Event-Based Hydrologic Calibration of Field-Scale Watersheds

Upper Fever River Watershed, Lafayette County, Wisconsin

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The SWAT Hydrologic Calibration Process

- Relies on a handful of the most sensitive parameters
- Typically based on a multi-subbasin, multi-HRU watershed
- Parameter aggregation within HRUs
- BMP forecasting usually based on adjusting parameter values
Pros and Cons of SWAT Field-Scale Application

**Pros**
- Reduce Spatial Heterogeneity
- Reduce Parameter Correlation Between HRUs
- Provide clearer understanding of SWAT Processes

**Cons**
- Daily time-step relatively long compared to process length, leads to storm aggregation

![Diagram showing 6 subwatersheds, 30 HRUs and 1 subwatershed, 1 HRU]
Primary Research Focus

Evaluation of the NRCS Curve Number on single HRU watershed calibration using event-based monitoring

Obtain better understanding of calibration trade-offs

Examine parameter correlation
Upper Fever River Watershed
Pioneer Farm

**Fever River Monitoring Sites**

- USGS Monitoring Station 05414850

**Edge of Field Monitoring Sites**

- S2 USGS Monitoring Station
- S3 USGS Monitoring Station

- **S2**
  - 8.6 Hectares

- **S3**
  - 5.2 Hectares
## SWAT Model Inputs

<table>
<thead>
<tr>
<th>Input Type</th>
<th>Dataset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>1-meter DEM</td>
</tr>
<tr>
<td>Landuse</td>
<td>2006 Hand Digitized Land cover</td>
</tr>
<tr>
<td>Soils</td>
<td>NRCS SSURGO</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Hand Digitized Ephemeral Grass Waterway</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Farm MET Station (Daily Precipitation / Temp)</td>
</tr>
<tr>
<td>ET Method</td>
<td>Hargreaves</td>
</tr>
<tr>
<td>Measured Flow Data</td>
<td>USGS Edge-of-Field Continuous Monitoring</td>
</tr>
<tr>
<td>Management</td>
<td>Dairy Rotation (Typical for Wisconsin)</td>
</tr>
</tbody>
</table>

- **Corn**
- **Corn**
- **Alfalfa**
- **Alfalfa**
- **Alfalfa**
- **Alfalfa**
Methodology

• Use of SWAT2005 Code

• Two Field-Scale Watersheds on Pioneer Farm
  S2 (8.6 Hectares Contributing Area)
  S3 (5.2 Hectares Contributing Area)

• Calibrated to Individual Storm Events
  ▪ USGS Edge-of-Field Flumes
  ▪ April – November, 2002-2007
  ▪ S2 (41 Events), S3 (27 Events)

• Autocalibration of Individual Events using PEST

• Assumed surface flow only, no groundwater parameters used
**Curve Number Background**

- CN depicts rainfall – runoff relationship (↑ Storm, ↑ Runoff)
- CN in SWAT dependent on antecedent moisture conditions (CN1 or CN3)

\[
Q = \frac{(P-0.2S)^2}{P + 0.8S}
\]

Curves on this sheet are for the case \( I_a = 0.2S \), so that
**Curve Number Background**

- Field-scale methodology allows CN to be calculated per event
  
  Larger Storms (>2.0”) = CN 40 - 60

- The Asymptotic CN for the Pioneer Farm fields ~ 55-60

- SWAT recommended CN for the Pioneer Farm fields ~ 59-77
Objective 1: Evaluation of Separate Calibration Strategies

Objective 2: CN Correlation and Sensitivity
### Evaluation of Separate Calibration Strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Spring Tillage</th>
<th>Corn</th>
<th>Fall Tillage</th>
<th>Alfalfa</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single CN,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All Other Parameters Fixed (ESCO, AWC, SOLK)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>CNOP Tillage</td>
<td>CNOP Cropped</td>
<td>CNOP Tillage</td>
<td>CNOP Alfalfa</td>
</tr>
<tr>
<td></td>
<td>All Other Parameters Fixed (ESCO, AWC, SOLK)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>CNOP Tillage</td>
<td>CNOP Cropped</td>
<td>CNOP Tillage</td>
<td>CNOP Alfalfa</td>
</tr>
<tr>
<td></td>
<td>All Other Parameters Variable (ESCO, AWC, SOLK)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Evaluation of Separate Calibration Strategies

- Used PEST to calibrate each strategy to measured storms (2002-2007)
- Single CN Approach (A) obtains CN similar to asymptotic approach
- Multiple CN’s provide greater range to account to seasonal variability

<table>
<thead>
<tr>
<th></th>
<th>Default</th>
<th>S2 Calibration Strategy</th>
<th>S3 Calibration Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>CN2</td>
<td>77</td>
<td>56</td>
<td>---</td>
</tr>
<tr>
<td>CNOP (Row Crop)</td>
<td>77</td>
<td>---</td>
<td>77</td>
</tr>
<tr>
<td>CNOP (Alfalfa)</td>
<td>59</td>
<td>---</td>
<td>47</td>
</tr>
<tr>
<td>CNOP (Tillage)</td>
<td>80</td>
<td>---</td>
<td>84</td>
</tr>
<tr>
<td>ESCO</td>
<td>0.95</td>
<td>Fixed</td>
<td>Fixed</td>
</tr>
<tr>
<td>AWC</td>
<td>0.22</td>
<td>Fixed</td>
<td>Fixed</td>
</tr>
<tr>
<td>SOLK</td>
<td>32.40</td>
<td>Fixed</td>
<td>Fixed</td>
</tr>
</tbody>
</table>
### Evaluation of Separate Calibration Strategies

- Practice dependent CN improved model calibration
- S2 improves per strategy, yet S3 does not which is likely due to the timing of the storm events / crops between the two fields

<table>
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<tr>
<th></th>
<th>S2 Calibration Strategy</th>
<th>S3 Calibration Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>% Difference in Discharge</td>
<td>-58%</td>
<td>-9%</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.05</td>
<td>0.67</td>
</tr>
<tr>
<td>Objective Function ($\phi$)</td>
<td>1599</td>
<td>476</td>
</tr>
<tr>
<td>AIC</td>
<td>154</td>
<td>109</td>
</tr>
</tbody>
</table>
Simulated Daily CNII

- Distribution of CN reflects daily moisture adjustments for runoff prevention & aid
- The use of the CN2 is rarely used
Conclusions

1.) SWAT provided a reasonable simulation of individual storms using a daily time-step

2.) The SWAT Soil Moisture CN:
   ✓ CN directly correlated to soil moisture properties
   ✓ Correlation presents non-unique solution combinations (The Whac-A-Parameter Theory)

3.) Varied CN Approach:
   ✓ Some evidence calibration can be improved with additional CN (Dependent on Storm’s Timing)
   ✓ Allows for simulation of tillage BMPs

4.) Use of Autocalibration tools (PEST) provides insight into parameter response, improves the calibration, and creates calibration efficiency

5.) Heterogeneity exists even on field-scale suggesting that parameter “lumping” is often necessary
Acknowledgements

Pioneer Farm (Randy Mentz & Dennis Bush)

USGS - Madison (Dave Owens)

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SWAT Midwest America Users Group
Questions?

Photo Credit: Randy Mentz (Pioneer Farm)
Field S2 (Strategy 1) Simulated Daily Curve Number

Simulated Soil Water Content

Simulated Daily Curve Number