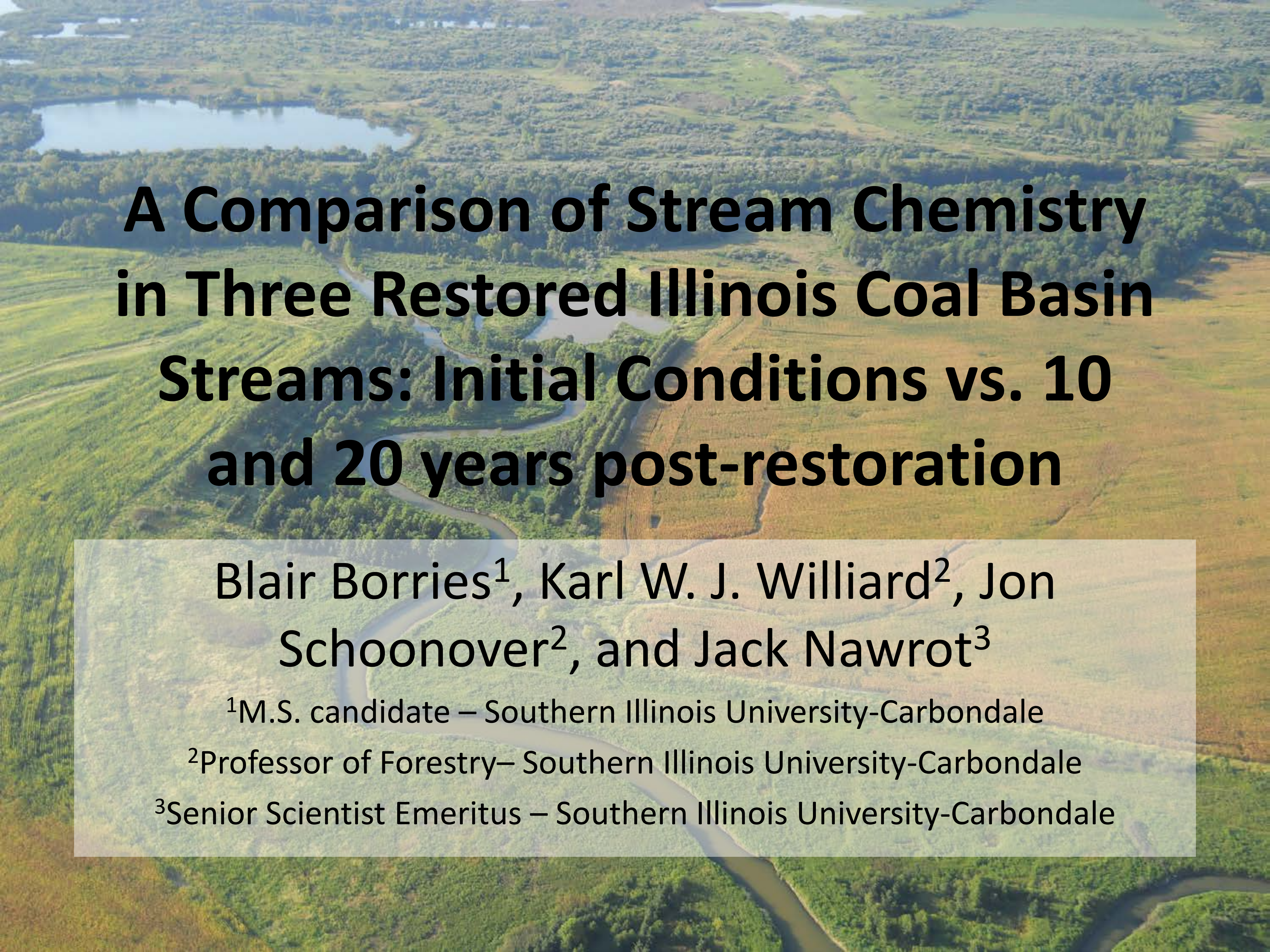


A Comparison of Stream Chemistry in Three Restored Illinois Coal Basin Streams: Initial Conditions vs. 10 and 20 years post-restoration

Blair Borries[1], Karl W. J. Williard[2], Jon Schoonover[2], and Jack Nawrot[3]

[1]M.S. candidate – Southern Illinois University-Carbondale

[2]Professor of Forestry– Southern Illinois University-Carbondale

[3]Senior Scientist Emeritus – Southern Illinois University-Carbondale

Water Quality: Total Dissolved Solids (TDS), Conductivity, Sulfate (SO_4), and metals

- TDS, Conductivity, SO_4, metals [Manganese (Mn), Iron (Fe), Zinc (Zn)] are often elevated in mined watersheds due to increased weathering
- Specific ions, especially SO_4 are more strongly negatively correlated with macroinvertebrate biodiversity than TDS or conductivity – elevated chloride (Cl) increases this effect, elevated hardness decreases it
- Metals have negative impacts on aquatic health, these are more pronounced in low pH conditions

Water Quality: Total Suspended Solids (TSS) and biodiversity

- TSS can affect feeding success, increase the risk for infection, smother habitat and dislodge aquatic life
- TSS concentration is a function of the stream’s capacity to transport sediment and the amount of sediment entering from upstream
- It has been suggested that incline pits could reduce the TSS from upstream agricultural watersheds (Nawrot 2011)

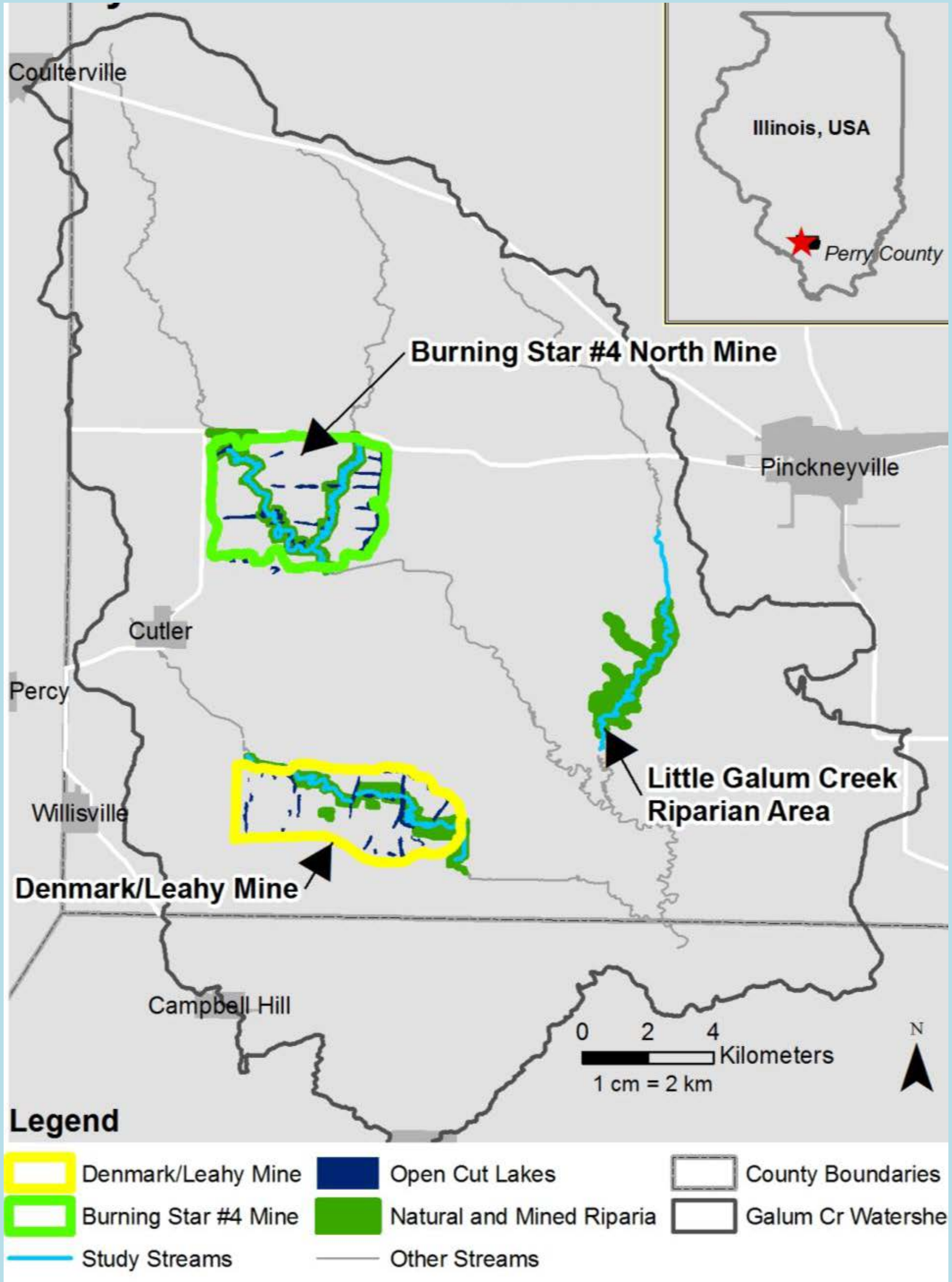
OBJECTIVE 1: EVALUATE THE CHANGE IN WATER QUALITY IN STREAMS RESTORED ON SURFACE MINES OVER TIME

- Does water quality in streams restored on surface mines change over time?
  - As measured by temperature, pH, specific conductivity, total suspended solids (TSS), total dissolved solids (TDS), manganese (Mn), iron (Fe), or sulfate (SO_4)
- Do overall trends in water quality by length of relocated streams change over time
  - As measured by temperature, pH, conductivity, TSS, TDS, Mn, Fe, and SO_4

OBJECTIVE 2: EVALUATE THE EFFECTIVENESS OF INCLINE PITS FOR REMOVING SUSPENDED SOLIDS FROM STREAMS RESTORED ON SURFACE MINES

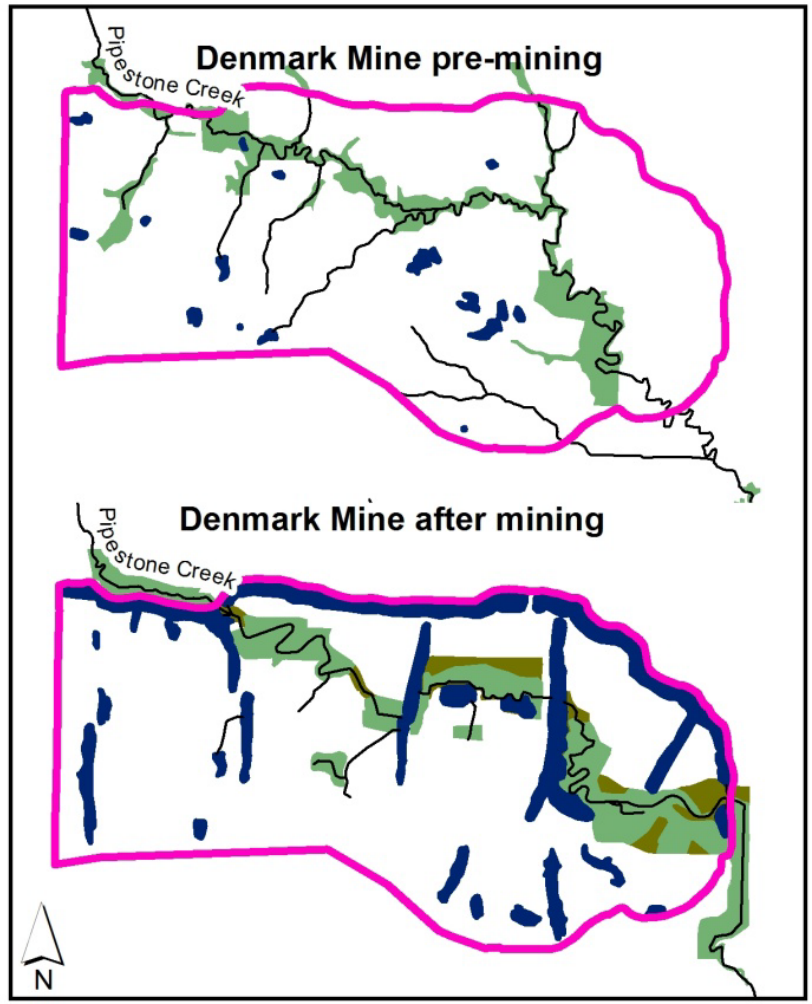
- Does the concentration of TSS change across incline pits left inline of restored streams?
  - As measured by samples taken during storm events

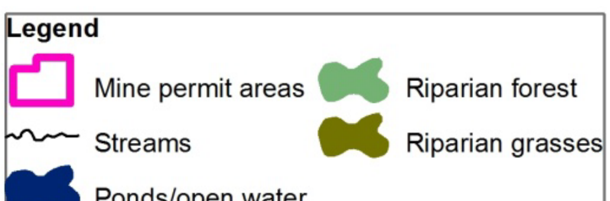
Study Area


Coulterville
Illinois, USA
Perry County
Burning Star #4 North Mine
Pinckneyville
Cutler
Percy
Little Galum Creek
Riparian Area
Willisville
Denmark/Leahy Mine
Campbell Hill
0 2 4
Kilometers
1 cm = 2 km
N
Legend
Denmark/Leahy Mine
Burning Star #4 Mine
Study Streams
Open Cut Lakes
Natural and Mined Riparia
Other Streams
County Boundaries
Galum Cr Watershe

Study Area: Before and after mining at Denmark/Leahy mine

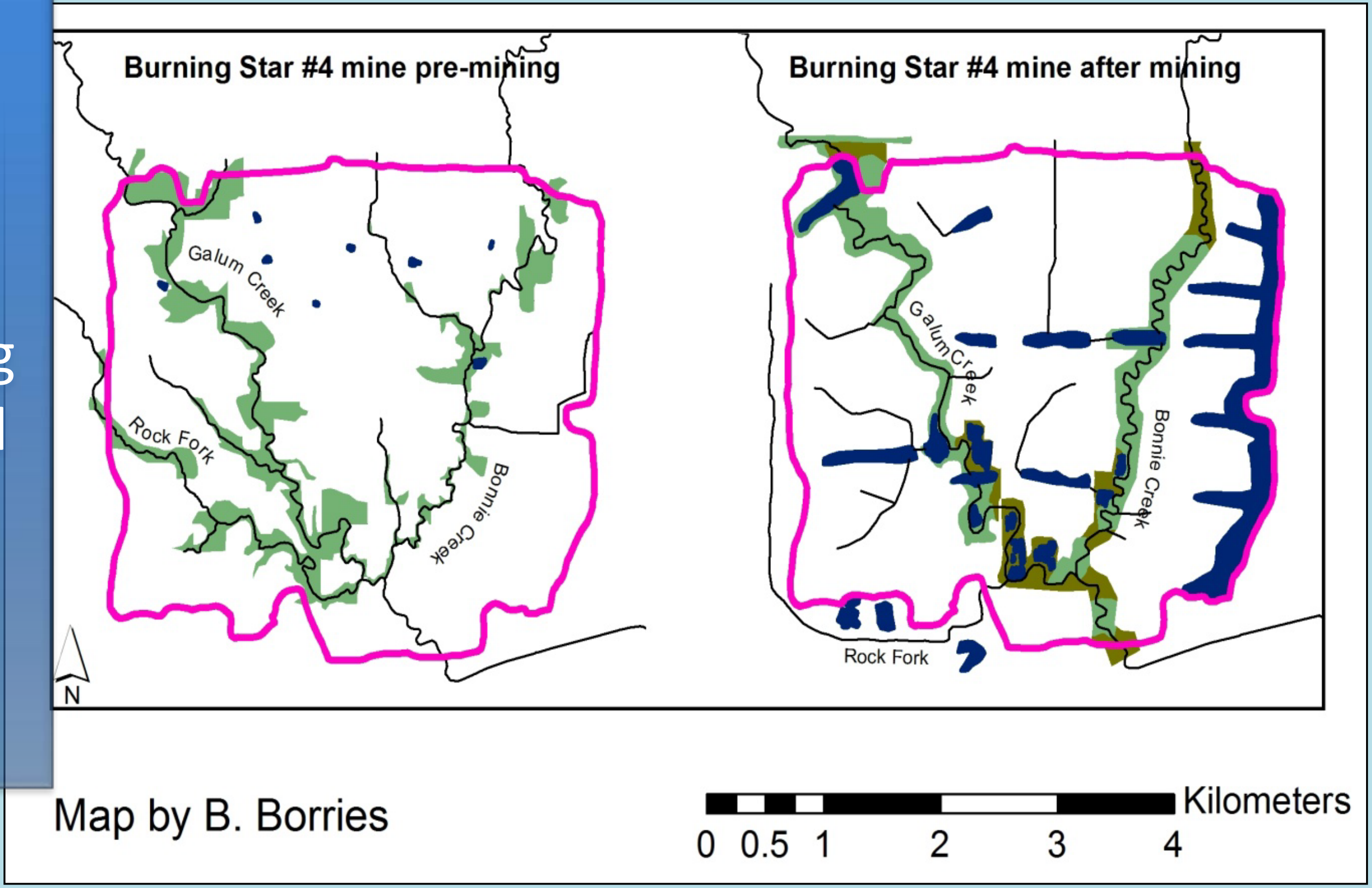
Pipestone Creek was diverted in the early 1970s. In 1979 a new meandering channel was dug for pipestone creek through reclaimed mine spoils. It was reconnected to the upstream watershed in late 1991





Study Area: Before and after mining at Burning Star #4 North mine

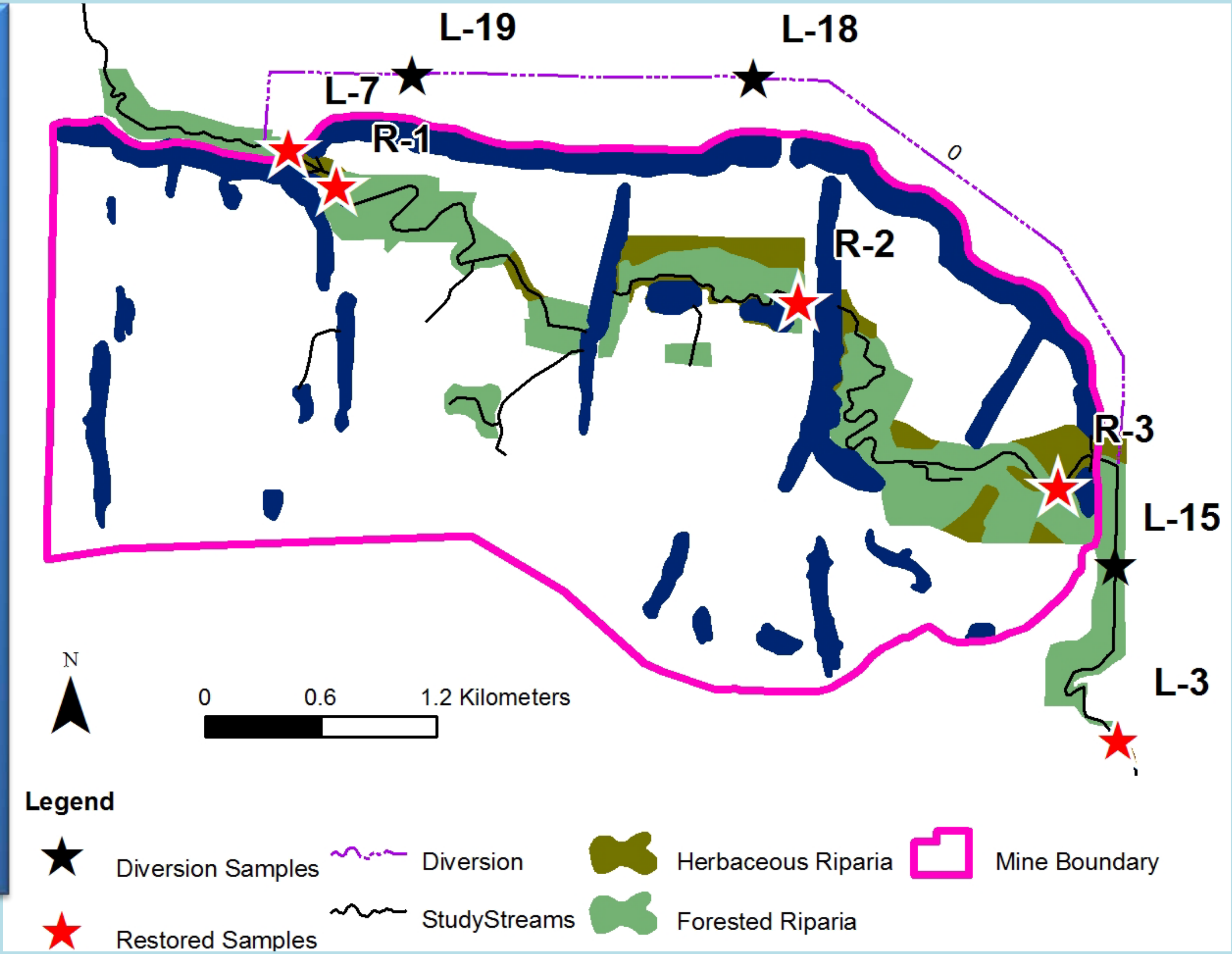
Bonnie and Galum Creek were diverted in the 1980s. New meandering channels were dug through reclaimed mine spoils 1983-1997. Reconnection occurred in 2001.



Study Design: Grab sample locations along Bonnie and Galum Creeks at BS4N mine

Post-restoration monitoring (SIUC-Wildlife): spring & fall 1992-1995

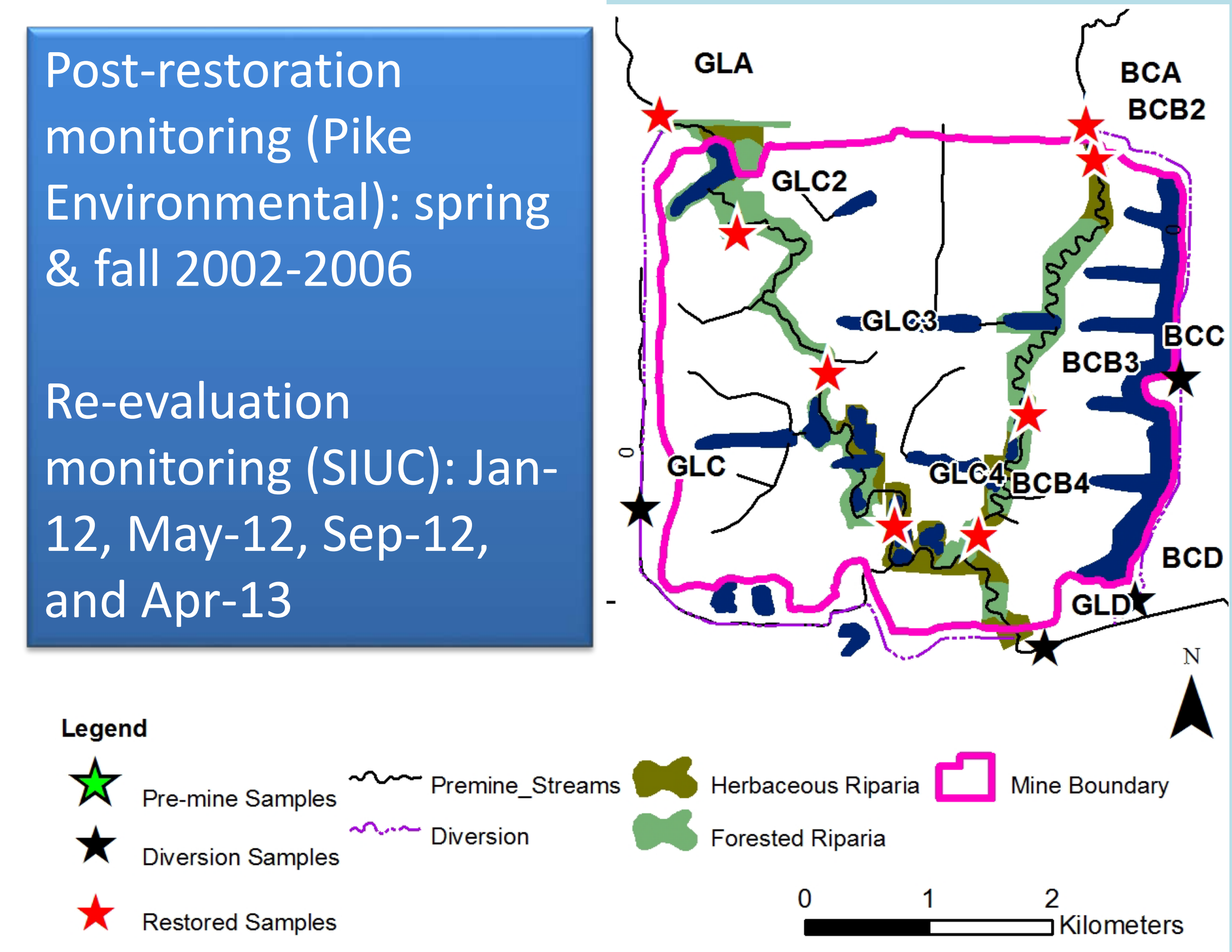
Re-evaluation monitoring (SIUC): Jan-12, May-12, Sep-12, and Apr-13



Study Design: Grab sample locations along Bonnie and Galum Creeks at BS4N mine

Post-restoration monitoring (Pike Environmental): spring & fall 2002-2006

Re-evaluation monitoring (SIUC): Jan-12, May-12, Sep-12, and Apr-13



Analyte	Method	Lab
Alkalinity	SM 2320 B – Titration*	Standard Labs
Chloride	EPA 300.1 Ion Chromotography **	SIUC Forestry Lab
Fluoride	EPA 300.1 Ion Chromotography **	SIUC Forestry Lab
Iron, total	EPA 200.7 ICP **	Standard Labs
Manganese, total	EPA 200.7 ICP **	Standard Labs
Zinc	EPA 200.7 ICP **	Standard Labs
Nitrate	EPA 300.1 Ion Chromotography **	SIUC Forestry Lab
Sulfate	EPA 300.1 Ion Chromotography **	SIUC Forestry Lab
Total Dissolved Solids	SM 2540 C*	SIUC Forestry Lab
Total Suspended Solids	SM 2540 D*	SIUC Forestry Lab

* methods used are from Eaton and Franson (2005)
** methods used are from USEPA (2000)

Statistics and Calculations: Step trends with time

- To reduce seasonal variability, data from the control along each creek (BCA, GLA, and L-7) was subtracted from each sample point similar to a Before-After Control-Impact (BACI) design:

Deviation = Impact - Control

- Tested for step-trends rather than monotonic trends due to large gaps – via Mann-Whitney-Wilcoxon rank sum test

Statistics and Calculations: Monotonic trend with length of stream located

- Test for monotonic trends also used a modified (BACI) design:

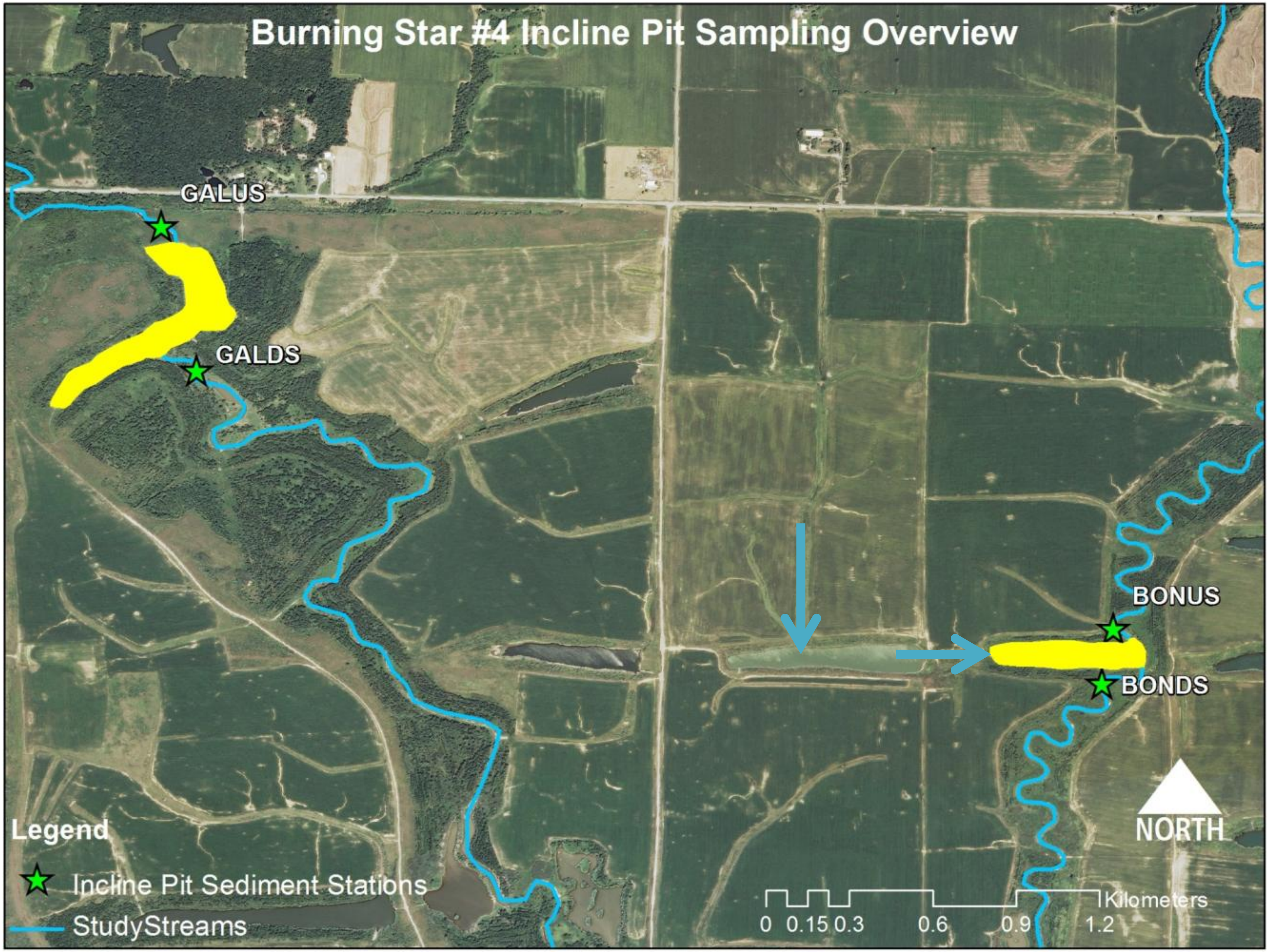
  Deviation = Impact - Control

- Tested for monotonic trend with the non-parametric regional-Kendall test
  - Deviation is the dependent variable
  - Length of stream relocated as the independent variable
  - Tests for a trend in the deviation along the restored reach individually for each sampling period and then compares all the trends together

Sample Point	Lat (dd)	Long (dd)	Distance Relocated (km^2)	Watershed (km^2)
L-7	**37.994590**	**-89.533263**	**Control**	**25.79**
R-1	**37.992830**	**-89.530442**	**0.34**	**26.34**
R-2	**37.987286**	**-89.503251**	**3.99**	**28.52**
R-3	**37.978565**	**-89.488016**	**6.65**	**31.23**
L-3	**37.966740**	**-89.484576**	**8.84**	**33.24**
GLA	**38.087367**	**-89.553919**	**Control**	**55.46**
GLC2	**38.078721**	**-89.546893**	**1.62**	**64.04**
GLC3	**38.068555**	**-89.538646**	**3.51**	**66.29**
GLC4	**38.057399**	**-89.532574**	**5.77**	**69.47**
BCA	**38.086496**	**-89.514718**	**Control**	**39.49**
BCB2	**38.083956**	**-89.513962**	**0.39**	**39.80**
BCB3	**38.065433**	**-89.520179**	**4**	**44.60**
BCB4	**38.056632**	**-89.524896**	**5.72**	**49.32**

Methods: Suspended solids concentration above and below incline pits

- ISCO auto-sampling units positioned above and below the first incline pits inline of Bonnie and Galum Creeks – a stilling well was installed to record gage
- 24 samples were taken during events – samples were consolidated – 11-17 samples per storm event
- Repeated measures ANOVA used to test for differences between TSS concentrations above and below two (n=2) incline pits

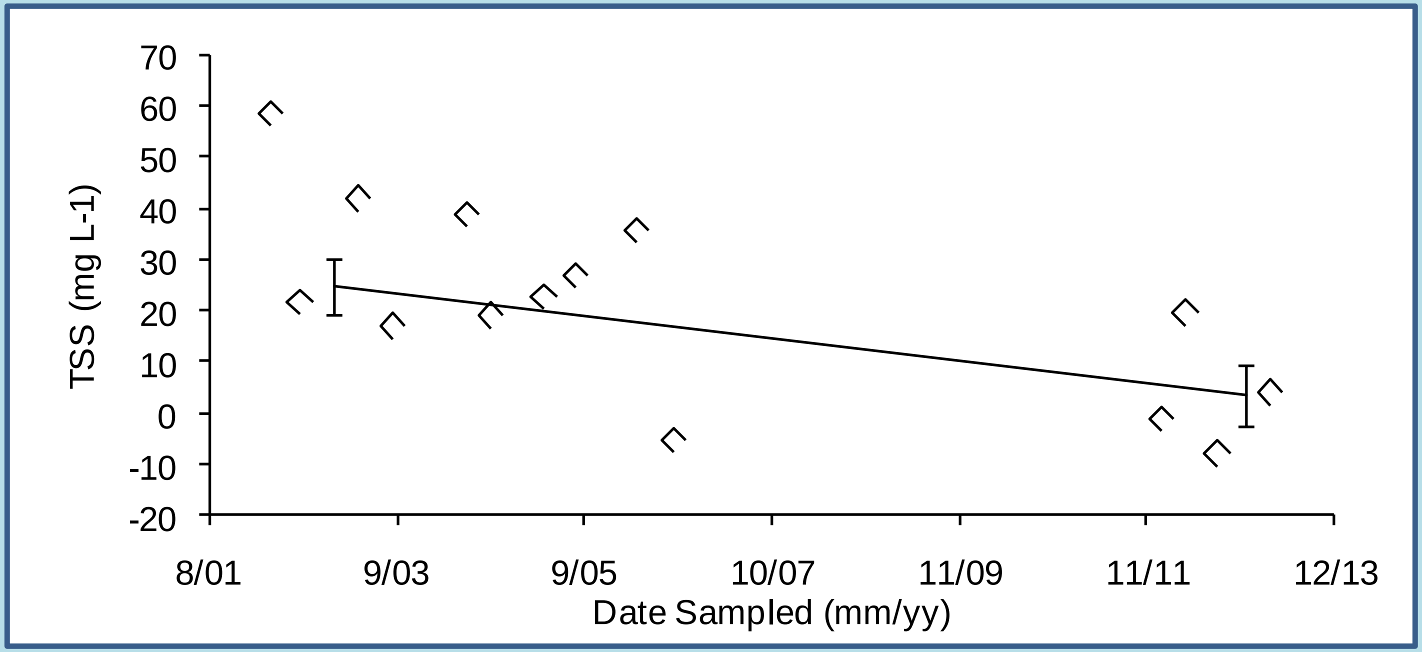

Burning Star #4 Incline Pit Sampling Overview
GALUS
GALDS
BONUS
BONDS
Legend
Incline Pit Sediment Stations
StudyStreams
NORTH
0 0.15 0.3 0.6 0.9 1.2
Kilometers


RESULTS/DISCUSSION
Photo: Jack Nawrot

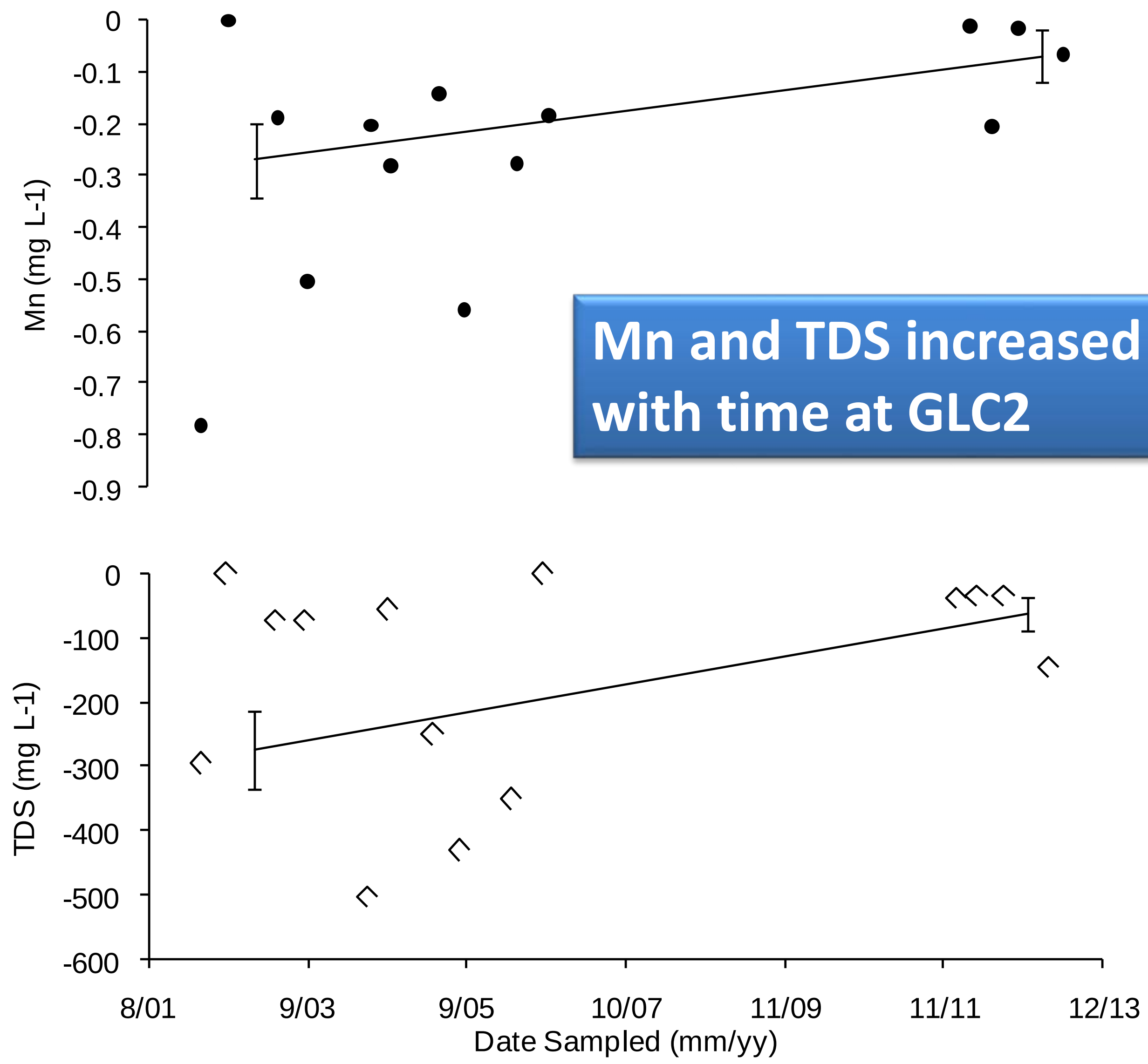
Bonnie Creek - BCB3 TSS(Deviation from control):

Significant step trends with time

TSS decreased with time at BCB3

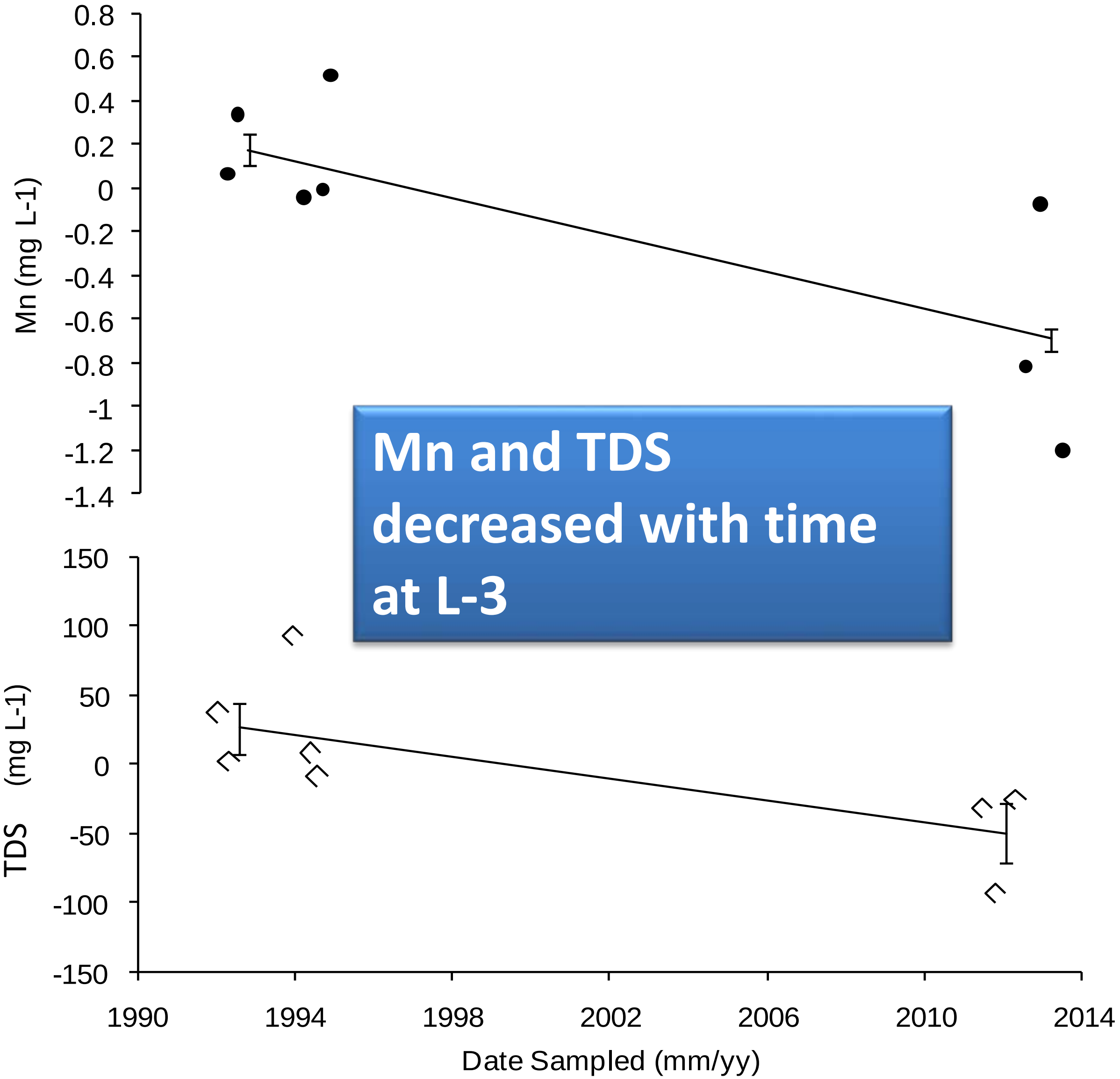


Galum Creek - GLC2 Mn and TDS(Deviation from control): Significant step trends with time

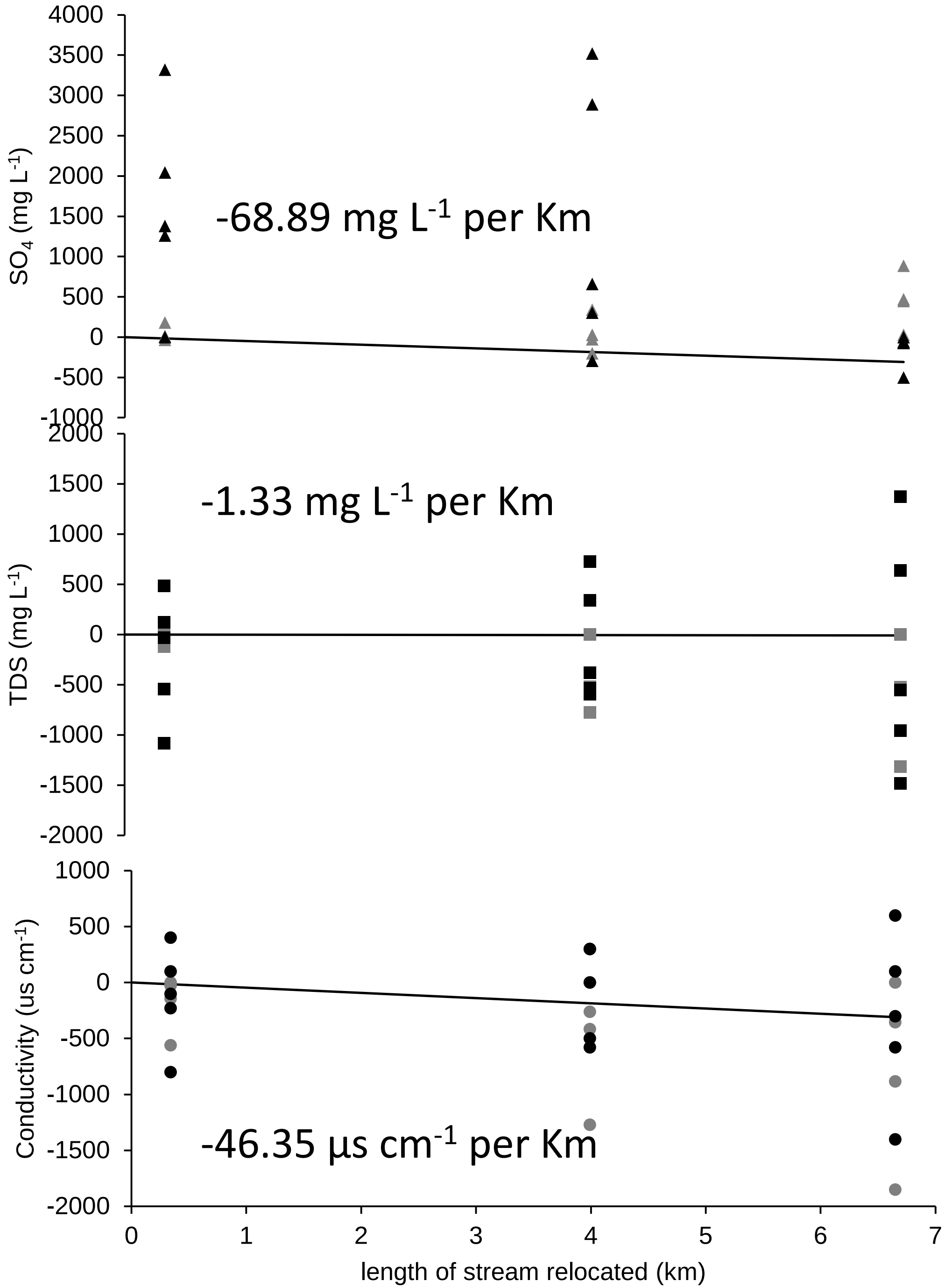


Mn and TDS increased with time at GLC2

Pipestone Creek - L-3 Mn and TDS (Deviation from control): Significant step trends with time



Mn and TDS decreased with time at L-3

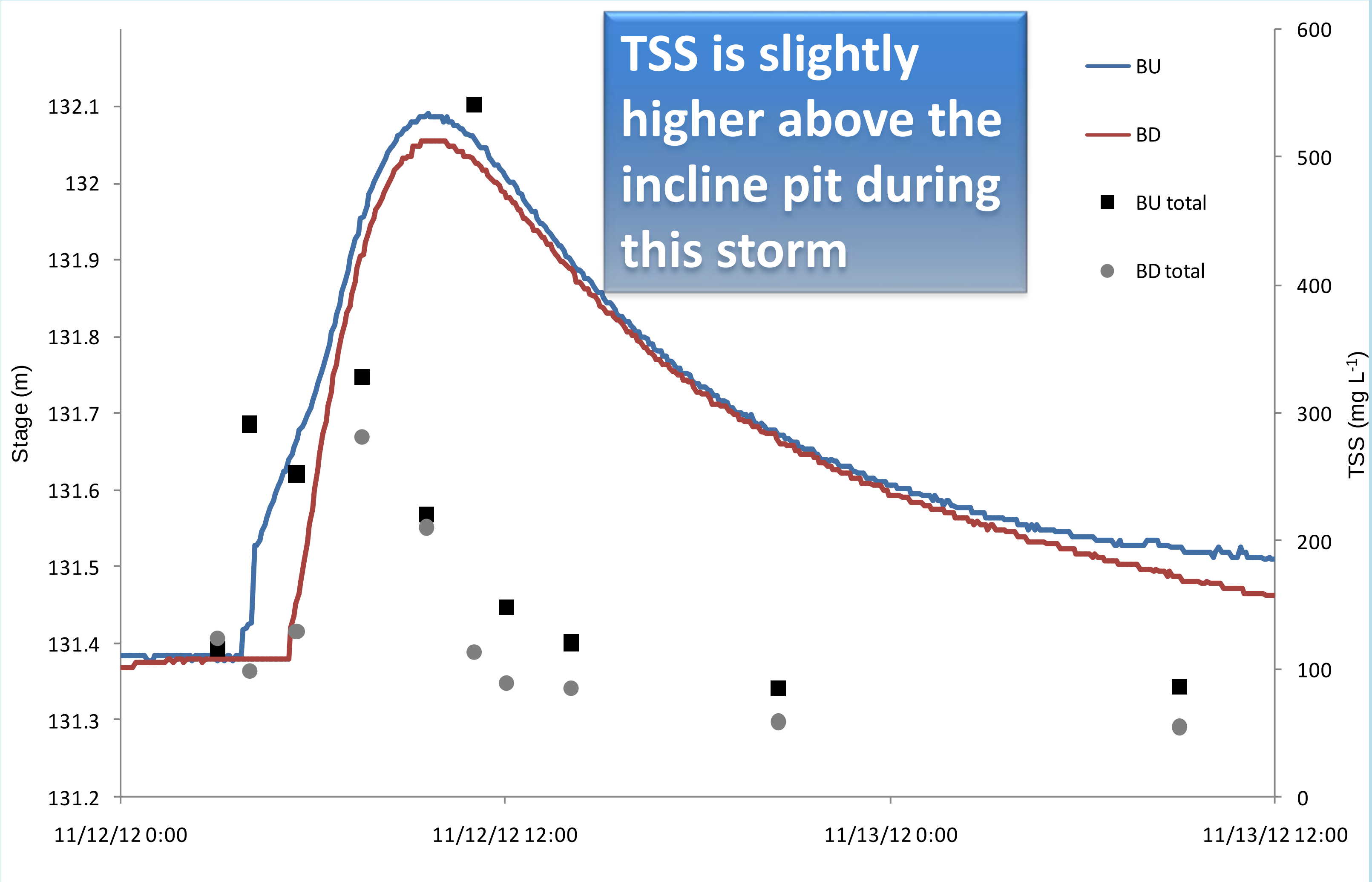


SO4, TDS, and Conductivity along Pipestone Creek (deviation from control):

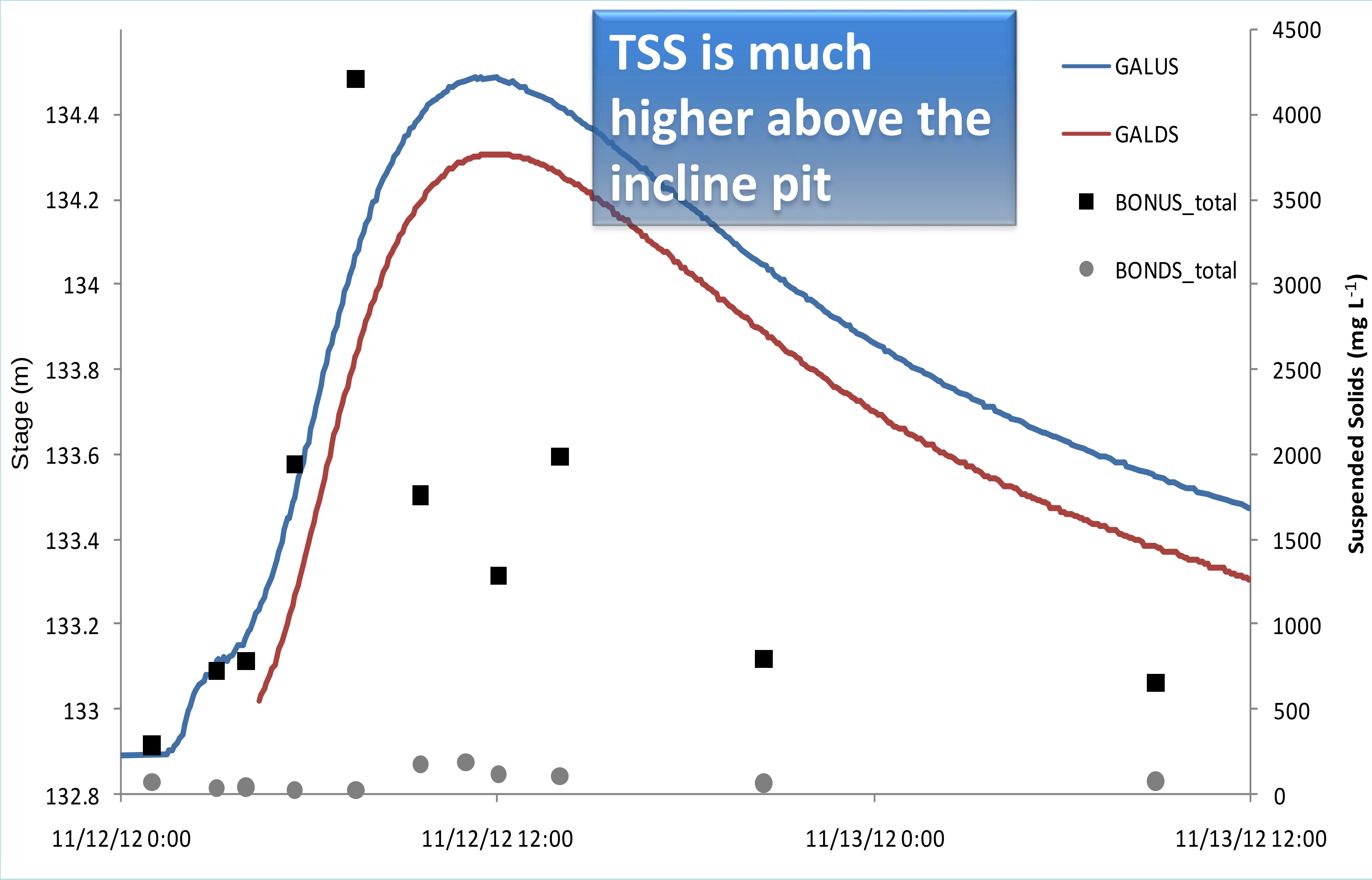
Significant monotonic trends along the length of the relocated stream

SO4, TDS, and Conductivity concentration are high at the control due to “pre-SMCRA” mines upstream. significant negative trends were found during the 2012-2013 sampling period, but not 1992-1995

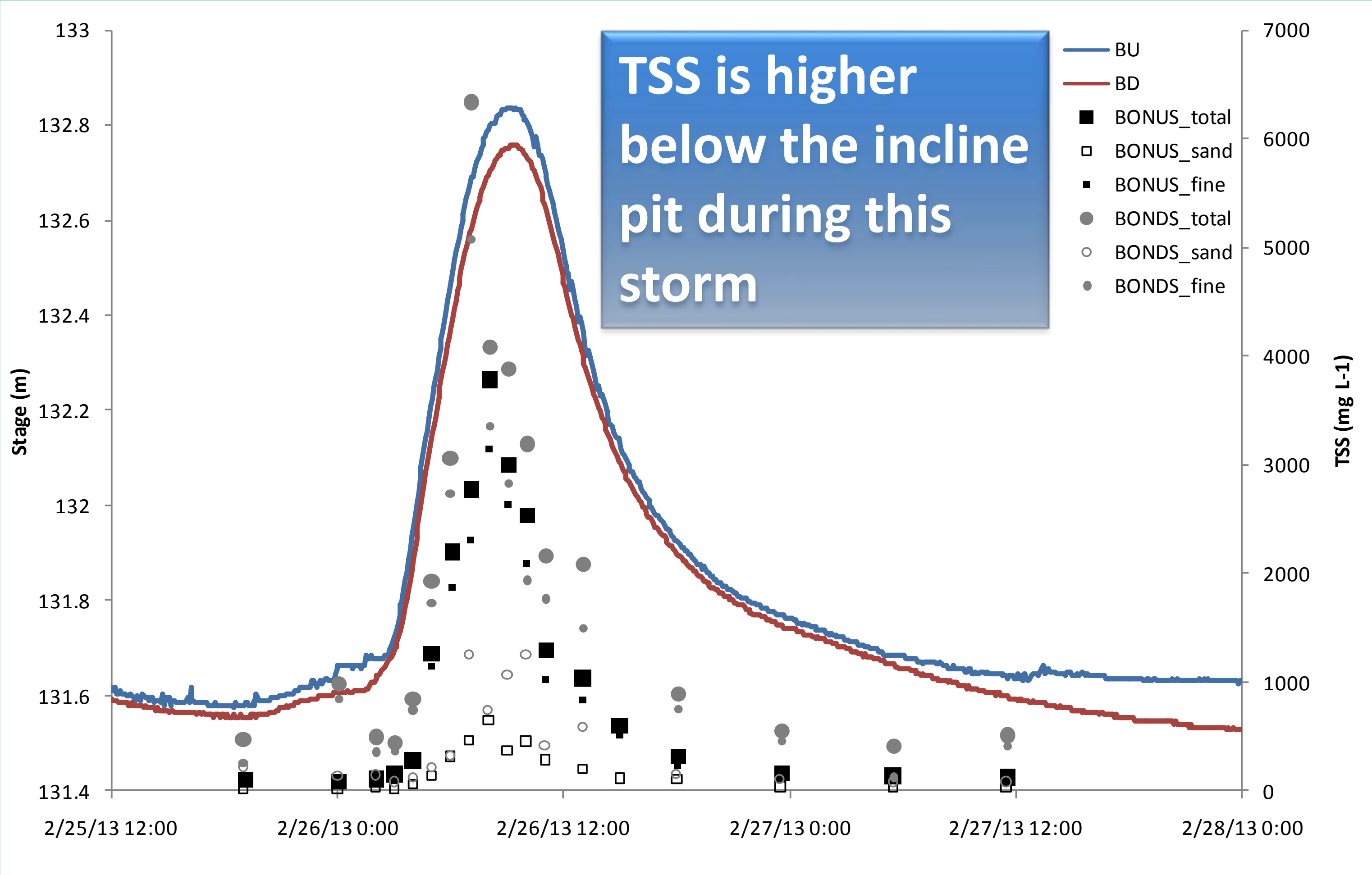
Storm 1 (11/12/2012) hydrograph and TSS at incline pit 1 on Bonnie Creek: Hydrographs above (blue) and below (red) are shown with TSS above (black) and below (grey) incline pit 1



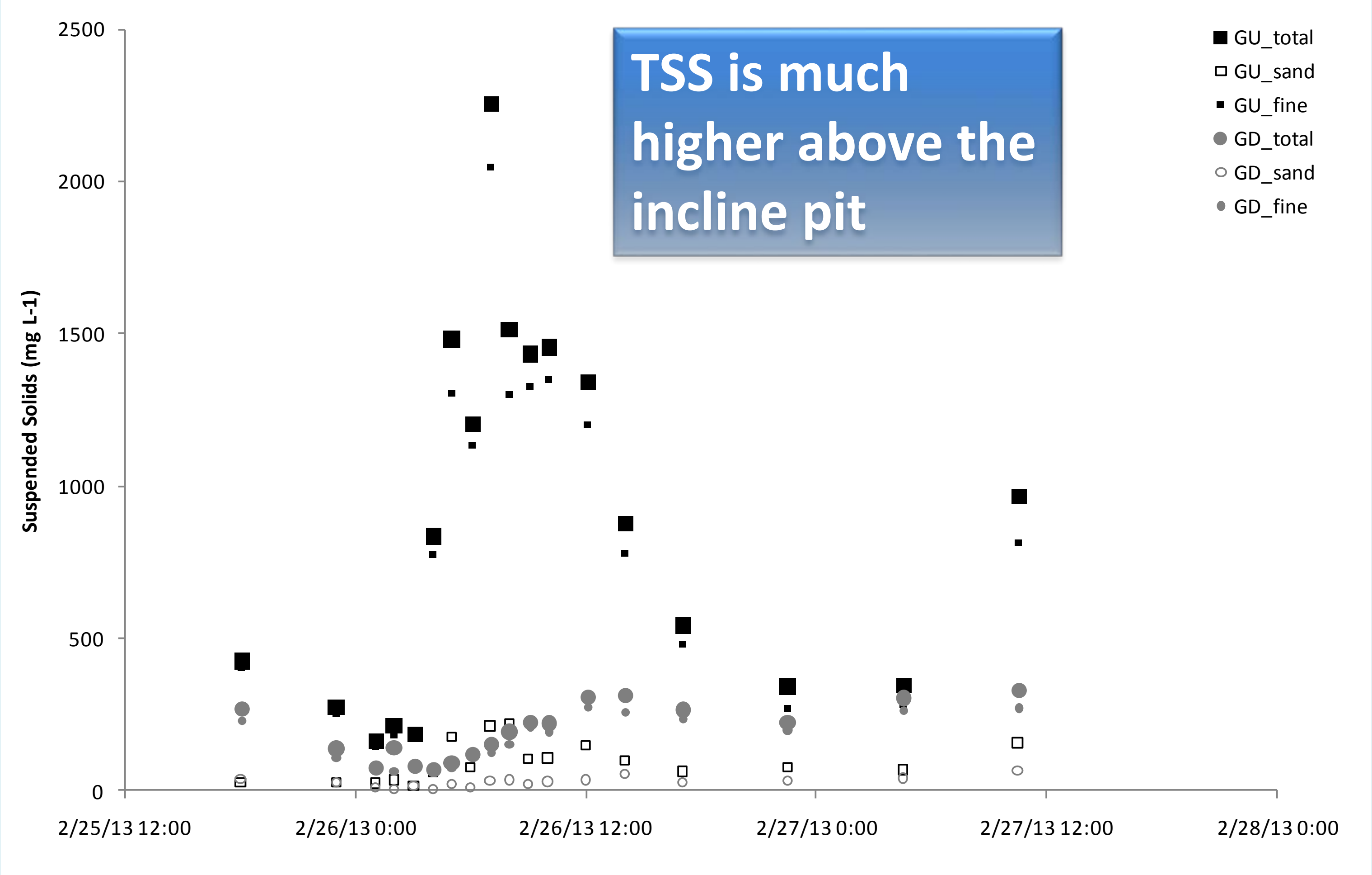
Storm 1 (11/12/2012) hydrograph and TSS at incline pit 1 on Galum Creek: Hydrographs above (blue) and below (red) are shown with TSS above (black) and below (grey) incline pit 1



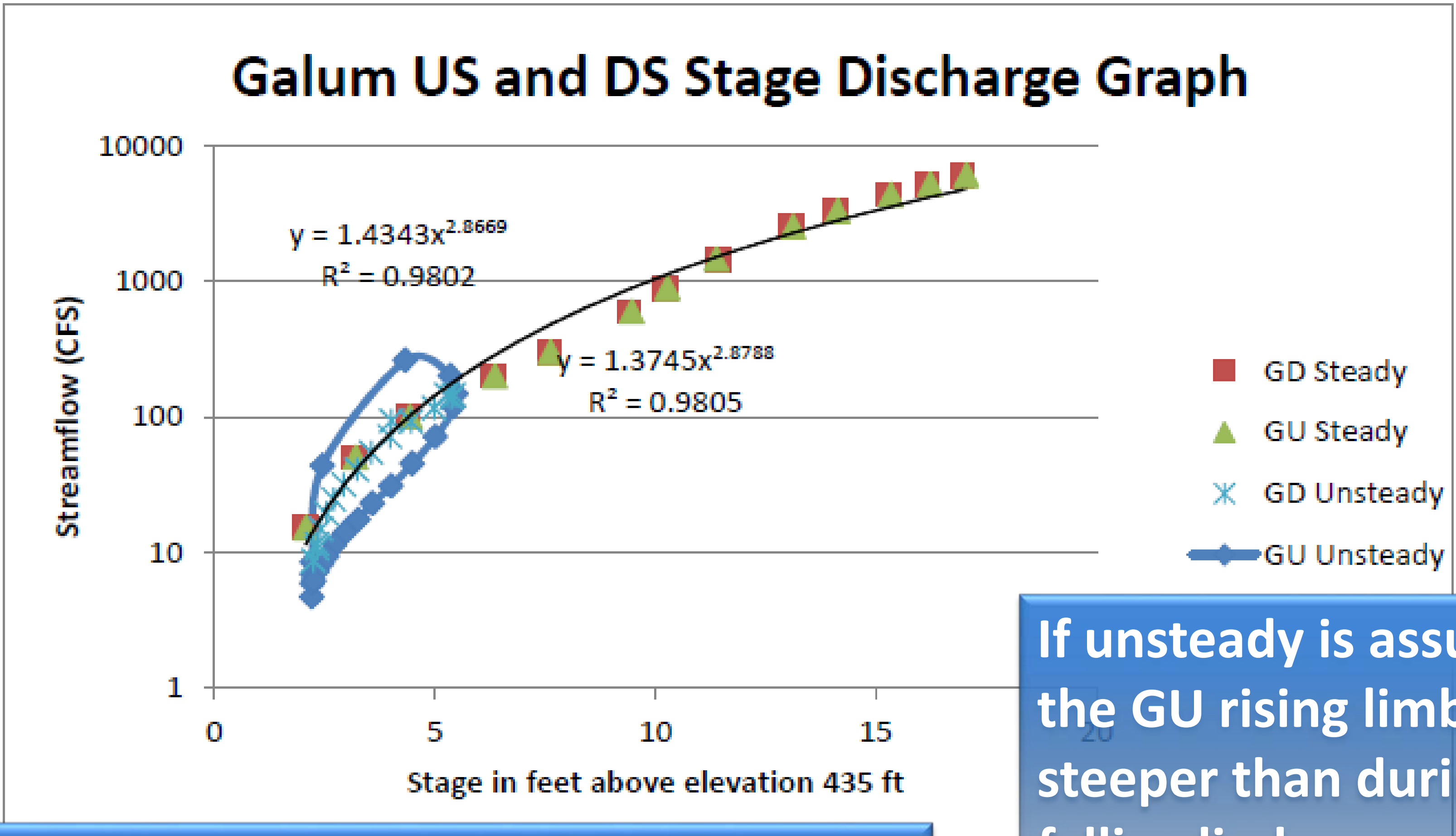
Storm 2 (2/21/13) hydrograph and SS at incline pit 1 on Bonnie Creek: Hydrographs above (blue) and below (red) are shown with TSS (black square), fine split (small black square), and sand split (open box) above and TSS (grey circle), fine split (grey dot), sand split (open grey box) below incline pit 1



Storm 2 (2/21/2013) suspended solids at incline pit 1 on Galum Creek: TSS (black square), fine split (small square), and sand split (open box) above and TSS (grey circle), fine split (grey dot), sand split (open grey box) below incline pit 1 are shown



Storage in Galum Incline Pit 1: Stage discharge curves created from a HEC-RAS model calibrated with stage data. GD (red square) and GU(green triangle) curves from a steady-state model are compared to GD (blue asterisk) and GU (blue diamond) curves from an unsteady model



Graph created by Tim Straub/Don Roseboom USGS

If unsteady is assumed, the GU rising limb curve is steeper than during the falling limb

Conclusion: Changes in Pipestone Creek water quality with time and length of relocated stream

- Most downstream sample point (L-3) TDS and Mn decreased with time
- Contaminated water from historic mining was present at the control point (L-7) – in-stream processes reduced conductivity, TDS, and SO_4 during 2012-2013
- Aquatic plants *Ceratophyllum demersum*, *Stuckenia pectinata*, and *Potamogeton* sp. abundant in Pipestone Cr., useful for phytoremediation, esp. metal attenuation
- SO_4 can be reduced to H_2S in organic rich bed sediments present at Pipestone Creek.

Conclusion: Incline pits may reduce TSS concentration depending on size of the pit and TSS load

- The Galum pit significantly reduced TSS concentration during both storm events
  - TSS concentrations peaked earlier upstream, later downstream
  - 1st wave of water was stored low TSS water
- Bonnie pit: TSS higher downstream during “wet” condition storm event.
  - Additional inflow overcame the storage
  - Incline pits may not be sufficient to reduce TSS concentration from “ag ditches” with no riparian area

Management Implications: The amount of storage provided should be compared to what is needed. An incline pit along may not be enough to reduce TSS

- Incline pits won’t reduce loads unless it is providing storage – upstream riparian restoration and erosion control efforts are recommended
- HEC-RAS can be used to predict the amount of storage that can be provided by an incline pit during preliminary design

Acknowledgements

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- John Gefferth, Consol Energy
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- Ron Balch, Midwest Reclamation
- Funding provided by the OSM Technology Transfer Applied Science research grant
- Timothy Straub and Donald Roseboom, USGS

Questions?