Adapting Infrastructure to Extreme Weather Events: Best Practices and Key Challenges

Workshop Summary Report

Infrastructure Adaptation Workshop
AASHTO Spring Meeting 2012
8am-11am
May 20th, 2012

Prepared for:

American Association of State Highway Transportation Officials (AASHTO)

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Table of Contents

Introduction and Context 3

Executive Summary of Challenges, Barriers, and Recommended Actions for AASHTO 4

- Challenges and Barriers 4
- Recommended Actions for AASHTO 4

Framing Adaptation as a Priority for AASHTO and FHWA 5

- Welcome, Mr. John Horsley (AASHTO) 5
- Welcome, Mr. Butch Wlaschin (FHWA, Office of Asset Management) 5

Adaptation Efforts Underway Across the Country: Washington State, California, and Iowa Panel 5

- Washington State, Dave Dye 5
- California, Rick Land 7
- Iowa, John Adam 8

Europe's Adaptation of Infrastructure to Climate Change and Extreme Weather 9

- Introduction, Philippe Crist 9
- Extreme Weather Impacts on European Networks of Transport (EWENT), Dr. Pekka Leviäkangas 10

Challenges and Barriers to Climate Change Adaptation 10

Appendix A 12

Appendix B 13

Introduction and Context

On May 20th, 2012, the American Association of State Highway and Transportation Officials (AASHTO) hosted a 3-hour workshop titled, *Adapting Infrastructure to Extreme Weather Events: Best Practices and Key Challenges*. The purpose of the workshop was to provide a forum for information exchange on state transportation agencies' past experiences and future plans for managing impacts of extreme weather events on transportation infrastructure. Representatives from Washington State DOT (WSDOT), Caltrans, and Iowa DOT discussed their recent experiences addressing extreme weather and shared perspectives on how to manage weather-related risks.

This workshop was also an opportunity to exchange ideas with members of the International Transport Forum, an international intergovernmental organization for transportation policy meeting under the auspices of the Organization for Economic Co-operation and Development (OECD). Specifically, the workshop provided an opportunity for members of this international organization to hear more about state experiences in the U.S. and also to share information on efforts underway to address similar risks to transportation systems across the globe. The organization focuses on identifying and transferring lessons learned and best practices, particularly as they relate to asset management.

Dr. Michael Meyer from Georgia Tech kicked off the workshop by welcoming participants, facilitating a round of introductions, referencing a background paper distributed to participants in advance of the meeting, and articulating the goals of the workshop. Next, he introduced Mr. John Horsley, the Executive Director of AASHTO. Mr. Horsley opened the workshop by noting that infrastructure adaptation is an area of national concern and emphasizing AASHTO's commitment to addressing the needs of the transportation community. Following his introduction, Mr. Butch Wlaschin, the Director of the Office of Asset Management at the Federal Highway Administration (FHWA), welcomed the participants and recommended asset management as one of the starting points for integrating weather and climate considerations into decision-making. Both Mr. Horsley and Mr. Wlaschin focused on the importance of working closely with state DOTs and chief engineers to help increase the resilience of transportation systems to extreme weather events.

AASHTO will use suggestions made by meeting participants to inform its program prioritization over the upcoming year. The Executive Summary of this report synthesizes the challenges and barriers identified during the workshop as well as the recommended actions suggested for AASHTO. The remainder of the report summarizes the presentations, discussions, and recommendations provided during the workshop. Finally, Appendix A contains the final workshop agenda, Appendix B contains the final participant list, and Appendix C contains the list of presentations given during the exchange. State DOTs and other interested transportation practitioners are invited to participate in a webinar on this topic that AASHTO is holding on Wednesday, June 27th, at 1 pm Eastern.

Executive Summary of Challenges, Barriers, and Recommended Actions for AASHTO

Challenges and Barriers

The main challenge identified by meeting participants is the difficulty of investing in increased system resilience over the mid- and long-term when state DOTs currently lack sufficient resources to maintain existing system function. Due to this challenge, states agreed that it was unlikely that a state DOT would have an adaptation-specific investment program, but would likely tie any such improvements to more traditional program investments, such as rehabilitation and maintenance.

Institutional barriers and challenges related to collaborative and cooperative efforts to rebuild infrastructure after an event were cited as barriers to the "adaptive capacity" of the transportation system in areas prone to experience climate and weather-related risks. Some examples of challenges mentioned at the workshop include mobilizing crews, hiring contractors, and processing paperwork and funds. Assets will be impacted by extreme weather, but the ability of the DOTs to get the system functioning quickly after an event relies on swift mobilization immediately following the event. An additional challenge is that in many cases, more adaptive designs for replacing lost or damaged infrastructure are not allowable uses of disaster response funding.

Finally, the inability of models to accurately predict the occurrence of extreme events, such as sand storms, at a local scale hampers the speed and efficiency of state DOT responses.

Recommended Actions for AASHTO

At the close of the workshop, both John Horsley and Shannon Eggleston urged participants to identify actions that AASHTO can take to facilitate DOT activities in this area.

John Horsley noted that AASHTO would like to make infrastructure adaptation a priority and asked participants for suggestions of near-term technical needs. The participants responded with the following suggestions for state DOT support:

- Help states develop improved predictive models for extreme weather events.
- Research the relationship between weather impacts and infrastructure damage in order to identify the threshold points at which weather begins to cause structural damage.
- Define a research agenda for adaptation tied to different stages in project development. For example, what type of research would be needed to study the linkage between planning and adaptation? Between environmental analysis and adaptation? Between operations/maintenance and adaptation?
- Engage a broad range of states in an ongoing conversation about impacts due to high and extreme weather events; include discussion of dust, fires, and temperatures rather than just sea-level rise and other coastal issues.
- Facilitate a national conference to bring together various state DOT disciplines, including planners, asset managers, environment, design, hydrologists, construction, maintenance and

operations to discuss and share experiences related to high and extreme weather events and issues and challenges related to infrastructure adaptation.

- Examine the emergency response program and suggest ways that it could be improved to better handle escalating extreme weather events (e.g., Iowa's streamlined expense system).
- Develop and distribute materials and guidance to help states conduct workshops in this area (e.g., distribute information about WSDOT's approach or oversee the coordination of states meeting with WSDOT to learn more about their approach).

Framing Infrastructure Adaptation as a Priority for AASHTO and FHWA

Welcome, Mr. John Horsley (AASHTO)

Mr. John Horsley opened the workshop and described the growing importance of infrastructure adaptation both to AASHTO and the country. He noted that in 2008, the United States was on the brink of passing climate legislation. At that time, the transportation community witnessed a surge of activity from governors and state legislatures to make emissions reductions across the country. Since that time, AASHTO has engaged with the issues surrounding climate change and extreme weather events, educating its members and ensuring that transportation-based solutions to climate change are fair and transparent.

Mr. Horsley noted that the impacts of extreme weather events on infrastructure are increasingly apparent. For example, Midwestern and Northeastern states are experiencing unprecedented flood damage. The Standing Committee on Highways (SCOH) will ultimately have the role of setting any standards and conducting technical analyses if hydraulic solutions become necessary. Mr. Horsley concluded by noting that AASHTO is prepared to remain a leader on these cutting-edge issues. This event will be the start of an ongoing conversation.

Welcome, Mr. Butch Wlaschin (FHWA, Office of Asset Management)

Mr. Butch Wlaschin began his introduction by noting that asset management is one of the most logical places for a state DOT to begin integrating adaptation into decision-making. Since mainstreaming climate considerations is critical, he emphasized the importance of engaging state DOTs and chief engineers. In addition, he facilitated the participation of a work group from the International Transport Forum in Paris in the AASHTO Spring Meeting to encourage the exchange of information across national boundaries.

Infrastructure Adaptation Efforts Underway Across the Country: Washington State, California, and Iowa Panel

Washington State, Dave Dye

Mr. Dave Dye, the Deputy Secretary of the Washington State DOT, described the climate change adaptation work that has occurred in the state to date. In 2009, the Washington State legislature

published the *Washington Climate Change Impacts Assessment*, developed by the Climate Impacts Group (CIG) located at the University of Washington. The state legislature oversaw the work of this group and has directed state agencies to use the science from CIG, which was critical for progressing infrastructure adaptation efforts.

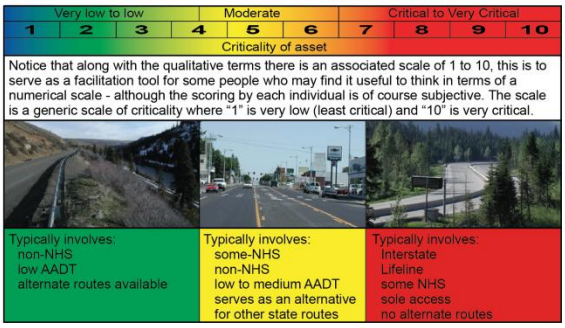


FIGURE 1: SCALE USED BY THE WSDOT PILOT TO RANK CRITICALITY OF ASSETS

The remainder of Mr. Dye's presentation focused on WSDOT's participation as a pilot in the FHWA Vulnerability Assessment pilot program in 2011. Washington State is already experiencing changes in weather patterns such as record-setting high and low temperatures. Weather-related impacts to the transportation system include faster roadway deterioration, flooding, increased stormwater concerns, more closed roads, and increasing maintenance and emergency costs. Prior to the pilot study, CIG's research and outreach efforts had provided WSDOT with a clear grasp of the regional climate threats. However, the agency wanted to know what these changes meant for the agency's infrastructure and operations. When the agency became one of five pilot projects selected to test the FHWA conceptual framework of vulnerability assessment, WSDOT focused on existing assets (roads, rails, ferry terminals, and maintenance shops) to understand areas of high risk. The scope of the assessment included only assets that the agency controlled. The main data sources for the vulnerability assessment were asset management and cost/risk assessment tools, Pacific Northwest climate change data, and the institutional knowledge of field personnel.

The WSDOT approach relied heavily on internal expertise to assess vulnerability. Experts from local maintenance, bridge preservation, hydraulics, geotechnical materials, project development, planners, and environmental staff contributed to vulnerability rankings. Over a period of 14 months, the WSDOT team conducted more than a dozen workshops across the state with WSDOT's local experts and recorded their qualitative rankings of risk. The WSDOT pilot team started the workshops by asking field staff, "What keeps you up at night now?" and then asked, "Would your concerns get worse, stay the same, or decrease with these projected changes in climate?" The agency found these questions to be enormously effective in eliciting important input from participants.

Over the course of 14 4-hour workshops, the pilot team was able to successfully rate all of the state's highways, maintenance sheds, ferry terminals, air strips, and rail. The study found that the highly vulnerable areas of the system are generally in the mountains, along rivers that have melting glaciers at their headwaters, in low lying areas/floodplains, and near sea level. While many of the study results confirmed what WSDOT already knew, there were several valuable findings. For example, the consultations revealed that the bridge approaches were more vulnerable to flood damage than the bridges themselves.

Following the completion of the statewide vulnerability assessment, WSDOT has been sharing project results internally and externally and working to understand how the agency can use the results. The key objective going forward is to integrate these considerations into existing asset management processes and to update manuals to help employees recognize when they should think about climate impacts. WSDOT is not considering developing a new climate adaptation program; rather, the agency plans to use these climate risk findings as one of many inputs into responsible long-term investment management.

California, Rick Land

Mr. Rick Land, the Acting Chief Deputy Director for Caltrans, began his presentation by providing context on transportation in California. California is a large, diverse state extending nearly 800 miles. The state has 16 distinct climate zones ranging from arid deserts in the south to rainforests in the north. This diversity makes it difficult to project local changes in climate. At a regional scale, the state has focused on managing sea-level rise on the coast and increased heat in the central valley.

California's adaptation efforts began when the Global Warming Solutions Act of 2006 (Assembly Bill 32) was passed, which required reductions in GHG emissions to 1990 levels by 2020. Following AB32, Senate Bill 375 enhanced California's ability to reach AB 32 goals by promoting good land use and transportation planning with the goal of creating more sustainable communities. Finally, Governor Schwarzenegger implemented Executive Order S-13-08 which requires state agencies to incorporate sea-level rise assumptions into project development. It also required the National Academies of Sciences to prepare a sea-level rise assessment which is due to be completed in June of 2012. The Executive Order also required the development of the 2009 California Climate Adaptation Strategy.

Sea-level rise is the first climate change impact that the DOT is aggressively addressing. California has over 1,000 miles of coastline and contains many highway segments (including Highway 1 and 101) that are built along the coast. A sea-level rise of only a few meters would inundate large portions of the San Francisco Bay area, including the San Francisco and Oakland airports. In addition, higher sea levels will increase coastal bluff erosion, making coastal routes more susceptible to slides and slip-outs.

In 2011, Caltrans assisted in developing the state's *Guidance on Incorporating Sea level Rise: For Use in the Planning and Development of Project Initiation Documents*. This guidance document provides project-level engineering guidance as well as planning-level guidance to help determine which projects should consider sea-level rise. Caltrans will update the document as more information on sea-level rise becomes available. Mr. Land mentioned that there is not currently enough information to suggest that the design standards currently in use need to be modified.

Year		Average of Models	Range of Models
2030		7 in (18 cm)	5-8 in (13-21 cm)
2050		14 in (36 cm)	10-17 in (26-43 cm)
2070	Low	23 in (59 cm)	17-27 in (43-70 cm)
	Medium	24 in (62 cm)	18-29 in (46-74 cm)
	High	27 in (69 cm)	20-32 in (51-81 cm)
2100	Low	40 in (101 cm)	31-50 in (78-128 cm)
	Medium	47 in (121 cm)	37-60 in (95-152 cm)
	High	55 in (140 cm)	43-69 in (110-176 cm)

FIGURE 2: SEA-LEVEL RISE GUIDELINES FROM CALTRANS *GUIDANCE ON INCORPORATING SEA LEVEL RISE*

In addition to the *Guidance on Incorporating Sea level Rise*, Caltrans is using high-resolution elevation data to map the coast of California and highlight infrastructure that is vulnerable to sea-level rise. This Climate Change Adaptation Hot Spot

Map is anticipated to provide internal Caltrans Function Divisions, Districts, and local governments with the specific locations where the State Highway System will be vulnerable to sea-level rise. One challenge with this map is that it communicates risk related to the roadway surface, but does not consider drainage facilities.

In addition to sea-level rise impacts, precipitation and temperature patterns are projected to change in California over the coming years. Scientists predict that more precipitation will fall as rain, rather than snow, reducing the Sierra Nevada snowpack by as much as 70-90%. The increased amount of rain will lead to more flooding and landslides. Mr. Land emphasized that better data on precipitation changes are needed in order to assess the potential impacts to our system. California is expected to experience dramatically warmer temperatures over the next 100 years. Impacts to the transportation system could include increased thermal expansion of bridge joints and paved surfaces, concerns regarding pavement integrity and asphalt degradation, limits on periods of construction activity, and increased maintenance and construction costs. Mr. Land noted that while California has experienced challenging mud slide conditions over the past year, the agency is very good at fixing damage due to slides quickly. The agency wants to balance retrofitting needs with emergency response and recovery adaptation options. Mr. Land also noted that a vulnerability for Caltrans is likely to be bridge approaches.

Caltrans is aiming to provide its local transportation partners, such as MPOs, with guidance and direction on the data, methods, and strategies to best incorporate climate change adaptation into long range transportation plans. This guidance will expand existing knowledge and assist with the development of tools to help MPOs and RTPAs with planning, design, engineering, and operational decisions. Caltrans is also undertaking a wide range of mitigation activities, including efficient construction, construction waste management, and low carbon fuels.

Iowa, John Adam

Mr. John Adam, the Director of the Highway Division at the Iowa DOT, focused his comments on the operations, infrastructure, and design issues currently facing the state.

Since Iowa is not a coastal state, winter events and floods are the two main weather impacts. In 2007, the state experienced one of the worst blizzards in memory, which shut down I-80 in western Iowa for 4-5 days. This blizzard spurred the DOT to put together an operations center and begin better preparing for extreme weather events. One of the most important outcomes from this effort was the development of predetermined closure points, shelter, and parking areas. Snow events have become more frequent in Iowa and the DOT is putting a lot of effort into technology and management options to ensure that routes remain open. Iowa has developed new strategies for managing the increased snowfall, including living snow fences and snow storage areas on agricultural land.

Iowa has also been experiencing more frequent extreme rain events, followed by heavy snowfalls and quick snow melt. Earlier springs and warmer, wetter winters are also contributing to increased frequency and intensity of flooding events. Mr. Adam noted that Iowa is starting to experience four to six rain events of eight to ten inches per year. For example, the June 2008 flooding in Cedar Rapids was a $15 billion disaster which wiped out large areas of infrastructure and buildings. During the summer of 2011, the Missouri River flood affected most of the upper Midwest and far surpassed all initial flood

inundation estimates. Since designing for that kind of a rain event is impractical, the state has focused on improving its response and emergency management systems. For example, the DOT has streamlined the disaster recovery reimbursement process by making it entirely electronic and web-based.

Mr. Adam noted that while the majority of Iowa's emphasis has been on emergency response, the state DOT is selectively retrofitting overflow bridges in certain cases. He noted that the state cannot afford to have a regular retrofit program because there is not enough funding to maintain the status quo. To the extent that it is possible, the agency is updating structures during the design phase to account for these localized extreme events. In addition, the DOT is building a new levee to channel flood waters away from the bridge abutments of an important highway bridge in Des Moines, thereby protecting the bridge structure. Since FEMA funding cannot be used for that type of expenditure, the DOT is paying for this structure itself.

One of the challenges that Mr. Adam described is that the flooding is so severe that the traditional timelines for reimbursement are no longer practical.

Europe's Adaptation of Infrastructure

Introduction, Philippe Crist

Mr. Philippe Crist of the International Transport Forum noted that the same conversations on extreme weather events are happening in Europe. While Ministers of countries in the OECD are relatively certain they are experiencing changes in weather, they are uncertain as to how these changes will impact investments, especially with regard to asset timeframe. Mr. Crist emphasized that the countries in Europe cannot afford to deploy all of the actions that they would like to due to project and resource constraints. A key issue involves increasing the robustness of some assets and allowing others to fail. Another strategy to increase resilience across a range of uncertain futures is to maintain redundant networks. Countries are also designing infrastructure that may fail and investing resources in recovery and emergency response instead.

Table 8. Threshold values for winter conditions.

Low temperature – daily mean temperature		
Threshold	**Impacts**	**Consequences**
≤ 0°C	This is an important threshold related to slipperiness (ice formation, form of precipitation: rain/sleet/snowfall). The temperature itself is rather a modifier of hazardous conditions for transportation than a main cause. Low temperature combined with precipitation and wind can have a disruptive effect on traffic. Occurrence of freezing drizzle, increased frequencies of freeze-thaw cycles.	Increased accident risk in road traffic. The occurrence of freezing drizzle might be hazardous for aviation and road traffic. Premature deterioration of road and runway pavements.
≤ -7°C	The effect of salting for ice removal decreases in low temperatures. So, even relatively small amounts of snowfall can cause slippery conditions on highways when packed on the road surface by traffic. Rail points may get stuck by drifting snow in low temperatures (observed in Finland and Canada). Ice formation on rivers may start if there are many cold days in a row. Some vehicles might have fuel problems ("summer diesel sort").	Increased accident risk, delays and cancellations in road and rail traffic (e.g. Eurostar trains during winter 2009/10). Inland waterway transport might be disrupted.
≤ -20°C	Some vehicles might have fuel problems (Oslo, winter 2009/10). Rivers get ice-covered if there is a long-lasting cold period. Dangerous wind chill conditions occur when moderate winds prevail.	Public transport may encounter breaks due to fuel problems. (Oslo, winter 2009/10), riverboat traffic may stop. Limitations to transport personnel working outdoors.

FIGURE 3: EXAMPLE TABLE OF THRESHOLD VALUES FROM THE VTT WORKING PAPER, "EXTREME WEATHER IMPACTS ON TRANSPORT SYSTEMS"

Extreme Weather Impacts on European Networks of Transport (EWENT), Dr. Pekka Leviäkangas (VTT Technical Research Center of Finland)

Dr. Leviäkangas, the Principal Scientist at the VTT Technical Research Center of Finland, stated that conversations similar to this workshop are happening in Europe. In addition, with the economic crisis occurring now, climate change has lost importance as an issue for many European countries. Dr. Leviäkangas introduced the VTT as a multidisciplinary, not-for-profit organization with about 50 transportation researchers. VTT has offices across the world, including Berkeley, California. The goal of EWENT is to assess the impacts of extreme weather events on the European Union transport system. The project began by identifying the hazardous phenomena, including probability and consequences. Next, the project will assess the expected economic losses caused by extreme weather. EWENT examines the damage to the transport system from three perspectives: the direct impacts to physical infrastructure, the harmful impacts on traffic safety and operations, and indirect impacts to third parties, such as supply chain customers. In order to analyze these perspectives, EWENT built casual relationships between weather phenomena and impacts such as time delays, accidents, and increased maintenance. The project began in 2009 and will have a total duration of 30 months.

The first EWENT project deliverable was a VTT Working Paper entitled, "Extreme Weather Impacts on Transport Systems." This report lists the extreme weather phenomena with critical threshold values and includes a set of causality maps. The EWENT project assigned probabilities to each link in the causal relationships between weather phenomena and impacts. When it was not possible to use empirical information, the project relied on expert opinion to assign probabilities.

According to the initial results of the cost analysis, the impacts of climate change and variability are likely to cost billions of euros. Currently, the biggest cost is road accidents in winter conditions.

During the risk assessment, the project defined risk as a product of hazards and vulnerability. Hazards were calculated as the probability of extreme weather phenomena. The results indicated that the former eastern European countries are most vulnerable. EWENT also found that the road system is the most vulnerable, but also the most flexible of all the transportation systems.

Challenges and Barriers to Climate Change Adaptation

Following the presentations, Ms. Anne Choate, Vice President at ICF International, facilitated a discussion to identify the key challenges and barriers to infrastructure adaptation. At the start of the discussion, she gave a brief presentation to frame the discussion.

Over the past year and a half, Ms. Choate has supported the FHWA in hosting 5 adaptation peer exchanges with states and MPOs. These workshops have shown that while each region of the country is unique, many DOTs and MPOs are struggling with similar challenges. Common challenges include:

- There is both too much and too little vulnerability assessment information available. For example, high quality elevation, facility location, and maintenance records are often poorly managed or non-existent. However, paradoxically, DOTs and MPOs also often feel overwhelmed

by the amount of climate data available. Much of the available data on climate are provided in disparate formats and require significant manipulation.

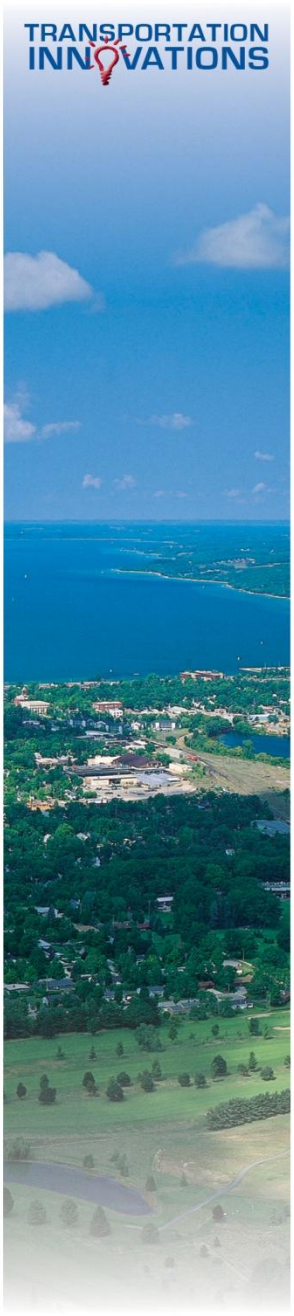
- Transportation decision-makers sometimes feel that available climate information is too uncertain for use in decision-making.
- State DOTs and MPOs have found that the public perception that climate change is a "political" issue leads to difficulty communicating with stakeholders.
- Many agencies feel that there is insufficient funding to maintain the status quo, let alone funding available for projects that increase system resilience.
- Many transportation agencies have not historically kept detailed maintenance records, asset inventories, and other data management systems.

Transportation agencies across the country are addressing these challenges in different ways. However, several common lessons learned emerged from the five FHWA peer exchanges:

- Vulnerability assessments are not "one-size-fits-all" and can be scaled up or down to fit specific needs. Further, vulnerability assessments offer opportunities for interagency collaboration and cooperation, in addition to stated goals to reduce climate vulnerability. In many cases, building these relationships is an important outcome of the assessment.
- Real possibilities exist for "mainstreaming" adaptation in emergency management, asset management, and other areas.
- Strong leadership at all levels is a prerequisite for climate adaptation action.

Appendix A: Agenda

AASHTO Infrastructure Adaptation Workshop



Adapting Infrastructure to Extreme Weather Events: Best Practices and Key Challenges

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Grand Traverse Resort & Spa

Agenda

	May 20th, 2012
8:00 AM	**Welcome and Introductions** • John Horsley, AASHTO • Butch Wlaschin, Federal Highway Administration
8:15 AM	**State Case Studies – Panel and Facilitated Discussion** Three states, selected based on different climate/extreme weather experiences and the approaches being used, will briefly discuss their experience with adaptation strategies. Facilitated discussion among the states will follow. • David Dye, Washington State DOT • Rick Land, CalTrans • John Adam, Iowa DOT
9:40 AM	**Europe's Adaptation of Infrastructure to Climate Change and Extreme Weather** • Philippe Crist, Administrator, International Transport Forum, Paris, France
10:00 AM	**Key Challenges and Risks – Facilitated Discussion** Participants will exchange information on current best practices in infrastructure adaptation for extreme weather events and discuss existing and potential future challenges in addressing these events.
10:30 AM	**Recommended Actions for AASHTO – Facilitated Discussion** Participants will discuss actions that AASHTO could take to help State DOTs address these challenges and mitigate climate change risks.
10:50 AM	**Wrap-up**
11:00 AM	**Adjourn**

Appendix B: Final Participant List

AASHTO Infrastructure Adaptation Workshop

Adapting Infrastructure to Extreme Weather Events: Best Practices and Key Challenges

LIST OF PARTICIPANTS

Name	Title	Affiliation	Email
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Shinri Sone		Nilim, Japan	
Grant Levi		North Dakota DOT	
Hal Kassoff	Senior Vice President	Parsons Brinckerhoff	
Gary McVoy	Transportation Sustainability Lead	Parsons Brinckerhoff	
Bob Skinner		Transportation Research Board	
Chris Jenks		Transportation Research Board	
Michael Taylor		University of South Australia	
Mal Kerley	Chief Engineer	Virginia DOT	Mal.Kerley@vdot.virginia.gov
Pekka Leviahargas		VTT	
Dave Dye	Deputy Secretary of Transportation and Chief Operating Officer	WSDOT	DyeD@wsdot.wa.gov

Appendix C: Presentations

The presentations given at the peer exchange were:

1. Caltrans Climate Change Adaptation *(Rick Land, Caltrans)*

2. Washington State DOT's Vulnerability Assessment: Asking the "Climate Question" *(Dave Dye, WSDOT)*

3. Extreme Weather Impacts on European Networks of Transport (EWENT), *(Dr. Pekka Leviäkangas, VTT Technical Research Center of Finland)*

4. State and Local Infrastructure Adaptation: Lessons Learned from Across the United States *(Anne Choate, ICF International)*

The presentations are available on AASHTO's Center for Environmental Excellence and Transportation and Climate Change Resource Center.