The Impact of Climate Change and Projected Development on Culvert Capacity in Keene, NH

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The impacts of climate change are now unavoidable, due to the persistence of greenhouse gases in the atmosphere, as well as the high levels of greenhouse gases that will continue to be emitted for the foreseeable future. Communities may have a window of opportunity to prepare civil infrastructures. While expensive, these preparations can be affordable if undertaken far enough in advance. The professional community historically has taken a "wait-and-see" approach rather than actively preparing for climate change. However, this "wait-and-see" approach is no longer tenable. Findings of significant rainfall intensification have become substantially consistent across the general circulation models (GCM's) maintained by the international climate research community. In addition, the useful life of storm water management infrastructures and the lengthy municipal planning process place currently conceived systems well within the time period when climate change impacts will manifest. In fact, evidence accumulates that we are already experiencing these impacts.

A consistently reported finding of climate change research is that, on a regional and global scale, storms will intensify in response to global warming. We sought to examine the potential impact of such storm intensification on local infrastructures, specifically the system of culverts used to drain storm water under roads. Although our research focused only on a small section of Keene, NH, the model we developed to project climate change induced culvert failures could be applied to any region of the world. The results from this study may be of interests to municipal planners and public works officials as they consider how they will prepare for forecasted changes to rainfall intensity and watershed run runoff.

Our findings indicate that between 30% and 80% of the culverts in Keene are likely to fail under expected conditions of climate change and continued development based on current plans and forecasts. Culvert systems in New England are likely to be stressed beyond capacity more frequently than specified under currently accepted design standards; this will likely result in more frequent culvert failures.

The paramount importance that we placed on maximizing the reliability of results governed a number of decisions related to the methods used to perform analyses. We strove to utilize conservative, long-established methods that are well-accepted by the community of scientists and civil engineers, over methods that are currently less-proven. All assumptions, methods, and computations used in this study were repeatedly assessed to ensure their appropriateness of use and correctness of application.

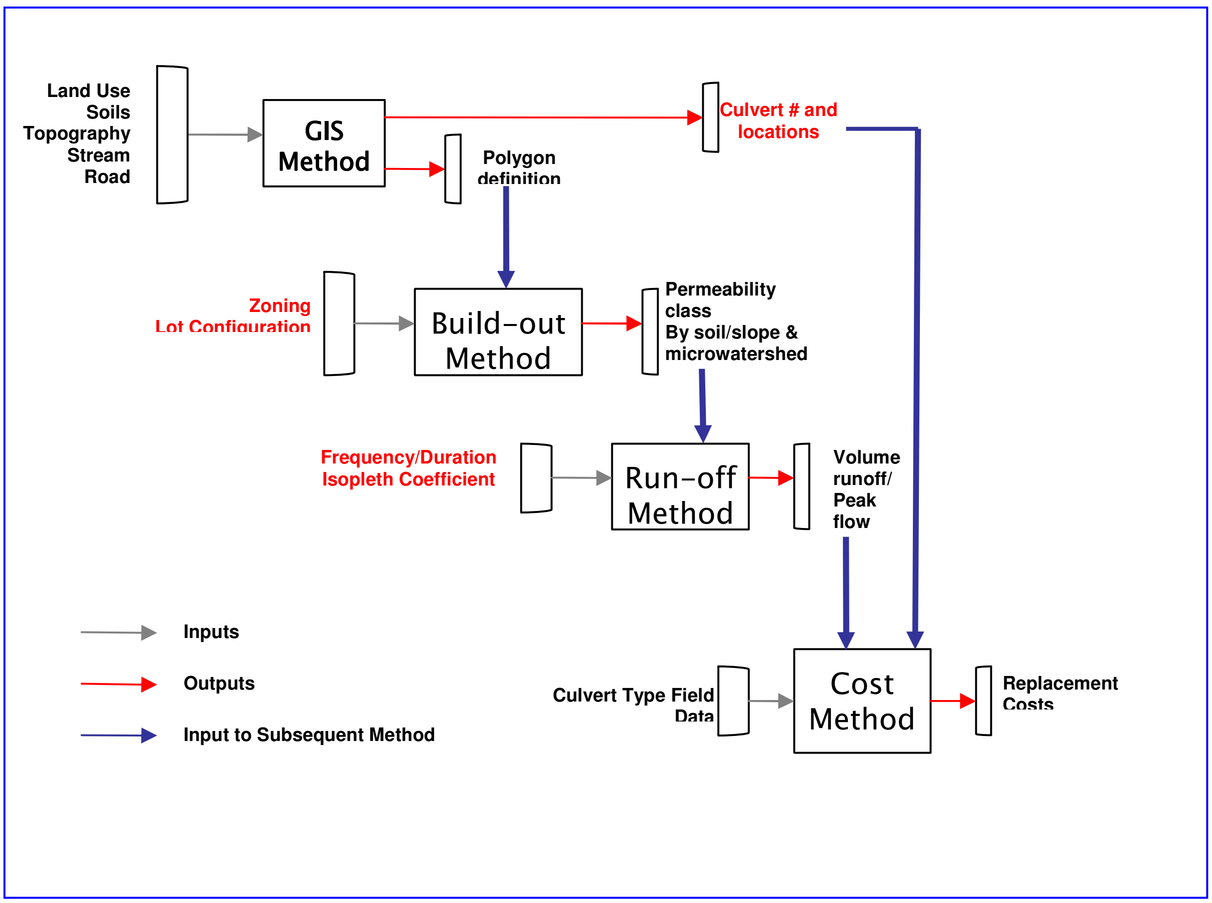
The goal of this study was not to recommend for Keene a specific 24-hour, 25-year design storm precipitation amount resulting from a climate changed by greenhouse gas emissions. Rather we sought to measure the range by which the 24-hour, 25-year design storm value might change based on predicted impacts from global warming, and to determine the impact of precipitation at this range of design values on culvert capacity.

Keene's culvert system additionally will be stressed by increased rainfall runoff resulting from population growth and the related development of open space. We therefore also modeled potential impacts of population growth on culvert capacity by performing a build-out analysis of the study area using, as proxy for population growth, zoning changes today and possibly in the future that might reduce minimum lot size.

What follows is a brief summary of our research methodology and results, structured according to the conceptual model shown in Figure 1. This includes the steps taken to collect the data on landscape parameters that influence run-off and peak flow, to collect the actual field data of culvert configuration by road class and stream order intersection, and to obtain historical rainfall data for Keene and the surrounding area.

These data sets were used to develop the overall model construct of the rainfall-runoff relationship that included calculating rainfall amounts for different duration storms. We applied projected changes to rainfall intensity predicted by global GCM's to the specific historical rainfall for Keene and surrounding weather stations. We used the National Resource Conservation Service (NRCS), previously known as the Soil Conservation Service (SCS), TR-55 Curve Number method to estimate the percentage of rainfall that would run off of the watershed and require transport by culverts. This analysis was based on a Geographic Information System (GIS) database of catchment physical features such as slope, soil, and vegetative cover. We modeled changes to the runoff rate based on the increased impermeability and loss of vegetative cover resulting from building-out the watershed as allowed under current and possible future zoning regulations.

The capacity of a sample of existing culverts within the studied watershed was determined based on actual dimensions and construction materials. We used projected rainfall volumes and runoff rates to calculate peak flow into specific culverts in the studied watershed and used actual capacities for these culverts to estimate which culverts would be under-sized. Finally, standard construction cost rates were used to estimate the cost of replacing undersized culverts, in order to estimate the cost of preparing Keene's culvert system for climate change. Replacement cost was based on enlarging culvert dimensions to meet the projected increase in peak flow resulting from the standard 24-hour 25-year design storm as altered by a combination of projected increase in storm intensity and build-out.



A window of opportunity may exist during which preparation for the impacts of climate change may be possible. Although uncertainty remains in estimates of the impact on precipitation intensity for a specific site, this should not deter the provision of this information to leaders. A core facet of leadership is the necessity of decision-making under conditions of uncertainty. Coping with the uncertainty inherent in conservative, best-available information on the potential impacts to storm water management systems from climate change is no more unusual for leaders than coping with the uncertainty inherent in projections of population, zoning, or other factors in the design of municipal infrastructures.