Targeted Maintenance Efforts to Ensure a Decade of Successful Passive Treatment

Robert W. Nairn
Boren Distinguished Professor and Viersen Presidential Professor
CREW Director

Bryan Page, Brandon Holzbauer-Schweitzer, and Nicholas Shepherd
Water doesn’t flow downhill either. **Study Site**

**Conclusions**
Tar Creek (OK) Superfund Site

- Tri-State Pb-Zn Mining District
- National Priorities List (1983)
- 137 km$^2$ watershed
- Elevated Fe, Zn, Cd, Pb, As in water, soils, wastes, and biota
- Ten Native American Tribes
- Mining “mega-site”
Ecological engineering field research site

• Designed for 1400 m$^3$/d
• Receives elevated Fe, Zn, Pb, Cd, As, SO$_4$
• Six distinct process units (10 total)
• Parallel treatment trains
• No fossil fuel use
• Limited operation/maintenance
• Discharge meets receiving stream criteria

Mayer Ranch Passive Treatment System, Tar Creek Superfund Site, Commerce, OK

System start up 11/08
Mayer Ranch
Passive Treatment System

- USEPA funding 2004-10
- 10 process units
  - 8 in parallel trains
  - Coupled oxidative-reductive mechanisms
  - Solar- and wind-powered re-aeration
- First PTS in entire Tri-State Mining District
- Continuous operation since 11/2008
- Long-term CREW ecological engineering research site
# MRPTS Water Quality Changes

<table>
<thead>
<tr>
<th></th>
<th>In</th>
<th>Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.95</td>
<td>7.02</td>
</tr>
<tr>
<td>Tot. Alk. (mg/L)</td>
<td>393</td>
<td>224</td>
</tr>
<tr>
<td>Net Alk. (mg/L)</td>
<td>29</td>
<td>224</td>
</tr>
<tr>
<td>Fe (mg/L)</td>
<td>192</td>
<td>0.13</td>
</tr>
<tr>
<td>Zn (mg/L)</td>
<td>11</td>
<td>0.25</td>
</tr>
<tr>
<td>Ni (mg/L)</td>
<td>0.97</td>
<td>0.15</td>
</tr>
<tr>
<td>Cd (µg/L)</td>
<td>17</td>
<td>&lt;PQL</td>
</tr>
<tr>
<td>Pb (µg/L)</td>
<td>60</td>
<td>&lt;PQL</td>
</tr>
<tr>
<td>As (µg/L)</td>
<td>64</td>
<td>&lt;PQL</td>
</tr>
<tr>
<td>SO$_4^{2-}$ (mg/L)</td>
<td>2239</td>
<td>2057</td>
</tr>
</tbody>
</table>
Extensive Ability to Manipulate Water Levels and Control Flows
Extensive Ability to Manipulate Water Levels and Control Flows (lots of buried pipes)
Extensive Ability to Manipulate Water Levels and Control Flows (lots of valves)
Extensive Ability to Manipulate Water Levels and Control Flows

C1-C2 (Surface Flow) Connection
(water doesn’t flow downhill)

C3N/C3S-C2 (Vertical Flow) Hydraulic Conductivity
(water doesn’t flow downgradient either)
Water doesn’t flow downhill
Extensive Ability to Manipulate Water Levels and Control Flows

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Water Surface Elevations

- **Staff gauges**
- **Data-recording pressure transducers**
  - Solinst Leveloggers
  - Barometric pressure-corrected
  - 30-minute data collection intervals
  - Deployed in every PTS unit and receiving stream
2017 C1 Oxidation Pond Water Levels

Surface Water Elevation (ft AMSL)

Jan-17, Mar-17, May-17, Jun-17, Aug-17, Oct-17, Dec-17

DSWE
Pipe is clogged?  Snake it!

- Rented sewer snake
- Tried every head attachment known to man
- Cloudy water, but no evidence of clog
- Reestablished flow for a few days/weeks
Pipe is clogged? Jet it!

- Down-sized 3” trash pump outflow to 1” with PVC fittings
- Cloudy water (and lots of it!), but no evidence of clog
- Reestablished flow for a few days/weeks
Pipe is clogged? Let’s see...

- Rented sewer camera
- Pipe stained, but no obstruction

Reestablished flow for a few days/weeks!
What is buried out there?

C1

C2N/C2S

Air Lock
PTS O&M with Limited *(No)* budget, No Time and Thoughts to the Future

- Leave existing infrastructure in place, but take off-line
- Open berm and install straight short pipes
- Install inlet *(not inline)* AgriDrain structures with weirs
- Set identical weir elevations to split flows evenly into C2N/C2S
- Cross our fingers...
Leave Existing Infrastructure in Place
Inlet AgriDrains and Short Open Pipes
It doesn’t flow downgradient either.
Extensive Ability to Manipulate Water Levels and Control Flows

C3N/C3S-C2 (Vertical Flow) Hydraulic Conductivity

(water doesn’t flow downgradient either)
Extensive Ability to Manipulate Water Levels and Control Flows
45% spent mushroom substrate

45% hard wood chips

10% manufactured limestone sand
What else is buried out there?

- Decrease in K over time
  - Obstruction of porosity
  - Organic degradation
What else is buried out there?

- Decrease in K over time
  - Obstruction of porosity
  - Organic degradation
Estimated Hydraulic Conductivity (K)

- Field-falling head tests
- Slug tests
- Modified single-ring infiltrometer
- Laboratory-falling head tests
Field-Falling Head Tests

Water cap

Organic mix

Gravel and perf pipe

PT
Field-Falling Head Tests

- Turn off inflow
- Pull the plug
Slug Test
Modified Infiltrometer

- Standpipe
- Manometer
- Added mass
- Infiltrometer
- Substrate

Dimensions:
- 151 cm
- 53 cm
Laboratory Falling Head Tests

- Klute and Dirkson (1986)
- ASTM 28-4.2

Diagram showing a falling head test setup with a 105 cm drop height, collected substrate, and clean gravel.
## Decreases in Hydraulic Conductivity

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<th>Method</th>
<th>C3N VFBR</th>
<th>C3S VFBR</th>
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<tbody>
<tr>
<td>2008 (pre-construction)</td>
<td>Laboratory-Falling Head</td>
<td>4.77</td>
<td>4.77</td>
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<tr>
<td>2016 (8-years operation)</td>
<td>Laboratory-Falling Head</td>
<td>0.51</td>
<td>---</td>
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<tr>
<td></td>
<td>Field-Falling Head</td>
<td>0.13</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Modified Infiltrometer</td>
<td>0.19</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Slug Test</td>
<td>1.25</td>
<td>0.43</td>
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*Restore Hydraulic Conductivity!*
Flip the Substrate
Intact 9-yr Old Substrate
Little Loss of Depth
Clean Underdrain Stone
Degraded Material Near C3S-In
Substrate Flipped
Proud Co-Author

Field-Falling Head Test
## Decreases in Hydraulic Conductivity

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<tr>
<td>2017 (after flipping)</td>
<td>Field-Falling Head</td>
<td>4.5</td>
<td>4.5</td>
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Conclusions
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- Reestablished surface flow connection between C1 and C2N/C2S
  - Eliminated buried flowpath
  - Installed inlet weir structures
  - One week of down time

- Reestablished C3N/C3S VFBR hydraulic conductivity
  - Flipped organic substrate
  - No evidence of underdrain failure
  - Ten days of down time
### “Major” O&M Costs

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<th>Item</th>
<th>C1-C2N/C2S Surface</th>
<th>C3N/C3S VFBR</th>
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<tr>
<td>2 x 8” x 5’ Inlet AgriDrains</td>
<td>$1200</td>
<td>---</td>
</tr>
<tr>
<td>Equipment (Takeuchi TB153)</td>
<td>$1500</td>
<td>$1900</td>
</tr>
<tr>
<td>Stone (for ramp)</td>
<td>---</td>
<td>$700</td>
</tr>
<tr>
<td>Labor</td>
<td>$1000</td>
<td>$1500</td>
</tr>
<tr>
<td>Misc. (pipe, fuel etc.)</td>
<td>$700</td>
<td>$200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$4400</strong></td>
<td><strong>$4000</strong></td>
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</table>
Mayer Ranch PTS - COCs

102±2.60

99.8% ΔFe
37,000 kg Fe/yr
~750 mt Fe/life

4.65±0.12

98.6% ΔZn
1700 kg Zn/yr
~35 mt Zn/life

“Major” O&M < $10K ($840/yr)
All monitoring and regular O&M ~ $10K/yr

~100% ΔPb
15 kg Pb/yr
~0.3 mt Pb /life

~100% ΔCd
3 kg Cd/yr
~0.1 mt Cd/life
Southeast Commerce PTS

C1: Oxidation pond

C2: Surface flow wetland

C3: Vertical flow bioreactor

C4: Final polishing unit