Water Residence Time and Nitrogen Loss in a Mississippi River Delta: A Modeling Approach

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And their data!

Impetus

Eutrophication is the number one coastal pollution problem in the U.S.

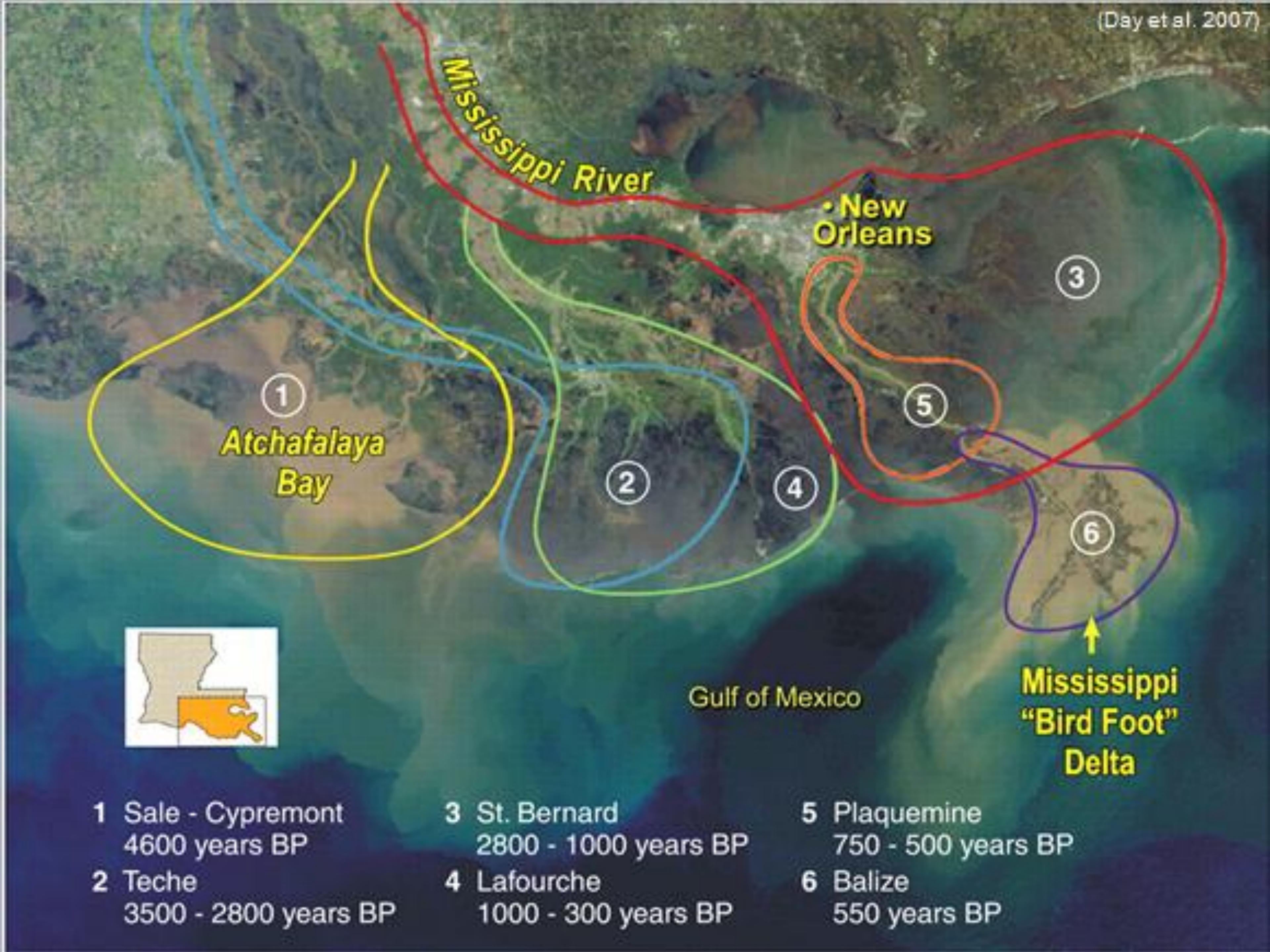
-NRC, 2000

Uncertainty in wetland nitrogen cycling, especially pertaining to prograding deltaic landscapes.

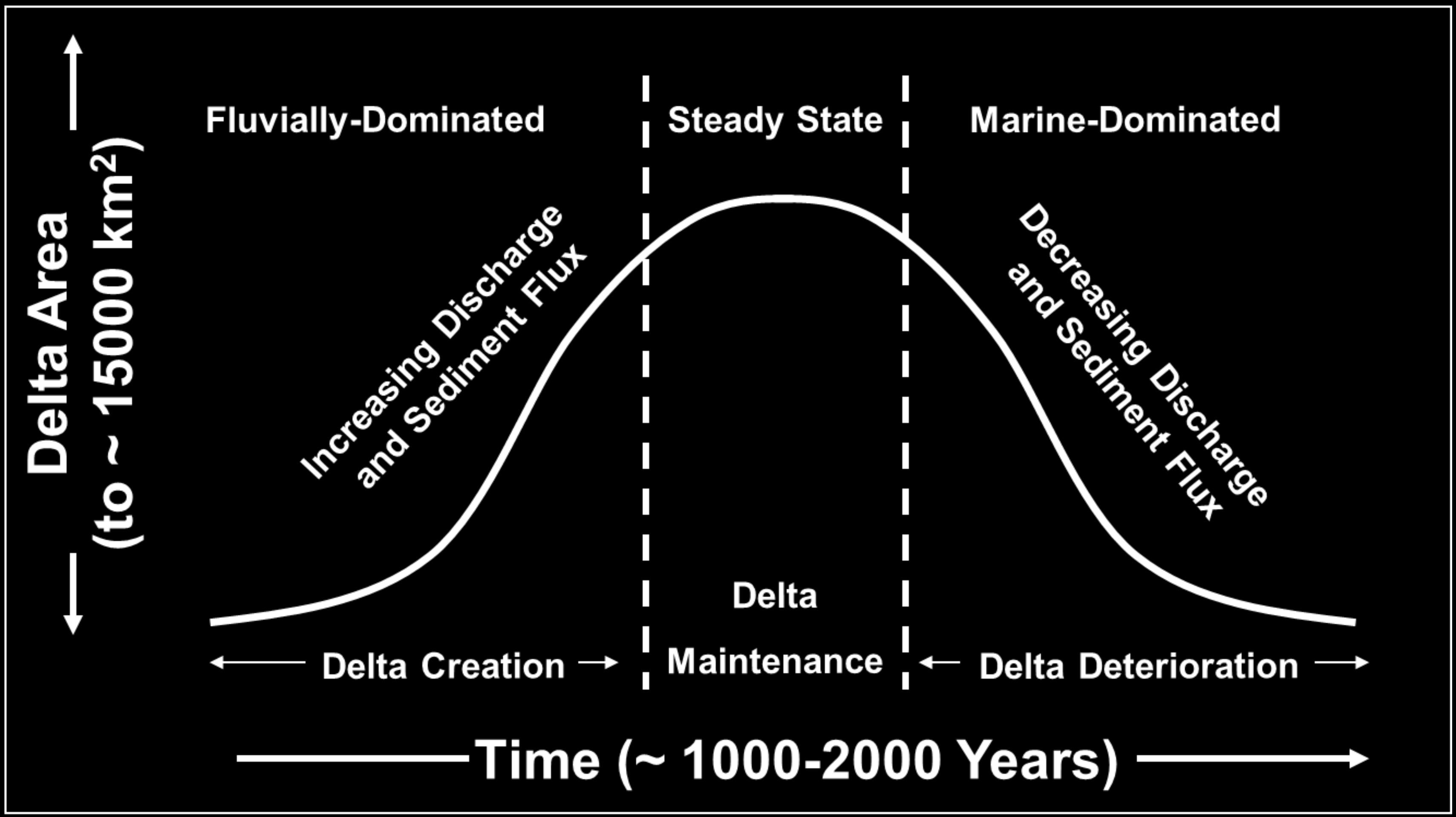
- Burgin and Hamilton, 2007; Brock, 2001; Kroeze et al., 2003

Major sediment diversions planed for the Louisiana coast

-LACPRA, 2012

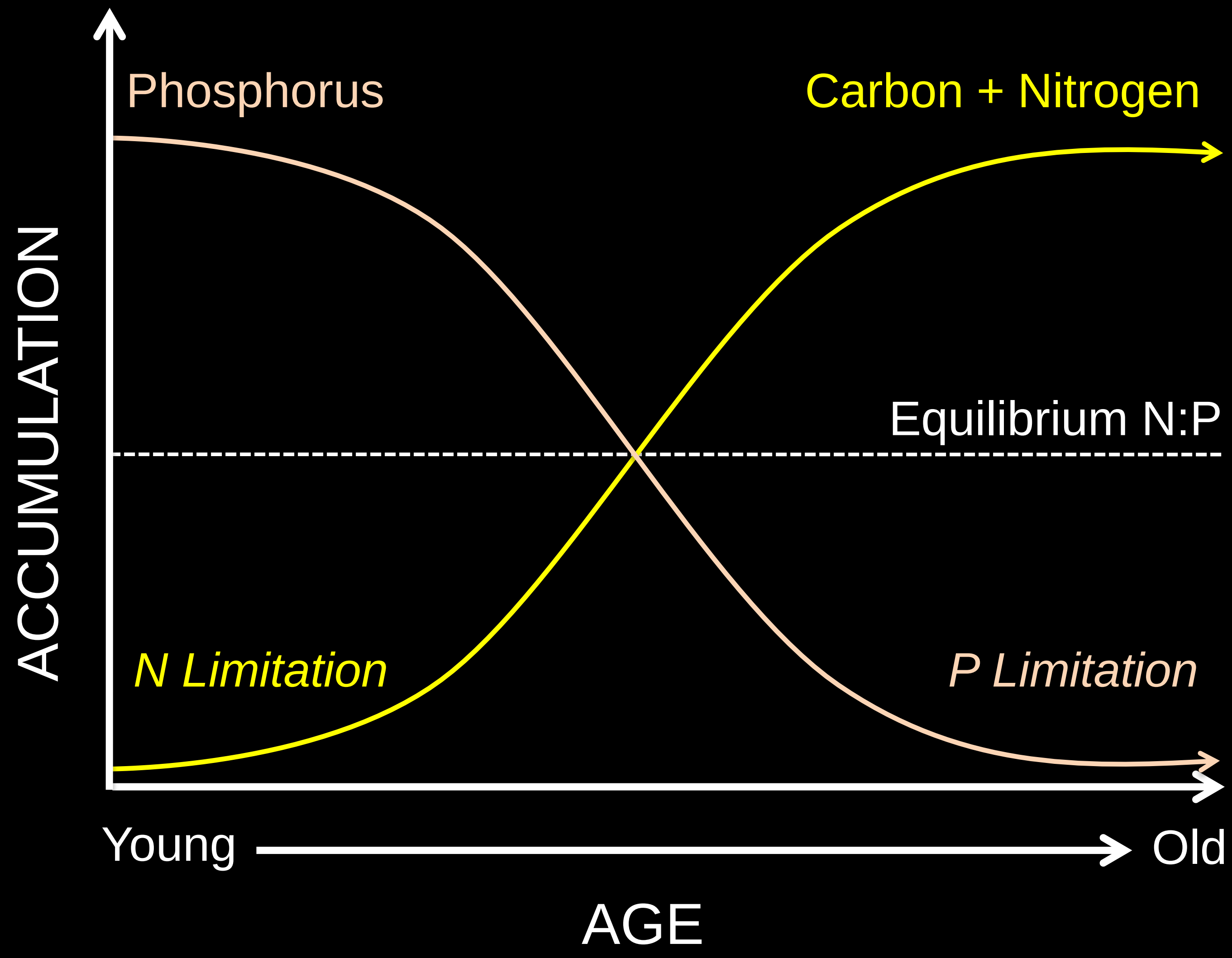

(Day et al. 2007)
Mississippi River
• New Orleans
3
1
Atchafalaya Bay
2
4
5
6
Gulf of Mexico
Mississippi "Bird Foot" Delta
1 Sale - Cypremont 4600 years BP
2 Teche 3500 - 2800 years BP
3 St. Bernard 2800 - 1000 years BP
4 Lafourche 1000 - 300 years BP
5 Plaquemine 750 - 500 years BP
6 Balize 550 years BP

The delta cycle



(Adapted from Roberts 1997 by G. Snedden)

Soil formation during delta development



(Adapted from Walker and Syers 1976 by A. Bevington)

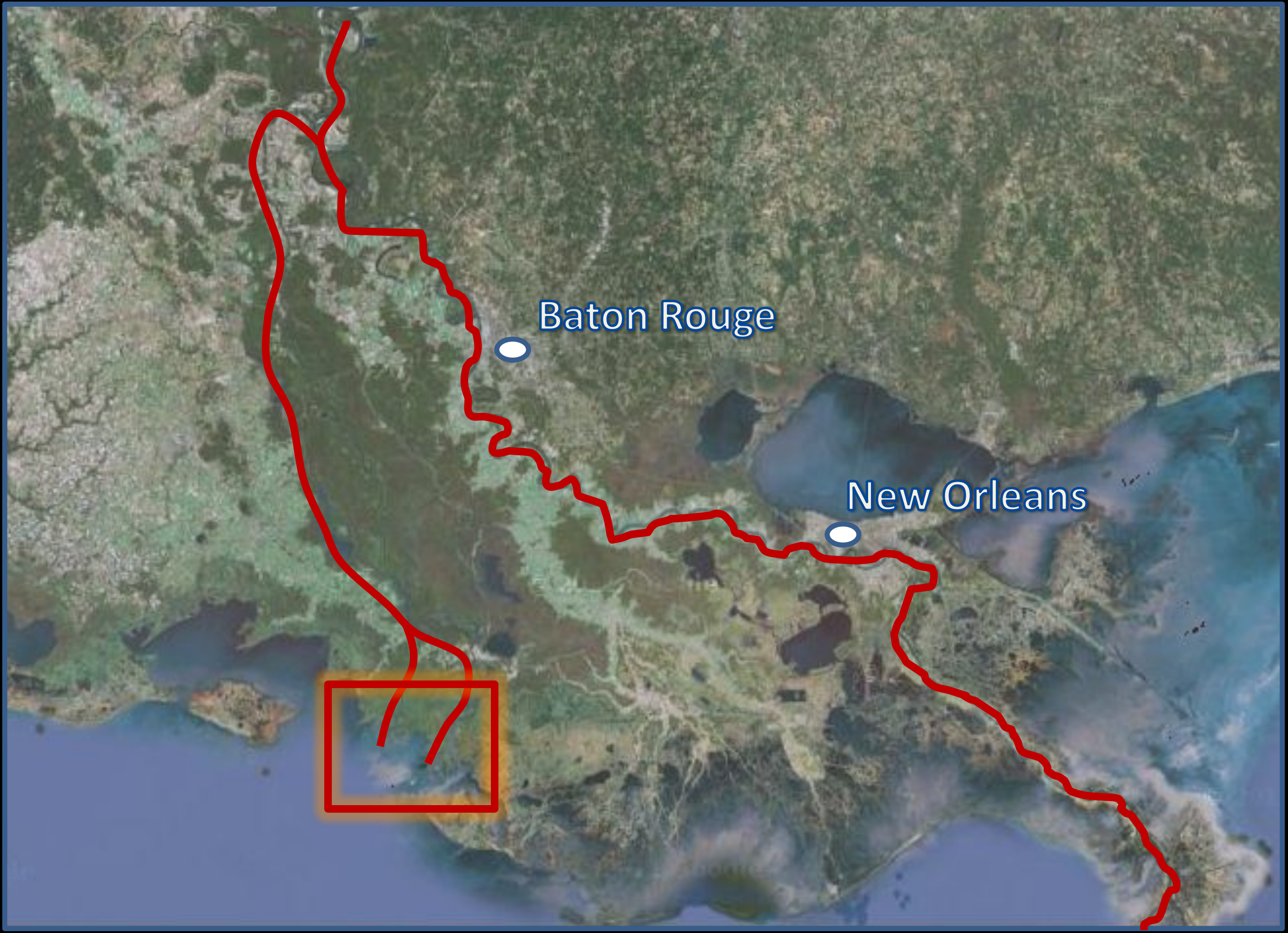
Sediment Diversions

LACPRA

2012 LA Master Plan for a Sustainable Coast

- $3.8 billion to sediment diversions
- Projected 777 km^2 of new land
- Up to 50% of the River's peak flow
- 8% of Miss. R. flow for each project

Sediment Diversions

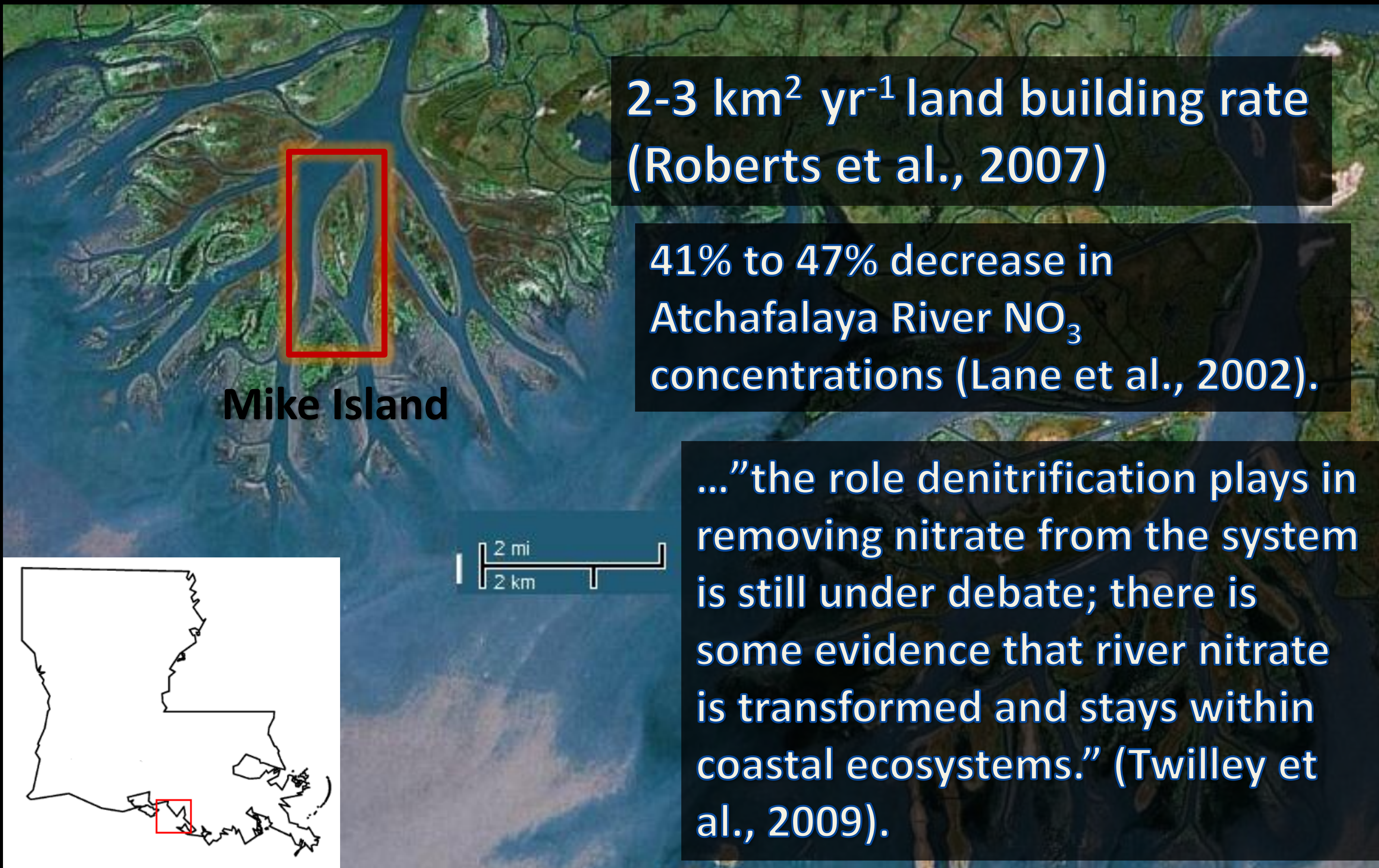


1963:
30% of
Mississippi flow
diverted down
Atchafalaya

30-45% of Atch.
diverted to
Wax Lake Outlet

=10-15% of
Mississippi flow

Atchafalaya and Wax Lake Deltas



$2\text{-}3\ km^2\ yr^{-1}$ land building rate (Roberts et al., 2007)

41% to 47% decrease in Atchafalaya River NO_3 concentrations (Lane et al., 2002).

…"the role denitrification plays in removing nitrate from the system is still under debate; there is some evidence that river nitrate is transformed and stays within coastal ecosystems." (Twilley et al., 2009).

Hypotheses and Objectives

Hypotheses

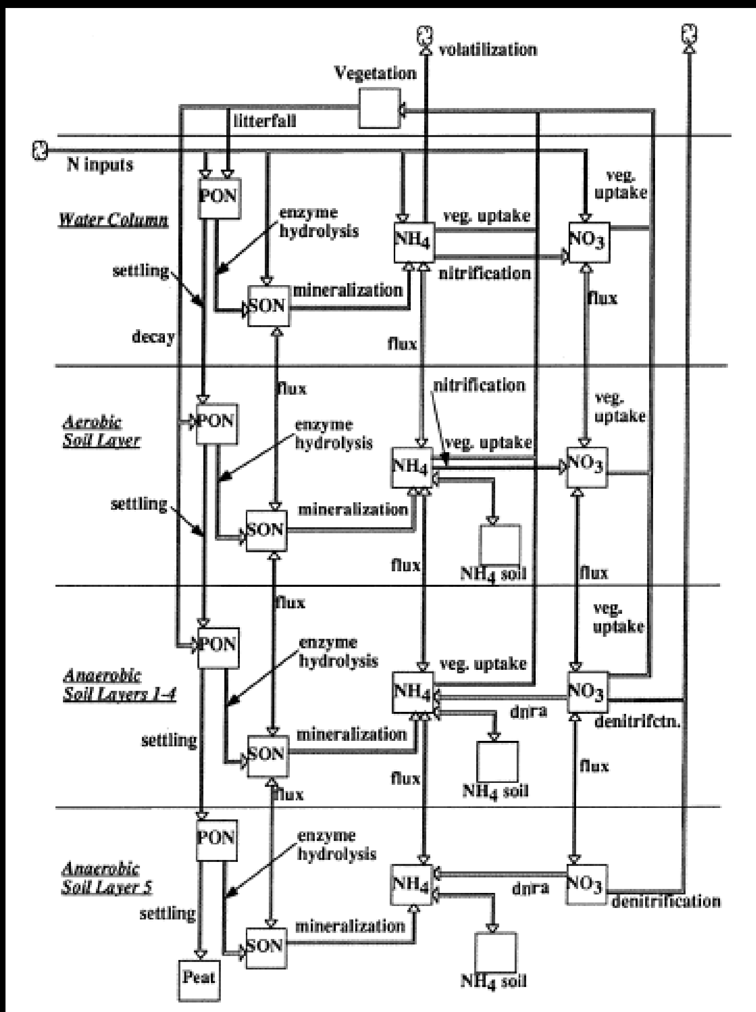
- Denitrification is the primary mechanism of nitrate removal from the Wax Lake Delta .
- Nitrogen removal efficiency is proportional to the residence time in the estuary.
- Temperature thresholds influence the balance of nitrogen transformations in this river delta.

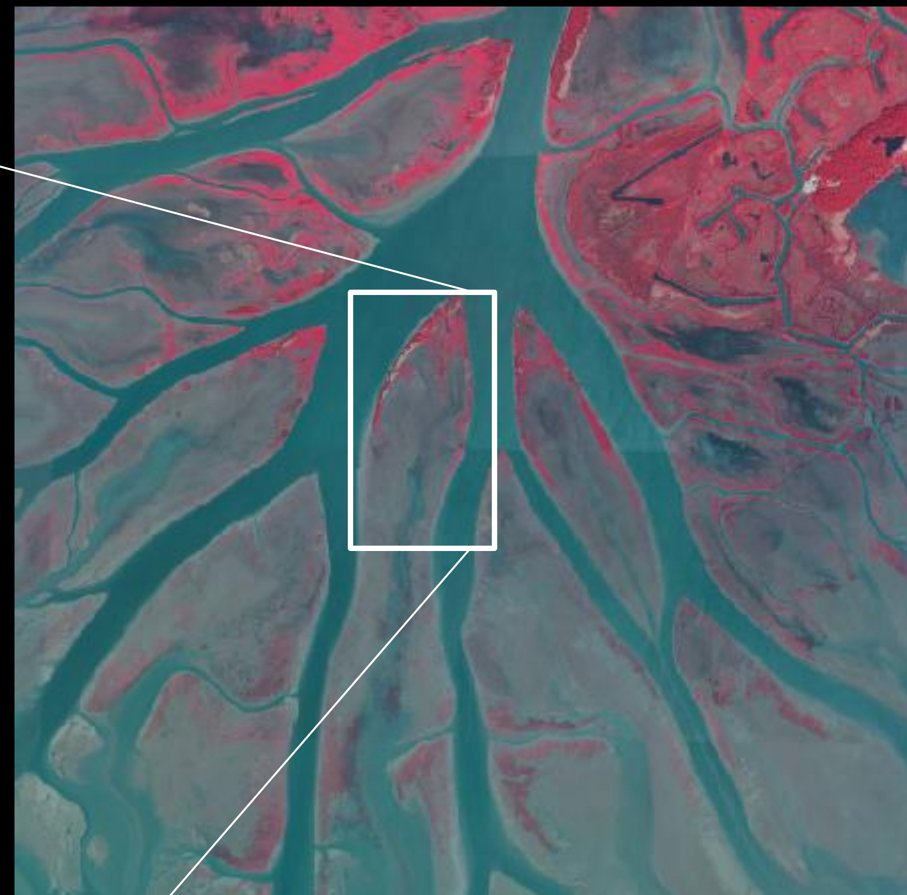
Objectives

- Develop a biogeochemical model to more clearly define the nitrogen cycle process.
- Evaluate the fate of nitrogen in the Wax Lake Delta according to ecological parameters.

Mike Island

Martin and Reddy, 1997

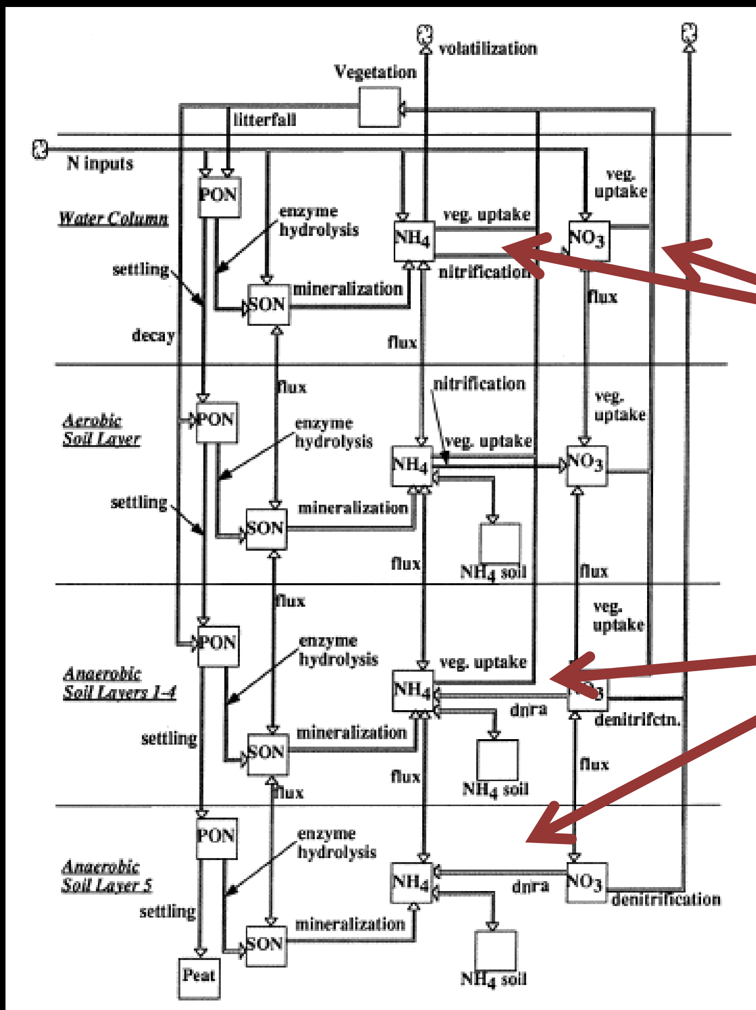




How is nitrogen processed in this system?
What role does denitrification play?
What role do the various wetland properties play?

Methods: The Model

Martin and Reddy, 1997



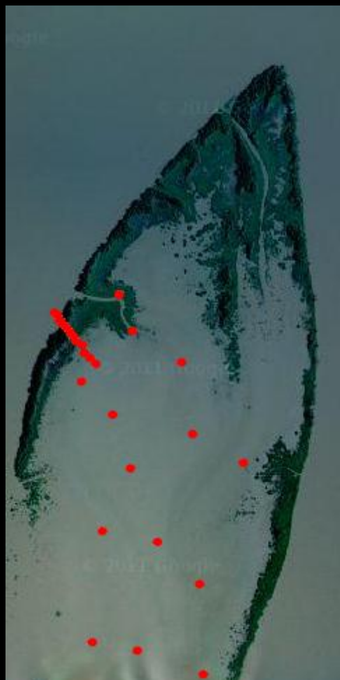
Modifications

Visual Basic

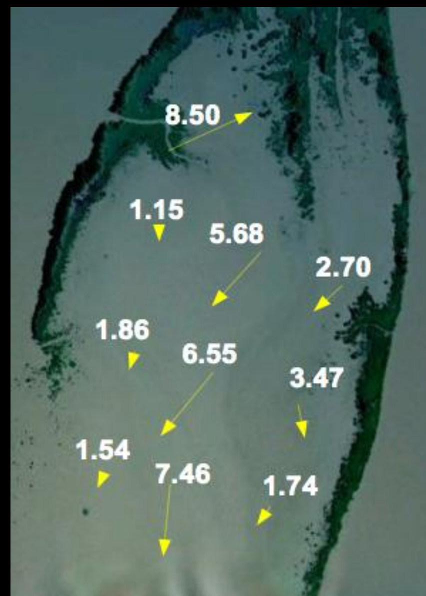
Nitrogen assimilation from the surface water

Dissimilatory Nitrate Reduction to Ammonium

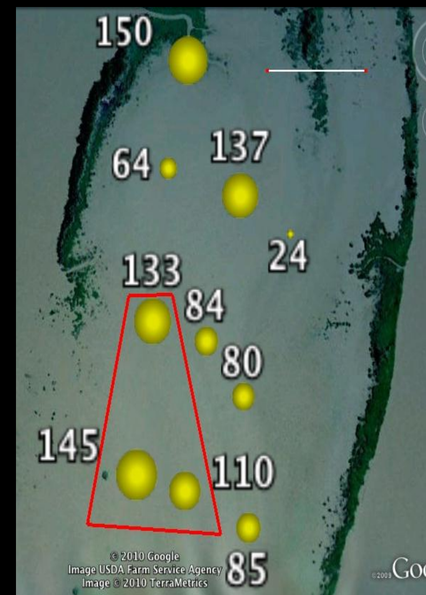
Field Site: Mike Island



Velocity (cm s^{-1})

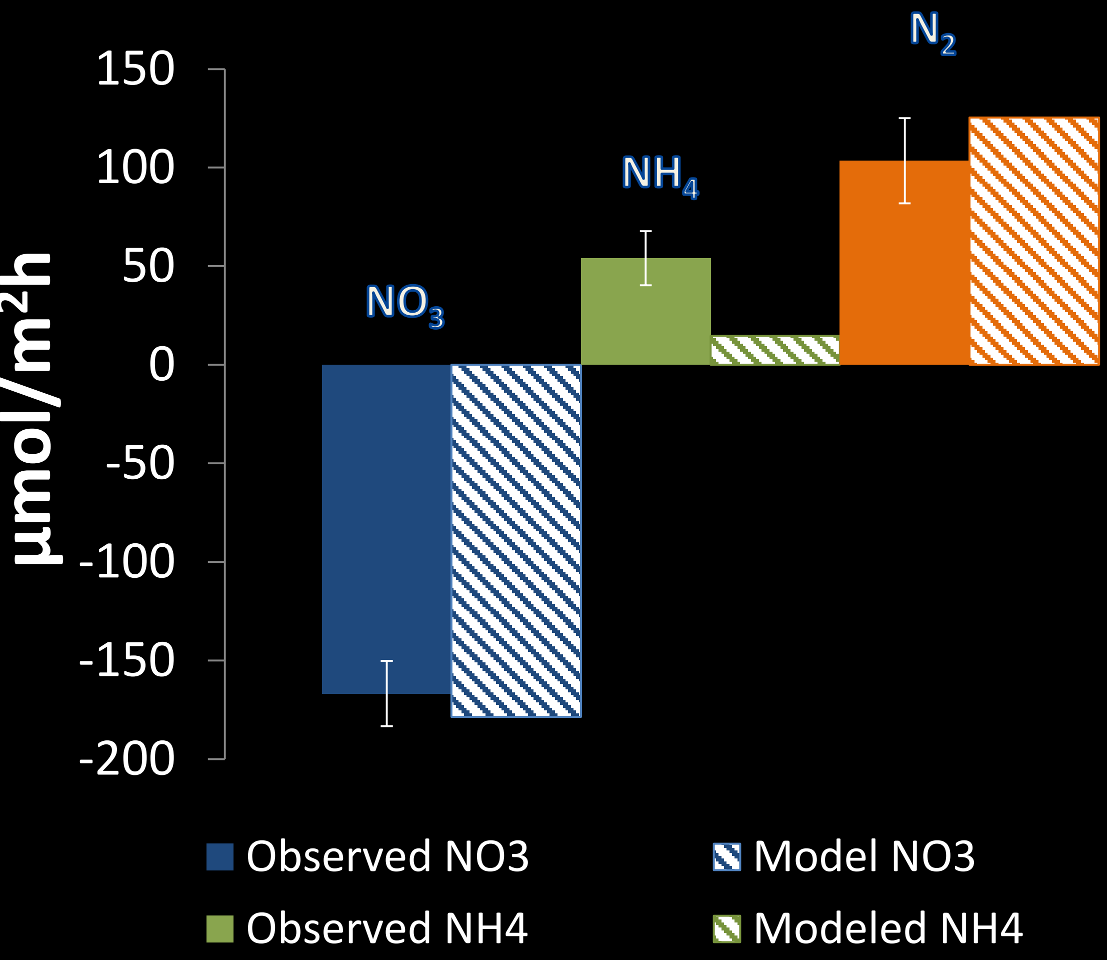


Nitrate (μM)



- Surface and pore water quality
- Daily Temperature
- Daily Water Levels
- Depths
- Vegetation Coverage
- Soil Core Experiments

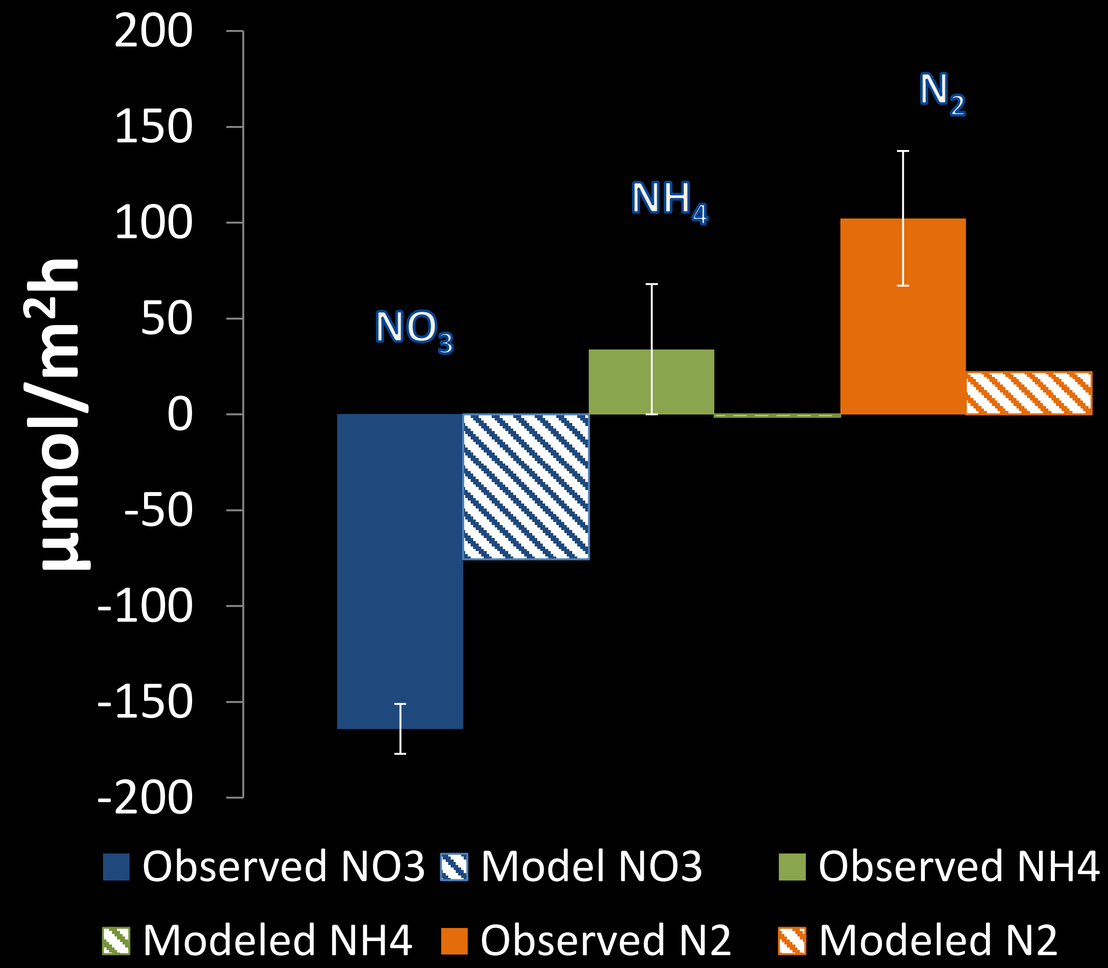
Methods: Calibration



Soil core Incubation experiments

Optimize model parameters to fit observed results

Methods: Calibration

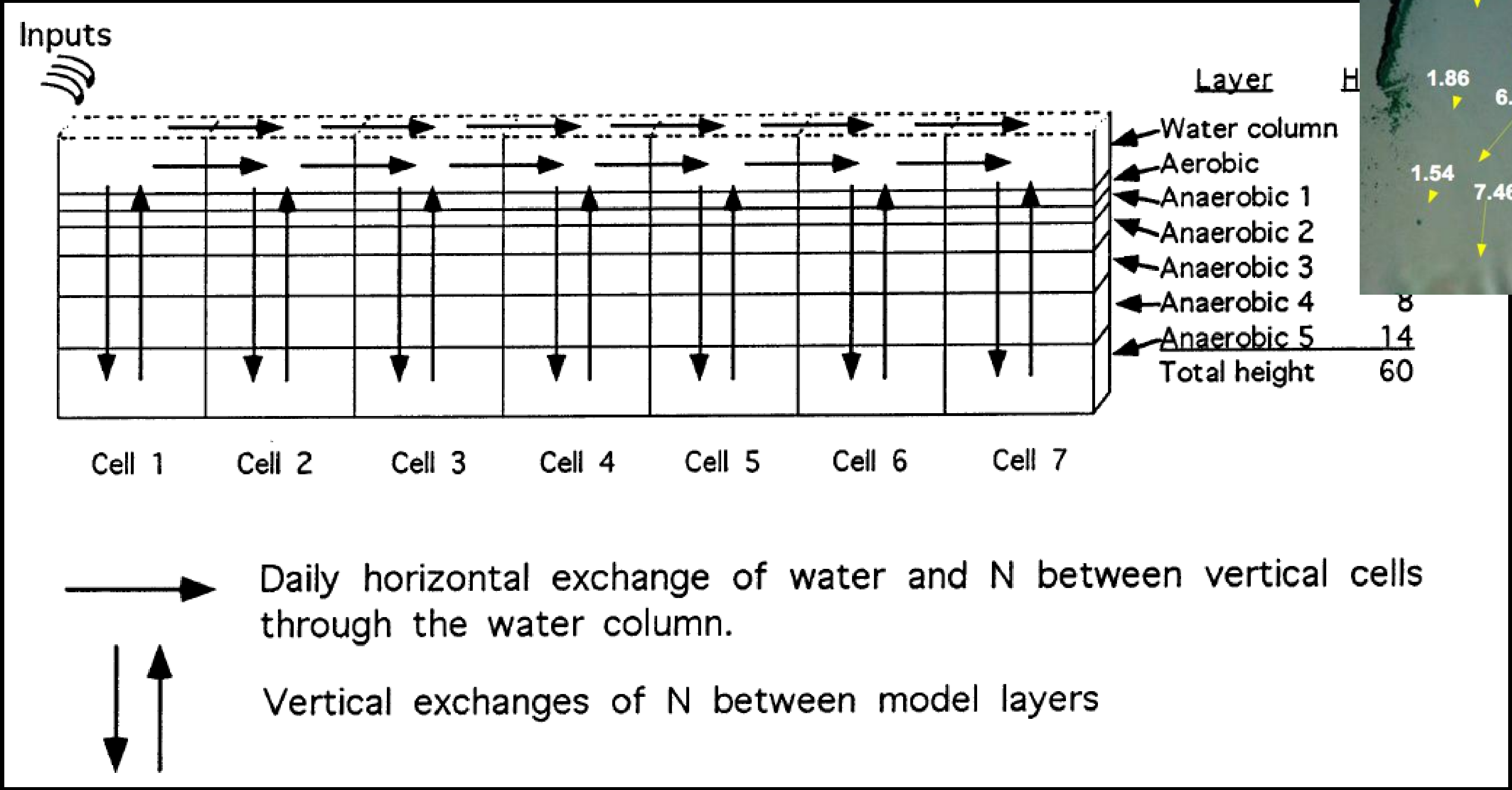


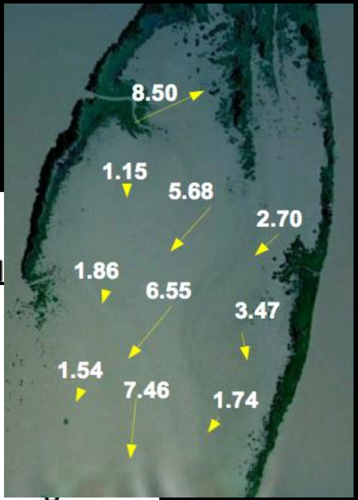
Soil core Incubation experiments

Optimize model parameters to fit observed results

Methods: Spatial Simulation

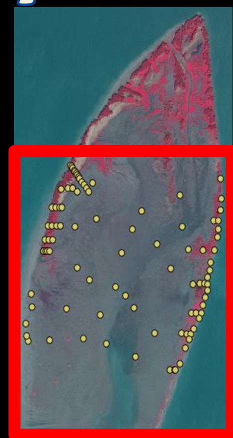
Martin and Reddy, 1997



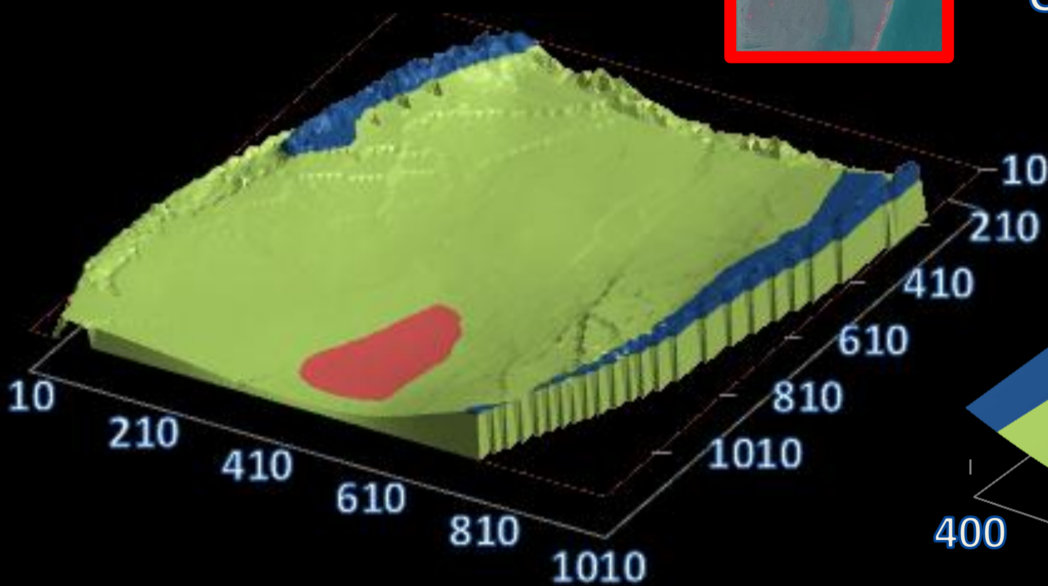


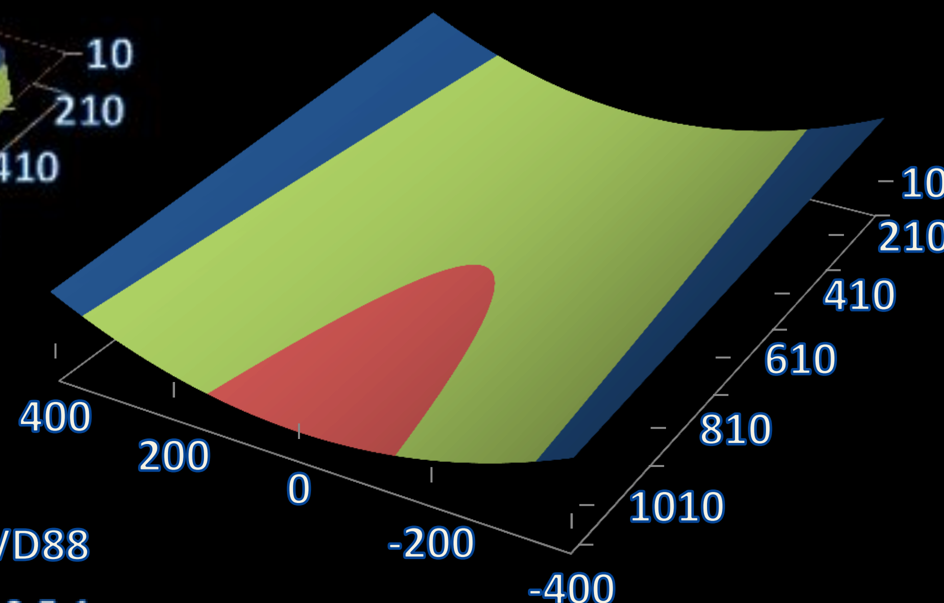
Hydrodynamic Modeling

Mike Island
via Kriging Interpolation



Quadric: $z = ax^2 + by^2 + cxy - dx - ey + f$

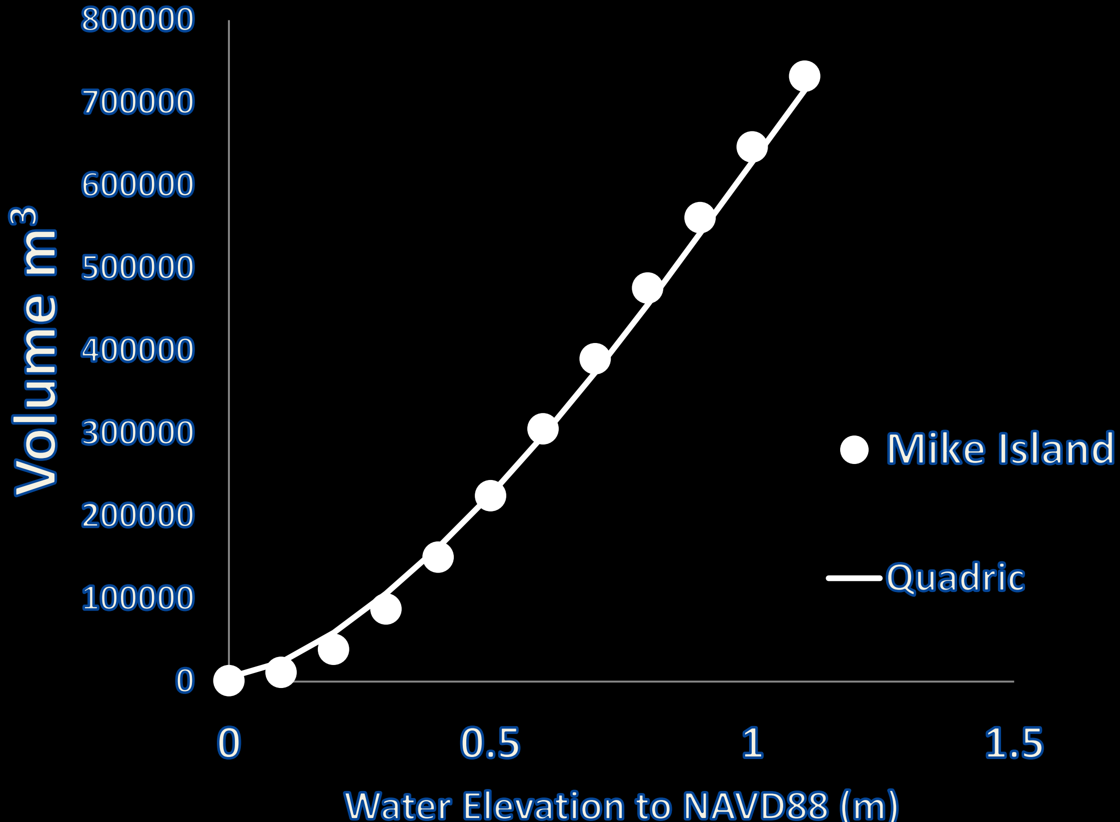




Elevations to NAVD88

-0.5-0 0-0.5 0.5-1

Hydrodynamic Modeling

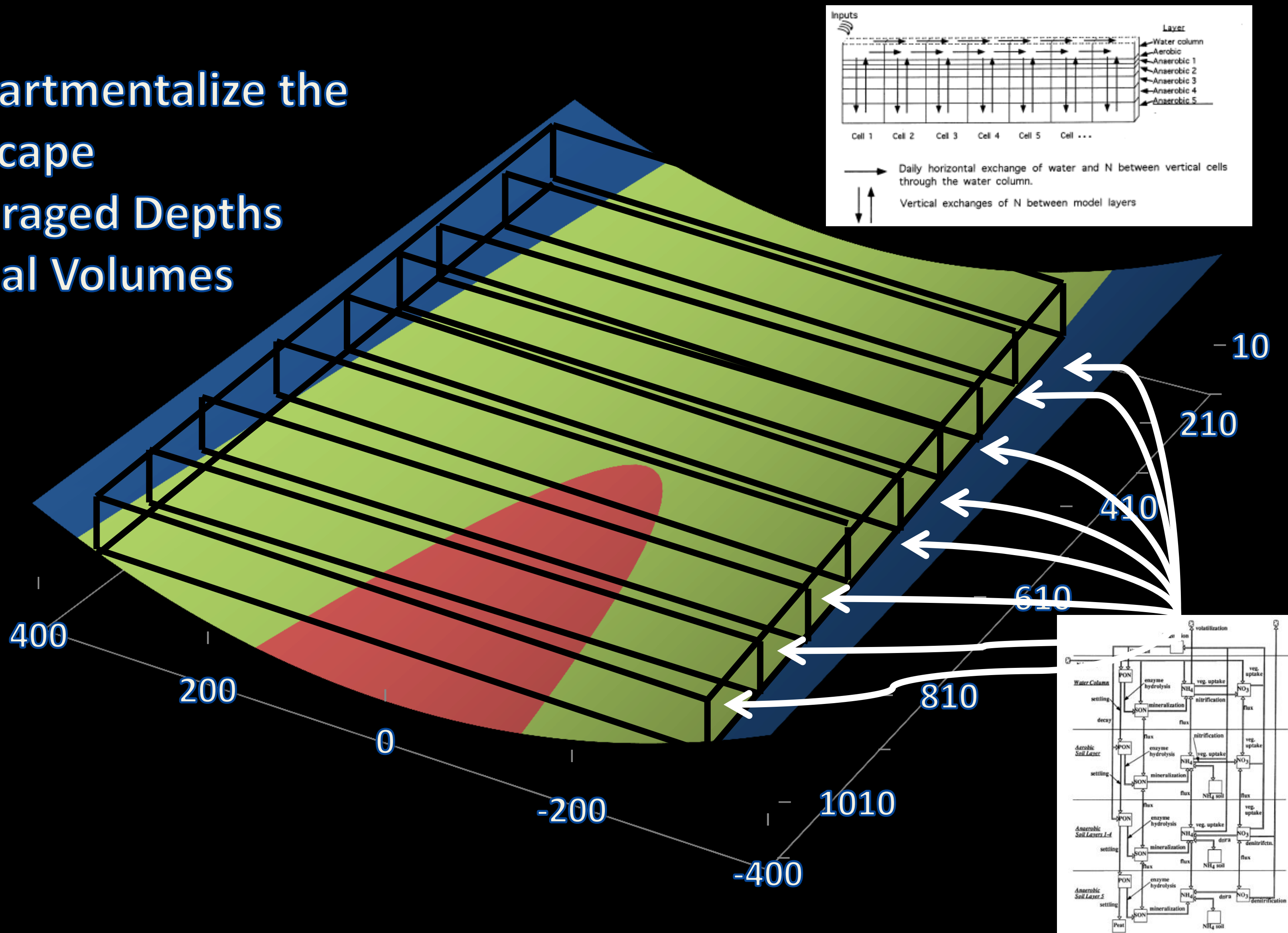


- Basins compare excellently with respect to water elevation and total volume.
- Quadric is a good approximation of the site bathymetry.

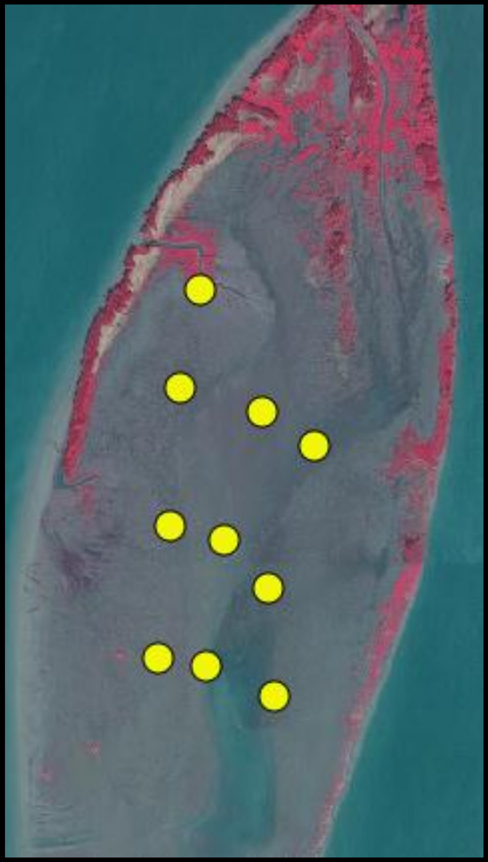
Hydrodynamic Modeling

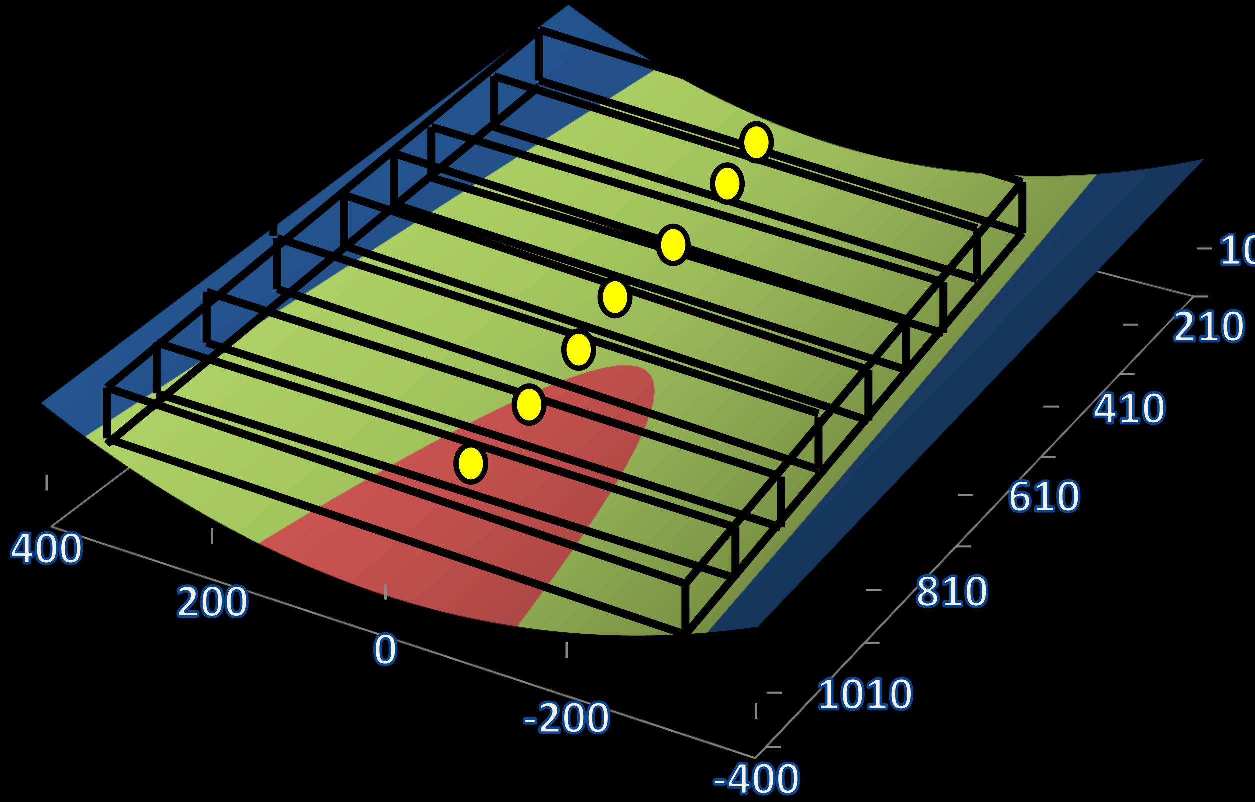
Compartmentalize the Landscape

- Averaged Depths
- Equal Volumes



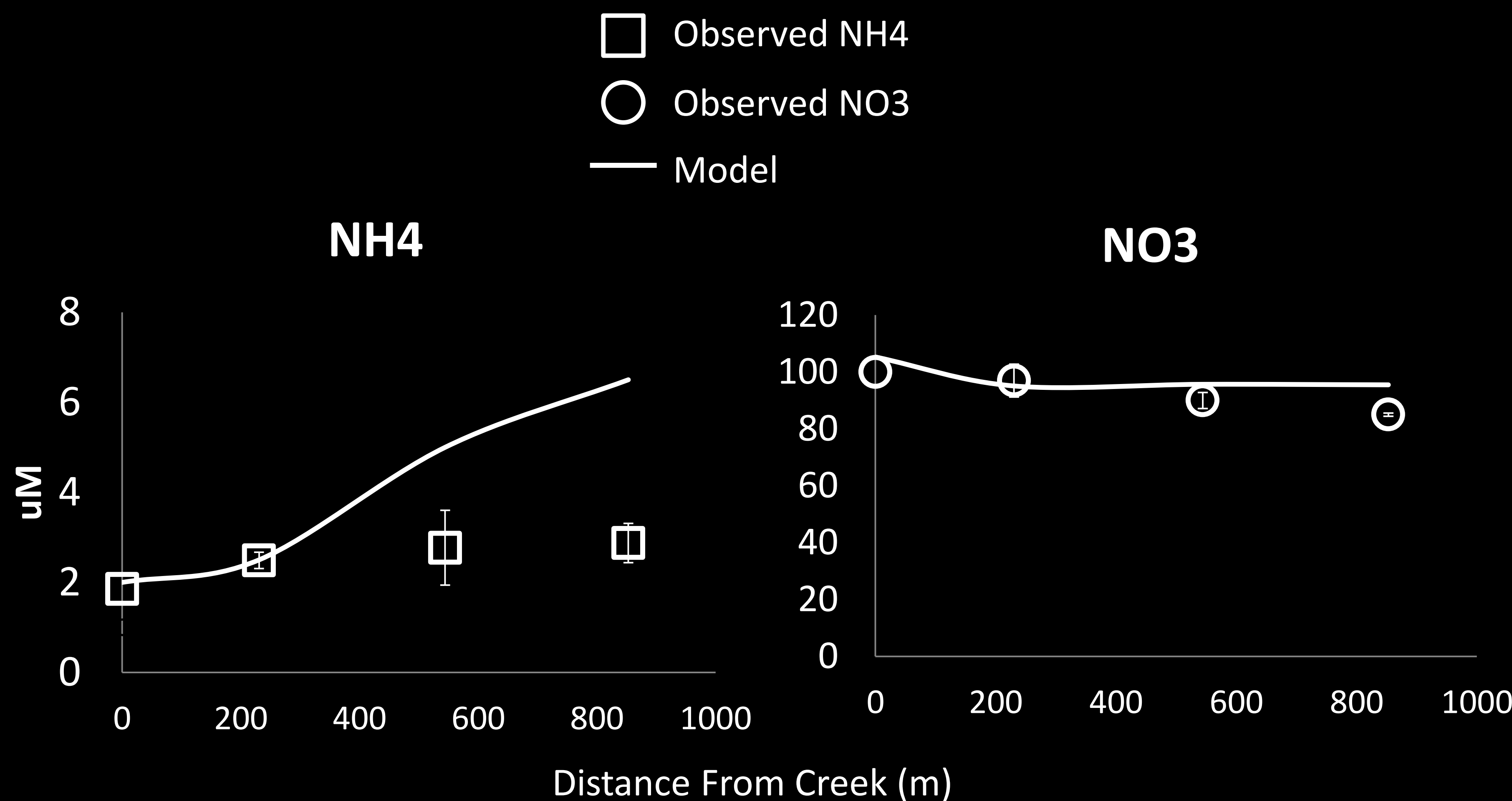
Surface Water Nitrogen Simulations





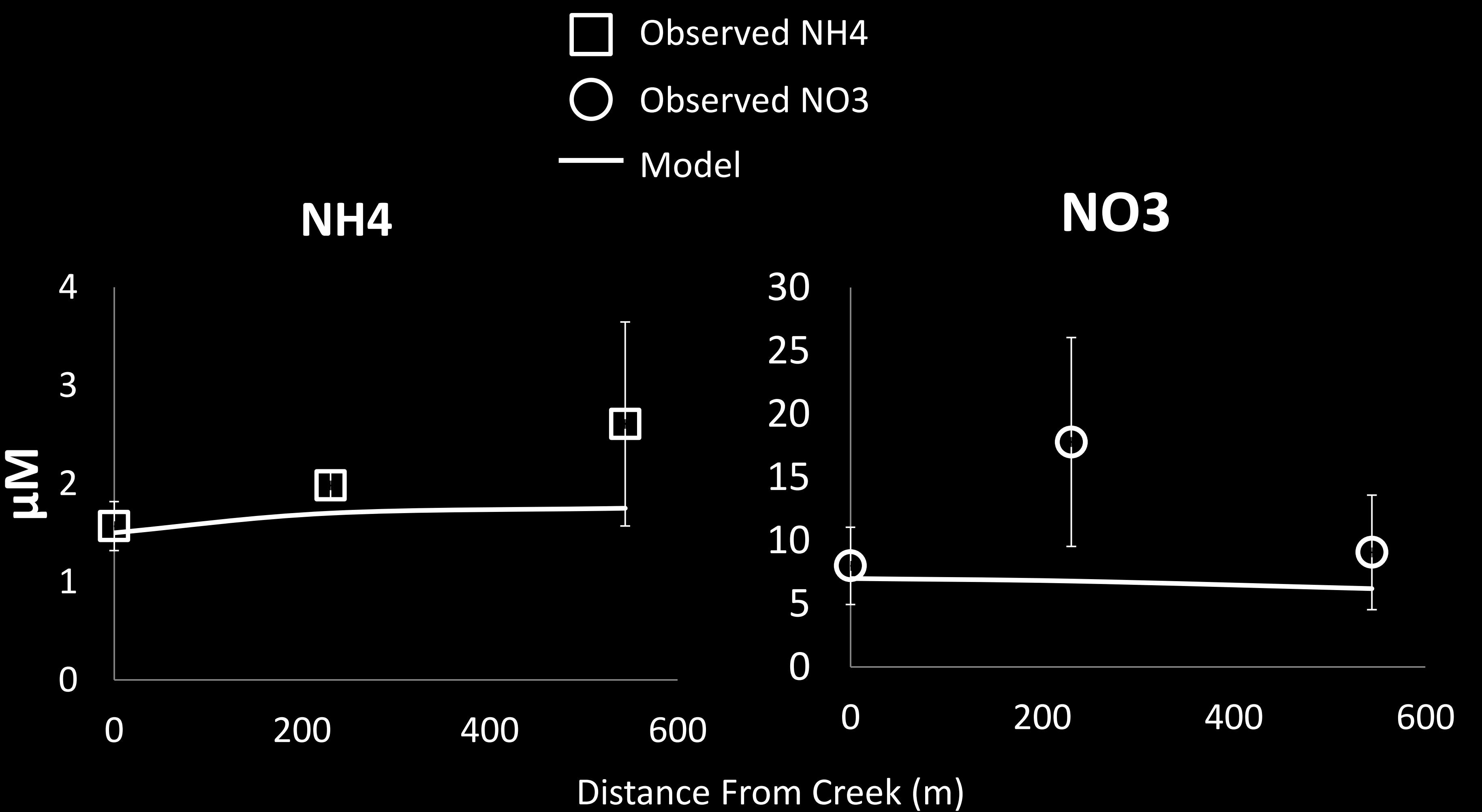
Surface Water Nitrogen

March

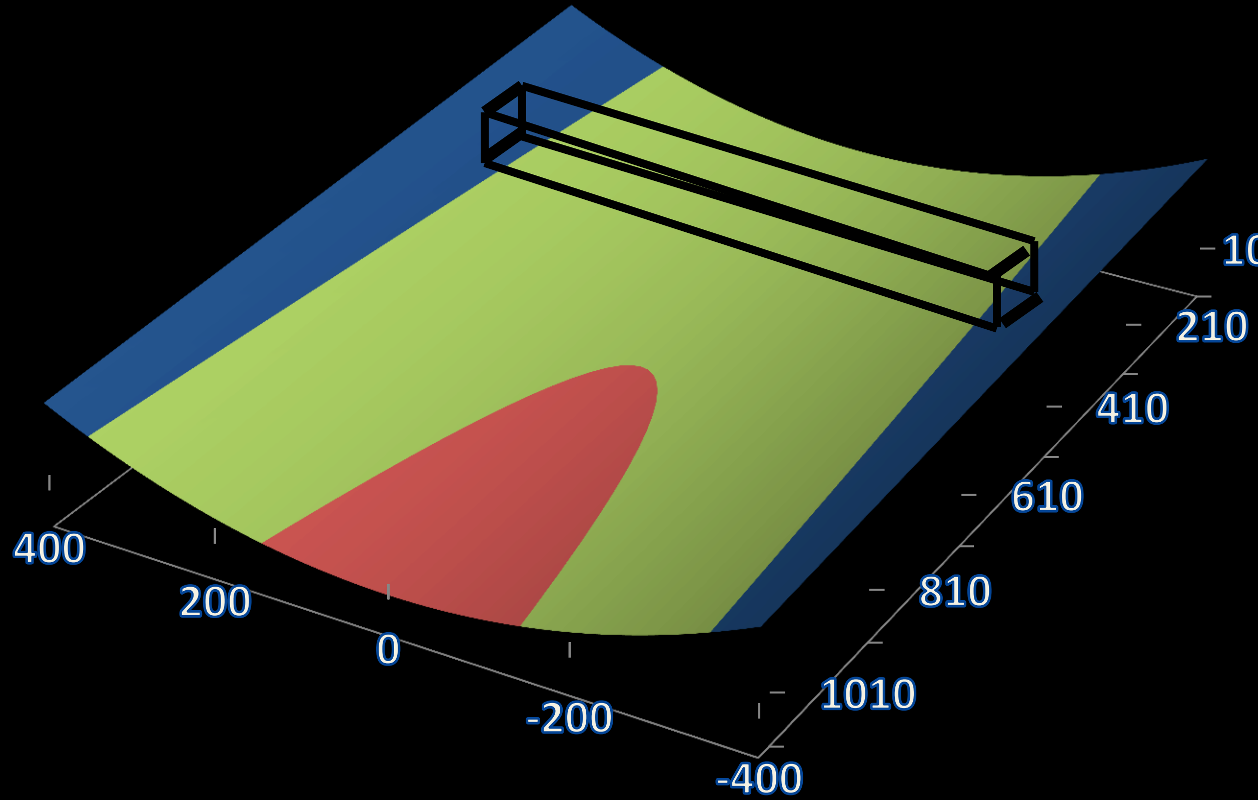


Surface Water Nitrogen

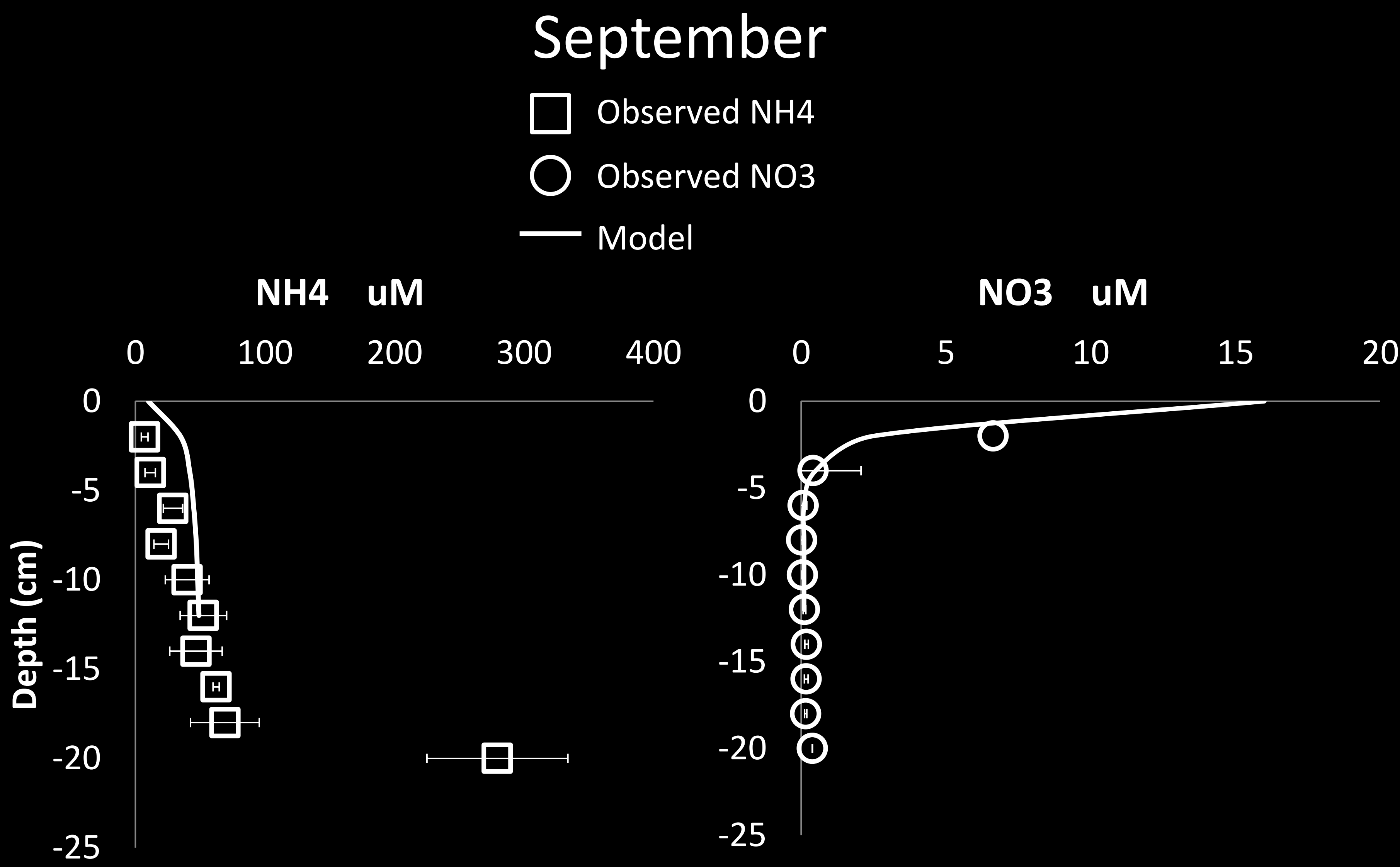
April



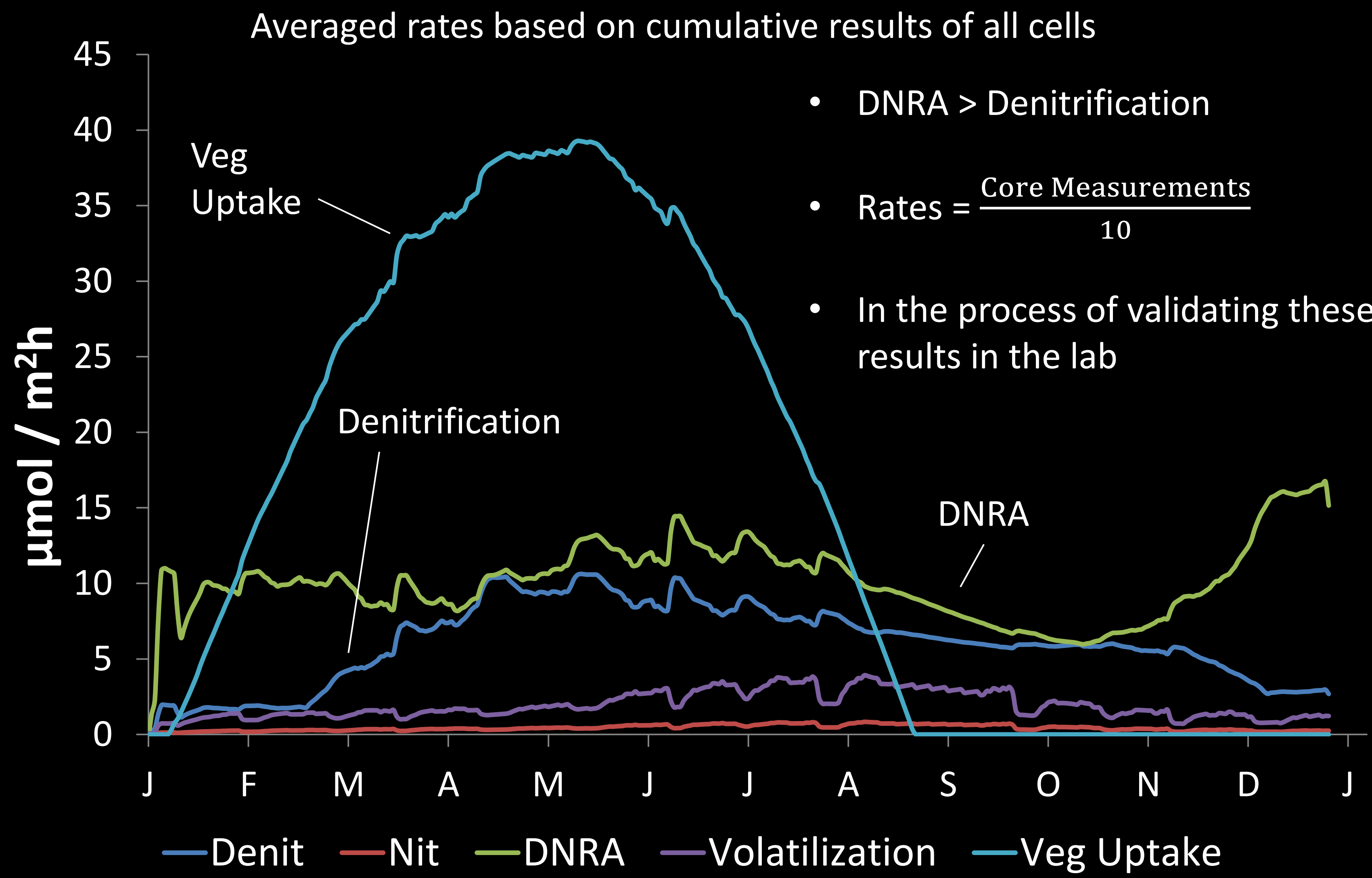
Pore Water Nitrogen Simulations



Pore Water Nitrogen



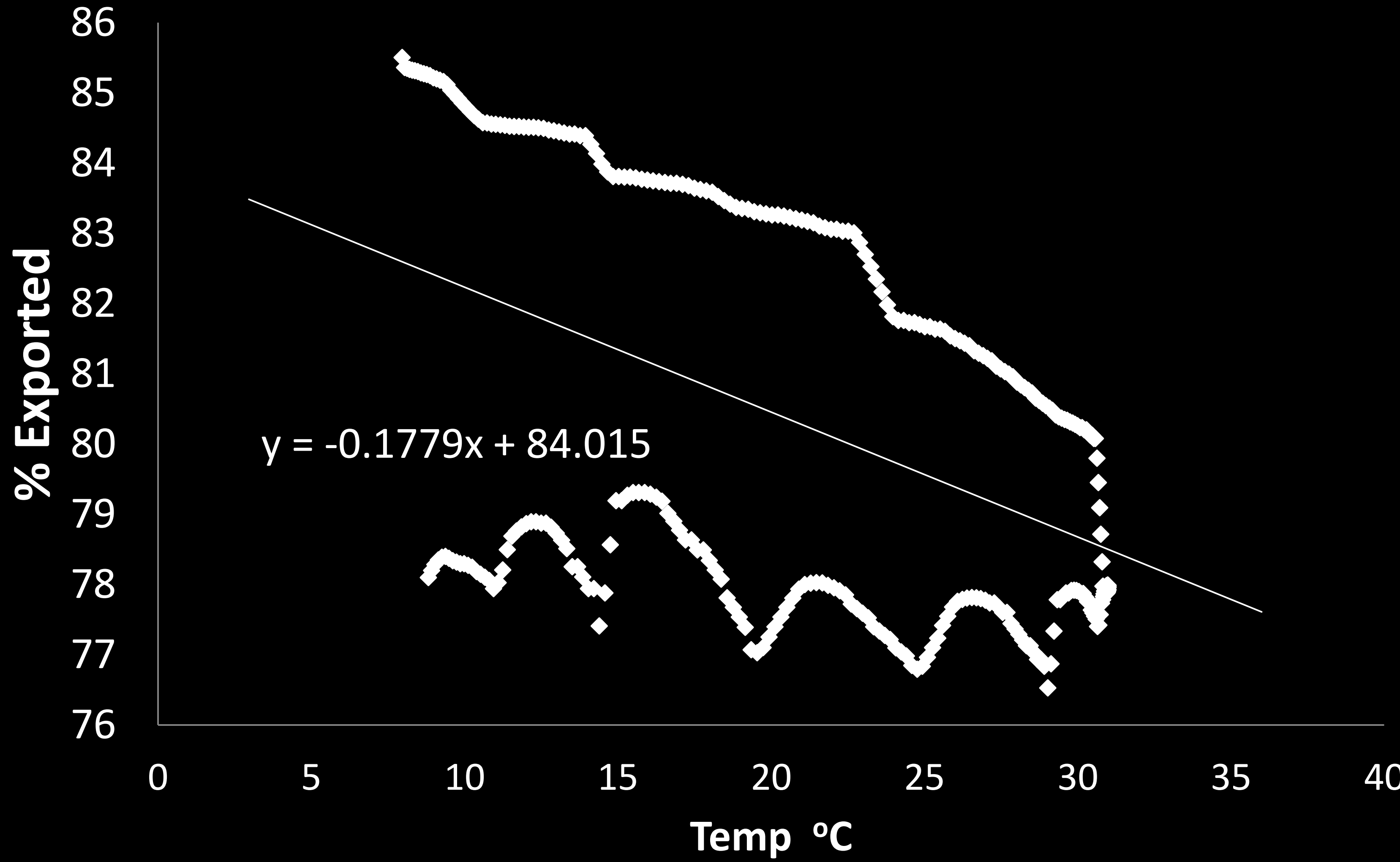
Results: Annual Rates



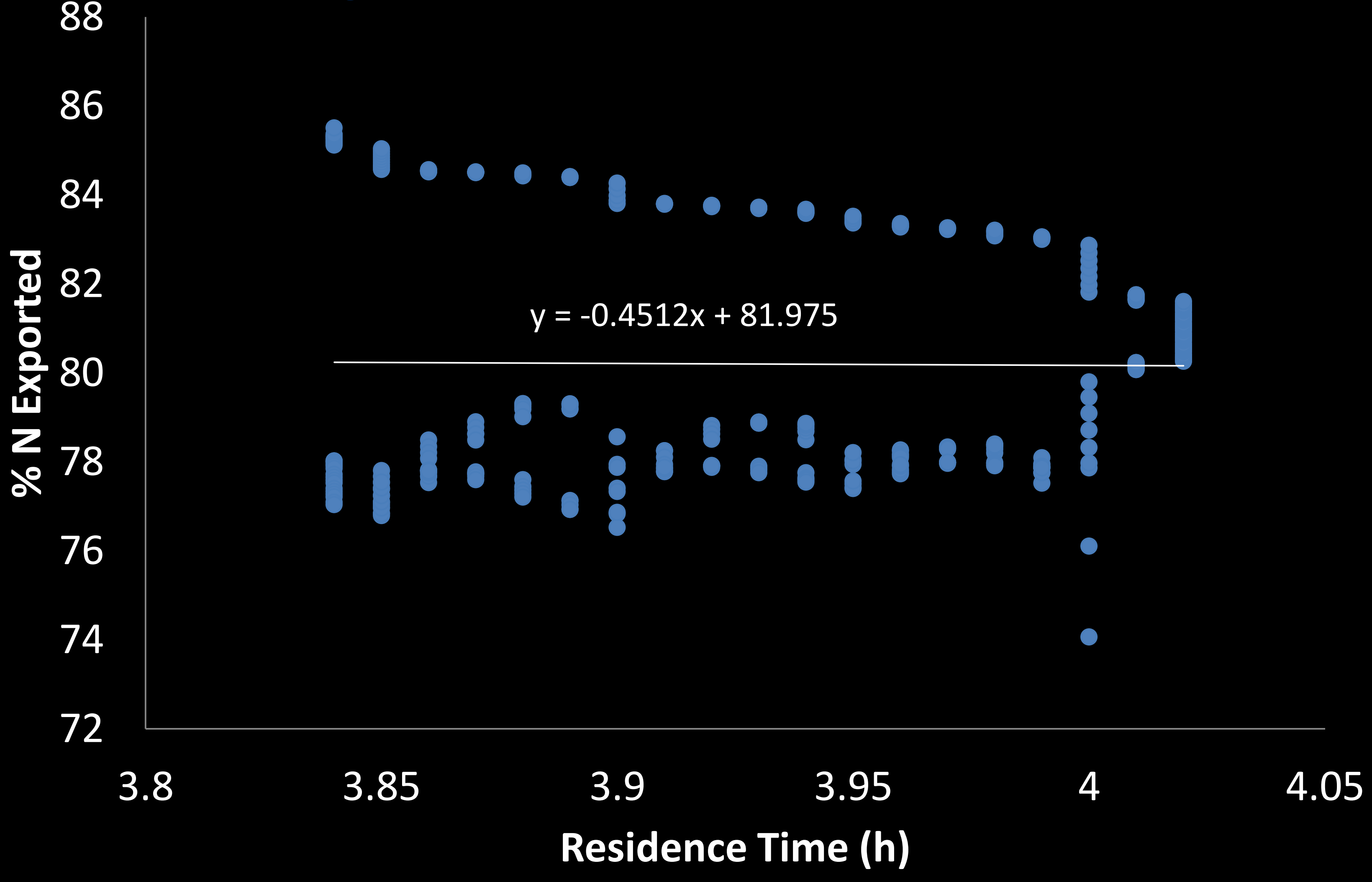
- DNRA > Denitrification
- $\text{Rates} = \frac{\text{Core Measurements}}{10}$
- In the process of validating these results in the lab

Results: Annual N Export

Results:
N Export and Temperature

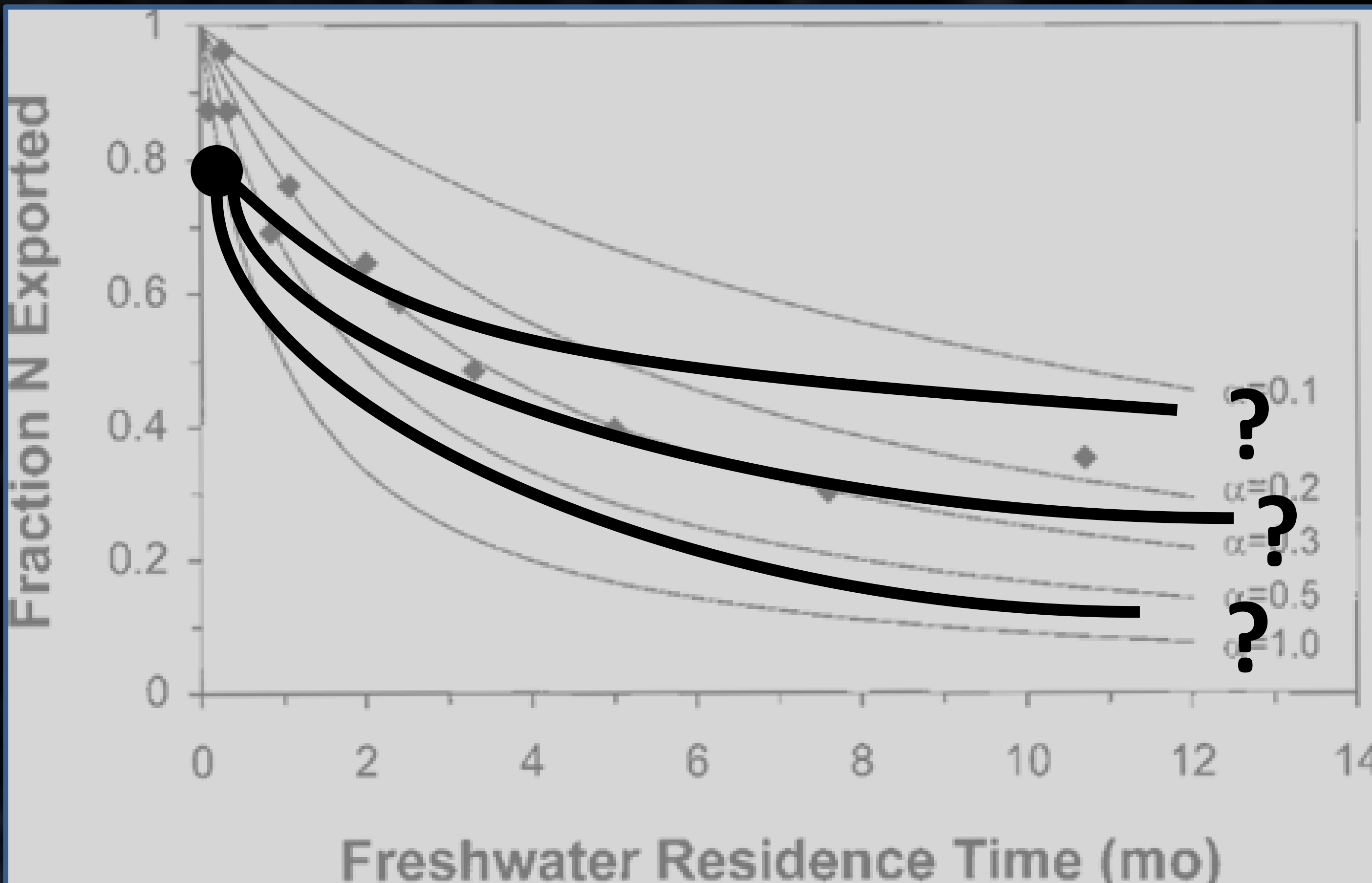


Results:
N Export and Residence Time



Results: Annual N Export

Dettman, 2001



Where is the Wax Lake Delta operating?

How will it change with time

Conclusions

- Ecosystem Rates = $\frac{\text{Core Incubation Rates}}{10}$

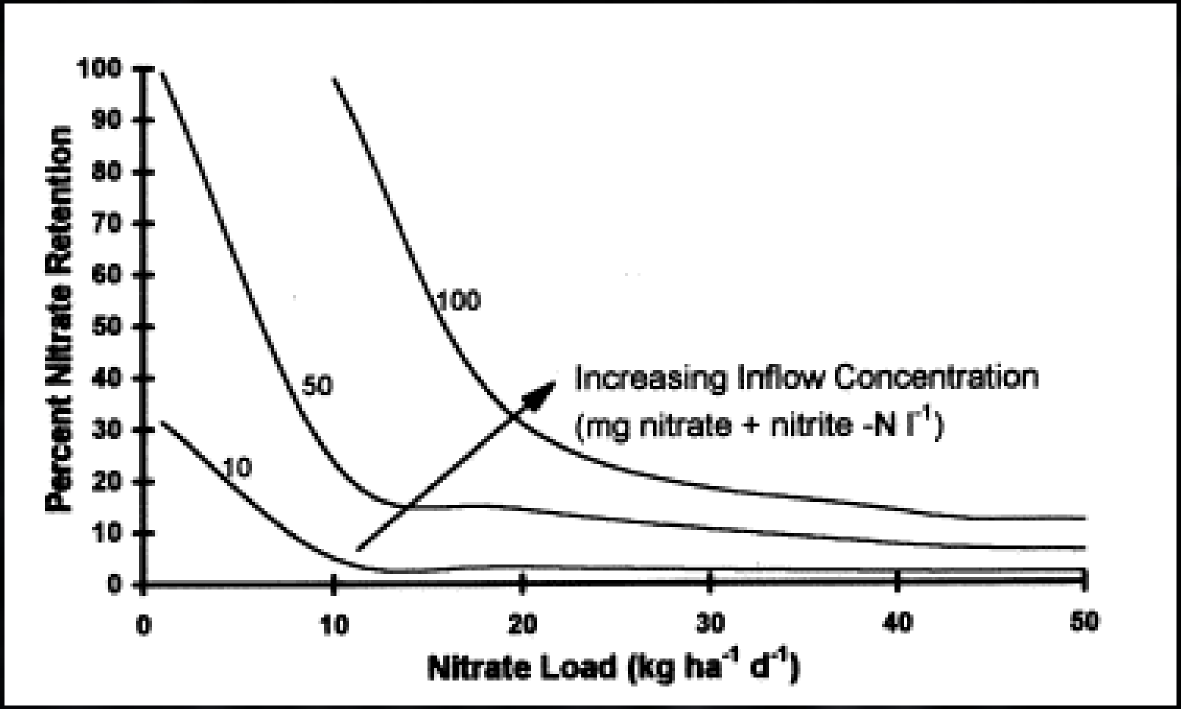
- Vegetation uptake is the dominant process of the nitrogen cycle within the model
  - Denitrification plays a secondary role with DNRA

- Nitrogen export increases throughout the year from January to December
  - Residence time has little to do with this
  - Temperature is highly correlated

Questions?

What's Next?

- Evaluate mass transfer rates and comparisons to other systems



Speieles & Mitsch, 1999

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