GALLOGLY COLLEGE OF ENGINEERING
SCHOOL OF CIVIL ENGINEERING AND ENVIRONMENTAL SCIENCE
The UNIVERSITY of OKLAHOMA

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West Virginia Task Force and

International Mine Water Association Meeting

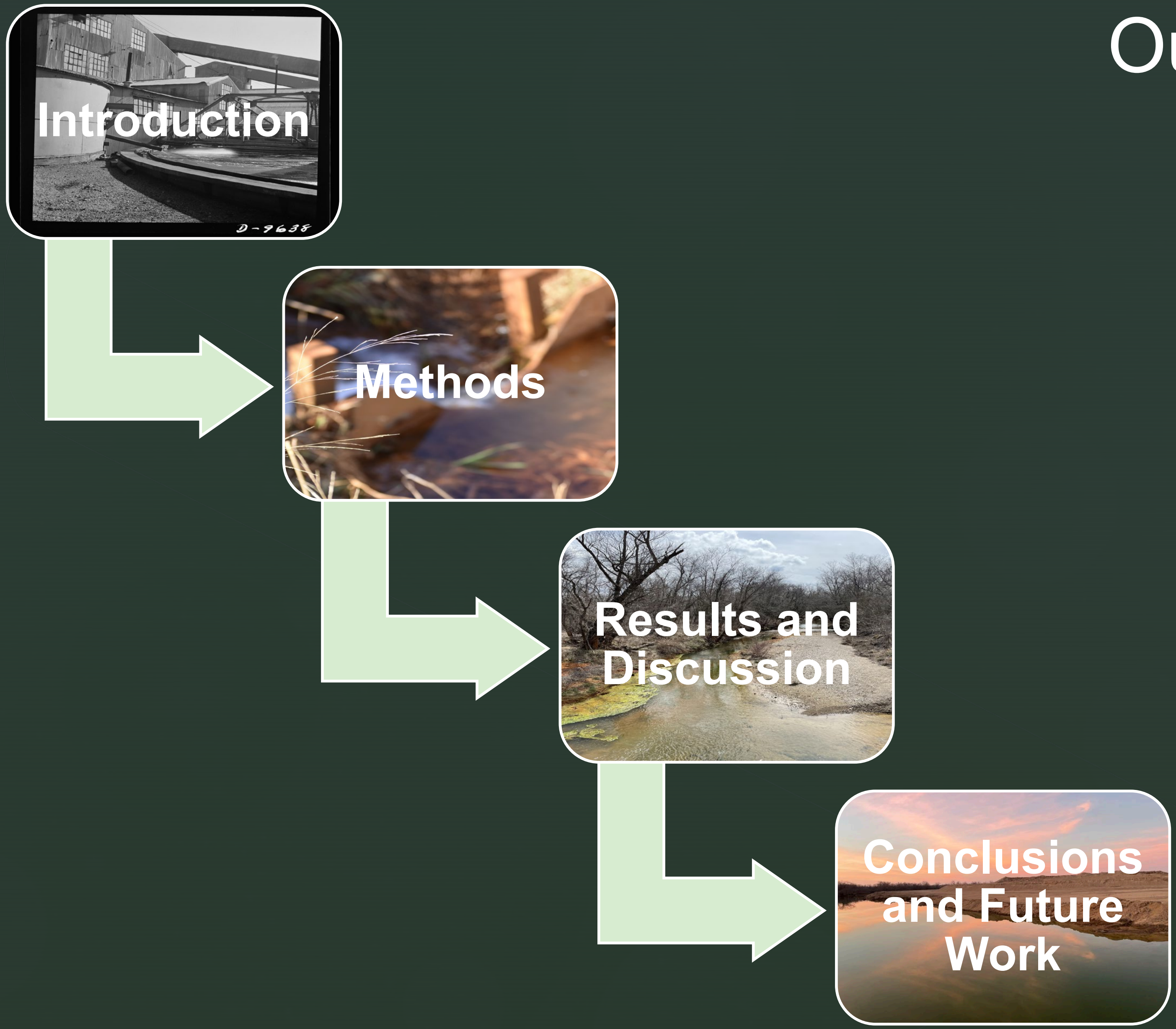
April 23, 2024

Metal Loads Accounting at a Legacy Mine Site: The Tar Creek Superfund Site, Oklahoma, USA

CREW
Center for Restoration of Ecosystems and Watersheds
The University of Oklahoma

WVTF IMWA 2024

Outline

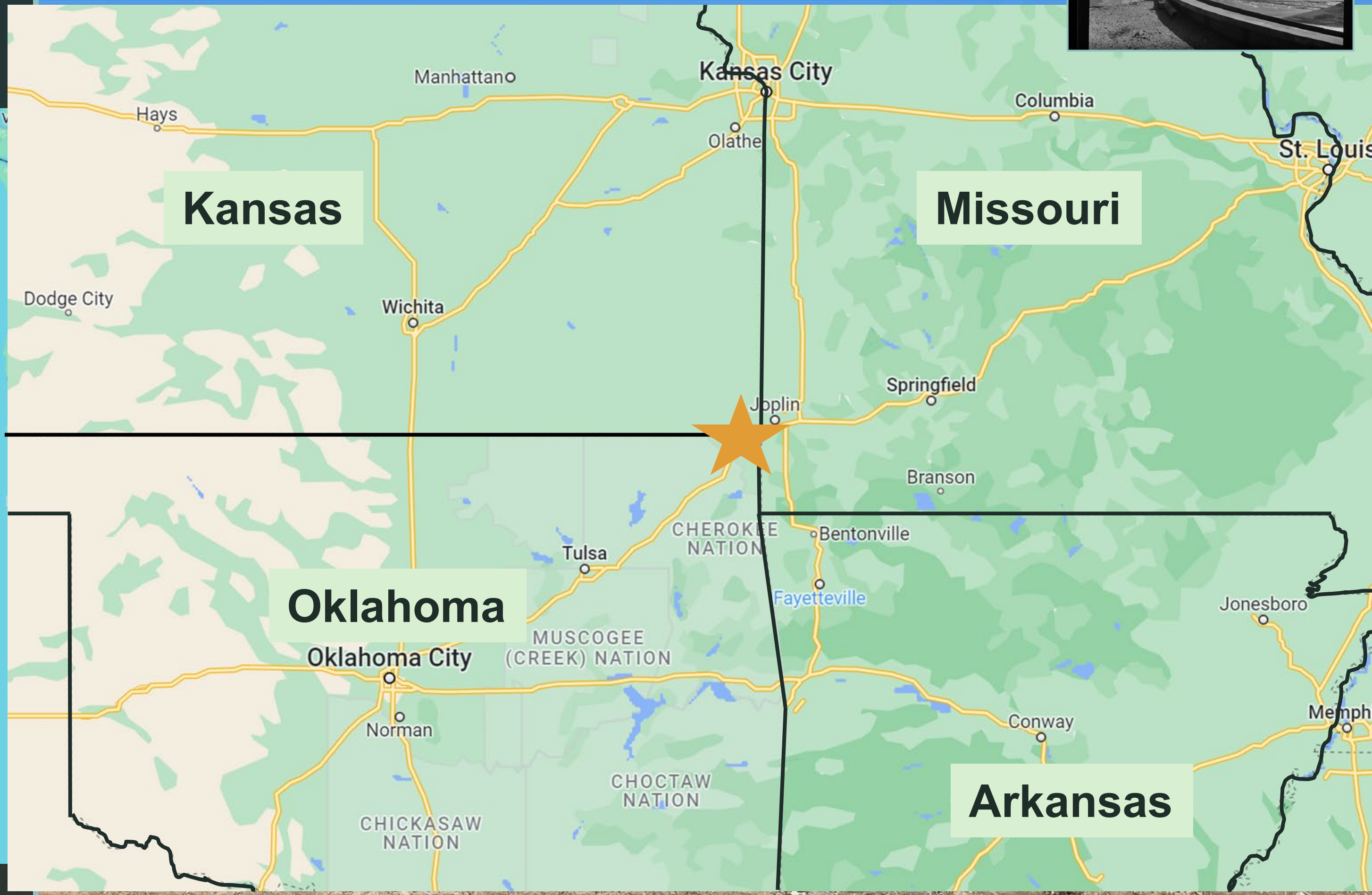

Introduction
D-9638
Methods
Results and Discussion
Conclusions and Future Work

Introduction

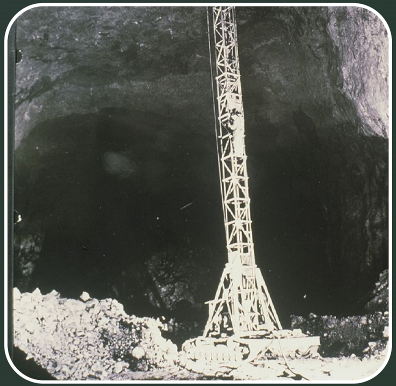
Photo courtesy of Nick Shepherd

Introduction

- Legacy mining and industrial sites
  - Complexity
  - Primary and secondary contamination sources
  - Limited funding
- Tri-State Mining District
  - Mine waste on surface
  - Subsurface mine pool



Tri-State Lead-Zinc Mining District



Mining

- 19th and 20th centuries
- Missouri, Kansas, Oklahoma

Closure

- Late 1960s
- Mine drainage in late 1970s

EPA

- National Priorities List
- Addressing different waste streams

EPA Operable Units

Groundwater

- Diversion of Lytle Creek
- Surface water deemed “irreversibly damaged”
- Plugging of potential threats to drinking water

Mine, Mill, and Smelter Waste

- Removal of waste
- Reuse programs

Surface Water and Sediments

- Remedial investigation ongoing
- Interim measures

Previous Remedial Work

- Artesian discharges
  - Passive treatment
  - Identifying inflows and outlets
- Surface piles of mine waste
  - Mine waste runoff study
  - Sieving operations
  - Dig and haul
- Sediment and surface water
  - Removal of mine waste from stream

Research Questions

- Where can remedial efforts have the greatest impact?
- What sets those areas apart?
- How can sources of metals pollution be addressed sustainably?

Photo courtesy of Brandon Holzbauer-Schweitzer

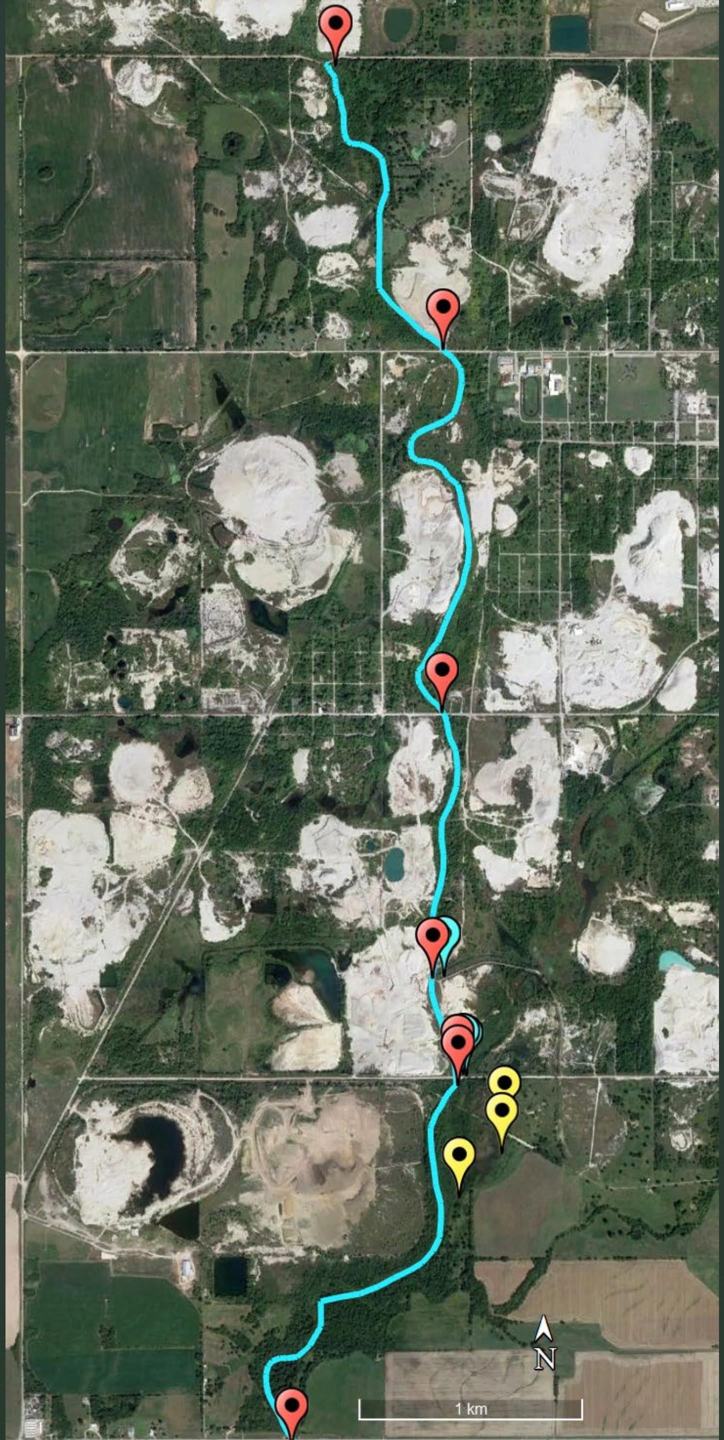
Metals Load Accounting in Tar Creek

Hypothesis

- Mine drainage seeps, when flowing, contribute more metals loading in Tar Creek than interactions with mine waste

Objective

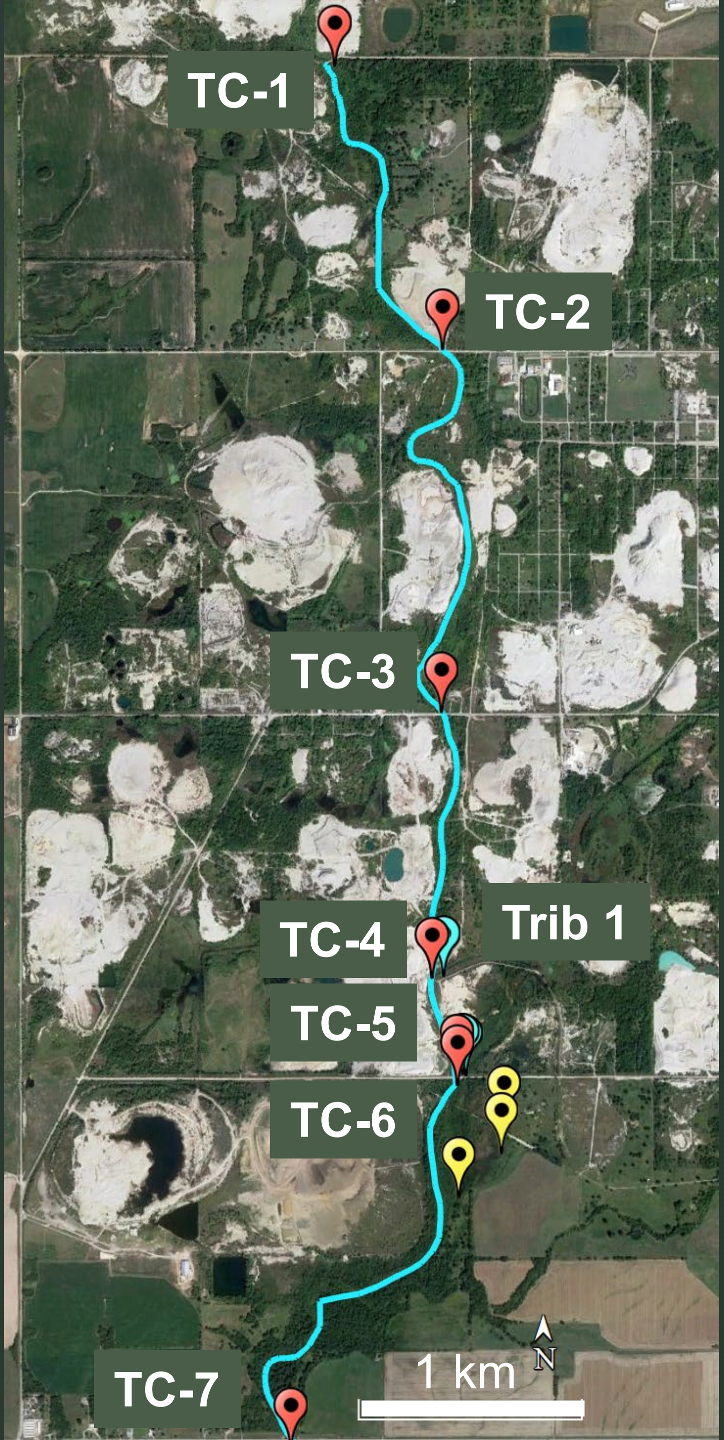
- Quantify loading of metals from different potential source areas within mine-impacted stream

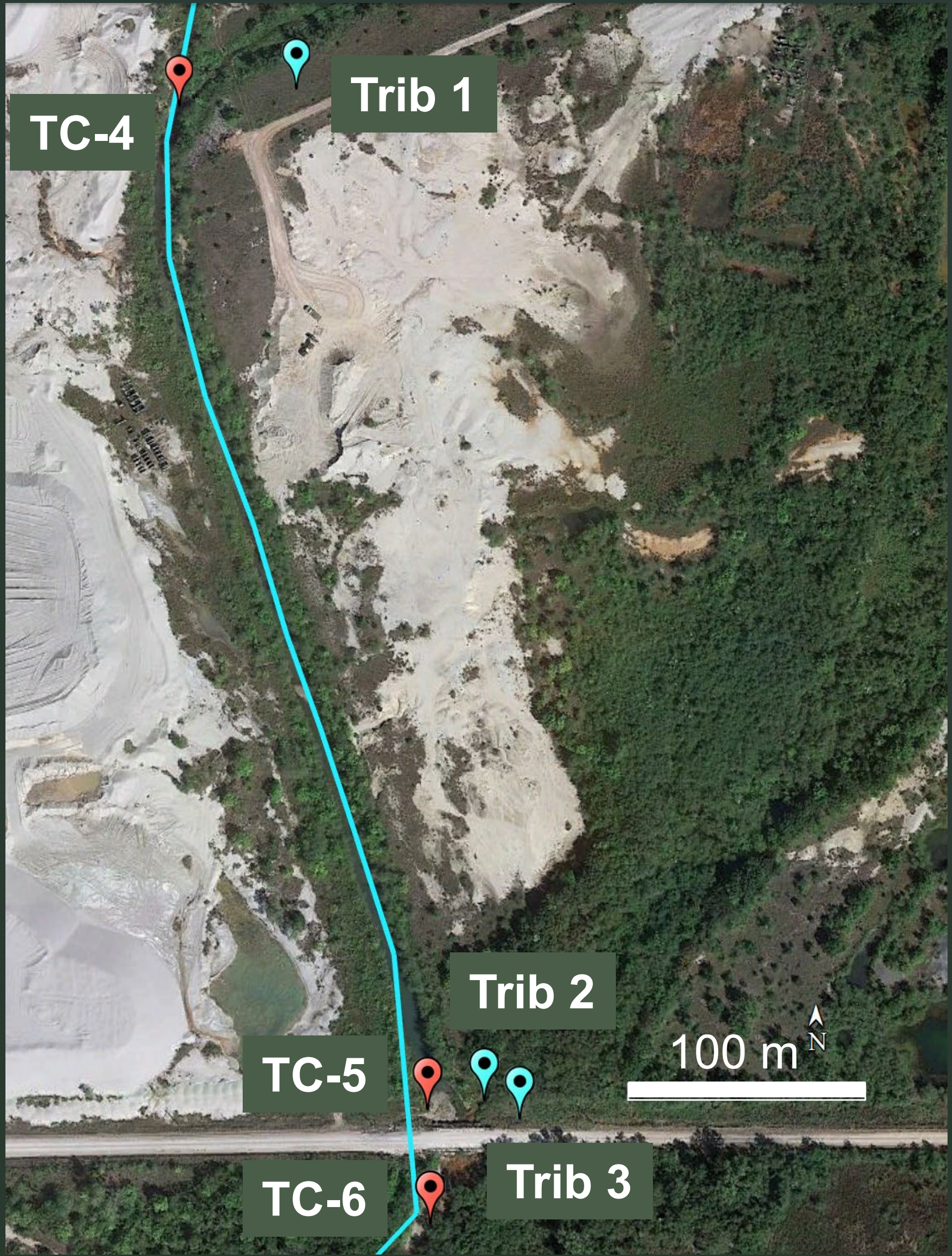


Methods

Photo courtesy of Maria Nairn

Stream Sampling Sites





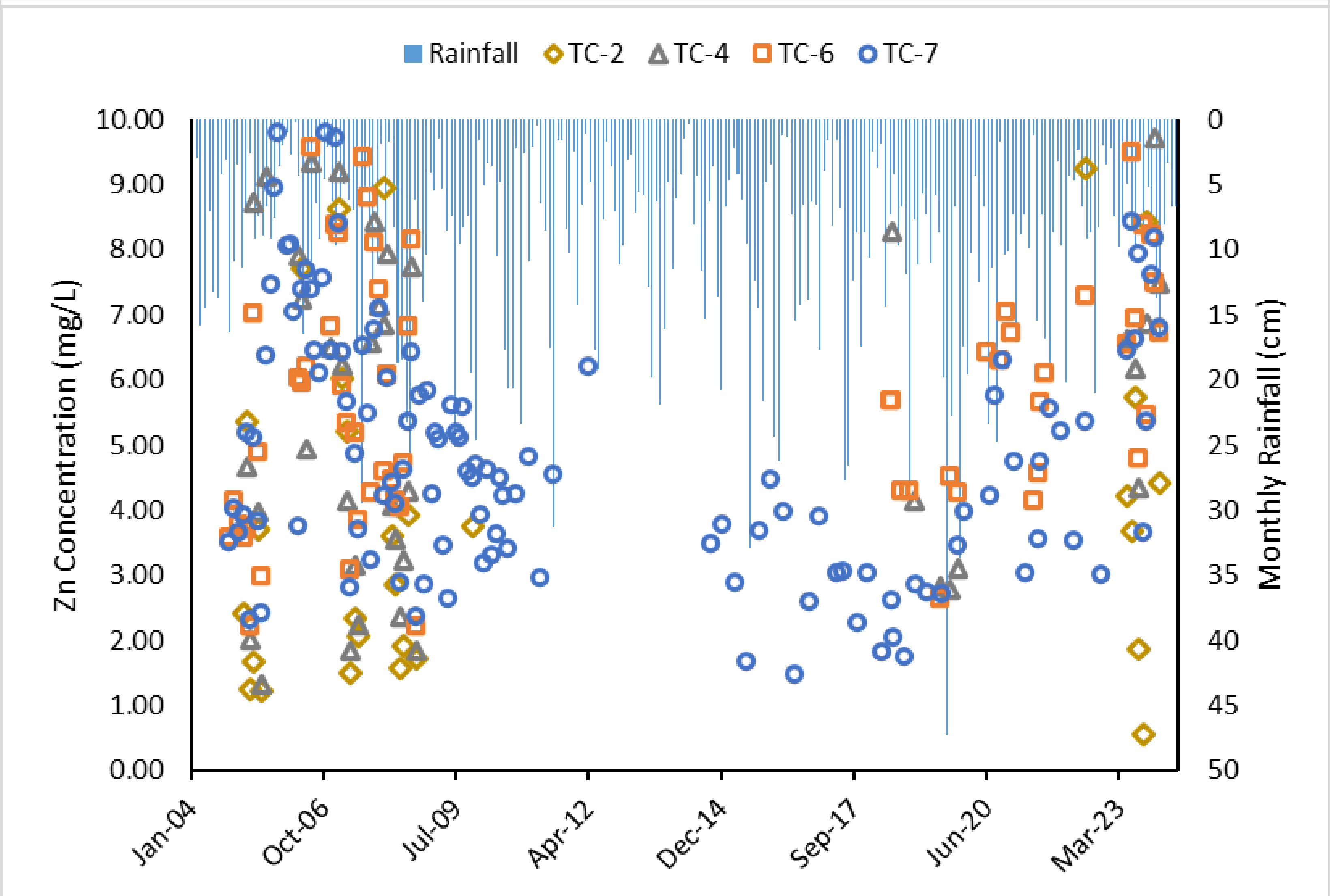
Sample Collection and Analysis

- Flow measurements -- acoustic doppler velocimeter
- Metals concentrations via ICP-OES
- Loads = concentrations x flows
- Expected load = upstream load + tributary load

Photo courtesy of Dayton M. Dorman

Results and Discussion

Long-Term Zinc Trends



Metals Load in Stream

- **Conditions neither especially dry nor wet**
- **Increase at most sites**
  - **Decrease at TC-3 -- wetland**

Site	Measured Zn Load – Expected Zn Load (mg/min)			
	Mar	Apr	May	Oct
TC-2	**14.5**	**6.4**	**12.8**	**2.5**
TC-3	-2.0	**5.1**	-4.4	-2.7
TC-4	**8.6**	-0.2	**26.8**	**6.0**
TC-5	**17.1**	**15.5**	**4.6**	**3.0**
TC-6	**5.7**	**6.9**	**11.9**	0.5
TC-7	**8.7**	-8.8	1.4	**5.2**

Metals Load in Stream, Continued

- **Samples taken right after rainstorms**
- **August sampling:**
  - **Peak flow between TC-2 and TC-3**
  - **TC-4 sampled after upstream samples**

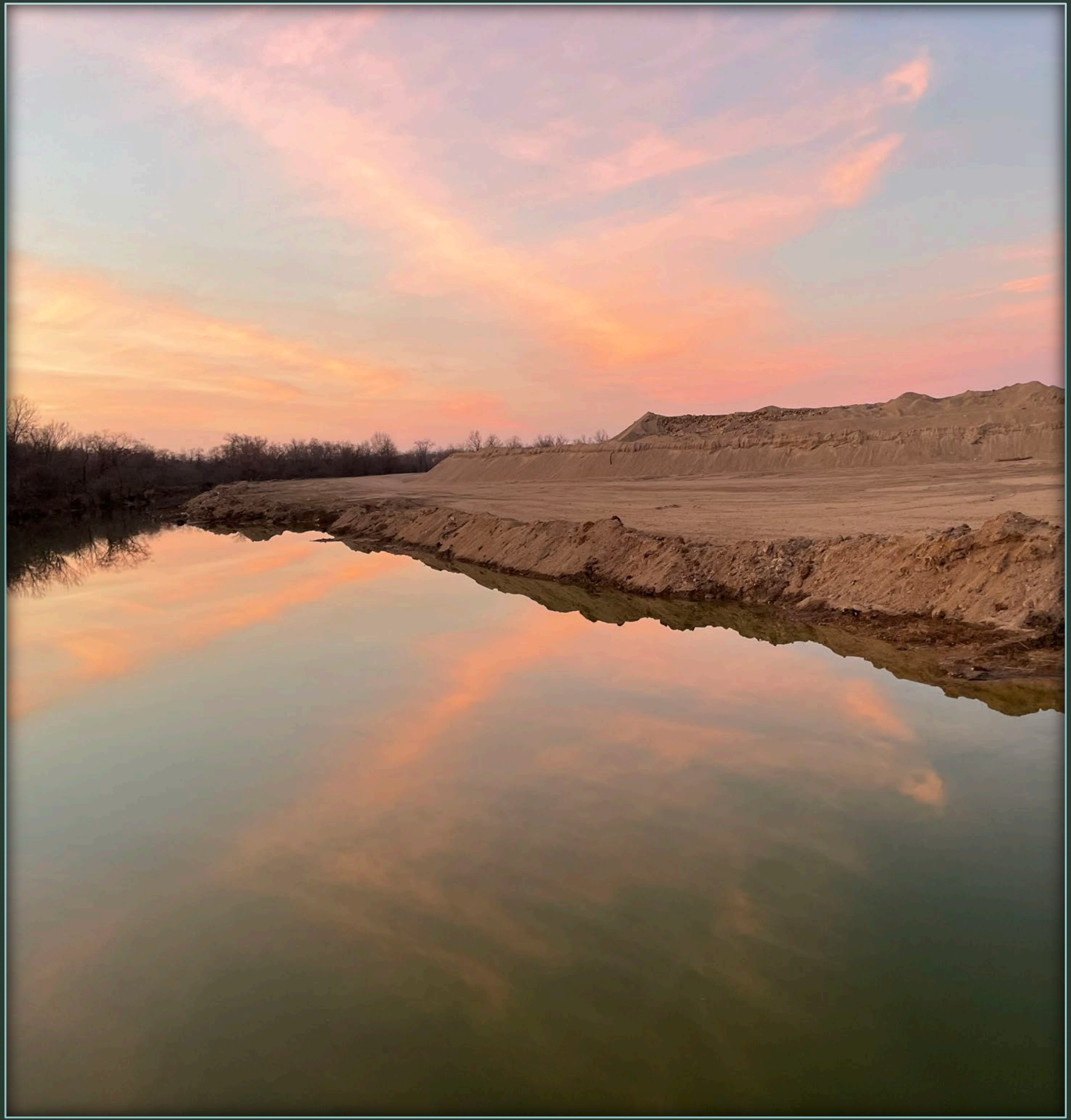
Site	Measured Zn Load – Expected Zn Load (mg/min)		
	Jul	Aug	Jan
TC-2	**42.2**	**40.4**	**13.9**
TC-3	-15.3	-59.1	-9.5
TC-4	**86.1**	**87.2**	**20.6**
TC-5	22.1	-73.7	**13.9**
TC-6	2.7	**4.4**	**11.7**
TC-7	-84.9	**124.1**	**34.3**

Metals Load in Stream, Continued

- **June, September, November, and December drier than long term average**
- **No flow at TC-2 and TC-3 in later months**
  - **Zinc load at TC-4 in these months just measured load**
- **TC-1 not sampled in September**

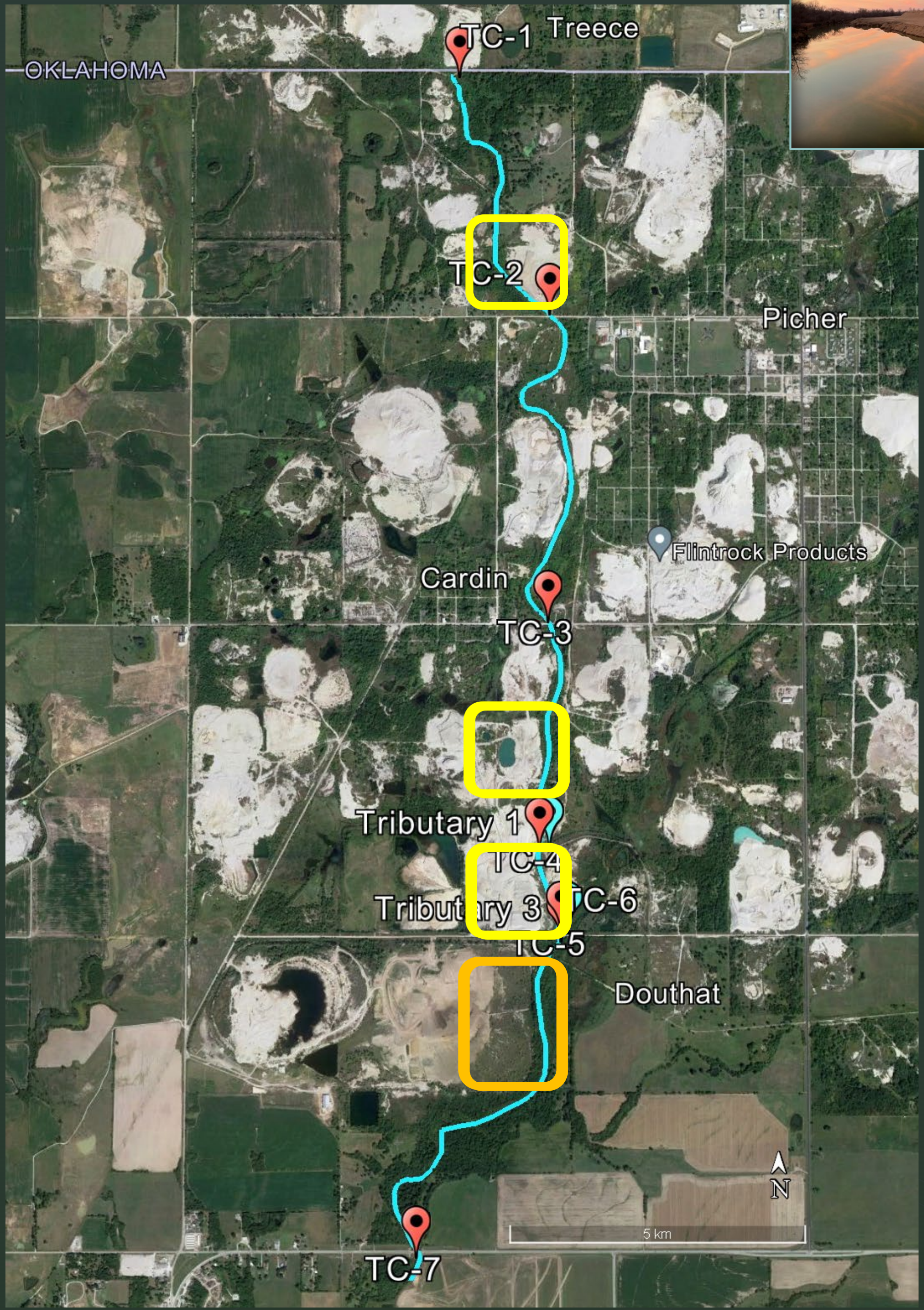
Site	Measured Zn Load – Expected Zn Load (mg/min)			
	Jun	Sep	Nov	Dec
TC-2	-0.01	-	**-**	**-**
TC-3	**0.03**	**-**	-	-
TC-4	**0.75**	*0.4*	*0.4*	*1.0*
TC-5	**0.9**	-0.1	0.2	-0.5
TC-6	-1.7	-5.3	-6.2	-12.7
TC-7	-2.6	-0.9	**1.0**	**1.6**

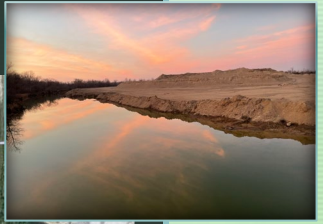
Conclusions and Future Work

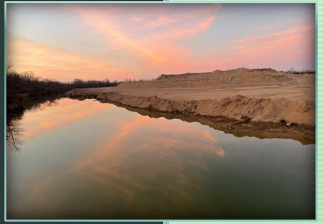


Nonpoint Source Tracking

- Neither dry nor stormy conditions, increases occur upstream of TC-2, TC-4, TC-5, and TC-6
- Wet conditions, increases occur everywhere but TC-3
- Dry conditions, increases occur mostly at TC-2
- Initial hyporheic zone investigations at all sites







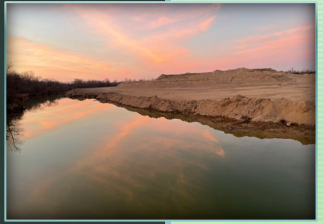
Future Studies: Perched Groundwater and Stormwater Runoff

- Pile north of TC-1
  - Relatively intact
- Area north of TC-2
  - Site of current interim measure
- Bases north and south of TC-4
  - Processed for asphalt aggregate
- Area south of TC-6
  - Fine tailings impoundment

From Cope et al. 2008

Photo courtesy of Maria Nairn

Looking Forward



- **Identify long-term post-remediation patterns**
- **Guide future remedial action**
- **Gain insight into stream dynamics**

Acknowledgements

- Dr. Nairn and dissertation committee
- WVTF & IMWA meeting organizers
- CREW
- Quapaw Nation
- Oklahoma Department of Environmental Quality
- Grand River Dam Authority

Photo courtesy of Brandon Holzbauer-Schweizer

Thank you!

Questions?