RIPARIAN ECOLOGICAL FUNCTION INDEX (REFI)

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EMRRP Webinar Series
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PRESENTATION OVERVIEW

- Overview of riparian zones functions and processes
- A review of existing riparian models
- REFI (structure, function, assessment)
- Utoy Creek: a case study
- Future applications

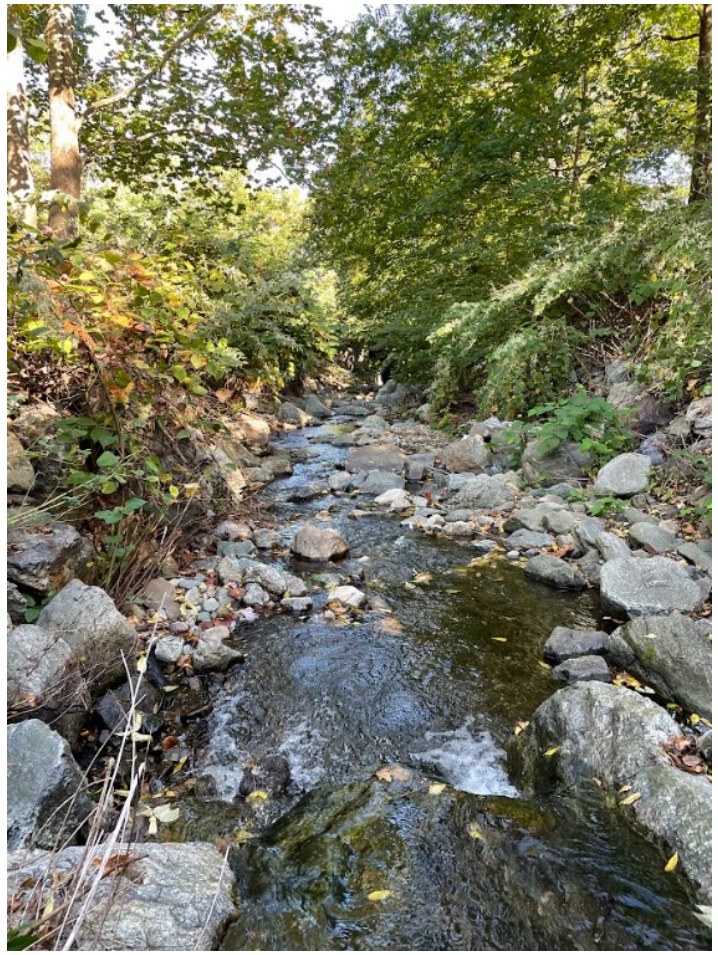
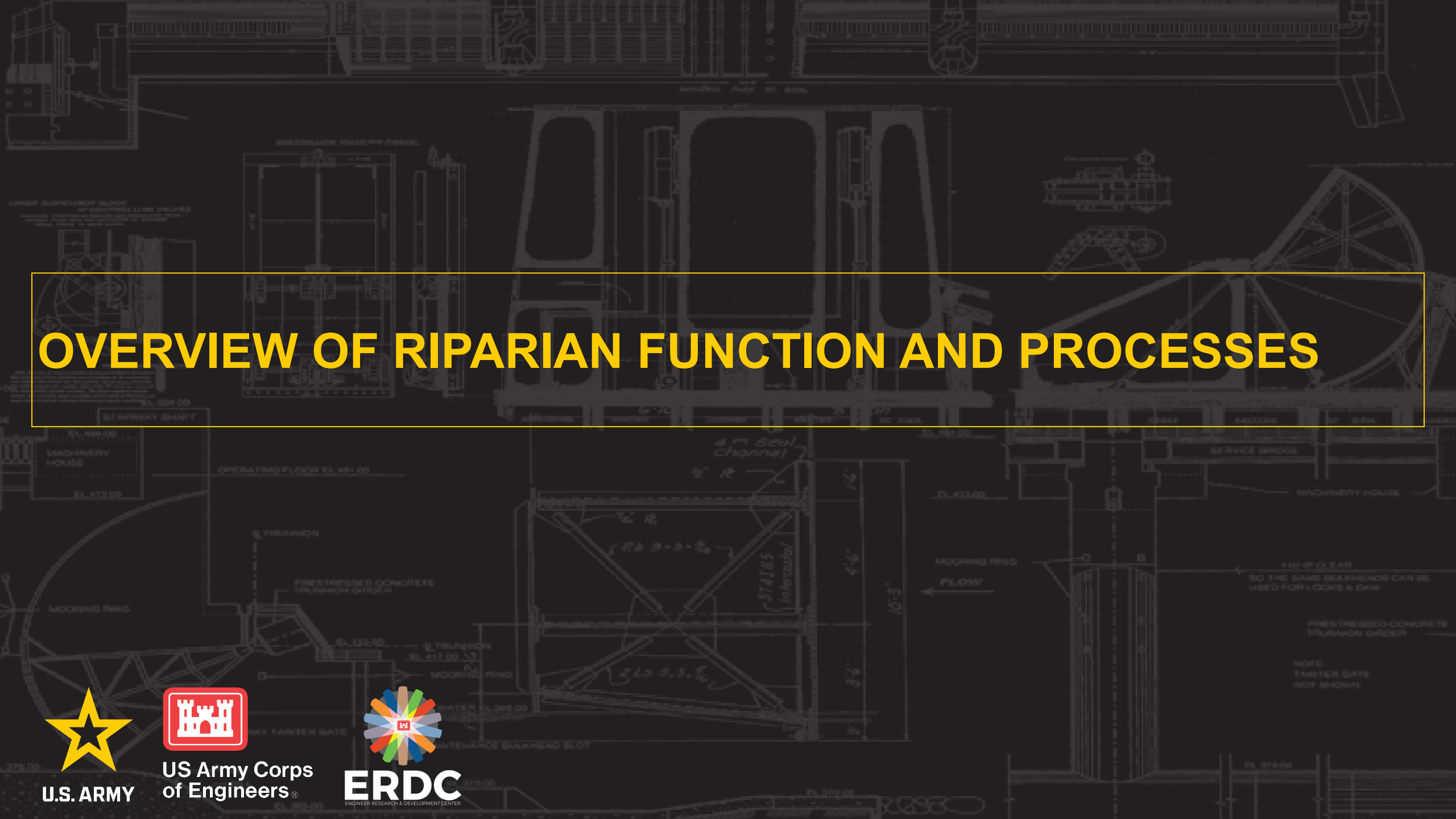


Photo: West Point Military Academy, New York (Samantha Wiest)

OVERVIEW OF RIPARIAN FUNCTION AND PROCESSES



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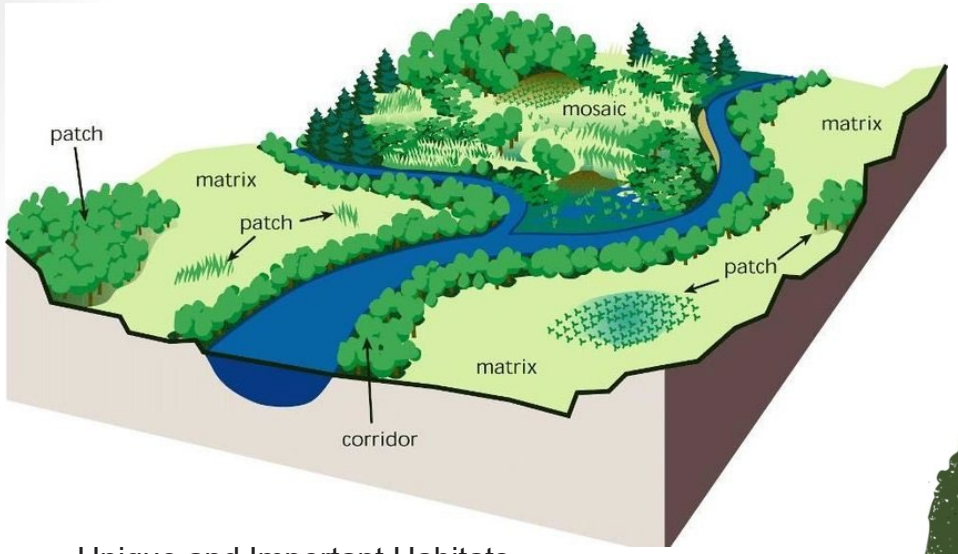
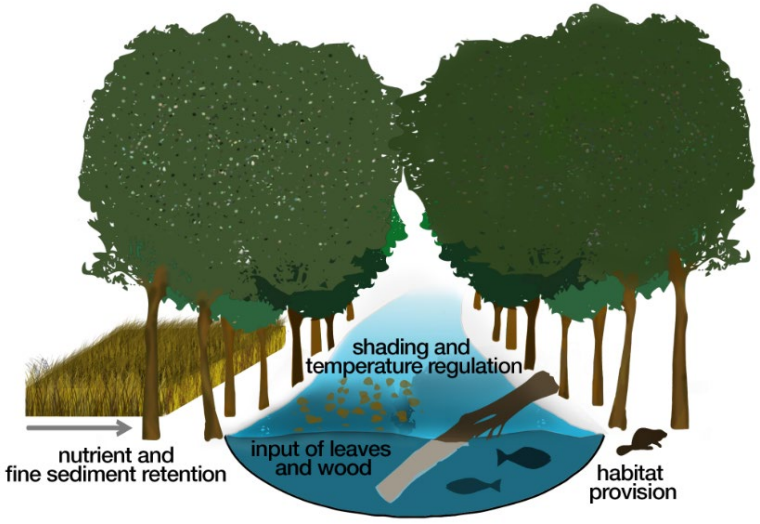
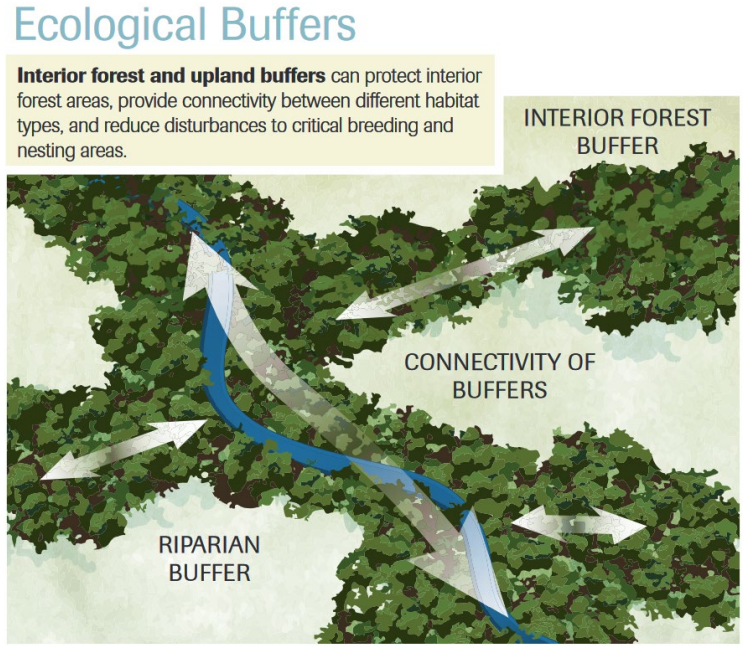
RIPARIAN ZONES AS KEY TRANSITIONAL ECOSYSTEMS LINKING FRESHWATER AND TERRESTRIAL AREAS



Unique and Important Habitats



Instream Processes



Ecological Connectivity

RIPARIAN ZONE FUNCTION IS DEPENDENT ON ADJACENT LAND USE

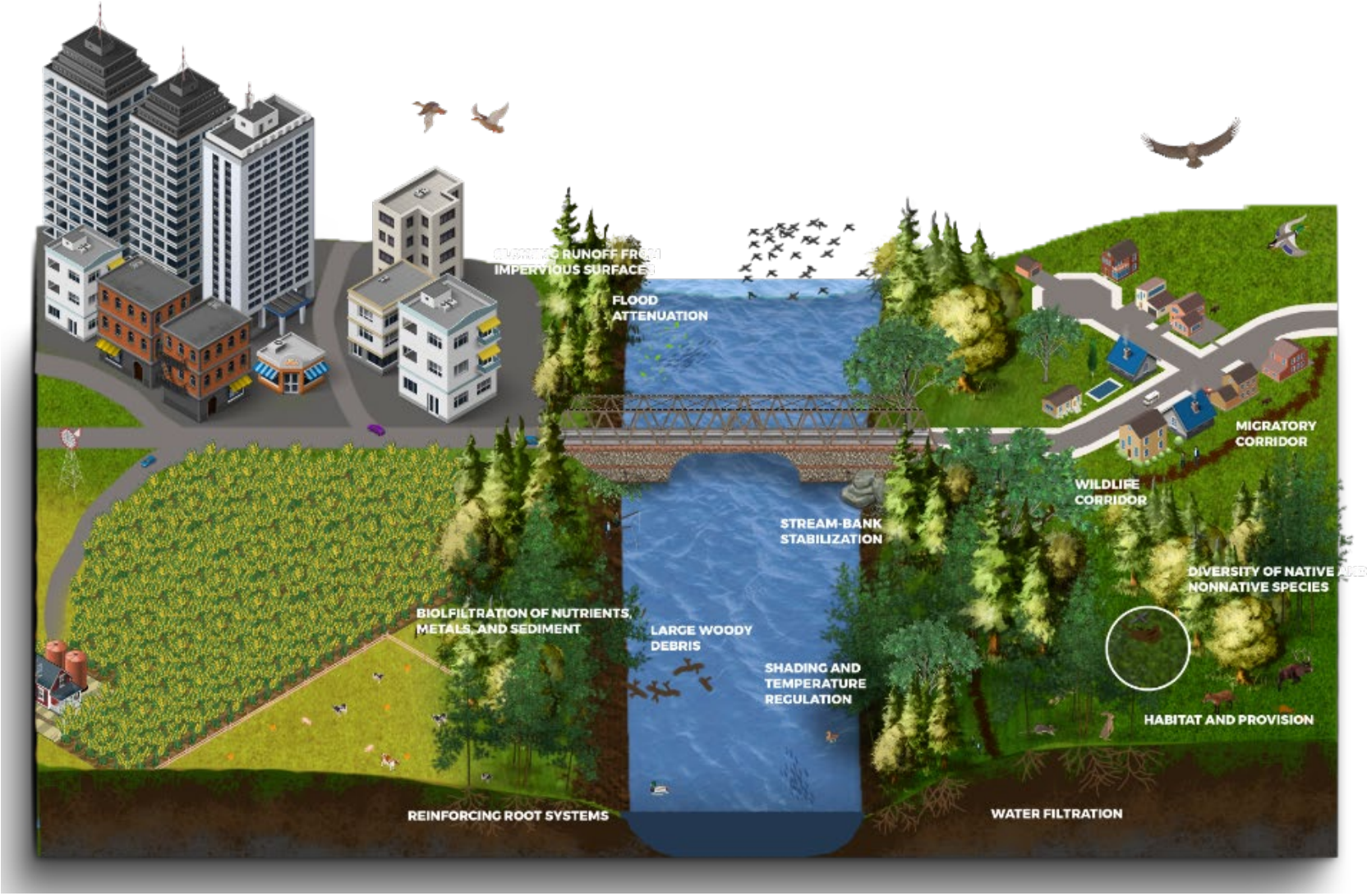
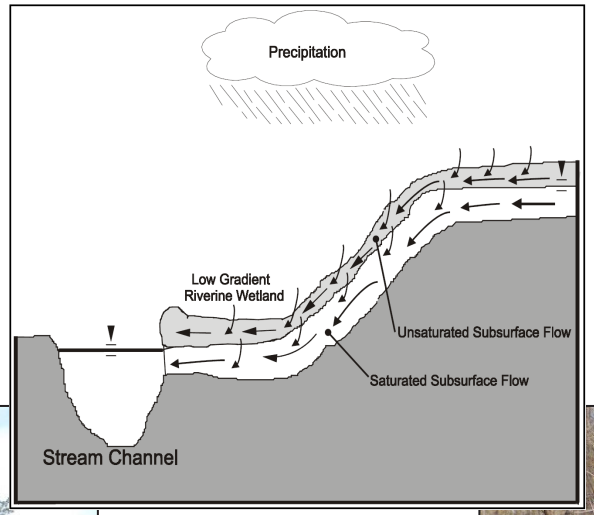


Figure: Conceptual model of riparian functions (Samantha Wiest, Alvin Foster)

LOTS OF FORMS OF RIPARIAN MANAGEMENT

Regulatory choices about buffer widths (usually state and local)

Regulatory Riparian Wetlands



Impact Assessment

Restoration Benefits

Figures: Mississippi River Basin Conservation Network, Ainslie et al. (1999, ERDC WRP-DE-17), Sacramento levee system, California (McKay), Proctor Creek, Atlanta, Georgia (McKay)

TIERED APPROACH TO RIPARIAN MODEL DEVELOPMENT

	Low level of effort	Moderate level of effort	High level of effort
Scope	Rapid, desktop tools for order-of-magnitude estimates comparing sites	Rapid assessment for comparing the relative effects of alternatives at the site-scale	Regionally tailored methods that target specific ecological targets and have often been field verified
Metric Types	Simple geospatial	Simple geospatial Rapid, semi-quantitative field assessment	Typically empirical measurements
Time commitment	minutes-hours	hours-days	varies
Geography	Global meta-analysis	National, on-the-shelf field assessment tool	Regionally scoped models (compiled into a web applications)
Processes included	Instream processes Taxa-oriented outcomes Corridors	Instream processes Taxa-oriented outcomes Corridors	Instream processes Taxa-oriented outcomes Corridors

Levels of effort in ecological modeling:
Harris et al. (2023, ERDC/TN EMRRP-EM-11)

PROJECT OBJECTIVES

- Develop a rapid, screening tool for assessing the impacts and benefits of riparian zones
  - Follows a semi-quantitative approach
  - Incorporates a scoring system + rapid GIS protocol
  - Nationally applicable to a wide range of multi-taxa riparian zones
  - A conceptual structure that addresses instream processes and habitat provision

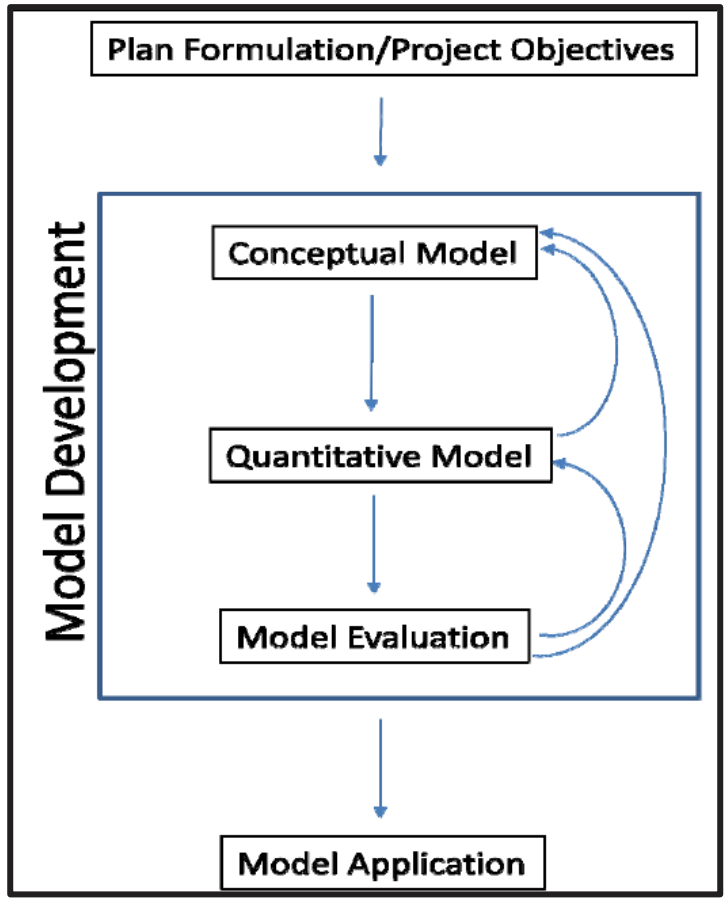


Figure: Swannack et al. (2012)

A REVIEW OF EXISTING MODELS

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REVIEW OF RIPARIAN MODELS FOR ASSESSING ECOLOGICAL IMPACTS AND BENEFITS

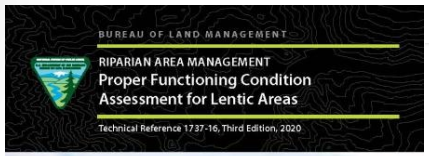
How are we reviewing the models?

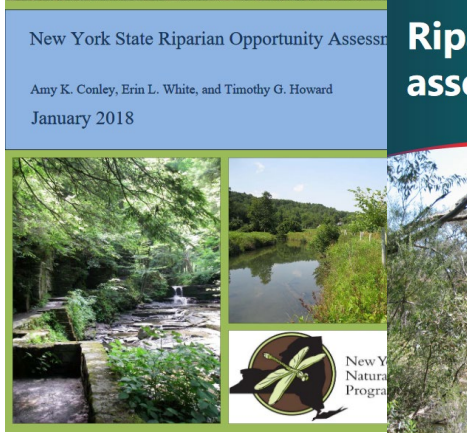
- What models are out there?
- What functions are included?
- What was the scope of modeling (philosophy, geography, review)?
- What are consistencies (and discrepancies) across models?
- What is missing in these tools?

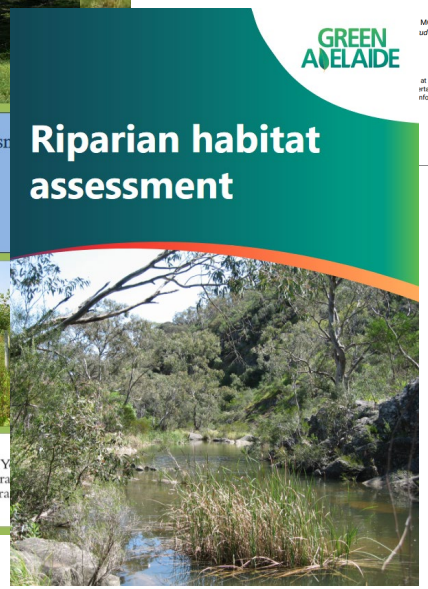
Existing Riparian Modeling Tools	Instream Processes					Riparian Zones Processes											Region of Application
	Physical Characteristics	Stream Condition	Stream Hydrologic Processes	Adjacent Land Use	Climate and Weather	Bank Characteristics	Habitat Connectivity	Stream Habitat	Canopy/Groud Cover	Native/Invasive species	Vegetation Composition	Species Richness	Riparian Functions	Floodplain Functions	Landscape Connectivity	Buffer Functionality	
1. Resaca Reference Condition Model	1	1				1		1	2	1	1	1					Southwest
2. Upper Mississippi River System									1	1	3						Southeast
3. Modified Riverine HSI Model for Mink		1						1	3		1						Varying
4. Simple Model for Urban Riparian Function	1	1	2				3								2	1	Northeast
5. Community-Based Ecosystem Response Model for the Cottonwood Riparian Forests of Missouri River	2			1					2	1	2	1		1	3		West/Midwest/ Southeast
6. Middle Rio Grande Bosque Riparian Community Index Model	1			1	3	1			5	1				3	3		Southwest
7. Ecological Functions Approach at Chatfield Reservoir	2	1	4				2				1					1	Varying
8. Lower Willamette River Ecosystem Restoration Project Model									8		3						Northwest
9. Skokomish River Ecosystem Restoration Project Environmental Benefits Analysis			1					2	1				1	1			Northwest
10. The Riparian Ecosystem Management Model		2		2	1						1					1	Varying
11. Riparian Aquatic Interaction Simulator											1		1				Northwest
12. Wetland and Riparian Forests in Ouachita Mountains and Crowley's Ridge Regions of Arkansas	3		2				1	1	3		6		2	1		2	South Central
13. Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains	1			1			1		4	1	1		1	2	1		Southwest
14. High-Gradient Headwater Streams and Low-Gradient Perennial Streams in Appalachia	2			1		3			3	1	1	4	1				Southeast/Mid-Atlantic

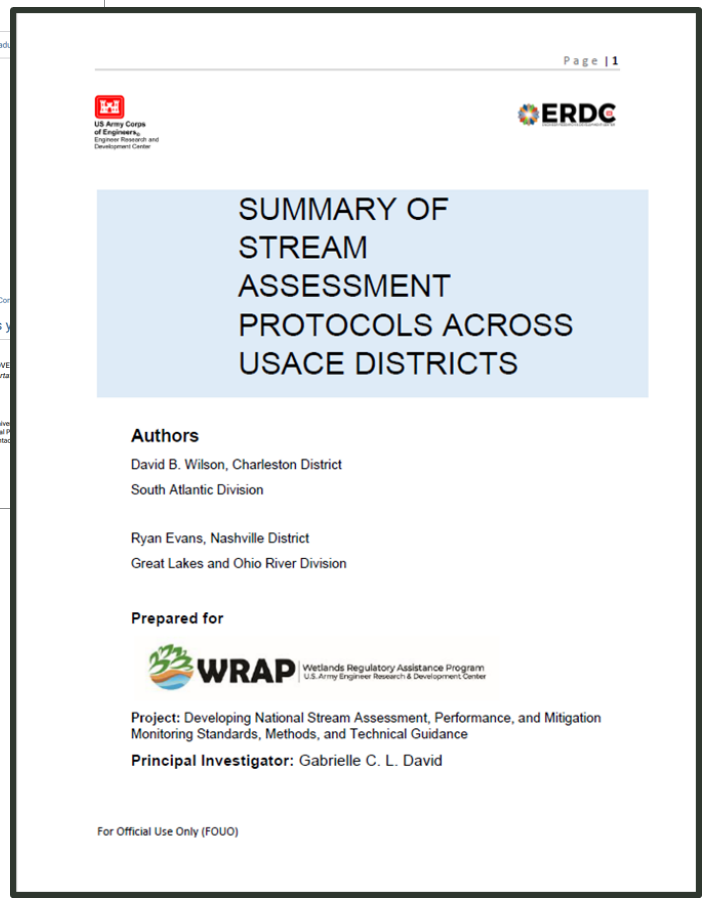
Figure: Wiest et al. (2023)

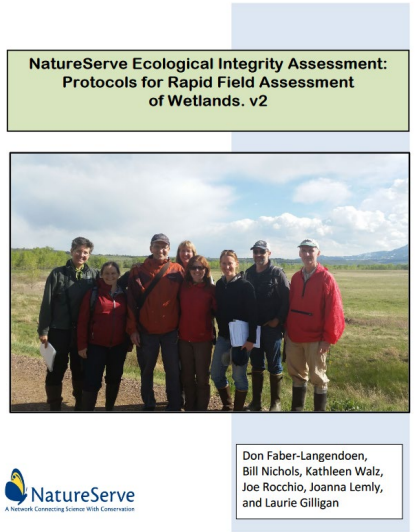
OTHER FEDERAL AGENCY, GOVERNMENT, AND PRIVATE SECTOR MODELS



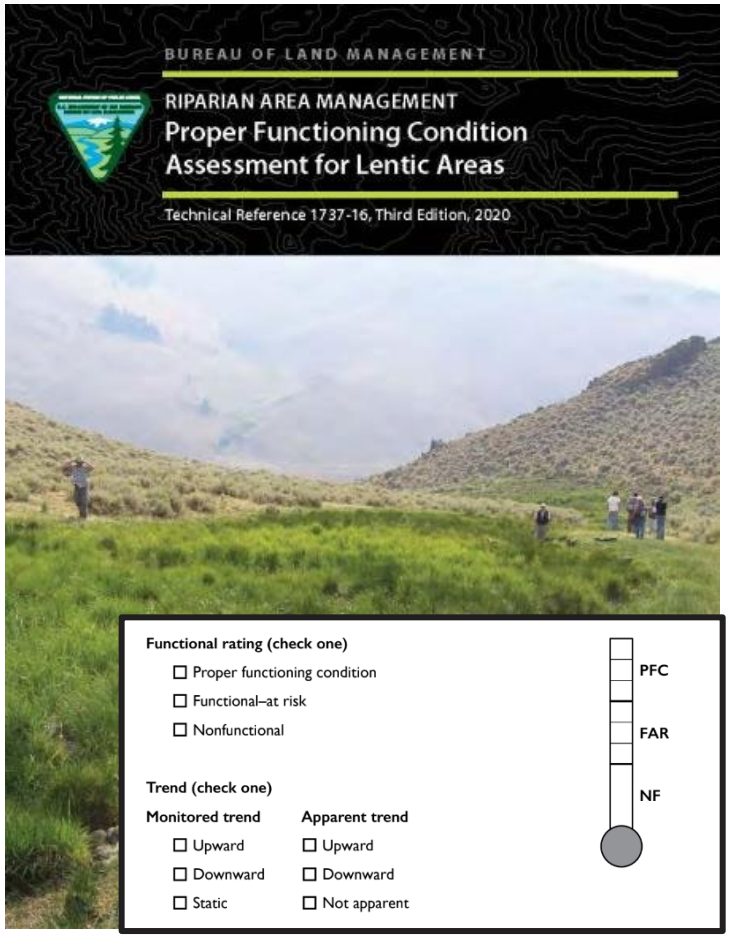


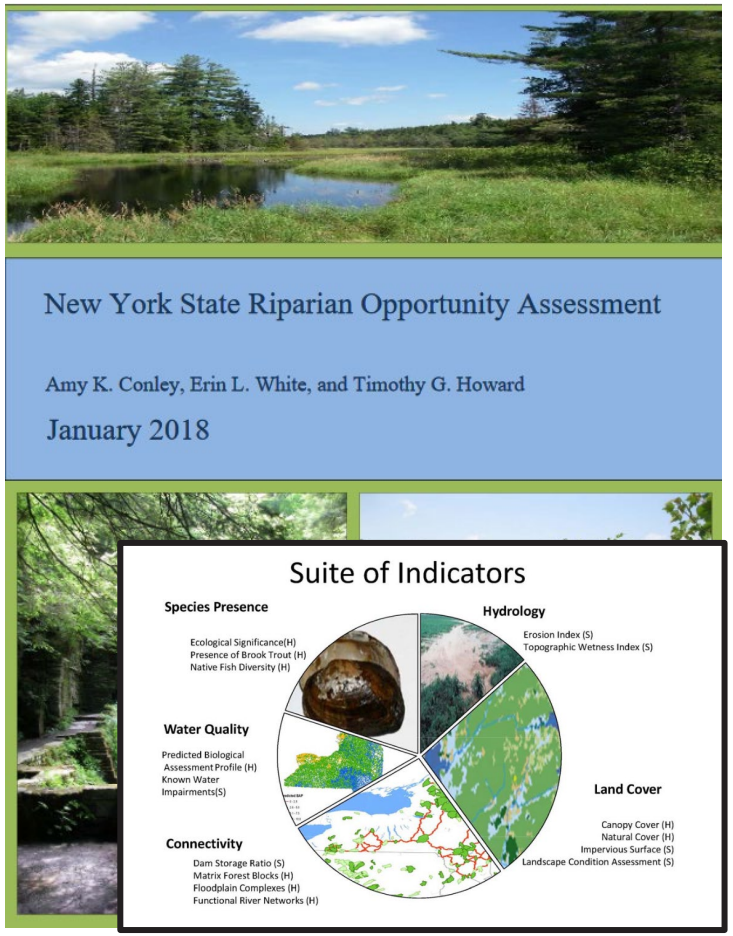


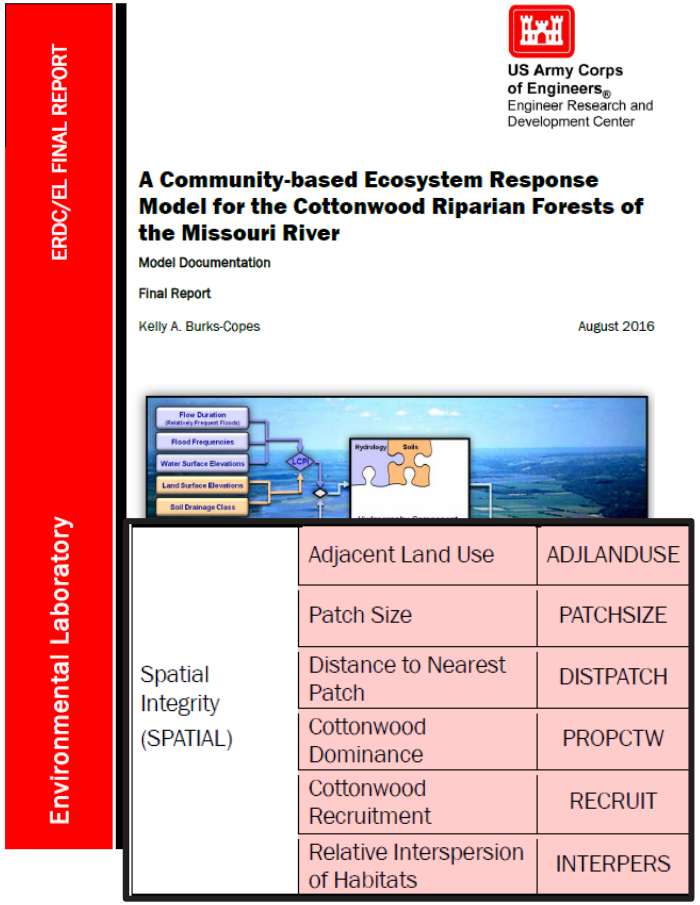




ADOPTION OF MODEL ATTRIBUTES







UNDERLYING APPROACH TO MODEL DEVELOPMENT

Semi-quantitative rapid assessment model

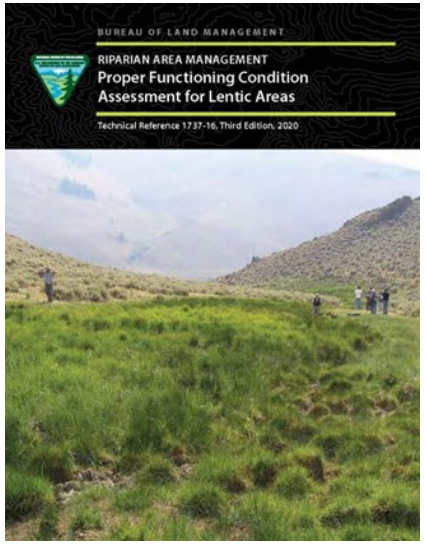
Broad

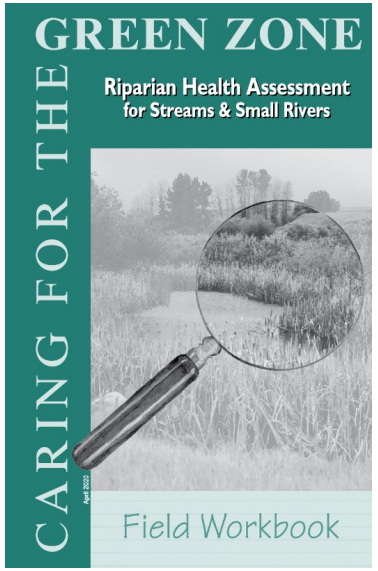
Detailed

Complexity

PFC, Riparian Health Assessments (more qualitatively-based)

Detailed Regional Assessments (generally HSI-based)





Existing Riparian Modeling Tools	Instream Processes: Physical Characteristics	Stream Condition	Stream Hydrologic Processes	Adjacent Land Use	Climate and Weather	Riparian Zones Processes: Bank Characteristics	Habitat Connectivity	Stream Habitat	Canopy/Groud Cover	Native/Invasive species	Vegetation Composition	Species Richness	Riparian Functions	Floodplain Functions	Landscape Connectivity	Buffer Functionality	Region of Application
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9. Skokomish River Ecosystem Restoration Project Environmental Benefits Analysis			1					2	1				1	1			Northwest
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EMRRP

ERDC/TN EMRRP-ER-26
September 2023

Review of Riparian Models for Assessing Ecological Impacts and Benefits

by Samantha Wiest[1], Darixa Hernandez-Abrams[2], and S. Kyle McKay[3]

RIPARIAN ECOLOGICAL FUNCTION INDEX: REFI (FRAMEWORK)

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WHAT IS REFI?

Intended Purpose:

REFI is rapid screening tool to assess the riparian condition, which could include monitoring, impact assessment, or benefit quantification.

Possible Uses:

- Planning Studies (e.g., ecosystem restoration)
- Environmental Impact Studies / Environmental Damage Assessments

WHAT IS REFI?

REFI is..

- Methodology for assessing riparian ecological functions and condition
- A first step/jumping off point for a more detailed assessment
- Snapshot of current conditions
- Useful for assessment, monitoring, planning, environmental impact studies
- A rapid, consistent, semi-quantitative approach based on physical field conditions
- Nationally applicable, regardless of land use, valley type, stream type
- Intended for wadeable streams at a reach scale

REFI is not..

- A stream model
- A replacement for more detailed methods: vegetation inventory, long-term monitoring, quantitative methods, modeling
- An indicator of past or future conditions

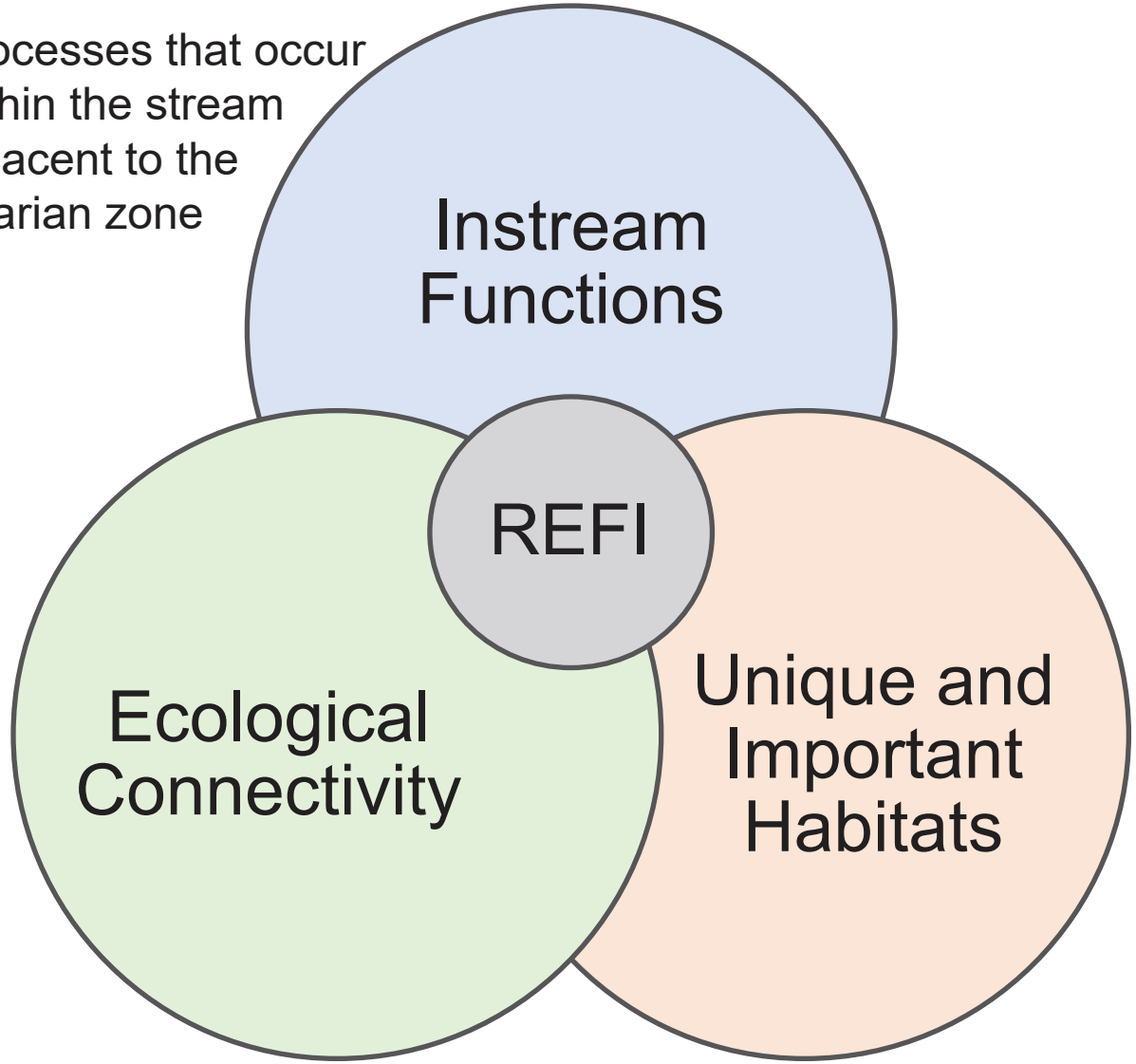
MODEL FRAMEWORK

REFI includes multiple levels of analysis that group related riparian functions that are transferrable across regions.

- **Outcomes**: Large scale ecological functions of the riparian zone
- **Categories**: Groups of Variables by similar discipline or scientific topic
- **Variables**: Represent functional condition
- **Indicators**: Field data metrics describing riparian zone conditions and observations

MODEL FRAMEWORK - OUTCOMES

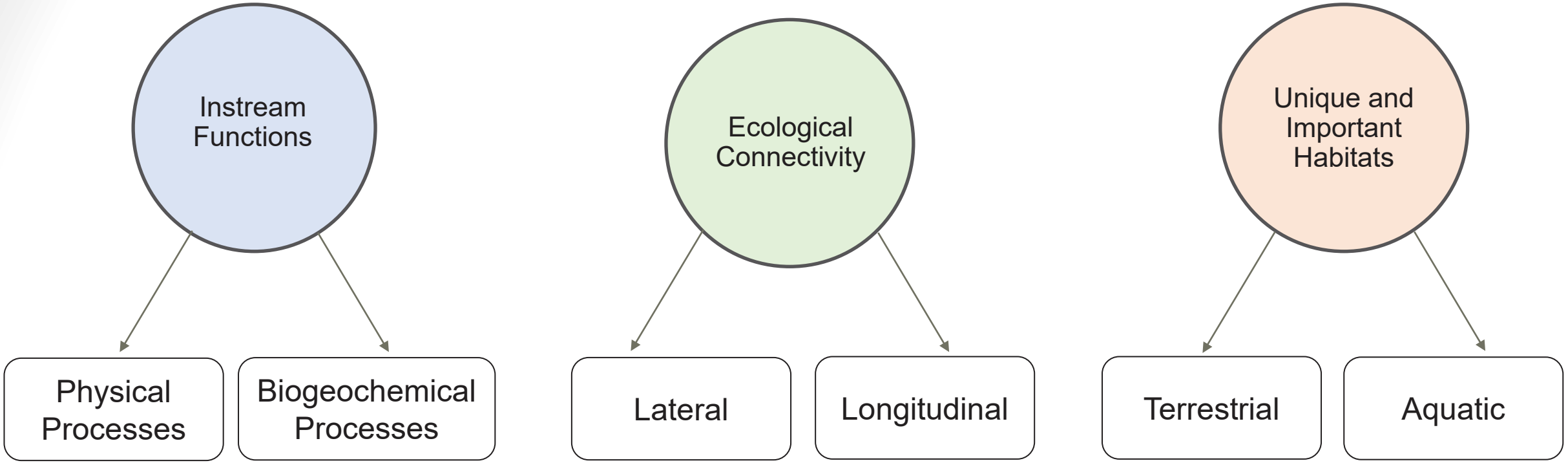
Processes that occur within the stream adjacent to the riparian zone



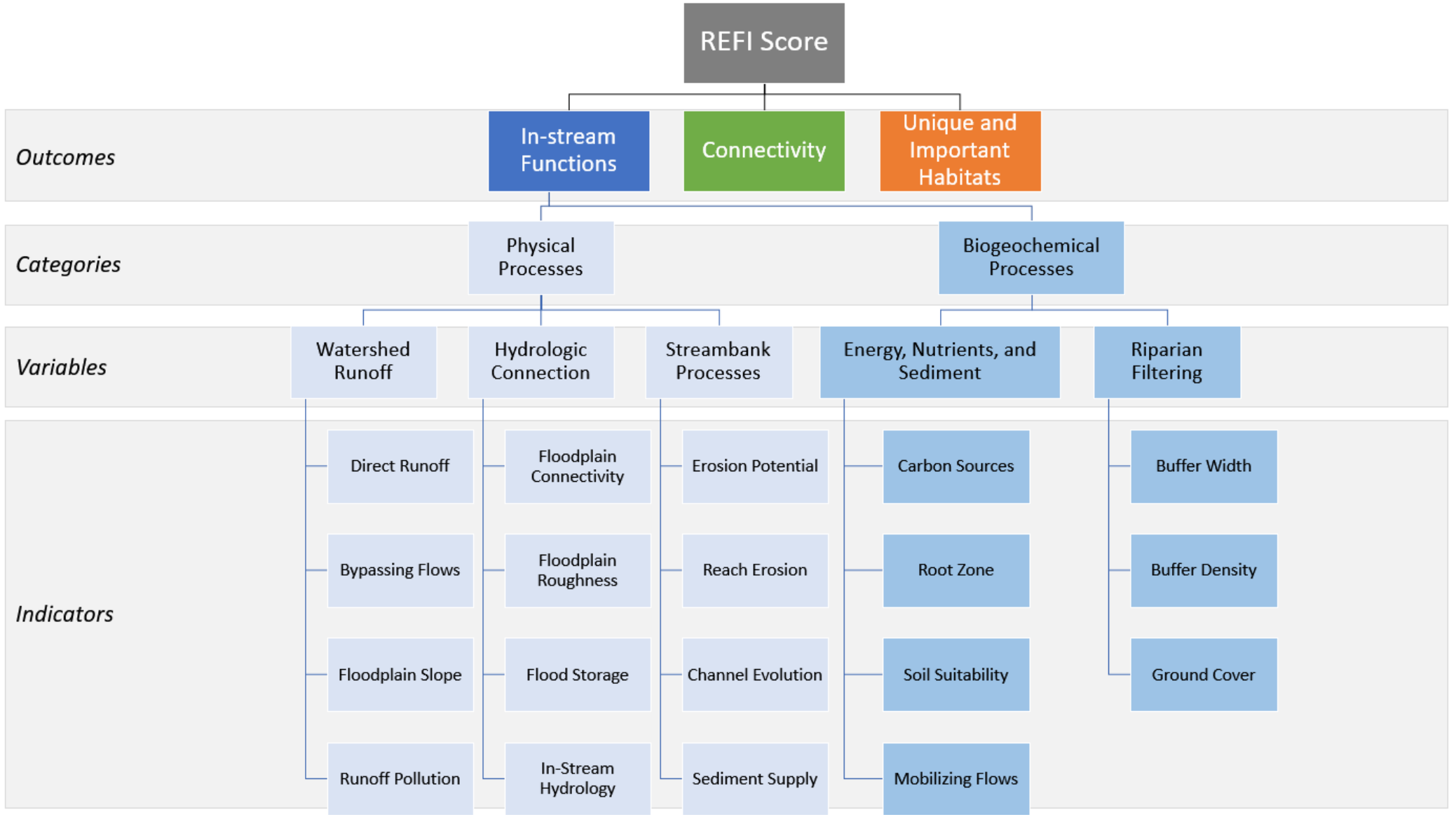
Spatial and ecological connection between natural environments

Quality of habitats supporting diverse flora and fauna

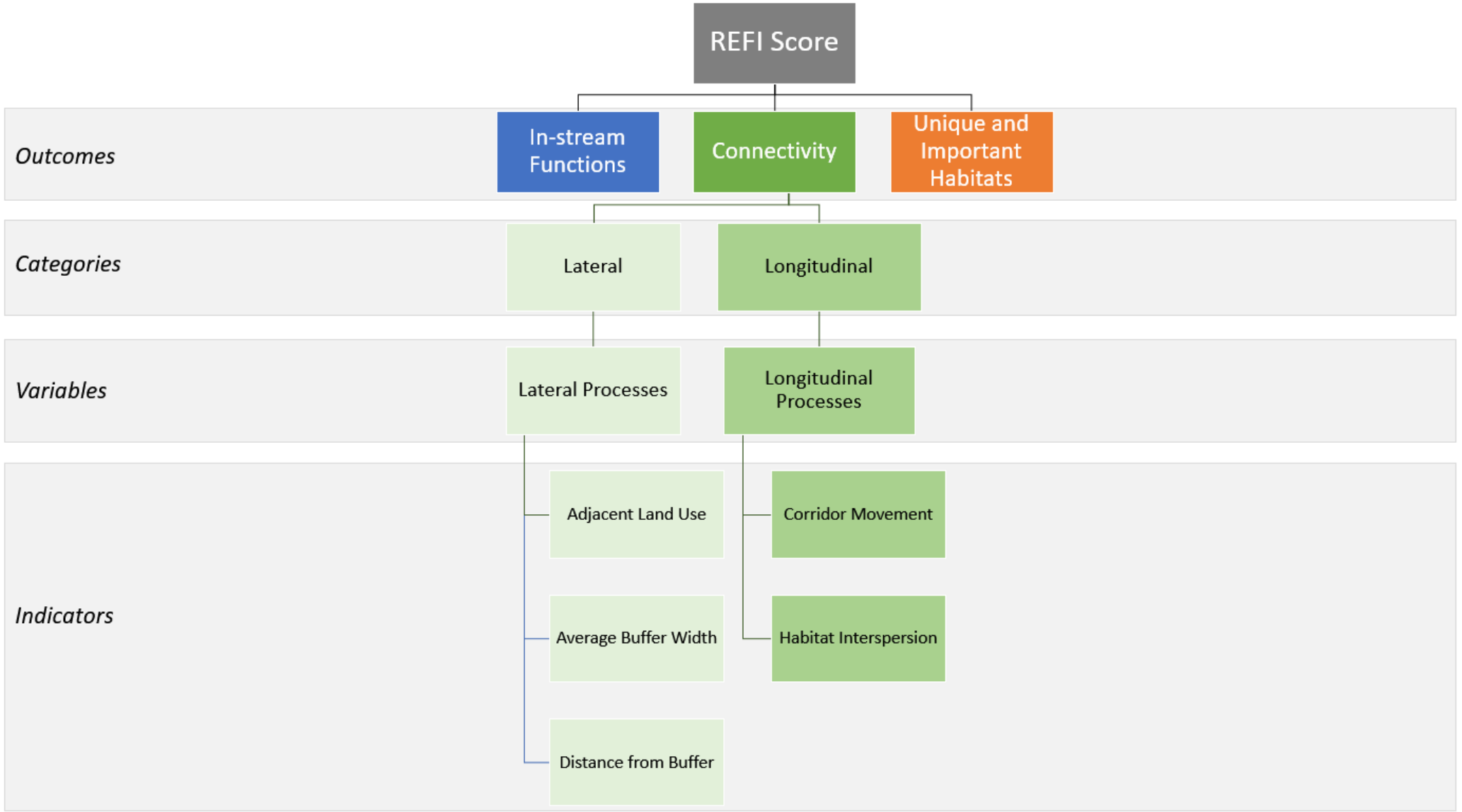
MODEL FRAMEWORK - CATEGORIES



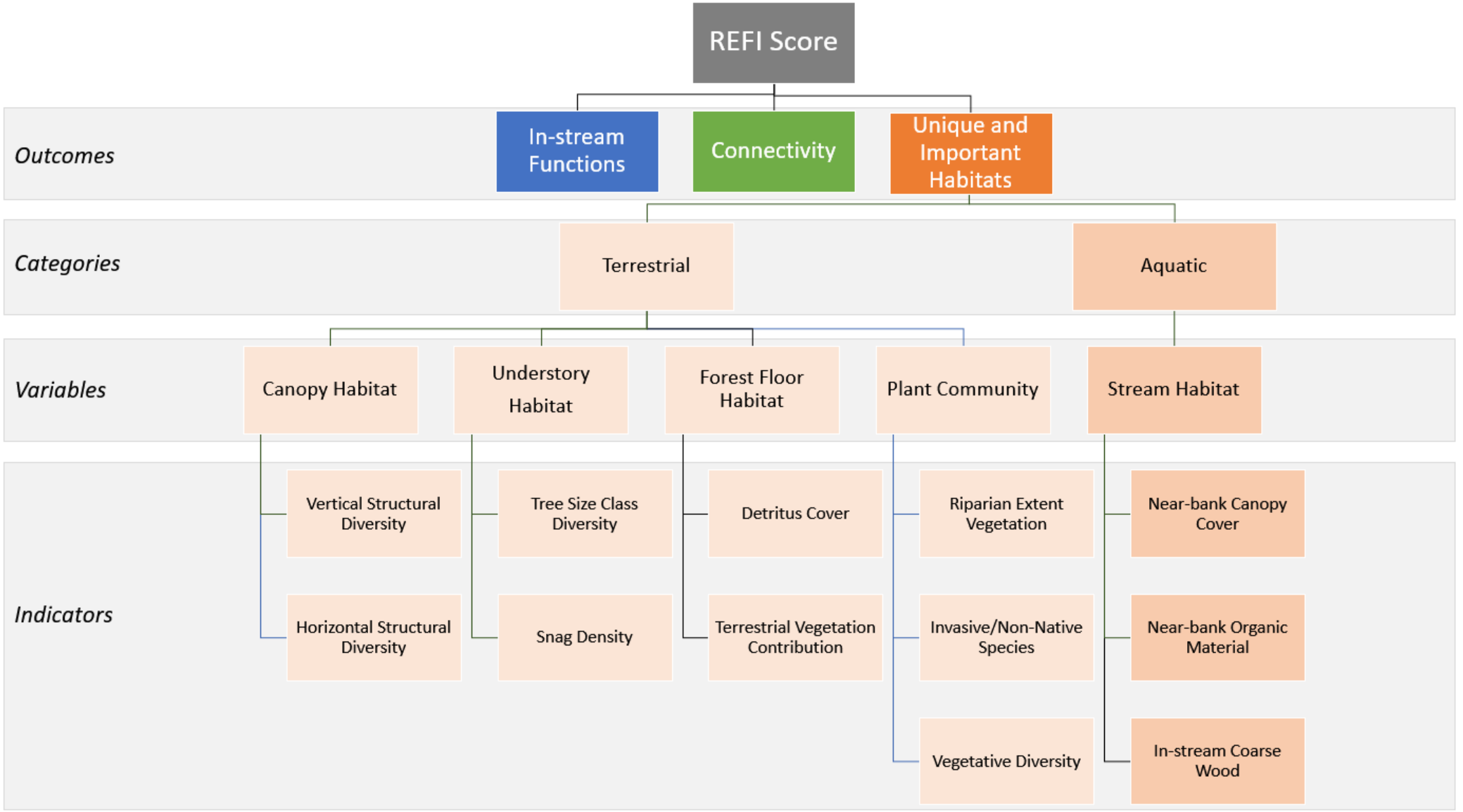
MODEL FRAMEWORK



MODEL FRAMEWORK

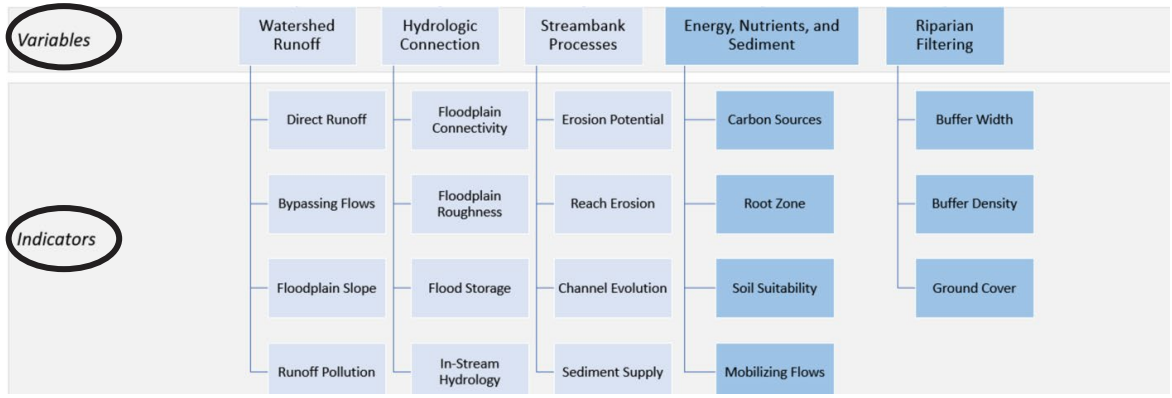


MODEL FRAMEWORK



VARIABLES AND INDICATORS

- Variables and indicators are the building blocks for this assessment (and what are scored)
- Familiarize yourself before and in the field
- What do variables and indicators look like in the field?



VARIABLES AND INDICATORS

Instream Processes

Ecological Connectivity

Unique and Important Habitats

Watershed Runoff

Hydrologic Connection

Riparian Filtering

Streambank Processes

Energy, Nutrients and Sediment

Longitudinal Processes

Lateral Processes

Canopy Habitat

Plant Community

Understory Habitat

Stream Habitat

Forest Floor Habitat

VARIABLES AND INDICATORS

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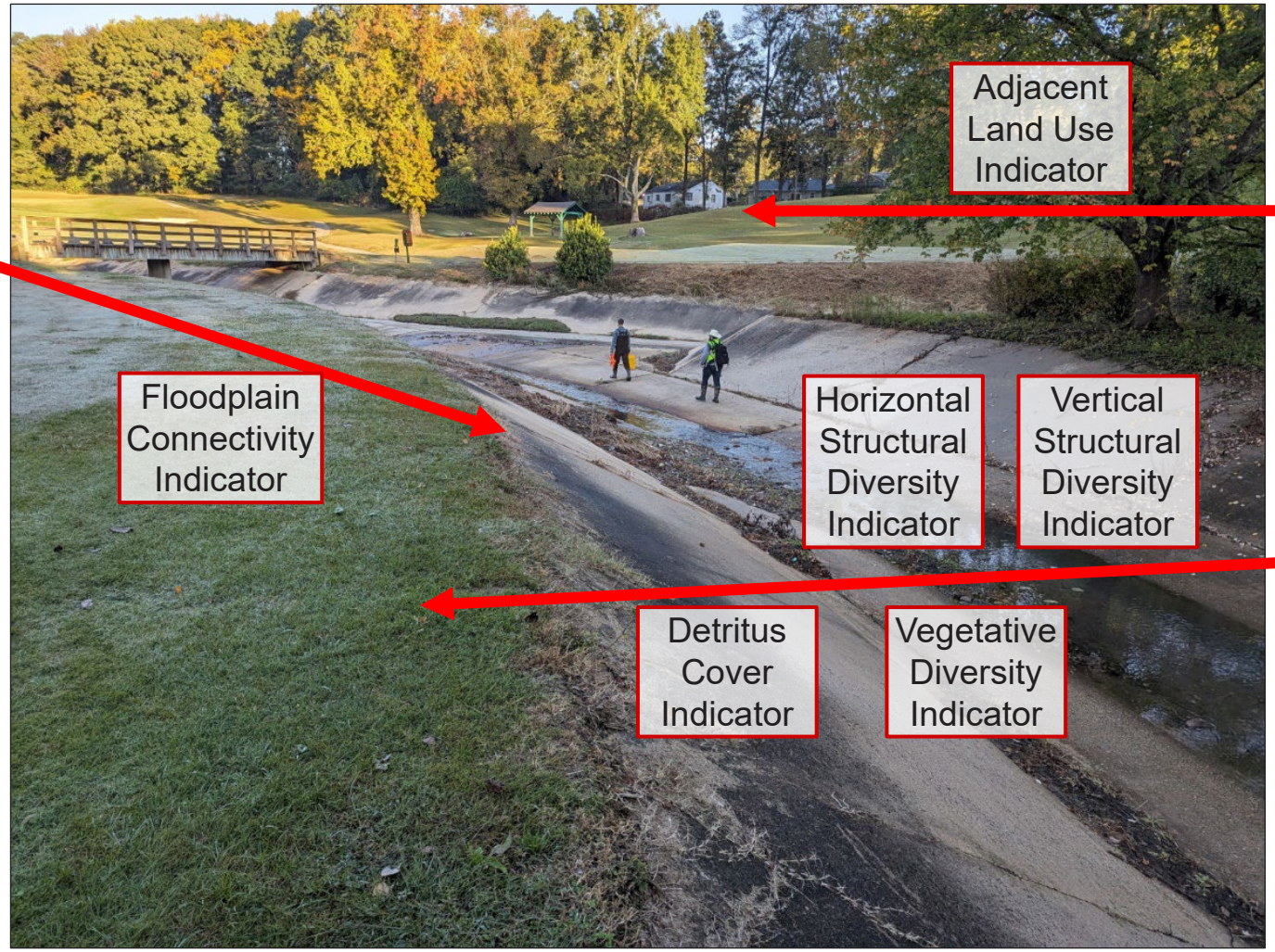

Longitudinal Processes

Lateral Processes

Canopy Habitat

Plant Community

Understory Habitat

Stream Habitat

Forest Floor Habitat

RIPARIAN ECOLOGICAL FUNCTION INDEX: REFI (ASSESSMENT)

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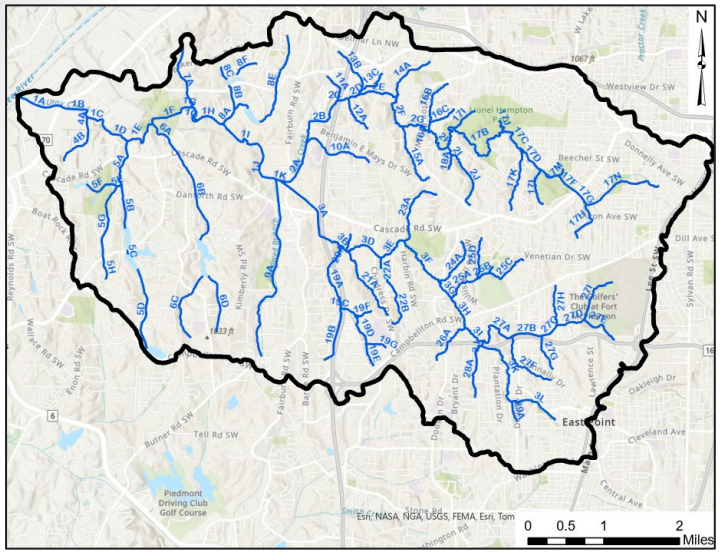
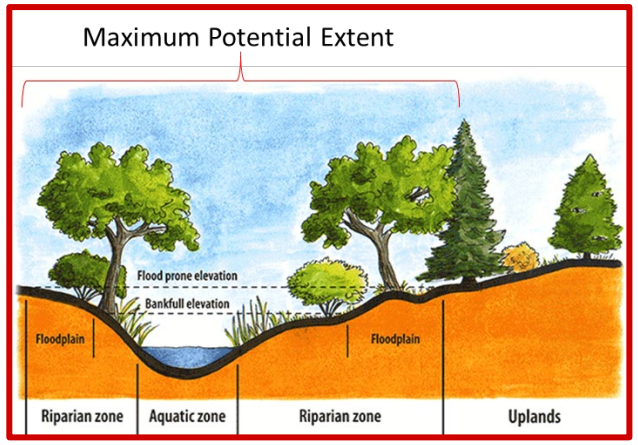
HOW DO YOU COMPLETE A REFI ASSESSMENT?

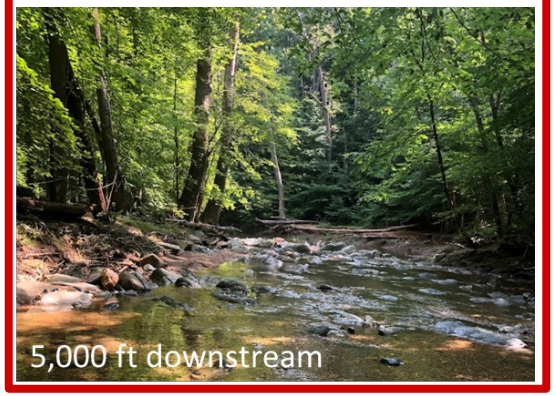
Divide Site into Reaches





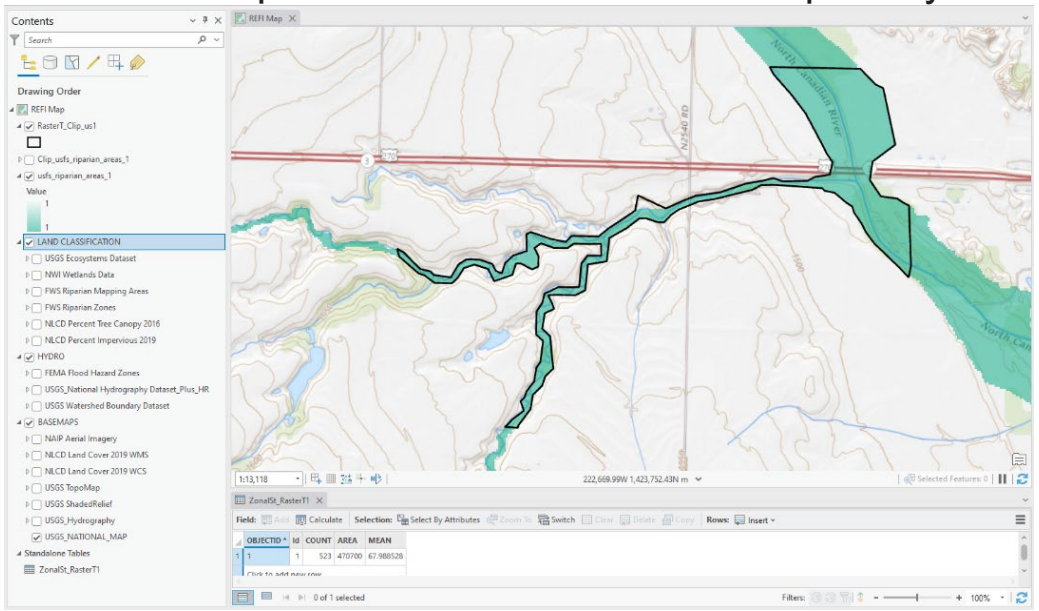
1. Site selection (wadeable)
2. Divide site into reaches (500-10,000 ft):
   - Tributaries
   - Valley type/watershed characteristics
   - Project Goals
3. GIS Analysis: create base-maps for field work and metrics
   - We give you a file with basemaps
   - Aerial Imagery, Stream Map, Watershed Map
   - Land Cover Map, Tree Canopy Map, USGS Terrestrial Ecosystems Map
   - Print maps
4. Map Riparian Zone Extent
   - Before field work or during site visit
   - Vegetation ≠ Maximum Potential Extent
   - USFS 2019 Riparian Area Basemap
   - Floodplain map (e.g., 50-yr)

Possible Reach Divisions



NOTE STEP 3 & 4: DESKTOP GEOSPATIAL ANALYSIS

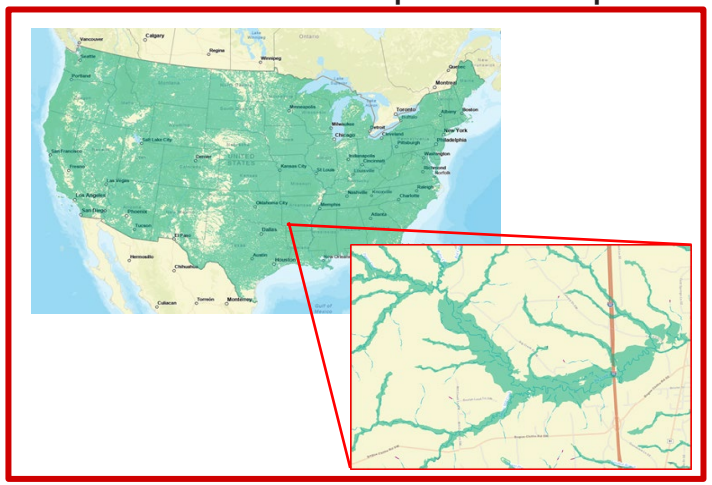
We've set up an ArcGIS file with basemaps for you



Geospatial Assessment:

- Folder compiled with basemaps
- Map your own riparian zone boundaries
- Not required, but ***recommended*** step
- Not all metrics can be easily observed in the field (e.g., estimating buffer width)
- Limited by time, equipment, etc.
- Abundance of available spatial data

USFS 2019 National Riparian Basemap



HOW DO YOU COMPLETE A REFI ASSESSMENT?

Reach 'level of detail' scoping

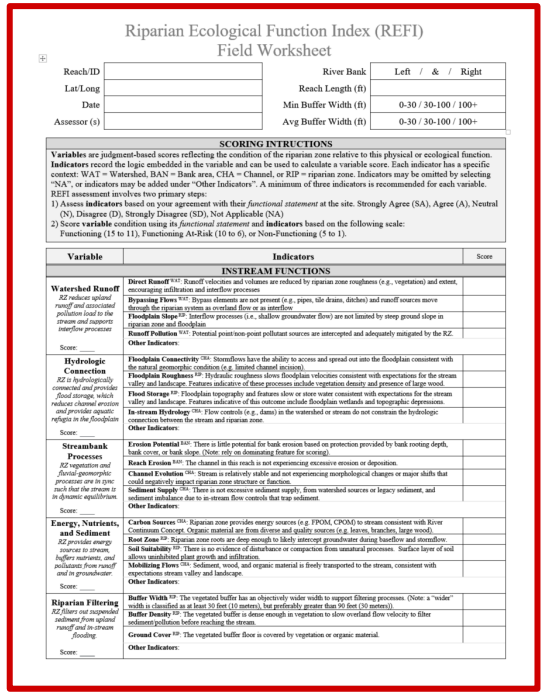
Reach has single score
(1 Worksheet)

Reach has two scores (L/R bank)
(2 Worksheets)

Reach has multiple scores
(Multiple Worksheets per bank)

5. Reach 'level of detail' scoping: single vs multiple assessments per reach
   - How much detail needed to sufficiently capture riparian condition in the reach?
   - Separate left/right bank scores
   - Balance of time/resources and accuracy
   - Can be decided in the field too
6. Field Assessment Worksheet
   - Complete field assessment worksheet(s)
   - Detailed notes on field map
   - Repeat for each reach!
7. At office: Complete Excel Worksheet to roll-up reach score into condition indices

Field Assessment Worksheet



Riparian Ecological Function Index (REFI)
Field Worksheet

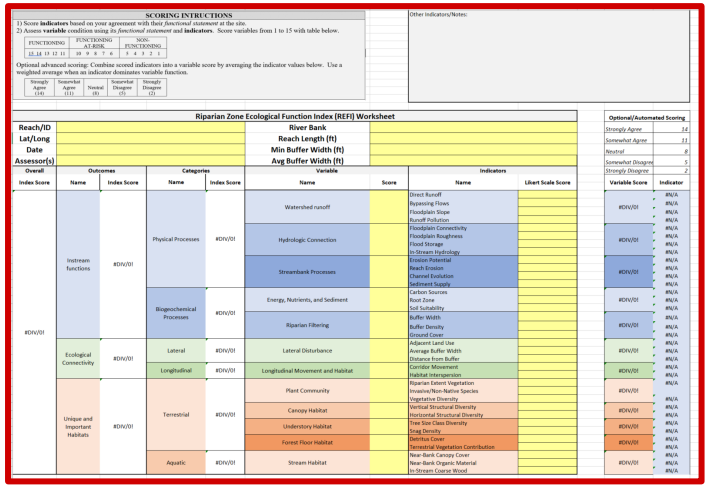
Reach/ID		River Bank	Left / & / Right
Lat/Long		Reach Length (ft)	
Date		Min Buffer Width (ft)	0-30 / 30-100 / 100+
Assessor (s)		Avg Buffer Width (ft)	0-30 / 30-100 / 100+

SCORING INTRUCTIONS

Variables are judgment-based scores reflecting the condition of the riparian zone relative to this physical or ecological function. **Indicators** record the logic embedded in the variable and can be used to calculate a variable score. Each indicator has a specific context: WAT = Watershed, BAN = Bank area, CHA = Channel, or RIP = riparian zone. Indicators may be omitted by selecting "NA", or indicators may be added under "Other Indicators". A minimum of three indicators is recommended for each variable.
REFI assessment involves two primary steps:
1) Assess **indicators** based on your agreement with their *functional statement* at the site. Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), Strongly Disagree (SD), Not Applicable (NA)
2) Score **variable** condition using its *functional statement* and **indicators** based on the following scale:
Functioning (15 to 11), Functioning At-Risk (10 to 6), or Non-Functioning (5 to 1).

Variable	Indicators	Score
	INSTREAM FUNCTIONS	
Watershed Runoff *RZ reduces upland runoff and associated pollution load to the stream and supports interflow processes*	**Direct Runoff** WAT: Runoff velocities and volumes are reduced by riparian zone roughness (e.g., vegetation) and extent, encouraging infiltration and interflow processes	
	Bypassing Flows WAT: Bypass elements are not present (e.g., pipes, tile drains, ditches) and runoff sources move through the riparian system as overland flow or as interflow	
	Floodplain Slope RIP: Interflow processes (i.e., shallow groundwater flow) are not limited by steep ground slope in riparian zone and floodplain	
	Runoff Pollution WAT: Potential point/non-point pollutant sources are intercepted and adequately mitigated by the RZ.	
	Other Indicators:	
Score: ____		
Hydrologic Connection *RZ is hydrologically connected and provides flood storage, which reduces channel erosion and provides aquatic refugia in the floodplain*	**Floodplain Connectivity** CHA: Stormflows have the ability to access and spread out into the floodplain consistent with the natural geomorphic condition (e.g. limited channel incision).	
	Floodplain Roughness RIP: Hydraulic roughness slows floodplain velocities consistent with expectations for the stream valley and landscape. Features indicative of these processes include vegetation density and presence of large wood.	
	Flood Storage RIP: Floodplain topography and features slow or store water consistent with expectations for the stream valley and landscape. Features indicative of this outcome include floodplain wetlands and topographic depressions.	
	In-stream Hydrology CHA: Flow controls (e.g., dams) in the watershed or stream do not constrain the hydrologic connection between the stream and riparian zone.	
	Other Indicators:	
Score: ____		
Streambank Processes *RZ vegetation and fluvial-geomorphic processes are in sync such that the stream is in dynamic equilibrium.*	**Erosion Potential** BAN: There is little potential for bank erosion based on protection provided by bank rooting depth, bank cover, or bank slope. (Note: rely on dominating feature for scoring).	
	Reach Erosion BAN: The channel in this reach is not experiencing excessive erosion or deposition.	
	Channel Evolution CHA: Stream is relatively stable and not experiencing morphological changes or major shifts that could negatively impact riparian zone structure or function.	
	Sediment Supply CHA: There is not excessive sediment supply, from watershed sources or legacy sediment, and sediment imbalance due to in-stream flow controls that trap sediment.	
	Other Indicators:	
Score: ____		
Energy, Nutrients, and Sediment *RZ provides energy sources to stream, buffers nutrients, and pollutants from runoff and in groundwater.*	**Carbon Sources** CHA: Riparian zone provides energy sources (e.g. FPOM, CPOM) to stream consistent with River Continuum Concept. Organic material are from diverse and quality sources (e.g. leaves, branches, large wood).	
	Root Zone RIP: Riparian zone roots are deep enough to likely intercept groundwater during baseflow and stormflow.	
	Soil Suitability RIP: There is no evidence of disturbance or compaction from unnatural processes. Surface layer of soil allows uninhibited plant growth and infiltration.	
	Mobilizing Flows CHA: Sediment, wood, and organic material is freely transported to the stream, consistent with expectations stream valley and landscape.	
	Other Indicators:	
Score: ____		
Riparian Filtering *RZ filters out suspended sediment from upland runoff and in-stream flooding.*	**Buffer Width** RIP: The vegetated buffer has an objectively wider width to support filtering processes. (Note: a "wider" width is classified as at least 30 feet (10 meters), but preferably greater than 90 feet (30 meters)).	
	Buffer Density RIP: The vegetated buffer is dense enough in vegetation to slow overland flow velocity to filter sediment/pollution before reaching the stream.	
	Ground Cover RIP: The vegetated buffer floor is covered by vegetation or organic material.	
	Other Indicators:	
Score: ____		

Excel Worksheet



SCORING INTRUCTIONS

1) Score **indicators** based on your agreement with their *functional statement* at the site.
2) Assess **variable** condition using its *functional statement* and **indicators**. Score variables from 1 to 15 with table below.

FUNCTIONING		FUNCTIONING AT-RISK		NON-FUNCTIONING					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Optional advanced scoring: Combine scored indicators into a variable score by averaging the indicator values below. Use a weighted average when an indicator dominates variable function.

Strongly Agree (14)	Somewhat Agree (11)	Neutral (8)	Somewhat Disagree (5)	Strongly Disagree (2)

Other Indicators/Notes:

Riparian Zone Ecological Function Index (REFI) Worksheet

Reach/ID		River Bank	
Lat/Long		Reach Length (ft)	
Date		Min Buffer Width (ft)	
Assessor(s)		Avg Buffer Width (ft)	

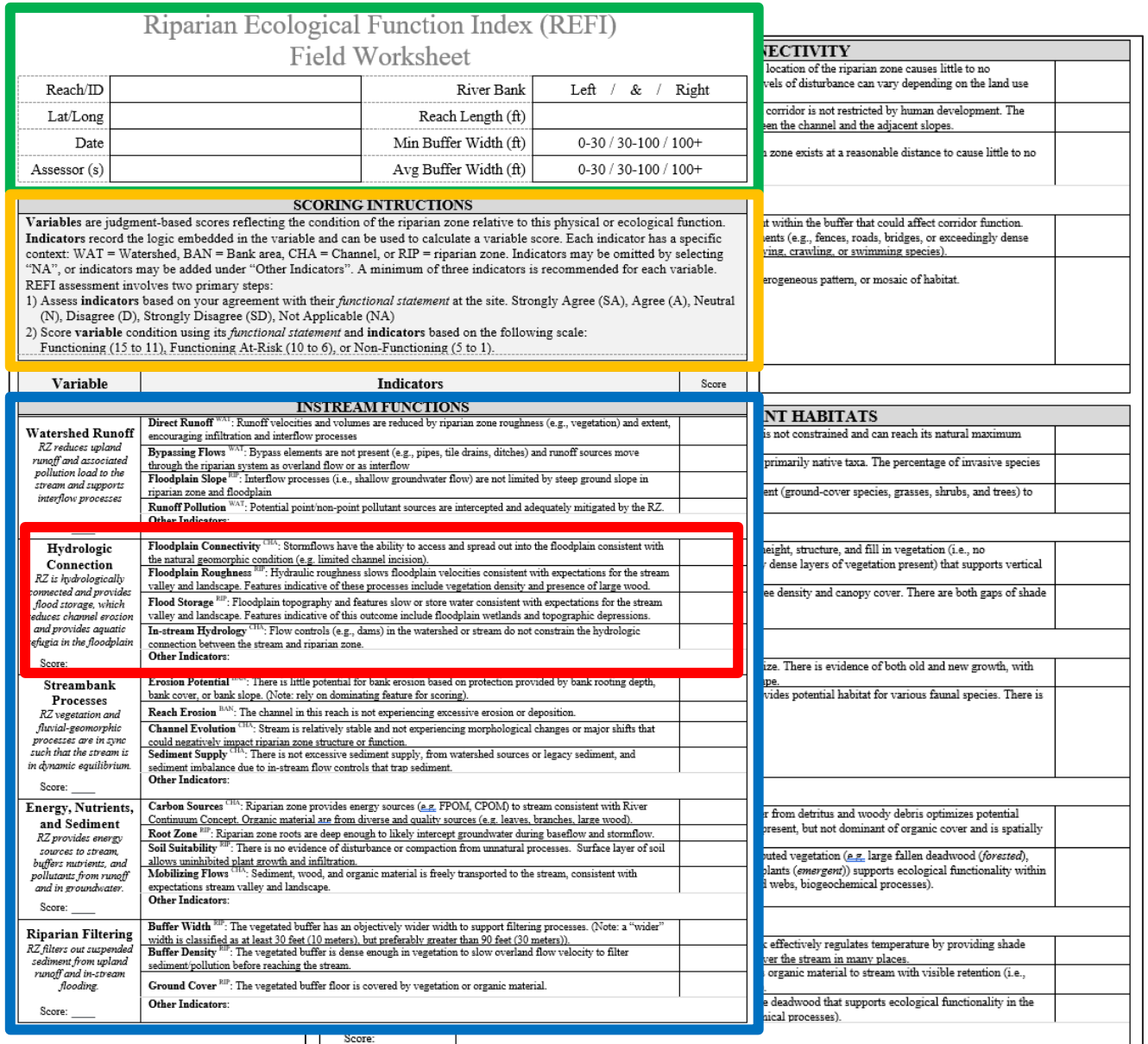
Overall	Outcomes		Categories		Variable		Indicators		Optional/Automated Scoring	
Index Score	Name	Index Score	Name	Index Score	Name	Score	Name	Likert Scale Score	Variable Score	Indicator
#DIV/0!	Instream Functions	#DIV/0!	Physical Processes	#DIV/0!	Watershed runoff		Direct Runoff		#DIV/0!	#N/A
							Bypassing Flows			#N/A
							Floodplain Slope			#N/A
							Runoff Pollution			#N/A
					Hydrologic Connection		Floodplain Connectivity		#DIV/0!	#N/A
							Floodplain Roughness			#N/A
							Flood Storage			#N/A
							In-Stream Hydrology			#N/A
					Streambank Processes		Erosion Potential		#DIV/0!	#N/A
							Reach Erosion			#N/A
							Channel Evolution			#N/A
							Sediment Supply			#N/A
			Biogeochemical Processes	#DIV/0!	Energy, Nutrients, and Sediment		Carbon Sources		#DIV/0!	#N/A
							Root Zone			#N/A
							Soil Suitability			#N/A
					Riparian Filtering		Buffer Width		#DIV/0!	#N/A
							Buffer Density			#N/A
							Ground Cover			#N/A
	Ecological Connectivity	#DIV/0!	Lateral	#DIV/0!	Lateral Disturbance		Adjacent Land-Use		#DIV/0!	#N/A
							Average Buffer Width			#N/A
							Distance from Buffer			#N/A
			Longitudinal	#DIV/0!	Longitudinal Movement and Habitat		Corridor Movement		#DIV/0!	#N/A
							Habitat Interspersion			#N/A
	Unique and Important Habitats	#DIV/0!	Terrestrial	#DIV/0!	Plant Community		Riparian Extent Vegetation		#DIV/0!	#N/A
							Invasive/Non-Native Species			#N/A
							Vegetative Diversity			#N/A
					Canopy Habitat		Vertical Structural Diversity		#DIV/0!	#N/A
							Horizontal Structural Diversity			#N/A
					Understory Habitat		Tree Size Class Diversity		#DIV/0!	#N/A
							Snag Density			#N/A
					Forest Floor Habitat		Detritus Cover		#DIV/0!	#N/A
							Terrestrial Vegetation Contribution			#N/A
			Aquatic	#DIV/0!	Stream Habitat		Near-Bank Canopy Cover		#DIV/0!	#N/A
							Near-Bank Organic Material			#N/A
							In-Stream Coarse Wood			#N/A

Optional/Automated Scoring	
Strongly Agree	14
Somewhat Agree	11
Neutral	8
Somewhat Disagree	5
Strongly Disagree	2

REFI WORKSHEET

Rapid field assessment method
- Mostly observational
- No field sampling or field procedures
- No specialized equipment

Worksheet Structure
1. Reach and assessment info
2. Detailed scoring instructions
3. Variables and Indicators are grouped by General Outcome and are scored separately



Riparian Ecological Function Index (REFI)
Field Worksheet

Reach/ID		River Bank	Left / & / Right
Lat/Long		Reach Length (ft)	
Date		Min Buffer Width (ft)	0-30 / 30-100 / 100+
Assessor (s)		Avg Buffer Width (ft)	0-30 / 30-100 / 100+

SCORING INTRUCTIONS

Variables are judgment-based scores reflecting the condition of the riparian zone relative to this physical or ecological function. **Indicators** record the logic embedded in the variable and can be used to calculate a variable score. Each indicator has a specific context: WAT = Watershed, BAN = Bank area, CHA = Channel, or RIP = riparian zone. Indicators may be omitted by selecting "NA", or indicators may be added under "Other Indicators". A minimum of three indicators is recommended for each variable.
REFI assessment involves two primary steps:
1) Assess **indicators** based on your agreement with their *functional statement* at the site. Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), Strongly Disagree (SD), Not Applicable (NA)
2) Score **variable** condition using its *functional statement* and **indicators** based on the following scale: Functioning (15 to 11), Functioning At-Risk (10 to 6), or Non-Functioning (5 to 1).

Variable	Indicators	Score
	INSTREAM FUNCTIONS	
Watershed Runoff *RZ reduces upland runoff and associated pollution load to the stream and supports interflow processes*	**Direct Runoff** WAT: Runoff velocities and volumes are reduced by riparian zone roughness (e.g., vegetation) and extent, encouraging infiltration and interflow processes	
	Bypassing Flows WAT: Bypass elements are not present (e.g., pipes, tile drains, ditches) and runoff sources move through the riparian system as overland flow or as interflow	
	Floodplain Slope RIP: Interflow processes (i.e., shallow groundwater flow) are not limited by steep ground slope in riparian zone and floodplain	
	Runoff Pollution WAT: Potential point/non-point pollutant sources are intercepted and adequately mitigated by the RZ.	
	Other Indicators:	
Score: ____		
Hydrologic Connection *RZ is hydrologically connected and provides flood storage, which reduces channel erosion and provides aquatic refugia in the floodplain*	**Floodplain Connectivity** CHA: Stormflows have the ability to access and spread out into the floodplain consistent with the natural geomorphic condition (e.g. limited channel incision).	
	Floodplain Roughness RIP: Hydraulic roughness slows floodplain velocities consistent with expectations for the stream valley and landscape. Features indicative of these processes include vegetation density and presence of large wood.	
	Flood Storage RIP: Floodplain topography and features slow or store water consistent with expectations for the stream valley and landscape. Features indicative of this outcome include floodplain wetlands and topographic depressions.	
	In-stream Hydrology CHA: Flow controls (e.g., dams) in the watershed or stream do not constrain the hydrologic connection between the stream and riparian zone.	
	Other Indicators:	
Score:		
Streambank Processes *RZ vegetation and fluvial-geomorphic processes are in sync such that the stream is in dynamic equilibrium.*	**Erosion Potential** BAN: There is little potential for bank erosion based on protection provided by bank rooting depth, bank cover, or bank slope. (Note: rely on dominating feature for scoring).	
	Reach Erosion BAN: The channel in this reach is not experiencing excessive erosion or deposition.	
	Channel Evolution CHA: Stream is relatively stable and not experiencing morphological changes or major shifts that could negatively impact riparian zone structure or function.	
	Sediment Supply CHA: There is not excessive sediment supply, from watershed sources or legacy sediment, and sediment imbalance due to in-stream flow controls that trap sediment.	
	Other Indicators:	
Score: ____		
Energy, Nutrients, and Sediment *RZ provides energy sources to stream, buffers nutrients, and pollutants from runoff and in groundwater.*	**Carbon Sources** CHA: Riparian zone provides energy sources (e.g. FPOM, CPOM) to stream consistent with River Continuum Concept. Organic material are from diverse and quality sources (e.g. leaves, branches, large wood).	
	Root Zone RIP: Riparian zone roots are deep enough to likely intercept groundwater during baseflow and stormflow.	
	Soil Suitability RIP: There is no evidence of disturbance or compaction from unnatural processes. Surface layer of soil allows uninhibited plant growth and infiltration.	
	Mobilizing Flows CHA: Sediment, wood, and organic material is freely transported to the stream, consistent with expectations stream valley and landscape.	
	Other Indicators:	
Score: ____		
Riparian Filtering *RZ filters out suspended sediment from upland runoff and in-stream flooding.*	**Buffer Width** RIP: The vegetated buffer has an objectively wider width to support filtering processes. (Note: a "wider" width is classified as at least 30 feet (10 meters), but preferably greater than 90 feet (30 meters)).	
	Buffer Density RIP: The vegetated buffer is dense enough in vegetation to slow overland flow velocity to filter sediment/pollution before reaching the stream.	
	Ground Cover RIP: The vegetated buffer floor is covered by vegetation or organic material.	
	Other Indicators:	
Score: ____		

VARIABLE SCORING: 2 STEPS

Indicators: "Build the case" for the variable score by recording your logic
Likert scale (sentiment) scores

Variable: Judgment-based numerical score (1-15) of functional statement

Variable Scoring

15	
14	
13	**Functioning**
12	
11	
10	
9	**Functioning At-Risk**
8	
7	
6	
5	
4	
3	**Non-Functioning**
2	
1	

Step 2
Variable

Hydrologic Connection
RZ is hydrologically connected and provides flood storage, which reduces channel erosion and provides aquatic refugia in the floodplain
Score: 10

Step 1
Indicators

	Score
Floodplain Connectivity CHA: Stormflows have the ability to access and spread out into the floodplain consistent with the natural geomorphic condition (e.g. limited channel incision).	SA
Floodplain Roughness RIP: Hydraulic roughness slows floodplain velocities consistent with expectations for the stream valley and landscape. Features indicative of these processes include vegetation density and presence of large wood.	A
Flood Storage RIP: Floodplain topography and features slow or store water consistent with expectations for the stream valley and landscape. Features indicative of this outcome include floodplain wetlands and topographic depressions.	A
In-stream Hydrology CHA: Flow controls (e.g., dams) in the watershed or stream do not constrain the hydrologic connection between the stream and riparian zone.	NA
Other Indicators:	

Functional statement

Indicator context:
WAT = watershed
BAN = bank area
CHA = channel
RIP = riparian zone

Indicator Scoring

Strongly Agree (SA)
Agree (A)
Neutral (N)
Disagree (D)
Strongly Disagree (SD)
Not Applicable (NA)

FIELD ASSESSMENT

Variable Scoring

15 14 13 12 11	Functioning
10 9 8 7 6	Functioning At-Risk
5 4 3 2 1	Non-Functioning

Hydrologic Connection *RZ is hydrologically connected and provides flood storage, which reduces channel erosion and provides aquatic refugia in the floodplain* Score: **5**	**Floodplain Connectivity** CHA: Stormflows have the ability to access and spread out into the floodplain consistent with the natural geomorphic condition (e.g. limited channel incision).	**SD**
	Floodplain Roughness RIP: Hydraulic roughness slows floodplain velocities consistent with expectations for the stream valley and landscape. Features indicative of these processes include vegetation density and presence of large wood.	**A**
	Flood Storage RIP: Floodplain topography and features slow or store water consistent with expectations for the stream valley and landscape. Features indicative of this outcome include floodplain wetlands and topographic depressions.	**A**
	In-stream Hydrology CHA: Flow controls (e.g., dams) in the watershed or stream do not constrain the hydrologic connection between the stream and riparian zone.	**NA**
	Other Indicators/Notes: *Concrete channel decreases frequency of riparian flooding*	

Indicator Scoring

Strongly Agree (SA)
Agree (A)
Neutral (N)
Disagree (D)
Strongly Disagree (SD)
Not Applicable (NA)

SCORE ROLL-UP WITH EXCEL FILE

Riparian Zone Ecological Function Index (REFI) Worksheet

Reach/ID	1D, Utoy Creek	River Bank	Left	&	Right
Lat/Long	33°44'13.1"N 84°32'46.0"W	Reach Length (ft)			
Date	7/15/2023	Min Buffer Width (ft)	0-30	30-100	100+
Assessor(s)	Garrett and Sam	Avg Buffer Width (ft)	0-30	30-100	100+

Overall	Outcomes		Categories		Variable		Indicators	
Index Score	Name	Index Score	Name	Index Score	Name	Score	Name	Likert Scale Score
0.59	Instream functions	0.3	Hydrology and Hydraulics	0.3	Watershed runoff	4	Direct Runoff	Agree
							Bypassing Flows	Neutral
							Floodplain Slope	Agree
							Runoff Pollution	Agree
					Hydrologic Connection	6	Floodplain Connectivity	Strongly Disagree
							Floodplain Roughness	Agree
							Flood Storage	Neutral
							In-stream Hydrology	Neutral
					Streambank Processes	4	Erosion Potential	Agree
							Reach Erosion	Disagree
							Channel Evolution	Agree
							Sediment Supply	Strongly Disagree
			Biogeochemical Processes	0.3	Energy, Nutrients, and Sediment	2	Carbon Sources	Disagree
							Root Zone	Strongly Disagree
							Soil Suitability	Agree
							Mobilizing Flows	Neutral
					Riparian Filtering	8	Buffer Width	Strongly Agree
							Buffer Density	Agree
							Ground Cover	Disagree
	Ecological Connectivity	0.7	Lateral	0.8	Lateral Disturbance	12	Adjacent Land Use	Strongly Agree
							Average Buffer Width	Neutral
							Distance from Buffer	Strongly Agree
			Longitudinal	0.7	Longitudinal Movement and Habitat	10	Corridor Movement	Strongly Agree
							Habitat Interspersion	Agree
	Unique and Important Habitats	0.7	Terrestrial	0.7	Plant Community	10	Riparian Extent Vegetation	Disagree
							Invasive/Non-Native Species	Agree
							Vegetative Diversity	Strongly Agree
					Canopy Habitat	12	Vertical Structural Diversity	Strongly Agree
							Horizontal Structural Diversity	Agree
					Understory Habitat	14	Tree Size Class Diversity	Neutral
							Snag Density	Agree
					Forest Floor Habitat	5	Detritus Cover	Agree
							Terrestrial Vegetation Contribution	Disagree
			Aquatic	0.9	Stream Habitat	13	Near-Bank Canopy Cover	Agree
							Near-Bank Organic Material	Agree
							In-Stream Coarse Wood	Strongly Agree

Condition Index

1.0	
	Functioning
0.7	
	Functioning At-Risk
0.4	
	Non-Functioning
0.1	

Variable Scoring

15	
14	
13	Functioning
12	
11	
10	
9	
8	Functioning At-Risk
7	
6	
5	
4	
3	Non-Functioning
2	
1	

Indicator Scoring

Strongly Agree (SA)
Agree (A)
Neutral (N)
Disagree (D)
Strongly Disagree (SD)
Not Applicable (NA)

"Build the Case" Check

Indicator to Variable Score

14	Strongly Agree (SA)
11	Agree (A)
8	Neutral (N)
5	Disagree (D)
2	Strongly Disagree (SD)
	Not Applicable (NA)

Variable Score Check	Indicator
10	11, 8, 11, 11
7	2, 11, 8, 8
7	11, 5, 11, 2
7	5, 2, 11, 8
10	14, 11, 5
12	14, 8, 14
13	14, 11
10	5, 11, 14
13	14, 11
10	8, 11
8	11, 5
12	11, 11, 14

UTOY CREEK: A CASE STUDY

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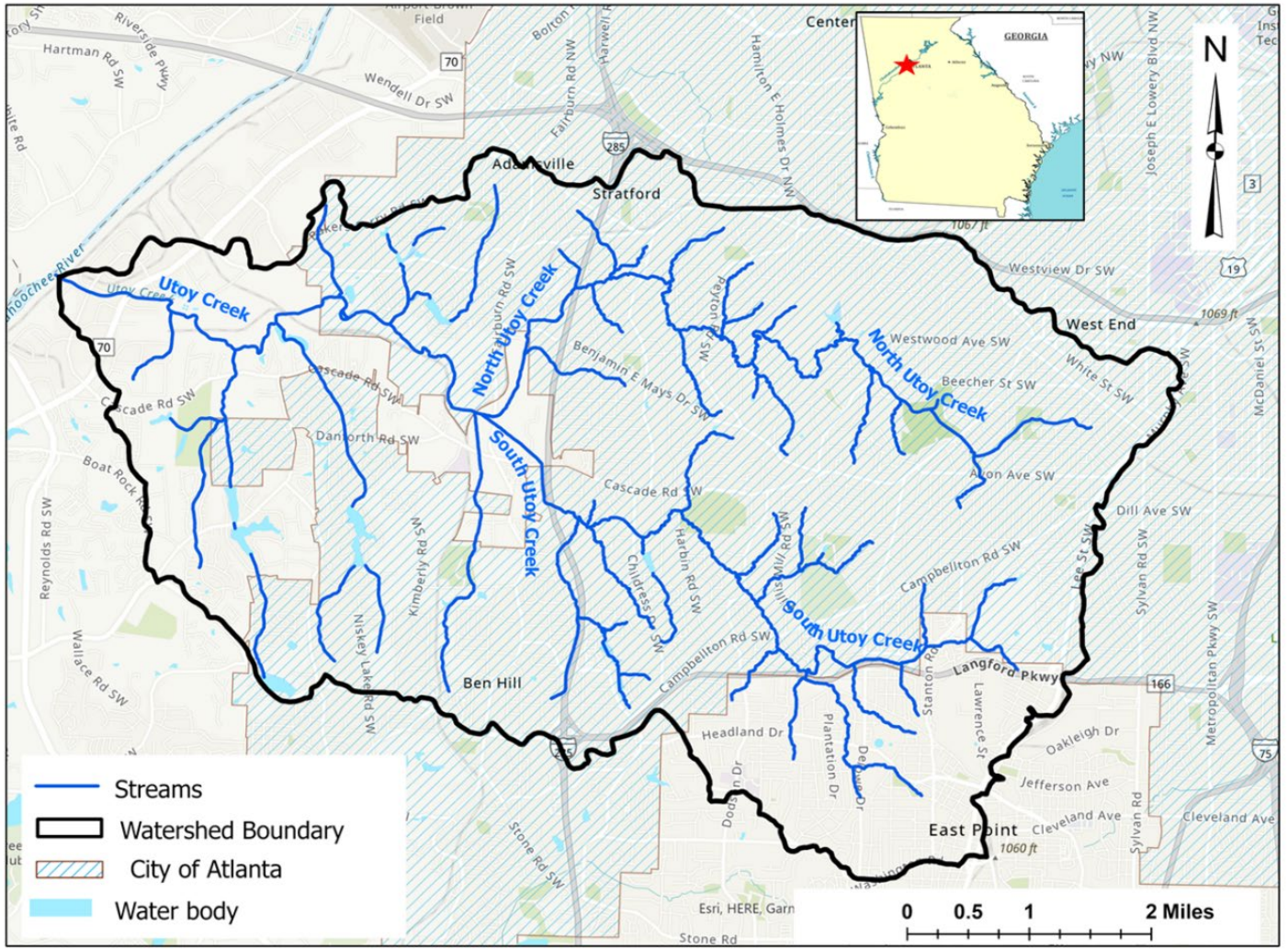
ENGINEER RESEARCH & DEVELOPMENT CENTER

UTOY CREEK RIPARIAN ASSESSMENT

- Part of a larger ecological model in an ecosystem restoration planning study
- 33.7 mi^2 drainage basin
- ~70% developed watershed
- 63 reaches considered for restoration
- Over 15 mi of river
- Rapid, semi-quantitative assessment of riparian zone condition across all reaches

Watershed Drivers and Stressors

Channelization & Stream Piping	Bank Armoring	Impervious Area
Channel Degradation & Widening	Invasive Species	Non-Point Pollution
Watershed Development	Sediment Supply	Riparian Buffer Encroachment
Sewer Lines/ Crossings	Road Crossings	Urban Runoff Thermal Pollution



UTOY CREEK RIPARIAN CONDITIONS

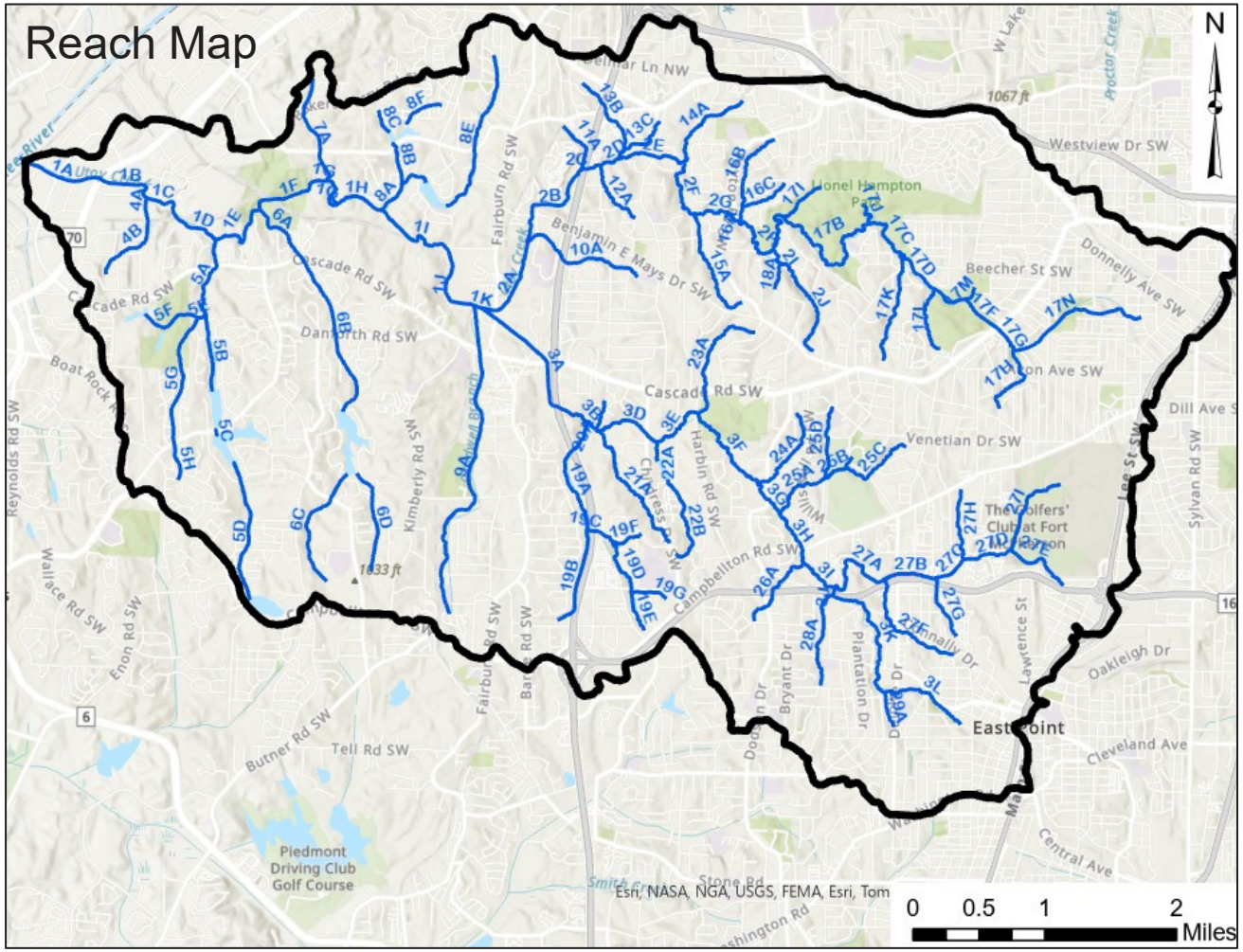
Riparian conditions vary widely across the watershed,
contributing to instream processes, ecological connectivity, and habitat.






LOGISTICS OF APPLYING REFI

- Watershed divided into ~30 reaches
- Each reach planned to have 2 assessments (two worksheets), one for left and right bank
- Site visit over 3 days to assess ~12 mi of stream
- Riparian Team: 4 people
- Reach-averaged scores for Left and Right bank (2 people per bank)



APPLYING REFI TO A REACH (FIELD STEPS)

1. Walk length of riparian zone along the streambank, noting riparian conditions on a field map
2. At the end of the reach, the 2-person team discussed and completed the assessment worksheet

Riparian zone field map with notes

Riparian Ecological Function Index (REFI)
Field Worksheet

Reach/ID	17D	River Bank	Left / & / Right
Lat/Long		Reach Length (ft)	
Date	10/16/2023	Min Buffer Width (ft)	0-30 / 30-100 / 100+
Assessor (s)	Mickal, McKay	Avg Buffer Width (ft)	0-30 / 30-100 / 100+

SCO

Variables are judgment-based scores reflecting the co
Indicators record the logic embedded in the variable
context: WAT = Watershed, BAN = Bank area, CHA
"NA", or indicators may be added under "Other Indic
REFI assessment involves two primary steps:
1) Assess **indicators** based on your agreement with th
(N), Disagree (D), Strongly Disagree (SD), Not Ap
2) Score **variable** condition using its *functional state*
Functioning (15 to 11), Functioning At-Risk (10 to

Variable	INS
Watershed Runoff *RZ reduces upland runoff and associated pollution load to the stream and supports interflow processes* Score: 5	**Direct Runoff** WAT: Runoff velocities a encouraging infiltration and interflow **Bypassing Flows** WAT: Bypass element through the riparian system as overla **Floodplain Slope** RIP: Interflow proces riparian zone and floodplain **Runoff Pollution** WAT: Potential point/ **Other Indicators:**
Hydrologic Connection *RZ is hydrologically connected and provides flood storage, which reduces channel erosion and provides aquatic refugia in the floodplain* Score: 5	**Floodplain Connectivity** CHA: Stormfl the natural geomorphic condition (e. **Floodplain Roughness** WAT: Hydraulic r valley and landscape. Features indicativ **Flood Storage** RIP: Floodplain topograp valley and landscape. Features indicativ **In-stream Hydrology** CHA: Flow contr connection between the stream and r **Other Indicators:**
Streambank Processes *RZ vegetation and fluvial-geomorphic processes are in sync such that the stream is in dynamic equilibrium.* Score: 3	**Erosion Potential** BAN: There is little p bank cover, or bank slope. (Note: re **Reach Erosion** BAN: The channel in t **Channel Evolution** CHA: Stream is relat could negatively impact riparian zone **Sediment Supply** CHA: There is not ex sediment imbalance due to in-stream **Other Indicators:**
Energy, Nutrients, and Sediment *RZ provides energy sources to stream, buffers nutrients, and pollutants from runoff and in groundwater.* Score: 8	**Carbon Sources** CHA: Riparian zone pr Continuum Concept. Organic materia **Root Zone** RIP: Riparian zone roots are **Soil Suitability** RIP: There is no evidenc allows uninhibited plant growth and **Mobilizing Flows** CHA: Sediment, woo expectations stream valley and lands **Other Indicators:**
Riparian Filtering *RZ filters out suspended sediment from upland runoff and in-stream flooding.* Score: 6	**Buffer Width** RIP: The vegetated buffer width is classified as at least 30 feet **Buffer Density** RIP: The vegetated buf sediment/pollution before reaching th **Ground Cover** RIP: The vegetated bu **Other Indicators:**

ECOLOGICAL CONNECTIVITY

Lateral Processes *RZ maintains lateral ecological connectivity between the river, floodplain, and upland in response to human disturbance..* Score: 4	**Adjacent Land Use** WAT: The type of land use adjacent to the location of the riparian zone causes little to no disturbance to the ecological function of the riparian zone. Levels of disturbance can vary depending on the land use type (i.e., natural, rural, suburban, urban).	SD
	Average Buffer Width RIP: The average width of the riparian corridor is not restricted by human development. The riparian vegetation maintains connection to upland land between the channel and the adjacent slopes.	SD
	Distance from Buffer RIP: Human activity adjacent to riparian zone exists at a reasonable distance to cause little to no disturbance to riparian function.	D
	Other Indicators:	
Longitudinal Movement and Habitat *RZ maintains longitudinal ecological connectivity in response to human disturbance within the corridor and supports a diverse habitat mosaic* Score: 4	**Corridor Movement** RIP: There is no evidence of development within the buffer that could affect corridor function. Barriers likely to affect dispersal or impede migratory movements (e.g., fences, roads, bridges, or exceedingly dense walls of foliage) are not present. (Note: consider barriers to flying, crawling, or swimming species).	SD
	Habitat Interspersion RIP: A variety of vegetation appears in "patches" and creates a heterogeneous pattern, or mosaic of habitat.	SD
	Other Indicators:	

UNIQUE AND IMPORTANT HABITATS

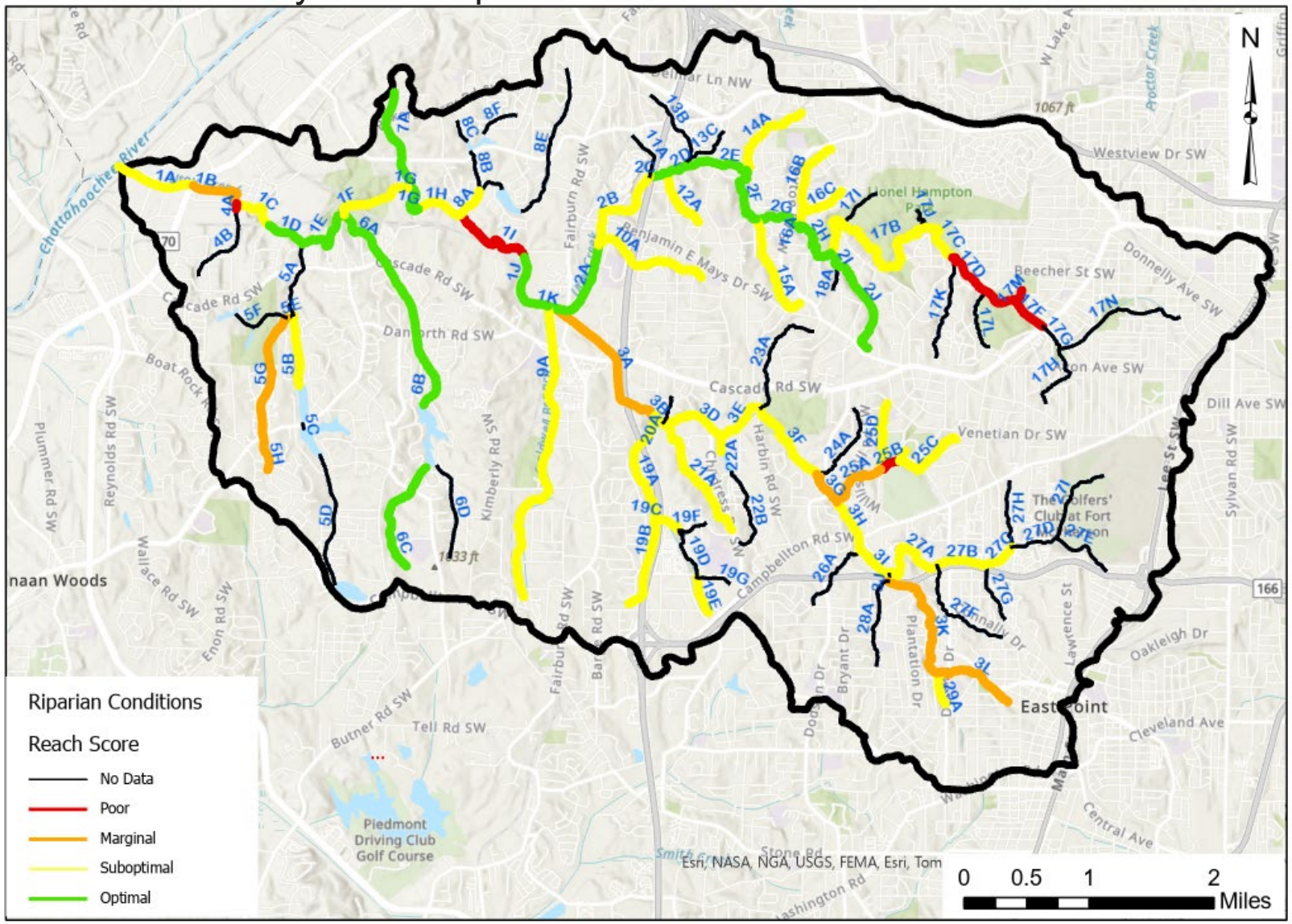
Plant Community *RZ supports a wide range of flora that has a structure contributing to many functions of the ecosystem.* Score: 2	**Riparian Extent Vegetation** RIP: The vegetated buffer width is not constrained and can reach its natural maximum potential extent.	SD
	Invasive/Non-Native Species RIP: The riparian zone supports primarily native taxa. The percentage of invasive species minimally influences riparian quality and function.	SD
	Vegetative Diversity RIP: A wide variety of vegetation is present (ground-cover species, grasses, shrubs, and trees) to provide suitable habitat for varying fauna.	SD
	Other Indicators: Kudzu / Ivy	
Canopy Habitat *(Forested RZs) RZ provides suitable habitat for faunal species (e.g., birds) in the canopy* Score: 7	**Vertical Structural Diversity** RIP: There is variability in the height, structure, and fill in vegetation (i.e., no monocultures of similarly heighted vegetation or thick, evenly dense layers of vegetation present) that supports vertical stratification of species.	N
	Horizontal Structural Diversity RIP: There is variability in tree density and canopy cover. There are both gaps of shade and of light visible.	D
	Other Indicators:	
Understory Habitat *(Forested or scrub-shrub RZs) RZ has suitable habitat for faunal species (e.g., mammals, birds, herps) in understory layer* Score: 5	**Tree Size Class Diversity** RIP: Trees vary greatly in age and size. There is evidence of both old and new growth, with trees of various size classes mixed spatially across the landscape.	D
	Snag Density RIP: Presence of snag(s)/standing deadwood provides potential habitat for various faunal species. There is also a presence of live trees for future snag development.	D
	Other Indicators:	
Floor Habitat *RZ provides and supports suitable habitat for various faunal species (i.e., herps and mammals) on the forest floor.* Score: 4	**Detritus Cover** RIP: Litter fall buildup of organic ground cover from detritus and woody debris optimizes potential habitat for various faunal species. (Note: Vegetative cover is present, but not dominant of organic cover and is spatially intermixed and not part of a dense monoculture.)	D
	Terrestrial Vegetation Contribution RIP: Presence of contributed vegetation (e.g. large fallen deadwood (*forested*), branches/brush piles (*scrub-shrub*), aquatic/terrestrial rooted plants (*emergent*)) supports ecological functionality within terrestrial riparian zone (i.e., habitat formation, terrestrial food webs, biogeochemical processes).	D
	Other Indicators:	
Stream Habitat *RZ canopy shades stream and regulates water temperatures. RZ shapes in-stream habitat* Score: 3	**Near-Bank Canopy Cover** CHA: Canopy cover along the bank effectively regulates temperature by providing shade cover for majority of the stream edge as well as several feet over the stream in many places.	A
	Near-Bank Organic Material CHA: Riparian zone contributes organic material to stream with visible retention (i.e., packs of leaves, twigs, or woody debris in stream are evident).	SD
	In-Stream Coarse Wood CHA: Riparian zone contributes large deadwood that supports ecological functionality in the stream (i.e., habitat formation, aquatic food webs, biogeochemical processes).	SD
	Other Indicators:	

RIPARIAN ZONE EXISTING CONDITIONS

Summary of assessment scores

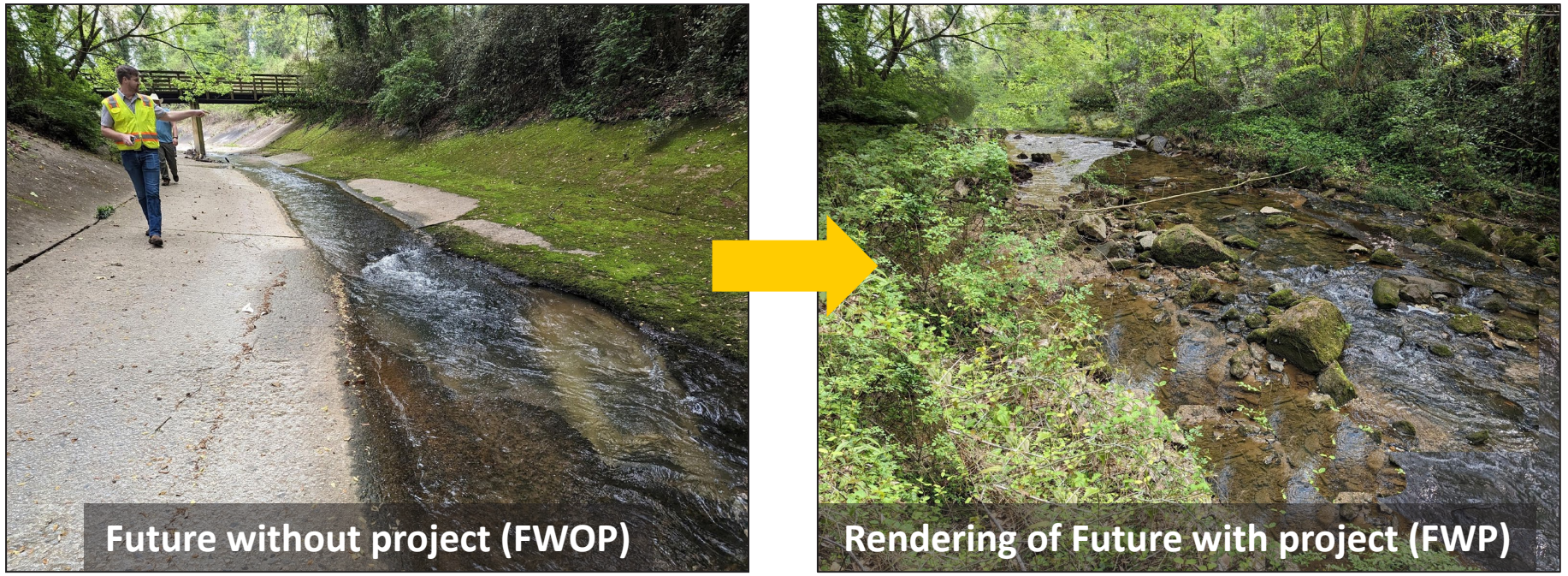
Reach	Bank Side	Instream Functions	Ecological Connectivity	Unique and Important Habitats	Overall
17C	Left	0.5	0.4	0.5	0.65
	Right	0.8	1.0	0.7	
17B	Left	0.6	0.7	0.8	0.78
	Right	0.7	0.9	1.0	
2A	Left	0.3	0.4	0.2	0.47
	Right	0.7	0.5	0.8	
2B	Left	0.4	0.4	0.6	0.49
	Right	0.5	0.3	0.7	
25B	Left	0.4	0.1	0.1	0.20
	Right	0.4	0.1	0.1	
25C	Left	0.7	0.8	0.7	0.73
	Right	0.7	0.8	0.7	
3A	Left	0.6	0.2	0.4	0.39
	Right	0.6	0.2	0.4	
3F	Left	0.7	0.8	0.8	0.77
	Right	0.7	0.8	0.8	
1C	Left	0.6	0.7	0.6	0.41
	Right	0.3	0.1	0.3	
1D	Left	0.6	0.5	0.7	0.70
	Right	0.8	0.9	0.7	
1E	Left	0.5	0.6	0.8	0.68
	Right	0.6	0.9	0.7	
19A	Left	0.7	0.6	0.8	0.68
	Right	0.7	0.6	0.8	
17D	Left	0.4	0.3	0.3	0.29
	Right	0.2	0.2	0.4	
17E	Left	0.4	0.9	0.6	0.40
	t (Golf Cou	0.3	0.1	0.2	
	ight (Fores	0.3	0.2	0.6	
17F	Left	0.1	0.1	0.1	0.10
	Right	0.1	0.1	0.1	

Utoy Creek Riparian Zone "Overall" Condition



ECOLOGICAL FORECASTING ALTERNATIVES WITH REFI

- Restoration alternatives being developed to improve instream and riparian conditions
- REFI being used in the ecological model to forecast ecological lift and benefits
- REFI scores represent riparian condition and utilized in habitat unit calculations



FUTURE APPLICATIONS AND NEXT STEPS

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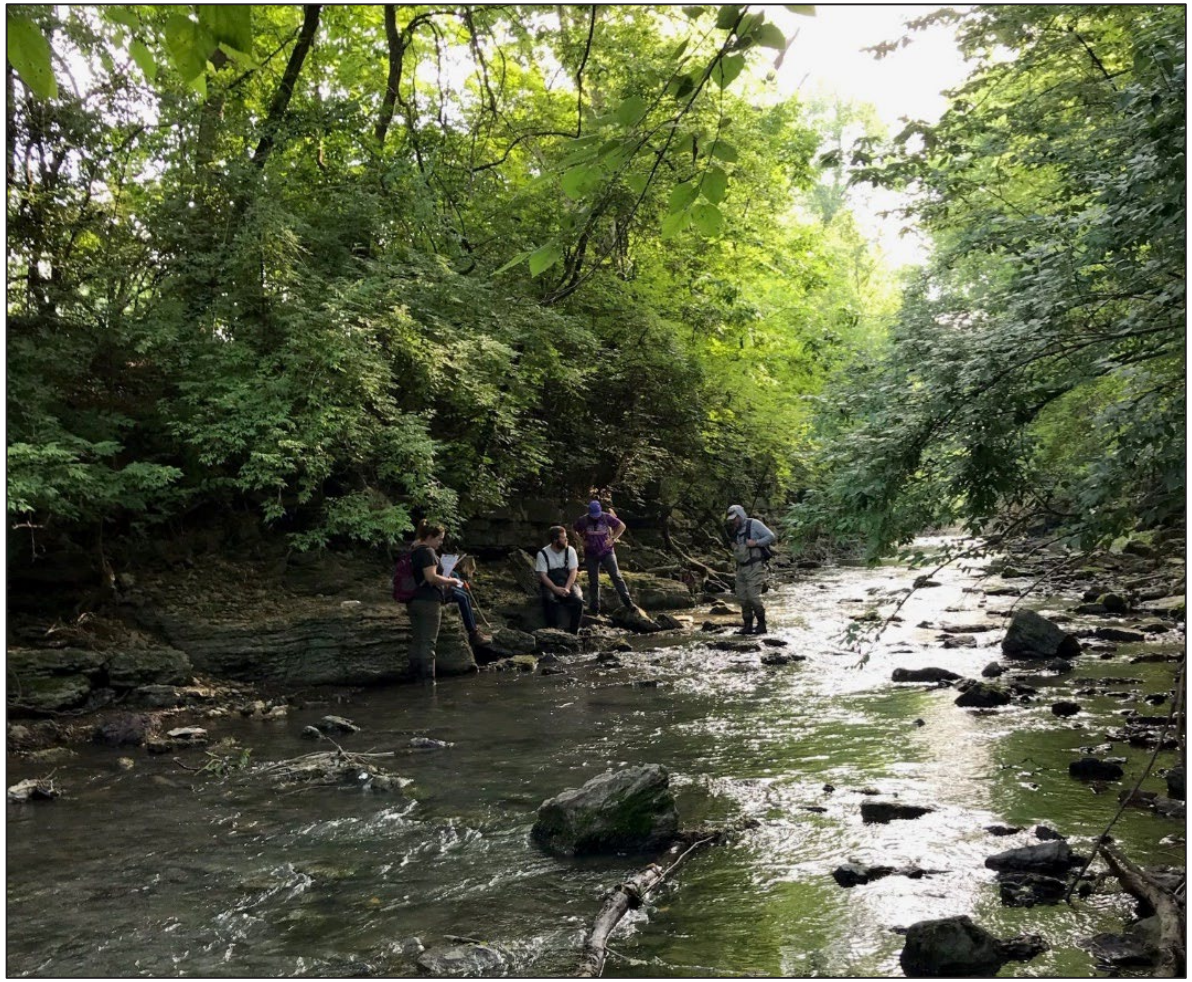
NEXT STEPS…

- Model certification
- Beta testing for different regions
- National Conference for Ecosystem Restoration 2024
- National Stream Restoration Conference 2024
- Include REFI in Web Application for Riparian Models (WARM)
- Working on making REFI widely available
  - Reach out to us for testing!



THANK YOU FOR YOUR TIME!

Take-away messages

- Developing a suite of riparian modeling tools applicable across a spectrum of low to high effort
- A rapid screening tool to assess riparian zones across varying regions for impacts and benefits (via REFI)
- A simple habitat-style model is being developed for high-level screening across sites

Upcoming Webinars!

- Jan 31: Web Application for Riparian Models (WARM)

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We want to hear from you!

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