A Regionalized Flow Duration Curve Method to Predict Streamflow for Ungauged Basins: a Case Study of the Rappahannock Watershed in Virginia, USA

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Outline

- Flow duration curve: historical background
- Development of regionalized flow duration curve (RFDC)
- Separation of flow magnitude and time sequence: new paradigm
- Modeling streamflow for ungauged sites using regionalized flow duration curve (RFDC) and HSPF
- Comparison of RFDC and HSPF predictive performance

Flow duration curve applications

- Extending short period data records and filling missing data points

- Predicting flow and water quality time series data for ungauged sites

- Forecasting flow and water quality time series

- FDC can be used for baseflow separation

- FDC can be used for calibrating rainfall-runoff models particularly for ungauged basins

Effect of geology on low flows (Searcy, 1963)

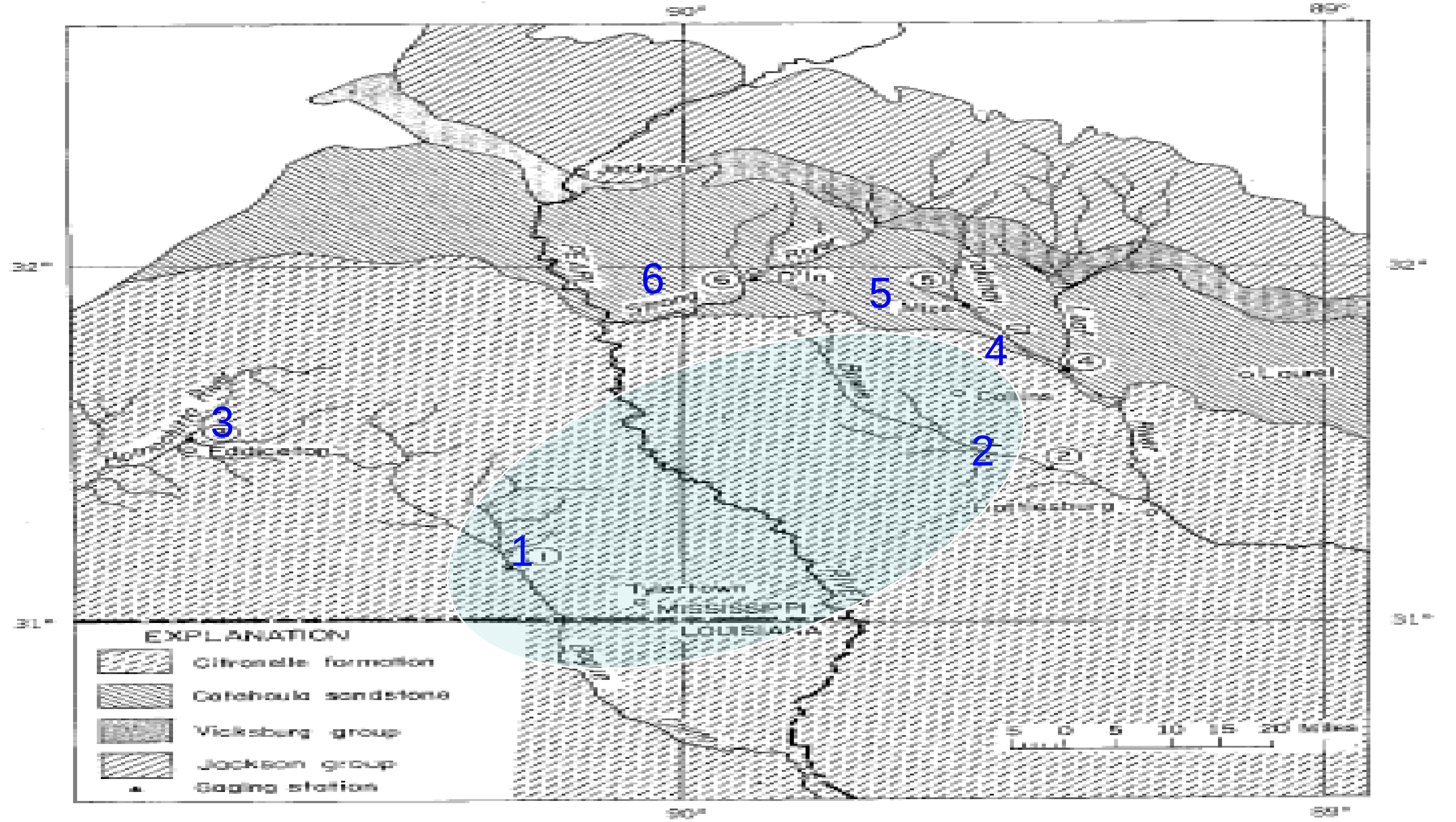


FIGURE 11.—Geologic map of area in southern Mississippi having approximately uniform climate and altitude.

Information content in flow duration curves (after Searcy, 1963)

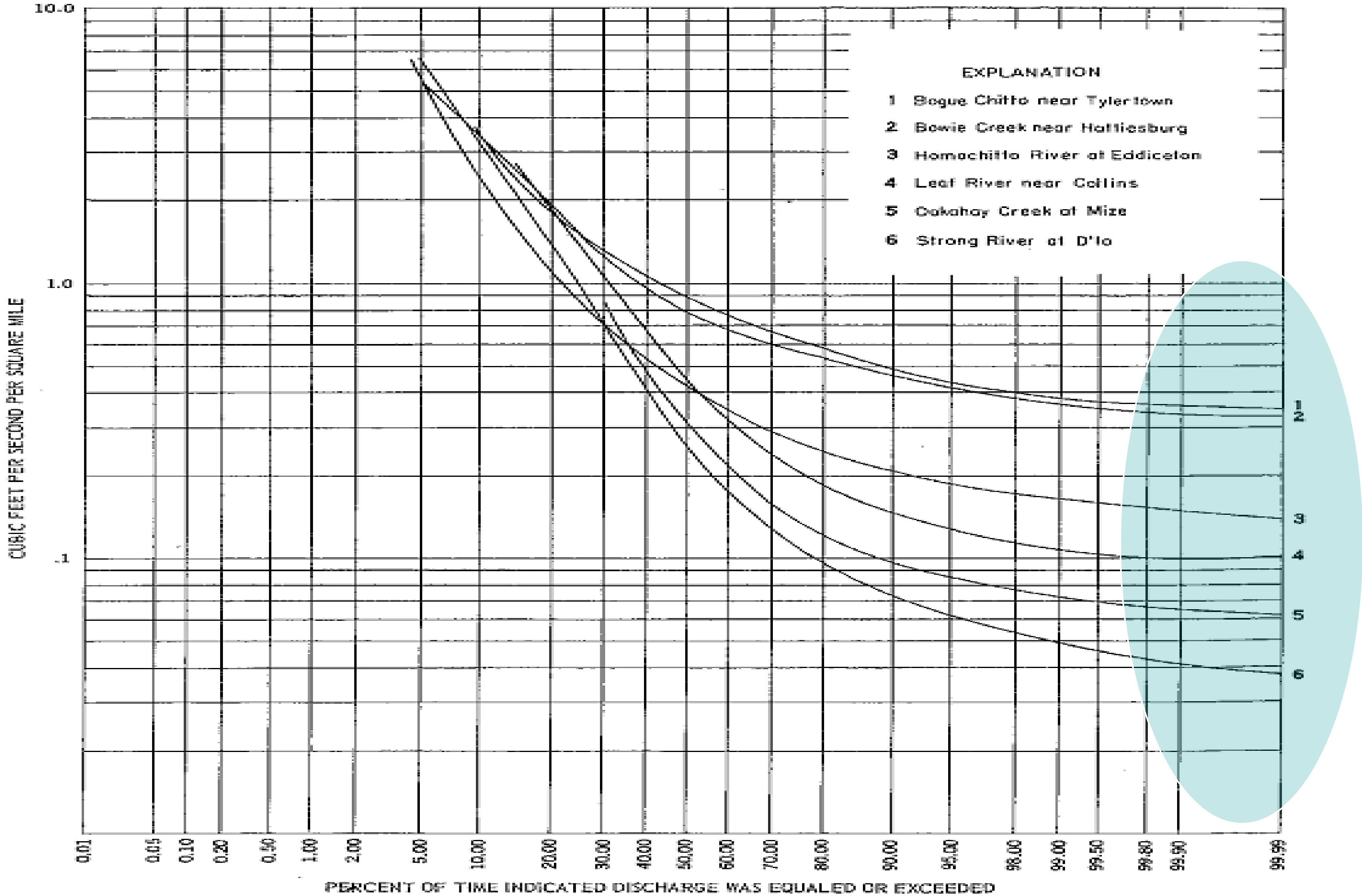
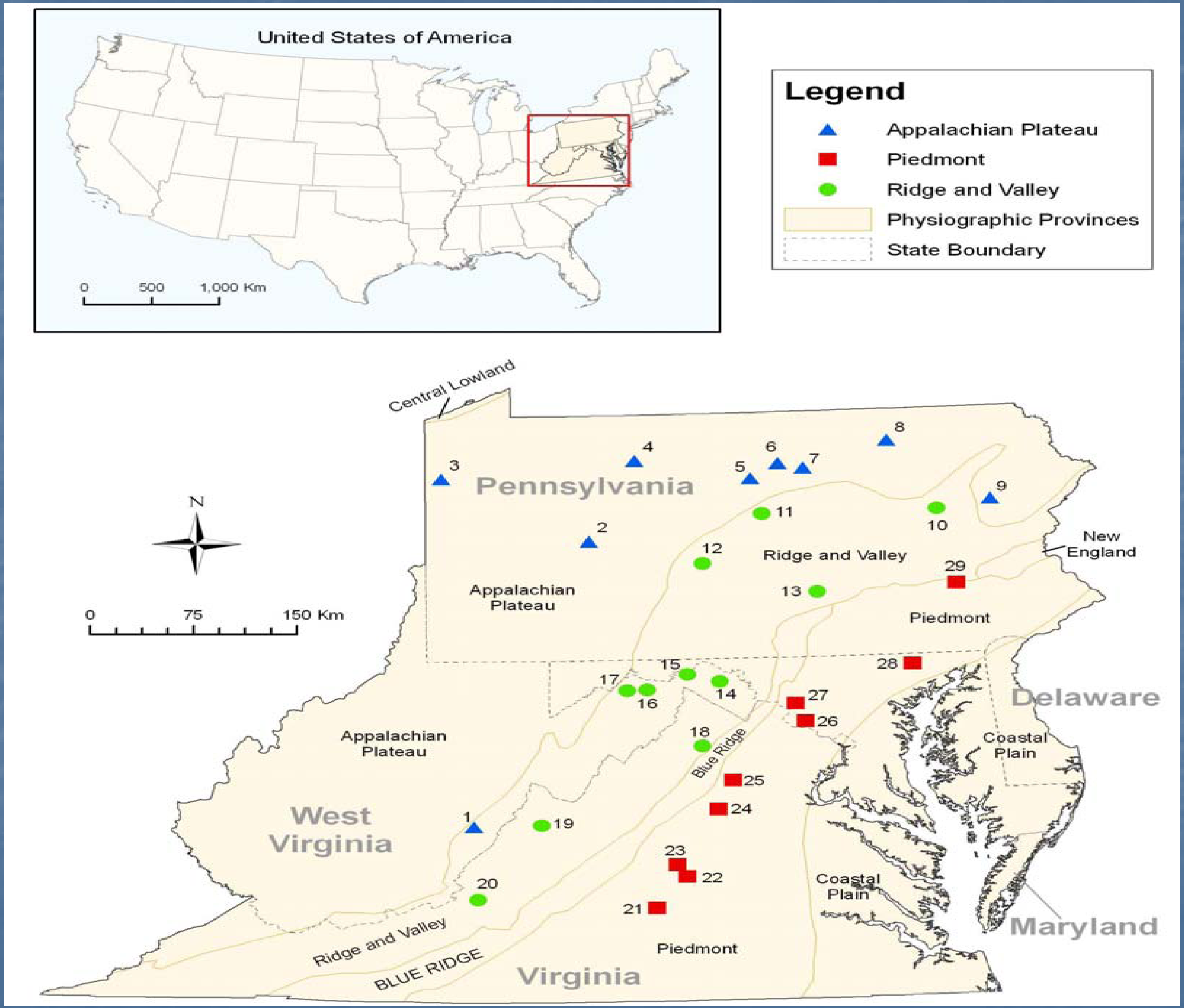


FIGURE 12.—Flow-duration curves for selected Mississippi streams, 1939–48.

Prediction of flow duration curve (FDC) and streamflow

- Step 1. Develop regional regression equations ($Q_{.1}$ to Q_{99}) for watersheds in the Appalachian, Ridge and Valley, and Piedmont physiographic provinces
- Step 2. Predict FDC for gauged and ungauged sites of the Mid-Atlantic region
- Step 3. Convert FDC to streamflow time series data
- Step 4. Test FDC method's predictive performance
- Step 5. Compare FDC and HSPF

Regionalization approaches: Mid-Atlantic Region



A new paradigm: flow, duration curve, percentile flows

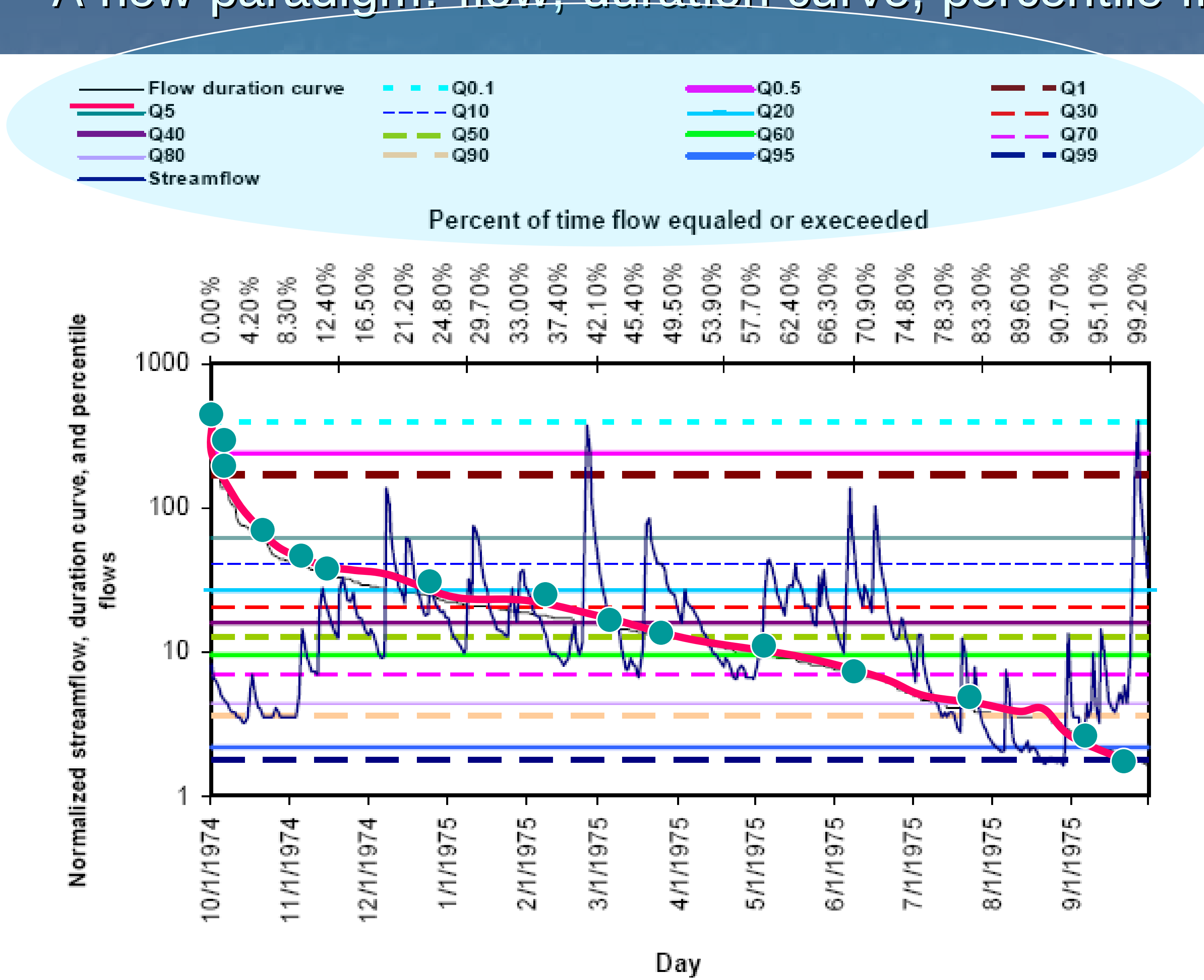
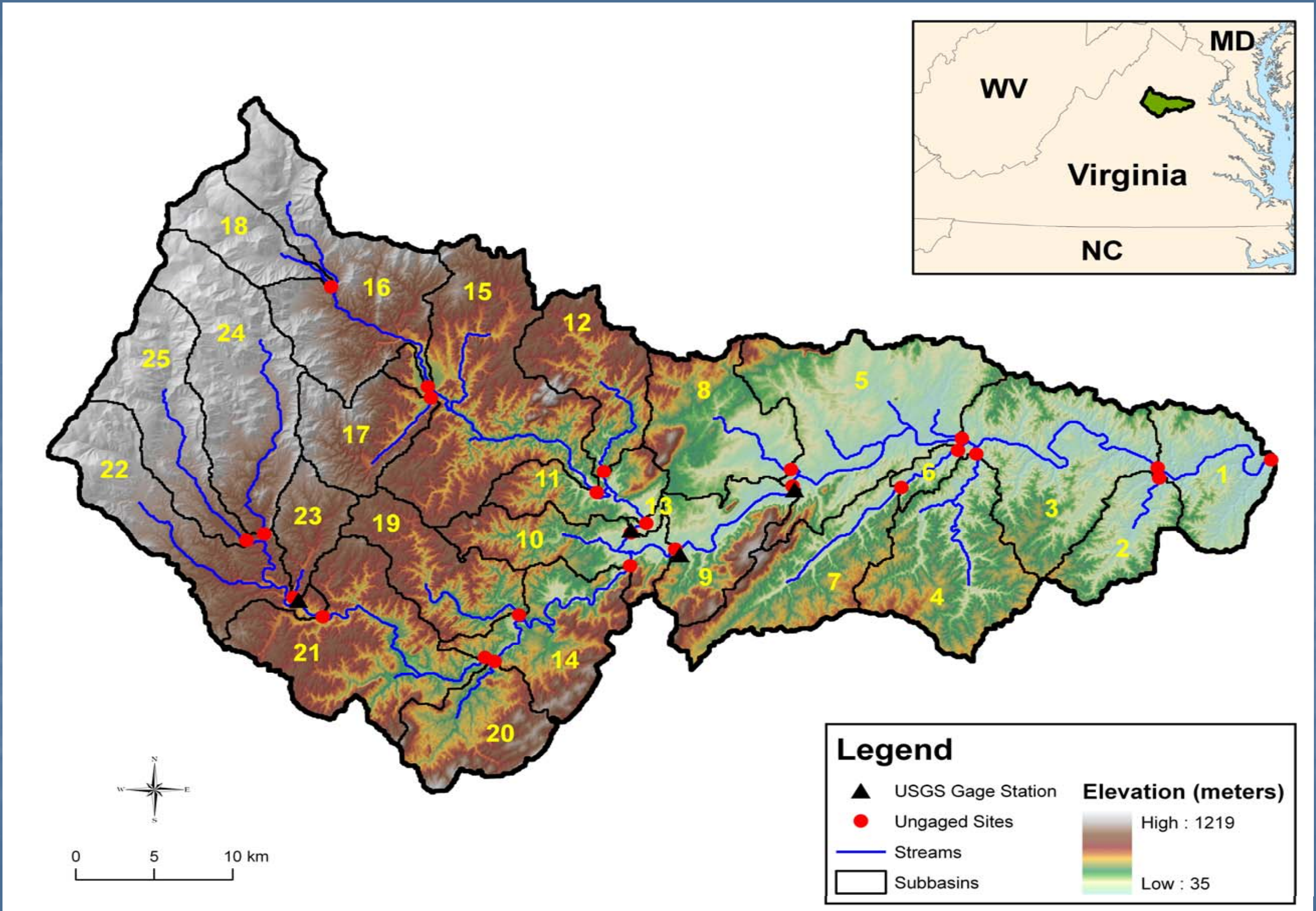
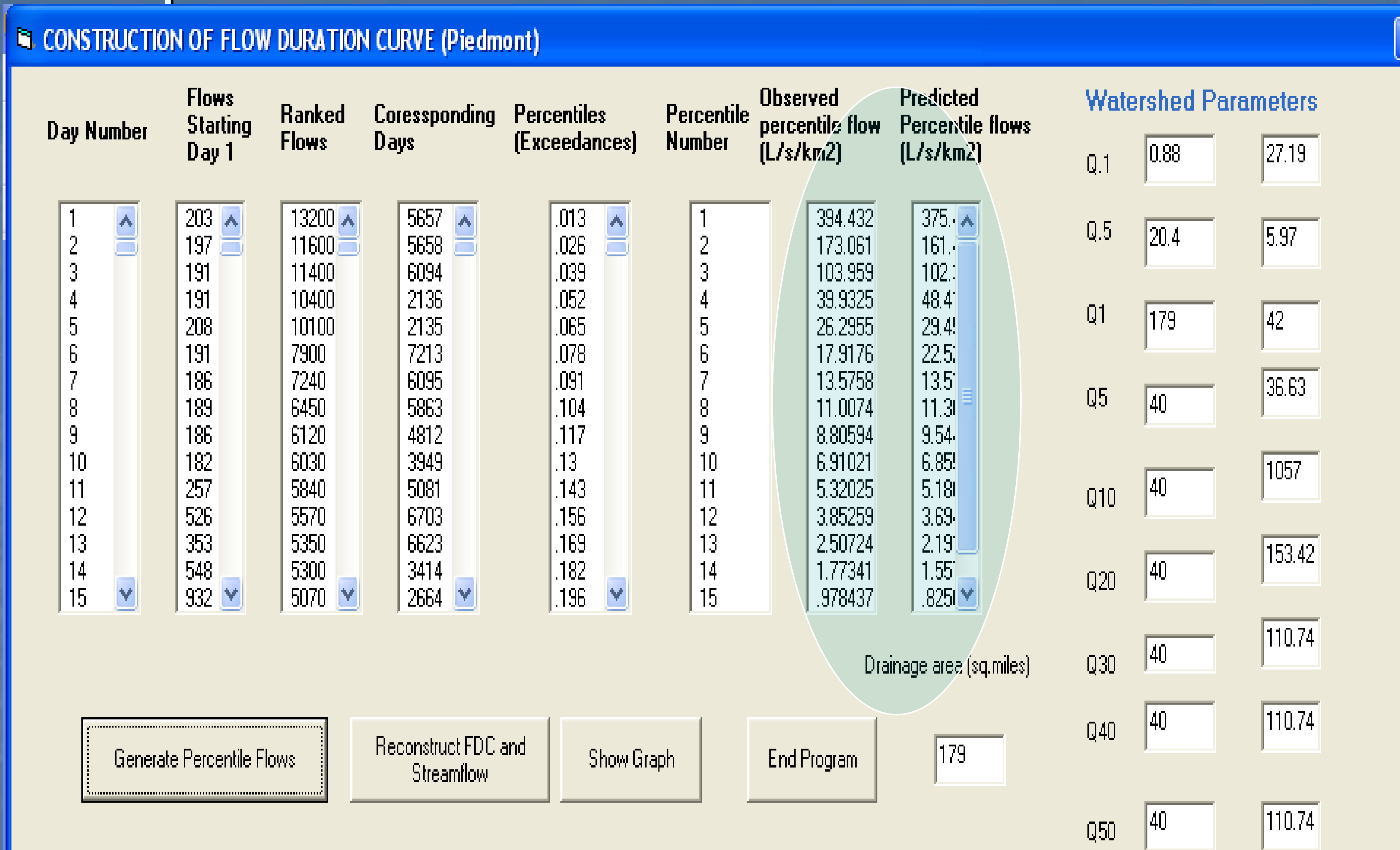


Fig. 2 Relationships between normalized flow duration curve, daily streamflow and the 15 percentile flow points ($Q_{0.1}$ to Q_{99}) generated from a single year streamflow time series data.

Map of the study watershed showing gauged and ungauged sites

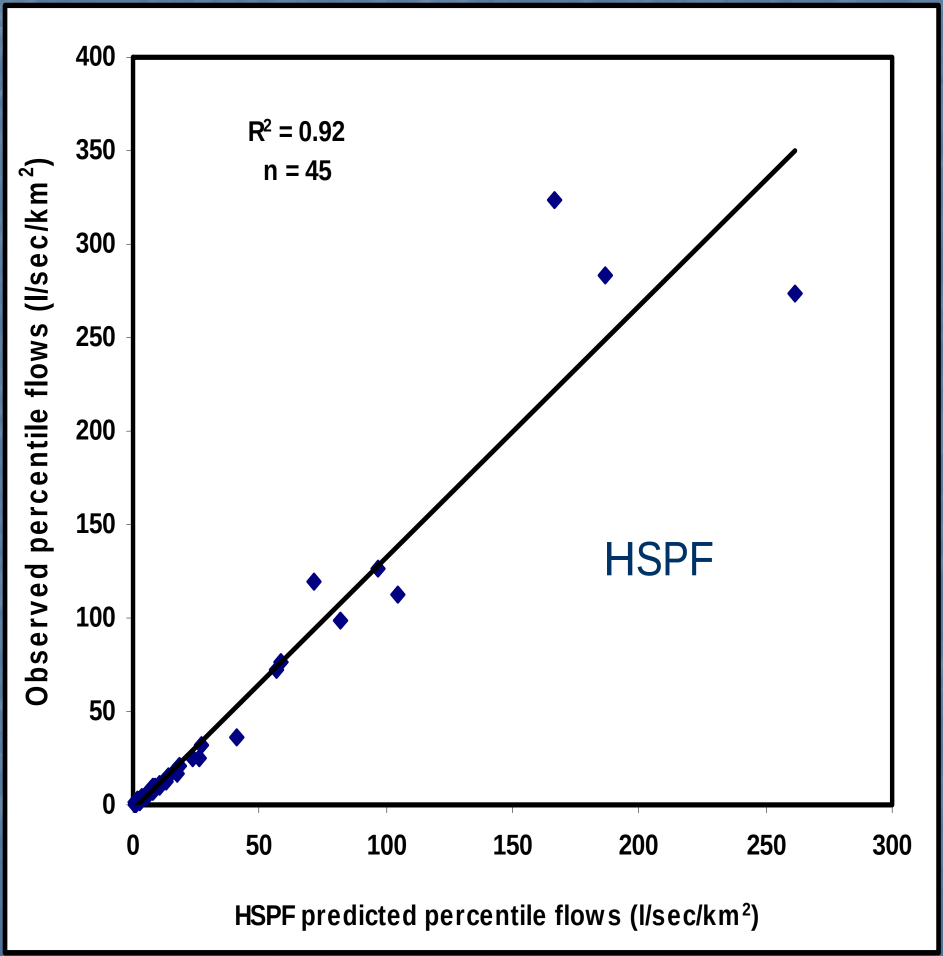


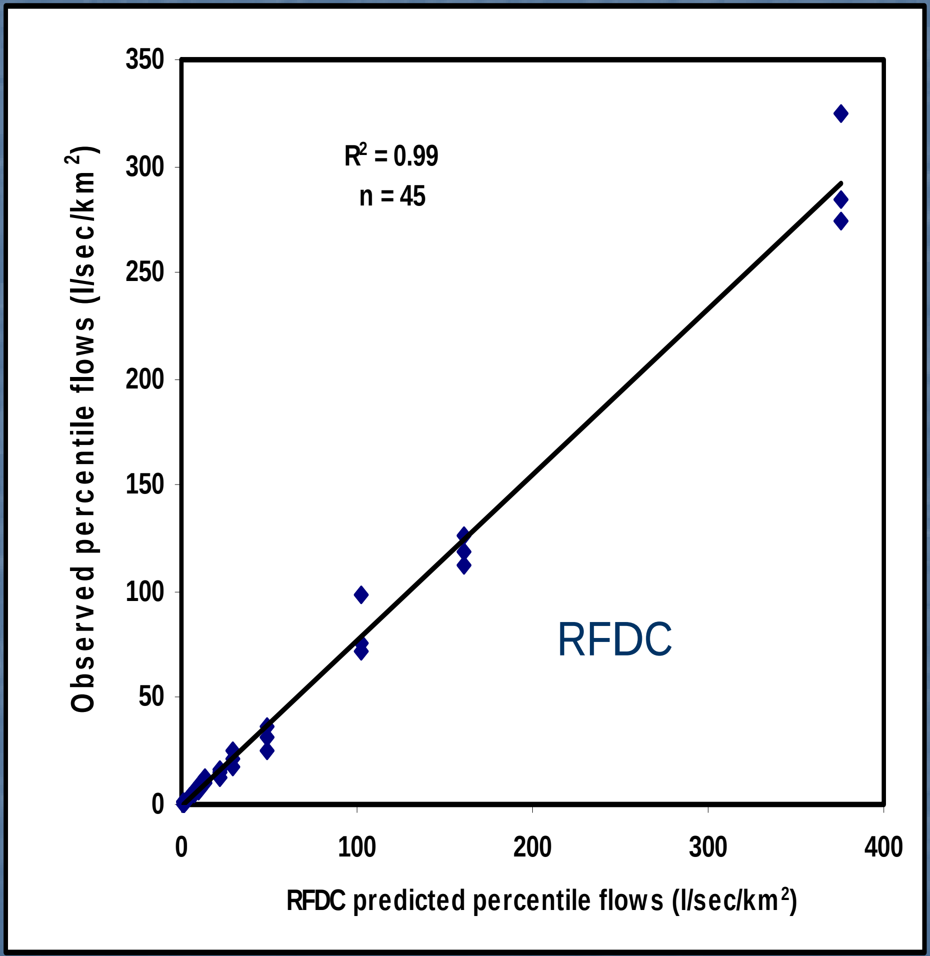
FDC prediction and streamflow conversion tool



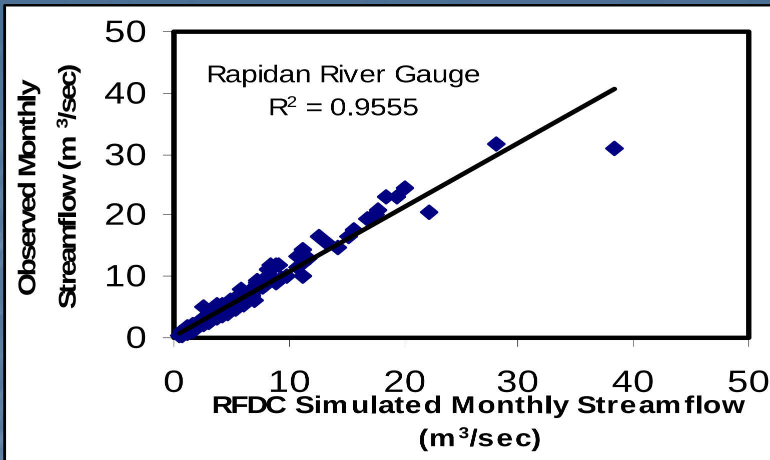
Soils, climate, geology, geomorphology, land use (watershed descriptors)

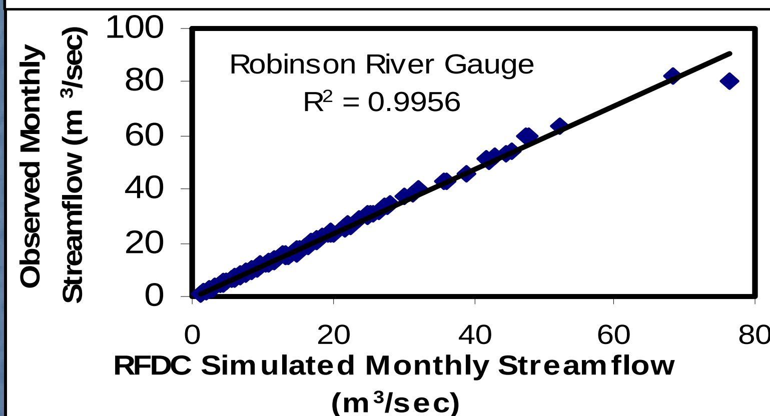
Comparisons of observed percentile flows and percentile flows predicted by HSPF and RFDC methods For Site 9, 13, and 22
(FDC predicts only the magnitude component of streamflow)

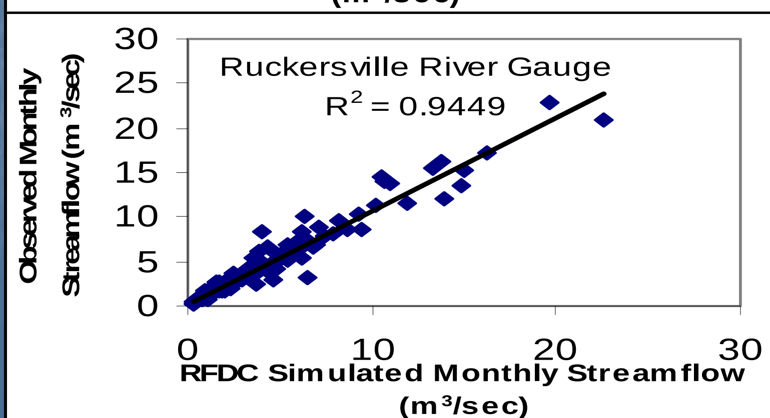


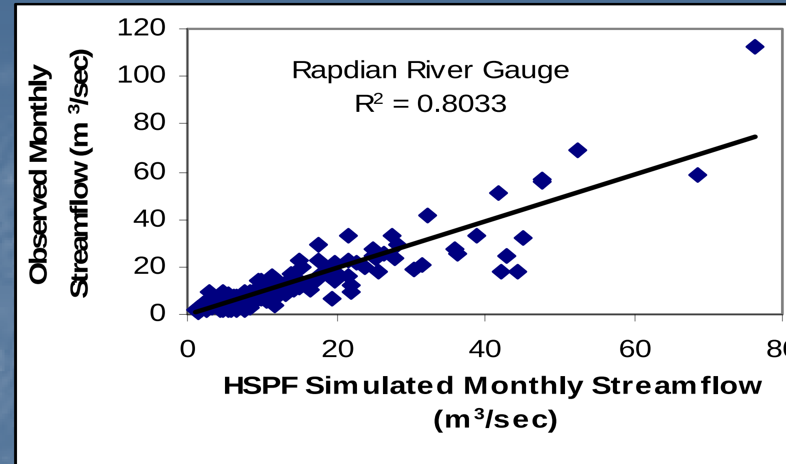


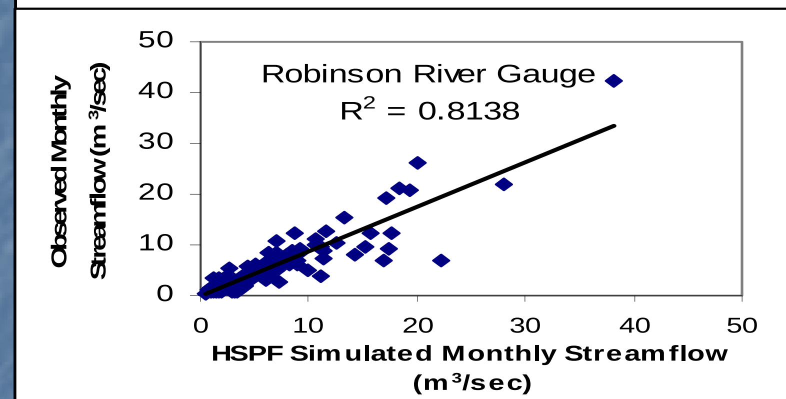
Comparison of observed mean monthly streamflow vs. mean monthly streamflow simulated by RFDC and HSPF for three gauged sites

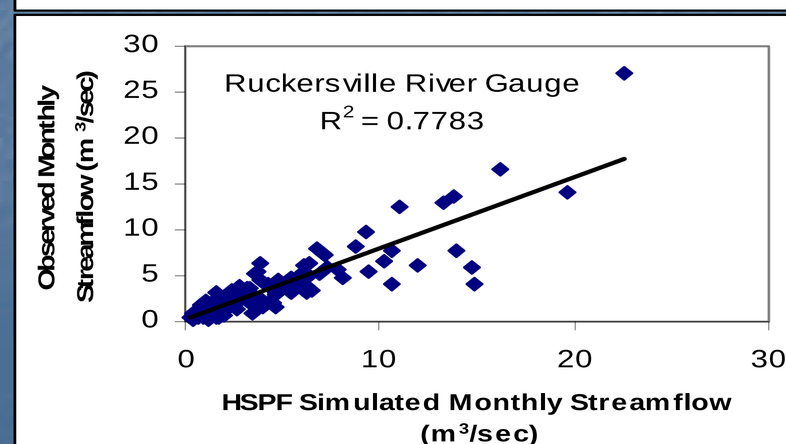




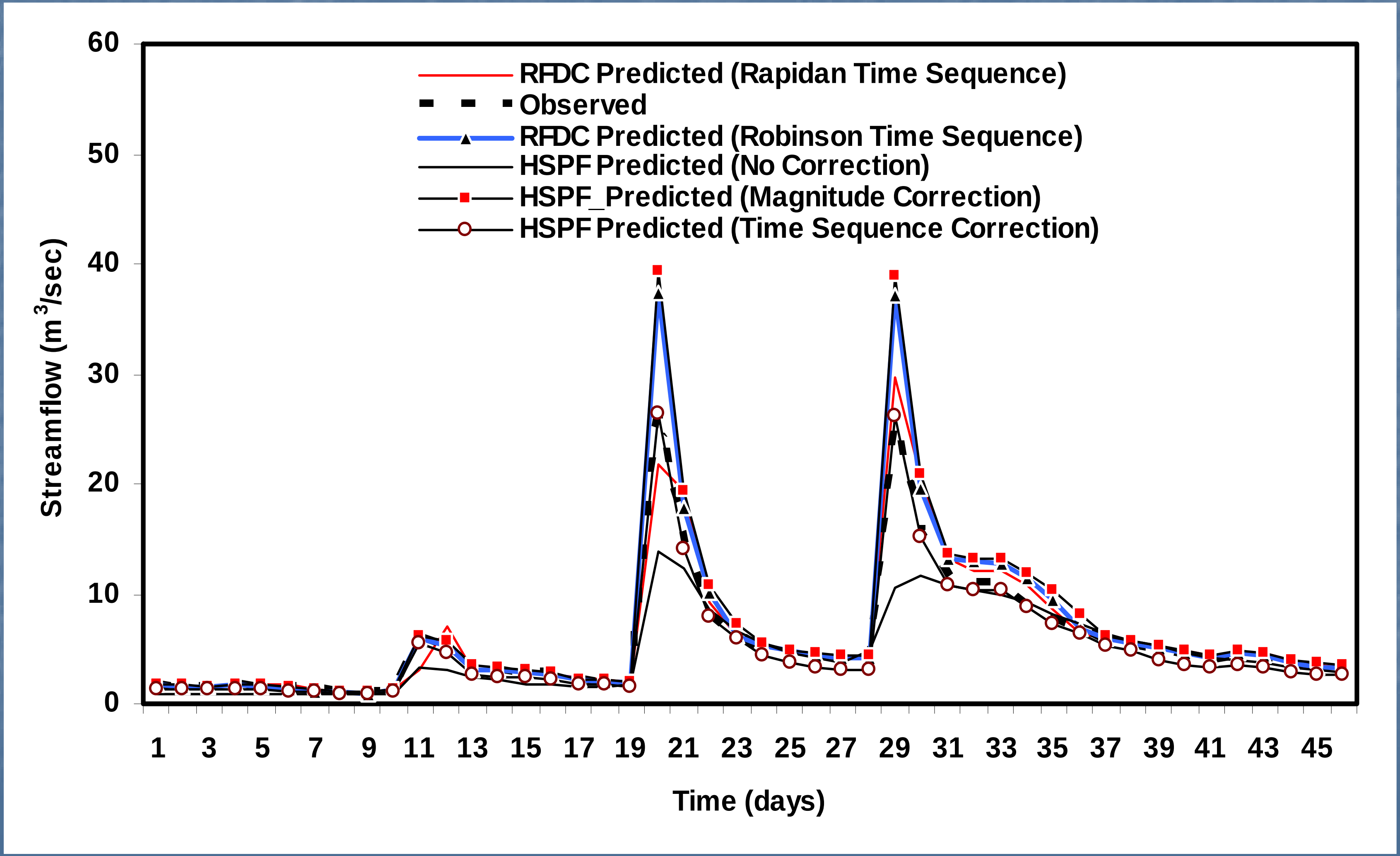




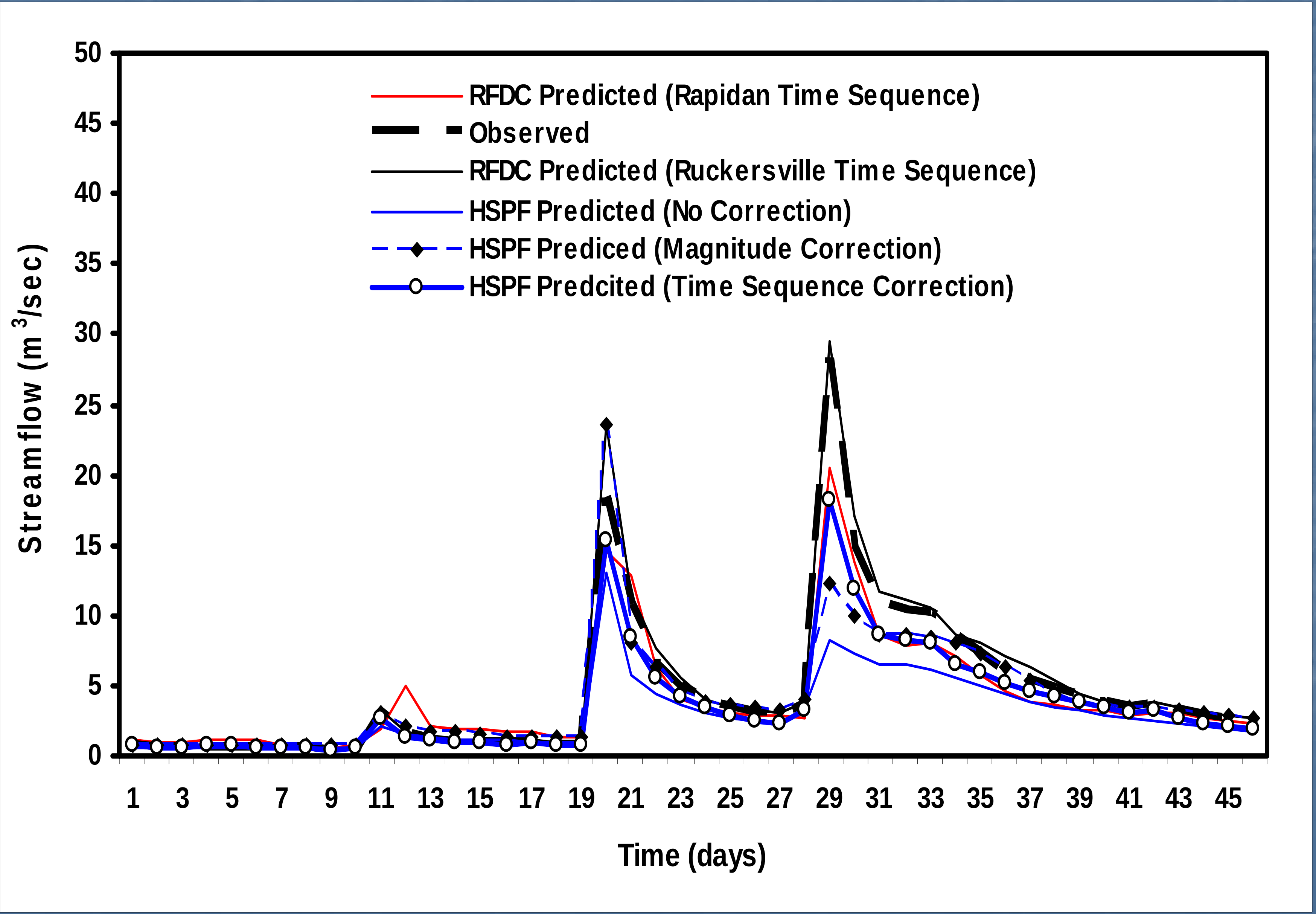




Comparisons of observed hydrograph and hydrographs predicted by HSPF and RFDC methods for the Robinson Site (Site 13)



Comparison of observed hydrographs and HSPF and RFDC predicted hydrographs for the Ruckersville evaluation sites (Site 22)



Comparisons of observed streamflow and streamflow predicted by HSPF for the period between (01/01/1980 through 12/31/1990)

Destination Site	Source Site	Model Calibration	
		R^2 Daily (monthly)	N-S Daily (monthly)
Site 9-Rapidan River	Site 9	0.65 (0.80)	0.65 (0.76)
		Model Evaluation	
Site 13-Robinson River	Site 9	0.68 (0.66)	0.66 (0.55)
Site 22-Ruckersville	Site 9	0.68 (0.64)	0.78 (0.74)
Sequence adjusted-HSPF			
Site 13- Robinson	Site 13	0.92 (0.97)	0.89 (0.91)
Site 22-Ruckersville	Site 22	0.95 (0.99)	0.93 (0.92)

Comparisons of observed streamflow and streamflow predicted by RFDC for the period between (01/01/1980 through 12/31/1990)

Destination Site	Source Site	Model Calibration	
		R^2 Daily (monthly)	N-S Daily (monthly)
Site 9-Rapidan River	Site 9	0.96 (1.0)	0.92 (0.95)
		Model Evaluation	
Site 13-Robinson River	Site 9	0.93 (0.98)	0.93 (0.95)
Site 22-Ruckersville	Site 9	0.80 (0.95)	0.76 (0.91)
Sequence adjusted-HSPF			
Site 13- Robinson	Site 13	0.93 (0.99)	0.93 (0.95)
Site 22-Ruckersville	Site 22	0.95 (0.99)	0.94 (0.97)

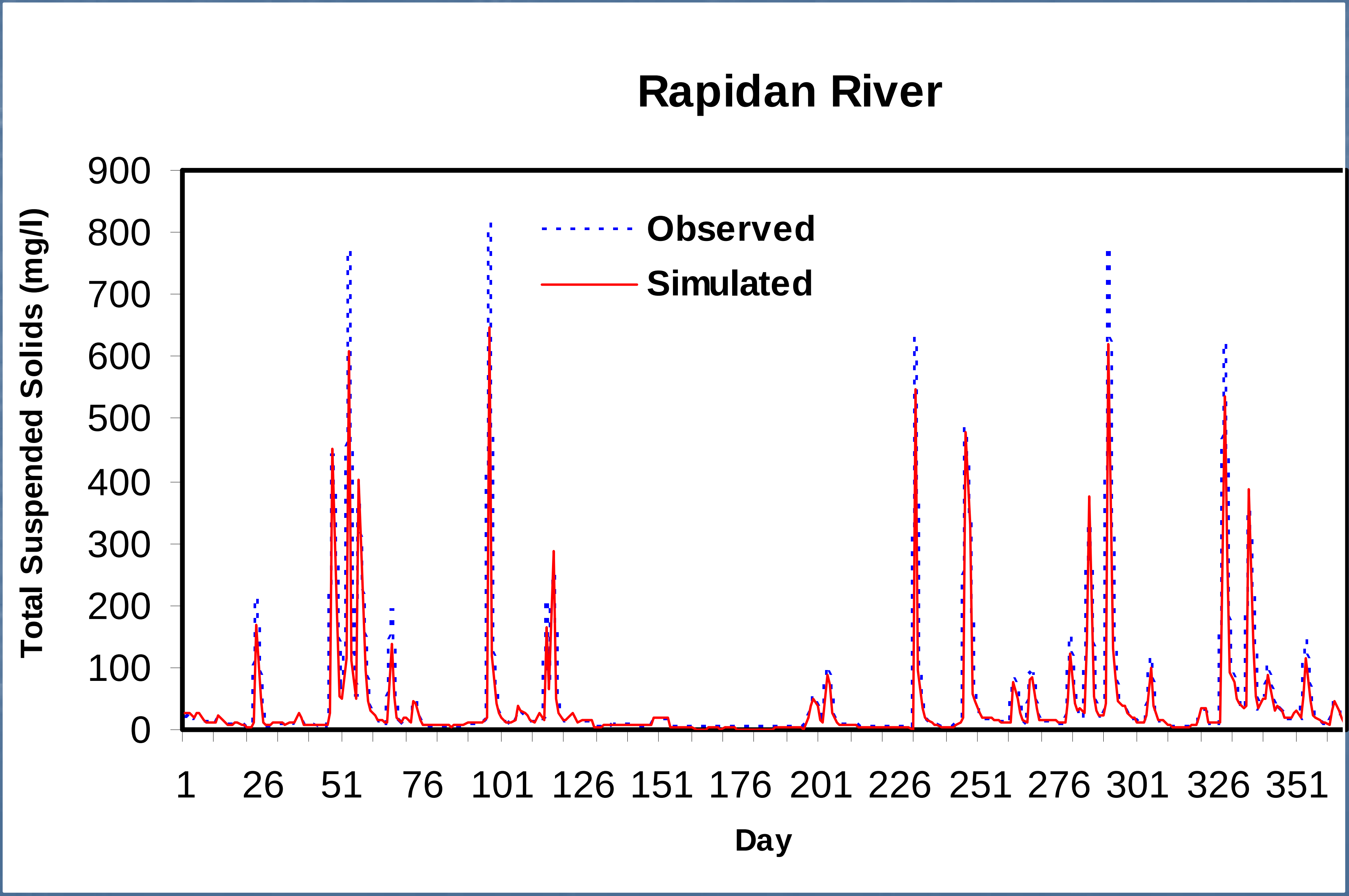
Comparison of HSPF and RFDC simulated streamflow for 22 ungauged sites and 3 gauged sites of the Rapidan Watershed

	HSPF Simulated versus RFDC Simulated Streamflow		
	R^2	N-S	RMSE
Site	Daily (monthly)	Daily (monthly)	(m^3/sec/km
Site 25	0.59 (0.78)	0.53 (0.65)	0.017
Site 24	0.58 (0.78)	0.51 (0.64)	0.017
Site 23	0.53 (0.75)	0.52 (0.68)	0.022
Site 22	**0.56 (0.77)**	**0.49 (0.68)**	**0.017**
Site 21	0.59 (0.78)	0.51 (0.64)	0.017
Site 20	0.57 (0.78)	0.54 (0.65)	0.018
Site 19	0.57 (0.77)	0.47 (0.68)	0.019
Site 18	0.57 (0.78)	0.53 (0.65)	0.018
Site 17	0.58 (0.78)	0.54 (0.66)	0.017
Site 16	0.58 (0.78)	0.52 (0.65)	0.017
Site 15	0.59 (0.78)	0.52 (0.66)	0.017
Site 14	0.58 (0.78)	0.49 (0.65)	0.017
Site 13	**0.57 (0.77)**	**0.50 (0.71)**	**0.016**
Site 12	0.59 (0.78)	0.47 (0.73)	0.017
Site 11	0.59 (0.78)	0.51 (0.72)	0.016
Site 10	0.58 (0.78)	0.52 (0.72)	0.016
Site 09	**0.57 (0.78)**	**0.51 (0.72)**	**0.016**
Site 08	0.58 (0.78)	0.47 (0.72)	0.017
Site 07	0.58 (0.78)	0.47 (0.71)	0.017
Site 06	0.58 (0.78)	0.48 (0.71)	0.017
Site 05	0.56 (0.78)	0.50 (0.65)	0.017
Site 04	0.57 (0.78)	0.47 (0.70)	0.017
Site 03	0.53 (0.78)	0.34 (0.61)	0.017
Site 02	0.58 (0.78)	0.45 (0.65)	0.018
Site 01	0.51 (0.78)	0.31 (0.64)	0.017

Future Research

- Separation of streamflow magnitude and sequence components
  - Which variables and parameters are related to magnitude ?
  - Which variables and parameters are related to time sequence?
  - Can streamflow prediction be improved through improved magnitude prediction?
  - Can streamflow prediction be improved through improved sequence prediction?
  - Extend the RFDC method to predicting nutrient, sediment, and pathogen concentration and load duration curves

Other Applications: Prediction of total suspended solids using the RFDC method



Conclusion

- FDC only captures the magnitude component of streamflow (FDC has no time sequence)
- Time sequence is obtained from a nearby gauged site (no magnitude is required)
- RFDC method had higher predictive performance than HSPF
- RFDC can be useful to improving rainfall-runoff models
- Regionalization methods are suitable for FDC prediction hence flow magnitude
- Predicting magnitude and time sequence components of streamflow together is a major weakness of rainfall-runoff models (e.g., HSPF)
- Predicting magnitude and time sequence components of streamflow separately makes RFDC highly suitable for predictions of ungauged basins

Questions