VTrans Climate Change Adaptation
White Paper Topic Outline

Gina Campoli, March 2011

1. <u>Background</u>

The 2007 Governor's Commission on Climate Change recommendations included the need for a council or other mechanism to address climate change adaptation in Vermont. Some states notably California, Washington State and Massachusetts have passed legislation directing state agencies to take various actions on climate change impacts.

In 2010 the UVM/State of Vermont Climate Collaborative asked various sectors, including transportation and thus VTrans, to prepare a brief white paper indentifying such things as the state of knowledge regarding how climate change in Vermont is expected to affect the sector, what information is needed, information gaps, and any known strategies to address the known effects.

The focus of the paper is on transportation's *adaptation* to inevitable climate change not *mitigation* of greenhouse gas emissions to avoid worsening effects. Adaptation is the notion that society will need to adapt to climate known changes that will occur regardless of our success at reducing or mitigating the growth in green house gases.

> *Regardless of the causes of climate change, it is widely accepted in the climatology community (and a growing proportion of the transportation community) that global temperatures, precipitation, and sea levels are undergoing changes that could have a direct impact on existing and proposed roadways and bridges.* (***An Approach to Addressing the Impacts of Climate Variability on Roadway and Bridge Design***, paper prepared for the 2011 Transportation Research Board (TRB) Annual Meeting by Jake Keller, Amit Armstrong, Michael Flood and Michael D. Meyer)

2. <u>How are Vermont's climate and the associated environmental conditions expected to change in the next 50 years</u>?

Seasonal transitions are shifting in Vermont, i.e. winter is coming later, and spring is coming earlier. Winter is shorter and warmer and spring, summer and fall are longer overall. Precipitation in the form of rain is occurring in more intense events with greater run-of and less soil moisture absorption. (Betts 2010)

The report ***Confronting Climate Change in the Northeast*** by the Northeast Climate Impacts Assessment Synthesis Team, 2007, Union of Concerned Scientists reports:

> *Since 1970 the Northeast has been warming at a rate of nearly 0.5 degrees Fahrenheit (F) per decade. Winter temperatures have risen even faster, at a rate of 1.3° F per decade from 1970 to*

2000. This warming has been correlated with many other climate-related changes across the region, including:

- *More frequent days with temperatures above 90° F*
- *A longer growing season*
- *Less winter precipitation falling as snow and more as rain*
- *Reduced snowpack and increased snow density*
- *Earlier breakup of winter ice on lakes and rivers*
- *Earlier spring snowmelt resulting in earlier peak river flows*
- *Rising sea-surface temperatures and sea levels*

The October 2006 report, ***Climate Change in the US Northeast***, also by the Northeast Climate Impacts Assessment Synthesis Team, describes the following for our region:

We are already experiencing an increase in the rate of climate change in the Northeast. Annual average temperatures are rising, with the greatest increases occurring in winter temperatures. These changes have been accompanied by a reduction in snow cover, earlier snowmelt, earlier arrival of spring, an extension of the summer season, and an increased risk of extreme heat. These changes are expected to grow in the future, with the amount of change depending on whether we follow a pathway of lower or higher greenhouse gas emissions.p.10

Precipitation p. 15:

- *Winter precipitation (in the form of both snow and rain falling in winter months) has been increasing over the past few decades, and is projected to continue increasing, with slightly larger changes under the higher-emissions scenario than the lower-emissions scenario.*
- *Little change is expected in summer rainfall, although projections are highly variable.*

Extreme Precipitation and Storms p.16:

- *The frequency of heavy rainfall events is increasing across the Northeast.*
- *Under both emissions scenarios, rainfall is expected to become more intense. In addition, periods of heavy rainfall are expected to become more frequent.*
- *Some East Coast winter storms are projected to shift from earlier to later in the winter season as temperatures rise, and more storms are expected to travel further up the coast and affect the Northeast.*

Heat Waves and Temperature Extremes p. 13:

- *The number of very hot days is increasing across the Northeast.*
- *By the end of the century, many northeastern cities can expect 30 or more days over 90oF under the lower-emissions scenario, and 60 or more days per year under the higher emissions scenario.*

- *Currently, northeastern cities experience one or two days per summer over 100F. This number could increase by late century to between three and nine days under lower emissions and between 14 and 28 days under higher emissions.*

Stream flow and Water Supply p. 20:

- *Warmer winter and spring temperatures in the Northeast are melting the snow earlier and causing earlier high spring flows.*
- *As temperatures continue to rise, snow and ice will melt even earlier, advancing spring stream flow 10 days earlier under the lower emissions scenario and more than two weeks earlier under the higher emissions scenario.*
- *Warming temperatures will also cause more water to evaporate in the summer months, extending the summer low-flow period by nearly a month under the higher-emissions scenario and increasing the risk of water shortages and drought.*
- *Global warming is also expected to increase the likelihood of high flow events in the winter, particularly under the higher-emissions scenario, which implies a greater risk of*

Winter Snow p. 22:

- *The number of snow-covered days across the Northeast has already decreased, as less precipitation falls as snow and more as rain, and as warmer temperatures melt the snow more quickly.*
- *Snow density has increased as the snow has become wetter and heavier (i.e., more "slushy").*
- *By the end of the century, the northern part of the Northeast, currently snow-covered for almost the entire winter season, could lose up to one-quarter of its snow-covered days under the lower-emissions scenario and more than half of its snow-covered days under the higher emissions scenario.*
- *By the end of the century, the southern and western parts of the Northeast could experience as few as 5 to 10 snow-covered days in winter, compared with 10 to 45 days historically.*

3. <u>Transportation literature reviews that identify potential climate change impacts to transportation at the national level:</u>

- ***USDOT Gulf Coast Study Phase 1***
- ***Transportation Research Board Special Report 290*** focusing on the consequences of climate change for infrastructure and operations of the entire US Transportation system
- ***Global Climate Change Impacts in the United States***, Karl T.J. Melillo, Cambridge University, 2009

4. <u>Potential threats and vulnerabilities of transportation infrastructure in Vermont from climate change</u>

The principle elements of the climate that affect physical infrastructure include, temperature, water and wind …When these variables change to the point that they extend beyond the typical ranges that designers consider, the results can lead to reduced service life of the specific structure, reduced performance or other un-intended consequences such as increased operation and maintenance costs. (p. 4 Keller et. al)

The paper goes on to describe how changes in temperature, storm duration or intensity and high winds, drought and sea level rise might affect accessibility, performance and structural life expectancy and operations and maintenance.

In 2007 several VTrans managers identified potential threats and vulnerabilities to the transportation system in Vermont from climate change. This list has been expanded based on new literature and observations by VTrans personnel:

- Flooding and erosion of low lying roads, railroads and other infrastructure
- With changes in the intensity and frequency of storm events, the need for culverts, bridges, erosion controls and stormwater systems to be designed and maintained to adequately handle the associated increased flow, sediment and debris transport
- With Increased stream flow, comes increased bridge scour
- Increased moisture and corrosion damage on pavements and structures
- Failure of pavement and bridge expansion joints
- The effects on roadbed and pavement longevity from an increase in freeze thaw cycles.
- Increased pavement rutting and vehicle hydroplaning potential
- Increases in extreme wind events and associated downed trees, power lines and debris blocking roadways, waterways and ROW. Also higher wind loading on bridges
- Increased emergency preparedness and evacuation demands
- Changing winter maintenance demands due to more or less snow or an increase in freeze events
- Compromised availability and the need to stockpile diesel fuel, salt, and sand
- Effects of new exotic species and longer growing season on ROW vegetative management and streambank longevity

5. <u>Need to improve understanding of threats to transportation infrastructure and programs now and in the future</u>

   Overall Challenge: Global scale climate information needs to be downscaled to a watershed or bioregional level in Vermont to best inform VTrans' policy, practice, and standards regarding transportation planning, design and operations.

   Immediate Strategies:

   a. Identify and prioritize existing data and information sources related to historic rainfall and water flow. (See attached table.)
   b. Identify and prioritizes other historic data and information sources such as temperature, snowfall data, wind speeds, growing season that would be helpful to transportation managers
   c. Identify data gaps and modeling needs
   d. Create a collaboration mechanism and/or partnership with other state and federal agencies, UVM and other institutions to address information and data and modeling efforts needed to inform agency action.

6. <u>Identify how the risk of threats will be incorporated into agency decision-making related to systems and project planning, design, and operations</u>

   The Council on Environmental Quality (CEQ) recently amended the National Environmental Protection Act (NEPA) regulations to include consideration of climate adaptation in the NEPA process. The proposal to amend the regulations states that

   > *Environmental analysis and documents…should provide the decision maker with relevant and timely information about the …the relationship of climate change effects to a proposed action or alternatives, including the relationship to proposal design, environmental impacts, mitigation, and adaptation measures.*

   The FHWA will be considering its NEPA regulations in the months ahead in response to this CEQ directive. It's not certain what effect this will have on VTrans efforts to address climate change adaptation.

   As other policies and regulations are developed to address climate change adaptation at the federal and state levels, VTrans will need to have an improved understanding of changing environmental conditions and the consequences for transportation infrastructure.

   A key question is how far can VTrans go in expending resources to address a challenge that is not as of yet a regulatory requirement and might go beyond current common engineering practice and agency standards to address climate change when future conditions vary and planning and designing for the worst case scenario is not practical? How does the agency best assess the risk presented by climate change and act accordingly?

   Keller et al p.9 suggests a *risk assessment* process in the design process that would include the following elements:

   - Determine the design elements potentially impacted by climate change.
   - Identify the best available information on probabilities for climate change including timing. (This is contingent on data and information identified above.)
   - Determine the resiliency of infrastructure if the design is using current standards that do not account for climate change.
   - Determine the resiliency of the infrastructure for a range of future conditions within a reasonable bound established by identified probabilities. (Again future conditions must be better defined by the data.)
   - Determine the risk to infrastructure and document conclusions on an approach to addressing risk.

   The authors go on to explain that the outcomes from this process would range from the engineers in their professional judgment determining there is no risk, that the risk is only expected at a timeframe beyond the life of the structure, that variations of risk are so diverse as to make a reasonable assumption of risk impossible, or that the climate factors do pose some risk and an adaptation strategy must be incorporated in the engineering and design of the infrastructure.

The authors advise that the first step to manage risk is to avoid it similar to the way environmental planners consider flood plains and wetlands. Another approach is to develop a flexible approach. Rigid standards will fail if the conditions and understanding of those conditions change. Scientific evidence is mounting that climate change is not occurring on a linear path but instead there are tipping points with sudden rapid changes. "Thus a bottom-up approach to adaptation might be most promising that is know your system thresholds and determine the probability that climate factors will exceed them."

VTrans maintenance activities should also factor in the risk of more extreme weather. For example removing dead and diseased trees in the ROW to avoid wind storm debris blocking roads and waterways or maintaining ditches, catch basins and other stormwater infrastructure to avoid flood damage make sense. The degree to which these pro-active maintenance activities take place must be weighed against the cost of the activity and the weather risk.

Questions to consider as VTrans moves ahead in addressing the risk to transportation infrastructure from climate change:

- Is VTrans currently accepting too much risk? What additional risk will we assume by not adapting? Is it enough risk to warrant adaptation?
- Are we overdesigning and accepting too little risk? Is it possible that we are currently too conservative?
- How should the agency best determine risk?
- Should infrastructure of higher importance be held to higher standards of risk?

Sources of Data/Information for VTrans in Understanding Environmental Conditions Possibly affected by Climate Change

Sizing of Bridges and Culverts, Stormwater Infrastructure Design and System Maintenance

	Sponsoring Entity	Date(s) of Publication	Notes
Atlas of Precipitation Extremes for the NE US and SE Canada	NRCS through the Cornell University Climate Center	1993, update to begin next year	VTrans funded this study for VT in 1993. The rainfall prediction modeling guides current VTrans hydraulic analyses.
Rainfall Atlas for the Northeast (TP 40)	FHWA funded and endorsed. NOAA undertakes the work	1964, funding is being sought for a 3 year project starting next year	This is a parallel effort to the Cornell Center work.
FEMA Flood Plain Mapping	FEMA	XXXX County by county GIS digitizing underway	Includes minor updates and correction of known problems. No new analyses
Stream Gauge Data	USGS	Ongoing data collection on specific stream reaches	Static information in GIS format available
Geomorphic Assessments for specific water sheds/municipalities	ANR and various municipalities	Varies	VTrans is aware information is available. Application in structure design varies.
Ortho Photos	Google Earth		Evaluate upstream land use over time to help assess flood effects
VT Flood Flow Frequency	USGS	1997 (?) Update anticipated next year?	Stormwater Design Regression analysis needed to convert rainfall related data to run-off rates
GIS Mapping of VTrans Storm-Related Expenditures	VTrans	To begin in 2011 and on-going	VTrans Operations expenditures in response to flooding and other extreme weather events will be included in GIS layers