Supplementary Material to Accompany:
Long-term Agro-ecosystem Research in the Central Mississippi River Basin, USA -
Goodwater Creek Experimental Watershed Flow Data

Claire Baffaut, E. John Sadler and Fessehaie Ghidey
USDA-ARS Cropping Systems and Water Quality Research Unit
Columbia, Missouri

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### S1. Stream gauges in the LTAR-CMRB

The flow monitoring sites in Mark Twain Lake Watershed include stream sites established in 1971, field sites established in 1991, and additional sites established in 2005.

Supplemental Table S1. LTAR-CMRB monitoring sites: infrastructure, instruments and method.

<table>
<thead>
<tr>
<th>Station ID</th>
<th>Measurement Structure</th>
<th>Period</th>
<th>Instrument</th>
<th>Measurement frequency</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOGC0408 to MOGC0427</td>
<td>Berms, wing walls, and 15-cm Parshall flumes</td>
<td>1997-2002</td>
<td>Hach Pressure sensor</td>
<td>2 min</td>
<td>Rating table</td>
</tr>
<tr>
<td>MOGC0291</td>
<td>3:1 broad-crested V-notch weir with stilling well</td>
<td>1992-2002 and 2003-present</td>
<td>3230 ISCO bubbler, 4230 ISCO bubbler, and Belfort FW-1 stage recorder</td>
<td>5 min/5 min Breakpoint</td>
<td>Adjusted theoretical rating table</td>
</tr>
<tr>
<td>MOGC0292</td>
<td>3:1 broad-crested V-notch weir with stilling well</td>
<td>1992-2002</td>
<td>3230 ISCO bubbler</td>
<td>5 min</td>
<td>Adjusted theoretical rating table</td>
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<tr>
<td>MOGC0293</td>
<td>3:1 broad-crested V-notch weir with stilling well</td>
<td>1992-2002</td>
<td>3230 ISCO bubbler</td>
<td>5 min</td>
<td>Adjusted theoretical rating table</td>
</tr>
<tr>
<td>MOGC0296</td>
<td>5:1 broad-crested V-notch weir with stilling well</td>
<td>1971-1995 and 1995-2002</td>
<td>Belfort FW-1 stage recorder, 3230 ISCO bubbler</td>
<td>Breakpoint 5 min</td>
<td>Rating curve</td>
</tr>
<tr>
<td>MOGC0297</td>
<td>5:1 broad-crested V-notch weir with stilling well</td>
<td>1971-1995 and 1995-1997</td>
<td>Belfort FW-1 stage recorder, 3230 ISCO bubbler</td>
<td>Breakpoint 5 min</td>
<td>Rating curve</td>
</tr>
<tr>
<td>MOGC0298</td>
<td>5:1 broad-crested V-notch weir with stilling well</td>
<td>1971-1995 and 1995-2003 and 2003-present</td>
<td>Belfort FW-1 stage recorder, 3230 ISCO bubbler</td>
<td>Breakpoint 5 min/5 min</td>
<td>Rating curve</td>
</tr>
<tr>
<td>MOYC0001</td>
<td>Natural stream cross-section</td>
<td>2006-present</td>
<td>Sigma 9000, pressure transducer</td>
<td>5 min</td>
<td>Rating curve</td>
</tr>
<tr>
<td>MOBC0001</td>
<td>Natural stream cross-section</td>
<td>2006-2011</td>
<td>Sigma 9000, pressure transducer</td>
<td>5 min</td>
<td>Rating curve</td>
</tr>
<tr>
<td>MOOC0001</td>
<td>Natural stream cross-section</td>
<td>2006-2011</td>
<td>Sigma 9000, pressure transducer</td>
<td>5 min</td>
<td>Rating curve</td>
</tr>
</tbody>
</table>
Supplemental Table S2. Characteristics of the flow measurements conducted at the 3 stream weirs in GCEW.

<table>
<thead>
<tr>
<th></th>
<th>Weir 1</th>
<th></th>
<th>Weir 9</th>
<th></th>
<th>Weir 11</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Stage range (mm)</td>
<td>Number</td>
<td>Stage range (mm)</td>
<td>Number</td>
</tr>
<tr>
<td>1990-1994</td>
<td>7</td>
<td>353 - 2368</td>
<td>4</td>
<td>229 – 2390</td>
<td>5</td>
</tr>
<tr>
<td>2006-2011</td>
<td>8</td>
<td>302 - 2114</td>
<td>0</td>
<td>NA</td>
<td>0</td>
</tr>
</tbody>
</table>

S2. Construction of the wing walls for the Parshall flume.

A subsurface V-shaped concrete wall was built to ensure the capture of subsurface flow. Several options were considered for the wing-walls: interlocking concrete blocks, straw bales, and metal sheets. The final solution consisted in sections of metal sheet screwed and caulked to a board bolted to the top of the concrete wall. These sheets were removed as needed to allow entrance of production equipment onto the plot for field operations.

Supplemental Figure S1. Top of the subsurface concrete wall
Supplemental Figure S2. Construction of the subsurface concrete wall

Supplemental Figure S3. Parshall flume, subsurface concrete wall and wood board on which metal sheets will be fastened.
Supplemental Figure S4. Flume and wing wall made of sheet metal fastened to the top of the subsurface concrete wall and interlocked concrete blocks.

Supplemental Figure S5. Flume and wing walls made of sections of sheet metal bolted to the top of the concrete wall. The metal sheets can be removed to let field equipment drive over the flume and sampling equipment.

S3. Derivation of SI units Parshall flume coefficients from USDI-BR ratings

Because of the lack of geometric similarity between Parshall flumes of different sizes, each standard flume was calibrated individually and has its own rating table. However, equations have been proposed for flumes of specific sizes that result in less than 1% error. The USDI Bureau of Reclamation [2001] gives the following general equation for standard Parshall flumes:

\[ Q = C H^n \]
Where:

\[ Q \text{ is the flow rate in cubic feet per second} \]
\[ H \text{ is the measured head in feet,} \]
\[ C \text{ and } n \text{ are coefficients determined for each size flume.} \]

For flumes sizes 6”, and 9”, C and n are 2.06 and 1.58; and 3.07 and 1.53, respectively.

A similar equation can be written in the metric system of units:

\[ Q_m = C_m H_m^n \]

Where:

\[ Q_m \text{ is the flow rate in cubic meters per second} \]
\[ H_m \text{ is the measured head in meter,} \]
\[ C_m \text{ and } n_m \text{ are coefficients determined for each size flume.} \]

The relationship for C and n between the metric and English systems of units are:

\[ C_m = C \times 3.2808^n / 3.2808^3 \]
\[ n_m = n \]

**S4. Characteristics of the stream weirs that support stream gaging in GCEW.**

Clear images are available on Google Earth using the coordinates given in Table 1. For weirs 9 and 11, the weirs are a few meters upstream of a road bridge while the footbridges are 20 to 30 m downstream of it. At weir 1, the weir and the foot bridge are both downstream of the road bridge.

Supplemental Figure S6. Weir 9 channel and bridge cross-section.
S5. Young’s Creek measurements

Supplemental Table S3. Young’s Creek flow measurements and differences with values estimated from the rating curve.

<table>
<thead>
<tr>
<th>Date</th>
<th>stage (ft)</th>
<th>Flowrate (cfs)</th>
<th>Rating flow (cfs)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/31/2006</td>
<td>4.433</td>
<td>9</td>
<td>12.62</td>
<td>-26%</td>
</tr>
<tr>
<td>3/15/2006</td>
<td>4.583</td>
<td>18</td>
<td>23.65</td>
<td>-25%</td>
</tr>
<tr>
<td>5/4/2006</td>
<td>5.349</td>
<td>128</td>
<td>120.59</td>
<td>6%</td>
</tr>
<tr>
<td>6/1/2006</td>
<td>9.757</td>
<td>2037</td>
<td>1712.83</td>
<td>19%</td>
</tr>
<tr>
<td>3/18/2008</td>
<td>11.029</td>
<td>2501</td>
<td>2394.65</td>
<td>4%</td>
</tr>
<tr>
<td>4/30/2009</td>
<td>13.69</td>
<td>4905</td>
<td>4465.20</td>
<td>10%</td>
</tr>
</tbody>
</table>

S6. Flow metadata

Daily flow volumes are available for all the GCEW sites, i.e. plots, fields, and stream weirs site, from the Sustaining the Earth’s Watersheds, Agricultural Research Data System (STEWARDS) ([www.ars.usda.gov/watersheds/stewards](http://www.ars.usda.gov/watersheds/stewards), accessed June 1, 2012) [Steiner et al. 2008, 2009a, 2009b; Sadler et al. 2008]. All data available through STEWARDS are in the public domain, and are not restricted by copyright. Sub-daily stage and flow data are also
available on request at the 5- or 15-min time step. Metadata document methods for obtaining these data and successive updates.

Eight of the flow gauges in the Mark Twain Lake watershed are owned and operated by USGS. Daily data for these sites can be found on the USGS National Water Information System (http://waterdata.usgs.gov/nwis, accessed June 1, 2012). Sub-daily data were obtained from USGS and are available on request. The Young’s Creek flow gauging station in the Mark Twain Lake Watershed is owned and operated by ARS. Daily flow volumes are available from STEWARDS and sub-daily data are available on request.

The flow data are maintained in three different structures. The first is when it is flow data downloaded from the ISCO sampler are uploaded to a desktop computer for review using the Flowlink 4® program. After weekly review, stage and time data are exported to ASCII files and uploaded to a highly relational Oracle® database for use by research scientists of the Cropping System and Water Quality (CSWQ) research unit. This database pre-existed the STEWARDS project, and the decision has been made to maintain the local database structure and content until the next platform migration project. Thus, steps needed to transform the local tables from the CSWQ format to the STEWARDS format were developed. The upload to STEWARDS is done annually, with STEWARDS maintained within 2 years of current data. The agency has committed to maintaining STEWARDS as the permanent public access to this data store. The data are available to the public at (http://www.nrrig.mwa.ars.usda.gov/stewards/stewards.html). See the navigation aid for SETWARDS below.

**Navigation aid for STEWARDS access to Goodwater Creek Experimental Watershed data.**

- Click ‘OK’
- Click ‘tt’ icons in Missouri for short description of Goodwater Creek or Mark Twain Lake/Salt River Basin. From that short description, click the hyperlink for the longer watershed description file.
  - Click ‘X’ to exit the description
- Hover over ‘Tools’ to display options in that section.
  - ‘Summary by location’ displays data holdings across watersheds
  - ‘Select Research Location’ does the same as the direct method shown next.
- Click the blue pin labeled ‘Select Research Location, then click the drop-down arrow to display locations.
  - Select Goodwater Creek or Mark Twain Lake/Salt River Basin. The display will zoom in on the selected watershed.
  - The ‘tt’ map tips can be clicked for display of the unique SiteID or clickable descriptions of the individual measurement site.
  - Under the Select Research Location box:
    - The watershed description file can be accessed (same file as above).
    - The data holdings can be examined for the selected watershed
Note: Viewing data in table or graph form is possible, but downloading is enabled only after signing in (new users need e-mail, name, and organization; existing users need only email). Assuming one wants data, click User Login from main screen. Once logged in, one can get data two ways. One is direct data access from the login box, which is ftp access to the whole STEWARDS data base (identified by the state/location codes, MOGC is Goodwater Creek and MOSR is Salt River). The other is by theme/parameter/site queries.
• Hover over ‘Tools’ button
  o Select ‘View Location Data’
    ▪ One can search by theme or parameter, then select site of interest.
    ▪ Once selections are made, Click ‘Get data’
• There are three selections at the upper left of the new window.
  o Show graph gives a quick visualization in a time series plot.
  o Show metadata give the FGDC-compliant metadata for the GIS layer, in which entity
    attributes contain some metadata about the measurements at that site.
  o Show methods lists the fields in the measurement descriptions
• There are also three additional download options
  o Location GIS files provides the GIS files relevant to the selected parameter
  o Site description provides the site description file
  o Location description provides the watershed description file.
• Assuming all three additional download options are clicked, Save to Text File (csv) delivers a
  download package to your PC, using the standard Windows file dialog box. This is a compressed
  (zipped) folder, containing:
  o The data file itself, named by date and time, in csv form, e.g., ARS-
    DATA_mmddyyyyhhmmss(am/pm)
  o A readme file with _README appended to the same name, in csv form
  o The methods description, e.g., ARS_Methods in pdf form
  o The site description, e.g., ARS_Sites in pdf form
  o The watershed description file, e.g., Goodwater Creek MO in html form
  o A compressed set of GIS files, e.g., MOGC_StewardsGIS.gdb
  o The GIS layer metadata, e.g., MOGC_WeirsAndFlumes_metadata in html form
  o The STEWARDS data use policy in pdf form

The data themes and methods tables in STEWARDS that are relevant to the flow data are shown below.
<table>
<thead>
<tr>
<th>arcGIS feature class</th>
<th>Table name</th>
<th>Parameter Description</th>
<th>TopicID</th>
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</thead>
<tbody>
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<td>MOGC_FieldWeirs</td>
<td>MOGC_FieldWeirs_FlowBreakpoint</td>
<td>Site identifier&lt;br&gt; Date &amp; time&lt;br&gt; Stream stage, water, meters&lt;br&gt; Discharge, rate, water, cubic meters per second&lt;br&gt; Discharge, volume, water, cubic meters</td>
<td>SiteID&lt;br&gt; DateTime&lt;br&gt; STAGE_HEIGHT_M&lt;br&gt; FLOW_RATE_CMS&lt;br&gt; VOL_CU_M</td>
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<td></td>
<td>MOGC_FieldWeirs_FlowDaily</td>
<td>Site identifier&lt;br&gt; Date &amp; time&lt;br&gt; Discharge, volume, water, daily, cubic meters</td>
<td>SiteID&lt;br&gt; DateTime&lt;br&gt; VOLUME_CU_M</td>
</tr>
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<td>MOGC_PlotFlumes</td>
<td>MOGC_PlotFlumes_FlowBreakpoint</td>
<td>Site identifier&lt;br&gt; Date &amp; time&lt;br&gt; Discharge, rate, water, cubic meters per second&lt;br&gt; Discharge, volume, water, cubic meters</td>
<td>SiteID&lt;br&gt; DateTime&lt;br&gt; FLOW_RATE_CMS&lt;br&gt; VOL_CU_M</td>
</tr>
<tr>
<td></td>
<td>MOGC_PlotFlumes_FlowDaily</td>
<td>Site identifier&lt;br&gt; Date &amp; time&lt;br&gt; Discharge, volume, water, daily, cubic meters</td>
<td>SiteID&lt;br&gt; DateTime&lt;br&gt; VOLUME_CU_M</td>
</tr>
<tr>
<td>MOGC_StreamWeirs</td>
<td>MOGC_StreamWeirs_FlowBreakpoint</td>
<td>Site identifier&lt;br&gt; Date &amp; time&lt;br&gt; Stream stage, water, meters&lt;br&gt; Discharge, rate, water, 2012 rating curve, cubic meters per second&lt;br&gt; Discharge, volume, water, 2012 rating curve, cubic meters&lt;br&gt; Discharge, rate, water, 1993 rating curve, cubic meters per second&lt;br&gt; Discharge, volume, water, 1993 rating curve, cubic meters</td>
<td>SiteID&lt;br&gt; DateTime&lt;br&gt; STAGE_HEIGHT_M&lt;br&gt; FLOW_RATE_CMS_2012&lt;br&gt; VOL_CU_M_2012&lt;br&gt; FLOW_RATE_CMS_1993&lt;br&gt; VOL_CU_M_1993</td>
</tr>
<tr>
<td></td>
<td>MOGC_StreamWeirs_FlowWithRainDaily</td>
<td>Site Identifier&lt;br&gt; Date &amp; time&lt;br&gt; Discharge, volume, water, 2012 rating curve, cubic meters&lt;br&gt; Discharge, volume, water, 1993 rating curve, cubic meters&lt;br&gt; Precipitation, no media, millimeters</td>
<td>SiteID&lt;br&gt; DateTime&lt;br&gt; VOLUME_CU_M_2012&lt;br&gt; VOLUME_CU_M_1993&lt;br&gt; DEPTH_MM</td>
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<td>Stream stage, water, meters</td>
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<td>DateTime</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>Discharge, volume, water, daily, cubic meters</td>
<td>VOLUME_CU_M</td>
</tr>
</tbody>
</table>
S7.  Plots and fields management

CS1 plots and Field 1 (F1) were managed in a mulch-till corn soybean cropping system, with chisel plow or cultivation in the early spring, pre-planting application of fertilizers and herbicides, and incorporation of these inputs by cultivation followed by planting. One exception to this rotation was in 1995 when a very wet spring prevented any field operations until late June. In the field, sorghum was planted instead of corn because of its shorter growing season and a late December tillage was needed to remedy the compaction that resulted from field operations on wetter than normal soils.

CS2 plots were managed in a no-till corn soybean cropping system, with application of herbicides and fertilizers on planting day. Field 2 (F2) was similar to F1 from 1993 to 1996 but with sorghum instead of corn. Fertilizer rates were slightly lower in expectation of lower yields and nutrient uptake from sorghum than from corn. In 1997, the management was switched to a corn-soybean no-till system similar to the CS2 plots and in phase with that of F1. Fertilizer rates were lower than those of F1 because of expected lower rates with a no-till system than when fertilizers are incorporated.

From 1993 to 1996, CS5 plots were managed as a mulch-till corn-soybean-wheat system, with wheat a cover crop during all winters. In 1996, tillage stopped on these plots but the rotation was conserved.

From 1993 to 1996, Field 3 (F3) was managed as a corn-soybean-wheat no-till system, with wheat over the winter 1993, corn in 1994, and soybean in 1995 followed by a winter wheat crop harvested in June 1996. This management stopped in 1996; starting in 1997 and until 2001, F3 was managed as a corn-soybean no-till system, in phase with the systems on F1 and F2, with variable application rates of fertilizer and herbicides. Rates of nitrogen were calculated as a function of expected yields, themselves a function of the soil depth above the claypan. Rates of phosphorus and potassium were derived from soil P and K contents in 1996 samples, assuming a 4 year-buildup. Fertilizers were only applied during the corn phase of the rotation.

S8.  References.


