Modeling to Support an Appeal of FEMA Preliminary Flood Insurance Rate Maps

Inlet Hydraulics Improvements (Deliverable 2.1)
Task Order #1778-05

August 20, 2021 | 13134.202

Baird.
Innovation Engineered.

baird.com

Modeling to Support an Appeal of FEMA Preliminary Flood Insurance Rate Maps

Inlet Hydraulics Improvements (Deliverable 2.1)
Task Order #1778-05

Prepared for:

Jeremy McBryan, PE, CFM
Palm Beach County
301 North Olive Avenue, 11th Floor
West Palm Beach, FL 33401
jmcbryan@pbcgov.org
561-355-4600

Prepared by:

Baird.
Innovation Engineered.

W.F. Baird & Associates Ltd.

13134.202

Z:\Shared With Me\QMS\2021\Reports_2021\13134.202.R1.Rev0_PBC FEMA Appeal_Task 2 Inlet Hydraulics Improvements.docx

Revision	Date	Status	Comments	Prepared	Reviewed	Approved
A	2021-04-16	Draft		TH	GT	TH

Table of Contents

1. Task Overview

During a Review and Evaluation of the Federal Emergency Management Agency's (FEMA) Coastal Flood Risk Study (Task Order No. 1778-01), Baird identified several issues related to the accuracy of the modeling that was conducted by FEMA in support of the preparation of preliminary Florida Insurance Study (FIS) reports and Flood Insurance Rate Maps (FIRMs) for eastern Palm Beach County (County). These modeling issues may have resulted in erroneous 1-percent annual chance water surface elevations (WSE) [i.e., Base Flood Elevations (BFE)] and/or FEMA assigning an incorrect flood hazard flood zone to properties.

For Task 2 of Task Order 1778-05, Modeling to Support an Appeal of FEMA Preliminary Flood Insurance Rate Maps, Baird's specific objective was to further investigate the FEMA model setup including instabilities that were noted at several inlets.

2. Review of Model Setup

The SWAN+ADCIRC model requires a model mesh and nodal attributes that sufficiently represents bathymetric, topographic, and land cover features within the study area. Mesh resolution and its distribution should be a function of the hydrodynamics to be simulated. If the mesh has not been created or edited to be numerically stable, the model runs will be inconsistent, and the results will not be reliable.

In the Intermediate Data Submittal (IDS) 3: Section 1 Production Runs Report Appendix A (FEMA 2018), FEMA describes the instabilities encountered during the productions runs, and the approaches applied to resolve these instabilities. This report will be referred to as FEMA's report in this section.

FEMA encountered several model instabilities summarized as below:

- Instabilities related to wetting/drying (e.g., artificial propagation of the surge wave, nuisance flooding)
- Instabilities related to oblique forward velocities (e.g., in the case of West storms exiting East, storm track/landfall close to parallel with shoreline – not perpendicular)
- Instabilities due to lack of resolution to model hydrodynamics near the Caribbean islands

FEMA's report lists other potential solutions that failed to improve model stability as:

- Decreasing spatially variable tau0 base values to numerically correct instabilities near the Caribbean islands
- Increasing Manning's n coefficient to 0.15 to dampen instabilities via higher bottom friction near Caribbean shorelines
- Changing SWAN time step from 20 minutes to 10 minutes to increase the frequency of the wave coupling
- Decreasing H0 to dampen unrealistic wetting
- Decreasing HABSMIN (within the SWAN+ADCIRC wetting and drying algorithm directly) to further restrict wetting
- Deactivating the NOFF array through the fort.15 &wetDryControl namelist to turn off elemental wetting and drying, which could theoretically encourage nodes to dry more quickly depending on the element's water surface elevation slope

Finally, FEMA applied the following approaches to resolve the instabilities described above by:

- Restricting localized water level gradient by applying elemental slope limiter (ESL) nodal attributes.
- Canal filling
- Disabling wind stress forcing locally
- Deepening of the Caribbean bathymetry

2.1 Restricting Localized Water Level Gradient

FEMA's report states: "Overall, 376 out of 392 storm simulations applied elemental slope limiter (ESL). The team developed eleven versions of ESL datasets, titled ESL-v1 through ESL-v11. Production simulations ultimately did not use all eleven datasets. Each time a production run displayed a hot spot in a new location, the team expanded the ESL dataset by adding in the new nodes. Several hot spots appeared repeatedly throughout production simulations, so expanding rather than replacing the previous ESL dataset allowed future runs to benefit from previously corrected hot spots."

Ideally, a well-established model mesh and nodal attributes should not require the application of the ESL nodal attribute. FEMA's report indicates that ESL dataset was expanded by adding new nodes as the instabilities occurred. The report states: "ESL datasets included between 7,000 and 33,500 nodes out of 2.25 million in the SFLSSS model mesh." and "Production simulations did not use all eleven datasets". FEMA used 8 different versions of the ESL datasets. (Note: SFLSSS refers to the South Florida Storm Surge Study)

FEMA defined ESL nodal attributes at two locations within Palm Beach County near the northern and southern ends of the Lake Worth Lagoon as shown in **Figure 1**. The model nodes where localized gradients were specified are indicated by the blue and purple dots.

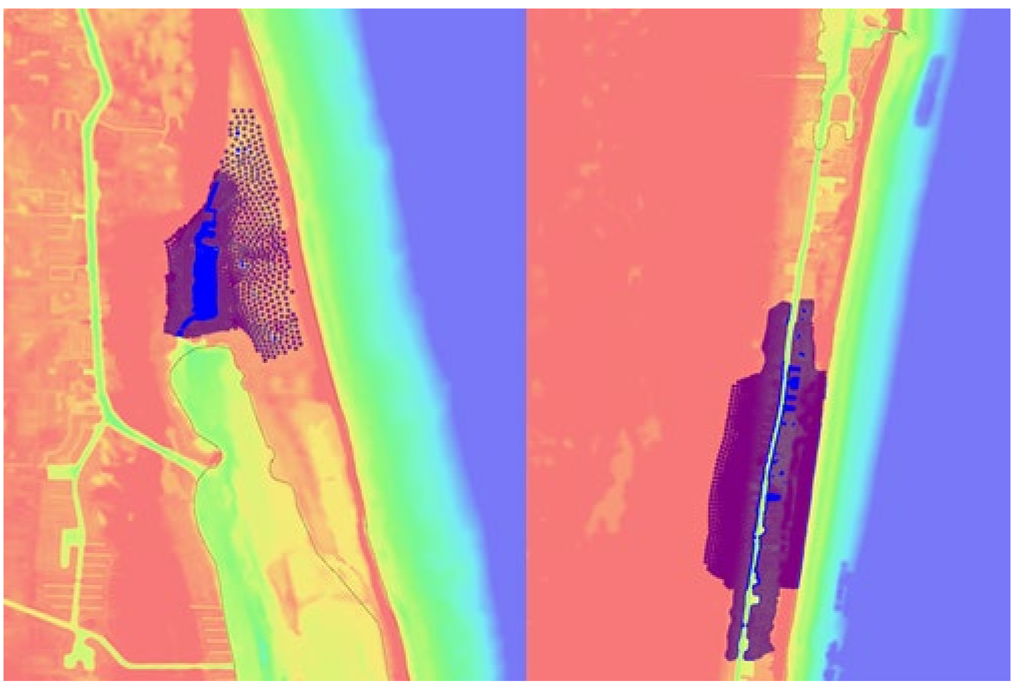


Figure 1. Model Instabilities – Restricted Localized Water Level Gradients

Canal Filled Mesh

The FEMA report states: "In its post-simulation reviews, the production run review team noted many instabilities in or adjacent to narrow navigation or SFWMD water control canals. The mesh contains many canals less than 150 ft wide; in some locations, the mesh captures canals as narrow as 30 ft (see IDS1, Section 7). The Southwest Florida Storm Surge Study (SWFLSSS) found that narrow canals often invoked instabilities. As a solution, the SWFLSSS team artificially "filled in" problematic canals for certain production simulations by raising nodes falling inside the channel banks to a constant, dry elevation (with global initial water level at mean sea level). Effectively removing certain canals narrower than 120 ft from the mesh by raising their node elevations to +3 ft-NAVD (at or below the bank elevation)."

Disabled Wind Stress Forcing in Broward County

FEMA disabled wind stress forcing in select overland locations to allow the wetting front to propagate solely through local hydrodynamics. Baird did not review the impacts of this application on model results in Palm Beach County.

Deepening of the Caribbean bathymetry

The 2018 FEMA report states: "fatal instabilities in the Caribbean were resolved by disabling wind stress near the shorelines of Cuba and Bahamian islands. The team further eliminated instabilities in shallow areas of the Caribbean by artificially deepening nodes near the shorelines of Cuba and the Bahamas. This group of mesh changes occurred at least 90 miles from the project area." Baird did not review the impacts of this application on model results in Palm Beach County.

Identifying Instabilities

FEMA's 2018 report states: "The team first verified results which truly constituted instabilities or numerically-induced water masses rather than anomalous, yet reasonable, water levels. Difficult to drain areas serve as examples that sometimes yielded unrealistic results yet at other times yielded reasonable results. Because the SWAN+ADCIRC production run phase of the project did not model hydrology or stormwater drainage, gravity and offshore winds served as the only means for a surge wave to recede. If the topography did not support surge recession, then the team could potentially accept the area remaining inundated throughout the rest of the simulation. If the inundated area remained static and did not drain, the team classified simulation as stable. If the inundated area featured an unrealistically propagating wetting front, or unrealistically escalating water levels, the team classified the simulation as unstable."

The description from FEMA on what a numerically unstable model run is vague. It is perfectly reasonable for an area to remain "statically" dried after a powerful storm. Generally, ADCIRC, non-fatal instabilities can be identified by looking at anomalous maximum velocities. It is also possible to use non-fatal error override (NFOVER) option in ADCIRC. FEMA uses 1 for this parameter. ADCIRC documentation explains this option and its potential uses as:

NFOVER = non-fatal error override option;

= 0, inconsistent input parameters will cause program termination.

= 1, inconsistent input parameters will, (when possible), be automatically corrected to a default or consistent value and execution continued. Be sure to read the nonfatal warning messages to see whether any parameters have been modified. Note that not all inconsistent parameters can be corrected automatically and therefore fatal error messages and program termination may still result.

Note for NFOVER:

Occasionally, the elevation solution becomes unphysically large due to improper numerical parameter settings, time step stability criteria violation. It can be useful for ADCIRC to terminate based on a user-specific limit to the computed water elevation. To enable this feature, ADCIRC must be compiled with the DEBUG_WARN_ELEV compiler directive. This is set in the cmplrflags.mk file. For example, for the serial model,

DA := -DREAL8 -DLINUX -DCSCA –DDEBUG_WARN_ELEV

and for the parallel model:

DP := -DREAL8 -DLINUX -DCSCA -DCMPI -DDEBUG_WARN_ELEV

This enables extra parameters in the fort.15 file, specified on the NFOVER line:

NFOVER, WarnElev, iWarnElevDump, WarnElevDumpLimit, ErrorElev

ADCIRC then monitors the maximum water elevation and behaves as follows:

A warning is issued if the elevation exceeds WarnElev.

A global elevation file (written to fort.69) will be written if WarnElev is exceeded AND iWarnElevDump == 1

Execution will be terminated if WarnElevDumpLimit global elevation files have been written due to the above warning limits.

Execution will be terminated if elevation exceeds ErrorElev.

SFLSS simulates 392 storms in a large and complex domain. It is not feasible to identify instabilities based on vague descriptions of what instabilities are. ADCIRC provides the tools to identify potential numerical instabilities which were not used by FEMA.

2.2 Lack of Quality Assurance/Quality Control (QA/QC) at local level

Some of the approaches discussed above that were employed by FEMA are routine and customary for numerical models if it is demonstrated that they do not alter the hydrodynamic and coastal flooding processes elsewhere within the study area.

FEMA's report indicates several times that the sensitivity to the changes made to the meshes and nodal attributes were examined at a regional scale.

- "The team also conducted sensitivity testing to examine effects of model mesh and nodal attribute changes to regional maximum water levels"
- "Any potential solution may induce small, localized changes in maximum water level that are not practical to trace, so the team focused on regional-scale changes."
- "Fortunately, several model mesh and parameter changes did alleviate instabilities without affecting regional-scale results."

As an example of mesh edits, mesh filling by FEMA in canals within Palm Beach County along the Loxahatchee River and Intracoastal Waterway (ICWW) in Jupiter and Tequesta are shown in **Figure 2**. The left graphic shows the model mesh based on topographic elevations prior to “filling” canals; the right graphic shows the model mesh after “filling” canals. The red circles identify the areas that the model mesh was manipulated (Figure copied from FEMA 2018).

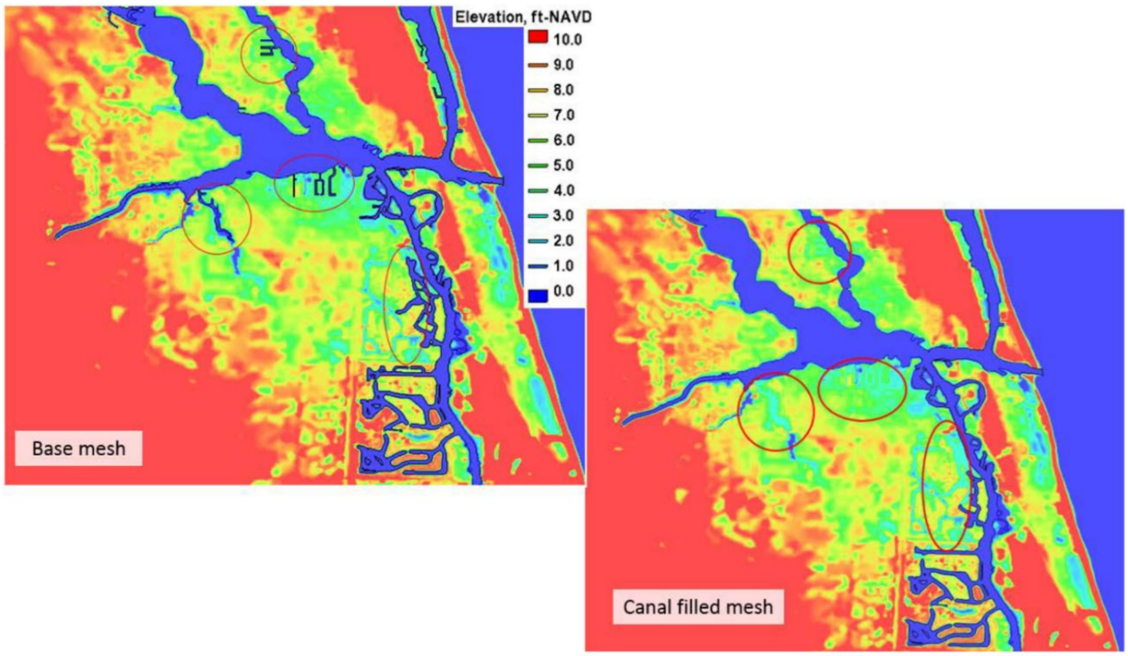


Figure A.11. Base Mesh vs. Canal Filled Mesh Node Elevations in Narrow Canals, Palm Beach County

Figure 2. Filled Canals in Palm Beach County

FEMA report states: “filling the shorter narrow canals in Palm Beach County and Miami-Dade County did not induce regional differences in maximum water surface elevation. Figure A.16 (**Figure 3**) shows a difference plot of maximum water level for storm 65, which made landfall in Boca Raton and produced significant surge throughout coastal Palm Beach County. The prevalence of green contours indicates minor influence of the canal filled mesh on regional-scale maximum water levels.”

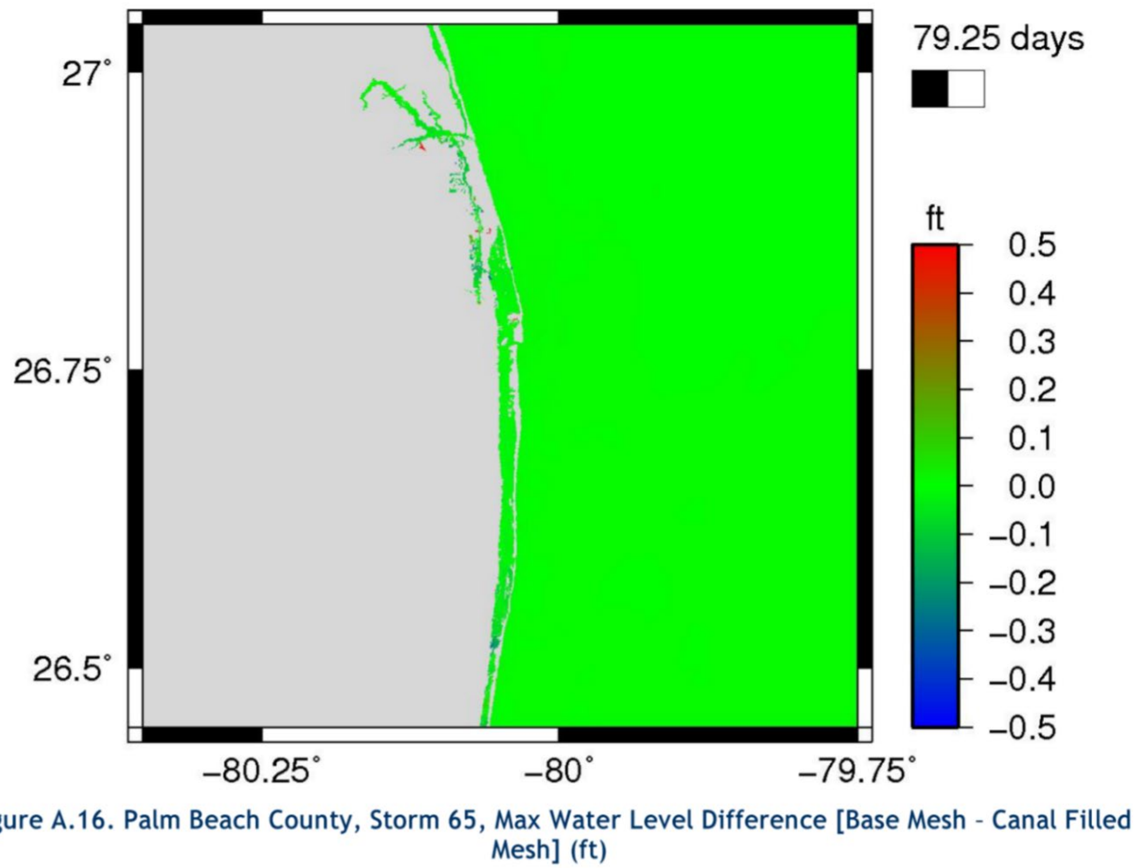


Figure 3. Maximum Water Level Difference Storm 65 (Figure A.16 from FEMA Report)

Figure 3 indicates minor influence of the canal filled mesh on regional scale maximum water levels. However, FEMA does not ask nor answer the question why canals filled at the north end of the County have a local impact near Boynton Inlet (a drop in WSE of ~0.5 feet can be seen) 30 miles away from the canal fills. Numerical instabilities often present themselves on a single node which may or may not be visible/significant from a regional point of view. Similarly, a completed run does not necessarily mean a stable run. Prevalence of the "green color" cannot be considered as a scientific quantification to conclude that the changes made to the mesh and the nodal attributes have no impact on model results on the local level at which the findings of the study are applied to drive FIRMs. Furthermore, FEMA states that "storm 65, made landfall in Boca Raton and produced significant surge throughout coastal Palm Beach County". Storm 65 was identified to generate WSEs equivalent to only a 30-year return period near Boynton Inlet. The impacts should have been investigated and presented using multiple storms representing different return period intervals.

Importance of consistent model setups in producing reliable results

FEMA used 24 unique combinations of different meshes and nodal attributes to complete model runs for 392 storms used for the study (FEMA 2018). **Figure 4** shows the maximum WSE simulated by FEMA in Palm Beach County per Storm id bins of 20. Simulated maximum elevations from all production runs were extracted and the storm responsible for creating the maximum WSE elevation were plotted at each node with a unique color for each bin. The numbers seen on each storm bin indicates the number of unique combinations of mesh and nodal attributes used to be able to complete the runs in that area. In Palm Beach County, FEMA used 7 to 11 unique combinations within any given area as indicated in **Figure 4**.

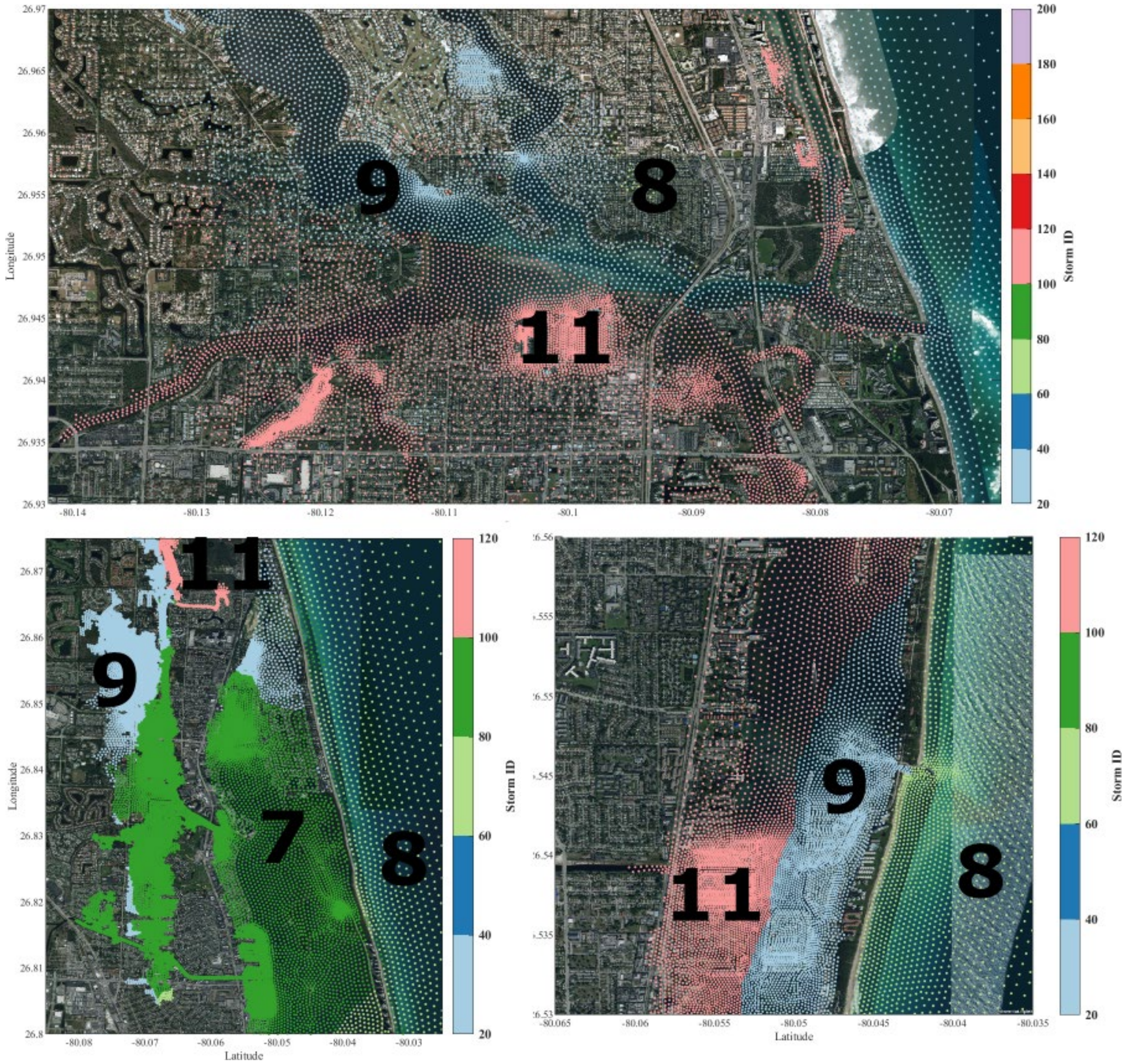


Figure 4. Maximum elevation Storm ids and mesh/nodal attributes combinations used for each group.

For instance, the maximum water surface elevations near Boynton Inlet area are results of models for Storms 20 through 40. FEMA used 9 unique combinations of mesh and nodal attributes to complete 20 synthetic storm runs in this area (**Table 1**). The County acknowledges the need to edit meshes and nodal attributes to achieve stable model results. However, this practice should converge to a single mesh and a single nodal attributes file that will be used for the entirety of the SFL Study. Otherwise, every single combination used (total 24) needs to be cross checked against each other, which is not feasible and was not carried out by FEMA.

Table 1. Mesh and Nodal Attributes Applied in Final Storm Run from the FEMA report - Full Table in Appendix A

Storm	Track	Mesh Description	SCC (surface canopy coefficient)	ESL (elemental slope limiter)	MN (manning's N)
20	**JPM_30002006**	**canal filled**	**v3**	**v5**	**canal filled edit**
21	JPM_30002007	canal filled	v3	v5	canal filled edit
22	**JPM_30002008**	**canal filled**	**v3**	**v6**	**canal filled edit**
23	JPM_30002009	canal filled	v3	v5	canal filled edit
24	**JPM_30002010**	**canal filled+ deepened_Carib_v2**	**v3**	**v6**	**canal filled edit**
25	**JPM_30002011**	**canal filled+ deepened_Carib_v2**	**v3+Everglades+ CoralGables**	**v9**	**canal filled edit**
26	**JPM_30002012**	**canal filled+ deepened_Carib_v2**	**v3+Everglades**	**v7**	**canal filled edit**
27	JPM_30002013	canal filled+ deepened_Carib_v2	v3+Everglades	v7	canal filled edit
28	**JPM_30002014**	**canal filled**	**v3+Everglades**	**v6**	**canal filled edit**
29	JPM_30002015	canal filled	v3+Everglades	v6	canal filled edit
30	**JPM_30002016**	**canal filled**	**v3+Everglades**	**v5**	**canal filled edit**
31	**JPM_30002017**	**base**	**CCAP**	**v2**	**base**
32	**JPM_30002018**	**base**	**CCAP**	**none**	**base**
33	JPM_30002019	base	CCAP	v2	base
34	JPM_30002020	base	CCAP	v2	base
35	JPM_30002021	base	CCAP	v2	base
36	JPM_30002022	base	CCAP	v2	base
37	JPM_30002023	base	CCAP	none	base
38	JPM_30002024	base	CCAP	v2	base
39	JPM_30003025	base	CCAP	v2	base
40	JPM_30003026	base	CCAP	v2	base

2.3 Local numerical instabilities at PBC inlets

FEMA reported that the model mesh developed for the SFL Study provided sufficient resolution to "include channels at least 30-feet wide," while channels narrower than 30 feet were excluded. Review of FEMA's model mesh and results of synthetic storm revealed several locations within Palm Beach County where the mesh resolution was insufficient to accurately model hydrodynamic and coastal flooding processes within the study area. The insufficient mesh resolution and/or improper mesh definition was identified in four locations and are discussed below.

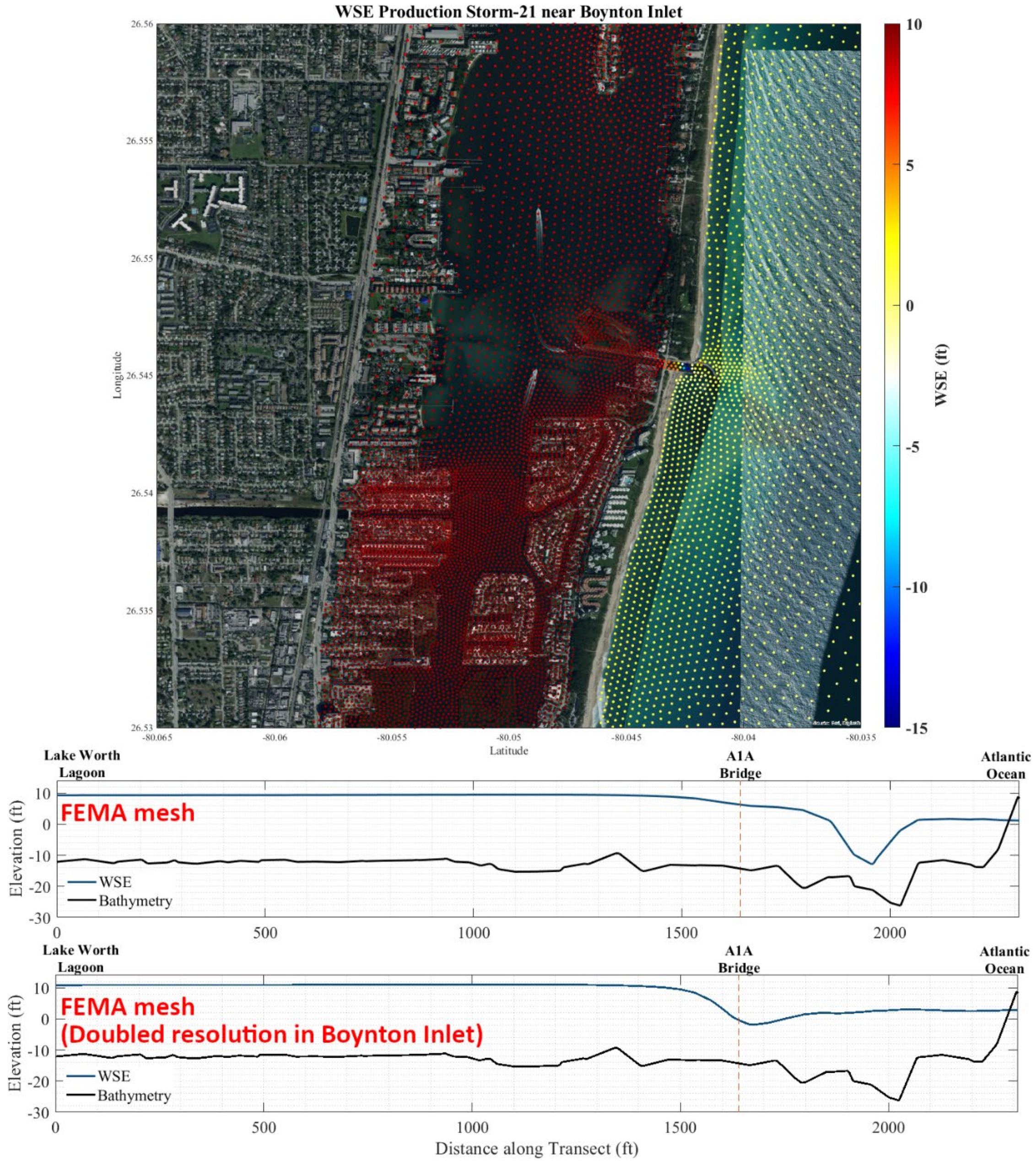
- Boynton Inlet: The inlet is located at the southern end of the Lake Worth Lagoon where some of the highest modeled WSE that contributes to 1-percent Stillwater Elevations (SWEL) within Palm Beach County were simulated by FEMA. The inlet is narrow (~120 feet wide) as compared to other east coast inlets, but 4 times wider than FEMA's 30-foot minimum criteria. During the synthetic storm (21) that produced the highest WSE within the lagoon, FEMA's model did not allow water to flow out through the inlet creating unrealistic WSE changes in the inlet thereby affecting WSE within the lagoon as the storm passed to the north. This was evident by the elevated WSE within the lagoon (+10 feet, NAVD88), rapid drawdown of the WSE within the inlet (-10 feet, NAVD88), and then the rapid rise to match the WSE within the Atlantic Ocean (+2 feet, NAVD88) as shown by the red dashed circle in **Figure 5**. The WSE changes occurred within approximately 500 feet. A closer look at the model mesh revealed that within the inlet, one node had been included along the inlet centerline with adjacent nodes along the inlet banks. The wetting/drying of nodes within the SWAN+ADCIRC model combined with insufficient mesh resolution appears to have contributed to the unrealistic WSE changes thereby not accurately simulating hydrodynamics through the inlet and in turn affecting WSE within the lagoon.

  In addition, the model mesh at Boynton Inlet was found to include a gap (bottom panel in **Figure 5**) in the north jetty at the intersection with the coastline creating an additional hydraulic connection, which does not exist.

There are two sources of error in this kind of modeling: physical representation error and numerical truncation error. Numerical solutions to partial differential equations can be sensitive to the level of spatial resolution. In general, the so-called truncation error decreases as the spatial resolution increases. The rate at which the error decreases depends on the order of the numerical scheme used in implementing the numerical model.

For critical hydraulic features, such as inlets and channels that connect the open ocean to protected waters behind barrier islands, it can be important to ensure that adequate resolution in the cross-channel direction is available so that sufficient flux passes through.

It is generally accepted as good practice to ensure that a few model nodes span the width of a tidal inlet, particularly when the bathymetry exhibits a convergent characteristic, as does Boynton Inlet on the ocean end of the channel.



WSE Production Storm-21 near Boynton Inlet
Longitude
Latitude
WSE (ft)
Lake Worth Lagoon
A1A Bridge
Atlantic Ocean
FEMA mesh
WSE
Bathymetry
Elevation (ft)
FEMA mesh
(Doubled resolution in Boynton Inlet)
Distance along Transect (ft)

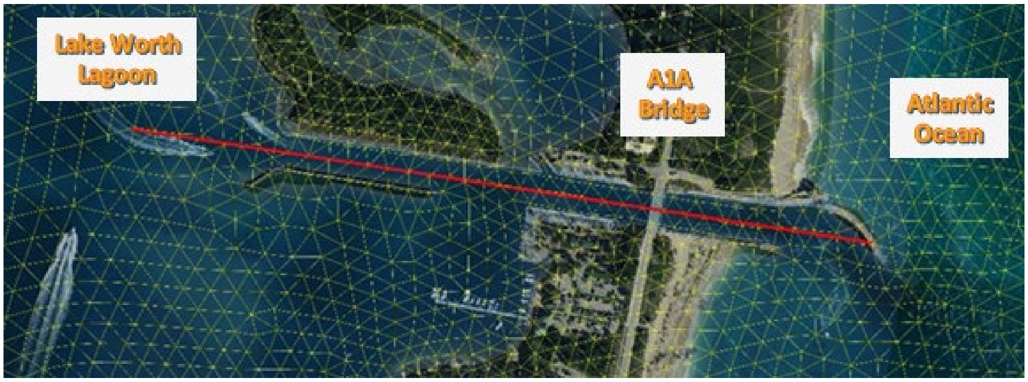


Figure 5. Water Surface Elevation – Boynton Inlet – Synthetic Storm 21 (FEMA mesh vs Double resolution at Boynton Inlet)

The basic resolution test of Boynton Inlet (the doubled resolution Boynton Inlet grid) indicates that two nodes (one cross-channel element edge) does not adequately resolve the complex hydraulic nature of the inlet. When increasing the resolution in the area, the water surface elevation difference in the along-channel direction decreases significantly (as compared to the solution on the FEMA grid), indicating that the FEMA grid resolution is not sufficient to ensure the computed water level solution is adequately resolved. Ideally, a “convergence” experiment would have revealed to FEMA that the computed solution changes significantly when the resolution is doubled. The doubled resolution test indicates that FEMA solution is not yet adequately resolved in the Boynton Inlet area. It should be noted that the resolution in other inlets in the region (e.g., Palm Beach Inlet) are much better resolved compared to Boynton Inlet. **Figure 6** shows that the hydraulic jump at Boynton Inlet was visible in FEMA’s QA/QC plot for Boynton Inlet.

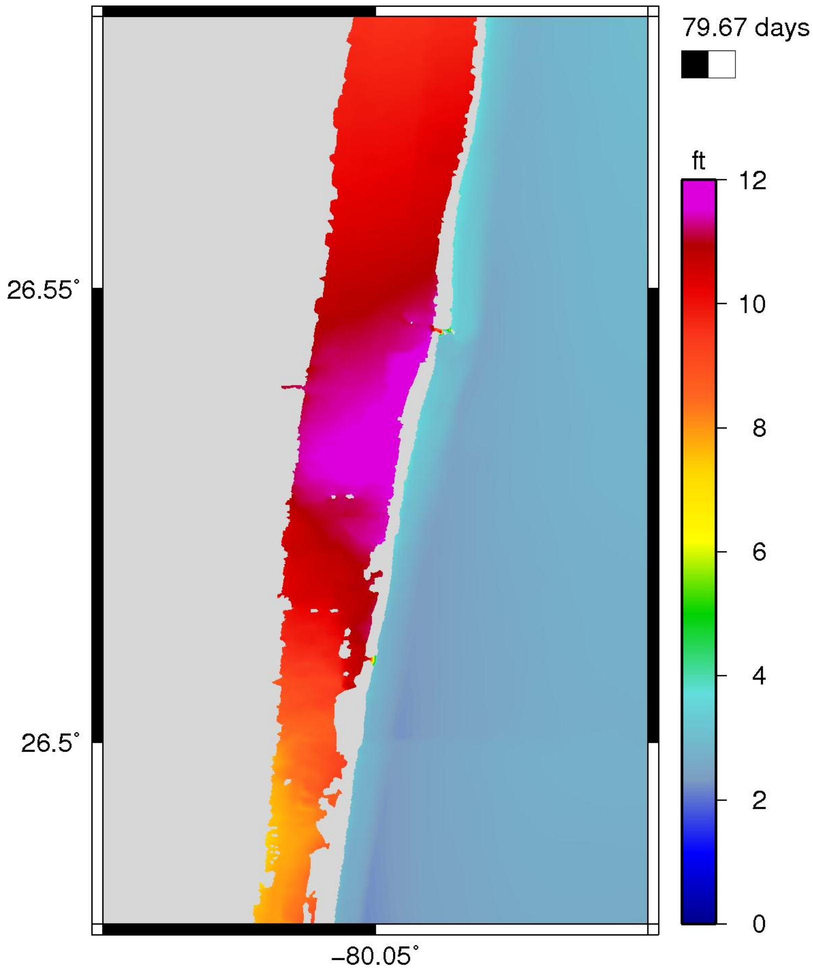


Figure 6. Maximum WSE produced (Storm-21) for QA/QC purposes by FEMA south Palm Beach County – Near Boynton Inlet. (Source: FEMA 2018)

2.4 Assignment of Nodal Attributes

The SWAN+ADCIRC model accounts for the effect of topographic and vegetation features through the nodal attribute input file (or fort.13 file). This input file allows model parameter definition on a node-by-node basis to account for spatial variation in the parameter values. SWAN+ADCIRC model parameters that can receive values in the fort.13 file include

• Surface directional effective roughness length

• Surface canopy coefficient

• Manning's n coefficient at the sea floor

• Sea surface height above geoid

• Average horizontal eddy viscosity in sea water

• Primitive weighting in continuity equation parameters

Here, the County focuses on the use of Manning's n coefficient values as derived from the updated 2010 Coastal Change Analysis Program (C-CAP) data coverage.

"The SWAN+ADCIRC model applies values of Manning's n at the sea floor to account for hydraulic roughness in wet areas of the model domain. Notably, as storm surge inundates upland areas, initially dry topographic areas become wet and require Manning's n values in the model. Therefore, the stated parameter name proves somewhat misleading as the model requires Manning's n values at all nodes. The ADCIRC model component converts Manning's n values to an equivalent quadratic friction coefficient before the model calculates bottom stress. The ADCIRC model incorporates the bottom stress as a resistance to flow in the depth-averaged momentum equations (Luettich et. al, 1992)."

For Manning's n, the nodal attribute file (fort.13) contains a default value, and a list of nodes where the user defines the Manning's n values. In common practice, the list of nodes provided by the modeler are land nodes where the values are interpolated from a land cover database while the default value represents the water nodes (a commonly used value is n=0.02, as in the case of SFLSSS).

In this study, FEMA assigned 2,095,907 nodes with Manning's n values interpolated from the 2010 C-CAP land cover database and used a default value of n=0.1 on the remaining 153,186 nodes (n=0.01 is the C-CAP suggested value for Mixed Forest / Palustrine Forested Wetland).

Figure 7 through **Figure 9** shows the FEMA's assigned Manning's n values throughout the entire study area, for Palm Beach County and near Boynton Inlet respectively. **Figure 11** shows the land and water nodes using the default Manning's n values (0.1) assigned by FEMA.

In **Figure 9**, it can be observed that the mouth of Boynton Inlet is covered with Manning's n value of 0.05 (Classified as scrub/shrub/wetlands). This is most likely caused by the source used to interpolate Manning's n values on to the mesh nodes. 2010 C-CAP Landcover is a coarse dataset, it does not resolve all narrow channels and inlets (**Figure 10**). It appears a modification to the Manning's n values was carried out in the lagoon side of the Boynton Inlet while the connection to the ocean was "blocked", "slowed-down" by using Manning's n values used to represents shrubbery and wetlands.

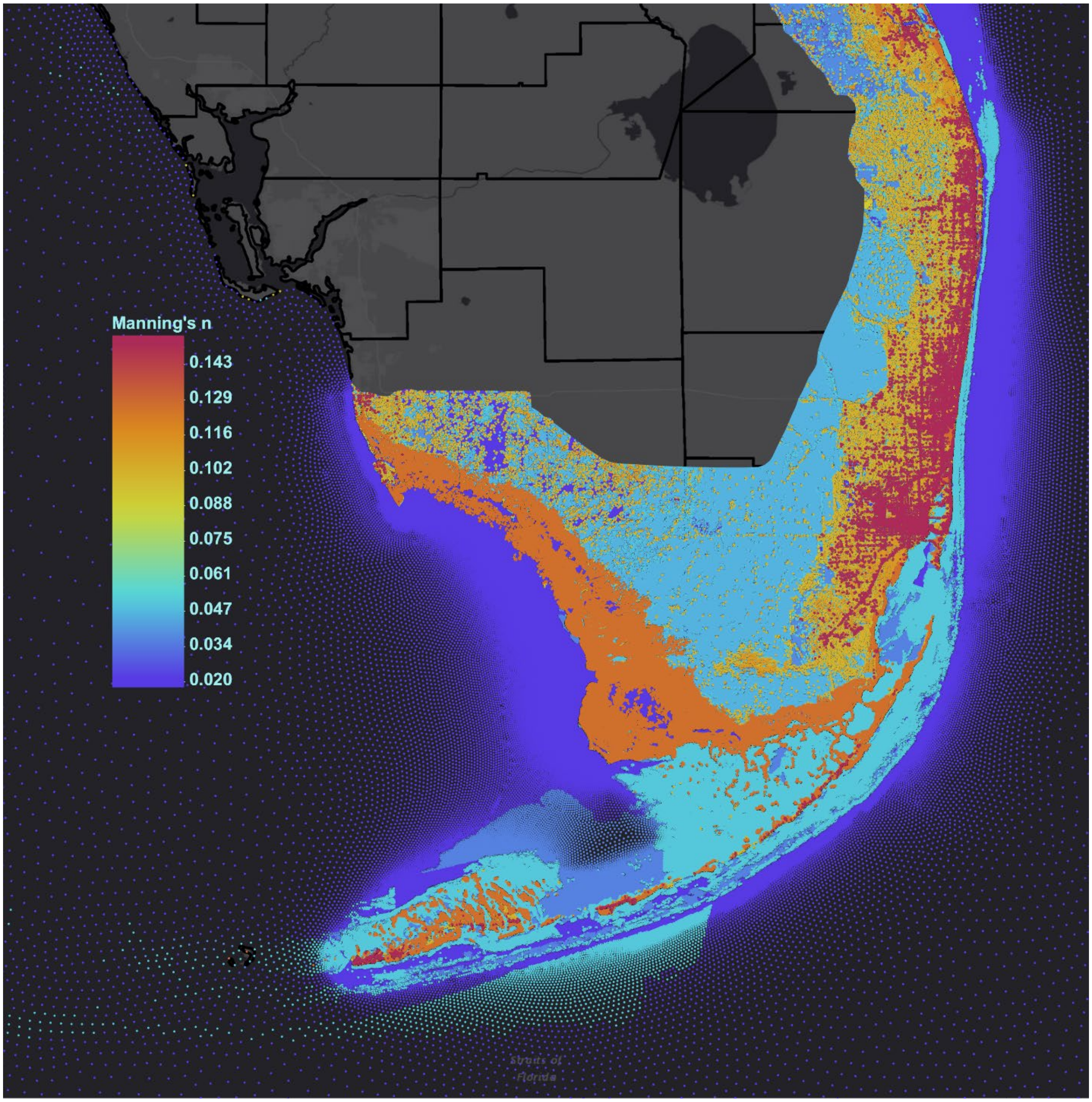


Figure 7. FEMA's assigned Manning's n values (Entire SFL Study area)

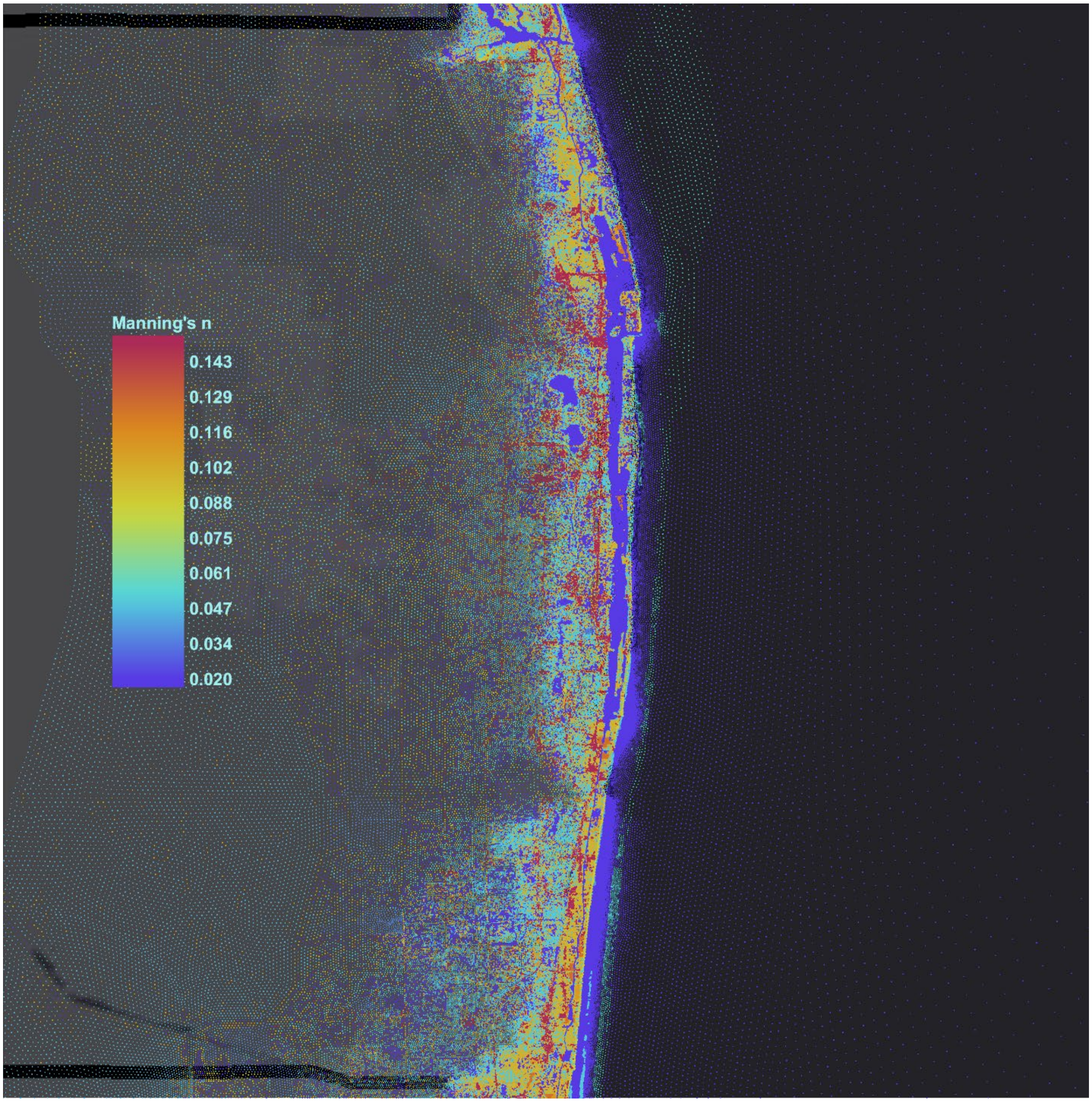


Figure 8. FEMA's assigned Manning's n values (Palm Beach County)

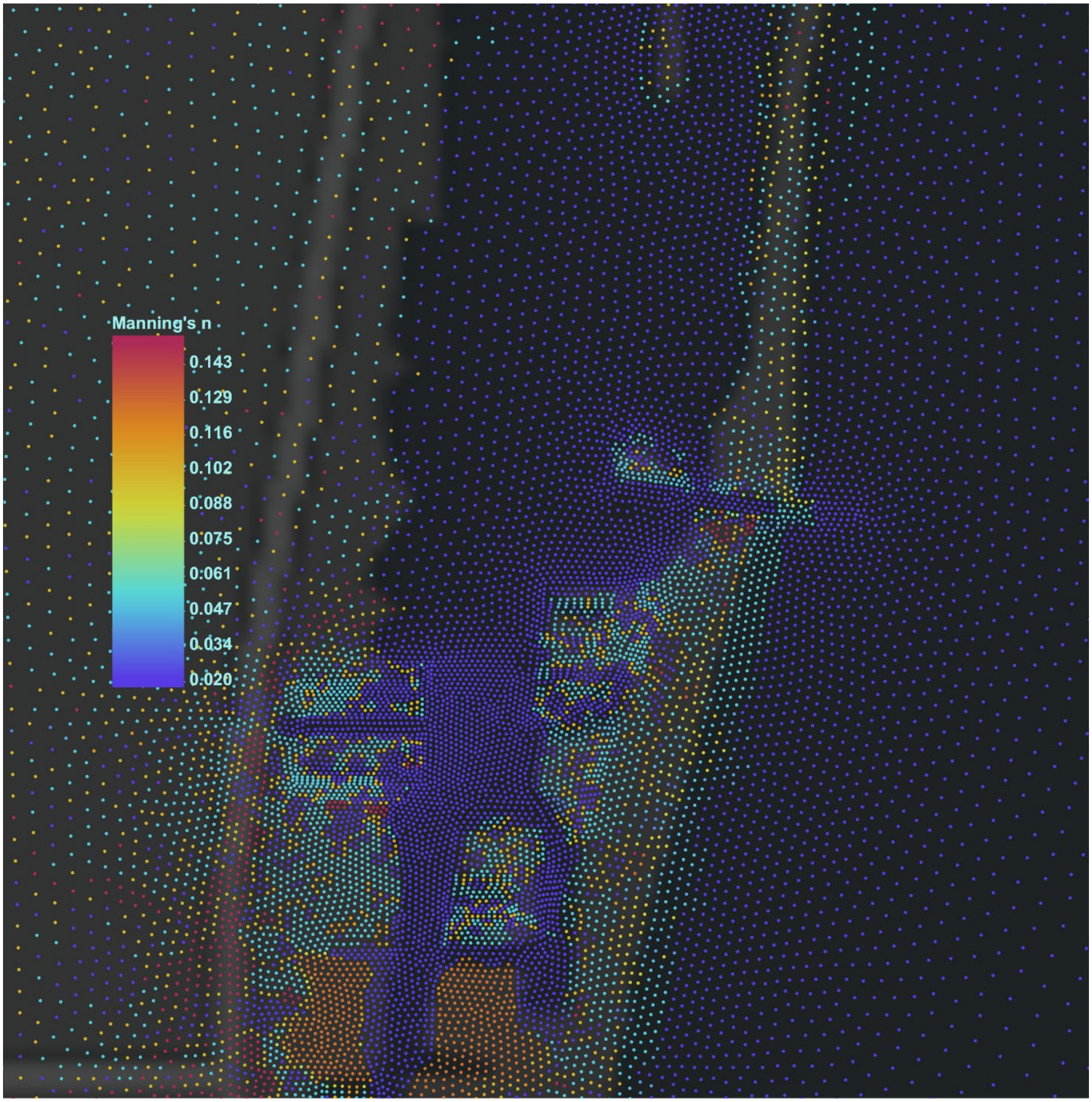


Figure 9. FEMA's assigned Manning's n values (Boynton Inlet)

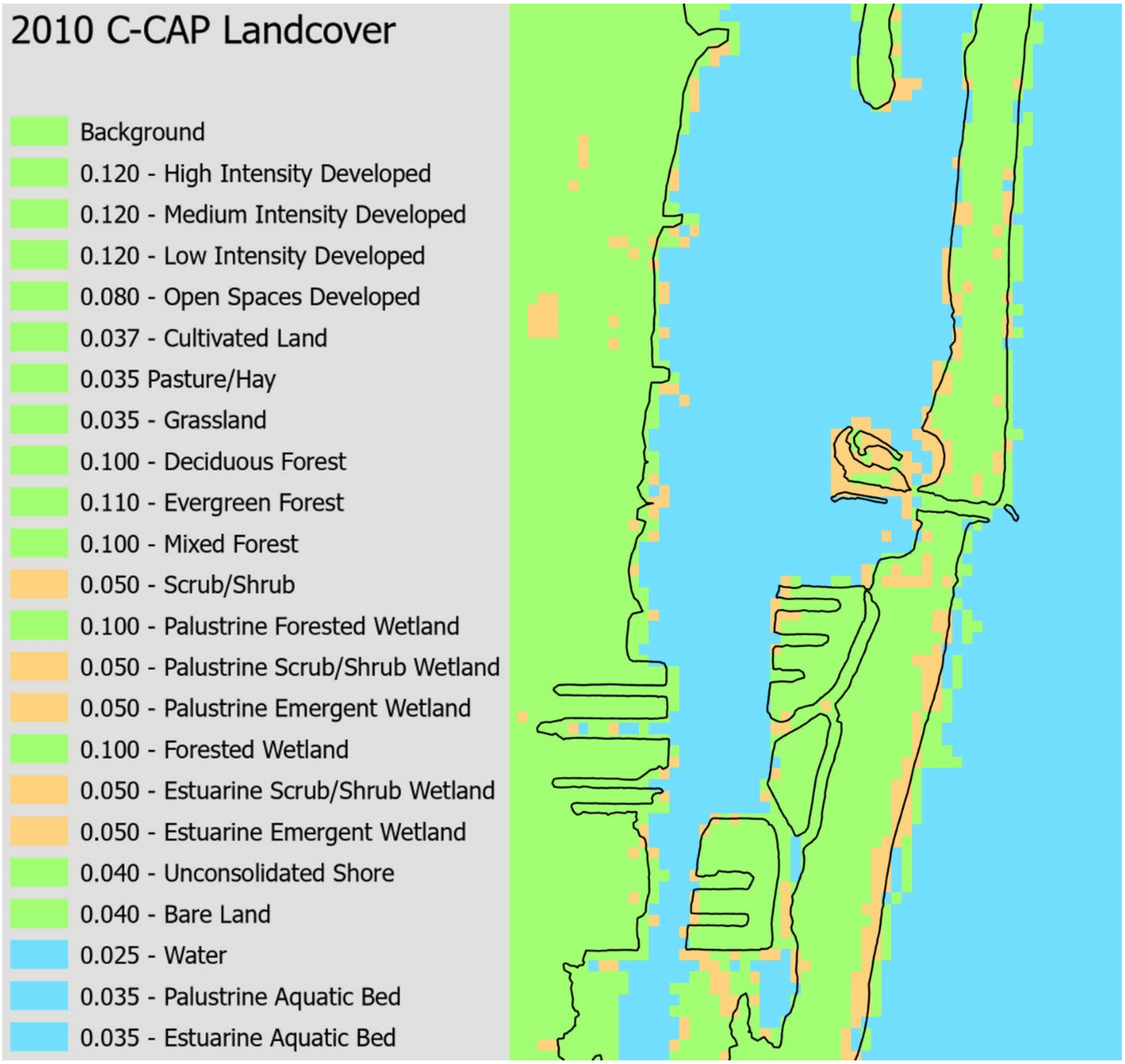


Figure 10. 2010 C-CAP Landcover map simplified – Land classification near Boynton Inlet

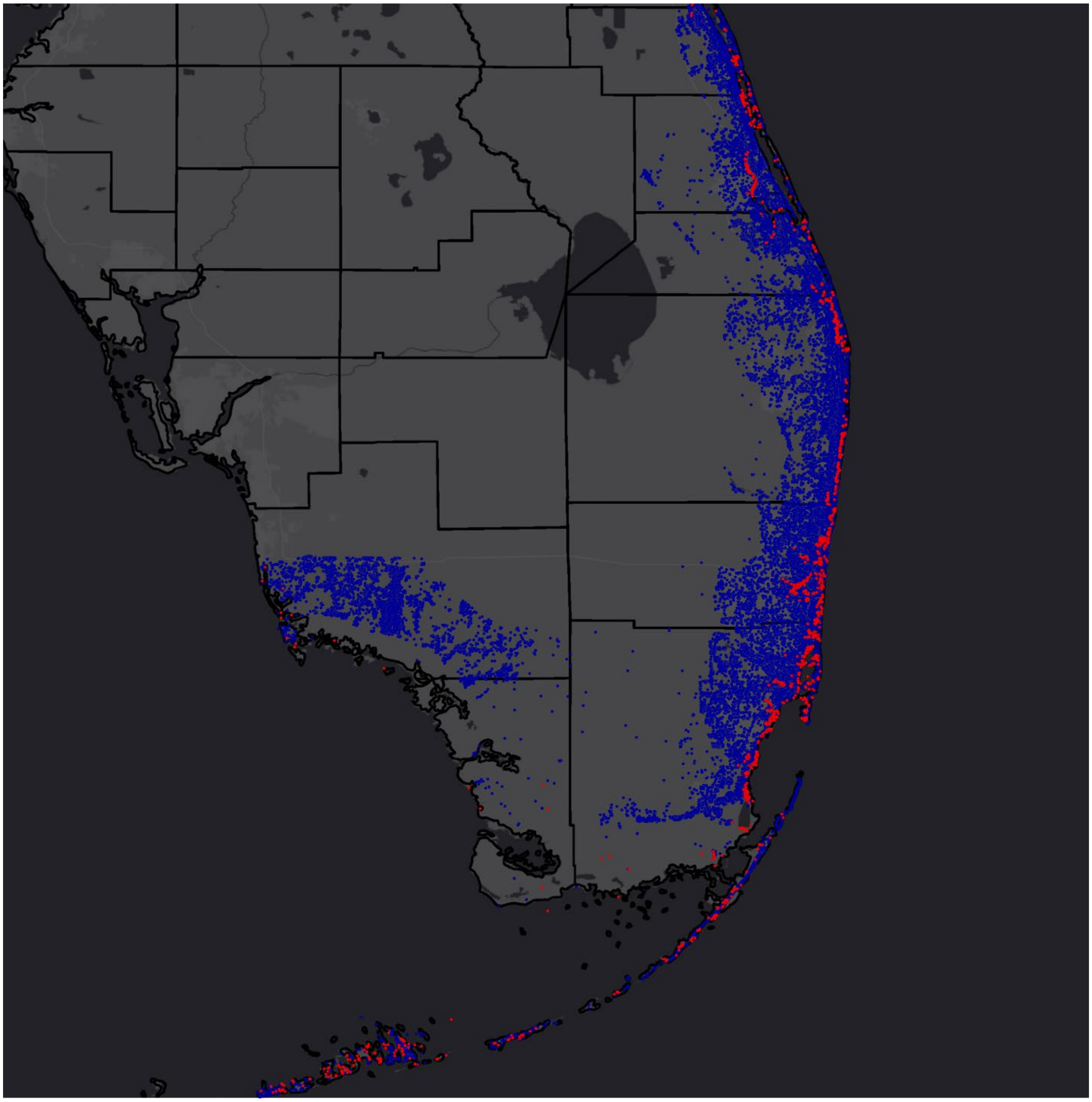


Figure 11. Default Manning's n (0.1) coverage for the entire study area. Red (nodes in canals), Blue (overland).

Figure 11 shows the default Manning's n coverage for the study area. FEMA defined the default Manning's n value of 0.1 in the nodal attributes file (fort.13) used in the study. This is an acceptable approach; however, the assigned default value (0.1) represents forests and wetlands. Therefore, this default value should not be applied to water nodes. Red nodes in **Figure 11** shows where this is not the case for the entire study area whereas **Figure 12** focuses on Palm Beach County.

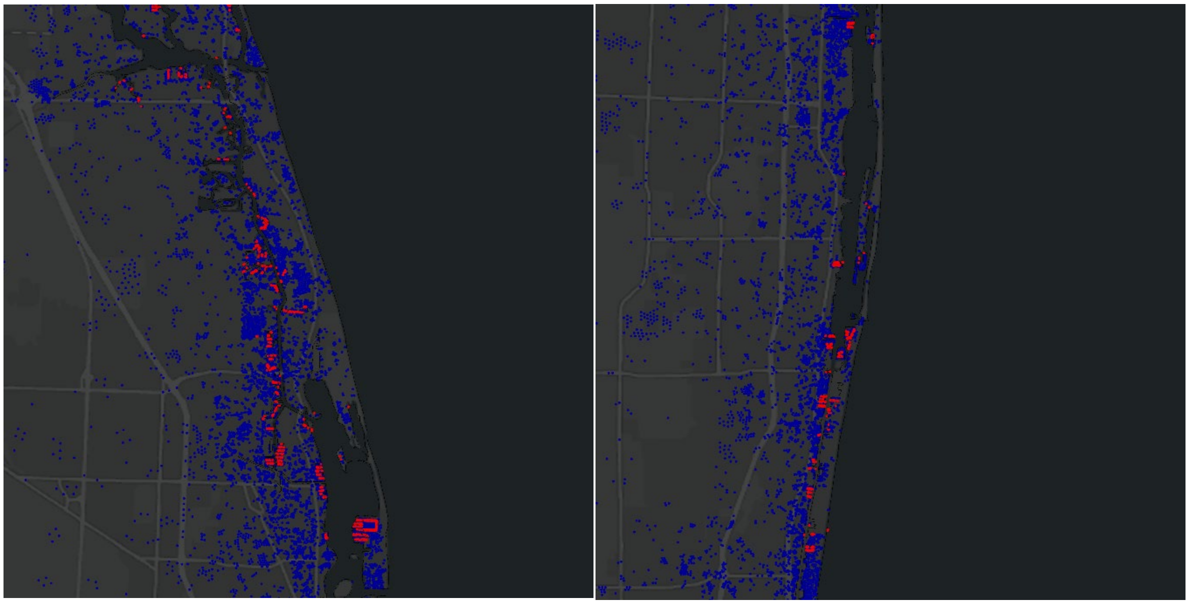


Figure 12. Default Manning's n (0.1) coverage for PBC. Red (nodes in canals), Blue (overland).

The nodes with high Manning's n values represent rougher terrain and have a direct impact on the hydrodynamics calculated on them. It was apparent that some of these nodes were used for numerical stability purposes, however it is not listed or presented as one of the approaches applied to overcome instabilities. The impact of employing high manning values in water nodes was not explored.

2.5 Re-simulated storms with FEMA inputs do not match original results

To complete its review and analysis of FEMA's preliminary results, Baird re-ran selected storms. The selected storms were re-simulated using the original setup files provided by FEMA. Additionally, reruns were completed using the same source codes for ADCIRC/SWAN (v52.30) as reported by FEMA. FEMA's original maximum water surface elevation results (maxele_400sec.63 files provided by FEMA) were compared to the County's rerun of the same storms. A difference of maximum water surface elevations is also presented for each storm rerun. **Figure 13, Figure 14, and Figure 15** show the results of Storm 18 maximum water surface elevation results from the County's rerun, maximum water surface elevation results provided by FEMA and the difference between the two results (Original FEMA results minus County rerun results) respectively.

Similarly, **Figure 16, Figure 17, and Figure 18** show the results for Storm 20. **Figure 19, Figure 20, and Figure 21** show results for Storm 21.

The differences between FEMA's maximum water surface elevation results and the County's reruns are significant. Specifically, storm 20 and storm 21 are on the tail end of the probability distributions ultimately used to calculate BFEs. Even small changes in the results of higher return period events (e.g., storm 20, storm 21) can have a big impact on the results.

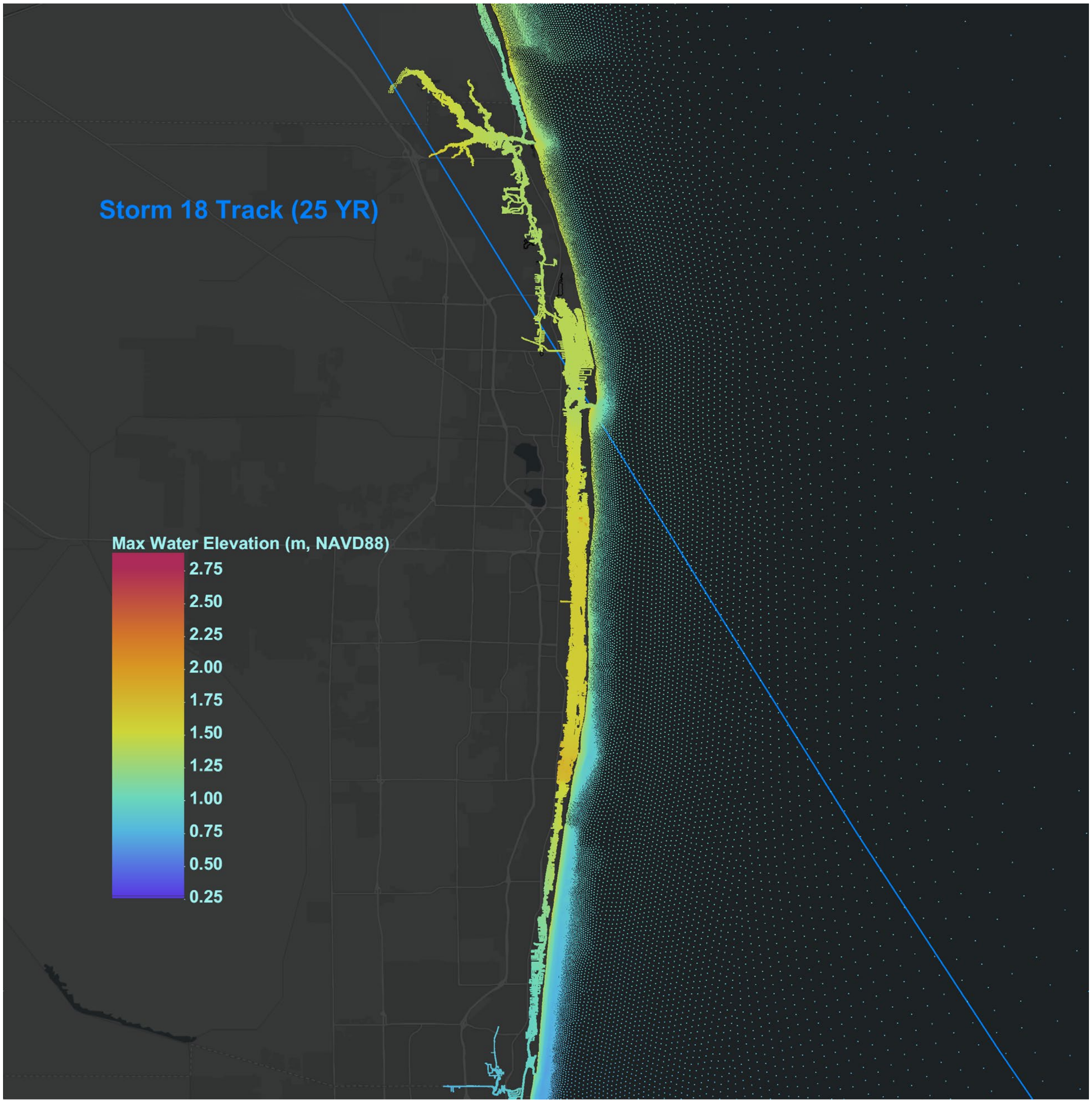


Figure 13. Storm 18 (25 Year Return Period) Original maximum water surface elevation results (County rerun)

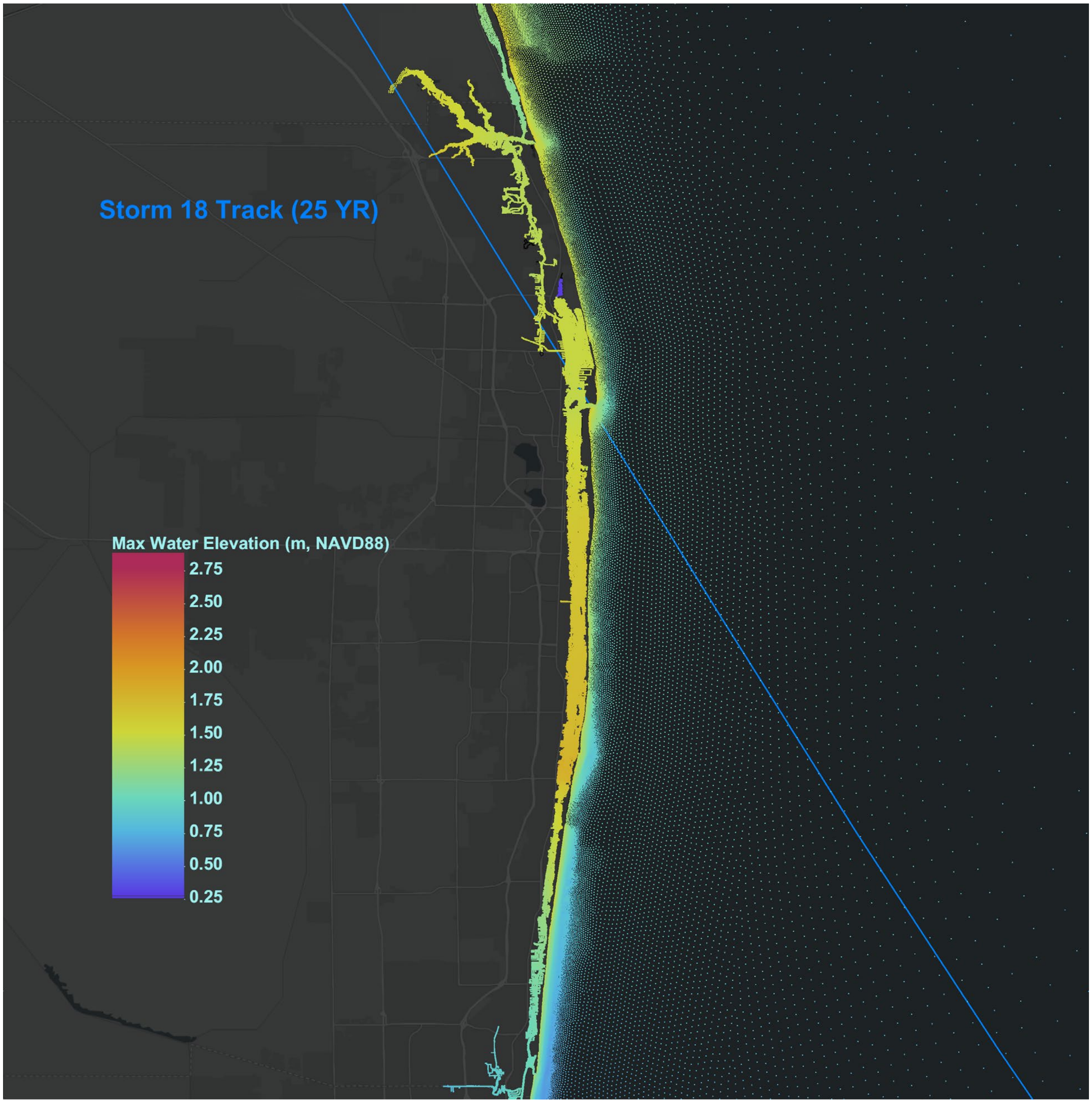


Figure 14. Storm 18 (25 Year Return Period) Original maximum water surface elevation results provided by FEMA

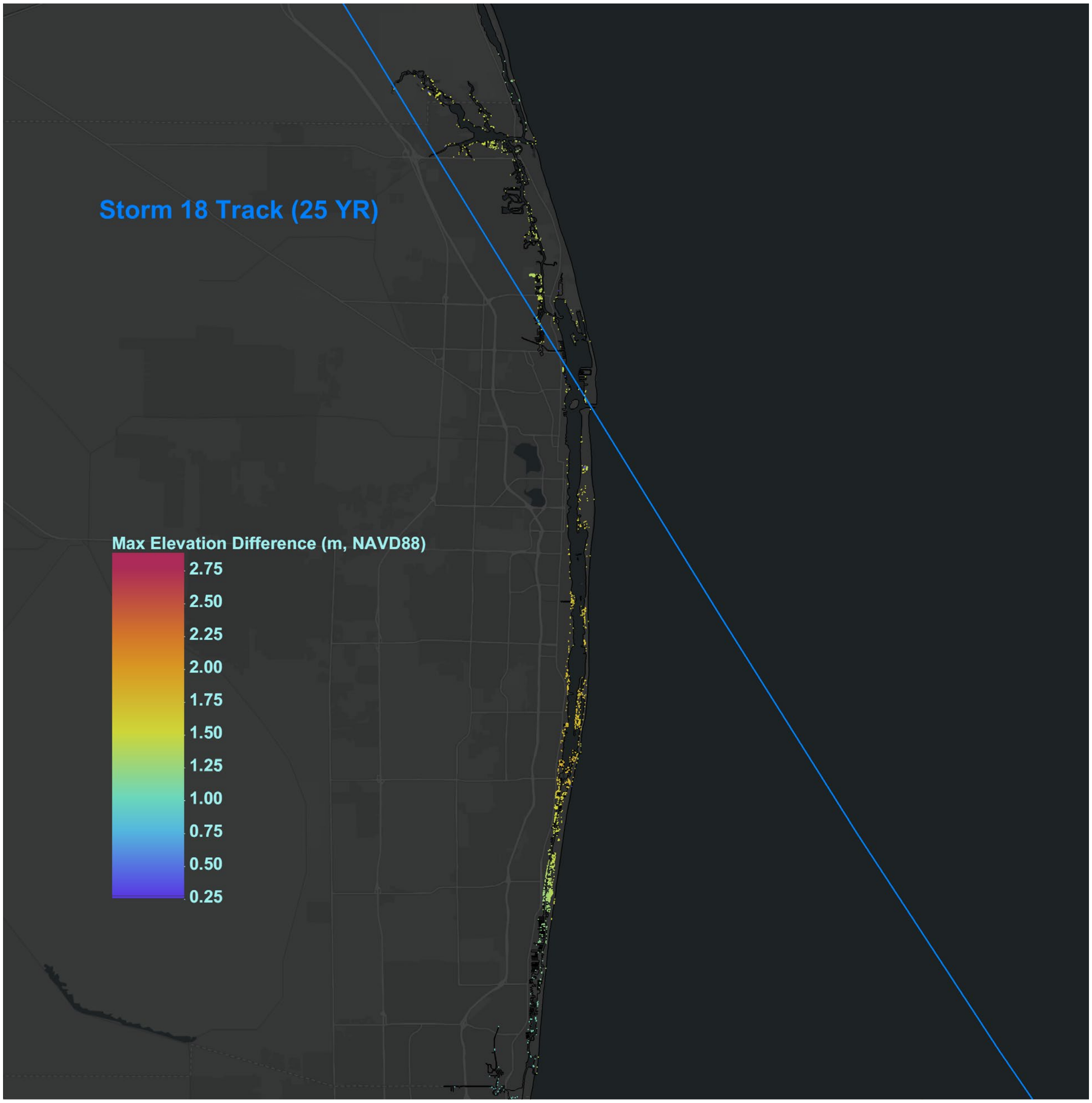


Figure 15. Storm 18 (25 Year Return Period) Original maximum water surface elevation difference (Original minus rerun)

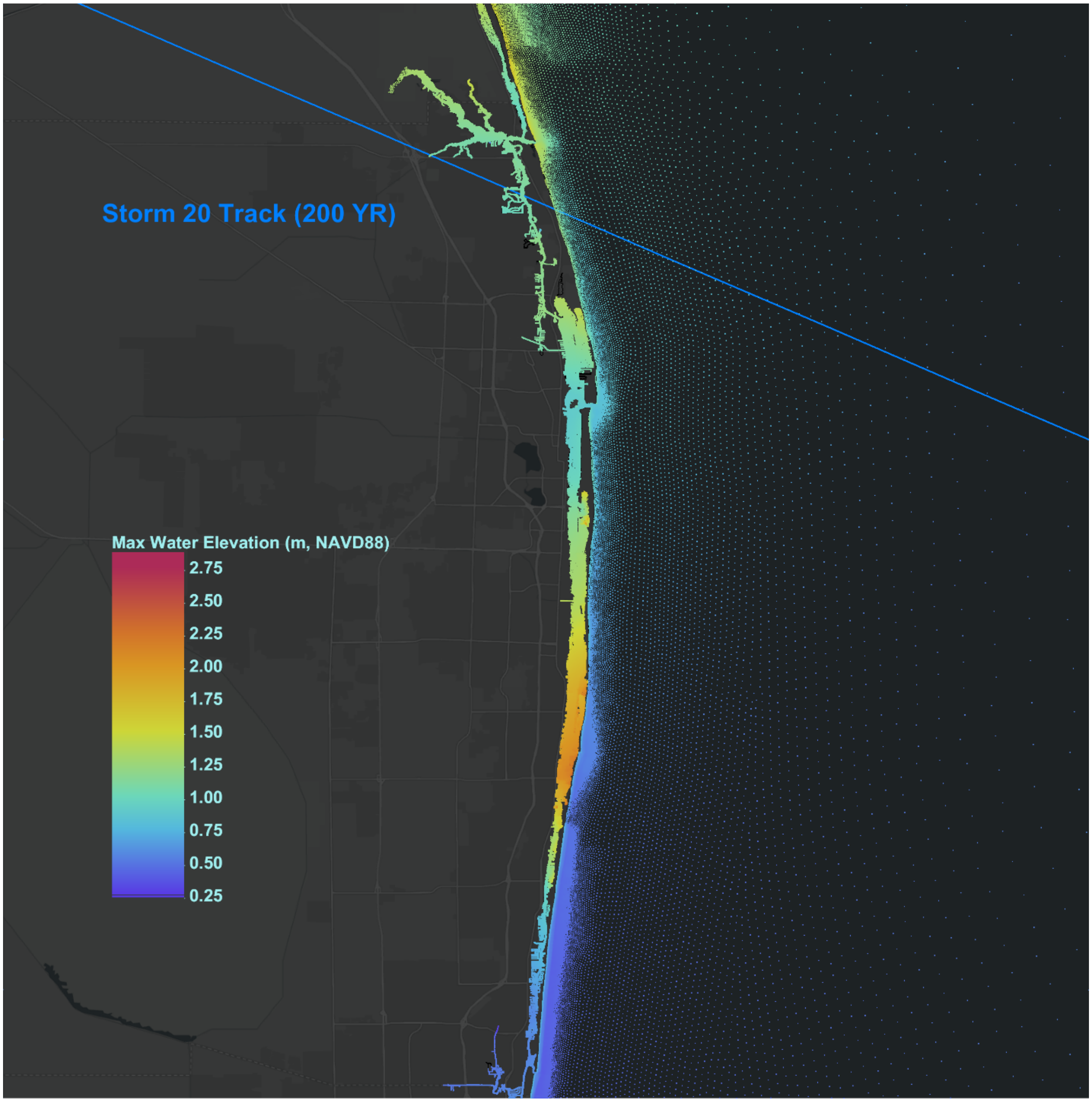


Figure 16. Storm 20 (200 Year Return Period) Original maximum water surface elevation results (County rerun)

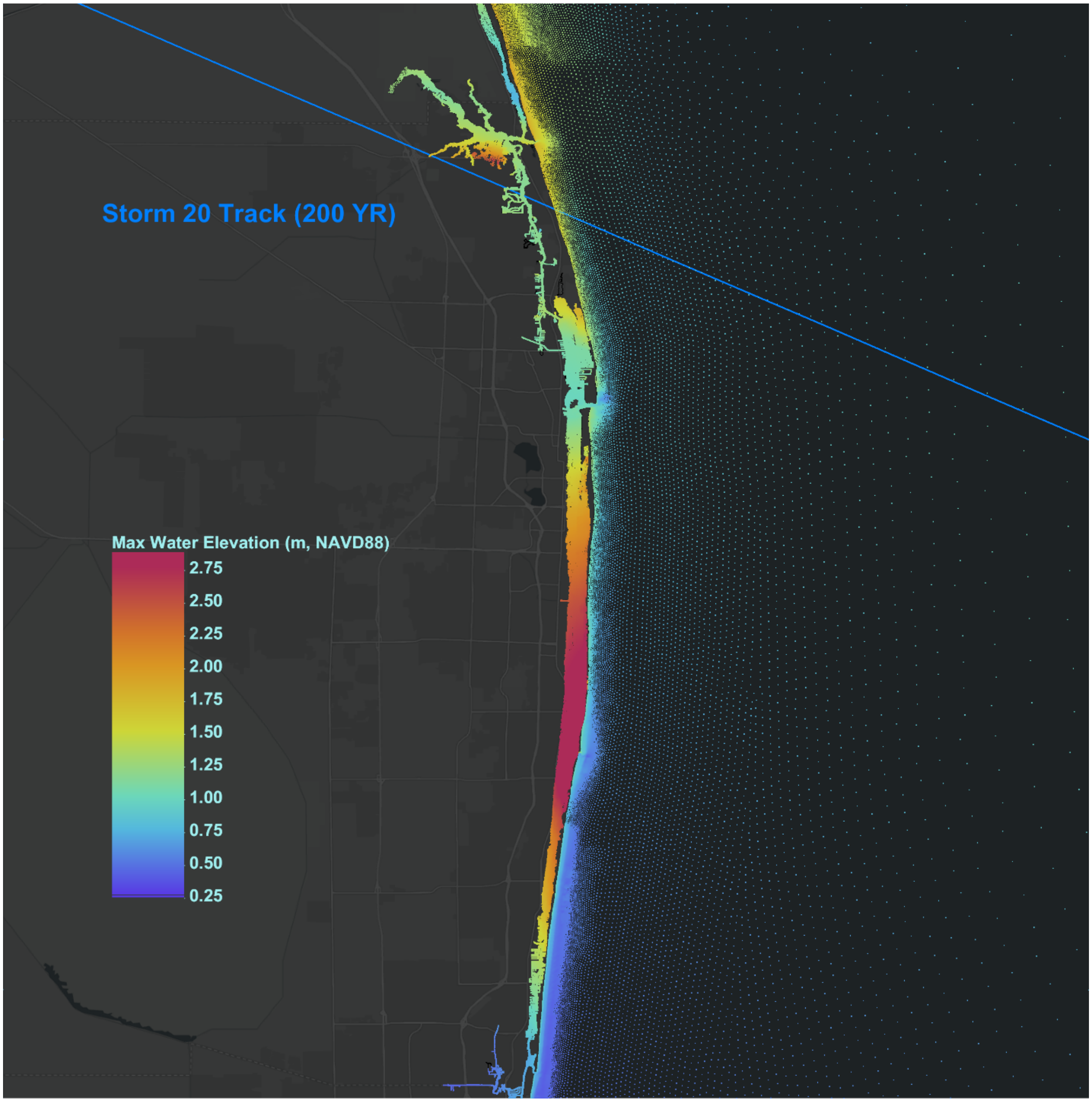


Figure 17. Storm 20 (200 Year Return Period) Original maximum water surface elevation results provided by FEMA

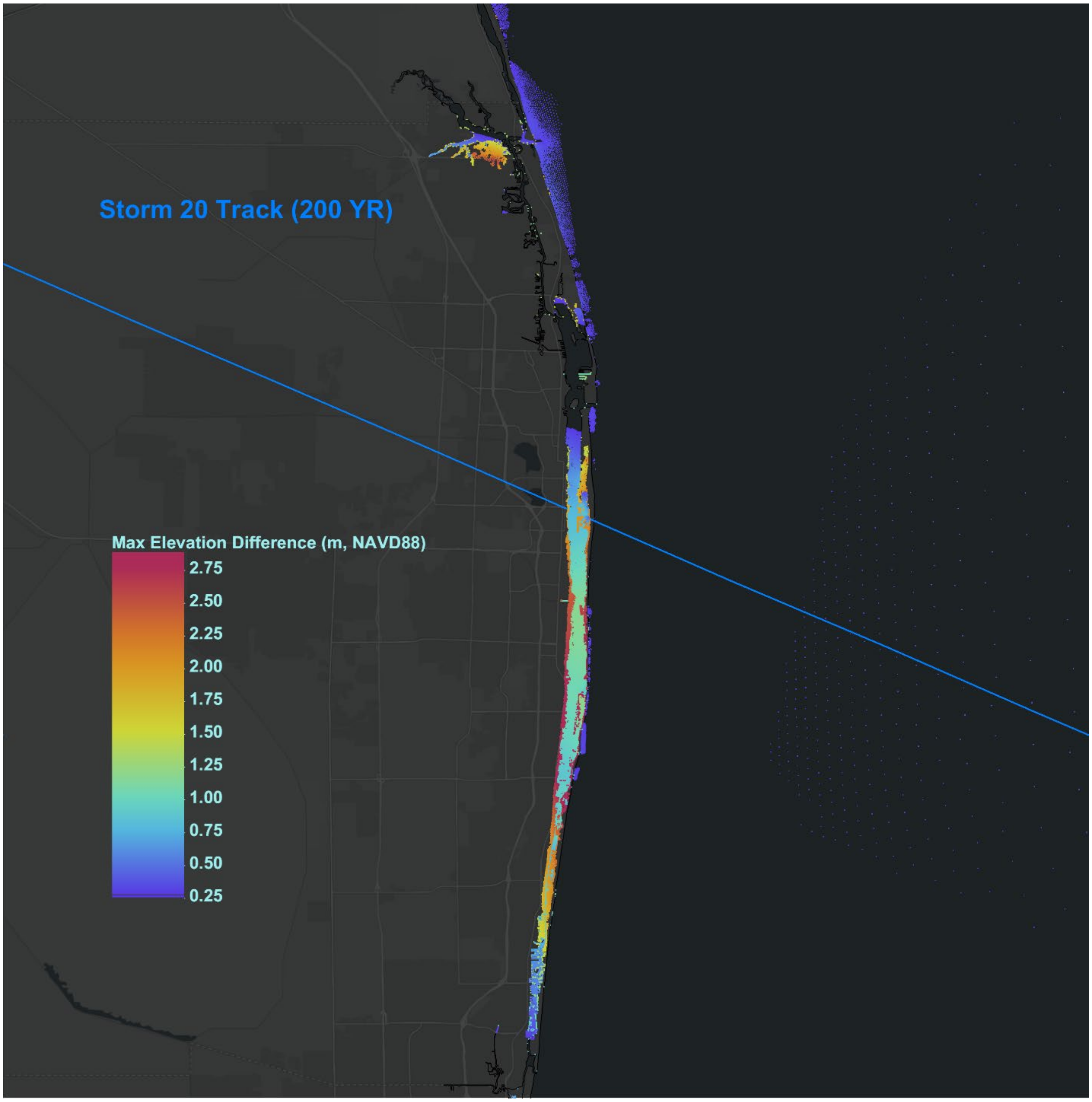


Figure 18. Storm 20 (200 Year Return Period) Original maximum water surface elevation difference (Original minus rerun)

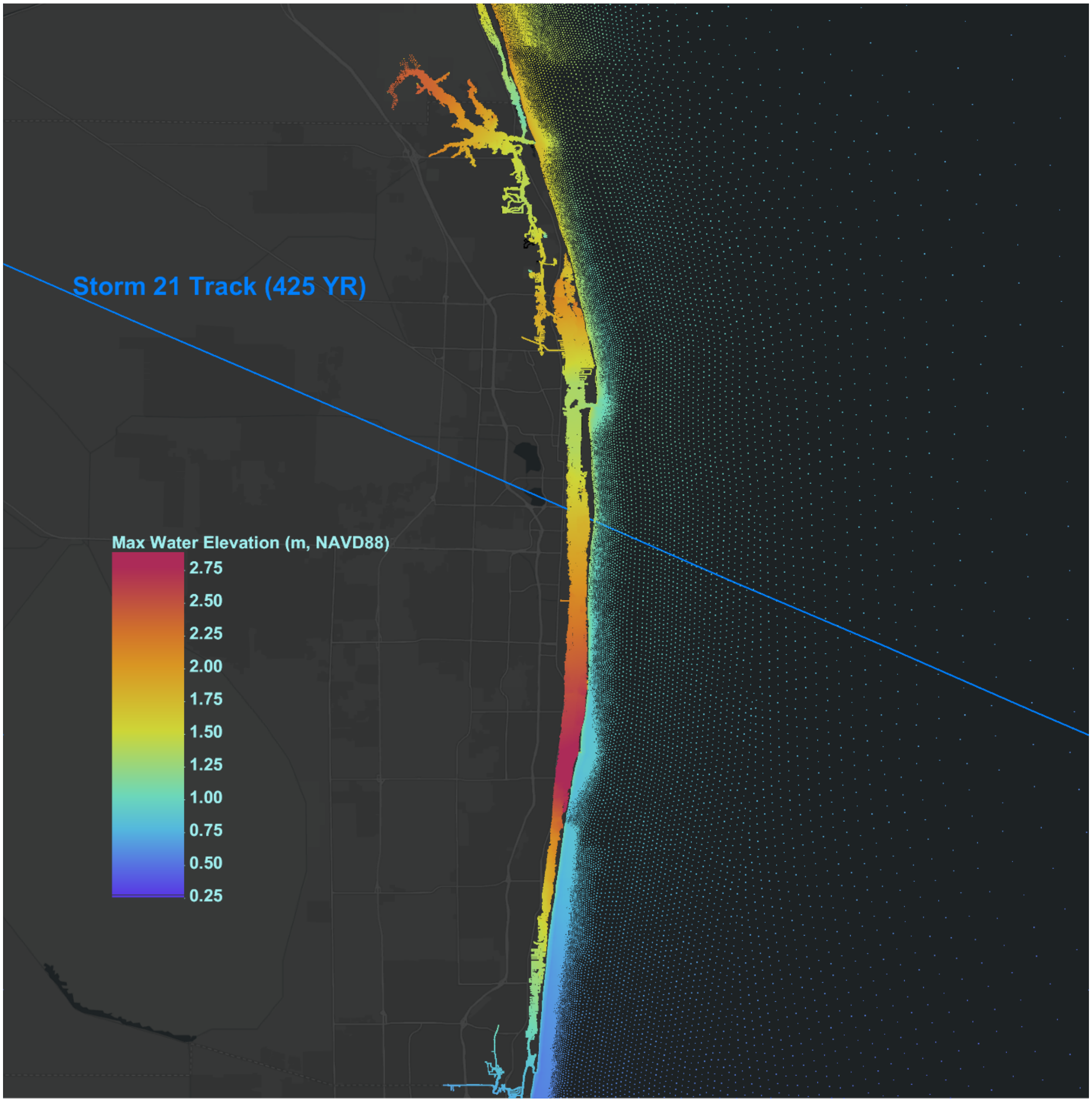


Figure 19. Storm 21 (425 Year Return Period) Original maximum water surface elevation results (County rerun)

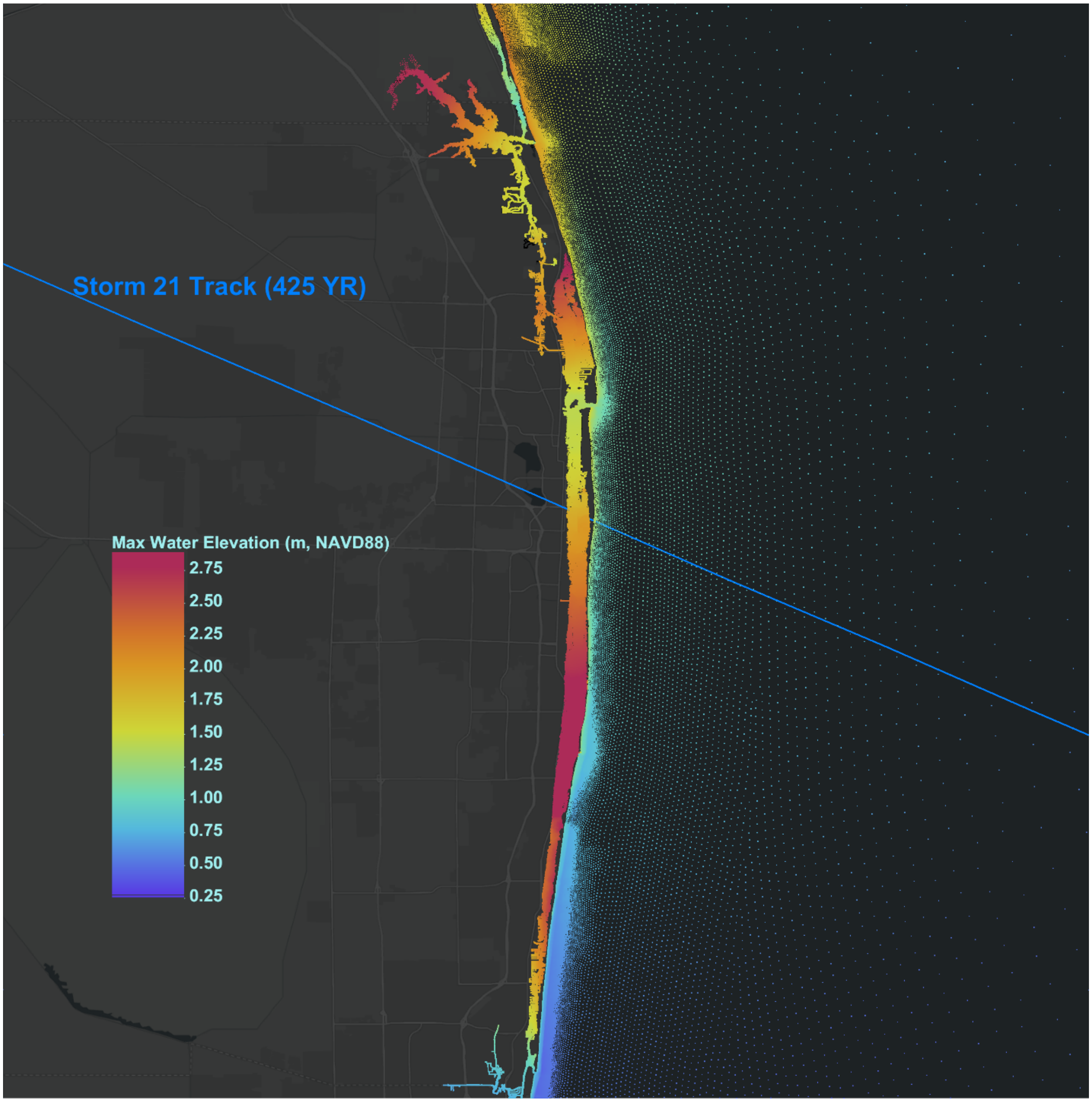


Figure 20. Storm 21 (425 Year Return Period) Original maximum water surface elevation results provided by FEMA

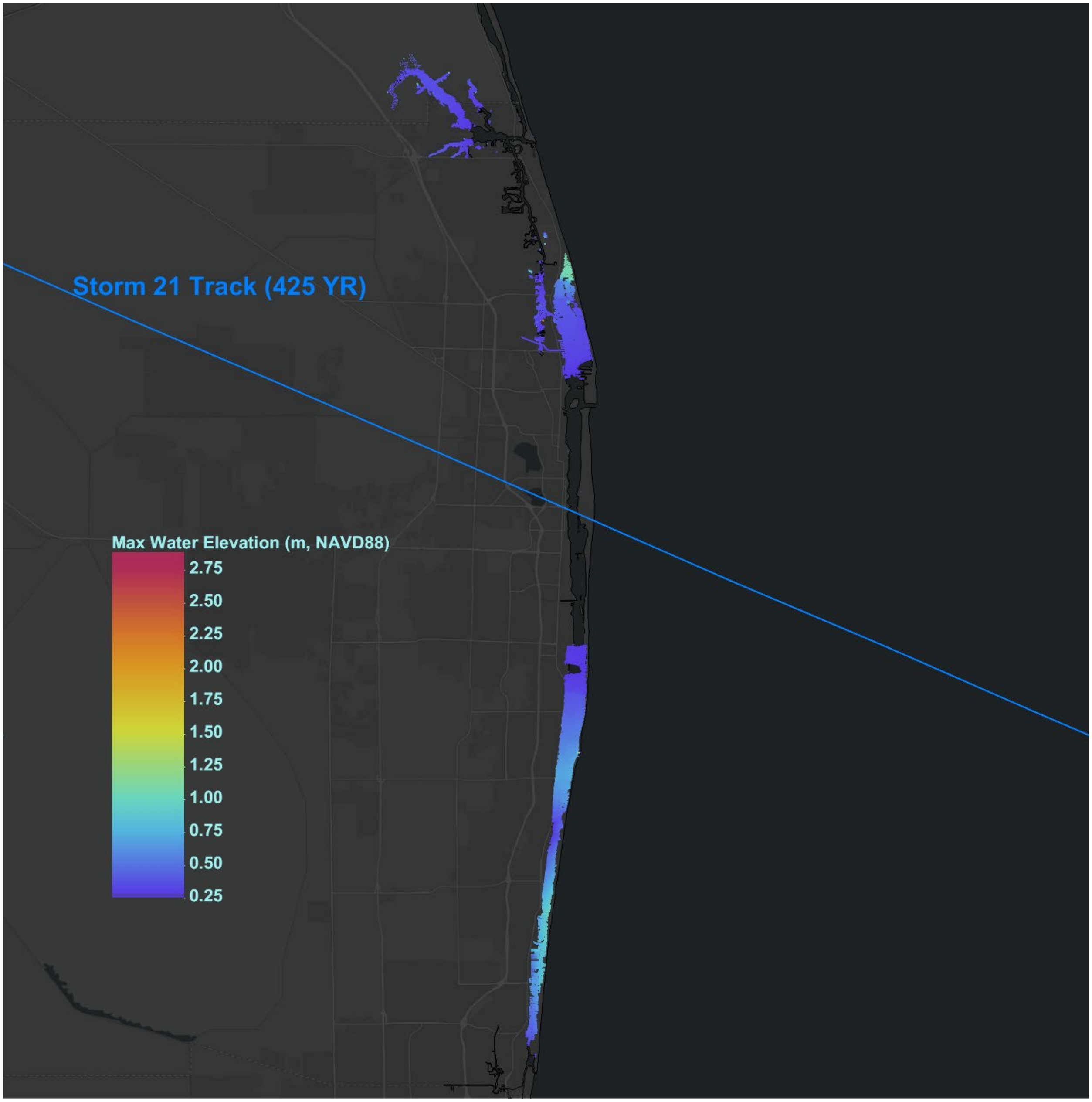


Figure 21. Storm 21 (425 Year Return Period) Original maximum water surface elevation difference (Original minus rerun)

2.6 Model run for tide effects

FEMA's 2018 reports states: "Each production run began with a model hot-start tide level derived from a three-month tide simulation. The tide simulation covered the period from August 1 to October 31, 2015 to cover the period when most major hurricanes make landfall along Florida's east coast. The three-month simulation followed a 30-day spin-up period to provide sufficient tidal forcing ramping before the first storm occurred."

The 2018 FEMA report however does not state that the three-month tidal simulation is a combination of short runs between each synthetic storm start time. Each short tidal run is hot-started from the previous tidal run. This is a very uncommon application since it creates an environment very susceptible to error. If an error occurs at any point during the three-month tide simulation, the error is then carried over to all the tidal runs that follows. Common practice is to run a 30-day tidal ramp for each storm separately. FEMA also converted the Monte Carlo distribution of start times for each storm into days (as required by ADCIRC). This conversion creates input values that are irrational numbers (e.g., RNDAY = 79.66666…). This not only makes the application error prone but also known to create problems with ADCIRC, especially if the source code is compiled with GFORTRAN compilers. This could have been easily prevented by rounding the start times to the nearest quarter hour with negligible implications on starting tidal levels

3. Summary

Baird investigated the FEMA model setup including instabilities that were noted at several inlets and found potential issue that impact the final Base Flood Elevations. Issues with the modeling that were identified include: restricting the localized water gradient, the lack of quality control at the local level, numerical instabilities at inlets, the assignment of nodal attributes and the fact that re-simulated storms with FEMA inputs do not match original results.

4. References

FEMA 2018. Production Runs IDS3: Section 1 Task Order 99: South Florida Flood Insurance Study Version 3.0 June 2018: Final Report Including Appendices Digital File Name: SFL_IDS3_Sect1_Prod_Rept_IncAppendecies_Final_June2018.pdf, June 2018

Luettich, R.A., Jr., Westerink, J.J., and Scheffner, N.W. 1992. ADCIRC: An advanced three-dimensional circulation model for shelves coastal and estuaries, Report 1: theory and methodology of ADCIRC-2DDI and ADCIRC-3DL. Dredging Research Program Technical Report DRP-92-6. U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.

NOAA. NOAA C-CAP Land Coverage. Website, 2011. http://www.csc.noaa.gov/digitalcoast/data/ccapregional/index.html

Woods Hole Group. 2021. Appeal Submittal: Monroe County, FL, Appeal of FEMA's Preliminary Flood Insurance Rate Maps and Flood Insurance Study (issued 12/27/2019). Prepared for Monroe County, Florida. June 2021.