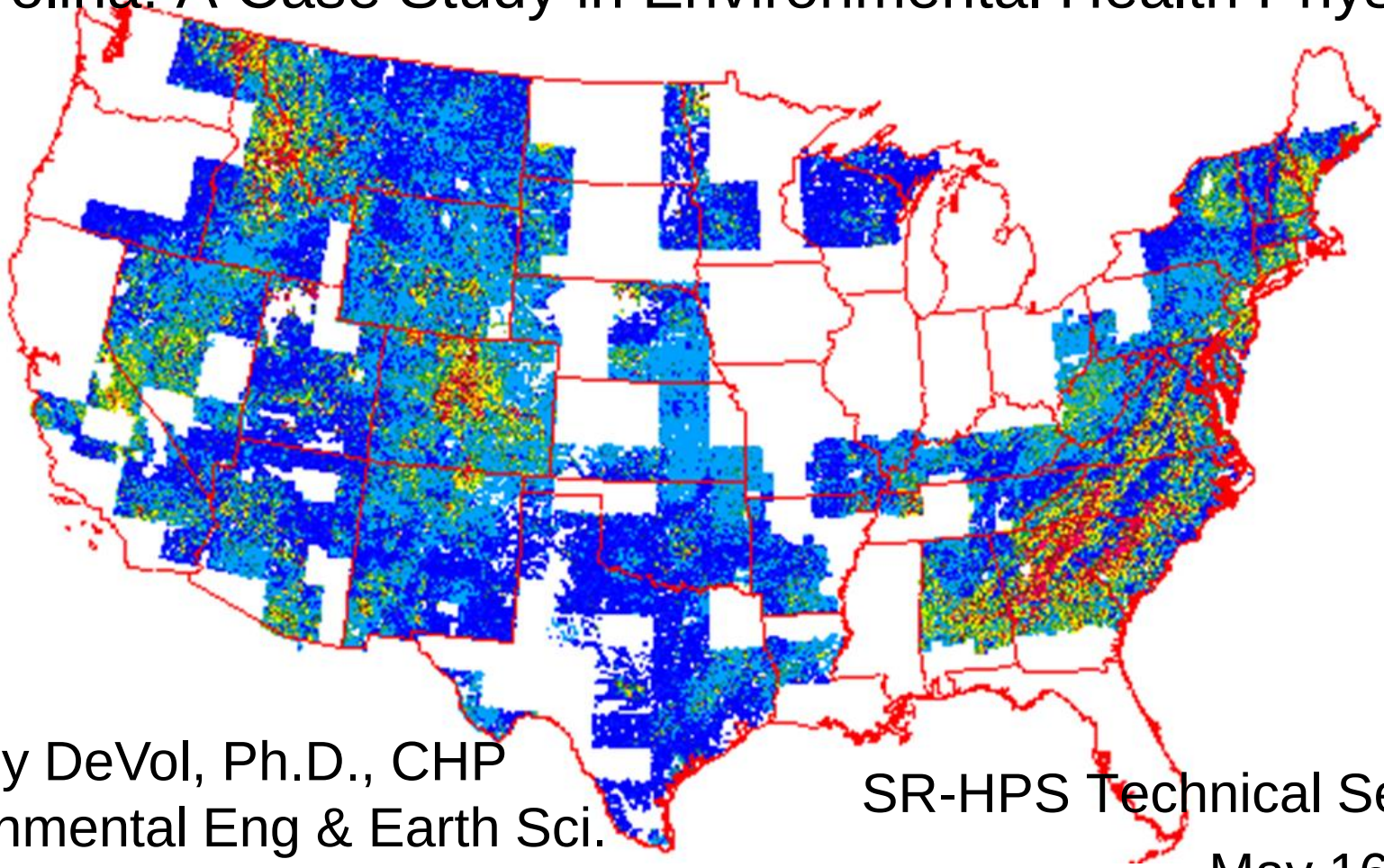


Natural Uranium and Thorium Deposits in Upstate South Carolina: A Case Study in Environmental Health Physics



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Clemson University

SR-HPS Technical Seminar
May 16, 2014

Outline

- Background
- NORM in Upstate SC
 - Simpsonville/Fountain Inn
 - Central, SC
 - Nantahala National Forest in SC
- Current Research Project



Southeastern Monazite Belt

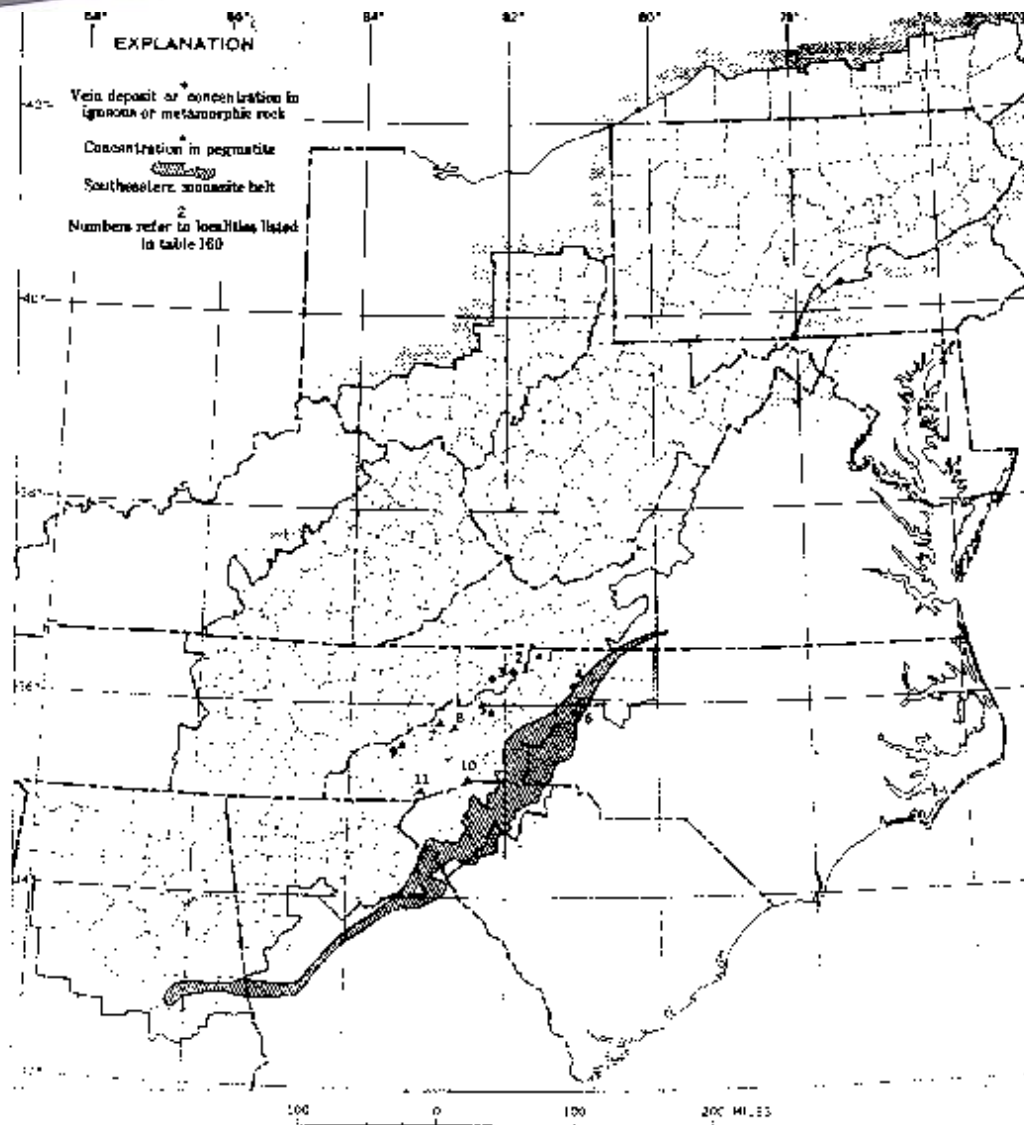
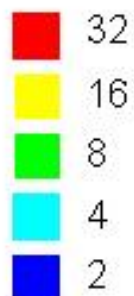


FIGURE 109.—Thorium and rare earths in the Appalachian Region. From Mertie (1953) and Overstreet, Theobald, and Winkler (1959).

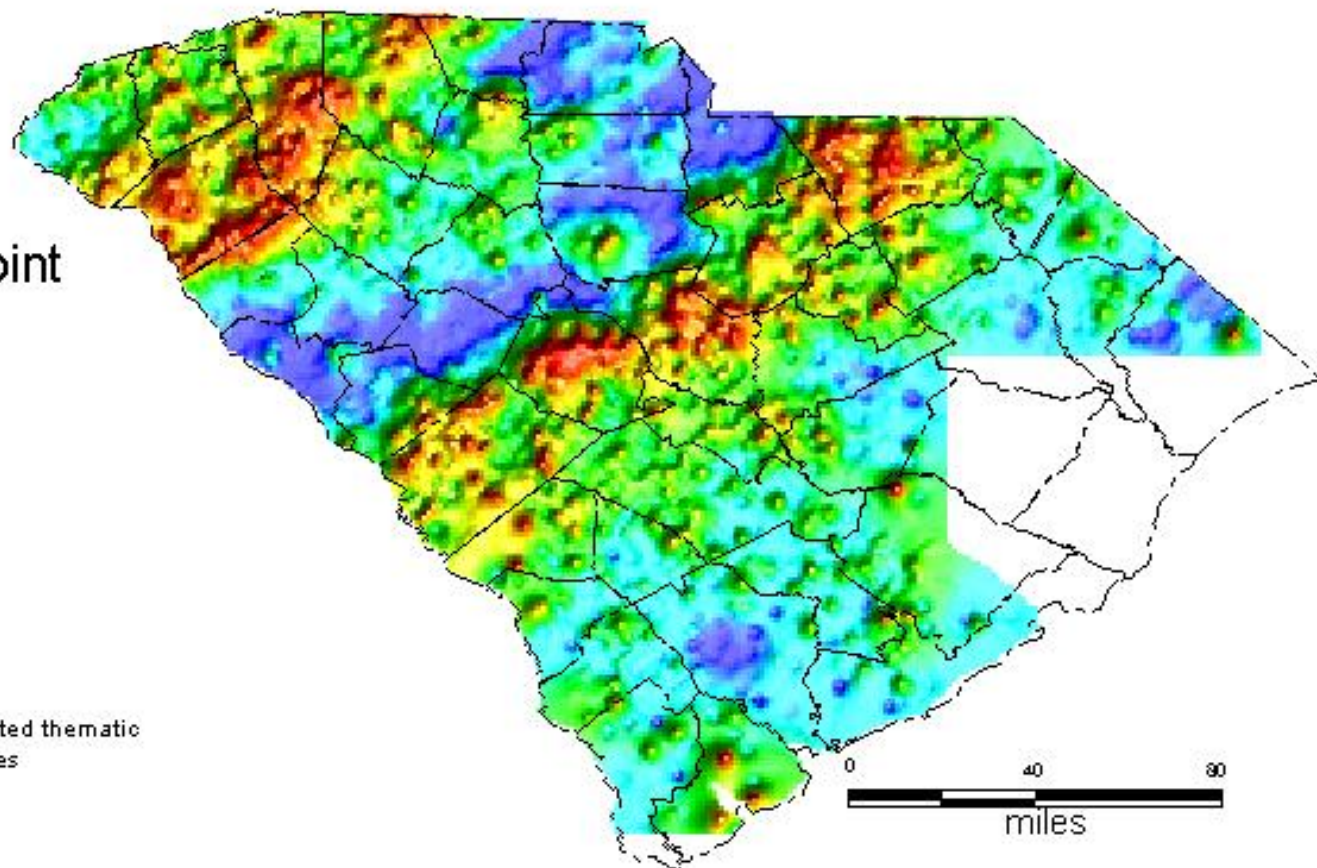
NURE U in Sediment

Uranium - Stream Sediment

Inflection Point
U (ppm)



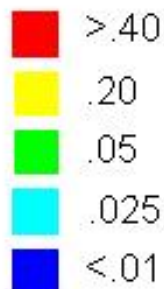
Grid Cell Interpolated thematic
Grid cell = .85 miles



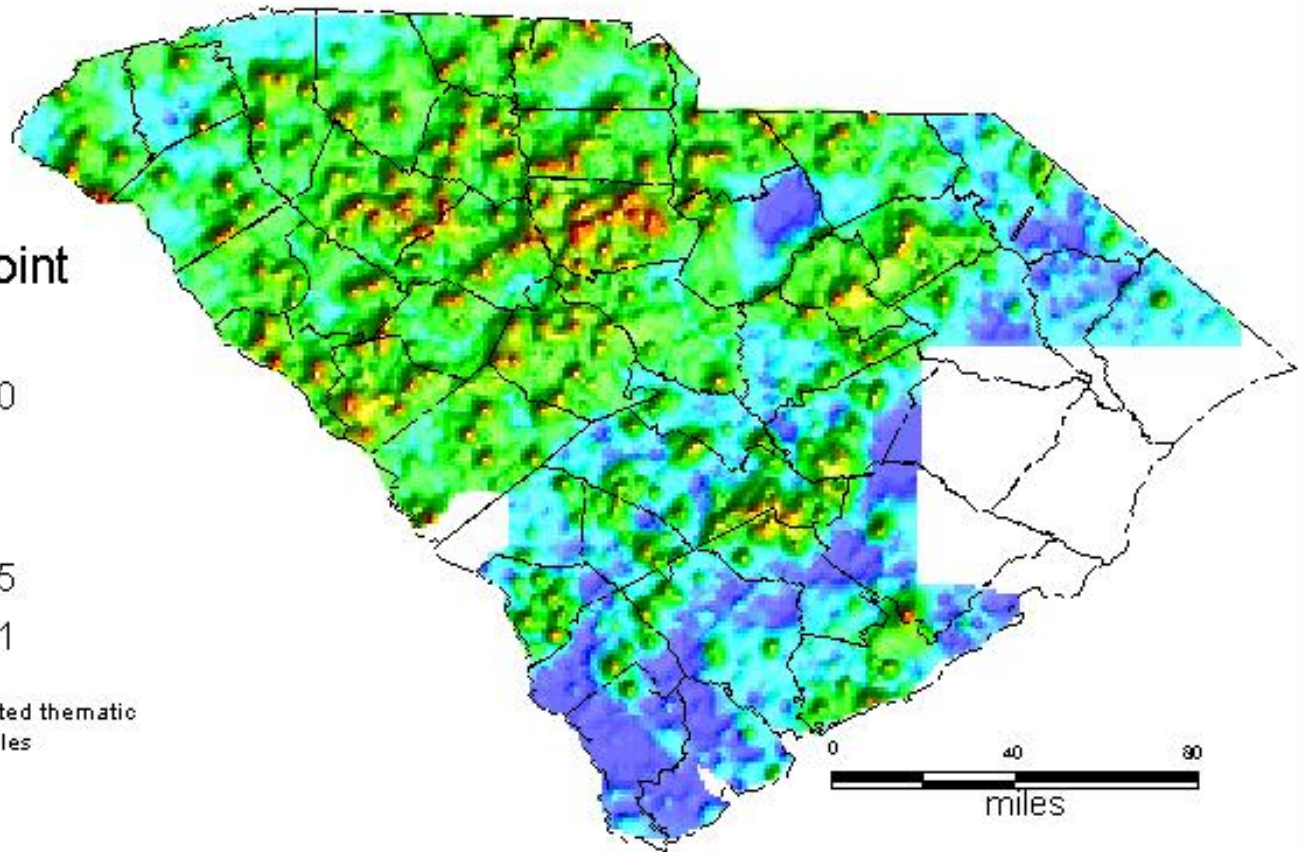
NURE U in Groundwater

Uranium - Ground Water

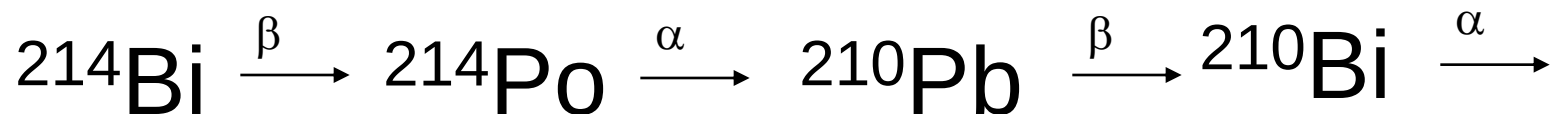
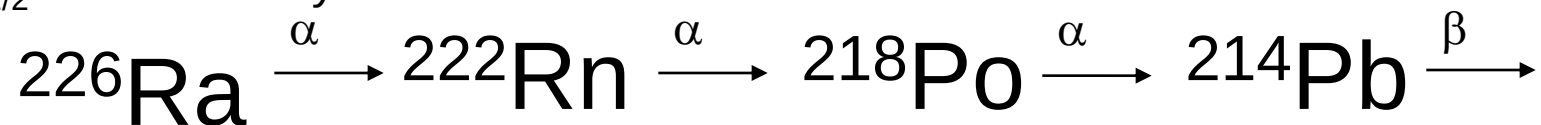
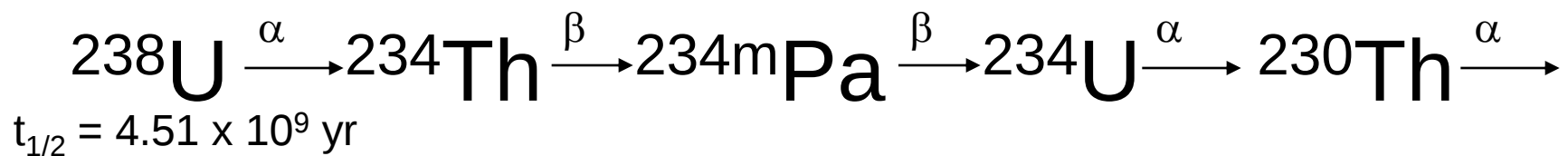
Inflection Point
U (ppb)



Grid Cell Interpolated thematic
Grid cell = 1.06 miles



Uranium Decay Series



Implemented and Proposed Regulations

(Radionuclides in drinking water and air)

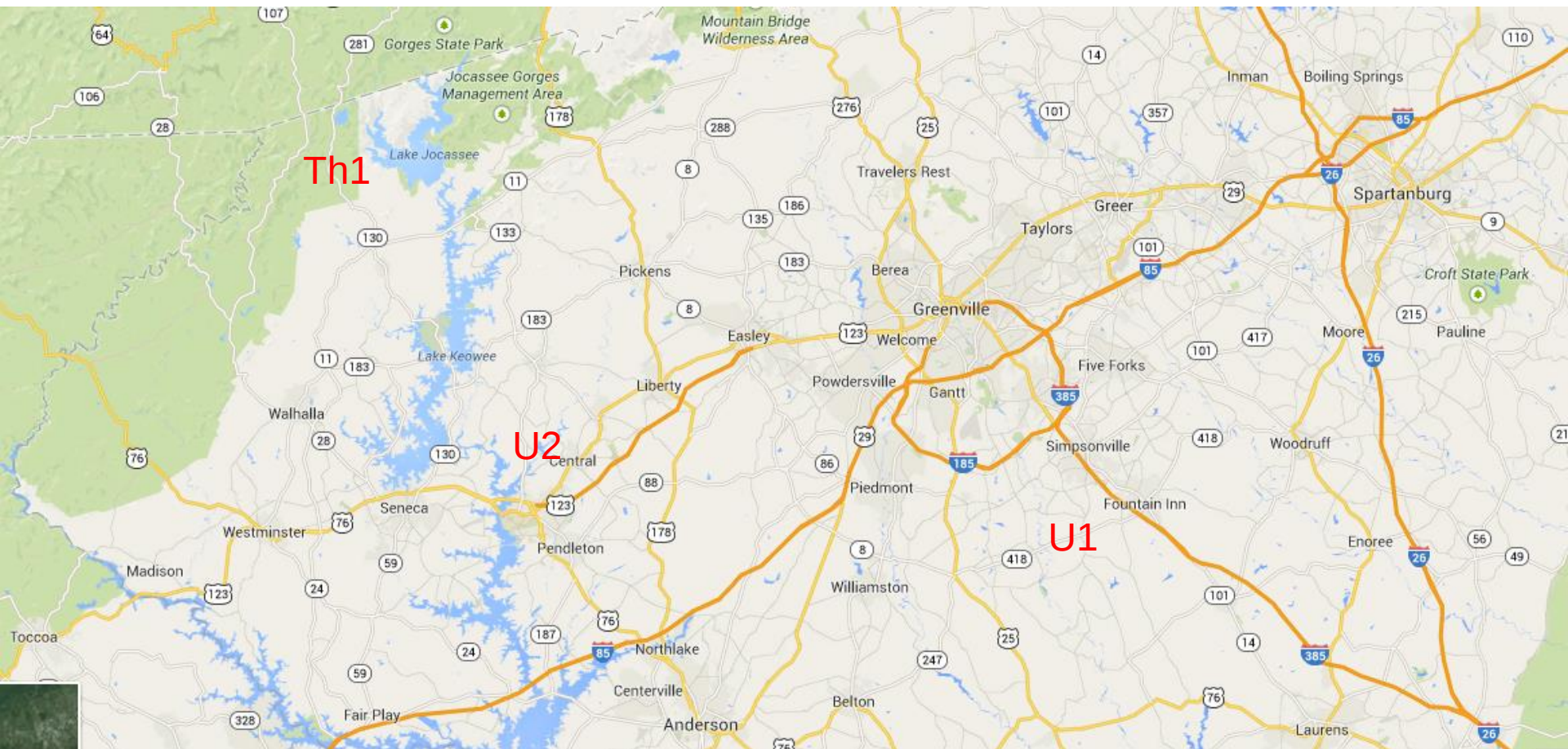
Radionuclide	Regulation level
Total uranium	30 $\mu\text{g/L}$
Total radium (Ra-226 and Ra-228)	5 pCi/L
Radon-222 in H_2O	300 or 4,000 pCi/L
Pb-210	4 mrem/yr (total beta dose)
Rn-222 in air	4 pCi/L

Revised SDWA,
effective 12/2003

US EPA, 1999



NORM in Upstate SC



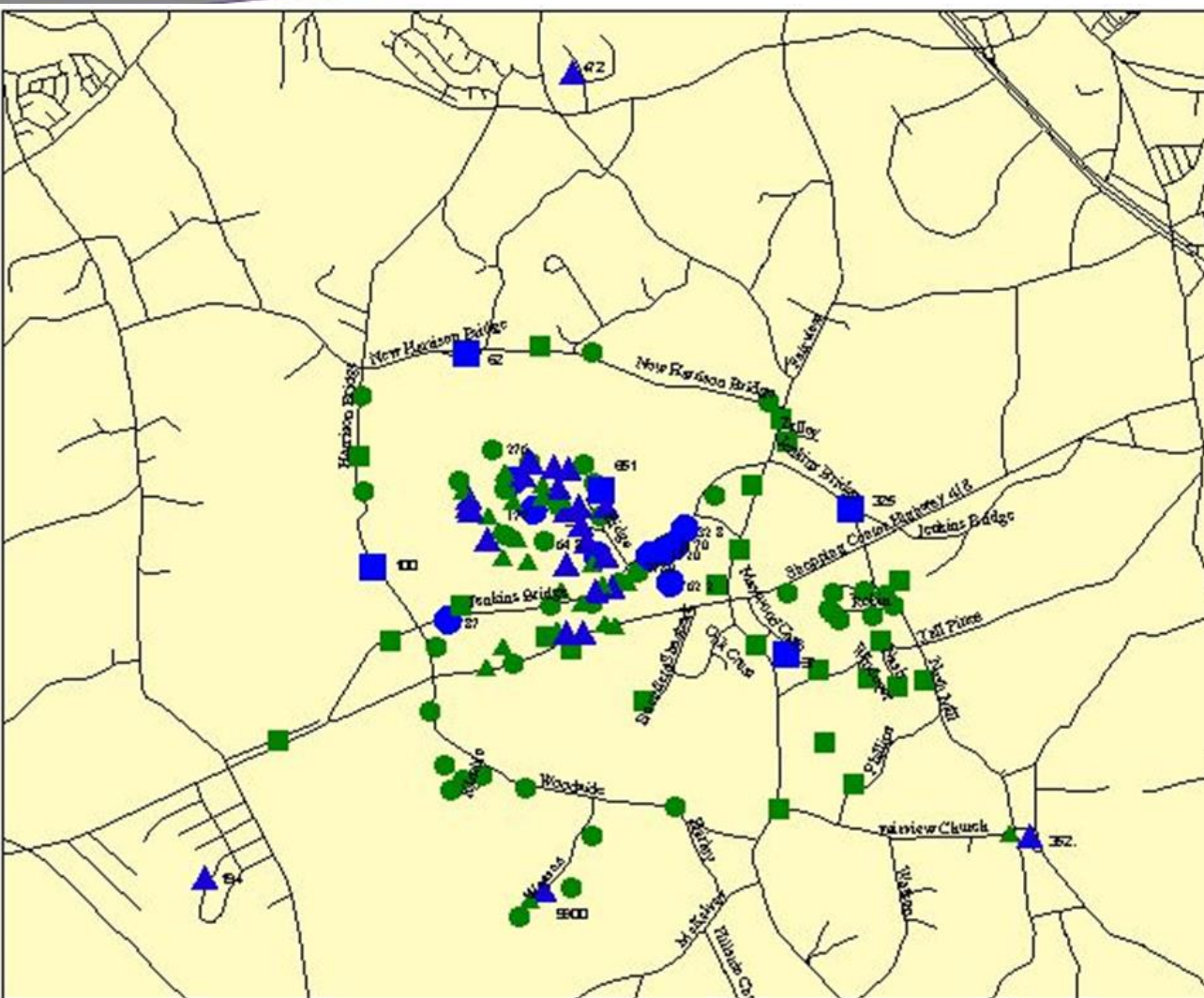
U1 - N34 39.0' W 82 16.5'

Simpsonville/Fountain Inn

- U concentration in hair was reported to be the highest ever recorded by the laboratory
- Friday, January 26, 2001, SC DHEC alerted of high uranium levels in 3 private wells on Jenkins Bridge Rd.
- SC DHEC conducted a three phase study
- Clemson University conducts independent study
 - Measurement of U, ^{226}Ra , ^{222}Rn , ^{210}Pb in water
 - Measurement of ^{222}Rn in air
 - Treatment of water containing U, ^{226}Ra , ^{222}Rn
 - Measurement of U in hot water tanks
 - *In-situ* measurement of U, Th, and ^{40}K



DHEC Phase I and II

**Homeowner**

▲ 0 - 29.9

▲ 30 - 9900

DHEC Phase 2

■ 0 - 29.9

30 - 651

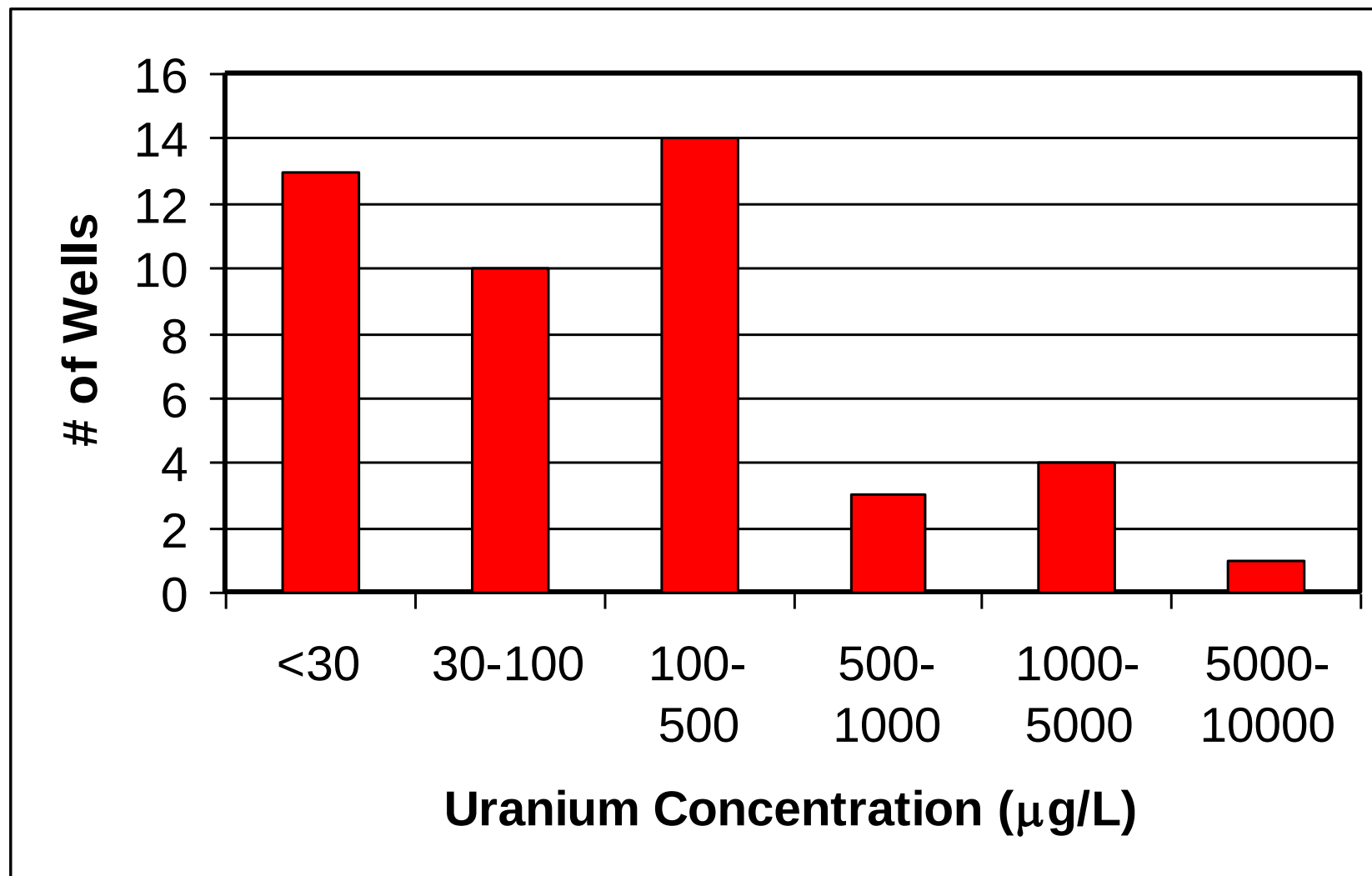
DHEC Phase 1

● **-0.265 - 29.9**

● 30 - 1620



Summary of Phase II



Rn and Ra Well Results

- 22 Wells sampled for ^{222}Rn in water
 - Range 1650 - 195,000 pCi/L
 - All above proposed limit of 300 pCi/L
- 10 Wells sampled for ^{226}Ra
 - 1 well at 24 pCi/L
 - Others below Ra MCL of 5 pCi/L

DHEC Phase III

- Smaller public water systems using wells in NW South Carolina
 - 322 wells sampled
 - 7 wells above Uranium MCL (4 in Oconee; Round House Point 460 $\mu\text{g/L}$)
- Wider sampling of private home wells in the same general area of the Piedmonts
 - 166 wells
 - 6 wells above Uranium MCL (highest 147 $\mu\text{g/L}$)



Chronic Ingestion of Uranium

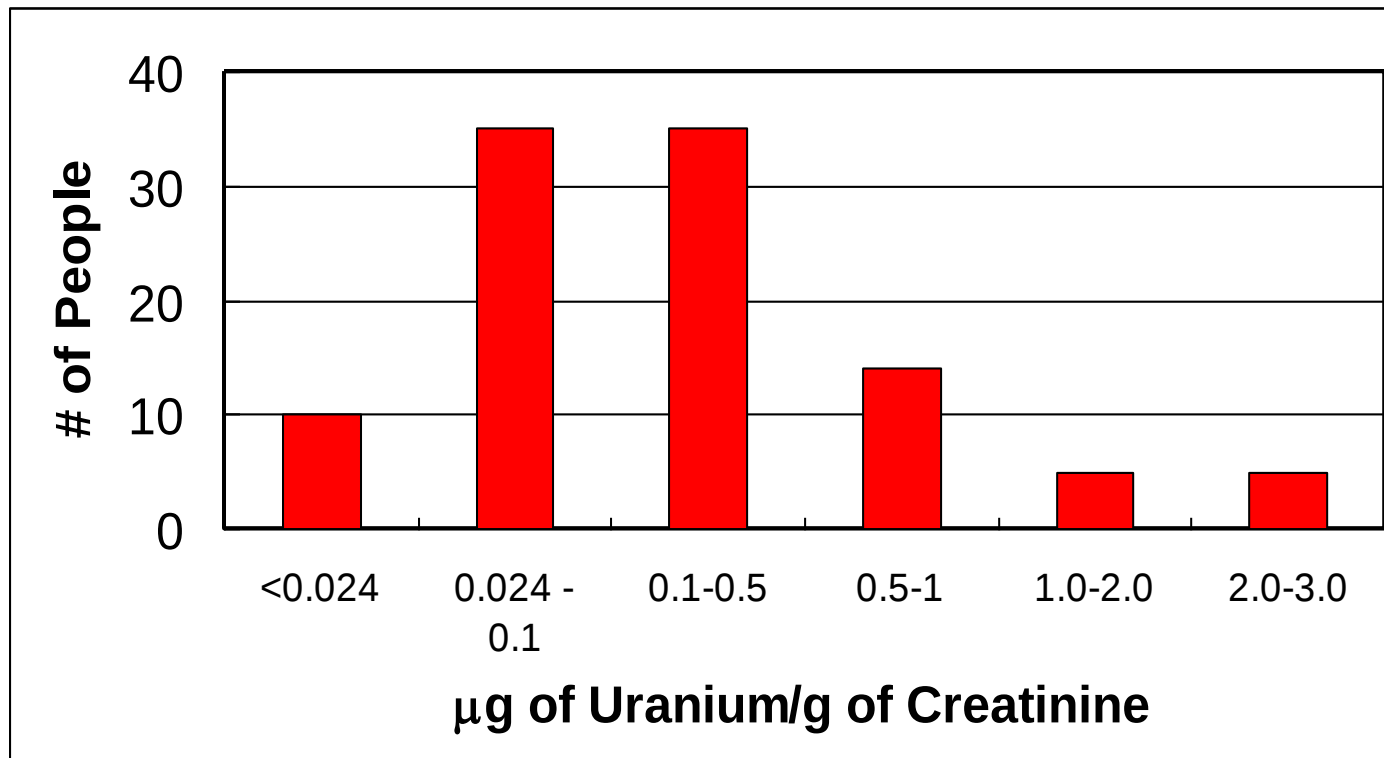
- Nephrotoxic effect rather than a radiological effect
- **Canadian Study**, Zomora et al., Toxicological Sciences 43 (1998) 68-77.
 - 3 to 59 years of exposure (15 people ingested >60 $\mu\text{g}/\text{day}$)
 - 2 to 781 $\mu\text{g}/\text{L}$ in drinking water wells
 - Loss of kidney function, proximal tubule site of interference
 - Observed effects may be due to subclinical toxicity which may not lead to kidney failure
- Other considerations?



Health Effects from Chronic Ingestion of U

- 90th Percentile for U in Urine (500 person control)
0.024 μg of Uranium/g of Creatinine

B.G. Ting et al., *Environmental Research, Section A*, 81 (1999) 45-51



Results for
104 urinalysis
Simpsonville
residence

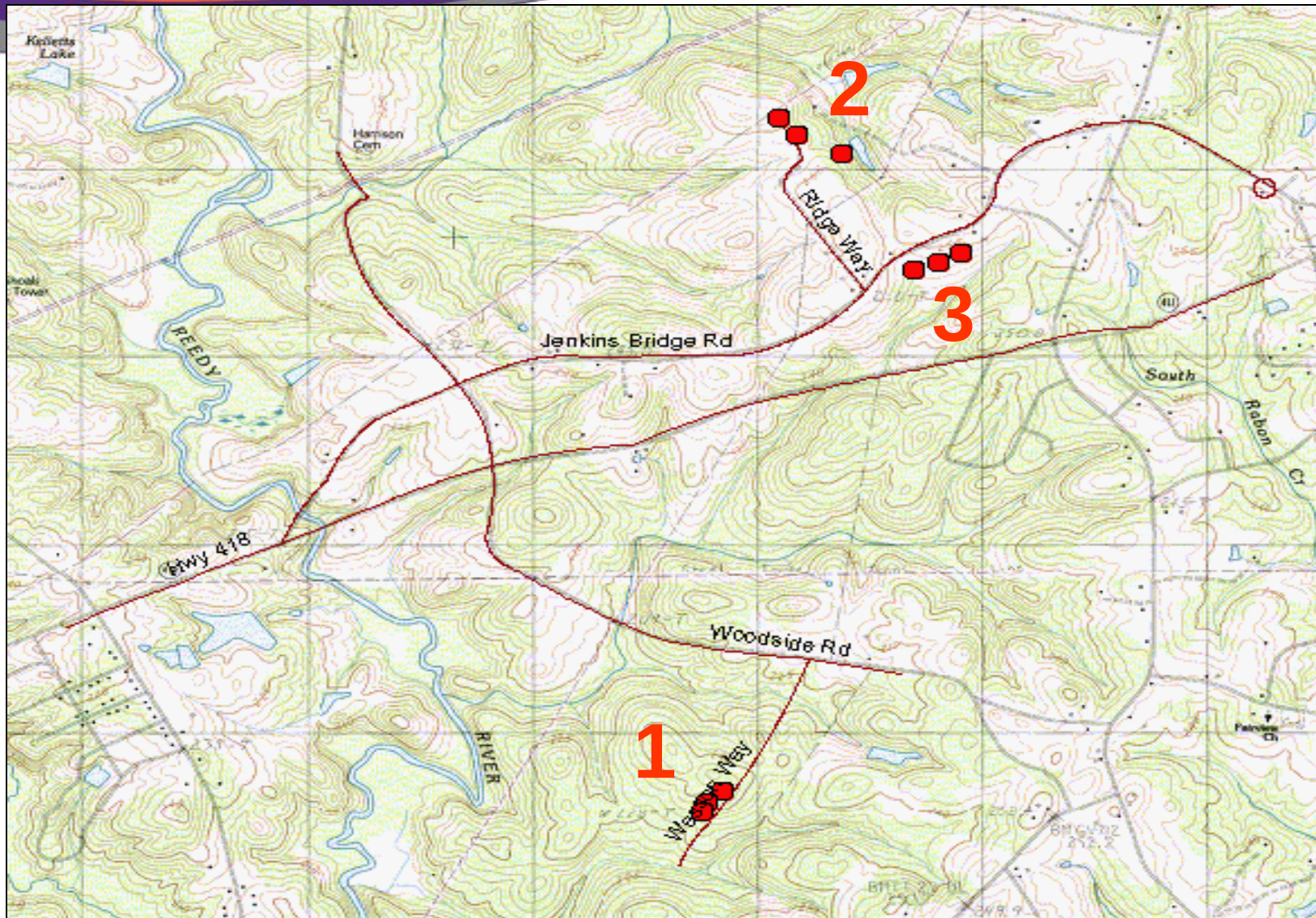


Clemson University study

- Measurement of U, ^{226}Ra , ^{222}Rn , ^{210}Pb in water
- Measurement of ^{222}Rn in air
- Treatment of water for U, ^{226}Ra , ^{222}Rn removal
- Measurement of U in hot water tank
- *In-situ* measurement of U, Th, and ^{40}K



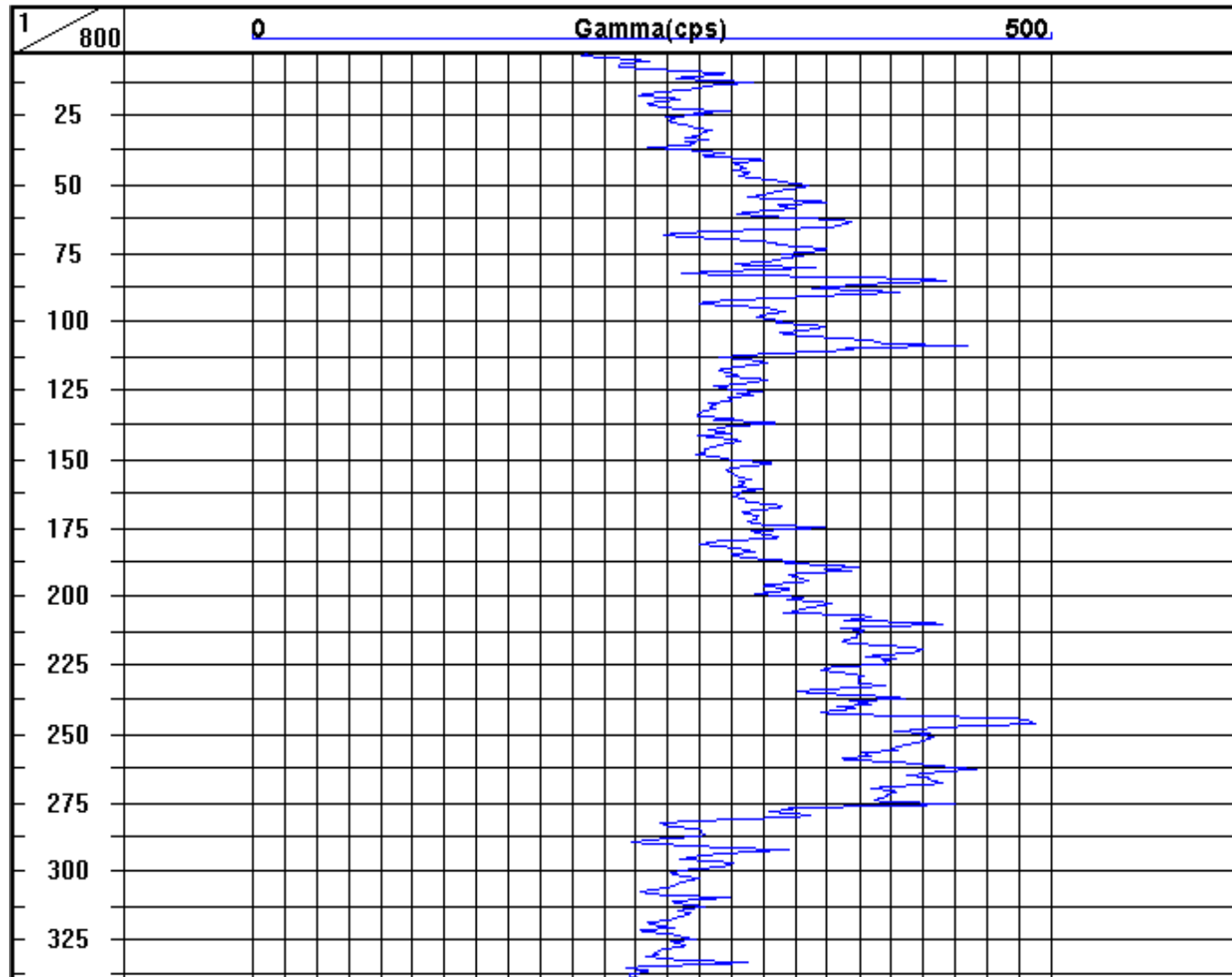
Sampling Locations



5 km (3.1 mi)

6 km (3.7 mi)

1B Gamma-ray Well Log



Analyses methods



Uranium:

- KPA: total U (mass)
- Concentration/purification + alpha spectroscopy: – isotopic ratio of U-234/U-238



Radium:

- Concentration/purification + alpha spectroscopy: Ra-226 only
- Gamma spectroscopy for Ra-228 progeny Ac-228



Radon:

- LSC: Rn-222 alpha activity in water
- Electret Ion Chambers: Rn-222 in air



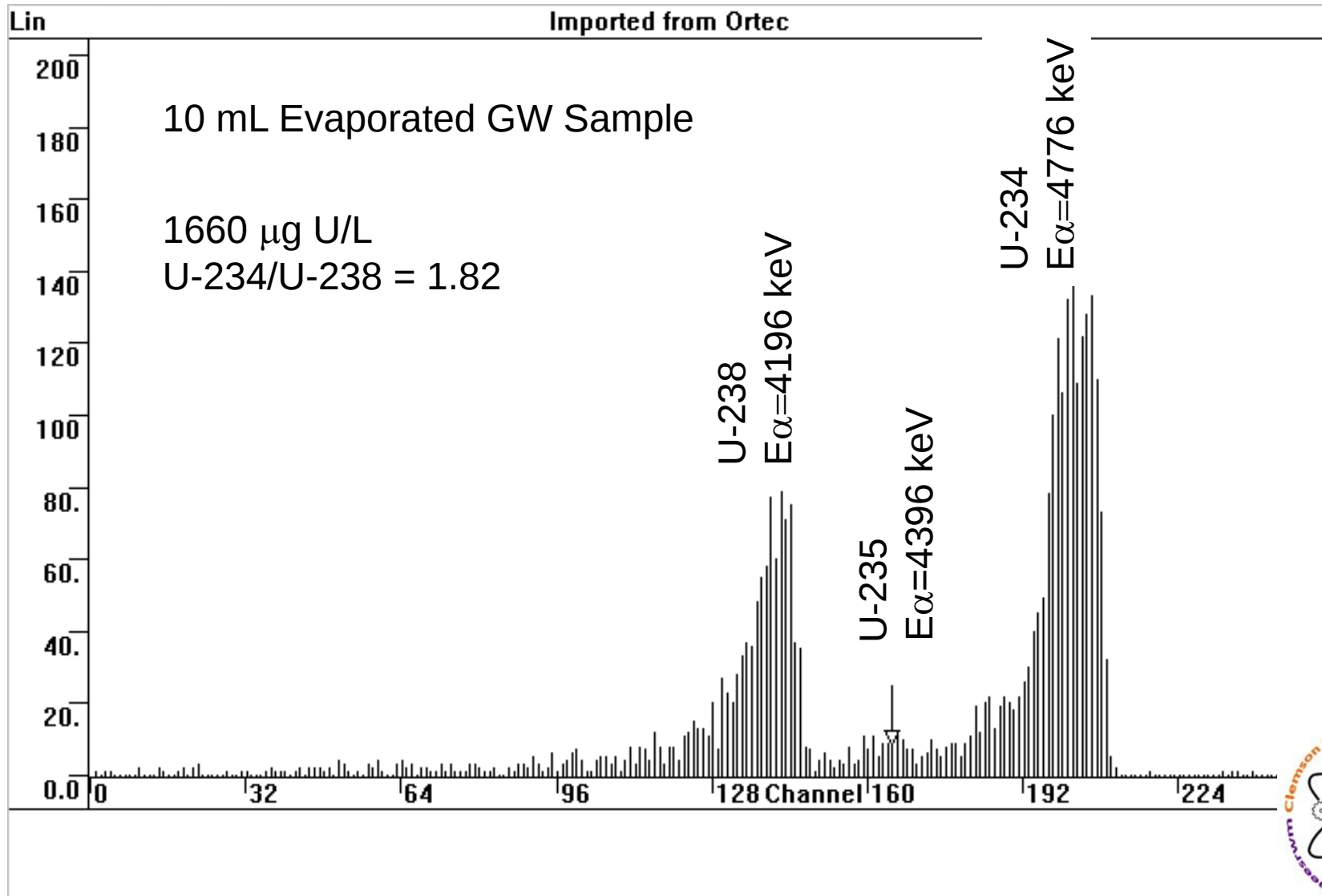
Lead-210:

- Concentration/purification and LSC: progeny Bi-210 in equilibrium

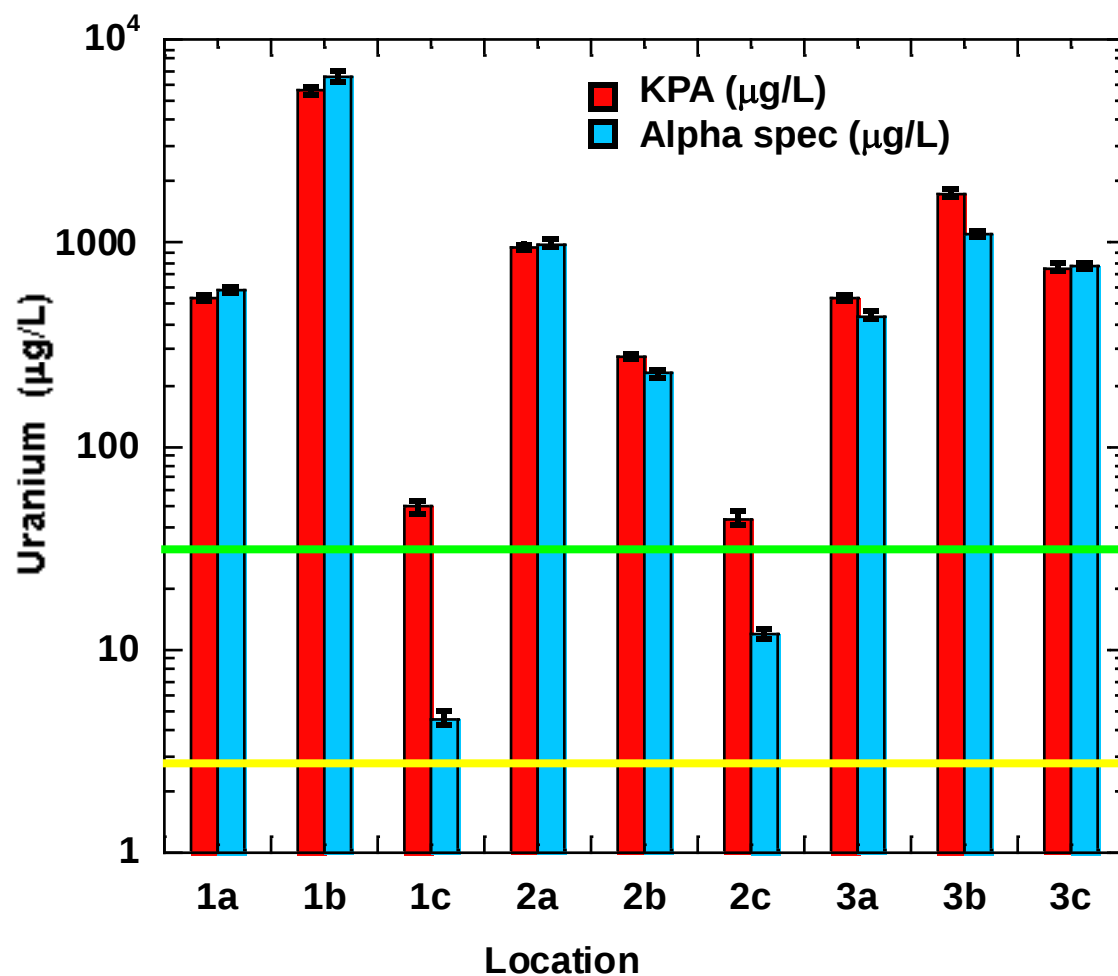
All are established methods by EPA, DOE, AWWA or manufacturer



Alpha Spectroscopy



Uranium results



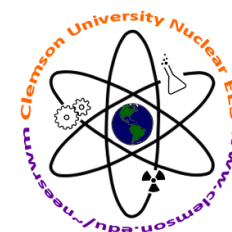
Activity per mass:
0.72 -1.18 pCi/ μg

US max.: 6,900 pCi/L

1b high: 10,100 $\mu\text{g/L}$
(7,575 pCi/L)

MCL

US avg.



Summary

Nuclide	Published max.	This study max.	Regulation Level	US average
Total U	6,900 pCi/L	4,930 $\pm$ 277 pCi/L	30 μ g/L (~20 pCi/L)*	1.8 pCi/L
Rn-222 in H ₂ O	> 10 ⁵ pCi/L	40,800 $\pm$ 91 pCi/L	300 or 4,000 pCi/L	249 pCi/L
Rn-222 in air	1200 pCi/L	8.5 pCi/L	4 pCi/L	N/a
Ra-226 Ra-228	22.5 pCi/L 72.3 pCi/L	31.2 $\pm$ 8.5 pCi/L 14.4 $\pm$ 3.9 pCi/L	5 pCi/L	< 1 pCi/L
Pb-210/gross beta dose	(18.1 mrem/yr)* 7.6 pCi/L	(54.4 $\pm$ 7.1 mrem/yr)* 22.3 $\pm$ 3.0 pCi/L	4 mrem/yr (1.85 pCi/L)*	0.02-0.12 pCi/L

* Calculated values

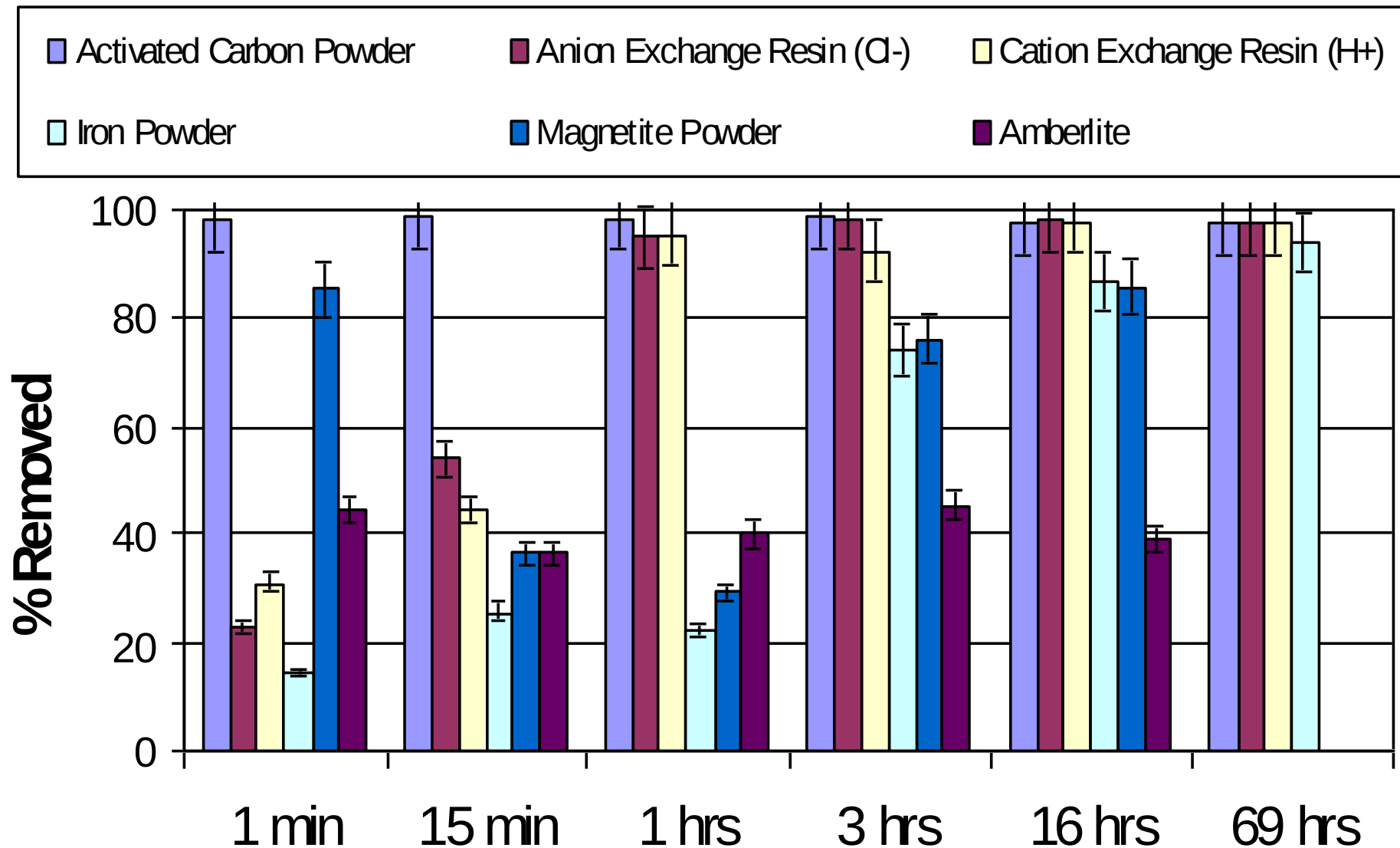


Commercial Water Treatment Systems

- Culligan donated system
 - Filtration, Aeration, Anion/Cation exchange, Granular Activated Carbon, UV
 - U removal 99.8%
Ra removal 54.5%*
Rn removal 93.3%
- Lowes donated Reverse Osmosis unit
 - U removal 99.9%
Ra removal 53.2%*
Rn removal 97.2%

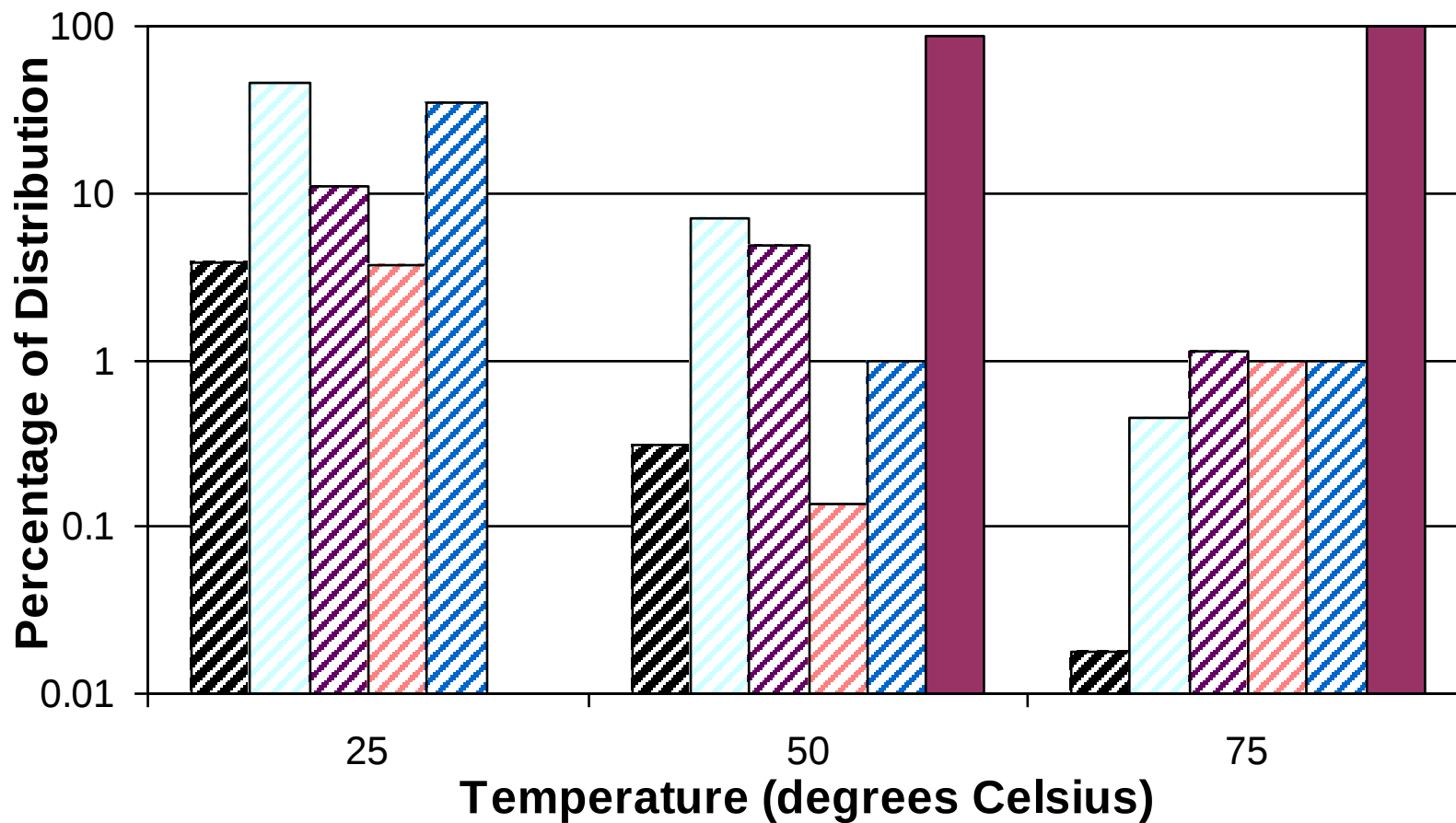
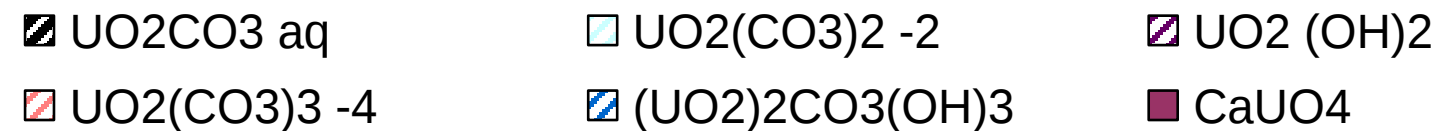


Water Treatment

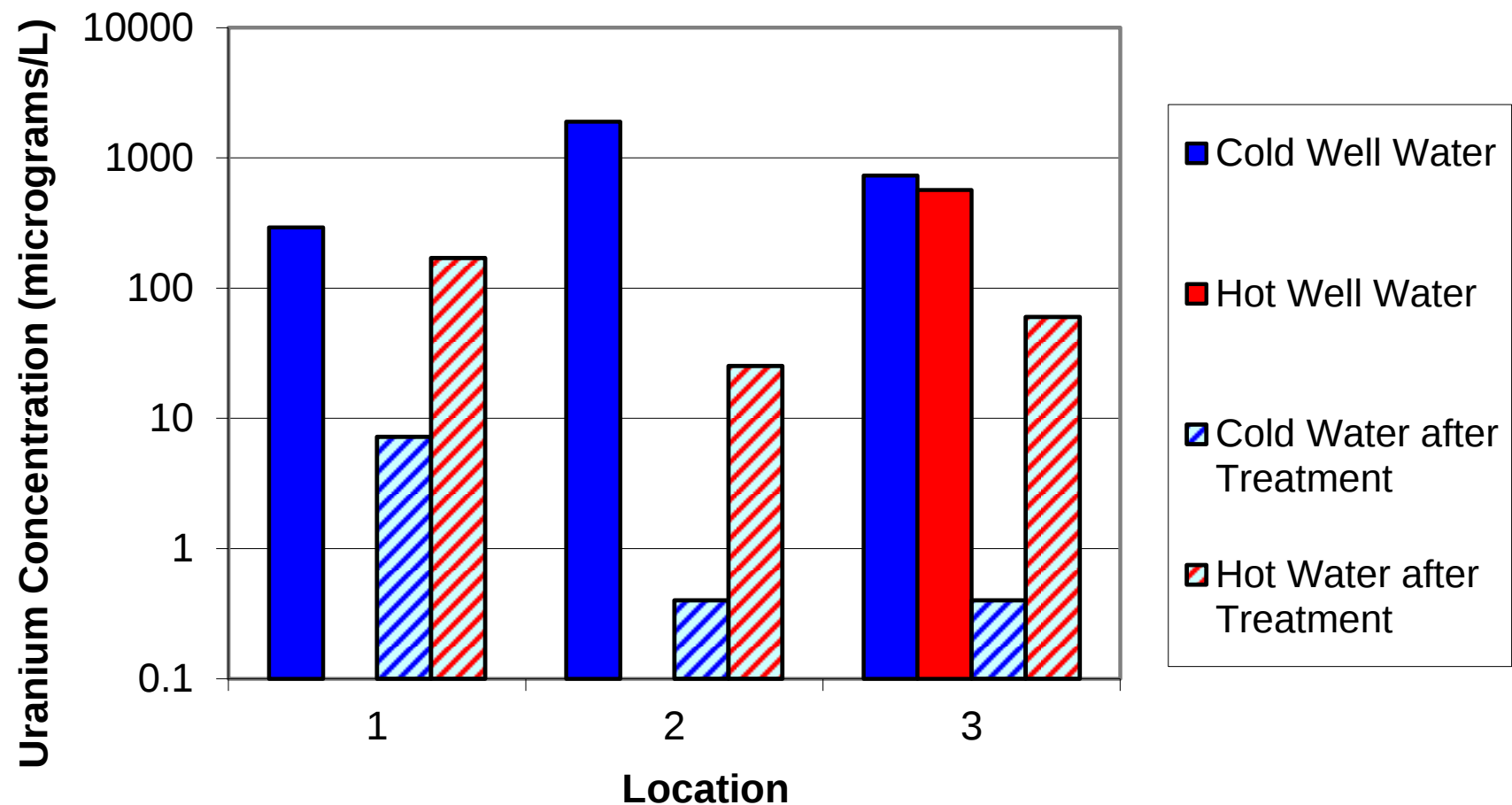


Uranium Speciation Vs. Water Temp.

MINTEQA2

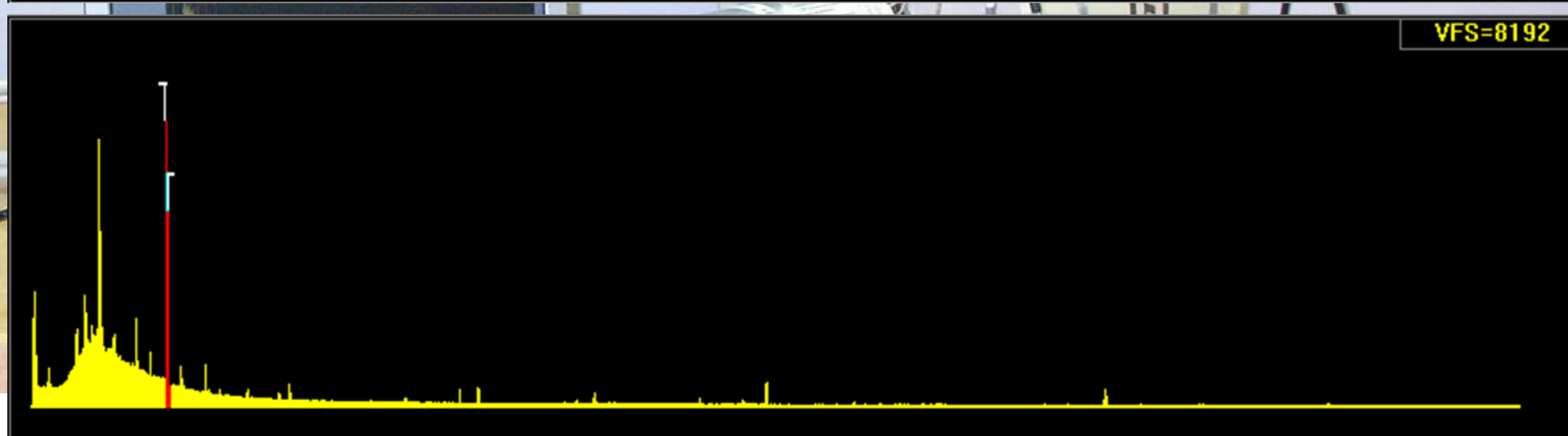
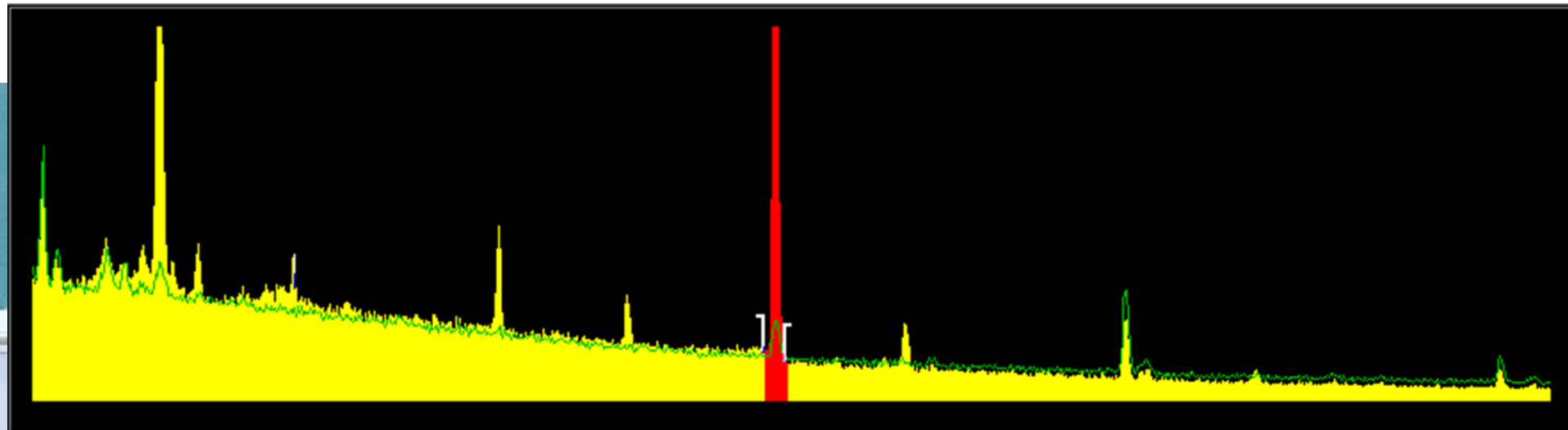


U in Hot Water Tanks

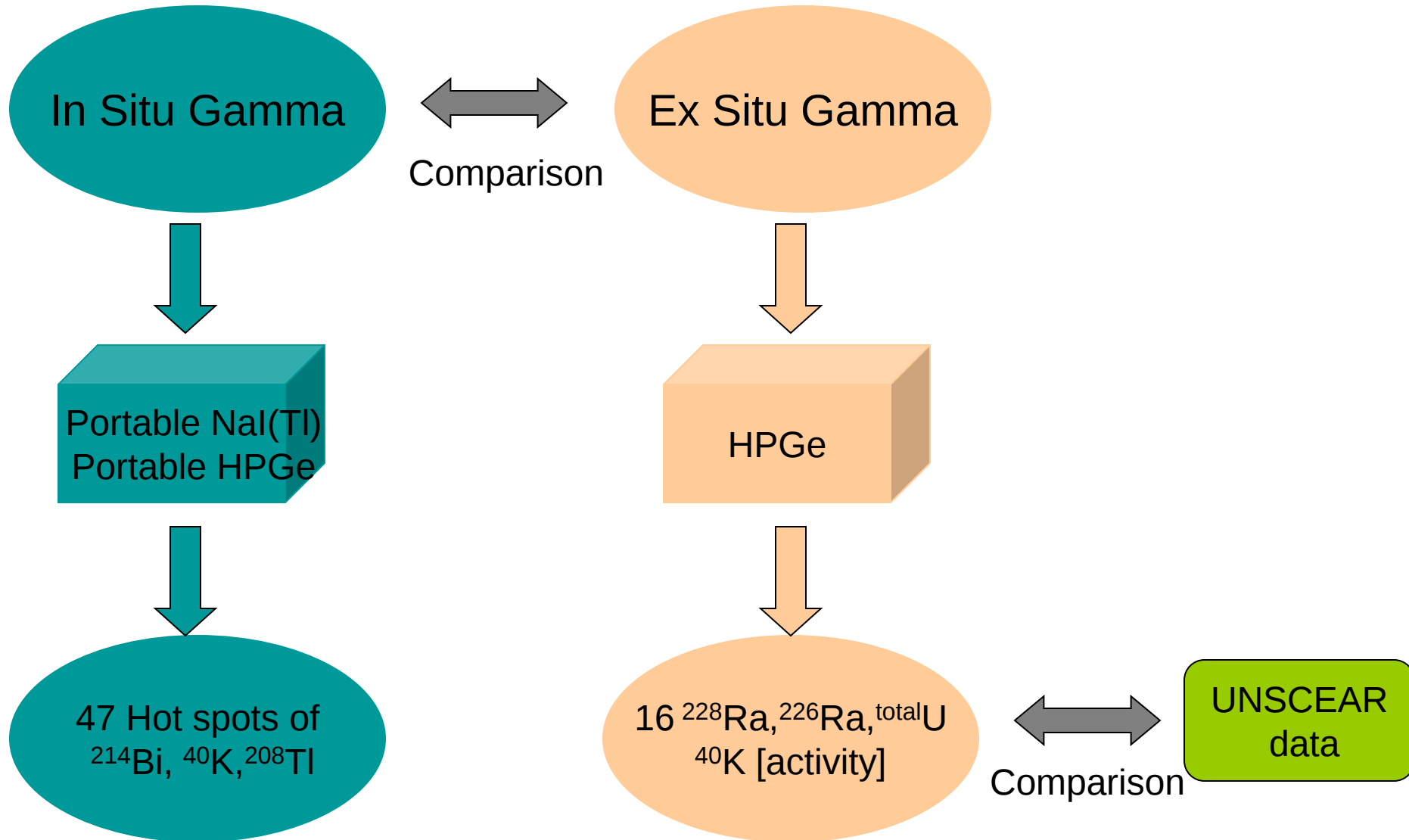


Gamma-ray Spectroscopy

U (total) present: 5.7 – 68.8 g/tank



In Situ and Ex Situ NORM Measurements

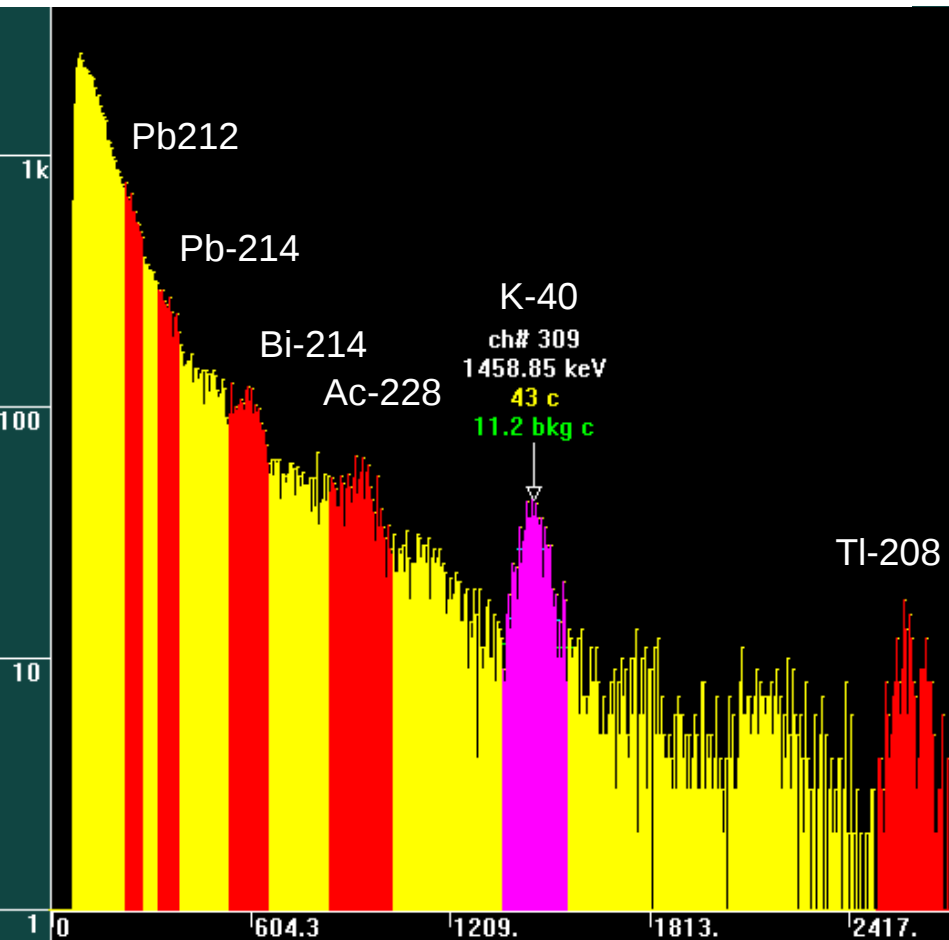


In-situ Gamma-Ray Spectroscopy

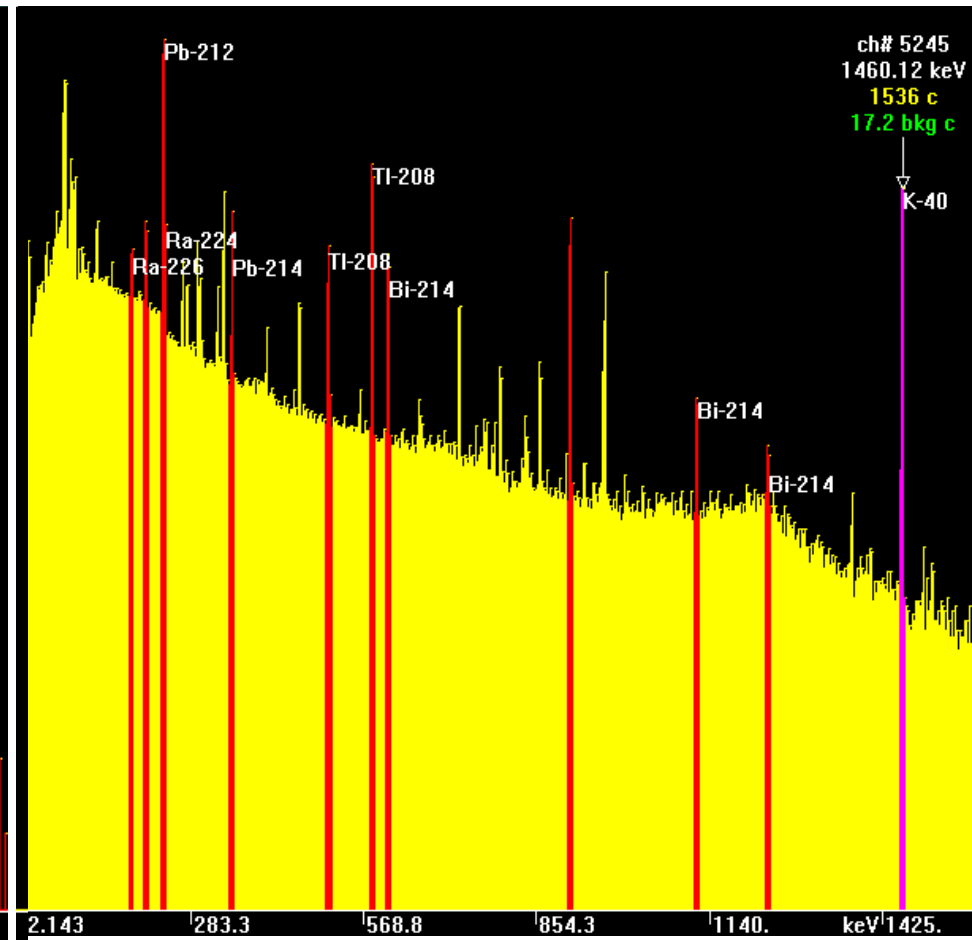


In Situ and Ex Situ Gamma-Ray Spectroscopy

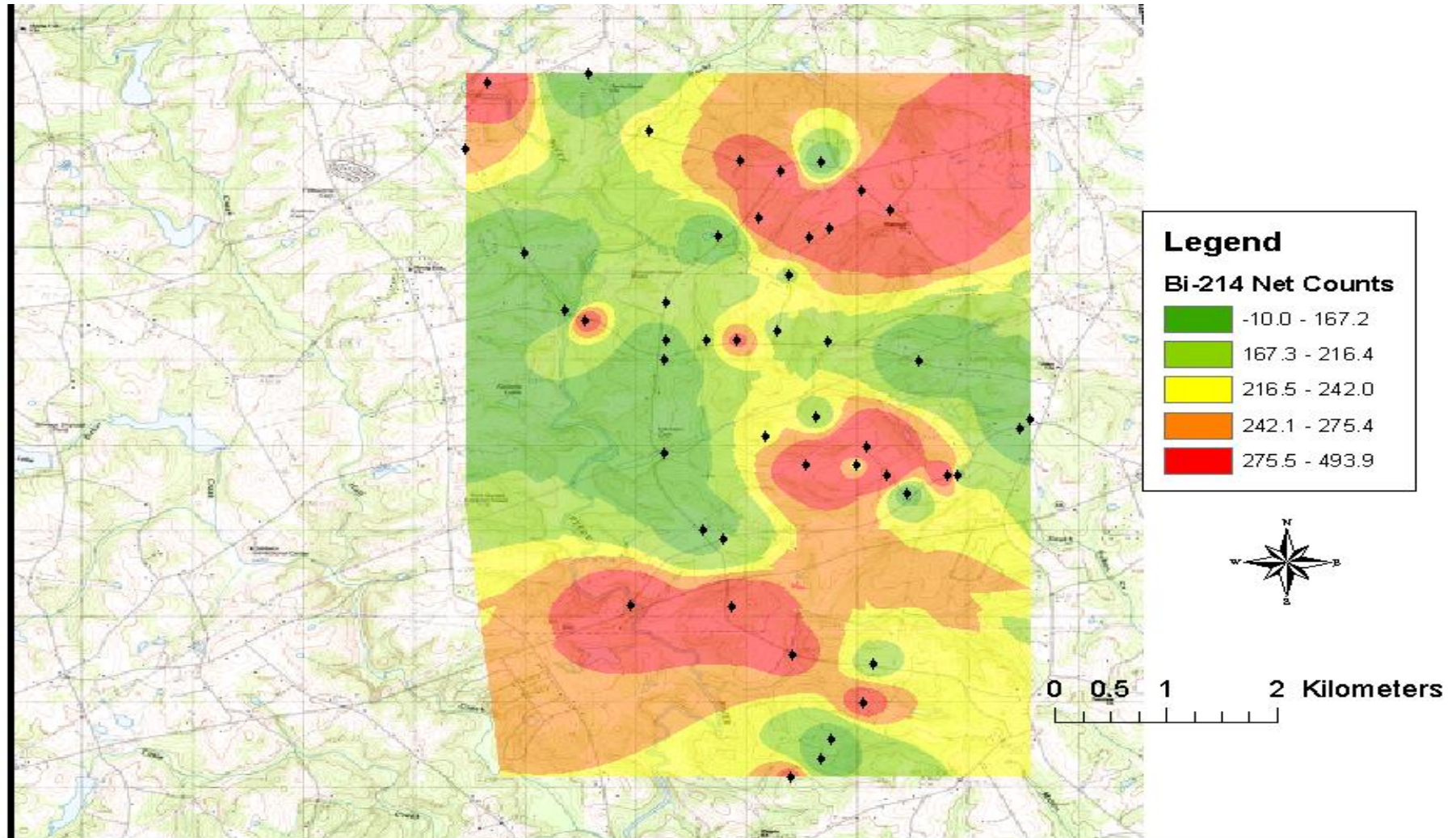
3"x3" NaI(Tl)



HPGe

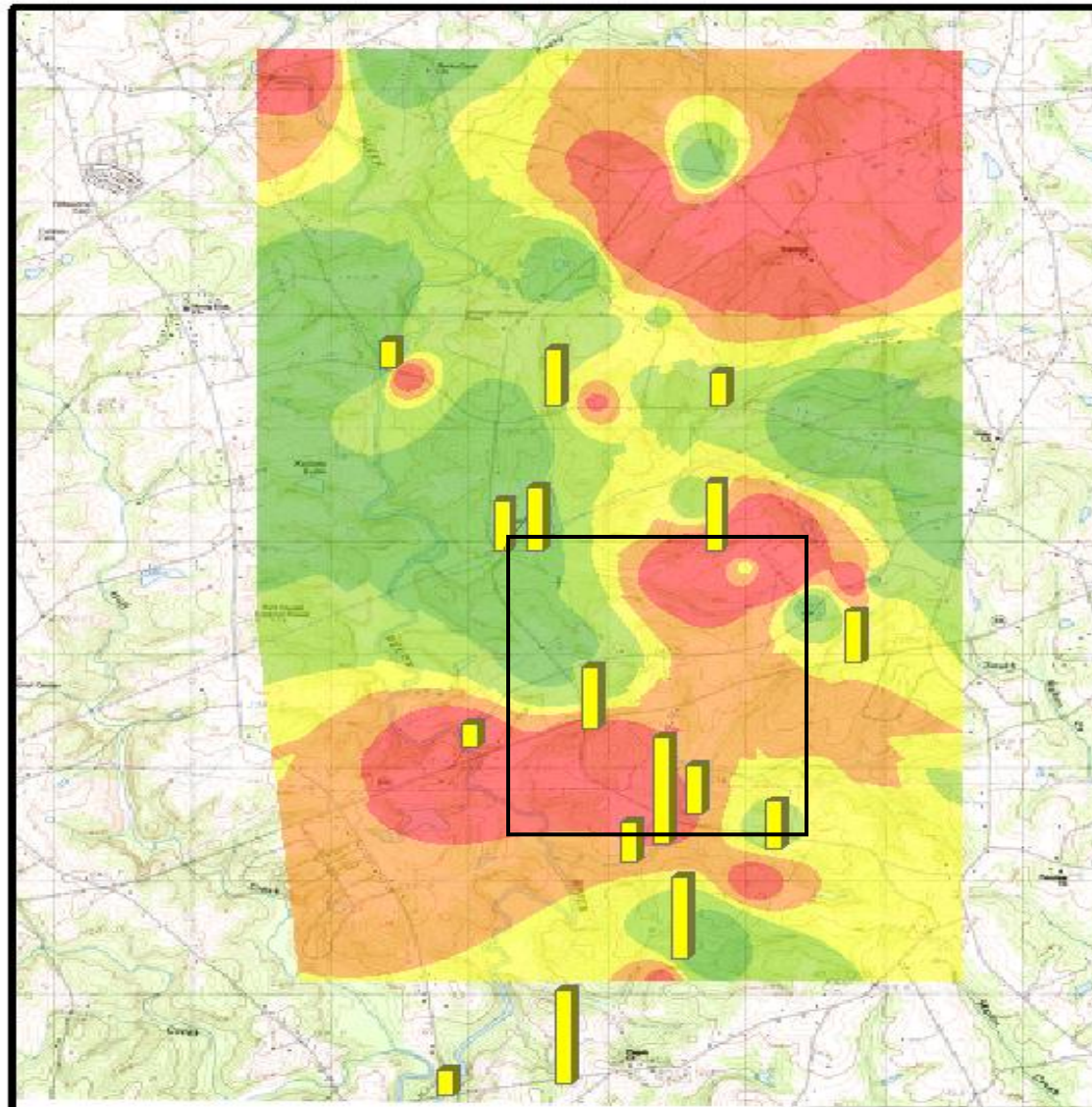


In-situ eU Measurement



Contours determined using Inverse Distance Weighting

Comparison of in-situ and ex-situ measurements



Legend



3.1 Bq per gram



TOTAL_U

Bi-214 Net Counts



-10.0 - 167.2



167.3 - 216.4



216.5 - 242.0



242.1 - 275.4



275.5 - 493.9



0 0.5 1 2 Kilometers

Comparison with UNSCEAR 2000

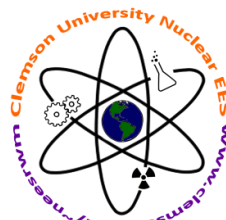
Nuclide	experimental [Activity] (Bq/g)	From γ at	UNSCEAR (Bq/g)	[Activity] ratio	High?
^{40}K	0.386-1.047	1460.8keV	0.370	1.04-2.8	yes
^{238}U *	0.011-0.073	185.7keV***	0.035	0.31-2.1	Some high
^{226}Ra	0.011-0.041	1764.5keV (Bi214)	0.040	0.28-1.03	Normal or low
^{232}Th **	0.013-0.186	911keV (^{228}Ac)	0.035	0.37-5.32	Some high

* $^{238}\text{U} = 0.49 \times \text{total U}$; **Assumed ^{232}Th in equ. with ^{228}Ra ; *** - ^{226}Ra contribution

Maw Bridge Pegmatite; Central SC



N34 44.692' W82 47.963'



Maw Bridge Pegmatite Sampling



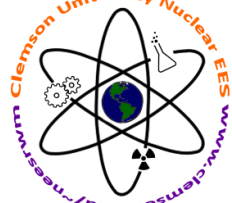
Maw Bridge Pegmatite Samples



Nantahala National Forest in SC



N 34.97208 W83.03143



O'Leary Prospect



Current Research



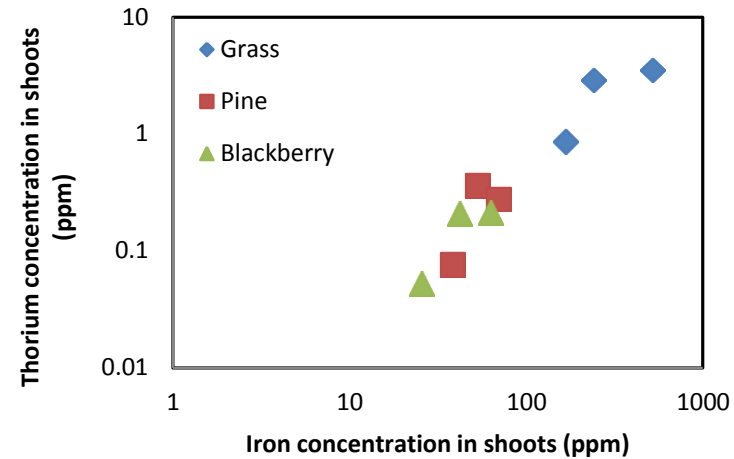
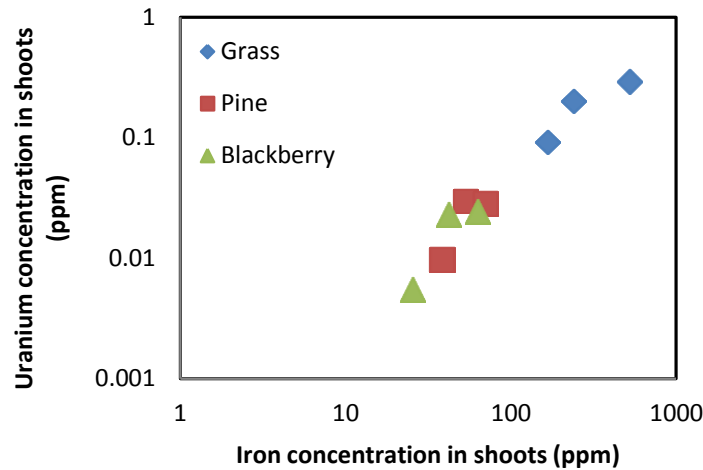
Blackberry

Grass

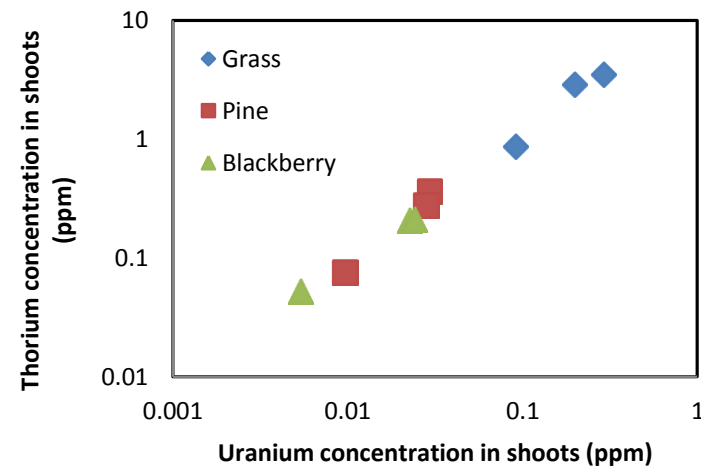


Pine

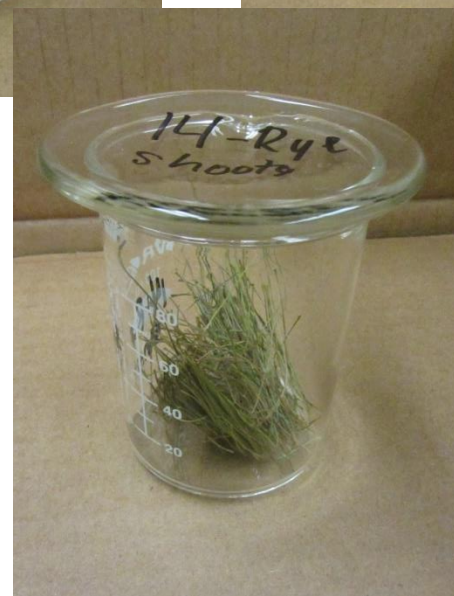
Bioaccumulation of U and Th



Comparisons of U and Fe (top left), Th and Fe (top left), and Th and U (bottom right) uptake in shoots of grass, pine, and blackberry taken from a monazite outcropping site in upstate South Carolina.



EEES Greenhouse



Acknowledgements

- Dr. Richard Warner
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 - Aurelie Soreefan
 - Michael Wall
 - Debra Falta
 - Brian Powell
- Current student
 - Stephanie Ely

References

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- Hughes, L. D., Powell, B. A. Soreefan, A. M., Falta, D. A., DeVol, T. A., “Anomalous High Levels of Uranium and Other Naturally Occurring Radionuclides in Private Wells in the Piedmont Region of South Carolina,” *Health Physics*, Vol. **88**, No. 3, 248-252 (2005).
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