D.2.1 Atlantic and Gulf Coast Guidelines Overview

Section D.2 is organized to:

- Present background information (Section D.2.1);
- Provide guidance on selecting study methodologies (Section D.2.2);
- Provide a set of technical methods as potential tools to be used in various study settings (Sections D.2.3 to D.2.10);
- Provide guidance on flood hazard mapping (Section D.2.11);
- Provide guidance on study documentation (Section D.2.12); and
- Provide reference information (Sections D.2.13 to D.2.16).

Figure D.2.1-1 shows the general layout of the document. Because it is anticipated that few readers will use the guidance by reading sequentially from beginning to end, Subsection D.2.2 provides a framework for overall study methodologies that Mapping Partners can use to refer to more detailed analysis methods in subsequent subsections. In many cases, multiple methods are presented for analysis of a single coastal process. Often, coastal processes necessitate that the analysis begin offshore and proceed onshore to produce hazard zone designations for a coastal Flood Map Project. Subsection D.2.2 provides guidance on selecting analysis methods that are applicable to particular coastal settings and on linking the analysis of individual coastal processes together in a study methodology. In this sense, the document is organized with a set of general instructions in Subsection D.2.2, and a toolbox for selection of specific methods in Subsections D.2.3 to D.2.10. The appropriate tools must be selected based on study objectives, coastal exposure, geomorphic setting, and available data.

Coastal flooding on the Atlantic and Gulf coasts is a product of combined offshore, nearshore, and shoreline processes. The interrelationships of these processes are complex, and their relative effects vary significantly with coastal setting. These complexities present challenges in the determination of the base (1-percent-annual–chance) flood for FEMA hazard mapping purposes. The fundamental philosophy of this subsection is to provide a set of technical tools that can be selected and applied, as needed, to match specific site conditions and physical processes relevant to coastal flood hazards.

These guidelines offer insight and recommended methods to analyze complex Atlantic and Gulf coast flood processes in a reasonable way. However, they require technical judgment and experience in their application, and are not a prescriptive technique that can be applied uniformly in all study areas. The guidelines are intended to apply to a range of settings, but they cannot address all settings and conditions due to the broad variability of the Atlantic and Gulf coasts.

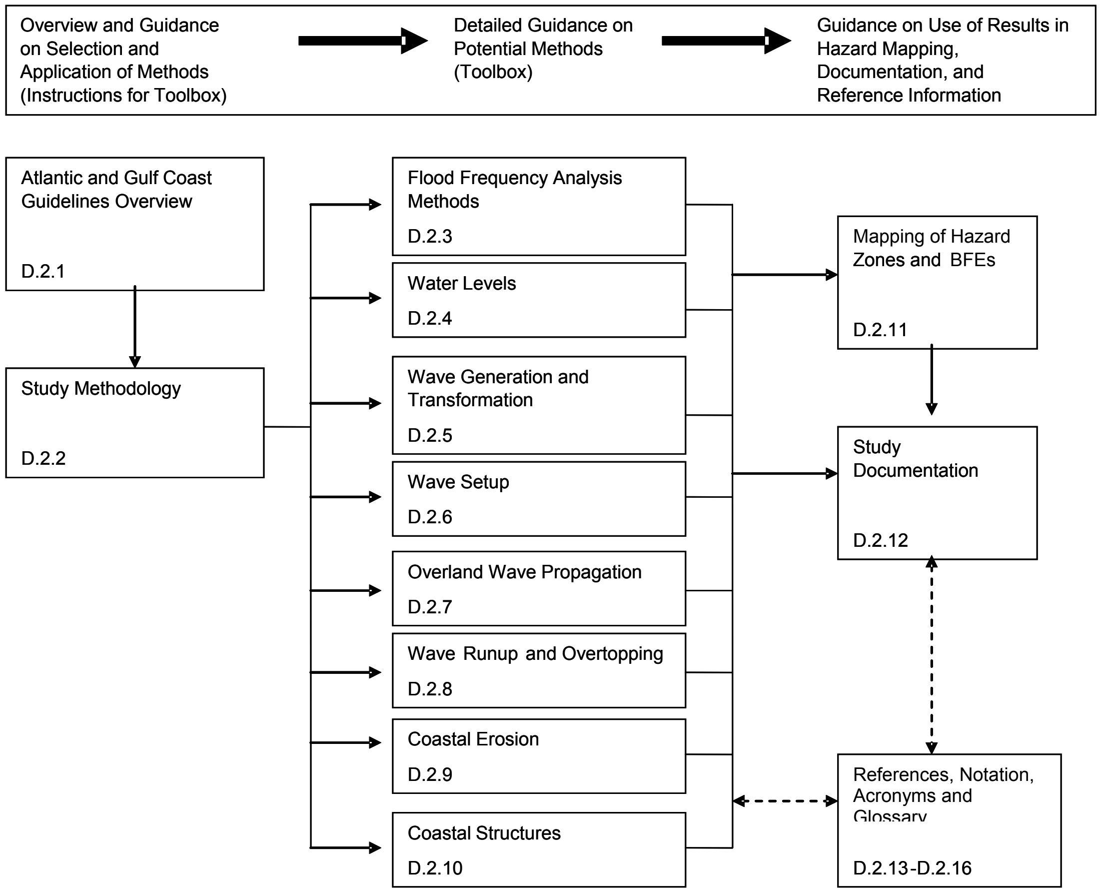

Figure D.2.1-1. Atlantic and Gulf Coast Guidelines Overview

These guidelines include new methods that were developed over a 1-year period by the Technical Working Group (TWG) assembled by FEMA. As always, application of experience and judgment in coastal engineering is necessary to apply the procedures described. The Mapping Partner may determine that minor modifications or deviations from these guidelines are necessary to adequately define the coastal flooding conditions and map flood insurance risk zones in specific areas. In these cases, documentation of these differences is required as part of intermediate and final study submittals.

Other appendices provide specific information on subjects such as project scoping (Appendix I), aerial mapping and surveying (Appendix A), treatment of levee systems (Appendix H), formats for FIS reports and rate maps (Appendices J and K), formats for draft digital data and Digital Flood Insurance Rate Map (DFIRM) databases (Appendix L), guidance for technical and administrative support data (Appendix M), and draft data capture standards and guidelines (draft Appendix N). The guidance provided here is intended only to supplement these subsections with information specific to coastal flooding on the Atlantic and Gulf coasts. The Mapping Partner shall refer to other appendices where specific guidance is required on technical elements common to most FEMA Flood Map Projects.

Subsection D.2.1.1 provides an overview of the Atlantic and Gulf Coast settings relevant to flood hazards, and Subsection D.2.1.2 provides an introduction to FEMA Flood Map Projects for the Atlantic and Gulf coasts.

D.2.1.1 Atlantic and Gulf Coast Settings and Characteristics

The Atlantic and Gulf coasts of the contiguous United States are approximately 1,800 and 1,500 miles in overflight length, respectively, but significantly longer when inlets, bays, headlands, and islands are considered. They encompass a broad spectrum of geological and biological provinces.

Trailing-edge coasts occur on the trailing edge of a landmass that moves with the plate. They are thus situated on passive continental margins that form the stable portion of the plate, well away from the plate margins. The Atlantic coast is an example of a mature, trailing-edge coast. These coasts typically have broad continental shelves that slope into deeper water without a bordering trench. The coastal plain is also typically wide and low-lying and usually contains lagoons and barrier islands.

Marginal sea coasts are those that develop along the shores of seas enclosed by continents and island arcs. Except for the Mediterranean Sea, these coasts do not usually occur along plate margins because the spreading center margins are commonly in ocean basins, while the collision edges of plates face oceans. These coasts are typically bordered by wide shelves and shallow seas with irregular shorelines. The coastal plains of marginal sea coasts vary in width and may be bordered by hills and low mountains. Rivers entering the sea along marginal sea coasts often develop extensive deltas because of the reduced intensity of wave action associated with small bodies of water. The Gulf of Mexico is an example of a typical marginal sea coast (Inman, 1994).

Just as the geology differs spatially along the coasts, so too do the risks associated with flood hazard events. The most severe Atlantic and Gulf coast storms can generally be classified as one of two types: hurricanes and northeasters.

Hurricanes are characterized by large windfields driven by pressure gradients from a central low pressure and temperature gradients in the atmosphere. They can sustain winds of more than 150 miles per hour and are accompanied by large storm surges and waves. The States along the Gulf and Atlantic coasts, from Texas to New York, are most at risk, though hurricanes have been known to reach as far north as Maine.

Unlike hurricanes, northeasters are frontal storms that track the shoreline as they progress northwards following the Gulf Stream. They move slowly and although the winds are typically weaker than hurricanes, they still pose a significant risk because they are accompanied by considerable precipitation and can affect a given area for multiple continuous days. Northeasters are primarily hazards for Atlantic coast states from Maine to North Carolina. (See Figure D.2.1-2.) It should be noted, however, that these regional distinctions are presented for guidance to the Mapping Partner when considering local risks in the study area and do not indicate a prescriptive technique for identifying hazards.

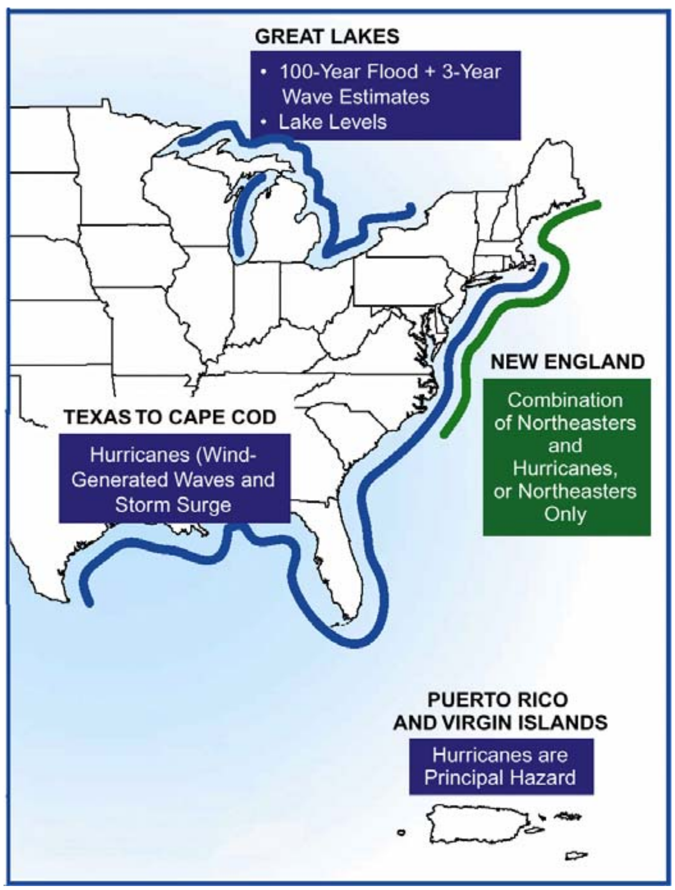

Figure D.2.1-2. Considerations for Determining Coastal Hazards and BFEs

The Atlantic and Gulf coastlines can be generalized into five distinct geological classifications: glaciated, barrier and drowned valley, coral and mangrove, wetland mangrove and barrier, and barrier coasts. The coral and mangrove coasts are found on both the Atlantic and Gulf coasts, while the glaciated and barrier and drowned valley coasts are found primarily on the Atlantic coast. The wetland mangrove and barrier and barrier coasts are found primarily on the Gulf coast, as shown in Figures D.2.1-4 and D.2.1-5 (USACE, 2003). Information in the following subsections, taken from the *Coastal Engineering Manual* (CEM), prepared by the USACE, Coastal and Hydraulics Laboratory, provides a detailed explanation of each of the five classifications.

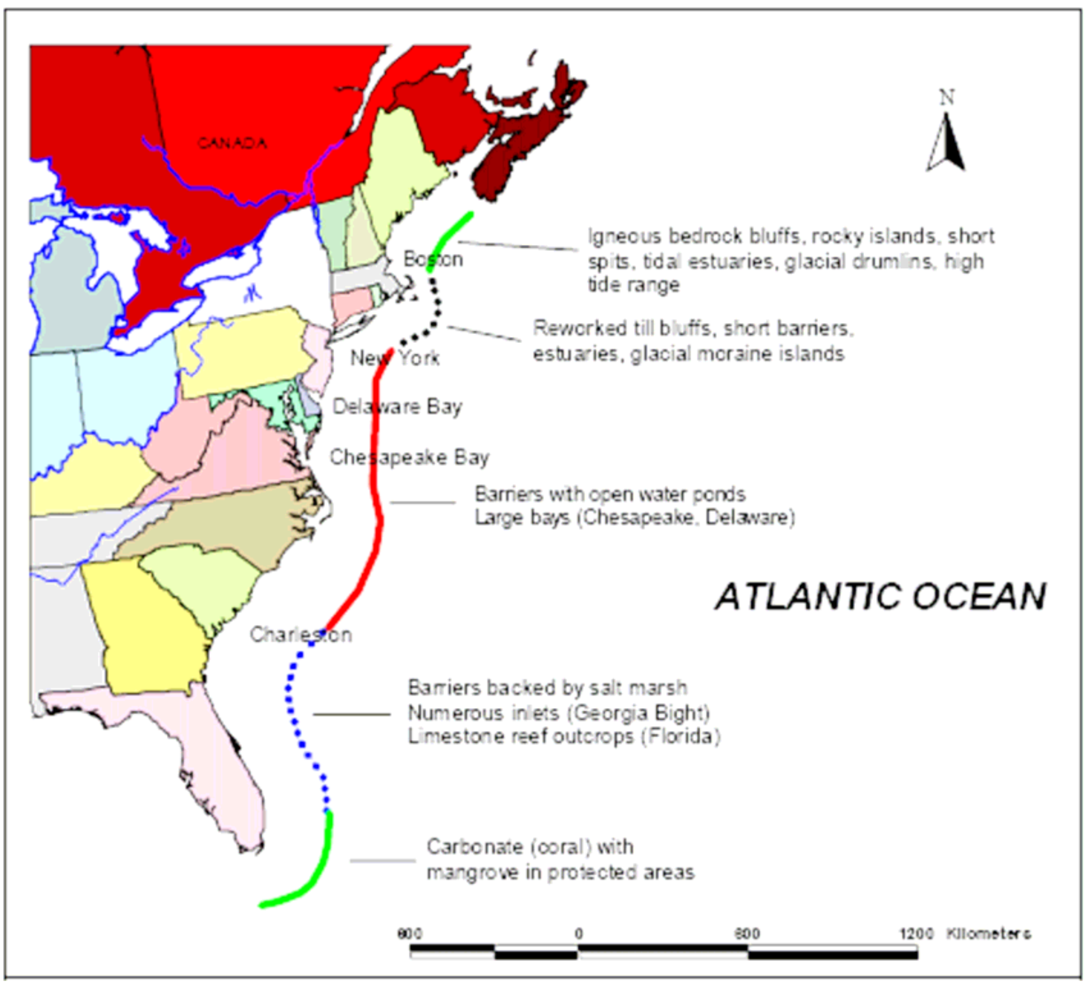

Figure D.2.1-3. Atlantic Coast Geological Characteristics

- *Atlantic North: Glaciated coast*

  These coasts are normally deeply indented and bordered by numerous rocky islands. The embayments usually have straight sides and deep water as a result of erosion by glaciers. Uplifted terraces may be common along these coasts that were formerly weighted down by ice. Abrupt changes in coastal character occur where glacial deposits, particularly glacial outwash, play a dominant role; while in some rocky areas, few glacial erosion forms can be found. Moraines, drumlins, and sand dunes, the result of reworking outwash deposits, are common features. Glaciated coasts in North America extend from the New York City area north to the Canadian Arctic; on the west coast, from Seattle, Washington, north to the Aleutian Islands and in the Great Lakes (Shepard, 1982).

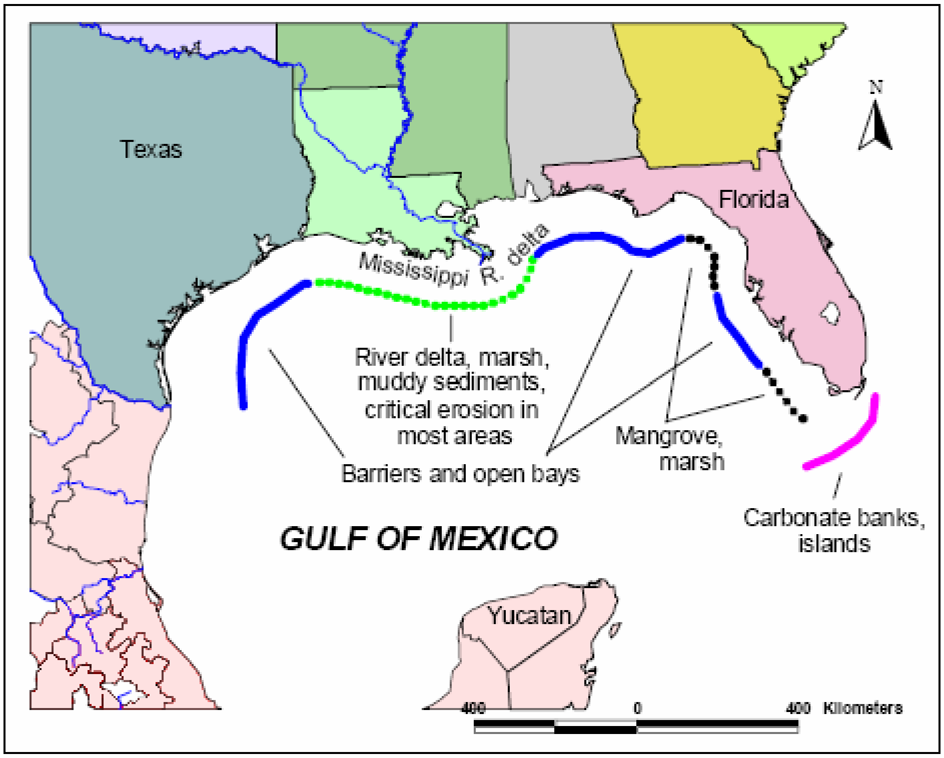

Figure D.2.1-4. Gulf Coast Geological Characteristics

- *Atlantic Central and South: Barrier and Drowned Valley Coasts*

South of the glacial areas begins the coastal Atlantic plain, featuring almost continuous barrier islands interrupted by inlets and by large embayments with dendritic drowned river valleys, the largest being the Delaware and Chesapeake Bays. Extensive wetlands and marshes mark much of the coast, where sediment and marsh vegetation have partly filled the lagoons behind the barriers. Some coasts have inland ridges of old barrier islands, formed during interglacial epochs, separated from the modern barrier islands by low marshes or lagoons. The best exhibit of cuspate forelands in the world extends from the mouth of the Chesapeake Bay to Cape Romain, South Carolina. The coast is much straighter south of Cape Romain and the only cuspate foreland is that of Cape Canaveral, Florida. Barrier Islands and drowned valleys continue south to Miami, Florida, except for a brief length of coast near Myrtle Beach, South Carolina, where the barriers are attached to the coastal plain. Much of the southeast coast of Florida was extensively filled, dredged, and reshaped in the early 20th century to support development (Lenček and Bosher, 1998). From Miami, around the tip of Florida, through Alabama, Mississippi, and eastern Louisiana, coastal characteristics alternate between swampy coast and white sand barriers (Shepard 1982).

- *The Atlantic and Gulf of Mexico: Coral and Mangrove Coasts*

  South of Miami, the barrier islands change from quartz sand to carbonate-dominated sand, eventually transforming into coral keys and mangrove forest. The Florida Keys are remnants of coral reefs developed during a higher sea level stage of the last interglacial period. Live reefs now grow along the east and south side of the keys and the shallows of Florida Bay are studded with mangrove islands extending north and west into the Everglades and the Ten Thousand Islands area that comprises the lower Florida Gulf Coast (Shepard 1982).

- *Gulf of Mexico East: Wetland Mangrove and Barrier Coasts*

  On Florida's Gulf Coast, barrier islands begin at Cape Romano and extend north as far as Cedar Keys. Enclosed bays usually have an abundance of mangrove islands and the topography is low with many lakes and marshes. North of Cedar Keys, the barrier islands end. They are replaced by a vast marsh dotted with small vegetated islands. The rock strata in this area are limestone, which, along with the low river gradients and numerous ponds or sinkholes, accounts for the absence of sand in the region. Because of its location and the large shallow water area offshore, little wave energy is present except during hurricanes. Some 130 kilometers (km) to the northwest, the swamp coast ends. Here the coastal trend changes direction from north-south to east-west, and Ochlockonee Bay, with drainage from the southern Appalachian Mountains, provides quartz sand for redevelopment of barrier islands. These sandy islands, with their various openings for access to the lowland port cities, continue westward as far as the Mississippi River delta.

  Studies of the Mississippi River delta indicate that the river has built a series of deltas into the Gulf of Mexico during postglacial times and that the Balize Delta (Bird Foot) is the latest, with an age of about 1,500 years. The Bird Foot delta is southeast of New Orleans, lying among a series of old passes that extend for 300 km (186 miles) along the coast. Most of the greater Mississippi River Delta is marshland and mud flats, with numerous shallow lakes and intertwining channels. Aquatic plants cover the marshland, which is renowned for the huge population of waterfowl it supports. The principal rivers have built natural levees along their course. These natural levees are about a meter above the normal water level, but many of them have been artificially raised to provide flood protection to towns and cities. In the areas of old delta lobes, subsidence has left only the natural levees above water, in some instances.

- *Gulf of Mexico West: Barrier Coast*

  From western Louisiana, west of the Mississippi River Delta marsh coast, toward the southwest, barrier islands become the dominant coastal features. Some of the longest barrier islands in the world are located along the Texas coast. Padre Island and Mustang Island, combined, extend for 208 km and feature extensive dune fields behind the broad beaches. The dunes rarely rise more than 10 meters in height, and many marshy wash-over deltas have extended into the large lagoons behind the barriers. The lagoons and estuaries decrease in depth toward Mexico. A large part of Laguna Madre is only inundated during flood periods or when the wind blows water from Corpus Christi Bay onto the flats. River deltas are responsible for much of this infilling, resulting in large differences between recent chart depths and those of 100 years ago (Shepard 1982).

D.2.1.2 Atlantic and Gulf Coast Flood Map Projects

This subsection briefly introduces Atlantic and Gulf coast studies through a discussion of general study considerations, including special considerations for sheltered waters and unique study conditions. Descriptions of typical project scoping activities, flood insurance risk zone definitions, and reporting requirements are also provided. Additional information on flood insurance risk zone mapping and study documentation is provided in Subsections D.2.11 and D.2.12, respectively.

D.2.1.2.1 Project Scoping

Project scoping is defined as the process of determining the extent of a particular coastal study and defining the fundamental methodologies to be used in completing the study. As presented in this subsection, this process includes two major tasks.

The first task is designed to assess the need for flood hazard mapping for communities and to assign priorities. Mapping Partners should evaluate the study area, prioritize study reaches, assign rankings and designate funds for specific aspects of the study according to the needs of the community and FEMA.

The second task involves determining general study methodologies based on study area setting, morphology, and coastal processes. This step also includes practical considerations of data availability and data collection needs, as well as study time and budget requirements. Subsections D.2.2 and D.2.3 on study methodology and analysis methods shall be consulted by Mapping Partners to determine which methods are appropriate for a particular coastal study setting and their general requirements for data and flooding analysis. In some complex study areas, a scoping phase of the coastal Flood Map Project may be needed to determine the availability of data and define a study methodology that combines a number of analysis methods and mapping procedures. When scoping for coastal redelineation studies, the Mapping Partner shall consult Subsection D.2.11 on mapping procedures in order to become familiar with potential datum conversion and other redelineation issues.

The following general procedures shall be followed for scoping the study methodology:

1. Define the objectives of the project based on information from the communities, and information from the FEMA Study Representative.
2. Review prior flood studies at the site or in the vicinity.
3. Review the study area setting exposure and shoreline morphology.
4. Make an initial assessment of the probable types and extent of hazard zones in the study area.

5. Identify subregions and reaches based on onshore conditions (e.g., shore geometry, structures), nearshore conditions (e.g., local exposure, profile morphology), and offshore conditions (e.g., depth contours, geometry of sheltered waters).
6. Define potentially applicable study methodologies using Subsections D.2.2 and D.2.3 as guidance.
7. Determine data requirements and data availability to support various analysis methods.
8. Assess the probable study methods in terms of level of complexity and probable accuracy of results – in general, the simplest methodology that provides reliable results shall be chosen. Incremental benefits of more sophisticated or detailed analysis may be assessed in this step.
9. Refine selection of analysis methods based on data requirements and reliability to synthesize an overall study methodology that effectively combines multiple analysis methods. For some studies, alternatives to the methods described in this subsection may be required to address specific situations.
10. Confirm that the study methodology is adequate to support development of anticipated flood insurance risk zones and produce required mapping.
11. Estimate time and budget requirements.
12. Adjust study extent, data collection, analysis methods, or overall methodology, if necessary, to meet study time and budget constraints.

Some flexibility is desirable in selecting study methodologies with respect to the procedures defined in these guidelines. Overarching considerations in selecting study methodologies shall include a basis in physical processes and quality-assured data, use of technically reliable and current analysis methods, reproducibility using standard engineering methods, verification of results using sensitivity tests and simple checks, and consistency with this appendix and other FEMA guidance.

D.2.1.2.2 Regional Versus Local Studies

Flood Insurance Studies were traditionally been performed for a single political jurisdiction, most commonly a community, with the FIS reports and FIRMs/DFIRMs being specifically developed for that community. Adjacent communities have been addressed only insofar as necessary to ensure that Base Flood Elevations (BFEs) match at the community boundaries. The hydrologic and hydraulic efforts have also typically stopped at the community boundaries, or have extended only so far beyond them as to encompass complete hydrologic units, such as drainage basins, which are necessary to determine conditions within the study community.

This local study approach has been followed, in part, due to the demanding computational effort necessary to encompass large regions within the analysis. For example, storm surge calculations require large computational grids, which in turn require large computer capacity and long execution time. To model more than a limited coastal region was difficult or impossible with the computer capabilities of only a few years ago. Similarly, ocean wave simulations have been restricted to limited zones in past studies. Although this community-by-community approach proved tractable, it also introduces some compromise into the studies. For example, a long length of coast that is simulated by breaking it into small sections means that boundary conditions must be specified for each segment, with some probable loss in both efficiency and accuracy.

A second compromise in local studies is that different Mapping Partners may make different assumptions that lead to differences between adjacent studies. Furthermore, not all Mapping Partners have the necessary tools and experience to perform some types of coastal flooding analyses.

The idea of regional studies is to perform large-scale regional analyses for certain portions of the engineering tasks needed in a community study and to make these analyses available as input to the local studies. For example, Subsection D.2.4 of these guidelines describes large regional databases (e.g., Global Reanalysis of Ocean Waves [GROW] data) of wave hindcast data. These data can be transformed to the nearshore area, just outside the surf zone, as part of a regional study effort covering a very large portion of the Atlantic and/or Gulf Coasts, using a single, consistent, state-of-the-art methodology. The advent of modern computational abilities makes these regional efforts feasible and more cost-effective than community-by-community repetition of a similar effort.

Regional studies can be implemented to varying degrees. Regional studies need not be as large as an entire coastline or a statewide analysis, but instead might cover a limited number of counties. This would be the case if there is a physical characteristic of a region that makes it logical to treat it as a unit, instead of breaking it up into smaller areas. For example, wave studies might be accomplished regionally according to directional exposure, island sheltering, breadth of shelf, or other physical factors. In general, processes that originate in the far field – such as storm surge – are candidates for regional analysis because a single coherent source might affect a large coastal reach. In an event-selection analysis, the selected event might be adopted regionally, controlling behavior within a multi-community basin such as a large sound.

The extent to which regional studies, perhaps focused on particular coastal processes, are available and can be used in local studies depends on planning and implementation of these studies by FEMA. The Mapping Partner shall consult with FEMA Study Representatives during the project scoping to determine if relevant regional information or analysis is available and should be incorporated into the study methodology.

D.2.1.2.3 Sheltered Waters

A generally accepted definition for "sheltered waters," which is taken here to include inland waters, enclosed basins, fetch-limited waters, and low-energy beaches, does not exist (Jackson et al., 2002). For the purposes of these guidelines, "sheltered" is assumed to imply a significant sheltering effect on the inland propagation of storm surge, waves, and wind by land masses and vegetation. "Sheltered waters" are water bodies or regions that experience diminished forces from wind and/or wave action relative to the open coast due to the presence of physical barriers, both natural and human, either on land or under water.

Sheltered water areas are exposed to the same flood-causing processes as are open coastlines (i.e., high winds, wave setup, runup, overtopping), but sheltering effects reduce the wave energy and flood potential. The Mapping Partner shall evaluate these potential sheltering effects at both a regional scale and a local site scale.

At a regional scale, wind-generated waves in sheltered water areas are highly dependent on the shape and orientation of the surrounding terrain to prevailing wind directions. Wave generation and transformation in sheltered waters are usually limited by the open water fetch distance, complex bathymetry, and often the presence of in-water and shoreline coastal structures. Other processes, such as the effects of flood discharges from rivers, can modify local tidal and storm surge elevations, and relatively strong tidal and/or fluvial currents can combine to create tidal and hydrodynamic conditions only found in sheltered water areas. (See Subsection D.2.4 for details on statistical determination of flood levels in areas with multiple flooding sources.)

Bays and estuaries often display significant spatial variability in tidal still water elevations as a result of the combined effects of complex tidal hydraulics, residual currents, local winds, and river runoff. Oceanic storm surge can also be modified in estuaries, with surge heights sometimes uniformly additive to local tidal datums throughout an estuary, or amplified or muted within a given region of a large estuary.

The Mapping Partner shall review bathymetric and topographic maps and aerial photographs, and make field observations to determine if a coastal flood study site is located within sheltered waters and to assess the degree of sheltering from swell, waves, and wind. The Mapping Partner shall investigate local site scale features contributing to sheltering from wind and waves and affecting flooding at the study site. It is important to note that sheltered water characteristics and processes viewed at a regional scale may be different at a local scale due to site-specific controls (Jackson and Nordstrom, 1992). In general, a more detailed examination of local conditions will be required in sheltered waters than on the open coast.

General wave transformation conditions within a sheltered water body may be inferred from wave patterns observed on vertical aerial photographs. During field reconnaissance, the Mapping Partner shall make field observations to identify conditions that affect selection of a study approach. Jackson et al. (2002) have identified characteristics of sheltered water shorelines that may be useful as a guide for field reconnaissance.

The Mapping Partner shall define a general approach to a sheltered water study at the scoping phase of the project. Because sheltered water areas experience the same flood-causing processes as open coast areas, guidance for performing coastal flood studies in sheltered waters is integrated throughout the remainder of these guidelines. Where procedures apply specifically to sheltered waters, they are identified in the individual subsections.

Beyond the initial effort to determine if a study site is located within a sheltered water area, as described above, a general approach to sheltered water studies shall address the following topics:

- **Topography/Bathymetry:** The Mapping Partner shall obtain backshore topography to define hazard zones, obtain nearshore bathymetry to define beach profiles, and define the geometry (size and volume) of the sheltered water body to evaluate hydrodynamic conditions. Detailed bathymetric data will likely be required in tidal inlets to assess their hydrodynamic characteristics, which may control the magnitude and timing of flood components, such as tidal stillwater levels and wave propagation.

- **Wind:** The climate in sheltered waters is dependent on localized wind conditions, and wave data are typically unavailable at a suitable resolution. The study approach will typically focus more on the identification of appropriate wind data sources rather than wave data (as may be relied upon for open-coast studies). Accordingly, the Mapping Partner shall identify, obtain, and review available wind data from the nearest appropriate sources; augment long-term data from established weather stations with available short-term data from local governments, industries, or private landowners to verify local wind conditions; and define characteristics related to fundamental wind parameters, such as wind source, seasonal direction, duration, magnitude, and vertical velocity distribution.

- **Tide and Currents:** The Mapping Partner shall identify, obtain, and review available tide gage data to define fundamental tide characteristics, such as astronomical tide, storm surge, tidal amplification, wind setup, and tidal and fluvial currents. Long-term tidal elevation data from established tide stations may need to be augmented with data from other sources. In some cases, estimates of natural tidal datums from landscape features, such as mud and vegetation lines, may provide verification of estimated extreme tidal elevations.

- **Waves:** The Mapping Partner shall obtain available data on observed wave height, wave length, and wave period, and shall assess probable extreme wave conditions given potential bathymetric and vegetative effects on wave energy.

These general topics can define the forcing functions, boundary conditions, and constraints necessary for analytical and/or numerical modeling approaches to flood determination. Sheltered water physical processes can be complex and may require detailed numerical modeling to adequately define the flood hazards. Given the availability and relative ease of use of modern numerical models, the Mapping Partner shall consider a numerical modeling approach to a sheltered water study where simpler methods do not appear reliable.

Model selection shall be made with consideration of the level of complexity of physical processes, data available for calibration, flood risk, and available study budget. If the physical scale of the sheltered water coastal flood study is small and the geographic setting and physical processes are relatively well understood and simple, the Mapping Partner shall confer with the FEMA Study Representative about the feasibility of using simplified analytical approaches instead of numerical models. A limited analytical approach may also be appropriate to obtain a quick assessment of physical conditions and/or to provide a check of the results from a numerical modeling approach.

D.2.1.2.4 Debris

Debris entrained in tidal floodwaters and cast inland by storm surge and wave propagation may occur along parts of the Atlantic and Gulf coasts. Natural debris consists of floating woody debris, such as drift logs, branches, cut firewood, and other natural floatable materials. Wave-cast beach sediments, such as cobbles and gravel, also constitute natural debris.

Debris from human sources may originate from flood damage. This debris may include broken pieces of shore revetment cast inland by extreme surge and wave attack, or floatable materials, such as construction materials, building materials, and home furnishings.

Debris hazards depend on the beach type and configuration, debris sources, the inland extent of wave propagation, the proximity of insured structures to the shoreline, and the height of the structures above the BFE. At present, debris hazards are not explicitly included in FEMA flood insurance risk zones and therefore a detailed debris analysis is not required. However, the Mapping Partner shall note significant debris hazards in a study area, document the hazards in the "Principal Flood Problems" section of the FIS report, and confer with the FEMA Study Representative so relevant information may be shared with community floodplain managers.

D.2.1.2.5 Beach Nourishment and Constructed Dunes

Current FEMA policy is not to consider the effects of beach nourishment projects in flood hazard mapping. Beach nourishment, in effect, is treated as a temporary shoreline disturbance, or an "uncertified" coastal structure (a structure not capable of withstanding the 1-percent-annual-chance flood event and/or a structure without an approved maintenance plan).

However, given that beach nourishment is conducted by more and more communities in response to coastal erosion, it is becoming increasingly difficult to obtain recent topographic data that do not reflect prior beach nourishment. In many communities, beach nourishment has been ongoing for a decade or more (predating the NFIP in some cases). Mapping Partners should be aware that flood hazard mapping of coastal areas could potentially be affected by various types of beach nourishment, and that current topographic data may reflect beach nourishment efforts.

The Mapping Partner shall determine whether beach nourishment affects a study area, research any beach nourishment projects identified, identify any available data that would allow the performance of the beach nourishment project(s) to be assessed, and determine whether the beach nourishment is likely to persist and have an effect on flood hazard mapping. If it is determined that beach nourishment will likely affect flood insurance risk zones or BFEs, the Mapping Partner shall contact the FEMA Study Representative to determine whether an exception to current FEMA policy should be considered.

The presence of constructed dunes in the study area may raise similar questions. For all practical purposes, the Mapping Partner shall treat constructed or reconstructed dunes (i.e., "artificial" dunes) as natural dunes during the study process if they meet the criteria set forth in the NFIP regulations. Paragraph 65.11(a) of the NFIP regulations does not allow an artificial dune to be considered an effective barrier against coastal flooding unless it has well-established, longstanding vegetative cover, regardless of its size and cross section.

D.2.1.2.6 Data Requirements

To conduct a study for a coastal community, the Mapping Partner shall first collect the wide variety of quantitative data and other site information required to perform the required analyses. Some data are entered directly into computer models of flood effects, while other data are used to interpret and integrate the calculated results.

Each computer model of a separate flood effect is executed along transects, which are cross sections taken perpendicular to the mean shoreline to represent a segment of coast with similar characteristics. Thus, collected data are compiled primarily for transects, which, in turn, are situated on work maps at the final scale of the DFIRM. Work maps are used both to locate and develop the transects and to interpolate and delineate the flood zones and elevations.

In addition to the necessary quantitative information, the Mapping Partner shall collect descriptions of previous flooding and the community in general to aid in the evaluation of flood hazards and for inclusion in the FIS report. The Mapping Partner shall begin this data collection effort at the community level and then turn to county, State, and Federal data sources. The Mapping Partner also shall contact private firms specializing in topographic mapping and/or aerial photography at the suggestion of government agencies.

D.2.1.2.6.1 Stillwater Elevations

The Mapping Partner performing the analysis shall determine the SWELs in a rational, defensible manner and shall not include contributions from wave action either as a result of the mathematics of the predictive model or of the data used to calibrate the model. Only the 1-percent-annual-chance SWEL is required for the coastal analyses, although 10-, 2-, and 0.2-percent-annual-chance elevations are provided in the FIS report and the 0.2-percent-annual-chance floodplain boundary is mapped on the DFIRM.

SWELs may be defined by statistical analysis of available tide gage records or by calculation using a storm surge computer model. FEMA also has specified procedures and documentation for coastal flood studies using a storm-surge model, as presented previously in Subsections D.2.3 and D.2.4. Of particular importance in this determination, the surge model study can provide estimates of the wind and water levels likely to occur over the course of the 1-percent-annual-chance flood.

D.2.1.2.6.2 Selected Transects

The Mapping Partner performing the analysis shall locate transects with careful consideration of the physical and cultural characteristics of the land so that the transects will closely represent conditions in their locality. The transects shall be placed closer together in areas of complex topography, dense development, unique flooding, and areas where computed wave heights and runup may be expected to vary significantly. Wider spacing may be appropriate in areas with more uniform characteristics. For example, a long stretch of undeveloped shoreline with a continuous dune or bluff of fairly constant height and shape and similar landward features may require a transect every 1 to 2 miles. However, a developed area with various building densities, protective structures, and vegetation cover may require a transect every 1,000 feet.

If good judgment is exercised in placing required transects, the Mapping Partner will avoid excessive interpolation of elevations between transects, while also avoiding unnecessary study effort. In areas where runup may be significant, the proper location of transects is governed by variations in shore slope or gradient. On coasts with sand dunes, the Mapping Partner shall site transects according to major variations in the dune geometry and the upland characteristics. In areas where dissipation of wave heights may be most significant in the computation of flood hazards, the Mapping Partner shall base transect location on variations in land cover (i.e., buildings, vegetation, and other factors). The Mapping Partner should site a separate transect at each flood protection structure. However, if areas with similar characteristics are scattered throughout a community and have the same SWEL, the Mapping Partner may apply the results from one transect at various locations within this common area. This is to be done only after careful consideration is given to topographic and cultural features to assure accurate representation of coastal hazards.

The Mapping Partner shall locate transects on the work map and compile the input data on a separate sheet for each transect. The data for each transect should not be taken directly along the line on the work map. Rather, they should be taken from the area, or length of shoreline, to be represented by each particular transect so that the input data depict the average characteristics of the area. Because of this, the Mapping Partner may find it is useful to divide the work map into transect areas for purposes of data compilation.

D.2.1.2.6.3 Topography

The topographic data must have a contour interval no greater than 5 feet or 1.5 meters. More information regarding topographic data can be found in Appendix A of these Guidelines. The topographic data, usually in the form of maps, must be recent and reflect current conditions or, at a minimum, conditions at a clearly defined time. Transects need not be specially surveyed unless available topographic data are unsuitable or incomplete. The Mapping Partner shall examine the topographic data to confirm that the information to be used in the analysis and mapping represents the actual planimetric features that might affect identification of coastal hazards.

If possible, the Mapping Partner shall field-check shore topography to note any changes caused by construction, erosion, coastal engineering, or other factors. The Mapping Partner shall document any significant changes with location descriptions, drawings, and/or photographs. The community, county, and State are usually the best sources for topographic data. The Mapping Partner shall examine U.S. Geological Survey (USGS) 7.5-minute series topographic maps. If the contour interval of the USGS maps are greater than 5 feet, they still may prove useful as reference or base maps.

D.2.1.2.6.4 Land Cover

The land-cover data include information on buildings and vegetation. Stereoscopic aerial photographs can provide the required data on structures and some of the data on vegetation. The Mapping Partner shall ensure that aerial photographs are not more than 5 years old unless they can be updated by surveys. Local, county, or State agencies may have the coastline photographed on a periodic basis and may provide photographs or permission to obtain them from their source.

Aerial photographs can provide the required data on tree- and bush-type vegetation. However, although they are useful in identifying areas of grass-like vegetation, they cannot identify specific types. National Wetland Inventory maps from the U.S. Fish and Wildlife Service and color infrared aerial photographs can provide some more specific data required for marsh plants. Ground-level photographs are also useful in providing information on plants. State offices of coastal zone management, park and wildlife management, and/or natural resources should be able to provide information.

The Mapping Partner also may contact local universities with coastal studies and/or Sea Grant programs. The Mapping Partner may conduct field surveys in lieu of obtaining data from the above sources, but field surveys are more cost effective when used only to supplement or verify data.

D.2.1.2.6.5 Bathymetry

The Mapping Partner may acquire bathymetric data from National Ocean Service nautical charts, although any reliable source may be used. The bathymetry must extend far enough offshore to include the breaker location for the 1-percent-annual-chance flood. Although that depth may not be exactly known during the data collection phase, the Mapping Partner may assume that a mean water depth of 40 feet will encompass all typical breaker depths. Bathymetry further offshore also may be useful in interpreting likely differences between nearshore and offshore wave conditions and may be necessary where offshore waves are more readily specified.

D.2.1.2.6.6 Storm Meteorology

The 1-percent-annual-chance flood elevations represent a statistical summary and likely do not correspond exactly to any particular storm event. However, the meteorology of storms believed to have been approximations of the 1-percent-annual-chance flood can be useful information in selecting recurrence intervals for historical events and in assessing wave characteristics likely associated with the 1-percent-annual-chance flood. An important distinction of the flood source from Delaware to Maine is whether the 1-percent-annual-chance flood is more likely to be caused by a hurricane or by a Northeaster. The Mapping Partner must make this distinction in the course of defining SWELs because the time history of water levels can be radically different in each case.

D.2.1.2.6.7 Storm Wave Characteristics

The basic presumption in conducting coastal wave analyses is that wave direction must have some onshore component, so that wave hazards occur coincidentally to the 1-percent-annual-chance flood. This presumption appears generally appropriate for open coasts and along many mainland shores of large bays, where the 1-percent-annual-chance SWEL must include some contribution from direct storm surge and thus requires an onshore wind component. However, an assumption of onshore waves coincident with a flood may require detailed justification along the shores of connecting channels, in complex embayments, near inlets, and behind protective islands. Once it is confirmed that sizable waves likely travel onshore at a site during the 1-percent-annual-chance flood, the storm wave condition must be defined for assessments of coastal structure stability, sand dune erosion, wave runup and overtopping, and overland elevations of wave crests.

It is important to recognize that somewhat different descriptions of storm waves (Table D.2.1-1) can be appropriate in assessing each distinct flooding effect. This depends mainly on the formulation of an applicable empirical or analytical treatment for each effect. In Flood Map Project models and analyses, the different wave descriptions include the following:

- Various wave statistics (e.g., mean wave condition for runup elevations, but an extreme or controlling height for overland waves);

- Various dominant parameters (e.g., incident wave height for overtopping computation, but incident wave period for overland crest elevations); and

- Various specification sites (e.g., deep water for estimating runup elevations, but transformation of waves actually reaching a structure in shallow water for most stability or overtopping considerations).

To proceed with general orientation, the Mapping Partner may develop storm wave conditions from actual wave measurements, wave hindcasts or numerical computations based on historical effects, and specific calculations based on assumed storm meteorology. Where possible, the Mapping Partner shall pursue two or all three of these possibilities in estimating wave conditions expected to accompany the 1-percent-annual-chance flood at a study site. Using all available information can improve the level of certainty in estimated storm wave characteristics.

Table D.2.1-1. Some Commonly Used Specifications of Irregular Storm Waves

Symbol	Name	Description
Wave Heights (water depth must be given)		
H_s	Significant	average over highest one third of waves
H_c	Controlling	defined as (1.6 H_s) in NAS (1977)
$\overline{H}$	Mean	average over all waves
H_{mo}	zero moment	defined by the variance of water surface (about equal to H_s in deep water)
Wave Periods (basically invariant with water depth)		
T_s	significant	associated with waves at significant height
T_p	peak	represents the maximum in energy spectrum
$\overline{T}$	mean	average over all waves

D.2.1.2.6.8 Coastal Structures

The Mapping Partner shall obtain documentation for each coastal structure that may provide protection from the 1-percent-annual-chance flood. That documentation shall include the following:

- Type and basic layout of the structure;
- Dominant site particulars (e.g., local water depth, structure crest elevation, and ice climate);
- Construction materials and present integrity;
- A historical record for the structure, including construction date, maintenance plan, responsible party, repairs after storm episodes; and.

- Clear indications of the effectiveness or ineffectiveness of the structure as protection.

The Mapping Partner shall develop much of this information through office activity, including a careful review of aerial photographs. In some cases, site inspection would be advisable for major coastal structures to confirm preliminary judgments.

D.2.1.2.6.9 Historic Floods

While not required as input to any of the FEMA coastal models, local information regarding previous storms and flooding can be very valuable in developing accurate assessments of coastal flood hazards and validation of storm-surge models. General descriptions of flooding are useful in determining what areas are subject to flooding and in obtaining an understanding of flooding patterns. More specific information, such as the location of buildings flooded and damaged by wave action, can be used to verify the results of the coastal analyses. Detailed information on pre- and post-storm beach or dune profiles is valuable in checking the results of the erosion assessment.

When quantitative data are available on historical flooding effects, the Mapping Partner shall make a special effort to acquire all recorded water elevations and wave conditions for the vicinity. This information can be used in estimating recurrence intervals for SWELs and for wave action during a flood event and in assisting an appropriate comparison to the 1-percent-annual-chance flood.

Local, county, and State agencies are good sources of historical data, especially more recent events. It is becoming common practice for these agencies to record significant flooding with photographs, maps, and/or surveys. Some Federal agencies (e.g., USACE, U.S. Geological Survey (USGS), and the National Research Council) prepare post-storm reports for more severe storms. Local libraries and historical societies may provide useful data.

D.2.1.2.7 Hazard Zone Definitions and Use by FEMA

Coastal flood insurance risk zones shown on the FIRM are generally divided into three categories: 1) VE zone (the coastal high hazard area); 2) AE zone (and other A zones, where flood hazards are not as severe as in VE zones); and 3) X zone (which is only subject to flooding by floods more severe than the base flood). AH zone and AO zone designations are used in special situations.

Delineation of flood insurance risk zones involves a set of analyses (waves, water levels, wave effects, and shoreline response) combined into a methodology for a particular study area. The criteria for establishing flood insurance risk zones are briefly described below. The reader should refer to subsequent subsections for a detailed description of the mapping parameters and their derivation.

D.2.1.2.7.1 VE Zone

VE zones are coastal high hazard areas where wave action and/or high-velocity water can cause structural damage during the base flood. They are subdivided into elevation zones with BFEs assigned. VE zones are identified using one or more of the following criteria for the base flood conditions:

1. The ***wave runup zone*** occurs where the (eroded) ground profile is 3.0 feet or more below the 2-percent wave runup elevation
2. The ***wave overtopping splash zone*** is the area landward of the crest of an overtopped barrier, in cases where the potential 2-percent wave runup exceeds the barrier crest elevation by 3.0 feet or more($\Delta R > 3.0$ feet). (See Subsection D.2.8.2.)
3. The ***breaking wave height zone*** occurs where 3-foot or greater wave heights could occur (this is the area where the wave crest profile is 2.1 feet or more above the total stillwater level).
4. The ***primary frontal dune zone***, as defined in 44 CFR Section 59.1 of the NFIP regulations.

D.2.1.2.7.2 AE Zone

AE zones are areas of inundation by the 1-percent-annual-chance flood, including areas with the 2-percent wave runup elevation less than 3.0 feet above the ground and areas with wave heights less than 3.0 feet. These areas are subdivided into elevation zones with BFEs assigned. The AE zone will generally extend inland to the limit of the 1-percent-annual-chance flood SWEL.

D.2.1.2.7.3 AH Zone

AH zones are areas of shallow flooding or ponding with water depths generally limited to 1.0 to 3.0 feet. These areas are usually not subdivided, and a BFE is assigned.

D.2.1.2.7.4 AO Zone

AO zones are areas of sheet-flow shallow flooding where the potential runup is less than 3.0 feet above an overtopped barrier crest ($\Delta R < 3.0$ feet). The sheet flow in these areas will either flow into another flooding source (AE zone), result in ponding (AH zone), or deteriorate because of ground friction and energy losses and merge into the X zone. AO areas are designated with 1-, 2-, or 3-foot depths of flooding.

D.2.1.2.7.5 X Zone

X zones are areas above the 1-percent-annual-chance flood level. On the FIRM, a shaded X zone area is inundated by the 0.2-percent-annual-chance flood, and an unshaded X zone area is above the 0.2-percent-annual chance flood.

Detailed guidance on hazard zone mapping is provided in Subsection D.2.11.

D.2.1.2.8 Reporting Requirements

Reporting requirements for coastal studies shall follow guidance provided in Appendix M for the preparation of a Technical Support Data Notebook (TSDN). The TSDN shall consist of the following four major sections, which are more specifically described in Appendix M:

- General documentation;
- Engineering analyses;
- Mapping information; and
- Miscellaneous reference materials.

In general, the material compiled for these sections of a coastal study TSDN will be similar to a riverine study, with the exception of the engineering analyses section. The engineering analyses section of a TSDN for a coastal study shall be formatted to reflect the required intermediate data submissions, together with the subsequent correspondence from FEMA and any other subsequent documentation related to a particular intermediate data submission. The purpose and content of individual intermediate data submissions are briefly described below.

Due to the differences between coastal and riverine flood studies and the complexity of coastal studies, intermediate data submissions are required from the Mapping Partner. Intermediate data submissions provide defined milestones in the coastal flood study process where independent reviews are conducted to confirm that the methods and findings are acceptable to FEMA. The primary purpose of this submission and review process is to minimize revisions to analysis methods late in the study.

Coastal analyses involving hydrodynamic modeling for development of water levels and wave processes (transformation, refraction, and diffraction) are highly specialized and complex. Changing or correcting the water-level and wave analyses after they have been used in analysis of shoreline processes and in flood insurance risk zone mapping is expensive and time consuming. Therefore, FEMA has established intermediate data submission requirements to facilitate review of analysis methods and results at appropriate milestones. Additional specific information on reporting requirements is provided in Subsection D.2.12. In general, the Mapping Partner shall submit the data for FEMA review in accordance with the sequence discussed below.

D.2.1.2.8.1 Intermediate Submission No. 1 – Scoping and Data Review

In this phase of reporting, the Mapping Partner provides the background information on the study setting and available data relevant to the study area. Any new data needed for the detailed coastal analyses in subsequent phases should be identified in this phase. The study should not proceed until all of the information is available and incorporated in the scoping document for approval.

D.2.1.2.8.2 Intermediate Submission No. 2 – Storm-surge Model Calibration and Storm Selection

Documentation of this phase shall include a description of the calibration, validation and sensitivity analysis of the storm-surge model to be used in the generation of surge elevations for flood frequency-of-occurrence analysis. It shall also include a description of the selection and definition of storm events to be used in the statistical analysis.

D.2.1.2.8.3 Intermediate Submission No. 3 – Storm-surge Modeling and Flood-Frequency Analysis

Documentation shall be provided on the methods used to estimate the 1- and 0.2-percent–annual-chance coastal flooding conditions. Documentation may include response-based and simulation methods (e.g., JPM, Monte Carlo, or EST), depending on study setting. Methods of extrapolation of hindcast and/or measured data to 1- and 0.2-percent–annual-chance values should be documented, including comparisons between alternate procedures, if appropriate. In cases for which extreme value analyses of wave, wind, water level, and residual tides are used, the submission shall include documentation of the analyses to develop frequency relationships, including a description of the data sets and analytical assumptions.

D.2.1.2.8.4 Intermediate Submission No. 4 – Nearshore Hydraulics

This submission shall be completed before flood hazard mapping is conducted and shall document the analyses related to the following four classes of coastal processes: water level and wave analyses to develop base flood conditions at the shoreline, including wave modeling for transformation, refraction, diffraction, and shoaling; wave runup, setup, and overtopping assessments in the surf zone; coastal structure and erosion analyses; and inland and overland water level and wave propagation analyses. This submission should include data on control, field, aerial, and bathymetric surveys. It should also include validation of results with available historical flood data, and discussion of modeling results by transect (as needed for interpretation of flood hazards). Where riverine sources influence coastal flood insurance risk zones in the study area, this submission shall include analysis of riverine flood stages and frequencies.

D.2.1.2.8.5 Intermediate Submission No.5 – Hazard Mapping

This submission will be prepared at the completion of draft delineations of flood insurance risk zones. The Mapping Partner shall document the analysis results used in the determination of hazard zone limits and BFEs and provide draft work maps for the study area showing all flood insurance risk zone boundaries.

The Mapping Partner will receive review comments within 30 days of the receipt of each data submission. The Mapping Partner shall include the interim review in the project schedule and shall plan the study work to minimize the effect of the reviews on the overall schedule for FIS report and DFIRM production.