DEVELOPMENT OF STATISTICAL MODELS TO QUANTIFY SEDIMENT AND PHOSPHORUS LOADS IN SMALL, RURAL WATERSHEDS

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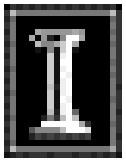

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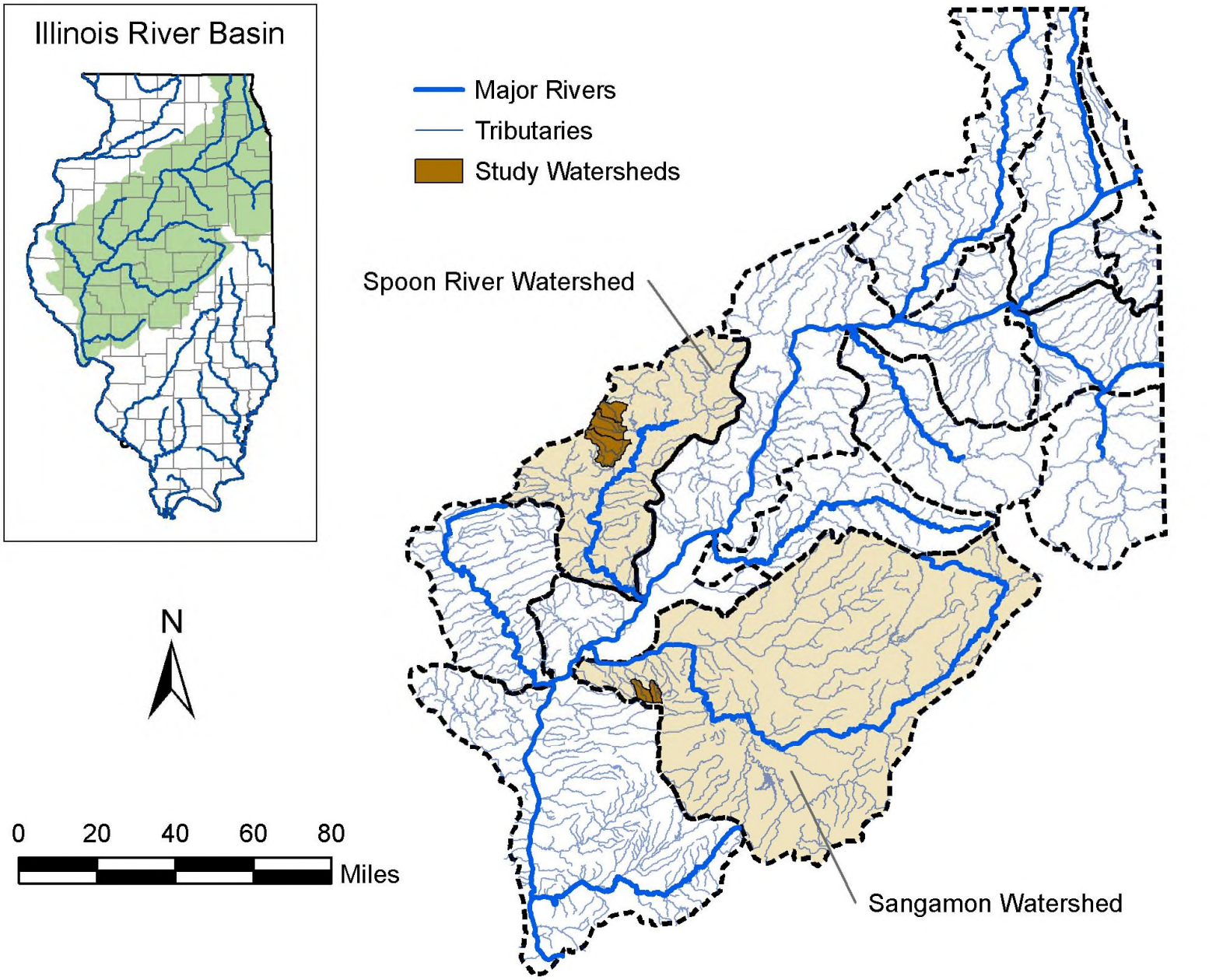
Research Question

- What is the most appropriate TP and SSC load calculation technique for small watersheds with fixed interval and storm event sampling?

Primary Data Set (2000-2009)

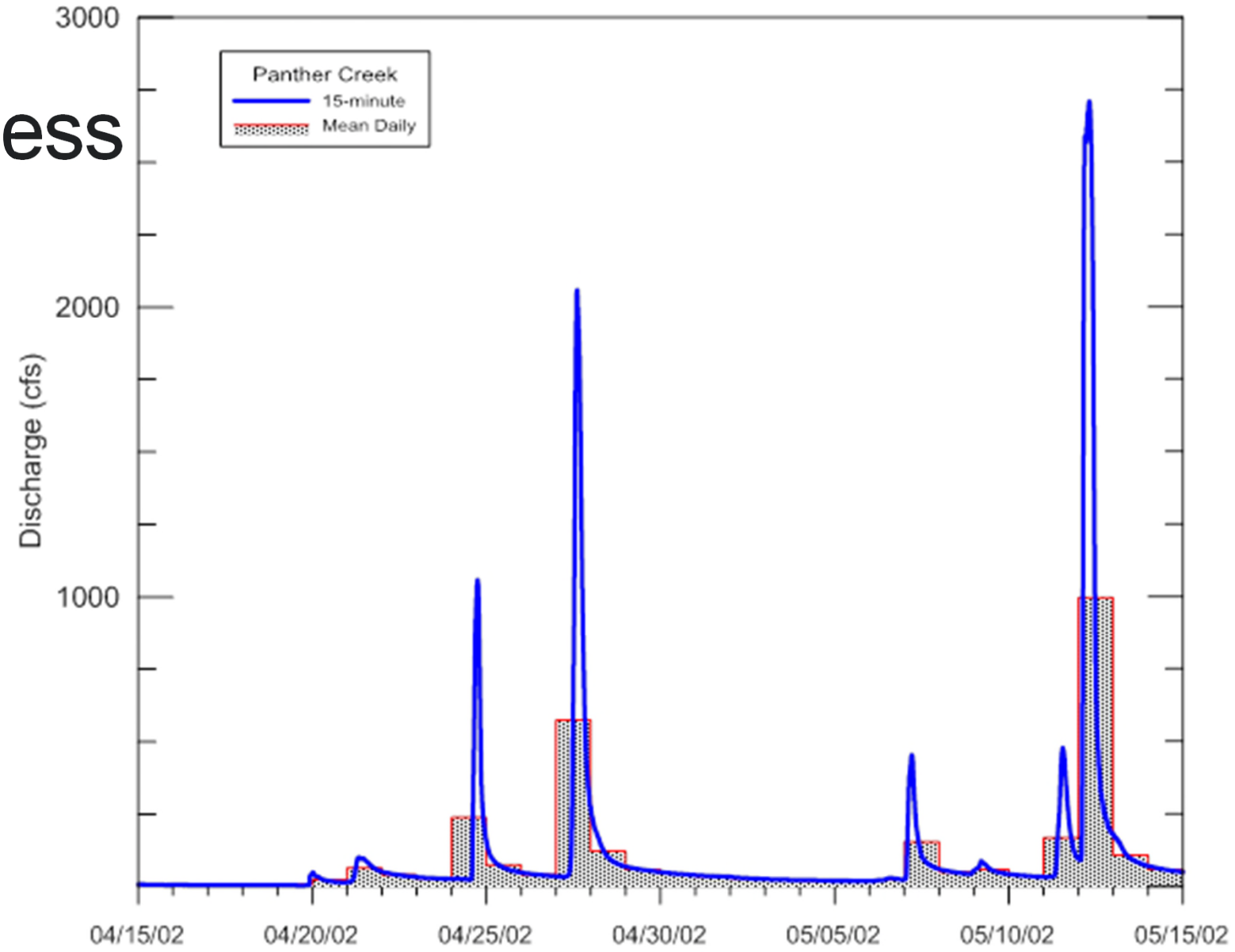
- 5 sites in western Illinois operated by the Illinois State Water Survey (Demissie et al., 2001)
- 15-minute streamflow records
- Sediment samples (routine and event sampling)
  - Daily samples during normal flows
  - Weekly samples during low flows
  - Multiple samples throughout storm hydrograph
- Phosphorus samples (routine and event sampling)
  - Monthly samples
  - Few samples throughout storm hydrograph


Illinois River Basin
Major Rivers
Tributaries
Study Watersheds
Spoon River Watershed
Sangamon Watershed
N
0
20
40
60
80
Miles

Study Sites

Site ID	Site Name	Drainage Area (sq mi)	Stream Slope (ft/mi)	Land Use (Percent of Study Watershed)			Major Watershed
				Agriculture	Forest	Other	
1	Cox Creek	11.7	13.6	93	6	1	Sangamon
2	Panther Creek	16.5	13.3	75	22	3	Sangamon
3	North Creek	26.6	21.1	65	31	4	Spoon
4	Haw Creek	55.3	8.3	80	14	6	Spoon
5	Court Creek	67.4	14.5	69	23	8	Spoon

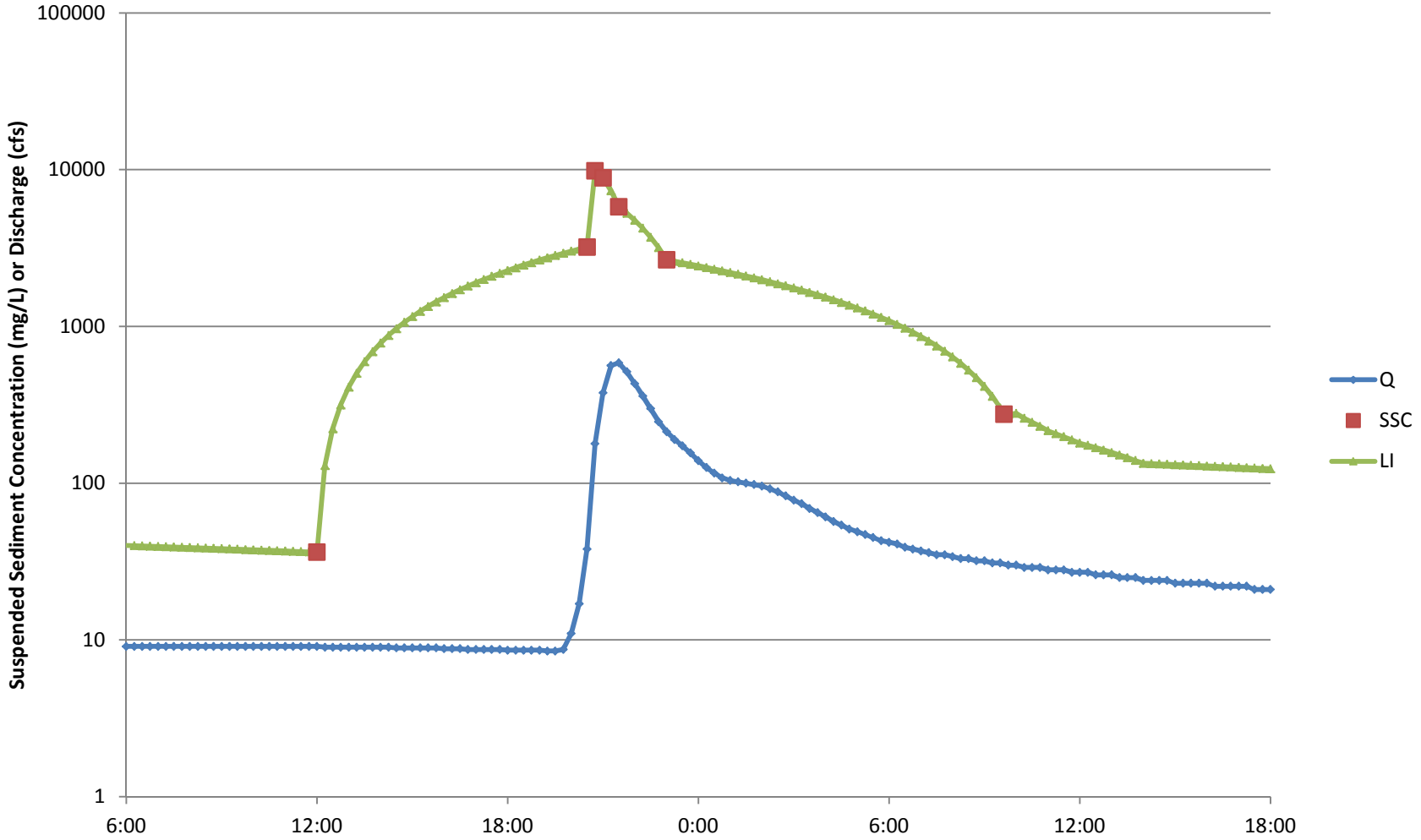
Stream Flashiness



Possible Methods for Load Calculation

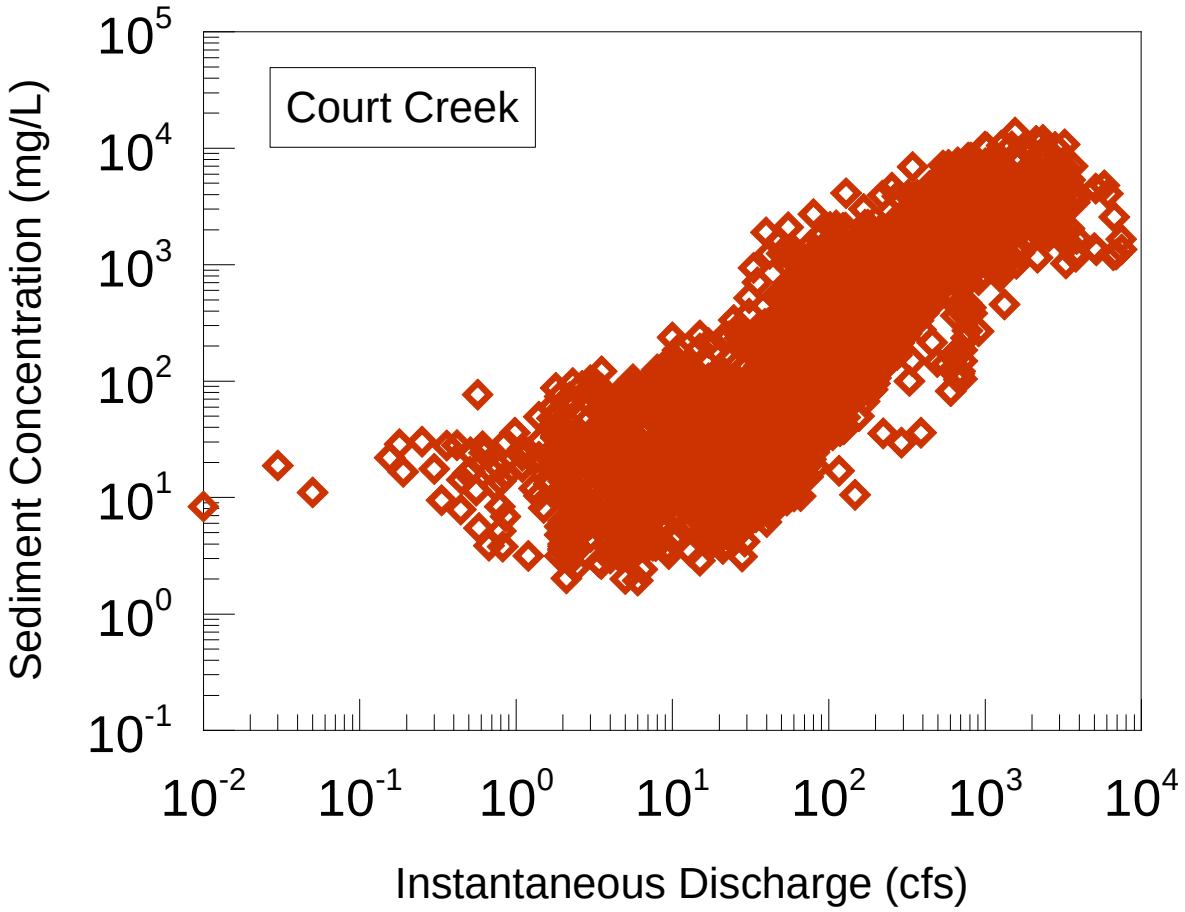
- Linear interpolation of samples
- USGS worked record approach (Porterfield, 1972)
- Regression model – “Big Rivers” approach
  - Estimate concentration or loads based on several explanatory variables
  - Multiple linear regression model are often used in nutrient studies (Goolsby et al., 1999; Aulenbach et al., 2007; Terrio, 2006).
- Composite method – Utilizes observed concentrations to improve load estimation (error correction)

Simulating Continuous Concentration – Linear Interpolation



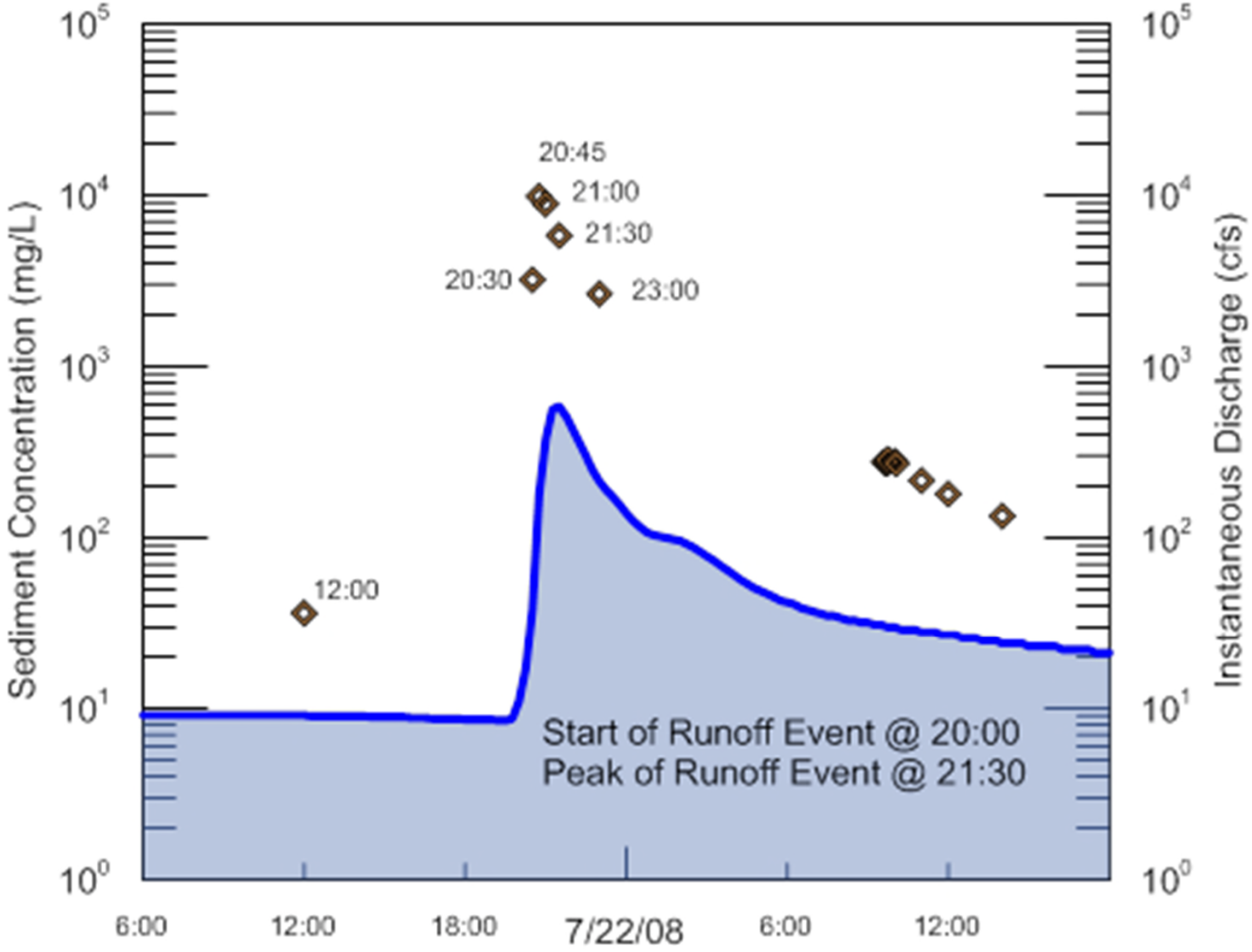
Estimating Continuous Concentration Records

- Despite intensive sampling strategy there are still runoff events that are not sampled or under-sampled
- To estimate a continuous concentration curve must take into consideration:
  - Flow
  - Season
  - Position on hydrograph

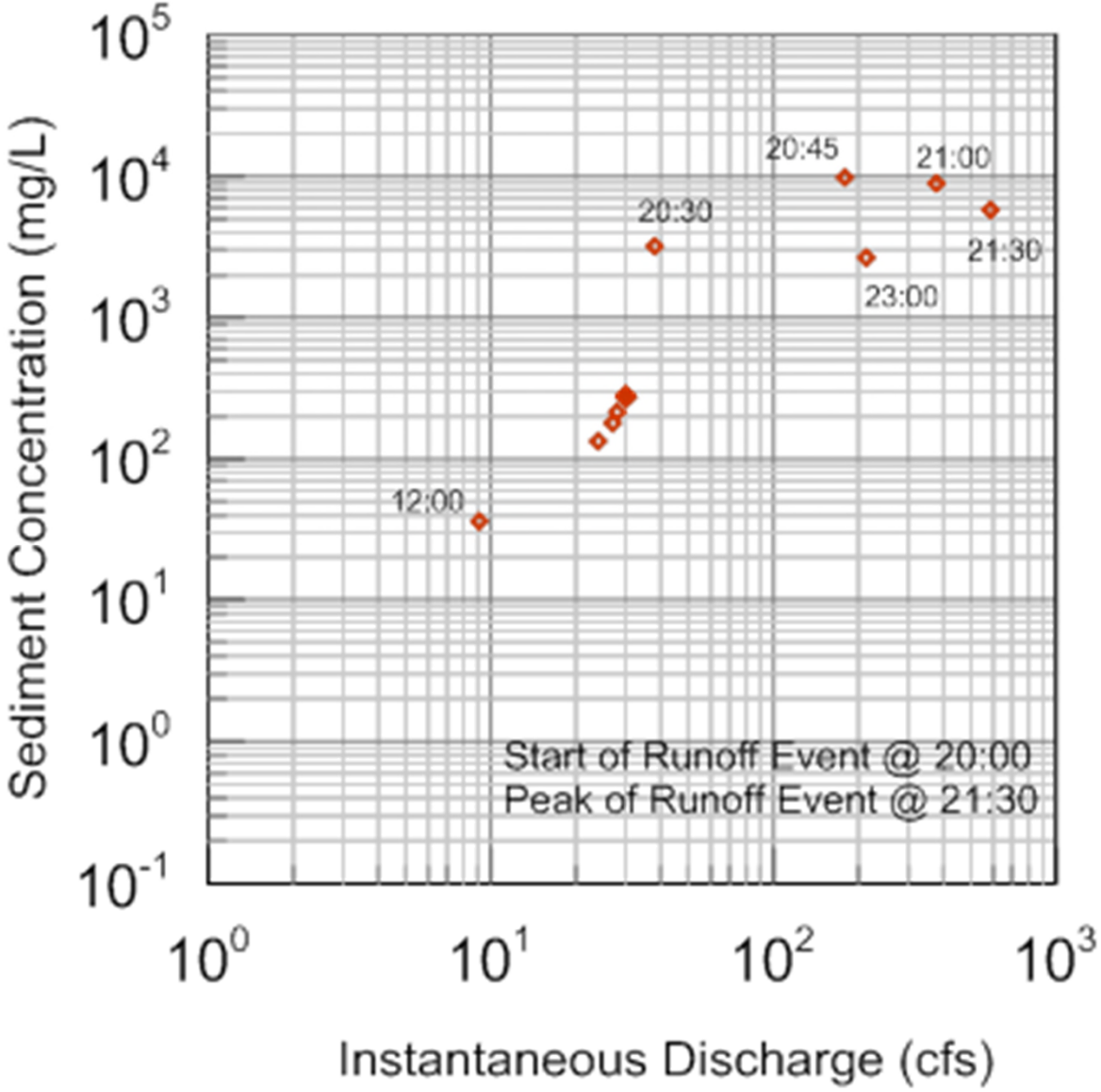


What is the relationship between sediment and flow?

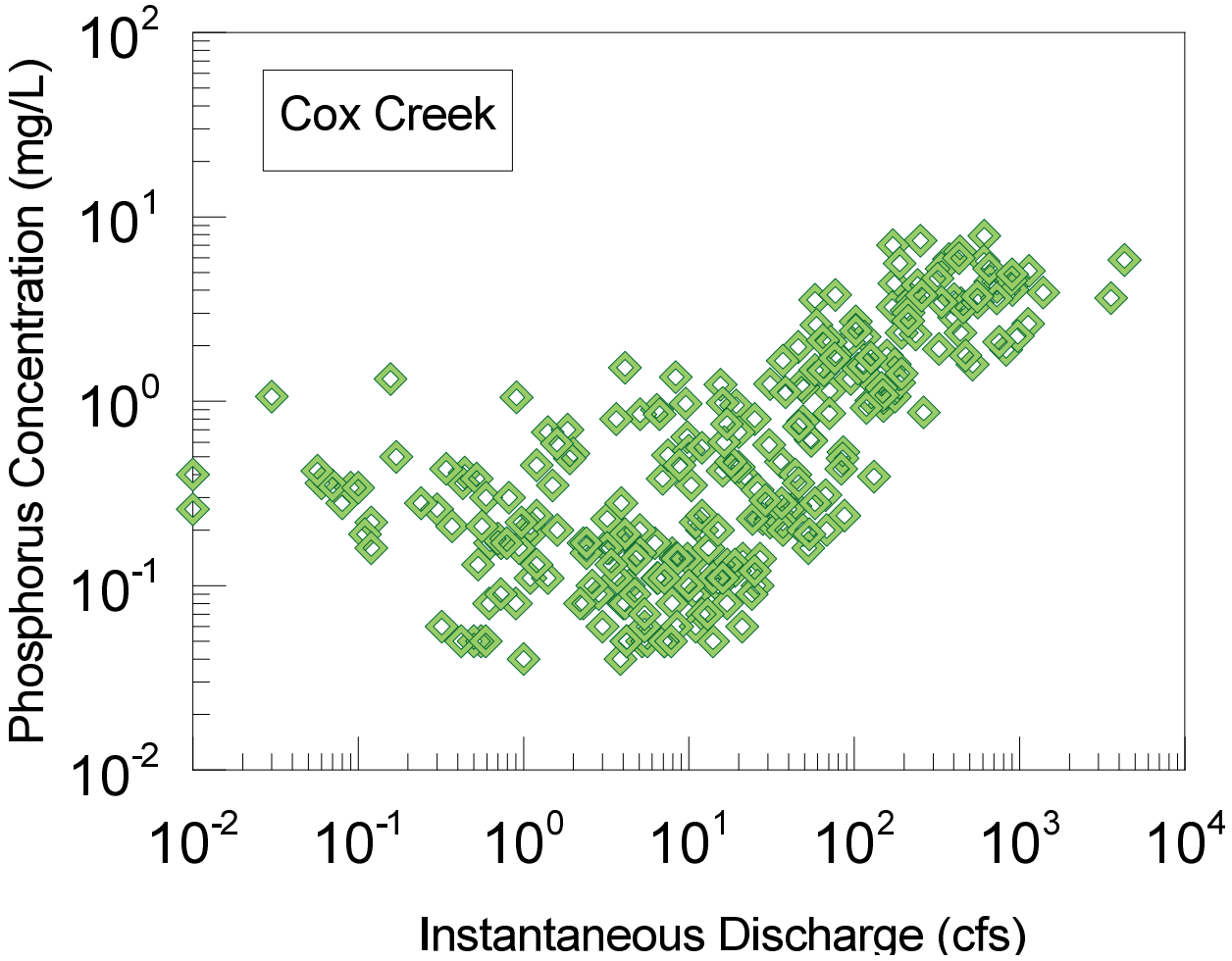
Hysteresis Effect



Hysteresis Effect

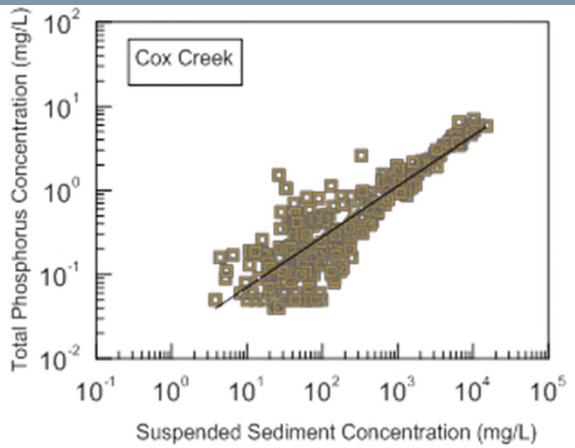


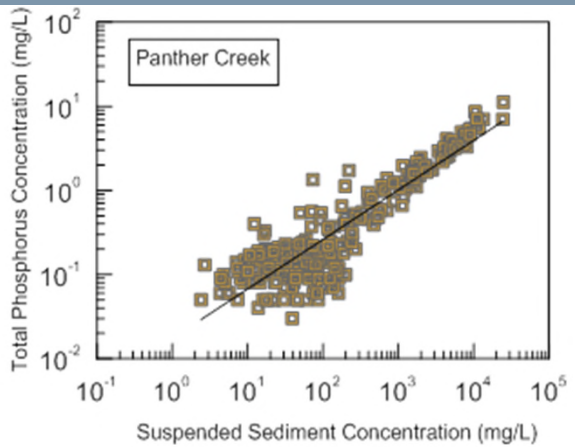
Total phosphorus and flow?

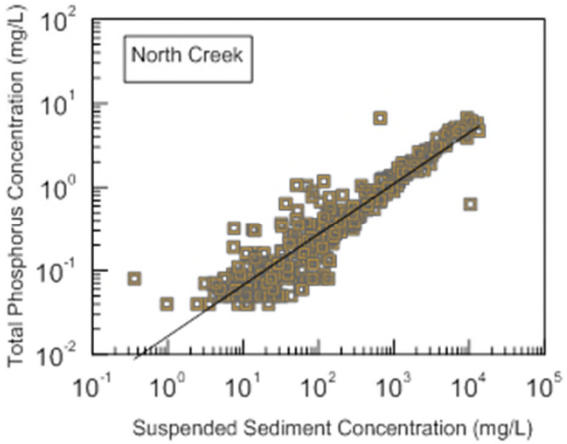


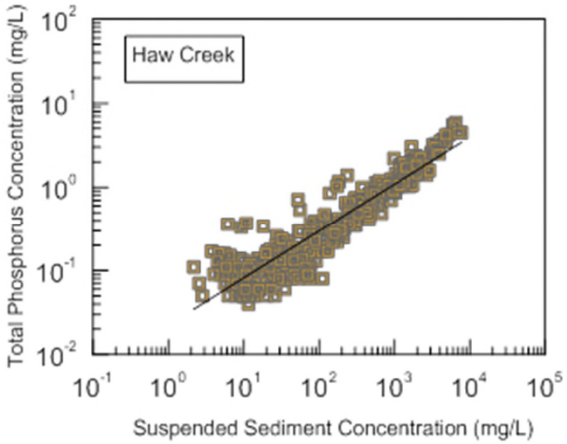
Concurrent TP and SSC samples

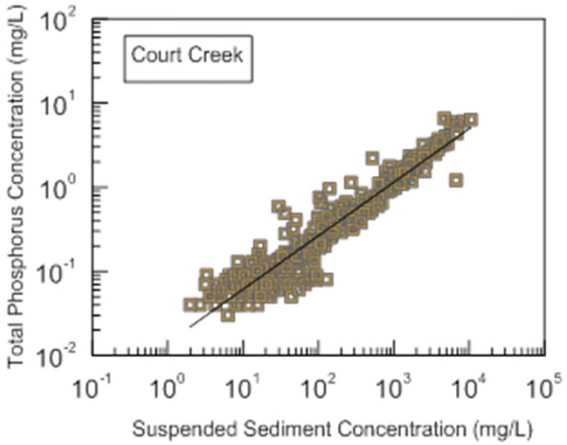
Kendall's Tau Correlation Coefficient ranged from 0.64 at Site 1 (Cox Creek) to 0.83 at Site 5 (Court Creek)











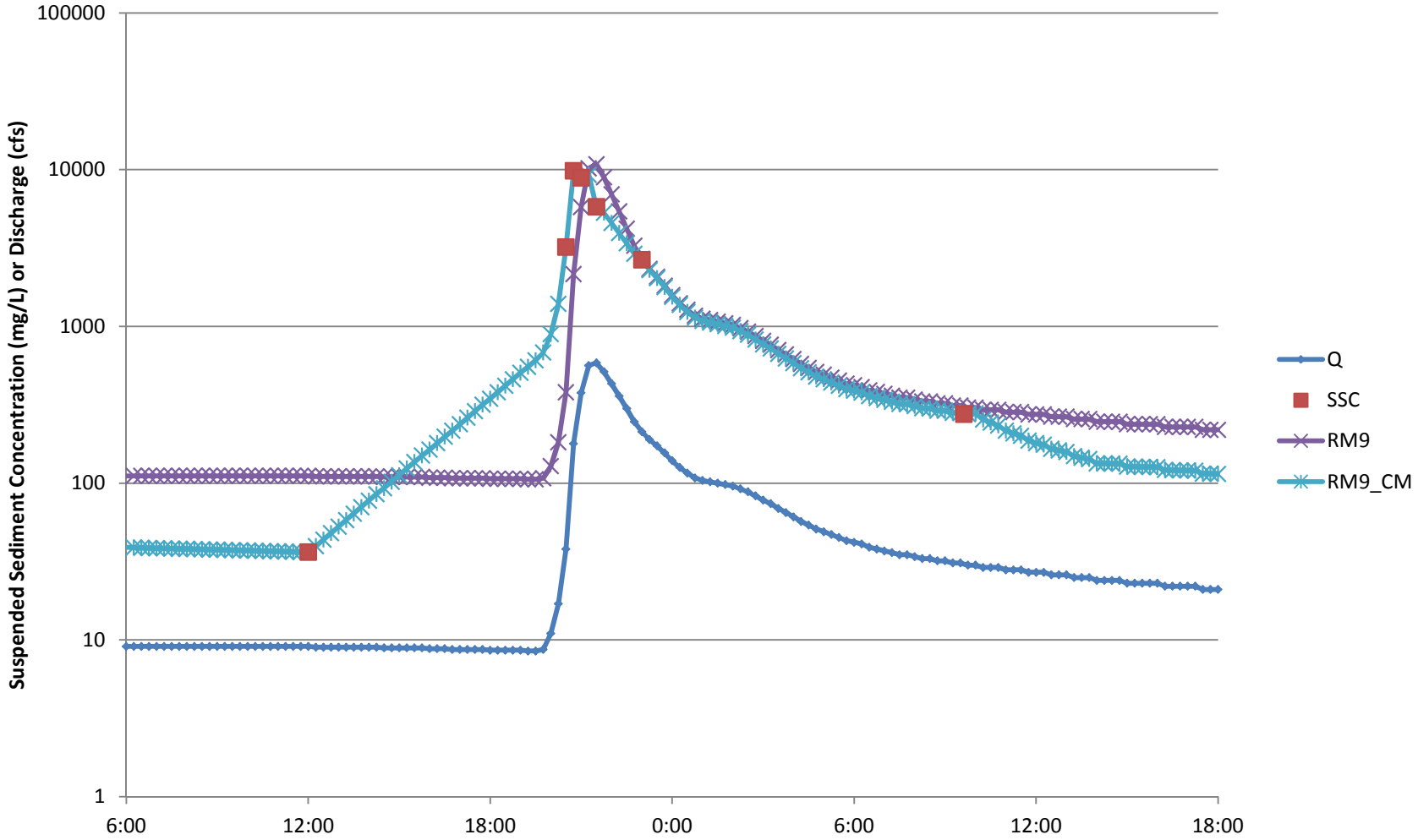
SSC and TP Models

- An 8-parameter model with terms for streamflow, seasonality, time trends, and a variable to describe the rate of change in flow was identified as the best performing SSC model (RM10).

- $a_0 + a_1 \, lnQ + a_2 \, lnQ^2 + a_3 \, sin(2\pi T) + a_4 \, cos(2\pi T) + a_5 T + a_6 T^2 + a_7 \, ln(Q_i/Q_{i-1})$

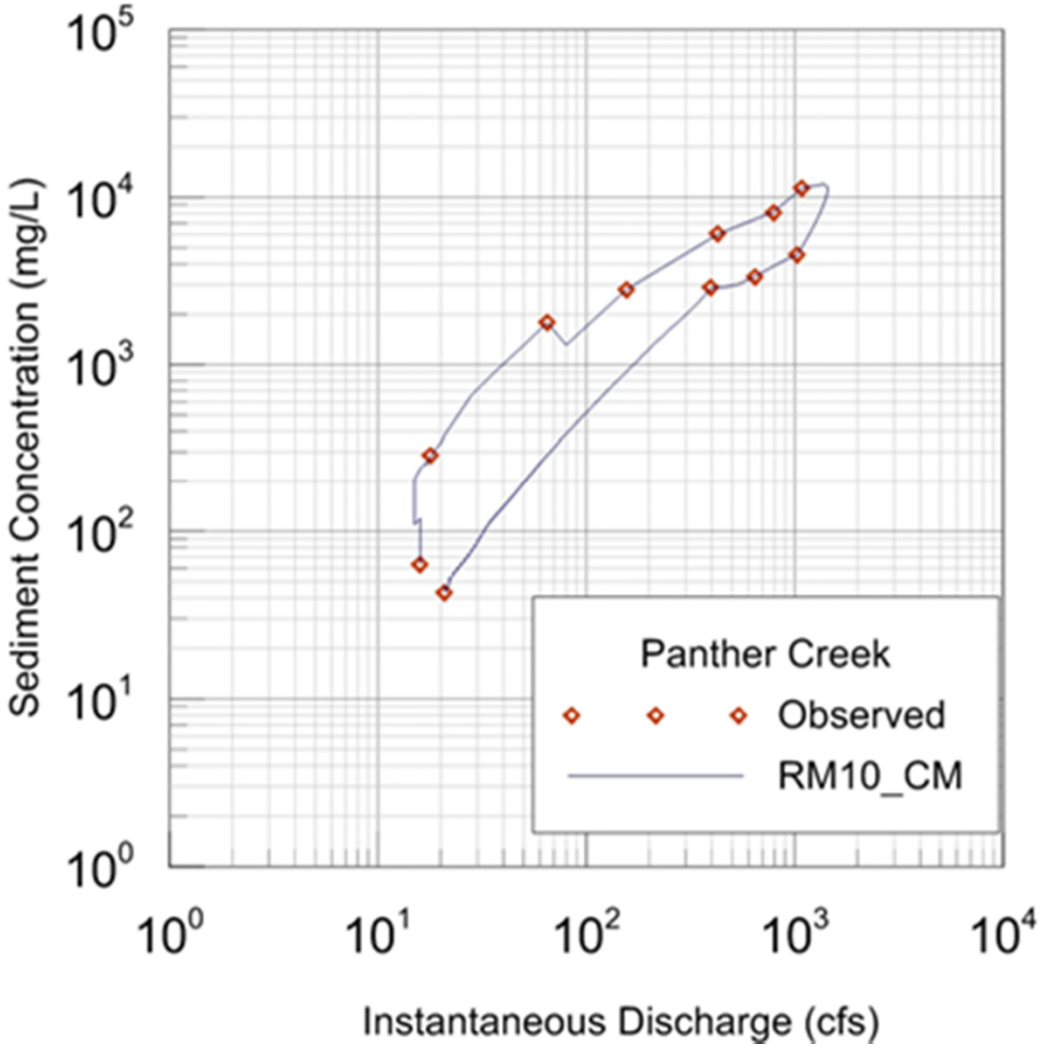
- The addition of SSC to the model described above was identified as the best performing model (RM12) for TP prediction.
- Model development and regression analysis programmed in MATLAB.

Simulating Continuous Concentration - Error Correction

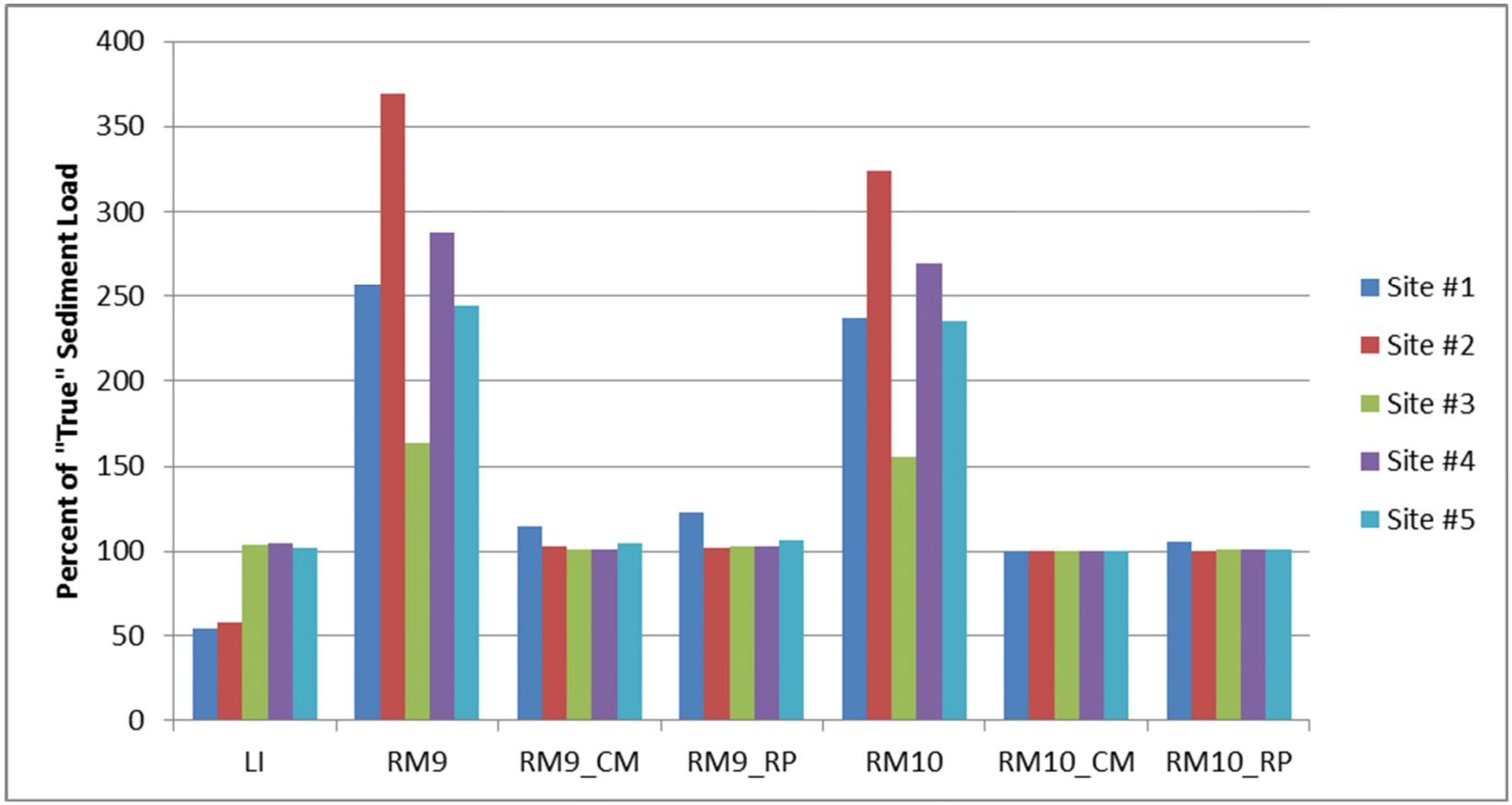


Recommended Method

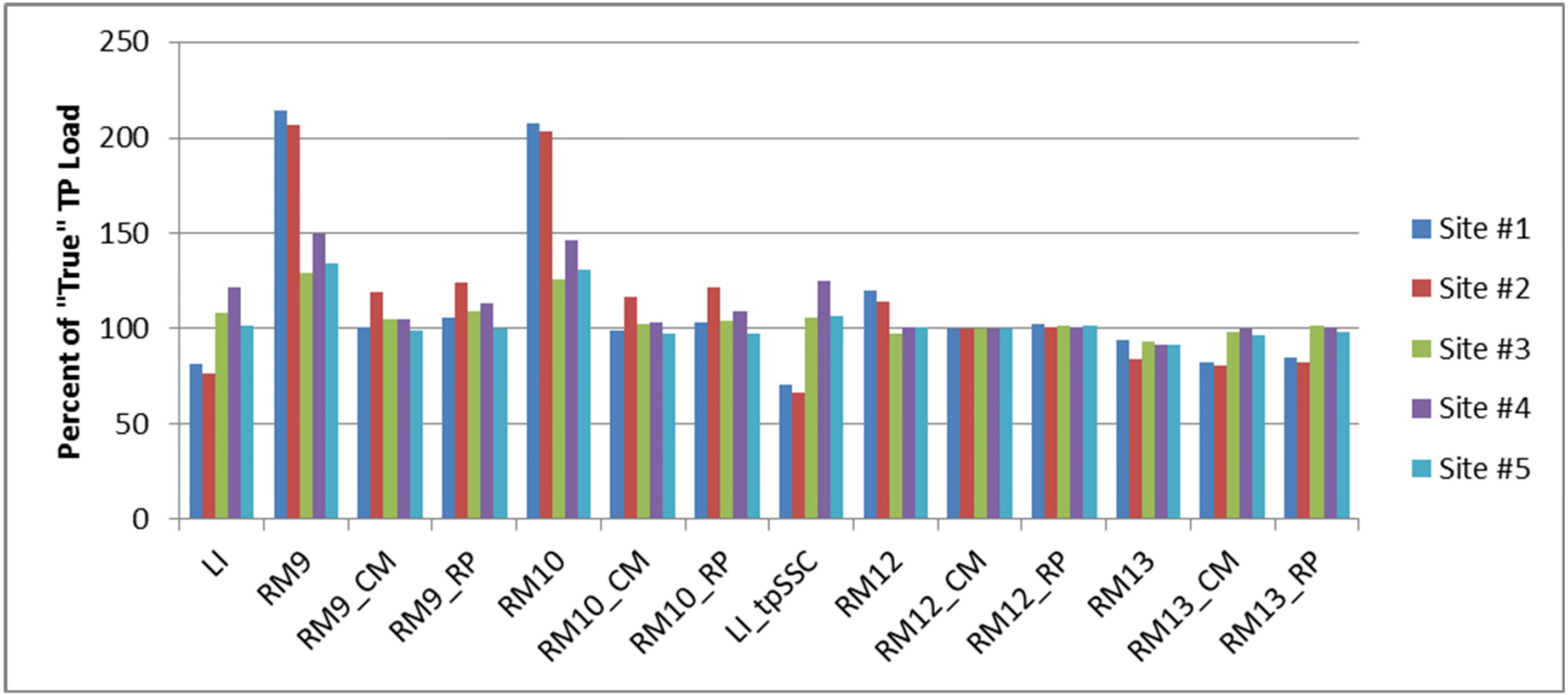
- Regression Model 10 with Error Correction by the Composite Method



Cumulative Variation in Sediment Load Estimates

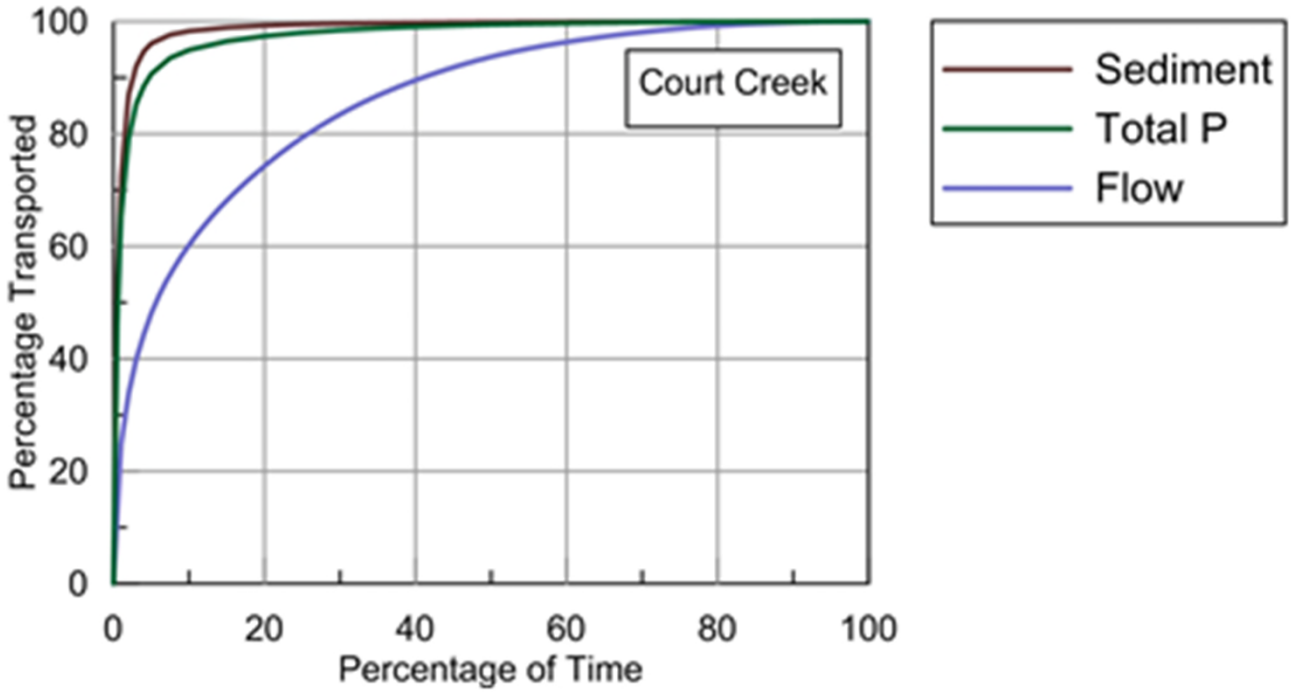


Cumulative Variation in Total Phosphorus Load Estimates



Percentage Transported

- During the ten-year study period, 5% of the time accounted for approximately
  - 50% of flow,
  - 91% of TP load
  - 96% of the sediment load.
- On average, the 1-day maximum accounts for 10% of annual flow and more than 30% of annual sediment and phosphorus load.

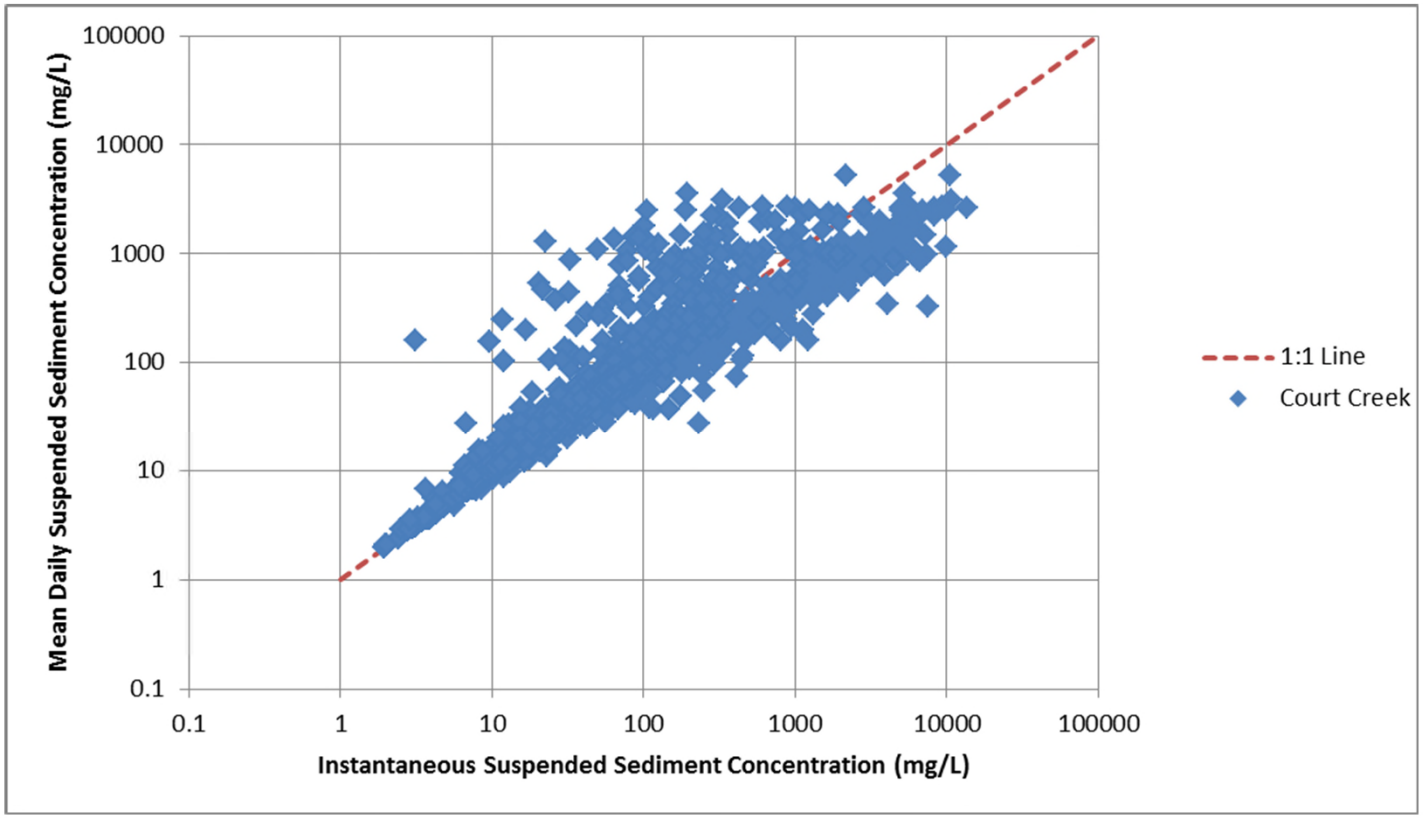


Study Conclusions

- Small, rural streams in western Illinois exhibit the following behavior:
  - During a single storm event, sediment and phosphorus concentrations change by several orders of magnitude
  - High stream flashiness leads to sub-daily peaks in sediment and total phosphorus.
  - Most flow, sediment, and phosphorus is transported in an incredibly small proportion of time.
- Due to this behavior, a load calculation method must be selected that allows for investigating small time scales.

Study Conclusions

- Caution against assumption that instantaneous water quality samples are representative of mean daily conditions for particulate constituents on small, flashy streams

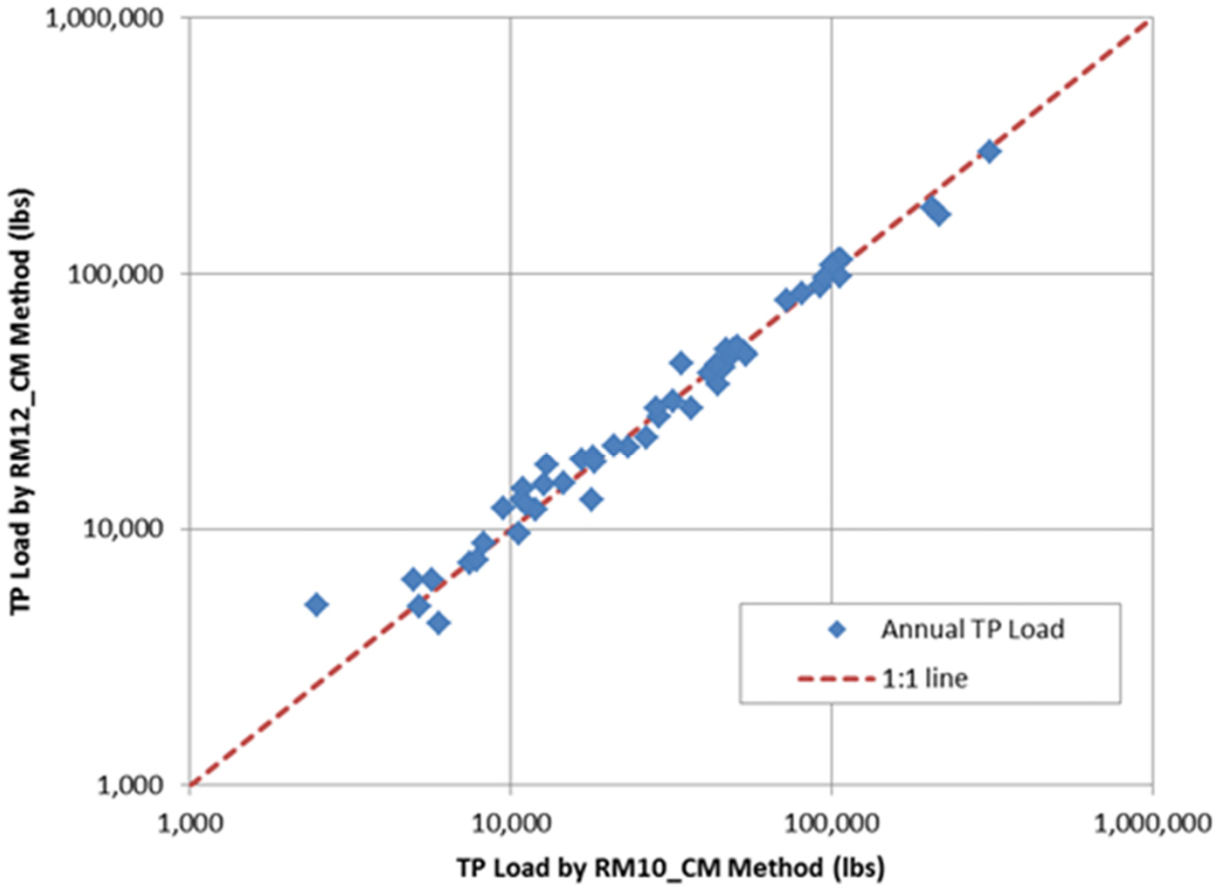


Recommendations

- Error-corrected regression models for intensively monitored streams (i.e. frequent fixed interval and storm event samples)
- For suspended sediment load estimates, RM10_CM is a suitable alternative to the worked record approach.
- For total phosphorus load estimates, RM12_CM is the recommended approach for TP load calculations when concurrent SSC is available for model building.

Recommendations

- When concurrent SSC samples are not available, RM10_CM is the recommended approach for TP load estimation.



Special Thanks

- Jim Slowikowski
- Kip Stevenson
- Ted Snider
- Josh Stevens
- Mike Smith