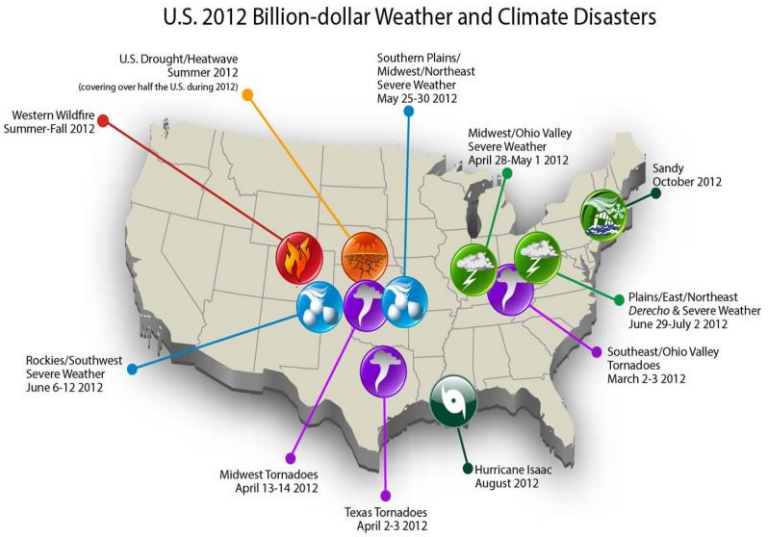
AASHTO
EXTREME WEATHER & THE TRANSPORTATION SYSTEM

How Do Extreme Weather Events Affect Highway Design?

Extreme weather events affect nearly every state in the U.S. In 2012, for example, a total of 133 disaster events[i] occurred resulting in about $881 billion in damages[ii] (see NOAA NCDC graphic[iii] at right). Events ranged from hurricanes, droughts, heat waves, severe local storms, non-tropical floods, and winter storms, to wildfires and freezes. In addition, many parts of the country have witnessed gradual shifts in average temperatures and rainfall patterns over the past several decades. 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. These trends prompt questions about whether and how to approach highway design differently given these changes.



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

Although transportation agency experiences will vary by state and topic, below is a "Top 10" list of design suggestions to better prepare for extreme weather and shifting climate trends.

1. **Risk Policies**: Consider criticality of assets and develop agency procedures for at-risk critical assets that apply a lower risk tolerance and also recognize uncertainty in available data sources. Incorporate new policies into transportation facility design.
2. **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 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**: 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, 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, especially in urban areas.
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 and 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, "hardening" sign structures and traffic signal wires, and armoring 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.

Center for Environmental Excellence

Design Resources for Extreme Weather Preparedness and Resilience

PUBLICATIONS

- **Adapting Infrastructure and Civil Engineering Practice to a Changing Climate** (American Society of Civil Engineers, 2015). Report identifying the technical requirements and civil engineering challenges raised by adaptation to a changing climate.
- **Climate Change, Extreme Weather Events and the Highway System** (NCHRP Report 750, Volume 2, 2014). Guidance for practitioners on adaptation strategies for likely impacts of climate change in the planning, design, construction, operation, and maintenance of infrastructure assets in the United States.
- **Gulf Coast Study Phase II Engineering Assessments of Climate Change Impacts and Adaptation Measures** (U.S. DOT, August 2014). Report discussing 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 engineering assessment process.
- **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.
- **Port Authority of New York and New Jersey (PANYNJ) Engineering Department Design Guidelines for Climate Resilience** (PANYNJ, January 2015). Guidelines for how to address anticipated climate impacts in infrastructure and buildings.
- **Assessment of Key Gaps in the Integration of Climate Change Considerations into Transportation Engineering** (FHWA, September 2014). Report summarizing gaps in information and practice related to integrating climate change into transportation engineering. Public release expected in 2015.

FEDERAL GUIDANCE AND RULES

- **FHWA Order 5520 – Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events** (Dec. 15, 2014). Directive establishes FHWA policy that FHWA programs, policies, and activities must integrate consideration of climate change and extreme weather event impacts and adaptation into planning, operations, policies, and programs.
- **FHWA Hydraulic Engineering Circular No. 25, Vol. 2** (2015). Highways in the Coastal Environment: Assessing Extreme Events. Document focuses on quantifying exposure to sea level rise, storm surge, and waves considering climate change.
- **FHWA Hydraulic Engineering Circular No. 17, Vol. 2** (update pending in 2015). The update will provide technical guidance and methodologies for considering/incorporating floodplain management, risk, extreme weather events, resilience, and adaptation considerations when addressing highway planning and design within the riverine environment.
- **U.S. Army Corps of Engineers Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation** (2014). Technical letter provides guidance for understanding the direct and indirect effects of projected future sea level change on infrastructure 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/
- **The Infrastructure and Climate Network:** http://theicnet.org/
- **Center for Climate and Energy Solutions:** Interactive map depicting extreme weather events, 1990-2013. www.c2es.org/science-impacts/maps/extreme-weather

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/technical_assistance_program.aspx)

For questions or for more information, please contact Patricia Bush, Program Manager for Engineering at PBush@aashto.org or Gabriel Weil, Program Manager for Environment at GWeil@aashto.org.

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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: NOAA NCDC at www.ncdc.noaa.gov/billions/summary-stats