The Fate of Nitrogen in Biosolids Amended Mineral Sands Mine Soils

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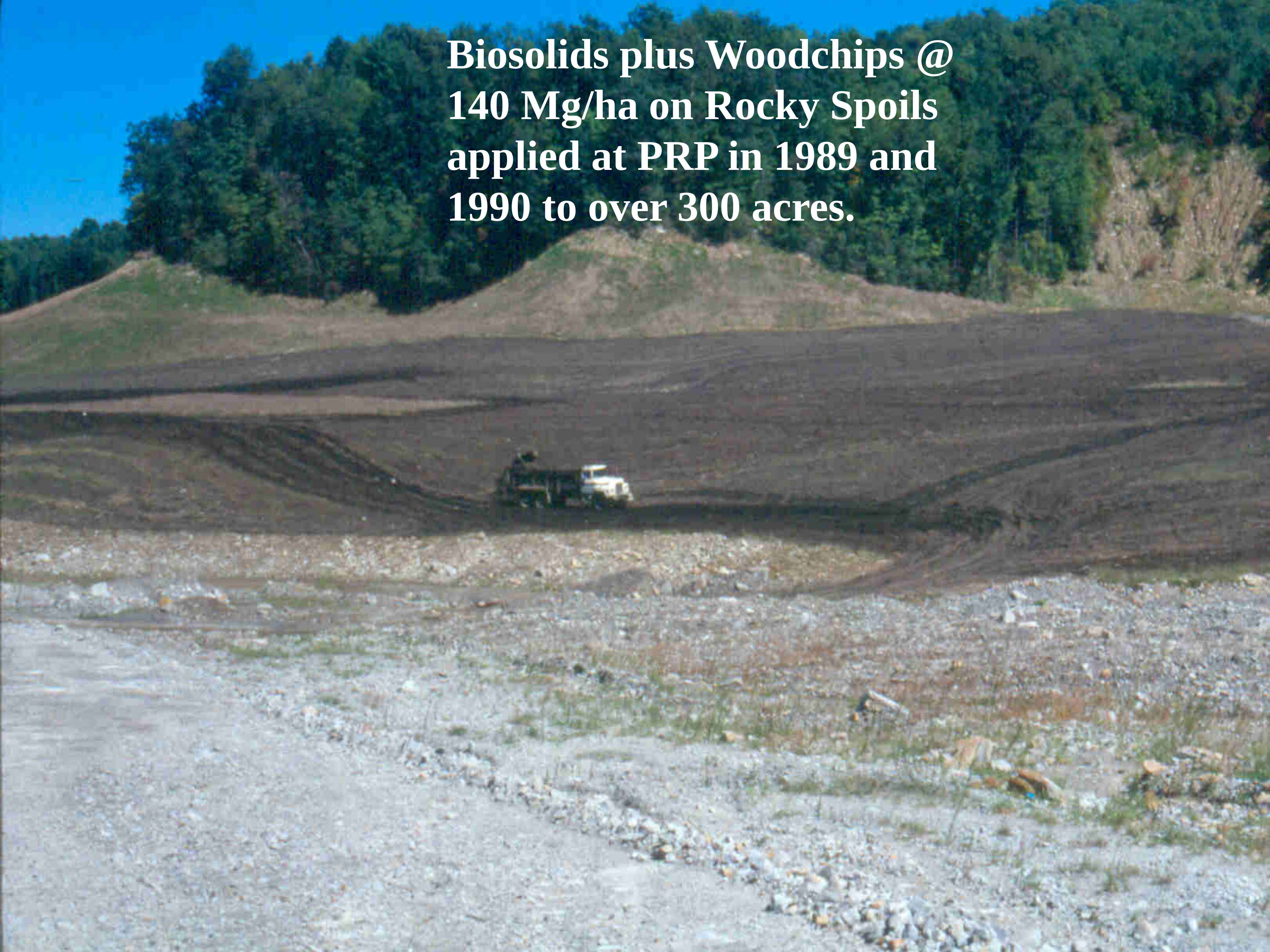
Crop & Soil Environmental Sciences

A Better Title!

How I spent my winters chasing nitrates around the Coastal Plain.

Typical Appalachian Haul-Back Contour Mine


Biosolids plus Woodchips @
140 Mg/ha on Rocky Spoils
applied at PRP in 1989 and
1990 to over 300 acres.

Over a five-year period, a 150 ha application of 140 Mg/ha of biosolids + woodchips (C:N = 30) had no effect on ground water NO_3 levels.

In fact, NO_3 levels were highest before application due to the use of NH_4NO_3 explosives!

Powell River Project area 10 years after application with biosolids.

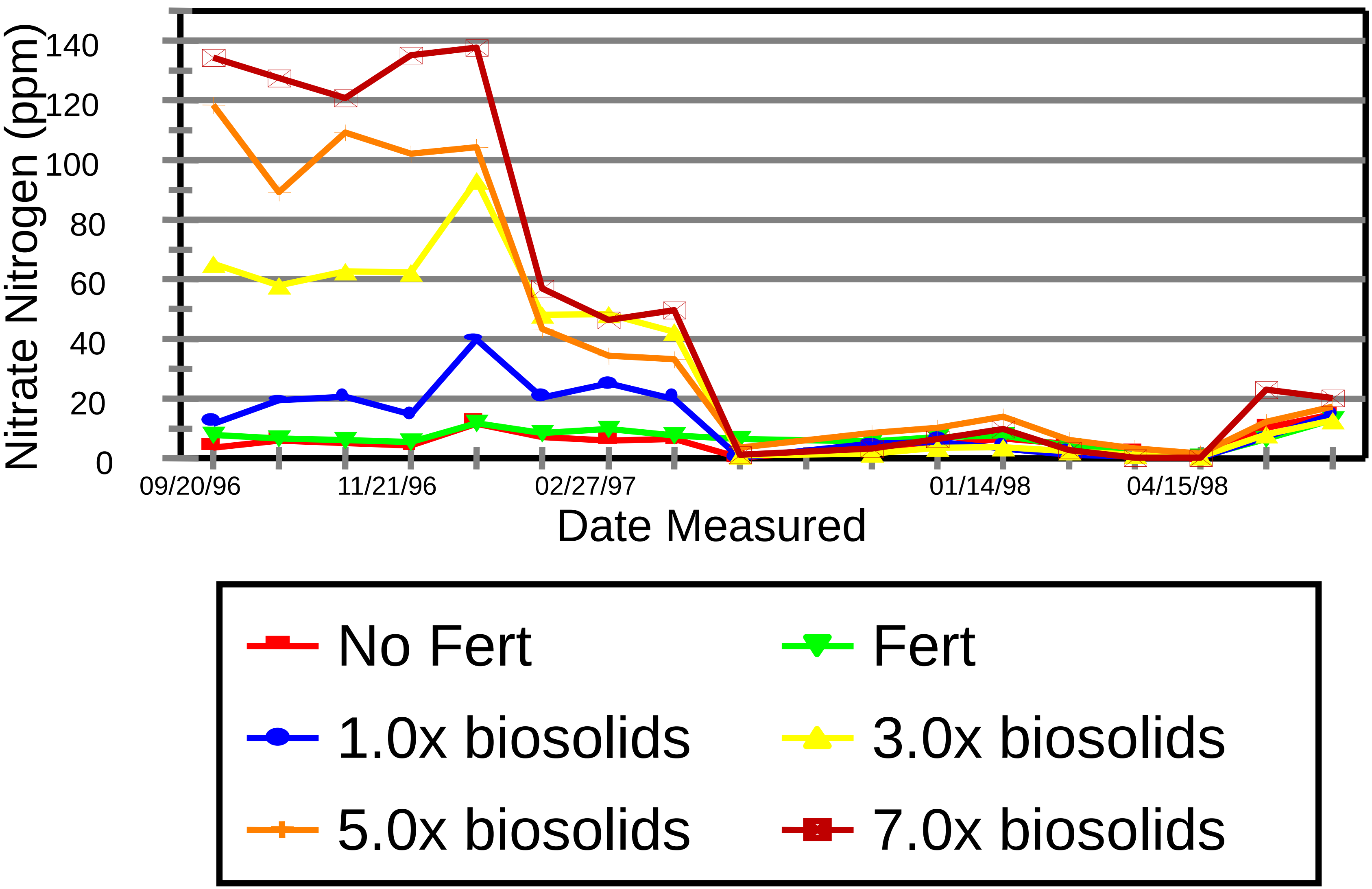
Land application of municipal biosolids to large experimental plots at Shirley in April 1996.


Biosolids cake (C:N = 8)
land-applied on gravel
mine at 42 Mg/ha.
4 4 '96

Wheat response to biosolids on unmined control plots at Shirley Plantation one year after application.

Figure 1. Shirley Plantation

Lysimeters:Biosolids **0 tension @ 1.0 m**

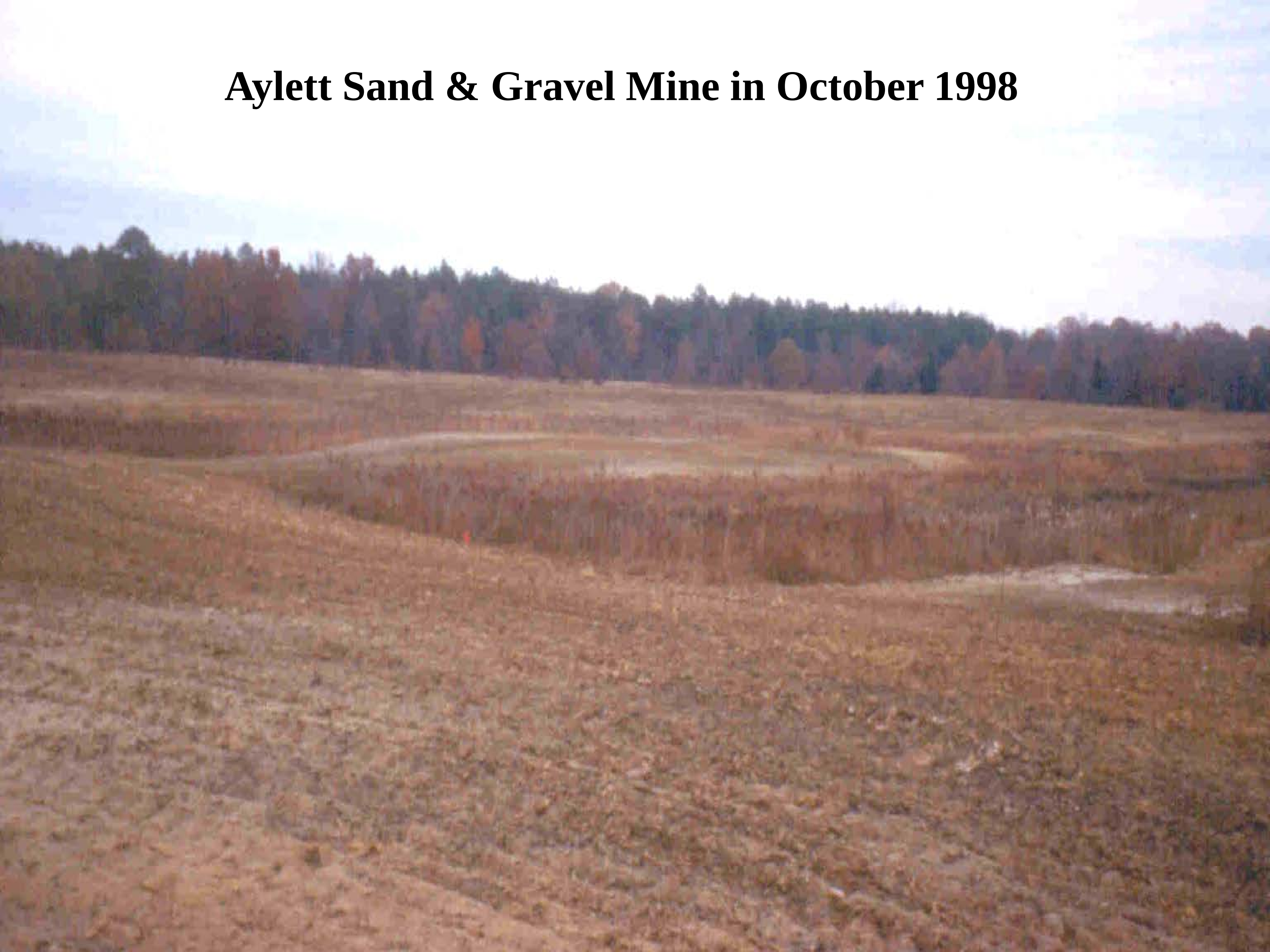


Nitrate-N leached over two seasons without sawdust added:

Treatment	Total-N Applied	NO_3-N Lost	% App.
	---------------- kg/ha	-------------------	
Control	0	5.9 c	N.A.
Fertilized	269	7.6	2.8
1X Biosolids	626	19.2	3.1
3X Biosolids	1252	37.4	3.0
5X Biosolids	3130	28.2	0.9
7X Biosolids	4382	59.8	1.4

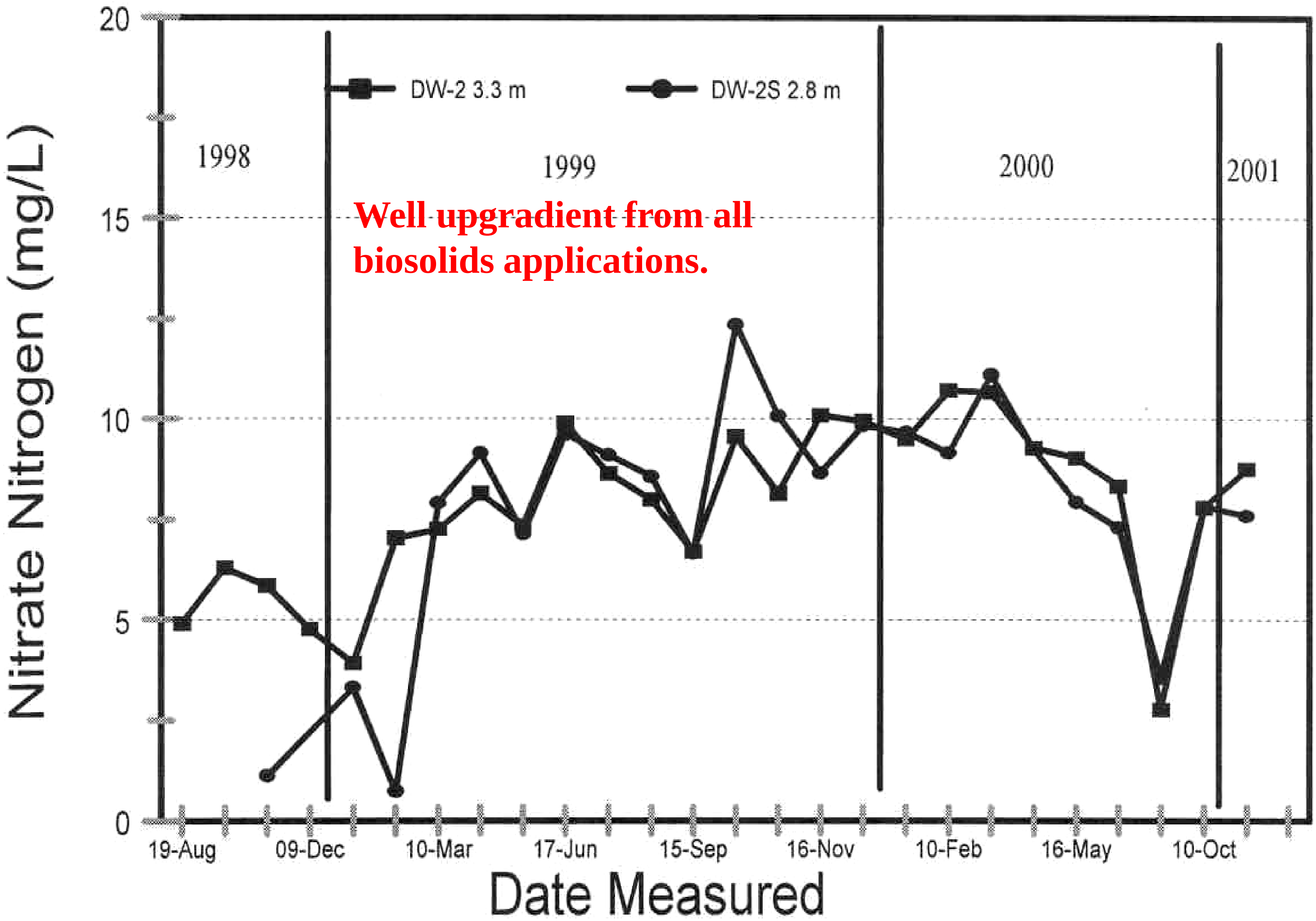

Well!
Sampling from zero-tension lysimeter @ 1 m.
2 26 '97

Aylett Sand & Gravel Mine in October 1998



Western portion of site in April of 1999 following fall 1998 application of mixed PVSC and Blue Plains biosolids at 78 and 34 Mg/ha, respectively.


SW-11
Mattaponi R.
SW-10
pipe
SW-8
SW-9
DW-2
staff gauge
SW-6
SW-4
SW-3
DW-3
Adjacent
Agricultural
Fields
SW-5
SW-2
SW-7
SW-1
DW-1


Nitrate Nitrogen (mg/L)
20
15
10
5
0
DW-2 3.3 m
DW-2S 2.8 m
1998
1999
2000
2001
Well upgradient from all biosolids applications.
19-Aug
09-Dec
10-Mar
17-Jun
15-Sep
16-Nov
10-Feb
16-May
10-Oct
Date Measured

Overall Hydrology and Water Quality Results

No treatment effects were observed in the surface water on site (sampled at staff gauge and discharge pipe) or the two well between the mine dike and the Mattaponi River that were clearly downgradient.

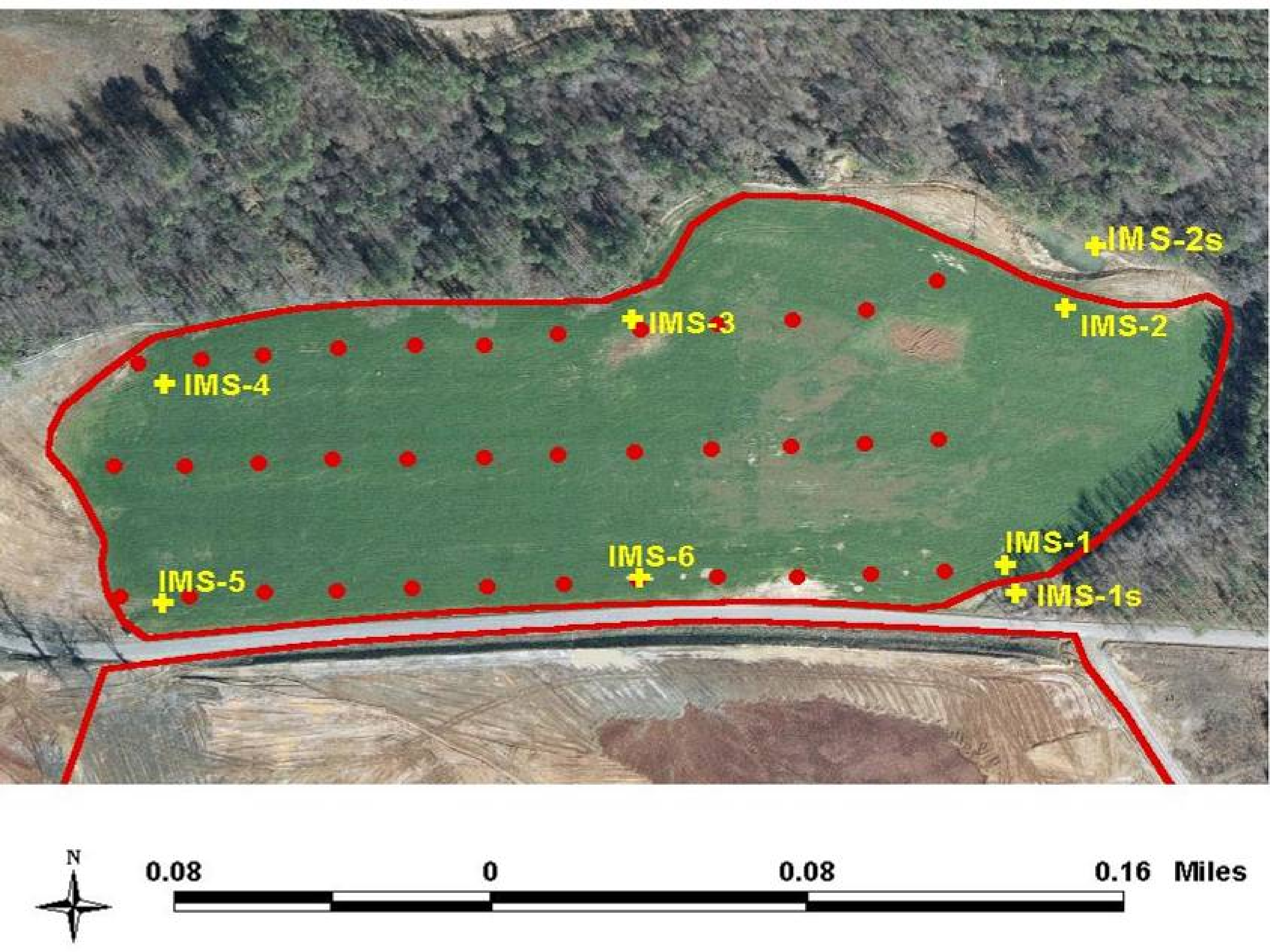
Two of 13 shallow wells on-site showed elevated nitrate-N at ~11 and 35 mg/L for < 2 months and then immediate return to background.


Y
X

Typical tails+slimes pit dewatering. Material in foreground is clayey slimes; background is sandy tailings

Iluka Resources Project

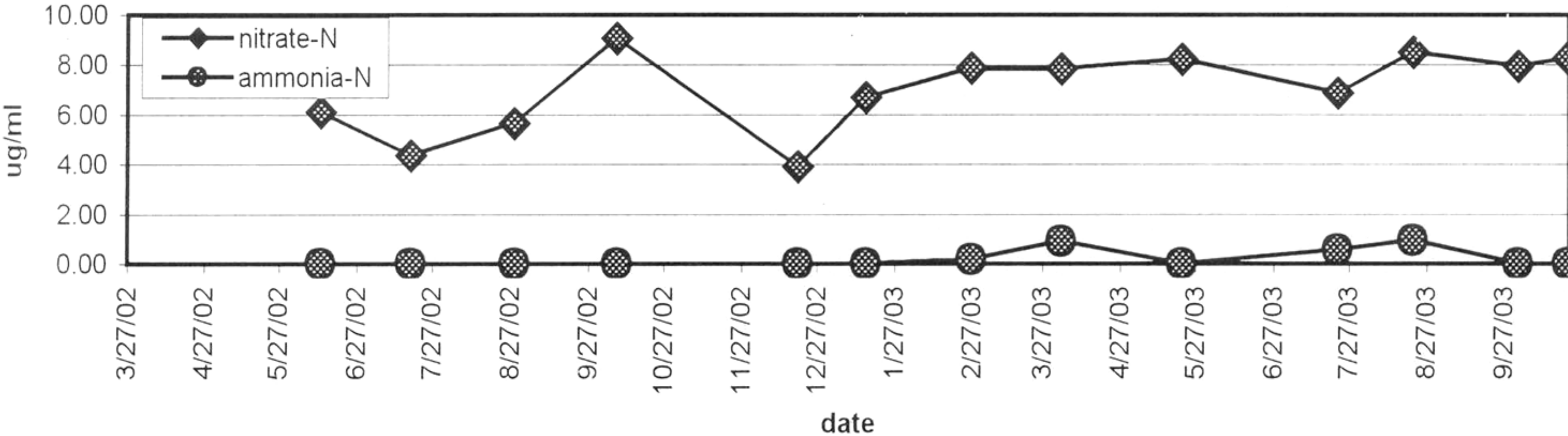
- Large (2000 ha) mineral sands mining operation in upper Coastal Plain.
- Lime-stabilized biosolids were applied to 10 ha mining pit reclaimed without topsoil in August of 2002.
- Water quality monitored monthly at 6 ground water wells and 2 surface water discharge points.



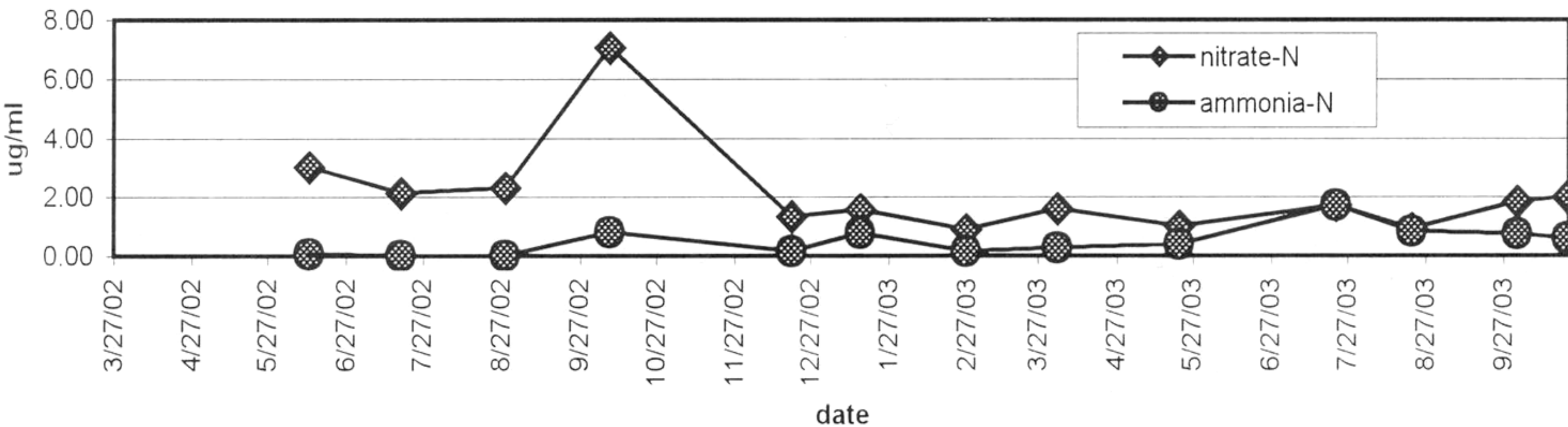
IMS-2s
IMS-2
IMS-3
IMS-4
IMS-1
IMS-6
IMS-5
IMS-1s
N
0.08
0
0.08
0.16 Miles

Lime stabilized biosolids being applied at 35 T/Ac

IMS-5: Nitrate- and Ammonia-N



IMS-6: Nitrate- and Ammonia-N

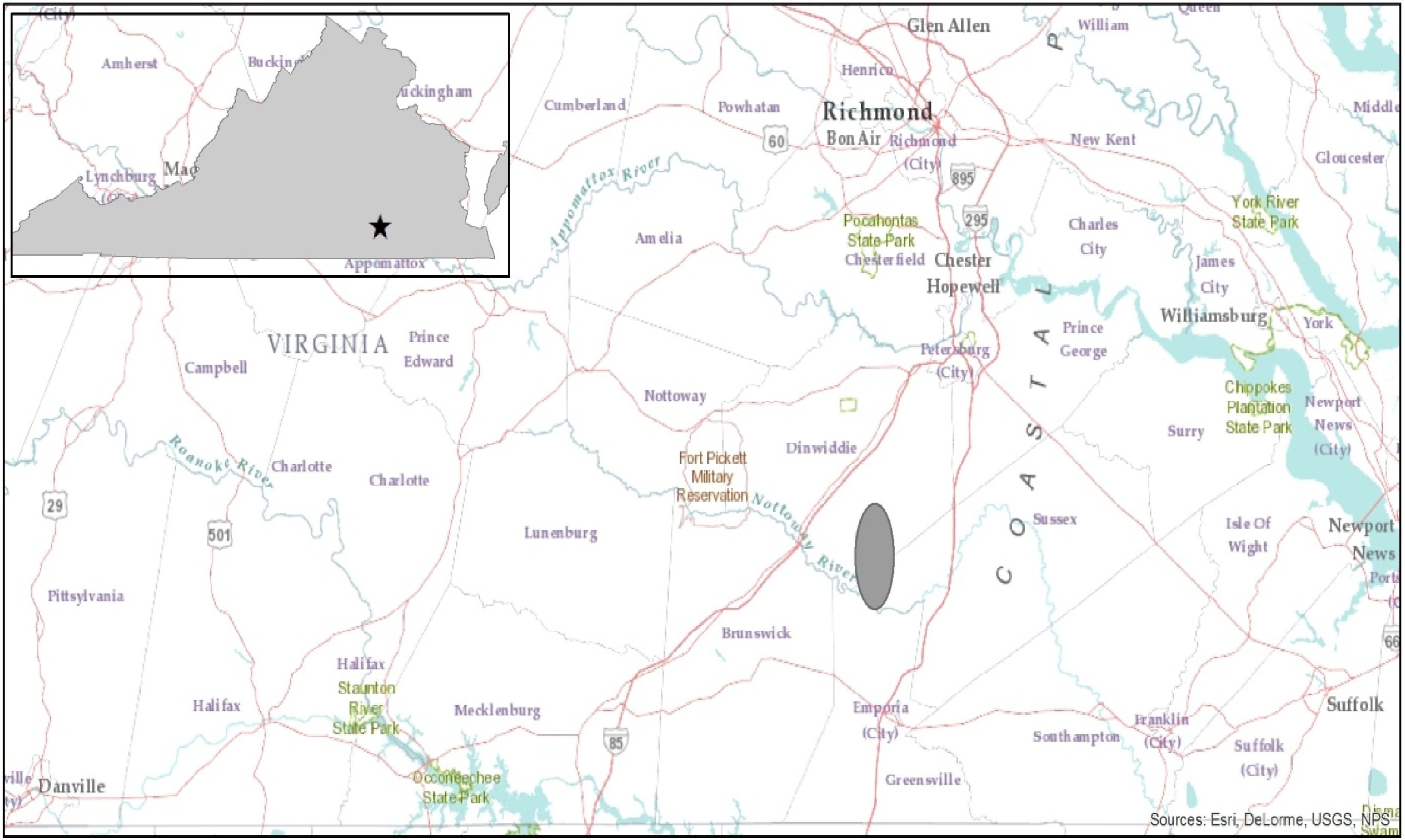


Iluka Rate Study Objectives

- **To compare the effect of biosolids applications at higher than agronomic rates with standard fertilization practices on nitrate-N leaching**

- **To compare the effects of biosolids and standard fertilization practices on vegetation establishment and production**

Study Site Location in Dinwiddie County, Virginia



Iluka Research Farm: new well locations: March 24, 2011
Wells and corner flags located with Trimble ProXRS differential GPS

Treatment	N	P_2O_5	K_2O
	------------------- kg ha^{-1} -------------------		
1. 0 N Control	0	400	175
2. Fertilized Control	115	400	175
3. Agron Rate of Biosolids (4.2 Mg/ha) + P&K	121	349 (as biosolids)+109	7.3 (as biosolids)+167
4. Reclam. Rate (5X) Biosolids + K	607	1748 (as biosolids)	36.5 (as biosolids)+137

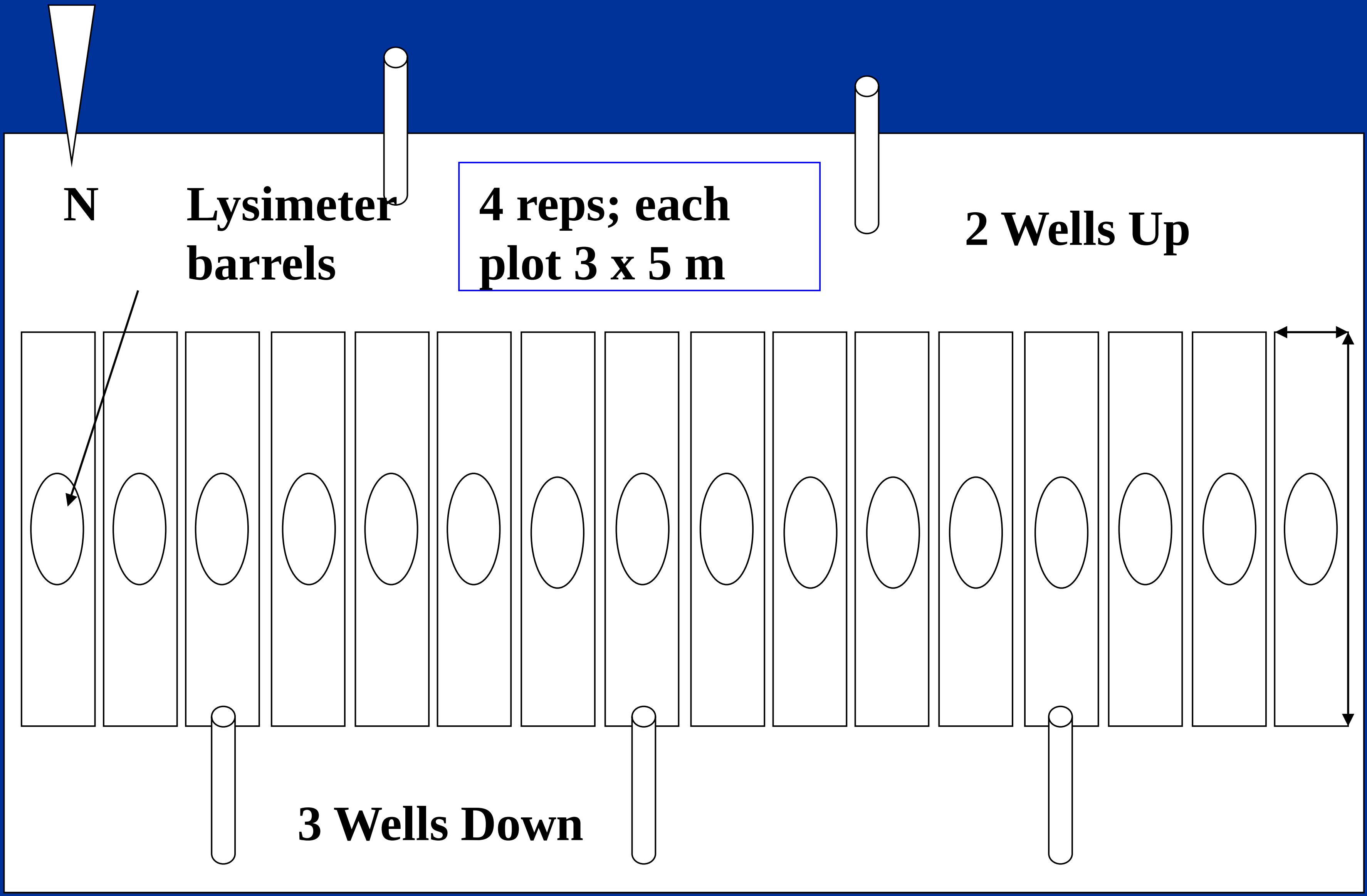

N
Lysimeter barrels
4 reps; each plot 3 x 5 m
2 Wells Up
3 Wells Down

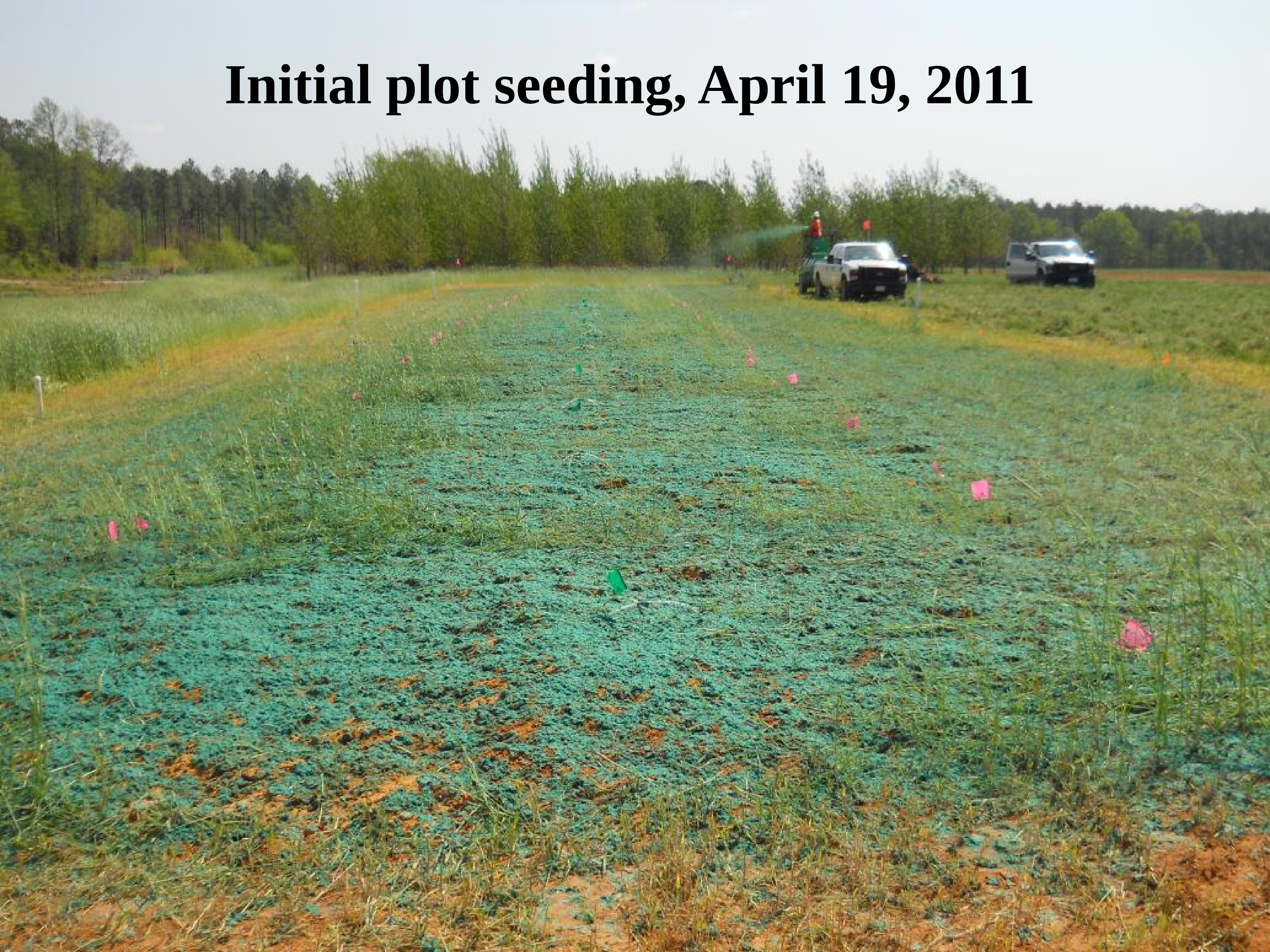
Table 3: Alexandria Sanitation Authority biosolids analysis, and analytical methods by A&L Eastern Laboratories

(SM = American Public Health Association, 2011; SW = U.S. EPA, 2012).

Parameter	Value ---- mg/kg----	Method
Solids	300,000 (30%)	SM-2540G
TKN	54,500 (5.45%)	SM-4500-NH_3C-TKN
NH_4-N	22,900	SM-4500-NH_3C
Org N	31,600	Calculation
P	36,300	SW6010C
K	1400	SW6010C


maroon

Initial plot seeding, April 19, 2011



April and September 2011 species and rates.

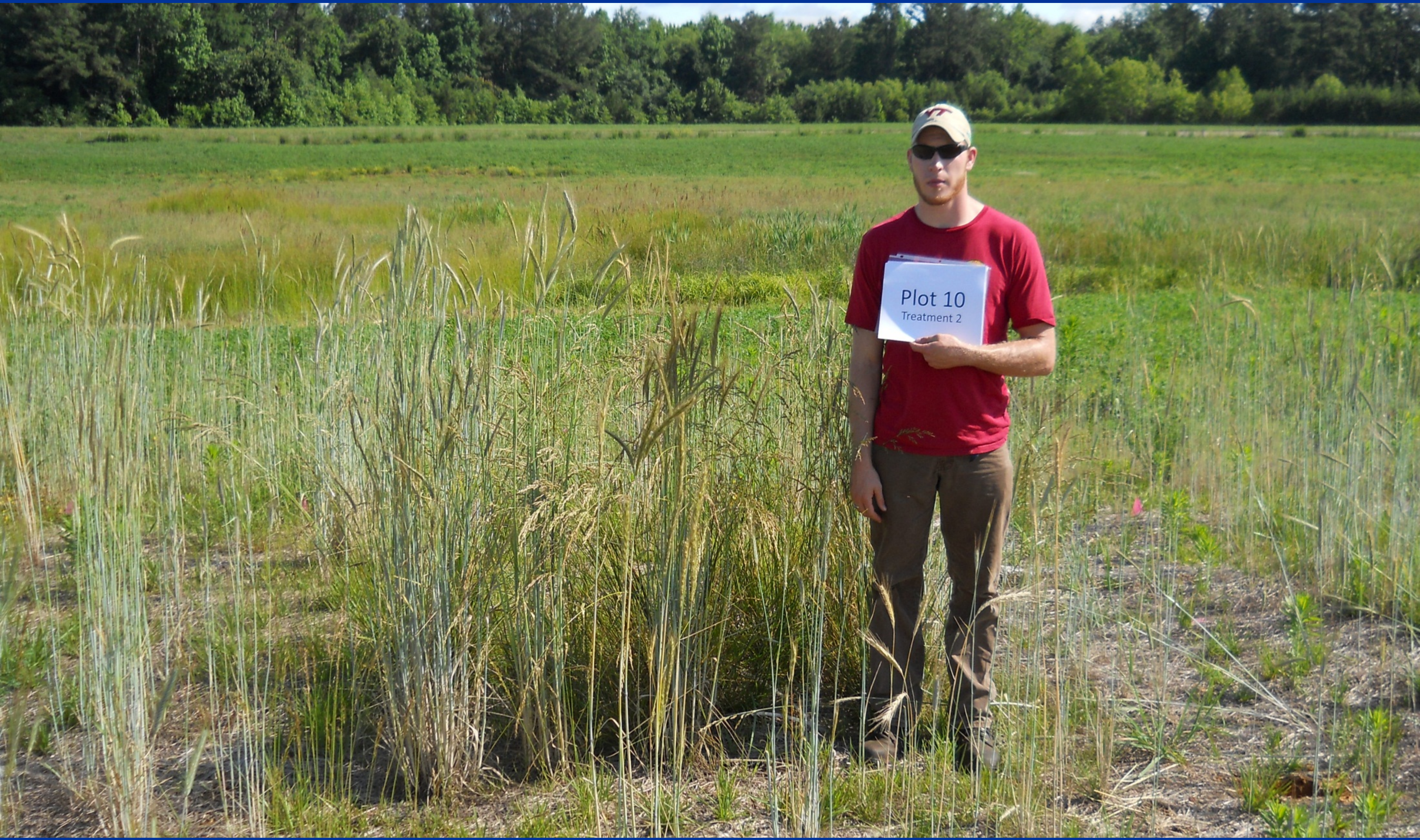
After initial seeding failed in April, lysimeters were reseeded in late May by hand applying 40-50g of seed per lysimeter. Second attempts failed, so in mid-September, tall fescue and cereal rye were seeded again at rates below with an additional 115 kg/ha N to fertilized N treatment only.

Forage Species	Seeding Rate, kg ha^{-1}
Tall Fescue	75
German Millet	30
Cereal Rye	45


N fertilized control; July 2011


Agronomic 1X biosolids; July 2011

0 N control; May 2012 at time of vegetation sampling.



N-fertilized (230 kg/ha PAN) plot in May 2012.

Reclamation rate biosolids (21 Mg/ha) at May 2012 harvest date.

Forage biomass yield and N-uptake from (left to right) for September 2011 and May 2012 samplings, combined yields and total annual plant N-uptake.

Treatment	Sept. 2011 Biomass (p=0.057)	May 2012 Biomass (p=0.213)	Total Biomass (p=0.045)	N-uptake kg ha^{-1} (p=0.349)
	------------------ kg ha^{-1} ------------------			
Control	2740a*	1145a	3885b	30.5a
Fertilized Control	6298a	3667a	10,661a	79.4a
Biosolids: Agronomic Rate	9802a	2862a	12,979a	93.3a
Biosolids: Reclamation Rate	9202a	4028a	13,231a	133.2a

* Treatment values followed by the same letter for given date are not different (α=0.05: Fishers LSD).

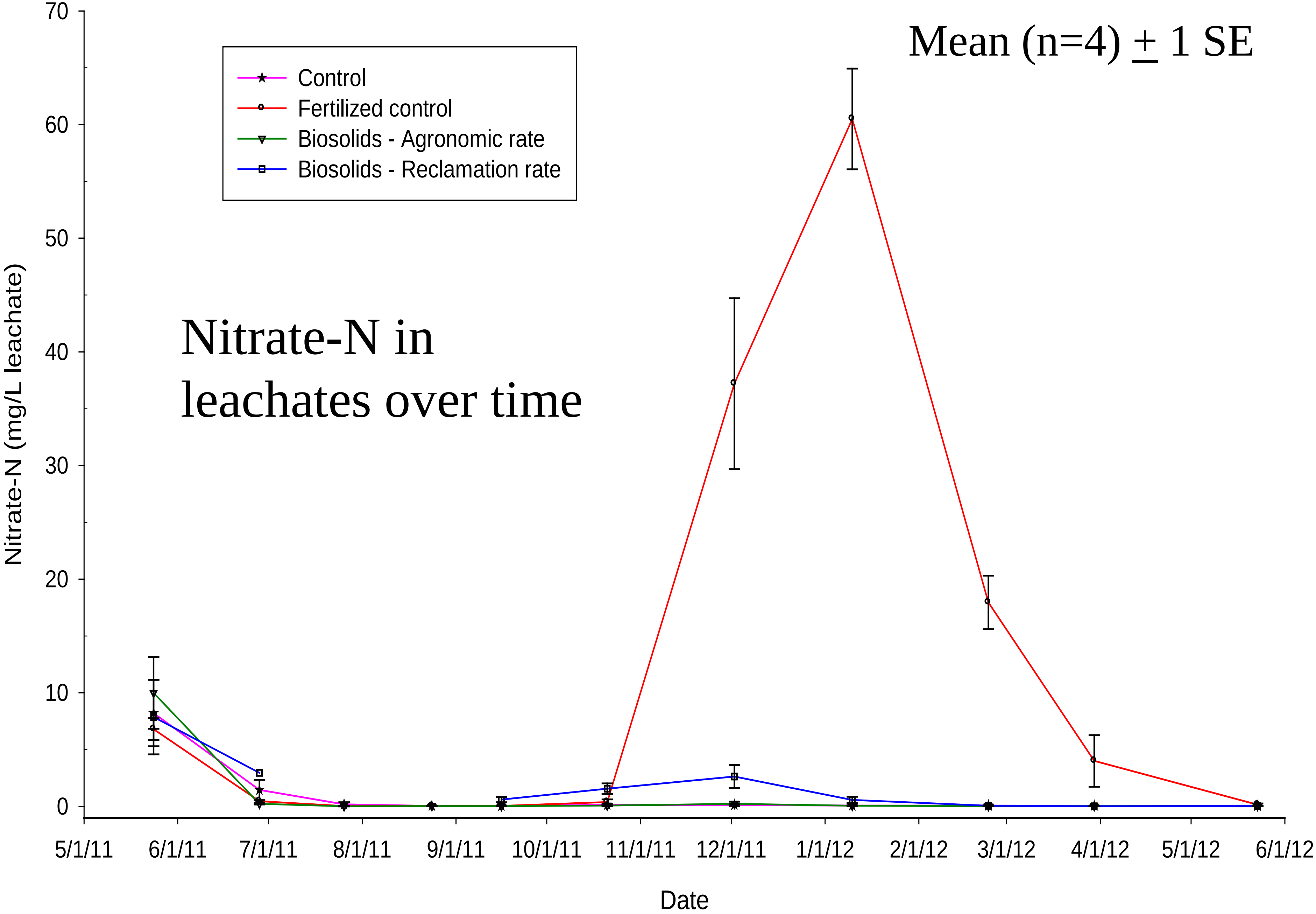
Table 6. Estimated PAN applied to each treatment, and total mass N, nitrate-N, ammonium-N and % N lost by leaching.

Treatment	PAN Applied	Total-N Applied	Total-N Leached [2]	Nitrate-N Leached	Ammon.-N Leached	PAN/Total-N Lost by Leaching
	------------------------------ kg ha^{-1}	------------------------------				-------- % -------
Control	0.0	0.0	1.6b[1]	1.0b	0.6	N/A
Fertilized Control	230*	230*	62.4a	59.3a	3.2	27.1 / 27.1
Biosolids: Agronomic Rate (1x)	121	763	1.3b	0.5b	0.8	1.1 / 0.06
Biosolids: Reclamation Rate (5x)	607	3800	7.2b	5.6b	1.6	1.2 / 0.1

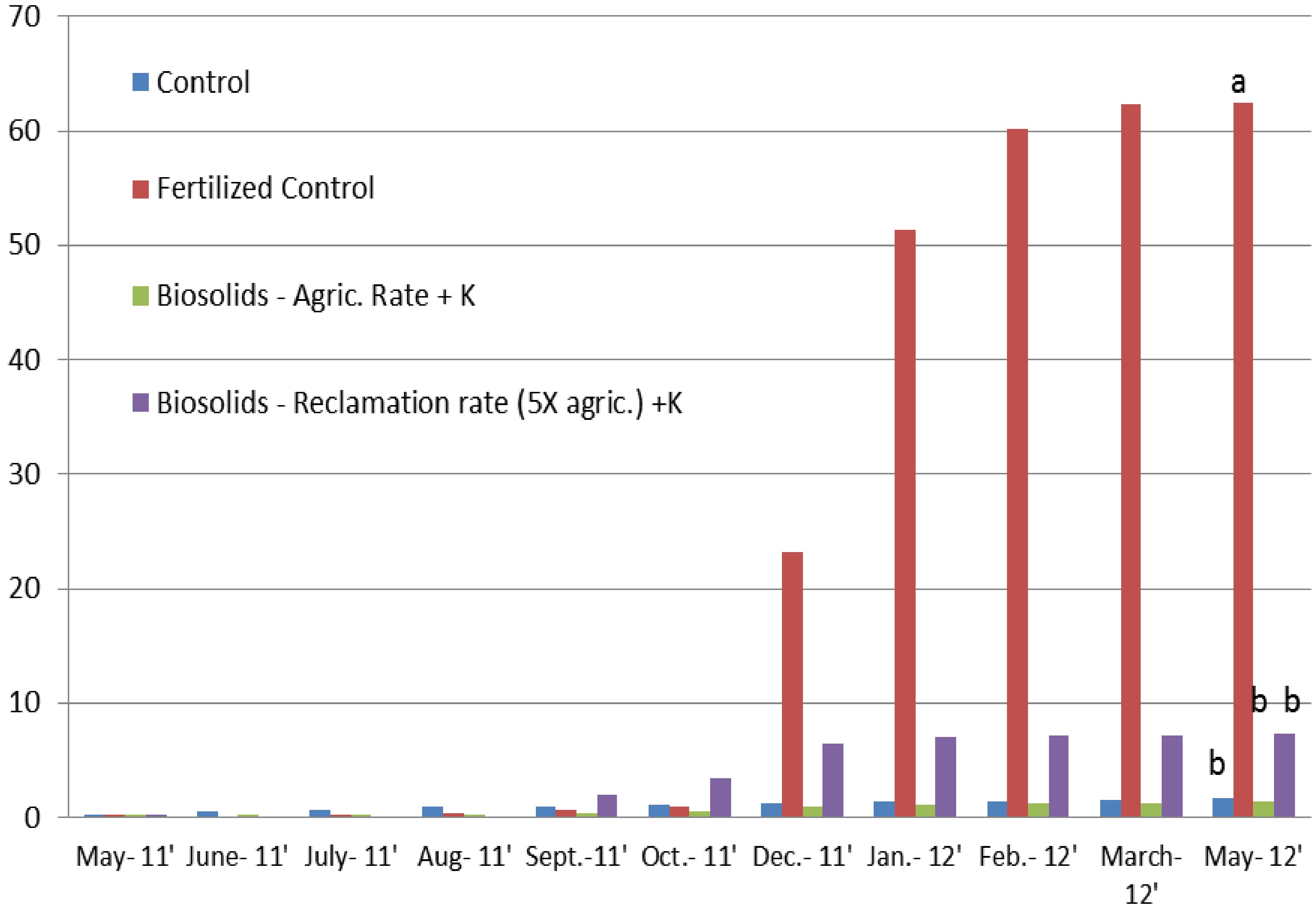
*Two applications of 115 kg ha^{-1}. [1]Treatment means followed by the same letter for given date are not different Fisher's protected LSD. [2]Total-N is equal to sum of nitrate-N plus ammonia-N.

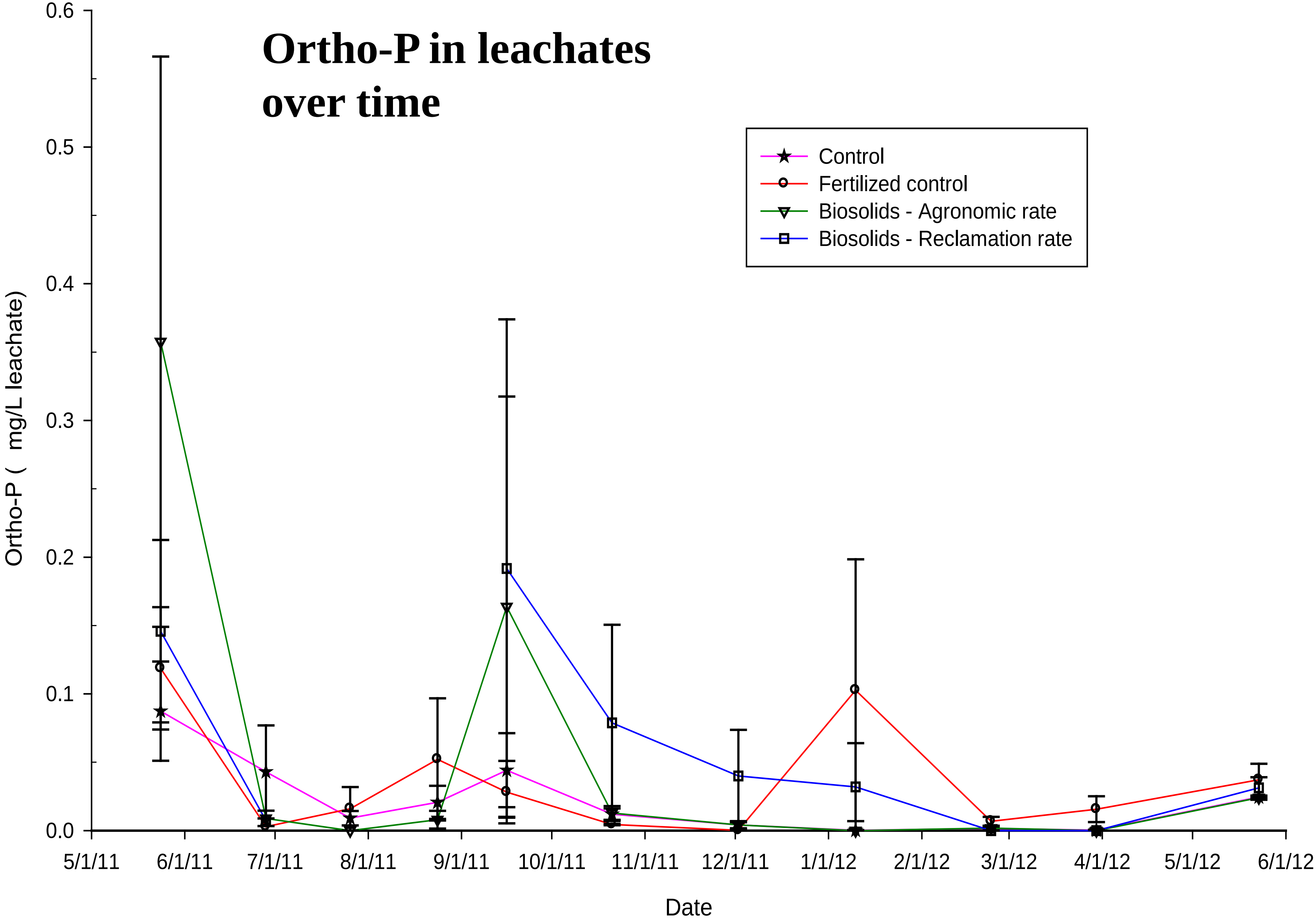
Nitrate-N in leachates over time

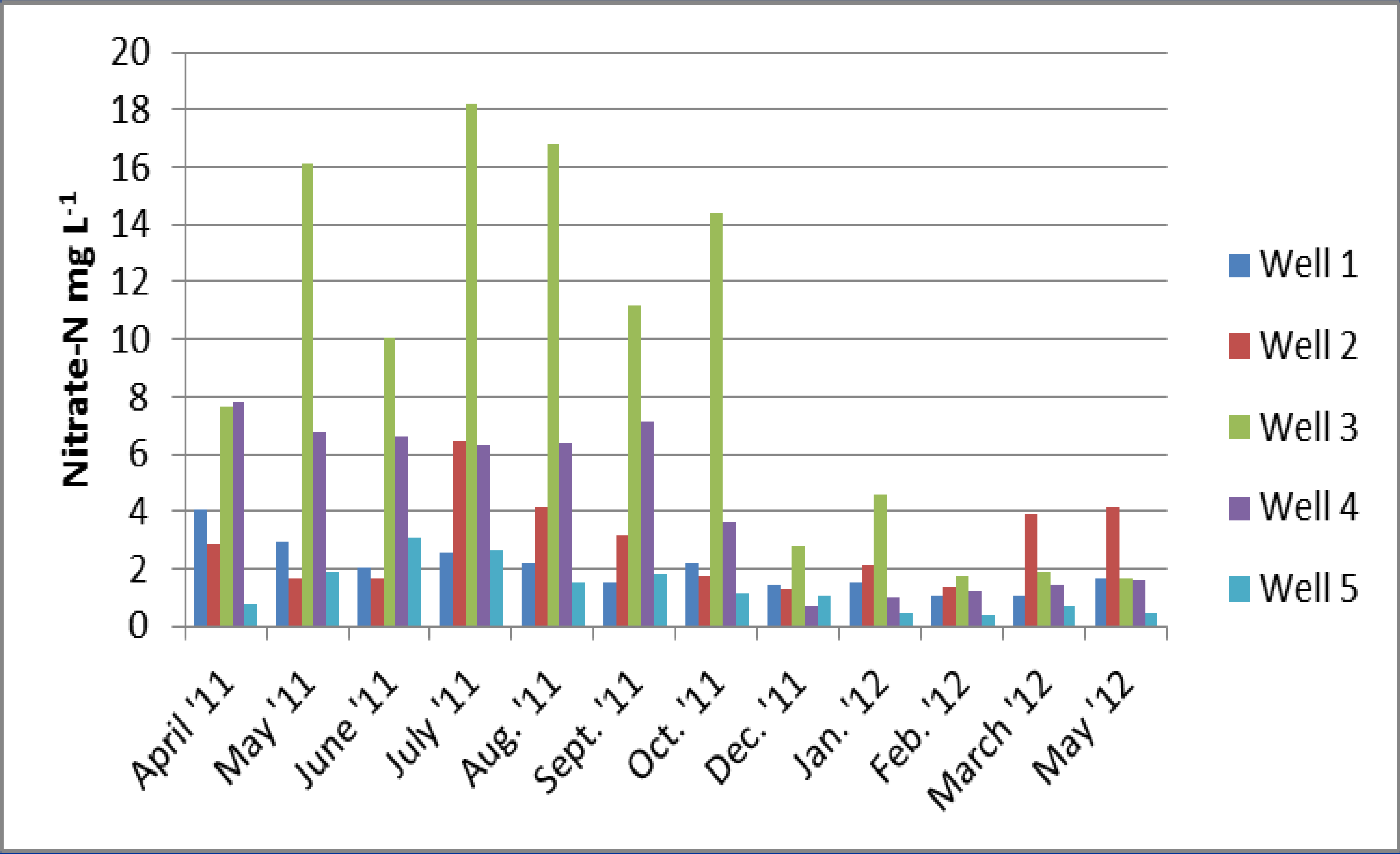
Mean (n=4) $\pm$ 1 SE



Cumulative mass nitrate-N leached over time




Ortho-P in leachates over time
Control
Fertilized control
Biosolids - Agronomic rate
Biosolids - Reclamation rate
Ortho-P (mg/L leachate)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
5/1/11
6/1/11
7/1/11
8/1/11
9/1/11
10/1/11
11/1/11
12/1/11
1/1/12
2/1/12
3/1/12
4/1/12
5/1/12
6/1/12
Date



Nitrate-N in shallow (< 5 m) groundwater over time. Wells 1 and 2 are up-gradient and wells 3, 4 and 5 are down-gradient.

Conclusions

All treatments produced relatively poor vegetation in both years, but the 1x reclamation treatment did not need to receive additional N fertilization the first fall and was able to maintain a similar or even better vegetation stand over the life of the experiment than the N-fertilized control.

Both biosolids treatments were superior and much more efficient in terms of plant N-supply than conventional fertilization in this setting.

Conclusions

The only treatment that leached nitrate-N over the EPA standard for drinking water in this study period was the conventional fertilizer treatment.

While the biosolids treatments also produced a limited amount of nitrate-N leaching, this event occurred during the first winter and only lasted a couple months.

Conclusions

Both biosolids treatments lost less than 1% of their total N applied (vs. 27% for the N-fertilized plots). Furthermore, these minor losses occurred under harsh environmental conditions where establishment of an N-assimilating vegetative cover was suboptimal.

Some leaching losses were also noted for ortho-P. While some P leaching loss was evident for all treatments, it was less than 0.15% of total P applied in the worse case (5x biosolids).

Acknowledgments

We want to thank Iluka Resources for financial support, Carl Clarke for his assistance in plot establishment and maintenance, and the Alexandria Sanitation Authority for biosolids and logistical support.