Climate Change and Transportation in Maine

Purpose

This document meets two distinct, but related needs. First, it prepares Maine's Department of Transportation (MaineDOT) to respond to the challenges presented in LD 460, Resolve to Evaluate Climate Change Adaptation Options for the State, passed during the First Regular Session of the 124th Maine State Legislature. LD 460 directed the Maine Department of Environmental Protection to "establish and convene a stakeholder group to evaluate the options and actions available to Maine people and businesses to prepare for and adapt to the most likely impacts of climate change". The resulting stakeholder group is comprised of representatives of business, industry, and trade associations; non-governmental organizations; and state agencies with a current interest in these concerns and likely involvement in the implementation of recommendations, including MaineDOT. The LD 460 stakeholders were directed via the legislation to focus on the climate impact assessment, *Maine's Climate Future* (Jacobson et al., 2009), completed by the University of Maine at the Governor's direction. According to this report, climate change is already manifesting itself in Maine as a result of greenhouse gases in the atmosphere. This document summarizes the best available science on observed and projected climate patterns in Maine and is part of the flow of activity following the legislature's passing of LD 460.

Second, this document positions MaineDOT to receive support for its proactive approach from funding and policy agencies such as the Federal Highway Administration (FHWA) because it constitutes a commitment to action. As is summarized in more detail in subsequent sections, climatic variation is felt through changing weather patterns, which are having increasingly acute effects on Maine's transportation infrastructure. Acute risk occurs as a result of events, such as storms and flooding, while chronic risk surrounds longer range changes due to climate over time. It is acute risk that results in an increased need for disaster designation and response, increased risk of collateral property damage, and threats to the safety of the traveling public. It is this type of risk that can be mitigated by early preparation, and the risk that FHWA seeks to limit proactively through responsible transportation planning. Because of the uncertainty about the future of climate and weather variability and about how people will respond in terms of emission reduction and other long term mitigation measures, chronic risk is much harder to gauge. This uncertainty can create paralysis in an agency charged with making and justifying long-term, fiscally-responsible decisions around the safety and efficiency of public travel. But the long lifecycles of most transportation infrastructure demand early preparation to protect significant taxpayer investments into a reasonably foreseeable future.

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A Warmer Climate

Maine's climate has fluctuated between warmer and cooler periods in the past and will continue to do so in the future. According to the best scientific data available, the warming trend Maine is currently experiencing is expected to continue over the course of this century and may even accelerate (Jacobson, Fernandez, & Mayewski, 2009). As average seasonal temperatures continue to rise, Maine will undergo a significant climatic shift to a warmer, wetter and stormier environment (Jacobson et al., 2009).

- Average temperatures are expected to rise significantly during this century (2.5 - 4°F in winter and 1 - 3°F in summer (Frumhoff, McCarthy, Melillo, Moser, & Wuebbles, 2006).

- Summer will begin sooner and will last longer; the number of days with temperatures exceeding 90° will increase; droughts may become more frequent in the late summer months; as a result, fresh-water flows may be reduced at that time (Frumhoff et al., 2006).

- Winter/Spring will be shorter and milder; more precipitation will fall as rain and less as snow; ice-out on rivers and lakes will also take place earlier in the spring season (Frumhoff et al., 2006).

- The frequency and severity of heavy rainfall events is expected to increase; this will lead to a rise in the volume of stormwater run-off during these events and will increase the incidents of severe flooding and subsequent erosion (Frumhoff et al., 2006).

- An expected rise in sea level between 8" and 3' within the next 100 years will inundate low-lying coastal areas and increase shoreline erosion; this process is expected to be exacerbated by the increased frequency and severity of storms (Frumhoff, McCarthy, Melillo, Moser, & Wuebbles, 2007).

- As northern and southern fringes of habitat ranges shift in correlation with changes in Maine's climate, wildlife migrations are expected to increase and patterns shift as "edge-of-range" species adjust to changes in their environment (Jacobson et al., 2009).

- Additional stress will be placed on some already endangered species dependent on specific, climatically-driven landscape characteristics: e.g., Atlantic salmon dependent on cold, fresh water (Jacobson et al., 2009).

Impacts on Transportation

These anticipated changes in climate will impact Maine's transportation systems in a number of ways. Many of these projected impacts already occur today with noticeable frequency (Frumhoff et al., 2006); however, these events and consequences are expected to become more commonplace and more exacting in the near future. While no specific timetable can be set for when each impact will reach a tipping point in terms of directly affecting transportation operations to an extreme degree, all are expected to be prevalent by the end of this century.

- The current infrastructure will be subjected to longer periods of intense heat that may accelerate the degradation of structural integrity; e.g., increased rutting on pavement.

- Tourism-related traffic is likely to increase for two reasons: (1) the summer season in Maine will last longer; and (2) as temperatures rise in major cities and southern regions of the country, more people will seek to escape the oppressive heat by traveling to places with relatively more moderate climates, such as Maine's coastal areas.

- Management practices for snow and ice removal will need to adapt to shorter, milder and wetter winters as more precipitation falls as rain and less as snow.

- The number of road closures due to flooding and washouts will rise, as will the potential for extreme incidents of erosion at project sites as heavy rain events take place more frequently.

- Sea level rise will pose numerous threats, including: (1) inundation of low-lying coastal infrastructure; (2) increased beach and coastline erosion; and (3) higher tides in combination with severe storms will increase the cost and occurrence of natural disasters (e.g. Patriot's Day Storm 2007 which caused $31.5 million in damage to roads alone (Gallagher, 2008)).

- Potential barriers to predicted wildlife migration corridors (e.g. roads that fragment essential wildlife habitat; culverts that bar fish passage) may be subjected to more stringent environmental regulations as more species sensitive to climate change are listed as threatened or endangered.

- Current regulatory and permitting burdens in relation to species that are already listed as threatened or endangered species may increase as climate change places additional stress on those species as Maine becomes fringe habitat.

Adaptation Strategies

Adaptation strategies are policies and practices that can be implemented to prepare, protect and maintain the state's transportation infrastructure in the face of the numerous challenges posed by climate change. Government agencies such as the Federal Highway Administration (FHWA) and organizations such as the Transportation Research Board (TRB) have recognized that by addressing these challenges now, transportation agencies can curtail future costly infrastructure investments and disruptions in transportation operations can be avoided. Fortunately, many of the issues associated with climate change are expected to be more intense versions of the same problems MaineDOT already deals with effectively. This will allow the department to incorporate short-term and long-term adaptation strategies on a gradual basis to confront the impacts of climate change on the state's transportation system without forcing it into a significant paradigm shift.

Short-term Approaches

Many of these strategies can be implemented now by MaineDOT as an initial first step towards adaptation, but can also be conducted on a continual basis in the future and can be adjusted to meet potentially unforeseen impacts. Some of these include:

- Monitor the changing environment to gain operational information about climate change in Maine and its effects.

- Assess the current infrastructure's ability to handle worst-case climate change scenarios to identify potential threats associated with those impacts and determine where these weaknesses overlap (e.g., is there a bridge that is vulnerable to a rise in sea level, coastal flooding and severe storms?).

- Conduct cost/benefit analyses to identify and prioritize the most vulnerable infrastructure for retrofit now to avert future direct and collateral damage from impacts. TRB (2008) cites **Probabilistic Risk Assessment (PRA)** as a potential methodology that could be utilized to assess climate change impacts on infrastructure components. PRA can be summarized as follows: **<u>Total Risk</u> = Prob(hazard) X Prob(consequence)**. As the TRB report explains:

  > The central idea behind PRA is to define risk as the product of the magnitude of adverse consequences and the probability that those consequences will occur. For instance, the risk of the loss of a coastal road due to a storm surge would be the likelihood of a storm surge rising high enough to inundate the road, multiplied by both the dollar cost of replacing the flooded road and the costs of the economic disruption during the time the road was disabled.

- Incorporate climate change considerations into current decision-making and planning. For example, when maintenance requires culvert replacement, replace old culverts with new ones that are adequate to handle more frequent/severe floods and maintain or restore habitat connectivity for species' movement (to the extent practicable).

- Continue to collaborate with MDIF&W's Beginning with Habitat Program to identify, retain and restore prime habitat for threatened and endangered species to make them less susceptible to climate change.

Long-term Approaches

State governments are continually challenged with balancing shrinking budgets and many legislators and constituents may question any additional expenses incurred on projects in anticipation of "theoretical" climate change impacts. Nevertheless, it is important to assert that infrastructure is an investment in the state's economy. Without it, the flow of people and commerce is not possible. Many of Maine's transportation structures are designed and built for a life of 25, 50 or 100 years. To ensure that these structures do not fail in the future as a result of environmental stressors associated with predicted climate changes, adaptation strategies must be integrated into long-term outlooks.

- To the extent practicable, design and build infrastructure to withstand a warmer and wetter climate.
  - Bridges may need to be built with larger capacities to compensate for sea level rise or increased flood events
  - Highways may need to be designed to reduce the volume of standing water on the travel surface associated with frequent heavy rain events
  - Highways and roads in coastal areas (especially those in York County) may need to be relocated further inland from where they are presently located to compensate for rising sea levels, beach erosion and increased coastal flooding

- Take advantage of opportunities to maintain or restore habitat connectivity for wildlife migration (especially for species for which Maine constitutes their northern or southern fringe range).

How Maine Compares

The Pew Center on Global Climate Change (2008) has identified a small number of states that have formed climate change stakeholder groups and have developed their own Climate Change Action Plans (CCAPs) that focus in part on adaptation strategies: Alaska, California, Florida, Maryland, Oregon and Washington. The Vermont Agency of Transportation (2008) has also developed a CCAP with adaptation components. While these states are at various stages of implementing those adaptation strategies, there was broad consensus among the stakeholder groups that developed the CCAPs that climate change is already impacting each state and that steps need to be taken to confront those impacts to avoid future economic hardship. Four of the possible adaptation strategies suggested in this paper were also recommended by nearly all of the CCAPs and appear in bold in the chart below: 1) monitor the changing environment; 2) assess the current infrastructure's ability to withstand the adverse impacts of climate change; 3) incorporate climate change into current and future planning; 4) design infrastructure to withstand climate change impacts. The chart also reflects Maine's recommendations prior to this paper.

Adaptation Strategies State's Have Recommended

RECOMMENDED STRATEGY	AK	CA	FL	MD	OR	VT	WA	**ME**
Monitor the changing environment	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Assess infrastructure's resiliency to climate change impacts	**X**	**X**	**X**	**X**	**X**	**X**		
Cost/benefit or risk based analysis of retrofitting/replacing vulnerable infrastructure	X	X			X			
Incorporate climate change into current and future planning	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Reduce stress on threatened and endangered species			X				X	X
Design/build infrastructure to withstand climate change impacts	**X**	**X**	**X**	**X**	**X**		**X**	
Maintain/restore habitat connectivity and/or natural barriers to sea level rise			X	X			X	X

A Model of Adaptation: The California Seismic Retrofit Program

The TRB (2008) has documented that in response to the Loma Prieta earthquake in 1989 the California Department of Transportation (Caltrans) was tasked with evaluating 25,000 bridges for seismic retrofitting. Retrofitting all of the bridges to the highest standard was not financially possible and, although earthquakes take place in California with relative frequency, there was (and still is) considerable uncertainty about when or where they would occur or their degree of magnitude. To deal with these challenges, Caltrans developed a manageable prioritization method designed to efficiently allocate available resources to the most vulnerable bridges.[*]

First, a required performance standard was set. Most bridges were given a "no collapse" standard; however 750 bridges were given a higher standard based on the significance of the investments that had been made in them and to ensure they would remain in service during a seismic emergency.

[*] California's eleven major toll bridges were dealt with separately because of their complexity and importance to the overall transportation system.

Next, a risk algorithm was developed based on four evaluation criteria: seismic activity, seismic hazard, impact and vulnerability. Seismic activity was based on the bridge's location in one of four fault activity zones. Seismic hazard was based on conditions at the bridge site, such as soil composition. Impact was based on considerations such as daily traffic volume, route type and detour length. Vulnerability was determined on the basis of structural characteristics such as structure age, structure type, presence of expansion joints. The score on each criterion was multiplied by a weighting factor and summed together to arrive at the final score. All 12,600 state highway bridges were processed using the risk algorithm and prioritized based on score; 7,000 bridges that failed to meet the minimum standard were further evaluated for specific deficiencies to determine if the bridge should be in the program or if retrofitting could be delayed to a future work plan cycle.

Finally, an in-depth field inspection was conducted on the 2,194 bridges that were determined to be in need of immediate retrofitting. Bridges that were found to have met the required standard of "no collapse" during these inspections were removed from the list. At the time of the TRB report the program was considered 99% complete; all 2,194 bridges had been retrofitted at a cost of $3 billion.

The TRB (2008) suggests that a similar approach could be used by government agencies to screen and identify critical infrastructure that is vulnerable to the impacts of climate change. A required performance standard would need to be established, as well as weighting factors for different climate change effects. Moreover, by analyzing the impact to the transportation system from the failure of a given piece of infrastructure, available resources can be allocated to ensure that the system's critical components remain in service even under increasingly extreme environmental conditions.

The Collateral Costs of Inaction

"The transportation system is the very foundation of Maine's economy and at the base of Maine's quality of life."

- Laurie Lachance, President & CEO
Maine Development Foundation

The economic hardship that results from the disruption of a portion of the transportation system is not limited to the financial cost of replacing damaged infrastructure. When a highway or road is closed due to a culvert washout or coastal flooding, businesses suffer when their access to consumers is closed off and there are considerable delays in delivering or receiving goods and supplies. The Maine Development Foundation (MDF) (2009) found that "every hour of unscheduled delay costs a trucker $350" and that 85% of Maine's freight movement is carried out over state roads. Citizens also lose time and money due to lengthy detours and disruptions in their daily routines. On average, poor roads cost Maine's motorists $263 million a year (MDF, 2009). It would seem to follow then, that these collateral costs would be even more acute if infrastructure were to fail in areas that generate significant amounts of revenue during times of peak economic activity. For example, if portions of the already congested Route 1 highway were closed due to infrastructure failure during the months of July and August, one would expect the adverse economic impact on local businesses along that route to be severe.

Furthermore, a "wait-and-see" approach to climate change would pressure the department to be reactive and would force it to respond to impacts that may negatively affect a large number of infrastructure components all at once, at a time when adequate funds may not be available to cope with such a situation. On the other hand, by taking proactive steps to adapt to climate change at a gradual pace, the department could protect the significant investments made in the transportation system in an efficient and cost effective manner over an extended period of time. This approach is similar to the recommendation made in *Keeping Our Bridges Safe* (2007), that funding for bridge maintenance and replacement should be increased now to avoid forcing future generations to fund a large number of bridge replacements and repairs all at once.

MaineDOT's Current Policy Direction

MaineDOT's long-range transportation plan, *Connecting Maine* (2008), acknowledges that climate change is expected to occur and that it will present numerous threats to the transportation system. Moreover, *Connecting Maine* (2008) also recognizes that, "[a]dapting to the changing environment will create new infrastructure demands that must be planned for." MaineDOT, through its environmental stewardship and initiatives, has taken many affirmative steps towards maintaining and restoring the natural environment in the state. Many of these current environmental policies are implemented on a continual basis and go a long way towards preparing the state's transportation infrastructure for the future impacts of climate change.

- Measuring and documenting annual peak flows and rainfalls in conjunction with USGS.
- Maintaining and restoring habitat and hydrologic connectivity to allow free movement of species and water; (e.g. Gorham Bypass; fish passage projects).
- Maintaining and improving GIS mapping, project and candidate screening and information gathering.
- Collaboratively supporting state agencies' modeling, data collection, mapping and outreach efforts related to climate change. For example, by participating as part of the steering committee for Inland Fisheries and Wildlife's "Beginning with Habitat" program.
- Implementing stormwater management through a memorandum of agreement with the Maine Department of Environmental Protection to maintain and restore surface water quality.
- Working through the Surface Water Quality Unit with Project Development and Maintenance & Operations to minimize surface water impacts from all construction projects.
- Minimizing and mitigating impacts on endangered species, such as Canada lynx and Atlantic salmon.
- Maintaining and restoring natural buffers to sea level rise and increased stormwater run-off, such as wetlands and coastal salt marshes (e.g. Sherman Marsh).
- Inspecting all bridges at a maximum of every 24 months; underwater inspections for scour and structural integrity are conducted every 60 months (unless a finding determines that more frequent inspection is required in either case).

What MaineDOT Can Do To Build Adaptive Capacity

Making sound investments today to ensure a high quality of life tomorrow has always been a difficult task for individuals and societies because the future is invariably clouded with uncertainty. Given this uncertainty, decisions made today have to be based on the best information available. The best information available today indicates that climate change is occurring and that it will negatively affect Maine's transportation system if we do not have an eye toward the future. To maintain the State's economy, environment and quality of life in the decades to come, steps need to be taken to prepare for and adapt to the adverse impacts of climate change. As MaineDOT begins to build the transportation system's adaptive capacity, several inexpensive, proactive approaches are being put in place to address changing weather patterns and climate. These approaches include:

- Provide technical guidance to entities outside of MaineDOT to construct crossings and reduce risks.
- Take advantage of institutional knowledge by applying lessons-learned from previous projects to increase adaptive capacities in the future.
- Upgrade design standards from Q50 to Q100 to build in resiliency in the face of extreme weather events; this can increase the cost of stand-alone strut replacement by approximately 10% and the total project cost for highway projects by substantially less.
- Habitat-conscious design-incorporate measures that maintain and restore habitat connectivity in anticipation of projected and reasonably foreseeable species movement.

Furthermore, the department will be able to actively rely on efforts currently underway focusing on identifying areas of the system that are particularly vulnerable to climate change and extreme weather events.

- USGS / NOAA / EPA – East Coast Climate Change Risk-Assessment (anticipated to occur in conjunction with federal SAFETEA-LU reauthorization).
- DEP / MaineDOT M&O – Pipe and culvert vulnerability assessment (begin fall 2009).
- MaineDOT Bridge Maintenance Division – Scour report (complete 2009) and bridge-specific scour plans (under development).

MaineDOT already participates in a number of activities and policies that would help to facilitate the adaptation of the transportation system to the changing environment. What is needed next is a concerted effort to focus these actions towards proactively addressing the detrimental effects of climate change. The department has already taken the first step by including climate change as a factor to be considered in future planning. Furthermore, MaineDOT actively monitors the changing environment and routinely inspects many components of the transportation infrastructure. These efforts could be combined and focused towards assessing the transportation system's resiliency to the impacts of climate change. Once this is accomplished, a technical, risk-based assessment could be implemented to prioritize for retrofit those critical pieces of infrastructure that are at the greatest risk of failure from present and future environmental variations. The California Seismic Retrofit Program could be used as a model for successfully adapting the transportation infrastructure to guard against future extreme environmental events in an efficient and cost-effective manner, even when it is uncertain where or when those events will occur. In the meantime, the transportation system can be safeguarded by continuing the policies and practices that bolster the natural environment's resiliency to the impacts of climate change.

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