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1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study investigates the existence and severity of flood hazards in the Town of Sandwich, Barnstable County, Massachusetts, and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study will be used to convert Sandwich to the regular program of flood insurance by the Federal Insurance Administration (FIA). Local and regional planners will use this study in their efforts to promote sound flood plain management.

In some states or communities, flood plain management criteria or regulations may exist that are more restrictive or comprehensive than those on which these Federally-supported studies are based. These criteria take precedence over the minimum Federal criteria for purposes of regulating development in the flood plain, as set forth in the Code of Federal Regulations at 24 CFR, Part 1910.1(d). In such cases, however, it shall be understood that the state (or other jurisdictional agency) shall be able to explain these requirements and criteria.

1.2 Authority and Acknowledgements


The hydrologic and hydraulic analyses for this study were performed by Anderson-Nichols & Company, Inc., for the Federal Insurance Administration under Contract No. H-4605. This study was completed in December 1978. Flood elevations were obtained from the New England Division of the U. S. Army Corps of Engineers.

1.3 Coordination

The areas studied by detailed methods were discussed in an initial Consultation and Coordination Officer's (CCO) meeting on November 1, 1977. Representatives of the study contractor and the FIA gave a presentation to a group of community officials. This presentation included a description of the nature and extent of the Flood Insurance Program.
The New England Division of the U. S. Army Corps of Engineers (COE), the U. S. Geological Survey (USGS), the Commonwealth of Massachusetts Department of Public Works, the National Weather Service and the National Ocean Survey (NOS) were contacted for various types of information. An intermediate CCO meeting was held in January 1979, at which time the maps were reviewed by community officials.

This report and associated maps were reviewed at a final CCO meeting attended by representatives from the FIA, the Town of Sandwich, and the study contractor on June 12, 1979.

2.0 AREA STUDIED

2.1 Scope of Study

This Flood Insurance Study covers the incorporated area of the Town of Sandwich, Barnstable County, Massachusetts. The area of study is shown on the Vicinity Map (Figure 1).

Detailed tidal flood analysis was performed on the entire coastline of the Town of Sandwich, whose flooding source is Cape Cod Bay to the northeast. Approximate analyses were incorporated to study various inland areas having a low development potential or minimal flood hazards.

The areas studied were selected with priority given to all known flood hazard areas, and areas of projected development or proposed construction for the next five years, through December 1983.

2.2 Community Description

The Town of Sandwich is located in Barnstable County in southeastern Massachusetts, at the beginning of Cape Cod, 61 miles southeast of Boston. The town is bordered by Cape Cod Bay on the northeast, Barnstable and Mashpee on the east, Bourne on the west, and Falmouth on the south. Sandwich has a land area of 42.6 square miles and 26.5 miles of tidal shoreline (Reference 1).

The population of Sandwich in 1965 was 2,438. In 1970, the population figure was 5,239; however, this 150-percent increase reflects the inclusion of military personnel at Otis Air Force Base (Reference 1).

Sandwich has a moderate coastal climate with a mean annual temperature of 50 degrees Fahrenheit (°F) and a rainfall precipitation figure of 47 inches per year. The average temperatures vary from 32°F in January to 71°F in July (Reference 1).
The terrain is mostly flat except for a ridge that rises to 100 feet and runs a mile inland along the shores of Cape Cod Bay. The soil of Sandwich is mostly well watered, good textured loam. There are two large tracts of droughty, sandy soil in northern Sandwich. The Cape Cod Canal, operated and maintained by the COE, passes through the northwestern corner of Sandwich and flows in a westerly direction, connecting Cape Cod Bay with Buzzards Bay (Reference 1).

The coast of Sandwich extends for 7.9 miles along Cape Cod Bay. However, when the numerous inlets and small bays extending from Sandwich Harbor and Scorton Harbor are included, the tidal shoreline measures 26.5 miles. Development along the coast is predominantly residential, however, because many of the homes along the coast are built on a 20-foot ridge, the shoreline subject to flooding is sparsely settled.

Sandwich is a prosperous summer resort town with an economy based principally upon retail businesses. Cranberry harvesting, small manufacturing firms and the presence of Otis Air Force Base bolsters the year-round economy.

2.3 Principal Flood Problems

Flooding along the coast of Sandwich generally results from high tides and storm surges associated with "northeasters." These storms can occur at any time of the year, but are more prevalent in winter.

The highest tide recorded at the Cape Cod Canal gage, which has been in operation since 1955, was 10.1 feet caused by the February 6th, and 7th, 1978, storm (Reference 2). Prior to 1978, the flood of record was December 29, 1959, with a flood height of 8.87 feet. Flooding in Sandwich resulting from the February 1978 blizzard is documented in photographs shown in Figures 2 through 5 (Reference 3).

In February 1940, before the Cape Cod Canal gage was in operation, a "northeaster" caused damage throughout the Cape Cod area and primarily in Sandwich. Most of the damage was to summer homes (Reference 4).

Although a rare occurrence, hurricanes have in the past caused flooding within Cape Cod Bay. On September 11, 1954, Hurricane Edna caused waves as high as 15 feet in the Town of Sandwich (Reference 4).
Figure 2 - Flooding on Bye-a-brook at Tupper Road, Sandwich, Massachusetts, 1978

Figure 3 - Flooding on landing at the east end of North Shore Boulevard, Sandwich, Massachusetts, 1978
Figure 4 - Flooding at seawall near Freeman Road and Town Neck Road, Sandwich, Massachusetts, 1978

Figure 5 - Flooding near Factory Street, Sandwich, Massachusetts, 1978
2.4 Flood Protection Measures

The Town of Sandwich presently has no flood control structures planned or proposed. However, the town has adopted an ordinance in its Protective Zoning Bylaws limiting construction to 10.0 feet above mean high-water elevations, and 300 feet away from the mean high-water line if the area is a sand dune (Reference 5).

3.0 ENGINEERING METHODS

For the flooding source studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude which are expected to be equalled or exceeded once on the average during any 10, 50, 100, or 500 year period (recurrence interval), have been selected as having special significance for flood insurance premium rates. These events, commonly termed the 10, 50, 100, and 500 year floods, have a 10, 2, 1, and 0.2 percent chance, respectively, of being equalled or exceeded during any year. Although the recurrence interval represents the long term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than one year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (one percent chance of annual occurrence) in any 50-year period is about 40 percent (four in ten), and for any 90-year period, the risk increases to about 60 percent (six in ten). The analyses reported here reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak elevation-frequency relationships for floods of the selected recurrence intervals for the flooding source studied in detail affecting the community.

Storm surge elevations used in this study were taken from coastal surge profiles previously developed by the New England Division, COE (Reference 6). The COE determination of coastal surge profiles for recurrence intervals of 10-, 50-, 100-, and 500-years required a statistical regression analysis of long term NOS tidal gage records for Boston and Woods Hole gaging stations (Reference 7). Stage-recurrence interval relationships at these locations served as control points on the coastal surge profiles. Stage-recurrence interval relationships at locations between control points were
determined from an analysis of historical high-water marks. Storm elevations on Cape Cod Bay in Sandwich during the floods of March 17, 1956, December 29, 1959, January 20, 1961 and February 6th and 7th, 1978, were 8.9, 8.9, 8.8, and 10.1 feet, respectively (References 8, 4, and 2).

The analysis consisted of comparison of simultaneous observations at high-water mark locations and control points. By this method, the stage-recurrence interval relationships at control points were transposed to high-water mark locations, resulting in continuous coastal surge profiles for the 10-, 50-, 100-, and 500-year flood events. The elevations as developed by the COE for Sandwich are tabulated in Table 1, "Summary of Elevations."

<table>
<thead>
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<th>TABLE 1 - SUMMARY OF ELEVATIONS</th>
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<tbody>
<tr>
<td>FLOODING SOURCE AND LOCATION</td>
</tr>
<tr>
<td>CAPE COD BAY</td>
</tr>
<tr>
<td>Entire shoreline, along</td>
</tr>
<tr>
<td>northeast coast</td>
</tr>
</tbody>
</table>

The study contractor verified these elevations using meteorological models of northeasters, which are typical of the latitudes of Cape Cod (Reference 9). The resulting parameters were used to develop wind velocities, which were employed in ocean surge calculations. These calculations were performed along traverse lines from the edge of the continental shelf to points along the north and east shores of Cape Cod. For this study, the traverse line ended at the east end of the Cape Cod Canal.

The elevations listed in Table 1 were delineated along the entire coastline of the Town of Sandwich. The delineation of the 100- and 500-year floods in the Cape Cod Canal is based upon a straight-line relationship assumed between the elevations at the east and west ends of the canal.

The delineation of areas by approximate methods is based upon the delineation on the Flood Hazard Boundary Map prepared in January 1977 (Reference 10). However, recently developed criteria pertaining to drainage area and flood plain width were incorporated.

3.2 Hydraulic Analyses

Hydraulic analyses of the shoreline characteristics of the flooding source studied in detail were carried out to provide estimates of
the elevations of floods in the selected recurrence intervals along the shoreline of Sandwich.

Special consideration was given to the vulnerability of coastal Sandwich to wave attack during severe northeasters. Sandwich has suffered beach front and property damage.

Areas of coastline subjected to wave attack are referred to as coastal high hazard zones. The COE, Galveston District, has developed methods to determine which sections of a coastline fall into this category (References 11 and 12). The factors considered for such a determination include: choice of a suitable fetch (continuous area of water over which the wind blows), fetch length and width, sustained wind velocities, coastal water depths, and physical features of the coastline which would appreciably affect wave propagation. All these factors are analyzed to determine at which locations a critical breaking wave with a height of 3 feet can be generated. This has been selected by the COE as the minimum size wave capable of causing major damage upon impact to a conventional wood or brick veneer frame structure.

Field reconnaissance and the 1:4,800 scale topographic maps were incorporated into the analysis of the coastal high hazard zones (Reference 13).

All elevations in this study are referenced to the National Geodetic Vertical Datum of 1929 (NGVD), formerly referred to as Sea Level Datum of 1929. Locations of the elevation reference marks used in this study are shown on the Flood Insurance Rate Map.

4.0 FLOOD PLAIN MANAGEMENT APPLICATIONS

The National Flood Insurance Program encourages state and local governments to adopt sound flood plain management programs. Therefore, each Flood Insurance Study includes a flood boundary map designed to assist communities in developing sound flood plain management measures.

4.1 Flood Boundaries

In order to provide a national standard without regional discrimination, the 100-year flood has been adopted by the FIA as the base flood for purposes of flood plain management measures. The 500-year flood is employed to indicate additional areas of flood risk
in the community. The 100- and 500-year flood boundaries along the coastline of Sandwich were delineated using topographic maps of Sandwich with a contour interval of 5 feet and a scale of 1:4,800 (Reference 13).

Flood boundaries shown by the Flood Hazard Boundary Map on Hoxie, Nye, Pimlico, Hog, Little Hog, and Weeks Ponds and several cranberry bogs have been determined to constitute minimal flood hazards and have not been mapped (Reference 10).

Flood boundaries are indicated on the Flood Insurance Rate Map. On this map, special flood hazard areas inundated by the 100-year flood which have additional hazards due to wave action have been designated as Zone V3. The 100-year flood boundary corresponds to the boundary of the areas of special flood hazards (Zone A3); and the 500-year flood boundary corresponds to the boundary of areas of moderate flood hazards (Zone B). In cases where the 100- and 500-year flood boundaries are close together, only the 100-year flood boundary has been shown.

Small areas within the flood boundaries may lie above the flood elevations and, therefore, may not be subject to flooding. Owing to limitations of the map scale and lack of detailed topographic data, such areas are not shown.

5.0 INSURANCE APPLICATIONS

In order to establish actuarial insurance rates, FIA has developed a process to transform the data from the engineering study into flood insurance criteria. This process includes the determination of reaches, Flood Hazard Factors (FHF's), and flood insurance zone designations for the flooding source affecting the Town of Sandwich.

5.1 Reach Determinations

Reaches are defined as lengths of watercourses having relatively the same flood hazard. In tidal areas, reaches are limited to the distance for which the 100-year flood elevation does not vary more than 1.0 foot. Using these criteria, the entire shoreline qualifies as one reach whose flooding source is the Cape Cod Bay. The location of this reach is shown on the Flood Insurance Rate Map.

5.2 Flood Hazard Factors

The FHF is the FIA device used to correlate flood information with insurance rate tables. Correlations between property damage from floods and their FHFs are used to set actuarial insurance premium rate tables based on FHFs from 005 to 200.
The FHF for a reach is the average weighted difference between the 10- and 100-year flood water-surface elevations expressed to the nearest 0.5 foot, and shown as a three-digit code. For example, if the difference between water-surface elevations of the 10- and 100-year floods is 0.7 foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 015; if the difference is 5.0 feet, the FHF is 050. When the difference between the 10- and 100-year water-surface elevations is greater than 10.0 feet, accuracy for the FHF is to the nearest foot.

5.3 Flood Insurance Zones

After the determination of reaches and their respective FHFs, the entire incorporated area of the Town of Sandwich was divided into zones, each having a specific flood potential or hazard. Each zone was assigned one of the following flood insurance zone designations:

Zone A3: Special Flood Hazard Areas inundated by the 100-year flood, determined by detailed methods; base flood elevations shown, and zones subdivided according to FHF.

Zone V3: Special Flood Hazard Areas along coasts inundated by the 100-year flood as determined by detailed methods, and that have additional hazards due to velocity (wave action); base flood elevations shown, and zones subdivided according to FHFs.

Zone B: Areas between the Special Flood Hazard Area and the limits of the 500-year flood, including areas of the 500-year flood plain that are protected from the 100-year flood by dike, levee, or other water control structure; also, areas subject to certain types of 100-year shallow flooding where depths are less than 1.0 foot; and areas subject to 100-year flooding from sources with drainage areas less than 1 square mile. Zone B is not subdivided.

Zone C: Areas of minimal flooding.

Zone D: Areas of undetermined but possible flood hazard.

Table 2, "Flood Insurance Zone Data," summarizes the flood elevation differences, FHFs, flood insurance zones, and base flood elevations for the flooding source studied in detail in the Town of Sandwich.
<table>
<thead>
<tr>
<th>FLOODING SOURCE</th>
<th>PANEL¹</th>
<th>ELEVATION DIFFERENCE² BETWEEN 1.0% (100-YEAR) FLOOD AND</th>
<th>FHF</th>
<th>ZONE</th>
<th>BASE FLOOD ELEVATION³ (NGVD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cape Cod Bay</td>
<td>01,02,03</td>
<td>-1.7</td>
<td>-0.5</td>
<td>+1.6</td>
<td>015</td>
</tr>
</tbody>
</table>

¹Flood Insurance Rate Map Panel
²Weighted average
³Rounded to the nearest foot - see map
5.4 Flood Insurance Rate Map Description

The Flood Insurance Rate Map for the Town of Sandwich is, for insurance purposes, the principal result of the Flood Insurance Study. This map contains the official delineation of flood insurance zones and base flood elevation lines. Base flood elevation lines show the locations of the expected whole-foot water-surface elevations of the base (100-year) flood. This map is developed in accordance with the latest flood insurance map preparation guidelines published by the FIA.

6.0 OTHER STUDIES

Several studies pertaining to tidal flooding in the area adjacent to Sandwich have been completed. Flood elevations developed by the New England Division COE, published in Flood Level Profile No. 10 were used for the elevations on Cape Cod Bay (Reference 6). The COE also prepared a Type 15 Flood Insurance Study for the Town of Bourne in 1972, for the Town of Barnstable in 1977, and for the Town of Mashpee in 1978 (References 14, 15, and 16). The study contractor is currently preparing updated Type 19 Flood Insurance Studies for the Towns of Bourne, Barnstable and Mashpee and careful coordination will insure complete agreement with this report for the Town of Sandwich.

This study is authoritative for purposes of the Flood Insurance Program, and the data presented here either supersede or are compatible with previous determinations.

7.0 LOCATION OF DATA

Survey, hydrologic, hydraulic, and other pertinent data used in this study can be obtained by contacting the office of the Federal Insurance Administration, Regional Director, Region I Office, 15 New Chardon Street, Boston, Massachusetts 02114.

8.0 BIBLIOGRAPHY AND REFERENCES

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