CENTRAL MISSISSIPPI RIVER BASIN LTAR SITE OVERVIEW

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Abstract—The Central Mississippi River Basin (CMRB) member of the Long-Term Agro-ecosystem Research (LTAR) network is representative of the southern Corn Belt, where subsoil clay content makes tile drainage challenging and make surface runoff and associated erosion problematic. Substantial research infrastructure has been in place for more than 40 years, and the recent establishment of the CMRB LTAR site has prompted additional activity. This paper describes a brief history of the research infrastructure, points to resources for further details of documentation and access for research data obtained to date, and describes current plans for expansion.

INTRODUCTION

The Central Mississippi River Basin (CMRB) member of the Long-Term Agro-ecosystem Research (LTAR) network is operated by the USDA-ARS Cropping Systems and Water Quality Research Unit in Columbia, Missouri. The CMRB LTAR represents a runoff-prone (despite gentle slopes) geophysical context with documented erosive soils found in the southern Corn Belt. Land, originally prairie dissected by wooded riparian river corridors, is intensely agricultural. The primary row crops are soybean, corn, and sorghum, and forage is mainly tall fescue. However, row crop production in this region is economically marginal and environmentally risky. In contrast to the rest of the Corn Belt, the CMRB area is not tile drained.

The core research infrastructure is the 73 km^2 Goodwater Creek Experimental Watershed (GCEW). Rain gauge network data have been collected since 1969 and streamflow and sediment load since 1971. In 1991, water quality measurements were added for surface and ground water. Scales studied ranged from plots at 0.0034 km^2, to whole fields at 0.12 to 0.35 km^2, to streams up to 73 km^2. In 2005, 12 larger-scale watersheds (200 to 1200 km^2) within the Salt River basin were instrumented; 8 of these were co-located with USGS flow sites. Since 2010, 3 of the 12 have been retained for a maximum area of 466 km^2. Collateral infrastructure includes cooperator research facilities proximal to and nearly surrounding GCEW.

The 0.34-ha plots are replicated treatment comparisons with summit, backslope, and footslope landscape positions, in place since 1991, with yield measured for the landscape positions. Eighteen of the 30 have been instrumented to measure flow and sample water quality. Adjacent is a 35-ha field (Field 1, or F1) managed conventionally from 1992-2004, and then converted to a “Precision Agriculture System” (PAS). The PAS was developed with input from stakeholders on four criteria (profitability and environmental impact for erosion, surface water quality, and ground water quality). The PAS includes no-till, cover crops, wheat instead of corn where the topsoil was thin, reflectance-based site-specific N applications for wheat and corn, grid-sample-based variable-rate P, K, and lime, and targeting of herbicides. A close parallel treatment to the PAS also exists in the plots. Another plot treatment represents conventional production.

Substantial infrastructure development is underway. A conventional practice field (Field 3, or F3) to serve as Business as Usual (BAU) will be instrumented for surface runoff sampling and measurement and a flux tower. Upgrades to existing flow and sampling equipment are underway, and a historical GCEW stream site at 12 km^2 is being re-installed to help differentiate the urban influence at the headwaters. Radio telemetry has been implemented for the rain gauge network and will extend throughout the 72 km^2 GCEW. Multiple modes

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of telemetry are being implemented in the intensively studied field site that includes the aspirational practice (ASP) and replicated plots of multiple cropping systems, including ASP and BAU. An overview of the physical infrastructure, telecommunications, and vision for the data communications plan is presented below.

PHYSICAL CONTEXT AND HISTORY

At the broad scale, the CMRB comprises a range of ARS and University of Missouri infrastructure (fig. 1) The core, established in 1971, is within GCEW. The ARS Cropland CEAP (Conservation Effects Assessment Project) broadened the scope to the entire Mark Twain Lake, which catches the upper Salt River basin and serves as primary drinking water supply to more than 40,000 residents over much of northeast Missouri. From 2004 to 2011, 12 sites, including GCEW, were sampled on a seasonal basis with automated samplers, and manually on a biweekly basis through the rest of the year where continuous flow from USGS stations existed. Surrounding the Salt River Basin are a number of USDA and University of Missouri Research Centers (RC) that provide controlled space to test hypotheses and provide contexts for comparison and contrasts. These include the Greenley RC, Bradford RC, South Farm RC, Horticulture and Agro-Forestry RC, Tucker Prairie (relic native prairie), Prairie Forks Conservation Area (restored prairie), Baskett Wildlife RC (forested Ameriflux site), and NRCS Plant Introduction Center at Elsberry.

Within the infrastructure shown in figure 1, the Long Branch Watershed remains the focus of current research (fig. 2). At this scale, the riparian forests are clearly visible, and the predominance of cropland in the broad, flat divides between the watersheds is also clear. From the Lower Long Branch USGS flow station, there is a nested flow structure through Young's Creek, then the GCEW itself. From 1971 to ~2000, the GCEW design was a 3-stage nested structure, with 72, 28, and 12 km^2 watersheds up the main stem (on the west). In parallel with Young's Creek is Upper Long Branch. The latter two are natural channels; Lower Long Branch has a low-water crossing as control.

The nested design within GCEW is visible in figure 3, with Weirs 1, 9, and 11 annotated below. In 1990, intensive infrastructure was established at the field and

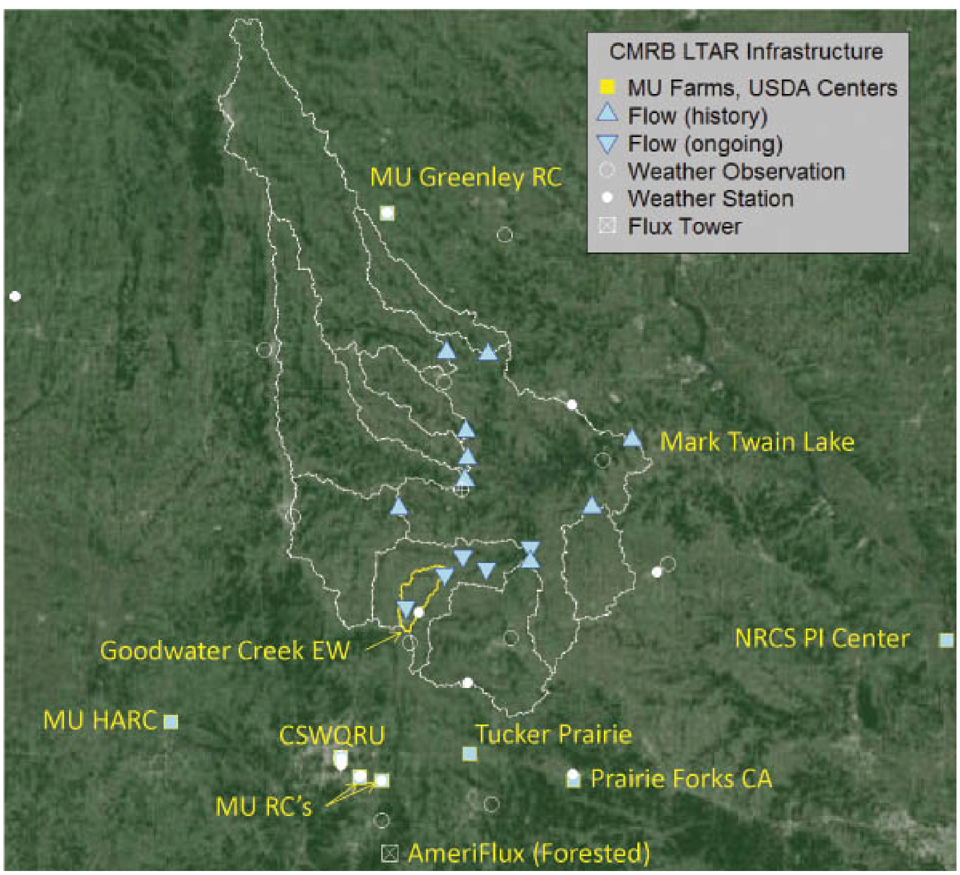

Figure 1—The Central Mississippi River Basin LTAR location and associated research infrastructure. For reference, the gray area at the extreme SE corner is Saint Louis, and the CSWQRU annotation is in Columbia MO.

plot scale. The fields are visible in figure 2, as clusters of well nests that were established in the 1990s, as is the current deployment of weighing rain gauges.

Intensive research infrastructure at the primary field site is shown in figure 4. The right half of the image is a 35-ha field with a weir to gauge runoff and an automated sampler to enable laboratory measurement of sediment, nutrient, and pesticide water quality. The site annotated as weather station includes both an ARS weather station deployed since 1993 and an NRCS SCAN station recently installed (id: CMRB LTAR). To the left are 30 plots of 0.34-ha size, arranged in 3 replications of 10 cropping systems treatments. All are separated by surface berms and in-ground curtains to prevent cross-plot movement of water and soluble constituents. Eighteen of these also have berms at the bottom that route surface runoff through concrete approaches and flumes that are instrumented with automated samplers. These have been constructed with heated stilling wells to enable sampling during periods with temperatures near freezing. They are controlled with separate dataloggers, and stage is measured using a pressure transducer with in-house calibration and temperature compensation algorithms that improve accuracy.

Description of the CMRB/GCEW Database

The data from the CMRB/GCEW was recently documented in a multi-paper special collection in the Journal of Environmental Quality (http://www.ars.usda.gov/Research/Docs.htm?docid=25264). The introduction includes the scientific, physical, and historical context for the research infrastructure (Sadler et al, 2015a). Papers describing data for weather (Sadler et al, 2015b), streamflow (Baffaut and others 2015b), and both herbicide (Lerch and others 2015b) and nutrient (Lerch and others 2015c) water quality follow. The series includes four research papers that address groundwater nutrients (Kitchen and others 2015), stream transport of nutrients (Lerch and others 2015a), and remote sensing of lake water quality (Sudduth and others 2015), plus modeling of the GCEW scale using the SWAT model (Baffaut and others 2015a). The series makes extensive use of supplemental online materials, and potential users of the data are strongly encouraged to examine that. The contents of the papers and the supplemental online materials are also described in more detail through the link. In addition, several additional earlier publications are listed (and linked) that provide critical information regarding sediment (Baffaut and others 2013), hydrologic

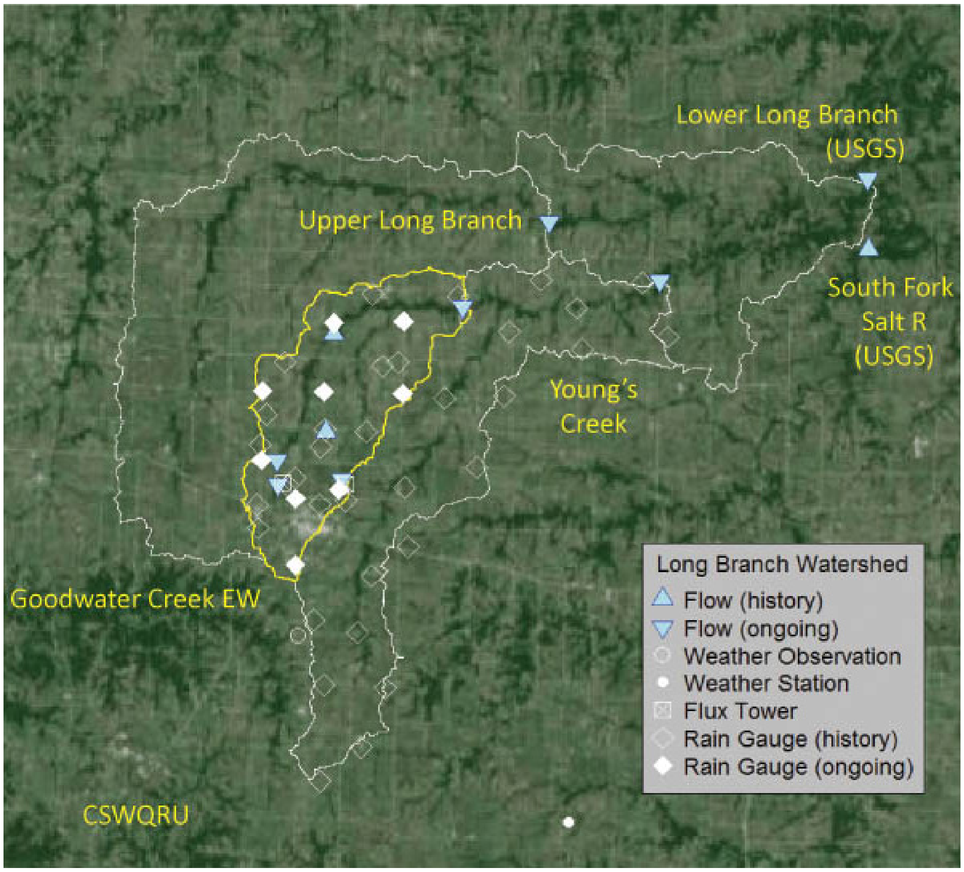

Figure 2—Research infrastructure in the Long Branch watershed of the Salt River.

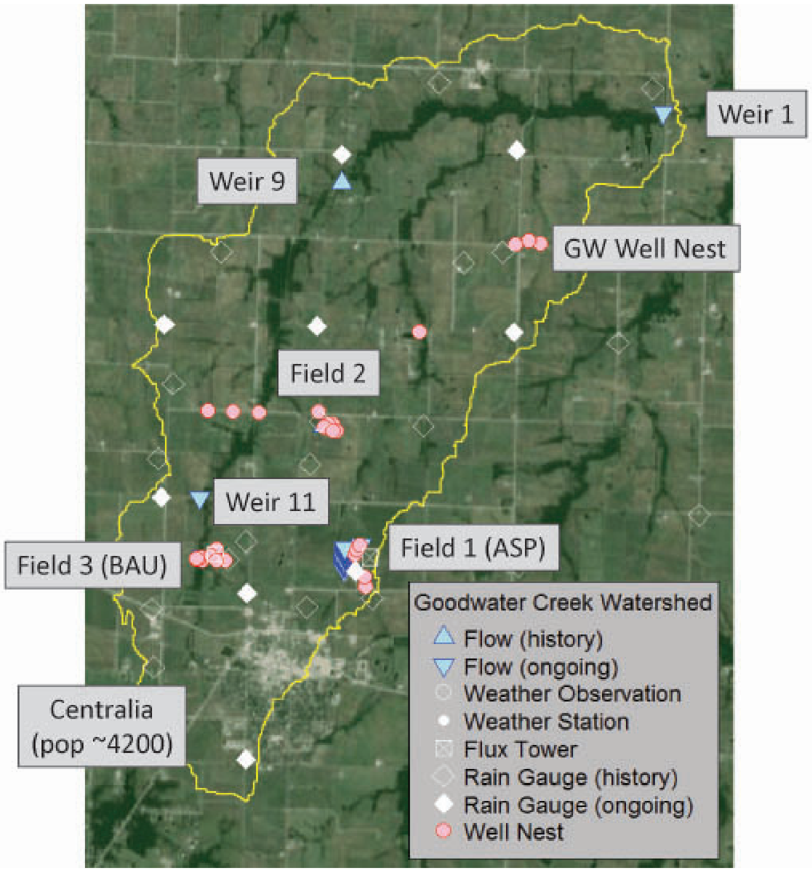

Figure 3—Infrastructure visible at the Goodwater Creek Experimental Watershed scale.

methods (Baffaut and others 2014), and the cropping systems in the research fields and plots (Lerch and others 2005; Kitchen and others 2005, Lerch and others 2008). The data described in this series are available to the public through the STEWARDS database system (Steiner and others 2008a; 2009a, b; Sadler and others 2008).

In addition, extensive soil quality assessments have been conducted at the field and plot scale at the GCEW site (Fig. 4). In 2008, a baseline assessment was initiated on all GCEW management systems, and included a broad range of soil physical, chemical, and biological indicators of soil quality. The soil quality assessments were repeated in 2010 and 2014, and will continue to be periodically done to evaluate the long-term effects of management practices.

Telecommunications development

At this time, the GCEW raingauge network is linked with a radio-frequency telecommunications network to a tower and base station located at the Field 1 weir site. This network is expected to provide the telecommunications backbone for all instruments outside the Field 1 campus, plus the weather station, rain gauge, and planned flux towers within Field 1. Another, lower power, network connects the dataloggers on the plot flumes north of the building and is expected to be able to accept other close-range equipment in that area. Both of these networks will connect to a server in the on-site building. That server will connect through a local ISP to the internet, where servers at the Columbia ARS offices exist. The server also will host WiFi for the field site, providing data access via smartphones and laptops and receiving camera images and video feeds for both security and research purposes.

The server will provide local control and storage, and automatically forward data, as it is received, to the Columbia servers. Scientists will normally access data from the Columbia servers, such that the field server would function as backup. In operation, raw data are not overwritten but rather, edits are added as a separate data product with metadata describing the replacement or transformation. Primary quality assurance (QA) through outlier screening will be performed at dataloggers or the field server, with reports and alerts contingent on those screens. Secondary QA will be performed by technicians and scientists during normal work hours, usually on

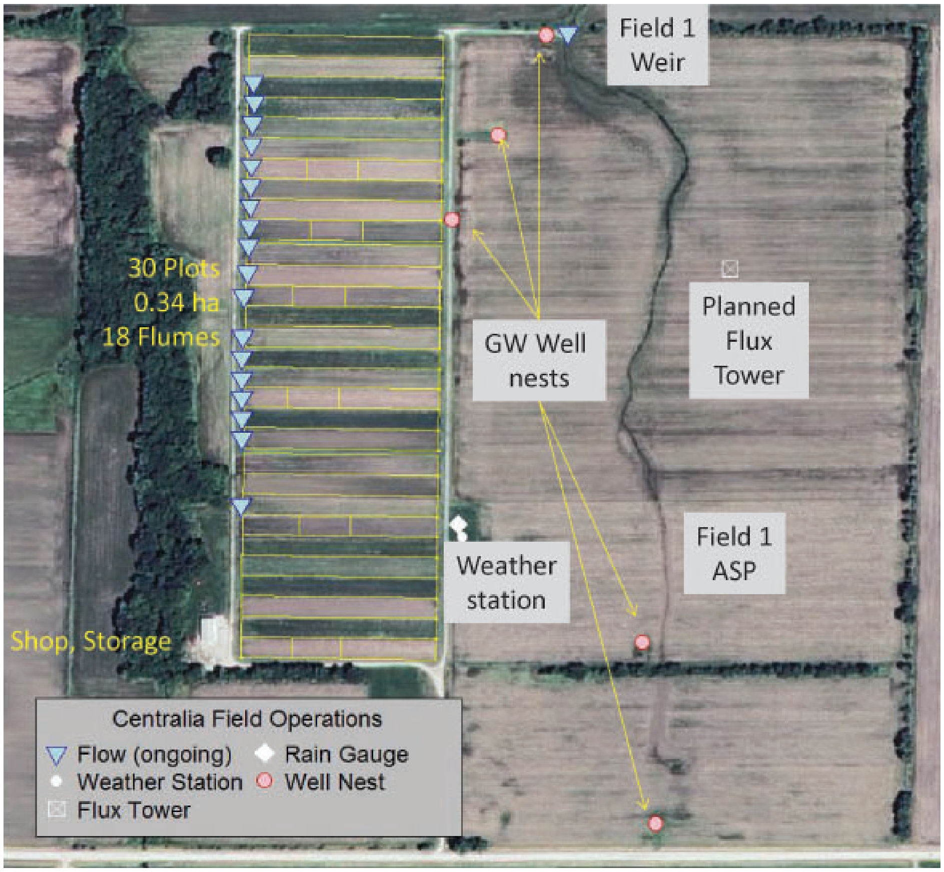

Figure 4—Infrastructure at the Goodwater Creek Experimental Watershed Field 1 site.

a timeframe from daily to monthly, depending on the data stream. This level would involve lab and field standards, cross-site or cross-instrument comparisons, and comparisons with long-term normal data as appropriate. Tertiary QA is done on the annual cycle and involves those and additional comparisons plus statistical comparisons with related or similar instruments. This latter step is required before provisional data is tagged as final.

Planned Research Equipment

Eddy flux towers will be installed in Field 1 as ASP (2015 season) and in Field 3 as BAU (2016) (see fig. 3 for sites). A parallel comparison across two instrument types will be established in Field 1 (2015). Averages at 30-minute intervals will be transmitted and forwarded using on-board post-processing. The high-frequency data will be moved to the server on a weekly basis via storage modules.

The Field 3 BAU site has an existing weir for measuring runoff, but flow measurement and sampling equipment were removed some years ago. Modern versions of that equipment will be installed, and data communication established. Once that is operable, a water sampling protocol for the site will be established and implemented. Similarly, the Weir 11 site was operable from 1971 through 2002, at which time the instrumentation was removed, but the weir remained. Modern equivalents to the instrumentation and sampling equipment will be installed. The Field 3 and Weir 11 sites are high priorities. Upgrading the larger stream sites will involve similar activities – obtaining permissions from right-of-way jurisdictions and landowners, establishing power, building the platform and housing, installing sampling equipment and flow instruments, and establishing communications (cellular modem at those sites). They will be sequenced after the Field 3 and Weir 11 sites.

Historical rainfall data in GCEW was measured with unshielded weighing rain gauges. The SCAN station and other automated stations use unshielded tipping bucket gauges. The LTAR requirement is expected to be a shielded weighing rain gauge. For longitudinal and cross-instrument purposes, statistical descriptions of the relationships among these instruments are required. A 2x2 measurement design will be established at the Field 1 weather station site, exploiting the existing unshielded weighing and tipping bucket gauges and adding the equivalents with double alter shields, all at the same height. This deployment will include air temperature and wind speed at the height of the gauges, as relationships among these gauges is known to depend on wind, and temperature is expected to provide correlation to both seasonal droplet size and rain vs snow relationships.

Similarly, SCAN weather stations use a type of soil moisture measurement that is known to have difficulties in soils with high fractions of 2:1 lattice clays, as exist at this site. An alternative instrument that is expected to perform better in the local soils will be installed in parallel and proximal to the SCAN instruments, and the necessary relationship established. Gravimetric soil moisture and bulk density measurements will be made on a periodic basis for calibration purposes.

The SCAN weather station automatically uploads hourly and daily data to the NRCS weather data server. Software has been developed locally to extract data from the NRCS server. It will be adapted to operate on the native time basis and create a local copy of those data for cross-instrument comparisons and QA purposes. The ARS weather station will be relocated approximately 10 m north to escape the shadow of the SCAN radio antenna during the winter months, and upgraded to current equipment and sensors at that time. Programming to match the 5-minute near real time frequency of the University of Missouri AgEBB weather station mesonet will be implemented at that time. Software to transmit the data to the AgEBB will be implemented as well as storing on the field and office servers. A second AgEBB weather mesonet station will be established near the Paris MO high school, where weekly maintenance will be performed by students as a vocational education activity.

Facilities Plans

The current building on the field site is a 24x12-m metal frame construction, with 1/3 floored and a small area heated and air conditioned. The rest is used for farm equipment storage. A project starting this year will add ~32x12m under roof, with about half farm equipment storage and the rest electronic and hydrologic workshop, multi-purpose space for farm machinery setup, instrumentation, repair, and field day/meeting area, and restroom/shower facilities. Architectural and engineering work will begin in 2015, with construction intended for 2016.

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