Tracing the Source of Suspended Sediment in Lower Fox River using Radionuclide Analysis

Paul Baumgart[1], Val Klump[2] and Kevin Fermanich[1]

1. University of Wisconsin – Green Bay

Lower Fox River Watershed Monitoring Program –

www.uwgb.edu/watershed

2. University of Wisconsin – Milwaukee

Great Lakes Water institute

AWRA

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THE LOWER FOX RIVER watershed monitoring program

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Disclaimer

1) Preliminary Results

2) Not fully reviewed or approved by other authors, yet

3) Be-7 analysis very preliminary, sometimes delivered to lab late, given short half-life

Primary objective

Determine relative contributions of suspended sediment sources to streams in Lower Fox watersheds
(particulate phosphorus sources later)

Presentation Outline

- Lower Fox River Sub-basin Description
- Methods
- Results: sources compared
- Baird Creek Comparison, source estimation

Why Radionuclides as Tracers?

- Relatively uniform distribution within a region
- Half lives different
- Pb-210 (22 years) Cs-137 (30 yr) Be-7 (53 days)

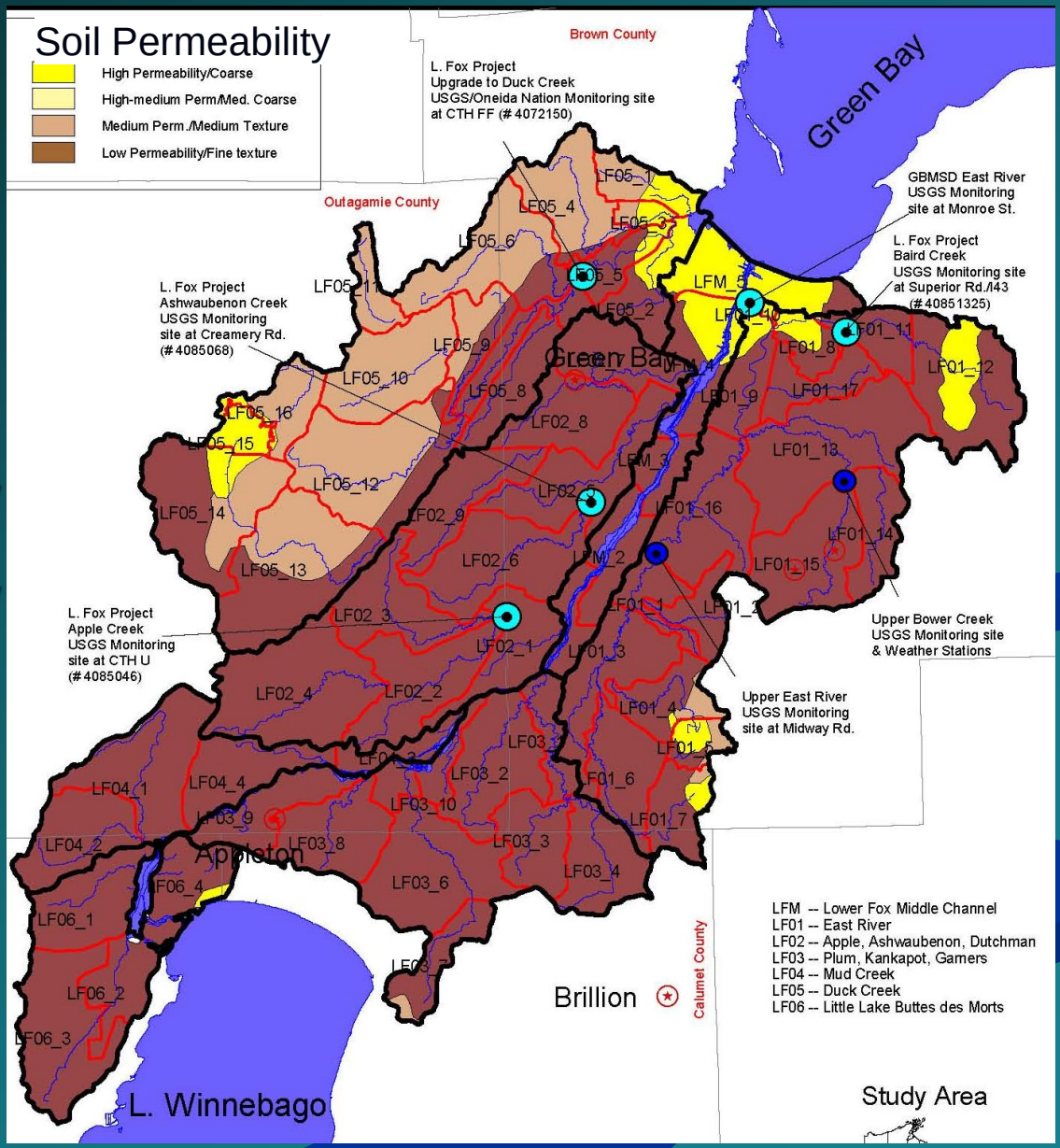
- Cs-137, historical peak in 1960's, essentially no more deposition

- Pb-210 and Be-7, both naturally present, continuous deposition

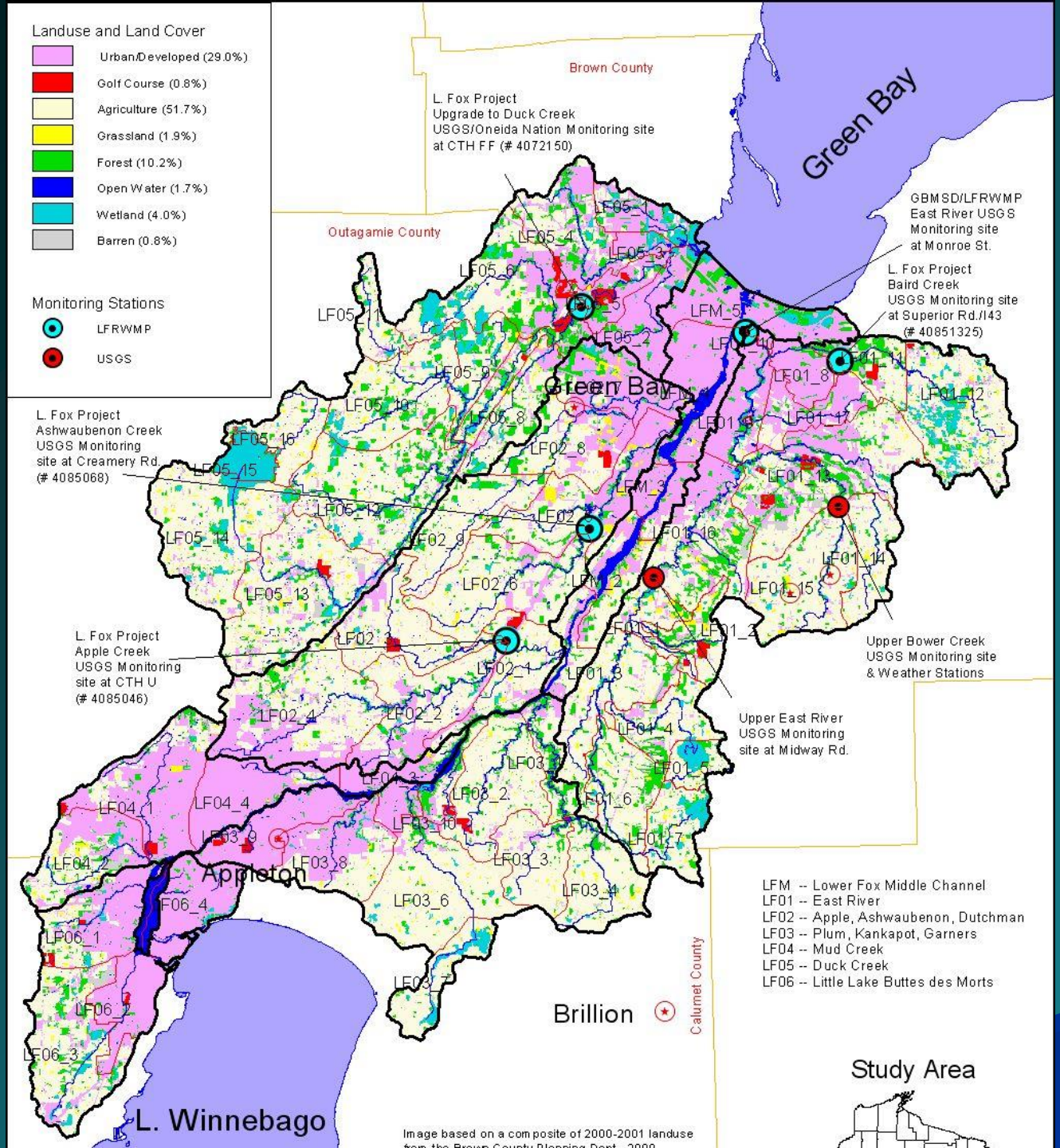
- Pb-210: excess (atmospheric deposition) vs supported

Watershed background:

- Clay soils
- High % runoff
- 730 mm precip avg
- ~ 200-240 mm flow
- ~ 16-27% baseflow



Lower Fox River Year 2000 Landuse and Land cover



Methods

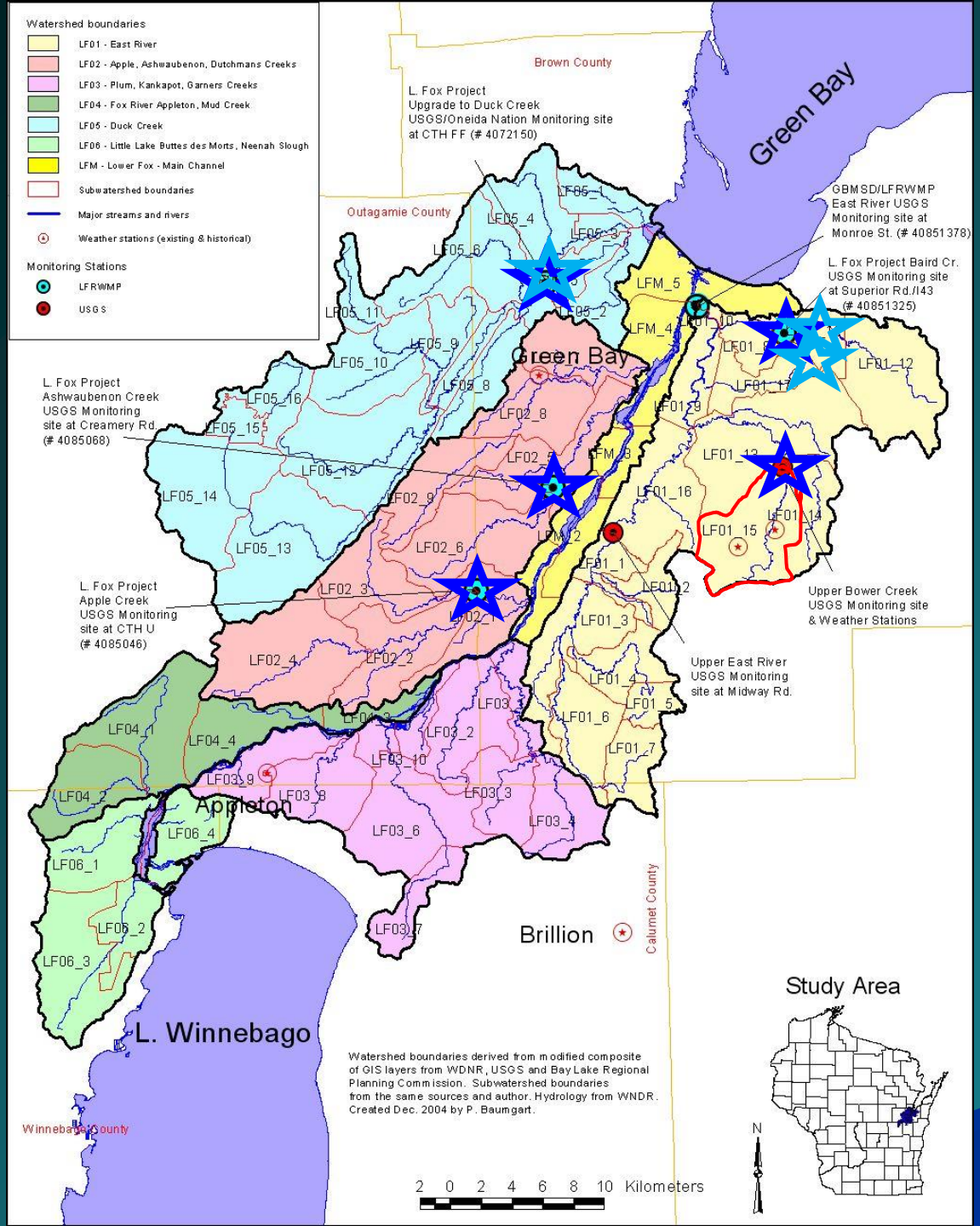
- Soil samples
- Stream bank samples
- Suspended sediment sample
- Detention pond
  - 6 cores analyzed: 2 to 4 cm sections

Methods

- UW-Green Bay sampling, processing, chemical analysis
- UW-Milwaukee (Val Klump) radionuclide analysis (Cs-137, Pb-210, Be-7)
- Sources: rural runoff, stream bank, construction site, urban
- Samples collected/analyzed from 2006 to Nov. 2010

1. Suspended sediment (streams) including limited winter and Spring snowmelt samples from Baird North/South (total of 73 samples, sufficient mass for analysis)

2. Soils – 4 fields (along transects, composite for each sample, surface 2 cm, top 10 cm, bottom 10 cm, total of 17 cores; total of 37 sections)
3. Sub-soil (4 samples)
4. Stream bank (6 samples - Baird Creek)
5. Detention ponds - 4 sites: Huron-Sitka, Whittier, I-43 NE, I-43 NW (6 cores, 2 to 4 cm sections, 35 sections analyzed)



Lower Fox River watersheds & subwatersheds

LFRWMP Total of 8 stations

3 in Baird Creek, main stem, N & S channels

Suspended Sediment Trap

Time-integrated suspended sediment sampler

Phillips, J.M., Russell, M.A., and Walling, D.E., 2000. Time-integrated sampling of fluvial suspended sediment: a simple methodology for small catchments: Hydrological Processes, v. 14, p. 2589-2602.

Russell, M.A., D.E. Walling, and R.A. Hodgkinson. 2000. Appraisal of a simple device for collecting time-integrated fluvial suspended sediment samples. p. 119–127. In M. Stone (ed.) The role of erosion and sediment transport in nutrient and contaminant transfer. IAHS Publ. 263. Int. Assoc. of Hydrol. Sci., Wallingford, UK.

Table 1. Suspended sediment & water quality monitoring sampling locations.

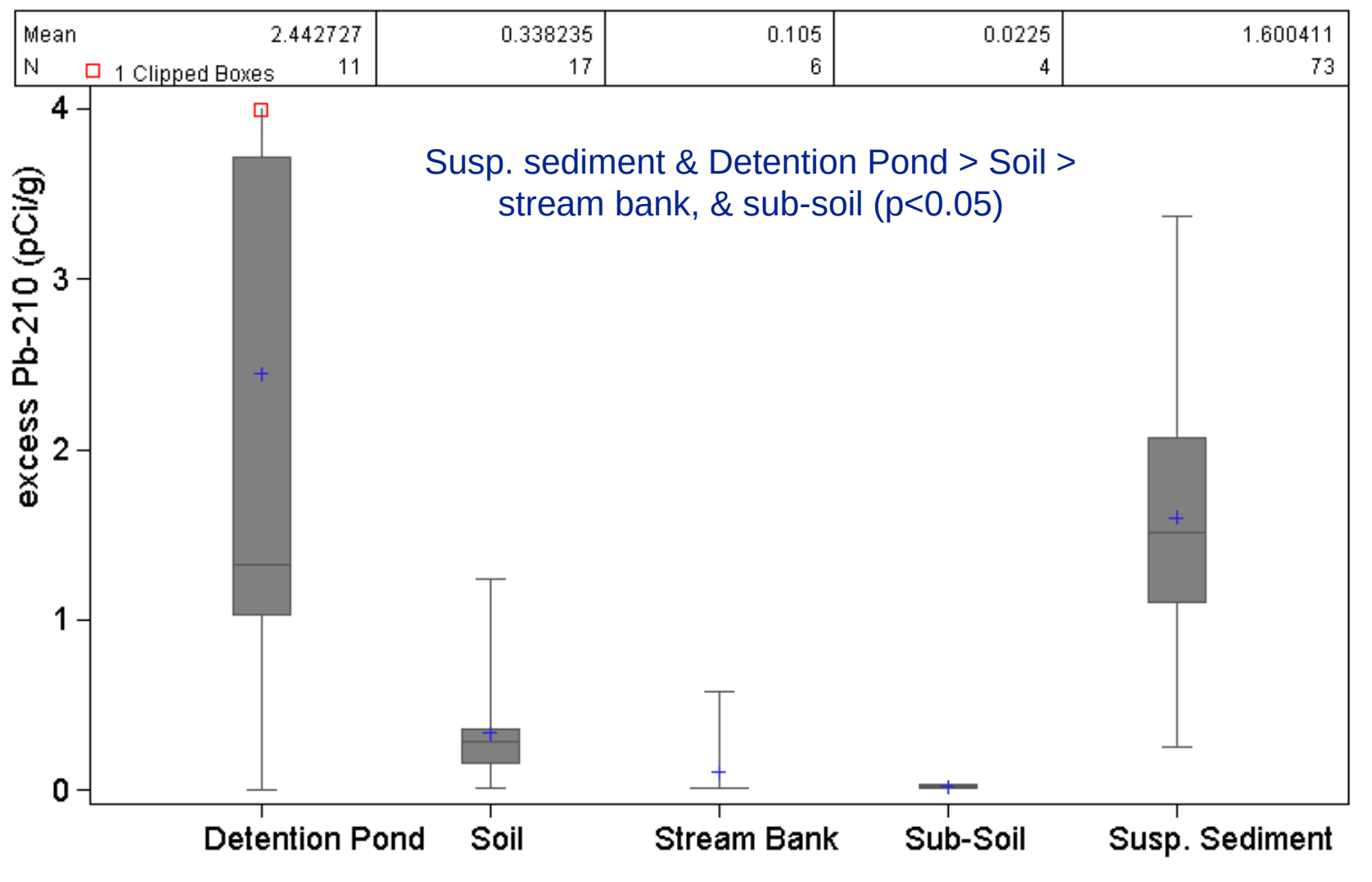
Watershed	Water sampling (flow, TSS, TP, DP), and continuous flow monitoring period (High quality loads *)	Suspended sediment tube sampling period	Initial sediment tube placement
Apple Creek at CTH U / Campground (117 km2)	LFRWMP: **2004-2006***	2006-09	6/6/2006
Ashwaubenon Creek at (48 km2)	LFRWMP: **2004-2006***	2006-09	7/19/2006
Baird Creek Main Stem at (54 km2)	LFRWMP: **2004-2008***	2006-10	6/6/2006
Baird Creek North Branch	intermittent	2006-10	8/10/2006
Baird Creek South Branch	intermittent	2006-10	8/10/2006
Bower Creek at CTH MM (36 km2)	USGS/WDNR: **2007-2008***	2006-09	10/1/2006
Duck Creek at CTH FF (276 km2)	LFRWMP: **2004-2008***	2006-09	8/1/2006
Trout Creek at CTH FF	UWGB: 2008	2008-09	5/1/2008

Results
Mean Activity by Source Material

		activity level of each radionuclide				
Source	n	Pb-210 (pCi/g)	Ex-Pb-210 (pCi/g)	Cs-137 (dpm/g)	Be-7 (dpm/g)	K-40 (dpm/g)
Suspended sediment	74	2.18	**1.60**	**0.23**	**10.74**	6.20
Detention Pond	19	3.18	2.49	0.22	1.23	6.54
Soil	37	0.99	**0.33**	**0.28**	0.32	7.28
Sub-Soil	4	0.82	0.02	0.02	0.07	8.36
Stream Bank	6	0.38	0.10	0.05	0.10	5.35

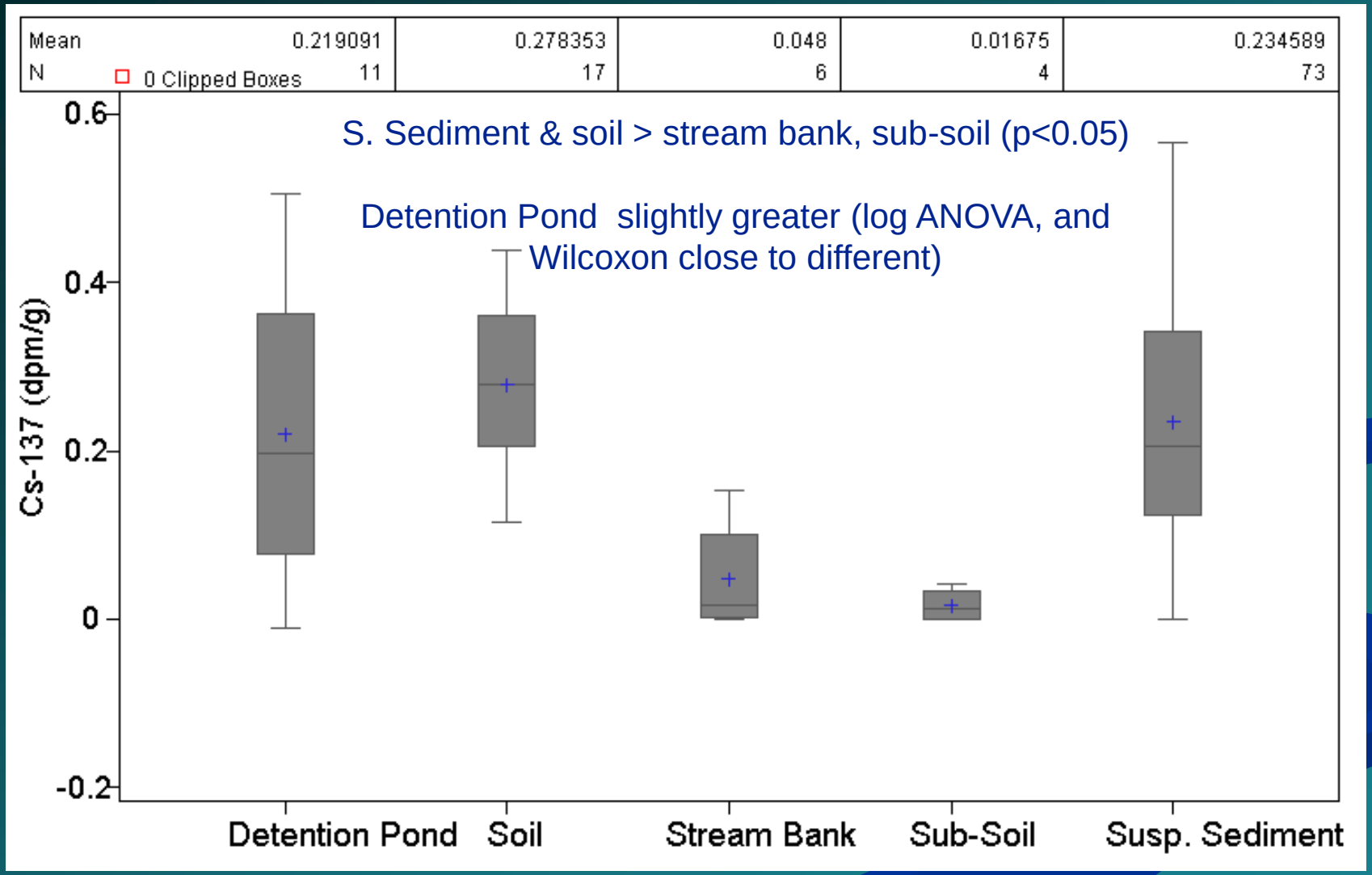
Excess Pb-210, by source

(2 & 4 cm det. Pond sections included; only surface soil surface sections)



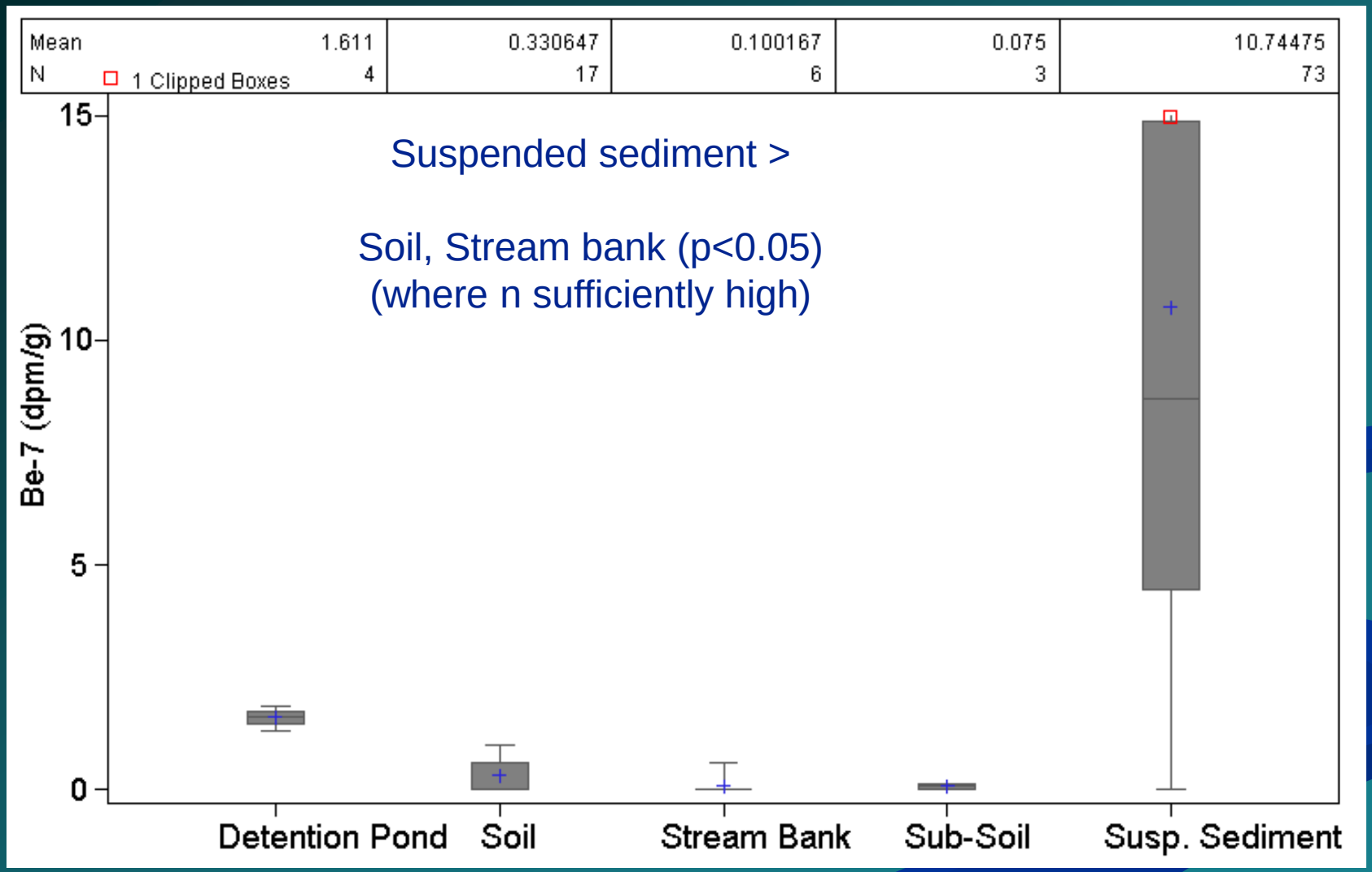
Cs-137, by source

(2 & 4 cm det. Pond sections included; only surface soil surface sections)

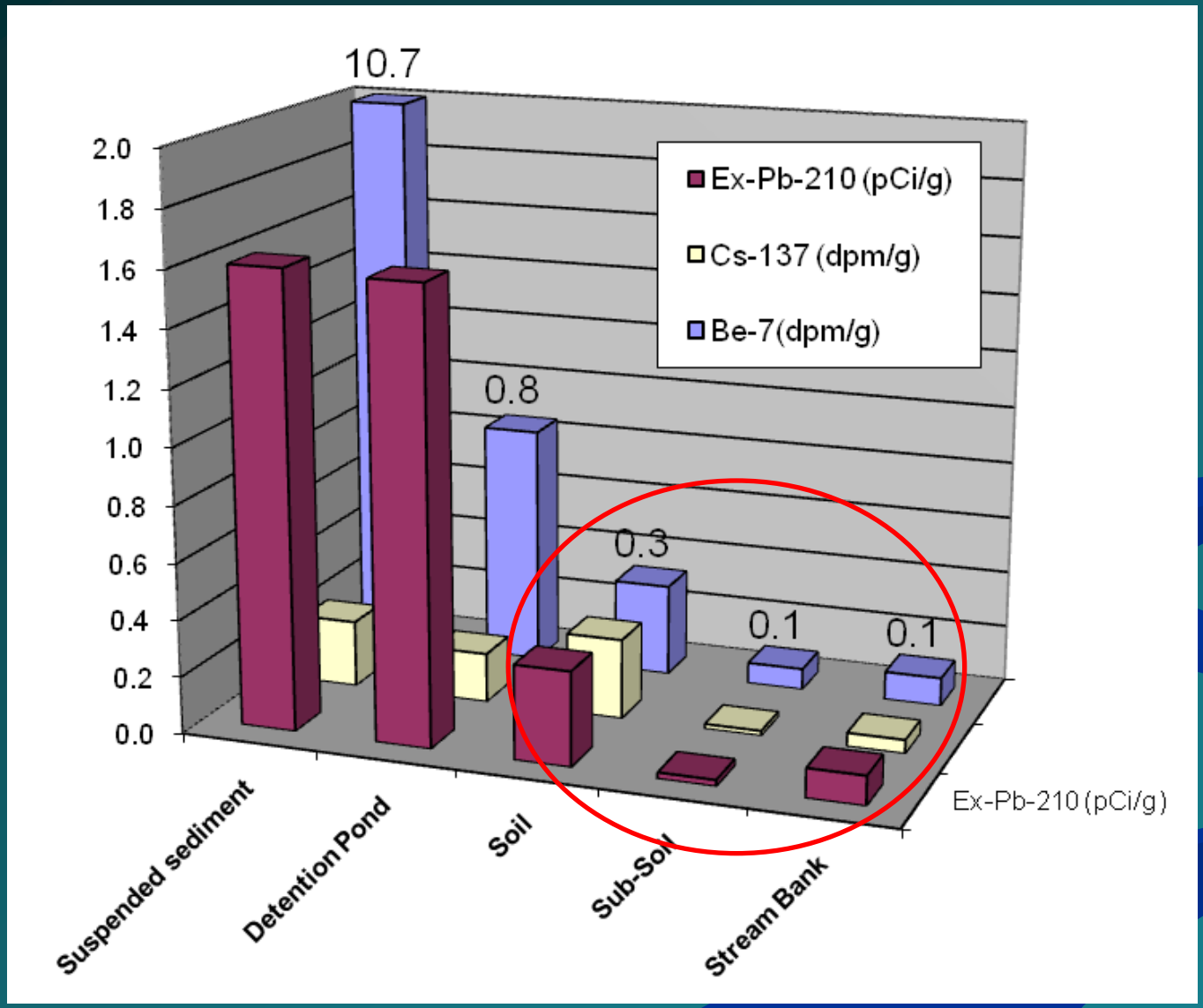


Be-7 (preliminary), by source

(2 & 4 cm det. Pond sections included; only surface soil surface sections)



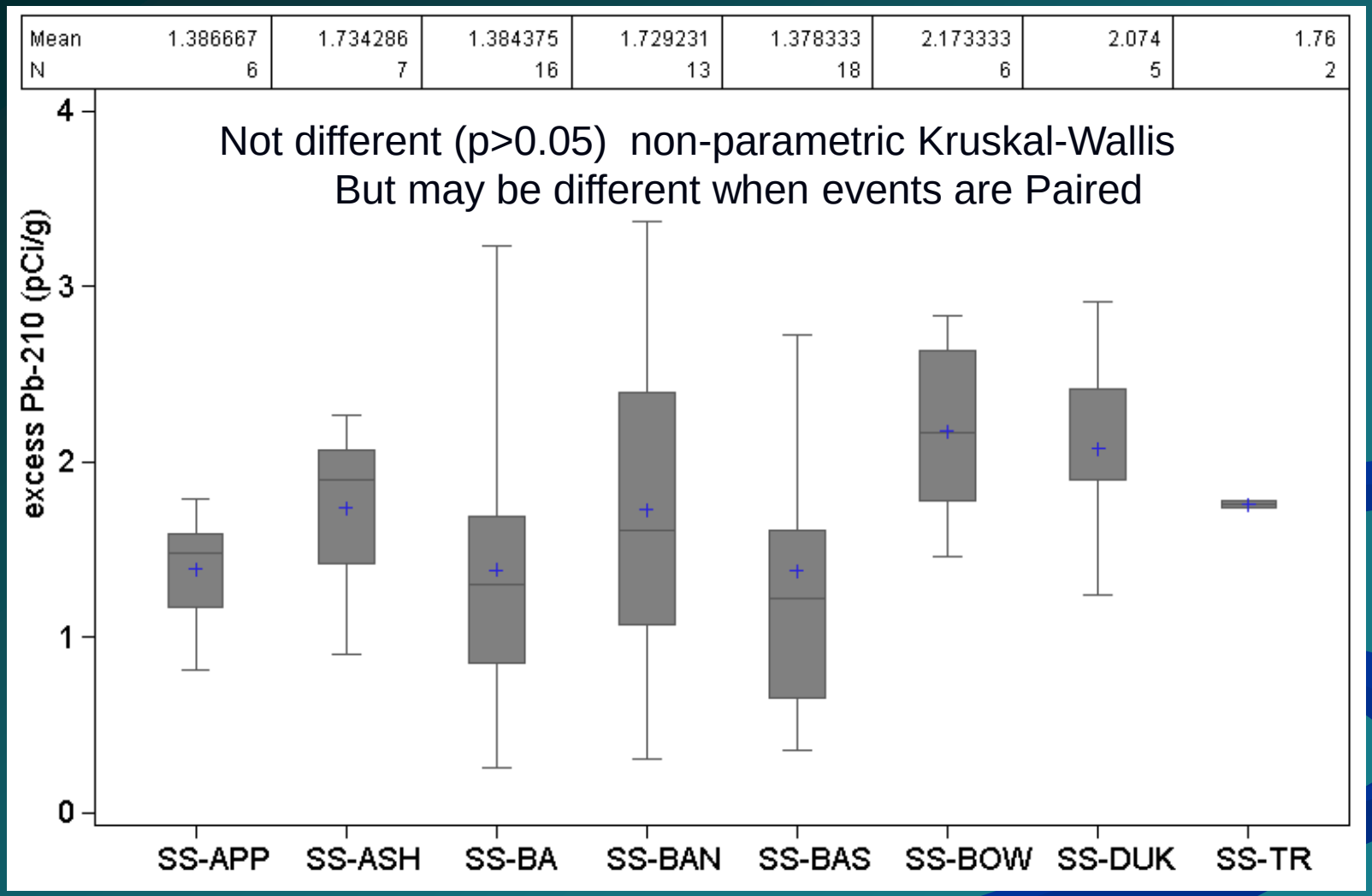
Radionuclide Mean Activities
Preliminary Results (Be-7)



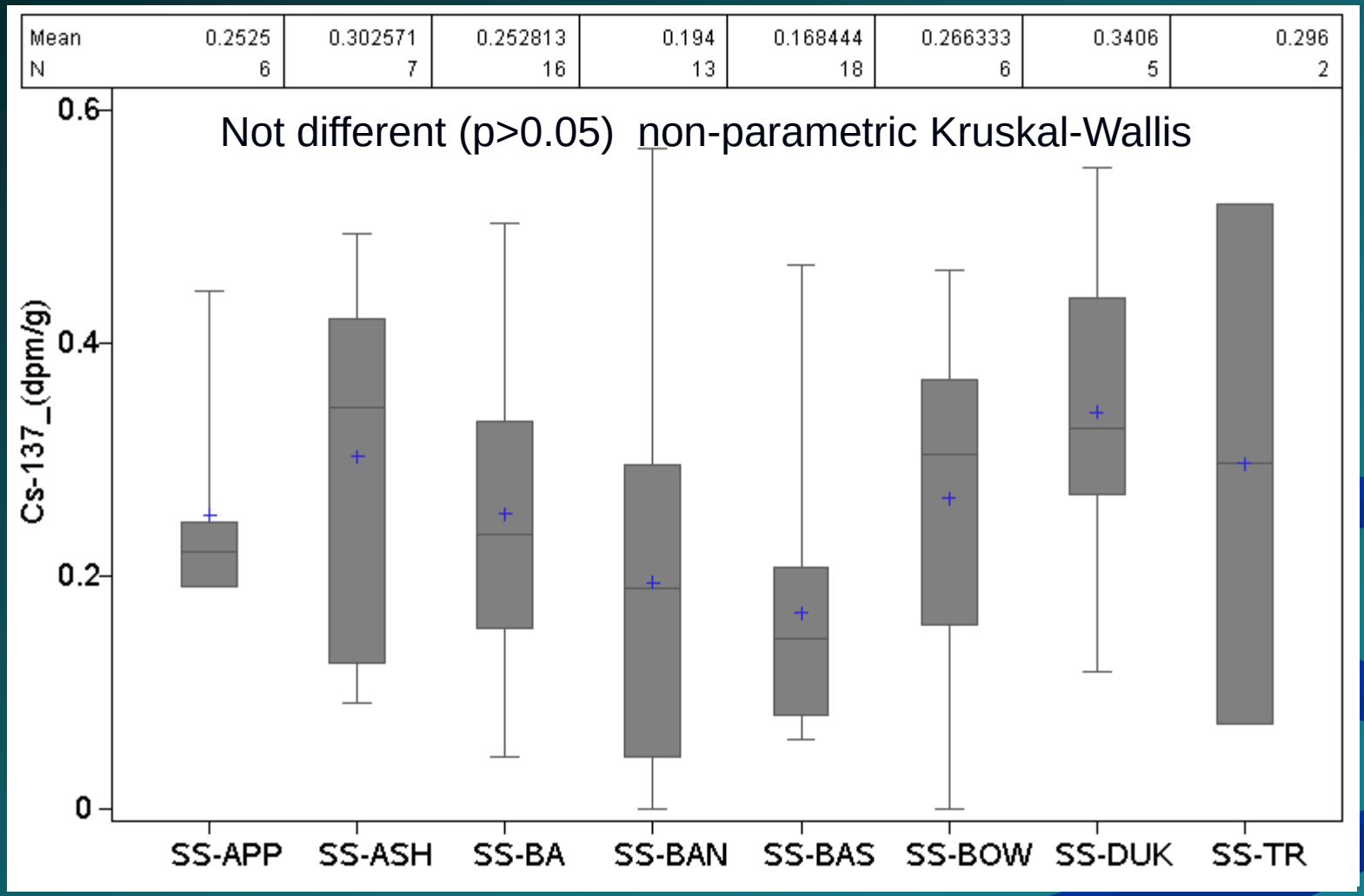
Source Materials as Tracers?

- Can distinguish source materials such as soils from stream bank based on: Cs-137 & excess Pb-210
- Over all streams combined, suspended sediment in traps more likely from soils than stream banks
- Next step: mixing models

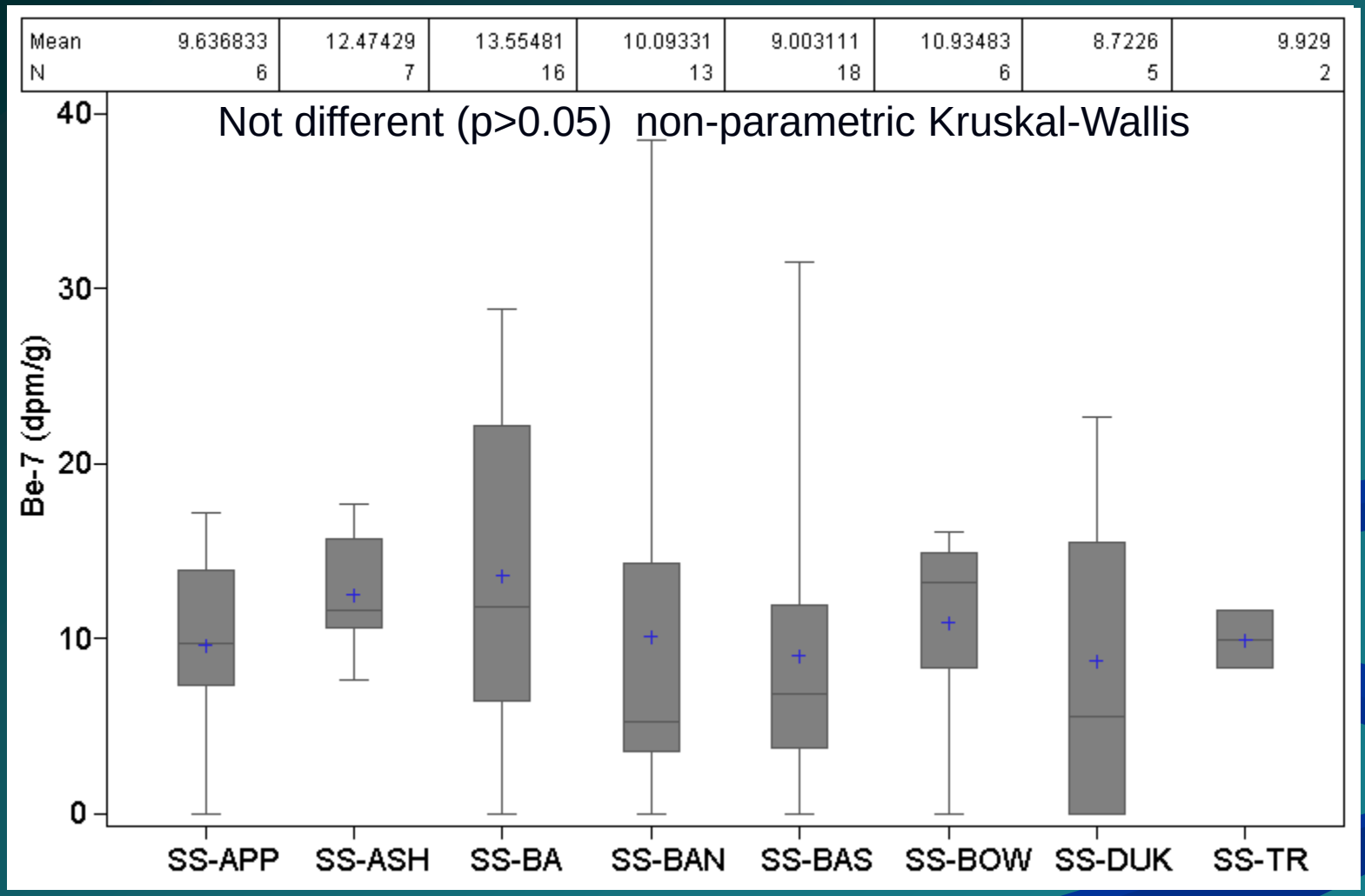
Streams: Suspended Sediment (ex Pb-210)



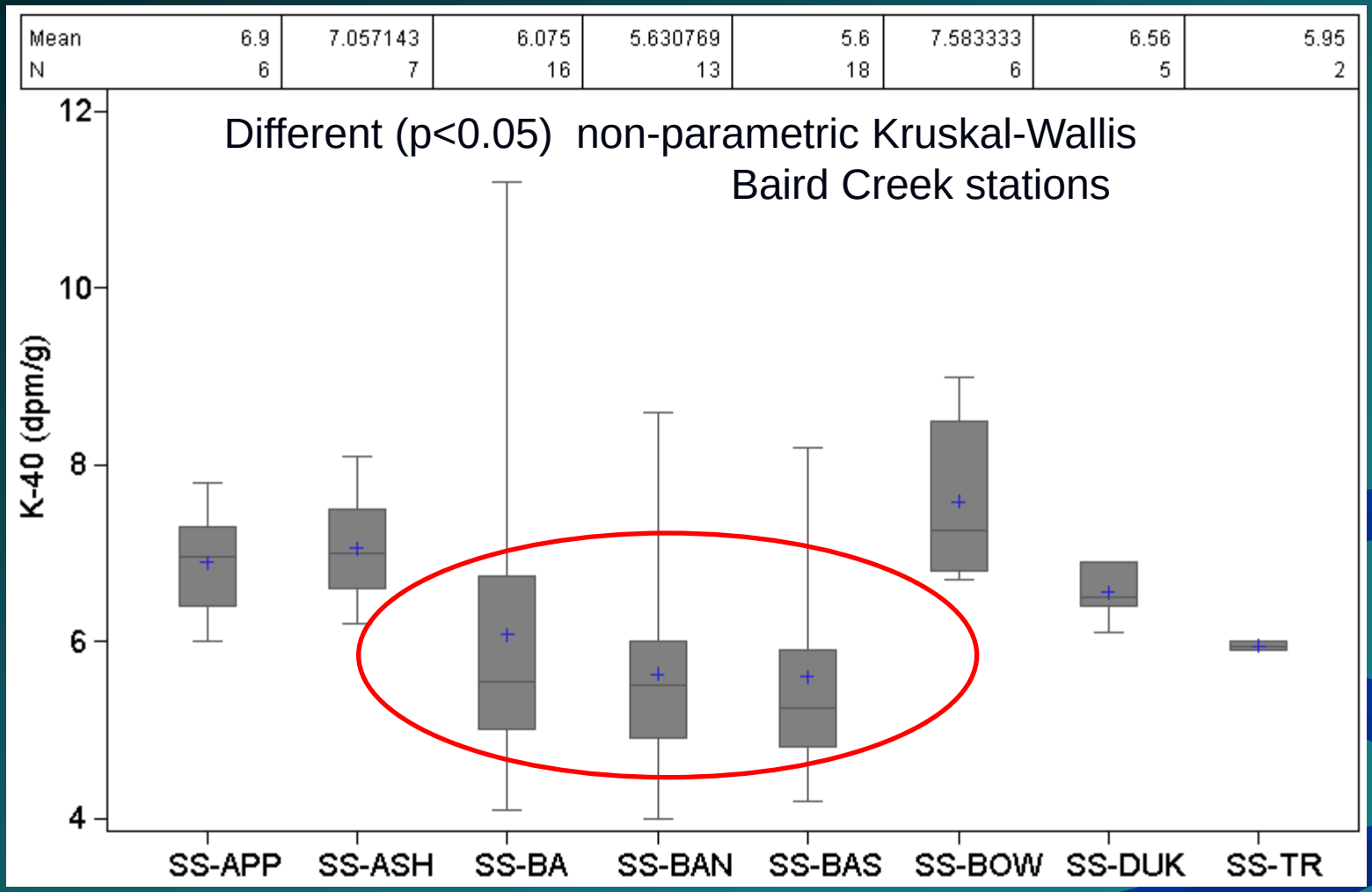
Streams: Suspended Sediment (Cs-137)



Streams: Suspended Sediment (Be-7)

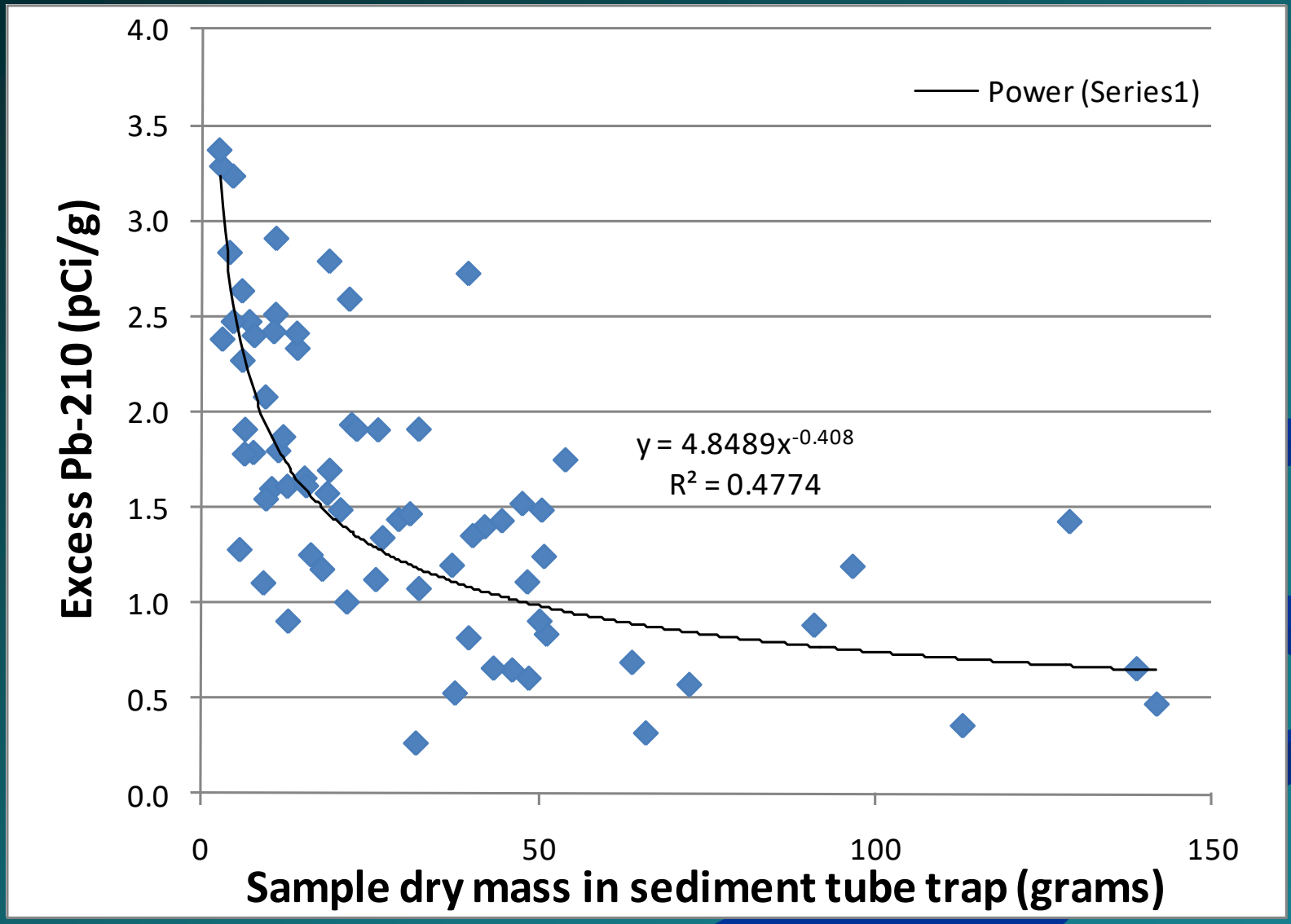


Streams: Suspended Sediment (K-40)

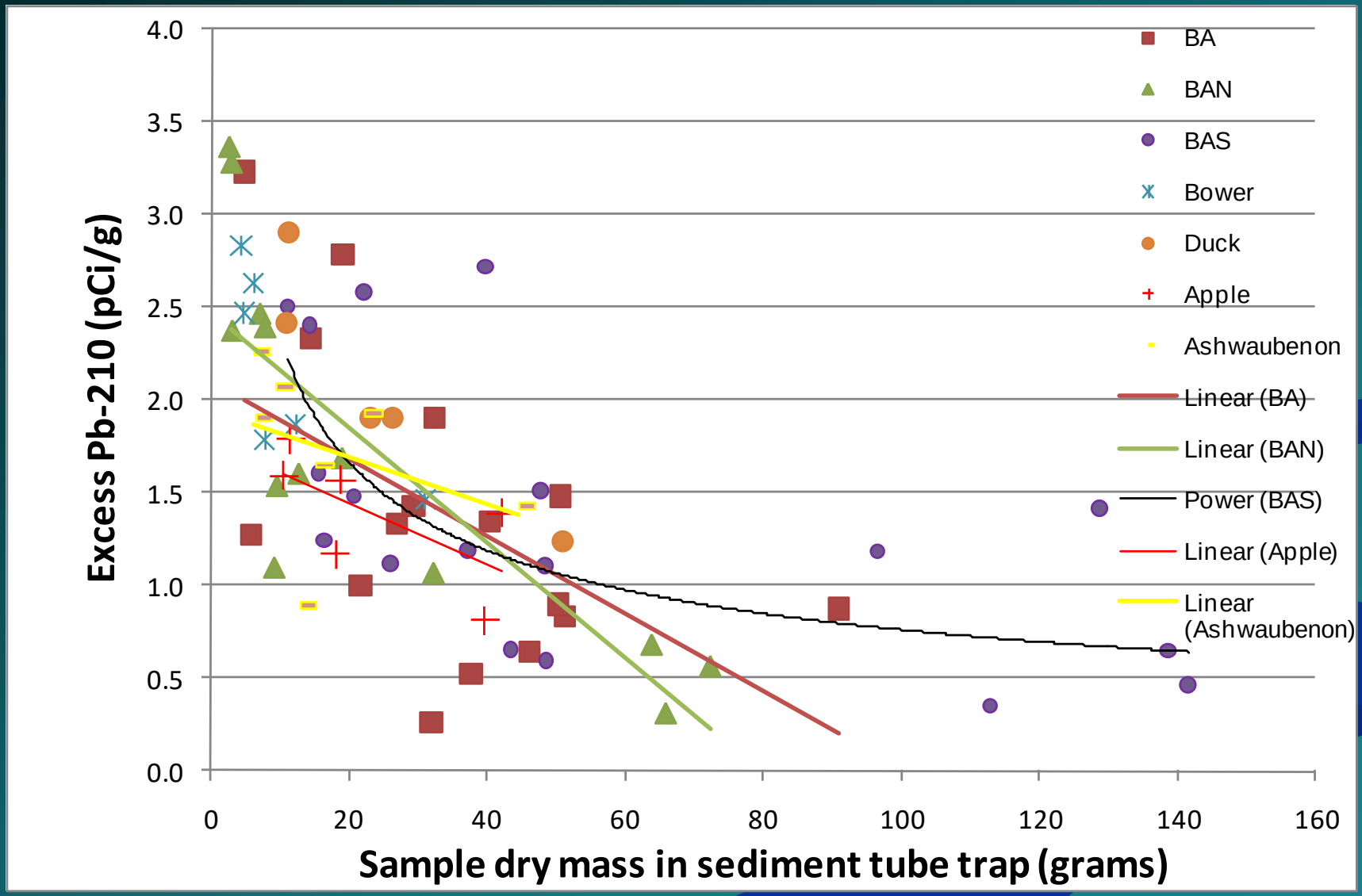


Stream Station

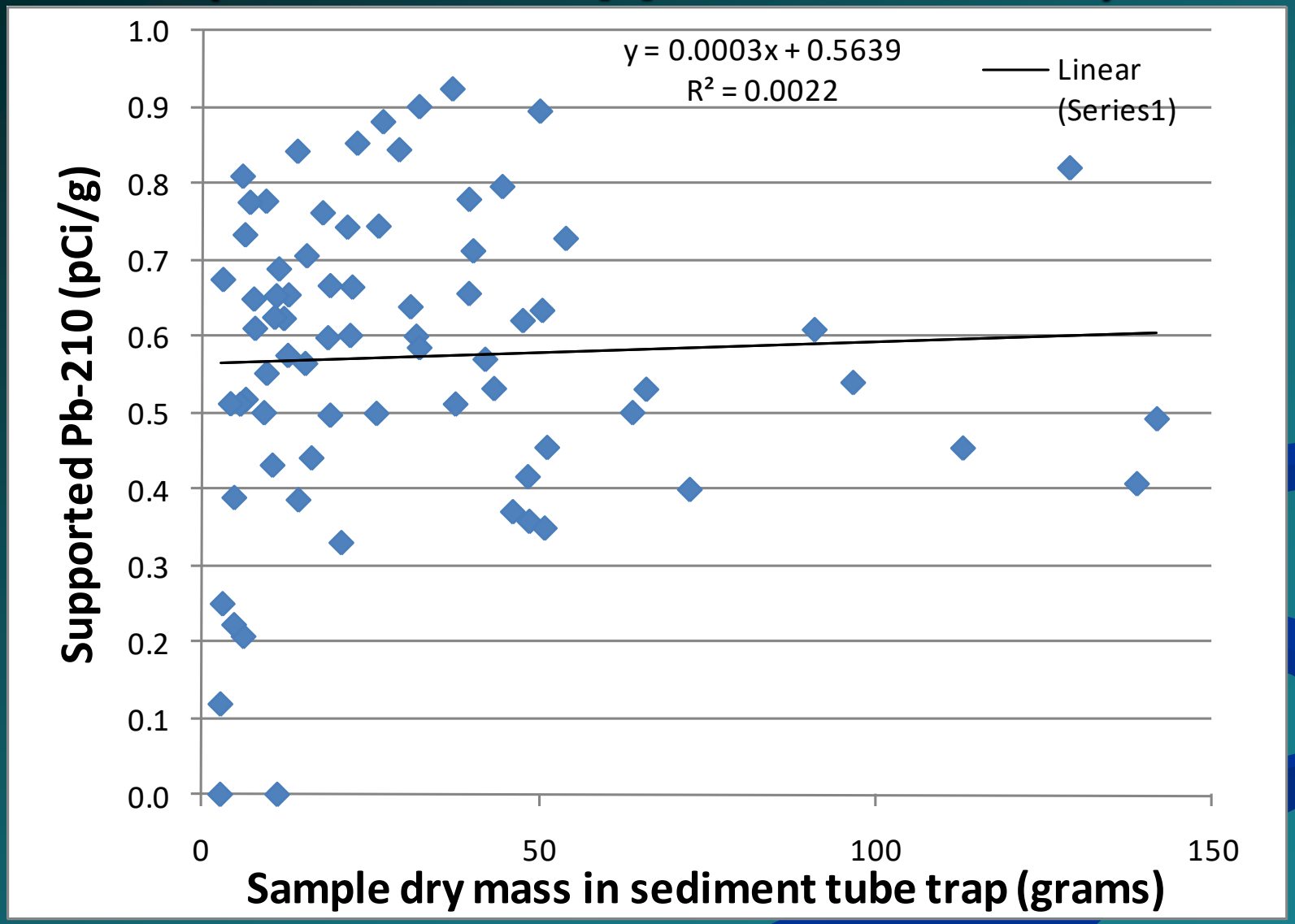
Suspended Sediment Traps (mass vs Excess Pb-210)



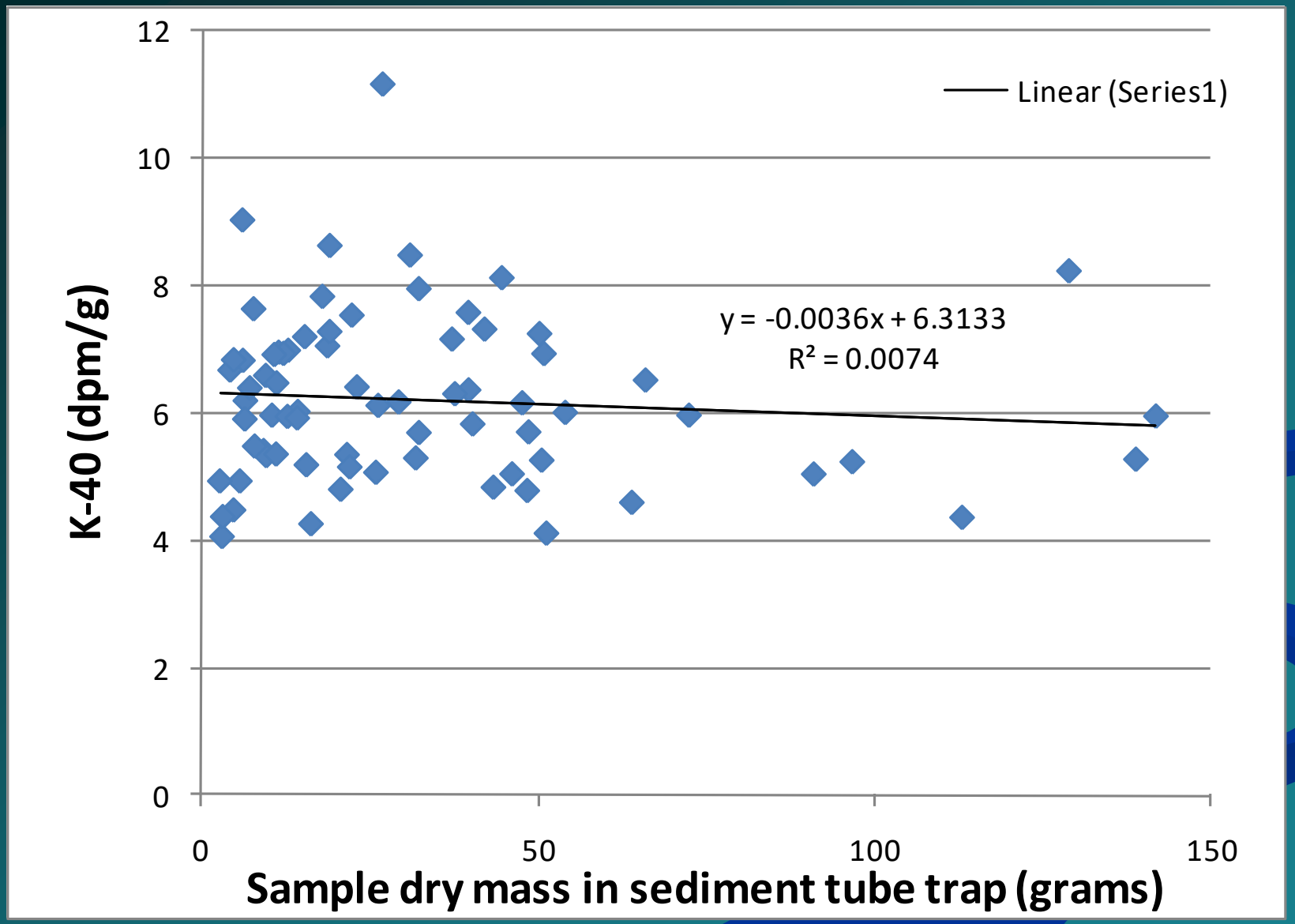
Suspended Sediment Traps (mass vs Excess Pb-210)



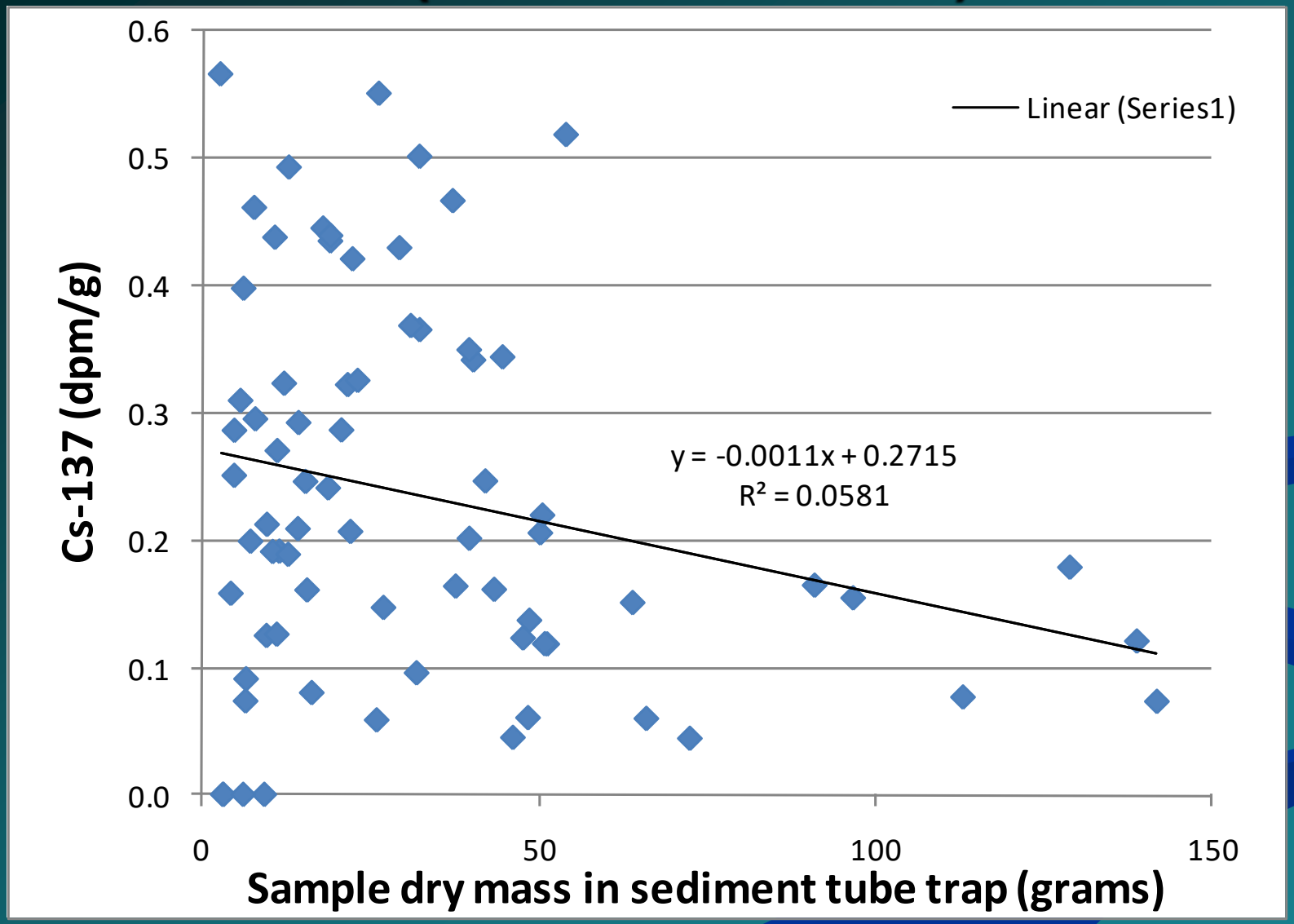
Suspended Sediment Traps (mass vs supported Pb-210)



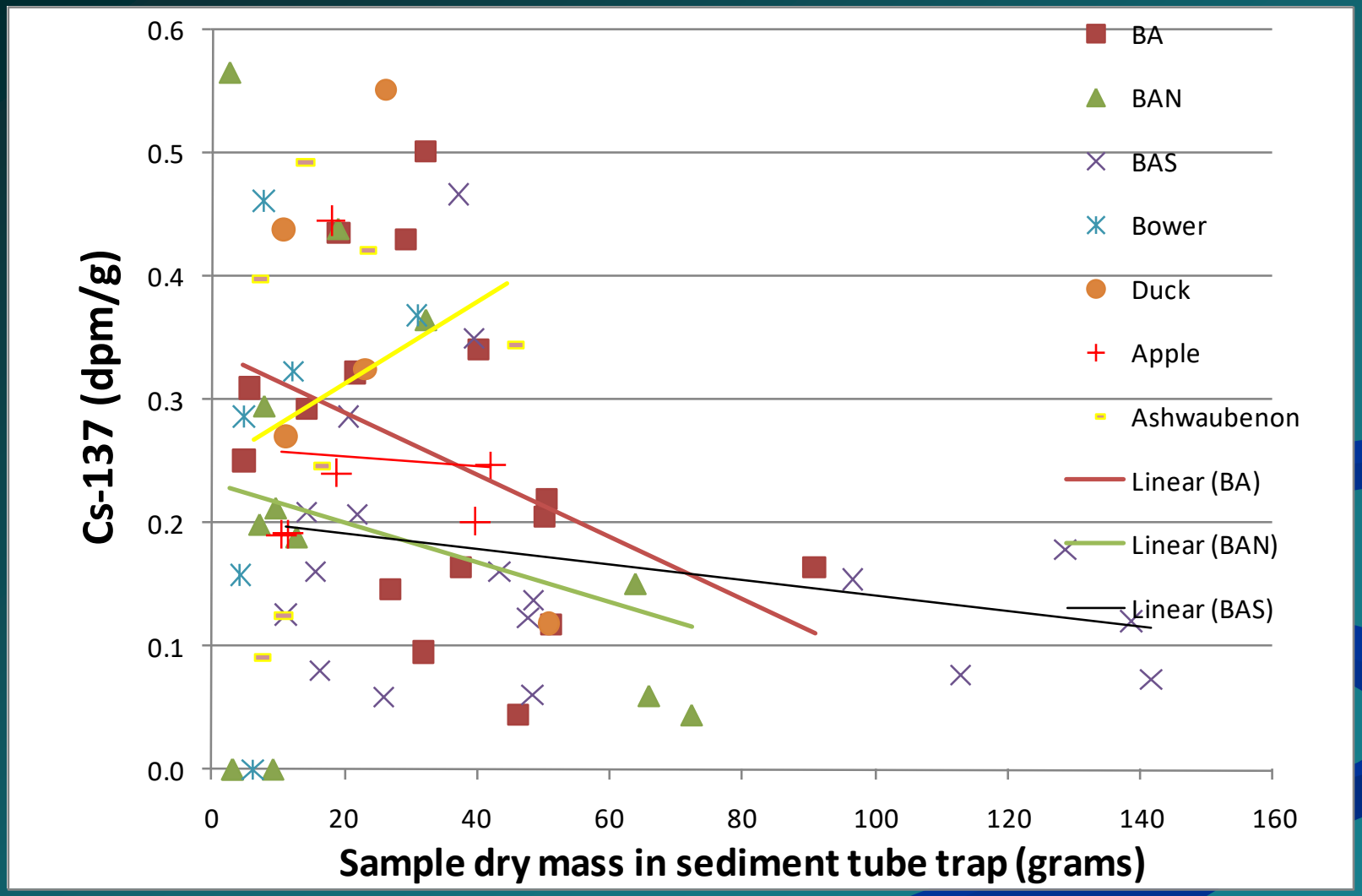
Suspended Sediment Traps (mass & K-40)



Suspended Sediment Traps (mass vs Cs-137)

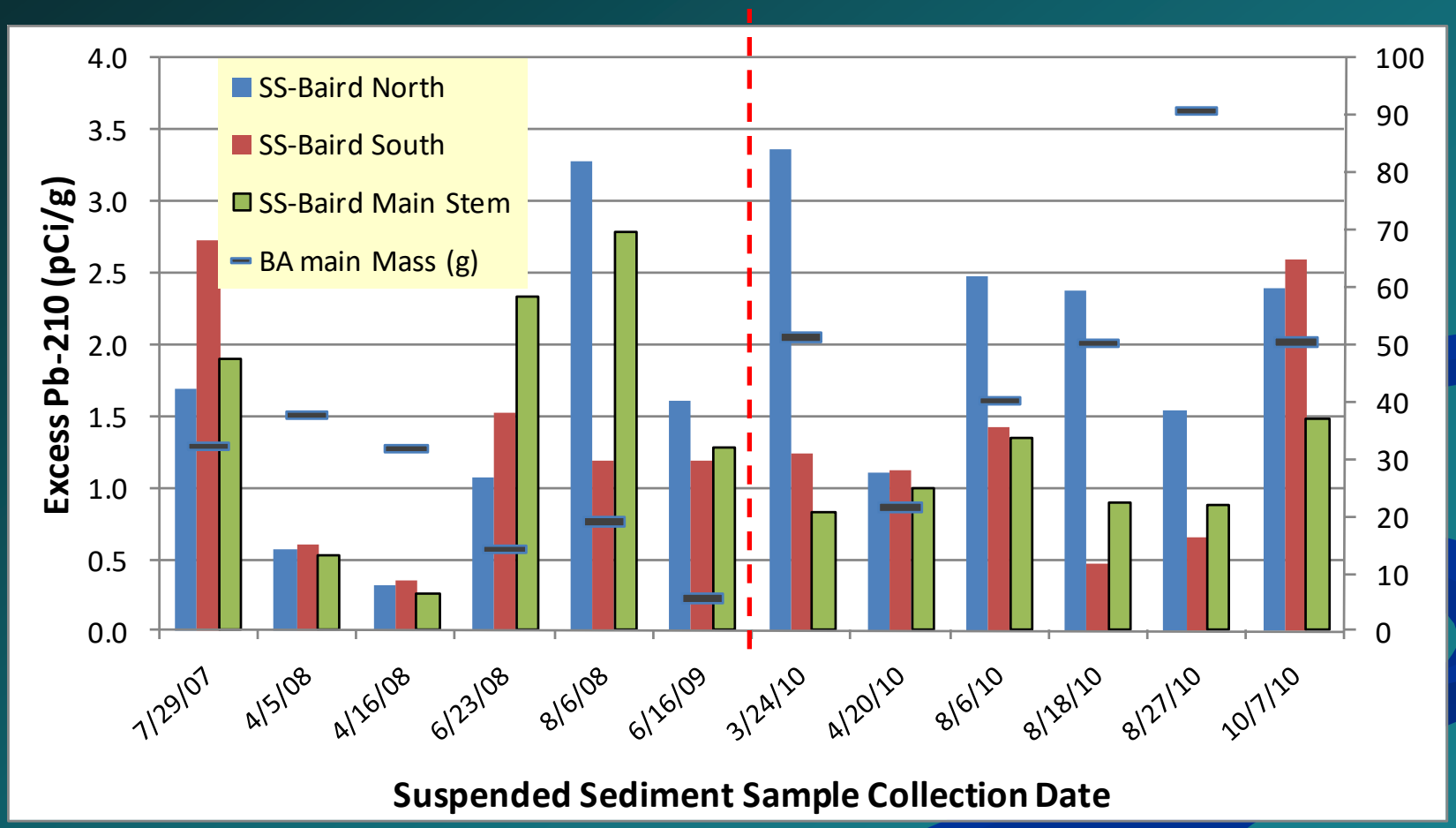


Suspended Sediment Traps (mass vs Cs-137)

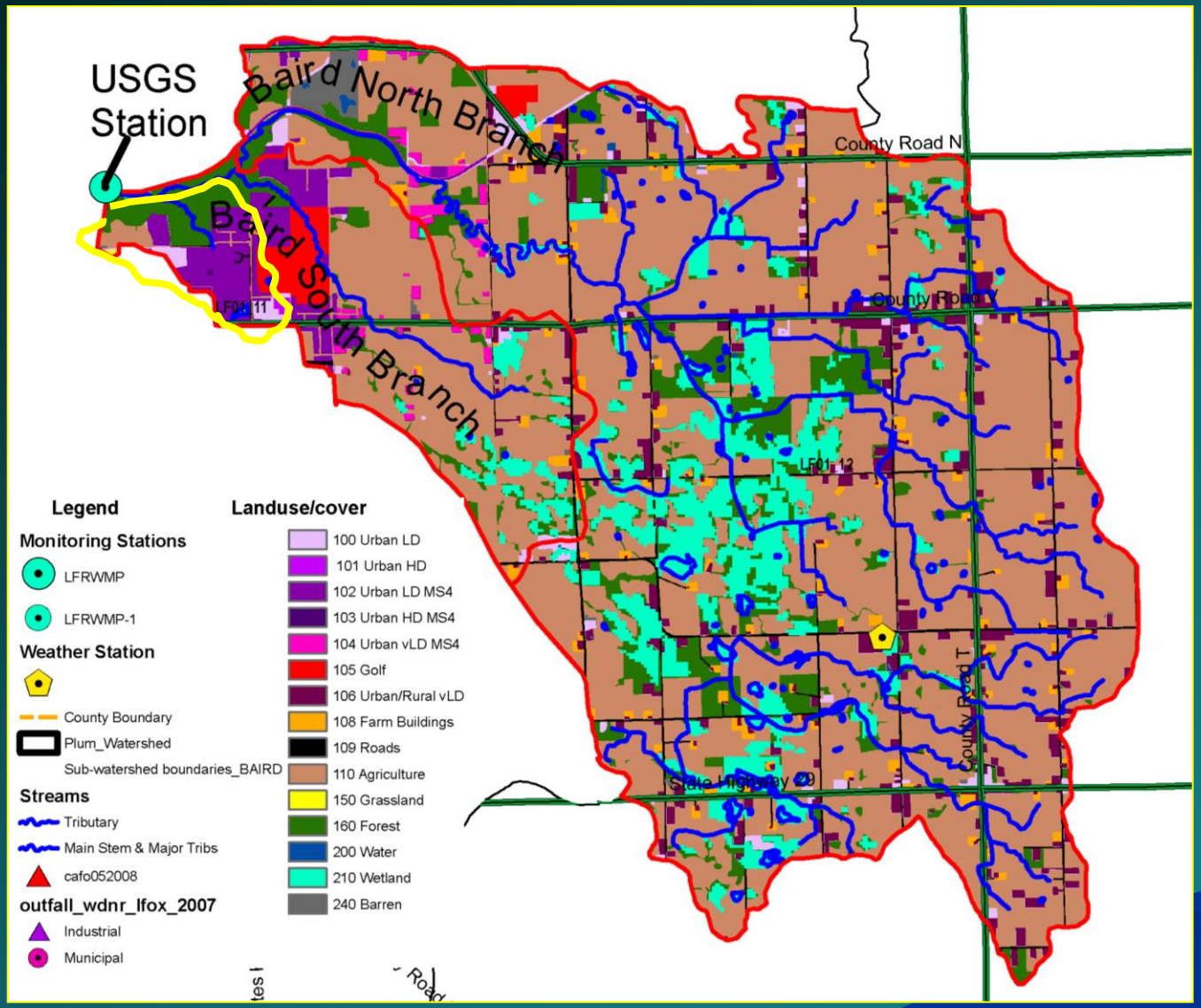


Baird Creek: North, South, Main stem Compared

- 12 Paired events/periods compared for Baird Main, North & South tribs



Baird Creek 2004 landuse



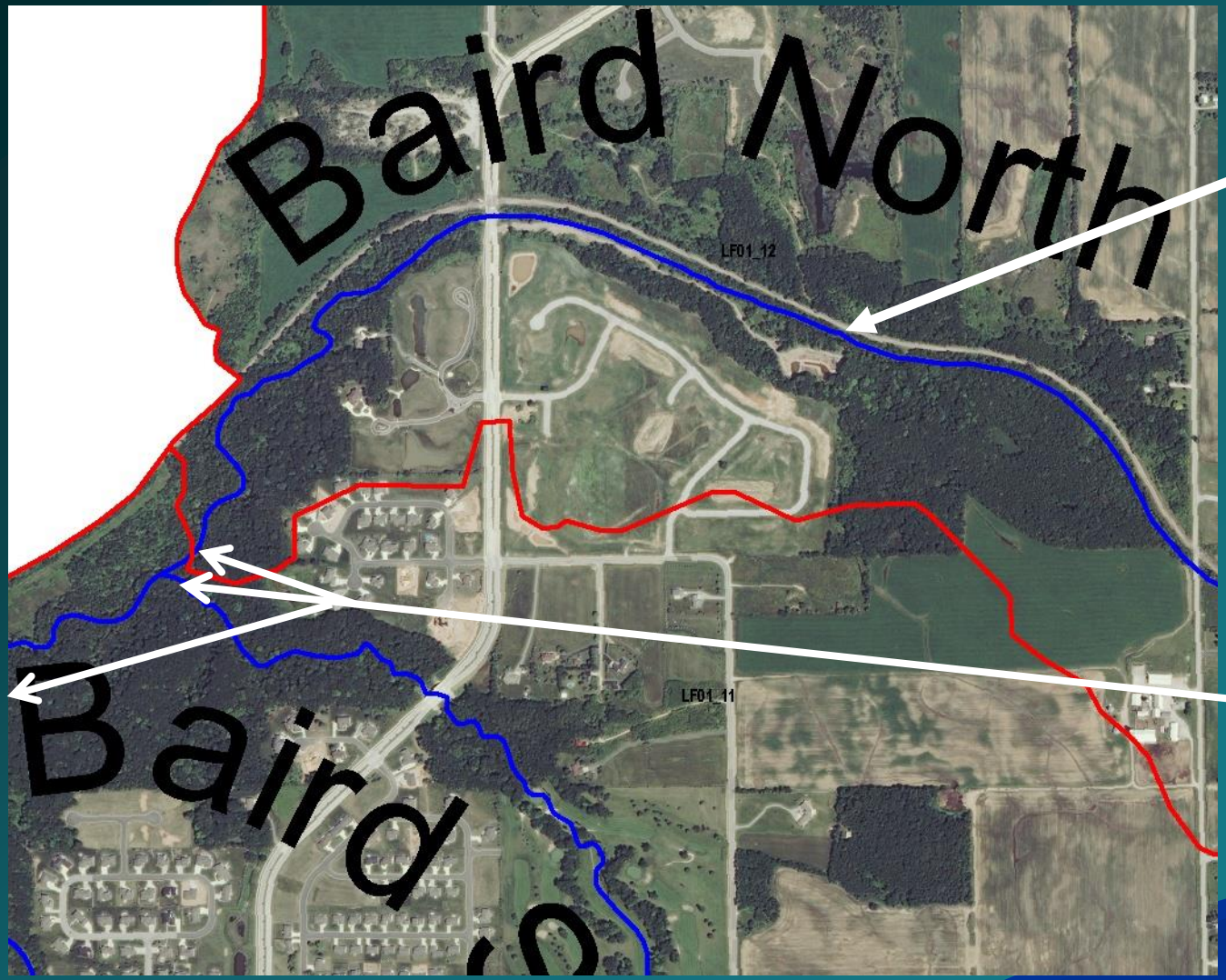
- Which trib contributes more suspended sediment?
- North branch = 45 km^2, Ag (brown), wetland (cyan)
- South branch < 8.8 km^2, more urban (purple)
- Lower main stem, banks & catchment?

Baird Creek: North, South, Main stem Compared

- 12 Paired events/periods compared for Baird Main, North & South tribs
- Excess Pb-210: Nonparametric Wilcoxon Scores by Station: p = 0.08 Kruskal-Wallis test (Cs-137 not significant at p = 0.17), not paired sign rank sum test YET
- Log-transformed Excess Pb-210: p = 0.069, significant at 0.1 level with ANOVA repeated measures on event (highly signif. on event); BAN different than BAS & BA; BA & BAS NOT different, suggests over all 12 events, BAS major source to BA
- Minimize Sums of Squares error on excess Pb-210 (natural log)
- 1st cut analysis SUGGESTS:
  - 12 events: North branch ~ 30%, Baird South ~ 70% of S. Sediment (2007-10)

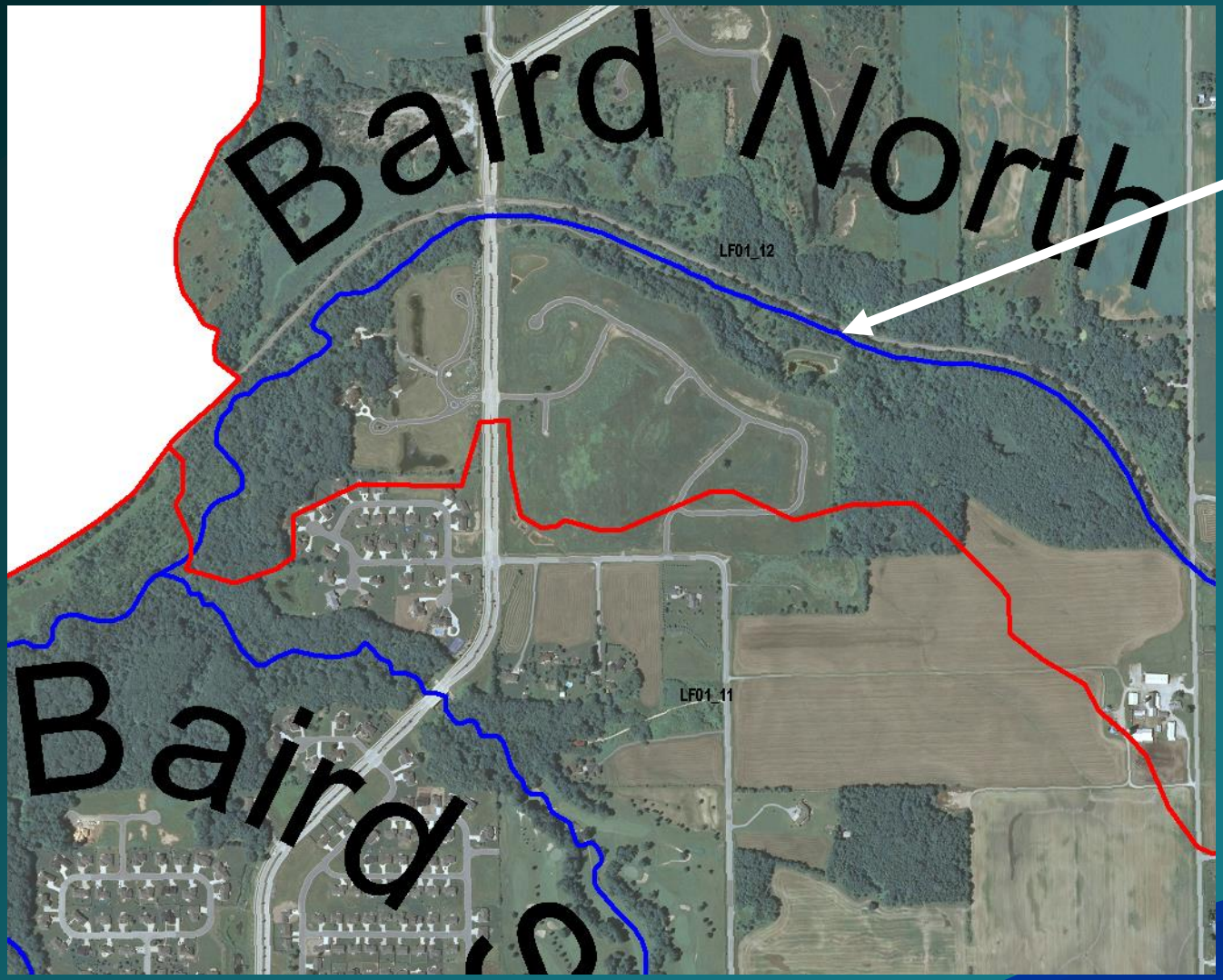
(not weighted by flow or mass)

Baird Creek 2008: road/pond built



- North branch development with road and detention pond
- Trib contribution of suspended sediment?
- Sediment trap tubes placed just before junction, and DS @ main stem

Baird Creek 2010 after road/pond built



- North branch road and detention pond now finished
- Which trib contributes more suspended sediment

Estimated Contribution of Suspended Sediment

- Last 6 events/periods compared: Baird Main, North & South tribs
- Excess Pb-210: Anova – repeated measure on event
- Station effect significant ($p = 0.012$) Tukey multiple paired comparisons: Baird North significantly different than Baird South and downstream Main Stem ($p < 0.05$)
- Baird South and Main Stem not significantly different
- Minimize SSE on excess Pb-210 (natural log) during last 6 events estimate contributions
- 1st cut PRELIMINARY analysis SUGGESTS:
  - If minimize SSE on Last 6 events: North branch ~ 20%, Baird South ~ 80% of S. Sediment (2007-2010 entire period)

(not weighted by flow, just concentration)

Baird Creek: 1st (2007-09) vs 2nd period (2010)

- Paired Periods/Events (6 in each period)
- Non-parametric test: Exact Wilcoxon (rank sums)
- Hypothesis: Effect of Construction activity/failures adjacent to Baird North Channel reduced by 2010
  - 1st Period Excess Pb-210 lower at Baird North (p=0.09*)
    Cause - Mixing with lower activities from banks, deeper soils?
  - 1st Period: K-40 lower (larger particle sizes) Reject/opposite
- All others, test to see if different, including Combined

Channel	**Ex Pb-210**	Cs-137	**K-40**
Baird North (n=12)	0.0898*	0.94	0.18
Baird South (n=12)	1.00	0.48	0.37
Baird Main Stem (n=12)	0.59	0.70	0.20
Combined (n=36)	0.69	0.58	0.039

* Single sided test

Baird Creek: 1st (2007-09) vs 2nd period (2010)
First cut conclusions

- Impact of Construction activity/failures adjacent to Baird North Channel possibly reduced by 2010 (ex Pb-210 higher by 2010, less dilution by low level soils/banks, p=0.09*)
  - K-40 NOT lower (similar or smaller particles in 1st period)
- Combined streams (18 pairs compared)
  - K-40 significantly lower in 2010 (high erosion year) (p=0.039)
  - Cause? Greater contributions from coarse materials with lower K-40 activities/mass (i.e., stream banks, larger grained soils)

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Possible Explanations for ex. Pb-210 in Baird - Why are North and South Channels Different?

- Last period: North channel SS has higher excess Pb-210 than South and DS main channel during 2010 (after detention pond/road construction mostly completed) --- Why?
- Upland slopes steeper in South sub-watershed, more intense/deeper soil erosion > dilution with deeper lower level excess Pb-210 soil > reduces overall excess Pb-210 in runoff
- In general, South sub-watershed may have greater bank erosion, and stream banks are lower in excess Pb-210
- Conversely, North sub-watershed may have less bank erosion (except 2007-early 2009), so stream bank contribution too small to reduce high levels of excess Pb-210 from thin surface erosion

- 1st take, Initial 6 paired events/periods saw no significant differences in excess Pb-210 among Baird North, South and downstream main channel ---- maybe due to excessive sediment from new construction site adjacent to North channel

Difficulties

- Representative samples: sample spring snowmelt?
- If leave tube over winter, ice forms in tube
- Early March, put in stream --- cut through up to 18” ice
- Timing critical, Ice rises, stakes & tubes get pulled out
- Low to very low baseflow vs moderate baseflow
- Debris plugging tube inlet
- High flow conditions – clays --- capture efficiency?

Future Analysis

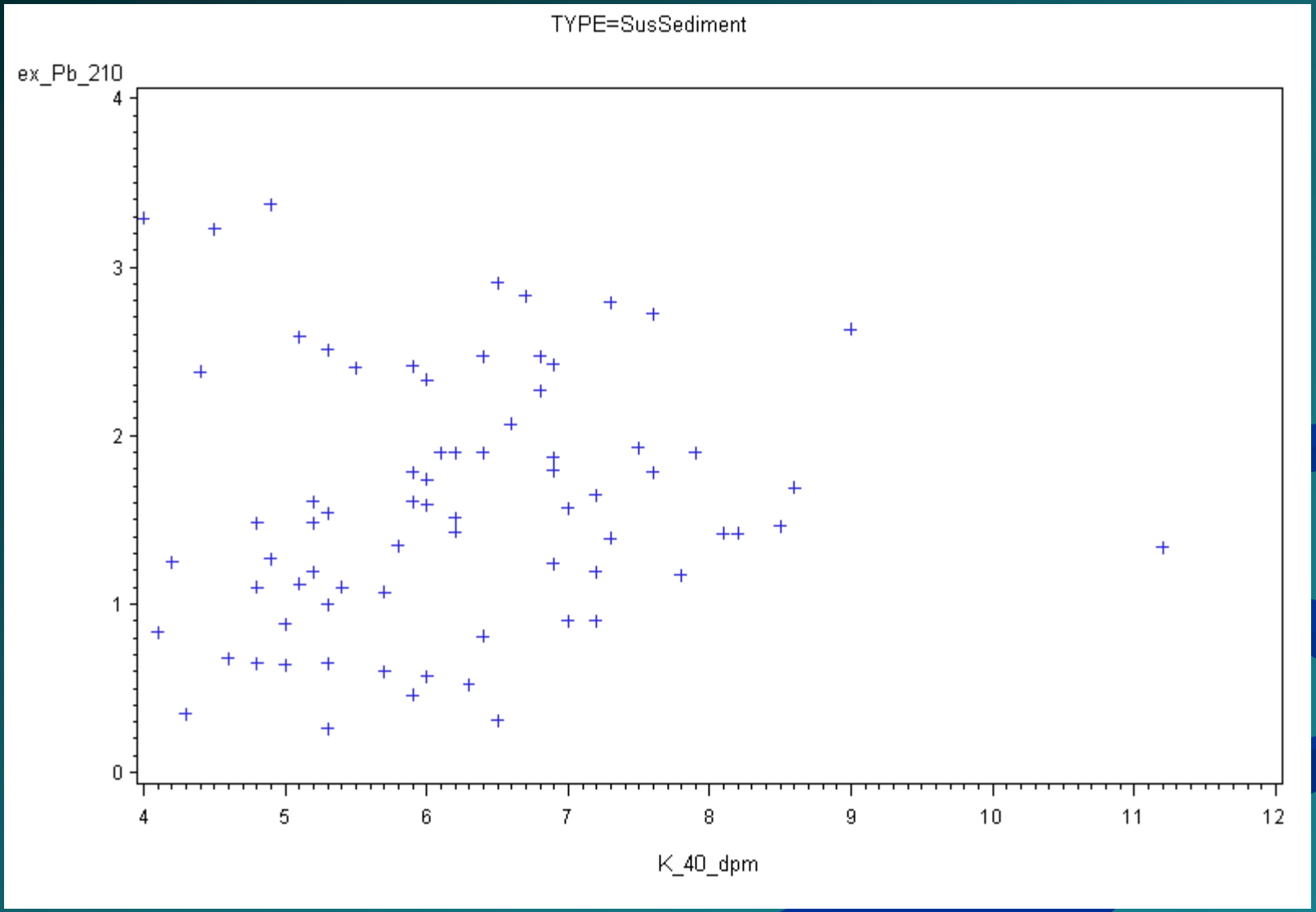
- P – phosphorus
- Pb – lead
- Zn – zinc
- Al – aluminum
- Cd - cadmium
- Cu – copper
- Ni – nickel
- Mn – manganese
- Cr – chromium
- Mg – magnesium
- K – potassium
- Ca – calcium
- Fe – iron

- Potential metals for future analysis
- Started sample digestions
- Mixing Model

Questions?

Email: baumgarp@uwgb.edu

Web site: www.uwgb.edu/watershed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ex_Pb_210
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K_40_dpm