Historical Changes in Annual Peak Flows in Maine and Implications for Flood-Frequency Analyses

Annual peak flows have increased at most rivers in Maine during the last century. What effect does this have on computed peak flows, such as the 100-year flows, that are used for designing bridges and other structures?

Introduction

To safely and economically design bridges, culverts, and other structures that are in or near streams (fig. 1 for example), it is necessary to determine the magnitude of peak streamflows such as the 100-year flow. Flood-frequency analyses use statistical methods to compute peak flows for selected recurrence intervals (100 years, for example). The recurrence interval is the average number of years between peak flows that are equal to or greater than a specified peak flow. Flood-frequency analyses are based on annual peak flows at a stream. It has long been assumed that annual peak streamflows are stationary over very long periods of time, except in river basins subject to urbanization, regulation, and other direct human activities.

Stationarity is the concept that natural systems fluctuate within an envelope of variability that does not change over time (Milly and others, 2008). Because of the potential effects of global warming on peak flows, the assumption of peak-flow stationarity has recently been questioned (Milly and others, 2008).

Maine has many streamgaging stations with 50 to 105 years of recorded annual peak streamflows. This long-term record has been tested for historical flood-frequency stationarity, to provide some insight into future flood frequency (Hodgkins, 2010). This fact sheet, prepared by the U.S. Geological Survey (USGS) in cooperation with the Maine Department of Transportation (MaineDOT), provides a partial summary of the results of the study by Hodgkins (2010).

Figure 1. St. John River at Ft. Kent, Maine, April 29, 2009. Photo credit: Andrew Cloutier, USGS.

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Annual peak flows have increased at most streamgaging stations in Maine during the last century. The median change in peak flows over time at 28 stations (fig. 2), including 8 stations with substantial streamflow regulation, was an increase of 15.9 percent based on a linear change; the median change for the 20 unregulated stations was 18.4 percent.

Peak flows with 100-year and 5-year recurrence intervals were computed for 28 stations using the full annual peak-flow record and multiple sub-periods of that record for each station. Magnitudes of 100-year and 5-year peak flows computed from sub-periods were then compared to those from the full period. Thirty-year sub-periods with starting years staggered by 10 years were used (1907–1936, 1917–1946, 1927–1956, 1937–1966, 1947–1976, 1957–1986, 1967–1996, and 1977–2006). Because previous studies suggest that changes over time in peak flows may have occurred as a step change around 1970, two other sub-periods were evaluated: older data (start-of-record to 1970) and newer data (1971 to 2006).

The 1967-1996 sub-period had the highest 100-year and 5-year peak flows overall when compared to peak flows based on the full period of record. The median difference for all 28 stations was 8 percent for both 100-year and 5-year peak flows. Overall, peak flows based on the 1977-2006 and 1971–2006 sub-periods were higher than the full-period peak flows, but not as high as the 1967–1996 peak flows. The 1937–1966 sub-period had the lowest 100-year and 5-year peak flows overall. In general, peak-flow differences between the sub-periods and the full periods, based on the 20 unregulated stations, were similar to those based on all 28 stations.

The increases in 5-year peak flows based on data from recent decades are consistent with the observed increasing annual peak flows in Maine. The increases in 100-year peak flows based on data from recent decades are generally consistent with observed increasing annual peak flows. In limited cases, 100-year peak flows, based on data from recent decades, are relatively low. Many of these stations had a very high peak flow early in their record, which affected the magnitude of the 100-year peak flows more than it affected the magnitude of long-term changes in annual peak flows.

Do the Results of this Study Offer Guidance on Computing Peak Flows of Selected Recurrence Intervals for Future Flows in Maine?

Although peak flows in Maine, in general, have increased during the last 50 to 100 years, it is difficult to determine whether peak flows are stationary because multi-decadal changes can turn out to be oscillations in longer streamflow records (Koutsoyiannis, 2006; Hamed, 2008). Increases in 5-year and 100-year peak flows in recent years in Maine were, in general, modest when compared to peak flows based on complete periods of record and the highest computed peak flows are based on the 1967–1996 sub-period rather than the most recent sub-period (1977–2006). Peak flows of selected recurrence intervals are sensitive to very high peak flows that may occur once in a century or even less frequently.

Because large floods in Maine typically result from a combination of snowmelt and rainfall, and in the future may be affected by global warming and by multidecadal variability (related to sea surface temperature variability or large scale atmospheric patterns), future patterns of change are likely to be complex in both space and time. Because peak flows of selected recurrence intervals in Maine may or may not be stationary, it is difficult to determine whether peak flows for selected recurrence intervals based on recent years of record are more accurate than peak flows of selected recurrence intervals based on the entire historical period (the traditional method). One possible conservative approach to computing peak flows of selected recurrence intervals would be to compute these peak flows from both recent annual peak flows and from the entire period of peak flows and then choose the higher computed value (Collins, 2009).

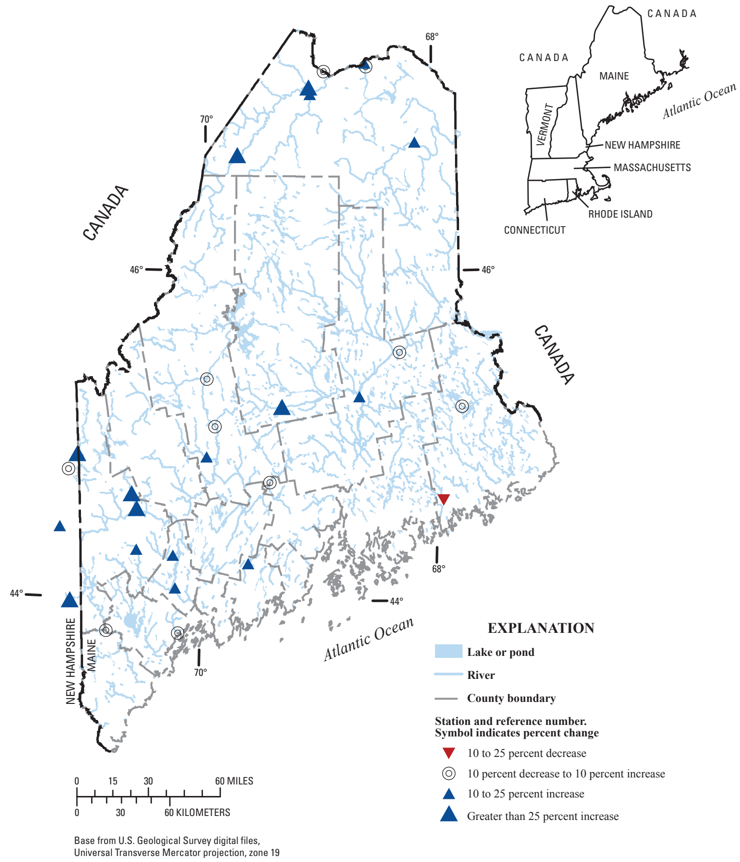

Figure 2. Magnitude of linear changes over time for annual peak flows at streamgaging stations on rivers in and near Maine, as computed by use of the Sen slope.

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