# FHWA Climate Change Resilience Pilots Peer Exchanges

Baltimore, Maryland

July16-17, 2014

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U.S. Department of Transportation
**Federal Highway Administration**

# FHWA CLIMATE RESILIENCE PILOTS PEER EXCHANGES SUMMARY

*BALTIMORE, MARYLAND*
*JULY 16-17, 2014*

**Pilot Program Overview**

The Federal Highway Administration's (FHWA)'s Climate Resilience Pilot Program seeks to assist state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and Federal Land Management Agencies (FLMAs) in enhancing resilience of transportation systems to extreme weather and climate change. In 2010-2011, FHWA sponsored five teams led by MPOs and state DOTs to conduct vulnerability and risk assessments of their transportation infrastructure. These teams pilot-tested the FHWA Climate Change and Extreme Weather Vulnerability Assessment Conceptual Model, and FHWA created a Vulnerability Assessment Framework based on feedback from these pilot projects.[1]

In 2013-2014, the Climate Resilience Pilot Program is continuing to advance the body of work and refine the Vulnerability Assessment Framework. The nineteen pilots selected to participate represent state DOTs, MPOs, and FLMAs from across the country. These pilot teams are partnering with FHWA to assess transportation vulnerability and evaluate options for improving resilience.

In order to build relationships and facilitate small group interaction, FHWA organized the nineteen pilot teams into three groups focused on the following topics: vulnerability assessments, adaptation options, and adaptation options focused on hydraulics. Throughout the program, the pilot teams are participating in webinars and peer exchanges that are tailored to the needs of each group. At the peer exchanges summarized in this report, the "adaptation options" and "adaptation options focused on hydraulics" groups were combined into one "adaptation" group.

[1] To learn more about the five 2010-2011 pilot projects, the draft conceptual model that was tested, and the revised framework, please see https://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/vulnerability_assessment_framework/index.cfm

## List of Acronyms

| | |
|---|---|
| ADOT&PF | Alaska Department of Transportation & Public Facilities |
| AASHTO | American Association of State Highway and Transportation Officials |
| ASCE | American Society of Civil Engineers |
| AADT | Annual average daily traffic |
| ADOT | Arizona Department of Transportation |
| BART | Bay Area Rapid Transit Authority |
| Broward MPO | Broward Metropolitan Planning Organization |
| Caltrans District 1 | California Department of Transportation District 1 |
| CAMPO | Capital Area Metropolitan Planning Organization |
| CTDOT | Connecticut Department of Transportation |
| CHART | Coordinated Highways Action Response Team |
| CMIP | Coupled Model Intercomparison Project |
| DST | Decision Support Tool |
| DOT | Department of Transportation |
| EIR | Environmental Impact Report |
| EPA | Environmental Protection Agency |
| FEMA | Federal Emergency Management Agency |
| FHWA | Federal Highway Administration |
| VAST | Federal Highway Administration Vulnerability Assessment Scoring Tool |
| FLMA | Federal Land Management Agency |
| FTA | Federal Transit Administration |
| GIS | Geographic information system |
| GRP | Gross Regional Product |
| HMCE | Hazard Mitigation Cost Effectiveness |
| Hillsborough MPO | Hillsborough County City-County Planning Commission/Metropolitan Planning Organization |
| HEC | Hydraulic Engineering Circular |
| IPCC | Intergovernmental Panel on Climate Change |
| Iowa DOT | Iowa Department of Transportation |
| LTEC | Least total expected cost |

| | |
|---|---|
| LIDAR | Light Detection and Ranging |
| LRTP | Long Range Transportation Plan |
| Maine DOT | Maine Department of Transportation |
| Maryland SHA | Maryland State Highway Administration |
| MassDOT | Massachusetts Department of Transportation |
| MPO | Metropolitan Planning Organization |
| MTC | Metropolitan Transportation Commission |
| MDOT | Michigan Department of Transportation |
| MnDOT | Minnesota Department of Transportation |
| MICA | Mobile Information Collection Application |
| NEPA | National Environmental Policy Act |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NWS | National Weather Service |
| NYSDOT | New York State Department of Transportation |
| NCTCOG | North Central Texas Council of Governments |
| ODOT | Oregon Department of Transportation |
| POSM | Project of Special Merit |
| REMI | Regional Economic Models, Inc. |
| RTEMP | Regional Transportation Emergency Management Plan |
| SLOSH | Sea, Lake, and Overland Surges from Hurricanes |
| Tn DOT | Tennessee Department of Transportation |
| TNC | The Nature Conservancy |
| T-COAST | Transportation-version of the Coastal Adaptation to Sea level rise Tool |
| USACE | U.S. Army Corps of Engineers |
| USDA | U.S. Department of Agriculture |
| USGS | U.S. Geological Survey |
| VHT | Vehicle hours traveled |
| VMT | Vehicle miles travelled |
| WSDOT | Washington State Department of Transportation |
| WCRP | World Climate Research Programme |

## Overview of Peer Exchanges

On July 16 – 17th, 2014, FHWA hosted a set of peer exchanges in Baltimore, Maryland, that brought together the pilot teams to share ideas, success stories, and lessons learned related to assessing and managing climate-related impacts on transportation assets and operations. This document is a summary of the key takeaways and insights from the peer exchange presentations and discussions. The following table lists the pilot teams represented. The appendix includes a list of the tools, resources, and needs identified; meeting agendas; the full participant list; and a list of presentations.

| Vulnerability Assessment Group | Adaptation Group |
|---|---|
| • Alaska DOT & Public Facilities (ADOT&PF) and FLMAs<br>• Arizona DOT (ADOT)<br>• Capital Area Metropolitan Planning Organization (CAMPO)<br>• Maine DOT<br>• Michigan DOT (MDOT)<br>• North Central Texas Council of Governments (NCTCOG)<br>• Tennessee DOT (TDOT) | • Broward Metropolitan Planning Organization (Broward MPO)<br>• California Department of Transportation District 1 (Caltrans District 1)[2]<br>• Connecticut DOT (CTDOT)<br>• Hillsborough County City-County Planning Commission/MPO (Hillsborough MPO)<br>• Iowa DOT<br>• Maryland State Highway Administration (Maryland SHA)<br>• Massachusetts DOT (MassDOT)<br>• Metropolitan Transportation Commission (MTC)<br>• Minnesota DOT (MnDOT)<br>• New York State DOT (NYSDOT)<br>• Oregon DOT (ODOT)<br>• Washington State DOT (WSDOT) |

The pilot team representatives convened on the morning of the first day to provide the full group with updates on their pilot project work. Each pilot representative introduced their team and presented a brief "elevator" speech that provided a high-level overview of their pilot efforts. Representatives from four pilot teams gave presentations that provided greater detail about their projects.

Attendees then split into two peer groups—vulnerability assessment and adaptation—on the afternoon of the first day and the morning of the second day for presentations and facilitated discussions.

- The vulnerability assessment group focused on ways to integrate vulnerability results into transportation planning and practice; strategies to develop proxy indicators; engaging partners and stakeholders; and tools and resources.

[2] Caltrans District 1 participated remotely during the second morning of the adaptation peer exchange.

- The adaptation group focused on ways to integrate adaptation results into transportation planning and practice; approaches to benefit cost analysis; strategies to establish and apply evaluation criteria; engaging partners; and adaptation at the asset level.

The full group reconvened at the end of the second day to share thoughts on discussions from the peer exchanges and areas where they need additional support.

## Presentations to the Full Group

### Introductory Pilot Project Presentations

Maryland SHA and ODOT provided updates on their pilot projects' progress and lessons learned.

Maryland SHA shared their vulnerability assessment process. Key data sets and resources used included the SHA's Coordinated Highways Action Response Team (CHART) road closure data (although data sets were incomplete); a geographic information system (GIS) database of road centerlines; National Pollutant Discharge Elimination System (NPDES) discharge data; the FHWA Coupled Model Intercomparison Project (CMIP) Climate Data Processing Tool precipitation projections; and university-developed sea level rise maps.

Maryland SHA developed a three-tiered process for conducting county-level vulnerability assessments. The tiers are as follows:

1. Based on a GIS overlay of assets and climate stressors, Maryland SHA eliminated assets from their study that are not projected to be exposed to climate stressors.
2. Using the FHWA Vulnerability Assessment Scoring Tool (VAST) and the Maryland SHA developed hazard vulnerability index (HVI), the pilot team rated assets that were not eliminated in tier 1.
3. If needed, Maryland SHA would conduct a detailed, site specific watershed analysis to better understand impacts and design adaptation strategies.

Under the current pilot project, Maryland SHA is not conducting any tier three assessments; however, this next step would be required to develop detailed adaptation strategies.

Overall, Maryland SHA found VAST to be a useful tool but they provided some lessons learned from using it. VAST was most useful for assessing the vulnerability of bridges, but for small pieces of infrastructure, it became an overly cumbersome process. In order to minimize this issue, Maryland SHA would consider conducting a watershed analysis of areas that are dense with small assets. This would likely result in useful information for a smaller level of effort. SHA developed the HVI to evaluate flood impacts to roads. HVI is a formula that generates a score based on functional class, emergency evacuation route status, and extent and depth of projected flooding. Maryland SHA decided to eliminate annual average daily traffic (AADT) from the vulnerability indicators to ensure that critical but low volume rural roads were not discounted. As an alternative approach, they sorted vulnerabilities by functional class to compare vulnerabilities across similar assets. Maryland SHA held a series of workshops with their engineers to review and modify the VAST vulnerability results. The

engineers identified inundation depth and peak discharge as the most valuable vulnerability indicators and downplayed the value of the current floodplain vulnerability.

Maryland SHA concluded there are no one-size-fits-all adaptation solutions and that many locations will require detailed watershed analyses to determine appropriate adaptation strategies. As part of the adaptation development process, Maryland SHA is struggling to determine the appropriate level of resiliency to build into infrastructure that serves low-lying communities. It is difficult to assess whether the local communities will adopt a protection or retreat strategy and, therefore, it is difficult to determine the appropriate transportation adaptation strategy. Their adaptation strategy development process is also influenced by Maryland House Bill 615, which requires all state-funded structures to maintain two feet of free board above the 100 year floodplain. The regulation currently only applies to buildings; however, the draft guidance document applies the regulation to all infrastructure, including roadways on state land. This requirement would increase resiliency but could also considerably increase the cost of roadway construction.

Ultimately, Maryland SHA plans to integrate the processes developed for this pilot project into a risk-based asset management system that can be used to inform policy actions. Additionally, Maryland SHA is incorporating climate change requirements (e.g., questions, check-boxes) into their National Environmental Policy Act (NEPA) process.

ODOT is studying a variety of climate stressors including increases in temperatures and wildfires, changes in winter precipitation and concentrated precipitation events, decreases in snowpack and summer water supplies, and sea level rise. ODOT has selected focus areas to look at the impact of these climate stressors on landslides, coastal erosion, rock slope failures, and flooding.

ODOT is using a variety of sources of climate data. First, they used the past five years of maintenance dispatch data to map weather-related issues and identify "hot spots" within their system that have historically been susceptible to climate impacts. They analyzed what types of climate events have caused problems in the past. It was found that three to six inches of rain over a five-day period caused peak impacts. Even with this data set, it was still valuable to speak with maintenance personnel to prioritize study corridors, ground truth the data, and provide qualitative input. Second, ODOT found the CMIP Climate Data Processing Tool to be highly valuable for providing downscaled precipitation data at a site level. Third, ODOT is currently leading the development of sea level rise maps for the state and will continue to move the work forward until another entity takes over. ODOT used these maps to conduct an initial GIS-based screen for exposed assets by flagging assets. Based on these various sources of qualitative and quantitative data, ODOT assigned a qualitative vulnerability rating to roads within their focus areas.

After conducting the vulnerability analysis, ODOT used a statewide economic model to determine the economic impacts of losing a road. In almost all cases, the economic impacts were found to be minimal due to low AADT and the availability of alternate routes.

In the future, ODOT will be working to close gaps in their asset maintenance database related to capturing storm impacts on coastal locations, standardizing reporting of climate impacts, and gathering information on the rate of coastal erosion. Additionally, they plan to

replicate the methods of the pilot project in other locations in order to inform investment decisions.

## Integrating Pilot Project Results into Transportation Planning and Practice

MTC and MassDOT presented on actions they have undertaken to integrate climate change adaptation into their current planning and engineering practices, and their plans for integrating the pilot project results.

MTC conducted a vulnerability assessment during the first round of Climate Resilience Pilots and is now refining that analysis and undertaking an adaptation planning process for a portion of the San Francisco Bay Area. The results from the first pilot project were used in the Long Range Transportation Plan (LRTP) Environmental Impact Report (EIR). This report included a section on sea level rise and documented all transportation investments and proposed areas of land use development that would be impacted by mid-century sea level rise. Additionally, it included descriptions of a series of adaptation measures that local agencies could undertake to minimize climate change impacts.

The current pilot project consists of developing a series of adaptation measures for three core focus areas with a variety of multi-modal transportation assets. In order to develop effective adaptation strategies, MTC assessed the shoreline hydrodynamics and the sea level rise water flow paths to determine "weak points" in the coastal protection system. Their proposed adaptation options vary from asset-specific, to focus-area wide, to implementing agency-specific strategies. In order to select amongst the wide range of adaptation options, MTC assigned qualitative scores to the strategies to determine their alignment with the overall project and agency goals. Once the adaptation strategies had been refined to a subset of the original list, they were vetted with a technical working group. The next step is to conduct an economic analysis and evaluate the strategies for their impacts on the environment, the economy, social equity, and governance. Currently, the most promising adaptation strategies include an offshore breakwater, several living levees, an informational drainage study, and the integration of the Bay Area Rapid Transit Authority (BART) vulnerability assessments into their planning process.

In the future, MTC plans to:

- expand this work to other geographic areas and/or assets;
- further refine the adaptation strategies;
- use the information gathered to inform local and regional long range planning processes;
- identify ways to integrate adaptation planning into existing planning processes;
- prioritize funding for vulnerable assets through a robust asset management program;
- include flooding/inundation in Regional Transportation Emergency Management Plan (RTEMP) updates; and
- update design standards to account for future changes in climate.

MassDOT is assessing the vulnerability of and adaptation options for the Boston Central Artery Tunnel. They have invested in building an extremely detailed model of storm surge

and flooding which shows water advancement, spread through the city, and retreat over time. The model uses a Monte Carlo method to model numerous storm tracks over thousands of scenarios. Every model run contains information on the probability of flood occurrence and the projected depth of inundation at every node of the model grid. The highest densities of grid nodes are clustered over the central artery to ensure sufficient data resolution. However, due to current limitations in Light Detection and Ranging (LIDAR) data, small structures such as walls may not be properly represented in the model. In some places, MassDOT was able to correct for this with hand-held GPS devices from the U.S. Army Corps of Engineers (USACE).

MassDOT has determined that there are a significant number of vulnerabilities within the tunnel system due to ventilation grates, sub-grade electrical equipment, etc. When conducting their vulnerability assessment, they found it useful to distinguish between individual assets that were vulnerable and vulnerable facilities which house a number of assets.

MassDOT is considering expanding their flood model to cover the entire Massachusetts coast with funding from additional partners. A model of this type could help inform revisions to Federal Emergency Management Agency (FEMA) floodplain maps.

## Vulnerability Assessment Peer Exchange

### Integrating Vulnerability Assessment Results into Transportation Planning and Practice

The representative from each vulnerability assessment pilot identified tangible next steps to integrate the project results into planning and practice. The most common next steps are:

- **Integrate results into broader transportation planning:** Incorporate the criticality and vulnerability findings into the broader context, such as the long range plan.
- **Integrate results into asset management systems:** Incorporate criticality and vulnerability findings into an asset or project database to drive the project prioritization process or risk-based decision making when an asset comes up for renewal.
- **Inform maintenance procedures:** Share the results, such as a list of vulnerable assets and thresholds, with the maintenance department.
- **Inform upper management:** Continue to meet with upper management to inform them on key findings and potential next steps to reduce vulnerability and explore sources of funding to continue the work.
- **Inform stakeholders:** Share the project results with stakeholders to get their buy-in and engage with them to begin to elicit socially and politically feasible strategies to reduce vulnerability. Furthermore, share results with other groups working on related issues in the project area in order to coordinate efforts.
- **Stay informed on strategies for adaptation:** The pilot teams would like to learn more about strategies to advance adaptation, such as approaches for conducting cost-benefit analysis of adaptation options and updates to design standards.

The agencies will need to engage a range of actors including commissioners and decision-making bodies, project and asset database staff, chief engineers, technical committees, maintenance crews, and public stakeholders.

## Developing Proxy Indicators for Vulnerability

Representatives from NCTCOG and MDOT presented on their approaches for using existing data sets to assess vulnerabilities. NCTCOG worked with project partners to collect data on local and regional historical weather, future climate, soil and hydrology, heat island effects, and transportation asset maintenance. The team utilized this data to develop an index of regional criticality based on performance measurements; conduct a coarse GIS screening of the region to identify areas that are potentially vulnerable; and establish asset thresholds for exposure, sensitivity, and adaptive capacity based on data and partner consultation. The pilot team found the soil data from U.S. Department of Agriculture (USDA) and the local university's subject matter expertise particularly useful; the study combined proxy information to develop a map of drought and heat-sensitive soils and analyze soil moisture content as a proxy for flash flooding.

NCTCOG identified a set of best practices and lessons learned for utilizing existing data sets and the results of the analysis:

- Establish a linked framework for multiple applications of the varied existing data sets. For example, to reconcile overlay of data from multiple sources, the pilot team integrated non-spatial data by making informed assumptions.
- Use the analysis of climate vulnerabilities to prioritize investments, inform approaches to maximize the life-cycle of existing assets, and start the discussion on adaptation.
- Use the data and outcomes from the analysis to improve transportation performance, accountability, and delivery. These practices can help meet the public's expectations to provide the best service using available resources.
- Data can have gaps. The reliability of the data and openness for distribution varies by source and the last set of data can be expensive to collect. Although most existing data sets can be plentiful, be proactive to "ground-truth" them, or connect the information from reports with knowledge from stakeholders.

MDOT utilized the department's existing asset management dataset and road weather information for the pilot project's vulnerability assessment. MDOT's database contains robust data on infrastructure assets and conditions, including elevation, age, usage, and renewal cycle. The state is particularly subject to snow events and has invested in road weather management technology to better manage winter maintenance, operations, and service. The pilot team also gathered data from roadside environmental sensor stations and MDOT-owned snow plow vehicles equipped with technology to collect real-time data on weather and road conditions. The pilot team is working on applying climate model scenarios to the asset information. MDOT intends to integrate the results of the vulnerability assessment into the long range plan, five-year call for projects, and the asset management system and plan in order to inform future planning and decision making.

The vulnerability assessment pilot representatives pointed to similar resources they are using to collect data, such as CMIP climate data and the U.S. Geological Survey's (USGS) StreamStats. However, some of the pilot teams are struggling with data gaps, particularly on the asset side and at the local level. The pilot teams would also like data and approaches to quantify costs and benefits to assist in conveying the magnitude of extreme weather-related costs and the benefits of adaptation.

## Partner and Stakeholder Engagement

The peer exchange participants discussed the partnerships developed for their projects, key strategies for successful engagement, and lessons learned.

The pilot teams relied on partnerships and relationships to gain buy-in and gather data and input for the vulnerability assessments. The representatives from the pilot teams also recognized they would continue to utilize these relationships to ground-truth the results and integrate the results into transportation planning. The types of partners and stakeholders ranged depending on the pilot project's context, and the most common and valuable people the pilot teams engaged were:

- **Maintenance staff:** Field staff have a detailed understanding of the conditions and performance of local assets. In some cases, the knowledge is not formally recorded or the way information is captured locally differs across the state; pilot teams found that engaging these departments early in the vulnerability assessment facilitated data collection.
- **Internal technical advisors:** In addition to the maintenance staff, other internal staff such as engineers and asset management staff informed the vulnerability assessments.
- **External experts**: External stakeholders provided insight on the transportation systems and climate and other local stressors. For example, the DOT pilot teams engaged local MPOs and vice versa. Researchers at local universities provided expertise and existing data on conditions specific to the region, such as soil and climate data. Local, state, and federal agencies (e.g., Army Corps of Engineers) also shared flooding and climate data.
- **Internal and external leadership**: The pilot teams found it very useful to gain input and support from internal leadership and local government officials.

The peer exchange participants identified the following strategies for successfully engaging partners and stakeholders:

- Maps featuring local assets and basic environmental systems helped engage stakeholders. Meeting or workshop participants, such as field staff, were asked to identify areas on the maps that are vulnerable under existing climate conditions and may experience potential issues under future scenarios.
- In some instances, the pilot teams had to prioritize which partners and stakeholders to engage because of the wide range of options. Maryland SHA recommended starting with a department or group that can serve was a hub of information to help narrow the group of contacts and guide referrals to other relevant sources.

- Some pilot teams had to manage and coordinate the expectations of their partners and stakeholders within the scope of their studies. One strategy is to adhere to the defined scope and emphasize the benefits of the study and how results can be applied to other assets. A few project teams also recognized that they will need to continue to coordinate with partners, especially since some of the pilot efforts and findings might exceed their traditional agency roles.

## Using Tools and Resources to Assist in Vulnerability Assessments

Representatives from the MaineDOT pilot presented on their use of a tool to evaluate the vulnerability of transportation assets to sea level rise and storm surge and evaluate the costs and benefits of alternative design structures. The project team is working with six towns that overlap with the study area of an ongoing Environmental Protection Agency (EPA)-funded Project of Special Merit (POSM).

The study intended to utilize and refine the consultant's (Catalysis Adaptation Partners) stakeholder-driven Transportation-version of the Coastal Adaptation to Sea level rise Tool (T-COAST) and the associated Decision Support Tool (DST) to rank the criticality of roads, bridges, and culverts. However, the pilot team found that they did not find enough specific data about assets (e.g., scour critical information) to input into the DST. Furthermore, the small sample size of the assets in the towns meant that the team did not need to rank multiple critical assets. The revised overall project approach:

- selected three modeled scenarios (no sea level rise, 3.3 feet, and 6.6 feet);
- used historical flooding reports and local expert knowledge to select one critical asset per town;
- developed three adaptation design options (replace in-kind, replace with resiliency up to 3.3 feet of sea level rise, and up to 6.6 feet); and
- used the T-COAST tool to apply a depth-damage function (which describes the damage and costs for an asset at each flood elevation) to the scenarios to estimate costs.

The T-COAST tool is designed to examine the costs and benefits of the design alternatives. Costs are defined as the initial replacement or construction costs and maintenance and repair after each storm surge event. Benefits are the avoided damages from a range of sea level rise and storm surge scenarios. In the tool, users can specify parameters such as exceedance curves, sea level rise curves, and depth-damage functions. The pilot team worked with the local engineers and maintenance crew to create depth-damage functions specific to the critical asset in each town. The model output provides a matrix of expected damage estimates under the sea level rise and adaptation design scenarios and the resulting benefit-cost ratios can be applied to prioritize action. After this pilot project, the project team intends to test the DST in the greater region with a larger sample size of assets.

The peer exchange participants noted that tools for vulnerability assessments help facilitate the conversation about impacts and adaptation. For example, an "abandon" scenario is not included in the T-COAST tool but the results from the tool should start a discussion with communities and decision makers about selecting adaptation options, social impacts, and the possibility of an abandon scenario.

## Adaptation Peer Exchange

### Integrating Adaptation Results into Transportation Planning and Practice

Representatives from the adaptation-focused pilots discussed concrete steps they are planning to undertake to integrate climate change vulnerability into their existing planning and practices. They also discussed barriers to implementation, and assistance that would help them reach the point of successful implementation. Some key takeaways included:

**Plans**

- Pilot teams plan to begin adaptation implementation by addressing infrastructure that has historically been impacted by weather events and then moving on to assets that are anticipated to be affected by future weather events.
- Several pilot teams are striving to incorporate the results of their project into their transportation asset management plan; however, there is no clear template to follow. If successful, this integration will allow them to appropriately allocate funding to high risk assets.
- Some of the pilot teams are considering ways to integrate climate change vulnerability into the environmental review process. At a minimum, this could include a checkbox on whether or not the asset is exposed to sea level rise and if so, requiring that sea level rise be addressed in the project design. For a higher level of effort, projects may consider a climate change specific design alternative to demonstrate the costs and impacts of not addressing these issues.
- At a minimum, the pilot teams were looking to ensure that the most up to date climate data, such as National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Rainfall, is being used in project design.
- Several pilot teams included a next step of conducting thorough inventories of existing assets. This was considered a necessity for obtaining a complete picture of risk and vulnerability.
- Pilot teams anticipate that immediate next steps include engaging upper management on the results of the project to discuss further action.

**Needs**

- Developing climate projections tied to the design life of the asset would help alleviate the confusion over what climate information should be used in design.
- Pilot teams would like assistance in providing design guidance to the hydraulic community on how to design based on future climate projections rather than historic data.
- Some pilot representatives identified the need to shepherd climate change into seismic resiliency plans and emergency response plans in order to achieve comprehensive corridor resilience.
- Pilot teams need guidance on how to best monitor and capture the frequency, severity, and trends in existing natural stressors (e.g., landslides and erosion) in order to be better prepared for them and better predict future changes in these events.
- Most pilot teams conducted or are going to conduct some public outreach as part of their pilot; however, the pilot representatives recognize the need to conduct more

comprehensive public outreach on the impacts of climate change and potential adaptation strategies.
- Pilot representatives emphasized the need to identify the co-benefits of adaptation such as the economic benefits of being a "climate resilient city" in which businesses will be able to maintain business continuity in the event of an extreme weather event.

**Lessons Learned**
- Some pilot teams found that the process of discussing future climate change impacts with a wide range of agency employees has already led to the incorporation of some climate change information into planning and operations without the need for mandated action by agency management. This bottom-up process has resulted in significant benefits to the organization.
- It is the responsibility of the MPO to provide information to their member agencies, but not to directly design or build transportation assets. They are, thus, planning different ways to use the resources available to them to influence projects, including incorporating performance measures on resiliency into long-range transportation plans and considering vulnerability and risk in the allocation of funding.

## Benefit Cost Analysis

Hillsborough MPO and NYSDOT presented on their approaches to conducting benefit cost analyses. Hillsborough MPO is assessing the economic impacts of flooding due to sea level rise using FEMA floodplain data, the NOAA Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model, the GeoPlan sea level rise viewer from the University of Florida, and an economic model from Regional Economic Models, Inc. (REMI). Hillsborough used the REMI model to calculate the change in Gross Regional Product (GRP) and a suite of other economic indicators from the loss of vulnerable transportation assets. The impacts on regional transportation patterns were assessed by removing individual assets from the Hillsborough MPO's travel model. This provided information on changes in recreational and commute trips, freight patterns, etc. One problem with this approach is the assumption that only the individual asset will be affected by sea level rise or a storm event. In reality, surrounding assets are likely to be impacted and additionally increase disturbances in the transportation network. Hillsborough MPO also took into account the replacement cost of the asset, AADT on the roadway, the time required to recover, delay hours, increases in vehicle miles travelled (VMT), vehicle hours traveled (VHT), and lost trips. For one asset, these factors combined to result in a calculated loss of $4-5 million in weekly GRP. In order to reduce these costs, Hillsborough has developed a phased response plan to bring assets back on-line sooner.

Hillsborough is working to incorporate the results of this study into their long range plan by including a performance measure on "reducing crashes and vulnerability." They are also developing various investment strategies which could include investing at historic rates (that was estimated to result in an 8-week disruption and $447 million loss to the economy following a major storm event), or heightened levels of investment (that could reduce both the time delays and the economic costs of recovery). These investments are documented in a matrix of risk management strategies which outline appropriate investment levels and guidance on implementation.

Hillsborough's lessons learned from throughout this process include the need for sufficient time to coordinate across agencies; the value of having one agency and one staff member lead the project; the difficulty of obtaining project cost data, variation in travel model outputs; and that travel impacts are regional in nature (so analyzing the impacts of climate change on a single asset may not capture the complete picture).

NYSDOT and The Nature Conservancy (TNC) are assessing the impacts of increased temperature and precipitation, and the resultant flooding and landslides in the rural Lake Champlain Basin. Storm events are overwhelming local culverts but the funding to replace them exceeds local budgets. The community and TNC are concerned about the triple bottom line when discussing adaptation options – ecological impacts (e.g., fish, habitat, water quality), economic impacts (e.g., flood damage, travel delay, tourism), and social impacts (e.g., health and safety). To help assess the benefits and costs of adaptation strategies, TNC is building an economic tool. This tool aids NYSDOT in determining when to invest in a culvert upgrade by providing information on long term costs to NYSDOT as well as the social, environmental, and ecological costs. TNC has decided to use a qualitative decision support tool for the social and environmental costs. The quantitative portion of the tool (the economic factors) includes the capital cost of the asset, the ongoing operations and maintenance costs, and the cost of replacement. The qualitative economic benefits include avoided flood damage and freight disruptions as well as improved mobility and safety. The quantification methodology is based on FEMA and DOT/EPA practices and FEMA records of historic damage costs.

The Nature Conservancy found that climate resilient culverts are 15% to 100% more expensive than traditional designs; however, those costs can be recouped over a 25-50 year time period due to reduced failures during large storms. The Nature Conservancy has found it to be useful to use fish passage as the driving argument for upsizing the culverts.

Existing barriers to moving forward with implementation include the current federal emergency funding requirements which makes it more cost effective for rural communities to wait until after a failure to repair a culvert rather than proactively upgrading the facility to eliminate future failures.

## Establishing and Applying Evaluation Criteria for Adaptation Strategies

The pilot representatives discussed the process of developing evaluation criteria by which to rank various adaptation strategies. Some of the insights shared are summarized below.

Several pilot representatives emphasized the importance of using metrics that are consistent with other agency goals and performance measures such as moving people, creating jobs, and strengthening the economy. These metrics have already been vetted within the agency and the consistency allows for streamlined integration into existing planning processes.

Stakeholder needs were identified as important to consider at the outset. For example, efforts to identify good strategies should consider the public's tolerance for risk of service disruption which varies between communities

One pilot representative also noted that the public preferred to discuss adaptation when an environmental group was leading the conversation (as opposed to politicians) and the public is often interested in the near-term co-benefits of adaptation (such as ecological benefits)

Some examples of good criteria to use included:

- The lifecycle cost of the adaptation options. Some options will provide full protection while others will provide increased protection but still require occasional maintenance efforts and re-evaluation as the climate changes. For this reason, the lifecycle cost of the strategies must be considered, not just the upfront cost. A no-action option provides a baseline against which the adaptation measures can be evaluated.
- The ability of options to dovetail with existing funding opportunities such as maintenance, emergency, and ecology. The ability to leverage these funding sources increases the practicality of the adaptation option.

## Partner Engagement

The pilot representatives discussed the types of partners that they found to be most beneficial and best practices for partner engagement.

- **Universities:** In general, universities were found to be good partners for developing climate change data. The pilot representatives remarked on the affordability of graduate student work and the credibility that the academic institution lends to the science. However, some pilot teams did encounter problems with academic arguments over different "philosophical approaches" to sea level rise mapping.
- **U.S. Army Corps of Engineers (USACE):** The pilot teams had mixed experience partnering and coordinating with the USACE. The level of interaction and partnership seemed to vary based on the local USACE office, their existing workload, and the particular office that needed to be engaged.
- **Local Engineers:** Pilot teams that were able to engage local engineers found their input to be highly beneficial, though they also noted some challenges in collaborating. Several pilot teams conducted engineering-focused stakeholder meetings to obtain their input on risk tolerance and adaptation strategies. For example, Broward MPO developed a unique and highly beneficial partnership with the local American Society of Civil Engineers (ASCE) chapter. The ASCE chapter received funding through their organization to hold a public meeting for the project, which allowed civil engineers to come together and perform a peer review of the work. Broward MPO is hoping that this technical review will lend additional credibility to the project and lead to professional buy-in on the adaptation strategies.
- **State Agencies:** Oregon DOT has benefited from their partnership with other state agencies. A system of annual coordination meetings and ad-hoc communications throughout the year has resulted in a unified approach to vulnerability and adaptation planning with everyone using the same base climate change data.
- **Economists:** Several pilot teams formed partnerships with economists (either internal or external to their organization) to assist with the cost benefit analysis;

however, this is an area where the pilot representatives expressed a strong desire for additional support from FHWA. Their engineers were typically able to estimate construction costs but methods for calculating the socioeconomic benefits of adaptation do not exist. There was also confusion over how far the geographic extent of the analysis should extend and how to ensure that the asset is not being considered in isolation. For example, there has been a tendency to assume that if a community raises a bridge approach than the bridge will be resilient to storm surges and traffic over the bridge will be unaffected by storm events. However, the surrounding roads which may be low lying and inundated during future storm events. If this was to occur then even though the bridge approach would remain above water level, the traffic over the bridge would most certainly be affected by the storm.

- **Operations and Maintenance Staff:** Almost all of the pilot teams found it beneficial to partner with their maintenance departments to gain a deeper understanding of historical impacts to the system and repair and management strategies that have worked in the past. This ground-truthing with the experts who know the assets better than anyone else provided details that were unavailable in any other format. Complementary to this partnership, several pilot teams are considering refining their maintenance record processes to allow this information to be recorded in a more systematic fashion.

## Developing Adaptation Strategies at the Asset Level

MnDOT and Caltrans District 1 provided insights on their processes for developing appropriate adaptation strategies at the asset level.

MnDOT has experienced significant flooding events in recent years so their study is focused on assessing risk and developing adaptation strategies for a suite of transportation assets along rivers and floodplains. MnDOT is using SimCLIM to gather historical data on precipitation and develop gridded projections along watersheds. MnDOT is considering historical events in their vulnerability assessment (not future changes in climate); however, they are taking climate change into account when developing adaptation options.

MnDOT is using the 11-Step General Process for Transportation Facility Adaptation Assessments developed under the U.S. DOT Gulf Coast Phase 2 project to develop and assess the effectiveness of adaptation strategies. This process can be applied to both new facilities and retrofits to existing facilities. The steps are as follows:

1. Describe the Site Context
2. Describe the Existing / Proposed Facility
3. Identify Climate Stressors that May Impact Infrastructure Components
4. Decide on Climate Scenarios and Determine the Magnitude of Changes
5. Assess Performance of the Existing / Proposed Facility
6. Identify Adaptation Option(s)
7. Assess Performance of the Adaptation Option(s)
8. Conduct an Economic Analysis
9. Evaluate Additional Decision-Making Considerations
10. Select a Course of Action
11. Plan and Conduct Ongoing Activities

MnDOT used VAST to assist with assessing asset vulnerability through an indicator-based scoring approach. MnDOT selected indicators for each component of vulnerability:

- Exposure indicators included stream velocity; previous flooding issues; belt width to span length ratio of bridge, culverts, and pipes; median stream belt width of roads; number of potential stream bank erosion locations; and natural drainage capacity
- Sensitivity indicators included pavement type; scour rating; substructure condition; channel condition; culvert condition; pipe condition; and percent change in peak design flow required for overtopping
- Adaptive capacity indicators included AADT; detour length; flood control; and truck VHT

MnDOT found the tool to be more effective at assessing adaptive capacity at a system level rather than at the asset level. In the future, they may consider assessing adaptive capacity in a workshop setting rather than as a desk-top activity.

MnDOT cautions against expanding all culverts to increase resiliency; expanding a culvert can cause a velocity drop which encourages the deposition of settlement in the culvert and leads to maintenance concerns.

Caltrans District 1 is developing adaptation strategies at four locations, including:

- a coastal rural area with only one access road;
- a highway that is low lying and adjacent to Humboldt Bay;
- an inland connector that has historically experienced flooding from Clear Lake; and
- a bridge on Highway 1 over Garcia River.

Caltrans is using a variety of existing models to determine precipitation runoff patterns, coastal cliff erosion from storms and sea level rise, and a coastal dune erosion model. This information is being corroborated with maps of historic maintenance needs due to weather-related events. Caltrans prepared these maps to display hot spots for weather-related maintenance costs and maintenance frequency to establish patterns of past impacts. In general, the data was easier to manipulate in Microsoft Excel but the visual maps were an effective communication tool.

Caltrans is considering four types of adaptation strategies:

1. **Accommodating** (e.g., raising the highway on piers to allow sea level rise to pass under). This strategy would reduce damage from storms in the near term but in the long term it would no longer offer the same protection due to sea level rise.
2. **Defending** (e.g., building a sea wall)
3. **Planned retreat** (e.g., retreating inland over time)
4. **Forced retreat** (e.g., allowing the highway to be overtopped during storm events and eventually allowing it to be inundated during the daily high tides)

For each asset, Caltrans is developing a phased adaptation process with short term, operational, and long-term strategies. These strategies are being vetted by a technical advisory group, a stakeholder group, and through public outreach meetings to discuss concerns and timeframes of interest. Caltrans is also weighing their adaptation options

against four criteria: equity, economy, equality, and governance. After this process is complete, Caltrans will conduct a benefit cost assessment for two to three adaptation options within each of their focus areas.

## Appendix A: Summary of Needs Identified

### Historical Data Collection

- Standardized approaches to gathering information on coastal storm impacts.
- A mobile phone or tablet application to allow maintenance crew to document weather event impacts. A starting point could be the USACE Mobile Information Collection Application (MICA) tool, which is currently only available on devices supplied by USACE (not available for public download).
- Standardized approaches to monitoring and projecting future rates of coastal erosion. This would be used to project the appropriate time to implement adaptation strategies.

### Identification and Application of Climate Change Data

Even in locations where there is agreement over the impacts of climate change, there is still hesitancy to use data from climate models due to the levels of uncertainty in the information. In addition, local agencies are concerned about their ability to frequently update their climate change data. Pilot representatives indicated they would like guidance on:

- Where to locate the most recent and relevant information;
- How frequently to go through the process of updating their design processes to account for different future conditions; and
- How to develop the most appropriate and locally-relevant future climate scenarios and how to integrate climate change considerations into planning and engineering design (potentially through revised design standards).

### Benefit Cost Assessments

Benefit cost analyses are crucial for creating a business case for investment in climate change adaptation. Without a long-term perspective on benefits, it is difficult to justify the higher initial cost of projects that are designed to be resilient to future changes in climate. The pilot representatives indicated a need for the following:

- Analyses to help convey the magnitude of extreme weather-related costs and the benefits of adaptation;
- A method for estimating adaptation costs for a type of asset instead of a specific project; and
- A centralized compilation of benefit cost analysis resources (e.g., adaptation economic reports).

### Integrating Vulnerability into Planning and Design

- Information on how to integrate climate change into engineering designs (e.g., changes to the design standards versus other approaches). State DOTs are hesitant to take a "one-off" approach to altering design standards; they would prefer to be provided with template changes by FHWA or the American Association of State Highway and Transportation Officials (AASHTO).

- Information on how to *balance* the risks of climate change with all the other stressors that planners and engineers must consider. For example, in some locations seismic risk remains a higher risk event and, therefore, eclipses public interest around planning for climate change. Climate change needs to be studied alongside all other considerations rather than being the sole driver of engineering design.
- Assistance in determining how to frame discussions of risk tolerance and determine appropriate levels of future risk for their agency (since it may become necessary at some point to abandon an asset or accept more frequent service disruptions than is currently acceptable).

**Funding**

Pilot representatives expressed concerns over the limitations of emergency relief funding. For example, once vulnerability has been identified by a DOT, it is no longer eligible for FEMA disaster relief funding (since it was a known risk). This is a concern for all of the pilot teams conducting vulnerability assessments that are unable to immediately fund adaptation strategies to minimize their risks.

FHWA emergency relief funds are not limited to repairing a facility to its pre-disaster condition. They can be used to repair to a higher standard if the total cost of the project being funded does not exceed the cost of repair or reconstruction of a "comparable facility" (defined as "a facility that meets the current geometric and construction standards required for the types and volume of traffic that the facility will carry over its design life"[3]). They can be used to rebuild to a standard that is more resilient to future extreme weather events if applicants present a cost effectiveness analysis to the FHWA Division Office.[4]

The pilot representatives are additionally frustrated with the lack of incentives to prepare infrastructure for extreme weather events prior to being impacted by one.

The peer exchange participants indicated a need for:

- Greater flexibility within existing funding sources;
- Additional federal funding for climate change adaptation projects; and/or
- Guidance on local funding mechanisms.

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[3] FHWA, MAP-21 – Moving Ahead for Progress in the 21st Century, Emergency Relief (ER) Questions & Answers, Accessed online September 24, 2014 at: http://www.fhwa.dot.gov/map21/qandas/qaer.cfm.

[4] See FHWA Emergency Relief Manual (updated May 31, 2013) for more information: http://www.fhwa.dot.gov/reports/erm/er.pdf.

## Appendix B: Tools and Resources

**Climate Data**

- Downscaled CMIP3 and CMIP5 Projections – Provides downscaled climate projections at spatial and temporal scales relevant to some of the watershed and basin-scale decisions facing water and natural resource managers and planners dealing with climate change. Content is based on global climate projections from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset referenced in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report and the phase 5 (CMIP5) multi-model dataset that informed the IPCC Fifth Assessment. http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/
- CMIP Climate Data Processing Tool – Microsoft Excel tool that translates downscaled climate model outputs into more relatable terms for planners and engineers. Pending posting on the U.S. DOT website.
- SimCLIM – Proprietary software with maps, graphs and charts of various aspects of historical and future climate change data that can be generated spatially for cities, counties, provinces, nations and the world. http://www.climsystems.com/simclim/
- Sea, Lake, and Overland Surges from Hurricanes (SLOSH) Model – SLOSH is a computerized numerical model developed by the National Weather Service (NWS) to estimate storm surge heights resulting from historical, hypothetical, or predicted 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. http://www.nhc.noaa.gov/surge/slosh.php
- StreamStats – Developed by USGS, StreamStats allows users to easily obtain historical records of streamflow statistics, drainage-basin characteristics, and other information for user-selected sites on streams. http://water.usgs.gov/osw/streamstats/

**Data Collection**

- Mobile Information Collection Application (MICA) – A mobile reporting application developed by USACE's Engineering Research and Development Center Information Technology Laboratory, provides easy-to-use, cost-effective method for fully-digital data collection and transfer from in-the-field. This technology has been effectively used to capture the impact of extreme weather events such as flooding and hurricanes. http://www.erdc.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/9254/Article/476670/mobile-computing-mica-and-blue-roof.aspx

**Benefit-Cost Guidance and Tools**

- Hazard Mitigation Cost Effectiveness (HMCE) Tool – The Federal Transit Administration (FTA) developed this tool to help transit agencies determine the long-term cost effectiveness of proposed adaptation measures. Use of the tool was required for submission to the Hurricane Sandy Competitive Resilience Notice of Funding Availability. http://www.fta.dot.gov/documents/FTA-User_Guide-final.pdf

- Regional Economic Model, Inc. (REMI) – A dynamic forecasting and policy analysis tool that can be variously referred to as an econometric model, an input-output model, or even a computable general equilibrium model. http://www.remi.com/
- HAZUS – Hazus was created by FEMA and is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes. It can estimate physical damage, economic loss, and social impacts from current extreme weather events. http://www.fema.gov/hazus
- Transportation-version of the Coastal Adaptation to Sea level Rise Tool (T-COAST) – Using economic data, climate projections, and water depth-damage functions developed by the USACE, T-COAST can present the total economic loss for specific severe weather event scenarios by economic sector. http://gis.fhwa.dot.gov/webcast10_coast.asp

**Vulnerability and Adaptation Methodologies**

- FHWA Climate Change and Extreme Weather Vulnerability Assessment Framework – A guide for transportation agencies interested in assessing their vulnerability to climate change and extreme weather events. It gives an overview of key steps in defining objectives and scope, assessing vulnerability, and incorporating results into decision making. The framework draws from the experience and work of the agencies involved in FHWA's 2010-2011 Climate Change Vulnerability and Risk Assessment Pilot Program. https://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/vulnerability_assessment_framework/
- FHWA Vulnerability Assessment Scoring Tool (VAST) – Microsoft Excel tool that guides the user through the process of conducting an indicator-based vulnerability screen of selected assets. Pending posting on the U.S. DOT website.
- Procedures to Evaluate Sea Level Change: Impacts Responses and Adaptation – Provides guidance for understanding the direct and indirect physical and ecological effects of projected future sea level change on USACE projects and systems of projects and considerations for adapting to those effects. http://www.iwr.usace.army.mil/Media/NewsStories/tabid/11418/Article/494304/procedures-to-evaluate-sea-level-change-impacts-responses-and-adaptation.aspx
- Monte Carlo Simulations – This is a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results; typically, one runs simulations many times over in order to obtain the distribution of an unknown probabilistic entity (e.g., the probability of a particular hurricane strength and trajectory).
- FHWA Gulf Coast Phase 2, 11-step General Process for Transportation Facility Adaptation Assessments – This Process is contained in the project's Task 3.2 Engineering Analysis and Assessments Report. It provides a methodology for determining how specific transportation assets could be affected by climate change, and assessing which adaptation options are effective and feasible. http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/gulf_coast_study/
- Hydraulic Engineering Circular (HEC) No. 25: Highways in the Coastal Environment – This manual provides guidance for the analysis, planning, design and operation of highways in the coastal environment. The focus is on roads and bridges (highways)

near the coast that are always, or occasionally during storms, influenced by coastal tides and waves. It is in the process of being updated to provide guidance on incorporating coastal climate change hazards into project design. http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm

- HEC 17: The Design of Encroachments on Flood Plains Using Risk Analysis – HEC 17 provides a methodology for following a least total expected cost (LTEC) design process. This document was drafted in the 1980's to characterize the risk of a particular site and build according to risk-based, life-cycle costs. FHWA is in the process of updating this document. http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm

## Appendix C: Conference Materials

# FHWA CLIMATE RESILIENCE PILOT PEER EXCHANGE

*VULNERABILITY ASSESSMENT GROUP AGENDA*

**July 16, 2014**

| | FHWA Climate Resilience Pilot Peer Exchange - Day 1 |
|---|---|
| **8:30 AM** | **Welcome and Introductions**<br>• Welcome and goals for the peer exchange– Becky Lupes (FHWA)<br>• Participant introductions, including "elevator speech" description of pilot project |
| **9:40 AM** | **Pilot Project Presentations + Q&A**<br>*Presentations*<br>• Maryland SHA<br>• ODOT |
| **10:40 AM** | **Break** |
| **11:00 AM** | **How to Integrate Pilot Project Results into Transportation Planning and Practice**<br>*Presentation*<br>• MTC<br>• MassDOT |
| **12:00 PM** | **Lunch** |
| **1:15 PM** | **How to Integrate Vulnerability Assessment Results into Transportation Planning and Practice**<br>*Activity*<br>1. Identify 3 tangible next steps for integrating the results of your pilot project into your everyday practice (and indicate key actors/collaborators who you will need to engage)<br>2. Identify barriers to taking these steps<br>3. Brainstorm solutions to overcome these barriers<br>4. Identify actions for advancing from vulnerability assessments to adaptation planning |
| **2:30 PM** | **Break** |
| **2:50 PM** | **Developing Proxy Indicators for Vulnerability**<br>*Presentations*<br>• NCTCOG – using regional data sets to assess local vulnerabilities<br>• MDOT – using asset management system and other existing data to assess vulnerability<br>*Discussion*<br>1. What are best practices for utilizing existing data sets to assess vulnerabilities?<br>2. What data sets have proven useful in your efforts?<br>3. What are some of the challenges (and work-arounds) in using these data sets to develop indicators of vulnerability? |
| **4:50 PM** | **Wrap-up and Plan for Day 2** |

| | FHWA Climate Resilience Pilot Peer Exchange - Day 1 |
|---|---|
| **5:00 PM** | **Adjourn** |

## July 17, 2014

| | FHWA Climate Resilience Pilot Peer Exchange - Day 2 |
|---|---|
| **8:30 AM** | **Recap of previous day (Tina Hodges)** |
| **8:45 AM** | **Getting the Most from Partner and Stakeholder Engagement**<br>*Discussion*<br>1. Which partners and/or stakeholders have been most valuable to your efforts? Why?<br>2. What best practices have you discovered in engaging these people? (e.g., format for soliciting information, appropriate role for partners and/or stakeholders in informing and advising project, communication techniques, approaches for documenting information, sharing data)<br>3. Have you identified any pitfalls to avoid? |
| **9:45 AM** | **Break** |
| **10:00 AM** | **Using Tools and Resources to Assist in Vulnerability Assessments**<br>*Presentation*<br>• Maine DOT – COAST and Decision support tool<br>*Discussion*<br>1. What tools or resources (e.g., guidance) have other pilot teams used to assist them with assessments of vulnerability?<br>2. Did the use of tools or resources provide any unexpected benefits (e.g., assist in communication with stakeholders)?<br>3. What additional resources, tools, and/or tool functionality would be nice to have?<br>4. What additional support, if any, is needed to assist in the use of tools? |
| **11:15 AM** | **Looking Back while Racing to the Finish**<br>*Discussion*<br>1. What lessons have emerged that surprised you?<br>2. What advice would you give to other agencies embarking on a vulnerability assessment?<br>3. What information or tools are you still struggling with that you need to complete your projects? How can FHWA help?<br>4. Any questions, concerns, or anticipated challenges with: report development; briefing management and gaining buy-in; follow-on work (and staff to support it) |
| **12:15 PM** | **Closing Remarks** |
| **12:30 PM** | **Adjourn** |

# FHWA CLIMATE RESILIENCE PILOT PEER EXCHANGE

*ADAPTATION GROUP AGENDA*

**July 16, 2014**

| | FHWA Climate Resilience Pilot Peer Exchange - Day 1 |
|---|---|
| **8:30 AM** | **Welcome and Introductions**<br>• Welcome and goals for the peer exchange– Becky Lupes (FHWA)<br>• Participant introductions, including "elevator speech" description of pilot project |
| **9:40 AM** | **Pilot Project Presentations + Q&A**<br>*Presentations*<br>• Maryland SHA<br>• ODOT |
| **10:40 AM** | **Break** |
| **11:00 AM** | **How to Integrate Pilot Project Results into Transportation Planning and Practice**<br>*Presentations*<br>• MTC<br>• MassDOT |
| **12:00 PM** | **Lunch** |
| **1:00 PM** | **How to Integrate Adaptation Results into Transportation Planning and Practice**<br>*Activity*<br>1. Identify 3 tangible next steps for integrating the results of your pilot project into your everyday practice (and indicate key actors/collaborators who you will need to engage)<br>2. Identify barriers to taking these steps<br>3. Brainstorm solutions to overcome these barriers<br>4. How will you implement the adaptation strategies that you have identified? |
| **2:00 PM** | **Benefit Cost Analysis**<br>• Hillsborough<br>• NYSDOT<br>*Discussion*<br>• What are best practices that have worked well to assess economic implications of adaptation strategies?<br>• What data sources, tools, experts have proven useful?<br>• What challenges remain? |
| **3:30 PM** | **Break** |

| | FHWA Climate Resilience Pilot Peer Exchange - Day 1 |
|---|---|
| **3:50 PM** | **Establishing and Applying Evaluation Criteria for Adaptation Strategies**<br>*Discussion*<br>1. What evaluation criteria do you plan to use in distinguishing between alternatives and identifying the most promising options?<br>2. What evaluation criteria do you think will be most useful in communicating with stakeholders?<br>3. What evaluation criteria will best reflect the needs and priorities that decision makers are concerned with? |
| **4:50 PM** | **Wrap-up and Plan for Day 2** |
| **5:00 PM** | **Adjourn** |

## July 17, 2014

| | FHWA Climate Resilience Pilot Peer Exchange - Day 2 |
|---|---|
| **8:30 AM** | **Recap of previous day (Becky Lupes)** |
| **8:45 AM** | **Getting the Most from Partner Engagement**<br>*Discussion*<br>1. Which partners have been most valuable to your efforts? Why?<br>2. What best practices have you discovered in engaging partners? (e.g., format for soliciting information, appropriate role for partners in providing institutional knowledge that informs identification and evaluation of adaptation strategies, communication techniques, approaches for documenting information, sharing data)<br>3. When is the best time to engage partners in the project?<br>4. Have you identified any pitfalls to avoid? |
| **9:45 AM** | **Developing Adaptation Strategies at the Asset Level (Part I)**<br>*Presentations*<br>• MnDOT<br>• Caltrans |
| **10:25 AM** | **Break** |
| **10:45 AM** | **Developing Adaptation Strategies at the Asset Level (Part II)**<br>*Discussion*<br>1. What types of strategies are other pilot teams considering?<br>2. What are options for considering upstream and downstream effects or surrounding assets?<br>3. How do adaptation strategies fit in with asset management? |

| | |
|---|---|
| **11:15 AM** | **Looking Back while Racing to the Finish**<br>*Discussion*<br>1. What lessons have emerged that surprised you?<br>2. What advice would you give to other agencies embarking on adaptation planning?<br>3. What information or tools are you still struggling with that you need to complete your projects? How can FHWA help?<br>4. Any questions, concerns, or anticipated challenges with: report development, briefing management and gaining buy-in, follow-on work (and staff to support it) |
| **12:15 PM** | **Closing Remarks** |
| **12:30 PM** | **Adjourn** |

# FHWA Climate Resilience Pilot Peer Exchange

**July 16th – 17th, 2014**
**Baltimore, Maryland**

*VULNERABILITY ASSESSMENT GROUP LIST OF PARTICIPANTS*

| Name | Affiliation |
|---|---|
| **Vulnerability Assessment Pilot Participants** | |
| Kristen Gade | Arizona Department of Transportation |
| Cathy Stephens | Capital Area Metropolitan Planning Organization |
| Judy Gates | Maine Department of Transportation |
| Samuel Merrill | Maine pilot team (Catalysis Adaptation Partners) |
| Niles Annelin | Michigan Department of Transportation |
| Jeff Neal | North Central Texas Council of Governments |
| Alan Jones | Tennessee Department of Transportation |
| **Federal Highway Administration** | |
| Amit Armstrong | FHWA – Western Federal Lands Highway Division (Alaska pilot team) |
| Tina Hodges | FHWA – Headquarters |
| Cassandra Chase | FHWA – Maine |
| Rachael Tupica | FHWA – Michigan |
| **Facilitators, Note takers, Observers** | |
| Susan Asam | ICF International |
| Angela Wong | ICF International |
| Erin Lesh | MD State Highway Administration |
| William Tardy | MD State Highway Administration |
| Ryan Bennett | Sandy Project (Cambridge Systematics) |

# FHWA Climate Resilience Pilot Peer Exchange

**July 16th – 17th, 2014**
**Baltimore, Maryland**

*ADAPTATION GROUP LIST OF PARTICIPANTS*

| Name | Affiliation |
|---|---|
| **Adaptation Pilot Participants** | |
| James Cromar | Broward Metropolitan Planning Organization |
| Rob Holmlund (remote) | Caltrans District 1 pilot team (GHD) |
| Stephanie Molden | Connecticut Department of Transportation |
| Wally Blain | Hillsborough County City-County Planning Commission/MPO |
| David Claman | Iowa Department of Transportation |
| Christopher Anderson | Iowa State University |
| Elizabeth Habic | MD State Highway Administration |
| Steve Miller | Massachusetts Department of Transportation |
| Sara Dunlap | Minnesota Department of Transportation |
| Stefanie Hom | Metropolitan Transportation Commission |
| Michelle Brown | The Nature Conservancy |
| Geoff Crook | Oregon Department of Transportation |
| Carol Lee Roalkvam | Washington State Department of Transportation |
| **Federal Highway Administration** | |
| Brian Beucler | FHWA – Headquarters |
| Rebecca Lupes | FHWA – Headquarters |
| Nick Blendy | FHWA – Delaware/Maryland |
| Tracy Troutner | FHWA – Iowa |
| Joy Liang | FHWA – Maryland |
| **Facilitators, Note takers, Observers** | |
| Anne Choate | ICF International |
| Brenda Dix | ICF International |
| Dana Havlik | MD State Highway Administration |
| Michel Sheffer | MD State Highway Administration |

*PRESENTATIONS*

Please contact Becky Lupes (Rebecca.Lupes@dot.gov) for copies of the pilot project short descriptions and presentations. The presentations given at the exchanges were:

**Full Group:**

- Climate Change Adaptation Plan with Detailed Vulnerability Assessment (Elizabeth Habic, Maryland SHA)
- ODOT Climate Change Vulnerability Assessment and Adaptation Options Study (Geoff Crook, ODOT)
- Climate Change and Extreme Weather Adaptation Options for Transportation Assets in the San Francisco Bay Area (Stefanie Hom, Metropolitan Transportation Commission)
- MassDOT Presentation (Steve Miller, MassDOT)

**Vulnerability Assessment Peer Exchange:**

- Developing Proxy Indicators for Regional Climate/Extreme Weather Vulnerability: Federal Highway Administration Pilot Study for the North Central Texas Region (Jeff Neal, NCTCOG)
- Climate Change and Asset Management (Niles Annelin, Michigan DOT)
- Integrating Vulnerability Assessments and Criticality Analyses into Asset Management at Maine DOT (Judy Gates, Maine DOT; Samuel Merrill, Catalysis Adaptation Partners)

**Adaptation Peer Exchange:**

- Hillsborough County MPO Critical Transportation Infrastructure Analysis & Scenario Planning (Wally Blain, Hillsborough County City-County Planning Commission/MPO)
- NYSDOT Presentation (Michelle Brown, The Nature Conservancy)
- Flash Flood Vulnerability and Adaptation Analysis: Adaptation Strategies (Sara Dunlap, MnDOT)
- Caltrans District 1, Climate Change Pilot Study: Peer Exchange (Rob Holmlund, Caltrans District 1 pilot)