Mount Mansfield Stream Gages

Water Year 2016 report

U.S. Geological Survey
in cooperation with
Forest Ecosystem

Introduction

Since September 2000, the U.S. Geological Survey (USGS) has continuously operated stream gages at Ranch Brook and West Branch near Stowe, Vermont (Wemple et al., 2007). The gaging was designed as a paired watershed study, with Ranch Brook (9.6 km^2) as the forested control watershed, and West Branch (11.7 km^2) as the developed watershed. The West Branch watershed contains nearly the entire development of the four-season Stowe Mountain Resort, including ski trails and lifts, lodges, a golf course, roads, and vacation homes. In the classic paired watershed approach, monitoring is conducted prior to any development in order to quantify natural differences, but the resort was established long before this study began. However, the resort underwent a significant expansion during the course of the study, so the study design is appropriate to assess the effect of the expansion. This document is the annual report on the Mt. Mansfield gages for Water Year (WY) 2016 (October 2015 through September 2016). The report interprets the WY16 streamflows in the context of the full 16-year record. Historic and near real-time flow data are available on the USGS website (url's at end of this report).

From start up in WY2001 through WY2015, the two gages were jointly funded through a cooperative agreement between the USGS and the Vermont Monitoring Cooperative (now Forest Ecosystem Monitoring Cooperative: FEMC). Beginning in WY2016, the Lake Champlain Basin Program (LCBP) funded the USGS share. By contract, FEMC funds supported Ranch Brook and LCBP funds supported West Branch, but we report here on both gages as in the past.

The gages provide valuable information on mountain hydrology in Vermont, and how mountain landscapes respond to development and extreme events. To our knowledge these are still the only gaged watersheds at a ski resort. The gages have supported projects on snow hydrology and water quality by University of Vermont, Sterling College, Vermont ANR, and others. In particular, Beverley Wemple and students at University of Vermont have used the gages as a base for student projects and hands-on learning, and to attract additional funding for value-added research.

Water Year 2016 – another dry year

WY16 marked the third consecutive year of below average runoff. Total runoff was 15.1% less than the long-term average at Ranch Brook and 13.5% less than the long-term average at West Branch. Only four of the 16 years at Ranch Brook and three of the 16 years at West Branch had lower runoff than in WY16.

WY16 streamflow started off low following the very dry summer of 2015. After continued dry weather in October, the drought ended and November and December were rainy, as most late fall precipitation fell as rain (Figure 1). After a quiet start to the winter, with well below average snowfall (Figure 2), flows became very active in March and April, with earlier than usual snowmelt accompanied by rain-on-snow. The low snowmelt set up drying conditions and a return to below average flow in the summer (Figure 3).

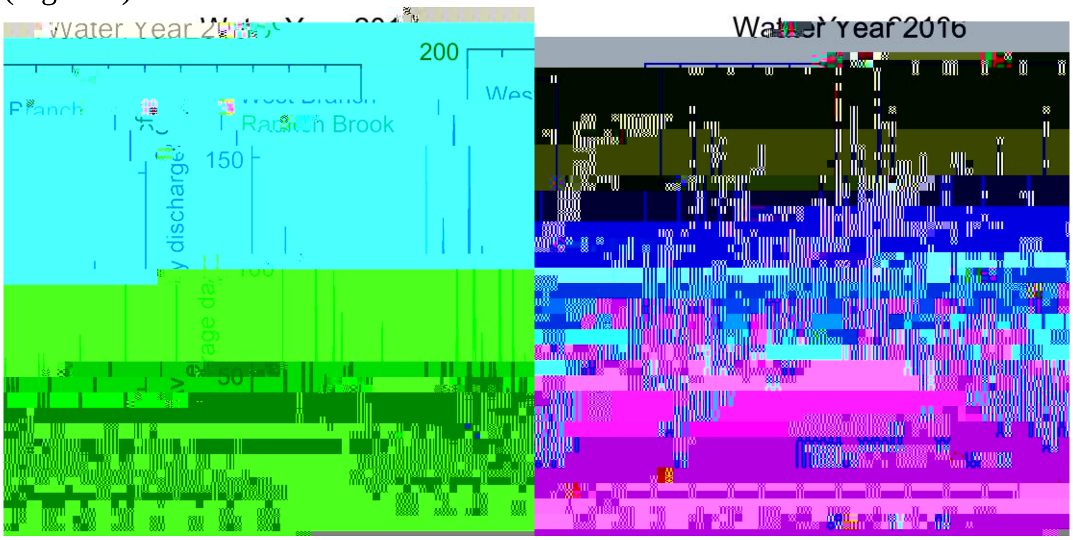

Figure 1. Streamflow at West Branch and Ranch Brook gages for Water Year 2016 (October 2015 through September 2016) in linear (left) and log (right) scales. The log scale plot highlights the higher sustained base flow levels at West Branch.

Figure 2. Snow depth during 2015-2016 winter (red line) vs, long-term average (green background). Image from: http://www.uvm.edu/skivt-l/?Page=depths.php, accessed 1/18/18.

Discharge vs. runoff

Streamflow, or discharge, is commonly reported as a volume per unit time – in the U.S., typically as cubic feet per second, or cfs (Figure 1). Throughout this report we typically refer to runoff rather than flow. Runoff is discharge divided by watershed area, and allows for direct comparison of flow in basins of different size. For example, if one basin is twice the size of another and has twice the flow, runoff would be the same. The dimensions of runoff are depth per unit time, i.e. the same as precipitation, thus runoff can be directly compared to precipitation. For example, if a watershed receives 1500 mm/yr of precipitation and has 1000 mm/yr of runoff, that means 500 mm/yr was lost to evapotranspiration plus or minus a change in the amount of water stored in the watershed, e.g. in soils.

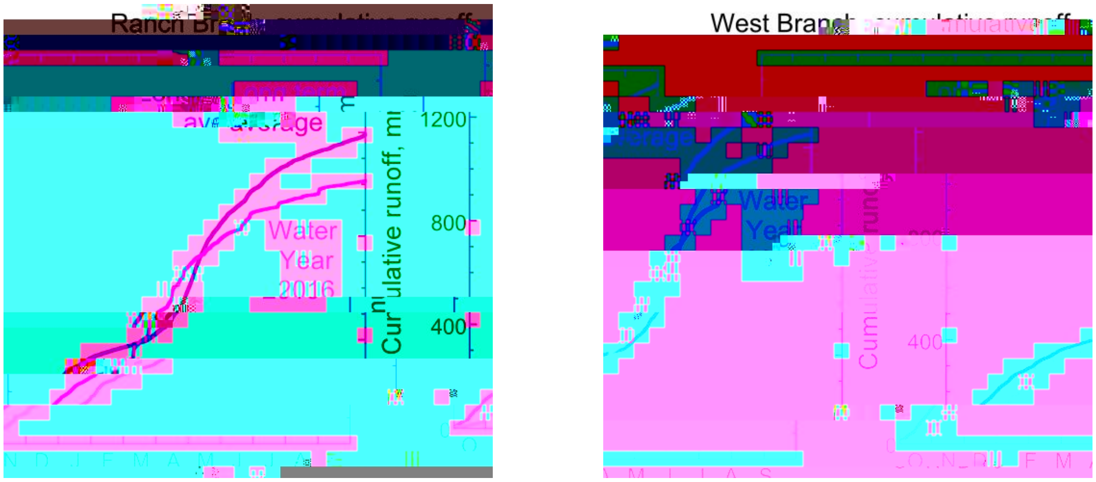

Figure 3. Cumulative runoff for Water Year 2016 (light blue lines) at Ranch Brook (left) and West Branch (right) plotted on the long-term (2001-2016) average at each site (dark blue lines).

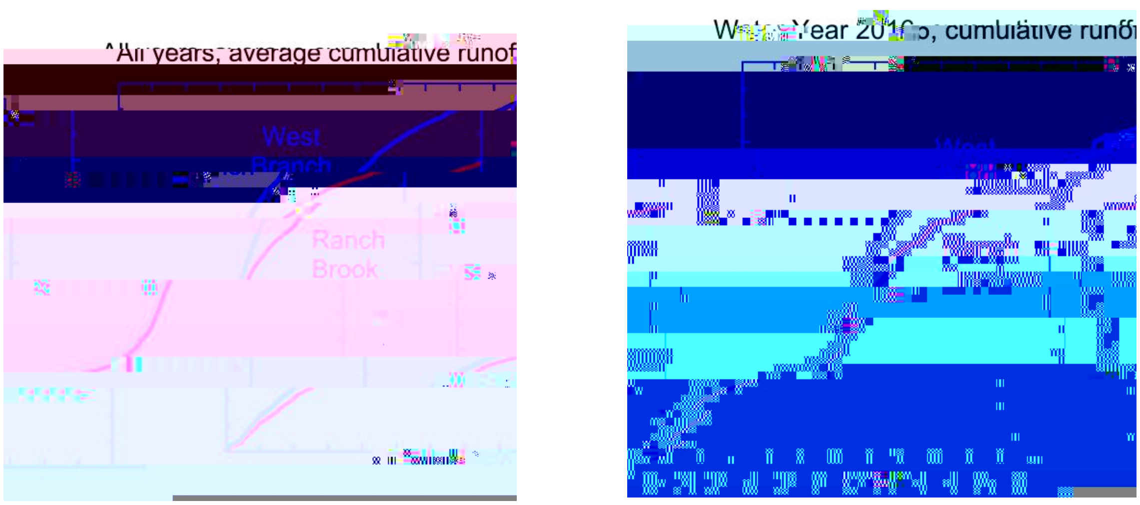

Figure 4. Average annual cumulative runoff at West Branch and Ranch Brook based on the daily averages across the 16-year record (left) and for Water Year 2016 only (right).

The unusually early snowmelt and winter rain events led to high flows in March and April (Figure 1), and these months marked the only time that the WY16 cumulative runoff curve rose above the long-term average (Figure 3). With the snowpack largely gone in April and the ensuing average spring and dry summer, the WY16 curve quickly fell below the average. Although one year should not be viewed in isolation because of the high natural interannual variability in weather and climate patterns, WY16 conforms to future climate scenarios, with a higher percentage of winter precipitation as rain, less snowpack accumulation, and an earlier snowmelt, leading to a redistribution of runoff across the annual cycle toward earlier in the year.

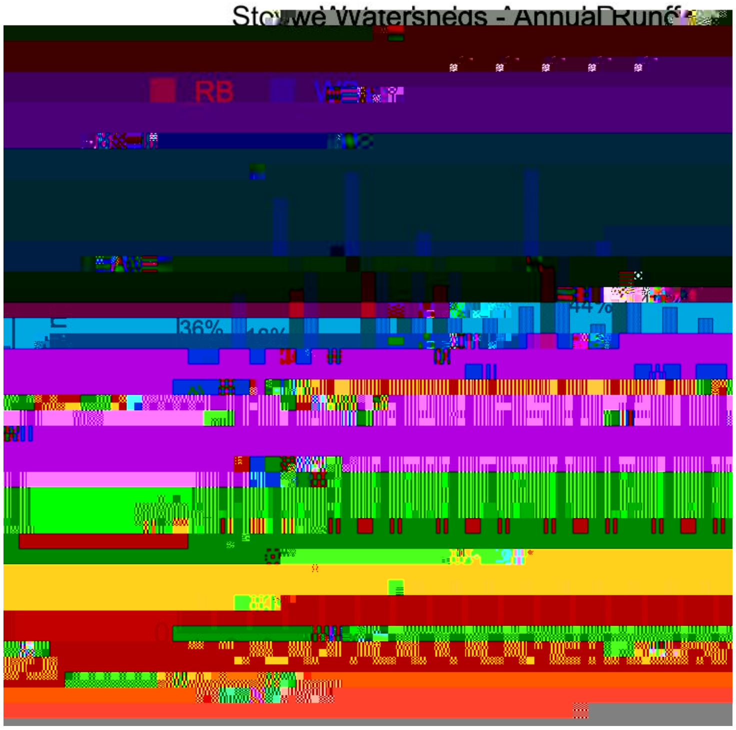

Figure 5. Annual runoff in mm at Ranch Brook (RB) and West Branch (WB) for the duration of the study though the present report year. The percentage of greater runoff at WB relative to RB is given for each year.

As noted in previous reports, West Branch has consistently yielded higher runoff (flow normalized to watershed area) than Ranch Brook (Wemple et al., 2007) (Figures 4 and 5). Over the long-term, the average difference has been 21% greater runoff at West Branch. The Water Year 2016 differential was slightly above average at 24% (Figure 5). We have repeatedly noted that greater runoff at West Branch is what we would expect from the creation of open land and development, but that the high magnitude of the differential suggests that some part of the difference may be natural. Historically, runoff from the two basins agreed quite closely until they diverged late in the snowmelt season and continued to diverge through the summer. Water withdrawals for snowmaking from West Branch (see gray box on snowmaking below) may have limited the natural difference between the two basins in fall and early winter, while that water returns to West Branch in spring as late snowmelt, accentuating the natural difference. Greater summer flow at West Branch is caused mainly by higher sustained baseflow (Figure 1). Cumulative runoff across the two basins in WY16 had a similar pattern to the long-term average, but the late-snowmelt divergence occurred about two weeks earlier.

West Branch data are accessible at
https://waterdata.usgs.gov/vt/nwis/uv?site_no=04288225
Ranch Brook data are accessible at
http://waterdata.usgs.gov/vt/nwis/uv?site_no=04288230

Role of snowmaking in hydrology

Snowmaking alters the annual streamflow pattern by removing water that was headed downstream and storing it back up on the mountain as snow. This water has a “second chance” to make it out of the basin when the snow melts, usually several months later. Stowe Mountain Resort withdraws water for snowmaking from West Branch, at a point just upstream of the USGS gage. The position of the intake upstream of our gage assures that we are not double counting the water, and no water is imported from outside the basin (as at some ski resorts); therefore we can analyze the hydrology at West Branch as a “closed system”. The effect of snowmaking is to redistribute water across the annual cycle. We measure less flow during withdrawal, and more flow during snowmelt. While

References

Wemple B, Shanley J, Denner J, Ross D, Mills K., 2007. Hydrology and water quality in two mountain basins of the northeastern US: assessing baseline conditions and effects of ski area development. Hydrological Processes 21(12):1639-1650.