In this supplement, we provide greater details regarding 1) step-backwater modeling of the influence of dams on mean velocities in the South River, 2) the visual classification method used to determine the density of riparian trees, and 3) methods used to compute the transport intensity of high storm discharges.

Details of the Step Backwater Modeling

We computed water levels upstream of most of the dams in our study reach to determine their influence on water levels and mean water velocities. Many features of the dams and the river are not precisely known during the time when the dams were in place, and therefore computations were performed for a range of dam heights and bed elevations in the impoundments upstream of the dams. Results are illustrated below for predicted ranges of velocities and water levels for all the conditions of the simulations.

Locations of Dams

We computed water surface elevations and velocities upstream of 5 of the 8 dams illustrated in Figures 1 and 3. We did not perform computations for the Patrick Mill dam, because its location along the river could not be precisely determined. We also did not perform computations for the two dams that were only visible on the 1957 aerial photograph (these dams are located about 9 and 25 km downstream of Waynesboro), because the significance of these dams remains uncertain.

Topography and Morphology

Backwater computations require specifying 1) channel width, 2) bed elevations, and 3) a roughness coefficient. The channel width at Harriston was estimated from high resolution aerial photographs taken in 2005 (pixel resolution of 0.6 m), and a constant value of 40 m was used for all the computations. Bed elevations were determined by smoothing high resolution aerial LiDAR data for the study site (the resulting longitudinal profile of the river is presented by Rhoades et al., in press). A roughness coefficient equivalent to a Manning’s “n” value of 0.03 was used throughout. This value was obtained by calibrating a HEC-RAS model to measured stage-discharge relationships at several locations along the study reach (URS Corporation, unpublished data).

We also recognize the possibility that bed elevations just behind the dams had been increased by the accumulation of sediment. This process could substantially influence water surface elevations, particularly during higher discharges. Lacking any systematic means of estimating the extent of these deposits, we simply assumed that such deposits would have a slope of 0.0001 and an upstream extent of 640 m. Depending on the local slope of the river, this created “deposits” with maximum thicknesses ranging from 0.5 – 1.0 m just upstream of the dams. We performed computations both with and without these deposits, and we report the range of answers resulting from both conditions.
The computations ignore the potential for overbank flows, and therefore the bankfull depth or characteristics of the floodplain did not need to be specified (note that the storm transport index computed below does include overbank flows).

Determining the Discharge and Water Surface Elevation At the Dam

Backwater computations require specifying the discharge and water surface elevation at the dam (the latter value is used as a downstream boundary condition). We performed computations for a 5-year recurrence interval discharge, which is estimated to be 283 m$^3$/s at the Harriston stream gaging station (URS Corporation, unpublished data). To estimate the 5-year recurrence interval discharge at the locations of the dams, a linear interpolation scheme was used based on the location of each site (expressed in terms of the distance along the channel) between the gaging stations at Waynesboro and Harriston. This interpolation approach has been validated for a wide range of discharges (unpublished analyses reported by the U.S. Geological Survey).

To determine the water surface elevation at the dam, the dam was treated as a sharp-crested weir. This assumption provides an equation specifying the water surface elevation as a function of the discharge and channel width (French, 1985).

Results

The influence of historical dams on velocities at the 14 study sites is illustrated in Figure S1. Results are expressed as the ratio of mean velocity with the dam in place to that without the dam in place. Values are plotted as a function of the distance to the nearest dam downstream. The backwater effect of the dam reduces velocities by a factors ranging from 2.5 to 1. Velocities are reduced as far as 3 km upstream of the dams for maximum backwater conditions, and as far as about 1.5 km upstream of the dams for minimum backwater conditions.

Visual Classification of Tree Density

Hess (2007) developed a visual classification method to estimate the density of riparian trees along the South River in Virginia. Hess’ (2007) classification is based on comparing sites to representative areas where the actual tree density was measured from high resolution aerial photographs (Figure S2). The tree density classes illustrated in Figure S2 are simplified for this analysis to include densities of 0, ~1, or >3 trees per 400 square meters of the floodplain surface near the eroding banks. Estimates of tree density were applied to floodplain areas approximately 5-10 channel widths in length, and within a distance of 1 channel width measured perpendicular to the stream banks.

Computing the Storm Transport Index

The Storm Transport Index computations involve 5 different steps: 1) determining the water surface elevation from the specified daily average water discharge, 2)
computing the average boundary shear stress, 3) computing the volume of bed material in
transport during a single day’s flow, 4) summing the daily transport volumes for a given
year, and 5) dividing the total transport for a particular year by the amount of bed
material transported during a 2-year flood with a duration of 1 day.

The relationship between water depth (h) and discharge (Q) was specified using
Bray’s resistance equation for gravel-bed rivers (Chang, 1988). For a rectangular channel
with the water surface elevation below the bankfull depth of the stream (h_{bf}), this takes the form

\[ h = \left( \frac{K_s b Q_c}{aW \sqrt{gS}} \right)^{1 \over b+1.5} \]

where \( Q_c \) is the discharge in the channel, \( W \) is the channel width, \( g \) the acceleration of
gravity, \( K_s \) a roughness length, and \( a \) and \( b \) coefficients equal to 1.36 and 0.281,
respectively. For overbank flows, three equations must be solved by trial for \( h \)

\[ Q_c = \frac{aW \sqrt{gS}}{K_s b} h^{1.5+b} \]

\[ Q_f = \frac{aW_f \sqrt{gS}}{K_{sf} b} (h - h_{bf})^{1.5+b} \]

\[ Q = Q_c + Q_f \]

where \( Q \) is the total discharge, \( Q_f \) the discharge on the floodplain, \( K_{sf} \) the roughness
length of the floodplain, and \( W_f \) the width of the floodplain.

Once the water depth was determined, the boundary shear stress, \( \tau \), was computed
by assuming steady uniform flow in a “wide” channel

\[ \tau = \rho g h S \]

where \( \rho \) is the density of water. The boundary shear stress is then used to compute the
bed material transport rate using the Meyer-Peter-Muller equation:

\[ q_s = 8(\tau_s - \tau_{**})^{1.5} \]

where the \( \tau_s \), the Shields parameter, is given by

\[ \tau_s = \frac{\tau}{(\rho_s - \rho) g D_s} \]
and $\tau_c$ is the Shields parameter at incipient sediment motion. $D_s$ is the grain diameter, and $\rho_s$ is the density of the sediment. $q^*$ is the Einstein transport parameter, defined by

$$q_s = \frac{q^*}{(3 - 1)gD_s^{1/2}}$$

where $q_s$ is the volumetric bed material transport rate per unit channel width.

Parameter values listed in Table DR1 were used for the computations. The bankfull depth of 2.5 m is higher than the average value of 1.5 m described in the study area section of the main paper. The value listed in Table DR1 was determined from survey data near the gaging station at Harriston; it is appropriate for this reach, where the storm transport index is computed.
Figure DR1. The ratio of predicted mean velocity without historical dams in place to predicted mean velocity with historical dams in place for the study sites. Results are plotted as a function of the distance to the nearest dam downstream. A range of values is given for each site, depending on the influence of varying dam height and extent of sediment fill upstream of the dam. An envelope of maximum and minimum backwater effects encompasses the data. Diamond-shaped symbols indicate velocity ratios equal to one.

Figure DR2. Illustration of the tree density classes defined by Hess (2007). The aerial photographs illustrate (from top to bottom) areas of (a) low, 1-2 trees/400m$^2$, (b) medium, 3-4 trees/400 m$^2$, and (c) high, greater than 5 trees/400m$^2$, tree densities along South River (the category of “0” trees, though part of Hess’ (2007) classification, is not shown).
Figure DR1
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