Trends in Baseflow in New Jersey Streams and Correlation with Imperviousness using Different Metrics and Timeframes

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Motivation

- **Much of NJ depends on surface water for water supply**
- **Droughts are common; perhaps to become more common and/or severe with climate change**
- **Streams and reservoirs rely on baseflow during drought**
- **Sufficient baseflow is critical to stream ecology**
- **Historically rural, water-supply watersheds have been/are urbanizing**

Motivation (cont.)

- **Urbanization (replacing pervious surfaces with impervious, like pavement and rooftops) reduces infiltration, theoretically reducing baseflow**

- **Therefore, urbanization could therefore pose an important threat to surface water supply (and stream ecology), especially during drought**

- **But, several confounders to the theoretical relationship**
  Urbanization is a lot more complex than just paving over the soil!

Possible confounders to the theory
increased urbanization → decreased baseflow

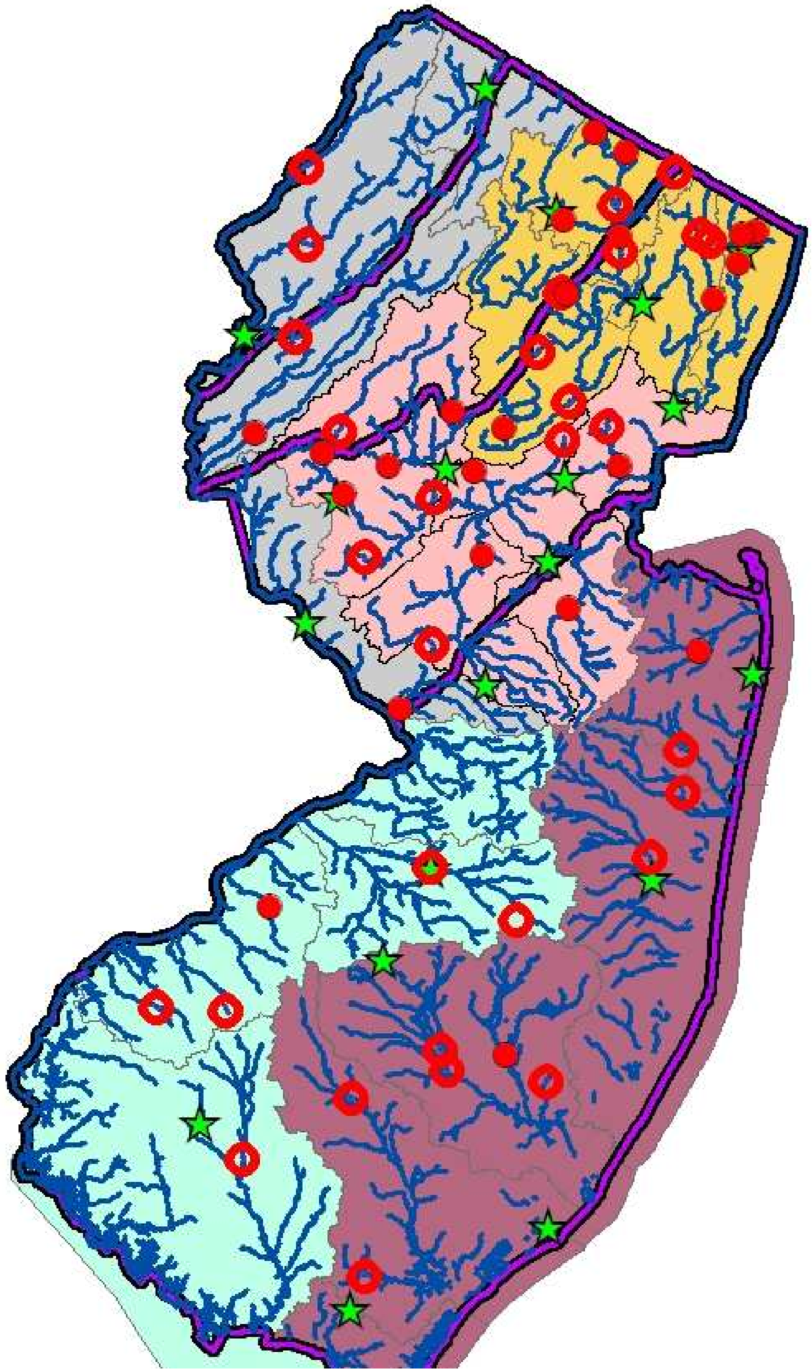
- Septic systems recharge groundwater;
- Lawn watering can recharge groundwater; lawn watering is likely to be high during drought
- This artificial recharge water may have originated from a significant distance (vertically or horizontally) from where it was recharged
- Wastewater treatment plants discharge feed streams constantly; population growth increases discharge
- Leaky sewers or water pipes can recharge groundwater
- Detention/retention basins and constructed ponds/lakes can moderate baseflow
- Replacing one type of vegetation with another could affect evapotranspiration and recharge

So, Is Urbanization Causing Declines in Stream Baseflow?

First Step: Analyze for trends in historic baseflow records as measured at long-term USGS stream gages

Long-term stream and precipitation gages in NJ

- >25 years of record; few missing years
- drainage area <350 sq mi
- 53 gages
  - 31 “unregulated”
  - 22 “regulated”
- 19 long-termprecipitation

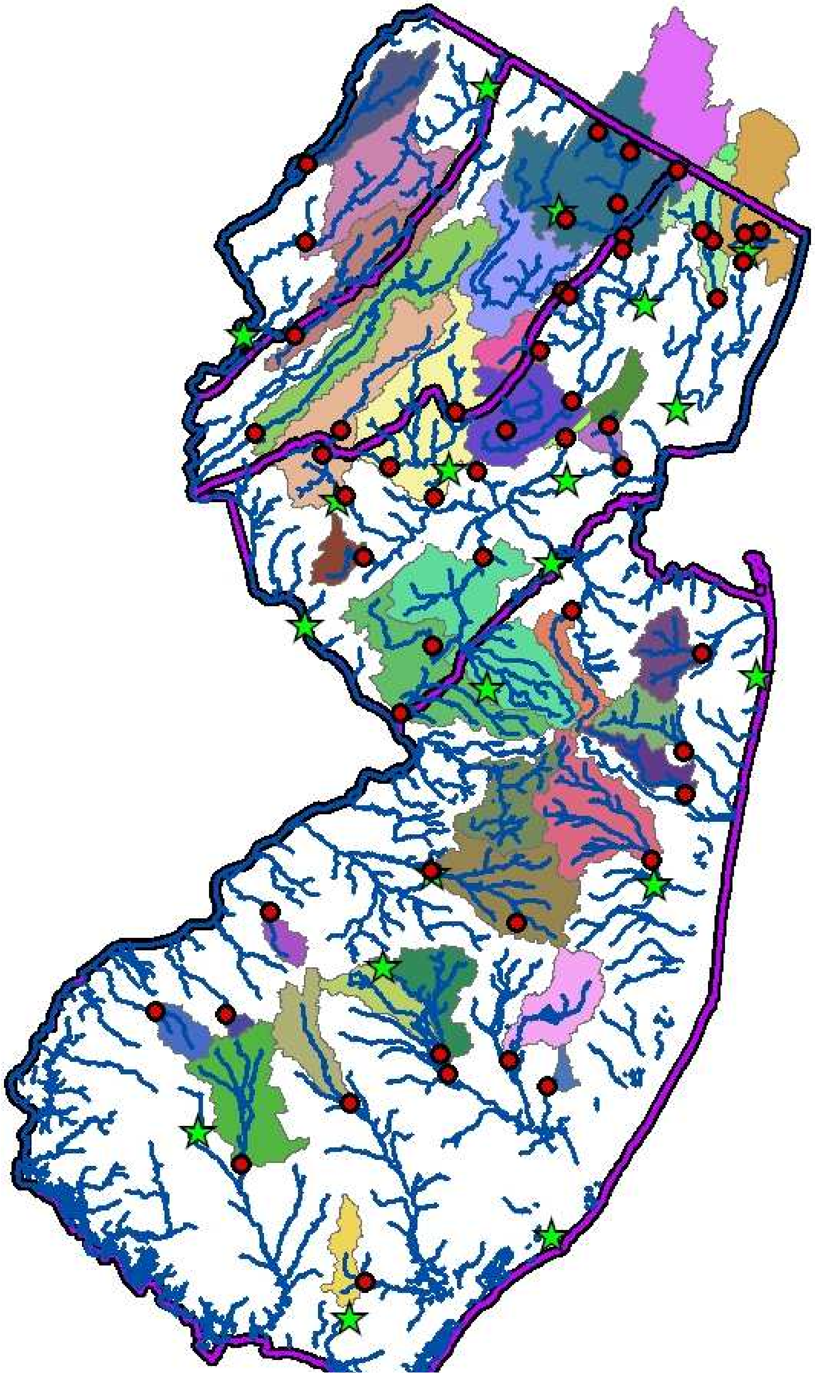


● Stream Gage -- Regulated

○ Stream Gage -- Unregulated

★ Precipitation stations

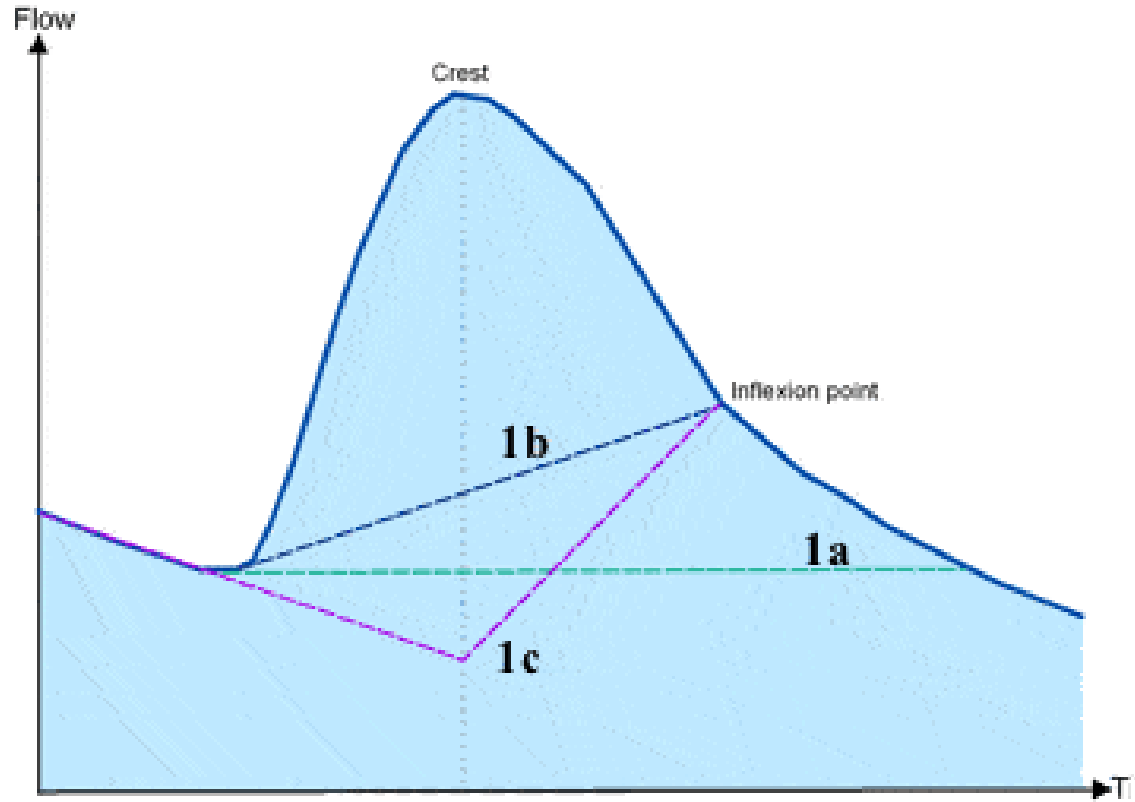
Watersheds of long-term stream gages



- Stream gages
- Precipitation stations

Need to separate measured daily flow into "stormflow" and "baseflow"

- No definitive answer
- Several, automated "hydrograph interpretation" methods available (HYSEP, PART)
- Another type of method: digital filter
- "WHAT" is a web implementation of the Eckhardt digital filter
- compute daily baseflow; aggregate to annual



Investigate Different Baseflow Metrics

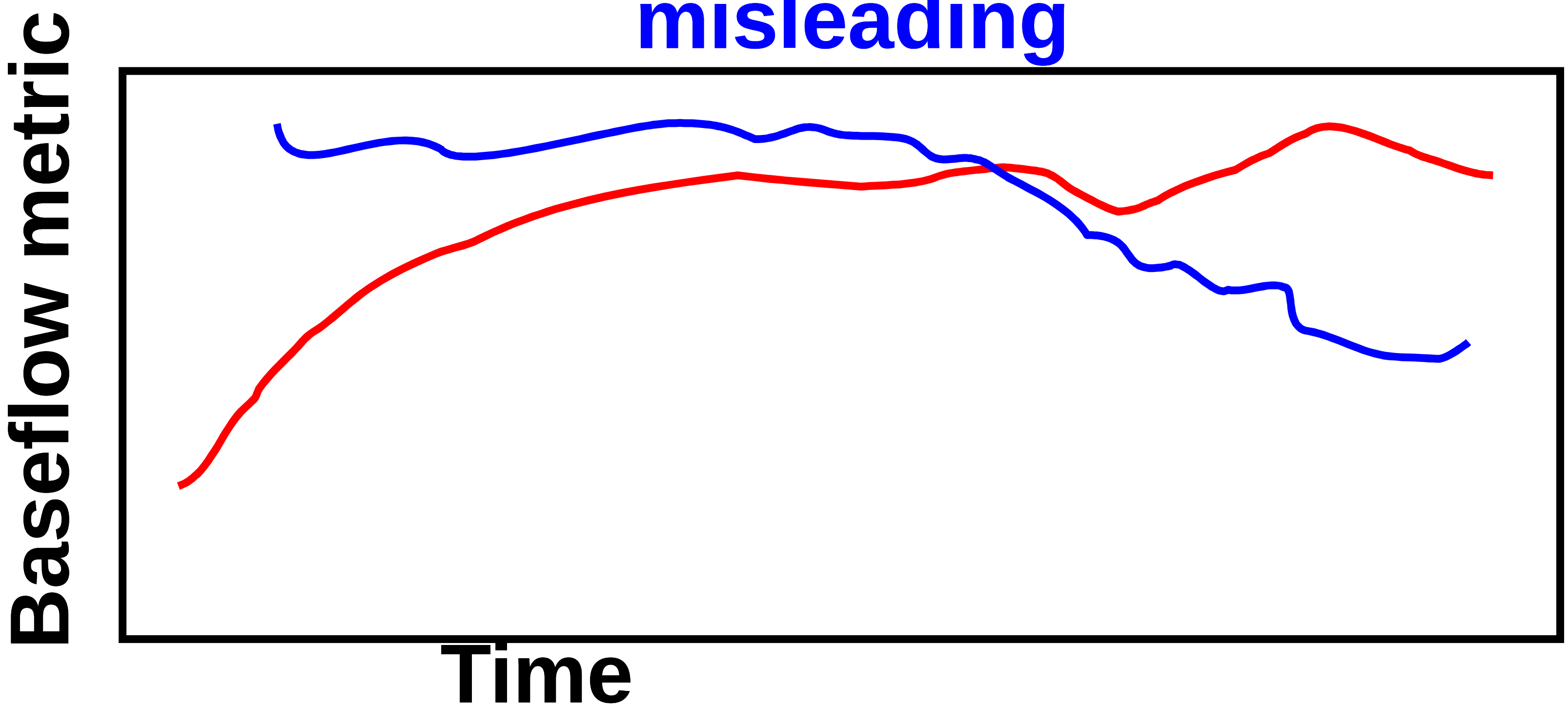
- **Normalized annual baseflow (m^3/yr) by**
  - **watershed area (BF, cm/yr)**
  - **annual precipitation (BF/P, unitless)**
  - **total flow (BF/TF, aka baseflow index)**

- **analyze for baseflow trends using Mann-Kendall test**

Investigate for Trends in each Metric Using the Mann-Kendall Test

- **Commonly used for trend detection in hydrology**
- **Each value is compared to all successive values**
- **The direction of change (increase, decrease or no change) is determined for each pair of values (magnitude of change is not considered)**
- **If (number of increases) >> (number of decreases), then statistically “significant” increasing trend**
- **If (number of increases) << (number of decreases), then statistically “significant” decreasing trend**

If you examine only the whole record, the trend detection results might be misleading



So, investigate successive blocks of years, adding 10-year increments, moving backwards in time from 2005

Percentage of gages with decreasing and increasing trend

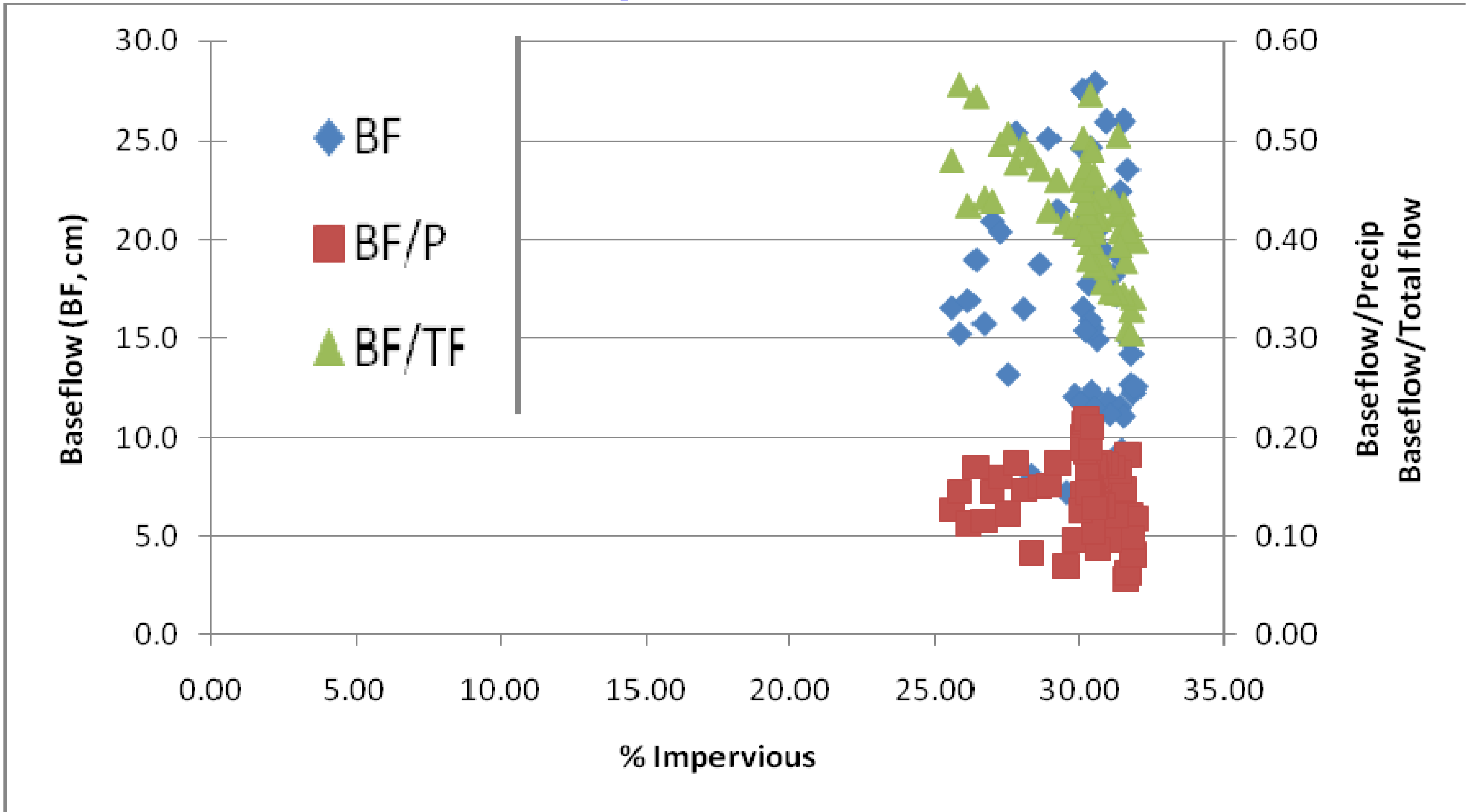
(p=.10, ie., 90% certainty of level)

Start Year	Number of years	Number of gages	BF		BF/TF		BF/P	
			Inc	Dec	Inc	Dec	Inc	Dec
1996	10	24	0%	4%	13%	0%	0%	0%
1986	20	28	0%	4%	4%	4%	4%	7%
1976	30	26	0%	0%	0%	0%	0%	12%
1966	40	24	0%	4%	8%	0%	0%	25%
1956	50	23	0%	4%	9%	13%	13%	39%
1946	60	19	0%	0%	11%	21%	16%	42%

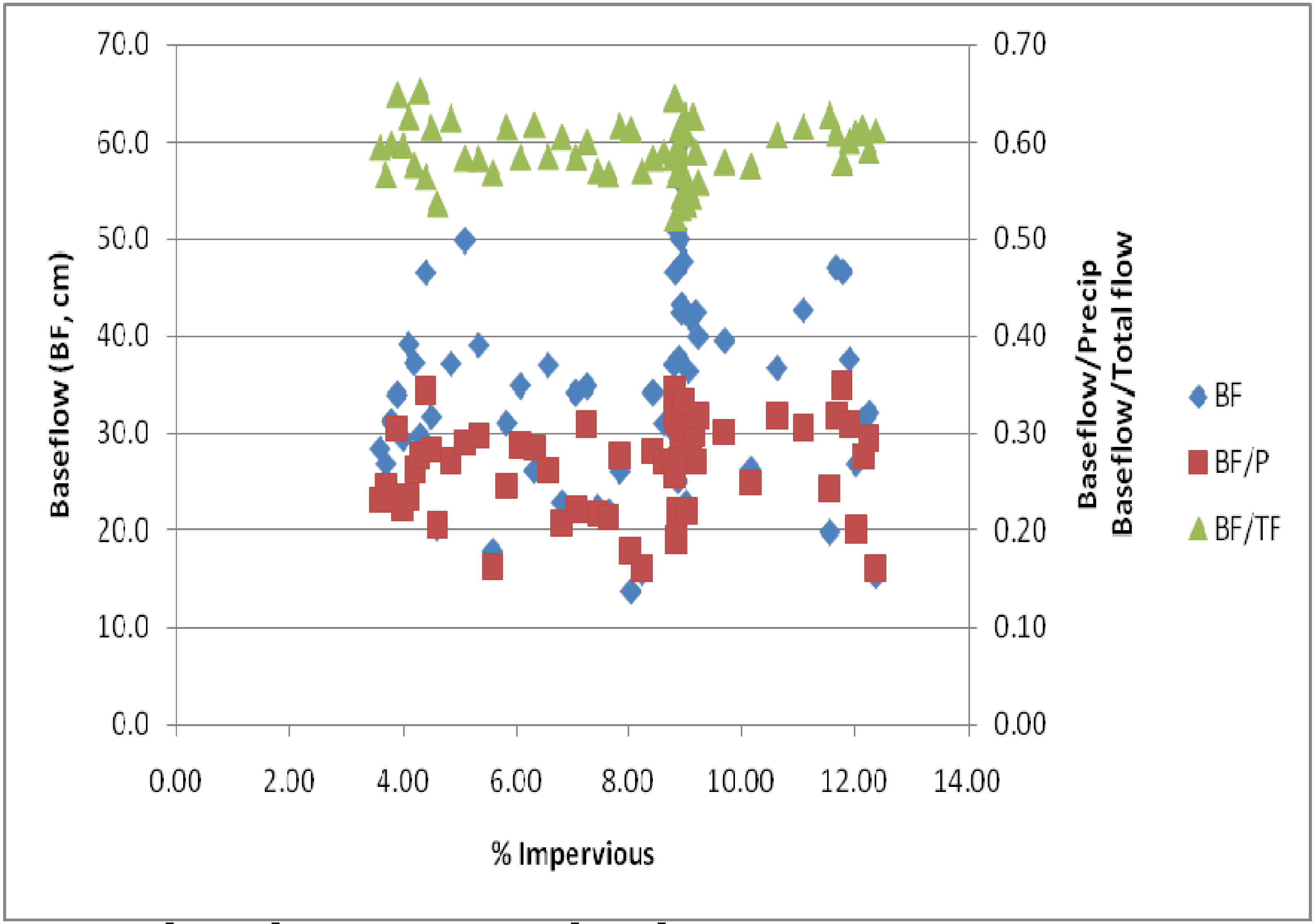
Is baseflow correlated with imperviousness?

- **Develop population density – imperviousness correlation using current data from NJDEP and US Census**
- **Develop historical population density timeseries for each watershed using historical census data back to 1940**
- **Develop historical imperviousness timeseries by correlation with historical population**
- **Within each basin, are historical annual baseflow metrics correlated with concurrent imperviousness?**

Correlation between baseflow and imperviousness for a particular watershed using historical, concurrent baseflow and imperviousness , 1940-2002



Rahway River near Springfield – the most urbanized basin



Passaic River near Chatham

Percentage of Watersheds with Significant Correlation between Baseflow and Imperviousness
1940-2002
(n=41 watersheds)

	BF	BF/Pi	BF/TF
Positive Correlation	5%	12%	7%
Negative Correlation	5%	15%	15%
No Correlation	90%	73%	78%

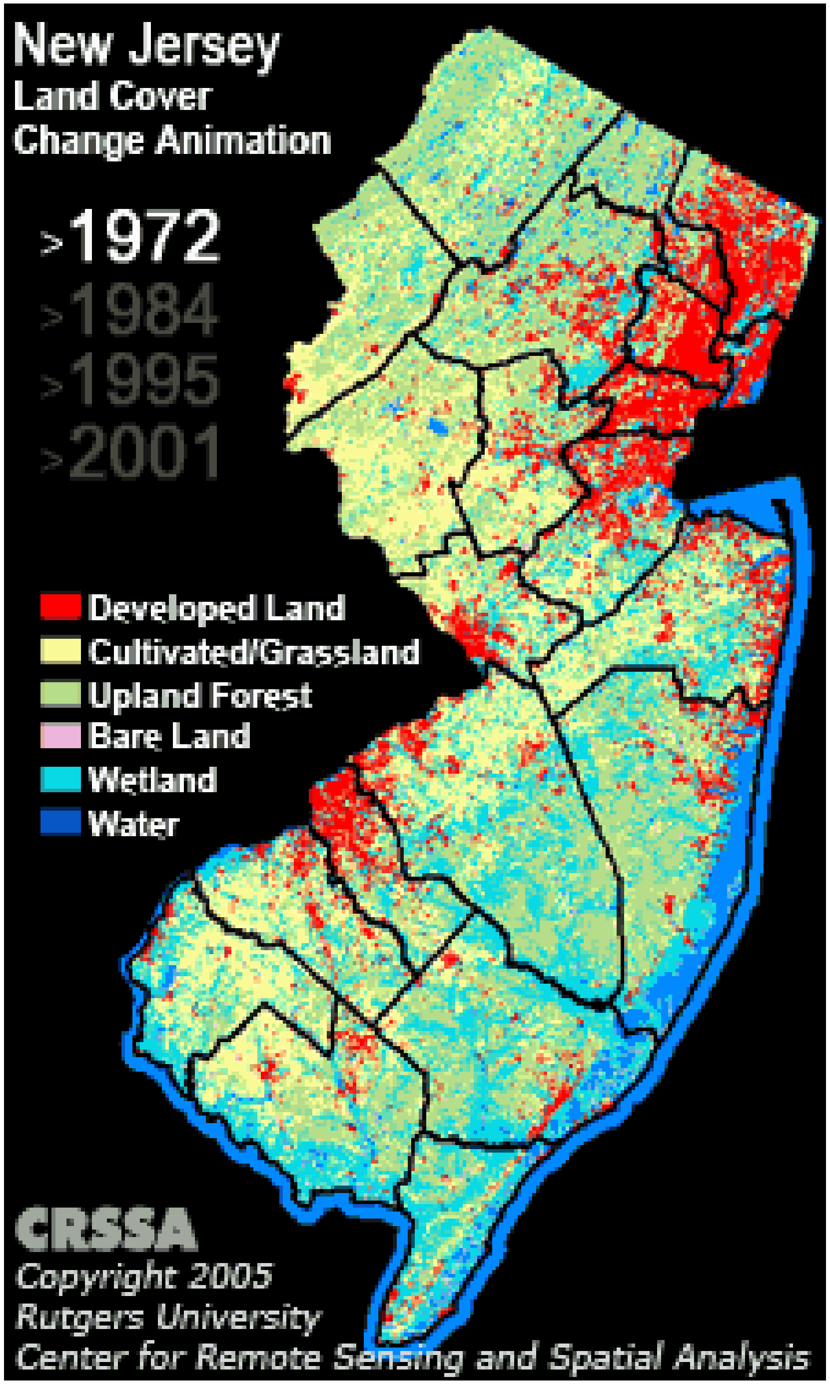
CONCLUSIONS

- Few trends in baseflow proper
- Trends in BF/TF balanced between increasing and decreasing
- In last 20 years, no many trends in BF/P, but trends decreasing trends are more common over longer time periods
- Baseflow and imperviousness were mostly not correlated; positive ~= negative

So, does this mean urbanization is not a threat to baseflow in NJ?

Is this the definitive method of analysis?
Will the future be like the past?


Thank you
Questions, Comments, Suggestions?


New Jersey
Land Cover
Change Animation
>1972
>1984
>1995
>2001
Developed Land
Cultivated/Grassland
Upland Forest
Bare Land
Wetland
Water
CRSSA
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Percentage of gages with decreasing and increasing trend

(p=.05; 95% confidence level;)

METRIC	Unregulated gages n=31		Regulated gages n=22	
	Inc	Dec	Inc	Dec
BF	13%	6%	18%	36%
BF/P	16%	23%	18%	14%
BF/TF	13%	13%	14%	18%
AMDF	16%	13%	27%	18%

FOR UNREGULATED GAGES

- **Good news: Absolute baseflow (BF, cm): increasers outnumber decreasers 2 to 1**
- **Normalizing by P → 4-fold increase in decreasers**
- **For BF/TF Increasers ~= Decreasers**

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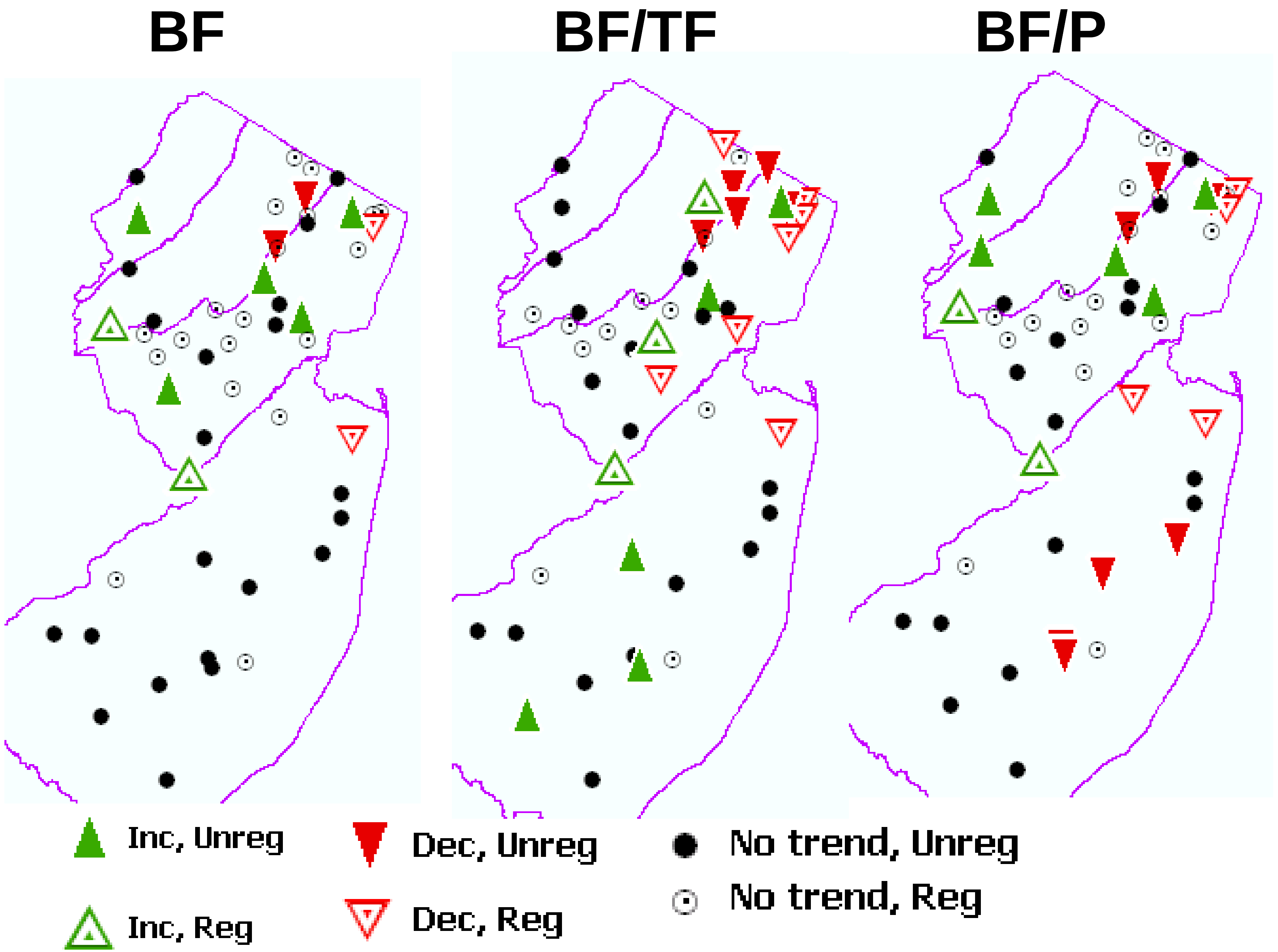
FOR <u>REGULATED</u> GAGES

- **Absolute baseflow, decreasers < increasers**
- **BF/TF and BF/P: decreasers > increasers**

  Why? Increasing withdrawals?


BF
BF/TF
BF/P
Inc, Unreg
Inc, Reg
Dec, Unreg
Dec, Reg
No trend, Unreg
No trend, Reg

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Note sizeable differences in results among metrics – each metric is measuring something different