Stream Crossings and Climate Change (Part 1)

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Several aspects of climate change should be considered in the design and construction of stream crossings for forest access. These factors include both the need to plan for resilient structures against the backdrop of continued change in precipitation patterns and the need to minimize fragmentation of streams as climate warms and aquatic species move in search of suitable habitat. As the atmosphere warms an increasing percentage of precipitation is coming in heavy precipitation events. Warming ocean temperatures provide a conducive environment for larger, more powerful coastal storms. Both of these trends are increasing the potential for extreme precipitation events that can increase erosion and sedimentation and damage improperly designed stream crossings.

Stream crossings can play a significant role in limiting movement of fish and other aquatic species along stream corridors if not properly designed. As stream temperatures warm the opportunity for cold water fish to move to refuge areas with sufficiently cool waters is increasingly important to their viability. Emerging approaches to linking infrastructure and ecological resiliency through the design of structures that take stream function and form into account hold the promise of simultaneously addressing both changing precipitation patterns and ecosystem stressors.

Changing Precipitation Patterns

Precipitation patterns are changing as the climate warms. The warming of the atmosphere and the oceans have combined impacts that are causing long term changes in both global precipitation intensity and regional precipitation totals.

- Warming atmosphere:
  - As the atmosphere warms it can hold more water vapor (7% increase for every 1 degree C increase in atmospheric temperature).1 This is a key factor in the global increase in the percentage of precipitation coming in heavy precipitation events. As the climate continues to warm this trend is projected to continue with a diminishment in light and moderate precipitation and continued increase in heavy precipitation.
  - As the atmosphere warms evaporation rates are increasing. In geographic areas with ample surface water this leads to increasingly high levels of water vapor in the atmosphere. In areas with limited surface water this phenomenon can exacerbate drought.[1] In a general sense wet regions of the planet are getting wetter and dry regions are getting dryer.

- Warming oceans:
  - As sea surface temperatures warm evaporation rates are increasing.
  - As sea surface temperatures warm more energy is available to fuel tropical storms, hurricanes and extra-tropical coastal storms. This trend is creating background conditions that are conducive for larger, more powerful storms with both stronger winds and more precipitation.[2] The influence of climate change on the frequency of ocean storms is uncertain leading to differing projections of future storm frequency.

As a result of these trends, the percentage of total precipitation coming in heavy precipitation events is increasing across all of the U.S. and Canada. Total annual precipitation is also changing with some regions such as the northeastern U.S. and Canada getting more total precipitation over time and other regions such as the southwestern U.S. receiving less. These long-term, climate change-driven trends in precipitation interact with cyclical phenomenon such as the El Nino/Southern Oscillation and the Atlantic Multi-decadal Oscillation. Depending on the phase of these cyclical patterns they can enhance or retard the precipitation changes associated with longer-term climate trends.

Statistical analysis of regionally-specific precipitation rates and frequencies provides an important benchmark for sizing of stream crossings. However, as climate continues to warm it is likely that historic statistics will become a less reliable predictor of future precipitation patterns. Two of the primary sources of precipitation frequency data for the U.S. are *Technical Paper No. 40: Rainfall Frequency Atlas of the United States*, 1961 (http://www.nws.noaa.gov/oh/hdsc/PF_documents/TechnicalPaper_No40.pdf) and the NOAA Precipitation Frequency Data Server (http://dipper.nws.noaa.gov/hdsc/pfds/). Both of these sources are based on the notion of a static climate. The NOAA Precipitation Frequency Data Server is intended as an update to Technical Paper 40 but due to funding limitations the project has not been completed for all of the U.S. To address this gap and provide insight on changes in extreme precipitation, the Northeast Regional Climate Center created a web-based tool titled Extreme Precipitation in New York and New England (http://precip.eas.cornell.edu/). These more recent data indicate that what was considered a 100-year storm event in the northeast in 1950 is now likely to occur twice as often.

The Role of Watershed Characteristics and Conditions

Watershed conditions such as soil moisture, topography and ground cover determine how a given watershed responds to changing precipitation inputs. It is important to differentiate between watersheds that are vulnerable to flash floods and those that are not. Watersheds that are conducive to flash flood events due to steep slopes and stream channels that rapidly concentrate flow are exhibiting increases in flooding as climate warms and heavy downpours become more prevalent. Flood vulnerability in watersheds that are less conducive to flash floods is dependent on precursor conditions such as soil moisture, snow pack and ground cover. Trends in flood magnitude differ by region with generally increasing trends in the Northeast and Midwest and decreasing trends in the southwest.[3] Significant variation in flood trends occurs within regions based on differing watershed characteristics and differing local precipitation patterns.

Linking Infrastructure and Ecosystem Resiliency

Consideration of the geomorphic and ecological processes that a healthy stream supports is an important element of intelligent stream crossing design. A properly designed crossing maintains connectivity for upstream and downstream movement of fish and other aquatic organisms, maintains natural flow regimes, and supports the transport of organic and inorganic materials. Crossings that match the slope of the stream, span the full width of the stream, and have natural stream bed materials that continue through the structure are likely to address these concerns.4

Inclusion of these elements in stream crossing design will often result in a wider opening width than would be selected based purely on hydrologic concerns and will bias selection towards the use of open-bottom structures such as pipe arches or bridges as opposed to culverts. Both of these decisions often have the added benefit of resulting in a structures that will accommodate a larger design storm.

Managing Risk

As the atmosphere and oceans continue to warm the likelihood of extreme precipitation events will continue to increase. The risk for increased flooding will be highest in those watersheds that are conducive to flash flooding and in those regions with increasing total precipitation. Minimizing risk and costs associated with stream crossings in this changing environment should include consideration of the following:

Minimize the number of new stream crossings: Planning road and trail systems to minimize the number of new stream crossings is a sure-fire method of reducing cost and risk.

Use of temporary structures where feasible: Temporary stream crossings reduce exposure to flooding due to the limited time that they are in place and completely eliminate long-term maintenance headaches and long-term stream impacts. In addition, some states offer loaner bridges and cost share programs.

Link infrastructure and ecosystem resiliency in design and construction: Designing new structures and upgrading old structures to address both changing precipitation patterns and ecosystem function will minimize failure of structures and the need to rebuild prematurely.

A synopsis of a recent Manomet evaluation of the costs and benefits of stream crossing best management practices is available on page 44, Table 5 of the following publication: http://www.wri.org/sites/default/files/WRI13_Report_4c_NaturalInfrastructure_v2.pdf

(Part 2 of Stream Crossings and Climate Change will provide practical, on the ground advice for sizing stream crossings. To be posted in September 2014.)

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References

1. *Climate Change 2007: Working Group 1: The Physical Science Basis*. (Intergovernmental Panel on Climate Change, 2007). at <http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-3-2.html>

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3. Peterson, T. Monitoring and understanding changes in heatwaves, cold waves, floods and droughts in the United States: State of knowledge. *Bull. Am. Meteorology Soc.* **94,** 821–834 (2013).

4. *New Hampshire Stream Crossing Guidelines*. (University of New Hampshire, 2009). at <http://www.streamcontinuity.org/pdf_files/nh_stream_crossing_guidelines_unh_web_rev_2.pdf>