EXECUTIVE SUMMARY: COMPARISON OF STREAM CHARACTERISTICS IN SMALL GAGED, UNMINED AND MOUNTAINTOP-REMOVAL MINED WATERSHEDS, BALLARD FORK, WEST VIRGINIA, 1999-2001

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Introduction: The U.S. Geological Survey (USGS) began a study of the effects of mountaintop removal coal mining on flow in the Ballard Fork watershed, in the upper Mud River basin near Madison, W.Va., in November 1999. Three continuous flow-gaging stations were installed. One gaging station was located on an Unnamed Tributary to Ballard Fork, directly downstream from a valley fill, and upstream from the sediment pond (fig. 1). The entire watershed of this stream

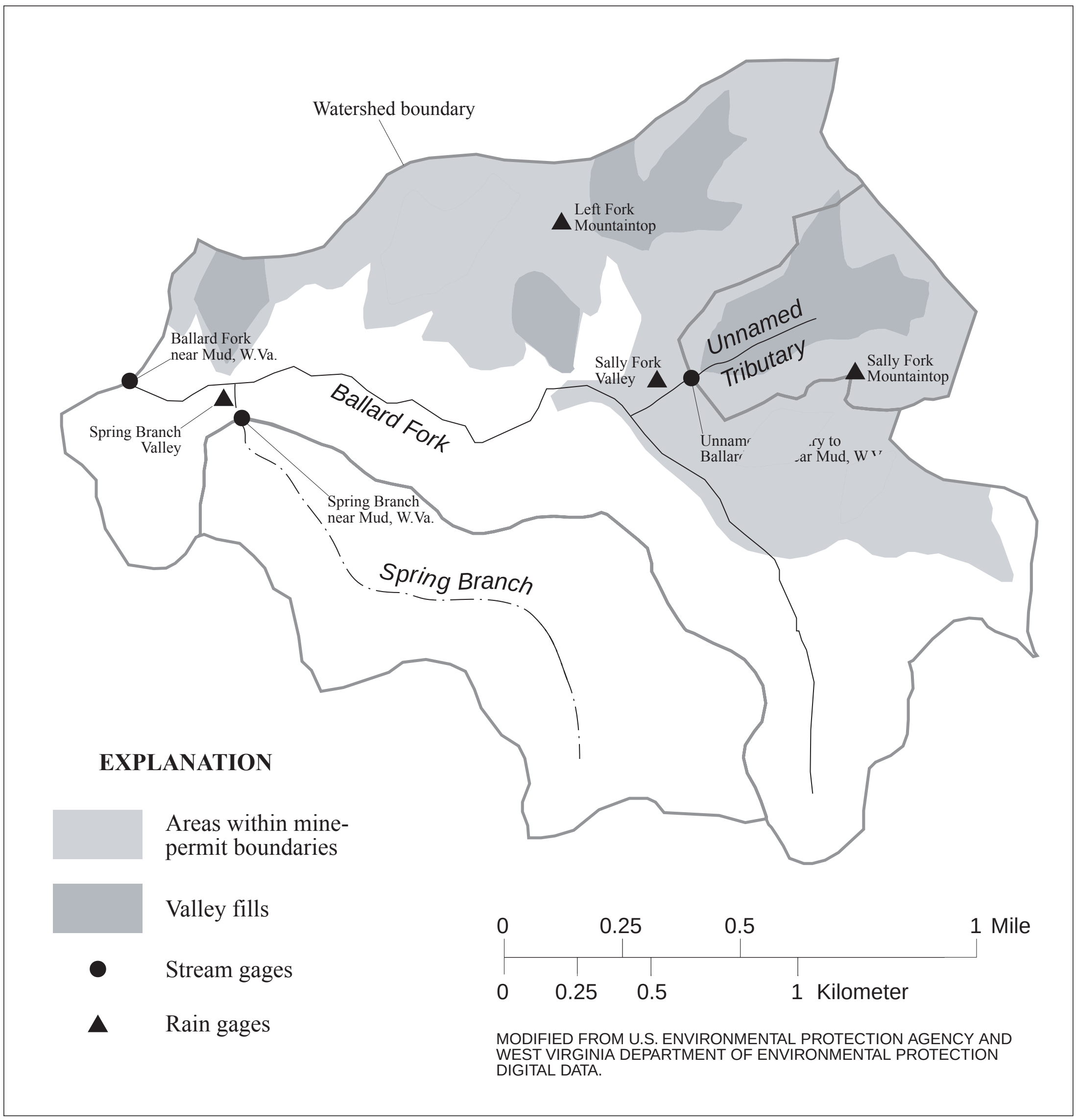

Figure 1. Streams, gages, valley fills, and areas permitted for mining in the Ballard Fork watershed.

(0.19 mi^2) is within an area permitted for mining, and all but a few acres is mined. The second gaging station, near the mouth of Spring Branch, drains an unmined, forested watershed (0.53 mi^2). The third gaging station was located on the main stem of Ballard Fork, which drains an area (2.12 mi^2) that includes both the Unnamed Tributary and Spring Branch watersheds. The entire Ballard Fork watershed is either surface mined or forested. Forty percent of the Ballard Fork watershed is within areas that had been permitted for mining, although less (about 30 percent) of the watershed was actually mined. About 44 percent of the Unnamed Tributary and 12 percent of the Ballard Fork watersheds is covered by valley fills.

Four rain gages were used during this study to collect precipitation data. Two rain gages were operated in mined areas on mountaintops, and the other two were in open areas on the valley floor. Precipitation amounts reported in this document are the average of amounts recorded at these four rain gages.

Mines in the Ballard Fork watershed received a Phase 1 bond release in August 2000, although mine inspection forms filed since November 1997 estimated that grading and backfilling was complete on all but 10 acres. The mined areas had grasses and other herbaceous vegetation typical of a newly reclaimed surface mine. Forest in Spring Branch and the rest of Ballard Fork was second- or third-growth, and dominant canopy species included white and red oak, several hickory species, sycamore, and tulip poplar.

Hydrologic conditions: Because this study began in November 1999, long-term conditions were assessed by comparison with nearby sites with long periods of record. Hydrologic conditions observed during the study period at three nearby long-term sites, the USGS stream-gaging station East Fork Twelvepole Creek near Dunlow, W.Va., and two NOAA rain gages at Madison and Dunlow, W.Va., were drier than long-term averages. Total precipitation in 2000 at both Madison and Dunlow (46.2 and 47.4 inches, respectively) was close to long-term averages (47.8 and 45.7 inches, respectively, 1971-2000), but was decreased substantially in 2001 (40.2 and 35.0 inches, respectively). Flow at East Fork Twelvepole Creek was well below the long-term average both years. The disparity between normal precipitation and low flow in 2000 was caused by the season when the precipitation was received. Precipitation at Madison was 4.71 inches below average from November 1999 through March 2000, the season of maximum recharge and runoff, and exceeded the long-term average during only three months, April (by 0.24 inches), June (by 1.76 inches), and July (by 0.20 inches), in the period of maximum evapotranspiration.

Total Flow: Total unit flow for the two-year study period on the Unnamed Tributary (11,700 $ft^3/s/mi^2$) was almost twice that on Spring Branch (6,260 $ft^3/s/mi^2$), and about 1.75 times that on Ballard Fork (6,690 $ft^3/s/mi^2$). The highest monthly flow in the study period in Spring Branch and Ballard Fork was during May 2001, because of a series of thunderstorms that produced 6.22 in. of rain in eight days, May 15-May 22. In contrast, the maximum monthly total flow on the Unnamed Tributary was in June 2001, although flows were similar from May through July 2001, the usual period of maximum evapotranspiration in forested watersheds.

The daily hydrograph shows that summer and autumn flows were relatively higher in the Unnamed Tributary than Ballard Fork, and relatively higher in Ballard Fork than in Spring Branch (fig. 2). Spring Branch was dry during much of October and November 2000, and its

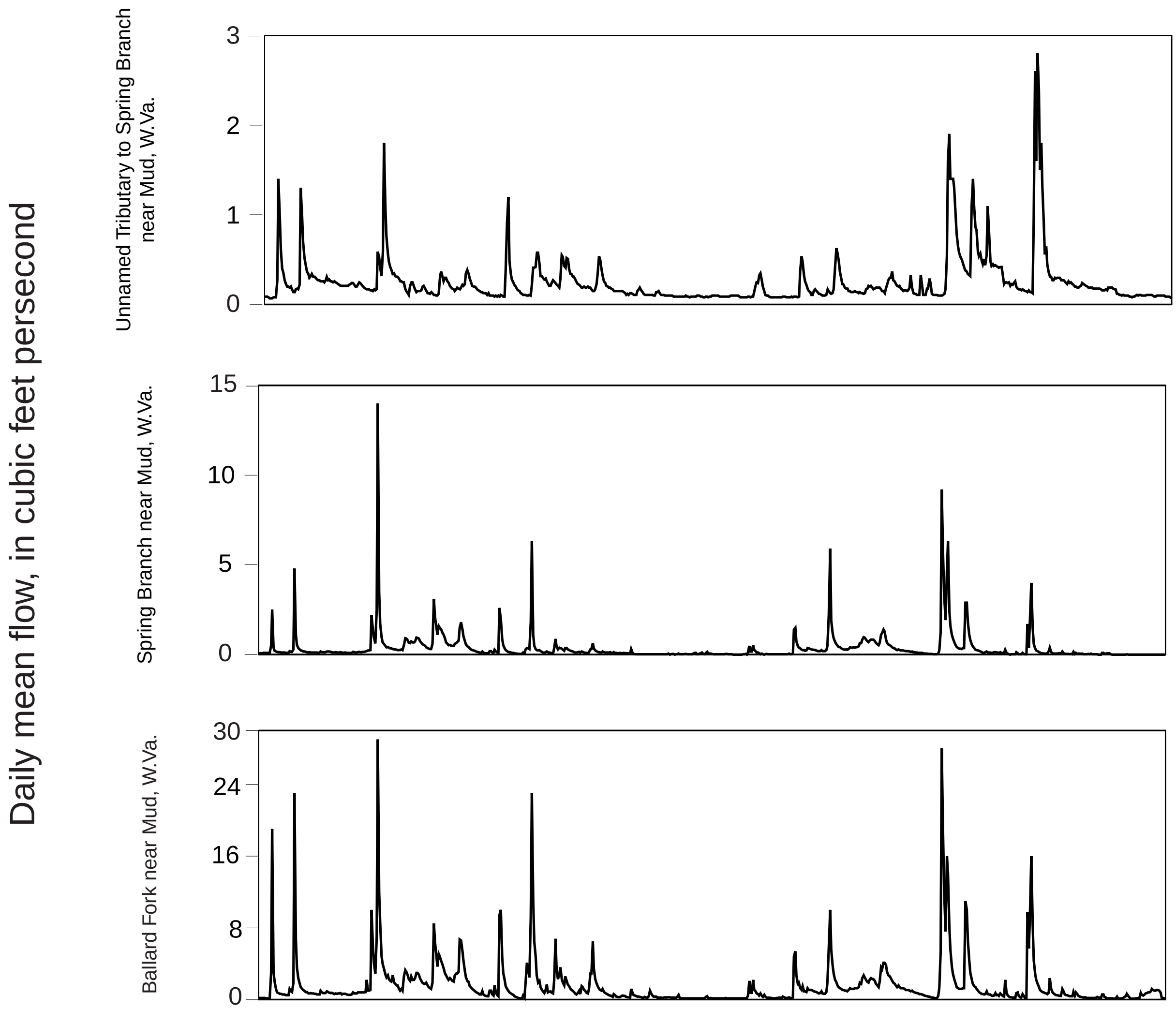

Figure 2. Hydrographs for three streams in the Ballard Fork watershed, W.Va., November 15, 1999-November 14, 2001.

monthly mean flow for October 2001, was zero. Ballard Fork and the Unnamed Tributary had flow throughout the study period. Daily mean flow was significantly ($P < 0.01$) correlated among the three streams in the Ballard Fork watershed. This correlation was strongest between Spring Branch and Ballard Fork ($R^2 = 0.723$), weakest between Spring Branch and the Unnamed Tributary ($R^2 = 0.370$), and intermediate between Ballard Fork and the Unnamed Tributary ($R^2 = 0.569$).

Flow duration: Flow duration curves show the lowest unit flows from Spring Branch, the highest unit flows from the Unnamed Tributary, and intermediate unit flows from Ballard Fork (fig. 3). Unit flow from the Unnamed Tributary watershed was the highest of the three streams at

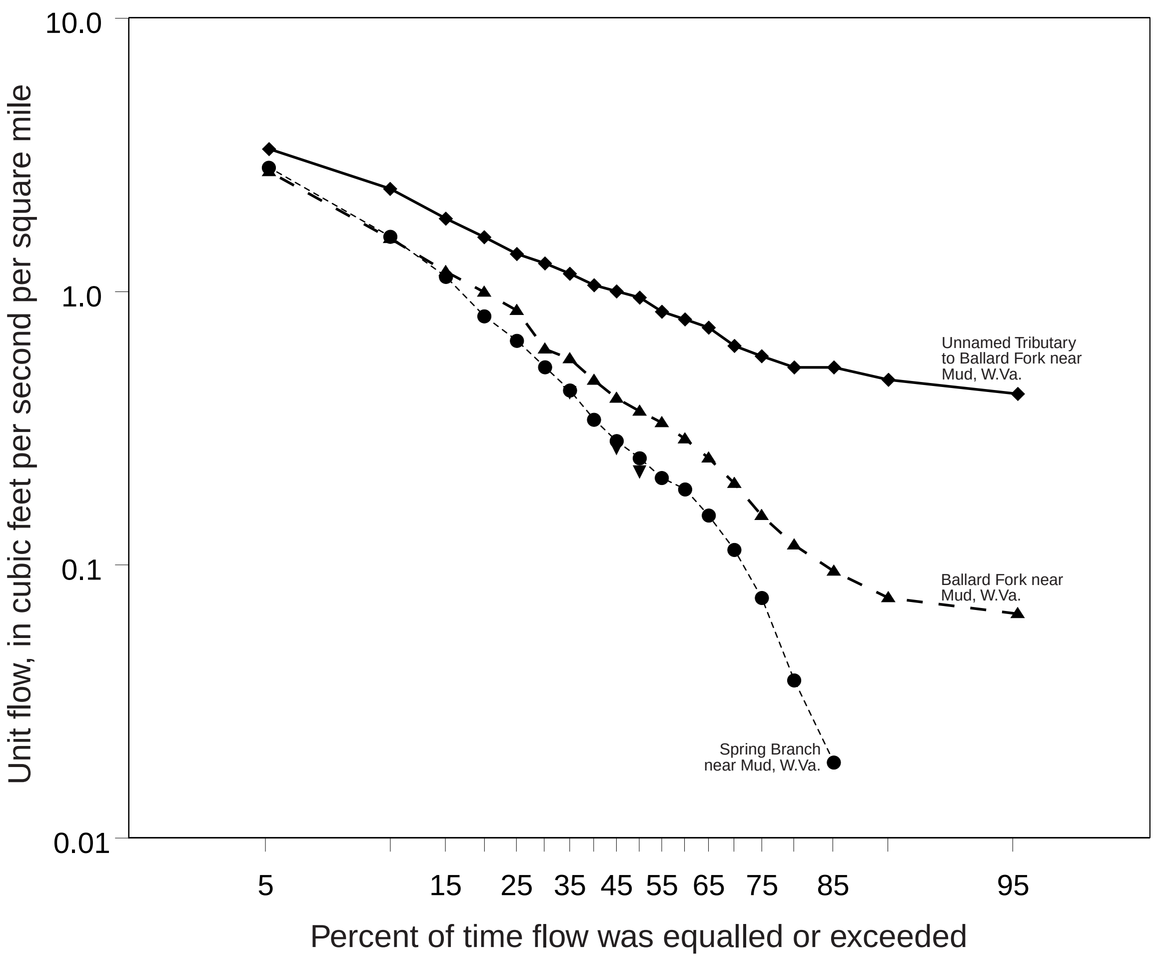

Figure 3. Flow duration of three streams in the Ballard Fork watershed, W.Va.., November 15, 1999-November 14, 2001.

all flows analyzed, between 5 and 95 percent flow duration, but the relative difference was greatest for low flows. Low flows in the Unnamed Tributary were probably increased because of decreased evapotranspiration on the mine as compared to the forest and delayed drainage of water stored in the valley fill. Unit flows from Ballard Fork and Spring Branch were about the same at higher flows, but unit flow from Ballard Fork was much higher than that from Spring Branch at low flow.

Evapotranspiration: Reduced evapotranspiration in mined areas probably accounts for the marked difference in total and low unit flow between the Unnamed Tributary and Spring Branch watersheds. Evapotranspiration, as a percentage of total rainfall, decreased from the first to the second, drier, year from the Unnamed Tributary watershed (from 61 percent to 45 percent) but changed relatively little from the Spring Branch (from 77 to 74 percent) and Ballard Fork (76 to 78 percent) watersheds. Evapotranspiration from the East Fork of Twelvepole Creek watershed was much higher during the study period (76 percent the first year, and 78 percent the second year) than the 1965-2001 average (60 percent). Most of the mechanisms of evapotranspiration appear to be lower on reclaimed surface mines than in forests, because most of them are mechanisms that evolved in plants to use or conserve water. Plant biomass in the mined areas is much less than in forested areas.

Unit flow per unit precipitation from Spring Branch only exceeded that from the Unnamed Tributary during spring months, February-April 2000 and February-March 2001, but even then, exceeded it by less than measurement error (fig. 4). Unit flow per unit precipitation from the

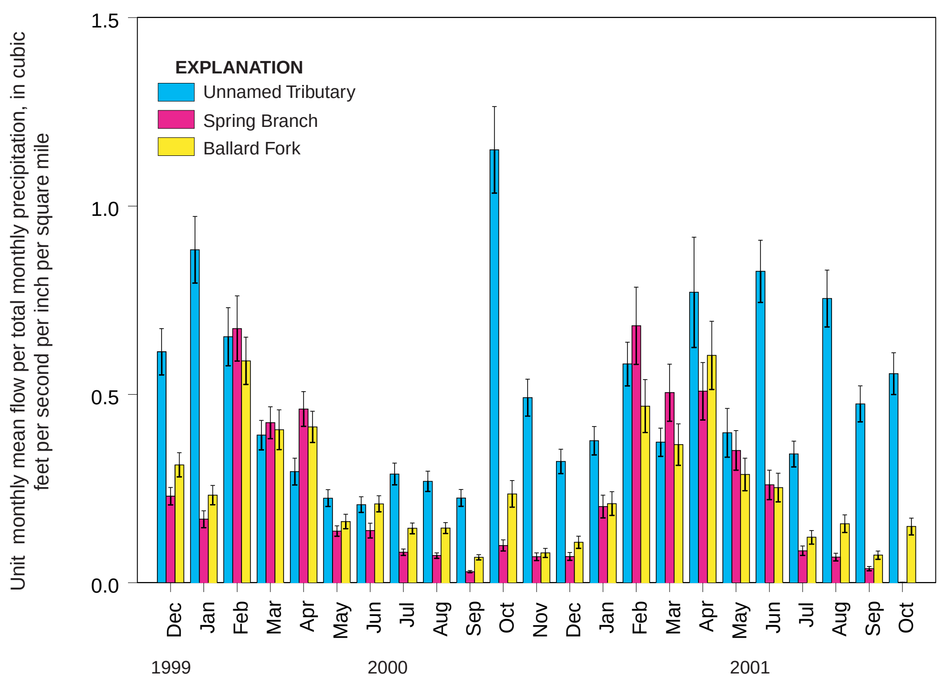

Figure 4. Unit monthly mean flow per total monthly precipitation for three sites in the Ballard Fork watershed, W.Va., 1999-2001. Only whole months are shown. Error bars represent the sum of daily-mean streamflow variance determined from estimates of data quality made by Ward and others (2001, 2002). Spring Branch had an average flow of zero during October, 2001.

Unnamed Tributary watershed was more or much more than that from the Spring Branch watershed during summer and fall months.

Conclusions: Unit daily mean flow was higher from the Unnamed Tributary, which drains a predominantly mined watershed, than from Spring Branch, which drains an unmined, forested watershed, at all flows between 5 and 95 percent duration. The relative difference was greatest at lower flows. Unit daily mean flows from Ballard Fork, which drains a watershed including both these other streams and is about 30 percent mined, were about the same as those from Spring Branch at higher flows (greater than about 15 percent duration), and were intermediate between the Unnamed Tributary and Spring Branch at lower flows. Spring Branch dried up both years of the study, and its mean flow in October 2001 was zero; the Unnamed Tributary had flow throughout the study period. Some mechanism delays some of the flow from the mined area. Storage of water in or under the valley fill is the most likely mechanism.

Total unit flow from the Unnamed Tributary was nearly twice that from Spring Branch during the two-year study period. Storage of water in the mined areas does not account for this difference, because all the flow in the Ballard Fork watershed originated as precipitation, and precipitation was the same on mined and unmined areas. Reduced evapotranspiration in the mined areas probably accounts for the difference in total flow. Evapotranspiration from mined areas was probably less than that from forested areas because most mechanisms of evapotranspiration, such as interception and transpiration, are functions of plants and plant biomass is much less in mined areas than in unmined areas. The difference in total flow and low flow between the mined and unmined areas will probably change as plant cover and biomass change on the reclaimed mines.