SOME USEFUL APPLICATIONS OF THE PUERTO RICO STORM SURGE ATLAS

CRITICAL INFRASTRUCTURE, SEA LEVEL RISE, AND COASTAL FLOODING IN PUERTO RICO

In the following sections we will use the Puerto Rico Storm Surge Atlas (PRSSA) results to present a visual/qualitative evaluation of the exposure of critical facilities to seawater flooding due to the stillwater elevation (SWE) from storm surges (remember, no wave runup/overtopping included yet, so we might be missing a large portion of the coastal inundation by seawater). For each location we will also show the actual FEMA FIRM for comparison purposes. For this reason I will briefly describe how the present FEMA maps were prepared, and released in 2007.

The FEMA Maps:

- In contradistinction to the preparation of the PRSSA, which is a purely numeric deterministic approach, the FEMA maps are based on a combination of numerical simulations and probabilistic approaches. This is so because what the FEMA maps show are the so-called 100-, and 500-year inundations. That is why you often hear the expression that the FEMA maps are not made to save lives, but to provide guidance for establishing flood insurance rates.
- The present FEMA maps were made using flooding results (SWE) from the same model (ADCIRC) we used for the PRSSA, but for obvious reasons, an earlier version of the model was used. The probabilistic part was made using the so-called Empirical Simulation Technique (EST), a kind of Monte Carlo approach.
- As mentioned above, in the PRSSA the wave setup was computed by the coupling of the ocean circulation model, ADCIRC, with the spectral wave model, SWAN. They iteratively passed information back and forth between themselves, allowing for the computation of pressure+wind+wave setups. On the other hand, in the FEMA maps the wave setup was added to the ADCIRC SWEs (just pressure+wind seutps) after the 100-, and 500-, year SWEs were computed by the EST. And those wave setups were computed by a simple formula, not taking into consideration the very complex bathymetry around the island.
- Very importantly, the non-structured mesh resolution used for the PRSSA was higher than the resolution used by FEMA. Resolution is very important in coastal flooding calculations.
- In the FEMA study, once the SWEs (pressure+wind+wave setups) were estimated, the very important component of including wave runup/overtopping (used to estimate the boundaries between AE and VE zones, and the Base Flood Elevations) was carried out using a set of Fortran programs, WHAFIS (Wave Height Analysis for Flood Insurance Studies) and RUNUP, which are based on two dimensional (1D) transects (x vs z) taken at distinct locations along our coastline. These two Fortran programs use laboratory data given in tables obtained during the middle of the last century. As an example, Figure 1 shows where transects were located in the Rio Grande area (straight lines). The triangles show where EST results were computed. The figure also shows the profiles used to compute runup/overtopping. Supposedly the spacing between the profiles is determined by the geomorphology of the coast. Where the coast consists of long stretches with similar configuration (like the long beaches along the eastern seaboard of the USA), the spacing can be larger, but where the coast is very irregular (like in Puerto Rico), the spacing should be much more narrow. The fact is that the very irregular coastline we have would have required thousands of transects, something which could not be done due to practical limitations. In between transects some type of interpolation is carried out to fill the gaps where

there was no model guidance to estimate AE/VE zone boundaries. Notice, as an example, that Punta Miquillo lies between EST stations 141 and 145. That is, no WHAFIS and RUNUP run was made at all for Punta Miquillo. And the results from these runs are used to determine the Base Flood Elevations (BFE) and the VE zone width. Henceforth, it is worrying how the very important delimiting line between VE and AE zones, and its BFE, were determined for Punta Miquillo. The same happens for the rest of the island. In the recently initiated wave runup/overtopping study we have started, we will run 2D – in the horizontal - Boussinesq models to estimate the runup/overtopping all over the island.

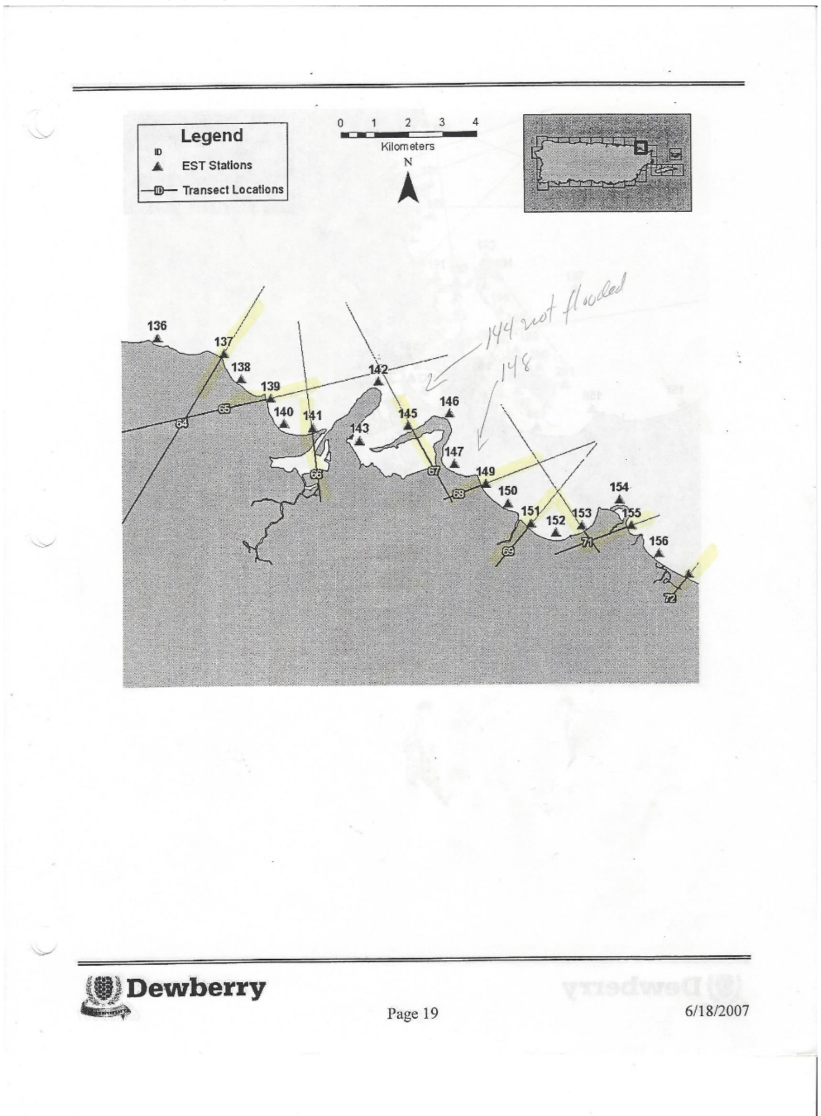

Figure 1 – Location of Empirical Simulation Technique stations (black triangles) and WHAFIS & Runup transects for the Rio Grande area.

- A very important positive factor of the FEMA maps is the inclusion of rainfall/riverine flooding, something which is not included in the PRSSA maps (see Caveats in 3 - STORM SURGES IN PUERTO RICO_THE PUERTO RICO STORM SURGE ATLAS_Intro.pdf).

Having stated these factors, we will now proceed with the analyzing the maps for several critical infrastructure in the island. For comparison purposes, for each site a map will be shown of the impact of sea level rise of +0.5 and +1.0 m. In this way we can more readily see the impact of a storm surge on top of the sea level rise. As a matter of fact, sea level rise presents a moving target for any attempt to predict storm surge flooding. Even if nothing about storm surges and hurricanes changes, the impact of storm surges will increase over the years. There is no stopping this.

All of the maps used as the baseline information for the modeling were based on Digital Elevation Models prepared by the National Geophysical Data Center of NOAA, for tsunami flood mapping purposes. These maps used Lidar (topographic and bathymetric) data obtained in the early 2000s as part of a proposal I submitted to FEMA after the passage of Hurricane Georges. The DEMs resolution varied from 1 arc-seconds (approximately 30 m resolution) covering the whole island, and a set of 1/3 arc-seconds (approximately 10 m resolution) DEMs for the coastal areas.

A more detailed explanation on how A and V zones are determined is given in the document "Construccion en Zona Costanera.pdf". The following link opens a pdf version of a paper explaining how the coastal FEMA maps, valid until 2007, were prepared using the National Weather Service SLOSH model (Natural Hazards 10 235-246 1994.pdf).