



Prepared in cooperation with  
New York State Department of Environmental Conservation  
New York Department of State  
New York State Department of Transportation  
New York City Department of Environmental Protection

# Bankfull Discharge and Channel Characteristics of Streams in New York State

Scientific Investigations Report 2009-5144

U.S. Department of the Interior  
U.S. Geological Survey

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By Christiane I. Mulvihill, Barry P. Baldigo, Sarah J. Miller, Douglas DeKoskie,  
and Joel DuBois

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## Conversion Factors, Datum, and Acronyms

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
inch (in.)	25.4	millimeter (mm)
Area		
square foot (ft <sup>2</sup> )	0.09290	square meter (m <sup>2</sup> )
square mile (mi <sup>2</sup> )	259.0	hectare (ha)
square mile (mi <sup>2</sup> )	2.590	square kilometer (km <sup>2</sup> )
Flow rate		
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second (m <sup>3</sup> /s)
cubic foot per second per square mile [(ft <sup>3</sup> /s)/mi <sup>2</sup> ]	0.01093	cubic meter per second per square kilometer [(m <sup>3</sup> /s)/km <sup>2</sup> ]

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

## LIST OF ACRONYMS

DCSWCD	Delaware County Soil and Water Conservation District
GCSWCD	Greene County Soil and Water Conservation District
GIS	Geographic information system
HEC-RAS	Hydraulic Engineering Center River Analysis System
HHM	Hydrologic and Habitat Modification
LOWESS	Locally weighted scatterplot smoother
MAR	Mean annual runoff
NPSCC	Nonpoint-Source Coordinating Committee
NYCDEP-SMP	New York City Department of Environmental Protection Stream Management Program
NYSDEC	New York State Department of Environmental Conservation
NYDOS	New York Department of State
NYSDOT	New York State Department of Transportation
USGS	U.S. Geological Survey



# Bankfull Discharge and Channel Characteristics of Streams in New York State

By Christiane I. Mulvihill<sup>1</sup>, Barry P. Baldigo<sup>1</sup>, Sarah J. Miller<sup>2</sup>, Douglas DeKoskie<sup>3</sup>, and Joel DuBois<sup>4</sup>

## Abstract

Equations that relate drainage area to bankfull discharge and channel characteristics (such as width, depth, and cross-sectional area) at gaged sites are needed to help define bankfull discharge and channel characteristics at ungaged sites and can be used in stream-restoration and protection projects, stream-channel classification, and channel assessments. These equations are intended to serve as a guide for streams in areas of similar hydrologic, climatic, and physiographic conditions. New York State contains eight hydrologic regions that were previously delineated on the basis of high-flow (flood) characteristics. This report seeks to increase understanding of the factors affecting bankfull discharge and channel characteristics to drainage-area size relations in New York State by providing an in-depth analysis of seven previously published regional bankfull-discharge and channel-characteristics curves.

Stream-survey data and discharge records from 281 cross sections at 82 streamflow-gaging stations were used in regression analyses to relate drainage area to bankfull discharge and bankfull-channel width, depth, and cross-sectional area. The  $R^2$  and standard errors of estimate of each regional equation were compared to the  $R^2$  and standard errors of estimate for the statewide (pooled) model to determine if regionalizing data reduced model variability. It was found that regional models typically yield less variable results than those obtained using pooled statewide equations, which indicates statistically significant regional differences in bankfull-discharge and channel-characteristics relations.

Statistical analysis of bankfull-discharge relations found that curves for regions 4 and 7 fell outside the 95-percent confidence interval bands of the statewide model and had intercepts that were significantly different ( $p \leq 0.10$ ) from

the other five hydrologic regions. Analysis of channel-characteristics relations found that the bankfull width, depth, and cross-sectional area curves for region 3 were significantly different ( $p \leq 0.05$ ) from the other six regions.

It was hypothesized that some regional variability could be reduced by creating models for streams with similar physiographic and climatic characteristics. Available data on streamflow patterns and previous regional-curve research suggested that mean annual runoff, Rosgen stream type, and water-surface slope were the variables most likely to influence regional bankfull discharge and channel characteristics to drainage-area size relations. Results showed that although all of these factors had an influence on regional relations, most stratified models have lower  $R^2$  values and higher standard errors of estimate than the regional models.

The New York statewide (pooled) bankfull-discharge equation and equations for regions 4 and 7 were compared with equations for four other regions in the Northeast to evaluate region-to-region differences, and assess the ability of individual curves to produce results more accurate than those that would be obtained from one model of the northeastern United States. Results indicated that model slopes lack significant differences, though intercepts are significantly different. Comparison of bankfull-discharge estimates using different models shows that results could vary by as much as 100 percent depending on which model was used and indicated that regionalization improved model accuracy.

## Introduction

Regional bankfull-discharge and channel-characteristic models use linear regression equations to relate bankfull discharge and bankfull-channel dimensions (width, depth, and cross-sectional area) to drainage-area size. Bankfull discharge is the flow that reaches the transition between the channel and its flood plain and is thus morphologically significant (Leopold and others, 1964). Bankfull may be functionally defined and identified as the stage or flow at which the stream is about to overtop its banks (Leopold and others, 1964; Leopold, 1994) and is reported to occur every 1 to 2 years (Dunne and Leopold, 1978; Rosgen, 1996; Harman and Jennings, 1999),

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## 2 Bankfull Discharge and Channel Characteristics of Streams in New York State

or 1.5 years on average (Rosgen, 1994). Bankfull discharge is important to watershed managers because it is considered to be the most effective flow for moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphological characteristics of channels (Dunne and Leopold, 1978).

Different types of regional curves (models) have been introduced over the past 50 years to respond to a number of interrelated stream resource-management needs. Bankfull-discharge and channel-characteristics curves were first developed in the mid-1900s to describe stream depth, velocity, and cross-sectional area as functions of discharge to aid in the analyses and interpretation of sediment flow models at sites with U.S. Geological Survey (USGS) streamflow-gaging stations (Leopold and Maddock, 1953; Leopold and others, 1964). Investigations defining average channel dimensions and relating bankfull to effective discharge showed the relative consistency of average bankfull-channel dimensions and function for streams of similar drainage-area size (Wolman and Miller, 1960; Leopold and others, 1964). Regression models (regional curves) developed by Dunne and Leopold (1978), and reproduced with minor changes by Rosgen (1998a), depict several generalized regions of the United States. These generic models were developed with locally disparate data sets, so were inaccurate outside the sampling area because they did not account for specific differences in geomorphic characteristics caused by regional variations in landform, climate, geologic conditions, and runoff.

The demand for regional curves in New York State was spurred by an increase in the use of fluvial-geomorphology concepts in stream channel and bank restoration projects designed to decrease suspended sediment loads, reduce flood-related damages, improve aquatic habitat, and generally stabilize stream channels (U.S. Geological Survey, 2008). Geomorphology techniques such as those required for stream assessment, restoration design, and project monitoring have experienced an upswing in use among Federal, state, county, and local agencies in the State in part because appropriate use of these methods has been shown to reduce the need for repetitive site visits to remove sediments or repair streambanks, thus, reducing long-term channel-maintenance expenses (U.S. Geological Survey, 2008). Geomorphology-based restoration projects (often called “natural channel design” projects) require data that define what a stable stream channel should look like in a given region (U.S. Geological Survey, 2008). A critical set of information used in designing these geomorphologic restoration projects is the regional bankfull-discharge and channel-characteristics curves (U.S. Geological Survey, 2008). Prior to 1999, these regional data had not been compiled or analyzed in New York State.

This document summarizes a 9-year (2000–2008) statewide cooperative effort to develop regional bankfull-discharge and channel-characteristics models through a process established by the New York City Department of Environmental Protection Stream Management Program (NYCDEP-SMP; Miller and Davis, 2003; Powell and others,

2004). This study was led by the USGS and overseen by the New York State Hydrologic and Habitat Modification (HHM) subcommittee of the New York State Nonpoint-Source Coordinating Committee (NPSCC). Other cooperators included the New York State Department of Environmental Conservation (NYSDEC), New York State Department of Transportation (NYSDOT), New York Department of State (NYDOS), Greene County Soil and Water Conservation District (GCSWCD), and Delaware County Soil and Water Conservation District (DCSWCD).

This report seeks to increase understanding of the factors affecting bankfull discharge and channel characteristics to drainage-area size relations in New York State by providing an in-depth analysis of seven previously published regional bankfull-discharge and channel-characteristics curves (Miller and Davis, 2003; Westergard and others, 2005; Mulvihill and others, 2005, 2006, 2007; Mulvihill and Baldigo, 2007). The objectives of the analysis are to determine if the curves: (1) correspond to other published ranges for bankfull-discharge return intervals, (2) differ significantly from each other sufficiently to support data regionalization, (3) differ significantly or are less accurate than statewide (pooled) curves, (4) change significantly or are less accurate than curves redeveloped using existing data for New York State and redefined (updated) hydrologic-region boundaries (Lumia and others, 2006), (5) can be improved (made more accurate) if bankfull-discharge data are stratified by mean annual runoff, Rosgen stream type, or slope, and (6) differ from those developed for other nearby states or provinces. Additional uses of regional curves are also identified and discussed to encourage increased dialogue on their potential utility beyond confirmation of bankfull features in reference reaches or other ungaged sites. The information presented herein provides a more in-depth analysis of the factors that effect bankfull discharge and channel characteristics in New York State and is not intended to supersede previously published hydrologic-region reports.

## Methods

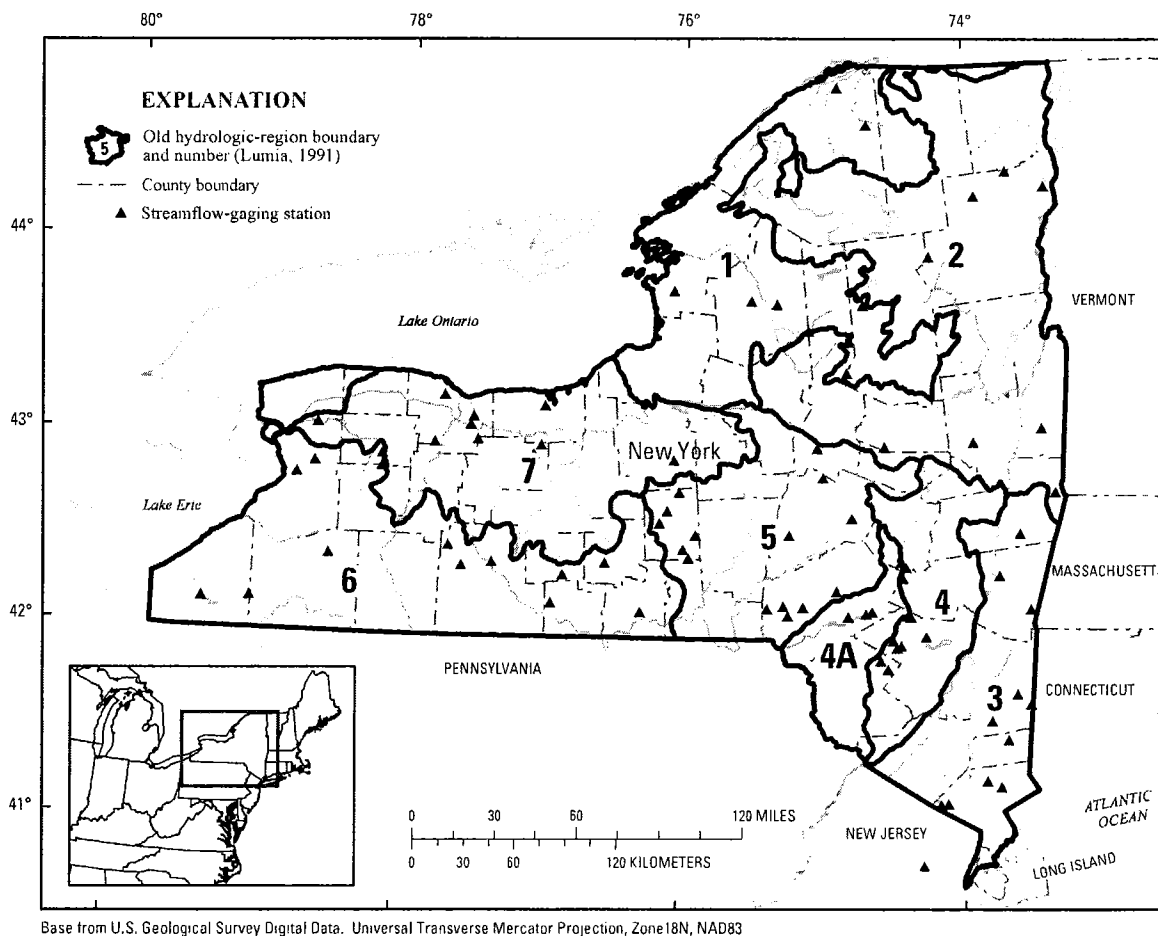
A detailed explanation of the methods used to select stable stream-channel sites, collect field data, and calculate bankfull discharge and bankfull-channel characteristics are given in Powell and others (2004). Explanations of any unique circumstances encountered at individual streamflow-gaging stations—for example, period of record less than 10 years, using a LOWESS (locally weighted scatterplot smoother; Ott and Longnecker, 2001) smooth to identify the elevation of bankfull stage, using the HEC-RAS computer program (Brunner, 1997) to calculate bankfull discharge, streamflow-gaging station being inactive (lacking a current stage-to-discharge rating curve)—can be found in previously published hydrologic-region reports (Miller and Davis, 2003; Westergard

and others, 2005; Mulvihill and others, 2005, 2006, 2007; Mulvihill and Baldigo, 2007) and appendix 1.

## Hydrologic-Region Delineation

A premise of this investigation was that a single model depicting bankfull discharge and channel characteristics to drainage-area size relations was not appropriate in New York State because of the highly variable physiography and climate of the State. Therefore, the state needed to be divided into hydrologic regions on the basis of the physiographic and geologic characteristics that affect streamflow. A previous investigation predicting the magnitude and frequency of flood discharges in New York divided the state into eight hydrologic regions (Lumia, 1991; fig. 1). These regional boundaries were based on multiple linear regression analyses that related the peak-discharge recurrence intervals to basin characteristics

such as drainage area, main-channel slope, basin storage, mean annual precipitation, percentage of basin covered by forest area, mean main-channel elevation, and a basin-shape index (ratio of basin length to basin width) (Lumia, 1991). Resulting hydrologic regions refer to areas in which streamflow-gaging stations indicate a similarity of peak-discharge response that differs from the peak-discharge response in adjacent regions (Lumia, 1991). These hydrologic regions were considered ideal candidates for the preliminary stratification of bankfull-discharge and channel-characteristics data because it was hypothesized that peak-discharge and bankfull-discharge responses were being influenced by the same climatic and physiographic variables. This report presents a single model for hydrologic regions 1 and 2 (fig. 1), because in 2004, an additional 12 years of annual peak-discharge data updated skews (Lumia and Baevsky, 2000) for computing station flood-frequency curves as outlined in U.S. Water Resources Council Bulletin 17B (1981), and updated basin characteristics



**Figure 1.** Boundaries of hydrologic regions defined by Lumia (1991), and the locations of the 82 streamflow-gaging stations surveyed, 1999–2006.