

Ecosystem-based Integrated Water Resource Management (IWRM) in Today's Social Ecological System (SES) Context

A "One-Water" Example for Connecticut

Earth at Night
More information available at:
<http://antwrp.gsfc.nasa.gov/apod/ap001127.html>

NASA Earth Observatory



**One Water:
All for One and
One for Water**

**NEWEA 2024
Annual Conference
& Exhibit**

January 21–24
Boston Marriott Copley Place
Boston, Massachusetts



Paul E. Stacey
**FOOTPRINTS
IN THE WATER**

Working to Make Nature Great Again
FootprintsInTheWater@outlook.com

Changing Management Perspectives for Changing Times:

Pre Clean Water Act
Nature for Itself – Conservation

1972 – Clean Water Act
Nature Despite People – Regulation

**ONE
WATER**

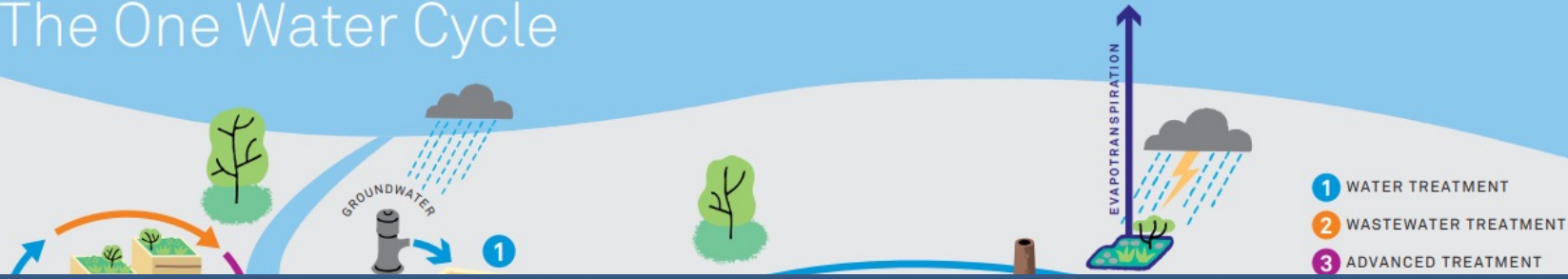


2000s – Ecosystem Structure & Function
Nature for People – Ecosystem Services

2010 – Sustainability & Resilience
People and Nature – Social Ecological Systems

Social-Ecological System Management:

The One Water Cycle

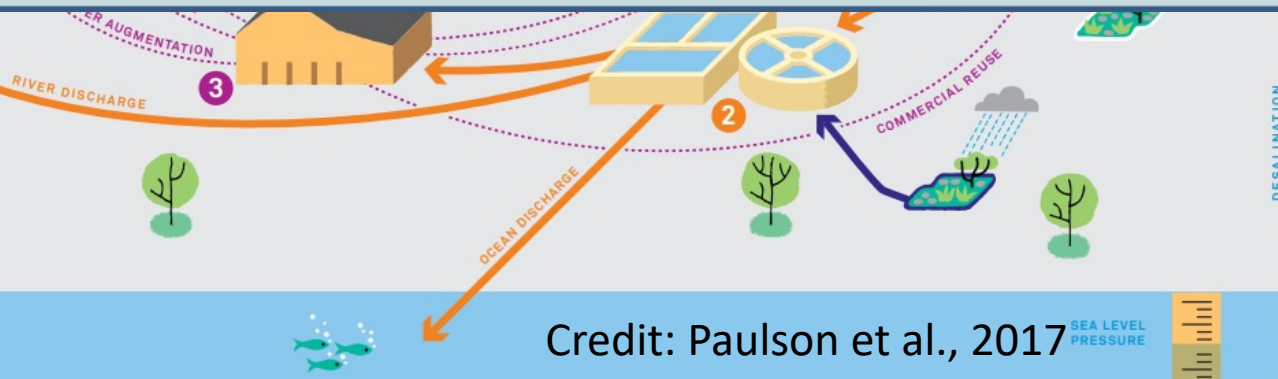


1972 – Clean Water Act
Nature Despite People –
Regulation

ONE WATER

**2010 – Sustainability &
Resilience**
People and Nature –
Social Ecological Systems

Mace, 2014



Credit: Paulson et al., 2017

One Water Defined

One Water is an integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community **and ecosystem needs**

Credit: Paulson et al., 2017

The difference between animals and humans is that animals change themselves for the environment, but humans change the environment for themselves

– Ayn Rand

One Water Ecosystem-Based Mgmt:

Healthy Watersheds Initiative Vision:

Protect and maintain the aquatic ecological integrity of watersheds and supporting habitat networks to ensure that future generations may enjoy these resources and the social and economic benefits that they provide.

Identifying and Protecting Healthy Watersheds

Concepts, Assessments, and Management Approaches

February 2012



EPA, 2012

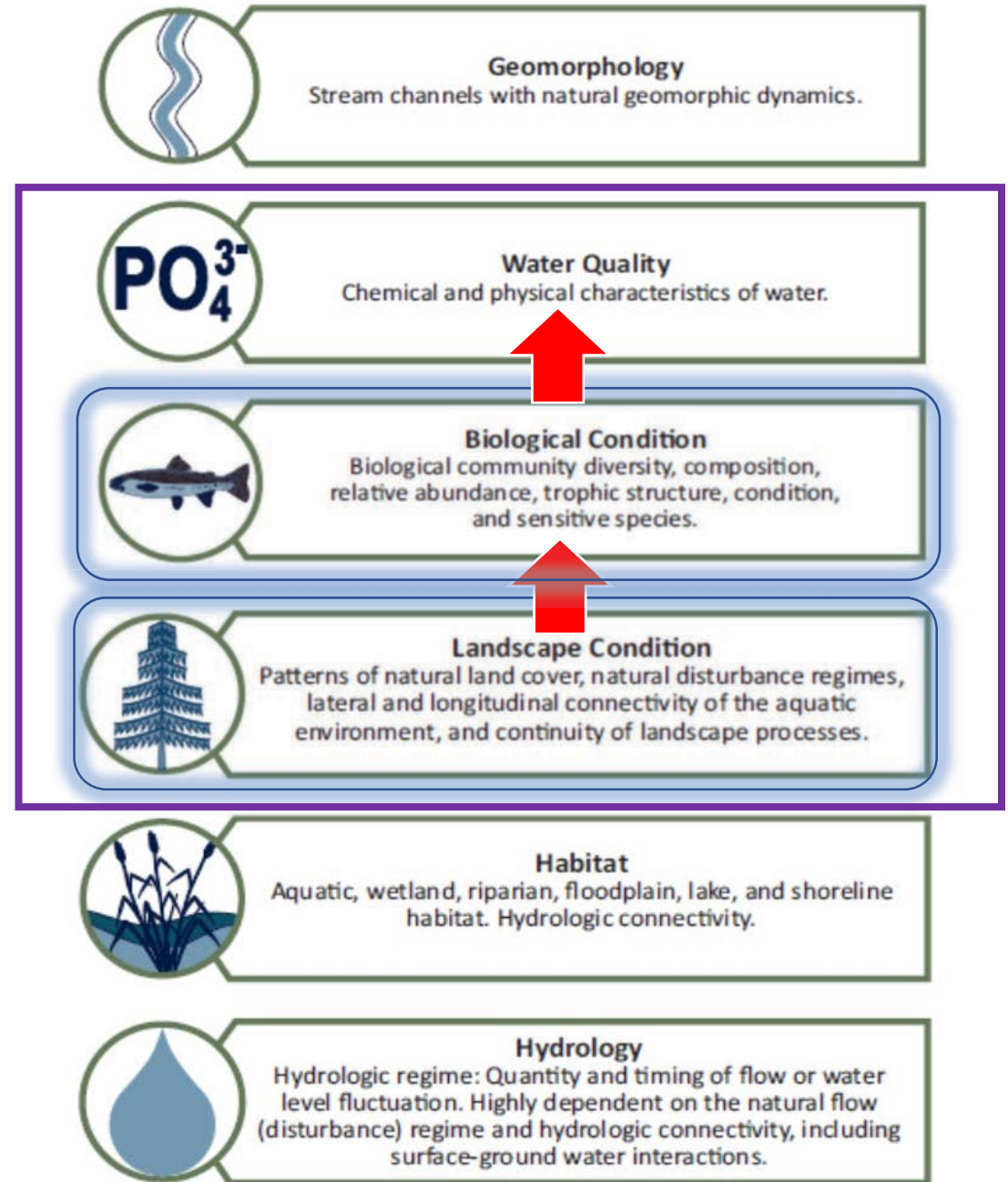
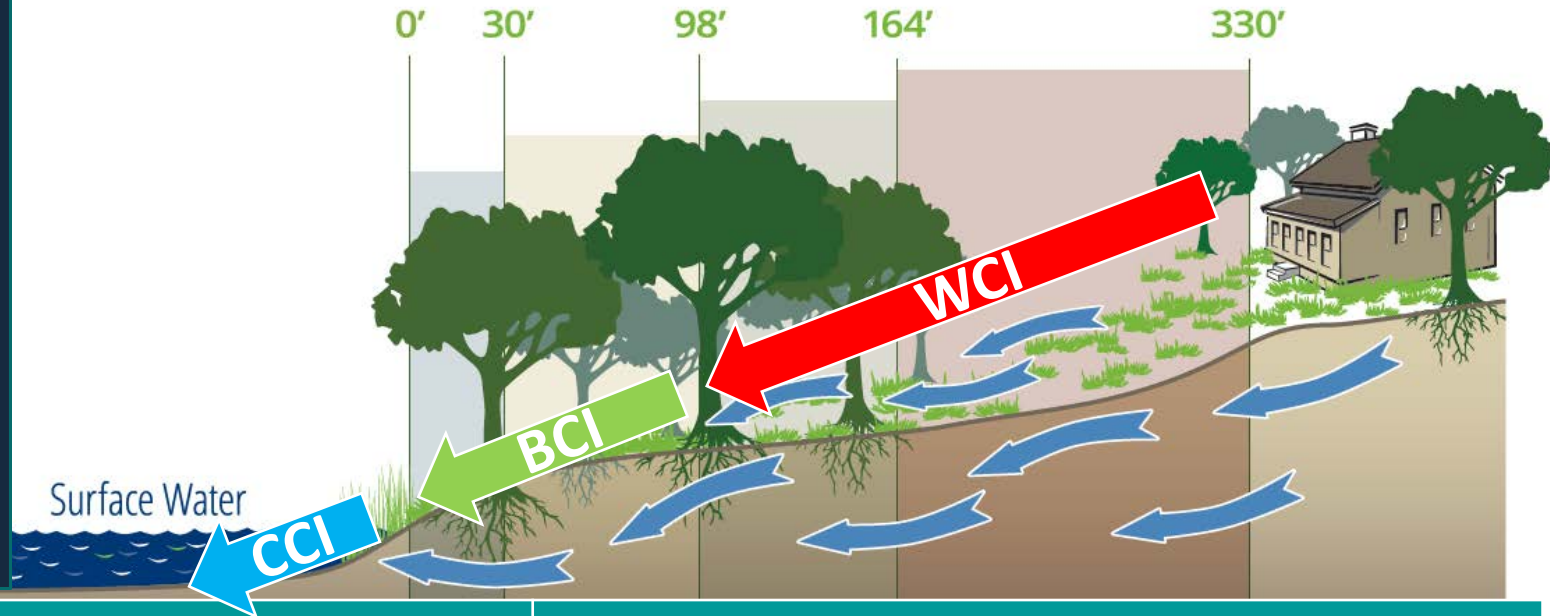


Figure 2-4 Healthy watersheds assessment components

Combined Condition Index (CCI):

- Combined Condition Index (CCI)
- Watershed Condition (WCI)
- Buffer Condition (BCI)

$$CCI = WCI \times (1 + (BCI - WCI))$$



CCI is Based on:

- Structural and
- Functional Health of the Watershed

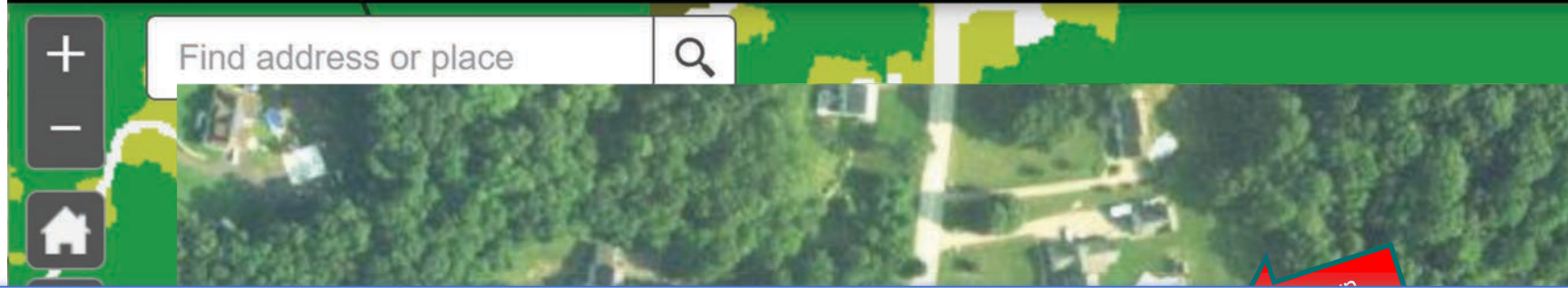
Degree of "Naturalness"

Graphic Credit: Buffer Options for the Bay NH

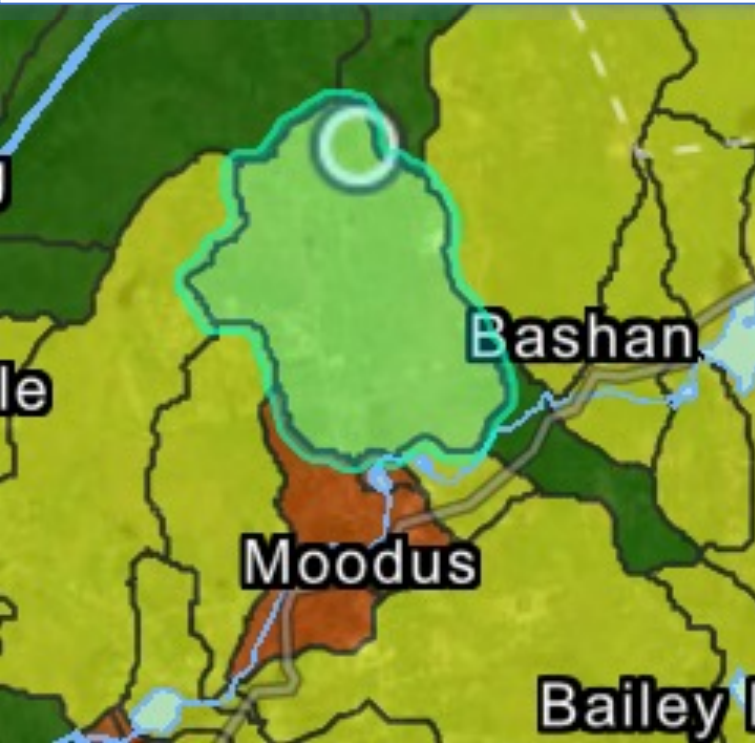
Indicator	Equation
Watershed Condition Index (WCI)	WCI = Natural acres / (Natural acres + (Ag-Like acres * 2) + (Impervious acres * 7))
Buffer Condition Index (BCI)	BCI = Natural acres / (Natural acres + (Ag-Like acres * 2) + (Impervious acres * 7))
Weighted Combined Condition Index (CCI)	Weighted CCI = WCI * (1 + (BCI - WCI))

1-Meter Resolution Precise & Accurate!

CT ECO CLEAR CT High Res Land Cover (NOAA CCAP)



CLEAR Local Watershed Assessment Tool (LWAT)



Moodus River - Local Watershed 4710-08			
Outcomes	100-ft Buffer	Upland of Buffer	Total
Area (acres)			
Impervious	0.63	33.7	34.3
Ag-Like	8.1	109	117
Natural	24.9	390	415
Total	33.7	533	566
Condition Indices			
	BCI	WCI	CCI
Index Value	0.55	0.46	0.50
Nitrogen	Nitrogen Yield (EF) =		4.0
	Nitrogen Load (tons/yr)		1.14

Aggregated Class	1-meter CCAP - 2016 CLEAR
Natural	Grassland
	Mixed Forest
	Scrub/Shrub
	Palustrine Forested Wetland
	Palustrine Scrub/Shrub Wetland
	Palustrine Emergent Wetland
	Estuarine Scrub/Shrub Wetland
	Estuarine Emergent Wetland
	Unconsolidated Shore
	Bare Land
	Open Water
	Palustrine Aquatic Bed
	Estuarine Aquatic Bed
Agriculture-Like*	Developed Open Space
	Cultivated Land
	Pasture/Hay
Developed*	Impervious

*Originally comprised the "Non-Natural" category.



1



2



7

Ecosystem Context:

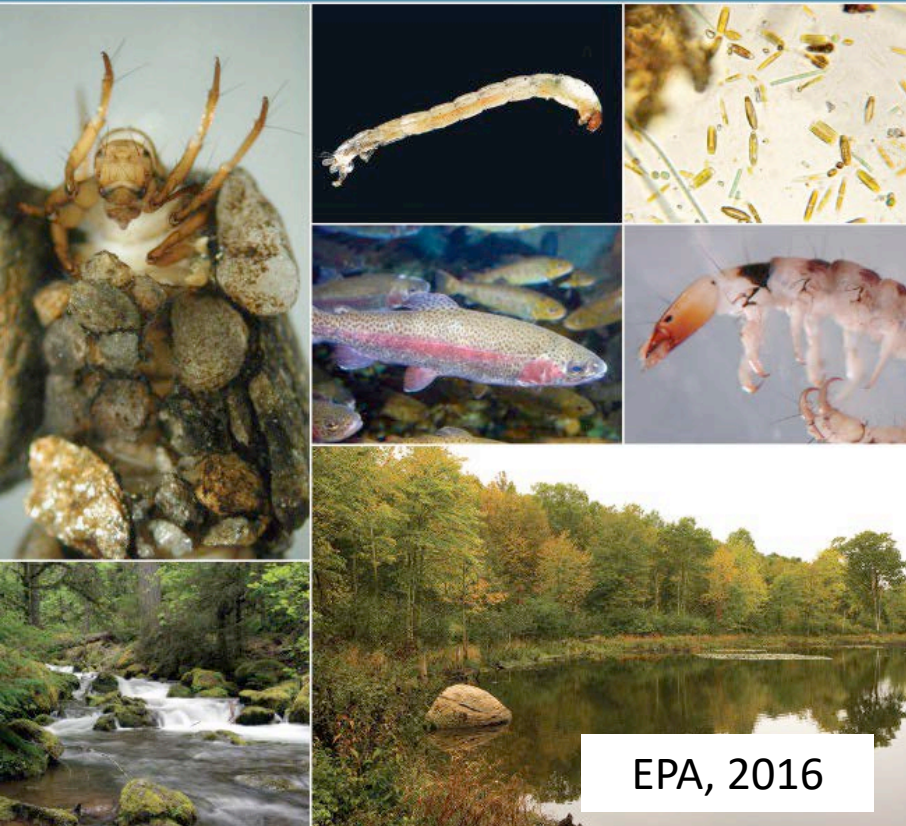
The Biological Condition Gradient (BCG)



EPA 842-R-16-001

A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems

February 2016



EPA, 2016

The Six Levels of the BCG

Levels of Biological Condition

Natural structural, functional, and taxonomic integrity is preserved.

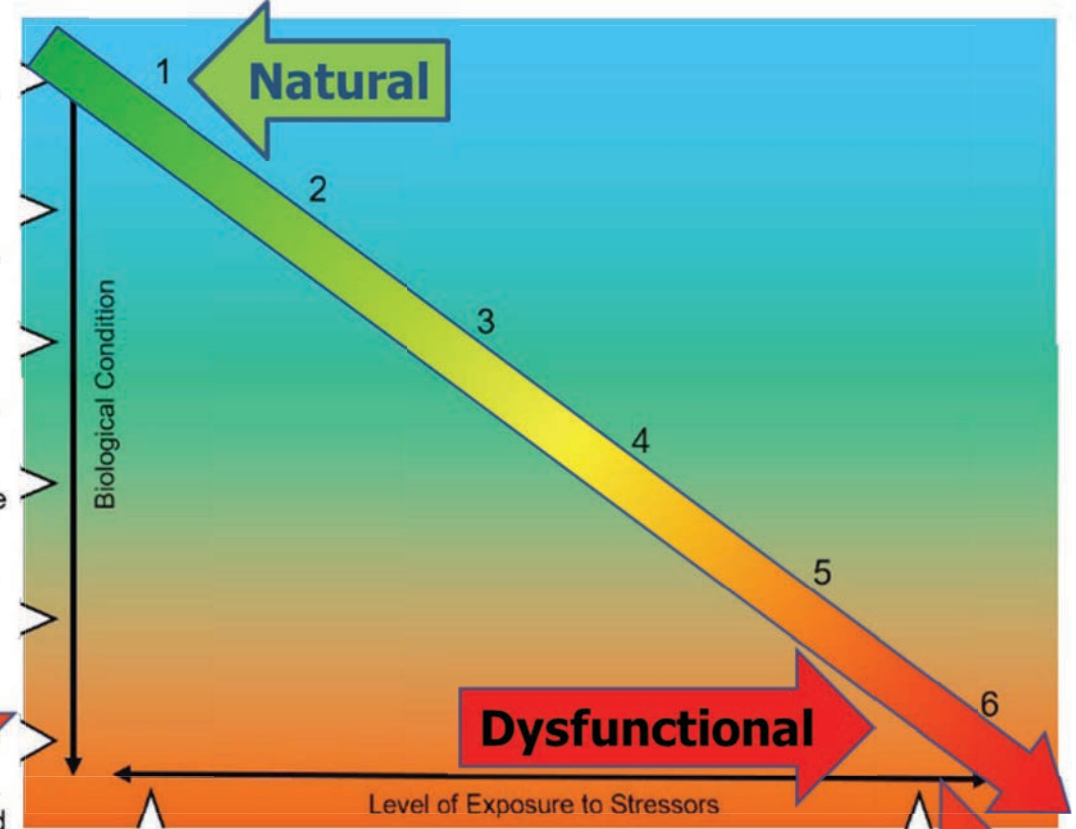
Structure & function of natural community is maintained; additional taxonomic diversity; ecosystem level functions fully maintained.

Evident changes due to loss of sensitive taxa; shifts in abundance; ecosystem functions largely intact.

Moderate changes due to replacement of sensitive taxa by tolerant taxa; functions largely intact.

Sensitive taxa diminished; community structure unbalanced due to loss of major taxonomic groups; ecosystem functions reduced; redundancy.

Extreme changes in structure and ecosystem function; wholesale changes in taxonomic composition; extreme alterations from normal densities.



Response Index
Macroinvertebrate
Multimetric Index (MMI)

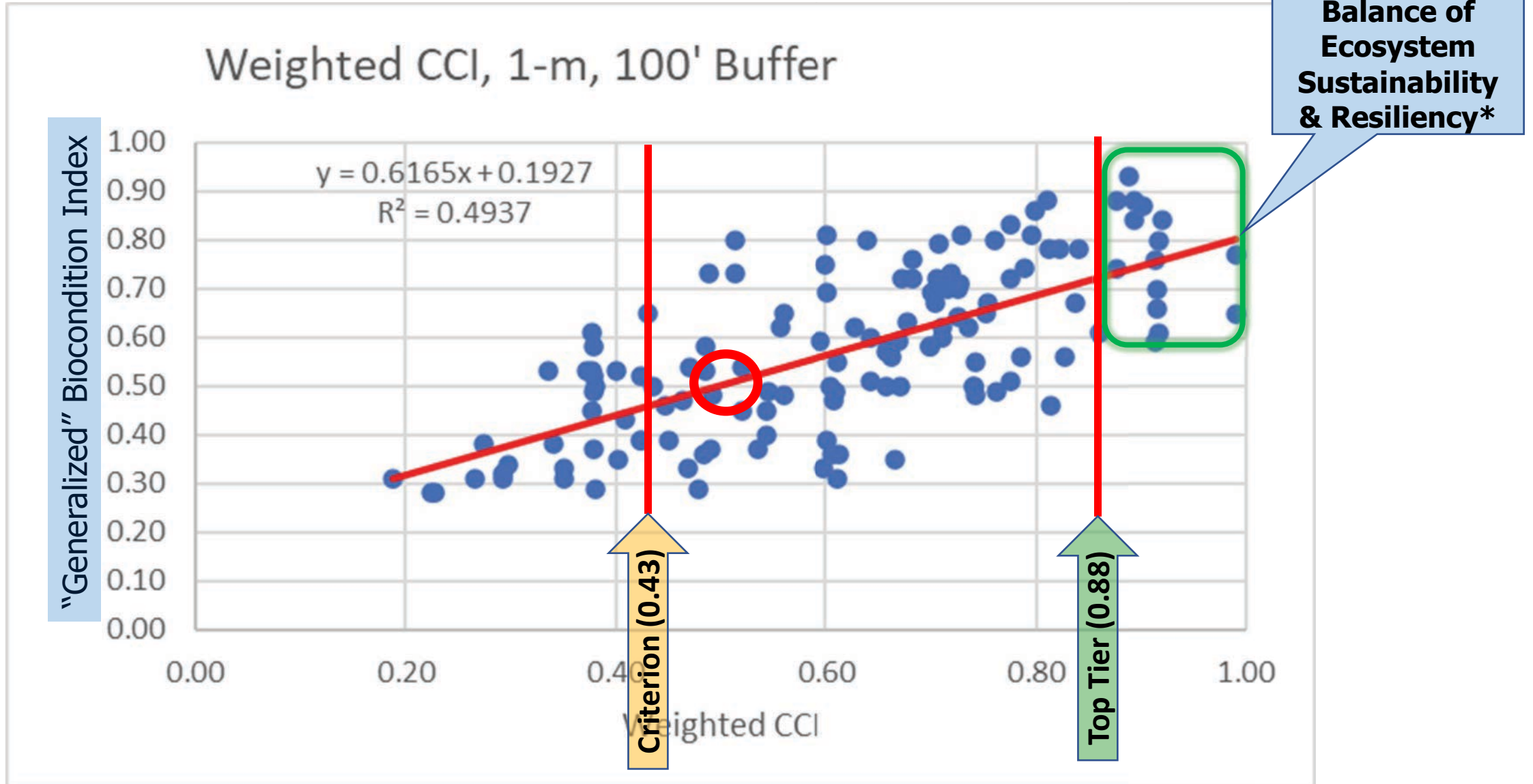
Dysfunctional

Stress Exposure Index (Watershed Condition)

Combined Condition Index (CCI)

Figure 2. The Biological Condition Gradient (BCG) shows the effects of anthropogenic stress on aquatic ecosystems, ranging from naturally occurring conditions to extreme degradation. In this figure, the color gradient is a quick visual cue for condition level.

The CCI and Biointegrity:



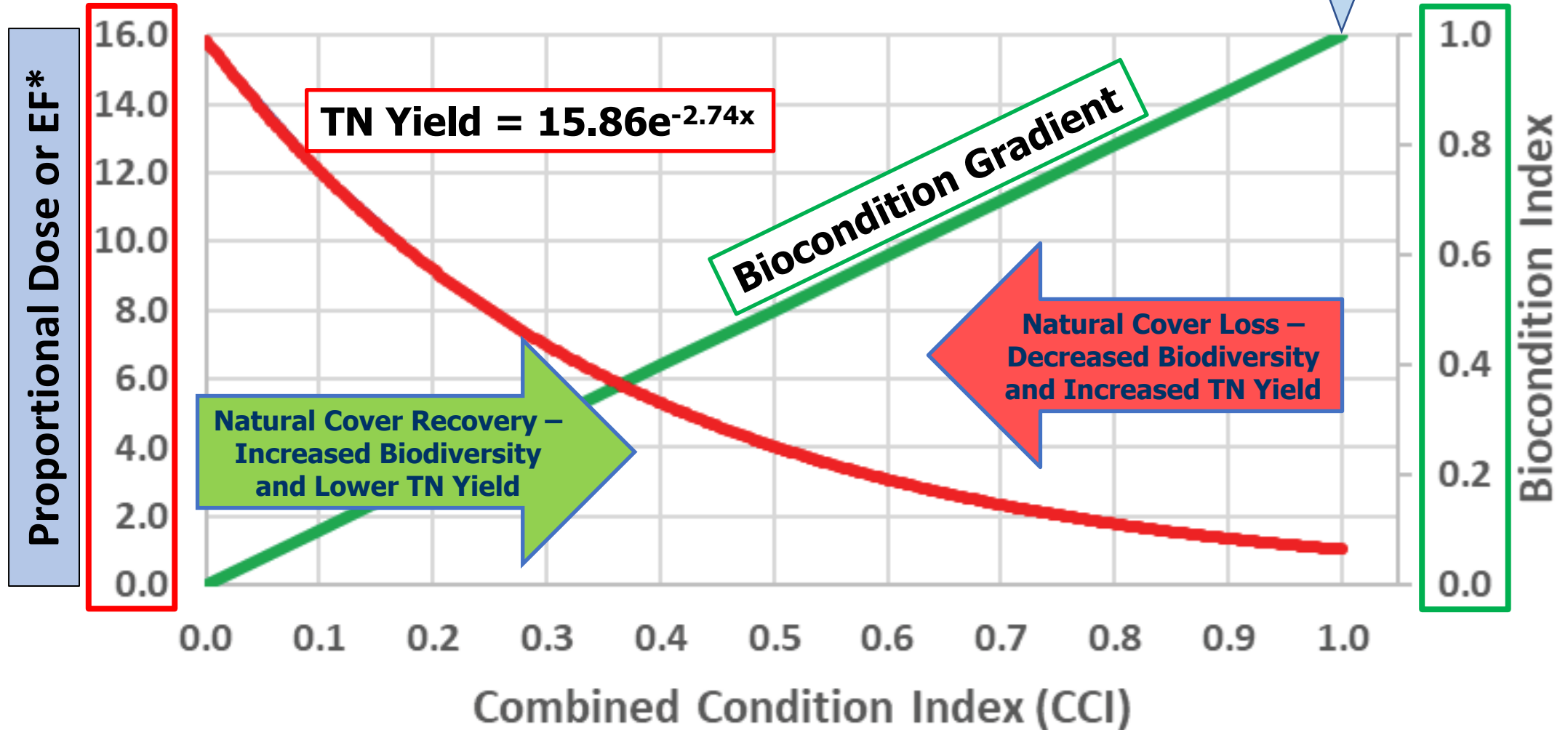
Data Source: CT DEEP Ambient Biological Monitoring Program

*Concept – Lietaer et al. 2010
Interpretation – Belchamber, 2010

Management Model Summary – Simple, Salient, Effective:

Optimum for Ecosystem Sustainability & Resiliency

Combined Condition Index v. TN Yield




*EF = Enrichment Factor (Becker, 2014)

Natural/Nature-Based Solutions:

What are natural and Nature-based (NNB) solutions?

Actions to protect, sustainably manage, recover or restore natural or modified ecosystems to address societal challenges, simultaneously providing benefits for people and the environment

NATURE-BASED SOLUTIONS (NBS)
ROADMAP FOR AMERICA



PRIMING ACTIONS
Announcements from the Executive Office of the President to catalyze federal actions

- Revise central guidance on benefit-cost analysis
- Encourage NBS for infrastructure resilience
- Coordinate access to funds to reduce floods and benefit wildlife
- Strengthen agency climate adaptation plans with NBS
- Embed NBS in federal sustainability policy and operations
- Decision support tool for flood NBS
- Launch federal benefit-cost analysis technical group
- Synthesize evidence of effectiveness

RECOMMENDATIONS TO AGENCIES
Recommendations to the National Climate Task Force

FEDERAL ASSET

WORK FOR

Nature-Based Solutions Achieve Their Full Potential for Climate, Equity, Nature & Prosperity

Social-Ecological System Benefits of Integrated "One Water" Management		
Outcomes	Ecosystem	Society
Resiliency	✓	✓
Sustainability	✓	✓
Risk Reduction		
Land Cover	✓	✓
Climate	✓	✓
Pollution	✓	✓
Health & Well-Being	✓	✓

Box 1. Benefits of Nature-Based Solutions.
This list is not exhaustive.

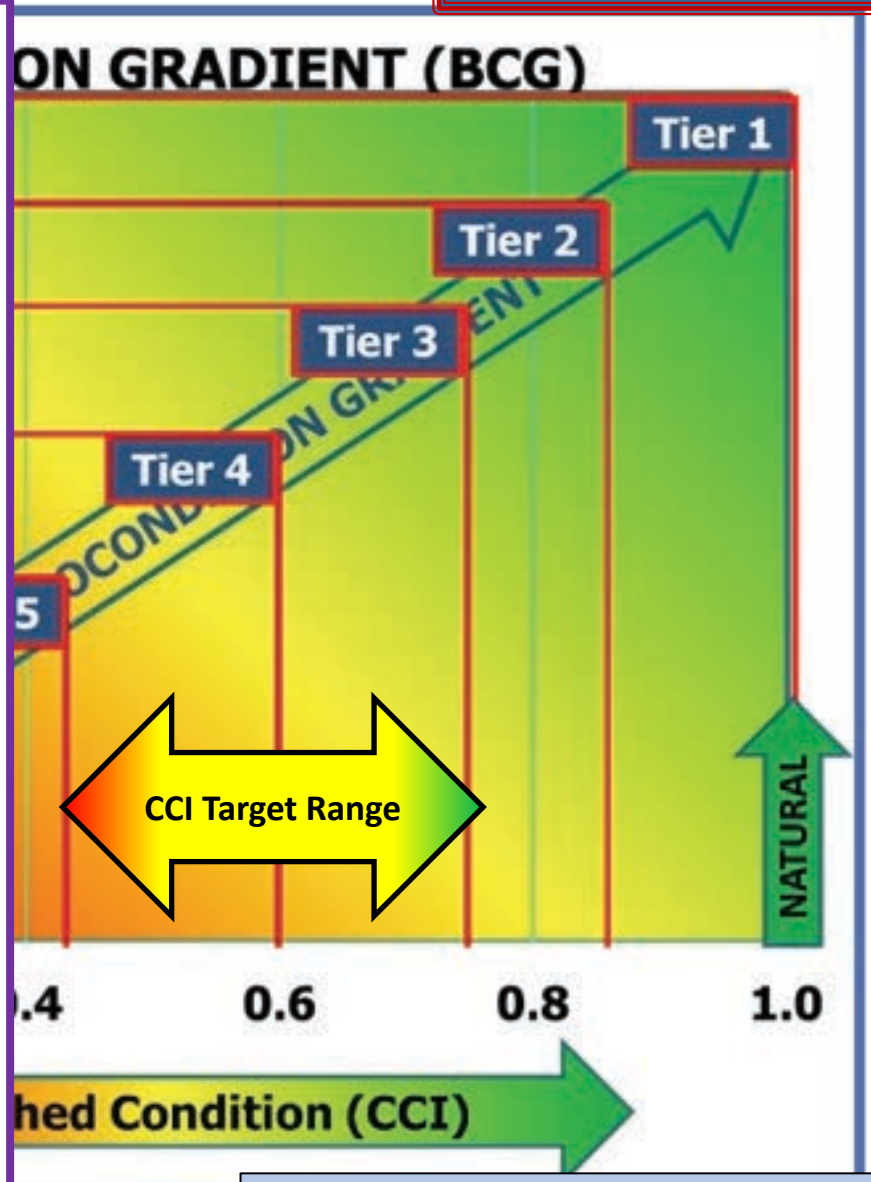
- Climate mitigation (reduced greenhouse gas emissions and enhanced carbon storage)
- Reduction of major climate risks, such as:
 - Coastal floods and shoreline erosion
 - Inland floods
 - Stormwater and sewer overflow
 - Extreme heat
 - Wildfire
 - Drought
- Job opportunities
- Improved water and air quality
- Fish, timber, and other natural products
- Recreational opportunities and access
- More resilient infrastructure
- Improved physical and mental health
- Cultural benefits
- Wildlife and biodiversity support
- Community development and economic revitalization

Benchmarking CCI & TN to Aquatic Life Tiers:

$$\text{Enrichment Factor} = \text{Yield} / \text{Natural Yield}$$

$$\text{TN Yield} = 15.86e^{-2.74x}$$

Tier	Combined Condition Index	EF
1	0.88 - 1.00	1.5 - 1.0
2	0.75 - 0.88	2.0 - 1.5
3	0.60 - 0.75	3.0 - 2.0
4	0.43 - 0.60	5.0 - 3.0
5	0.20 - 0.43	9.0 - 5.0
6	0.00 - 0.20	16 - 9.0



Designated Use

ALUS = Aquatic Life Use Support
 TALU = Tiered Aquatic Life Use*

*Gerritsen and Jessup (2007)

EF = Enrichment Factor (Becker, 2014)

BCG Strategic Management:


Resist-Accept-Direct (RAD) Framework

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager

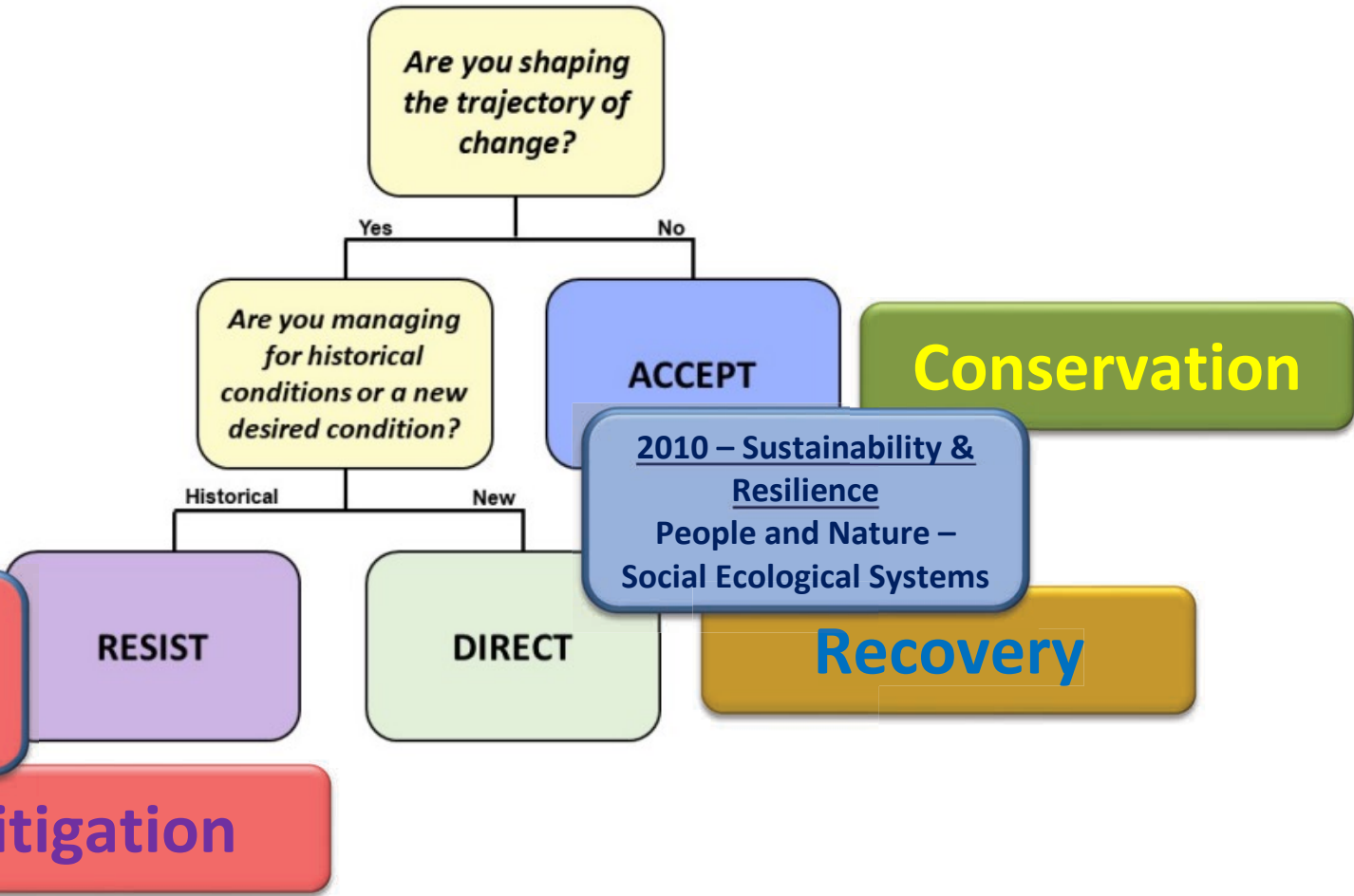
Natural Resource Report NPS/NRSS/CCRP/NRR—2020/ 2213



1972 – Clean Water Act
Nature Despite
People – Regulation

Mitigation

...a tool for responding to ecosystems facing the potential for rapid, irreversible ecological change.

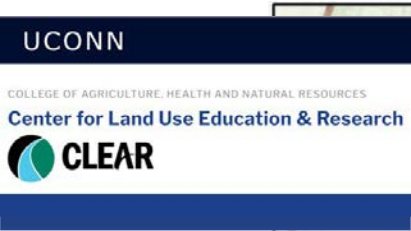


“...making informed, purposeful choices about how to respond to the trajectory of change... [using] a straightforward approach to support resource managers in collaborating at larger scales across jurisdictions, which today is more urgent than ever..”

Biointegrity Distribution:

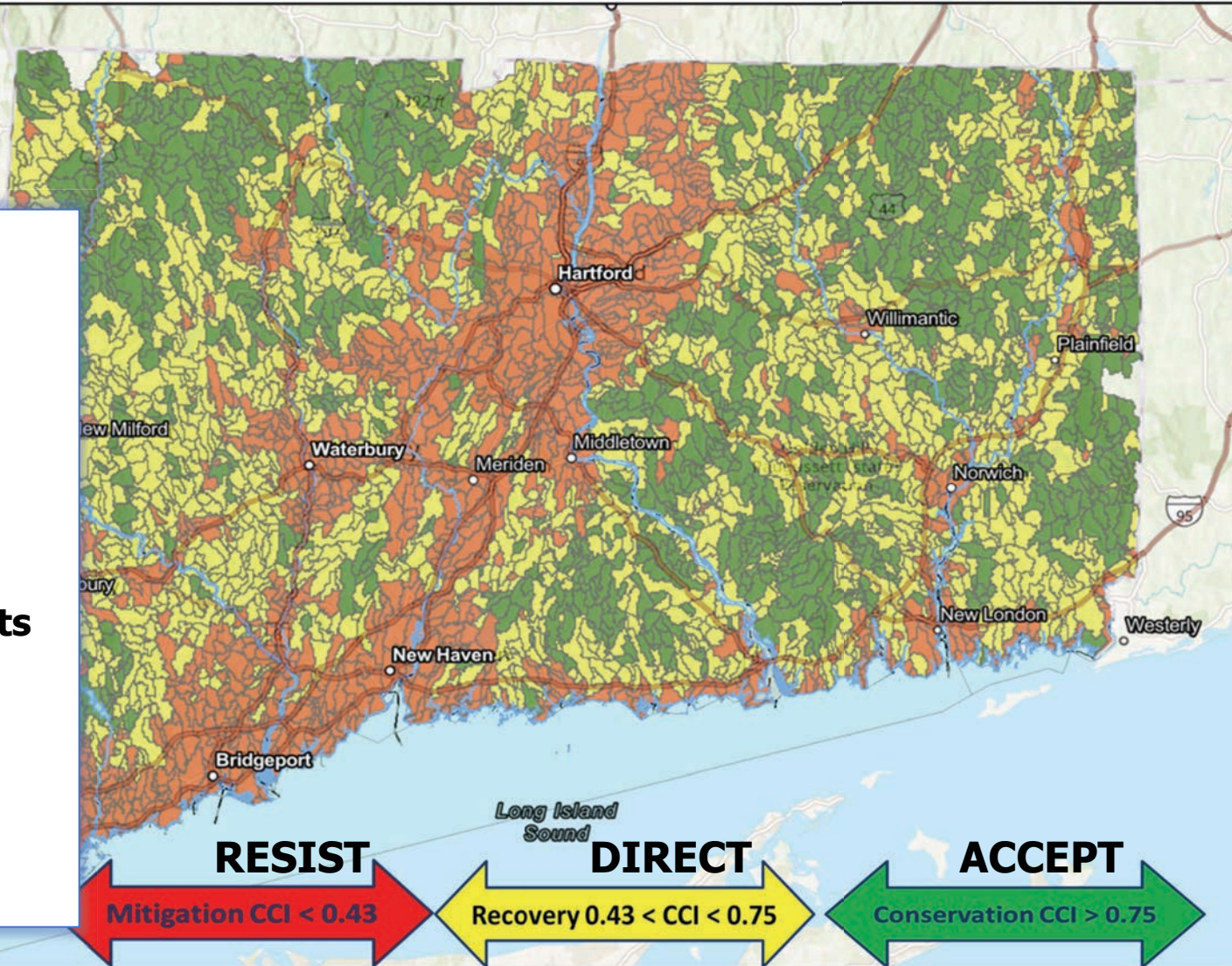
CLEAR Local Watershed Assessment Tool* (LWAT)

* Local Watershed Assessment Tool (arcgis.com) <https://clear.uconn.edu/>



Decision Support Framework:

- Watershed-Based Plans
- TMDLs
- Criteria and Targets
- Offsets & Trading
- Unambiguous Implementation Tracking



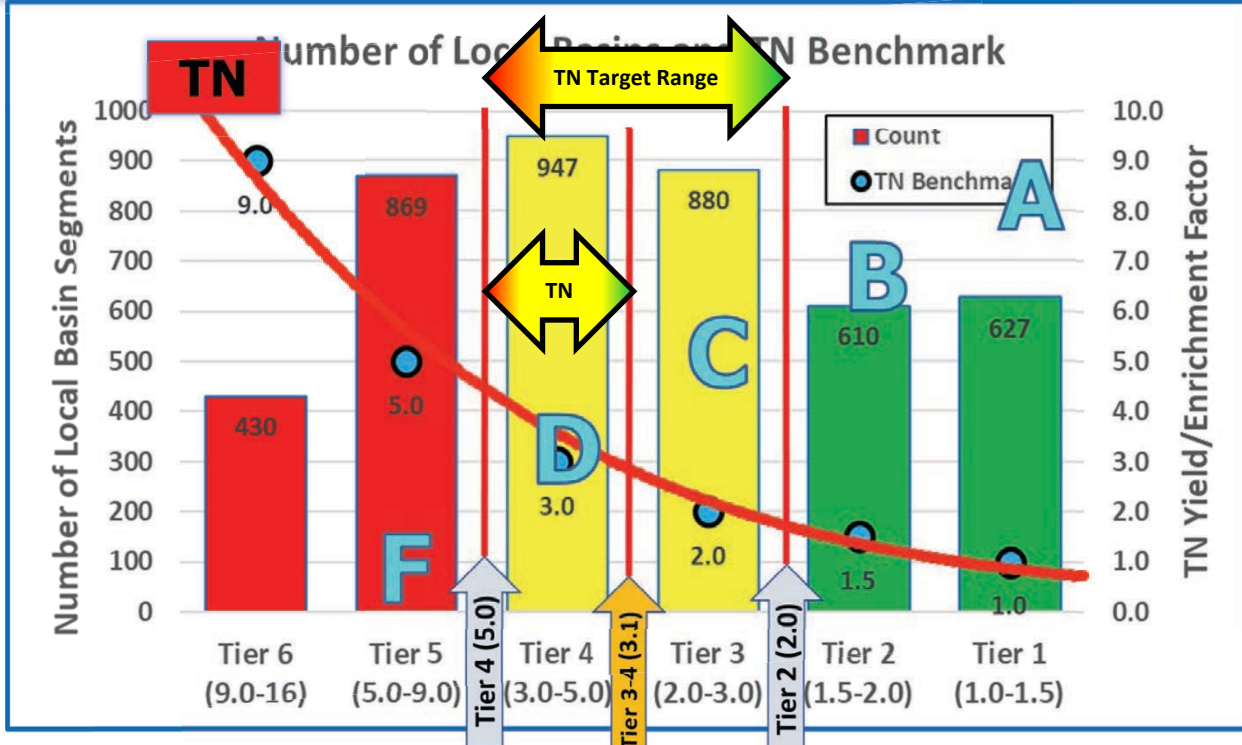
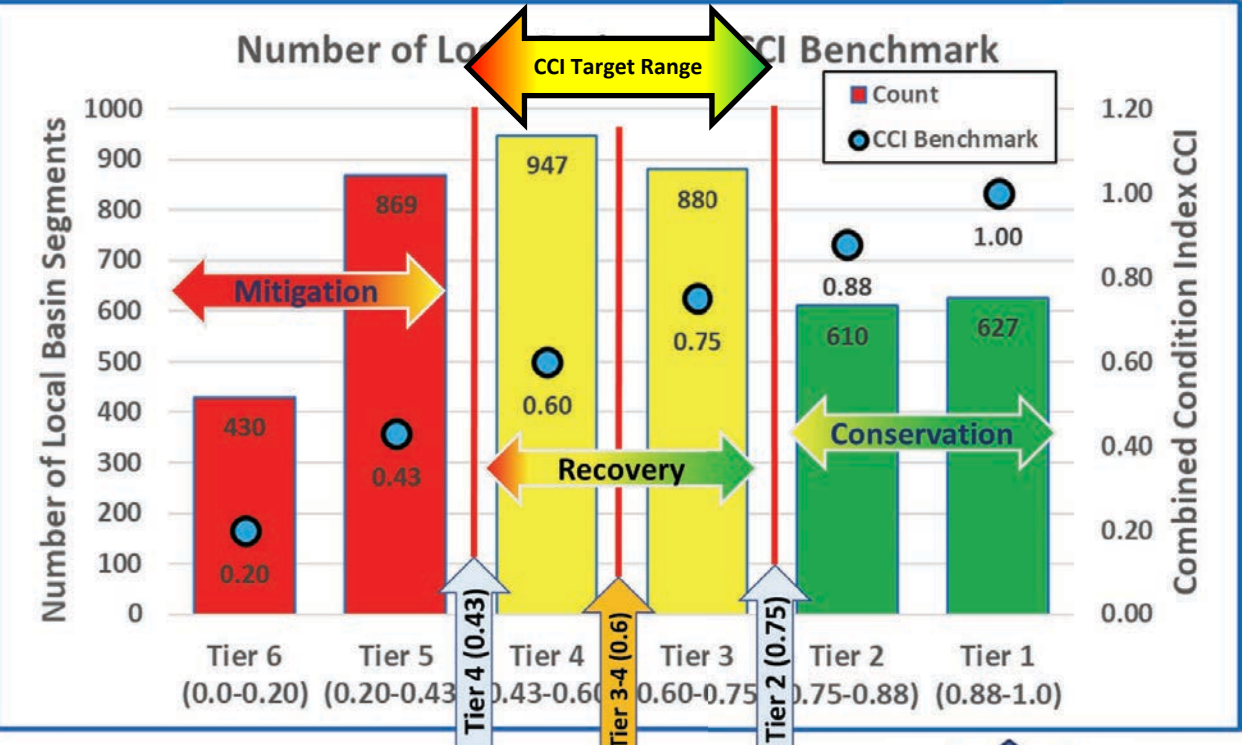
LWAT Attributes:

- 1-meter resolution
- 4363 local basins
- Median <500 acres
- TALU Application
- Biointegrity and TN loading assessments
- Strategic Management

Tier	Combined Condition Index	EF
1	0.88 - 1.00	1.5 - 1.0
2	0.75 - 0.88	2.0 - 1.5
3	0.60 - 0.75	3.0 - 2.0
4	0.43 - 0.60	5.0 - 3.0
5	0.20 - 0.43	9.0 - 5.0
6	0.00 - 0.20	16 - 9.0

Biointegrity Distribution – CCI:

Total Nitrogen Distribution:



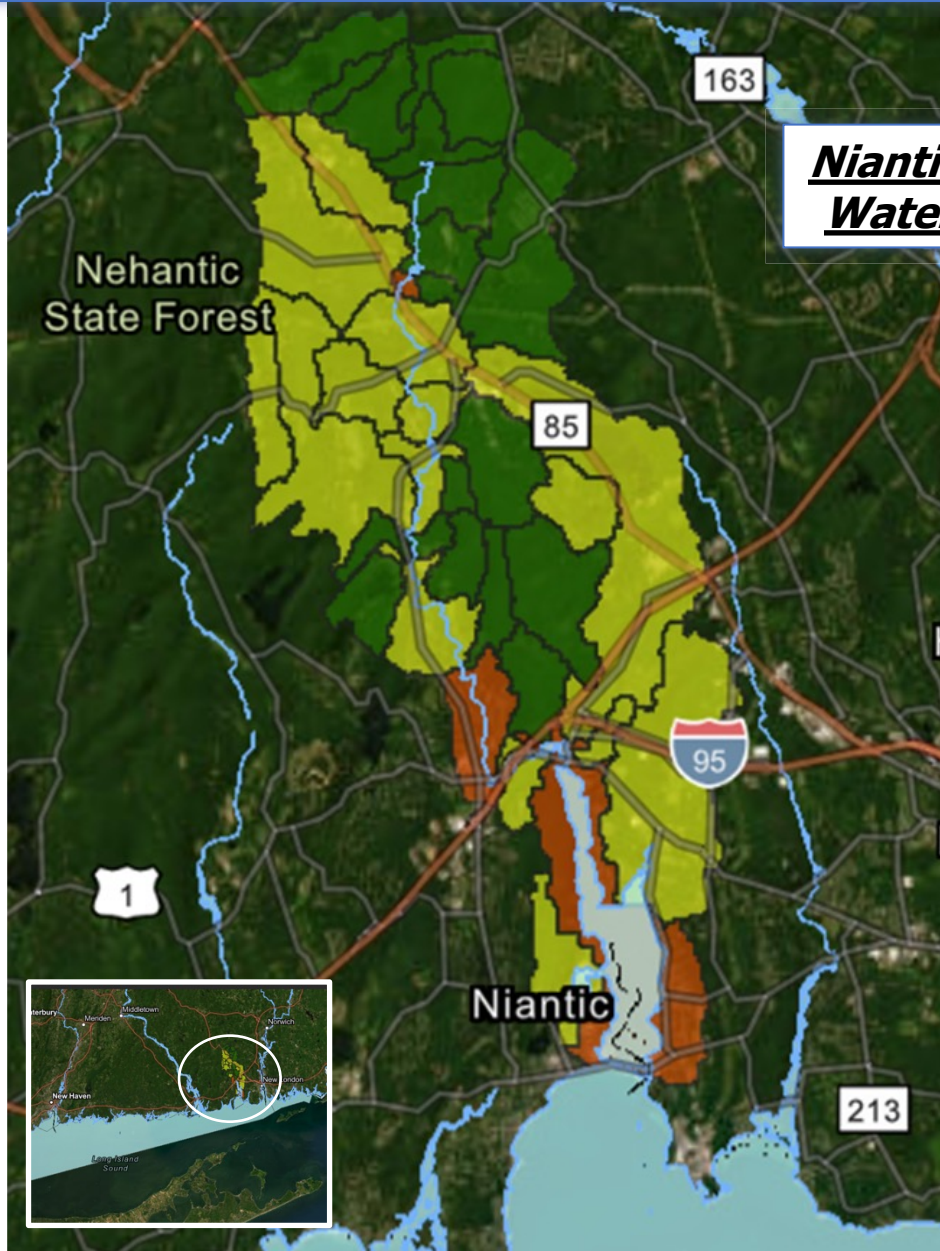
CCI	
Mean	0.57
Median	0.59
Minimum	0.00
Maximum	1.00
Count	4363

Tier	Combined Condition Index	EF
1	0.88 - 1.00	1.5 - 1.0
2	0.75 - 0.88	2.0 - 1.5
3	0.60 - 0.75	3.0 - 2.0
4	0.43 - 0.60	5.0 - 3.0
5	0.20 - 0.43	9.0 - 5.0
6	0.00 - 0.20	16 - 9.0

Local Watershed Distribution by Tier and Management Strategy				
Tier	Number	Strategy	Number	Percent
1	627	Conservation	1237	28
2	610			
3	880	Recovery	1827	42
4	947			
5	869	Mitigation	1299	30
6	430			
Total	4363		4363	100

TN Yield or EF	
Mean	4.20
Median	3.11
Minimum	1.02
Maximum	15.7
Count	4363

LWAT Decision Support Framework:



37 Segments

28

2202-00-1-L1	551			
2202-00-1-L2	129			
2202-00-1-L3	374	180		
2202-00-1-L4	247	450		
2202-00-1*	393			
2202-01	453	279		
2202-00-2-R1	41	1196		
2202-05	1117	561		
2202-06	381	204	570	
<2202-09 2202-08>	348	1320	231	100
2202-10	127	90		
2202-00-3-L8	320	489	245	
2202-00-3-L9	509	233		
2202-00-3-R1	214	>	>	>

Sub-watershed Size (acres)

Latimer Brook	11353
Oil Mill Brook	3334
Niantic River	4666
Coastal	758
TOTAL	20111

20,111 Acres

Oil Mill Brook

3

2203-01	353
2203-07	689
	2291

Niantic River

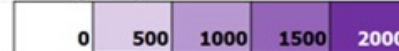
4

2204-01	341
	1959
2204-04	469
2000-35	559
2000-38	199
TOTAL=	20111
(acres)	

Latimer Brook

Coastal

Scale (acres)



LWAT Decision Support Framework:

TN

Current Condition

**EF = 3.0
TIER 4
TARGET**

BAC – Best Attainable Condition

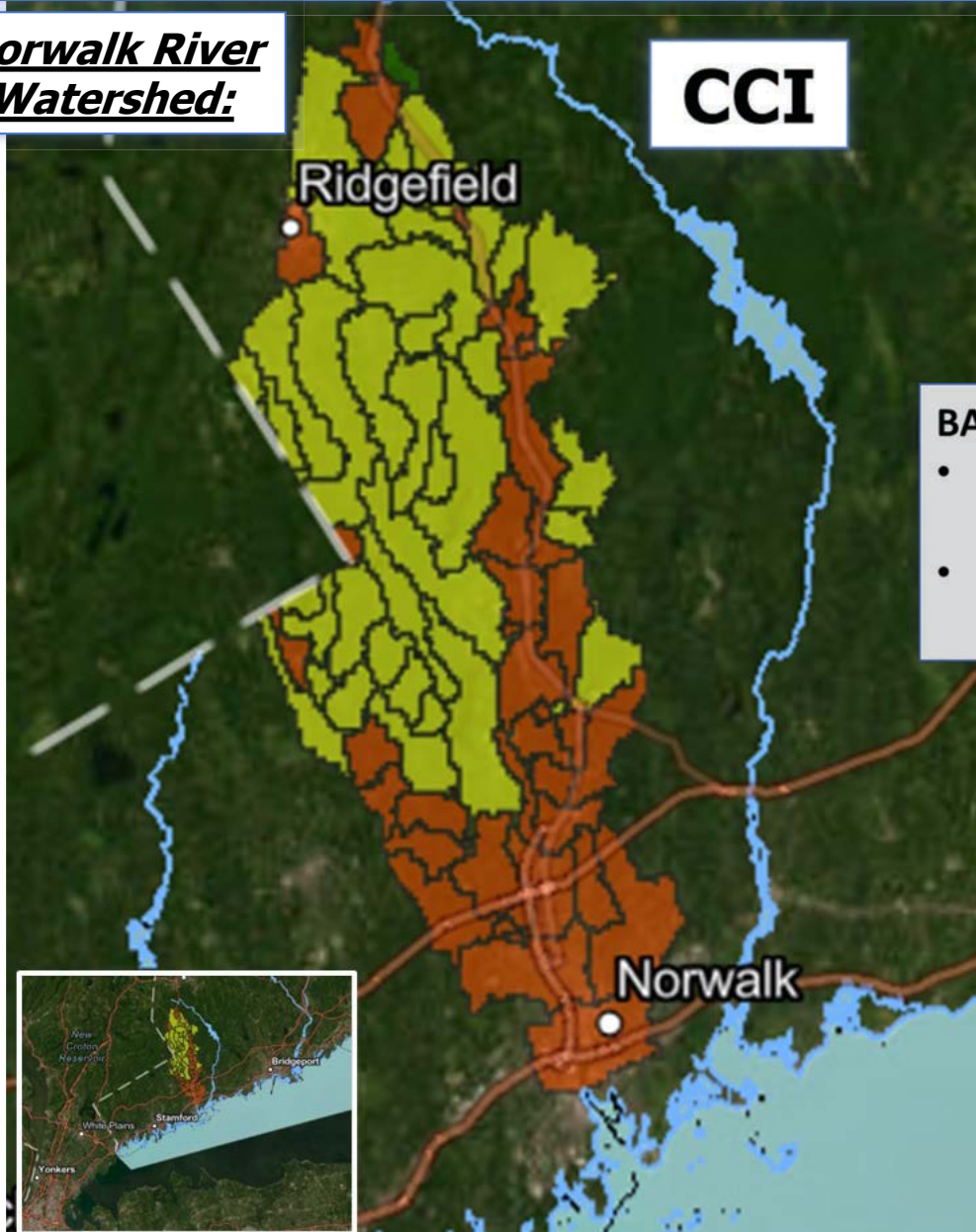
Total Nitrogen	Natural		Current		Target		BAC	
	Sub-watershed	Tons/yr	EF	Tons/yr	EF	Tons/yr	EF	Tons/yr
Latimer Brook	5.7	1.0	13.4	2.4	17.0	3.0	8.5	1.5
Oil Mill Brook	1.7	1.0	3.6	2.2	5.0	3.0	2.2	1.3
Niantic River	2.3	1.0	9.8	4.2	7.0	3.0	4.6	2.0
Coastal	0.4	1.0	3.8	10.2	1.1	3.0	2.5	6.7
NPS/SW Total	10.1	1.0	30.7	3.1	30.2	3.0	17.8	1.8
Sewage	0.0		0.0		0.0		0.0	
TOTAL	10.1	1.0	30.7	3.1	30.2	3.0	17.8	1.8

Sub-watershed Condition (CCI)	Current	Current Grade	BAC	BAC Grade
Latimer Brook	0.708	C	0.892	A
Oil Mill Brook	0.734	C+	0.913	A
Niantic River	0.465	D	0.766	B
Coastal	0.163	F	0.316	F+
TOTAL	0.598	D+	0.837	B

Tier	Combined Condition Index	EF
1	0.88 - 1.00	1.5 - 1.0
2	0.75 - 0.88	2.0 - 1.5
3	0.60 - 0.75	3.0 - 2.0
4	0.43 - 0.60	5.0 - 3.0
5	0.20 - 0.43	9.0 - 5.0
6	0.00 - 0.20	16 - 9.0

LWAT Decision Support Framework:

Norwalk River Watershed:



CCI

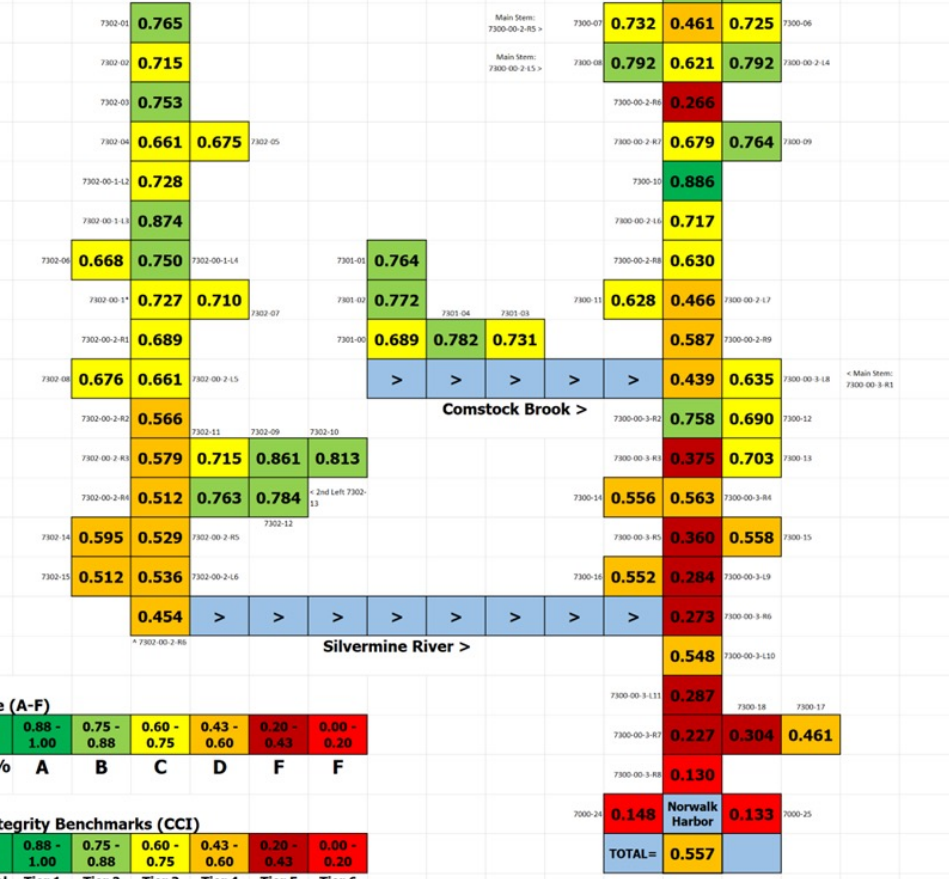
BAC =

- 100% Natural Riparian Buffer
- 50% Upland Ag-Like to Natural

Best Attainable Condition:

Sub-watershed Condition (CCI)	Current	Current Grade	BAC	BAC Grade
Comstock Br	0.537	D	0.746	C+
Silvermine R	0.434	D-	0.676	C
Norwalk River	0.263	F	0.474	D
TOTAL	0.332	F	0.557	D

CRM Class	CCI	Tier	Grade
Conservation	0.88 - 1.00	1	A
Conservation	0.75 - 0.88	2	B
Recovery	0.60 - 0.75	3	C
Recovery	0.43 - 0.60	4	D
Mitigation	0.20 - 0.43	5	F
Mitigation	0.00 - 0.20	6	F



Grade (A-F)

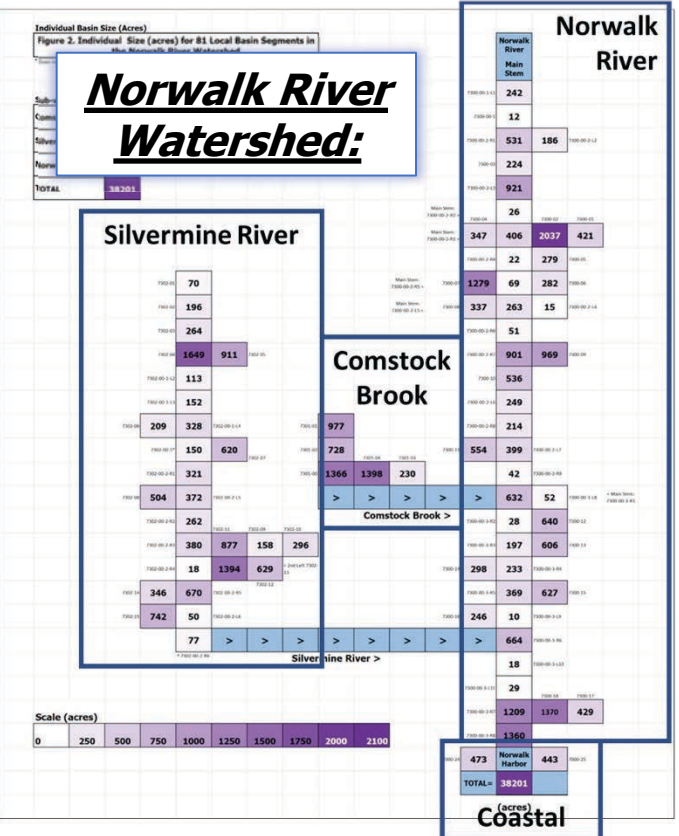
1.00	0.88 - 1.00	0.75 - 0.88	0.60 - 0.75	0.43 - 0.60	0.20 - 0.43	0.00 - 0.20
100%	A	B	C	D	F	F

Biointegrity Benchmarks (CCI)

1.00	0.88 - 1.00	0.75 - 0.88	0.60 - 0.75	0.43 - 0.60	0.20 - 0.43	0.00 - 0.20
Natural	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Tier 6

(CCI)

LWAT Decision Support Framework:



TN

Tier	Combined Condition Index	EF
1	0.88 - 1.00	1.5 - 1.0
2	0.75 - 0.88	2.0 - 1.5
3	0.60 - 0.75	3.0 - 2.0
4	0.43 - 0.60	5.0 - 3.0
5	0.20 - 0.43	9.0 - 5.0
6	0.00 - 0.20	16 - 9.0

**EF = 5.0
TIER 4
TARGET**

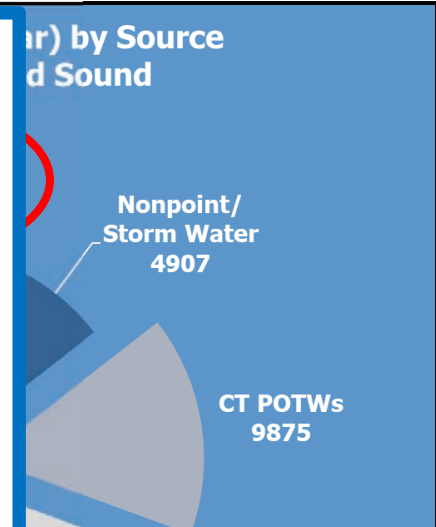
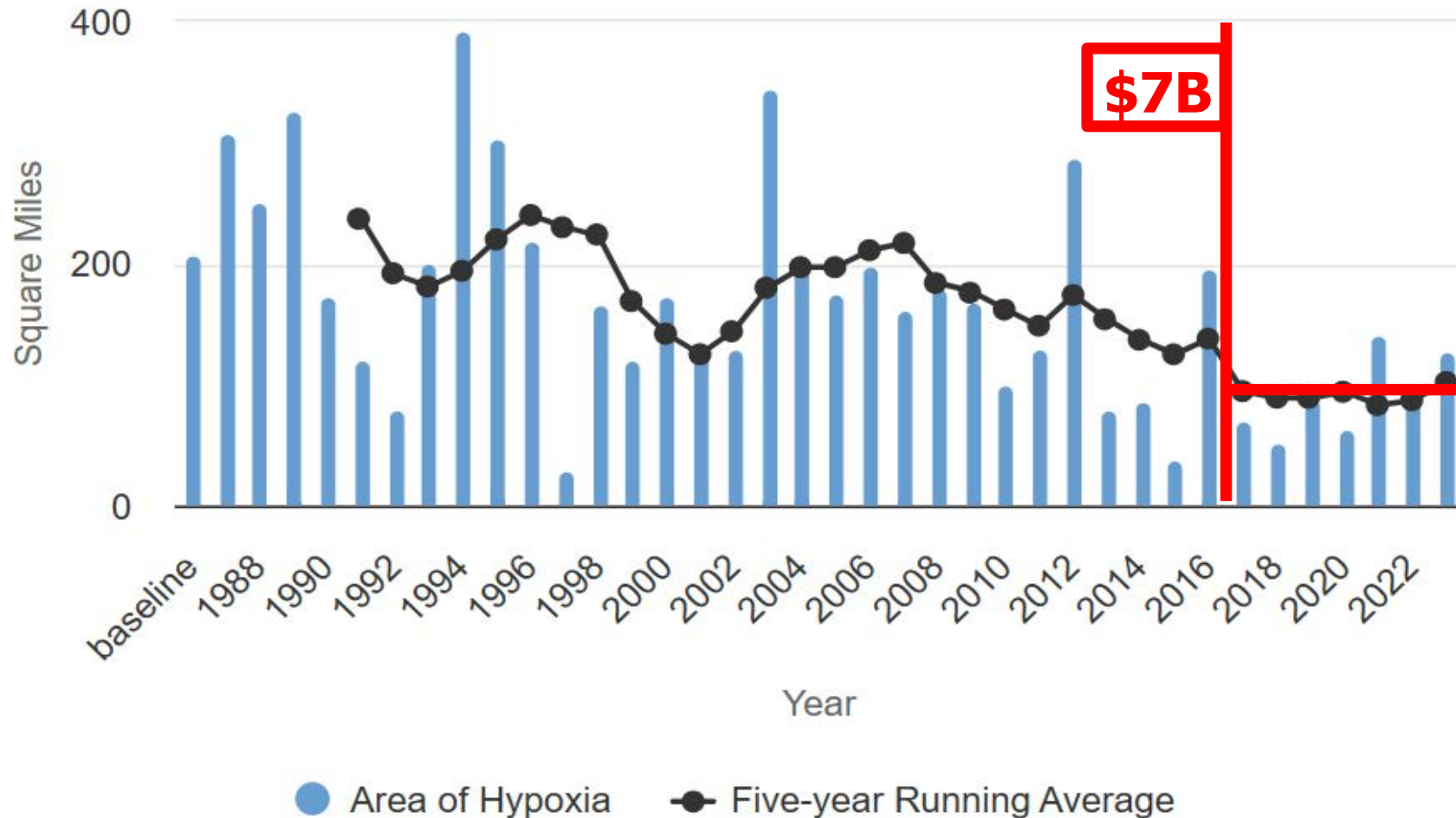
Sub-watershed	Total Nitrogen		Natural		Current		Target		BAC	
	Tons/yr	EF	Tons/yr	EF	Tons/yr	EF	Tons/yr	EF	Tons/yr	EF
Comstock Br	2.3	1.0	8.6	3.7	11.8	5.0	4.8	2.1		
Silvermine R	5.9	1.0	28.3	4.8	29.4	5.0	14.9	2.5		
Norwalk River	10.9	1.0	78.1	7.2	54.4	5.0	48.6	4.5		
NPS/SW Total	19.1	1.0	114.9	6.0	95.5	5.0	68.3	3.6		

Sub-watershed Condition (CCI)	Current	Current Grade	BAC	BAC Grade
Comstock Br	0.537	D	0.746	C+
Silvermine R	0.434	D-	0.676	C
Norwalk River	0.263	F	0.474	D
TOTAL	0.332	F	0.557	D

Application to Long Island Sound TN Management:

Source: Long Island Sound Study (LISS)

Hypoxia (Dissolved Oxygen \leq 3 mg/L) in Long Island Sound



Source
CT Land
CT Sewage
CT Total
LIS Land
LIS Sewage
LIS Basin

Load Reduction To Date	Additional Load Reduction
1000 Tons TN/yr	1000 Tons TN/yr
0.4	
6.3	
6.7	3.2
0.5	
24.1	
24.6	11.8

Making Nature Great Again

(Occam's Razor – the rationality of simple explanations)

Takeaway Conclusions:

Managing watersheds back to health is the ***best action that can be taken to meet biodiversity and nutrient/pollutant goals*** for:

- ❖ Resilient and Sustainable Social & Ecological Outcomes
 - ❖ Watershed and Stream Aquatic Ecosystems
 - ❖ Benefits that cascade downstream
 - ❖ Local Estuaries
 - ❖ Greater Long Island Sound

With contributing benefits to ***Human Health and Welfare*** including ***Environmental Justice*** in the watershed – ***Where People Live!***

Acknowledgements, Credits, and References:



Long Island Sound Study

A Partnership to Restore and Protect the Sound

LISS Enhancement Project
*Development of a Watershed and Nonpoint Source
Decision Support Framework and Tool at a Local Scale
using a Conservation Approach*

UConn

COLLEGE OF AGRICULTURE, HEALTH AND NATURAL RESOURCES

Center for Land Use Education & Research



Chet Arnold
Qian (Rachel) Lei-Parent
Emily Wilson

David Dickson
Cary Chadwick



CT DEEP
**Ambient Biological
Monitoring Program**

Credits:

Paulson, C., L. Stephens and W. Broley. 2017. Blueprint for One Water. Project 4660. Denver, CO: The Water Research Foundation.

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Source: Long Island Sound Study (LISS). Area of Hypoxia: <https://longislandsoundstudy.net/ecosystem-target-indicators/lis-hypoxia/>

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Source: UConn, CLEAR, CTECO (CT Env. Cond. Online. <https://maps.cteco.uconn.edu/https://maps.cteco.uconn.edu/projects/landcover/ct-highres/>

Source: UConn CLEAR Local Watershed Assessment Tool (LWAT): <https://experience.arcgis.com/template/68b1ebdd244a4f1a800a15af0e600307>

White House CEQ. 2022. <https://www.whitehouse.gov/wp-content/uploads/2023/12/Nature-Based-Solutions-Resource-Guide-2.0-FINAL.pdf>

Thank you!



***One Water:
All for One and
One for Water***

**NEWEA 2024
Annual Conference
& Exhibit**

January 21–24

**Boston Marriott Copley Place
Boston, Massachusetts**



Paul E. Stacey

**FOOTPRINTS
IN THE WATER**

Working to Make Nature Great Again

FootprintsInTheWater@outlook.com