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New York State
Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act

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New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act

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New York State Flood Risk Management Guidance

Executive Summary

Climate change is the defining environmental issue of our time. We are already seeing the impacts of a changing climate in the form of more frequent and intense storms, rising sea levels and extreme flooding. In 2014, Governor Cuomo signed the Community Risk and Resiliency Act to build New York's resilience to these risks. The development of the Flood Risk Management Guidance will help to ensure the health, safety and well-being of New Yorkers now, and in the future.

This document provides guidance to state agencies on consideration of flooding risk by applicants for projects involving new and substantially improved structures or repair of substantially damaged structures in New York State. The Department of Environmental Conservation (DEC) has prepared this guidance, in consultation with the Department of State (DOS) and other stakeholders, as fulfillment of the Community Risk and Resiliency Act's (CRRA's) requirement that DEC develop guidance for implementation of the statute. This guidance serves as an interim step in the ongoing incorporation of climate change-related considerations and requirements into relevant DEC and other agency regulatory and funding programs.

DEC intends that this guidance will inform development of all subsequent guidance prepared pursuant to CRRA, as well as any program-specific changes made to incorporate additional consideration of flood risk. This guidance incorporates possible future conditions, including the greater risks of coastal flooding presented by sea-level rise and enhanced storm surge, inland flooding expected to result from increasingly frequent extreme-precipitation events and the increasing risk of compound flooding, resulting from simultaneous storm surge and heavy precipitation.[1] Sea-level rise is just one of the risks identified. This guidance builds upon DEC's regulations establishing a range of sea-level rise projections based on various rates of rise at several time slices through 2100.

This guidance document does not itself establish any legally binding standards or criteria for any particular structure, permit or approval. This guidance provides recommendations to agencies regarding how to consider sea-level rise and other flood risk, as required for certain programs covered by CRRA. DEC and other state agencies responsible for implementation of programs listed in CRRA should consult this guidance as they consider future physical risk due to climate change and as they develop any regulatory changes and/or program-specific guidance, as appropriate, to require that applicants demonstrate consideration of sea-level rise, storm surge and flooding, consistent with CRRA and program-specific authorizing statutes and operating regulations. While CRRA requires that applicants for certain specified permitting and funding programs demonstrate that they have considered future physical climate risk due to sea-level rise, storm surge, and flooding, whether and how each individual

[1] Wahl et al. 2015

program ultimately adopts the recommended guidelines in this guidance as binding standards or criteria may require future rulemaking actions and will depend on the relevant program's statutory authority and other appropriate factors.

Among other things, CRRA amended Environmental Conservation Law (ECL), Agriculture and Markets Law (AML), and Public Health Law (PHL) to require applicants for permits or funding in a number of specified permitting and funding programs to demonstrate they have considered future physical climate risk due to sea-level rise, storm surge and flooding. In CRRA-covered permit programs, CRRA requires demonstration of consideration of these flooding hazards for major projects, i.e., those not defined as minor by the Uniform Procedures Act (UPA, ECL Article 70). CRRA also requires DEC to consider these climate hazards if it amends certain facility-siting regulations.

This guidance provides the foundation for or informs several additional guidance documents that DEC and DOS intend to produce as part of CRRA implementation:

- ECL Article 15/Clean Water Act Section 401 Protection of Water Guidance for Bridges, Culverts and Other Structures
- ECL Article 15/Clean Water Act Section 401 Protection of Water Guidance for Streamway Setbacks
- Smart Growth Public Infrastructure Policy Act-Project Assessment Guidance
- Natural Resiliency Measures Guidance
- Tidal Wetland Migration Guidance
- Conservation of Natural Functions of Floodplains and Streams, and Mitigating Floodplain Encroachment
- Coastal Consistency Guidance
- Living Shorelines in the Marine District Guidance
- Model Local Laws for Community Resiliency

Within the context of regulatory programs affected by CRRA, the recommended flood-risk management guidelines are intended primarily for consideration in determination of the suitable location for construction of a proposed structure or other regulated activity, given future physical risks, within a permit's jurisdictional area. This guidance may also be used as a technical resource in development of program-specific guidance for state or local regulatory or funding programs not covered by CRRA, but for which flooding is a concern.

Most of the programs affected by CRRA already included some consideration of flooding prior to CRRA's passage. These programs generally prohibit or apply additional requirements to projects located in special flood-hazard areas, i.e., the area of the one-percent annual chance flood (commonly known as the one hundred-year flood), as indicated on flood insurance rate maps (FIRMs) issued by the Federal Emergency Management Administration (FEMA).

FEMA FIRMS include the elevation of the one-percent annual chance flood, otherwise known as the base flood elevation (BFE) for most floodprone areas of New York. However, because floods of any given annual likelihood, e.g., the one-percent annual chance flood, are expected to increase in depth and extent, the flood-risk management guidelines and other considerations described in this guidance are recommended as replacements for the one-percent floodplain typically used in funding and regulatory programs. That is, the recommended flood-risk management guideline would be used to describe a horizontal area, beyond the currently mapped special flood hazard area, in which additional flood-risk reduction measures may be appropriate. The recommended flood-risk management guidelines would also determine recommended design elevations within that area. DEC recommends regulatory and funding agencies adopt and apply these guidelines as appropriate, to the extent possible given the programs' authorizing statutes, implementing regulations, regulatory efficiency and other appropriate factors.

Table ES-1 identifies general flood-risk management guidelines for consideration in planning and review of project siting and design. Due to the uncertainties inherent in estimating true current flood risk, likely changes associated with changing climatic conditions, and the potential consequences for public health, safety and welfare, this guidance recommends that the highest (i.e., most protective) of the applicable flood-risk management guidelines be applied where practical and cost-effective. Avoiding construction in the defined by the applicable guidelines areas is generally preferable. Where avoiding the area defined by the most protective flood-risk management guidelines is not feasible, e.g., in the case of functionally dependent infrastructure or facilities such as culverts and bridges, applicants should demonstrate consideration of the applicable guidelines in project design. This guidance recognizes, however, that application of the highest flood-risk management guideline is not warranted in all cases for reasons of feasibility, cost, funding eligibility, risk tolerance, environmental effects, etc.

Table ES-1. General flood-risk management guidelines recommended for implementation of the Community Risk and Resiliency Act.

• The vertical flood elevation and corresponding horizontal floodplain determined by a climate-informed science approach in which adequate, actionable science is available.
• The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet (three feet for critical facilities[2]) of freeboard to the base flood elevation and extending this level to its intersection with the ground.
• The vertical flood elevation and corresponding horizontal floodplain associated with the 0.2-percent annual chance flood.

Tables ES-2 and ES-3 describe flood-risk management guidelines applicable to specific types of structures and to transportation infrastructure, respectively. These guidelines

[2] Critical facilities are defined and discussed in the section Critical Facilities below.

are derived from the general guidelines described in Table ES-1 but have been selected in consideration of the design process applicable to each structure type and data accessibility. Tables ES-2 and ES-3 describe one guideline elevation for most structure types, particularly in tidal areas. In all cases, application of the climate-informed science guideline (i.e., a guideline that includes sea-level rise or projected riverine flows) is preferred. However, in cases where more than one guideline is provided, either may be applied, at the regulatory or funding agency's discretion.

Table ES-2. Summary of recommended New York State flood-risk management guidelines. Applicants should demonstrate that plans for construction or other activities consider the listed guidelines, considering practicality, costs, financial burden, funding eligibility, risk tolerance and environmental effects.

Category	Nontidal Areas	Tidal Areas
Large lakes and Great Lakes: All structures	• The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}). • The vertical flood elevation and corresponding horizontal floodplain associated with the flood of record.	
One- and two-family residential, and small nonresidential structures	• The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).	• The vertical flood elevation and corresponding horizontal floodplain that result from adding the medium sea-level rise projection over the expected service life of the structure, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.
Multi-family and large non-residential structures	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q100) to account for projected future flows, adding two feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).	• The vertical flood elevation and corresponding horizontal floodplain that result from adding the medium sea-level rise projection over the expected service life of the structure, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.
Critical facilities and critical non-transportation infrastructure, designed to be functional during flooding	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q_{100}) to account for projected future flows, adding three feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).	• The vertical flood elevation and corresponding horizontal floodplain that result from adding the high sea-level rise projection applicable for the full, expected service life of the facility, plus three feet of freeboard, to the BFE and extending this level to its intersection with the ground.
Non-critical facilities and non-critical non-transportation infrastructure designed to survive flooding and regain functionality within an acceptable period	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q_{100}) to account for projected future flows, adding two feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground.	• The elevation and special flood hazard area that result from adding the medium sea-level rise projection applicable for the full, expected service life of the facility, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.

<table>
<tr><td rowspan="2">Water supply and wastewater treatment plants, and pump stations</td><td>Non-critical equipment</td><td colspan="2">• The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.</td></tr>
<tr><td>Critical equipment</td><td>• The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flow parameters, e.g., Q_{100}, to account for projected peak flows, adding three feet of freeboard, and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.
• The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).</td><td>• The vertical flood elevation and corresponding horizontal floodplain that result from adding the high sea-level rise projection applicable for the full, expected service life of the infrastructure to the BFE, adding three feet of freeboard, and extending this level to its intersection with the ground.</td></tr>
<tr><td colspan="4">Notes:
• The source for all sea-level rise projections referenced in this table shall be 6 NYCRR Part 490, Projected Sea-level rise.
• See Other Risk Zones for discussion of situations in which no BFE is available.
• Non-critical infrastructure, for which some flooding is acceptable, may be built without freeboard but should maintain capacity to survive events defined by the applicable guidelines or be restored to operating capacity quickly.
• Large lakes to which these guidelines apply are named in the guidance text.</td></tr>
</table>

Table ES-3. Recommended flood-risk management guidelines for transportation infrastructure. Consideration should be given to the highest of these guidelines practicable, considering feasibility, project costs, costs of flooding, funding eligibility, risk tolerance, environmental effects and historic preservation per design documentation or verification.

Category	Nontidal Areas	Tidal Areas
Critical linear transportation infrastructure	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flows, e.g., Q_{50}, Q_{100}, to account for projected peak flows for the full, expected service life of the infrastructure, adding freeboard per current applicable engineering requirements or recommendations (three feet preferred), and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).	• Applicable coastal design criteria that incorporate the higher of the 0.2-percent annual chance flood (Q_{500}) or a range of sea-level rise projections, up to and including the high sea-level rise projection, applicable for the full, expected service life of the infrastructure.
Category	**Nontidal Areas**	**Tidal Areas**
Non-critical linear transportation infrastructure	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flows, e.g., Q_{50}, Q_{100}, to account for projected peak flows for the full, expected service life of the infrastructure, adding freeboard per current requirements or recommendations, and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, applicable for the full, expected service life of the infrastructure.
	• The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the bridge, and adding two	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the high sea-

Critical bridges	feet of bridge freeboard. An additional foot of bridge freeboard should be considered for critical bridges. The projected Q_{100} flow should pass below the lowest chord without going into pressure flow. • The vertical flood elevation and corresponding flows resulting from the 0.2-percent annual chance flood (Q_{500}).	level rise projection, applicable for the full, expected service life of the bridge, and the 0.2-percent annual chance flood (Q_{500}).
Non-critical bridges	• The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the bridge, and adding two feet of bridge freeboard. The projected Q_{100} flow should pass below the lowest chord without going into pressure flow.	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, applicable for the full, expected service life of the bridge.
Critical culverts	• The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the culvert, and that allow the culvert to fully pass the design flood without increasing headwater and that provide at least two feet of roadway freeboard above the projected checkflow. An additional foot of roadway freeboard should be considered for culverts on critical roadways. • The vertical flood elevation and corresponding flows resulting from the 0.2-percent annual chance flood (Q_{500}).	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the high sea-level rise projection, applicable for the full, expected service life of the culvert, and the 0.2-percent annual chance flood (Q_{500}).
Non-critical culverts	• The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the culvert, and that provide at least two feet of roadway freeboard above the projected checkflow.	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, and projected peak flows applicable for the full, expected service life of the culvert.

Notes:

- The source for all sea-level rise projections referenced in this table shall be 6 NYCRR Part 490, Projected Sea-level Rise.
- “Roadway freeboard” applies to roads and is defined as the vertical distance from the specified water surface elevation to the outside edge of the roadway shoulder.
- “Bridge freeboard” applies to stream crossings and is defined as the vertical distance from the specified water surface elevation to the lowest horizontal element (low chord).
- Non-critical infrastructure, for which some flooding is acceptable, may be built without freeboard but should maintain capacity to survive events defined by applicable guidelines or be restored to operating capacity quickly.

Although DEC recommends program-specific regulations and/or guidance ultimately require consideration of the highest of the flood-risk management guidelines applicable to a specific structure type, other considerations, including, but not limited to, human health and safety, environmental effects, cost, funding-source requirements, feasibility and community impact, may preclude application of the highest of the flood-risk management guidelines in some cases. This guidance also recognizes that siting and design based on the highest applicable guideline may not be the most protective in some cases. However, applicants to CRRA-covered programs should be required to provide rational bases for the flood-risk management guideline included in their project designs.

Although development of requirements that applicants demonstrate consideration of the most protective guideline for determining elevation are strongly encouraged, agency programs responsible for implementation of regulatory or funding programs covered by CRRA may, with appropriate justification, e.g., regulatory efficiency, practicality, public availability of information or limits to statutory authority, elect to apply a specific guideline or set of guidelines.

Although the primary purpose of this guidance is to guide state agencies responsible for programs affected by CRRA as they consider future flood risks and develop appropriate regulatory changes and/or program-specific guidance for staff and applicants, it may also be valuable as a resource in other planning and regulatory programs:

- State funding and regulatory programs that CRRA does not cover, but in which flooding is a concern, may use this guidance as a technical resource or amend, as appropriate, program-specific guidance for consistency with this guidance.
- Title 6 of the New York Codes, Rules and Regulations (NYCRR), Part 502, Floodplain Management for State Projects, provides floodplain management criteria, including a definition of the special flood-hazard area as the area of one-percent or greater annual chance of flooding, for state-constructed or state-financed projects. This guidance may be considered in any future revision of Part 502.
- DEC provides model language for local flood-damage protection laws. This model language describes the minimum requirements for a community to participate in the National Flood Insurance Program (NFIP). Communities may, however, adopt more protective standards, and DEC provides optional additional language for such standards. DEC and DOS have incorporated this guidance into model local laws for voluntary local adoption.
- The New York State Uniform Fire Prevention and Building Code (Uniform Code) includes a requirement that building design include two feet of freeboard above the base flood elevation. The Uniform Code could be amended to incorporate this guidance statewide (except New York City, which has its own building code), but this process is a lengthy one. Municipalities may adopt their own flood hazard maps to include higher design flood elevations from which freeboard is measured, or they may adopt more restrictive local standards. DEC and DOS could develop guidance and model language to facilitate local adoption of the guidelines included in this guidance.

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1 Introduction

1.1 Community Risk and Resiliency Act

1.1.1 Background

In response to extreme flooding in much of New York State, the state enacted the Community Risk and Resiliency Act (CRRA) in 2014. The legislative purpose of the act, as stated in the bill sponsor's memorandum, "is to ensure that state monies and permits include consideration of the effects of climate risk and extreme weather events," specifically flooding, storm surge and sea-level rise.

Among other things, CRRA amends the Environmental Conservation Law (ECL), Agriculture and Markets Law (AML), and Public Health Law (PHL) to require applicants for permits or funding in a number of specified permitting and funding programs to demonstrate they have considered future physical climate risk due to sea-level rise, storm surge and flooding. In CRRA-covered permit programs, for which the State Uniform Procedures Act (UPA, ECL Article 70) defines minor projects, CRRA requires demonstration of consideration of flooding, etc., for major projects, i.e., those not defined as minor by the UPA. Table 1 lists the programs covered by CRRA and their authorizing statutes. Note that for some permit programs, CRRA amends the UPA to require consideration of flooding, etc., rather than the program's authorizing statute.

CRRA also requires the Department of Environmental Conservation (DEC) to consider these factors if it amends certain facility-siting regulations.

CRRA requires DEC, in consultation with the Department of State (DOS), to prepare guidance on the implementation of the act, "including but not limited to available and relevant data sets and risk analysis tools and available data predicting the likelihood of future extreme weather events."

CRRA requires DEC and DOS to "develop additional guidance on the use of resiliency measures that utilize natural resources and natural processes to reduce risk." CRRA requires DOS, in cooperation with DEC, to "prepare model local laws that include consideration of future physical climate risk due to sea level rise, and/or storm surges and/or flooding, based on available data predicting the likelihood of future extreme weather events including hazard risk analysis..."

CRRA amends the State Smart Growth Public Infrastructure Policy Act (ECL Article 6) to add "to mitigate future physical climate risk due to sea level rise, and/or storm surges and/or flooding, based on available data predicting the likelihood of future extreme weather events, including hazard risk analysis data if applicable" to the list of smart-growth public-infrastructure criteria.

DEC has developed this New York State Flood Risk Management Guidance (SFRMG), in consultation with DOS and other stakeholders, as fulfillment of CRRA's requirement to develop guidance to implement the statute.[3] This document provides guidance to state agencies on consideration of flooding risk by applicants for projects involving new and substantially improved structures or repair of substantially damaged structures in New York State. The Department of Environmental Conservation (DEC) has prepared this guidance, in consultation with the Department of State (DOS) and other stakeholders, as fulfillment of the Community Risk and Resiliency Act's (CRRA's) requirement that DEC develop guidance to implement the statute. This guidance serves as an interim step in the ongoing incorporation of climate change-related considerations and requirements into relevant DEC and other agency regulatory and funding programs.

DEC intends this guidance will inform development of all subsequent guidance prepared pursuant to CRRA, as well as any program-specific changes made to incorporate additional consideration of flood risk. This guidance incorporates possible future conditions, including the greater risks of coastal flooding presented by sea-level rise and enhanced storm surge, and of inland flooding expected to result from increasingly frequent extreme precipitation events.

This guidance document does not itself establish any legally binding standards or criteria for any particular structure, permit or approval and cannot be used to impact insurance rates. This guidance provides recommendations to agencies regarding how to consider sea-level rise and other flood risk, as required for certain programs under CRRA. DEC and other state agencies responsible for implementation of programs listed in CRRA should consult this guidance as they consider future physical risk due to climate change and as they develop any regulatory changes and/or program-specific guidance, as appropriate, to require applicants demonstrate consideration of sea-level rise, storm surge and flooding, consistent with CRRA and program-specific authorizing statutes, operating regulations, policies, etc. While CRRA requires that applicants for certain specified permitting and funding programs demonstrate that they have considered future physical climate risk due to sea-level rise, storm surge and flooding, whether and how each individual program ultimately adopts the recommended guidelines in this guidance as binding standards or criteria may require future rulemaking actions and will depend on the relevant program's statutory authority and other appropriate factors.

This guidance provides the foundation for several additional guidance documents that DEC and DOS intend to develop as part of CRRA implementation:

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[3] A team led by DEC's Division of Water, Bureau of Flood Protection and Dam Safety, and including representatives from various state agencies, including Department of State (DOS), Energy Research and Development Authority (NYSERDA), Department of Transportation (DOT), Division of Homeland Security and Emergency Services (DHSES),Dormitory Authority (DASNY) and DEC's Office of Climate Change developed this guidance. Support has also been provided by the New York State Floodplain and Stormwater Managers Association and U.S. Geological Survey (USGS).

- ECL Article 15/Clean Water Act Section 401 Protection of Water Guidance for Bridges, Culverts and Other Structures
- ECL Article 15/Clean Water Act Section 401 Protection of Water Guidance for Streamway Setbacks
- Smart Growth Public Infrastructure Policy Act-Project Assessment Guidance
- Natural Resiliency Measures Guidance
- Tidal Wetland Migration Guidance
- Coastal Consistency Guidance
- Living Shorelines in the Marine District Guidance
- Model Local Laws for Community Resiliency

Within the context of regulatory programs affected by CRRA, the recommended flood-risk management guidelines are intended primarily for consideration in determination of the suitable location for construction of a proposed structure or other regulated activity, given future physical risks, within a permit's jurisdictional area. This guidance may also be used as a technical resource in development of program-specific guidance for state or local regulatory or funding programs not covered by CRRA, but for which flooding is a concern.

Most of the programs affected by CRRA already included some consideration of flooding prior to CRRA's passage. These programs generally prohibit, or apply additional requirements to, projects located in special flood-hazard areas, i.e., the area of the one-percent annual chance flood (commonly known as the one hundred-year flood), as indicated on flood insurance rate maps (FIRMs) issued by the Federal Emergency Management Administration (FEMA). However, as floods of any particular annual likelihood, e.g., the one-percent annual chance flood, are expected to increase in depth, vertical flood elevations and the associated horizontal floodplain determined by the flood-risk management guidelines described in this SFRMG are recommended as replacements for the one-percent floodplain typically used. DEC recommends regulatory and funding agencies adopt and apply those guidelines as appropriate, to the extent possible given the programs' authorizing statutes, implementing regulations, regulatory efficiency and other appropriate factors.

Table 1. Programs affected by the Community Risk and Resiliency Act.

	Authorizing Statute
Permit Programs	
Oil and Natural Gas Well Siting	ECL 23(3)
Protection of Water*	ECL 15(5)
Sewerage Service*	ECL 17(15)
Liquefied Natural Gas or Petroleum Gas Facilities*	ECL 23(17)

Mined Land Reclamation*	ECL 23(27)
Freshwater Wetlands*	ECL 24
Tidal Wetlands*	ECL 25
Coastal Erosion Hazard Area*	ECL 34
Facility-siting Regulations	
Hazardous waste transportation, storage and distribution facility siting	ECL 27(11)
Petroleum bulk storage	ECL 17(10)
Hazardous substance bulk storage	ECL 40(1)
Funding Programs	
Water Pollution Control Revolving Fund	ECL 17(19)
Drinking Water Revolving Fund	PHL 1161
State Land Acquisition	ECL 49(2)
Open Space Project Operation and Maintenance Agreements	ECL 54(3)
Landfill Closure Assistance	ECL 54(5)
Coastal Rehabilitation Project Assistance	ECL 54(11)
Local Waterfront Revitalization	ECL 54(11)
Agricultural and Farmland Protection	AML 325

*CRRA amends the Uniform Procedures Act (ECL 70-0117) to apply to applicants for major projects in this program.

1.2 Applicability

The primary purpose of this guidance is to guide state agencies responsible for programs affected by CRRA as they consider future physical risks due to sea-level rise, storm surge and flooding, and as they develop program-specific guidance for staff and applicants required by CRRA to demonstrate consideration of these hazards. This guidance may also be used to inform state actions not covered by CRRA, and to help communities and the public understand the risks to both public and private development from flooding under current and anticipated future conditions.

Although this guidance describes various guidelines to determine vertical flood elevations and horizontal floodplains, it does not establish a new elevation standard. Rather, the vertical flood elevation and corresponding horizontal floodplain determined using the guidelines described in this guidance establish the level that should be considered in siting and design decisions by applicants and others. Each regulatory or funding program should develop requirements for adequate documentation of consideration of flood hazards.

This guidance describes preferred flood-risk management guidelines but recognizes that regulatory and funding agencies may adopt and apply those guidelines as appropriate given their programs' authorizing statutes, implementing regulations or regulatory efficiency. This guidance further recognizes that application of the highest flood-risk management guideline is not warranted or practical in all cases for reasons of feasibility; costs, including costs of future flooding; actual risk; and environmental effects.

This guidance has additional potential applicability in a number of planning and regulatory programs:

- State funding and regulatory programs that CRRA does not cover, but in which flooding is a concern, could use this guidance as a technical resource or amend, as appropriate, program-specific guidance for consistency with this guidance.
- Title 6 of the New York Codes, Rules and Regulations (NYCRR), Part 502, Floodplain Management for State Projects, provides floodplain management criteria, including a definition of the special flood-hazard area as the area of one-percent or greater annual chance of flooding, for state-constructed or state-financed projects. This guidance could be considered in any future revision of Part 502.
- DEC provides model language for local flood-damage protection laws. This model language describes the minimum requirements for a community to participate in the National Flood Insurance Program (NFIP). Communities may, however, adopt more protective standards, and DEC provides optional additional language for such standards. DEC and DOS have incorporated this guidance into model local laws for voluntary local adoption.
- The New York State Uniform Fire Prevention and Building Code (Uniform Code) includes a requirement that structure design include two feet of freeboard above the base flood elevation (BFE—The elevation of a flood with a 1-percent chance of being equaled or exceeded in any given year. The Uniform Code could be amended to incorporate this guidance statewide (except New York City, which has its own building code), but this process is a lengthy one. Municipalities may adopt their own flood hazard maps to include higher design flood elevations from which freeboard is measured, or they may adopt more restrictive local standards. DEC and DOS could develop guidance and model language to facilitate local adoption of the guidelines included in this guidance.

2 Flood Risk Management

It is important to note the many ways in which flood risk has changed and continues to change. Since the 1950s, an increasing proportion of New York State's annual precipitation has fallen in the heaviest precipitation events, increasing the risk of floods in the state. This trend is expected to continue because, as the climate warms, the atmosphere will hold more moisture. Further, flood risks in tidal areas are increasing due to sea-level rise and potentially stronger storm surges. However, climate change is not the only factor in changing flood risk. Human-caused changes to our waterways and shorelines, and the very nature of development, change flood risk.[4] Flood risk also changes naturally as rivers meander and natural dynamic shoreline processes take place.

Although the changing nature of flood risk is well understood by floodplain managers, current floodplain regulations are largely based on historical flood probabilities and assume stationary rainfall patterns and sea levels. The value of extrapolating historical observations as a guide to future conditions is decreasing as the climate changes because climate change not only affects the average of future temperature and precipitation, but also the extremes. Both flood and drought are measured at the extremes of hydrologic data. A wider variation around the average means that even if the average does not change significantly, the frequency and severity of large floods are likely to increase. DEC offers this guidance to assist agencies and applicants in assessment of flood risk under future conditions.

2.1 Flood Risk and Flood Risk Data

2.1.1 Development and Flood Risk

Current and projected trends show increasing flood risk in New York. It is easy to see how development can significantly increase riverine flooding. As land is covered with buildings or pavement, water runs off more rapidly and streams have higher flood peaks. The amount of precipitation that runs into streams after natural land is altered can be significant, as seen in Figure 1. The very nature of development increases runoff from storms and decreases the lag time between the precipitation event and peak flows. Runoff moves more rapidly over hard paved or roofed surfaces than over natural vegetation. The result is higher rates of flow during storms, resulting in higher peak floods.

The Saw Mill River in Yonkers is an example of the effect of development on river flows. Figure 2 shows the Saw Mill River's peak annual flows. The Saw Mill River watershed in the 1940s was much less developed than it is today. As development has increased over time, peak annual flow has also increased. Increased levels of development cause stormwater and snowmelt to run off faster rather than infiltrating into the soil. As a result,

[4] FEMA defines *development* as "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."

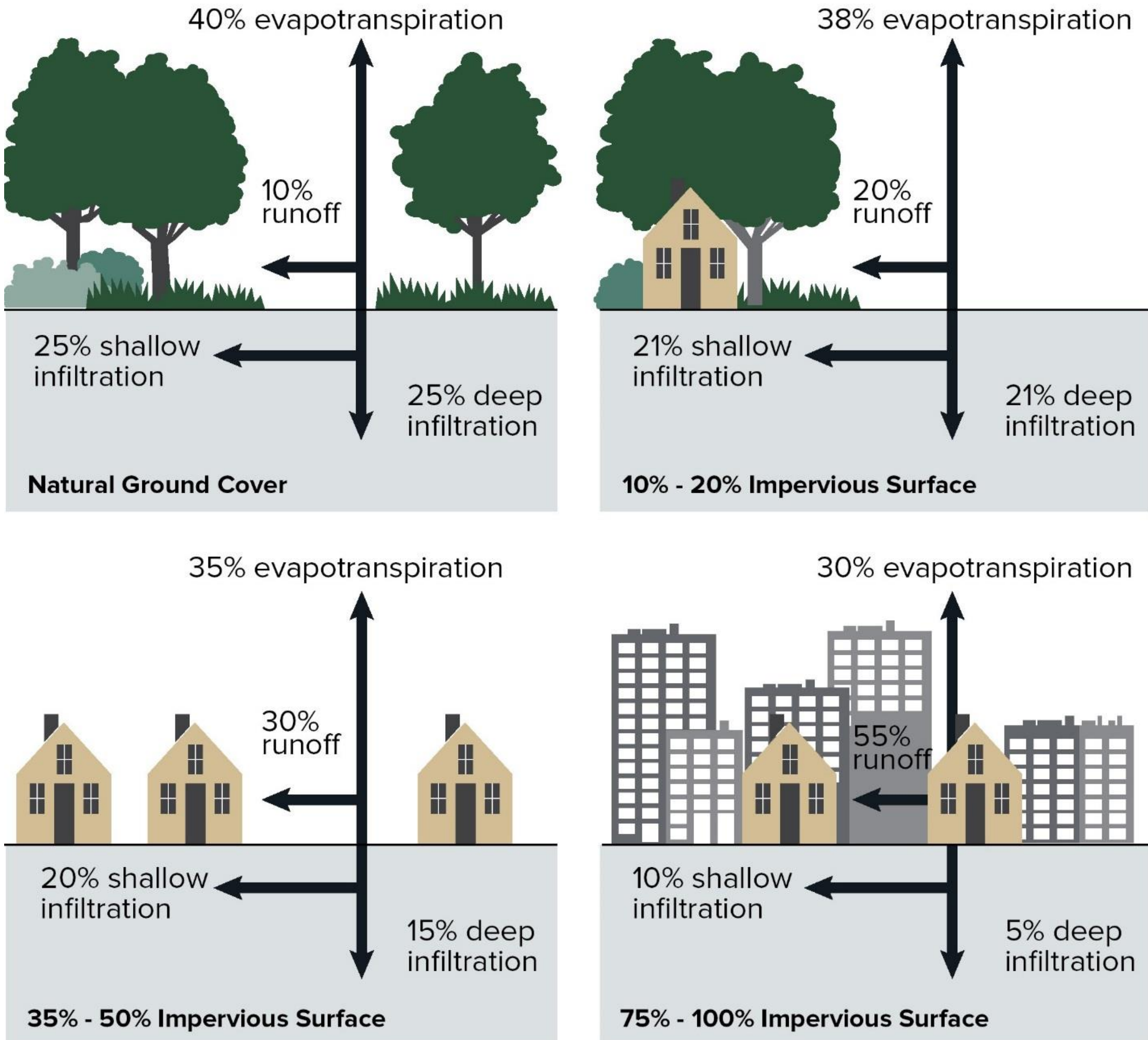


Figure 1. Effect of development on water runoff. Source: Stream Corridor Restoration: Principles, Processes and Practices. Federal Interagency Stream Restoration Working Group. GPO Item No. 0120-A; SuDocs No. A 57.6/2: EN 3/PT.653. ISBN-0-934213-59-3.

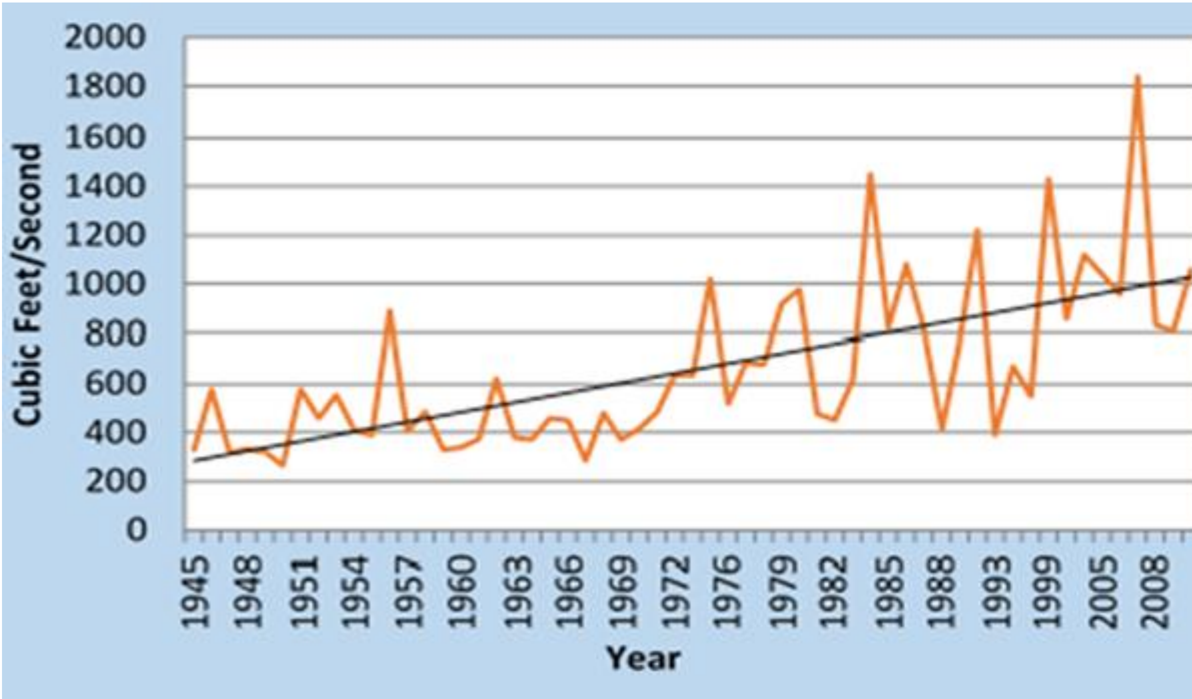


Figure 2. Peak annual flows, Saw Mill River, Yonkers, NY. Source: USGS Peak Annual Flows.

streams have a more rapid water level increase and a higher rate of flow during storm and melt events. Development, more than climate change, has caused this trend in the Sawmill River.

Stormwater runoff is regulated by DEC and the federal government. In particular, under its General Permit for Stormwater Discharges from Construction Activities, DEC requires a stormwater pollution prevention plan for any construction activity that will disturb one acre of land or more. See http://www.dec.ny.gov/chemical/8468.html.

Various forms of green infrastructure are effective at slowing down, spreading out and absorbing rainfall, potentially resulting in reduced peak flows. Consult DEC's guidance for use of natural resiliency measures and the New York State Stormwater Management Design Manual[5] for additional information.

It is difficult to accurately measure changes in the size of the state's population living in floodprone areas due to lack of digital flood maps until recent years. Anecdotal evidence and land-cover maps indicate that in coastal areas and areas around lakes and other scenic waterfronts, the amount and scale of development have increased. This may have increased the population in flood-prone areas and the number of buildings at risk. The 2014 New York State Hazard Mitigation Plan[6] estimates that about 733,000 people live within the FEMA-determined special flood hazard areas, which are the areas subject to a one-percent or greater annual chance of flooding. A Brookings Institution analysis of FEMA data determined that the number of people living in flood-prone areas of Nassau and Suffolk counties increased by more than 158,000 between 2000 and 2015. These two counties have been among the national leaders in the number of flood-damage claims reported to FEMA since 1978.[7]

Along shorelines that experience erosion, hardening of shorelines (such as through construction of seawalls and bulkheads) can lead to increased erosion on the water side of the hardened structure, and alteration of shoreline and water dynamics, which could increase both flooding and erosion. Such structures can also direct floodwaters to adjacent, unprotected properties.

Channel straightening and dredging can also increase flood hazards. The idea behind such

Reducing Flood Insurance Premiums

FEMA's Community Rating System (CRS) is a voluntary program that recognizes community floodplain management activities that exceed minimum NFIP standards. Communities participating in the NFIP CRS earn points toward their CRS ratings. The higher a community's CRS rating, the higher the discounts residents receive on their NFIP premiums.

Among the activities earning points:

- Programs that minimize increases in future flooding
- Use of regulatory flood elevations that reflect future conditions, including sea-level rise
- Use of regulatory maps based on future conditions, including sea-level rise
- Regulation of stormwater runoff from future development
- Hazard assessment to address future conditions

[5] New York State Department of Environmental Conservation 2015
[6] New York State Division of Homeland Security and Emergency Services 2014
[7] Kane and Puentes 2015

activities is that a straight, smooth channel will move water downstream faster. However, straightening and dredging alter the stream-flow characteristics upstream and downstream by failing to account for the need to dissipate the flowing water's energy and by changing the dynamics of sediment transport.[8] Stream straightening may increase flows and erosion downstream, and dredging can increase bank "cut back" or initiate a "head cut" or unraveling of the upstream streambank as the stream channel adjusts to its new shape. Sometimes modification of the stream channel or structural stabilization of the channel stream are unavoidable due to extreme flood risk to developed areas, or to accommodate roads and bridges. However, flood risk can increase in some places as a result.

2.1.2 Flood Risk and Climate Change

In general, climate change is expected to increase flood risk in most portions of New York State. One factor in this increased risk will be increases in the frequency and severity of heavy-precipitation events. There has already been a shift in the northeastern United States toward more extreme precipitation events. The Northeast experienced a greater than 71-percent increase in the amount of precipitation falling in the heaviest one percent of all daily events between 1958 and 2013 (Figure 3).[9] ClimAID projects that annual average precipitation will increase, but with significant variation, across New York State.[10] There is also evidence that the intensity of sub-daily rainfall is increasing. Intense precipitation events can often exceed the absorption rate or ability of rainwater to infiltrate into the ground, which can dramatically increase runoff and the potential for flooding.

Sea levels along New York's tidal coast have risen approximately 1.2 inches per decade since 1900 (Figure 4). The rate of rise is expected to increase, and rising sea levels will have major consequences for New York's coastal communities, including but not limited to

- magnification of dangerous storm surges caused by high winds and tides, which increase the risk of flooding, beach erosion, and damage to infrastructure in low-lying areas;
- increased areas of coastal inundation during regular tidal cycles; and
- regular inundation of coastal wastewater infrastructure.

Climate Change
Information

DEC has prepared a summary of likely climate-change effects in New York State (New York State Department of Environmental Conservation 2015). Additional information is available in the National Climate Assessment (2014) and ClimAID reports (Rosenzweig et al. 2011, Horton et al. 2014).

[8] Chemung County Soil and Water Conservation District 2006
[9] Melillo et al. 2014
[10] Rosenzweig 2011

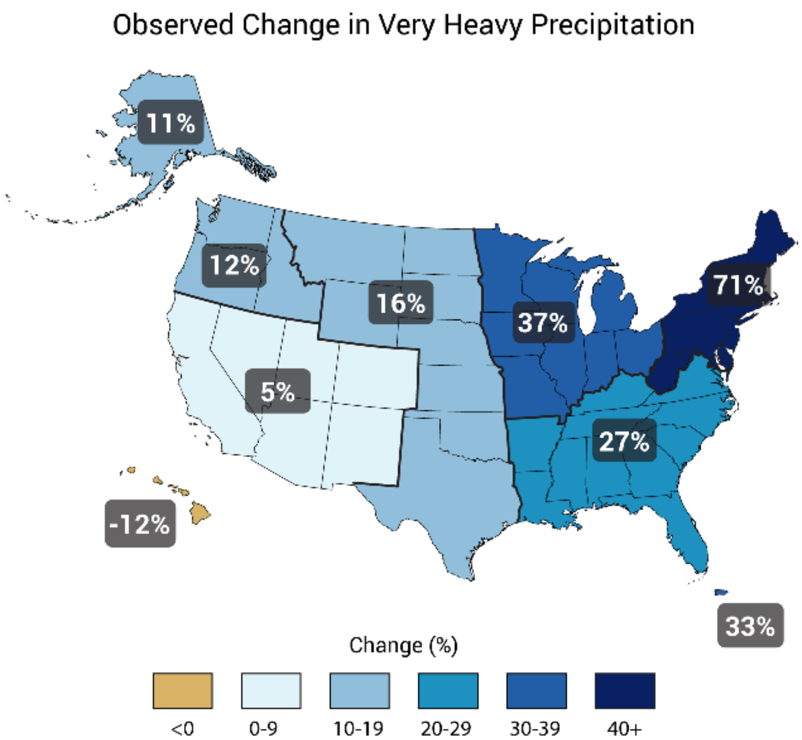


Figure 3. Percent increases in the amount of precipitation falling in heaviest 1% of all daily events from 1958 to 2013.

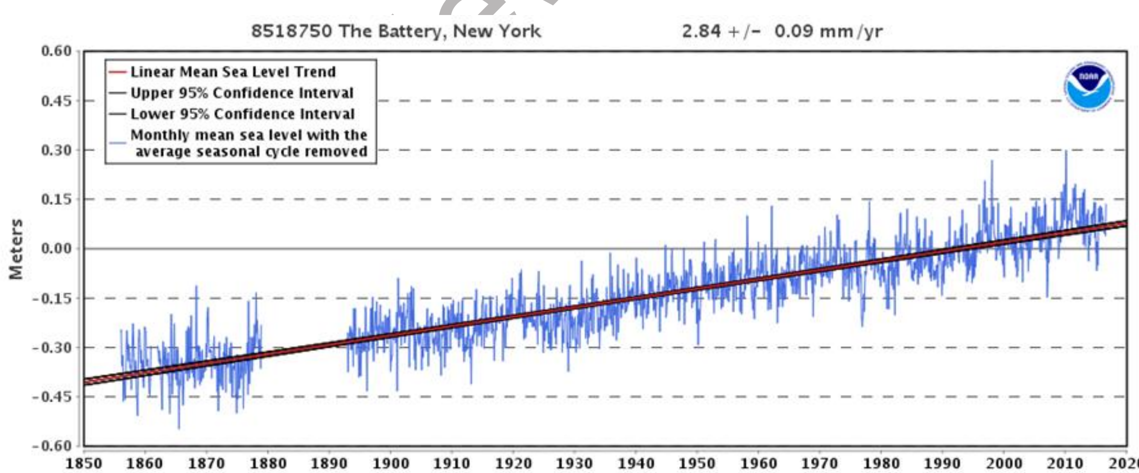


Figure 4. Sea level trend, the Battery, New York.

New York State has adopted sea-level rise projections based on the ClimAID report (Appendix A).[11]

2.1.3 Flood Risk in New York

New York State has 70,000 miles of rivers and streams, 127 miles of Atlantic Ocean coastline, 8,778 miles of lakeshore, 231 miles of shorefront on Long Island Sound, 548 total miles of Long Island beachfront, more than 300 miles of tidal Hudson River waterfront and 83 miles of coastal barrier islands off Long Island. There are 6,700 ponds, lakes and reservoirs of one acre or greater, 76 of which have an area of at least one square mile. Ten lakes each cover at least ten square miles. Every inch of shoreline along the state's rivers, streams, coastlines and lakefronts is prone to flooding.

Flood disasters can include hurricanes, tropical storms, summer storms, extreme non-tropical rain events, ice jam flooding and Great Lakes shoreline flooding. There are several kinds of flooding: coastal flooding, fluvial flooding from rivers, and pluvial or surface flooding. Flooding can also be caused by high groundwater levels, urban drainage system failures, and failures of dams, berms, flood walls and levees. Each general type of flooding has different features.

Climate Change & Floodplains

The firm AECOM (2013) found the following:

- Nationwide, the depth and extent of special flood hazard areas (SFHA) will increase by about 45% in riverine areas by 2100. About 70% of this increase will be due to climate change.
- Coastal SFHAs could increase by as much as 55% by 2100.
- The number of NFIP policies will increase by 80 to 100%; about 70% of this expected increase is attributable to climate change.
- NFIP premiums could increase by 10 to 70% by 2100 to offset projected flood losses.

2.1.3.1 Coastal Flooding

In New York, coastal flooding occurs in and along tidal waters and along the Great Lakes shorelines. Our larger lakes, such as Lake Champlain and the larger Finger Lakes, may also experience coastal flooding from wind generated wave action. Coastal flooding is caused by hurricanes, tropical storms, Nor'easters and other severe storms. Persistent high wind and changes in air pressure push water toward the shore causing a storm surge. Waves form on top of the storm surge, which can be highly destructive as the waves move inland, causing structural damage as well as erosion.

The total flooding from coastal storms results from a combination of storm surge, tides, and waves. Tides are the normal rise and fall of water along the coast due to the

[11] Horton et al. 2014.

gravitational pull of the moon and sun. When a high tide is combined with storm surge, it is called a storm tide and increases coastal flooding.

Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tide, caused by strong winds of a hurricane, tropical storm or nor'easter. Factors that contribute to a storm surge include the central air pressure of the storm, storm intensity, the size of the storm, the storm's forward speed, the angle of the storm's approach to the coast, the shape of the coastline, the width and slope of the ocean bottom, and local features such as barrier islands, inlets, sounds, bays and rivers. For example, Katrina was a much more powerful storm than was Superstorm Sandy, but Sandy was a much larger storm, so its surge was much higher than if it had been the size of Katrina. Air pressure accounts for only about five percent of the total surge.

Breaking waves contribute destructive energy to coastal floods. The heights of waves are determined by wave runup and wave setup. Wave runup occurs when a wave breaks and the water is propelled onto the beach. Wave setup occurs when waves continually break onshore and the water from the runup piles up along the coast because it cannot flow back to the sea. The water level continues to rise as a storm approaches; the waves become larger, and more water is pushed onshore.

Heavy rain ahead of a hurricane can add to coastal flooding as rivers, streams, and urban drainage cannot flow into a surging sea.

Lake Erie and Lake Ontario shorelines are also faced with coastal flooding. Sometimes higher water in the lakes can cause long-term shore flooding. This can be due to seasonal runoff or to above-normal runoff over a longer time. Strong winds can also push water and waves toward one side of the lake. Lake Erie, in particular, is prone to seiches as winds along the lake cause the lake water to slosh back and forth as in a bathtub. The eastern end of Lake Erie can rise by eight feet or more over a short period. The 2008 seiche caused considerable flooding in Buffalo.

Shorelines often have natural protective features such as sand dunes, bluffs and barrier islands, which are formed and shaped by wind and waves. When development takes place on or seaward of the natural protective features, or when the features are altered or damaged, flood and erosion risk increases.

2.1.3.2 Fluvial (Riverine) Flooding

Rivers and streams vary widely, from narrow, confined channels in steep valleys of hilly and mountainous areas to wide, flat areas along major rivers. The amount of water carried by a river or stream at any point is defined by its watershed, an area of land that drains into a single outlet and is separated from other drainage basins by a divide. The flow is not only determined by the size of the watershed, but also by its shape, topography, land cover, dams, lakes and wetlands. Different areas of the state have somewhat different climate characteristics that influence stream flows during normal and flood periods.

In steep narrow valleys, flooding usually occurs quickly and is of short duration. Flooding can be rapid and deep. Such flash floods can occur with little warning. Because most of our smaller streams do not have active stream gages, warnings through the National Weather Service and county emergency management offices may not address specific streams. Because small streams have relatively small watersheds, localized heavy downpours can cause flash flooding even as neighboring watersheds remain relatively dry. Flash floods have caused deaths, injuries and serious property damage throughout New York's history.

Flooding from large rivers usually results from large-scale weather systems that generate prolonged rainfall over large areas. In relatively flat floodplains, areas may remain inundated for days, and the rivers respond more slowly to storms.

Snowmelt can cause or exacerbate flooding in both small and large rivers. Extreme flooding in 1996 resulted from a heavy January snow storm followed by a February thaw and rain storm.

Ice jams can also cause severe flooding in parts of New York. In some areas, ice jams are difficult to predict. The formation of ice jams depends on the weather and physical conditions in river channels. They are most likely to occur where the channel slope naturally decreases, in culverts and along shallows where channels may freeze solid. Ice jam flooding can occur during mid-winter cold spells if streams freeze solid forming "anchor ice." Most ice-jam floods are associated with sudden warm spells that increase the risk of ice moving down stream and piling up at shallow areas, bridge and culvert abutments, bends and islands to block the flow of water.

2.1.3.3 Pluvial (Surface) Flooding

There has been growing attention to this third major kind of flooding. Pluvial flooding is surface flooding caused when heavy rainfall creates flooding independent of an overflowing water body. This can be due to an urban drainage system being overwhelmed by runoff or flowing water from rain falling on hillsides that are unable to absorb the volume of water. Pluvial flooding may be shallow but can still cause extensive property damage. FEMA flood maps do not show this kind of flood risk.

2.1.3.4 Other Flood Risk

Flooding can be caused or intensified due to failure of features designed to hold back water, including dams, berms, floodwalls and levees. Such failures are uncommon. However, a dam break can result in severe flooding even in the absence of a storm. Levee breaks are associated with flood events that can overwhelm the integrity of a levee. In such cases, the sudden failure of a levee can cause catastrophic damage far in excess of the flood damage that would occur if the levee were not there. This is a rare occurrence. However, it is always possible to experience a flood event in excess of a levee or flood wall's design. There are no recent examples of levee collapse in New York; however, during the 2011 Tropical Storm Lee flooding in Broome County, part of the levee system along the Susquehanna River was overtopped, causing flooding in a town of Vestal neighborhood that had been thought to be safe from flooding.

Flooding can also be caused by high groundwater levels. Seasonally high groundwater is common in many areas and occurs only after long periods of above-average precipitation in others. High groundwater problems occur in urban areas where groundwater pumping has ended and aquifer levels have rebounded. Basement flooding is a particular complaint in areas susceptible to high groundwater levels. Areas of Long Island, including Queens and Brooklyn, experience high groundwater flooding, as have some areas in western New York. Rising seas will have the general effect of forcing groundwater higher in coastal areas.

Lakes and ponds can flood when inflow exceeds the capacity of the outlet river to drain, causing long-term shore flooding. This happens in some of the Finger Lakes. Cross Lake in Onondaga and Cayuga counties is part of the Seneca River, and the area's flat topography sometimes allows long-term shallow flooding. Lake Champlain hit record levels for several months in the spring of 2011 due to runoff from the surrounding watershed in both Vermont and New York.

According to the Spatial Hazard Events and Losses Data Base for the United States at the University of South Carolina, between 1960 and 2012, there were 3,312 individual flood event occurrences in New York, with property damage exceeding $3.8 billion. Between 2010 and 2012 alone, there were 287 flood events affecting 48 out of 62 counties in the state with $1.1 billion in property damage.

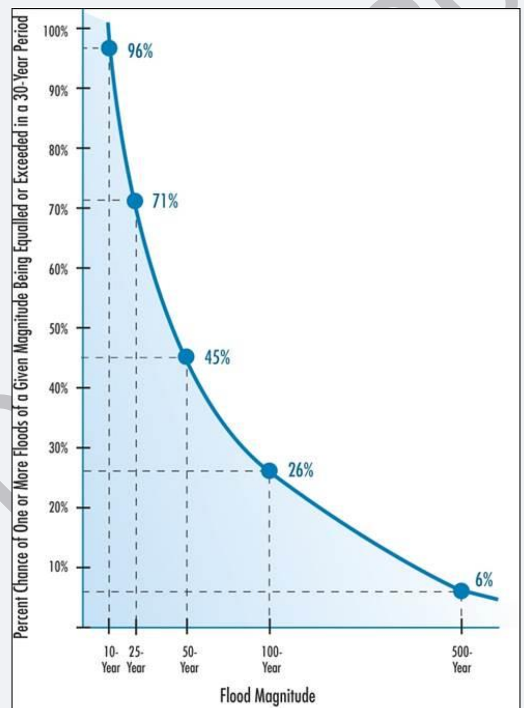
New York cannot afford to continue to suffer flood losses at recent rates, even without the added threat of climate change. DEC intends this guidance to help agencies, communities and the public build and develop in a way that will reduce flood risk, now and in the future. Flooding will continue as long as there are rain and coastal storms. Climate change and urbanization are increasing the severity of floods, and that trend will continue for the foreseeable future. However, we can reduce damage from flooding by planning and building smarter.

When properly implemented, land-use and floodplain-development standards executed under the National Flood Insurance Program (NFIP) and building standards in the Uniform Code do a great deal to reduce flood damages. However, those standards should be considered minimum standards and are based on flood maps that often are outdated in that they do not include recent flood information. Further, no FEMA FIRMs consider future changes in flood risk associated with climate change.[12] In addition, the standards are designed to protect against a one-percent annual chance flood. The probability of experiencing a one-percent annual chance flood in a special flood hazard area is 26 percent over any 30-year period. The probability of seeing a 0.2-percent annual chance flood is six percent over any 30-year period. That is greater than the chance of suffering a damaging fire.

Measures that reduce flood risk are often cost-effective and contribute to greater community resilience. The risk of flooding to a community is not just to the structures and land that are flooded. The regional economy suffers as businesses are forced to close, and health and safety are at risk as key infrastructure for water, electricity, transportation and health care is compromised.

River and coastal flooding are natural phenomena essential to maintaining ecosystems; however, flooding in areas of human disturbance often compromises water quality, affecting critical drinking water supplies and recreational resources. Floodwaters erode shorelines and stream banks, and wash contaminants into waterways, and can damage farm fields and crops. Preserving floodplains and limiting development in flood-prone areas allow the natural landscape to absorb and dissipate floodwaters, reducing flooding to adjacent areas, recharging

Flood Risk Over a 30-year Mortgage



SOURCE: U.S. Geological Survey, Guidelines for Determining Flood Flow Frequency, Bulletin 17B (Appendix D).

There is a 26-percent chance that a home in the one-percent annual chance floodplain will be flooded during a 30-year period, and a 45-percent chance for a home in the two-percent annual chance floodplain.

[12] Local governments may only impose standards that exceed the Uniform Code by following the Code Council's more-restrictive-local-standard process. (See New York State Department of State, Guide for the Incorporation of More Restrictive Local Standards, https://www.dos.ny.gov/dcea/mrls.html .) Further, local governments must include at least special flood hazard areas designated on the most recent FIRM but are free to include more areas in flood hazard areas. (See 2015 IBC section 1612.3, as amended by the 2016 Uniform Code Supplement).

groundwater and sustaining healthy ecosystems. Storing potential contaminants in more secure locations avoids potential spills.

The goal of floodplain management is not only to ensure new development is reasonably safe from flooding but to address existing risks, to avoid increasing flood risk to others and to sustain natural capacities to slow and diffuse flood flows. Flood-risk reduction measures often have the added benefit of improving the natural functions of floodplains.

Acts of Man

The late Gilbert White is widely recognized as the founder of the concept that land-use and building standards can reduce flood damages more than can engineering approaches. He famously stated, "Floods are 'acts of God,' but flood losses are largely acts of man."

Reducing development in flood-prone areas allows the natural landscape to absorb more floodwaters, reducing flooding to adjacent areas, recharging groundwater and providing a healthy ecosystem. Local governments have the authority to limit development in the floodplain based on risk. DOS's model local laws for community resiliency provide additional information.

As climate change increases the frequency and severity of floods, it is not enough to build for today's flood. Infrastructure and buildings often last for 100 years or more. While there is considerable uncertainty about the magnitude of the new flood risk 20, 50 or 100 years from now, it is virtually certain it will be higher in New York as the frequency of extreme-precipitation events increases[13]. It is sensible to incorporate best available information about future conditions and to plan for an additional margin of safety beyond current floodplain development standards as we build and rebuild buildings and infrastructure that must serve future generations.

Implementing sensible flood-risk design and development approaches will make our shores and waterways more resilient to flooding, likely reducing future flood damages by billions of dollars. There will be less loss of life, and fewer instances of communities and regions experiencing economic losses beyond the direct cost of flooding when major employers or critical community services are damaged or destroyed by flooding.

2.1.4 Obtaining Flood Risk Data

Our knowledge of existing flood risk is primarily derived from FEMA's FIRMs (available at www.msc.fema.gov) and from National Oceanic and Atmospheric Administration (NOAA) coastal products (available on NOAA's Digital Coast website at https://coast.noaa.gov/digitalcoast/). FEMA's flood mapping products define the baseline for regulatory floodplain development standards. At their best, the FEMA products are derived from detailed coastal engineering, and river and lake hydrologic and hydraulic analyses. These products provide detailed information about areas that

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[13] Rosenzweig et al., 2011.

are most likely to flood. However, they are based on analyses of historical data; they are not designed to include changes of risks in the future. Appendix C provides information on available decision-support tools and data sources.

2.1.5 Flood Modeling and Uncertainty

The three main components of flood mapping are the hydrologic analysis, hydraulic analysis and topographic data. *Hydrology* is the study of the distribution and movement of water in the atmosphere, on land and underground. A hydrologic analysis is used to calculate flood flows that have a fixed probability of being exceeded each year. Typically, FEMA maps that have detailed riverine analyses use the 0.2-percent, one-percent, two-percent and 10-percent flows, corresponding to what is commonly thought of as 500-year, 100-year, 50-year and 10-year flood flows, respectively.

Hydrologic analyses are based on gage records or indirectly on USGS regionalized regression equations that apply gage data to streams for which gage records are not available. Because gage records do not exist everywhere and the period of record is limited, the statistical study of past floods includes a degree of uncertainty that cannot be avoided. Regression equations, for example, may include a standard error of as much as 40 percent for the one-percent annual chance flood. In other words, if the flow estimate for a one-percent annual chance flood is 10,000 cubic feet per second, there is about a 68-percent chance that the actual one-percent flood is between 6,000 cubic feet per second and 14,000 cubic feet per second. This uncertainty should be considered in planning decisions.

A hydraulic analysis may be required to assess the consequences of a project or action on the floodplain environment.

Ideally, topographical data are derived from *lidar*, an aerial remote sensing technique in which the ground is scanned with laser pulses of light from a plane and the return time is used to develop a detailed ground elevation model (Figure 5). FEMA uses lidar data to develop digital elevation models in which 95 percent of the data points are accurate to plus or minus one foot. Lidar data are then supplemented with ground surveys of stream channels, bridges, culverts and dams.

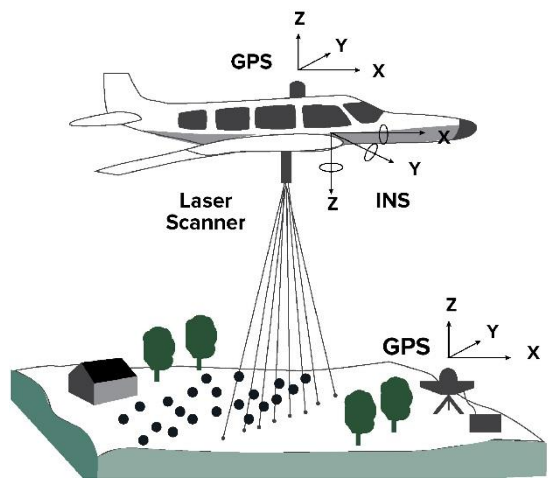


Figure 5. Lidar data collection.

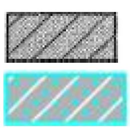
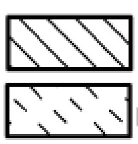
The hydrologic data are combined with the topographical data to determine flood elevations and to establish regulatory floodways. The computation is very precise but is only as accurate as the hydrologic and hydraulic analyses, and topography that go into it. Flood elevations are calculated at each cross section. A cross section is a line drawn perpendicular to the direction of flow (Figure 6).

Existing flood models already include unavoidable uncertainty due to limited or nonexistent historical data and the limits of mapping technology. The uncertainty will grow as climate change increases the volume of peak precipitation events, as well as the variability of precipitation. The elevation and horizontal extent of the real 100-year flood, when it comes, will likely be greater than the currently determined BFE, due to climate change.

As with riverine studies, a coastal hydraulic analysis determines where moving water goes. The analysis uses coastal transects instead of riverine cross sections. A transect shows the elevation of the ground both onshore and offshore. The ground elevation data are used to determine the expected height of the wave crests and wave runup above the storm surge. Zones and elevations are determined along each transect and interpolated between transects.

In coastal areas, including the Great Lakes, uncertainty arises because the shape of the shore and offshore lands is not static. While the storm surge determination in tidal areas may change with sea-level rise, the physics of wave runup can change with each storm and with each attempt to protect the shore in either tidal on nontidal areas. Figure 7 depicts a coastal flood zone.

Table 2. FEMA flood zone designations.

Flood Zone	Description
A	Area of special flood hazard without water surface elevations determined.
A1-A30, AE	Area of special flood hazard with water surface elevations determined. This can be riverine, coastal, or lakeshore.
AO	Area of special flood hazard having shallow water depths of one to three feet and/or unpredictable flow paths. Water depths are labeled.
AH	Area of special flood hazard having shallow water depths and/or unpredictable flow paths between one and three feet, and with water surface elevations determined.
VE	Area of special flood hazard with water surface elevations determined and with additional hazards due to storm-induced velocity and inundated by tidal floods of at least three feet in height.
B, X (shaded)	Areas of moderate flood hazards. 0.2-percent annual chance flood zone.
C, X (unshaded)	Area of minimal flood hazard.
Floodway 	Area within an A1-A30 or AE zone along a river, which must be kept free of most new development to pass flood flows without allowing any increase in the BFE. Shown on older flood boundary and floodway maps as an unshaded area within the shaded A1-A30 zone, or on newer maps as an area with a diagonal parallel line symbol within a riverine AE zone.
LiMWA 	Limit of moderate wave action: Area within a coastal flood zone subject to a wave of up to 1.5 feet. This is designated by a dashed line on coastal flood maps. More stringent building requirements are recommended.
Coastal Barrier Resources System 	Areas established by Congress in or adjacent to special flood-hazard areas in undeveloped portions of coastal and barrier systems, including along the Great Lakes. Due to the value of natural resources and vulnerability of development in these areas, federal law prohibits federal investment, including flood insurance, in CBRS areas.

2.1.6 FEMA Riverine Flood Maps

An understanding of flood-risk zones requires knowledge and use of FEMA flood maps. Table 2 defines FEMA's various flood zone designations. FEMA's FIRMs and flood insurance studies (FIS) provide the most detailed information available on current flood risk. The maps are issued for individual municipalities or counties. The purpose of FIRMs is to identify and communicate information on floodprone areas for purposes of the National Flood Insurance Program (NFIP). However, they are often used to identify flood zones for regulatory and other purposes.

Flood mapping under the NFIP began in the early 1970s and continues. Early flood maps were simply delineations of flat areas next to streams and other water bodies, utilizing paper USGS topographical maps. The flood zone delineations may not have been more accurate than the ten- or twenty-foot contour intervals on the topographical maps. Some of those early generation maps are still in use. They do not show flood elevations. They only show areas that are likely to flood during a one-percent annual chance event. The flood zones shown on such maps are known as A zones, subject to a one-percent or greater annual chance of flooding but with no flood elevations determined. Zones outside the A zones are simply called C or X zones. Such zones have a less than one-percent annual chance of flooding. Figure 8 provides an example of an early FEMA "flat" FIRM from the Town of Leyden, N.Y.

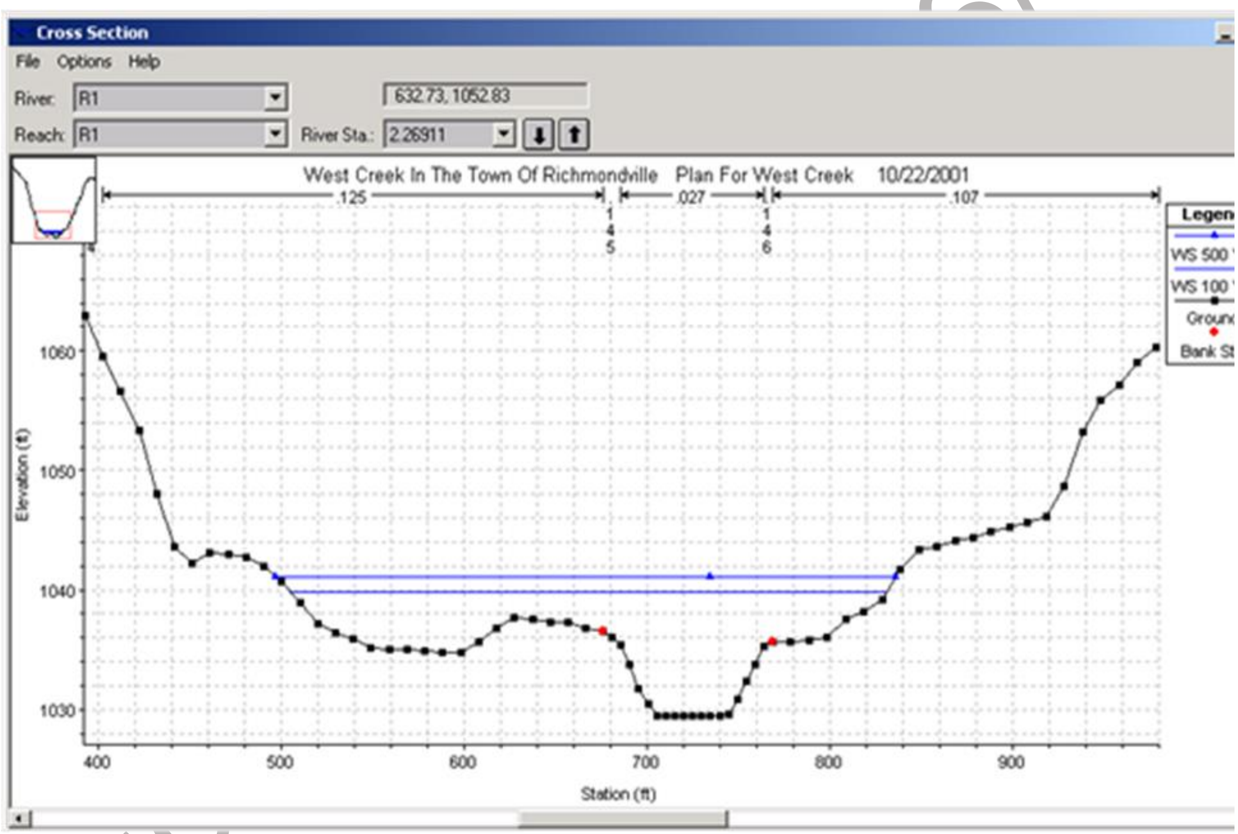


Figure 6. Example of a hydraulic model at a cross-section.

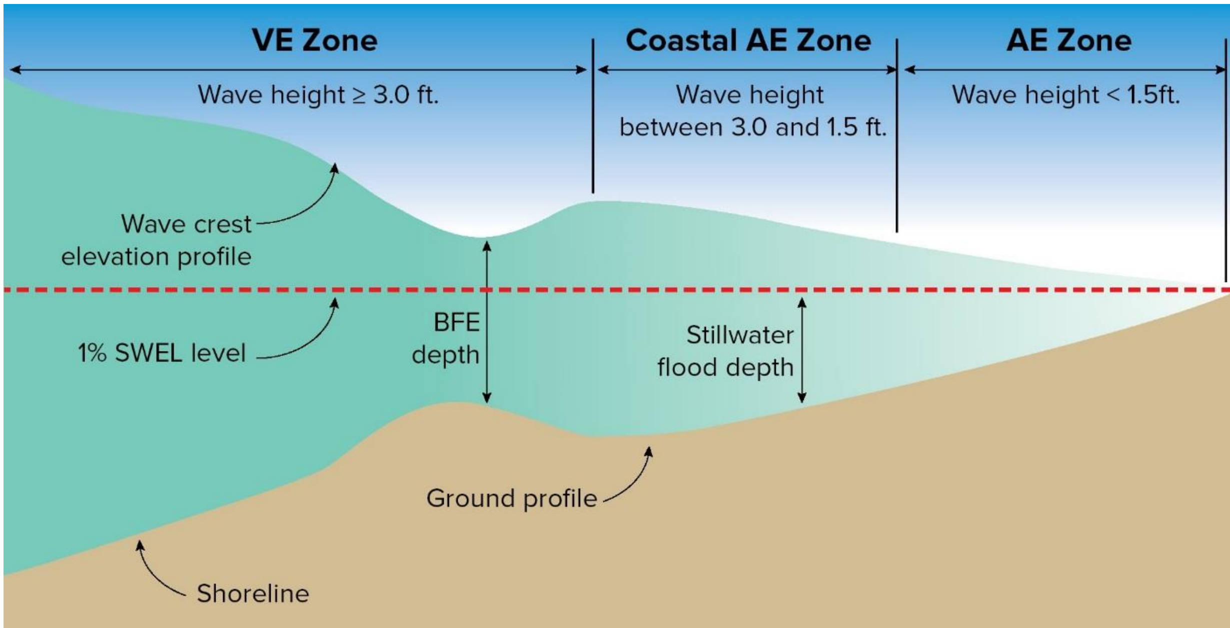


Figure 7. Coastal flood zones. Source: FEMA.

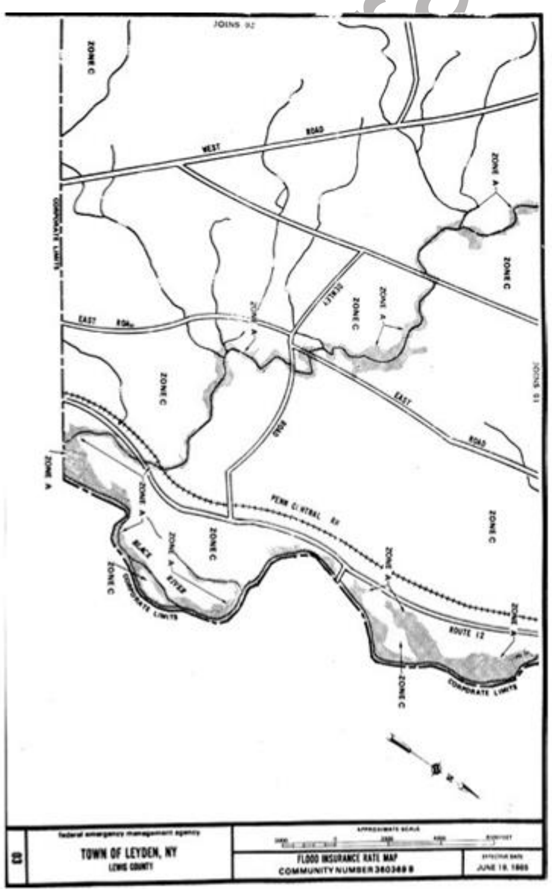


Figure 8. Flood insurance rate map, Town of Leyden, N.Y., illustrating an early "flat" FIRM, showing only A Zones with no base flood elevations.

FEMA conducts detailed riverine flood insurance studies (FIS) to determine BFEs. Elevations are determined at cross sections on the FIRM and are shown on stream-profile line graphs in the FIS. In this way, where there is a detailed flood study, the user can easily determine the BFE to about a tenth of a foot at any location along the stream or river. Stream profiles can also be used to determine the location and elevation of bridges, culverts and dams; their influence on flood elevations; and whether they are undersized. Flood zones in areas with detailed studies are labeled A1 through A30 on flood maps that pre-date 1987, or AE on later flood maps. The A1 through A30 designations were used to determine different flood insurance risk zones. Those designations are no longer used. Note that the Alfred, N.Y. example (Figure 9) also shows light grey shaded areas that indicate the 0.2-percent annual chance flood (500-year flood).

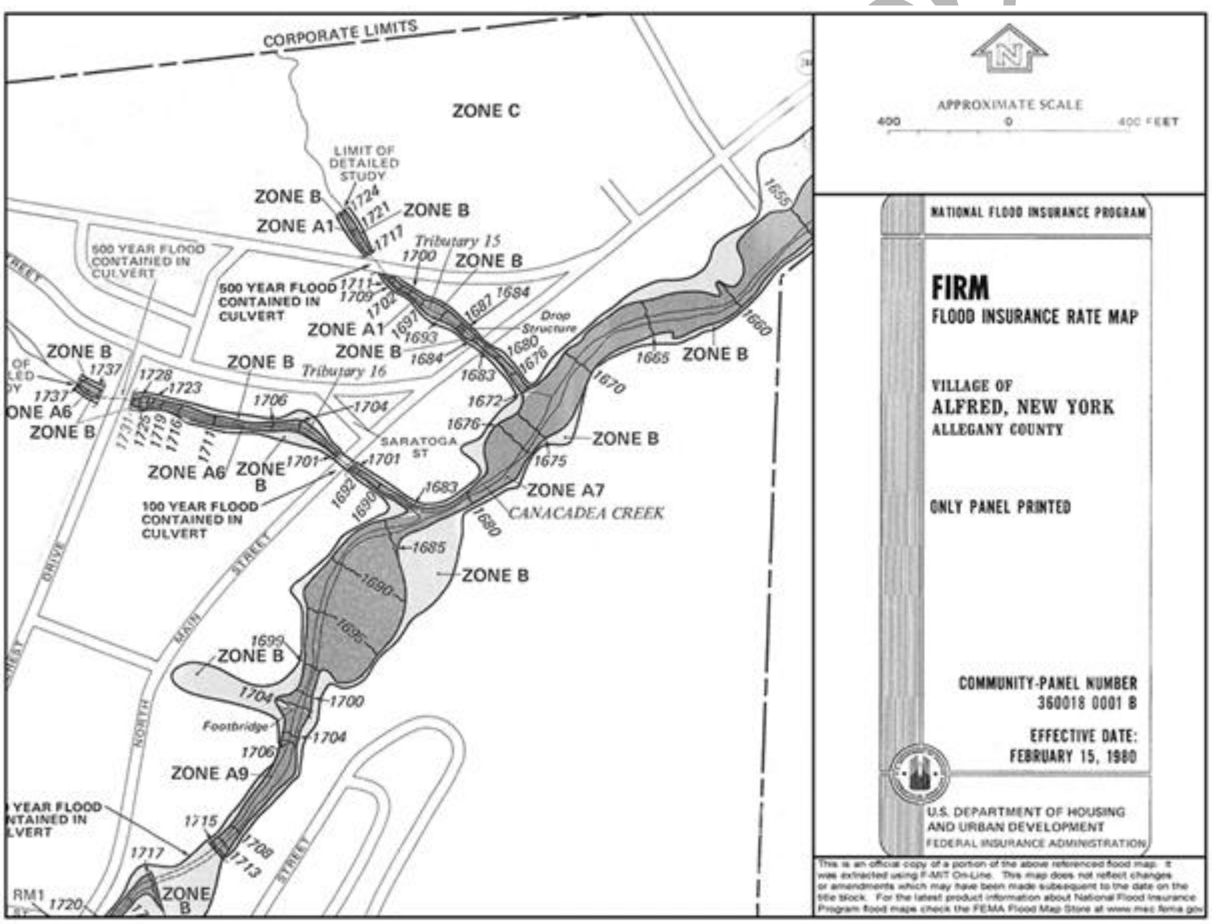


Figure 9. Floodway Map, Alfred, NY. Detailed riverine studies prior to 1987 have floodway delineations on separate map panels.

Detailed studies also include floodway delineations. *A floodway* is the channel of a river or other watercourse and the adjacent land areas that must be reserved to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. Figure 10 illustrates floodway terminology.

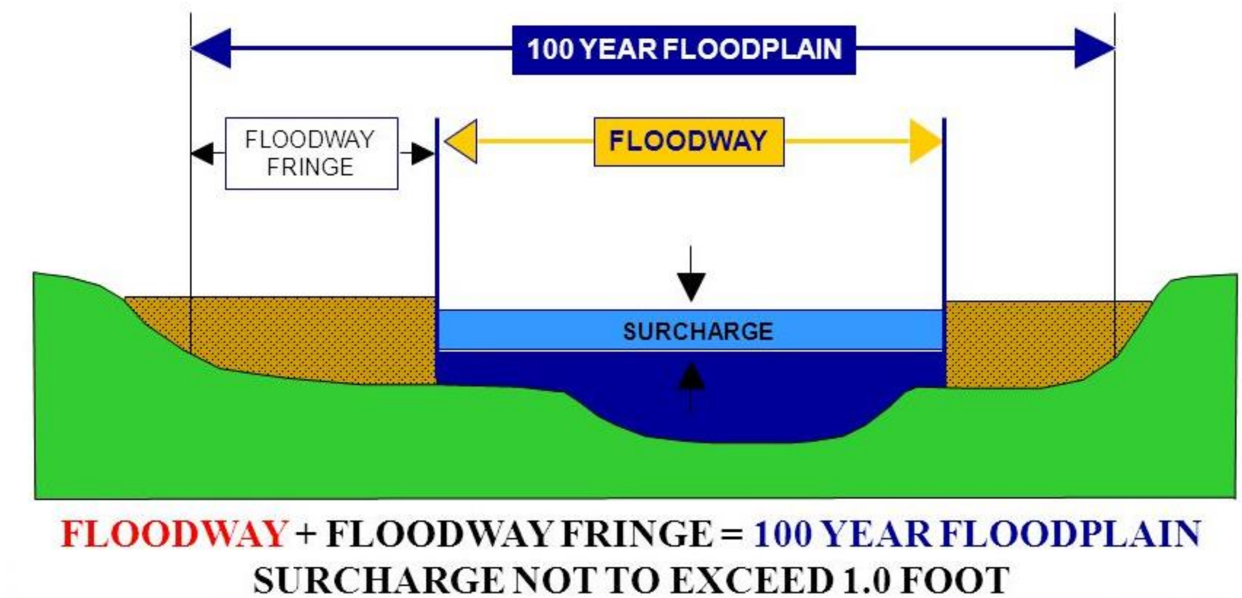


Figure 10. Floodway schematic and terminology. Source: FEMA.

Encroachment on floodplains, such as fill, reduces the flood-carrying capacity of the waterbody and increases flood heights. The minimum floodway standard used on FEMA's flood maps and studies in New York is an increase in flood heights of up to one foot, as long as hazardous velocities are not produced.

To delineate floodways, mapping engineers assume equal conveyance from each side of the floodplain. The floodplain is then theoretically squeezed on both sides until a one-foot rise in flood elevations is shown at some location. The floodway boundary is then smoothed to provide more stable flow conditions. This is tabulated at cross sections along the river. Between cross sections, the boundaries are interpolated. On pre-1987 flood maps, the floodway was shown as a white area between the two floodway-fringe areas on a separate flood boundary and floodway map. Figure 11 provides an example from the Village of Alfred, N.Y.

Since 1987, the floodway has been shown as a diagonal line symbol within the floodplain. The floodway-fringe area, plus the floodway area, together make up the regulated portion of the floodplain prone to the one-percent or greater annual chance of flooding. Figure 12 displays a later map showing the floodway, full one-percent annual chance floodplain and 0.2-percent chance (500-year) floodplain on the same map panel.

Digital FIRMs began replacing the black and white paper maps around the year 2000. The maps contain the same flood risk information as the Evans Mills map shown in Figure 12. However, they also include ortho-imagery, making it easier to determine the locations of structures. The maps are produced with digital data that can be downloaded and used with a GIS, or viewed online (Figure 13).

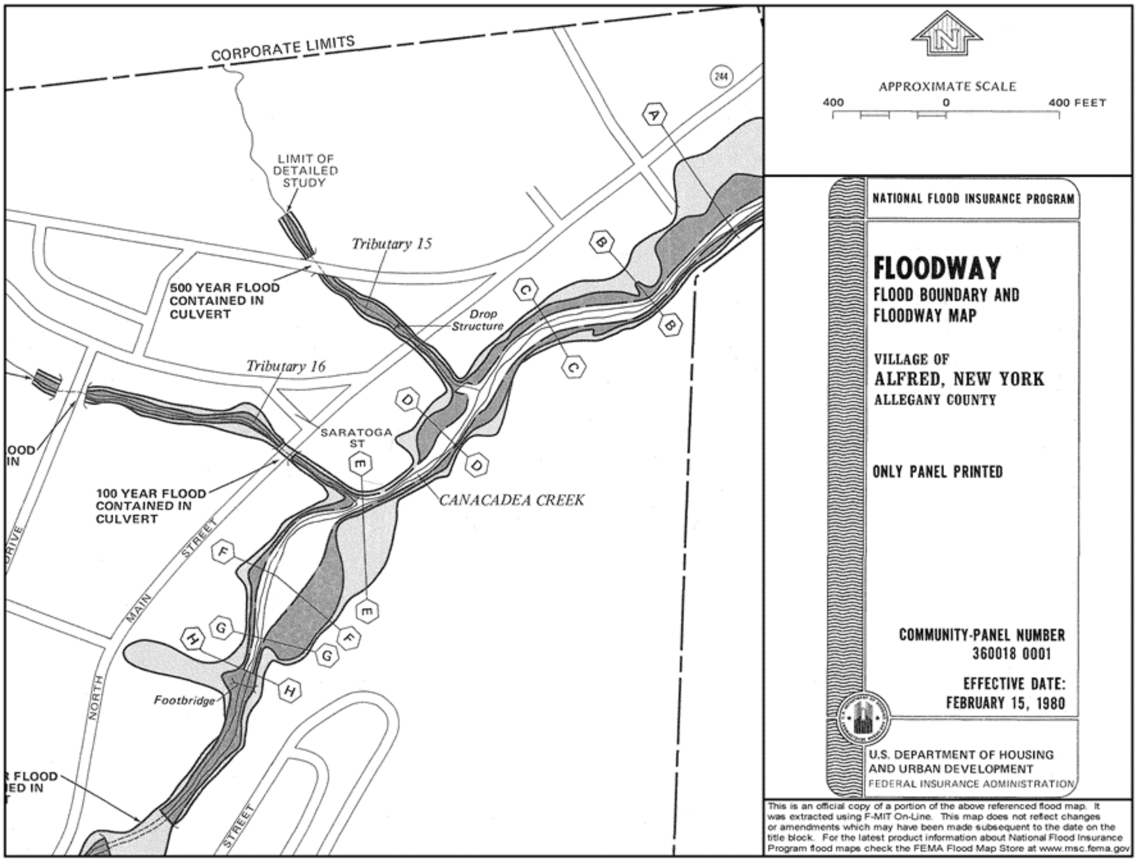


Figure 11. Floodway map, Alfred, N.Y. Detailed riverine studies prior to 1987 delineated floodways on separate map panels.

Most recent FIRMs have been produced countywide rather than by individual city, town or village. One advantage to this approach is that flood studies do not stop at the municipal boundary. However, countywide maps still have the disadvantage that they are not done by watershed, so study disconnects exist at county boundaries. Flood insurance studies (FIS) accompany all countywide and municipal FIRMs that have flood elevations. FISs contain descriptions of the study, stream profiles, flood flows, floodway data tables and still-water lake flood elevations where applicable. FIRMs only show flood elevations to the nearest whole foot. Information in flood insurance studies may be used to develop flood elevations to about a tenth of a foot.

A FIRM should be seen as a graphical representation of the effective flood insurance study. Figure 14 illustrates how the data fit together.

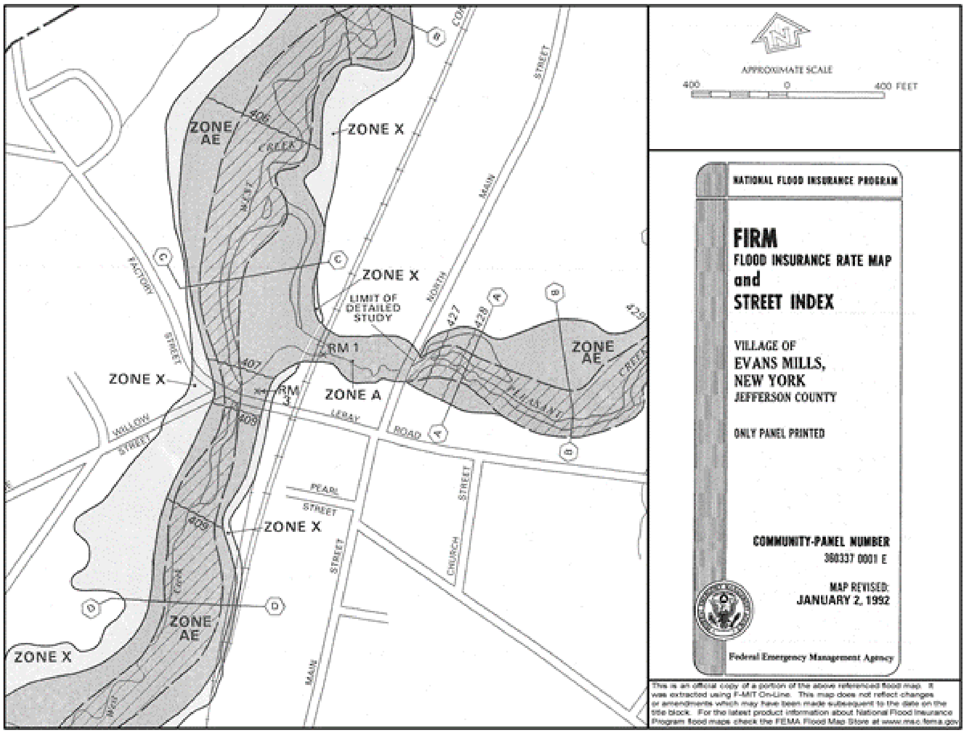


Figure 12. FIRMette, Evans Mills, NY, showing AE Zone with BFEs, cross section, floodways, and shaded X zone indicating 500-year flood zone.

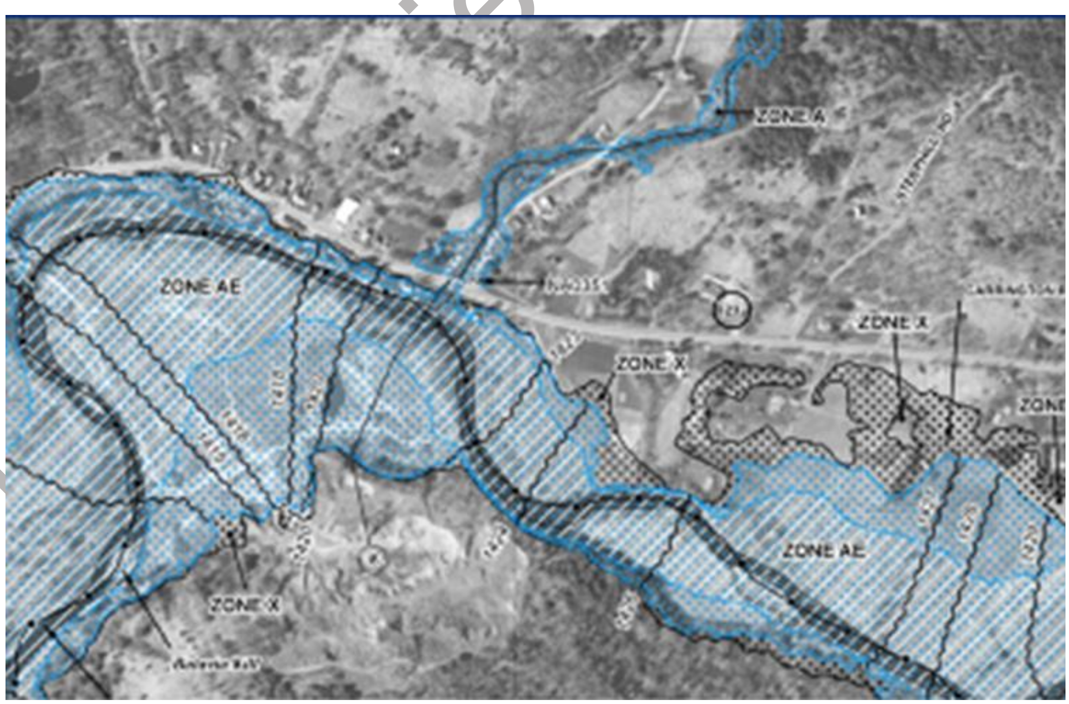


Figure 13. Portion of digital flood insurance rate map (dFIRM), Greene County, N.Y.

It is easy to determine precise regulatory flood elevations at cross sections by using the floodway data table together with the map (Figure 14). Between cross sections, the stream profile should be used to determine flood elevations. The stream profile can also be used to find bridges and culverts and determine if they are properly sized. The culvert placement on the profile indicates the overburden. The top of the symbol represents the top of the road or ground surface. The culvert pipe is assumed to be the open area between the streambed and the bottom of the overburden.

Stream profiles can also be used to evaluate approximate elevations of bridge decks. Bridges are represented by an "I" symbol. The top of the symbol represents the top of the road and the bottom of the symbol represents the low chord, or low steel, of the bridge (Figure 15). Care should be taken to verify bridge elevations and low chords, which are often inaccurately portrayed.

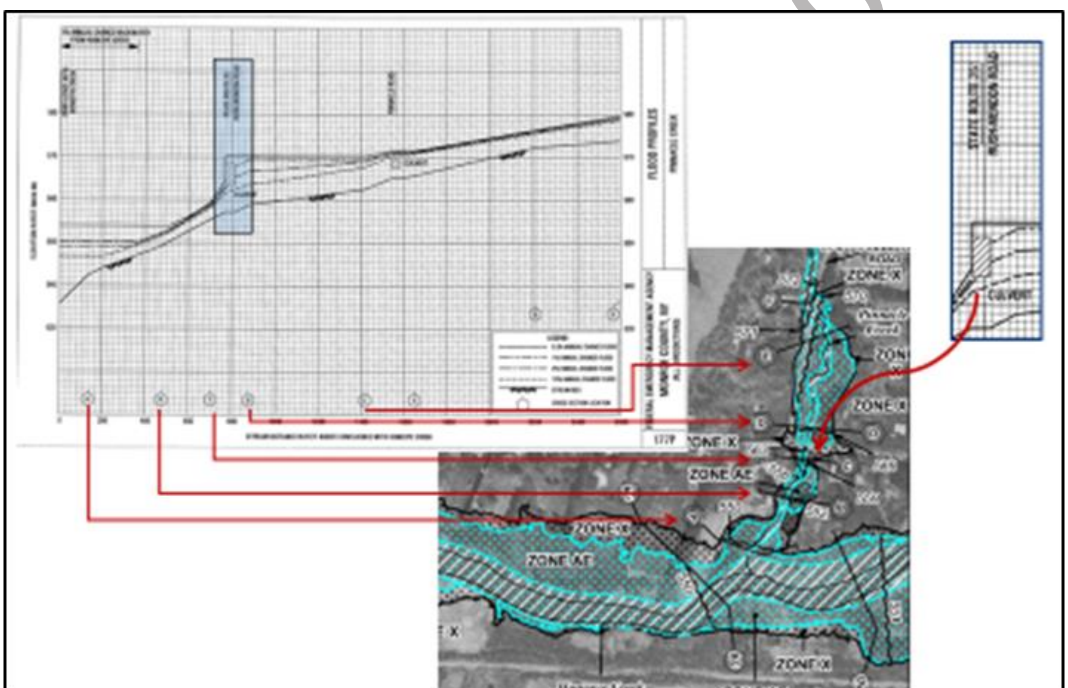


Figure 14. Stream profile, Pinnacle Creek, Rush, N.Y. The profile also shows the blockage caused by an undersized culvert.

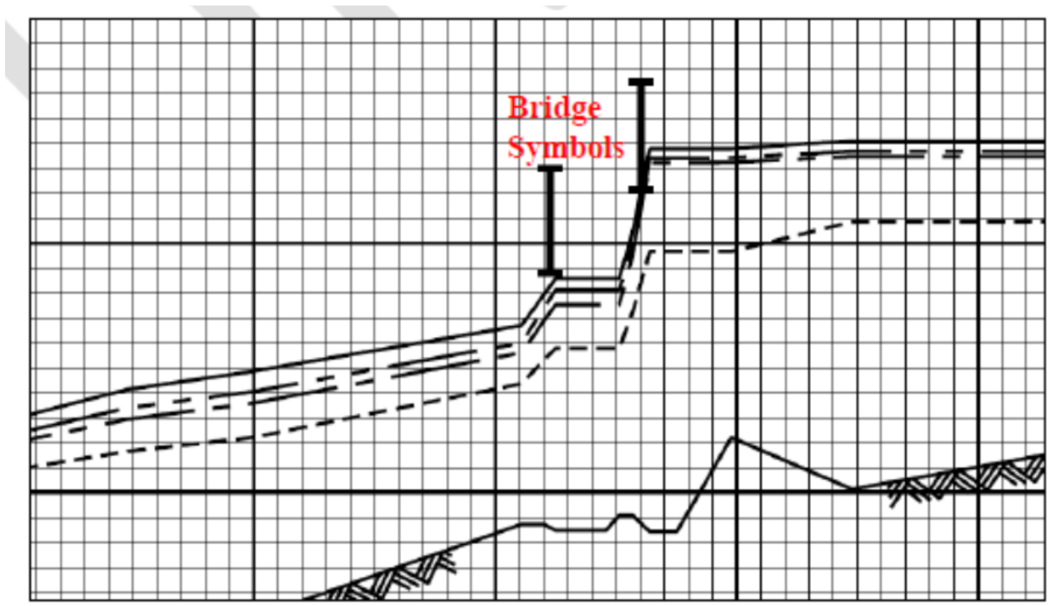


Figure 15. Stream profile illustrating bridge symbol. There are five profile lines on this example. They represent, from bottom to top, the streambed, the 10%, 2%, 1% and 0.2-% annual chance flow elevations. Bridge symbol to right indicates likely restrictions of 1% and 0.2% flows.

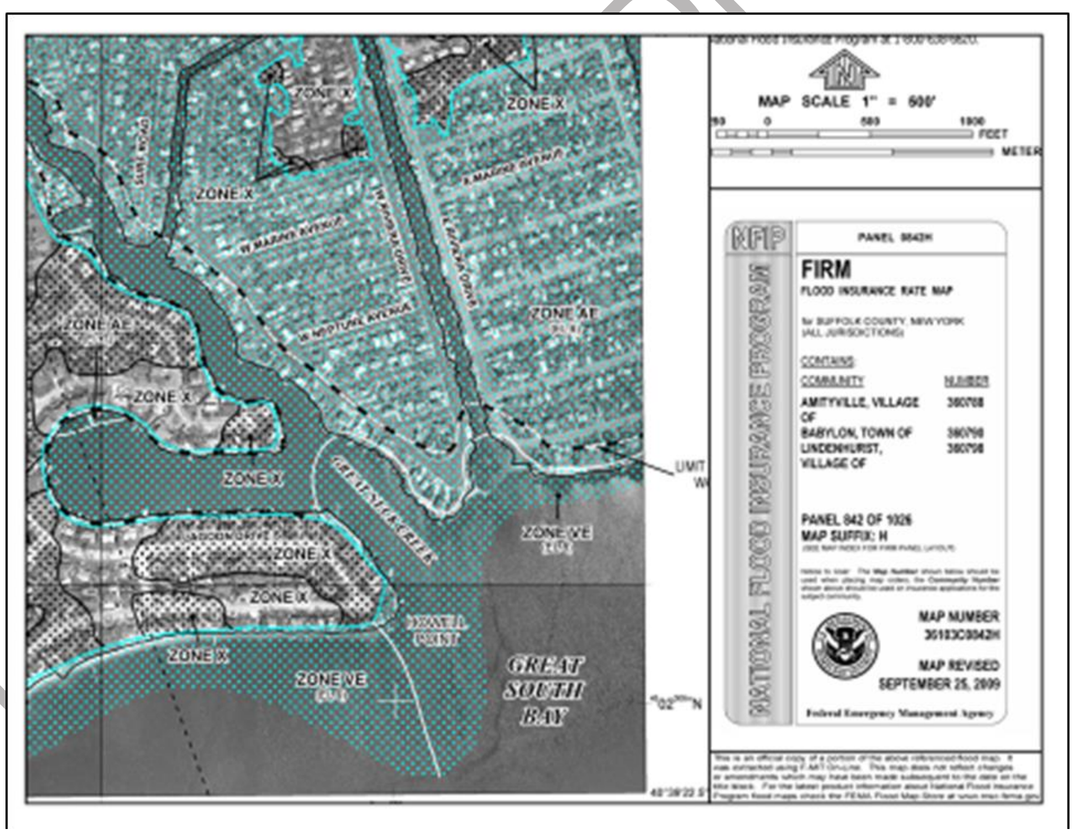


Figure 16. Coastal flood map, Long Island South Shore.

2.1.7 FEMA Coastal Flood Maps

Coastal flood studies are used to establish a BFE (one-percent annual chance flood elevation) and may designate a coastal high hazard area (VE Zone) as well as the "limit of moderate wave action (LiMWA)." The VE Zone has different building standards than does the AE Zone. VE Zones identify areas that are subject to a three-foot or higher breaking wave on top of the storm surge. On newer coastal maps, FEMA designates a LiMWA line, which is the landward limit of the area that can experience a breaking wave of at least 1.5 feet.

As the storm surge moves inland, waves break, and the surge dissipates. Coastal flood maps show flood elevations including wave height. The nature of the shoreline makes a huge difference in how the coastal flood behaves. As a result, the BFE changes as the surge moves inland.

Figures 16 and 17 present two examples of coastal flood maps. Figure 16 shows a complex coastal area along the Great South Bay in Suffolk County. Because this area is somewhat protected from heavy wave action, the VE zone is narrow. However, the AE zone extends a considerable way inland, carried along the inlets. Figure 17 shows an

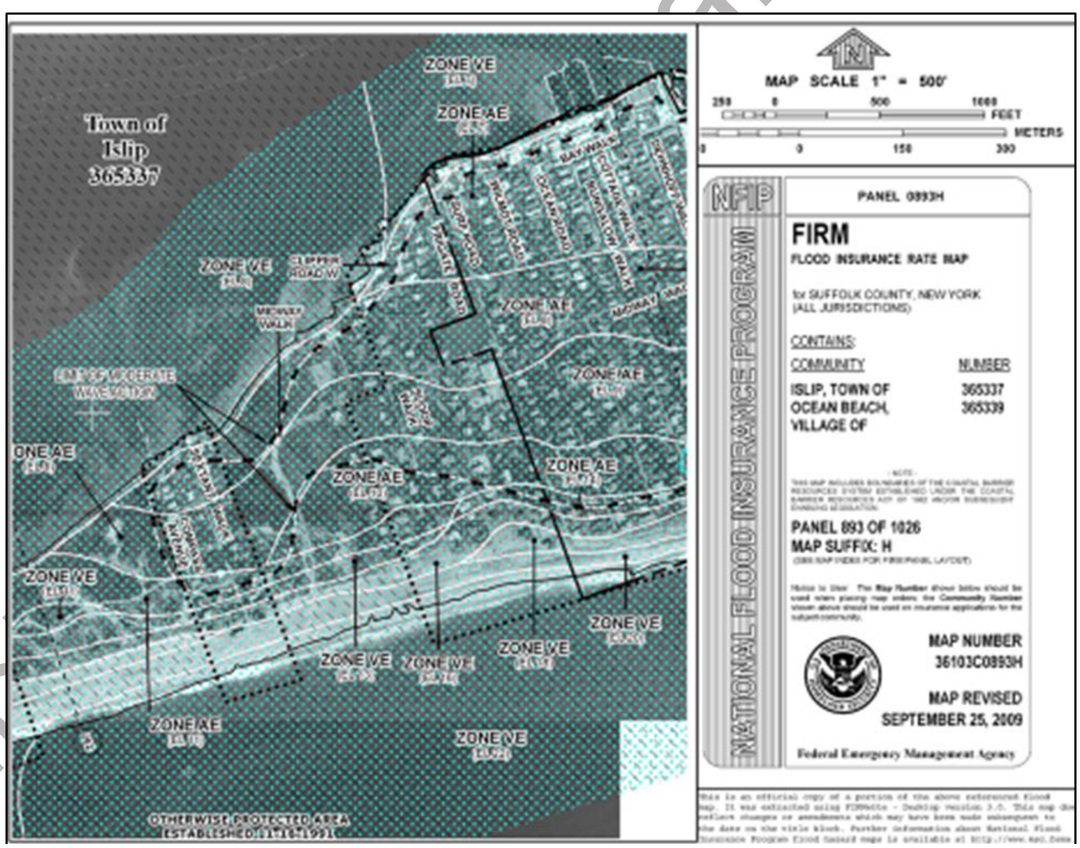


Figure 17. Coastal flood map, Fire Island, N.Y.

open ocean coastline on a developed part of Fire Island. The white lines divide areas of different flood elevations.

The regulatory flood elevations on coastal flood maps are rounded to the nearest whole foot (Figure 18). However, flood insurance studies include additional information for each transect. Transect locations are published in the flood insurance studies for coastal maps published through the 2000s. As of this writing, FEMA is developing new coastal flood maps for New York City and Westchester County. Those maps will show the coastal transect locations on the FIRMs (Figure 19).

Each FEMA flood map panel has a legend. Through the years, the display of map features, and the letters and numbers used to designate flood zones have changed. However, the information conveyed by the features and letters has not changed (Table 2).

FEMA flood maps use the best data and engineering available within the constraints of mapping budgets. However, maps and studies are not updated frequently enough. Some flood maps in New York are up to 40 years old. The status of FIRMs in New York State is available at https://www.rampp-team.com/ny.htm. Experience has shown that even older flood maps often do a good job of predicting areas likely to flood. However, development, the impacts of flooding, and changes to the climate, landscape, shorelines and streams, all combine to reduce the accuracy of flood maps.

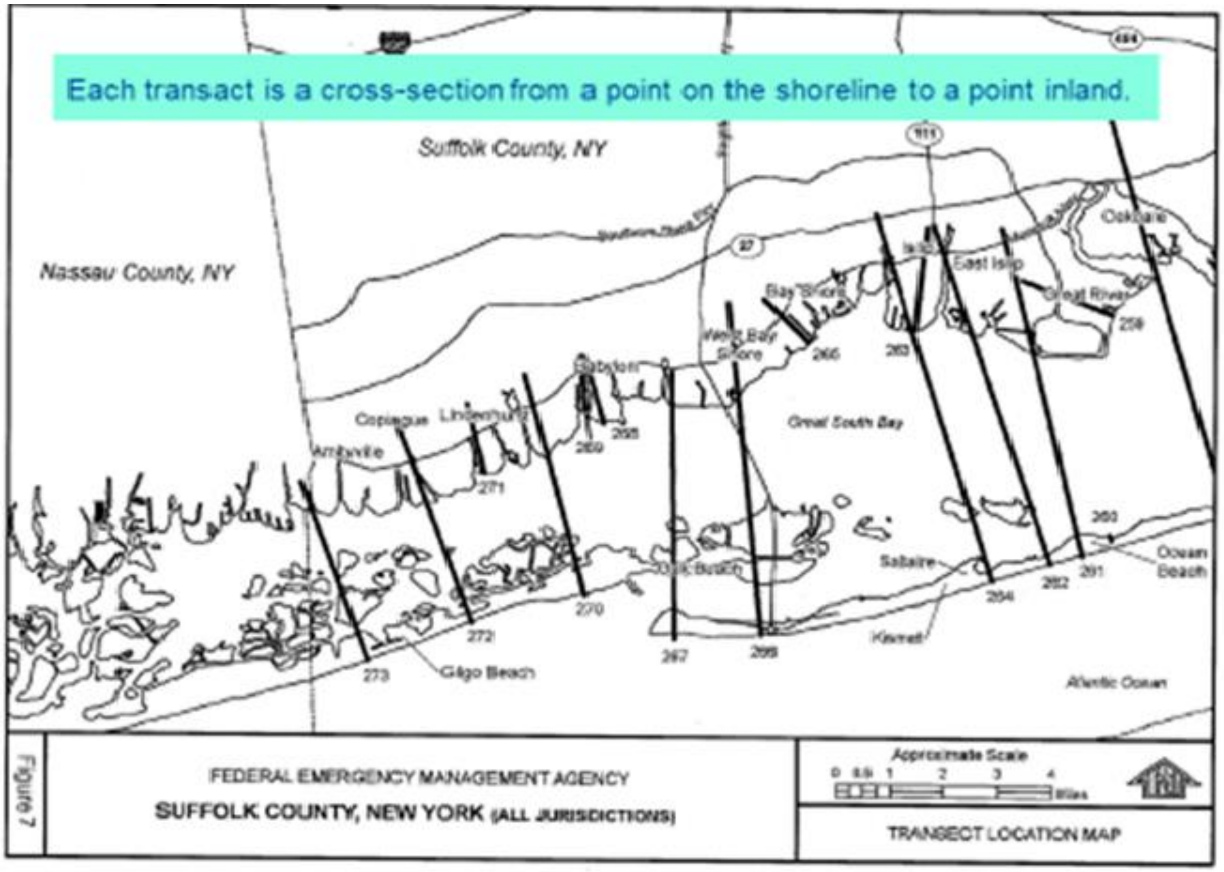


Figure 18. Example of transect location map.

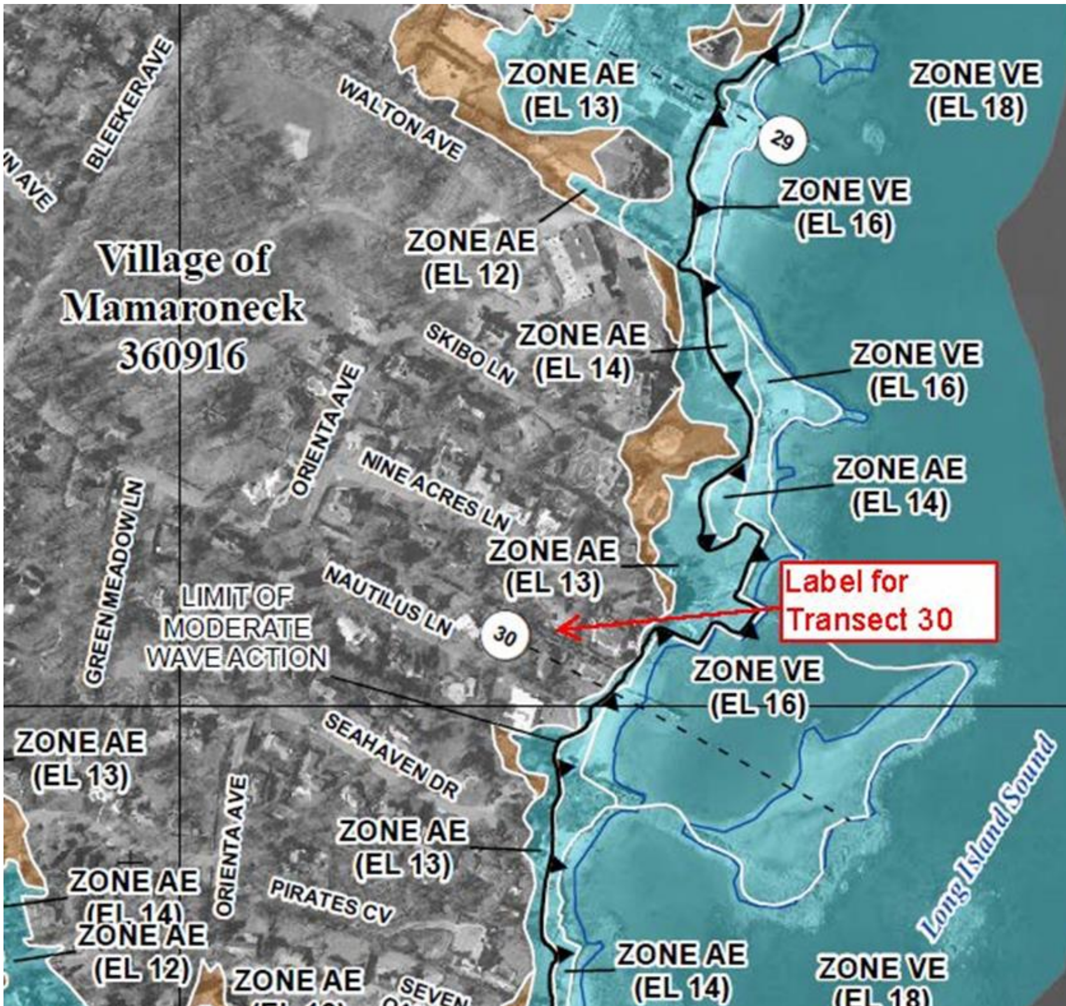


Figure 19. New FEMA coastal transect mapping.

2.2 Existing Floodplain Regulations and Standards

2.2.1 National Flood Insurance Program Standards

Detailed standards for development in floodplains already exist. FEMA's NFIP provides minimum development standards in federal regulation 44 CFR 60.3. States and municipalities must pass and enforce development standards at least as stringent as those contained in the federal regulation to participate in the NFIP. Those standards regulate encroachment into known high-risk flood zones, and determine how new and substantially improved or substantially damaged buildings must be constructed to minimize the risk of flood damages.[14] Nationwide, these standards are estimated to save over $1 billion in flood related damages annually.[15]

Congress established the NFIP in large part because the private insurance market would not offer flood insurance due to high-risk properties and because those most likely to purchase flood insurance are those also most likely to use it. By not being able to spread the risk, private insurance companies found flood insurance to be too risky.

The NFIP provided for a federal flood insurance product. However, to reduce the risk on the insurance fund, the National Flood Insurance Act of 1968 allows federal flood insurance to be sold only within states and municipalities that pass and enforce standards that meet or exceed those in 44 CFR 60.3. The federal government also does not allow any disaster assistance to be spent on damaged buildings within mapped flood-hazard areas (zones beginning with or consisting of the letters A or V on the FIRM) unless the municipality participates in the NFIP.

Since municipalities may not regulate development on state land, 6 NYCRR Part 502 regulates state projects in floodplains.

2.2.2 New York State Building Code Standards

In addition to the NFIP requirements, state building codes, including the Building Code of New York State, the Existing Building Code of New York State, and the Residential Code of New York State, including Appendix J: Existing Buildings and Structures, contain language that meets or exceeds FEMA standards for structures. An important distinction is that the building codes only regulate structures, defined as walled and roofed buildings, and do not regulate all structures. However, the NFIP regulations pertain to all development in floodplains.

The Residential Code of New York applies to one- and two-family residential structures. The Building Code of New York applies to other regulated structures.

In March 2016, the State Fire Prevention and Building Code Council completed an update of the state building code by incorporating the 2015 international building codes published by the International Code Council.

2.2.3 Special Flood Hazard Area Designations

Current FEMA and building code development standards pertain only to the special flood hazard area, which is defined as the land in the floodplain subject to a one-percent or greater chance of flooding in any given year. The area may be designated as Zone A,

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[14] Substantial improvement is defined by FEMA and the Building Code of New York as any reconstruction, rehabilitation, addition, or other improvement of a structure the cost of which equals or exceeds 50 percent of the market value of the structure before the “start of construction” of the improvement. The term includes structures that have incurred “substantial damage” regardless of the actual repair work performed. Substantial damage means damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

[15] Federal Emergency Management Agency 2005.

AO, AH, A1-30, AE, A99, AR, V1-30, VE or V. Areas within the 0.2-percent floodplain, although often shown on FIRMs, are not currently subject to specific FEMA development standards.

2.2.3.1 A Zones

A Zones are shown on FIRMs but do not have published BFEs. The Residential Code of New York State requires the lowest floor in residential buildings, including basement, to be elevated at least three feet above the highest adjacent grade prior to construction (Figure 20). The Building Code of New York is silent with respect to A Zones without BFEs. FEMA's regulations for A zones, when there is no other BFE information, only require permits for all proposed construction and other developments. FEMA requires the building site to be "reasonably safe from flooding," adequately anchored to prevent flotation, collapse, or lateral movement resulting from flood forces, and constructed with materials resistant to flood damage, and with utilities and other service facilities designed and/or located to prevent water from entering or accumulating within the components during conditions of flooding.

If a proposed development disturbs at least five acres, or if it consists of a subdivision or manufactured home park of at least 50 lots, FEMA regulations require the permittee to develop a BFE and build accordingly, as though in an AE zone. If the five-acre/50-lot threshold is not reached, the applicant is required to obtain and use a BFE and floodway data available from a federal, state or other source.

Figure 20. Example of properly elevated home with flood vents.

2.2.3.2 AE, A1-A30 Zones

AE and A1-A30 Zones are zones for which FEMA has determined BFEs. The Residential Code requires the lowest floor of residential structures, including basements, to be at least two feet above the BFE. This two-foot "freeboard" standard is more restrictive than FEMA's regulations, which only require the lowest floor to be at or above the BFE.

Non-residential structures must meet a freeboard standard of zero to two feet, depending on the nature of the structure. The specific standards are provided in

American Society of Civil Engineers ASCE-24[16], which is the reference document for the flood standards in the Building Code of New York. Most structures require a one-foot freeboard standard. Buildings and other structures that are designated as "essential facilities" require a freeboard of two feet. Agricultural facilities, certain temporary facilities and minor storage facilities[17] are not required to meet a freeboard standard.

Non-residential structures may be flood-proofed in lieu of elevation. Flood proofing includes a certification by a registered professional engineer that the building, together with attendant utility and sanitary facilities, is designed so that below the base flood level, the structure is watertight with walls substantially impermeable to the passage of water and structural components have the ability to resist hydrostatic and hydrodynamic loads and the effects of buoyancy.

Rules applicable to AE zones also apply to construction in A zones without BFEs where the BFEs are derived in accordance with the minimal development size threshold or if a BFE is available from another source.

2.2.3.3 Floodways

As detailed earlier, the regulatory floodway is the channel of a river or other watercourse and the adjacent land areas that must be reserved to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. Generally, this is the area of more rapidly moving and hazardous floodwaters. No encroachment, including fill, new construction, substantial improvement, or any other development, is allowed within the floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in the BFE at any location.

If it is not possible to develop within a floodway without causing an increase in the BFE, the applicant must mitigate the project to provide equivalent hydraulic capacity to alleviate any increase in the BFE. If that is not possible, the applicant, working through the municipality (or the state if it is on state land), must apply to FEMA for a FIRM and floodway revision through a letter of map revision (LOMR). A LOMR results in a physical change to the FIRM and sometimes to information in the flood insurance study.

2.2.3.4 VE Zones

VE Zones are also known as coastal high-hazard areas. They are areas of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast or any other area subject to high-velocity wave action where the wave height is greater than three feet. Due to the destructive force of wave action, there are more stringent requirements for structures in VE Zones.

[16] American Society of Engineers 2005

[17] For the purposes of this guidance, minor storage facilities do not include commercial storage facilities.

VE Zones exist in Nassau County, Suffolk County, all five boroughs of New York City, and Westchester and Rockland counties. The only current VE Zones in Great Lakes communities are along the breakwater on Lake Ontario in the city of Oswego. However, FEMA could identify additional Great Lakes VE Zones on new coastal flood maps, currently being developed by FEMA. BFEs have been determined for all VE Zones in New York State.

Within VE zones, structures must be elevated on pilings, columns or shear walls such that the bottom of the lowest horizontal structural member supporting the lowest elevated floor is elevated to or above the BFE plus two feet so as not to impede the flow of water (Figure 21). Excluded from the elevation standards are columns, piles, diagonal bracing attached to the piles or columns, grade beams, pile caps and other members designed to either withstand storm action or break away without imparting damaging loads to the structure.

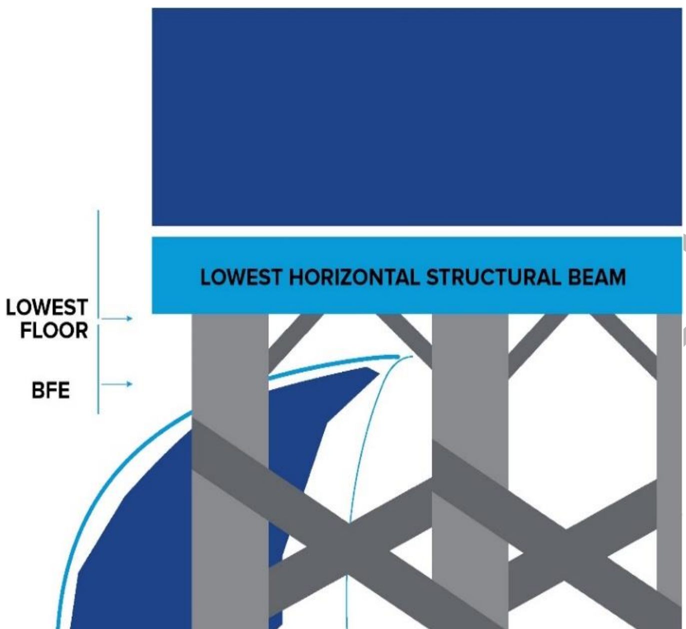

Figure 21. Elevated structure in VE zone.

There are detailed foundation design standards, and standards for piles and column foundations, connectors and fasteners, projecting members such as cantilevers, roof sheathing, doors and windows and breakaway walls. Fill is not to be used for structural support of buildings in VE zones. Additional FEMA requirements can be found in federal regulations at 44 CFR 60.3e and in local laws for flood damage prevention in coastal communities, in R324.3 of the Residential Code, and in the Building Code of New York State, which references American Society of Civil Engineers: Flood Resistant Design and Construction, ASCE 24.

Although the current flood map for Rockland County does not have a VE zone within the town of Stony Point, the shoreline area was heavily damaged by waves on the Hudson River during Superstorm Sandy. FEMA produced an advisory flood map showing VE zones. The town of Stony Point decided to adopt the more restrictive VE zone standard from the advisory map for reconstruction purposes. Figure 22 shows a home built to VE zone standards in Rockland County.

Figure 22. Home repaired to VE Zone standards, Stony Point, Rockland County, N.Y.

2.2.3.5 Limit of moderate wave action

FEMA has designated an area bounded by the limit of moderate wave action (LiMWA) on more recent coastal flood maps, including Nassau and Suffolk counties, and on preliminary flood insurance rate maps (pFIRMs) for New York City and Westchester County (Figure 23). The LiMWA is equivalent to a "*Coastal A Zone,*" defined by the American Society of Civil Engineers as

> "an area within the special flood-hazard area, landward of a V zone or landward of an open coast without mapped V zones. In a Coastal A zone, the principal source of flooding must be astronomical tides, storm surges, seiches, or tsunamis, not riverine flooding. During the base flood conditions, the potential for breaking wave heights should be greater than or equal to 1.5 feet."

Concern about areas subject to waves of at least 1.5 feet grew because experience has shown that buildings constructed to A zone standards suffer severe damages when hit by waves of at least 1.5 feet. FEMA has not passed any regulations with respect to development within the LiMWA defined area. FEMA does recommend that buildings constructed within LiMWA defined areas be built to V Zone standards. Several municipalities in New York have adopted LiMWA or Coastal A Zone standards.

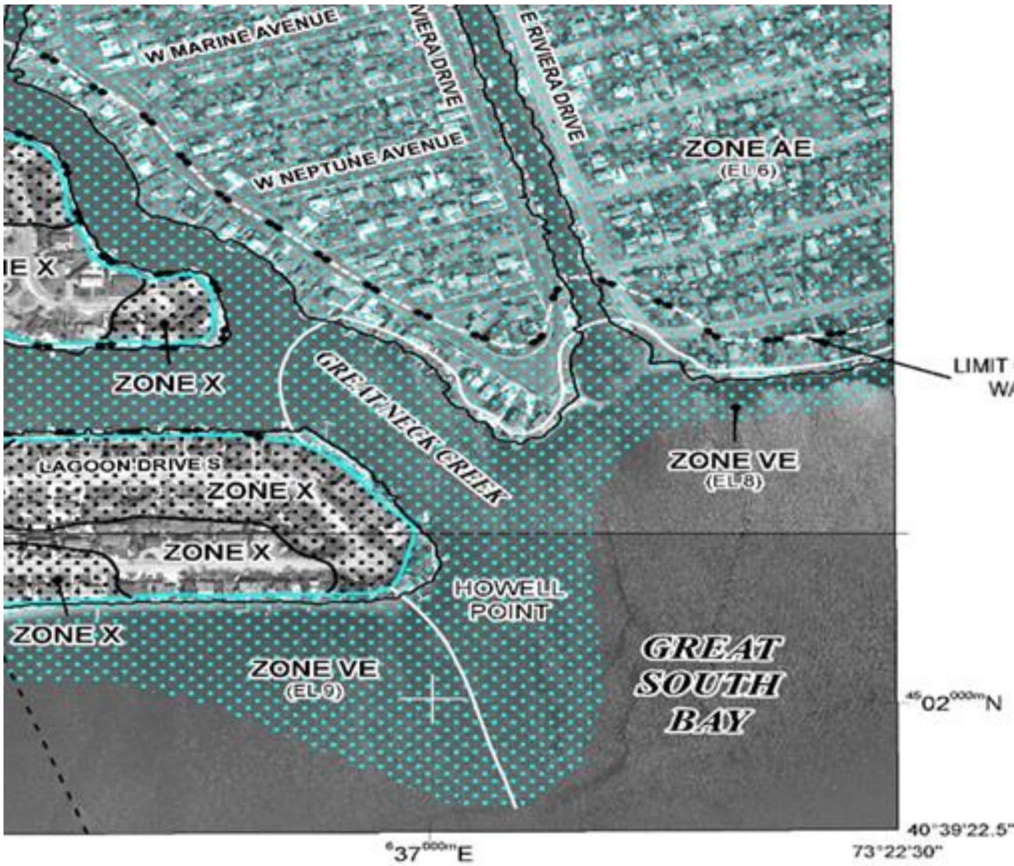

Figure 23. FIRM showing LiMWA line, Town of Babylon, N.Y.

The Residential Code of New York State does not currently include a LiMWA or coastal A Zone standard. However, the Building Code of New York State, through its reference to ASCE 24, does require V Zone construction standards in coastal A Zones for buildings other than one- or two-family residential structures. Check with the municipal building department for local codes applicable to residential structures.

2.2.3.6 Building Utilities, Water Supply and Sanitary Sewage Systems

Utilities include electrical equipment, heating, ventilating, air conditioning, plumbing connections and other service equipment for the building. All such equipment must be located at or above the BFE plus the required freeboard, or it must be designed and installed to prevent water from entering or accumulating within the components and to resist hydrostatic and hydrodynamic loads and stresses, including the effects of buoyancy, during flooding. Utilities may be located in dry flood-proofed areas of non-residential structures, but flood-proofed rooms or enclosures for utilities are not allowed for residential structures.

Indoor furnaces, boilers, water heaters and other utilities often represent the most commonly damaged building components during floods. Dangers increase due to extinguishing of gas flames and short-circuiting of electrical components. Such equipment must be elevated above the BFE plus freeboard or enclosed within watertight walls that extend above the BFE plus freeboard.

Gas or liquid storage tanks that are principally above ground must meet the same standards as buildings. They must be above the BFE plus freeboard and should be on platforms that are anchored to resist movement during a flood.

Detailed guidance on how to design, elevate or protect building utilities can be found in “Protecting Building Utilities from Flood Damage,” FEMA P-358, November 1999.

Water supply and sanitary sewage systems have underground pipes and pipes that enter buildings from below. They cannot be elevated above the BFE. FEMA and building codes require them to be designed to minimize or eliminate infiltration of floodwaters into the systems. This includes use of backflow preventer valves and requires openings such as wellheads and manhole covers to be either sealed or elevated.

2.2.3.7 Building Foundations and Areas below the Lowest Floor

The lowest floor of a building is defined by FEMA and building codes as the “floor of the lowest enclosed area, including basement, but excluding any unfinished flood-resistant enclosure used solely for parking of vehicles, building access or storage in an area other than a basement.” *A basement* is defined as any part of a building that is sub-grade on all sides. Thus, a basement is not allowed within a special flood hazard area, and there are standards for non-basement areas below the lowest floor. In A Zones, structures may be elevated on properly engineered fill, on a solid slab or elevated filled stem wall foundation, or on solid perimeter foundation walls that are open inside. All structures must be properly anchored, and areas of the structure below the BFE must be unfinished and used only for vehicle parking, building access or limited storage.
All enclosures beneath the lowest elevated floor must be properly vented (Figure 24). The purpose of flood vents is to allow floodwater to enter the building without damaging the structure. This equalizes the flood forces against the foundation wall. Vents also allow the water to drain when floodwaters subside. Vents must meet the standard of a net opening of at least one square inch per square foot of enclosed floor space. There must be at least two vents. The bottom of all vents must be no higher than the lower of either the outside or inside grade. Engineered vents that allow for a reduction in the net opening area are available. Such products must be certified by a registered design professional as meeting the required performance and design requirements.[18]

[18] Federal Emergency Management Agency 2008.

Figure 24. Engineered flood vent. The vent automatically opens under the pressure of water.

Areas below the elevated horizontal structure support for V-zone structures must be completely open, enclosed by insect screening or lattice, or covered with non-structural breakaway walls. Breakaway walls must be designed to have a design safe loading resistance of not less than 10 pounds per square foot and not more than 20 pounds per square foot. The idea is that under flood forces, breakaway walls will separate from the building structure without causing structural damage.

All areas of a building below the BFE must be unfinished and constructed of flood resistant materials. Flood resistance materials guidance is available in FEMA's Technical Guidance Series at http://www.fema.gov/media-library/collections/4.

2.2.3.8 Variances

A variance is a grant of relief from the requirements to permit construction in a manner that would otherwise be prohibited. Buildings constructed in compliance with NFIP building standards suffer about 80 percent less damage annually than those not built in compliance.[19] On rare occasions, it may not be possible to precisely meet all design standards. Both the local laws passed to participate in the NFIP, and the state building codes, contain variance procedures. A variance from a municipality's flood damage prevention law is issued by the community through an independent body such as a zoning board of appeals. The form of such bodies varies by community. Variances from the state building codes are decided by regional boards of review.

[19] International Code Council 2014

Under the NFIP, FEMA periodically reviews a municipality's findings justifying the granting of variances. FEMA's regulations contain a list of conditions and generally permissible standards for variances:

- Must pertain to a piece of property and are not personal in nature.
- Will not be issued within any designated regulatory floodway if any increase in flood levels during the base flood would result.
- Will not cause additional threats to public safety or create nuisances.
- Will not result in extraordinary public expense.
- Will not result in increased flood heights.
- Will not cause fraud on or victimization of the public.
- Will not result in conflict with existing local laws or ordinances.
- Must be the minimum necessary to afford relief.
- As the lot size increases beyond one-half acre, the necessary technical justification for a variance increases.
- There must be good and sufficient cause.
- Failure to grant the variance would result in exceptional hardship. However, the hardship must be exceptional, unusual and specific to the property involved and not personal in nature.

FEMA guidance states that inconvenience, aesthetic considerations, physical disabilities, personal preferences, the disapproval of one's neighbors, or homeowners association restrictions cannot, as a rule, qualify as exceptional hardships.

Flood insurance rates can be extremely high for new structures that do not meet elevation standards. Therefore, FEMA regulations require that the community notify the applicant in writing that the issuance of a variance to construct a structure below the BFE will result in increased premium rates for flood insurance and that construction below the BFE increases risks to life and property. Examples of common variances include functionally dependent uses that must be along waterways, such as facilities for boat docking or repair facilities, or port or shipbuilding. A building on a small urban lot may be granted a variance if it is not feasible to elevate the building within the confines of the lot. Variances have sometimes been granted for temporary construction facilities during building or repair of roads, bridges and dams.

FEMA provided guidance on one variance that allowed an auto repair facility on a tight lot in which elevating the facility would not allow for vehicle access. That facility was subsequently flooded. Another variance permitted a ferry terminal on Fire Island that had to be at a lower elevation to accommodate ferry passengers. For both cases, the variance was the minimum necessary to afford relief and was specific to the property and not the owner.

The New York State Fire Prevention and Building Code Act (Article 18, Executive Law) contains a variance procedure should any provision or requirement of the Uniform Code entail "practical difficulties or unnecessary hardship or would otherwise be unwarranted." Any variance may not substantially adversely affect provisions for health, safety and security, and equally safe and proper alternatives may be prescribed. Specific variance procedures exist in Part 1205 of 19 NYCRR, entitled Uniform Code: Variance Procedures.

Part 1205 establishes regional boards of review to be appointed by the secretary of State and standards for board membership. Although FEMA guidance requires exceptional hardship from failure to grant a variance to be specific to the property involved, and not the personal circumstances of the applicant, the building code variance procedures allow for a variance if a provision of the code would create an excessive or unreasonable economic burden.

Other reasons for a variance under Part 1205 include a finding that a provision or requirement of the code would result in one or more of the following:

- Would not achieve the code's intended objective
- Would inhibit achievement of some other important public policy
- Would be physically or legally impracticable
- Would be unnecessary in light of alternatives that ensure the achievement of the code's intended objective or in light of alternatives that, without loss in the level of safety, achieve the code's intended objective more efficiently, effectively or economically
- Would entail a change so slight as to produce a negligible additional benefit consonant with the purposes of the code

Differences exist between FEMA requirements for a variance and requirements under the state building codes. Therefore, proposals that would violate both the local law for flood protection passed to participate in the NFIP, and the state Uniform Fire Prevention and Building Code require variances from both. This is particularly important because a municipality's standing in the NFIP may be in jeopardy if it allows development in accordance with a state variance and it has not gone through its own local variance procedure.

2.2.4 Standards for Federal Agency Actions

The federal government has standards (Executive Order 11988, 1977) for federal projects in floodplains. The standards essentially reflect minimum NFIP standards for the one-percent annual chance flood and require federal agencies to go through an eight-step process when evaluating projects in floodplains. All federal agencies were required to develop regulations to comply with E.O. 11988. The eight steps are common through all of the regulations. FEMA's regulations for the eight steps are contained in 44 CFR 9.6. These steps also apply to federal actions in wetlands.

Actions are defined as having the potential to result in the long- or short-term effects associated with the occupancy or modification of floodplains, and the direct or indirect support of floodplain development, or the destruction and modification of wetlands and the direct or indirect support of new construction in wetlands.

E.O. 11988 requires regulations and procedures that govern construction of federal structures to comply with NFIP standards. FEMA regulations to implement E.O. 11988 further restrict critical action, which are defined as actions for which even a slight chance of flooding is too great. FEMA's regulations further define the floodplain for critical actions as the area subject to a 0.2-percent annual chance flood. FEMA regulations prohibit locating a critical action in a 0.2-percent annual chance floodplain if a practicable alternative exists.

2.2.5 Standards for New York State Agency Actions

Development on state land is exempted from local control. Because of that exemption, to continue to participate in the NFIP and to be eligible for federal disaster assistance to state-owned buildings in flood-hazard areas, the state has a regulation pertaining to state projects in floodplains. 6 NYCRR Part 502 regulates all state projects in floodplains.

A *project* is any undertaking or activity, including financing at any location or any activity on state-owned lands involving any change to improved or unimproved real estate. Examples include, but are not limited to, the following:

- Construction, installation, expansion, substantial improvement, reconstruction or restoration of structures, highways, access roads, bridges, canals, railroads, airports, sewage disposal systems and any other waste disposal systems, water treatment works, levees, dikes and dams, sewers, gas or water mains, electrical transmission or other service lines and solid waste disposal facilities
- Mining, dredging, filling, grading, paving, excavation or drilling operations
- Any action of a state agency resulting in a change in the use of a state-owned or leased building or facility from nonresidential to residential usage, or in any other change in usage where flood damage to the facility would pose a serious danger to life or health or widespread social or economic dislocation

Evaluating Federal Actions: FEMA's 8 steps

1. Determination of whether the project is in a floodplain
2. Early public review
3. Evaluation of alternatives
4. Identification of impacts
5. Minimization of harm
6. Re-evaluation of alternatives
7. Findings and public explanation
8. Implementation

A project does not include

- ordinary maintenance and repair of existing structures or facilities,
- work on any structure listed in the National Register of Historic Places where the work is undertaken in a manner designed to maintain the character of the structure, or

- any permits, certifications or other approvals issued by a state agency on lands other than lands owned by the state, unless the state is financing the project.

The standards in Part 502 mirror the minimum FEMA standards with the exception of more restrictive standards for critical structures. Critical facilities are defined as facilities that would result in serious danger to life and health, or widespread social or economic dislocation in the event of flooding. Part 502 prohibits state agencies from siting or financing the following new projects within any flood-hazard area:

- Hospitals, rest homes, correctional facilities, dormitories or patient care facilities
- Major power generation, transmission or substation facilities, except for hydroelectric facilities
- Major communications centers, such as civil defense centers
- Major emergency service facilities, such as central fire and police stations
- Facilities designed for bulk storage of chemicals, petrochemicals, hazardous or toxic substances or floatable materials

Part 502 is self-regulating. Each state agency is responsible for enforcing the standards on its own activities. DEC's Floodplain Management Section is available to provide technical assistance to state agencies. Should a project be unable to meet the requirements of Part 502, DEC may issue a variance under strict conditions. However, no variance is allowed for a project in a regulatory floodway if the project results in an increase in the BFE.

2.3 Standards for Future Resiliency

Although current codes and standards for development in floodplains significantly reduce flood damages, a changing climate and uncertainty in flood risk requires standards that meet tomorrow's conditions. Most buildings and infrastructure built today will still be in place in 50 years. Many will be in place in 100 years.

2.3.1 Federal Guidance

The federal government has recognized that today's floodplain development standards will not protect against tomorrow's floods. On January 18, 2015, President Barack Obama signed Executive Order 13690, *Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input*, which amends Executive Order 11988 (1977) and includes detailed guidelines for implementation, including Appendix H: Climate-Informed Science Approaches and Resources. The new standard and related documents are found at http://www.fema.gov/federal-flood-risk-management-standard-ffrms.

DEC's proposed flood-risk management guidelines were informed by approaches to determining floodplains described in federal E.O. 13690. Most importantly, the order redefines "floodplain." It has long been recognized that the so-called 100-year floodplain (one-percent annual chance exceedance) is an insurance standard rather than a safety standard.[20] One of the biggest problems with the standard as used is its “in or out” nature. A development just outside the special flood hazard area is not subject to any flood protection standards yet the ground elevation may be well within the margin of error of a flood study.

Flood risk is a continuum; it does not end at an arbitrary line on the map, and future flood risk is expected to increase. Therefore, it is important to add some flexibility to current standards to provide for consideration of future conditions as they are relevant to the project and location. The federal flood risk management standard (FFRMS) described in EO 13690 does this and provides guidelines that the state can use. However, given that New York has one of the most densely developed tidal shorelines in the nation, and that the Northeastern United States is expected to see the greatest increases in heavy precipitation events in the nation, this document recommends a somewhat more stringent application of the guidelines provided by the FFRMS.

The FFRMS makes some significant changes to the definition of the floodplain. It uses the one-percent and 0.2-percent flood elevations as starting points. However, it establishes the floodplains for development purposes according to one of the following three approaches:

- The elevation and special 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 includes an emphasis on whether the action is a critical action as one of the factors to be considered when conducting the analysis.
- The elevation and special flood-hazard area that result from using the freeboard value, reached by adding an additional two feet to the BFE for non-critical actions and by adding an additional three feet to the BFE for critical actions.
- The area subject to flooding by the 0.2-percent annual chance flood.

The standard does not specify which approach should be used. Instead, it leaves it to federal agencies to update their regulations on utilization of the approaches. Those regulatory updates have not occurred as of this writing.[21]

2.3.1.1 Federal Climate-informed Science Approach

The guidelines for implementing the executive order do not specify numbers or formulas on how to use a climate-informed science approach but instead provide guidance on resources and general approaches. Executive Order 13690 requires a climate-informed

[20] Association of State Floodplain Managers Foundation 2004

[21] On August 22, 2016, FEMA proposed to amend its regulations on “Floodplain Management and Protection of Wetlands” to implement EO 13690, and proposed a supplementary policy (FEMA Policy 078-3) to clarify FEMA’s application of the FFRMS (81 FR 56558). The Department of Housing and Urban Development proposed a rule describing its application of the FFRMS on October 28, 2016 (81 FR 74967).

science approach to use “best-available” and “actionable” hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science. The accompanying guidance states that a climate-informed science approach is the preferred method that federal agencies should use when data to support such an analysis are available.

E.O. 13690 Appendix H describes “best available” climate-informed science, as it applies to federal agency use:

- 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 the 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 must adapt and continuously update their approaches, consistent with the 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
- meeting the needs of, and readily accessible by, stakeholders.

2.3.2 Updating FEMA’s Flood Risk Data

While FEMA FIRMs and FISs contain the most thorough flood risk data across the state and the nation, they are not intended to predict future flooding conditions. Congress recognized that limitation in the 2012 Biggert-Waters Flood Insurance Reform Act. The act established a technical mapping advisory council (TMAC) to, among other requirements, make recommendations to FEMA on how to ensure that FIRMs incorporate the best available climate science to assess flood risks and ensure that FEMA uses the best available methodology to consider the effect of the rise in sea level and future development on flood risk. The TMAC findings are presented in Appendix B.

The TMAC made recommendations to FEMA to improve the technical credibility of future FEMA map products and communication of flood risk, and identified important issues related to inclusion of future conditions, including climate change, into FEMA map products. However, the TMAC provided no guidance on the use of currently available flood-risk information in planning or regulatory decision making. Therefore, this guidance does not assume the availability of new map products or other flood-risk management information. Rather, it provides direction on the use of currently available products and information. DEC will amend this and associated guidance and procedures as new map products and information become available.

2.3.3 Flood-resiliency Incentives

In recognition that meeting flood risk standards can pose significant fiscal challenges to some communities, state and federal authorities provide incentives and grant funding for communities to integrate flood mitigation and resiliency into their planning and implementation efforts. Funding availability may be subject to change. Some current opportunities are as follows:

- FEMA's Community Rating System recognizes and encourages community floodplain management activities that exceed the minimum NFIP standards. Depending upon the level of participation, flood insurance premium rates for policyholders can be reduced up to 45%. Besides the benefit of reduced insurance rates, CRS floodplain management activities enhance public safety, reduce damages to property and public infrastructure, avoid economic disruption and losses, reduce human suffering, and protect the environment. Technical assistance on designing and implementing some activities is available at no charge. Participating in the CRS provides an incentive to maintaining and improving a community's floodplain management program over the years. Implementing some CRS activities can help projects qualify for other Federal assistance programs. https://www.fema.gov/community-rating-system
- Climate Smart Communities is a network of New York communities engaged in reducing greenhouse gas emissions and improving climate resilience. http://www.dec.ny.gov/energy/50845.html
- DOS Local Waterfront Revitalization Program consists of a planning document prepared by a community, and the program established to implement the plan. An LWRP may be comprehensive and address all issues that affect a community's entire waterfront, or it may address the most critical issues (e.g., climate change and flooding) facing a significant portion of its waterfront. http://www.dos.ny.gov/opd/programs/lwrp.html
- NOAA Resiliency Grants. https://coast.noaa.gov/resilience-grant/
- U.S. Climate Resilience Toolkit funding opportunities. https://toolkit.climate.gov/content/funding-opportunities

3 Consideration of Flood Risk

3.1 General Guidelines

This document describes flood-risk management guidelines that account for enhanced future physical risk due to sea-level rise, storm surge and flooding, and recommends regulatory and funding programs covered by CRRA require applicants to demonstrate consideration of these guidelines in addition to complying with all other applicable standards and codes, including state and local building codes and FEMA's National Flood Insurance Program (NFIP) requirements.

3.1.1 Design Considerations

The flood-risk management guidelines described in this document are recommended for consideration in new construction of structures (walled and roofed buildings; and above ground, permanently installed gas or liquid storage tanks), other than minor storage and parking facilities; and repair or substantial improvement of such structures as described below. Consistent with NFIP requirements, *substantial improvement* should be considered to be any reconstruction, rehabilitation, addition, or other improvement of a building or permanently installed gas or liquid storage tank, the costs of which are at least 50 percent of the market value of the structure prior to the improvement, regardless of whether the improvement is related to flooding.

This guidance also recommends flood-risk management guidelines for consideration by applicants for projects involving new and replacement public infrastructure and facilities, and privately owned, but critical, infrastructure and facilities, and during substantial improvement or repair of such infrastructure and facilities, as described below and as practical, considering feasibility, cost, actual risk, environmental effects, the nature of associated infrastructure, etc. Guidelines recommended for infrastructure are primarily intended to reduce the risk of flood damage to nearby built and natural assets.

Within the context of regulatory programs affected by CRRA, the recommended flood-risk management guidelines are intended primarily for consideration in determination of the suitable location for construction of a proposed structure or other regulated activity, given future physical risks, within a permit's jurisdictional area.

3.1.2 Compliance with Other Standards

DEC does not intend the flood-risk management guidelines described in this guidance to supersede provisions of applicable building codes or engineering standards, provided such standards are sufficiently protective of both the structure and nearby built and natural assets under projected climatic conditions, consistent with the recommended flood-risk management guidelines. Rather, within the context of DEC permit programs, these guidelines are intended primarily as guides to project siting. No interpretation of this guidance should result in siting or design guidelines that are less protective than applicable standards described in the following:

- New York State Uniform Code
- New York City Construction Code

- Federal standards, including, but not limited to,
    - Federal Highway Administration Hydraulic Design Series No. 7, *Hydraulic Design of Safe Bridges*,
    - Federal Highway Administration Hydraulic Engineering Circular No. 17, *Highways in the River Environment-Floodplains, Extreme Events, Risk, and Resilience*,
    - Federal Highway Administration Hydraulic Engineering Circular No. 25, *Highways in the Coastal Environment.*
- Standards adopted by the American Society of Civil Engineers (ASCE), as incorporated into the New York State Uniform Code or New York City Construction Codes, including, but not limited to,
    - ASCE Standard 7-10, *Minimum Design Loads for Buildings and Other Structures,*
    - ASCE Standard 24-17, *Flood Resistant Design and Construction*.

Many of these standards are intended primarily to ensure resiliency of the structures themselves; they do not consider future climatic conditions and have inconsistent freeboard recommendations. These standards, therefore, constitute the minimum for location and design consideration. The flood-risk management guidelines described in this guidance are intended to reduce risk, not only to the structures themselves, but to nearby built and natural assets under future conditions.

In addition to meeting minimum engineering standards, programs should consider requiring applicants to demonstrate consideration of the highest applicable flood-risk management guidelines, according to program-specific guidance. Although factors such as practicality, costs, funding eligibility, risk tolerance and environmental effects may preclude incorporation of the highest applicable flood-risk management guidelines into final design, programs should consider requiring applicants to document the rationale for not doing so. State agencies and authorities may follow their own internal, approved guidance consistent with this guidance and verify to the permitting agency that applicable flood-risk management guidelines have been considered.

Table 3. General flood-risk management guidelines recommended for implementation of the Community Risk and Resiliency Act.

- The elevation and horizontal flood-hazard area that result from adding two feet (three feet for critical facilities[22]) of freeboard to the base flood elevation and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood.
- The elevation determined by a climate-informed science approach in which adequate, actionable science is available.

Table 3 lists three general flood-risk management guidelines that define flood-hazard areas for the purposes of CRRA implementation:[23]

The elevation and horizontal flood-hazard area that result from adding two feet (three feet for critical facilities[24]) of freeboard to the base flood elevation and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground. Freeboard is a factor of safety expressed in feet above a specified flood level for purposes of floodplain management. Base flood elevation (BFE) is the elevation of surface water that has a one-percent chance of being equaled or exceeded in any year, commonly known as the one-hundred year flood. This guideline includes extending the elevation determined by adding two feet of freeboard (three feet for critical facilities) to the BFE to the point at which that elevation intersects the ground. The effect of this extension is to include areas at the edge of the floodplain that are potentially at risk, even though they are above the BFE. (Figure 24.)[25]

The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood. This guideline defines the area inundated by a flood level that has a 0.2-percent annual chance of being equaled or exceeded in any year, commonly known as the 500-year flood.

The elevation determined by a climate-informed science approach in which adequate, actionable science is available. In most cases, application of the climate-informed science approach will consist of addition of elevation, as determined by projected sea-level rise, enhanced storm surge or future flooding, to the base flood elevation, and then adding the standard freeboard requirement

[22] Critical facilities are defined and discussed in the section Critical Facilities below.
[23] As used in this guidance, *flood-hazard area* refers to an area defined by the general flood-risk management guidelines and should not be confused with the *special flood hazard area*, defined by FEMA as the area covered by floodwaters during a one-percent annual chance flood.
[24] Critical facilities are defined and discussed in the section Critical Facilities below.
[25] Federal Emergency Management Agency 2016

of two feet (three feet for critical facilities). The climate-informed science guideline is illustrated by Figure 25.

The general flood-risk management guidelines described in Table 3 are based on the first three FFRMS approaches described above for determining the floodplain. As described below, this guidance further identifies one or more of the three general flood-risk management guidelines that are applicable to each of several structural types. This guidance expands on FEMA's proposed implementation of the FFRMS by recommending applicants be required to demonstrate consideration of the highest flood-risk management guidelines applicable to the type of structure in question. This recommendation is based on the premise that, given the uncertainties inherent to any approach to defining future flood risks, and the potential sea-level rise and flood risks to public health, safety and welfare; to public infrastructure investments; and to natural resources, review of many projects should include an assessment of potential worst-case scenarios.

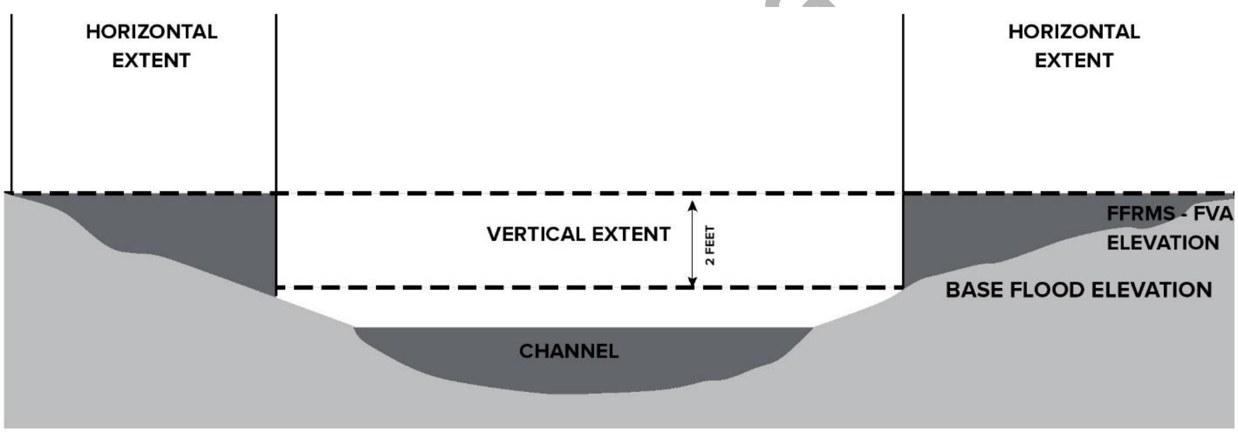

Figure 24. Illustration of determination of flood-hazard area by horizontal extension of the level determined by adding freeboard to the base flood elevation.

This guidance recognizes sufficient actionable climate science is available in New York to justify application of a climate-informed science approach in the review of many projects. Accordingly, the climate-informed science-based flood-risk management guideline is preferred where applicable. As discussed below, the FFRMS freeboard approach, which does not include a factor to account for climate change, is not applicable for most structure types in New York. Rather, the guidelines included in this guidance for most structure types are based on the addition of elevation, determined by a climate-informed science approach, to the BFE plus freeboard.

A climate-informed science based guideline should not be applied if it results in a lower elevation than other flood-risk management guidelines applicable to the structure type. This recommendation is consistent with FEMA's proposed implementation of the FFRMS. The intent of this recommendation is to ensure that applying climate projections, with their inherent uncertainties, would not result in siting or construction to less protective guidelines than might be in place now. The implication of applying a climate-informed science elevation lower than a freeboard-based guideline is that the risk of flooding will decrease with climate change. There is little reason to believe flood risk will decrease anywhere in New York State.

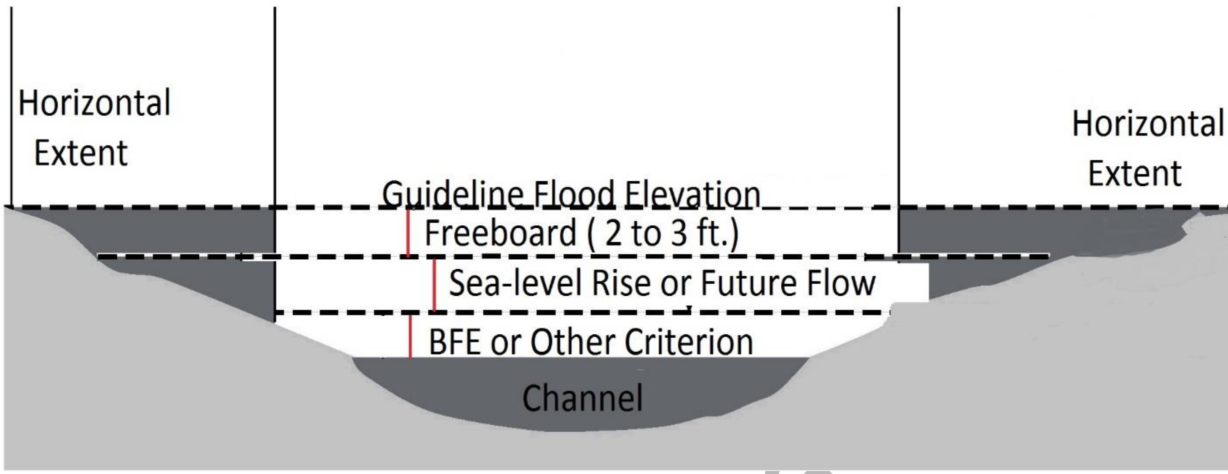

Figure 25. Illustration of determination of flood-hazard area and elevation by application of the climate-informed science approach.

The general flood-risk management guidelines provide a framework to ensure resilience to enhanced future flood risk. Further, this guidance applies the general flood-risk management guidelines to specific structure types for tidal and nontidal areas. This guidance recommends these guidelines for flood protection be incorporated into program-specific guidance and other documents as described above.

It is always preferable to site any proposed project outside the area defined by the highest of the general flood-risk management guidelines, described in Table 3, if practicable. If it is not practical to avoid the highest flood-hazard area, reduction of density and uses in the area or additional flood protection measures should be considered.

Programs should consider requiring applicants for projects involving new or replacement structures and infrastructure, and during repair or reconstruction of substantially damaged structures and infrastructure to demonstrate consideration of the highest flood-risk management guideline applicable to the structure or infrastructure type. Other considerations, including, but not limited to, human health and safety, environmental effects, cost, funding requirements, feasibility and community impact, may preclude inclusion of the highest of the flood-risk management guideline in final design. However, applicants to CRRA-covered programs should be required to provide rational bases for the flood-risk management guideline included in their project designs.

Although requirements that applicants demonstrate consideration of the most protective guidelines for determining elevation are strongly encouraged, agency programs responsible for implementation of regulatory or funding programs covered by CRRA may, with appropriate justification, e.g., regulatory efficiency, practicality, public availability of information or limits to statutory authority, elect to apply a specific guideline or set of guidelines.

3.1.3 Freeboard

The concept of freeboard is a critical one in flood-risk management. FEMA defines freeboard as a safety factor, usually expressed as the distance, in feet, between a specified flood level, usually the BFE, and the lowest floor, including basement, or in coastal VE zones, the lowest horizontal structural member supporting the structure. Freeboard can compensate for uncertainties such as wave action, structural openings and effects of urbanization that can result in flood levels higher than calculated for a selected flood size and floodway conditions.

Freeboard is not intended to compensate for higher floods expected under future climatic conditions, e.g., those due to sea-level rise or more extreme precipitation events. Maintenance of current risk profiles, therefore, would require application of current freeboard recommendations or requirements, in addition to flood levels adjusted for projected climatic conditions. As discussed above, this guidance includes, for most structure types, a guideline based on the addition of additional elevation determined by climate science, e.g., projected sea-level rise or increased stream flows, plus the specified freeboard, to the BFE.

This guidance recommends applicants demonstrate consideration of flood-risk management guidelines that include two feet of freeboard for most projects. This recommendation is consistent with the 2016 Uniform Code Supplement, which amends the IBC and, by extension, ASCE-24, to require two feet of freeboard.

This guidance recommends applicants demonstrate consideration of three feet of freeboard for critical facilities and infrastructure, consistent with FEMA's proposed rule to implement the FFRMS, which includes three feet of freeboard for critical actions. Although inclusion of overly risk-averse flood elevations in structure siting and design could introduce concerns of costs and feasibility, given the inherent uncertainties in flood projection, and the high social and economic costs of flooding of critical infrastructure, three feet of freeboard should be factored into risk assessment and cost-benefit analyses for critical projects.

Unless otherwise specified in this document, freeboard refers to the distance between a specified water elevation and the lowest horizontal portion of the structure in question. However, for transportation infrastructure, this document differentiates between roadway freeboard and bridge freeboard. See Transportation Infrastructure for definitions and discussion of roadway and bridge freeboard.

3.1.4 Service Life

Many of the structure-specific climate-informed science guidelines described below require inclusion of projected sea-level rise or greater peak stream flows over the course of the full, expected service life of the structure. Applicants should demonstrate consideration of risks associated with flooding and other hazards under climate conditions projected by the end of the full, expected service life of the project.

Applicants should apply engineering estimates of expected service life applicable to the proposed project from reputable sources.

In some cases, applicants should also demonstrate consideration of risks of flooding and other hazards as conditions change, e.g., with sea-level rise, from current conditions to those projected for the end of service life. For example, a bridge deck may become subject to wave attack and associated damage before sea levels rise to the point of overtopping the deck.

3.1.5 Additional Considerations

Applicants and programs are also encouraged to consider the following during project siting, design and review.

- The BFE should be the highest of any elevation shown on a FIRM and accompanying effective flood insurance study (FIS), a FEMA preliminary or advisory FIRM and accompanying FIS, or an engineering analysis of current conditions using accepted hydrologic and hydraulic engineering techniques.
- Programs should consider requiring applicants to demonstrate consideration of the highest flood-risk management guidelines applicable to the project type as described in Table 5. Siting and design decisions should incorporate the highest guideline, as feasible and practicable. Applicants for projects involving new or replacement critical infrastructure should consider the full range of projected flooding, including the highest adopted projections of sea-level rise, during the expected service life of the project. Where adherence to the highest guideline is not feasible, due to practicality, costs, risk tolerance and environmental effects, applicants should carefully describe and justify designs not adhering to the most restrictive guideline.
- The vertical elevation and horizontal flood-hazard area that result from adding two feet (three feet for critical facilities) of freeboard to the BFE and extending this level to its intersection with the ground are not mapped. As a result, some applicants may not be able to determine if their projects are located within a flood-hazard area defined by this guideline. Until maps or other means to make such determinations are readily available to applicants, programs may decide to specify alternative guidelines for some or all project types.
- Some infrastructure can be allowed to be flooded if it is designed to flood without suffering severe damages or compromising public health, safety or welfare.
- Some projects near streams and wetlands require permits from DEC or other regulatory agencies that may incorporate additional requirements.

3.2 Climate-informed Science Approach

The climate-informed science approach may include an assessment of the costs and benefits of designs based on various projections of sea-level rise, storm surge and flooding. The level of analysis required of applicants should consider the level of investment of the facility, its criticality and risk tolerance. Decision making should include a determination of the consequences associated with the purpose and lifetime of the investment should it be subject to severe flooding, common nuisance flooding, or shoreline erosion. Use of the climate-informed science approach must recognize the inherent uncertainty of both flood models and projections of future climatic conditions and include sufficient measures of safety.

Estimating future flood elevations using climate-informed science will provide an added margin of safety for buildings and infrastructure that will be in place decades into the future. However, by its nature, any climate-informed science approach will contain some uncertainty, with the level of uncertainty increasing with attempts to project further into the future. This guidance recommends use of resources available at the time of publication. Products developed or refined in the future should be used if they provide more accurate data or projections.

Design flood elevations

3.2.1 Tidal Areas

Use of the climate-informed science approach must first consider the source of flooding. Tidal flooding can occur on any tidal waters, including the Hudson River north from New York City to the Federal Dam at Troy. For tidal flooding, the sea-level rise projections described in 6 NYCRR Part 490, Projected Sea-level Rise (Appendix A), should be used. In general, the appropriate sea-level rise projection should be added to the current FEMA BFE, along with an appropriate amount of freeboard. Sources of sea-level rise information, including online map viewers, are provided in Appendix C, Decision-support Tools for Flood Risk. Some of the tools described in Appendix C include projected flood elevations and horizontal extents based on the effects of coastal storms and precipitation under various sea-level rise scenarios.

Tidal riverine systems receive water inputs from tides, storm surge, sea-level rise and freshwater tributaries, which in turn receive precipitation input. Future flood risk in tidal riverine systems could potentially be affected by sea-level rise, increased frequency and severity of extreme precipitation events and stronger storm surges. Projections of future coastal floodplains that incorporate changes in all of these factors are not currently available for all of New York's tidal coast. However, the Hudson River Flooding Decision Support Tool[26] maps projected flood events on the Hudson River at various flood return periods, incorporating both storm surge and freshwater inputs, at several levels of sea-level rise. The tool also displays locations of infrastructure and selected facilities relative to projected floodplains and provides summary statistics on infrastructure, natural features and social characteristics of populations at risk from selected flood events. Applicants and review staff are encouraged to apply this tool during risk-assessments on projects along the Hudson River.

[26] http://www.ciesin.columbia.edu/hudson-river-flood-map/

It is anticipated that changes in risk due to sea-level rise will be more significant than changes in precipitation and storm surge. Accordingly, this guidance generally recommends, for areas in which more sophisticated modeling and mapping are not yet available, sea-level rise projections simply be added to the current BFE—the so-called bathtub approach. This approach assumes that the frequency and magnitude of storm surge events will not deviate from the historical patterns on which the current BFE is based and that the relationship between precipitation events and storm surge will remain the same.

3.2.1.1 Selection of Sea-level Rise Projections

6NYCRR Part 490, Projected Sea-level Rise (Appendix A) provides science-based sea-level rise projections based on five sea-level rise scenarios for three tidal areas of the state through 2100. As global sea-level rise will continue for centuries or millennia after 2100 and the global system is already committed to an estimated 6.6 feet of sea-level rise, the five sea-level rise scenarios reflect different rates of rise rather than ultimate increases in sea level.

The preferred climate-informed science flood risk management guideline in tidal areas consists of adding projected sea-level rise over the design life of a project to the current BFE and adding an appropriate amount of freeboard. Selection of the appropriate sea-level rise projection is an important step in identifying a design flood level that is sufficiently protective while not being so risk averse as to be maladaptive.

In general, this guidance recommends applicants demonstrate consideration of the high sea-level rise projection for critical projects, as described in Section, 3.3.2.3.1 Critical facilities and infrastructure, and the medium projection for non-critical projects. As stressed elsewhere in this guidance, the actual design flood elevation for any particular project should reflect other factors, including feasibility, project costs, costs of flood damage, risk tolerance and environmental effects. However, although available data from New York tidal gauges do not allow a statistically valid assessment of relative sea-level rise since the Part 490 projections were last updated in 2014, available data indicate that recent rise has exceeded rates associated with the low projections. Therefore, application of the low sea-level rise projection should not generally be considered sufficiently protective. Critical infrastructure should, at a minimum, incorporate the medium projection and non-critical infrastructure, the low-medium projection, unless the applicant provides a valid justification for use of lower projections.

As there is a possibility that global sea-level rise will exceed 6.6 feet by 2200[27], careful consideration should be given to the effects of such rise on projects expected to remain in place beyond 2100, including incorporation of the capacity for the project to be adapted to future conditions.

27 Kopp et al. 2014

New York State has not yet adopted projections of sea-level rise beyond 2100. Applicants for projects with expected service lives significantly beyond 2100 should consider sea-level rise projections provided for New York published in sources such as Kopp et al., 2016.

3.2.2 Nontidal Areas

Flood elevations depicted on FEMA FIRMs are based on historical information and do not include projections of flooding under future climate conditions. Although FEMA has taken steps to address this deficiency, FIRMs will not include future conditions for the foreseeable future. (See Appendix B, Federal Technical Mapping Advisory Committee (TMAC). Presently, the best approach for projecting future flood-hazard areas is to project the peak flow of a stream for the return interval of interest. A hydraulic analysis can then determine the projected flood elevation associated with the return interval of interest.

Projection of peak flows under various climate change scenarios is an active area of research in New York State. For example, USGS's StreamStats application provides hydrologic information for streams. USGS has developed Future Flow Explorer[28] (FFE), a web-based extension of StreamStats for riverine areas north of New York City. FFE applies predictions of future precipitation to the existing runoff regression equations in StreamStats to provide projected peak flows. However, FFE has not been fully tested as of this writing, and USGS advises that projected future flows be used only as an exploratory tool to inform selection of appropriate design flow. (See Appendix D, Suggestions Regarding Use, Application, and Limitation of Results Derived from U.S. Geological Survey Future Peak Flows Web Application.)

Pending further development of future flood projection models, including FFE, applicants should adjust peak flows for future conditions by multiplying relevant peak flow parameters, currently used in hydraulic analysis, e.g., Q_{50}, by a factor specific to the expected service life of the structure and the geographic location of the project. Table 4 lists the recommended design-flow multipliers for two regions of the state that approximate several USGS hydrologic regions. For ease of use, the boundaries of these regions have been matched to county boundaries (Figure 26).

[28] United States Geological Survey 2015

Table 4. Recommended design-flow multipliers.[29]

End of Design Life	Western New York	Eastern New York
2025-2100	110%	120%
Western New York: approximate USGS hydrologic regions 5 and 6 Eastern New York: approximate USGS hydrologic regions 1, 2, 3 and 4; New York City and Long Island		

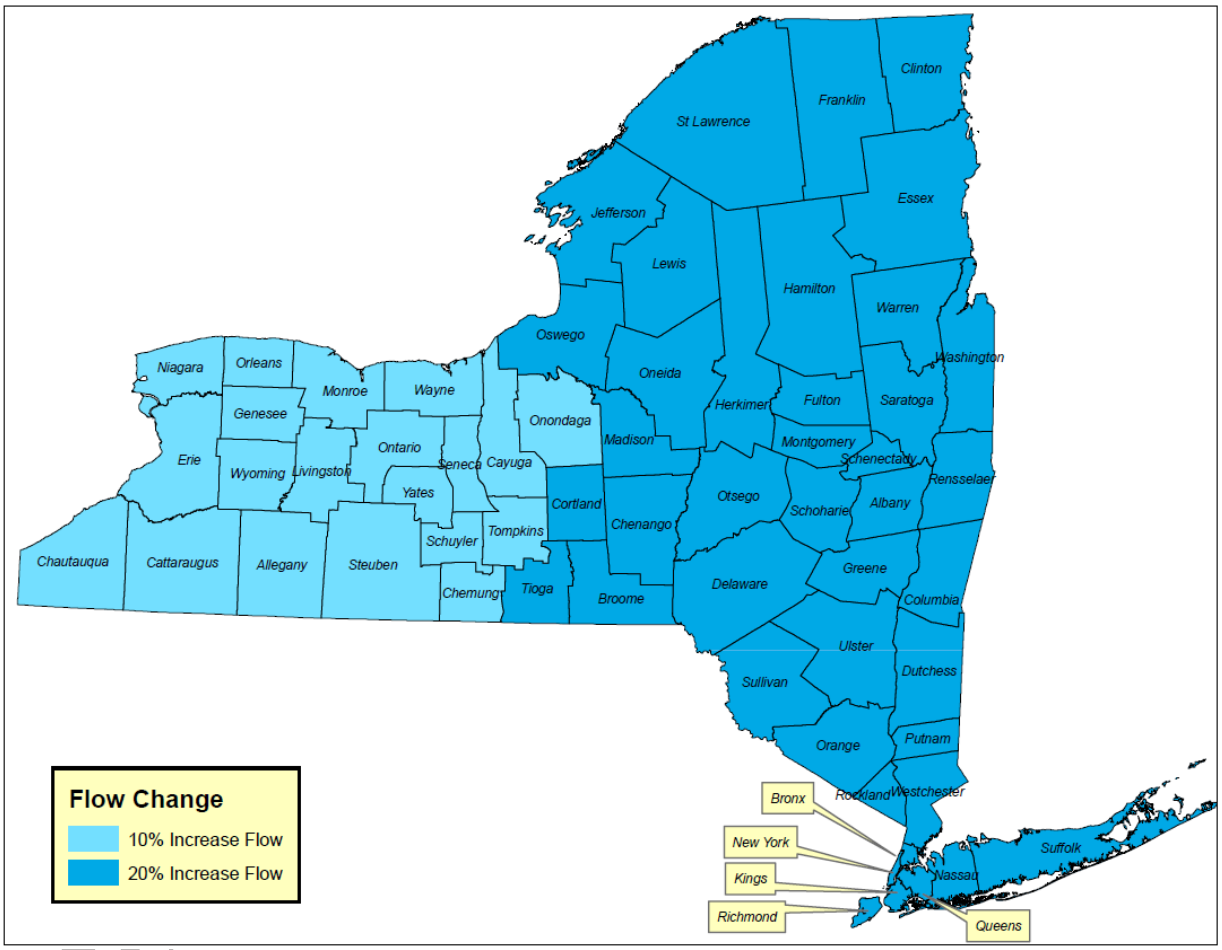

Figure 26. Design flow multipliers by county.

Where current FIRMs have a detailed flood study with a BFE, DEC or FEMA may be able to assist with the interpretation of flood flows and flood elevations. Some newer digital flood insurance rate maps (dFIRMs) contain advisory flood elevations in the

[29] New York State Department of Transportation 2016

digital data for areas with A zones but no flood elevations. DEC's Floodplain Management Section (518-402-8185 or floodplain@dec.ny.gov) can provide advice regarding their use. Instructions for ordering technical mapping data from FEMA are available at https://www.fema.gov/how-order-technical-administrative-support-data.

3.2.2.1 Other Risk Zones

3.2.2.1.1 A Zones with no BFE data

Analysis of flood risk often begins with determination of the site BFE from a FIRM. Application of freeboard-based guidelines in areas where BFEs are readily available is discussed above. Review of a project site where a BFE has not been identified creates a special case.

FEMA FIRMs for many areas indicate only A Zones, with no available flood elevations. If newer digital flood studies are available for these areas, the digital data underlying the study may be used to estimate advisory flood elevations. The digital data may be downloaded from http://msc.fema.gov and viewed using GIS, or DEC's Floodplain Management Section can be consulted (floodplain.floodplain@dec.ny.gov, 518-402-8185).

Simplified approaches to estimating BFEs in un-numbered or approximate A zones are also available. FEMA's publication, "Managing Floodplain Development in Approximate Zone A Areas," FEMA 265, 1995, (https://www.fema.gov/media-library/assets/documents/1911) provides guidance for when no BFE information in an A Zone exists on a FIRM. Because the older A Zones were determined using existing contour lines, a contour interpolation method, as described in FEMA's guidance, can sometimes work.

Large Development—No BFE

Where a proposed project exceeds five acres and encroaches upon an A zone without a BFE, FEMA requires use of standard hydrologic and hydraulic engineering techniques to determine a BFE. This guidance recommends that applicants conduct such an analysis to determine a BFE for projects exceeding two acres of disturbed land.

If a BFE is not available from a FIRM or other reputable source, e.g., DEC or licensed design professional, the flood-hazard area may be defined by an elevation of three feet above the highest adjacent grade for residential, small non-residential and non-critical facilities and infrastructure. If there is a high-water mark from a flood, that mark should be used as the flood-risk management guideline if it is higher than three feet above the highest adjacent grade. Applicants for all other project types, i.e., multi-family, large non-residential, and critical facilities and infrastructure must determine flood elevations according to accepted engineering techniques.

3.2.2.1.2 Locations with no flood data

No FEMA flood maps are available for some locations with sources of flooding. In such locations, applicants in project types for which consideration of a BFE-based guideline is required should develop a BFE using standard engineering techniques. This requirement should apply wherever historical flooding indicates a flood risk even if any existing FEMA maps do not designate flood zones. Areas of historical flooding may be identified through discussions with local authorities and regional DEC flood protection staff.

3.2.2.1.3 Residual risk zones

Residual risk zones may exist downstream of dams or behind flood control projects. Any engineered structure can fail. Dams can fail during flooding conditions or on a sunny day. Levees can be overtopped or breached during a flood. FEMA maps that show levees as providing protection generally show a shaded X zone (newer maps) or a B zone (older maps) in the levee-protected areas. Dam break analyses are not shown on FEMA maps, though dam operators are often required by the state to develop dam break analyses. Results of such analyses are available by making a request to the Dam Safety Section in DEC's Bureau of Flood Control and Dam Safety (518-402-8185, DOWinformation@dec.ny.gov).

3.2.2.1.4 Streams with unstable banks

Stream corridor geometry is dependent on several landscape factors, including slope, soil types, sediment bedload and seasonal flow patterns. Some streams naturally meander and can maintain their banks and volume where sufficient undeveloped floodplain is available to allow meander adjustments in response to sediment deposits and stream flows (Figure 27).

When streams and floodplains are disturbed by construction or confined by roadways, development or other factors, banks can become unstable and subject to erosion. Streams with unstable banks present additional flood-risk evaluation challenges due to "fluvial erosion hazards"-channel movements that may be more damaging to property than the flooding itself. In such situations, attention should be paid to the potential for flood damage beyond the FEMA-defined floodplains. The Nature Conservancy's Natural Resource Navigator[30], Active River Area layer is a potential source of information.

During extreme floods, streams may shift and flood areas that were not mapped as flood zones. Aerial photographs are particularly useful in determination of areas where streams have historically flowed. Soil types and cobble in an area near the stream may also provide evidence of former channels. Empirical studies have shown a range of buffer widths to be effective for the protection of stream banks and prevention of bank

[30] http://www.naturalresourcenavigator.org/

erosion. Vegetated buffers of 30 to 98 feet have been shown to be effective for erosion control.[31,32]

3.2.2.1.5 Perennial streams without any mapped flood hazards

Design of projects, other than necessary stream crossings, near perennial streams without mapped flood hazards should demonstrate consideration of a stream buffer in accordance with applicable DEC guidance. If soil or geological conditions indicate the building site is in an active stream channel, the location should be avoided if possible. If avoiding the location is not possible, the building should be elevated to at least three feet above the highest adjacent grade.

For more information on streams, see DEC's guidance on use of natural resiliency measures.

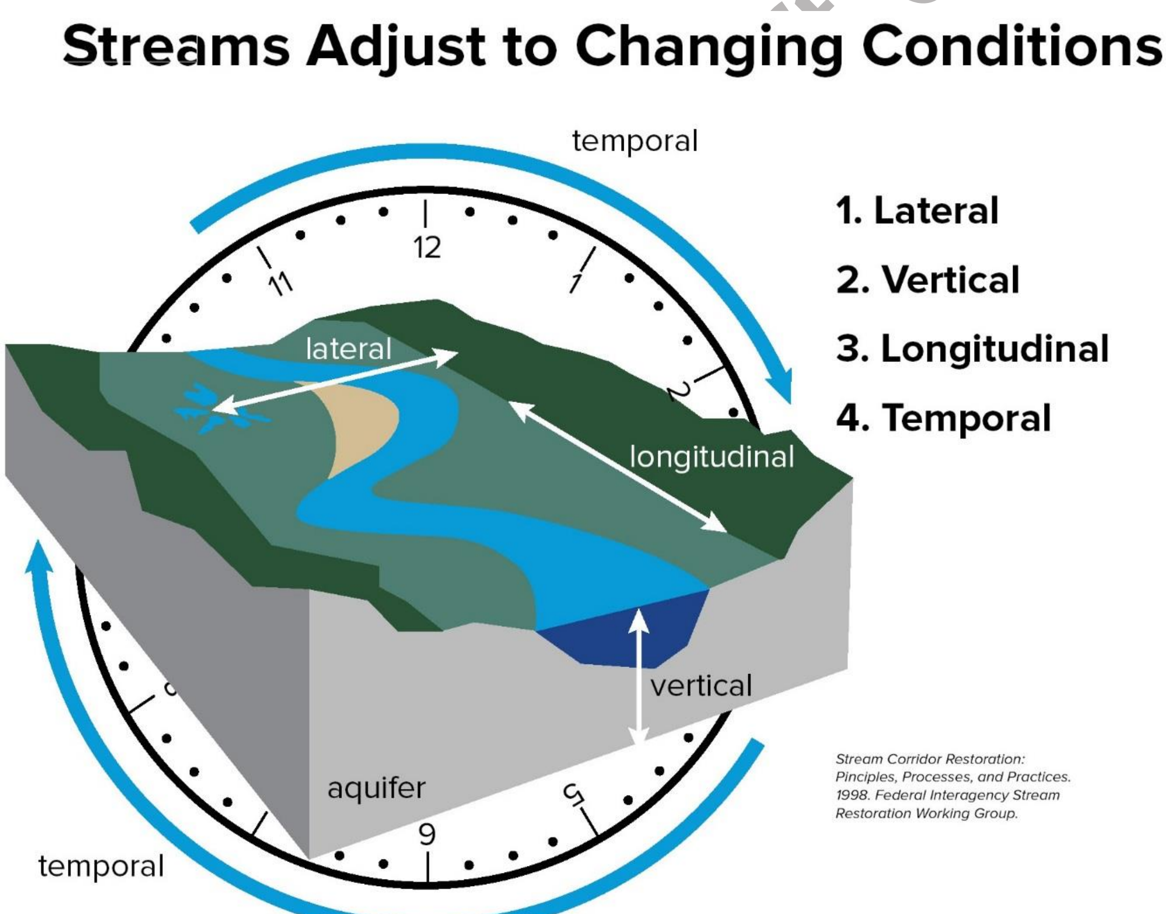

Figure 27. Stream migrations.

[31] Hawes and Smith 2005
[32] New York State Department of Environmental Conservation 2007

3.3 Flood-risk Management Guidelines

Tables 5 and 6 describe flood-risk management guidelines applicable to all structures near large lakes and to specific types of structures in areas other than near large lakes. These guidelines are derived from the general guidelines described in Table 3 but have been selected in consideration of the design process applicable to each structure type.

3.3.1 Large Lakes

Table 5 lists flood-risk management guidelines for all structures near large lakes. FEMA currently provides flood-risk information for large lakes, including the Great Lakes, in the form of FIRMs and FISs. This information generally includes only stillwater lake elevations and does not account for storm surge, seiches and waves.[33] Trends in lake levels will be determined by both climatic conditions and human activity, both of which entail considerable uncertainty. Thus, actionable water-level projections from climate science are not yet available for the Great Lakes or other large lakes in New York.[34] Programs should consider requiring applicants to demonstrate consideration of the following flood-risk management guidelines for shorelines of large lakes and the Great Lakes for all structures until a climate-informed science approach is available.

- The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood.
- The vertical flood elevation and corresponding horizontal floodplain associated with the flood of record.

For the large inland lakes, historical records of high water elevations may be available from the USGS Lake Level Viewer or other sources and should be considered if they are higher than the guidelines above.

3.3.2 Structure-specific Guidelines

Flood-risk management guidelines for common structure types are summarized in Table 5. Table 6 summarizes the flood-risk management guidelines applicable to transportation infrastructure.

Table 5. Summary of recommended New York State flood-risk management guidelines. Applicants should demonstrate that plans for construction or other activities consider the listed guidelines, considering practicality, costs, financial burden, funding eligibility, risk tolerance and environmental effects.

Category	Nontidal Areas	Tidal Areas

[33] FEMA is currently developing updated FIRMs for the Great Lakes with analyses including wave action.
[34] New York's large lakes are lakes Champlain, Chautauqua, Erie, George, Ontario; Oneida and Onondaga lakes; and the Finger Lakes: Canadice, Canandaigua, Cayuga, Conesus, Hemlock Honeoye, Keuka, Otisco, Owasco, Seneca and Skaneateles

Large lakes and Great Lakes: All structures	• The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}). • The vertical flood elevation and corresponding horizontal floodplain associated with the flood of record.	
One- and two-family residential, and small nonresidential structures	• The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).	• The vertical flood elevation and corresponding horizontal floodplain that result from adding the medium sea-level rise projection over the expected service life of the structure, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.
Multi-family and large non-residential structures	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q100) to account for projected future flows, adding two feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).	• The vertical flood elevation and corresponding horizontal floodplain that result from adding the medium sea-level rise projection over the expected service life of the structure, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.
Critical facilities and critical non-transportation infrastructure, designed to be functional during flooding	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q_{100}) to account for projected future flows, adding three feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).	• The vertical flood elevation and corresponding horizontal floodplain that result from adding the high sea-level rise projection applicable for the full, expected service life of the facility, plus three feet of freeboard, to the BFE and extending this level to its intersection with the ground.
Non-critical facilities and non-critical non-transportation infrastructure designed to survive flooding and regain functionality within an acceptable period	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q_{100}) to account for projected future flows, adding two feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground.	• The elevation and special flood hazard area that result from adding the medium sea-level rise projection applicable for the full, expected service life of the facility, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.

<table>
<tr><td rowspan="2">Water supply and wastewater treatment plants, and pump stations</td><td>Non-critical equipment</td><td colspan="2">• The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.</td></tr>
<tr><td>Critical equipment</td><td>• The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flow parameters, e.g., Q_{100}, to account for projected peak flows, adding three feet of freeboard, and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.
• The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).</td><td>• The vertical flood elevation and corresponding horizontal floodplain that result from adding the high sea-level rise projection applicable for the full, expected service life of the infrastructure to the BFE, adding three feet of freeboard, and extending this level to its intersection with the ground.</td></tr>
<tr><td colspan="4">Notes:
• The source for all sea-level rise projections referenced in this table shall be 6 NYCRR Part 490, Projected Sea-level rise.
• See Other Risk Zones for discussion of situations in which no BFE is available.
• Non-critical infrastructure, for which some flooding is acceptable, may be built without freeboard but should maintain capacity to survive events defined by the applicable guidelines or be restored to operating capacity quickly.
• Large lakes to which these guidelines apply are named in the guidance text.</td></tr>
</table>

In determining the values of the flood-risk management guidelines at any location, BFEs should be derived from the highest flood elevation obtained from the following current maps:

- FEMA flood insurance study
- FEMA flood insurance rate map
- FEMA advisory BFE map
- FEMA preliminary flood insurance rate map

3.3.2.1 One- and Two-family Residential and Small Nonresidential Structures

The guidelines described in this section apply to all one- and two-family residential structures regardless of size, and ASCE Flood Design Class 2[35] nonresidential structures of less than 4000 square feet in gross floor area.[36]

[35] American Society of Civil Engineers 2005

[36] For purposes of this guidance, cellar or basement space is considered part of the gross square foot area of the facility.

3.3.2.1.1 Nontidal Areas

The analysis associated with the climate-informed science approach may not be warranted for inland individual residential and small nonresidential construction. Such structures, built or substantially improved (including substantially damaged structures), should be sited or elevated such that the lowest floor is at or higher than the highest of the following:

- The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood.

3.3.2.1.2 Tidal Areas

In tidal areas, an approach that incorporates projected sea-level rise provides an additional margin of safety for future flood-risk reduction. Individual residential and small nonresidential buildings, built or substantially improved (including substantially damaged structures), should be sited or elevated such that the lowest floor or other structural member is at or higher than the following, considering feasibility, project costs, risk tolerance and environmental effects:

- The vertical flood elevation and corresponding horizontal floodplain that result from adding the medium sea-level rise projection over the expected service life of the structure, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.

Design-flow Multipliers

The climate-informed science-based guideline for some structures described in this guidance requires calculation of a projected flow or flood elevation. To calculate a projected flow, multiply the current value for the relevant parameter, e.g., Q_{50}, taken from an FIS, StreamStats or other reliable source, by the appropriate multiplier taken from Table 4. To calculate the projected BFE, multiply the current value of the Q_{100} flow by the appropriate multiplier taken from Table 4. Use the result to calculate the projected BFE.

3.3.2.2 Multi-Family Residential Buildings and Large Non-Residential Buildings

The flood-risk management guidelines included in this section apply to ASCE Flood Class 2 nonresidential buildings of greater than 4000 square feet and ASCE Flood Class 3 buildings not otherwise specifically addressed in this guidance. Such structures often have long life spans or may be critical to the local economy. Multi-family residential structures that are inundated by flooding could result in large numbers of people losing their homes or being put in physical danger. Even high-rise buildings, where most of the living space is higher than flood levels, have been significantly damaged by flooding such that residents could not access the building for weeks or even months after a flood. For such structures, a climate-informed science approach that incorporates projected sea-level rise and enhanced storm surge, or greater riverine flooding is often warranted. As discussed above, the design-flow multipliers listed in Table 4 may be used to calculate future peak flows for use in a hydraulic analysis to generate projected flood elevations and return intervals. This level of analysis is generally within the capability of owners of large buildings.

3.3.2.2.1 Nontidal Areas

Multi-family and non-residential buildings in nontidal areas should be sited or elevated such that the lowest floor is at or higher than the highest of the following, considering feasibility, project costs, risk tolerance and environmental effects:

- The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q_{100}) to account for projected future flows, adding two feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground.
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood.

3.3.2.2.1.1 Developments in approximate A Zones without BFEs

For developments in A Zones that do not have BFEs available (approximate A zones), the applicant should determine a BFE using accepted hydrologic and hydraulic engineering techniques, or apply a climate-informed science approach, estimating the future vertical flood elevation and corresponding horizontal floodplain by multiplying the current one-percent annual chance peak flow (Q_{100}) by the appropriate design-flow multiplier (Table 4) and adding two feet of freeboard. FEMA provides engineering guidelines for determination of BFEs in approximate A Zones.[37]

3.3.2.2.2 Tidal Areas

Multi-family and non-residential buildings in Coastal High Hazard Areas (Zone V) and Coastal A Zones should be sited or elevated such that the bottom of the lowest horizontal structural member is at or higher than the higher of the following elevations, considering feasibility, project costs, risk tolerance and environmental effects:

- The vertical flood elevation and corresponding horizontal floodplain that result from adding the medium sea-level rise projection over the expected service life of the structure, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood.

As sea levels rise, damaging waves will reach further inland during storms. FIRMs in areas subject to wave action show areas of damaging waves as VE Zones or as areas

[37] Federal Emergency Management Agency 1995

within the limit of moderate wave action (LiMWA). VE Zones experience waves of at least three feet during the base (i.e., one-percent annual chance) flood. Areas within the LiMWA zone experience potential waves of between 1.5 feet and three feet. Construction in VE zones requires more restrictive building practices, including construction on piles to survive wave action. The Uniform Code also requires VE zone construction techniques to be used within LiMWA zones.

The Coastal New York Future Floodplain Mapper (See Appendix C) delineates the one-percent and 0.2-percent floodplains, as well as LiMWA, under future sea-level rise scenarios in the Hudson Valley and on Long Island, and provides a land-loss estimation tool. This tool can be used for multi-family and non-residential development to determine if the development should be constructed to VE zone standards. This determination should be based on the projected one-percent annual chance flood, assuming the medium sea-level rise projection through the expected service life of the structures.

3.3.2.3 Facilities and Non-transportation Infrastructure

An important application of this guidance is ensuring that applicants for projects involving facilities and infrastructure are protective of human health and safety, and of public investment, during worst-case weather events, including events that will become more frequent or severe with climate change. Flood events involving some structures, such as those listed below, have the potential to endanger the health and safety of many New Yorkers, the environment and/or the vitality of the regional economy.

ASCE differentiates between structures "that pose a high risk to the public or significant disruption to the community should they be damaged, be unable to perform their intended functions after flooding, or fail due to flooding (Flood Design Class 3), and those that contain essential facilities and services necessary for emergency response and recovery, or that pose a substantial risk to the community at large in the event of failure, disruption of function, or damage by flooding (Flood Design Class 4). Flood-risk management guidelines described in this guidance for critical facilities and non-transportation infrastructure are applicable to Flood Design Class 4 structures; guidelines described for noncritical facilities and non-transportation infrastructure are applicable to Flood Design Class 3 structures.

Transportation and water infrastructure are considered separately below.

3.3.2.3.1 Critical facilities and infrastructure

The American Society of Civil Engineers defines *critical infrastructure* as

> "Systems, facilities and assets so vital that if destroyed or incapacitated would disrupt the security, economy, health, safety, or welfare of the public. Critical infrastructure may cross political boundaries and may be built (such as structures, energy, water, transportation, and communication systems), natural (such as surface or groundwater

resources), or virtual (such as cyber, electronic data, and information systems)."[38]

This category comprises critical public and private facilities, and critical non-transportation, non-water infrastructure, designed to be functional during a flood. Applicants for projects involving new or replacement critical facilities and infrastructure should demonstrate consideration of the applicable flood-risk management guidelines below.

3.3.2.3.1.1 Key utilities

Generating stations and substations should be located outside the flood-hazard area described by the highest of the three general flood-risk management guidelines (Table 3), if possible. If avoiding the flood-hazard areas is not possible, all components should be elevated or protected above the highest of the critical facilities guidelines (Table 5).

Power and communications transmission lines are generally constructed above any flood elevation standards. However, underground lines in flood-hazard areas must be designed to be safe during conditions of flooding. Manhole covers should be sealed or elevated, provided road conditions allow.

Cell phone and other communication towers are essential during emergencies. Any utility buildings servicing a communication tower should be considered critical infrastructure.

To prevent flood damage that would result in serious danger to life and health, or widespread social or economic dislocation, no new critical facilities should be constructed within any flood hazard area, as defined by the applicable flood-risk management guidelines described in this guidance, unless no feasible alternatives exist. Critical facilities include the following:[39]

- Hospitals, rest homes, correctional facilities, residence halls, patient care facilities
- Major power generation, transmission or substation facilities, except for hydroelectric facilities
- Major communications centers, such as civil defense centers
- Major emergency service facilities, such as central fire and police stations
- Roads that provide sole access to critical facilities and emergency evacuation routes, but nothing in this guidance should be construed as a prohibition of, or recommendation against, construction or maintenance of infrastructure to provide access to critical facilities or evacuation routes.

[38] http://ciasce.asce.org/working-definitions

[39] This list is based on 6 NYCRR Part 502, Floodplain Management Criteria for State Projects, which prohibits location of any such new projects within any flood-hazard area.

- Facilities designed for bulk storage of chemicals, petrochemicals, hazardous or toxic substances or floatable materials

Other types of facilities may also be considered critical. These include major employment centers, aviation facilities, transportation hubs, food distribution points, and water and wastewater utilities. Location of the latter in the floodplain often cannot be avoided. However, adherence to the flood-risk management guidelines and other forward-looking design standards should allow the facility to continue operation through most flood events or return to operation quickly when floodwaters have subsided.

To ensure public health and safety for any project within the largest of the areas defined by the three general flood-reduction guidelines described in Table 3, a determination should be made as to whether the project is a critical facility, even if it does not fall into one of the aforementioned categories. Such projects could include construction, substantial reconstruction or modification of buildings and other structures; mining; dredging; filling; paving; excavation; drilling; or storage of equipment or materials.

The ability to maintain services to and from critical facilities in the event of a natural disaster and the security of critical supporting facilities should be factors in determining or modifying allowable land uses.

If the project is a critical facility, the flood-hazard area should be avoided if possible. If it cannot be avoided, an explanation should be provided as to why not and how risks will be mitigated. With many types of critical infrastructure, it is not sufficient that the facility is not damaged by floods but that it remain in service and accessible during times of critical need.

3.3.2.3.1.2 Nontidal Areas

Applicants for projects involving new or replacement critical facilities and infrastructure (except transportation and water infrastructure) in nontidal areas should demonstrate consideration of the higher of the following guidelines, considering feasibility, project costs, risk tolerance and environmental effects:

- The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q_{100}) to account for projected future flows, adding three feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood

3.3.2.3.1.3 Tidal Areas

Applicants for projects involving new or replacement critical facilities and non-transportation infrastructure in tidal areas should demonstrate consideration of the following guideline, considering practicality, costs, risk tolerance and environmental effects:

- The vertical flood elevation and corresponding horizontal floodplain that result from adding the high sea-level rise projection applicable for the full, expected service life of the facility, plus three feet of freeboard, to the BFE and extending this level to its intersection with the ground

Construction of any *critical facility in the VE Zone* should be avoided. If the project is a building and is within the current or projected *LiMWA defined area*, it should be built using VE Zone construction techniques, but a higher flood elevation, as defined above, must be applied. Developments other than buildings, such as key transportation arteries, pipes, wastewater treatment plant settlement tanks, or other facilities, should be constructed to withstand the force of wave action during a base flood.

Protection of buildings means elevation or flood proofing in accordance with building code and FEMA standards, or other applicable engineering guidance.

3.3.2.3.1.4 Areas with No BFE

Applicants for projects involving new or replacement critical facilities and non-transportation infrastructure in approximate Zone A areas must develop BFEs and demonstrate consideration of the flood-risk management guidelines described above. FEMA provides engineering guidelines for determining BFEs in approximate Zone A areas.[40]

3.3.2.4 Water and Wastewater Facilities

Drinking water and wastewater treatment plants (WWTPs) are critical to human health, and flooding of WWTPs can result in large releases of untreated sewage. While some portions of such facilities can recover from, or even remain operable during flooding, critical components such as electrical controls, basins and clarifiers should be treated as critical facilities.

Due to their functions, many wastewater treatment plants, water supply pumping, and treatment plants are located in areas subject to current and escalating flood risk. When a water or wastewater plant is compromised by a flood, an entire community, as well as the surrounding area, affected. For that reason, it is essential that improvements to such facilities be completed in a manner that protects the facility from flooding for many years to come.

Critical equipment for wastewater facilities includes conveyance and treatment system components that must be protected to ensure continuous operation of the facility. Critical equipment includes, but is not limited to, all electrical, mechanical and control systems associated with pump stations and treatment facilities that are responsible for conveyance of wastewater to and through the treatment facility to maintain primary treatment and disinfection during the flood event. Other critical equipment includes equipment that, if damaged by flood conditions, would prevent the facility from returning to pre-event operation after cessation of flood conditions. For water supply facilities,

[40] FEMA 1995

critical equipment would include similar components used for pumping and treatment, and wells that could be subject to contamination during a flood. Less critical equipment can be flooded but brought back into operation quickly.

This guidance recommends specific flood-risk management guidelines for projects involving new drinking water and wastewater facilities and upgrade or expansion of facilities in areas defined by the highest of the general flood-risk management guidelines Protection for existing equipment that is below the recommended elevation may be achieved by means other than elevation to protect the equipment from water damage or wave action, and salt-water exposure if in tidal zones. Such other means may include construction of barriers, watertight enclosures or additional methods of protection. There should also be protection from salt corrosion in marine environments as warranted.

Applicants should be required to demonstrate consideration of the highest of the flood-risk management guidelines listed below and in Table 5.

3.3.2.4.1 Non-critical Water Infrastructure

Applicants in projects involving non-critical water treatment and supply equipment in both tidal and nontidal areas should demonstrate consideration of the following guideline, considering practicality, costs, risk tolerance and environmental effects:

- The vertical flood elevation and corresponding horizontal floodplain that result from adding two feet of freeboard to the BFE and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground

3.3.2.4.2 Critical Water Infrastructure

3.3.2.4.2.1 Nontidal Areas

Applicants in projects involving new or replacement critical water treatment and supply equipment, including wellheads and critical electronic equipment, in nontidal areas should demonstrate consideration of the higher of the following guidelines, considering practicality, costs, risk tolerance and environmental effects:

- The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flow parameters, e.g., Q_{100}, to account for projected peak flows, adding three feet of freeboard, and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood

3.3.2.4.2.2 Tidal Areas

Applicants in projects involving new or replacement critical water treatment and supply equipment in tidal areas should demonstrate consideration of the higher of the following guidelines, considering practicality, costs, risk tolerance and environmental effects:

- The vertical flood elevation and corresponding horizontal floodplain that result from adding the high sea-level rise projection applicable for the full, expected service life of the infrastructure to the BFE, adding three feet of freeboard, and extending this level to its intersection with the ground.
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood

3.3.2.5 Non-critical Facilities and Non-critical Non-transportation Infrastructure

This category includes any facilities and non-transportation infrastructure not deemed critical according to the definitions above. It would include facilities and infrastructure whose flooding would not constitute a threat to human health, safety or welfare; impose an excessive economic burden on the community or government; or threaten natural resources. While temporary flooding of such structures may be tolerable, the assets should be designed to survive flooding and to retain the capacity to regain their functionality within an acceptable time and at acceptable costs.

3.3.2.5.1.1 Nontidal Areas

Applicants in projects involving non-critical facilities and infrastructure in nontidal areas should demonstrate consideration the following guideline elevation, as practical, considering feasibility, project costs, costs of flooding, funding eligibility, risk tolerance, environmental effects and historic preservation:

- The vertical flood elevation and corresponding horizontal floodplain that result from increasing the current one-percent annual chance peak flow (Q_{100}) to account for projected future flows, adding two feet of freeboard to the resultant flood level, and extending this level to its intersection with the ground.

3.3.2.5.1.2 Tidal Areas

Applicants in projects involving non-critical facilities and infrastructure in tidal areas should demonstrate consideration of the following guideline elevation, as practical, considering feasibility, project costs, costs of flooding, funding eligibility, risk tolerance, environmental effects and historic preservation:

- The elevation and special flood-hazard area that result from adding the medium sea-level rise projection applicable for the full, expected service life of the facility, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground.

3.3.2.6 Transportation Infrastructure

Transportation infrastructure warrants special consideration in this guidance for several reasons, and this guidance provides the foundation for additional, program-specific guidance for evaluation of transportation projects. Public infrastructure to support transportation represents the single largest category of state infrastructure investment. Transportation infrastructure is critical to New York’s economy, and to the health, safety and welfare of its residents and visitors. Transportation assets may be vulnerable to extreme-weather events and at risk of gradual inundation by sea-level rise. Some assets are likely to be most vulnerable at times when they are needed most, e.g., to support evacuations and emergency response during flood events. Some transportation assets have the potential to cause or exacerbate flood damage to other built assets and to natural resources. Conversely, some transportation infrastructure can serve to reduce flood risk to other assets. Applicants for projects involving transportation infrastructure should demonstrate consideration of resiliency of the asset itself under both current and future climatic conditions and current and future flooding risks to neighboring built and natural assets.

Table 6. Recommended flood-risk management guidelines for transportation infrastructure. Consideration should be given to the highest of these guidelines practicable, considering feasibility, project costs, costs of flooding, funding eligibility, risk tolerance, environmental effects and historic preservation per design documentation or verification.

Category	Nontidal Areas	Tidal Areas
Critical linear transportation infrastructure	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flows, e.g., Q_{50}, Q_{100}, to account for projected peak flows for the full, expected service life of the infrastructure, adding freeboard per current applicable engineering requirements or recommendations (three feet preferred), and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground. • The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood (Q_{500}).	• Applicable coastal design criteria that incorporate the higher of the 0.2-percent annual chance flood (Q_{500}) or a range of sea-level rise projections, up to and including the high sea-level rise projection, applicable for the full, expected service life of the infrastructure.
Category	**Nontidal Areas**	**Tidal Areas**
Non-critical linear transportation infrastructure	• The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flows, e.g., Q_{50}, Q_{100}, to account for projected peak flows for the full, expected service life of the infrastructure, adding freeboard per current requirements or recommendations, and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, applicable for the full, expected service life of the infrastructure.
Critical bridges	• The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the bridge, and adding two feet of bridge freeboard. An additional foot of bridge freeboard should be considered for critical bridges. The projected Q_{100} flow should pass below the lowest chord without going into pressure flow. • The vertical flood elevation and corresponding flows resulting from the 0.2-percent annual chance flood (Q_{500}).	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the high sea-level rise projection, applicable for the full, expected service life of the bridge, and the 0.2-percent annual chance flood (Q_{500}).
Non-critical bridges	• The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the bridge, and adding two feet of bridge freeboard. The projected Q_{100} flow should pass below the lowest chord without going into pressure flow.	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, applicable for the full, expected service life of the bridge.
Critical culverts	• The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the culvert, and that allow the culvert to fully pass the design flood without increasing headwater and that provide at least two feet of roadway freeboard above the	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the high sea-level rise projection, applicable for the full,

	projected checkflow. An additional foot of roadway freeboard should be considered for culverts on critical roadways. • The vertical flood elevation and corresponding flows resulting from the 0.2-percent annual chance flood (Q_{500}).	expected service life of the culvert, and the 0.2-percent annual chance flood (Q_{500}).
Non-critical culverts	• The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the culvert, and that provide at least two feet of roadway freeboard above the projected checkflow.	• Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, and projected peak flows applicable for the full, expected service life of the culvert.

Notes:
- The source for all sea-level rise projections referenced in this table shall be 6 NYCRR Part 490, Projected Sea-level Rise.
- "Roadway freeboard" applies to roads and is defined as the vertical distance from the specified water surface elevation to the outside edge of the roadway shoulder.
- "Bridge freeboard" applies to stream crossings and is defined as the vertical distance from the specified water surface elevation to the lowest horizontal element (low chord).
- Non-critical infrastructure, for which some flooding is acceptable, may be built without freeboard but should maintain capacity to survive events defined by applicable guidelines or be restored to operating capacity quickly.

Complicating evaluation of transportation projects are requirements associated with funding, the linear nature and sheer size of some assets, their relationship to adjacent land uses, other structures and natural resources, and guidance provided by other governmental and professional authorities. This guidance recognizes that complexity, and the guidelines described herein should not be interpreted as defining new design standards. Rather, this guidance recommends flood-risk management guidelines that applicants should incorporate into currently accepted design and risk-assessment protocols for consideration along with all other relevant factors, including feasibility, project costs, costs of flooding, funding eligibility, risk tolerance, environmental effects and historic preservation.

Some transportation entities, e.g., the Metropolitan Transportation Authority and Port Authority of New York and New Jersey, have identified design-flood elevations that incorporate future conditions. Those entities, and DEC as the permitting agency, may, as appropriate given the criticality and service life of the project at issue, consider those design-flood elevations in addition to other flood management guidelines identified in this guidance in implementing CRRA's requirement that applicants demonstrate consideration of sea-level rise, storm surge and flooding.

In no case should the guidelines described in this guidance be applied if doing so would increase risk of flood damage. Where applying the flood-risk management guidelines described in this guidance would result in increased flooding, or the need to take additional private or improved property, applicants should analyze an appropriate range of options to determine the optimum approach to minimize flood risk while protecting properties and natural resources.

This guidance recommends that applicants for projects involving transportation infrastructure demonstrate consideration of climate-informed science-based flood-risk management guidelines. Applicants should also demonstrate consideration of flood elevations and flows consistent with the 0.2-percent annual chance flood for critical infrastructure. Climate-informed science-based flood-risk management guidelines are determined by adjusting flood levels currently in use by design professionals, e.g., Q_{50}, for future conditions (i.e., sea-level rise for tidal areas and increased riverine peak flows for nontidal areas), and adding at least the currently required or recommended freeboard. This approach maintains protective risk profiles under future conditions, without radically altering design procedures.

This guidance recommends flood-risk management guidelines for three types of new and replacement transportation infrastructure:

- linear infrastructure, including roadways, railways, pipelines, tunnels, runways and port facilities, and associated structures
- bridges
- culverts.

Table 6 provides flood-risk management guidelines for tidal and nontidal environments, and for critical and noncritical transportation infrastructure.

3.3.2.6.1 Transportation Freeboard

This guidance differentiates between two types of freeboard in discussion of transportation infrastructure. Bridge freeboard is defined as the vertical distance in feet between the design flood elevation and the lowest chord of the bridge (Figure 28). Roadway freeboard is defined as the vertical distance, in feet, between the design flood elevation and the outside edge of the roadway shoulder (Figure 29).

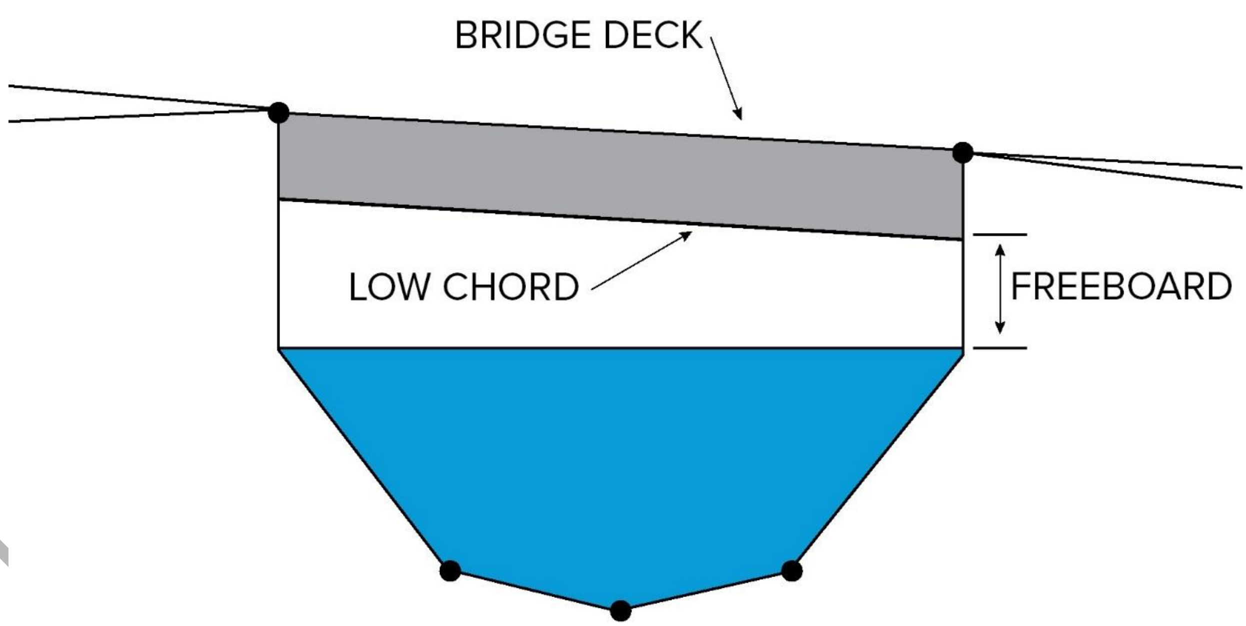

Figure 28. Illustration of bridge freeboard.

Bridges and culverts should be sized to pass flood flows without damaging the structure or causing flooding to neighboring properties, as practical and feasible. Applicants should consider two feet of bridge freeboard, consistent with the New York State Department of Transportation (DOT) Bridge Manual, to ensure adequate hydraulic capacity. Applicants should consider incorporating three feet of bridge freeboard for bridges on critical transportation infrastructure, which must remain operable during flood events.

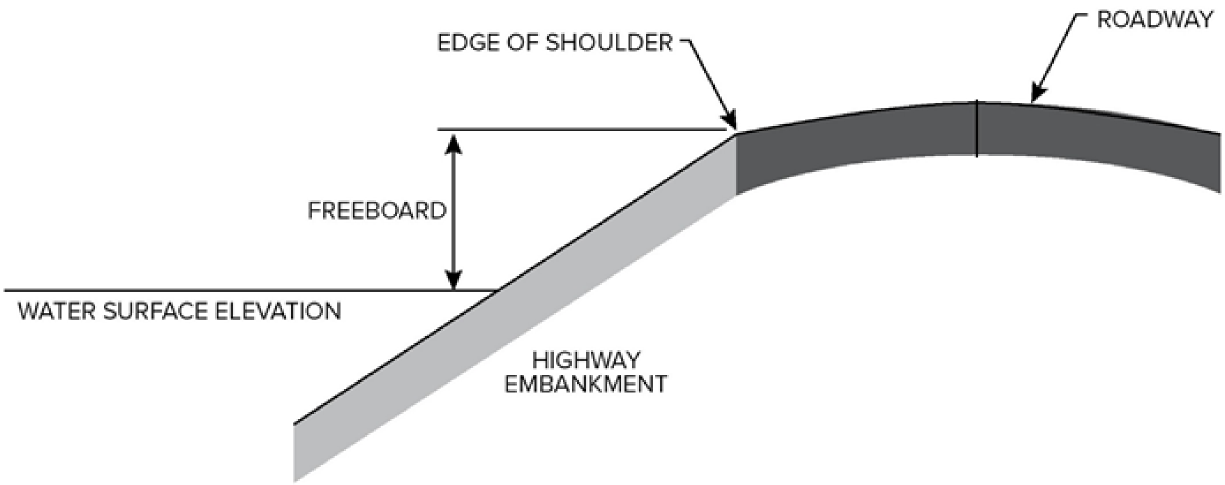

Figure 29. Illustration of roadway freeboard.

This guidance does not recommend addition of freeboard to design parameters where it is not currently used, unless additional flood protection is deemed necessary during the design process. For example, the DOT Bridge Manual recommends addition of two feet of freeboard to the 2-percent annual chance flow (Q_{50}), and bridge designers check to determine if a bridge is capable of passing the 1-percent annual chance flow (Q_{100}). Applying this guidance to noncritical infrastructure, two feet of freeboard would be added to the projected (i.e., adjusted for future conditions, as described below) Q_{50} flow. A check for pressure flow would be performed for the projected Q_{100} flow, but additional freeboard above the projected Q_{100} flow would not be necessary under this guidance.

This guidance recommends consideration of three feet of freeboard for critical infrastructure. As described above, this freeboard would be added to the Q_{50} flow level, adjusted for future conditions, and a check for pressure flow would be performed at the projected Q_{100} flow level. Additional freeboard or span extension would not be necessary under this guidance if the bridge or culvert is capable of passing the Q_{100} flow, adjusted for future conditions, even if the asset has been deemed critical.

3.3.2.6.2 Additional Considerations

If a bridge or culvert results in an increase in the base flood elevation that would affect improved property, the increase must be mitigated, as practical.

Roadways may be constructed in a manner that allows the road to periodically flood without causing damage. In fact, elevating a road to keep the road free of flooding without accommodating flood flows could create a barrier to flood flows and increase neighboring damages.

Many state and local road construction projects involve federal spending and are subject to Federal Highway Administration Order 5520. This order requires transportation agencies and others to minimize climate and extreme-weather risks and to protect critical infrastructure using the best available science, technology and information. As such, the Federal Flood Risk Management Standard discussed above would apply, unless more protective state standards exist. Federal agencies will be developing new guidelines for projects involving use of federal highway funds. (See Appendix B. Federal Technical Mapping Advisory Committee (TMAC) Findings.) DEC will assess the effect of any new federal guidelines on this guidance as they are released.

New road and replacement bridge and culvert projects should include the following considerations:

- FEMA requires analysis of any encroachments into FEMA-identified floodways.[41]
- If an increase in the BFE cannot be avoided, FEMA requirements include an evaluation of alternatives that would not increase the BFE and demonstrating why these alternatives are not feasible, notification of affected property owners, and certification that no structures are located in areas that would be affected by the increased BFE.[42]
- FEMA requires that any change to FEMA-defined flood elevations or floodways as a result of new or modified bridges or roads must be accompanied by a letter of map revision to update the flood map to provide up-to-date information on flood risk.[43]

Railroad bridge, culvert or right-of way construction or reconstruction should meet the same requirements as roads and highway bridges. Railroad companies and agencies are urged to analyze future flood conditions along rights of way to plan for protective features to protect against future flooding.

Key transportation assets that must be built in the VE Zone should be constructed to withstand the force of wave action during a base flood.

Protection of buildings means elevation or flood proofing in accordance with building code and FEMA standards, or other applicable engineering guidance.

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[41] 44 CFR 60.3(d)
[42] 44 CFR 65.12
[43] 44 CFR 65.3

If the planned infrastructure will establish or promote a significant change in land use, e.g., expansion of a roadway into a previously undeveloped riparian area, the evaluation should include an assessment of the effects of future flooding on that new land use.

Risk assessments involving transportation infrastructure should consider the close interdependencies among the transportation, fuel and electricity sectors. The reader is referred to the discussion of transportation infrastructure in Flynn, 2015.[44]

3.3.2.6.3 Critical Transportation Infrastructure

Critical transportation infrastructure must remain in service (passable) during the design flood event, as practical. Critical transportation infrastructure includes roads, bridges and other assets to which any of the following conditions apply:

- Transportation asset provides sole access to any of the following facilities and practical detour routes are not available in case of loss or closure of the asset:
    - facilities designed for bulk storage of chemicals, petrochemicals hazardous or toxic substances or floatable materials
    - hospitals, rest homes, correctional facilities, dormitories, patient care facilities
    - major power generation, transmission or substation facilities
    - major communications centers, such as civil defense centers
    - major emergency service facilities, such as central fire and police stations
- Transportation asset is part of a designated evacuation route.
- Other transportation infrastructure likely to be considered critical includes
    - tunnels and tunnel entrances,
    - power distribution facilities necessary to transportation,
    - emergency generators necessary to transportation,
    - fire protection systems, and
    - aircraft fueling systems.

Although application of the climate-informed science guideline is preferred, applicants should also demonstrate consideration of the 0.2-percent annual chance flood guideline, if available on a FEMA FIRM or other reliable source, and if it is higher than the climate-informed science-based guideline. This recommendation is consistent with FEMA's requirement that design of critical projects incorporate the 0.2-percent annual chance flood. It also helps to ensure that siting and design decisions do not afford less protection than would be required under current conditions.

Applicants for critical transportation infrastructure projects should be required to demonstrate consideration of at least two feet of bridge or roadway freeboard, as applicable. However, since critical transportation infrastructure must, by definition, remain operable during flood events, this guidance recommends applicants demonstrate consideration of three feet of bridge or freeboard as applicable. Application

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[44] Flynn 2015

of three feet of freeboard is consistent with FEMA's proposed implementation of the Federal Flood Risk Management Standard for critical projects.

3.3.2.6.4 Non-critical Transportation Infrastructure

For the purposes of this guidance, non-critical transportation infrastructure shall be any transportation infrastructure not defined as critical. Non-critical transportation infrastructure may be allowed to flood, provided such flooding does not materially increase risk to human health and safety, or the environment, and the asset can be returned to service at reasonable cost and with reasonable timeliness. Poorly designed or under-sized infrastructure can increase flood damage to communities and nearby assets, even if it has been deemed non-critical. Whether risk to the infrastructure itself or nearby built or natural assets under future conditions warrants different or larger structures should be determined on a case-by-case basis, considering practicality, costs, costs associated with flooding, funding eligibility, risk tolerance and environmental effects.

3.3.2.6.5 Climate-informed Science Guidelines for Transportation Infrastructure

3.3.2.6.5.1 Nontidal Areas

This guidance recommends applicants demonstrate consideration of site-specific climate-informed science flood-risk management guidelines by adjusting design parameters to account for projected future conditions. In environments not subject to sea-level rise, this adjustment may be accomplished by applying multipliers to standard design parameters to account for anticipated increases in peak flows associated with projected increases in heavy-precipitation events and runoff. Table 3 lists recommended design-flow multipliers for two regions of the state.

3.3.2.6.5.2 Tidal Areas

Design and engineering of coastal structures is a complex process involving many siting and design considerations that are not amenable to simple adjustments for future conditions. It is important, however, that applicants demonstrate consideration of the full range of available sea-level projections in their project planning or design documentation. Applicants should demonstrate consideration of rates of sea-level rise consistent with the high sea-level rise projection included in 6 NYCRR Part 490 (Appendix A) over the entire expected service life of the facility for critical infrastructure. The Part 490 medium sea-level rise projection should be considered for non-critical infrastructure.

As sea-level rise will continue for centuries, design of infrastructure likely to remain in service beyond the year 2100 should consider the Part 490 high projection of sea-level rise. Although New York State has not yet adopted projections of sea-level rise beyond 2100, applicants for projects with expected service lives significantly beyond 2100 should consider sea-level rise projections provided for New York and the northeast coast published in sources such as Kopp et al., 2016 and Sweet et al., 2017. These reports also include high projections of sea-level rise that are considerably higher than the Part 490 projections. Designers of extremely critical infrastructure may wish to incorporate projections based on these reports.

Where sufficient information exists, applicants should also consider the risk of combination flooding, i.e., a flood resulting from surge during a sea-level rise enhanced coastal storm accompanied by heavy precipitation. Final design guidelines should incorporate the highest sea-level rise projections feasible, considering practicality, costs, risk tolerance, funding eligibility and environmental effects. Applicants may also consider the accommodation of future adaptations to changing conditions.

3.3.2.6.6 Critical Linear Transportation Infrastructure

3.3.2.6.6.1 Nontidal areas

Applicants for projects involving new or replacement critical linear transportation infrastructure, as defined by this guidance, including new and replacement roadways, railways, pipelines, runways, and associated structures, in areas not subject to sea-level rise, should demonstrate, through design documentation or verification, consideration of the higher of the following flood-risk management guidelines as part of a comprehensive risk-management approach:

- The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flows, e.g., Q_{50}, Q_{100}, to account for projected peak flows for the full, expected service life of the infrastructure, adding freeboard per current requirements or recommendations (three feet preferred), and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.
- The vertical flood elevation and corresponding horizontal floodplain subject to flooding from the 0.2-percent annual chance flood.

3.3.2.6.6.2 Tidal areas

Applicants for projects involving new or replacement critical linear transportation infrastructure, as defined by this guidance, including new and replacement roadways, railways, pipelines, runways, and associated structures in areas subject to sea-level rise, should demonstrate, through design documentation or verification, consideration of the following as part of comprehensive risk-management approach:

- Applicable coastal design guidelines that incorporate the higher of the 0.2-percent annual chance flood or a range of sea-level rise projections, up to and including the high sea-level rise projection, applicable for the full, expected service life of the infrastructure.

Applicants should demonstrate consideration of rates of sea-level rise consistent with the high sea-level rise projection included in 6 NYCRR Part 490 (Appendix A), over the entire expected service life of the asset. Final design guidelines should incorporate the highest sea-level rise projections feasible, considering practicality, costs, risk tolerance, funding eligibility and environmental effects.

3.3.2.6.7 Non-critical Linear Transportation Infrastructure

3.3.2.6.7.1 Nontidal areas

Applicants for projects involving new or replacement non-critical transportation linear infrastructure in nontidal areas should demonstrate, through design documentation or verification, consideration of the following climate-informed science guideline as part of a comprehensive risk-management approach:

- The vertical flood elevation and corresponding horizontal floodplain that result from increasing current, relevant peak flows, e.g., Q_{50}, Q_{100}, to account for projected peak flows for the full, expected service life of the infrastructure, adding freeboard per current requirements or recommendations, and extending this level (transversely to the direction of flow in riverine situations) to its intersection with the ground.

3.3.2.6.7.2 Tidal areas

Applicants for projects involving new or replacement non-critical linear transportation infrastructure, as defined by this guidance, in areas subject to sea-level rise, should demonstrate, through design documentation or verification, consideration of the following climate-informed science guideline as part of a comprehensive risk-management approach:

- Applicable coastal design guidelines that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, applicable for the full, expected service life of the infrastructure.

Applicants should demonstrate consideration of rates of sea-level rise consistent with the medium sea-level rise projection included in 6 NYCRR Part 490 (Appendix A), over the entire expected service life of the asset. Final design guidelines should incorporate the highest sea-level rise projections feasible, considering practicality, costs, risk tolerance, funding eligibility and environmental effects.

3.3.2.6.8 Critical Bridges

3.3.2.6.8.1 Nontidal areas

Applicants for projects involving new or replacement bridges on critical roadways, as defined by this guidance, crossing inland streams, should demonstrate, through design documentation or verification, consideration of the higher of the following flood-risk management guidelines as part of a comprehensive risk-management approach:

- The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the infrastructure, and adding at least two feet of bridge freeboard. An additional foot of bridge freeboard should be considered for critical bridges. The projected Q_{100} flow should pass below the lowest chord without going into pressure flow.
- The vertical flood elevation and corresponding flows resulting from the 0.2-percent annual chance flood.

3.3.2.6.8.2 *Tidal areas*

Applicants for projects involving new or replacement critical brides, as defined by this guidance, in areas subject to sea-level rise, should demonstrate, through design documentation or verification, consideration of the following as part of a comprehensive risk-management approach:

- Applicable coastal design guidelines that incorporate a range of sea-level rise projections, up to and including the high sea-level rise projection, applicable for the full, expected service life of the infrastructure, and the 0.2-percent annual chance flood.

Final design guidelines should incorporate the highest sea-level rise projections feasible, considering practicality, costs, risk tolerance, funding eligibility and environmental effects.

3.3.2.6.9 Non-critical Bridges

3.3.2.6.9.1 *Nontidal areas*

Applicants for projects involving new or replacement bridges on non-critical roadways, as defined by this guidance, and other structures, e.g., pipelines, crossing inland streams, should demonstrate, through design documentation or verification, consideration of the following flood-risk management guideline as part of a comprehensive risk-management approach:

- The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the infrastructure, and adding two feet of bridge freeboard. The projected Q_{100} flow should pass below the lowest chord without going into pressure flow.

3.3.2.6.9.2 *Tidal areas*

Applicants for projects involving new or replacement bridges on non-critical roadways, as defined by this guidance, and other structures, e.g., pipelines, in areas subject to sea-level rise, should demonstrate, through design documentation or verification, consideration of the following as part of a comprehensive risk-management approach. Final design guidelines should incorporate the highest sea-level rise projections feasible, considering practicality, costs, risk tolerance, funding eligibility and environmental effects.

- Applicable coastal design guidelines that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, applicable for the full, expected service life of the infrastructure.

3.3.2.6.10 Culverts on Critical Roadways

3.3.2.6.10.1 *Nontidal areas*

Applicants for projects involving new or replacement culverts on critical roadways, as defined by this guidance, crossing inland streams, should demonstrate, through design documentation or verification, consideration of the higher of the following flood-risk management guidelines as part of a comprehensive risk-management approach:

- The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the infrastructure, and that allow the culvert to fully pass the design flood without increasing headwater and that provide at least two feet of roadway freeboard above the projected Q_{100} flood. An additional foot of roadway freeboard should be considered for culverts on critical roadways.
- The vertical flood elevation and corresponding flows resulting from the 0.2-percent annual chance flood.

3.3.2.6.10.2 Tidal areas

Applicants for projects involving new or replacement culverts on critical roadways, as defined by this guidance, in areas subject to sea-level rise, should demonstrate, through design documentation or verification, consideration of the following as part of a comprehensive risk-management approach. Final design guidelines should incorporate the highest sea-level rise projections feasible, considering practicality, costs, risk tolerance, funding eligibility and environmental effects.

- Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the high sea-level rise projection, applicable for the full, expected service life of the infrastructure, and the 0.2-percent annual chance flood.

3.3.2.6.11 Culverts on Non-critical Roadways

3.3.2.6.11.1 Nontidal areas

Applicants for projects involving new or replacement culverts on non-critical roadways, as defined by this guidance, crossing inland streams, should demonstrate, through design documentation or verification, consideration of the following flood-risk management guideline as part of a comprehensive risk-management approach:

- The vertical flood elevation and corresponding flows that result from increasing current, relevant peak flows, e.g., Q_{50}, to account for projected peak flows for the full, expected service life of the culvert, and that provide at least two feet of roadway freeboard above the projected checkflow.

3.3.2.6.11.2 Tidal areas

Applicants for projects involving new or replacement culverts on non-critical roadways, as defined by this guidance, in areas subject to sea-level rise, should demonstrate, through design documentation or verification, consideration of the following as part of a comprehensive risk-management approach. Final design guidelines should incorporate the highest sea-level rise projections feasible, considering practicality, costs, risk tolerance, funding eligibility and environmental effects.

- Applicable coastal design criteria that incorporate a range of sea-level rise projections, up to and including the medium sea-level rise projection, and projected peak flows applicable for the full, expected service life of the culvert.

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Glossary

Adaptation—The process of adjustment to actual or expected climate and its physical, social or economic effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Adaptive capacity—The ability of systems, institutions, humans and other organisms to adjust to potential stress or damage, to take advantage of opportunities, or to respond to consequences.

Base flood—Flood with a 1 percent chance of being equaled or exceeded in any given year.

Base flood elevation (BFE)—The elevation of a flood with a 1-percent chance of being equaled or exceeded in any given year.

Biggert-Waters Flood Insurance Reform Act of 2012– Legislation that was later revised by the Homeowner Flood Insurance Affordability Act of 2014 requiring FEMA and other agencies to make a number of changes to the way the NFIP is run. Key provisions of the legislation required the program to raise rates to reflect true flood risk and make the program more financially stable. The legislation also authorized the Technical Mapping Advisory Council to re-convene.

Bridge—A structure carrying a road, path, railroad or canal across a river, ravine, railroad or other obstacle and spanning more than 20 feet through the centerline.

Bridge freeboard—The vertical distance, usually expressed in feet, between the design flood elevation and the lowest chord or horizontal structural element of a bridge.

Channel—A natural or artificial watercourse of perceptible extent with a definite bed and banks to confine and conduct continuously or periodically flowing water.

Checkflow—A stream flow used to assess the performance of a hydraulic opening of a bridge or culvert at flows other than the design condition. For bridges and culverts on New York State system, the checkflow is Q_{100}. For design flows other than Q_{50}, the checkflow may be different. Additional check flows may be used in specific situations where structure performance at other flows is a concern.

Climate—Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The typical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate-Informed Science Approach—The use of data and methods informed by best-available, actionable climate science.

Coastal Flooding—Flooding that occurs along the Great Lakes, the Atlantic and Pacific Oceans, and the Gulf of Mexico.

Coastal High Hazard Area—An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave actions from storms or seismic sources.

Code of Federal Regulations (CFR)—The codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the federal government.

Critical Action—Any activity for which even a slight chance of flooding would be too great.

Critical Facilities—In the context of floodplain management, critical facilities are defined as facilities designed for bulk storage of chemicals, petrochemicals, hazardous or toxic substances or floatable materials; hospitals, rest homes, correctional facilities, dormitories, patient care facilities; major power generation, transmission or substation facilities, except for hydroelectric facilities; major communications centers, such as civil defense centers; or major emergency service facilities, such as central fire and police stations. (6 NYCRR Part 502.4(a) (17))

Culvert—A tunnel carrying a stream or open drain under a road or railroad and having a span of less than 20 feet through the centerline of the road.

Design flood—The largest flood that a given project is designed to accommodate.

Design flood elevation—The elevation of the design flood.

Development—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.

Ecosystem—A functional unit consisting of living organisms, their non-living environment and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases, they are relatively sharp, while in others they are diffuse. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms, or are influenced by the effects of human activities in their environment.

Encroachment—Activities or construction within the floodway including fill, new construction, substantial improvements, and other development. These activities are prohibited 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.

Exposure—The degree to which elements of a climate-sensitive system are in direct contact with climate variables and/or may be affected by long-term changes in climate conditions or by changes in climate variability, including the magnitude and frequency of extreme events.

Facility—Any man-made or man-placed item other than infrastructure.

Federal Flood Risk Management Standard (FFRMS)—The national flood risk management standard established by Executive Order 13690 to be incorporated into existing processes used to implement Executive Order 11988.

Flood—The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods and glacial lake outburst floods.

Flood design class—Any of several categories of buildings defined by the American Society of Civil Engineers.

Flood fringe—Area between the floodway boundary and limit of the one-percent annual chance floodplain.

Flood hazard—Flood conditions (e.g., depth, wind, velocity, duration, waves, erosion, debris) that have the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss.

Flood insurance rate map (FIRM)—The insurance and floodplain management map produced by FEMA that identifies, based on detailed or approximate analyses, the areas subject to flooding during a 1-percent-annual-chance (100-year) flood event in a community. Flood insurance risk zones, which are used to compute actuarial flood insurance rates, also are shown. In areas studied by detailed analyses, the FIRM shows BFEs to reflect the elevations of the 1-percent-annual-chance flood. For many communities, when detailed analyses are performed, the FIRM also may show areas inundated by 0.2-percent-annual-chance (500-year) flood and regulatory floodway areas.

Flood insurance study (FIS)—A compilation and presentation of flood hazard data for specific watercourses, lakes, and coastal flood-hazard areas within a community. When a flood study is completed for the NFIP, the information and maps are assembled into an FIS.

Flood insurance study report (FIS Report)—The FIS Report contains detailed information of the FIS, including flood elevation data in flood profiles and data tables.

Floodplain—Any land area that is susceptible to being inundated by water from any source.

Flood profile—A graph showing the relationship of water-surface elevation to location, with the latter generally expressed as distance above the mouth for a stream of water flowing in an open channel.

Floodway—See Regulatory Floodway.

Freeboard—A factor of safety usually expressed in feet above a flood level for purposes of floodplain management. It tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, bridge openings, and the hydrological effect of urbanization of the watershed.

Freeboard Value Approach—The use of two feet above the 1-percent-annual-chance flood (also referred to as the base flood) as the elevation for standard projects and three feet above the 1-percent-annual-chance elevation for critical buildings, like hospitals and evacuation centers.

Geographic information system (GIS)—A system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems.

Hazard—The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems or environmental resources.

Hydraulic analysis—An engineering analysis of a flooding source carried out to provide estimates of the depths of floods of selected recurrence intervals.

Hydrograph—A graph showing the rate of flow (discharge) versus time past a specific point on a river, or other channel or conduit carrying flow.

Hydrologic analysis—An engineering analysis of a flooding source carried out to establish peak flood discharges and their frequencies of occurrence.

Hydrology—The science encompassing the behavior of water as it occurs in the atmosphere, on the surface of the ground, and underground.

Impacts (consequences, outcomes)—Effects on natural and human systems.

Infrastructure—The basic physical and organizational structures (e.g., buildings, roads and power supplies) needed for the operation of a society or enterprise.

Light detection and ranging (LiDAR or lidar) system—An airborne laser system, flown aboard rotary or fixed-wing aircraft, that is used to acquire x, y, and z coordinates of terrain and terrain features that are both manmade and naturally occurring. LiDAR systems consist of an airborne Global Positioning System (GPS) with attendant base station(s), Inertial Measuring Unit, and light-emitting scanning laser.

Limit of moderate wave action (LiMWA)—The inland limit of the coastal area expected to receive 1.5-foot or greater breaking waves during the 1-percent-annual-chance flood event.

Map Service Center (MSC)—The official public source for flood hazard mapping produced in support of the NFIP. The MSC can be used to find official flood maps, access a range of other flood hazard products, and take advantage of tools for better understanding flood risk.

Mean sea level—Sea level measured by a tide gauge with respect to the land upon which it is situated. Mean sea level is normally defined as the average relative sea level over a period, such as a month or a year, long enough to average out transients such as waves and tides.

National Flood Insurance Program (NFIP)—An ongoing program under which the FEMA Administrator shall review, update, and maintain NFIP rate maps in accordance with 42 U.S.C. § 4101b.

Percentile—One of the values of a variable that divides the distribution of the variable into 100 groups having equal frequencies, e.g., ninety percent of the values lie at or below the ninetieth percentile; ten percent lie above it.

Practicable—Able to be done within existing constraints. What is practicable will be context specific and include consideration of pertinent factors, such as environment, statutory authority, legality, cost, technology and engineering.

Pressure Flow—Flow occurring when the water surface elevation reaches the lowest chord of a bridge.

Q_x—The flow volume that is equaled or exceeded at the return period indicated by x, where x equals the number of years, on average between occurrences of the specified flow, e.g., Q_{50} indicates the flow volume that is expected to occur at least once every 50 years, i.e., with a 2% annual probability.

Regulatory Floodway—A floodplain management tool that is the regulatory area defined as the channel of a stream, plus any adjacent floodplain areas that must be kept free of encroachment so that the base flood discharge can be conveyed without increasing the BFEs more than a specified amount. The regulatory floodway is not an insurance rating factor. (TMAC)

Representative Concentration Pathways (RCPs)—Scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. RCPs usually refer to the portion of the pathway extending to 2100. Four RCPs were selected from the published literature and are used in the present IPCC assessment (Assessment Report 5, AR5) as a basis for the climate predictions and projections presented in the AR5. (IPCC, based on Moss et al., 2008 and Moss et al., 2010)

Resilience—The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation. (IPCC, derived from Arctic Council, 2013)

Risk—The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and/or infrastructure. (IPCC)

Riverine – All inland or non-coastal flooding sources (e.g., alluvial fans, major rivers, tributaries, and rivers that are influenced by coastal effects as applicable). (TMAC)

Roadway Freeboard—The vertical distance, usually expressed in feet, between the design flood elevation and the outside edge of the roadway shoulder.

Sea-level rise—Increases in sea level, globally or locally, due to (i) changes in the shape of the ocean basins, (ii) changes in the total mass and distribution of water and land ice, (iii) changes in water density, and (iv) changes in ocean circulation. Sea-level changes induced by changes in water density are called steric. Density changes induced by temperature changes only are called thermosteric, while density changes induced by salinity changes are called halosteric. See also Mean sea level. (IPCC SREX)

Seiche—A standing wave in an enclosed or partially enclosed body of water.

Sensitivity—The degree to which a system will respond to a change in climate, either beneficially or detrimentally. (ClimAID)

Service Life—The time during which a structure or other asset is expected to be operable.

Special Flood Hazards Area (SFHA)—Area delineated on an NFIP map as being subject to inundation by the base flood. SFHAs are determined using statistical analyses of records of river flow, storm tides, and rainfall; information obtained through consultation with a community; floodplain topographic surveys; and hydrologic and hydraulic analyses.

Storm surge—The temporary increase, at a particular locality, in the height of the water due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from normal variation alone at that time and place.

Storm water—Storm water means storm water runoff, snow melt runoff, and surface runoff and drainage.

Structure—For floodplain management purposes, a walled and roofed building, including a gas or liquid storage tank that is principally above ground, as well as a manufactured home. For flood insurance purposes, a walled and roofed building, other than a gas or liquid storage tank, that is principally above ground and affixed to a permanent site, as well as a manufactured home on a permanent foundation.

Sub-daily—Related to measurement of events less than 24 hours in duration.

Sustainability—A dynamic process that guarantees the persistence of natural and human systems in an equitable manner.

Technical Mapping Advisory Council (TMAC)—A Federal advisory committee established to review and make recommendations to FEMA on matters related to the national flood mapping program, authorized by Biggert Waters Act of 2012.

Uniform Code—The New York State Uniform Fire Prevention and Building Code, which establishes standards for fire prevention and building construction. The Uniform Code is adopted pursuant to Article 18 of the Executive Law and is applicable in all parts of New York State except New York City.

Vulnerability—The propensity to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Watershed—An area of land that drains into a single outlet and is separated from other drainage basins by a divide.

Wave Crests—The highest point of a wave.

Wave Runup—The maximum vertical extent of wave uprush on a beach or structure above the still water level.

Wave Setup—The increase in mean water level above the still water level due to momentum transfer to the water column by waves that are breaking or otherwise dissipating their energy.

Zone A—The flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs or depths are shown within this zone.

Zone AE—The flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by detailed methods. In most instances, whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH—The flood insurance rate zone that corresponds to the 100-year shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot BFEs are derived from detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AR—The flood insurance rate zone used to depict areas protected from flood hazards by flood control structures, such as a levee, that are being restored. FEMA will consider using the Zone AR designation for a community if the flood protection system has been deemed restorable by a Federal agency in consultation with a local project sponsor, a minimum level of flood protection is still provided to the community by the system, and restoration of the flood protection system is scheduled to begin within a designated time period and in accordance with a progress plan negotiated between the community and FEMA. Mandatory purchase requirements for flood insurance will apply in Zone AR, but the rate will not exceed the rate for unnumbered A zones if the structure is built in compliance with Zone AR floodplain management regulations. For floodplain management in Zone AR areas, elevation is not required for improvements to existing structures. However, for new construction, the structure must be elevated (or floodproofed for non-residential structures) such that the lowest floor, including the basement, is a maximum of 3 feet above the highest adjacent existing grade if the depth of the BFE does not exceed 5 feet at the proposed development site. For infill sites, rehabilitation of existing structures, or redevelopment of previously developed areas, there is a 3-foot elevation requirement regardless of the depth of the BFE at the project site. The Zone AR designation will be removed and the restored flood control system shown as providing protection from the 1-percent-annual-chance flood on the NFIP map upon completion of the restoration project and submittal of all the necessary data to FEMA.

Zone AO—The flood insurance rate zone that corresponds to the 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses. The highest top of curb elevation adjacent to the lowest adjacent grade (LAG) must be submitted if the request lies within this zone.

Zone A99—The flood insurance rate zone that corresponds to areas of the 100-year floodplain that will be protected by a Federal flood protection system where construction has reached specified statutory milestones. No BFEs or depths are shown within this zone.

Zone D—The flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined but possible.

Zone E—An area of flood-related erosion hazards, defined by the NFIP, but as yet unused on FIRMs.

Zone V—The flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. Because approximate hydraulic analyses are performed for such areas, no BFEs are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone VE, V1-30—The flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Zone X (shaded), Zone B—The flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 500- year floodplain, and areas of 100-year flooding where average depths are less than 1 foot, areas of 100-year flooding where the contributing drainage area is less than 1 square mile, and areas protected from 100-year flood by levees. No BFEs or depths are shown within this zone.

Zone X (unshaded), Zone C—Areas determined to be outside the 1-percent-annual-chance and 0.2-percent-annual-chance floodplains. Flood insurance is not federally mandated, but lenders can require the purchase of flood insurance in these areas. No minimum federal floodplain management standards apply.

Appendix A. 6 NYCRR Part 490, Projected Sea-level Rise

6 NYCRR Part 490 Projected Sea-level Rise (inches of rise relative to 2000-2004 baseline).

Region	**Long Island**					**New York City/Lower Hudson**					**Mid-Hudson**				
Descriptor	Low	Low-medium	Medium	High-medium	High	Low	Low-medium	Medium	High-medium	High	Low	Low-medium	Medium	High-medium	High
2020s	2	4	6	8	10	2	4	6	8	10	1	3	5	7	9
2050s	8	11	16	21	30	8	11	16	21	30	5	9	14	19	27
2080s	13	18	29	39	58	13	18	29	39	58	10	14	25	36	54
2100	15	21	34	47	72	15	22	36	50	75	11	18	32	46	71

Appendix B. Federal Technical Mapping Advisory Committee (TMAC) Findings

In July 2016, TMAC delivered its 2016 National Flood Mapping Program Review.[1] The review includes recommendations to assist FEMA to provide credible future flood-hazard data.

TMAC did not develop the science and techniques themselves but recommended that FEMA follow through with the development of specific recommended approaches to flood mapping. With respect to the impacts of climate change on flood risk, TMAC recommended that FEMA publish several future conditions flood layers that incorporate uncertainty to provide a basis for building designs. Other key recommendations include the following:

- FEMA should use at least two scenarios for future conditions flood hazards in coastal areas: one in which the shoreline is held at its current location and another in which the shoreline is eroded according to the best available shoreline erosion data. However, TMAC recommends that such products be advisory.
- FEMA should develop guidance for incorporating future conditions into coastal inundation and wave analyses.
- FEMA should use Parris et al, 2012 or similar global mean sea level scenarios, adjusted to reflect location conditions.
- FEMA should work with other federal agencies (e.g., NOAA, USACE, USGS), the U.S. Global Change Research Program and the National Ocean Council to provide a set of regional sea-level rise scenarios, based on Parris et al. scenarios, up to the year 2100, for future coastal flood hazard estimation.
- FEMA should prepare map layers displaying the location and extent of areas subject to long-term erosion along coastal and Great Lakes areas.
- Utilization of Great Lakes future lake level elevations due to a changing climate is not currently recommended due to uncertainty in projections of future lake levels.
- FEMA should demonstrate consideration of relative sea-level rise scenarios in existing FEMA coastal flood insurance study processes through either direct analysis for regions where additional sea level is determined to affect the BFE non-linearly or through linear superposition where appropriate.
- FEMA should calculate wave effects based on higher stillwater elevations, including sea-level rise.
- FEMA should provide a digital layer showing long-term riverine erosion hazard areas.
- FEMA should demonstrate consideration of the impacts of future development and land-use change on future conditions hydrology for riverine flood mapping.
- FEMA should demonstrate consideration of an "E" zone that defines riverine channel migration zones.

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[1] FEMA Technical Mapping Advisory Council. 2016. National Flood Mapping Program Review. 72pp.

- FEMA should use best available science to determine future riverine hydrology and flood hazards.
- FEMA should work with other federal agencies via the Advisory Committee on Water Information sub-committee to produce a new method to estimate future riverine flood flow frequencies, including ways to consistently estimate future climate-affected riverine floods.
- FEMA should perform a study to quantify the accuracies, degree of precision and uncertainties associated with flood studies and mapping products for existing and future conditions.

The TMAC recommendations do not provide a clear direction to current use of future conditions flooding. Instead, TMAC directs FEMA to develop the more detailed applications. This will provide products that are more useful in the future but presents challenges in designing for future conditions today.

Although there will be some time until FEMA develops new future conditions mapping standards, and even longer before new maps are developed using those standards, current resources and techniques can be used to supplement and improve current flood-risk data. The best approach is to use the FEMA products as a minimum standard and use freeboard-based criteria or climate-informed science approaches, to increase the protection level.

Appendix C. Decision-support Tools for Flood Risk

Updated FEMA Maps

Although FEMA effective flood insurance rate maps are the source of regulatory flood information, other sources of flood data exist. FEMA may have produced preliminary flood insurance rate maps (pFIRMS) with updated data, or advisory flood maps released after floods. Check the FEMA mapping web site at www.msc.fema.gov to find maps for any area in the nation, or check with the DEC Floodplain Management Section if you have questions. Preliminary and revised preliminary FIRM information for portions of coastal New York are available. http://www.region2coastal.com/community-officials/info-for-community-officials/

Data Portals

New York Climate Change Science Clearinghouse

Provides maps, climate change data and documents to support scientifically sound decision making. Digital FIRMS are accessible through the Clearinghouse for areas where they exist. https://www.nyclimatescience.org/

New York State Department of State Geographic Information Gateway

Provides climate and flood overlays for online viewing. The overlays use the FEMA maps as one layer and add additional layers. Over 500 data sets are on the gateway, with one focus on climate change and resilience. Map layers can be downloaded or viewed. The data set incorporates NOAA data, including sea-level rise data, for New York State. http://opdgig.dos.ny.gov/#/home

The Nature Conservancy Natural Resource Navigator

An online, interactive decision support and mapping tool for natural resource managers. In addition to the mapping tool, it provides research studies, reports and guidance. http://www.naturalresourcenavigator.org/

DEC Environmental Assessment Form Mapper

Online mapper specifically designed to facilitate the NYS environmental review process by answering the geographic or place-based questions on the environmental assessment forms. The tool produces a digital PDF copy of the appropriate form with these place-based questions completed. http://www.dec.ny.gov/eafmapper/

Sea-level Rise and Coastal Viewers

Sea Level Rise Tool for Sandy Recovery

Developed by NOAA in partnership with FEMA and the Army Corps of Engineers. It provides a set of map services that integrate the best available FEMA flood hazard data. Maps of New York City apply projections equal to New York State projections; maps for the remainder of the state apply projections developed for the National Climate Assessment. Maps show the horizontal expansion of the floodplain associated with sea-

level rise, highlighting areas at risk in the future due to flood inundation from the one-percent annual chance flood event.
http://www.globalchange.gov/browse/sea-level-rise-tool-sandy-recovery

USGS Lake Level Viewer

An interactive web-based tool that illustrates the scale of potential flooding or land exposure at a given water level for all five Great Lakes.
https://www.coast.noaa.gov/llv/

Sea Level Affecting Marshes Model (SLAMM)

SLAMM simulates the dominant processes in wetland conversions under sea-level rise to project transfers among land-cover classes. This decision-support tool allows users to plan adaptation strategies for marsh conversion and improve coastal community resilience in New York.
http://warrenpinnacle.com/prof/SLAMM/NYSERDA/

Storm-impact and Flooding Models and Mappers

Sea, Lake and Overland Surges from Hurricanes (SLOSH) Model.

Developed by the National Weather Service, is used to estimate storm surge heights resulting from historical, hypothetical or predicated hurricanes by taking into account the atmospheric pressure, size, forward speed and track data. These parameters are used to create a model of the wind field, which drives the storm surge. The model is used by emergency managers but cannot predict the specific impact of a storm surge on individual properties, nor does it model the impacts of waves on top of the surge. Maps show inundation areas and heights for hurricane categories one through four in New York State.
http://noaa.maps.arcgis.com/apps/StorytellingTextLegend/index.html?appid=b1a20ab5eec149058bafc059635a82ee

Hudson River Flood Hazard Decision Support System

This online mapping tool allows users to assess the impacts of flood inundation posed by sea level rise, storm surge and rain events on communities bordering the lower Hudson River. Flood simulations merge all sources of flooding. The resulting 5-year to 1000-year flood zone maps are applied to newly created social and critical infrastructure vulnerability layers, to measure and map flood risk for the Hudson River coastal region. The customized mapping tool allows users to select a particular region of interest and predicted flood scenarios and then visualize the impact on community resources. Users can download maps and summary statistics on structures, populations and critical facilities affected by specific predicted flood events.
http://www.ciesin.columbia.edu/hudson-river-flood-map/

Coastal New York Future Floodplain Mapper

Provides information for seven sea-level rise scenarios for the tidally influenced shoreline of New York State, with the exception of New York City. The mapper provides the following flood hazard information for each sea level rise scenario: future coastal floodplain extents and summaries, extent of structurally damaging wave action, building exposure, and chance of flooding.
http://services.nyserda.ny.gov/SLR_Viewer/About

3.3.2.7 NYC Flood Hazard Mapper

A product of the New York City Department of City Planning, the NYC Flood Hazard Mapper provides a comprehensive overview of the coastal flood hazards that threaten New York City today, as well as how these flood hazards are likely to increase in the future with climate change.
http://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page

NOAA Digital Coast Sea Level Rise Viewer

Includes data on hurricane tracks and sea-level rise data, as well as a wealth of complex flood risk data.
https://coast.noaa.gov/digitalcoast/

Flow Information

USGS Surface Water Conditions

Current surface water conditions for more than 300 surface water sites across New York, including a number of tidal gages.
http://waterdata.usgs.gov/ny/nwis/current?type=sw&group_key=basin_cd&search_site_no_station_nm

USGS Peak Streamflow

Peak streamflow data are available for more than 750 sites in New York, although a number of the sites have incomplete data and many sites have been discontinued. Peak streamflow data are the maximum instantaneous discharge of a stream or river at a given location. Sites can be searched by county, hydrologic unit, latitude/longitude, or by name. For most sites, gage height is also included; however, this is a gage specific height and is not shown as an elevation above sea level. For each year of record, the data include the peak flow for that year.
http://nwis.waterdata.usgs.gov/usa/nwis/peak

USGS StreamStats

Streamstats provides flow data where stream gages are not available. It allows the user to click on any point on any stream in the state north of New York City and obtain flow data based on recurrence intervals, or exceedance probabilities based on regression equations. Variables include basin area, storage within the basin, channel slope, annual precipitation and forested area. Flows can be obtained for a range of recurrence

intervals in years, from the 1.25-year flow to the 500-year flow.
http://water.usgs.gov/osw/streamstats

USGS Future Flow Explorer

Future Flow Explorer was developed by USGS in partnership with the New York State Department of Transportation. This application for StreamStats projects future stream flows in New York State. The USGS team examined 33 global climate models and selected five that best predicted past precipitation trends in the region. The results were then downscaled to apply to all six hydrologic regions of New York State. Three time periods can be examined: 2024-49, 2050-74 and 2075-99, as well as two IPCC greenhouse gas emission scenarios: RCP 4.5 and RCP 8.5

Users are strongly encouraged to review "Development of Flood Regressions and Climate Change Scenarios to Explore Estimates of Future Peak Flows," Open File Report 2015-1235[2] before using Future Flow Explorer and the discussion in Appendix D. USGS notes that FFE currently will not provide accurate results for basins that extend across more than one hydrologic region in New York. Climate model forecasts are expected to improve and as they do, the existing regression approach will be tested and refined.

The future conditions StreamStats contains considerable uncertainty. Climate models are better at forecasting temperature than precipitation. USGS recommends using the data as "qualitative guidance" to see likely trends within any watershed. Based on the models, flood magnitudes are expected to increase in nearly all cases, but the magnitudes vary among regions. While the product is still being upgraded, it can be used with appropriate caution.
http://dx.doi.org/10.5066/F7WS8R9S

USGS Flood Inundation Mapping Program.

The USGS Flood Inundation Mapping Program can produce more detailed depictions of potential flood areas, including a wide range of flood return frequencies and water depths, but these web-accessible products are created only when external partners share production costs with the USGS. New York sites are limited to the west branch of the Delaware River and Schoharie Creek.
http://water.usgs.gov/osw/flood_inundation/.

[2] http://pubs.usgs.gov/of/2015/1235/index.html

Appendix D. Suggestions Regarding Use, Application, and Limitation of Results Derived from U.S. Geological Survey Future Peak Flows Web Application[47]

The U.S. Geological Survey published a data release on Dec. 28, 2015 titled, "Application of flood regressions and climate change scenarios to explore estimates of projected peak flows" (Burns and others, 2015a; available at http://dx.doi.org/10.5066/F7WS8R9S). A report titled, "Development of flood regressions and climate change scenarios to explore estimates of projected peak flows" (Burns and others, 2015b; available at http://pubs.usgs.gov/of/2015/1235/index.html) provides a detailed explanation of the basis, assumptions, and intended use of this application. The purpose of the application is to provide a range of future peak-flow estimates for ungaged streams and rivers in New York (and the Lake Champlain basin of Vermont) as governed by climate change projections derived from downscaled results of global climate models. The projected peak flow application operates in conjunction with the StreamStats program (http://water.usgs.gov/osw/streamstats/new_york.html), which provides estimates of current peak flows for gaged and ungaged streams and rivers across New York State.

The future peak-flows application was developed in cooperation with the New York State Department of Transportation to fill an immediate need for preliminary estimates of a range of peak flows under potential climate change scenarios. Other recent activities related to climate change and flooding in New York such as implementation of: (1) the Community Risk and Resiliency Act (http://www.dec.ny.gov/energy/104113.html), and (2) Federal Executive Order 13690 (https://federalregister.gov/a/2015-02379) have provided additional impetus for use of the future peak-flows application. The purpose of this appendix to the New York State Hazard Mitigation report is to provide some additional information on the limitations of the future peak-flows application and some suggestions for use and interpretation of the output.

The future peak-flows application is constrained to operate within the framework of the current version of StreamStats, which is based on a set of regression equations developed by Lumia and others (2006) for unregulated and rural streams and rivers across New York State. Current peak-flow estimates derived from these regressions are governed by a set of predictive variables that represent aspects of basin geomorphology, land cover, and annual precipitation or runoff. The approach of Lumia and others (2006) was to divide New York State into six hydrologic regions, each with a separate set of peak-flow regressions (Figure 1). The designation of regions was primarily based on minimizing bias in the regression residuals of the 2-percent annual exceedance probability (AEP; 50-year flood) peak flow predictions. In applying these regression equations to make estimates of projected peak flows, all geomorphic and land cover variables are assumed to remain the same as current values. Therefore, any projected changes in the magnitudes of projected peak flows are dictated by the projected changes in annual precipitation or runoff derived from the downscaled climate model output. The results of the current

[47] Provided by Douglas Burns, Ph.D., New York Water Science Center, U.S. Geological Survey, 425 Jordan Rd., Troy, New York 12180-8349.

regionalization approach have implications for future peak-flow estimates because annual precipitation or runoff are expressed in the regression equations as exponential terms (e.g.—P^x or R^x), and these exponents differ among the regions. Therefore, a projected change in annual precipitation or runoff that is the same across multiple regions of New York will result in different projected peak flow estimates across these regions.

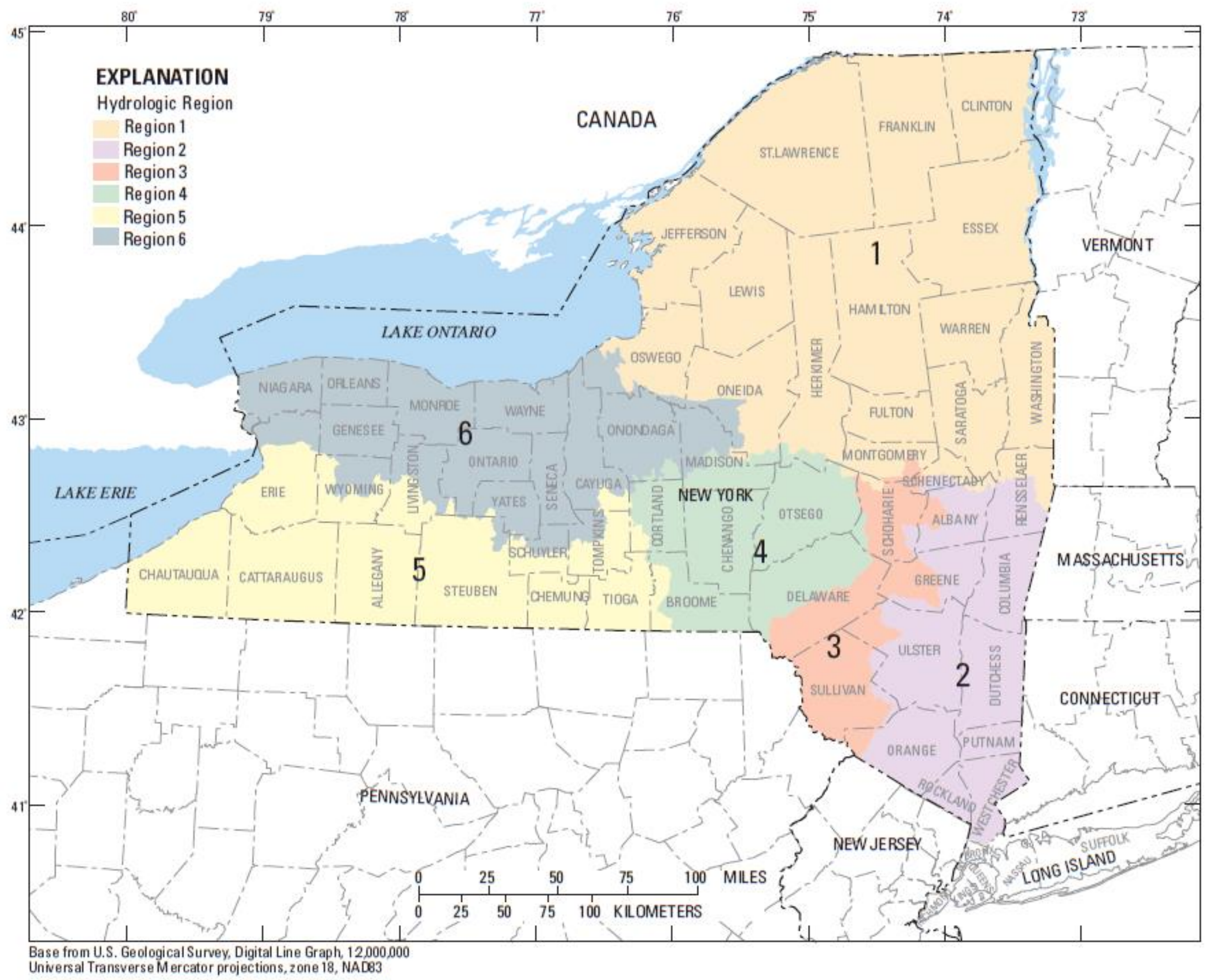

Figure 1. Six hydrologic regions of New York State as defined by Lumia and others (2006).

Several assumptions and sources of uncertainty in the estimates of projected peak flows are discussed by Burns and others (2015b) including that the historic relation between annual precipitation or runoff and the magnitudes of various peak flows will be the same in the future as currently. Another assumption is that values of the exponents of the precipitation or runoff variable will remain the same in the future. Practically, this means that the designation of these six hydrologic regions and the boundaries among them are preserved when making estimates of projected peak flows with the web application. The user is cautioned of uncertainty as to whether these regional designations will remain the same in the future. In fact, the number, locations, and boundaries of these regions have varied among previous evaluations of flood frequencies across New York (Lumia, 1991; Zembrzuski and Dunn, 1979). The implications of these regional designations along with some suggestions regarding the use of the future peak-flow application in this regard are described below.

To illustrate the implications of the current hydrologic region designations on estimates of projected peak flows derived from the web application, 12 basins (2 in each of the 6 regions) across New York State were delineated and results were obtained for the ensemble of 5 climate models, 2 greenhouse gas scenarios, and 3 time periods as described by Burns and others (2015b). Basin locations and drainage areas are provided in Table 1.

Table 1. Twelve basins in New York State that were selected to provide examples of how projected changes in future annual precipitation or runoff will affect projected peak-flow magnitudes according to the StreamStats-based application developed by the U.S. Geological Survey.

Stream/River Name	*Bridge Location*	*Region*	*Latitude (decimal)*	*Longitude (decimal)*	*Drainage Area (mi^2)*
Bouquet River	Rte. 22, Willsboro	1	44.3639	-73.3907	271
John's Brook	Rte. 73, Keene Valley	1	44.1945	-73.7866	19.6
Esopus Creek	Rte. 28A, Boiceville	2	42.0039	-74.2678	191
Wappinger Creek	Rte. 55, Poughkeepsie	2	41.6845	-73.8664	177
E Br Delaware River	Rte. 41, Roxbury	3	42.2840	-74.5669	21.2
Schoharie Creek	Rte. 23, Prattsville	3	42.3197	-74.4364	237
Chenango River	Rte. 319, Norwich	4	42.5328	-75.5065	330
Platner Brook	Rte. 10, Delhi	4	42.2429	-74.9647	13.9
Buffalo Creek	Rte. 20A, Wales Center	5	42.7681	-78.5307	105
Cassadaga Creek	Rte. 394, Jamestown	5	42.1332	-79.1821	143
Oatka Creek	Rte. 5, LeRoy	6	42.9777	-77.9887	137
Tonawanda Creek	Rte. 238, Attica	6	42.8642	-78.2836	76.5

The effects of the magnitude of the precipitation or runoff exponents in the peak-flow regressions are illustrated by a comparison of the results from Platner Brook in Region 4 and Cassadaga Creek in Region 5 (Table 2). A 9% projected increase in future annual runoff at Platner Brook, with a runoff exponent of 1.431, results in an 11% projected increase in the 1-percent AEP (Q_{100}) peak flow. In comparison, a larger 19% projected increase in future annual precipitation at Cassadaga Creek, with a precipitation exponent of only 0.590, will produce the same 11% projected increase in the 1-percent AEP peak flow at this latter site. Given the divergent exponent values in the regression equations among the regions and the resulting implications for projected peak flows combined with the close proximity of these regions to each other in which basins in adjoining regions may only be tens of miles apart or less, the user of information derived from the future peak-flow application is cautioned about applying the results in too specific of a manner.

Table 2. Projected change in future annual precipitation or runoff and the 1-percent AEP peak flow for the period 2050-74 according to the RCP 8.5 emissions scenario. The median values from five climate downscaled global climate models are shown as a percent future change relative to the values obtained from the current version of StreamStats. A positive (negative) percentage indicates an increase (decrease) in the future peak-flow estimate relative to the current peak-flow estimate. The exponents of the precipitation or runoff variables from the peak-flow regressions described by Lumia and others (2006) are shown as well.

Basin and Region	*Region*	*Exponent of Runoff or Precipitation Variable*	*Median Projected Future Change in Runoff or Precipitation (percent)*	*Median Projected Future Change in the Magnitude of the 1-percent AEP Peak Flow (percent)*
Bouquet River	1	1.106	26	27
John's Brook	1	1.106	24	26
Esopus Creek	2	1.104	14	14
Wappinger Creek	2	1.104	18	20
E Br Delaware River	3	0.341	-2	-1
Schoharie Creek	3	0.341	9	2
Chenango River	4	1.431	9	12
Platner Brook	4	1.431	9	11
Buffalo Creek	5	0.590	7	4
Cassadaga Creek	5	0.590	19	11
Oatka Creek	6	0.505	12	6
Tonawanda Creek	6	0.505	15	7

Future projected changes appear to be greatest, in the range of about +20% +/- 6%, in the Adirondack Mountains and eastern Catskill Mountains, Regions 1 and 2, respectively (Table 2). Elsewhere, the projected changes are smaller, in the range of about +6% +/- 6%. These changes are projected to be minimal in the western Catskill Mountains north to the Mohawk River (Region 3). However, because Region 3 is very narrow, the extent to which the projected future changes in the 1-percent AEP peak flow will differ from the higher values to the east in Region 2 and to the west in Region 4 is not known. It is therefore suggested that results from Region 3 be used with caution and consideration be given to the likelihood that future changes in the 1-percent AEP peak flow in Region 3 will be similar to those of Regions 2 and 4 and in the range of +10% to +20%. Note that these suggestions are based on analysis of 12 basins and not an exhaustive analysis that represents the full extent of each of these regions. Furthermore, there are differences among the exponents of the precipitation or runoff variable across regions for all of the other AEP peak flows, but these differences are not the same as those of the 1-percent AEP peak flow. Therefore, it is suggested that the user explore projected changes across a range of regions for any AEP of interest, and consider applying the results broadly.

In summary, this peak-flow application was constrained to the use of a previously derived set of peak-flow regressions in which New York State was divided into six hydrologic regions, each with a unique set of regression equations. Ideally, when applying the space-for-time substitution logic that was used in developing this web application, the climatic range within each region where the regressions are applied, should approximately match the temporal range among current and future climate. These regions in New York, therefore, are smaller than is ideal for this approach. This suggests that the estimates developed with the application for individual regions in New York be used with caution and interpreted as broadly as possible. This application is one of the early efforts to apply peak-flow regressions in this manner, and therefore, further testing and validation of this approach is warranted. Uncertainty as to the magnitudes of projected peak flows is currently high, and the user of any single approach is encouraged to seek guidance from other approaches or from additional expert opinion. Future efforts to project the magnitudes of peak flows with climate change may seek to overcome the limitations of this current application and provide improved guidance.

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