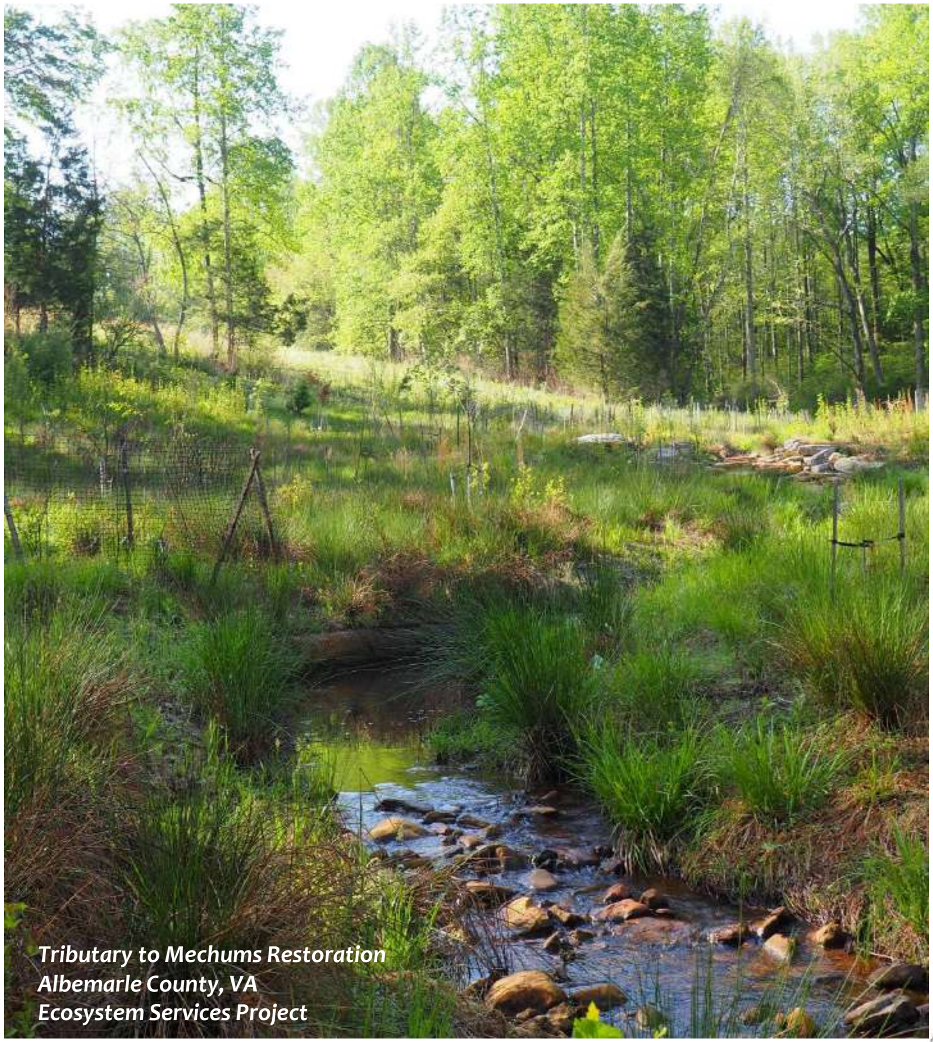
City of Alexandria
Stream Improvement Projects

Outline

1. Stream Restoration Overview
2. The Social Context
3. Evaluating Tradeoffs



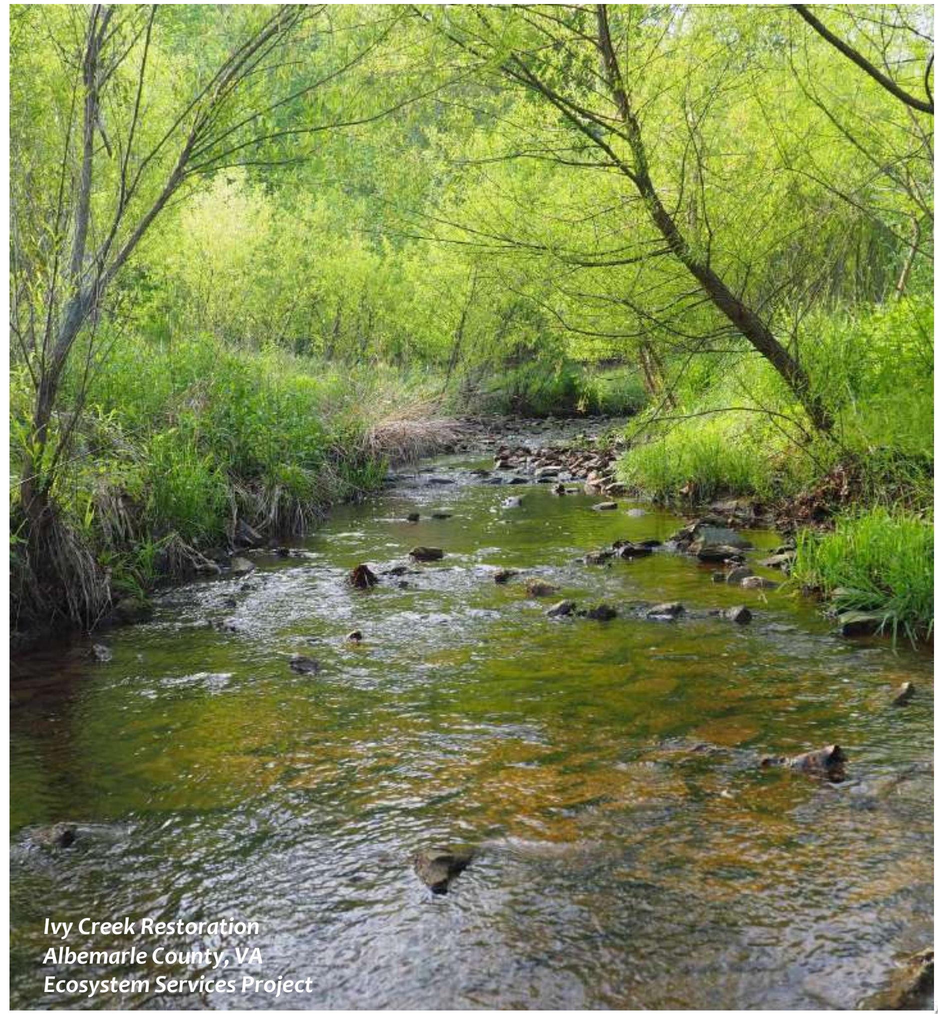
Tributary to Mechums Restoration
Albemarle County, VA
Ecosystem Services Project

Presentation Objective

Propose a common understanding of stream restoration and stream processes

Describe how stakeholder goals and perceptions influence restoration approaches and outcomes

Propose a framework for evaluating tradeoffs



Ivy Creek Restoration
Albemarle County, VA
Ecosystem Services Project

Presentation Objective

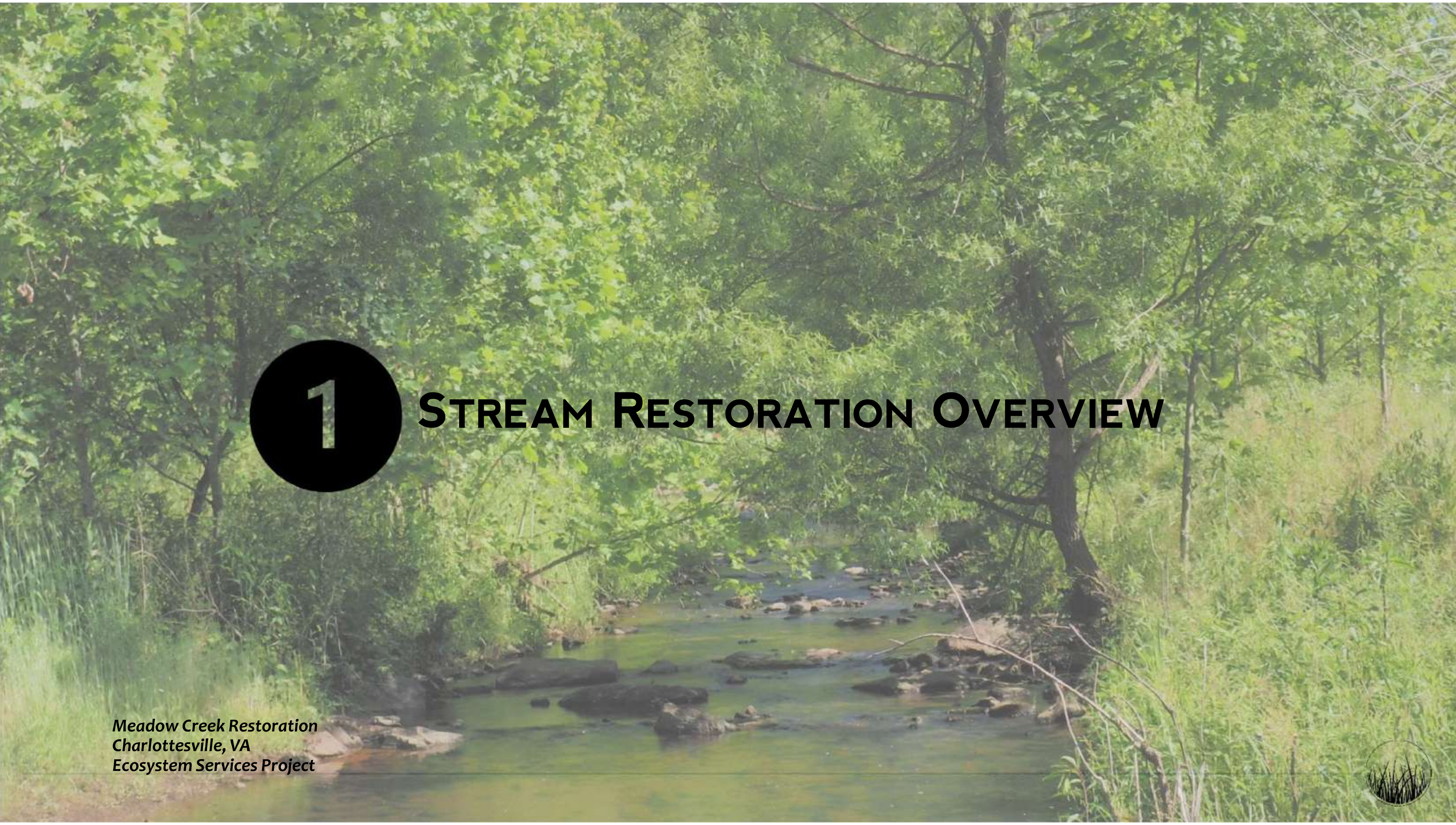
Propose a common understanding of stream restoration and stream processes

Describe how stakeholder goals and perceptions influence restoration approaches and outcomes

Propose a framework for evaluating tradeoffs

What this presentation is not…

- *advocating for a specific approach to restoration*
- *making claims about the specific conditions at the project sites*



1 Stream Restoration Overview

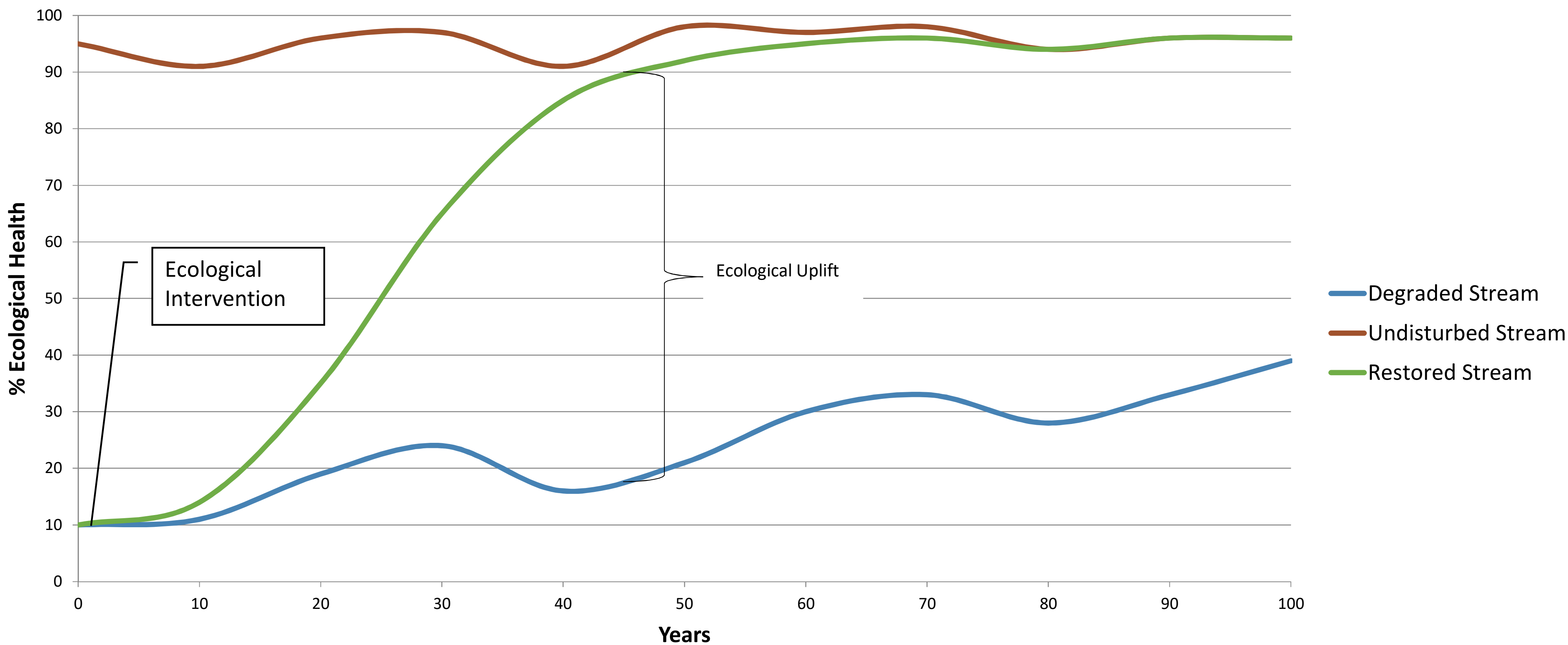
Meadow Creek Restoration
Charlottesville, VA
Ecosystem Services Project

What is Stream Restoration?

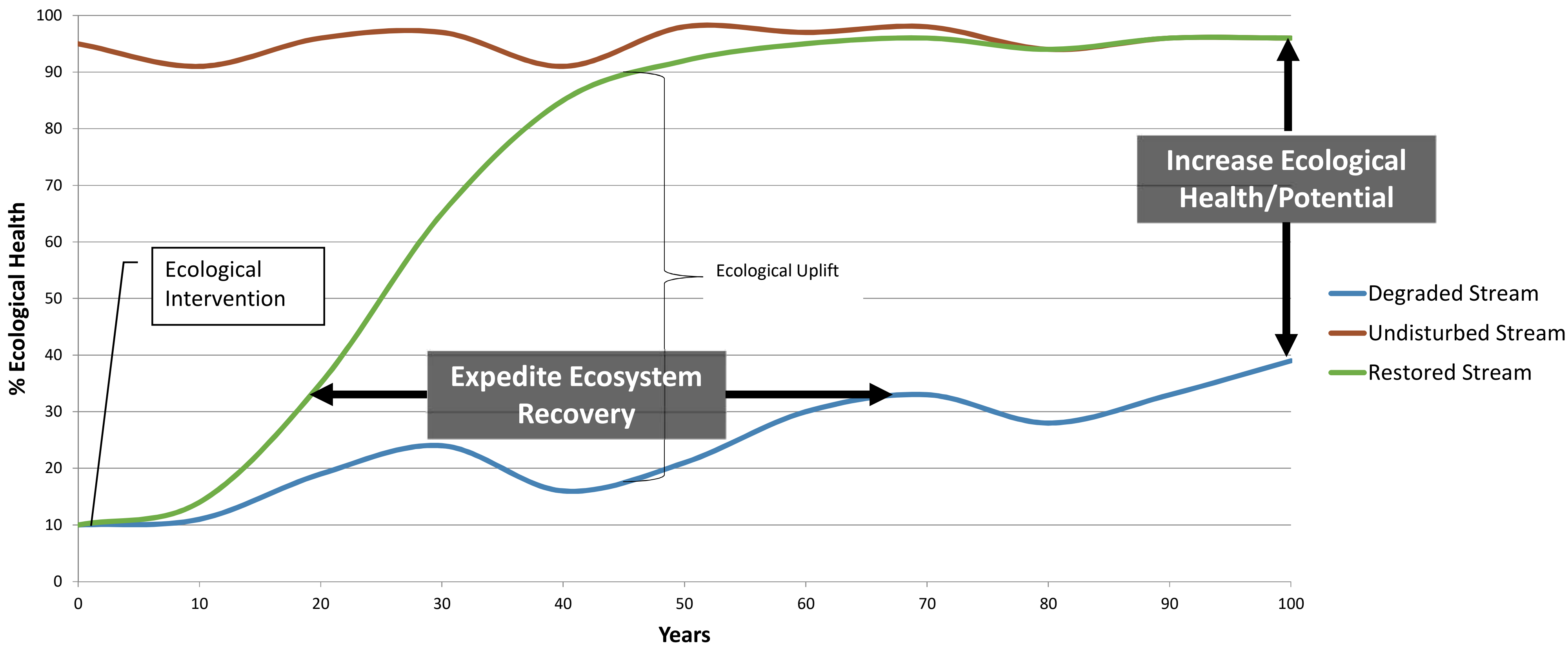
The process of assisting in the recovery of an ecosystem that has been degraded, damaged or destroyed.

Society of Ecological Restoration (SER)

Simplified Ecological Recovery Model



Simplified Ecological Recovery Model



The "Restoration" Umbrella

Restoration design goals:

- Restoring to an historical antecedent and associated functions
- Restoring lost ecological function in part
- Creating new ecological functions
- Using natural materials primarily designed to benefit the built environment and/or aesthetics

Terms that are used to describe stream corridor interventions:

- Restoration
- Enhancement
- Establishment
- Rehabilitation
- Stabilization
- Naturalization
- Regenerative stream/stormwater conveyance

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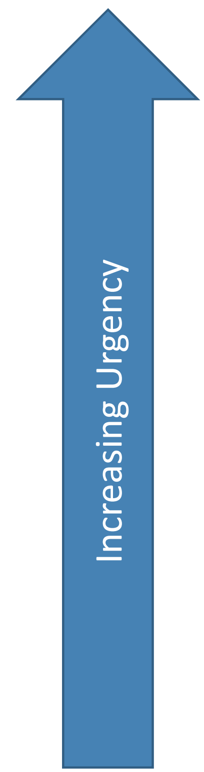
Improving Function

The Medical Metaphor

Interventions



- Channel realignment, valley excavation, and/or profile alteration = Surgery
- Stabilization and structure installation = Casts and splints
- Planting = Physical therapy
- Adding structure (e.g., large wood) = Food/meals and exercise
- Watershed retrofits = Diet

The Medical Metaphor

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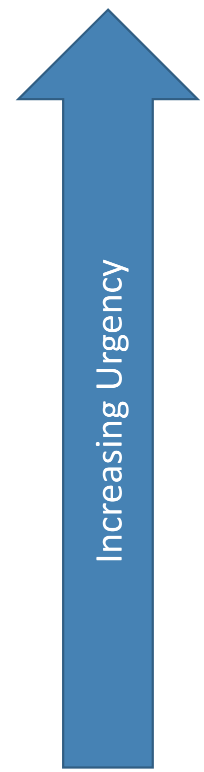
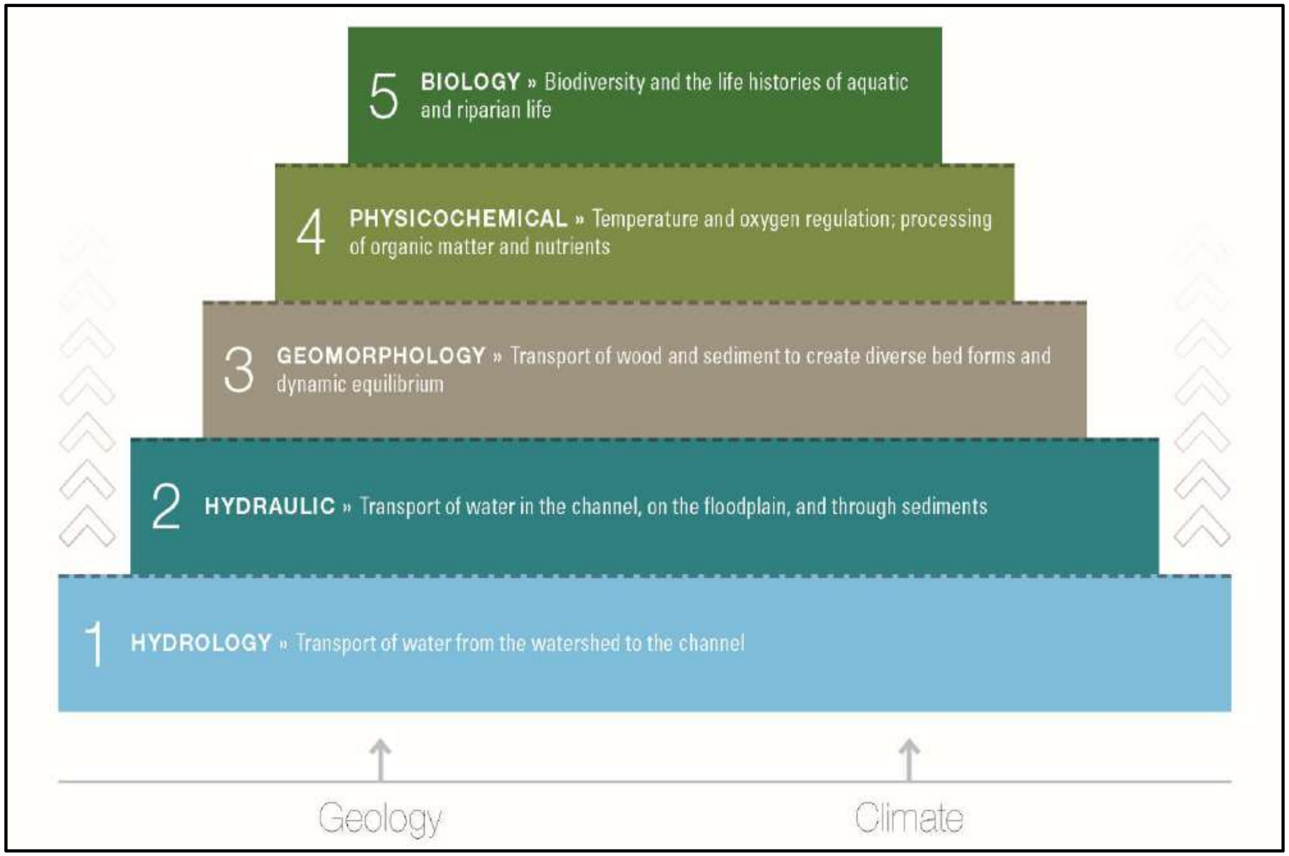
- Daylighting = Resurrection



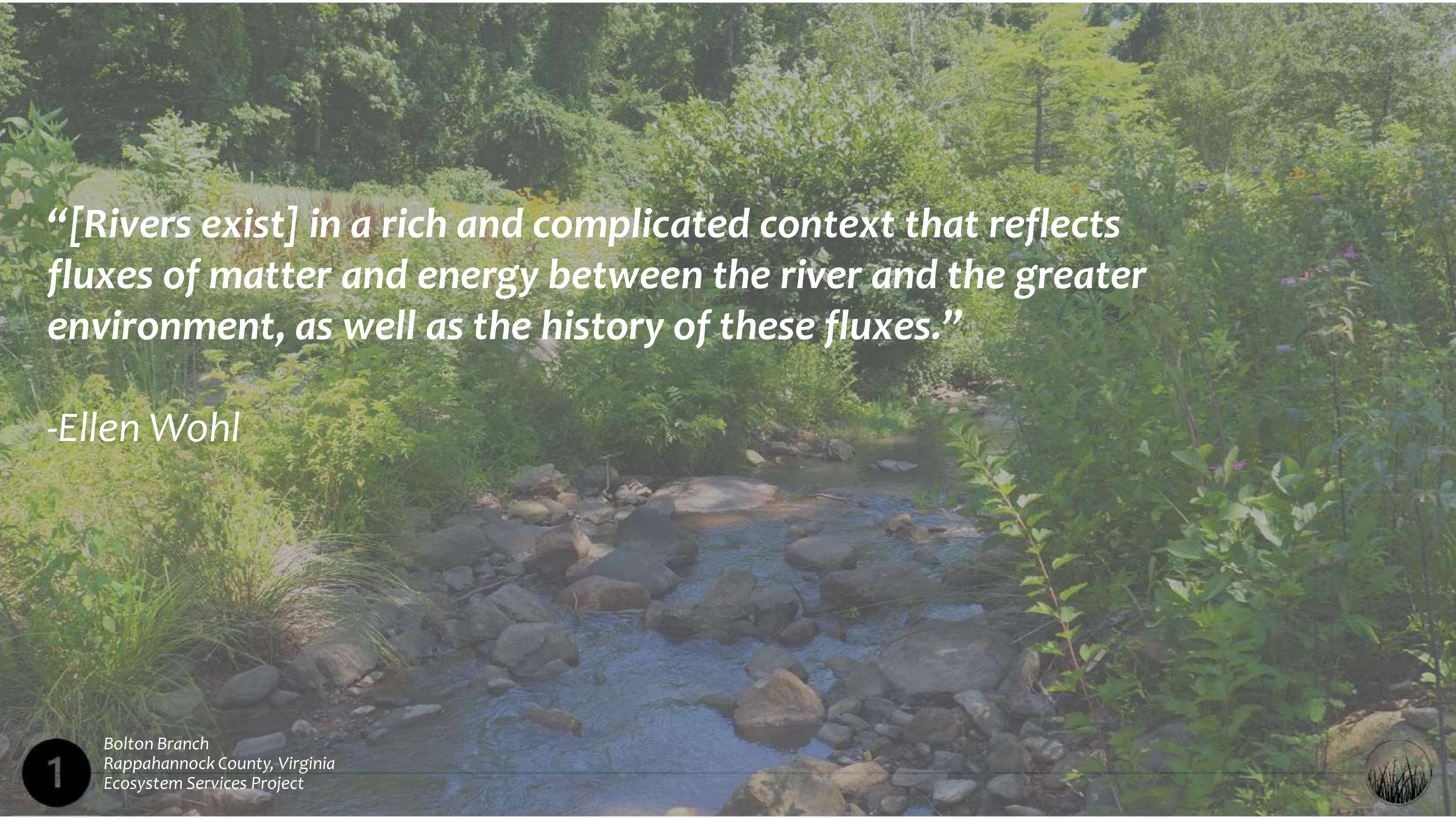
Stream Functions

Healthy streams support and maintain basic functions associated with either structure or processes.

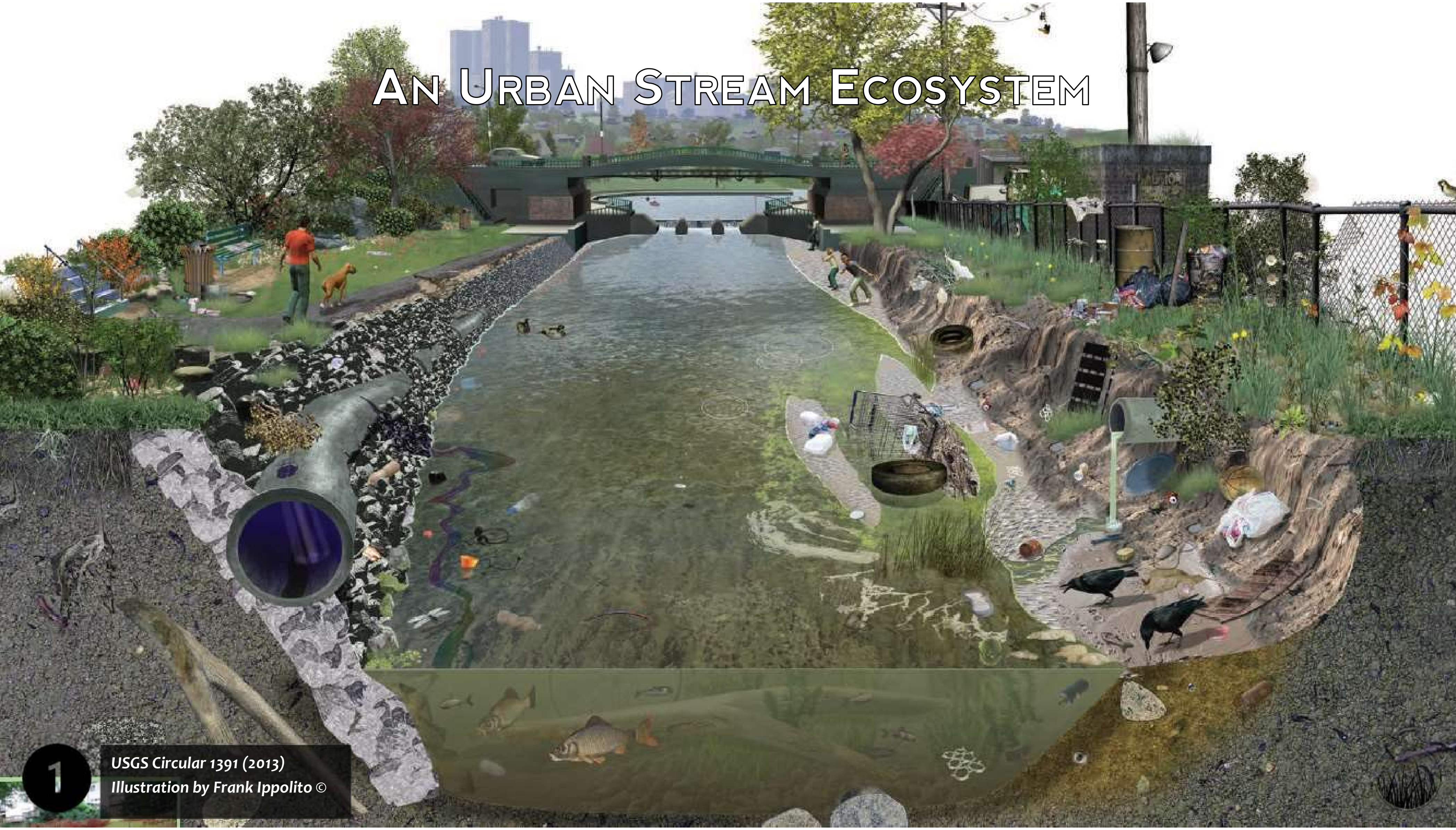
Higher-level functions build on and are a response to lower-level functions.



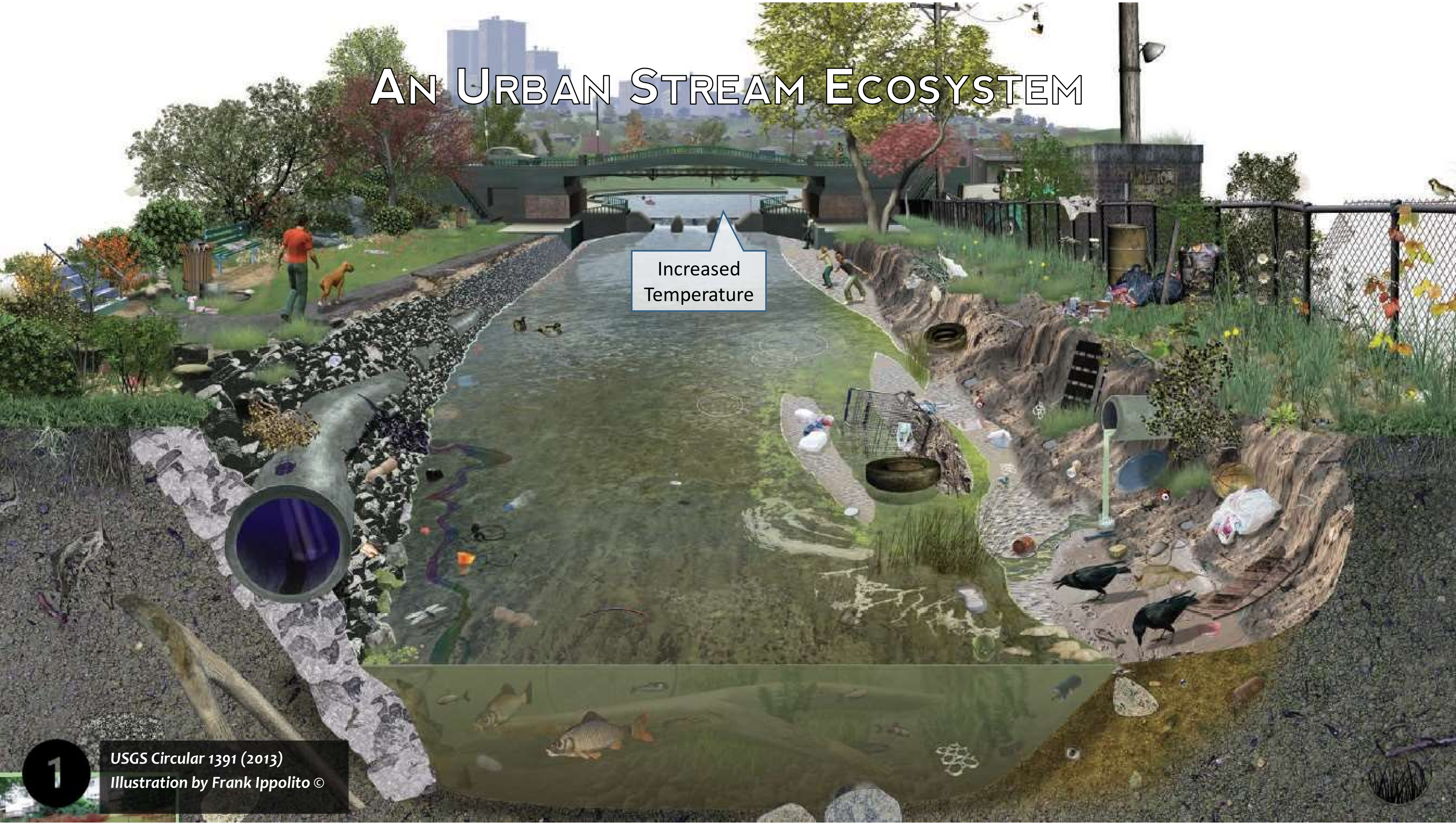
Stream Functions Pyramid (Harman, 2012)


“[Rivers exist] in a rich and complicated context that reflects fluxes of matter and energy between the river and the greater environment, as well as the history of these fluxes.”
-Ellen Wohl
1
Bolton Branch
Rappahannock County, Virginia
Ecosystem Services Project

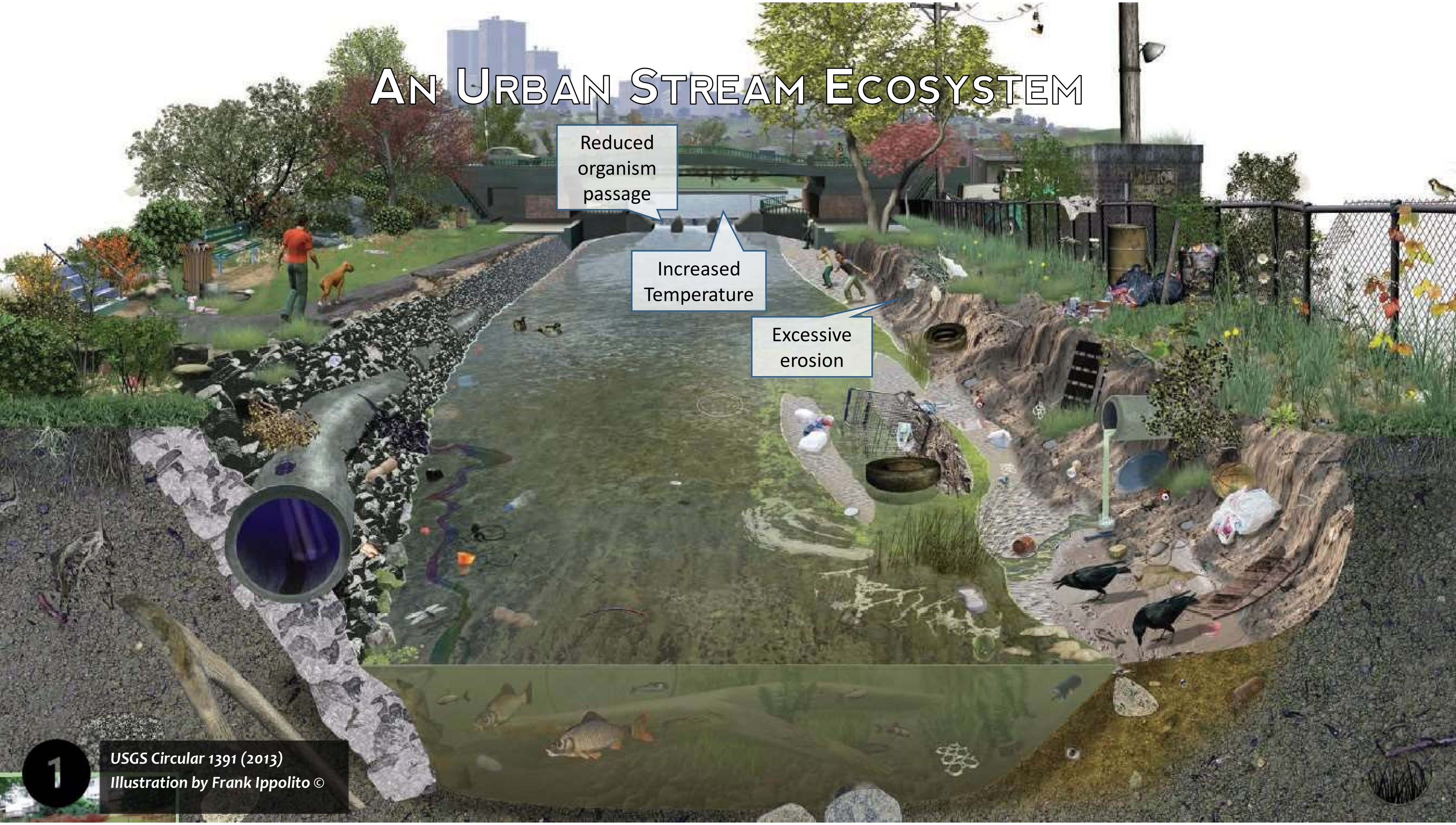
An Urban Stream Ecosystem



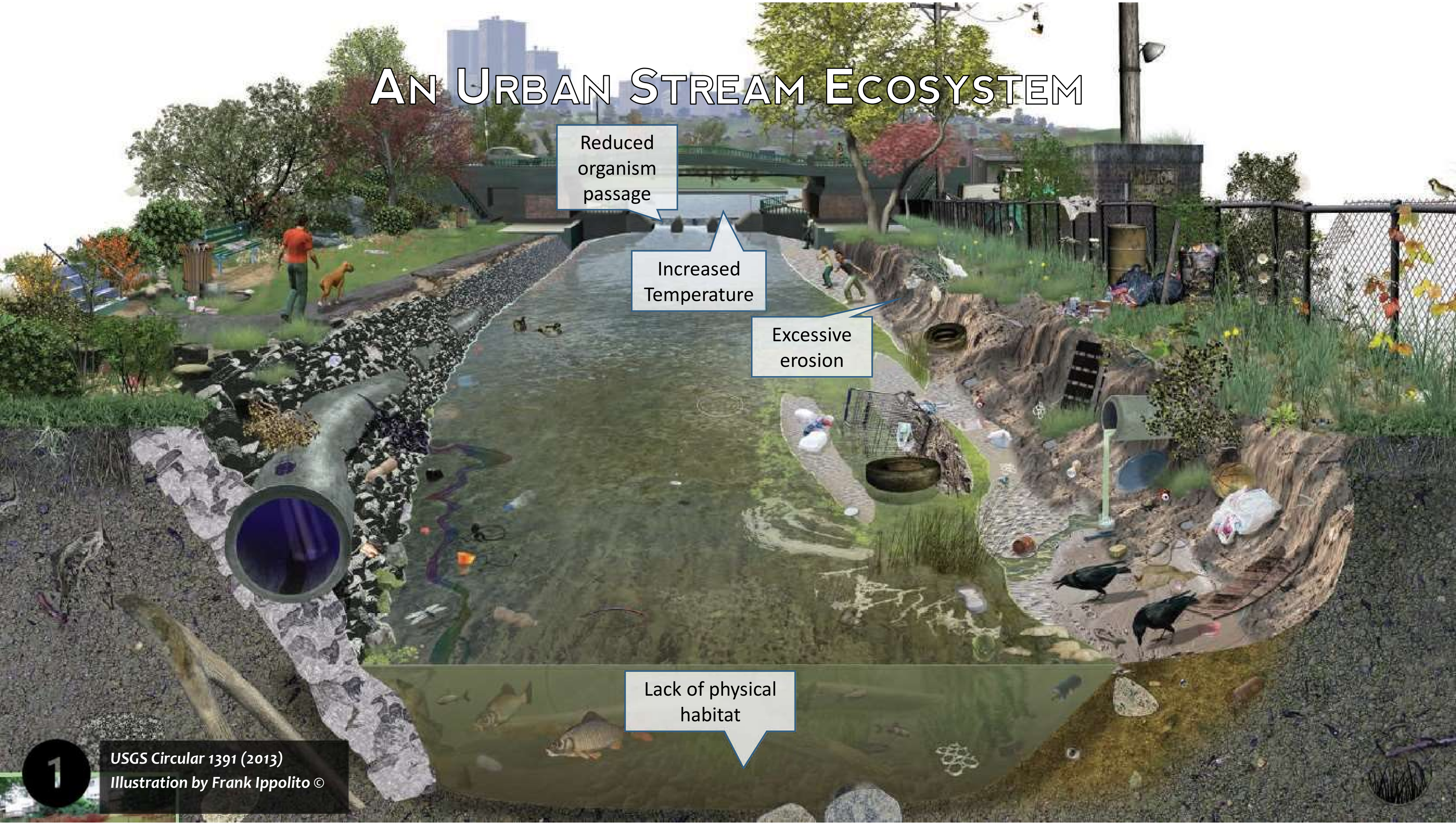
1 *USGS Circular 1391 (2013)*
Illustration by Frank Ippolito ©

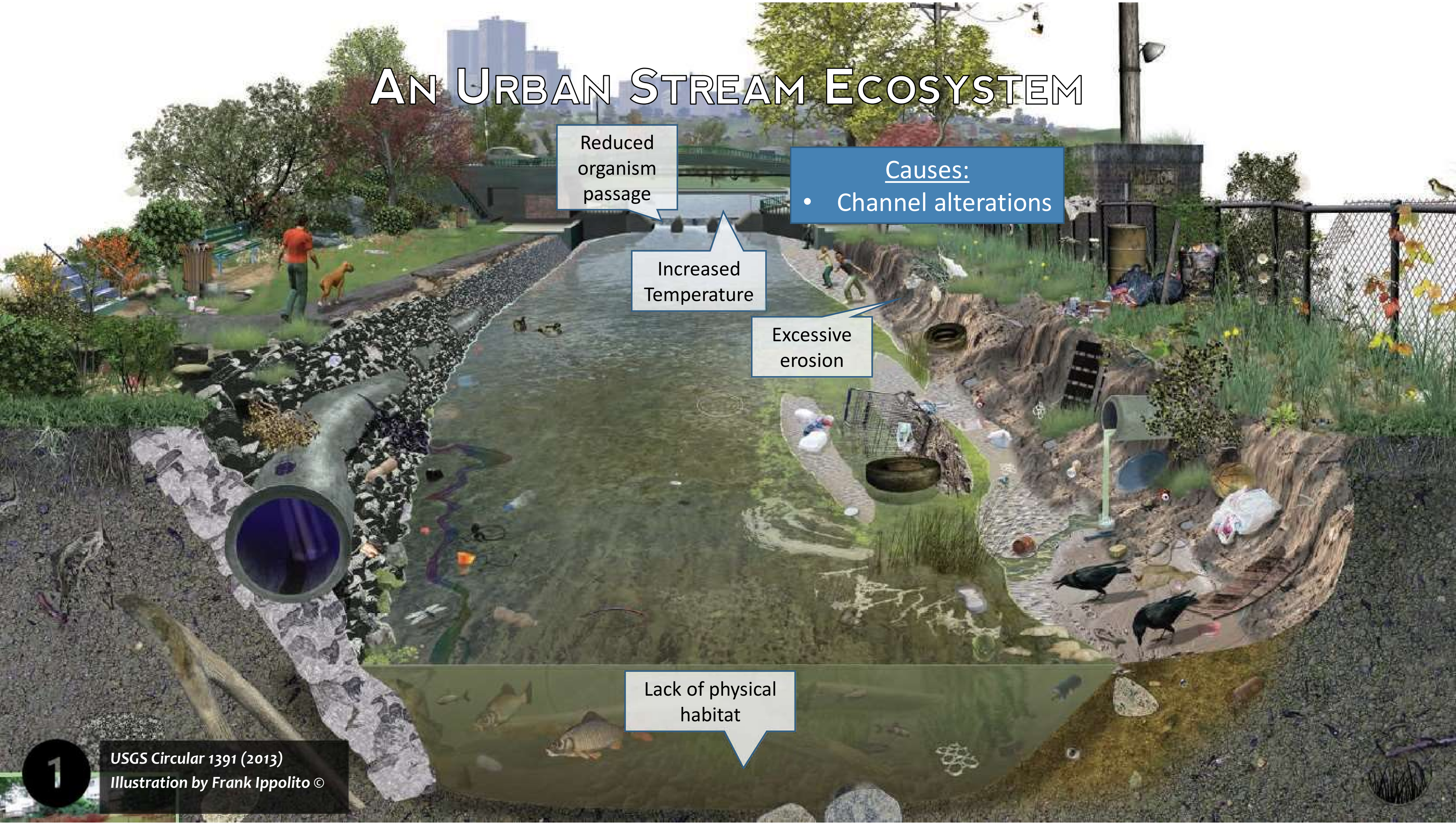

An Urban Stream Ecosystem
Increased Temperature
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©

AN URBAN STREAM ECOSYSTEM
Reduced organism passage
Increased Temperature
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©

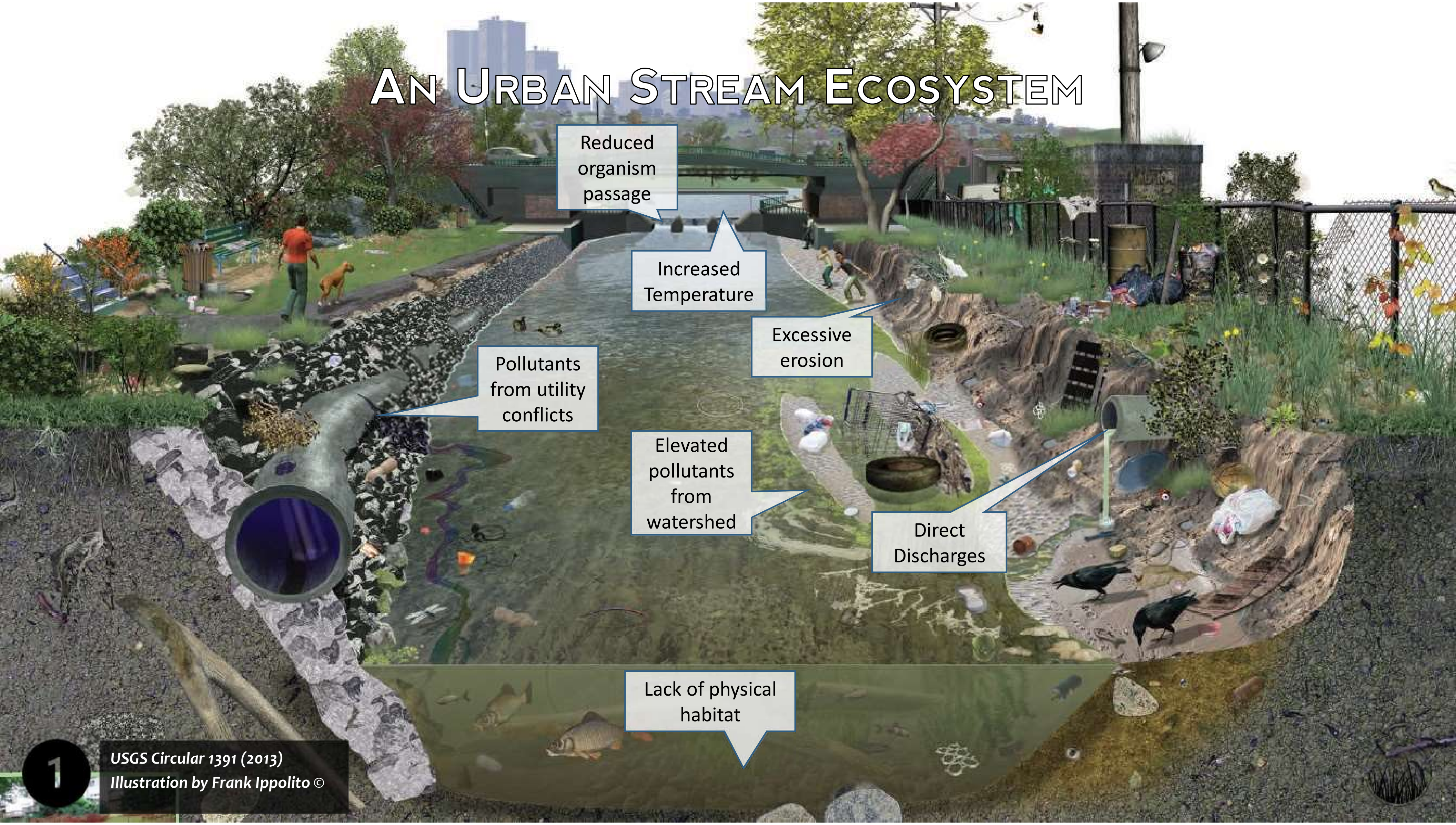


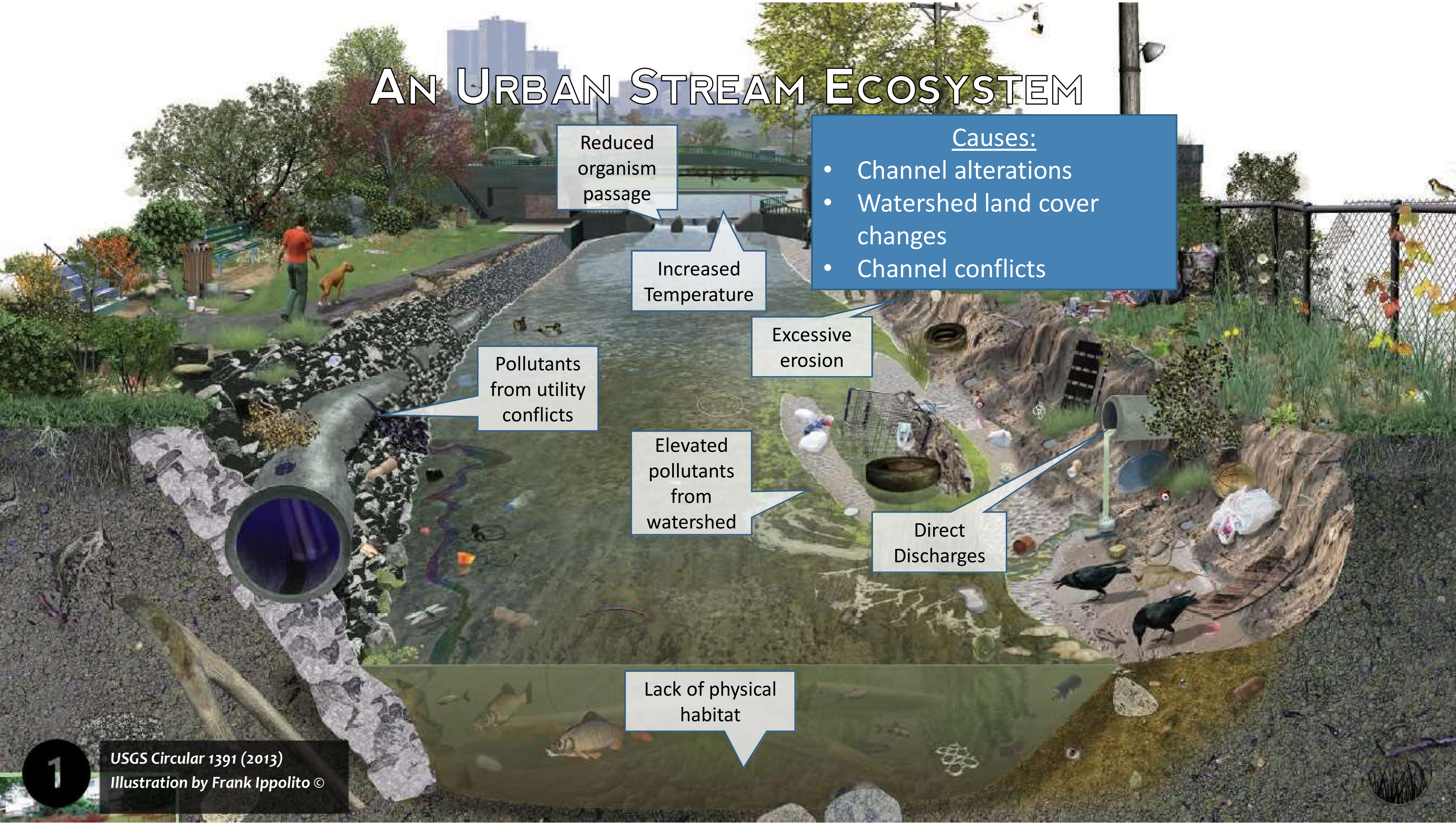
An Urban Stream Ecosystem
Reduced organism passage
Increased Temperature
Excessive erosion
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©

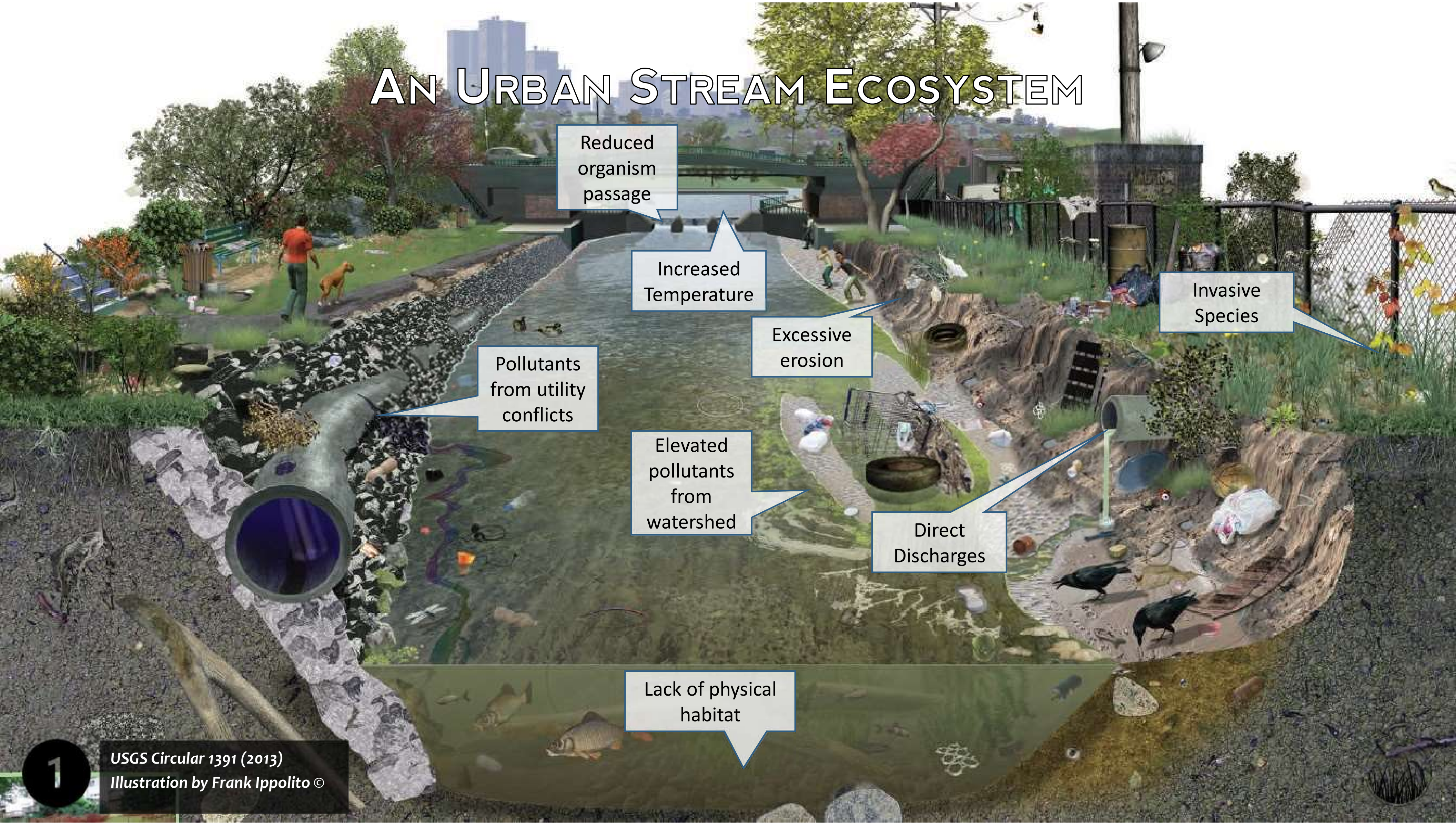

AN URBAN STREAM ECOSYSTEM
Reduced organism passage
Increased Temperature
Excessive erosion
Lack of physical habitat
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©

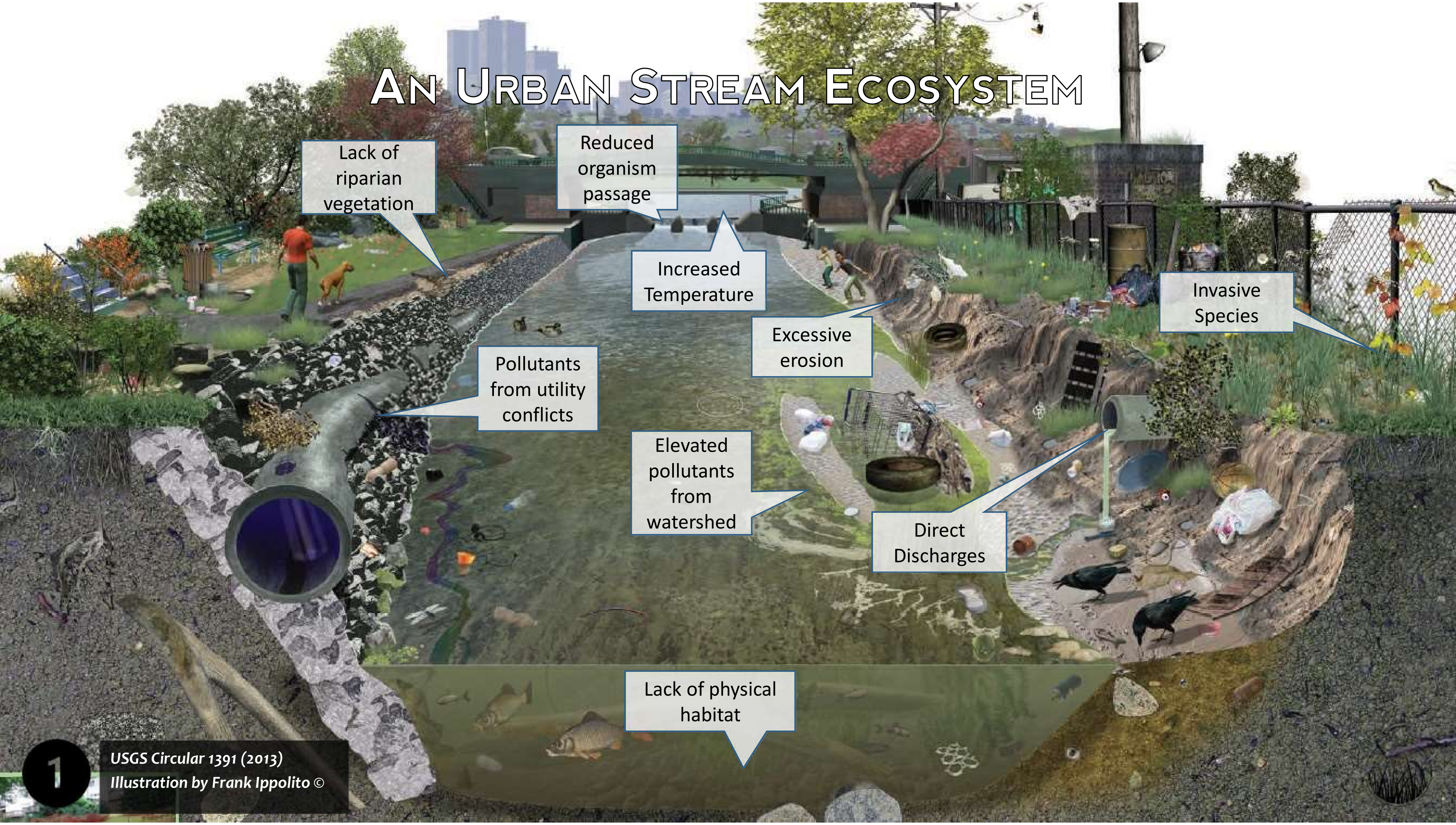


An Urban Stream Ecosystem
Reduced organism passage
Causes:
• Channel alterations
Increased Temperature
Excessive erosion
Lack of physical habitat
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©

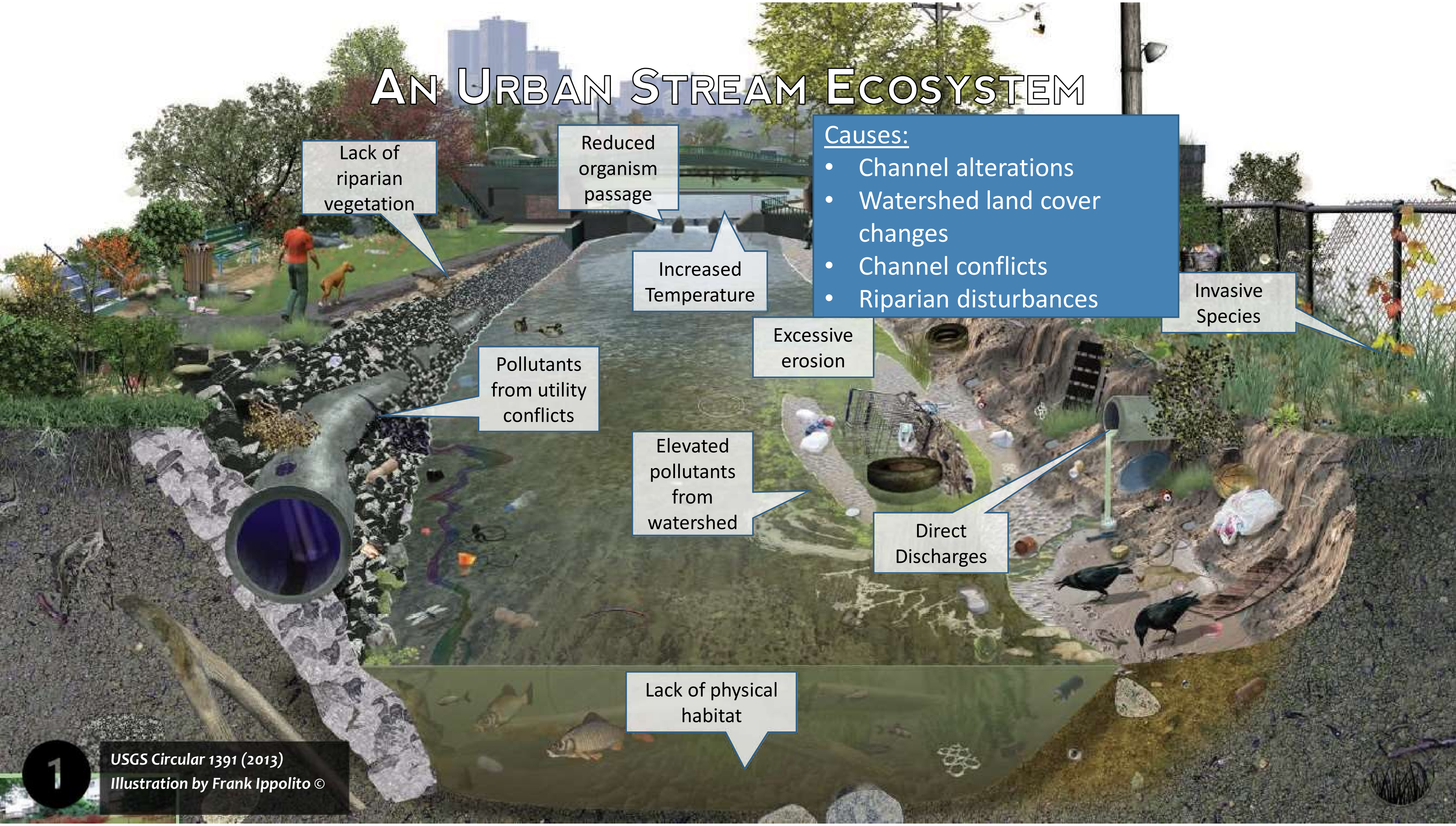

An Urban Stream Ecosystem
Reduced organism passage
Increased Temperature
Excessive erosion
Pollutants from utility conflicts
Elevated pollutants from watershed
Direct Discharges
Lack of physical habitat
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©


An Urban Stream Ecosystem
Reduced organism passage
Increased Temperature
Causes:
• Channel alterations
• Watershed land cover changes
• Channel conflicts
Excessive erosion
Pollutants from utility conflicts
Elevated pollutants from watershed
Direct Discharges
Lack of physical habitat
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©

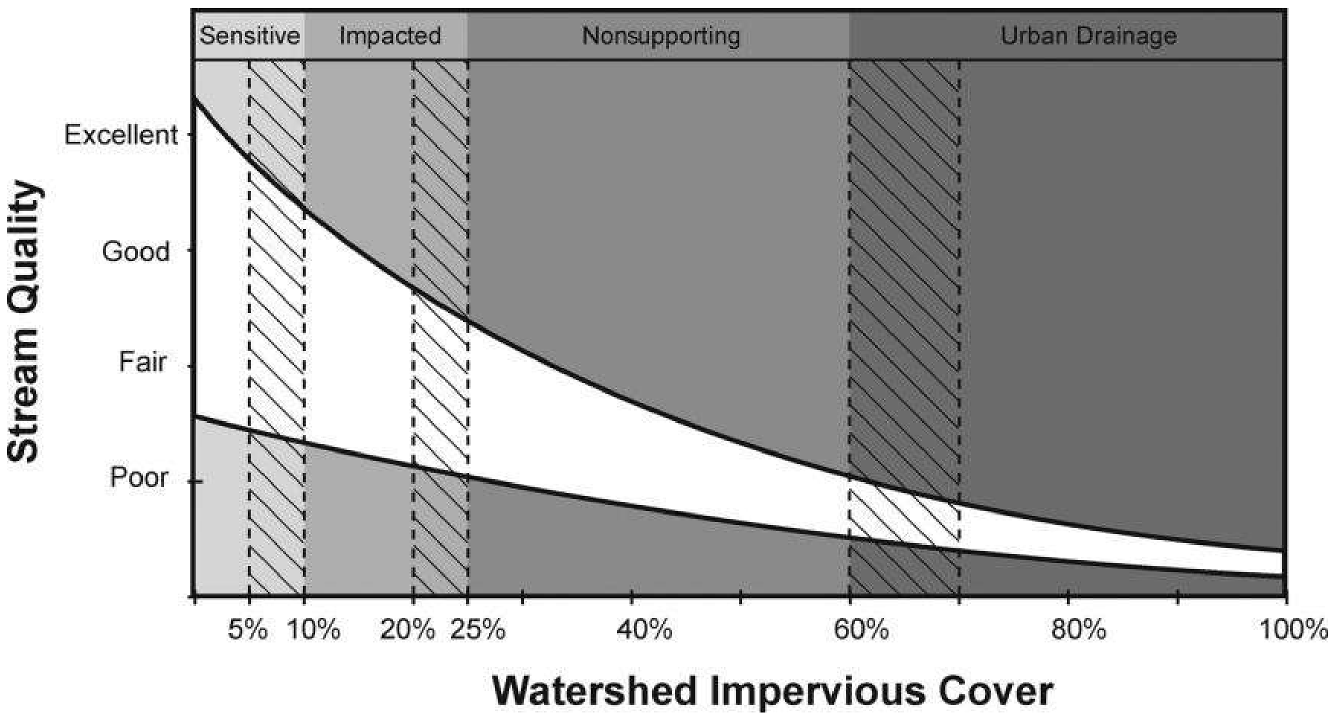

An Urban Stream Ecosystem
Reduced organism passage
Increased Temperature
Excessive erosion
Invasive Species
Pollutants from utility conflicts
Elevated pollutants from watershed
Direct Discharges
Lack of physical habitat
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©



An Urban Stream Ecosystem
Lack of riparian vegetation
Reduced organism passage
Increased Temperature
Excessive erosion
Invasive Species
Pollutants from utility conflicts
Elevated pollutants from watershed
Direct Discharges
Lack of physical habitat
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©


An Urban Stream Ecosystem
Causes:
• Channel alterations
• Watershed land cover changes
• Channel conflicts
• Riparian disturbances
Lack of riparian vegetation
Reduced organism passage
Increased Temperature
Invasive Species
Excessive erosion
Pollutants from utility conflicts
Elevated pollutants from watershed
Direct Discharges
Lack of physical habitat
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©

Impervious Cover Model



"Not every degraded [stream] is a product of intense urban development, [but] all highly urban watersheds produce severely degraded receiving waters."

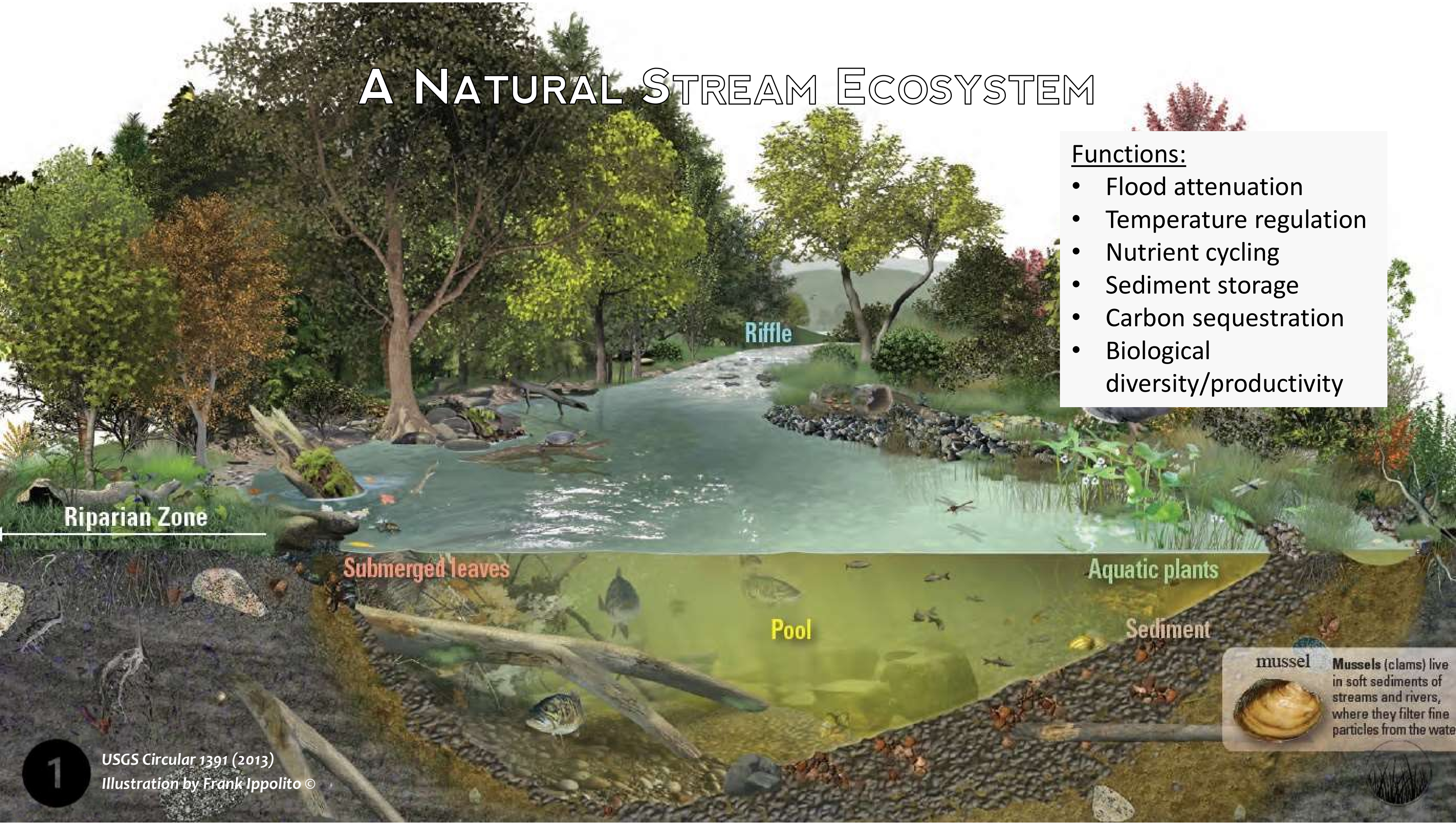
Committee on Reducing Stormwater Discharge Contributions to Water Pollution, "Urban Stormwater Management in the United States" 2009

Is impervious cover still important? Review of recent research (Schueler, 2009)

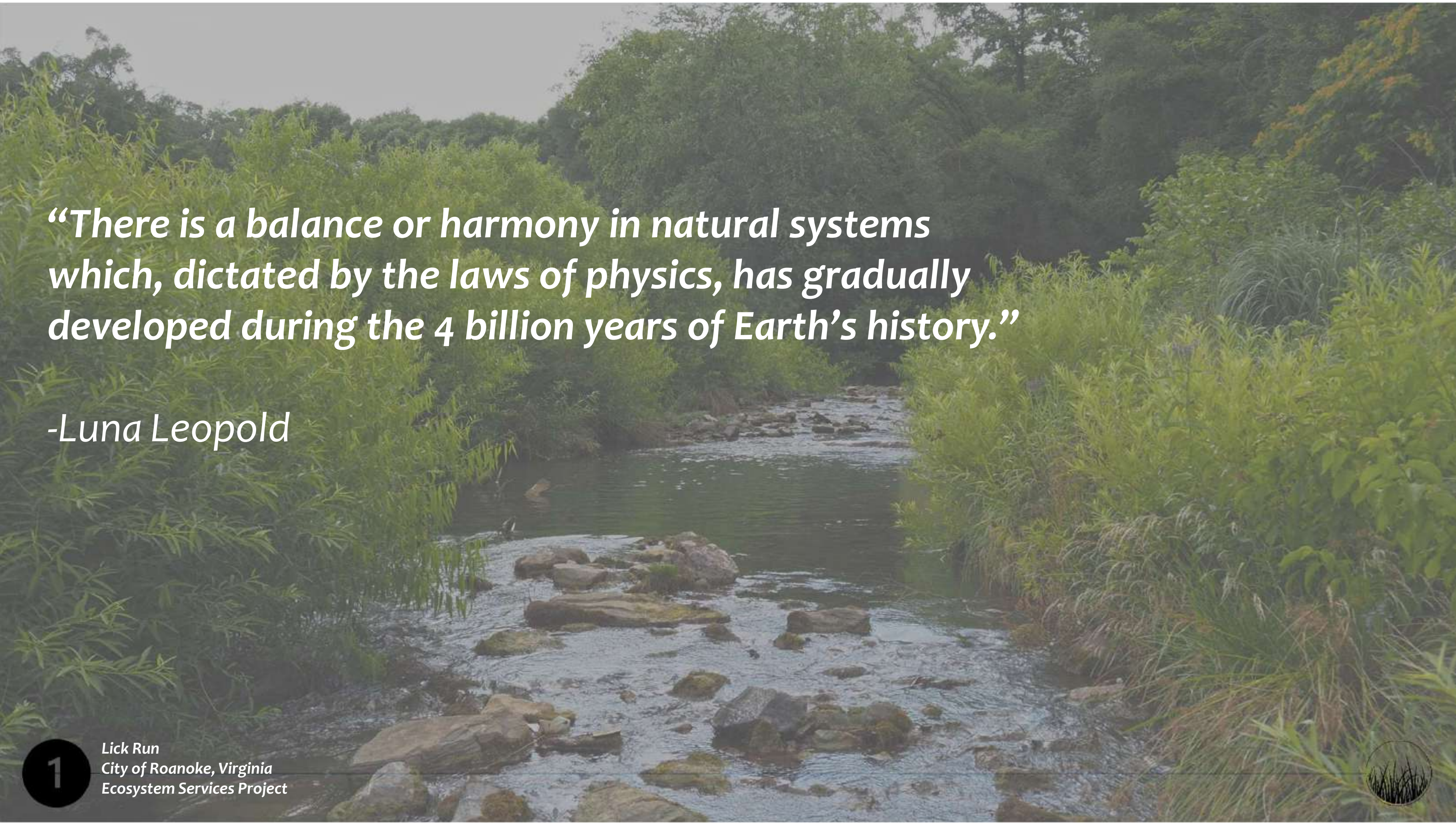

A Natural Stream Ecosystem
Riffle
Riparian Zone
Submerged leaves
Aquatic plants
Pool
Sediment
mussel
Mussels (clams) live in soft sediments of streams and rivers, where they filter fine particles from the wate
1
USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©

A Natural Stream Ecosystem

Functions:
- Flood attenuation
- Temperature regulation
- Nutrient cycling
- Sediment storage
- Carbon sequestration
- Biological diversity/productivity

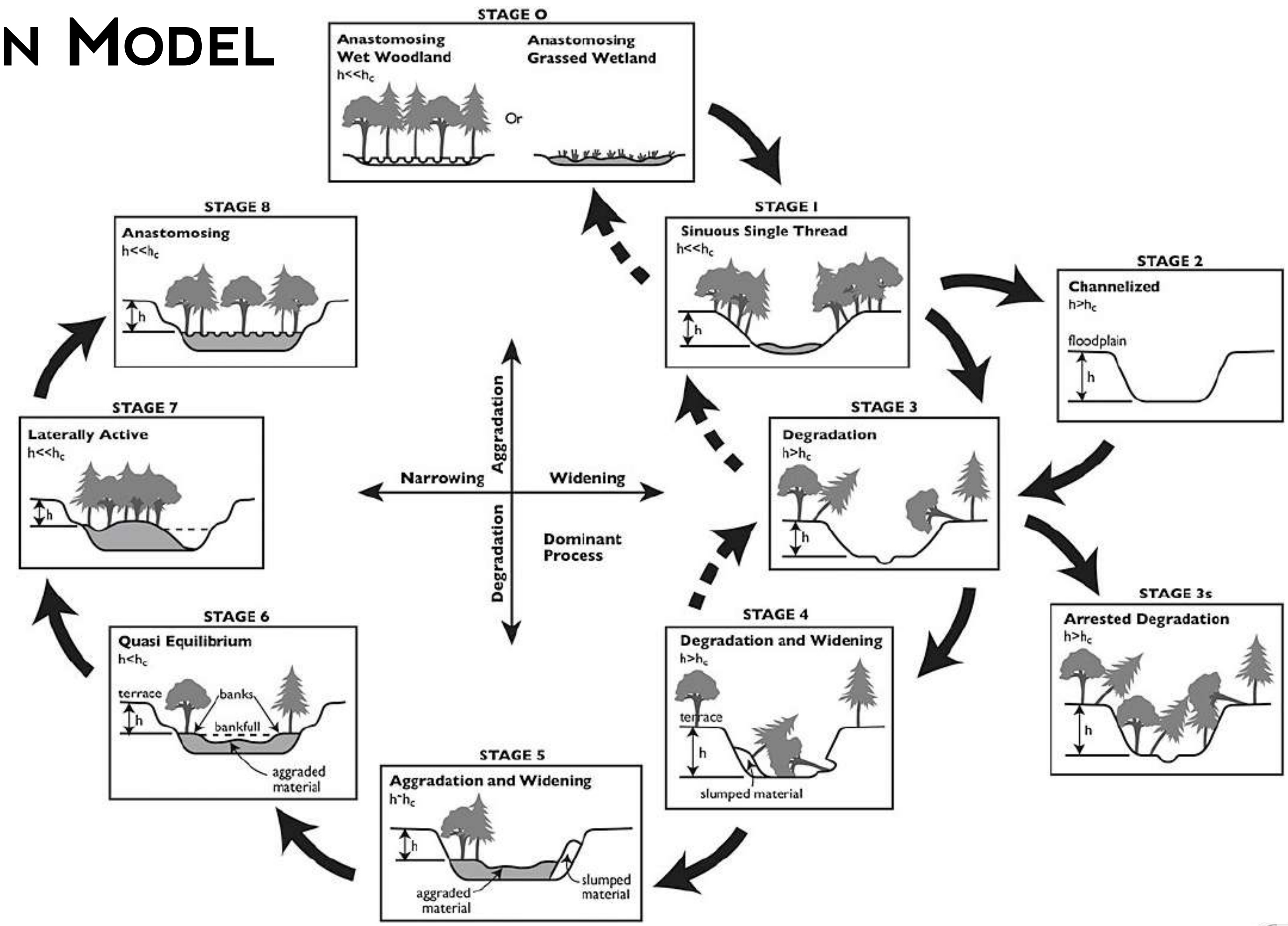


USGS Circular 1391 (2013)
Illustration by Frank Ippolito ©


"There is a balance or harmony in natural systems which, dictated by the laws of physics, has gradually developed during the 4 billion years of Earth's history."
-Luna Leopold
1
Lick Run
City of Roanoke, Virginia
Ecosystem Services Project

Stream Evolution Model

Understanding where a stream exists within the Stream Evolution Model can provide insight to its morphological & ecological trajectory.



Stream Evolution Model (Cluer and Thorne 2014).

2 The Social Context

JMU EJC Arboretum
Harrisonburg, VA
Ecosystem Services Project

"… social forces shape the morphology of restored streams."

Martin W. Doyle, Jai Singh, Rebecca Lave, and Morgan M. Robertson.

The morphology of streams restored for market and nonmarket purposes: Insights from a mixed natural-social science approach

Tributary to Ivy Creek
Albemarle, Virginia
Ecosystem Services Project

Community Preferences

According to project managers… **post-project appearance and positive public opinion were the most commonly used metrics of success."**

Bernhardt et al

Restoring streams in an urbanizing world

"… **natural elements of a river landscape, which may be the aim of an ecologically driven restoration, may be viewed negatively [by the public].**" –

Ellen Wohl, Stuart N. Lane, and Andrew C. Wilcox

The science and practice of river restoration

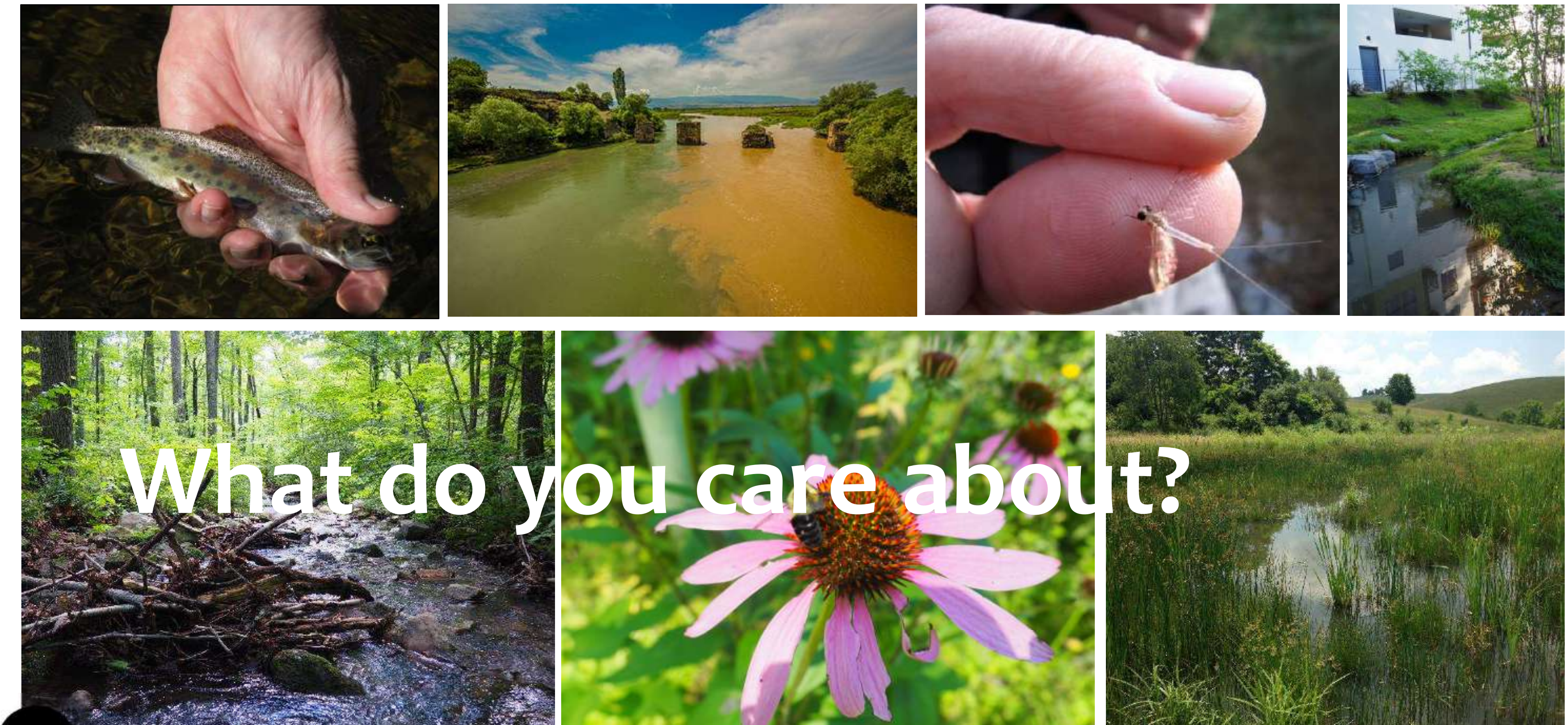
Regulatory & Practitioner Preferences

NWP 27-Aquatic Habitat Restoration, Establishment, and Enhancement Activities

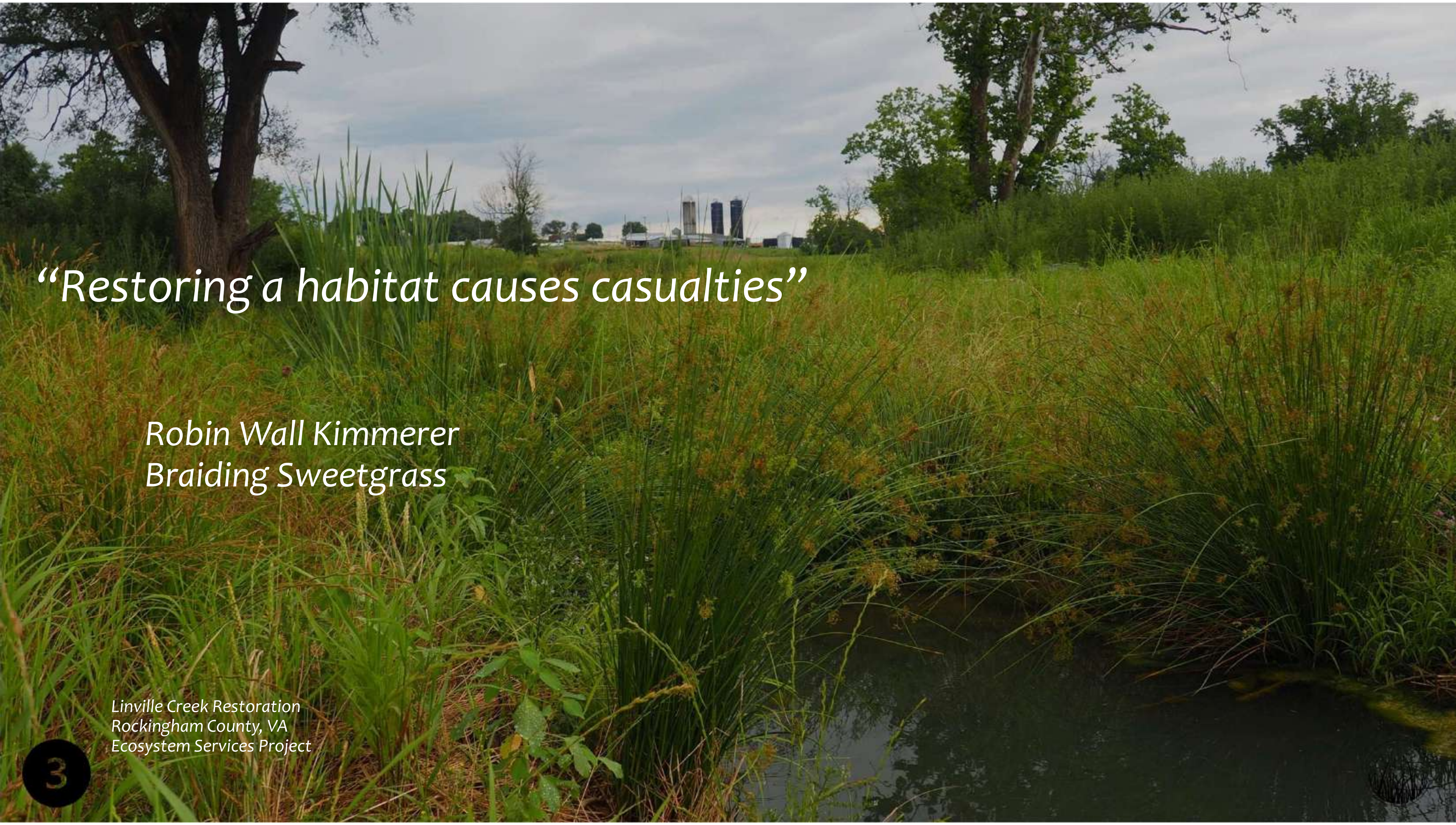
1. For all projects proposing stream restoration, when a PCN is required, proponents must provide a completed Natural Channel Design Review Checklist and Selected Morphological Characteristics form, including the name and location of the reference reach, unless the district engineer waives this criterion by making a written determination concluding that the discharge will result in no more than minimal adverse environmental effects. These forms and the associated manual can be located at:

   https://www.fws.gov/chesapeakebay/PDF/stream-restoration/Natural-Channel-Design-Checklist-Doc-V2-Final-11-4-11.pdf

Restoration Approach and Success



3 Evaluating Tradeoffs


“Restoring a habitat causes casualties”
Robin Wall Kimmerer
Braiding Sweetgrass
Linville Creek Restoration
Rockingham County, VA
Ecosystem Services Project
3

The Framework

Develop goals related to perceived problems (i.e., stressors)

↓

Develop measurable objectives related to stream function and social context

↓

Develop metrics & collect associated data

↓

Evaluate solutions in terms of goals and metrics

Evaluating Tradeoffs

Developing quantitative and qualitative scoring of project attributes with stakeholder involvement can improve restoration outcomes

Environmental

- Riparian condition
- Erosion rate
- Instream habitat
- Trees
- Soil health

Regulatory

- Floodplain encroachment
- Sensitive features conflict
- Cultural resource conflict

Social

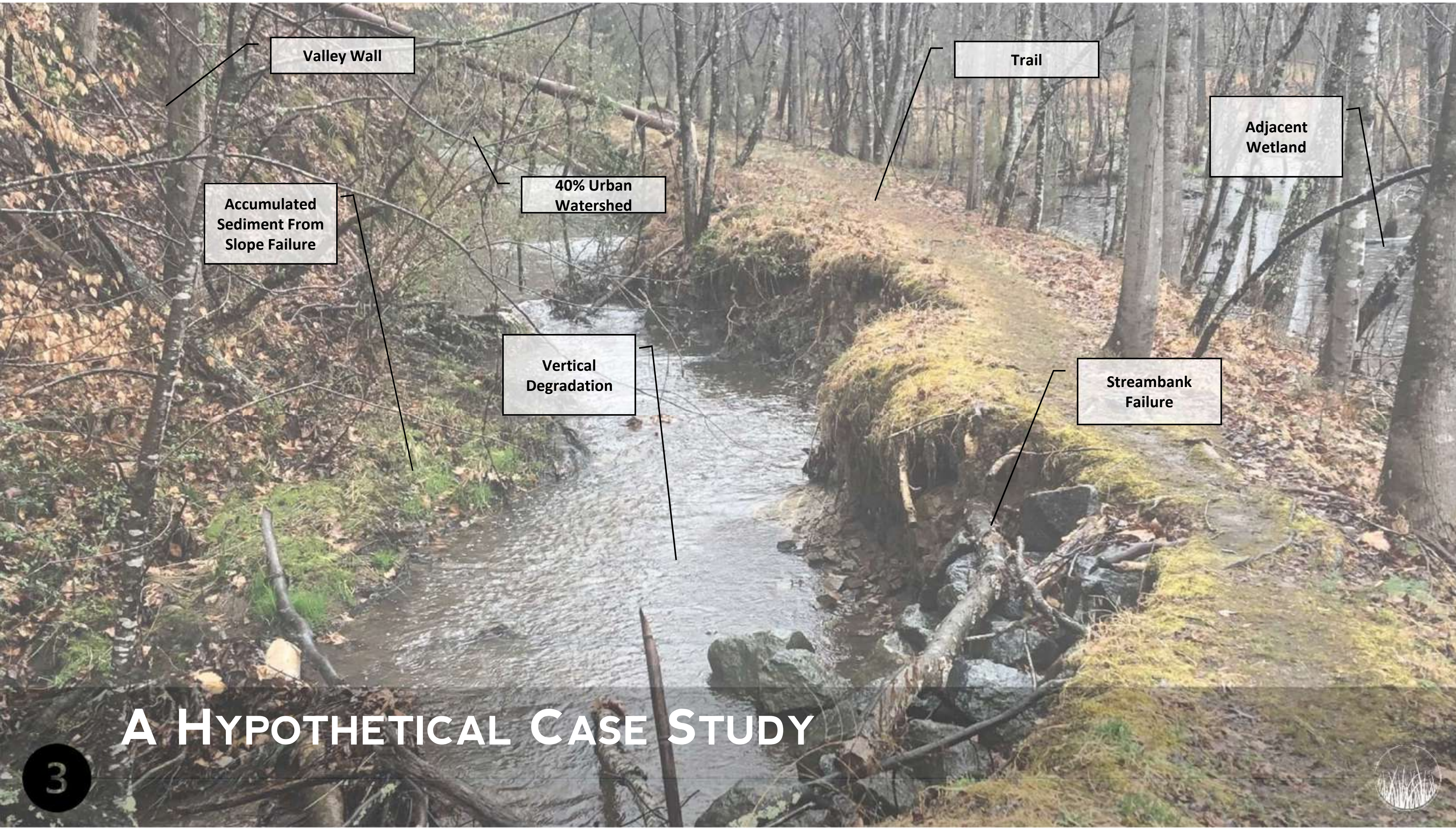
- Safety
- Recreation
- Aesthetics
- Restoration preference
- Economics

Physical

- Access
- Valley constraints
- Utility conflict
- Geology

Resilience

- Flow/Sediment Input
- Watershed condition
- Habitat connectivity
- Water storage



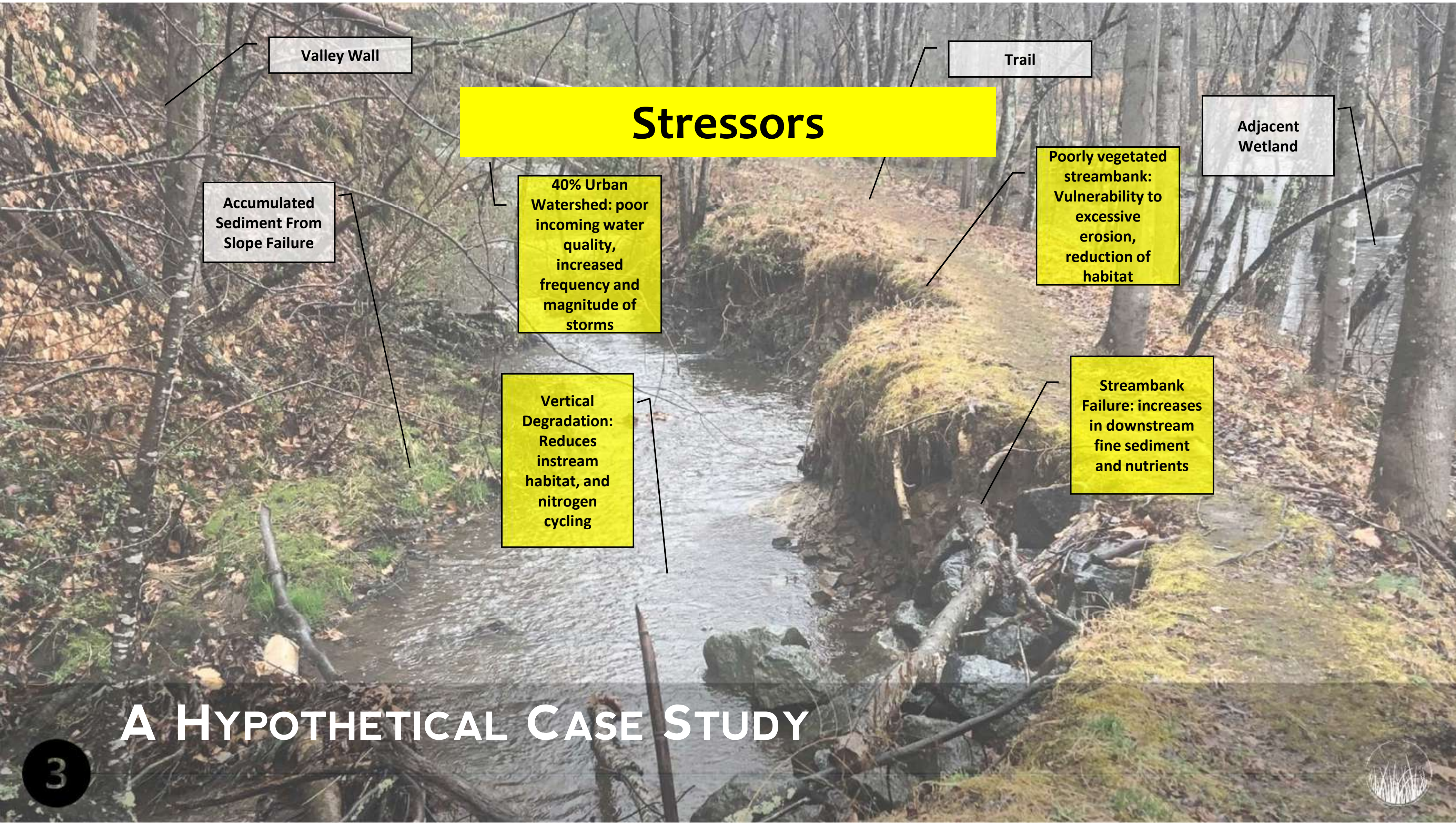
A Hypothetical Case Study

3


THE PERFECT SOLUTION!
3


Onsite material
THE PERFECT SOLUTION!
3


Only 20% failure!
Onsite material
THE PERFECT SOLUTION!
3


Stressors
Valley Wall
Trail
Adjacent Wetland
Accumulated Sediment From Slope Failure
40% Urban Watershed: poor incoming water quality, increased frequency and magnitude of storms
Poorly vegetated streambank: Vulnerability to excessive erosion, reduction of habitat
Vertical Degradation: Reduces instream habitat, and nitrogen cycling
Streambank Failure: increases in downstream fine sediment and nutrients
A Hypothetical Case Study
3


Goal #1: Reduce Erosion
Goal #2: Preserve Trail Circulation & Access
Goal #3: Vegetated Streambank Condition
Goal Setting
3

G1: Reduce Erosion

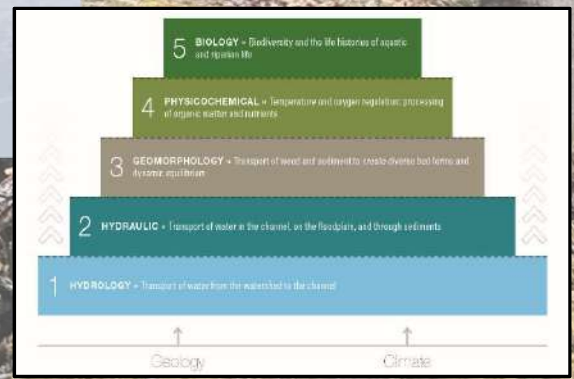
- Geomorphology: Stream shall have a Bank Erodibility Hazard Index of Low after Year 1
- Hydraulic: Streambank shall be non-erodible up to a 25-yr storm
- Hydrology: Peak storms will be reduced to reflect forested watershed disturbance regime

G2: Preserve Trail

- Recreation: Maintain a 4' min. walking path
- Safety: Path will have no more than a 50% chance of flooding in a given year (2-yr storm)

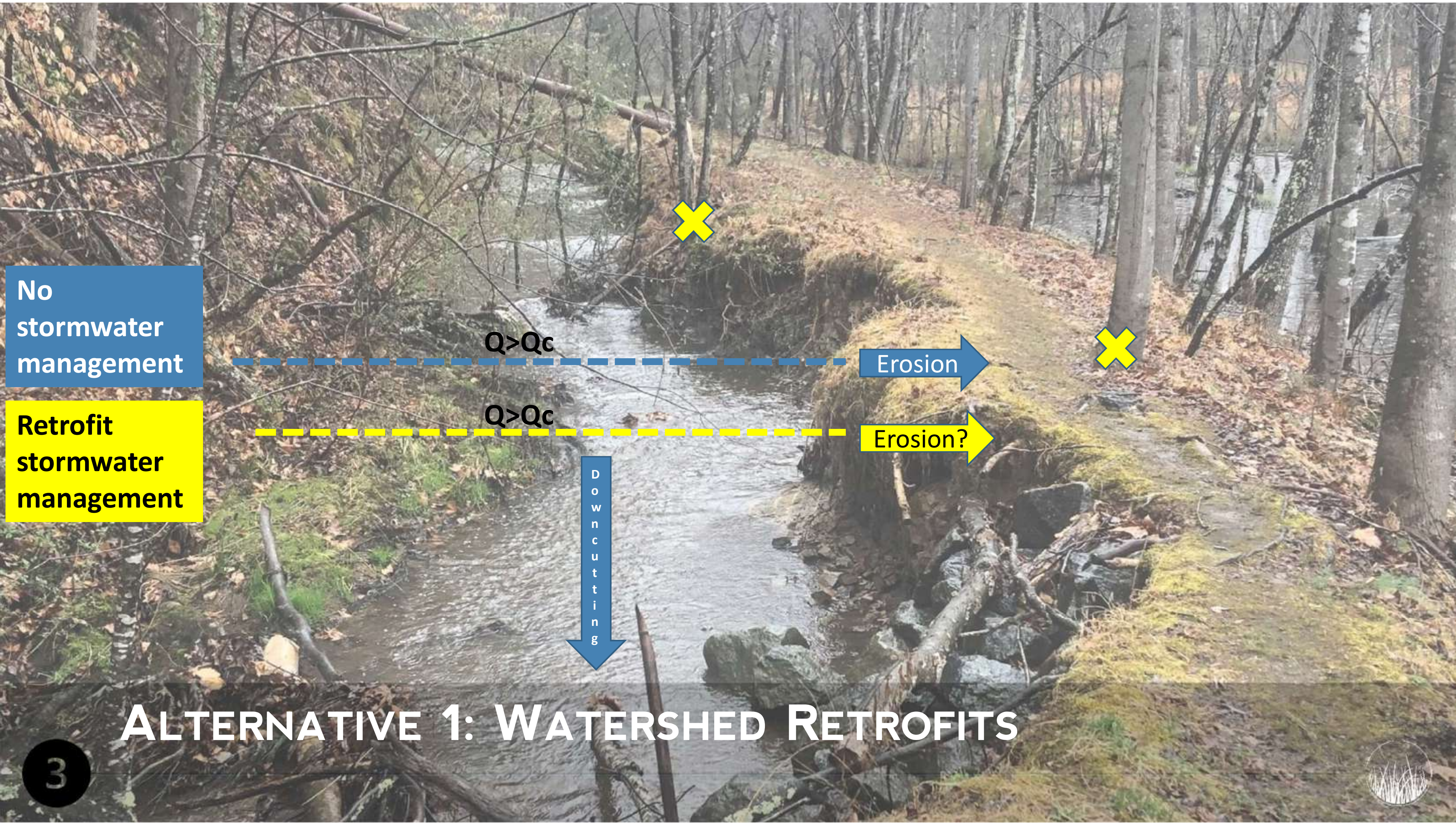
G3: Vegetated Streambank Condition

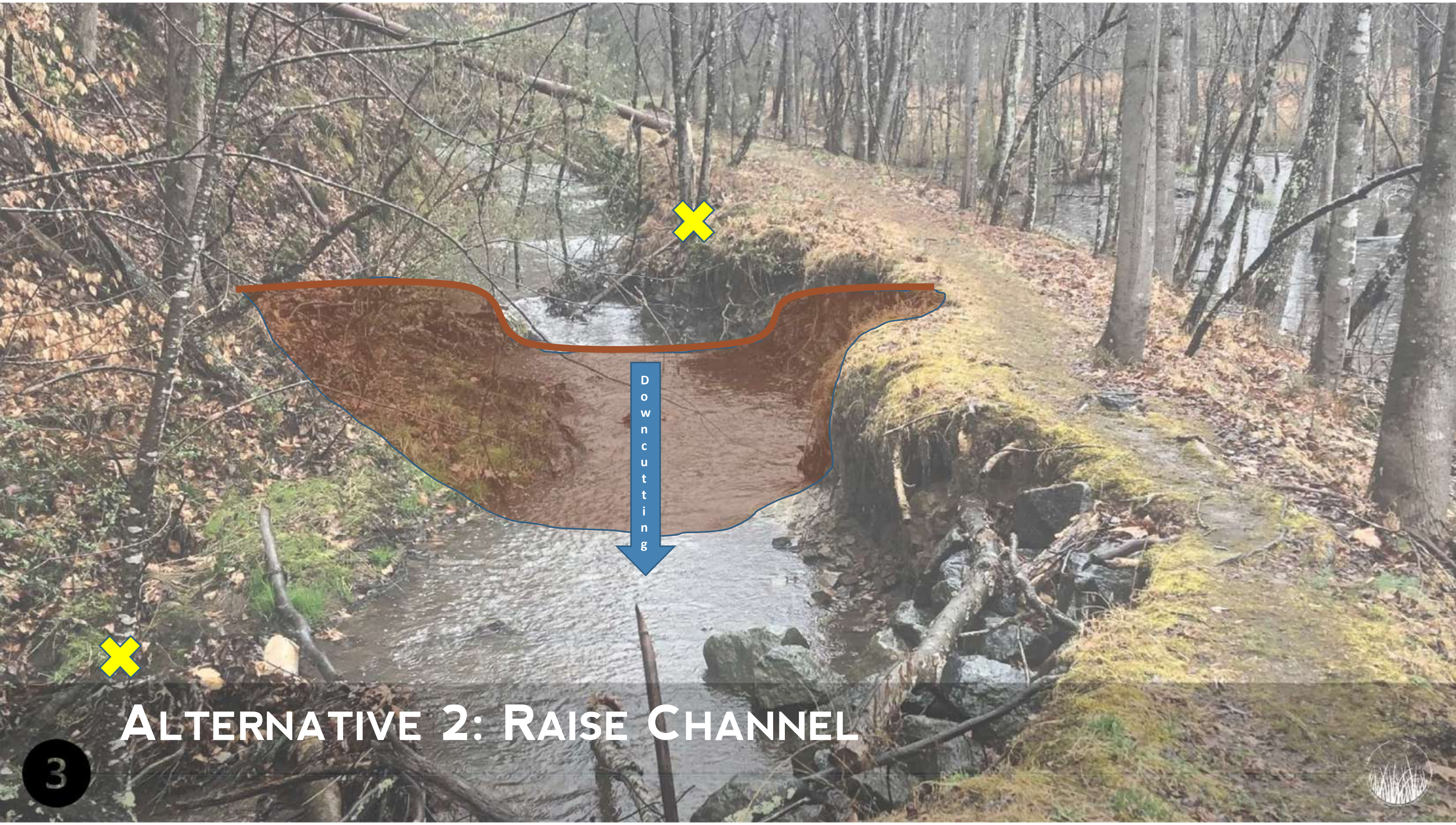
- Biology: Maintain native herbaceous, shrub, and tree material on streambank after 1-year

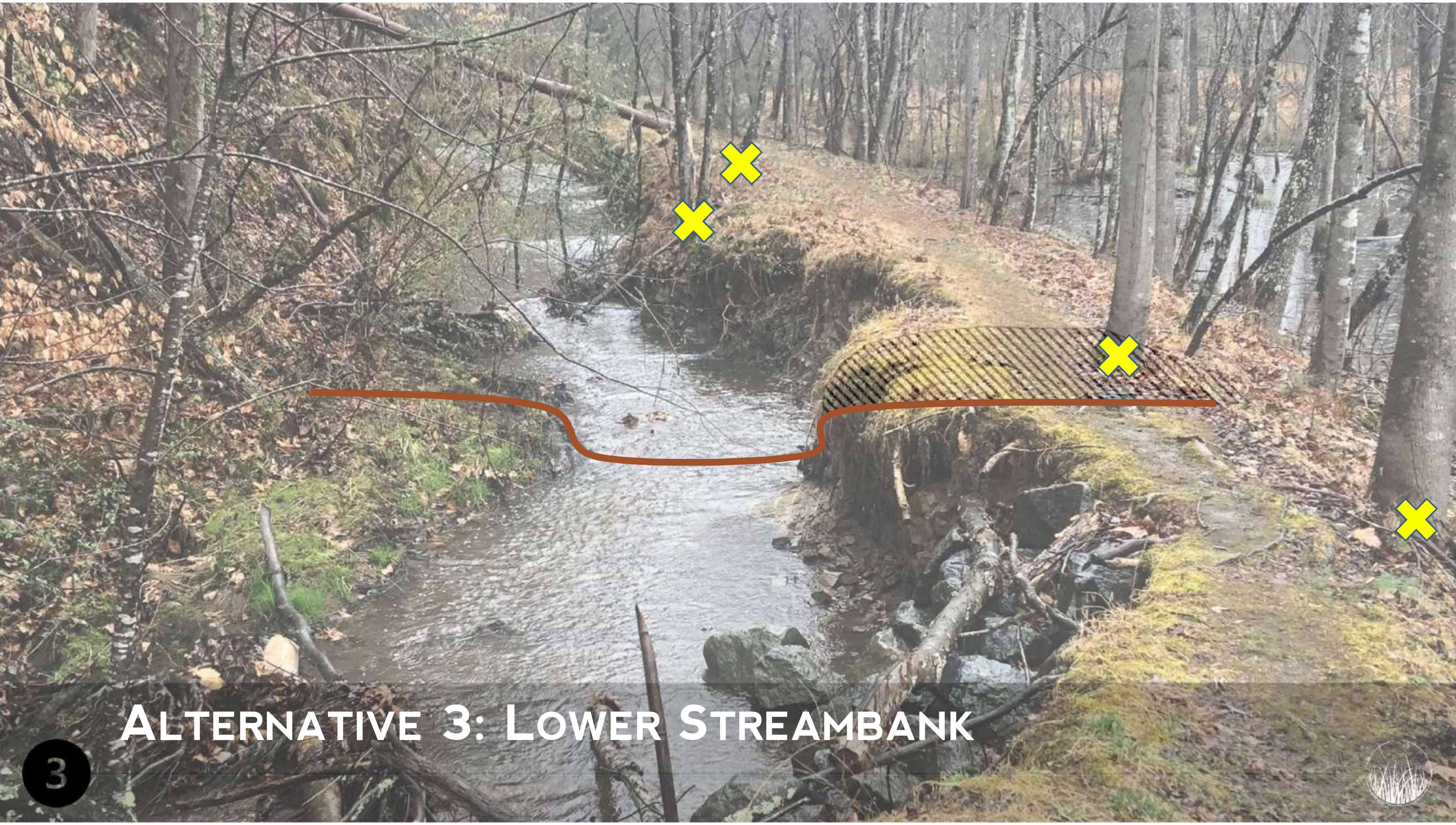


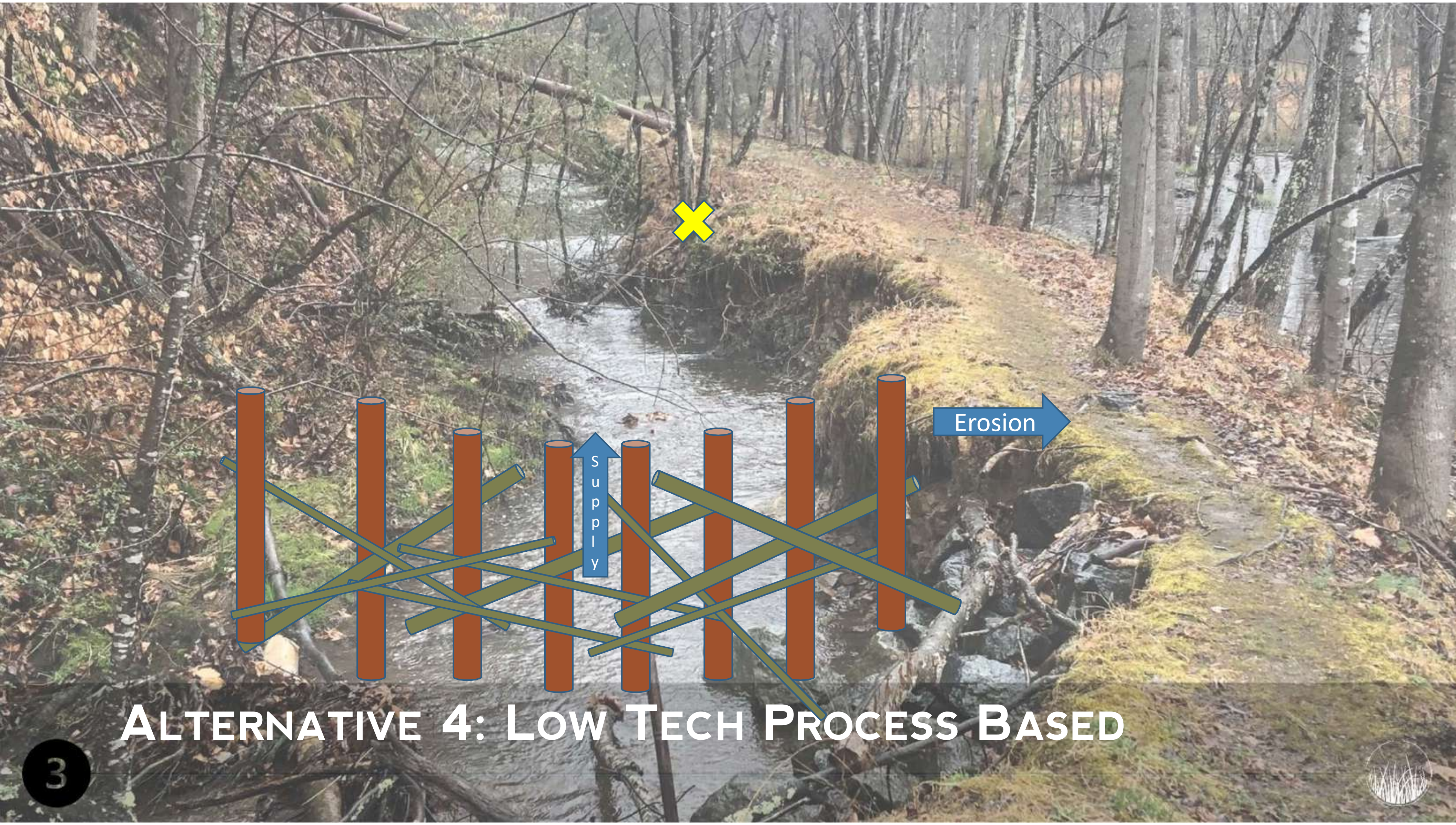
Objective Setting

3


No stormwater management
Retrofit stormwater management
Q>Qc
Q>Qc
Erosion
Erosion?
Downcutting
Alternative 1: Watershed Retrofits
3


Downcutting
Alternative 2: Raise Channel
3


ALTERNATIVE 3: LOWER STREAMBANK
3


Supply
Erosion
Alternative 4: Low Tech Process Based
3


Minimal to no vegetation
Erosion
Downcutting
Alternative 5: Stabilize in Place
3

Takeaways

Restoration seeks to set a trajectory for greater ecological functions

Agree on goals and objectives first

All interventions involve tradeoffs – subject alternatives to the same metrics

Success is dependent upon what you care about (Goals!)

Resources

- **A Functions-Based Framework:** https://www.epa.gov/cwa-404/function-based-framework-stream-assessment-and-restoration-projects-under-cwa-section-404
- **Guidance for Stream Restoration:** https://efotg.sc.egov.usda.gov/references/public/CO/TN-102.3_Yochum_106p_2017_sm.pdf
- **Low-Tech Process-Based Restoration:** https://lowtechpbr.restoration.usu.edu/manual/
- **Stream Mechanics, Restoration Checklists:** https://stream-mechanics.com/resources/

ECOSYSTEM SERVICES

ENGINEERING | ECOLOGICAL RESTORATION | CONSULTING

ORIENTATION

NASA's Earth Observatory

What's "Natural"?

WHAT'S "NATURAL"?

Common Stressors & Causes

Stressors

- Elevated pollutants from watershed runoff (e.g., sediment, nutrient, salt, etc.)
- Excessive streambank erosion
- Increased temperature
- Lack of physical structure and associated habitat diversity
- Invasive species
- Altered hydrology

Causes

- Historical stream corridor alterations
- Watershed land cover changes
- Direct discharges (e.g., illicit, wastewater, stormwater)
- Imported vegetation

The Urban Stream Syndrome

Bed coarsening, riffle shortening, and channel enlargement in urbanizing watersheds, northern Kentucky, USA

Robert J. Hawley [a,*], Katherine R. MacMannis [a,1], Matthew S. Wooten [b,2]

[a] Sustainable Streams, LLC, 1948 Deer Park Avenue, Louisville, KY 40205, USA
[b] Sanitation District No. 1 of Northern Kentucky, 1045 Eaton Drive, Fort Wright, KY 41017, USA

- Increases in frequency and magnitude of events contributed to morphological changes despite stormwater management (primarily peak control)
- Changes are sustained but degradation varies depending on the rate and stage of the developing watershed
- Since resilience is typically lacking in urban environments, the response sequence can prevent future stormwater management from being effective

Biological Response

Community-Level Response of Fishes and Aquatic Macroinvertebrates to Stream Restoration in a Third-Order Tributary of the Potomac River, USA

Stephen M. Selego,[1,2] Charneé L. Rose,[1,3] George T. Merovich Jr.,[1]
Stuart A. Welsh,[4] and James T. Anderson[1,5]

[1] *Wildlife and Fisheries Resources Program, Division of Forestry and Natural Resources, West Virginia University, P.O. Box 6125, Percival Hall, Morgantown, WV 26506, USA*
[2] *Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon 97331, USA*
[3] *Department of Forest Ecosystems and Society, Oregon State University, Corvallis, Oregon 97331, USA*
[4] *U.S. Geological Survey, WV Cooperative Fish and Wildlife Research Unit, West Virginia University, Morgantown, WV 26506, USA*
[5] *Environmental Research Center, West Virginia University, P.O. Box 6125, Percival Hall, Morgantown, WV 26506, USA*

- Biological recovery in very short time span
- Likely more recolonization opportunities

Biological Response

Ecological resistance in urban streams: the role of natural and legacy attributes

Ryan M. Utz[1,9], Kristina G. Hopkins[2,10], Leah Beesley[3,11], Derek B. Booth[4,12], Robert J. Hawley[5,13], Matthew E. Baker[6,14], Mary C. Freeman[7,15], and Krista L. Jones[8,16]

[1]Falk School of Sustainability, Chatham University, 6035 Ridge Road, Gibsonia, Pennsylvania 15044 USA
[2]National Socio-Environmental Synthesis Center, University of Maryland, 1 Park Place Suite 300, Annapolis, Maryland 21401 USA
[3]Centre of Excellence in Natural Resource Management, University of Western Australia, Albany, Western Australia 6332 Australia
[3]Cooperative Research Centre for Water Sensitive Cities, Clayton 3800 Australia
[4]Bren School of Environmental Science and Management, University of California Santa Barbara, Santa Barbara, California 93106 USA
[5]Sustainable Streams, LLC, 1948 Deer Park Avenue, Louisville, Kentucky 40205 USA
[6]Department of Geography and Environmental Systems, University of Maryland-Baltimore County, Baltimore, Maryland 21250 USA
[7]US Geological Survey Patuxent Wildlife Research Center, Athens, Georgia 30602 USA
[8]US Geological Survey Oregon Water Science Center, 2130 SW 5th Avenue, Portland, Oregon 97201 USA

- Connection to intact ecosystems necessary for biological recovery

Biological Response

When do macroinvertebrate communities of reference streams resemble urban streams? The biological relevance of $Q_{critical}$

Robert J. Hawley[1,2,3,5], Matthew S. Wooten[4,6], Katherine R. MacMannis[1,7], and Elizabeth V. Fet[4,8]

[1]Sustainable Streams, LLC, 1948 Deer Park Avenue, Louisville, Kentucky 40205 USA
[2]Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, Colorado 80523 USA
[3]Department of Civil Engineering, University of Kentucky, Lexington, Kentucky 40506 USA
[4]Sanitation District No. 1 of Northern Kentucky, 1045 Eaton Drive, Fort Wright, Kentucky 41017 USA

- Disturbances associated with > Qc in natural conditions reduce macro populations (biologic integrity) and resemble urban regimes
- Recolonization and infrequency of Qc results in recovery of the system

Chemical Response

EFFECTS OF STREAM RESTORATION ON DENITRIFICATION IN AN URBANIZING WATERSHED

Sujay S. Kaushal,[1,5] Peter M. Groffman,[2] Paul M. Mayer,[3] Elise Striz,[3] and Arthur J. Gold[4]

[1]University of Maryland, Center for Environmental Science, Appalachian Laboratory, 301 Braddock Road, Frostburg, Maryland 21532 USA
[2]Institute of Ecosystem Studies, Box AB, Route 44 A, Millbrook, New York 12545 USA
[3]Office of Research and Development, National Risk Research Management Laboratory, U.S. Environmental Protection Agency, Ada, Oklahoma 74820 USA
[4]University of Rhode Island, Department of Natural Resources, Kingston, Rhode Island 02881 USA

- Floodplain connection necessary for hyporheic exchange and denitrification