AN ESTIMATION OF WATERSHED PRIMARY PRODUCTIVITY USING JUMP DISCONTINUITIES IN WATER FLOW RECORDS

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INTRODUCTION:

Casual observations show that river water levels jump during October, concurrent with the seasonal fall of leaves. On the West Branch of the Westfield River (Western Massachusetts, background figure), this jump is approximately 0.5 m. It is likely that this jump is a direct result of trees and other plants stopping photosynthesis. As trees become less productive (less photosynthesis) they use less water for respiration and transpiration (Figure 1). This increases runoff and infiltration, and hence river base flow. In this research we show the existence of this jump in the Westfield River base flow and quantify the amount of water being used by the West Branch watershed's transpiration.

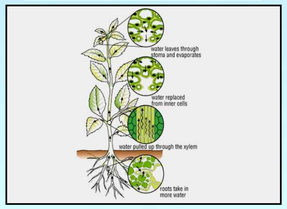

FIGURE 1. Transpiration is water's path through a plant.

This consumption can be expressed in an amount of water per unit area. The rates of transpiration and amount of water plants absorb varies from season to season based on the amount of sunlight, photo period, temperature, and the saturation of the soil. Research has shown that the amount of water used during forest transpiration in the United States ranges from 438 gallons/acre per day to 2191 gallons/acre per day. These rates take into account several different variables including species of plants/trees, sizes of plants/trees, density of vegetation, precipitation, and temperature (Vose 2003).

METHODS:

1. Obtain USGS river flow data from the West Branch Westfield river gauging station (Figure 2). The raw data obtained represent average daily flow for a 72 year period, approximately 25,000 observations (Figure 3).

FIGURE 2. Sample site for West Branch Gauging Station (Westfield River).

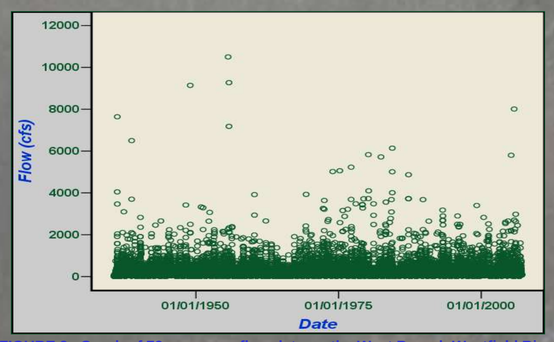

FIGURE 3. Graph of 72 years raw flow data on the West Branch Westfield River

2. Next we aggregated the data by taking the median reading for each day of the year. Using the median allowed us to reduce the effects of outliers which distort the average of these rates. These high flow outliers are the results of storm events (Figure 4). This left us with 366 observations.

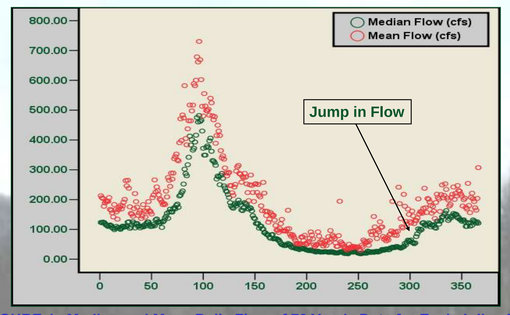

FIGURE 4. Median and Mean Daily Flow of 72 Year's Data for Each Julian Day

3. Next we calculated the difference in median flow from day to day allowing us to view the dynamic behavior of flow as opposed to the actual flow (Figure 5). The hypothesized jump would show up as a unusually large difference.

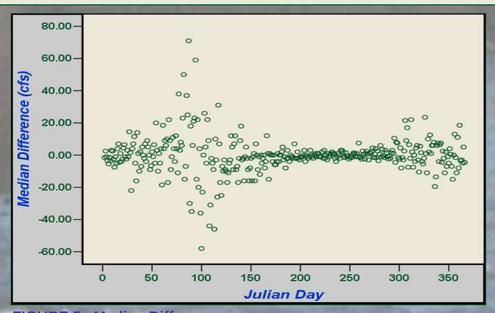

FIGURE 5. Median Difference.

4. Careful analysis of Figures 4 & 5 shows that a jump exists during the hypothesized time period, but the jump is not distinct and its existence is subjective. The data contained a lot of noise. To reduce this noise we used a centered moving average incorporating the surrounding 15 observations (Figure 6). This moving average graph visually emphasizes the jump.

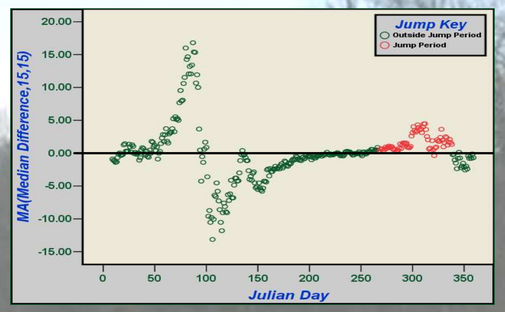

FIGURE 6. Smoothed Median Daily Flow Difference Showing Jump Discontinuity

5. Using a T-test we showed that the pre-jump and jump periods were statistically significantly different, i.e. the hypothesized jump discontinuity exists and can be quantified. To do this we had to chose pre-jump and jump periods of at least 30 days to avoid testing for normality.
   - Pre-Jump: Julian Days 268-299 (9/24-10/25)
   - Jump: Julian Days 300-330 (10/26-11/25)

6. Next we calculated the total amount of change and converted it into a total volume per day during the jump period. This volume was 8,106,912 cubic feet per day.

7. By delineating the sub-watershed and finding its area, an average volume per day can be assigned per unit area within the sub-watershed (Figure 7). This value was 1018.5 gallons/acre per day.

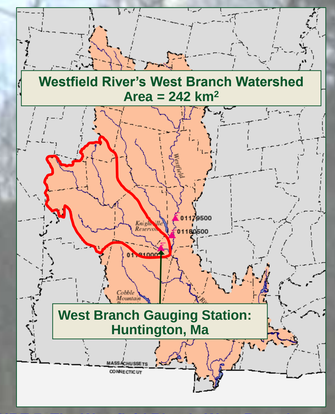

FIGURE 7. The Westfield River's West Branch watershed.

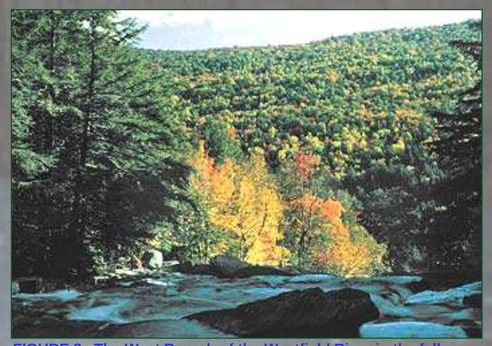

FIGURE 8. The West Branch of the Westfield River in the fall.

REFERENCES:

•Vose, J.M., G.J. Harvey, K.J. Elliot, and B.D. Clinton "Measuring and Modeling Tree and Stand Level Transpiration". *Phytoremediation: Transformation and Control of Contaminants* (2003).
•http://media.allrefer.com/s4/l/p0002630-transpiration.gifm
•www.usgs.gov

RESULTS AND CONCLUSIONS:

Based on the methods implemented in this study we conclude that there exists a jump in flow which concurs with the seasonal fall of leaves. Furthermore, we quantified this jump and determined that it would take an increase of 1018.5 gals/acre per day throughout the 39 day jump period to cause this increase in river base flow. Research has shown that amounts of water used in transpiration range from 438 gals/acre per day to 2191 gals/acre per day. Our calculations agree well with these values reported in the literature. In conclusion, this technique allows one to estimate transpiration for any watershed where the primary vegetation is deciduous and sufficient flow records exist.

FUTURE PLANS:

Future plans for this research lay in a more biological framework. There is a definite relationship between the primary productivity of plants and transpiration. Therefore we hypothesize that it is possible to use our technique to estimate the primary productivity of any given watershed.