Effects of watershed land use and geomorphology on stream baseflows in the southern Blue Ridge Mountains

Katie Price
U.S. Environmental Protection Agency
Office of Research and Development, Ecosystems Research Division (Athens, GA)

C. Rhett Jackson
The University of Georgia, Warnell School of Forestry and Natural Resources

Albert J. Parker
The University of Georgia, Department of Geography

John Dowd
The University of Georgia, Department of Geology

Trond Reitan
The University of Oslo, Department of Biology

Mike Cyterski
U.S. Environmental Protection Agency
Office of Research and Development, Ecosystems Research Division (Athens, GA)

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Presentation Outline

1. Introduction to baseflow
2. Motivation for this study
3. Research objectives
4. Study area
5. Methods of site selection, discharge measurement, and statistical analysis
6. Results
7. Discussion of implications
8. Conclusions

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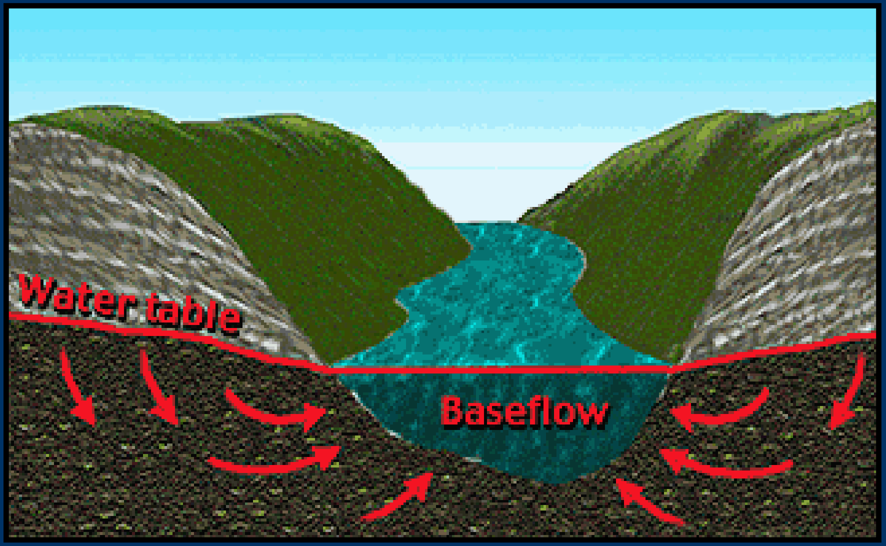
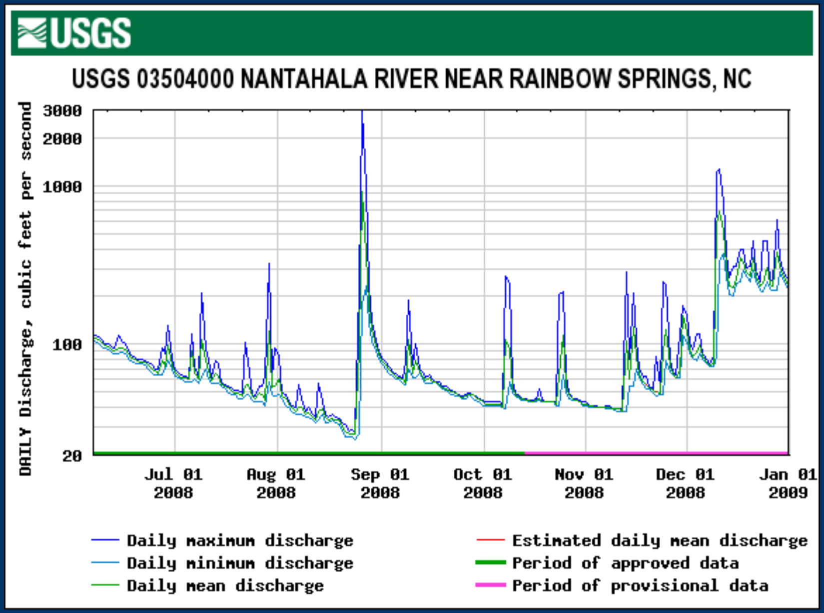
Baseflow refers to streamflow sustained between precipitation and snowmelt events, contributed from storage reservoirs such as bedrock, saprolite, alluvium, or soil.





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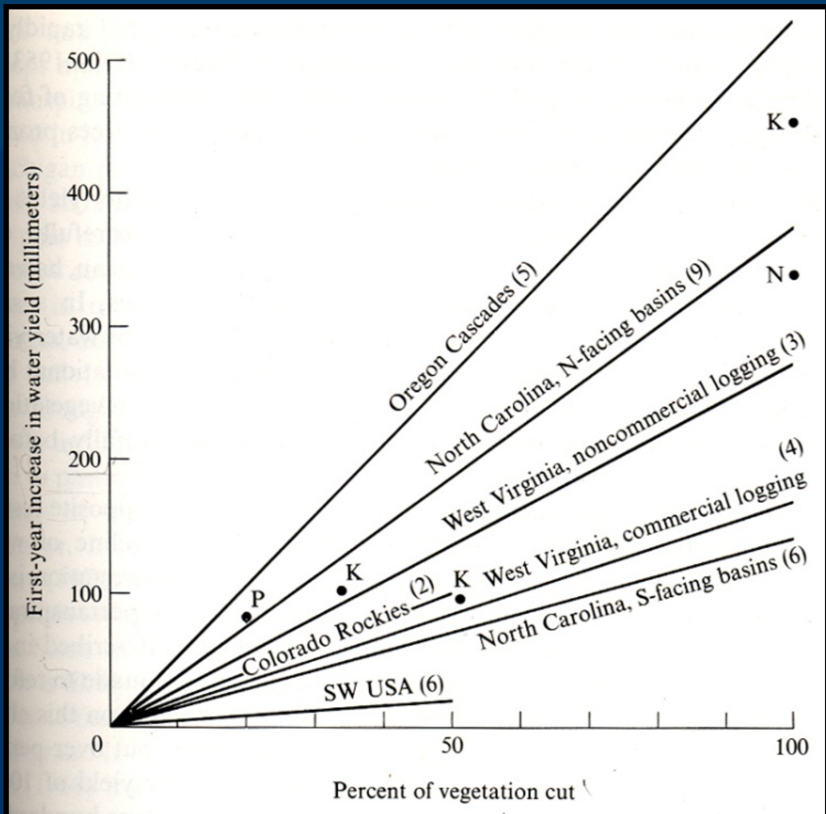

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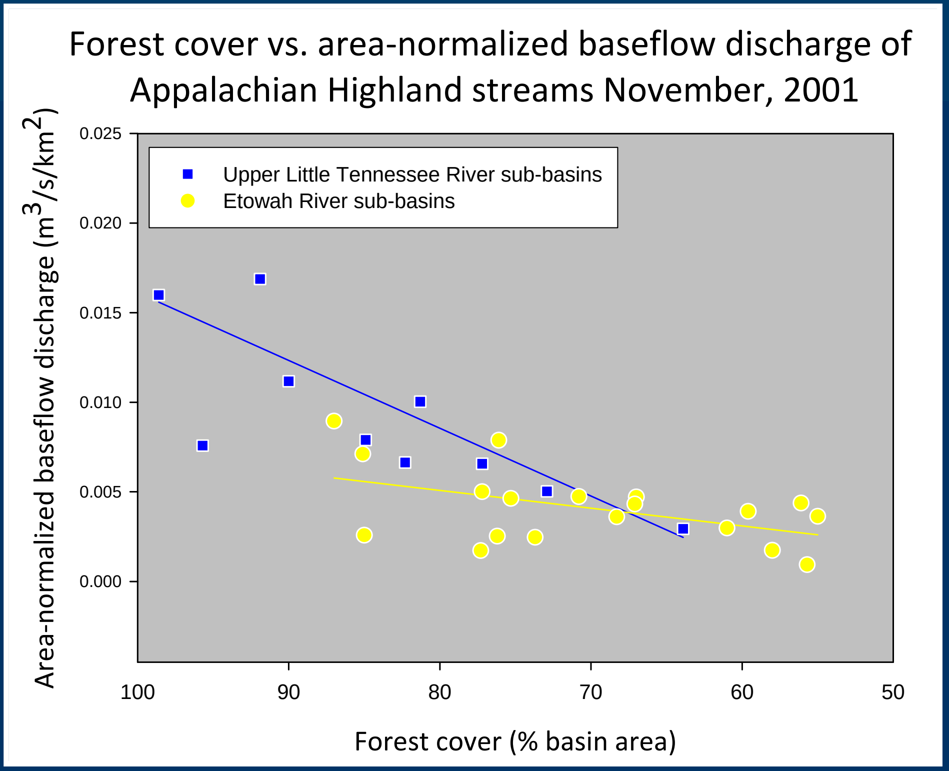

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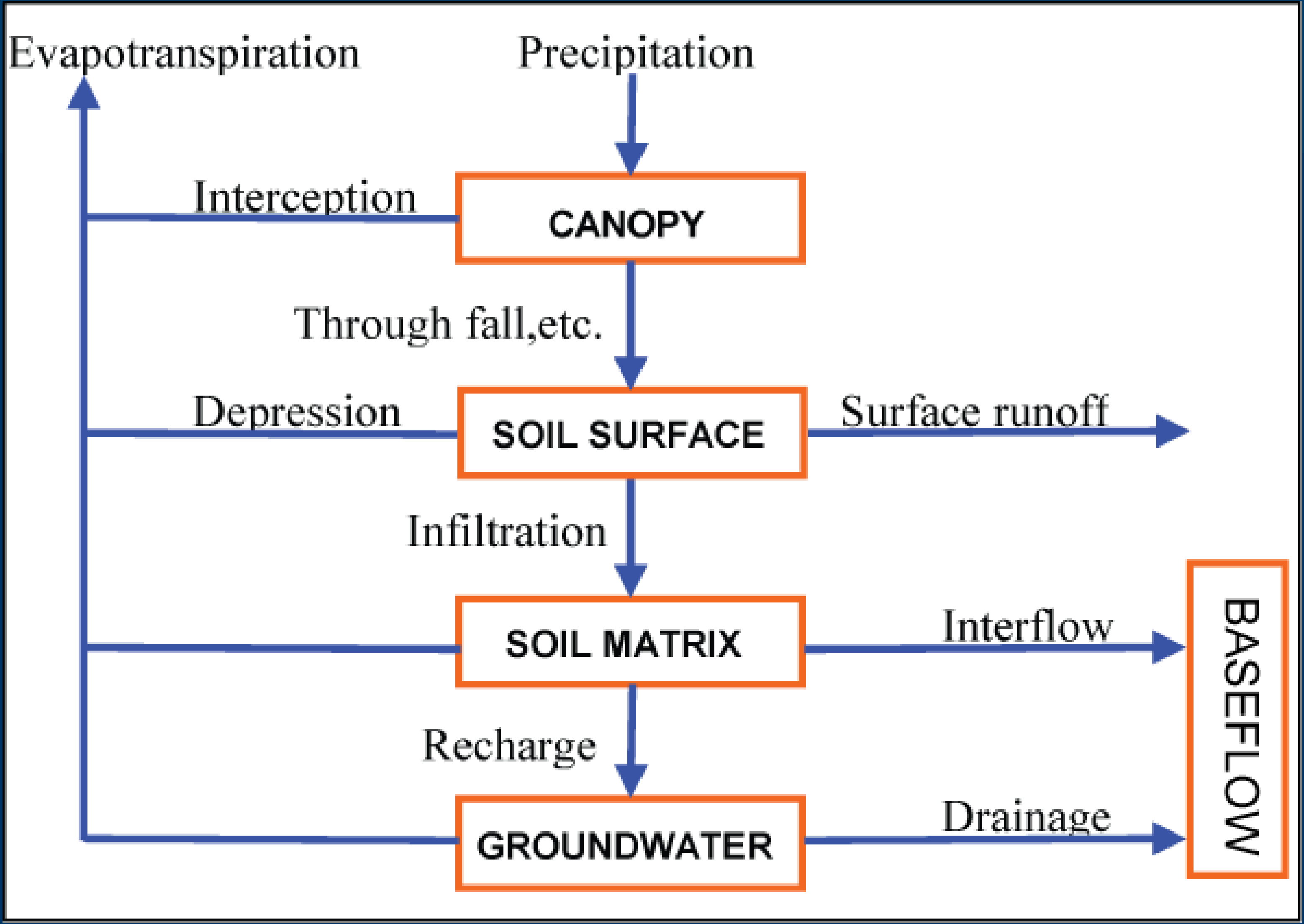

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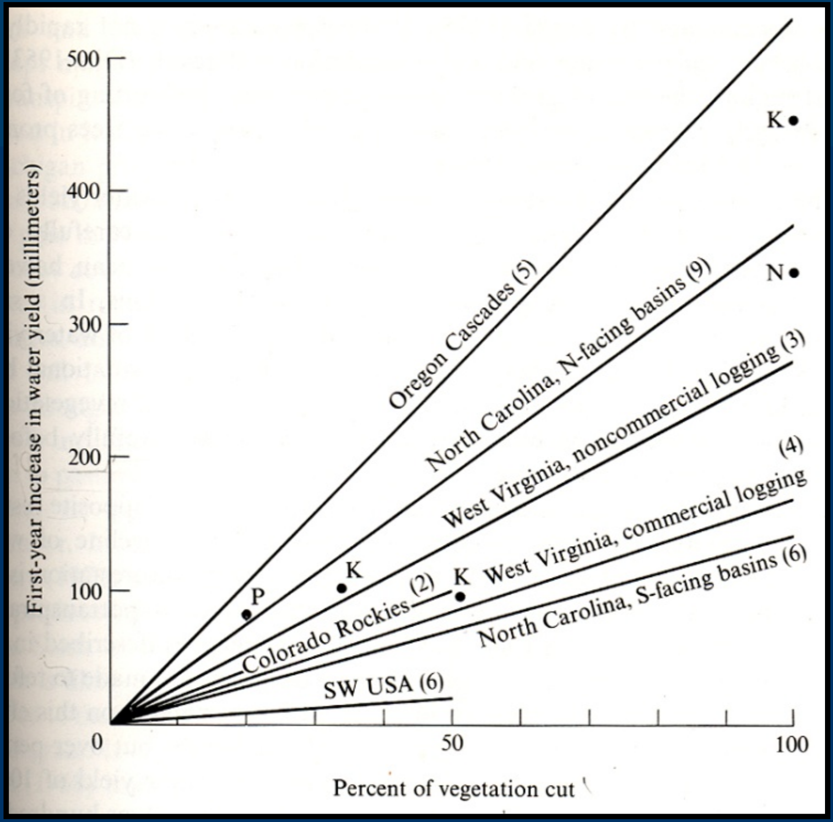

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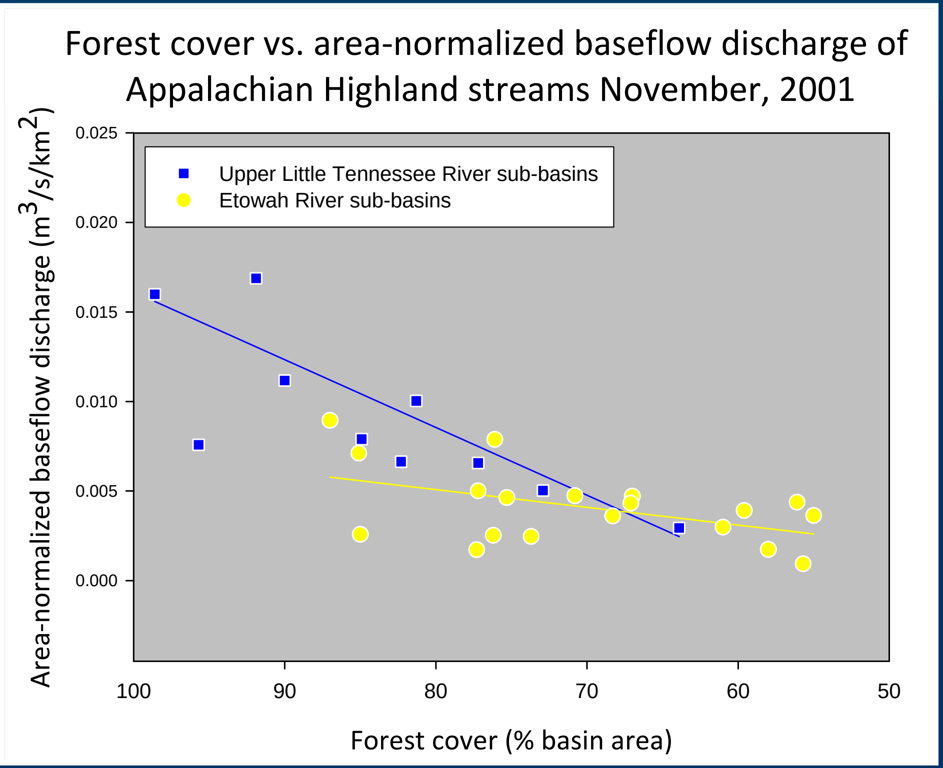

Objectives

Empirical analyses of the relationship between watershed characteristics and baseflow:

1. To determine the relative influences of watershed geomorphology and land use on baseflows in the southern Blue Ridge Mountains

2. To determine whether watershed forest cover is associated with higher or lower baseflows

Lake Fontana
Sylva
Tuckasegee R.
Nantahala R.
Franklin
Little Tennessee R.
NC
GA
0 2.5 5 10 Km

Asheville
NORTH CAROLINA
Atlanta
SOUTH CAROLINA
GEORGIA

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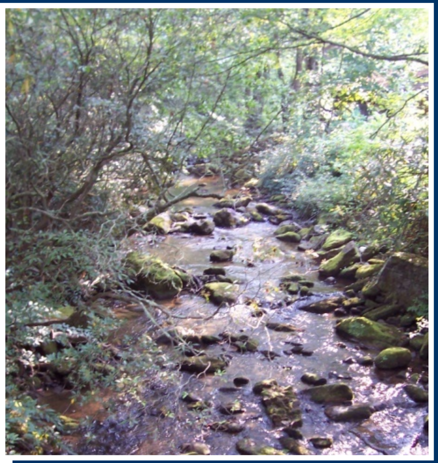
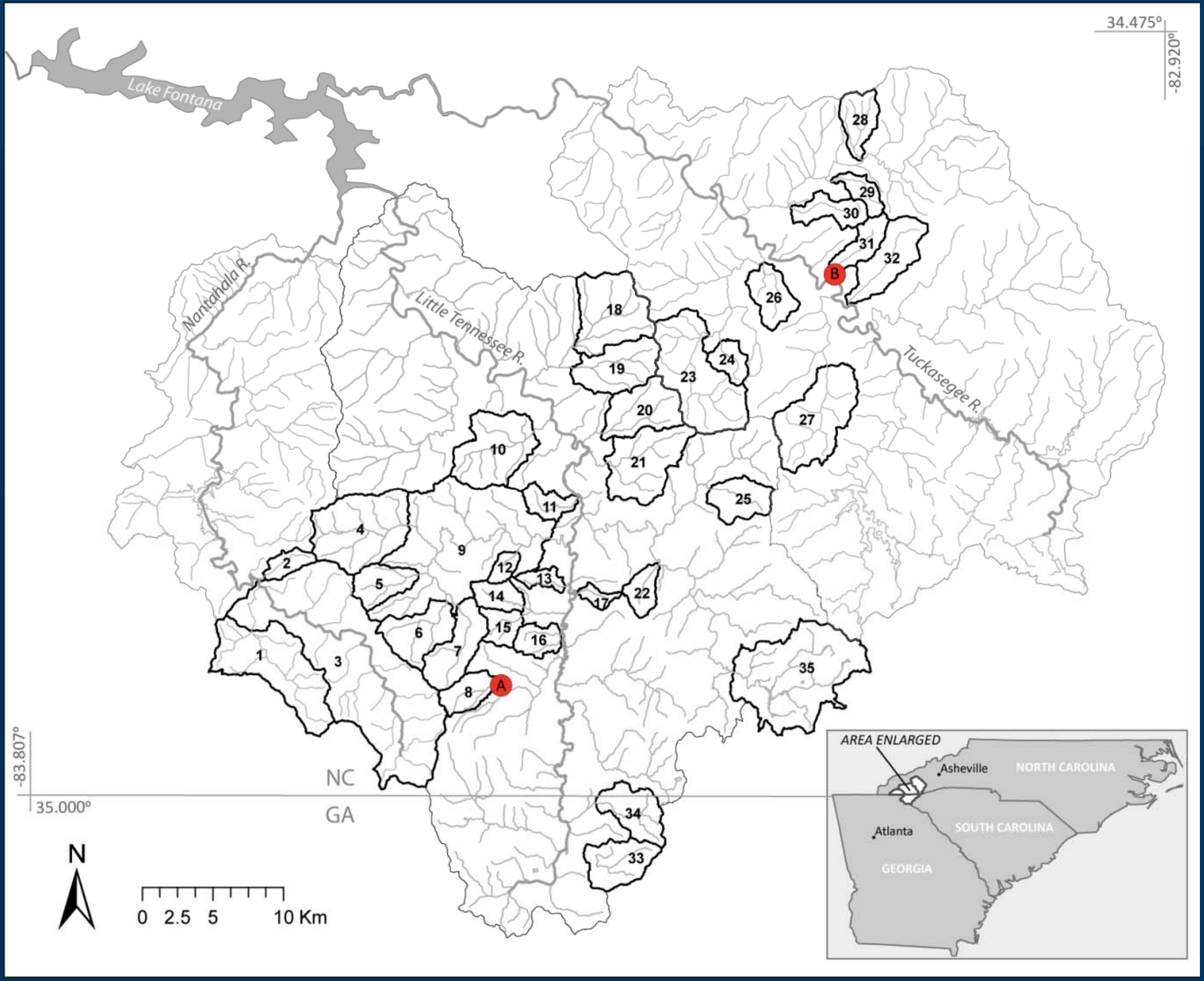
Study Area



Methods: Site selection



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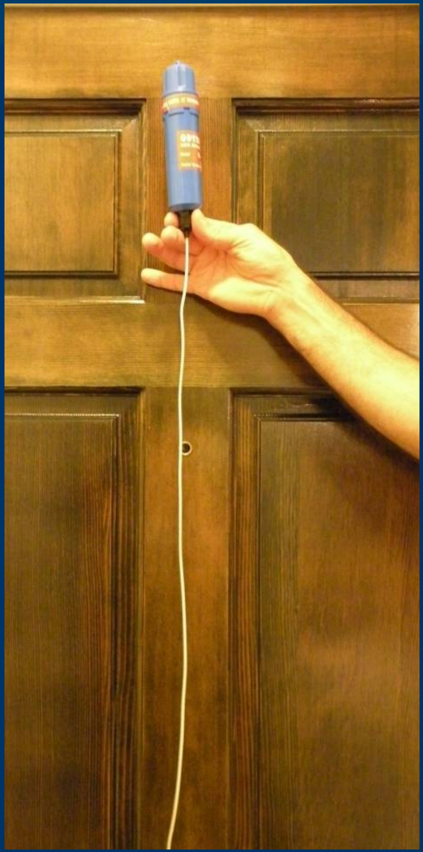
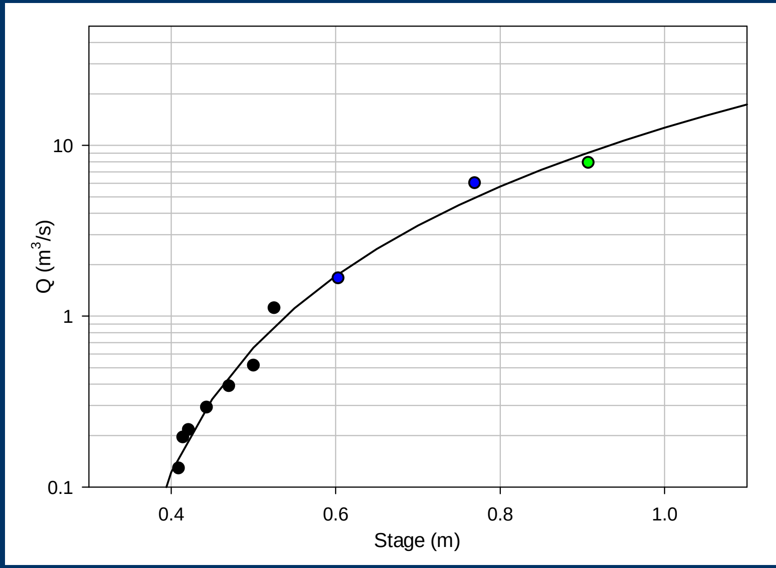
Water level monitoring



Water levels were converted to stream discharges based on 10+ stage/discharge measurements per stream



Bayesian power-law curve fitting program:

http://folk.uio.no/trondr/hydrasub/ratingcurve.html

Reitan and Petersen-Overleir (2008): *Stochastic Environmental Research and Risk Assessment* 22(3)

Baseflow Quantification

Baseflow metrics were calculated for 3 subsets of the monitoring period:

1. Low Flow Season 2007 (August 5 to November 12)
2. Low Flow Season 2008 (August 5 to November 12)
3. Water Year 2008 (October 1, 2007 to September 30, 2008)

For each of these three periods, 4 baseflow metrics were calculated:

1. **1-percentile flow (Q_{99})**
2. **1-day minimum flow (Q_{min-1})**
3. **7-day minimum flow (Q_{min-7})**
4. **Baseflow Index (BFI)**

Watershed characterization: Selection of explanatory variables

66 original variables:

Basin topography (15)

Basin morphometry (13)

Aspect (6)

Slope (11)

Channel network morphometry (7)

Soil and bedrock (7)

Land use (7)

→ Simple correlation analysis → Principal components analysis →

Reduced to 15:

- Forest cover (%)
- Median elevation
- Hypsometric index
- Basin elongation
- South-facing slopes (% area)
- Slope standard deviation
- Area with slope < 2%
- Bifurcation ratio
- Drainage density
- % stream length as 1^{st} order
- % alluvium
- % colluvium
- % clay
- Precipitation
- Area

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Statistical analyses

• Backward stepwise regression was used to identify the best model for each baseflow metric (4), for each time period (3), resulting in a total of 12 models.

• Cluster analysis was used to distinguish more- and less- forested watersheds. Baseflow metrics of these groups were compared using t-tests.

• Precipitation totals for each watershed were determined by using ordinary Kriging to interpolate point data available for 35 regional stations.

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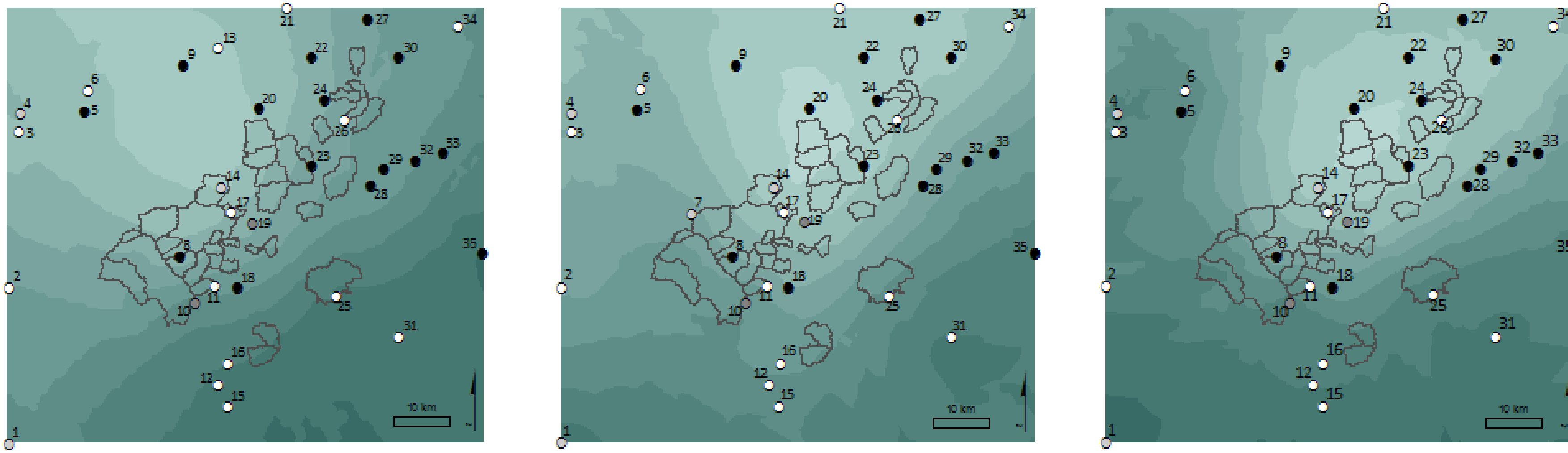
Results: Precipitation Interpolation



Total Precipitation (mm)
Low Flow Period 2007

141 - 160	239 - 258
160 - 180	258 - 278
180 - 200	278 - 298
200 - 219	298 - 317
219 - 239	

Total Precipitation (mm)
Low Flow Period 2008

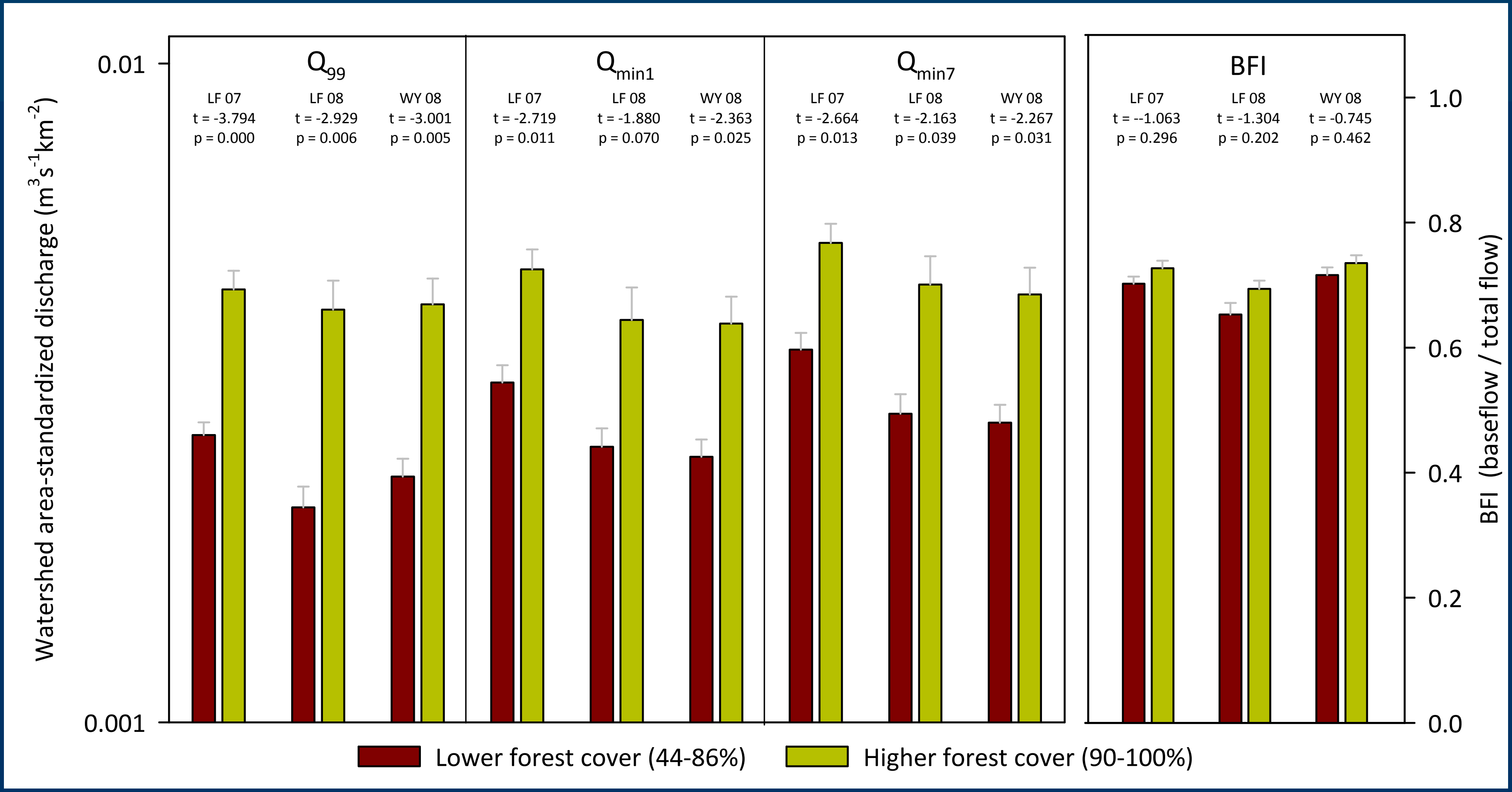
128 - 157	274 - 303
157 - 187	303 - 332
187 - 216	332 - 361
216 - 245	361 - 390
245 - 274	

Total Precipitation (mm)
Water Year 2008

756 - 854	1,134 - 1,199
854 - 940	1,199 - 1,273
940 - 1,014	1,273 - 1,358
1,014 - 1,078	1,358 - 1,457
1,078 - 1,134	1,457 - 1,570

Precipitation Gages: Coweeta LTER IFLOWS NCDC State Climate Office of North Carolina Study watersheds

Results: Effects of Watershed Forest Cover on Baseflow



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Results: Effects of Watershed Forest Cover on Baseflow

		% +/-			
		1	2	3	4
Forest (%) Difference		**(6.0)**	**(12.6)**	**(15.5)**	**(24.1)**
Mean	LF07	-	-	-	+19
	LF08	-3	-13	+25	+59
	WY08	+60	+32	-	+20
Q_{99}	LF07	-	.	-	+18
	LF08	+36	+47	+132	+78
	WY08	+10	+49	-	+83
Q_{min1}	LF07	-	-	-	+13
	LF08	+25	+26	+78	+76
	WY08	+7	+27	-	+77
Q_{min7}	LF07	-	-	-	+12
	LF08	+41	+38	+74	+72
	WY08	+31	+38	-	+72
BFI	LF07				+23
	LF08	-14	-13	+4	+40
	WY08	-7	+10		+11

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Results: Multiple Regression Analysis

	Time Pd.	Total DF	Adj. R^2	R^2	AICc	AIC	F (p)	Independent Variables	t (p)
Q_{99}	LF07	29	0.56	0.65	-76.2	-83.1	7.09 (<0.001)	Drainage Density	-2.94 (0.007)
								Slope Std. Dev.	2.45 (0.022)
								Colluvium	2.12 (0.045)
								Bifurcation Ratio	1.92 (0.068)
								First Order	-1.84 (0.078)
								Slope < 2%	-1.79 (0.087)
Q_{99}	LF08	31	0.32	0.36	-54.5	-56.0	8.27 (0.001)	Precipitation	3.35 (0.002)
								Slope < 2%	-2.35 (0.026)
Q_{99}	WY08	31	0.26	0.33	-55.6	-57.9	4.57 (0.010)	Precipitation	2.53 (0.017)
								Forest	2.46 (0.020)
								Clay	1.62 (0.116)
Q_{min1}	LF07	29	0.46	0.54	-74.0	-77.7	7.24 (<0.001)	Slope Std. Dev.	2.79 (0.010)
								Drainage Density	-2.71 (0.012)
								Colluvium	2.31 (0.029)
								First Order	-2.25 (0.034)
Q_{min1}	LF08	31	0.12	0.15	-26.3	-27.1	5.27 (0.029)	Drainage Density	-2.30 (0.029)
Q_{min1}	WY08	31	0.59	0.65	-63.1	-67.8	9.73 (<0.001)	Slope Std. Dev.	4.23 (<0.001)
								South-Facing Slopes	3.79 (<0.001)
								Alluvium	-3.39 (<0.001)
								Clay	3.04 (0.005)
								Precipitation	2.96 (0.006)
Q_{min7}	LF07	29	0.47	0.54	-80.0	-83.6	7.46(<0.001)	Slope Std. Dev.	2.92 (0.007)
								Drainage Density	-2.61 (0.015)
								Colluvium	2.25 (0.021)
								First Order	-1.99 (0.057)
Q_{min7}	LF08	31	0.29	0.36	-55.8	-58.1	5.19 (0.006)	Drainage Density	-2.40 (0.023)
								Colluvium	1.90 (0.067)
								Precipitation	1.69 (0.103)
Q_{min7}	WY08	31	0.28	0.35	-56.4	-58.7	5.08 (0.006)	Drainage Density	-2.64 (0.014)
								Slope Std. Dev.	2.29 (0.030)
								Precipitation	1.74 (0.093)
BFI	LF07	29	0.81	0.85	-154.1	-160.9	21.41 (<0.001)	Alluvium	-7.71 (<0.001)
								Clay	6.80 (<0.001)
								Area	6.74 (<0.001)
								Median Elev.	-4.84 (<0.001)
								Bifurcation Ratio	2.60 (0.018)
								Precipitation	-2.06 (0.051)
BFI	LF08	31	0.33	0.40	-115.3	-117.6	6.11 (0.002)	Precipitation	-3.25 (0.003)
								Area	3.04 (0.005)
								Drainage Density	-1.95 (0.061)
BFI	WY08	31	0.33	0.42	-143.1	-146.5	4.86 (0.004)	Area	3.42 (0.002)
								Alluvium	-3.21 (0.003)
								Clay	3.14 (0.004)
								Median Elevation	-1.65 (0.111)

Results: Multiple Regression Analysis

66 original variables:

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Basin morphometry (13)

Aspect (6)

Slope (11)

Channel network morphometry (7)

Soil and bedrock (7)

Land use (7)

→ Simple correlation analysis → Principal components analysis →

1. Forest cover (%)
2. Median elevation
3. Hypsometric index
4. Basin elongation
5. South-facing slopes (% area)
6. Slope standard deviation
7. Area with slope < 2%
8. Bifurcation ratio
9. **Drainage density**
10. % stream length as 1st order
11. % alluvium
12. % colluvium
13. % clay
14. **Precipitation**
15. Area

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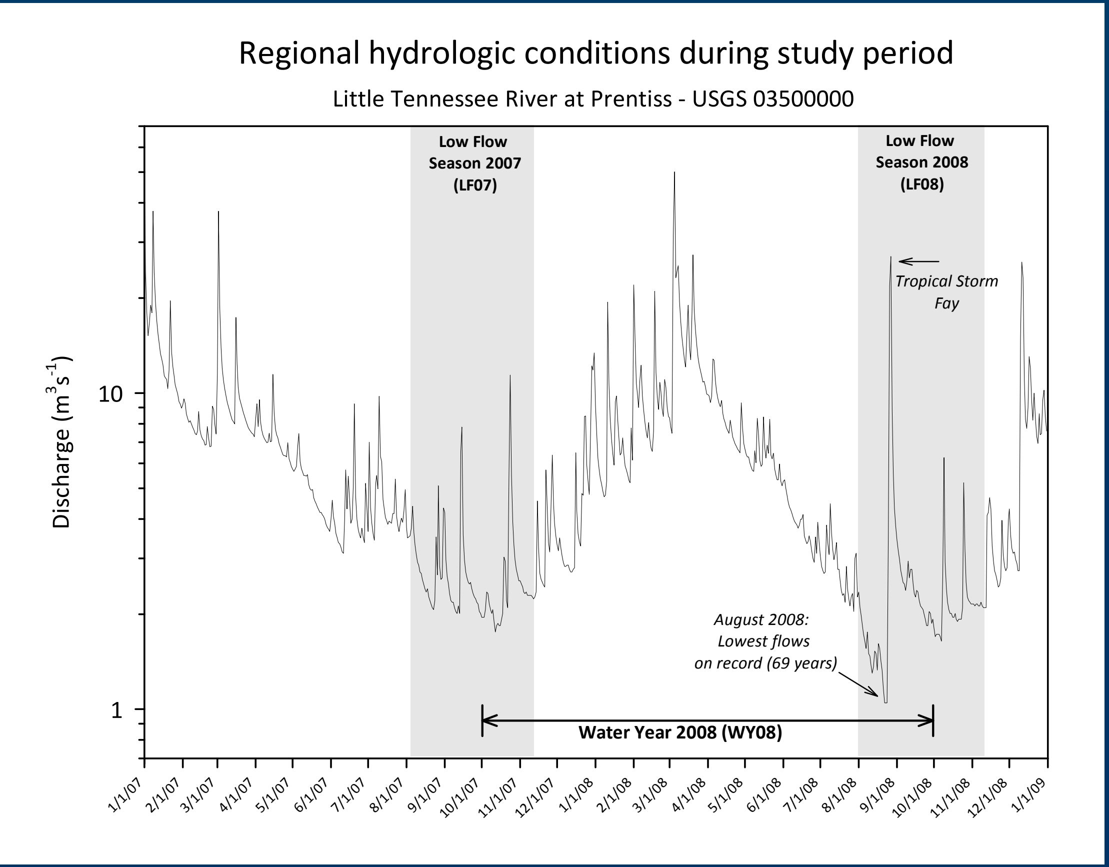

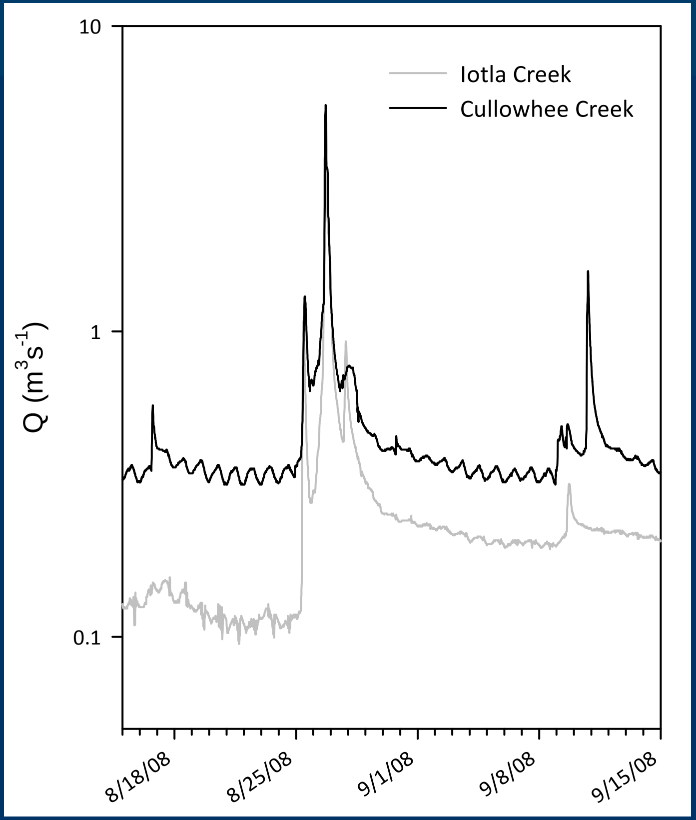

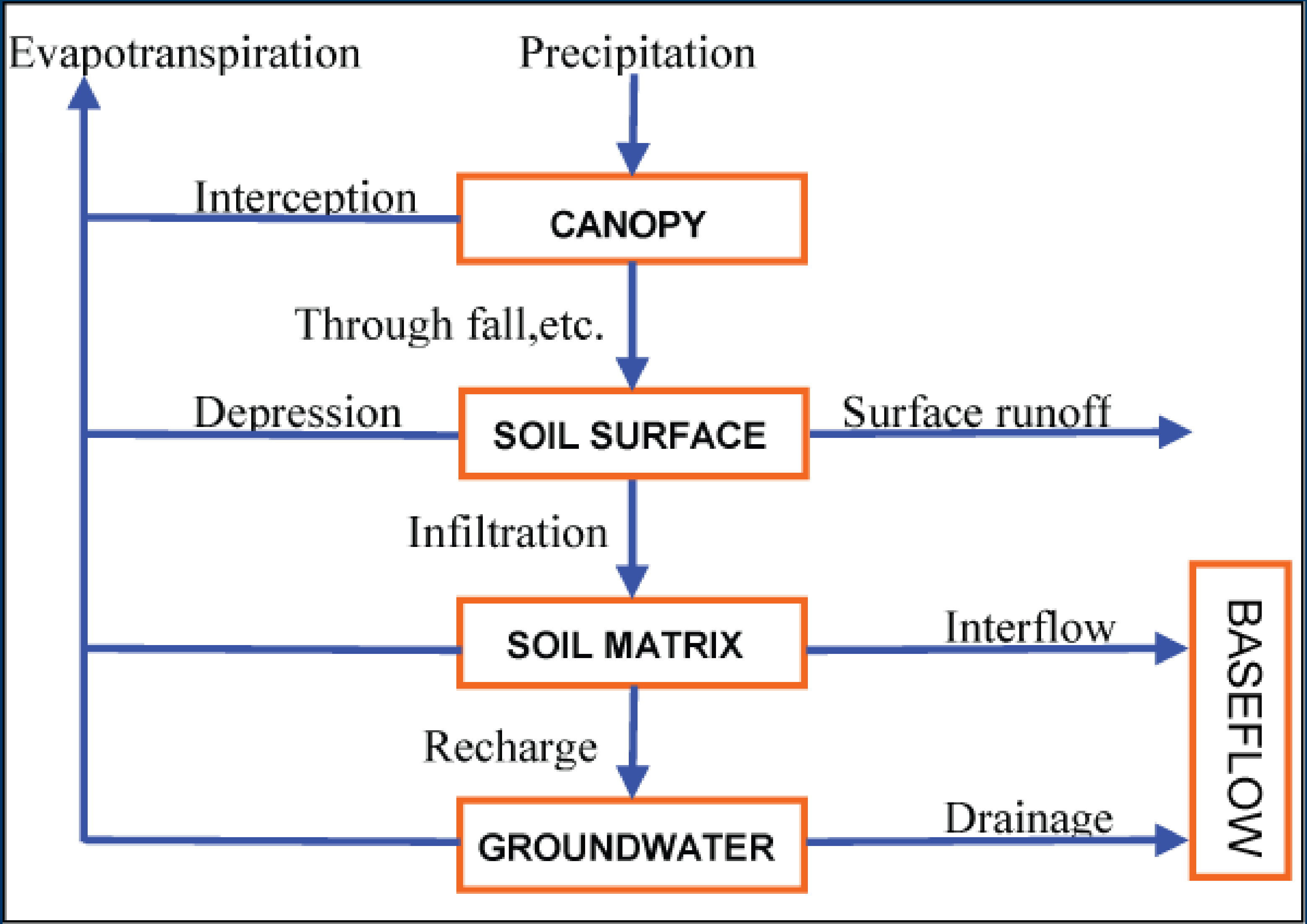

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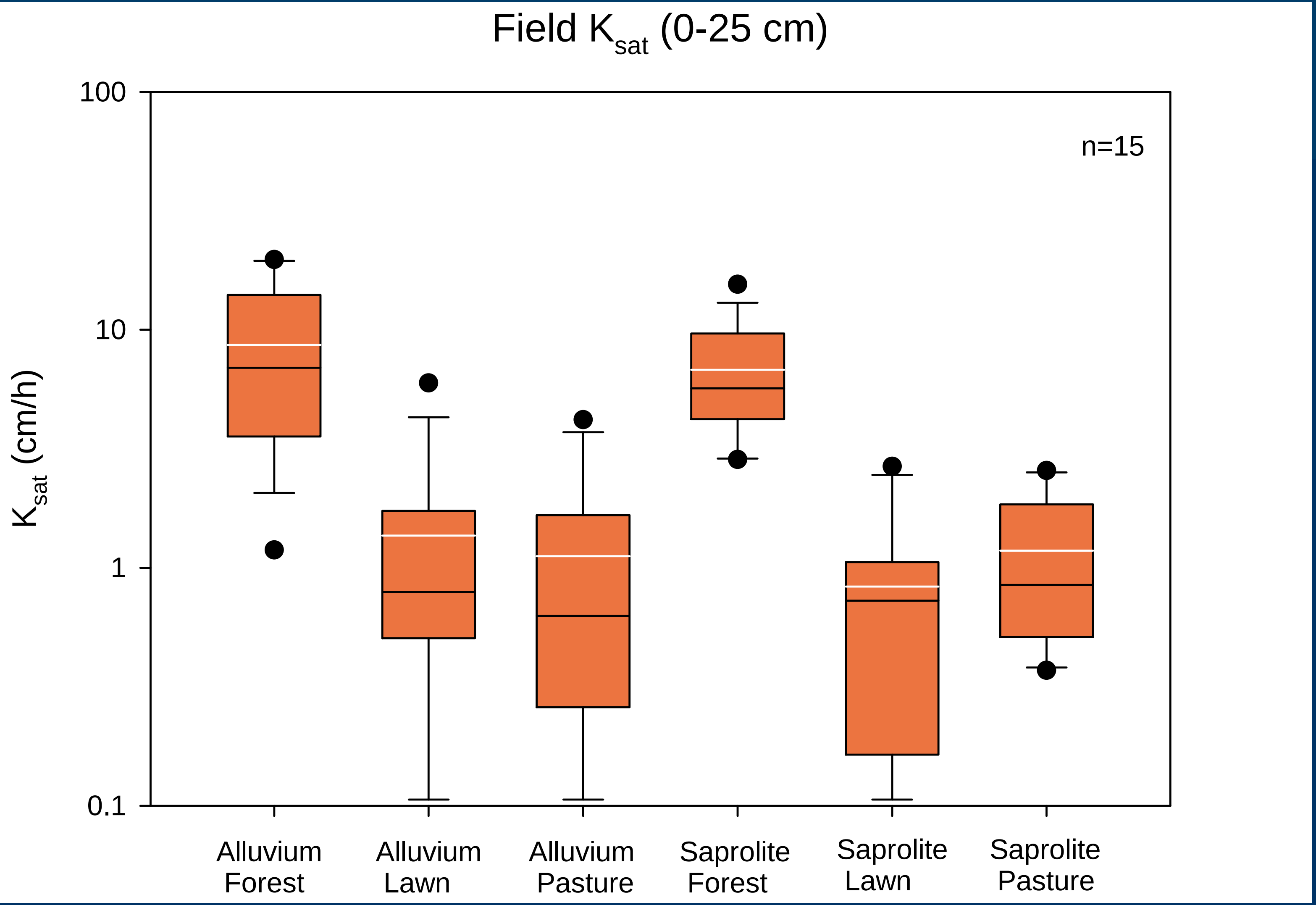
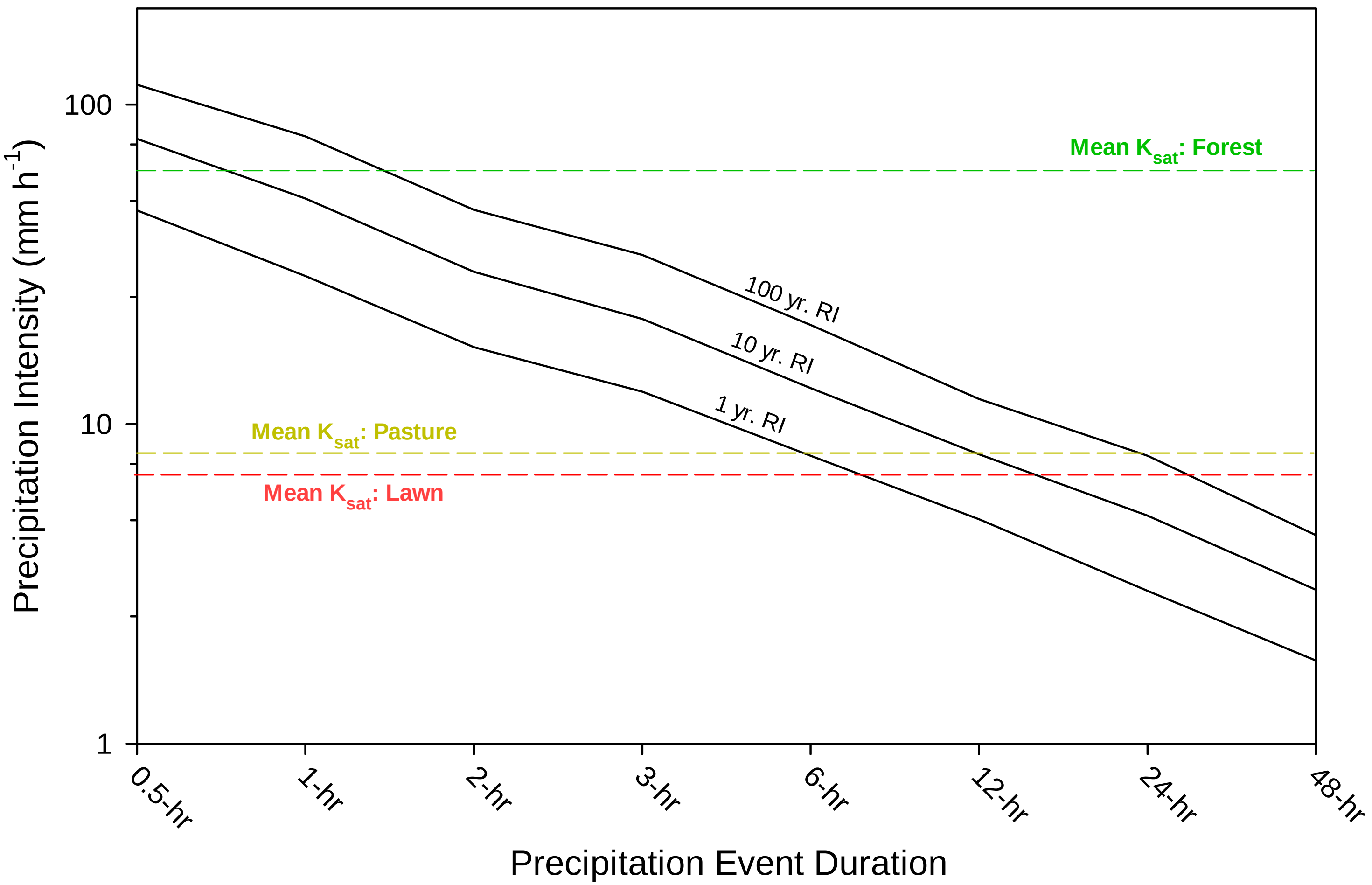


Price et al., 2010 *Journal of Hydrology* 383



Price et al., 2010 *Journal of Hydrology* 383

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Conclusions

• Streamflow of 35 streams was monitored for 1.5 years, and baseflow metrics were calculated for low flow season 2007, low flow season 2008, and water year 2008.

• Watersheds with greater forest cover were associated with higher baseflow, by all metrics. This is attributed to soil compaction and loss of recharge associated with forest conversion to other land use

• Multiple regression modeling indicated that drainage density, precipitation, and topographic variability (as slope standard deviation) were most important for explaining baseflow quantity.

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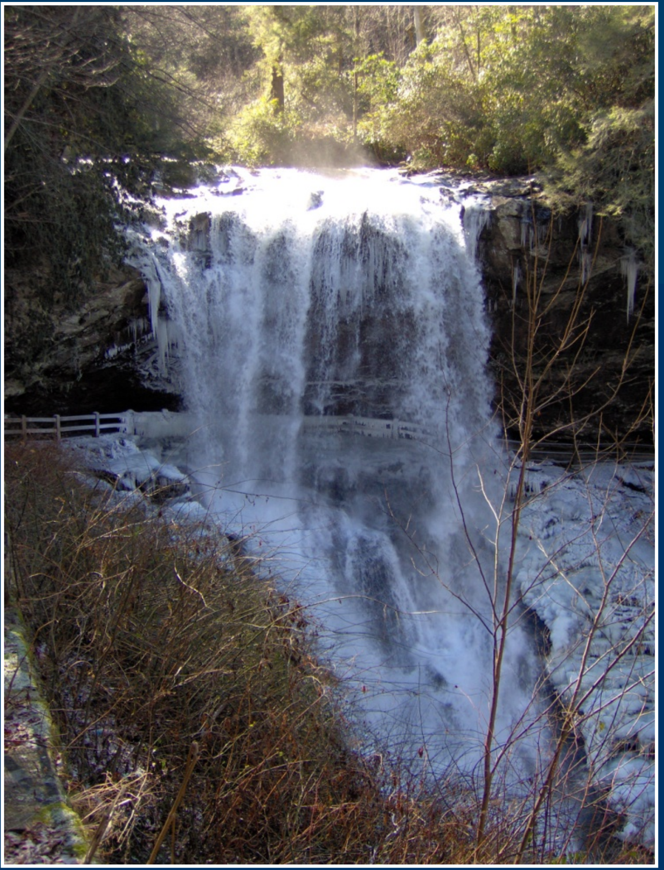

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