Why Aren't All Reclamationists Considered Ecological Engineers?

Robert W. Nairn and William H.J. Strosnider

The University of Oklahoma, Gallogly College of Engineering, School of Civil Engineering and Environmental Science

CREW – Center for Restoration of Ecosystems and Watersheds, University of Oklahoma

Saint Francis University, Founded 1847

Saint Francis University Environmental Engineering

Center for Watershed Research & Service (CWRS)

Appalachian Regional Reforestation Initiative (ARRI)
West Virginia Mine Drainage Task Force
American Society of Mining and Reclamation

What's Next for Reclamation?
Joint Conference
April 9 - 13, 2017
Morgantown, WV

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A New Way of Thinking

- American Society of Civil Engineers 2017 Infrastructure Report Card
  - Roads, bridges, water and wastewater treatment facilities
  - "Gray" infrastructure

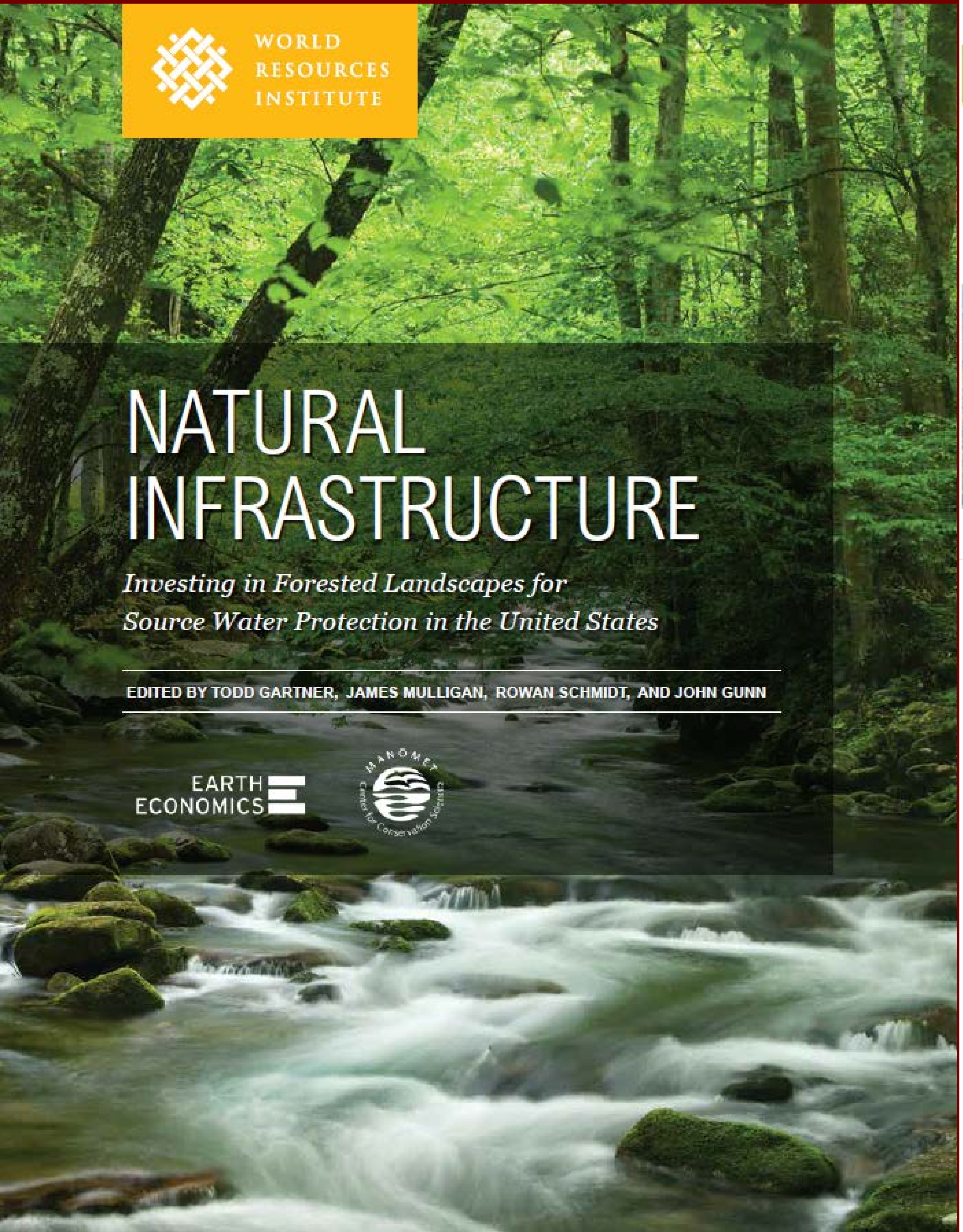
- "Green" or "natural" infrastructure provides multiple technical, social and economic co-benefits

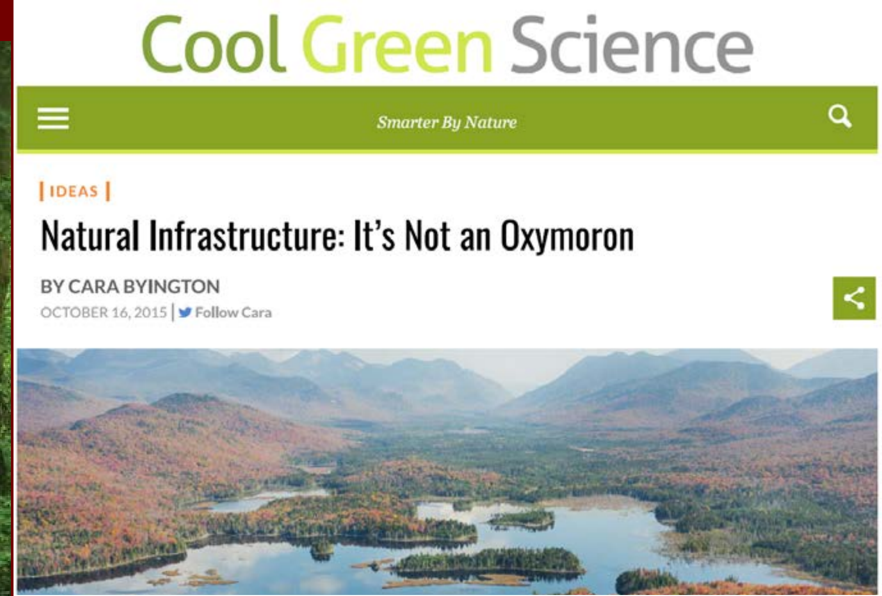

Natural Infrastructure

Natural Infrastructure

- Conservation of intact natural ecosystems
- Creation and restoration of **ecologically engineered** ecosystems
- Green vs. gray infrastructure

North Texas Municipal Water District, East Fork Raw Water Supply Project and John Bunker Sands Wetlands Center




Cool Green Science

Smarter By Nature

IDEAS

Natural Infrastructure: It's Not an Oxymoron

BY CARA BYINGTON
OCTOBER 16, 2015 | Follow Cara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TODD GARTNER AND KARA DIFRANCESCO AUGUST 4, 2015 Agriculture Energy Environment Society

From Gray to Green, Investing in Natural Infrastructure to Address Water, Food and Energy Nexus* Challenges

Search

Thematic Areas

Agriculture
Climate Change
Energy
Environment

Recent extreme droughts and floods have forced an evaluation of how water infrastructure impacts other sectors, highlighting the need for a multi-disciplinary, cross-sectoral approach to balance environmental, social and economic concerns against a backdrop of climate change.

Investing in natural infrastructure to achieve food, water and energy security can be transformational in making water available for agriculture, electricity generation and water supply. The success of natural infrastructure investments depends on partnerships between sectors and the rise of champions to scale up natural infrastructure to make iter en part of the solution for current and future resource challenges.

The Economic Case for Ecosystems

Green-Gray Analysis for the Portland Water District—Best Case for Green

Infrastructure Options	**Quantity**	**Present-Value Costs (millions)**
Riparian buffers (acres)	367	$16.33
Culvert upgrades and replacements (units)	44	$1.38
Certification (acres)	4,699	$0.14
Reforestation (acres)	9,395	$14.67
Conservation easements—80 percent forest cover (acres)	13,215	$11.85
Green infrastructure total		$44.37
Gray infrastructure (membrane filtration) total		$155.28
Savings (green minus gray):		*-$110.91*

Talberth et al. 2013. Green versus Gray: Nature's Solutions to Infrastructure Demands. *Solutions* 4(1): 40-47.

What is Ecological Engineering?

Olentangy River Wetland Research Park
The Ohio State University

Approaches to Environmental Problem Solving

Conventional

- Anthropocentric
- Work against natural processes
- Energy-intensive
- Nonrenewable resource-intensive

Innovative

- Mutualistic
- Work with natural processes
- Renewable energy use
- Renewable resource use

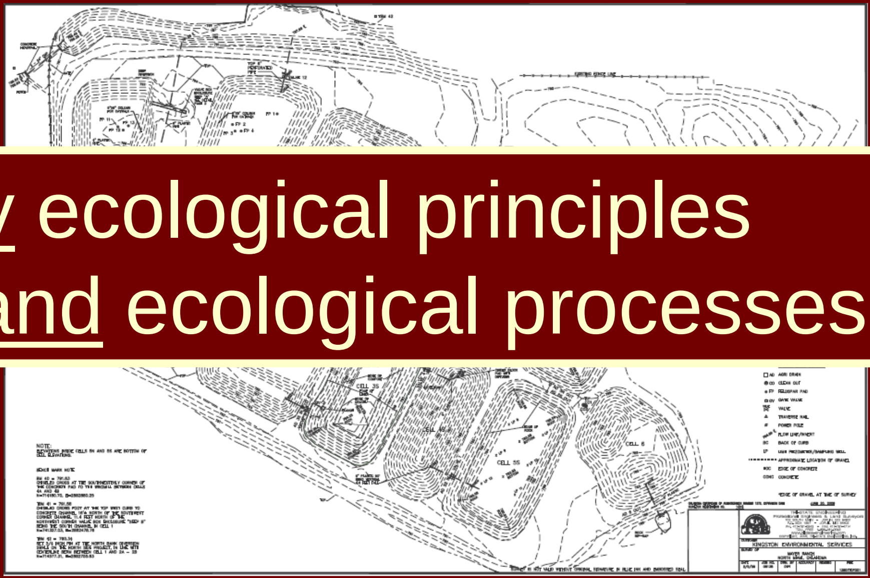
Innovative Environmental Problem Solving

Ecology

- Study of our house
- Relationships between organisms / environment
- Descriptive science

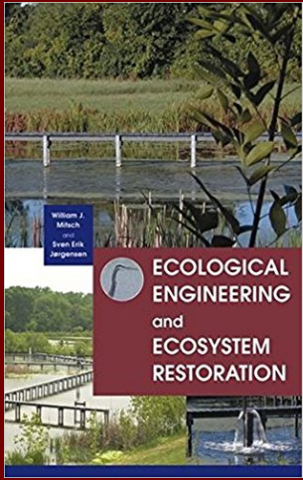
Engineering

- Application of science to meet societal needs
- Design-oriented
- Prescriptive solutions



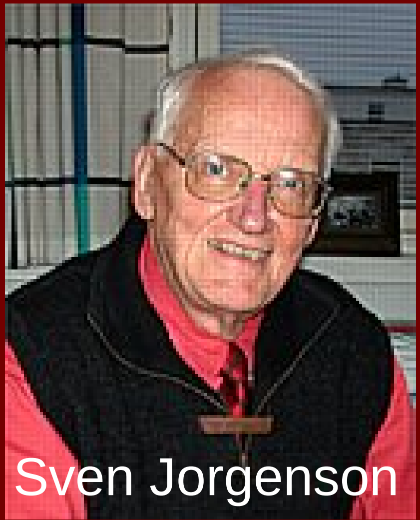
Ecologists must apply ecological principles
Engineers must understand ecological processes

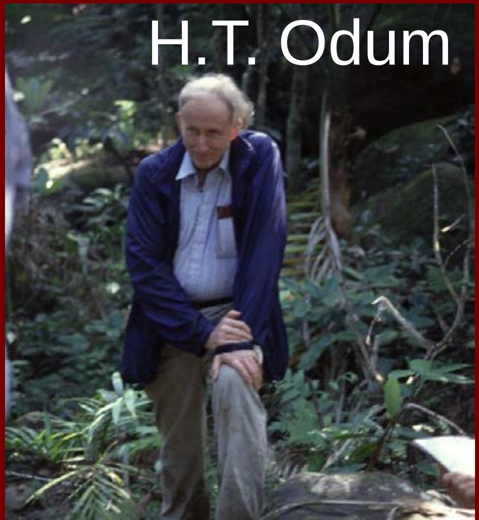
Ecological Engineering



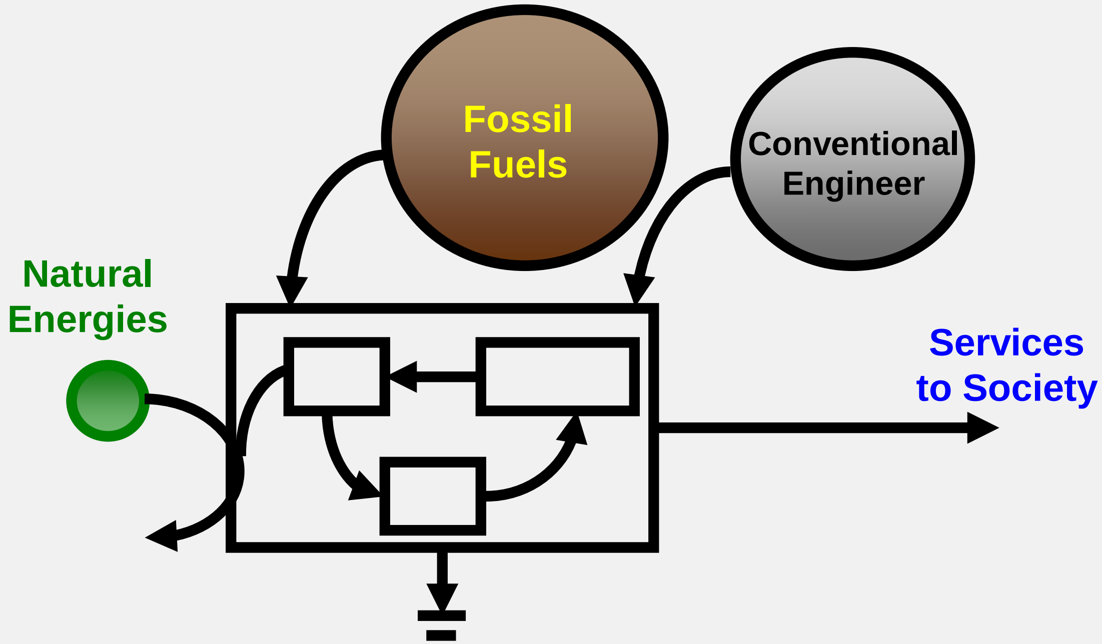
The design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both

(Mitsch and Jorgenson 2004)



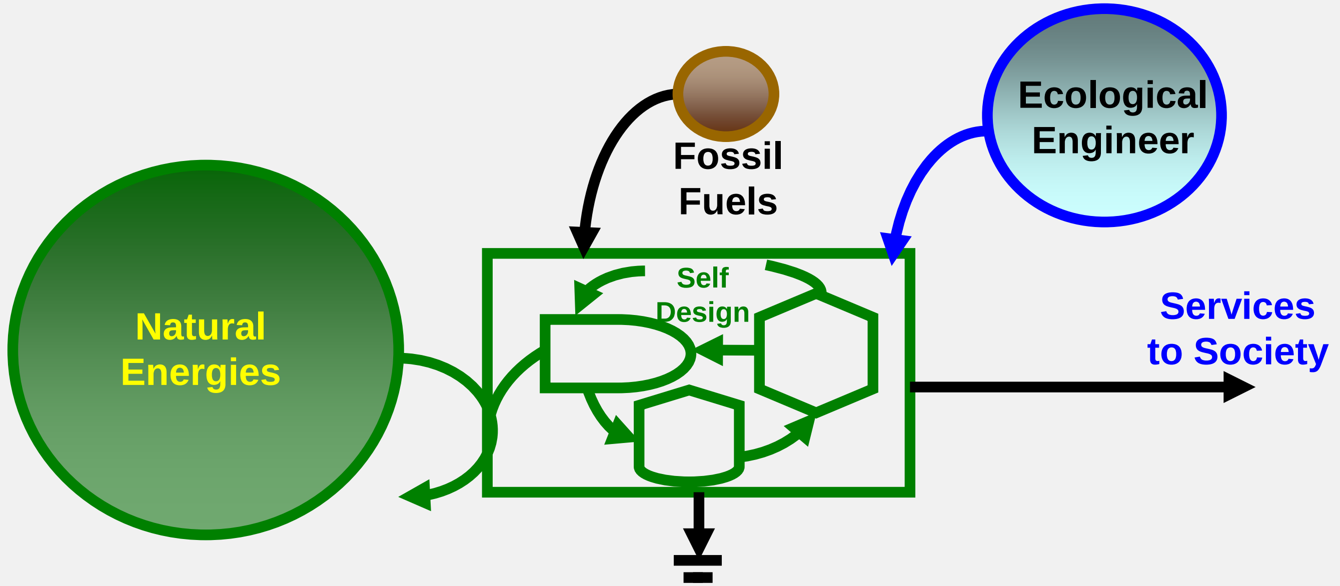


The Father of Ecological Engineering, Ecological Economics, and Ecological Modeling



Conventional Engineering

Ecological Engineering



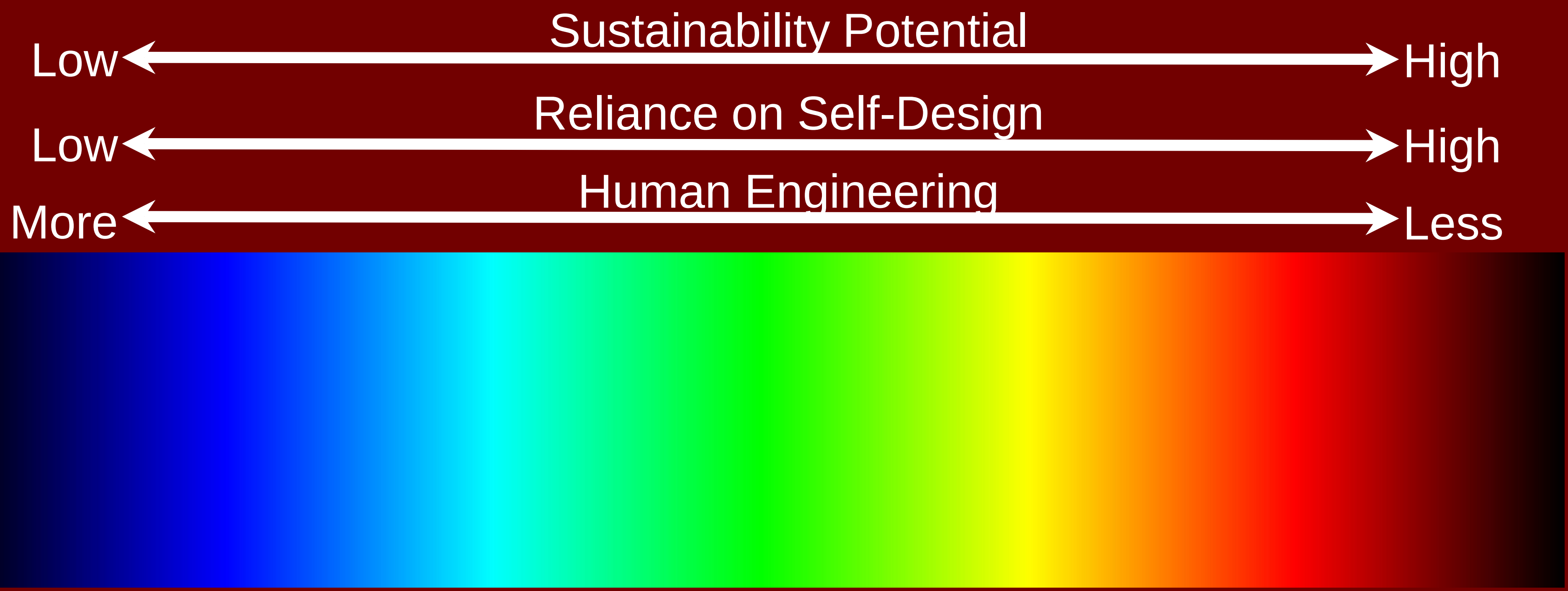
Ecological Engineering

- Goals
  - Restoration of disturbed or polluted ecosystems
  - Development of new sustainable ecosystems with human and ecological value
  - Prescriptive approach to problem solving
- ASMR Purpose
  - "encourage and assist... efforts to reestablish, enhance, or protect our natural resources disturbed by mining or other human activities, or... natural events"

Tenets of Ecological Engineering

- Self-design
  - Ecosystems self-organize to maximize efficiency
  - Pay attention to your Mother!
- Biological components
  - Explicitly includes bio-processes and species
  - Including humans!
- Sustainability
  - Solar energy-based
  - Modest human influence
- Integration
  - Blending engineered and natural landscapes

Ecological Engineering Spectrum of Practices



BioSphere 2
Biomanipulation
Prairie restoration
Soil bioremediation
Wetland creation
Wetland restoration
Solar aquatics
Wastewater wetlands
Mine land reclamation
Agroecological engineering

(Mitsch and Jorgenson 2004)

Ecological Engineering
Spectrum of Mining Reclamation Practices

Sustainability Potential
Low ⟷ High

Reliance on Self-Design
Low ⟷ High

Human Engineering
More ⟷ Less

Semi-passive treatment

Vertical flow bioreactors

Al flushing beds

Biochemical reactors

Fe oxidation ponds/ wetlands

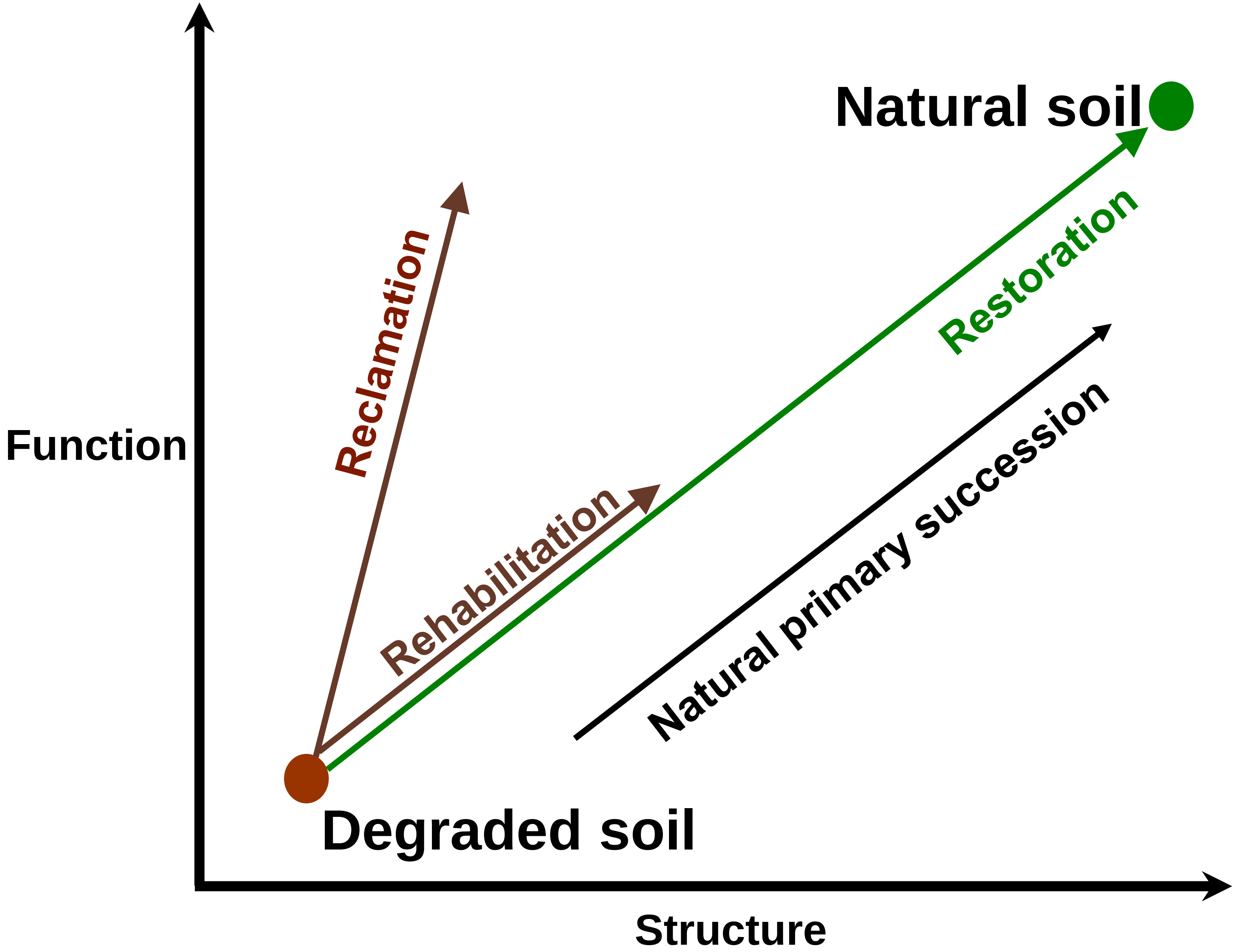
Mn limestone beds

Open limestone channels

Polishing Wetlands

Anoxic limestone drains

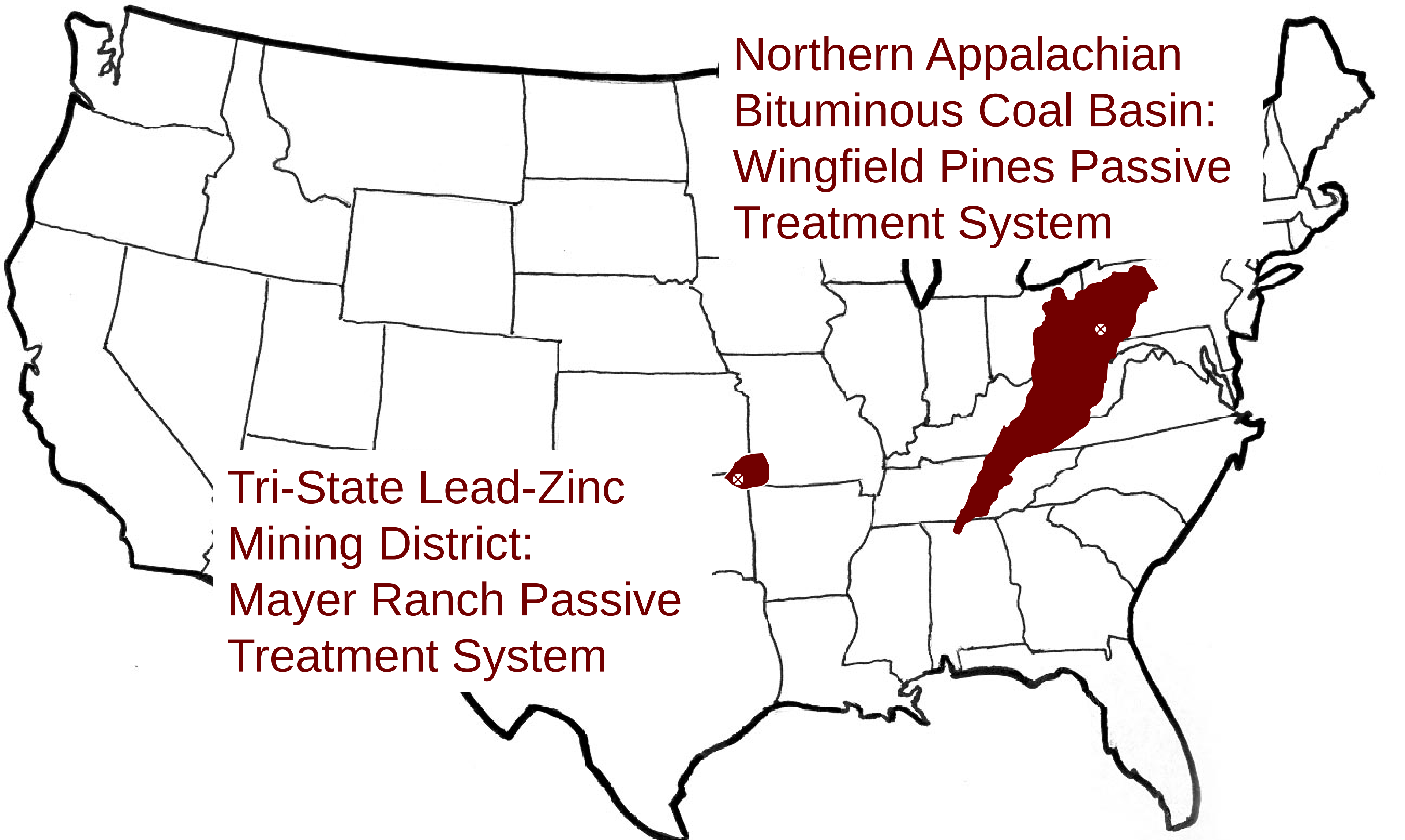
Soil Restoration (after Bradshaw 1997)



Why Aren't All Reclamationists Considered Ecological Engineers?

- Mine reclamationists inherently recognize critical roles of self-design, biological development and sustainability
- Reclamationists build ecosystems!
- US-based "engineering bias" may play role

Ecological Engineering Case Studies



Wingfield Pines

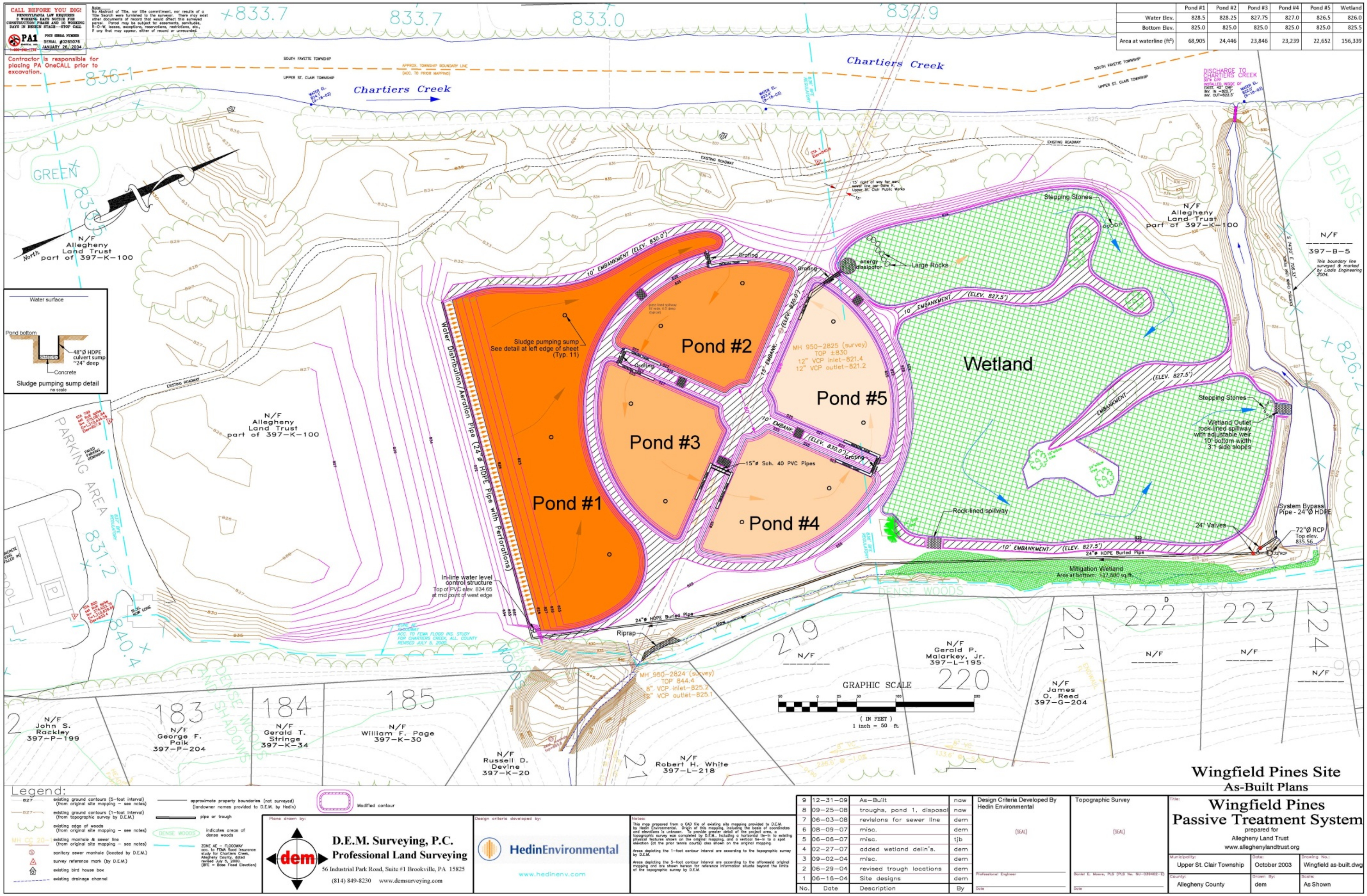
- Abandoned strip/deep mines
- Golf / swimming
- 80 acres
- Polluted Chartiers Creek for decades

HedinEnvironmental

Allegheny Land Trust

Helping local people save local land.

Schroth, 2013 PA-AMRC
Hedin, 2015 PA-AMRC



	Pond #1	Pond #2	Pond #3	Pond #4	Pond #5	Wetland
Water Elev.	828.5	828.25	827.75	827.0	826.5	826.0
Bottom Elev.	825.0	825.0	825.0	825.0	825.0	825.5
Area at waterline (ft^2)	68,905	24,446	23,846	23,239	22,652	156,339

Hedin, 2015 PA-AMRC


Hedin, 2015 PA-AMRC

Hedin, 2015 PA-AMRC


Hedin, 2015 PA-AMRC

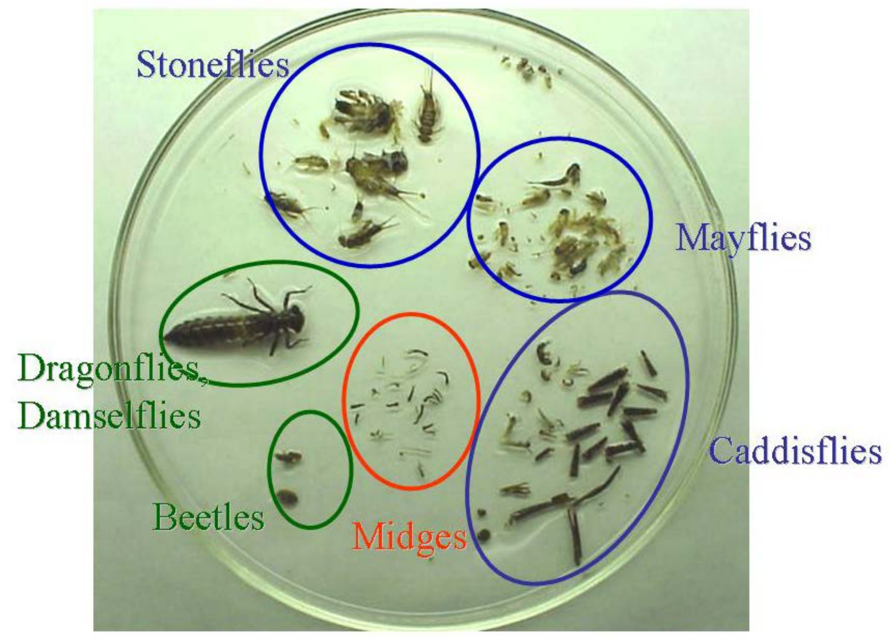
Water Treatment Performance

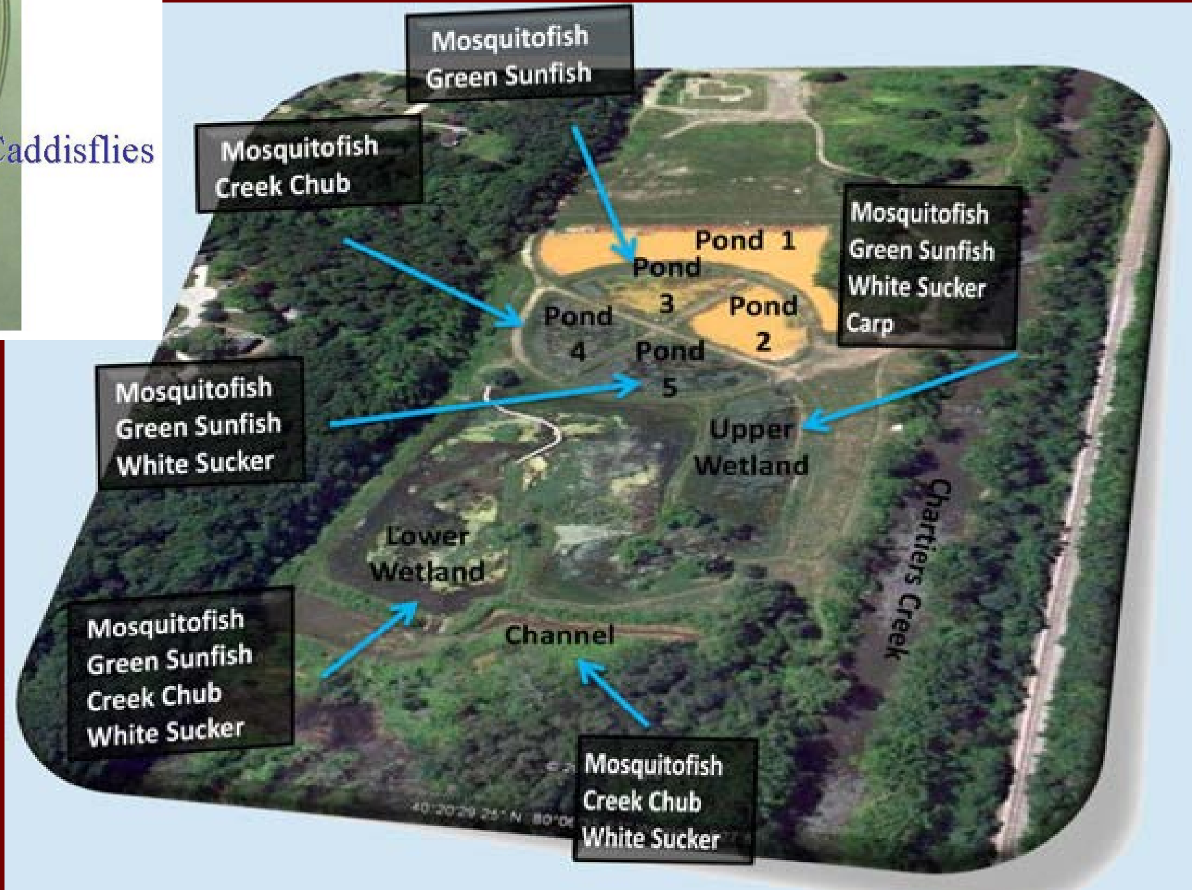
Schroth, 2013 PA-AMRC
Hedin, 2015 PA-AMRC

2009 - 2016

	Flow gpm	pH s.u.	Fe mg/L	Mn mg/L	SO_4 mg/L	TSS mg/L
Influent	1,444	6.6	15.1	0.3	311	24
Pond out	na	7.8	2.9	0.2	303	12
Wetland out	na	7.9	1.1	<0.1	314	4

True Ecological Engineering





Schroth, 2013 PA-AMRC

Vibrant Habitat or Maintenance Liability?

- Muskrat and beaver impacts
  - Vegetation
    - Woody growth
    - Macrophytes
  - Flow
  - Berms

- What if design goals were more inclusive?
  - Treatment “eco”system

Impacts to Water Quality

- Seasonal variability
- Wetland filter less effective in winter
  - muskrats ate much vegetation
  - created swimming channels through wetland
- Vegetation always has come back
  - 2016 densest wetland vegetation to date
- Site owner (Allegheny Land Trust) learned that vegetation comes back so prefers not to “manage” muskrats


June 2016


February 2017

Ecological success conflicts with land use

- Site developed as leash-free dog walking zone
- Passive system very popular dog walking area because of trails (berms)
- Dense summer wetland vegetation attracts birds and bird watchers
- Bird watchers conflict with dogs
- In 2016, Virginia Rail (*Rallus limicola*) nested and fledged young – first time observed in Allegheny County, PA
- In 2017, dogs will be excluded

Tar Creek (OK) Superfund Site

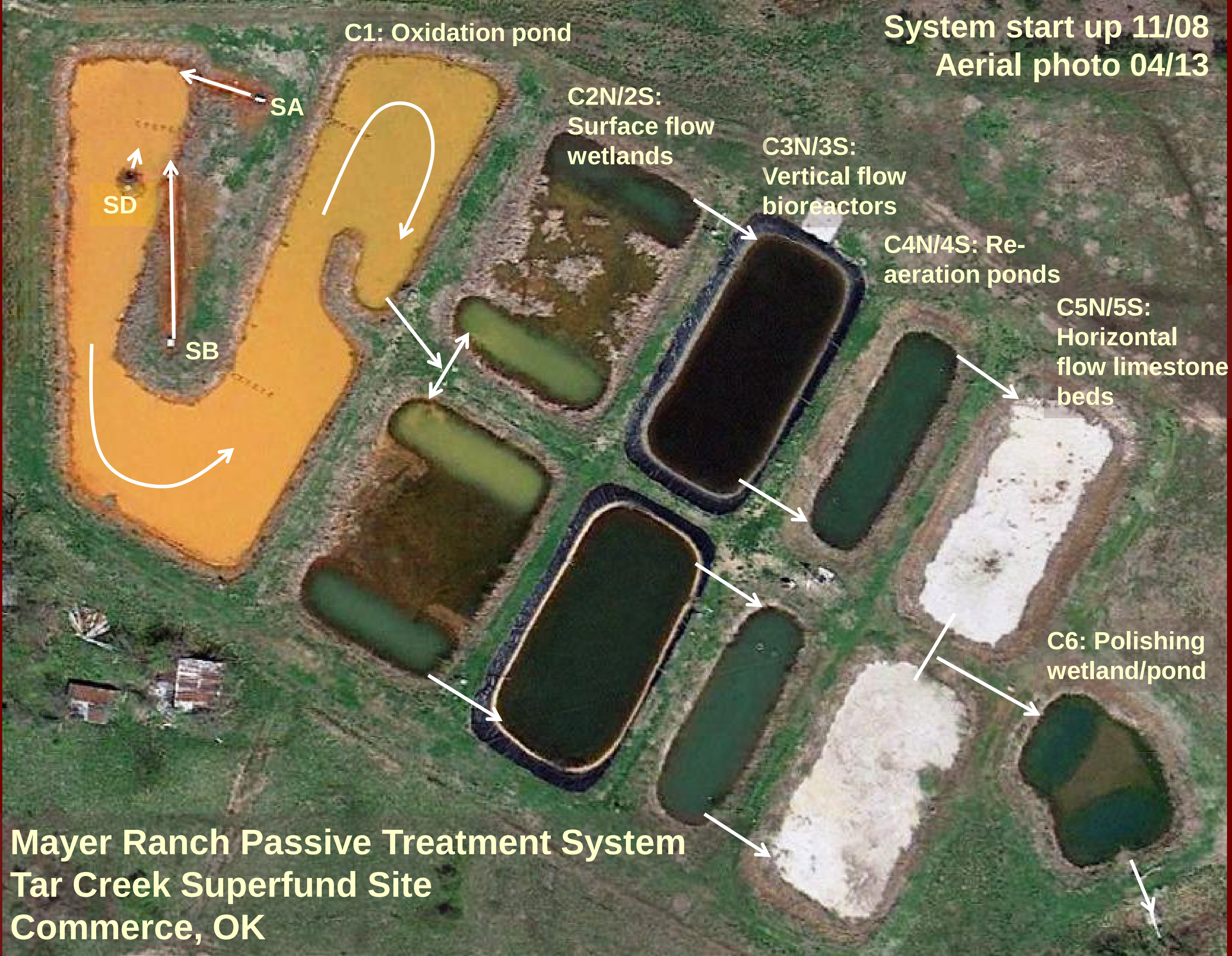
- Part of Tri-State Mining District
- National Priorities List (1983)
- 137-km^2 watershed
- Elevated Fe, Zn, Cd, Pb, As in water, chat, soils and biota
- Ten Native American Tribes

Tar Creek Surface and Ground Water Decision

- Initial artesian discharges (1979)
- USEPA concluded that (1984):

  *"impacts to (surface waters) are due to **irreversible man-made damages** resulting from past mining operations at the site"*

- Fund-balancing waiver used
  - Costs prohibitively high to address surface water contamination


System start up 11/08
Aerial photo 04/13
C1: Oxidation pond
SA
SD
SB
C2N/2S:
Surface flow
wetlands
C3N/3S:
Vertical flow
bioreactors
C4N/4S: Re-
aeration ponds
C5N/5S:
Horizontal
flow limestone
beds
C6: Polishing
wetland/pond
Mayer Ranch Passive Treatment System
Tar Creek Superfund Site
Commerce, OK

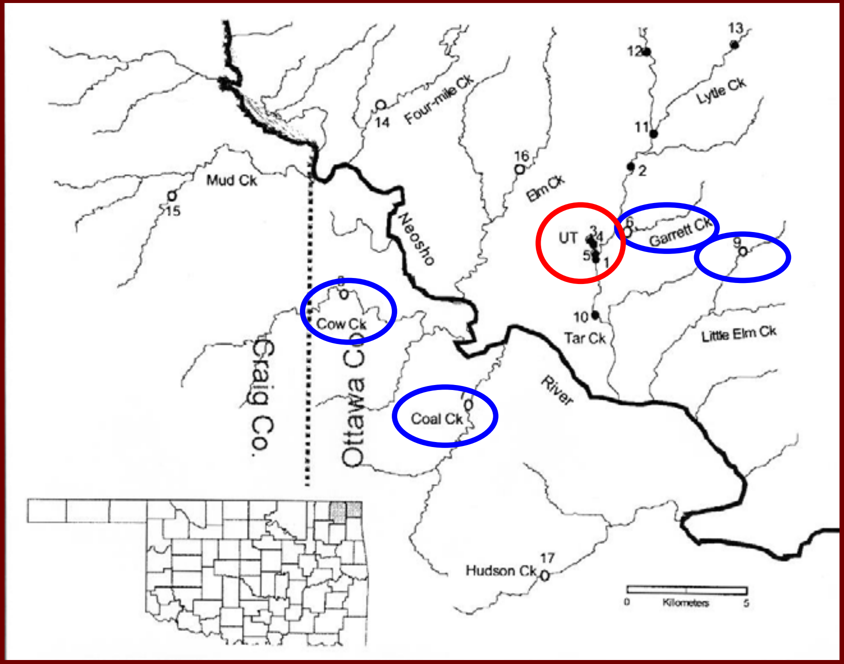
Mean Water Quality Changes

	In	Out
pH	5.95	7.02
Tot. Alk. (mg/L)	393	224
Net Alk. (mg/L)	29	224
Fe (mg/L)	192	0.13
Zn (mg/L)	11	0.25
Ni (mg/L)	0.97	0.15
Cd (μg/L)	17	<PQL
Pb (μg/L)	60	<PQL
As (μg/L)	64	<PQL
SO_4^{-2} (mg/L)	2239	2057

Receiving stream downstream of system effluent

Receiving Stream Ecological Recovery

- Marked improvement in water quality
- Early indications of return of fish community



Selected Unnamed Tributary fish data (W.J. Matthews, OU Biology)

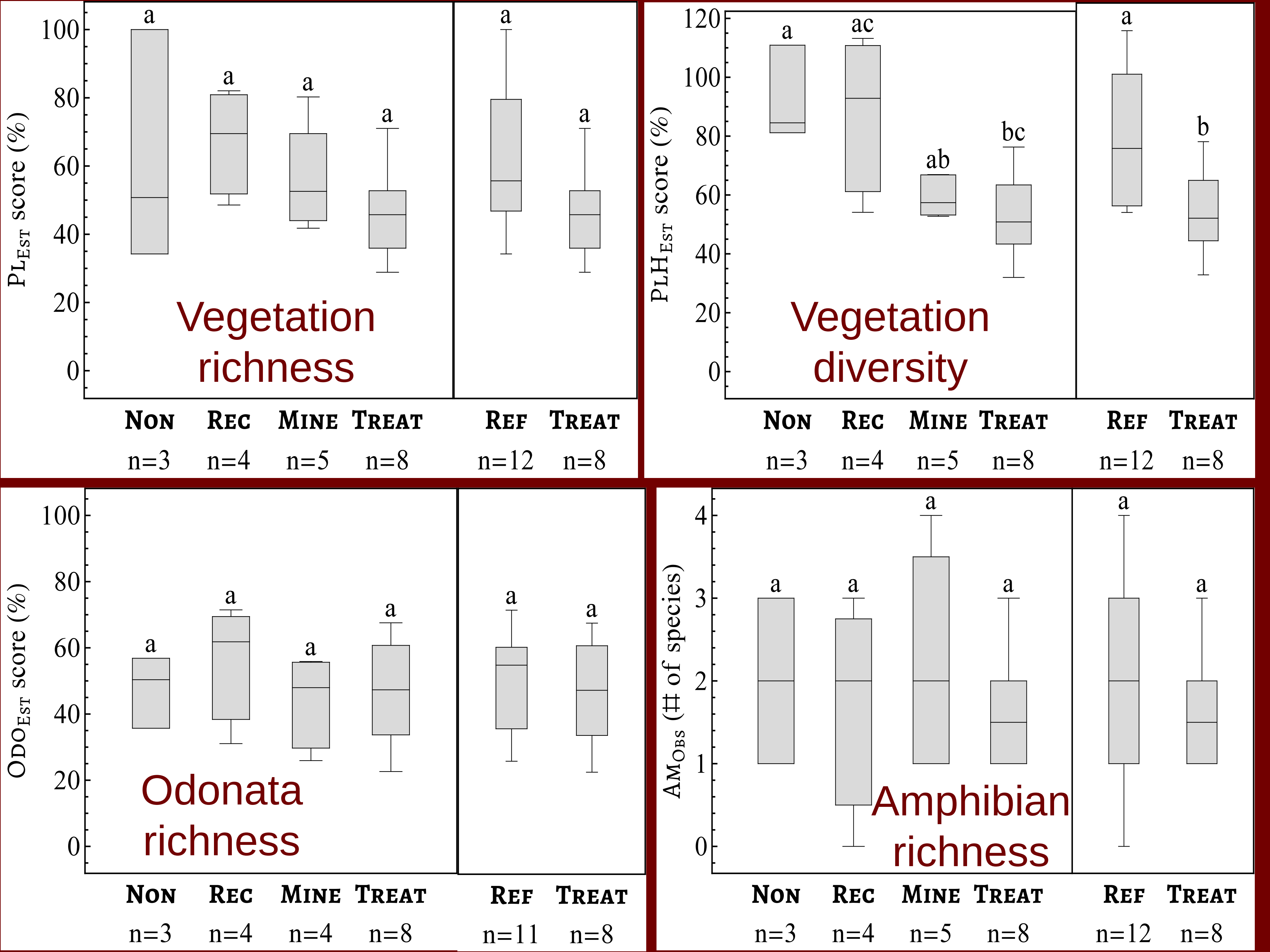
		Catch per unit effort (CPUE)	
Scientific name	Common name	2005-07	2009-16
Gambusia affinis	Western mosquitofish	39.24	187.60
Lepomis cyanellus	Green sunfish	0.81	16.80
Lepomis macrochirus	Bluegill	1.00	3.00
Lepomis megalotis	Longear sunfish	0.02	6.80
Notemigonus crysoleucas	Golden shiner	0.17	0.60
Lepomis gulosus	Warmouth	0.07	1.0
Lepomis microlophus	Redear sunfish	0	18.00
Lepomis sp.	Sunfish hybrid	0	2.5
Labidesthes sicculus	Brook silversides	0	2.0
Etheostoma gracile	Slough darter	0	0.80
Ameiurus melas	Black bullhead	0	0.40
Fundulus notatus	Blackstriped topminnow	0	0.40
Pomoxis annularis	White crappie	0	0.30
Micropterus salmoides	Largemouth bass	0	0.20
	Species richness	6	14

Passive treatment system as an ecosystem?

- Treat - Pond-like cells at MRPTS
- Mine - Ponds in abandoned mining area
- Rec - Ponds in reclaimed mining area
- Non - Ponds not in mining area
- Ref – Combination of Mine, Rec, Non

Passive treatment system as an ecosystem?

Group	Kingdom / Phylum	Trophic Level	Dispersal	Sample Method
Plant	Vascular Plants	Producer	Varies	Quadrats
Odonata	Arthropod	Carnivore	Flight	Visual Survey
Amphibian	Vertebrate	Herbivore (larva) Carnivore (adult)	Walking	Aquatic Traps, Acoustic Monitoring, Visual Survey


Vegetation richness
PL_{EST} score (%)
Non n=3
Rec n=4
Mine n=5
Treat n=8
Ref n=12
Treat n=8
Vegetation diversity
PLH_{EST} score (%)
Non n=3
Rec n=4
Mine n=5
Treat n=8
Ref n=12
Treat n=8
Odonata richness
ODO_{EST} score (%)
Non n=3
Rec n=4
Mine n=4
Treat n=8
Ref n=11
Treat n=8
Amphibian richness
AM_{OBS} (# of species)
Non n=3
Rec n=4
Mine n=5
Treat n=8
Ref n=12
Treat n=8

Vibrant Habitat or Maintenance Liability?

- Muskrat and beaver impacts
  - Vegetation
    - Woody growth
    - Macrophytes
  - Flow
  - Berms
- What if design goals were more inclusive?
  - Treatment “eco”system


Beaver maintenance of
v-notch weir

Beaver deceiver fencing

Beaver deceiver fencing


Southeast Commerce Passive
Treatment System, OK

Why Aren't All Reclamationists Considered Ecological Engineers?

American
Ecological
Engineering
Society

- Perhaps they should be!
- AEES Certified Ecological Designer (CED)
  - expertise in integration of science of ecology and practice of design
  - academic credentials, participation in workshop, portfolio of experience
- Bridge the gap between reclamation and restoration

Questions? Comments? Criticisms?

Very special thanks to Bob Hedin!

HedinEnvironmental