Distributed Modeling of Extreme Floods on a Large Watershed

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Abstract. Estimates of extreme floods and probabilities are needed in hydrologic engineering and in risk analysis to assess the safety of dams. A multidisciplinary approach was used to estimate extreme floods that integrated four main elements: radar hydrometeorology, stochastic storm transposition, paleoflood data, and rainfall-runoff modeling. The research focused on developing and applying a two-dimensional, distributed model to simulate extreme floods on the 12,000 km2 Arkansas River above Pueblo, Colorado with return periods up to 10,000 years. The four objectives were to: (1) develop a two-dimensional model suitable for large watersheds (area greater than 2,500 km2); (2) calibrate and validate the model to the June 1921 and May 1894 extreme floods on the Arkansas River; (3) develop a flood frequency curve with the model using the stochastic storm transposition technique; and (4) conduct a sensitivity analysis for initial soil saturation, storm duration and area, and compare the flood frequency curve with gage and paleoflood data.

The Two-Dimensional Runoff, Erosion and EXport (TREX) model was developed based on CASC2D. A new channel mesh generator was developed to provide spatially-distributed channel geometry inputs to TREX, based on field data collected at 20 sites. An improved channel topology algorithm was implemented to allow channels to be connected in eight directions. The TREX model was then applied to the 12,000 km2 Arkansas River basin above Pueblo, Colorado. The model was successfully calibrated to the record June 1921 flood. The May 1894 flood was used to validate the model. Basin-average rainfall depths and probabilities were estimated using DAD data and stochastic storm transposition with elliptical storms. From these extreme rainstorms, the TREX model was used to estimate a flood frequency curve for this large watershed. Model-generated peak flows were as large as 90,000 to 282,000 ft3/s at Pueblo for 100- to 10,000-year return periods. Sensitivity analysis showed that initial soil moisture was important and affected peak flows by a factor of 1.18 to 2.15. The temporal distribution of rainstorms did not significantly affect flood frequency predictions. By limiting storm areas and centers based on radar data, basin-average depths and estimated peak-flow probabilities were reduced. Model-generated frequency curves were generally comparable to peak flow and paleoflood data-based frequency curves. This model provides a unique physically-based method for determining flood frequency curves under varied scenarios of antecedent moisture conditions, space and time variability of rainfall and watershed characteristics, and storm center locations.

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