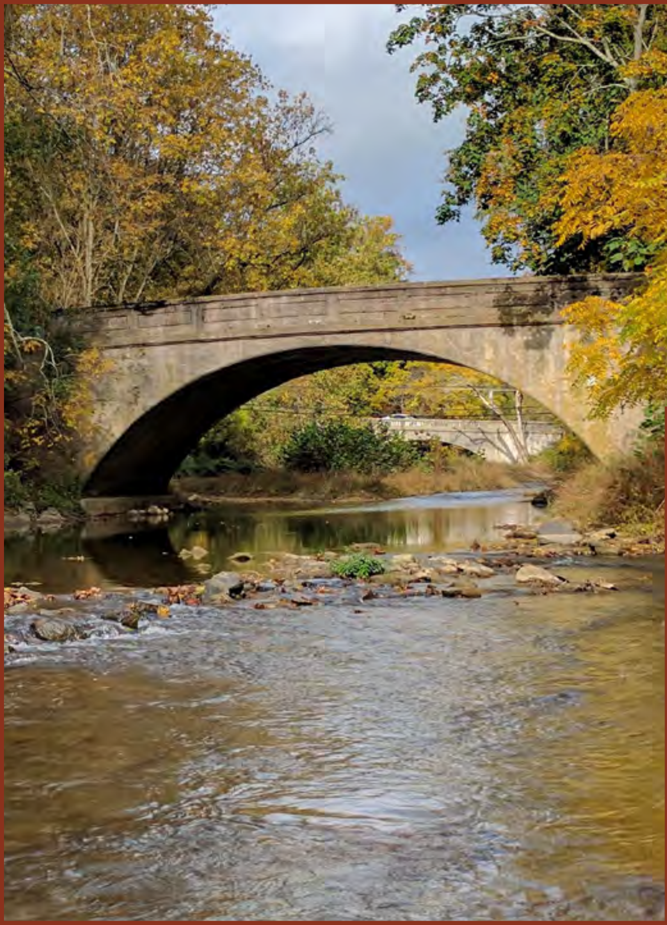
Prepared in cooperation with the Harford County Department of Public Works

Precipitation, Peak Streamflow, and Inundation in the Bynum Run and Winters Run Watersheds in Harford County, Maryland



Scientific Investigations Report 2021–5007

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

Left photo: Winters Run stream at Lake Fanny Road bridge taken on October 21, 2016 by Christopher Nealen from U.S. Geological Survey.
Right top photo: Bynum Run at Moores Mill taken on August 20, 2015. Photograph by Harford County Department of Public Works.
Right bottom photo: Bynum Run at Rt. 22 taken on August 20, 2015. Photograph by Harford County Department of Public Works.

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By Christopher W. Nealen and Edward J. Doheny

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U.S. Geological Survey, Reston, Virginia: 2021

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
section (640 acres or 1 square mile)	259.0	square hectometer (hm^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile ($[ft^3/s]/mi^2$)	0.01093	cubic meter per second per square kilometer ($[m^3/s]/km^2$)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
inch per hour (in/h)	0.0254	meter per hour (m/h)

Datum

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.

Abbreviations

DPW	Department of Public Works
NWS	National Weather Service
USGS	U.S. Geological Survey

Precipitation, Peak Streamflow, and Inundation in the Bynum Run and Winters Run Watersheds in Harford County, Maryland

By Christopher W. Nealen and Edward J. Doheny

Abstract

The Harford County Department of Public Works and the U.S. Geological Survey have been working cooperatively to monitor continuous streamflow at several streamgages in Harford County, Maryland, including Bynum Run and Winters Run. A perceived recent uptick in the number of flooding events in the Bynum Run and Winters Run watersheds have led to questions about the relative frequency and magnitude of floods experienced by county residents. Precipitation, stage (water elevation), and peak flow analyses and trends were evaluated. Although there was no one contributor to point to for the perceived increase in flooding, it is most likely attributable to a combination of precipitation, stage, and peak flow. There have been numerous rainfall events with exceedingly long return intervals, but none were statistically out of the ordinary. The stages of the streams at higher flows are slightly higher (less than 0.5 feet) than historical stages, but likely are not great enough to cause a significant increase in flooding. The ratings (stage discharge relationship) for the streams have changed slightly. The latest ratings indicate erosion and deposition in the streambed over the years of observation, but again these alone do not result in more flooding. These factors taken together may point to an observational bias for incidental flooding. With the increase in land development, there may simply be more observations of flooding in the county.

Introduction

The Harford County Department of Public Works (DPW) and the U.S. Geological Survey (USGS) have been working cooperatively to monitor continuous streamflow at several stations in Harford County, Maryland (fig. 1), including Bynum Run and Winters Run. The perception of an increase in the number of flooding events in the Bynum Run and Winters Run watersheds has led to questions about the relative frequency and magnitude of flooding affecting county residents.

Harford County, within the Northeast United States, has had increased annual rainfall from 1927 to 2014 (Rice and others, 2017). The study area lies in a swath of the country that appears to experience larger floods than the rest of the country and the Northeast region. O'Connor and Costa (2003) investigated the largest historical floods at more than 22,000 streamgages in the United States and Puerto Rico that occurred during the period of record through September 1997 to determine where and why large floods happen on a regional basis. Streamgages reporting the highest 13 percent of floods appear to be concentrated in the Eastern United States. One particular band of floods runs directly through the northeastern section of Maryland (fig. 2). O'Connor and Costa (2003) note that the pattern of large flows within the Eastern United States closely corresponds to moisture from the Gulf of Mexico and the Atlantic Ocean and that the local topography of the Appalachian Mountains further explains the finer scaled patterns of floods in the region. The influence from the Gulf of Mexico has wide-ranging effects on moisture transport and precipitation processes that cause large floods, including individual thunderstorm cells, mesoscale convective complexes (see Glossary), Atlantic hurricanes, and quasi-stationary upper atmospheric circulation patterns that can produce several weeks or months of persistent precipitation (O'Connor and Costa, 2003).

Purpose and Scope

The purpose of this study is to describe (1) precipitation frequency and (or) duration in the Bynum Run and Winters Run watersheds and compare changes documented over time; (2) the expected frequency of peak streamflows, along with any changes to precipitation frequency and duration over time; and (3) changes in stage-discharge relations, including specific stages, at USGS streamgages in the area to determine whether floods with selected frequencies are tending to inundate larger areas of the watersheds than previous floods within the period of record.

Description of Study Area

Recent events in the Bynum Run and Winters Run watersheds have led to questions about the relative frequency and magnitude of flooding being experienced by residents

Figure 1. Map showing location of study area, Harford County, Maryland.

in Harford County, Maryland (fig. 1). USGS operates a streamgage (01581500) on Bynum Run, which drains an area of 8.52 square miles. USGS also operates two streamgages on Winters Run; one streamgage (01581700) drains an area of 34.8 square miles, and another a little downstream (01581750) drains an area of 36.8 square miles. USGS also operates two rain gages in the study area—Rain Gage in Winters Run Basin at Fallston, Md. (gage 393126076244301), hereafter Fallston Rain gage, and Atkisson Reservoir near Bel Air, Md. (gage 01581753), hereafter Atkisson Reservoir gage. (fig. 3).

Methods

The USGS compiled selected precipitation and streamflow characteristics that describe conditions in Harford County. Precipitation, peak streamflow, and stage records were analyzed to identify any physical characteristics that could indicate a change in flooding frequency.

Precipitation Frequency

National Weather Service (NWS) historical precipitation data as well as USGS precipitation data from the Fallston (U.S. Geological Survey, 2018a) and Atkisson Reservoir (U.S. Geological Survey, 2018b) gages were reviewed for magnitude and duration of major storms. The NWS had compiled a series of maps (Bonnin and others, 2006) describing how often rainfall events of a set magnitude occurred. These NWS maps are useful in describing how rare or common certain events are. Storms are described in terms of their annual frequency such that a 100-year frequency event would likely occur 1 year in 100 years, or a 1-percent chance that it will occur in a given year. NWS precipitation frequency information was used to

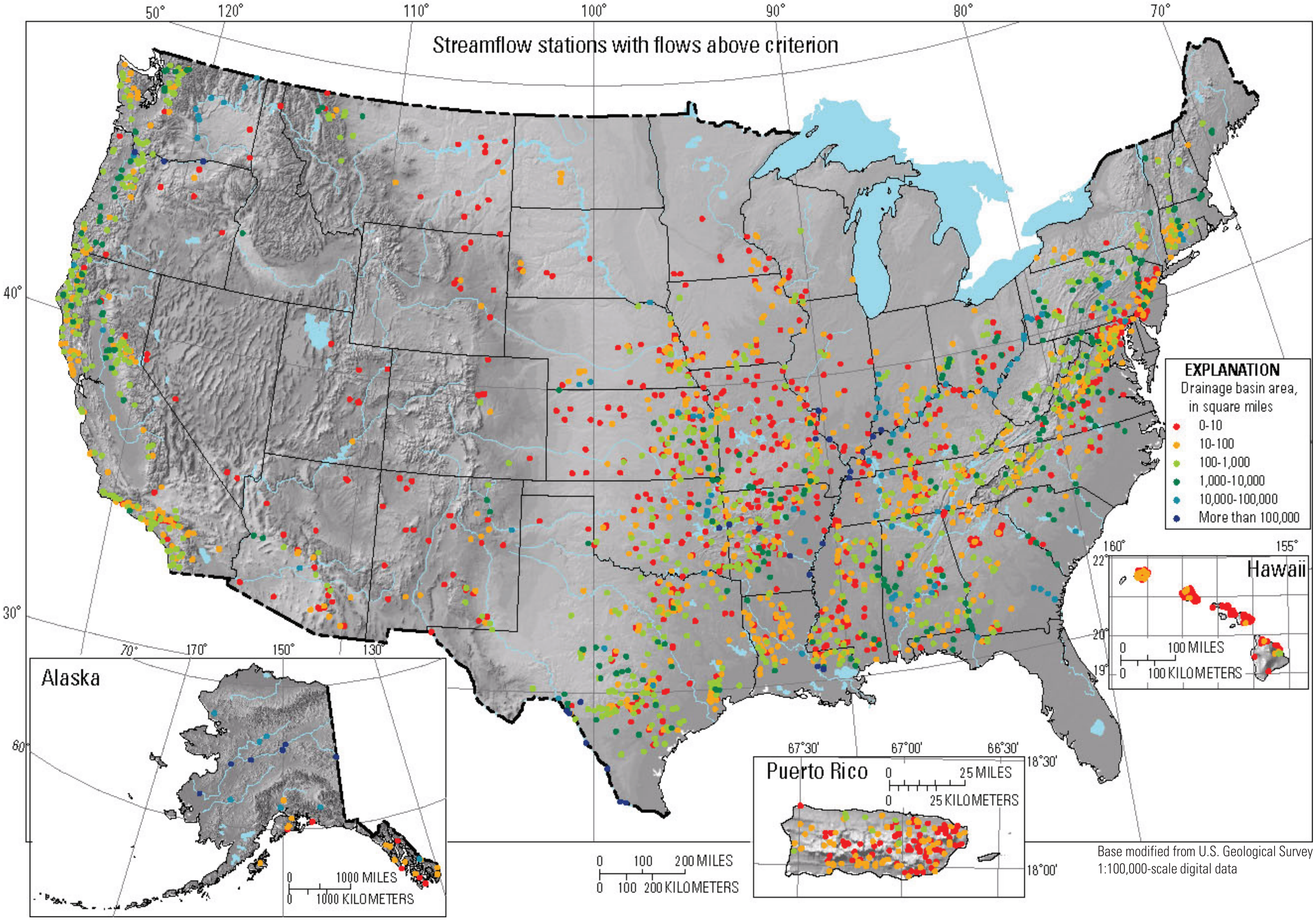

Figure 2. Locations of 2,929 stations, color coded by drainage area, for which the largest peak discharges are larger than other, similarly sized basins.

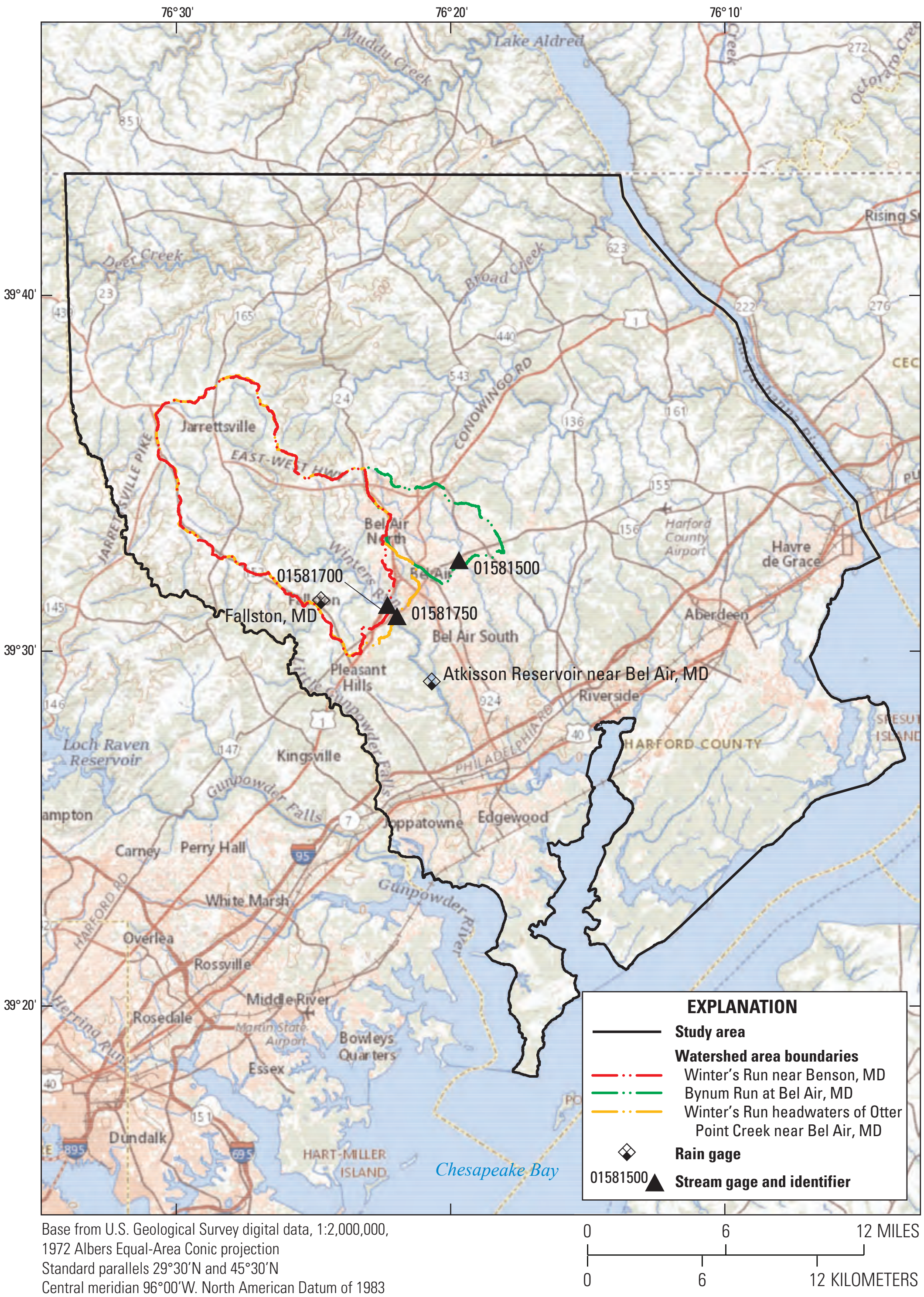

Figure 3. Location of USGS streamgage monitoring sites with associated watersheds, and rain gages.

evaluate the frequency of storms of this magnitude occurring in the watersheds and whether more, fewer, or an equal number of storms occurred during the period of record.

Stage Analysis

Streamflow and stage records for streamgages 01581500, Bynum Run at Bel Air, Md., and 01581700, Winters Run near Benson, Md., (U.S. Geological Survey 2018c, 2018d) were reviewed using USGS Techniques and Methods for Discharge Measurements (Turnipseed and Sauer, 2010) and Discharge Ratings at Measuring Stations (Kennedy, 1984). This information was used to determine whether sedimentation or erosion in the streams contributed to an increase in incidental flooding. Stage-discharge ratings over time also were analyzed to determine trends. Specific stage analyses were used to determine if the elevation of the streambed has changed over time. These analyses enable the detection of changes in streambed elevation by assessing changes in water stage over time for specific streamflow values (Jones and others, 2012).

Rating Analysis

The stage-discharge ratings associated with streamgages 01581500, Bynum Run at Bel Air, Md., and 01581700 Winters Run at Bel Air, Md., were analyzed for any changes over time. The rating for a site is changed when the previously defined relation between stage and stream discharge at the monitoring location is shown to have changed significantly enough to require re-definition. These changes are caused by some difference in the physical channel characteristics at or near the monitoring location, including sediment deposition or scour of the stream channel, bank erosion, or other physical changes that alter the hydraulic properties of the stream channel. (Kennedy, 1984). This discharge is calculated separately and compared to the existing rating with any adjustments applied. If the observed differences are caused by temporary or cyclical changes to the stream channel, they are called “shifts”; they shift the rating either to the left (if there is more backwater) or right (if the control of flow is observed to be scoured) If the changes in channel are assessed to be permanent, and not part of a cyclical adjustment, a completely new rating may be developed to define discharge at the location.

Peak Streamflow

The peak-flow files for streamgages 01581500 Bynum Run and 01581700 Winters Run were plotted verses time to determine any irregularities or patterns that might suggest either natural or anthropogenic causes of change to flooding characteristics and to identify the timing of any such changes. These files were plotted and analyzed using the PeakFQ software (Veilleux and others, 2014) to quantify any statistical anomalies (trends) that could help to explain changes to flood frequency or magnitudes.

Land Cover Analysis

The area of impervious surfaces (for example, roads, parking lots, sidewalks) in a watershed can affect the hydrologic characteristics of a watershed. When rainfall lands on a vegetated lot, the water may evaporate from leaf surfaces, or be absorbed in the soil, slowing the travel to a stream. When rain falls on impervious surfaces, the water is directed to runoff systems or structures which then lead to a stream. High amounts of impervious area in a watershed tend to increase the proportion of rainfall that runs off the watershed immediately via the surface drainage network (stream channels) and may also decrease the time-to-peak, resulting in the “flashiness” of a stream. An increase in impervious surface decreases the amount of time a raindrop takes to enter a stream and could therefore lead to more a more rapid water rise in the stream channel during intense rainfalls. The change in the amount of developed land over time, as well as the change in the amount of impervious surface within each of the study watersheds, was analyzed using the web-based StreamStats application (U.S. Geological Survey, 2012).

Results

Precipitation Frequency

Technical Paper 40 (Hershfield), published in 1963 by the Weather Bureau of the U.S. Department of Commerce which preceded the NWS, describes rainfall intensities in terms of amount of precipitation per period of time. The values published for Harford County, Md., were updated by the NWS in 2006 in NOAA Atlas 14, Volume 2, Version 3.0 (Bonnin and others, 2006). The amount of precipitation occurring within 1 hour for a 10-year storm was 2.4 inches, as presented in Technical Paper 40 (Hershfield, 1963), and decreased to a range of 2.0 to 2.1 inches (Bonnin and others, 2006). The amount of precipitation occurring within 1 hour for a 100-year storm was 3.5 inches as presented in Hershfield (1963), and decreased to a range from 2.9 to 3.1 inches as presented in Atlas 14 (Bonnin and others, 2006, Benson Police Barracks, Station ID 18-0732). These values indicate that rainfall intensities have decreased between 1940 and 2006. Note that the available data in 1940 are substantially different from the data collected in 2006, and other reports with a broader focus point to an increased frequency and severity of extreme precipitation events (IPCC, 2014).

Continuous-record precipitation data from two stations in Harford County were analyzed to determine the largest storms for the periods of record. These data were collected and reported every 15 minutes. Point-precipitation frequency estimates developed from NOAA Station 18-0732, Benson Police Barracks, in Bel Air, Md., were used to determine frequency estimates for precipitation totals recorded at USGS streamgage 01581753, Atkisson Reservoir near Bel Air, Md., and rain gage 393126076244301 in Winters Run Basin at Fallston, Md.

Storms with a frequency of 10 years or greater that were recorded at the two Harford County rain gages between October 2005 and October 2018 are shown in table 1. The table indicates that the period from 2005 to 2017 was an active period as far as intense, low-probability storms. Two storms—June 24–28, 2006, and September 30–October 1, 2010—were greater than 100-year frequency. The storm in June 2006 produced more than 16 inches of rainfall in about 3.4 days, which is a point frequency of about 800–850 years. A third event in October 2005 has frequencies in the range of the 75–80 years.

Four storms of shorter duration, between 30 minutes and 2 hours, occurred in July 2007, July 2015, August 2015, and August 2017 (table 1). Point precipitation frequencies for the short duration storms ranged from 10 years to about 50 years.

A longer period of particularly wet weather that stands out in the precipitation records is August and September 2011 when the Tropical Storms Irene and Lee passed through in succession. Total rainfall during the 60-day period from August 1, 2011, to September 29, 2011, was more than 23 inches at the Fallston rain gage and nearly 25 inches at the Atkisson Reservoir rain gage. Point precipitation frequencies ranged from 90 to 200+ years for this 60-day period at the two rain gages in Harford County.

The study area and the state as a whole set rainfall records in 2018. The year 2018 was the wettest year on record in the region, with 71.82 total inches of rain falling at the Baltimore/Washington International airport, which is about 24 inches greater than normal for the year. The previous record was slightly more than 62 inches in 2003 (National Oceanic and Atmospheric Administration, 2019). Streamflow in James Run near Belcamp, Md. (streamgage 01581649), just southeast of the study area in Harford County, set records as well. At about 7 p.m. on August 31, 2018, the stream reached a record 11.11 feet and 9,170 cubic feet per second (ft^3/s). The previous record was 2,000 ft^3/s in 2017.

Stage Analysis

To investigate whether the geomorphology of the streambank can cause an increase in streambed elevation, even at base flow, a specific stage analysis was completed on data available for the Bynum Run streamgage from January 2010 through 2018. The specific stage analysis enables the detection of changes in streambed elevation by assessing changes in stage over time for specific streamflow values (Jones and others, 2012). As shown in Figure 4, after a relatively stable relation from 2000 through 2014, the stage started to increase with associated streamflows at an increased rate starting in early 2015. It is unlikely that this relatively subtle rise in stage could be responsible for more frequent flooding.

Table 1. Point precipitation frequency estimates for selected storms in Harford County, Maryland, water years, 2006–17.

Precipitation station	Date(s)	Rainfall amount (inches)	Duration	Frequency (years)
Fallston	June 24–28, 2006	16.14	3.4 days	800–850
Fallston	June 24–28, 2006	16.14	3.4 days	800–850
Fallston	July 16, 2007	1.65	30 minutes	10+
Fallston	Aug. 1–Sept. 29, 2011	23.09	60 days	90–95
Atkisson Reservoir	Aug. 1–Sept. 29, 2011	24.93	60 days	200+
Fallston	Sept. 30–Oct. 1, 2010	9.15	1.04 days	100–125
Atkisson Reservoir	Sept. 5–10, 2011	8.09	5.25 days	20+
Fallston	Sept. 23, 2011	5.45	12.25 hours	25–30
Fallston	Oct. 28–30, 2012	7.3	1.8 days	25–30
Atkisson Reservoir	Oct. 28–30, 2012	7.33	1.9 days	25
Atkisson Reservoir	April 29–30, 2014	6.58	1.5 days	20+
Fallston	July 6, 2015	1.62	30 minutes	10
Fallston	Aug. 20, 2015	3.43	2 hours	45–50
Fallston	Aug. 18, 2017	2.47	1 hour	25
Atkisson Reservoir	July 27, 2018	1.18	15 minutes	25

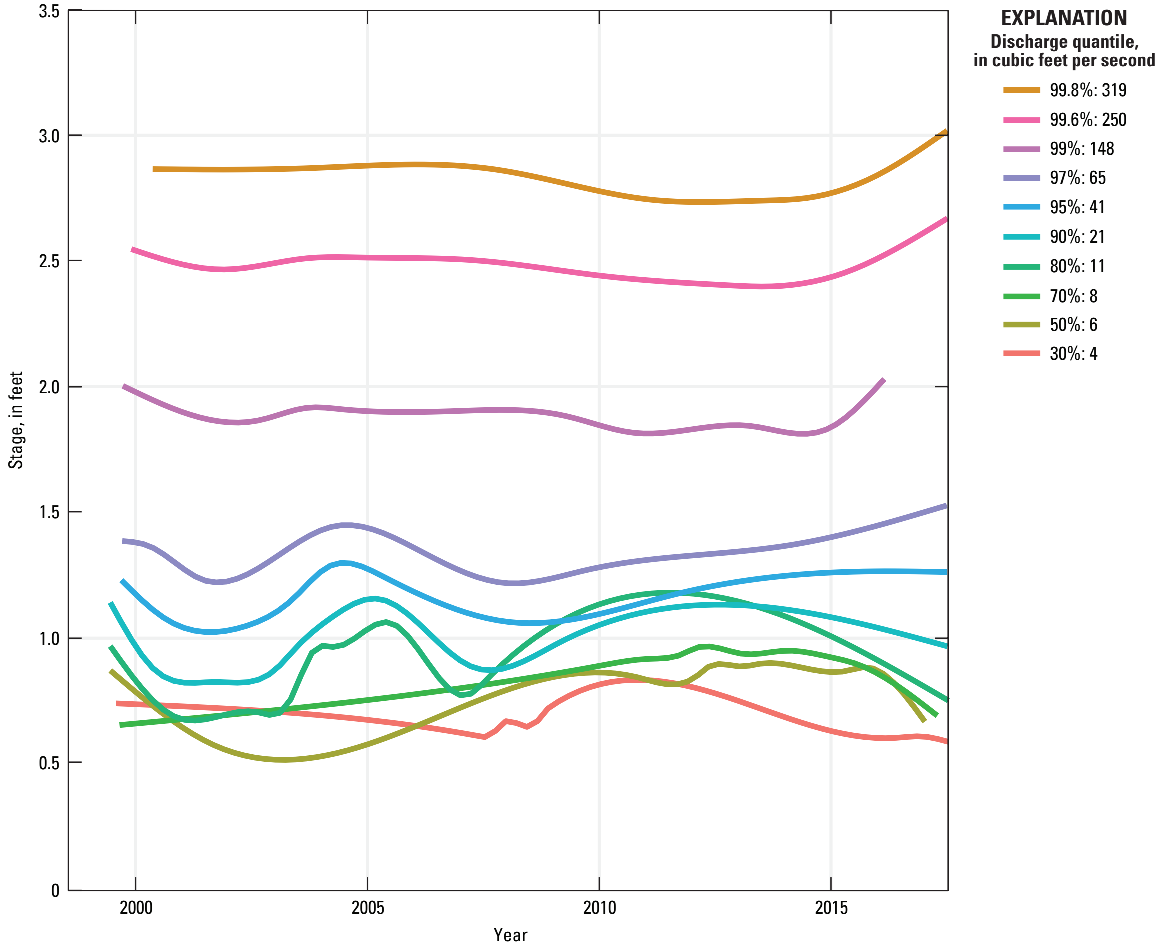

Figure 4. Graph showing specific stage analysis for streamflow in Bynum Run at Bel Air, Maryland (streamgage 01581500).

Rating Analysis

Analysis of the stage-discharge ratings at Winters Run near Benson, Md. (streamgage 01581700), indicate relative stability over time in the mid- and high-flow ranges. When a recorded flow is observed to be higher than recently recorded events, the flow is calculated separately and compared to the existing rating. Peak flow computations in June 2006 and two in August 2017 were close to the existing rating with a maximum difference of 8.5 percent with no changes to the rating. Ratings are adjusted as necessary after field measurements. At the Winters Run near Benson streamgage, shifting tends to occur more often on the low end of the rating and blends into the rating once the section control (rock riffle below the streamgage) is inundated at higher stages.

At Winters Run near Benson, the single-opening arch bridge at U.S. Route 1 Business is the first roadway crossing downstream from the streamgage. This bridge was installed in 1930, well before activation of the streamgage in August 1967 (Maryland Department of Transportation, State Highway Administration, 1999). Reconnaissance of the stream channel in August 2017 indicated no major obstructions or debris blockages between the streamgage and the bridge crossing on U.S. Route 1 Business that would be the cause of any backwater. The downstream bridge has been in place throughout the period of record, and no major obstructions or debris blockages are present in the stream channel. Therefore, no special conditions of this type would affect the stage-discharge rating.

The high end of ratings at Bynum Run at Bel Air, Md. (streamgage 01581500), is further to the left on the stage/discharge graph (which means more backwater in this case) during the later period of record than it was during the earlier period, which ended in the early 1970s. This was discovered during a slope-area indirect measurement for the storm and flood of September 30, 2010, which had a peak gage height of 8.36 feet and peak streamflow of 2,700 ft^3/s. This rating change is likely the result of the pedestrian bridge that crosses the stream about 600 feet downstream from the streamgage. The pedestrian bridge was installed sometime during the mid-1970s when the streamgage was inactive, which explains why no effects from the bridge were observed on the rating until the streamgage was restarted and high-flow measurements in the effective range of stage were obtained. Recent (2010-2018) high-flow measurements at the streamgage have shown that the extreme high end of the stage-discharge rating is farther to the left, as a result of the width-area contraction imposed on the stream channel by the pedestrian bridge. This condition creates backwater, which is reflected in a higher stage for the same streamflow or increased inundation of the reach between the streamgage and the pedestrian bridge.

It is also possible that tree growth and increased vegetation on the overbank areas downstream from the streamgage may contribute to the rating change. Increased vegetation means increased roughness, which decreases the mean velocity during high flows. Slower moving flow for an equivalent streamflow indicates an increased cross-sectional area, which could contribute to the backwater condition.

Peak Flow Analysis

The Bynum Run gage was inactive from 1951 through 1955 and 1970 through 1999; therefore, there are long periods without data. Bynum Run reached the NWS defined flood stage of 9 feet three times during the period of record, notably all during the summer months—June, August, and September. Winters Run reached the flood stage of 9 feet 18 times during its period of record, and these instances also occurred more often during the summer. In fact, 33 percent of the events above flood stage occurred during September.

The peak-flow files for Bynum Run and Winters Run streamgages were plotted to determine any irregularities. The streamflow at Winters Run stands out because it appears to be bimodal (fig. 5). There appears to be two categories where there are peaks—below 3,000 ft^3/s and above 5,000 ft^3/s. There are two main stems to this watershed, creating a “Y” shape. It appears that the highest of the high peaks occurred only when both stems of the watershed had high flows. The timing of the storms may contribute to this effect. During the summer, pop-up/localized thunderstorms are much more frequent than the area-wide frontal boundary events of the spring and fall.

The bimodal trend also appears when the streamflow return intervals, or the likely chance of a streamflow of a certain magnitude, are compared to streamflow. The data for Bynum Run (fig. 6) are much more uniform than data for Winters Run (fig. 7), where a deviation can be seen at around 5,000 ft^3/s with a 3-year return interval. Generally, the peak flows at both streamgages are within expected ranges and do not indicate any reason for the expectation of more frequent flood occurrences.

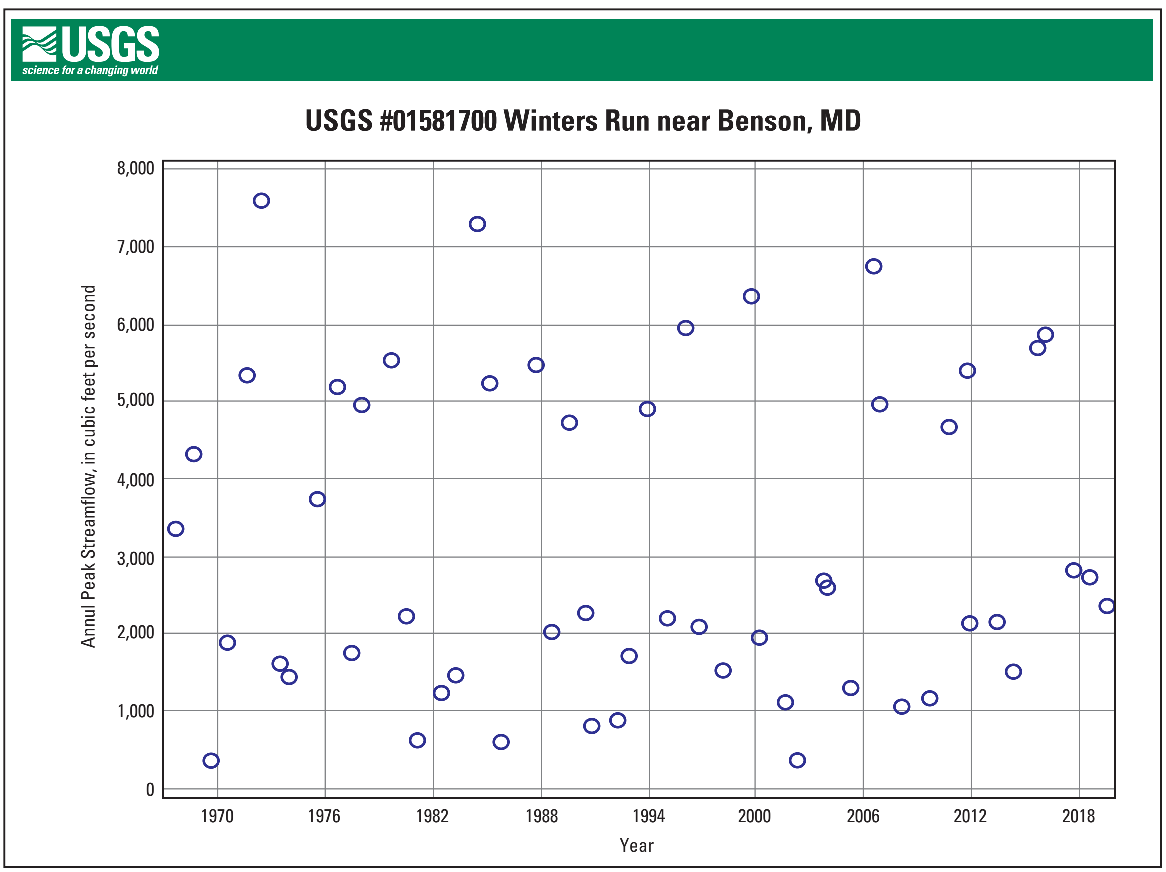

Figure 5. Annual peak streamflow record for Winters Run near Benson, Maryland. (streamgage 01581700).

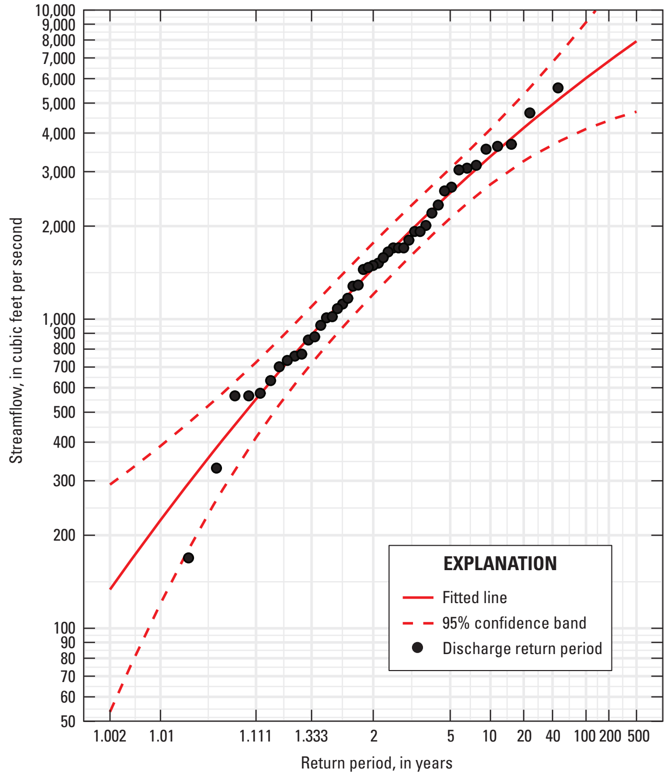

Figure 6. Discharge return intervals for Bynum Run at Bel Air, Maryland.

Land Cover Changes Over Time

As in most of the region, land use in Harford County has shifted toward developed lots in the last several decades (1973–2010). The amount of developed land in Harford County increased to more than 67,000 acres from 1973 to 2010. High density residential areas have increased by 24.2 percent, and commercial areas have increased by 21.4 percent, from 2002 to 2010 (Maryland Department of Planning, [2012?]). According to StreamStats, the Bynum Run watershed is more developed than Winters Run watershed. Bynum Run has impervious area covering 33.3 percent of the watershed, whereas Winters Run near Benson has much less, 13.0 percent (Ries and Eng, 2010). Harford County requires land developers to provide stormwater plans to the county for review for any new construction according to Chapter 214, Article II of the Harford County code. It states, "The goal is to manage stormwater by using environmental site design (ESD) to the maximum extent practicable (MEP) to maintain after development as nearly as possible, the pre-development runoff characteristics, and to … reduce local flooding … and minimize damage to public and private property and reduce the impacts of land development." Topographic structures, such as stormwater ponds and other control features, delay storm runoff and reduce the chance of flooding.

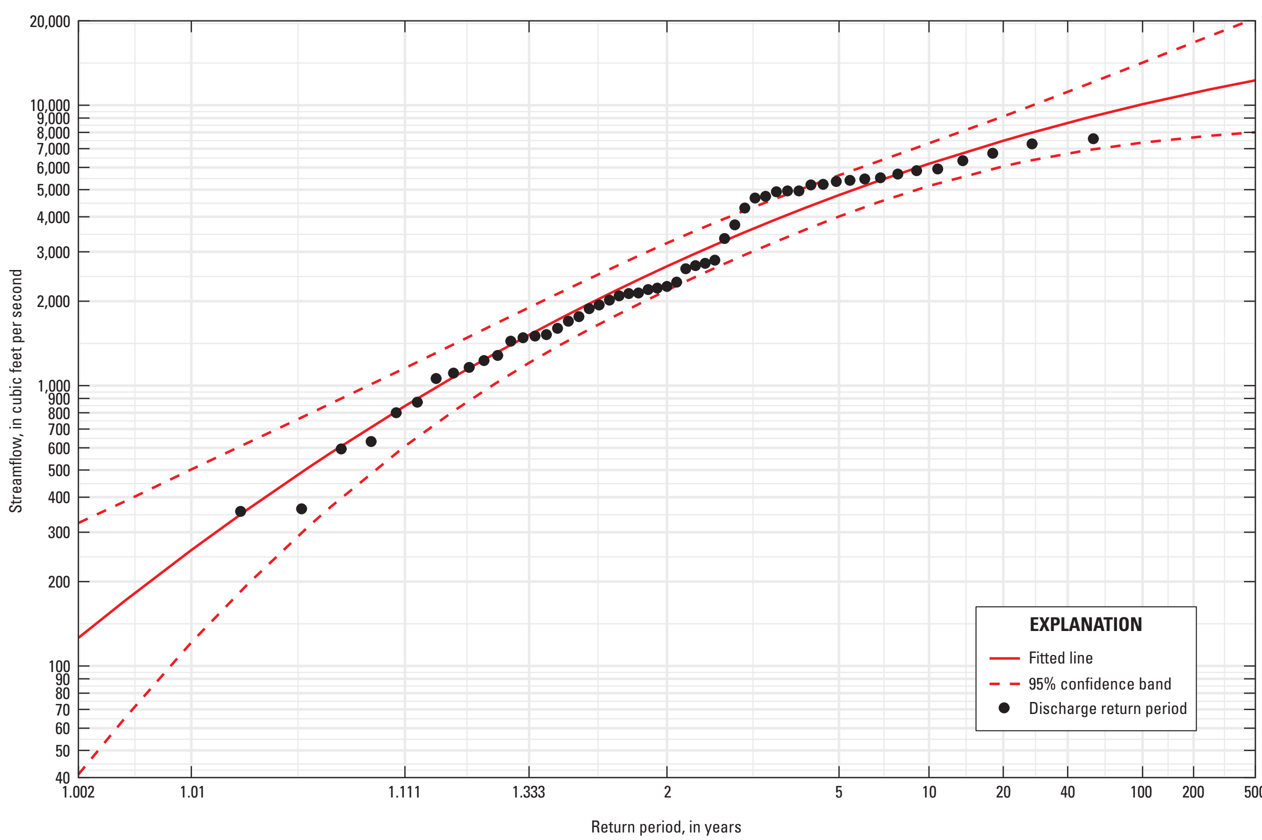

Figure 7. Discharge return intervals for Winters Run near Benson, Maryland.

Summary

Precipitation, stage, and peak flow analyses were conducted and trends were evaluated by the U.S. Geological Survey for Winters Run and Bynum Run in Harford County, Maryland. No one contributor was identified for the perceived increase in flooding. The perception is most likely attributable to a combination of all factors. There have been numerous rainfall events with exceedingly long return intervals, but none are statistically extreme. The stream stages are slightly higher (less than 0.5 feet) at higher streamflows than historical stages but likely are not high enough to cause a significant increase in flooding. The ratings for the streams have changed slightly and indicate that erosion and deposition occurred in the streambed over the years of observation, but again this alone does not result in more flooding. These factors may also point to an observational bias of incidental flooding. With the increase in land development in the county, there may simply be more observed instances of flooding in the county than in the past.

The peak-flow analysis diagram for the Winters Run watershed showed an interesting trend. It appears that there are two main stems in the watershed; the highest of the high peaks occurred only when both areas of the watershed had high flows. The timing of the storms may contribute to this effect. During the summer, pop-up/localized thunderstorms are much more frequent than the area-wide frontal boundary events of the spring and fall. More work is needed to analyze the bimodal nature of this trend.

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Glossary

M

mesoscale convective complex: A unique complex of thunderstorms that becomes organized on a larger scale than individual thunderstorm cells, but smaller than extratropical cyclones, and normally persists for several hours or more. They tend to be long-lived, often form nocturnally, and commonly contain heavy rainfall, wind, hail, lightning, and possibly tornadoes.

U

upper atmospheric circulation pattern: The large-scale movement of air in the upper levels of the atmosphere.

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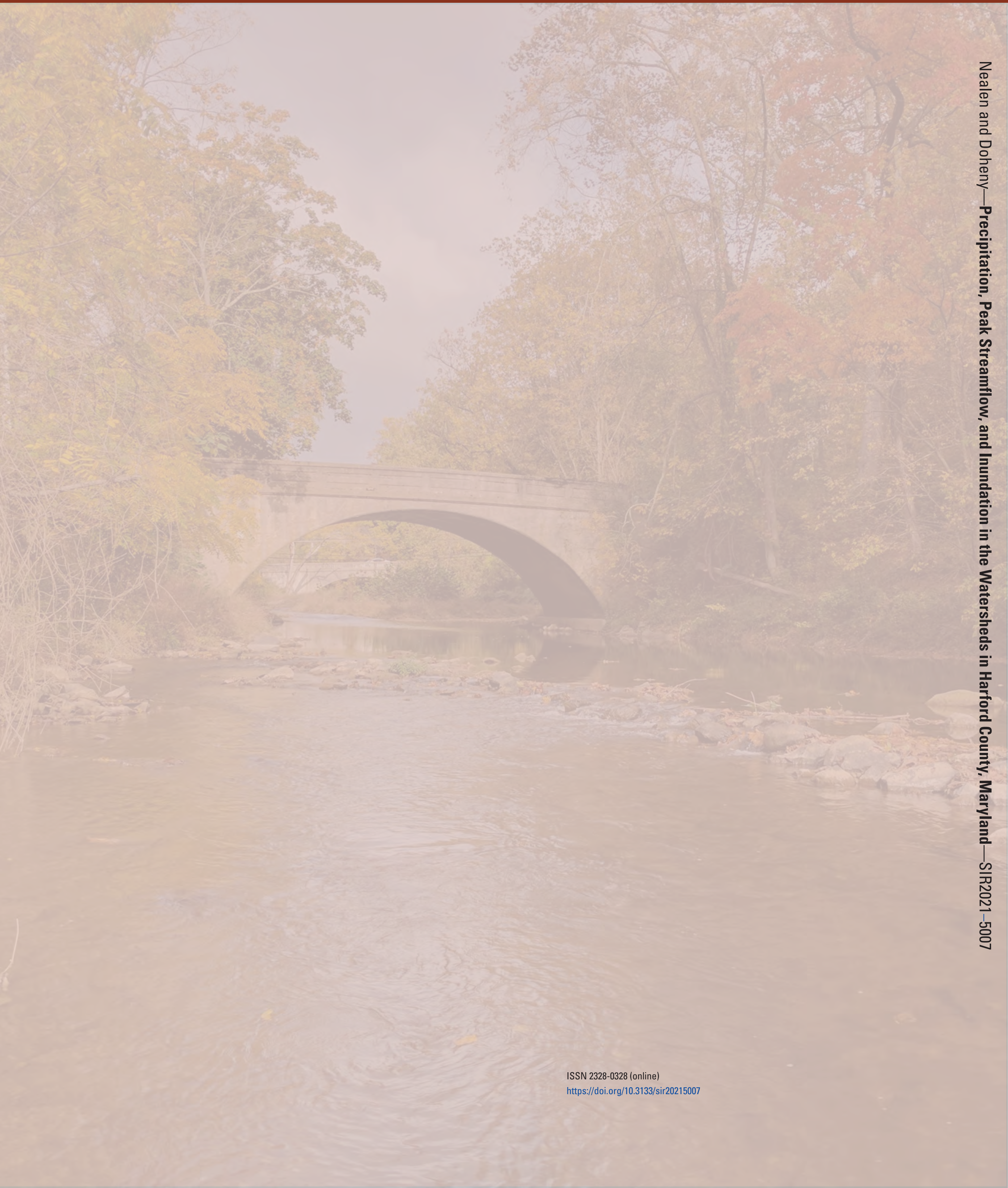

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