Pathways to Resilient Communities:

Infrastructure Designed for the Environmental Hazards in Your Region

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

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ASCE

AMERICAN SOCIETY OF CIVIL ENGINEERS

ASCE is an educational non-profit organization that serves the civil engineering profession. ASCE provides training and education to many project stakeholders on all our standards, along with resources to understand the needs of current projects and regulatory requirements.

Introduction

America's infrastructure is the foundation of its economy, global competitiveness, and quality of life. While often taken for granted when it is working properly, American households and business immediately feel the impact of just one inefficiency or failure in our built environment. Our infrastructure is an interconnected system of highways, streets, public buildings, mass transit, ports, airports, inland waterways, water systems, waste facilities, electrical grids, broadband networks, dams, levees, and other public and private facilities. Building and maintaining these networks to withstand extreme weather events is essential to meet economic demands and protect public health and safety.

Unfortunately, in communities across the U.S., disasters of greater intensity, duration, and frequency are wreaking havoc on these important systems. In 2024, 27 extreme weather events were billion-dollar disasters; causing 568 deaths and over $182 billion in damages. Since 1980, the U.S. has experienced more than 400 events with at least $1 billion in damages with their total costs exceeding $2.9 trillion. The impacts of these disasters extend beyond life and property losses. Over time, these disasters not only deteriorate the infrastructure networks of buildings, roads, bridges, electrical lines, water resources that communities rely on, but infrastructure disruptions can threaten the long-term viability of communities themselves.

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Severe heat, flooding, wind, fire, snow, ice, and earthquakes damage and destroy these critical lifelines that residents, businesses, and communities depend on. Measures to mitigate the impacts of natural disasters have led to an increased focus on resilience. The costs associated with building stronger infrastructure and structures yield significant returns on investment. Every dollar spent on resilience and preparedness saves communities $13 in post-disaster costs, according to a 2024 study from Allstate and the U.S. Chamber of Commerce.

Therefore, projects should be modernized or replaced by prioritizing resilience to withstand extreme weather. Resilience-focused measures may add to upfront costs but will save billions of dollars for United States households and taxpayers in the long run by mitigating the effects of extreme weather and reducing the large financial stress connected to disaster-related infrastructure damages.

As communities prepare on how to meet the challenges of increasingly extreme weather, they will need to integrate resilience into their plans. An important first step being adopting the most up to date codes and standards when designing and building infrastructure systems.

Pathways to Resilient Communities:

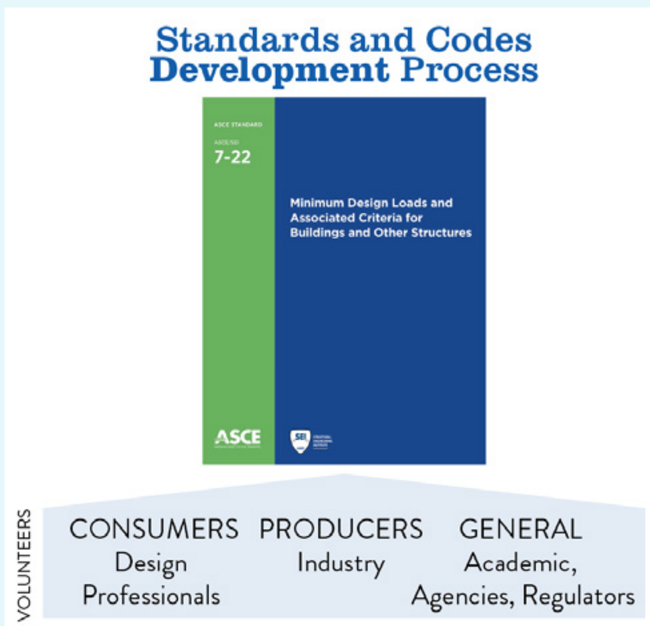
Infrastructure Designed for the Environmental Hazards in Your Region

One of the most reliable ways to ensure increased performance and resilience of our nation's built environment is the widespread adoption and enforcement of up to date, modern building codes and standards.

The American Society of Civil Engineers (ASCE) stands at the forefront of a profession that plans, designs, constructs, and operates society's economic and social engine – the built environment – while protecting and restoring the natural environment. ASCE is a principal provider of technical and professional conferences and continuing education material, the world's largest publisher of civil engineering content, and an authoritative source for codes and standards that advance infrastructure and protect the public. ASCE publishes manuals of practice, peer-reviewed papers, and a myriad of technical resources that communities and owners can use to ensure their infrastructure is designed and built to withstand natural hazards including earthquakes, floods, hurricanes, and tornadoes.

Beyond the hundreds of articles and publications dedicated to advancing infrastructure and building resilient communities, ASCE is an influential standards development organization (SDO). Developing standards that incorporate the best available hazard data and undergo a comprehensive peer review process are typically multi-year efforts, but they help ensure that buildings and other structures are safe and resilient to the latest climate threats. Following ASCE standards like *ASCE 7-22, Minimum Design Loads and Associated Criteria for Buildings and Other Structures* improves community resilience and can help reduce the risk of damage, injury, and loss of life during extreme events. More resilient infrastructure can also minimize the cost associated with rebuilding after a major event.

ASCE urges federal, state, and local governments to adopt and incentivize the use of the most up to date codes and standards. Widespread adoption and enforcement of current codes and standards is the best way to ensure our infrastructure and communities are resilient against increasingly severe storms and other hazards. The hierarchy of regulatory documents includes codes, standards, and in some cases manuals of practice.



ASCE is a standards development organization (SDO)

ASCE Standards provide technical requirements or guidelines for promoting safety, reliability, productivity, and efficiency in civil engineering. Many of our standards are referenced by model building codes and adopted by state and local jurisdictions. They also provide guidance for design projects around the world. Accredited by the American National Standards Institute (ANSI), ASCE has a rigorous and formal process overseen by the Codes and Standards Committee (CSC). Standards are created or updated by a balanced, volunteer standards committee, followed by a public review period.

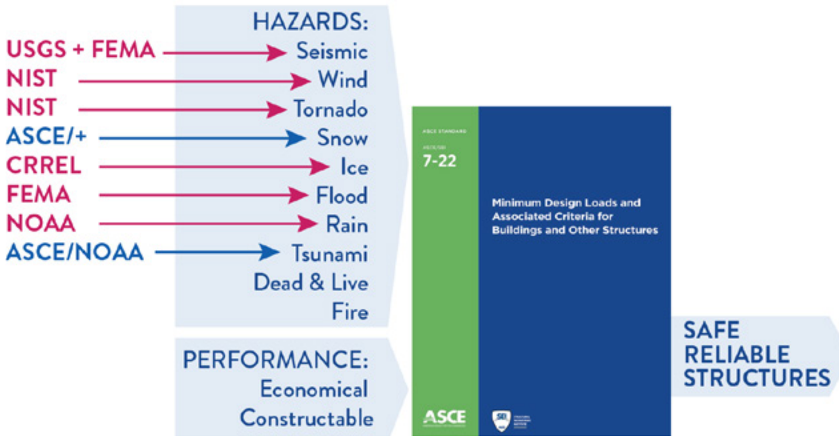
Glossary of Terms

A CODE is a set of minimum, mandatory requirements and regulations established by a government authority. Codes are legally enforceable. Building codes, for example, specify how buildings must be constructed to ensure the health, safety, and welfare of the public. A code can incorporate certain standards by reference, therefore making those standards part of the mandatory requirements.

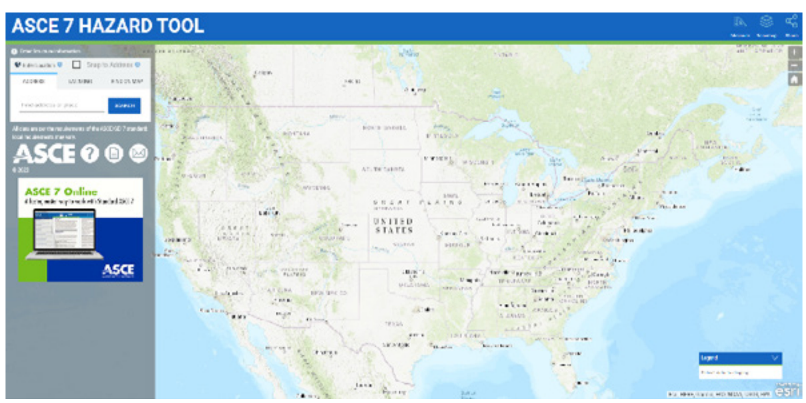
A STANDARD is a set of requirements or guidelines that provide industry best practices, procedures, or technical specification to maximize the reliability of a material, product, method, or service. Standards are developed by industry experts and can either be used on their own or adopted into other regulatory documents, such as building codes.

A MANUAL OF PRACTICE (MOP) includes best practices and guidance for a particular topic and is designed to help engineers and other stakeholders to improve their practices. Unlike standards, MOPs aren't typically adopted by government authorities into code or other regulatory requirements, yet they provide salient technical guidance to the industry.

How can your community build more resiliently?



Many ASCE standards and MOPs directly address the environmental hazard impacts for many new and legacy infrastructure systems including buildings, piers, wharves, pipelines, stormwater systems, and electrical transmission systems. Buildings can include residential, commercial, industrial, institutional, and critical facilities. Additionally, ASCE standards and MOPs specify infrastructure design procedures to mitigate the impact from the following Natural Hazards identified in the FEMA National Risk Index (https://hazards.fema.gov/nri/): Coastal Flooding, Earthquake, Hurricane, Ice, Riverine Flooding, Strong Wind, Tornado, Tsunami, and Winter Weather. Resilient design and engineering are founded in environmental hazard data that is developed and maintained by many federal agencies.



ASCE's Hazard Tool (https://asce7hazardtool.online/) offers an easy way for building officials and other community regulators to understand the required environmental hazard values, coefficients, and factors used by civil and structural engineers in the design of buildings and other structures for flood, seismic, wind, ice, tornado, tsunami, and snow load.

Process to get Standards and Codes adopted

Why should I follow standards voluntarily, or encourage others to do so?

Often, design standards that are intended to be referenced in the code are available for use for several years before your local jurisdiction adopts the new codes. However, there is no reason communities could not voluntarily adopt the latest version of a standard as soon as its available to take advantage of the latest hazard data and industry knowledge. Many federal grant programs incentivize the use of and cite the most currently available consensus-based standards.

What hazard-specific standards are available for my community?

The FEMA National Risk Index (https://hazards.fema.gov/nri/) identifies both risk and peril exposure for Coastal Flooding, Earthquake, Hurricane, Ice, Riverine Flooding, Strong Wind, Tornado, Tsunami, and Winter Weather, and more.

Flood – Rain

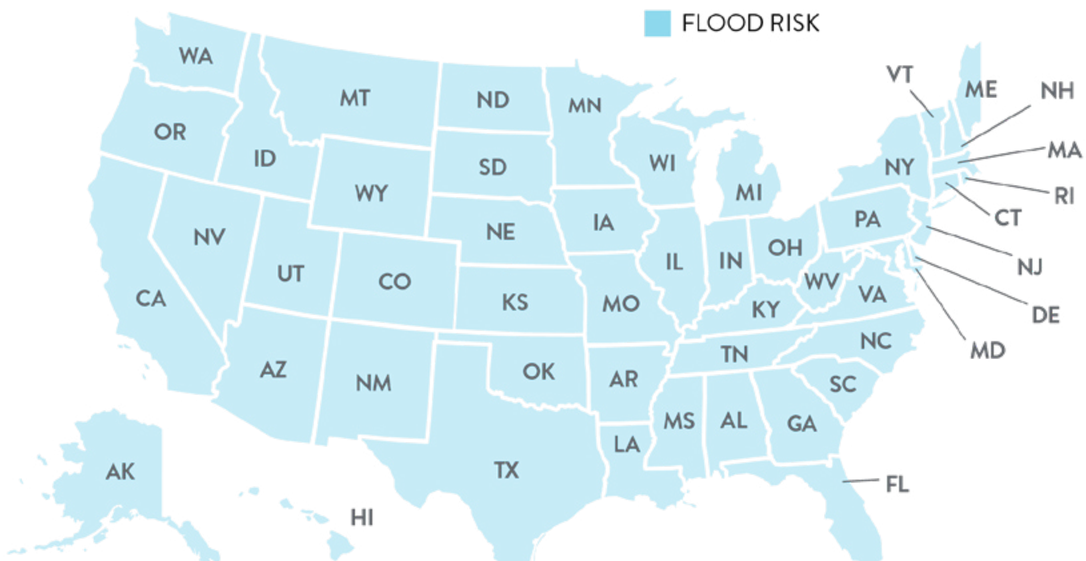


Figure highlights states affected by flooding and rain.

ASCE 7 standard defines the environmental hazards for structural design of buildings and other structures. Specifically, the ASCE 7 standard **defines the national approach for flood design of buildings and other structures**. The procedures defined in ASCE 7 rely on flood data developed by the Federal Emergency Management Agency. Additionally, the *ASCE 7-22 Supplement 2 for Chapter 5* **improves the expected performance of buildings and structures located in flood hazard areas by using the 500-year flood as its threshold**, up from the 100-year threshold. A 500-year flood threshold more accurately captures the risk of more severe flooding events and performance is further improved with requirements to include relative sea level rise for flood conditions and loads. Additionally, the underlying data and methodology source is from the US Army Corps of Engineers, including use of the USACE Sea Level Change Curve Calculator.

ASCE 24 Flood Resistant Design and Construction standard **improves the safety of buildings and structures located in flood-prone areas by giving specific design and construction instructions**. This can include raising the building higher above the ground and using special walls that break away in the event of a flood. By following these requirements, jurisdictions and owners can ensure that buildings and structures will be better protected against flood damage and losses.

This set of three standards, *ASCE 45, 46, and 47, Standard Guidelines for the Design, Installation, and Operation and Maintenance of Urban Stormwater Systems*, **establishes guidelines for the design, installation, operation, and maintenance of urban stormwater systems.** The set offers comprehensive guidance and is a useful tool for the nation's airports, roads, and other transportation systems. Maintaining stormwater systems is especially important as communities look to mitigate the impacts of flooding, because legacy systems were generally not built to accommodate changing rainfall patterns and intensity.

This set of three standards, *ASCE 62, 63, and 64, Standard Guidelines for the Design, Installation, and Operation and Maintenance of Stormwater Impoundment*, establishes guidelines for the design, construction, and operation and maintenance of stormwater impoundments, which are man-made structures designed to capture and store stormwater runoff from heavy rainfall events. **Stormwater impoundments can help mitigate flooding and erosion by reducing the volume and rate of water** flowing into nearby streams, rivers, or other bodies of water.

Earthquakes

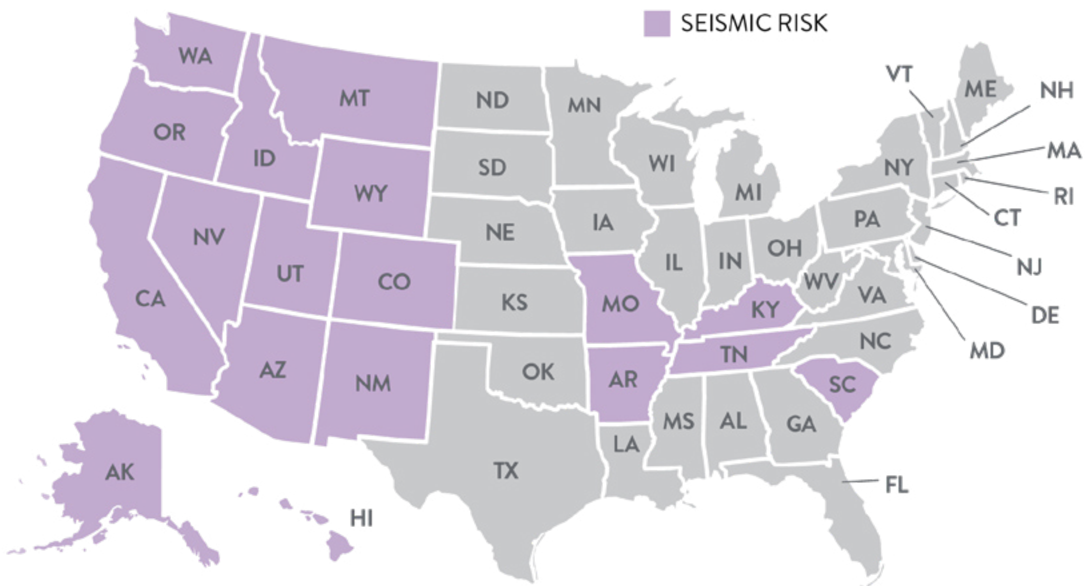


Figure highlights states affected by earthquakes.

The *ASCE 7* standard **defines the national approach for seismic design of buildings and other structures**. The procedures defined in ASCE 7 rely on seismic data developed by US Geological Survey on a cyclical basis and funded as part of the well-funded National Earthquake Hazard Reduction Program. Additionally, ASCE *Manual of Practice 74 Guidelines for Electrical Transmission Line Structural Loading* – which is currently being developed into a mandatory standard – includes provisions **to improve the resilience of electrical transmission lines against the seismic hazard**.

The standard *ASCE 41 Seismic Evaluation and Retrofit of Existing Buildings*is used by many communities to improve legacy building performance in the event of an earthquake. This document **standardizes retrofitting strategies and methods** so existing buildings to better withstand seismic events.

The pair of standards *ASCE 4 and 43, Seismic Analysis and Design Criteria for Structures, Systems, and Components in Nuclear Facilities*, and *ASCE 1, Design* and *Analysis of Nuclear Safety Related Earth Structures*, combine to **provide a coordinate set of stringent design requirements for all facilities that support nuclear power production** outside of the reactor.

ASCE 61, Seismic Design of Piers and Wharves, standardize industry practice for piers and wharves for the port/marine industry. Seismic provisions **improve resilience of waterfront structures, such as pile-supported structures** that do not have public access and are explicitly excluded from the building code.

Testing for Seismic Evaluation of Pipeline Systems is a proposed ASCE standard on how to design and construct **pipelines that can withstand earthquakes**.These guidelines are intended for utility agencies, pipe manufacturers, consultants, and testing facilities. The standard should be coupled with the *ASCE Manual of Practice for Seismic Design of Water and Wastewater Pipelines*, which is also under development.

ASCE is currently developing a new manual of practice for *Seismic Design of Buried Pipelines* focused on making water and wastewater infrastructure more resilient to seismic events. The document will provide **minimum seismic design guidelines for new water and wastewater pipelines**, with the understanding that in time, aging pipelines will be replaced and ideally will be rebuilt under these seismically resilient guidelines.

Wind – Hurricane – Tornado

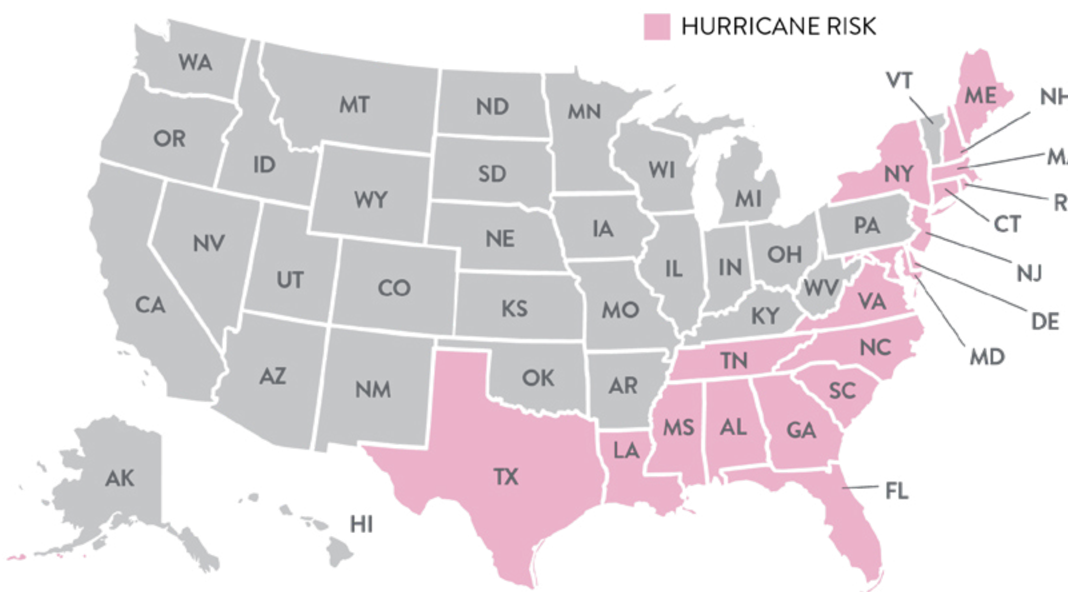


Figure highlights states affected by hurricanes – every jurisdiction is affected by windstorms.

The *ASCE 7* standard **defines the national approach for wind design of buildings and other structures**.The procedures defined in ASCE 7 – including updated values along the hurricane coastline – rely on wind data developed with funding from the National Institute of Standards and Technology as part of the unfunded National Windstorm Hazard Reduction Program. Additionally, ASCE *Manual of Practice 74 Guidelines for Electrical Transmission Line Structural Loading* – which is currently being developed into a mandatory standard – includes provisions **to improve the resilience of electrical transmission lines against the wind hazard**.

Tornado

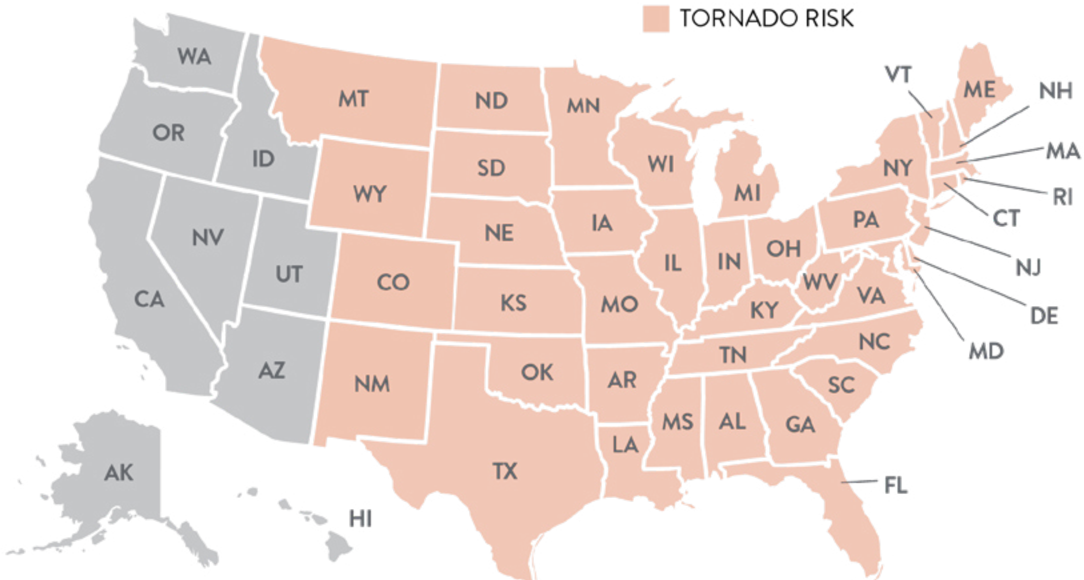


Figure highlights states affected by tornadoes.

Following a decade-long partnership with the National Institute of Standards and Technology, the 2022 edition of ASCE 7 includes, for the first time, a chapter dedicated to tornado loads. The requirements **improve the ability of critical facilities and structures in tornado-prone areas to withstand and protect** against extreme wind by utilizing the latest research and data. Tornado data was developed with initial funding from the National Institute of Standards and Technology as part of the unfunded National Windstorm Hazard Reduction Program.

Tsunami

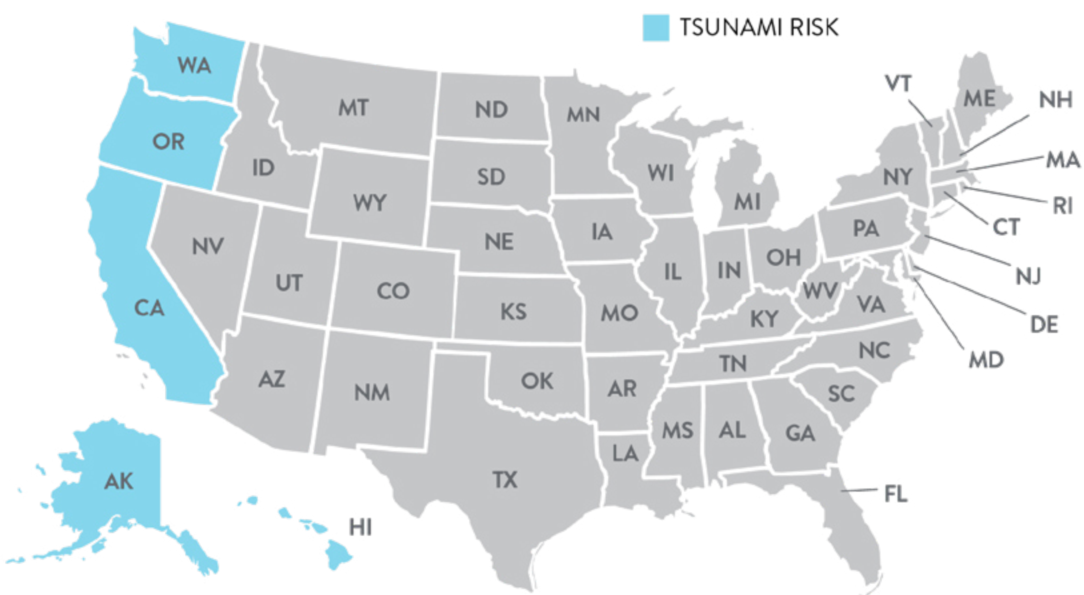


Figure highlights states affected by tsunamis.

Developed in 2016, the *ASCE 7* standard **defines the national approach for tsunami design of buildings and other structures**. The procedures defined in ASCE 7 were developed by ASCE and rely on offshore and runup data developed with partial, one-time funding from the National Ocean and Atmospheric Administration. The affected states of California, Hawaii, Washington, and Alaska have made investments to further develop the data for critical local, heavily populated regions.

Winter Weather – Ice

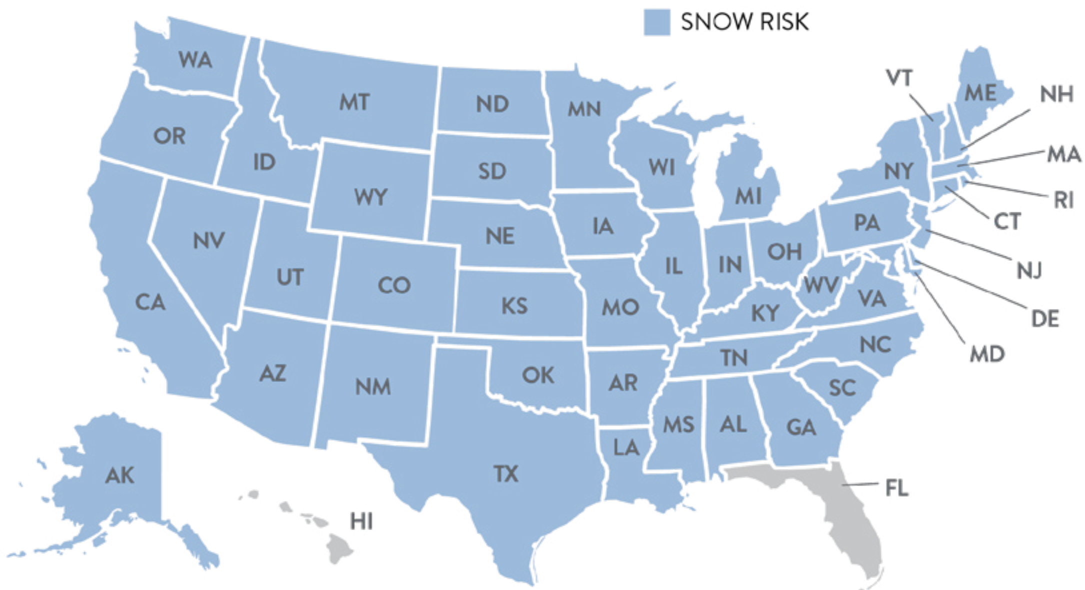


Figure highlights states affected by winter weather and ice.

The *ASCE 7* standard **defines the national approach for design of buildings and other structures against snow and ice**. The procedures defined in ASCE 7 rely on data developed by ASCE with industry support because federal funding for the snow hazard is unavailable. Additionally, ASCE *Manual of Practice 74 Guidelines for Electrical Transmission Line Structural Loading* – which is currently being developed into a mandatory standard – includes provisions **to improve the resilience of electrical transmission lines against the winter weather and atmospheric ice hazard**.

The *ASCE 7* standard also **defines the national approach for rain load design on buildings and other structures**. The procedures defined in ASCE 7 rely on precipitation data developed by the National Oceanic and Atmospheric Administration's ATLAS 14. NOAA's strategic partnership with ASCE has focused efforts to update precipitation data to be nationally comprehensive and include effects of future conditions.

Climate Informed Environmental Hazards

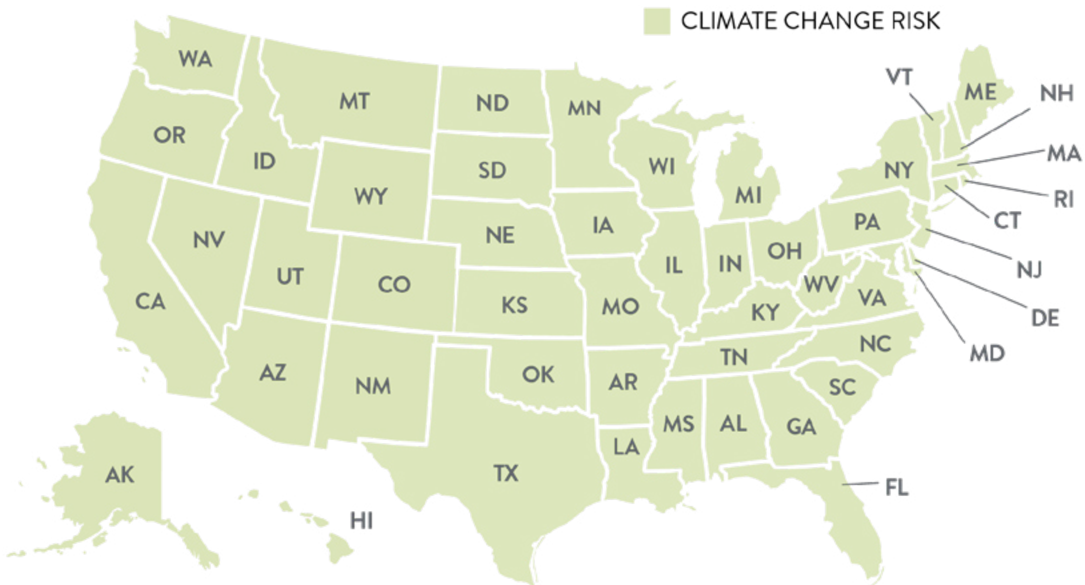


Figure highlights that every jurisdiction is affected by climate impacts.

The 2028 edition of ASCE 7 will include a new, first-ever chapter **addressing future conditions of the environmental hazards** used to design buildings and other structures. Having a consensus-based industry standard that includes effects from climate will provide a forward-looking, resilient approach to mitigate the natural perils.

ASCE *Manual of Practice 140 Climate-Resilient Infrastructure: Adaptive Design and Risk Management* **helps communities design infrastructure that can better withstand climate-related hazards**, including flooding. Recognizing that historical data cannot always serve as a guide given the rapid and accelerating trends of climate change, the guide incorporates adaptive strategies to adjust to new challenges over time.

ASCE *Manual of Practice 144 Hazard-Resilient Infrastructure: Analysis and Design* provides guidance and an underlying framework for **creating consistency across hazards, systems, and sectors in the design of new infrastructure systems**. The MOP also discusses enhancing the resilience of existing systems and relates this framework to the economics associated with system lifecycle, including organizational and socioeconomic considerations. ASCE's suite of Objective Resilience Manuals of Practice 146, 147, 148, and 149 examine **policies, technologies, applications, and processes that communities can utilize to enhance resilience.**

The Impacts of Future Weather and Climate Extremes on United States Infrastructure: Assessing and Prioritizing Adaptation Actions publication summarizes how **extreme weather and climate events may change in the future, and which infrastructure sectors are most vulnerable to these changes**. The book provides a framework that decisionmakers can use to prioritize limited budgetary resources for adaptation efforts.

The pair of standards – *ASCE 75 Standard Guidelines for Recording and Exchanging Utility Infrastructure Data and ASCE 38 Standard Guideline for Investigating and Documenting Existing Utilitie*s – help manage underground and aboveground utilities and **ensure that accurate records of utility locations are always available to the public**. ASCE 38 provides guidance on how to perform utility investigations and document results, while ASCE 75 specifies essential elements for documenting the location and other attributes of underground and aboveground utility infrastructure, especially newly installed or exposed infrastructure.

ENVISION

Developed and operated by the Institute of Sustainable Infrastructure, the **Envision** program and rating system is a voluntary tool that provides communities and owners with a consistent, consensus-based framework for assessing sustainability, resiliency, and equity in civil infrastructure that is "horizontal", such as roads, bridges, airports, and water systems. The framework provides a flexible system of criteria and performance objectives to aid decisionmakers and help project teams identify sustainable, resilient, and equitable approaches during the planning, design, and construction that will continue throughout the project's operations, maintenance, and end-of-life phases. Envision recognizes resource constraints and the diversity of mandates, schedules, budget cycles, and funding sources.

Envision was developed by American Public Works Association (APWA), the American Society of Civil Engineers (ASCE), and the American Council of Engineering Companies (ACEC). The Envision program offers certifications for policymakers, engineers, and infrastructure owners. There are virtual or on-demand trainings offered to get your Env SP certification.

Envision provides a consistent, consensus-based framework for assessing sustainability, resiliency, and equity in civil infrastructure.

Developing Sustainable Communities ASCE 73-23

One of the most reliable ways to ensure increased performanceand resilience of our nation's built environment is the widespread adoption and enforcement of up-to-date, modern building codes and standards.

Standard Practice for Sustainable Infrastructure, ASCE/COS 73-23

ASCE 73 is a first-of-its-kind, performance-based standard that provides infrastructure owners with much-needed guidance on their obligations to develop and implement sustainable solutions over a project's entire life cycle.

The standard calls for infrastructure owners to develop infrastructure that:

- Achieves environmental benefits and resilience measures and reduces embodied carbon.
- Reuses existing infrastructure to the fullest extent possible.
- Reduces energy demand for a project and uses renewable energy sources.
- Reduces waste and hazardous materials over the life cycle of the project.
- Engages community involvement to enhance community liveability, health and safety.
- Creates jobs and provides skills development to those in the community who wish to participate in construction of the project.

How does ASCE 73-23 help communities?

This standard provides guidance to infrastructure owners, engineers, and contractors on the creation of projects that minimize the environmental impact and protect natural ecosystems, while simultaneously meeting the diverse needs.

- Eco-friendly solutions such as recycling of infrastructure materials, reducing energy demands, and using renewable energy sources to lower the project's overall carbon footprint are highly encouraged.
- Job creation within a project's community is emphasized.
- Preserving cultural resources and facilitating community engagement ensures equity, improves the quality of life, and integrates the infrastructure solution into the community.
- Life-cycle cost analysis requirements are included to optimize the allocation of private and public funds and ensure that economic, social, environmental, and climate resilience benefits are achieved over the life of the project.

How do ASCE 73-23 and the ENVISION rating system interact?

The standard serves as a **complement to the Envision rating** system for sustainable infrastructure. Standard 73-23 addresses development and implementation of sustainable infrastructure solutions by meeting stakeholder needs and issues through the entire infrastructure life cycle. Envision is a sustainable infrastructure rating system that serves as a common method of measuring progress. ***sustainableinfrastructure.org/envision/about***

RESOURCES:

Standards

- ***ASCE/SEI 1 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures (1982) –*** *ASCE 1 provides geotechnical parameters, guidelines, and criteria to be used when constructing earth structures to protect nuclear power plant sites from flood, storm surge, other natural or man-made hazards.*
- ***ASCE/SEI 4 Seismic Analysis of Safety-Related Nuclear Structures (2016) –*** *ASCE 4 provides requirements to ensure the reliability of nuclear facilities during an earthquake.*
- ***ASCE/SEI 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures (2022) –*** *ASCE 7 defines the environmental hazards for structural design of buildings and other structures.*
- ***ASCE/SEI 24 Flood Resistant Design and Construction (2024) –*** *ASCE 24 helps improve the expected performance of buildings and structures located in flood hazard areas.*
- ***ASCE/SEI 41 Seismic Evaluation and Retrofit of Existing Buildings (2017) –*** *ASCE 41 standardizes methods to retrofit existing buildings to increase resiliency of communities in the face of a seismic event.*
- ***ASCE/SEI 43 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities (2016) –*** *ASCE 43 provides requirements to ensure the reliability of nuclear facilities through the design and assessment of new or existing nuclear structures, systems, or components. The standard can also be used for facilities where safety, mission, or investment protection is an explicit design goal.*
- ***ASCE/EWRI 45, 46, 47 Standard Guidelines for the Design, Installation, and Operation and Maintenance of Urban Stormwater Systems (2016) –*** *This set of three standards establishes guidelines for the design, installation, operation and maintenance of urban stormwater systems.*
- ***ASCE/COPRI 61 Seismic Design of Piers and Wharves (2014) –*** *ASCE 61 uses design methods to establish guidelines for the design of piers and wharves to withstand the effects of earthquakes, as these structures differ considerably from buildings and similar structures.*
- ***ASCE 62, 63, 64 Standard Guidelines for the Design, Installation, and Operation and Maintenance of Stormwater Impoundment (2016) –*** *This set of standards establishes guidelines for the design, construction, and operation and maintenance of stormwater impoundments, which are critical to reduce the impact of stormwater in downtown areas.*
- ***ASCE 73 Standard Practice for Sustainable Infrastructure (2023)*** *– a first-of-its-kind, performance-based standard that provides infrastructure owners with much-needed guidance on their obligations to develop and implement sustainable solutions over a project's entire life cycle.*

Manuals of Practice

- ***Manual of Practice 74 Guidelines for Electrical Transmission Line Structural Loading –*** *MOP 74 provides guidance on loading criteria, in particular weather-related loads such as wind and ice, for transmission structures and wires.*
- ***Manual of Practice 140 Climate-Resilient Infrastructure: Adaptive Design and Risk Management*** *– MOP 140 details flood resistant design criteria and provides communities with an approach to build in flood resilience as a part of infrastructure planning.*
- ***Manual of Practice 144 Hazard-Resilient Infrastructure: Analysis and Design –*** *MOP 144 provides guidance and an underlying framework for creating consistency across hazards, systems, and sectors in the design of new infrastructure systems.*
- ***Manual of Practice 146 | Objective Resilience: Policies and Strategies –*** *MOP 146 examines polices and strategies related to community asset resilience and provides stakeholders with a comprehensive, recommended set of practices.*
- ***Manual of Practice 147 | Objective Resilience: Objective Processes –*** *MOP 147 illustrates some of the objective processes, including uncertainty quantification, modeling, and complex systems resilience and simulation, which are used to manage community and asset resilience.*
- ***Manual of Practice 148 | Objective Resilience: Technology*** *– MOP 148 examines different technologies to enhance community and asset resilience, including the role of concrete, structural steel, remote sensing, highway bridge monitoring, and seismic isolation and protection devices.*
- ***Manual of Practice 149 | Objective Resilience: Applications –*** *MOP 149 provides different applications that aim to enhance community and asset resilience from the community viewpoint. The manual of practice will be of interest to groups focusing on pandemic mitigation and response, blast protection, public and private transit organizations, and natural hazards.*
- ***Manual of Practice for Seismic Design of Buried Pipelines*** *– ASCE is currently developing a new manual of practice on making water and wastewater infrastructure more resilient to seismic events. The new document will provide minimum seismic design guidelines for new water and wastewater pipelines, with the understanding that in time aging pipelines will be replaced and ideally rebuilt under these seismically resilient guidelines. The manual will be considered a pre-standard with a full standard being undertaken in the forthcoming years.*
- ***The Impacts of Future Weather and Climate Extremes on United States Infrastructure: Assessing and Prioritizing Adaptation Actions –*** *This document summarizes the likely changes in extreme weather events and assesses the vulnerabilities of infrastructure within critical sectors.*

Additional Resources

- ***Integrating Resilience and Sustainability in Civil Engineering Projects (2023) –*** *This publication seeks to inform and engage the engineering community in the concepts of resilience and sustainability, how they compare, and how engineers, owners, and contractors can adopt these concepts into practice.*

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