



United States  
Department of  
Agriculture

Forest Service

**Northern  
Research Station**

Research Paper NRS-3



# **Factors Affecting Large Peakflows on Appalachian Watersheds: Lessons from the Fernow Experimental Forest**

**James N. Kochenderfer  
Mary Beth Adams  
Gary W. Miller  
J. David Helvey**



---

---

## Abstract

Data collected since 1951 on the Fernow Experimental Forest near Parsons, West Virginia, and at a gaging station on the nearby Cheat River since 1913 were used to evaluate factors affecting large peakflows on forested watersheds. Treatments ranged from periodic partial cuts to complete deforestation using herbicides. Total storm precipitation and average storm precipitation intensity were the most significant variables affecting peakflows, and were far more important than timber harvesting activities. Since January 1913, of the 20 highest-ranked peakflows on the Cheat River at the Parsons gaging site, 11 have occurred since 1984 during a period of limited timber harvesting. These results support earlier findings that forests do not prevent floods and that prudent forest harvesting operations do not increase large flood peakflows.

---

---

---

---

## The Authors

JAMES N. KOCHENDERFER and MARY BETH ADAMS are, respectively, research forester (retired), and, project leader/research soil scientist with the U.S. Forest Service's Northern Research Station at Parsons, West Virginia.

GARY W. MILLER is a research forester with the Northern Research Station at Morgantown, West Virginia.

J. DAVID HELVEY (retired) was a project leader and research hydrologist with the Northeastern Forest Experiment Station at Parsons, West Virginia.

---

---

---

---

## Cover Photos

Top: stormflow from a 3,355-acre forested watershed on the Fernow Experimental Forest after 1.33 inches of rain fell in March on 8 inches of snow. Bottom: baseflow from the watershed in May at the same location.

---

---

Manuscript received for publication 1 March 2007

---

---

Published by:  
USDA FOREST SERVICE  
11 CAMPUS BLVD SUITE 200  
NEWTOWN SQUARE PA 19073-3294

September 2007

For additional copies:  
USDA Forest Service  
Publications Distribution  
359 Main Road  
Delaware, OH 43015-8640  
Fax: (740)368-0152

---

---

Visit our homepage at: <http://www.nrs.fs.fed.us/>

## INTRODUCTION

A common misconception, often repeated by the lay public and professional land managers, is that floods are associated with timber harvesting. As far back as 1863, G.P. Marsh proposed in “Man and Nature” that flooding is affected by forest clearing (Hewlett and Doss 1984). The controversy over the influence of forest harvesting on streamflow regulation continued into the early part of the 20<sup>th</sup> century (Dodds 1969). Despite a dearth of scientific evidence at the time, conservationist Gifford Pinchot, when asked at a Congressional hearing whether floods along southern Appalachian rivers were traceable to the denuding of forests, replied: “Directly, directly...It is a perfectly clear cut proposition” (House of Represent. 1907).

The possible relationship between forest clearing and flooding gained national attention in March 1907 when heavy rains in the headwaters of the Monongahela River were blamed for flooding at Pittsburgh, Pennsylvania. The flooding caused millions of dollars in property damage (McKim 1970), and flooding was attributed to excessive cutting and burning of forests in the watersheds of the Allegheny and Monongahela Rivers. After reviewing the historical records, Kite<sup>1</sup> concluded that the Cheat River, a major tributary of the cut and burned watersheds, apparently contributed little to the flood. His conclusion is supported by a lack of evidence of flooding in community newspapers, such as the *Parsons Advocate*, during March 1907. This small community was located on a flood plain at the convergence of two rivers forming the Cheat River, the second largest tributary of the Monongahela River, downstream from some of the most severely denuded forest land in the East.

---

<sup>1</sup>Kite, Steven J. 1997. A short history of flooding in the Cheat River Basin in West Virginia and Pennsylvania. Unpublished report on file at the U.S. Forest Service, Timber and Watershed Laboratory, Parsons, West Virginia.

On the other side of the forest-flood issue was Colonel H. M. Chittenden (1909), a member of the U.S. Army Corps of Engineers. He disagreed with Pinchot, arguing that “periods of long-continued, wide spread and heavy precipitation alone cause great floods in large rivers.” Chittenden added that during such periods, “The forest bed becomes completely saturated, its storage capacity exhausted, and it has no more power to restrain floods than the open country itself.” He proposed that engineering solutions such as reservoirs, levees, the clearing of river channels, and raising grades were necessary for flood protection.

Although the controversy surrounding the degree of control that forests exert on streamflow would continue for many years (Dodds 1969, Anderson et al. 1976), on March 1, 1911, Congress passed the Weeks Law, which authorized “the purchase of forested, cut-over, or denuded lands within the watersheds of navigable streams necessary to the regulation of the flow of navigable streams.” This law authorized government agencies to purchase land after state consent, which eventually became the national forests of the Eastern United States.

During the next several decades, forest research stations were established to better understand how to manage forests to achieve multiple objectives, including a dependable supply of clean water. As part of this effort, watershed research was initiated in 1951 on the Fernow Experimental Forest near Parsons, West Virginia (Fig. 1). Results from watershed studies at such research stations including the Fernow refuted commonly held concepts about forests and water. For example, the once popular notion that cutting trees causes springs to dry up (e.g., Maxwell 1894) and reduces streamflow was disproved (e.g., Hibbert 1967, Hornbeck et al. 1993). Other research demonstrated that cutting trees actually increases streamflow temporarily, particularly during growing seasons, because water losses to interception and

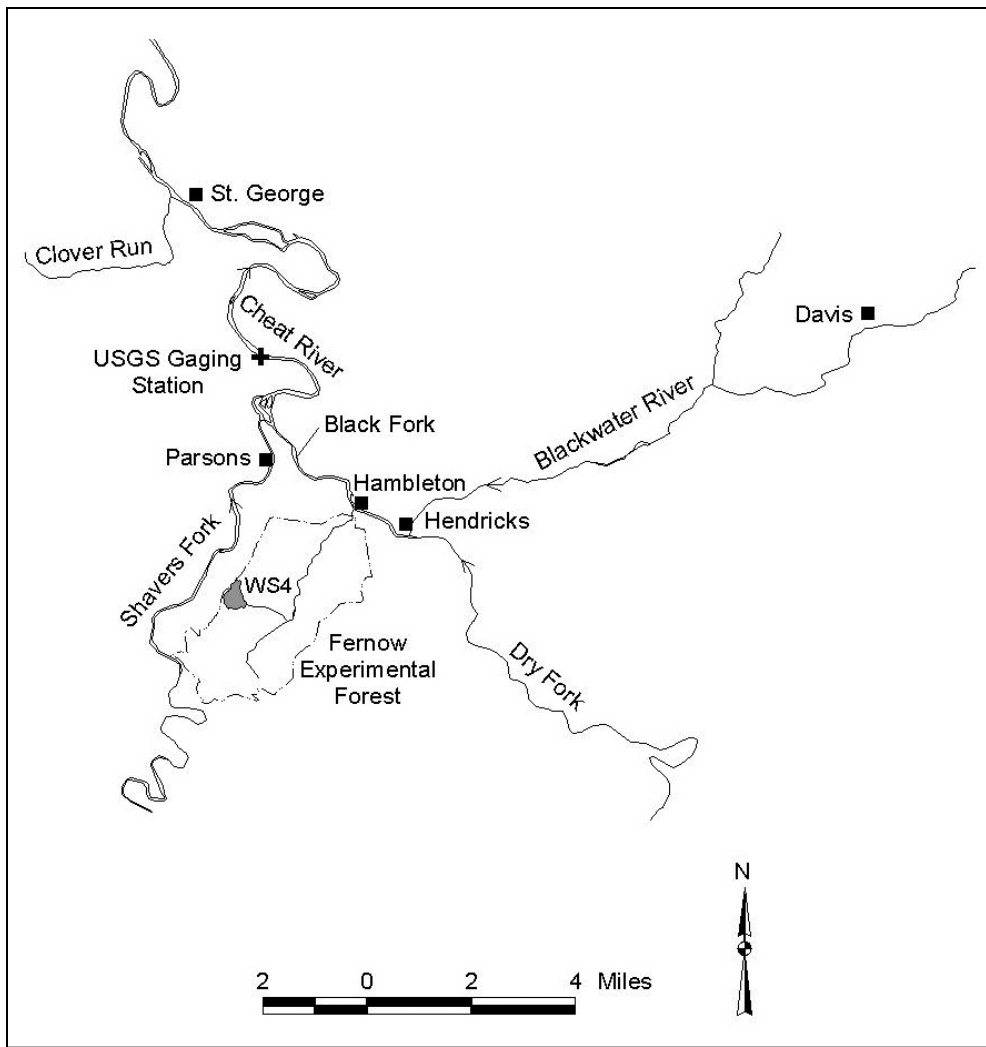


Figure 1.—U.S. Geological Survey gaging station on the Cheat River and the Fernow Experimental Forest.

transpiration are reduced, thereby increasing soil moisture and streamflow. Still other research demonstrated that reforestation of abandoned farmland on large drainage basins in Massachusetts (Patric and Gould 1976) and the southern Piedmont (Trimble et al. 1987) reduced streamflow.

Some of this research also focused on peak stormflows and flooding. Perhaps the most widely quoted study on the relationships between forests and floods was that of Lull and Reinhart (1972). They concluded that:

- “The forest, because of its full occupancy, provides for any site a maximum opportunity for controlling runoff from flood-producing rainfalls; even so, the forest cannot prevent floods.”

- “Infiltration capacities of the forest floor are almost everywhere greater than rainfall intensities.”
- “The forest is the best of all possible natural cover for minimizing overland flow, runoff, and erosion.”
- “With reasonable care, the forest can be cut with little detriment to its site-protective capacity.”

Hewlett (1982a) supported those findings, stating that “forest operations do not seriously increase flood flows in major streams.”

More than 90 years after the Pinchot-Chittenden debate, and despite much significant research, the perceived relationship between forests and floods continues to exert

a major influence on land-management decisions in the United States. Recent floods in West Virginia have again raised concerns that land-use activities such as timber harvesting are influencing the frequency and magnitude of flood events. This is not surprising because forests currently cover 78 percent of the State (Griffith and Widmann 2003) and timber harvesting is widespread, occurring on an estimated 235,000 acres in 2005, according to the West Virginia Division of Forestry.

Since the impacts of various kinds of timber harvesting and other land uses on streamflow have been evaluated on gaged watersheds on the Fernow Experimental Forest since 1951, we felt that an evaluation of Fernow data for large storms would provide timely and useful information. We assembled a data set of peak streamflows for the 50 largest storms between 1951 and 2004 for seven watersheds on the Fernow (<http://www.fs.fed.us/ne/parsons/webdata/data/downloads>). Although much of our present knowledge about forest hydrology has been obtained from experimental watersheds (Hewlett et al. 1969), caution should be used when extrapolating results from studies evaluating timber harvesting impacts on peakflows from small (fewer than 100 acres) experimental watersheds to large river basins containing thousands of acres. Entire research watersheds typically are subjected to the same treatment in short timespans so that the impacts of various forest practices on the quantity and quality of streamflow can be evaluated (e.g., Reinhart et al. 1963). In reality, entire watersheds of major streams are not subjected to these same intense land-use practices. Patterns of land ownership and multiple management objectives ensure a variety of uncoordinated management activities on larger watersheds. For example, timber harvesting activities, which occur on about 2 percent of the forest land in West Virginia each year, usually are confined to small portions of larger watersheds. A review of West Virginia Division of Forestry Timber Harvest Notification forms submitted between 2000 and 2006 on the 462,080-acre Cheat River watershed above Parsons revealed that annual harvesting occurred on less than 2 percent of the watershed.

Also, such harvests typically remove only part of the vegetation (selection or diameter-limit harvests).

The effect of harvesting will differ from those due to deforestation or conversion to other land uses (Hornbeck 1973). The regrowth of eastern forests is so rapid and vigorous that the effects of timber harvesting on streamflow diminish rapidly (Hornbeck et al. 1993). In this paper we focus on the impacts of forest management activities on peakflows and flooding. Our objectives were to: 1) use peakflow data from the Fernow Experimental Forest to evaluate dominant factors believed to affect peak streamflow from forested watersheds; and 2) compare results from small (Fernow) and large watersheds (Cheat River basin) with respect to flooding and peakflows.

## STUDY AREAS AND HISTORICAL USE

The Fernow Experimental Forest is located in the unglaciated Allegheny Plateau region of north-central West Virginia (Fig. 1). Topography in this region of the Allegheny Mountains is characterized by steep mountains and narrow valleys. The average elevation of the study area is about 2,500 feet. The predominant soil is Calvin silt loam with moderate erosion hazard (Losche and Beverage 1967) underlain with fractured sandstone and shale of the Hampshire formation. Soil depth usually is less than 3 feet. The first harvesting activity occurred between 1905 and 1910. At that time, most smaller trees and species such as sugar maple (*Acer saccharum* Marsh), American beech (*Fagus grandifolia* Ehrh.), and black birch (*Betula lenta* L.) were considered unmerchantable and often were left standing. Today, dominant tree species include various oaks (*Quercus* spp.), yellow-poplar (*Liriodendron tulipifera* L.), and sugar maple.

Research on forest hydrology began on the Fernow in 1951 when streamflow and precipitation measurements began on watersheds 1 through 5 (Fig. 2, Table 1). Data were collected continuously while the watersheds were undisturbed during a 6-year calibration period to develop relationships between the watersheds. In 1957-58, studies were initiated to evaluate the effects of four cutting practices on streamflow (Reinhart et al. 1963). Watershed 4 (WS4) has not been cut since the original 1905-10 harvesting, and serves as the reference watershed. Data collection began on WS6 and WS7 in 1956.

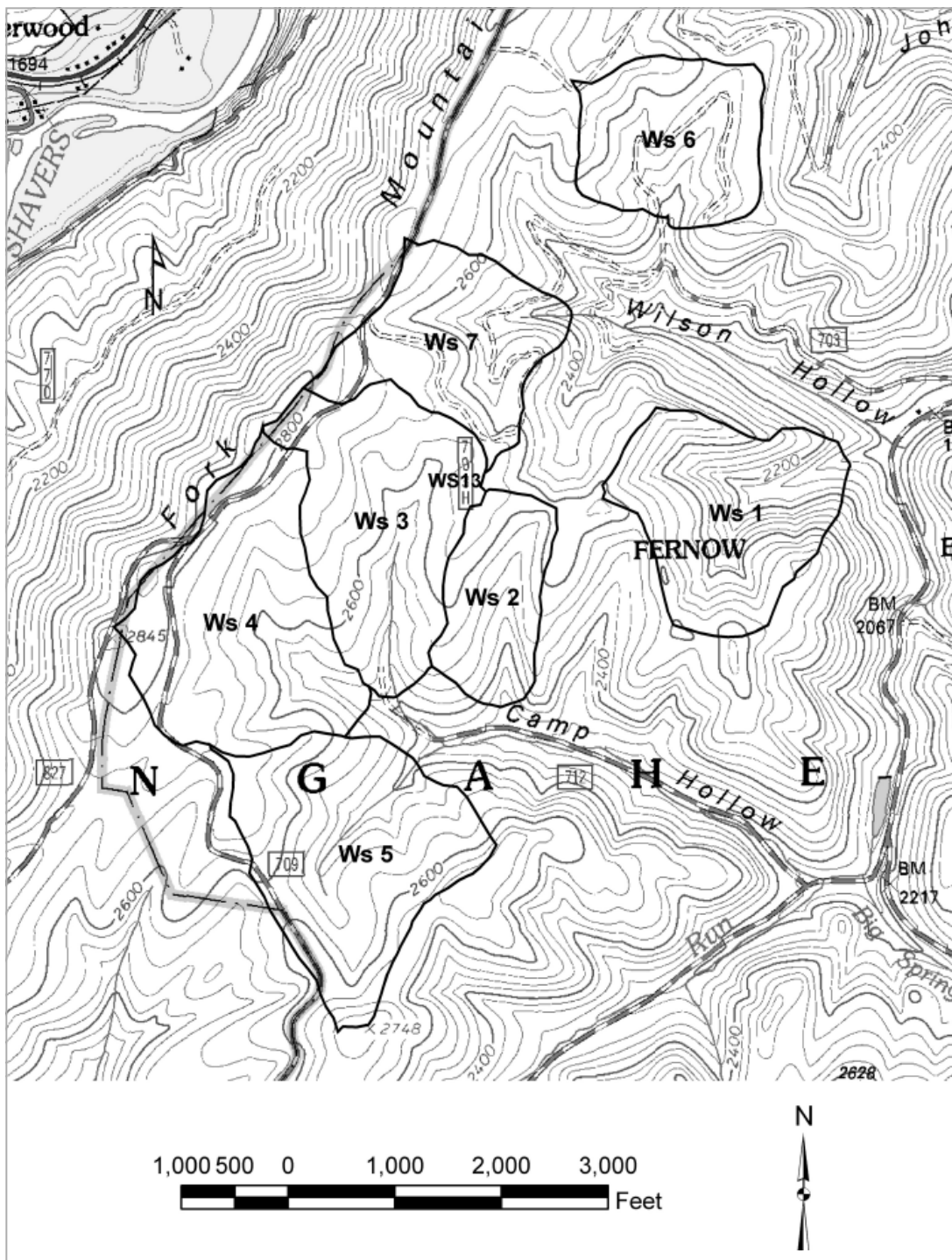


Figure 2.—Watersheds on the Fernow Experimental Forest used in this study.

A wide range of treatments has been applied to the Fernow watersheds over the years (Table 1), ranging from none or minimal treatments (reference WS4), partial cutting (WS2, WS5), commercial clearcut with no best management practices (BMPs) (WS1), and normal silvicultural clearcutting harvests using BMPs (WS3), to clearcutting followed by herbicide treatments

that rendered the watersheds (WS6, WS7) barren of vegetation for several years. Gaps in the records represent periods before the construction of gaging stations or periods when they were inactive.

The Cheat River watershed above the Parsons gaging station (Fig. 1) contains 722 square miles (462,080

**Table 1.—Treatment history and some characteristics of seven Fernow watersheds used in the study**

WS	Treatment	Treatment date	Basal-area	Aspect	Area
			cut		
			<i>percent</i>		
1	Clearcut to 6 inches d.b.h., except culls Fertilized with 500 lb/acre urea	5/57-6/58 5/71	74	NE	74.4
2	Diameter-limit				
	Cut trees ≥17.0 inches d.b.h.	6/58-11/58	37	S	38.3
	Cut trees ≥17.0 inches d.b.h.	8/72	16		
	Cut trees ≥17.0 inches d.b.h.	1/78	3		
	Cut trees ≥17.0 inches d.b.h.	5/88-7/88	24		
	Cut trees ≥17.0 inches d.b.h.	9/96	10		
3	Intensive selection cut, including cull trees > 5 inches d.b.h. Repeat treatment 0.4-acre patch cuttings totaling 5.6 acres, cut down to 5 inches, 1- to-5-inch. stems sprayed with herbicide Clearcut to 1 inch d.b.h., except for a partially cut 7.4-acre shade strip along the stream channel Shade strip clearcut Ammonium sulfate fertilizer applied	10/58-2/59 9/63-10/63 7/68-8/68 7/69-5/70 11/72 12/89 - present	13 8 6 91 9	S	84.7
4	No treatment/natural recovery since 1905		0	SE	95.7
5	Single-tree selection				
	Select trees ≥ 11.0 inches d.b.h.	8/58-12/58	21	NE	90.0
	Select trees ≥ 11.0 inches d.b.h.	2/68-5/68	14		
	Select trees ≥ 11.0 inches d.b.h.	1/78-6/78	17		
	Select trees ≥ 11.0 inches d.b.h.	2/83-3/83	4		
	Select trees ≥ 11.0 inches d.b.h.	2/88-5/88	23		
	Select trees ≥ 11.0 inches d.b.h.	4/98-11/98	22		
6	Lower 27.5 acres clearcut Maintained barren with herbicides Upper 27.5 acres clearcut Entire watershed maintained barren with herbicides Planted with Norway spruce Aerially sprayed with herbicides	3/64-10/64 5/65-10/69 10/67-2/68 5/68-10/69 3/73 8/75, 8/80	51  49	S	55.2
7	Upper 30 acres clearcut Maintained barren with herbicides Lower 30 acres clearcut Entire watershed maintained barren with herbicides Natural recovery	11/63-3/64 5/64-10/69 10/66-3/67 5/67-10/69 10/69 to present	49  51	E	59.9

acres) of drainage area. Elevations range from 1,600 to 4,861 feet at Spruce Knob, the highest point in West Virginia. Annual precipitation averages about 53 inches. The original forest included extensive dense stands of red spruce (*Picea rubra* L.) and eastern hemlock (*Tsuga canadensis* L.) above an elevation of 3,000 feet (Fig. 3). It was estimated that the original spruce forest in West Virginia contained nearly 500,000 acres (Hopkins 1891), including 140,000 acres of spruce forests on the Cheat

River watershed. Since 72 percent of the Cheat watershed above the Parsons gaging station is above 3,000 feet in elevation, it is reasonable to assume that the original spruce and hemlock forests covered at least half of the watershed. A forest inventory in 2000 indicated that the two counties (Tucker and Randolph) that comprise most of the Cheat River watershed above Parsons are about 86-percent forested (Griffith and Widmann 2003).





Figure 3.—This logging railroad was constructed in 1913 through a dense red spruce stand in the Cheat River watershed (photo courtesy of Dr. Roy B. Clarkson).

In the mid-1880s, loggers began harvesting timber in the Cheat River watershed (Fansler 1962); this large-scale logging continued until the early 1920s (Fig. 4). Clarkson (1964) described the cutting as heavy, resulting in large accumulations of dried slash. Sparks from steam-powered logging equipment often set fire to the highly inflammable slash. These fires resulted in the conversion of large areas of spruce forest to fire cherry (*Prunus pennsylvanica* L.), blackberry (*Rubus* spp.), and bracken fern (*Pteridium aquilinum* L.). In some areas, deep humus was burned down to bedrock (Fig. 5) (Brooks 1911). The effects of wildfires remain evident in the high plateaus of Tucker and Randolph Counties within the Cheat River

watershed. Merely cutting these original forests without burning would not have inflicted the long-term damage associated with burning because undamaged soil, spruce regeneration, and some spruce seed sources would have remained after cutting. Although some of this land was planted by U.S. Forest Service crews in the early 1930s (Fig. 6), much of the high-elevation land formerly occupied by red spruce and hemlock includes inferior stands of hardwoods today (Hornbeck and Kochenderfer 1998). The area of West Virginia occupied with forests dominated by red spruce has shrunk from the original estimate of 500,000 acres to the current estimate of less than 50,000 acres (Griffith and Widmann 2003).





Figure 4.—The Babcock Lumber Co. logging Blackwater Canyon in the Cheat River watershed in 1910 (photo courtesy of David F. Strahin).



Figure 5.—Fire, which often followed logging in the red spruce-hemlock, destroyed the thick organic layer that once covered exposed roots and rocks (National Archives photo).



Figure 6.—Forest Service tree planting crew in the early 1930s in the Cheat River watershed near Davis, West Virginia (photo courtesy of Monongahela National Forest).

## METHODS

### Data Acquisition and Analyses

#### Fernow Storms Data Set

On the Fernow, stream discharge used for these evaluations was measured with 120° V-notch weirs. Precipitation is measured with recording gages and standard 8-inch rain gages (Adams et al. 1994). Annual precipitation averages 58 inches and is distributed evenly between dormant (November 1 to April 30) and growing seasons (May 1 to October 31). Annual streamflow from WS4 averages 26 inches: 6 inches during the growing season and 20 inches during the dormant season.

Data from seven Fernow watersheds with the longest period of record were used in this study (Fig. 2, Table 1). Streamflow records were examined for the reference watershed (WS4) to determine the 50 largest peakflows since record collection began in May 1951. Peakflows on the other six watersheds also were determined for these storm dates. These 50 largest storms were chosen because they have the greatest potential to influence downstream

flooding. We also were trying to increase the number of observations available for statistical analysis, though the “optimum” number of storms for such statistical analyses is unknown. Precipitation measured during each storm, taken from recording rain gages, also includes snow that may have been on the ground at the time of each event; about 38 percent of the storms were influenced by snow. Meteorological records from the Fernow were used to determine the snow contribution for each event.

The total storm precipitation was measured with the Fork Mountain rain gage, the gage closest to the watersheds. As a result, the precipitation amount, independent of snow, is the same for each watershed for a single storm event. Because of the proximity of the watersheds and because most of these storms are unlikely to be limited geographically summer thunderstorms that could vary in precipitation delivery among watersheds (34 percent of the storms occurred during the growing season), this single value is believed to be a reasonable representation of total storm precipitation. Antecedent

**Table 2.—Range of values for variables used in multiple regression analysis, by watershed, Fernow Experimental Forest**

Variable	WS1	WS2	WS3	WS4	WS5	WS6	WS7
BASAL AREA (ft <sup>2</sup> /acre)	2.1 - 138.4	60.8 - 0 111.1	0.0 -151.8	100.1 - 158.2	87.3 - 116.4	0.0 - 139.1	0.00 - 119.4
SKIDROAD LENGTH (mi)	0.0 -3.22	0.0 - 1.05	0.0 - 2.10	0.00	0.00 -2.80	0.00 - 1.28	0-.00 - 1.27
LOGGING INTERVAL (years)	1 - 52	1 - 53	0 - 53	49 - 97	0 - 53	0 - 59	0 - 59
14 day-AP (inches)	0.97 - 6.88	0.81 - 6.88	0.67 - 6.95	0.69 - 7.20	0.73 - 6.26	0.69 - 6.53	0.73 - 6.64
MDA streamflow (csm)	0.15 - 24.02	0.17 - 34.32	0.23 - 22.97	0.29 - 23.42	0.29 - 26.84	0.18 - 29.99	0.29 - 29.58
ELEV (ft)	640	320	400	405	348	240	480

precipitation for each watershed was determined by the Thiessen polygon method (Hewlett 1982b), which weights rain-gage catch by the area each gage represents, and was calculated for 7 and 14 days before each storm.

Nine variables that were hypothesized to affect peakflow were recorded or estimated for each of the seven watersheds. These are related to both the character of the storm event and to a variety of watershed physical features: These include:

1. AVG. INTENSITY—Average storm intensity, in inches per hour (in/hr), is total storm precipitation (inches) divided by storm duration (hours); average storm intensity ranged from 0.02 to 0.92 in/hr.
2. BASAL AREA—Estimated total stand basal area in square feet per acre (ft<sup>2</sup>/acre) of woody vegetation growing on the watersheds at the time of each storm. This variable reflects the average density of woody vegetation on each watershed.
3. SKIDROAD LENGTH—Total length of skidroads (miles) on each watershed at the time of each storm event.
4. LOGGING INTERVAL—Time interval (years) on each watershed since logging activity for each storm event. This variable describes the recency of the timber-cutting effect.
5. TOTAL STORM PRECIP—the precipitation (inches), including snow, measured during each

storm event without a 6-hour precipitation-free period. It ranged from 1.37 to 6.06 inches.

6. 14 day-AP—Total 14-day antecedent weighted precipitation (inches) measured on each watershed prior to each storm event.
7. MDA streamflow—Mean daily antecedent streamflow in cubic feet/second/square mile (csm) recorded for each watershed on the day before each storm event.
8. ELEV—Maximum elevational difference (in feet) is the difference between the highest and lowest elevations on each watershed.
9. SNOW—Snow accumulation on the ground at the time of the storm (an indicator variable). Water equivalent of snow ranged from 0.47 to 3.0 inches.

The ranges of values for the variables that differed among watersheds is shown in Table 2. Other variables such as 1-hour storm intensity and 7-day weighted watershed antecedent precipitation were considered but excluded because they were duplicative or correlated with these variables. Data are available at <http://www.fs.fed.us/ne/parsons/webdata/data/downloads>.

### Statistical Analyses

To help identify factors with the greatest influence on peak streamflows, we developed nine candidate models

**Table 3.—Candidate models used to evaluate hypotheses about influences on peak storm flows**

Model	Independent variable					
Total Storm Precip.	TOTAL STORM PRECIP					
Snow model	TOTAL STORM PRECIP	Snow (an indicator variable, yes or no)				
Storm Intensity	AVG. INTENSITY					
Precipitation amount and intensity	TOTAL STORM PRECIP	AVG. INTENSITY				
Soil wetness	14 day- AP	MDA Streamflow	TOTAL STORM PRECIP			
Simplest soil wetness	TOTAL STORM PRECIP	14 day- AP				
Road	SKID ROAD LENGTH	LOGGING INTERVAL	TOTAL STORM PRECIP	AVG. INTENSITY	MDA Streamflow	
Watershed characteristics	LOGGING INTERVAL	BASAL AREA	TOTAL STORM PRECIP	ELEV		
Trout Fisherman's	BASAL AREA	LOGGING INTERVAL	AVG. INTENSITY	TOTAL STORM PRECIP	14 day- AP	
	MDA Streamflow					

**Table 4.—Average standardized peakflows (csm/100 acres), standard deviation, and number of storms, Fernow Experimental Forest (pretreatment calibration descriptive statistics refer to storms occurring before 1957)**

Watershed	50 storms data set			Pretreatment calibration storm data set		
	Mean	SD	n	Mean	SD	n
WS4	10.32	4.39	50	9.935	3.70	14
WS1	11.31	5.37	50	10.95	5.16	14
WS2	12.29	5.29	43	12.04	6.04	14
WS3	11.06	5.09	50	10.00	4.05	14
WS5	13.37	6.10	34	11.25	4.36	14
WS6	11.06	2.17	46	9.74	4.81	10
WS7	11.78	4.68	46	10.99	4.20	10

based on hypotheses about the relationship between peakflows and the other variables (Table 3). Flow from the watersheds was standardized to cubic feet per second (cfs) per 100 acres to account for size differences among watersheds. The dependent variable is standardized peakflow (cfs/100 acres) and the explanatory variables are related to the storm events and physical parameters on the watersheds. The peakflows from the various watersheds expressed on a unit-area basis generally were consistent (Table 4). For comparison, descriptive statistics are also provided for peakflows recorded only during the pretreatment calibration period (Table 4).

The nine candidate models were evaluated using multimodel regression inference techniques described by Burnham and Anderson (1998). These models, representing hypotheses developed using expert judgment, were compared to determine a most plausible model. Each model was analyzed separately using multiple regression to derive Akaike information criterion and to determine goodness of fit for each model. The Akaike coefficients were then used to calculate Akaike weights and a most plausible model was selected. This method is believed to be superior to stepwise regression techniques when the number of possible models

**Table 5.—Dates and peak flow rates for the six largest flood events observed at the Parsons gaging site on the Cheat River.**

Rank	Flood date	Peakflow (cfs)	Source
1	November 5, 1985	170,000	Ward et al. (2001)
2	January 19, 1996	90,100	Ward et al. (1997)
3	July 6, 1844	85,000	Ward et al. (2001)
4	October 15, 1954	81,200	U.S. Geological Survey (1995)
5	February 9, 1994	78,300	U.S. Geological Survey (1995)
6	July 10, 1888	71,000	Ward et al. (2001)

**Table 6.—Peak discharge for 20 largest storms on Watershed 4, 1951 to 2000, and on Cheat River, 1913 to 2000**

Watershed 4			Cheat River near Parsons		
Rank	Date	Peakflow	Rank	Date	Peakflow
		<i>cfs</i>			<i>cfs</i>
1	11/4/1985	25.44	1	11/5/1985	170000
2	2/9/1994	18.41	2	1/19/1996	90100
3	10/15/1954	18.06	3	10/15/1954	81000
4	7/19/1996	17.59	4	2/9/1994	78300
5	6/6/1981	17.18	5	2/19/2000	57800
6	1/19/1996	15.88	6	5/8/1994	52700
7	5/7/1994	15.58	7	7/19/1996	52500
8	2/10/1957	15.49	8	3/19/1963	52400
9	2/19/2000	13.33	9	3/12/1917	50500
10	5/24/1968	13.19	10	5/17/1996	50000
11	7/29/2001	11.87	10	7/31/1996	50000
12	3/5/1963	11.67	12	9/6/1996	46600
13	3/6/1967	11.35	13	3/7/1967	44000
14	7/31/1996	11.24	14	5/28/1956	42900
15	12/22/1970	10.99	15	2/4/1932	42800
16	5/28/1956	10.55	16	5/26/1990	42500
17	8/11/1984	9.97	17	3/29/1924	41100
18	4/30/1966	9.90	18	10/9/1976	40900
19	1/22/1959	9.67	19	11/29/1985	39600
20	3/21/1962	9.40	20	1/22/1917	37500

exceeds sample size. Uncertainty in model selection is reduced significantly by the candidate model process. These models produce output that is interpreted more readily from a hydrologic sense than one developed by a statistical technique that builds models by arbitrary selection of parameters.

#### Cheat River Basin Data

Data on peak discharge for the gaging site on the Cheat River near Parsons (U.S. Geol. Surv. 1995, 2002; Ward et al. 1997, 2001; <http://nwis.waterdata.usgs.gov/wv/nwis/peak>) were examined to determine the largest peak discharges recorded or estimated from July 6, 1844

through September 2001 (Tables 5, 6). Streamflow measurements began at this site in January 1913; hourly streamflow data for the four largest storm events recorded since 1913 at the gaging site on the Cheat River were used to plot hydrographs for these events.<sup>2</sup> Earlier peakflows were estimated from USGS Water Data Reports. Precipitation data for Parsons (1899 to 1950) were obtained from the National Climatic Data Center (2000). Precipitation data collected at the U.S. Forest Service Timber and Watershed Laboratory at Parsons since 1951 were used in these analyses.

<sup>2</sup>Data furnished by Ronald Enaldi, U.S. Geological Survey, Charleston, West Virginia.

**Table 7.—Results of multiple regression analyses**

Model	R <sup>2</sup>	Probability of greater F	AIC	Akaike weights	Ranking
Total Storm Precip.	0.391	< .0001	845.506	0.000	
Snow	0.465	< .0001	807.113	0.031	4
Storm intensity	0.039	0.0005	987.185	0.000	
Precip amount and intensity	0.430	0.0001	800.579	0.822	1
Soil wetness	0.396	< .0001	846.688	0.000	
Simplest soil wetness	0.391	< .0001	847.276	0.000	
Road	0.431	< .0001	806.368	0.045	3
Watershed characteristics	0.397	< .0001	848.466	0.000	
Trout Fisherman's	0.437	< .0001	804.780	0.101	2

## RESULTS AND DISCUSSION

### Fernow Large Peakflows

The 50 largest peakflows on WS4 since 1951 ranged from 5.93 cfs (December 31, 1989) to 25.44 cfs (November 4, 1985), with an average value of 9.87 cfs (SD = 4.20). Storm precipitation ranged from 1.37 inches for the February 24, 1977 storm to 6.06 inches for the November 4, 1985 storm, with average storm precipitation of 3.06 inches (SD = 0.98). Note that while the largest storm peakflow (November 4, 1985) was associated with the highest precipitation amount, this relationship does not always hold as some of the smaller peakflows also were associated with high precipitation amounts. Of these 50 storms, 17 occurred in the growing season and 33 during the dormant season.

### Factors Affecting Peakflows on the Fernow Watersheds

Results of the candidate model analyses suggest that the most plausible model is Precipitation amount and intensity, which includes the variables TOTAL STORM PRECIP and AVG. INTENSITY (Table 7). We hypothesized that these two meteorological variables would be more important than the watershed characteristics and management activities for the largest storms. During large storms, the water-holding capacity of the soil (watershed) may be exceeded and streamflows can increase rapidly as a result. Although forests use large amounts of water compared with most other land uses, interception and transpiration are greatly reduced in hardwood forests during dormant seasons. Soil-moisture deficits are greatly reduced and similar during

dormant seasons in both cut and uncut hardwood forests (Troendle 1970). Growing-season moisture deficits also may be reduced temporarily when a sufficient number of trees is cut on forested watersheds, because moisture losses from transpiration and interception are reduced. Thus, streams draining forested watersheds are more responsive to precipitation during periods when soil-moisture deficits are low and storage space for additional water is limited (as during the dormant season).

Also, since infiltration rates of forest soil usually exceed rainfall rates, there is virtually no overland flow on forest land (Patric 1976). When a steep 64-acre watershed was clearcut on the Fernow, overland flow occurred only on skid roads with no water control structures (Reinhart 1964). Stuart and Edwards (2006) concluded that timber harvesting has little effect on water resources because canopy removal and normal harvesting activities do not significantly affect the function of the forest floor. Bates (2000) concluded that during most storms, even after harvesting, subsurface flow remains the primary mechanism for stream generation. In our analyses, total storm precipitation alone explained 39 percent of the variability in the model; adding average storm intensity explained another 4 percent. By comparison, adding basal area and logging interval rather than average storm intensity explained less than 1 percent of additional variability.

Note that most of the storms occurred more than 5 years after the most recent logging disturbance: 84, 60, 62, 76, and 76 percent for WS1, WS2, WS3, WS6, and WS7,

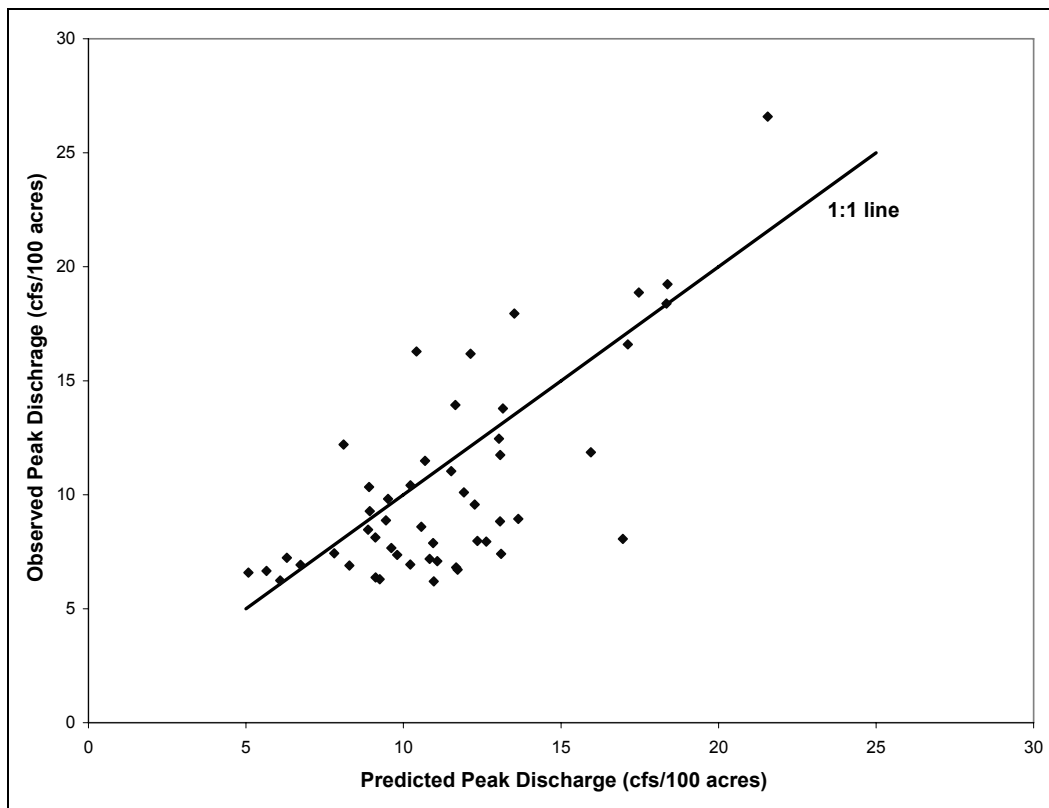


Figure 7.—Comparison of predicted peakflows (using total precipitation and average storm intensity) vs. observed peakflows, Watershed 4 on the Fernow Experimental Forest.

respectively. For WS5, 35 percent of the storms occurred more than 5 years after logging; the percentage was 100 for WS4, which had not been logged since 1910. About 30 percent of the storms occurred within the first 3 years after logging disturbance. This illustrates the inherent difficulty of evaluating streamflow response to extreme storms. Since these large storm events occur randomly at unpredictable times, their occurrence rarely coincides with watershed treatments on experimental watersheds and they cannot be replicated in controlled experiments.

The relatively low  $R^2$  values we observed also may result from other factors that differ among watersheds or that were not measured in our analyses. For example, differences in the variable source area, which could vary with soil depth or stream channel morphology, were not quantified and may have improved our ability to predict peakflows. Although soil depth is assumed to be reasonably uniform across these watersheds, some differences are likely. Because of these minor differences as well as with differences in stream channel morphology, the source area for streamflow generation may differ among these otherwise homogeneous watersheds. Aspect,

which can affect snowmelt, was not quantified in our analysis.

We conclude that storm characteristics explained a considerable amount of variability in peakflow while disturbance history characteristics explained little or none of the variability in peakflow, and that the meteorological variables (storm precipitation characteristics) were the most important in explaining the variability of large peak stormflows from these forested watersheds even when different impacts of timber harvesting are considered.

Brewer et al. (1982) performed similar analyses but with data from 1952-78 snow-free periods from WS4. They found that rainfall depth and initial streamflow rate accounted for 87 percent of the variation in peakflow. Their preferred models generally underestimated larger peakflows. A graph of predicted versus observed peak flows for WS4 based on the Precipitation Amount and Intensity model (Fig. 7) suggests that while there is considerable scatter around the equal peakflow line (the 1:1 line), this model predicted peakflows reasonably well over most of the range of flows.



Snow can be an important component of storms during the dormant season, so including an indicator variable for snow accumulation on the ground (Snow model) increased the  $R^2$  over that of the Total Storm Precip. model. Indeed, the Snow model had the highest  $R^2$  (Table 7), suggesting that storms that include snowmelt behave differently than those not influenced by snow. A model that included the variables TOTAL STORM PRECIP, AVG. INTENSITY and SNOW was the most plausible in a post-hoc exploratory analysis, providing additional evidence for the importance of snow in dormant-season peakflows. The influence of a snowpack on peakflow was demonstrated in the storm of January 19, 1996. This storm would not have been included among the top 10 (Table 6) without the additional water derived from 18 inches of snow (2.39 inches of water equivalent) on the ground before the storm. The storm on February 9, 1994, also was influenced by a snowpack as 5 inches of snow (0.5 inch of water equivalent) was on the ground prior to the storm.

Two of the three largest stormflows are related to hurricanes that deposited significant amounts of rain in a relatively short period and during the dormant season. The storm in November 1985 was the result of Hurricane Juan, and the storm in October 1954 was related to Hurricane Hazel. Large rainfall events over wide areas often are associated with hurricanes in the central Appalachians. The presence of forest cover did not appreciably reduce flood peaks in the Shenandoah River watershed of Virginia during an extreme rainfall event in 1996 caused by Hurricane Fran (Sturdevant-Rees et al. 2001). Lull and Reinhart (1972) pointed out that floods from forested watersheds are common and provided numerous examples of record peakflows from well forested watersheds in the Eastern United States. Kochenderfer et al. (1997) showed that while timber harvesting can increase growing-season stormflow volumes and peakflow rates of small storms temporarily, these increases do not have important downstream implications, that is, they generally are not associated with flooding.

Stormflows and peakflows were increased during the growing season after forest clearing in New Hampshire but stormflows that occurred after soil-moisture recharge

in the fall and before spring snowmelt were unaffected (Hornbeck 1973). The increased response on the cleared watershed during the growing season was attributed to reduced transpiration and interception, which caused wetter soils and reductions in moisture storage capacity. In a paired watershed experiment in which the hydrologic impacts of clearcutting and site preparation on the Georgia Piedmont were evaluated, it was found that small stormflows generated under dry antecedent conditions could be increased by 50 percent or more but that larger flood discharges, which usually occur under wet conditions, are little affected (Hewlett and Doss 1984). Results of a watershed study in which forest-harvest and site-preparation treatments in the Ouachita Mountains of Arkansas were evaluated showed that stormflow and peakflow for a large, 100-year event were not significantly increased by the treatments (Miller et al. 1988). In evaluating the effects of clearcutting on stormflow hydrographs in Missouri, Settergren and Krstansky (1987) concluded that clearcutting may increase total stormflow yields and peakflows, but that the magnitudes are not important with respect to flood flow generation.

### **Largest Cheat River Peakflows**

The Cheat River has experienced major floods since the arrival of European settlers in that area in the 1700s. The first recorded flood in July of 1844 did little damage to the settlements, perhaps because the area was sparsely populated at that time. The next recorded flood, in July 1888, was much more damaging even though the estimated peak discharge was lower than the flood in 1844. According to Fansler (1962): "The flood of July 1888 must have been the highest ever to come to the Cheat River ... the whole valley from Parsons to Rowlesburg was under water. Horses, cattle, sheep, and hogs were washed away." However, the available evidence indicates that the November 1985 flood was much greater and many times more destructive than any experienced since the area was settled. Peakflow rates at the Parsons gaging site on the Cheat River for the six largest floods observed since settlement are shown in Table 5. These storms also are ranked in descending order according to the maximum peakflows recorded for each event. Peak discharge for 1844 and 1888 were estimated from floodmarks and datum in use prior to August 17, 1944 (Ward et al. 2001).

A major storm occurred on July 17, 1907, but it was excluded from this analysis because no estimate of peakflow was available at the Parsons gaging site. The aerial extent of this storm is unknown but the 4.7 inches of rain recorded by National Weather observer S.W. Swisher, on that date at Parsons (Nat. Clim. Data Cent. 2000) were similar to the 4.3 inches recorded at Parsons during the storm in October 1954. Similar peak discharges were reported for these storm events on the Cheat River at Rowlesburg (U.S. Army Corps of Eng. 1963). The flood of November 5, 1985, was the largest event recorded on the Cheat River (Kite and Linton 1993). Peakflow for this storm was nearly twice that recorded for the next largest storm (Table 5).

### **Comparison of Peak Discharge on the Cheat River and WS4 Watersheds**

Peak discharges for the 20 largest storms for the Cheat River basin near Parsons and WS4 are shown in Table 6. Only four of the largest storms on the Cheat River at the Parsons gaging site occurred before 1951 when the Fernow watersheds, including WS4, were gaged. Except for the sixth-ranked storm (January 19, 1996), only the four highest-ranked storms on WS4 resulted in major downstream flooding on the Cheat River. There are both differences and similarities in rankings but the 1985 storm was the largest on both watersheds, and the storm on October 15, 1954 ranked third on each list. A major difference in ranking occurred with the storm on January 19, 1996, which ranked sixth on WS4 but second on the Cheat River watershed at the Parsons gaging site. Precipitation records on WS4 and at the Bearden Knob weather station near Davis, West Virginia, indicate that about 2 inches of rain fell at both sites between 3 and 9 a.m. on January 19. The difference in storm response probably can be attributed to the greater depth of the snowpack on the high-elevation Cheat watershed.

Measurements on January 5 at the Bearden Knob station indicated a snow depth of 28 inches versus 18 inches measured on WS4 (equivalent to 3.72 and 2.39 inches of water, respectively). Temperatures remained above freezing at both sites from about 10 a.m. on the 16th until 9 a.m. on the 19th when it stopped raining. Average wind speed on January 18 and 19 was 10 to 20 miles per hour; this also enhanced snowmelt. The melting

snowpack along with the rainfall were sufficient to cause the Cheat River to flood. The dramatic temperature drop recorded at Bearden Knob, from 53 °F at 3 a.m. to 20 °F at noon peaking time on the Cheat at Parsons resulted in a rapid decline in snowmelt and streamflow. This illustrates how the interaction of meteorological events can influence peak discharges.

It is interesting that 6 and 7 of the 10 largest peakflows recorded since 1951 on WS4 and since 1913 at the Cheat gaging site, respectively, have occurred since 1984 (Table 6). Most of the largest peakflows were recorded during the dormant season for both WS4 and the Cheat River when evapotranspiration losses were low. This was not unexpected because watersheds usually are wetter and more responsive to precipitation during those periods. The occurrence of individual large storms is comparable between the two watersheds. Seven of the top 10 storms on the Fernow also were included in the 10 highest ranked storms on the Cheat.

Note the large number of peakflows recorded at the Parsons gaging station in 1996 (Table 6). Five of the 20 largest peakflows were recorded during that year; 4 occurred during the growing season. In 1996, 70.4 inches of precipitation fell at Parsons, the greatest amount since official measurements began in January 1899. Many large storms occurred during 1996, reducing soil-moisture deficits (lower storage capacity), thereby making streams more responsive to precipitation in 1996 than in years with less precipitation.

The storms of October 14, 1954, and November 5, 1985, are the two largest recorded on Fernow WS4 that were unconfounded with snow. A more detailed look at these events provides insight into the relationship between streamflow and precipitation during large storm events. The distribution of precipitation in West Virginia during the 1954 storm is shown in Figure 8. Rainfall amounts probably were greater over limited areas, but the rain-gage network was too sparse to define individual storm cells. Some hydrologic characteristics of this storm are shown in Figure 9. On October 14, rain fell from 7:30 a.m. until 11 p.m. This storm had the highest 4-hour rainfall intensity (2.25 inches) of the 10 highest ranked storms on WS4. Streamflow rose rapidly, peaking

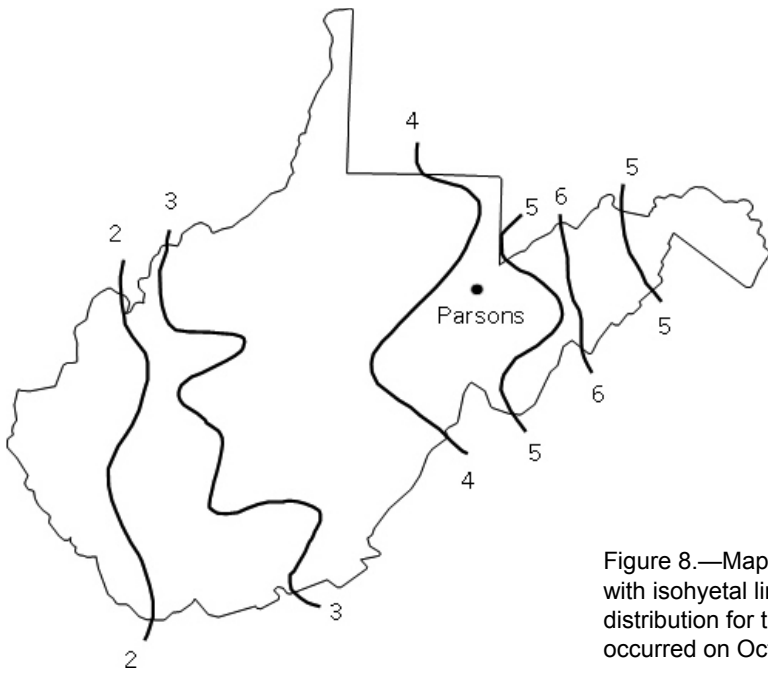


Figure 8.—Map of West Virginia with isohyetal lines showing rainfall distribution for the storm that occurred on October 15-16, 1954.

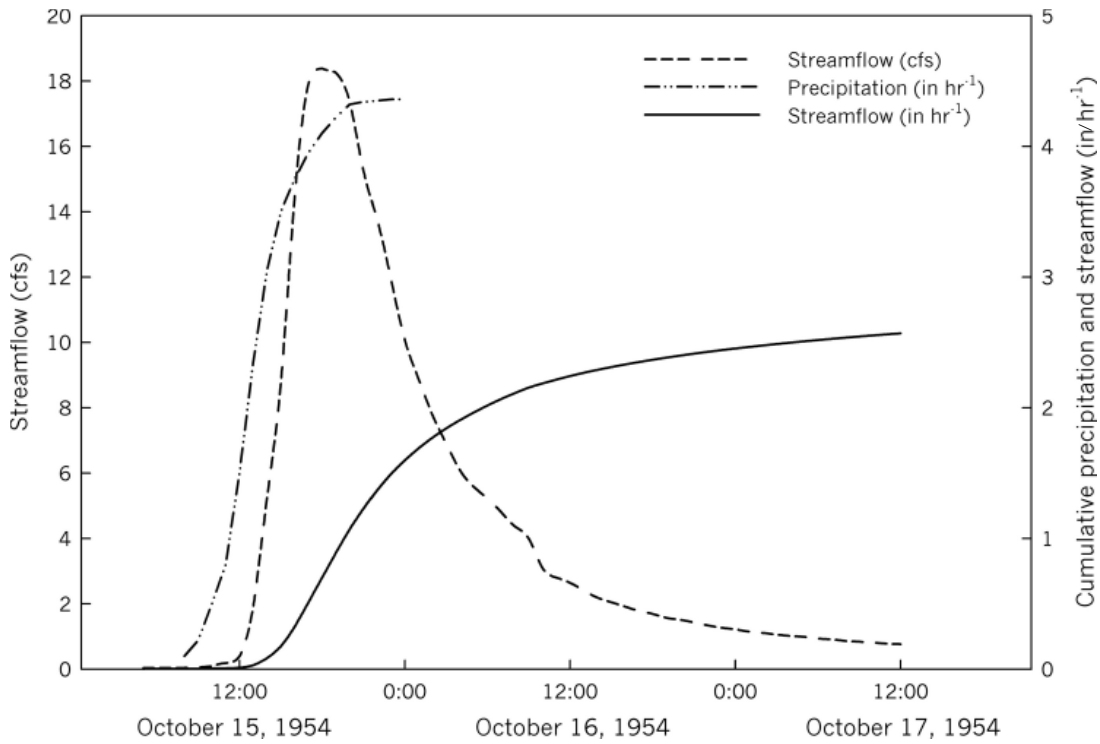


Figure 9.—Hydrologic characteristics of the storm of October 15-16, 1954, from data collected on Watershed 4 on the Fernow Experimental Forest.

at about 6 p.m. Antecedent soil-moisture content was low judging from the streamflow rate just before the storm began (0.04 cfs). The hydrologic response factor, defined by Hewlett (1967) as the percentage of storm

rainfall converted to streamflow, was about 60 percent. Flood damage was severe in the small communities of Hambleton and Hendricks. Several houses and basements were damaged extensively by floodwater, forcing many

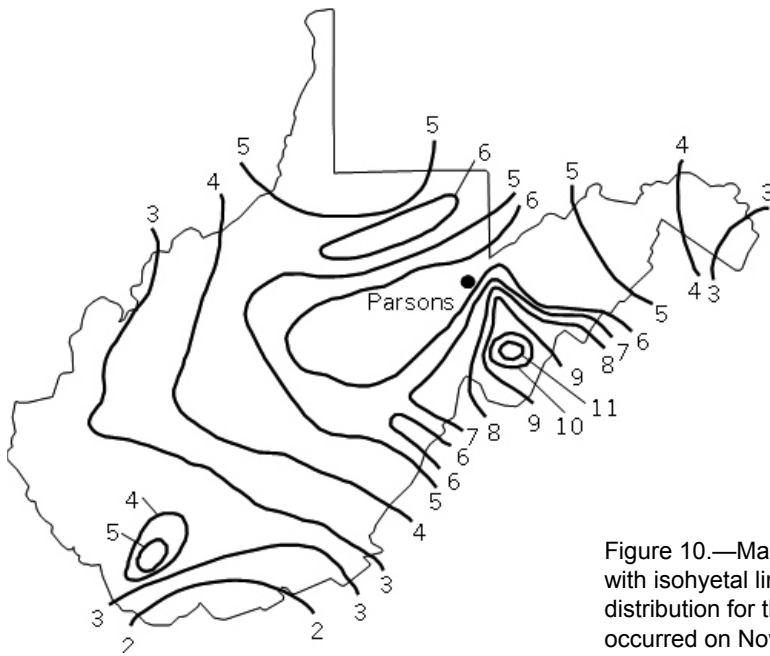


Figure 10.—Map of West Virginia with isohyetal lines showing rainfall distribution for the storm that occurred on November 4-5, 1985.

residents to vacate their homes until the next morning. Fortunately, no lives were lost and no homes were washed away or damaged beyond repair.

The 1985 storm resulted from a complex sequence of meteorological events beginning when Hurricane Juan made landfall in the Gulf Coast on October 31 (Colucci et al. 1993). The approximate precipitation distribution over the study area is shown in Figure 10. Unfortunately, rain gages usually are located in areas where people live and records for high-elevation remote areas are scarce. Although the rainfall patterns between the 1954 and 1985 storms were similar, with maximum amounts in the headwaters of Dry Fork River, the total amounts were much greater during the 1985 storm. In the study area, initial rainfall intensity was low; less than an inch of total rainfall was recorded for November 2 and 3 on the Fernow (Fig. 11). At about 9 a.m. on November 4, rainfall intensity increased over the entire study area. During the next 15 hours, about 5 inches of rain fell at the Fernow and more than 7 inches were reported at Spruce Knob. Maximum rainfall intensity was not unusual (0.50 in/hr) but an average rainfall rate of 0.34 in/hr was sustained over a 15-hour period.

Streamflow response on WS4 is shown in Figure 11. Antecedent soil-moisture content was moderate when

the intense rainfall began on November 4, as indicated by the base flow rate of 0.06 cfs. The response factor (70 percent) was greater than that recorded for the 1954 storm. A larger percentage of precipitation was returned as streamflow under the wetter conditions created by the additional 1.4 inches of precipitation in the 1985 storm.

Flood damage from the 1985 storm was many times greater than ever experienced before in this region. Many homes and businesses were washed away or damaged beyond repair (Fig. 12). The rarity of a flood of this magnitude can be inferred from other bits of information. First, several homes and other buildings along the Cheat River and its tributaries were washed away by the floodwaters. Many of these structures had stood for more than 100 years. For example, the house shown in Figure 13 was under construction adjacent to the Cheat River below Parsons during the 1888 flood. The gentleman in the photograph, Ernest Fitzwater (1901-1990) stated that his father told him that while he was helping construct the house, the water reached the first floor and floated flooring boards that were being installed. By contrast, the water level was about 8 feet higher during the 1985 flood. Also, many large trees growing along the streams were uprooted by the floodwaters. Figure 14 shows a red oak tree that grew along the Black Fork River just upstream from Parsons.

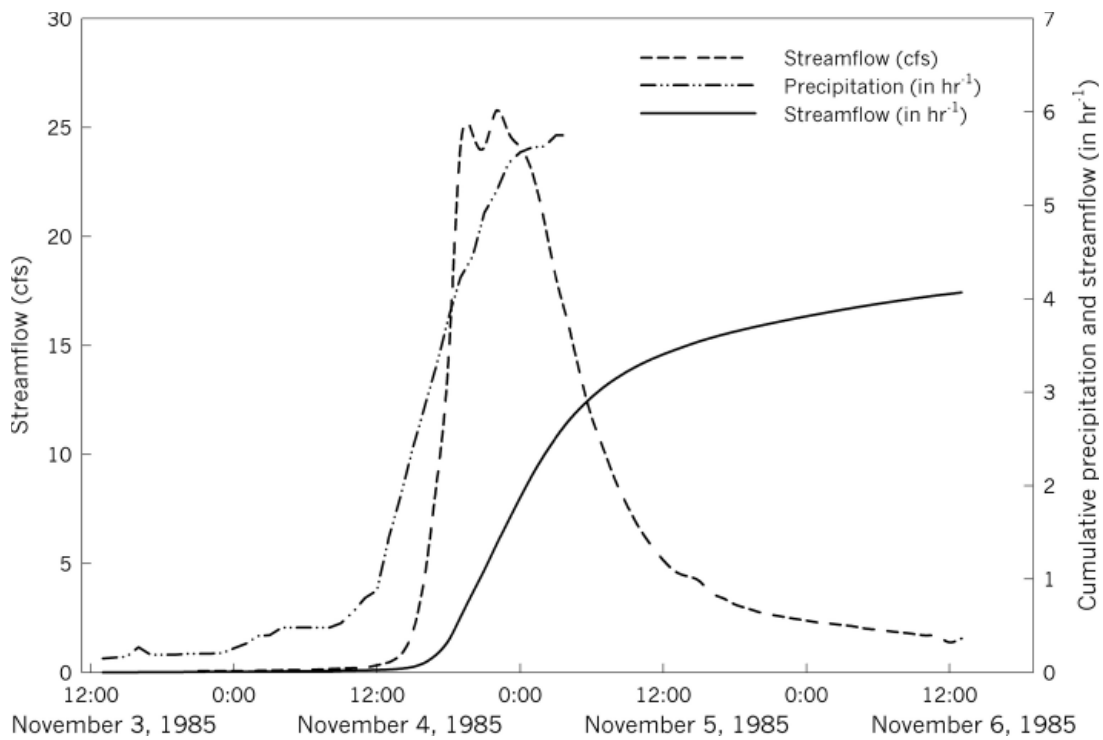


Figure 11.—Hydrologic characteristics of the November 1985 storm from data collected on Watershed 4 on the Fernow Experimental Forest.



Figure 12.—Damage along Pennsylvania Avenue in Parsons, West Virginia, from a flood that occurred on November 4-5, 1985 (photo courtesy of John Warner).



Figure 13.—Water barely reached to the first story of this house during the 1888 flood on the Cheat River. During the flood of November 1985, water reached the second floor.



Figure 14.—This 130-year-old red oak near Parsons, West Virginia, was uprooted during the flood of November 1985.



Figure 15.—The chair (circled) in the tree behind the young swimmer was deposited during the November 1985 flood on the Dry Fork River near Hendricks, West Virginia.

A growth-ring count indicated that the tree was 130 years old. Before the flood, the tree grew on a bank several feet above the river edge. Most of the bank was stripped away by the floodwaters. The magnitude of the 1985 flood is illustrated in Figure 15, which shows baseflow on the Dry Fork River above Parsons during the summer of 1986. The photo shows a chair deposited in a tree behind the young swimmer.

### Comparison of Storm Hydrographs

Hydrographs are compared in Figures 16 and 17 for the four largest storms recorded on WS4 with the same storms recorded at the gaging site on Cheat River near Parsons. An additional lower ranked storm (January 19, 1996) also is shown for WS4 so it can be compared with the same storm that ranked second at the Cheat River

gaging site. A hydrograph is not shown for the 1985 storm on the Cheat River because the gaging station was destroyed during that event. Peakflow for the 1985 storm was estimated from extension of the rating curve above 55,000 cfs (Ward et al. 2001). Estimated peakflow for the 1985 storm was much greater than peakflows recorded for the other highest ranked storms on the Cheat watershed. It was almost twice as high as that recorded for the second highest ranked storm in the Cheat watershed (January 19, 1996). On WS4, peakflow for the 1985 storm was only 28 percent larger than peakflow for the second highest ranked storm (February 9, 1994). The magnitude of peakflows for the other top ranked storms within both watersheds were similar. On average, stormflows at the Cheat gaging site peaked about 5 hours later than those on Fernow WS4.



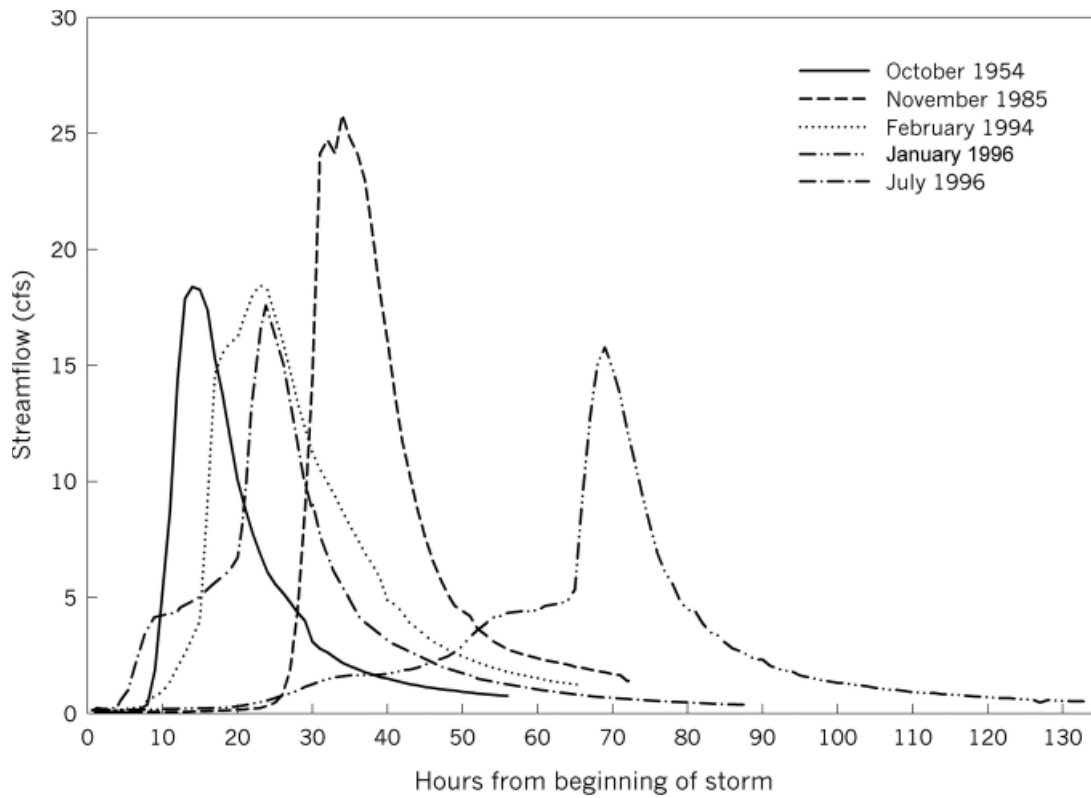


Figure 16.—Hydrographs of the four largest storms recorded on Watershed 4 on the Fernow Experimental Forest since measurements began in 1951. A lower ranked storm (January 19, 1996) is included for comparison purposes (see Figure 17).

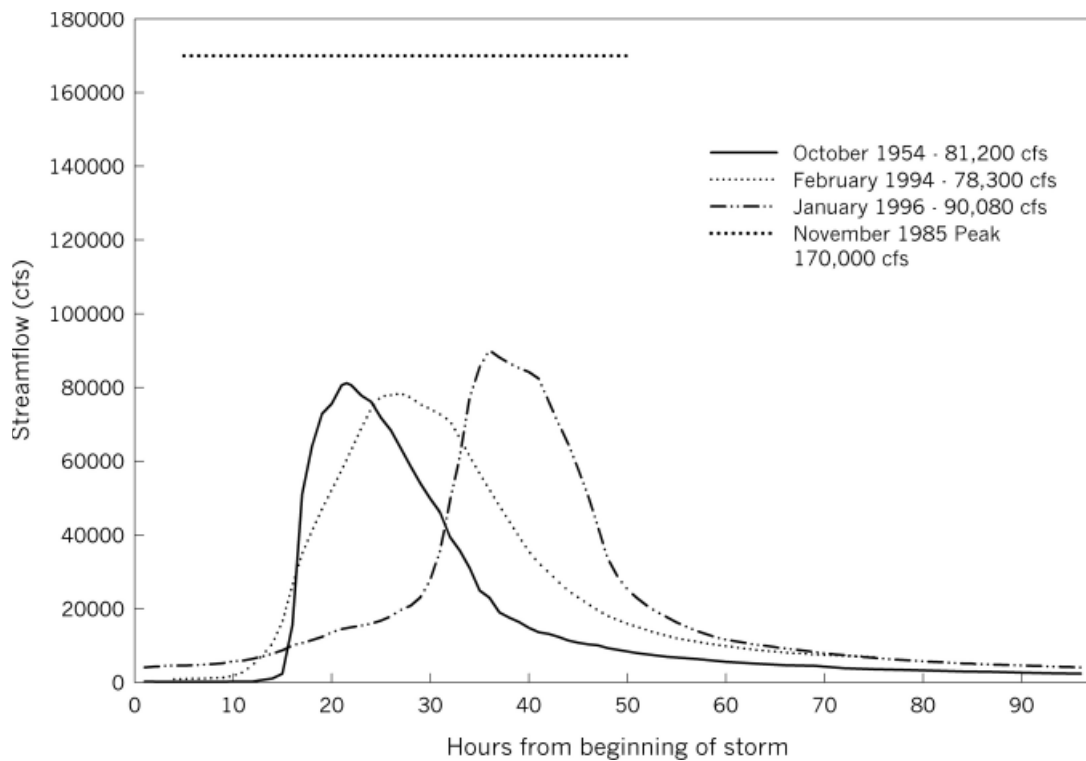


Figure 17.—A peakflow indicator line for the storm of November 1985 and hydrographs for the other three largest storms recorded at the gaging site on the Cheat River near Parsons, West Virginia, since measurements began in 1913.

## CONCLUSIONS

Results from our analyses and from other researchers provide little support for the commonly held view that timber harvesting increases the severity of floods. However, careful forest management, including planning and placement of roads, use of BMPs, and thoughtful execution of the operations is necessary so that other off-site effects, e.g., erosion and sedimentation, are minimized or negated. We conclude that:

- The total storm precipitation (39 percent) and average storm precipitation intensity (4 percent) model accounted for most of the variation (43 percent) in peakflow.
- Meteorological variables were more important than disturbance history in explaining the variability in large stormflows.
- The unexplained variation in our peakflow models probably reflects the complex interaction of meteorological variables that result in large peakflows as well as variables such as soil depth, stream channel morphology, and watershed exposure, none of which were included in our models.
- The two highest ranked peakflows on both the Fernow and Cheat watersheds occurred during the dormant season.
- Although prolonged snowpacks are uncommon in the central Appalachians, snow can be an important component of dormant-season peakflow.
- More than half of the 10 largest peakflows recorded on these well forested watersheds have occurred since 1984 during a period of limited timber harvesting and a high percentage of forest cover.
- The storm of 1985 generated record peakflows on both watersheds though the relative size of the 1985 peakflow was much larger on the Cheat than on the Fernow watersheds.

## ACKNOWLEDGMENTS

The authors thank Doug Owens, John Campbell (deceased) and Linda Plaughter of the Northern Research Station for compiling streamflow and precipitation data, assisting with literature searches, and typing the manuscript; and Ronald D. Evaldi of the U.S. Geological

Survey in Charleston, West Virginia for providing streamflow data. Frederica Wood provided assistance with data management and compilation of these data sets. Desta Fekedulegn provided guidance in our early analytical discussions. John Stanovick, statistician with the Northern Research Station, assisted in the statistical analyses. Reviews of the draft manuscript by Jim Vose, Jeffrey Wiley, and Bill Gillespie were most helpful and appreciated.

## LITERATURE CITED

- Adams, M.B.; Kochenderfer, J.N.; Wood, F.; Angradi, T.R.; Edwards, P.J. 1994. **Forty years of hydrometeorological data from the Fernow Experimental Forest, West Virginia**. Gen. Tech. Rep. NE-184. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 24 p.
- Anderson, Henry W.; Hoover, Marvin D.; Reinhart, Kenneth G. 1976. **Forests and water: effects of forest management on floods, sedimentation, and water supply**. Gen. Tech. Rep. PSW-18. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 115 p.
- Bates, N.S. 2000. **Hydrological effects of forest harvesting on headwater watersheds in West Virginia**. Princeton, NJ: Princeton University. 122 p. B.S. thesis.
- Brewer, Mike S.; Lee, Richard ; Helvey, J. David. 1982. **Predicting peak storm flow from an undisturbed watershed in the central Appalachians**. Water Resources Bulletin. 18(5): 755-759.
- Brooks, A.B. 1911. **Forestry and wood industries**. West Virginia Geologic and Economic Survey, Vol. 5. Morgantown, WV: Acme Publishing Co. 481 p.
- Burnham, K.P.; Anderson, D.R. 1998. **Model selection and multimodel inference: a practical information-theoretic approach**. New York: Springer Verlag. 353 p.
- Chittenden, H.M. 1909. **Forests and reservoirs in their relation to stream flow with particular reference to navigable rivers**. Transactions of the American Society of Civil Engineers: 62: 245-546.

- Clarkson, R.B. 1964. **Tumult on the mountain, lumbering in West Virginia, 1770-1920.** Parsons, WV: McClain Printing Co. 410 p.
- Colucci, Stephen J.; Jacobson, Robert B.; Greco, Steven. 1993. **Meteorology of the storm of November 3-5, 1985, in West Virginia and Virginia.** U.S. Geol. Surv. Bull. 1981. Washington, DC: U.S. Department of Interior, Geological Survey: B1-B31.
- Dodds, G.B. 1969. **The stream-flow controversy: a conservation turning point.** Journal of American History. 56: 589-69.
- Fansler, H.F. 1962. **History of Tucker County West Virginia.** Parsons, WV: McClain Printing Co. 702 p.
- Griffith, Douglas M.; Widmann, Richard H. 2003. **Forest statistics for West Virginia: 1989 and 2000.** Resour. Bull. NE-157. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 119 p.
- Hewlett, John. 1967. **A hydrologic response map for the state of Georgia.** Water Resources Bulletin. 3(3): 4-20.
- Hewlett, John D. 1982a. **Forests and floods in the light of recent investigation.** In: Proceedings, Canadian hydrology symposium; 1982 June 14-15; Fredericton, New Brunswick. Ottawa, ON: National Research Council of Canada: 543-559.
- Hewlett, John D. 1982b. **Principles of forest hydrology.** Athens, GA: University of Georgia Press. 183 p.
- Hewlett, John D.; Doss, Ray. 1984. **Forests, floods, and erosion: a watershed experiment in the Southeastern Piedmont.** Forest Science. 30(2): 424-434.
- Hewlett, J.D.; Lull, H.W.; Reinhart, K.G. 1969. **In defense of experimental watersheds.** Water Resources Research. 5(1): 306-316.
- Hibbert, A.R. 1967. **Forest treatment effects on water yield.** In: Sopper, W.E.; Lull, H.W., eds. International symposium on forest hydrology; 1965 August 29-September 10; University Park, PA. Oxford: Pergamon: 527-543.
- Hopkins, A.D. 1891. **Forest and shade tree insects. II. Black spruce.** Preliminary report. Bull. No. 17. Vol. II(5). Morgantown, WV: West Virginia Agriculture Experiment Station: 93-104.
- Hornbeck, J.W. 1973. **Storm flow from hardwood-forested and cleared watersheds in New Hampshire.** Water Resources Research. 9: 346-354.
- Hornbeck, J.W.; Adams, M.B.; Corbett, E.S.; Verry, E.S.; Lynch, J.A. 1993. **Long-term impacts of forest treatments on water yield: a summary for northeastern USA.** Journal of Hydrology. 150: 323-344.
- Hornbeck, J.W.; Kochenderfer, J.N. 1998. **Growth trends and management implications for West Virginia's red spruce forests.** Northern Journal of Applied Forestry. 15(4): 197-202.
- House of Representatives. 1907. **Hearings before the committee on expenditures in the Department of Agriculture.** 59th Congress, 2nd Session. Washington, DC: Government Printing Office. 806. p.
- Kite, J. Steven; Linton, Ron C. 1993. **Depositional aspects of the November 1985 flood on Cheat River and Black Fork, West Virginia.** U.S. Geol. Surv. Bull. 1981. Washington, DC: U.S. Department of Interior, Geological Survey: D1-D24.
- Kochenderfer, James N.; Edwards, Pamela J.; Wood, Frederica. 1997. **Hydrologic impacts of logging an Appalachian watershed using West Virginia's best management practices.** Northern Journal of Applied Forestry. 14(4): 209-218.
- Losche, C.K.; Beverage, W.W. 1967. **Soil survey of Tucker County and part of northern Randolph County, West Virginia.** Morgantown, WV: U.S. Department of Agriculture, Soil Conservation Service; West Virginia Agricultural Experiment Station. 78 p.

- Lull, H.W.; Reinhart, K.G. 1972. **Forests and floods in the eastern United States.** Res. Pap. NE-226. Broomall, PA. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 86 p.
- Maxwell, H. 1894. **History of Tucker County.** Kingwood, WV: Preston Publishing Co. 590 p.
- McKim, C.R. 1970. **50 year history of the Monongahela National Forest.** Elkins, WV: Monongahela National Forest. 66 p.
- Miller, E.L.; Beasley, R.S.; Lawson, E.R. 1988. **Forest harvest and site preparation effects on stormflow and peakflow of ephemeral streams in the Ouachita Mountains.** Journal of Environmental Quality. 17(2): 212-218.
- National Climatic Data Center. 2000. **Meteorological records 1899-1950 Parsons, Tucker County, WV Station.** Asheville, NC: U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Climatic Data Center.
- Patric, James H.; Gould, Ernest M. 1976. **Shifting land use and the effects on river flow in Massachusetts.** Journal American Water Works Association. 68(1): 1106-1110.
- Patric, J.H. 1976. **Soil erosion in the eastern forest.** Journal of Forestry 74(10): 621-677.
- Reinhart, K.G.; Eschner, A.R.; Trimble, G.R., Jr. 1963. **Effect on streamflow of four forest practices in the mountains of West Virginia.** Res. Pap. NE-1. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 79 p.
- Reinhart, K.G. 1964. **Effect of a commercial clearcut in West Virginia on overland flow and storm runoff.** Journal of Forestry. 62: 167-171.
- Settergren, Carl D.; Krstansky, John J. 1987. **Hydrograph responses to timber harvesting in the Missouri Ozarks.** In: Hay, Ronald L.; Woods, Frank W.; DeSelm, Hal, eds. Proceedings of the central hardwood forest conference VI; 1987 February 24-26; Knoxville, TN: [publisher name unknown]: 503-506.
- Stuart, G.W.; Edwards, P.J. 2006. **Concepts about forests and water.** Northern Journal of Applied Forestry. 23(1):11-19.
- Sturdevant-Rees, P.; Smith, J.A.; Morrison J.; Barck, M.L. 2001. **Tropical storms and the flood hydrology of the Central Appalachians.** Water Resources Research. 37(8): 2143-2168.
- Trimble, Stanley W.; Weirich, Frank H.; Hoag, Barbara L. 1987. **Reforestation and the reduction of water yield on the southern Piedmont since circa 1940.** Water Resources Research. 23(3): 425-437.
- Troendle, C.A. 1970. **A comparison of soil-moisture loss from forested and clearcut areas in West Virginia.** Res. Note NE-120. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 8 p.
- U.S. Army Corps of Engineers. 1963. **Excerpts from: Review of reports on Rowlesburg Reservoir, Cheat River, WV.** Pittsburgh, PA: U.S. Army Engineer District.
- U.S. Geological Survey. 1995. **Peak discharge data for site U3069500 Cheat River near Parsons.** Charleston, WV: U.S. Geological Survey, Water Resources Division.
- U.S. Geological Survey. 2002. **Peak streamflow for West Virginia.** USGS 03069500 Cheat River near Parsons, WV. <http://nwis.waterdata.usgs.gov/wv/nwis/peak?>
- Ward, S. M.; Taylor, B.C.; Crosby, G.R. 1997. **Water resources data, West Virginia, water year 1996.** Water-Data Rep. WV-96-1. Charleston, WV: U.S. Department of Interior, Geological Survey. 258 p.
- Ward, S.M.; Taylor, B.C. Crosby, G.R. 2001. **Water resources data, West Virginia, water year 2000.** Water-Data Rep. WV-00-1. Charleston, WV: U.S. Department of Interior, Geological Survey. 262 p.

Kochenderfer, James N.; Adams, Mary Beth; Miller, Gary, W.; Helvey, David J. 2007.  
**Factors affecting large peakflows on Appalachian watersheds: lessons from the Fernow Experimental Forest.** Res. Pap. NRS-3. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 24 p.

Data collected since 1951 on the Fernow Experimental Forest near Parsons, West Virginia, and at a gaging station on the nearby Cheat River since 1913 were used to evaluate factors affecting large peakflows on forested watersheds. Treatments ranged from periodic partial cuts to complete deforestation using herbicides. Total storm precipitation and average storm precipitation intensity were the most significant variables affecting peakflows, and were far more important than timber harvesting activities. Since January 1913, of the 20 highest-ranked peakflows on the Cheat River at the Parsons gaging site, 11 have occurred since 1984 during a period of limited timber harvesting. These results support earlier findings that forests do not prevent floods and that prudent forest harvesting operations do not increase large flood peakflows.

KEY WORDS: Forest harvesting, floods, watershed research, peakflows

---

---

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternate means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, DC 20250-9410, or call (800)795-3272 (voice) or (202)720-6382 (TDD). USDA is an equal opportunity provider and employer.

---

---



Printed on Recycled Paper



*Capitalizing on the strengths of existing science capacity in the Northeast and Midwest to attain a more integrated, cohesive, landscape-scale research program*