Stream Gaging and Flood Forecasting

A Partnership of the U.S. Geological Survey and the National Weather Service

Flash Flood Watch
National Weather Service, Washington, D.C.
4:30 am EDT Tuesday, June 27, 1995

The National Weather Service in Washington, D.C. has issued a flash flood watch...Valid until 10 pm. EDT this evening...for a large part of western Virginia...A southward moving cold front will act to focus heavy rain producing showers and thunderstorms today, and tonight in and close to the watch area. A combination of a very moist air mass in place over the region and the added focus of the cold front will allow for widespread rain to develop. Saturated soil from recent rains will add to the flooding problem.

Persons in flood prone areas should monitor rainfall today and have a plan to move to high ground should persistent heavy rains occur.

Floods are among the most frequent and costly natural disasters in terms of human hardship and economic loss. As much as 90 percent of the damage related to natural disasters (excluding droughts) is caused by floods and associated mud and debris flows. Over the last 10 years (1985–94), floods have cost the Nation, on average, $3.1 billion annually in damages. The long-term (1925–88) annual average of lives lost is 95, mostly as a result of flash floods. One has only to recall the flash flooding of the Big Thompson River in Colorado in 1976, which killed 139 people as it swept through campgrounds and vacation homes nestled in a narrow canyon, to realize how unexpected and costly, in human life alone, such phenomena can be.

Important elements in the Nation's program to reduce flood damages include flood warnings and river forecasts. Timely warnings and forecasts save lives and aid disaster preparedness, which decreases property damage by an estimated $1 billion annually. Although the issuance of flood forecasts is now accepted as common and routine, their preparation is no minor feat. This technical achievement is made possible by the joint efforts of several Federal, State, and local agencies and many dedicated people across the Nation.

A Partnership

The National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration, is widely known as the Federal agency in charge of weather forecasting and warning for the Nation. Many people, however, are not aware that the NWS also is charged by law with the responsibility for issuing river forecasts and flood warnings. The National Weather Bureau Organic Act of 1890 (U.S. Code title 15, section 311) mandates that the National Weather Service is the responsible agent for "***the forecasting of weather, the issue of storm warnings, the display of weather and flood signals for the benefit of agriculture***." The NWS uses many sources of data when developing its flood forecasts. The U.S. Geological Survey (USGS) is the principal source of data on river depth and flow.

Chartered in 1879 by Congress to classify the public lands and to examine the geologic structure, mineral resources, and products of the national domain, the USGS is the Nation's leading earth science information agency. As part of its mission, the USGS provides practical information about the Nation's rivers and streams that is useful for mitigation of hazards associated with floods and droughts and defines the hydrologic and hydraulic characteristics needed for the design and operation of engineering projects, such as dams and levees. The primary source of this information is the USGS streamflow-gaging station network.

The USGS operates and maintains more than 85 percent of the Nation's stream-gaging stations, which includes 98 percent of those that are used for real-time river forecasting. Currently, this network comprises 7,292 stations dispersed throughout the Nation, 4,200 of which are equipped with earth satellite radios that provide real-time communications. The NWS uses data from 3,971 of these stations to forecast river depth and flow conditions at 4,017 forecast-service locations on major rivers and small streams in urban areas (fig. 1).

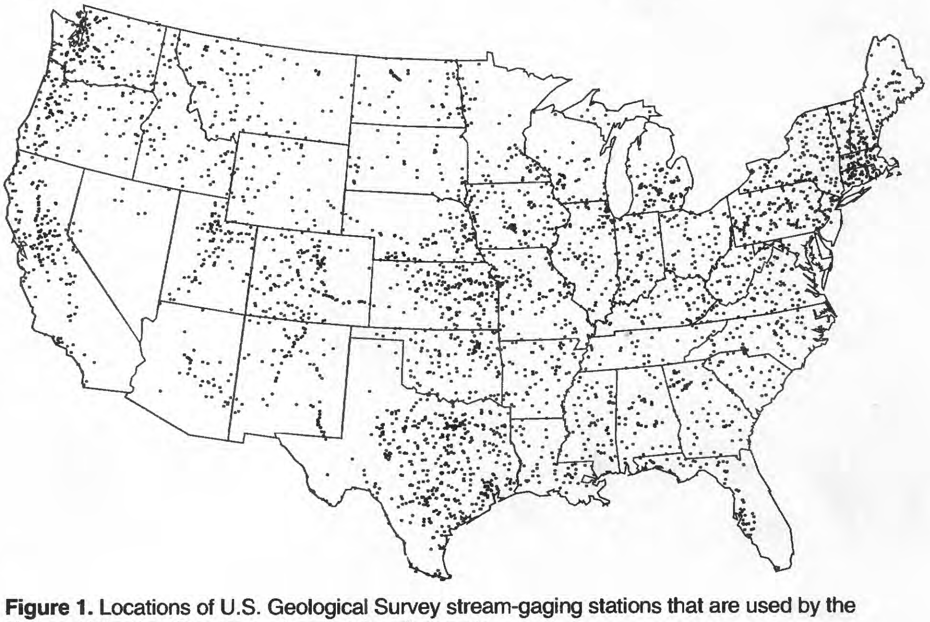

Figure 1. Locations of U.S. Geological Survey stream-gaging stations that are used by the National Weather Service to develop river forecasts.

Stream Gaging

The two most fundamental items of hydrologic information about a river are stage, which is water depth above some arbitrary datum, commonly measured in feet, and flow or discharge, which is the total volume of water that flows past a point on the river for some period of time, usually measured in cubic feet per second or gallons per minute. These two key factors are measured at a location on the river called a stream-gaging station (fig. 2).

By using automated equipment in the gaging station, river stage can be continuously monitored and reported to an accuracy of 1/8 of an inch. Linking battery-powered stage recorders with satellite radios enables transmission of stage data to computers in USGS and NWS facilities even when extreme high waters and strong winds disrupt normal telephone and power services. In this way, USGS and NWS hydrologists know the river stage at remote sites and how fast the water is rising or falling.

It is much more difficult to measure river discharge accurately and continuously. As a matter of practicality, discharge is usually estimated from pre-established stage/discharge relations, or rating curves. The rating curves are constructed by USGS field personnel who periodically visit the gaging station to measure river discharge (fig.3). For more information about measurement of river discharge see Wahl and others (1995).

National Weather Service
State College, Pa

Per your letter request dated June 5, enclosed are updated rating tables for the following USGS streamflow gaging stations in Virginia: James River at Lick Run, Jackson River below Gathright Dam, Jackson River at Covington, Maury River near Buena Vista, Rappahannock River near Fredericksburg, and Craing Creek at Parr. Ratings at the other six sites are unchanged....The low-end portion of the Gathright Dam rating is currently undergoing reassessment but the high flow portion of the rating is not expected to change.

U.S. Geological Survey
Richmond, Virginia

Changes in river cross sections that result from the scour or deposition of sediment or changes in streambed and bank roughness alter the stage/discharge relation. Such changes are particularly prevalent during floods. Occasionally, changes are so severe as to require development of a new stage/discharge rating; this occurred at the North River at Stokesville, Va., as a result of a major flood in 1985 (fig. 4). Thus, even after a stage/discharge rating is well established, additional discharge measurements are required periodically to detect and track changes and to update the rating. Updated rating curves are provided to the NWS. Because documentation of flood discharges is so important, USGS field personnel are routinely deployed to stream-gaging stations during periods of high flow to measure river discharge during inclement weather, day or night.

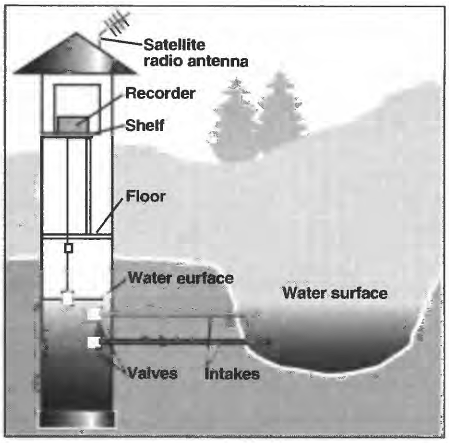

Figure 2. Schematic of a stilling well and shelter at a stream-gaging station.

Figure 3. Crane, current meter, and weight used for measuring the discharge of a river from a bridge.

By using an up-to-date stage/discharge rating and a river-stage reading, an accurate estimate of the river discharge can be produced. An important characteristic of a stage/discharge rating is that the process also works in reverse; given a discharge estimate, the corresponding river stage can be determined. This functionality enables the NWS to transform an obscure river parameter, its discharge, into an easily visualized and well-understood measure of public risk, the flood stage.

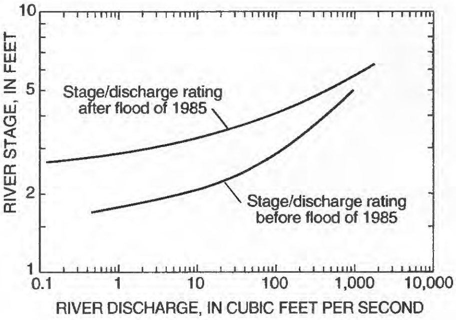

Figure 4. Stage/discharge relations at North River near Stokesville, Va., before and after the flood of 1985.

Flood Forecasting

River-flood forecasts are prepared by 13 NWS river-forecast centers and disseminated by NWS offices to the public. During periods of flooding, the NWS river-forecast centers issue forecasts for the height of the flood crest, the date and time when the river is expected to overflow its banks, and the date and time when the flow in the river is expected to recede to within its banks. These forecasts are updated as new information is acquired.

River Flood Warning
National Weather Service,
Washington, D.C.
4:15 pm EDT Tuesday, June 27, 1995

Heavy rain across the Rappahannock River basin in northern Virginia will cause significant flooding. At 4:10 pm the Rappahannock River at Remington was 12.4 feet and rising sharply. The river should reach its 15 foot flood stage tonight and crest between 18 and 20 feet early Wednesday morning.

vides one-half of the funds for the stations and the cooperating agencies provide the other half. Another 40 percent of the stations are funded entirely by the cooperating agency. However, the resulting streamflow data are available to all potential users through USGS data bases, on the Internet, and through USGS publications.

River Flood Statement
National Weather Service,
Washington, D.C.
4:26 am EDT Thursday, June 29, 1995

River stages are falling across the Rapidan and Rappahannock Rivers. At 3:45 am the level on the Rappahannock River at Remington was 13.46 feet, well below its 15 foot flood stage. The Rappahannock River at Fredericksburg crested at around 25.1 feet at 2:30 am this morning.

This will be the last statement of this flood event.

The NWS has developed extensive river-forecasting services that are based on access to USGS data. When cooperating agencies have obtained the information that they need from a stream-gaging station, they usually discontinue funding for that station. When either party (USGS or its cooperators) discontinues funding for a gage as a result of budget reductions or for other reasons, the operation of the station must be discontinued. This arrangement has an unintended consequence for the NWS and the communities that depend on NWS river-forecast services; gaging stations that are critical to the forecast service may be discontinued owing to circumstances beyond the control of the NWS or of its customers. Since 1983, 57 river-forecast service points have been affected by closure of one or more USGS stream-gaging stations and the trend accelerated during the early 1990's.

Demand for NWS river-forecast services continues to grow owing to an expanding population, urbanization, and economic growth—NWS now provides forecast services at about 4,000 locations. Although new radar technologies and computer visualization techniques hold significant promise for improving the timeliness and accuracy of river forecasts and flood warnings, ground-based verification will still be needed even after such technologies are in place. The need for real-time verification of river discharge and subsequent model adjustment is more than a scientific quest for accuracy; it is critically important to maintain model accuracy to minimize economic damage and human suffering. The detail and timeliness of the required data can be furnished only by on-site stream-gaging stations

—Robert R. Mason, Jr.,
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Benjamin A. Weiger,
National Weather Service

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——— 1995, *An overview of the stream-gaging program*: U.S. Geological Survey Fact Sheet FS–066–95, 4 p.

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Additional earth science information can be obtained by accessing the USGS "Home page" on the World Wide Web at
"http://www.usgs.gov"
or the NWS "Home page" at
"http://www.nws.noaa.gov."

For more information on all USGS reports and products (including maps, images, and computerized data), call 1–800–USA–MAPS.