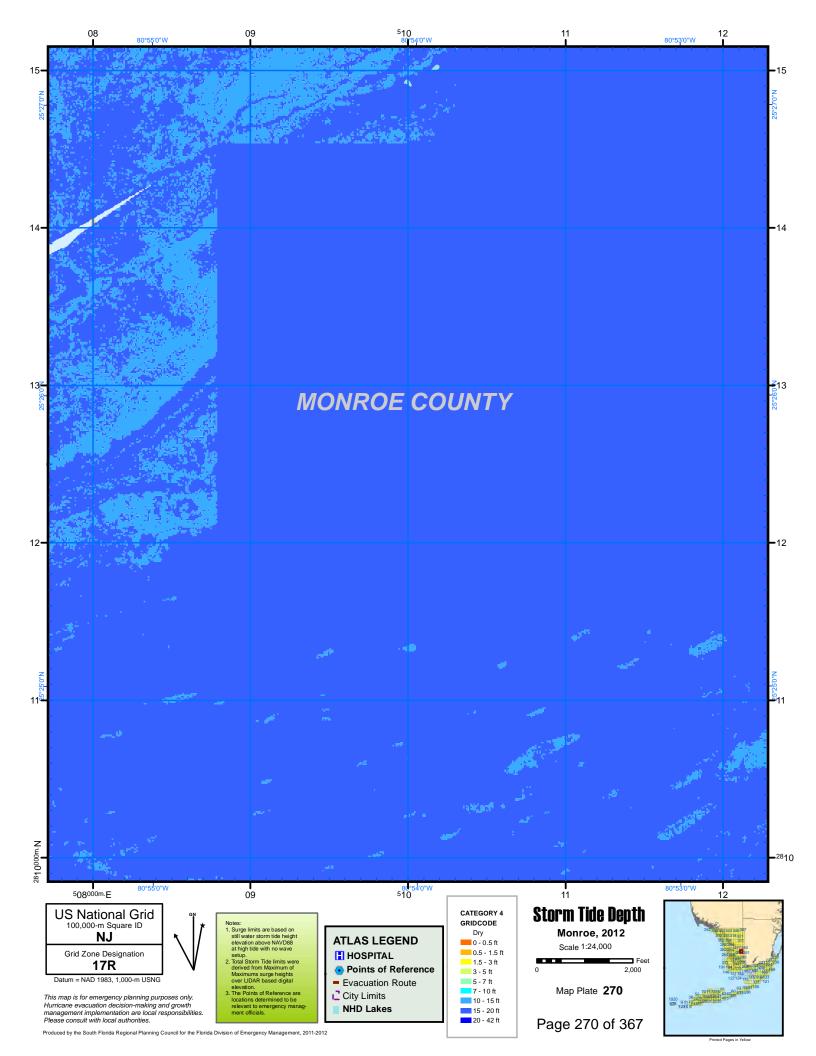


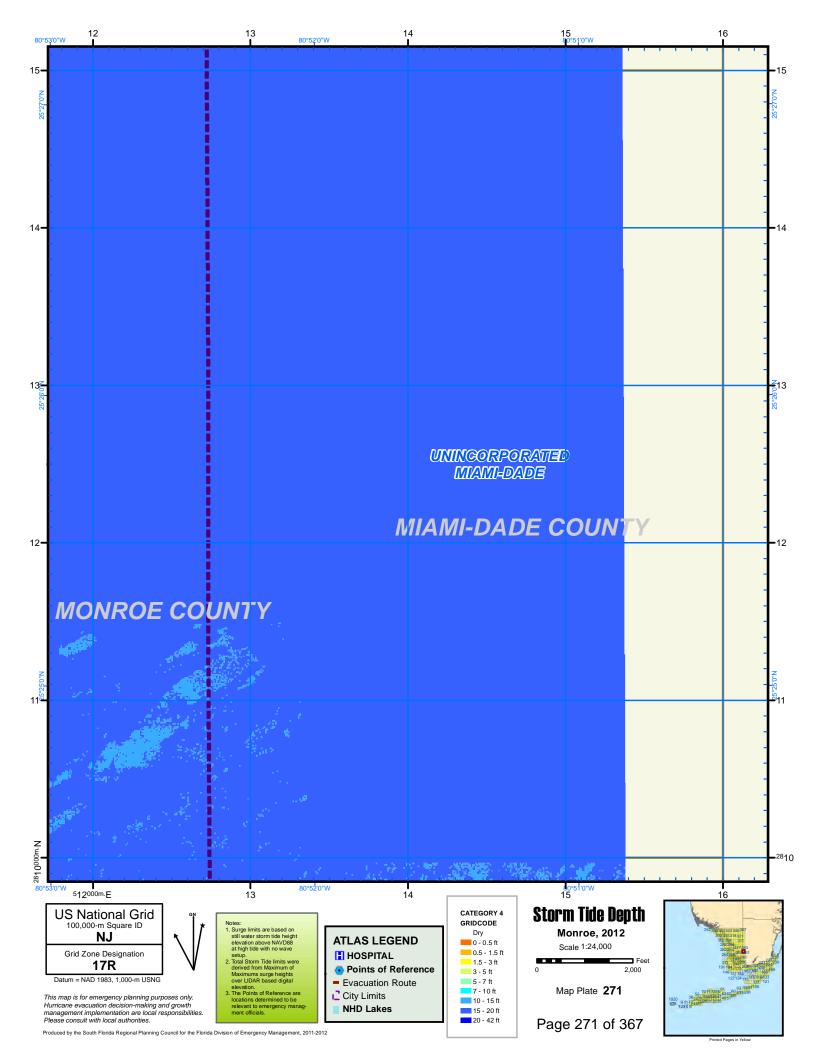


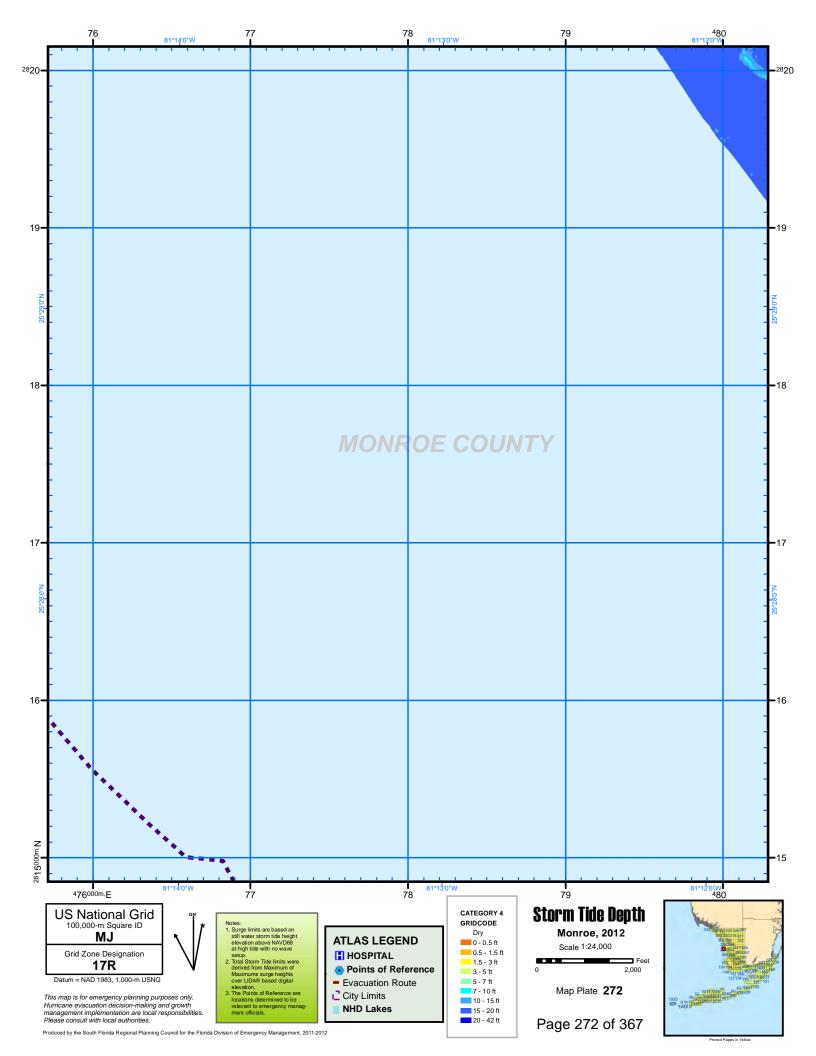


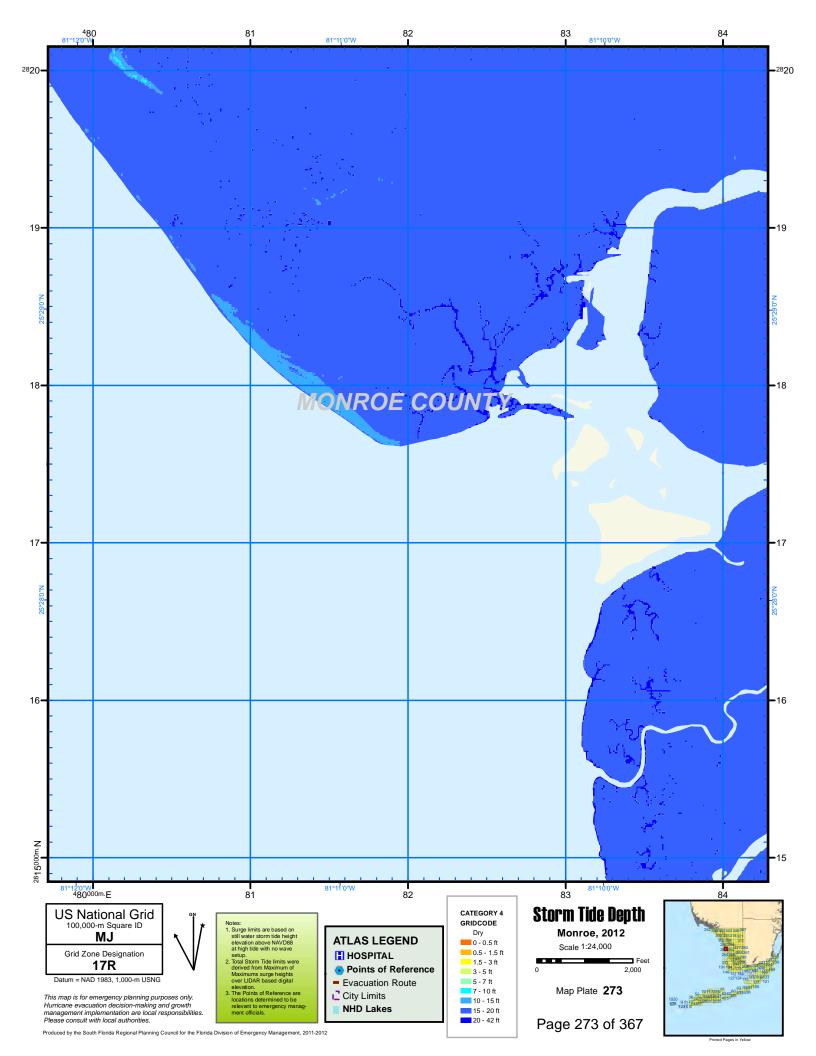


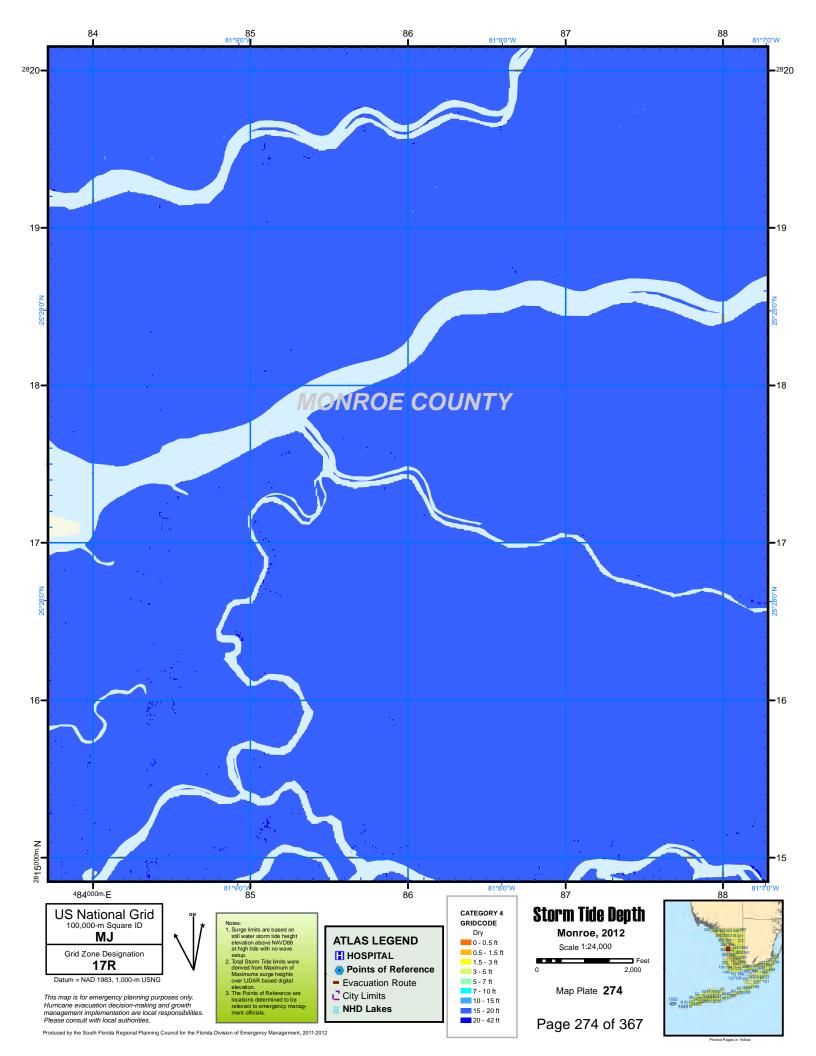


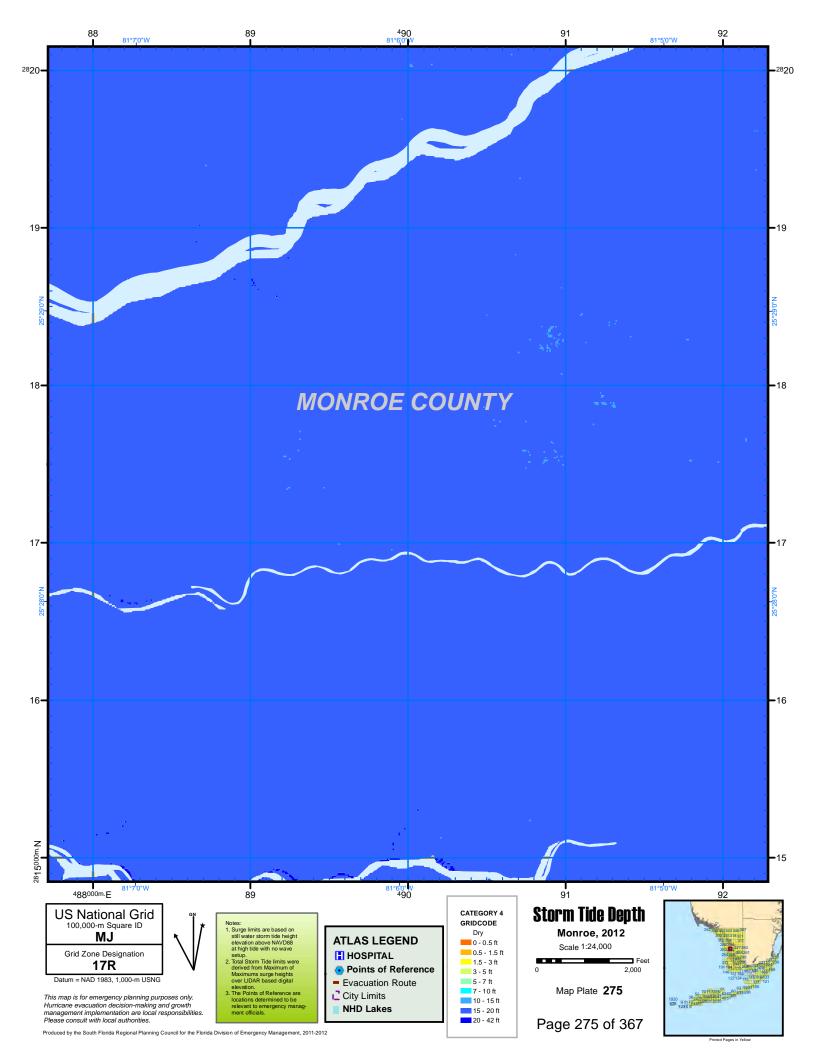


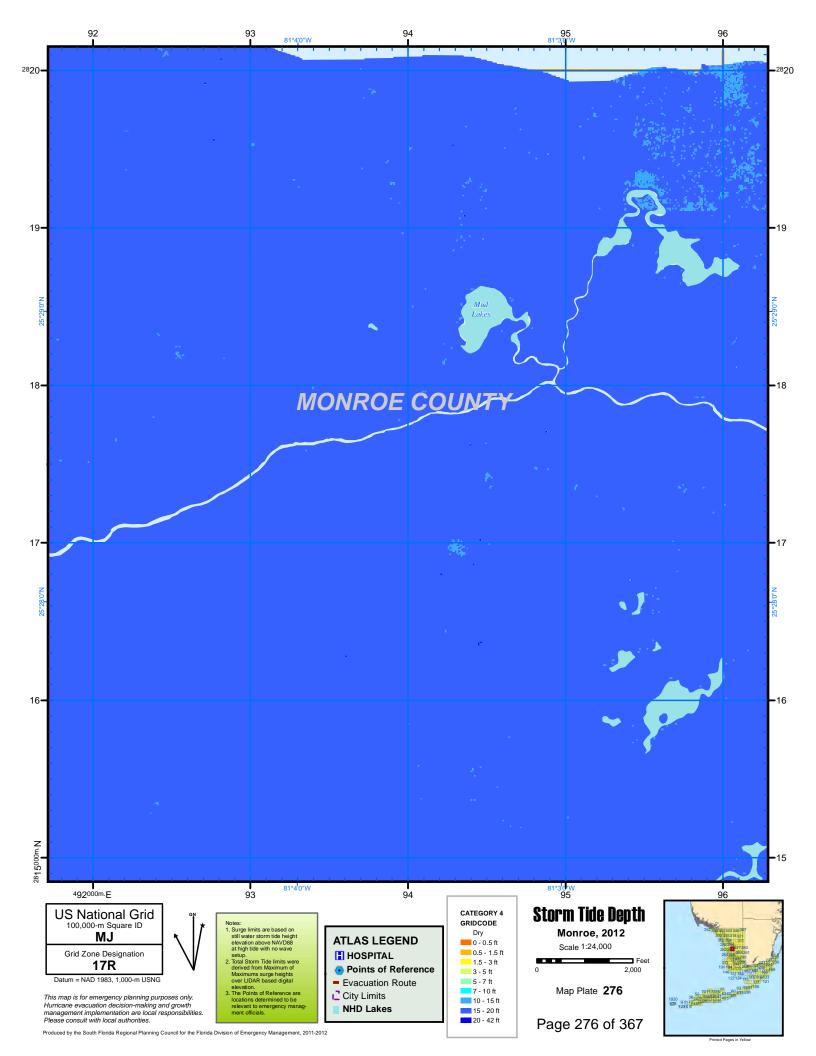


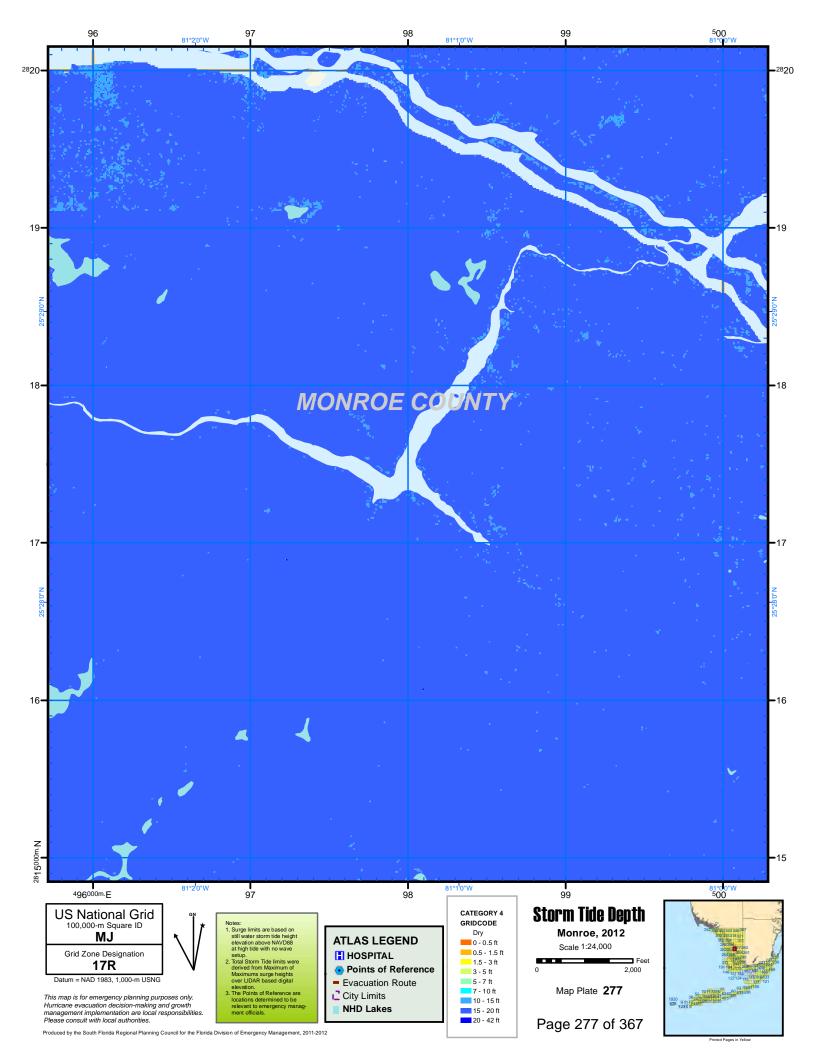


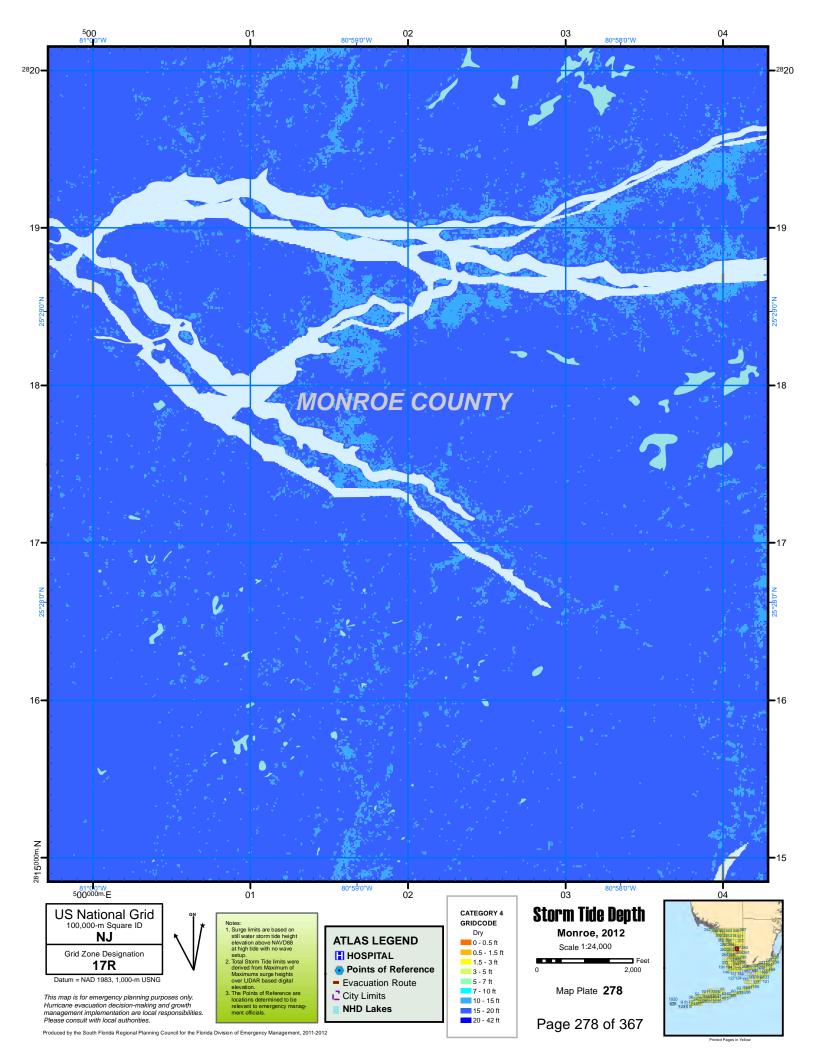


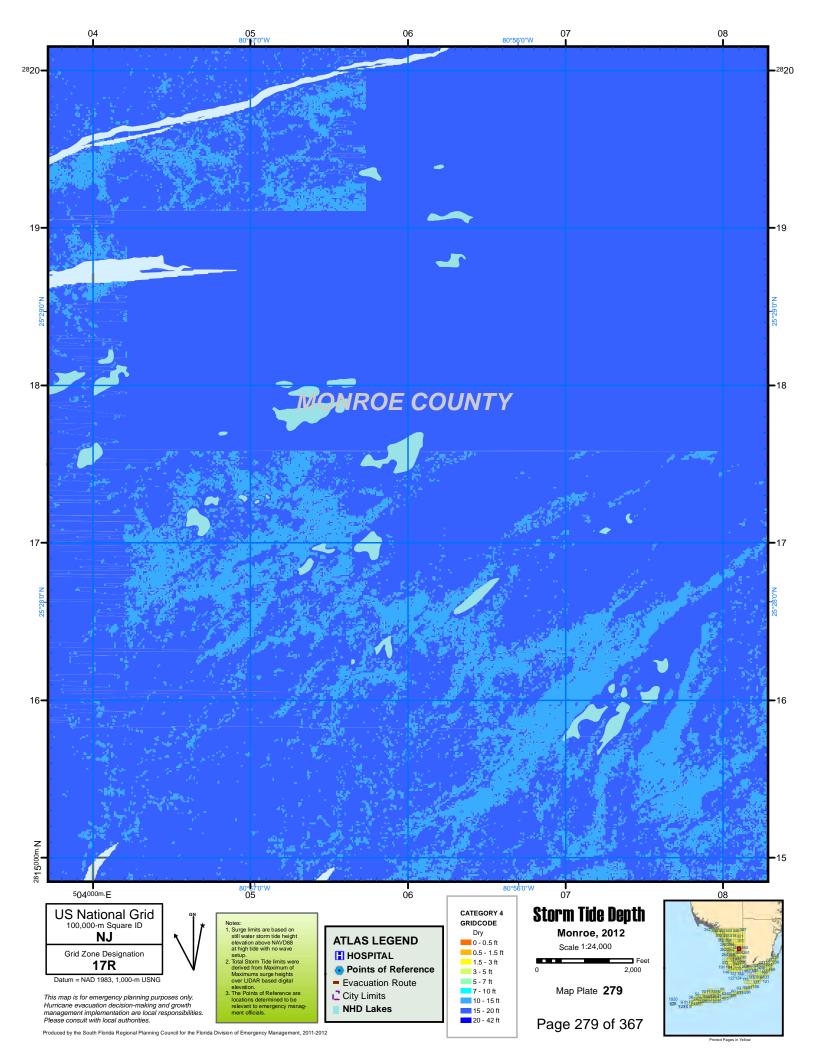


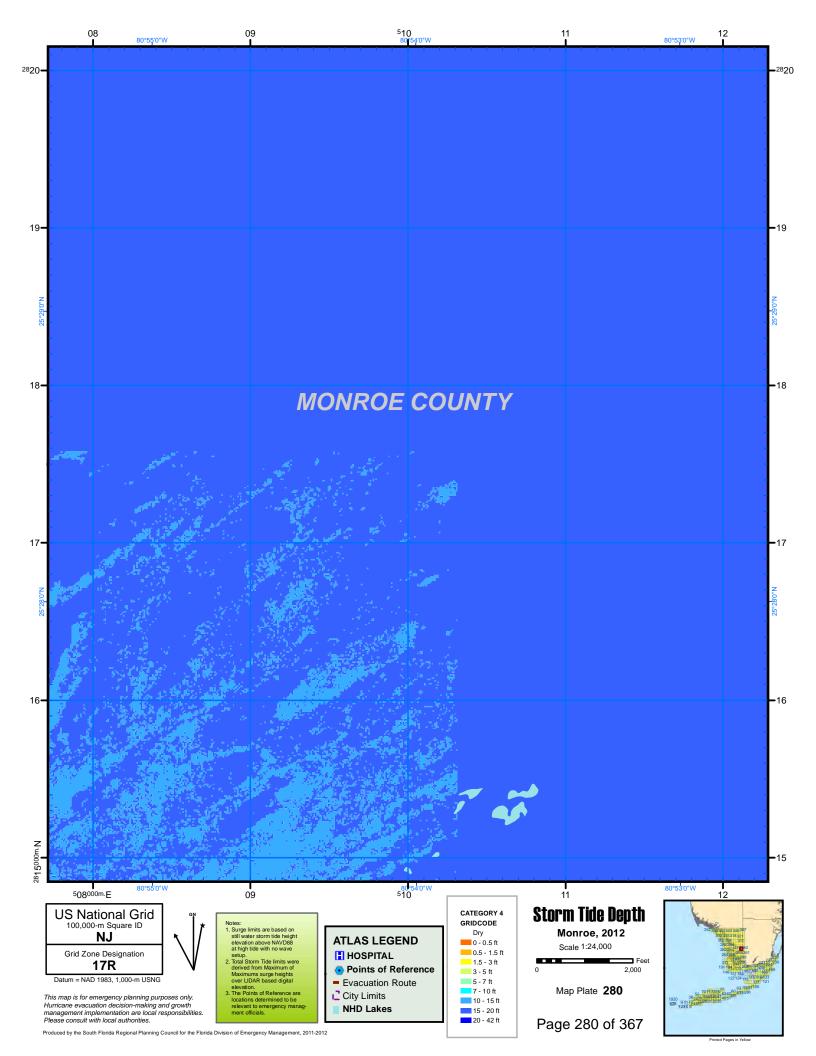


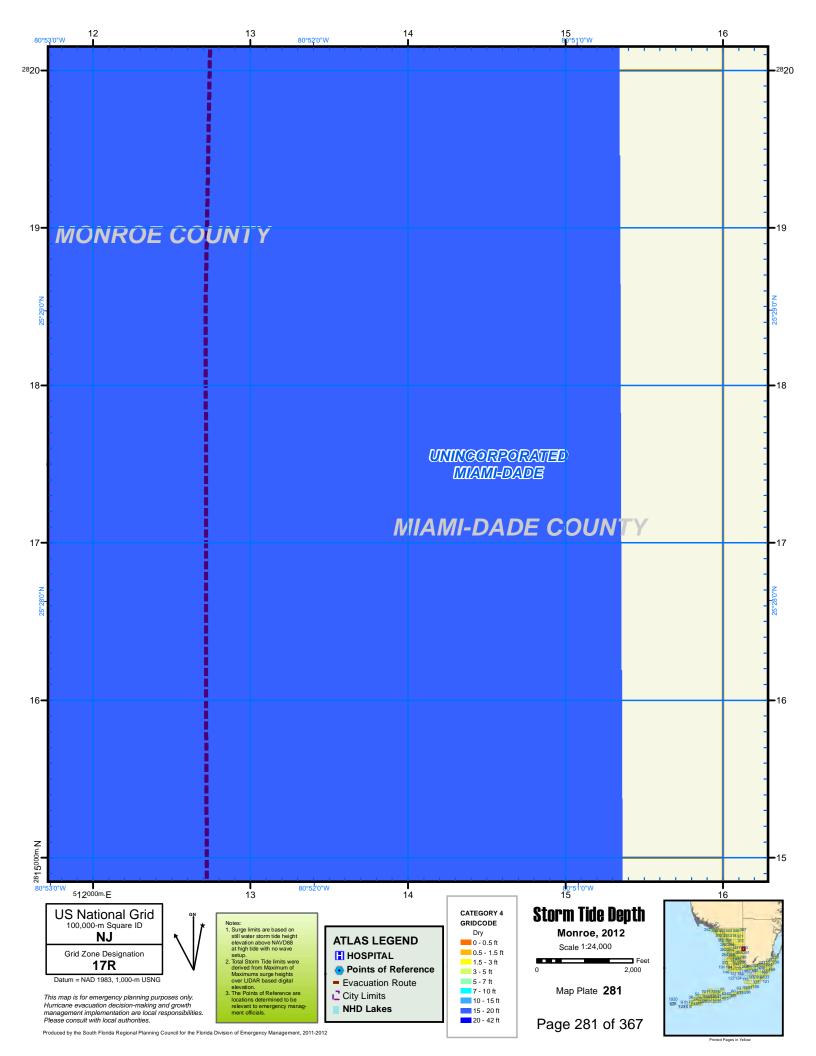


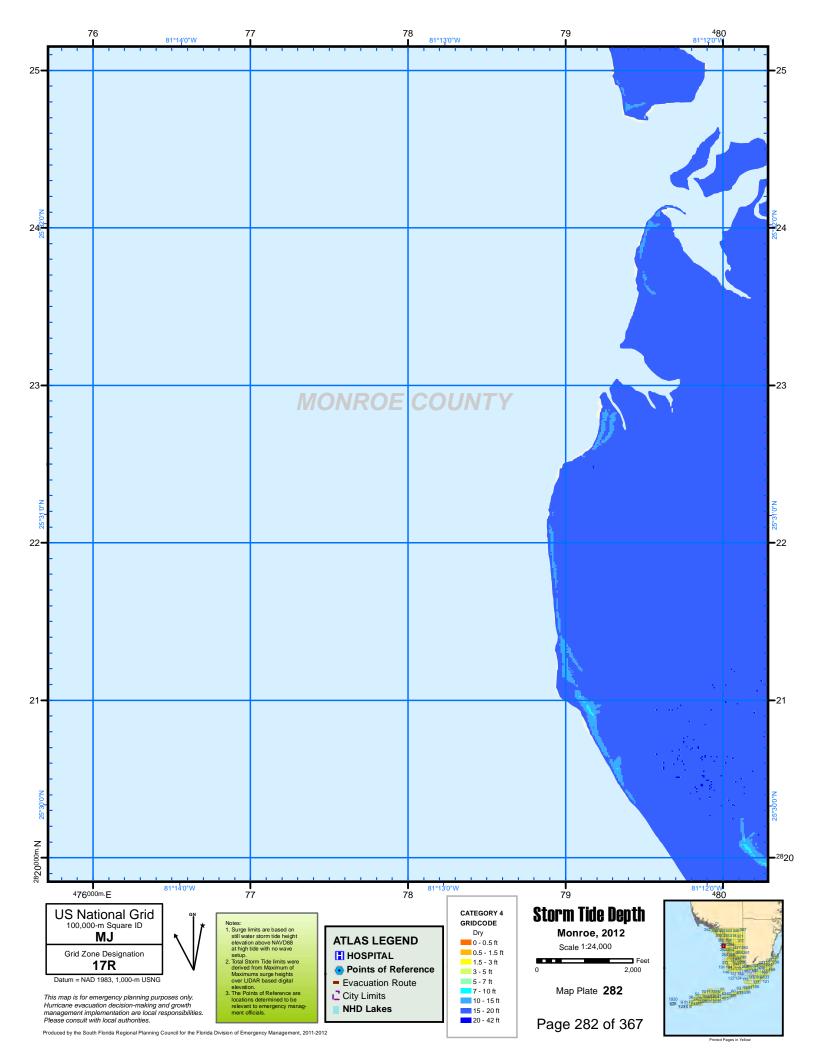


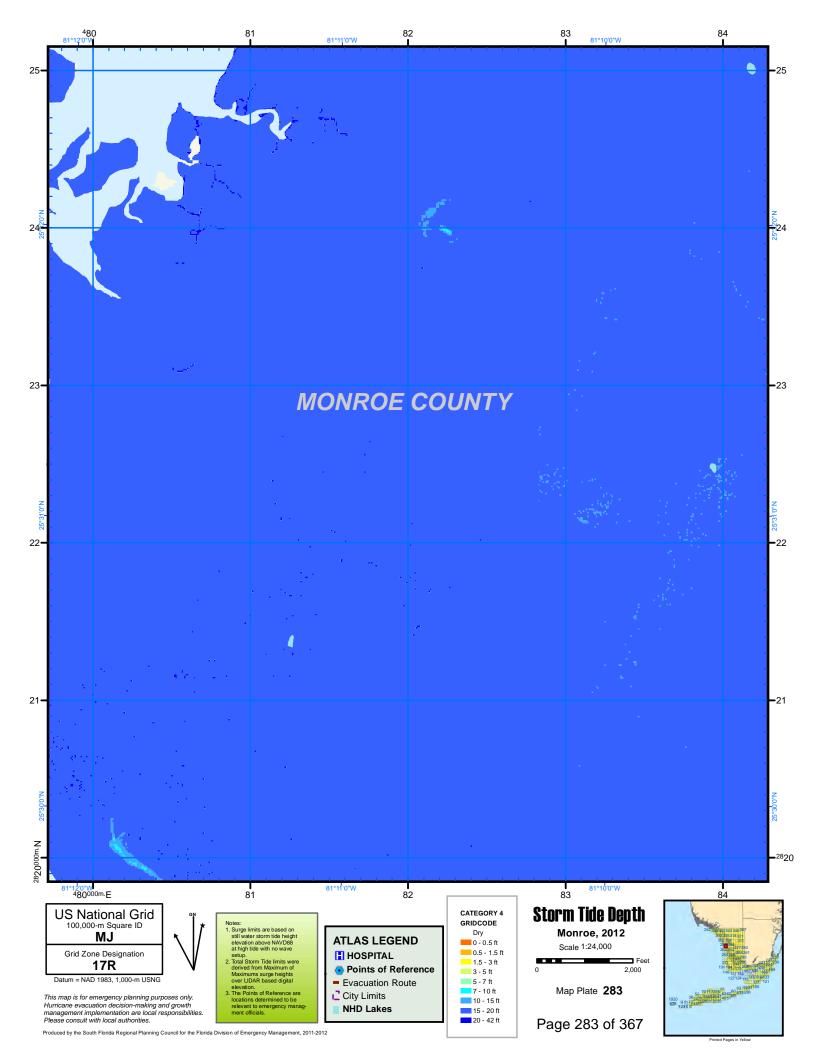


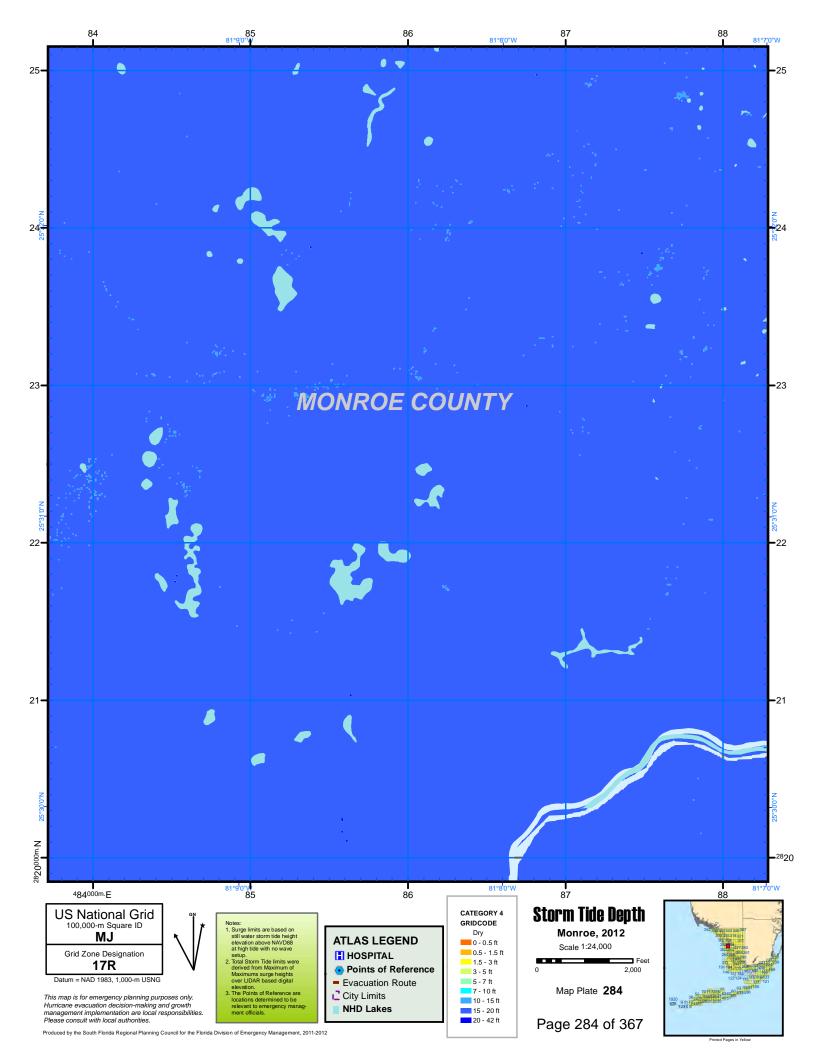


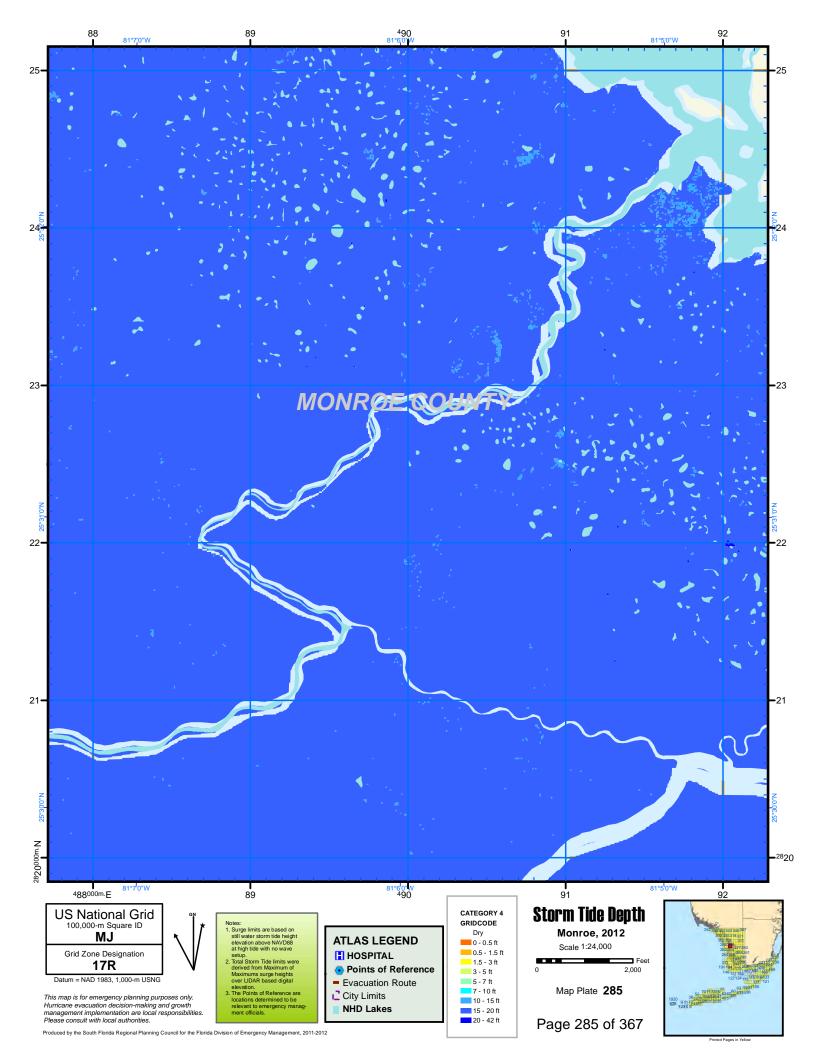


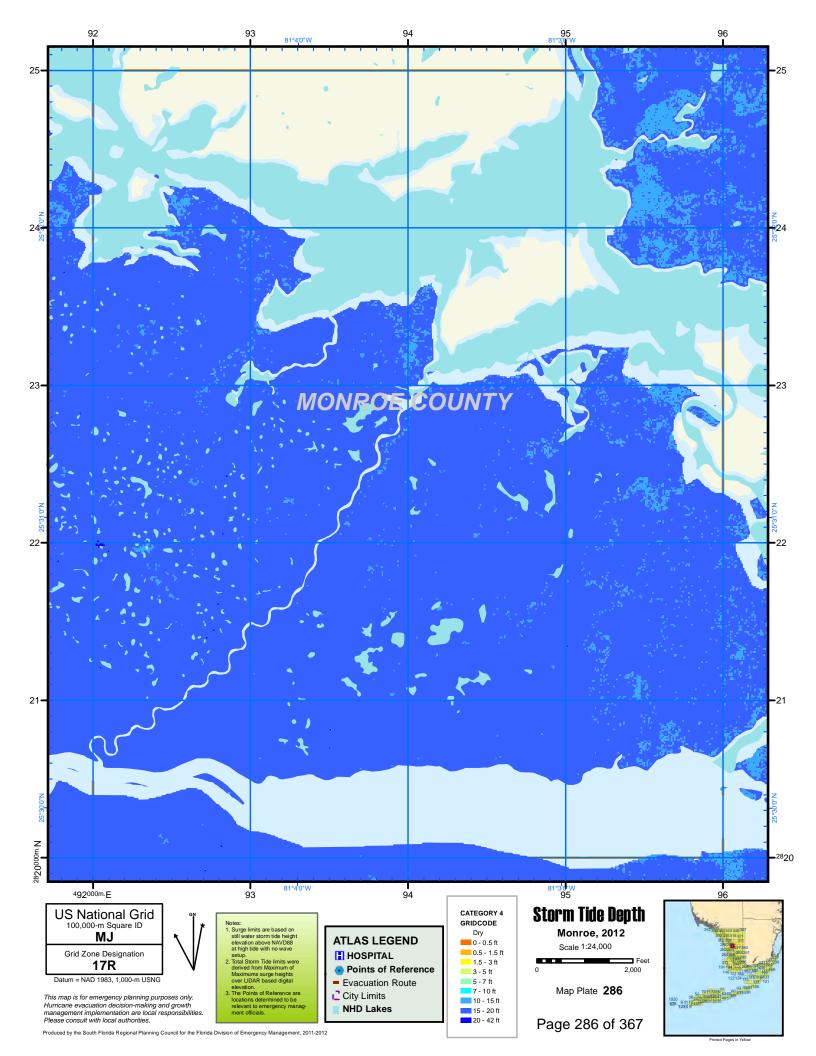


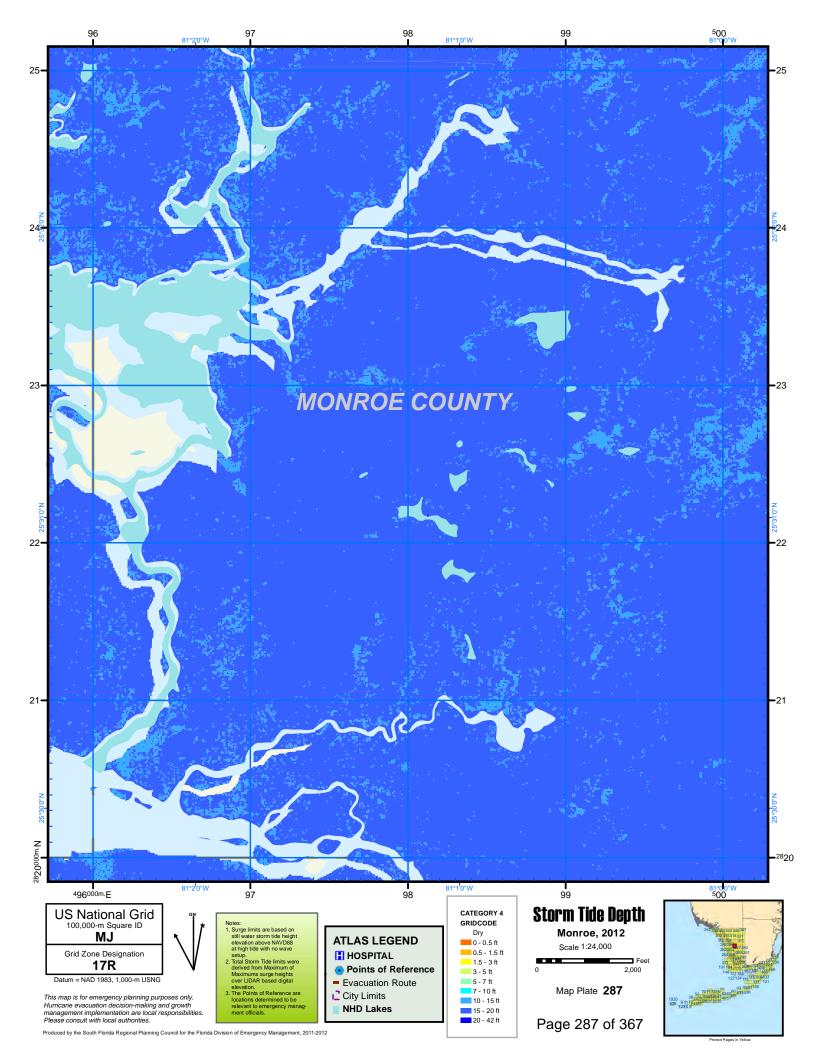


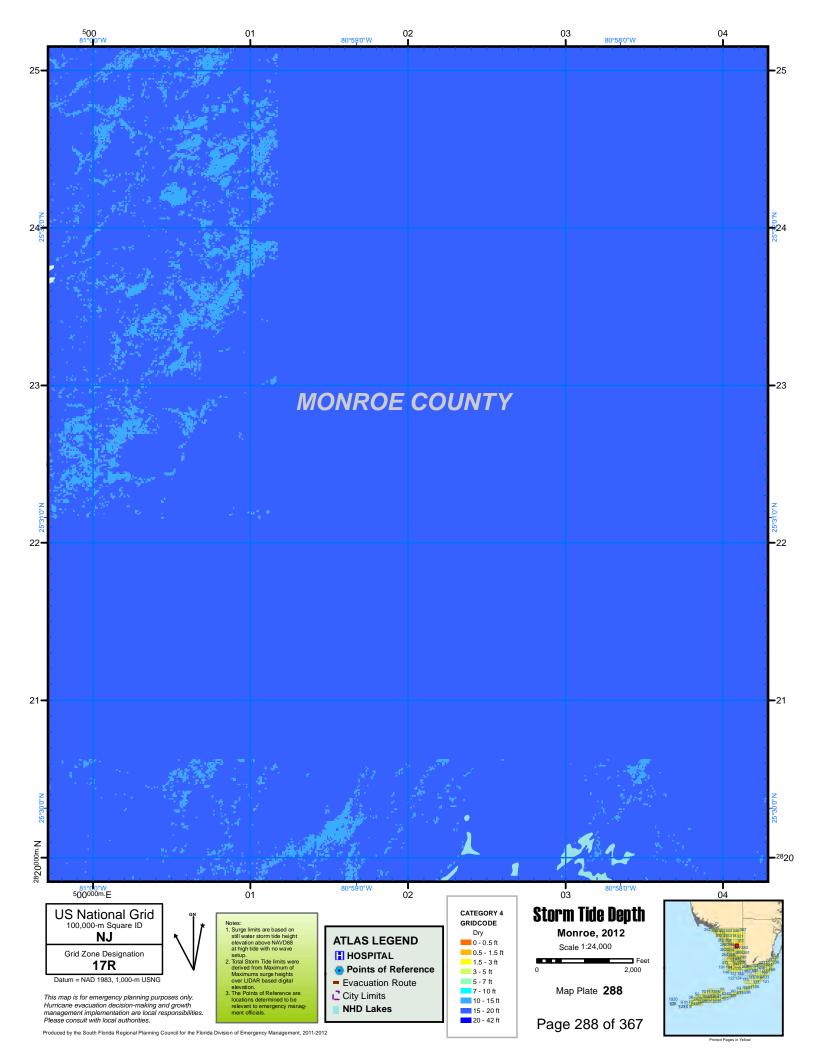


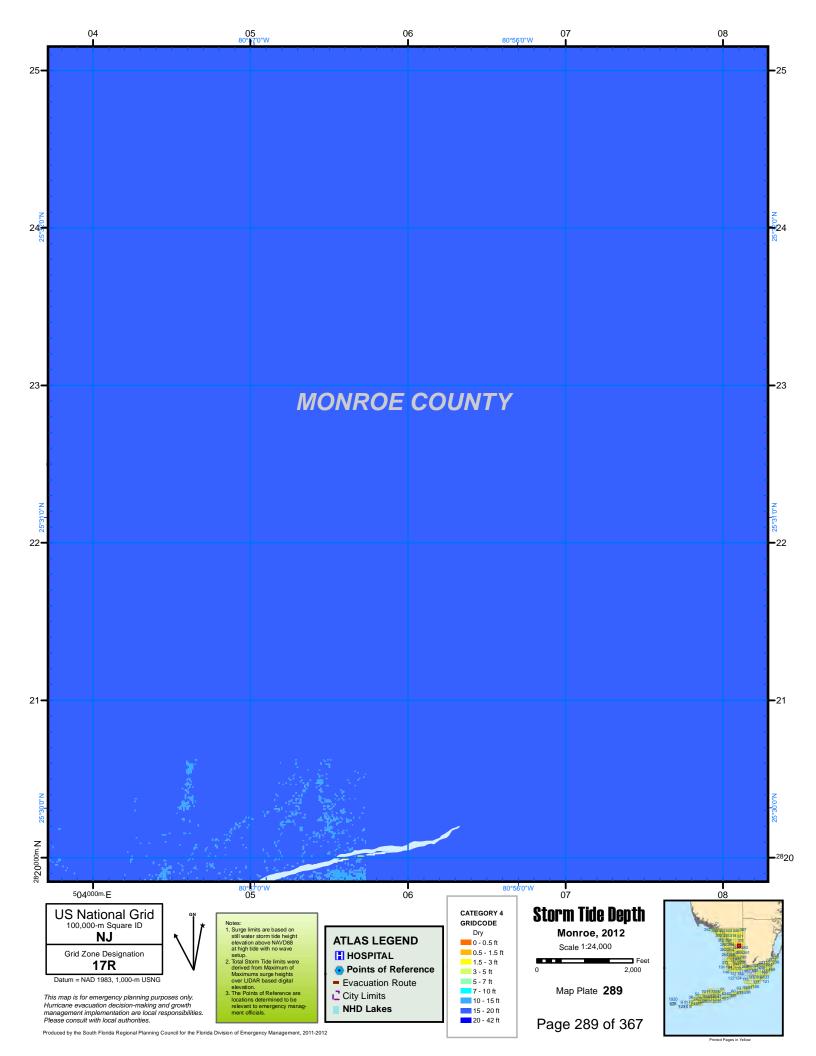


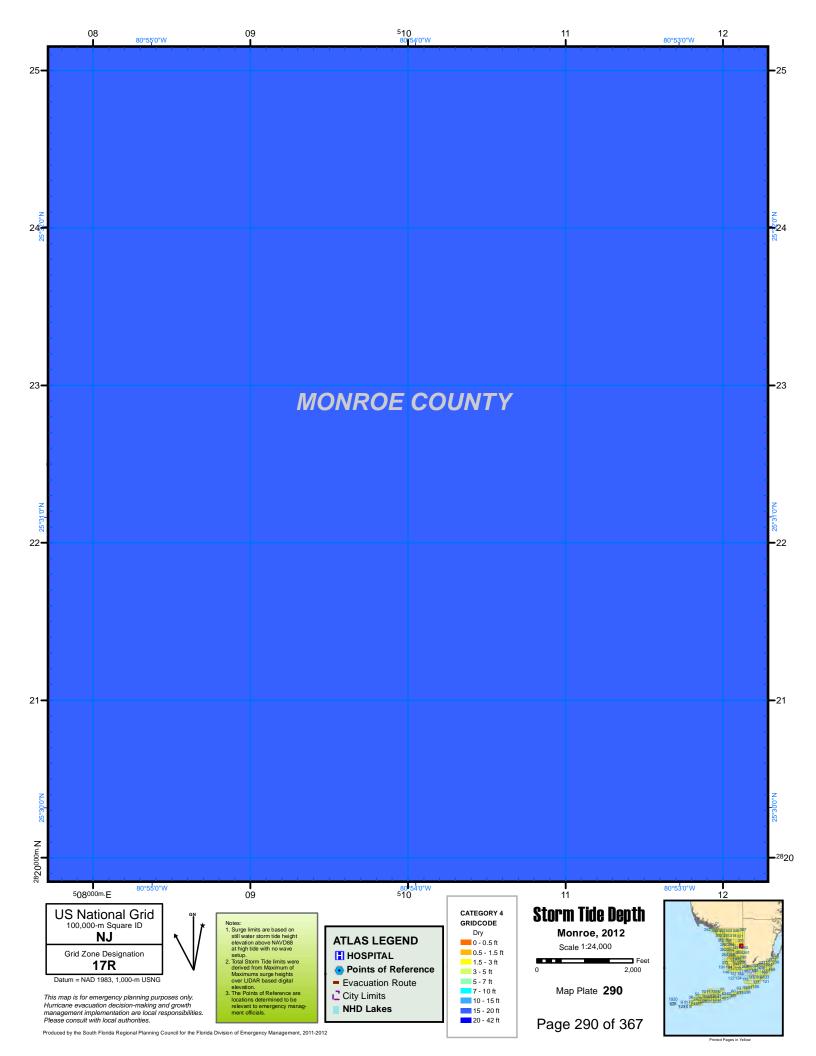


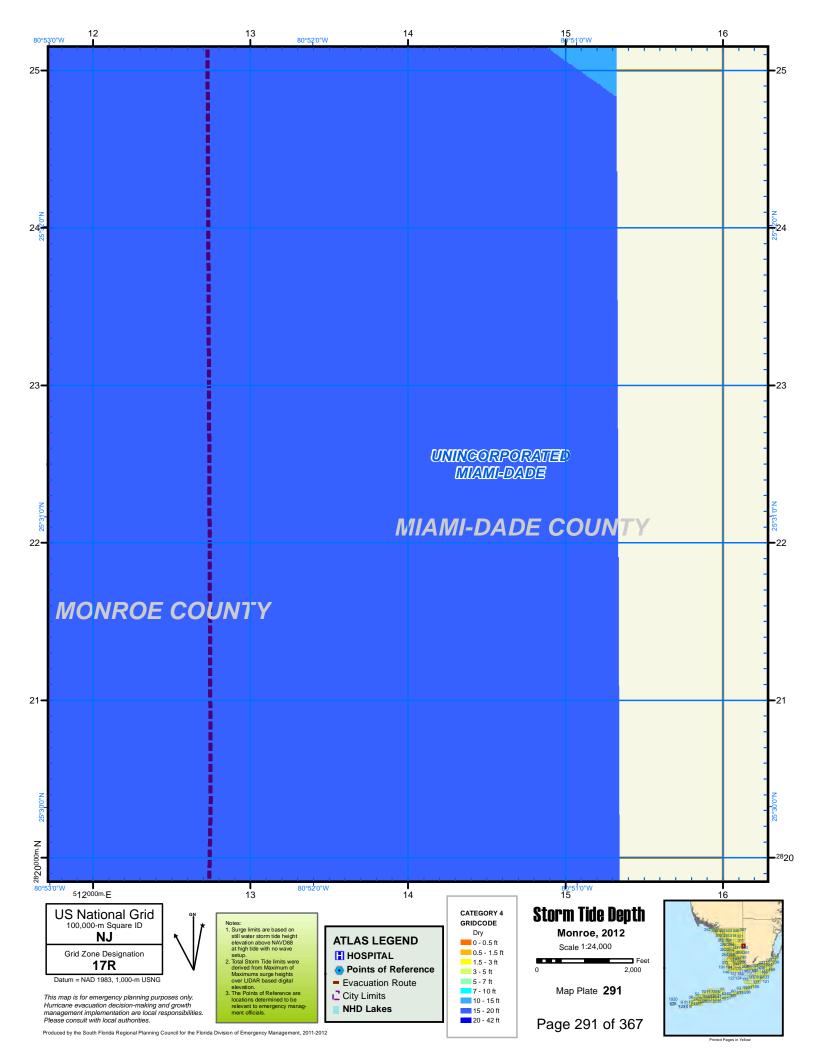


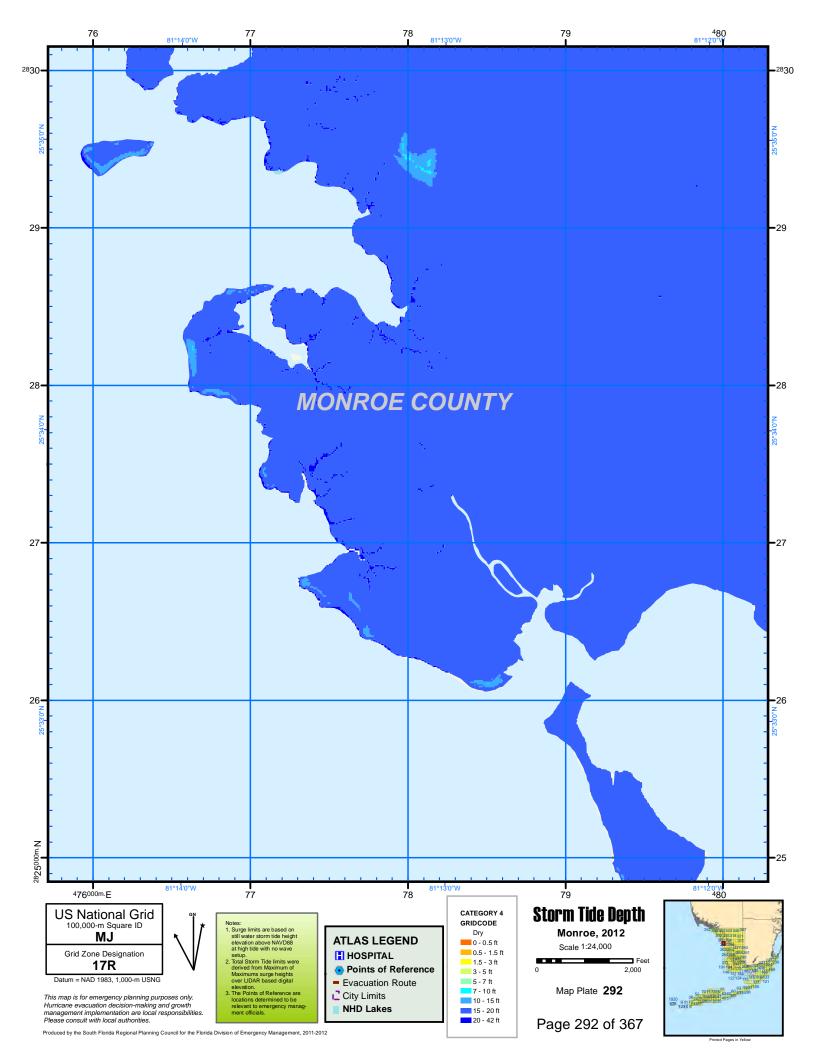


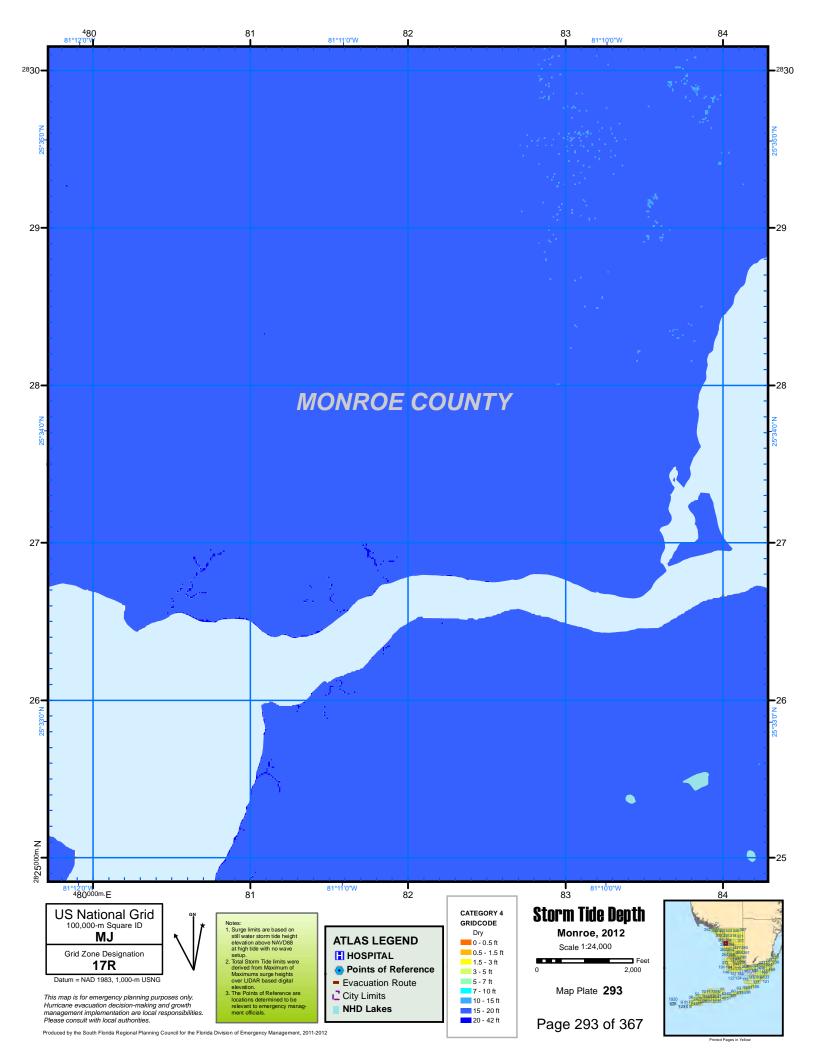


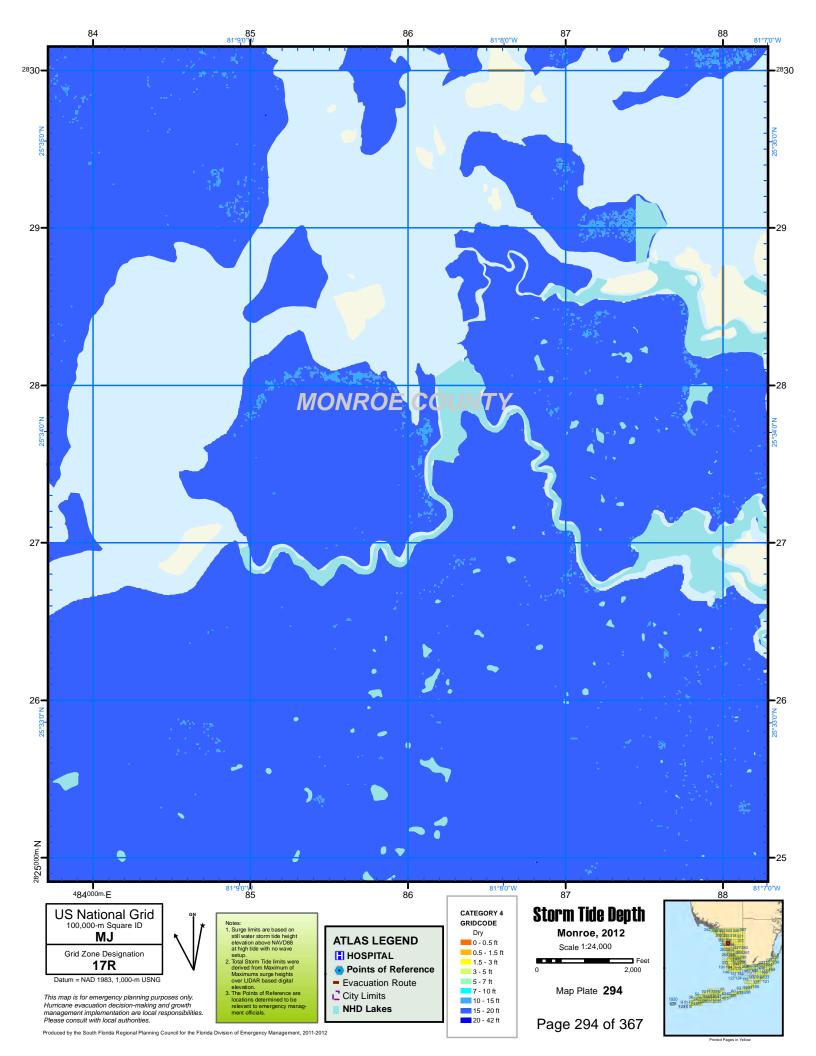


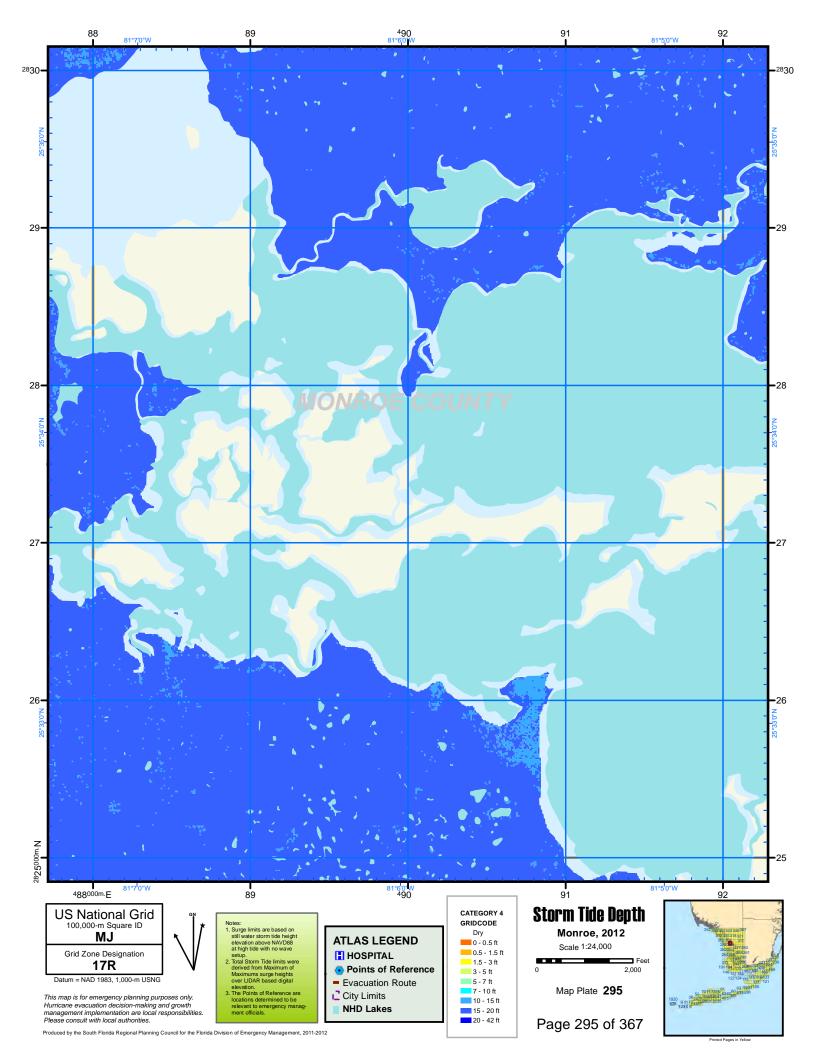


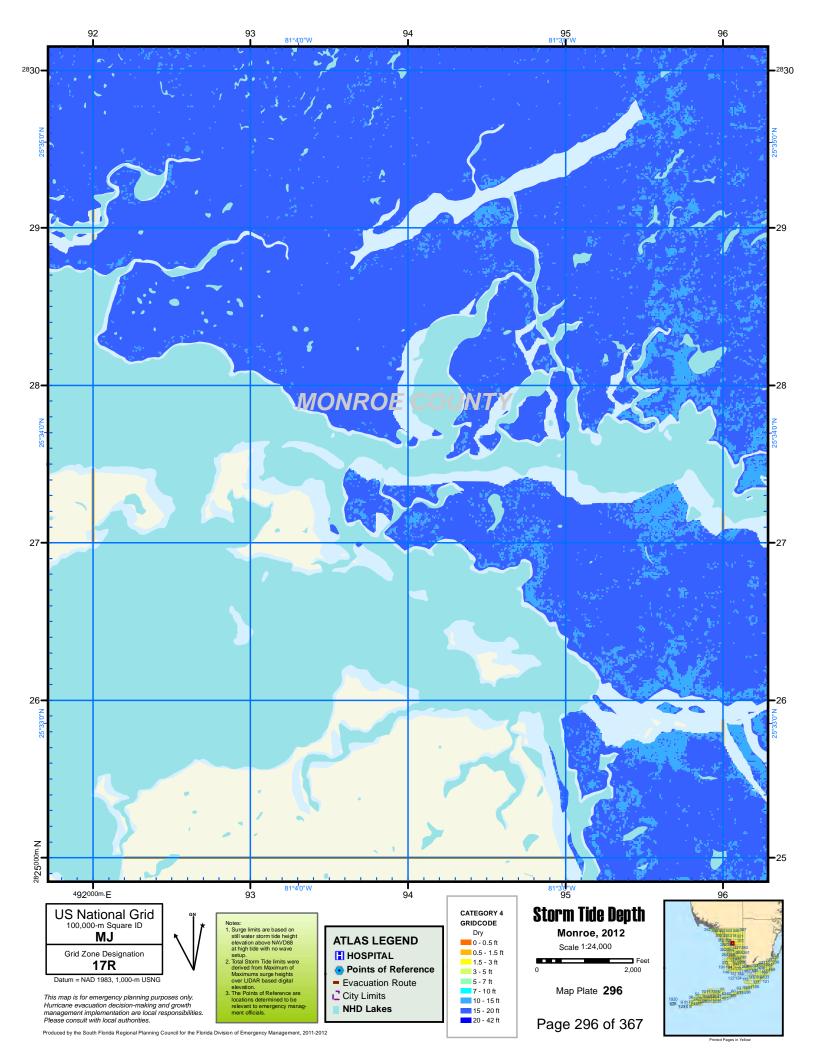


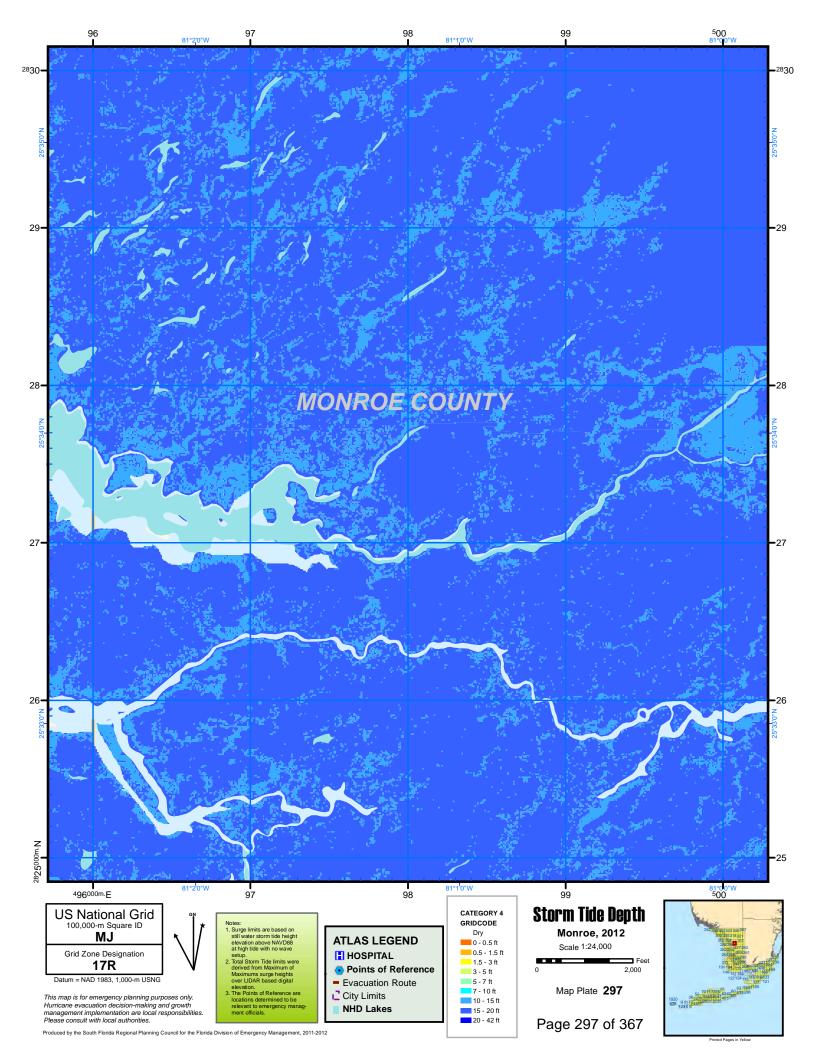


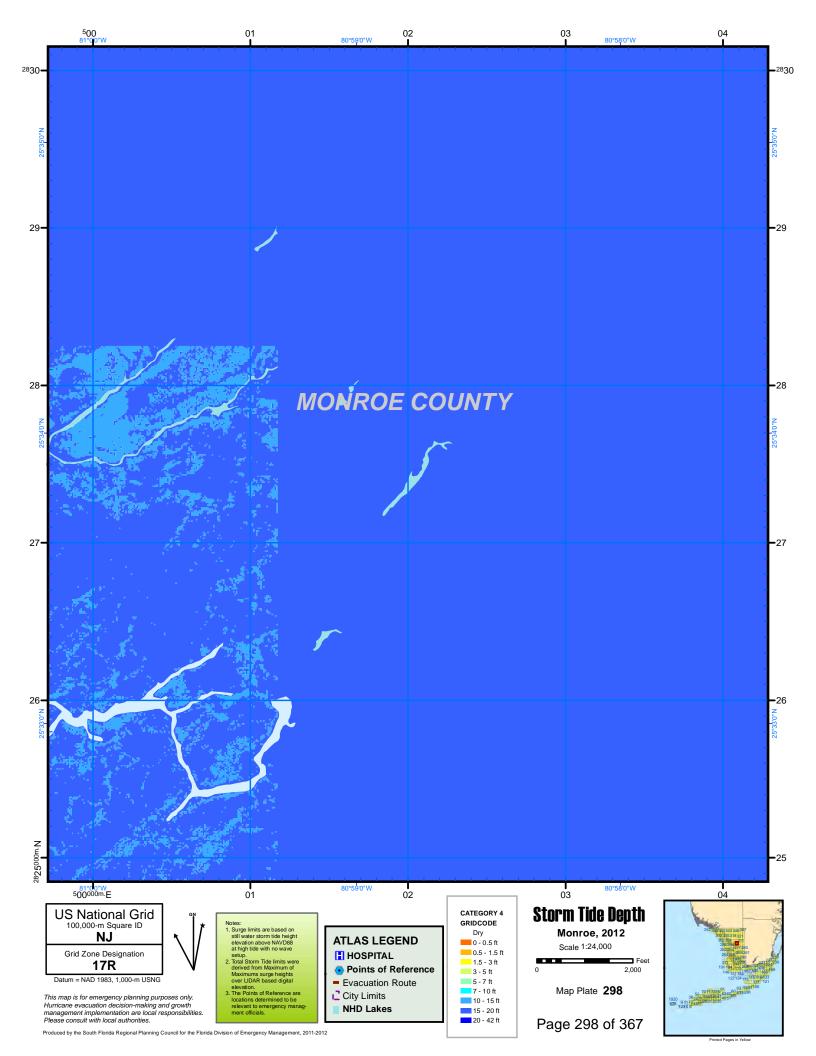


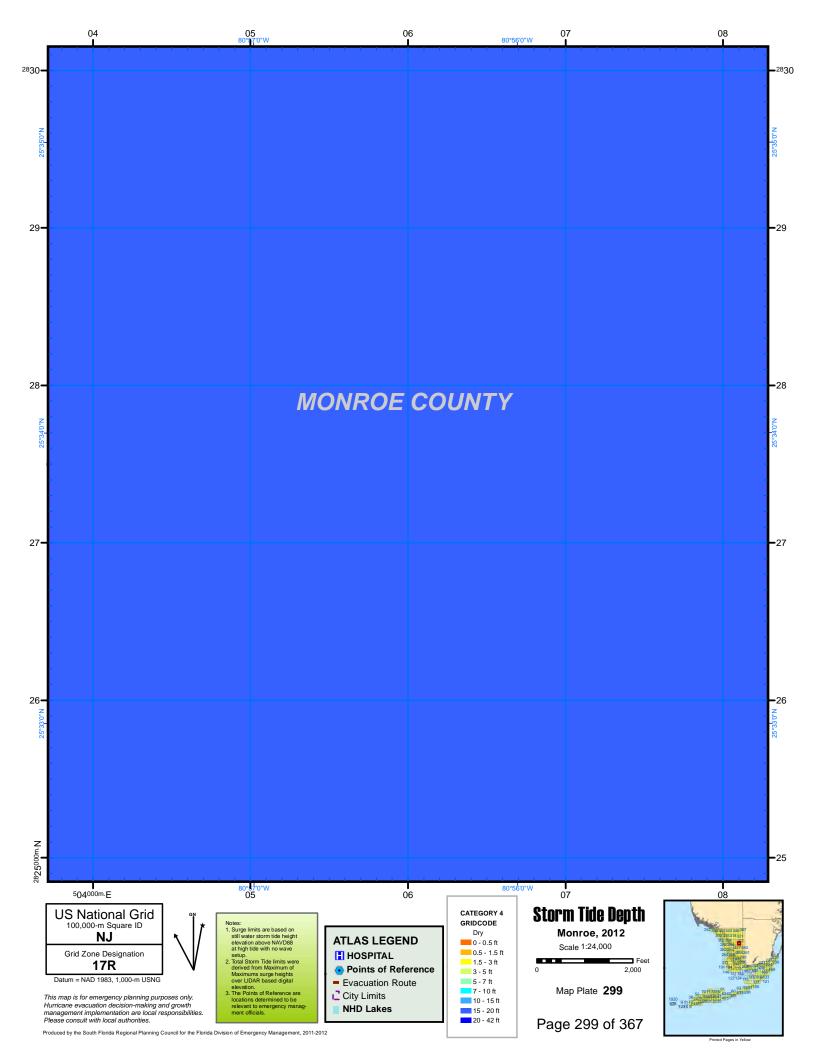


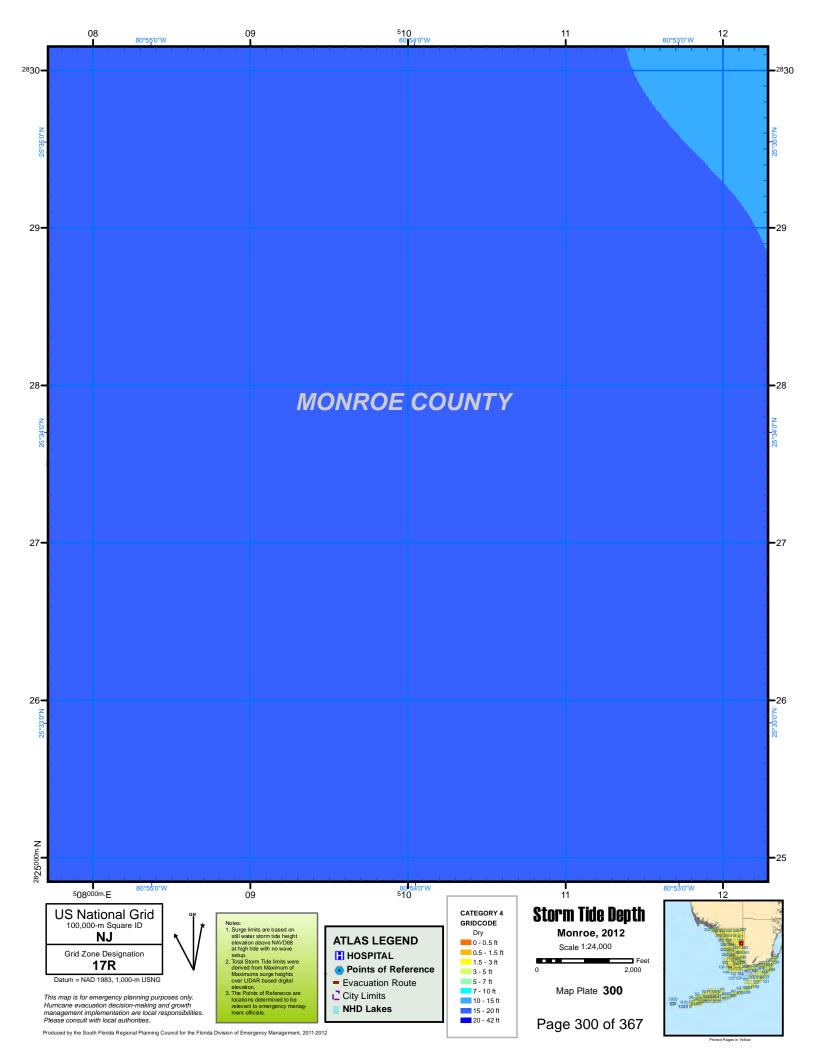


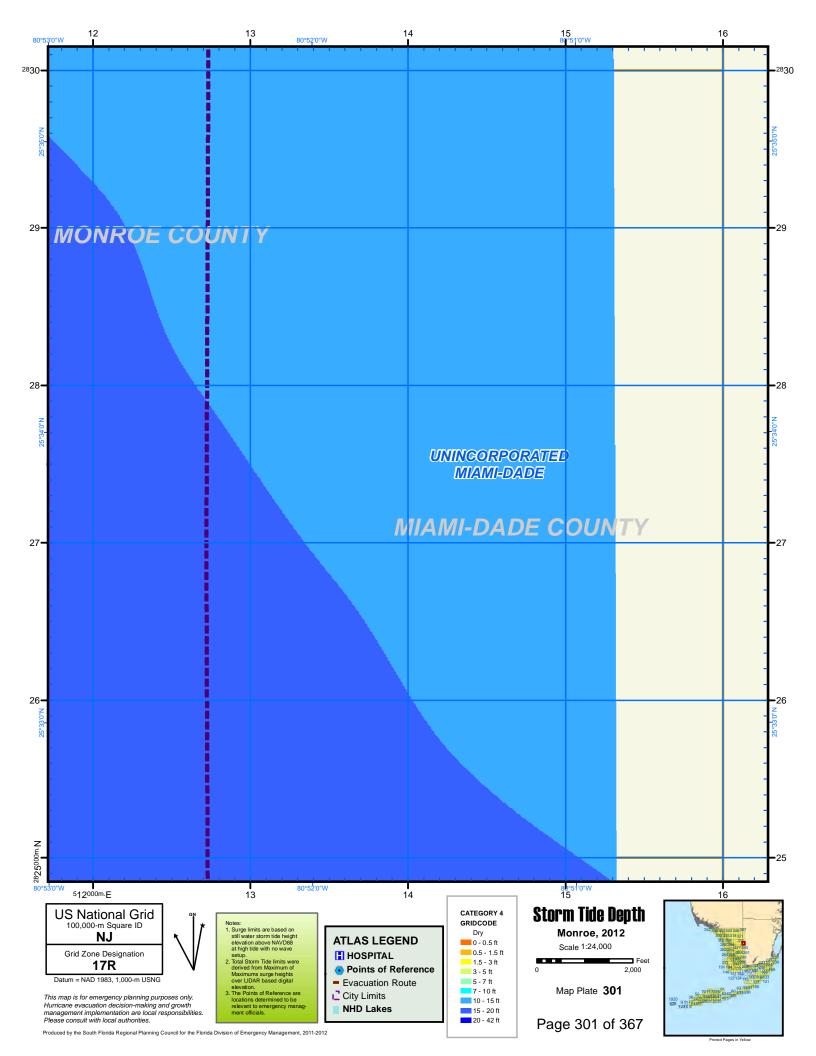


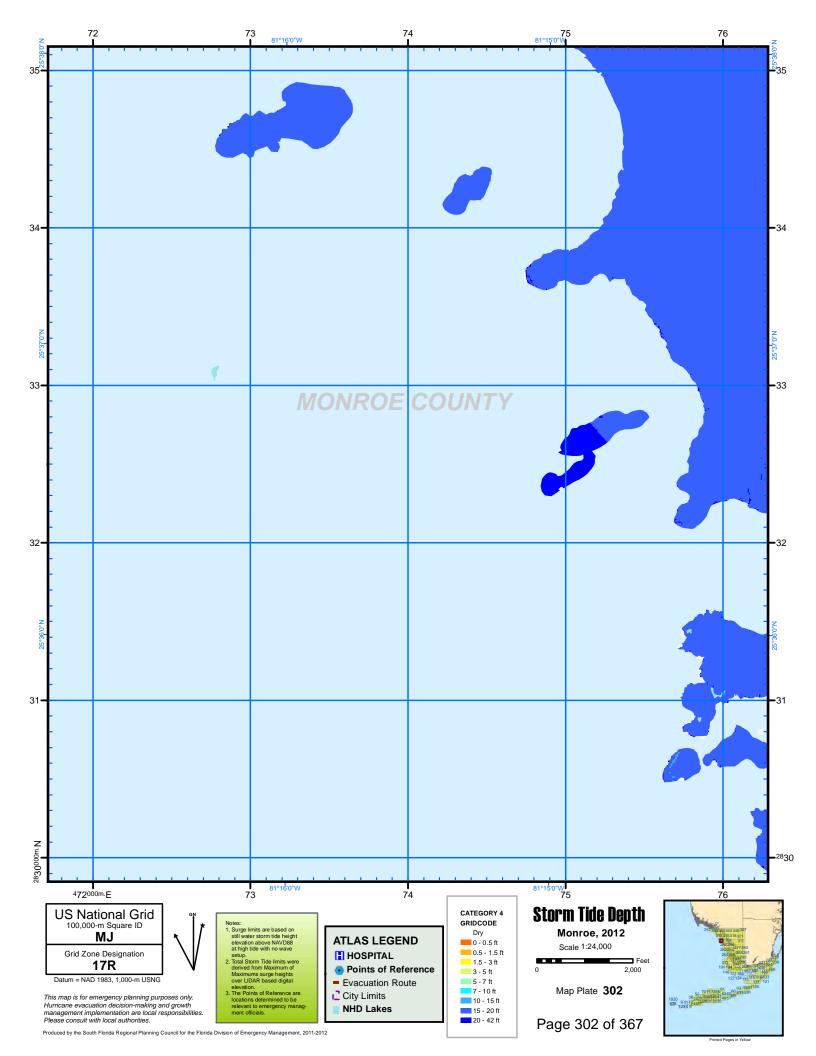


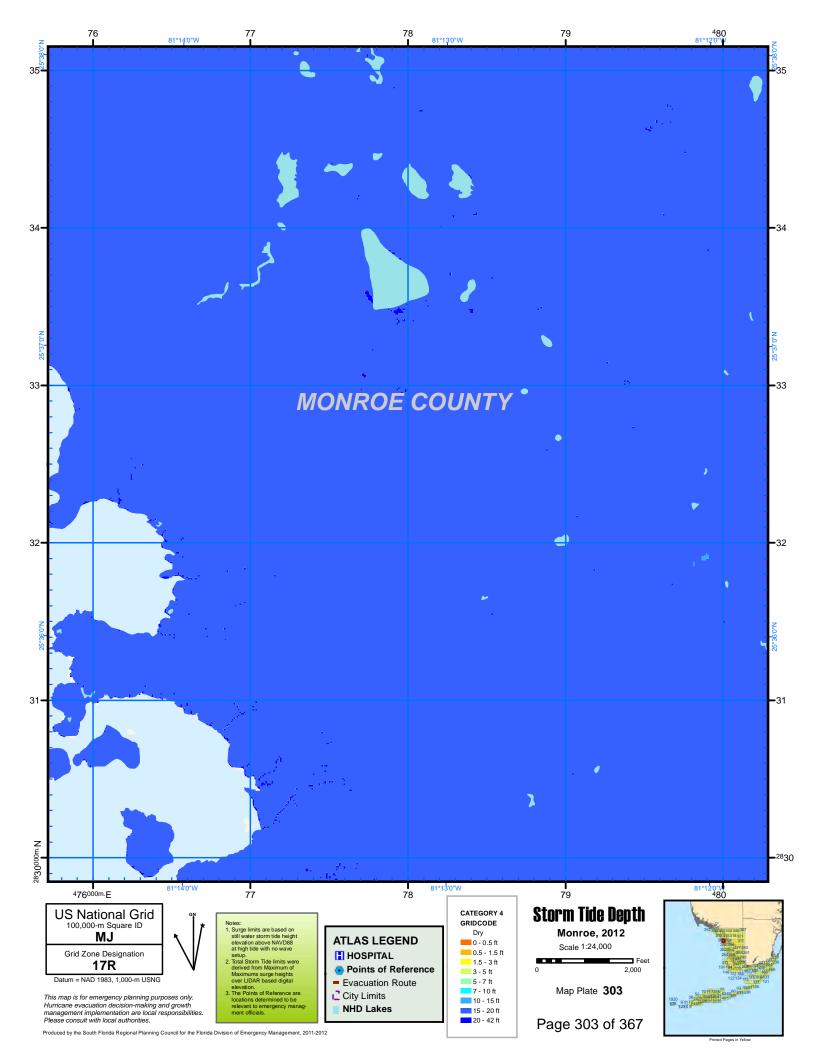


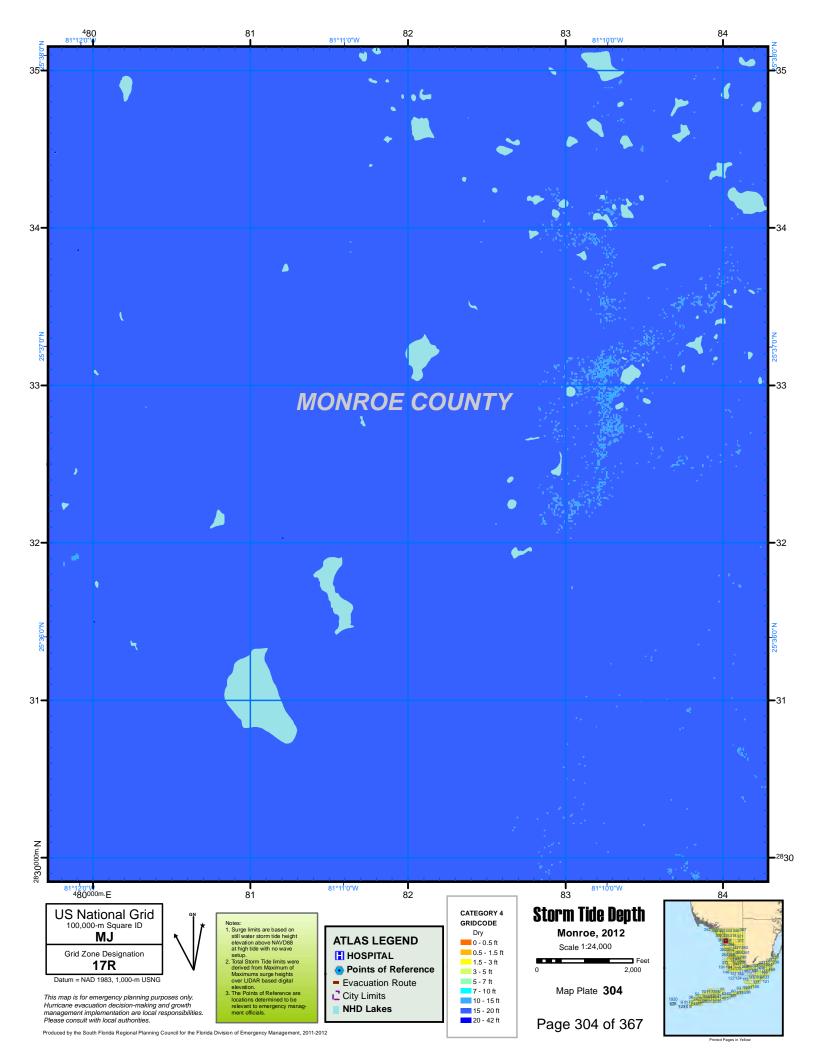


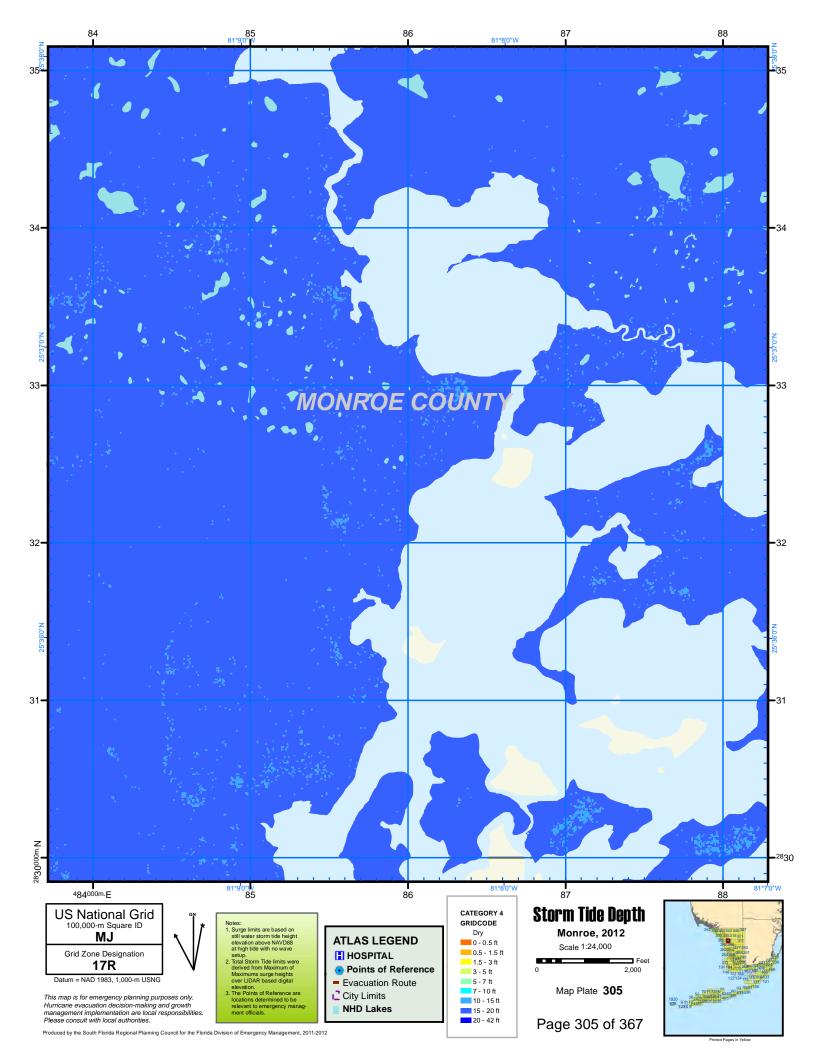


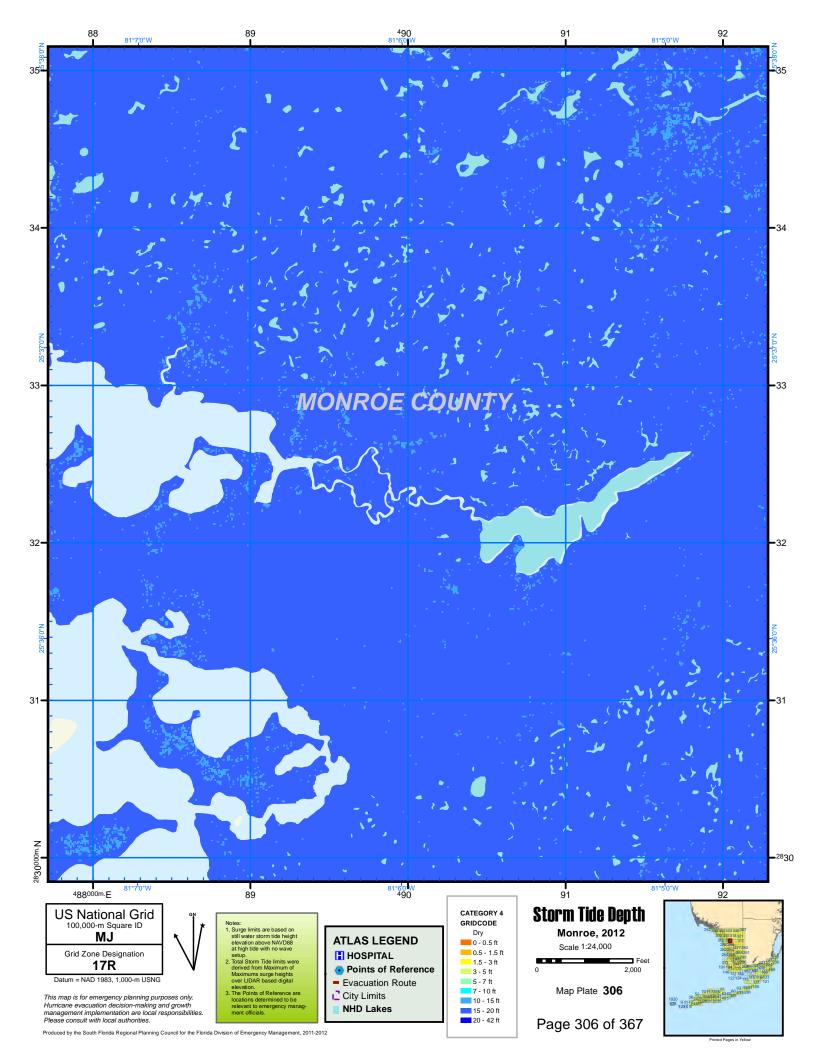


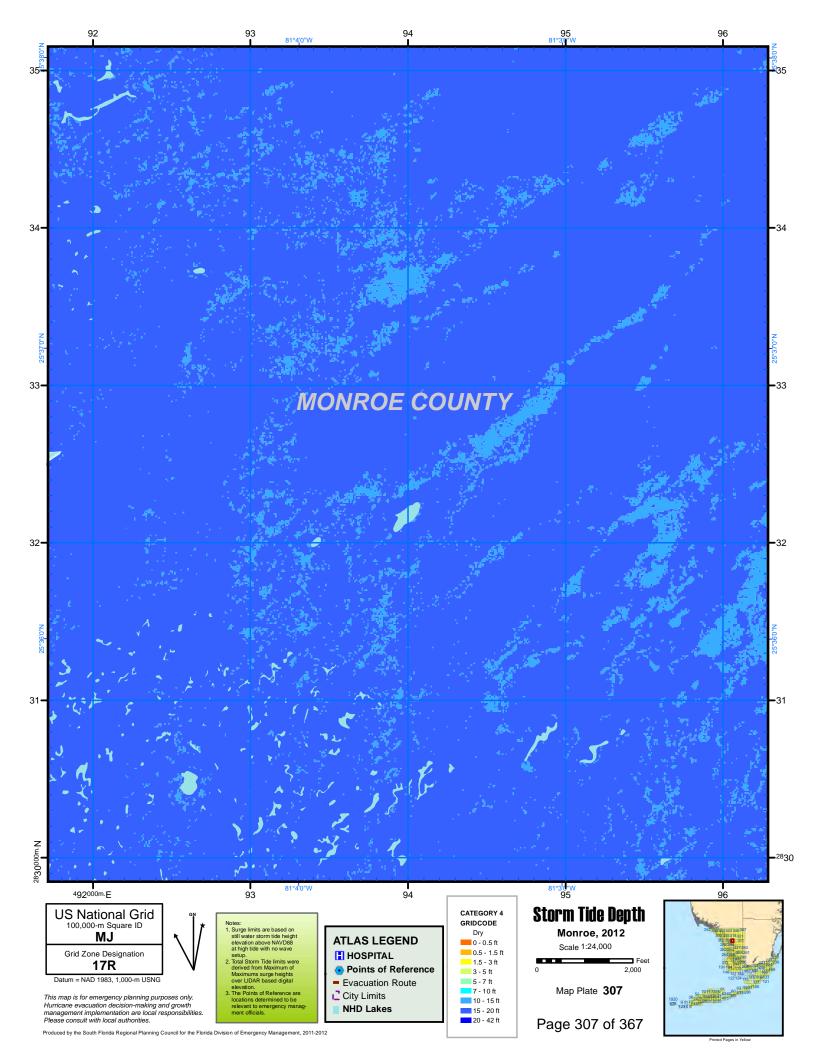


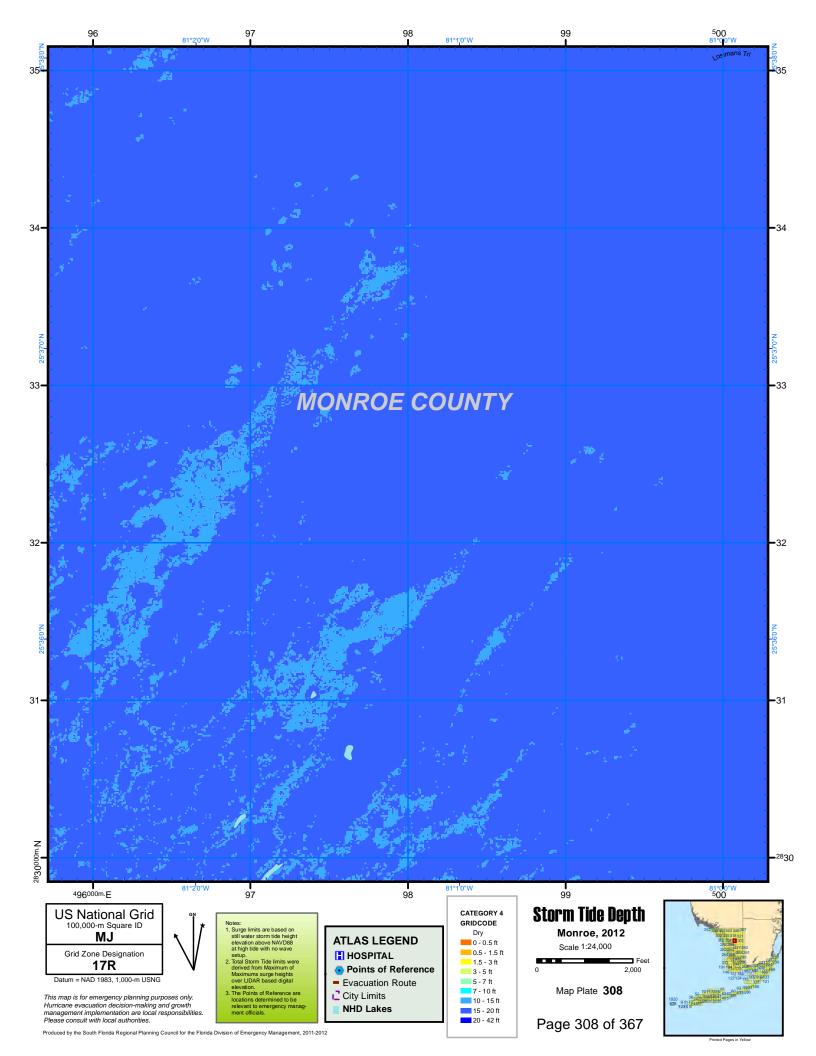


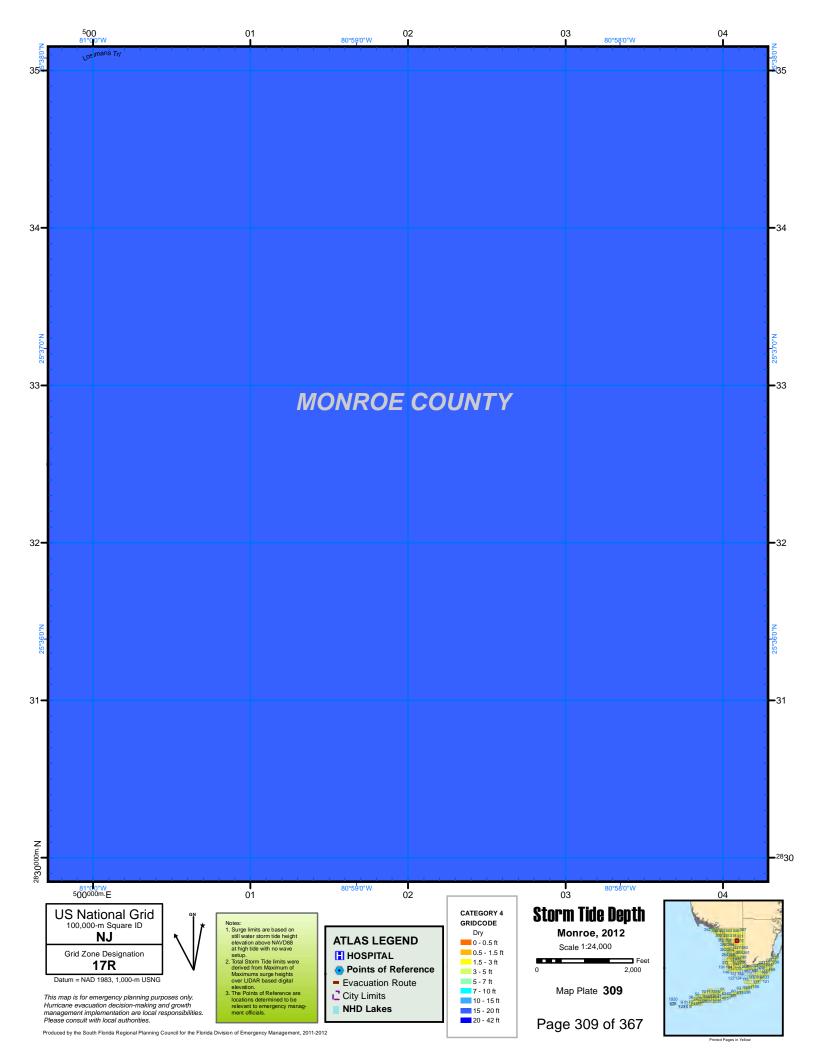


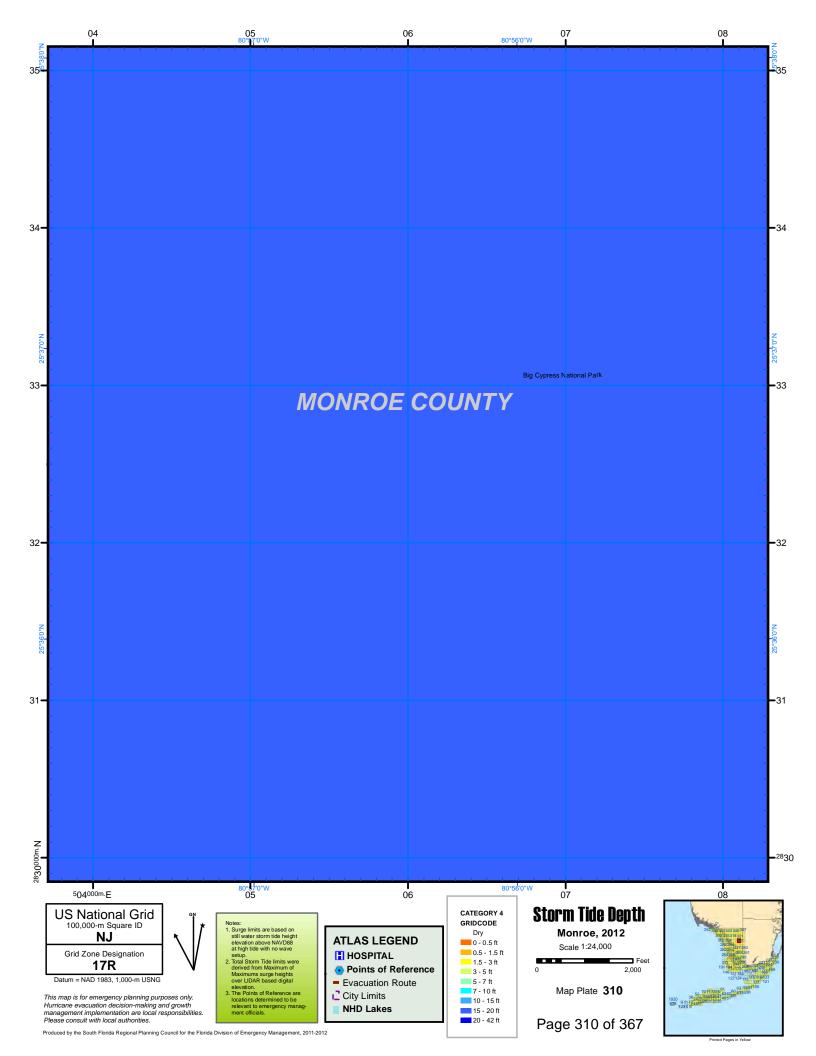


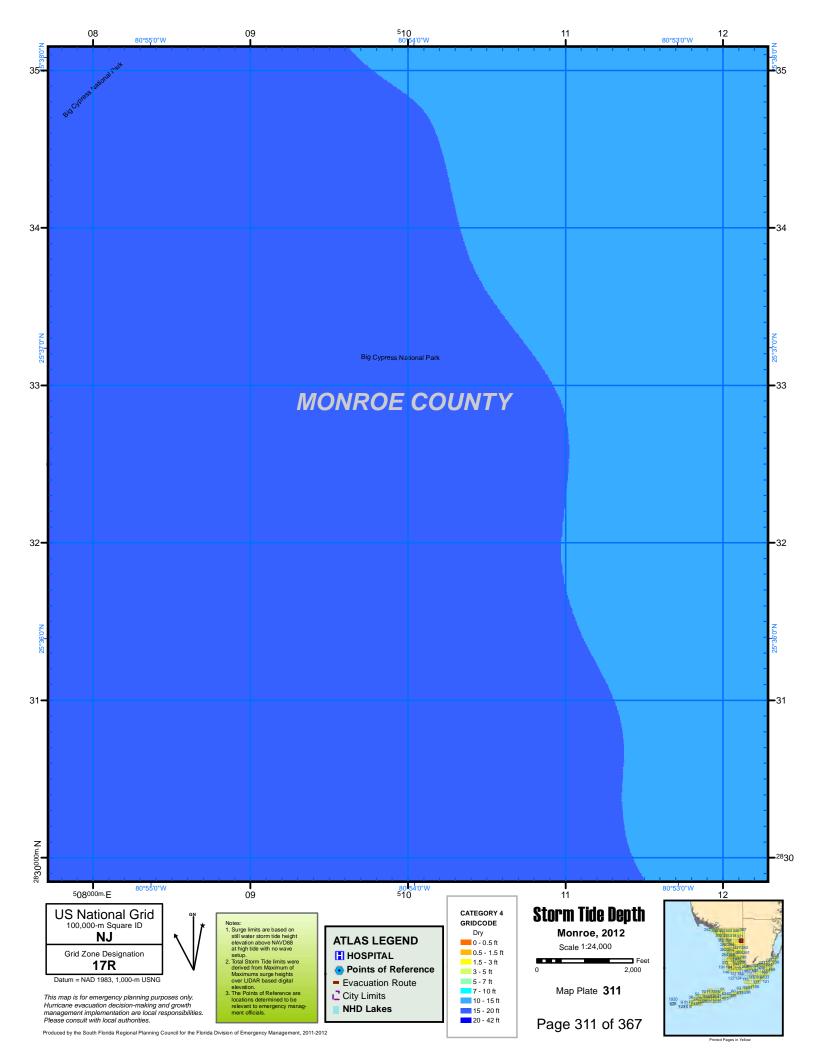


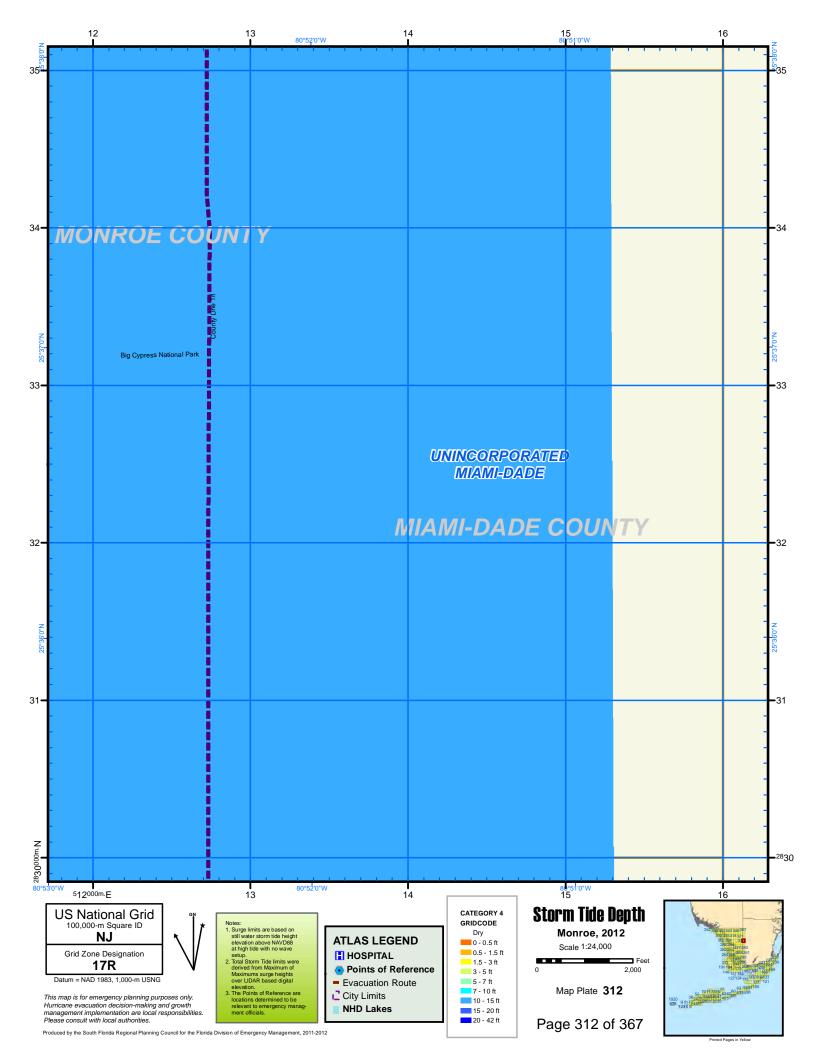


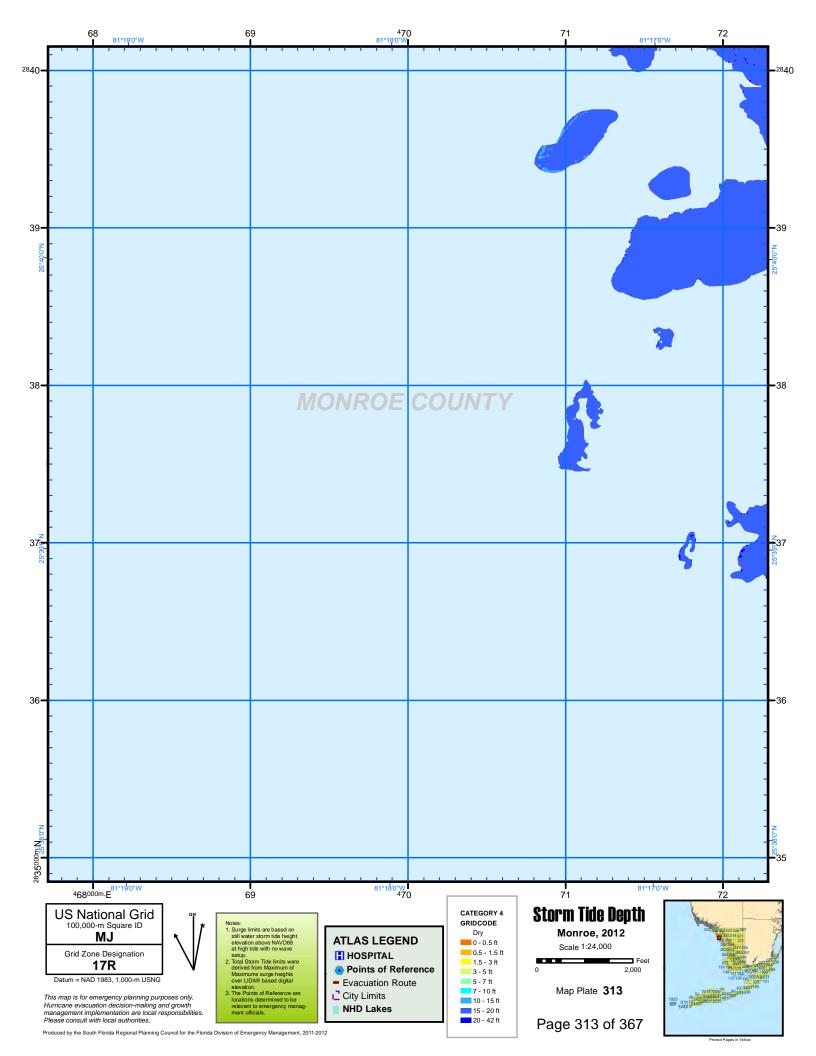


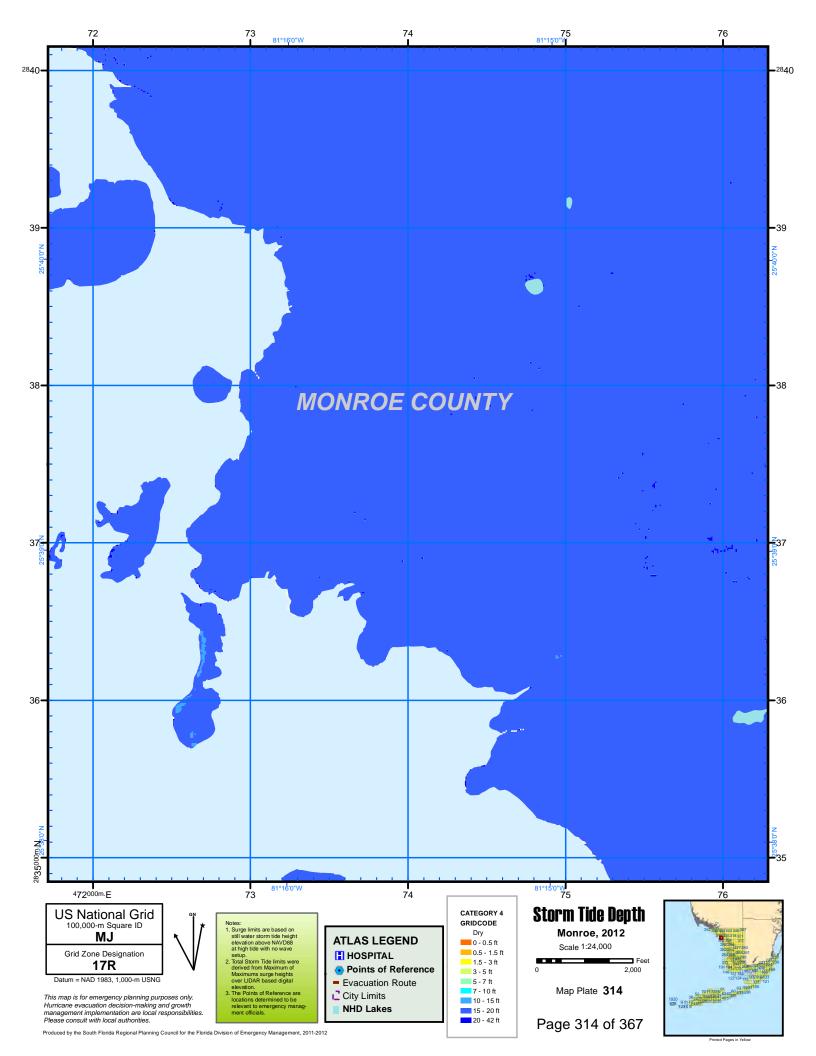


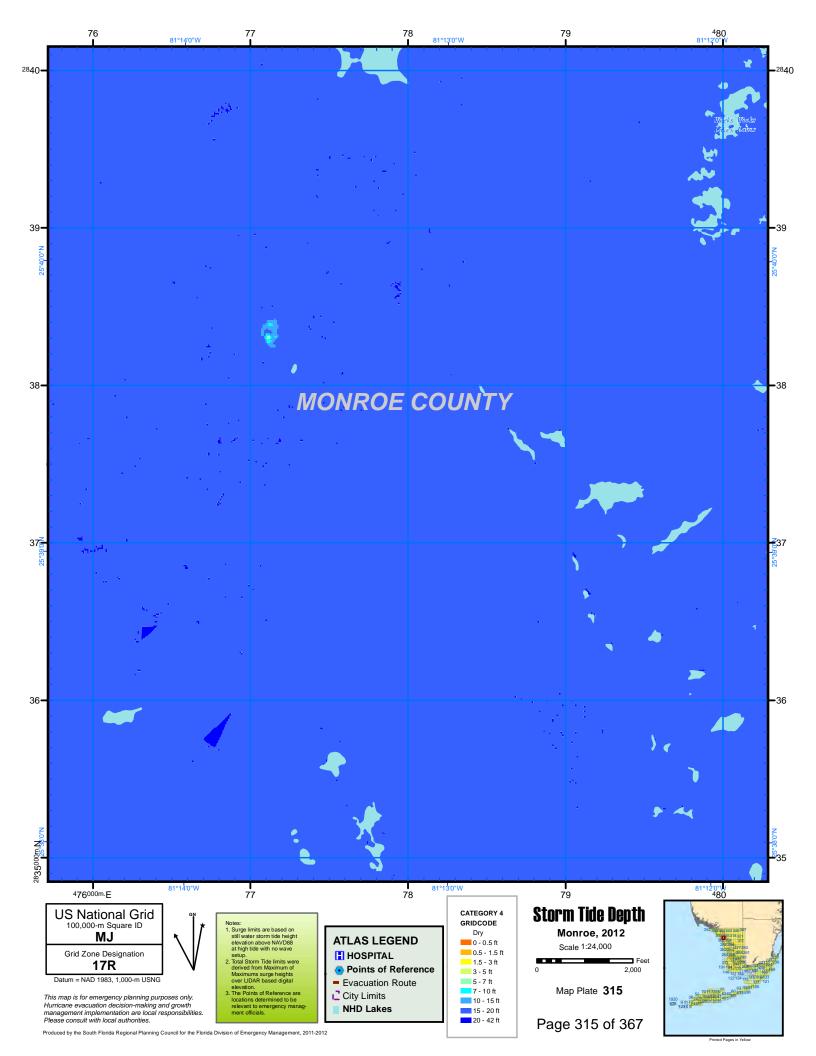


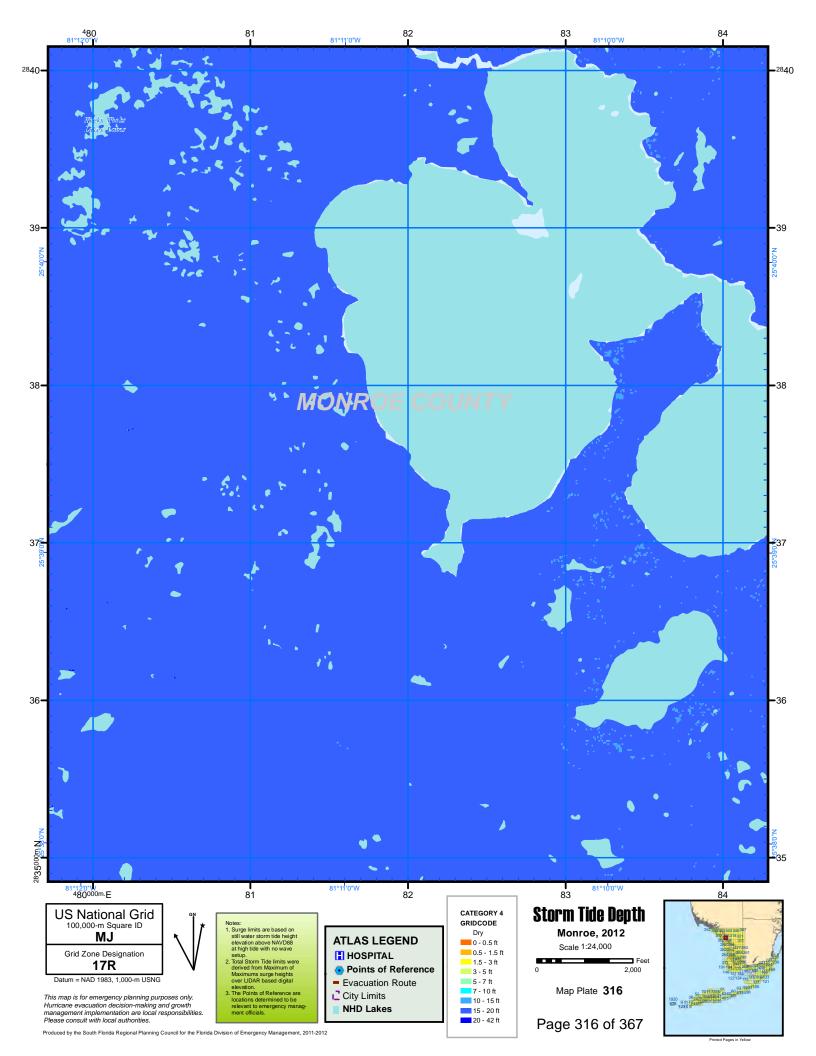


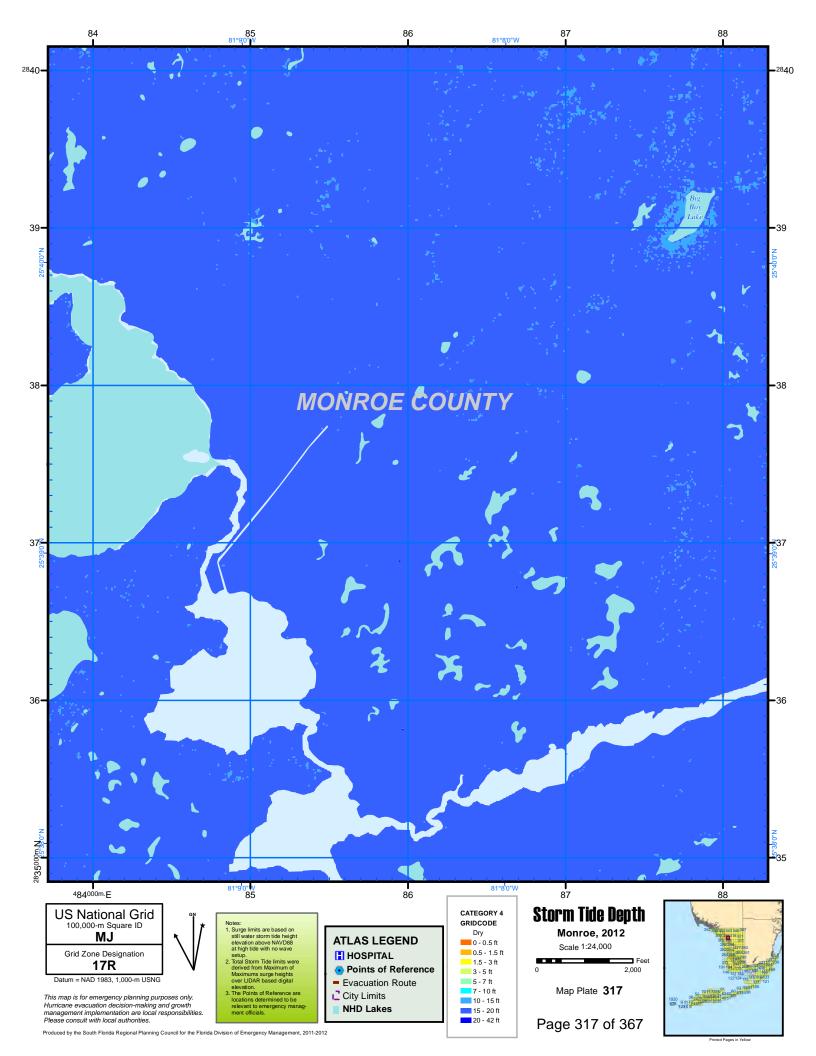


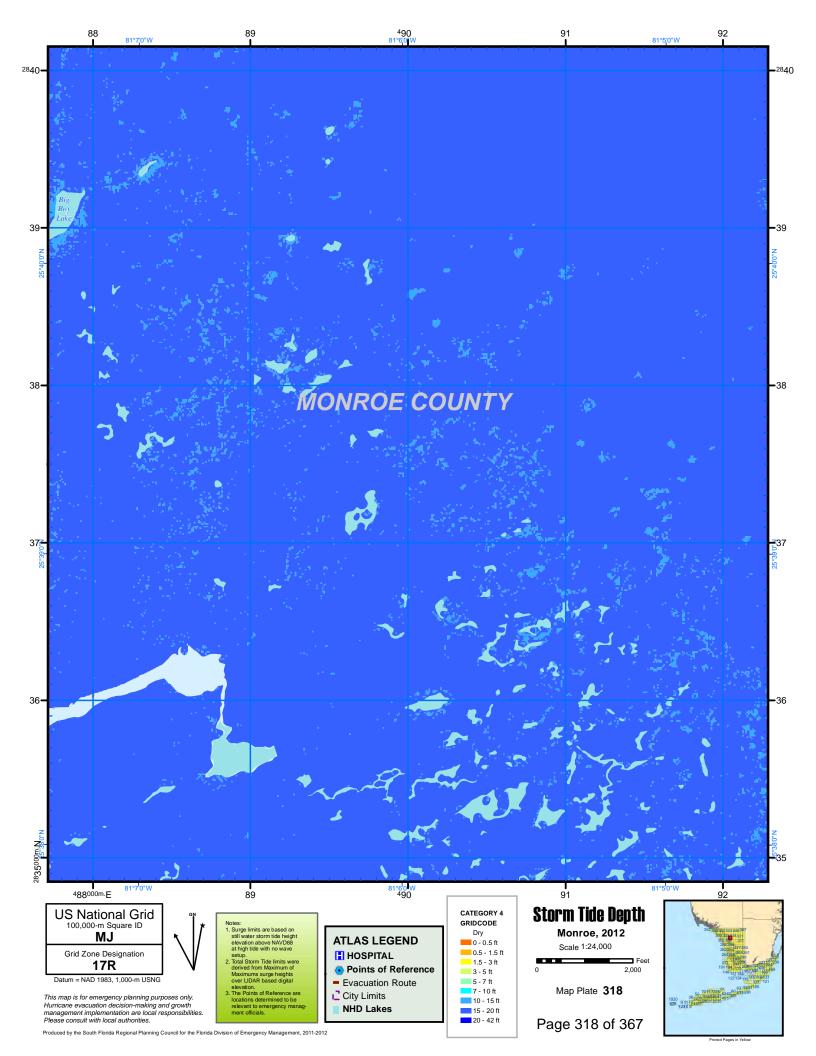


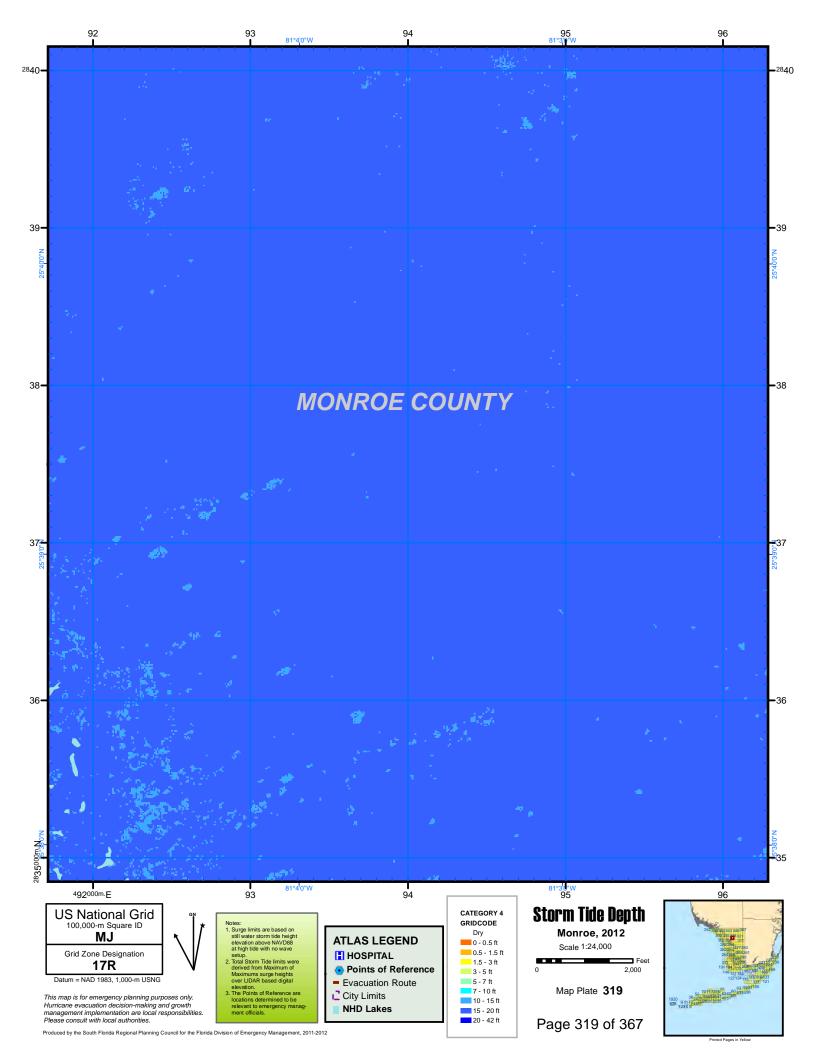


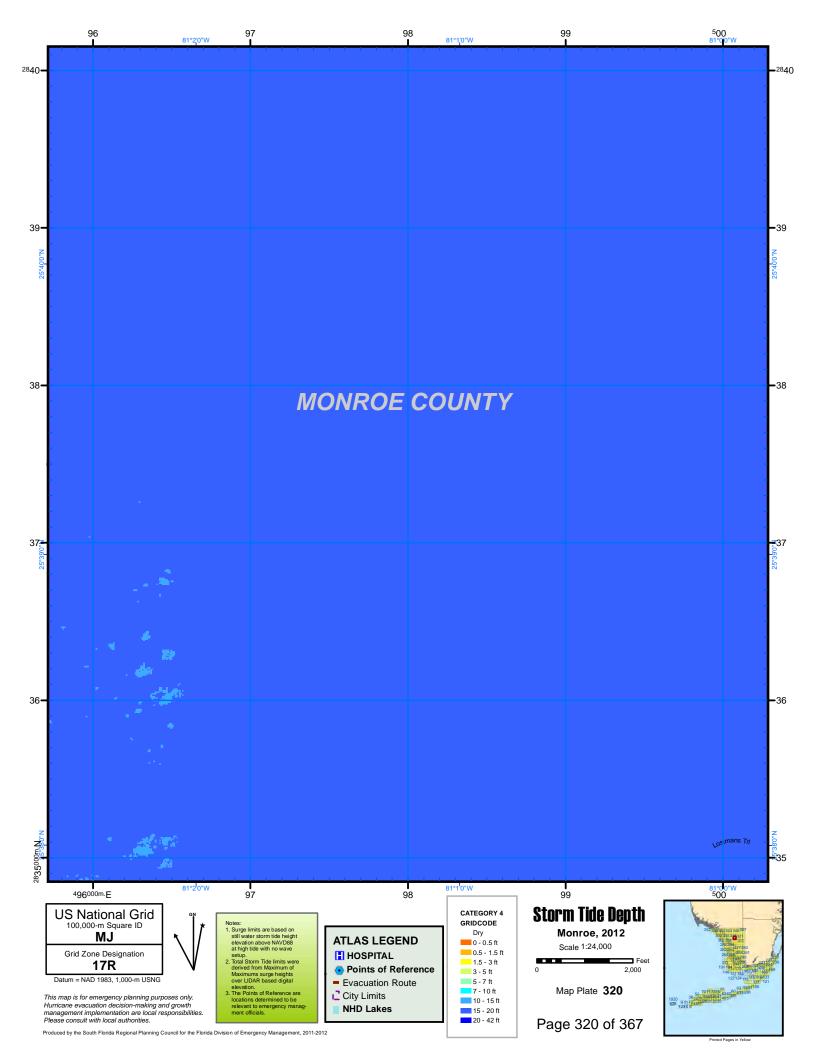


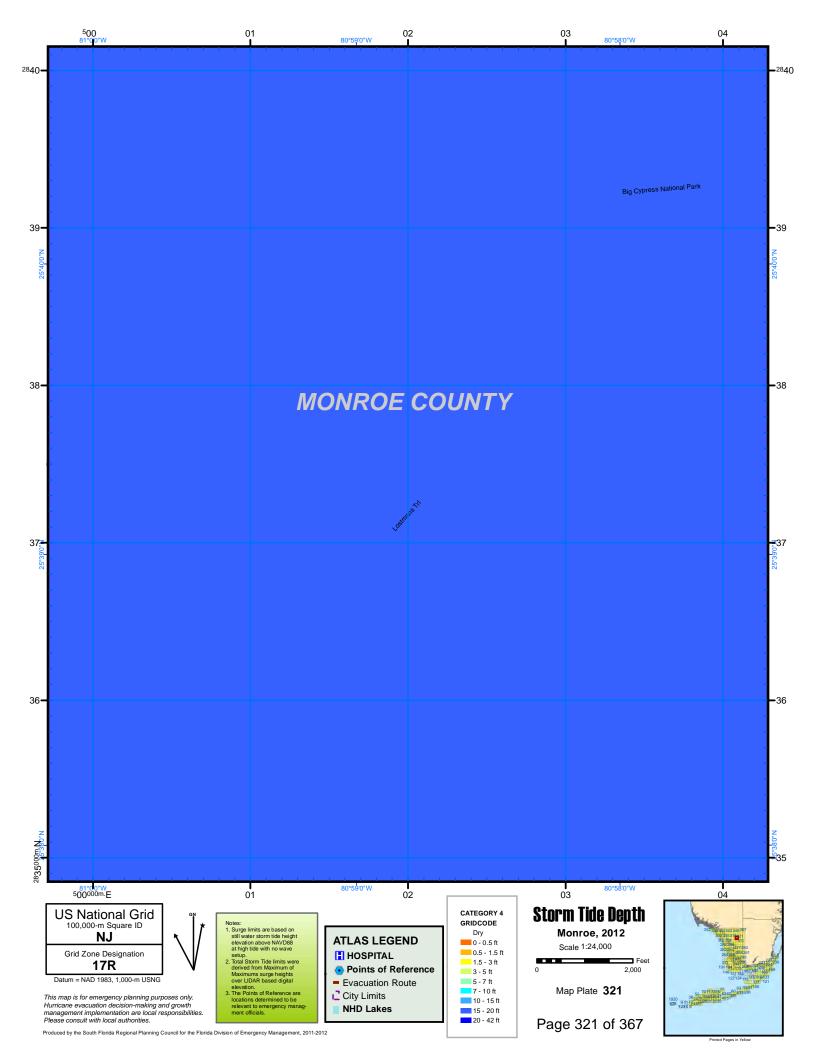


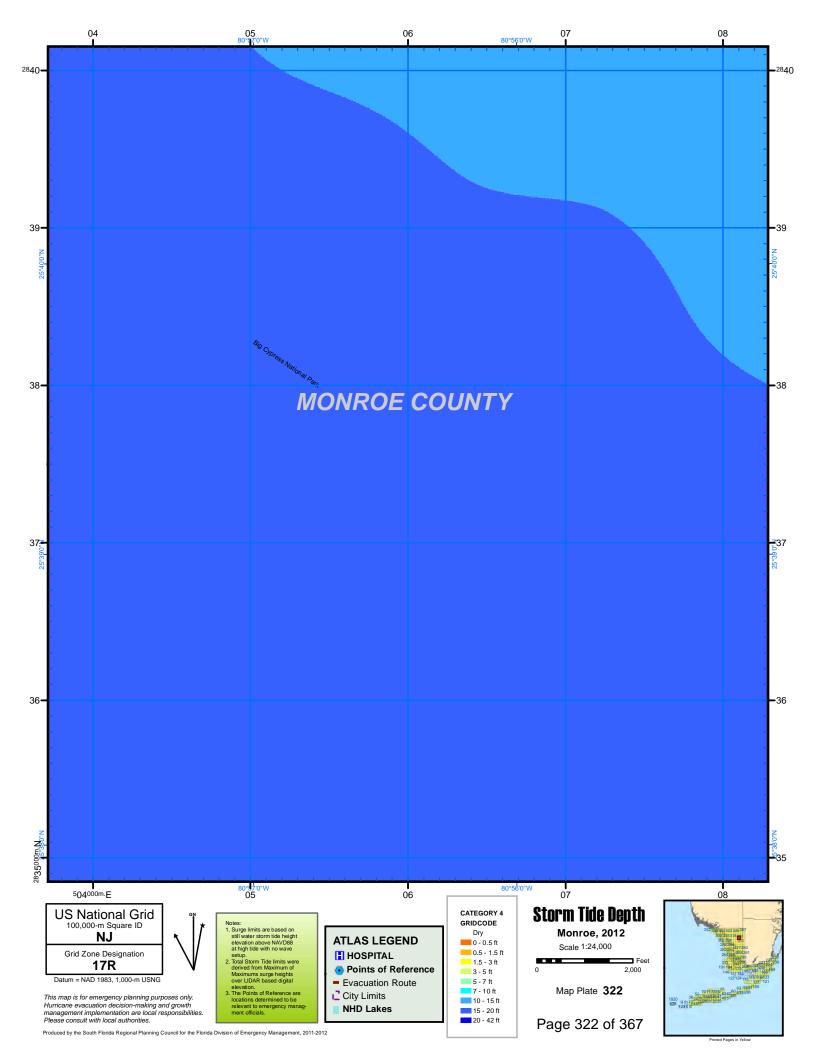


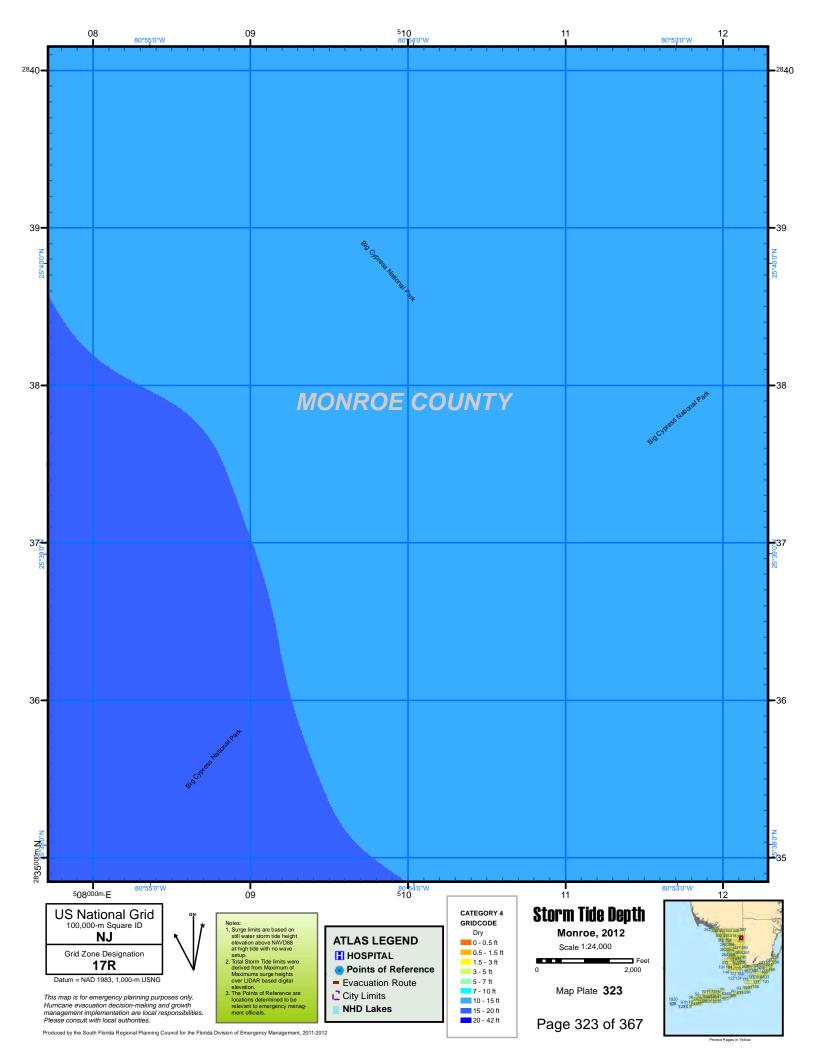


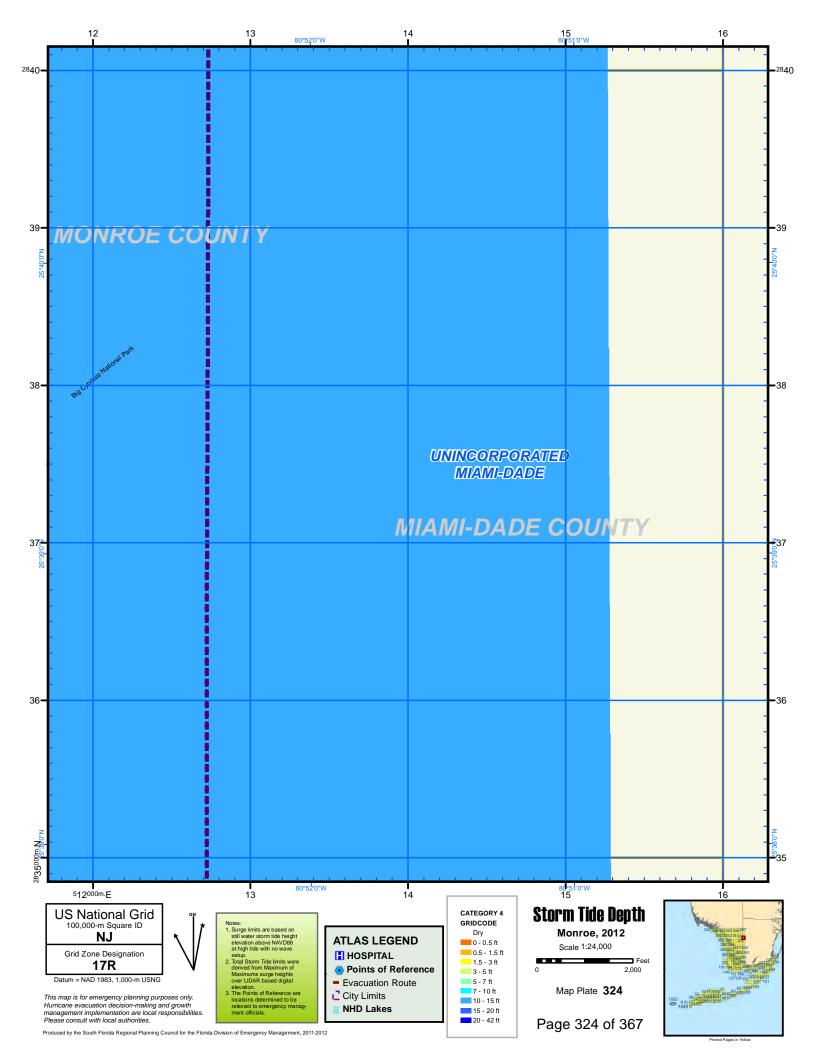


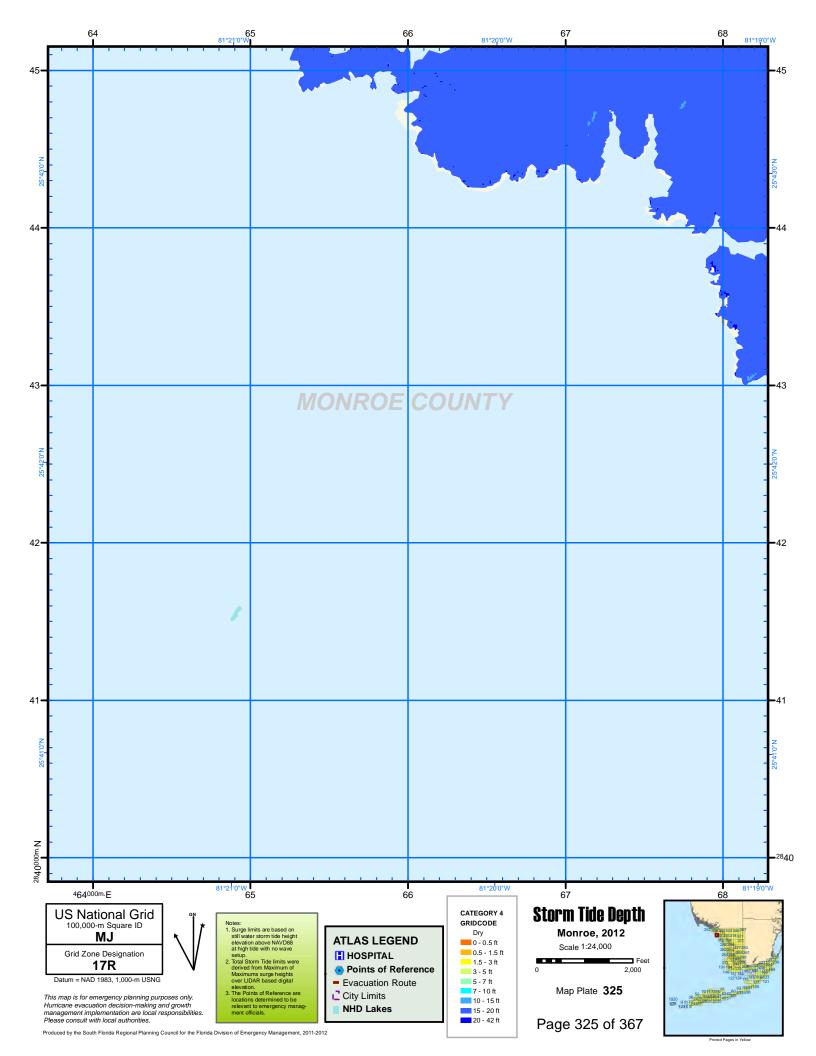


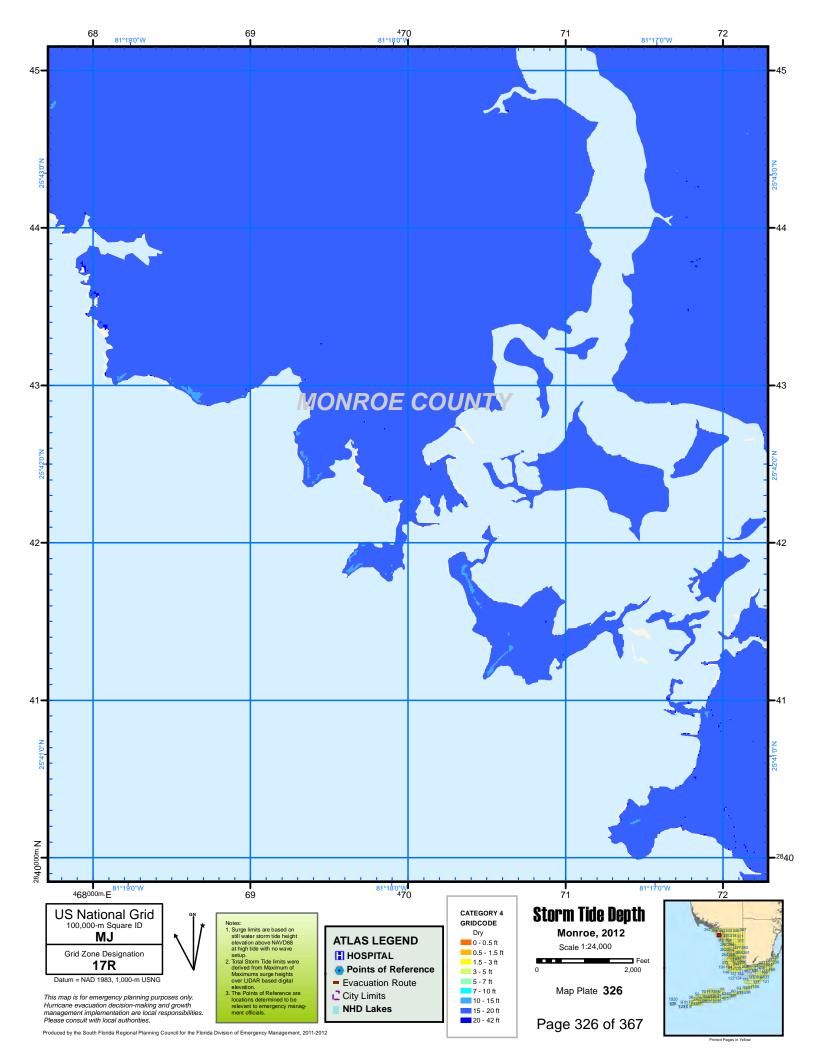


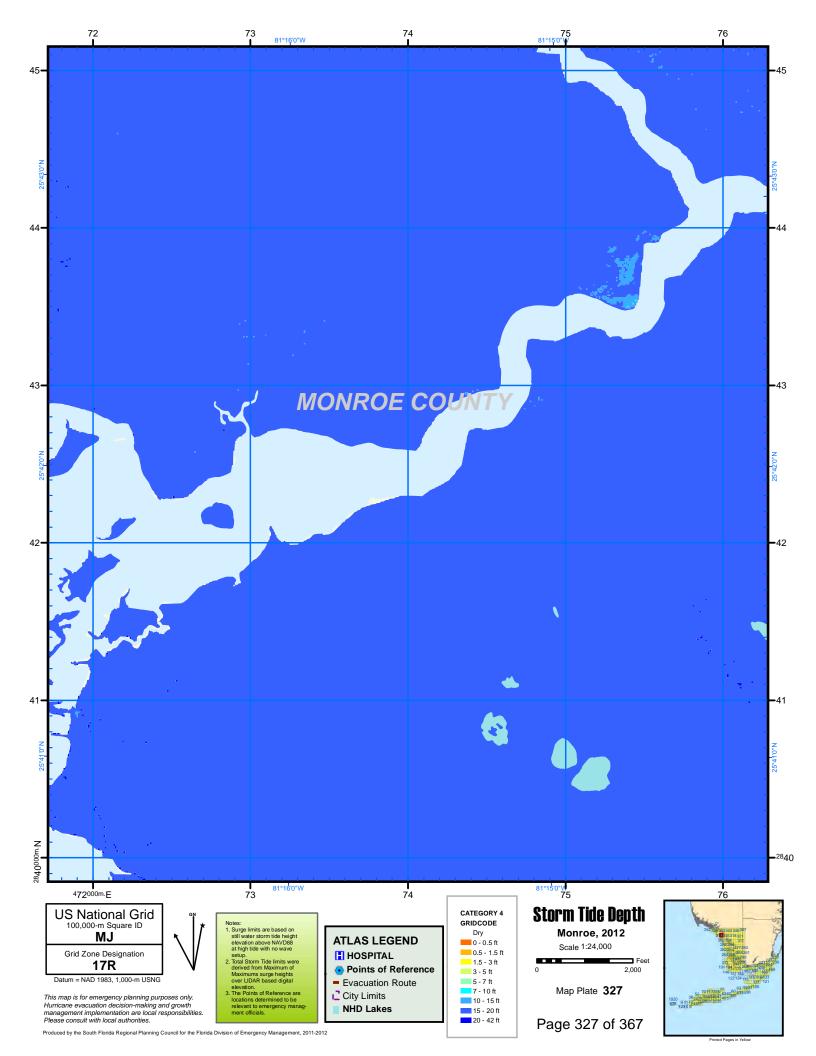


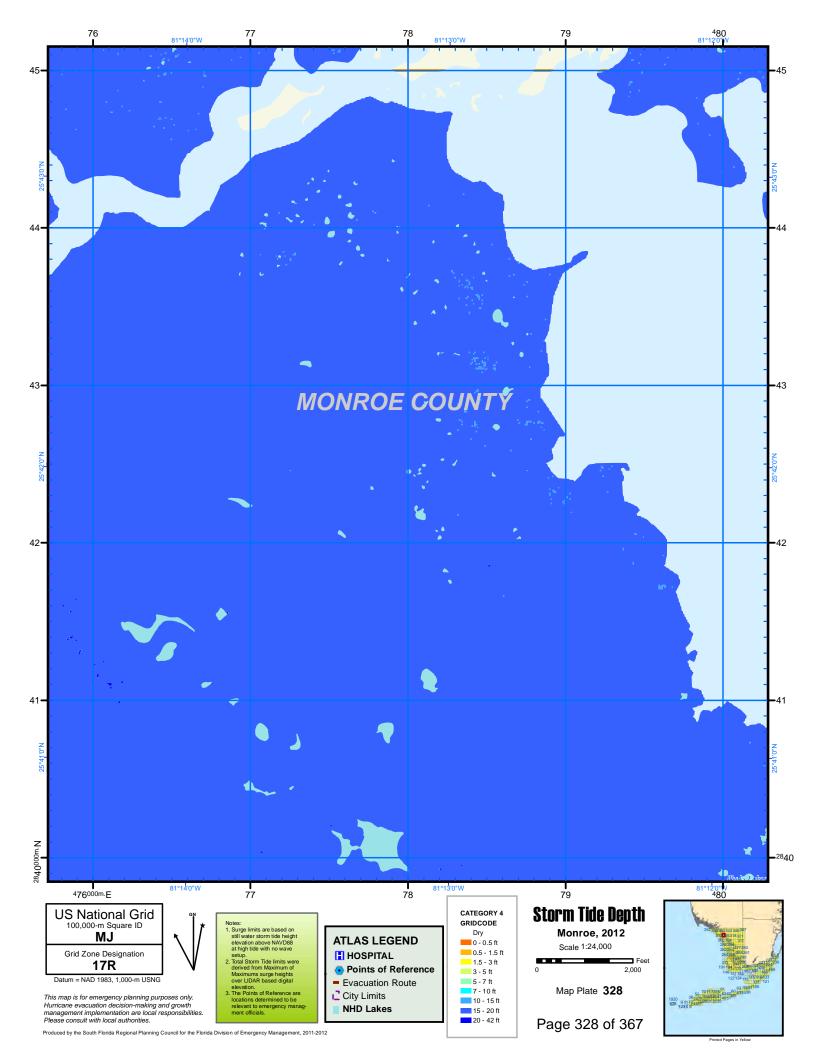


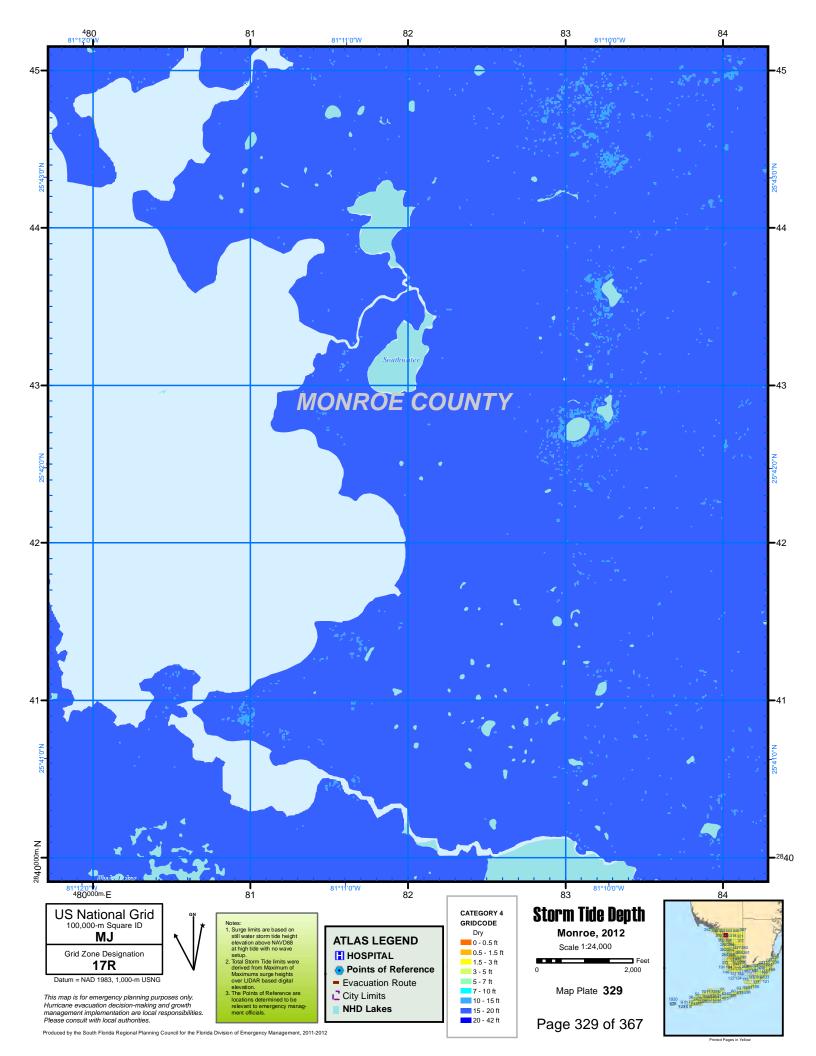


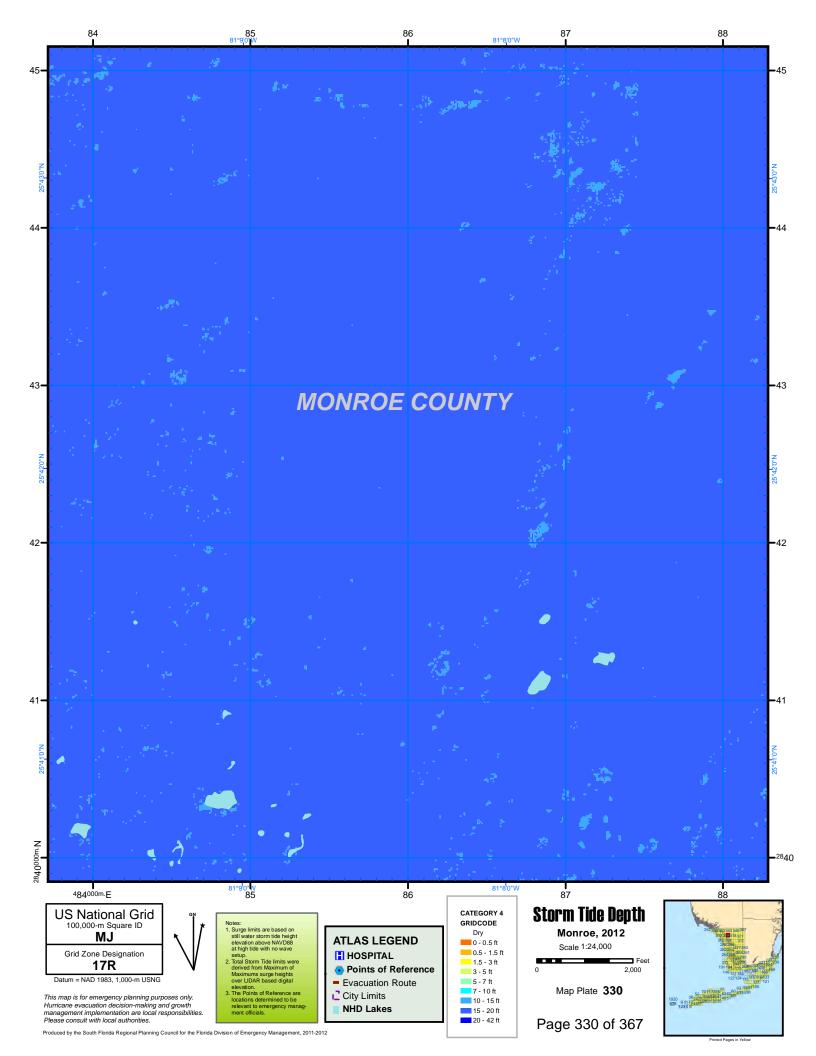


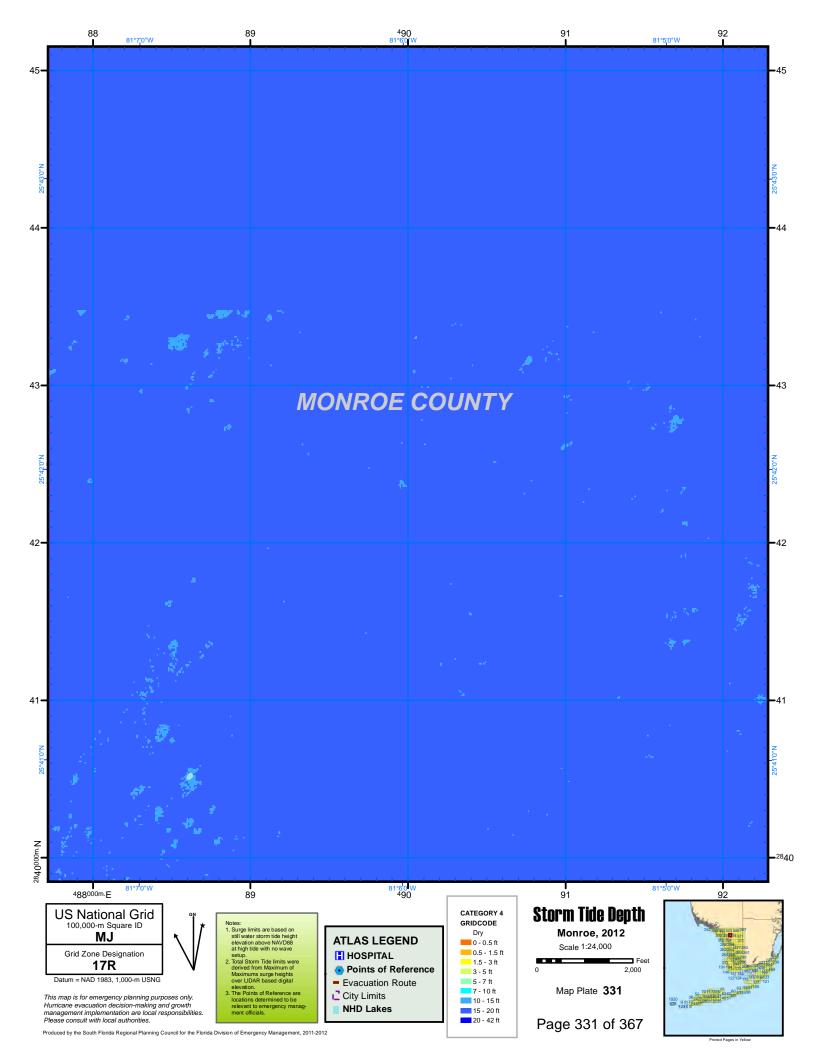


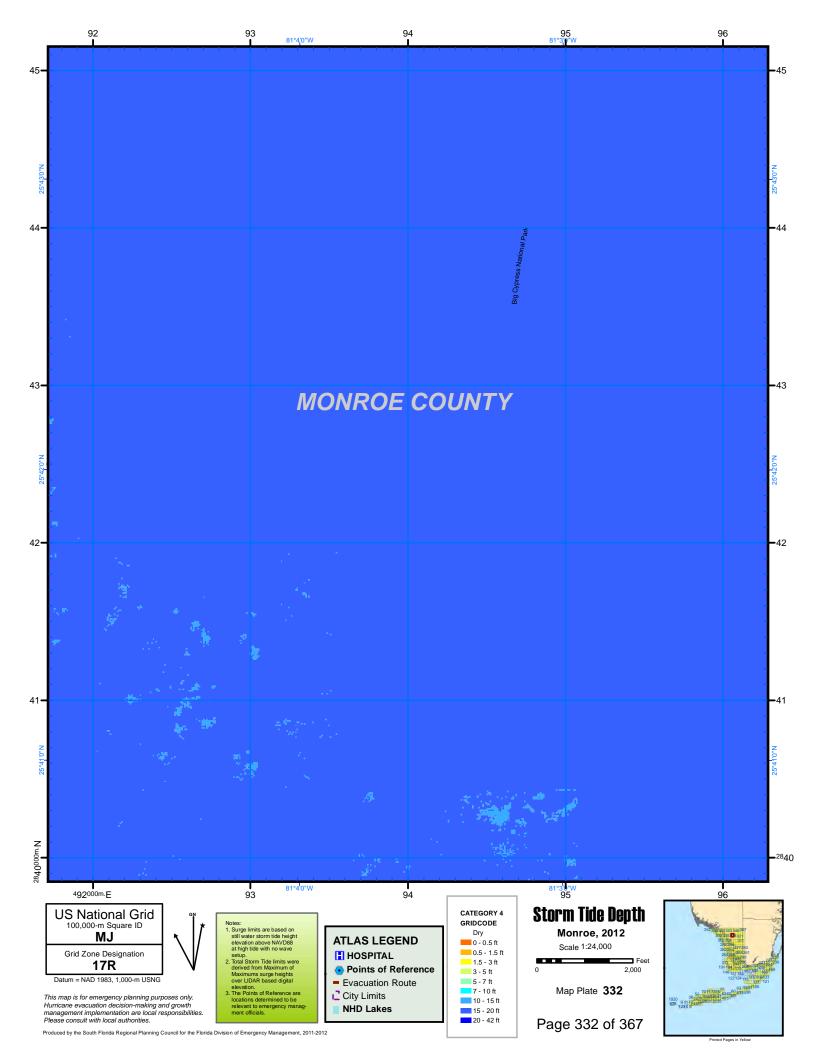


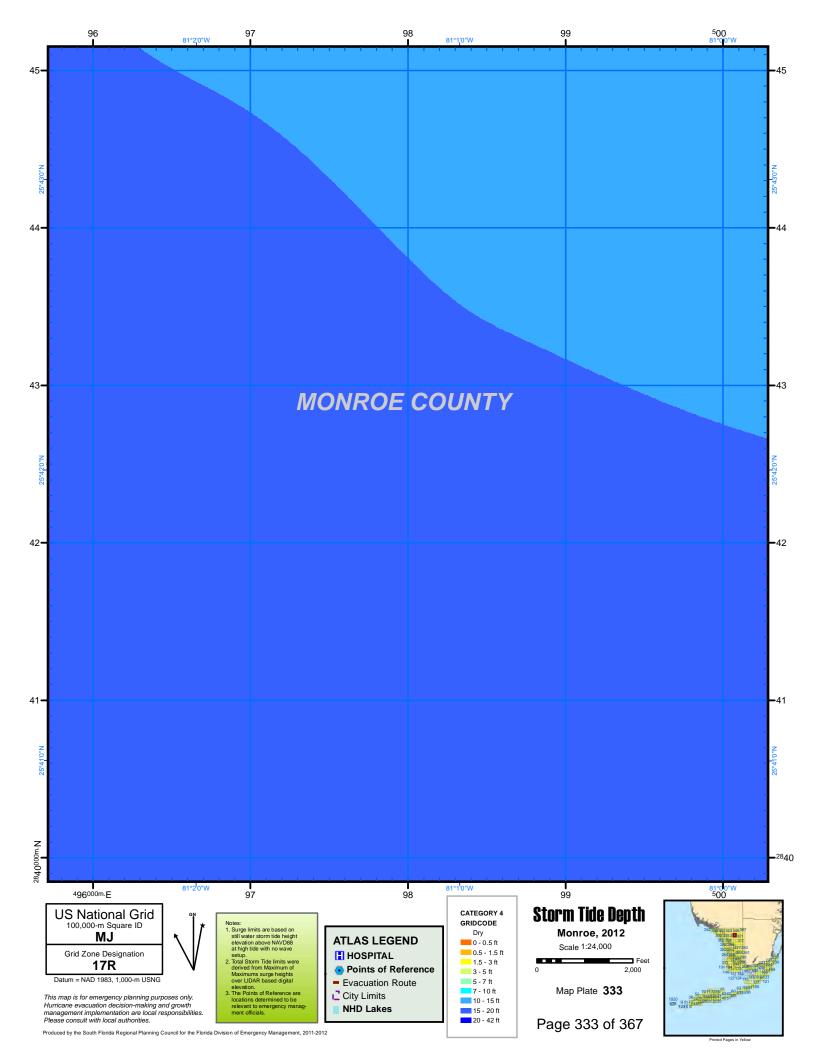


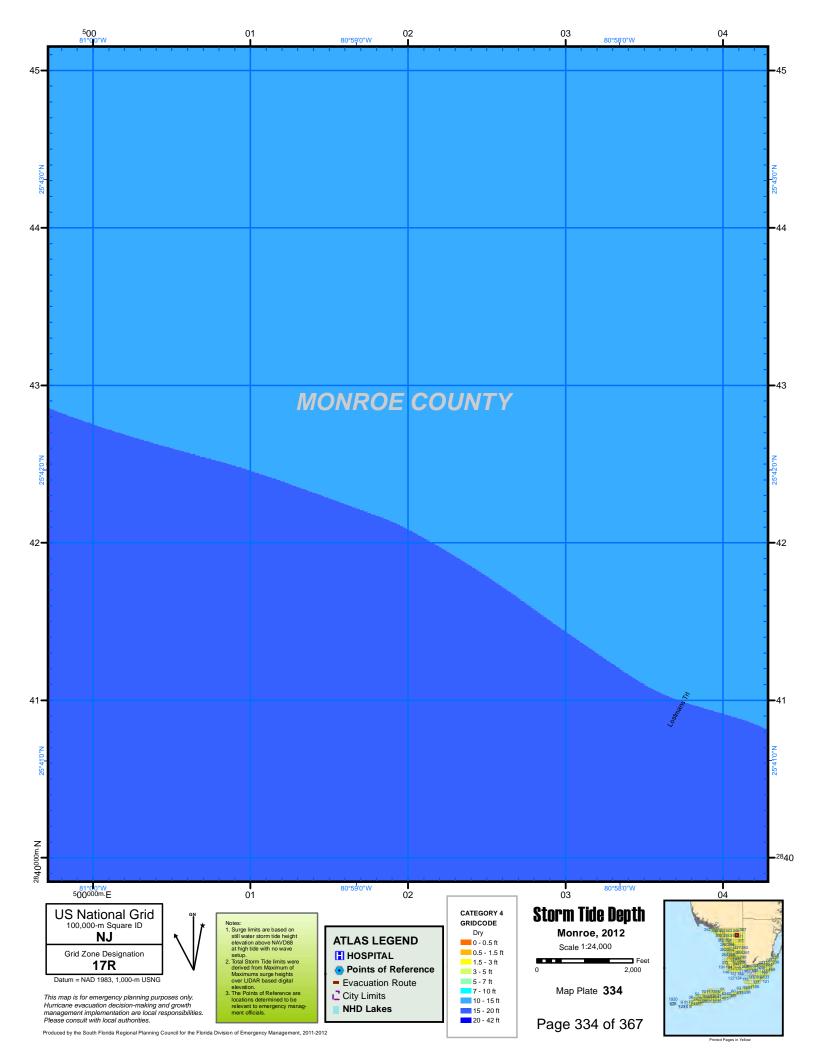


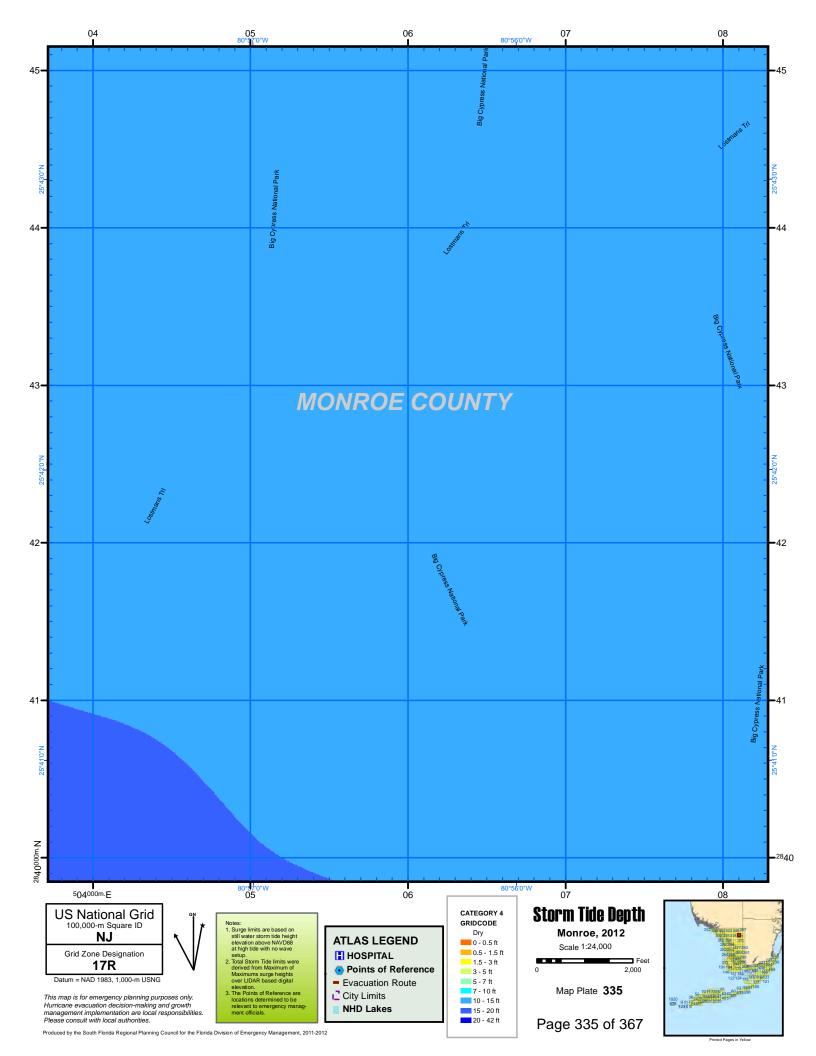


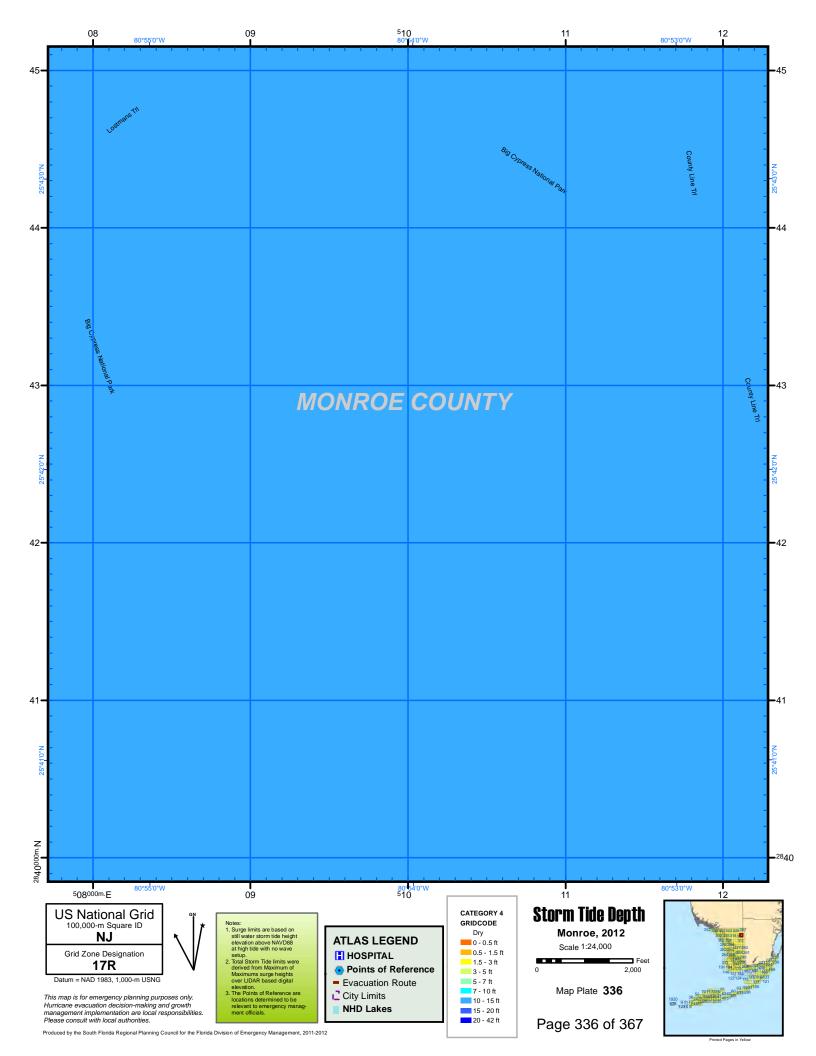


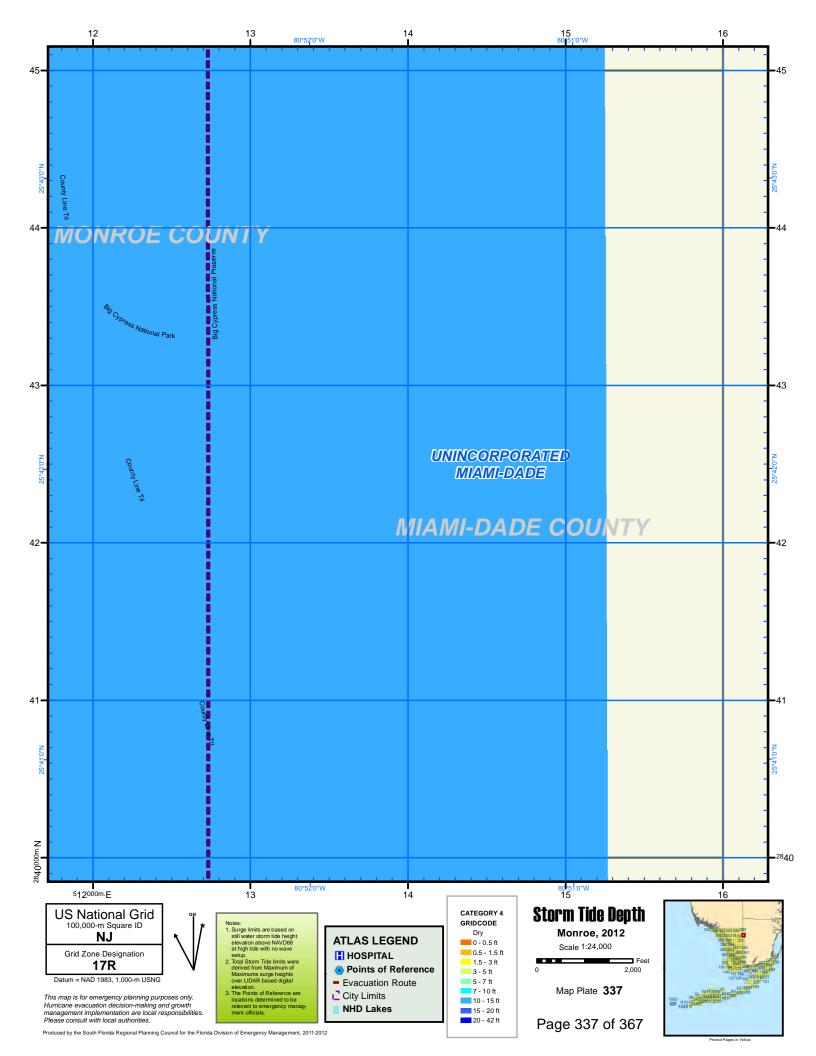


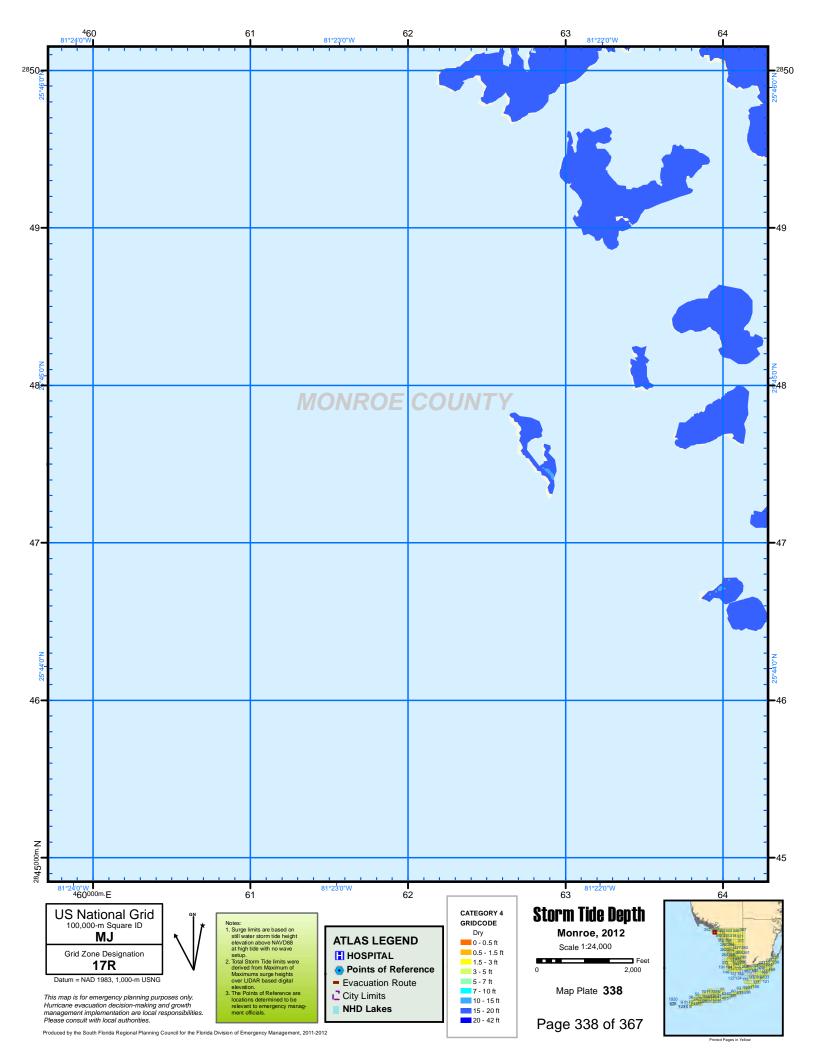


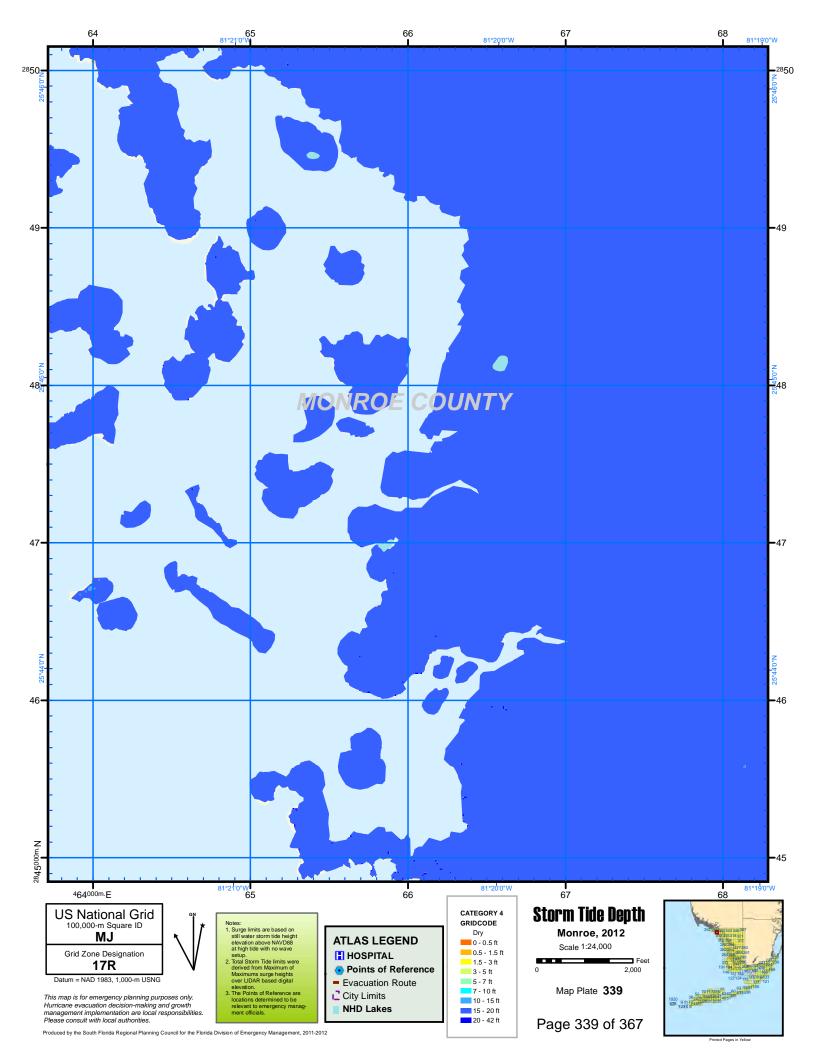


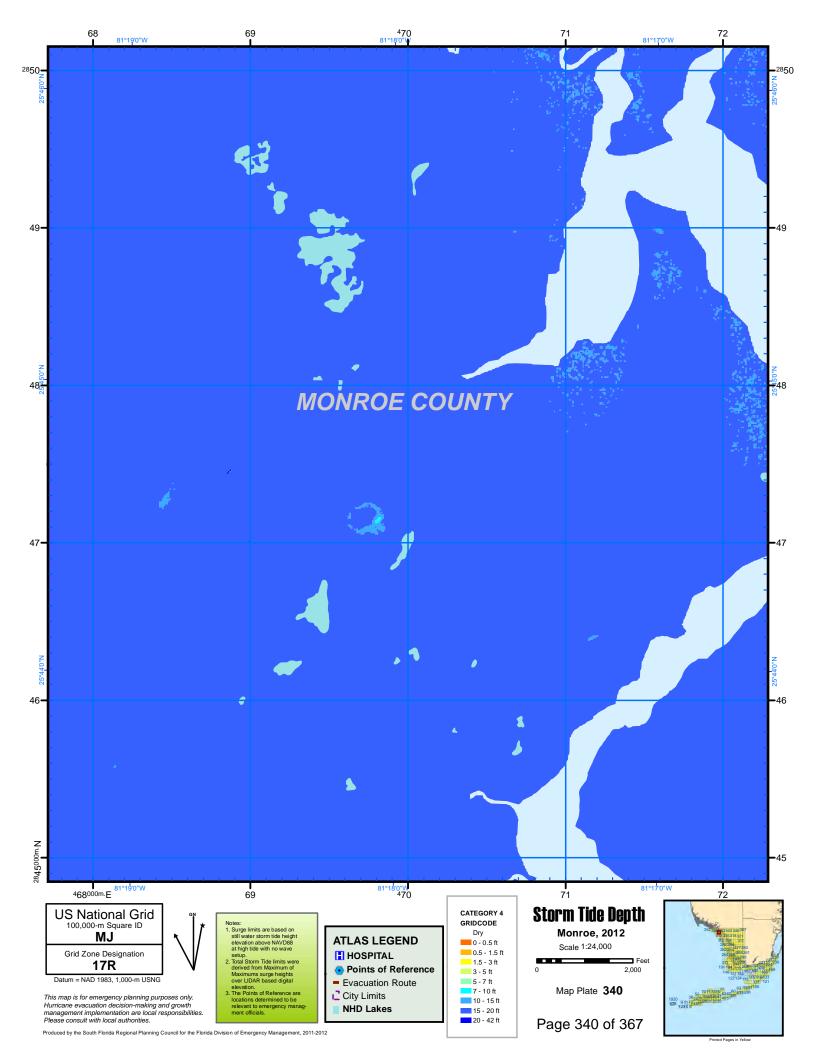


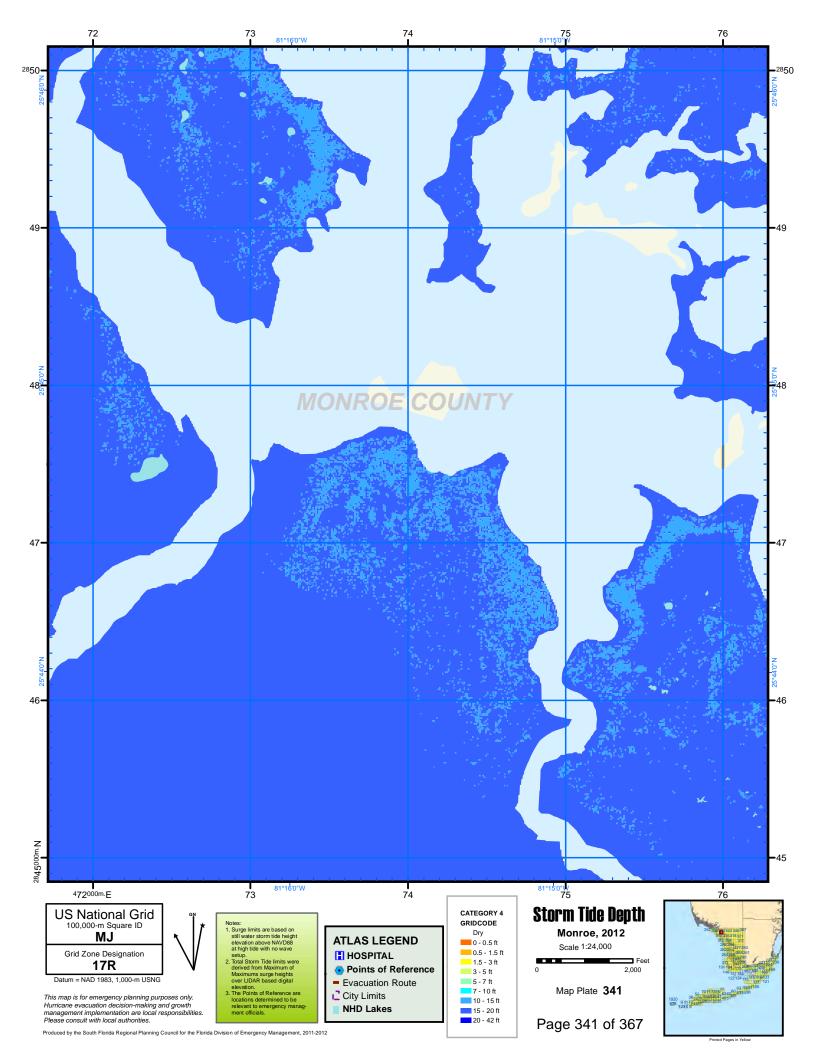


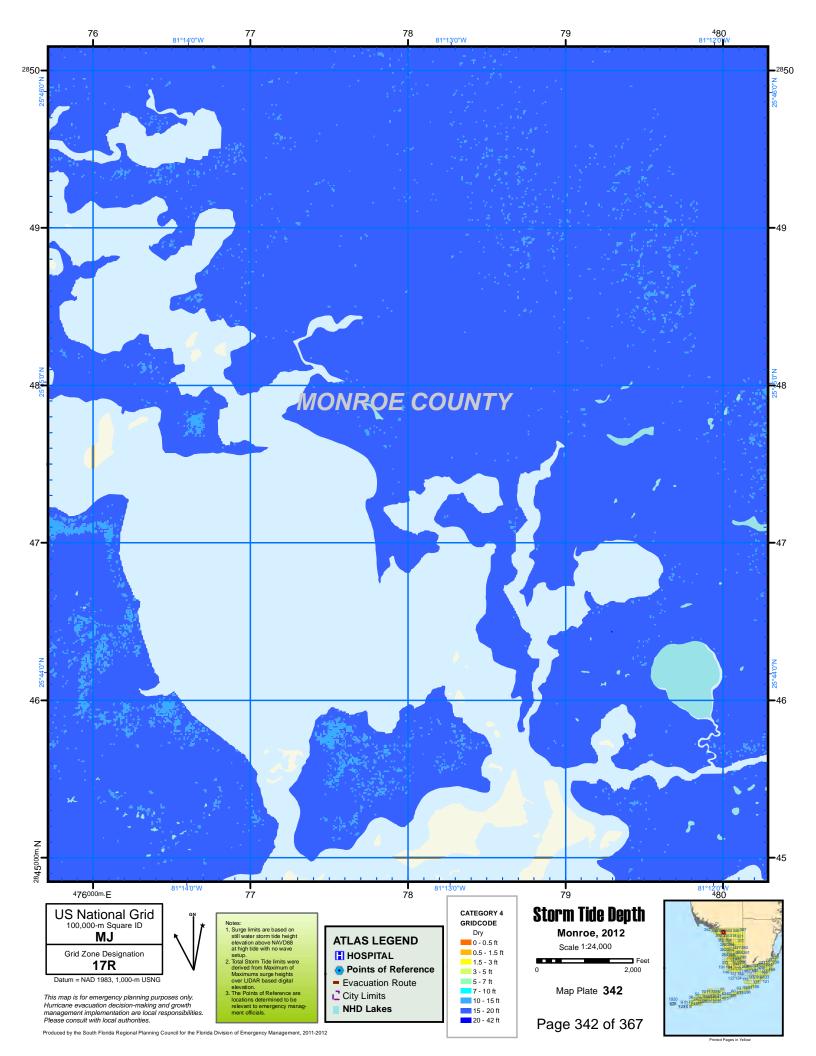


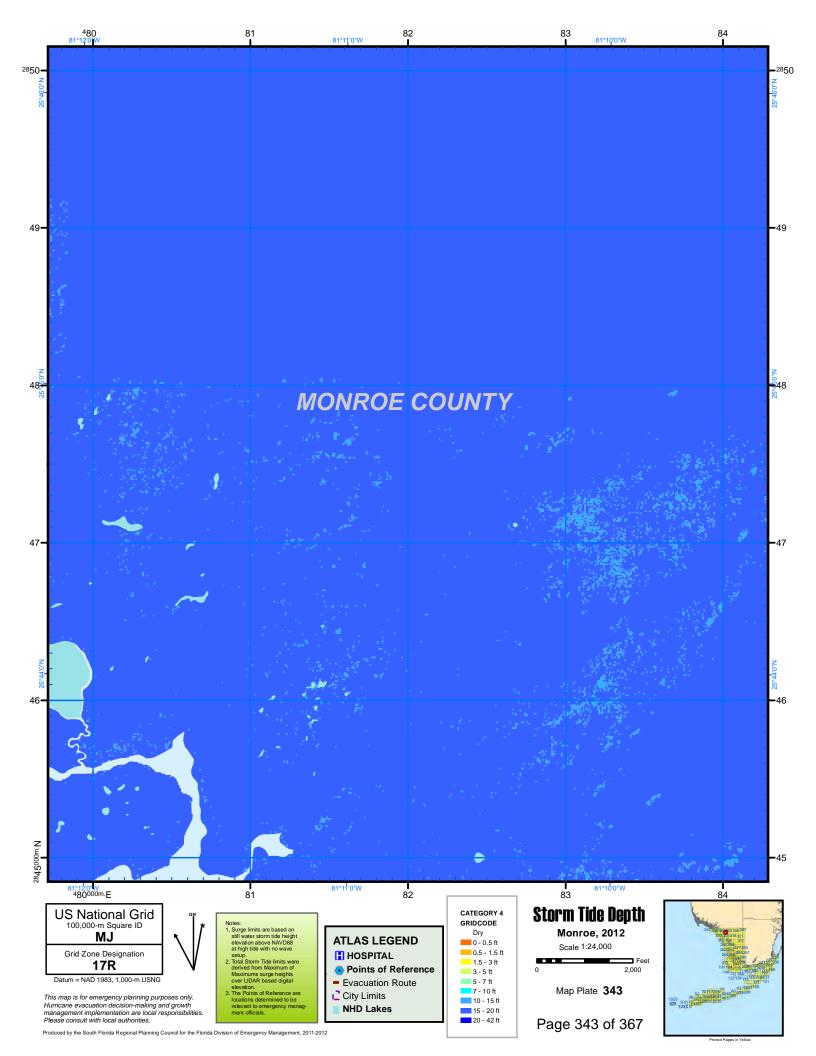


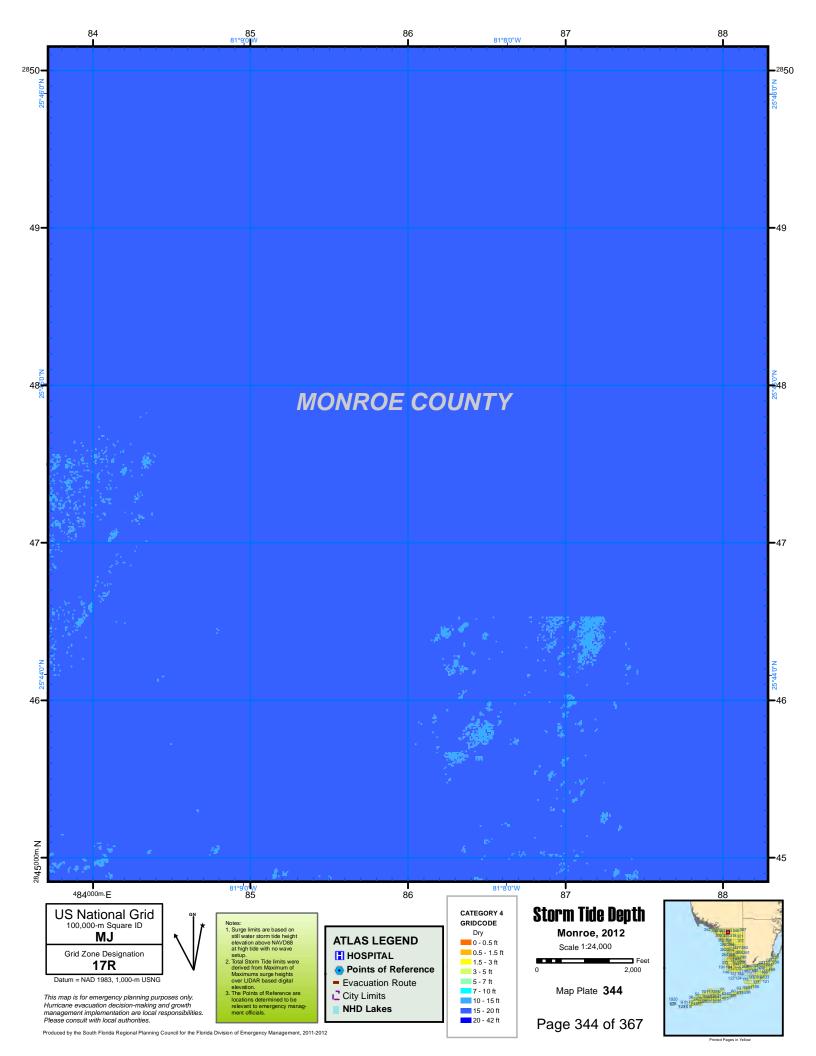


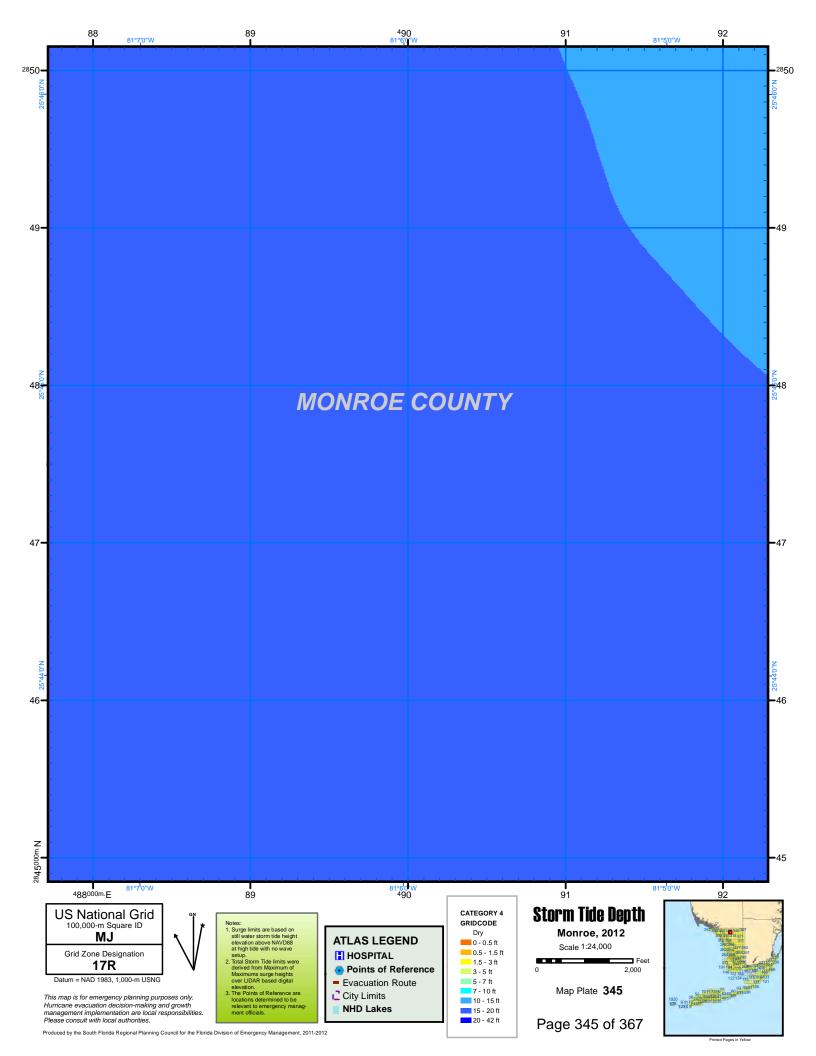


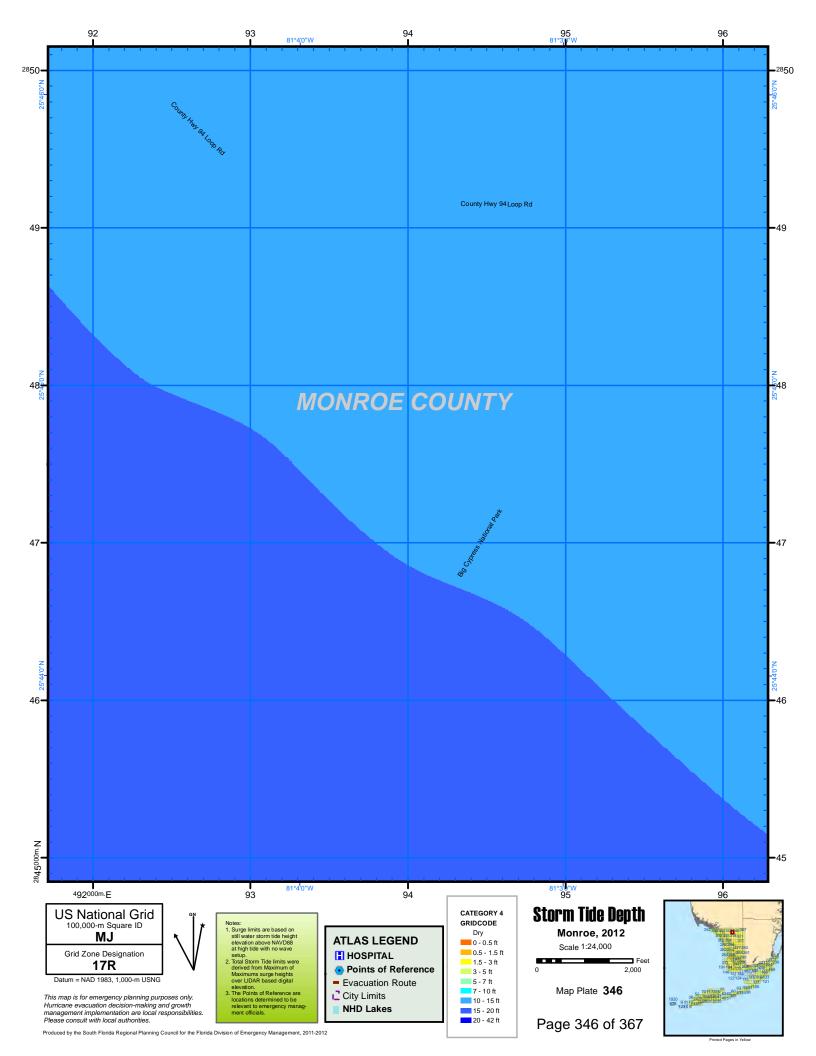


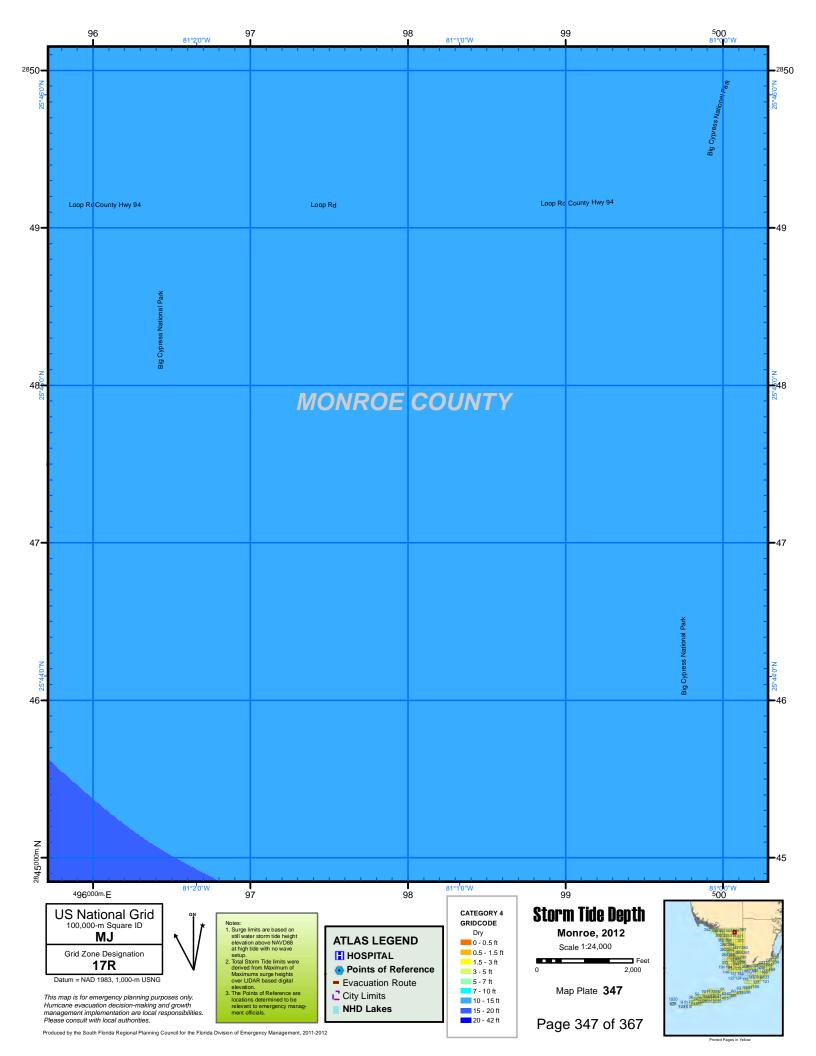


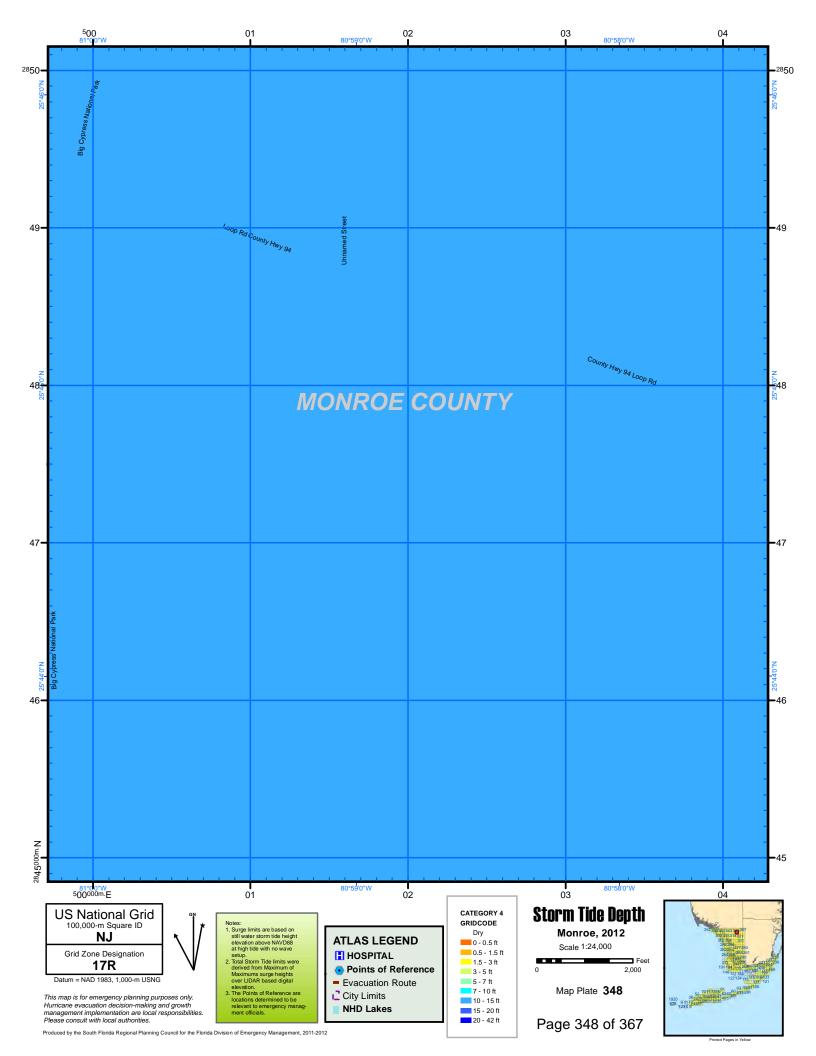


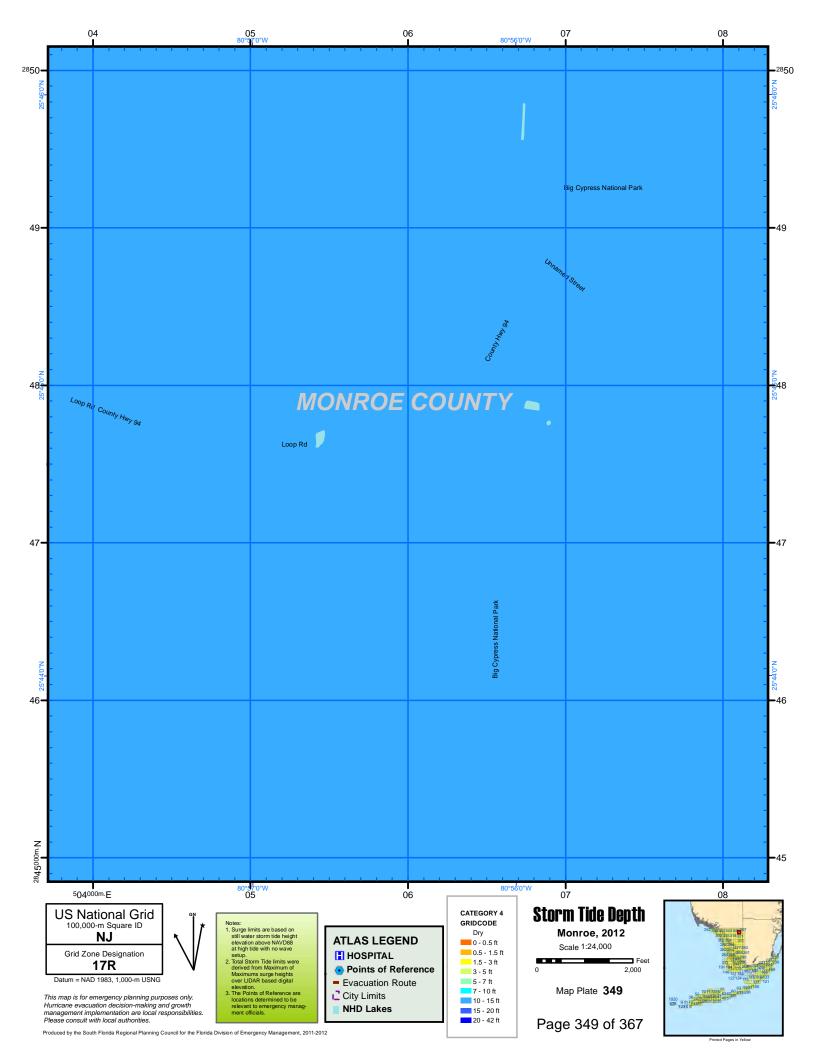


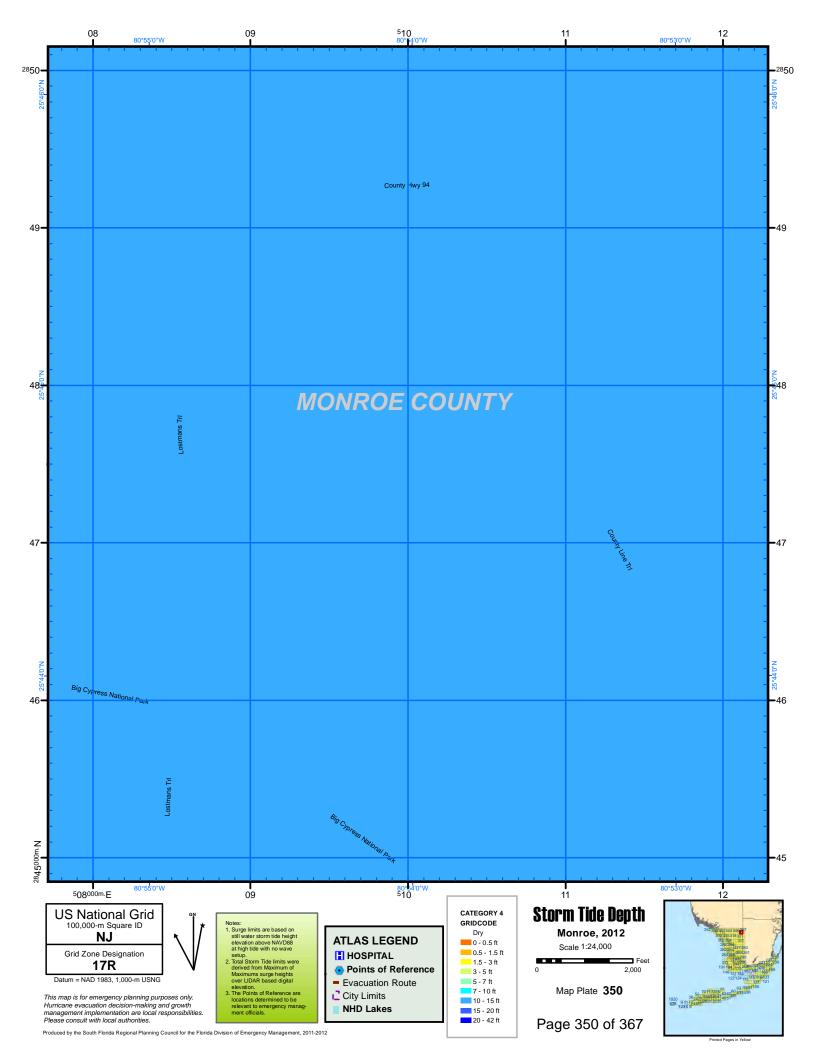


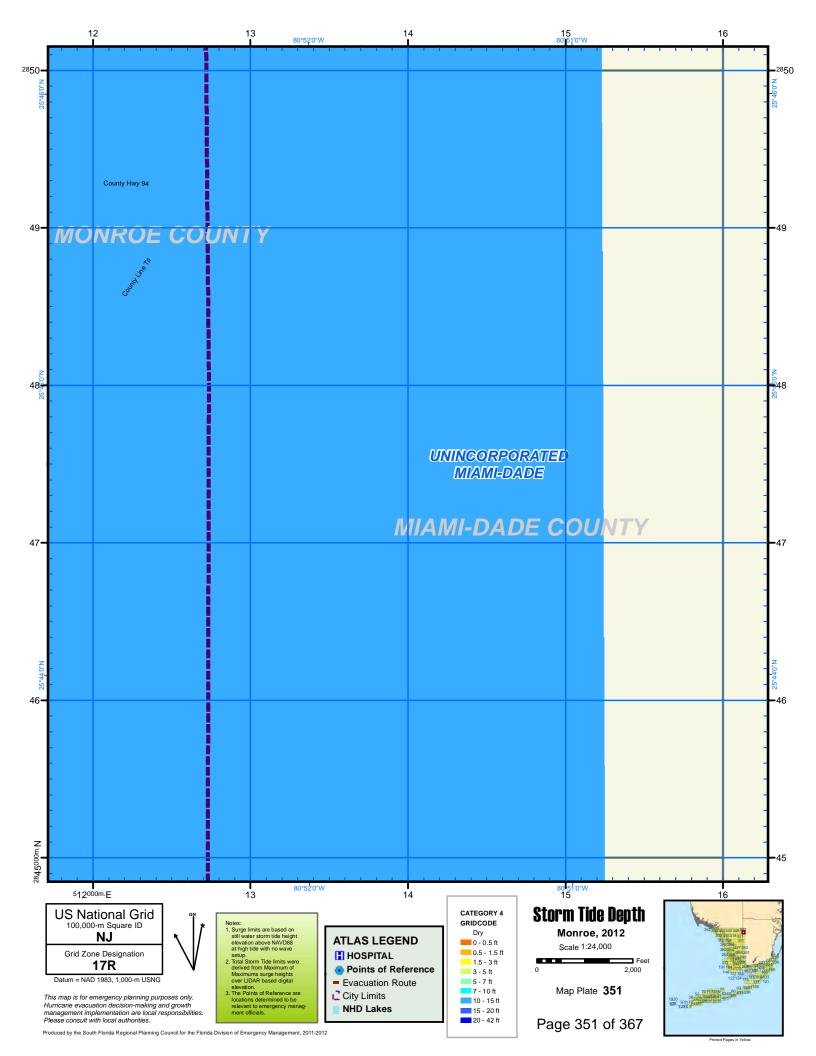


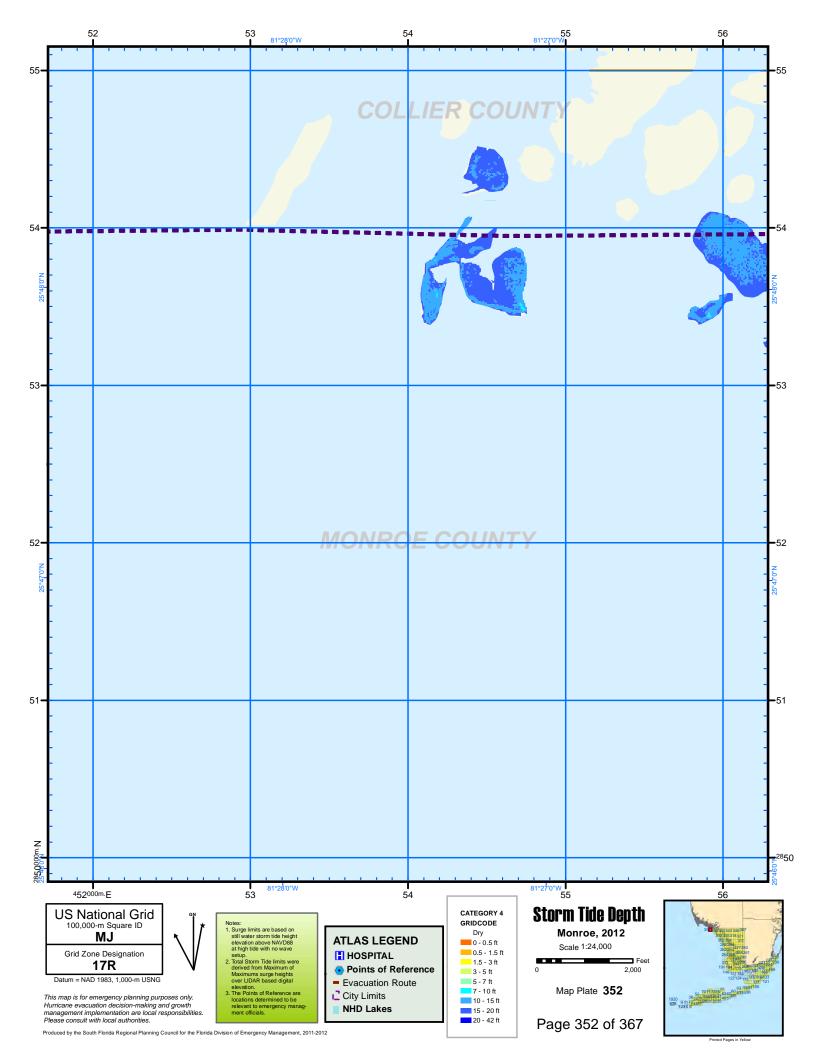


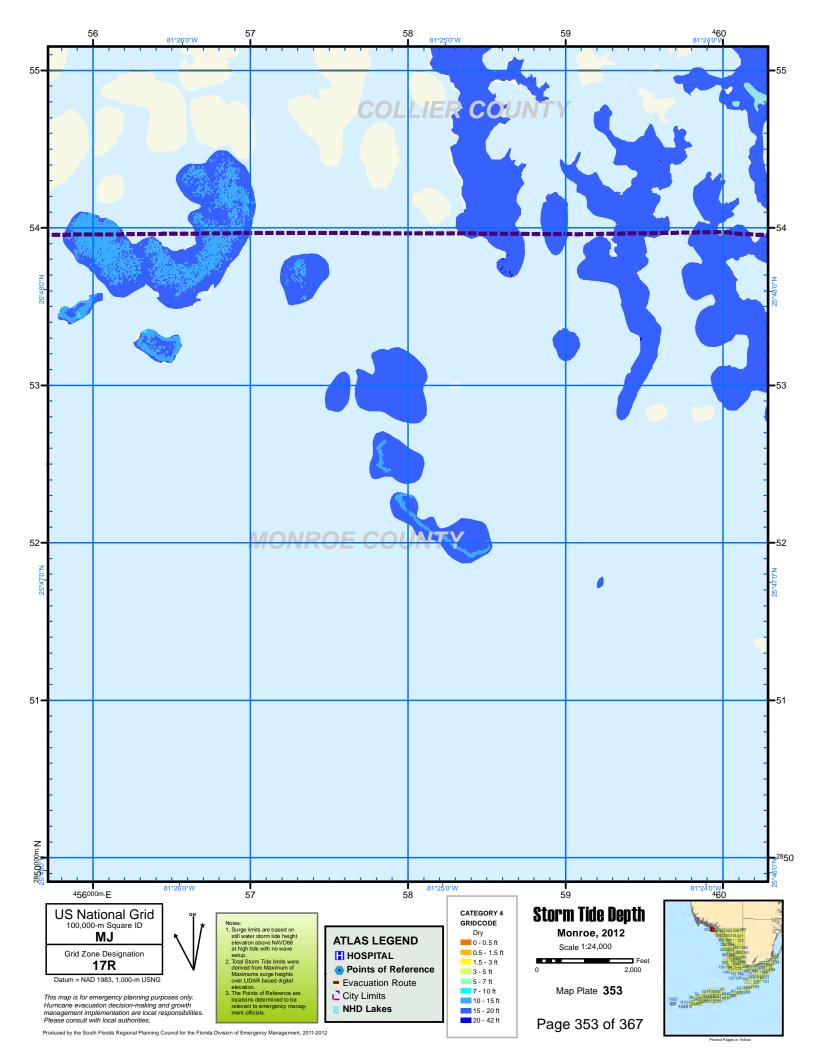


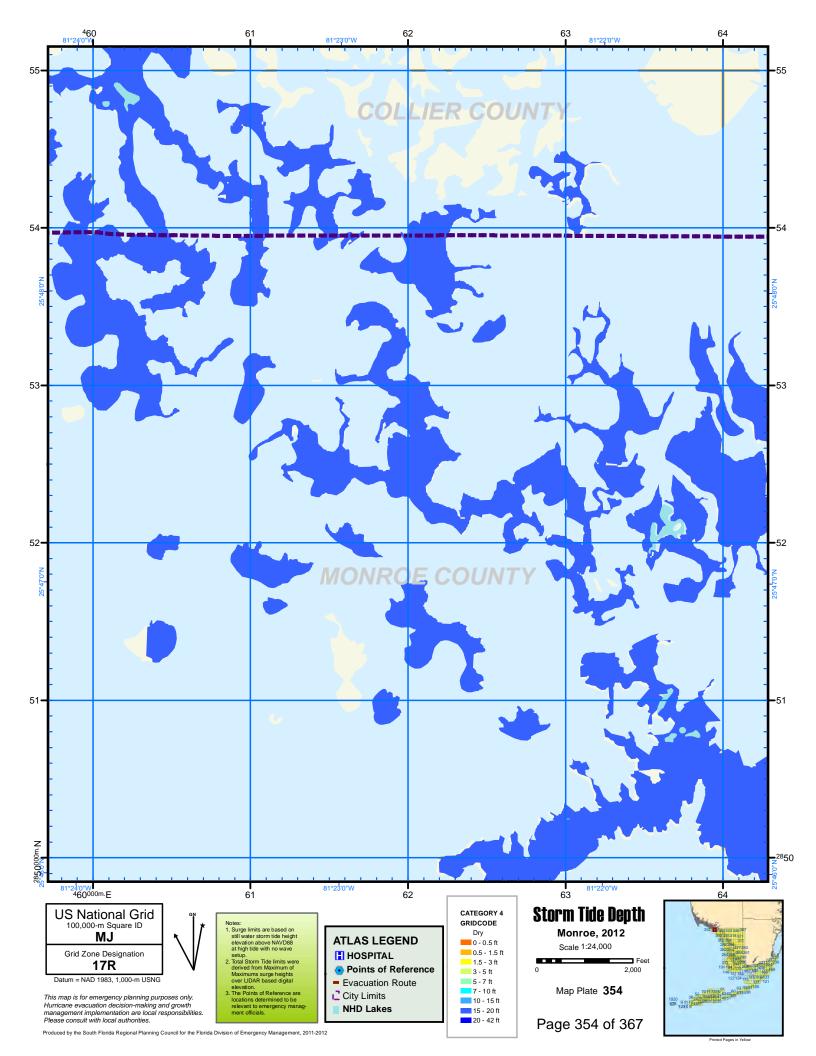


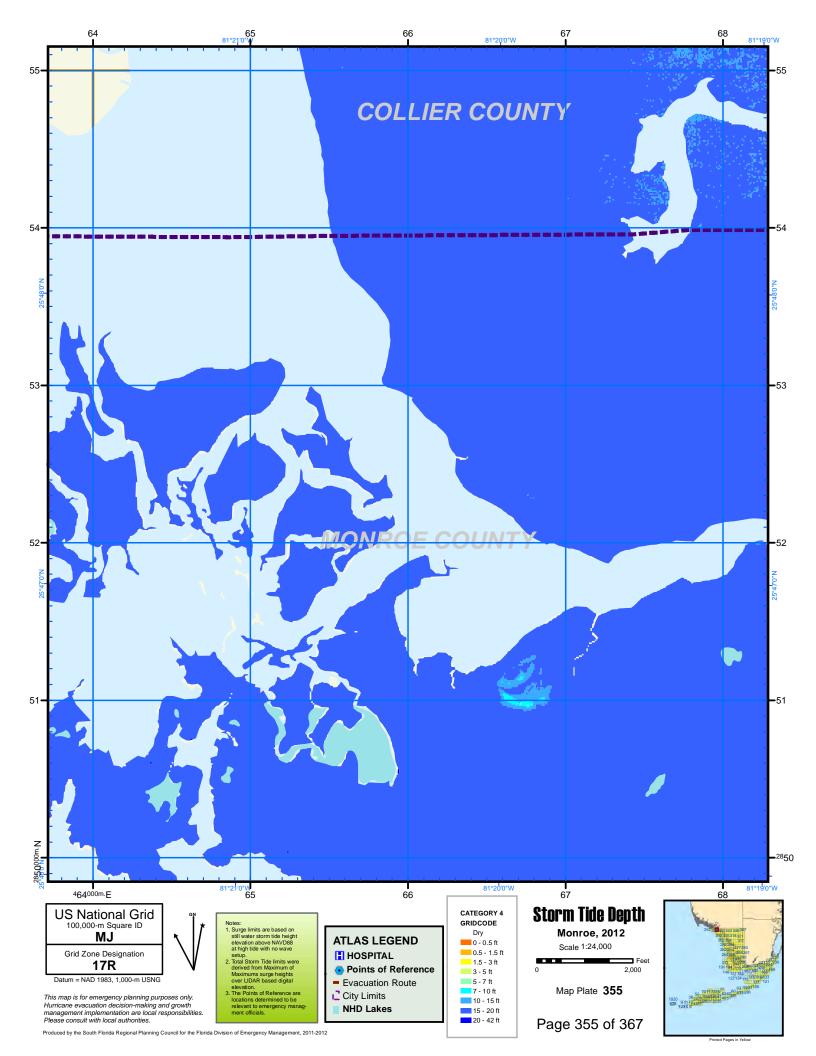


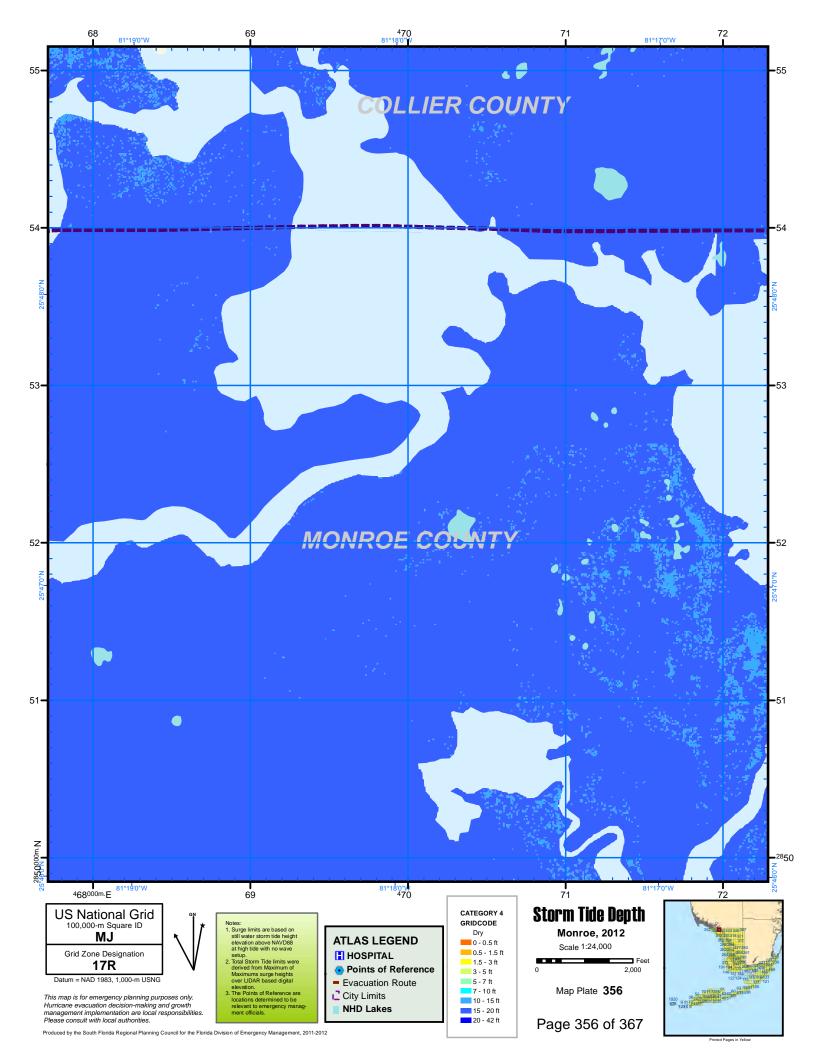


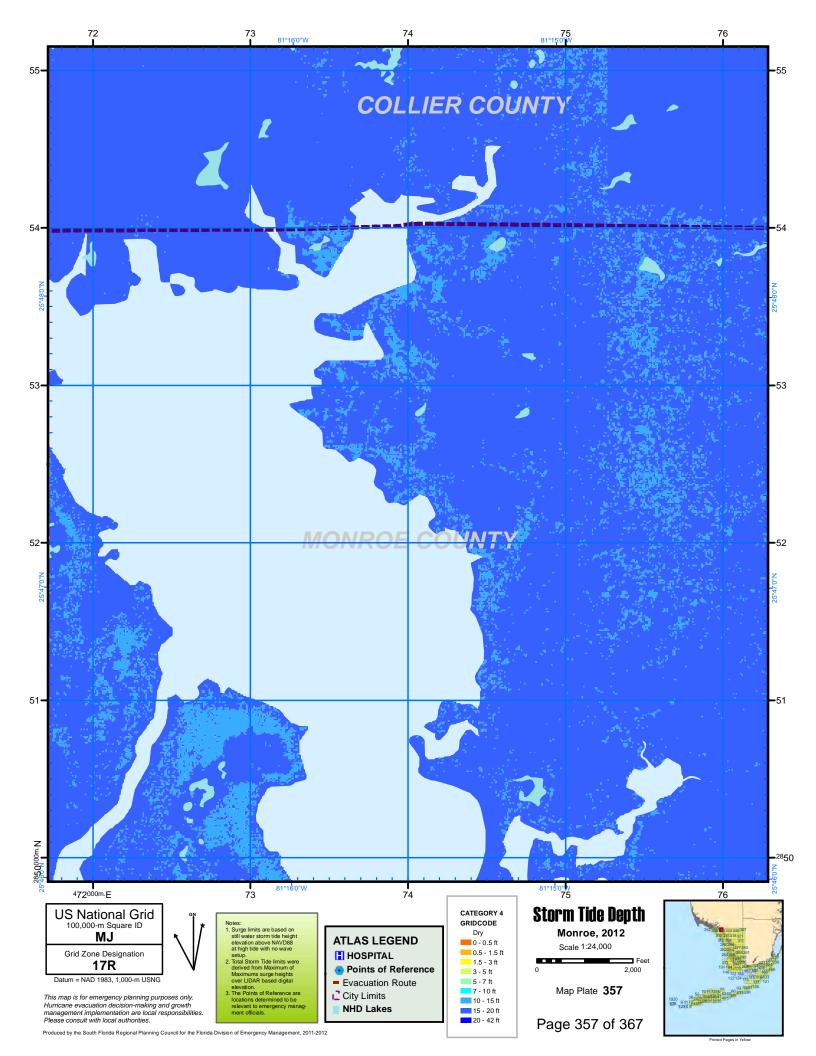


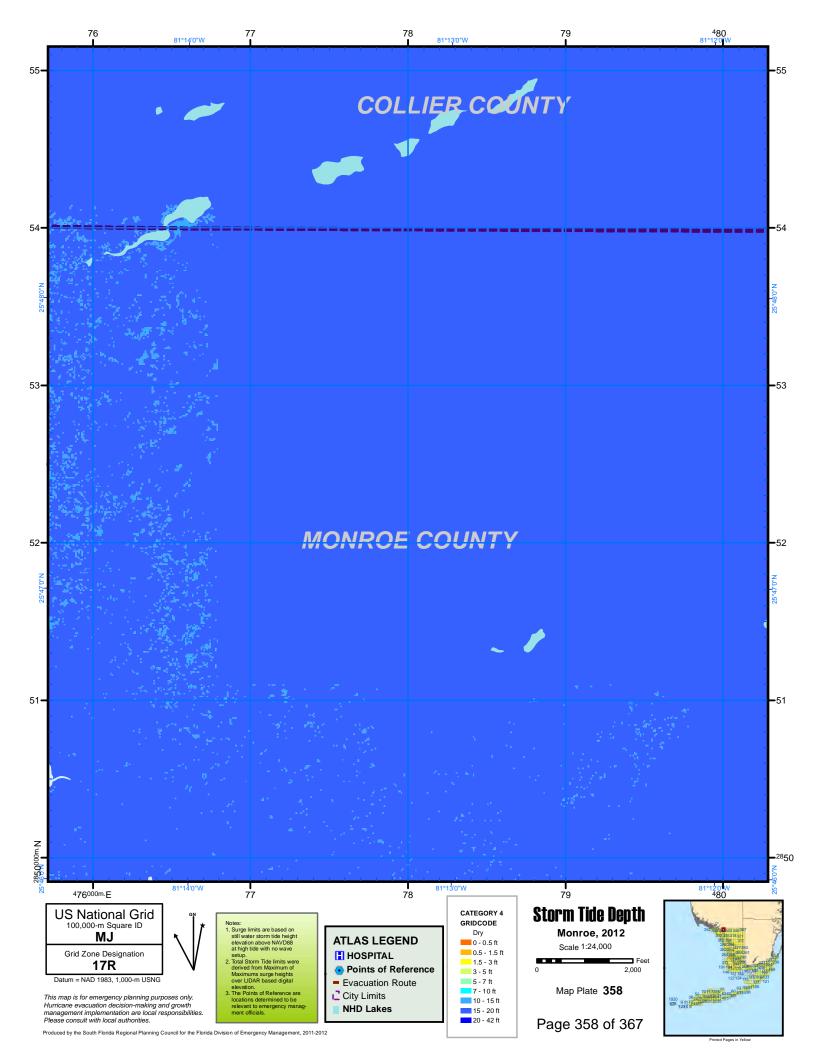


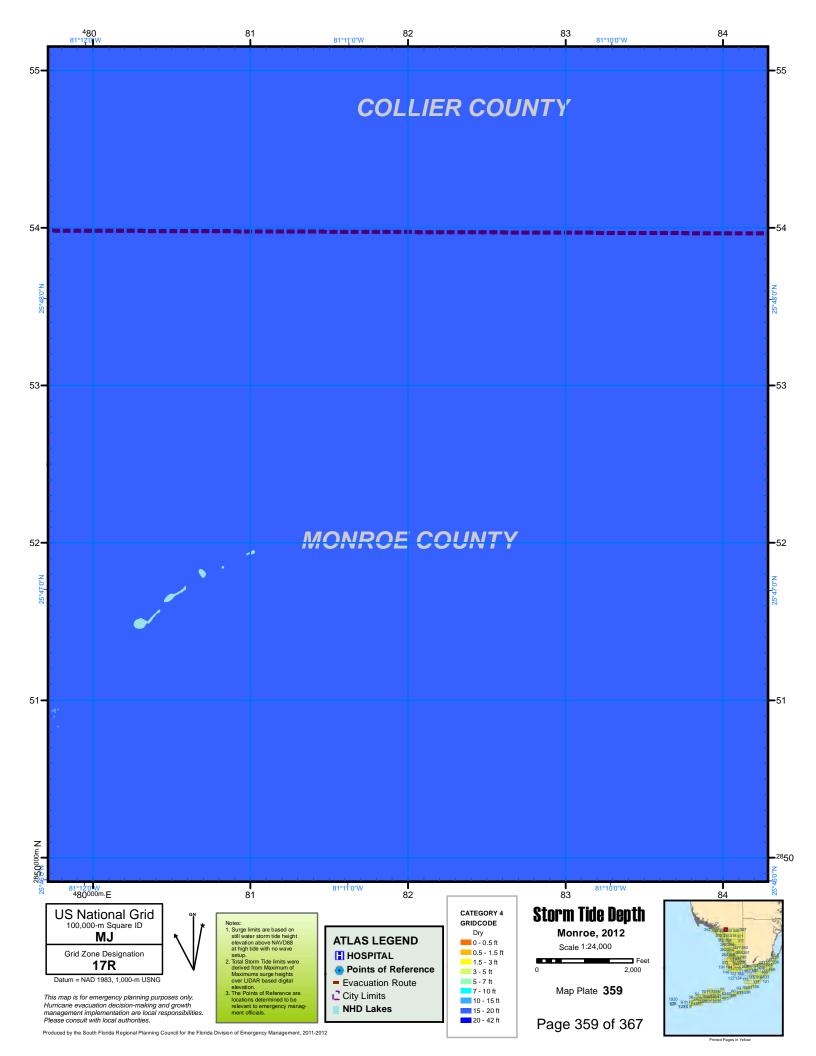


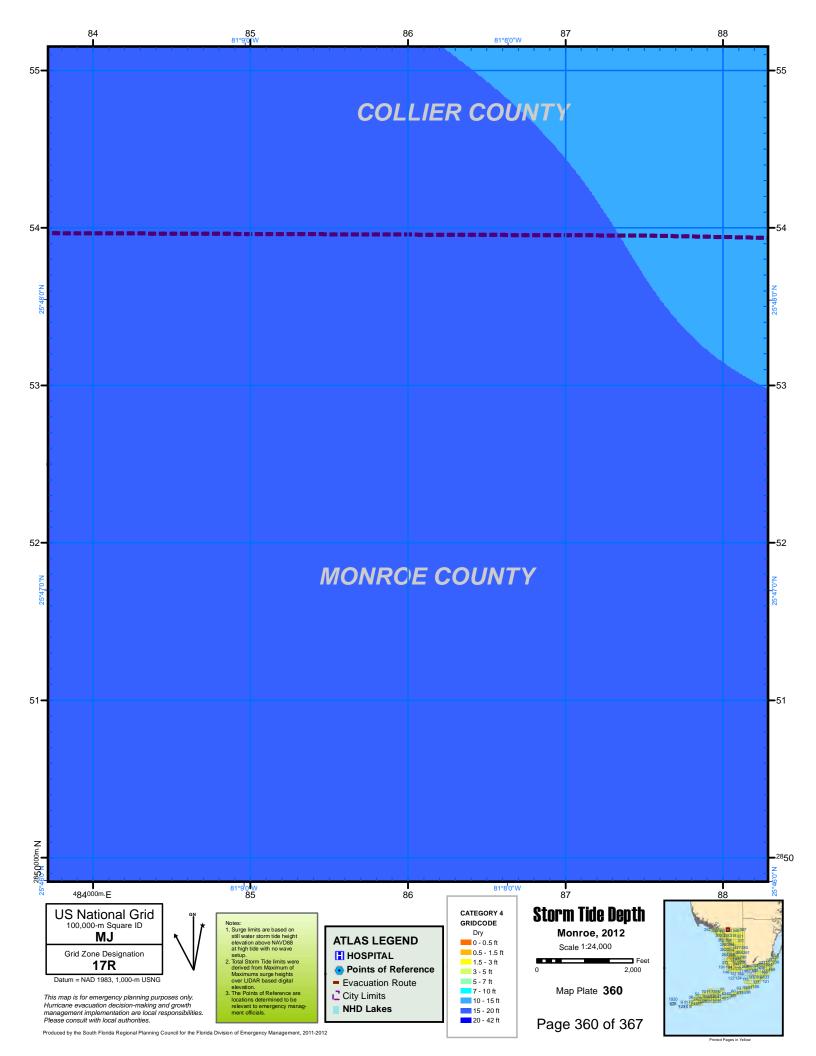


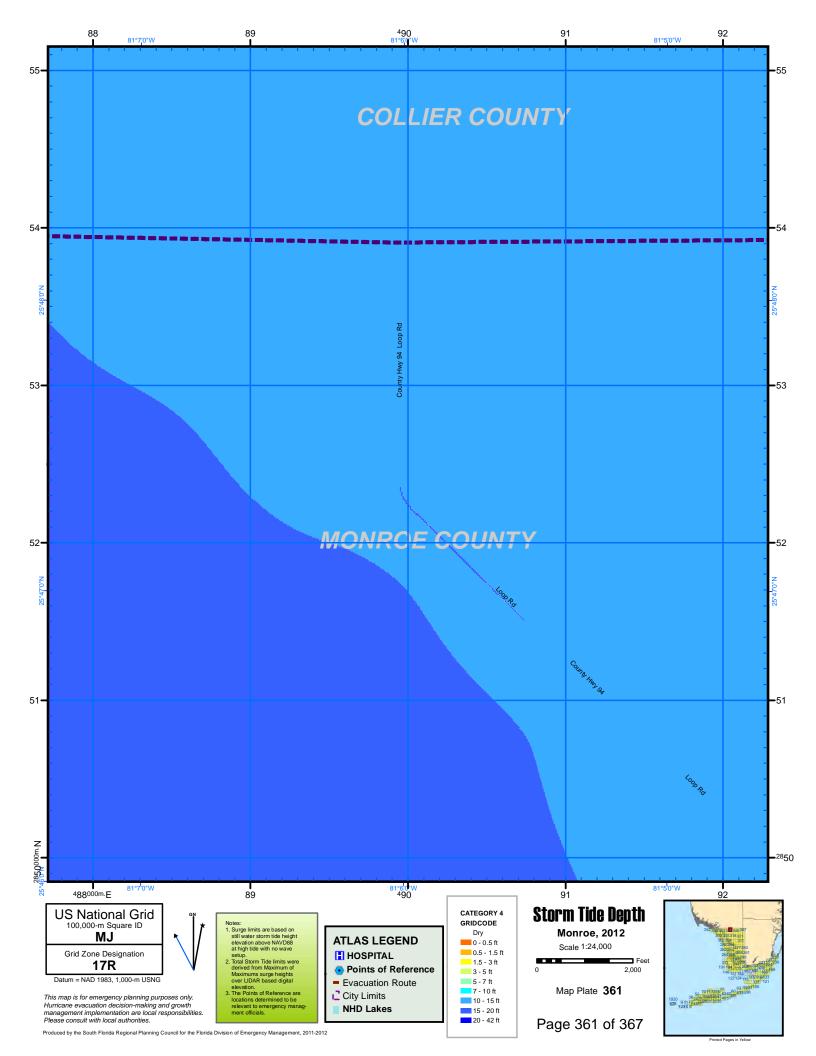


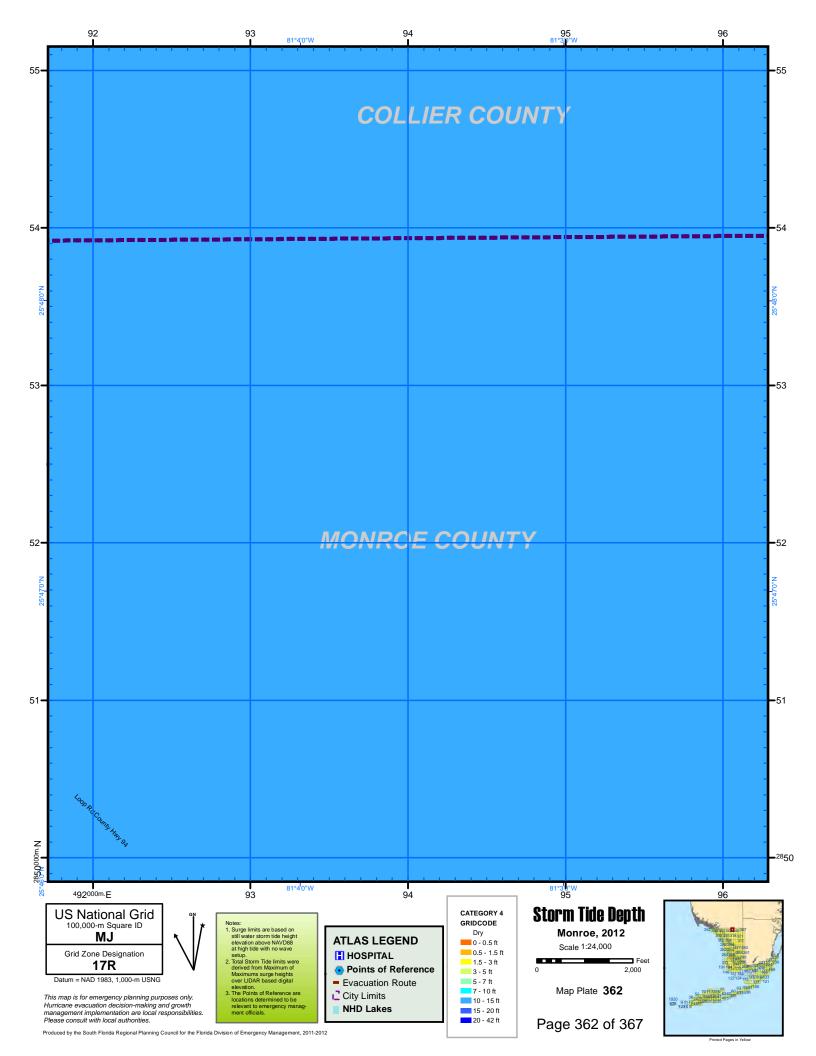


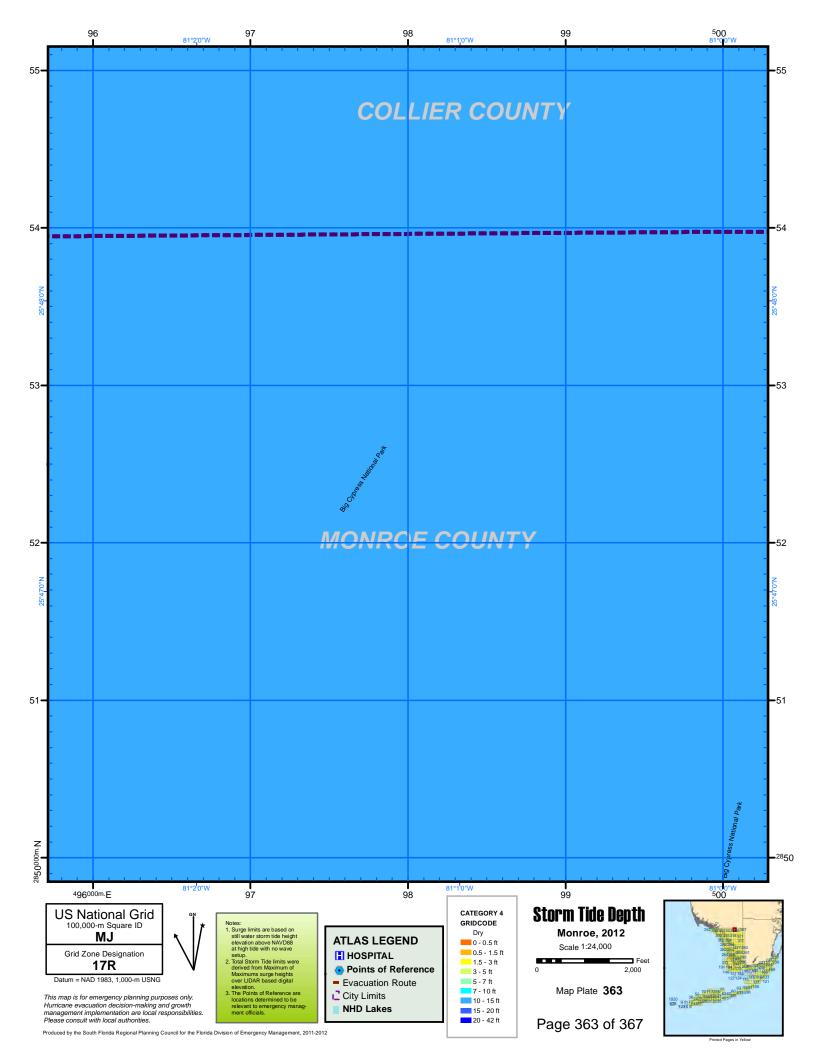


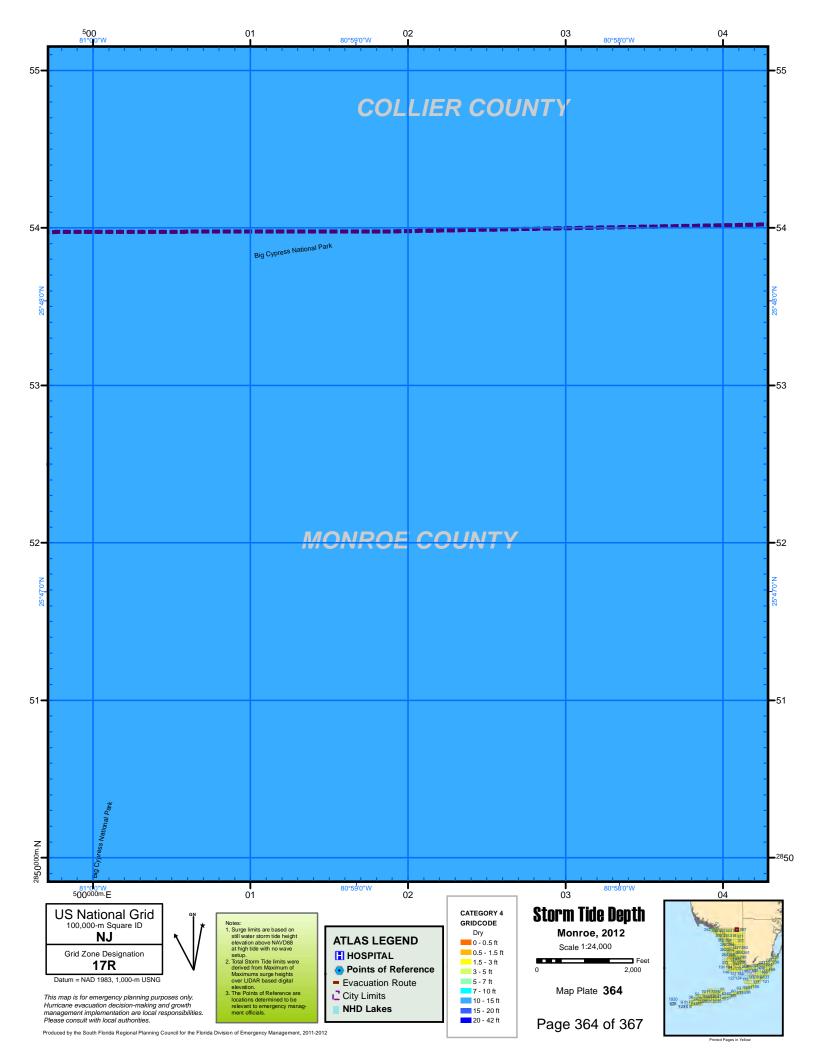


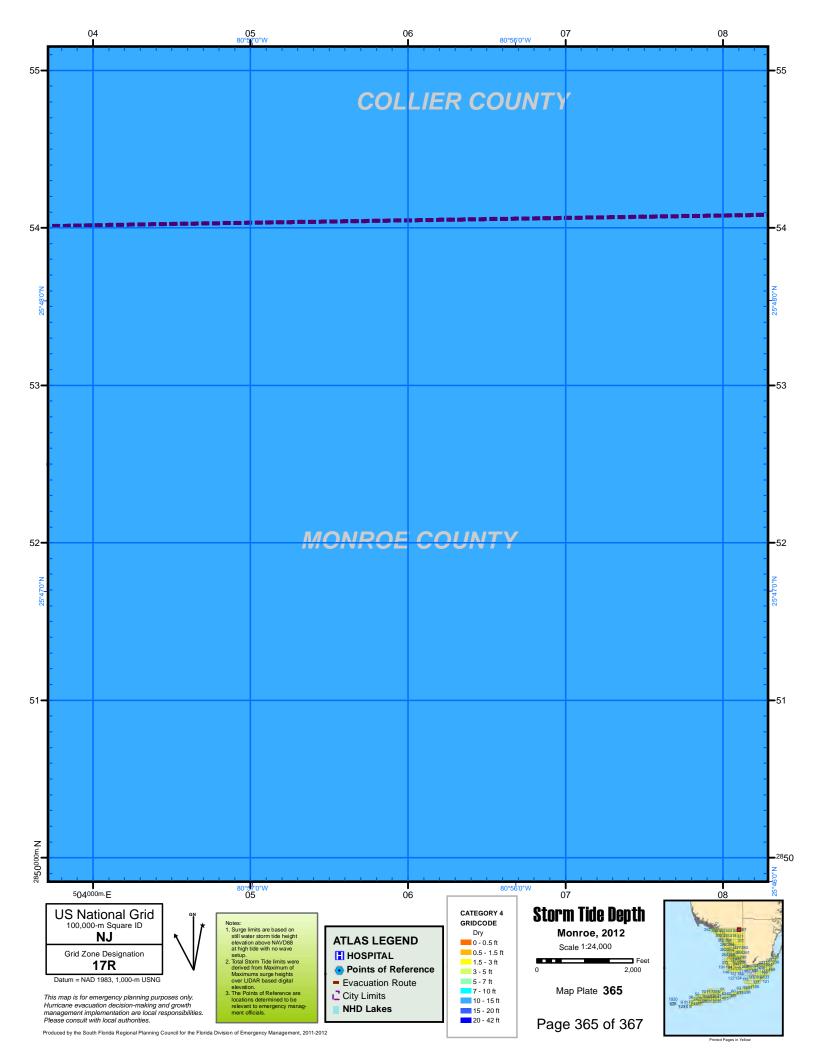


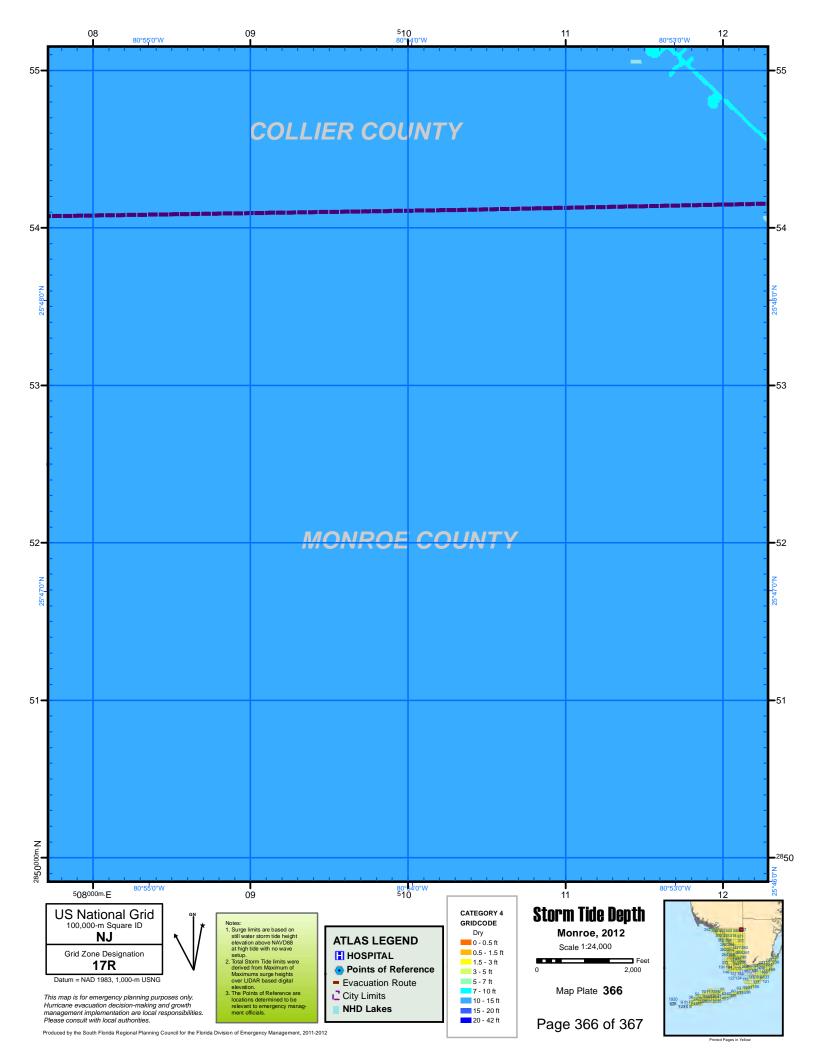


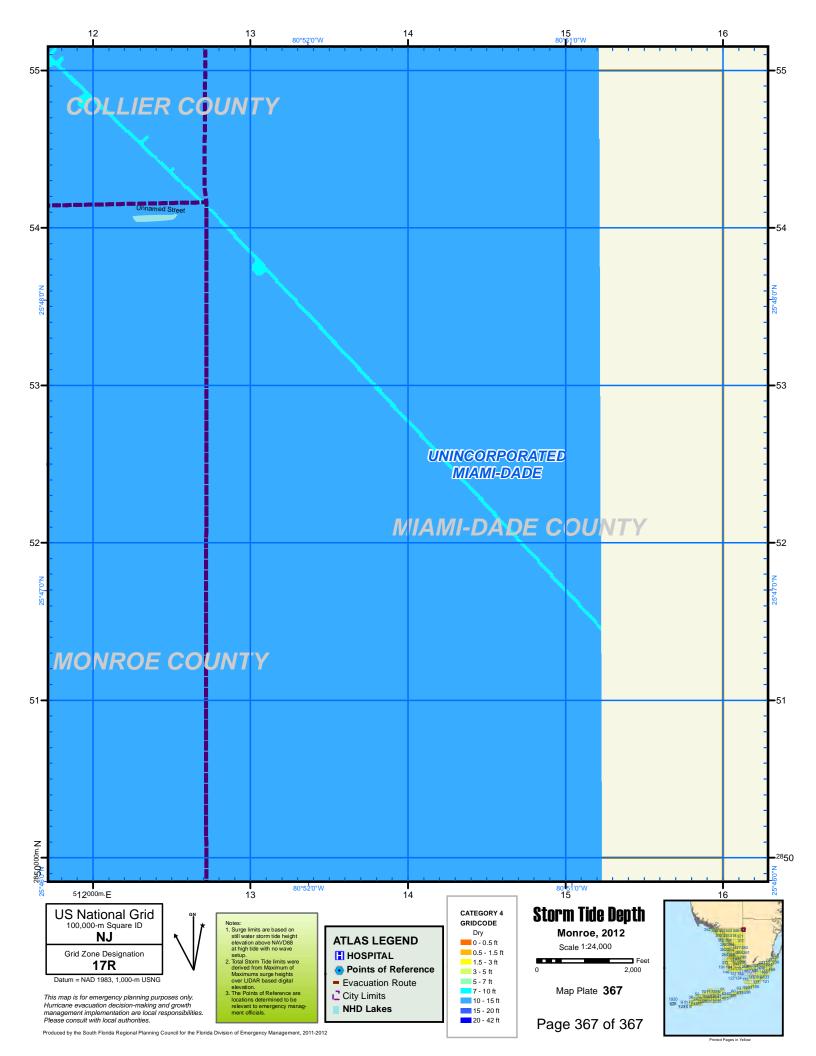
















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Florida Division of Emergency Management Bryan Koon, Director 2255 Shumard Oak Boulevard Tallahassee, Florida 32399



