Total Phosphorus Mass Balance Model – Lower Boise River, Ada and Canyon Counties, Idaho

Alexandra Etheridge
Thank you

- IDEQ – Cooperator
- Rex Barrie & Liz Cresto - IDWR
  - Diversion Flows
- Kate Harris - City of Boise
  - WWTP sampling
Objectives

- Determine gaining and losing reaches between Veteran’s Parkway and Parma
- Evaluate sources of phosphorus in the Boise River
Agenda

- Study Area & Sites
- Study Approach
- Sample Results
- Model Results
  - Approach
  - Assumptions / Limitations
  - Results
  - Scenarios
  - Observations
- Periphyton Discussion
Plumbing

Drains

Lower Boise River

Other tributaries and water conveyances
USGS Approach

- Sample returns & above / blw
- Sample WWTPs
- Measure flow at sample locations
- Diversion Q from IDWR
- Sample shallow wells and piezometers

Report

- Peer reviewed draft to DEQ 6/13
- Published 12/13
August 20 and October 29 Synoptics

- 14 BR, 2 N.Chan, 2 Snake
- 7 Point Sources
- 15 tribs, Riverside
- 49 Diversions (IDWR)

- August - during irr.
- October - post irr.
  - Indian Crk diverted
  - Dixie Drain elevated
Groundwater Gains & Losses

August

Gain or Loss, in cubic feet per second

River Mile

October

Average Q Uncertainty
7.4% main-stem
3.4% tributaries
10% diversions

Provisional – Subject to Peer Review
Sample Results

August

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Particulate Phosphorus

August

River Mile

RM & OP:TP

Coeff -0.03

OP:TP Ratio

Coeff 0.45

0.50
0.60
0.70
0.80
0.90
1.00

0 5 10 15 20 25 30 35 40 45 50 55 60 65

Suspended Sediment Concentration, mg/L

SSC & OP:TP

Coeff -0.63

0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00

0 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95 1.0

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October
Results Summary

- Two unnamed drains sampled below Notus

- August
  - GW gains & losses < Q uncertainty Veterans – Middleton
  - Significant GW gains Middleton – Parma
  - Significant correlations

- October
  - GW gains & losses < Q uncertainty Star - Middleton, Caldwell - Notus
  - GW gain Veterans – Caldwell, loss blw Caldwell to Parma
  - Insignificant correlations
**Model Results**

<table>
<thead>
<tr>
<th>Flow Dia</th>
<th>Original Flow</th>
<th>TP - No GW Assumptions</th>
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<th>TP Mass Conservation</th>
<th>Instream Concentration from Flow</th>
<th>Assumed GW TP</th>
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Modeling Approach

- **Step 1** - GW flow from flow balance

\[ \Delta Q = Q_{\text{end}} - (Q_{\text{start}} + Q_{\text{in}} - Q_{\text{out}}) \]

\[ \frac{\Delta Q}{L} = \frac{Q_{\text{gw}}}{L} \]
Calibrated Mass Balance Model

- Use measured mass
- No assumptions on GW TP

\[ M = Q \ast C \ast F \]

\[ \Delta M = M_{end} - (M_{start} + M_{in} - M_{out}) \]

\[ \frac{\Delta M}{L} \]
Uncalibrated Mass Balance Model

- Estimate GW concentrations
  - Account for gained & lost mass with GW exchange

\[
C_{\text{end}} = \frac{\left( C_{\text{start}} \cdot Q_{\text{start}} \right) - \left( C_{\text{start}} \cdot Q_{\text{out}} \right) + \left( C_{\text{in}} \cdot Q_{\text{in}} \right) + \left( - C_{\text{gw}} \cdot Q_{\text{gw}} \right)}{Q_{\text{end}}} = C_{\text{end}}
\]
Two Models

1. Calibrated - Conservation of Mass Model
2. Uncalibrated – GW concentration assumptions

- 3 GW Concentration Scenarios
  1. Back-calc $C_{GW}$ except $\Delta Q < Q$ uncertainty
  2. TP = 0.25 mg/L in gaining reaches
  3. TP = trib base flow
Assumptions & Limitations

- Steady state
  - No biogeochemical processes
  - Snap-shot for specified dates
- Groundwater
- Plumbing
  - Returns – no account for diverted load
- Storm events
August Results

- 14 main-stem samples
  - 97% $R^2$ uncalibrated model
  - Best Fit GW = back-calculated TP

Provisional – Subject to Peer Review
Flow Calibration Plot - August

Provisional – Subject to Peer Review
TP Load Calibration Plot - Aug

- Lander WWTP
- West Boise WWTP
- Fifteenmile Creek
- Mason Creek
- Caldwell WWTP
- Indian Creek
- Dixie Drain

River Mile

- Instantaneous Load
- Net Mass (-Diversions, +Returns)
- Estimated In-Stream Load - Mass Conservation
- Estimated In-Stream Load - GW Assumptions

Total Phosphorus Load, pounds per day

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October Results

- 14 mainstem samples
  - 0.83 – 0.80 R² for uncalibrated models
    - Best fit GW = trib TP
    - Best model includes GW Losses
Flow Calibration Plot - October

Provisional – Subject to Peer Review
TP Concentration Calibration Plot - Oct

Total Phosphorus, milligrams per liter

River Mile

0.0 0.1 0.2 0.3 0.4 0.5

70 65 60 55 50 45 40 35 30 25 20 15 10 5 0

Lander
West Boise WWTP
Fifteenmile Creek
Mason Creek
Caldwell WWTP
Indian Creek
Dixie Drain

Estimated Instream Concentration - GW Assumptions
Estimated Instream Concentration - Mass Conservation

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Modeling Scenarios

1. Reduce Point Sources
2. Reduce Nonpoint Sources
3. Reduce Point & Nonpoint Sources
Scenario 1 – Reduce Point Sources

- All WWTPs = 0.10 mg/L
  - Lander, West Boise, Middleton, Caldwell
- Indian, 15mile, Dixie = 0.10 mg/L
- GW = back-calc TP
- No account for $\Delta TP$ in diversions
Results: Reduce Point Sources

August
- 0.17 mg/L at mouth
  - 43% load reduction
- Riverside = 0.16 mg/L
- Nyssa = 0.07 mg/L

October
- 0.07 mg/L at mouth
  - 76% load reduction
- Riverside = 0.10 mg/L
- Nyssa = 0.04 mg/L
Scenario 2– Reduce Nonpoint Sources

- **Major tribs = 0.10 mg/L**
  - Mason Crk & Slough, Hartley, Conway, Willow, Mill, 2 Unnamed drains, Dixie

- **GW = 0.10 mg/L**

- **Indian & 15mile unchanged**
August Scenario 2 – Reduce Nonpoint Sources

October Scenario 2 – Reduce Nonpoint Sources

Provisional – Subject to Peer Review
Results: Reduce Nonpoint Sources

August
- 0.15 mg/L at mouth
  - 50% load reduction
- Riverside = 0.15 mg/L
- Nyssa = 0.07 mg/L

October
- 0.21 mg/L at mouth
  - 28% load reduction
- Riverside = 0.26 mg/L
- Nyssa = 0.05 mg/L
Scenario 3 – Reduce Point & Nonpoint Sources

- All WWTPs = 0.10 mg/L
  - Lander, West Boise, Middleton, Caldwell

- All major trib = 0.10 mg/L
  - Mason Crk & Slough, Hartley, Conway, 15mile, Willow, Mill, 2 Unnamed drains

- Indian Q = 0, Dixie = 0.07 mg/L

- GW = 0.10 mg/L

USGS
August Scenario 3 – Reduce Point and Nonpoint Sources

October Scenario 3 – Reduce Point and Nonpoint Sources

Provisional – Subject to Peer Review
Results: Reduce Point & Nonpoint Sources

August
- 0.07 mg/L at mouth
  - 76% load reduction
- Riverside = 0.07 mg/L
- Nyssa = 0.06 mg/L

October
- 0.06 mg/L at mouth
  - 79% load reduction
- Riverside = 0.05 mg/L
- Nyssa = 0.03 mg/L
Modeling Results Summary

- Both models – useful to evaluate BMP scenarios during specific season

- Both point and non-point sources impact TP in August

- Point sources more significant in late October

- More unexplained loss of mass in October
What about Periphyton?
Chlorophyll a, periphyton, milligrams per square meter

**Provisional Interpretation - Subject to Peer Review**

- **Synoptic Data**
  - Max
  - 75th Percentile
  - Median
  - 25th Percentile
  - Min

**Proposed Target**

<table>
<thead>
<tr>
<th>Location</th>
<th>Provisional Interpretation</th>
</tr>
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<tbody>
<tr>
<td>Eckert Rd Late IRR</td>
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<tr>
<td>Glenwood Late IRR</td>
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<tr>
<td>Glenwood Post IRR</td>
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<tr>
<td>Middleton Late IRR</td>
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<tr>
<td>Middleton Post IRR</td>
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<tr>
<td>Caldwell Late IRR</td>
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<td>Parma Late IRR</td>
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</tr>
<tr>
<td>Parma Post IRR</td>
<td>20</td>
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Considerations

- BMP implementation & WQ changes
  - Nitrogen
  - Suspended sediment
  - Uptake – P vs Periphyton
  - DO implications
Questions?