Nutrient Management at the Edge: Optimization and Innovations in Water Quality Treatment Strategies at the "Edge of the Field"

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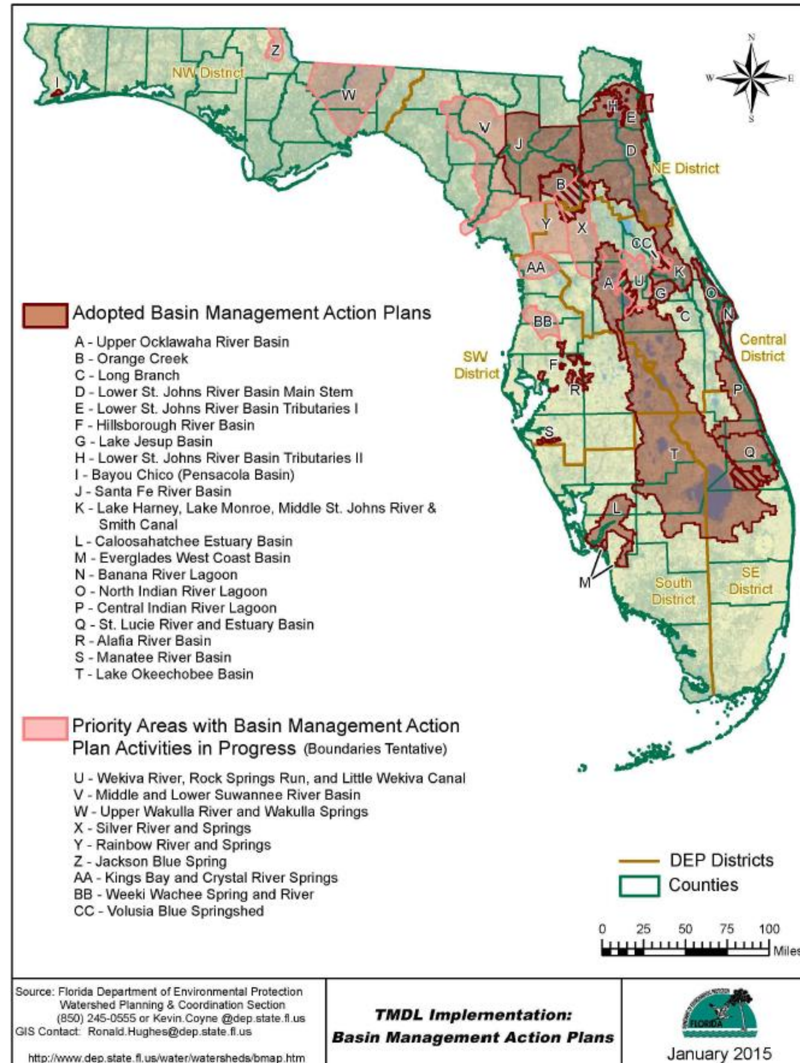
EPB/UNF Environmental Symposium

September 9, 2016

TMDL/BMAP Status in Florida

- 197 water body TMDL's
  - Fecal Coliform
  - Nutrient
  - Dissolved Oxygen
- Statewide Mercury TMDL
- 22 Adopted BMAPs
  - Many cover multiple TMDLs



Agriculture's Role in Water Quality Protection

- The Legislature provided for agricultural operations to implement BMPs as the preferred means to help meet TMDLs and otherwise protect water quality [s. 403.067(7) and (12), F.S.]

- Agricultural operations within BMAP areas have two options:

  Enroll in and implement FDACS BMP

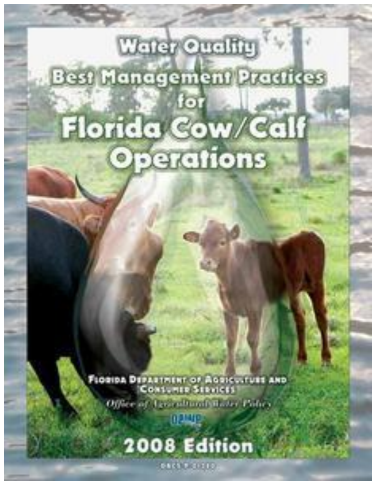
  OR

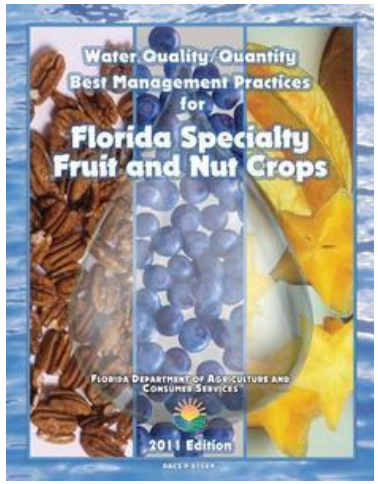
  Follow an FDEP- or WMD-prescribed water quality monitoring plan at the producer's own expense (complicated and costly)

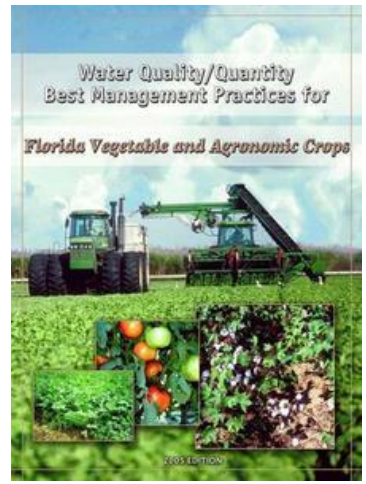
- Failure to do either could bring enforcement action by FDEP or the applicable WMD.

Slide provided by FDACS OAWP

Agricultural BMPs





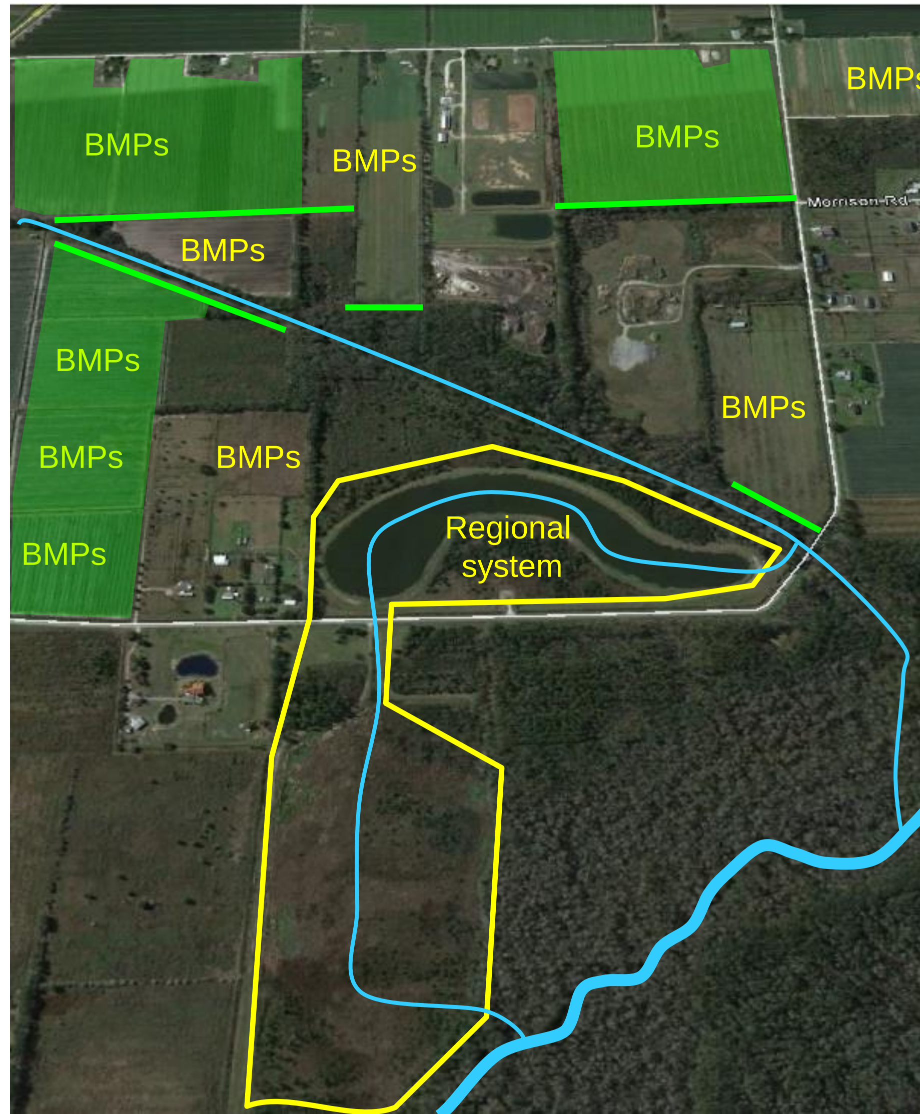


Is Implementation of BMPs Enough?

- Adopting BMPs does not necessarily mean that load reduction targets are achieved, only that levels are reduce to those that are “technically and economically feasible” for a commodity to implement.
- If estimated load reduction from BMPs does not achieve the load reduction required by the TMDL then additional measures are necessary.
- The cost of these additional reductions are shared with society:
  - regional treatment systems
  - “cost share” programs
    - Federal, State, Water Management Districts

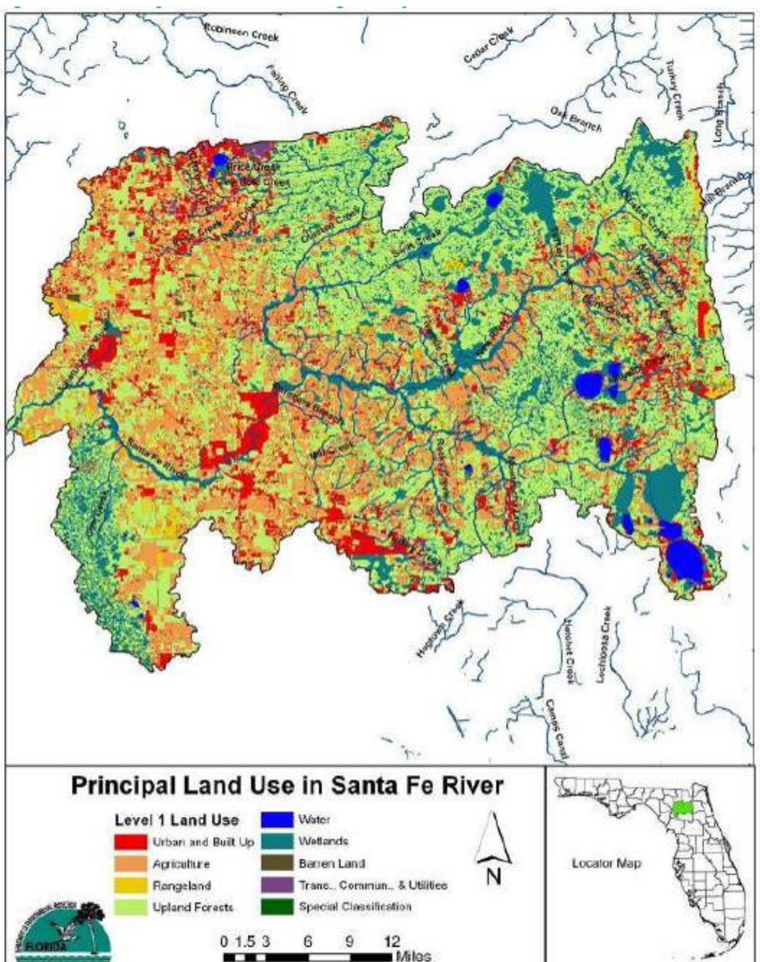
“Edge of Field” Practices

- Most BMP’s focus on source control and “in-field” practices.
- Regional systems occur at the catchment/watershed scale
- “Edge of Field” practices target nutrient losses in surface runoff or leachate that are below the root zone or production boundary
  - Typically located on downstream edge of field
  - May include subsurface manipulation

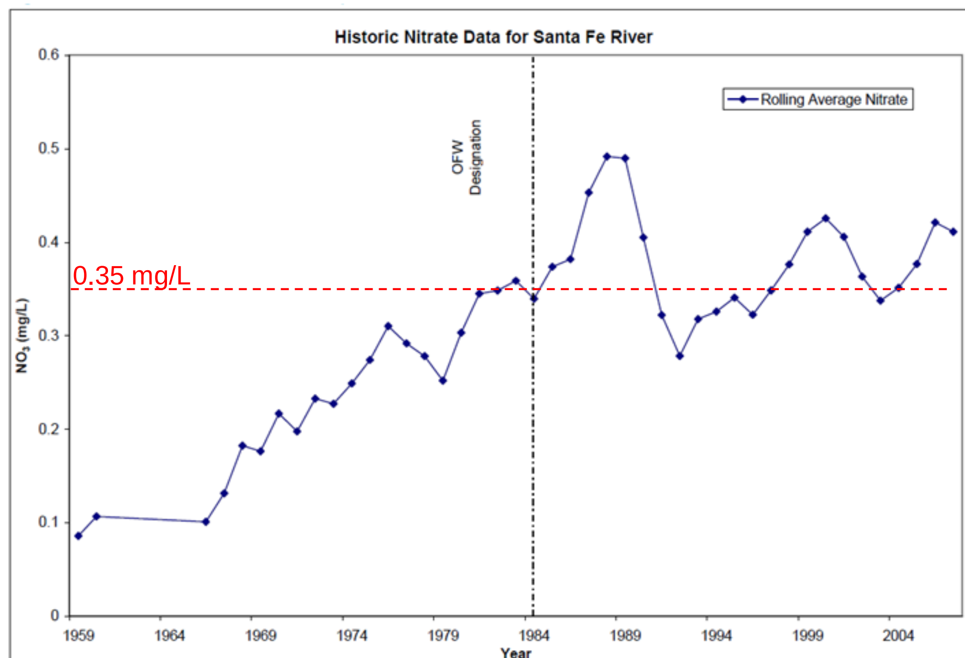


Permeable Reactive Barrier for Nitrate (a.k.a. Denitrification Wall)

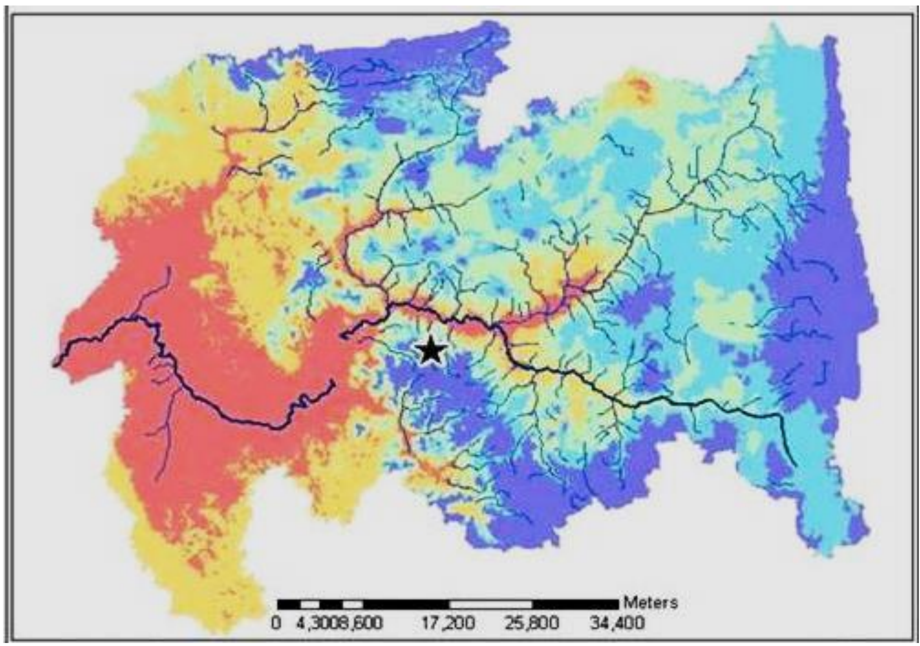
Casey Schmidt, Holly Factory Nursery, FDEP, FDACS



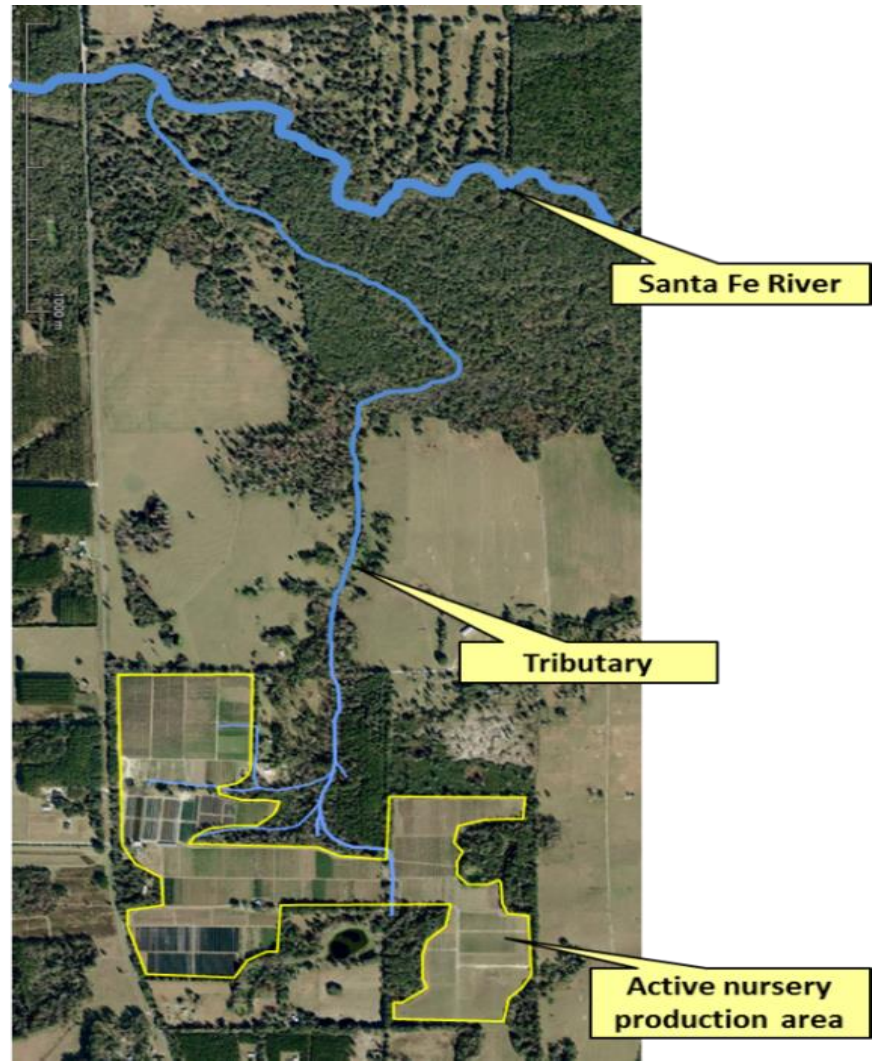
- TMDL established 2008
- Impaired for elevated Nitrate
- Nitrate-nitrogen target of 0.35 mg/L in Lower Santa Fe WBIDs



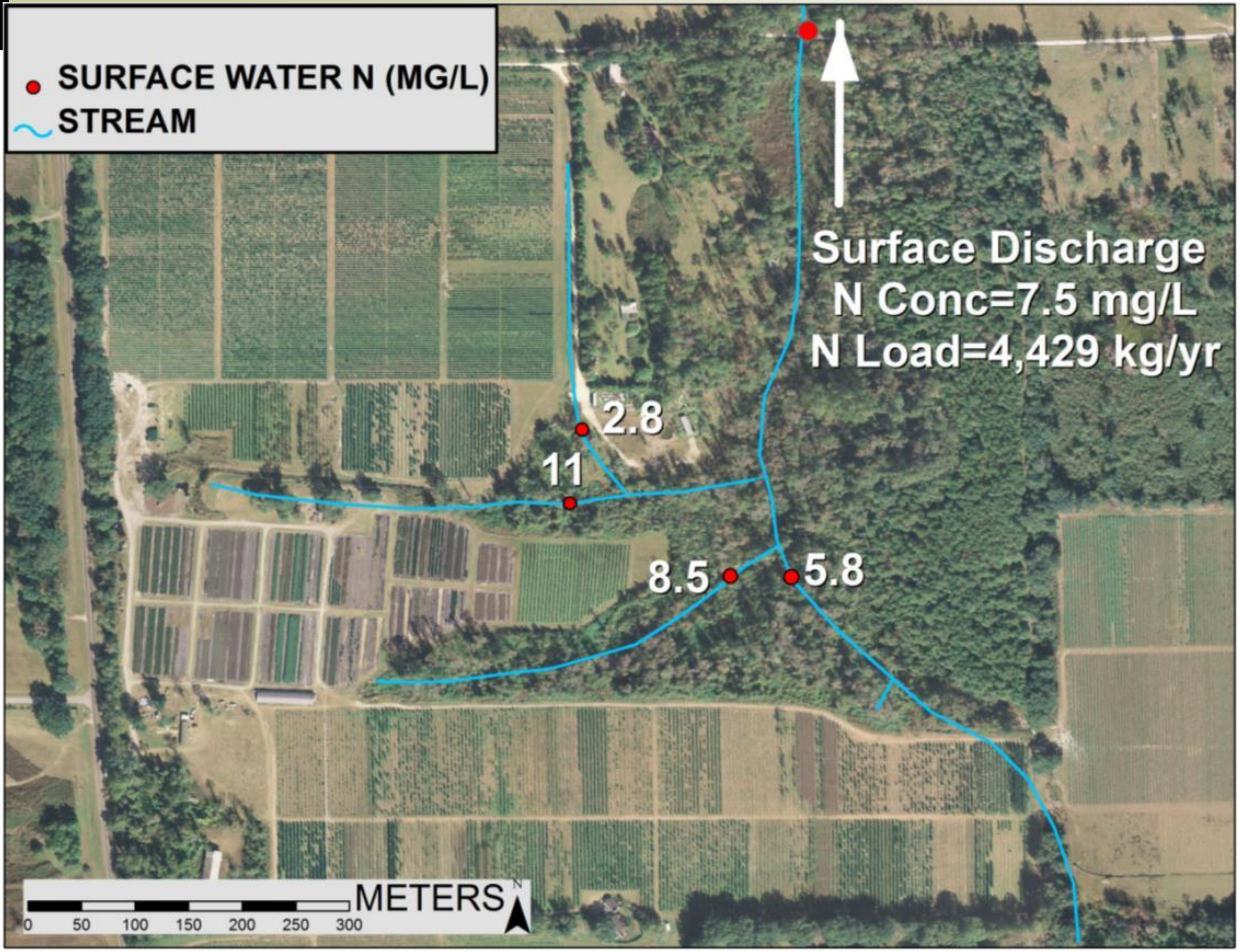
Denitrification Wall: Demonstration and Evaluation Site



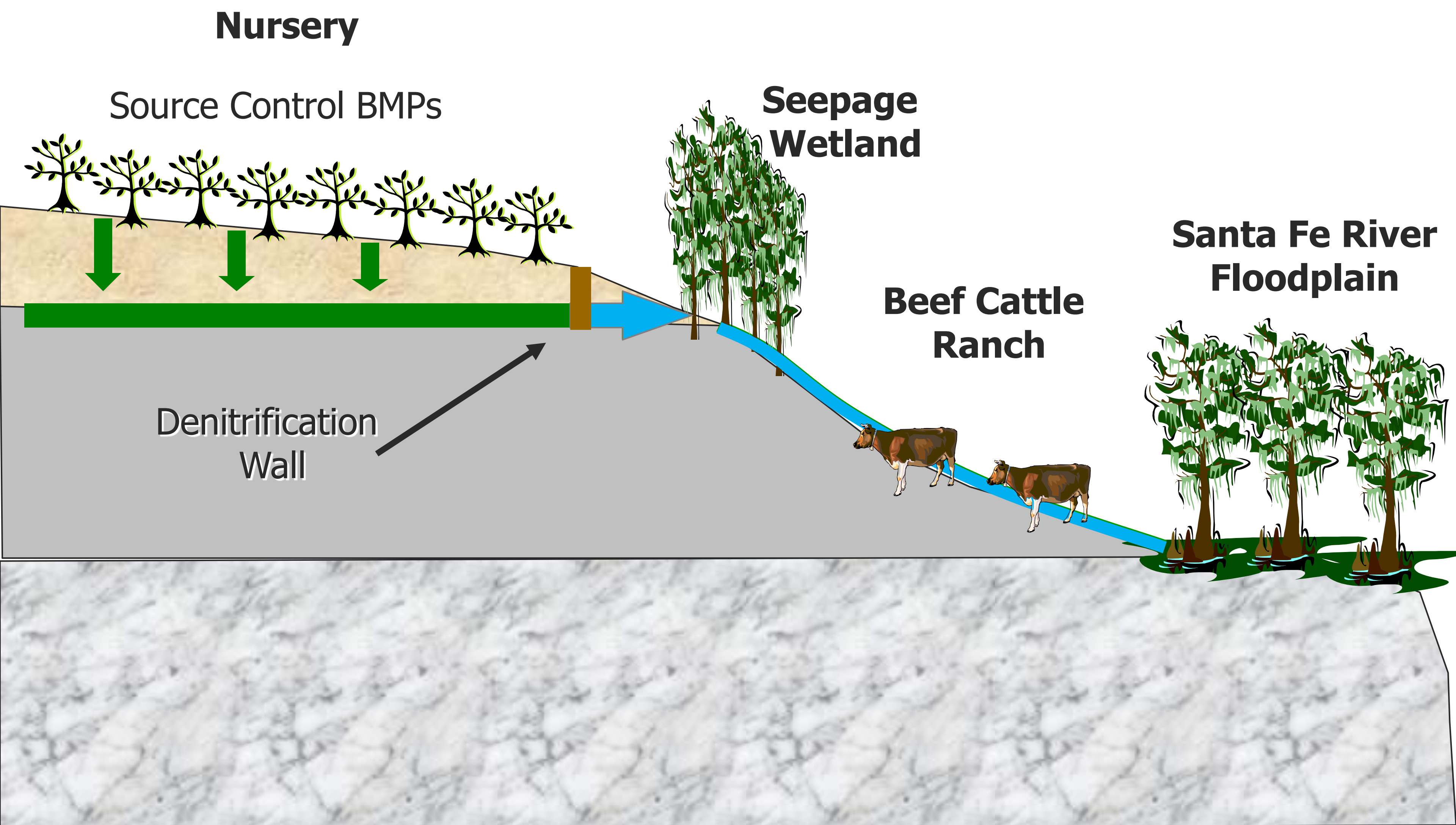
Elevation model of Santa Fe River Watershed



Elevated Nitrate in Shallow Groundwater and Tributaries



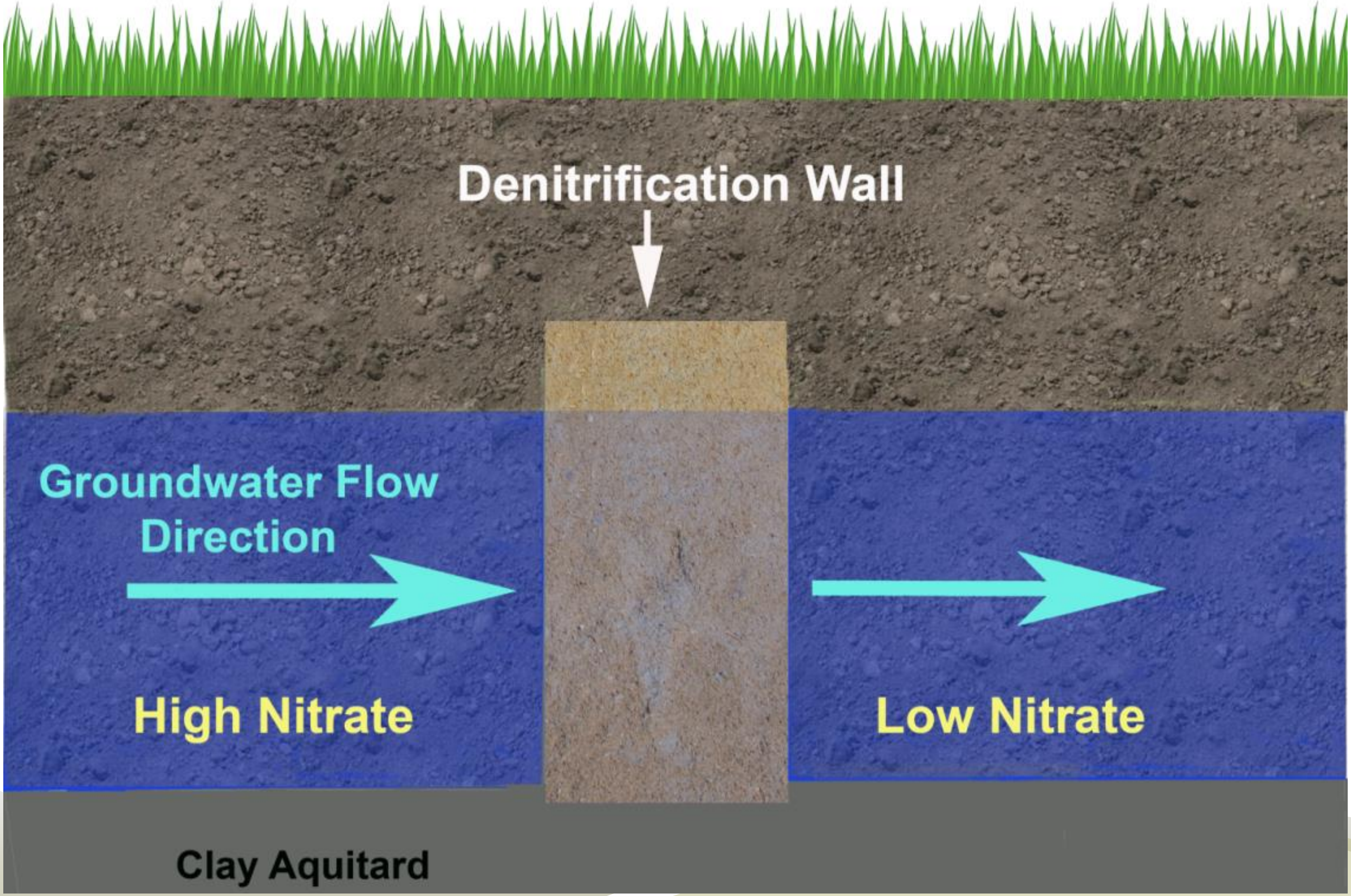
Integration Denitrification Wall

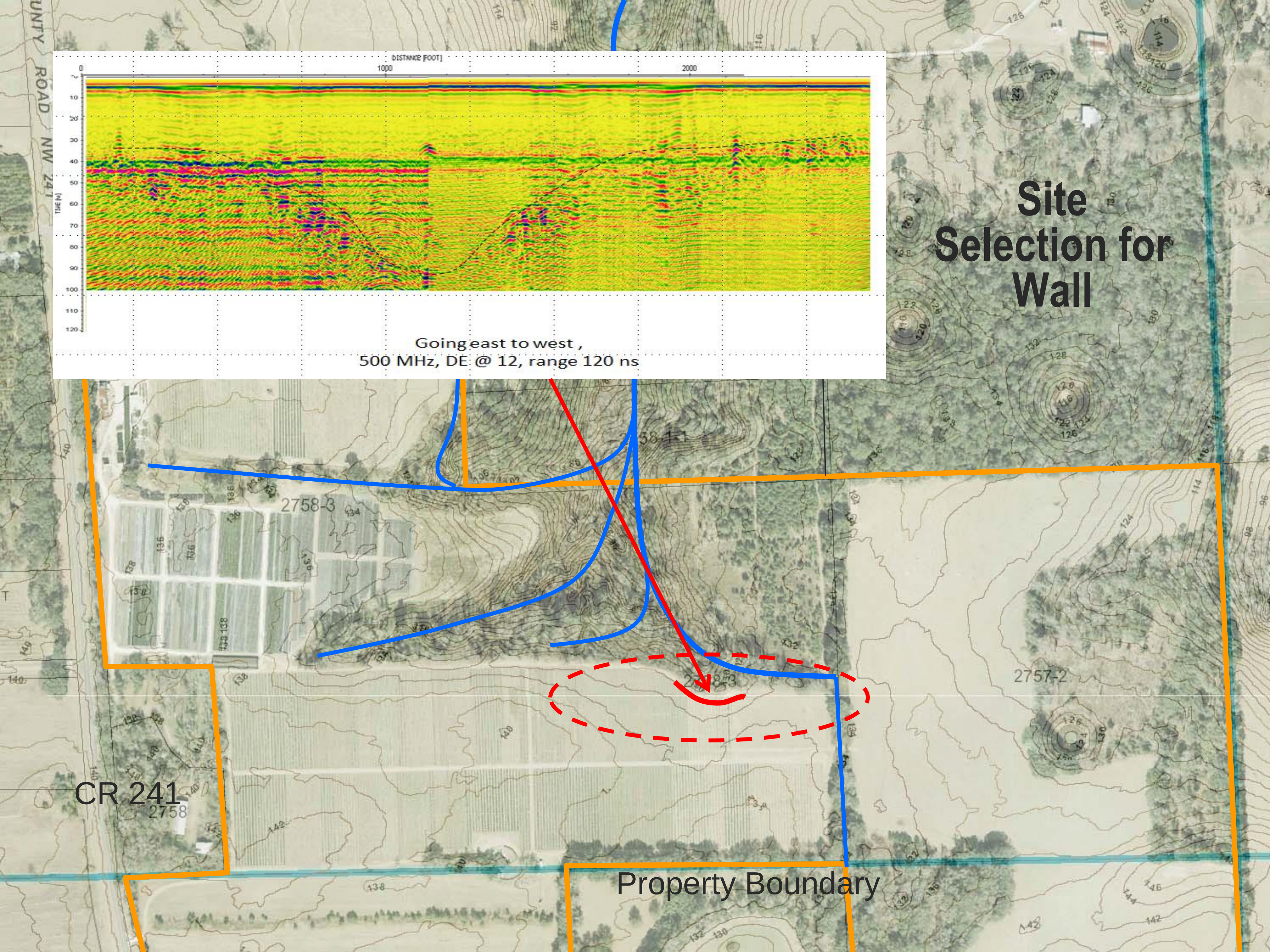


Denitrification Process

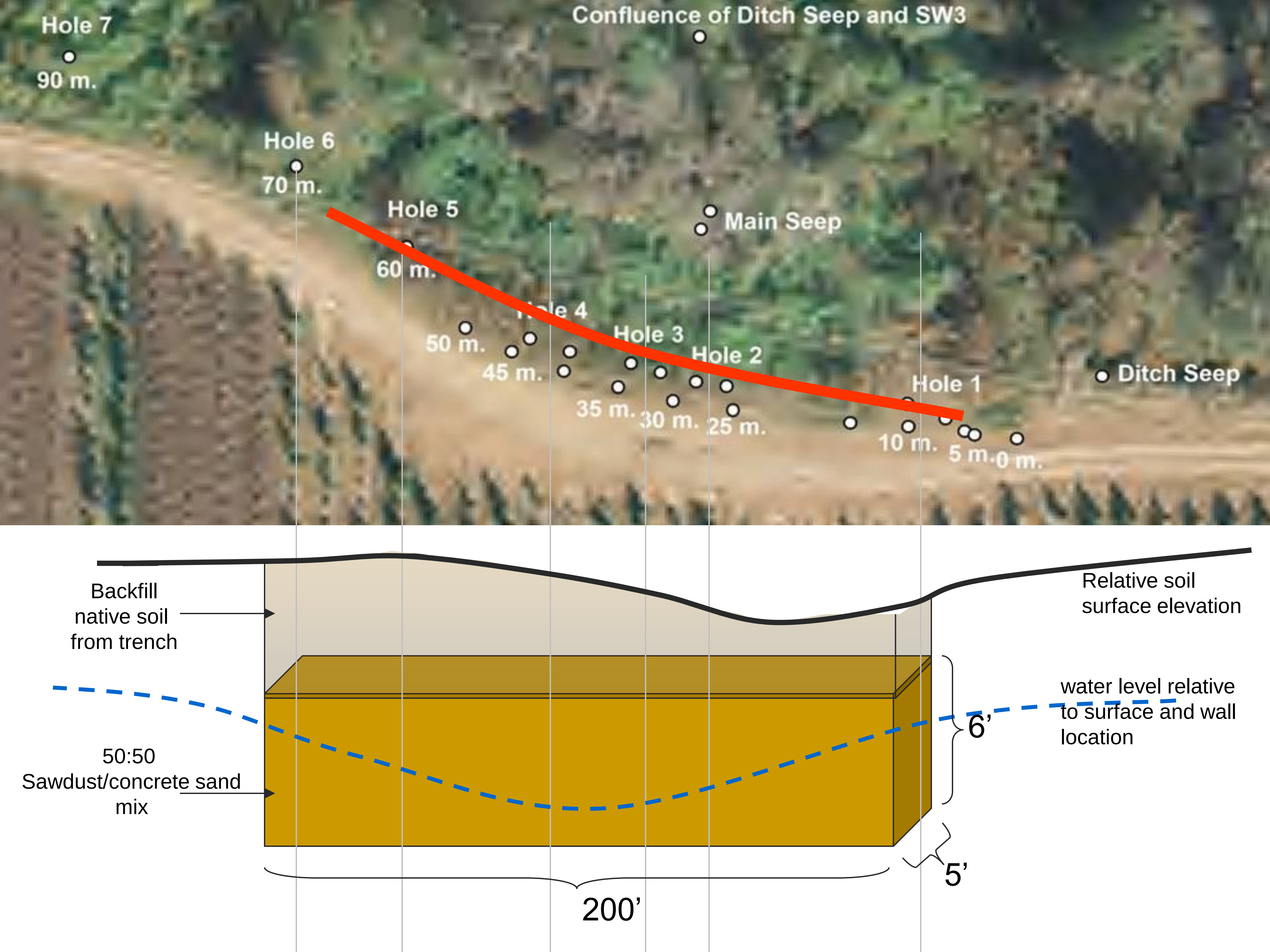
Organic Carbon $_{\text{(electron donor)}} + \cancel{O}_2$ $_{\text{(electron acceptor)}} \rightarrow CO_2$

Organic Carbon $_{\text{(electron donor)}} + NO_{3\text{(electron acceptor)}} \rightarrow N_2 + CO_2$



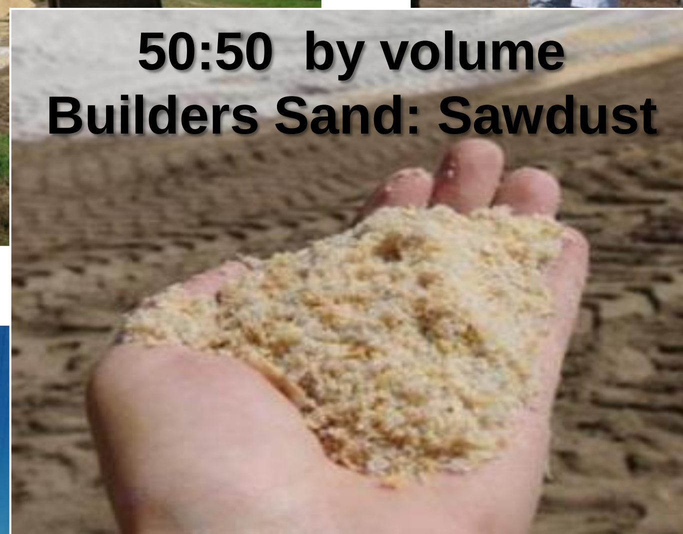


Site Selection for Wall
DISTANCE [FOOT]
0
1000
2000
Going east to west ,
500 MHz, DE @ 12, range 120 ns
2758-3
2757-2
CR 241
2758
Property Boundary



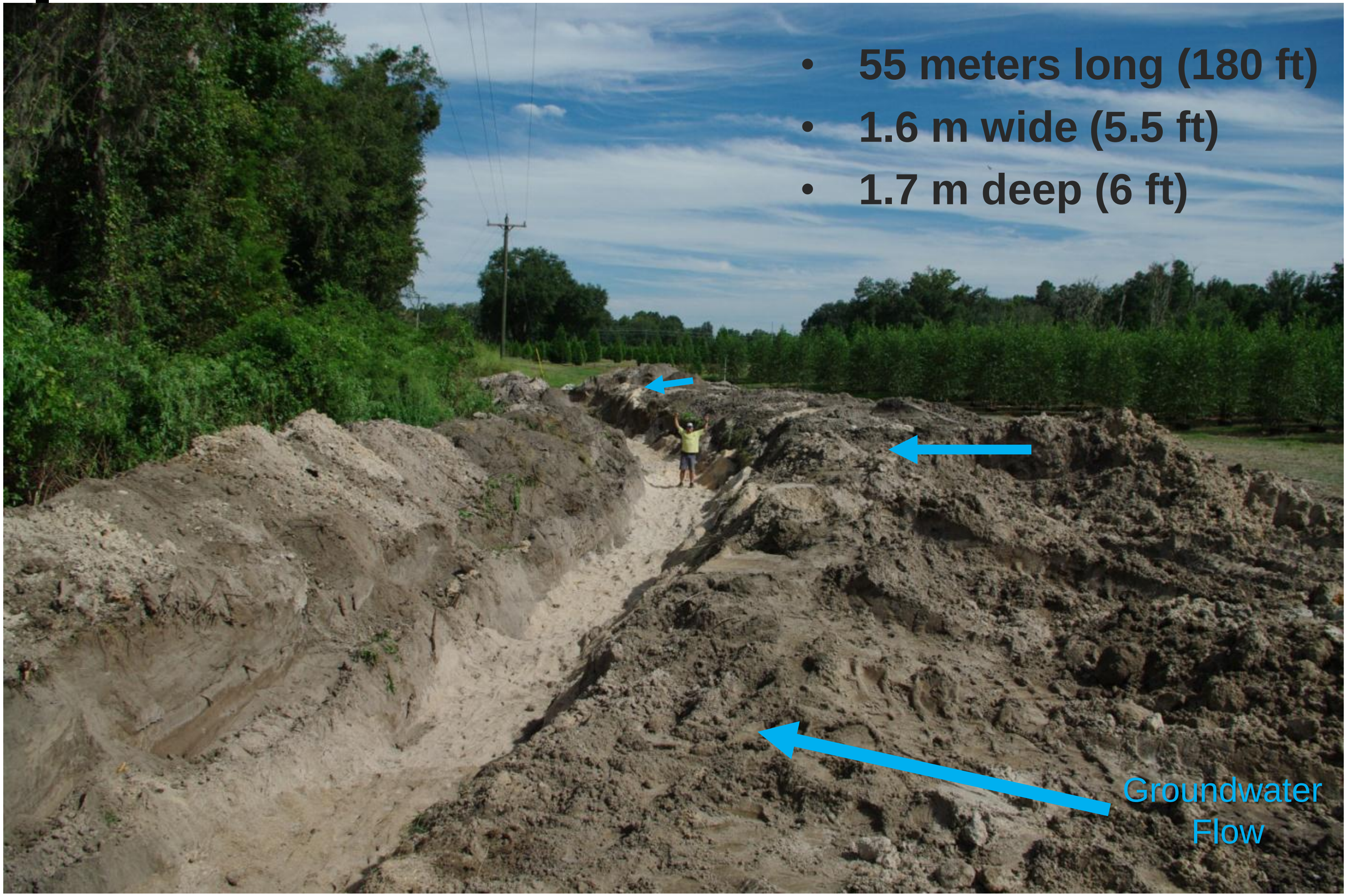
Confluence of Ditch Seep and SW3
Hole 7
90 m.
Hole 6
70 m.
Hole 5
60 m.
Main Seep
Hole 4
50 m.
45 m.
Hole 3
Hole 2
35 m.
30 m.
25 m.
Hole 1
Ditch Seep
10 m.
5 m.
0 m.
Backfill
native soil
from trench
Relative soil
surface elevation
water level relative
to surface and wall
location
6'
50:50
Sawdust/concrete sand
mix
5'
200'

Construction Methods: Mixing



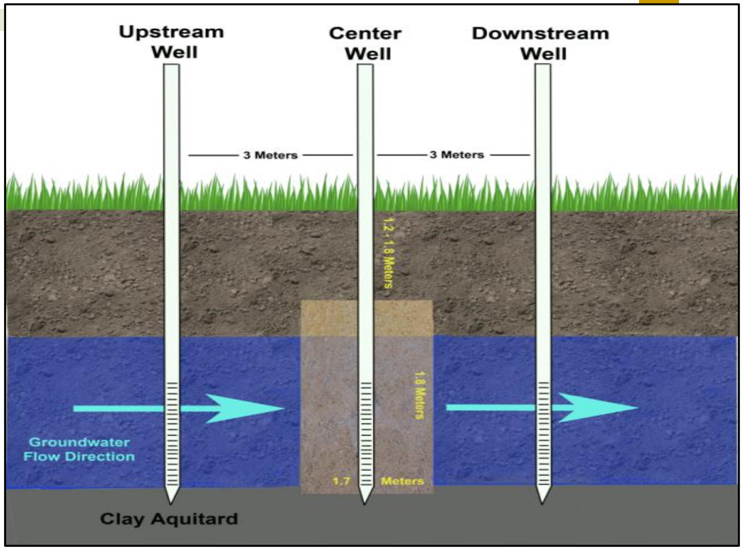
Construction Methods: Excavation and Filling

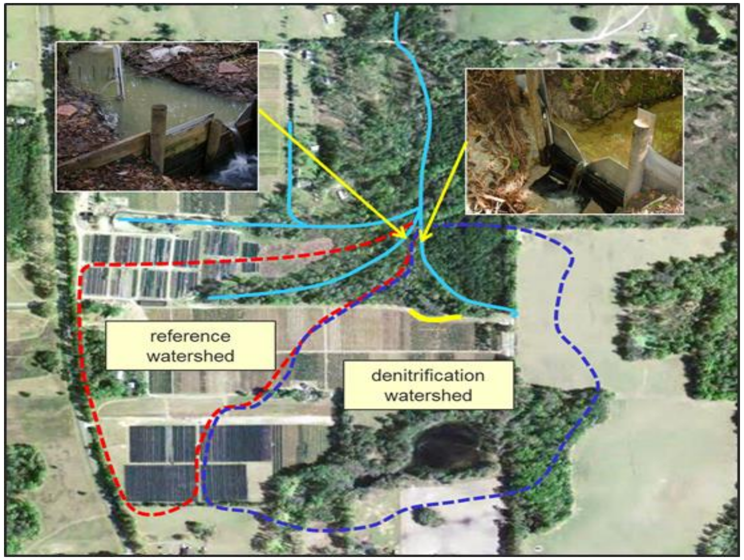
Final Installation



Monitoring Methods

- Groundwater - Upgradient, center and downgradient wells
- Groundwater Surface water interface - Downstream seep
- Surface water - Paired watershed approach

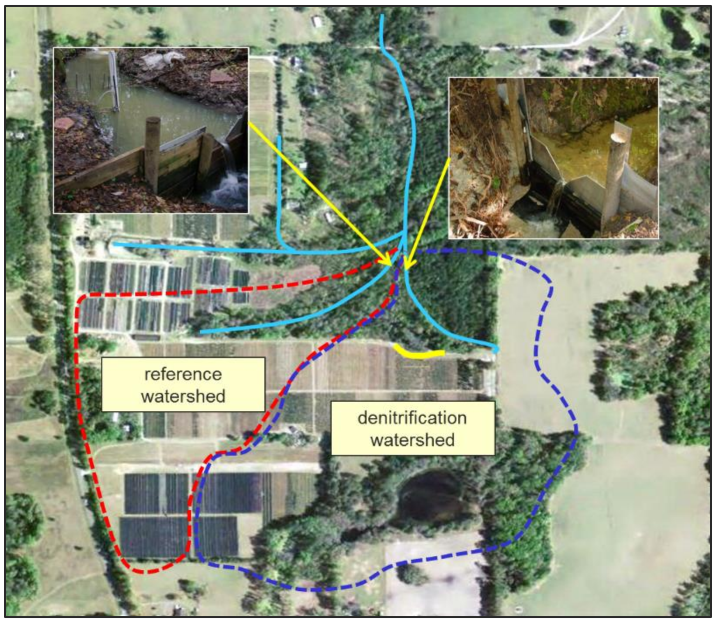


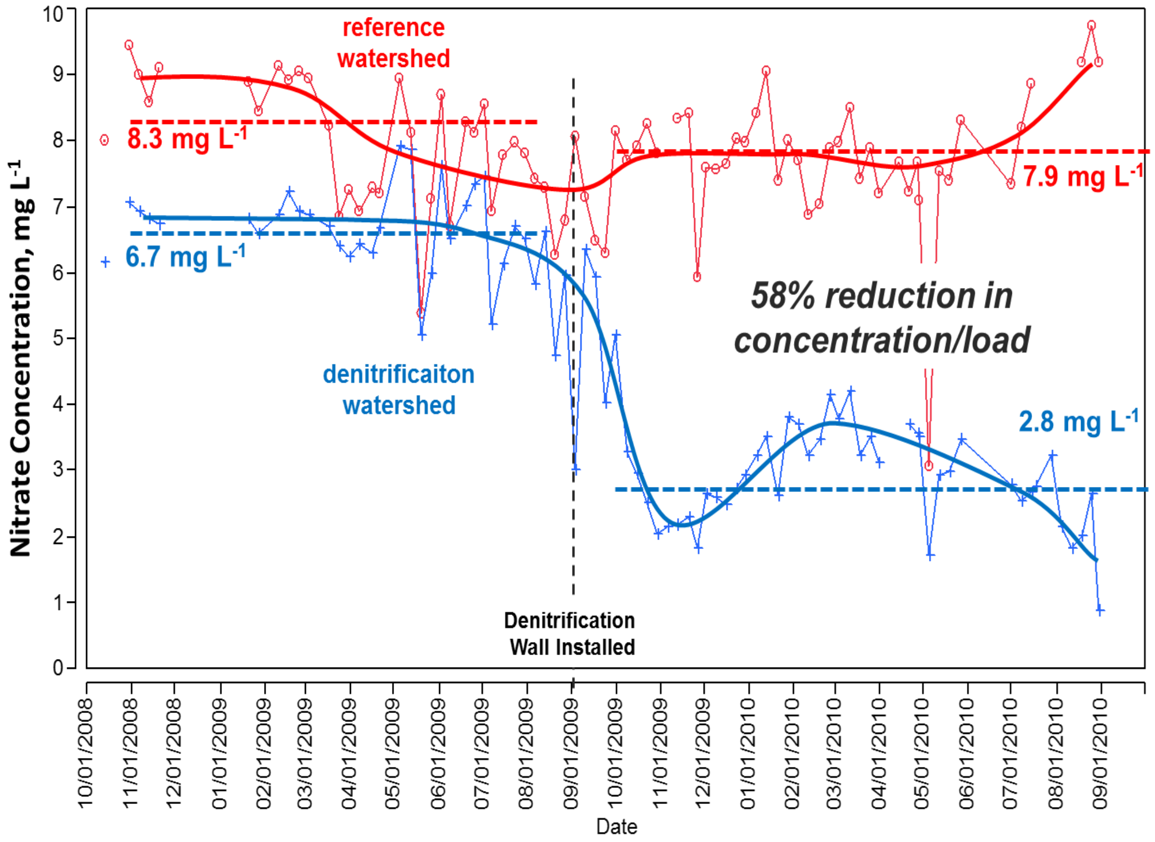


Nitrate Removed in Groundwater

- **Groundwater intercepted = 84,000 L d^{-1} at 5-9 mg L^{-1} Nitrate-N**
- **Nitrate-N removal rate = 3.2 $\pm$ 1.9 g N m^{-3} d^{-1}**
- **Conservative longevity of wall = 15 years**
- **Amortized cost per kilogram of Nitrate-N removed = \$0.79 (\$0.36/lb)**

Nitrogen Removed from Tributary

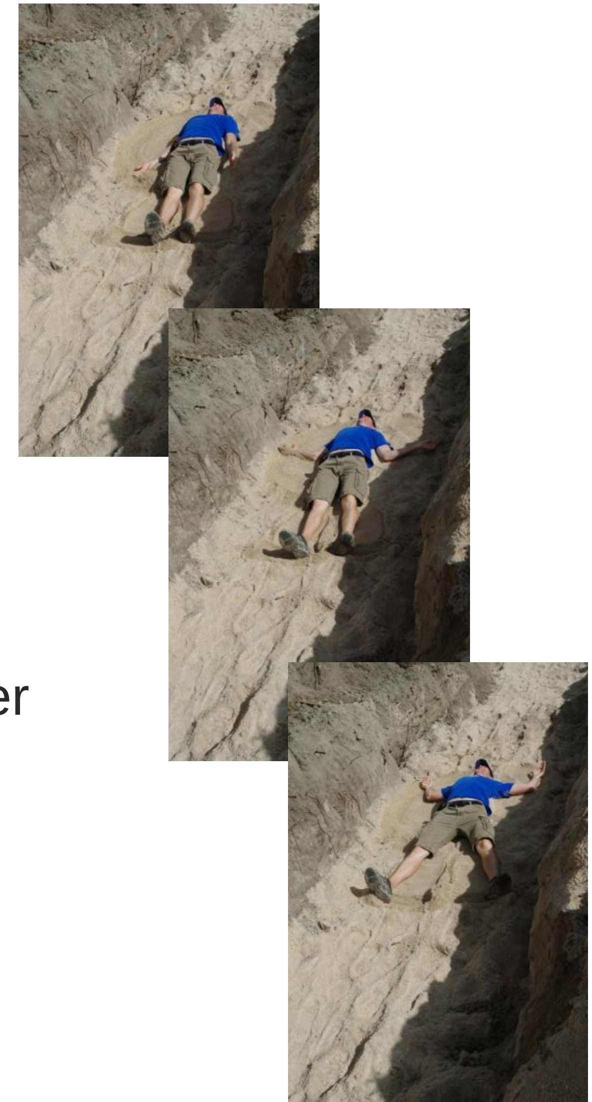




Summary of Denitrification Wall Application

- Effective low cost technique to lower nitrate nitrogen concentrations in surficial aquifer and seep to stream surface water.
- Other aspects of study developed design parameters for sizing of denitrification walls in north Florida.
- Economics limit application to shallow groundwater (<15’) and near surface aquitard.
- Site targeting techniques presently slowing larger scale application and are being investigated.

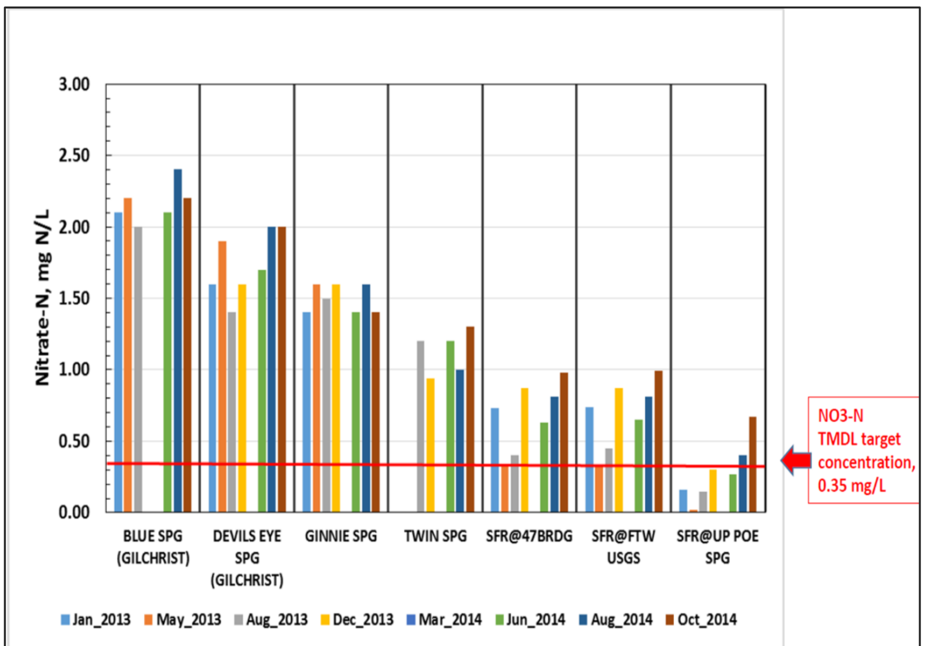
- What about unconfined areas where groundwater nitrate contamination is of greater concern?

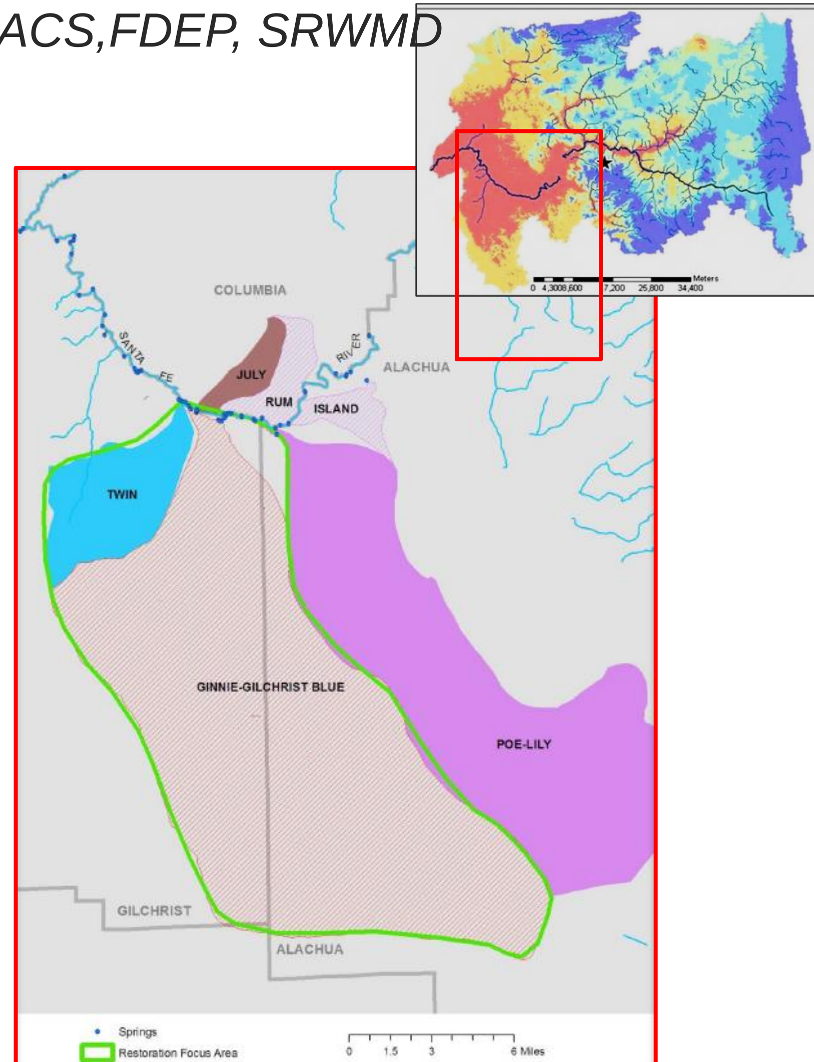


Santa Fe Resource Focus Area: Denitrification Bioreactor

Del Bottcher (SWET), Watson Dairy, FDACS,FDEP, SRWMD

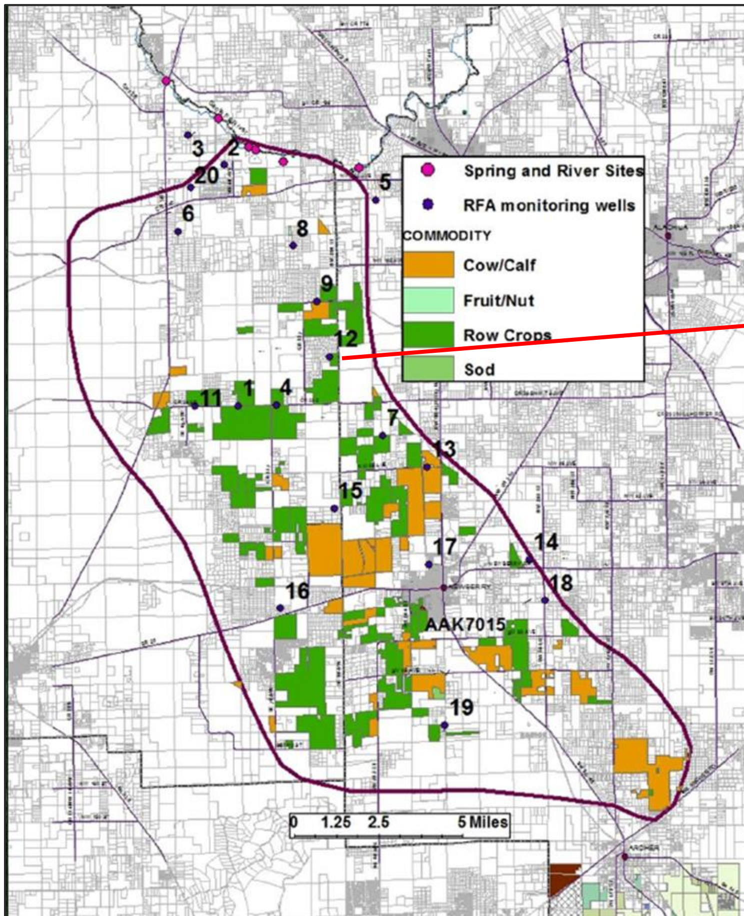
RFA designed to evaluate effectiveness of BMP's to reduce groundwater nitrate concentration.

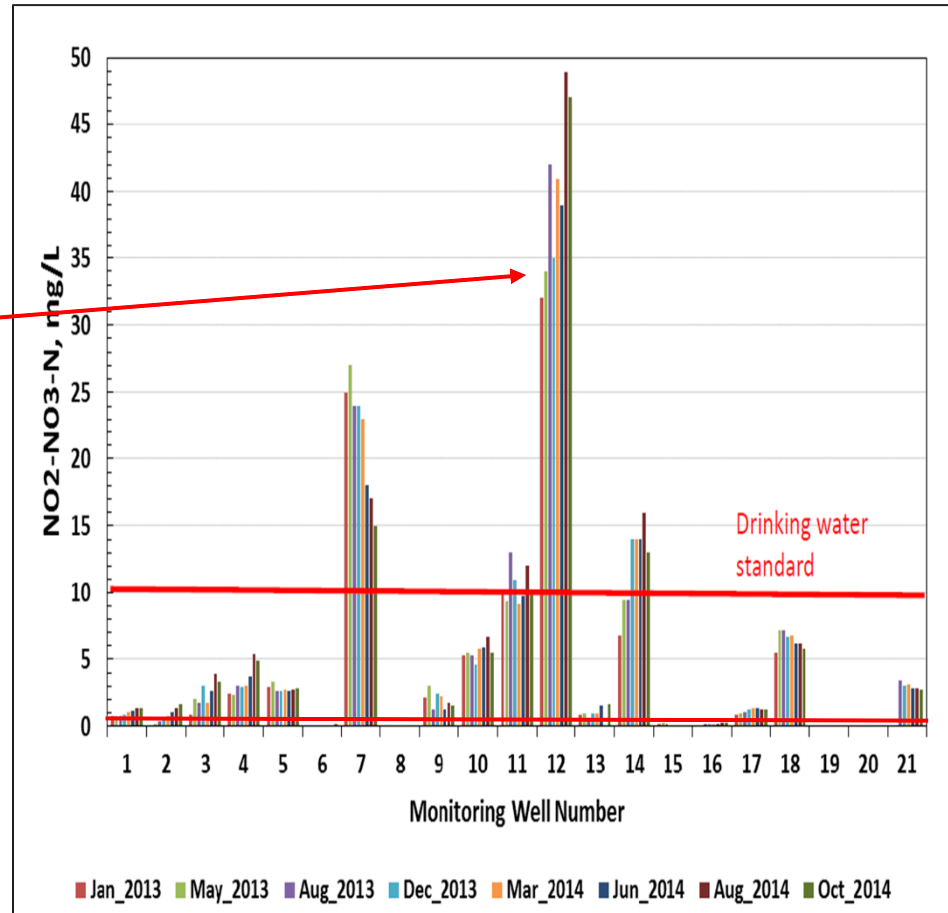




Groundwater Nitrate-Nitrogen: Intensive Land Use “hot spots”

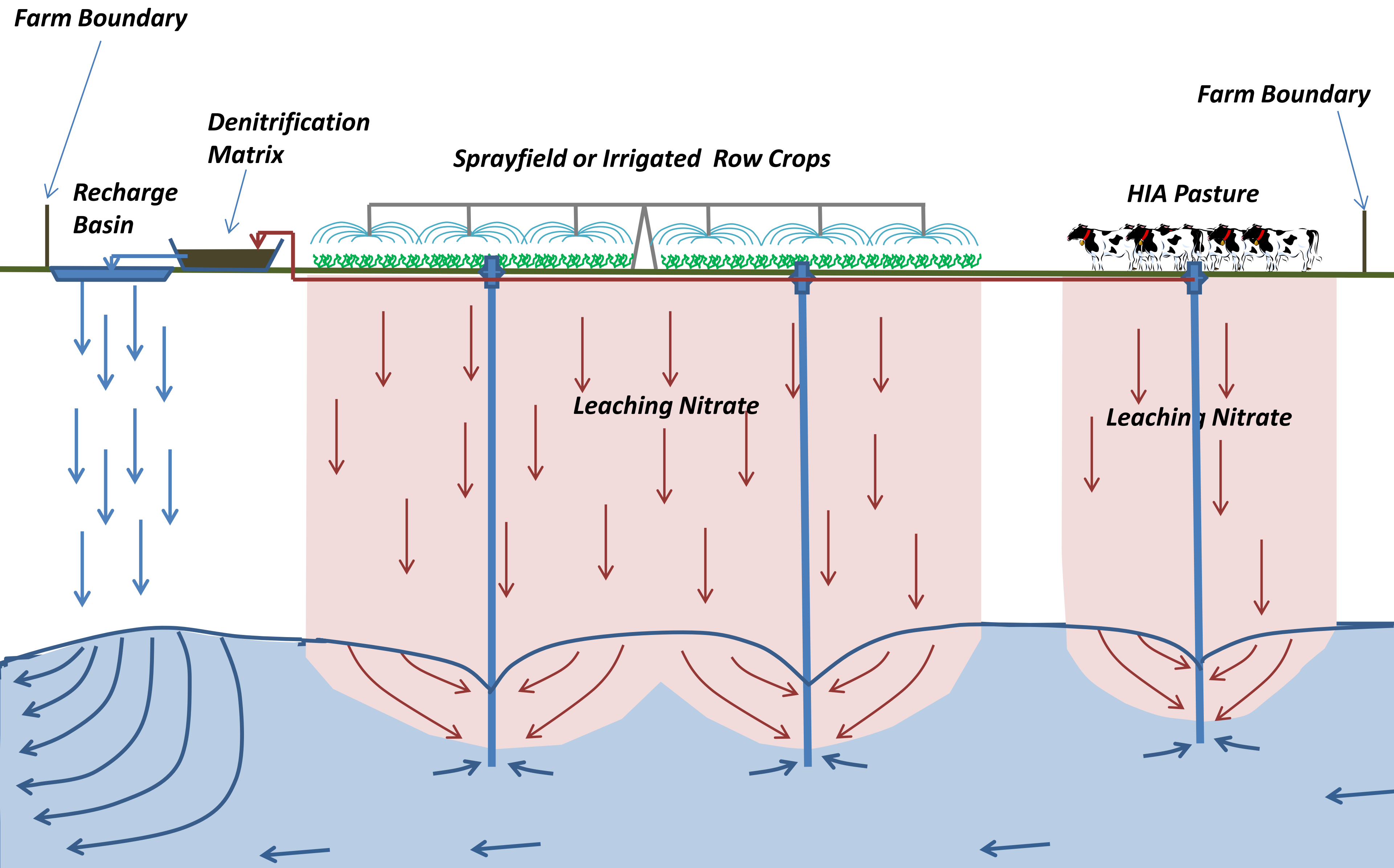
Approximately 34,350 acres in agriculture production
As of 2014 80% enrolled in BMP program



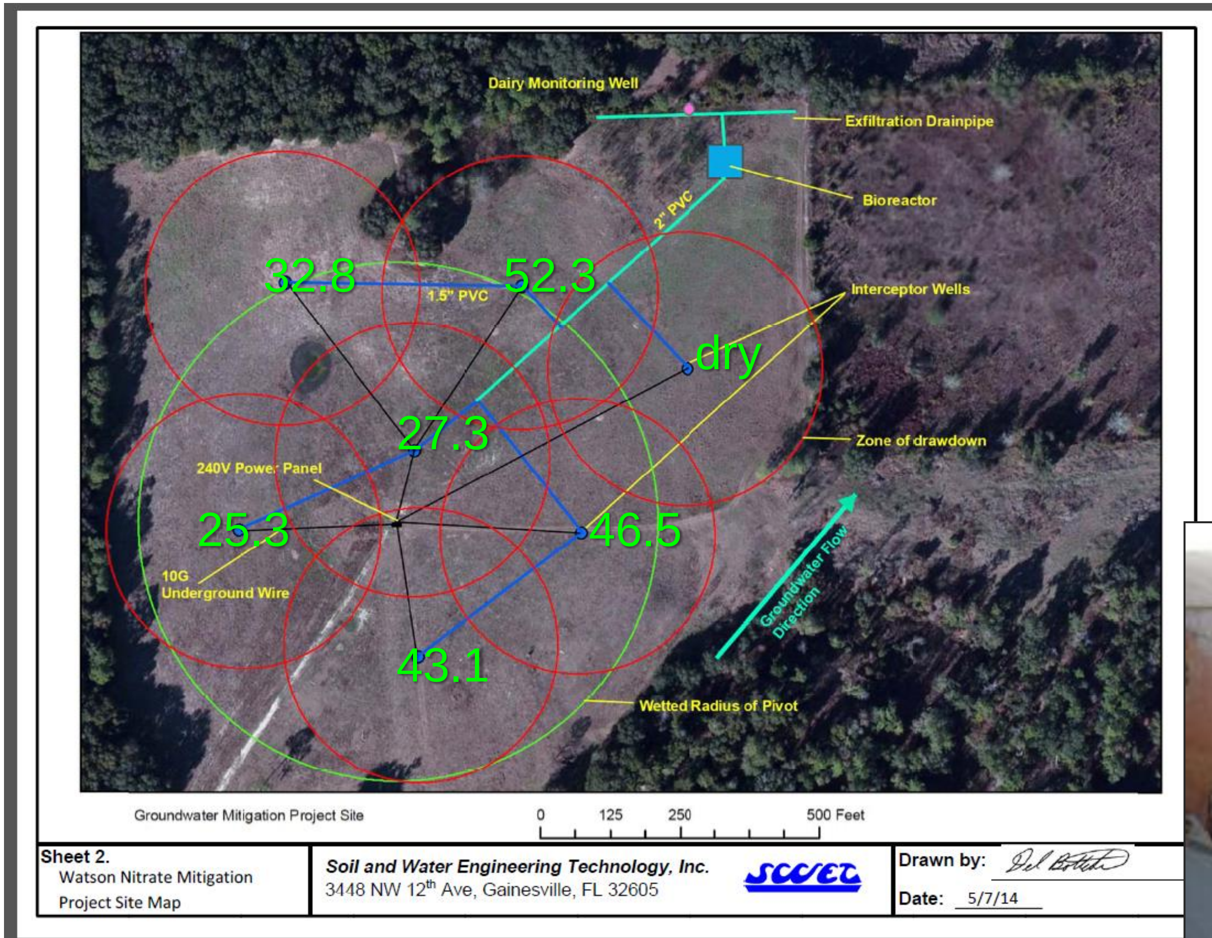


Nitrate Mitigation for Intensive Use Agricultural Fields – Existing Condition

Nitrate Mitigation for Agricultural Fields: Interceptor Wells and Denitrification Bioreactor



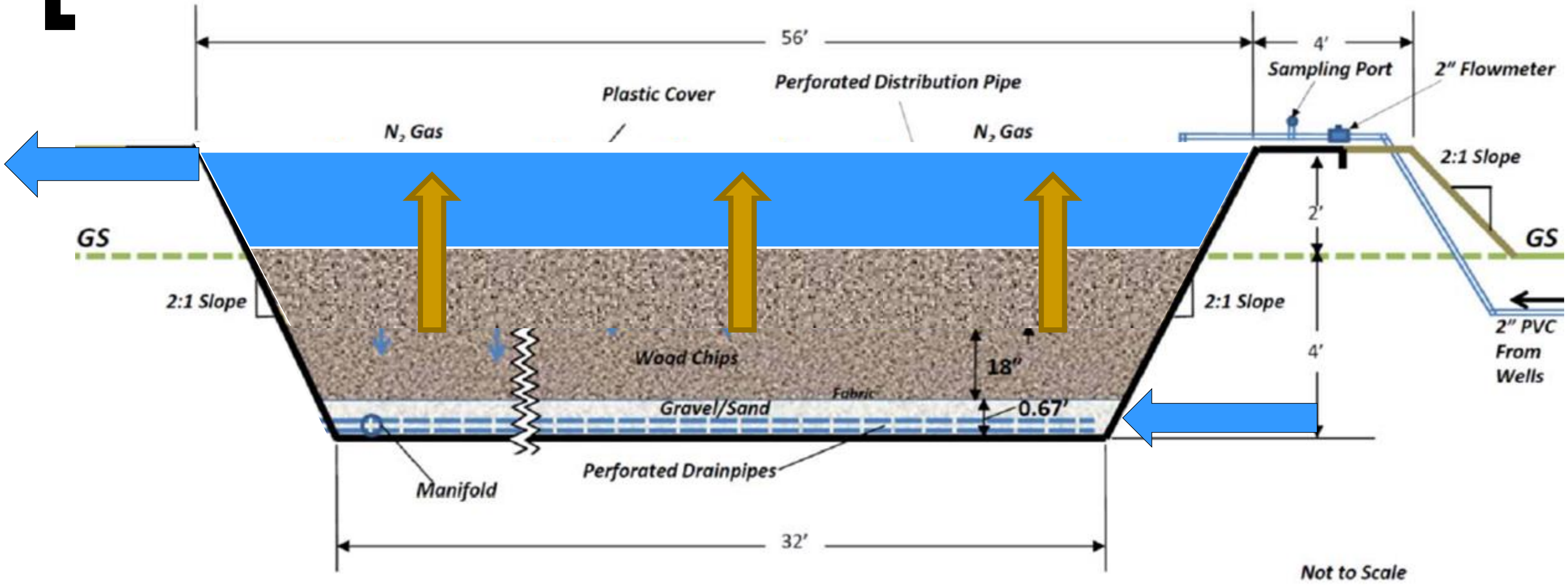
Interception Well Array



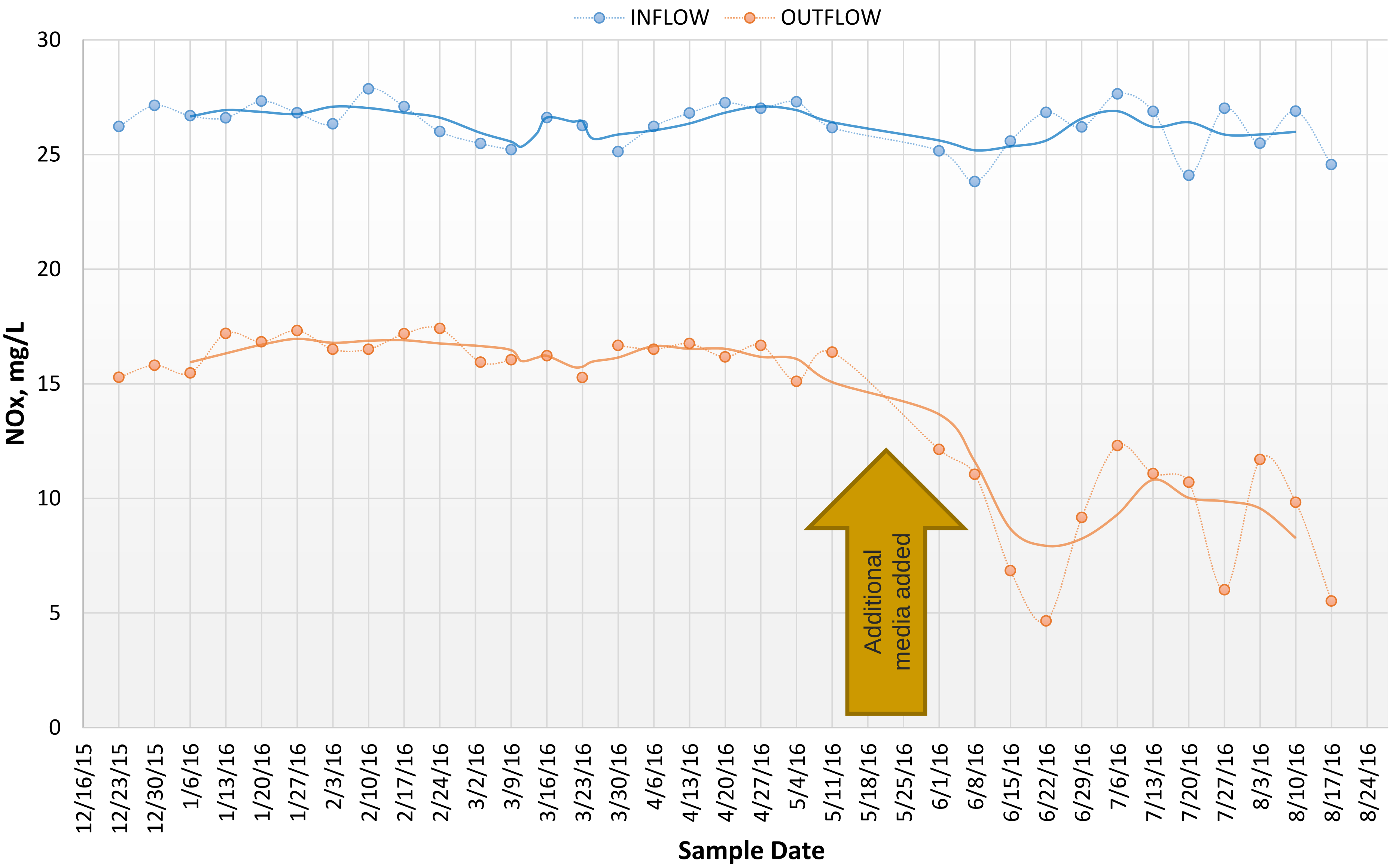
- 7 wells
- Pump rate equivalent to 15-18" per year infiltration
- 23 gpm total
- 2.3 g NOx-N/min


Monitoring Well
Recharge Basin
Outlet
Bioreactor
Inlet

Denitrification Bioreactor: Up-Flow Design



Denitrification Bioreactor Inflow and Outflow Nitrate Concentration

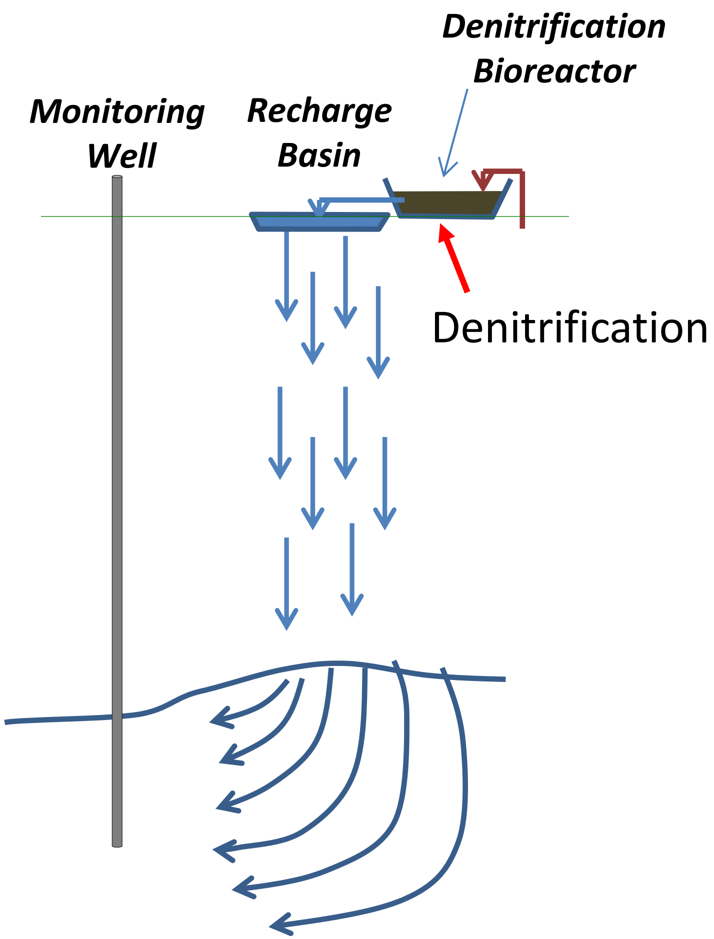


Preliminary Results from Up-flow Bioreactor

Sample Week	Inlet NOx (mg/L)	Outlet NOx (mg/L)	Reactor efficiency (%)	Monitoring well NOx (mg/L)	Groundwater NOx reduction (%)
12/16/15				57.6	
12/30/15	27.1	15.8	41.7%	39.9	30.7%
1/27/16	26.8	17.3	35.4%	13.8	76.0%
2/24/16	26.0	17.4	33.0%	13.6	76.4%
3/30/16	25.1	16.7	33.7%	14.6	74.7%
4/27/16	27.0	16.7	38.3%	16.4	71.5%
6/29/16	26.2	9.2	65.0%	15.5	73.0%
7/27/16	27.0	6.0	77.8%	10.8	81.2%
8/24/16	27.4	5.5	79.9%	10.3	82.1%

2.76 kg N day^{-1}
25.8 g N m^3 day^{-1}

*$6.73 / kg or $3.06/lb N



*$100,000 capital, $1200 annual electric, 15 year life

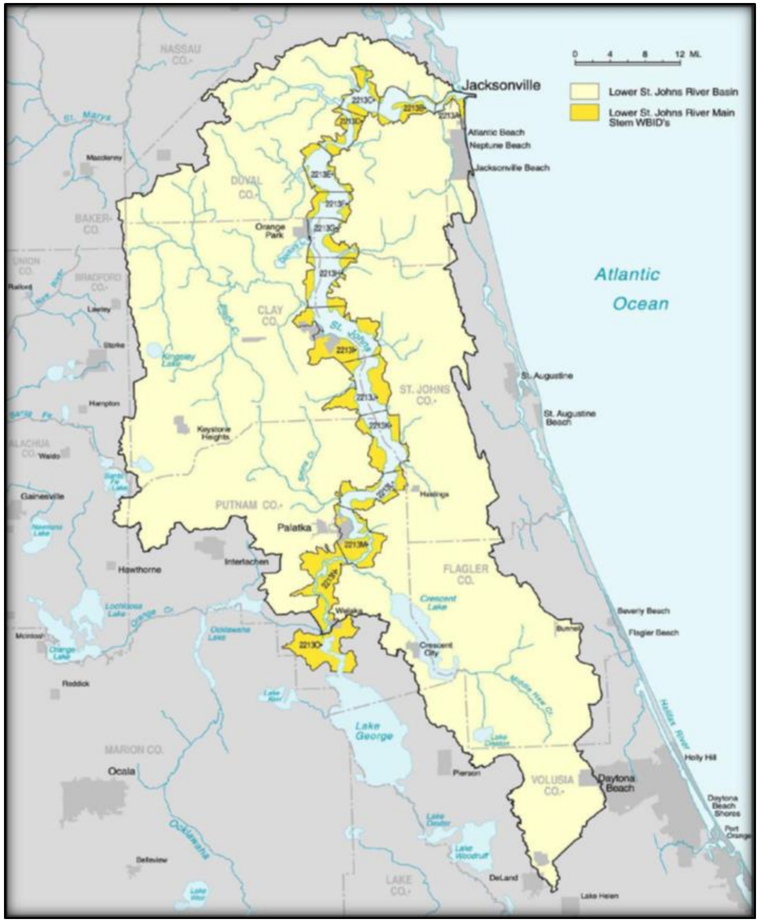
Summary of Denitrification Bioreactor

- Application has the potential to mitigate for high groundwater nitrate concentrations in unconfined areas.
- Up-flow design is working, but needs to be optimized with additional microbial substrate.
- Cost will come down with optimization and potentially increased NOx loading through higher flows.
- Better alternative - Where possible, high nitrate groundwater should be used for irrigation and crop production.

Tri-County Agricultural Area Irrigation Drain Tile

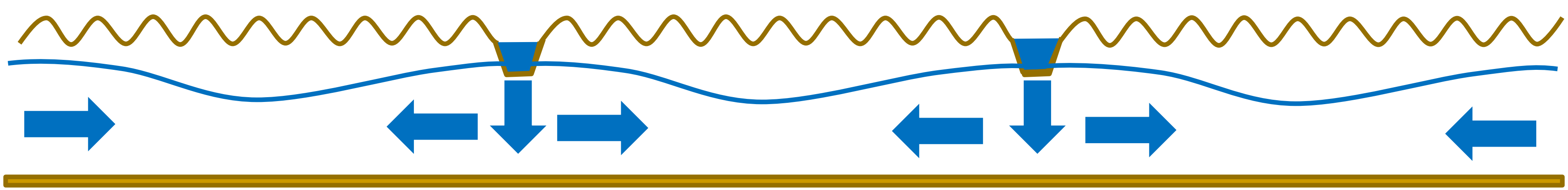
Picolata Farms, Riverdale Farms, Tater Farms, Sykes and Cooper Farms
FDEP, FDACS, SJRWMD

- Lower St. Johns River has a TMDL for Nitrogen and Phosphorus.
- Agriculture BMPs almost fully enrolled.
- Regional treatment systems helping to reduce loads.
- State and federal cost share programs underway to improved farm irrigation and nutrient management.
- Irrigation Drainage Tile (IDT) is one of several practices being evaluated.



Conventional “Seepage” Irrigation

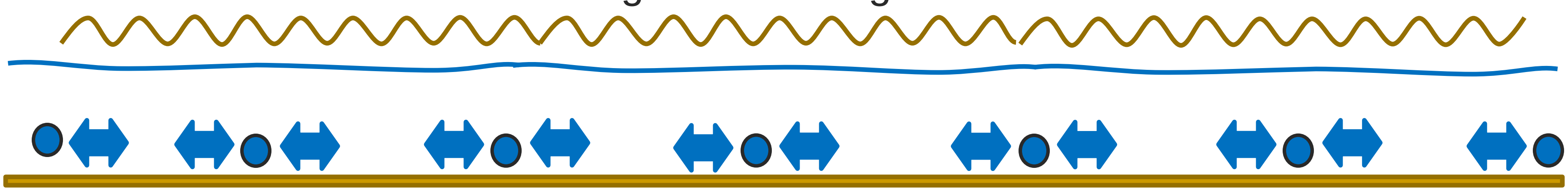
- Inefficient water use.
- Uneven moisture regime for crop.
- Crop loss due to flooding and limited drainage control.
- Significant particulate runoff of N and P.



Irrigation Drainage Tile

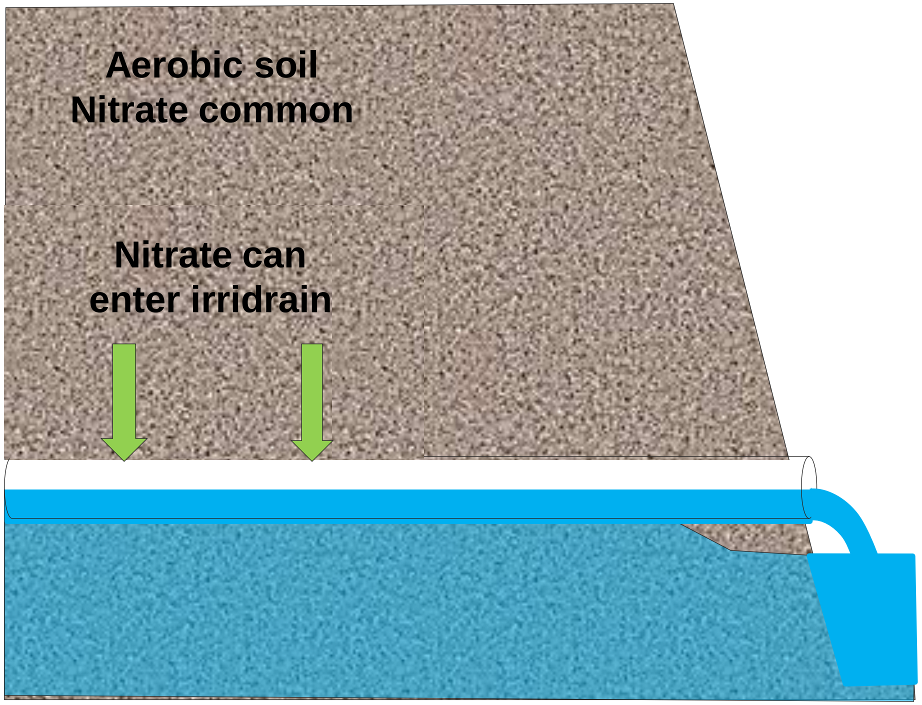
Conventional Seepage

Irrigation Drainage Tile

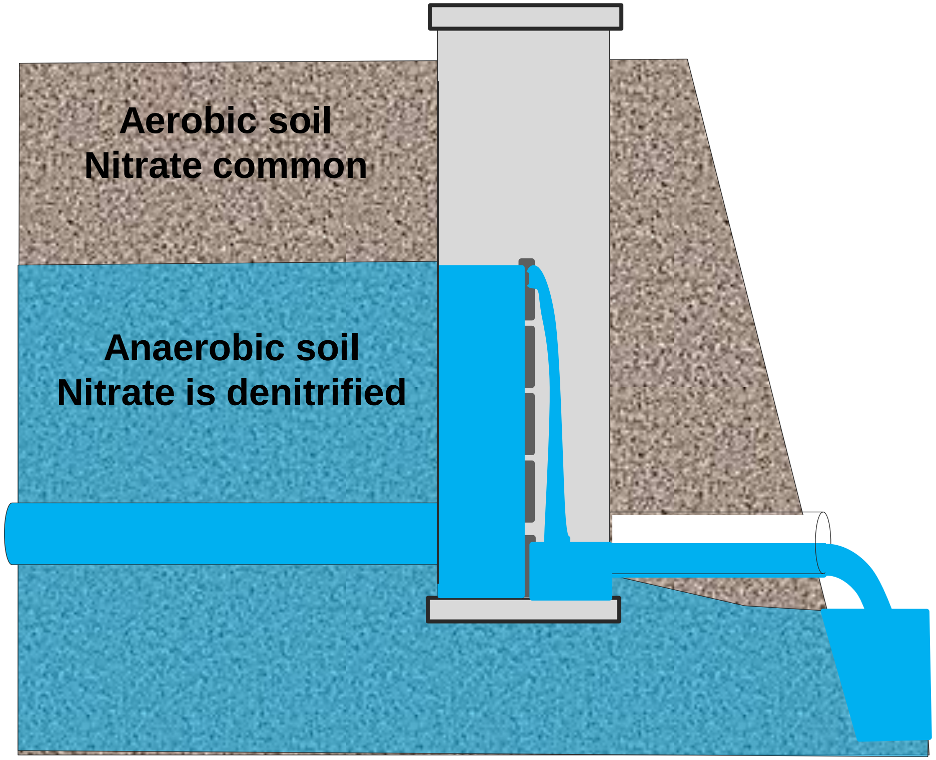


Free Drainage vs. Controlled Drainage

Free Drainage



Controlled Drainage

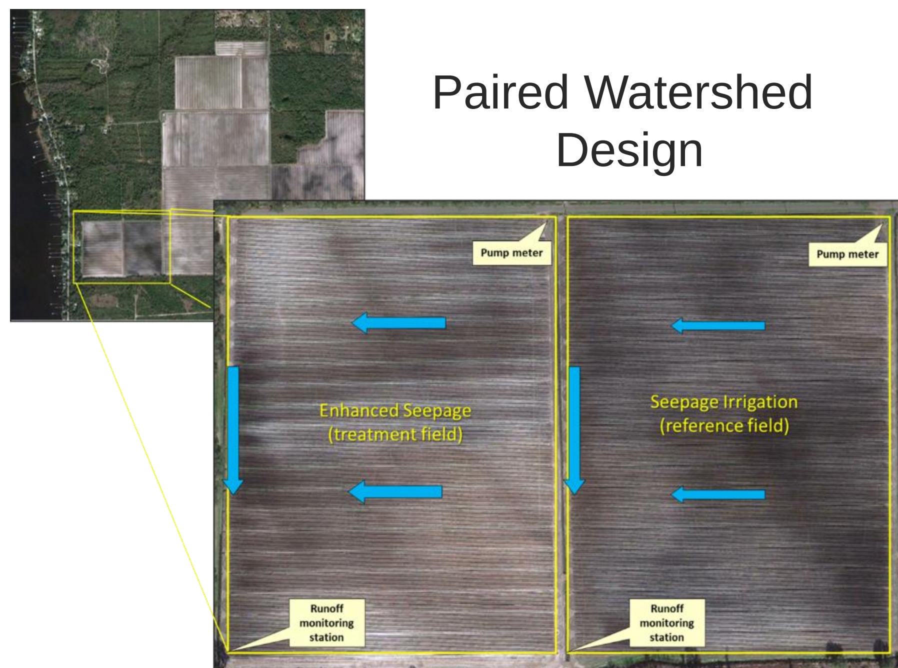


Study Sites and Monitoring Design

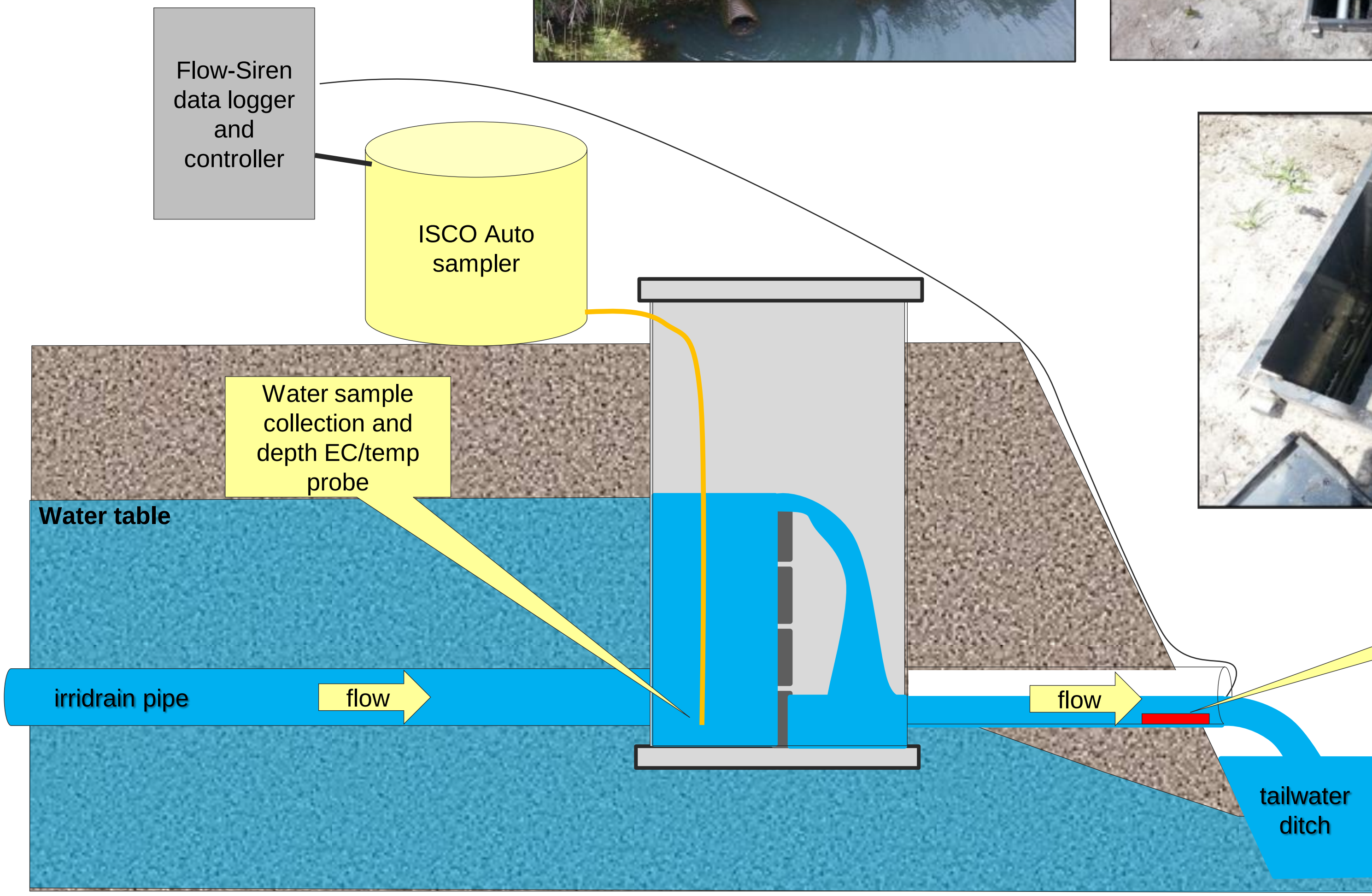
Cooperators in the Tri-County Agricultural Area

4 Farms
9 fields
13 monitoring stations

Paired Watershed Design



Irrigation Drain Tile Monitoring



Water Use and Nitrogen Load Reduction

(one year of monitoring)

Water Use and Runoff

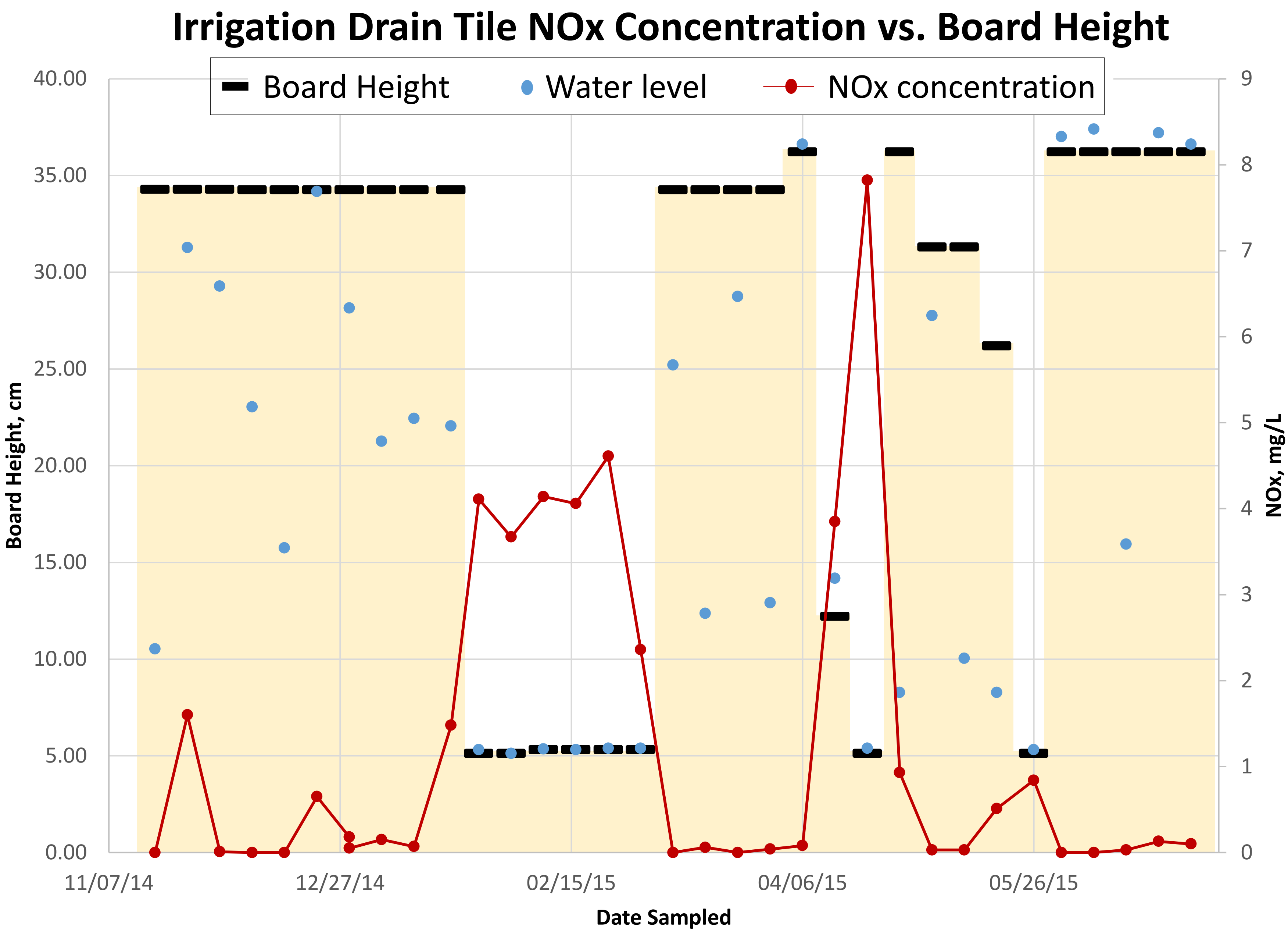
Farm	Irrigation	Runoff
	---- % reduction relative to control field ----	
Picolata Farm	42%	58%
Sykes and Cooper Farm	27%	40%
Tater Farms	52%	53%
	40.3%	**50.3%**

Total Nitrogen Runoff

Farm	Conventional Seepage	IDT (ground)	IDT (surface)
	----------------------	kg/ha^{-1}	----------------------
Picolata Farm	9.45	1.73	5.17
Sykes an dCooper Farm	12.8	7.04	8.07
Tater farms	1.87	1.48	2.6
	8.04 $\pm$ 4.57	3.42 $\pm$ 2.56	5.28 $\pm$ 2.23

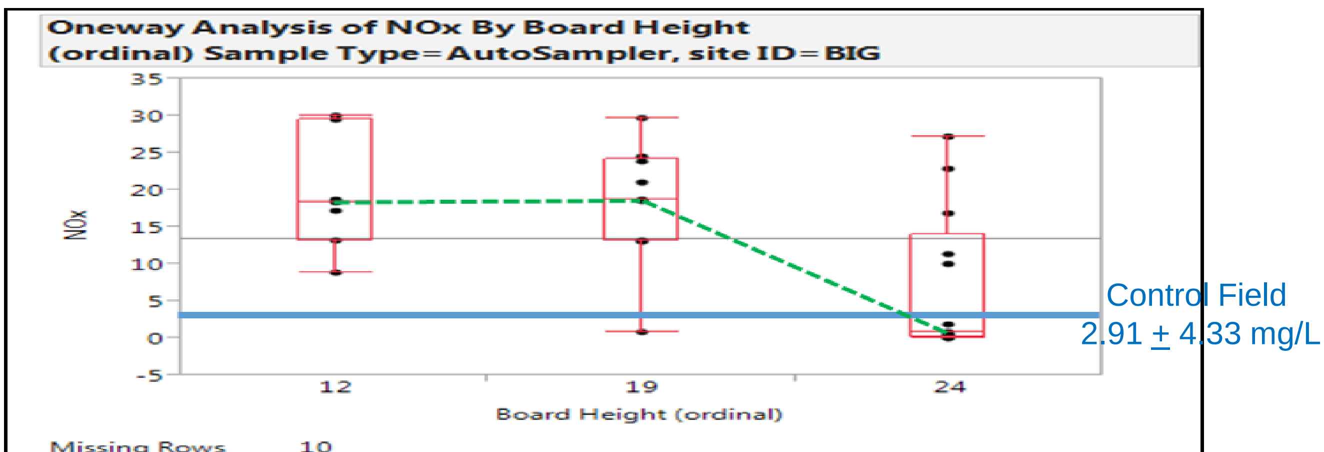
Farm TN average *57% decrease at IDT Pipe, 34% decrease in ditch*

With No Board Height Recommendations


Irrigation Drain Tile NOx Concentration vs. Board Height
Board Height
Water level
NOx concentration
Board Height, cm
NOx, mg/L
Date Sampled
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
9
8
7
6
5
4
3
2
1
0
11/07/14
12/27/14
02/15/15
04/06/15
05/26/15

Summary of Irrigation Drainage Tile

- Significant potential to reduce water use and runoff.
- Nitrogen reductions dependent on board height management to provide denitrification zone and reduce runoff volume.
  - Recent guidance to hold boards at 24”



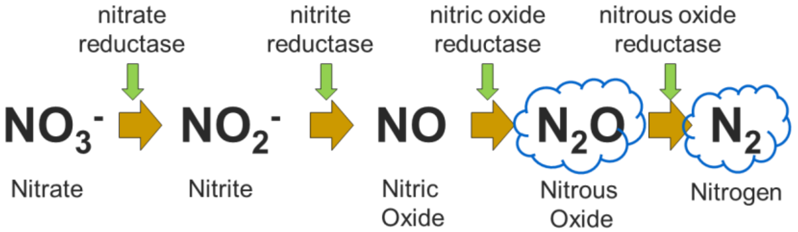
Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
12	8.91	8.91	13.24	18.35	29.52	29.98	29.98
19	0.88	0.88	13.115	18.64	24.17	29.6	29.6
24	0	0.02	0.24	0.9	14.055	25.48	27.2

Overall Summary of Edge of Field Practices

- With the increased requirement to address nutrient loads in the landscape, enhanced treatment practices are necessary.
- Source control measures, although the best solution, are limited to technical and economically feasible practices.
- Regional systems can be very effective, but take considerable land and are often costly.
- Edge of field practices will likely require cost share programs for implementation, but have limited impact on production area, can often be integrated into production system and could be operated by producer.

- **Denitrification Walls** look promising, but limited by groundwater depth and hydraulic gradient.
- **Denitrification Bioreactors** look promising for mitigation in unconfined areas, but needs additional evaluation and economic analysis, (best use - fertigation).
- **Irrigation Drain Tile** looks promising, but N reductions highly dependent on board management.



Questions?

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