NITRATE-N LOADING AND REMEDIATION IN THE KARLSRUH AND NEW ROCKFORD AQUIFERS North Central ND

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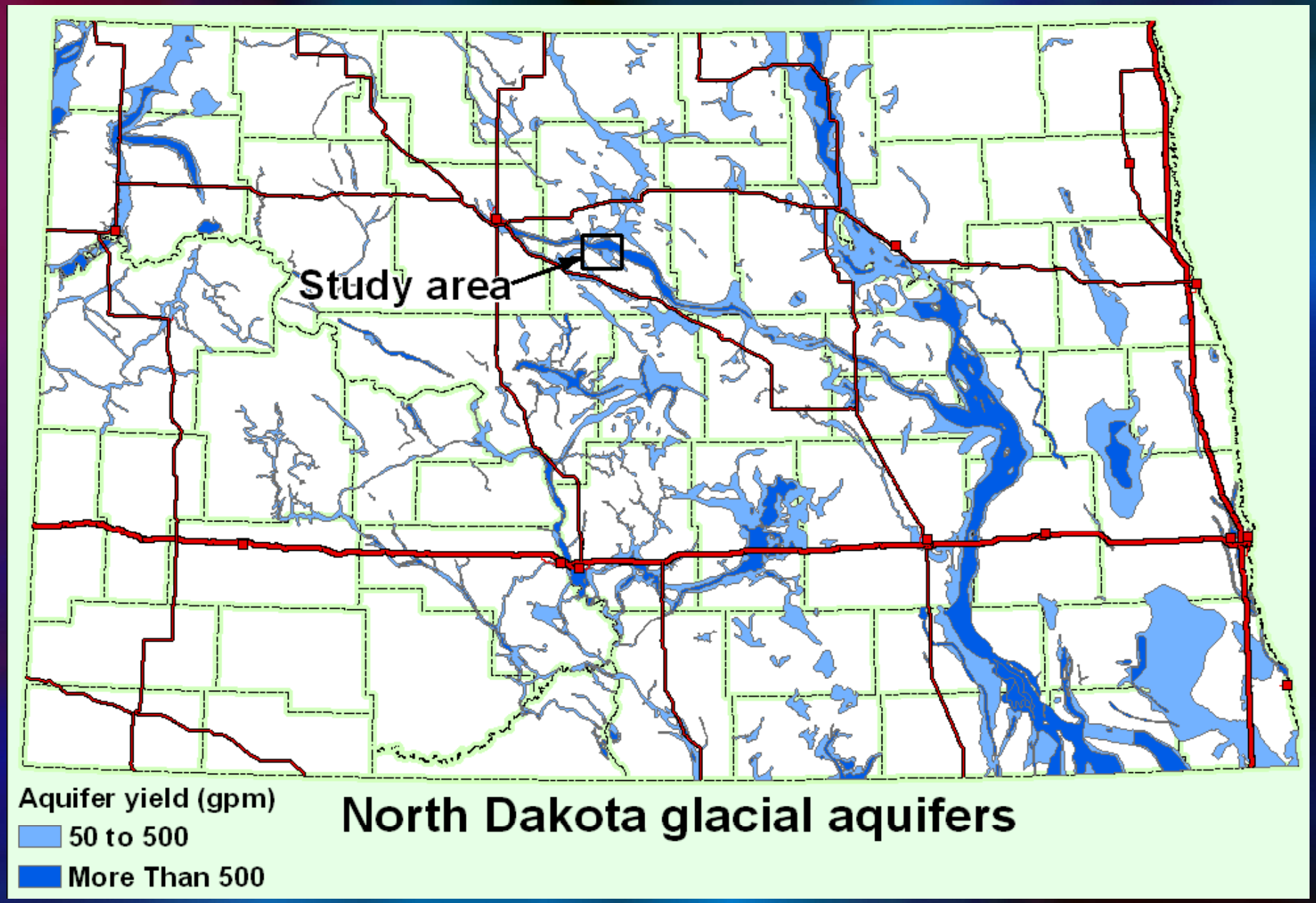
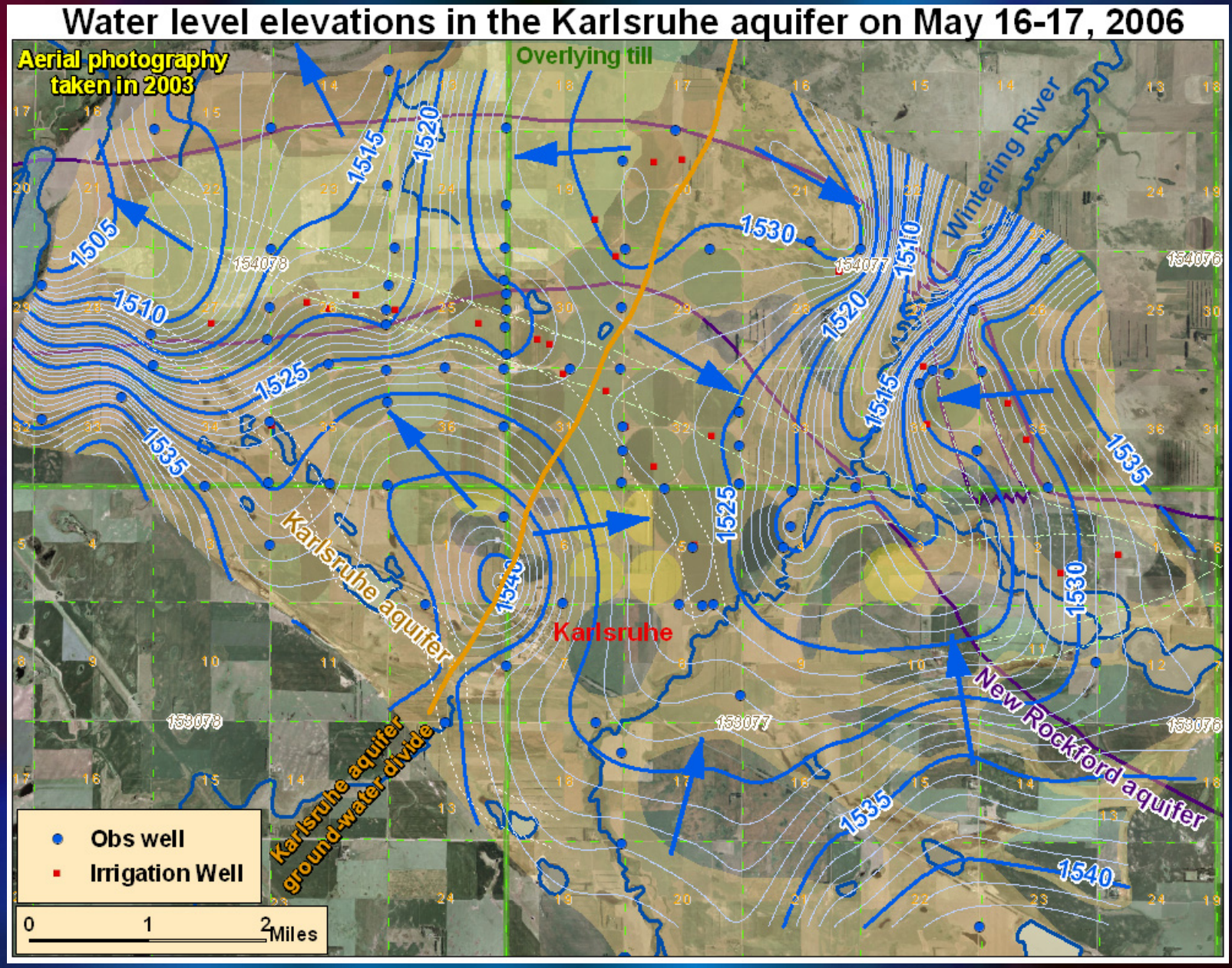
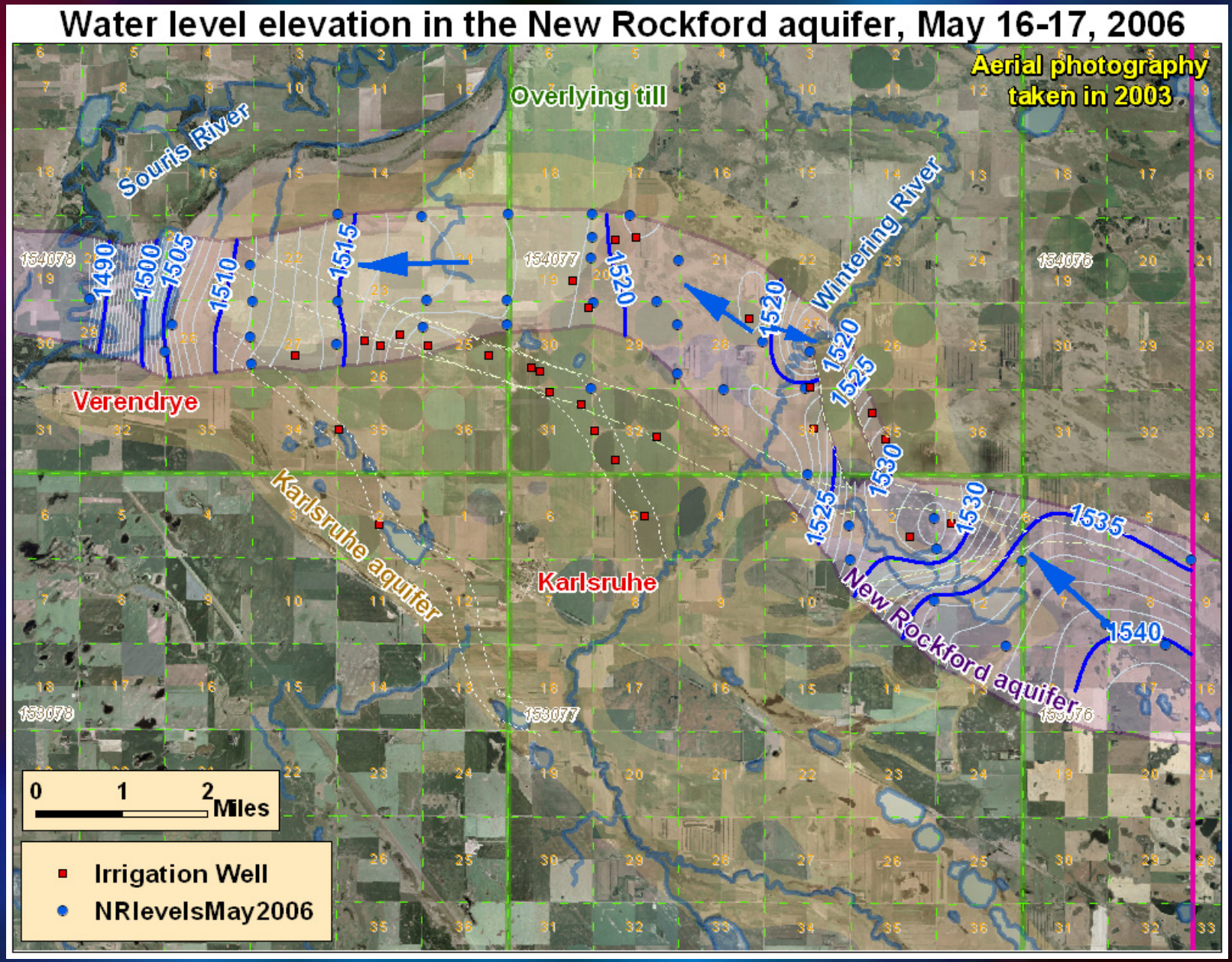
North Dakota State Water Commission

2012 Midwest Groundwater Conference
St. Paul, MN


Study area
Aquifer yield (gpm)
50 to 500
More Than 500
North Dakota glacial aquifers

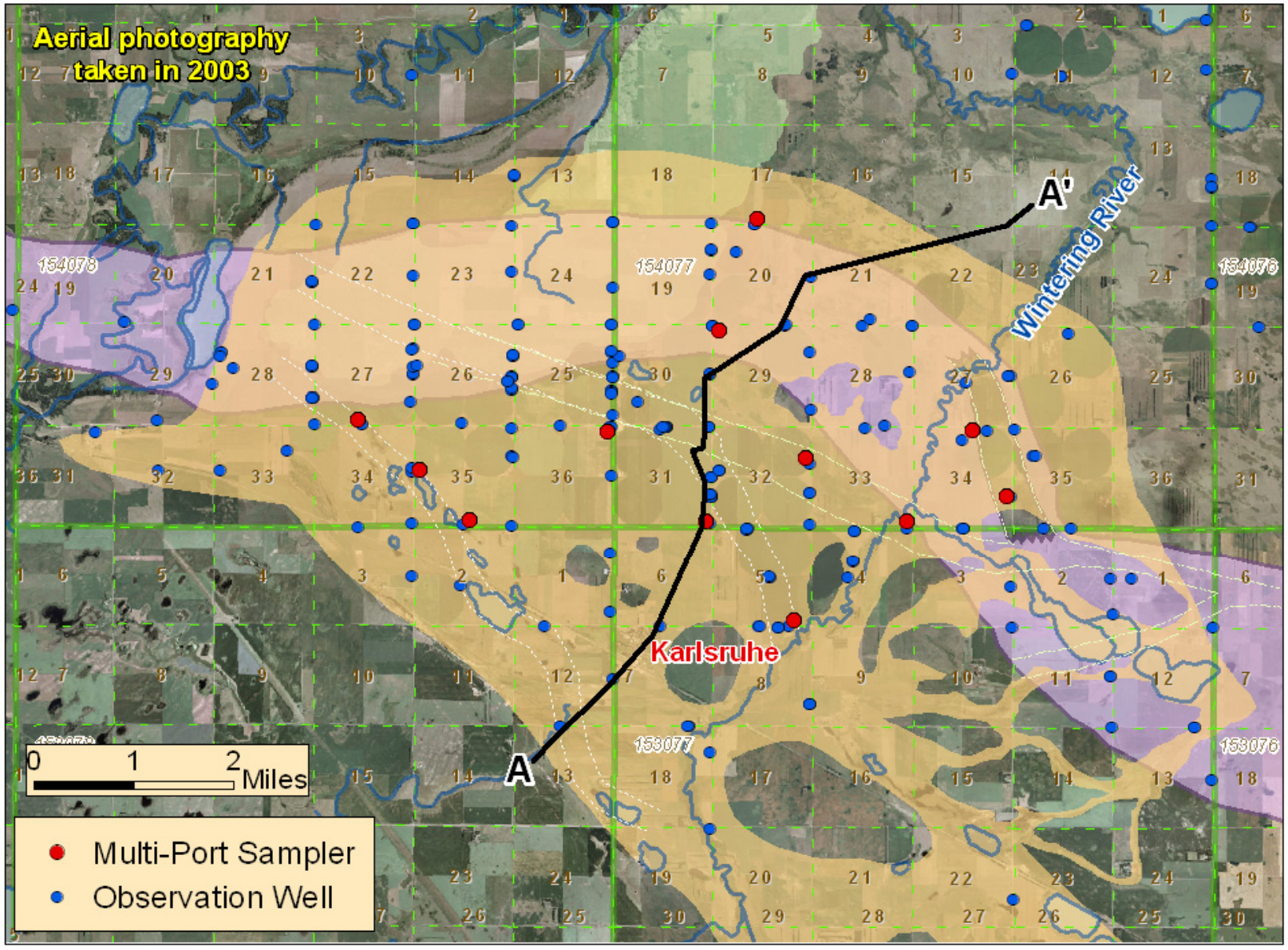


Map by Alan Wanek



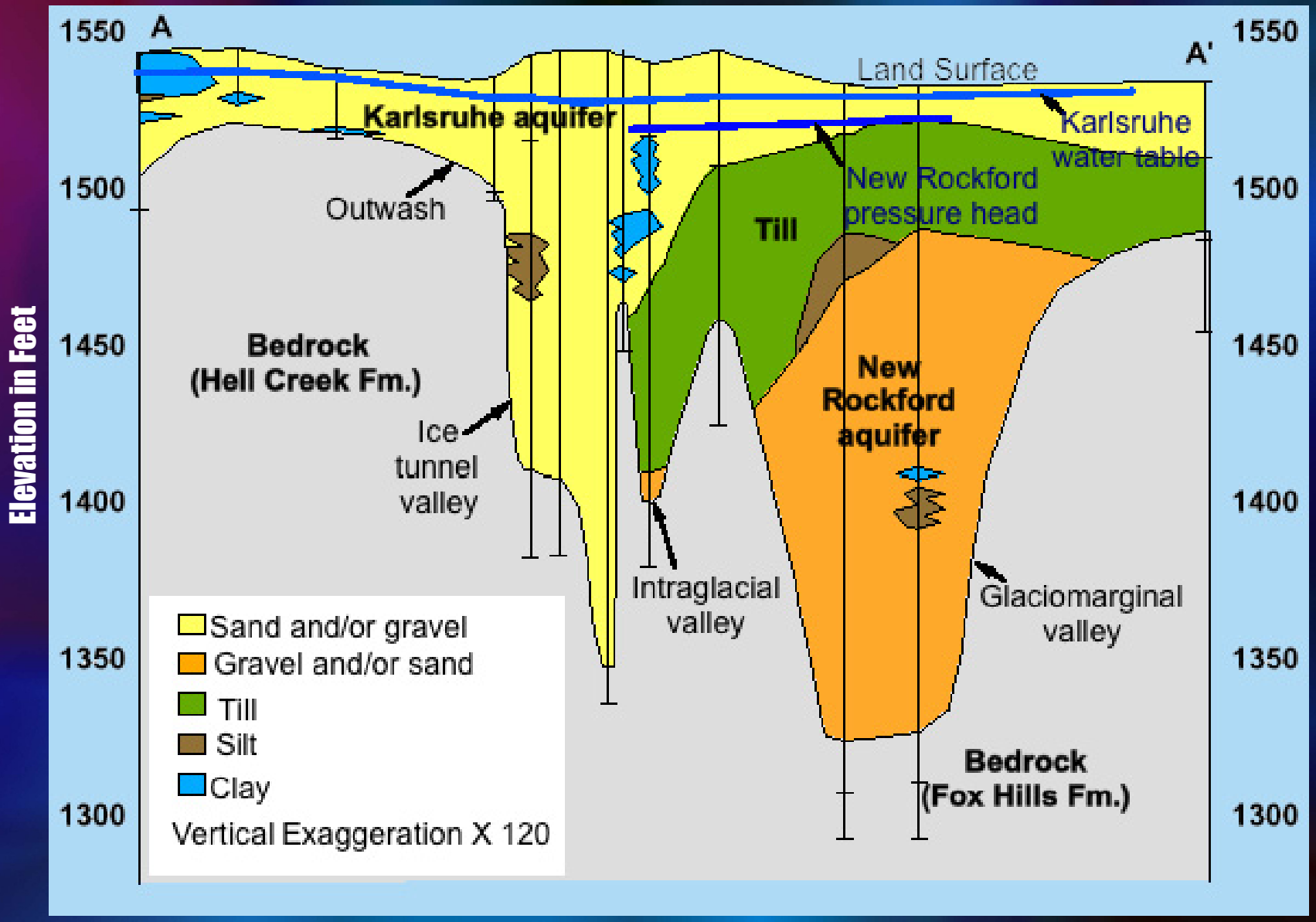
Map by Alan Wanek

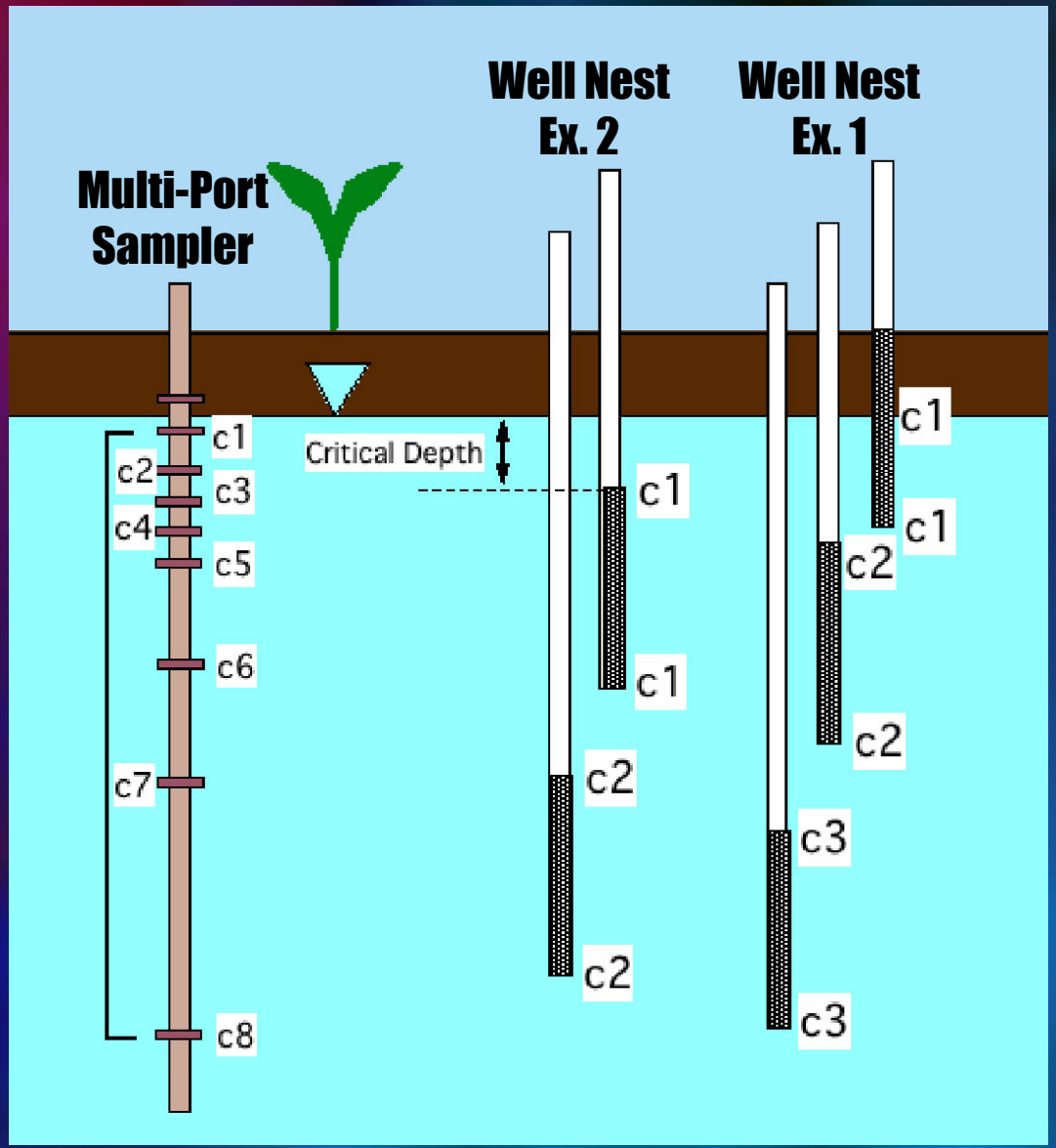
Trace of transverse vertical section



Map by Alan Wanek

Southwest to Northeast Vertical Section
One Mile Northwest of the Wintering River



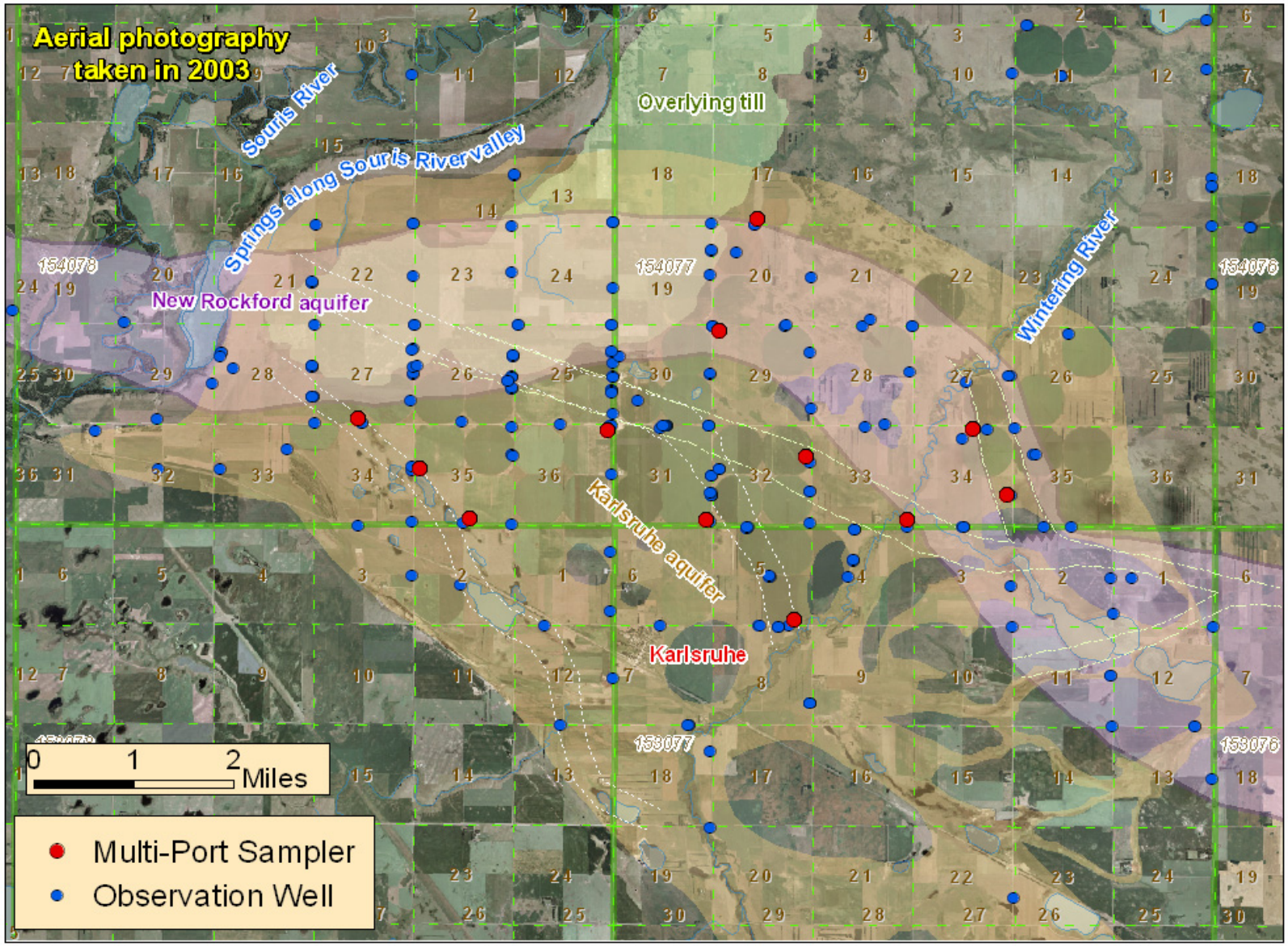


Some Selectors

- If top of shallowest well > 5 feet bwt, discard
- If wt intersects top well screen, use wt to bottom of well screen

Multi-Port Samplers

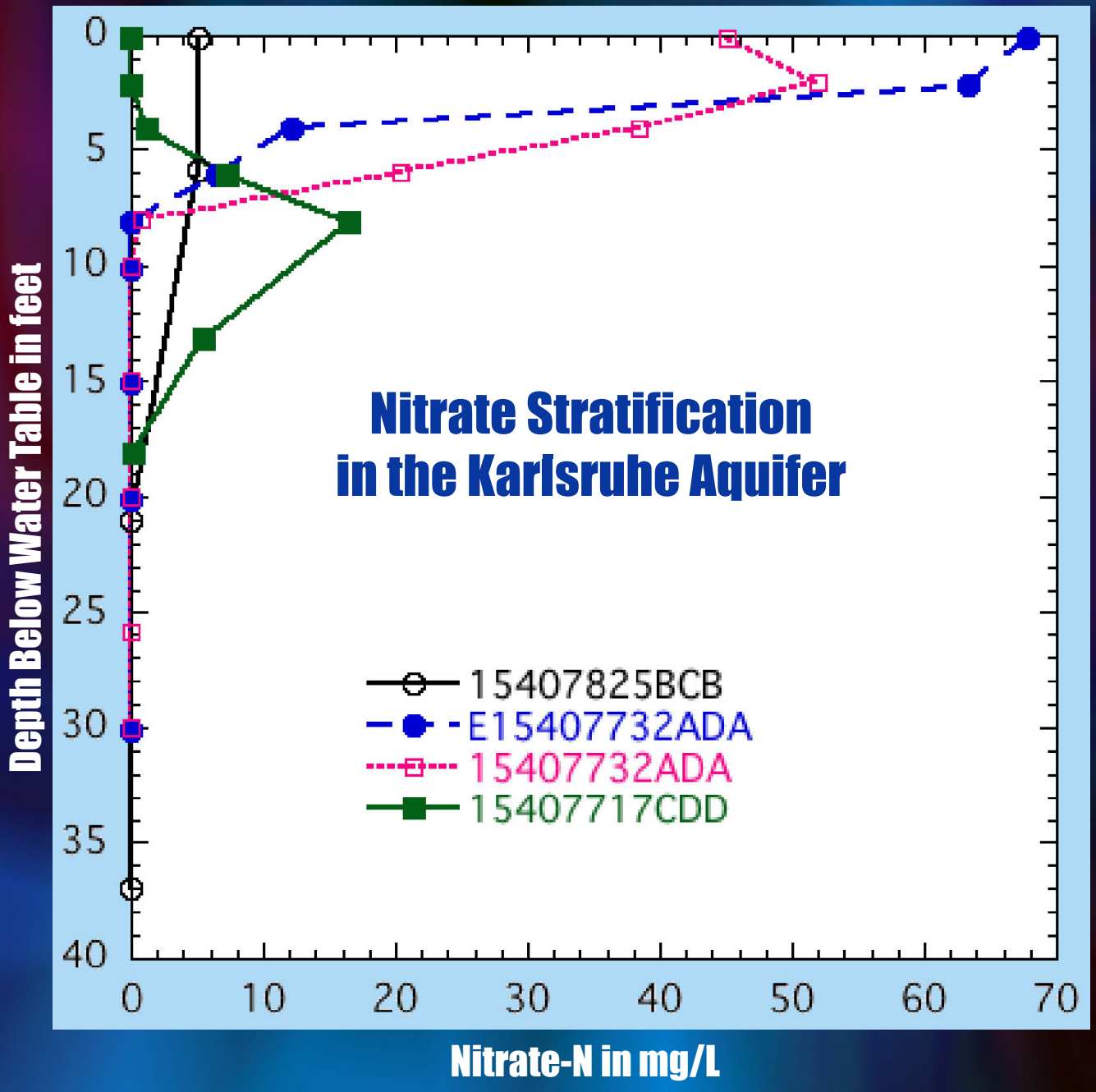
Monitoring wells and Multi-port samplers in the Karlsruhe area



Map by Alan Wanek

Design Problems for Assessment and Remediation of Stratified Nitrate

- Stratification
- Interpretation - Agricultural/Toxicology
- Spatial Interpretation
- Toxicological Assessment
- Goals


Nitrate Stratification
in the Karlsruhe Aquifer
Depth Below Water Table in feet
Nitrate-N in mg/L
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
15407825BCB
E15407732ADA
15407732ADA
15407717CDD

Stratification

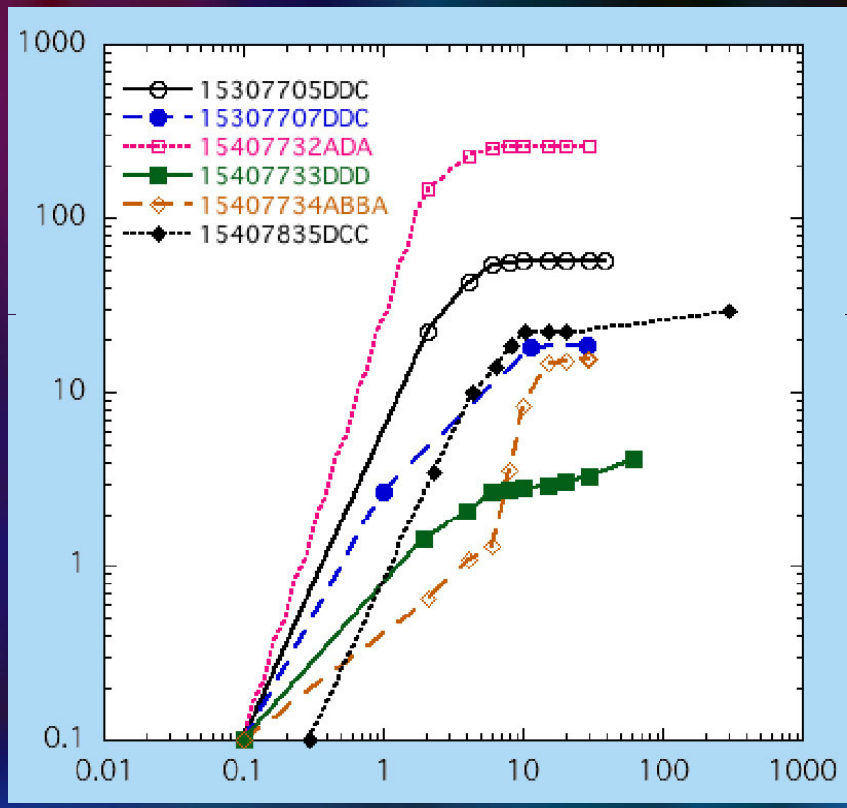
$$[N] = 0.226[NO_3^-]$$

$$N_t^* = \int_o^z [N]dz$$

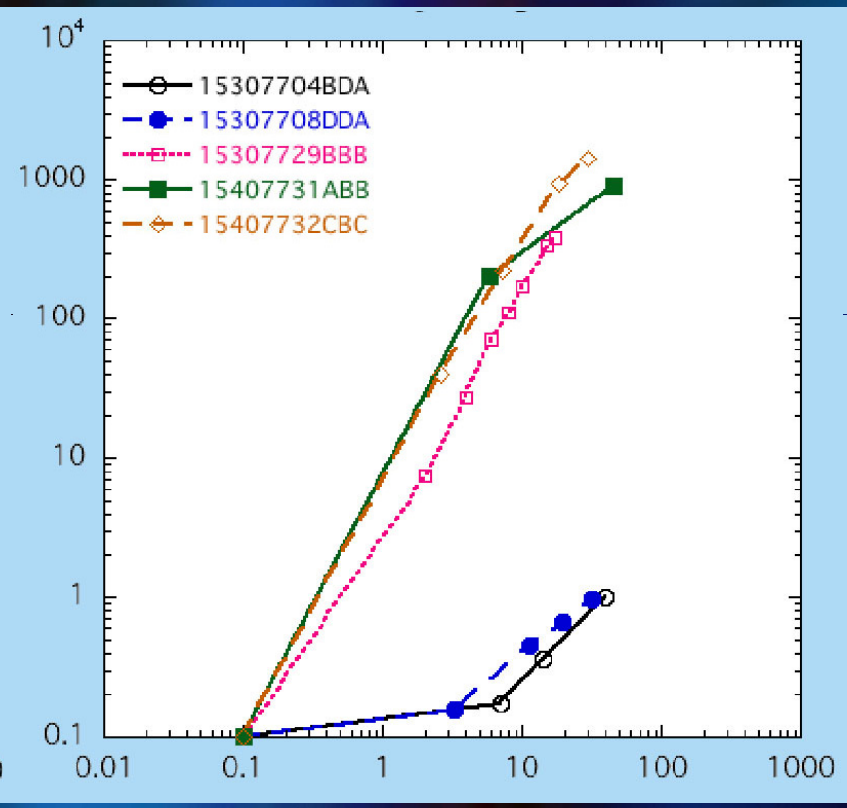
Fully Integrated

Not Fully Integrated

Cumulative N from Water Surface to Depth in Pounds per Acre



Depth Below Water Table in feet



Depth Below Water Table in feet

Agricultural Cross-Assessment

Fertilizer Loss VS. Aquifer Nitrate-N Concentrations

$$N_t\left(\frac{lb.}{a}\right) = N_t^*\left(\frac{mg-ft.}{L}\right)\bullet 10^{-6}\left(\frac{mg}{kg}\right)\bullet 10^{3}\left(\frac{L}{m^3}\right)\bullet 4.047\bullet 10^{-6}\left(\frac{m^2}{a}\right)$$

$$\bullet 0.305\left(\frac{m}{ft.}\right)\bullet 2.21\left(\frac{lb.}{kg}\right)\bullet 0.4(dimensionless)$$

$$N_t\left(\frac{lb.}{a}\right) = N_t^*\left(\frac{mg-ft.}{L}\right)\bullet 1.09\left(\frac{lb.-L}{a-mg-ft.}\right)$$

Spatial Interpretation

1. Local Load

2,500 m^2 nodes

Inverse-Square Distance Interpolation
- discrete, conservative -

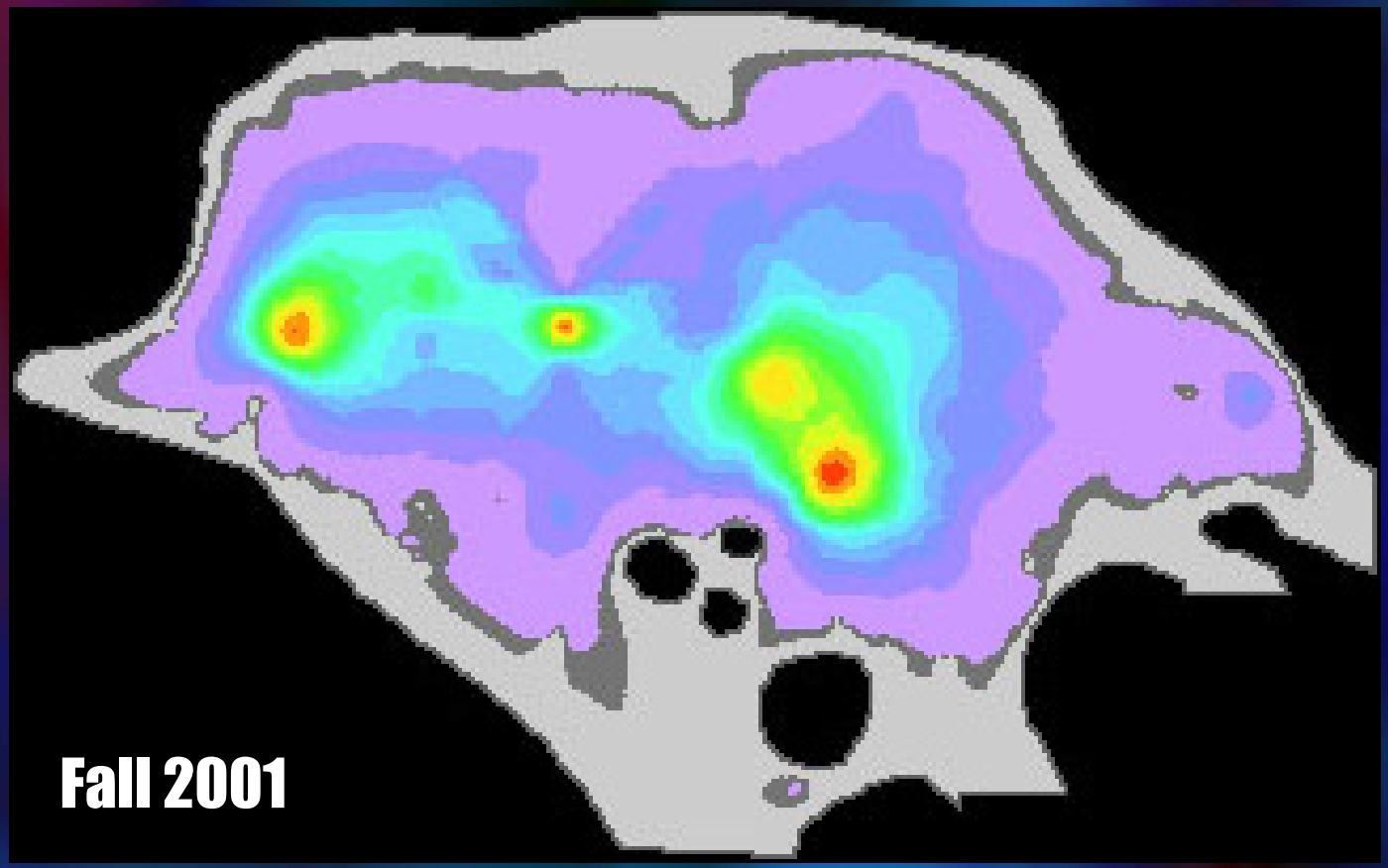
Zero concentration at aquifer boundaries

Spatial Interpretation

2. Total Load

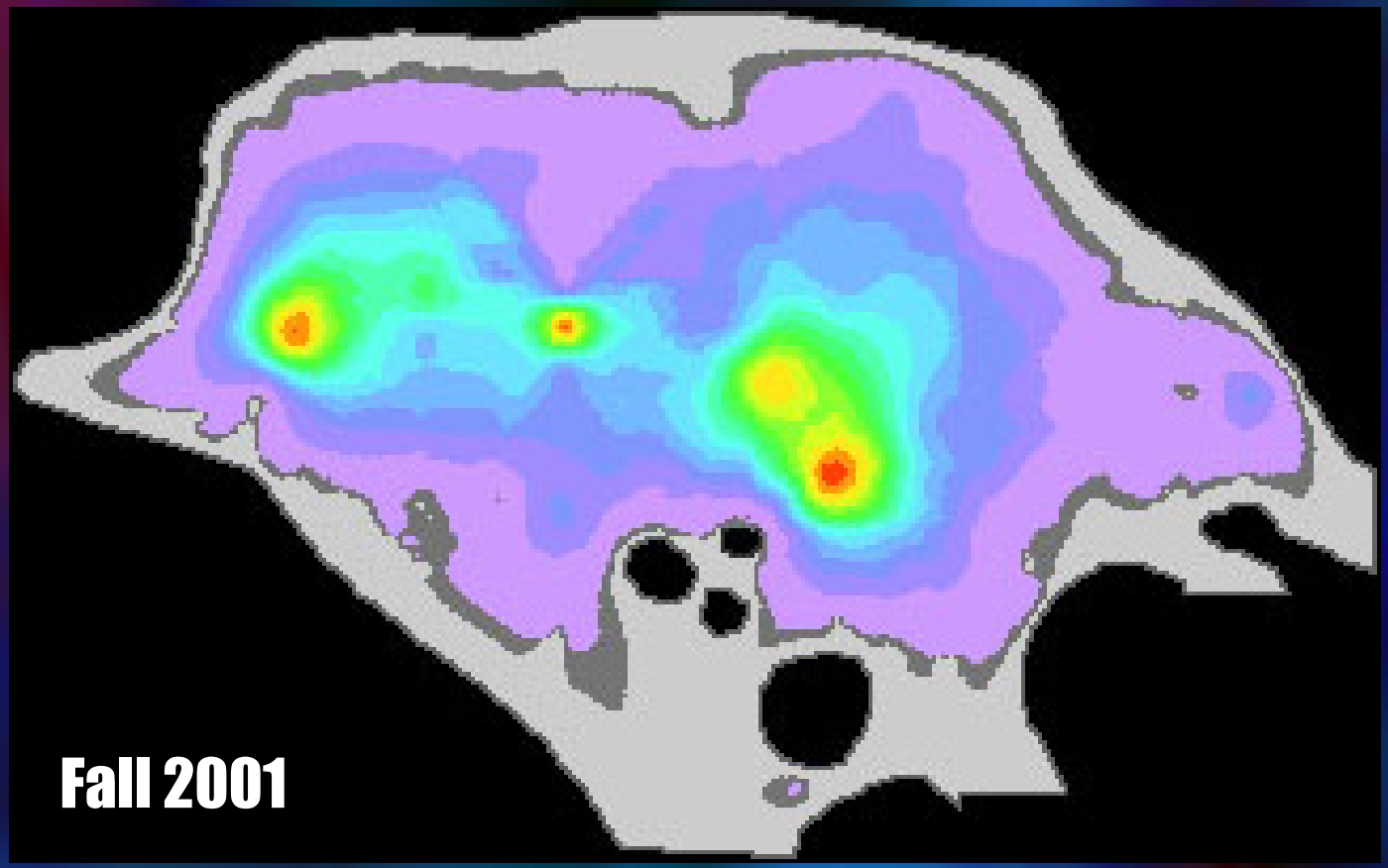
$$N(lb.) = \sum_{i=1}^{n} a_i N_{t,i}$$

Nitrate-N Load



TOTAL N - Pounds Per Acre

Nitrate-N Load



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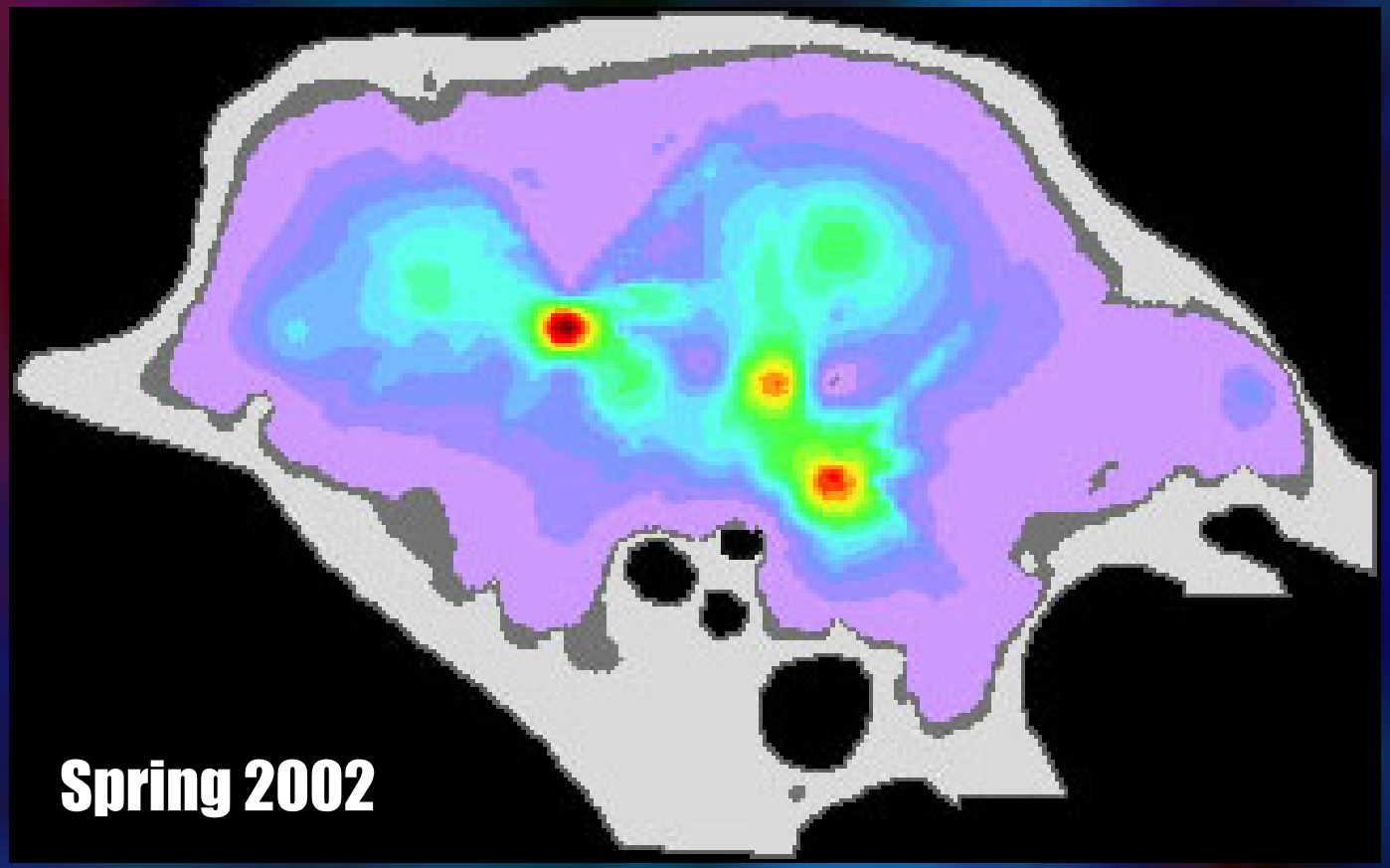

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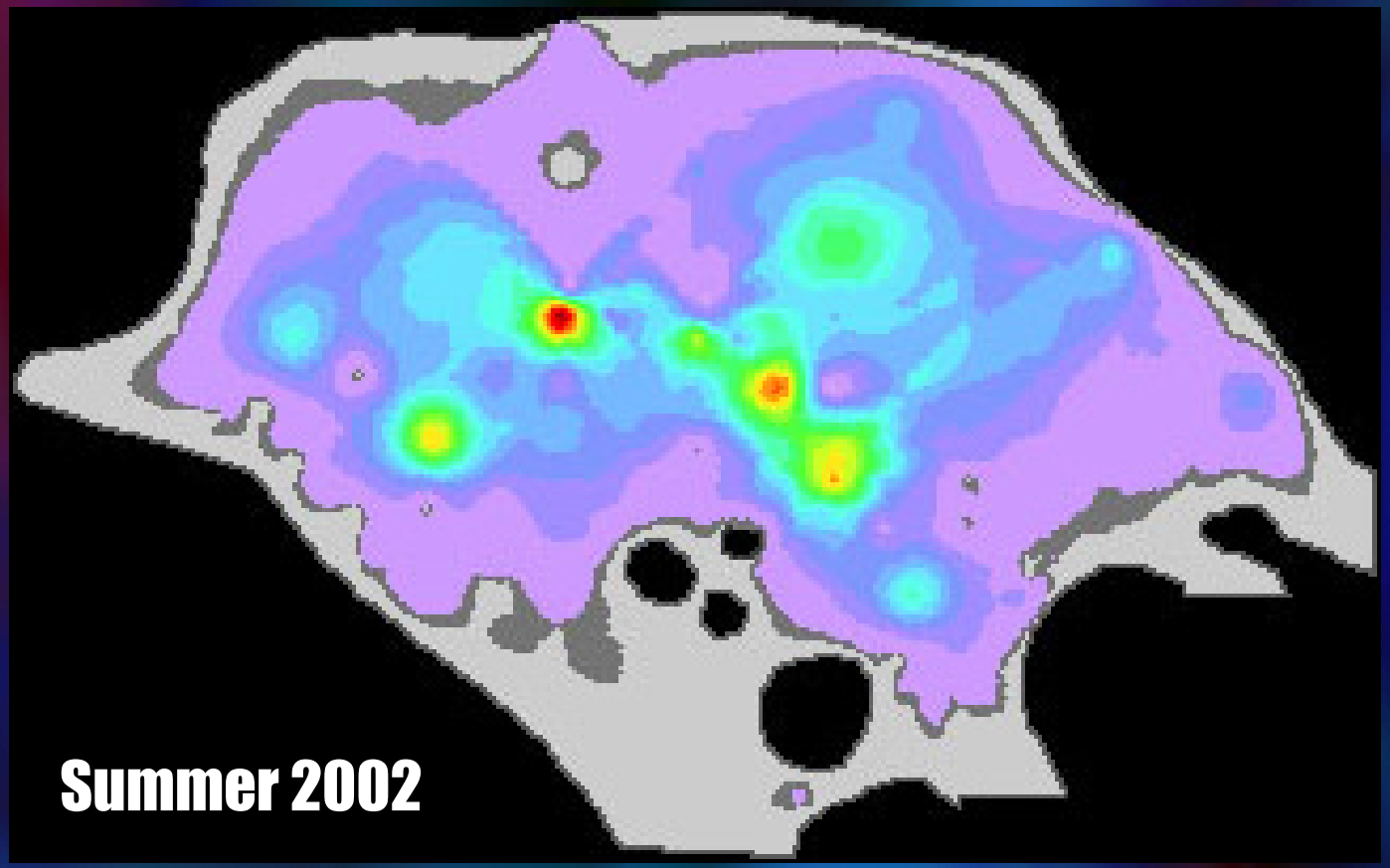

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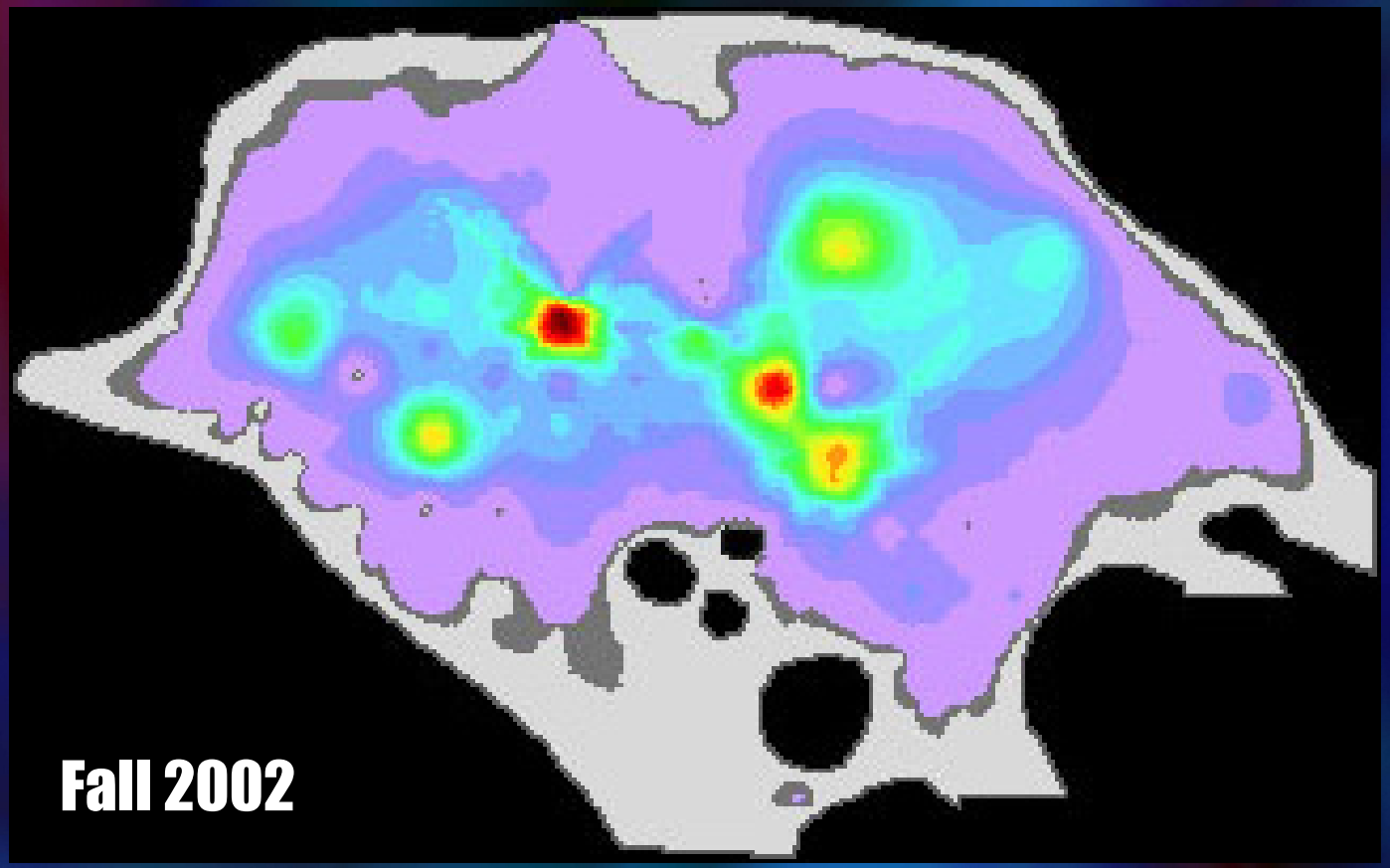

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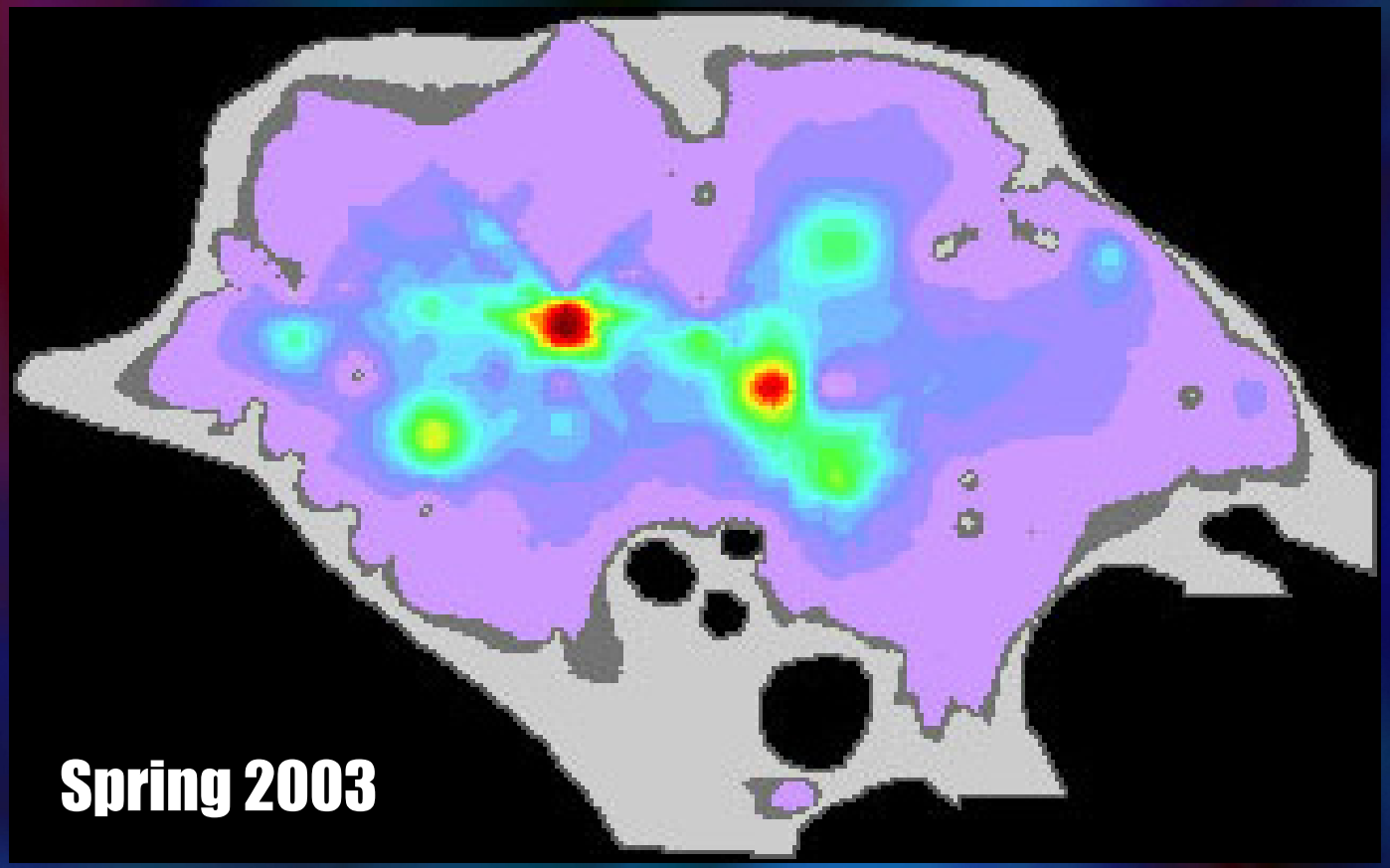

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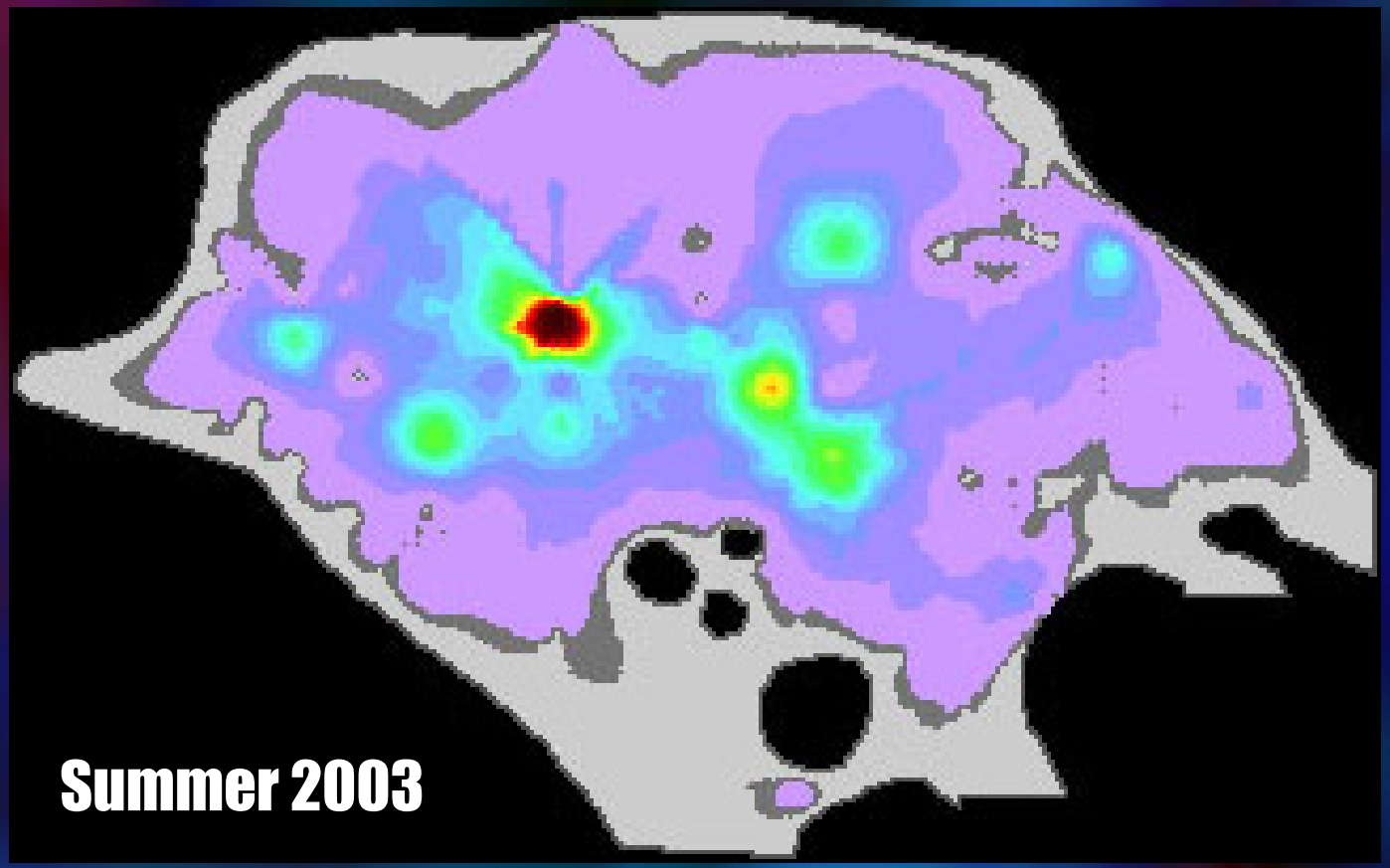

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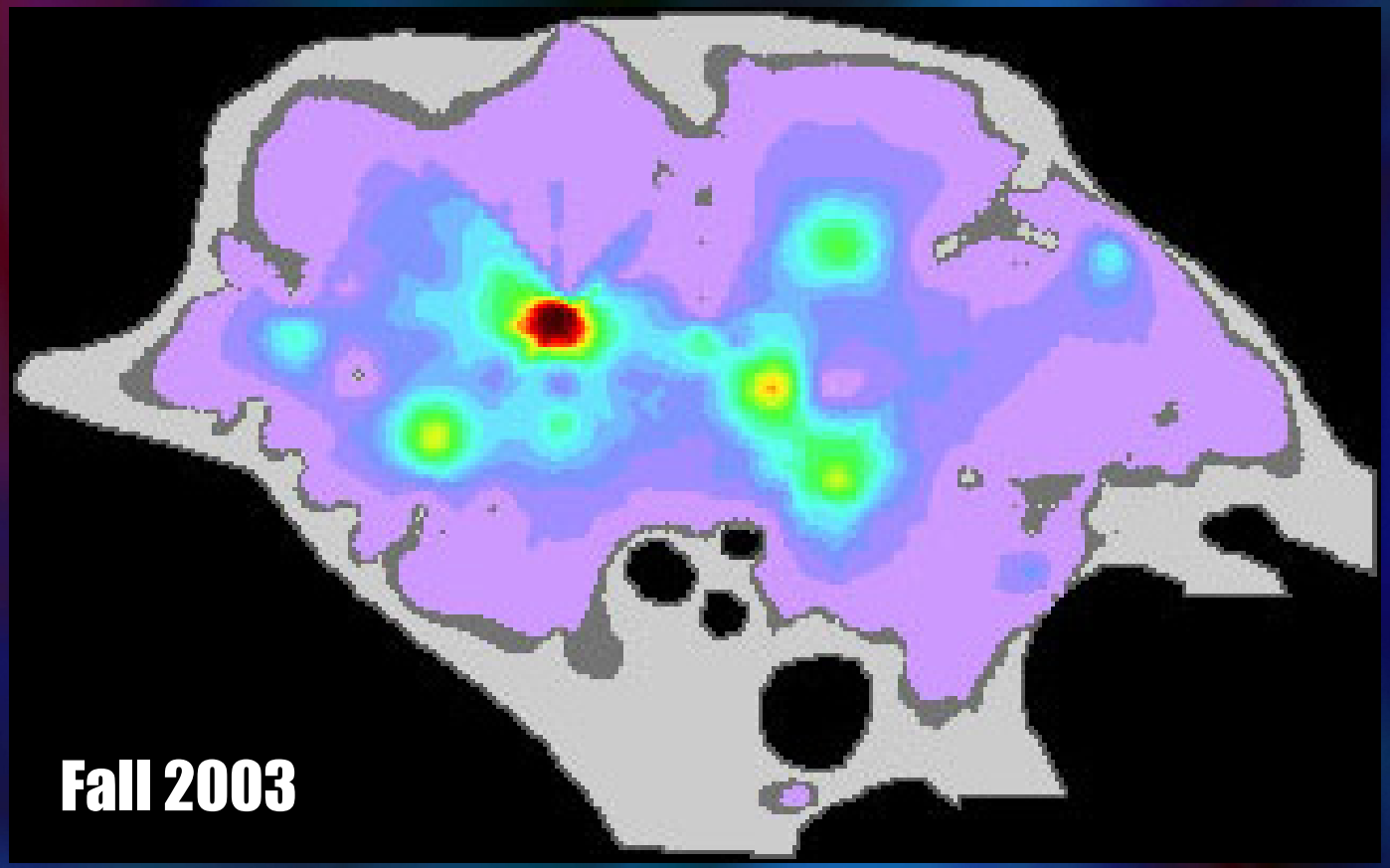

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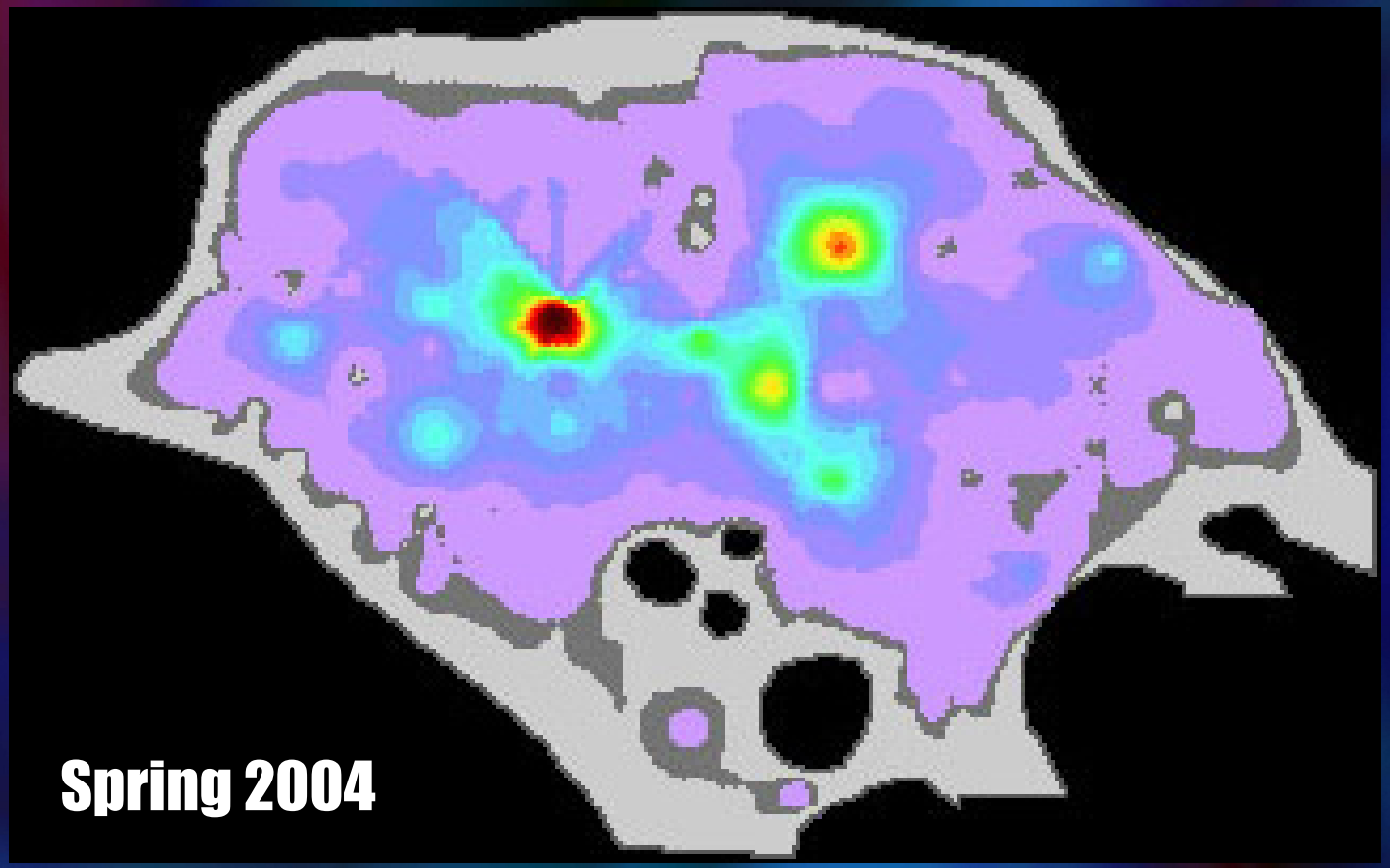

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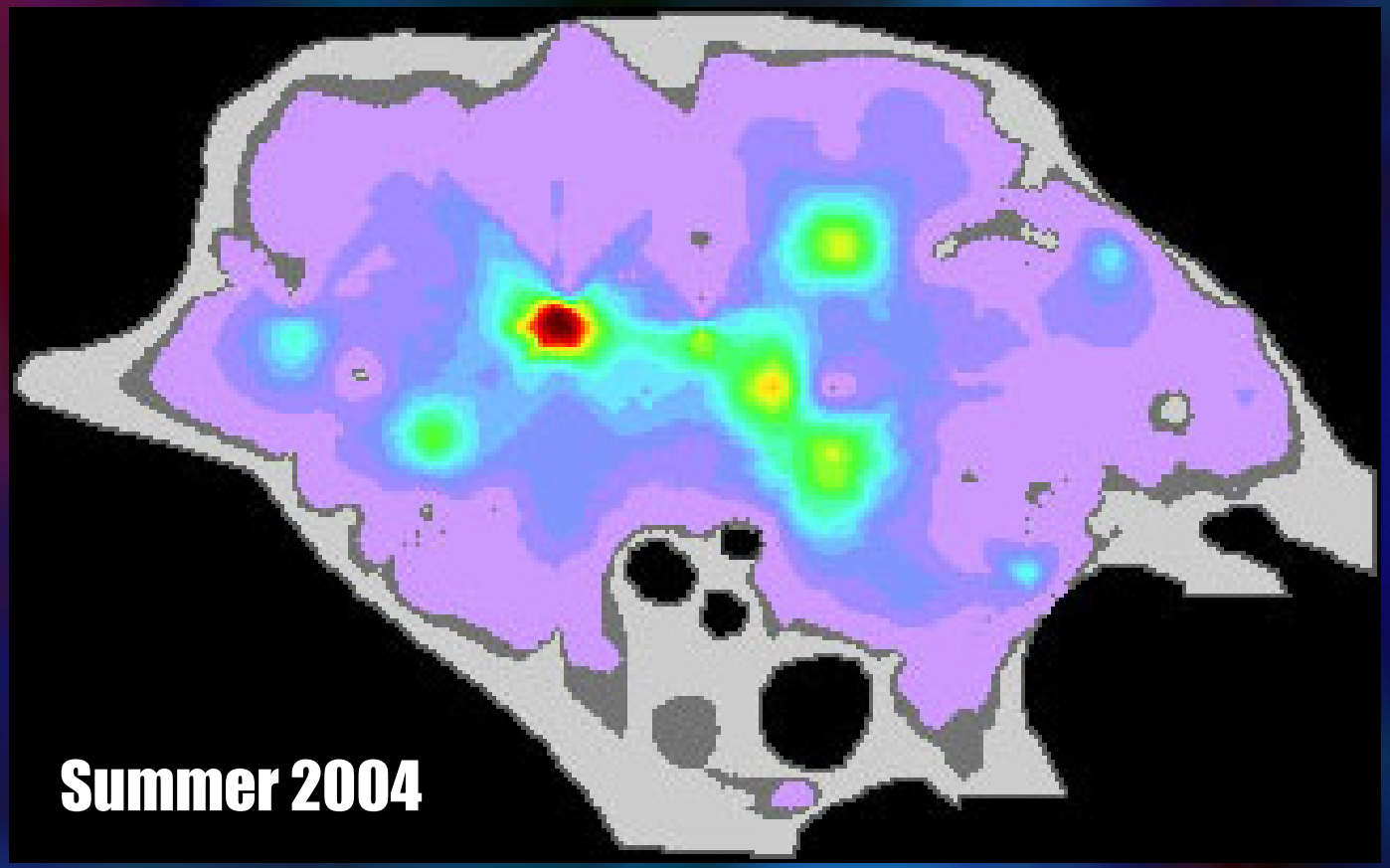
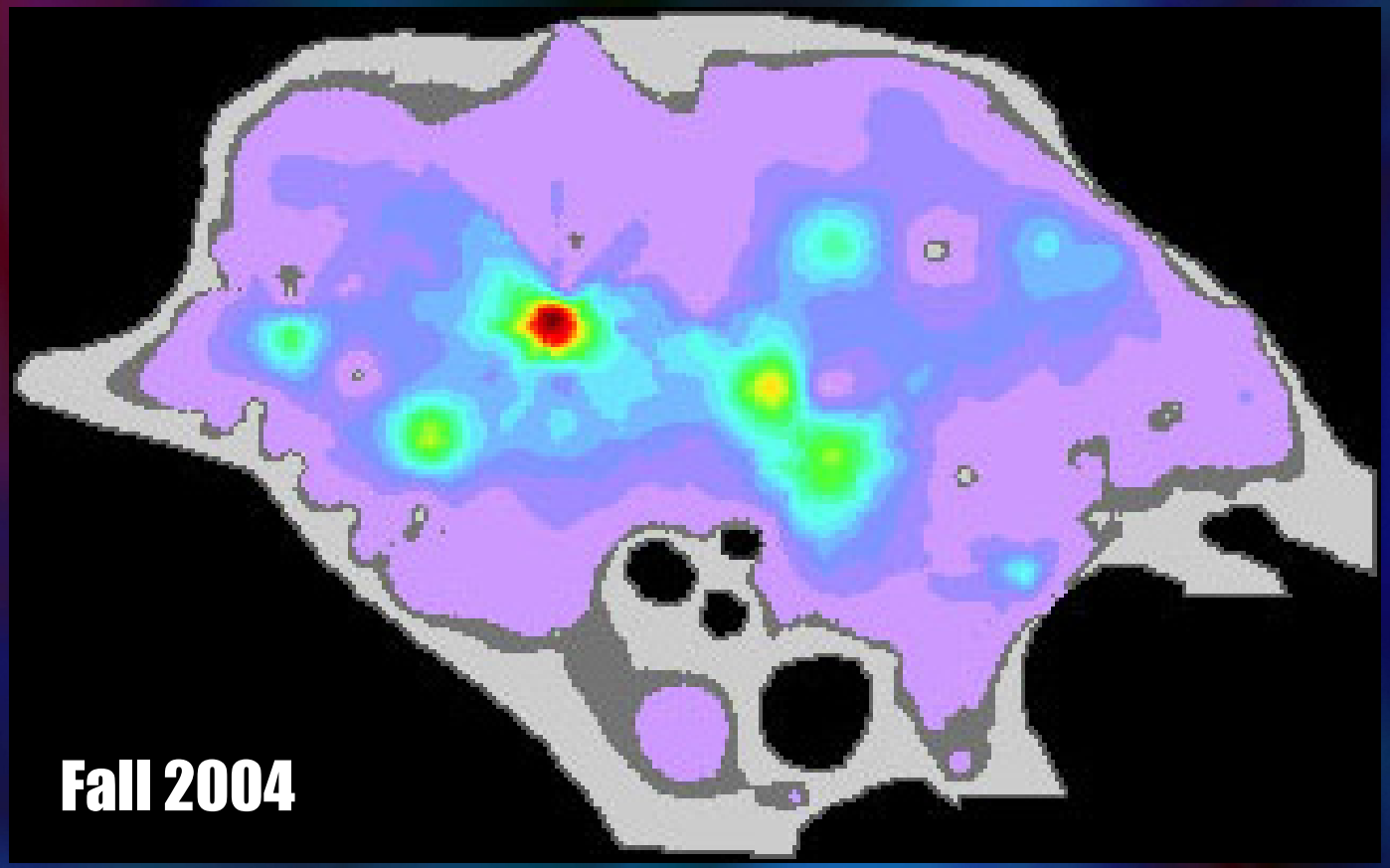


0 650 1300 1950 2600

TOTAL N - Pounds Per Acre

Nitrate-N Load



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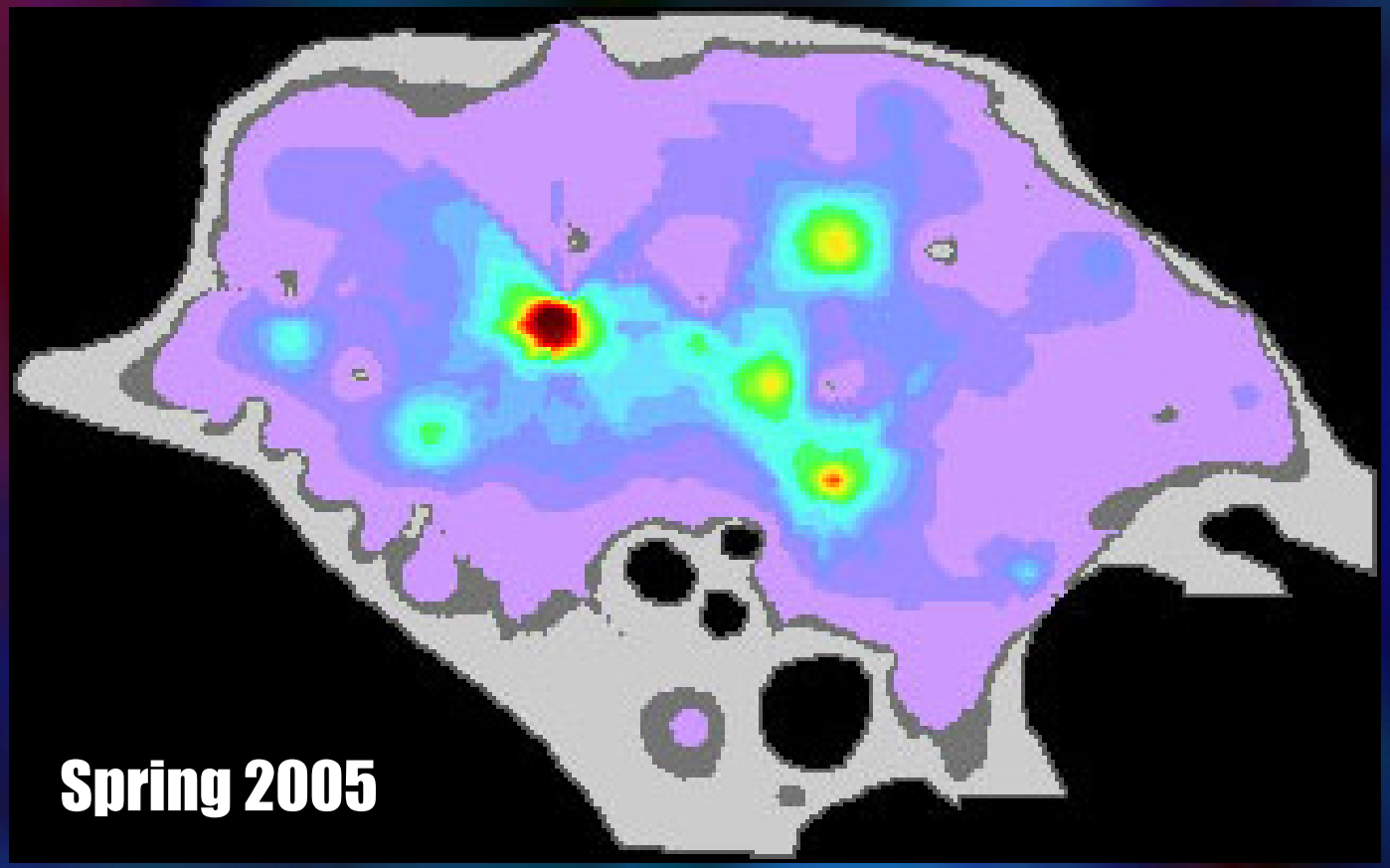

TOTAL N - Pounds Per Acre

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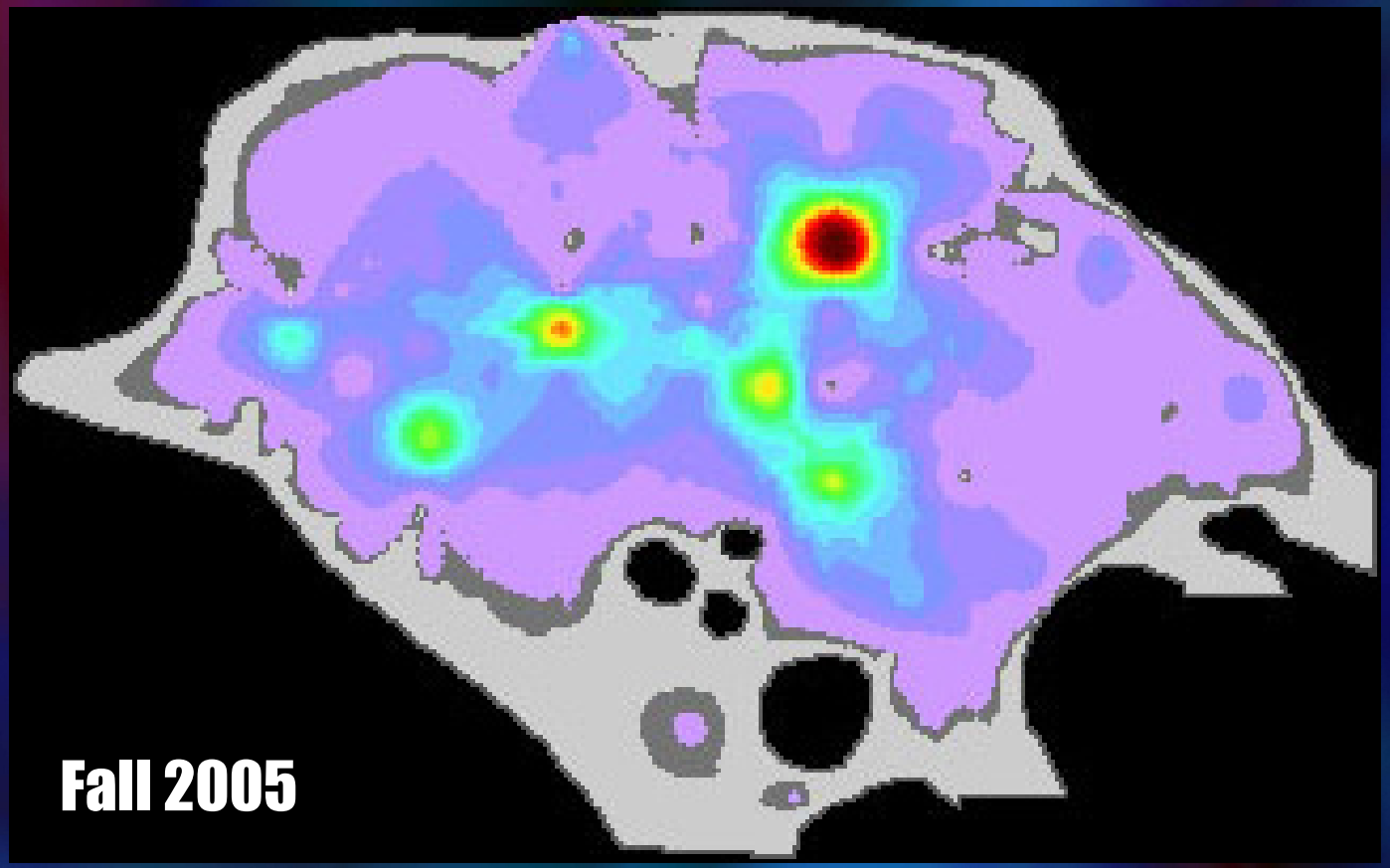

TOTAL N - Pounds Per Acre

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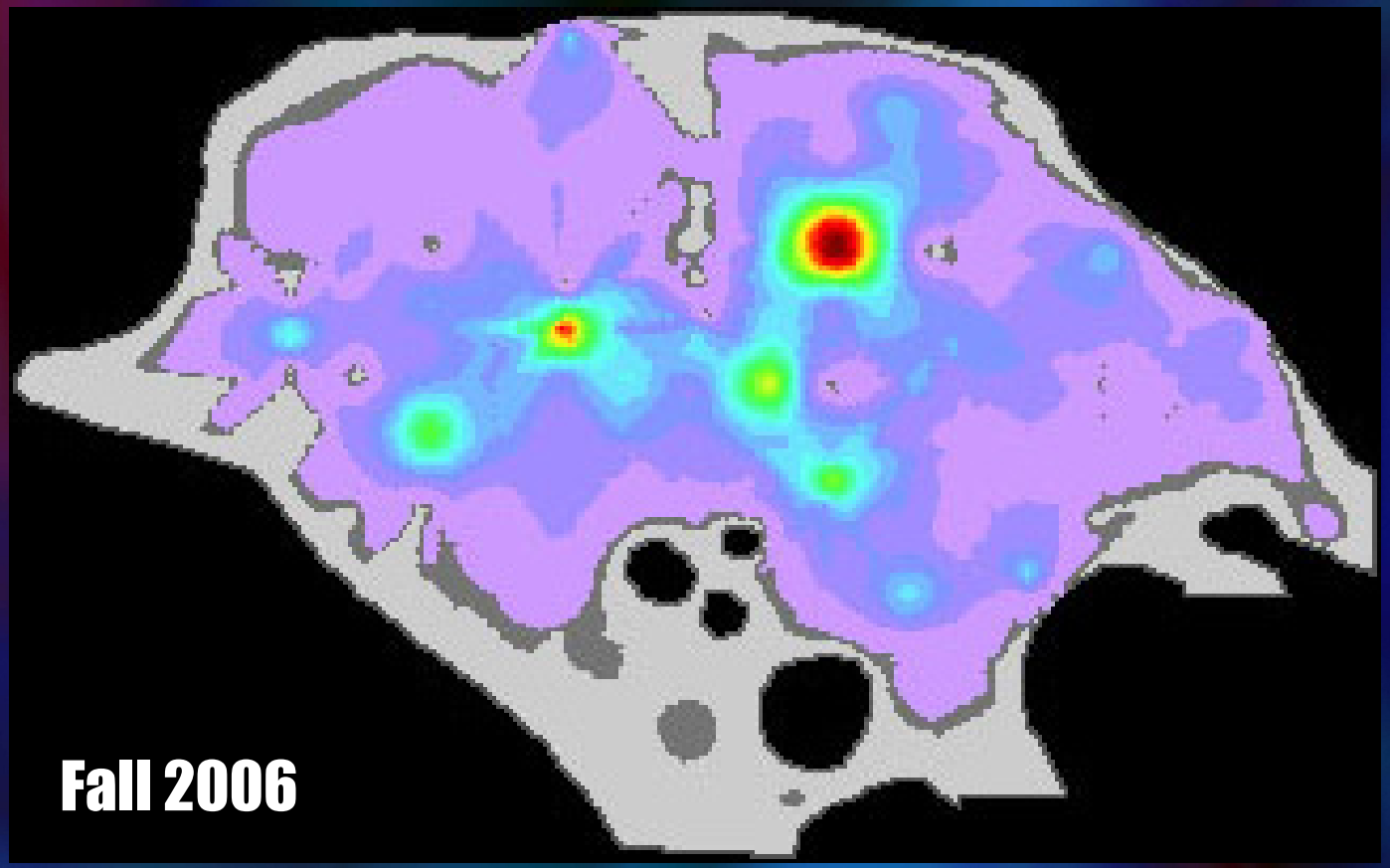

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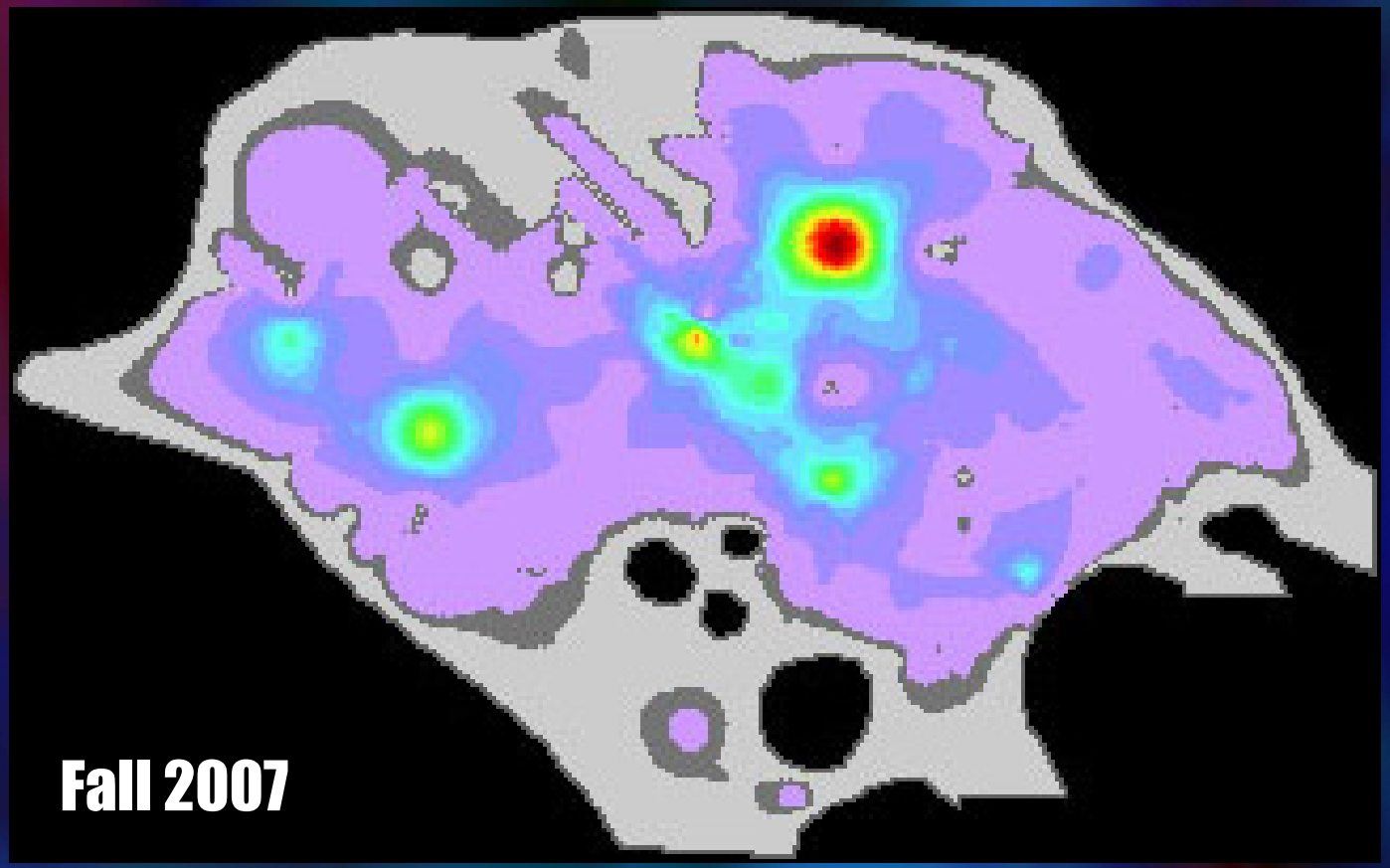
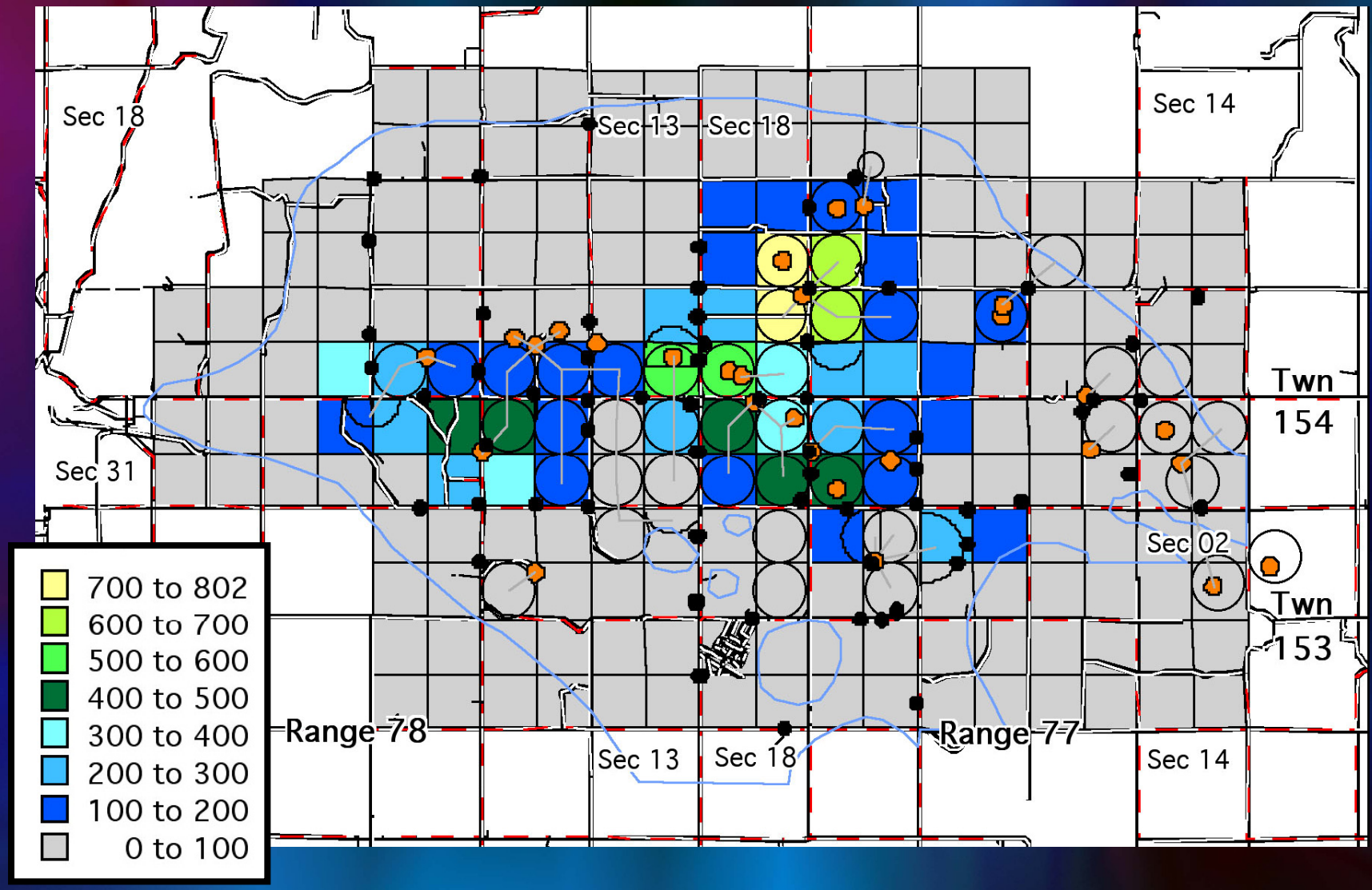
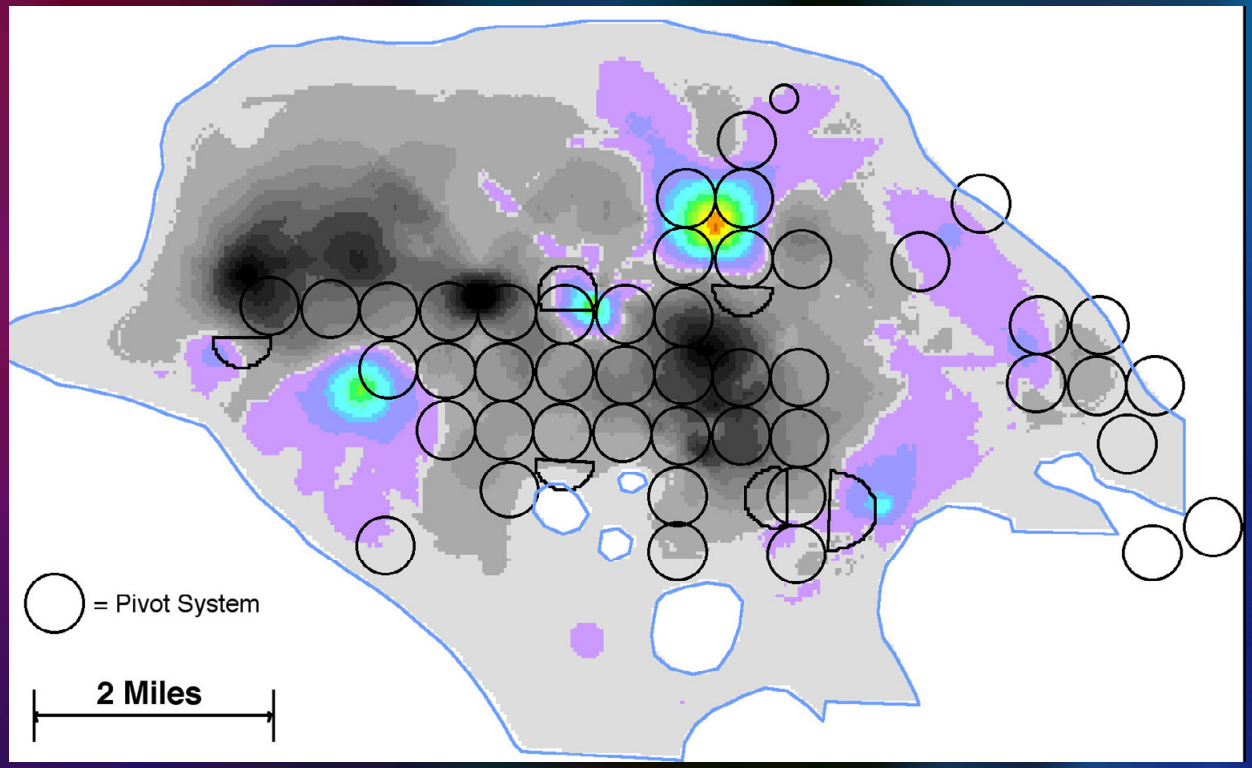


TOTAL N - Pounds Per Acre

Nitrate-N Load by Quarter Section, Karlsruhe Study Area





Delta Map: Pounds Per Acre Change

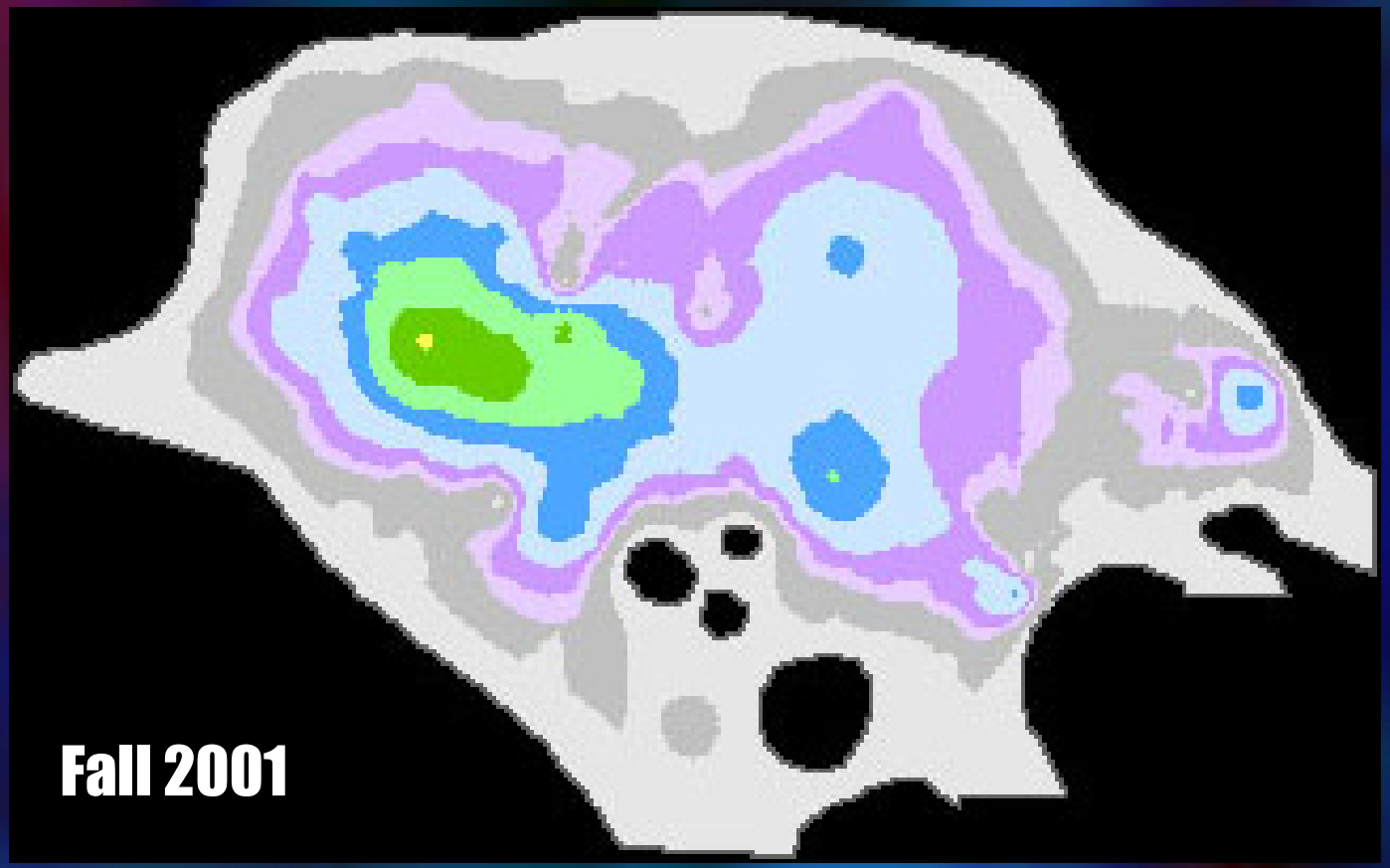
Legend of Total nitrate-N Differences (lbs. Per Acre)

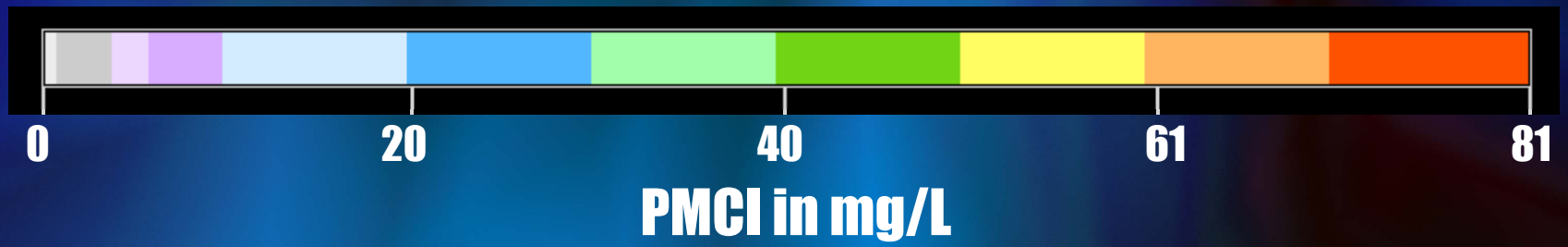
-1240 to -920	-119 to -20	720 to 819
-919 to -820	-19 to 19	820 to 919
-819 to -720	20 to 119	920 to 1019
-719 to -620	120 to 219	1020 to 1119
-619 to -520	220 to 319	1120 to 1219
-519 to -420	320 to 419	1220 to 1319
-419 to -320	420 to 519	1320 to 1330
-319 to -220	520 to 619	
-219 to -120	620 to 719	

Toxicological Assessment

$$PMCI\left(\frac{mg}{L}\right) = \frac{N_t^*}{Z}\left(\frac{mg - ft.}{L}\right) \Big/ ft.$$

Toxicological Assessment





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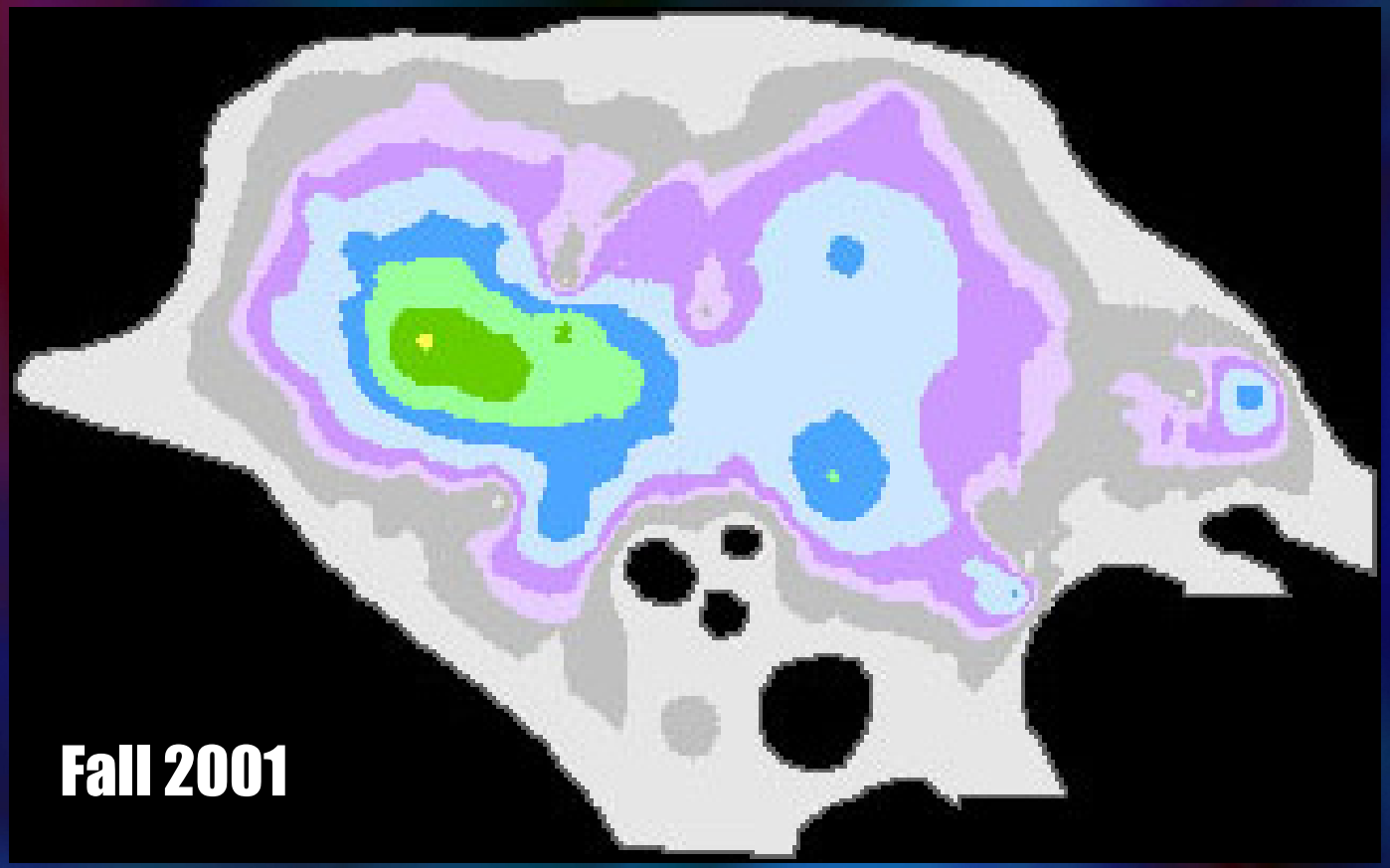

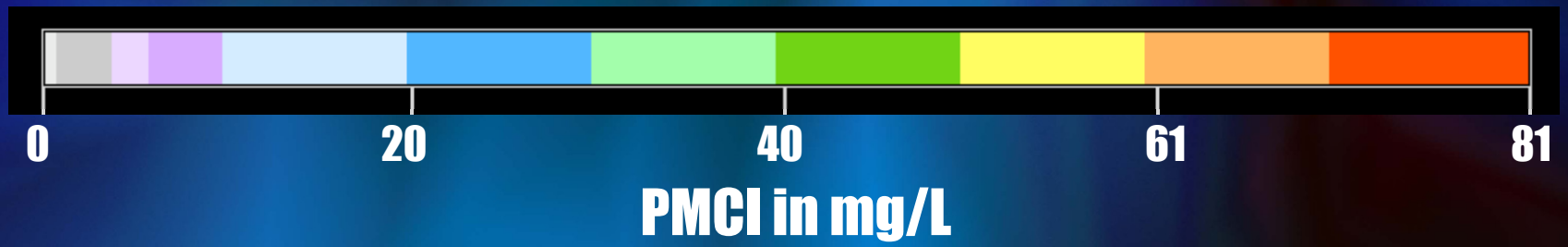

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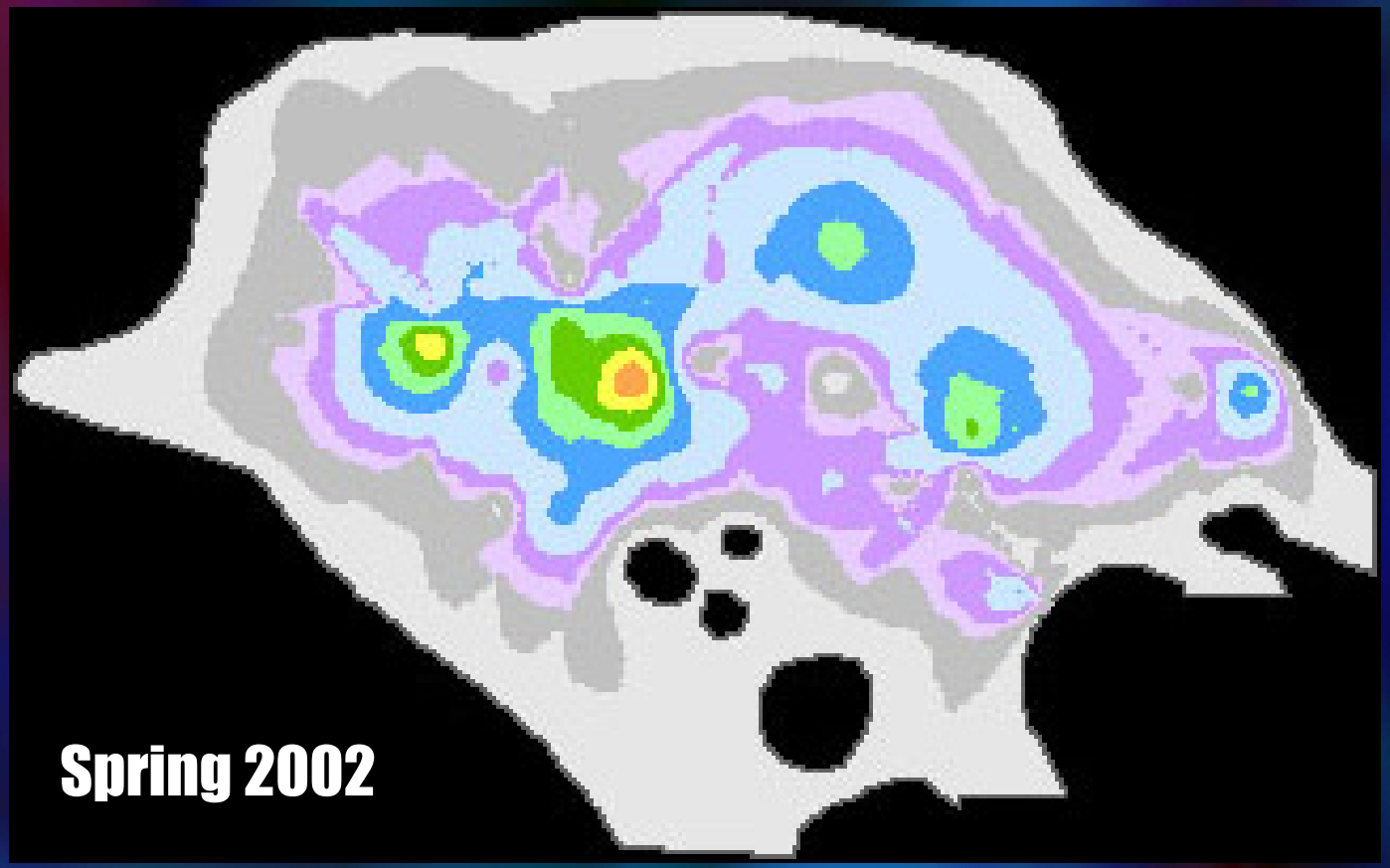

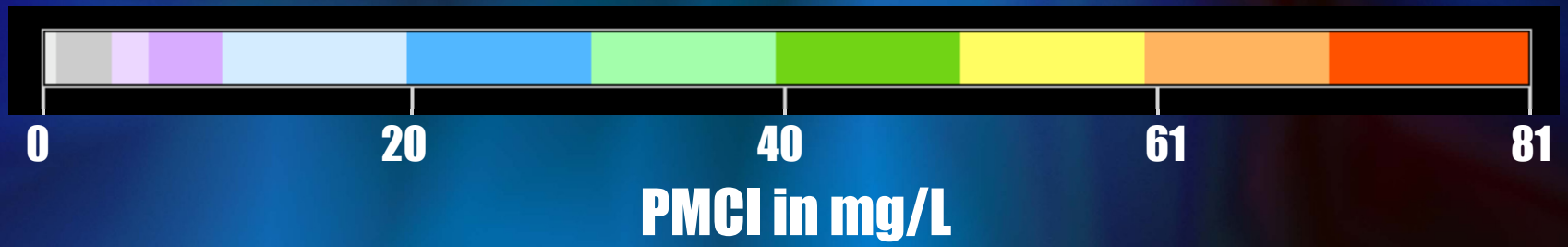

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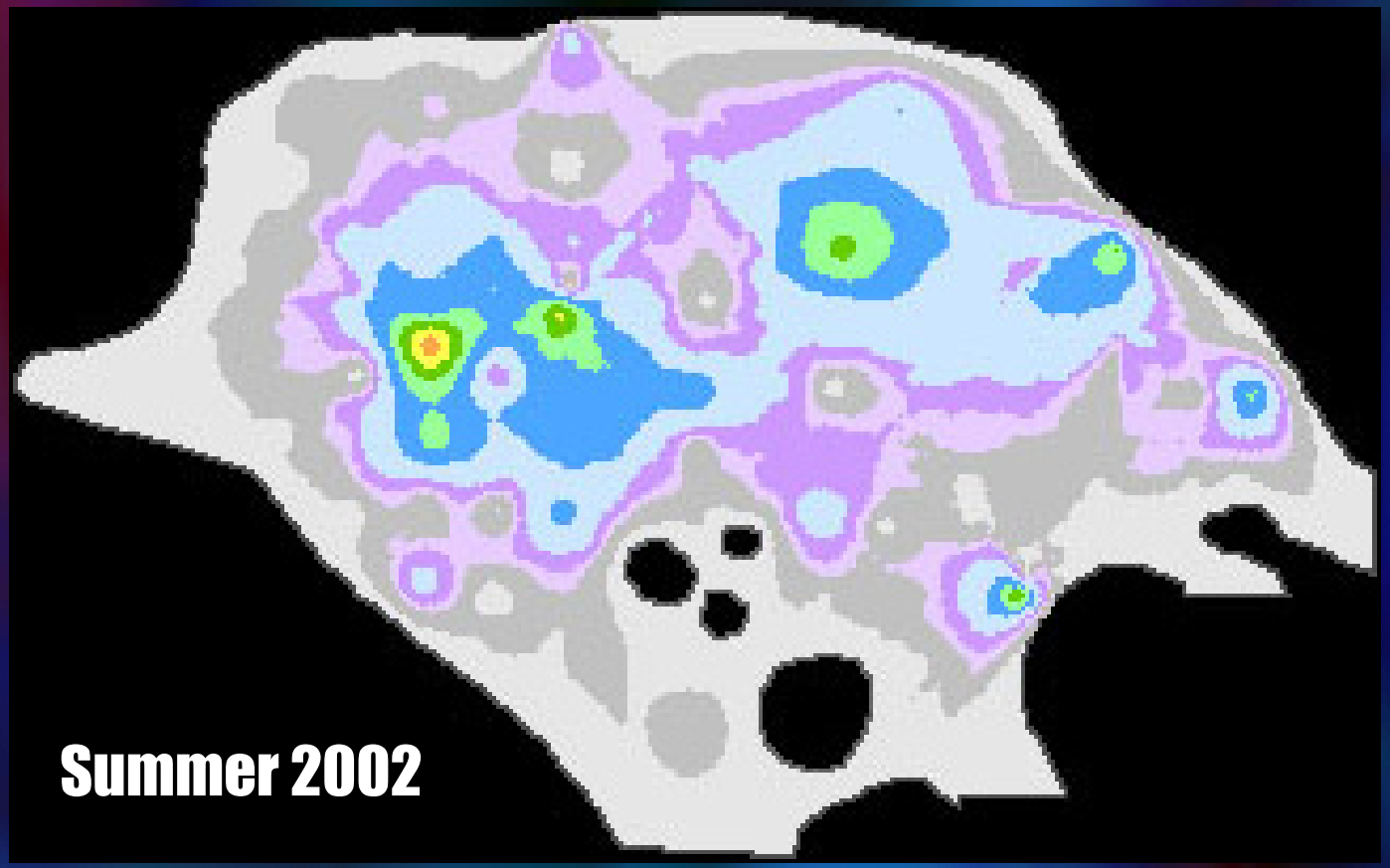

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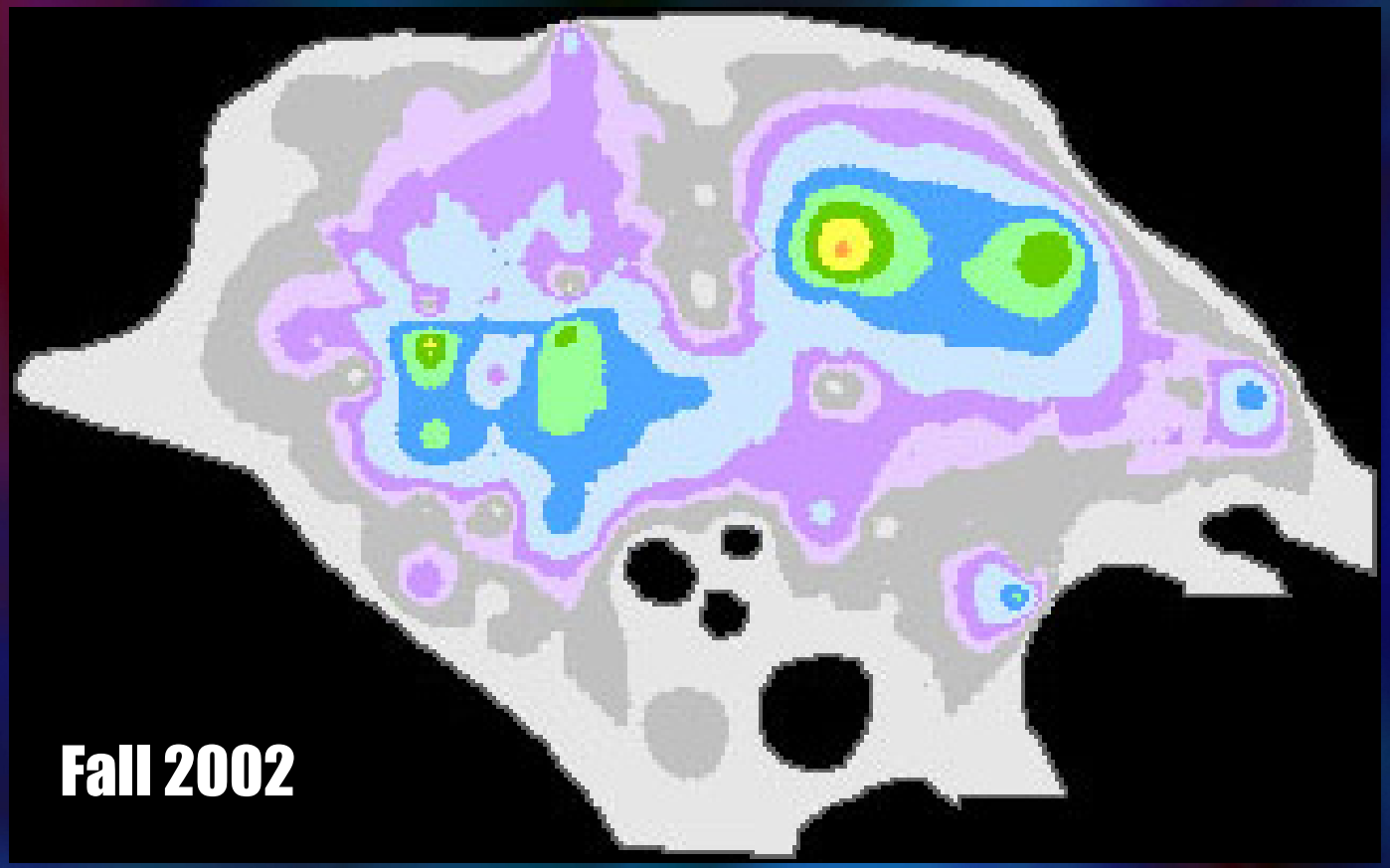

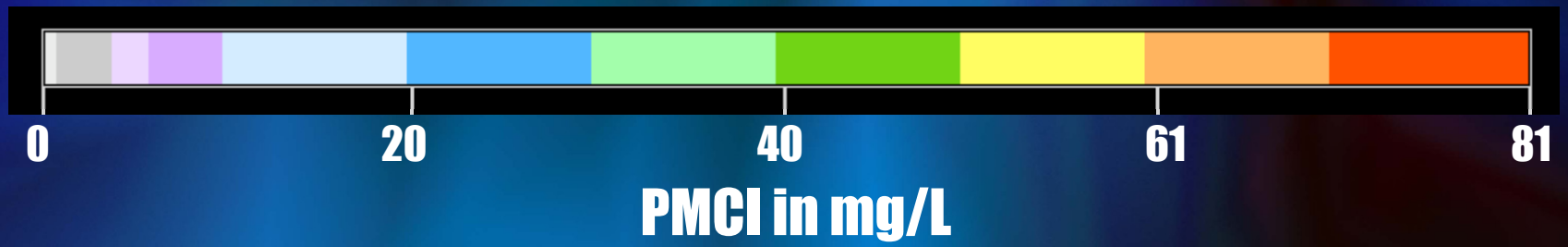

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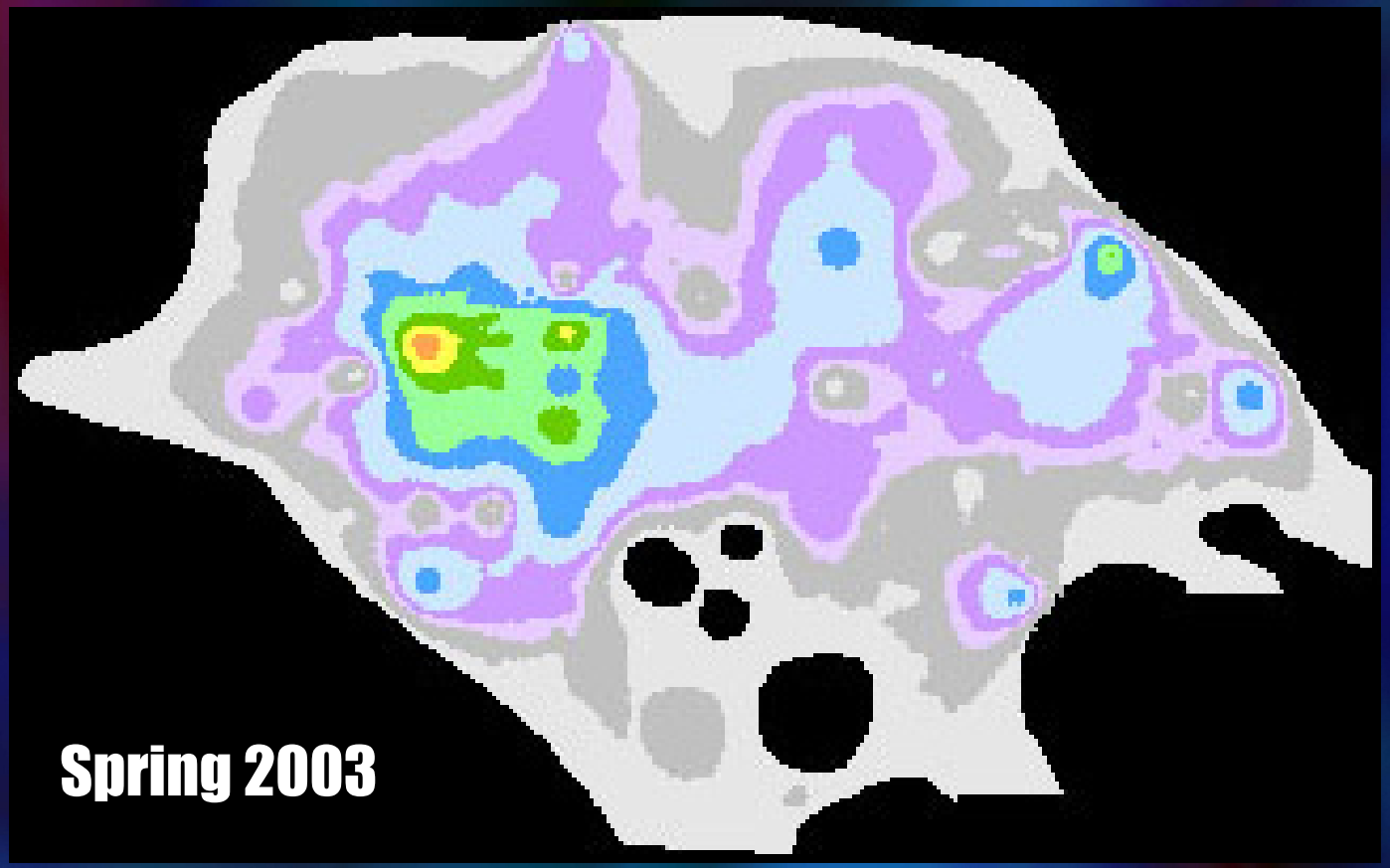

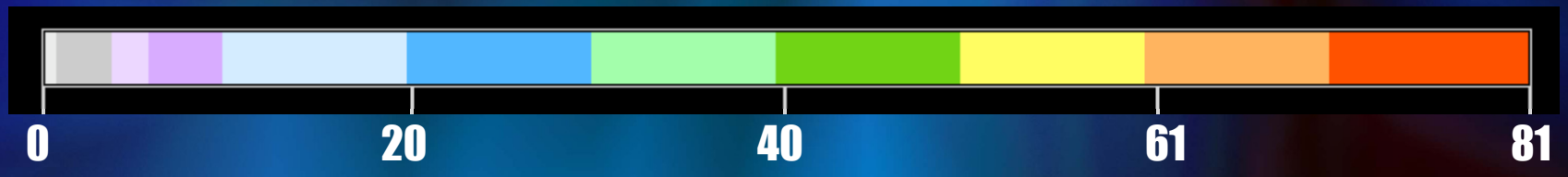

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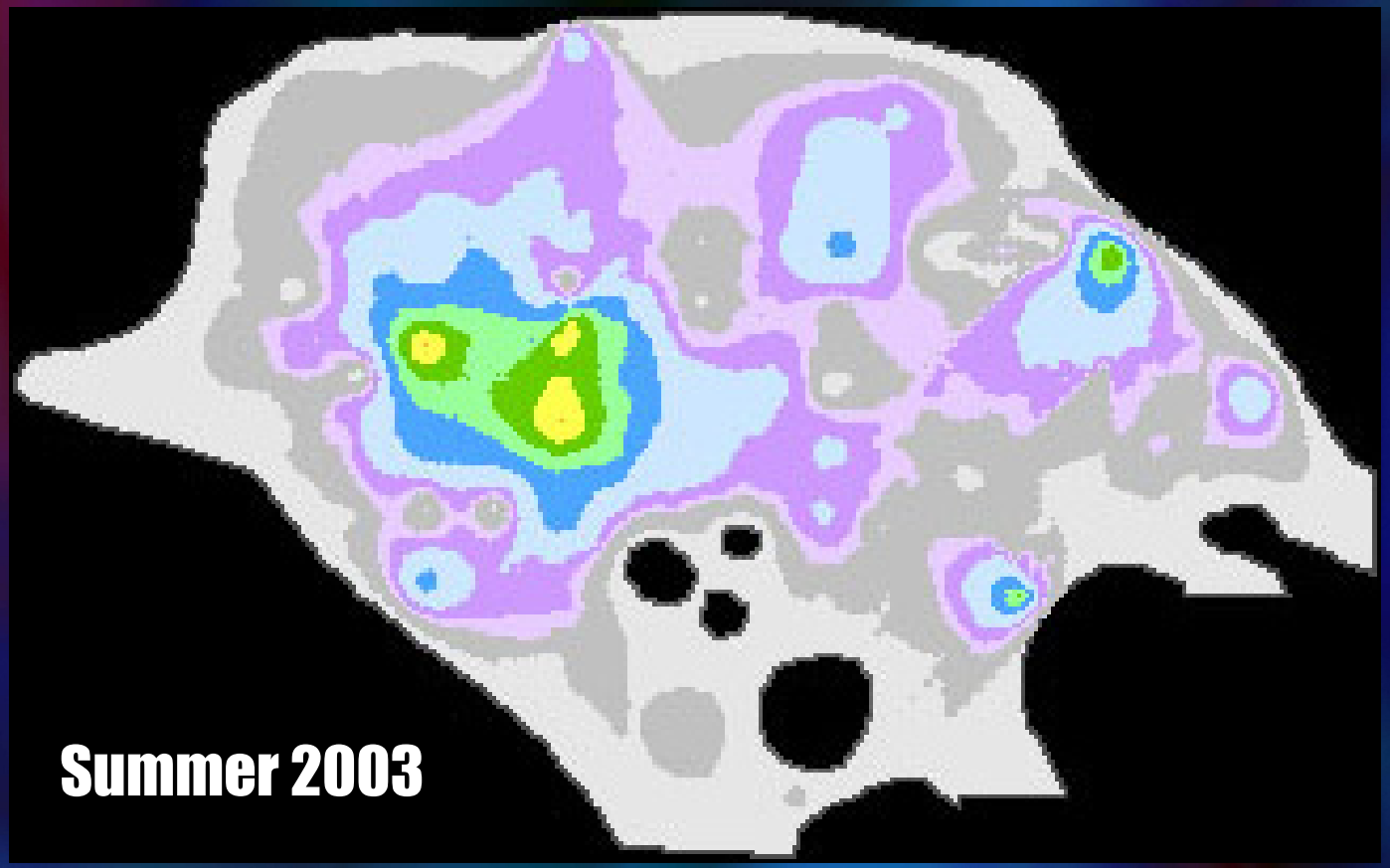

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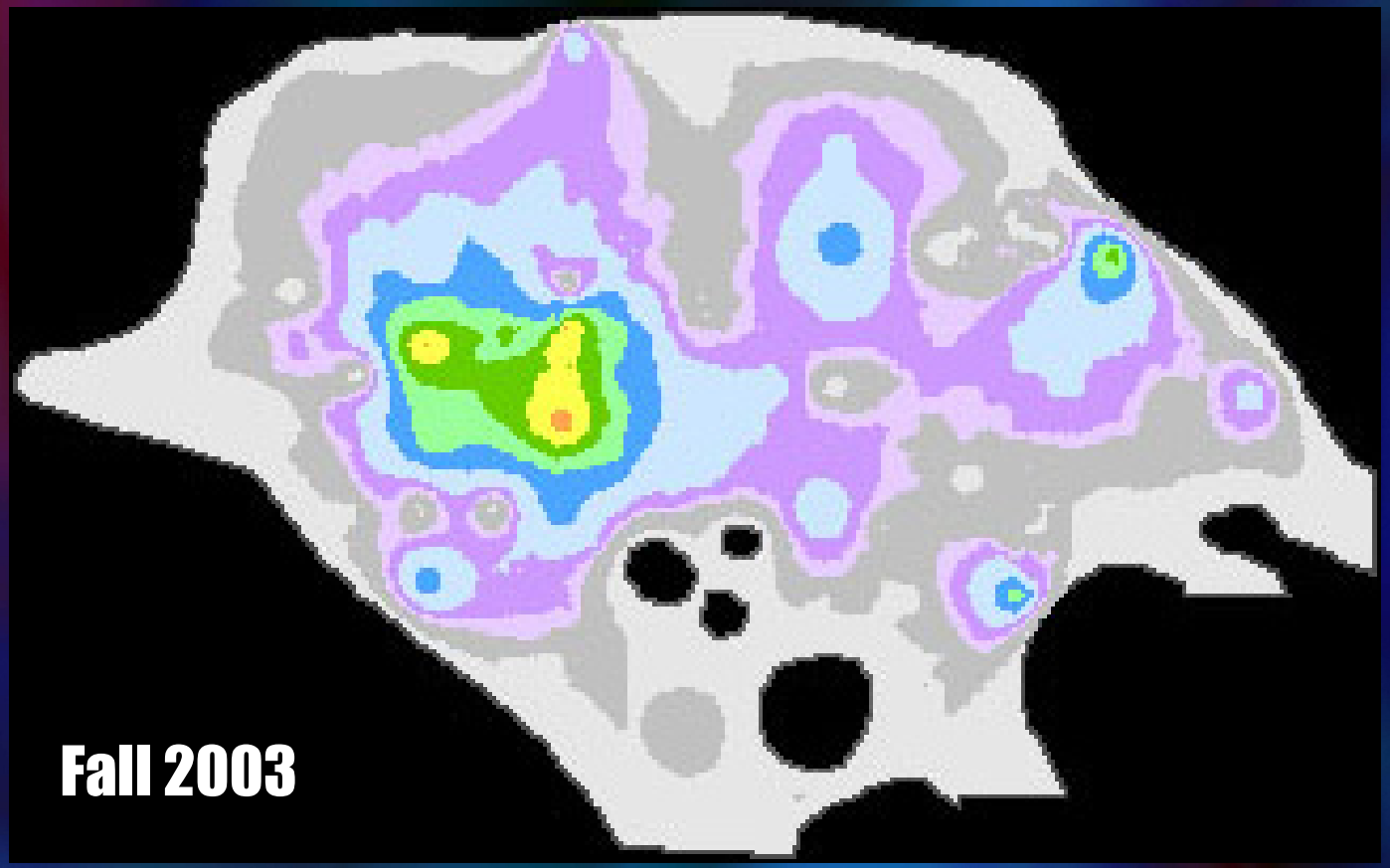

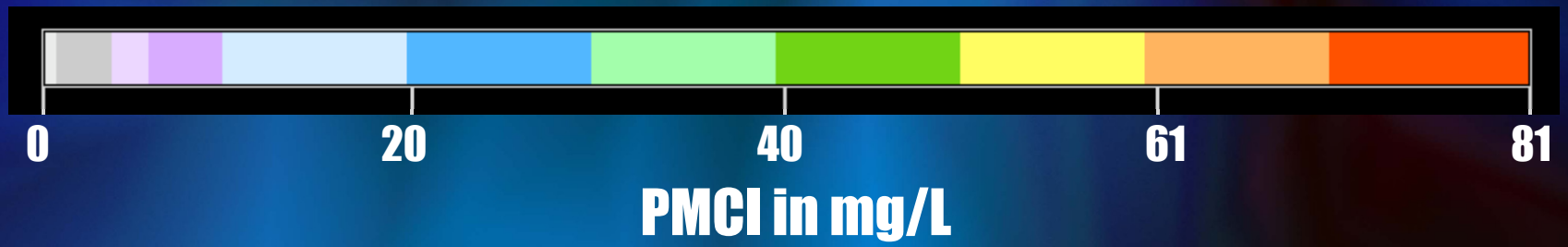

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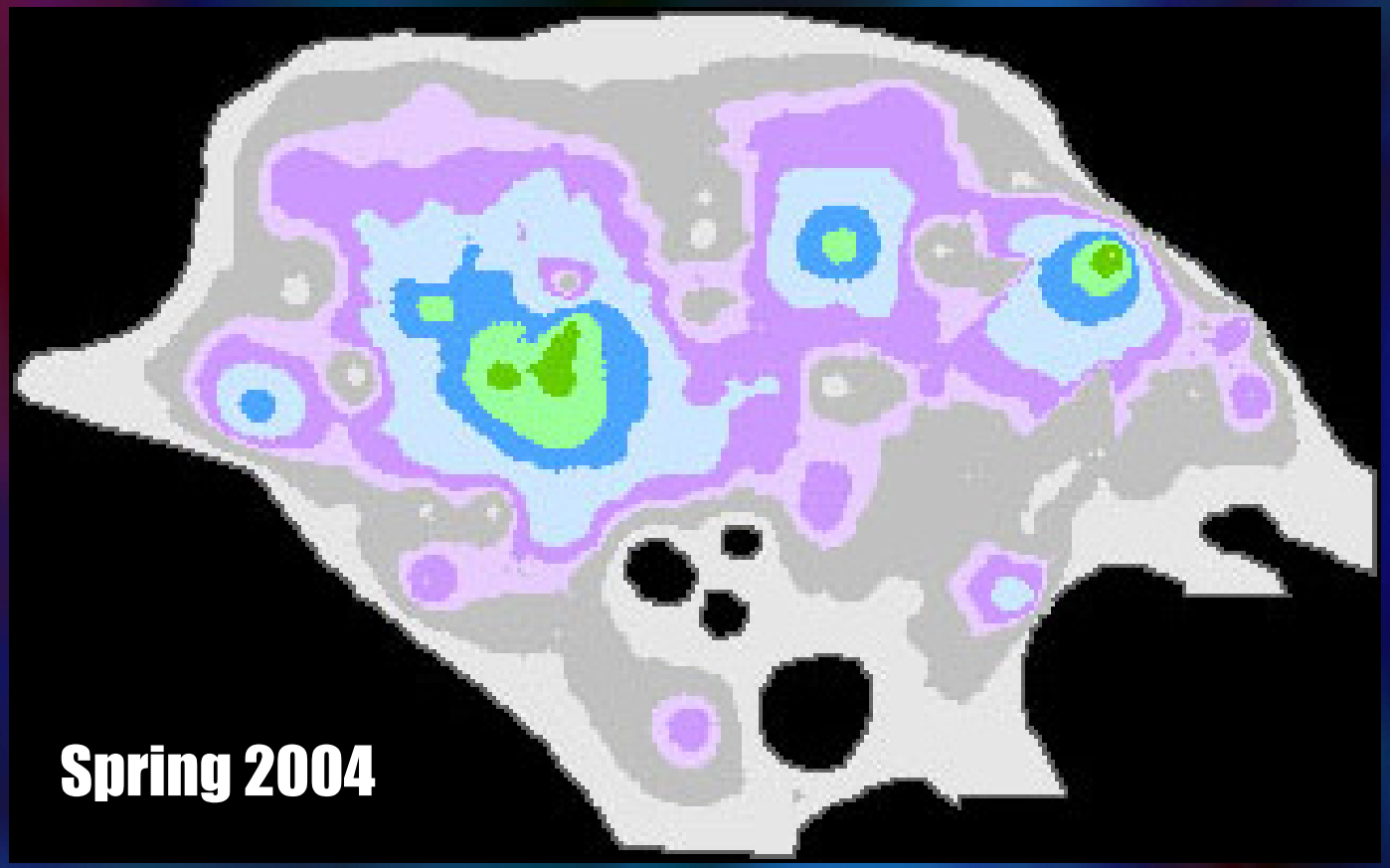

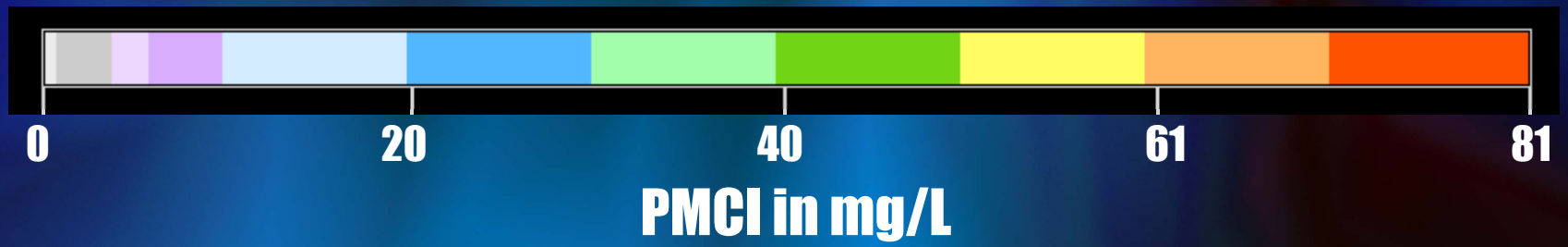

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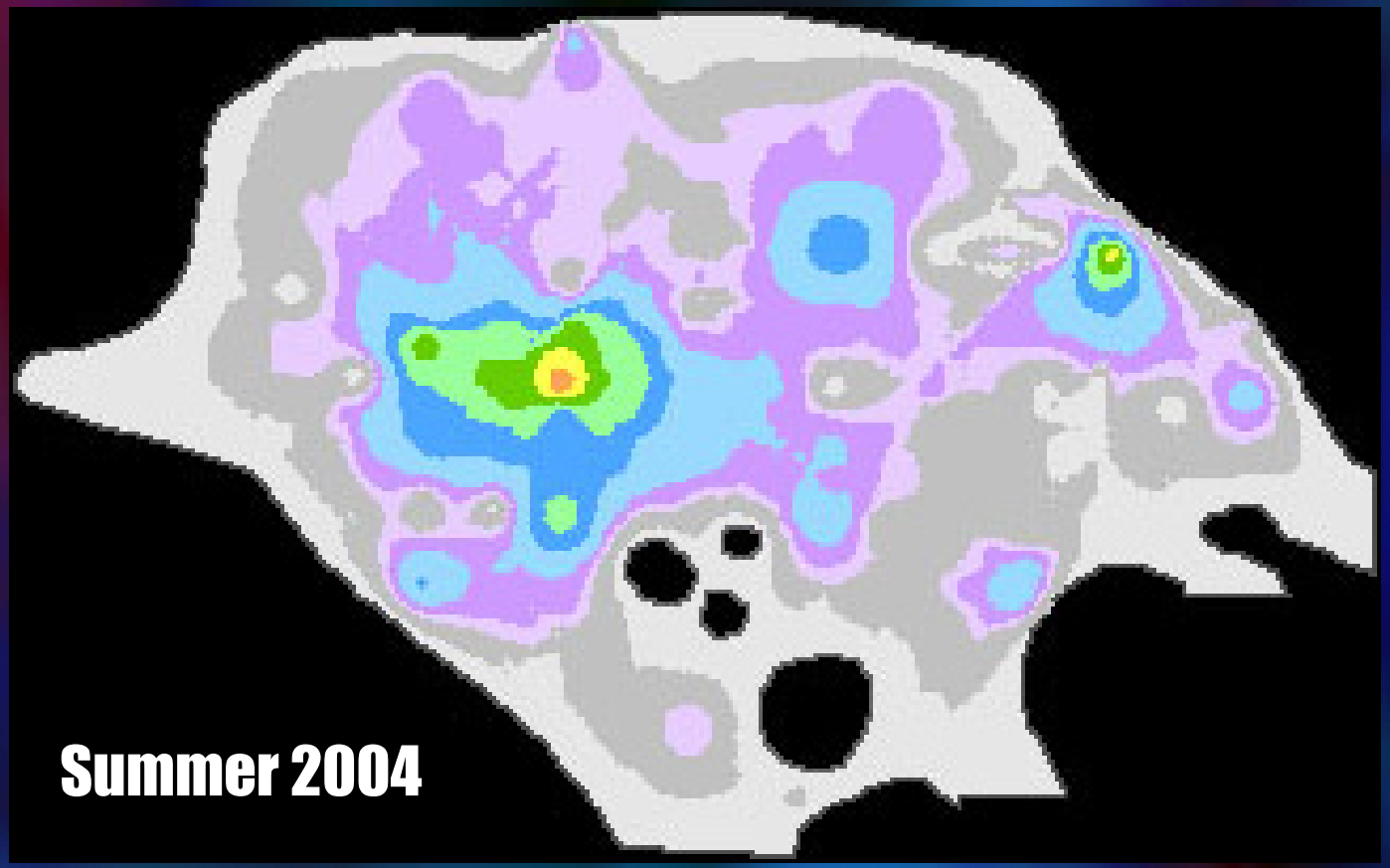

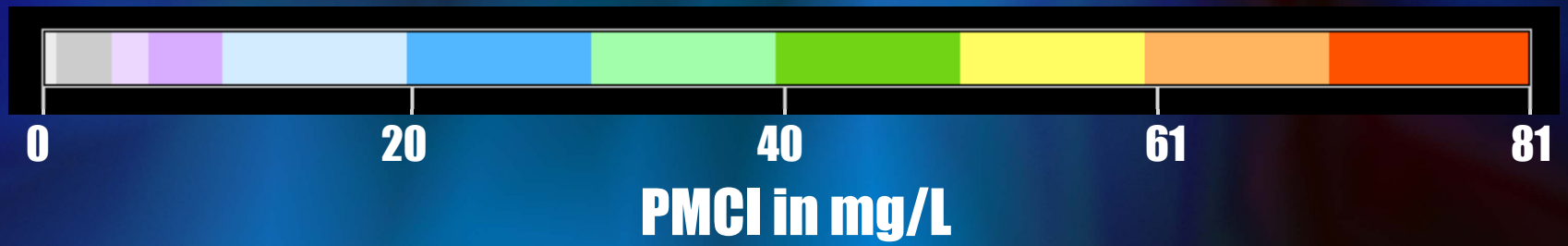

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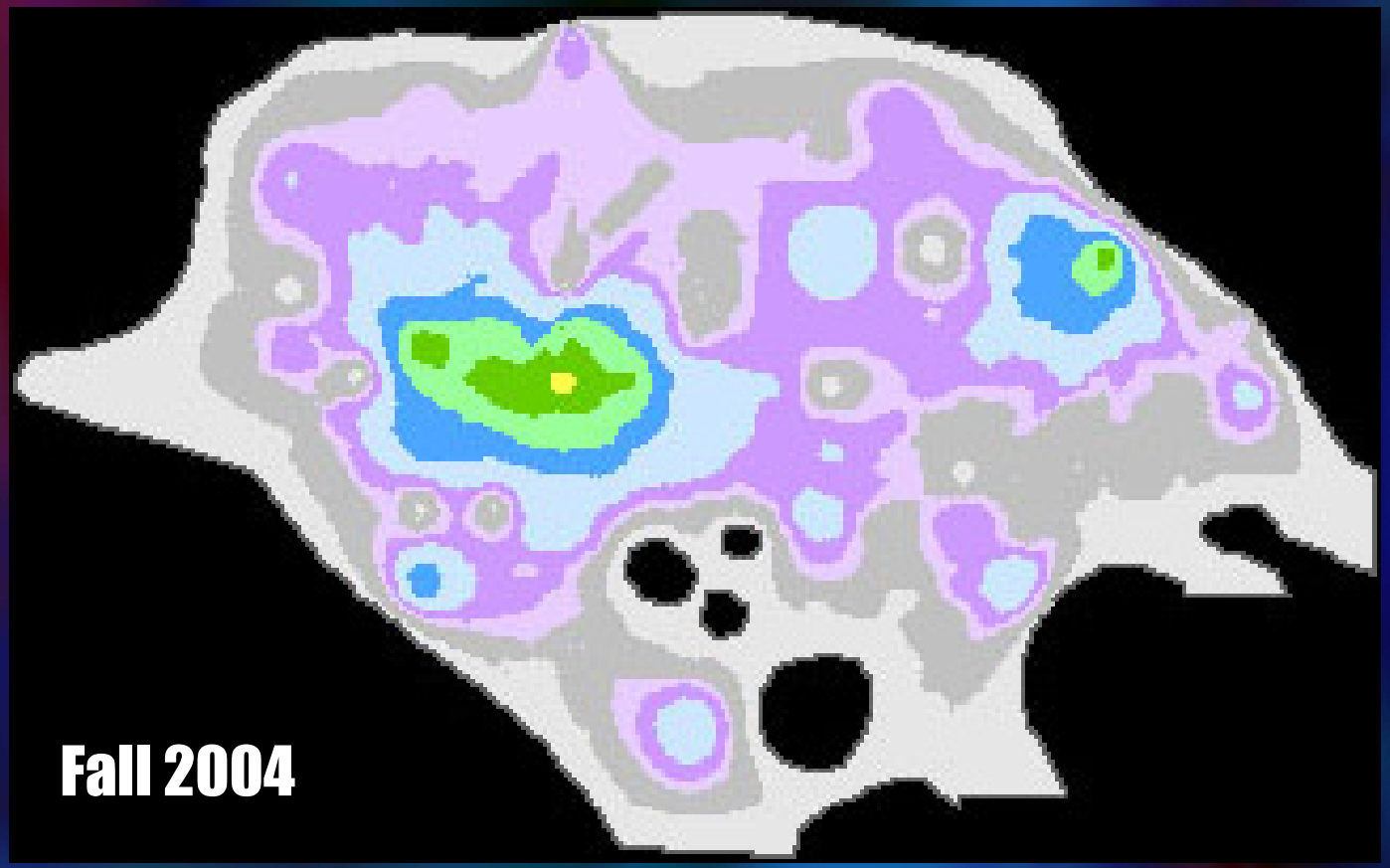

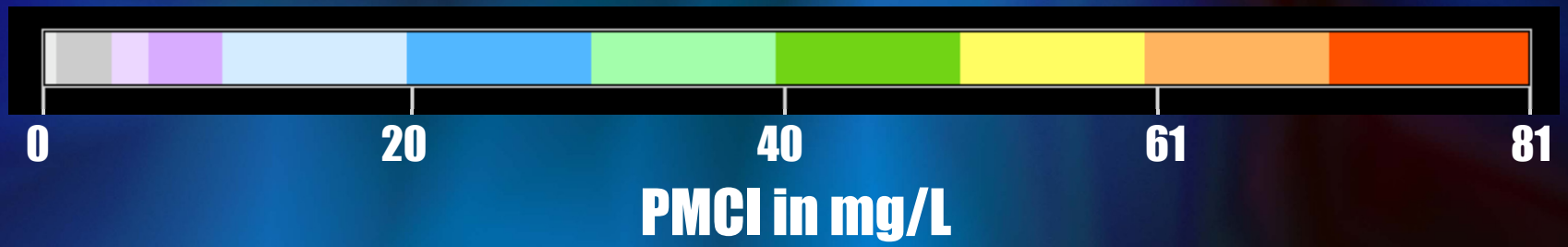

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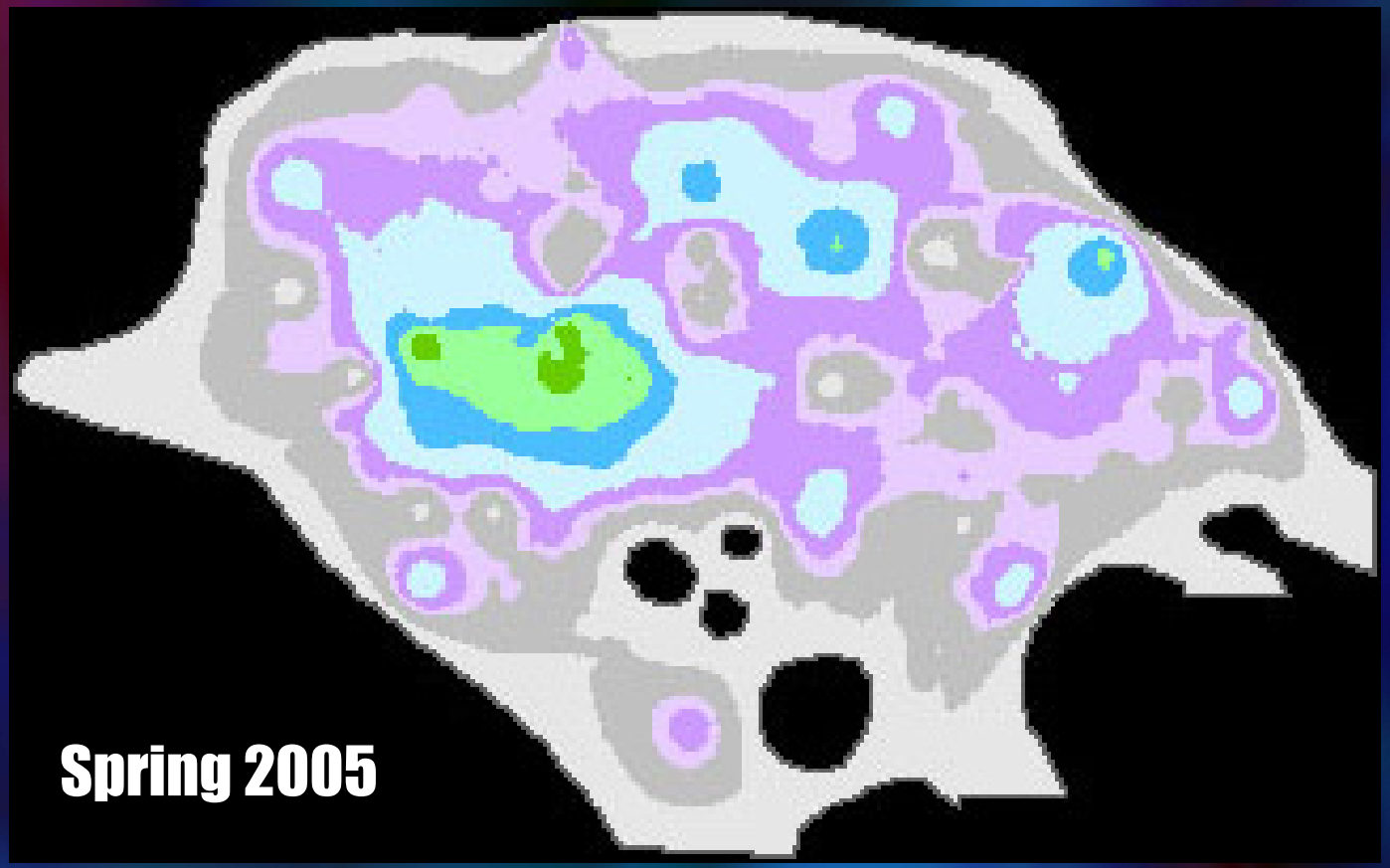

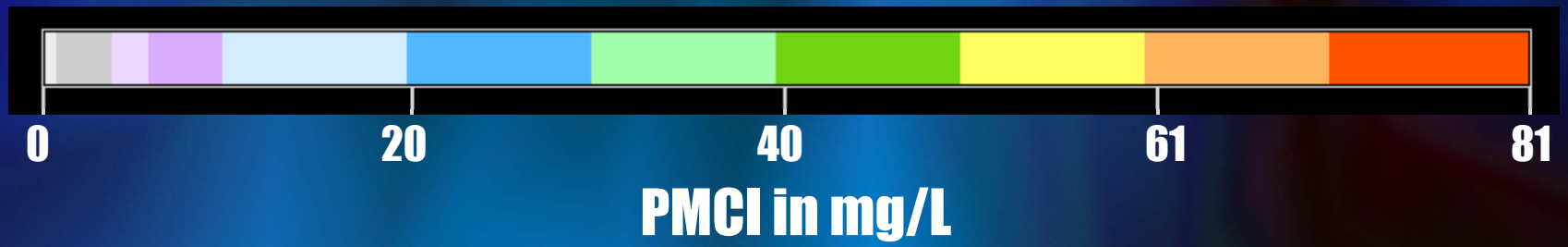

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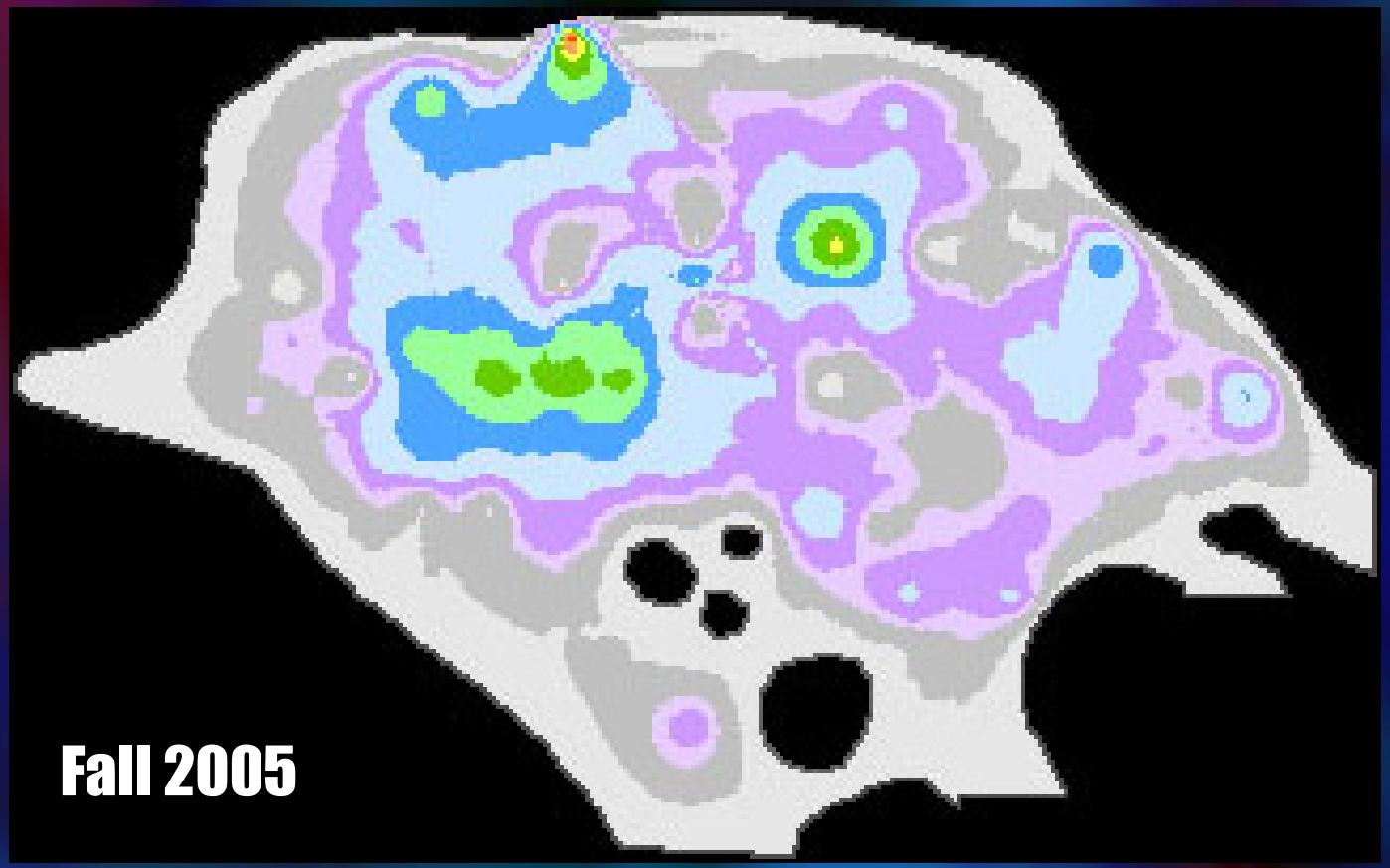

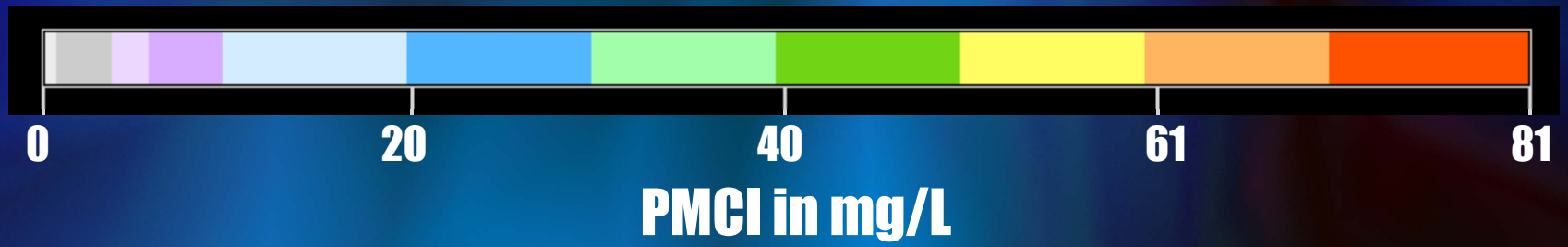

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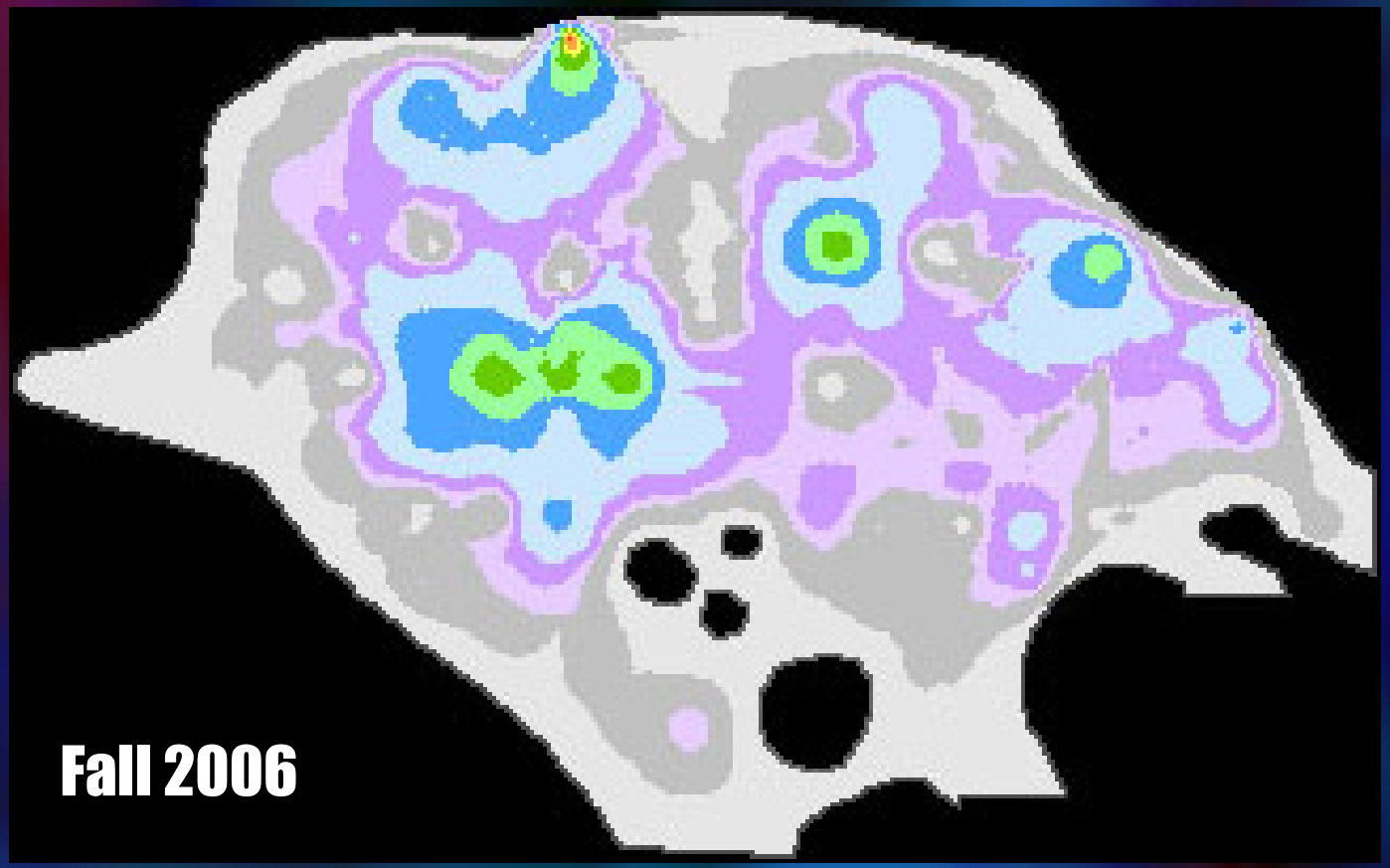
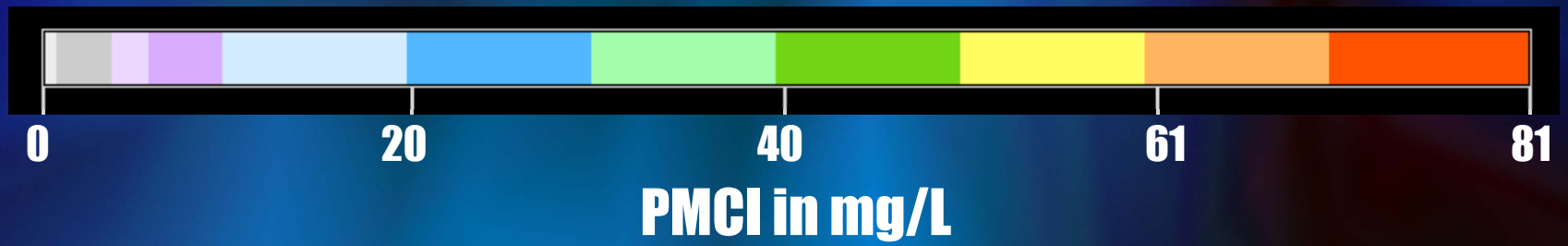
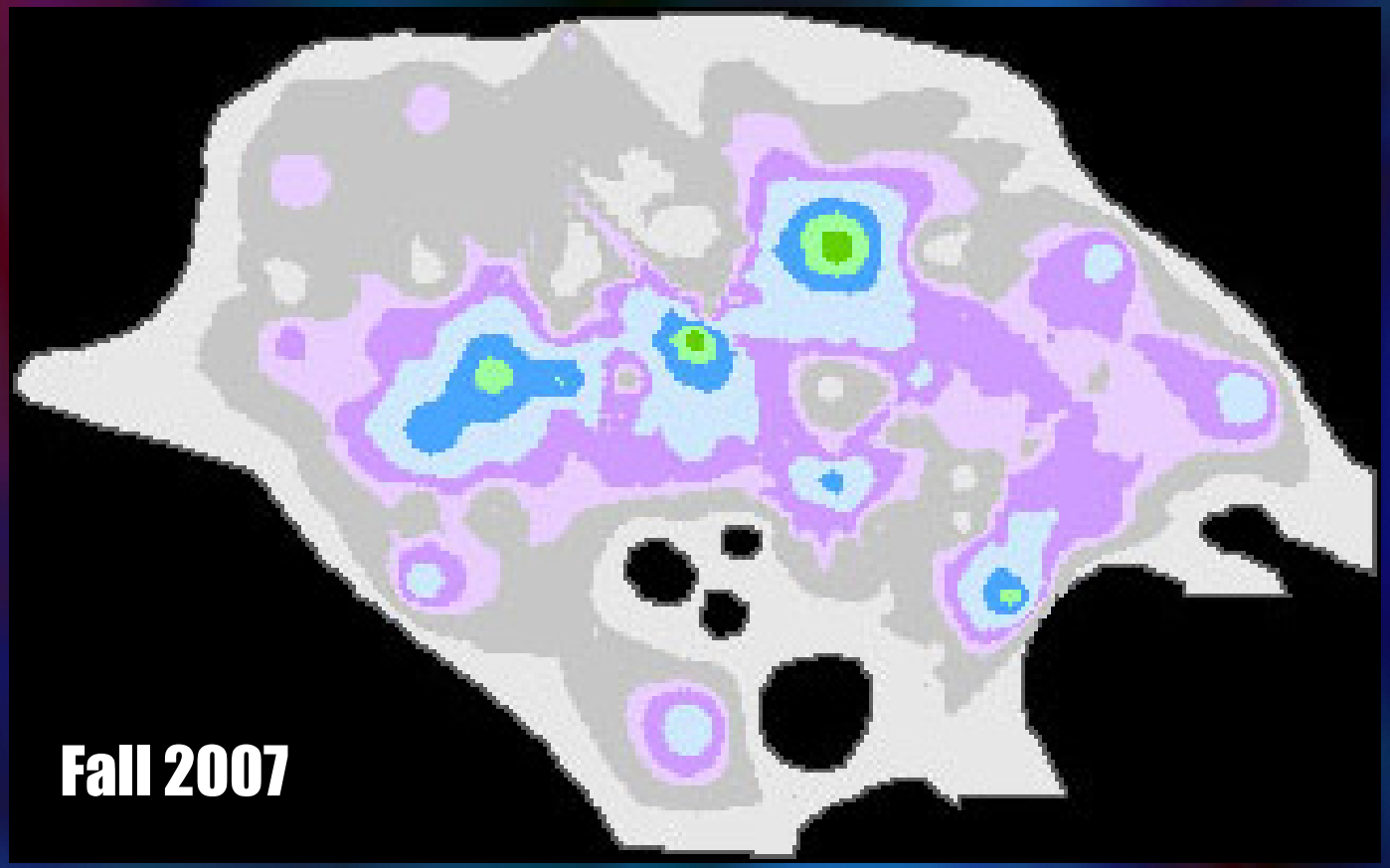
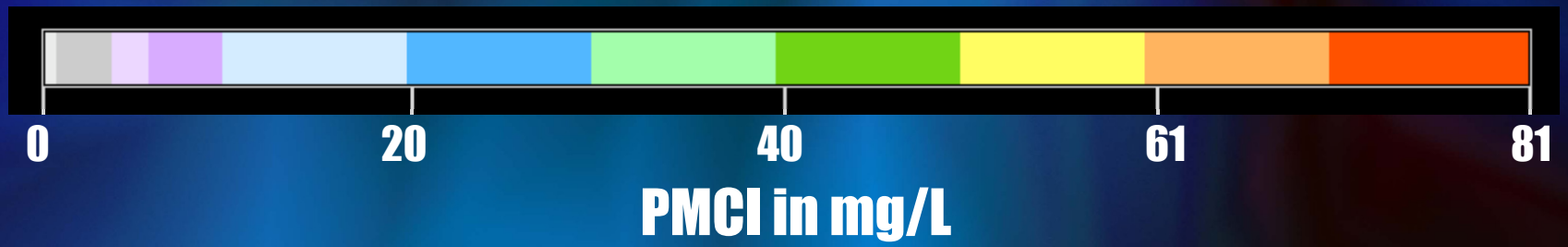


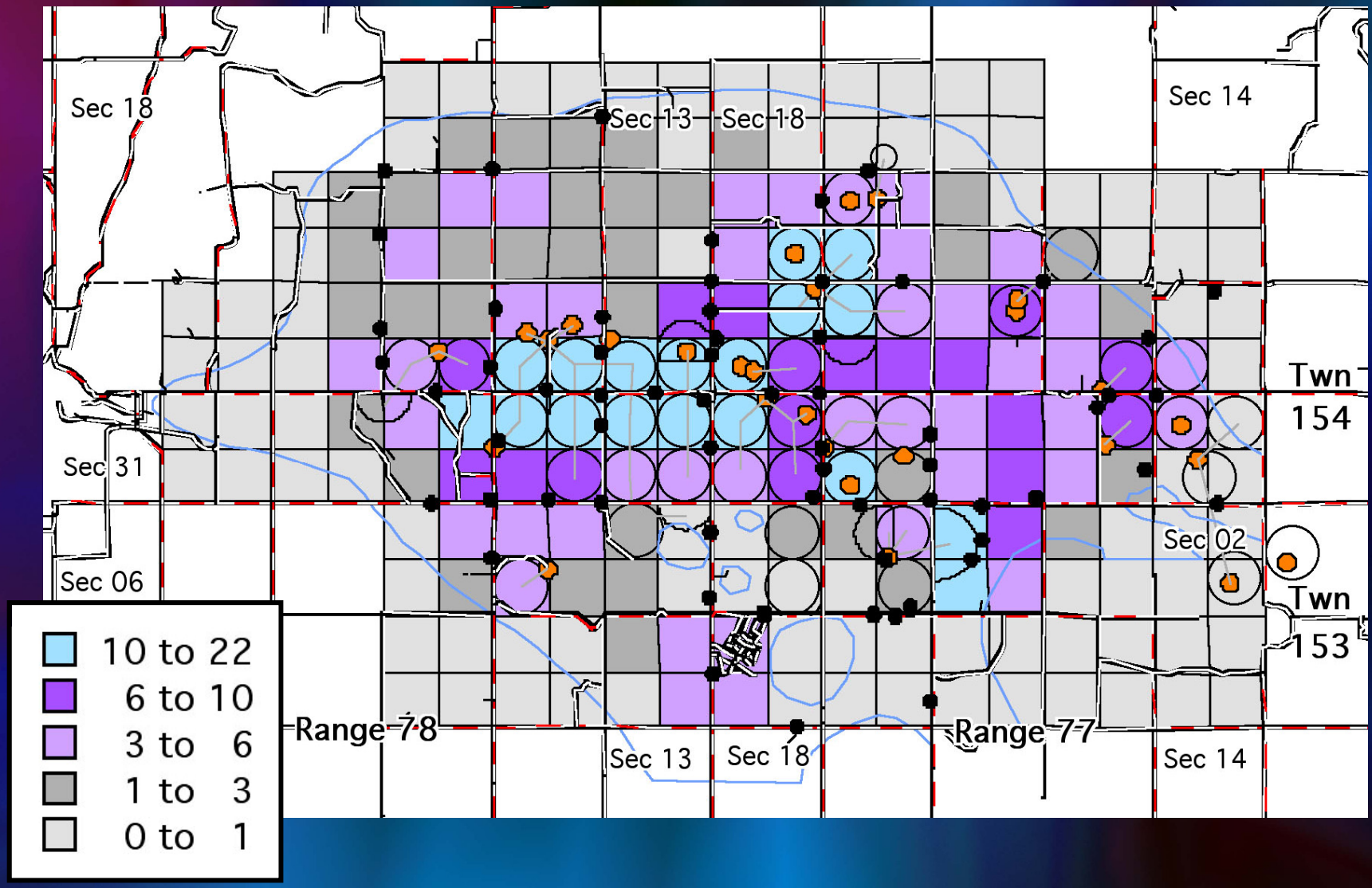


Toxicological Assessment





PMCI by Quarter Section, Karlsruhe Study Area



Remediation

- Denitrification
- Extraction through Pumping
- River Discharge
- BMPs -
  Environmentally Smart Nitrogen, etc.

Isotope Indicators of Denitrification

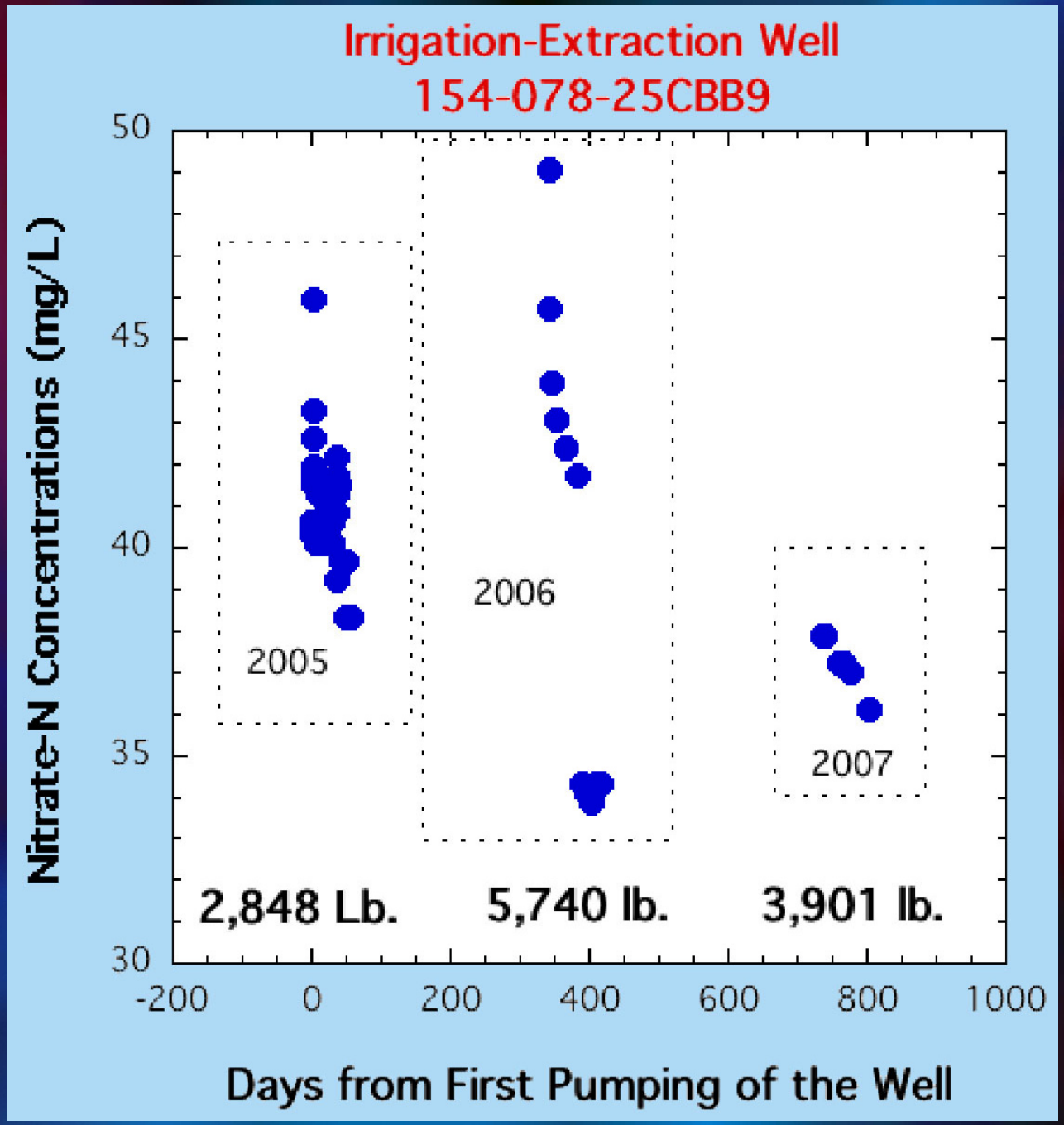
- "Residual Nitrate-N in ground water are enriched in both 15N and 180 during denitrification." SPENCER 2003
- "Both should increase proportionately with denitrification." SPENCER 2003
- "The expected relative rate of increase is: $\delta^{18}O / \delta^{15}N = 0.5$" MENGIS ET AL., 2001

Denitrification Results

- 4 of 7 sets of isotope samples from multiport samplers indicated likely denitrification SPENCER 2003
- 1 of 2 ISMs exhibited evidence of denitrification SPENCER 2003
- Electron donors: organic carbon, sulfide, iron
- The rate is first order, with k = .0031/d SPENCER 2003

$$\frac{dC}{dt} = -kC$$

$$\frac{dC}{dt} = -\frac{0.0031}{d}\left(40\frac{mg}{L}\right) = 0.121\frac{mg}{Ld} = 44\frac{mg}{Ly}$$



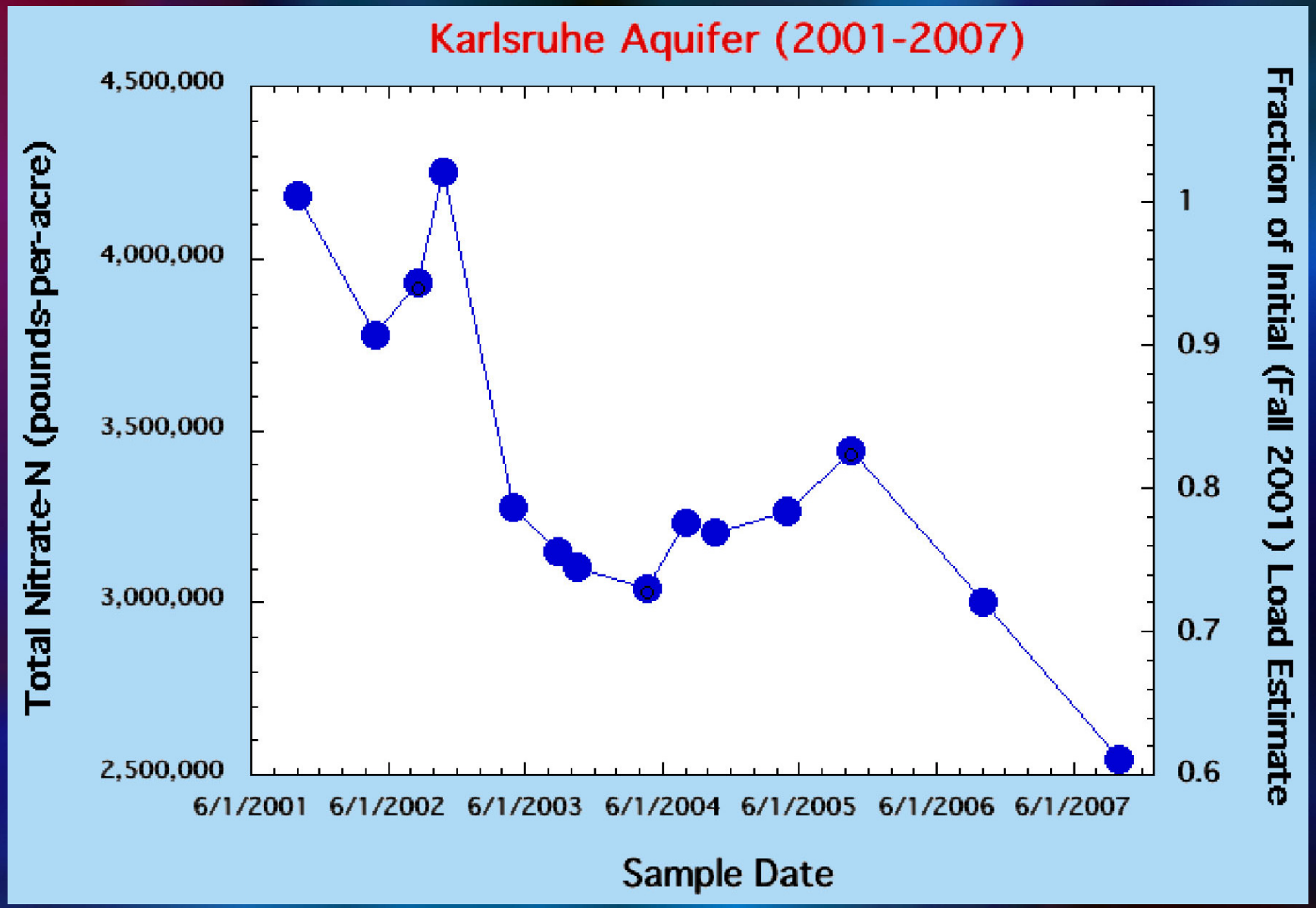
Total:

12,849 lbs.

Wintering River

0.193 mg/L x 4 cfs x 31,536,000 s/y x C

~2,000 Pounds Per Year


Karlsruhe Aquifer (2001-2007)
Total Nitrate-N (pounds-per-acre)
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
Fraction of Initial (Fall 2001) Load Estimate
1
0.9
0.8
0.7
0.6
6/1/2001
6/1/2002
6/1/2003
6/1/2004
6/1/2005
6/1/2006
6/1/2007
Sample Date

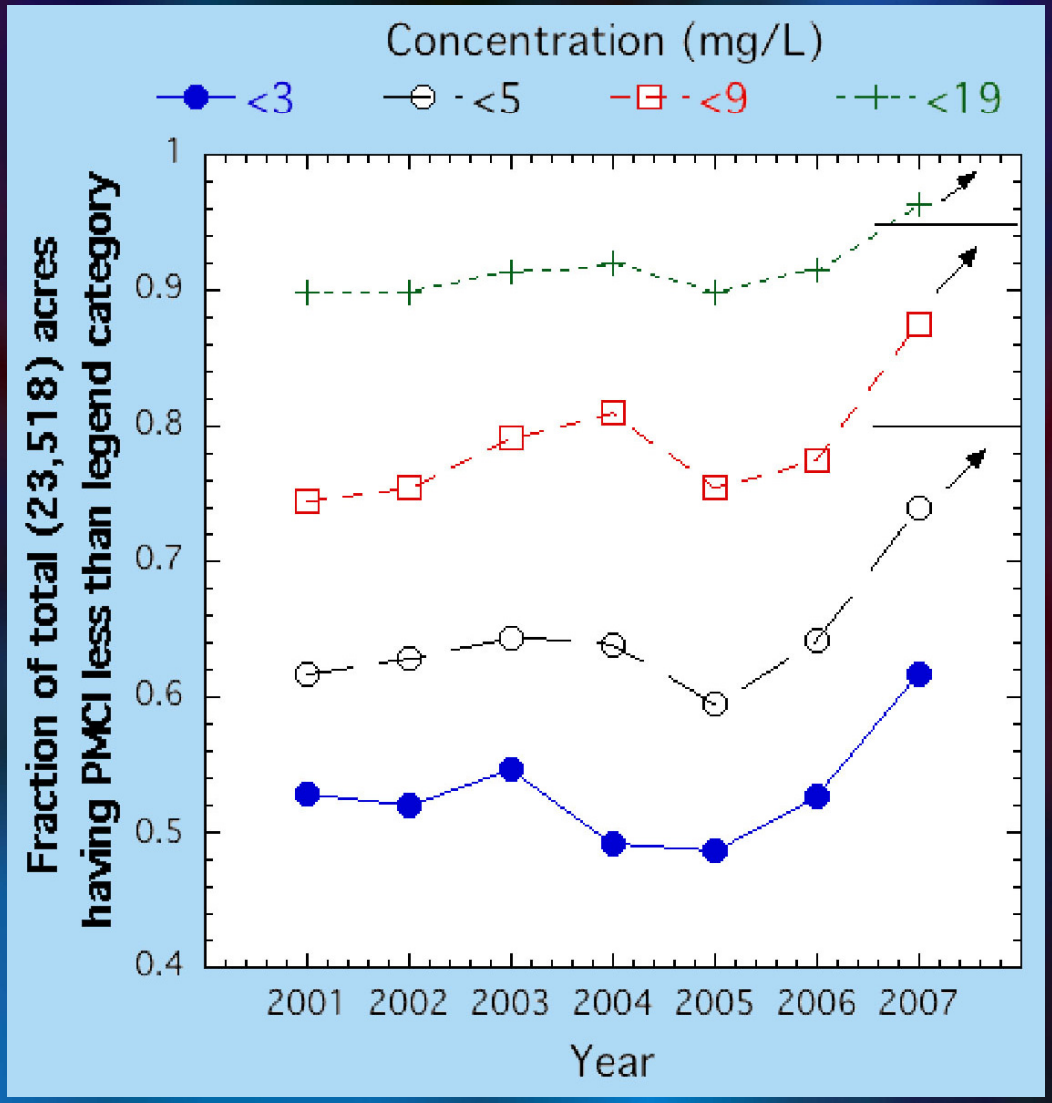
Aquifer Recovery Rates

Estimated:

Discharge	2,000 lb/y
Pumping	4,000 lb/y
Denitrification	145,000 lb/y
	151,000 lb/y

Measured 2001-2007: 225,000 lb/y

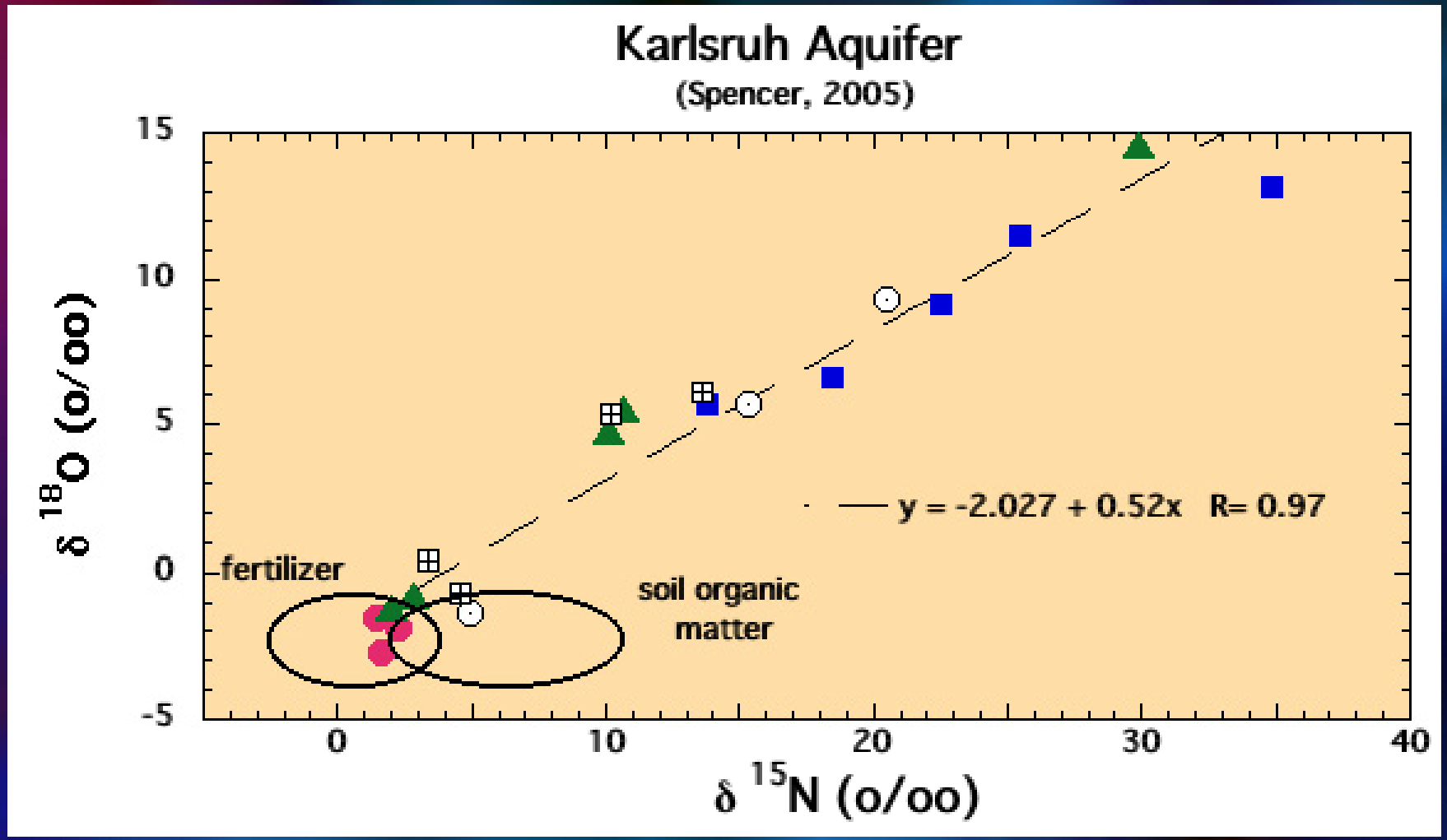
GOAL: Completion of Regulatory Action
80% < 5 mg/L, 95% < 9, 100% < 20



Conclusions

- About 4 million lbs. of Nitrate-N were lost into the Karsruhe aquifer
- Since Fall 2001, remedial factors have included: Voluntary BMPs, Extraction Wells, Natural Discharge, and Denitrification
- Current Nitrate-N load is about 2.5 million lbs. - 40% improvement
- Current bulk rate of Nitrate-N loss - about 224,000 lbs./y
- We hope to achieve total recovery

Questions?



Spencer 2003

In Situ Mesocosms