APPENDIX A: ENSURING CONSISTENCY WITH THE STANDARDS OF THE NATIONAL FLOOD INSURANCE PROGRAM (NFIP)

E.O. 11988 requires, to the extent permitted by law, Federal agencies consult with the Federal Emergency Management Agency (FEMA) to ensure that the agency's procedures and regulations are consistent with the NFIP, and that Federal structures and facilities are constructed, at a minimum, in accordance with the intent of the NFIP regulations.[1] Sections 2(e) and (f) of E.O. 13690 amend E.O. 11988 to include that the agency regulations and procedures must also be consistent with the Federal Flood Risk Management Standard (FFRMS). Agency regulations and procedures shall deviate only to the extent that the standards of the NFIP and the FFRMS are demonstrably inappropriate for a given type of structure or facility.

Section 1 below provides an overview of the NFIP. Section 2 provides specific NFIP construction requirements and provides further guidance to Federal agencies on how agency procedures assure that construction of Federal facilities and structures are in accordance with the standards and criteria of the NFIP and consistent with the intent of those standards" as defined in the Order. Finally, Section 3 addresses the requirements of the Order to elevate or floodproof structures and facilities rather than filling in the land and provides alternatives recommended by FEMA.

1. OVERVIEW OF THE NFIP

The National Flood Insurance Act (NFIA), the original authorizing legislation for the NFIP was passed in 1968. See NFIA, as amended, 42 U.S.C. § 4001 et seq. Congress expressly found that "a program of flood insurance can promote the public interest by encouraging sound land use by minimizing exposure of property to flood losses. . ." (FEMA, 2004).

The NFIP is administered by FEMA, which is part of the Department of Homeland Security. The NFIP is intended to encourage state and local governments to recognize and incorporate knowledge of flood hazards into their land use and development decisions. In some communities, this is achieved by guiding development to areas with lower risk. A participating community's application of the criteria set forth in Federal regulation (44 CFR § 60.3) to new development – including new, substantially improved, or substantially damaged buildings – is intended to minimize exposure and flood-related damage to that development. The NFIP

[1] This review by FEMA is in addition to any reviews or consultations an agency may have with the Water Resources Council, Federal Interagency Floodplain Management Task Force, or Council on Environmental Quality as described in E.O. 11988 or E.O. 13690.

regulations broadly define the term "development" at 44 CFR 59.1: "Development means any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials."

More than 22,000 communities currently participate in the NFIP and many of them have enforced floodplain management regulations for decades. Participating jurisdictions must incorporate at least the minimum NFIP requirements in their floodplain management regulations. Approximately 20 percent of those communities have adopted building codes, referred to collectively as International Codes (I-Codes), which contain provisions that are consistent with NFIP requirements for buildings and structures, in large part by references to ASCE 24-05 and ASCE 7-10, Minimum Design Loads for Buildings and Other Structures.

The NFIP has three main elements:

1. Flood hazard identification and mapping, in which engineering studies are conducted, and flood maps are prepared, to delineate areas of flood hazard.
2. Floodplain management criteria, which consist of the minimum floodplain management-related requirements that NFIP participating communities must adopt and apply to development within mapped special flood hazard areas.
3. Flood insurance, which provides financial protection for property owners by covering flood-related damage to insured buildings and contents.

Federal flood insurance is designed to provide an alternative to disaster assistance and disaster loans for home and business owners. Disaster assistance from FEMA usually covers only a portion of the costs to repair damaged buildings. Additionally, disaster assistance loans are available to qualified victims, but they may not significantly ease the financial burden on disaster survivors because they must be repaid. FEMA disaster assistance, including temporary housing, is available only after floods have been declared major disasters by the President of the United States. In contrast, NFIP flood insurance claims will be paid to NFIP policyholders for covered damage from any qualifying flood event.

An important objective of the NFIP is to break the cycle of flood damage. Many buildings have been flooded, repaired or rebuilt, and flooded again. In some parts of the country, this cycle occurs every few years. Before communities adopted floodplain management regulations, people tended to rebuild in the same flood-prone areas using the same construction techniques that did not adequately protect the structure when the first event occurred. To obtain funding through FEMA's grant programs, structures must be rebuilt to NFIP floodplain management requirements, which experience, on average, 80 percent less damage through reduced frequency of inundation and severity of losses.

By encouraging communities to guide development to lower risk areas, and by requiring the elevation of new buildings and existing buildings when owners propose significant improvement or when such buildings have sustained substantial damage, the long-term NFIP objective of reducing flood damage and losses is being realized. Older buildings that are required to comply with NFIP requirements may be removed, replaced, upgraded, or modified with techniques that lead to little or no flood damage.

Under the NFIP, Federal, State, tribal, and local levels of government have distinct responsibilities:

- Because they have land use authority, communities are responsible for regulating all development in mapped Special Flood Hazard Areas (SFHAs), including issuing and denying permits, and enforcing the permit requirements. Under the NFIP, participating communities are responsible for adopting the minimum floodplain management criteria into local ordinances and implementing/enforcing those requirements.
- States, in addition to participating in the NFIP, are generally also responsible for providing technical assistance to communities, monitoring community programs, and coordinating efforts between communities and the NFIP. Some states also administer regulatory programs and many are engaged in flood hazard mapping initiatives.
- FEMA, through administration of the NFIP, identifies and publishes information with respect to all flood plain areas, including coastal areas located in the United States, which has special flood hazards, updates the information as the Administrator determines necessary, promulgates the minimum NFIP floodplain management criteria, supports state programs, provides technical assistance, monitors and enforces programmatic compliance of the NFIP participating communities, and produces flood hazard maps.

2. THE NFIP REQUIREMENTS FOR STRUCTURES AND FACILITIES

Unless the standards of the NFIP and the FFRMS are demonstrably inappropriate for a given type of structure or facility, the agency procedures and regulations should be in accordance with the NFIP performance standards for flood-resistant construction for new construction, substantial improvement, and other development, at 44 CFR § 60.3(a)(3) which requires communities to:

> *Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall be:*
>
> *(i) Designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy;*
>
> *(ii) Constructed with materials resistant to flood damage;*
>
> *(iii) Constructed by methods and practices that minimize flood damages; and*

> (iv) *Constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding.*

Further, the regulations (44 C.F.R. § 59.1) identify specific requirements for buildings based on the nature of SFHAs (the land in the floodplain within a community subject to a 1 percent or greater chance of flooding in any given year). SFHAs are identified on FEMA's Flood Insurance Rate Maps (FIRMs) as riverine areas not subject to waves (labeled "Zone A" on FIRMs, coastal A Zones exist in riverine areas adjacent to coastal areas that meet certain conditions) and coastal areas subject to high-velocity wave action where wave heights of three feet and higher are predicted (these areas are labeled "Zone V" on FIRMs). In both A and V Zones, all buildings are required to be elevated and otherwise protected to resist damage associated with the base flood. In addition to requirements set forth in the regulations at 44 CFR § 60.3(a)(3), communities are required to ensure that proposed construction and other development meet the following specific requirements based on flood zone:

- 44 CFR § 60.1(c) and (d)
- 44 CFR § 60.3(b)(1) and (6) through (8)
- 44 CFR § 60.3(c)(1) through (12) – In Zone A, buildings shall have lowest floors elevated to or above the FEMA regulatory base flood elevation (FEMA BFE) (nonresidential buildings may be dry floodproofed in lieu of elevation). Enclosures below buildings in Zone A are required to have flood openings to permit the automatic entry and exit of flood waters to minimize unequal pressure that could cause structural damage to walls and foundations.
- 44 CFR § 60.3(d)(1), (3), and (4)
- 44 CFR § 60.3(e)(1) and (3) through (8) – In Zone V, buildings shall be elevated on columns or pilings such that the bottom of the lowest horizontal structural member of the lowest floor is elevated to or above the FEMA BFE. Enclosures with walls below buildings in Zone V are required to have walls that are designed to break away under specific flood loads to minimize the potential for damage to foundations.

(Note: References to the NFIP regulations above have been abbreviated for the purposes of this appendix and should not be read as complete summaries of the requirements in those sections. Please consult the NFIP regulations in their entirety at 44 CFR Parts 59 and 60.)

The NFIP also requires that communities regulate development in regulatory floodways [60.3(d)] to ensure that there are no increases in upstream flood elevations. For streams and other watercourses where FEMA BFEs exist, but no floodway has been designated [60.3(c)(10)], the community must review developments on a case-by-case basis – through an encroachment review – to ensure these increases do not occur.

3. ALTERNATIVES TO ELEVATING ON FILL

Section 2(g) of E.O. 11988 states that if new construction or rehabilitation of existing structures or facilities are to be located in a floodplain, agencies shall floodproof or elevate above the elevation of the floodplain rather than filling the land. Brief descriptions of the methods for meeting this requirement are listed below. See Appendix C for a list of references to technical publications that provide more detailed information. The NFIP recommends the following alternate methods to elevating on fill:

- Elevation on piles, posts, piers, or columns – are required in V Zones, and most appropriate for elevating where there is deep flooding, or for areas with high velocity flooding, or for areas where fill is prohibited. This design allows for the unobstructed flow of water beneath the upper floors of the building.
- Elevation on solid walls or a crawlspace – permitted in A Zones. Elevation on solid stem walls or a crawlspace will elevate the foundation of the building; however, it may create an enclosed area beneath the FEMA BFE or create an obstruction to floodwaters. Any enclosed areas below the FEMA BFE must have flood openings.

Nonresidential buildings must be elevated or floodproofed. If floodproofing is the only feasible alternative, this means that, for areas below the FEMA BFE, the following conditions must be met:

- Walls must be watertight (substantially impermeable to the passage of water).
- Structural components must be able to resist hydrostatic and hydrodynamic loads and effects of buoyancy.
- Utilities must be protected from damage.

For more technical information on floodproofing, see resources listed in Appendix C.

APPENDIX B: FLOOD HAZARD INFORMATION AVAILABLE FROM FEMA TO ESTABLISH THE FFRMS FLOODPLAIN

The first step in complying with E.O. 11988 is to determine whether or not a proposed action is located in a floodplain. Products from the Federal Emergency Management Agency (FEMA) must be consulted to determine whether Federal actions are proposed to be located in the 1-percent-annual-chance floodplain. FEMA products must also be used as a starting point in determining the elevation and extent of the floodplain for federally funded projects subject to the Federal Flood Risk Management Standard (FFRMS) as well as serve as a source of additional considerations when managing flood hazards. This appendix identifies and describes information depicted on the FEMA products that must be obtained and used, when available, to establish the FFRMS floodplain. Agencies may choose to utilize the 1-percent-annual-chance flood elevation and 0.2-percent-annual-chance flood elevation from another credible source and/or choose to develop the elevation and extent of the floodplain for the action being considered, so long as any Federal development project or Federal assistance is carried out consistent with FEMA's minimum floodplain management data requirements or more stringent best available data consistent with the FFRMS.

Section 1 below provides an overview of FEMA products available to obtain information to establish the FFRMS floodplain. Section 2 discusses the information that may be depicted on FEMA products that can be used when applying the Freeboard Value Approach and the 0.2-percent-annual-chance Flood Approach. The final section discusses additional information that may be depicted on FEMA products that inform Floodplain Management decisions, but is not used to establish the FFRMS floodplain.

1. FEMA PRODUCTS

The most widely distributed flood map product is the Flood Insurance Rate Map (FIRM). A FIRM is issued by FEMA and identifies Special Flood Hazard Areas (SFHAs), defined as areas subject to inundation by the 1-percent-annual-chance flood. In some areas, the map also shows FEMA Base Flood Elevations (FEMA BFEs), defined as FEMA regulatory 1-percent-annual-chance flood elevations, the boundaries of the 0.2-percent-annual-chance floodplain, and the regulatory floodways. FIRMs include some common physical features, such as major highways, secondary roads, lakes, railroads, streams, and other waterways. In some cases, the community may have Flood Hazard Boundary Maps (FHBMs) rather than FIRM panels, depending on the age of the flood study performed by FEMA.

Designating flood zones on FIRMs consists of three steps: frequency analysis, topography, and floodplain mapping. To prepare maps that illustrate the extent of flood hazards in a floodprone community, FEMA conducts engineering studies referred to as Flood Insurance Studies (FISs). In conducting an FIS, FEMA considers all available information. This can include statistical analyses of riverflow, storm tide, and rainfall records; information obtained through consultation with the community; topographic data; and hydrologic and hydraulic analyses. An FIS report consists of text, graphic flood profiles, floodway data, and descriptions of flood sources and prior flooding. It describes floodprone areas along rivers and streams, along coastal areas and lakeshores, or in shallow flooding areas. FEMA exercises care to ensure that the analytical methods employed in FIS reports are scientifically and technically appropriate, the engineering practices meet professional standards, and the results of the FIS are accurately represented on the flood maps.

Areas within extensive Federal or State holdings and certain sparsely populated areas may not have FIS reports and FIRM or FHBM maps available. In this event, information should be sought from the land administering agency, if applicable, or other Federal agencies. If no other agencies have information or can provide assistance, the services of an experienced consulting engineer should be obtained.

FEMA-issued FIRMs, FIS reports and, when available, FHBMs are available at the local map repository, an office that stores flood maps for public reference. The map repository is usually maintained by the community floodplain administrator or officials at the planning and zoning office. Digital copies of the FEMA products are available online at the Map Service Center (MSC) at http://msc.fema.gov.

FEMA products are tied to the SFHA, defined by the 1-percent-annual-chance flood; therefore, FIRMs, FHBMs, and FIS reports may not depict the floodplain as defined by the FFRMS. Agencies will start with the FEMA products to establish the FFRMS Floodplain when applying the Freeboard Value Approach and the 0.2-percent-annual-chance Flood Approach, unless updated information is available.

2. Use of FEMA Products to Determine the Floodplain for Federally Funded Projects

For federally funded projects subject to the FFRMS, a flood elevation and corresponding floodplain extent must be determined. FEMA products are the starting point for determining the floodplain in these situations; however, FEMA products are not required to be the sole source of information for these determinations. The following sections explain the information available on FEMA products agencies will use to establish the FFRMS floodplain when applying the Freeboard Value Approach and the 0.2-percent-annual-chance Flood Approach. (See Appendix

H for information on determining the FFRMS floodplain using the Climate-informed Science Approach.)

As a result of variations in format and content, all elements described here do not appear on every flood map. The figures in the following sections (Figures 1, 2 and 3) are examples of FEMA products to assist agencies in visualizing floodplains of various exceedances.

2.A Freeboard Value Approach

The basis of the Freeboard Value Approach is the 1-percent-annual-chance flood elevation with either 2 feet or, in the case of critical facilities, 3 feet of additional elevation. The SFHA is defined as the area that has a 1 percent or greater chance of flooding and therefore is a widely available source of the 1-percent-annual-chance flood elevation. The FIS report contains elevation data tables and flood profiles for studied flooding sources and may be used to determine FEMA BFEs for some areas. In most instances, once the vertical elevation of the FFRMS floodplain is established, comparison to ground elevations for the site can be used to determine the horizontal extent of the FFRMS floodplain. FEMA products do not contain site-specific ground elevations and therefore the following sections focus on using FEMA products to obtain the vertical extent of the FFRMS floodplain using the Freeboard Value Approach.

2.A.1 Riverine Hazard Areas

Riverine SFHAs are designated as zones that begin with the letter "A" (e.g. A, AE, A1-30) on FIRM panels (Figure 1) or FHBMs (Figure 2) issued by FEMA. A detailed FIS report may also contain flood profiles for these areas of riverine hazard. Flood profiles (Figure 3) are graphs that usually include elevations for the 10-percent, 2-percent, 1-percent, and 0.2-percent-annual-chance flood. Elevations depicted on the FIRM or FHBM are typically rounded to the nearest whole foot and are for informational purposes only; therefore, agencies should refer to the profile in the FIS report to obtain a more precise Base Flood Elevation.

For most of the Flood Maps produced since January 1985, flood insurance risk zones, base flood elevations, and the regulatory floodway are presented on FIRM panels. These FIRMs present simplified flood insurance risk zone designations for the 1-percent-annual-chance floodplain. Zone AE is used in place of Zones A1 to A30 in riverine areas, and Zone VE is used in place of Zones V1 to V30 in coastal areas. Before January 1985, the regulatory floodway was shown on separate flood maps, called Flood Boundary and Floodway Maps that accompanies the FHBM. Also since 1985, a number of the FIRMs depict areas for the 0.2-percent-annual-chance floodplain as a shaded Zone X. The shaded Zone X is comparable to Zone B on older flood maps. Areas outside the 0.2-percent-annual-chance floodplain are depicted as Zone X without shading. The unshaded Zone X is comparable to Zone C on older flood maps.

Flood hazard information for flooding sources that affect developed or developing areas are based on detailed studies whenever possible; limited-detail study methods, which are less rigorous than detailed methods and do not determine FEMA BFEs or floodways, may be used for undeveloped or sparsely developed areas. In general, the decision whether to use the detailed or limited-detailed method is based on existing and anticipated development in and near the floodplain.

Areas with a limited-detailed study, designated Zone A, are without FEMA BFEs or floodway designations on FIRMs or FHBMs. When FEMA BFE information is not available, agencies may determine the boundary of the 1-percent-annual-chance flood by drawing information from a variety of sources such as soils mapping, actual high water marks, aerial photographs of previous floods, and topographic maps.

Figure 1. Flood Map Panel Elements for a Riverine Flood Hazard Area

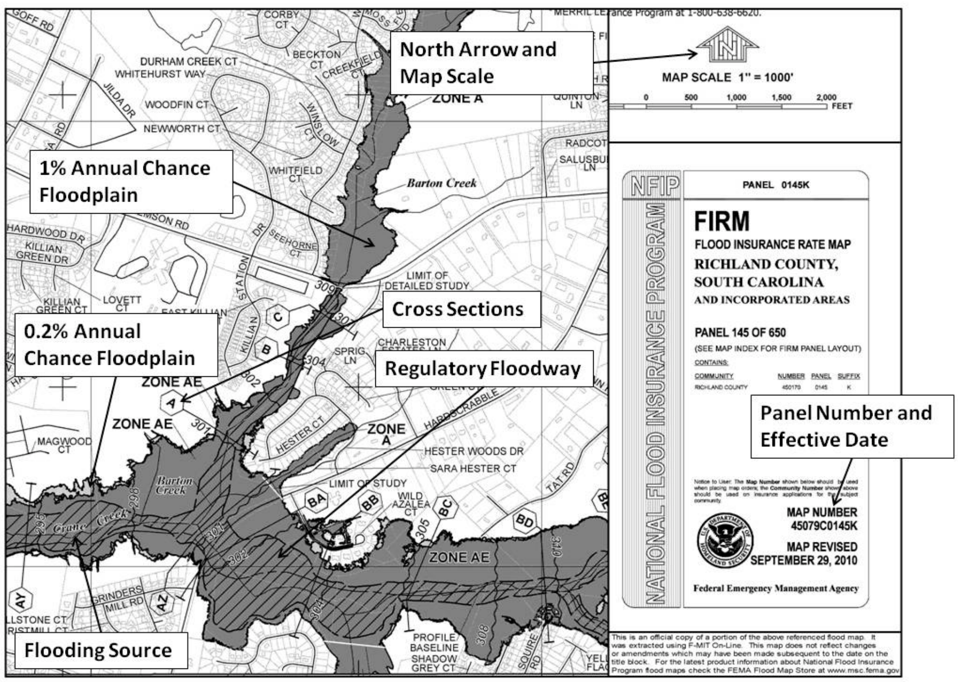


Figure 1 shows an excerpt of a sample FIRM for a riverine flood hazard area. In addition to the base map features (e.g., major highways, roads, railroads, and community boundaries), this map depicts a regulatory floodway, cross sections, flood zones and flood zone boundaries, 1-percent-annual-chance and 0.2-percent-annual-chance floodplains, a north arrow, panel number, effective date, community name, and NFIP community identification number.

Figure 2. Sample Flood Hazard Boundary Map (FHBM)

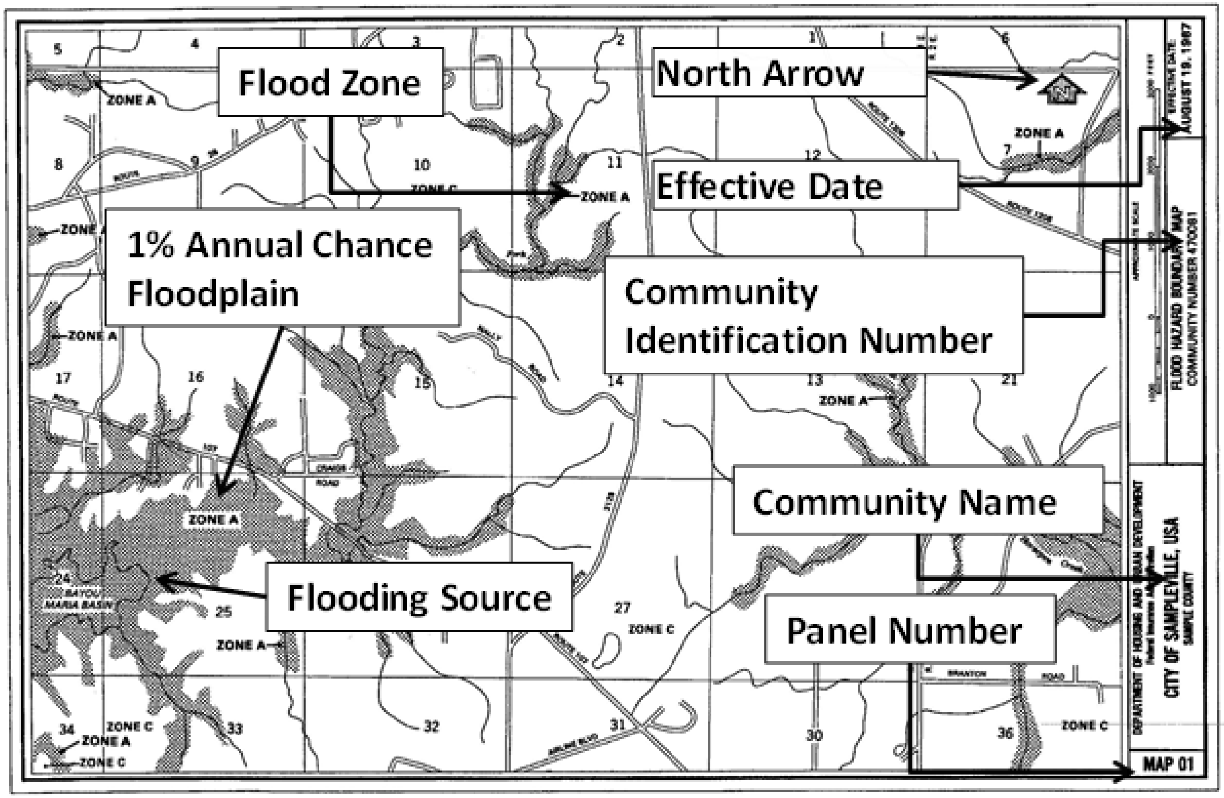


Figure 2 shows a sample FHBM for a riverine flood hazard area. In addition to the base map features (e.g., major highways, roads, and community boundaries), this map depicts riverine flooding sources, flood zones and flood zone boundaries, 1-percent-annual-chance floodplain (Zone A with no FEMA Base Flood Elevations (FEMA BFEs) shown) and areas outside the 0.2-percent-annual-chance floodplains (Zone C), a north arrow, panel number, effective date, community name, and community identification number.

Figure 3. Sample Flood Insurance Study (FIS) and Flood Profile

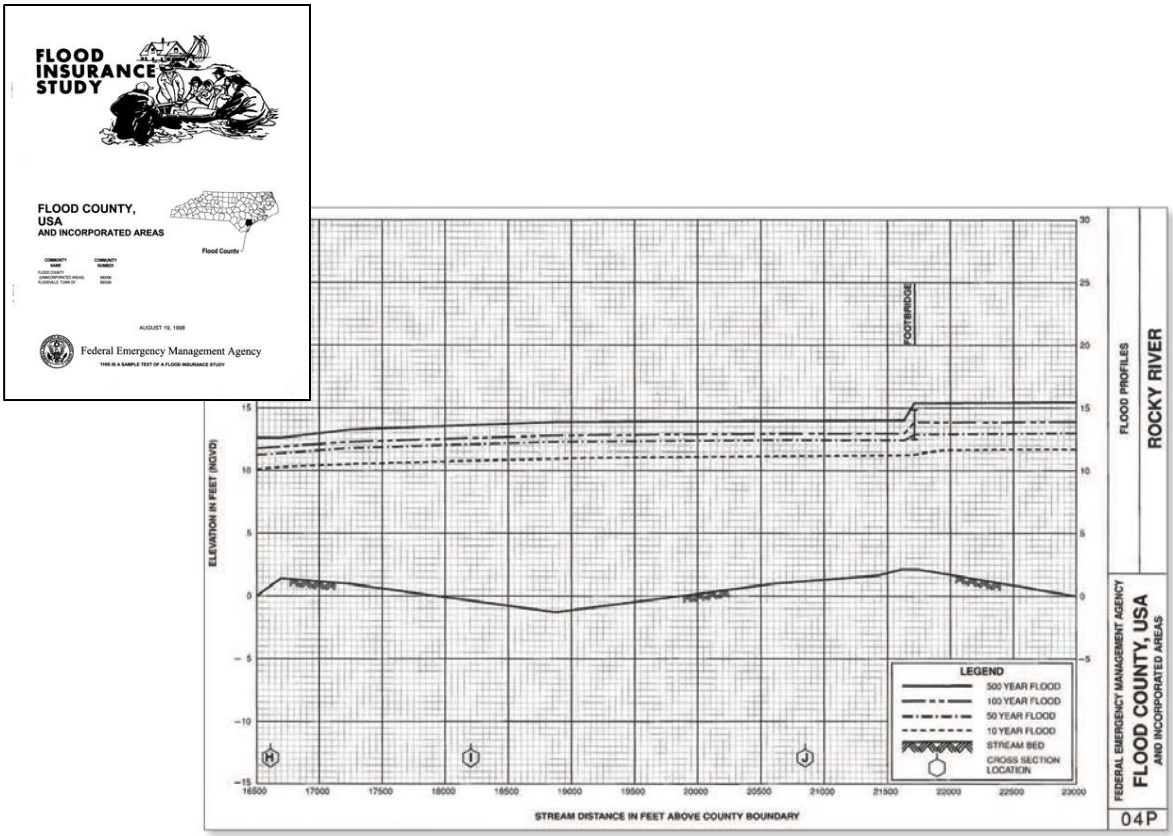


Figure 3 shows the cover of a sample FIS, which is a compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community. It also includes a sample flood profile from an FIS, which shows the stream distance in feet on the horizontal axis (or x-axis), flood elevations in feet on the vertical axis (or y-axis), cross section locations, the stream bed, and a footbridge location.

2.A.2 Coastal Flood Hazard Areas

Coastal flood hazard areas can be designated as V Zones (V, VE, V1-30) or A Zones (A, AE, A1-30) on the FIRMs and FHBMs issues by FEMA (Figure 4). Coastal High Hazard Areas are designated as V Zones where high velocity overland wave action, including wave runup and overtopping, could occur and also include Primary Frontal Dunes, when present. Where a detailed FIS report is produced by FEMA, a coastal analysis may include transects instead of cross sections or profiles. A transect (not exhibited) shows the elevation of the ground including any Primary Frontal Dunes and the expected height of the wave crests and run-up above the storm surge.

V Zones are the more hazardous coastal flood zones because they are subject to high-velocity wave action which will damage or destroy buildings if they are not properly designed and constructed. FEMA applies the V Zone designation to those areas along the coast where water depth and other conditions allow for significant wave hazards and requires agencies to meet the V Zone standards of the NFIP in these areas, including construction on piles and columns and with the construction on fill not allowed. FEMA also typically designates A Zones in coastal areas landward of the V Zone. Coastal flood hazard areas mapped as A Zones can be subject to similar, though somewhat of a lesser, hazard than those expected in V Zones. Post-storm damage assessments have shown that waves as small as 1.5 feet can cause significant damage and destruction to coastal development. As a result, agencies are encouraged to use construction standards for V Zones, including construction on piles and columns and without construction on fill, in coastal A Zones. Information associated with coastal flood hazard areas will be included in the FIS report.

Figure 4. Flood Map Panel Elements for a Coastal Hazard Area Map

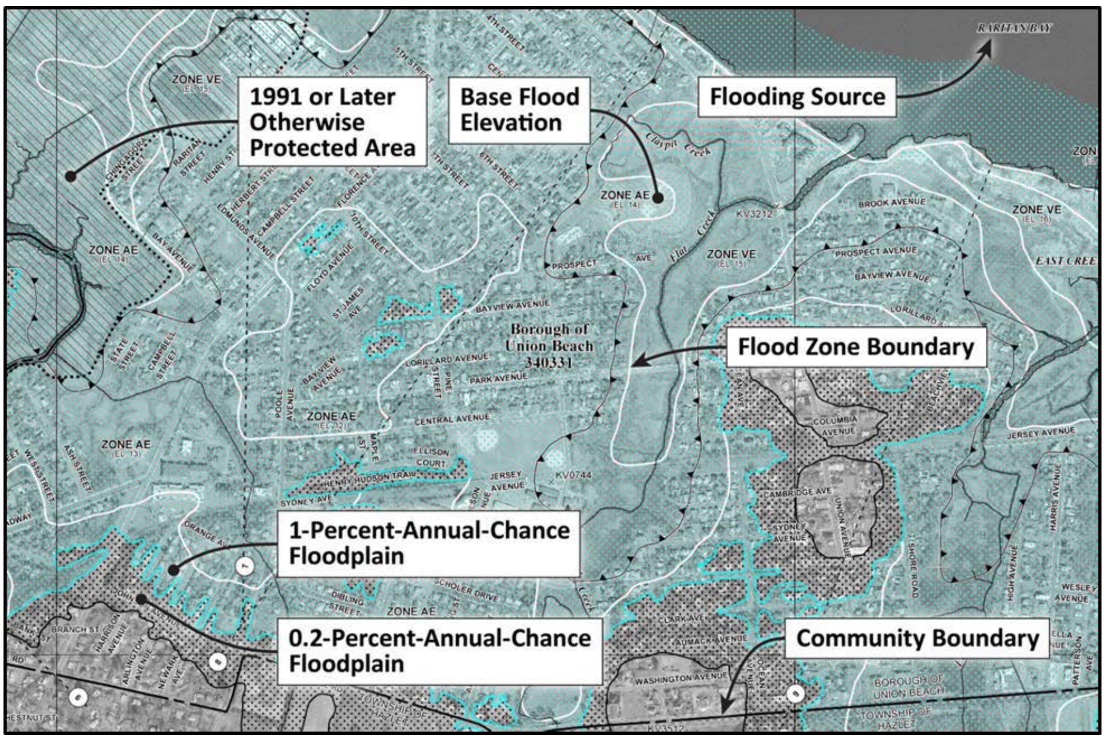


Figure 4 shows a portion of a sample FIRM for a coastal flood hazard area. In addition to the base map features (e.g., major highways, roads, and community boundaries), this map depicts coastal flooding sources, flood zones, 1-percent-annual-chance floodplains (Zone VE with FEMA BFEs rounded to the nearest whole foot and Zone V with no FEMA BFEs), 0.2-percent-annual-chance floodplains (Zone X (shaded)), areas outside the 0.2 percent-annual-chance floodplains (Zone X (unshaded)), and Otherwise Protected Areas (OPAs) of the Coastal Barrier Resources System where Federal flood insurance is unavailable, and which is administered by the U.S. Fish and Wildlife Service.

2.B 0.2-Percent-Annual-Chance Flood Approach

The effective FIRMs and FIS reports for a community typically have information regarding the 0.2-percent-annual-chance flood extent and elevation. When this information is available, the FIRMs can be used as a resource to delineate and establish the FFRMS floodplain.

In some cases where the FEMA 0.2-percent-annual-chance flood elevation does not include a wave height, or a wave height has not been determined, the result may be lower than the effective FEMA BFE or the FEMA BFE plus applicable freeboard. The 0.2-percent-annual-chance flood elevation should not be used in these cases. A Federal department or agency must use the applicable freeboard elevation (i.e., FEMA BFE + 3 feet for Critical Actions, or FEMA BFE + 2 feet for other actions) when higher than the available FEMA 0.2-percent-annual-chance flood elevation.

3. Floodplain Management Considerations

FIRMs depict information other than the SFHA and 0.2-percent-annual-chance floodplain. Additional flooding and floodplain information may be available for local floodplain management and FEMA will depict this information on the effective FIRMs. The following section discusses additional flooding and floodplain information available on FIRMs and the associated NFIP floodplain management considerations.

3.A FEMA Regulatory Floodway

The regulatory floodway is defined as the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the entire base flood (1-percent-annual-chance flood) discharge can be conveyed with no greater than a 1.0-foot increase to the FEMA BFE. A floodway is included in most detailed riverine studies and NFIP communities that have been provided a floodway by FEMA are required to adopt the floodway into their ordinances. The community is also responsible for prohibiting encroachments, including fill, new construction, and substantial improvements, within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge. A number of States have more restrictive floodway standards such as a requirement for a community to adopt a 0.001 to 0.5 foot rise that communities in those States must adopt.

Within the floodplain, extreme hazard is associated with those portions of riverine and coastal floodplains nearest to flood sources, where depths and velocities of floodwaters are greatest. The regulatory floodway in riverine flood hazard areas, with few exceptions, are locations to avoid. Locating buildings, facilities, and other development, including fill, can obstruct flood flows and cause the water to slow down and back up, resulting in higher flood elevations. Actions proposed in the floodway should undergo an encroachment review to determine if the action will cause any of these, or other, impacts to the flooding in the area.

3.B Coastal Flood Hazard

Post-storm field visits and laboratory tests have confirmed that wave heights as low as 1.5 feet can cause significant damage to structures when constructed without consideration to the full array of coastal hazards affecting the site. Additional flood hazards associated with coastal flooding include floating debris, high velocity flow, erosion, and scour, can cause damage to construction in coastal areas, even when designated Zone AE.

To help community officials and property owners recognize this increased potential for damage due to wave action in Zone AE, FEMA issued guidance in December 2008 that identified and mapped the 1.5-foot wave height line, referred to as the Limit of Moderate Wave Action (LiMWA). The LiMWA alerts local officials and property owners on the coastal side of the line that although their property is in the Zone AE area, their property may be adversely affected by waves as low as 1.5 feet high. Consequently, property owners and community officials need to be aware of the high flood risk in the area between this inland limit and the Zone VE boundary, although the risk is not as high as in Zone VE (see Figures 5 and 6).

Figure 5. Depiction of the Limit of Moderate Wave Action (LiMWA)

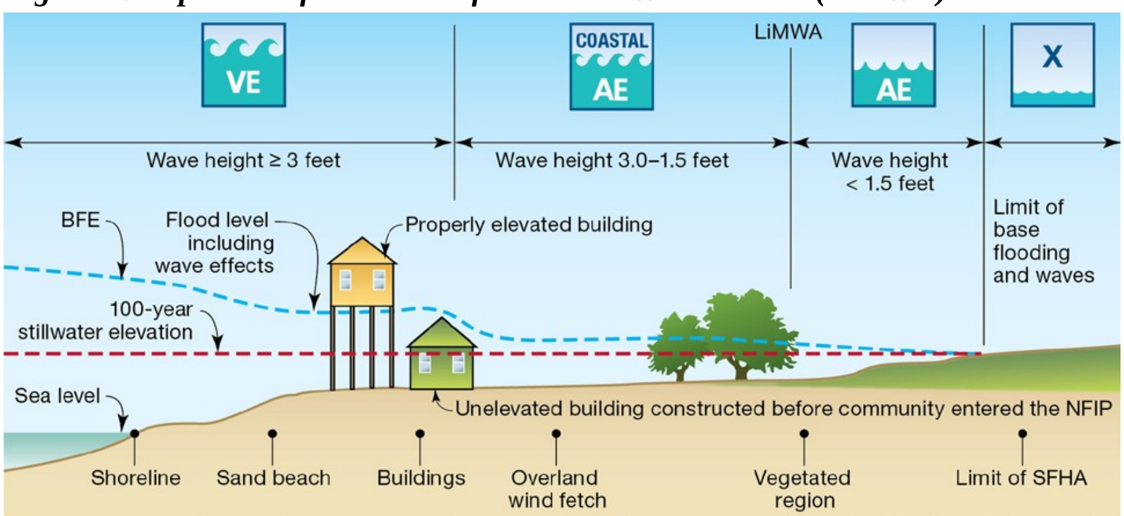
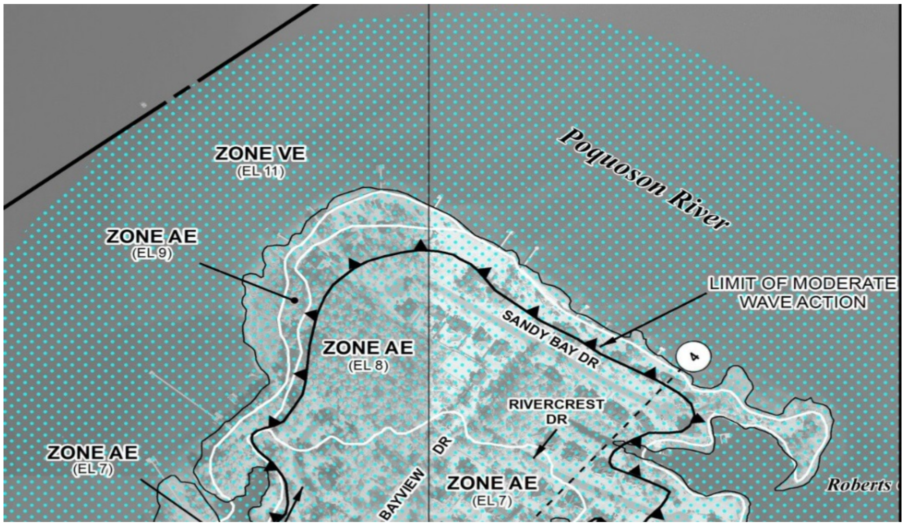


Figure 6. Excerpt of FIRM with Limit of Moderate Wave Action (LiMWA)



Extreme hazard is associated with those portions of coastal floodplains nearest to flood sources, where depths and velocities of floodwaters are greatest and, with few exceptions, are locations to avoid. The coastal high-hazard area, designated as Zones VE and V, is the most hazardous part of the coastal floodplain, due to its exposure to wave effects. These are the floodplain areas where flooding is not only most frequent and damaging, but where natural and beneficial values of the land and water interface are at their maximum. Due to the potential impact of waves, structure elevations in Zones VE and V are taken from the lowest horizontal member of the structure to be compliant with NFIP regulations.

3.C Other Flood Hazard Areas

Other flood hazard areas include sheet flow or shallow flooding areas, wetlands, mudflows, and ground failures such as sinkholes, subsidence, and liquefaction. When a clearly defined channel does not exist, the path of flooding is unpredictable. In some cases, high velocity flow may occur with sheet flow, as is commonly on, for example, alluvial fans, which are shown as Zone AO with depth and velocity on the FIRMs. Areas of shallow flooding are designated on the FIRMS as either AO, AH, AR/AO, or AR/AH and have a 1-percent- annual-chance or greater flooding to an average depth of one (1) to three (3) feet where a clearly defined channel does not exist, where the path of flooding is unpredictable, and where velocity flow may be evident.

An increase in flood hazards may be caused when development occurs in areas drained by sinkholes, which often become plugged. Subsidence and liquefaction of soil may cause flooding of areas in the immediate vicinity of the ground failure, while mudflows may cause damages downstream of the location where the initial ground failure occurred.

APPENDIX C: RELATED PROGRAMS AND REFERENCES

PUBLICATIONS AND WEBSITES

Useful information on many of the subjects discussed in this document is found in the following publications, which describe programs and studies related to the objectives of Executive Order 11988:

2012 International Building Code, International Code Council, Inc., Washington, D.C. http://www.iccsafe.org

A Perspective on Flood Plain Regulations for Flood Plain Management, U.S. Army Corps of Engineers, June, 1976 (Engineer Pamphlet 1165-2-304).

A Unified National Program for Floodplain Management, Federal Interagency Floodplain Management Task Force. 1994 (FEMA 248), Washington, DC.

A Unified National Program for Flood Plain Management, U.S. Water Resources Council. July, 1976.

A Unified National Program for Managing Flood Losses, House Document 465, 89th Congress, 2nd Session. A report by the Task Force on Federal Flood Control Policy, August, 1966.

Building with Nature, Building with Nature shows how to utilize natural processes and provide opportunities for nature while realizing hydraulic infrastructure.
http://www.ecoshape.nl/

Coastal Barrier Resources Act of 1982 (16 U.S.C. 3501 et seq., Pub. L. 97-348).
U.S. Fish and Wildlife Service. http://www.fws.gov/ecological-services/habitat-conservation/coastal.html

Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas (4th Edition) August 2011 (FEMA P-55). https://www.fema.gov/media-library/assets/documents/3293

Coastal Engineering Manual, U.S. Army Corps of Engineers, 2002 (Engineer Manual 1110-2-1100). http://chl.erdc.usace.army.mil/cem

Coastal Risk Reduction and Resilience: Using the Full Array of Measures,
U.S. Army Corps of Engineers, 2013 (CWTS 2013-3).
http://www.corpsclimate.us/docs/USACE_Coastal_Risk_Reduction_final_CWTS_2013-3.pdf

Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds (FEMA P-424) December 1, 2010.
https://www.fema.gov/media-library/assets/documents/5264?id=1986

Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings, (FEMA 543), January 2007.
https://www.fema.gov/media-library/assets/documents/8811?id=2441

Design Guide for Improving Hospital Safety in Earthquakes, Floods, and Winds (FEMA 577), June 2007.
https://www.fema.gov/media-library/assets/documents/10672?id=2739

Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, Water Resources Council, updated by the 2013 Principles and Requirements.
https://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG

Ecosystem-Service Assessment: Research Needs for Coastal Green Infrastructure, National Science and Technology Council - Committee on Environment, Natural Resources, and Sustainability, August 2015.
https://www.whitehouse.gov/sites/default/files/microsites/ostp/cgies_research_agenda_final_082515.pdf

Elevated Residential Structures, U.S. Department of Housing and Urban Development, Federal Insurance Administration. September, 1976.

Environmental Protection Agency's Green Infrastructure Website
Information, tools, case studies, and other resources for implementing green infrastructure.
http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm

Executive Order 13653, Preparing the United States for the Impacts of Climate Change, November 2013.

FEMA Map Service Center (www.msc.fema.gov) provides access to digital versions of effective, historic, and preliminary FIRM panels and associated Flood Insurance Study reports. Other flood risk products may also be available for the community. The Map Service Center also has digital information available to use in GIS applications. Access the above link for more information on these products.

FEMA Mitigation Assessment Team Reports and Recovery Advisories. Various disaster-specific reports can be found at https://edit.fema.gov/fema-mitigation-assessment-team-reports#.

FEMA Building Code Resources found at https://edit.fema.gov/building-code-resources.

FEMA's Technical Bulletins (TBs) found at https://edit.fema.gov/national-flood-insurance-program-2/nfip-technical-bulletins.

Floodproofing Regulations, U.S. Army Corps of Engineers, 1995 (Engineer Pamphlet 1165-2-314).
http://www.publications.usace.army.mil/Portals/76/Publications/EngineerPamphlets/EP_1165-2-314.pdf

Floodproofing Non-Residential Buildings (FEMA 936) July 2013.
https://www.fema.gov/media-library/assets/documents/34270

Flood-Resistant Design and Construction (ASCE-24), American Society of Civil Engineers, 2006.

Flood Plain Management Services Program, U.S. Army Corps of Engineers, 2012
http://www.iwr.usace.army.mil/Portals/70/docs/frmp/FPMS_Factsheet_13SEP2012.pdf

Flood Resilience: A Basic Guide for Water and Wastewater Utilities. EPA 817-B-14-006, September 2014.

Green Infrastructure – Tools, Training and Information (National Oceanic and Atmospheric Administration Digital Coast)
http://coast.noaa.gov/digitalcoast/topic/green-infrastructure

Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects, U.S. Army Corps of Engineers, 2014 (Engineer Construction Bulletin 2014-10).
http://www.iwr.usace.army.mil/Portals/70/docs/Climate%20Change/ecb_2014_10.pdf

Guidelines for Evaluating Hydrologic Hazards, U.S. Department of the Interior, Bureau of Reclamation, 2006

Hydrologic Frequency Analysis, U.S. Army Corps of Engineers, 1993 (Engineer Manual 1110-2-1415). http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1415.pdf

Hydrologic Frequency Estimates, U.S. Army Corps of Engineers, 1994 (Engineer Regulation 1110-2-1450). http://planning.usace.army.mil/toolbox/library/ERs/ER1110-2-1450_31Aug1994.pdf

Incorporating Sea Level Change in Civil Works Programs, U.S. Army Corps of Engineers, 2013 (Engineer Regulation 1100-2-8162). http://planning.usace.army.mil/toolbox/library/Ers/ER_1100-2-8162.pdf

Interagency Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html

National Flood Insurance Program (NFIP) Floodplain Management Requirements. A Study Guide and Desk Reference for Local Officials (FEMA-480). February 2005.

National Hydrography Dataset by the U.S. Geological Survey at: http://nhd.usgs.gov/ to include the “Watershed Boundary Dataset.”

The National Levee Database (NLD) (http://nld.usace.army.mil/) was developed by USACE to serve as the national resource of levee information. The NLD contains information and reports on levee location, the last inspection rating, and other relevant information that could assist with characterizing the level to which the given system is providing the intended level of service, and, therefore, the effects the system performance has on the potential for flooding.

The National Inventory of Dams (NID) (http://nid.usace.army.mil) was developed by USACE to inventory dams in the United States. The NID contains information on dams that likely pose a significant threat to human life or property or equal/exceed 25 feet in height, or impound at least 50 acre-feet in storage. This national resource can be used to consider whether there are dams located near a proposed action. Registered government users can also view dam condition and hazard potential data.

National Spatial Reference System: Replacing NAVD88 and NAD83, NOAA’s National Geodetic Survey is developing new datums, which are expected to be released in 2022. http://www.ngs.noaa.gov/datums/newdatums/index.shtml.

The Natural and Beneficial Functions of Floodplains: Reducing Flood Losses by Protecting and Restoring the Floodplain Environment, Task Force on the Natural and Beneficial Functions of the Floodplain, 2002 (FEMA 409) Washington, DC.

NOAA's River Forecasting Centers http://water.weather.gov/ahps/rfc/rfc.php

NOAA/NWS Atlas 14, Precipitation Frequency Data Server http://hdsc.nws.noaa.gov/hdsc/pfds/ to view local intense precipitation estimates and analyses for local and regional extreme precipitation events leading to flooding (primarily flash flooding).

Planning Assistance to States, U.S. Army Corps of Engineers
http://www.iwr.usace.army.mil/Portals/70/docs/frmp/PAS_Factsheet_13SEP12.pdf

The President's Climate Action Plan, June 2013.
https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

Principles and Requirements for Federal Investments in Water Resources (P&R), March 2013

Principles and Guidelines for Water and Land Relates Resources Implementation Studies (P&G), updated March 2013.

Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation,
U.S. Army Corps of Engineers, 2014 (Engineer Technical Letter 1100-2-1).
http://www.publications.usace.army.mil/Portals/76/Publications/EngineerTechnicalLetters/ETL_1100-2-1.pdf

Protecting Floodplain Resources: A Guidebook for Communities
Federal Interagency Floodplain Management Task Force. 1996 (FEMA 268) Washington, DC.

Rules and Regulations of the National Flood Insurance Program.
Title 44 CFR Emergency Management and Assistance, Parts 59 – 80.
http://www.ecfr.gov/cgi-bin/text-idx?gp=1&SID=a540da382b8d9c011dba25711e9ac7c1&h=L&mc=true&tpl=/ecfrbrowse/Title44/44CIsubchapB.tpl

Regulation of Flood Hazard Areas to Reduce Flood Losses.
A 2-volumework published by the Water Resources Council in 1971-1972. It contains legal aspects of and draft legislation for riverine and coastal floodplain regulation programs of States and local governments.

Recommended Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations, FEMA 550. Second Edition. November 2009.
https://www.fema.gov/media-library/assets/documents/3972

Sea-Level Change Curve Calculator (2014.88)
http://www.corpsclimate.us/ccaceslcurves.cfm

So, You Live Behind a Levee! Preparedness Guide, American Society of Civil Engineers. 2010
http://www.asce.org/Content.aspx?id=2147488910

Systems Approach to Geomorphic Engineering (SAGE)
SAGE is a Community of Practice of Federal, State, and local agencies, non-governmental organizations, academic institutions, engineers, and private businesses working together to use and promote green-gray approaches to ensure coastal community and shoreline resilience.
http://sagecoast.org/index.html

*Substantial Improvement/Substantial Damage Desk Reference (*FEMA P-758) May 2010.
https://www.fema.gov/ar/media-library/assets/documents/18562

U.S. Army Corps of Engineers Flood Risk Management related policies and procedures.
http://operations.usace.army.mil/policy.cfm?CoP=flood

U.S. Army Corps of Engineers Flood Risk Management Program website.
http://www.iwr.usace.army.mil/Missions/FloodRiskManagement/FloodRiskManagementProgram.aspx

U.S. Army Corps of Engineers National Nonstructural Flood Proofing Committee website.
http://www.usace.army.mil/Missions/CivilWorks/ProjectPlanning/nfpc.aspx

U.S. Army Corps of Engineers Silver Jackets Program website.
http://www.nfrmp.us/state/

U.S. Army Corps of Engineers Responses to Climate Change website.
http://www.iwr.usace.army.mil/Missions/ClimateandGlobalChange.aspx

Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience
http://www.nad.usace.army.mil/Portals/40/docs/NACCS/NNBF%20FINAL.pdf

RELEVANT STATUTORY AUTHORITY AND STATEMENT OF CONGRESSIONAL PURPOSE FOR MINIMIZING FLOODPLAIN ENCROACHMENT

There is a large body of Federal legislation relevant to preservation or restoration of floodplains. Some of the major Items of legislation are listed below.

Title and Lead Agencies

Water Resources Planning Act (42 USC 1962), WRC

Watershed Protection and Flood Prevention Act (16 USC 1001), NRCS

Rivers and Harbors Act of 1899 (33 USC 001), USACE

Flood Control Act of 1944 (16 USC 460d et al.), USACE

Flood Disaster Protection Act of 1973 (42 USC 4001), FEMA

Clean Water Act (33 USC 1251), EPA

Coastal Zone Management Act (16 USC 1451), NOAA

Surface Mining Control and Reclamation Act of 1917, OSMRE

"1890 Organic Act" of the National Weather Service (15 USC 311), NOAA

National Environmental Policy Act (42 USC 4321), CEQ

Wild and Scenic Rivers Act (16 USC 1271), NPS

National Trail Systems Act (16 USC 1241), NPS

Fish and Wildlife Coordination Act (16 USC 661), various

Fish and Wildlife Restoration Projects (16 USC 777 and 669), FWS

Endangered Species, Act (16 USC 1531), FWS and NOAA

The Wilderness Act (16 USC 1131). Various

Land and Water Conservation Fund Act (16 USC 4601), DOI

Antiquities Act of 1906 (16 USC 431), DOI

Archeological and Historic Preservation Act of 1974 (16 USC 469), DOI

Agencies should consider reviewing this body of law to uncover opportunities within their existing programs and authorities for protecting the natural and beneficial floodplain values as well as any areas where additional authorities or guidance are needed.

APPENDIX D: FLOODPLAIN SERVICES AVAILABLE FROM LISTED AGENCIES

DEPARTMENT OF AGRICULTURE (USDA)

Natural Resources Conservation Service (NRCS)

Technical and financial assistance available from the NRCS can help landowners and land managers maintain riparian and floodplain setbacks to protect these margins as waterfront areas come under development pressure. NRCS's natural resources conservation programs help people reduce soil erosion, enhance water supplies, improve water quality, increase wildlife habitat, and reduce damages caused by floods and other natural disasters. Additional information is available from NRCS at your local USDA Service Center. For more information, visit NRCS web site at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/mt/water/?cid=nrcs144p2_057954

Land owners and land managers interested in the conservation and enhancement of riparian and floodplain areas on their land may be eligible for technical and financial assistance through the NRCS conservation programs: Wildlife Habitat Incentives Program (WHIP), Environmental Quality Incentives Program (EQIP), Farm and Ranch Lands Protection Program (FRPP), Emergency Watershed Protection Program (EWP), and Wetlands Reserve Program (WRP). For more information, visit NRCS website at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/

DEPARTMENT OF THE ARMY

U.S. Army Corps of Engineers (USACE)

Despite the interdependencies among the numerous flood risk management activities at both the Federal and non-Federal level, no single agency or program exists that effectively addresses all the diverse needs during the flood risk life cycle (preparation, response, recovery and mitigation). The U.S. Army Corps of Engineers established the Silver Jackets Program to assist with ongoing interagency collaboration at the State level. The overarching strategy of the program is that of collaboration and partnership, in support of State-led teams. Teams provide an opportunity to consistently bring together multiple State, Federal, tribal and local agencies to collaboratively apply various programs to manage flood risk. State agencies, including those housing the State Hazard Mitigation Officer and the State National Flood Insurance Program Coordinator, create a common forum with the Federal family of agencies to address their State's flood risk management priorities. For more information, visit the Silver Jackets website at http://www.nfrmp.us/state/.

USACE's separately funded Flood Plain Management Services Program has units in 38 District and Division offices located throughout the country that provide information and assistance to promote effective flood risk and floodplain management. They utilize existing floodplain information, surveys, and other reports containing floodplain delineations, flood profiles, and data on flood discharges and hydrographs. Each office: (1) provides interpretations as to flood depths, velocities and durations from existing data; (2) develops new data through field and hydrologic studies for interpretation; and (3) provides guidance on adjustments to minimize the adverse effects of floods and floodplain development.

The Corps also offers Planning Assistance to States at a required 50/50 cost share. Planning assistance is a water and related resource planning effort that pertains to a drainage basin, or larger region, of a State for which USACE has expertise. The planning process can extend through the functional design process and the preparation of generic structural designs. However, in no case will the term planning assistance extend to the preparation of site-specific structural designs or construction specifications (See Appendix G of Engineer Regulation 1105-2-100).

The USACE Committee on Climate Preparedness and Resilience (CCPR) acts as the highest level of authority for climate preparedness and resilience within USACE. Through this steering committee, USACE develops, implements, and updates comprehensive plans that integrate consideration of climate change into agency operations and mission objectives. This group is responsible for annual updates to the Climate Change Adaptation Plan to describe the vision, goals, and strategic approaches, progress on priority areas, and how USACE plans, integrates, and evaluates measures to adapt to climate change and increase preparedness and resilience. In addition to providing this overarching policy and guidance, the CCPR has overseen the development of numerous guidance documents and tools related to climate change adaptation. Examples include guidance for evaluating and adapting to sea-level change impacts and qualitative approaches to incorporate climate hydrology in planning and design. USACE teams have developed a number of tools, including web-based tools to assess the vulnerability of USACE coastal projects and also watershed vulnerability across business lines, a USACE sea-level rise calculator, and the Sea Level Rise Tool for Sandy Recovery. The Sea Level Rise Tool for Sandy Recovery was developed based on the USACE sea-level rise calculator, in coordination with NOAA, FEMA, and the U.S. Global Change Research Program.

Points of contact for each of the programs described above can be identified through the local District office. To contact the local District office, the following website may be used: http://www.usace.army.mil/Contact/OfficeLocator.aspx.

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration (NOAA)

National Weather Service

Floodplain information and interpretative assistance for specific points on larger rivers of the United States can be obtained from NOAA's National Weather Service. Information available consists of the flood stage and/or flow for river forecast locations (the stage above which flood damage occurs), and historical flood information for that location. The National Weather Service provides all river forecast information products and services via the Advanced Hydrologic Prediction Service (AHPS). AHPS is a web-based suite of accurate and information-rich forecast products. They display the magnitude and uncertainty of occurrence of floods, from hours to days and months, in advance. These graphical products are useful information and planning tools for many economic and emergency managers. These new products enable government agencies, private institutions, and individuals to make more informed decisions about risk based policies and actions to mitigate the dangers posed by floods. The National Weather Service provides flood forecasts and warnings on larger rivers and provides flash flood warnings on smaller streams. Interested communities are assisted in establishing Flash Flood Warnings Systems. For information and assistance contact:

http://water.weather.gov
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East-West Highway
Silver Spring, MD 20910

The National Weather Service also provides storm surges forecasts associated with tropical and extratropical storms. For information and technical assistance regarding storm surge forecast products and services contact:

http://hurricanes.gov/
National Oceanic and Atmospheric Administration
National Weather Service
National Centers for Environmental Prediction
National Hurricane Center
11691 SW 17th Street
Miami, Florida 33165 U.S.A

National Ocean Service

NOAA's **Center for Operational Oceanographic Products and Services** (CO-OPS) is the authoritative source for accurate, reliable, and timely tides, water levels, currents and other oceanographic information. CO-OPS data, products and services support safe and efficient navigation, sound ecosystem stewardship, coastal hazards preparedness and response, and the understanding of climate change. For information and assistance contact:

http://tidesandcurrents.noaa.gov/
National Oceanic and Atmospheric Administration
National Ocean Service
Center for Operational Oceanographic Products and Services
1305 East-West Highway
Silver Spring, MD 20910

A top priority for NOAA's **Office for Coastal Management (OCM)** is unifying efforts to make communities more resilient to the impacts of coastal hazards and climate change. Many organizations are involved, including the private sector, nonprofits, the scientific community, and all levels of government. OCM works to be a unifying force in these efforts, providing unbiased NOAA data and tools and providing opportunities for the community to come together to define common goals and find ways to work smarter by working together. As part of this effort, OCM administers the National Coastal Zone Management Program, a voluntary partnership between the Federal government and U.S. coastal and Great Lakes States and territories authorized by the Coastal Zone Management Act of 1972 to address national coastal issues. Additionally, on behalf of a partnership of nine organizations, OCM hosts and manages the Digital Coast, a website that provides not only coastal data, but also the tools, training, and information needed to make these data truly useful. Content comes from many sources, all of which are vetted by NOAA. Coastal inundation, resilience planning, and coastal management are key focus areas for the Digital Coast.

http://coast.noaa.gov/
http://coast.noaa.gov/czm/about/
http://coast.noaa.gov/digitalcoast/
National Oceanic and Atmospheric Administration
National Ocean Service
Office for Coastal Management
1305 East-West Highway
Silver Spring, MD 20910

Oceanic and Atmospheric Research – Climate Program Office

NOAA's Climate Program Office (CPO) manages competitive research programs in which NOAA funds high-priority climate science, assessments, decision support research, outreach, education, and capacity-building activities designed to advance our understanding of Earth's climate system, and to foster the application of this knowledge in risk management and adaptation efforts.

CPO led NOAA's efforts to develop the global sea level rise projections used in the Third U.S. National Climate Assessment. This report synthesizes the scientific literature on global sea level rise and provides four global scenarios. The report includes input from national experts in climate science, physical coastal processes, and coastal management.

http://cpo.noaa.gov/
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Climate Program Office
1315 East-West Highway
Silver Spring, MD 20910

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD)

Office of Environment and Energy

HUD Office of Environment and Energy (OEE) staff at local and regional offices have specific knowledge of flood elevations for many urban locations. OEE staff can assist in making floodplain determinations for HUD-assisted projects. HUD staff can be found on the web at (https://www.hudexchange.info/environmental-review/hud-environmental-staff-contacts/) or by contacting:

HUD Office of Environment and Energy
451 Seventh Street SW, Room 7212
Washington, DC 20410
Telephone: 202-402-4571

DEPARTMENT OF HOMELAND SECURITY

Federal Emergency Management Agency (FEMA)

Flood Mapping

Requests for Flood Insurance Rate Maps (FIRMs), Flood Hazard Boundary Maps (FHBMs), Flood Insurance Study (FIS) reports, or other flood study data used in their development, should be addressed as follows:

The FEMA Flood Map Service Center (MSC) at http://msc.fema.gov is the official public source for flood hazard information produced in support of FEMA's National Flood Insurance Program (NFIP). FIRMs, FIS reports, and all other information available on the MSC may be accessed and downloaded at no cost. For questions, the MSC may also be contacted by telephone toll-free at 1-877-FEMA MAP (1-877-336-2627).

Subscription services are available that allow any user to receive notifications when new products matching their provided parameters are posted to the MSC, as well as enabling subscribers to download new products directly from their account.

Floodplain Management and Building Science

The Floodplain Management Branch in conjunction with the FEMA Regional Offices provides assistance and information to communities on how to join the National Flood Insurance Program, participate in the Community Rating System and other topics related to the adoption and enforcement of floodplain management standards.

To determine whether the proposed Federal action may take place in a community that participates in the NFIP, consult the Community Status Book (CSB), the official source of NFIP participation, on FEMA's website. The CSB contains the date of a community's entry into the program, whether it has a FIRM or FHBM, and the effective map date. The CSB also lists communities that are floodprone but do not participate in the NFIP and are considered "sanctioned communities."

The Building Science Branch in support of the Federal Insurance and Mitigation Administration (FIMA), States, local communities and other Federal Agencies develops multi-hazard mitigation guidance, tools, training and reports that focuses on creating disaster-resilient communities to reduce loss of life and property.

For questions, coordination, and technical assistance with FEMA's Regional Offices and information about community officials of the local jurisdiction within which the action is proposed to be carried out, contact:

Region I	Boston, MA, 877-336-2734
Region II	New York, NY, 212-680-3600
Region III	Philadelphia, PA, 215-931-5500
Region IV	Atlanta, GA, 770-220-5200
Region V	Chicago, IL, 312-408-5500

Region VI	Denton, TX, 940-898-5399
Region VII	Kansas City, MO, 816-283-7061
Region VIII	Denver, CO, 303-235-4800
Region IX	Oakland, CA, 510-627-7184
Region X	Bothell, WA, 425-487-4600

Requests for floodplain management technical services may be made to the Chief, Floodplain Management Branch, Risk Reduction Division, in writing to:

FEMA
500 C Street, SW
Washington, D.C. 20472

Please visit FEMA's website for current staff contact information.

DEPARTMENT OF THE INTERIOR

U.S. Geological Survey (USGS)

Using assistance centers at 48 locations, the USGS can provide: (A) factual information on flood peaks and discharges, flood depths, and velocities, profiles of the water surface during major floods, areas inundated during major floods, time of travel flood wave, and sediment transport data; (B) interpretive information regarding flood frequency relations, and estimates of the 10-, 50-, 100- and 500-year flood discharges in most communities in the United States with known flood problems; and (C) assistance in minimizing flood losses by quickly identifying areas of potential flood hazards. If the user assistance center address is not known, contact:

Chief, Surface Water Branch, Water Resources Division
U.S. Geological Survey, National Ctr.
Reston, VA. 22092
Telephone: 703-860-6837

The Bureau of Land Management (BLM)

The Bureau of Land Management has district offices located in the 11 Western States and Alaska involved in land use planning for public lands. Floodplain protection and flood prevention is a significant element in the BLM planning system, and each district office maintains a file of existing floodplain maps which are available for public inspection. If the location of the district office is not known, contact:

Bureau of Land Management

U.S. Department of the Interior
18th and C Streets, NW
Washington DC 20240
Telephone: 202-343-5717.

Bureau of Reclamation

The flood hydrologists in the five regional offices, the area offices, or the Denver office have knowledge of flooding and flood elevation for related locations associated with Bureau projects and can provide interpretive assistance for existing data. For information contact one of the five regional offices, an area office, or the Denver office. Contact can be found at:
http://www.usbr.gov/main/regions.html

U.S. Fish and Wildlife Service (FWS)

The FWS provides expertise and technical assistance relating to fish and wildlife resources across the country and internationally, habitat restoration and protection, tribal assistance, coastal resources including the Coastal Barrier Resources System, and FWS facility maintenance. FWS functions through eight regional offices and one headquarters office, as well as many field offices and refuges across the country. For information contact any FWS office, or the Fish and Wildlife Service, U.S. Department of the Interior, 18 and C streets and W Washington DC 20240. Telephone: 202-343-5715 and web http://www.fws.gov/

For information specific to the Coastal Barrier Resources System, send an email to cbra@fws.gov.

TENNESSEE VALLEY AUTHORITY (TVA)

Activities in water resources are confined to portions of the seven States in the Tennessee Valley Watershed. From 1953 to 1994, TVA conducted a program of floodplain management assistance to local governments. Reports were published for more than 130 communities, and profiles and flood data were provided to at least 70 others. Detailed information in files pertains to large floods which have occurred in the Valley since the 1930's, and in less detail, dating back to the large flood of 1867. TVA's River Management staff provides limited assistance to help those who propose developments in floodplains to use the floodplain wisely. Contact:

Tennessee Valley Authority, River Management-Flood Risk
400 West Summit Hill Drive
Mail Stop WT-10C
Knoxville, TN 37902-1499
http://www.tva.com/river/flood/index.htm

DELAWARE RIVER BASIN COMMISSION

The Commission maintains a file of floodplain information, delineation and flood Data Studies prepared by the Commission, Federal agencies and others. Where data exists, assistance with interpretation will be provided. Contact:

Head, Branch of operations
Delaware River Basin Commission
PO Box 7360
West Trenton, NJ 08628
Telephone: 609-883-9500

SUSQUEHANNA RIVER BASIN COMMISSION

The Commission maintains a file of detailed hydrologic and hydraulic information for 245 basin communities studied under the NFIP for HUD. Limited additional hydrologic data for other areas is also available. The Commission can provide general information and guidance on floodplain management measures. Contact:

Chief, Planning and Operations
Susquehanna River Basin Commission
1721 N. Front St.
Harrisburg, PA 17102
Telephone: 717-238-0425

STATES

Many (but not all) States have active floodplain management programs. They have on file, or access to, most floodplain information generated by Federal and State agencies, regional organizations, special districts and private consultants. State agencies are usually staffed and funded to: (1) coordinate floodplain management activities; (2) develop minimum standards for floodplain regulations; (3) assist local units of government (counties, cities, etc.) in developing floodplain management programs; and (4) interpret available floodplain information. For most States, the appropriate contact is the Department of Natural Resources or the Water Resources Division. At the sub-state level, regional agencies such as conservancy districts and multicounty planning agencies may be a source of floodplain data and interpretation.

APPENDIX E: EXECUTIVE ORDER 11988 - FLOODPLAIN MANAGEMENT (AS AMENDED BY EXECUTIVE ORDER 13690 ON 1/29/15)

Floodplain management
Source: The provisions of Executive Order 11988 of May 24, 1977, appear at 42 FR 26951, 3 CFR, 1977 Comp., p. 117, unless otherwise noted.

By virtue of the authority vested in me by the Constitution and statutes of the United States of America, and as President of the United States of America, in furtherance of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 *et seq.*), the National Flood Insurance Act of 1968, as amended (42 U.S.C. 4001 *et seq.*), and the Flood Disaster Protection Act of 1973 (Public Law 93-234, 87 Stat. 975), in order to avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative, it is hereby ordered as follows:

Section 1. Each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for (1) acquiring, managing, and disposing of Federal lands, and facilities; (2) providing federally undertaken, financed, or assisted construction and improvements; and (3) conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities.

Section 2. In carrying out the activities described in Section 1 of this Order, each agency has a responsibility to evaluate the potential effects of any actions it may take in a floodplain; to ensure that its planning programs and budget request reflect consideration of flood hazards and floodplain management; and to prescribe procedures to implement the policies and requirements of this Order, as follows, to the extent permitted by law:

(a)(1) Before taking an action, each agency shall determine whether the proposed action will occur in a floodplain--for major Federal actions significantly affecting the quality of the human environment, the evaluation required below will be included in any statement prepared under Section 102(2) (C) of the National Environmental Policy Act. To determine whether the action is located in a floodplain, the agency shall use one of the approaches in Section 6(c) of this Order based on the best-available information and the Federal Emergency Management Agency's effective Flood Insurance Rate Map.

(2) If an agency has determined to, or proposes to, conduct, support, or allow an action to be located in a floodplain, the agency shall consider alternatives to avoid adverse effects and incompatible development in the floodplains. Where possible, an agency shall use natural systems, ecosystem processes, and nature-based approaches when developing alternatives for consideration. If the head of the agency finds that the only practicable alternative consistent with the law and with the policy set forth in this Order requires sitting in a floodplain, the agency shall, prior to taking action, (i) design or modify its action in order to minimize potential harm to or within the floodplain, consistent with regulations issued in accord with Section 2(d) of this Order, and (ii) prepare and circulate a notice containing an explanation of why the action is proposed to be located in the floodplain.

(3) For programs subject to the Office of Management and Budget Circular A-95, the agency shall send the notice, not to exceed three pages in length including a location map, to the State and areawide A-95 clearinghouses for the geographic areas affected. The notice shall include: (i) the reasons why the action is proposed to be located in a floodplain; (ii) a statement indicating whether the action conforms to applicable State or local floodplain protection standards and (iii) a list of the alternatives considered. Agencies shall endeavor to allow a brief comment period prior to taking any action.

(4) each agency shall also provide opportunity for early public review of any plans or proposals for actions in floodplains, in accordance with Section 2(b) of Executive Order No. 11514 as amended, including the development of procedures to accomplish this objective for Federal actions whose impact is not significant enough to require the preparation of an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969, as amended.

(b) Any requests for new authorizations or appropriations transmitted to the Office of Management and Budget shall indicate, if an action to be proposed will be located in a floodplain, whether the proposed action is in accord with this Order.

(c) Each agency shall take floodplain management into account when formulating or evaluating any water and land use plans and shall require land and water resources use appropriate to the degree of hazard involved. Agencies shall include adequate provision for the evaluation and consideration of flood hazards in the regulations and operating procedures for the licenses, permits, loan or grants-in-aid programs that they administer. Agencies shall also encourage and provide appropriate guidance to applicants to evaluate the effects of their proposals in floodplains prior to submitting applications for Federal licenses, permits, loans or grants.

(d) As allowed by law, each agency shall issue or amend existing regulations and procedures within one year to comply with this Order. These procedures shall incorporate the Unified National Program for Floodplain Management of the Water Resources Council,[2] and shall explain the means that the agency will employ to pursue the nonhazardous use of riverine, coastal and other floodplains in connection with the activities under its authority. To the extent possible, existing processes, such as those of the Council on Environmental Quality and the Water Resources Council, shall be utilized to fulfill the requirements of this Order. Agencies shall prepare their procedures in consultation with the Water Resources Council, the Administrator of the Federal Emergency Management Agency, and the Council on Environmental Quality, and shall update such procedures as necessary.

[Sec. 2 amended by Executive Order 12148 of July 20, 1979, 44 FR 43239, 3 CFR, 1979 Comp., p. 412]

Section 3. In addition to the requirements of Section 2, agencies with responsibilities for Federal real property and facilities shall take the following measures:

(a) The regulations and procedures established under Section 2(d) of this Order shall, at a minimum, require the construction of Federal structures and facilities to be in accordance with the standards and criteria and to be consistent with the intent of those promulgated under the National Flood Insurance Program. The regulations and procedures must also be consistent with the Federal Flood Risk Management Standard (FFRMS).They shall deviate only to the extent that the standards of the Flood Insurance Program and FFRMS are demonstrably inappropriate for a given type of structure or facility.

(b) If, after compliance with the requirements of this Order, new construction of structures or facilities are to be located in a floodplain, accepted floodproofing and other flood protection measures shall be applied to new construction or rehabilitation. To achieve flood protection, agencies shall, wherever practicable, elevate structures above the elevation of the floodplain as defined in Section 6(c) of this Order rather than filling in land.

(c) If property used by the general public has suffered flood damage or is located in an identified flood hazard area, the responsible agency shall provide on structures, and other places where appropriate, conspicuous delineation of past and probable flood height in order to enhance public awareness of and knowledge about flood hazards.

(d) When property in floodplains is proposed for lease, easement, right-of-way, or disposal to non-Federal public or private parties, the Federal agency shall (1) reference in the conveyance those uses that are restricted under identified Federal, State or local floodplain

[2] **Editorial note:** Inactive as of Oct. 1, 1982.

regulations; and (2) attach other appropriate restrictions to the uses of properties by the grantee or purchaser and any successors, except where prohibited by law; or (3) withhold such properties from conveyance.

Sec. 4. In addition to any responsibilities under this Order and Sections 102, 202, and 205 of the Flood Disaster Protection Act of 1973, as amended (42 U.S.C. 4012a, 4106, and 4128), agencies which guarantee, approve, regulate, or insure any financial transaction which is related to an area located in an area subject to the base flood shall, prior to completing action on such transaction, inform any private parties participating in the transaction of the hazards of locating structures in the area subject to the base flood.

Sec. 5. The head of each agency shall submit a report to the Council on Environmental Quality and to the Water Resources Council on June 30, 1978, regarding the status of their procedures and the impact of this Order on the agency's operations. Thereafter, the Water Resources Council shall periodically evaluate agency procedures and their effectiveness.

Sec. 6. As used in this Order:

(a) The term "agency" shall have the same meaning as the term "Executive agency" in Section 105 of Title 5 of the United States Code and shall include the military departments; the directives contained in this Order, however, are meant to apply only to those agencies which perform the activities described in Section 1 which are located in or affecting floodplains.

(b) The term "base flood" shall mean that flood which has a one percent or greater chance of occurrence in any given year.

(c) The term "floodplain" shall mean the lowland and relatively flat areas adjoining inland and coastal waters including floodprone areas of offshore islands. The floodplain shall be established using one of the following approaches:

(1) Unless an exception is made under paragraph (2), the floodplain shall be:

(i) the elevation and flood hazard area that result from using a climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science. This approach will also include an emphasis on whether the action is a critical action as one of the factors to be considered when conducting the analysis;

(ii) the elevation and flood hazard area that result from using the freeboard value, reached by adding an additional 2 feet to the base flood elevation for non-critical actions and by adding an additional 3 feet to the base flood elevation for critical actions;

(iii) the area subject to flooding by the 0.2 percent annual chance flood; or

(iv) the elevation and flood hazard area that result from using any other method identified in an update to the FFRMS.

(2) The head of an agency may except an agency action from paragraph (1) where it is in the interest of national security, where the agency action is an emergency action, where application to a Federal facility or structure is demonstrably inappropriate, or where the agency action is a mission-critical requirement related to a national security interest or an emergency action. When an agency action is excepted from paragraph (1) because it is in the interest of national security, it is an emergency action, or it is a mission-critical requirement related to a national security interest or an emergency action, the agency head shall rely on the area of land subject to the base flood.

(d) The term 'critical action' shall mean any activity for which even a slight chance of flooding would be too great.

Sec. 7. Executive Order No. 11296 of August 10, 1966, is hereby revoked. All actions, procedures, and issuances taken under that Order and still in effect shall remain in effect until modified by appropriate authority under the terms of this Order.

Sec. 8. Nothing in this Order shall apply to assistance provided for emergency work essential to save lives and protect property and public health and safety, performed pursuant to Sections 403 and 502 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 (42 U.S.C. 5170b and 5192).

Sec. 9. To the extent the provisions of section 2(a) of this Order are applicable to projects covered by Section 104(h) of the Housing and Community Development Act of 1974, as amended (88 Stat. 640, 42 U.S.C. 5304(h)), the responsibilities under those provisions may be assumed by the appropriate applicant, if the applicant has also assumed, with respect to such projects, all of the responsibilities for environmental review, decisionmaking, and action pursuant to the National Environmental Policy Act of 1969, as amended.

APPENDIX F: EXECUTIVE ORDER 13690 ESTABLISHING A FEDERAL FLOOD RISK MANAGEMENT STANDARD AND A PROCESS FOR FURTHER SOLICITING AND CONSIDERING STAKEHOLDER INPUT

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to improve the Nation's resilience to current and future flood risk, I hereby direct the following:

Section 1. Policy. It is the policy of the United States to improve the resilience of communities and Federal assets against the impacts of flooding. These impacts are anticipated to increase over time due to the effects of climate change and other threats. Losses caused by flooding affect the environment, our economic prosperity, and public health and safety, each of which affects our national security.

The Federal Government must take action, informed by the best-available and actionable science, to improve the Nation's preparedness and resilience against flooding. Executive Order 11988 of May 24, 1977 (Floodplain Management), requires executive departments and agencies (agencies) to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative. The Federal Government has developed processes for evaluating the impacts of Federal actions in or affecting floodplains to implement Executive Order 11988.

As part of a national policy on resilience and risk reduction consistent with my Climate Action Plan, the National Security Council staff coordinated an interagency effort to create a new flood risk reduction standard for federally funded projects. The views of Governors, mayors, and other stakeholders were solicited and considered as efforts were made to establish a new flood risk reduction standard for federally funded projects. The result of these efforts is the Federal Flood Risk Management Standard (Standard), a flexible framework to increase resilience against flooding and help preserve the natural values of floodplains. Incorporating this Standard will ensure that agencies expand management from the current base flood level to a higher vertical elevation and corresponding horizontal floodplain to address current and future flood risk and ensure that projects funded with taxpayer dollars last as long as intended.

This order establishes the Standard and sets forth a process for further solicitation and consideration of public input, including from Governors, mayors, and other stakeholders, prior to implementation of the Standard.

Sec. 2. Amendments to Executive Order 11988. Executive Order 11988 is amended as follows:

(a) Section 2 is amended by inserting ", to the extent permitted by law" after "as follows".

(b) Section 2(a)(1) is amended by striking "This Determination shall be made according to a Department of Housing and Urban Development (HUD) floodplain map or a more detailed map of an area, if available. If such maps are not available, the agency shall make a determination of the location of the floodplain based on the best-available information. The Water Resources Council shall issue guidance on this information not later than October 1, 1977" and inserting in lieu thereof "To determine whether the action is located in a floodplain, the agency shall use one of the approaches in Section 6(c) of this Order based on the best-available information and the Federal Emergency Management Agency's effective Flood Insurance Rate Map".

(c) Section 2(a)(2) is amended by inserting the following sentence after the first sentence:

"Where possible, an agency shall use natural systems, ecosystem processes, and nature-based approaches when developing alternatives for consideration."

(d) Section 2(d) is amended by striking "Director" and inserting "Administrator" in lieu thereof.

(e) Section 3(a) is amended by inserting the following sentence after the first sentence:

"The regulations and procedures must also be consistent with the Federal Flood Risk Management Standard (FFRMS)."

(f) Section 3(a) is further amended by inserting "and FFRMS" after "Flood Insurance Program".

(g) Section 3(b) is amended by striking "base flood level" and inserting "elevation of the floodplain as defined in Section 6(c) of this Order" in lieu thereof.

(h) Section 4 is revised to read as follows:

"In addition to any responsibilities under this Order and Sections 102, 202, and 205 of the Flood Disaster Protection Act of 1973, as amended (42 U.S.C. 4012a, 4106, and 4128), agencies which guarantee, approve, regulate, or insure any financial transaction which is related to an area located in an area subject to the base flood shall, prior to completing action on such transaction, inform any private parties participating in the transaction of the hazards of locating structures in the area subject to the base flood.".

(i) Section 6(c) is amended by striking ", including at a minimum, that area subject to a one percent or greater chance of flooding in any given year" and inserting in lieu thereof:

". The floodplain shall be established using one of the following approaches:

"(1) Unless an exception is made under paragraph (2), the floodplain shall be:

"(i) the elevation and flood hazard area that result from using a climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science. This approach will also include an emphasis on whether the action is a critical action as one of the factors to be considered when conducting the analysis;

"(ii) the elevation and flood hazard area that result from using the freeboard value, reached by adding an additional 2 feet to the base flood elevation for non-critical actions and by adding an additional 3 feet to the base flood elevation for critical actions;

"(iii) the area subject to flooding by the 0.2 percent annual chance flood; or

"(iv) the elevation and flood hazard area that result from using any other method identified in an update to the FFRMS.

"(2) The head of an agency may except an agency action from paragraph (1) where it is in the interest of national security, where the agency action is an emergency action, where application to a Federal facility or structure is demonstrably inappropriate, or where the agency action is a mission-critical requirement related to a national security interest or an emergency action. When an agency action is excepted from paragraph (1) because it is in the interest of national security, it is an emergency action, or it is a mission-critical requirement related to a national security interest or an emergency action, the agency head shall rely on the area of land subject to the base flood".

(j) Section 6 is further amended by adding the following new subsection (d) at the end:

"(d) The term 'critical action' shall mean any activity for which even a slight chance of flooding would be too great.”

(k) Section 8 is revised to read as follows:

"Nothing in this Order shall apply to assistance provided for emergency work essential to save lives and protect property and public health and safety, performed pursuant to Sections 403 and 502 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 (42 U.S.C. 5170b and 5192).".

Sec. 3. Agency Action. (a) Prior to any action to implement the Standard, additional input from stakeholders shall be solicited and considered. To carry out this process:

(i) the Federal Emergency Management Agency, on behalf of the Mitigation Framework Leadership Group, shall publish for public comment draft amended Floodplain Management Guidelines for Implementing Executive Order 11988 (Guidelines) to provide guidance to agencies on the implementation of Executive Order 11988, as amended, consistent with the Standard;

(ii) during the comment period, the Mitigation Framework Leadership Group shall host public meetings with stakeholders to solicit input; and

(iii) after the comment period closes, and based on the comments received on the draft Guidelines during the comment period, in accordance with subsections (a)(i) and (ii) of this section, the Mitigation Framework Leadership Group shall provide recommendations to the Water Resources Council.

(b) After additional input from stakeholders has been solicited and considered as set forth in subsections (a)(i) and (ii) of this section and after consideration of the recommendations made by the Mitigation Framework Leadership Group pursuant to subsection (a)(iii) of this section, the Water Resources Council shall issue amended Guidelines to provide guidance to agencies on the implementation of Executive Order 11988, as amended, consistent with the Standard.

(c) To the extent permitted by law, each agency shall, in consultation with the Water Resources Council, Federal Interagency Floodplain Management Task Force, Federal Emergency Management Agency, and Council on Environmental Quality, issue or amend existing regulations and procedures to comply with this order, and update those regulations and procedures as warranted. Within 30 days of the closing of the public comment period for the draft amendments to the Guidelines as described in subsection (a) of this section, each agency shall submit an implementation plan to the National Security Council staff that contains milestones and a timeline for implementation of this order and the Standard, by the agency as it applies to the agency's processes and mission. Agencies shall not issue or amend existing regulations and procedures pursuant to this subsection until after the Water Resources Council has issued amended Guidelines pursuant to subsection (b) of this order.

Sec. 4. Reassessment. (a) The Water Resources Council shall issue any further amendments to the Guidelines as warranted.

(b) The Mitigation Framework Leadership Group in consultation with the Federal Interagency Floodplain Management Task Force shall reassess the Standard annually, after seeking stakeholder input, and provide recommendations to the Water Resources Council to update the Standard if warranted based on accurate and actionable science that takes into account changes to climate and other changes in flood risk. The Water Resources Council shall issue an update to the Standard at least every 5 years.

Sec. 5. General Provisions. (a) Nothing in this order shall be construed to impair or otherwise affect:

(i) the authority granted by law to an executive department, agency, or the head thereof; or

(ii) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(b) This order shall be implemented consistent with applicable law and subject to the availability of appropriations.

(c) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

(d) The Water Resources Council shall carry out its responsibilities under this order in consultation with the Mitigation Framework Leadership Group.

APPENDIX G: FEDERAL FLOOD RISK MANAGEMENT STANDARD

Federal Flood Risk Management Standard

October 8, 2015

This version of the FFRMS updates and supersedes the version released on January 30, 2015

CONTENTS

Use of Executive order 11988, Floodplain Management and Relationship to the FFRMS

This Federal Flood Risk Management Standard (FFRMS or Standard) was established by Executive Order (E.O.) 13690 which required agencies to incorporate it into their existing procedures for implementing E.O. 11988. The *Guidelines for Implementing Executive Order 11988, Floodplain Management* have been revised to provide additional direction to agencies responsible for implementation. The new document is titled *Guidelines for Implementing Executive Order 11988, Floodplain Management, And Executive Order 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input* (Guidelines).

Development and Update of the Federal Flood Risk Management Standard

The Mitigation Framework Leadership Group (MitFLG), established through the National Mitigation Framework (NMF) through Presidential Policy Directive 8 (PPD-8), developed this Standard and will continue to reassess the Standard in order to provide recommendations for updating the Standard to the Water Resources Council in consultation with the Federal Interagency Floodplain Management Task Force (FIFM-TF). The FIFM-TF works to promote the health, safety, and welfare of the public by encouraging programs and policies that reduce flood losses and protect the natural environment through improved coordination, collaboration, and transparency in floodplain management efforts within the Federal Government. As a senior-level group that promotes coordination of mitigation efforts across the Federal Government, MitFLG is responsible for assessing the effectiveness of Mitigation core capabilities as they are developed and deployed across the Nation. To that end, the MitFLG facilitates information exchange, coordinates policy implementation recommendations on national-level issues and oversees the successful implementation of the NMF.

Application of the FFRMS

As articulated in E.O. 13690, the FFRMS is the result of an interagency effort to create a new flood risk management standard for federally funded projects. The FFRMS is a flexible framework to increase resilience against flooding and help preserve the natural values of floodplains. Incorporating this standard into existing agency processes will ensure that agencies expand management from the current base flood level to a higher vertical elevation and corresponding horizontal floodplain so that federally funded projects will last as long as intended. In short, the FFRMS has been developed to create a national minimum flood risk management standard to ensure that federally funded projects that are located in or near the floodplain when there are no other practical alternatives last as long as intended by considering risks, changes in climate, and vulnerability.

The FFRMS improves the implementation of E.O. 11988 through the following enhancements: (1) it encourages the use of natural features and nature-based approaches in the development of alternatives for all Federal actions; and (2) it provides approaches to establishing a higher vertical elevation and corresponding floodplain that must be applied to federally funded projects to address current and future flood risks.

Federally funded projects are actions where Federal funds are used for new construction, substantial improvement, or to address substantial damage to a structure or facility. Individual agencies will determine thresholds for what constitutes substantial improvement and substantial damage. Agencies may use the Guidelines for guidance in making these determinations.

If desired, Federal departments and agencies may extend the determination of substantial improvement, or the repair of substantial damage, or both, to include a cumulative determination in which Federal investments are tracked over time. One approach that Federal departments and agencies can adopt to monitor activity is to track improvements and repairs until they meet or exceed 50 percent of the value of the structure. Federal departments and agencies interested in implementing a cumulative approach will need to develop a process to track their respective cumulative Federal investments.

Exceptions, Class Reviews, and Simplified Evaluation and Review Processes

The head of a Federal department or agency, or an appropriate designee as set forth in the agency implementing plan, may except particular department or agency activities and facilities from the provisions of the FFRMS where it is in the interest of national security, where the agency action is an emergency action, where application to a Federal facility or structure is demonstrably inappropriate, or where the agency action is a mission-critical requirement related to a national security interest or emergency action. Agencies will provide more specific descriptions of what may constitute a national security interest or an emergency action by that agency in its policies and rules.

In addition, Federal departments and agencies may use an altered or shortened decision-making process for actions with insignificant impacts or actions of a short duration, as the current E.O. 11988 process specifies. Federal departments and agencies may also choose to conduct general review of activities in lieu of site-specific reviews and class reviews of certain repetitive actions. The Guidelines provide detailed guidance to Federal departments and agencies regarding applicability, exceptions, and processes for documenting compliance with the FFRMS.

Critical Actions

Critical Action is defined in E.O. 11988, as amended, to include any activity for which even a slight chance of flooding is too great. The approaches for determining a floodplain in the FFRMS specify a higher level of resilience for Critical Actions based on the approach used. The concept of Critical Action reflects a concern that the impacts of flooding on human safety, health, and welfare for many activities could not be minimized unless a higher degree of protection or resilience than that delivered by the base flood elevation was provided.

Federal departments and agencies will be responsible for determining whether a Federal action constitutes a Critical Action. To assist in this determination, departments and agencies should consider the example questions below.

- If flooded, would the proposed action create an added dimension or consequence to the hazard?
  - Is the action a structure or facility producing and/or storing highly volatile, toxic, radioactive, or water-reactive materials?
- If the action involves structures such as hospitals, nursing homes, prisons, and schools, would the occupants of those structures be sufficiently mobile and have available transport capability to avoid loss of life and injury given the flood warning lead times available?

    - Would emergency services functions be delayed or unavailable as a result of the location of the action?
    - Are there routes to and from the structure that would be inaccessible during a flood and hinder evacuation?
    - Would the location of the structure result in unacceptable hazards to human safety, health, and welfare of the occupants?
- Would essential or irreplaceable resources, utilities, or other functions be damaged beyond repair, destroyed, or otherwise made unavailable?
    - Would utilities, critical equipment, systems, networks, or functions be damaged beyond repair or destroyed?
    - Would physical or electronic records without backups or copies be destroyed or made unavailable as a result of where these items are located in a structure? Would national laboratories' research activities or items of significant value to research communities be damaged or destroyed as a result?
    - Would items or structures of substantial cultural significance be damaged, destroyed, or otherwise harmed?
- Would the damage or disruption from a local flooding event lead to regional or national catastrophic impacts (e.g., a port being closed for a period following a storm event, which has an impact on transportation of goods nationally)?
- Would damage or disruption to a given facility or infrastructure component have potential for cascading damage or disruption to other facilities and infrastructure classes, some of which may already be stressed by flood conditions (e.g., electricity outage due to substation damage resulting in wastewater treatment facility shutdown or gasoline pump outage)?

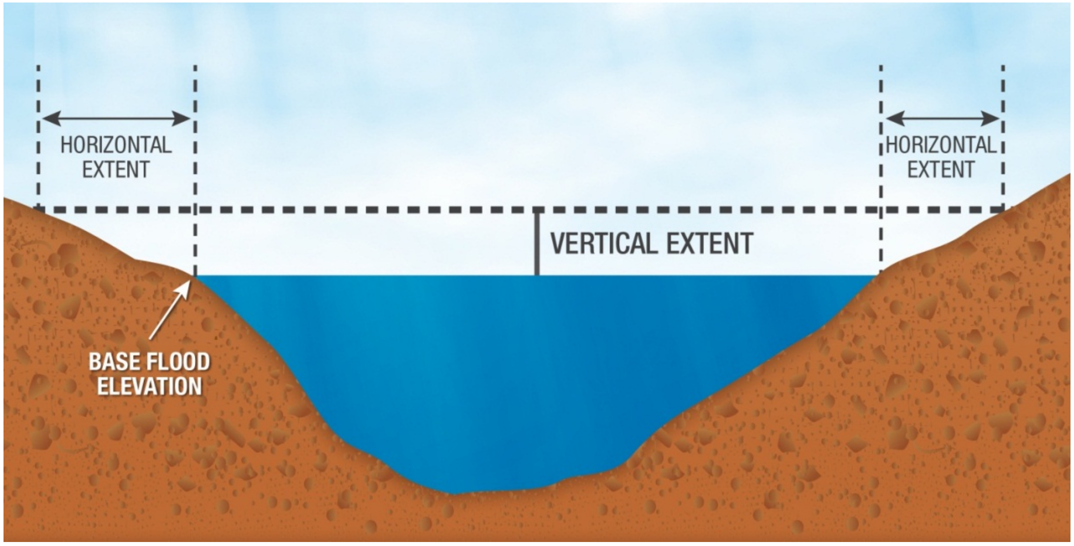
Use of Natural Features and Nature-Based Solutions

E.O. 13690 amended E.O. 11988 to require agencies, where possible, to use natural systems, ecosystem processes, and nature-based approaches in the development of alternatives for Federal actions in implementing E.O. 11988. This approach, combined with restoration of natural systems and ecosystem processes where appropriate, recognizes the growing role of natural and restored systems and of features engineered to mimic natural processes (generally known as “green infrastructure”) in mitigating flood risk and building the resilience of Federal investments both within and that will affect floodplains. Using natural and natured-based approaches is also consistent with Section 1 of E.O. 11988 which directs Federal departments and agencies to take action to restore and preserve the natural and beneficial values served by floodplains.

Encouraging the use of natural systems and nature-based approaches earlier in the planning and design of Federal actions is consistent with the Federal Government policy priorities and best practices, which promote the integration of green infrastructure for coastal flood risk management following Hurricane Sandy (e.g., Hurricane Sandy Rebuilding Strategy recommendations 19-22), and with the Climate Action Plan (e.g., references to “natural defenses”). This policy is also broadly consistent with and supports other policy and guidance documents, such as the *Principles and Guidelines for Water and Land Related Resources Implementation Studies (now updated and referenced as Principles, Requirements and Guidelines or PR&G), Guidance on Effective Use of Programmatic National Environmental Policy Act Reviews* and other agency implementing guidance.

Higher Vertical Elevation

The FFRMS provides approaches to establishing a higher vertical elevation to ensure that uncertainties associated with climate change and other future changes are more adequately accounted for in the department or agency decision processes for future federally funded projects. For federally funded projects, the FFRMS flood hazard elevation establishes the level to which a structure or facility must be resilient – this may include elevating the structure or, where appropriate, designing it to withstand or otherwise quickly recover from a flood event. In selecting the appropriate resilience approach, Federal departments and agencies should consider several factors such as flood depth, velocity, rate of rise of floodwater, duration of floodwater, erosion, subsidence, the function or use and type of structure or facility, and other factors. Additional guidance on these concepts are provided in the Guidelines for Implementing E.O. 11988 and E.O. 13690.



Approaches for Establishing the FFRMS Elevation and Flood Hazard Area

Agencies may establish the FFRMS floodplain using one of several approaches, including:

- Climate Informed Science Approach (CISA): Utilizing the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science.
- Freeboard Value Approach (FVA): Freeboard (base flood elevation + X, where X is 3 feet for Critical Actions and 2 feet for other actions).
- 0.2-percent-annual-chance Flood Approach (0.2PFA): 0.2 percent-annual-chance-flood (also known as the 500-year flood).

The CISA is preferred. Federal departments and agencies should use this approach when data to support such an analysis are available.

Climate-Informed Science Approach (CISA)

For areas vulnerable to coastal flood hazards, the CISA includes the regional sea-level rise variability and lifecycle of the project. The CISA for projects affected by coastal flood hazards includes:

- Use of the interagency (Parris et al., 2012)[3] or similar global mean sea level rise (GMSLR) scenarios or similar global mean sea-level-rise (GMSLR) scenarios, adjusted to local relative sea-level (LRSL) conditions.
- A combination of the LRSL conditions with surge, tide, and wave data using state-of-the-art science in a manner appropriate to policies, practices, criticality, and consequences (risk).

For areas vulnerable to riverine flood hazards, the CISA is as follows:

- Account for changes in riverine conditions due to current and future changes in climate and other factors (e.g., land use) by applying state-of-the art science in a manner appropriate to policies, practices, criticality, and consequences (risk).

The CISA for Critical Actions will utilize the same methodology as used for other non-critical actions that are subject to E.O. 11988, but with an emphasis on criticality as one of the factors for departments and agencies to consider when conducting the analysis. Note that the climate-informed science approach for Critical Actions will differ between coastal and riverine systems.

[3] Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss (2012) Global Sea Level Rise Scenarios for the U.S. National Climate Assessment. NOAA Technical Report OAR CPO-1. Washington, DC: National Oceanic and Atmospheric Administration, Climate Program Office. http://cpo.noaa.gov/sites/cpo/Reports/2012/NOAA_SLR_r3.pdf

The attached CISA Appendix provides the scientific foundation of the approach, from the impacts of climate change on coastal and riverine flooding to other processes known to affect future flood risk (e.g., land use change, long-term erosion, subsidence). The CISA Appendix also provides information on uncertainty in flood hazard analyses and links to key resources and tools available to aid agencies in applying this approach.

Freeboard Value Approach (FVA)

The Freeboard Value Approach defines the following freeboard values:

- An additional two (2) feet shall be added to the base flood elevation.
- For Critical Actions, an additional three (3) feet shall be added to the base flood elevation.
- These increases will apply to both the vertical elevation and the corresponding horizontal extent of the floodplain.

0.2-percent-annual-chance Flood Approach (0.2PFA)

Federal departments and agencies may elect to use available 0.2-percent-annual-chance (or "500-year") flood data as the basis of the FFRMS elevation and corresponding floodplain extent. Note that the 0.2-percent-annual-chance flood hazard data produced by the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) in coastal areas typically only considers storm-surge hazards. It is important that agencies evaluate the 0.2-percent-annual-chance flood data in coastal areas and conduct an analysis of coastal flood hazards at the site that incorporates the local effects of wave action, scour and erosion, wave run-up, and overtopping. Thus, agencies are encouraged to ensure that this approach will achieve an appropriate level of flood resilience for the proposed action. This approach may be used for either non-critical or critical actions.

Further Guidance on Application of 0.2 percent-annual-chance Flood Approach and Freeboard Value Approach

When a Federal department or agency does not use the CISA in a coastal flood hazard area, the department or agency must use, at a minimum, the Freeboard Value Approach. In some cases where the FEMA 0.2-percent-annual-chance flood elevation does not include a wave height, or a wave height has not been determined, the result will likely either be lower than the effective FEMA BFE or the base flood elevation plus applicable freeboard. The 0.2-percent-annual-chance elevation should not be used in these cases.

When actionable science is not available and a Federal department or agency opts not to follow the CISA for riverine flood hazard areas**,** the Federal department or agency may also select either the Freeboard Value Approach, or 0.2-percent-annual-chance Flood Approach, or a combination of approaches, as appropriate. A Federal department or agency is not required to use the higher of the elevations but may opt to do so.

Updates to the FFRMS

The FFRMS shall be reviewed after adoption and implementation, as Federal departments and agencies are able to identify scientific, technological, and economic information that may affect the implementation of the FFRMS. Periodic updates will allow the FFRMS to include requirements based on timely and relevant advances in science that takes into account changes to climate and other changes in flood risk. The MitFLG, established by the NMF, in consultation with the FIFM-TF, will reassess the FFRMS annually to determine if updates are warranted and will provide any recommendations to the Water Resources Council. The Water Resources Council shall issue an update to the Standard at least every 5 years. A full update will be conducted at least every five years.

Four areas have been identified that could trigger review and potential revision of the FFRMS: implementation experience; changes in national consensus standards on flood risk used to inform the policy; changes in the underlying flood risk information; and changes in current climate science that address critical data and information gaps.

Implementation Experience

As Federal departments and agencies implement the FFRMS, implementation challenges as well as opportunities to enhance or modify the FFRMS to account for changes to climate and other changes to flood risk may be identified. In order to ensure that the FFRMS continues to meet its stated objectives, implementation of the policy will be monitored. Federal departments and agencies should collect feedback on implementation from relevant programs and offices, identify potential gaps in the process, and outline areas for improvement with the Standard. Such information should be provided to the MitFLG as part of the annual reassessment of the FFRMS.

Consensus Standard Revised

As the International Code Series, published by the International Code Council, and reference standards such as the American Society of Civil Engineers (ASCE)-24 are updated, the Federal Government should consider whether such updates require reconsideration of the FFRMS.

Changes in the Underlying Flood Hazard Information

The Technical Mapping Advisory Council established by FEMA, as mandated by the Biggert-Waters Reform Act of 2012 (BW-12), will make recommendations on how to incorporate projected sea-level rise and other future climate change impacts into the existing flood study process. These recommendations may include mapping areas of future flood risk and developing methods to inform the potential revision of flood hazard elevations in both riverine and coastal areas. The MitFLG will review these recommendations for potential implications to the FFRMS and coordinated with activities undertaken to address the critical data and information gaps noted above.

Changes in Current Climate Science

In developing the guidance contained in the FFRMS, the MitFLG working group identified a number of critical data and information gaps. These gaps reflect challenges that Federal departments and agencies will likely face in implementing the current FFRMS, as well as other scientific issues that, if addressed in the near term (i.e., within two-to-three years), could be used to review and potentially revise the FFRMS. One important gap identified to improve the riverine climate-informed science option is to convene a working group that produces a new method to estimate projected future flood-flow frequencies.

References

1. Executive Order 11988, Floodplain Management, 1977, 42 CFR 26951, 3CFR 1977.
2. The Floodplain Management Guidelines for Implementing E.O. 11988, Water Resources Council, 1978.
3. Further Advice on Executive Order 11988, Federal Interagency Floodplain Management Task Force, 1987.
4. The Principles and Requirements for Federal Investments in Water Resources, March 2013.
5. The National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321 et seq.).
6. The National Flood Insurance Act of 1968, as amended (42 U.S.C. 4001 et seq.).
7. The Flood Disaster Protection Act of 1973 (Public Law 93-234, 87 Stat. 975).
8. The Coastal Barrier Resources Act of 1982 as amended (16 U.S.C. 3501 et seq.).
9. The Coastal Zone Management Act (16 U.S.C. 1451 et seq.).
10. The Coastal Barrier Improvement Act of 1990 (Public Law 101-591; 104 Stat. 2931).
11. The Endangered Species Act of 1973, as amended (15 U.S.C. 1531 et seq.).

APPENDIX H:
CLIMATE-INFORMED SCIENCE APPROACH AND RESOURCES

Table of Contents:

I. Introduction and Scope

The *President's Climate Action Plan* directed federal agencies to revisit and update their flood-risk reduction standards to improve the nation's resilience to flooding and to better prepare the United States for the impacts of climate change. Flood risk reduction standards must incorporate consistent yet flexible approaches that encompass the multiple, regionally variable physical phenomena that affect flood risk nationwide. This appendix reflects the efforts of a subset of agencies on the Mitigation Framework Leadership Group's (MitFLG's) Federal Flood Risk Management Standard (FFRMS) Workgroup (herein, MitFLG agency subgroup) to use ***best-available, actionable science*** (see next subsection and Section VI of this Appendix, Glossary) as the basis for methods to identify future flood risk when making investment decisions, including essential steps to understand and manage for uncertainty.

The FFRMS is the latest in a number of Administration directives that, in concert with Congressional mandates, have spurred agencies to assess and take action to minimize the adverse impacts of climate change on agency missions and operations. The standard builds upon the scientific, technical, and programmatic foundation established by multiple initiatives, including:

- Under the U.S. Global Change Research Program (USGCRP), which was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act of 1990, federal agencies collaborate with non-federal partners to develop and update a National Climate Assessment (NCA) every four years. USGCRP is currently strengthening its capacity to conduct assessments on a sustained basis.
- The USGCRP also oversees development of other products and services that support agency and other stakeholder decision-making, such as the Climate Resilience Toolkit (see Section V), which includes a focus area on coastal flood risk.
- Executive Orders 13423 (*Strengthening Federal Environmental, Energy, and Transportation Management*, published in 2007), 13514 (*Federal Leadership in Environmental, Energy, and Economic Performance*, published in 2009), and 13693 (*Planning for Federal Sustainability in the Next Decade*, published in 2015) have resulted in comprehensive planning across executive departments and agencies and actions to reduce greenhouse gas emissions and increase the nation's climate resilience.
- Many agencies have authorizing legislation that requires consideration of climate impacts, related planning, and other mission-specific actions to account for climate change. For example, the Biggert-Waters Flood Insurance Reform Act of 2012 established the Technical Mapping Advisory Council, whose products will include a report to the Federal Emergency Management Agency (FEMA) Administrator on the impacts of climate sciences and future conditions and how they may be incorporated into the National Flood Insurance Program (NFIP) mapping program.

A. What is the Climate-Informed Science Approach and Why is it Needed?

Climate change introduces new uncertainties into our understanding of and preparation for future flood risk. Historical experience may be limited in providing a guide to the future, given that climate change not only affects the mean expression of future temperature and precipitation, but also the variation around the mean—known as non-stationarity (Milly et al., 2008). For flood risk, changes in the extremes matter. Projected changes in other factors, such as land cover/land-use, have their own uncertainties whose ultimate effect on flood risk can be exacerbated by climate change. Although our understanding of the climate system is improving, the choices human societies make with respect to future emissions significantly impact how it evolves over time. Such choices, and how they play out over extended time periods, affect not only the future climate directly, but secondary effects such as sea-level rise. Finally, the uncertainties associated with climate change compel us to revisit our decisions over time as our scientific understanding improves and the response of climate and ocean systems is realized.

Deterministic approaches to decision-making can be problematic under the uncertainties of climate change. Robust decision-making or scenario-based approaches, in which a vulnerability or decision is assessed against a plausible range of future conditions, can help manage uncertainty. To make these approaches pragmatic and implementable, it is important to consider the nature of an affected decision, its desired operational life, and the tolerance for risk associated with the decision. These considerations dictate the range of scenarios or plausible futures that warrant consideration specific to that decision. As a result, the FFRMS climate-informed science approach (CISA) (1) treats the future as potentially non-stationary, (2) considers local conditions as well as global change, (3) can accommodate other factors beyond those that are climate-related, and (4) assists in bounding the decision space by considering plausible future conditions appropriate to a given decision.

For the FFRMS, the CISA is defined by a set of criteria:

1. Uses existing sound science and engineering methods (e.g., hydrologic and hydraulic analysis and methodologies) as have historically been used to implement E.O.11988, but supplemented with best available climate-related scientific information when appropriate (depending on the agency-specific procedures and type of federal action).
2. Is consistent with the climate science and related information found in the latest NCA report or other best-available, actionable science.
3. Combines information from different disciplines (e.g., new perspectives from the atmospheric sciences, oceanographic sciences, coastal sciences, and hydrologic sciences in the context of climate change) in addition to traditional science and engineering approaches.

4. Includes impacts from projected land cover and land use changes (which may alter hydrology due to increased impervious surface), long-term coastal and/or riverine erosion, and vertical land movement (for determining local changes to sea level) expected over the lifecycle of the action.

The CISA will yield scientifically and technically defensible flood elevations based on detailed analyses of current and projected hydrology, hydraulics, climate change, and other factors described above. These results may be different from those obtained using the FFRMS' Freeboard Value Approach or 0.2-percent-annual-chance Flood Approach, which may be considered simplified approaches that are appropriate based on the nature of the particular federal action and the agency-specific procedures. Managing for current and projected conditions over the project life cycle means that flood elevations calculated using the CISA will be at least as high as those calculated today for the current standard (i.e., current 1-percent-annual-chance flood elevation). As a matter of policy, the standard implemented should not be lower than the 1-percent-annual-chance flood elevation.

The CISA uses the terms "best available" and "actionable" in identifying what data or science should be applied in the approach. As with other aspects of the FFRMS and E.O. 11988 broadly, agencies are responsible for identifying the information used as the basis of their implementation. Agencies should consider the criteria below when assessing flood-related data, science, and information.

Best-Available Data and Science are:

- Transparent – clearly outlines assumptions, applications, and limitations.
- Technically credible – transparent subject matter or more formal external peer review, as appropriate, of processes and source data.
- Usable – relevance and accessibility of the information to its intended users. For the climate-informed approach, usability can be achieved by placing climate-related scenarios into appropriate spatial, temporal, and risk-based contexts.
- Legitimate – perceived by stakeholders to conform to recognized principles, rules, or standards. Legitimacy might be achieved through existing government planning processes with the opportunity for public comment and engagement.
- Flexible – scientific, engineering, and planning practices to address climate change-related information are evolving. To respond, agencies need to adapt and continuously update their approaches consistent with agency guidelines and principles.

Actionable Science consists of theories, data, analyses, models, projections, scenarios, and tools that are:

- Relevant to the decision under consideration.

- Reliable in terms of its scientific or engineering basis and appropriate level of peer review.
- Understandable to those making the decision.
- Supportive of decisions across wide spatial, temporal, and organizational ranges, including those of time-sensitive operational and capital investment decision-making.
- Co-produced by scientists, practitioners, and decision-makers, and meet the needs of and are readily accessible by stakeholders.

B. Appendix Scope and Updates

This appendix outlines guidance on risk-based framing (i.e., how agencies may consider current and future flood risks over the lifetime of the investment/project) (Section II), followed by specific considerations and methods (where available) to consider climate change (Section III). While information on other landscape changes that can affect future flood hazards is provided (Sections IV), detailed analysis and specific, recommended approaches for calculating flood elevations are beyond the scope of this document. Lastly, the appendix provides key resources to aid agencies in implementation (Section V), as well as a glossary of terms (Section VI of this Appendix) and a listing of references used as the basis of preceding guidance (Section VII).

Per E.O. 13690, in consultation with the Federal Interagency Floodplain Management Task Force, the MitFLG will reassess the FFRMS (including the CISA) annually and, after seeking stakeholder input, may provide recommendations for updates to the Water Resources Council. The Council is required to issue an update to the standard at least every five years. This reassessment process will enable updating of the standard itself to account for changes in climate and other factors affecting flood risk, as well as allow incorporation of new, actionable science and supporting resources into this appendix.

II. RISK-BASED FRAMING

Risk is typically defined as a likelihood of occurrence of some condition or event multiplied by the consequence. Given the uncertainties inherent to climate change—natural variability of the climate system, climate model input and output differences, and different possible emission futures — assigning probabilities to possible resultant futures becomes problematic. Herein a broader view of risk is taken that is not dependent on assigning likelihoods or probabilities. The focus, therefore, of a risk-based framing approach—versus a traditional risk assessment—is not to reduce uncertainty to enable a deterministic approach (whether probabilities are assigned or not), but rather to assist decision-makers and practitioners in managing uncertainty or to reduce risk when such uncertainty is largely irreducible (Hinkel et al., 2015) to increase the robustness of decisions against plausible future conditions. Such plausible future conditions can be defined by scenarios—even quantitatively—which are defined as descriptions of potential future conditions produced to inform decision-making under uncertainty (Parson et al., 2007). In the sections that follow, aspects of uncertainty in flood hazard information, risk management, and scenario application are further discussed.

A. Uncertainty in Flood Hazard Information

Estimating flood risk involves consideration of several components of overall uncertainty, with knowledge uncertainty and natural variability key among them. Knowledge uncertainty, sometimes called epistemic uncertainty, encompasses uncertainty that is attributed to a lack of knowledge, incomplete theory, or incomplete understanding of a population (e.g., the population of flood peaks), modeling limitations, and/or limited data. Uncertainty has been reduced over time as data and information about processes has been improved. One of the fundamental challenges of flood risk estimation lies in characterizing events whose return period is greater than the period during which flood data have been collected. Flood risk can be greatly underestimated or overestimated, if we have inadequate data on which to base our estimates. Natural variability is uncertainty that can be attributed to the inherent variability in the physical world, including heterogeneity, diversity, and natural, unpredictable variation in physical processes in nature. For example, river discharges vary constantly due to myriad physical processes, and floods typically result from combinations of extreme events associated with meteorological and other processes. Uncertainty is therefore inherent to any hydrologic and hydraulic analysis and resultant mapping of current condition flood hazards (e.g., Pathak et al., 2015), including (but not limited to) FEMA Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs).

The CISA approach explicitly accounts for uncertainties through the use of several emission pathway scenarios, multiple Global Circulation Models (GCMs), and GCM ensembles. As a result, analyses undertaken using the CISA will reflect combined uncertainty from both existing data and approaches, as well as from the assumptions and data used to represent future conditions. Although it is reasonable to expect uncertainty associated with the CISA to be reduced over time as new scientific understanding, data, and models become available, it can never be eliminated, especially given the dependency on the trajectory of future emissions. Therefore, considerations of risk tolerance and approaches for managing risk become critical in the planning, implementation, and maintenance of federal investments.

B. Risk Management

In developing the CISA for the FFRMS, the MitFLG agency subgroup set out to provide a general risk management framework that can be used to incorporate uncertain future conditions affecting flood-related processes into standard methods for estimating future flood risk. The ultimate goal is to provide plausible estimates of flood risk at any location for a given period of time in the future, as well as to describe corresponding uncertainties. However, because the science is still evolving and the farther out we project into the future the larger the uncertainties, practical operational methods for addressing climate change at this time may require use of approximate or simplified methods, depending on the particular type of flooding. Beginning with a firm foundation for risk management, future adjustments and refinements can be made as actionable science evolves to provide consistent and practical methods.

Although the theory behind risk-based flood management is well established and sound, as a practical matter it is not always easy to estimate flood risk given limited data (Federal Interagency Floodplain Management Task Force, 1987, p. 9). This is especially difficult when attempting to detect changes in the frequency of rare events (Georgakakas et al., 2013). Recently, additional complications have emerged associated with changes in climate and weather, combined with other changes such as land use and land cover. Observed trends include increased annual precipitation and river discharge in the Northeast and upper Midwest (Kunkel et al., 2010; Ryberg et al., 2014), and increases in very heavy precipitation events. These events are defined as “very heavy when it falls into the upper 1 and/or 0.3% of precipitation events in the continental U.S.” (Groisman 2005; Groisman et al., 2012). On the other hand, trends in the Southwest may indicate that flood magnitudes are decreasing (e.g., Hirsch and Ryberg, 2012). To date, uncertainties remain an important factor in both assessing observed records (Hirsch and Ryberg, 2012; Villarini et al., 2011a) and projected changes (e.g., Villarini and Smith, 2013). In the past, engineers could add a factor of safety to their results to account for uncertainty. When applied to flood elevations, this factor of safety is called “freeboard.” Later, engineers used probabilistic methods to describe uncertainty (e.g., Interagency Committee on Water Data, 1982). These traditional freeboard and computational approaches assume that flood processes are stationary and “vary within an unchanging envelope of natural variability” (Milly et al., 2008). By the time of the Milly et al. (2008) paper, however, the water resources engineering community recognized that climatic and land use changes may cause the possibility of substantial shifts in flood frequencies over coming decades, requiring explicit treatment of the potential for non-stationarity (i.e., the future does not look like the past). Engineers previously understood that the assumption of stationarity could be violated (e.g., Chow, 1964), but now recognize and account for non-stationary processes (Hirsch, 2011) using a variety of methods (e.g., Kiang, et al., 2011).

In considering future flood risks then, a risk-informed approach suggests that different approaches are appropriate for coastal and riverine flooding. For coastal flood risk, we generally know the directional change of local sea levels plus storm surge and other important factors, but not necessarily the magnitude that may occur and when. In this case, the use of scenarios is very common to help project plausible future coastal flood elevations and timing. For riverine flooding, it is currently difficult determine the direction of changes in precipitation and resulting flood elevations. Scenarios could be applied; for example, increasing the variance around the expected value. However, to date, this use of scenarios has not received the same level of consensus as in projecting coastal water elevations. The use of freeboard is another approach that may be appropriate for accounting for uncertainty in some types of decisions.

Uncertainty is Important

The CISA approach to address future flood risk must incorporate uncertainty. With respect to inland flooding, the magnitude and even the direction (i.e., increasing or decreasing) of future trends may be uncertain for any particular location (e.g., Hirsch and Ryberg, 2012; IPCC, 2012, p. 6). Depending on the location and the physical processes involved, the degree of uncertainty can increase substantially as we project further into the future (Stedinger and Griffis, 2011; Georgakakas et al., 2013). Ignoring uncertain or as-yet-unquantified trends is hazardous in itself, particularly for federal infrastructure investments that may be long-lived. Therefore, application of the CISA must account for uncertainties in projected future conditions. Considering the framework and initial science discussion above, application of the CISA should:

- Consider different levels of analysis to be commensurate with the level of investment, its criticality, and risk tolerance.
- Determine the consequences associated with the purpose and lifetime of the federal investment.
- Explicitly address uncertainty.

C. Applying Scenarios

As mentioned above, scenarios are descriptions of potential future conditions that can assist in informing decision-making under uncertainty. Moreover, they not only can help inform specific decisions but also can provide inputs to assessments, models, or other decision-support activities when these activities need specification of potential future conditions. Scenarios can include both quantitative and qualitative information and must be internally consistent. In general, the decision-maker or practitioner should consider multiple scenarios to assess the robustness of their decision against future change. The number and range of scenarios considered depends on a number of factors, including the type of decision to be made, the time horizon over which the decision must be effective, and the tolerance for risk.

Scenario approaches are often used to analyze problems that not only are characterized by large uncertainties but also are associated with large potential consequences. For example, the use of sea-level rise scenarios is a common method of dealing with uncertainties such as the complexity of the physical processes involved in changing sea levels, limitations in our understanding of important interactions and feedback cycles, and the importance of the long-term emissions trajectory that dictates the magnitude of ultimate change, (e.g., Parris et al., 2012; U.S. Army Corps of Engineers, 2013). Given the uncertainties involved, the scenarios place an emphasis on capturing the plausible range of future sea level without assigning a probability to any particular future.

Although the preceding references start with global scenarios of sea-level change, regional and local processes affect sea level at a particular location, sometimes significantly. The science on how to address this is emerging, especially when the effects of long-term changes in ocean circulation and glacier/land-based ice sheet melt are considered; however, dependent on the quality of local data, vertical land movement due to local subsidence and other factors often can be considered (see Section IV). Finally, the uncertainty involved in moving from global to local scenarios of sea-level change also is magnified when considering (1) the variability in responses of coastal systems and processes and (2) the combined effects of sea level rise and altered storm frequency or intensity (e.g., Woodruff, et al., 2013).

Deterministic approaches, on the other hand, are used when a great deal is known about the process in question or projections in future conditions are reasonably certain. That is why deterministic approaches are so common in evaluating past events – because we have observations on which to base these methods and can make best-guess estimates of important factors. These estimates, however, can be purely observation-based and do not necessarily reflect an understanding of the physical processes. Given that the processes themselves may be subject to change under climate change in ways we cannot yet predict, additional uncertainties are introduced. Moreover, although deterministic approaches have been proposed, they cannot be proven or otherwise validated until the future comes to pass. Thus, selection now of one particular deterministic approach entails the risk of false precision and decision-making based on a single future that may not materialize. Scenario analysis, on the other hand, enables the user to test the robustness of future choices against a range of plausible futures. A broader risk-management approach thus enables a range of possible outcomes to be examined (Kunreuther et al., 2013).

The decision-maker and practitioner should keep in mind the element of time and the ability to revisit a decision over time. For decisions in which the consequences of a wrong decision is low (high tolerance for risk) and the decision can be revisited over relatively short timeframes, a narrow range of less extreme scenarios may suffice for risk management. For a decision in which the consequences of a wrong decision is significant (low tolerance for risk) and which may constitute an irreversible decision that needs to operate over a relatively long timeframe, a wider range of scenarios or at least a consideration of the higher end scenarios may be appropriate. A hybrid approach also may be considered in which a decision can be phased in over time, such that a lower set of scenarios can guide decision-making in the near- (5 to 20 years) to moderate-term (20 to 35 years), while not precluding the capability to respond to the more extreme scenarios in the longer term (Hinkel et al., 2015).

Finally, the science supporting use of scenarios in the coastal environment is more robust at present than it is for guiding the response to riverine flood risk. This is due in part to at least being able to assign confidence to a directional trend in sea-level, whether global or at the local scale, even if the magnitude of the trend is non-stationary and has large uncertainties. The direction of change, however, in riverine flood risk is uncertain in many regions of the U.S., mostly due to the uncertainties associated with precipitation. Still, factors besides climate, such as land cover/land-use change, may at least in the near to moderate time horizons play a significant role in future flood risk. As a result, scenarios of future land cover/land-use change and how they affect flood risk may need to be considered.

III. Considering Impacts of Climate Change on Flood Hazards

Discussions of the scientific underpinnings and recommended approaches have been organized in this section by primary flooding source, coastal and riverine. Riverine areas also include rivers that are influenced by coastal effects, as appropriate. Coastal areas are determined by the extent of the current and future tidal influence. For the purposes of this document, the riverine guidance is applicable to Great Lakes tributaries, while the coastal guidance is applicable to the Great Lakes' shorelines, with differences as noted in the discussion below.

Among the key findings or considerations in this section:

- Each agency should factor potential relative sea level change into federal investment decisions located as far inland as the extent of estimated tidal influence, now and in the future, using the most appropriate methods for the scale and consequence of the decision. When using global SLR scenarios, agencies should account for, at a minimum, local vertical land movement adjustments to the global scenarios if such data are available.
- Agencies should use the interagency (Parris et al., 2012) or similar global mean sea level rise (GMSLR) scenarios, adjusted to reflect local conditions, including any regional effects (local relative sea level, or LRSL) such as vertical land motion. The LRSL conditions should be combined with surge, tide, and wave data using methods appropriate to policies, practices, criticality, and consequences.
- There is currently too much uncertainty in projections of future Great Lakes lake levels to support a recommendation to add or subtract freeboard to current flood risk elevations along their shoreline.
- As a result of the limitations of available and actionable science, agencies should account for projected changes in riverine conditions due to future changes in climate and land use by applying the CISA in a manner appropriate to policies, practices, criticality, and consequences.
- For areas subject to both coastal and riverine flooding, agencies should begin with an analysis of potential future coastal flood elevations, and then consider the associated backwater effects on estuarine and riverine areas using methods suggested by FEMA that consider projected changes in coastal storms and precipitation.

A. Science Underlying Coastal FFRMS

Defining future coastal flood risks requires an assessment of how sea level change will influence the frequency of extreme water level events or loading conditions. Future storm tides may reach higher elevations than past storms and may do so with more frequency in most areas of the country, impacting both flooding and structural loading.

Sea level observed along the coast changes in response to a wide variety of astronomical, meteorological, climatological, geophysical, and oceanographic forcing mechanisms (Nicholls, et al., 2007). At any location, changes in LRSL reflect the integrated effects of global mean sea level (GMSL) changes plus a combination of regional vertical land motion, regional oceanographic and atmospheric changes.

Global (eustatic) sea level changes result from global changes in the volume of water in the world's oceans principally in response to three processes: 1) ocean mass change by addition of water; 2) density changes related to total salinity; and 3) changes in ocean heat content (Church and White, 2006; Bindoff et al., 2007). In the 20th century, the dominant contributors to global sea-level rise have been ocean warming (thermal expansion) and accelerated melting of glaciers, with the Greenland and Antarctic ice sheet contributions increasing since the early 1990s (Church et al., 2013). GMSL changes can also result from basin changes driven by processes like seafloor spreading.

Recent research has indicated potential ranges of GMSL rise by year 2100 (NRC, 1987, 2012; Rahmstorf, 2007; Horton et al., 2008; Pfeffer et al., 2008; Vermeer and Rahmstorf, 2009; Jevrejeva et al., 2010; Katsman, et al., 2011). The use of sea level rise scenarios (e.g., Parris et al., 2012; U.S. Army Corps of Engineers, 2011) as opposed to individual scenario probabilities underscores the uncertainty in how GMSL will actually manifest in the future. The uncertainty is magnified when considering 1) the variability in responses of coastal systems and processes, and 2) the combined effects of sea level rise and altered storm frequency or intensity (e.g., Woodruff, et al., 2013).

For determination of LRSL, factors important in vertical land movement include regional tectonic movement, regional vertical land subsidence or uplift, compaction of sedimentary strata, crustal rebound in formerly glaciated areas, and subsidence due to local withdrawal of subsurface fluids (water or hydrocarbons) (Zervas et al., 2013). Atmospheric effects include climate oscillations such as the El Niño-Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO), which in turn impact LRSL at decadal time scales. Other sources of changing sea levels that can be regionally significant include alternations to ocean dynamics and melting of glaciers and ice sheets.

Long-term tide gauge records provide information on historical LRSL variations (e.g., Zervas, 2009). They measure sea level relative to local land elevations through repeat leveling surveys from the tide gauge reference zeros to local tidal benchmark networks. While there is reasonable consensus about what constitutes long term (tide gauge records with a length of two tidal epochs or 38 years is suggested, but may not always be available), the question of the required proximity of a tide gauge to be used in estimating trends is heavily influenced by regional factors such as vertical land movement and local factors such as the exposure of the tide gauge. Experts at the National Oceanic and Atmospheric Administration's (NOAA's) Center for Operational Oceanographic Products and Services can assist agencies when periods of record are short or records are otherwise ambiguous due to these factors. Over time, sea level variations are tracked relative to a fixed station datum maintained by the benchmark network. As a result, it is critical to consider vertical datums, including past and potential future changes in datum, when estimating future LRSL.

> **Key Point:** ***Each agency should factor potential relative sea level change into federal investment decisions located as far inland as the extent of estimated tidal influence, now and in the future, using the most appropriate methods for the scale and consequence of the decision. When using global SLR scenarios, agencies should account for, at a minimum, local vertical land movement adjustments to the global scenarios if such data are available.***

The Great Lakes shorelines are modeled for flood risk similarly to other U.S. coastal regions in that they account for surge (seiche) and waves; therefore, there is current flood risk information for the Great Lakes shorelines from the NFIP. Future flood risk in the Great Lakes will be determined by future fluctuations in lake levels. The 2014 NCA reported that projected lake levels are uncertain in magnitude and direction and stated that projections of Great Lakes water levels represent evolving research (Pryor et al., 2014). One area of research is to improve techniques to estimate evapotranspiration because previous estimates from temperature data may have overestimated evaporation losses. Accounting for land-atmosphere feedbacks may further reduce the estimates of lake level declines. Recent studies, along with the large spread in models, indicate that projections of Great Lakes water levels may decrease or increase and thus represent evolving research and are still subject to considerable uncertainty (IUGLSB, 2012; MacKay, 2012; Angel and Kunkel, 2010). Therefore, addition or subtraction of elevation to current flood hazard information for the Great Lakes is not recommended.

> **Key Point:** ***There is currently too much uncertainty in projections of future Great Lakes lake levels to support a recommendation to add or subtract freeboard to current flood risk elevations along their shoreline.***

B. Approaches and Resources for Estimating Future Sea Level Change

Federal investments that consider sea level change information should be based on the best available scientific information that has gone through agency review/peer review. Sea-level change rates relevant to the investment may be calculated by using a combination of global sea-level rise scenario curves and regional or local sea-level information, e.g., long-term tide gauges. Depending on the life expectancy of the project, multiple planning horizons may be necessary when assessing likely risk from sea-level change and the FFRMS floodplain.

Scenarios for Estimating Flood Risk Due to Sea Level Change

The interagency report, "*Global Sea Level Rise Scenarios for the United States National Climate* Assessment" (Parris et al., 2012) is a key source for global sea-level rise information today. Alternatively, agencies may use other sea level scenario curves that meet the peer review criterion noted above. Examples include the U.S. Army Corps of Engineers (USACE) Engineer Regulation 1100-2-8162, "*Incorporating Sea Level Change in Civil Works Programs,*" which contains scenarios similar to those in Parris et al. (2012), and the National Research Council (NRC, 2012) "*Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*." All of these sea-level change reports have similar scenarios. Multiple scenarios might be used as part of a broader risk management approach and considered, as possible, in project planning to evaluate risks across a range of conditions and to identify trigger points and thresholds that guide alternative solutions. Criteria defining appropriate scenarios include, but are not limited to:

- **Credibility –** Refers to the extent to which the sea-level rise scenarios were developed through rigorous scientific studies or assessment and synthesis processes. Credibility is generally achieved through transparent peer review processes and source data. In the context of developing future flood risk management practices, credibility should also include rigorous climate science and integration of relative sea-level factors (see Scenarios for Estimating Flood Risk section below).
- **Usability –** Refers to the relevance and usability of the information to its intended users. Usability can be achieved by placing sea-level rise scenarios into appropriate spatial, temporal, and risk-based contexts (see Phasing and Time Horizons and Risk-Based Framing sections below).
- **Legitimacy –** Refers to stakeholders' perception that information conforms to recognized principles, rules, or standards. Legitimacy might be achieved through existing government planning processes with the opportunity for public comment and engagement (see Risk-Based Framing section below).

For example, in addition to the NRC (2012) report for the Western U.S., the New York City Panel on Climate Change (2013) produced sea-level rise projections that formed the basis of the New York City Mayor's Office "Stronger, More Resilient New York" strategy.

Risk-Based Framing

Risk cannot be eliminated entirely. Evaluation of sea-level rise scenarios and flood levels is guided by the risk inherent in planning, designing and implementing particular types of projects and by their location. For example, projects with high consequences from failure may be more risk-averse than projects with lower consequences of failure. It is recommended, therefore, that scenarios be communicated in the context of risk tolerance to improve transparency and credibility. The four interagency scenarios presented in Parris et al. (2012) have been framed as such as the federal community and partners have begun using the information. This framing offers several points worth considering in the development and application of sea level change scenarios in the coastal FFRMS, including:

- The two lower Parris et al. (2012) scenarios, or comparable data, may be appropriate where there is a high tolerance for risk (e.g., projects with low consequences and short lifespan or with planning areas with flexibility to make alternative choices within the near-term). These scenarios primarily address ocean warming.
    - Where LRSL is falling, the use of the Parris et al. (2012) lowest scenario may be appropriate.
    - Where LRSL is rising, the Parris et al. (2012) intermediate-low scenario has been recommended as the minimum scenario because it includes the effects of accelerated ocean warming, whereas the lowest scenario is simply an extrapolation of the existing sea level trend into the future and assumes no acceleration.
- The two higher Parris et al. (2012) scenarios, or comparable data, such as USACE (2013), should be considered in situations where there is little tolerance for risk. These situations include projects with a long lifespan, where losses would be catastrophic, where there is limited flexibility to adapt in the near or long term, and those that serve critical economic and ecological function (e.g., ports or endangered species refuges). These scenarios primarily address both ocean warming and contributions from glaciers and ice sheets.

Key Point: ***Federal agencies should use the interagency (Parris et al., 2012) or similar global mean sea level rise (GMSLR) scenarios, adjusted to reflect local conditions, including any regional effects (LRSL) such as vertical land motion. The LRSL conditions should be combined with surge, tide, and wave data using methods appropriate to policies, practices, criticality, and consequences. Agencies should be aware that updates to the NOAA scenarios may be made through the NCA process.***

C. Science Underlying Hydrologic (or Riverine) FFRMS

No approach analogous to the scenario approach of Parris et al. (2012) has yet been developed to account for uncertainties due to climate change with respect to projected future precipitation and associated riverine flooding. Bulletin 17B (Interagency Committee on Water Data, 1981), the federal guidelines for estimating flood flow frequency, acknowledges that change, and in particular climate change, is a potential concern ("There is much speculation about climatic changes"). However, the guidelines assume climatic invariance (stationarity). Similarly, FEMA's *Guidelines and Specifications for Flood Risk Analysis and Mapping*, which outline the input data, analytical methods, and models required to support FISs, currently assume stationarity with respect to climate change. Lastly, the Water Sector chapter of the 2014 NCA elaborates further on the challenges in understanding the impacts of climate change on riverine flood hazards:

> *Large uncertainties remain in efforts to detect flood-statistic changes attributable to climate change, because a wide range of local factors (such as dams, land-use changes, river channelization) also affect flood regimes and can mask, or proxy for, climate change induced alterations. Furthermore, it is especially difficult to detect any kinds of trends in what are, by definition, rare and extreme events. Finally, the response of floods to climate changes are expected to be fairly idiosyncratic from basin to basin, because of the strong influences of within-storm variations and local, basin-scale topographic, soil and vegetation, and river network characteristics that influence the size and extent of flooding associated with any given storm or season.* (Georgakakos et al., 2014)

D. Methods for Determining Future Hydrologic (or Riverine) Flood Hazards

The science, understanding, and application of information about projected hydrologic conditions resulting from climate change are evolving. Today, there is a wide portfolio of possible approaches for producing and using climate science and derivative climate change information for hydrologic adaptation. Each method or analytical technique brings uncertainties and particular deficiencies, some of which are largely or only partly characterized and poorly quantified (e.g., Pathak et al., 2015). Different methods may be more or less appropriate for use in a particular decision environment, and this critical question needs further study before any single hydrologic FFRMS can be developed.

Key Point: ***As a result of the limitations of available and actionable science, agencies should account for projected changes in riverine conditions due to future changes in climate and land use by applying the CISA in a manner appropriate to policies, practices, criticality, and consequences.***

E. Locales Subject to Both Coastal and Riverine Flood Hazards

The United States contains over 90,000 square miles of estuaries (EPA 1998). The majority of these estuarine areas are subject to both coastal and riverine flooding, sometimes from coincident events, or compound events (e.g., Leonard et al., 2014). The coastal component of estuarine flooding is generally associated with a coastal storm in the U.S. and its resulting effects on storm surge and waves. For estuaries with little or no contributing riverine drainage area, the effects of the riverine flood component on estuarine flooding can be assumed to be negligible. For larger watersheds, the riverine component of estuarine flooding can occur as a result of precipitation associated with intense localized rainfall events, coastal storms, dam failures, or even precipitation events that occur far upstream in the watershed. For very large watersheds, the riverine component of estuarine flooding may result from inland flood events that are very far apart in space and time from coastal events. In some cases, compound flooding resulting from coastal and riverine events occurring at or near the same time can result in flood levels that are much greater than if either occurs in isolation (e.g., Leonard et al., 2014; Wahl et al., 2015).

Compound events are likely to increase given that the all U.S. regions are projected to experience increases in the frequency and intensity of extreme precipitation events (NCA, 2014), while the intensity, frequency, and duration of North Atlantic hurricanes and the frequency of the strongest (Category 4 and 5) hurricanes, have all increased since the early 1980s (Walsh et al., 2014). Recent research addresses quantification of rainfall associated with tropical cyclones (TCs) before or after landfall (Villarini et al., 2011b). The precipitation associated with Atlantic and Gulf Coast TCs is known to extend far inland (Villarini et al., 2011b, 2014), and is linked to compound flooding from both coastal processes and riverine flooding (Wahl et al., 2015). Wahl et al. (2015) report that compound flood events are more for the Atlantic and Gulf coasts than for the Pacific coast. They also note that compound flood events are increasing in frequency for some locations along the coastline of the continental U.S, and recommend the use of nonstationary analyses to evaluate future flooding.

Coastal total water levels that impact estuarine flooding result from the combination of tide, surge, seasonal or interannual variability, waves, and other factors. The coastal component can be a major determinant in all upstream water levels, whether compound or not, due to backwater effects on river flow. As LRSL (or lake level in the case of the Great Lakes) changes, total water levels, and hence backwater effects, will also change.

> **Key Point:** ***For areas subject to both coastal and riverine flooding, agencies should begin with an analysis of potential future coastal flood elevations, and then consider the associated backwater effects on estuarine and riverine areas using methods described in FEMA's Guidelines and Standards for Flood Risk Analysis and Mapping.***

IV. Considering Impacts of Other Landscape Changes on Flood Hazards

This section discusses other physical processes (land-use changes, riverine and coastal erosion, and vertical land movement) that, in addition to climate change, have the potential to affect future flood hazards. Projected changes in these processes have their own uncertainties whose ultimate effect, combined with climate impacts, can exacerbate flood risk. Agencies should review and determine whether these processes are applicable to a project site, and if so, seek further information on how to incorporate into flood hazard assessment. Specific methods for evaluating impacts of these processes at the project level are beyond the scope of this appendix.

A. Land-Use Changes

For some projects and activities, influences beyond climate change may yield significant impacts on the types and extents of flood hazards. Planners, scientists, and engineers have long recognized and attempted to account for the influences of changes to land use and land use characteristics.

Impervious Surface

The most commonly considered land use characteristic would be changes to impervious surfaces resulting from current to proposed development. Typical hydrologic practices quantifies the effects of this change in impervious surface on the rainfall/runoff relationships; relating the relationships to various aspects and changes in the hydrologic abstractions, soils, vegetation, cover, etc. Again, typical practice usually makes some comparison between previous or historical conditions and some proposed condition.

For example, a project seeks to build a structure within a wooded area. Design practice would determine the potential runoff from the undeveloped wooded area; determine the runoff from the proposed structure (and any facilities, such as roads); and contrast the two. Good practice has evolved to consider not just peak runoff differences, but also volumes and timing of those runoff comparisons. Perhaps, the project may require some best management practice to consider and mitigate these water quantity and water quality changes.

Consideration of Future Land Use

Less common in general practice is consideration of future land use characteristics. However, such consideration becomes an important approach as a means to anticipate runoff (and other hydrologic behavior) over the lifetime of the federal investment. The advantage of considering future land use allows a structure or facility to more completely mitigate flood hazards over that service or design life. Nor is such an approach "new." In 1956, the U.S. Bureau of Public Roads (U.S. Bureau of Public Roads, 1956) developed standards for the yet-unbuilt Interstate Highway System that required the hydraulic design of bridges and culverts to consider future land use occurring 20 years after construction. Other federal agencies consider future land use development as well; a 20-year window exists under §204 and §208 of the Clean Water Act for considering "projected population and associated commercial and industrial establishments" (albeit for sanitary, combined, and urban storm runoff) (FWPCA, 2002).

When considering future flood risk in coastal areas, changes in land use are seldom considered but, depending on the nature and scale of the changes, may be important to storm surge propagation, overland wave effects, and localized erosion hazards. For example, manmade conversion of wetlands or maritime forest habitats to residential or commercial development could result in vastly different local wave conditions and flood elevations. Similarly, conversion of wetlands, beaches, or other low-lying areas to open water due to sea level rise or other coastal processes could also affect modeled flood and erosion hazards, including the location of coastal high hazard areas (V Zones). There are no known procedures or case studies available; however, if an agency anticipates substantial changes in coastal land use at or seaward of their project site, sensitivity analyses may be warranted using current and projected land use characteristics. For example, agencies using FEMA's Wave Height Analysis for Flood Insurance Studies (WHAFIS) could explore the impacts of future land use by modifying the various vegetation and building "cards" in the model's 1-D transects.

Imperviousness and Non-Homogeneity

Just as with climate change-related concerns, ongoing development over time effectively changes both the land use and the assumptions of stationarity of the runoff assumptions. For example, McCuen (1996) describes that "…sensitivities of measured peak discharges suggest that a 1 percent increase in percent imperviousness causes an increase in peak discharge of about 1 to 2.5 percent for the 100-year and the 2-year events, respectively" (McCuen, 1996, 1989).

In such cases, inferential statistical hydrology has derived index-adjustment methods to recognize and account for urbanization (McCuen, 1989, 1996). The literature suggests applicability of such hydrologic approaches could be calibrated to "adjust for the effects of deforestation, surface mining activity, agricultural mining practices, or climate change" (McCuen, 1996).

Burned Areas

In addition to development-induced changes to land use, flood hazards may be influenced by other factors and situations, such as changes to landscape characteristics (i.e., burned areas) following wildfires (Moody et al., 2013). News reports often describe the flood risks occurring during or after a wildfire event. Normally, vegetation in a watershed absorbs rainfall, reducing runoff and/or altering its timing. Wildfires leave the ground charred, barren, and unable to absorb water, creating conditions conducive for flash flooding and mudflow (FEMA, 2015). Post-fire debris flows generally are triggered by one of two processes: surface erosion caused by rainfall runoff, and landsliding caused by infiltration of rainfall into the ground (USGS, 2005). Until the watershed can restore vegetation – which may take up to 5 years after the wildfire – flood risk remains significantly higher compared to prior to the event (FEMA, 2015). Properties directly affected by fires and those located below or downstream of burn areas are at greatest risk for flooding.

As an example, the June 2011 Las Conchas wildfire affected more than 156,000 acres in New Mexico, more than any other wildfire in the State's history (National Park Service, 2012, 2015). The burned areas covered a significant percentage of the regional watersheds, including drainage east of the Jemez Mountains serving as tributaries to the Rio Grande. Several August 2011 "monsoons" with 1.5 inch to 2 inches of rainfall followed, resulting in flooding events (and a Presidential major disaster declaration) in burned watersheds above Peralta and Cochiti Canyons (National Weather Service, 2011). The resulting flood events included mudflows, with reports of the flood width of 100 yards and waters of 10 to 20 feet deep (Postel, 2011).

Infrastructure losses included several facilities, including those designed to convey such 1.5 inch rainfall events from the "pre-fire" land-cover conditions.

For agencies needing to assess the post-fire flood potential for a project, site-specific information will be required as fire and flood hazard impacts can be dependent on many factors and subject to many uncertainties (Neal and Weir, 2015). Recent methods seek to help categorize these uncertainties into frameworks that allow assessment and discussions by a wider audience of groups and stakeholders (Neal and Weir, 2015). Federal agencies, such as FEMA and the U.S. Geological Survey (USGS), and state and/or local agencies have developed post-fire flood hazard maps to assist decision-makers following major events. These map products may provide useful guidance and/or methods for determining flood hazards provided there is sufficient similarity between the key physical environmental factors at the prior burn areas and the agency's proposed project site.

Other Considerations

Finally, land use changes may include consideration of future flood risk reduction measures, both structural and non-structural in the project watershed. Agencies should be cognizant of how changes to current and future flood management approaches (e.g., adding or removing structural or non-structural measures) may also cause changes to flood hazards. For example, adding such measures could have direct and indirect impacts (both positive and adverse) to such characteristics such as waterway hydraulics, floodplain storage, river mechanics, and sediment transport. Additionally, such measures have potential affects for perception of safety and potential development behind such measures.

B. Long-Term Erosion and Other Geomorphic Changes

Future manmade and natural alterations to the landscape will likely trigger changes in the location and severity of flood hazards. Riverine and coastal floodplains are very dynamic systems, with geomorphologies constantly changing in response to physical phenomena operating over a wide range of spatial and temporal scales. Coastlines and beaches evolve over time, transgressing or regressing in response to variations in storminess (surge and waves), water levels (sea level rise or fall), sediment volume, and underlying geology. Coastal inlets will migrate (some cyclically) in response to these same drivers. Riverine floodplains expand or contract based on flow, sediment regimes, and underlying geology. Changes in riverine geomorphology and in sedimentation can cause channel degradation (lowering the bed) in some locations and aggradation (elevating the bed) in others.

Coastal Erosion

Shorelines erode and prograde in response to a complex set of forcing phenomena, as noted above. Owing to their importance to navigation, commerce, and defense, U.S. shorelines have been mapped for more than a century by the U.S. Coast Survey and successor agencies. As mapping technologies have evolved, shoreline data have been collected more frequently and with greater accuracy by the federal government and other entities. Most coastal reaches of the U.S.

have sufficient data to support calculation of long-term rates of change, information that is vital to government agencies and other coastal stakeholders concerned with managing coastal hazards. For example, see the USGS's National Assessment of Coastal Change Hazards, or one of the many state-based coastal erosion mapping programs.

Although shoreline change can have a significant impact on the geographic distribution and severity of coastal flooding, FEMA FIRMs do not incorporate long-term erosion into the underlying flood modeling or depict erosion information separately. In the National Flood Insurance Act of 1994, Congress required the Director of FEMA to submit a report to Congress that evaluated the economic impact of erosion and erosion mapping on coastal communities and the NFIP. The report, which was prepared by the H. John Heinz Center (under contract to FEMA) and delivered to Congress in April 2000, recommended that Congress (1) instruct FEMA to map coastal erosion hazard areas, and (2) require FEMA to include the cost of expected erosion losses when setting flood insurance rates along the coast. While FEMA has taken steps to address losses stemming from long-term erosion in the NFIP's insurance premium rate structure, FEMA FIRMs do not include any erosion hazard information.

While the research community is making advances in the modeling of coastal geomorphic response to storms and sea level rise (e.g., Elko et al., 2015; Holman et al., 2015), no consensus models are currently available to determine detailed future flood hazards. In the interim, resources are available to aid agencies needing to assess the severity of long-term erosion hazards along U.S. shorelines; however, the granularity (or resolution) may or may not be sufficiently detailed to support detailed (i.e., parcel-scale) assessment. Agencies can combine analyses of sea-level rise based on simplified methods (e.g., linear superposition or "bathtub approach") with tools like the USGS's Coastal Vulnerability Index (Thieler et al., 1999) to identify areas where erosion is a risk and where a more detailed analysis may be required to more fully capture risks. The CVI provides national maps with an index of vulnerability and probabilities of high shoreline loss. The CVI was recently updated using probabilistic shoreline change data to predict long-term shoreline change associated with sea-level rise through the use of a Bayesian network (Gutierrez et al., 2014).

Riverine Erosion

Practitioners have long recognized that being able to predict the effects and magnitude of future human activities is a necessary constituent in properly considering riverine erosion (Richardson et al., 1975). As described by Lagasse (1991), practitioners typically consider geomorphic and hydraulic factors as affecting stream stability and riverine erosion. Response to human activities in the watershed (and/or natural disturbances of the fluvial system) can result in,

> *… rapid and unexpected changes in streams, making it important to anticipate changes in channel geomorphology, location, and behavior. Geomorphic characteristics of particular interest…are the alignment, geometry, and form of the stream channel… Upstream and downstream changes may affect future stability at the site. Natural disturbances such as floods, drought, earthquakes, landslides, and forest fires may result*

in large changes in sediment load in a stream and major changes in the stream channel. These changes can be reflected in aggradation, degradation, or lateral migration of the stream channel. (Lagasse et al., 1991)

In 1999, FEMA determined that it was technologically feasible to determine and map riverine erosion hazard areas (FEMA, 1999). These "hazard" areas were defined as locations where potential lateral migration is likely to result in damage to or loss of buildings and infrastructure within a 60-year period. Because the nature of riverine erosion involves highly complex and interacting physical processes, the determination of erosion hazards areas require many inputs including historical erosion rate information, geomorphic and engineering analysis, and mathematical modeling. Since issuance of the 1999 report, there have been improvements in the understanding of the various riverine erosion processes as well as numerical modeling and GIS techniques (Lagasse et al., 2012; Duan and Julien, 2010). However, as the 1999 FEMA report states, in all cases, flexibility is needed in the choice of analysis techniques to address site-specific conditions.

C. Vertical Land Movement

Many geologic factors contribute to vertical land movement, such as regional tectonic movement, regional vertical land subsidence or uplift, compaction of sedimentary strata, and crustal rebound in formerly glaciated areas (isostacy). Other factors include aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost (National Research Council, 1991). In the U.S., more than 17,000 square miles in 45 states (an area roughly the size of New Hampshire and Vermont combined) have been directly affected by subsidence.

Vertical land movement is a primary component of local relative sea level rise. In many locations, direct estimates of local vertical land uplift or subsidence can be obtained from co-located tide gages and Continuously Operating Reference Stations (CORS). The CORS allows for centimeter level accuracy of vertical change. Rates of vertical land motion can be factored into local sea level rise projections. The USACE Sea Level Calculator, for example, uses information at NOAA tide gages to add vertical land motion to global sea level projections such as those referenced in section B to make the projections relative to what is happening locally (Local Relative Sea Level Rise).

Vertical land movement associated with groundwater depletion and subsidence can have an impact on riverine baseflow and base level, causing steeper slopes and thus flood velocities and flood profiles. Several geographies in the U.S. subject to riverine flooding also have significant land subsidence issues, such as the Sacramento-San Joaquin Delta region, the Florida Everglades, Houston and surrounding counties, and Southern Louisiana. Agencies are encouraged to examine the potential for subsidence in their project sites, and if warranted, include subsidence as an explicit component of its future riverine flood hazard elevation.

V. RESOURCES

There is currently no consensus on the exact resources (data/tools/reference documents) that agencies should use to apply the CISA in implementing the FFRMS. This section consists of a non-curated, non-exhaustive list of example government resources that may serve as a starting point for applying the CISA. Not all resources are appropriate for all applications, and inclusion in this appendix does not connote endorsement by the MitFLG agency subgroup or any participating agency. Climate data and tool resources are evolving rapidly. This resource list will be updated as the FFRMS is updated to ensure currency.

General Resources

Climate.Data.Gov

Find data related to climate change that can help inform and prepare America's communities, businesses, and citizens. You can currently find data and resources related to coastal flooding, food resilience, water, ecosystem vulnerability, human health, energy infrastructure and transportation.

3rd National Climate Assessment

Summarizes the impacts of climate change on the United States, now and in the future. A team of more than 300 experts guided by a 60-member Federal Advisory Committee produced the report, which was extensively reviewed by the public and experts, including federal agencies and a panel of the National Academy of Sciences.

US Climate Resilience Toolkit

A website designed to help people find and use tools, information, and subject matter expertise to build climate resilience. The Toolkit offers information from all across the U.S. federal government in one easy-to-use location. The goal is to improve people's ability to understand and manage their climate-related risks and opportunities, and to help them make their communities and businesses more resilient to extreme events. Topic areas include Coastal Flood Risk and Water Resources, which includes flooding, where case studies and tools exist.

Climate Resilience Evaluation and Awareness Tool (CREAT)

Provides information on climate impacts to assist water utilities to assess future risks and vulnerabilities.

Using Scenarios to Explore Climate Change: A Handbook for Practitioners

Published by the National Park Service's Climate Change Response Program, this handbook describes the five-step process for developing multivariate climate change scenarios taught by the Global Business Network (GBN) during a series of training workshops hosted by the National Park Service in 2010 and 2011.

FEMA Flood Map Service Center

The official government distribution center for digital flood hazard mapping products. In order to help communities, the public, and other FEMA stakeholders manage and reduce flood risk, FEMA provides a suite of user-friendly tools that support the needs of the public in viewing, analyzing, and printing flood hazard maps.

Hurricane Sandy Rebuilding Strategy
Recommendation 2 discusses development of a minimum flood risk reduction standard and discusses the uniform flood risk reduction standard for Sandy rebuilding projects.

USACE Responses to Climate Change Website
This website provides information about how the USACE is addressing how the portfolio of USACE Civil Works water resources infrastructure and programs could be affected by climate change.

Resources Pertinent to Section III

Global Sea Level Rise Scenarios for the United States National Climate Assessment
Synthesizes the scientific literature on global sea level rise and provides four global scenarios. The report includes input from national experts in climate science, physical coastal processes, and coastal management. The website includes frequently asked questions about sea level rise scenarios.

USACE Sea Level Change Calculator
Produces the amount of predicted sea level change from 1992 forward. Calculate the rates of sea level change by selecting the closest NOAA tide gage to the location of interest. Developed to support screening and assessing the vulnerability of U.S. Army Corps of Engineers projects to the effects of sea level change.

USACE Engineering Technical Letter – *Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation*
Provides guidance for understanding the direct and indirect physical and ecological effects of projected future sea level change on USACE projects and systems of projects and considerations for adapting to those effects.

Sea Level Rise Tool for Sandy Recovery
Provides guidance for post-Sandy rebuilding. Supports scenario planning to help planners adapt to uncertainties. Showed risk associated with projected scenarios of sea level rise.

Incorporating Sea Level Change Scenarios at the Local Level
Outlines eight steps a community can take to develop site-appropriate scenarios. Due diligence is required for this process, but the result will be a reasonable and realistic approach to coastal community planning.

Technical Considerations for Use of Geospatial Data in Sea Level Change Mapping and Assessment
Provides technical guidance to agencies, practitioners, and coastal decision-makers seeking to use and/or collect geospatial data to assist with sea level change assessments and mapping products. There is a lot of information available today regarding sea level

change and navigating this information can be challenging. This document seeks to clarify existing data and information and provide guidance on how to understand and apply this information to analysis and planning applications by directing readers to specific resources for various applications.

Guidelines for Determining Flood Flow Frequency, Bulletin 17B
This guide describes the data and procedures for computing flood flow frequency curves where systematic stream gaging records of sufficient length (at least 10 years) to warrant statistical analysis as a basis for determination. FAQs

National Stormwater Calculator - Climate Assessment Tool
Estimates the annual amount of rainwater and frequency of runoff from a specific site anywhere in the United States (including Puerto Rico).

Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects
This engineering and construction bulletin provides USACE with initial guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaptation policy.

Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections
This archive contains fine spatial resolution translations of climate projections over the contiguous U.S. developed using two downscaling techniques CMIP3 hydrologic projections over the western U.S. and CMIP5 hydrology projections over the contiguous U.S. corresponding to monthly BCSD climate projections.

Resources Pertinent to Section IV

U.S. Forest Service Burned Area Emergency Response Program
This site provides links to publications and other technical documentation related to the Service's program, as well as a point of contact.

USGS Post-Wildfire Landslide Hazards
This site provides background information on post-wildfire hazards, post-fire hazard mapping, and landslide monitoring information. The USGS conducts post-fire debris-flow hazard assessments for select fires in the Western U.S. using geospatial data related to basin morphometry, burn severity, soil properties, and rainfall characteristics to estimate the probability and volume of debris flows that may occur in response to a design storm.

USGS Coastal Change Hazards Portal
The U.S. Geological Survey is uncovering the science behind coastal change hazards and providing data, tools, and scientific knowledge to help coastal planners as they work to reduce risk along our coastlines. The Portal is an online tool used to interactively "see" past, present, and future coastal hazards, with products and information organized into three coastal hazard themes: 1) extreme storms, 2) shoreline change, and 3) sea-level rise.

SLAMM: Sea Level Affecting Marshes Model
Simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. Map distributions of wetlands are predicted under conditions of accelerated sea level rise, and results are summarized in tabular and graphical form. It includes a stochastic uncertainty analysis module for assessing the effects of input data uncertainty on model predictions.

Riverine Erosion Hazard Area (REHA) Mapping Feasibility Study
Prepared by FEMA to address requirements in the National Flood Insurance Reform Act (NFIRA) enacted in September 1994. Section 577 of NFIRA required that FEMA submit a report to Congress that evaluated the technological feasibility of mapping REHAs and assessed the economic impact of erosion and erosion mapping on the National Flood Insurance Program (NFIP). The purpose of this study was to determine whether it was technologically feasible to map REHAs.

Land Subsidence and Relative Sea-Level Rise in the Southern Chesapeake Bay Region
Describes why there is land subsidence in the Southern Chesapeake Bay Region, how it is measured, rates of change, and what resource managers should know for planning for and preventing future land subsidence.

Land Subsidence in the United States
USGS Fact Sheet-165-00 December 2000. This publication is one in a series of fact sheets that describe ground-water resource issues across the United States, as well as some of the activities of the U.S. Geological Survey that provide information to help others develop, manage, and protect ground-water resources in a sustainable manner.

VI. Glossary

Actionable Science

Theories, data, analyses, models, projections, scenarios, and tools that are:

- Relevant to the decision under consideration.
- Reliable in terms of its scientific or engineering basis and appropriate level of peer review.
- Understandable to those making the decision.
- Supportive of decisions across wide spatial, temporal, and organizational ranges, including those of time-sensitive operational and capital investment decision-making.
- Co-produced by scientists, practitioners, and decision-makers, and meet the needs of and are readily accessible by stakeholders.

Best-Available Data and Science

Data and Science that is:

- Transparent – clearly outlines assumptions, applications, and limitations.
- Technically credible – transparent subject matter or more formal external peer review, as appropriate, of processes and source data.

- Usable – relevance and accessibility of the information to its intended users. For the climate-informed approach, usability can be achieved by placing climate-related scenarios into appropriate spatial, temporal, and risk-based contexts**.**
- Legitimate – perceived by stakeholders to conform to recognized principles, rules, or standards. Legitimacy might be achieved through existing government planning processes with the opportunity for public comment and engagement.
- Flexible – scientific, engineering, and planning practices to address climate change-related information are evolving. To respond, agencies need to adapt and continuously update their approaches consistent with agency guidelines and principles.

Climate Science

Climate science encompasses:

- Processes and products related to all components of Earth's linked climate system (the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere) that play a role in average weather over a generally accepted time interval, usually 30 years.
- Common variables include daily temperature ranges and extremes, mean and extreme precipitation duration and intensity, and ocean sea level.
- Complex and diverse information that may or may not correspond to users' needs for information to inform their very different decisions over a range of space and time.

Climate-Informed

Take climate-related information into account as input to the existing science and engineering processes:

- Using existing sound science and engineering methods (e.g., hydrologic and hydraulic analysis and methodologies) as have historically been used to implement E.O. 11988, supplemented with best available, climate-related scientific information when appropriate (depending on the agency-specific procedures and type of federal action).
- Consistent with the climate science and related information found in the latest NCA report or other best-available, actionable science.
- Combining information from different disciplines (e.g., new perspectives from the atmospheric sciences, oceanographic sciences, coastal sciences, and hydrologic sciences in the context of climate change) in addition to traditional science and engineering approaches.
- Including future land cover and land use changes (which may alter hydrology due to increased impervious surface), long-term coastal and/or riverine erosion, and vertical land movement (for determining local changes to sea level) expected over the life cycle of the action.

Coastal Floodplains

Coastal floodplains are normally dry land areas in coastal regions that are susceptible to being inundated by water from any natural source, including oceans (e.g., tsunami run-up, coastal storm surge, relative sea-level rise). Coastal studies are conducted for communities along the Atlantic and Pacific Oceans, the Gulf of Mexico, the Great Lakes, and the Caribbean Sea.

Coastal studies are used to establish a 1-percent-annual-chance flood and an SFHA, but they may also designate a coastal high hazard area (V Zone). Note that coastal communities, particularly counties, may also have riverine floodplains with designated floodways.

Discharge

Volume rate of water flow which is transported through a given cross-sectional area. A river's discharge at a given location depends on the rainfall on the catchment or drainage area and the inflow or outflow of groundwater to or from the area, stream modifications such as dams and irrigation diversions, as well as evaporation and evapotranspiration from the area's land and plant surface.

Riverine Floodplains

Riverine floodplains occur along rivers, streams, or other waterways that are subject to overbank flooding. Riverine studies involve, among other factors, the collection and analysis of information about the river's watershed, the topography or the lay of the land along the river, precipitation, and the characteristics of the river itself.

Storm Tide

Storm tide is the total ***observed*** seawater level during a storm, which is the combination of storm surge and normal high tide.

Vertical Datum

A surface of zero elevation to which heights of various points are referred in order that those heights be in a consistent system. More broadly, a vertical datum is the entire system of the zero elevation surface and methods of determining heights relative to that surface. Over the years, many different types of vertical datums have been used. The most dominant types today are tidal datums and geodetic datums. NAVD88, a geodetic vertical datum, is the one most commonly used by federal agencies involved in modeling and mapping flood hazards.

VII. References Cited

Angel, J.R. and Kunkel, K.E. (2010). The response of Great Lakes water levels to future climate scenarios with an emphasis on Lake Michigan-Huron. *Journal of Great Lakes Research*, 36, 51-58, 18 doi:10.1016/j.jglr.2009.09.006

Bindoff, N.L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley, and A. Unnikrishnan (2007). Chapter 5, Observations: Oceanic Climate Change and Sea Level. In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, Eds.). Cambridge, United Kingdom and New York, NY, U.S.A: Cambridge University Press. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter5.pdf

Burkett, V.R. and M.A. Davidson (Eds.). (2012) Coastal Impacts, Adaptation and Vulnerability: A Technical Input to the 2012 National Climate Assessment. *Cooperative Report to the 2013 National Climate Assessment*, 150.

Chow, V.T. (1964). *Handbook of Applied Hydrology: A Compendium of Water-Resources Technology*. New York: McGraw-Hill.

Church, J.A. and N.J. White (2006). A 20th century acceleration in global sea-level rise. *Geophysical Research Letters,* 33(1): L01602. doi:10.1029/2005GL024826

Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan. (2013). Sea Level Change. In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, U.S.A.

Duan, J.G., and Julien, P.Y. (2010). Numerical simulation of meandering evolution. *Journal of Hydrology,* doi:10.1016/j.jhydrol.2010.07

Elko, N., F. Feddersen, D. Foster, C. Hapke, J. McNinch, R. Mulligan, H.T. Ozkan-Haller, N. Plant, and B. Raubenheimer (Eds.). (2015). The future of nearshore processes research*. Shore & Beach*, v. 83 (1), 13-38.

EPA. (1998) EPA 1998, National Water Quality Inventory, *1998 Report to Congress.*

Federal Interagency Floodplain Management Task Force. (1987). *Further Advice on Executive Order 11988*. Washington, DC: Federal Emergency Management Agency, 68.

FEMA. (1999). *Riverine Erosion Hazard Areas Mapping Feasibility Study*, 154. http://www.fema.gov/media-library-data/20130726-1545-20490-3748/ft_rivfl.pdf

FEMA. (2014). Guidelines and Standards for Flood Hazard Mapping Partners. *FEMA Great Lakes Coastal Guidelines, Appendix D.3 Update.* http://www.fema.gov/media-library-data/1429644544360-ecb03d79af615495232b3e94c6f318f5/Great_Lakes_Coastal_Guidelines_Update_Jan2014.pdf

FEMA Floodsmart. (2015). https://www.floodsmart.gov/floodsmart/pdfs/FS_FloodRisksFloodAfterFire.pdf

U.S. Congress. (2002). *Federal Water Pollution Control Act.* §204(5) and §208 b(2)(A), 58, 72. http://www.epw.senate.gov/water.pdf

Georgakakos, A., F. Fleming, M. Dettinger, C. Peters-Lidard, T.C. Richmond, K. Reckhow, K.White, D. Yates. (2013). Chapter 3, Water Resources. *National Climate Assessment Development Advisory Committee (2013) Third National Climate Assessment Report.* Washington, DC: U.S. Global Change Research Program. Available at http://www.globalchange.gov/what-we-do/assessment

Groisman, P.Y., R.W. Knight, D.R. Easterling, T.R. Karl, G.C.Hegerl, and V.N. Razuvaev. (2005). Trends in Intense Precipitation in the Climate Record. *Journal of Climate* 18:1326-1350. doi:10.1175/JHM-D-11-039.1

Groisman, P. Y., R.W. Knight, and T.R. Karl. (2012). Changes in Intense Precipitation over the Central United States. *Journal of Hydrometeorology*, 13(1), 47-66.

Gutierrez, B.T., Plant, N.G., Pendleton, E.A., and Thieler, E.R. (2014). Using a Bayesian Network to predict shore-line change vulnerability to sea-level rise for the coasts of the United States. *U.S. Geological Survey Open-File Report 2014*, 1083, 26.

Hirsch, R.M. (2011). A perspective on nonstationarity and water management. *Journal of the American Water Resources Association,* 47(3): 436–446. doi: 10.1111/j.1752-1688.2011.00539

Jevrejeva, S., J.C. Moore, and A. Grinsted. (2010). How will sea level respond to changes in natural and anthropogenic forcings by 2100? *Geophysical Research Letters*, 37: L07703.

Hinkel, J., C. Jaeger, R.J. Nichols, J. Lowe, O. Renn, and S. Peijun. (2015). Sea-level rise scenarios and coastal risk management. Nature Climate Change, 5:188-190.

Hirsch, R.M. and K.R. Ryberg (2012) Has the magnitude of floods across the U.S.A changed with global CO2 levels? *Hydrolological Sciences Journal,* doi: 10.1080/02626667.2011.621895

Holman, R.A., M.C. Haller, T.C. Lippmann, K.T. Holland, and B.E. Jaffe. (2015). Advances in nearshore process research: Four decades of progress. *Shore & Beach*, v. 83 (1), 39-52.

Horton, R., C. Herweijer, C. Rosenzweig, J. Liu, V. Gornitz, and A.C. Ruane. (2008). Sea level rise projections for current generation CGCMs based on the semi-empirical method. *Geophysical Research Letters*, 35: L02715.

Interagency Committee on Water Data (IACWD). (1982). *Guidelines for determining flood flow frequency*. U.S. Geological Survey, Office of Water Data Coordination, Hydrology Subcommittee, Bulletin 17B.

International Upper Great Lakes Study Board (IUGLSB). (2012). Lake Superior Regulation: Addressing Uncertainty in Upper Great Lakes Water Levels. *Final Report to the International Joint Commission.* Ottawa, ON: International Upper Great Lakes Study Board, March 2012. Available at http://www.ijc.org/iuglsreport/wp-content/report-pdfs/Lake_Superior_Regulation_Full_Report.pdf

IPCC. (2012). Summary for Policymakers. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change.* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, U.S.A, 1-19.

Jevrejeva, S., J.C. Moore, and A. Grinsted. (2010). How will sea level respond to changes in natural and anthropogenic forcings by 2100? *Geophysical Research Letters*, 37: L07703.

Karl, T.R., Melillo, J.M, and Peterson, T.C. (Eds.). (2009). Global Climate Change Impacts in the United States. Cambridge University Press.

Katsman, C.A., A. Sterl, J.J. Beersma, H.W. Van den Brink, J.A. Church, W. Hazeleger, R.E. Kopp, D. Kroon, J. Kwadijk, R. Lammersen, J. Lowe, M. Oppenheimer, H.-P. Plag, J. Ridley, H. von Storch, D.G. Vaughan, P. Vellinga, L.L.A. Vermeersen, R.S.W. van de Wal, and R. Weisse. (2011). Exploring high-end scenarios for local sea level rise to develop flood protection strategies for a low-lying delta – The Netherlands as an example. *Climate Change*, 109: 617–645. doi 10.1007/s10584-011-0037-5

Kiang, J.E., J.R. Olsen, and R.M. Waskom. (2011). Introduction to the featured collection on Nonstationarity, Hydrologic Frequency Analysis, and Water Management. *Journal of the American Water Resources Association*, 47(3): 433–435. doi: 10.1111/j.1752-1688.2011.00551

Kunkel, K. E., D.R. Easterling, D.A.R. Kristovich, B. Gleason, L. Stoecker, and R. Smith. (2010). Recent increases in U.S. heavy precipitation associated with tropical cyclones. *Geophysical Research Letters*, 37(24), L24706. doi: 10.1029/2010gl045164

Kunreuther, H., G. Heal, M. Allen, O. Edenhofer, C. Field, and G. Yohe. (2013). Risk Management and Climate Change. *Published Articles & Papers.* Paper 172. http://research.create.usc.edu/published_papers/172

Lagasse, P.F., J.D. Schall, F. Johnson, E.V. Richardson, J.R. Richardson, F. Chang. (1991). *Stream Stability at Highway Structures. Hydraulic Engineering Circular (HEC) 20*. Washington, DC: Federal Highway Administration. Report FHWA-IP-90-014. February 1991.

Lagasse, P.F., L.W. Zevenbergen, W.J. Spitz, L.A. Arneson. (2012). *Stream Stability at Highway Structures. Hydraulic Engineering Circular (HEC) 20, 4th edition.* Washington, DC: Federal Highway Administration. Report FHWA-HIF-12-004. April 2012.

Leonard, M, S. Westra, A. Phatak, M. Lambert, B. van den Hurk, K. McInnes, J. Risbey, S. Schuster, D. Jakob, and M. Stafford-Smith. (2014). A compound event framework for understanding extreme impacts. *WIREs Climate Change,* 5, 113-128 (2014). doi: 10.1002/wcc.252

MacKay, M., and F. Seglenieks. (2012). On the simulation of Laurentian Great Lakes water levels under projections of global climate change. *Climatic Change*, 117, 55-67, doi:10.1007/s10584-012-0560-z

McCuen, R.H., P.A. Johnson, R.M. Ragan. (1996). Hydraulic Design Series 2, *Highway Hydrology*. Washington, DC: Federal Highway Administration, Report FHWA-SA-96-067, September 1996.

McCuen, R.H. (1989). *Hydrologic Analysis and Design.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

Milly, P.C.D, J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier, and R.J. Stouffer. (2008). Stationarity is dead: Whither water management? *Science,* 319(5863): 573.

Moody, J.A., R.A. Shakesby, P.R. Robichaud, S.H. Cannon, and D.A. Martin. (2013). Current research issues related to post-wildfire runoff and erosion processes. *Earth-Science Reviews*, 122: 10-37.

National Park Service. (2012). The Las Conchas Fire and Bandelier. NPS Resource Management Division. January 2012. http://www.nps.gov/band/learn/nature/upload/BAER-las-conchas.pdf

National Park Service. (2015). The Las Conchas Fire. http://www.nps.gov/band/learn/nature/lasconchas.htm (accessed August 2015).

Committee on Engineering Implications of Changes in Relative Mean Sea Level, Marine Board, Commission on Engineering and Technical Systems, National Research Council. (1987). *Responding to Changes in Sea Level, Engineering Implications.* Washington, DC: National Academy Press. http://www.nap.edu/catalog.php?record_id=1006

National Research Council. (1991). *Mitigating losses from land subsidence in the United States.* Washington, DC: National Academy Press, 58.

Committee on Sea Level Rise on California, Oregon, and Washington, Board on Earth Sciences and Resources and Ocean Studies Board, National Research Council. (2012). *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. Washington, DC: National Academy Press.

National Weather Service. (2011). *Advanced Hydrologic Prediction Service. August 2011 Archive Data. Gridded Rainfall Data.* http://water.weather.gov/precip/download.php (accessed August 2015).

Neale, Timothy, Jessica K. Weir. (2015). Navigating scientific uncertainty in wildfire and flood risk mitigation: A qualitative review. *International Journal of Disaster Risk Reduction*, 13 (2015), 255-265.

New York City Panel on Climate Change, C. Rosenaweig and W. Solecki (Eds). (2013). *Climate Risk Information 2013: Observations, Climate Change Projections, and Maps.* New York, NY: NPCC2 (Prepared for use by the City of New York Special Initiative on Rebuilding and Resiliency). 38. http://www.nyc.gov/html/planyc2030/downloads/pdf/npcc_climate_risk_information_2013_report.pdf

Nicholls, R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden, and C.D. Woodroffe. (2007). Chapter 6. Coastal systems and low-lying areas. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (Eds.)]. Cambridge, UK: Cambridge University Press. http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter6.pdf

Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. (2012). Global Sea Level Rise Scenarios for the U.S. National Climate Assessment. *NOAA Technical Report OAR CPO-1.* Washington, DC: National Oceanic and Atmospheric Administration, Climate Program Office. http://cpo.noaa.gov/sites/cpo/Reports/2012/NOAA_SLR_r3.pdf

Parson, E., V. Burkett, K. Fisher-Vanden, D. Keith, L. Mearns, H. Pitcher, C. Rosenzweig, M. Webster. (2007). Global Change Scenarios: Their Development and Use. *Sub-report 2.1B of Synthesis and Assessment Product 2.1 by the US Climate Change Science Program and the Subcommittee on Global Change Research. Department of Energy, Office of Biological & Environmental Research,* Washington, DC, 106.

Pathak, C., Teegavarapu, R., Olson, C., Singh, A., Lal, A., Polatel, C., Zahraeifard, V., and Senarath, S. (2015). Uncertainty Analyses in Hydrologic/Hydraulic Modeling: Challenges and Proposed Resolutions. *Journal of Hydrologic Engineering,* 10.1061/(ASCE)HE.1943-5584.0001231, 02515003

Pfeffer, W.T., J.T. Harper, and S. O'Neel. (2008). Kinematic constraints on glacier contributions to 21st-century sea-level rise. *Science*, 321(5894) 1340–1343.

Postel, Sandra. (2011). Fire and Rain: The One-Two Punch of Flooding after Blazes. http://voices.nationalgeographic.com/2011/08/31/fire-and-rain/ (accessed August 2015).

Pryor, S. C., D. Scavia, C. Downer, M. Gaden, L. Iverson, R. Nordstrom, J. Patz, and G. P. Robertson. (2014). Ch. 18: Midwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 418-440. doi:10.7930/J0J1012N

Rahmstorf, S. (2007). A semi-empirical approach to projecting future sea level rise. *Science,* 315(5810): 368–370.

Richardson, E.V., D.B. Simons, S. Karaki, K. Mahmood, and M.A. Stevens. (1975). *Highways in the River Environment – Hydraulic and Environmental Design Considerations. FHWA Report HHI-22/R6-83.* Federal Highway Administration: May 1975 (reprinted July 1983).

Ryberg, K., Lin, W., and Vecchia, A. (2014). Impact of Climate Variability on Runoff in the North-Central United States. *Journal of Hydrological Engineering*, 19(1), 148–158. doi: 10.1061/(ASCE)HE.1943-5584.0000775

Stedinger, Jery R., and Veronica W. Griffis. (2011). Getting From Here to Where? Flood Frequency Analysis and Climate. *JAWRA Journal of the American Water Resources Association,* 47.3: 506-513.

Thieler, E.R., and E.S. Hammar-Klose. (1999). *National Assessment of Coastal Vulnerability to Future Sea Level Rise: Preliminary Results for the U.S. Atlantic Coast.* U.S. Geological Survey, Open-File Report 99-593, 1 sheet

U.S. Army Corps of Engineers. (2013). *Incorporating Sea Level Change in Civil Works Programs.* ER 1100-2-8162. Washington, DC: U.S. Army Corps of Engineers.

U.S. Bureau of Public Roads. (1956). *Policy on Interstate System Projects.* Policy and Procedure Memorandum 20-4. August 10, 1956.

U.S. Department of Agriculture. (1986). *Urban hydrology for small watersheds. Technical Release 55 (TR-55) (Second Edition).* Natural Resources Conservation Service, Conservation Engineering Division.

U.S. Geological Survey. (2005). *Southern California – Wildfires and Debris Flows. Fact Sheet 2005-3106.* http://pubs.usgs.gov/fs/2005/3106/pdf/FS-3106.pdf

Vermeer, M., and S. Rahmstorf. (2009). Global sea level linked to global temperature. *Proceedings of the National Academy of Sciences,* 106(51): 21527–21532.

Villarini, G., J. A. Smith, M.L. Baeck, and W.F. Krajewski. (2011). Examining Flood Frequency Distributions in the Midwest U.S. *Journal of the American Water Resources Association (JAWRA),* 47(3): 447-463. doi: 10.1111/j.1752-1688.2011.00540.x

Villarini, G., J. A. Smith, M. L. Baeck, T. Marchok, and G. A. Vecchi. (2011). Characterization of rainfall distribution and flooding associated with U.S. landfalling tropical cyclones: Analyses of Hurricanes Frances, Ivan, and Jeanne (2004*). Journal of Geophysical Research*, 116, D23116, doi:10.1029/2011JD016175

Villarini, G. and J.A. Smith. (2013). Flooding in Texas: Examination of Temporal Changes and Impacts of Tropical Cyclones. *Journal of the American Water Resources Association (JAWRA)*, 1-13. doi: 10.1111/jawr.12042

Villarini, G., R. Goska, J.A. Smith, and G.A. Vecchi. (2014). North Atlantic tropical cyclones and U.S. flooding, *Bulletin of the American Meteorological Society*, 95(9), 1381-1388.

Wahl, T., S. Jain, J. Bender, S.D. Meyers, and M.E. Luther. (2015). Increasing risk of compound flooding from storm surge and rainfall for major U.S. cities. *Nature Climate Change*, 2015/07/27/online doi: 10.1038/NCLIMATE2736

Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville. (2014). Ch. 2: Our Changing Climate. *Climate Change Impacts in the United States: The Third National Climate Assessment*, U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT

Woodruff, J.D., J. L. Irish, S.J. Camargo. (2013). Coastal flooding by tropical cyclones and sea-level rise. *Nature*, 504:44-52. doi:10.1038/nature12855

Zervas, C. (2009). *Sea Level Variations of the United States 1854–2006. NOS CO-OPS 053. Silver* Spring, MD: Center for Operational Oceanographic Products and Services, National Ocean Service, National Oceanic and Atmospheric Administration.

Zervas, C., S.K. Gill, and W. Sweet. (2013). *Estimating Vertical Land Motion from Long-Term Tide Gauge Records. Technical Report.* Silver Spring, MD: Center for Operational Oceanographic Products and Services, National Ocean Service, National Oceanic and Atmospheric Administration.