COASTAL FLOODING IMPACT REPORT

(100-YEAR RETURN PERIOD EVENT)

CORDECO DISCOVERY BAY RESORT & MARINA

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submitted to

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Scope of Work:

Assess the exposure of the proposed complex (Cordeco Discovery Bay Resort & Marina) as to its exposure to coastal flooding due to the 100-year return period storm surge.

Methodology:

Locate the complex property in the applicable National Flood Insurance Program Flood Insurance Rate Map (FIRM) for the Commonwealth of Puerto Rico. The applicable FIRM is Community-Panel Number 720000 009 E, Panel 9 of 330, Revised in June 2, 1999.

For this purpose we will be working with various data sources. One will be the U.S. Geological Survey (USGS) quadrangle sheet for Aguadilla in Digital Raster Graphics (DRG) format (Figure 1). This DRG (obtained from the USGS itself) will be cropped so that only the map itself will be left, and geo-referenced using the known latitudes and longitudes of the corner points. Then we can zoom in on the area of interest, as shown in Figure 2.

Another source of data will be the FIRM mentioned above. The coordinates of the 4 corner points are also known, which will allow to, using a large digitizing table, define the 4 corner points of a smaller area encompassing the study area. Once these 4 corner points are marked on the map, this section of the map is cropped exactly along the 4 corner points, and the resulting image can then be geo-referenced. This will allow the superimposition (or overlay) of the polygons defining the periphery of the proposed complex and the proposed dikes to be built by the U.S. Army Corps of Engineers (USACoE) – see Figure 4. The polygons defining the periphery and the dikes were obtained by digitizing the plans for the proposed complex supplied by AHV & Associates (Antonio Hernández Virella & Assoc.).

Finally, another source of flood data is the Hurricane Storm Tide Atlas for this area, prepared by USACoE, June 2000 (see Figure 5). The map shows the expected flood elevations due to category 1, 3, and 5 hurricanes, based on the Saffir/Simpson scale. These maps are already geo-referenced (that is, they show latitude/longitude grid lines), which allow for overlay of digitized polygons. The color scale is given as Figure 6.

Discussion:

Figure 1 shows the USGS quadrangle for Aguadilla and Aguada, where the complex to be built just north of Barrio Espinar in the municipality of Aguada. Figure 2 shows a blowup of this map centered on the study area. The figure shows the location of the proposed dikes and the periphery of the complex. It also shows (as a brown line close to the northern part of the property) the approximate position of the 1.43 m contour line. This elevation happens to be the elevation of the 100-year Stillwater Level (SWL) for the storm surge computational cell in which this area falls within, according to the Flood

Figure 1 - USGS quadrangle for the study site. Note dates of topography data and revision.

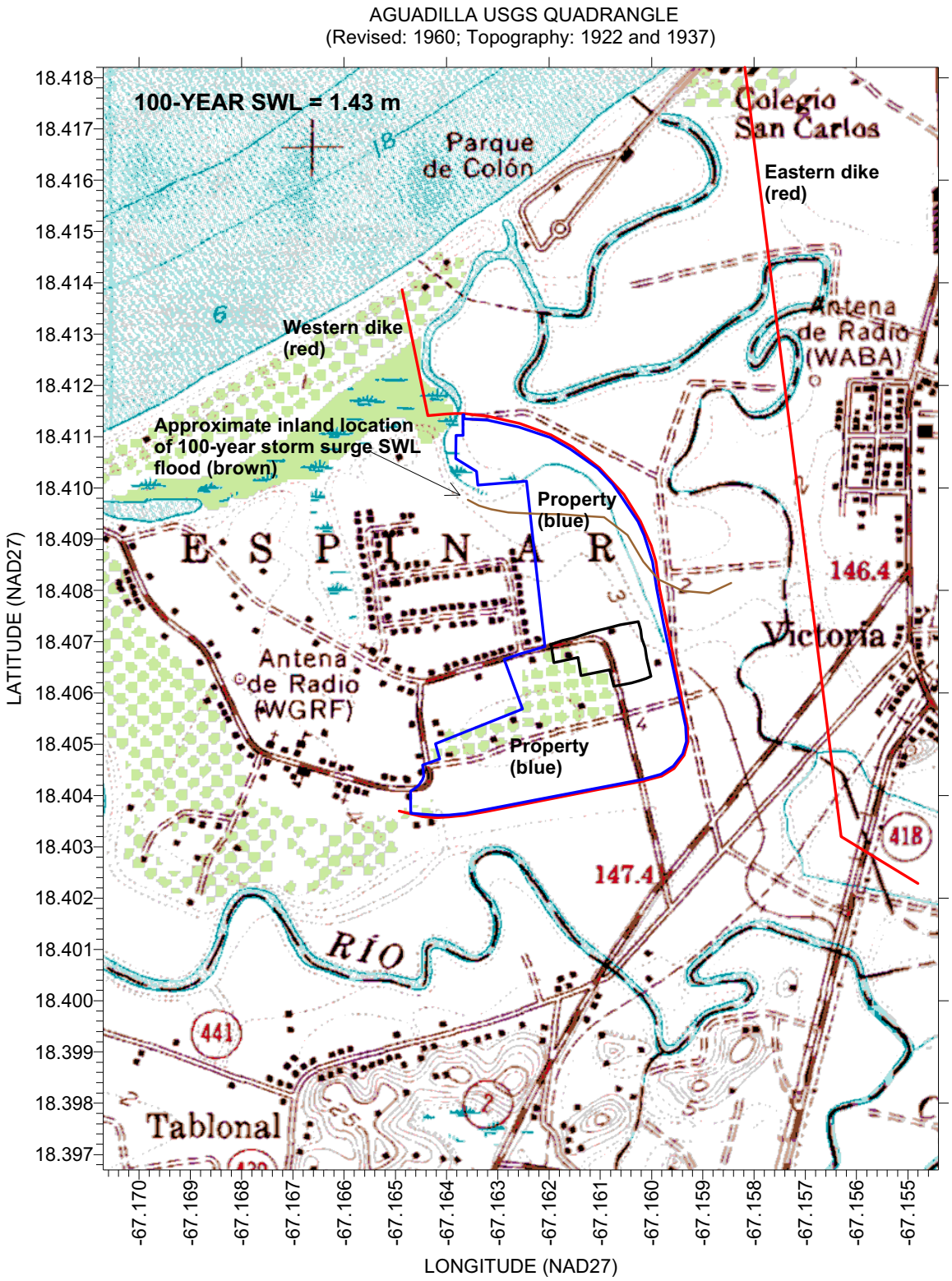

Figure 2 - Zoom in of the are where the complex is to be built. Also shown are the proposed dikes, the periphery of the complex, and the approximate inland penetration of the 100-year stillwater elevation.

Insurance Study done by Mercado for the federal Emergency Management Agency, also known as FEMA (Mercado, 1009, 1994). The SWL is the water elevation, relative to Mean Sea Level (MSL), that would be measured inside a flooded (closed) building where the influence of the high frequency waves has been filtered out but storm surge water still leaks in through gaps. The waves propagate on top of the SWL. It is important to notice that the Base Flood Elevation (BFE) for the study site in the VE zone is 2.3 m. This is higher than the SWL because, by definition, the BFE is the elevation of the crest of the highest waves that can propagate over the 100-year SWL at the site (see Figure 3). Its determination is based on the following equation (FEMA, 2000):

$$BFE\ (above\ MSL) = SWL + 0.7H$$

where H is the wave height of the maximum wave that can propagate over the study site. In this case SWL equals the 100-year storm surge elevation above MSL. The above formula assumes that near shore the water wave profile becomes asymmetrical relative to the SWL such that the elevation of the crest of the wave above the SWL is 0.7 of the wave height H (under normal conditions the elevation of the crest above the SWL is 0.5H). It is now also assumed that the maximum wave height equals 0.78 times the (total) local water depth, d. Therefore, the BFE is given by

$$BFE = SWL + (0.7)(0.78)d$$

Recall that in general (see Figure 3),

$$d = h + SWL.$$

where h = water depth relative to MSL.

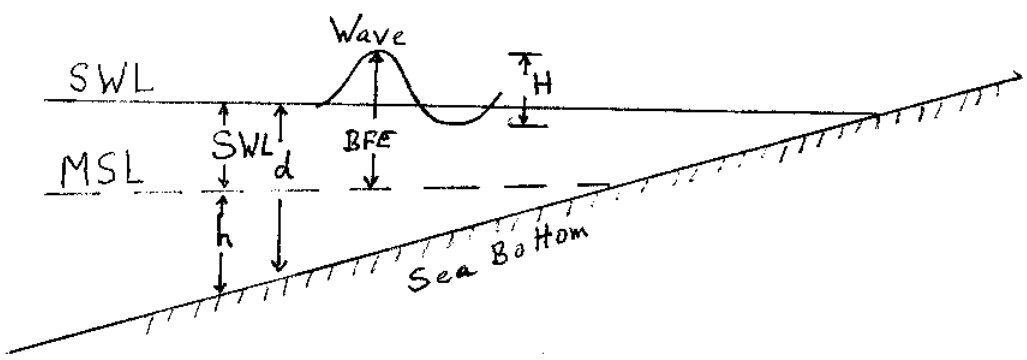

Figure 3 - Sketch showing the relationship between Mean Sea level, Stillwater Level (or Elevation), wave height, and Base Flood Elevation.

Therefore, the above equation can be rewritten as

$$BFE = SWL + 0.55\ SWL + 0.55\ h = (1.55)\ SWL + 0.55h.$$

But right at the MSL shoreline $h = 0$ (by definition). Therefore, right at the shoreline

$$BFE = 1.55\ SWL.$$

Using as SWL the value found by Mercado (1990, 1994), of 1.43 m, we get for the BFE at the study site the approximate value of BFE = 2.22 m, which is close to the value of 2.3 m listed in the FIRM.

Figure 2 shows that since the 1.43 m contour crosses the northern part of the complex, this northern part is potentially floodable by the 100-year coastal flood, or storm surge. This is assuming that the present topography is the same as the one shown in the USGS Aguadilla quadrangle, which is topography from the years 1922 and 1937. Therefore, all that the developers have to do to take the property above the 100-year storm surge is raise the topography of the complex above the elevation of 1.43 m above MSL. But the problem does not lie with coastal flooding, but with riverine flooding.

Figure 4 shows that, as is known, the entire complex is situated in an area floodable by the 100-year flood, but from the discussion above we can conclude that it is riverine flood which dominates all over the property. Note that, as expected, the entire property lies much inland of the inland boundary of the ocean wave VE Zone (which is the area where waves with heights of 3 or more feet can propagate). The inland boundary of the ocean VE Zone is shown as a white line paralleling the line representing the shoreline in Figure 4. The figure shows gutter lines (lines indicate changes in zones, and are solid lines extending across the entire 100-year flood plain) with flood elevations starting at 2.8 m (close to the mouth of Caño Madre Vieja) increasing to above 6 m above MSL as we move upstream the river discharge. It is obvious that this is not storm surge flooding.

We have seen (see Figure 2) that a fraction of the proposed complex can be flooded by the 100-year storm surge SWL, and that this can happen even if the dikes are constructed since the ocean water can move inland just west of the western dike. Again, this is as long as the topography on the USGS quadrangle has not changed. This is corroborated by Figure 5, which shows a geo-referenced scanned image of the Hurricane Storm Tide Atlas for the study site. The figure shows a reference point, number 40 – located right at the entrance of Caño Madre Vieja, at which the storm surge computer model has given as the SWL elevations for the category 1, 3, and 5 storm surges the values of 1.3, 2.1, and 2.9 m above MSL. The value for the Category 1 storm surge is close to the 100-year coastal SWL and its inland boundary does coincide closely with the 1.43 m contour line drawn in Figure 2, corroborating what we stated above about the fact that raising the property elevation above 1.43 m will take it above the 100-year ocean SWL. Figure 5 also shows that the entire property is floodable by the expected storm surge from a direct hit by a Category 5 hurricane. But Figure 4 shows that even then the 100-year river discharge will dominate over the Category 5 SWL.

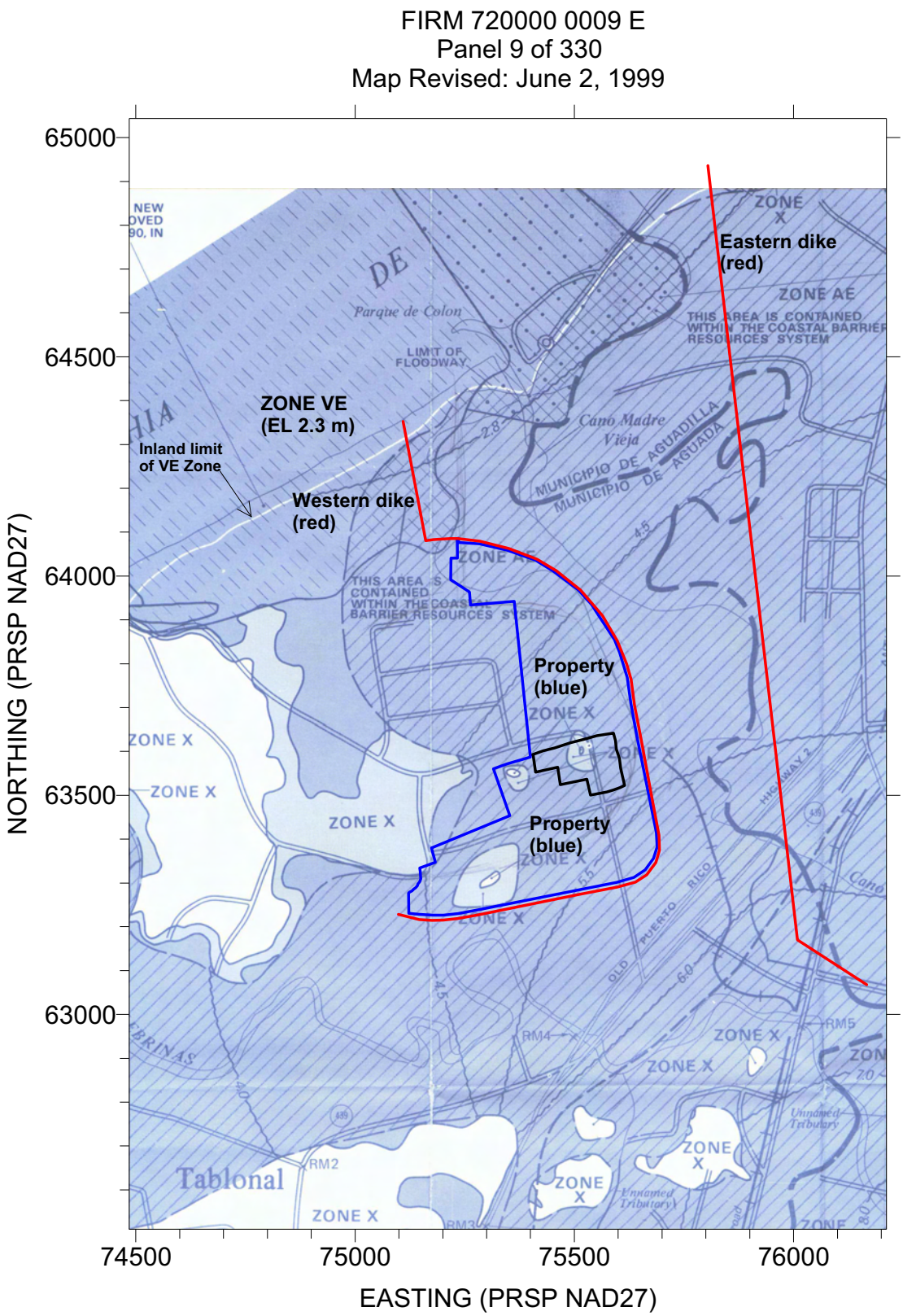

Figure 4 - Scanned map of the FIRM used in this study. Overlaid over the image are the proposed dikes and the periphery of the proposed complex.

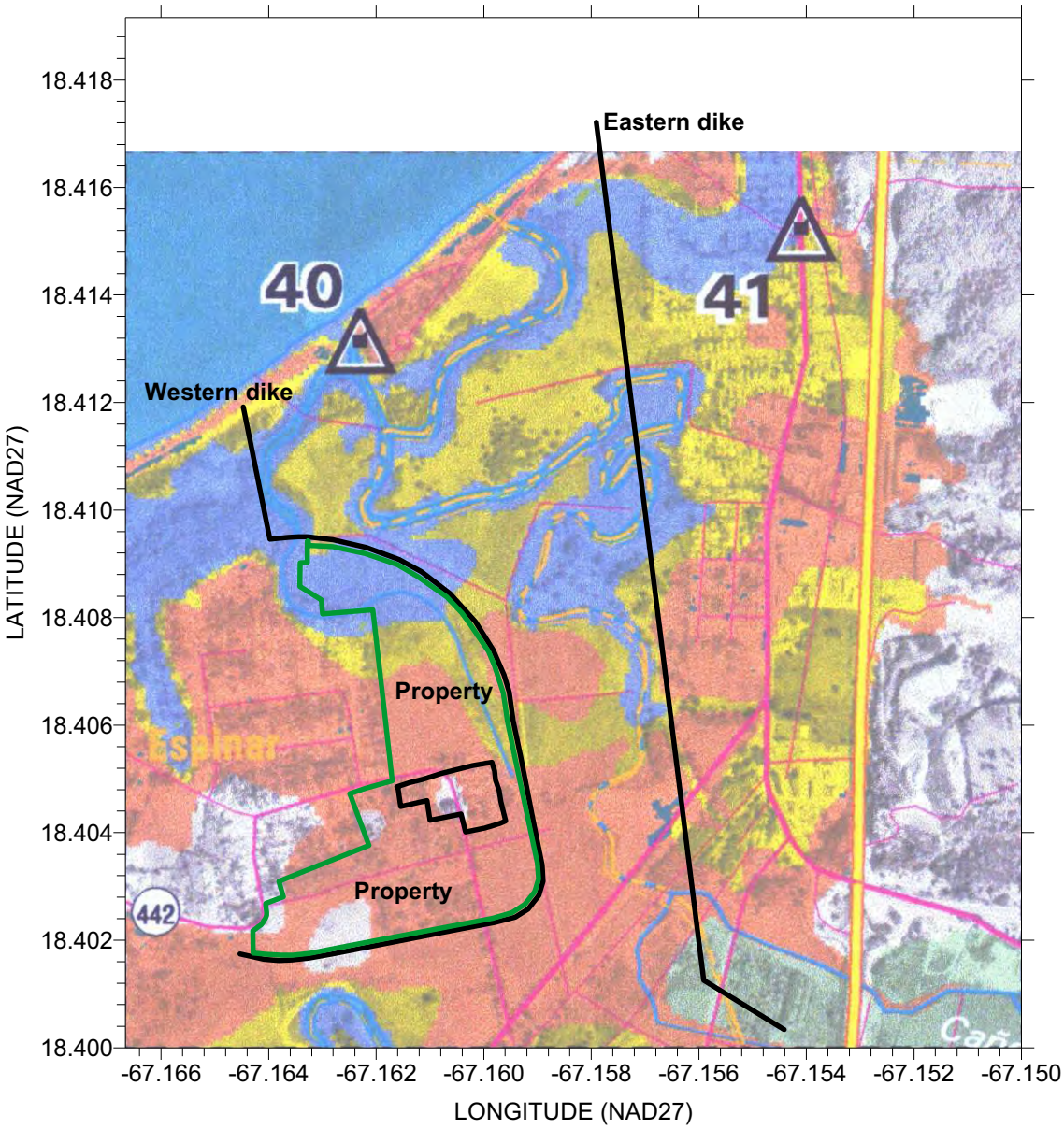

Figure 5 - Scanned image of the storm surge atlas map covering the area of the study. This shows the areas floodable by the storm surge due to Category 1, 3, and 5 hurricanes. See Figure 6 for the elevation color bar scale.

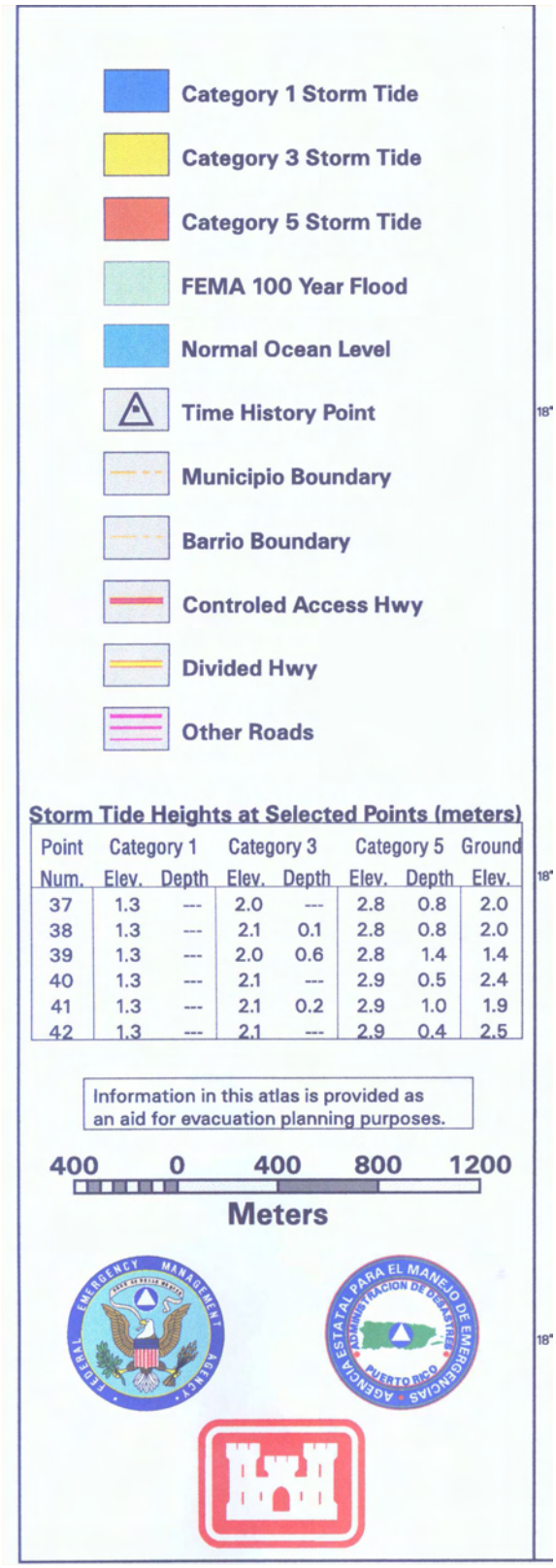

Figure 6 - Color bar code assigned to elevations shown in Figure 5. Also shown is a table indicating expected SWL due to category 1, 3, and 5 hurricanes.

Conclusion

This study shows that the proposed complex is potentially floodable by the 100-year storm surge SWL, but only a small fraction along its northern end. But this conclusion is based on the assumption that the present topography is the same as the one measured back in 1922 and 1937. This flooding can still occur even if the USACoE dikes are constructed since the ocean water can move inland just south of the western dike. Again, assuming that the topography along that pathway has not varied since the Aguadilla USGS quadrangle was made. One way to obviate this potential problem is by raising the property's topographical elevation above 1.43 m relative to MSL. We also proved that ocean wave action should be of no concern to the property developers and owners since the VE zone stays seaward of the part of the property closest to the shoreline.

We have also seen that the 100-year river discharge completely dominates over the 100-year storm surge flood, and that this scenario should be the big concern. On the other hand, although hurricane evacuation coastal flood maps are not regulatory, we have also seen that part of the property is floodable by the expected storm surge from a Category 3 hurricane. We also concluded that all of the property is floodable by the expected storm surge from a Category 5 hurricane, and that this flooding can occur even if the dikes are constructed. Again, this conclusion is valid if the present topography is the same as the one shown in the USGS Aguadilla quadrangle map because the Hurricane Storm Tide Atlas map is also based on the same topographic information. This concern can also be taken care off by raising the property topographical elevation above the expected storm surge elevation from these hurricanes (2.1 and 2.9 m for Category 3 and 5, respectively).

Construction of the dikes, if constructed to a sufficient height, should take the property out of the riverine flooding. Raising the topographical elevation of the property by the stipulated elevations should take the property out of the coastal flooding concern.

References

FEMA, 2000. Coastal Construction Manual. 3rd Edition, Chapter 11, page 11.7.

Mercado, A., 1990. Flood Insurance Study for the Commonwealth of Puerto Rico and the U.S. Virgin Islands. Vols. 1 to 5. Submitted to the Federal Emergency Management Agency, Washington, D.C.

Mercado, A., 1994. On the use of NOOA's storm surge model, SLOSH, in managing coastal hazards - the experience in Puerto Rico. ***Journal of Natural Hazards***, Vol. 10:235-246.