Engineering with Nature

Watershed Management Design

Aaron Byrd, Ph.D., P.E.

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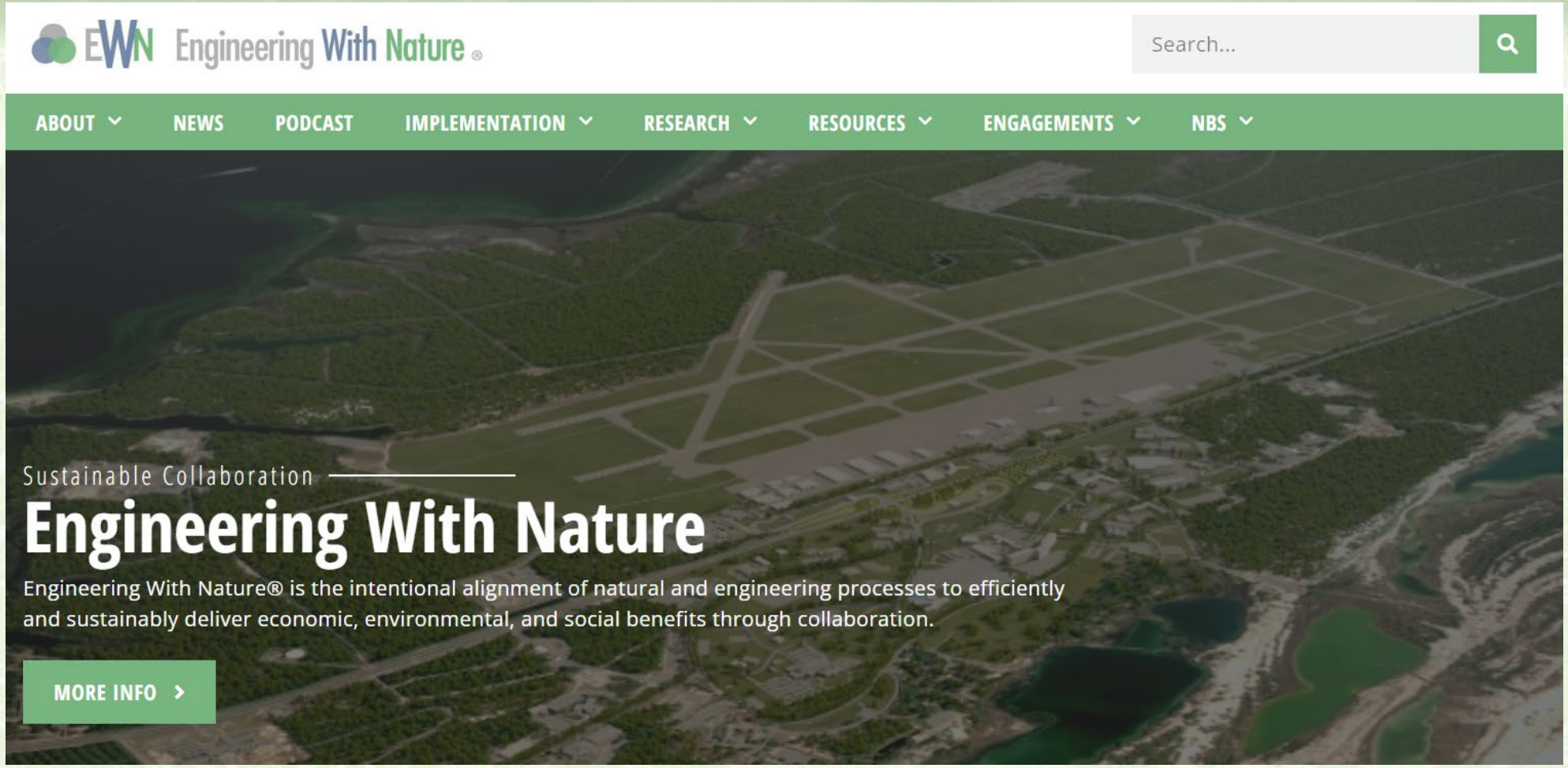
Engineering with Nature

Engineering With Nature® is the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaboration.

EWN website



https://ewn.erdc.dren.mil/

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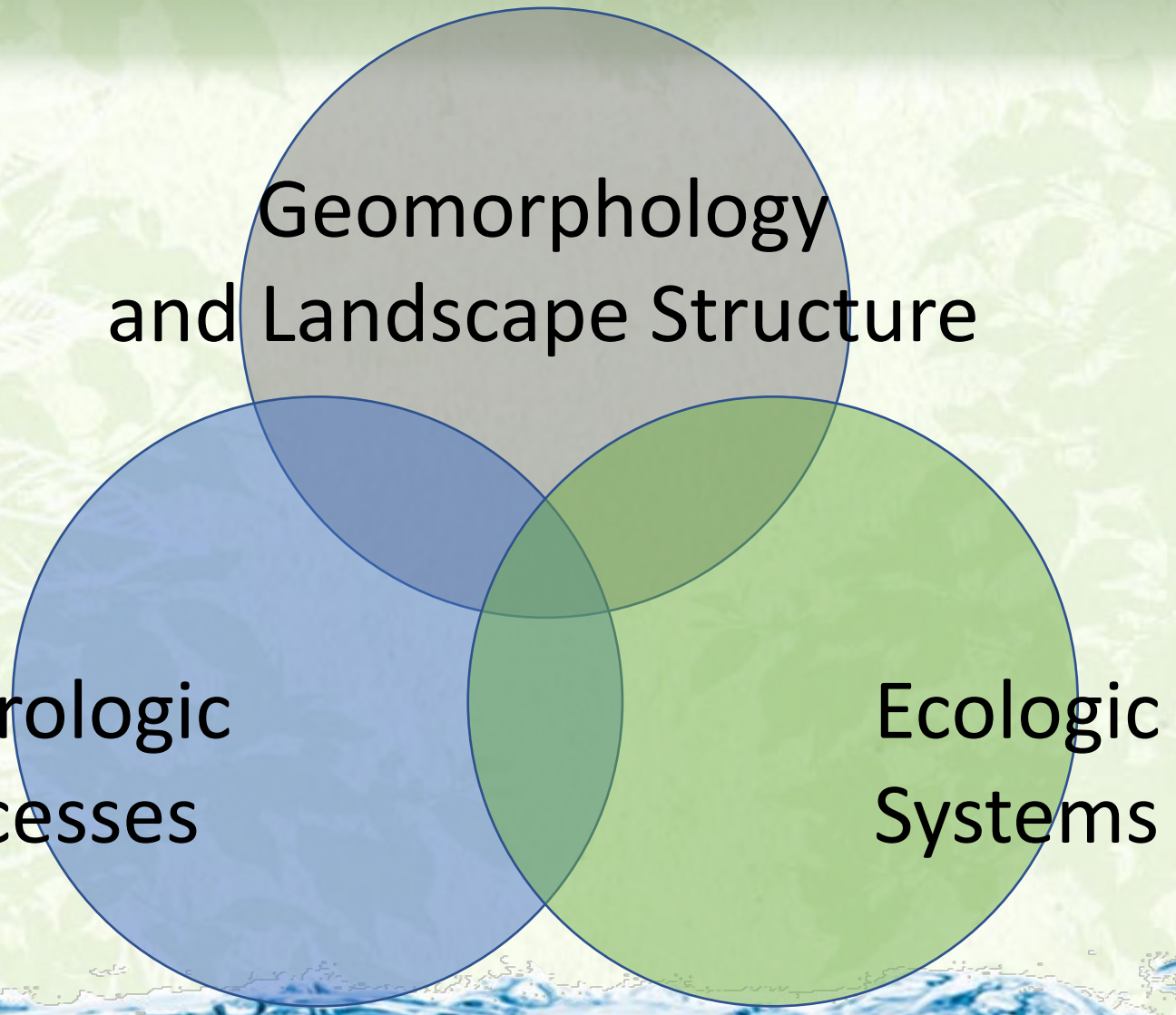
Watershed Engineering with Nature



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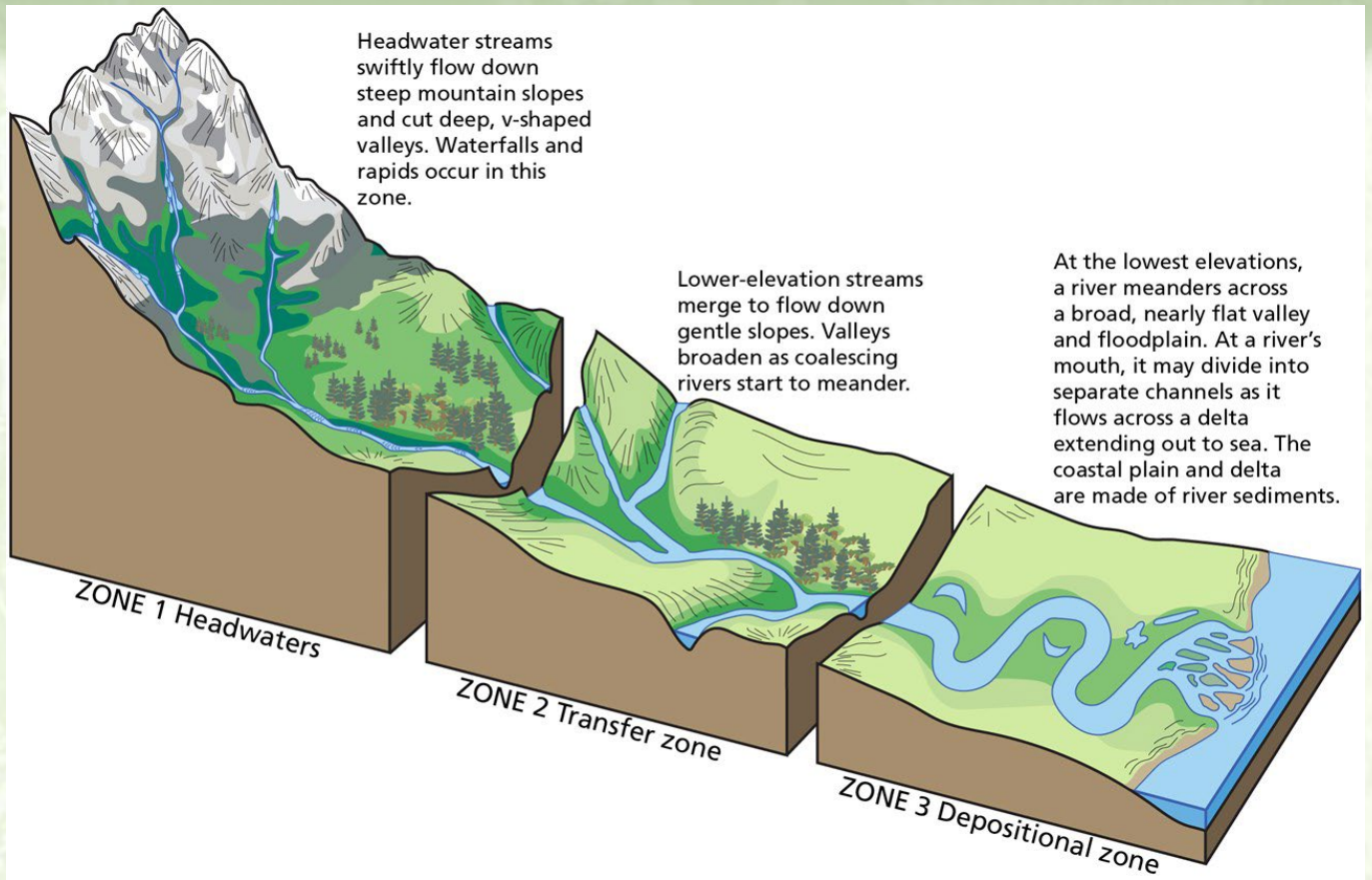
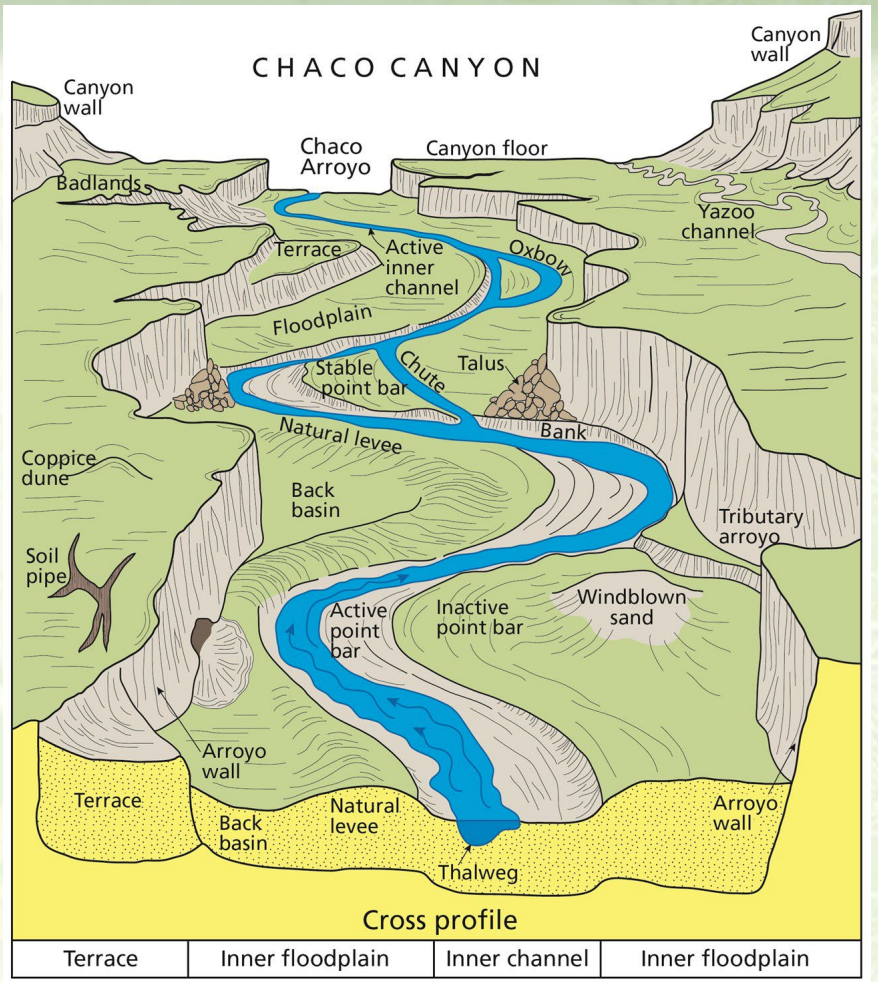
Geomorphologic Processes (Short-Short Overview)



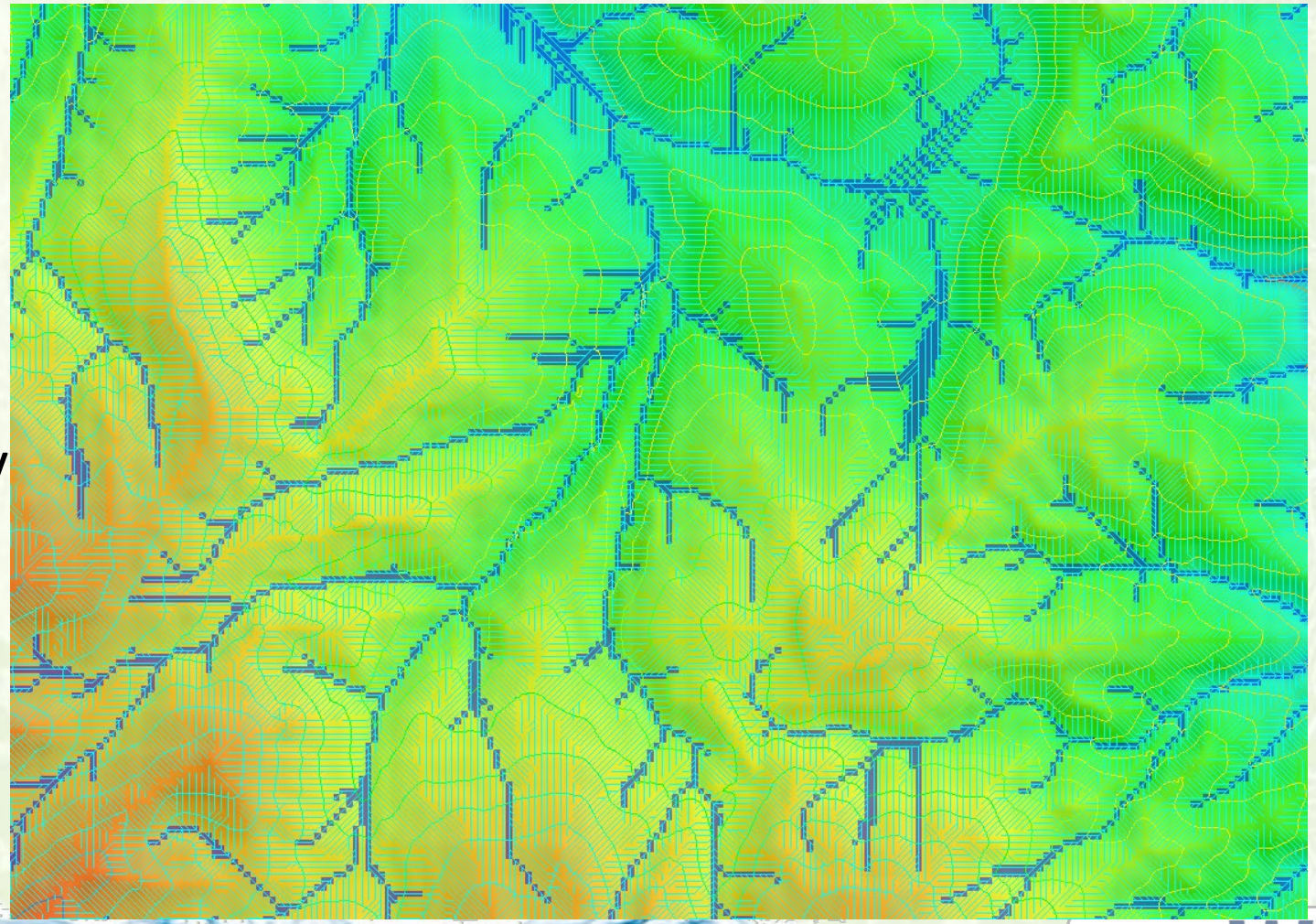


Trista L. Thornberry-Ehrlich, Colorado State University

https://www.nps.gov/subjects/geology/fluvial-landforms.htm

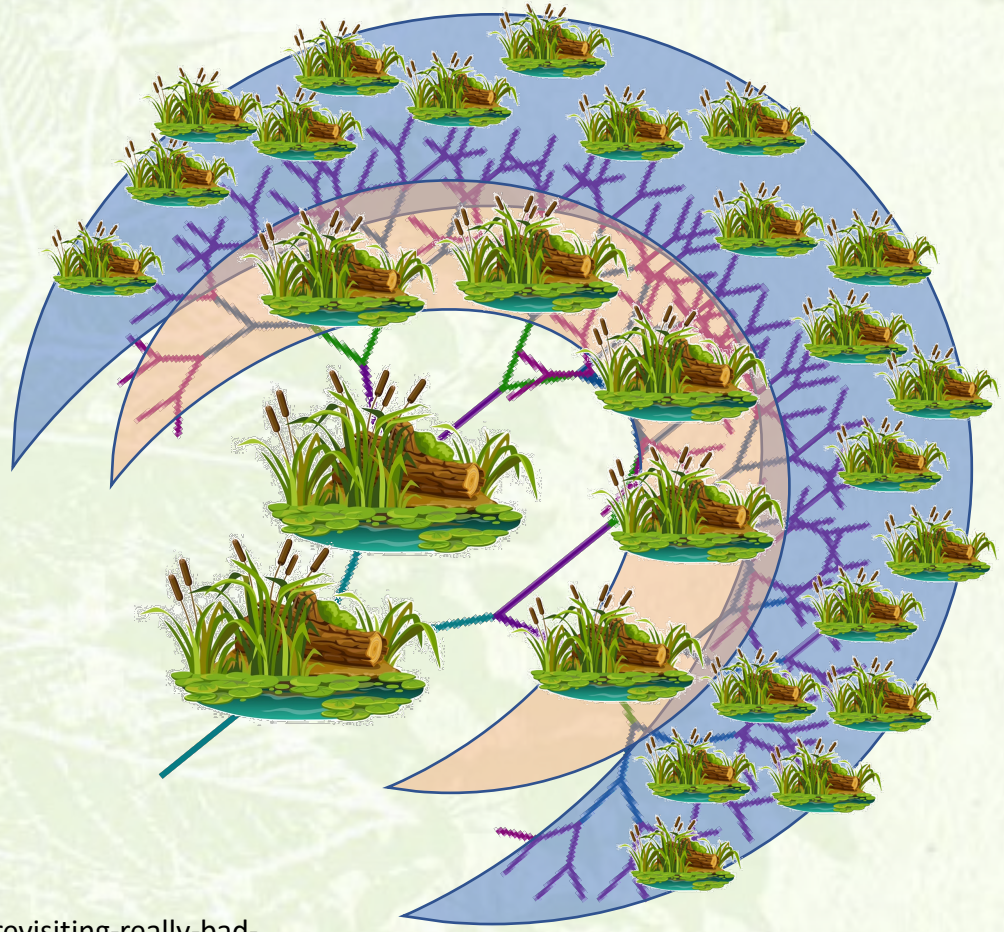
Scale and Scaling in Hydrology

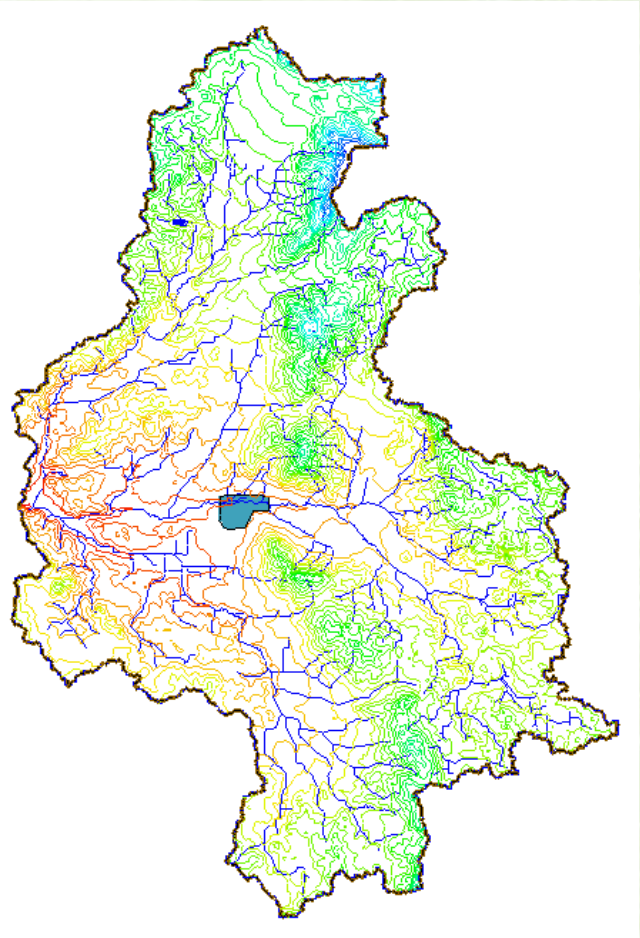
- Be cognizant of which scale the different processes operate at
- Land Cover = thin but omnipresent
- Small-order streams (headwater streams) = highly present, widely disbursed, smaller hydrologic impact but less cost
- High-order streams (larger) = fewer, have more influence, control larger amounts of water



The Fractal Nature of Stream Networks

https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/WR024i008p01317





https://hypixel.net/threads/revisiting-really-bad-scratch-projects-from-a-year-ago.3911747/

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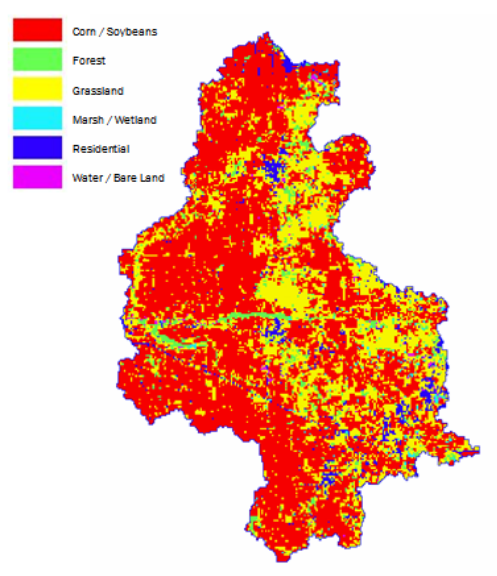
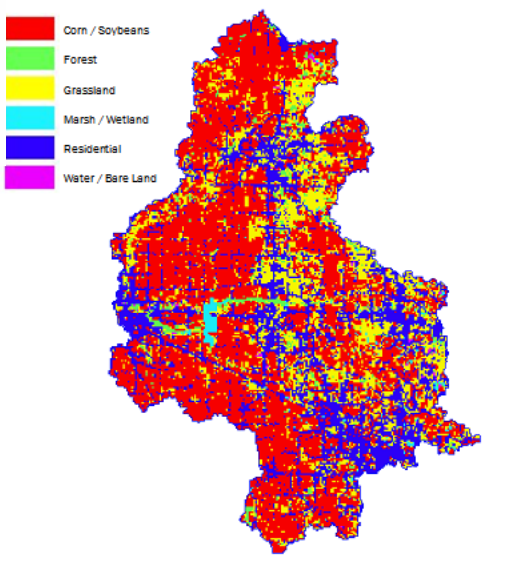
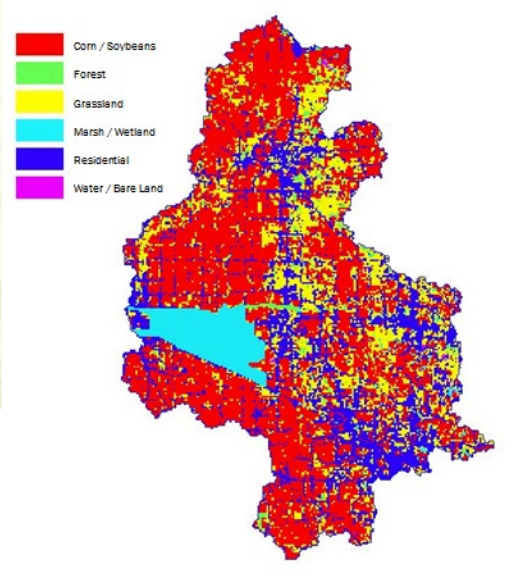
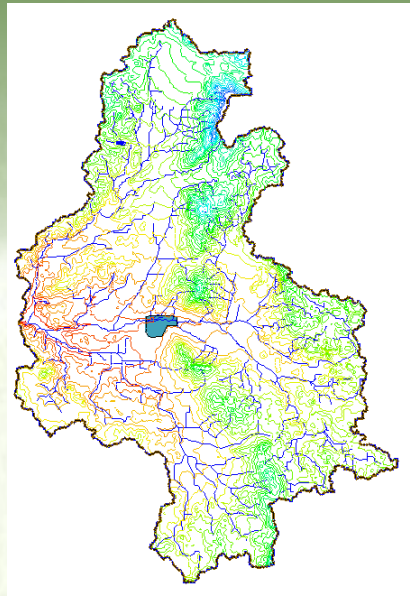
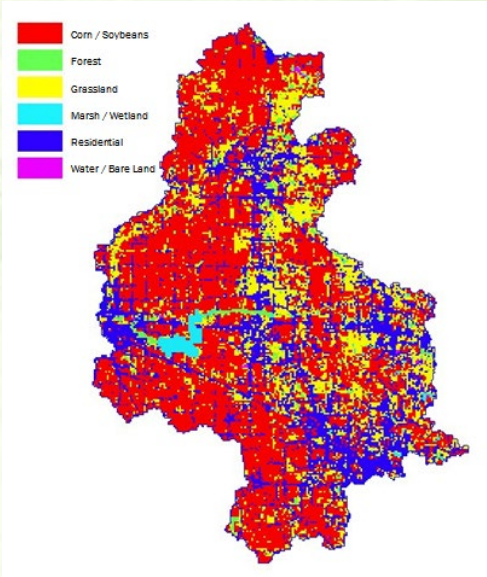
Kishwaukee Watershed:

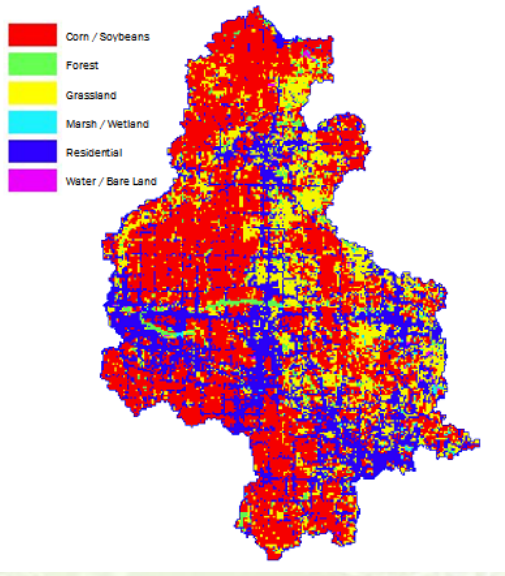












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Provo River Restoration

Aerial of 1999 pilot project before (left) and after (right)

Wetland pond: during construction (left) and after completion (right)

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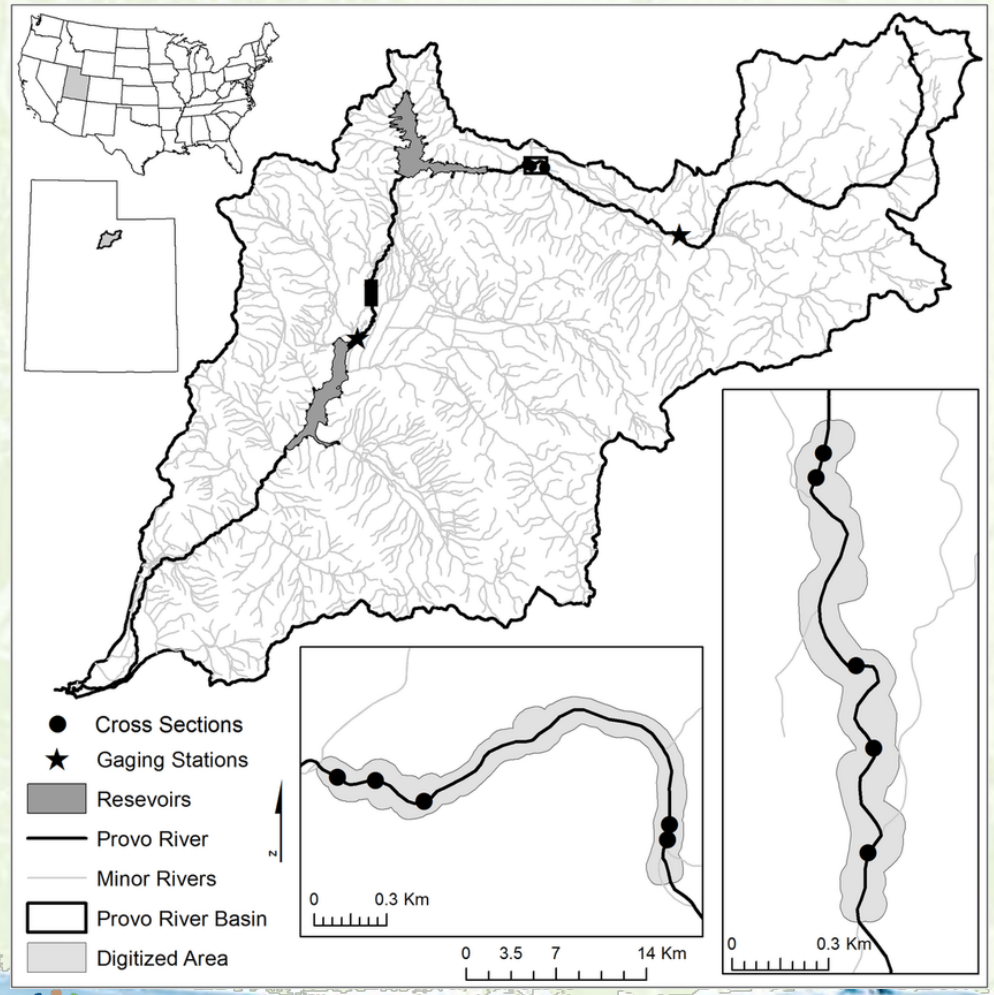
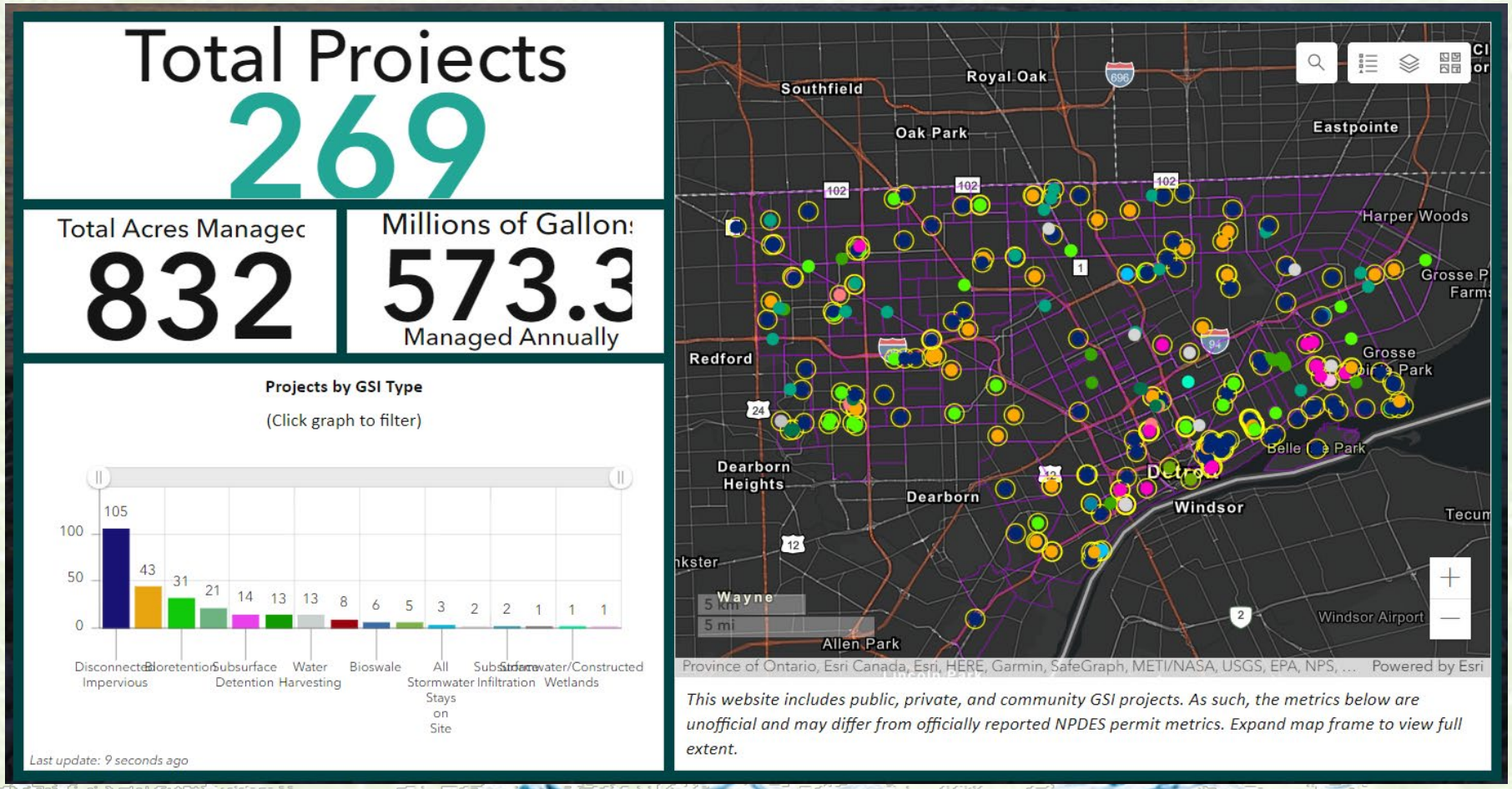
Provo River



https://www.researchgate.net/figure/Channel-reaches-and-associated-field-study-sites-within-the-Provo-River-watershed_fig1_322175352

Green Stormwater Infrastructure Projects in Detroit

https://detroitstormwater.org/projects



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Detroit Bioretention

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ENGINEER RESEARCH & DEVELOPMENT CENTER

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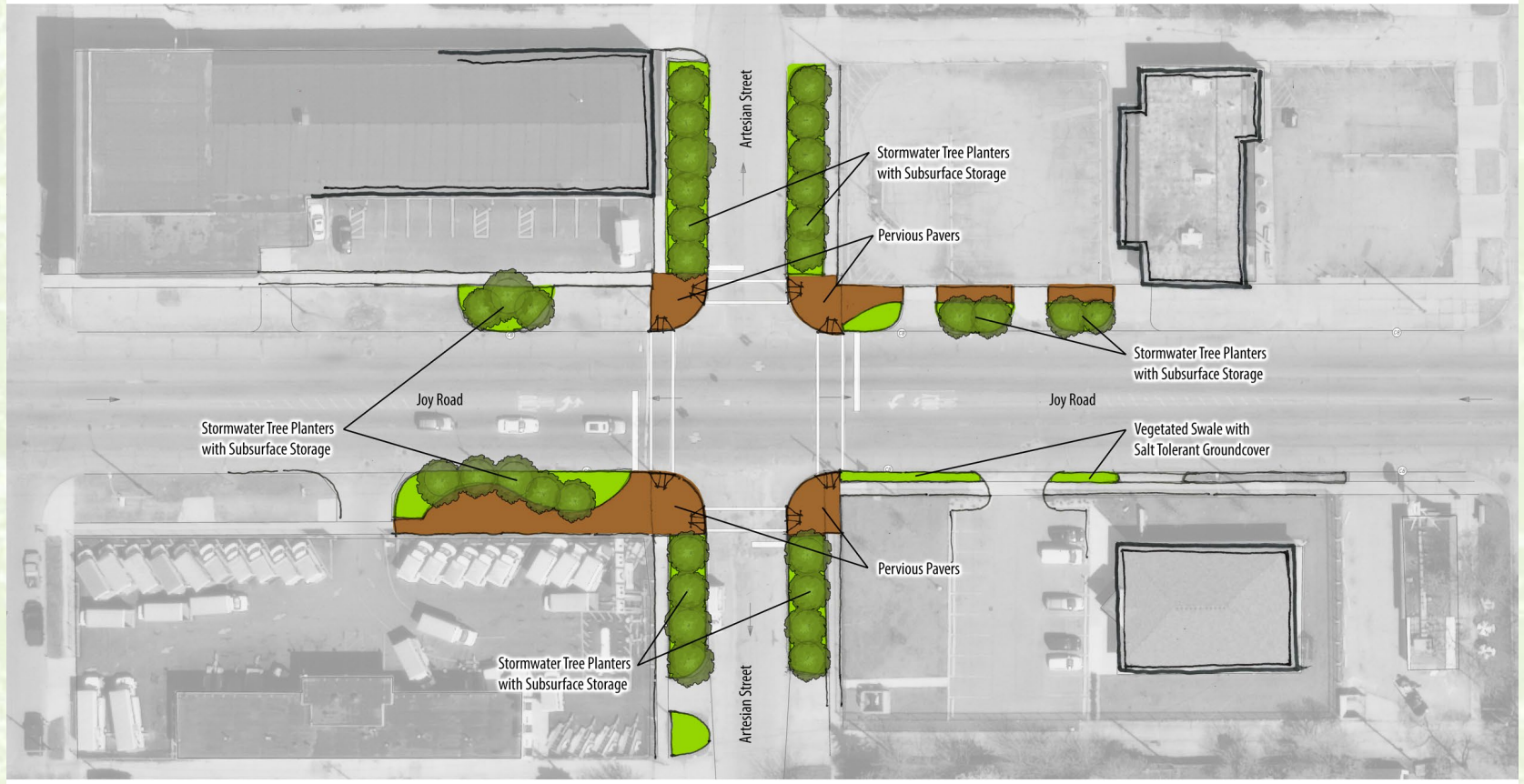
Detroit Permeable Pavement

Detroit: Local Projects Require Local Storage



Joy-Southfield
Community Development Corporation

Artesian Green Intersection

WadeTrim

North

1" = 40'

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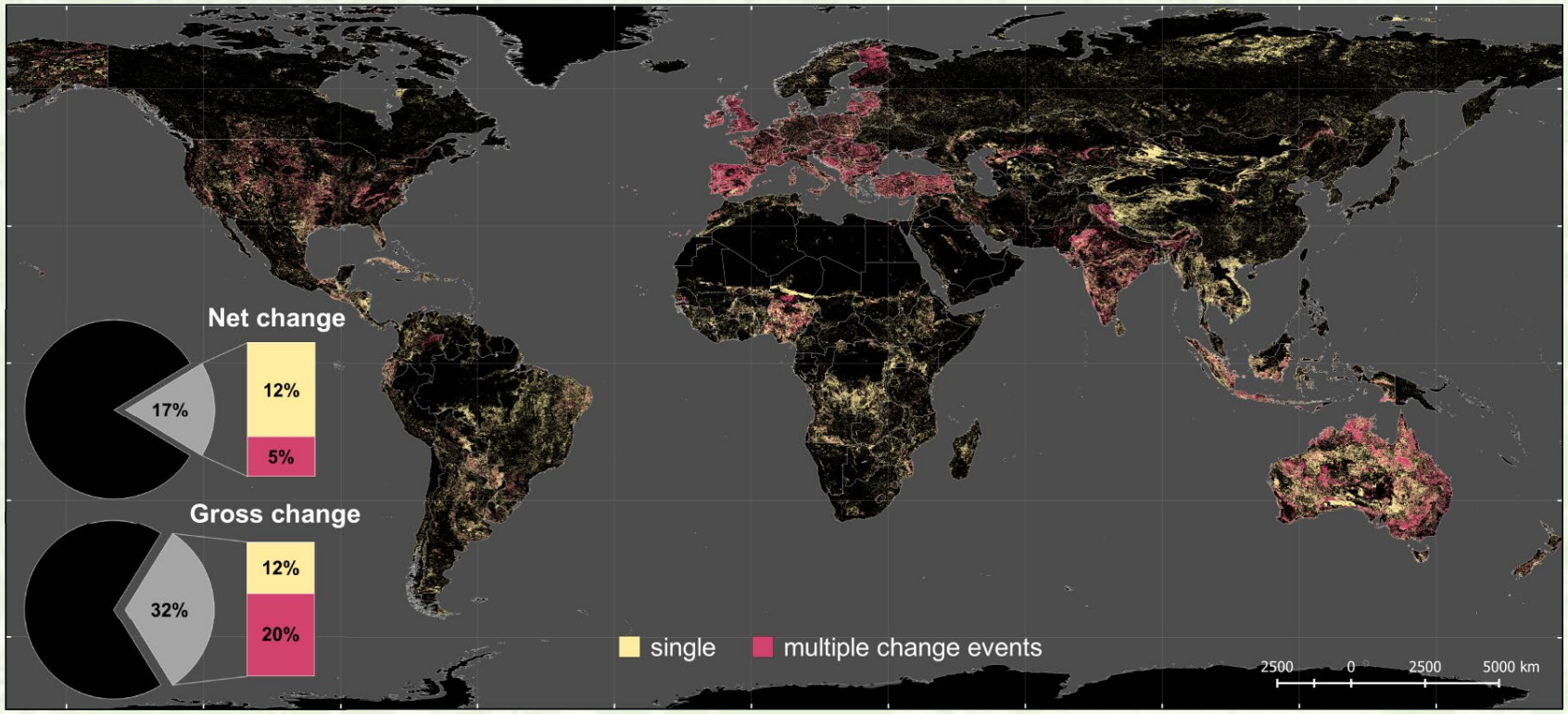
Process Transitions

- Interception, retention -> Overland Flow
- Overland Flow -> Stream Flow
  - Storm Drainage Networks
- Stream Flow -> Overbank (flood) Flows

Process Transition: Land Use Change



"We estimate that 17% of the Earth's land surface has changed at least once between the six land categories from 1960 to 2019"

Winker et. al. "Global Land Use Changes are four time greater than previously estimated."
https://www.nature.com/articles/s41467-021-22702-2

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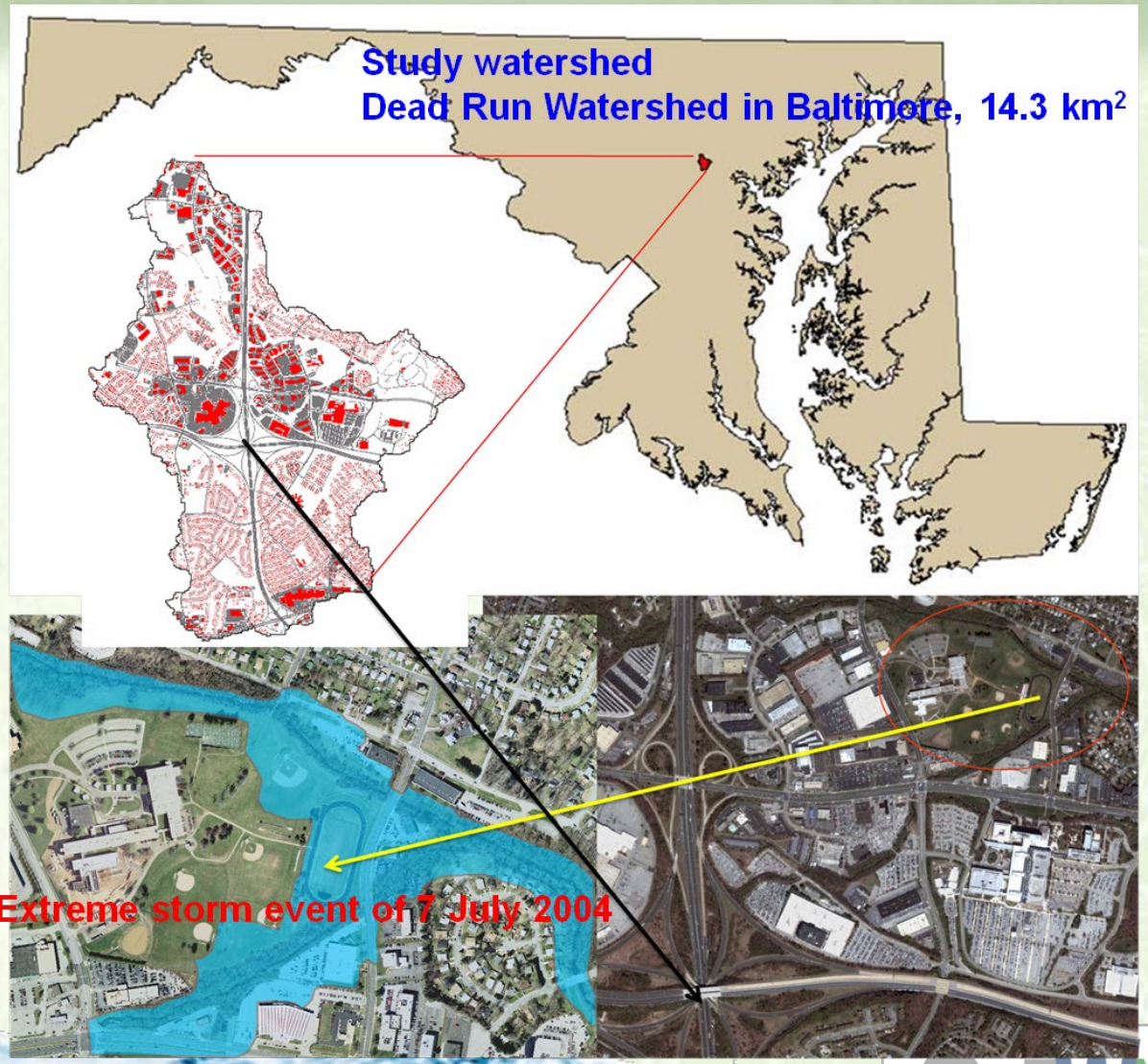
Storm Drain Networks

- Flood magnitude and frequency increase as urban development spreads throughout a watershed.
- Urban flooding poses enormous infrastructure, economic, and safety threats.
- Subsurface drainage contributes significantly to these increased risk.



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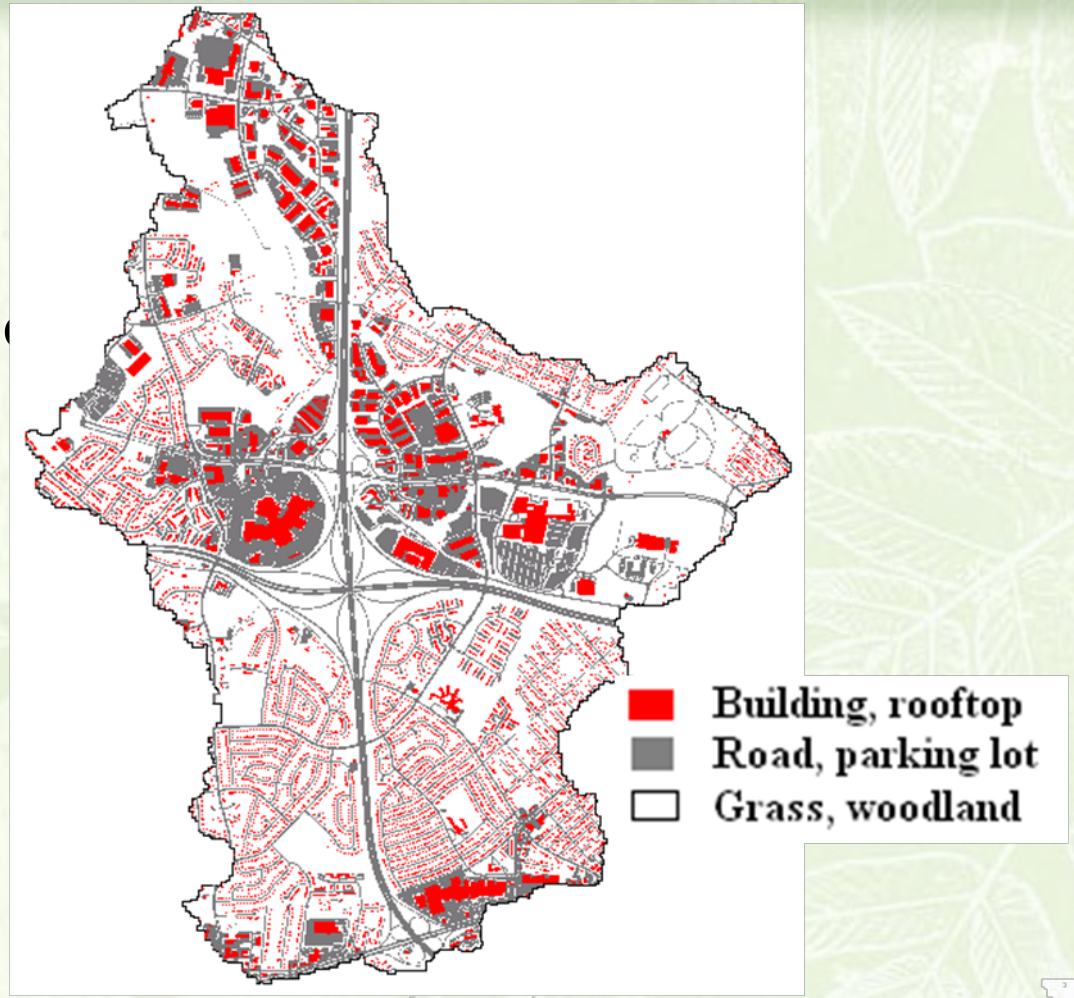
Land Use Changes Due to Urbanization

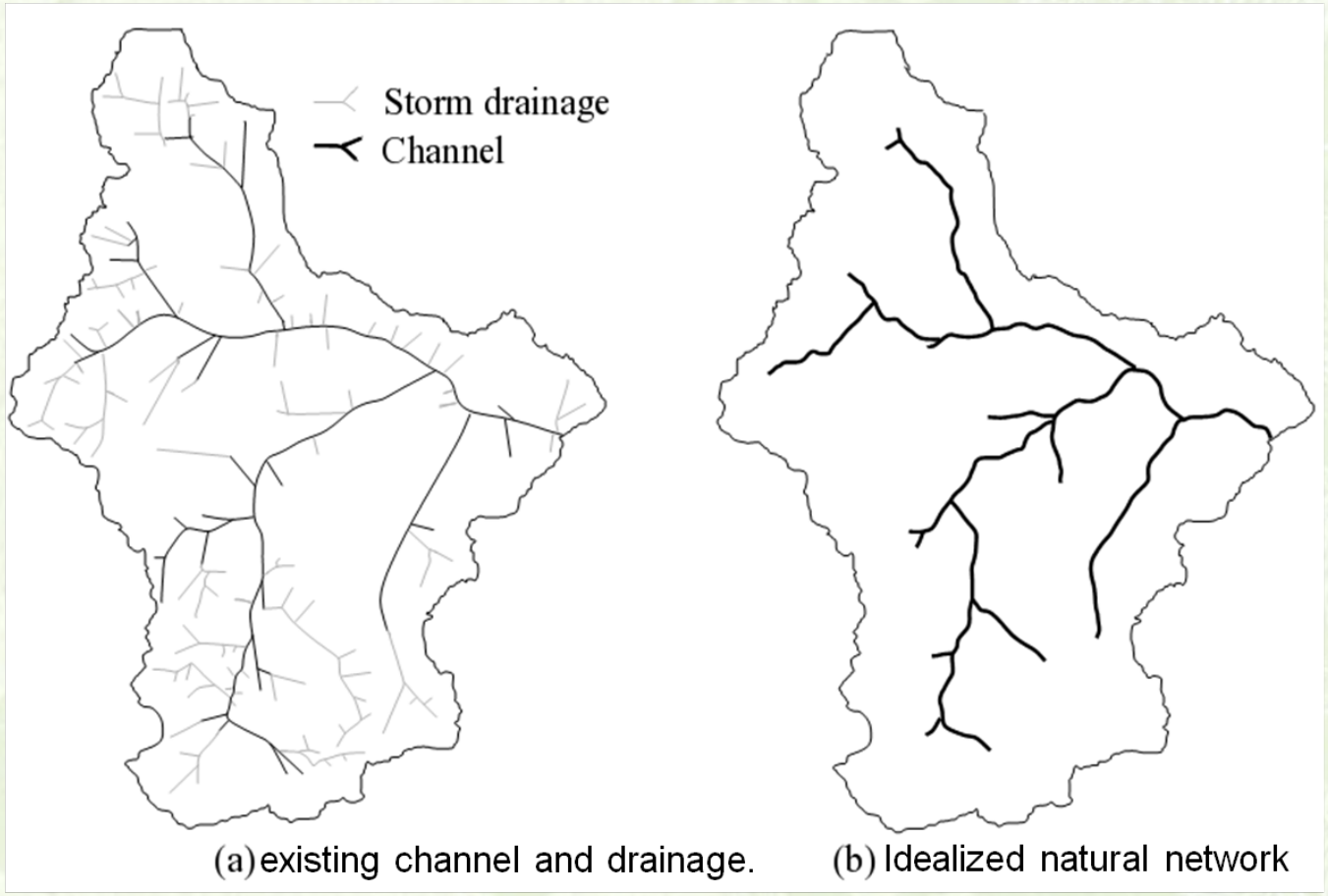
- Urbanization leads to greater impervious area.
- Greater impervious area leads to more runoff.
- Sub-surface drainage is provided to remove additi



Geomorphologic Changes Due to Urbanization

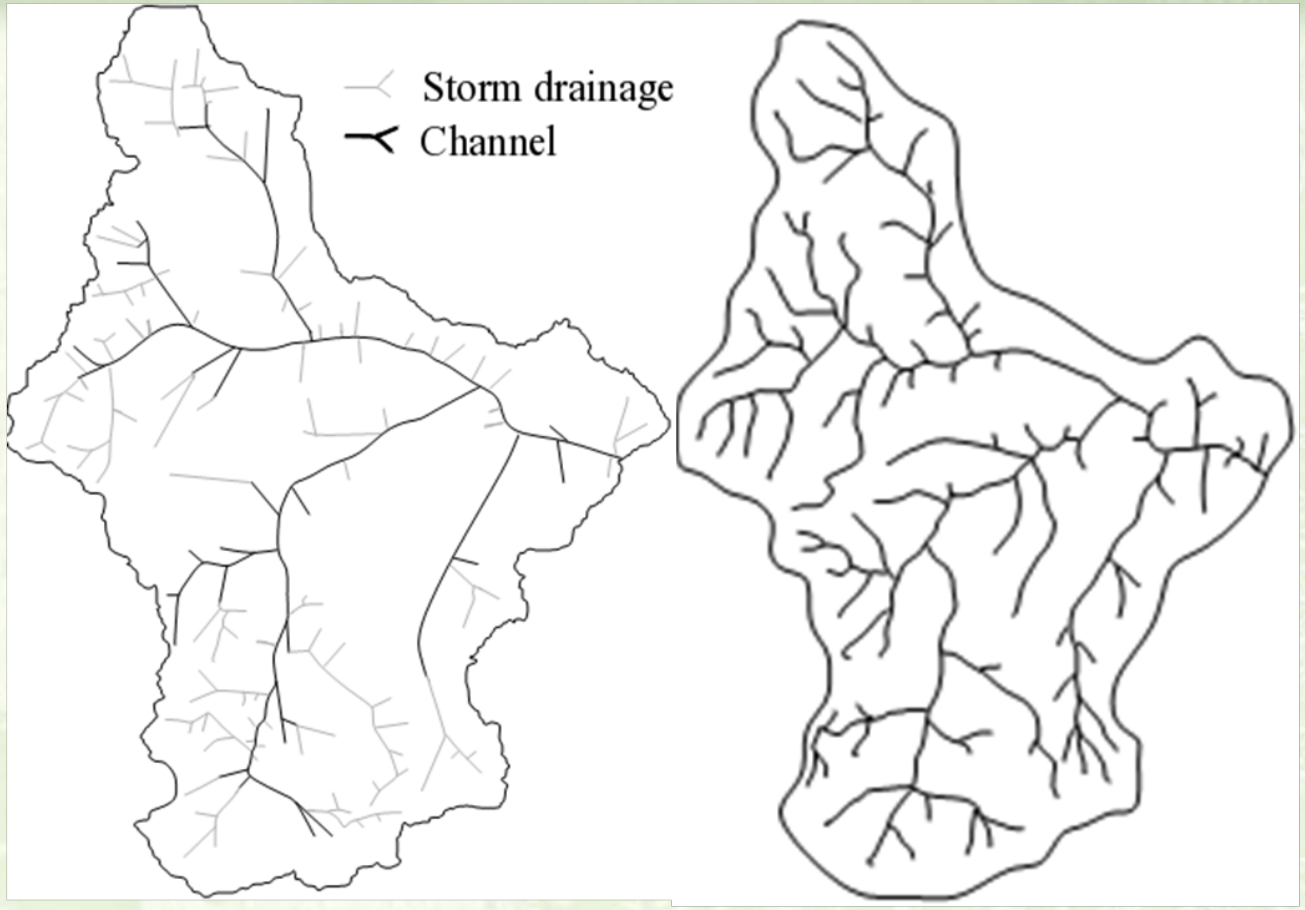
The subsurface network:

- Increases drainage density.
- Short-circuits the natural drainage.
- Increase drainage volume (fewer losses).
- Further increase peak flows.



Simulation of Drainage System

Subterranean drainage pipes are simulated as open channels in many hydrologic models.



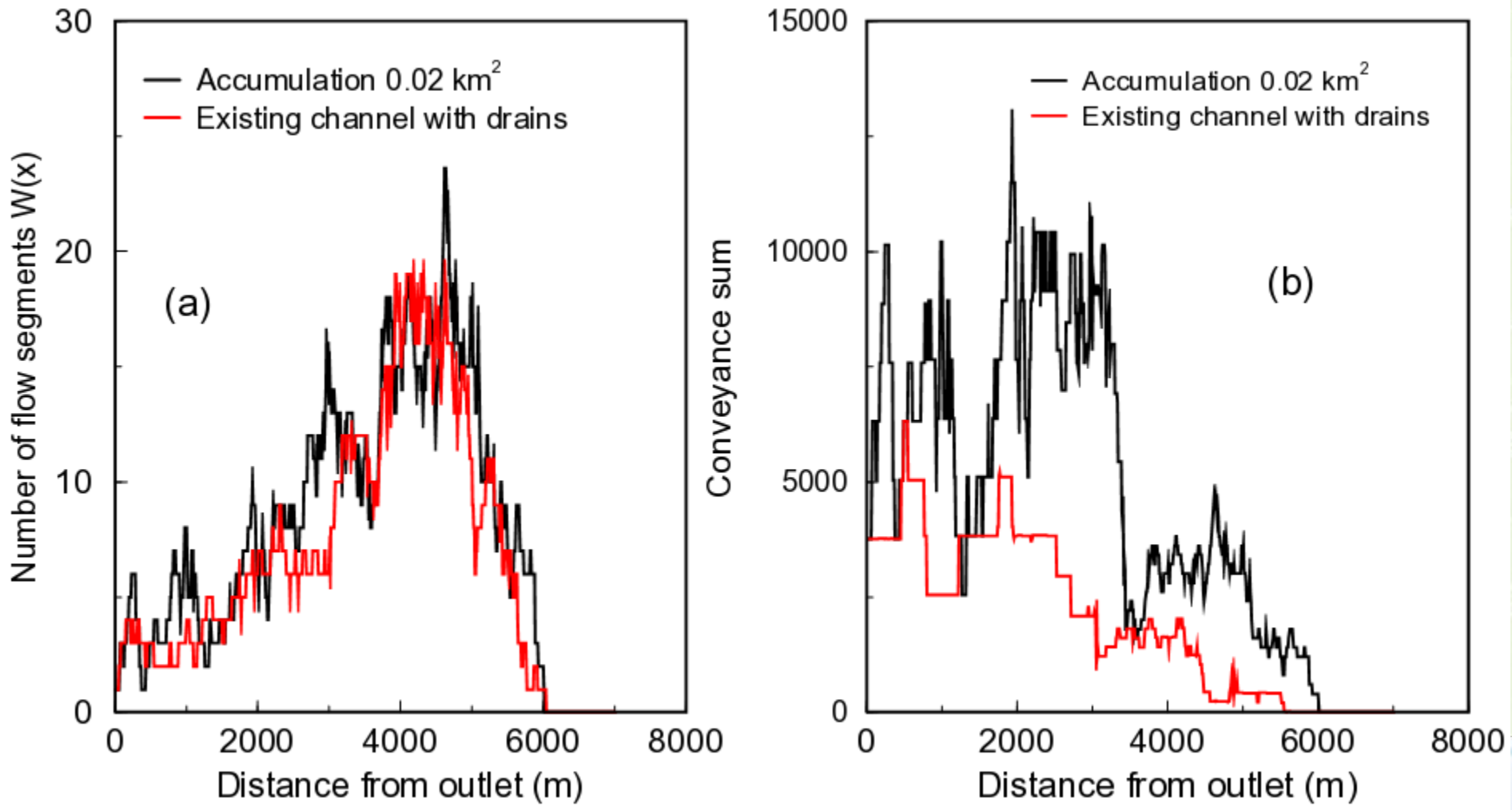
(a) existing channel and drainage. (Drainage density = 3.5 km/km^2)

(b) 0.02 km^2 threshold channel network (Drainage density = 3.5 km/km^2)

Width Function of Drainage Network Compared to Flow Accumulations

Even though the number of segments is about the same

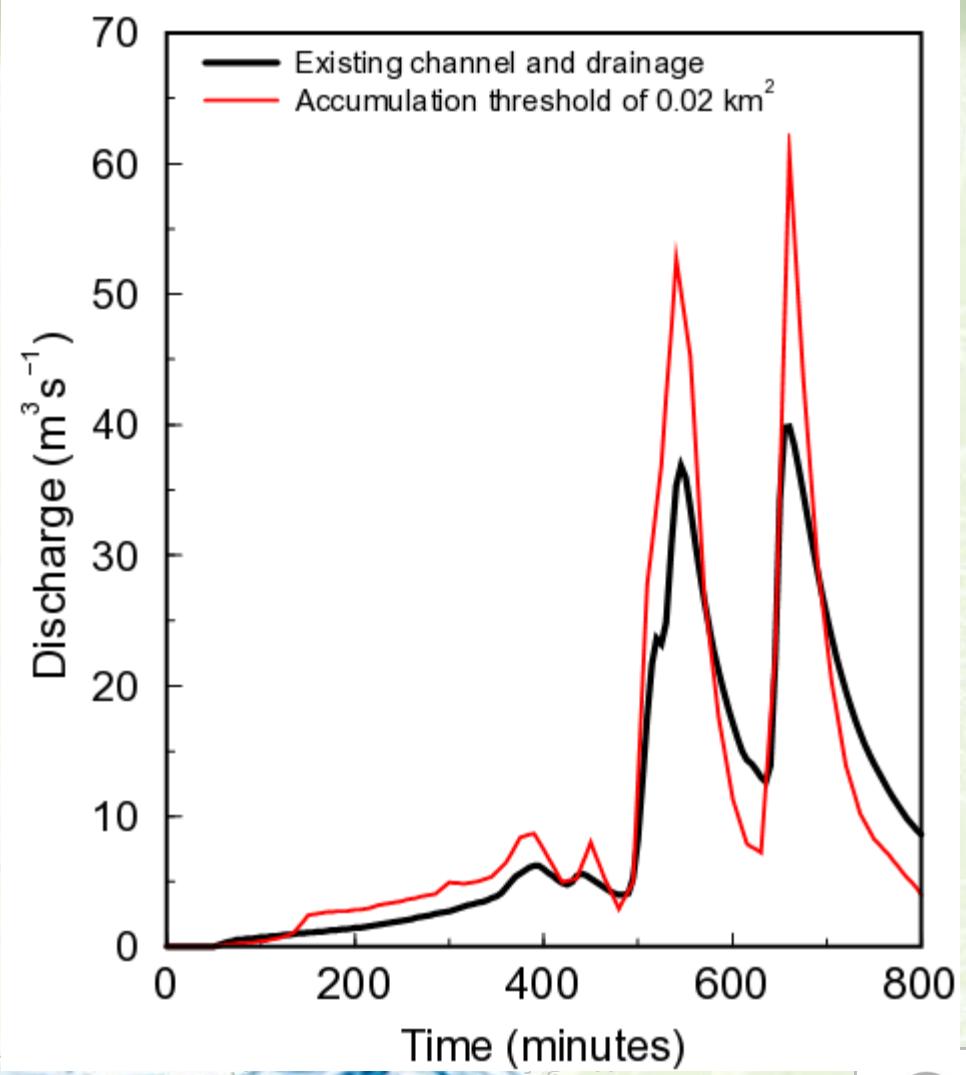
The conveyance is very different



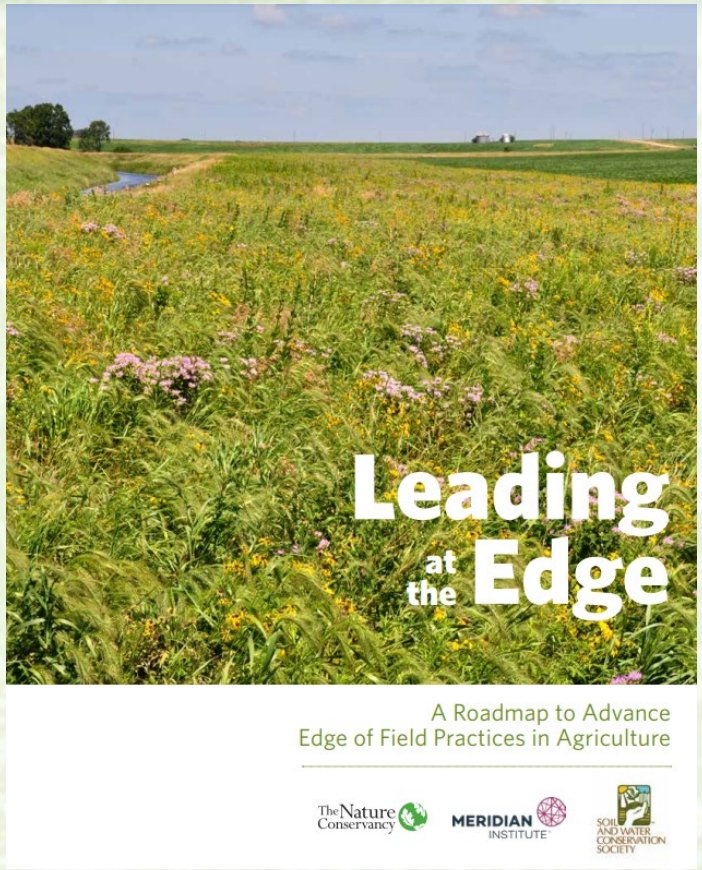
Significance of Subsurface Drainage Modeling in GSSHA

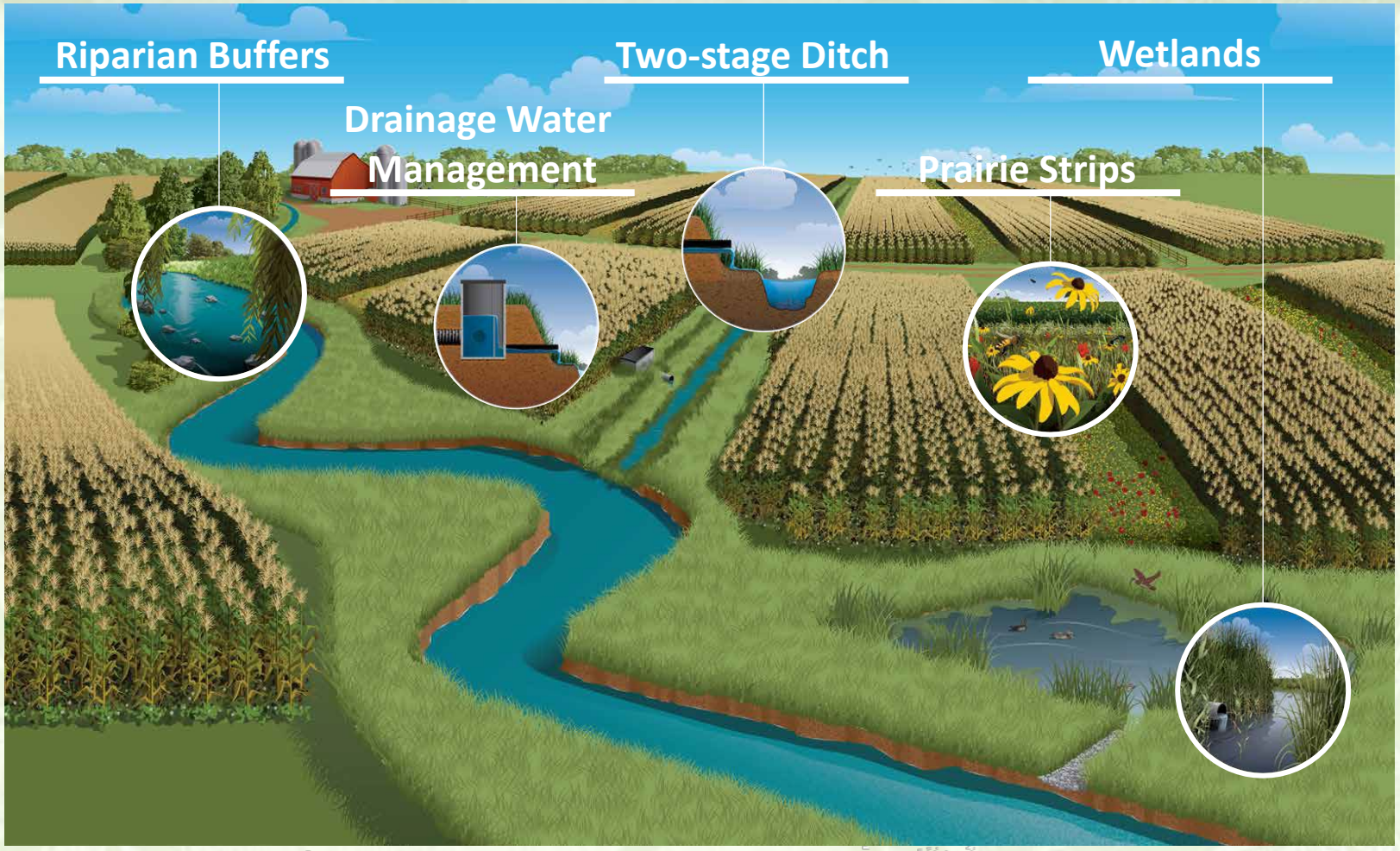
Critical Information from Simulations

- Open channel network conveyance far surpasses that of the subsurface storm drainage networks even though:
  - Widths are the same.
  - Number of segments is the same.
- This results in an over estimation of flow.



Improving Agricultural Practices - TNC





Nature.org/EdgeOfField

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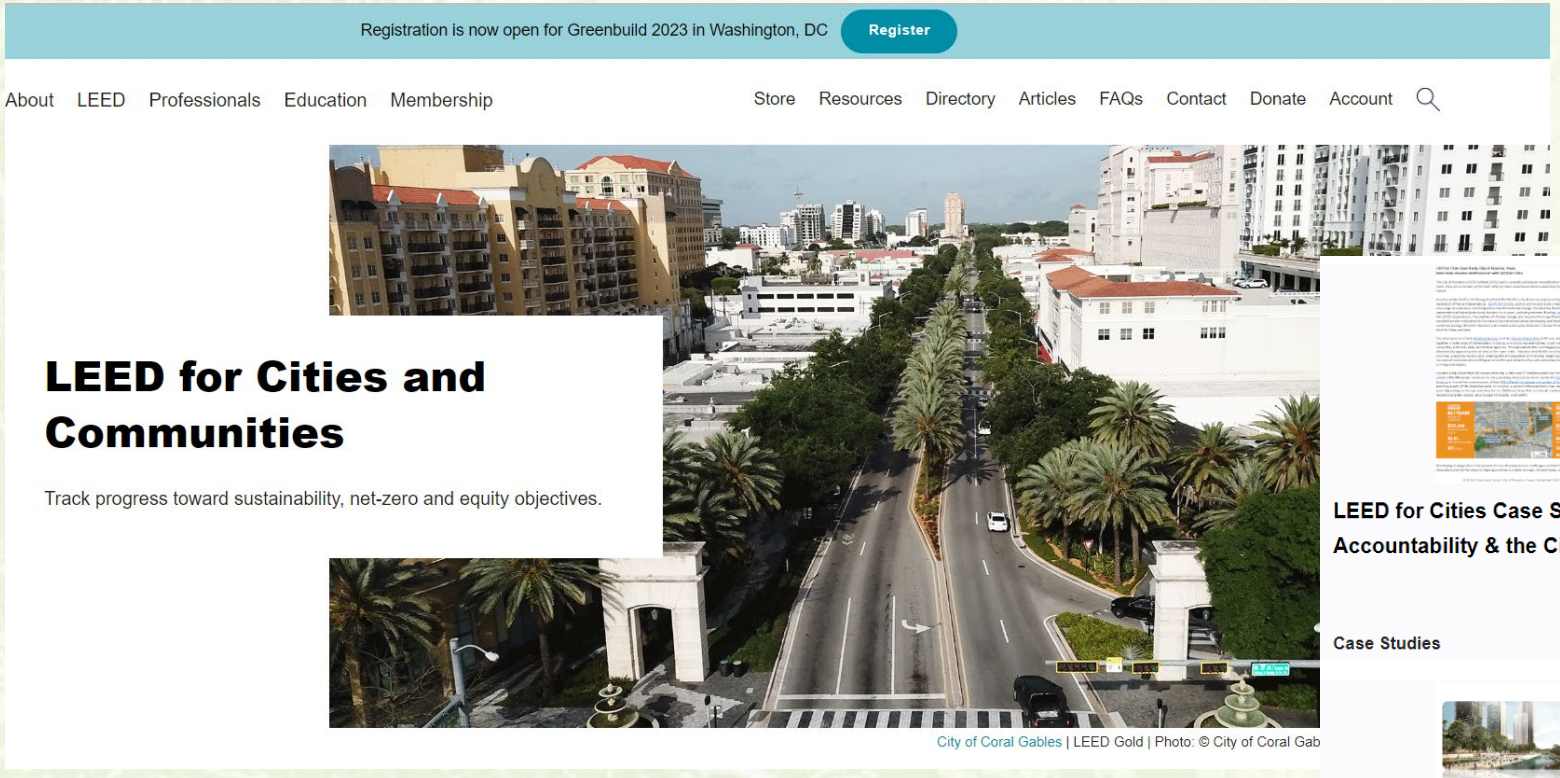
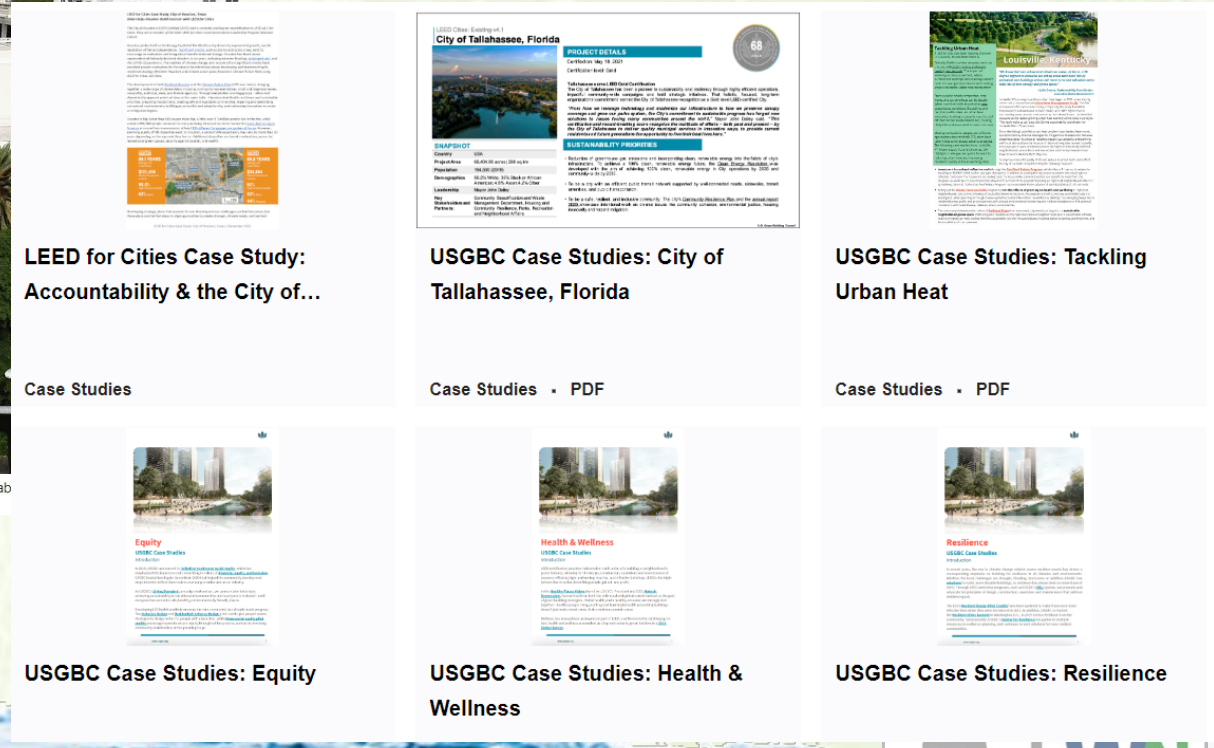
LEED Certification for Cities – Promoting green infrastructure





https://www.usgbc.org/leed/rating-systems/leed-for-cities-communities

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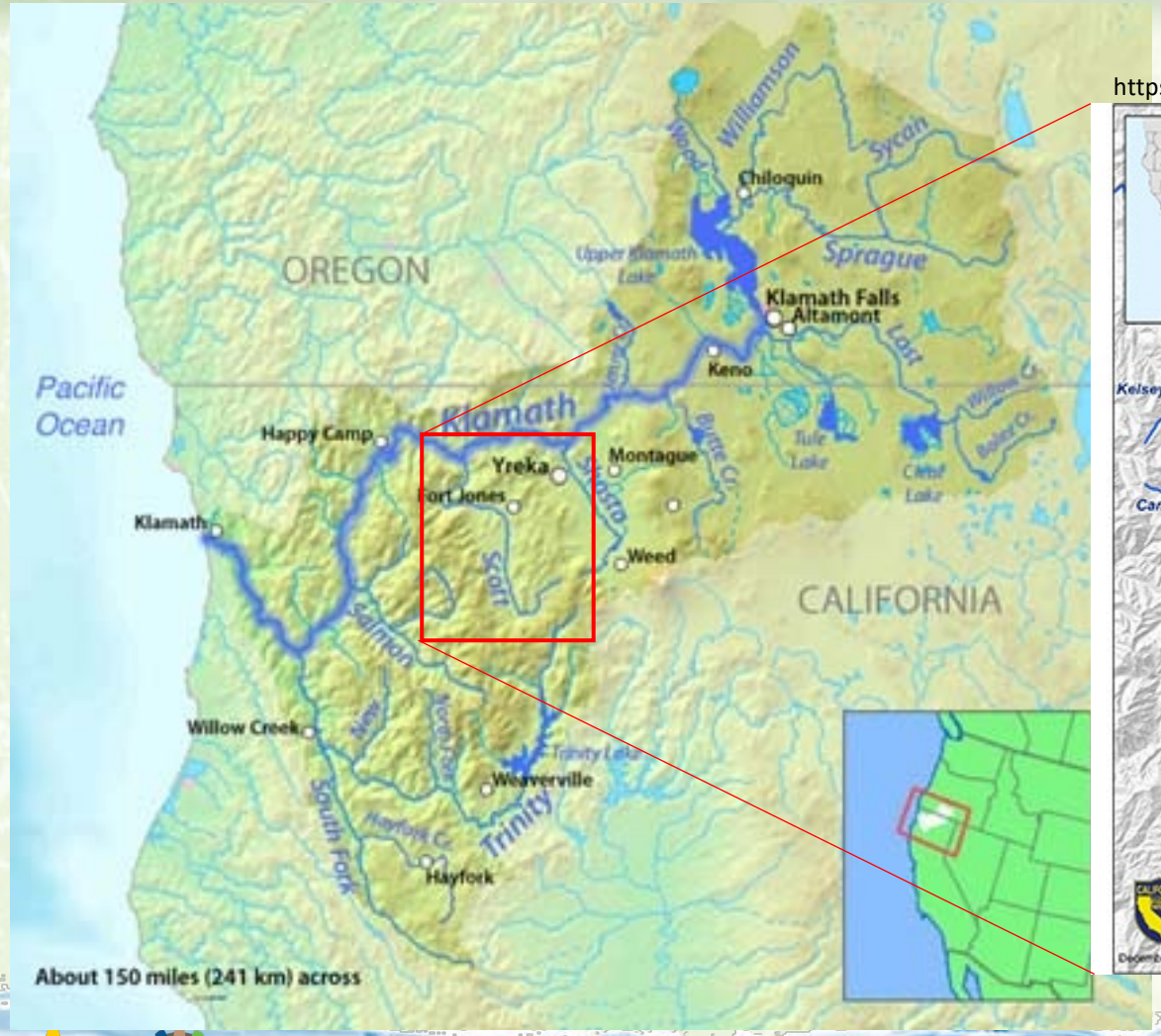
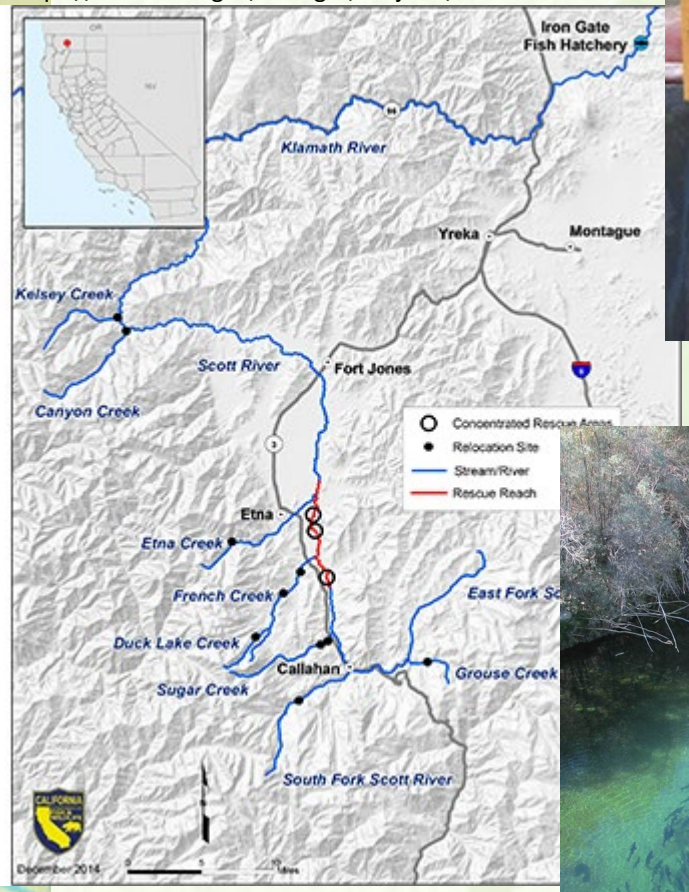
The Klamath River Basin and Scott River

https://www.fisheries.noaa.gov/west-coast/habitat-conservation/klamath-river-basin



https://wildlife.ca.gov/Drought/Projects/Scott-River-Coho



https://calsport.org/fisheriesblog/?p=1608

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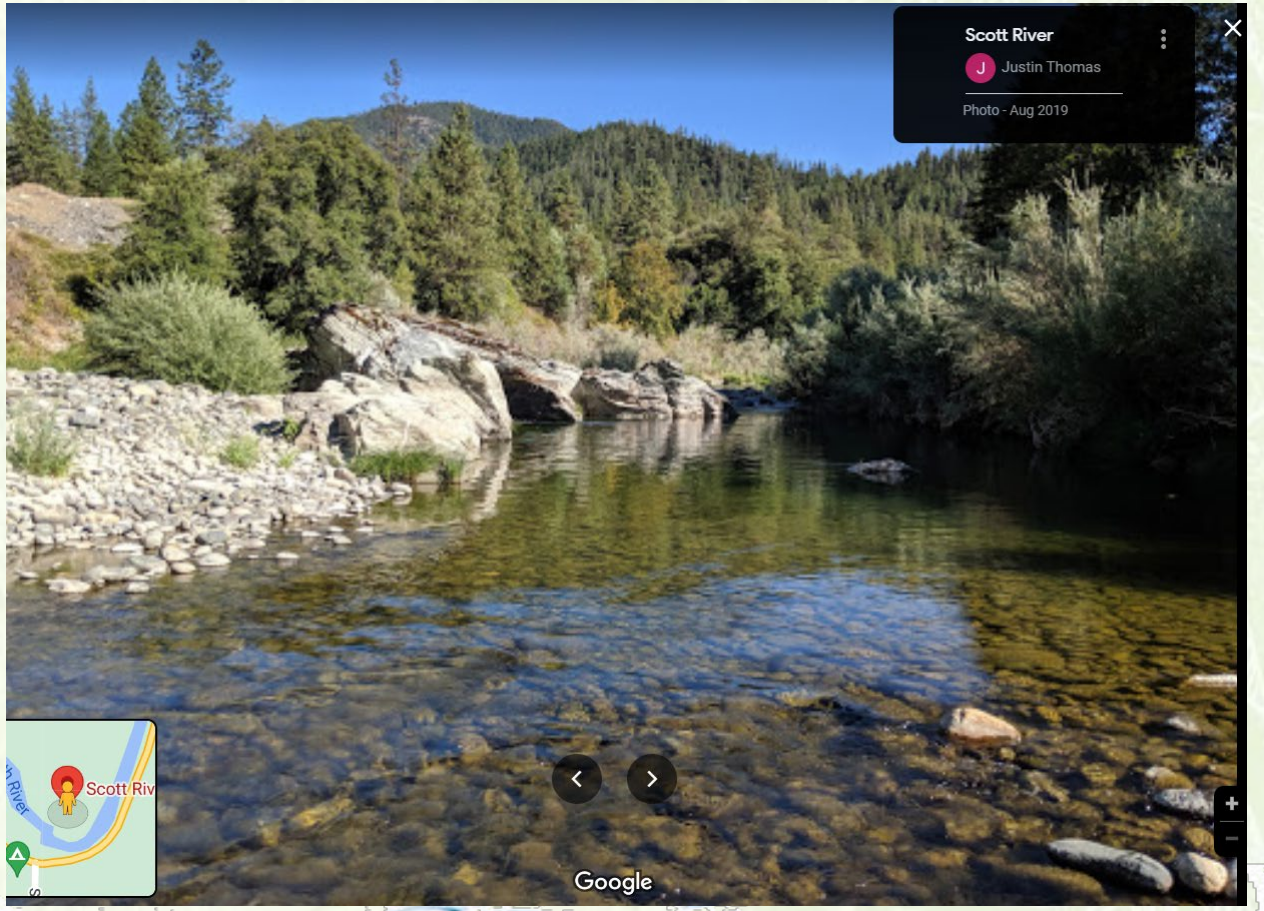
Scott River

https://calsport.org/fisheriesblog/?p=1608

https://goo.gl/maps/sMmpfHngeTMwxgQk8



Beaver Dam Analogs

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Valuing Beaver Dams

NPS Photo / Kent Miller
https://www.nps.gov/articles/buildabeaverdam.htm

- Regulating Services
  - Diminishing flood intensity, $124/ha/yr
  - Filtering water, $108/ha/yr
  - Capturing greenhouse gases, $75/ha/yr
- Provisioning Services
  - Groundwater recharge, $77/ha/yr
  - Rich habitats, $133/ha/yr
- Cultural Services
  - Recreation, bird watching, $167/ha/yr

=$684 / ha / hr

https://environment-review.yale.edu/busy-beavers-calculating-value-ecosystems-services-provided-beavers

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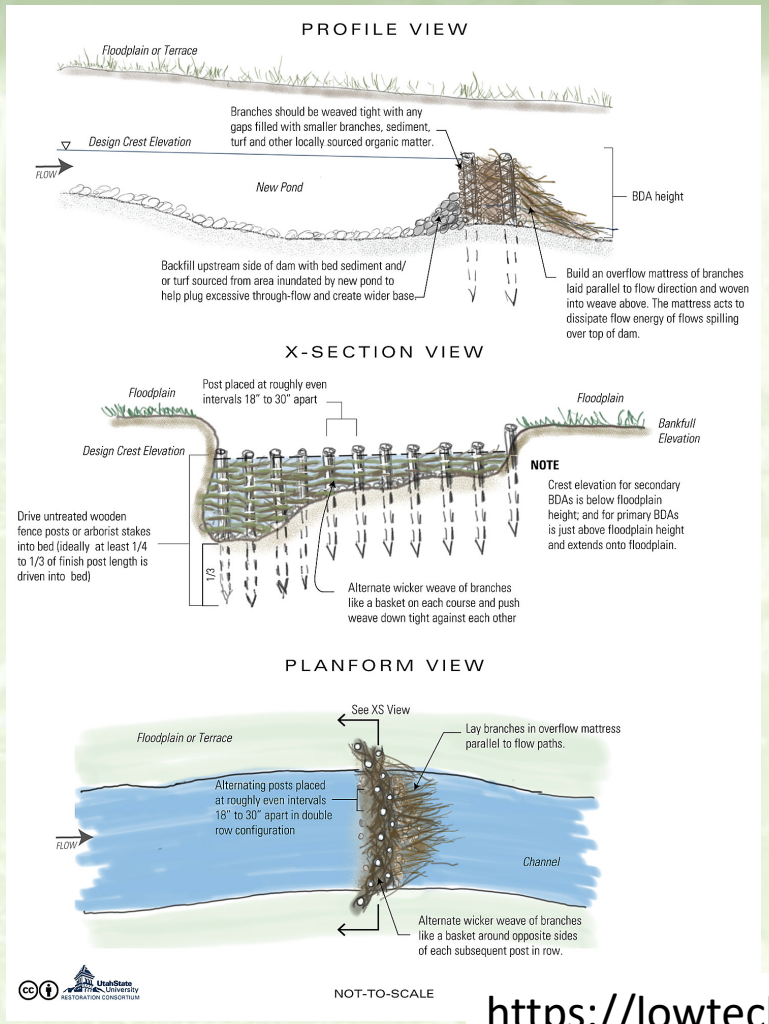
Downsides to Beavers

- Damage to timber industry, $25 to $118 / ha / yr
- Will forage up to 90m and consume agricultural produce (corn, soybeans, etc.)
- Will build beaver dams in front of culverts and other drainage infrastructure
- Will build burrows in banks and levees, destabilizing them

https://www.aphis.usda.gov/wildlife_damage/reports/Wildlife%20Damage%20Management%20Technical%20Series/Beaver-WDM-Technical-Series.pdf

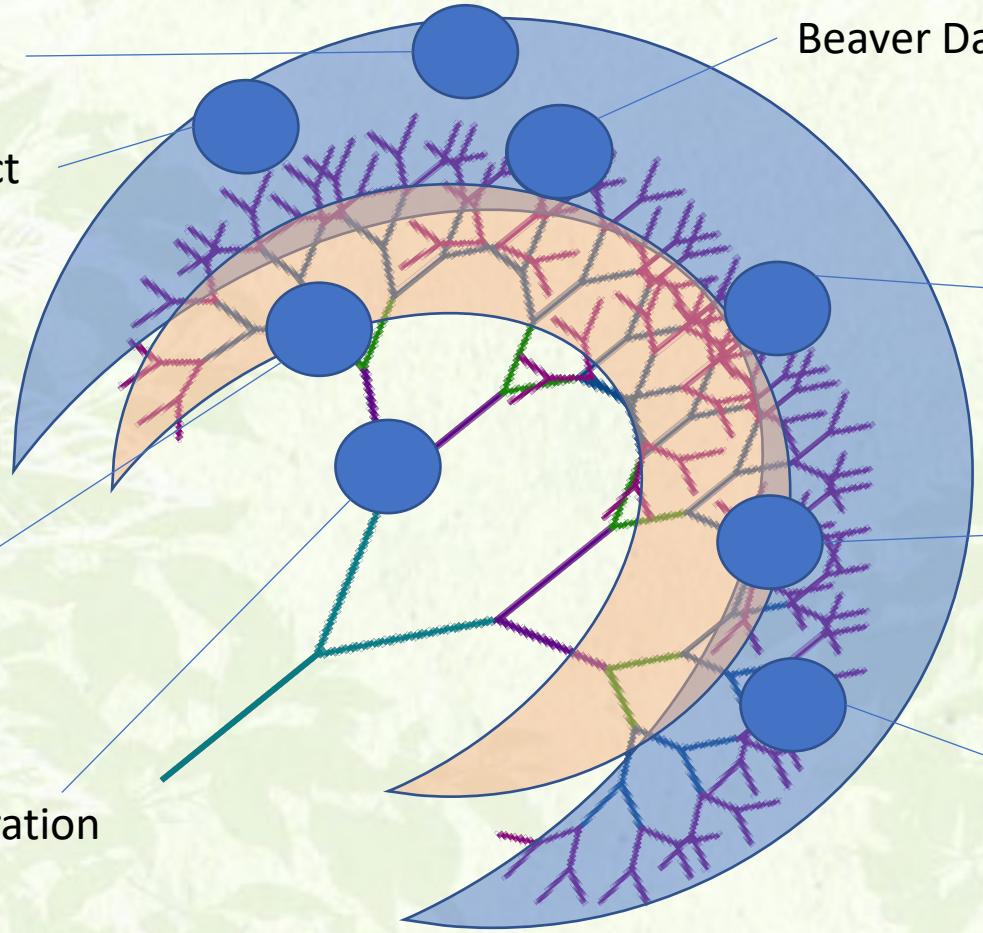
Beaver Dam Analogues



https://lowtechpbr.restoration.usu.edu/resources/recipes/Beaver/bda.html

https://www.youtube.com/watch?v=63jiOXFPwBQ

The Spectrum of Possibilities



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Constructed Wetlands

EPA United States Environmental Protection Agency

Search EPA.gov

Environmental Topics | Laws & Regulations | Report a Violation | About EPA

Wetlands

CONTACT US

- Wetlands Protection and Restoration Home
- Learn About Wetlands
  - Types
  - Functions
  - **The Science of Wetlands**
  - Monitoring and Assessment

Constructed Wetlands

Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality. The following documents provide additional information about constructed treatment wetlands.

- Constructed Treatment Wetlands (PDF) (2 pp, 269 K, About PDF)
- Guiding Principles for Constructed Treatment Wetlands: Providing Water Quality and Wildlife Habitat (PDF)(25 pp, 704 K, About PDF)

https://www.epa.gov/wetlands/constructed-wetlands

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Bioretention

Stormwater Best Management Practice

Bioretention (Rain Gardens)

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Filtration

Description

Bioretention practices, such as rain gardens, are landscaped depressions that treat on-site stormwater discharge from impervious surfaces such as roofs, driveways, sidewalks, parking lots and compacted lawns. They are used to collect stormwater and filter it through a mixture of soil, sand and/or gravel. The designs of bioretention practices mimic volume reduction and pollutant removal mechanisms that work in natural systems. The filtered stormwater soaks into the ground, provides water to plants and can help recharge the local groundwater supply. Through these processes, bioretention practices reduce peak flows within downstream sewer systems and allow pollutant removal through filtration and plant uptake.

Applicability

Bioretention practices are well suited to small sites in urbanized settings and can filter stormwater from small

A bioretention practice in a suburban road median, capturing stormwater during a rain event.

https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf