# Understanding urban stormwater runoff and urban issues

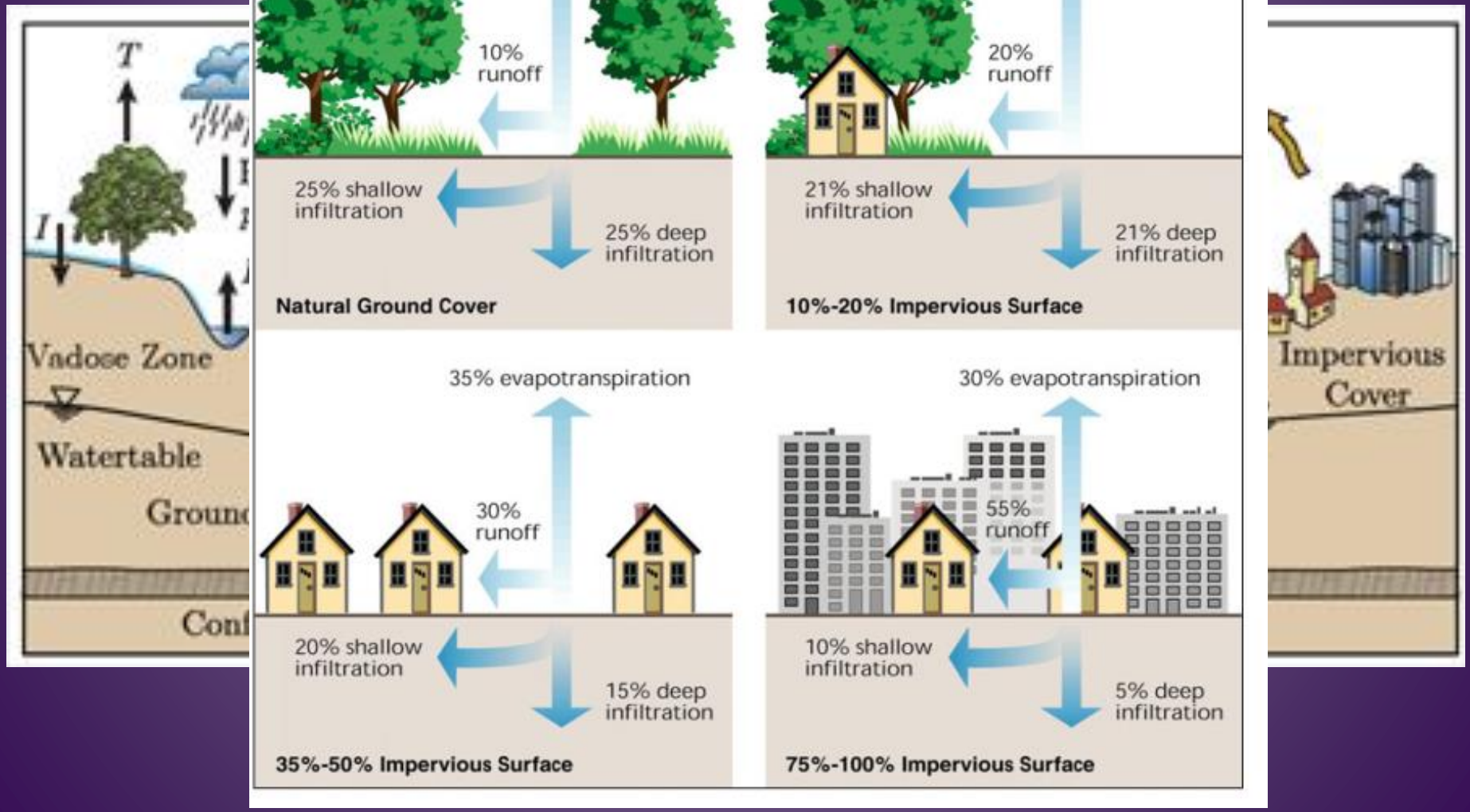
Trisha Moore

Kansas State University Biological & Agricultural Engineering Department

KANSAS STATE UNIVERSITY

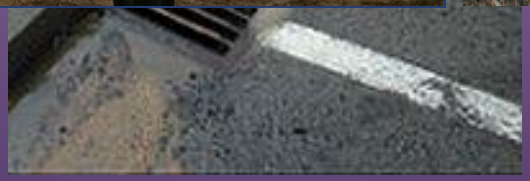
Biological and Agricultural Engineering

# Understanding urban watershed processes

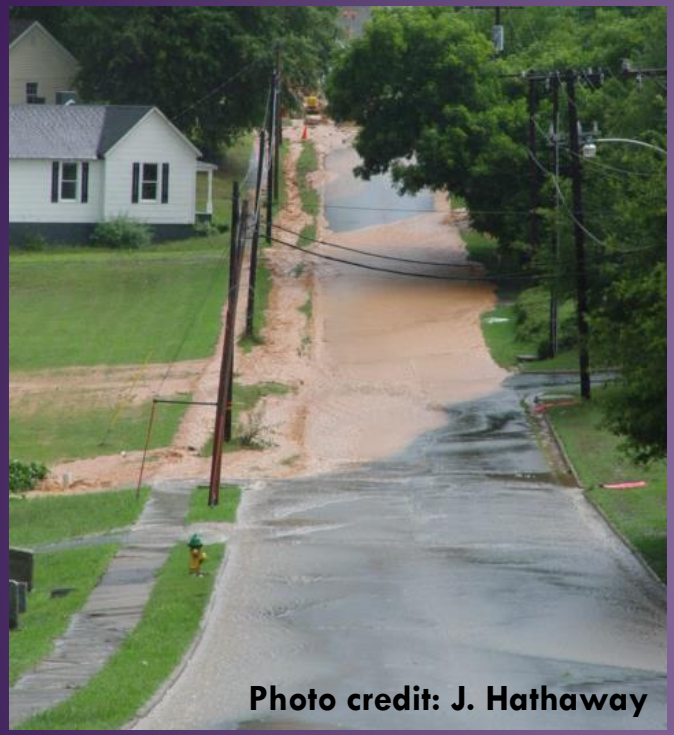


# Urban watersheds and stormwater runoff





# Pollutant sources in urban watersheds




# Pollutant sources in urban watersheds

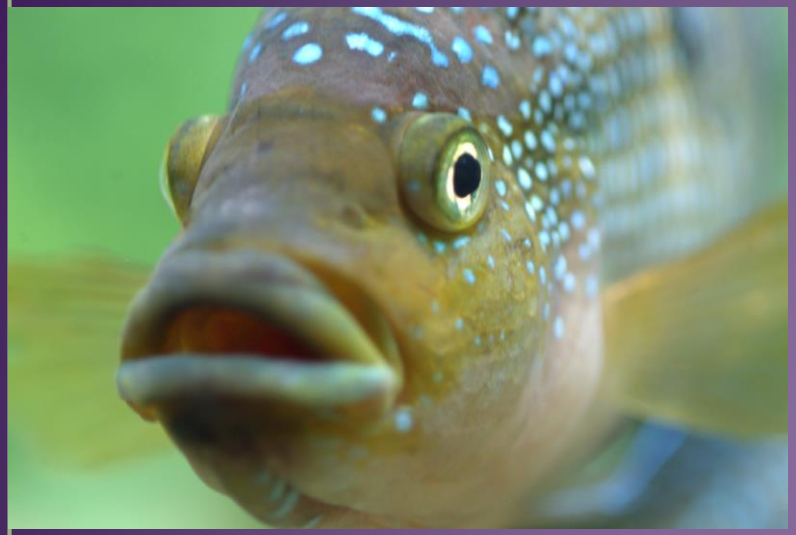

Atmospheric deposition
- TSS
- Nitrogen

Winter road maintenance
- Chlorides
- Sand

Heavy metals
Polycyclic aromatic hydrocarbons
Motor lubricants

**Photo credit: Kansascity.com**

# Stormwater pollutant impacts



**Health of aquatic biota**

- Physical habitat degradation (sediment)
- Acute and chronic toxicity (N, metals)
- DO depletion (BOD)

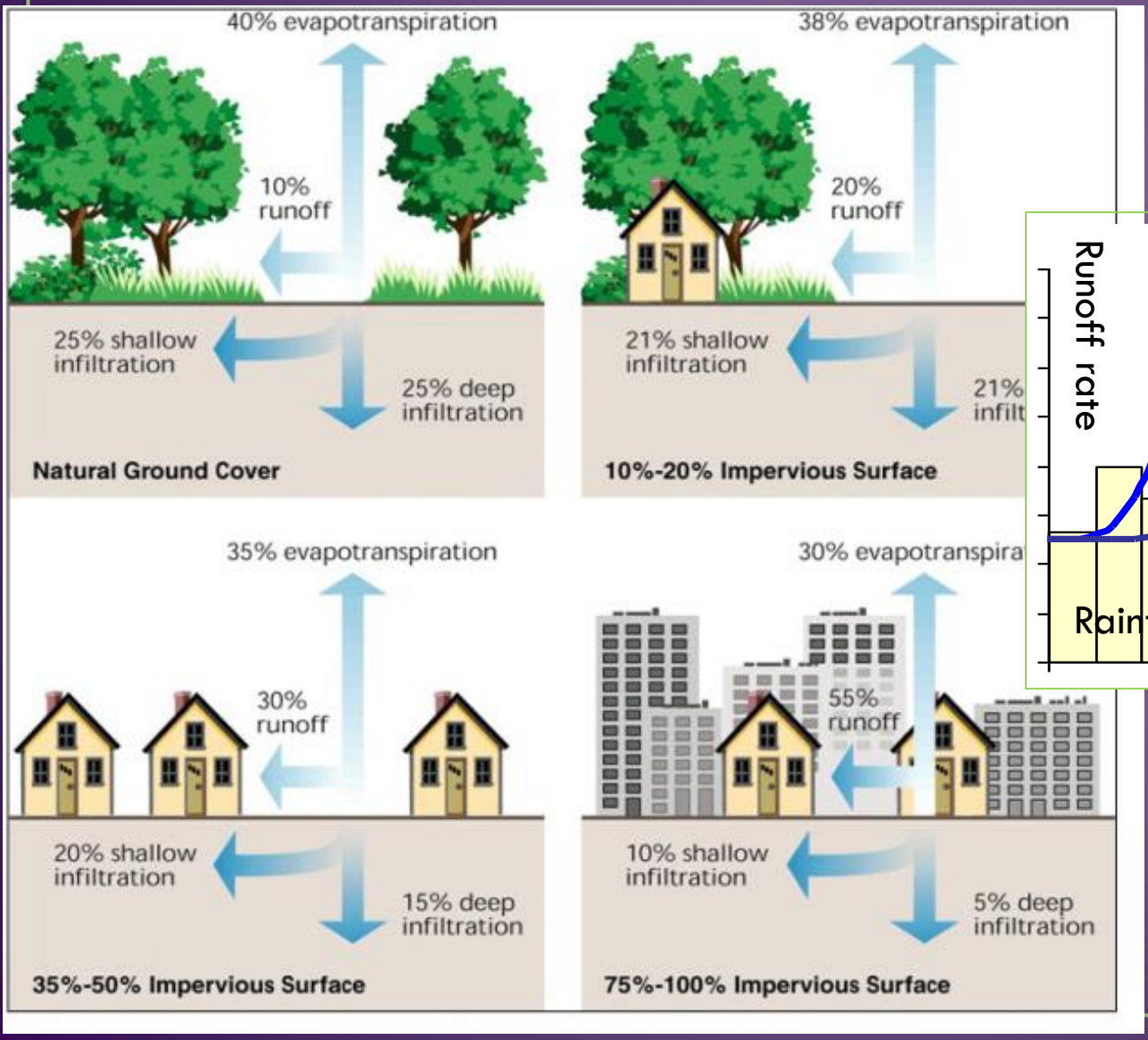
**Trophic state**

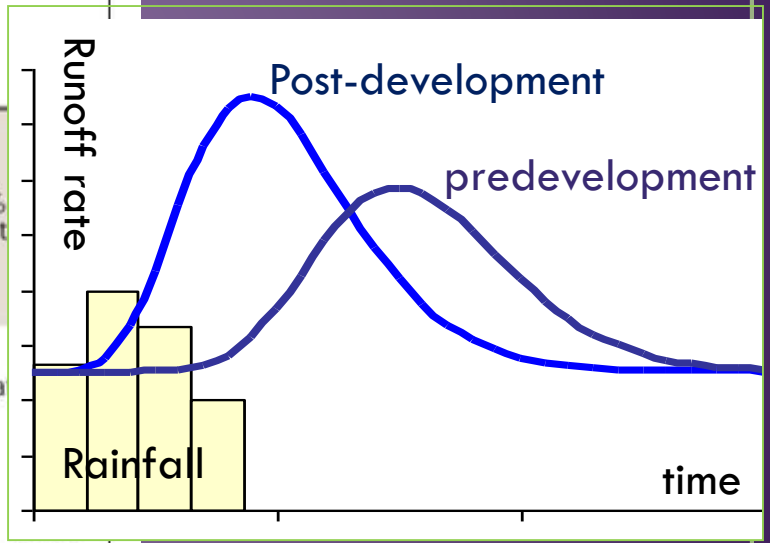
- Accelerate eutrophication (N, P)
- Light limitations


**Stream channel morphology and sedimentation**

- Aggradation due to excess sediment
- Reduced storage in impoundments

# The root of (most) all urban watershed issues is *hydrology*




USEPA

# It's not just the peak flow…

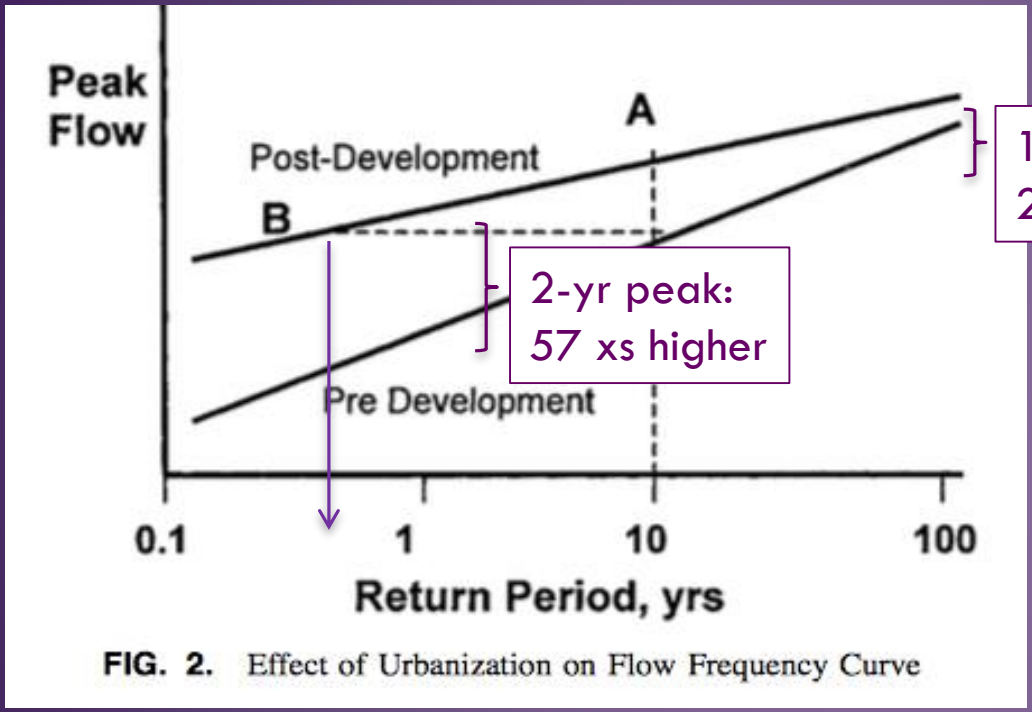



FIG. 2. Effect of Urbanization on Flow Frequency Curve

100-yr peak:
2 xs higher

2-yr peak:
57 xs higher

**Take home:** increasing frequency of runoff events increases opportunity for erosional work in receiving streams

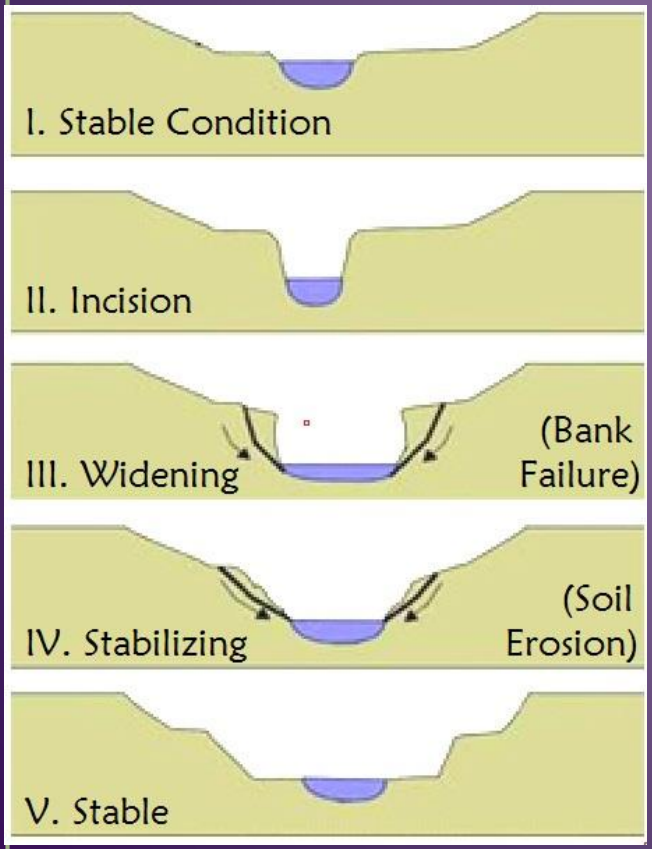
**TABLE 2.** Increase in Frequency of Two-Year Peak Runoff Rate due to Development (Joint Task Force 1998)

| Percent impervious | Frequency (times/year) |
|---|---|
| 30 (residential) | 3 |
| 50 (strip comm) | 6 |
| 80 (industrial) | 8 |

From: Roesner et al., 2001

# Hydrology: the master variable

Controls downstream geomorphic stability

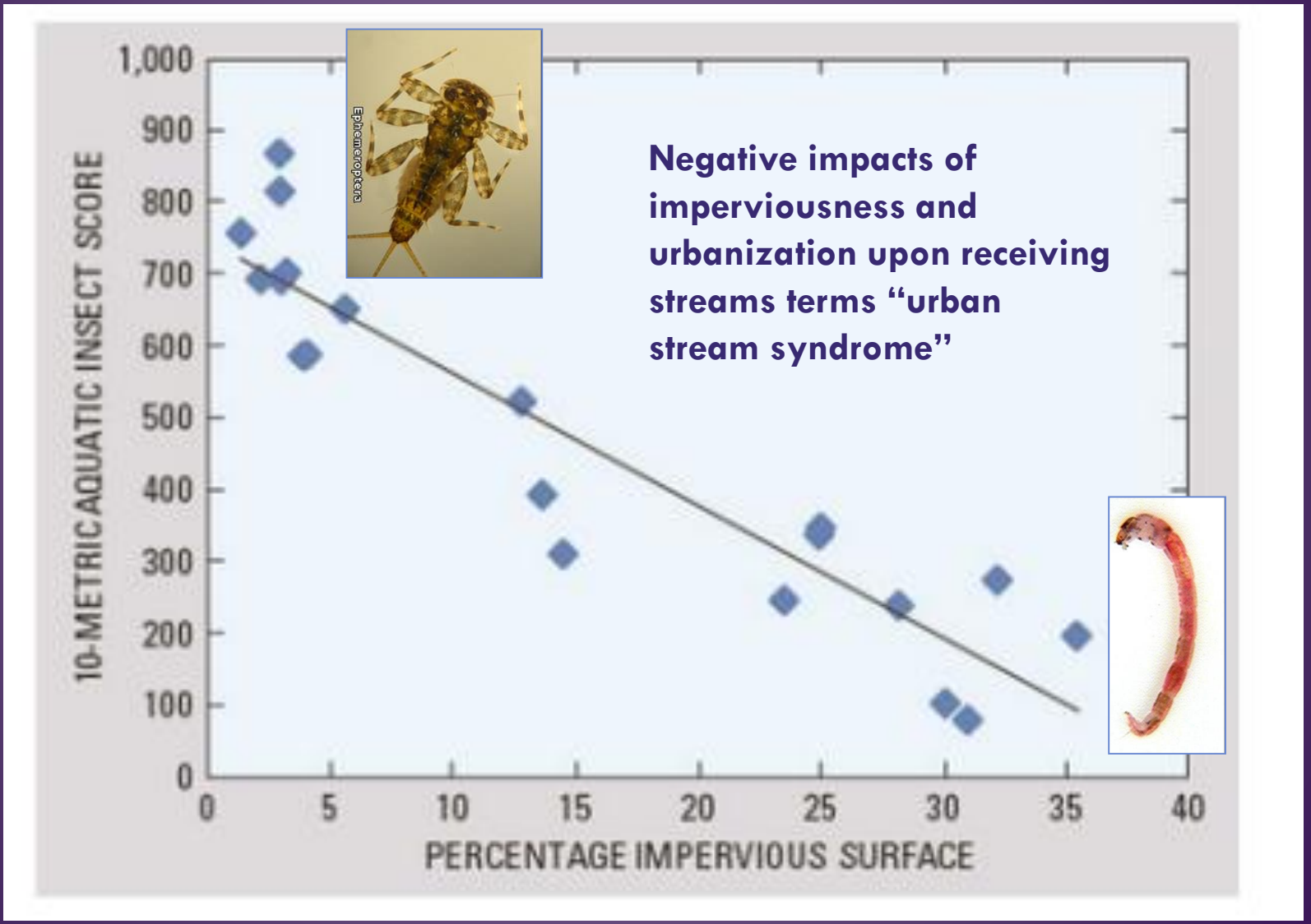



Controls downstream water quality


Controls downstream biotic integrity


# Impervious surfaces: the master culprit

USGS study, 2003-2007, Johnson County KS
http://pubs.usgs.gov/sir/2009/5235/



## Cleary, urban watersheds suffer from a number of maladies, including:

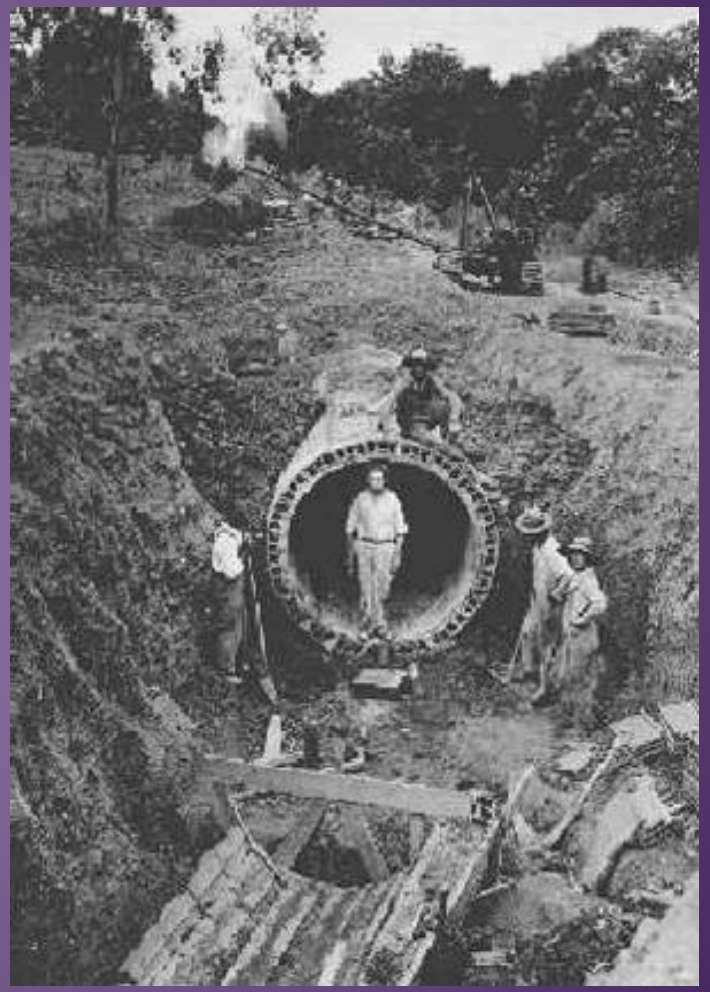
- Degraded water quality
- Channel erosion and habitat degradation
- Declines in integrity of biotic communities

## In remainder of presentation, I will discuss:

- Progression of efforts to manage urban stormwater runoff
- Opportunities and challenges for runoff management today

# History of stormwater management

**Goal:** Sanitation and Expedience

1900s

# The legacy of expedient drainage persists

# History of stormwater management

Retention!

Detention!



1970s

1990s

# Policy drivers of stormwater management

TITLE I--RESEARCH AND RELATED PROGRAMS

**Clean Water Act, 1972**

SEC. 101 [33 U.S.C. 1251] Declaration of Goals and Policy

(a) The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In order to achieve this objective it is hereby declared that, consistent with the provisions of this Act--

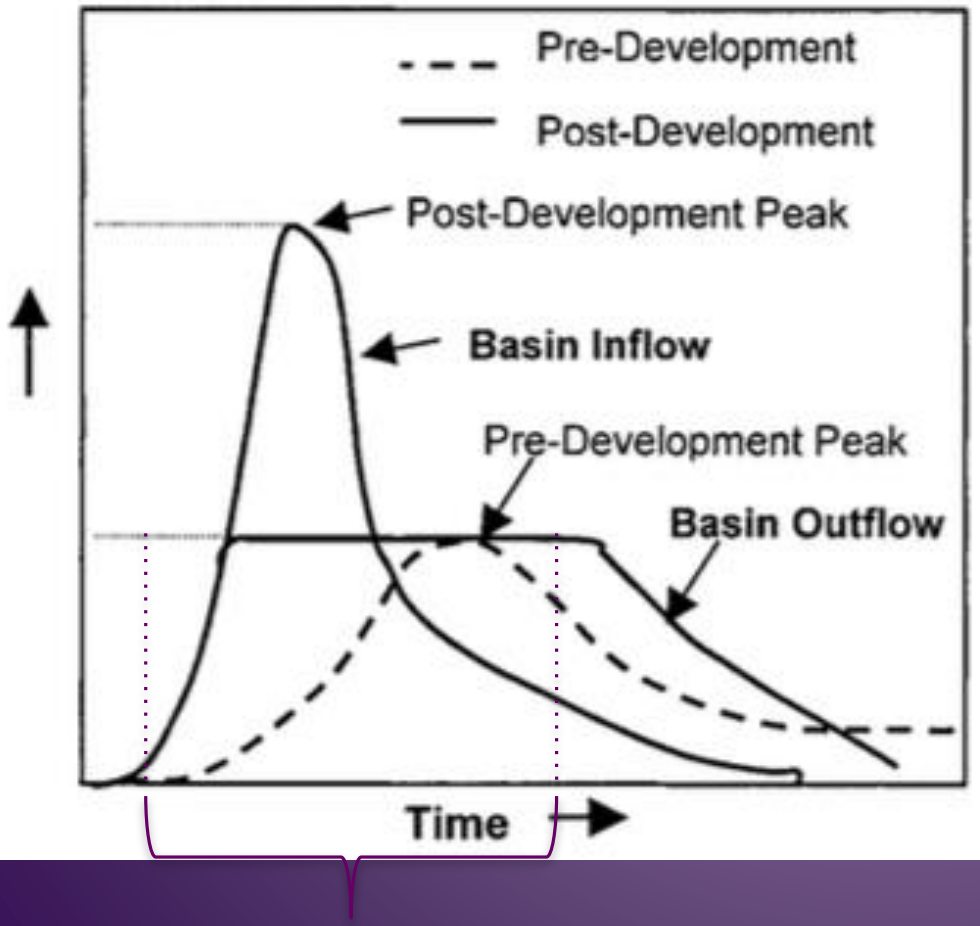
- Stormwater related amendments:
  - **NPDES* Phase I** (1990) – permit to discharge stormwater from MS4s** serving > 100,000 people
  - **NPDES Phase II** (2003) – permit to discharge stormwater from MS4s serving > 10,000 people AND from construction sites disturbing > 1 acre
  - **Section 303d –** requires states to develop lists of impaired waters and development of TMDLs***

*NPDES = Non Point Discharge Elimination System
**MS4 = Municipal Separate Storm Sewer System
***TMDL = Total Maximum Daily Load

# Policy drivers of stormwater management: NPDES & MS4 regulations

- Requires municipalities (and DOTs) to develop and implement "Stormwater Management Plan" or SWMP.
- 6 minimum control measures (pollution prevention)
- **Develop plan for post-construction water quality stormwater practices**
- Implement plan for additional monitoring and/or stormwater practices if TMDL developed for receiving water body

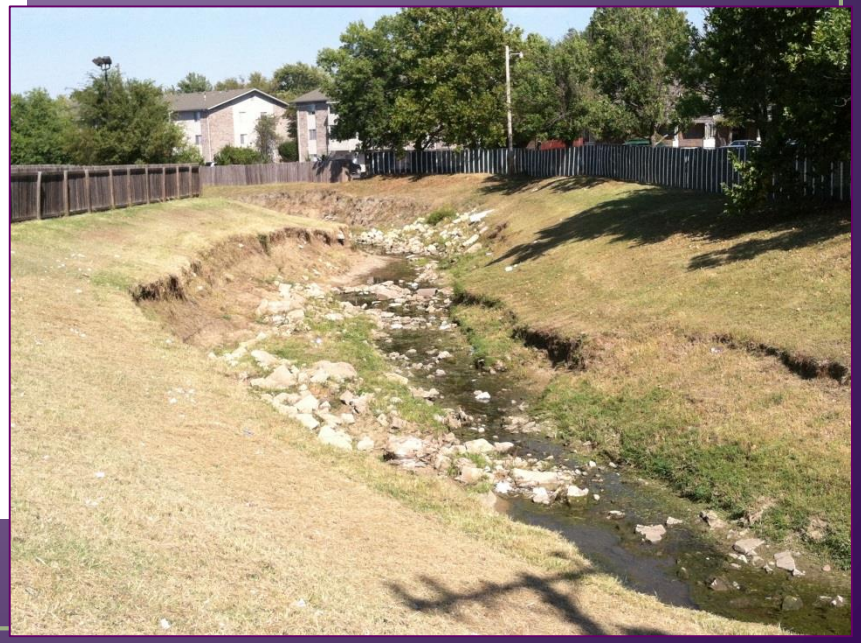
# Stormwater detention reduces runoff pollutant load. But does it help downstream ecosystems?




From: Roesner et al., 2001

Control magnitude of peak, but not

1. **Duration** of peak flows or
2. **Frequency** of peak flows



# History of stormwater management

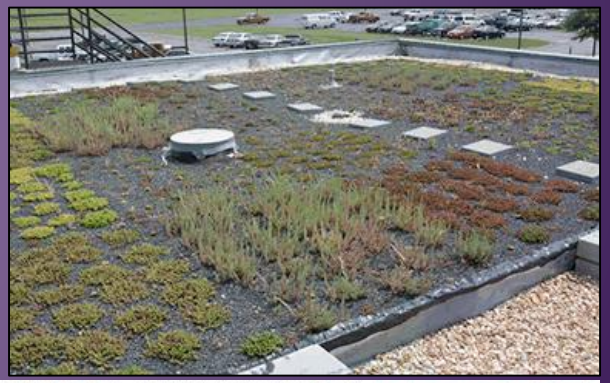

Infiltration!

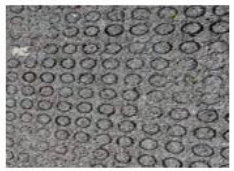
1970s

1990s

2000s

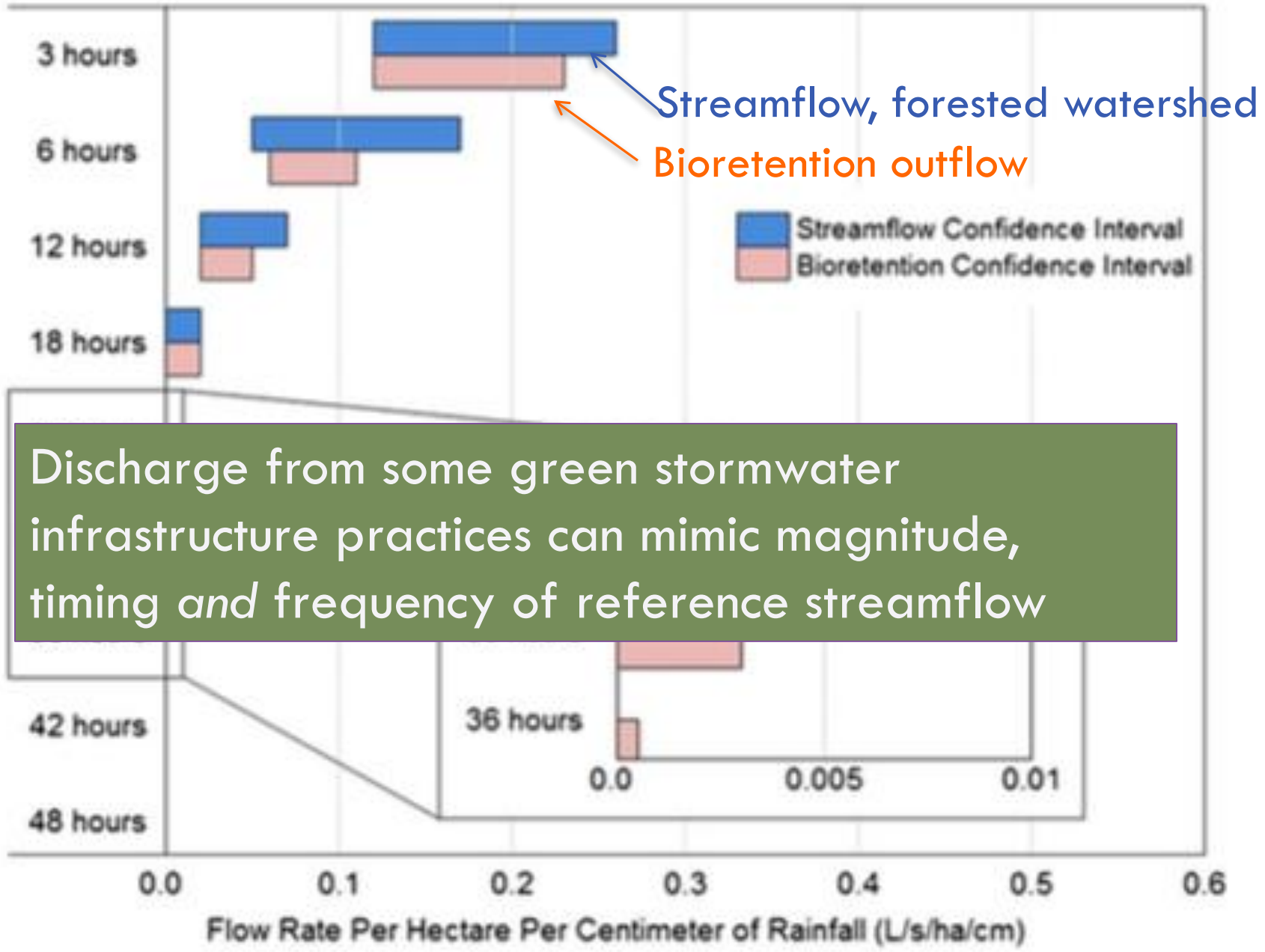
# Stormwater control measures that aim to mimic predevelopment hydrology





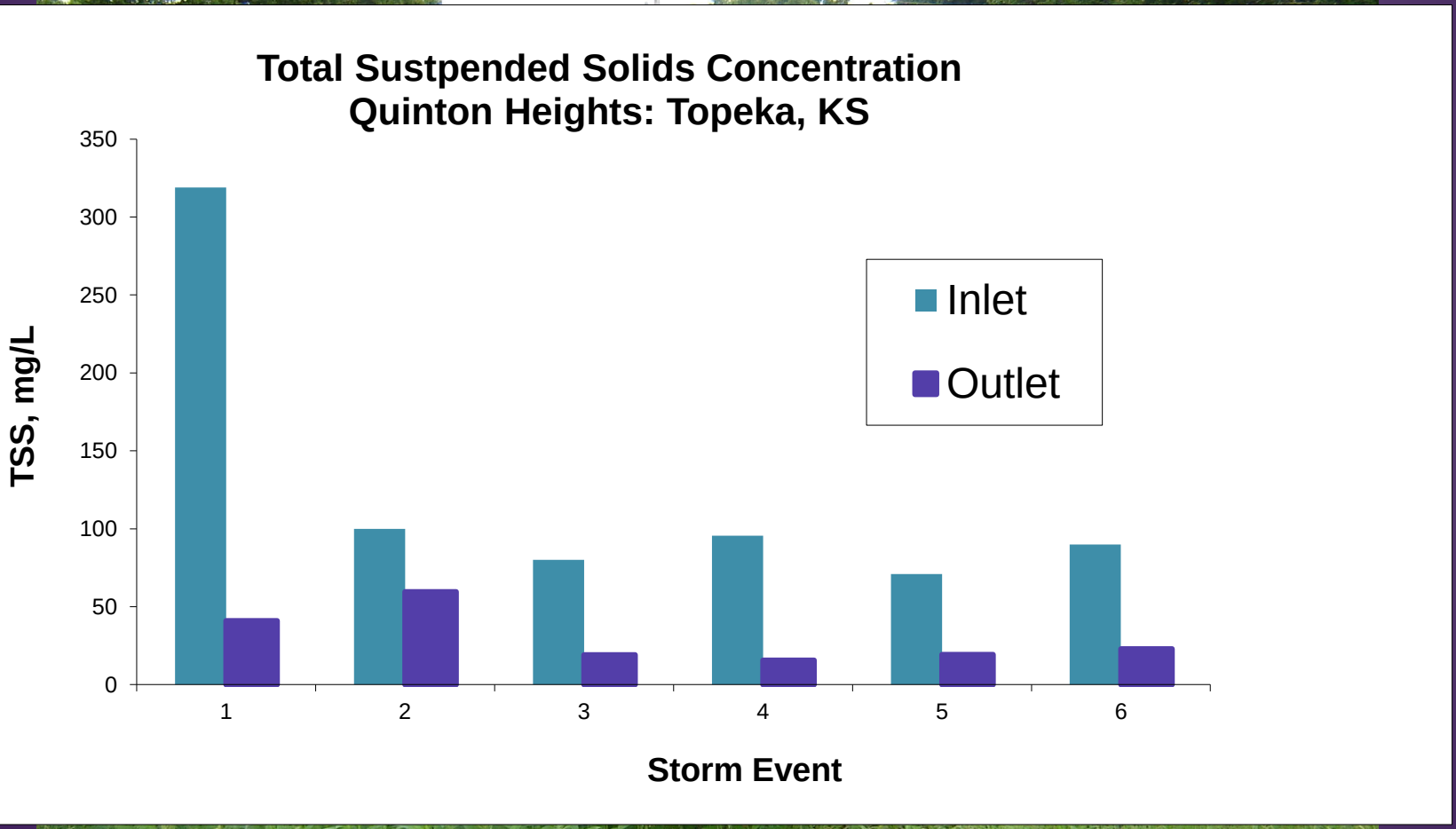
# Benefits: hydrologic regulation

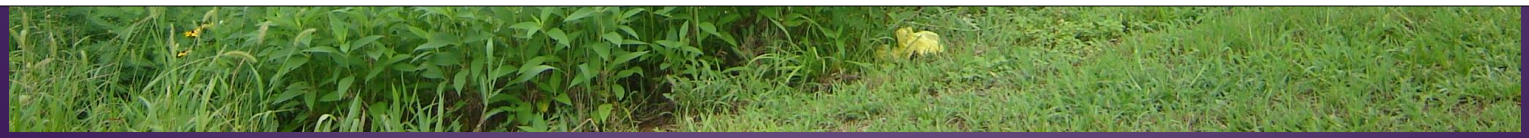
Adapted from www.greentopeka.org



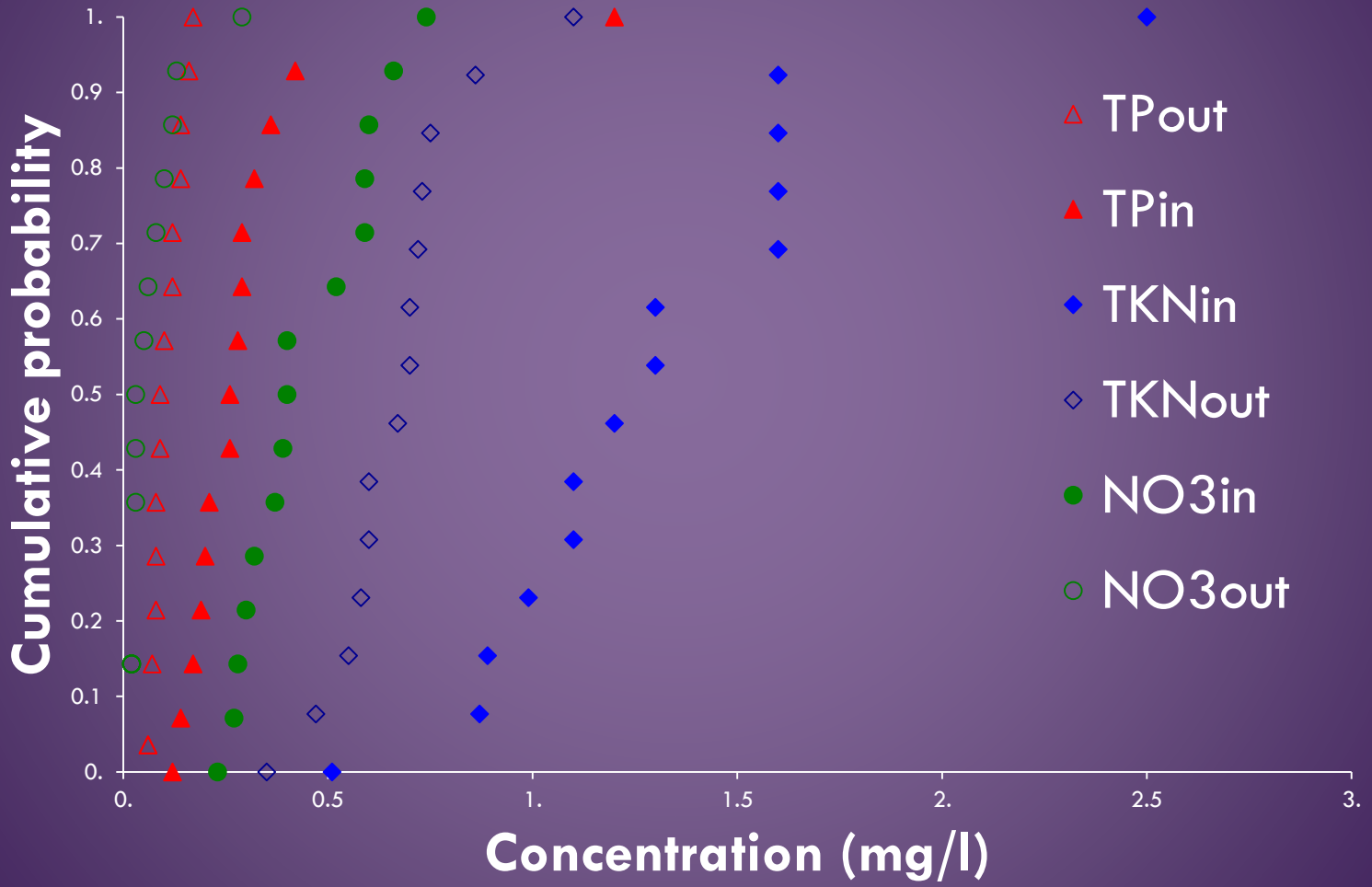

Debusk and Hunt, 2011

# Benefits: Water quality regulation



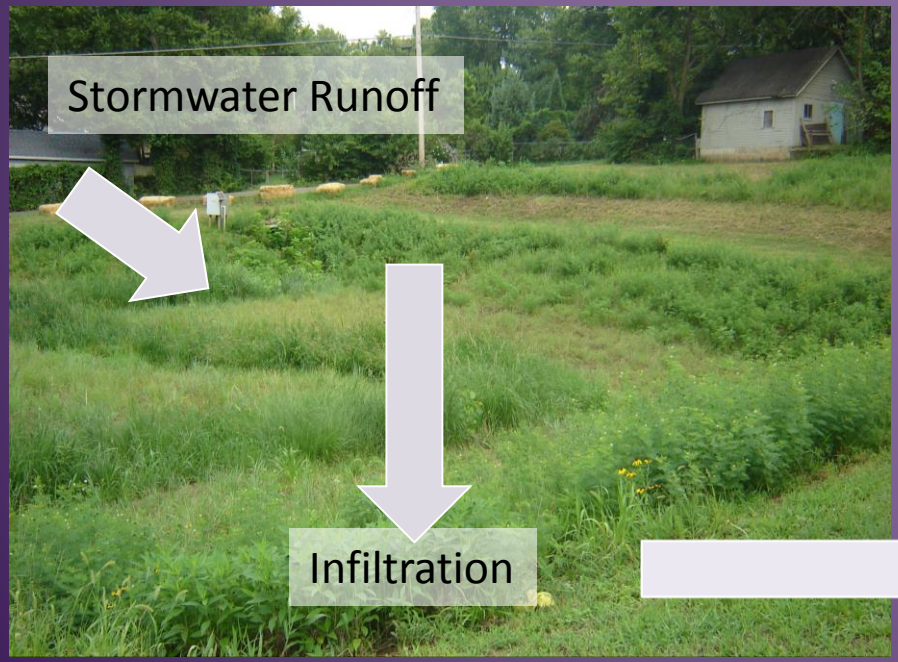



# Water quality benefits



# But wait, there's more!

# Enhance baseflow regulation in receiving streams*





*depends on underlying geology

# Biodiversity & Pest regulation in green stormwater infrastructure

- Food web functions can be promoted within green stormwater infrastructure systems
  - Wetland vegetation: habitat & attract adult dragon flies
  - Cattails: monoculture not desirable

*Gambusia*, aka Mosquitofish

Culex mosquito larvae, aka public enemy


Ferocious *Libellulidae* larvae

# Biodiversity & Pest regulation in green stormwater infrastructure

Wetland-pond hybtid: ponds with littoral shelf

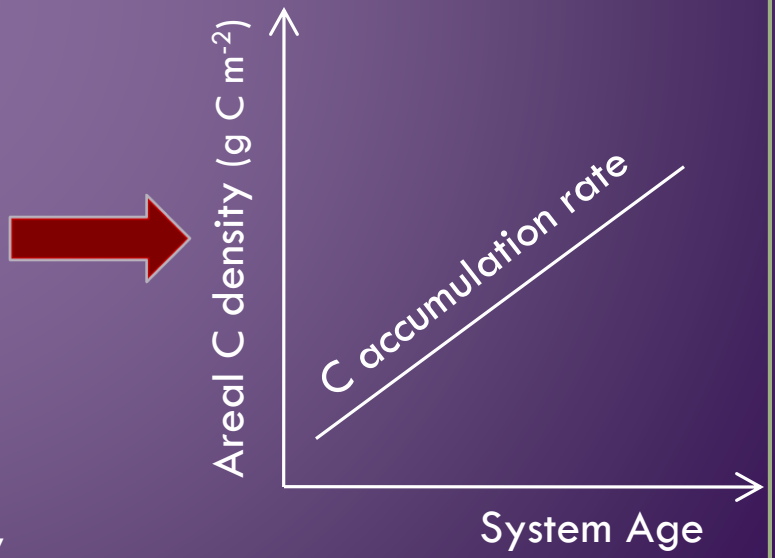
Ponds with littoral shelves supported **significantly greater** proportion of predators than non-vegetated ponds (Moore and Hunt, 2011)

# Carbon sequestration: comparison of "green" (wetland) and conventional (pond) stormwater management systems

% Soil C content – upper 10 cm

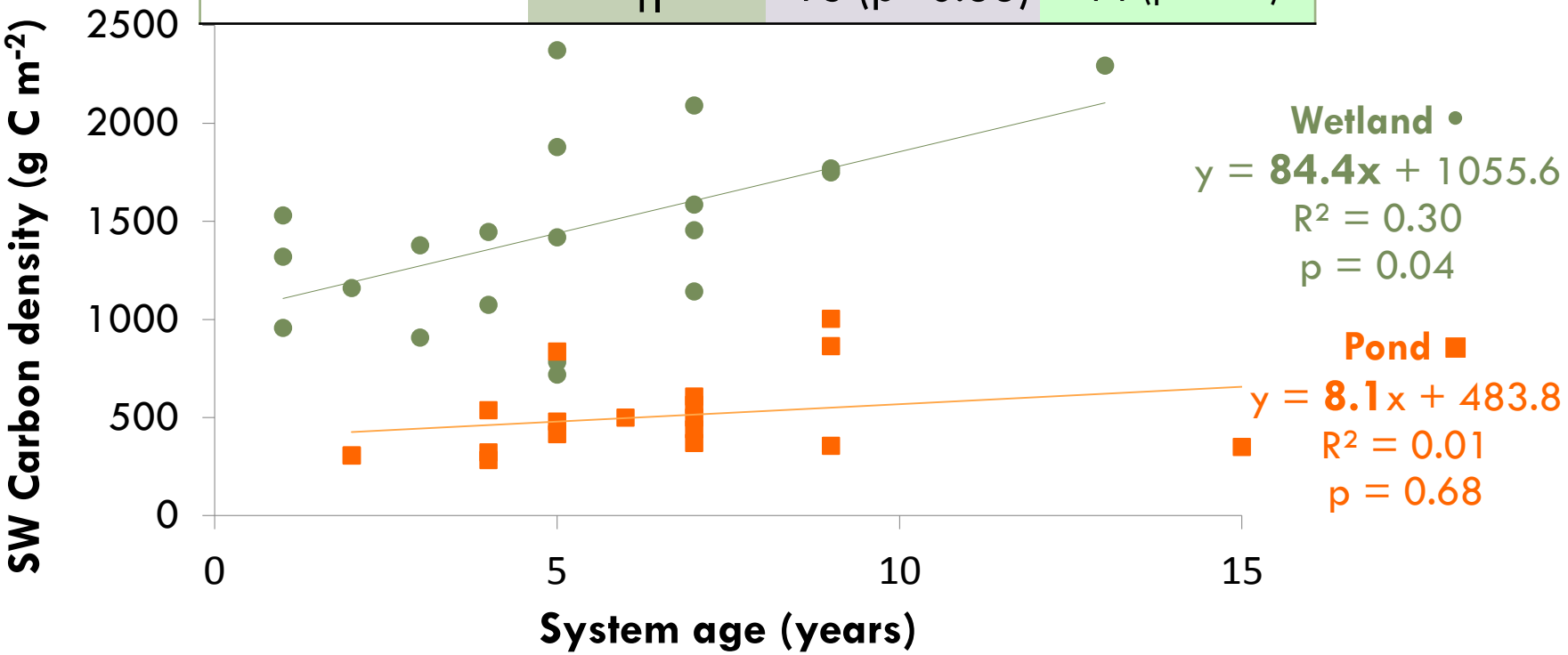
×

Soil bulk density



# Rates of carbon sequestration in wetland higher than pond

| C seq. g C $m^{-2}$ $yr^{-1}$ (slope estimate) | Zone | Pond | Wetland |
|---|---|---|---|
| | OW | 18 (p=0.43) | 160 (p=0.16) |
| | SW | 8.1 (p=0.68) | **84** (p=0.04) |
| | TI | -13 (p=0.88) | 44 (p=0.60) |



# Microclimate benefits

Reducing paved areas and increasing natural Vegetation in a “green stormwater” development cut back on summer cooling expenses, **helping reduce home energy bills by 33-50%compared to surrounding neighborhoods.**

(Village Homes, Davis, CA: RMI, 2006)

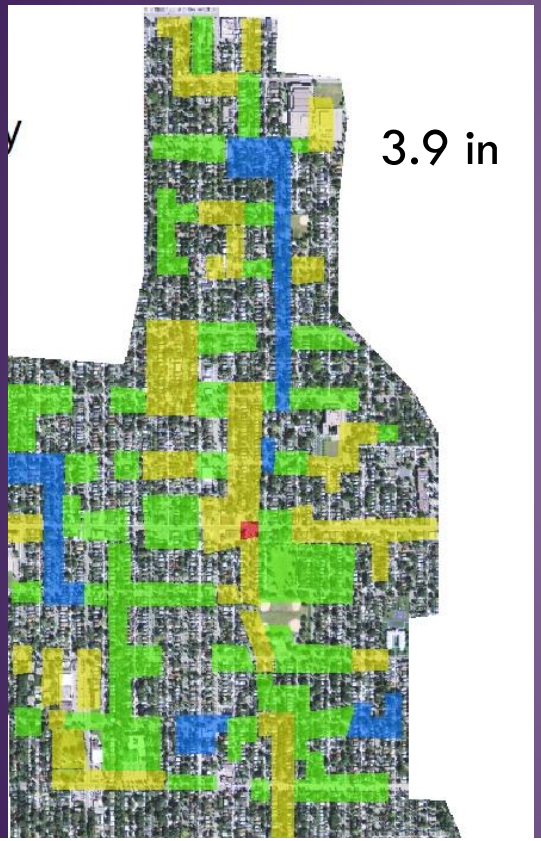
# Air quality benefits

- Natural vegetation (esp. trees) shown to have substantial impact on particulates and other air pollutants
  - Dust levels 4 to 100 times higher when trees removed (Nelson, 1975).
  - Ozone violations reduced 14% by increasing vegetation cover in San Francisco model simulations (Taha, 1997)

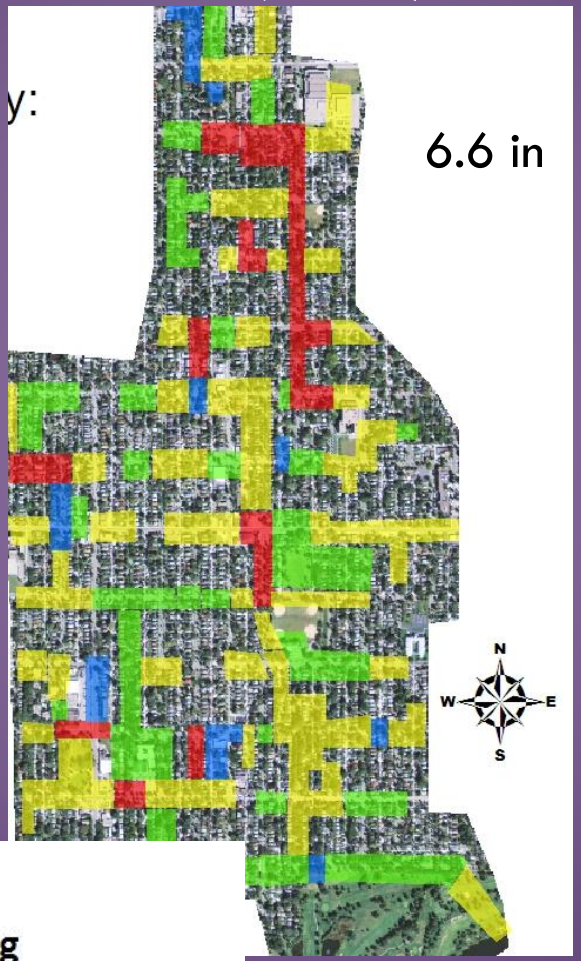

Deeproot.com

# Enhance adaptation capacity to changing climate

Current 10YR




"Moderate" mid-century 10YR (+70%)




"Pessimistic" mid-century 10YR (+160%)


No surcharge

Surcharged, No surface flooding

Surcharged, Streets contain surface flooding

Surcharged, Over-curb flooding

Up to 40 MG over-curb flooding

# Challenges: adapting a static design approach to a shifting climate

# Enhance adaptation capacity to changing climate

Current 10YR (3.9 in)

"Moderate" mid-century 10YR (6.6 in)

"Pessimistic" mid-century 10YR (10.1 in)

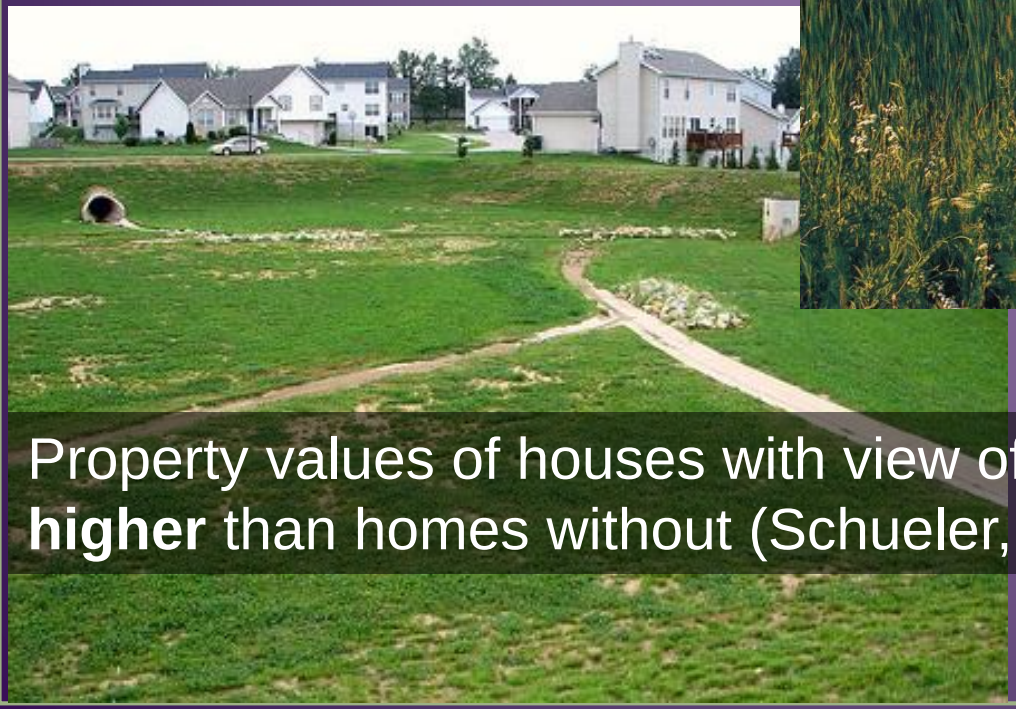

All flooding contained within streets (below curb) or public open spaces

# Cultural benefits


Photo courtesy of NCSU-BAE

# Cultural benefits

EPA study found developers could charge up to a **$10,000 premium** per lot for properties next to well-designed stormwater wetlands and wet ponds (USEPA, 1995).



Property values of houses with view of stormwater wetland were **1/3 higher** than homes without (Schueler, 2000).


2004


Jackson Street
STORMWATER SYSTEM
Evapotranspiration
Rainfall
Rainfall
Runoff
Runoff
Infiltration
What is a bioretention cell?

Before green infrastructure improvements

After green infrastructure improvements

Marlborough Neighborhood,
Blue River Watershed, KC MO

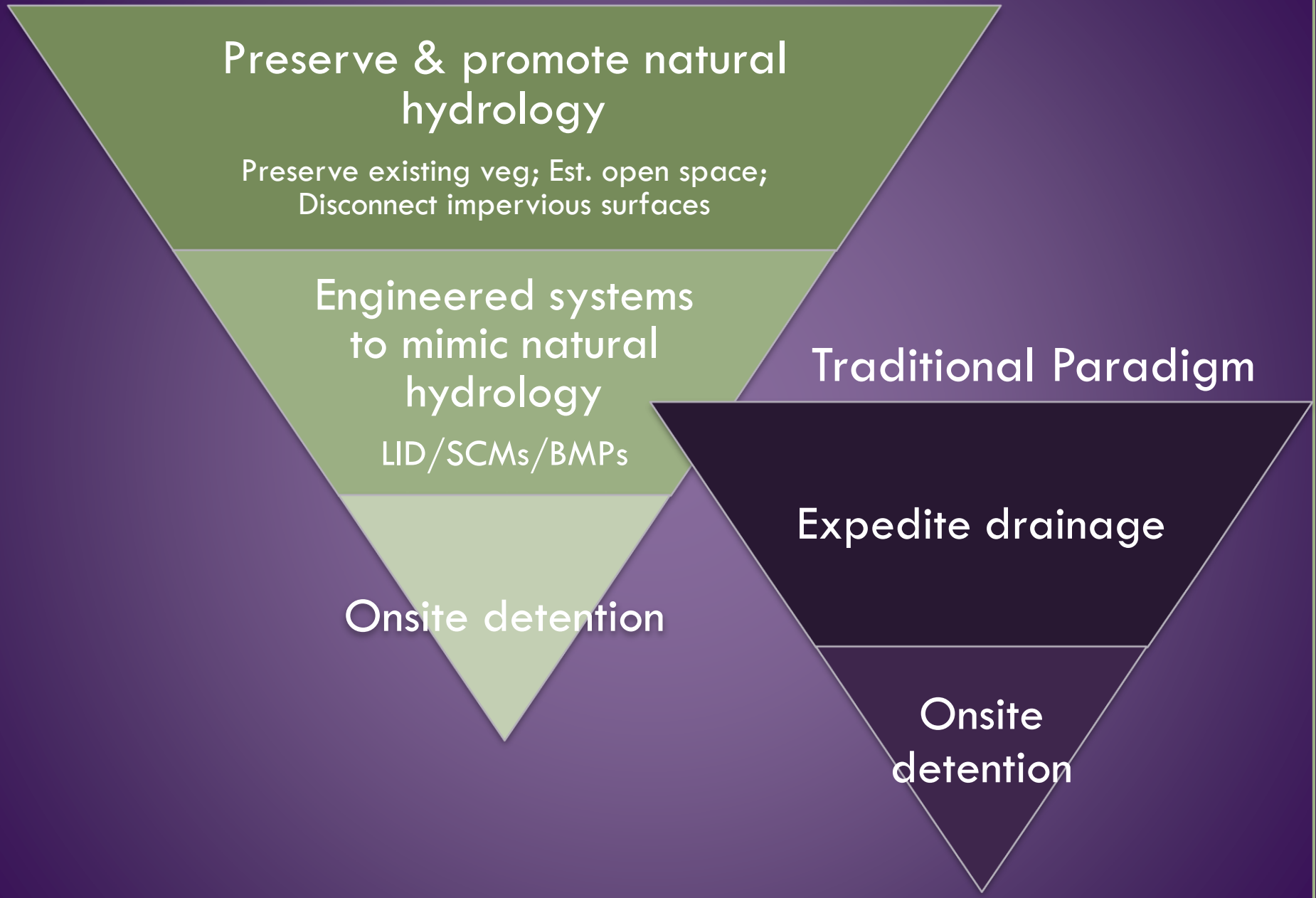
Bioretention systems to reduce hydraulic load on combined sewer system

(photos from MARC and nalgep.org)

# Challenges to adoption of green stormwater infrastructure

It's different: push back from engineering community, municipalities and/or individual community members

# Changing a paradigm is not easy (after APWA-MARC, pg 3-5)



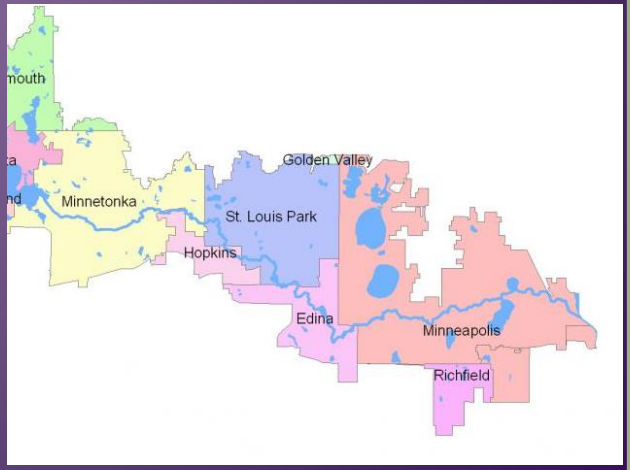
# Challenges to adoption of green stormwater infrastructure

It's different: push back from engineering community, municipalities and/or individual community members

"Growing Pains": When green stormwater infrastructure is implemented, construction and/or maintenance may limit design intent

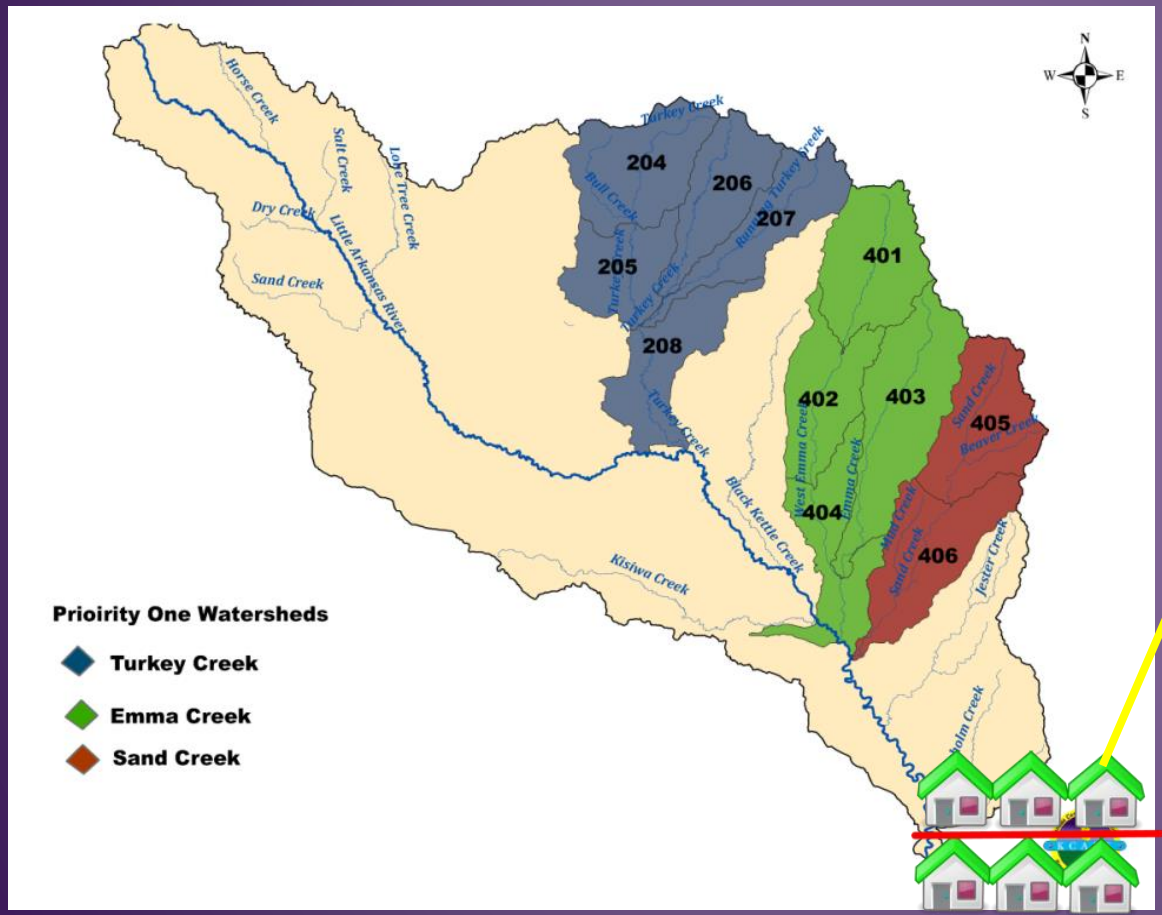
Regulatory mismatch: Most MS4 permits and other regulations focus on stormwater quality, not holistic hydrology (but this is changing)

Institutional mismatch: Bodies governing stormwater do not follow watershed bounds; thus, comprehensive planning difficult



# Opportunities for upstream partnerships

Little Arkansas River Watershed




TMDL pollutant retained in watershed

$$$ for TMDL pollutant retention

TMDL pollutant (e.g., TSS)

# Watershed partnerships: What does it take?

- Stakeholder buy-in
  - KDHE, City of Wichita, Sedgwick County, development community
- Watershed "champion"
  - WRAPS – prioritize watershed efforts, landowner/producer relationships
- Monitoring
  - Assess changes in eco service provision & adapt as necessary

# Urban or rural, the end goal is a "healthy" watershed

- Urban watersheds  characterized by extreme hydrology → cascade of downstream impacts
- Variety of management approaches, including engineering green stormwater infrastructure systems, developed to counter these impacts
- Watersheds cross multiple jurisdictions and MS4 permit holders. Strategic partnerships among watershed stakeholders may serve to meet watershed goals more effectively from *environmental* and *economic* standpoint.

# Questions?

Trisha Moore
Kansas State University, Biological &
Agricultural Engineering
tlcmoore@ksu.edu

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