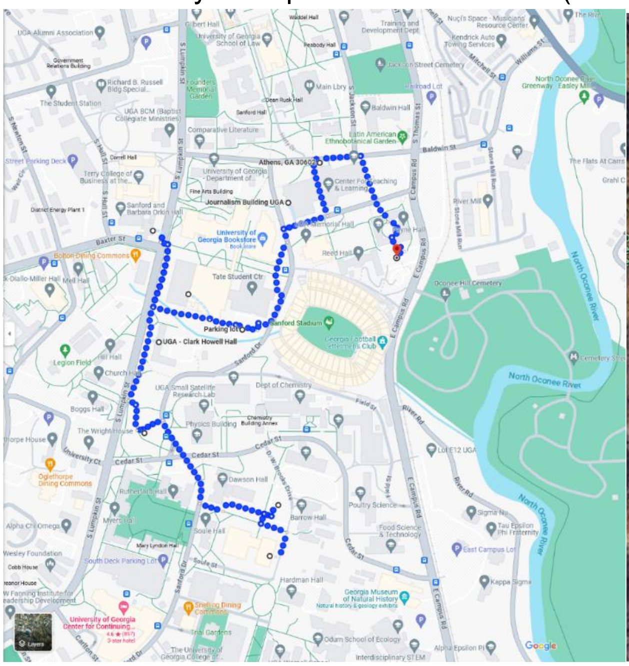
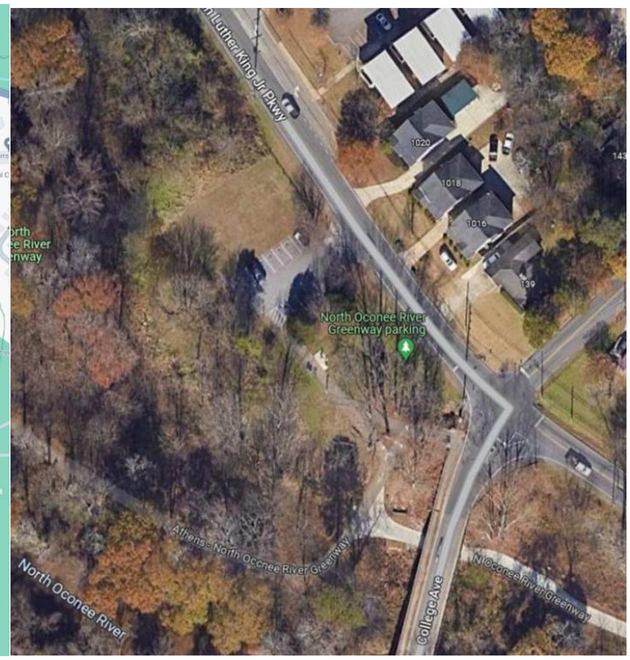
Day 2: Morning Handout

Themes for today:

- Urban / suburban land use effects on watershed processes
- Urban green infrastructure / natural infrastructure features and strategies
- Management of urban streams, floodplain corridors and riparian zones
- Equity considerations in urban NI
- Social benefits of urban NI

Plan for the day: Campus stormwater walk (morning, left). Greenway planning (afternoon, right).





INFRASTRUCTURE

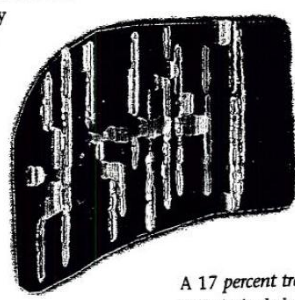
Texas City Relies on Tree Canopy to Reduce Runoff

Trees may be saving the city of Garland, Texas, more than $5 million a year in its measures to manage storm water, improve air quality, and save energy. American Forests, a nonprofit conservation organization in Washington, D.C., analyzed the trees' economic benefits in a study released earlier this year.

The city of Garland asked American Forests to conduct the study to address U.S. Environmental Protection Agency (EPA) water quality requirements. The city had been using innovative approaches to storm-water management for at least a decade. To satisfy the EPA, the city needed to demonstrate that the policies it had in place could reduce storm-water discharge enough to make an expensive structural solution unnecessary.

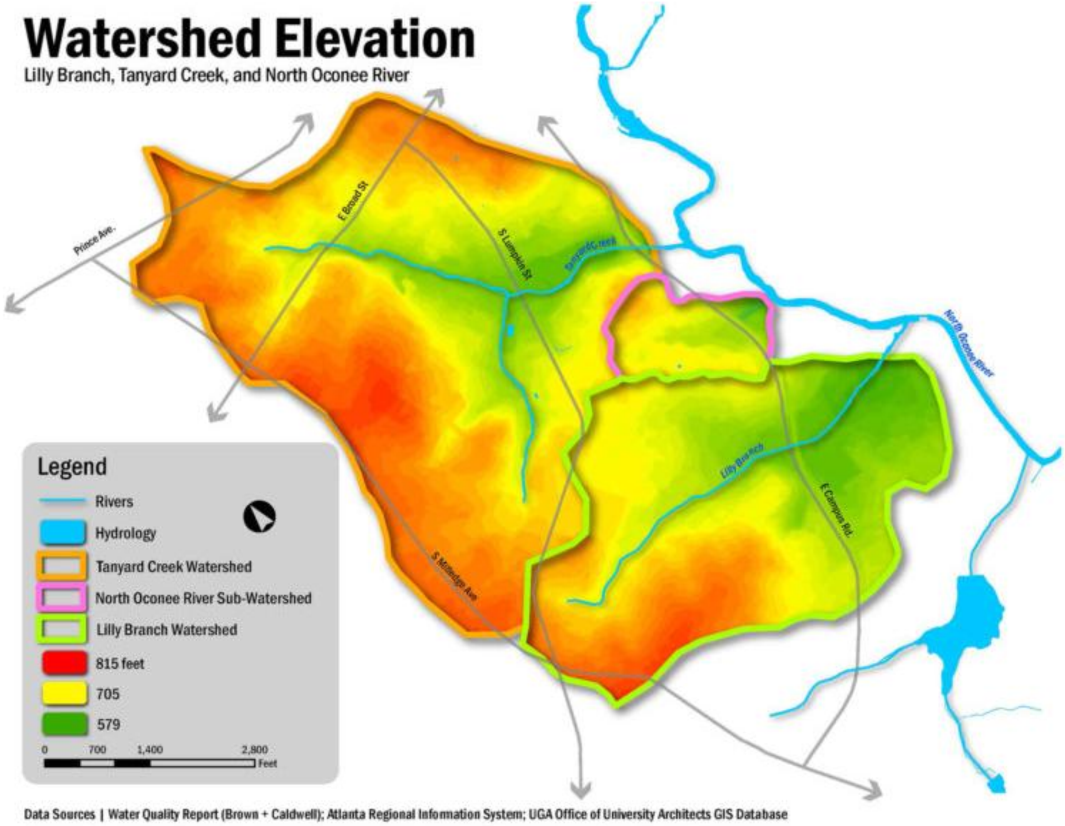
American Forests calculated that Garland's tree canopy reduces storm-water runoff by 19 million cu ft (540,000 m³) during a major storm. The amount of runoff was multiplied by the cost of building storm-water containment facilities, estimated at $2/cu ft ($71/m³).

Although Garland has a tree cover of only 11 percent—less than average for cities of its size—American Forests estimated that the trees save Garland $2.8 million annually in infrastructure costs. In addition, the study showed that because trees reduce air pollution and provide shade, they save the city $2.5 million annually in air quality costs and residential energy bills. ▼



A 17 percent tree canopy at this 8 acre (3 ha) site helped reduce runoff by nearly 7 percent.

UGA Campus Watersheds



Fecal coliform bacteria, dry sampling

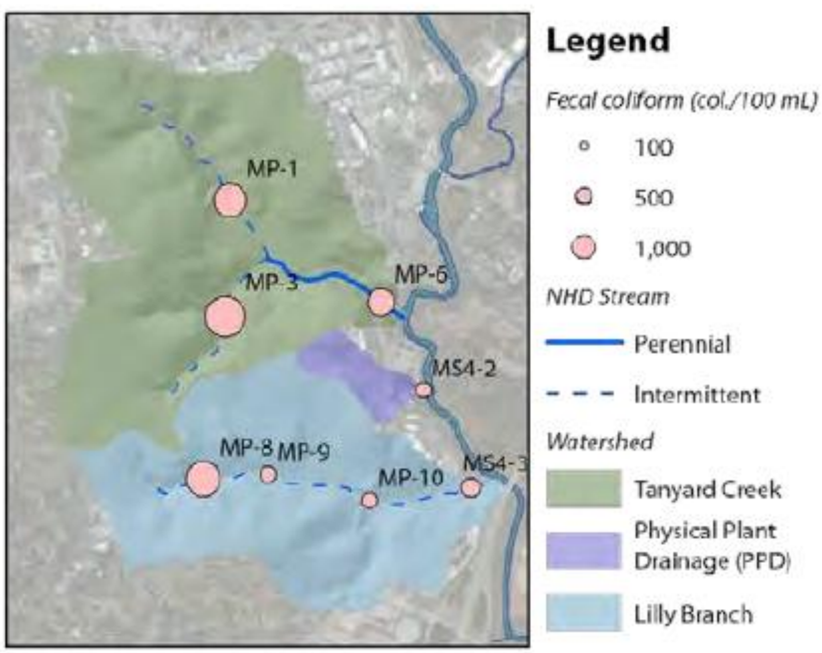


Table 8.1 Solids Accumulation and Associated Pollutant Concentrations in Urban Areas

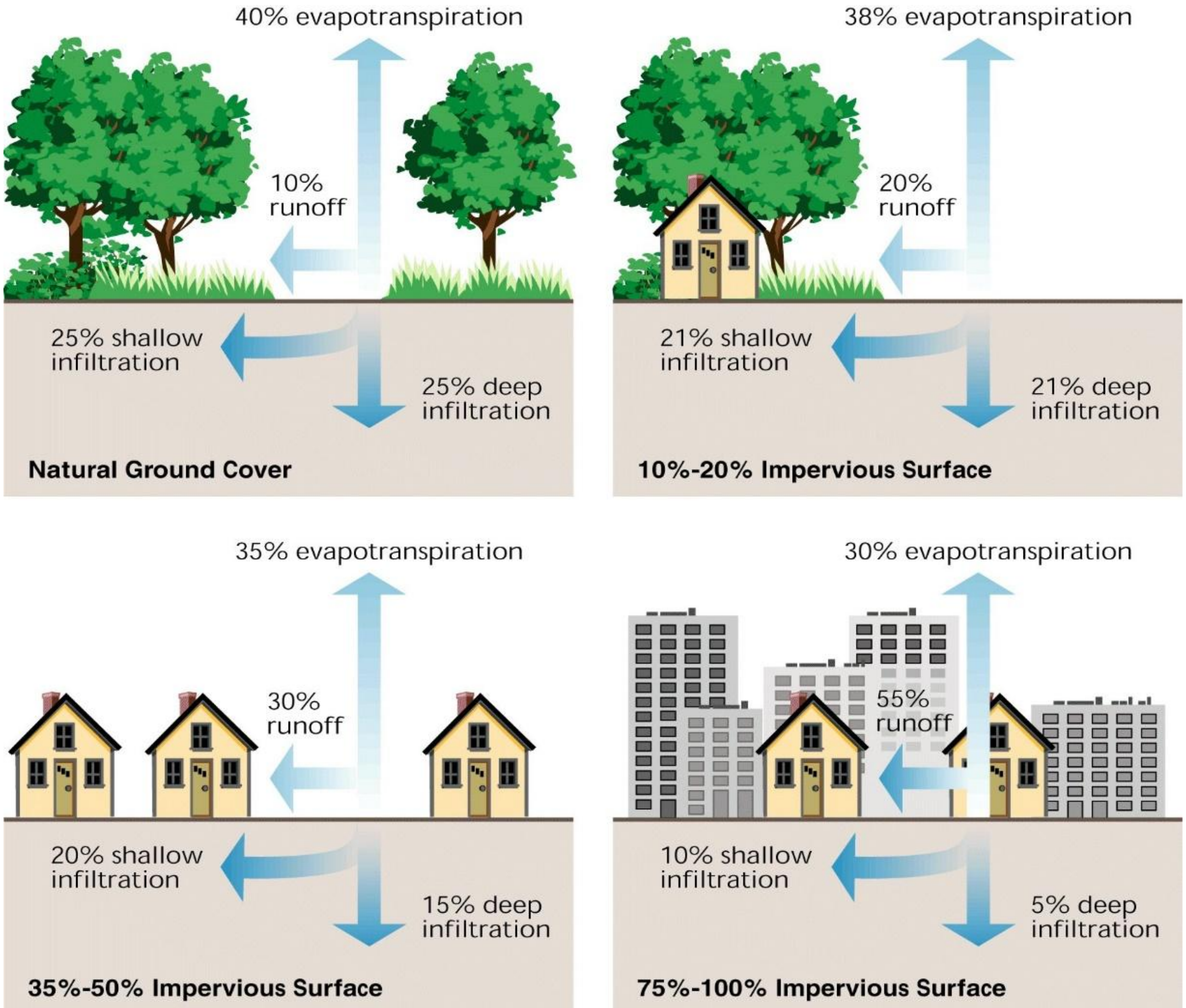
Land Use	Residential Low Density	Residential High Density	Commercial	Light Industrial	Highways
Solids accumulation (g/curb m)	10–182	30–210	13–180	80–288	13–1100
Pollutant concentration (μg/g)					
BOD_5	5,260	3,370	7,190	2,920	2,300–10,000
COD	39,300–40,000	40,000–42,000	39,000–61,730	25,100	53,650–80,000
Total N	460–480	530–610	410–420	430	223–1,600
Cd	3.2	2.7	2.9	3.6	2.1–10.2
Fecal coliforms (MPN/g)	60,570–82,500	25,621–31,800	36,900	30,700	18,768–38,000

Source: After Ellis (1986).

Table 8.8 Vehicle Emissions of Pollutants

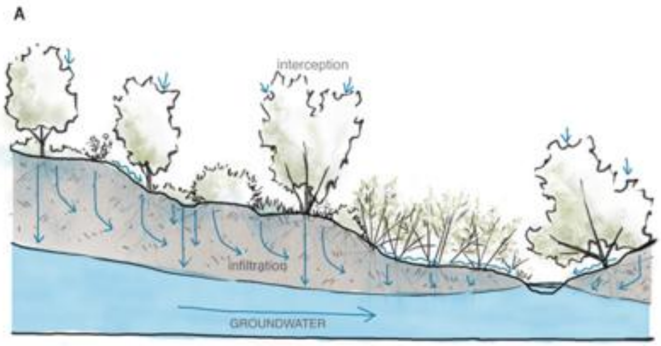
Pollutant	Emission Rate (g/km · vehicle[a]) Gasoline		Diesel
Total hydrocarbons[b]	10		1
Nitric oxides[b]	3		6
Lead[b]	0.01		0
Benzo[*a*]pyrene[b]	7×10^{-7}		2×10^{-6}
Fluoranthene[b]	2×10^{-5}		4×10^{-5}
Suspended solids[c]		1.3	
Total phosphorus[c]		0.001	
Zinc[b]		0.003 (total)	
Cadmium[b]		1×10^{-6} (total)	
Copper[b]		4.5×10^{-5} (total)	
Pyrene[d]			
Without catalyst		0.003	
With catalyst		0.0015	
Phenanthrene[d]			
Without catalyst		0.002	
With catalyst		0.00015	

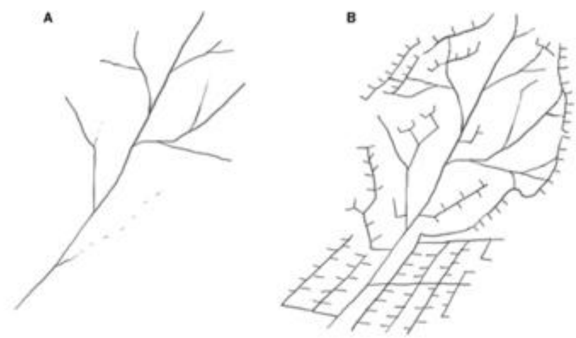
[a]Same as mg/m · vehicle.
[b]Compilation by Ball et al. (1991).
[c]Data from Shaheen (1975).
[d]Data from Acres (1991).

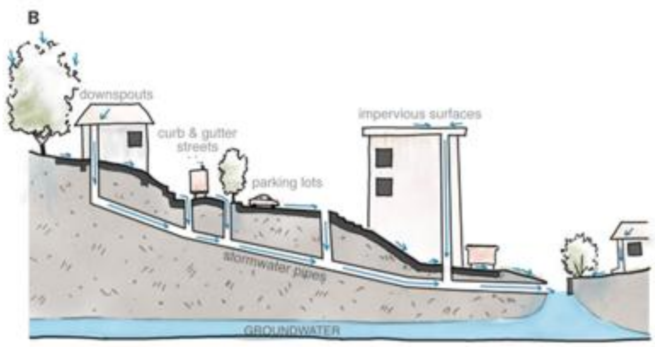


General stormwater principles

- The most effective runoff quality controls reduce both the volume and peak of runoff. How might this be done?
- Small storms are generally most important from a **quality** standpoint because they cause considerable washoff of pollutants without much dilution. Stormwater systems are generally designed to deal with larger storms and may not be effective for quality control.
- A rule of thumb is that SCMs and NI should limit the peak runoff of small storms less than two-years return period in addition to less frequent design storms.
- Most important pollutants in urban runoff can be settled out, but sometimes the dissolved form is also important. Control of dissolved pollutants can be more difficult than for adsorbed forms which settle out.
- Applicability of SCMs and NI is site specific.
- Longevity is a problem for some urban BMPs and NI features that tend to fill up with sediment and clog.







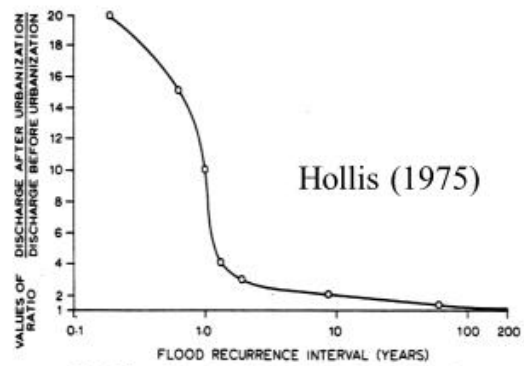
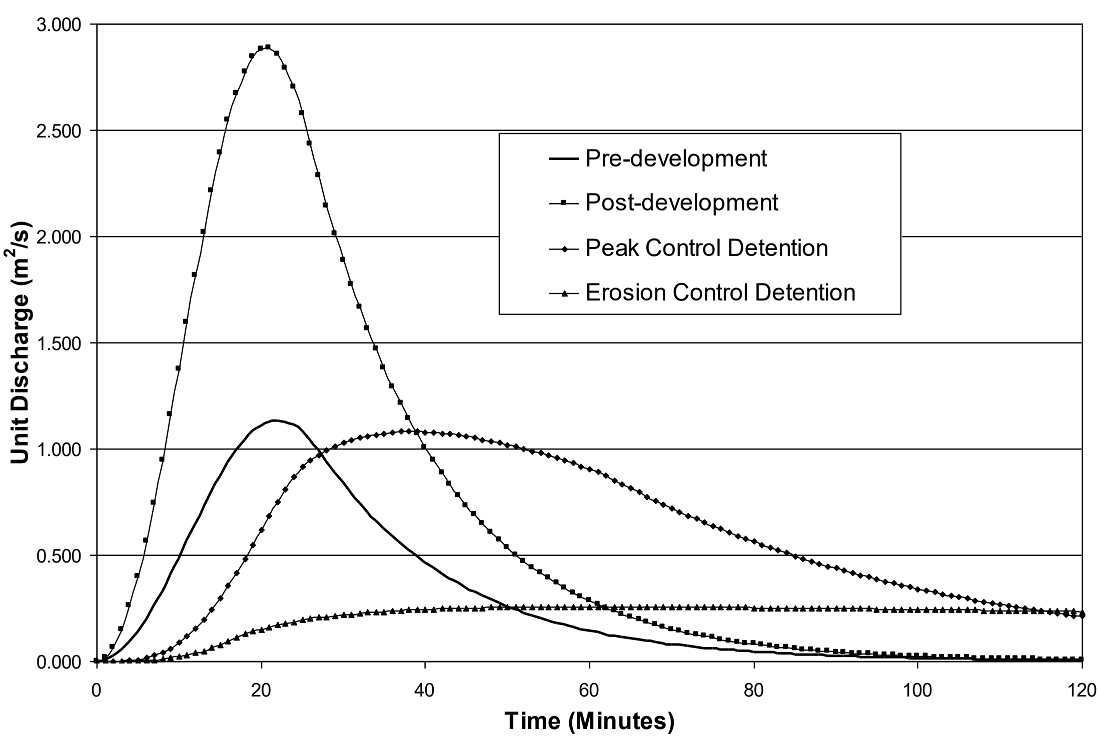
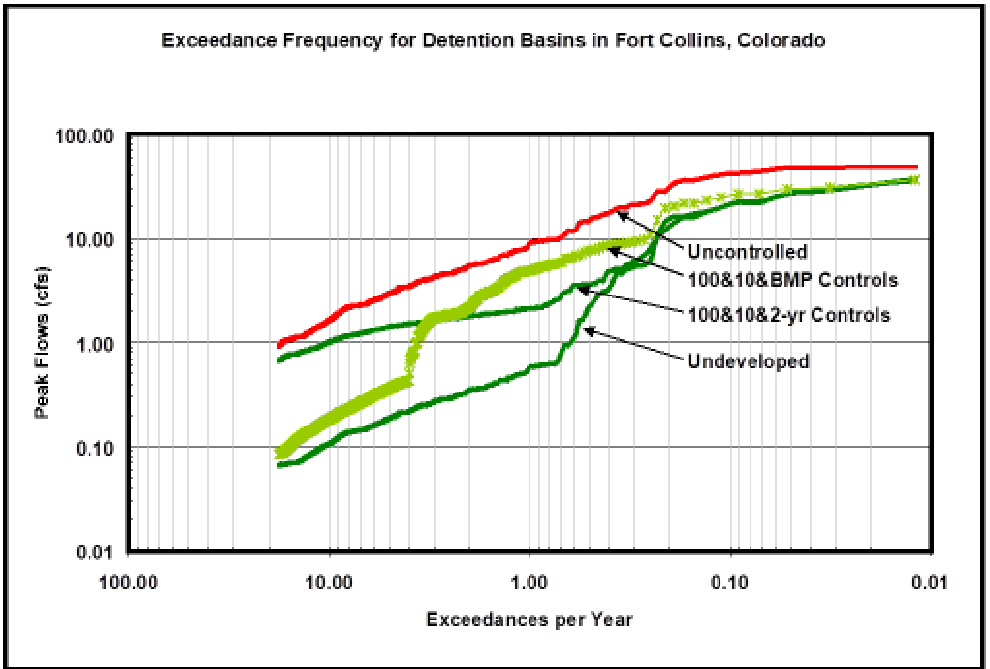


Fig. 3. Effect on flood magnitudes of paving 20% of a basin (based on Figure 2).

If you don't eat the energy, the energy will eat the channel!

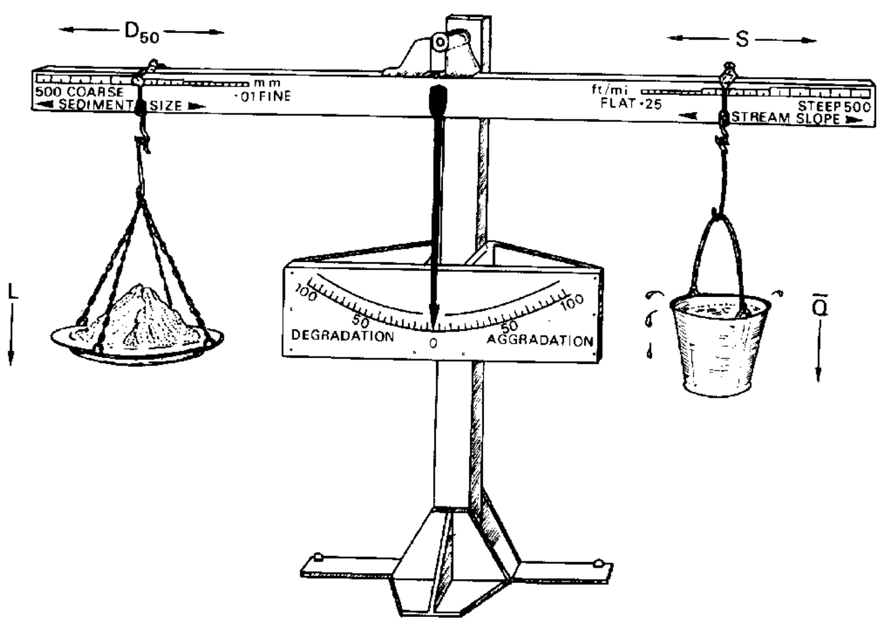
Mail Creek
Unit Discharge (2 year)





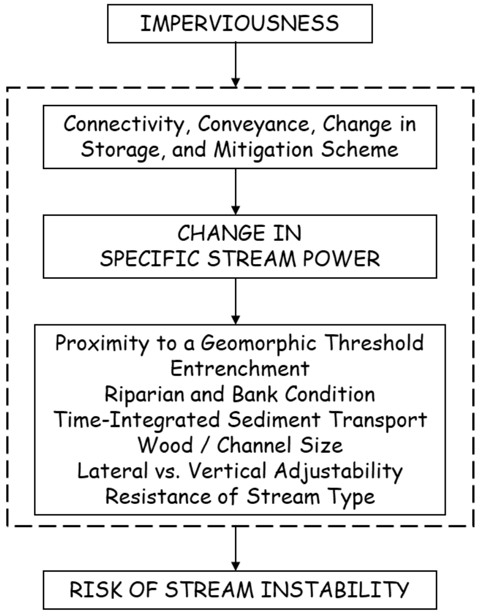
Note: BMP is "extended detention with 24-hr drawdown time.

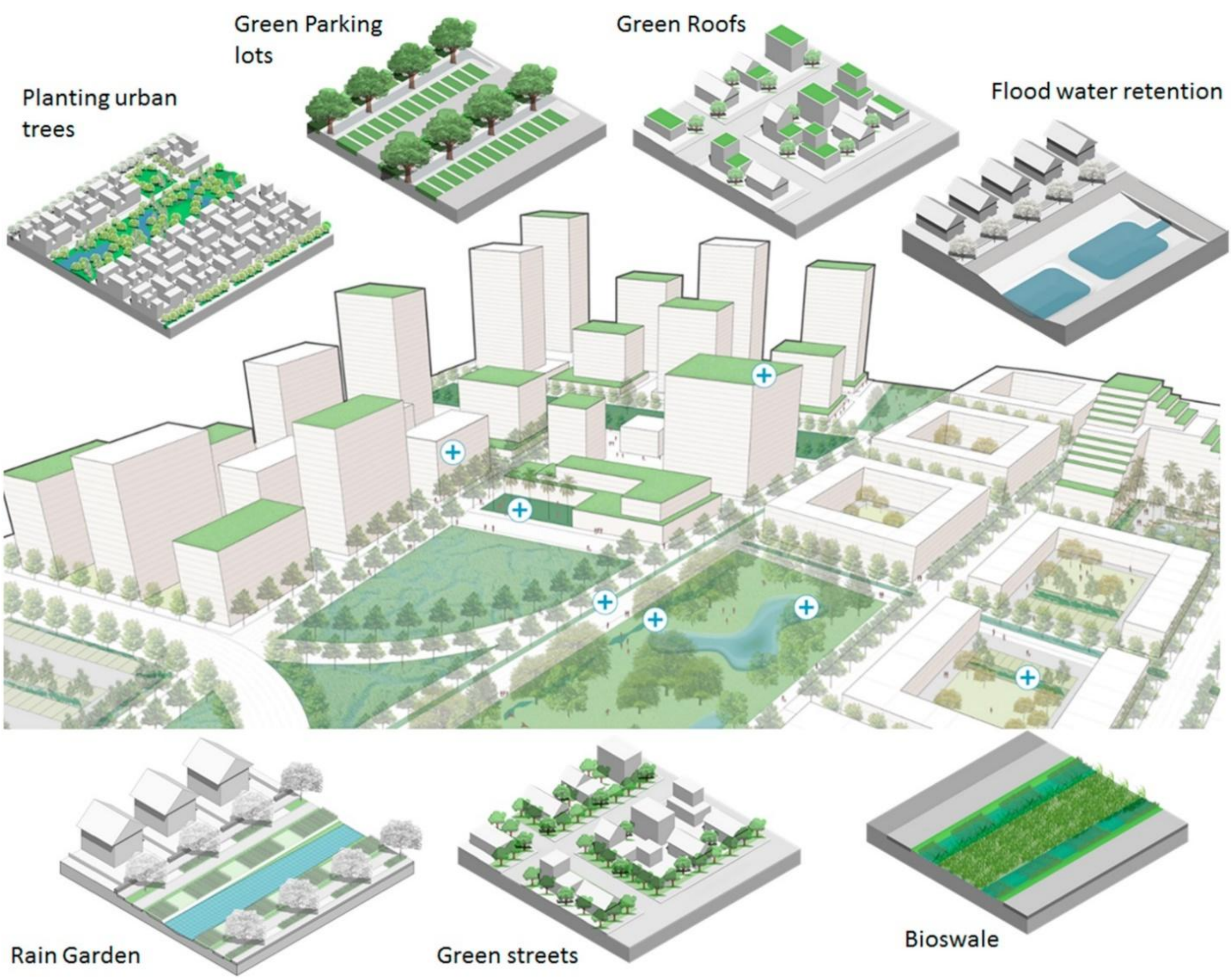
Effect of Detention and BMPs on the Post-development Flow Frequency Curve



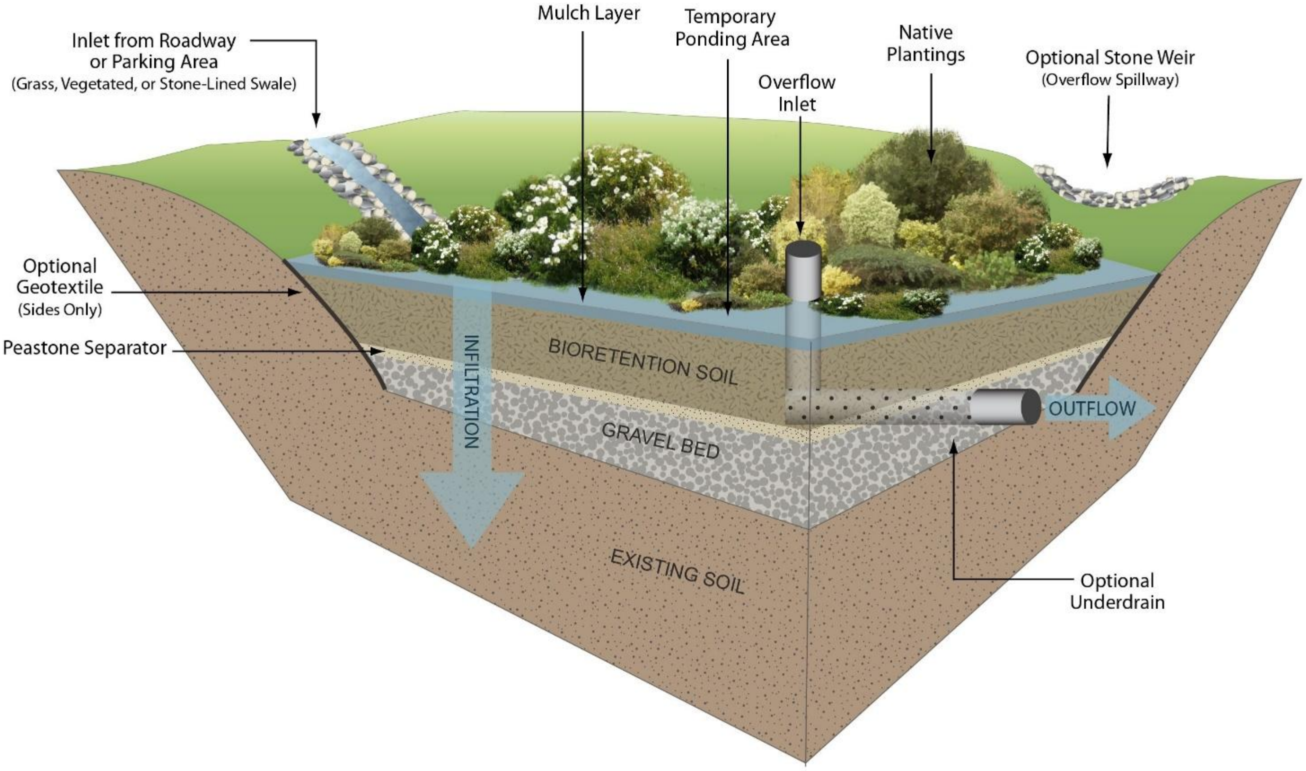
Must consider resistance of boundary materials and potential for reduced sediment load over time

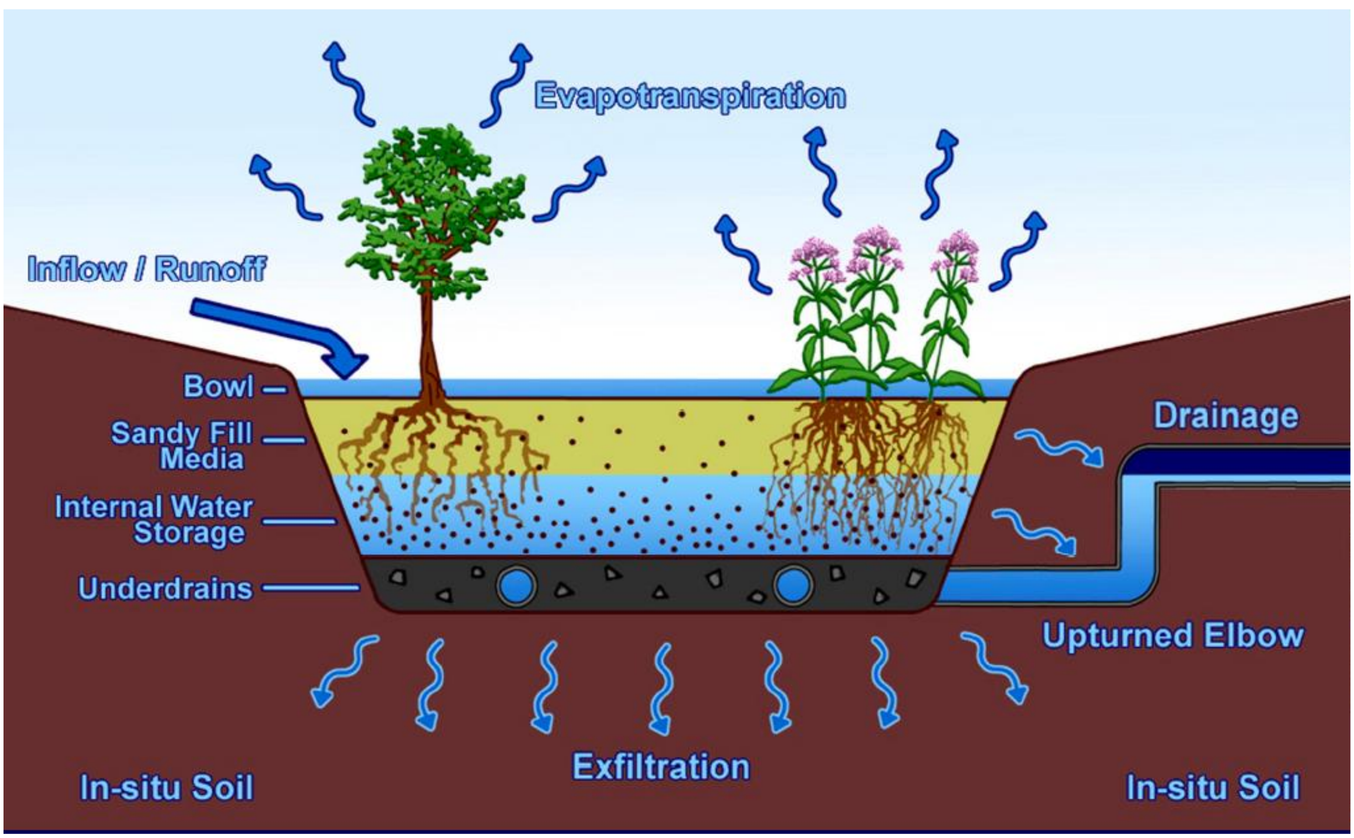
Must quantify bucket: all erosive flows over time (magnitude and duration)





Whelchel et al. (2018)


Inlet from Roadway
or Parking Area
(Grass, Vegetated, or Stone-Lined Swale)
Mulch Layer
Temporary
Ponding Area
Overflow
Inlet
Native
Plantings
Optional Stone Weir
(Overflow Spillway)
Optional
Geotextile
(Sides Only)
Peastone Separator
INFILTRATION
BIORETENTION SOIL
OUTFLOW
GRAVEL BED
EXISTING SOIL
Optional
Underdrain

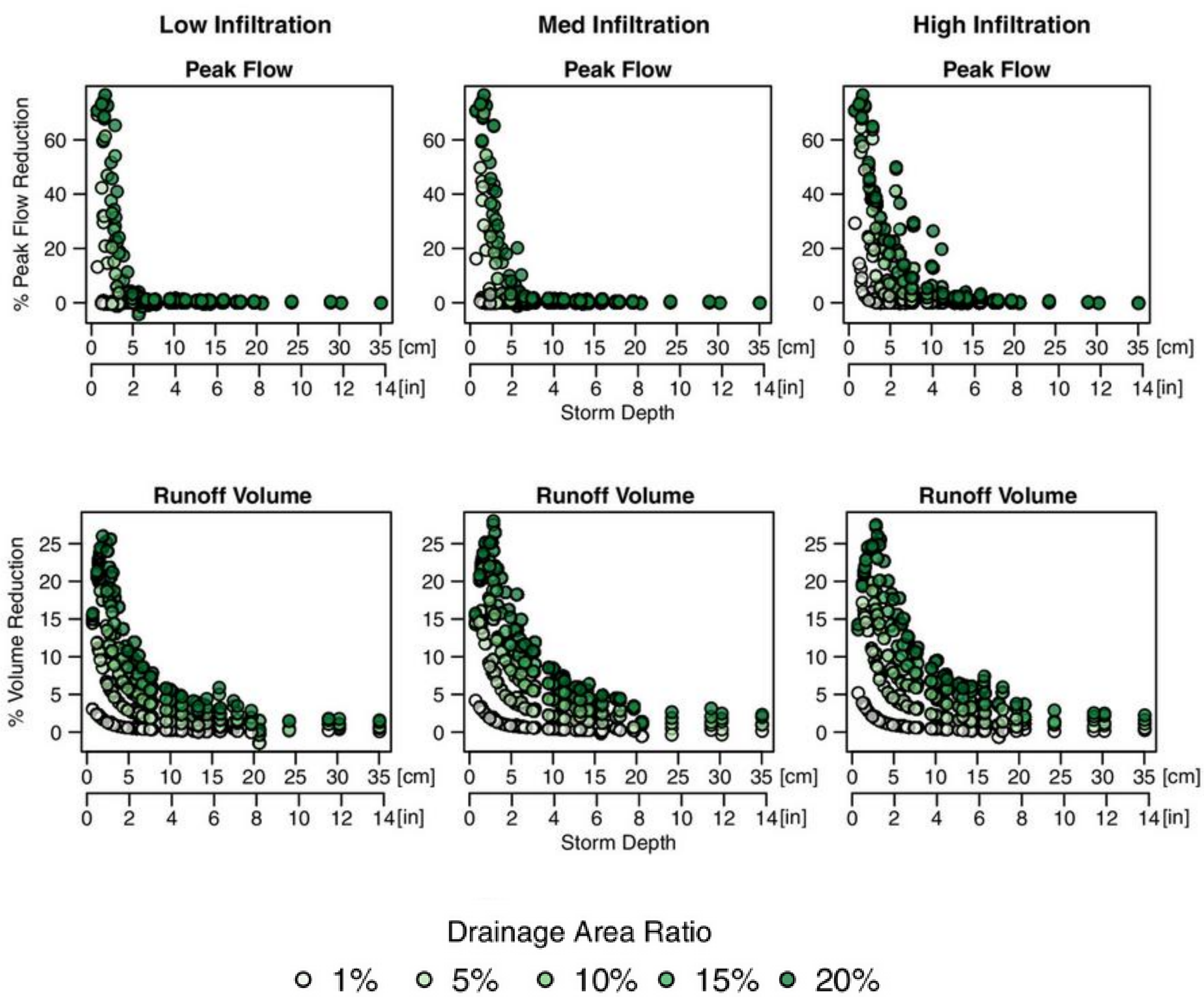

Evapotranspiration
Inflow / Runoff
Bowl
Sandy Fill
Media
Internal Water
Storage
Underdrains
Drainage
Upturned Elbow
Exfiltration
In-situ Soil
In-situ Soil

OPEN ACCESS | Technical Papers | Jul 14, 2022

Effects of Design and Climate on Bioretention Effectiveness for Watershed-Scale Hydrologic Benefits

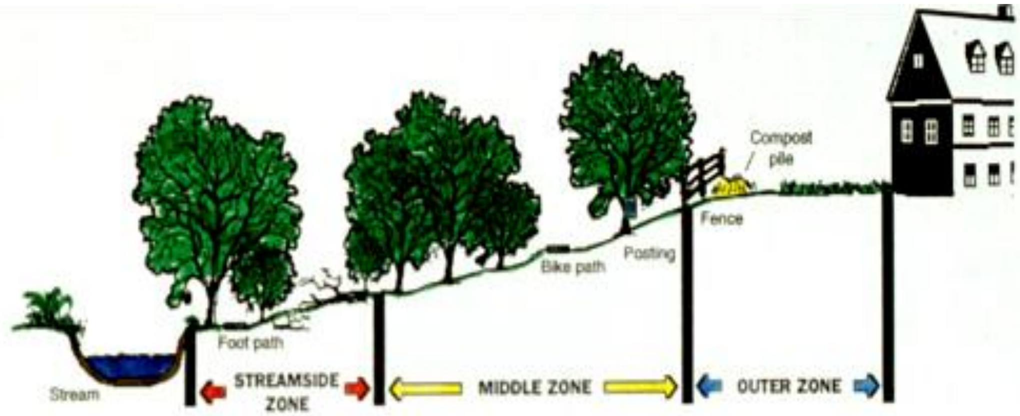
Authors: Roderick W. Lammers, Ph.D., Laura Miller, and Brian P. Bledsoe, Ph.D., M.ASCE | AUTHOR AFFILIATIONS

Publication: Journal of Sustainable Water in the Built Environment • Volume 8, Issue 4 • https://doi.org/10.1061/JSWBAY.0000993



Feature article from Watershed Protection Techniques. 1(4): 155-163

The Architecture of Urban Stream Buffers



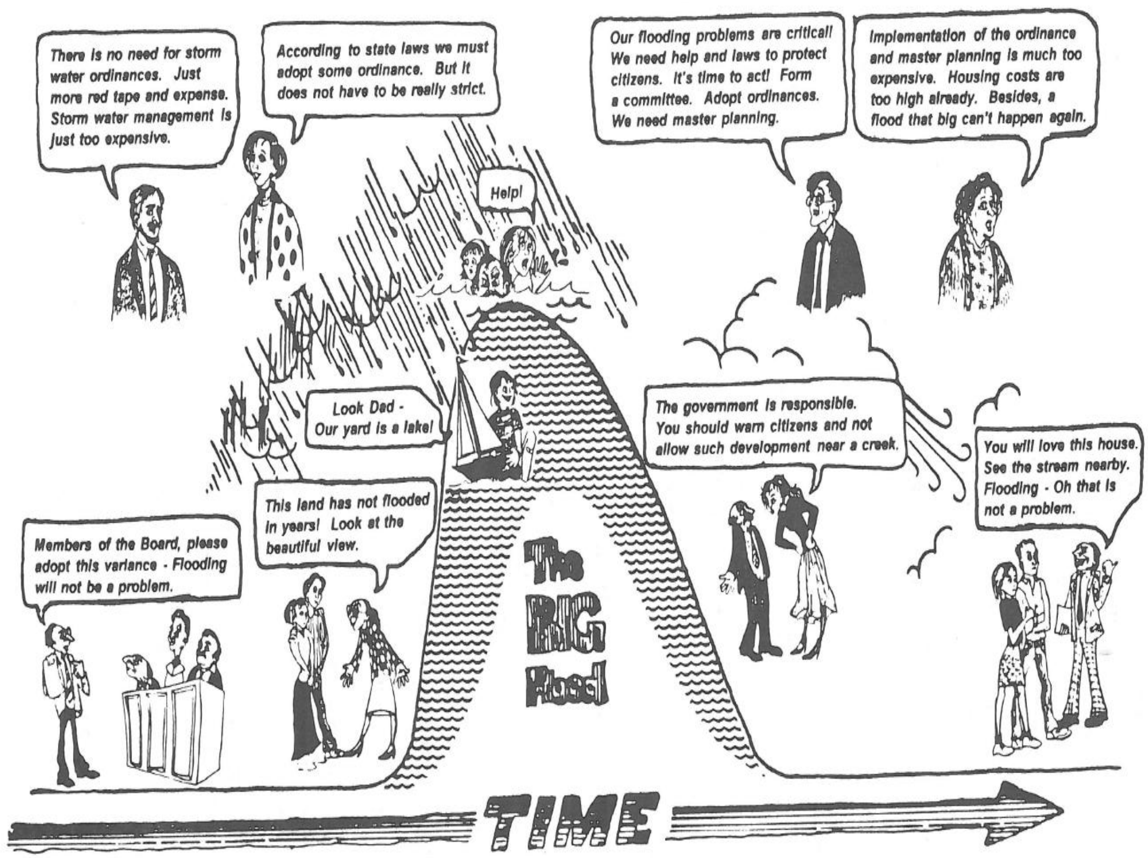
CHARACTERISTICS	STREAMSIDE ZONE	MIDDLE ZONE	OUTER ZONE
FUNCTION	Protect the physical integrity of the stream ecosystem	Provide distance between upland development and streamside zone	Prevent encroachment and filter backyard runoff
WIDTH	Min. 25 feet, plus wetlands and critical habitats	50 to 100 feet, depending on stream order, slope, and 100 year floodplain	25 foot minimum setback to structures
VEGETATIVE TARGET	Undisturbed mature forest. Reforest if grass	Managed forest, some clearing allowable	Forest encouraged, but usually turfgrass
ALLOWABLE USES	***Very Restricted*** e.g., flood control, utility right of ways, footpaths, etc.	***Restricted*** e.g., some recreational uses, some stormwater BMPs, bike paths, tree removal by permit	***Unrestricted*** e.g., residential uses including lawn, garden, compost, yard wastes, most stormwater BMPs

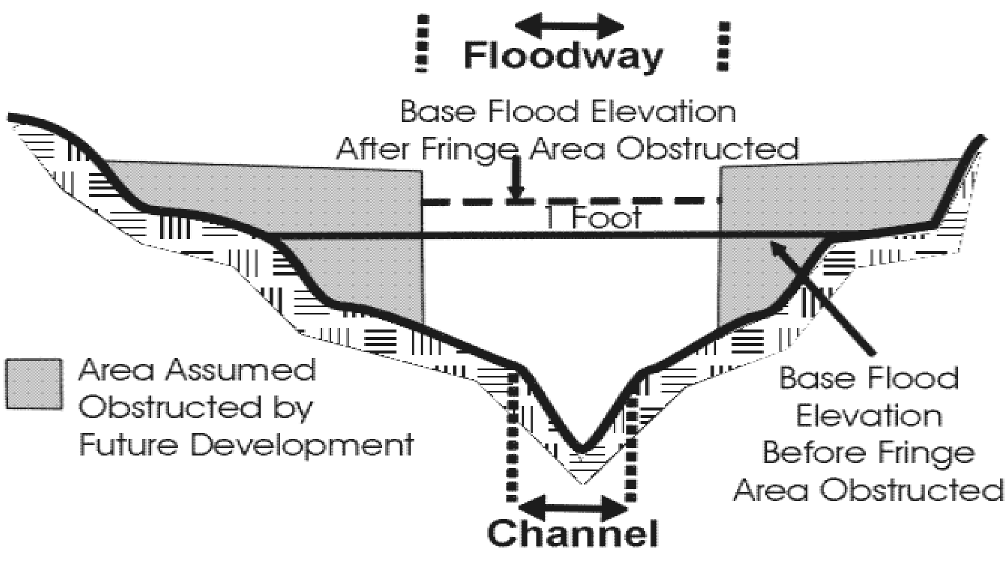
Table 2: Nuts and Bolts of an Urban Stream Buffer

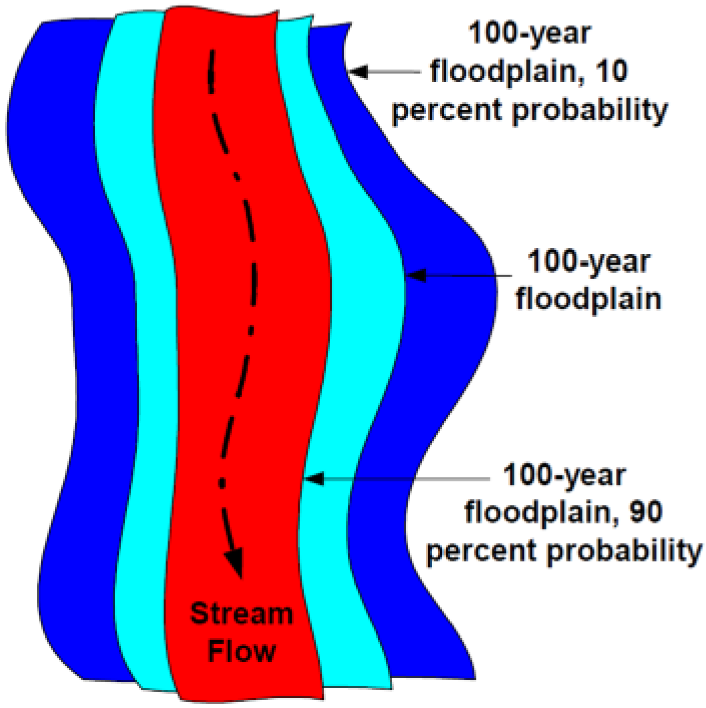
- Minimum total width of 100 feet, including floodplain
- Zone-specific goals and restrictions for the outer, middle, and streamside zones
- Adopt a vegetative target based on predevelopment plant community
- Expand the width of the middle zone to pick up wetlands,slopes and larger streams
- Use clear and measurable criteria to delineate the origin and boundaries of the buffer
- The number and conditions for stream and buffer crossings should be limited
- The use of buffer for stormwater runoff treatment should be carefully prescribed
- Buffer boundaries should be visible before, during, and after construction
- Buffer education and enforcement are needed to protect buffer integrity
- Buffer administration should be flexible and fair to landowners

Table 1: Twenty Benefits of Urban Stream Buffers
(*f*) = Benefit Amplified by or Requires Forest Cover

1. **Reduces watershed imperviousness by 5%.** An average buffer width of 100 feet protects up to 5% of watershed area from future development.
2. **Distances areas of impervious cover from the stream.** More room is made available for placement of stormwater practices, and septic system performance is improved. (*f*)
3. **Reduces small drainage problems and complaints.** When properties are located too close to a stream, residents are likely to experience and complain about backyard flooding, standing water, and bank erosion. A buffer greatly reduces complaints.
4. **Stream "right of way" allows for lateral movement.** Most stream channels shift or widen over time; a buffer protects both the stream and nearby properties.
5. **Effective flood control.** Other, expensive flood controls not necessary if buffer includes the 100-yr floodplain.
6. **Protection from streambank erosion.** Tree roots consolidate the soils of floodplain and stream banks, reducing the potential for severe bank erosion. (*f*)
7. **Increases property values.** Homebuyers perceive buffers as attractive amenities to the community. 90% of buffer administrators feel buffers have a neutral or positive impact on property values. (*f*)
8. **Increased pollutant removal.** Buffers can provide effective pollutant removal for development located within 150 feet of the buffer boundary, when designed properly.
9. **Foundation for present or future greenways.** Linear nature of the buffer provides for connected open space, allowing pedestrians and bikes to move more efficiently through a community. (*f*)
10. **Provides food and habitat for wildlife.** Leaf litter is the base food source for many stream ecosystems; forests also provides woody debris that creates cover and habitat structure for aquatic insects and fish. (*f*)
11. **Mitigates stream warming.** Shading by the forest canopy prevents further stream warming in urban watersheds. (*f*)
12. **Protection of associated wetlands.** A wide stream buffer can include riverine and palustrine wetlands that are frequently found along the stream corridor.
13. **Prevent disturbance to steep slopes.** Removing construction activity from these sensitive areas is the best way to prevent severe rates of soil erosion. (*f*)
14. **Preserves important terrestrial habitat.** Riparian corridors are important transition zones, rich in species. A mile of stream buffer can provide 25-40 acres of habitat area. (*f*)
15. **Corridors for conservation.** Unbroken stream buffers provide "highways" for migration of plant and animal populations. (*f*)
16. **Essential habitat for amphibians.** Amphibians require both aquatic and terrestrial habitats and are dependent on riparian environments to complete their life cycle. (*f*)
17. **Fewer barriers to fish migration.** Chances for migrating fish are improved when stream crossings are prevented or carefully planned.
18. **Discourages excessive storm drain enclosures/channel hardening.** Can protect headwater streams from extensive modification.
19. **Provides space for stormwater ponds.** When properly placed, structural stormwater practices within the buffer can be an ideal location for stormwater practices that remove pollutants and control flows from urban areas.
20. **Allowance for future restoration.** Even a modest buffer provides space and access for future stream restoration, bank stabilization, or reforestation.

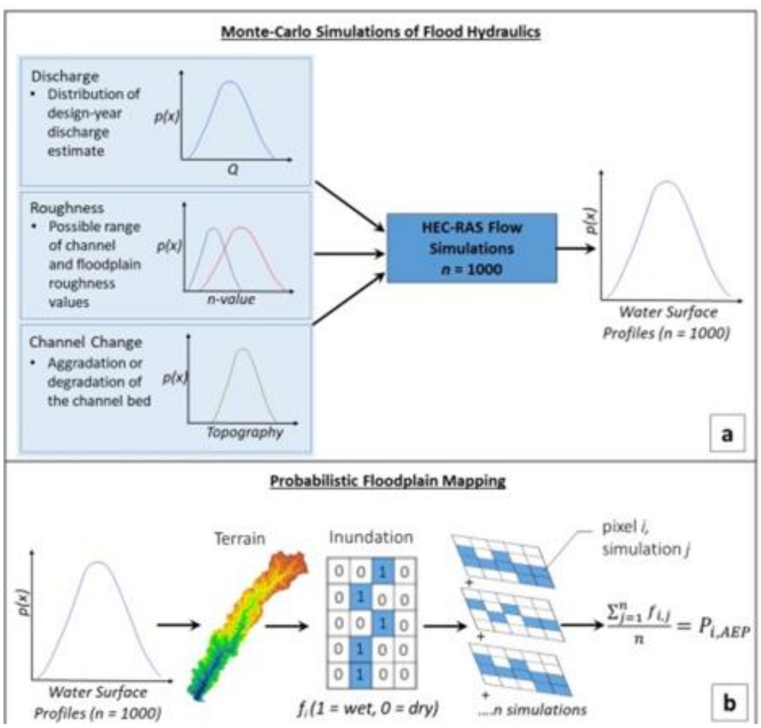

Members of the Board, please adopt this variance - Flooding will not be a problem.
There is no need for storm water ordinances. Just more red tape and expense. Storm water management is just too expensive.
This land has not flooded in years! Look at the beautiful view.
According to state laws we must adopt some ordinance. But it does not have to be really strict.
Look Dad - Our yard is a lake!
Help!
The BIG Flood
Our flooding problems are critical! We need help and laws to protect citizens. It's time to act! Form a committee. Adopt ordinances. We need master planning.
The government is responsible. You should warn citizens and not allow such development near a creek.
Implementation of the ordinance and master planning is much too expensive. Housing costs are too high already. Besides, a flood that big can't happen again.
You will love this house. See the stream nearby. Flooding - Oh that is not a problem.
TIME


Floodway
Base Flood Elevation After Fringe Area Obstructed
1 Foot
Area Assumed Obstructed by Future Development
Base Flood Elevation Before Fringe Area Obstructed
Channel

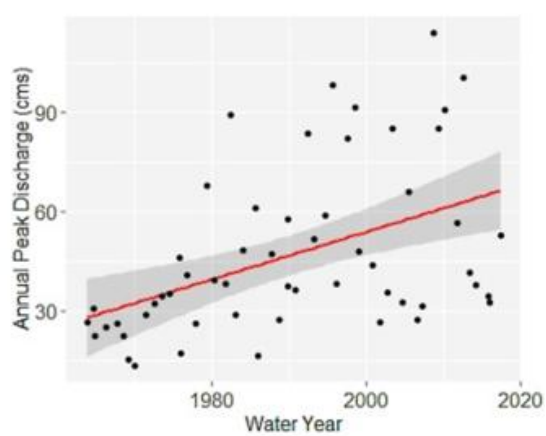


Floodplain maps that reflect uncertainty in:

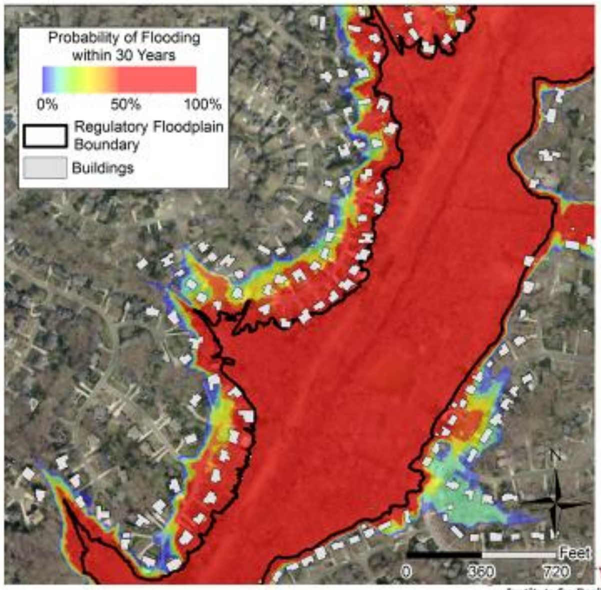
- Extreme precipitation
- Land use change
- Drainage infrastructure
- Channel geometry, channel change, sediment and debris
- Flow resistance / vegetation, debris
- Model parameters

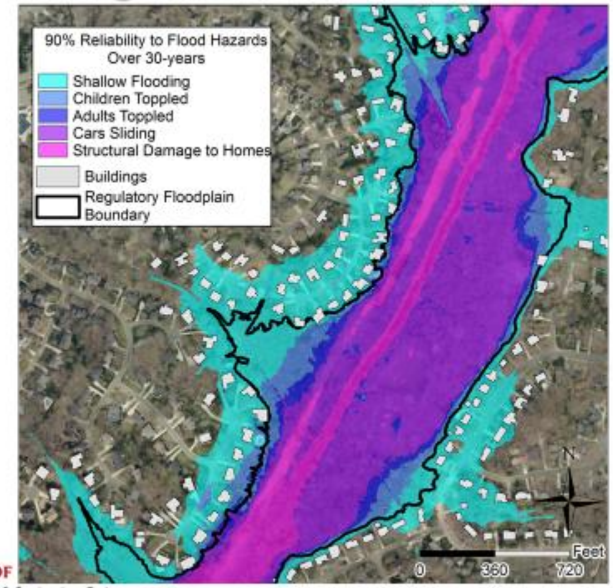


Probabilistic Floodplain Mapping



Risk Over a Planning Horizon





Y OF
Institute for Resilient Infrastructure Systems

Communicating flood risk:

- A 100-year flood has more than a 1 in 4 chance of occurring over a 30-year motgage.
- For 90% reliability over 30-years, structures must be above the 285-year flood.
- For 90% reliability over 50 years, structures must be above the 474-year flood.
- IF THE FUTURE BEHAVES LIKE THE PAST

Risk Ratios (Inequity > 1)

$$\textit{Race Flood Risk Ratio} = \frac{\left(\frac{At-Risk\ Black}{Total\ Black}\right)}{\left(\frac{At-Risk\ White}{Total\ White}\right)}$$

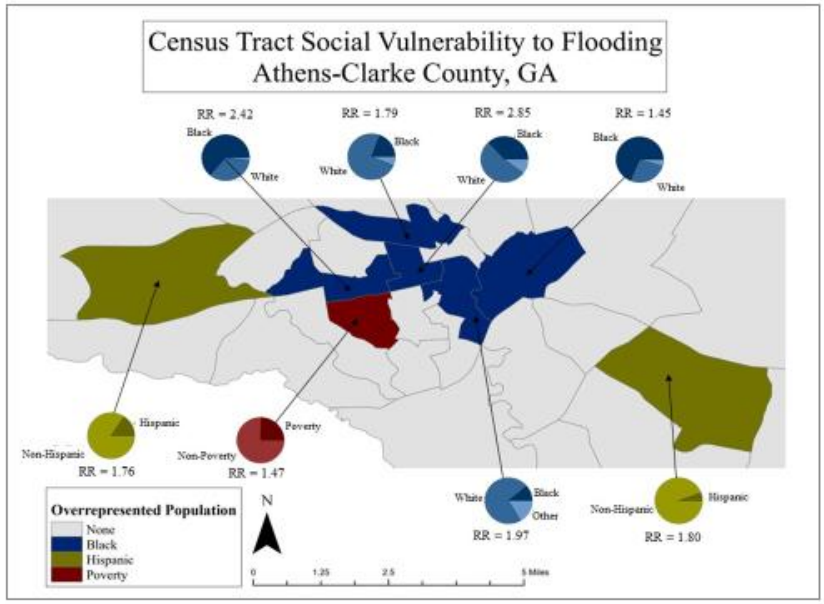
Benefit Ratios (Inequity <1)

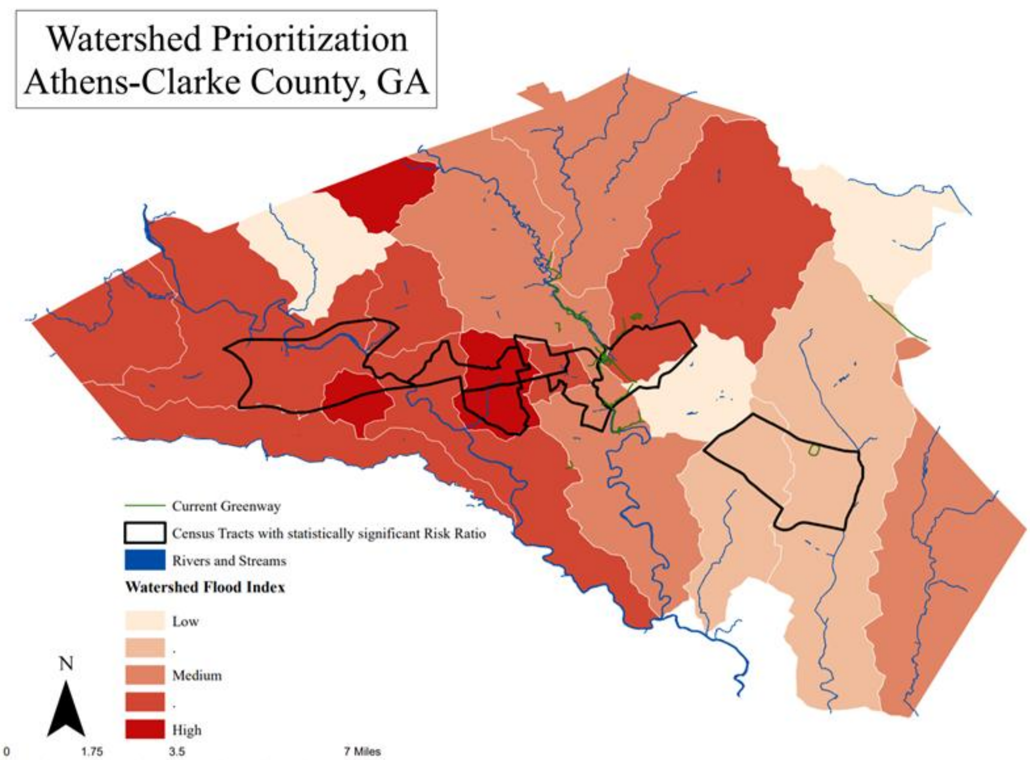
$$\textit{Poverty Benefit Ratio} = \frac{\left(\frac{Below\ Poverty\ w/Access}{Total\ Below\ Poverty}\right)}{\left(\frac{Above\ Poverty\ w/Access}{Total\ Above\ Poverty}\right)}$$

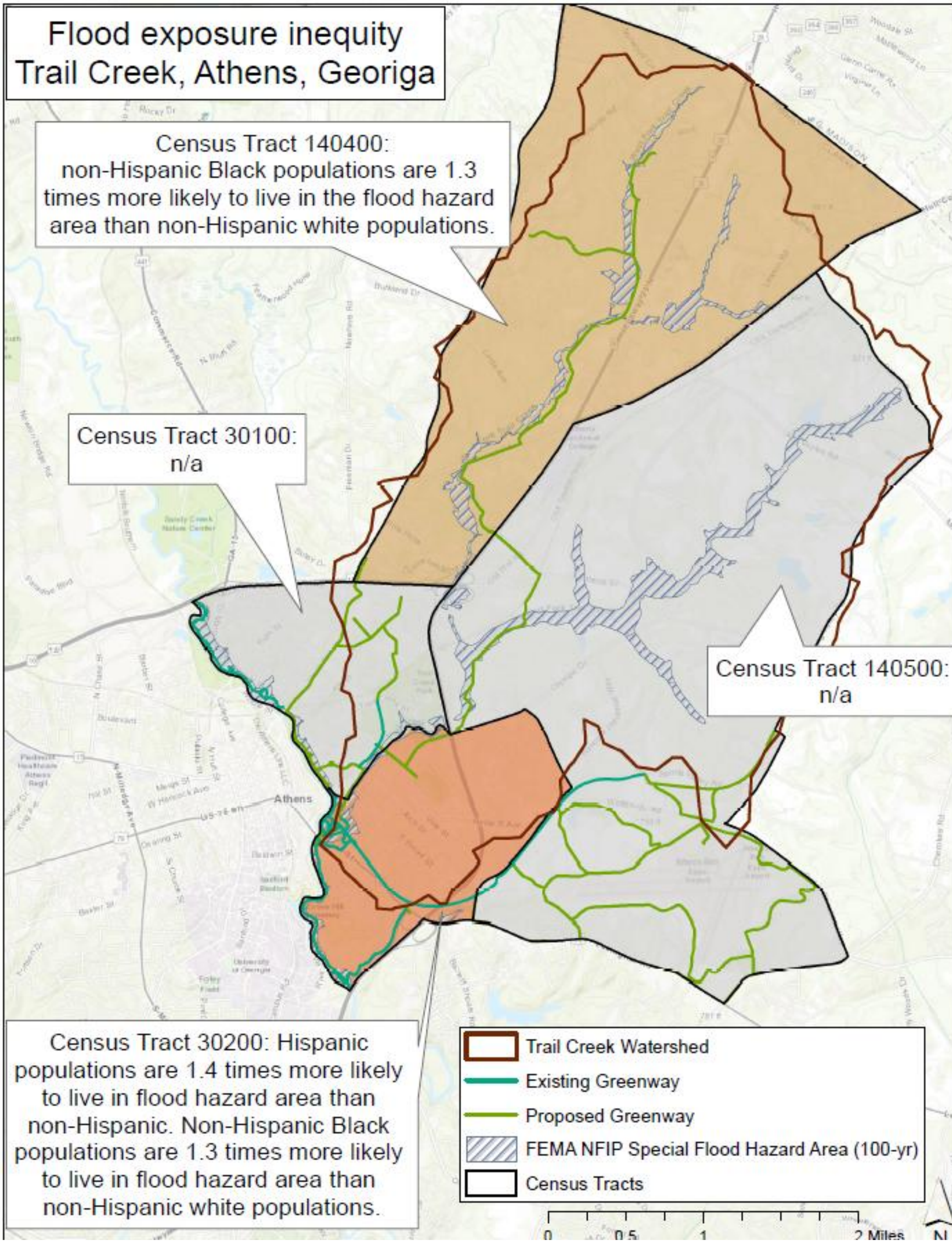
Debbage, N. A. 2019. Multiscalar spatial analysis of urban flood risk and environmental justice in the Charlanta megaregion, USA. Anthropocene 28:100226.

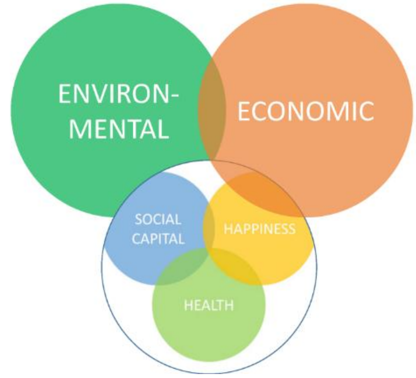
Socially vulnerable populations have higher flood exposure

Black, Hispanic, and low-income populations experience 38 to 185% greater flood risk than average in Athens, GA

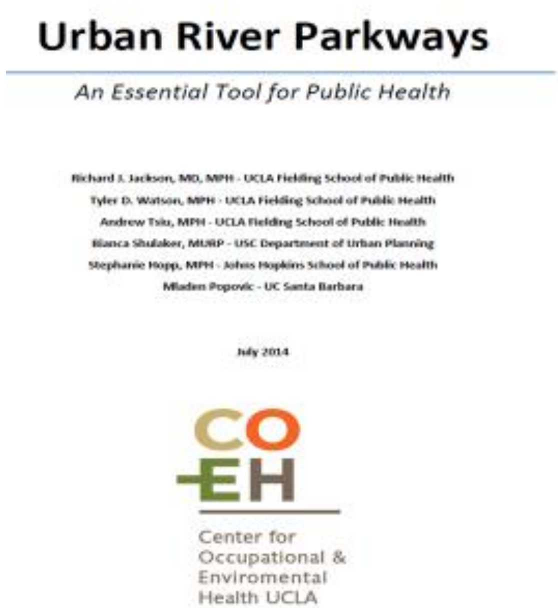





Flood exposure inequity
Trail Creek, Athens, Georiga
Census Tract 140400: non-Hispanic Black populations are 1.3 times more likely to live in the flood hazard area than non-Hispanic white populations.
Census Tract 30100: n/a
Census Tract 140500: n/a
Census Tract 30200: Hispanic populations are 1.4 times more likely to live in flood hazard area than non-Hispanic. Non-Hispanic Black populations are 1.3 times more likely to live in flood hazard area than non-Hispanic white populations.
Trail Creek Watershed
Existing Greenway
Proposed Greenway
FEMA NFIP Special Flood Hazard Area (100-yr)
Census Tracts
0
0.5
1
2 Miles
N
Athens



- Is there a role for the built environment and natural infrastructure in helping make people happier and healthier?
- This is a growing literature that suggests there is a "geography of happiness". This approach to place making aims: to make people happy, to connect them to each other, to promote good health, and to help them thrive!
- This might involve clean air, quiet, short commutes, nature contact, "third places", and beauty…
- To do this, we need to advance science and practice as well as stakeholder utility by:
    - Improving description of actual flood risks (combined effects of land use, climate, channels).
    - Identifying and addressing risk inequities.
    - Coorindating stream restoration and stormwater management to improve outcomes and define realistic expectations.
    - Scaling and targetting natural / hybrid infrastructure solutions to deliver a broader array of benefits (i.e., social, hydrological, water quality, habitat,…)
- Need to seek integration of floodplain management, stormwater (green+grey), stream and buffer restoration, urban design,…



Urban River Parkways

An Essential Tool for Public Health

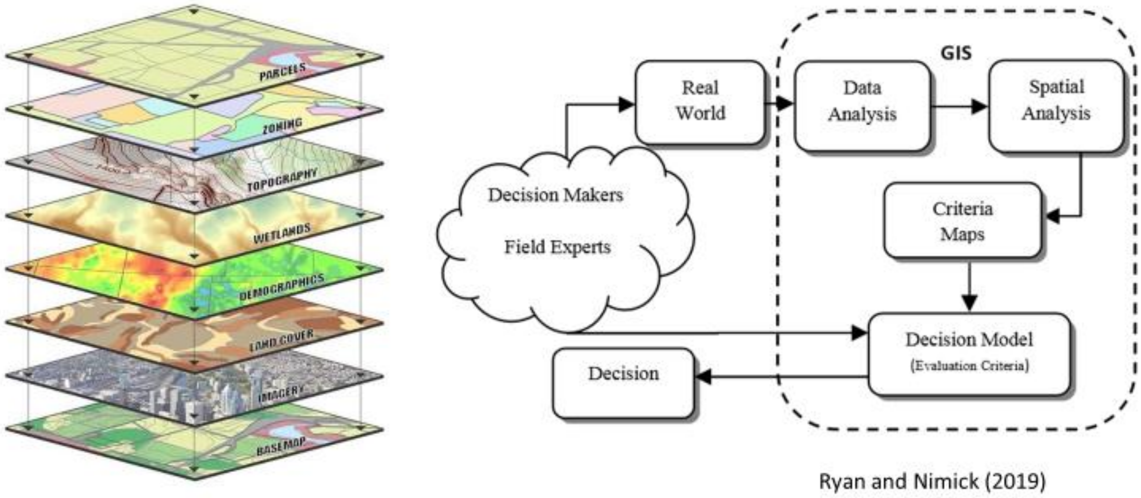
Richard J. Jackson, MD, MPH - UCLA Fielding School of Public Health
Tyler D. Watson, MPH - UCLA Fielding School of Public Health
Andrew Tsiu, MPH - UCLA Fielding School of Public Health
Bianca Shulaker, MURP - USC Department of Urban Planning
Stephanie Hopp, MPH - Johns Hopkins School of Public Health
Mladen Popovic - UC Santa Barbara

July 2014

CO
EH
Center for Occupational & Enviromental Health UCLA

Every 1 dollar spent on trails results in \$3 to >\$10 of direct medical benefit

Spatial Multi-criteria Decision Analysis (MCDA)



Ryan and Nimick (2019)

Spatial Prioritization

- Provide human and ecosystem benefits
- Choose among many challenges and potential opportunities
- Highest priority watersheds for meeting multiple objectives
- Operationalize environmental equity
- Align stream network investments
- Equitable distribution of benefits and protection from risks
- Multi-criteria decision analysis (MCDA)

Charlotte-Mecklenburg STORM WATER Services

Day 2: Exercise

Mike Wharton (ACC) and President Jere Morehead (UGA) have come to your team requesting a spatial MCDA analysis to support decision on where to allocate $10M in NI project funds in ACC and UGA, respectively. Form teams (with different people than yesterday) to identify the criteria and subcriteria that will be used to rank combinations of projects in a spatial MCDA.

Day 2: Afternoon Handout

Themes for today:

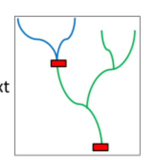
- Structured decision making is a family of methods (attempting) to make rational, transparent, and (potentially) reproducible choices. These methods INFORM decisions; people make decisions. Good decision methods don't guarantee good decision outcomes.
- Concepts of critical thinking, NBS, and structured decision-making sound great on paper, but they are really hard to execute in a constrained landscape. Ultimately, how do you "tell the story" of a project?
- Society asks water managers to simultaneously overcome past mismanagement, cope with present challenges, and adapt to future challenges, all while seeking novel solutions.

STRUCTURED DECISION MAKING:

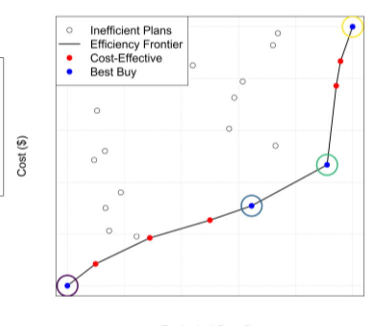
- A structured decision making framework helps (PrOACT):
  - Define the **<u>PR</u>**oblem
  - Set **<u>O</u>**bjectives
  - Develop **<u>A</u>**lternatives
  - Assess **<u>C</u>**onsequences
  - Make **<u>T</u>**rade-offs
- Tips for objective setting (Gregory and Keeney's four-step process). A few prompts they also suggest that might jar some thoughts lose...List problems and opportunities. Compose a wish list. Identify a best and worst outcome. Pros/cons of good/bad alternatives. Justify the project to the public.
  - Step 1: Write down the concerns you want to address.
  - Step 2: Convert the general concerns into specific, succinct objectives. Write objectives in verb-object format.
  - Step 3: Organize objectives. Separate the ends from the means. (Ask "Why?")
  - Step 4: Clarify what is meant by each objective.
- Tips for alternative development:
  - There should be clear alignment between your alternatives and objectives.
  - Always include a "no action" alternative. This is the null hypothesis.
  - When developing alternatives, identify a range of potential actions that could be applied. Mix and match actions to create logical sets (i.e., alternatives). Consider combinability and dependency. Make sure alternatives are substantially different in terms of philosophy, cost, and benefit. Iterate on your alternatives.

Assessing <u>Consequences</u>:
Summarizing Outcomes

What information does the decision maker need?
- Knowledge of the system, objectives, and decision context
- Analysis of costs, benefits, and return-on-investment
- Constraints and secondary objectives



Alternative	Cost	Ecological Benefit	Potential for Contamination?	Historical Preservation?	Failure Risk?
0: No action	0	0	No	No	High
1: Fish ladder	$$	+	No	Yes	High
2: Dam removal	$	++	Yes	No	Low
3: Removal with sediment mngmt	$$$	+++	No	No	Low



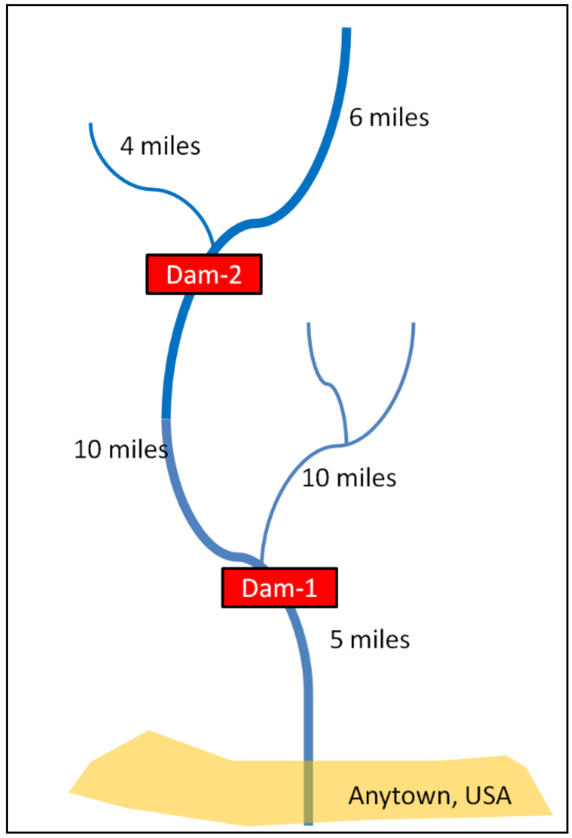
River Styx

Background:

- Small watershed on the Pacific coast
- Two obsolete mining dams, which present a flood risk to Anytown
- Commercially valuable salmon run blocked by dams
- Problem: State Environmental Agency wants to take action to reduce flood risks and benefit the environment, but funding is limited.

A few tasks:

- Set at least one **objective** beyond environmental benefit.
- Consider whether there are other **alternatives** to add to the matrix.
- Identify a mechanism to assess **consequences** for the objectives.
- Populate the decision matrix to examine **trade-offs.**
- Recommend an action.



Alternative	Cost	Ecological Benefit	
No action	0		
Remove Dam-1	2,000,000		
Remove Dam-2	1,500,000		
Remove both dams	3,000,000		