



Extreme Weather Events and Potential Impacts on Highway Design

Extreme weather events affect nearly every state in the U.S. In 2012, a total of 133 disaster eventsⁱ occurred resulting in about \$881 billion in damagesⁱⁱ (see NOAA NCDC graphicⁱⁱⁱ at right). Events ranged from hurricanes, droughts, heat waves, severe local storms, non-tropical floods, and winter storms, to wildfires and freezes. There is strong evidence that events related to heat, heavy precipitation, and coastal flooding will grow in frequency and severity in coming decades and we will likely continue to experience droughts and tropical storms. How does one look at highway design differently given changes in weather-related stressors like increased temperatures, precipitation, freeze-thaw cycles, and wind or storm exposure?

How Can Design Managers and Engineers Prepare for Extreme Weather Events?

Although DOT experience will vary by state, below is a "Top 10" list of design suggestions to better prepare for extreme weather.

1. **Assessment of Risk Policies:** Consider criticality of assets and develop agency procedures for at-risk critical assets which apply a lower risk tolerance and also recognize uncertainty in available data sources. Incorporate new policies into transportation facility design.
2. **Potential Overall Effects of Extreme Weather on Design:** Consider the effects (individually and combined) of extreme temperatures, wind, and precipitation events on pavements, piers and abutment protection, thermal expansion joints, bearings, superstructure elements, and bridge deck and roadway elevation and profile.
3. **Scenario-based Engineering Analysis:** When considering potential impacts of changing weather conditions, marry historical information with future estimated forecasts to identify potential stresses on assets. Consider application of a robust design process that uses a range of estimated climate conditions (scenarios) to establish design inputs that aim to minimize project life-cycle costs across possible scenarios.
4. **Flexible and Adaptive Design in Vulnerable Areas:** For those areas or assets particularly vulnerable to extreme weather impacts that carry high risk consequences for asset failure, incorporate flexible or adaptive design concepts into project design (such as shorter design lives and easily replaceable parts).
5. **Dual Purpose Designs:** Consider dual purpose designs especially in the urban areas, such as designing parks along portions of the right-of-way to act as water storage or infrastructure protection in times of heavy precipitation or significant coastal events.
6. **Drainage/Stormwater Management:** In areas highly vulnerable to higher levels of precipitation, design drainage and stormwater management systems to handle (divert, store, etc.) higher expected flows, consider stream morphology, overflow routes, and the possible impacts to the aquatic species.
7. **Interagency Coordination:** Accommodating extreme weather may require a larger or different footprint, requiring close coordination with resource agencies to discuss the rationale and opportunities for mitigation and/or enhanced environmental features.
8. **System Hardening:** Prepare for higher-than-normal weather events by creating: storage areas for backup power generators, "hardened" sign structures and traffic signal wires, and armoring of embankments.
9. **"Smart" Technology:** For critical assets or in areas of potential vulnerability, consider including sensor technology to monitor and warn of serious stresses (water or temperatures) impacting assets in real time.
10. **Future Protection:** Consult with materials and construction engineers about more durable materials and designs (e.g., paints, paving materials, drainage features) with consideration for likely future conditions (e.g., higher temperatures, increased rainfall intensities). Incorporate materials whose performance is less variable in weather extremes.

U.S. 2012 Billion-dollar Weather and Climate Disasters



U.S. Department of Transportation
Federal Highway Administration



Design Resources for Extreme Weather Preparedness and Resiliency

PUBLICATIONS

- **Caltrans Guidance on Incorporating Sea Level Rise** (May 2011). Guidance for planning and development of project initiation documents, including determining whether to incorporate sea level rise into project programming and design.
- **Climate Change, Extreme Weather Events and the Highway System** (NCHRP Report 750, Volume 2, 2014). Report presents guidance for practitioners on adaptation strategies to likely impacts of climate change in the planning, design, construction, operation, and maintenance of infrastructure assets in the U.S.
- **Engineering Assessments of Climate Change Impacts and Adaptation Measures** (Aug. 2014). Report discusses engineering assessments and adaptation options for a range of facilities and climate stressors in Mobile, AL. Includes lessons learned from applying an 11-step climate assessment process.
- **Response to Extreme Weather Impacts on Transportation Systems** (NCHRP Synthesis 454, May 2014). Report examines eight recent cases of extreme weather in the U.S. from the perspectives of transportation operations, maintenance, design, construction, planning, communications, interagency coordination, and data and knowledge management.

GUIDANCE AND RULES

- **AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms** (2008). Guide covers concepts not included in previous design provisions with comprehensive specifications for the design of bridges vulnerable to coastal storms.
- **AASHTO Guide Specifications and Commentary for Vessel Collision Design of Highway Bridges** (2009). Second edition incorporates lessons learned from use of the original 1991 Vessel Collision Guide Specification, additional research and clarification of risk procedure elements applicable in extreme weather events.
- **AASHTO LRFD Bridge Design Specifications** (2012). Comprehensive specifications employing the Load and Resistance Factor Design methodology "Extreme Event Limit States" to ensure structural survival of a bridge during extreme events.
- **Eligibility of Activities To Adapt To Climate Change and Extreme Weather Events Under the Federal-Aid and Federal Lands Highway Program** (Sept. 24, 2012). FHWA memo clarifies activities eligible for FHWA funding, including vulnerability assessments, design and construction of projects or features to protect assets from damage associated with climate change.
- **FHWA Hydraulic Design Series No.2 - Highway Hydrology** (2002). Second edition includes new sections on wetlands hydrology, snowmelt hydrology and special topics including but not limited to GIS approaches and applications.
- **FHWA Hydraulic Engineering Circular No. 25, Vol. 2 – Highways in the Coastal Environment: Assessing Extreme Events** (publication anticipated November 2014).
- **MAP-21, Section 1315 – USDOT Final Rule on Categorical Exclusions (CE) for Emergency Repair Projects** (Feb. 19, 2013). Rule revises the existing CE for emergency repair projects under Moving Ahead for Progress in the 21st Century Act (MAP-21).
- **US Army Corps of Engineers (USACE) Coastal Engineering Manual** (2012). Includes tools and procedures to plan, design, construct, and maintain coastal projects. Update covers studies for coastal flooding, shore protection, and navigation projects.

WEBSITES

- **AASHTO Transportation and Climate Change Resource Center: Extreme Weather Symposium, 2013.** Materials on recent extreme weather events, costs, and how DOTs can manage them. climatechange.transportation.org/symposium/
- **FHWA Climate Change Adaptation Website:** www.fhwa.dot.gov/environment/climate_change/adaptation/
- **Federal Emergency Management Agency (FEMA) Map Service Center:** <https://msc.fema.gov>

OTHER RESOURCES

AASHTO's Resilient and Sustainable Transportation Systems (RSTS) Technical Assistance Program provides timely information, tools, and technical assistance to State DOTs to manage challenging issues associated with extreme weather events. (http://climatechange.transportation.org/about/steering_committee.aspx)

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ⁱ "Disaster events" in this context have been defined as tropical cyclones (e.g., hurricanes), droughts/heatwaves, severe local storms, non-tropical floods, winter storms, wildfires, and freezes.

ⁱⁱ Smith and Katz, Natural Hazards, June 2013, Volume 67, Issue 2, pp. 387-410.

ⁱⁱⁱ Source: National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) at www.ncdc.noaa.gov/billions/summary-stats