PHOSPHORUS EXPORT ACROSS AN URBAN TO RURAL GRADIENT IN THE CHESAPEAKE BAY WATERSHED

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Introduction

- Watershed exports of P have increased due to anthropogenic activities
- P is a limiting nutrient
- Excess P and N can cause eutrophication
- P dynamics are different among land uses – urban, agricultural, rural.
- Urbanization can affect stream temperatures, potentially influencing P cycling.

Overview

- Introduction
- Hypotheses
- Study Site
- Data Collection
- Long Term Data Results
- Creation of a Model
- Model results
- Discussion

Hypotheses

- This study seeks to examine the effects of altered stream hydrology and temperature on P concentrations across an urban-to-rural gradient in the Chesapeake Bay watershed
  1. Altered hydrology has increased temporal variability of P export from urban watersheds with P dominantly exported during high flow periods
     - Investigated using long term data and a load calculation model
  2. Elevated temperatures in urban streams enhance the release of phosphorus from sediment to the water column
     - Investigated using sediment incubations and seasonal P data

Study Location

- Baltimore urban Long-Term Ecological Research project (LTER)
  - Baltimore Ecosystem Study (BES)

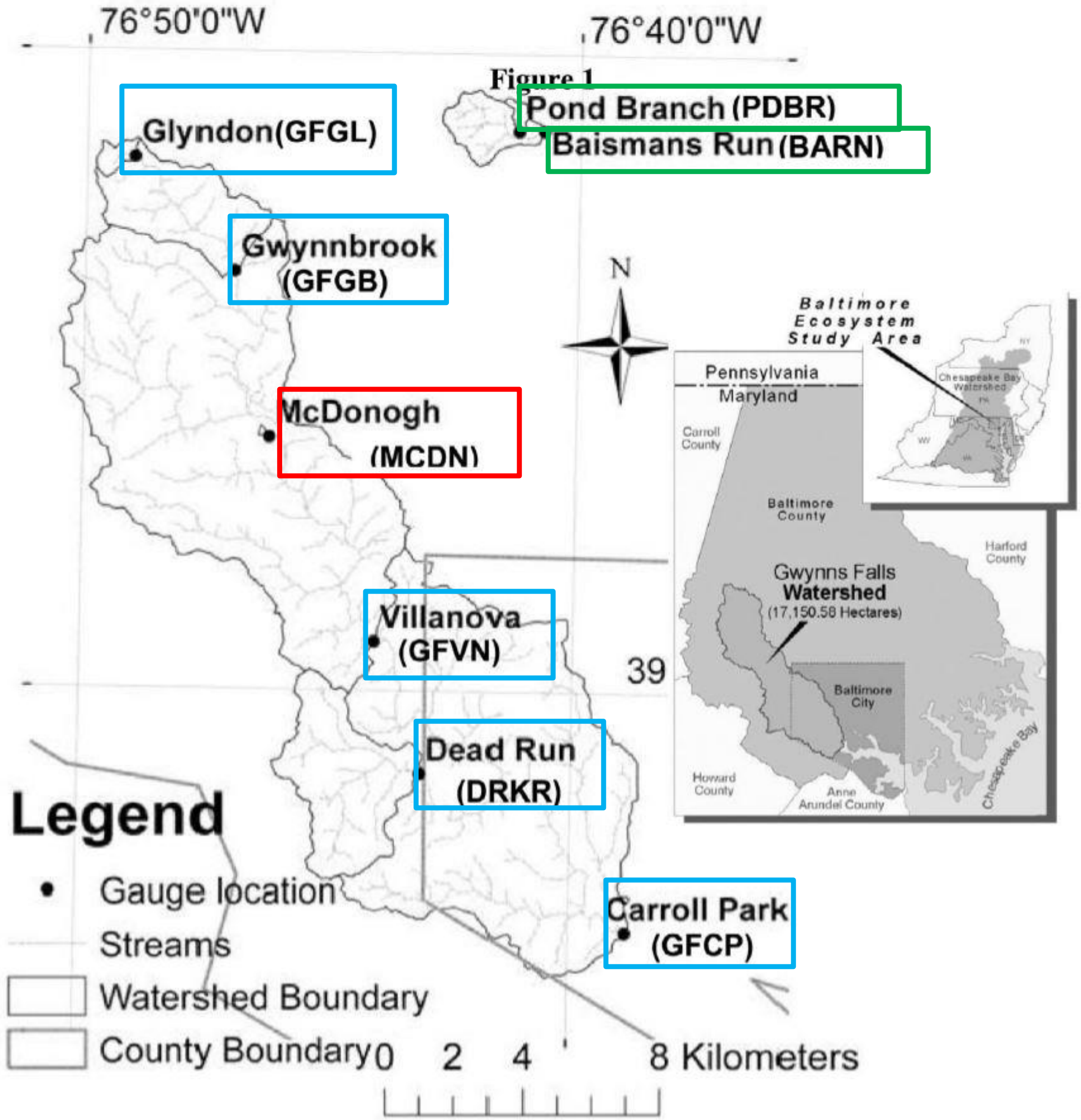
- Gwynns Falls watershed
  - Within Chesapeake Bay watershed
  - Piedmont region
  - Headwaters are suburban/residential
  - Middle and lower reaches are urban

Watershed Map

Urban

Agriculture

Forested



Watershed Characteristics

Table 1. Characteristics and P Exports of Gwynns Falls Main Channel Watershed (Segments), Selected Small Watersheds, and Nearby Reference Watershed[a]

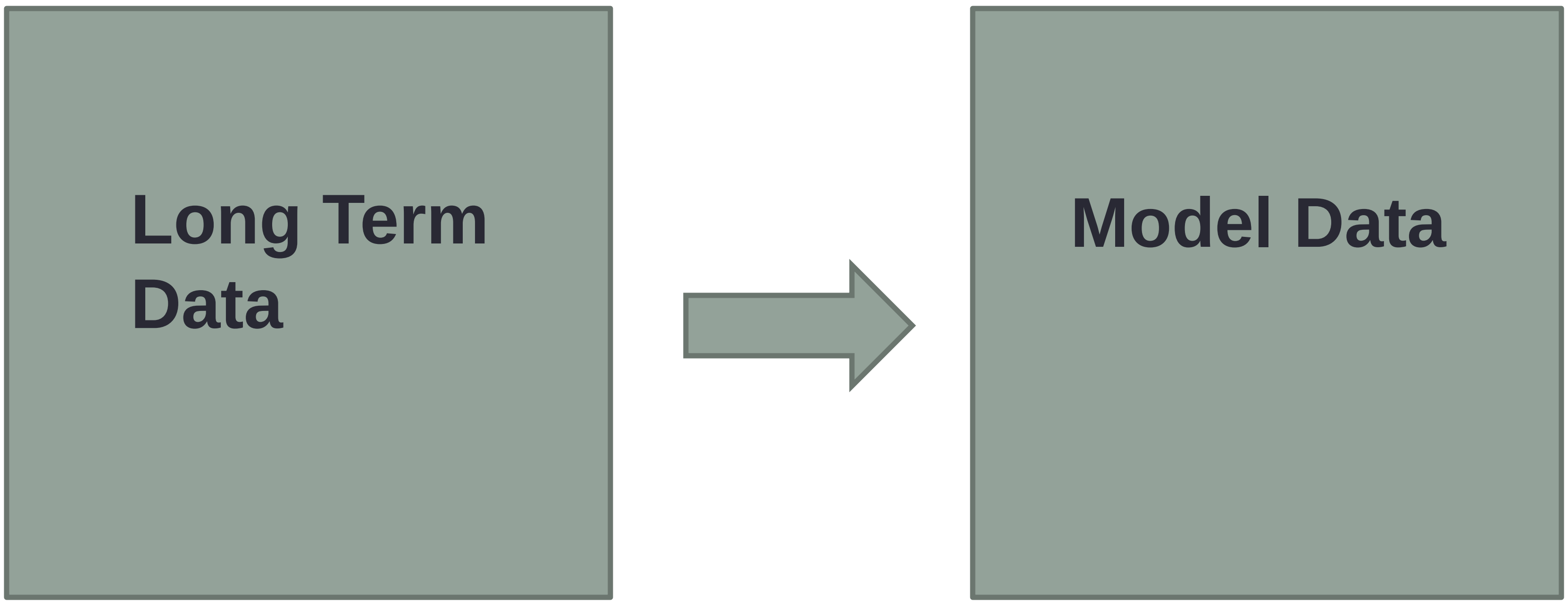
	Land Use/Context	Area (km^2)	Land Use (%) Impervious	Forest	Agricultural	Runoff (m)	Export ($kg\ km^{-2}\ yr^{-1}$) SRP	TP
			Main Channel Reaches					
Glyndon	suburban	0.8	19.0	19.0	5.0	0.34	9.2	48.4
Gwynnbrook	suburban	11.0	15.0	17.0	8.0	0.41	4.6	14.5
Villa Nova	suburban/urban	84.2	17.0	24.0	10.0	0.42	4.2	33.6
Carroll Park	urban	170.7	24	18.0	6.0	0.45	9.3	83.7
			Small- and Medium-Sized Watersheds					
McDonough	agriculture	0.1	0.0	26.0	70.0	0.35	11.6	24.6
Dead Run	urban	14.3	31.0	5.0	2.0	0.58	6.3	24.5
Pond Branch	forested	0.38	0.0	100.0	0.0	0.46	1.1	2.8
Baisman Run	low residential	3.8	0.3	71.0	2.0	0.41	1.2	3.1

[a]Watershed land cover and impervious surface data are from *Shields et al.* [2008] and the National Land Cover Database.

Data Collection and Analysis

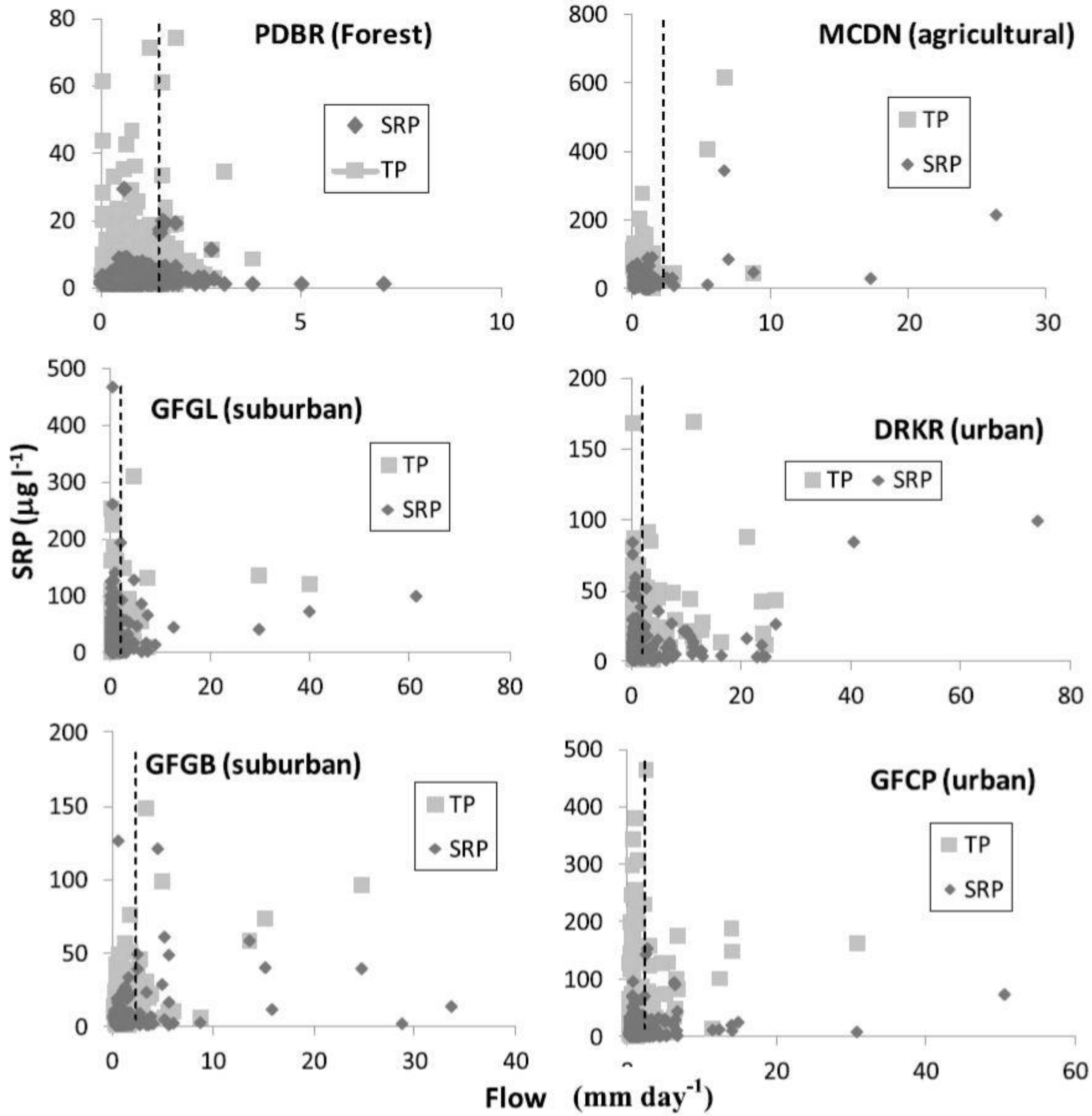
- Discharge monitored by USGS at all locations
- Weekly sampling, no regard for flow conditions
- SRP (Soluble Reactive Phosphorus) analyzed on <0.45µm
- TP (Total Phosphorus) analyzed on unfiltered sample
- Samples sent to Cary Institute of Ecosystem Studies
- Sampling design included checks, standards, blanks, and field spikes.
- Benefits of an LTER
  - Long term stream discharge and chemistry data from 1998/1999 to 2007 covering a range of climate conditions.
- Model developed to estimate long term export of P

Long term data used to create model



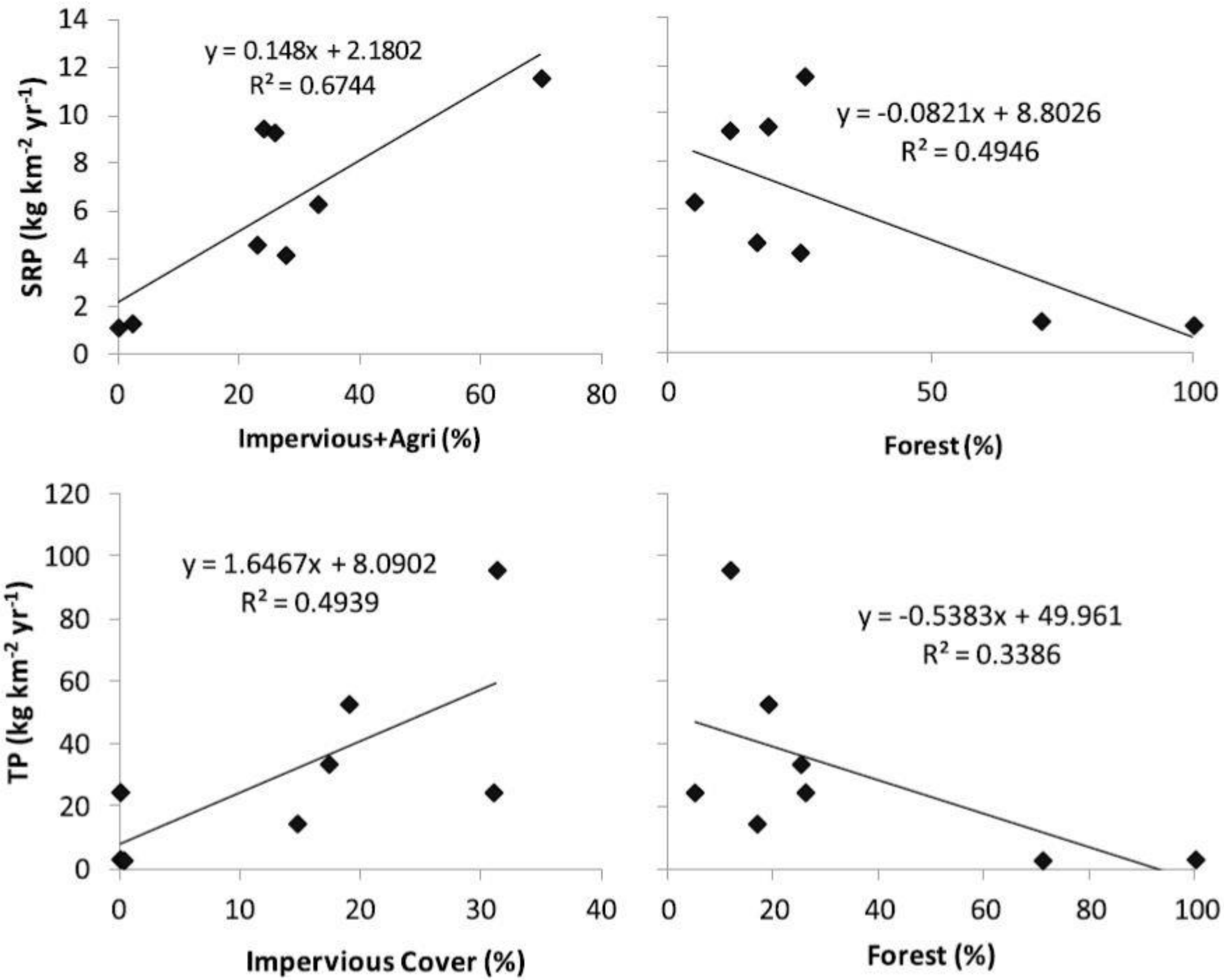
P changes with streamflow

- Actual measurements
- No significant relationship with P and discharge
- Different response from urban vs. forest



Land use and P export

- Impervious and Ag strongest correlation



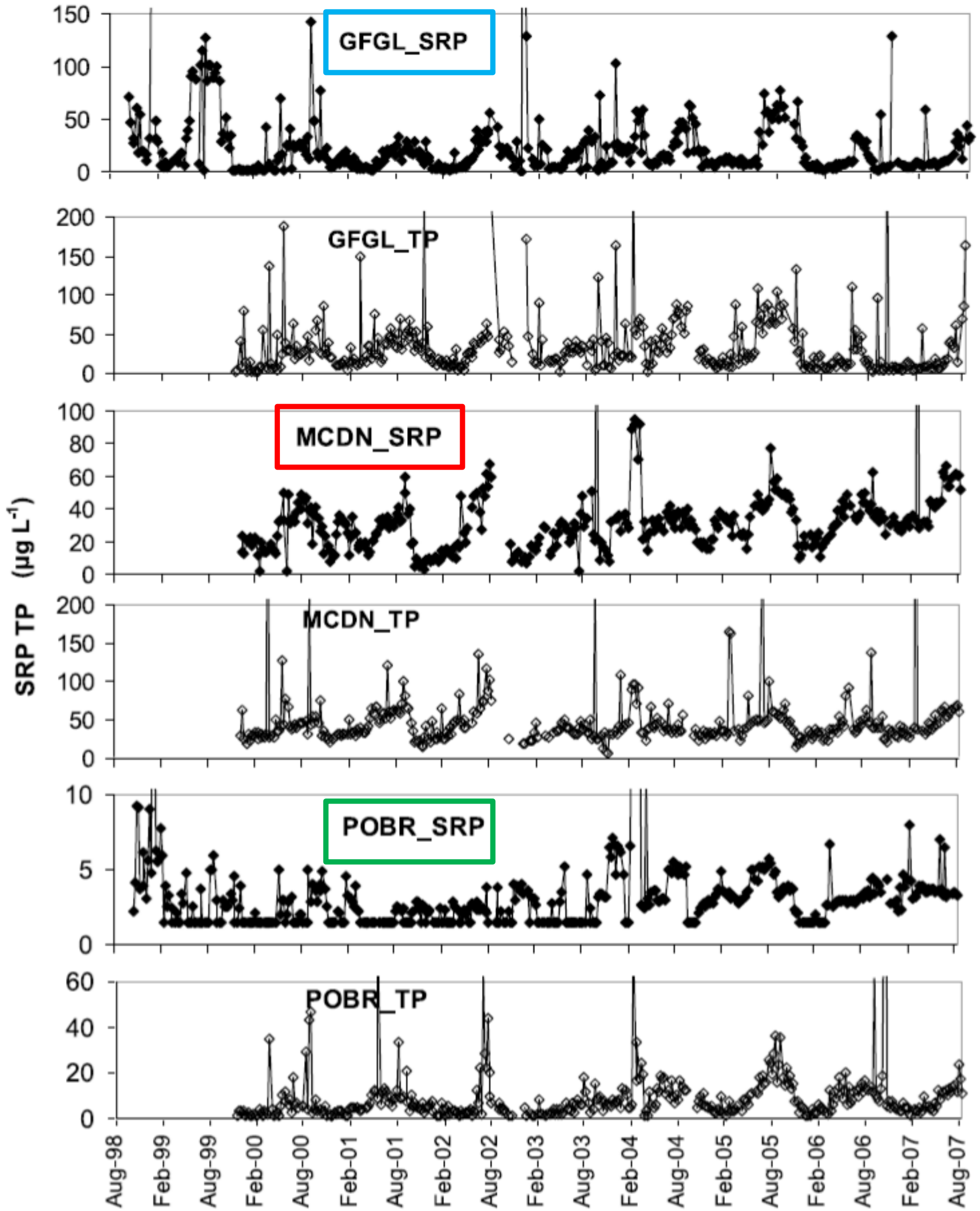
Seasonal Patterns of P

Seasonal Patterns of P in headwater catchments.

Summer = high
Winter = low
Significant difference

Temperature Effect

Note: Actual measurements, different scales

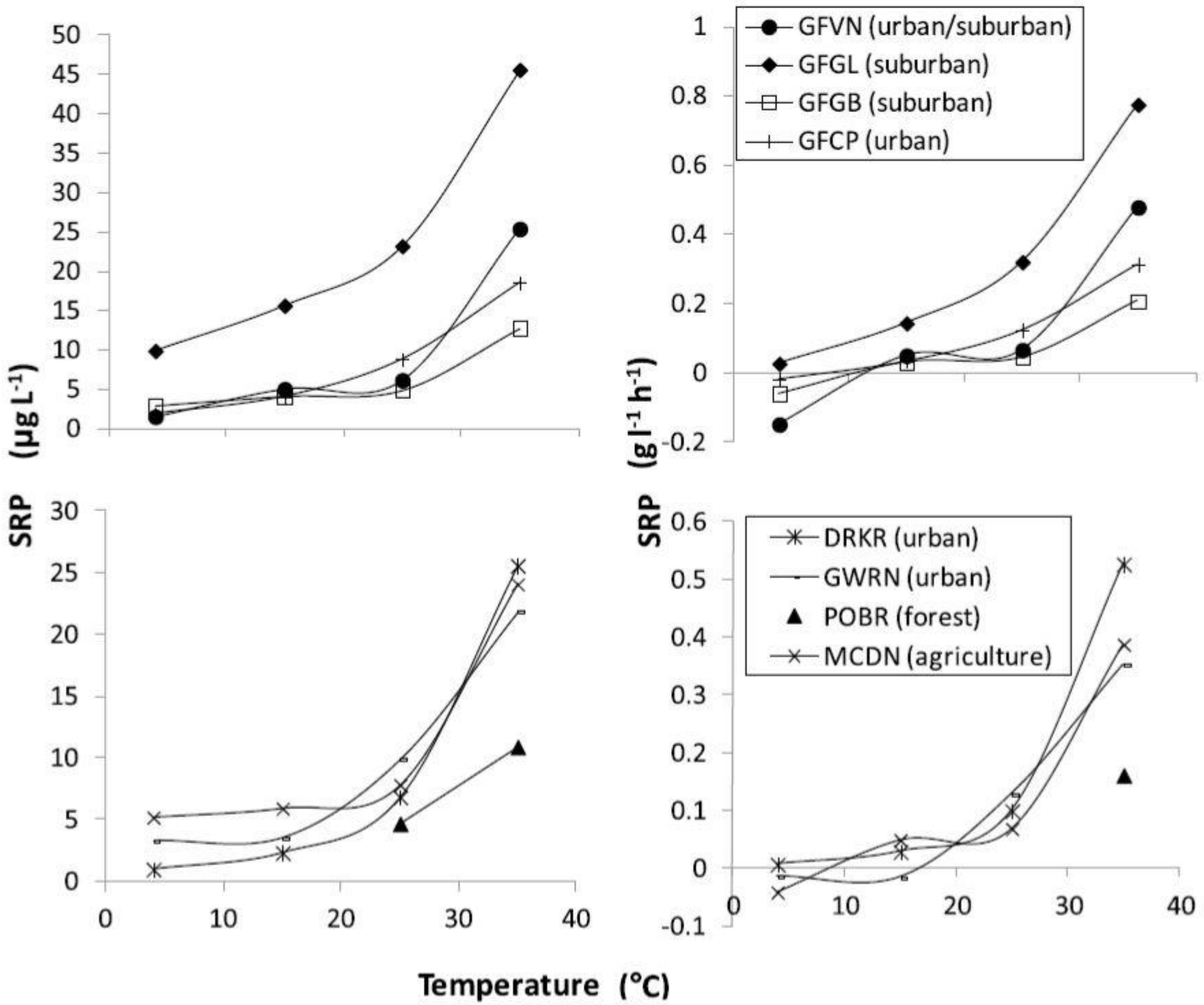


Sediment Incubations

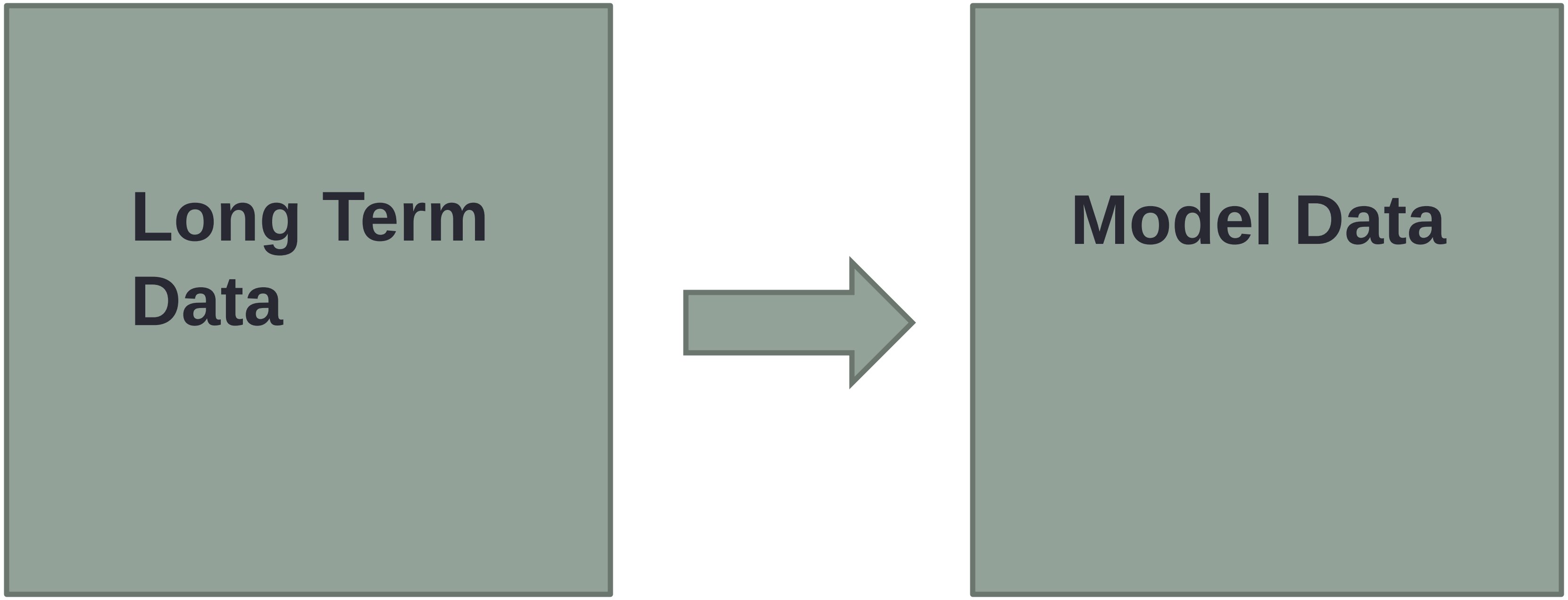
- Temperature effects on phosphorus release
- Sediment collected
  - Sieved at 2mm
  - Sediment and water mixed, allowed to settle
  - Incubated in the dark at 4,15, 25, and 35^{0}C
  - Water was collected at 0, 6, 12, 24, and 48hrs
  - SRP measured using a spectrophotometer

P release from sediment

- SRP increased with temp
- Release rates increased with temp



Long term data used to create model

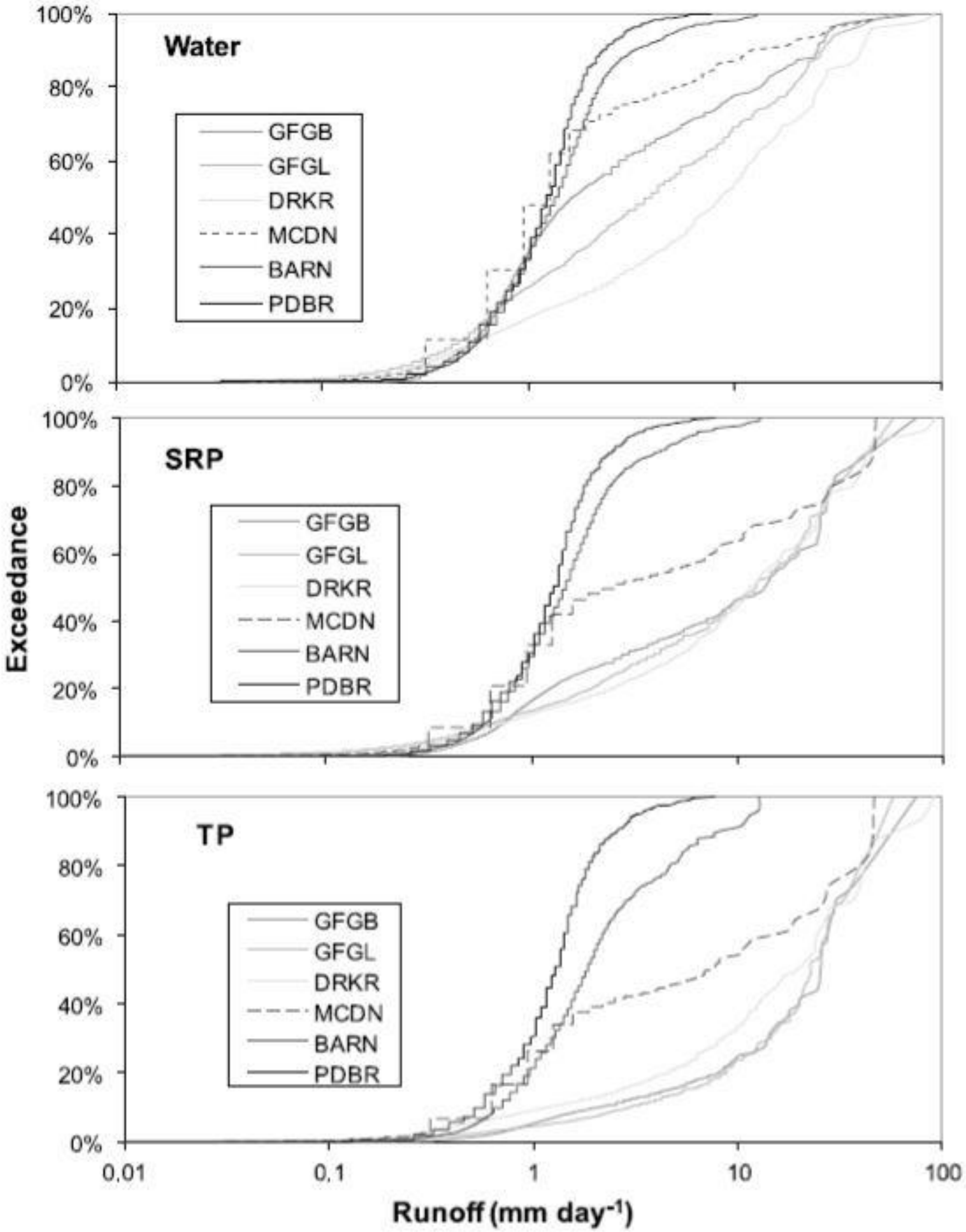


Model Development

- Estimation of TP and SRP for non-sampled days calculated from USGS Load Estimator (LOADEST)
  - Calculates mass export of sediment and chemicals to the bay
  - Uses continuous average daily flow and discrete chemical concentrations
  - Multiple parameter regression model with bias corrections
- Streamflow, SRP, and TP for each station were used to calibrate the model.
  - Dependence of concentration on:
    - Discharge
    - Season
    - Long-Term Trends
- Generated estimates of daily fluxes of SRP & TP which generated flux annual estimates

CFD's

- Modeled data
- Differences in flow response by land use
- P export response from urban watersheds favors more runoff



Cumulative Flow Distribution (CFD)

Table 2. Runoff Values When 20%, 50%, and 80% of Water, SRP, and TP Were Exported From Selected Subwatersheds[a]

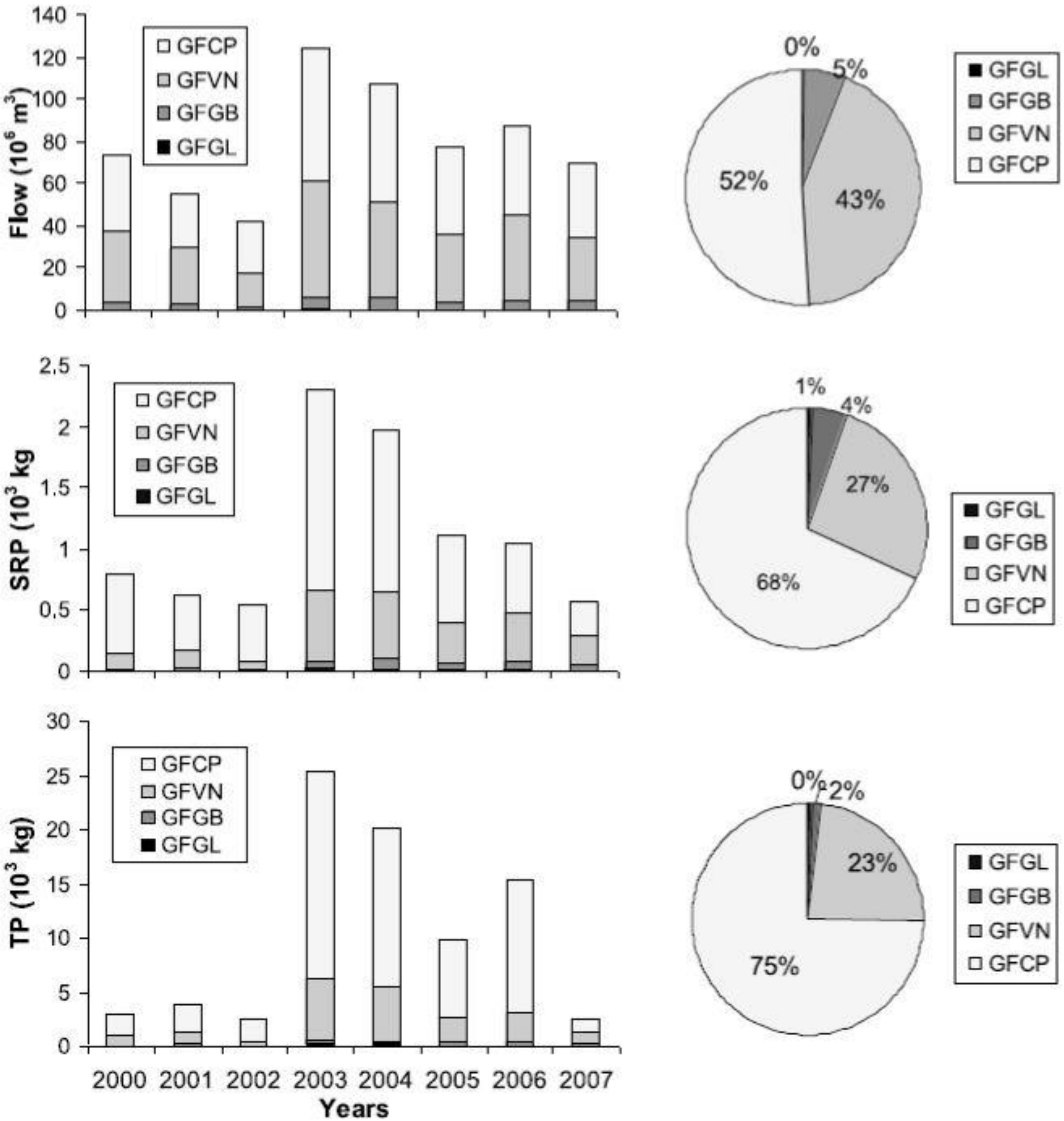
	Watershed/Land Use					
	POBR/Frosted (mm d^{-1})	BARN/Residential (mm d^{-1})	MCDN/Agricultural (mm d^{-1})	GFGB/Suburban (mm d^{-1})	GFGL/Suburban (mm d^{-1})	DRKR/Urban (mm d^{-1})
			Water			
20%	0.7	1.0	0.6	0.7	0.7	1.3
50%	1.2	1.4	1.3	1.6	3.6	8.5
80%	1.8	2.2	5.0	13.1	18.8	25.3
			SRP			
20%	0.8	0.8	0.6	1.2	2.0	2.4
50%	1.3	1.5	2.5	13.8	12.3	11.5
80%	1.8	2.4	28.2	28.9	29.3	36.0
			TP			
20%	0.8	0.8	0.9	8.0	8.8	4.5
50%	1.3	1.9	1.9	25.3	22.7	19.8
80%	1.9	4.7	36.1	39.0	39.3	41.9

[a]Data are from Figure 5.

- Figure 5 data presented in tabular format
- Significant difference between urban/suburban and forested/low density residential P export

Export of P

More urbanized portion of the watershed exports 51% of the water, but 68% of the SRP and 75% of the TP



Discussion- Annual Export

- Watershed Urbanization and Annual P Export
  - Strong correlations of SRP and TP with impervious cover
  - Urbanization and Agriculture increase annual P export
  - Higher export from most urbanized areas indicates potential leaky sewers (Fig. 7) However no intentional discharge

- Urbanizing areas have the potential to increase P export to the Chesapeake bay, contributing to algal blooms, and summer hypoxia

Discussion- Timing of Export

- Effect of Urbanization on the Timing of P Export
  - Flashy hydrographs
  - Elevated P at baseflow = sewage leaks?
    - Dilution at moderate flows
    - Elevated at high flows due to sanitary sewer overflow OR
  - SRP in channel sediment pore water or TP eroded with sediment
  - Most SRP and TP exported under **high flows** in urban areas.

- Load reductions should focus on urban areas and large storm events which transport more P from urban areas than small or medium size events.

Discussion- Temperature Effects

- Temperature Effects on Seasonal Changes in P concentration
  - SRP appears to be driven by temperature, highest in summer, lowest in winter
  - Sediment incubations showed temperature dependence of SRP release
  - Increasing temps could cause elevated release of P into waterways with changing climate conditions.

- Rising stream temperatures due to urbanization and changing climate could exacerbate the release of P.

Hypotheses (revisited)

- This study seeks to examine the effects of altered stream hydrology and temperature on P concentrations across an urban-to-rural gradient in the Chesapeake Bay watershed
  1. Altered hydrology has increased temporal variability of P export from urban watersheds with P dominantly exported during high flow periods
     - LTER data showed no correlation
     - Model data supported this hypothesis
  2. Elevated temperatures in urban streams enhance the release of phosphorus from sediment to the water column
     - LTER data of seasonal P fluctuations were supported by sediment incubations

Class Discussion

- The LTER data came to the conclusion that there was no correlation of storm flow with P export, the LOADEST model found that P export increased with large storm events.
- What factors do we think contributed to the authors reaching these two different conclusions?