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# Hydropedogy:
# Genesis, Properties, and Distribution of Hydromorphic Soils

**Overview** | **Objectives**

Because of the environmental and economic importance of wetlands and coastal resources to northeast, pedologists in this region have been developing expertise in the identification, characterization, classification, and land use interpretations for soils within these areas. In this project, we will establish a framework for the systematic study of saturated, hydric, and subaqueous soils across the northeastern US. This project will focus on: documenting the physical, chemical and morphological characteristics of these soils; establishing soil-landscape and soil-vegetation relationships; and developing an understanding of how these characteristics and relationships vary across the region and with changes in land use.

## Next Participants Meeting

The next participants meeting will be held in conjunction with the 2008 Northeast Regional Cooperative Soil Survey Conference, hosted by Connecticut and Rhode Island.

When: June 2-5, 2008
Where: University of Rhode Island, Narragansett Bay Campus

Minutes from the most recent participants meeting, held 6 November 2007 during the SSSA Annual Meeting in New Orleans, LA, are avaialble **here**.

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Maintained by **Jim Thompson**

# NE-1021 Multi-State Project: Hydropedology: Genesis, Properties, and Distribution of Hydromorphic Soils

NE-1021 Goals (the big picture) 2005-2009

- improve our understanding of the processes, characteristics, and interpretations of saturated, hydric, and subaqueous soils;
- establish a framework for the integration of studies investigating soils from a hydropedological approach throughout the northeastern US.

# NE-1021 Multi-State Project: Hydropedology: Genesis, Properties, and Distribution of Hydromorphic Soils

## Northeast NCSS Participants

- Martin Rabenhorst (MD)
- Brian Needelman (MD)
- Mark Stolt (RI)
- Henry Lin (PA)
- Jim Thompson (WVA)
- Bruce Vasilas (DE)
- Peter Veneman (MA)
- Laurie Osher (ME)
- Patrick Drohan (PA)
- John Galbraith (VA)

# NE-1021 Multi-State Project:

## Project Outputs

### Outreach

- Field Tours
  - Northeast Regional Graduate Student Pedology
    - West Virginia
    - Virginia
    - Pennsylvania
  - World Congress 2006
  - NENCSS Tours
  - Workshops
- Collaborations
  - Osher, Stolt, and Rabenhorst
  - Drohan and Stolt

# NE-1021 Multi-State Project:

**Project Outputs**

**Outreach**

- Publications (or similar)

Jespersen and Osher (subaqueous soils)

Stolt, Drohan, and Richardson (carbon)

Rabenhorst, Hively, and James (hydric soils)

New additions to Keys to Soil Taxonomy for subaqueous soils (Wassents and Wassists)

Glossary of terms for subaqueous soils (landforms and parent materials); Incorporated into NSSH

Hydric soil indicators:

TA6 mesic spodic test indicator added to national manual

Investigations to support TF2 in New England

**NE-1021 Papers, Presentations, and Participants at 2009 SSSA National Meetings**

- The Role of Soil Stratigraphy and Soil Moisture Dynamics in Stream Flow in a Mediterranean Catchment.Alexandre Swarowsky*, **Anthony O'Geen** and **Randy Dahlgren**.
- Repeated Electromagnetic Induction Surveys for Understanding Landscape Soil and Water Dynamics. Qing Zhu*, **Henry Lin** and James Doolittle.
- Soil and Landscape Factors Influencing Microbial Reduction of Iron Oxides. **Martin C. Rabenhorst***,Michelle Hetu, Vera Jaffe and Philip Zurheide
- Understanding Pedologic-Hydrology Relationships Across the Landscape: Carbon Accounting and Denitrification. **Mark H. Stolt***, Sean Donohue, Margot K. Payne, Christina Pruett and Arthur Gold.
- Endogenous and Exogenous Carbon Sequestration in a Constructed Flow-through Wetland Receiving Agricultural Runoff. Jonathan Maynard*, **Anthony O'Geen** and **Randy Dahlgren**.
- Development of Subaqueous Soil Interpretations: Eelgrass Restoration, Heavy Metal Accumulations and Carbon Storage. Christina Pruett* and **Mark Stolt**.
- Developing Subaqueous Soil Interpretations: Shellfish and Dredged Material Placement. Alexander R. Salisbury*, and **Mark H Stolt**.
- The Extent and Characterization of Freshwater Subaqueous Soils of Black Moshannon Lake, Pennsylvania. Emilie Erich*, **Patrick Drohan**, Mary Kay Lupton, Katherine S. Lindeburg, Elizabeth Boyer and Joseph Bishop.
- Functional Soil Mapping for Soil Moisture and Crop Yield Management in an Agricultural Landscape. Qing Zhu*, **Henry Lin** and James Doolittle.
- Confidence Intervals for Estimated Saturated Hydraulic Conductivity Measured Using Compact Constant Head Permeameters. John F. Beck*, **Jim Thompson**, Michael Harman, Philip Schoeneberger, Larry West and Skye Wills.
- Factors Controlling the Soil Moisture Spatial-Temporal Variability in the Shale Hills Watershed: A Hydropedologic Perspective. Kenneth Takagi* and **Henry Lin**.

# NE-1038 Multi-State Project: Hydropedology: Genesis, Properties, and Distribution of Hydromorphic Soils

## Objectives

- Evaluate the use of **field indicators of hydric soils** to characterize wetland hydroperiods;
- Test the effectiveness of proposed hydric soil **indicators to identify "problem hydric soils";**
- Test **monitoring protocols used to identify reducing conditions** to determine if they are effective within a range of soil conditions;
- Investigate the **hydraulic properties of hydromorphic soils with episaturation.**
- Initiate the development of **subaqueous soil-based use and management interpretations** for applications in shallow-subtidal habitats;
- Investigate the spatial extent **freshwater subaqueous soils** in riverine settings;
- **Quantify and better understand carbon pools** in a range of hydromorphic, wetland, created wetland, and subaqueous soil settings;
- Test the **relationship between surface soil C and field indicators of hydric soils;**
- **Test the application of various digital geospatial analysis tools to model C-pools** across the landscape based on point and polygonal carbon data.

# NE-1038

**Northeast NCSS Participants**

- Martin Rabenhorst (MD)
- Brian Needelman (MD)
- Jim Thompson (WVA)
- Bruce Vasilas (DE)
- Mark Stolt (RI)
- Henry Lin (PA)
- Peter Veneman (MA)
- Patrick Drohan (PA)
- John Galbraith (VA)

## M. C. Rabenhorst With Graduate Student Michelle Hetu


- *Assessing Reducing Conditions in Soil along a Topohydrosequence*
- *Effects of total carbon and temperature on reducing conditions in soils along a topohydrosequence: A mesocosm experiment*

**University of Maryland, Environmental Science and Technology**

M. C. Rabenhorst with Graduate Student Dan Fenstermacher

- *Potential Carbon Storage in Delmarva Bay Wetlands*

M. C. Rabenhorst with Graduate Student Annie Rossi

- *Recognition and Pedogenesis of Sandy Hydric Soils in the Near-Coastal Portions of the Mid-Atlantic Region*


**University of Maryland, Environmental Science and Technology**

# Carbon Sequestration in Piedmont Slope Wetlands

Bruce Vasilas, UD

Lenore Vasilas, NRCS

Mike Wilson, NRCS

Objectives: To assess the quantity and vertical distribution of SOC in slope wetlands

# Field Indicators of Hydric Soils in Disturbed Soils

Bruce Vasilas, UD

Objective: Identify field indicators in soils subjected to anthropogenic disturbance

# Disturbed Soils-Preliminary Results

- Paired disturbed and undisturbed sites usually have one Field Indicator in common.

# Fragipan Influence on Hydropedological Properties of Benchmark Soilscapes in West Virginia


# Investigate the hydraulic properties of hydromorphic soils with episaturation

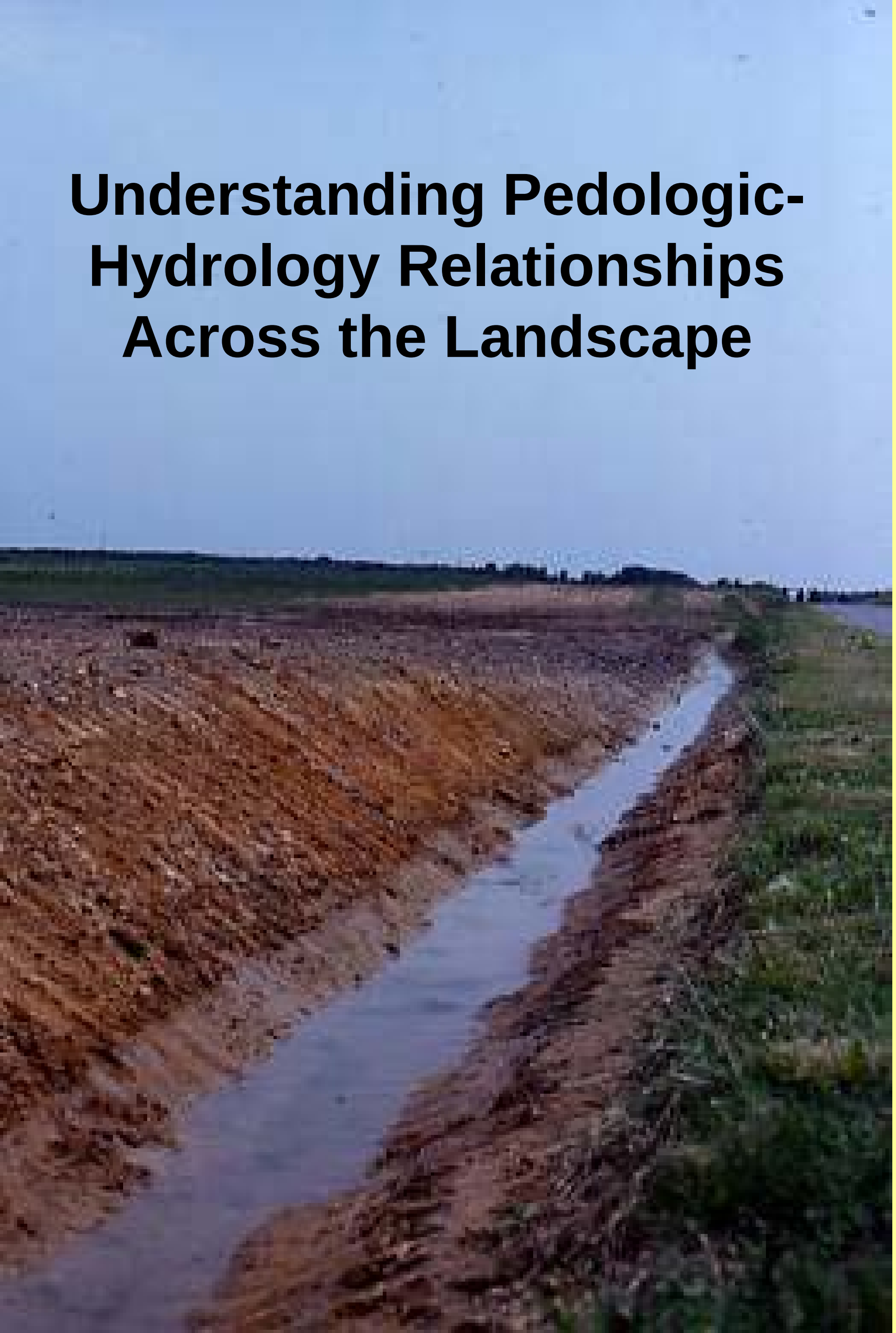
- Objective: Evaluate hydraulic properties on benchmark soils
- Study area: 50 ha watershed of fragipan dominated soils
- Methods: Link observed pedology with the real-time sensor data
  - Sensors record hydro activity from surface through vadose zone
  - Data recorded at 10 minute intervals
- Goal: Extrapolate the resultant data, model, and interpretations across similar landscapes

# Confidence Intervals for Estimated Saturated Hydraulic Conductivity

How many in situ Ksat measurements are necessary to measure Ksat using compact constant head permeameters?

- There are a minimum number of samples necessary
- Fewer “n” fail to meet a desired confidence level
- Additional “n” beyond target confidence is costly
- Objectives
  - Determine the threshold number of samples
  - Determine at what spacing observations should be made

# Understanding Pedologic-Hydrology Relationships Across the Landscape



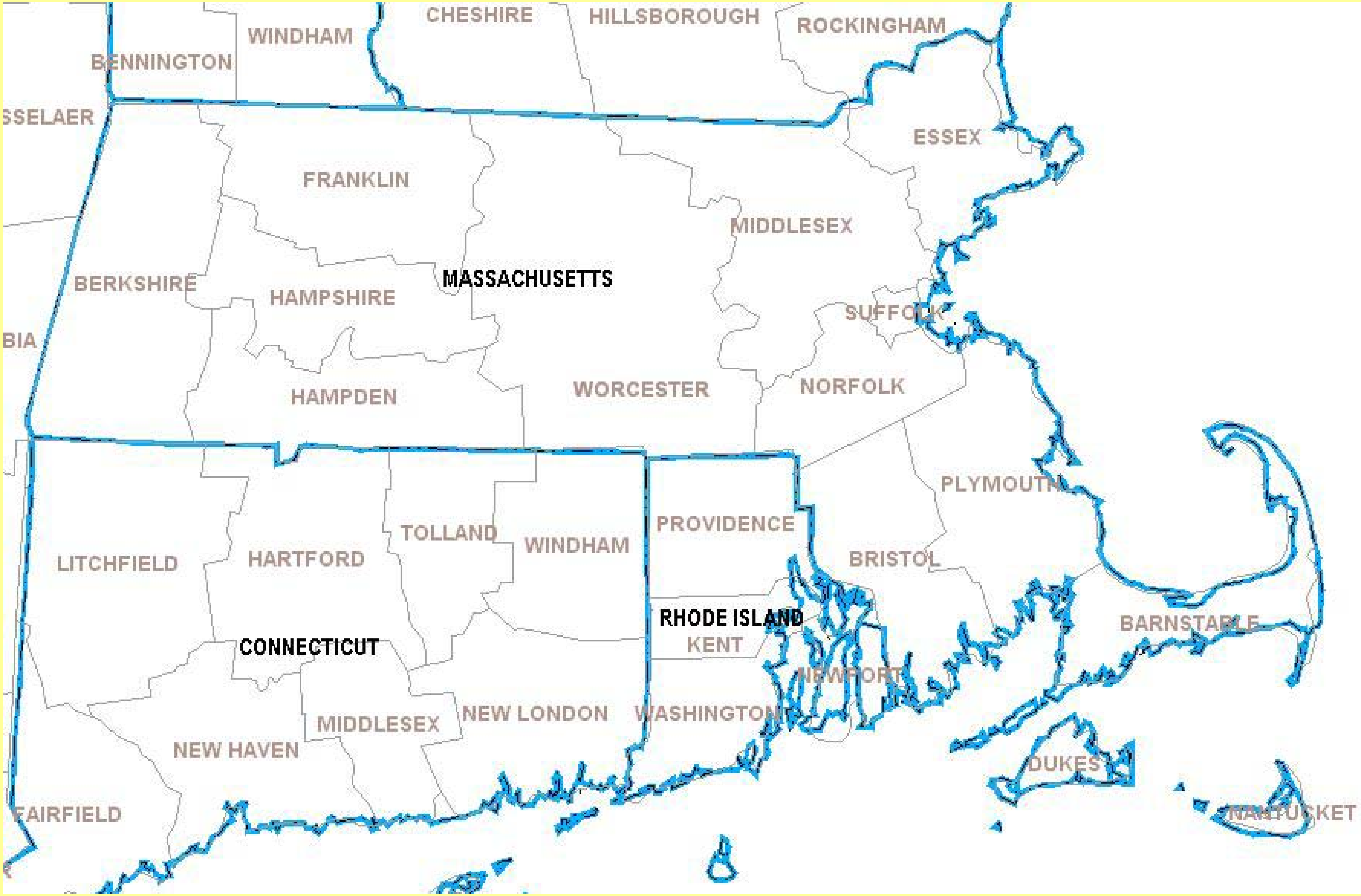
## Funding Sources

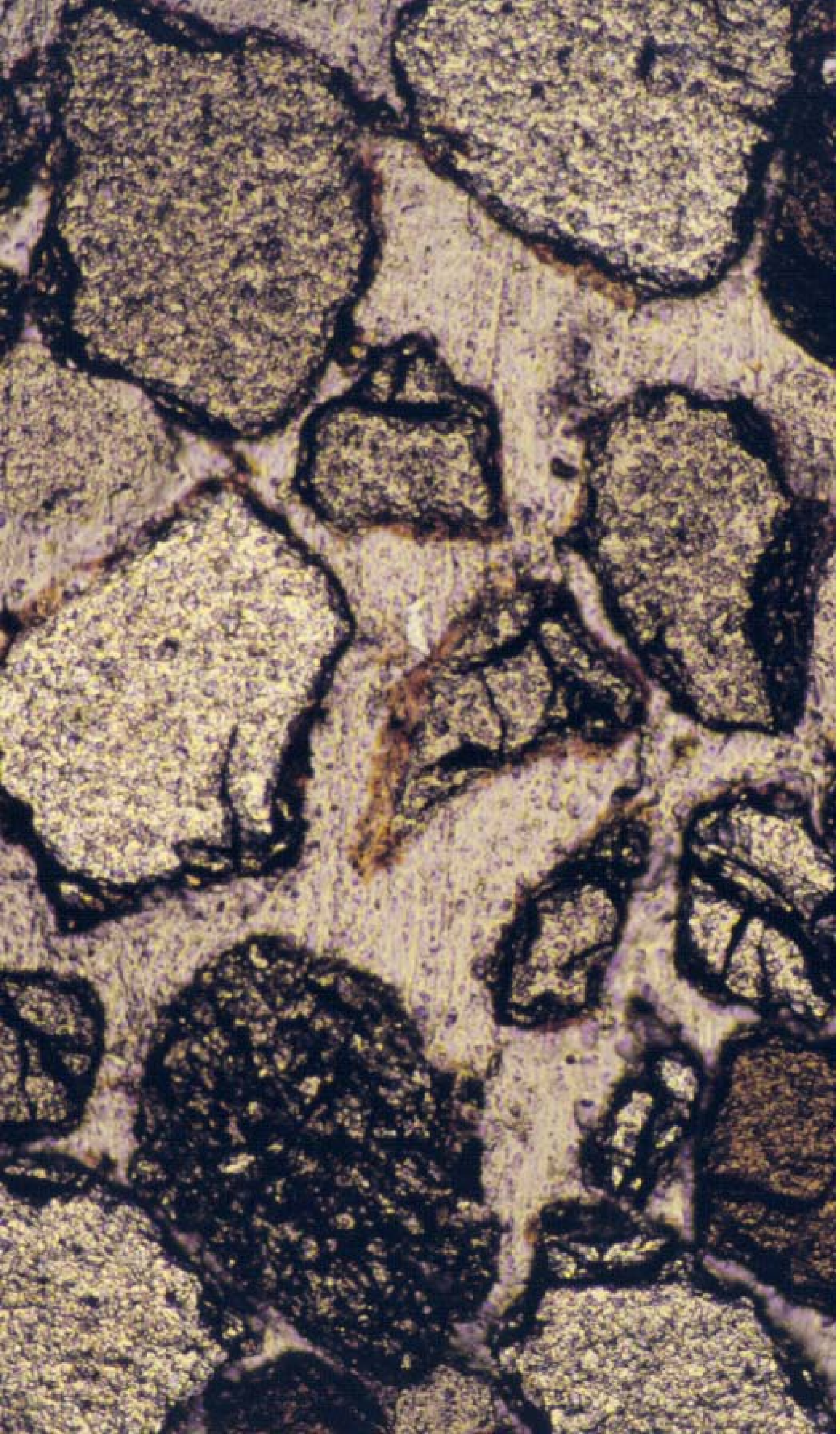
- USDA-NRI
- NOAA
- Rhode Island Sea Grant
- Rhode Island-AES

## Carbon Accounting and Denitrification

Mark Stolt, Sean Donohue, Maggie Payne, Chrissy Pruett, Art Gold, Peter Groffman, Gary Blazejewski, Noel Gurwick, Aletta Davis, and Matt Richardson

# Southern New England- Glaciated; primarily Forested



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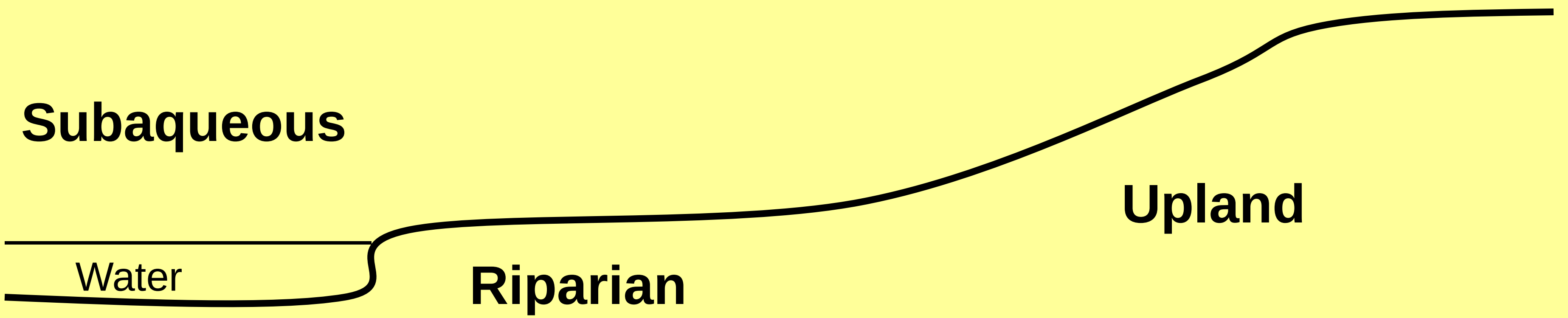
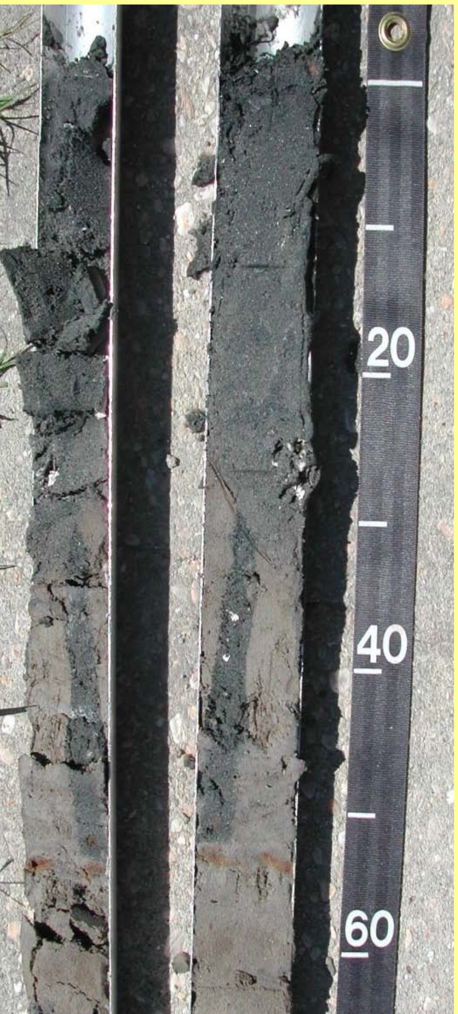
130
150
170
190


Subaqueous
Water
Riparian
Upland


20
40
60


1
2.

# Groundwater Denitrification Function?

**Subaqueous**

**Yes, but?**

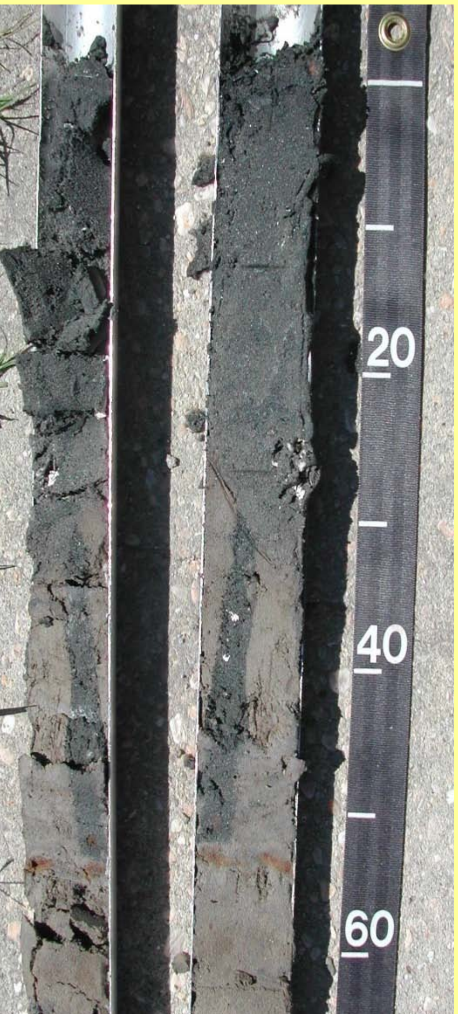
Water

**Riparian**

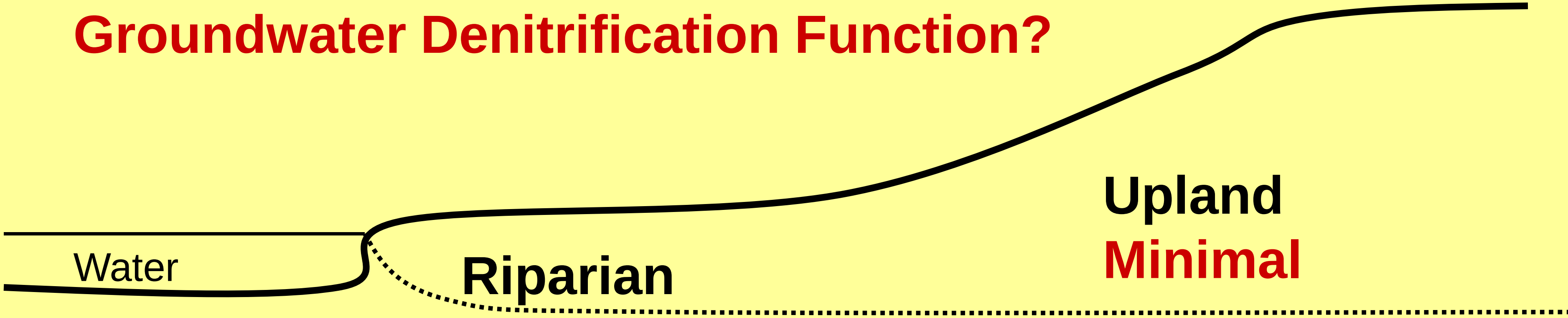
**Yes, but ?**

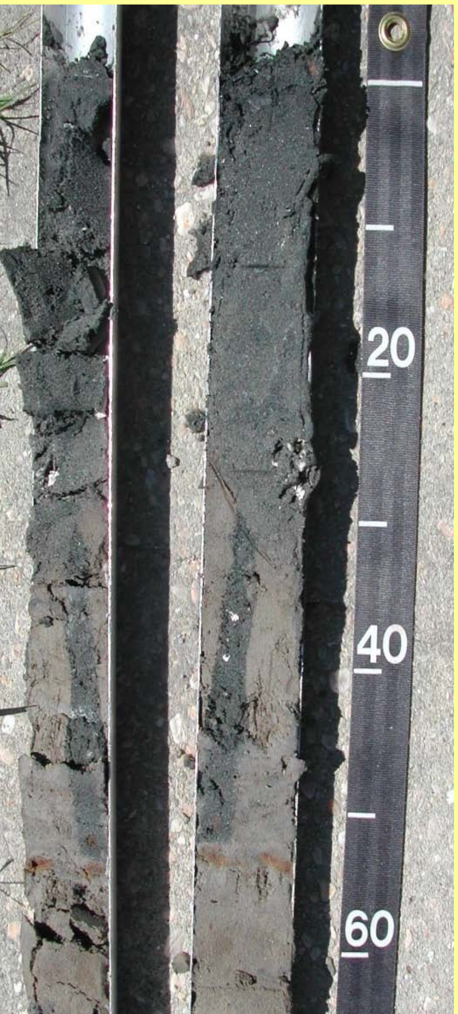
**Upland**

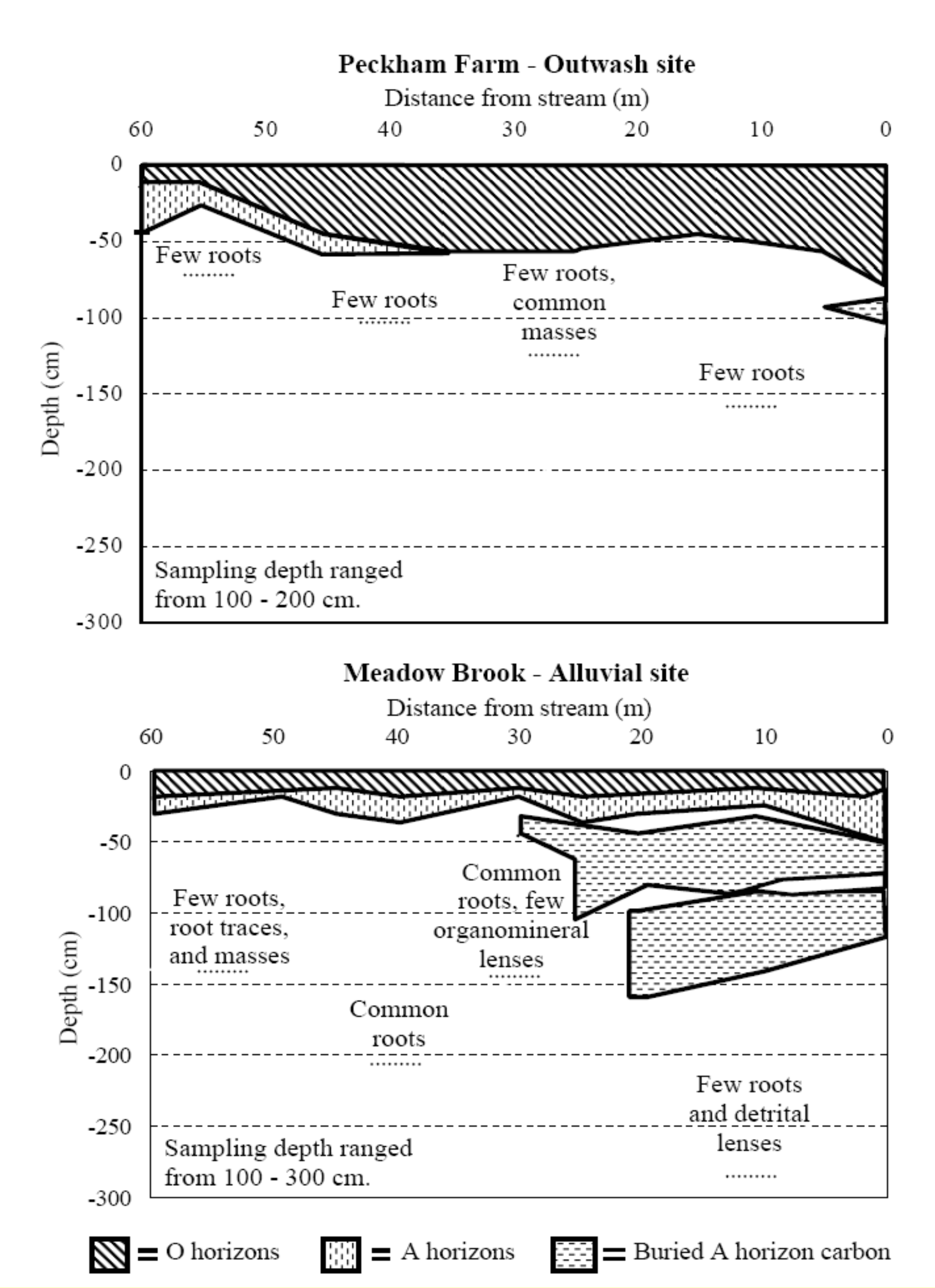
**Minimal**




# Groundwater Denitrification Function?



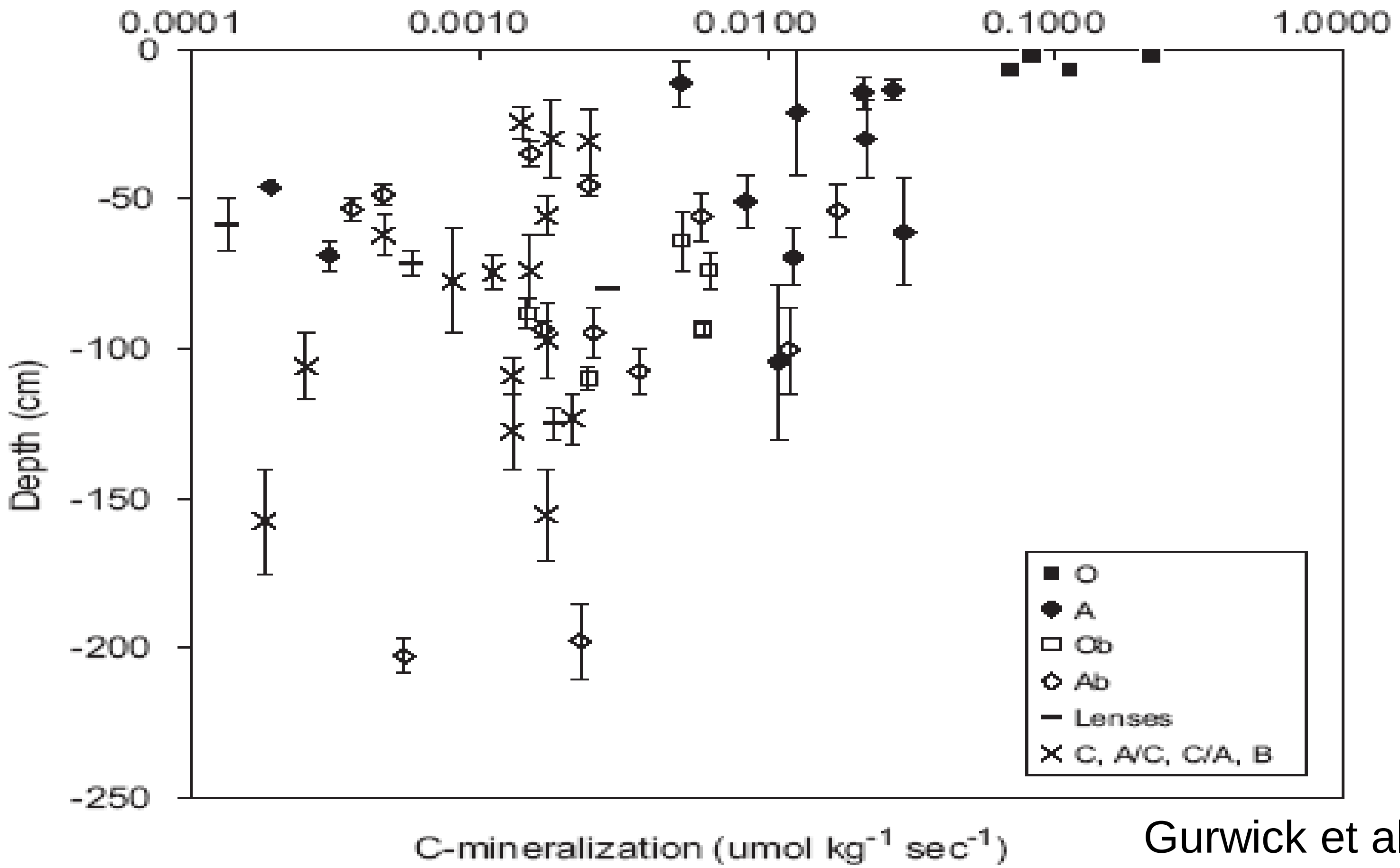

# Carbon Distribution and Form vs Denitrification Riparian Settings

**Outwash Settings: Minimal carbon to promote denitrification below 50 cm**

**Alluvial Settings: Significant carbon below 50 cm to promote denitrification**

Blazejewski et al., 2009

# Does function follow form?




Gurwick et al., 2008

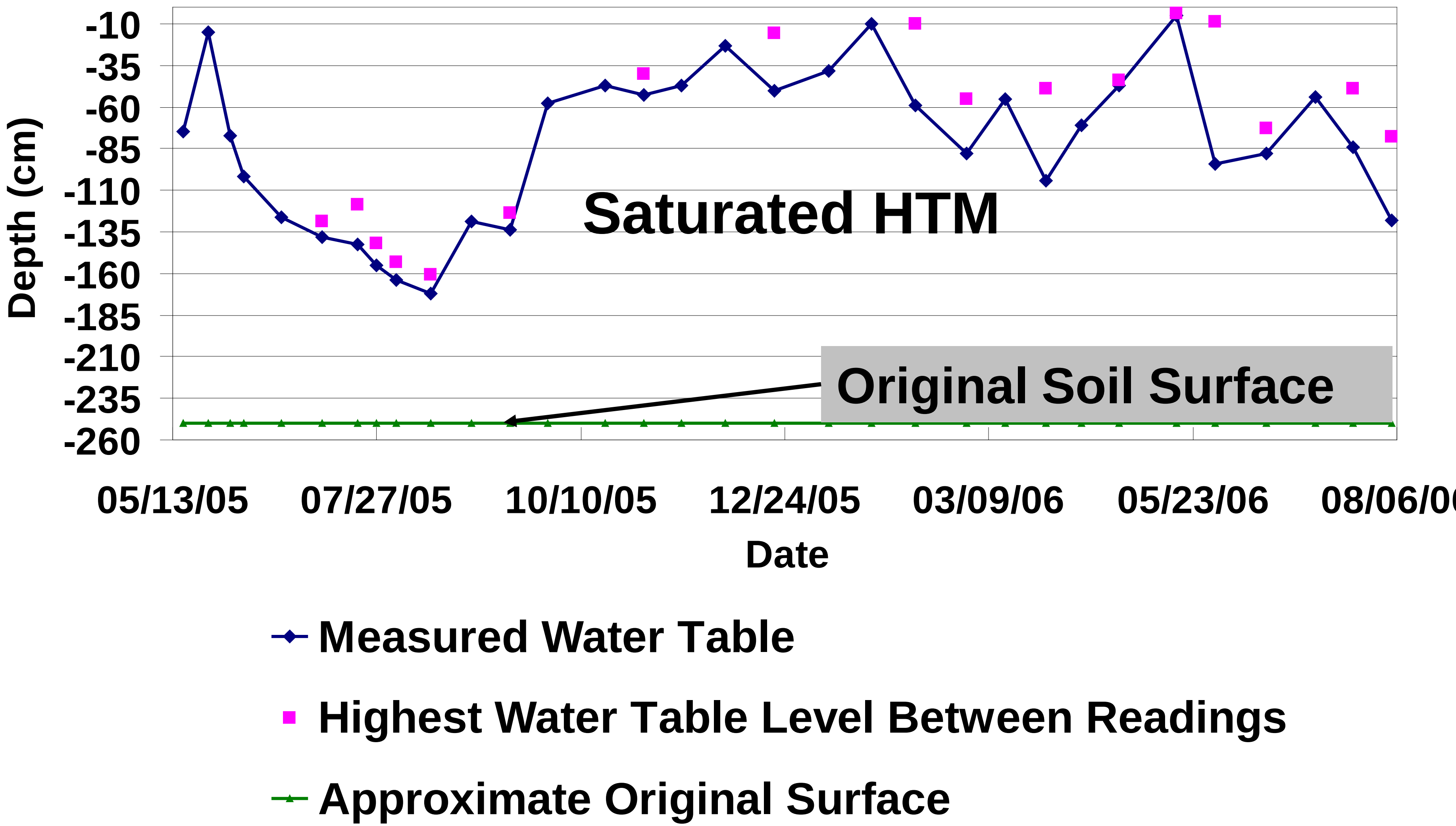
**regardless of depth C-mineralization was**

**O>A>Ab>A/C, C/A, and B horizons**

# Anthropogenic Soils, Carbon, and Reducing Conditions

# Water Table Fluctuation:

# Human Transported Materials (HTM) over a Tidal Marsh




Donohue et al., 2009

# Carbon Forms Were Abundant in the Saturated HTM Deposits

**Abundance of carbon forms below the water table within fill and dredge deposits. The depth to the water table was estimated as the equivalent to the first horizon with redoximorphic features.**

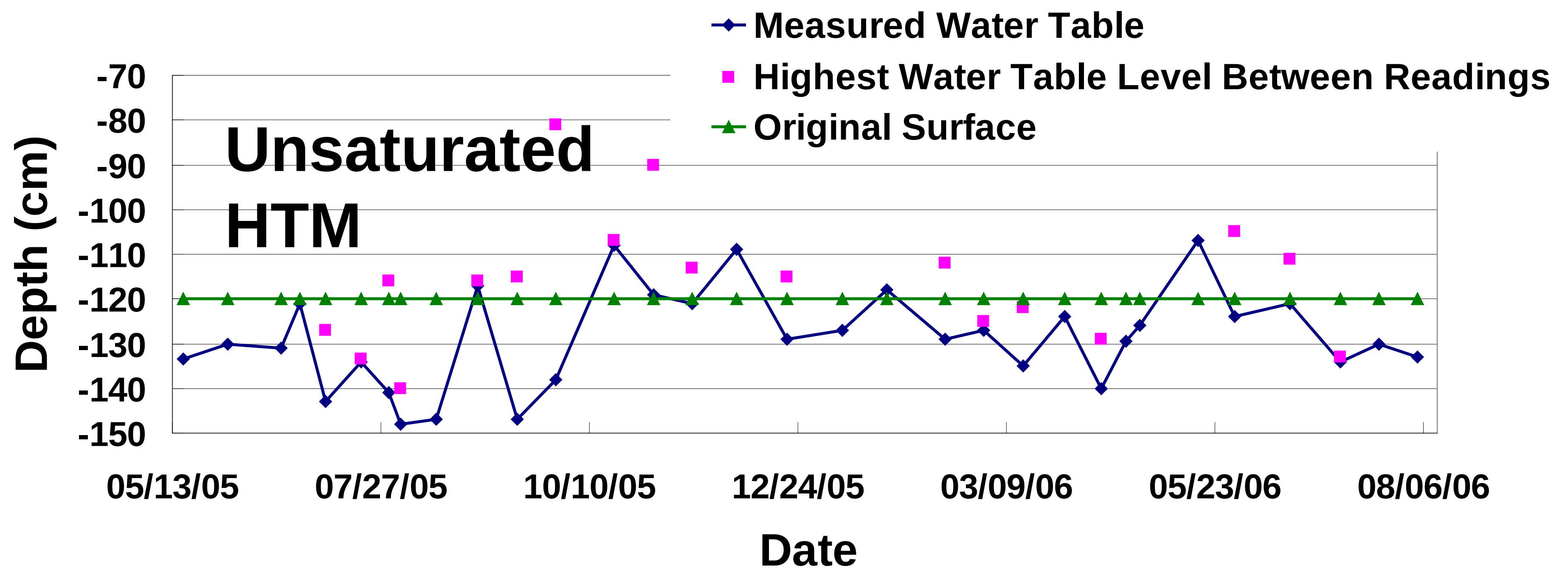
| Type of HTM | Total Number of Soils | Percent of Soils With Carbon Forms Present*: Roots | Root Traces | Masses | Lenses | Horizon Carbon | Non-Woody FOM** | Woody FOM** |
|---|---|---|---|---|---|---|---|---|
| Fill Materials | **51** | 67% | 4% | 49% | 4% | 45% | 29% | 12% |
| Dredge Spoils | **25** | 72% | 0% | 72% | 40% | 48% | 80% | 4% |

*Carbon forms defined by Blazejewski et al. (2005).

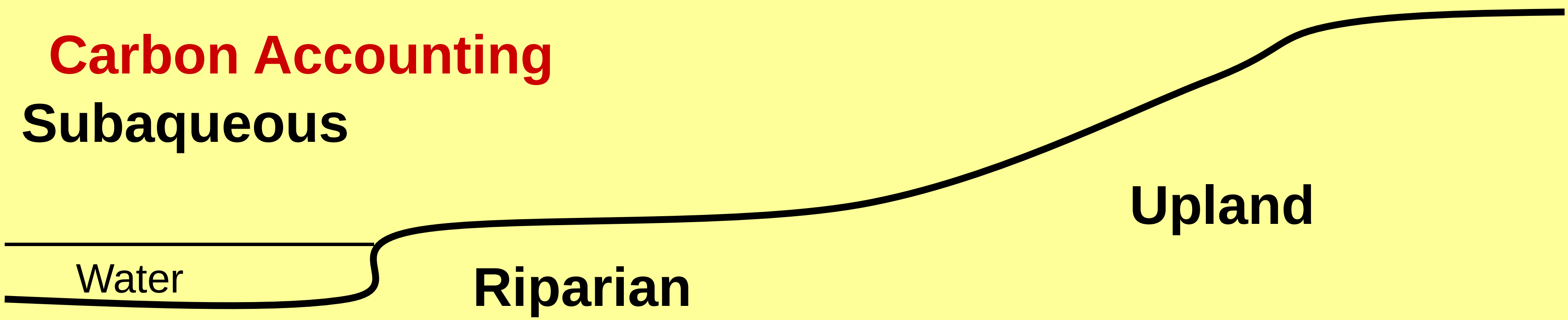
** FOM: Fragmental Organic Matter

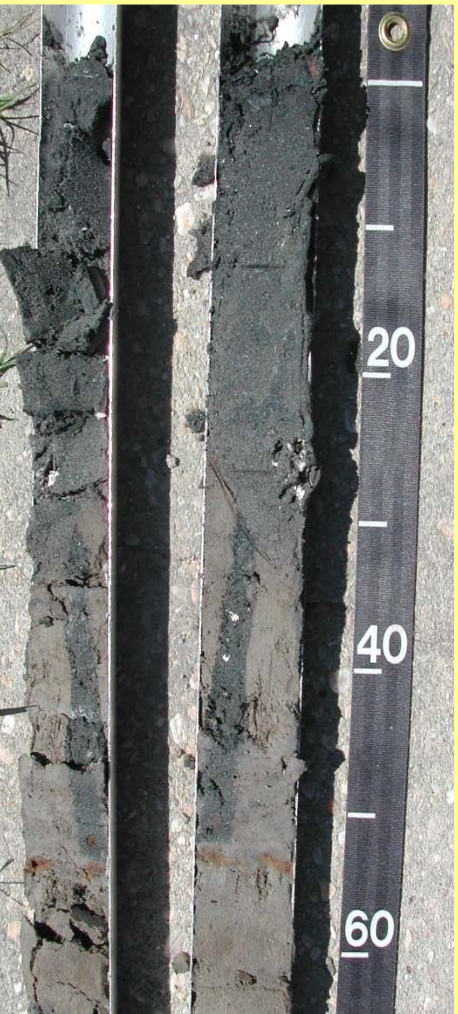

Of the 18 anthropogenic soils examined , 16 developed RMFs in HTM at depths corresponding to the depth of the SHWT and presence of carbon suggesting the potential for denitrification

# Water Table Fluctuation:
# HTM over Sandy Unconsolidated Shore

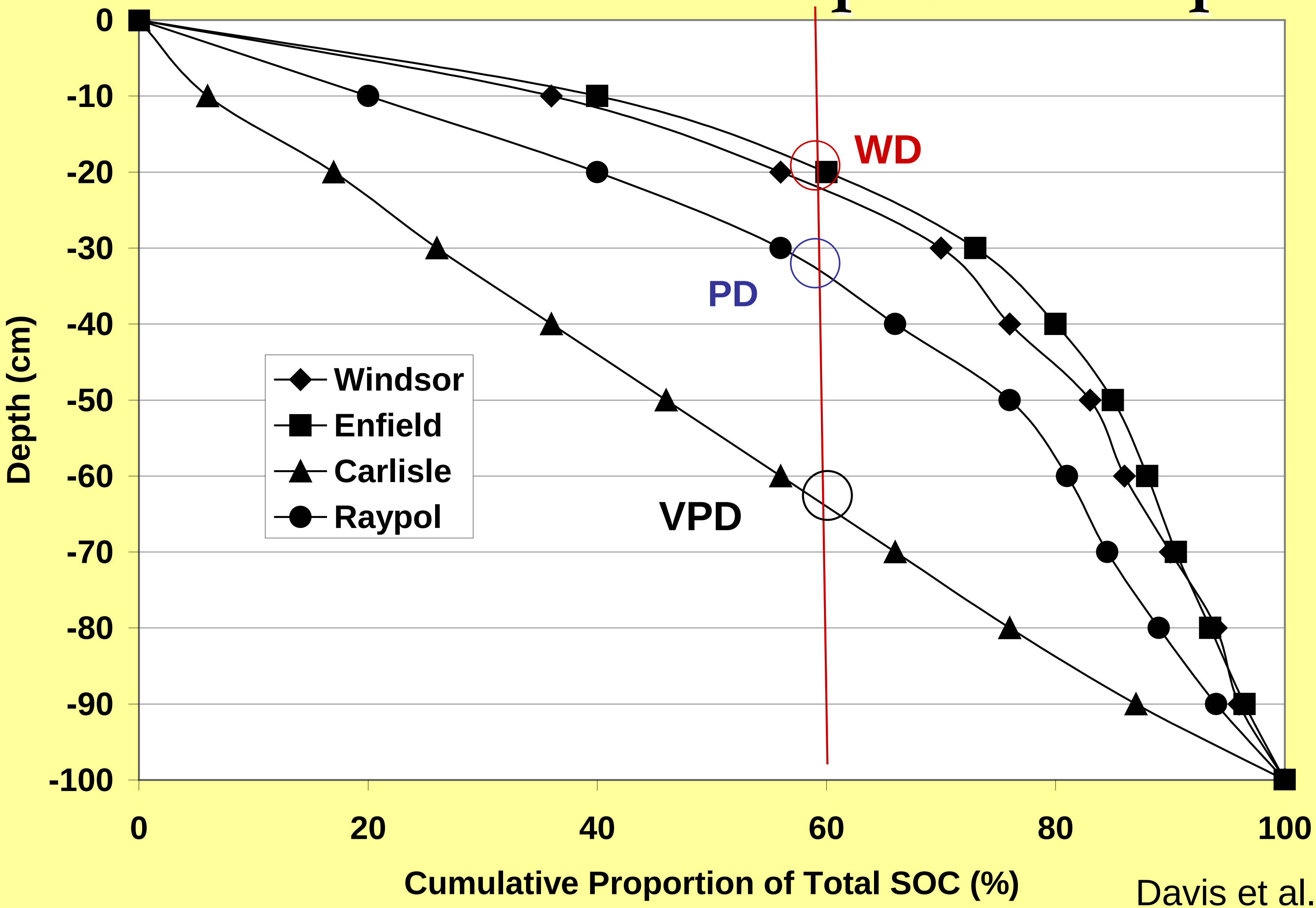


# Carbon Accounting




# What Percentage of the Total Carbon Pool Occurs above a Specified Depth

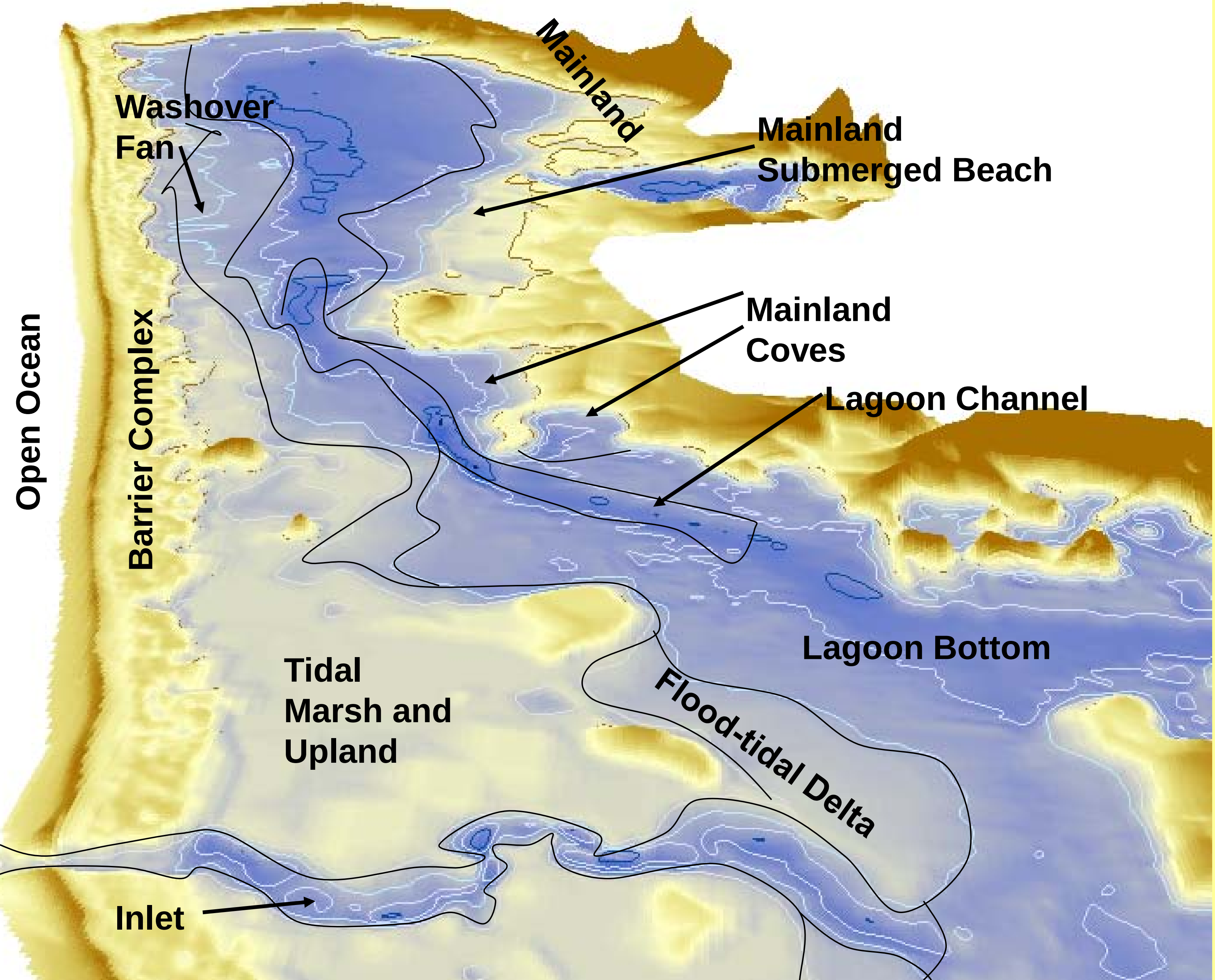


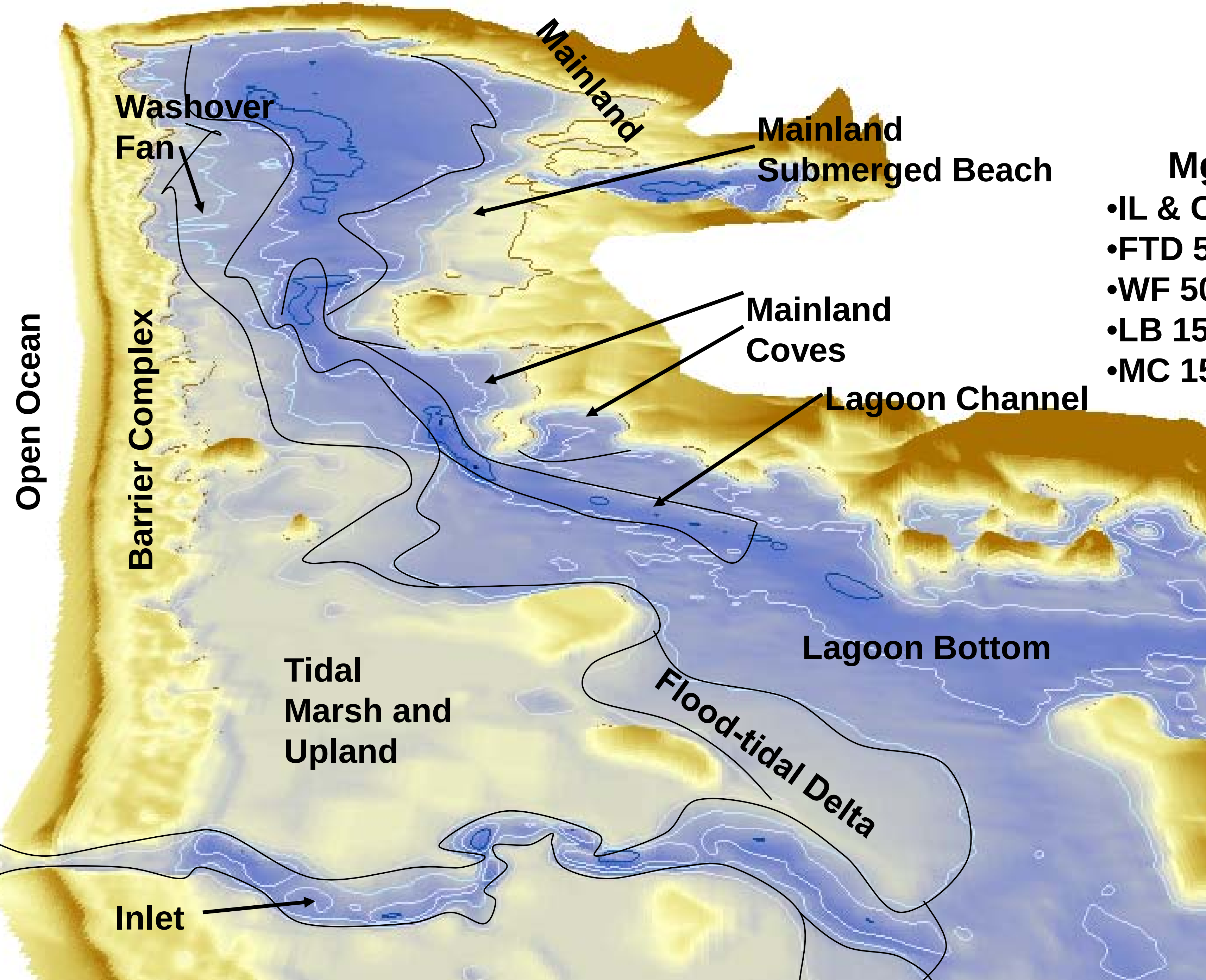

Davis et al., 2004

# Carbon Pools by Drainage Class for Forest Ecosystems

| Drainage Class | Number of Pedons | Carbon Pools Mean (Mg C ha$^{-1}$) | Carbon Pools Range (Mg C ha$^{-1}$) |
|---|---|---|---|
| Excessively | 20 | 110 | 94-127 |
| Well | 32 | 150 | 96-175 |
| Moderately Well | 12 | 154 | 110-245 |
| Poorly (palustrine) | 20 | 187 | 129-245 |
| Poorly (alluvial) | 29 | 246 | 117-495 |
| Very Poorly | 30 | 586 | 469-703 |
| Subaqueous* | 42 | 155 | 45-285 |

* Subaqueous are not Forested

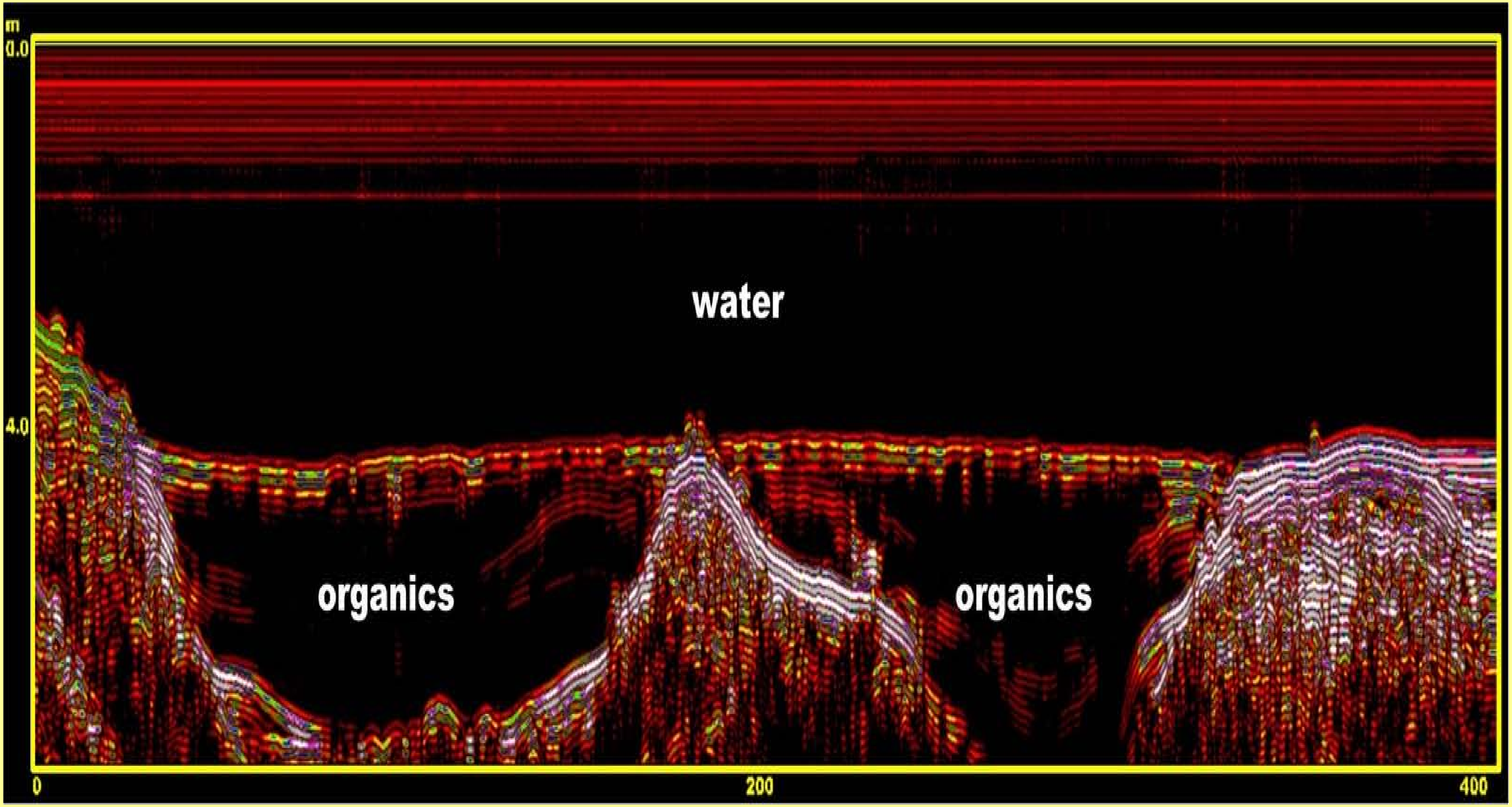

Mainland
Washover Fan
Mainland Submerged Beach
Mainland Coves
Lagoon Channel
Open Ocean
Barrier Complex
Lagoon Bottom
Tidal Marsh and Upland
Flood-tidal Delta
Inlet



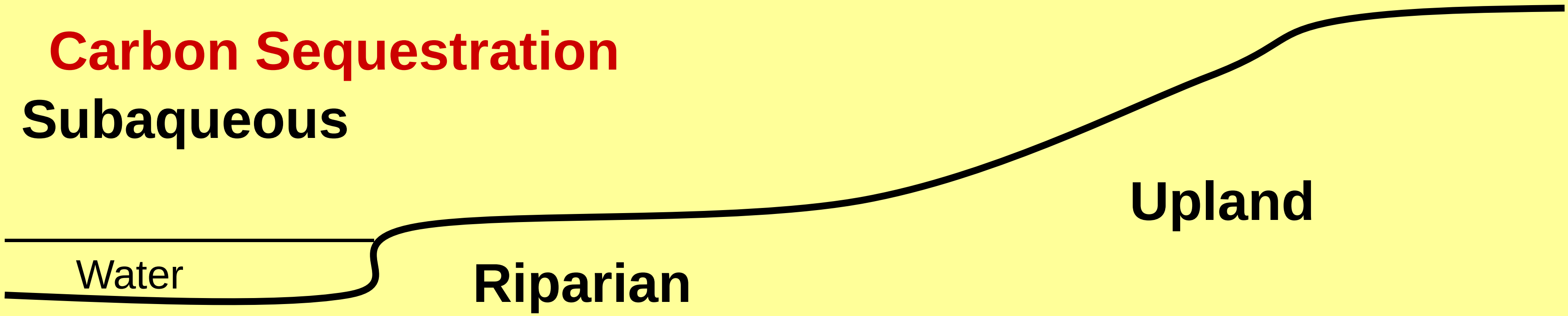

**Mg/ha**

- IL & CH <50
- FTD 50-100
- WF 50-100
- LB 150-200
- MC 150-300

# Freshwater Lake GPR Subaqueous Soils Image



# Carbon Sequestration





# Upland Soil C-Sequestration (Paired Site Approach)

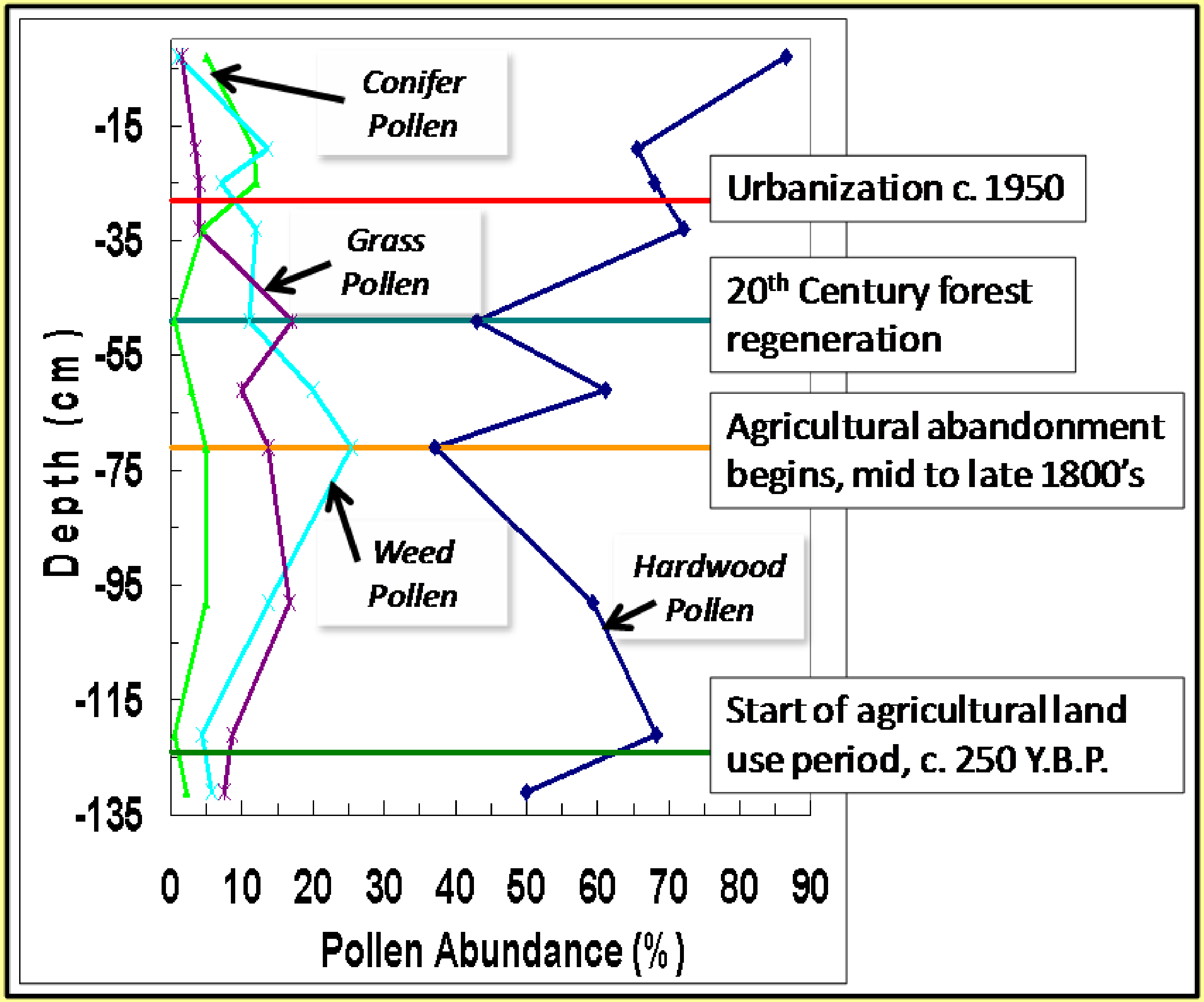
| Site | Age (Years) | Forest Type | Difference Between Field and Forest Pools (%) | Whole Soil SOC Sequestration Rate (Mg C $ha^{-1}$ $yr^{-1}$) |
|---|---|---|---|---|
| St6 | 25 | Coniferous | 31 | 1.42 |
| SR1 | 28 | Coniferous | 19 | 0.92 |
| SNK2 | 28 | Deciduous | 12 | 0.61 |
| S3 | 29 | Deciduous | 34 | 1.91 |
| MC3 | 37 | Coniferous | 10 | 0.39 |
| SBurr1 | 41 | Deciduous | 8 | 0.22 |
| SC2 | 41 | Deciduous | 30 | 1.10 |
| Me1-MA | 42 | Deciduous | 13 | 0.34 |
| MNK2 | 45 | Deciduous | 18 | 0.79 |
| SG1 | 46 | Deciduous | 7 | 0.49 |
| SR2 | 47 | Coniferous | 18 | 0.90 |
| MNK10 | 50 | Deciduous | 22 | 0.52 |
| SWG1 | 52 | Coniferous | 27 | 0.90 |
| SC2-II | 63 | Coniferous | 29 | 0.71 |
| ME1 | 71 | Coniferous | 34 | 0.66 |
| MHC1 | 79 | Coniferous | 54 | 1.31 |
| MC2 | 86 | Coniferous | 60 | 1.11 |

Mean sequestration rate = 0.84 Mg C $ha^{-1}yr^{-1}$.

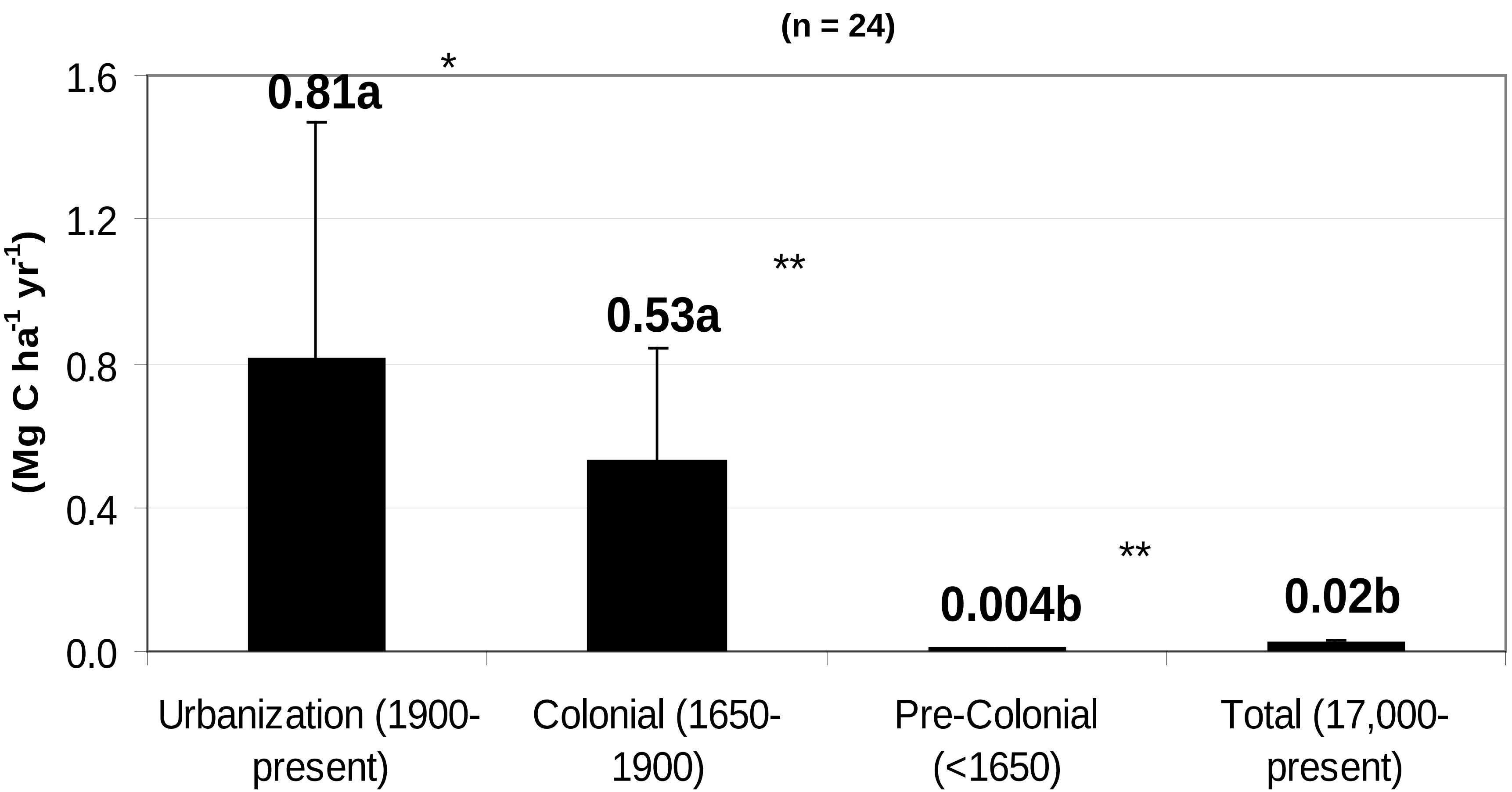
Richardson, 2005


1
2
3

# Multiproxy Approach to Identify Depositional Periods and Land Use History

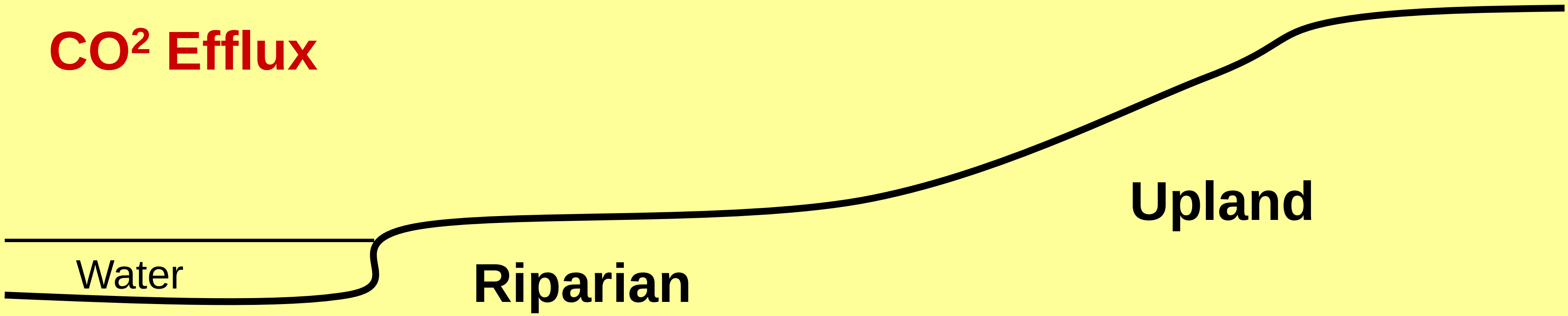


# Net Riparian Soil Carbon Sequestration Rates




Data compiled from Donohue (2007) and Ricker (2009)
Means with different letters are significantly different using one-way ANOVA and Tukey's HSD (• = 0.05), error bars represent 1 SD

# $CO^2$ Efflux




# Average Contribution of Root Respiration to $CO^2$ Efflux

| | Riparian Zone | | Upland | |
|---|---|---|---|---|
| **Site** | **Soil Drainage Class** | **Mean Root Respiration (%)** | **Soil Drainage Class** | **Mean Root Respiration (%)** |
| AMA-RI | PD | 67 (28) | ED | 37 (24) |
| EGA-RI | VPD | 14 (86) | WD | 28 (21) |
| HSP-RI | PD | 77 (8) | ED | 45 (33) |
| SBW-RI | PD | 82 (2) | WD | 37 (27) |
| WKC-RI | VPD | 72 (8) | WD | 14 (36) |
| Mean | - | 63 (44)[†] | - | 32 (56)[†] |

* CV (%) parentheses

[†] Significantly different based on student's t-test (• = 0.05), p-value 0.002

Ricker, 2009

# Conclusions

- Alluvial riparian soils offer the best place on the landscape for denitrification because of the proliferation of carbon throughout the profile.
- Many coastal riparian sites disturbed by anthropogenic activity (i.e. filling of wetlands) still maintain the potential for denitrification.
- Soil carbon pools (for the same land use) vary across the landscape as a function of soil wetness.
- Carbon pools on subaqueous soil landscapes are essentially equivalent to subaerial soils.
- The amount of energy on the subaqueous landscape (or particle-size distribution as a surrogate) dictates carbon pool quantity (less energy-more carbon).

# Conclusions

- Aggrading forest soils in southern New England are accumulating carbon at a rate of about 0.84 Mg C $ha^{-1}yr^{-1}$
- Carbon has been accumulating at about the same rate over the last 100 years riparian zone soils along 1st and 2nd order streams
- Total $CO^2$ flux is similar between uplands and riparian soils; however (apparently), root contributions to the flux are greater in riparian soils