INTERIM REPORT

EVALUATION OF RECOMMENDED METHODOLOGY FOR CALCULATING WAVE ACTION FOR INSURANCE PURPOSES

by

Robert G. Dean

and

Jagat N. Sharma

Prepared For

Department of Housing and Urban Development
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Department of Civil Engineering
University of Delaware
Newark, Delaware 19711

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INTERIM REPORT

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I. INTRODUCTION

This report presents the results of the first task of a project to evaluate methodology for calculating wave action for coastal flooding insurance purposes. In particular, this report presents comparisons of the calculation procedures as recommended by the NAS Panel[(4)] with the relevant data available from storms.

The remaining three work tasks include the following:

- Task B - Development of a Basis for Quantifying Relevant Features of Natural Vegetation.
- Task C - Wave Tank Studies of Features Causing Wave Height Reduction.
- Task D - Determination of the Portion of the Wave Height Included in the Surge Model.

II. ADVANCED SUMMARY

Scope of Report

The available storm tides and damages resulting from a total of seven hurricanes and one extra-tropical storm have been compared with the results of the calculation procedure recommended by the NAS Panel. Specifically, it has been possible to evaluate to some degree: (1) the wave height near the coast as limited by water depth, (2) the crest elevation of waves, and (3) the wave height reduction due to sheltering by a row of buildings.

Results of Evaluation

The evaluation indicates that the computation method recommended by the NAS Panel is certainly warranted as an interim procedure. In particular, for the available data, the calculation procedures would underestimate the damage primarily because of effects not accounted for in the Panel procedure. Specifically, effects which require further consideration for possible incorporation into a permanent methodology include: erosion of mobile sediment features such as dunes; wave runup, particularly due to long period waves; wave set-up; storm duration; and wave reflection at vertical seawalls.

Recommendations

It is recommended that:

(1) The Panel procedure be adopted on an interim basis for calculating wave effects, and

(2) Plans be initiated for a program to collect relevant data for further evaluation and refinement of the procedure.

III. BACKGROUND

Waves accompanying hurricane surges are known to have caused severe damage to structures and beaches. The degree of damage depends primarily on the heights of the waves reaching the structure and the duration of exposure to those waves. In earlier Flood Insurance Studies (FIS), the effects of waves and currents were incorporated as "high velocity zones". In a report entitled "Guidelines for Identifying Coastal High Hazard Zones" published in 1975, the U. S. Army Corps of Engineers, Galveston District attempted to rationalize the wave effects in terms of the maximum wave height which can occur in a locality. Based on a calculation for an average building, it was suggested that locations where wave heights greater than 3 ft. can occur should be designated as "High Hazard Zones". The computation of wave height was based on methods presented in the Shore Protection Manual (1973). Refinements suggested by Tetra Tech in their report dated August, 1976 submitted to the U. S. Department of Housing and Urban Development include the following:

(1) use of 100 year storm surge instead of 100 year storm to compute the local water depth and wind velocities.

(2) use different friction factors for various features of the flooded land such as dunes, grasslands, trees or buildings.

In 1977 a Panel was convened by the National Academy of Sciences to examine the two methods and recommended a procedure for calculating wave action effects associated with storm surges. The present interim report contains a preliminary evaluation of the procedure recommended by the National Academy of Sciences in the report "Methodology for Calculating Wave Action Effects Associated With Storm Surges". The evaluation is based on a comparison of the calculations with high water marks and structural damage reported for several hurricanes and one extra-tropical storm.

IV. NAS PANEL RECOMMENDATIONS

The basic premise of the recommended procedure is that both the n-year still water tide elevation and the waves are generated by a common storm wind condition. Also, it is desirable to derive wave heights that reflect the same n-year recurrence as the storm tide. This is done by relating the wave conditions primarily to the n-year storm tide elevation rather than to any one particular storm tide elevation. This is considered valid for the Atlantic Coast, the Gulf Coast, and the Great Lakes; it is not recommended for the West Coast or for the coasts of Hawaii or Alaska where flood levels and waves are often generated by independent causes.

The essential elements of the NAS Panel's recommendations are summarized below:

(1) The n-year still water storm tide elevation is computed by the use of SPLASH or a comparable numerical model and the method of joint probabilities.

(2) The local wave height H is computed as the smaller of the following:

  (a) breaking wave height computed as 0.78 times the local water depth, h. $H = 0.78\ h$.

  (b) wave height generated on the shore, $H = 0.78\ FS$ in which F is a fetch factor and S is the still water storm tide elevation.

  (c) The wave height, H_t, after transmission past obstructions, is $H_t = BH_i$ in which H_i is the incident wave height and B is a transmission coefficient.

  (d) The wave height is augmented to take into account the effect of high wind on the flooded coastal plain and bays.

(3) The n-year wave crest elevation including wave action effects is $S + .7\ H$.

The main objectives of this study are to evaluate the validity of the foregoing formulas where possible using field data and, if necessary, to identify areas that are not accounted for by the methodology. In the next section available data are described and compared to the computations based on the foregoing formulas.

V. COMPARISON WITH FIELD DATA

The type, quality and quantity of data desirable for evaluation purposes have proven difficult to locate. The major reasons for this are described below:

(1) After a calamity such as a hurricane, the major concern of the authorities is to protect lives and restore vital services. Data gathering may be relegated to a secondary level of concern.

(2) As the storm condition is most severe at the coast, data collected at coastal points have been considered adequate in the past for engineering purposes. These data do not yield adequate information relating to inland wave action.

(3) For astronomical tidal information, widely spaced gauges provide a reasonably adequate data base. For a storm tide and wave data base of similar adequacy for hurricane conditions, many more gauges spaced much more closely together are needed. As the location of hurricane landfall is unpredictable, either a closely spaced network of gauges must be operated at high cost or a set of mobile gauges developed and deployed on short notice near the most probable landfall area of a hurricane.

(4) In the past there was not any compelling demand for data on waves transmitted past obstructions. Therefore, it must be emphasized that the data utilized herein were not collected to satisfy the data needs of the present study.

Gulf Coast, Hurricane Eloise, September, 1975

Following Hurricane Eloise, high water marks were measured inside and outside buildings and are thus assumed to represent still water and still water plus crest elevations, respectively. This set of data has been used to provide a reasonable evaluation of the formula for wave height at the coast. Similar data for inland points are not available. From the reports on damages to buildings an attempt has been made to assess the validity of the suggested formula for the transmission coefficient through the rows of buildings. Data could not be located which would allow a similar assessment for other types of obstructions.

For eleven locations in the general area at which Hurricane Eloise made landfall, both wave height and the still water heights have been reported. For reference purposes, the description of the locations associated with the data used in this study as compiled by the Mobile District of the U. S. Army Corps of Engineers have been reproduced in Appendix A. Table 1 summarizes measured and computed elevations of the Hurricane Eloise data used in this study. The first column refers to station number given to each data point in the description reproduced in Appendix A. The second column presents the high water mark elevations observed inside buildings. In the third column, the outside high water mark elevations (presumed to include wave effects) are reported. The elevations including the effects of wave height have been computed for assumed local ground elevations of 5 and 10 ft. and are presented in Columns 4 and 5. As an example, for an assumed ground elevation of 5 ft., the local water depth was determined as the surge level minus the ground elevation. The maximum wave height which can occur is approximately .78 times the local water depth. Finally the additional crest height due to

TABLE 1

Observed Still Water Mark Elevations and Wave Crest Mark Elevations and Computed Wave Crest Height Elevations for Assumed Ground Elevations of 5 and 10 Feet. Hurricane Eloise

Station*	Observed Values		Computed Wave Crest Elevation (ft.) for Ground Level of	
	Still Water Mark Elevation (ft.)	Wave Crest Mark Elevation (ft.)	5 ft.	10 ft.
38	12.98	18.46	17.34	14.61
39	16.21	18.90	22.33	19.60
41	13.94	14.94	18.82	16.09
44	12.06	19.42	15.91	13.18
50	14.96	18.25	20.40	17.67
51	14.86	16.06	20.24	17.51
56	15.79	20.22	21.68	18.95
60	10.22	16.08	13.07	10.34
64	11.06	16.26	14.37	11.64
73	9.26	13.71	11.58	(9.26)**
74	9.11	14.2	11.35	(9.11)*

*As Designated by the Mobile District, U.S. Army Corps of Engineers, See Appendix A.

**Ground Level Taken as Still Water Mark Elevation, Since Could Not be Greater Than This Value.

a wave is approximately .7 times the wave height. The fourth column presents the computed crest elevation for a ground elevation of 5 ft. Similar calculations have been carried out for an assumed ground elevation of 10 ft. and the results presented in the last column.

The calculations in Table 1 are presented graphically in Figure 1. For each of the observed wave crest height levels, computed wave crest levels for assumed ground elevations of 5 and 10 ft. have been plotted. The crosses correspond to the 10 ft. ground elevation and circles correspond to the 5 ft. ground elevation. As expected there is considerable scatter around the line of equivalence. A portion of this scatter is due to the uncertainty in the ground elevation during the storms and to the error in obtaining the crest elevations in the field. To evaluate the effect of reducing the scatter in still water level, the numerous high water marks available have been plotted against distance along the coastline in Figure 2. A smooth (solid) line has been drawn through the scattered data. Based on the smoothed high water marks, wave crest elevations have been recomputed for assumed ground elevations of 5 and 10 ft. and plotted on Figure 2 as short and long dashes respectively. The observed wave crest elevations have been plotted as small squares on the figure. Most of the plotted points appear to correspond to local ground elevations between 5 and 10 ft.

For locations corresponding to each wave crest elevation observed in the field, smoothed still water elevations have been read from Figure 2 and tabulated in Table 2. The wave crest elevations have also been computed for assumed ground elevations of 5 and 10 ft. The results are presented in Figure 3 which is

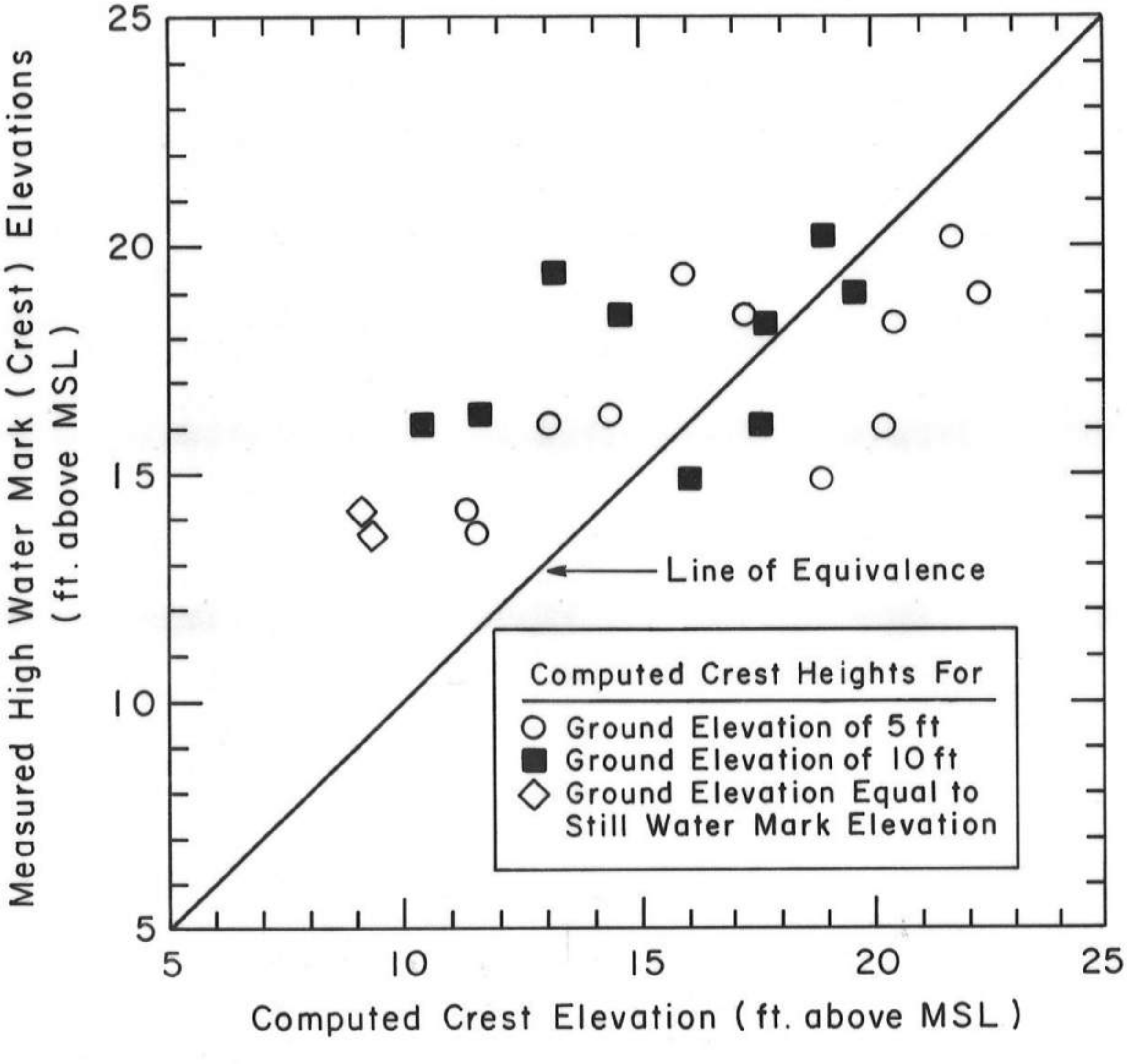

Figure 1. Comparison of Observed High Water Mark Elevations With Those Computed From Local Storm Surge Elevations.

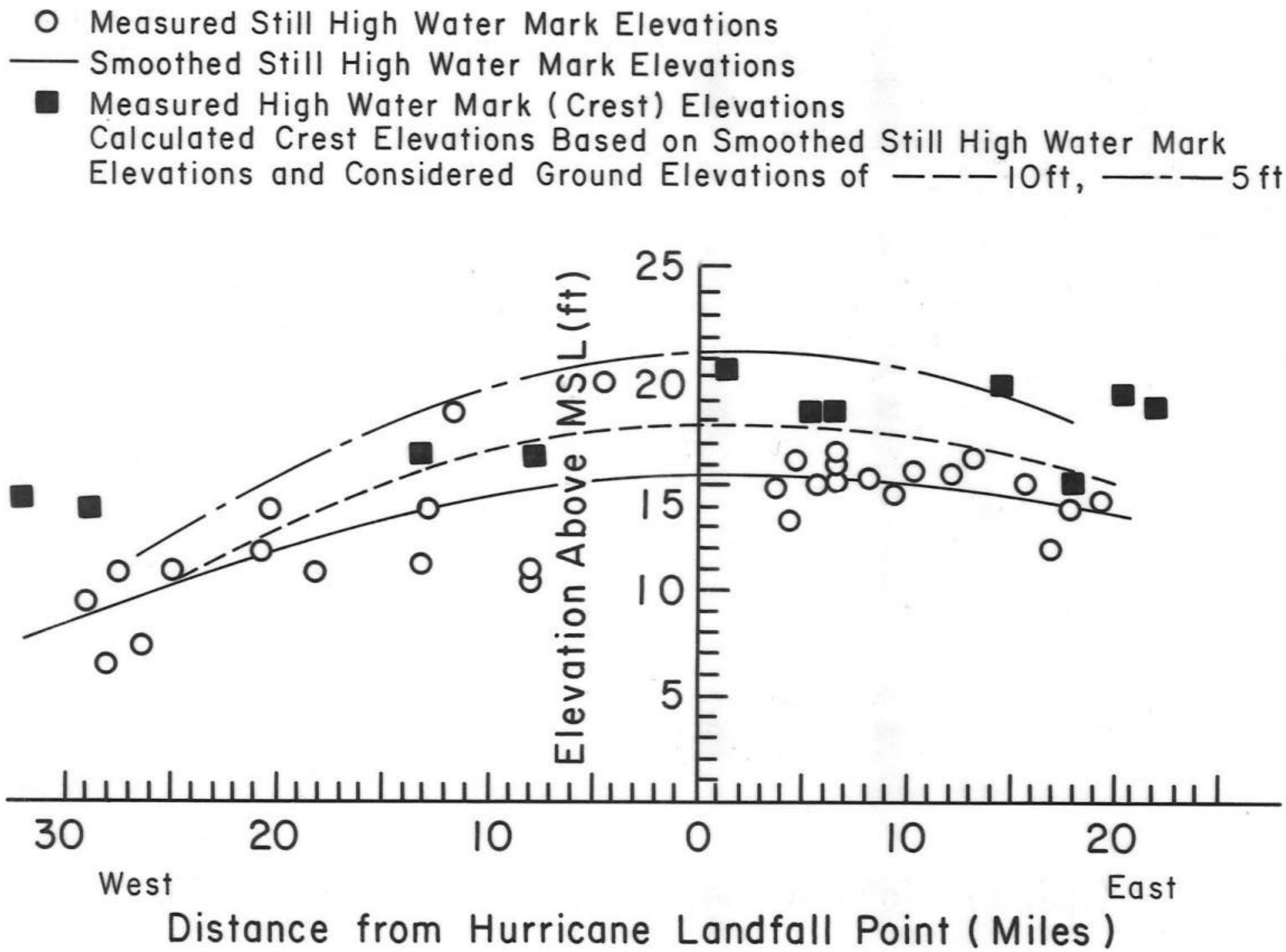

Figure 2. Comparison of Measured High Water Mark (Crest) Elevations With Those Obtained from Smoothed Still High Water Mark Elevations and For Considered Ground Elevations of 5 and 10 ft.

TABLE 2

COMPARISON OF CALCULATED AND OBSERVED CREST ELEVATIONS BASED ON SMOOTHED STILL WATER MARK ELEVATIONS AND GROUND LEVELS OF 5 AND 10 FT.

Station*	Smoothed Still Water Mark Elevations (ft.)	Observed Crest Elevations (ft.)	Calculated Crest Elevations Based on A Ground Elevation of	
			5 ft.	10 ft.
38	13.0	18.46	17.37	14.64
39	13.5	18.90	18.14	15.41
41	13.4	14.94	17.99	15.26
44	14.9	19.42	20.30	17.58
50	15.2	18.25	20.77	18.04
51	15.0	16.06	20.46	17.73
56	14.8	20.22	20.15	17.42
60	13.6	16.08	18.30	15.56
64	12.7	16.26	16.90	14.17
73	8.8	13.71	10.87	(8.8)**
74	7.5	14.2	8.86	(7.5)**

*As Designated by the Mobile District of the U. S. Army Corps of Engineers.
**Ground Level Taken as Still Water Mark Elevation, Since Could Not be Greater Than This Value.

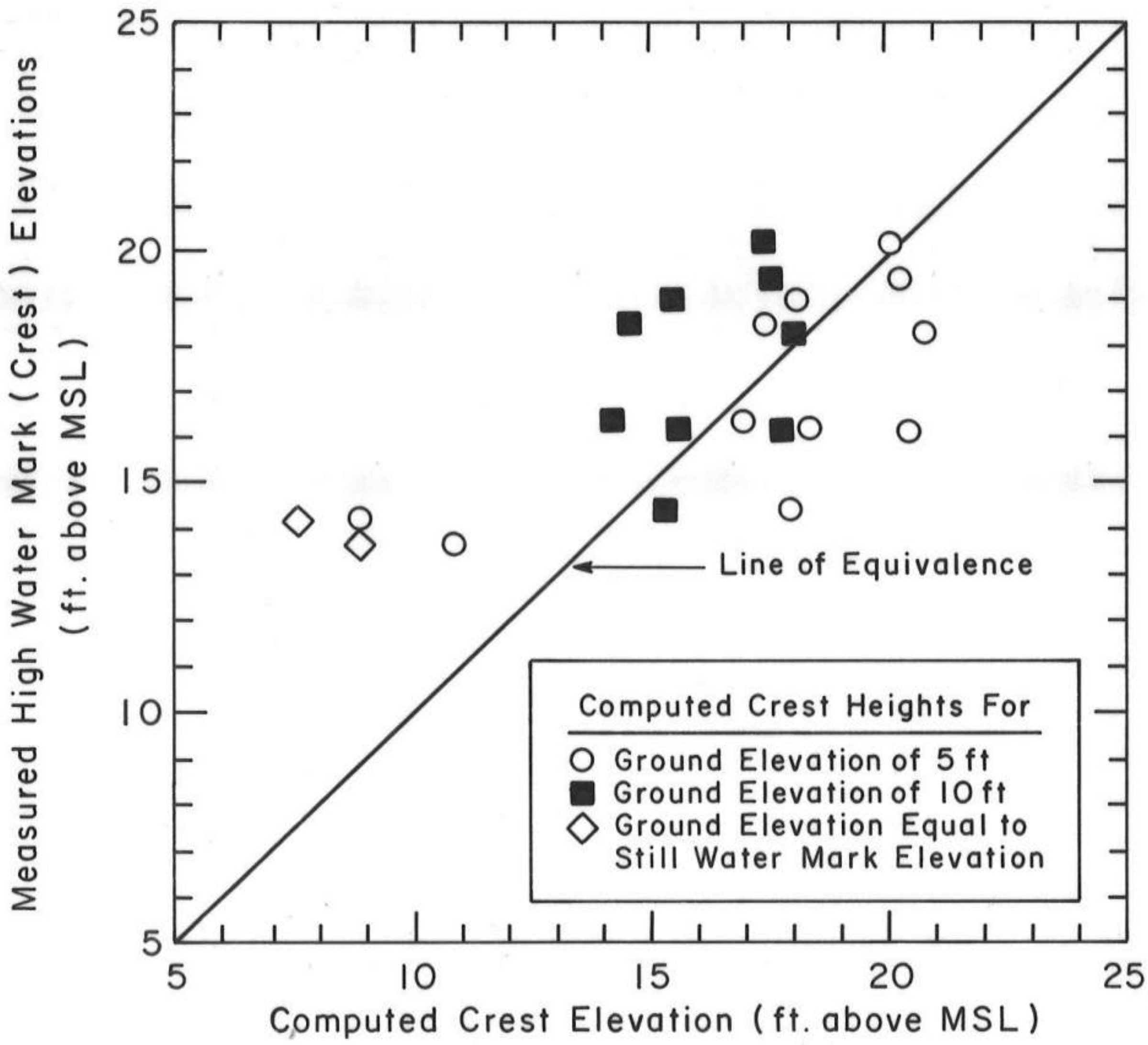

Figure 3. Comparison of Observed High Water Mark (Crest) Elevations With Those Computed From Smoothed Still High Water Mark Elevations.

very similar to Figure 1 except there is much less scatter in the plotted points. Compared to Figure 1 the plotted points are much closer to the line of equivalence. From these results it is tentatively concluded that the NAS method of wave crest elevation computation at the coast is reasonably good.

Similar observations have been reported for Hurricane Carla. The U. S. Army Corps of Engineers, Galveston District, has reported that "none of the waves exceeded about .8 of the water depth in which they occurred".

Virginia Beach Resort Area

In August 1933 this resort area experienced a storm surge of 8.5 ft. above mean sea level (MSL) caused by a hurricane crossing the coastline just south of Cape Hatteras. Cross-sections of the sourthern and northern portions of this resort area, based on information presented in Reference 3, are presented in Figure 4.

Structural damage in the southern (seawalled) portion of the resort area was much more severe than in the northern area where dunes were present. In particular, the first two rows of buildings behind the bulkhead were severely damaged. The extent of any storm-related scour at the base of the seawall is not known; however, two possible occurrences are discussed.

No Scour. If no scour occurred, then the largest wave height that could exist at the seawall would be 0.78 x 4.5 = 3.5 ft. The crest elevation would not reach the top of the wall using the criteria

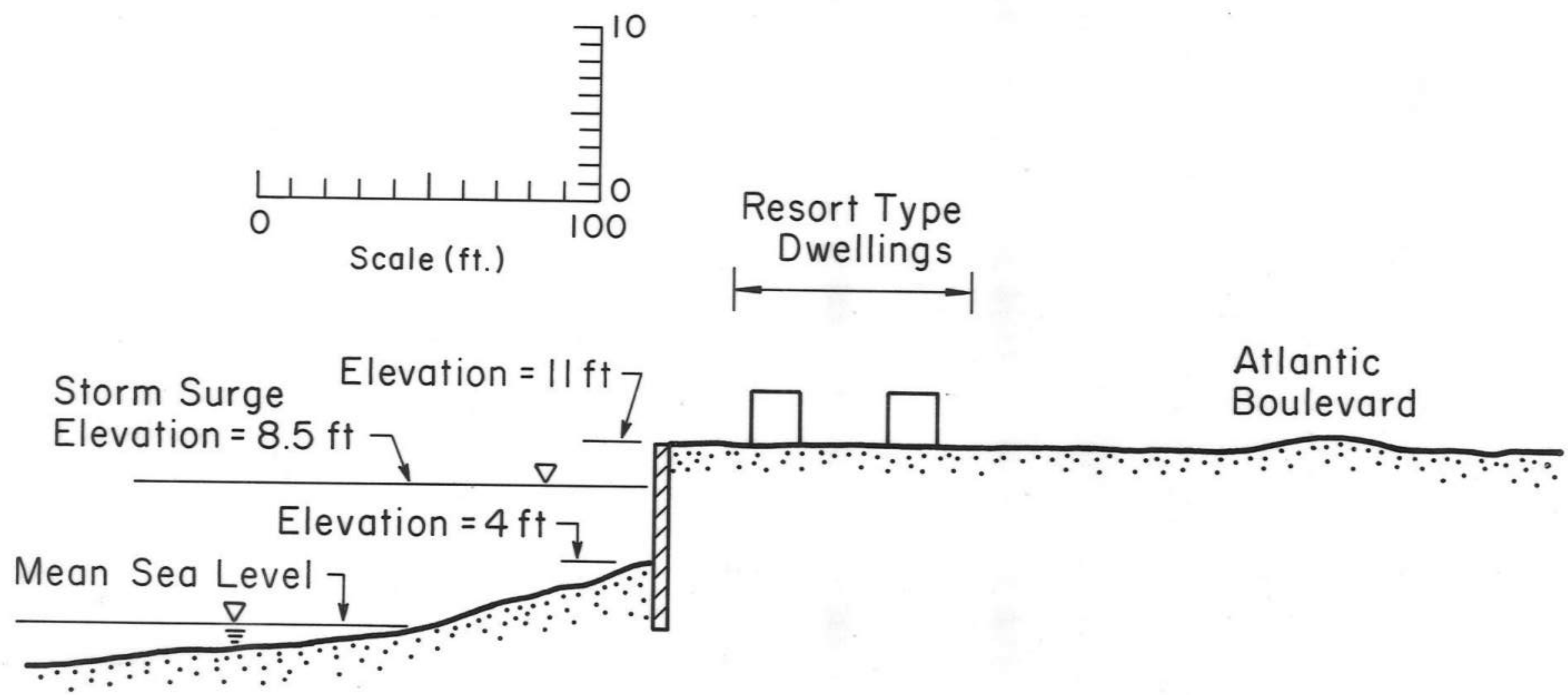

Figure 4. Schematic Cross-Section of Southern Part of Virginia Beach, Hurricane of 1933.

recommended by the NAS Panel and it is difficult to rationalize the damage reported. It is recognized that with considerations of the reflected wave and wave set-up, a wave of somewhat larger height could occur.

Scour. A reasonable assumption is that scour occurred at the base of the seawall to a depth of at least four feet. This would yield a wave height at the seawall of 0.78 x (8.5 - 0) = 6.63 ft., the crest of which would overtop the wall by only 1.64 ft. It is difficult to reconcile the observed damage results with these two scenarios.

The conclusions from examining the Virginia Beach results are that although the following two effects are not included in the Panel recommendations, they may be of substantial importance:

(1) scour at the base of a seawall may allow larger waves to occur, and

(2) reflection at a continuous seawall may result in doubling (at least to a first approximation) of the wave height.

(3) wave set-up may be important and should be evaluated for inclusion in the storm surge methodology.

Saltaire, Long Island, New York

The Hurricane of September, 1938 produced a maximum storm surge of 10 ft. at the small community of Saltaire which is located on Long Island, New York. Approximate profiles across the island, based on information in Reference 3, are presented in Figure 5. Prior to the hurricane, the dunes facing the ocean were several hundred feet wide

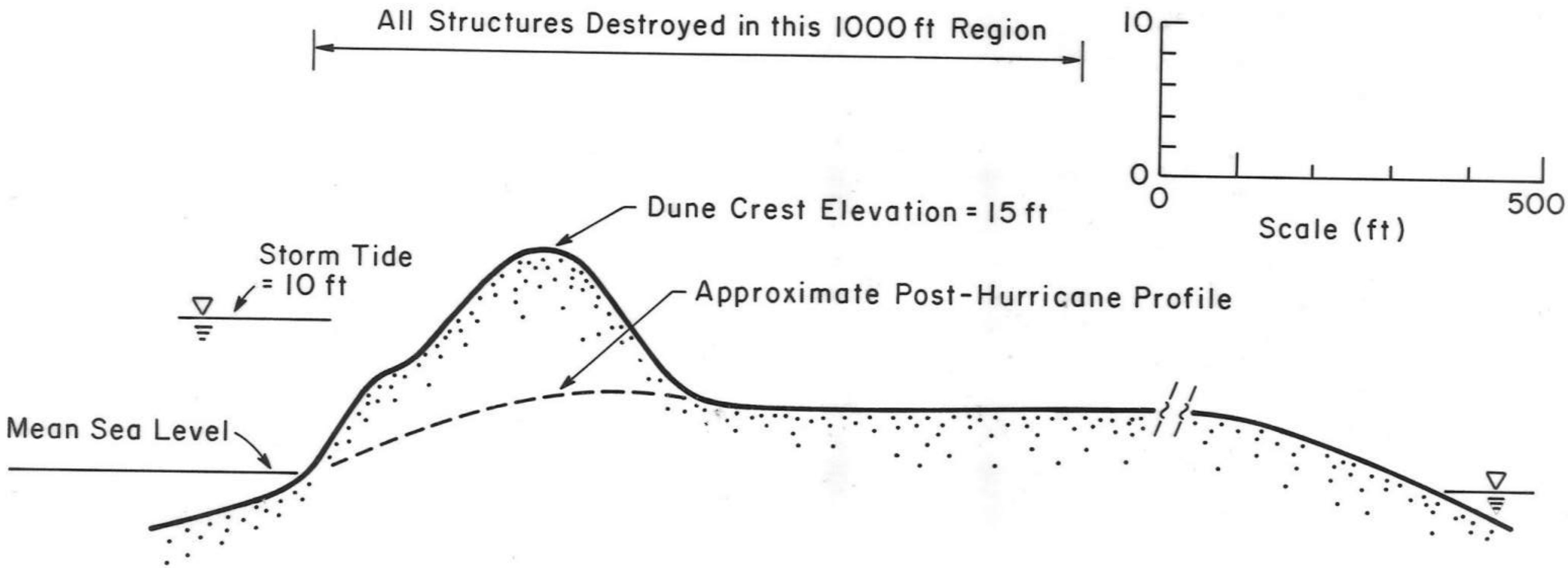

Figure 5. Schematic Cross-Section and Area of Damaged Structures Due to September 1938 Hurricane, Saltaire, Long Island.

at their base with crest elevations and widths of approximately 15 ft. and 25 to 50 ft., respectively. On the bayward side of these dunes, where the community of Saltaire was located, the ground elevation was approximately 5 ft. Most of the structures were built on block foundations with first floor elevations 1 to 2 ft. above ground level.

The hurricane caused extensive erosion of the sand dunes with the maximum elevations of the eroded profile only slightly above mean high water. All improvements were removed for a distance of 500 ft. inland from the Atlantic shore and only heavy debris remained for the next 500 ft. Further inland, a large mound of debris from destroyed structures formed and acted to protect structures farther inland from the effects of the storm waves. The maximum storm surge observed in the bay was only about 5 ft. above MSL.

The resulting damage at Saltaire again underscores the need to account for the mobile nature of the sand.

Gulf Coast, Hurricane Camille, 1969

Hurricane Camille made landfall near Pass Christian in August 1969 and was one of the most destructive hurricanes to affect the United States in recorded history. Maximum winds have been estimated at 140 mph and peak storm surges of 22 ft. were measured.

An artificial beach and seawall protect the coastal highway. Landward of the highway, the ground slopes upward to an elevation of about 20 ft. in a distance of 600 to 700 ft. Figure 6 presents the approximate terrain and the zone of damage. Severe damage was

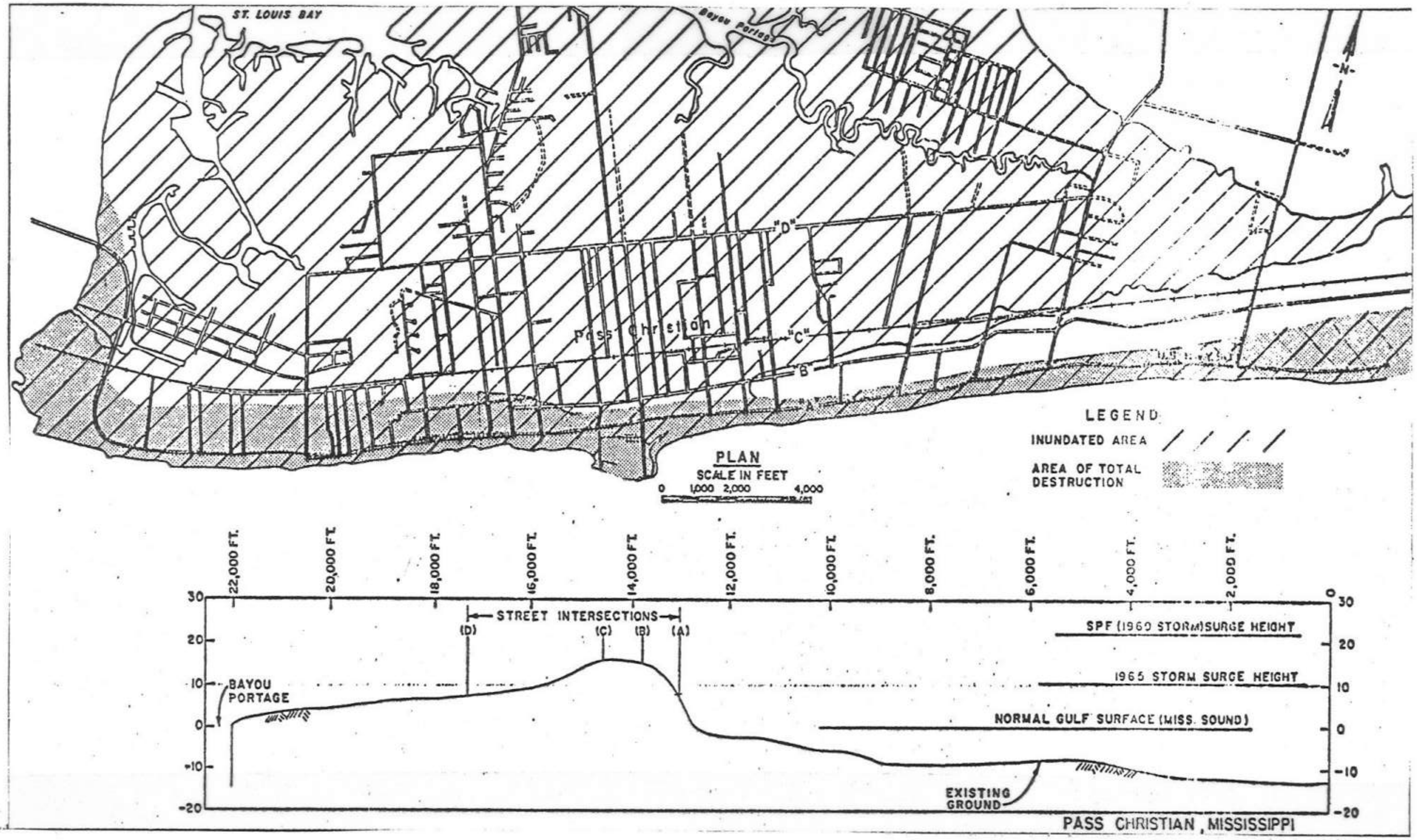

Figure 6. Map of Flooded and Damaged Area in Pass Christian During Hurricane Camille With a Typical Cross-Section. (From Reference 3).

reported to an elevation of 20 ft. Considering a storm tide of 22 ft., the wave height at the 20 ft. contour could be 1.6 ft. which is in reasonable agreement with the 3 ft. recommended for the High Hazard Zones. For the 18 ft. contour, the calculated wave height is 3.1 ft. The limited available information from Hurricane Camille is reasonably supportive of the recommendations of the Panel.

A direct evaluation of the transmission coefficients has not been possible in the absence of the detailed field data required for this purpose. An indirect assessment of the wave transmission coefficient past the buildings has been carried out and the results presented below.

The National Academy of Science Panel recommended that for waves travelling past rows of buildings, the transmission coefficient, B, is of the form

$$B = (r)^{n/2}$$

in which r is the percentage of "gaps" between houses and n is the number of rows of houses.

For several representative values of r and n, the transmission coefficients have been computed and are presented in Table 3. It can be seen that even for a large percentage of open space between houses, the transmission coefficient becomes very small as the number of rows increases. During Hurricane Camille, the highest storm surge of 22 ft. was recorded in the Pass Christian area. This surge depth could support a maximum wave height of 17 ft. at MSL. For an assumed relative spacing, r, of the houses of 0.5,a wave height of 17 ft. would be

TABLE 3

Wave Transmission Coefficients for N Rows of Buildings With Percentage Separation Distance r.

Number of Rows of Buildings, N	Decimal Percent Separation Distance Between Buildings, r			
	.3	.4	.5	.6
1	.55	.63	.707	.77
2	.30	.4	.5	.6
3	.16	.25	.35	.46
4	.09	.16	.25	.36
5	.05	.10	.17	.28
6	.027	.06	.12	.22
7	.015	.04	.09	.17
8	.008	.02	.06	.13

reduced to 3 ft. after passing four to five rows of houses. The published damage reports indicate that two to three blocks suffered structural damage, thereby indicating some degree of indirect confirmation.

Galveston, Texas, Hurricane of September, 1900

The hurricane of September, 1900 caused storm surges of 13 ft. in the Galveston area. The terrain of Galveston Island, based on Reference 3 is presented in Figure 7. It is of interest that the highest ground elevation on the island was approximately 8 ft., which would be 5 ft. under water at the time of the peak surge.

The damage caused by this hurricane was extensive. All improvements in a zone some 2,000 ft. wide were reported to be swept away by the storm. Further landward, a large mound of debris had formed which provided protection against the waves for structures located farther landward.

In summary, there are similarities between the types of damage caused by the 1900 hurricane on Galveston Island and that caused by the 1938 hurricane at Saltaire. In both cases, there was destruction of the seaward buildings and in both cases, the debris resulting from structures collected in a mound, served to limit further damage of other structures located landward.

Burnett, Crystal and Scott Bays, West Baytown, Texas, Hurricane Carla, 1961

The three small bays of Burnett, Crystal and Scott Bays are in the northwest portion of Galveston Bay. The storm surges due to Hurricane Carla in this area were 14.7 ft. The area adjacent

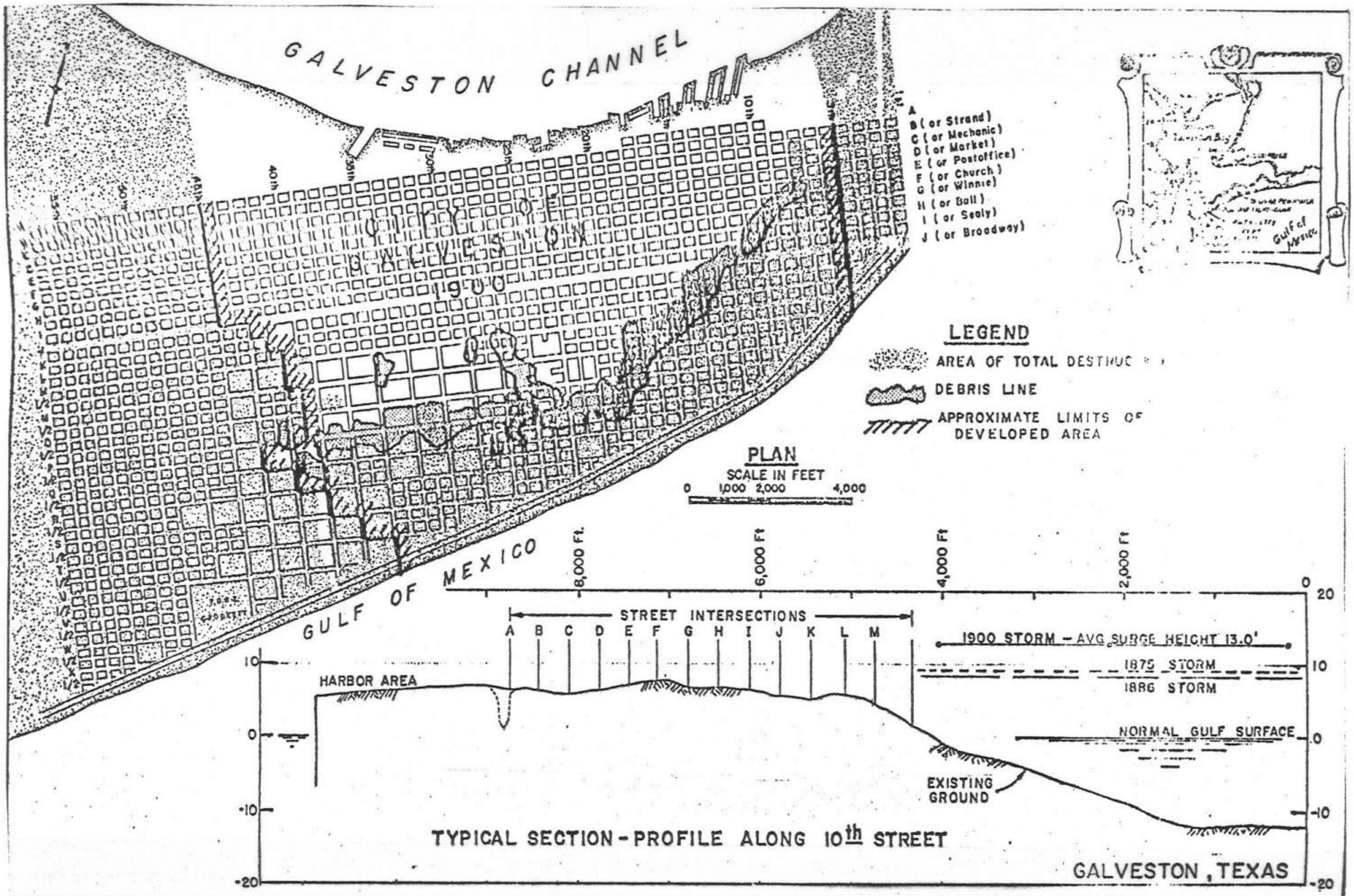

Figure 7. Map of Damaged Area in Galveston Due to Hurricane of 1900 With a Typical Cross Section. (From Reference 3).

to the bay had been developed into a residential area. The zone of severe damage extended over a horizontal distance of 600 to 900 ft. and to elevations of 8 ft. The longest fetch to the damaged area is on the order of 8,000 to 9,000 ft.

If it is assumed that the waves were depth limited and that damage occurred to depths that would support a wave height of 3 ft., then the contour, Z_c, to which damage extends is given by

$$0.78(S - Z_c) = 3 \text{ ft.}$$

where S is the storm surge. Substituting the recorded value of 14.7 for storm surge and solving for Z_c

$$Z_c = S - \frac{3}{0.78} = 10.8 \text{ ft.}$$

compared to the observed elevation of 8 ft. Although it is probable that the fetch of 8,000-9,000 ft. was not sufficient to generate breaking waves at the shoreline, it certainly should have been long enough to generate wave heights greater than 3 ft. The value of the discrepancy noted may be due to additional wave damping which occurred bayward of the 8 ft. land contour. An additional possible explanation may be that the storm tides and waves were not of sufficient duration to cause the full damage potential at the site.

Myrtle Beach, South Carolina, Hurricane Hazel, October 1954

Based on a high water mark, the peak storm surge was approximately 15.5 ft. above MSL and wind gusts in excess of 100 mph were recorded. The damage caused by this storm was very substantial. The elevation of Ocean Boulevard was approximately 18 ft. and is located some 500 ft. from the shoreline. Almost every building to the east (ocean side) of Ocean Boulevard sustained heavy damage. The ground level 100 ft. seaward of the centerline of Ocean Boulevard is approximately 16 ft. and according to the methodology being evaluated, a zero wave height would be indicated at this elevation; however, it is recognized that the combination of wave set-up and run-up could occur to well above this elevation. Examination of the damage subsequent to the storm suggested that the damage which occurred to the second row of buildings was due to floating debris that had broken loose when the first row of buildings had been damaged.

Outer Delaware Coast, Ash Wednesday Storm of March 1962

This winter storm was unique due to the fact that it occurred during a period of extremely high astronomical tides and also that it lasted at near peak strength over five successive high tidal cycles. The maximum recorded tidal elevation varied from 6.9 ft. to 7.3 ft. above MSL and waves of 20 to 30 ft. were reported offshore. At Fenwick Island, Delaware the houses were located at a 10 ft. contour and suffered severe structural damage. According to the NAS method, no damage to structures at the 10 ft. contours should have occurred. The damage at Fenwick Island is believed to be due to a combination of wave set-up, wave run-up and erosion of the foundations.

VI. SUMMARY AND RECOMMENDATIONS

Summary

The high water marks occurring during Hurricane Eloise and the damage resulting from seven hurricanes and one winter storm have been reviewed with a view of evaluating the calculation procedures recommended by the NAS Panel.

The results of this interim evaluation are summarized as follows:

(1) The available data are not of the quality, type or quantity considered necessary for a complete evaluation of the proposed NAS method.

(2) Based on limited high water mark elevations from inside and outside buildings (primarily from Hurricane Eloise), it appears that the method of computing wave crest elevation is approximately correct. An exception is that damage may occur above the storm surge elevation where wave set-up and wave run-up may be important, the latter presumably due to the longer waves.

(3) Indirect evidence indicates that the method of calculating the wave damping due to structures is reasonably appropriate.

(4) The recommendations do not take account of the alterations that occur to mobile bottom material during storms. In the case of a beach fronting a seawall, this can result in a greater depth at the seawall and a greater sustainable wave height. In the case of a dune, undermining of foundations can occur or dune systems can be reduced in elevation, allowing storm tides and waves to attack structures normally protected by the dunes.

(5) The effects of reflection of waves at a seawall may, to a first approximation, result in wave heights that are double those recommended by the NAS Panel.

(6) There are indications that the duration of the storm may be important as a parameter related to resulting damage.

Recommendations

(1) Based on the comparison of the NAS Panel calculation procedure with the available storm data, it is recommended that the NAS procedure be adopted on an interim basis.

(2) Plans should be developed now (December 1978) to collect the type, quality and quantity of data to conduct a more extensive and meaningful evaluation of the methodology recommended by the Panel and to develop any necessary modifications to this procedure.

(3) Efforts need to be initiated to develop an improved capability to predict the effects of increased tides and waves in altering beach and dune profiles. It can be argued that by founding structures on piling, the effect of undermining of foundations is prevented; however, a decrease in sand elevation at a location will result in a larger sustainable wave height. Moreover, in cases where complete dune systems can be effectively removed, the bayward structures can be exposed to significantly increased surges, velocities and wave heights.

(4) The need to incorporate wave set-up and wave run-up in the methodology should be evaluated.

(5) The need to account for wave reflection in front of a seawall and the resulting larger wave height needs to be evaluated.

(6) The need to incorporate simple procedures for quantifying storm duration in the joint probability method should be evaluated. For example, there may be a correlation between intense and short duration storm surge peaks.

VII. REFERENCES

1. U. S. Army Corps of Engineers, Galveston District, "Guidelines for Identifying Coastal High Hazard Zones", 1975.

2. U. S. Army Corps of Engineers, Coastal Engineering Research Center, "Shore Protection Manual", 1978.

3. Tetra-Tech, Incorporated, "Treatment of Wind Waves in Coastal Flood Insurance Studies", August 1976.

4. National Academy of Sciences, "Methodology for Calculating Wave Action Effects Associated With Storm Surges", 1977.

APPENDIX A

LISTING OF HURRICANE ELOISE

DATA USED IN FIGURES 1 AND 3

(Abstracted from more complete listing provided by the Mobile District of the U. S. Army Corps of Engineers)

HURRICANE ELOISE

HIGH WATER ELEVATIONS, NORTHWEST FLORIDA

SEPTEMBER 23, 1975

Station	Elevation Above MSL (ft.)	Location and Description
38	18.46 +/-.76	LAT 30 07' 20'', LONG 85 44' 00'', IN SE 1/4 SEC 22, T4S, R15W, BAY COUNTY, BEACON BEACH QUAD. WAVE HEIGHT F-38E IS WAVE WASH LINE ON SAND DUNES AT GULF BEACH EDGE NEAR ENTRANCE CHANNEL TO ST. ANDREW BAY AT ST. ANDREWS STATE PARK, FLA. REFERENCE POINT IS CE RANGE MON R-87, ELEV. 12.24. BK 398 PG 63
39	18.90	LAT 30 08' 16'', LONG 85 45' 05'', IN SE 1/4 SEC 16, T4S, R15W, BAY COUNTY, PANAMA CITY BEACH QUAD. WAVE HEIGHT F-39. IS A GOOD WAVE LINE ON DUNE AT BILTMORE BEACH, FLA. REFERENCE MARK IS FLA. DEPT. OF NATURAL RESOURCES MONUMENT R-90 BAY, 1972, ELEV. 16.85. BK 398 PG 51
41	14.94	LAT 30 09' 44'', LONG 85 47' 00'', IN SE 1/4 SEC 6, T4S, R15W, BAY COUNTY, PANAMA CITY BEACH QUAD. WAVE HEIGHT F-41A. ELEVATION IS TAKEN FROM THE SAND DUNES ON BEACH SIDE OF CONDOMINIUM ON SURF ROAD AT GULF LAGOON BEACH, FLA. REFERENCE MARK IS TBM NO. 41, A NAIL ONE FOOT ABOVE GROUND IN A POWER POLE 80 FEET NORTH OF WEST END OF BUILDING, ELEV. 14.95 BK 398 PG 52
44	19.42	LAT 30 11' 26'', LONG 85 49' 49'', IN SEC 34, T3S, R16W, BAY COUNTY, PANAMA CITY BEACH QUAD. WAVE HEIGHT F-44A IS A GOOD LINE TAKEN FROM SAND DUNE NEAR EAST SIDE OF AMUSEMENT PARK, NEAR EDGEWATER GULF BEACH, FLA. REFERENCE MARK IS TBM NO. 44, A CHISELED SQUARE ON THE SE CORNER OF THE WEST WING WALL, TWO FEET WEST OF BRIDGE HEAD WALL, ELEV. 19.25 BK 398 PG 53
50	18.25	LAT 30 14' 49'', LONG 85 56' 28'', IN NW 1/4 SEC 10, T3S, R17W, BAY COUNTY, LAGUNA BEACH QUAD. WAVE HEIGHT F-50C IS GOOD MARK ON DUNES NEAR HOUSE AT SUNNYSIDE, FLA. REFERENCE MARK IS BM USC+GS J-182 ELEV. 11.93 BK 398 PG 60

Station	Elevation Above MSL (ft.)	Location and Description
51	16.06	LAT 30 15' 10'', LONG 85 57' 18'', IN SW 1/4 SEC 4, T3S, R17W, BAY COUNTY, SEMINOLE HILLS QUAD. WAVE HEIGHT F-51A IS A GOOD MARK TAKEN 2.5 FEET ABOVE FLOOR OF HOUSE AT HOLLYWOOD BEACH, FLA. REFERENCE MARK IS TBM NO. 51 A NAIL IN A POWER POLE ACROSS STREET FROM BUILDING ELEV. 22.62. BK 397 PG 14
56	20.22	LAT 30 16' 26'', LONG 86 00' 24'', IN SW 1/4 SEC 36, T3S, R18W, WALTON COUNTY, POINT WASHINGTON QUAD. WAVE HEIGHT F-56A IS A WASH LINE ON THE SAND DUNE NORTH OF WALL STREET APPROX. 200 FEET NE OF HW F-56, AND AT INLET BEACH, FLA. REFERENCE MARK IS TBM NO. 56, A U. S. GENERAL LAND SURVEY MARKER IN CENTER OF THE STREET INTERSECTION NEXT TO BEACH, ELEV. 22.03. BK 397 PG 12
60	16.08	LAT 30 19' 42'', LONG 86 09' 26'', IN NE 1/4 SEC 17, T3S, R19W, WALTON COUNTY, GRAYTON BEACH QUAD. WAVE HEIGHT F-60C IS GOOD MARK LOCATED 500 FEET FROM WATERS EDGE AT GRAYTON BEACH, FLA. REFERENCE MARK IS TBM 60, A NAIL IN A POWER POLE IN FRONT OF A YELLOW HOUSE, ELEV. 9.94 BK 398 PG 67
64	16.26	LAT 30 21' 06'', LONG 86 14' 54'', IN SE 1/4 SEC 4, T3S, R20W, WALTON COUNTY, GRAYTON BEACH QUAD. WAVE HEIGHT F-64A IS A GOOD MARK TAKEN ALONG SAND DUNE WEST OF OYSTER LAKE, DUNE ALLEN BEACH, FLA. REFERENCE MARK IS TBM NO. 64, A CHISELED SQUARE ON EAST END OF NORTH HEADWALL OF DRAIN FROM OYSTER LAKE, ELEV. 9.38 BK 398 PG 60
73	13.71	LAT 30 23' 25'', LONG 86 31' 29'', FORT WALTON BEACH QUAD. WAVE HEIGHT F-73A IS A TRASH LINE LOCATED NEAR AIR FORCE N.C.O. BEACH CLUB WHICH IS LOCATED APPROX. 1000 FEET WEST OF U. S. 98 HIGHWAY EAST PASS BRIDGE. REFERENCE MARK IS BM USC+GS LC 1934, ELEV. 20.504, ADJUSTED IN 1957 TO ELEV. 20.479 BK 397 PG 23

Station	Elevation Above MSL (ft.)	Location and Description
74	14.2	LAT 30 23' 34'', LONG 86 34' 43'', FORT WALTON BEACH QUAD. WAVE HEIGHT F-74B IS AVERAGE OF THREE TRASH LINES ON DUNES EAST AND WEST OF END OF 800 FOOT ROAD TO BEACH FROM U. S. 98 HIGHWAY. ROAD IS LOCATED APPROX. 1.4 MILES EAST ALONG U. S. 98 HIGHWAY FROM SANTA ROSA SOUND BRIDGE AT FORT WALTON BEACH, FLA. REFERENCE MARK IS BM USC+GS K-27, RESET IN 1965, ELEV. 3.61. BK 397 PG 23