# Building a Better Wetland: Reference Data and Tools for Enhancing Wetland Projects

*A Mitigation and Restoration Design and Performance Webinar*
*20 May 2015*

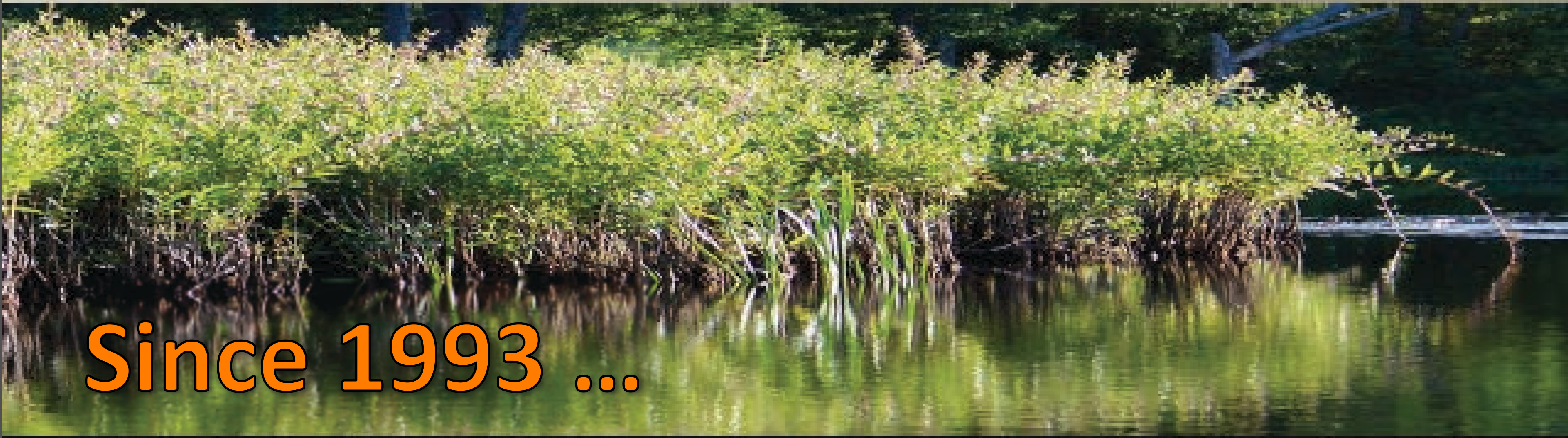

Robert P. Brooks, Director
Riparia at Penn State


*a Center where science informs policy and practice in wetlands ecology, landscape hydrology, and watershed management*

Hosted by: Natural Resources Conservation Service

# Riparia

A center where science informs policy & practice in wetlands ecology, landscape hydrology, and watershed management




Director: Robert P. Brooks

Associate Director: Denice H. Wardrop

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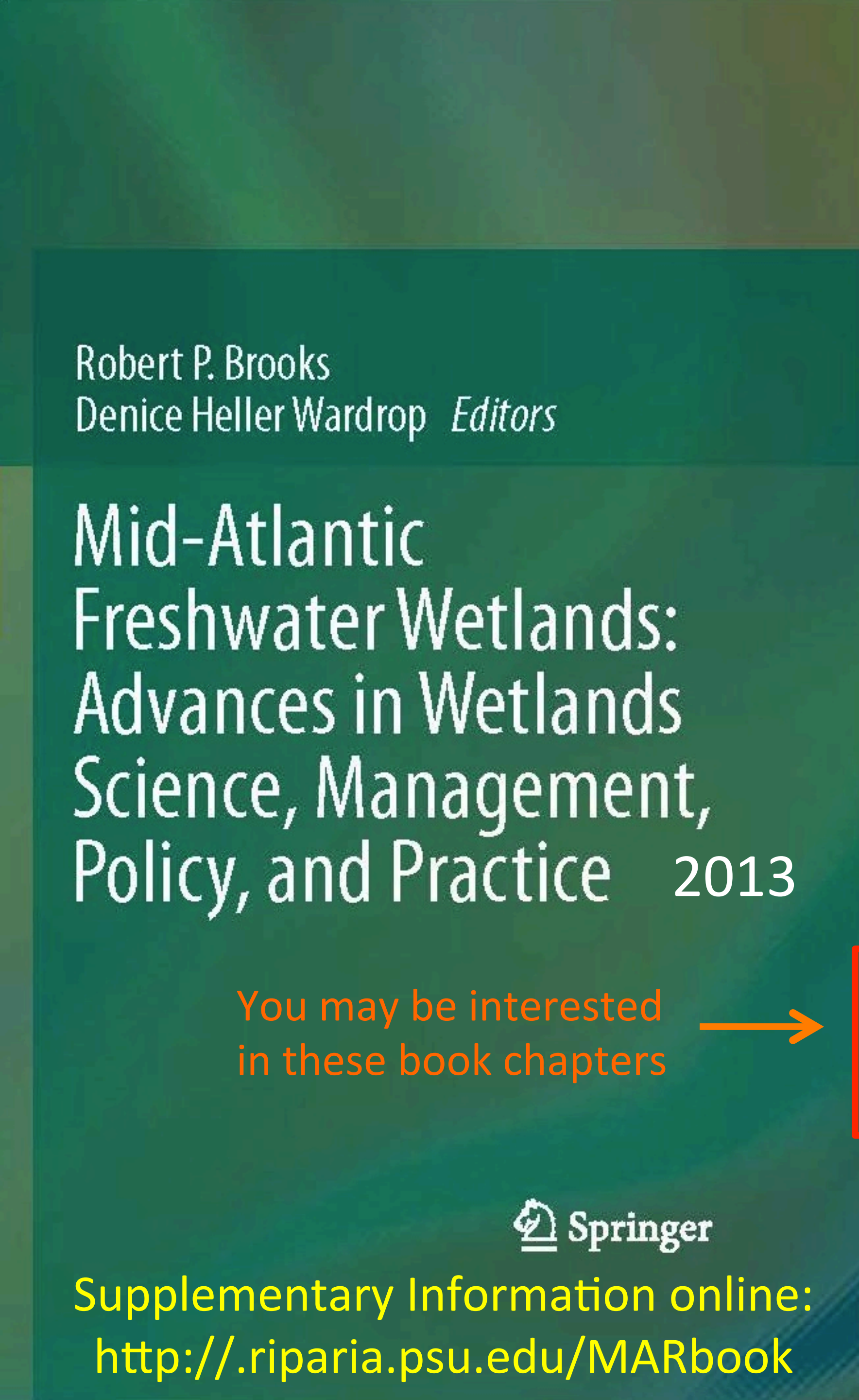



2013

You may be interested in these book chapters →

Supplementary Information online:
http://.riparia.psu.edu/MARbook


1 Aquatic Landscapes: the importance of integrating waters

2 Hydrogeomorphic (HGM) Classification, Inventory, and Reference Wetlands

3 Linking Landscape to Wetland Condition:
Case Study of Eight Headwaters

4 Hydrology of Mid-Atlantic Freshwater Wetlands

5 Hydric Soils of Mid-Atlantic Freshwater Wetlands

6 Hydrophytes of the Mid-Atlantic Region: Ecology, Communities, Assessment, and Diversity

7 Wetland-Riparian Wildlife of the Mid-Atlantic Region

8 Wetland-Riparian Birds of the Mid-Atlantic Region

9 Assessing Wetland-Riparian Amphibian and Reptile Communities

10 Freshwater Macroinvertebrates of the Mid-Atlantic Region

11 Monitoring and Assessment of Wetlands: Concepts, Case Studies, and Lessons Learned

12 Wetlands Restoration and Mitigation

13 Policy and Regulatory Programs Affecting Wetlands and Waters of the Mid-Atlantic Region

14 Conservation and Management of Wetlands and Aquatic Landscapes: Connectivity

## Acknowledgments:

Riparia at Penn State –faculty, staff, students

U.S. EPA– HQ & R3 (Regina Poeske) for *funding*

WHM Group, State College, PA – ex. mitigation site

NRCS Organizers & Hosts:

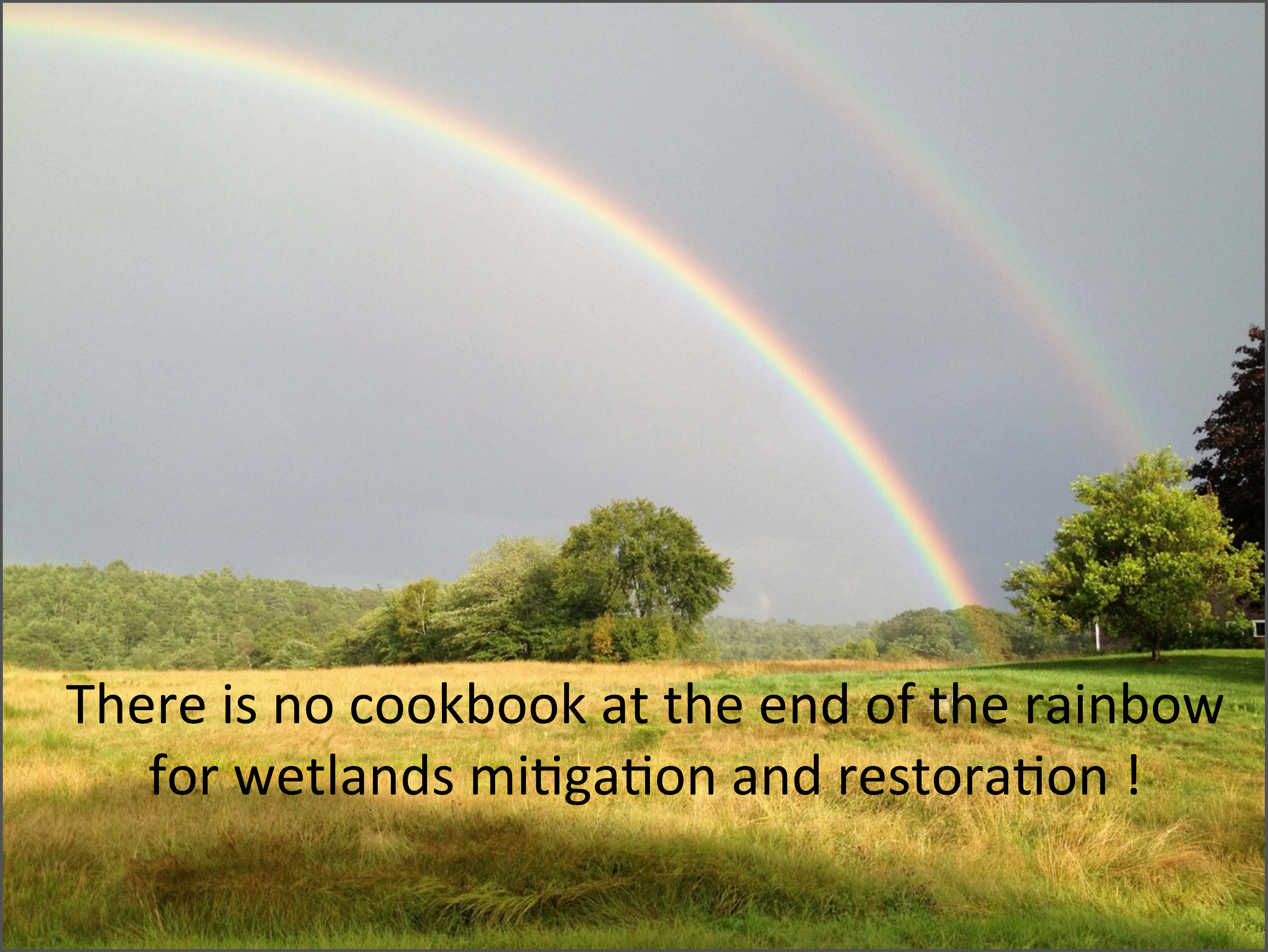
William Hohman (TX), Holli Kuykendall (NC),
Kim Farrell (NY)


# Webinar Outline

- Historical perspective on reference
- Hydrology and landscape:

  FOLLOW THE WATER !
- Reference data across a disturbance gradient
  - SHORT Q & A BREAK
- Mitigation & restoration projects

  under perform
- How reference data can improve mitigation & restoration
- Case studies and recommendations
- Availability of wetlands reference data, Q & A


There is no cookbook at the end of the rainbow
for wetlands mitigation and restoration !


We must embrace *reference* concepts for
wetlands mitigation and restoration,
if we want to be successful

## Historical Perspective

What is reference? Why do we need it? Definitions…

How do we use reference data?

1) assess condition
2) design projects
3) evaluate performance
4) …

## Current Applications – Mid-Atlantic Experience

Where do we get reference data? 3 Levels of Sampling

How can we use reference data? Condition & Mitigation

How do we distribute reference data to our best collective advantage? Riparia's Reference Interactive Database

"…So, when we experiment in planting forests, we find ourselves at last doing as Nature does. Would it not be well to *consult with Nature in the outset*? for she is the most extensive and experienced planter of us all…"

Henry David Thoreau
On the succession of trees, c1850s

"The time has come for science to busy itself with the earth itself. The first step is to *reconstruct a sample of what we had to begin with*."

Aldo Leopold, 1934, discussing a prairie restoration project on the UW-Madison Arboretum

"The characterization of *wetland reference condition is an important step* in the design of a wetland monitoring and assessment program."

EPA 2006 Elements of State Wetlands Program

**Concepts** – *when and where did they originate?*

Hughes et al. 1986. Regional reference sites for streams. Environ. Manage. [reference stream selection process]

Brooks and Hughes. 1986/88. [reference wetland selection process, standard biol. assessment guidelines] ASWM Proc.

Adamus & Brandt 1990. EPA [wetland stressors lit. review]

Kentula et al. 1992. EPA/Island Press book [reference wetlands for improving mitigation, restoration, creation]

Brinson 1993. [hydrogeomorphic concepts,
reference wetlands for functional assessments]

Smith et al. (1995) definitions for reference concepts:

**Reference Domain -** geographic area from where reference wetlands are selected
(also consider land use: forested, agriculture, urban)

**Reference Standards -** conditions exhibited by a group of reference wetlands that correspond to the highest level of functioning (*least disturbed, best attainable*, …)

**Reference Wetlands -** wetland sites that encompass the variability of a regional wetland subclass in a reference domain (*disturbance gradient of sites*)

Smith et al. (1995) definitions for reference concepts:

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**Reference Wetlands -** wetland sites that <u>encompass the variability</u> of a regional wetland subclass in a reference domain (*disturbance gradient of sites*)

**Mitigation** - (compensatory mitigation) – Using creation, restoration, enhancement or preservation of a wetland designed to offset permitted losses of wetland functions in response to special conditions of a permit.

**Restoration** - To return from a disturbed, degraded, or altered condition to a previously existing natural or altered condition by a human-induced action.

Creation - The conversion of a persistent area of one type to another type (e.g., upland to wetland).

Preservation - Protection of an existing and well-functioning wetland from prospective future threats.

Enhancement - The increase in one or more functions or values of all or a portion of an area.

Constructed Wetland - For the primary purpose of treating a contaminant or pollution in wastewater or runoff.


When choosing a site for wetlands mitigation or restoration, considering the landscape context and connectivity is critical.
Relative proportion of a landscape
Sources and availability of water
Type of wetland/water

SMALL: Headwater complex – stream and wetlands, PA

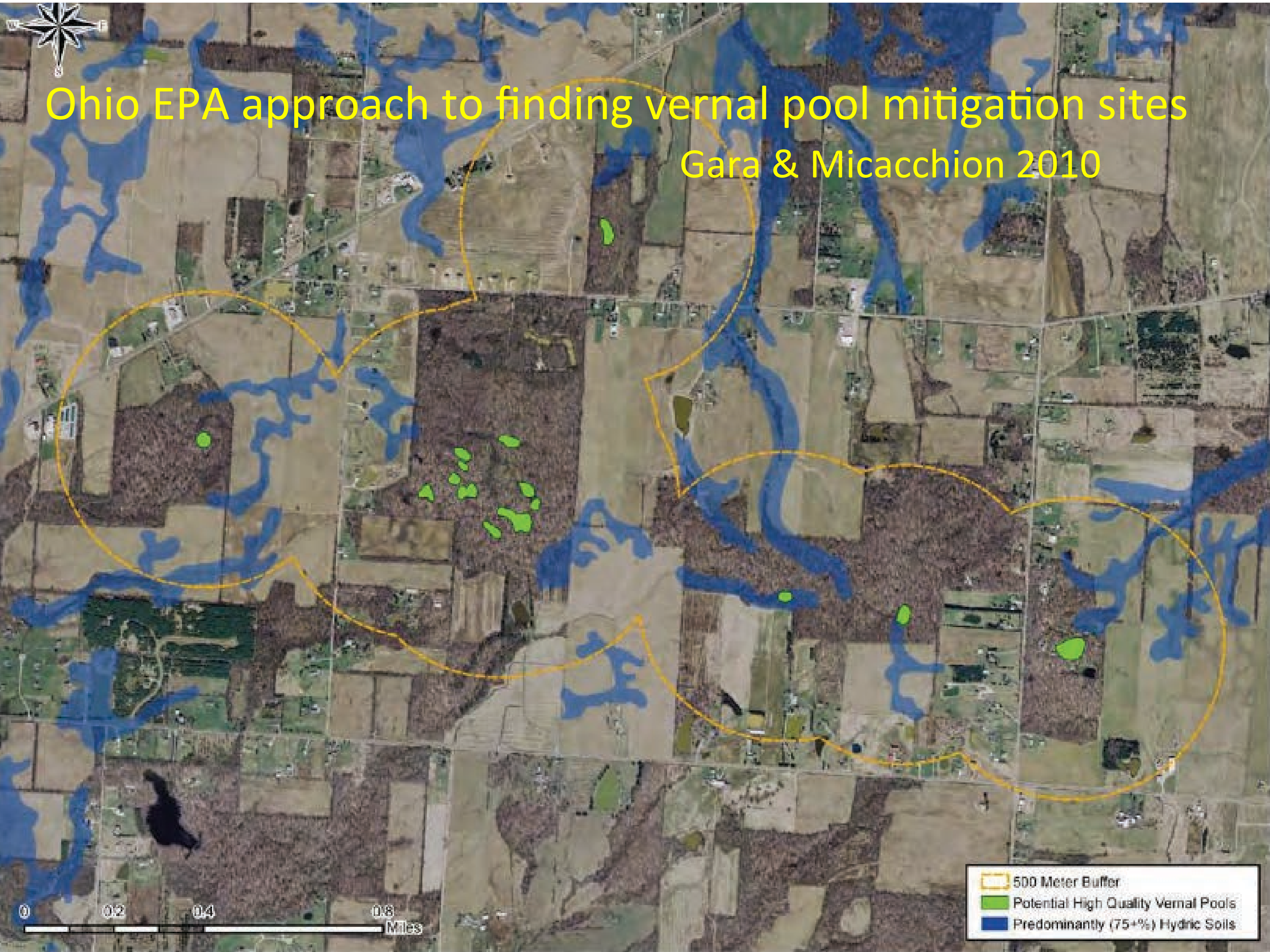
LARGE: Boreal forest wetlands, Downeast Maine

# SMALL: Depression temporary - *Vernal pool*, PA

Pond-breeding amphibians
Spotted salamander

# Ohio EPA approach to finding vernal pool mitigation sites

Gara & Micacchion 2010



# SMALL:  Depression , emergent - North Dakota


LARGE: Prairie Pothole Region, Waubay NWR, USFWS

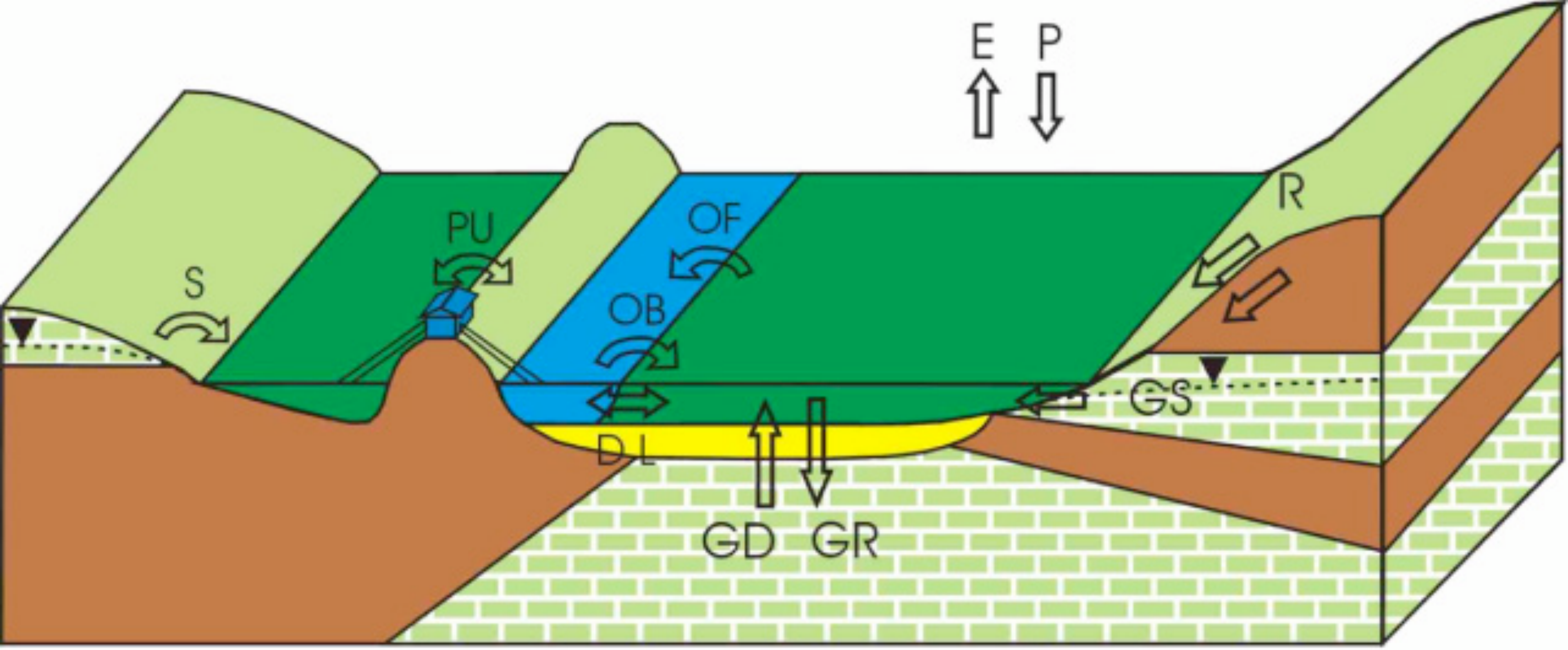
# LARGE: Natural forested riverine landscape, Texas

# Agricultural encroachment in riparian corridor, ND
*Potential restoration sites*

# Arid Regions - desert riparian zone, Truckee River
# Mid-latitude desert, 40 deg N lat., near Reno, NV

# Context for classification of wetlands and waters

1. Different types exist:
   - Vary structurally
   - Vary functionally
   - Vary in stressor responses
2. Where is the water and why it is there?
   - Nature resists compartmentalization, but what are the commonalities?
   - Realize that mixed types are common
   - FOLLOW THE WATER!




(Ramsar 2005)

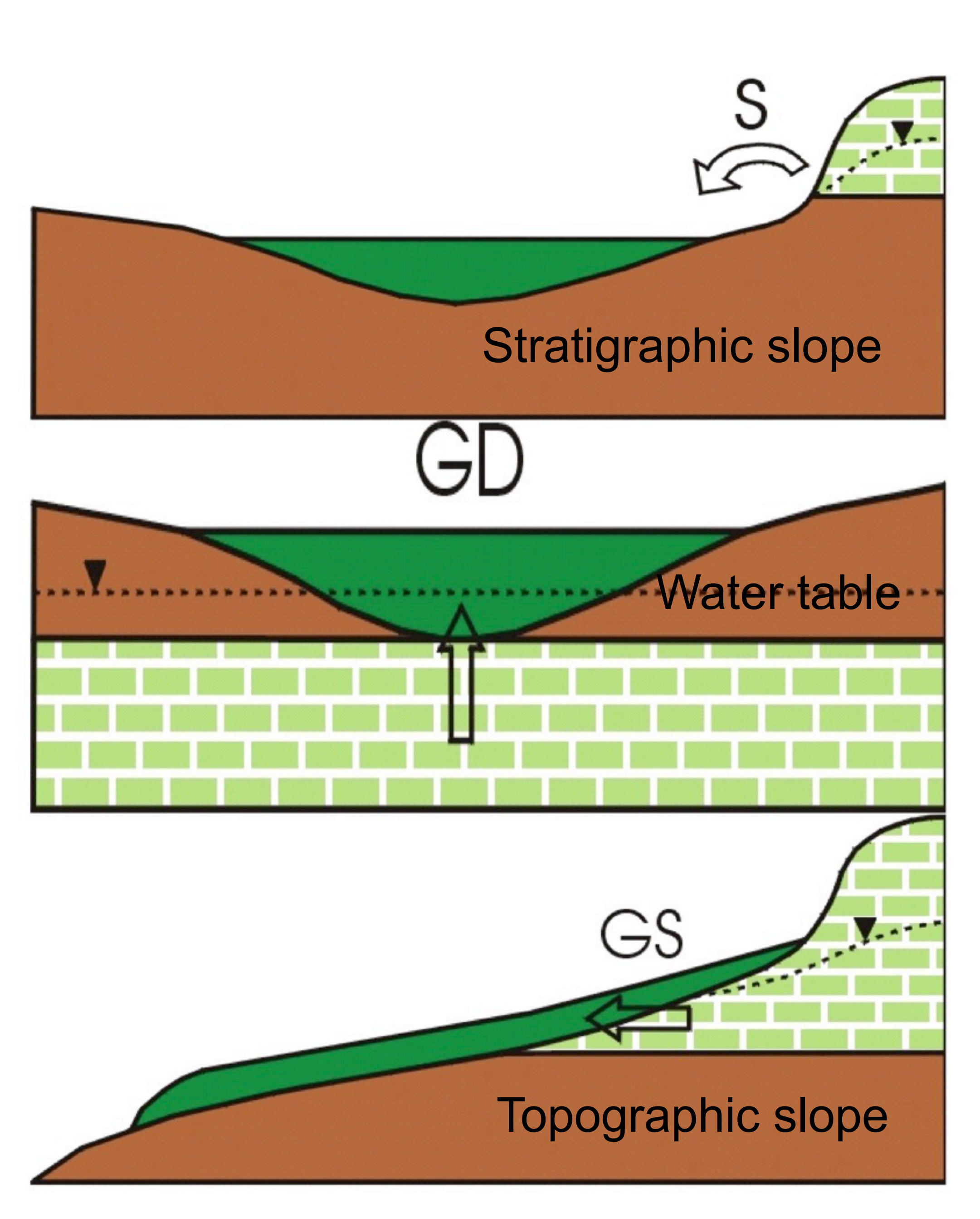
Water transfers in and out of a wetland

(evaporation, precipitation, runoff, groundwater, infiltration, overbank flooding, pumping)

Wetlands are highly interconnected with other waters.

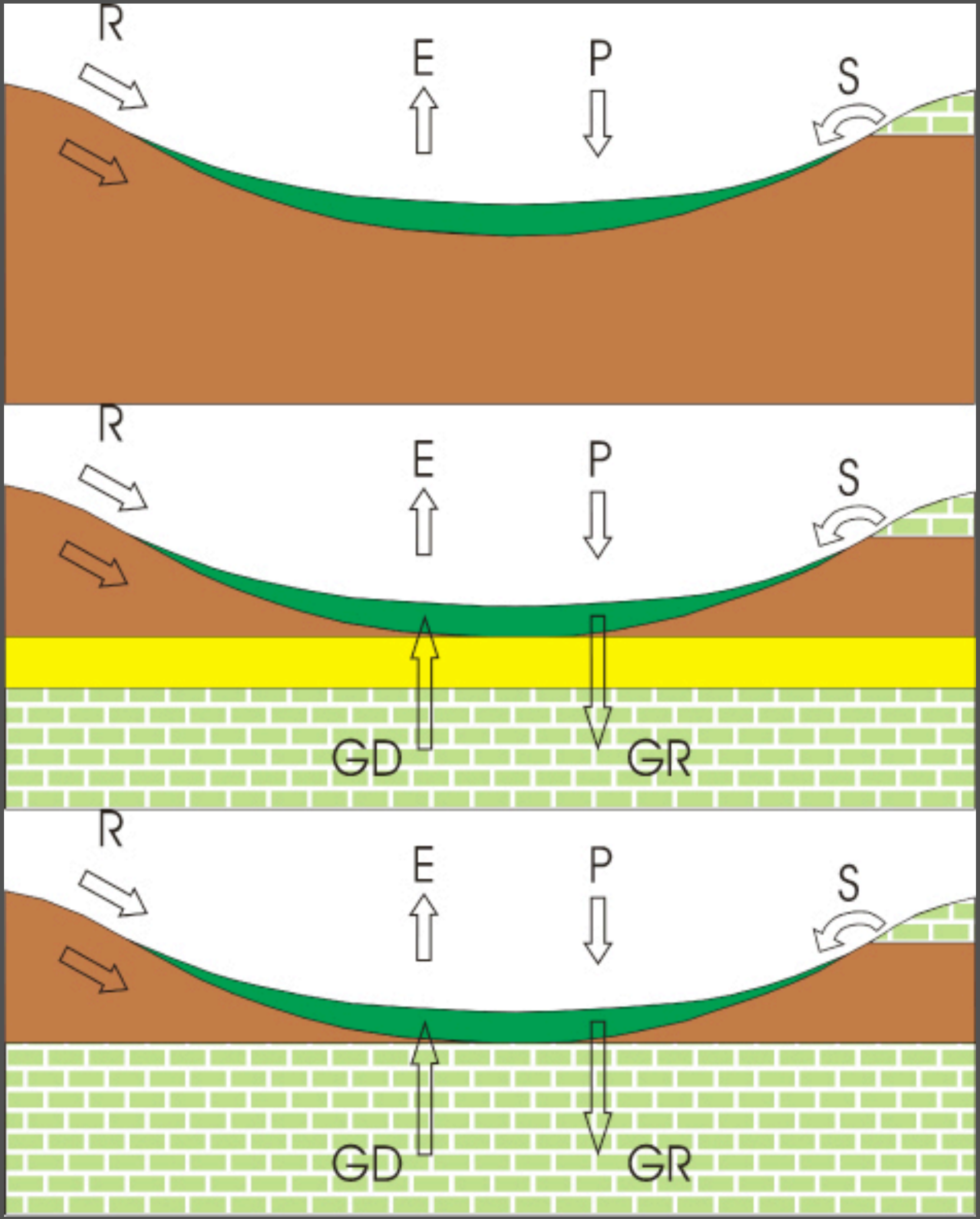
Groundwater sources for wetlands

(Ramsar 2005)



Depressions: water sources

(Ramsar 2005)



# Classification of Aquatic Ecosystems (NWI)

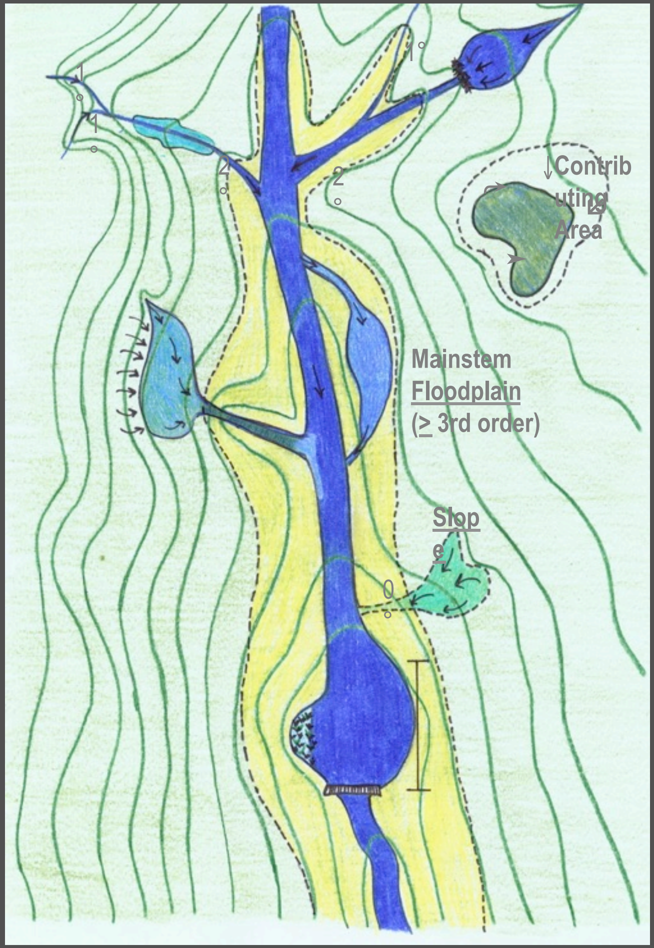
- Riverine - rivers and streams
- Lacustrine - lakes and ponds
- Palustrine - vegetated wetlands
- Estuarine - salt marshes, flats
- Marine - beaches, rocky shores, reefs

National Wetlands Inventory (NWI), Cowardin et al. (1979)

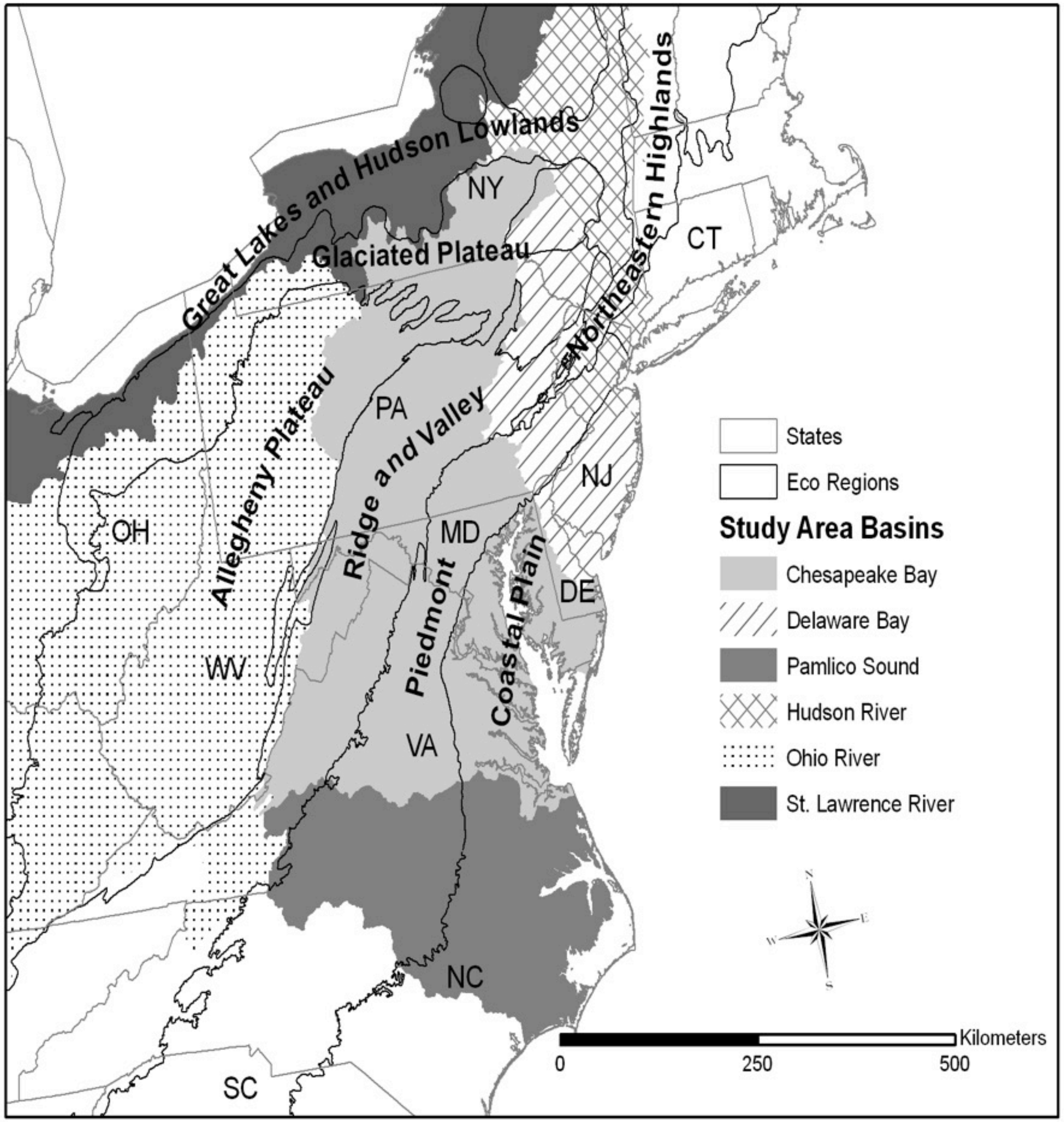
# Hydrogeomorphic (HGM) Classification

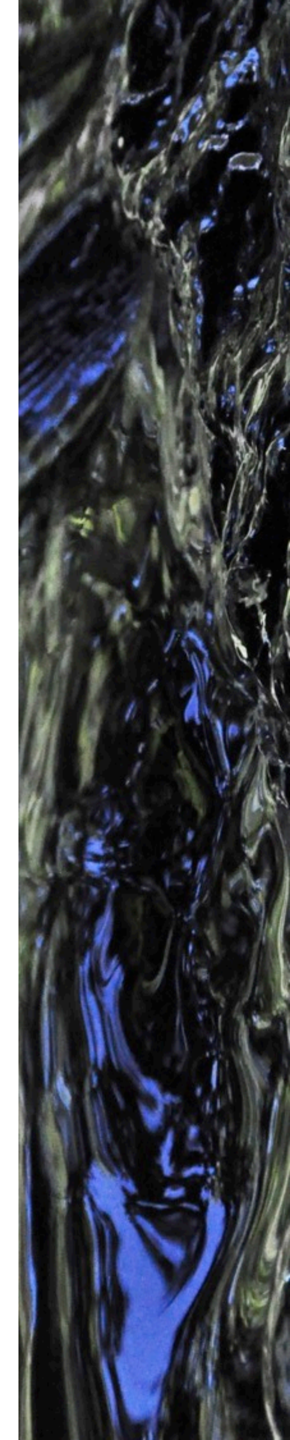
Brinson 1993, Smith et al. 1995, Brooks et al. 2011

- Water source
  - precipitation
  - surface runoff
  - groundwater
- Hydrodynamics
  - vertical - water table
  - uni-directional - stream or spring flows
  - bi-directional - tidal
- Landscape position
  - riverine, slope …
  - -- interconnected watershed



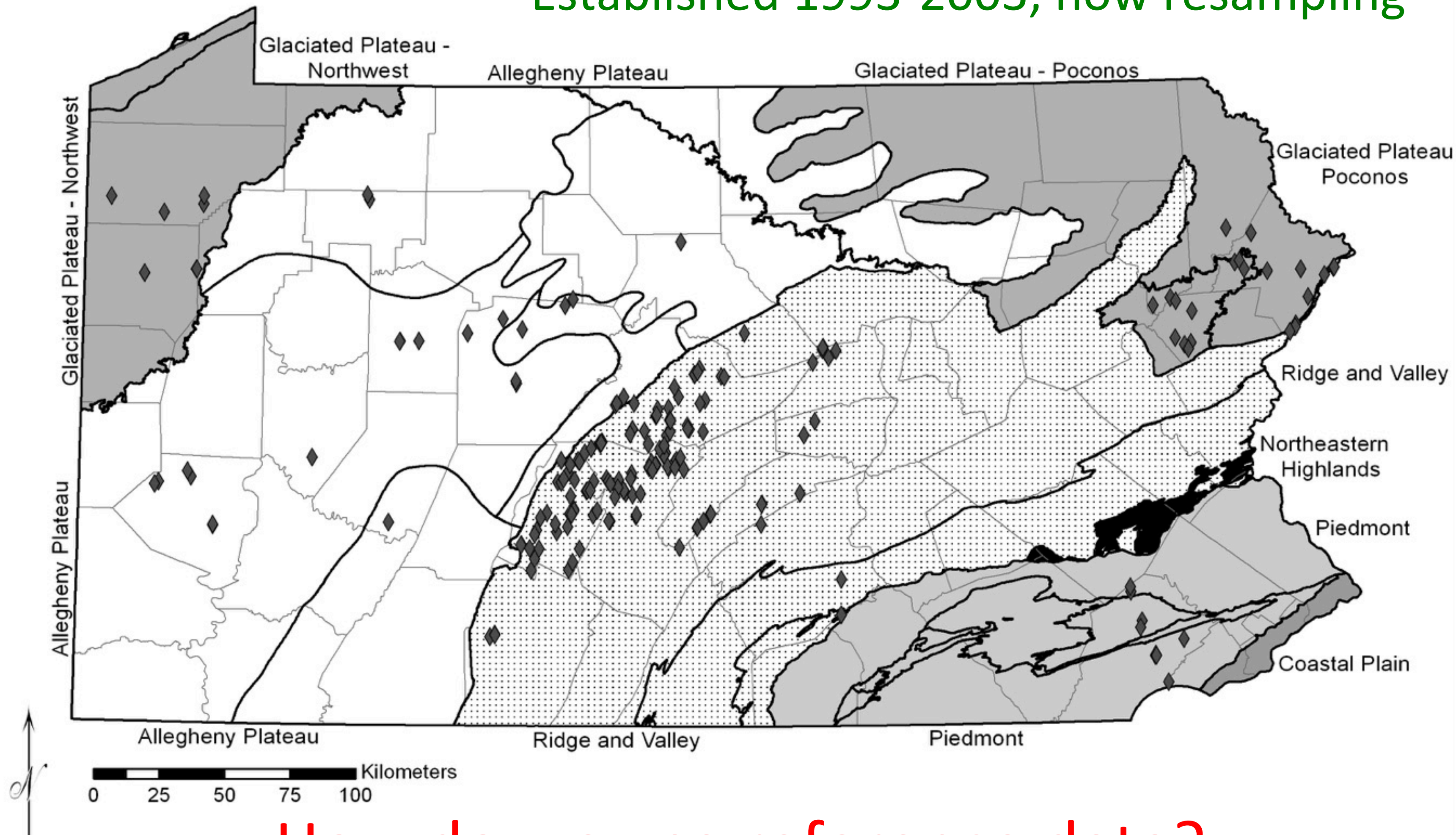
# Mid-Atlantic Experience



# Riparia's Reference Wetlands Collection (n = 220)

Established 1993-2003, now resampling




How do we use reference data?

## Recommendations for establishing reference wetlands

Establish multiple objectives that consider all needs, makes efficient use of limited human & resources:

- assessing condition
- designing better wetlands by region and type
- evaluating performance for mitigated & restored sites
- baseline for long-term trend analyses
- serve as experimental controls for managed sites
- enhance our understanding of wetland ecosystems

Sites should have long-term accessibility, if possible

*See Brooks et al. 2002, 2013 for detailed steps for establishing and selecting reference wetlands.*

## How do we inventory, assess the ecological integrity, and restore wetlands across geographic scales?

**LEVEL 1**
LANDSCAPE FROM GIS

- Enhanced inventory
- Condition assessment
- Mitigation site selection

**LEVEL 2**
RAPID FIELD ASSESSMENT

- Condition assessment
- Stressor identification

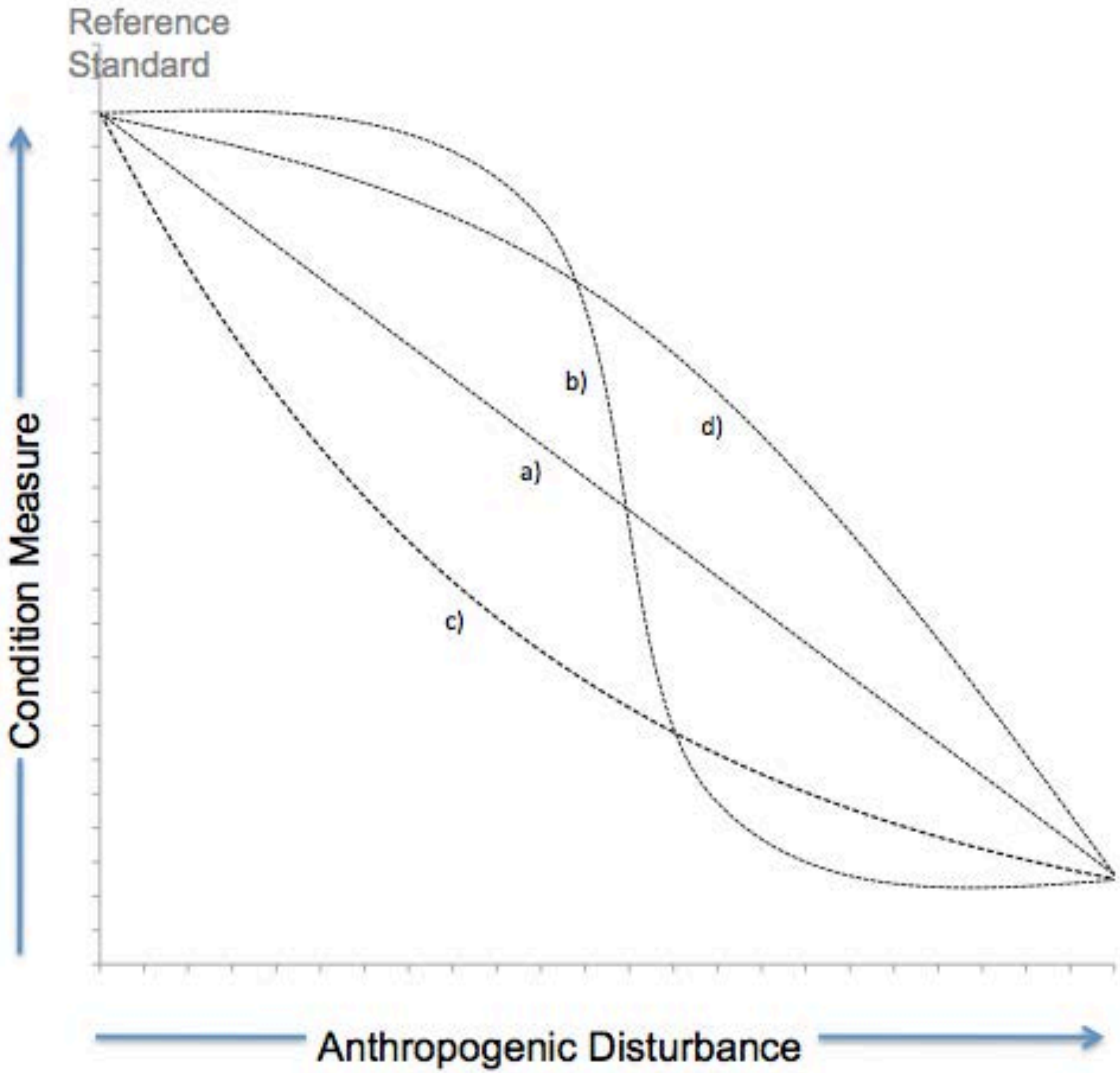
**LEVEL 3**
INTENSIVE FIELD ASSESSMENT

- Condition assessment
- Mitigation site design & performance

# Disturbance-Response Curve

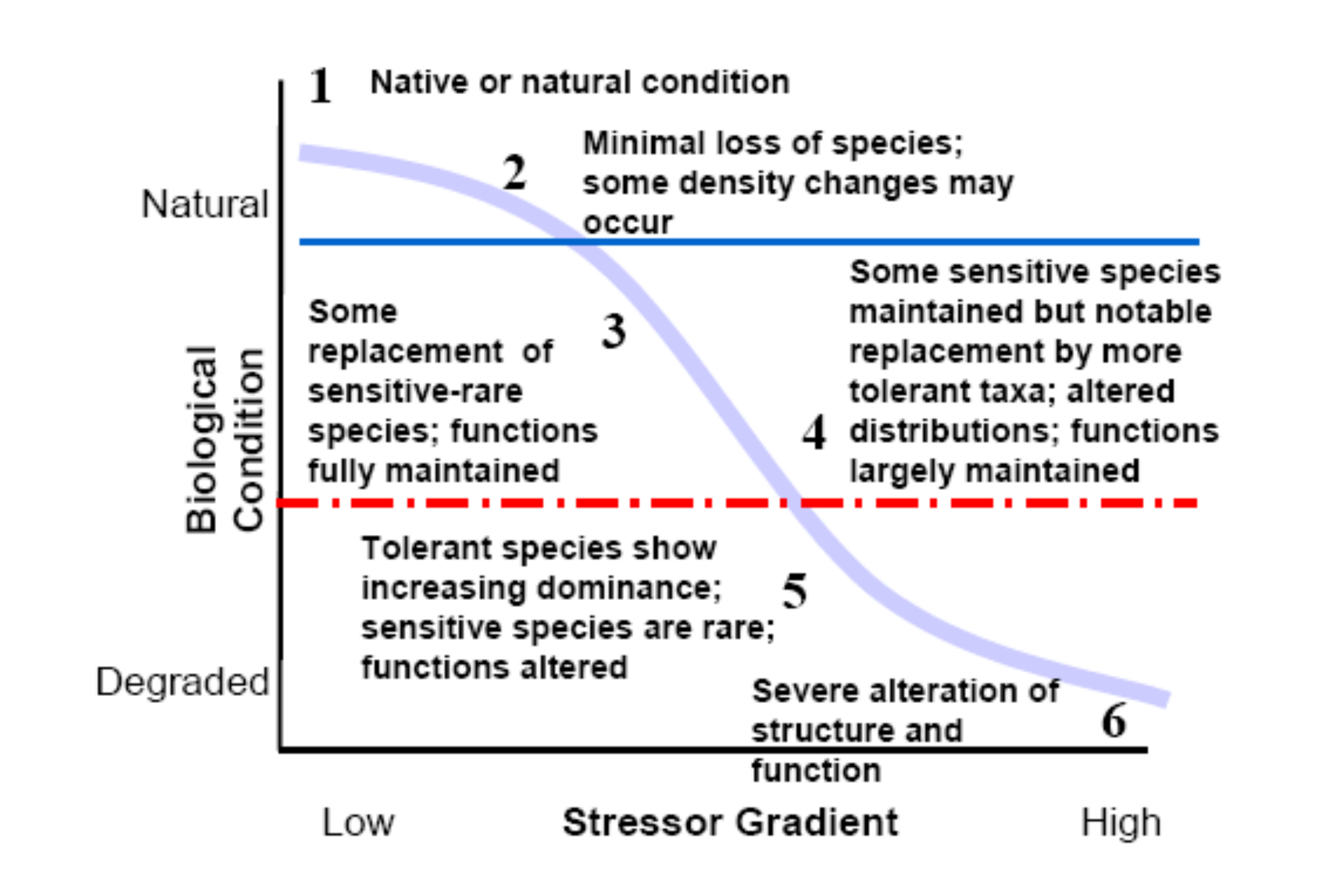
(dose-response)

Wardrop et al. 2013



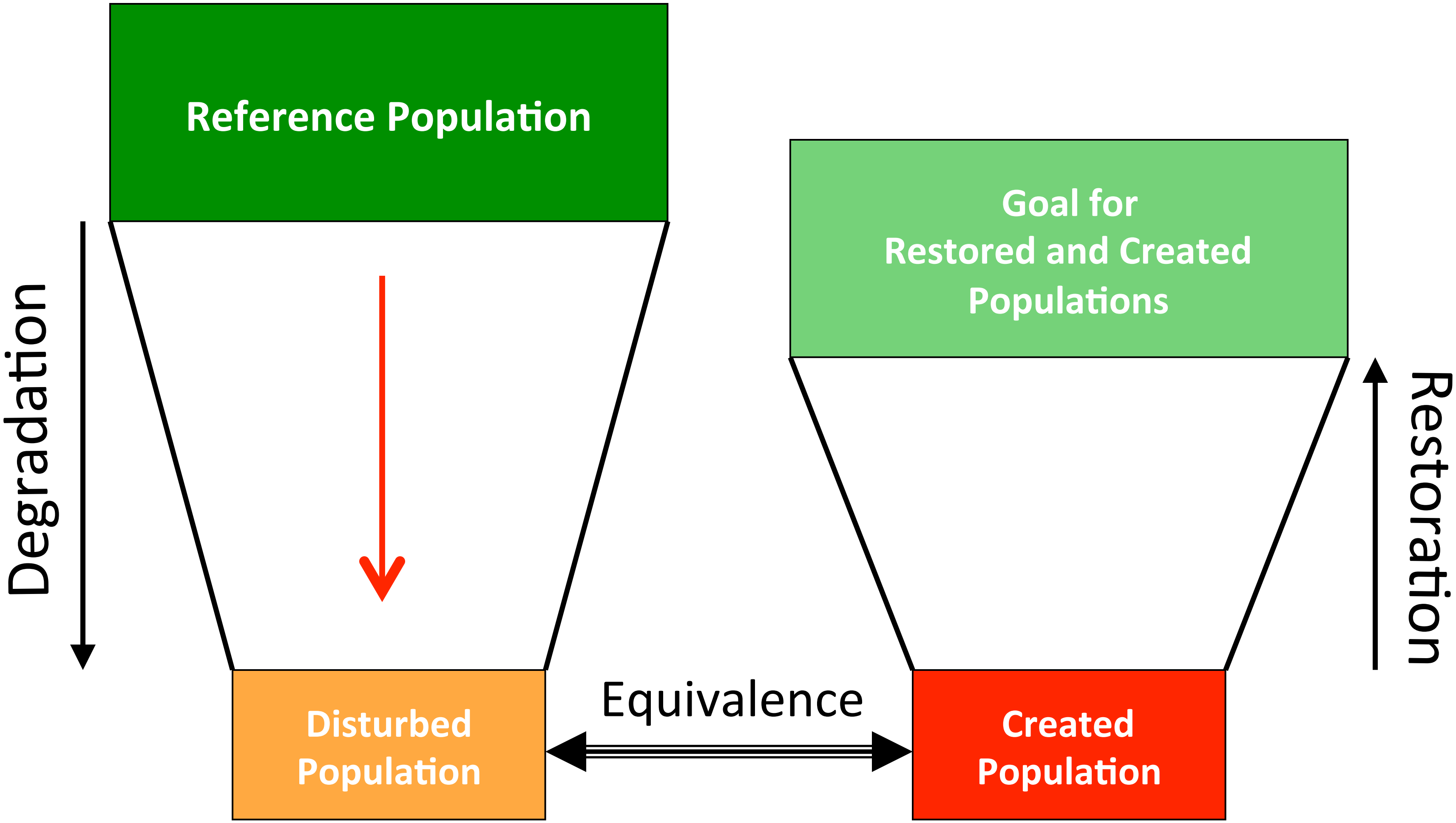
# Tiered Aquatic Life Use (TALU) as metric of condition for wetlands

- Used in stream monitoring programs
- Add precision & consistency to assessments
- Define categories of condition based on data
- Set restoration goals and standards




Davies and Jackson 2006

# Wetland Homogeneity Model




Brooks et al. 2005 Eco Engin.

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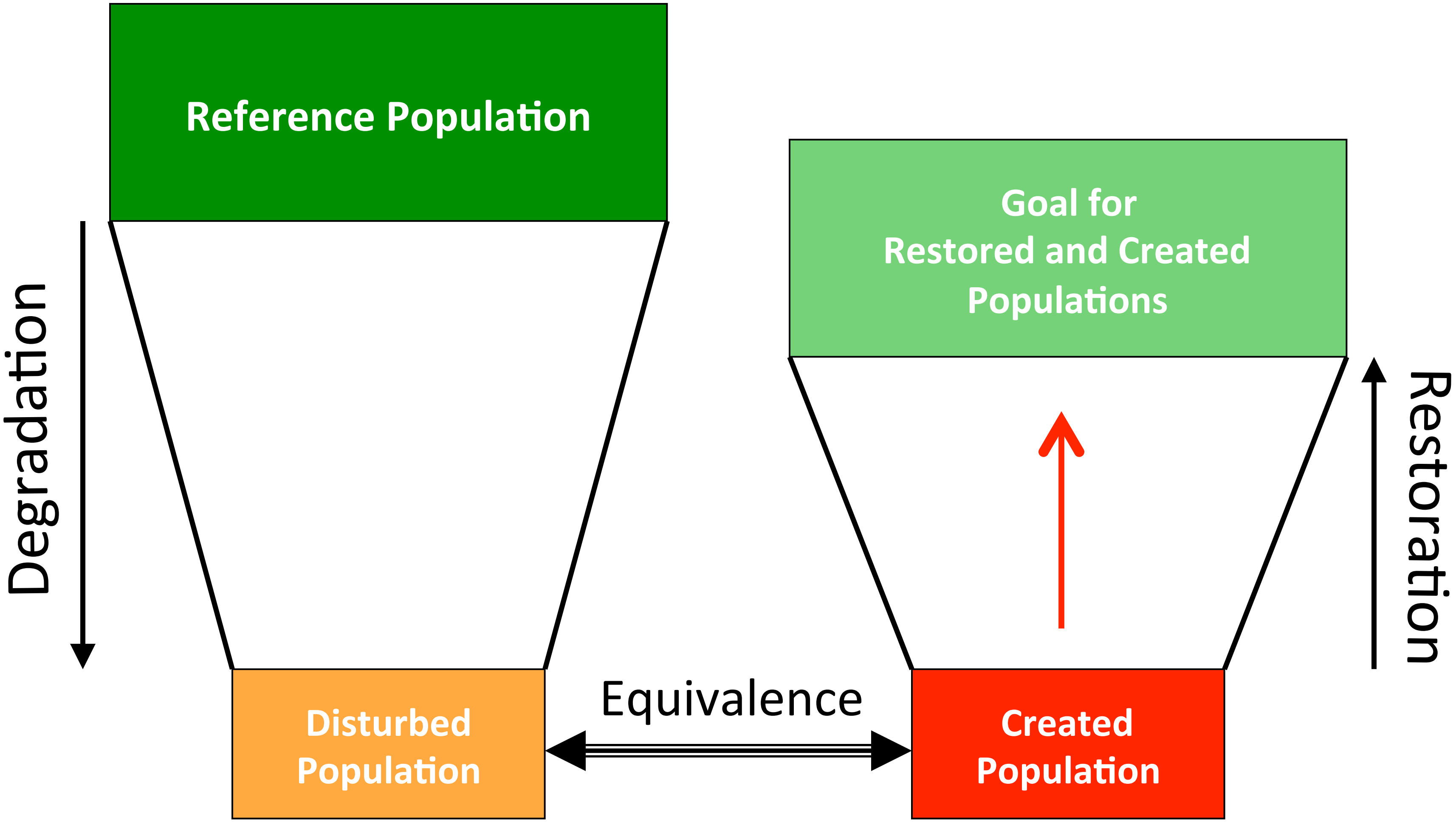
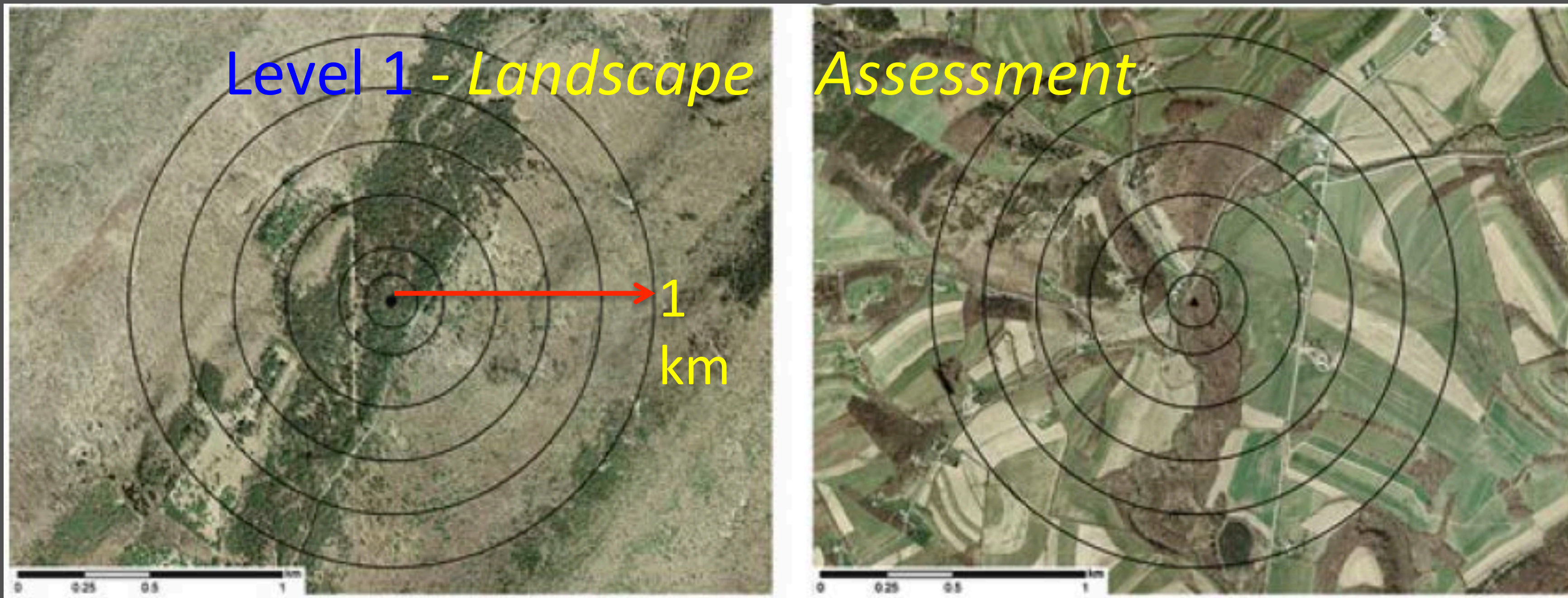



Brooks et al. 2005 Eco Engin.

# Level 1 - *Landscape Assessment*




Reference Standard　　　　　　Disturbed (Stressed)

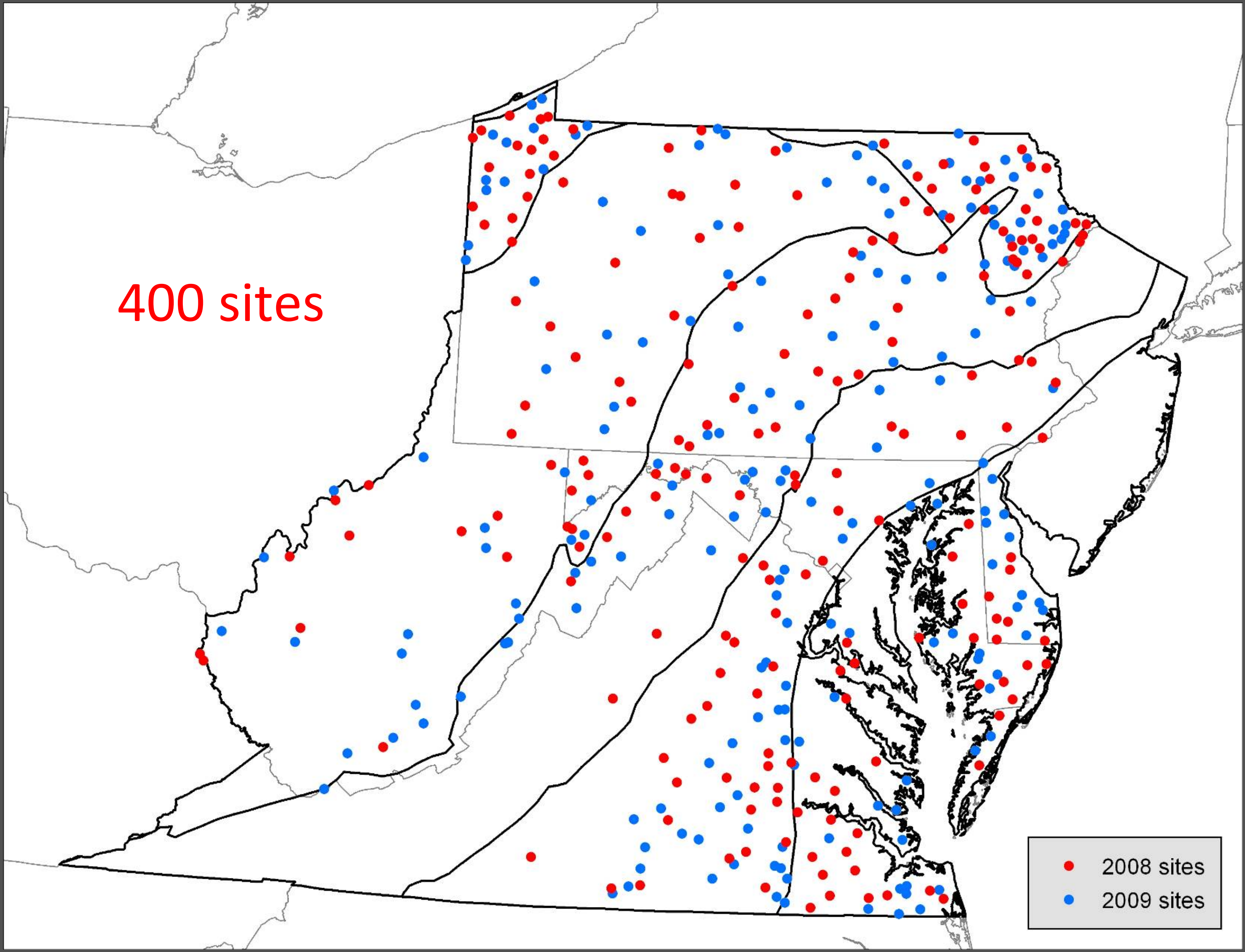
Moon 2012 and Moon & Wardrop 2013 found (for 8 headwater sites in central Pennsylvania) that *disturbed* sites had:

< forest cover

< core forest

> impervious surface

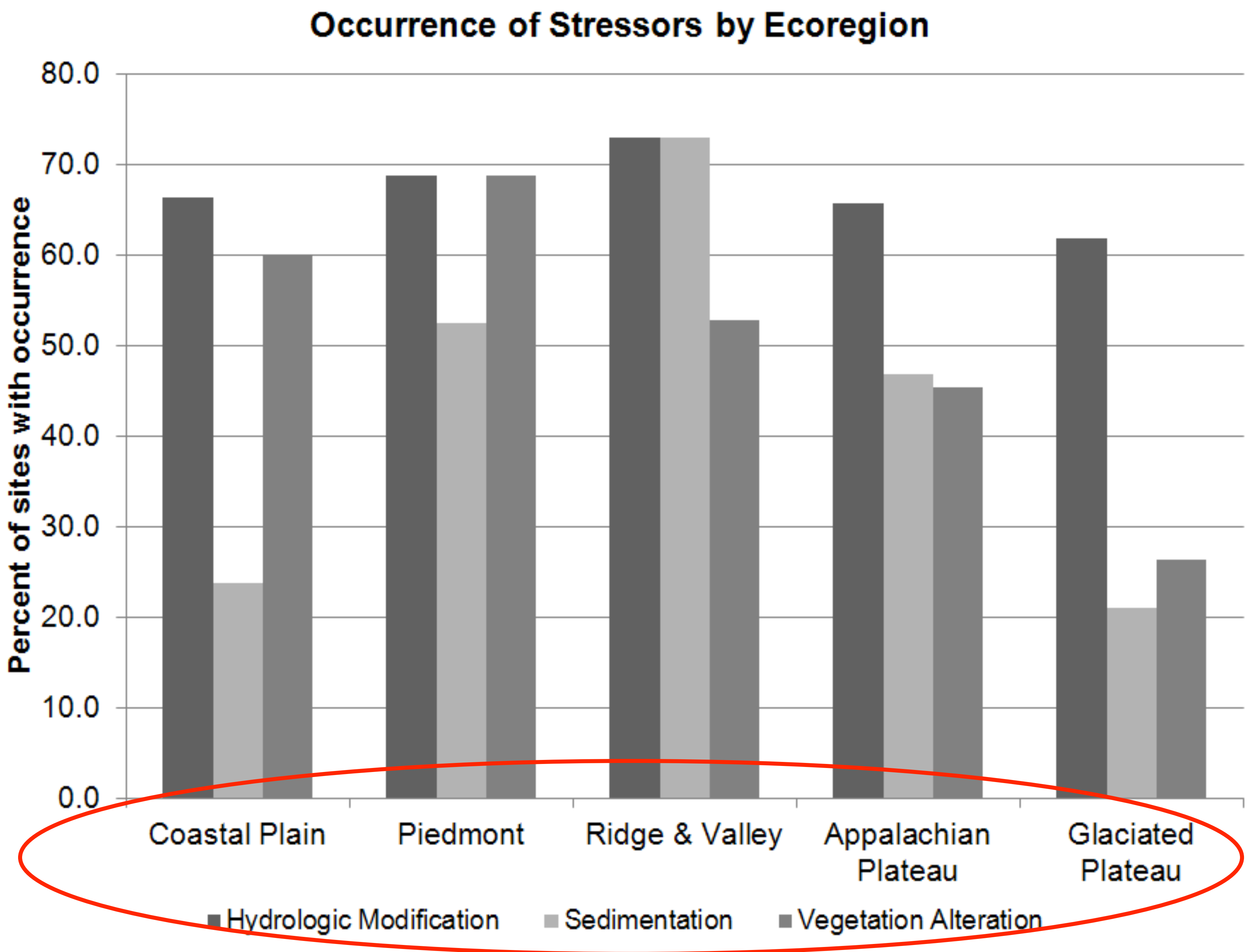
# Level 2 - Regional Wetland Assessment Locations



# Level 2 - Stressor Identification

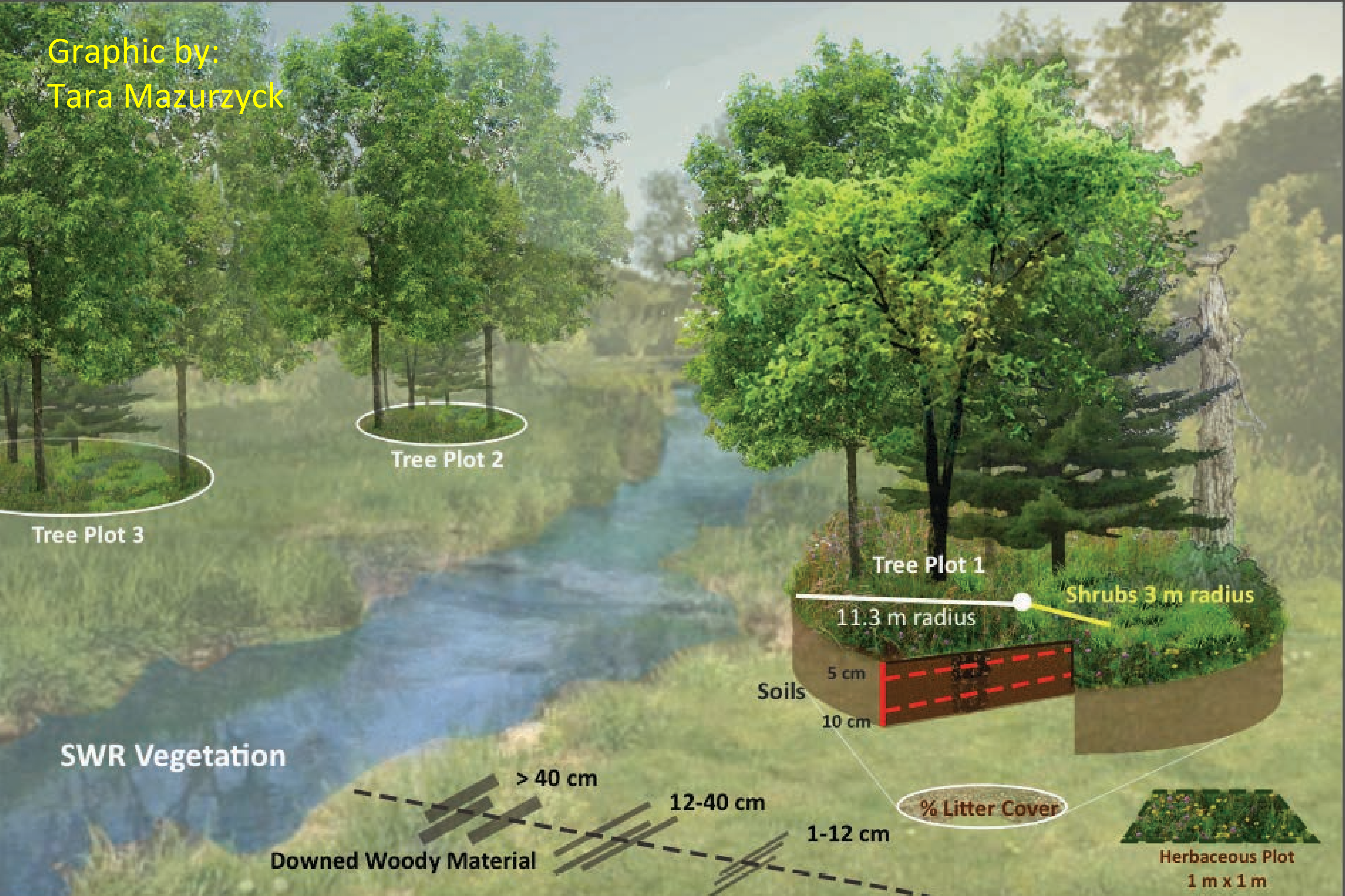
- Hydrologic Modification
- Sedimentation
- Dissolved oxygen
- Contaminant toxicity
- Vegetation alteration
- Eutrophication
- Acidification
- Turbidity
- Thermal Alteration
- Salinity

modified from Adamus & Brandt 1990

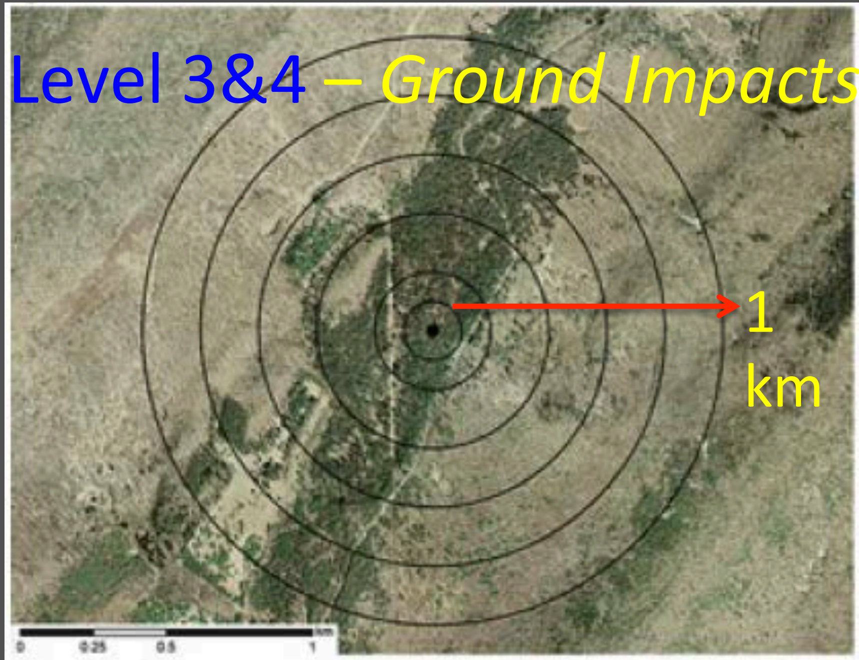


Occurrence of Stressors by Ecoregion
Percent of sites with occurrence
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Coastal Plain
Piedmont
Ridge & Valley
Appalachian Plateau
Glaciated Plateau
Hydrologic Modification
Sedimentation
Vegetation Alteration

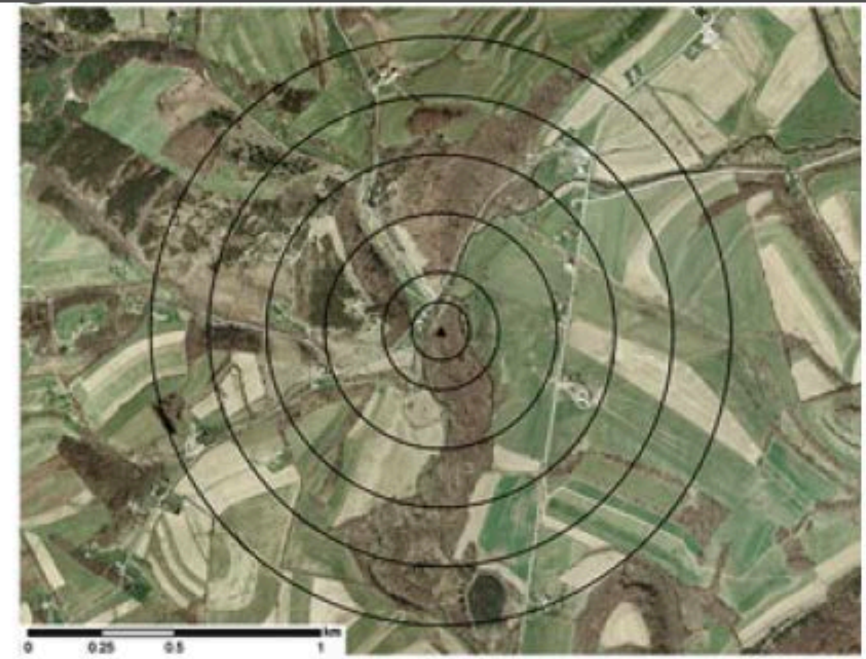
# Level 2&3 - Typical Sampling for Reference Wetlands



# Level 3&4 – *Ground Impacts*




Reference Standard



Disturbed (Stressed)

Moon 2012 and Moon & Wardrop 2013 found (for 8 headwater sites in central Pennsylvania) that *disturbed* sites had:

- drier soils

< soil organic matter

- more frequent and more intense fluctuation in hydrographs




# Welcome

The Mid-Atlantic Wetlands Workgroup (MAWWG) is currently funded through a Wetland Program Development Grant from the U.S. Environmental Protection Agency Region III to Riparia at The Pennsylvania State University.

MAWWG consists of participants representing federal and state regulatory personnel and scientists from the followingstates: Delaware, Maryland, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Virginia, and West Virginia. This focused membership includes both users and developers of monitoring and assessment tools.

# Announcements

- Delaware Wetlands Conference 2014 (Save the Date and Call for Abstracts)
- Delaware: Broadkill Watershed Website
- Mid-Atlantic Floristic Quality Index Calculator

Level 3

Intensive Assessment

Floristic Quality Assessment Index (FQAI)

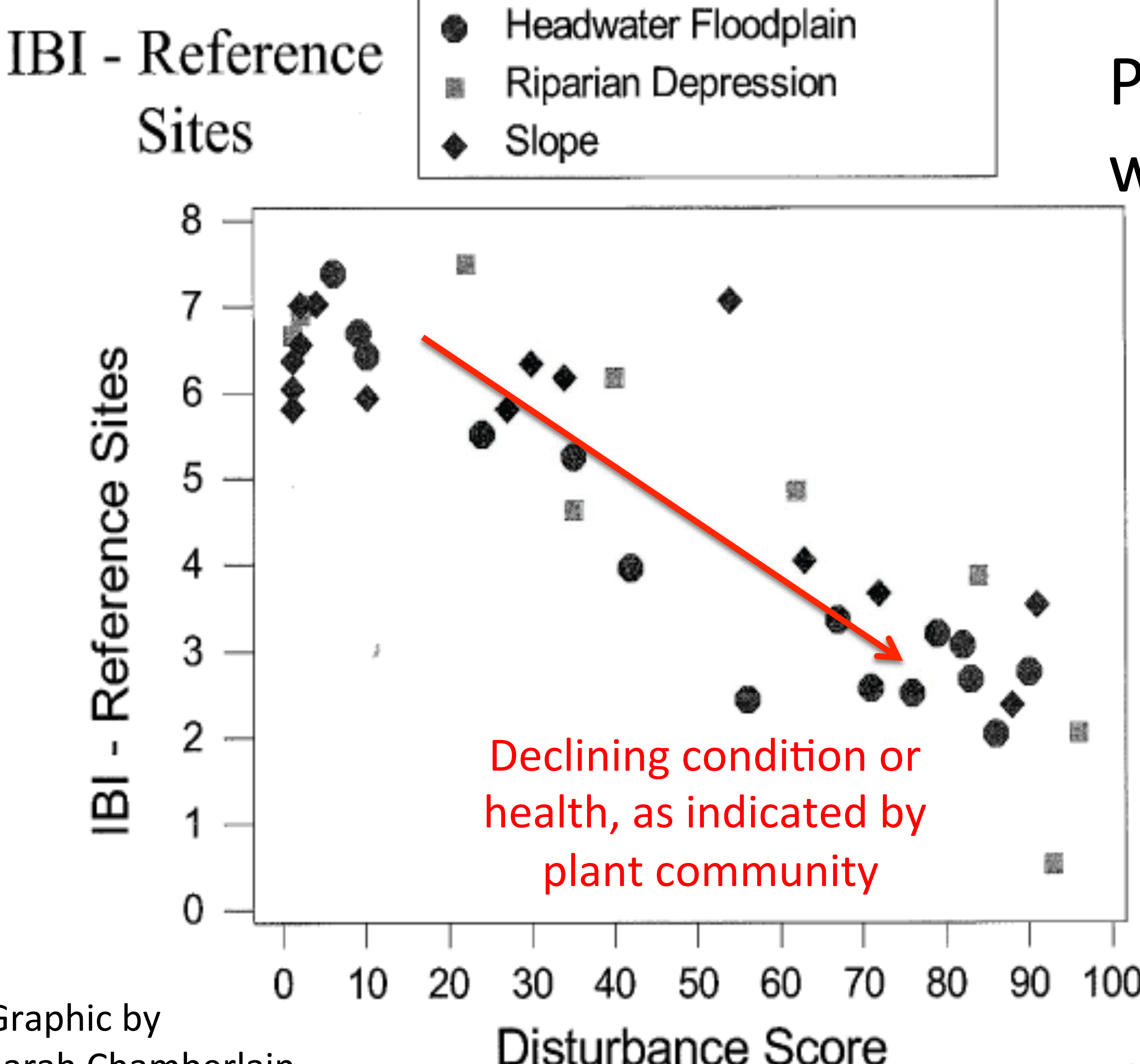
&

Plant Index of Biological Integrity

http://apps.cei.psu.edu/fqacalc/

Sarah Chamberlain - Riparia

# Plant IBI w/ FQAI




Graphic by Sarah Chamberlain


Short break for questions

# Calls for improving restoration, creation, and mitigation performance

- NRC 1992 - Restoration of Aquatic Ecosystems...
- NRC 2001 - Compensating for wetland losses...
- GAO 2001 - Fish & wildlife mitigation guidance...
- Corps 2002 - National wetlands mitigation action plan...
- EPA & Corps 2008 - National Wetlands Compensatory Mitigation Rule

# Requirements of the 2008 Mitigation Rule

- 2008 Mitigation Rule requires states to:
  - Implement mitigation in a watershed context
  - Prioritize placement of mitigation sites
  - Establish measureable performance standards and monitoring requirements

*(these same requirements are relevant to restoration)*

OPEN ACCESS Freely available online PLoS BIOLOGY

# Structural and Functional Loss in Restored Wetland Ecosystems

**David Moreno-Mateos[1,2]*, Mary E. Power[1], Francisco A. Comín[3], Roxana Yockteng[4]**

**1** Integrative Biology Department, University of California at Berkeley, Berkeley, California, United States of America, **2** Jasper Ridge Biological Preserve, Stanford University, Woodside, California, United States of America, **3** Department of Conservation of Biodiversity and Ecosystem Restoration, Pyrenean Institute of Ecology – CSIC, Zaragoza, Spain, **4** UMR CNRS 7205, Muséum National d'Histoire Naturelle, Paris, France

## Abstract

Wetlands are among the most productive and economically valuable ecosystems in the world. However, because of human activities, over half of the wetland ecosystems existing in North America, Europe, Australia, and China in the early 20th century have been lost. Ecological restoration to recover critical ecosystem services has been widely attempted, but the degree of actual recovery of ecosystem functioning and structure from these efforts remains uncertain. Our results from a meta-analysis of 621 wetland sites from throughout the world show that even a century after restoration efforts, biological structure (driven mostly by plant assemblages), and biogeochemical functioning (driven primarily by the storage of carbon in wetland soils), remained on average 26% and 23% lower, respectively, than in reference sites. Either recovery has been very slow, or postdisturbance systems have moved towards alternative states that differ from reference conditions. We also found significant effects of environmental settings on the rate and degree of recovery. Large wetland areas (>100 ha) and wetlands restored in warm (temperate and tropical) climates recovered more rapidly than smaller wetlands and wetlands restored in cold climates. Also, wetlands experiencing more (riverine and tidal) hydrologic exchange recovered more rapidly than depressional wetlands. Restoration performance is limited: current restoration practice fails to recover original levels of wetland ecosystem functions, even after many decades. If restoration as currently practiced is used to justify further degradation, global loss of wetland ecosystem function and structure will spread.

**Citation:** Moreno-Mateos D, Power ME, Comín FA, Yockteng R (2012) Structural and Functional Loss in Restored Wetland Ecosystems. PLoS Biol 10(1): e1001247. doi:10.1371/journal.pbio.1001247

**Academic Editor:** Michel Loreau, McGill University, Canada

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Ecological restoration to recover critical ecosystem services has been widely attempted, but the degree of actual recovery of ecosystem functioning and structure from these efforts remains uncertain.

Wetlands (2012) 32:321–331
DOI 10.1007/s13157-011-0267-3

ARTICLE

# Hydrogeomorphic (HGM) Assessments of Mitigation Sites Compared to Natural Reference Wetlands in Pennsylvania

Naomi A. Gebo · Robert P. Brooks

Received: 17 September 2010 / Accepted: 27 December 2011 / Published online: 28 January 2012


**Abstract** The U.S. Environmental Protection Agency and U.S. Army Corps of Engineers completed revisions to the Mitigation Rule of the Clean Water Act in 2008. These revisions encourage states to carry out mitigation in a watershed context, prioritizing mitigation site design and placement by overall watershed need, to the extent appropriate and practicable (33 C.F.R. 332.3(c)). States are expected to establish monitoring programs and measureable performance standards for mitigation wetlands. In Pennsylvania, hydrogeomorphic (HGM)-based assessments involving 222 reference wetlands were used to compare mitigation wetland performance. For this study, 72 mitigation wetlands were sampled in 2007 and 2008 from three categories – Pennsylvania Wetland Replacement Program sites, Pennsylvania Department of Transportation mitigation banks, and permit required compensatory mitigation sites. Mitigation wetlands were intensively sampled using a Level
3 - Intensive methodology developed by Riparia. Fiel
and GIS computed variables were used to derive the s
of 10 HGM functional capacities. Overall, mitigation
displayed lower potential to perform a characteristic we
function than reference ... show
greatest discrepancy, whi... d the
amount of difference from reference scores. Mitigatio
size, age, and type were not significant factors in func
capacity index scores.

**Keywords** Hydrogeomorphic functional assessment ·
Mitigation rule · Compensatory mitigation · Mitigation

## Introduction

Compensatory mitigation is intended to replace the areal extent and, ideally, the functions of the impacted wetlands. The latter has proven elusive to assess and difficult to achieve. According to recent reports, wetland mitigation has resulted in a net increase in wetland area nationwide (Dahl 2006). However, functional replacement is not necessarily associated with these gains in wetland area. The need to establish a high degree of function across a variety of forms has long been neglected in the mitigation process. There is wide consensus among researchers that mitigation is not adequately compensating for natural wetland losses structurally, functionally (Race and Fonseca 1996; Mitsch and Wilson 1996; Zedler and Callaway 1999; Kentula et al. 2004), or with regard to temporal lags in functional performance (Gutrich and Hitzhusen 2004; Bendor 2009). Created

Overall, mitigation sites displayed lower potential to perform a characteristic wetland function than reference wetlands.

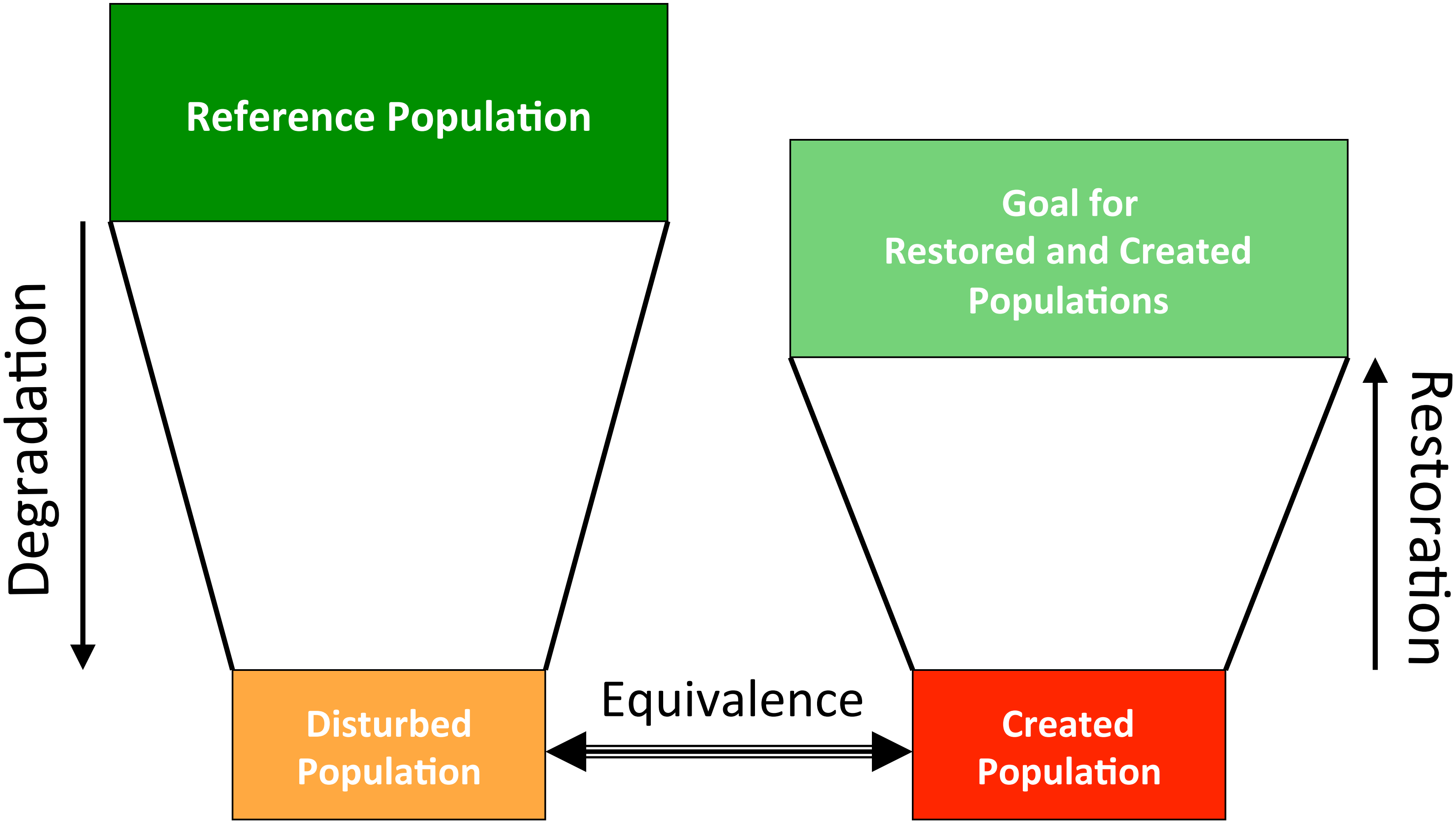
My Documents

How do we learn to build better wetlands?

By using data from reference wetlands for mitigation design and performance!

Gebo and Brooks 2012

# Wetland Homogeneity Model




Brooks et al. 2005 Eco Engin.

# Reference vs. Disturbed vs. Created

# Physical Indicators

| Parameter | Rip Depres | | Slope | | Hdwtr Fldpln | | Created |
|---|---|---|---|---|---|---|---|
| | Ref | Dis | Ref | Dis | Ref | Dis | |
| Soil Chroma (<2 = wet) | 1.1 | 2 | 1.5 | 1.9 | 1.2 | 2.1 | 2.3 |
| Organic Matter % (> OM = expected) | 24 | 9 | 21 | 8 | 13 | 6 | 4 |

Brooks et al. 2005

# Reference vs. Disturbed vs. Created

## Physical Indicators

| Parameter | Rip Depres | | Slope | | Hdwtr Fldpln | | Created |
|---|---|---|---|---|---|---|---|
| | Ref | Dis | Ref | Dis | Ref | Dis | |
| Soil Chroma | 1.1 | 2 | 1.5 | 1.9 | 1.2 | 2.1 | 2.3 |
| (<2 = wet) | | | Ref << Dis & Cre | | | | |
| Organic Matter % | 24 | 9 | 21 | 8 | 13 | 6 | 4 |
| (> OM = expected) | | | Ref >> Dis & Cre | | | | |

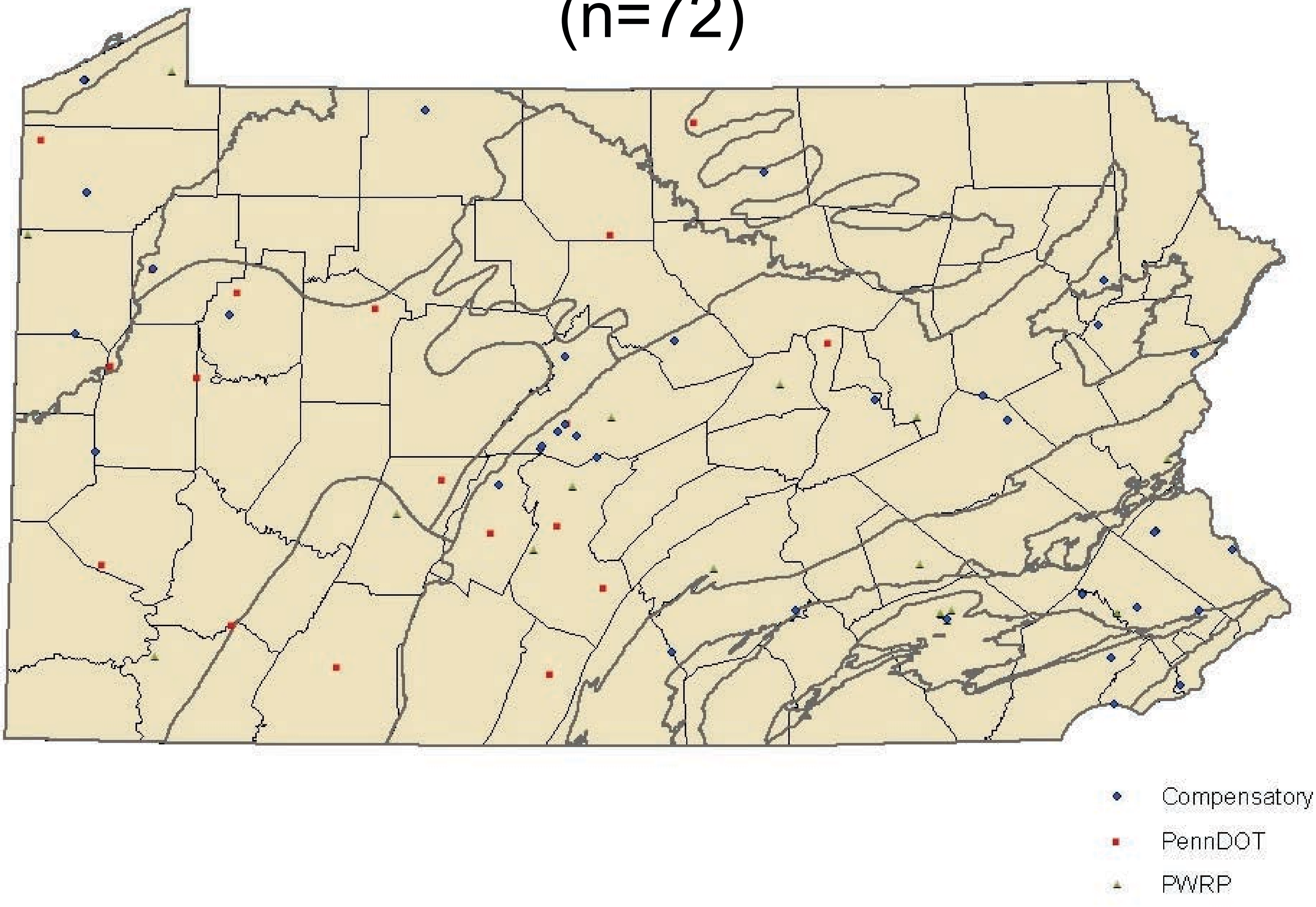
Brooks et al. 2005

Natural reference wetland vs. mitigation project

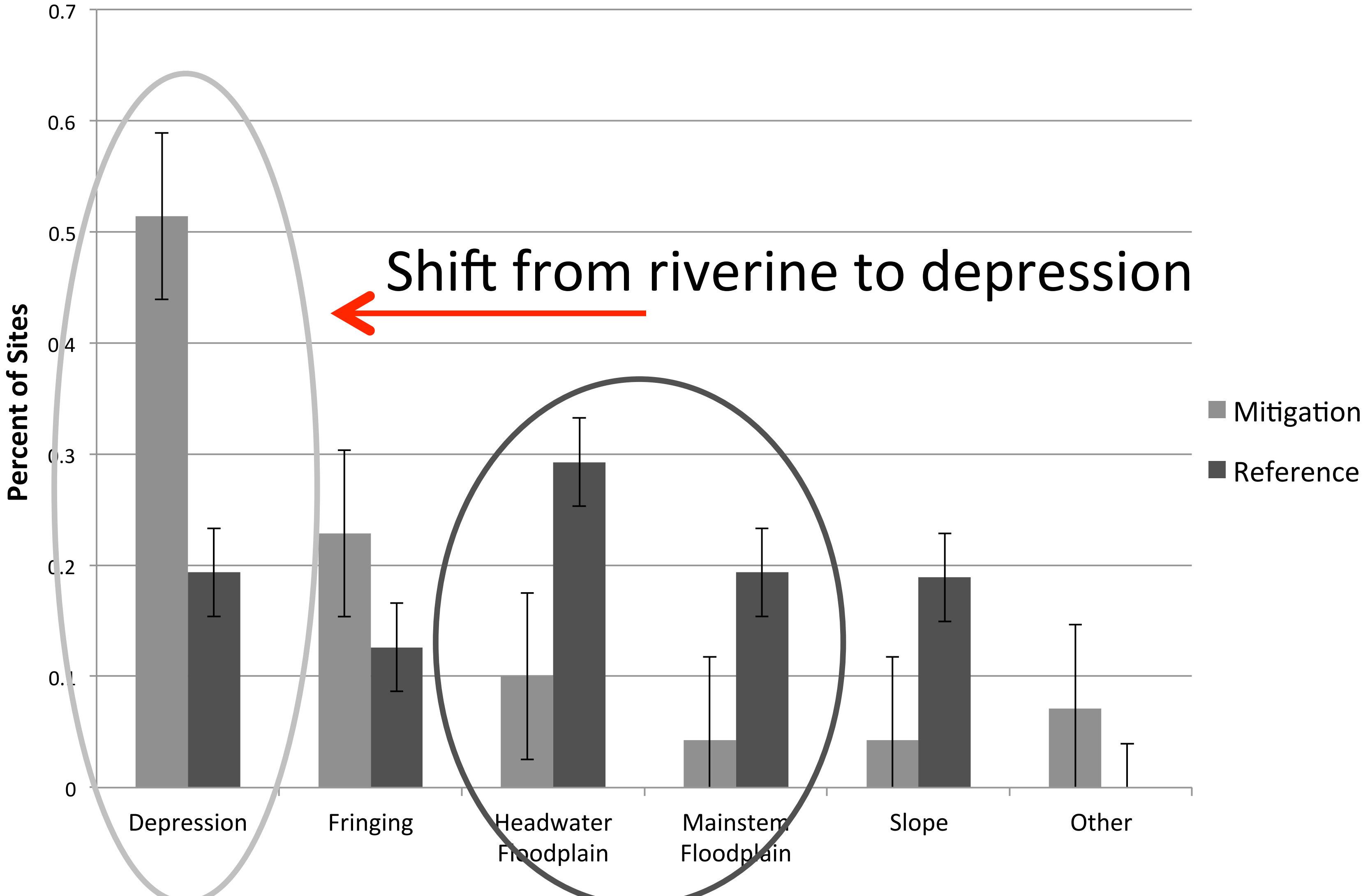
Gebo & Brooks 2012
Brooks & Gebo 2013


Naomi Gebo

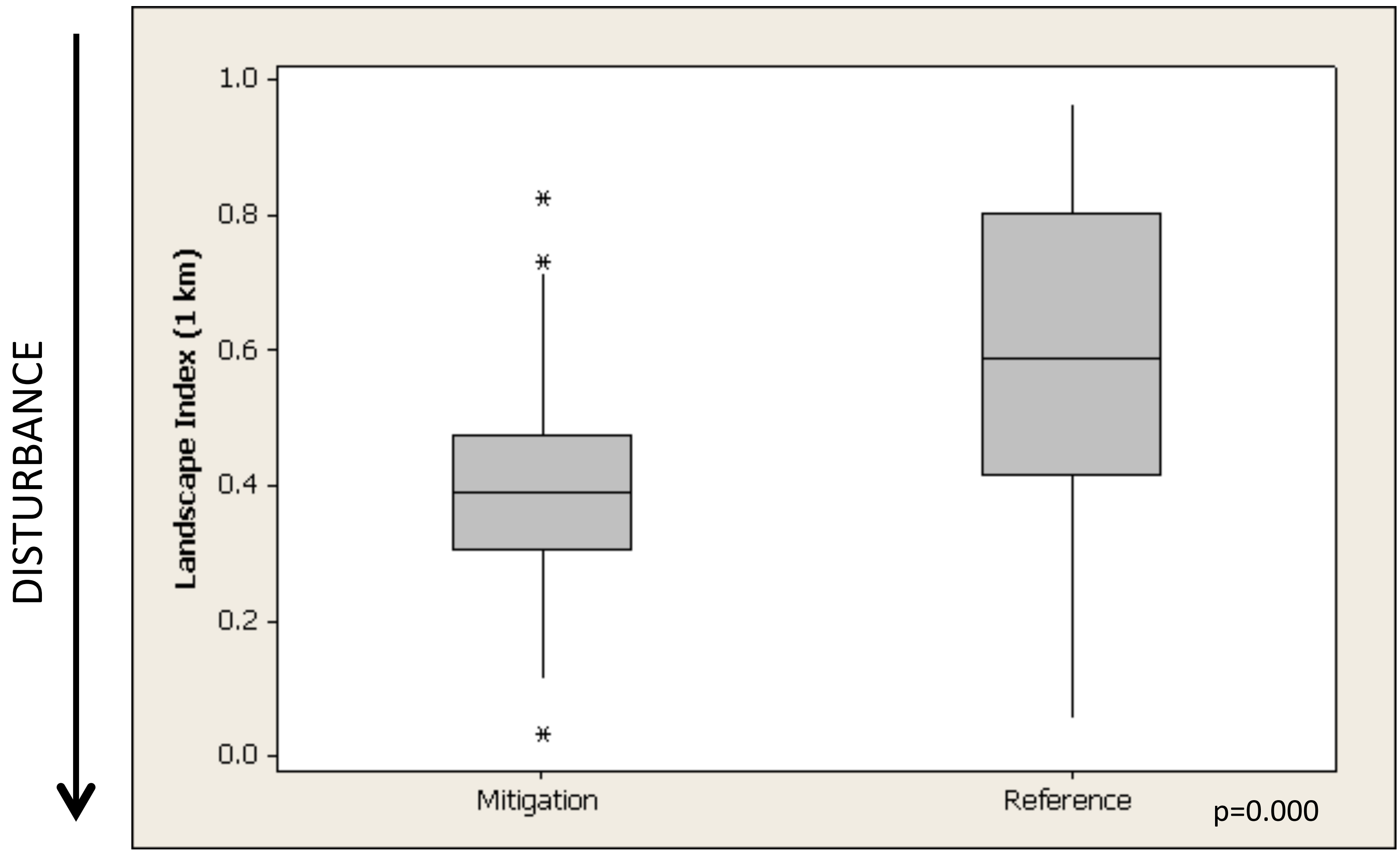
# Map of Mitigation Wetlands in Pennsylvania (n=72)



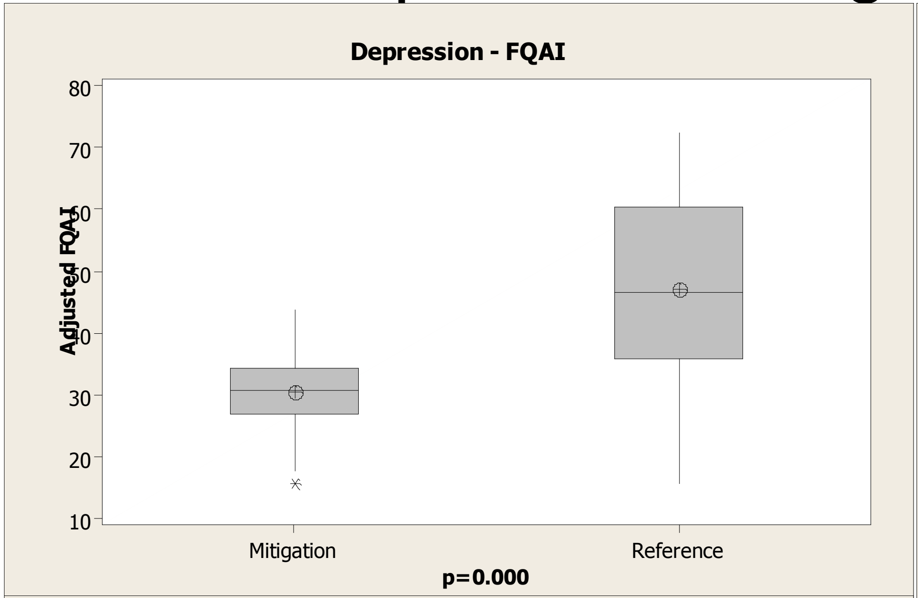
# HGM Distribution of Mitigation and Reference Wetlands in Pennsylvania

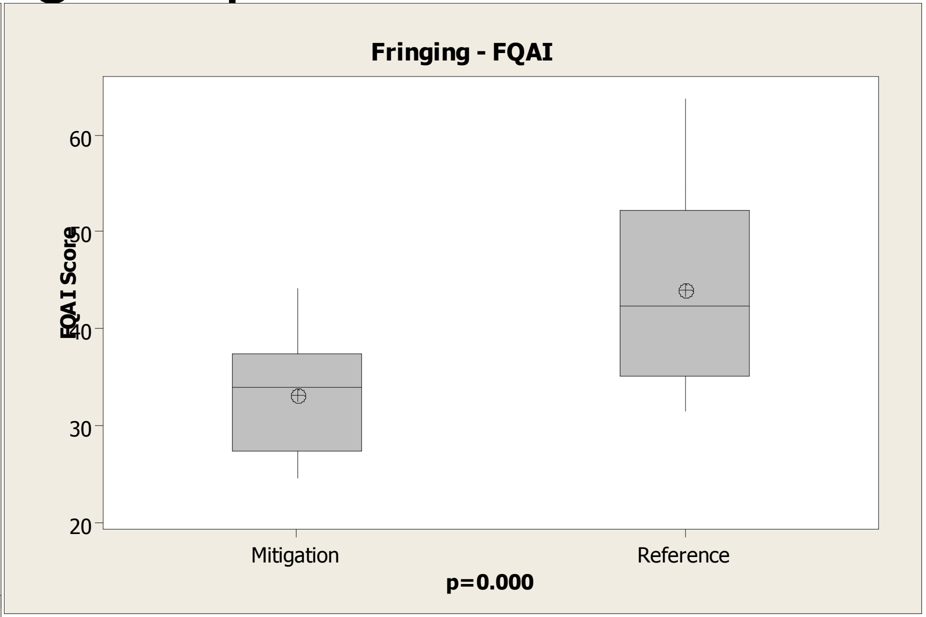


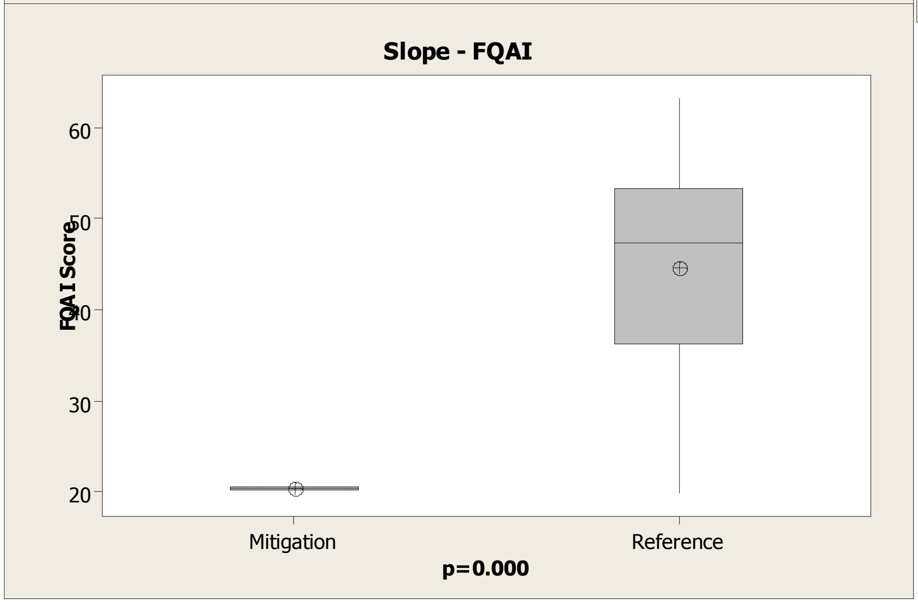
# Landscape Disturbance



# Floristic Quality Assessment Index (FQAI): Depression, Fringing, Slope Wetlands

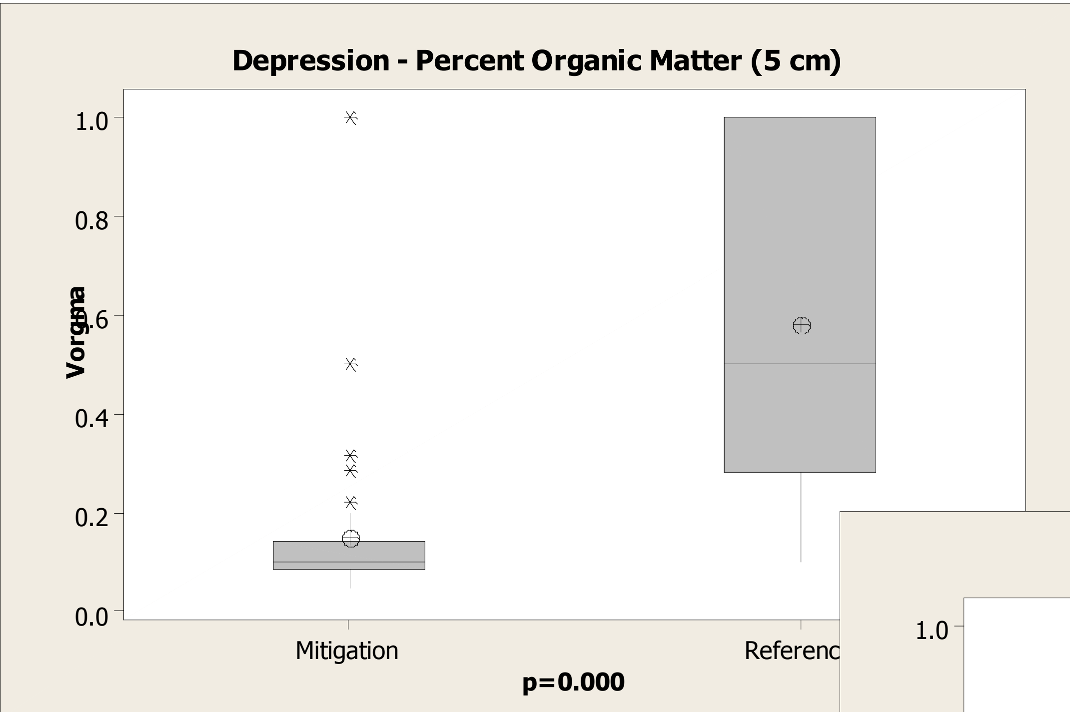


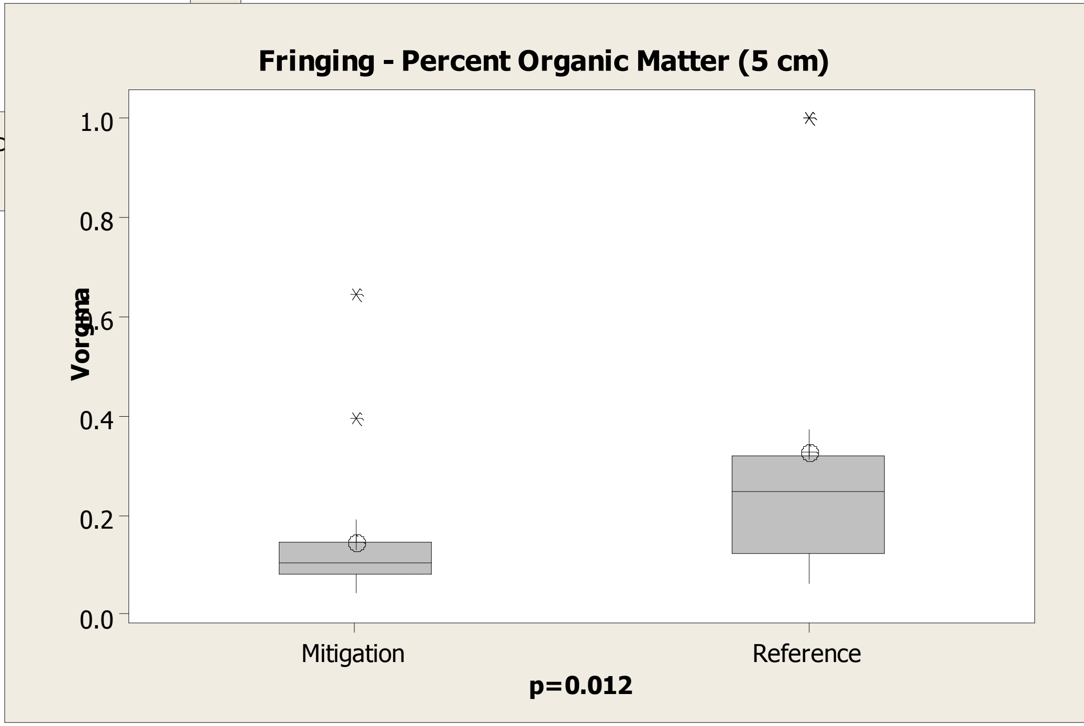



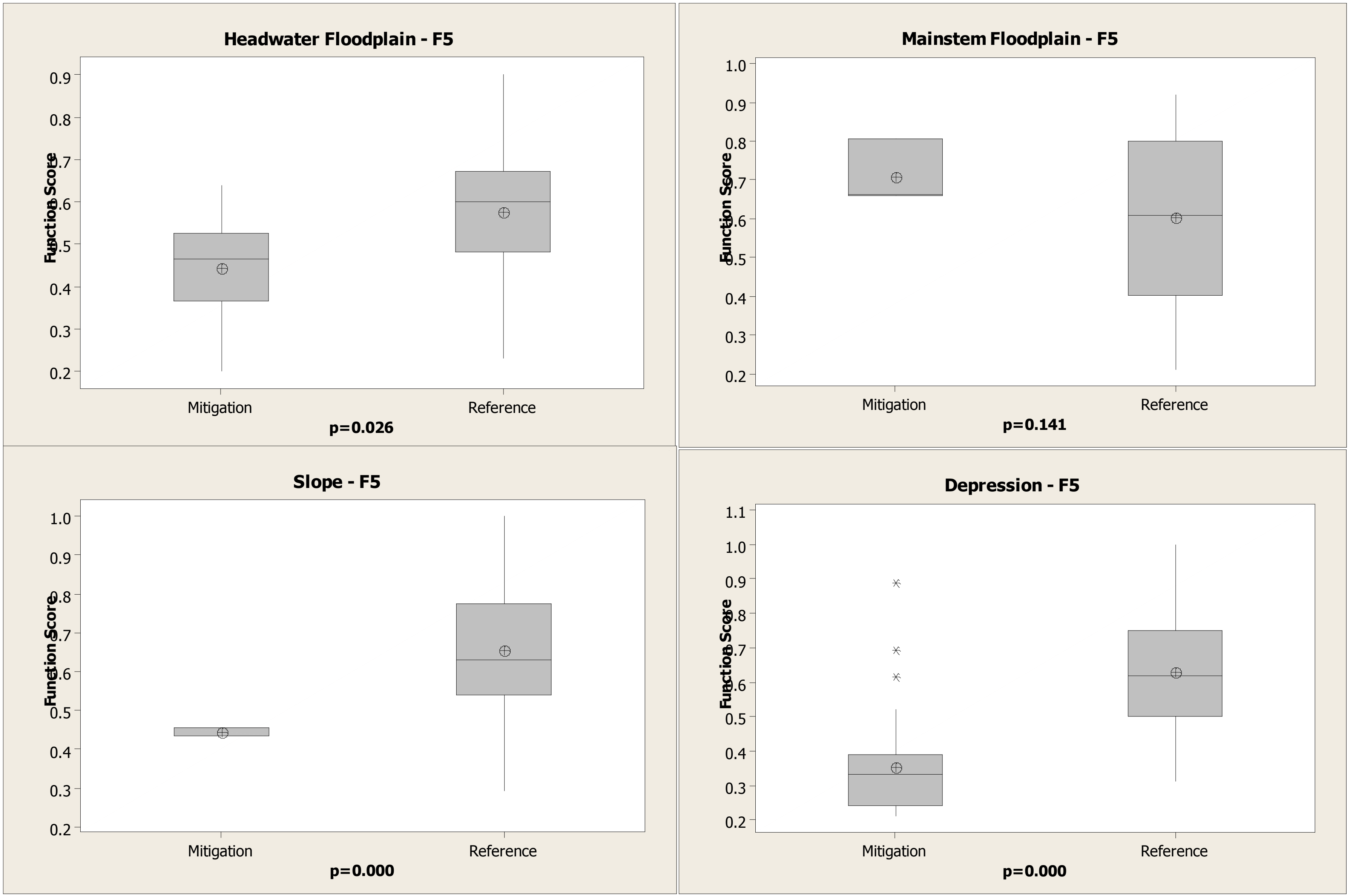

Reference wetlands had significantly higher scores than mitigation sites for these 3 types of wetlands.

# Soil Organic Matter:  Depression & Fringing Wetlands

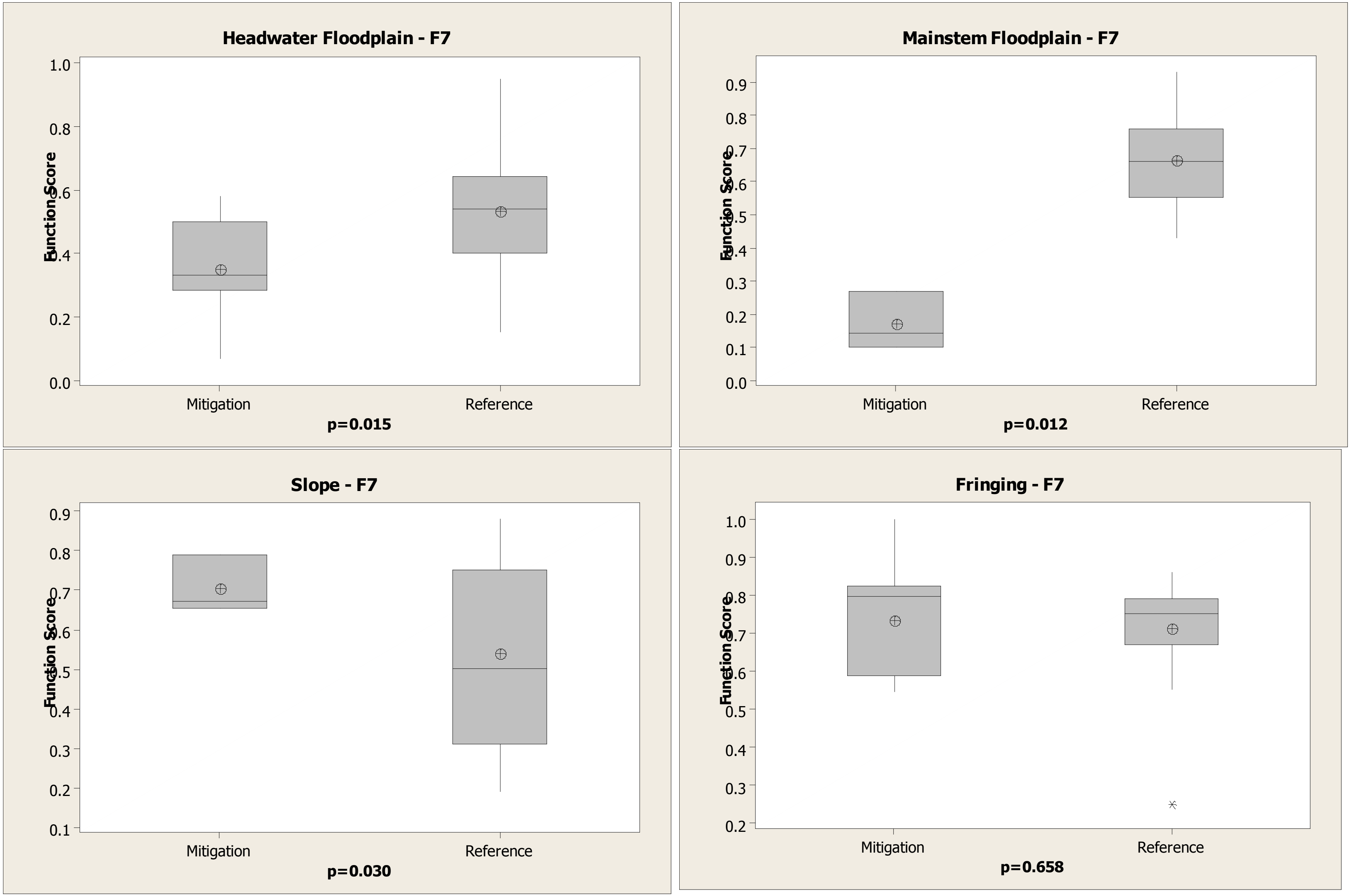


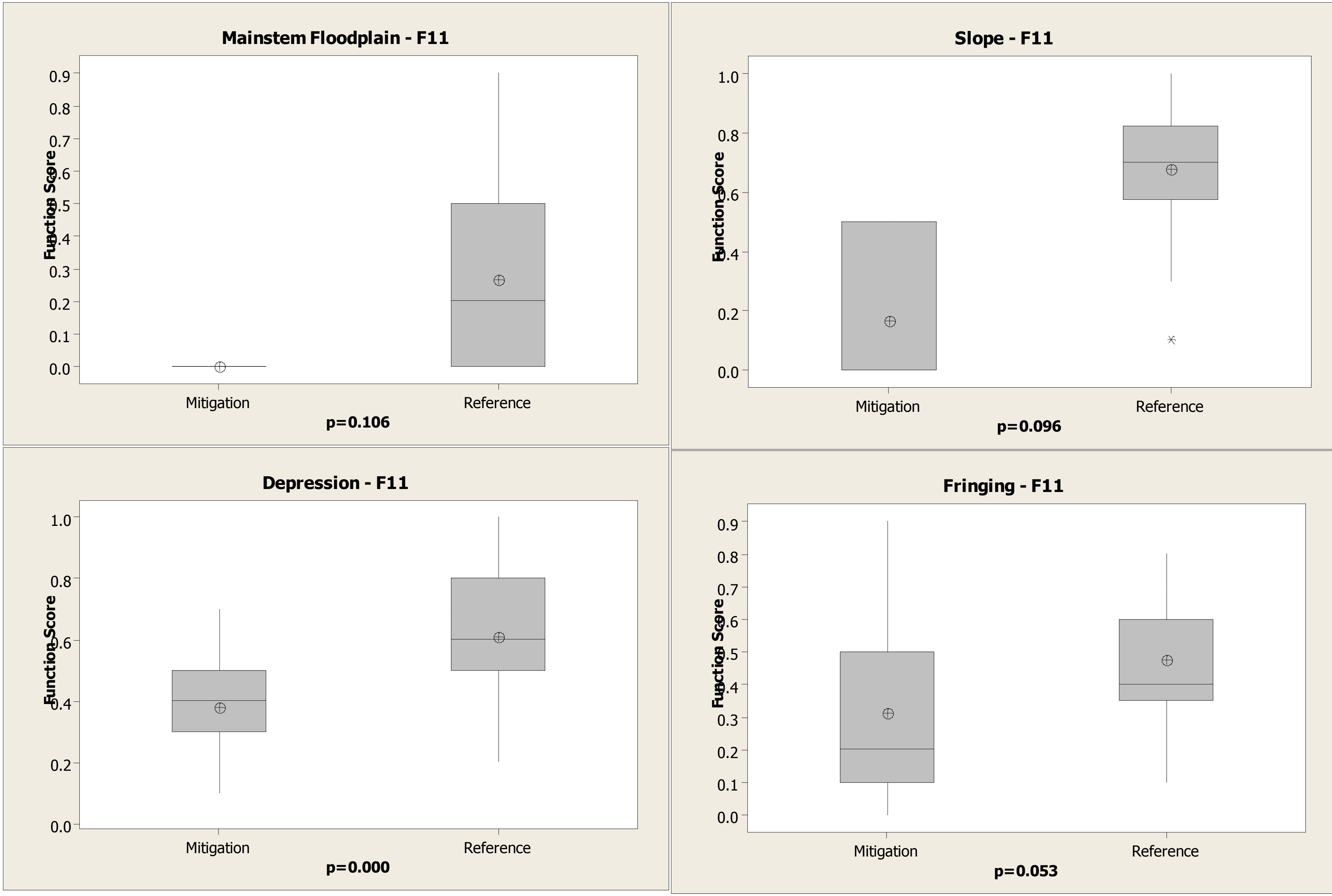
# Removal of Nitrogen (F5): Riverine, Slope, and Depression Wetlands



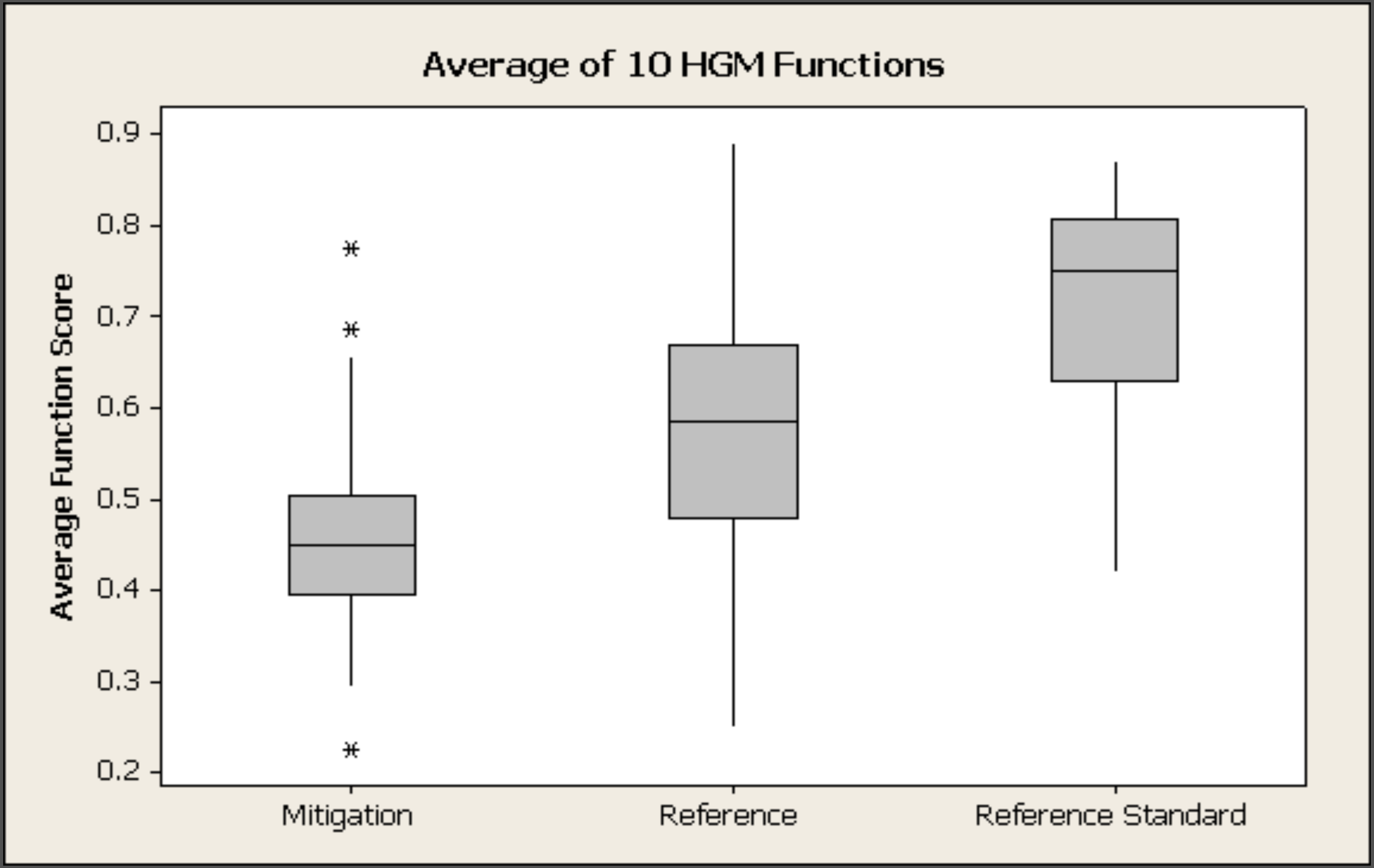
# Retention of Sediments (F7): Riverine, Slope, and Fringing



# Provision of Wildlife Habitat (10 species; F11): Riverine, Slope, Depression, and Fringing



# Comparison of Functions in Reference and Mitigation Wetlands in Pennsylvania



# Conclusions … thus far

- Mitigation wetlands are not providing high functioning replacements for natural wetland encroachments
  - Mitigation wetlands have lower average function scores
  - HGM class distribution is skewed toward depressions

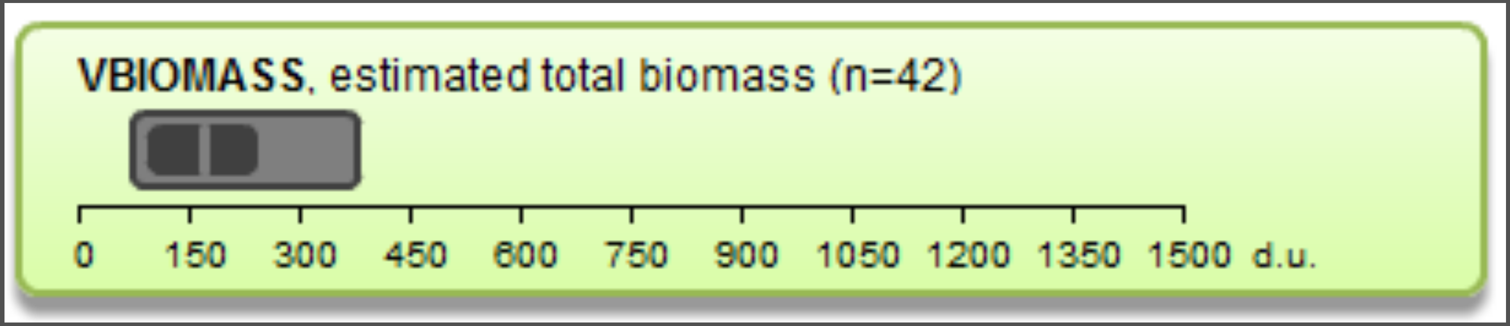
- Use reference data for design and construction.

- Link condition assessment, mitigation, and restoration with consistent monitoring protocols.

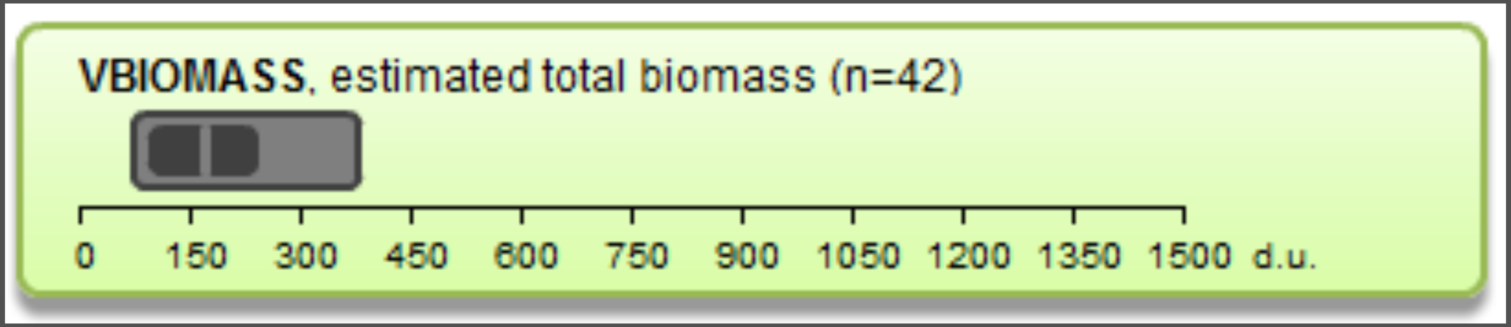
- Riparia's Database of Reference Wetlands
  - Assessing condition (due to stressors)
  - Designing mitigation and restoration projects
  - Evaluating performance of projects

  - Interactive website to provide data to practitioners

http://wa.cei.psu.edu/wetlands/



# Web-interface displays data in tiles and tables



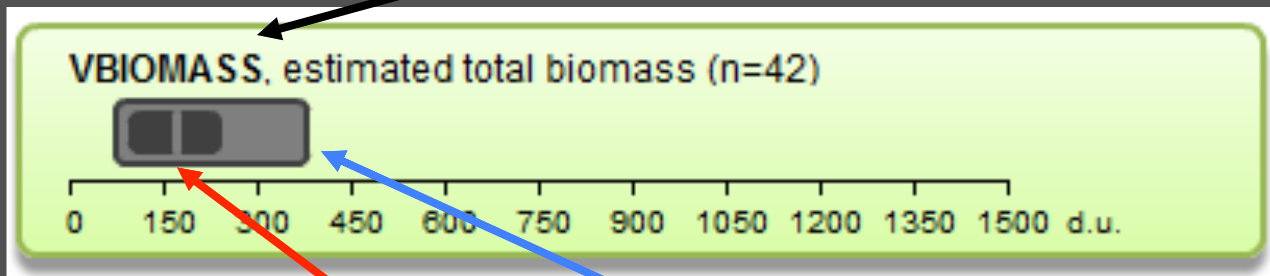

| Variable Description | N | Min | Avg | Max | SD |
|---|---|---|---|---|---|
| VBIOMASS estimated total biomass | 34 | 75.68 | 156.39 | 381.79 | 67.83 |
| VTREE estimated % cover of trees | 34 | 0 | 0.06 | 0.32 | 0.08 |
| VSHRUB estimated % cover of shrubs | 34 | 0 | 18.53 | 81.22 | 16.52 |
| VHERB estimated % cover of herbs | 34 | 31.25 | 78.78 | 100 | 20.25 |
| VCWD-BA coarse woody debris est BA | 34 | 0 | 69.2 | 633.25 | 129.12 |

…

# Variable Tile

(mouse over)

Estimates above-ground vegetative biomass using percent cover of tree, shrub and herbaceous layers. This variable is used as a relative estimate of the ability of the site to temporarily sequester nitrogen in above-ground biomass. It is comprised of three sub-variables: VTREE, VSHRUB and VHERB; no dimensions.



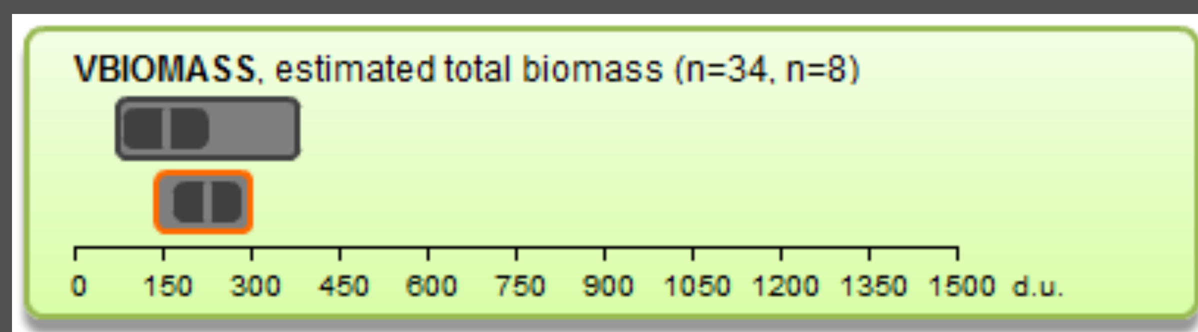

min: 76 max: 382

mean: 170 sd: 71

# Variable Tile (Stacked)

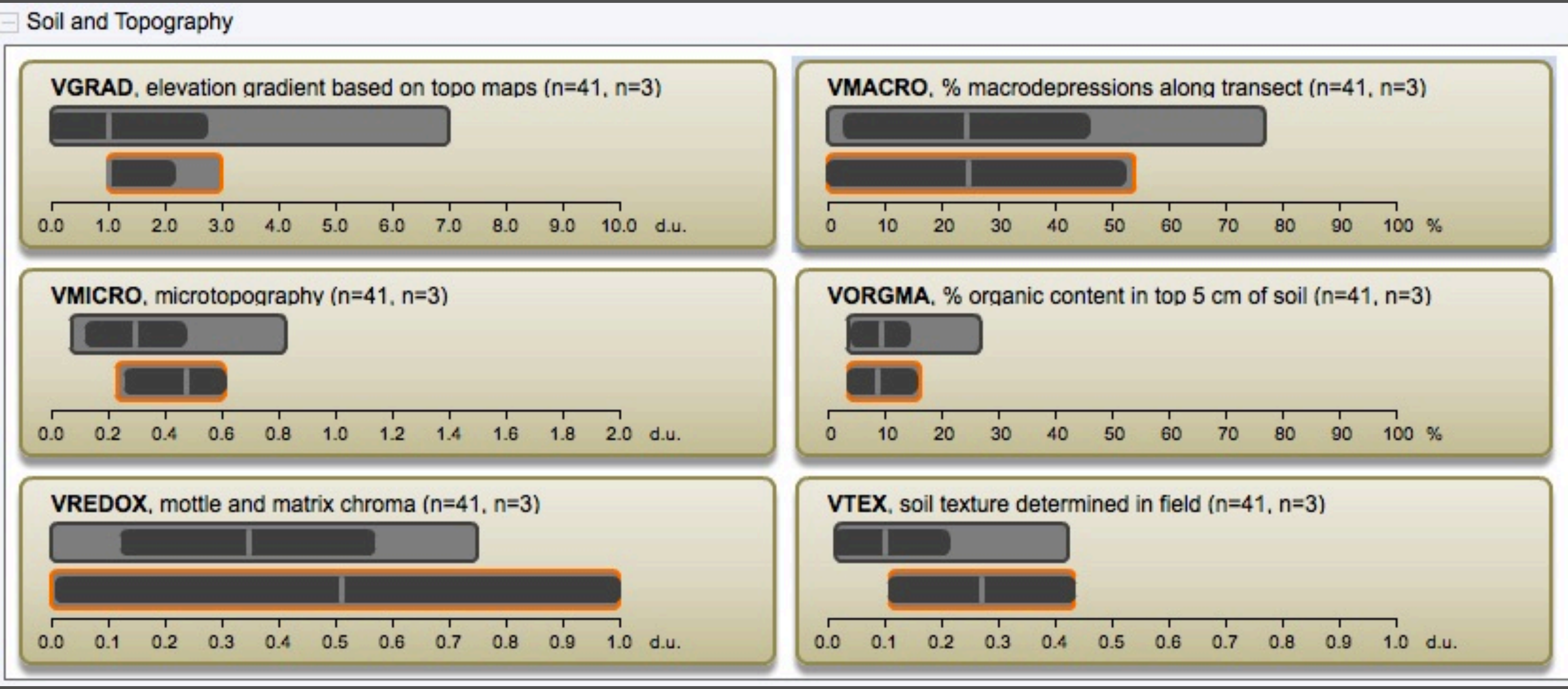
Reference sites

Reference standard sites




Landscape variables

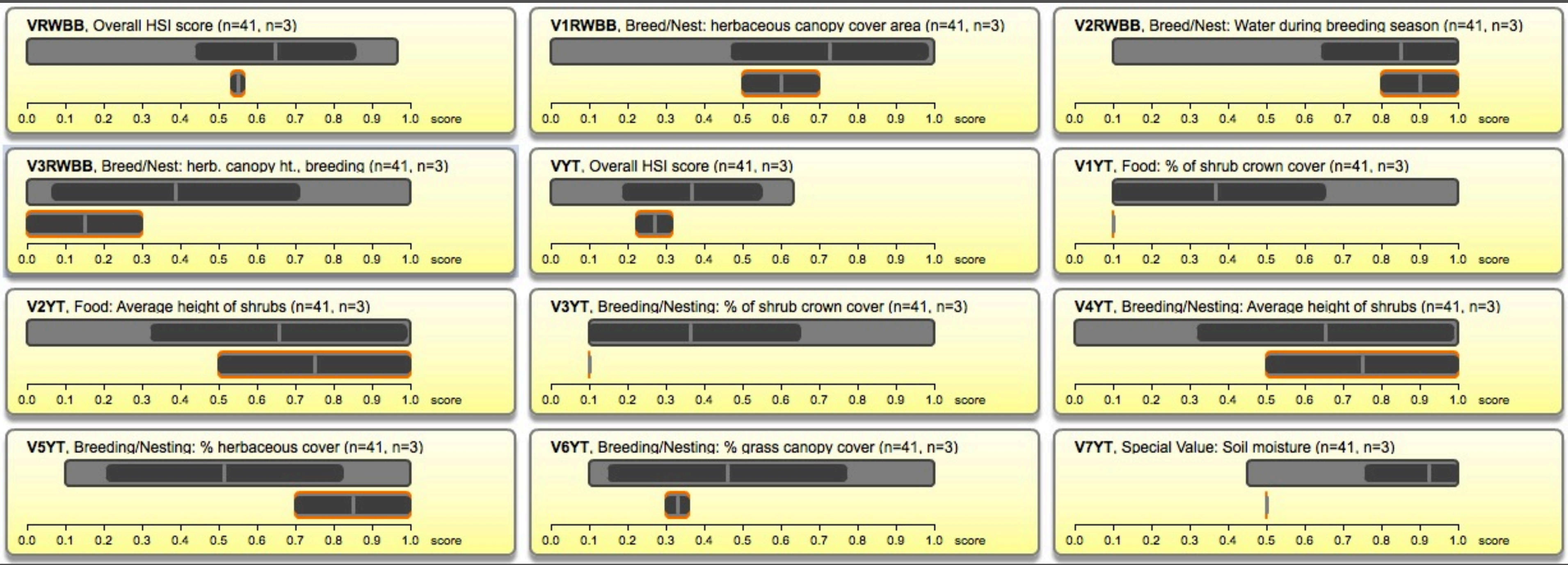
# Soils & Topography



# Vegetation

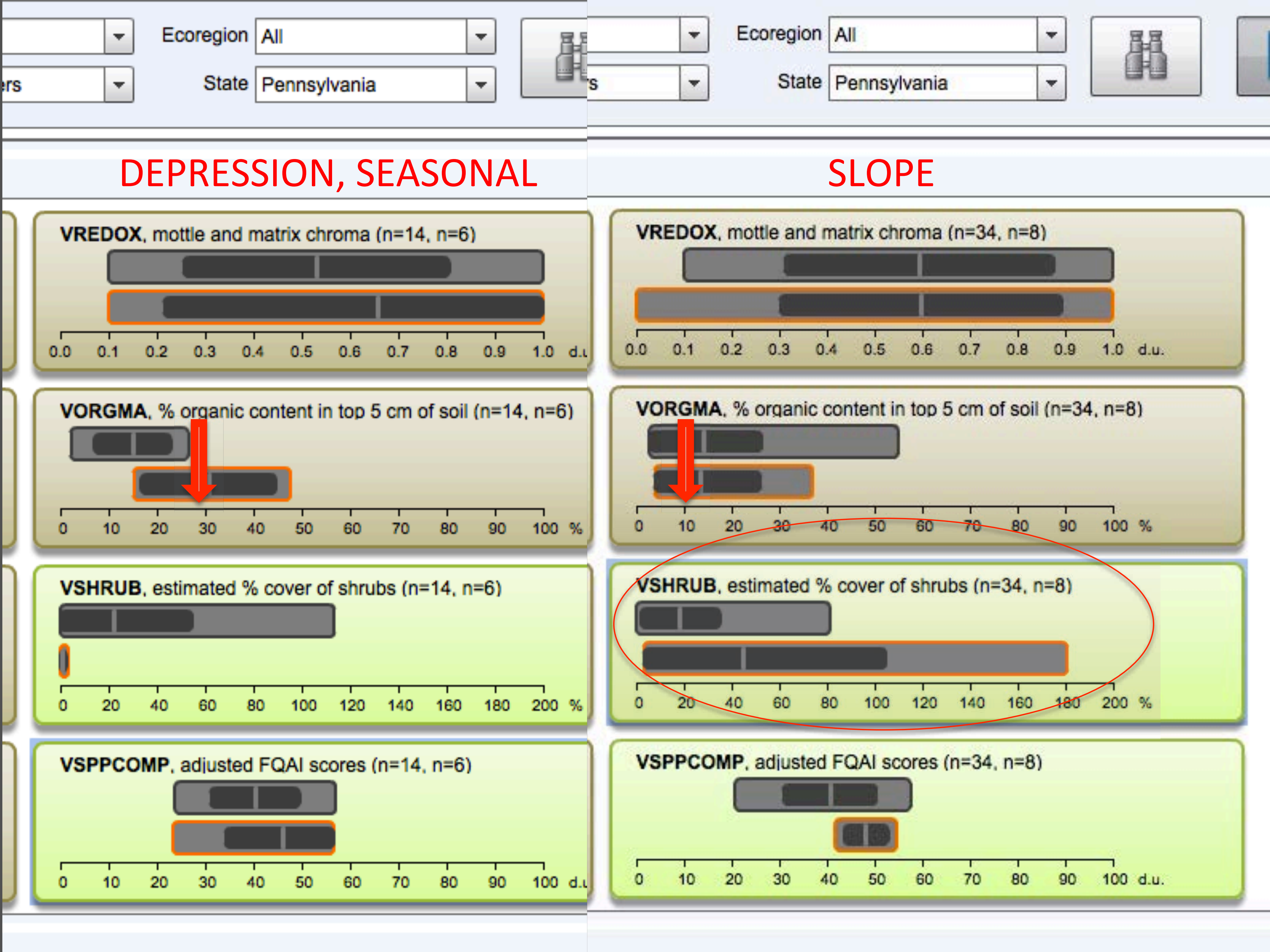

Vegetation
VBIOMASS, estimated total biomass (n=41, n=3)
0 150 300 450 600 750 900 1050 1200 1350 1500 d.u.
VTREE, estimated % cover of trees (n=41, n=3)
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 %
VSHRUB, estimated % cover of shrubs (n=41, n=3)
0 20 40 60 80 100 120 140 160 180 200 %
VHERB, estimated % cover of herbs (n=41, n=3)
0 15 30 45 60 75 90 105 120 135 150 %
VCWD-BA, coarse woody debris est. basal area (n=41, n=3)
0 100 200 300 400 500 600 700 800 900 1000 ?
VCWD-BA, CWD est. basal area, branches/saplings (n=41, n=3)
0 100 200 300 400 500 600 700 800 900 1000 ?
VCWD-BA, CWD est. basal area, trees (n=41, n=3)
0 100 200 300 400 500 600 700 800 900 1000 ?
VCWD-BA, CWD est. basal area, large trees (n=41, n=3)
0 100 200 300 400 500 600 700 800 900 1000 ?
VCWD-SZ, coarse woody debris size class tally (n=41, n=3)
0.0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7 3.0 class/site
VEXOTIC, % of species that are non-native (n=41, n=3)
0 10 20 30 40 50 60 70 80 90 100 %
VFWD, estimate of depth of litter layer (n=41, n=3)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 d.u.
VREGEN, regeneration of tree species (n=41, n=3)
0 10 20 30 40 50 60 70 80 90 100 d.u.
VROUGH, site roughness index (n=41, n=3)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 d.u.
VSNAG, snag size class tally (n=41, n=3)
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0 class/site
VSPPCOMP, adjusted FQAI scores (n=41, n=3)
0 10 20 30 40 50 60 70 80 90 100 d.u.

# Wildlife HSI
## Redwinged Blackbird & Common Yellowthroat (10 spp.)



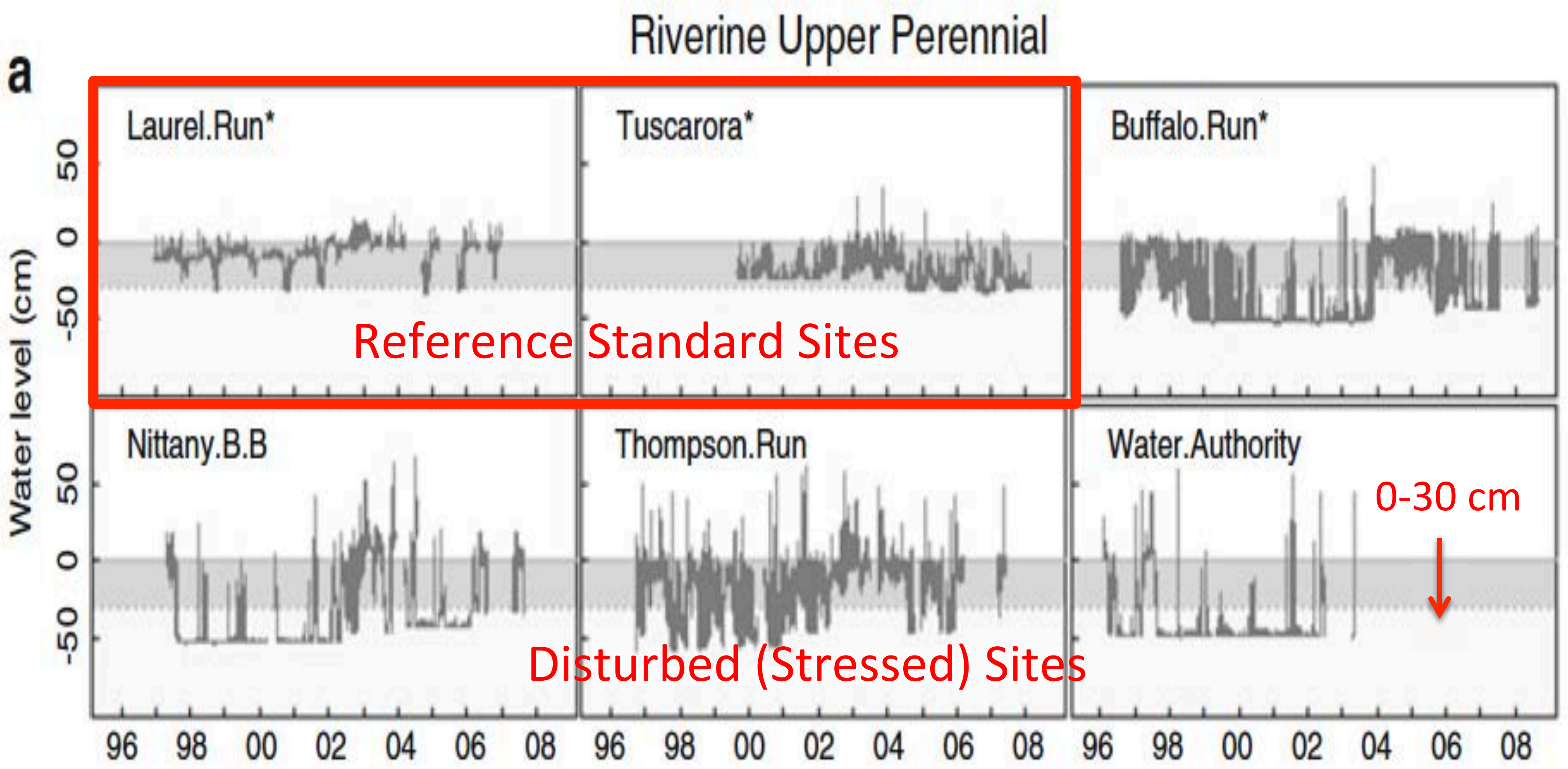
# Wildlife HSI - table

| Variable | Description | N | Min | Avg | Max | SD |
|---|---|---|---|---|---|---|
| VRWBB | Overall HSI score | 3 | 0.53 | 0.55 | 0.57 | 0.02 |
| V1RWBB | Breed/Nest: herbaceous canopy cover area | 3 | 0.5 | 0.6 | 0.7 | 0.14 |
| V2RWBB | Breed/Nest: Water during breeding season | 3 | 0.8 | 0.9 | 1 | 0.14 |
| V3RWBB | Breed/Nest: herb. canopy ht., breeding | 3 | 0 | 0.15 | 0.3 | 0.21 |
| VYT | Overall HSI score | 3 | 0.22 | 0.27 | 0.32 | 0.07 |
| V1YT | Food: % of shrub crown cover | 3 | 0.1 | 0.1 | 0.1 | 0 |
| V2YT | Food: Average height of shrubs | 3 | 0.5 | 0.75 | 1 | 0.35 |
| V3YT | Breeding/Nesting: % of shrub crown cover | 3 | 0.1 | 0.1 | 0.1 | 0 |
| V4YT | Breeding/Nesting: Average height of shrubs | 3 | 0.5 | 0.75 | 1 | 0.35 |
| V5YT | Breeding/Nesting: % herbaceous cover | 3 | 0.7 | 0.85 | 1 | 0.21 |
| V6YT | Breeding/Nesting: % grass canopy cover | 3 | 0.3 | 0.33 | 0.36 | 0.04 |
| V7YT | Special Value: Soil moisture | 3 | 0.5 | 0.5 | 0.5 | 0 |



DEPRESSION, SEASONAL
Ecoregion All
State Pennsylvania
VREDOX, mottle and matrix chroma (n=14, n=6)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 d.u.
VORGMA, % organic content in top 5 cm of soil (n=14, n=6)
0 10 20 30 40 50 60 70 80 90 100 %
VSHRUB, estimated % cover of shrubs (n=14, n=6)
0 20 40 60 80 100 120 140 160 180 200 %
VSPPCOMP, adjusted FQAI scores (n=14, n=6)
0 10 20 30 40 50 60 70 80 90 100 d.u.
SLOPE
Ecoregion All
State Pennsylvania
VREDOX, mottle and matrix chroma (n=34, n=8)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 d.u.
VORGMA, % organic content in top 5 cm of soil (n=34, n=8)
0 10 20 30 40 50 60 70 80 90 100 %
VSHRUB, estimated % cover of shrubs (n=34, n=8)
0 20 40 60 80 100 120 140 160 180 200 %
VSPPCOMP, adjusted FQAI scores (n=34, n=8)
0 10 20 30 40 50 60 70 80 90 100 d.u.

# Level 3/4 - Wetland Hydrograph Analysis



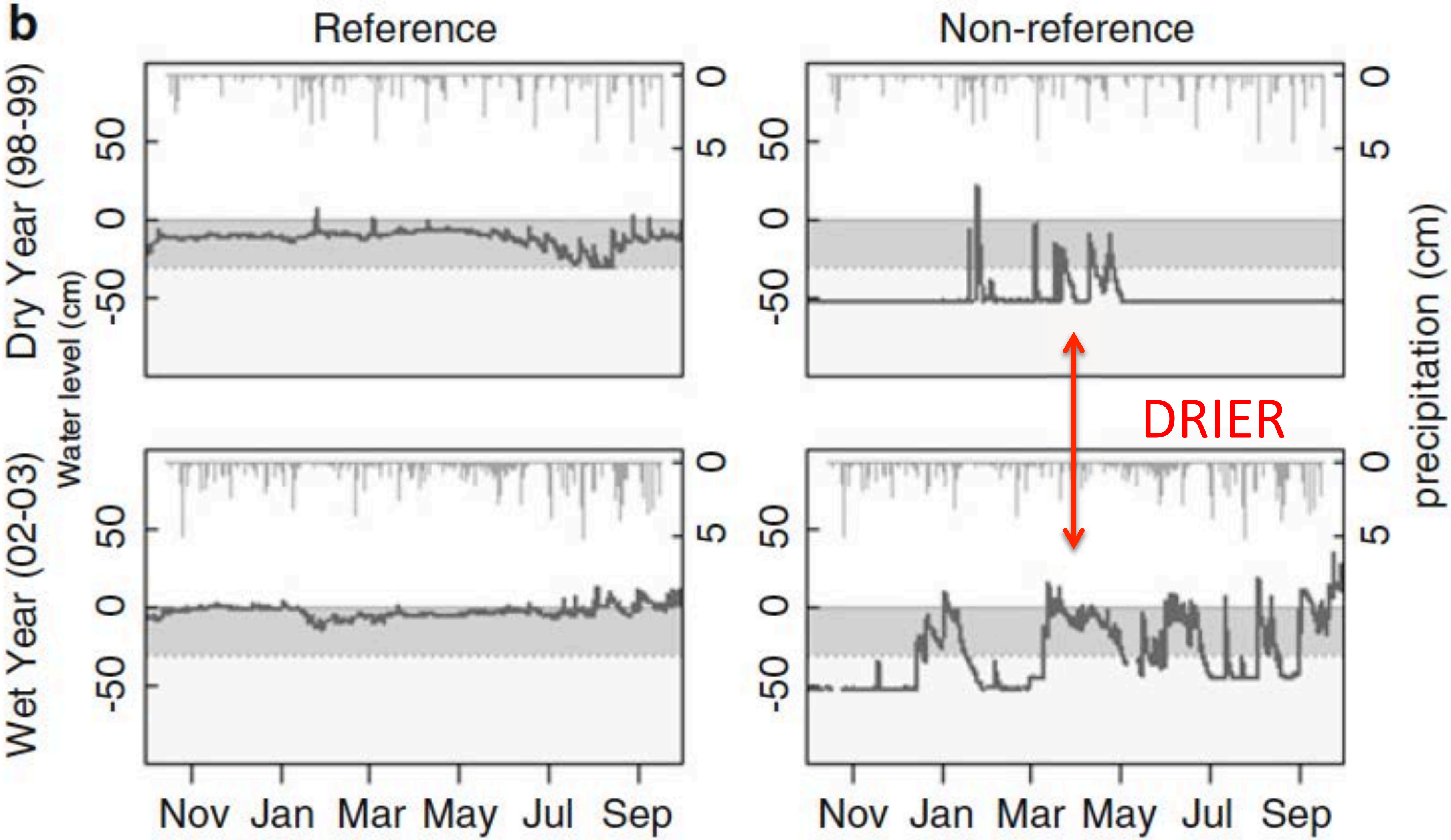

Hychka et al. 2013

# Palmer Hydrologic Drought Index
# 1999-2001 (dry) – 2003-2005 (wet)

| | | | Palmer Hydrologic Drought Index | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1995 | 3.21 | 2.45 | 1.16 | 0.93 | 0.95 | -1.35 | -1.97 | -3.28 | -3.83 | -2.55 | -1.55 | -1.66 |
| 1996 | 2.41 | 2.28 | 2.19 | 2.26 | 2.13 | 2.00 | 2.15 | 1.53 | 3.95 | 4.54 | 4.68 | 4.95 |
| 1997 | 4.25 | 3.69 | 3.61 | 2.48 | 2.22 | 1.59 | 0.85 | 1.69 | 1.99 | 1.15 | 2.54 | 2.06 |
| 1998 | 2.37 | 2.27 | 1.65 | 2.74 | 2.09 | 2.03 | 1.02 | 1.49 | -2.22 | -2.34 | -3.47 | -4.28 |
| 1999 | -2.33 | -2.64 | -2.49 | -2.01 | -2.89 | -3.35 | -4.16 | -4.22 | -3.32 | -3.52 | -3.31 | -3.27 |
| 2000 | -3.34 | -2.91 | -3.20 | -2.23 | -2.19 | -1.30 | -2.04 | -1.91 | -1.92 | -1.84 | -2.20 | -2.23 |
| 2001 | -2.56 | -2.90 | -2.09 | -2.48 | -2.86 | -2.67 | -3.11 | -3.41 | -2.60 | -2.47 | -2.87 | -2.77 |
| 2002 | -2.85 | -2.95 | -2.56 | -2.37 | -1.07 | 1.52 | -1.06 | -1.88 | -1.90 | -1.35 | -1.39 | -0.99 |
| 2003 | -0.97 | -0.60 | -0.78 | -1.20 | -0.84 | -0.55 | 1.57 | 2.39 | 4.20 | 4.23 | 4.53 | 4.68 |
| 2004 | 4.73 | 4.22 | 3.42 | 3.69 | 3.47 | 2.95 | 4.91 | 5.16 | 7.31 | 6.52 | 5.88 | 5.54 |
| 2005 | 6.34 | 5.83 | 5.12 | 4.00 | 2.94 | 1.69 | 0.74 | -2.78 | -3.60 | -2.68 | -1.73 | -1.80 |
| 2006 | -0.95 | -1.35 | -2.08 | -2.21 | -2.49 | -1.33 | -0.86 | 1.88 | 2.63 | ND | ND | ND |

| | |
|---|---|
| > 4.00 | Extreme wetness |
| 3.00 to 3.99 | Severe wetness |
| 1.50 to 2.99 | Mild to moderate wetness |
| -1.49 to 1.49 | Near normal |
| -1.50 to -2.99 | Mild to moderate drought |
| -3.00 to -3.99 | Severe drought |
| <-4.00 | Extreme drought |

# Wetland Hydrograph Analysis




Hychka et al. 2013

How can reference wetlands and an interactive database inform practitioners to improve mitigation and restoration?

Monitoring and Recommendations

Restoration of stream channel following mining

Completed stream restoration project

# Water - intersection of groundwater on restoration project.

Source of materials:

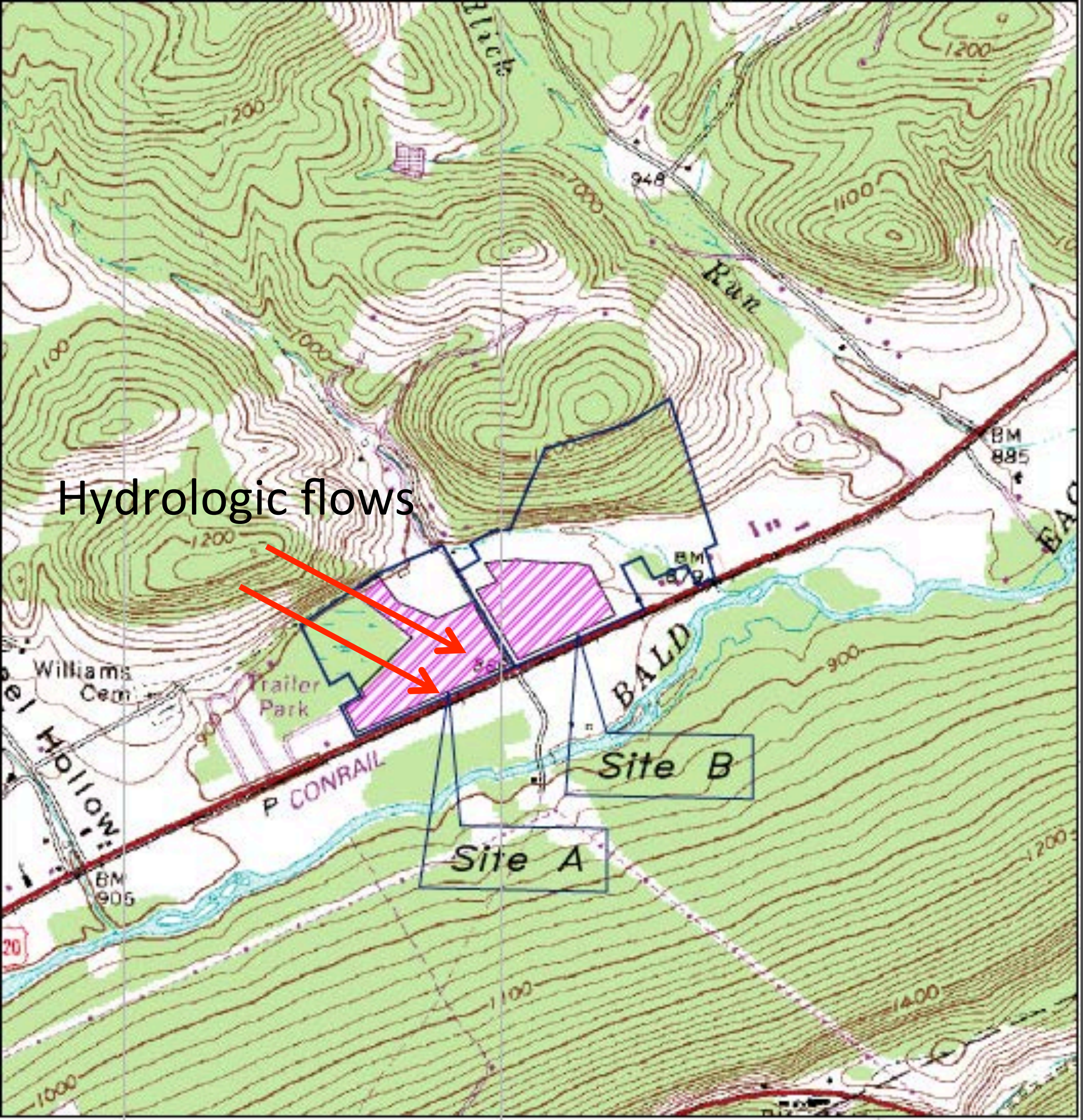
Wetland plant nursery
(Environmental Concern, MD)

# Wetland Mitigation and Restoration Workshops 2014

Sponsored by USEPA HQ, Region 3, USGS, & Riparia

- #1 Gainesville, VA
- #2 State College, PA (SWS Chapter mtg)
- #3 New Orleans, LA (SER National mtg)

- Participants examined pre- and post-construction sites and data for the interactive database for sites located in central Pennsylvania




USGS 7.5 MINUTE QUADRANGLE FOR JULIAN, PA
(1962, PR 1987)

## Landscape Context

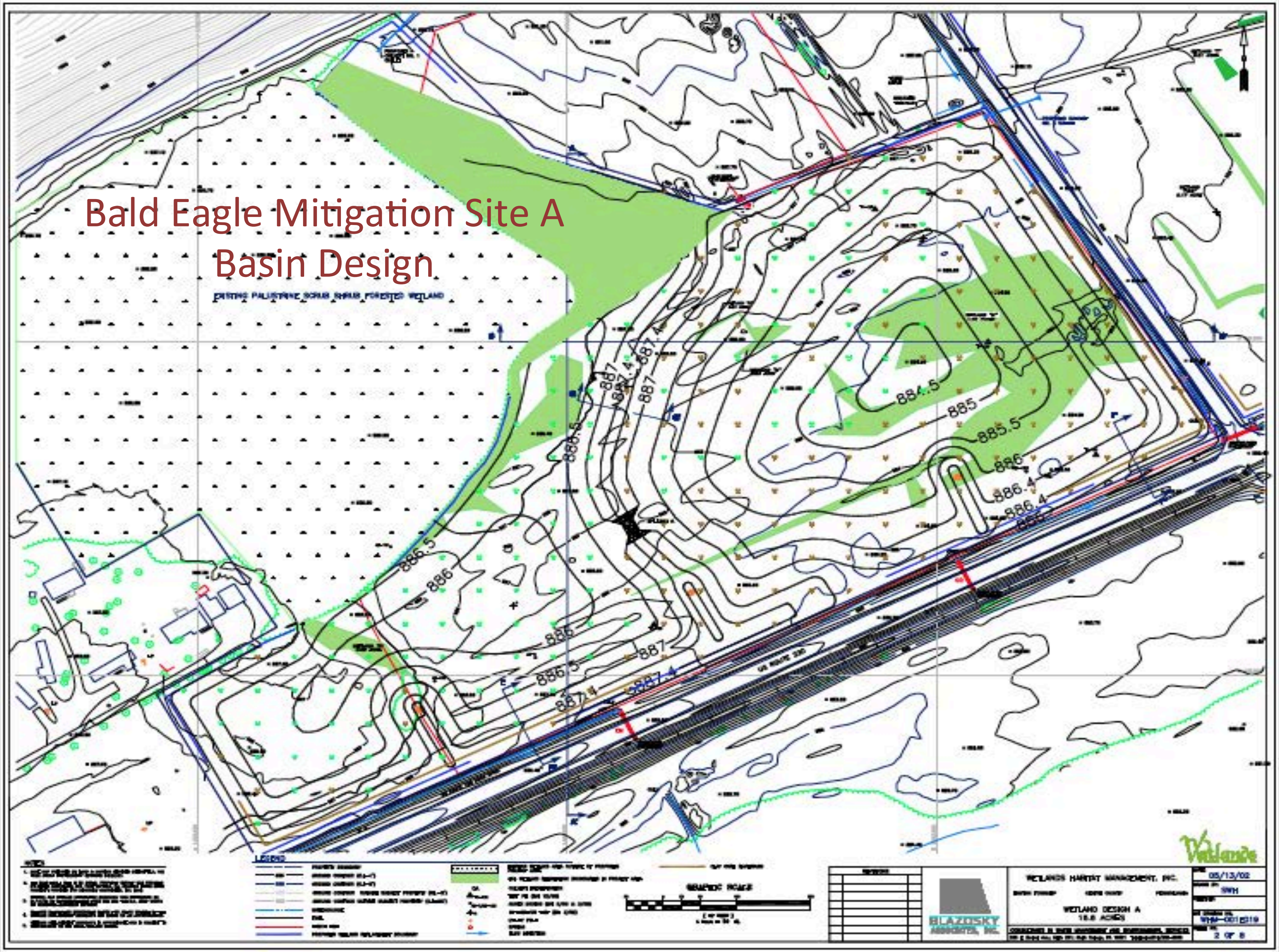
Bald Eagle Mitigation
Site A

Located between Ridge & Valley (S) and Allegheny Plateau (N)

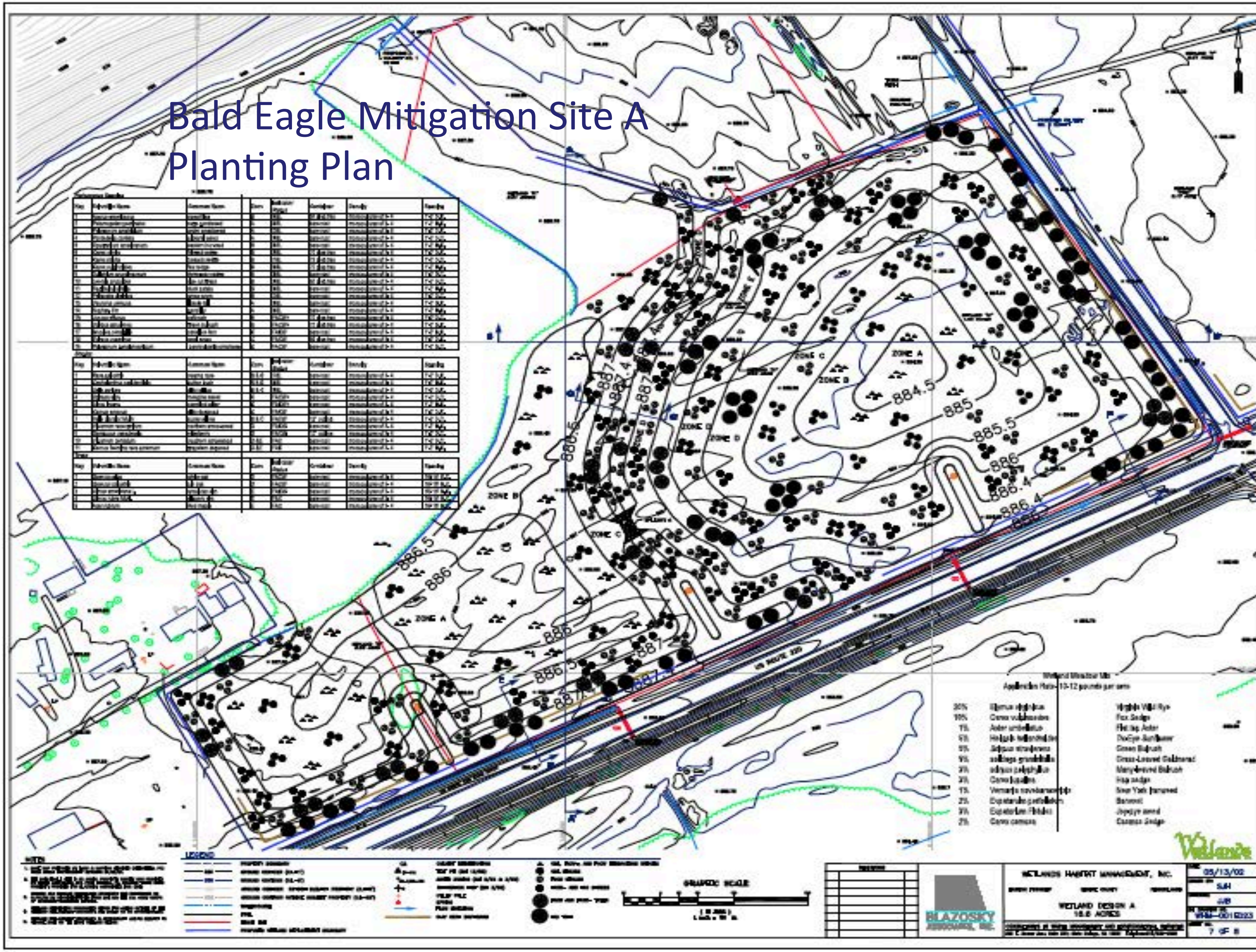
Associated with I-99 Highway mitigation

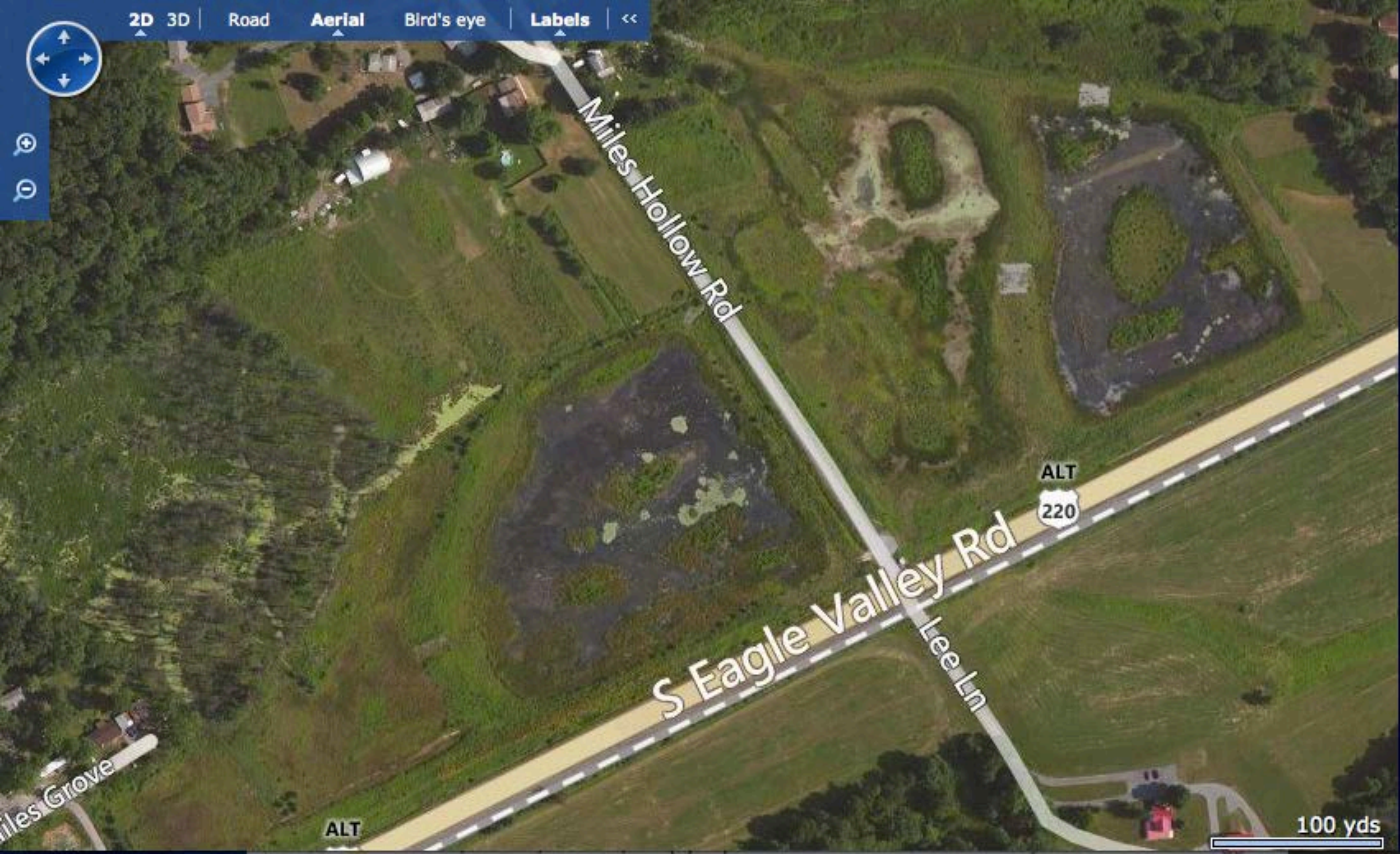
Designed & built by WHM, State College Pennsylvania

# Bald Eagle Mitigation Site A Basin Design



# Bald Eagle Mitigation Site A Planting Plan






Bald Eagle Wetland Mitigation Site – Aug 2012

Vegetation:

Reference sites can provide useful information to design and assess mitigation and restoration projects.

# Floristic Quality Assessment Report

Site name: Bald Eagle WHM 2007 Riparia mitigation monitoring
Ecoregion: Allegheny Plateau

## RESULTS

| FQI | 24.2 |
|---|---|
| Adjusted FQI | 34.7 |
| Total Mean C | 3.7 |
| Total Count | 39 |
| Native Mean C | 4.1 |
| Native Count | 35 |

| Tolerance | Count |
|---|---|
| high | 17 |
| intermediate | 13 |
| poor | 5 |
| very poor | 0 |
| not applicable | 4 |

| WIS | Count |
|---|---|
| OBL | 17 |
| FACW | 12 |
| FAC | 2 |
| FACU | 4 |
| UPL | 0 |
| NA | 4 |

http://apps.cei.psu.edu/fqacalc/

| Scientific Name | Native | C | WIS |
|---|---|---|---|
| Alisma triviale | Y | 4 | OBL |
| Ambrosia artemisiifolia | Y | 1 | FACU |
| Asclepias incarnata | Y | 5 | OBL |
| Carex comosa | Y | 8 | OBL |
| Carex cristatella | Y | 7 | FACW |
| Carex lupulina | Y | 5 | OBL |
| Carex tribuloides | Y | 4 | FACW |
| Carex vulpinoidea | Y | 2 | OBL |
| Cyperus strigosus | Y | 2 | FACW |
| Elymus riparius | Y | 5 | FACW |
| Epilobium coloratum | Y | 2 | FACW |
| Eupatorium perfoliatum | Y | 3 | FACW |
| Galium palustre | Y | 8 | OBL |
| Glyceria grandis | Y | 8 | OBL |
| Hypericum mutilum | Y | 3 | FACW |
| Impatiens capensis | Y | 3 | FACW |
| Leersia oryzoides | Y | 3 | OBL |
| Ludwigia palustris | Y | 2 | OBL |
| Lycopus americanus | Y | 4 | OBL |
| Lysimachia nummularia | N | | FACW |
| Mimulus ringens | Y | 5 | OBL |
| Myosotis laxa | Y | 6 | OBL |
| Oenothera perennis | Y | 6 | FAC |
| Penthorum sedoides | Y | 4 | OBL |
| Polygonum hydropiper | N | | |
| Polygonum pensylvanicum | Y | 3 | |
| Polygonum sagittatum | Y | 3 | |
| Pontederia cordata | Y | 8 | OBL |
| Prunella vulgaris | N | | FACU |
| Scirpus atrovirens | Y | 3 | OBL |
| Scirpus cyperinus | Y | 2 | FACW |
| Euthamia graminifolia | Y | 3 | FAC |
| Sparganium eurycarpum | Y | 6 | OBL |
| Trifolium pratense | N | | FACU |
| Typha latifolia | Y | 2 | OBL |
| Verbena hastata | Y | 3 | FACW |
| Juncus effusus var. pylaei | Y | 2 | FACW |
| Nuphar lutea ssp. variegata | Y | 5 | |
| Potentilla norvegica ssp. monspeliensis | Y | 1 | FACU |

# Bald Eagle A – Planting plan vs Performance

## (after 1 yr, after 5yr)

| | Planted | Performance | | Ref Slope | |
|---|---|---|---|---|---|
| | 2002 | 2003 | 2007 | Other | Stnd. |
| FQI | 27 | 13 | 24 | | |
| Adj FQI | 48 | 27 | 35 | 36 | 48 |
| Native Avg C value( 0-10 ) | 4.8 | 3.0 | | 3.7 | |
| Nativ sp/Tot sp | 32/32 | 13/16 | | 35/39 | |
| Wentworth Index (wetland status) | 1.8 | 2.3 | | 2.5 | |

# Bald Eagle A – Planting plan vs Performance
## (after 1 yr, after 5yr)

| | Planted | Performance | | Ref Slope | |
|---|---|---|---|---|---|
| | 2002 | 2003 | 2007 | Other | Stnd. |
| FQI | 27 | 13 | 24 | | |
| Adj FQI | 48 | 27 | 35 | 36 | 48 |
| Native Avg C value( 0-10 ) | 4.8 | 3.0 | | 3.7 | |
| Nativ sp/Tot sp | 32/32 | 13/16 | | 35/39 | |
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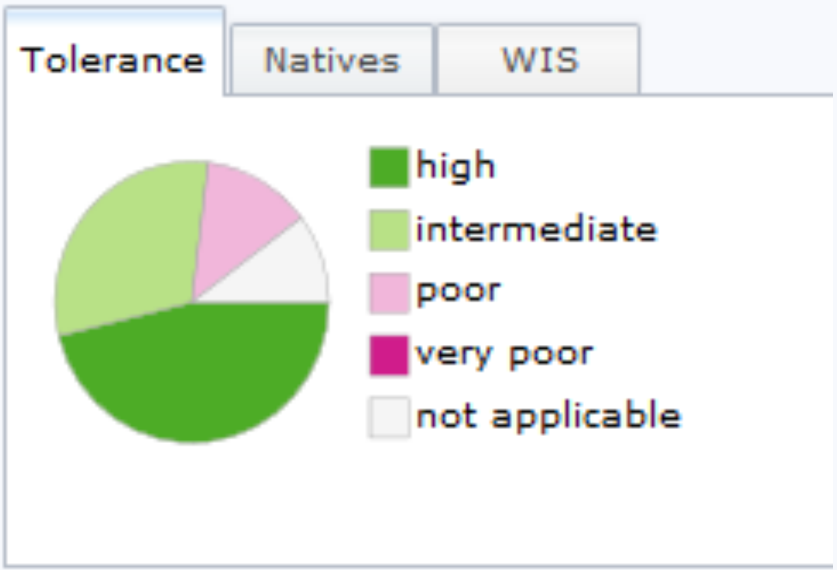
# Bald Eagle A – Planting plan vs Performance

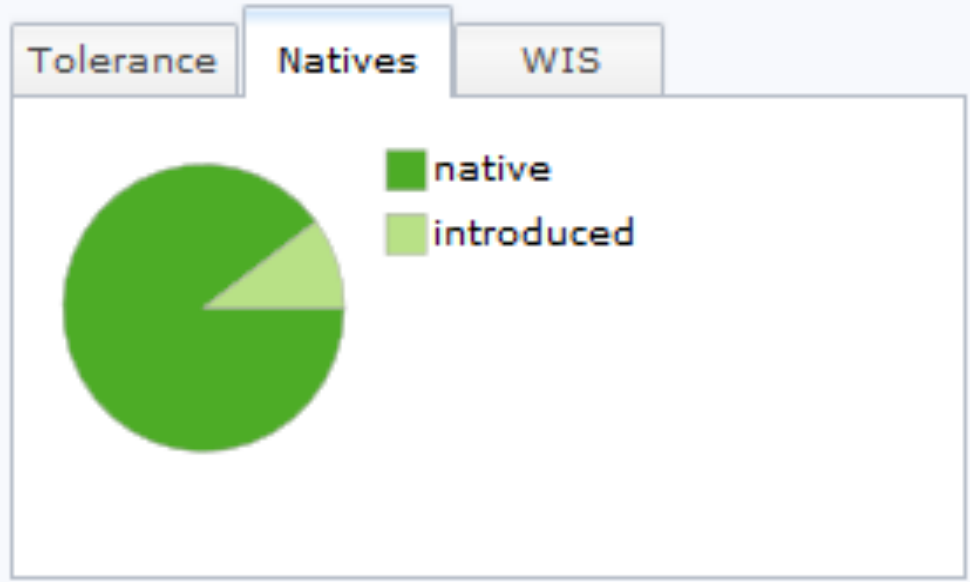
## (after 1 yr, after 5yr)

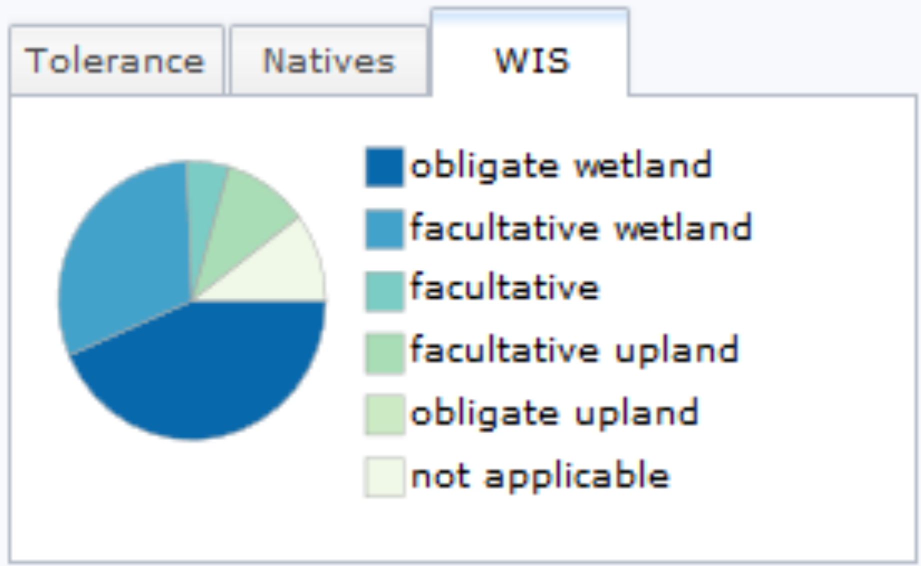
| | Planted | Performance | | Ref Slope | |
|---|---|---|---|---|---|
| | 2002 | 2003 | 2007 | Other | Stnd. |
| FQI | 27 | 13 | 24 | | |
| Adj FQI | 48 | 27 | 35 | 36 | 48 |
| Native Avg C value( 0-10 ) | 4.8 | 3.0 | | 3.7 | |
| Nativ sp/Tot sp | 32/32 | 13/16 | | 35/39 | |
| Wentworth Index (wetland status) | 1.8 | 2.3 | | 2.5 | |

drier

# Bald Eagle 2007 - Riparia mitigation monitoring output




Hydrologic connectivity
between streams and
floodplain wetlands
is critical

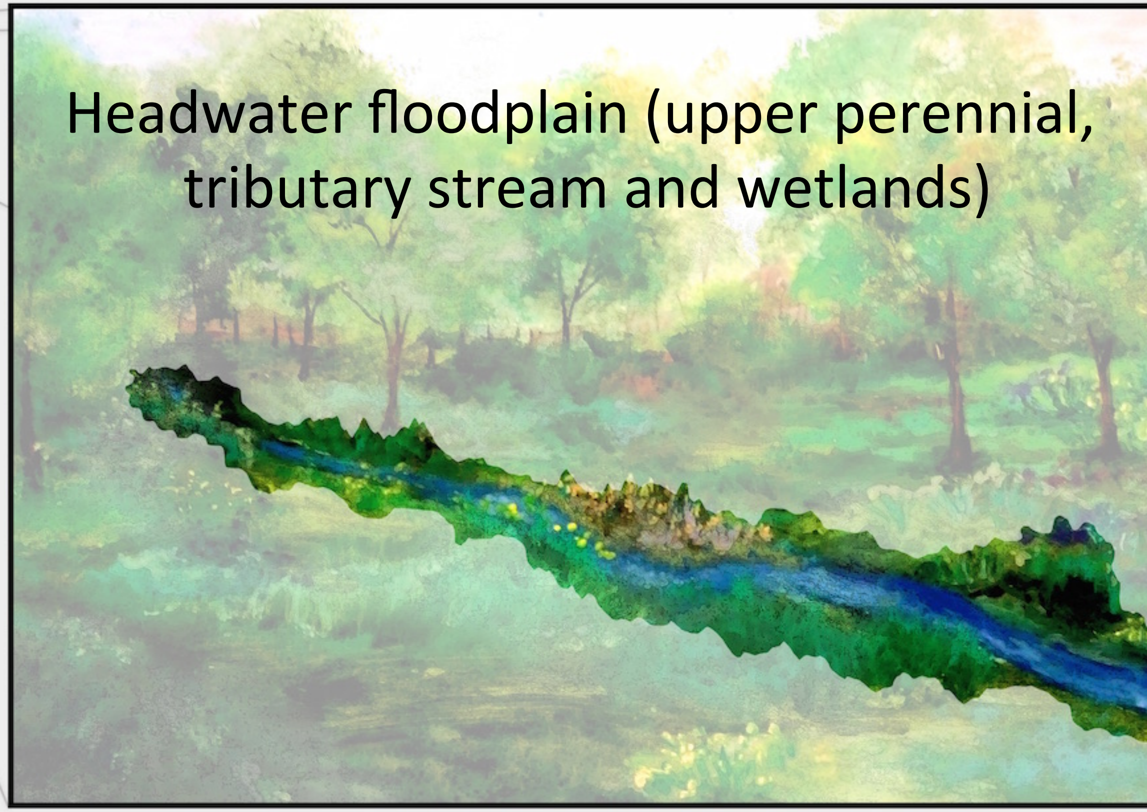

No natural bank vegetation
– unstable, poor habitat
Incised banks
– separates
stream from
floodplain &
wetlands
Photo by: Claire Regan


Adequate riparian forest buffer, but ...
Excess runoff from upstream leads to stream incision, and unstable banks


Cross vane used to reduce
incision and reconnect stream
to floodplain wetlands

Context Map of Watershed

# Headwater floodplain (upper perennial, tributary stream and wetlands)



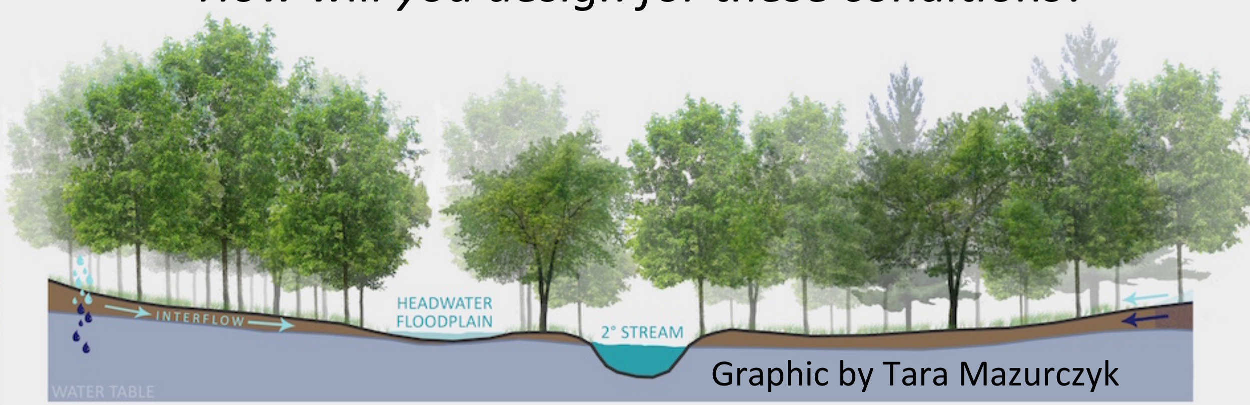
Most headwaters fed by runoff and baseflow of groundwater. Flooding or flows into the narrow floodplains are frequent, unless incised.

Soil organic matter is variable, but averages 10%

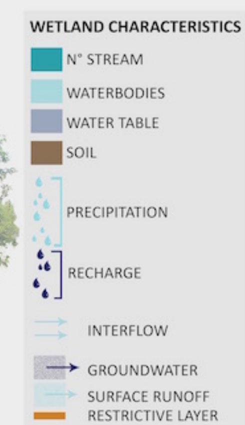
Salamanders & insects are typical predators

Ref standard sites in East often forested


*How will you design for these conditions?*

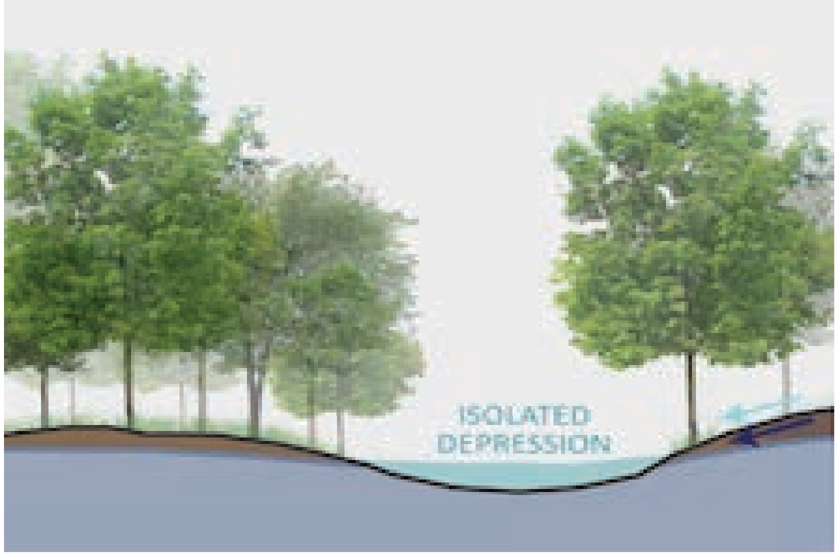



Graphic by Tara Mazurczyk



**Vernal Pools** (Calhoun et al. 2014)
(isolated depression, seasonal pool)

*Recommendations*




- If pool hydroperiod is successfully recreated, rest will follow if source populations exist within viable colonization distances – but most difficult parameter to reproduce.
- Carefully consider the effects of substrate composition, compaction, natural vegetation, and maintenance of canopy (in East).
- Generally have ephemeral hydrology, avoid permanent hydrology, should be fishless.
- Emulate gentle slopes of natural pools.
- Maintain adequate buffer distances, with suitable vegetation.
- Monitor for target species, documenting successful reproduction.

[see Tom Biebigenhauser's work]

# Technical issues with current status of mitigation and restoration

- Wetland mitigation and restoration projects do not mimic natural wetlands with regard to structure or function, resulting in a different landscape profile

- Methods used for assessing condition and evaluating performance must be the same

- Site selection tied to landscape position is critical to mimic hydrology and match soil conditions

- Recommend using reference wetlands to design and assess performance of mitigation projects

# Recommendations for wetlands mitigation & restoration

- Site selection: choose a site that mimics the hydrology for the type of wetland targeted
- Landscape setting: choose a site that will not be exposed to chronic stressors and impacts
- Soils: excavating into subsoil results in coarser texture and less organic matter, which will require soil amendments; or begin with hydric topsoil
- Design criteria: must reflect ranges for variables derived from reference wetlands of the same type

# CONCLUSIONS

Tackle problems with real solutions

Success = small, integrated projects

Level of passion governs the level of success and satisfaction

## Riparia's Reference Wetlands Database

http://wa.cei.psu.edu/wetlands/

## Riparia/MAWWG - Status & Use

Pennsylvania (Riparia) – complete, online (n = 220+)

Delaware (DNREC) – data compiled, next

West Virginia (DNR) – data acquired, after DE

Virginia (VIMS) – after WV (n = ?)

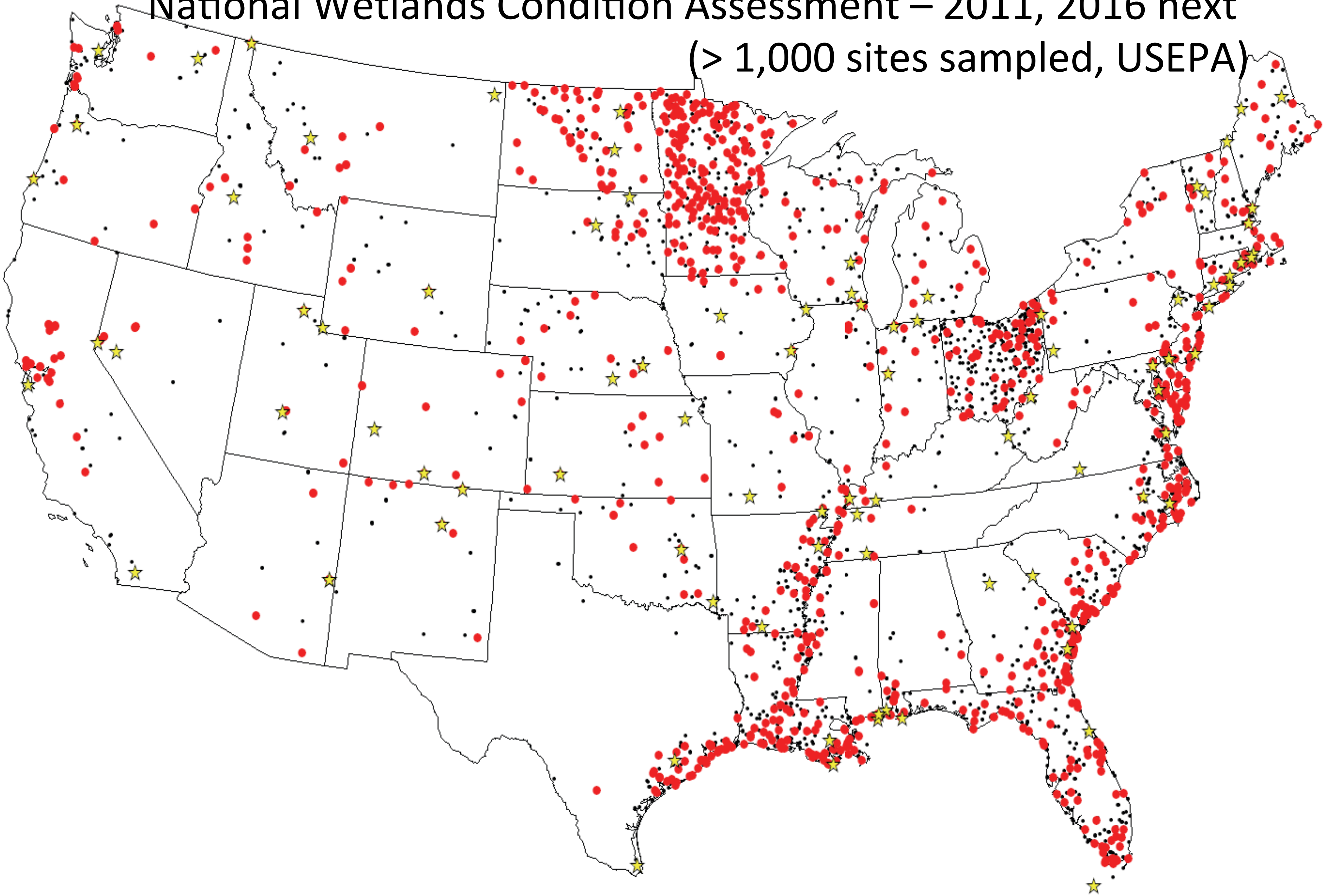
Maryland – no known reference data

May add other states …

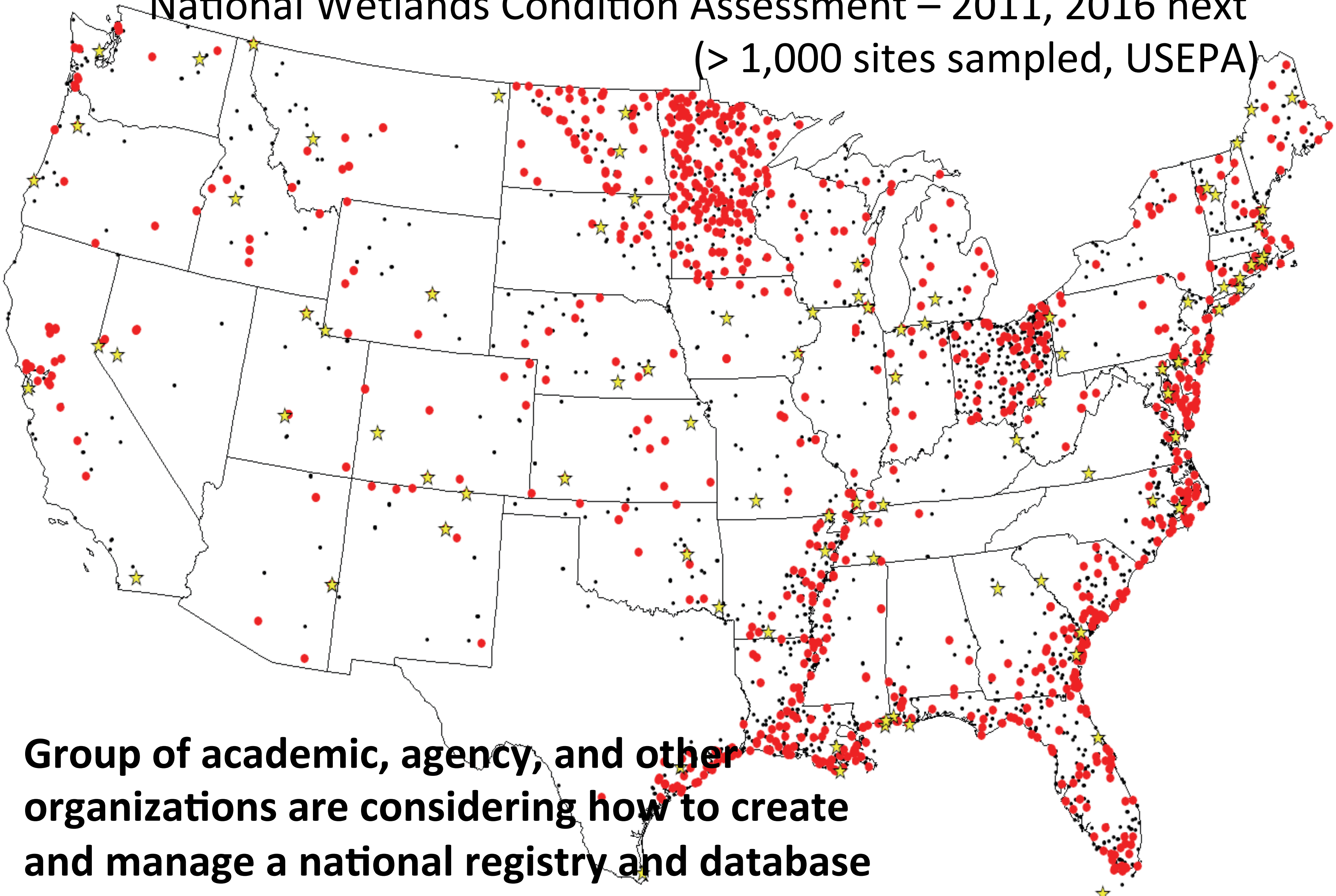
*will be 1,000+ reference wetlands*

Publicly available, interactive website – to enhance mitigation, restoration, and condition assessments

# National Wetlands Condition Assessment – 2011, 2016 next (> 1,000 sites sampled, USEPA)



National Wetlands Condition Assessment – 2011, 2016 next (> 1,000 sites sampled, USEPA)



**Group of academic, agency, and other organizations are considering how to create and manage a national registry and database for reference wetlands … stay tuned**

**Citations for literature and websites**:


Adamus P. R., K. Brandt. 1990. Impacts on quality of inland wetlands of the United States: A survey of indicators, techniques, and application of community-level biomonitoring data. EPA/600/3-90/073. US Environmental Protection Agency Environmental Research Laboratory, Corvallis, OR.

Brinson MM (1993) A hydrogeomorphic classifi cation for wetlands. Technical report WRP-DE-4, U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, DC, 79pp+app

Brooks, RP and RM Hughes. 1988. Guidelines for assessing the biotic communities of freshwater wetlands. Pages 276-282 in Proc. Nat. Wetland Mitigation Symp.: Mitigation of Impacts and Losses. Assoc. State Wetland Managers Tech. Rep. 3. 460pp.

Brooks, RP, DH Wardrop, CA Cole, and KR Reisinger. 2002. Using reference wetlands for integrating wetland inventory, assessment, and restoration for watersheds. Pages 9-15 in RW Tiner (compiler). Watershed-based wetland planning and evaluation. A collection of papers from the Wetland Millennium Event, 6-12 August 2000, Quebec City, Quebec, Canada. Distrib. by Assoc. State Wetland Managers, Inc., Berne, NY. 141pp.

Brooks, RP, DH Wardrop, CA Cole, and DA Campbell. 2005. Are we purveyors of wetland homogeneity?: A model of degradation and restoration to improve wetland mitigation. Ecological Engineering 24(4):331-340.

Brooks, RP, MM Brinson, KJ Havens, CS Hershner, RD Rheinhardt, DH Wardrop, DF Whigham, AD Jacobs, and JM Rubbo. 2011. Proposed hydrogeomorphic classification for wetlands of the Mid-Atlantic Region, USA. Wetlands 31(2):207-219.

Brooks, RP, MM Brinson, DH Wardrop, and JA Bishop. 2013. Hydrogeomorphic (HGM) classification, inventory, and reference wetlands. Pages 39-59, Chapter 2 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Brooks, RP, and NA Gebo. 2013. Wetlands restoration and mitigation. Pages 421-440, Chapter 12 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Calhoun, AJK, J Arrigoni, RP Brooks, ML Hunter, and SC Richter. 2014. Creating successful vernal pools: a literature review and advice for practitioners. Wetlands 34:1027-1038.DOI 10.1007/s13157-014-0556-8

Cowardin LM, Carter V, Golet FC, LaRoe ET (1979) Classifi cation of wetlands and deepwater habitats of the United States. FWS/OBS-79/31, U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, 131pp

Davies SP, Jackson SJ (2006) The biological condition gradient: a descriptive model for interpreting change in aquatic ecosystems. Ecol Appl 16:1251–1266.

Floristic Quality Assessment Index Calculator (for the Mid-Atlantic Region)    http://apps.cei.psu.edu/fqacalc/

Gara, B. D. and M. Micacchion. 2010. Assessment of wetland mitigation projects in Ohio. Volume 2: Developing a GIS-based tool to optimize vernal pool wetland mitigation site selection. Ohio EPA Technical Report WET/2010-1B. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Gebo, NA, and RP Brooks. 2012. Hydrogeomorphic (HGM) assessment of mitigation sites compared to natural reference wetlands in Pennsylvania. Wetlands 32:321-331.

Hughes RM, Larsen DP, Omernik JM (1986) Regional reference sites: a method for assessing stream potentials. Environ Manage 10(5):629–635.

Hychka, KC, RP Brooks, and CA Cole. 2013. Hydrology of Mid-Atlantic freshwater wetlands. Pages 109-127, Chapter 4 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Kentula ME, Brooks RP, Gwin SE, Holland CC, Sherman AD, Sifneos JC (1992) Wetlands. An approach to improving decision making in wetland restoration and creation. Island Press, Washington, DC, 151pp

Moon, JB, and DH Wardrop. 20130 Pages 61-108, Chapter 3 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Moreno-Mateos, D., et al. 2012. Structural and functional loss in restored wetland ecosystems. PLoS Biol 10(1): e1001247.

Ramsar – www.ramsar.org (numerous publications

Riparia's Reference Wetlands Database (reference wetlands summary data by type and ecoregion for PA; other states coming …)    http://wa.cei.psu.edu/wetlands/

Smith RD, Ammann A, Bartoldus C, Brinson MM (1995) An approach for assessing wetland functions using hydrogeomorphic classifi cation, reference wetlands, and functional indices.  Wetlands research program technical report WRP-DE-9. U.S. Army Corps of Engineers,  Waterways Experiment Station, Washington, DC, 79pp

Yetter, S. 2013. Freshwater Macroinvertebrates in the Mid-Atlantic Region. Pages 339-379, Chapter 10 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Wardrop, DH, ME Kentula, RP Brooks, MS Fennessy, SJ Chamberlain, KJ Havens, and C Hershner. 2013. Monitoring and assessment of wetlands: concepts, case studies, and lessons learned. Pages 381-419, Chapter 11 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

# Thank you!

# Q&A

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