Guidance for Flood Risk Analysis and Mapping

Coastal Study Documentation and Intermediate Data Submittals

May 2014

FEMA

This guidance document supports effective and efficient implementation of flood risk analysis and mapping standards codified in the Federal Insurance and Mitigation Administration Policy FP 204-07801.

For more information, please visit the Federal Emergency Management Agency (FEMA) Guidelines and Standards for Flood Risk Analysis and Mapping webpage (http://www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping), which explains the policy, related guidance, technical references, and other information about the guidelines and standards process.

Nothing in this guidance document is mandatory other than standards codified separately in the aforementioned Policy. Alternate approaches that comply with FEMA standards that effectively and efficiently support program objectives are also acceptable.

Document History

Affected Section or Subsection	Date	Description
First Publication	May 2014	Initial version of new transformed guidance. The content was derived from the *Guidelines and Specifications for Flood Hazard Mapping Partners*, Procedure Memoranda, and/or Operating Guidance documents. It has been reorganized and is being published separately from the standards.

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1.0 Introduction

This guidance summarizes the reporting requirements for coastal flood hazard studies, with emphasis on the intermediate data submissions (IDS) that document the basis and results of coastal flood hazard analyses during the course of the project. The IDS are required deliverables that Mapping Partners must provide to the FEMA Project Officer at key milestones during the engineering analysis and mapping process. They provide checkpoints after each phase in the study to allow for FEMA review and comment. Given the complexity and long durations of coastal studies, the IDS review process serves an important risk management function; it helps ensure that each phase of the study is completed satisfactorily prior to moving forward with the next phases of the study, which are dependent on the results of the earlier phases.

Documentation of the progress of a coastal flood hazard study is captured through IDS, while the final project deliverables are captured in the Technical Support Data Notebook (TSDN). The TSDN refers to the entirety of the final project datasets, such as base maps, bathymetric and topographic data, model input and output files, communication logs, technical reports, et cetera, that are archived for the study. The requirements of the TSDN are described in the *Data Capture Technical Reference*.

The final version of the information that is produced and provided for the IDS constitutes a subset of the material required for data capture in the TSDN. The IDS do not need to adhere to the same folder structure as the TSDN; the Mapping Partner may, however, find it convenient to utilize the TSDN organization throughout the study. In some studies, the Statement of Work (SOW) may require that the IDS be used to incrementally fulfill the requirements of the TSDN. In such cases, the IDS need to follow the TSDN folder structure and data requirements.

Similarly, some SOWs work may require more rigorous or extensive submittals than what is described in this guidance. In such cases, the IDS should follow the SOW, provided it is in compliance with the minimum expectation described here.

The guidance here is not intended to be exhaustive. The Mapping Partner should employ sound judgment in constructing each Intermediate Data Submittal. A thorough description of the work performed should allow the FEMA Project Officer, and any independent 3rd party reviewer, to fully understand the data development. The guidance provided herein is intended to be a minimum burden that the Mapping Partner must meet.

2.0 Intermediate Data Submittals

Intermediate data submissions provide defined milestones in the coastal flood hazard study process for review of the study approach and results. The Mapping Partner should submit the data to FEMA in the sequence indicated below. Some FEMA Regions or Mapping Partners may prefer to subdivide the submittals for more frequent touch points. Additionally, not all items listed below will be applicable to all studies. Mapping Partners should skip submittals, and items within submittals, that do not apply to their projects. If not specified in the SOW, submission expectations should be coordinated with the FEMA Project Officer and expectations transparently discussed between FEMA and the Mapping Partner during the Integrated Baseline Review.

Several different computer codes and programs may be used for the Flood Risk Project. In each section of the IDS reporting, the Mapping Partner should list and describe any modifications to these programs and special data inputs used in them. A complete list of technical references

should be provided, including computer program references. See 44 CFR Section 65.6 (a) (6) for additional requirements pertaining to computer programs used in FEMA studies to perform flood hazard analyses.

The study documentation in all IDS should include a description of any observations or measurements used to validate or adjust analysis results, any deviations from procedures recommended in FEMA guidelines, all assumptions made to apply the study methodology, any difficulties encountered in the analyses, and the technical decisions or approaches taken in their resolution. In all cases, the choices and decisions should be carefully evaluated for the unique study area and the study documentation should present the technical justifications for the decisions within the context of the present study effort. It is not sufficient, for example, to choose a model parameter input based on its use in other FEMA studies.

All submittals should describe and document any formal internal or 3rd-party Quality Assurance and Quality Control (QA/QC) processes. Documentation may take the form of QC forms, emails, or other correspondence.

If needed, each IDS may be revised as the study progresses. For example, if additional topography data becomes available, this information should be added and would result in a revised IDS #1 submitted to the FEMA Project Officer.

The IDS should be formally presented including title pages, table of contents, reference citations and applicable appendices. It is not sufficient to present a series of uncoordinated papers or ad hoc documentation. The IDS are core pieces of study documentation and the level of formality in their presentation should reflect this.

2.1 Intermediate Submission No. 1—Data Acquisition and Technical Approach

This submittal should provide background information on the study setting (i.e. geomorphic, hydrologic, hydraulic, and meteorological controls on flooding) 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. Data obtained from the community and local stakeholders during Discovery should be included if available at the time of submittal.

Topographic and Bathymetric Data: This submission should include survey control data, topographic data from aerial photography, Light Detection and Ranging (LiDAR) data, and field and bathymetric surveys. If data acquisition is still in progress, the submission should include available data at the time of submission and a detailed description of the acquisition plan. Information should be submitted on the extent of topographic and bathymetric mapping, the date of the data, key mapping parameters (e.g., contour intervals and accuracy standards), horizontal and vertical datum, location and extent of transects (for surveys), and other pertinent information describing the extent and quality of topographic and bathymetric information to be used in the study.

While the raw data are to be compiled in the TSDN, the Digital Elevation Model (DEM) should be submitted for review in IDS #1. If the DEM is subsequently updated to incorporate changes made to the model mesh (see IDS #2) or overland wave modeling (see IDS #4), updated versions of the DEM should be provided to the FEMA Mapping Partner for comment and review.

Field Reconnaissance: Documentation from site reconnaissance to support the hydrodynamic modeling should be presented. Documentation should include identification of existing bridges, coastal structures such as jetties and breakwaters, and any other structures that may influence

hydrodynamic and wave processes. Observations of beach and dune conditions such as eroded features or breaches, nourishment activity, and general observations of area topography should also be noted. Note that this is different from Site Reconnaissance, described in IDS 4, that may be performed for Overland Wave Hazard Modeling.

Tide, Wind, Wave, Current, and Flooding Data: This submission should include a description of available tidal elevation, wind speed, and wave data that relate to study analysis requirements. The submission should include an evaluation of local and regional tide gage records while recognizing that these records include astronomical tide, surge, and possibly other influences (e.g., El Niño, river flows and wave setup). The submission should include the review and selection of wind stations in the vicinity of the study area that can provide reasonable length of record, hourly values, and peak gusts to help estimate extreme wind statistics; the evaluation of available wave or wave hindcast data; the evaluation of available current data and the influence of currents on coastal flooding, if any; and the evaluation of available historical data (measured and anecdotal) on past coastal flood events.

Technical Approach: The submission should describe the technical approach proposed for the analysis of coastal processes and the mapping of flood hazards in the various settings and shoreline morphologies present in the study area. At this phase, the details of the analysis may not be final, but the general approach including model selection(s) and statistical approach should be described and any special considerations should be highlighted.

Numerical Models (if applicable): The Mapping Partner should document the numerical models, including their version, to be used for simulating astronomic tides, coastal/estuarine circulation, storm surge inundation, wind-wave growth, wave transformation, wave run-up/overtopping, etc. The documentation should include the following, with respect to the numerical models:

- Describe the unique model features to be used for the study, including a discussion of the grid (or mesh) and coordinate system to be employed (e.g. structured versus unstructured grids, Cartesian versus spherical coordinate systems, nested versus telescoping grids, etc.), proposed grid resolution, treatment of sub-grid features (e.g. levees, roadways, jetties, breakwaters, etc.), the location and conditions to be applied to the boundaries of the grid, and any sensitivity analyses conducted.

- Describe and document how coastal structures and shoreline features will be adjusted to account for failure and storm-induced erosion, respectively.

- Describe the methods to be used for interpolating bathymetric and topographic data on to the grid and measures to be taken preserve the locations and elevations of thin linear features.

- Describe the method used to relate wind speed to the surface drag coefficient.

- Discuss the Manning's "n" values used in the calculation of bottom and overland friction and provide values in tabular form, including a discussion of any sensitivity tests used to estimate these values in nearshore water. (Nearshore, bottom, and overland friction are important parts of the overall analysis and should be described with care and in sufficient detail.)

- Discuss the proposed treatment of barriers, inlets, rivers, ice cover, muddy bottoms, coastal structures, and other unique geomorphic, hydrologic and meteorological

characteristics of the project area that present challenges to the application of the proposed modeling tools.

- Describe all other user-developed model parameters.

2.2 Intermediate Submission No. 2— Offshore Water Levels and Waves: Storm Selection and Numerical Model Validation

This submittal should include a description of the setup, calibration and validation of numerical models to be used for the simulation of physical processes driving or contributing to coastal flooding. It should also include a description of the selection and definition of storm events to be used in the analysis of the recurrence frequency of flood elevations. Conclusions should be drawn with regards to the suitability of the model skill and any limitations in its application for this study. Where possible, comparison to technical standards and assessments of model skill should be presented.

Climatological Data and Meteorological Forcing: The Mapping Partner should document the source of the climatological data upon which the selection of historical storm events or the definition of synthetic storm events is based. The Mapping Partner should also document the source of the meteorological forcing (i.e. the surface wind and pressure fields) to be used to drive the numerical models. The documentation should include information about the formulations used for wind-stress and the drag coefficient, treatment of surface roughness, ice cover, etc.

The Mapping Partner must also tabulate and describe the storm parameters, including central pressure deficit, radius to maximum wind, forward speed, shoreline crossing point, and shoreline crossing angle used in the analysis. In addition, the Mapping Partner must describe the technique(s) employed to determine the spatial/temporal distribution of storm occurrences (i.e., storms/nautical mile/year), derivation and discretization of storm intensity parameters, exceedance probability distributions, and provide a graphical presentation of the results, including an overlay to show the orientation of the coast to storm path/direction. The Mapping Partner should also provide a discussion of storm parameter independence and any unique storm model treatments. Any optimization performed on a suite of storms in order to refine or reduce the final count of storms used within the simulations should be fully described and justified.

The wind field used in the analysis is a key component in the determination of the storm surge elevation. The Mapping Partner should give the exact equations used to parameterize the model wind field along with any unique values among the appropriate coefficients and constants used. The submission should include a diagram of the wind field model that shows the surface velocity structure as it changes radially outward from the storm center, provide a comparative graphic depiction of measured wind field(s) and the modeled wind field, if available, describe in detail the method by which winds are reduced as the storm approaches land and moves inland, and report the constants used in wind speed reduction. Documentation of the wind field model validation should also be provided if available.

Wave Data and Hindcasts: The submission should describe data and analyses used to select and define storm events for use in response-based analysis of nearshore processes and subsequent statistical analysis of 1- and 0.2-percent-annual-chance flood conditions. Documentation should include details of the sources of wave and wind data. It should also include comparisons between alternate sources, in cases for which more than one is available and feasible for use in the study, and comparison with local measurements. Documentation of

incident deepwater waves should include period, direction, and directional spreading parameters. The selection of coefficients for angular spreading and spectral peakedness parameters should be clearly stated and justified.

Model Calibration and Validation: The Mapping Partner should document the calibration and validation of the hydrodynamic surge and wave models. A complete description of the calibration and validation procedures should be provided, including a listing of measured and simulated tidal and/or wave data and a baseline to which the model performance is being measured against. It should also describe these activities and the model results with sufficient detail and care to allow an independent reviewer to understand the exact procedures in order to pass judgment on sufficiency of model performance.

Joint Probability Methodology (JPM): For studies applying the joint probability method (JPM or JPM-OS), the Mapping Partner should submit the following:

- Documentation of the determination of storm frequency and the probability distributions of storm parameters. This should include the treatment of correlations between storm parameters and measures taken to ensure that data was taken from a climatologically representative region.

- Documentation of the catalog of synthetic events (and the assigned recurrence frequencies or weights) selected from the joint probability distribution. The documentation should include a summary table listing all relevant storm parameters (including landfall, exit or nearest approach points) and a description of the treatment of storm in-filling prior to and after landfall.

- Sensitivity analysis showing that the storm catalog adequately represents the extent of flooding and flood elevations at the desired recurrence frequencies

- Description of how astronomic tides and river flows will be accounted for

- Description of any uncertainly being applied for model skill

Monte Carlo Simulations: The requirements for Monte Carlo study documentation are similar to those described above for JPM studies, but should also include a tabulation of the cases randomly simulated. The Mapping Partner should also provide justification for the number of simulations, including appropriate evidence of convergence at the extreme levels.

Empirical Simulation Technique (EST): For studies applying the Empirical Simulation Technique, the Mapping Partner should submit the following:

- Documentation of the average storm occurrence rate for the study area, as used in the Poisson annual occurrence assumption

- Documentation of the historical storm selection process, including a listing of all storms chosen for further analysis

- Documentation of the manner in which hypothetical storms were constructed, such as by alongshore displacement of historical storm tracks

- A summary of tide elevation data and a description of the methods by which the tides and storm surges are to be combined

- A discussion of any special steps to be taken to reduce the impact of sample error while addressing local geographic variability of storm occurrence

2.3 Intermediate Submission No. 3— Offshore Water Levels and Waves: Production Runs and Statistical Analyses

This submittal should provide documentation for the results of production runs for all numerical models being used. For studies employing an event-based framework, this submittal should include documentation of the methods used to determine recurrence frequencies for water levels and wave conditions. For studies applying the response-based framework, the determination of recurrence frequencies occurs after nearshore hydraulic analysis and hence the statistical analysis of recurrence frequencies should be submitted as part of IDS 4 for such studies.

All methods of extrapolation of hindcast and/or measured data to high and low frequency 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 should include documentation of the analyses to develop frequency relationships, including a description of the data sets and analytical assumptions. Documentation should include a description of the production run or hindcast design and a summary of input/output files as well as any QC steps taken.

Joint Probability Methodology (JPM): For studies applying the joint probability method (JPM or JPM-OS), the Mapping Partner should submit a listing of the results of the production runs, the corresponding recurrence rates and documentation of the construction of the exceedance frequency curve. For wave conditions determined using results from the JPM production runs, the documentation should describe methods used in determining wave conditions at the desired recurrence frequencies, including how wave direction was taken into account for application in subsequent nearshore analyses, for proposed transect locations. If possible, comparisons with results from nearby long-term gauges should be presented.

Monte Carlo Simulations: The requirements for Monte Carlo study documentation are similar to those described above for JPM studies. If possible, comparisons with results from nearby long-term gauges should be presented.

Empirical Simulation Technique (EST): For studies applying EST, the Mapping Partner should submit input and output files from the EST analysis. If possible, comparisons with results from nearby long-term gauges should be presented.

Tide Gauge/Wave Buoy Data Analyses: For studies employing tide gauge records as input water levels and/or wave buoy data as input wave conditions for nearshore hydraulic computations, the Mapping Partner should submit the following:

- A listing of the data and description of any adjustments made to the data to account for sea level rise, datum changes, missing records, etc.

- Documentation of the statistical analysis used to determine recurrence frequencies, including detailed documentation of any approaches based on regional inference

- In ungauged regions, documentation of the methodology used to transfer data from the gauged region to the ungauged region

Surge Results Surfaces: Where 2D hydrodynamic models are used for storm surge modeling, Geographic Information System (GIS) "surfaces" should be created from the production run results. Surfaces may be provided as a DEM, Triangulated Irregular Network (TIN), or other 2D surface product which provides a spatially comprehensive set of water levels across the study area. The Mapping Partner should explain methodologies used to calculate statistical water levels and develop the surface, particularly for inland areas. At a minimum, surfaces should be provided for the 1%- and 0.2%-annual-chance water levels.

Comparison to Historical and Adjacent Studies: The Mapping Partner should compare the new surge results to historical results. The Mapping Partner should explain the results, and any differences or similarities, to those determined previously. The Mapping Partner should also coordinate with adjacent study areas and determine if the surge results are similar or different. If any adjustments are made as a result of study boundary coordination, these should be fully documented.

2.4 Intermediate Submission No. 4 — Nearshore Hydraulics

This submittal should provide documentation of the analysis of inland flooding, including but not limited to: storm-induced erosion, wave setup, wave run-up, wave overtopping, sheet flow and ponding behind barriers, and overland propagation of waves. For studies applying the response-based framework, this submittal should also include documentation of the statistical analysis of recurrence frequencies.

Transect Location Map: The Mapping Partner should submit digital transect files and one or more maps as appropriate depicting the location and orientation of one dimensional model transects used in the overland wave analyses. The transect location map(s) should be at a suitable scale and should show transects of sufficient length to account for modeling of all coastal flooding conditions.

Wave Information: The Mapping Partner should present a summary table listing the nearshore wave conditions used as input for the analyses and document all assumptions and approximations used for wind-wave growth and wave transformation. In sheltered waters, when numerical models are not used for prediction of wind-wave growth, the documentation should include a summary of fetch determination, winds (speed, direction, and duration), and bathymetry used. When observational data, such as wave buoy data, are available, validation should be presented for the methods used for wind-wave growth and wave transformation.

Wave Setup, Runup, and Overtopping Analyses: The Mapping Partner should document the runup, setup, and overtopping analysis assumptions, methods, input data, and results. This should include a determination of runup heights and determination of flood hazard parameters that determine the flood zone designation and Base Flood Elevation (BFE) (e.g. 1- and 0.2-percent-annual-chance flood elevations, overtopping splash penetration and overtopping rate, and overland flow velocity) at each transect. This should include a description of ground elevation profiles used, runup reduction factors, and the basis for splash zones to be used in hazard mapping. The documentation should include a description of any observations or measurements used to validate or adjust analysis results, any deviations from procedures recommended in FEMA guidelines, any difficulties encountered in the analyses, and the technical decisions or approaches taken in their resolution.

Overland Wave Propagation Modeling: The Mapping Partner should describe the areas where overland wave propagation was evaluated with numerical models, and document the analysis assumptions, models and methods applied, input data, and results. This should include

documentation of any field observations or measurements, as well as available historical or anecdotal information regarding wave attenuation during flooding events.

Coastal Armoring Structures: The Mapping Partner should describe assumptions and investigations of the various coastal armoring structures (e.g., seawalls, revetments, bulkheads, levees, etc.) in the study area relevant to stability and capability to withstand 1-percent-annual-chance water-level and wave conditions. This documentation should include any assumptions or approximations used in the analyses. The same documentation should be required in the event that coastal structures are apparently buried and not visible, but are indicated by information collected during the study. In cases where multiple analyses were conducted for the structure (i.e., intact condition, failed condition/removed from the analysis transect), the Mapping Partner should document each analysis and record the structure condition used to map flood insurance risk zones and BFEs.

Beach Stabilization Structures: The Mapping Partner should document the treatment of beach stabilization structures (e.g., groins, offshore breakwaters, sills, etc.) during the study. If the Mapping Partner proposes removal or modification of beach stabilization structures (or their shoreline effects) during the 1-percent-annual-chance flood, the Mapping Partner should document the existence, history of, and shoreline response to beach stabilization structures and consult with the FEMA Project Officer.

Miscellaneous Structures: If miscellaneous structures (e.g., piers, port and navigation structures, bridges, culverts, tide gates, etc.) are present in the study area and could exert a significant influence on nearshore waves, currents, sediment transport, or backshore ponding, the Mapping Partner should document the data, methods, and procedures used to evaluate the stability of these structures during the 1-percent-annual-chance flood and their effects on coastal flooding. This documentation should include assumptions or approximations used in the analyses.

Erosion Analyses: The Mapping Partner should document the erosion analysis assumptions, methods, input data, and results.

Verification to an Observed Coastal Flood Event: Where available, background information shall be provided for measured and anecdotal historical coastal flood data at or near the study area that are used in verification of the analyses. This shall include a description of the method used (if any) to reconstruct wind and water-level data during the flood event, observed flood and wave conditions, flood elevations, areas of inundation and erosion. Where possible, the recurrence interval of the observed event should be estimated.

Site Reconnaissance: Documentation from site reconnaissance should be presented. Documentation should include characterization of exposure and coastal morphology, identification of existing coastal structures and levees (including buried coastal structures), and characterization of coastal vegetation where it may influence coastal flooding analyses and mapping. Observations of beach and dune conditions such as eroded features, nourishment activity, and dune vegetation should be included.

Special Study Considerations: The Mapping Partner should document any unique conditions in the study area and the methods used to evaluate flood hazards based on these conditions. These may include tsunami-related hazards, effects of beach nourishment, effects of flood-borne debris, special hydrodynamic considerations in tidal inlets and passages, effects of riverine inflows, unique erosion or other sedimentation characteristics, unique structure effects,

effects of multiple levees, and any other factors that the Mapping Partner considers relevant to evaluating flood hazards accurately.

2.5 Intermediate Submission No. 5—Flood Hazard Mapping

This submittal should provide the draft flood hazard work maps and documentation of the methods used to translate the results of the engineering analyses into flood insurance risk zones.

Flood Zone Designation and BFE Documentation: The Mapping Partner should document the results of the engineering analyses used for flood hazard zone designation and BFEs. This should include summary tables, by transect, of results for the initial 1-percent wave crest elevation, 1-percent and 0.2-percent stillwater elevations (SWELs), and other flood hazard parameters that determine the flood zone designation and BFE (i.e. runup elevations (or total water levels, TWLs), overtopping rates, extents of ponding or sheetflow, overland flow velocity, primary frontal dune (PFD) locations, etc.), as appropriate. Wave envelope profiles should be provided to depict overland wave propagation results (combined with wave runup results, as appropriate). A summary table showing the processes that control the flood hazard mapping at each transect should also be included. In addition, the summary should indicate the adjustments made to the transect profiles with structures that produced the results used for the flood hazard mapping (i.e., failed, partially-failed, intact, or buried coastal structure cases).

This submission should document instances where engineering judgment was used to interpolate and delineate hazard zones between transects. It should also provide detailed documentation and technical justification for adjustments to the hazard zone mapping due to observed historical flood data and/or damages in the study area. Documentation of primary frontal dune delineation and the assumptions and considerations that informed the delineation should also be presented. A comparison with the historical delineation should also be presented, where possible.

Where a combined rate of occurrence analysis of riverine and coastal flood elevations is performed, documentation of the analysis and a summary of the results should be provided.

Flood Hazard Workmap: The Mapping Partner should provide draft workmaps for the study area showing all flood insurance risk zone limits resulting from the detailed analyses. Workmaps may take the form of digital geospatial files or PDF maps—the FEMA Project Officer should be consulted to determine study preference. Where applicable, the Mapping Partner should provide shapefiles showing the study limits, Special Flood Hazard Area (SFHA), Limit of Moderate Wave Action (LiMWA), PFDs, BFEs, zone breaks and gutters, shoreline or transect baseline, and transects.

Special Study Considerations: The Mapping Partner should document any unique conditions in the study area. The documentation should describe how the flood hazard mapping accounted for such conditions. These unique conditions may include the influence of atypical coastal structures, effects of multiple levee systems, and any other factors that were not evaluated explicitly during the engineering analysis, that the Mapping Partner considers relevant (based on engineering judgment, historical evidence, etc.) for accurate portrayal of flood hazards. BFE and SFHA zone comparisons with adjacent studies at the study boundaries should be performed. Any adjustments made to provide for smooth transition at the boundary should be documented. If there is a discontinuity at the boundary, this should be documented and justification included.