Hydrogeologic Characterization and Groundwater Modeling at the Tar Creek Superfund Site

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Quapaw Tribe of OK
30,000,000 + acres

~48,000 acres
Quapaw Reservation Boundary by Treaty
Tar Creek
Tar Creek Superfund Site Boundary

Ottawa County, OK
MIAMI, OK
KS
History of Tar Creek

• Lead and Zinc mining began on Quapaw allotments in the early 1900’s.
• By 1940’s, it was the largest Lead and Zinc mine in the world.
• ~20,000 residents lived in Picher/Cardin area at peak of mining.
History of Tar Creek

- Mining ceased in early 1970’s.
- For every 1 ton of ore extracted, approx. 16 tons of tailings were left behind (~170 million tons ?).
- Mine drainage began to discharge in 1979.
- Site placed on Superfund NPL in 1983.
- Site had the highest Hazard Ranking of all sites nationwide (58).
- Thousands relocated via a Voluntary Federal Buyout.
Tar Creek...by the Numbers

- **230** ore mills built in the Picher Mining Field by 1918.
- **181,000,000** tons of crude ore mined in Ottawa County.
- **8,880,000** tons of Zinc concentrate produced.
- **1,690,000** tons of Lead concentrate produced.
- **13,000,000** gallons pumped per day to dewater the mines.
- **~32,000,000,000** gallons of water fill the mines today.
- **26,000** acres contained within Superfund Site boundary.
- **1,542** residential yards remediated from 1996-1998.
- **~40,000,000+** tons of chat remains at the Site.
- **1,064** mine shafts and subsidence features mapped.
- **678** residential properties eligible for relocation buyout.
- **$170,000,000+** cost over next 40 years for chat remedy.
Tar Creek Superfund Site
Hydrogeologic Characterization

• Contract awarded by EPA Region 6 to CH2M Hill in May 2008.

• Primary Objective: Determine if injection of fine tailings can be implemented in a manner that is compliant with the UIC regulations.

• Collaborative data collection effort between EPA, State of OK, Quapaw Tribe, University of Oklahoma, and other Fed. Agencies.
“Why Inject Fine Tailings?”

EPA’s OU-4 Chat Remedy = Chat Sales/Reuse

Chat Washing

~9 million yd$^3$ of fine tailings already on-site
# Data Collection Activities

**Groundwater**

- Enlarge/map well network.
- Map seeps and mine pool discharges.
- Assess groundwater levels and quality.
- Assess aquifer properties.
- Investigate the hydraulic connection between Boone and Roubidoux Aquifers.

**Surface Water**

- Acquire precipitation and climate records.
- Measure flow at mine seepage locations.
- Measure surface water stage and flow rates.
- Sample surface water quality along rivers/streams.
Conceptual Site Model

Mass Balance: $\Sigma IN - \Sigma OUT - \text{Storage} = 0$
Groundwater Modeling

- Started with an existing USGS model for the region (3 layers).
  - Layer 1: All units above the Boone
  - Layer 2: Boone aquifer mined zone
  - Layer 3: Boone aquifer beneath mined zone

- Added 2 new layers.
  - Layer 4: Aquitard below the Boone
  - Layer 5: Roubidoux Aquifer

- Modeled the mine workings using the new USGS Conduit Flow Package (CFP).
Areal Extent of GW Model

KS

OK

Core Area of Site

~5 miles

Neosho River

Spring River

Grand Lake
Conduit Flow Network - Mine Workings

KS
OK

~2 miles
Preliminary Findings

• The Hydraulic Conductivity of the Boone Aquifer is between 36 and 180 ft/day with an average value of about 80 ft/day.
• The Transmissivity of the Boone Aquifer is between 6,000 and 18,000 ft$^2$/day.
• Flux from the mine pool to the Boone Aquifer is about 10 cfs.
• Leakage from Boone Aquifer to Roubidoux is less than 11 gpm/mi$^2$ (or less than 0.4 cfs over the entire mined area).
• Median artesian discharge from the mine pool to the surface in the Douthat area is about 1.5 cfs.

Not final, please do NOT cite
Steady-State Simulated Water Budget from Modeling

\[ \Sigma \text{IN} = \Sigma \text{OUT} \]  
(No Storage)

- **Artesian Flow**: ~1.5 cfs
- **Rain Recharge**: ~2.3 cfs
- **Surface Water**: ~2.1 cfs
- **Groundwater**: ~11.5 cfs
- **Groundwater**: ~9 cfs
- **Casing Leakage**: ???
- **Aquifer Leakage**: <0.4 cfs
- **Confining Units Above Boone**
- **Confining Units Below Boone**
- **Boone Formation**
- **Roubidoux Aquifer**

*Not final, please do NOT cite*
Flow Rates in Mine Workings

~1 mile
Exchange Flow Rates/Direction in Mine Workings

- Highest GW Flow from Boone into Mine (6-71 gpm)
- GW Flow from Mine into Boone (0-5 gpm)
- Highest GW Flow from Mine into Boone (6-74 gpm)

~2 miles
Geochemical Modeling
For Injection of Fine Tailings

- **Objective:** Estimate geochemical reactions to explain observed data from Chat Injection Pilot Project (Sooner Pile).
  - **Solution:** PHREEQC model used to simulate reactions between chat and slurry water, and slurry and mine pool water.

- **Objective:** Estimate fate of trace metals as they migrate through the mine workings and into the Boone Aquifer.
  - **Solution:** PHAST model used to simulate reactive transport in groundwater.
Fine Tailings Injection

Water Quality?

Water Quality?

Water Quality?
Geochemical Modeling Results for Strategic Injection of Fine Tailings ~ 1 mile Upgradient of Unmined Boone Aquifer

(not final- please do NOT cite)
Geochemical Modeling: Preliminary Findings

• Injection of fine tailings temporarily increases metals concentrations in the mine pool near the point of injection.

• Metals concentrations return to original levels near the point of injection after injection stops.

• Metals concentrations are significantly reduced down-gradient of injection through mine pool mixing and dilution.

• Fine tailing Injection is expected to have little effect on discharge to the Boone Aquifer.

Not final, please do NOT cite
Ongoing Activities at Tar Creek

- “Tweaking” the GW Model is ongoing as more data is collected.

- Surface water flow measurement study is underway to quantify the interaction between surface water and the mine pool.

- Chat Injection Pilot Project with associated monitoring continues at the Sooner Pile.
Does your Tribe have Contaminated Groundwater?

• GW Modeling may help you better understand the extent of the problem.

• USGS provides free download of GW Modeling software (www.usgs.gov)

• GW Modeling experts are willing to help:  
  – USGS, university, private consultants, etc.
Credits

- EPA Region 6 Superfund Division
- Oklahoma DEQ
- CH2M Hill, contractor to EPA.
  - Brian Schroth
  - Peter Lawson
  - Fritz Carlson
  - Scott Irving
Thank You for Your Attention

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Enjoy the Conference!