USGS streamgaging and related research activity at Mount Mansfield, Vermont, for Water Year 2007 (October 2006 through September 2007)

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Water Year (WY) 2007 marks the seventh year of streamgaging by the USGS at West Branch (developed basin) and Ranch Brook (control basin) draining the east face of Mount Mansfield, Vermont. Included with this report is a file with the final daily flow compilation for WY2006 and the provisional daily flows (winter record will have major adjustments) for WY2007.

The WY2006 data can also be found on the internet. The USGS no longer publishes hard copy of its annual report, but the appropriate electronic pages for WY2006 for the 2 gages can be retrieved using the following links:

West Branch
http://wdr.water.usgs.gov/wy2006/pdfs/04288225.2006.pdf

Ranch Brook
http://wdr.water.usgs.gov/wy2006/pdfs/04288230.2006.pdf

This report focuses on WY2007, but here we give a brief summary of the first six years of gaging. As we have noted from the outset of this study, the runoff per unit area at West Branch (WB) is considerably greater than at Ranch Brook (RB). The finalized WY2006 flows verify this pattern yet again. WY2006 had the most runoff of any year to date (Table 1).

Water Year	West Branch runoff (mm)	Ranch Brook runoff (mm)	West Branch excess (%)
2001	1190	872	36.5
2002	1416	1173	20.7
2003	1132	958	18.2
2004	1812	1428	26.9
2005	1062	909	16.8
2006	1919	1614	18.9

Table 1. Runoff at West Branch and Ranch Brook near Stowe, Vermont, Water Years 2001-2006,

with percentage by which the runoff at West Branch is greater. Runoff is flow per unit area, which with appropriate conversions is expressed in millimeters (mm). Runoff in mm can then be directly compared to precipitation depth in mm (not shown). The difference is attributed primarily to evapotranspiration (ET), which is precipitation that does not run off because it is transpired by vegetation or evaporated from land surfaces to the atmosphere. Annual ET at Mt. Mansfield is estimated to average 300-500 mm.

Annual runoff during the six years ranged over nearly a factor of two within each basin. In four of the six water years the excess at WB ranged narrowly from 17 to 21%, but for two of the years the excess was considerably greater. The pattern of excess does not vary systematically with runoff amount, but may be related to seasonal timing of precipitation. We hypothesized that the development at West Branch could cause a runoff excess, but the magnitude of the discrepancy is likely too large to attribute solely to this factor. Likewise, snowmaking withdrawals (from above the gaging station) amount to less than 5% of the annual flow and cause a redistribution of the annual flow but should not appreciably change the overall amount. Thus, we still suspect that a difference in precipitation capture by the two watersheds is a big factor in the difference in runoff.

This is a particularly important time for the gaging effort because of the Stowe Mountain Resort (SMR) expansion on the Spruce Peak area. We have 3 years of pre-expansion data and now 3 years of data during the expansion. It is a bit early to assess whether we can see an effect of the outbuild on the hydrology. The situation is complex in that storm drainage from newly created impervious surfaces in the expansion area was routed to a point below our gage, necessitating a relocation of the gage in WY2004. The relocation resulted in a very minor increase in basin area, so did not affect the the ability to compare data for the 2 periods. Through Beverley Wemple's efforts we have renewed our investigation of whether enhanced precipitation in the West Branch basin is the underlying cause of this anomaly.

Beverley Wemple, Don Ross, and Leslie Morrissey and their students at UVM have used or are using the USGS gages as sampling points and background data for their research. The USGS has worked with Beverley since the start of the study to build an ongoing monitoring program for suspended sediment and major ion fluxes from the two basins. USGS collaborates on the monitoring but funding is external to VMC. Through this work Beverley and others have demonstrated chronic contamination from deicing salts at West Branch and large fluxes of salt and sediment at the start of spring melt. Beverley is the lead author on a paper for Hydrological Processes (Wemple et al., 2007) that presents data and interpretation on the first 3 years of the study (pre-expansion).

Bethany Zinni, a student of Beverley's, completed her M.S. in December 2005.

Bethany used major ion chemistry and water isotopes to differentiate hydrological flow paths in the 2 basins. We are all working on revisions for a journal article on Bethany's study. Matt Bruhn, a M.S. student of Leslie Morrissey at RSENR, is comparing E. Coli concentrations and loadings at the 2 sites, and Beverley has a M.S. student, Tiffany Larsen, funded in part by a grant from the Linthillac Foundation, who is investigating the possible precipitation discrepancy. Tiffany is also funded by a $25,000 UVM NASA-EPSCoR grant received in summer 2007, which has freed her from TA'ing so she can do research full time. Beverley recently received a new $25,000 UVM NSF-EPSCoR grant to perform hydrologic modeling of the two basins; the model will be driven largely by the USGS flow data and the UVM snow surveys.

Aside from the ongoing streamgaging in WY2007, USGS also assisted Tiffany Larsen's efforts to assess potential differences in snow accumulation and ablation in the two basins. Jamie Shanley serves on Tiffany's committee and has assisted in the design and implementation of snow surveys in 2007 and 2008. One tool we are using is ground penetrating radar mounted on a toboggan to meaasure snow depth on the ski trails. This technique holds promise for assessing how much snow is stored on the mountain on both trails with machine made snow and trails with natural snow cover. SMR supported this effort in WY2007 by assigning us a ski patrol escort for a day.

Our research team has developed a collaboration with Professors Chris Skalka and Jeff Frolik of UVM's School of Engineering. Jeff and Chris developed a sensor for continuous measurement and logging of snow water equivalent (SWE – the equivalent water depth of melted snow) and have deployed it near the Ranch Brook gage at one of Tiffany's snow measurement sites. Tiffany's periodic snow surveys will serve as "ground truth" for the sensor data and the logged SWE data will help Tiffany understand the day-to-day variation between her measured points.

On one final note, Beverley and Jamie revised and updated an article on mountain hydrology which was published in the Vermont Law Review in 2002, for inclusion as a chapter in a 2008 book, "Mountains and the Law", edited by Vermont Law School (Shanley and Wemple, in press). This is a rather general treatise but uses our results from the Mount Mansfield gages in a "case study" section.

The Mt. Mansfield gages continue to yield valuable data that can be used to assess the effect of high elevation development on water quantity and quality. They have attracted academic collaborations and have been used as a selling point in several successful proposals. The gaged watersheds also serve as an outdoor laboratory for field hydrology and snow hydrology courses offered by

UVM and Sterling College. We thank the Vermont Monitoring Cooperative for the past and present support of these stream gages, which form the core of this high-elevation research effort.

References cited:

Wemple, B., J.B. Shanley, J. Denner, D. Ross, and K. Mills, 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, 1639-1650. DOI:10.1002/hyp.6700.

Shanley J.B. and and Wemple, B., in press. Water quantity and quality in the mountain environment. Book chapter in "Mountains and the Law" edited by Vermont Law School. Ashgate Publishing Co., Ltd.