TEXAS TECH UNIVERSITY
CENTER FOR MULTIDISCIPLINARY RESEARCH IN TRANSPORTATION

PROJECT SUMMARY REPORT

Project Summary Report 0-4194-S

Project 0-4194

Authors
David B. Thompson, Texas Tech University
William H. Asquith, U.S. Geological Survey
Theodore G. Cleveland, University of Houston
and
Xing Fang, Lamar University

Dimensionless Hyetographs and Distribution of Storm Depth: Findings and Recommendations

For watersheds with drainage areas between 10 and 20 square miles (and some others, depending on circumstances), TxDOT hydraulic engineers use the hydrograph method for computing design discharges for hydraulic structures. Use of this method requires a unit hydrograph, a precipitation model (design storm), a loss model, and a computational tool such as HEC-HMS to put the pieces together.

Typically, the Natural Resources Conservation Service (NRCS) Type II precipitation distribution is used for the time distribution of precipitation. This distribution is very steep in the center of the storm, meaning that rainfall rates are high. It was the opinion of some TxDOT hydraulic engineers that these rainfall rates were excessive and might be resulting in design discharges that are larger than necessary for a given level of risk.

With new regulations about stormwater discharges, TxDOT designers are finding that they are designing stormwater management practices and Best Management Practices (BMPs) more frequently. TxDOT has no current guidelines for developing precipitation depths for such designs.

Therefore, the objectives of this research project were to:
(1) determine if the NRCS Type II rainfall distribution is appropriate for Texas hydrologic analyses;
(2) if not, then develop a rainfall distribution or distributions for use by TxDOT for hydrologic analysis; and
(3) develop a tool for design precipitation depth for BMP design.

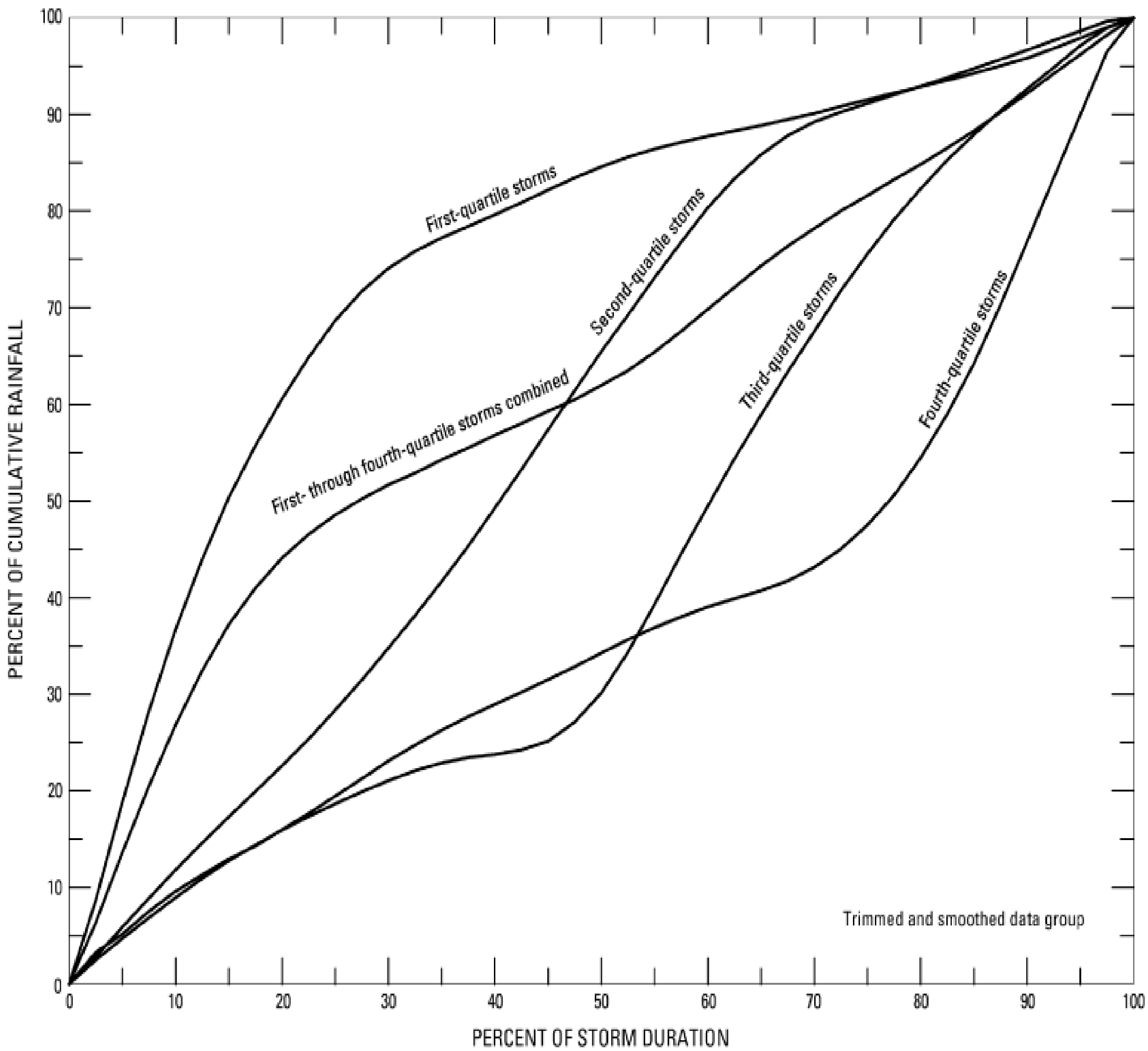
What We Did…

***Hyetographs*:**
Researchers assembled a dataset of about 1,600 known runoff-producing storms from about 100 watersheds. The hyetographs from this database were computed and compared with the NRCS Type II distribution. The Type II distribution had the maximum rainfall rate at the center of the storm, whereas the empirical hyetograph was front-loaded. That is, the maximum rainfall rate occurred in the first half of the storm. Furthermore, the maximum rainfall rate of the empirical hyetograph was substantially less than the maximum rate of the Type II

distribution. Therefore, further analyses were done.

Several custom programs were written to pass through the watershed dataset, extract the storms, and analyze the statistics of storm distribution. A number of possible shapes for the hyetograph were considered. The rainfall intensity hyetograph can be assumed to have a triangular shape. The simple geometry allows the shape to be fit to a dataset using relatively simple computations. For this analysis, the watershed dataset was supplemented with National Weather Service (NWS) hourly precipitation measurements. Then the parameters of the distribution were computed and a rainfall distribution developed.

The shapes of two probability distributions were considered as candidates for dimensionless hyetographs — the L-Gamma and the Wakeby. The L-Gamma distribution was fit to the watershed data and a



Dimensionless hyetograph curves for 50th percentile for a storm duration of 0-72 hours and a rainfall total of 1 inch or more.

hyetograph developed. The Wakeby distribution was fit to the NWS-supplemented dataset for development of a rainfall hyetograph.

In addition, an analysis after Huff's work was done on the watershed data. Huff's work separates rainfall events depending on whether the bulk of the storm event occurs in the first, second, third, or fourth quartile (on one-fourth of total storm duration) of the storm. (Huff, F.A. and Angel, J.R., 1989. "Frequency distributions of heavy rainstorms in Illinois," ISWS/CIR-172/89, Illinois State Water Survey, Champaign-Urbana, Illinois.)

Finally, storms were extracted from the watershed dataset and displayed as empirical hyetographs. A statistical analysis of these data was done to determine an empirical hyetograph. The results were smoothed to present a reasonable-looking hyetograph.

***Stormwater Management Precipitation Depth*:**
The combined watershed and NWS dataset was subjected to statistical analysis. The optimal minimum interevent time (MIT) was estimated by computing the autocorrelation coefficient of the time series of rainfall for durations from 0 to 24 hours.

The optimal minimum interevent time is the lag for which the autocorrelation coefficient becomes statistically indistinguishable from zero. The duration of the MIT was determined to be 8 or 9 hours. That is, if the time between adjacent storm events is 8 or 9 hours, then there is little correlation between the events and they can be considered independent.

L-moments were computed for each station in the dataset, and then regional analysis was performed on the L-moments so that site-specific parameters could be estimated. MIT considered in the analysis was 6, 12, 18, 24, 48, and 72 hours. Furthermore, on the basis of the regional analysis, a single curve can be used for Texas counties. A method of estimating the design depth based on MIT and nonexceedance probability was developed and is presented in the project report, 0-4194-1.

What We Found . . .

First, upon analysis of the data from the 100 watersheds, it was clear that runoff-producing rainfall events are not approximated by the NRCS Type II distribution.

Second, a number of different design hyetographs can be fit to available data. A triangular intensity hyetograph, L-Gamma and Wakeby distributions, and empirical distributions were all fit to either the watershed dataset, or the watershed dataset supplemented with NWS measurements.

Third, a method was developed for estimating the design depth of precipitation for a stormwater management problem, or design depth for a BMP. The optimal minimum interevent time is 8 or 9 hours. That is, rainfall events that are separated by 8 or 9 hours of no rainfall can be considered distinct and not part of the same storm.

The Researchers Recommend . . .

For hydrograph analysis, the NRCS method for estimating a rainfall distribution results in rainfall intensities that substantially exceed those observed in known runoff-producing storms. Furthermore, NRCS methods are based on the 24-hour duration. Therefore, use of NRCS rainfall distributions probably are not appropriate for TxDOT drainage design.

Therefore, a number of hyetographs were developed that can be used for drainage design by TxDOT designers. Analysts can choose from the triangular, L-Gamma, and empirical hyetographs.

For stormwater management or BMP design, precipitation depth to be used to size structures is not dependent solely on the return interval (or acceptable risk of failure). Design depth also depends on the minimum interevent time, that is, the time required for the structure or BMP to drain to full capacity.

Therefore, a set of tables was developed from which design precipitation can be determined by entry with the time-to-drain (which is set to the MIT) and the acceptable risk of failure. Use of this protocol should produce designs that are more defensible when compared with other empirical approaches.

For More Details…

The research is documented in the following report:

Report No. 0-4194-1

Research Supervisor: David B. Thompson, (806) 742-3523, david.thompson@coe.ttu.edu
Project Director: Amy Ronnfeldt, TxDOT Design Division, 118 E. Riverside Drive, Austin, TX, 78704, (512) 416-2328, aronnfel@dot.state.tx.us.

To obtain copies of the report, contact the Center for Transportation Research Library at (512) 232-3126, ctrlib@uts.cc.utexas.edu.

TXDOT IMPLEMENTATION STATUS
January 2005

The research developed an improved methodology to predict rainfall depth statewide for use in hydraulic design of BMPs. The new hydraulic methodology will be implemented statewide by the TxDOT Design Division by future incorporation into the online TxDOT Hydraulic Design Manual and will be made available online.

For more information, contact Sharon Barta, P.E., Research and Technology Implementation Office, at (512) 465-7403 or email sbarta@dot.state.tx.us.

Your Involvement Is Welcome...

This research was performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FWHA or TxDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names were used solely for information and not for product endorsement.

The University of Texas at Austin
Center for Transportation Research Library
3208 Red River #115
Austin, TX 78705-2650