Application for membership in the

ARS Long-Term Agro-ecosystem Research (LTAR) Network

# Goodwater Creek Experimental Watershed LTAR

## Representing Runoff-prone Environments

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## Summary

The USDA-ARS Cropping Systems and Water Quality Research Unit (CSWQRU) hereby applies for formal affiliation with ARS's Long-Term Agro-Ecosystem Research (LTAR) network. The core infrastructure upon which this application is based is the Goodwater Creek Experimental Watershed (GCEW). GCEW represents a runoff-prone geophysical context with documented erosive soils despite gently sloping topography, which is vulnerable environmentally and marginal economically.

While GCEW serves as the core infrastructure, collateral infrastructure surrounding the GCEW has provided substantial research data critical for understanding transport processes within and out of the GCEW. Expertise comprised within the CSWQRU scientific and support staff is well-suited to operate the research program centered on GCEW. Senior staff are productive scientists with documented high-impact cooperative research results, and they are nationally and internationally recognized in their disciplines and scientific societies. A wide range of complementary expertise is embodied in cooperators. Extensive cooperative relationships have been developed and maintained with numerous university departments at the University of Missouri and other universities, government agencies, industry, NGOs, and producers. Supporting research infrastructure is excellent, with laboratory and field facilities; machine and electronic fabrication; field and plot space for controlled research; field equipment for cropping operations at producer scales; vehicle fleet for transport of staff, materials, and equipment; and research equipment for relevant research. Equipment and staff provide excellent IT support for general computer operations, analysis, database management, GIS, CAD, statistics, image analysis, and process-level hydrologic simulation models at field and watershed scale. Institutional commitment exists at all levels. The CSWQRU and their cooperators stand ready to leverage the GCEW and surrounding infrastructure toward the LTAR network as representing the surface runoff prone southern corn belt.

Why an LTAR here? Agriculture is faced with increasing demands to implement sustainable management strategies in response to food- and energy-security needs, while concurrently addressing chronic water and soil quality degradation issues. Attention is especially needed for sensitive agroecosystem landscapes, such as represented by the GCEW in the southern fringe of the Corn Belt. In these landscapes significant field areas are both marginal and vulnerable. They have been shown to be *marginal* because significant field areas often have small or negative profitability due to reduced grain yield and greater risk of crop failure. These areas most often align with those where topsoil has been eroded. These same areas are also *vulnerable* to additional accelerated degradation, disproportionately responsible for delivering excess sediments, nutrients, and agrochemicals to surface water resources. The GCEW thus becomes representative of large areas of marginal and vulnerable landscapes within Major Land Resource Areas 113 and 109, primarily found in Missouri, Illinois, and Iowa, with areas of similar soils in Nebraska and Kansas. The physical and chemical properties of the soils endemic to this region are a root cause of poor water quality and lost crop productivity. Productive use of these lands is critical for farmers and communities, long-term grain crop production may be environmentally and economically unsustainable. The need for viable alternative management systems is apparent. Research associated with this LTAR application addresses these economic and ecosystem issues.

## General description of geophysical context containing GCEW

The GCEW is located in the SW headwaters of the Salt River Basin in NE Missouri, which is the source of water to the Mark Twain Lake, a 7,500-ha Army Corps of Engineers reservoir that is the major public water supplier in the region (Figure 1, with Figure 2 as finer detail). The Salt River system encompasses an area of 6,400 $km^2$ within portions of 12 northeastern Missouri counties. Topography within the watershed is flat to gently rolling, with most areas having 0-3% slopes. Soils within the basin were formed in Wisconsin and Illinoian loess overlying pre-Illinoian glacial till. Illuviation of the high clay content loess resulted in the formation of argillic horizons containing 40-60% smectitic clays. The Adco-

Putnam-Mexico soil association predominates in the flatter upland areas, and these soils tend to be less eroded and have greater depths to the argillic horizon than the terrace areas. The Mexico-Leonard soil associations occur in more sloping terrace and alluvial areas where the depth to clay is often <15 cm on side slopes because of erosion. The argillic horizon is not present within alluvial areas immediately adjacent to streams. The naturally formed argillic horizon represents the key hydrologic feature of the basin, and it is the direct cause of the high runoff potential of these soils. Most soils within the basin are classified as Hydrologic Group C or D by NRCS. Land use is predominately agricultural within the basin. The primary row-crops are soybeans, corn, and sorghum. Forage production is mainly tall fescue. Livestock production is mainly beef cattle; swine operations have increased and declined in response to market forces. Average annual precipitation is about 1000 mm per year, and stream flow (based on GCEW data) accounts for about 30% of precipitation. Runoff accounts for about 85% of total stream flow. Despite high runoff potential and poorly drained soils, sub-surface drainage is not employed because of the shallow soil layer above the clay layer and the ineffectiveness of drains in or below the clay.

While the geophysical context clearly represents the central US area with argillic horizons as the dominant feature, similar processes dominate other regions, and information gained in GCEW can inform science in those locations. Prior experience in the upper coastal plain of the SE USA indicates that the ~50% increase in clay in the argillic horizon seen there causes interflow that must also be accounted for to understand transport processes. As a specific illustration, the improvements made locally to the interflow calculations in the Soil and Water Assessment Tool (SWAT) hydrologic model should benefit SWAT model applicability in the SE US Coastal Plain.

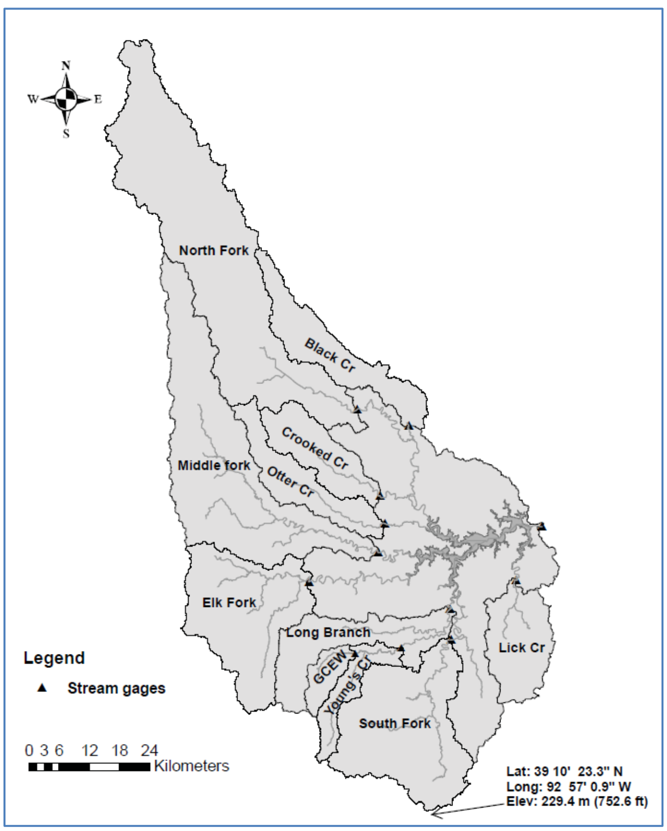


**Figure 1. The Salt River basin, draining to Mark Twain Lake, to illustrate the broader geophysical context containing GCEW.**

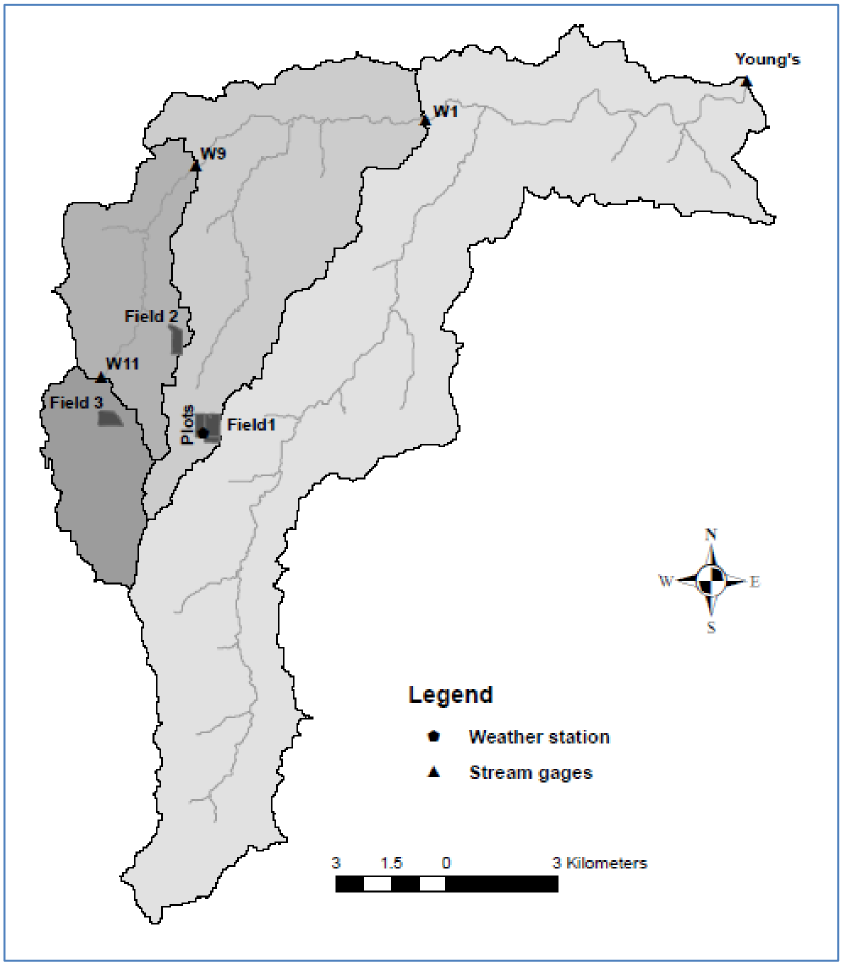


**Figure 2. Closer detail on GCEW, illustrating the 72 (W-1), 28 (W-9), and 12-km$^2$ (W-11) measurement scales, and the 195 km$^2$ Young's Creek. Field and plot scale infrastructure is located within GCEW as shown.**

The seven criteria for LTAR membership consideration are addressed below.

1) **Productivity**—*the track record of the current ARS research team and the level of existing process-based understanding (this information will be used to assess the overall strength of the research team and its leadership);*

The ARS research team includes 7 senior and 15 technical and administrative staff. Senior researchers include 3 Research Soil Scientists (John Sadler, Newell Kitchen, and Bob Lerch), 2 Research Agricultural Engineers (Ken Sudduth and Earl Vories), a Research Microbiologist (Bob Kremer), and a Research Hydrologist (Claire Baffaut). All are widely known in their respective fields. Briefs on these follow.

**John Sadler**, the Research Leader since 2003, has conducted research in many aspects of soil and water conservation, including water management, nutrient uptake rates, irrigation system design and management, precision agriculture, ammonia volatilization from wetlands, crop and structure modeling, field and watershed modeling, hydrologic database design, and pesticide transport at plot, field, and watershed scales. This research is documented in ~80 peer-reviewed and ~120 other publications (excluding abstracts). Since 2007, he has served as the field coordinator for the ARS cropland CEAP project involving 14 ARS research watersheds. One of the significant outputs from that project was the hydrologic database STEWARDS, for which he co-chaired the development team. He is acknowledged in professional societies by being named Fellow in the American Society of Agronomy, the American Association for the Advancement of Science, and the Soil Science Society of America.

**Newell Kitchen**, Research Soil Scientist. Research program mainly focuses on applying technologies for collecting high-resolution soil and crop information, thereby enabling improved management decisions for gain and bioenergy crop production. He also investigates the impact of various grain and bioenergy cropping systems on soil and water quality, including both production and water/soil quality impacts of a field-scale precision agriculture system. Additionally he conducts team research for on-the-go, in-season nitrogen fertilizer applications from reflectance sensors. His research is documented in >200 technical publications (abstracts excluded), including 75 peer-reviewed journal articles, 8 book chapters, and >30 invited papers. He is the recipient of the American Society of Agronomy Fellow (2007) and Soil Science Society of America Fellow (2008), active in organizing meeting symposia and editorial service, and served as ASA President in 2011.

**Robert Lerch**, Research Soil Scientist. Research interests include assessing factors controlling watershed vulnerability to herbicide transport, analytical methods development, the impact of prevailing and best management practices on water quality, and the effectiveness of vegetative buffer systems for reducing transport of herbicides and veterinary antibiotics. Several of these research topics exemplify long-term, systems level research that has resulted in the creation of extensive soil and water quality databases from field to regional scales. His research is documented in 95 technical publications (abstracts excluded), including 42 peer-reviewed journal articles; several papers on analytical methods and contaminant fate in the environment are widely cited. His recognition of important and relevant research topics has resulted in successfully-funded grant proposals totaling $4.09 million in external funding since 1997. His scientific stature is best exemplified by his invitation to serve on two EPA FIFRA Scientific Advisory Panels, appointment as Associate Editor for the Journal of Environmental Quality (2003-2009), eight invitations to present at national and international meetings (including the Netherlands, Switzerland, and China) and four invitations to author book chapters or manuscripts.

**Ken Sudduth**, Research Agricultural Engineer, conducts research on acquisition and interpretation of spatial data at multiple scales, from sub-field (precision agriculture) to basin. Specific research interests include development and application of soil and crop sensors, measurement and interpretation of soil and crop spatial variability, and development and evaluation of management systems for economic and environmental sustainability, specifically variable-rate nitrogen application and precision conservation. This research is documented in 100 peer reviewed and ~ 180 other publications (excluding abstracts). His professional recognitions include being named Fellow in the American Society of Agricultural and Biological Engineers (ASABE), appointment as Division Editor for the ASABE journals, and designation as an Honorary Scientist by the Rural Development Administration of the Republic of Korea.

**Bob Kremer**, Research Microbiologist, has conducted research in soil quality, plant-microorganism interactions, biological control of weeds, and ecological impacts of transgenic crops. His research has been documented in 115 peer-reviewed and 60 other publications (excluding abstracts) including 1 co-authored textbook. He currently leads in soil quality assessments within the crop management CRIS and CEAP projects. He has also served on the Science Advisory Panel of U.S. EPA evaluating assessment protocols of transgenic crops with plant-incorporated proteins. A significant research output is documentation of the relationship of rhizobacterial characterization with soil quality assessment. He is acknowledged in professional societies as recipient of the Distinguished Research Award from the North Central Weed Science Society, and being named as Fellow in the American Society of Agronomy and the Weed Science Society of America.

**Earl Vories**, Research Agricultural Engineer, conducts research on irrigation system management in sub-humid climates. Specific research interests include improving estimates of crop water requirements, site-specific irrigation technology, using automation to conserve water in surface irrigation management, water quality impacts of irrigation and irrigated agriculture, and development and evaluation of management systems for economic and environmental sustainability. This research is documented in >200 technical publications (abstracts excluded), including 50 peer-reviewed journal articles and bulletins and a book chapter. He is a member of several technical committees within the American Society of Agricultural and Biological Engineers (ASABE) and the Environmental and Water Resources Institute (EWRI) of the American Society of Civil Engineers (ASCE).

**Claire Baffaut,** Research Hydrologist. Research interests include all aspects of watershed management planning: modeling of hydrological processes under current and future climate scenarios, model calibration and validation, simulation of management practices, and scale effects. Current work includes research on critical areas identification, hydrological process simulation on claypan soils, eco-system services provided by grain and bioenergy cropping systems and targeting of cropping systems and management practices within watersheds and fields. The research is documented in more than 70 publications including 26 peer-reviewed papers (excluding abstracts). She is an active member of the Soil and Water Assessment Tool (SWAT) development team and the ASABE model calibration and validation standard development committee. Her professional recognition led to a three year appointment on the SWCS annual meeting program committee and her appointment as associate editor for ASABE journals.

**The level of process-based understanding** is documented by three examples in which understanding of processes enabled actions that have broader impact. In the first, Claire Baffaut noticed difficulties with SWAT simulations properly apportioning flow into surface runoff, interflow, and deep percolation. The geophysical context with the argillic horizon means that interflow is relatively larger compared with deep percolation, and this anomaly was difficult to explain in SWAT simulations. In studying the issue, she isolated an error in the algorithm and has forwarded to the SWAT team to incorporate in later releases. A second example was the precision agriculture project acting on spatial variation data for Field 1 in GCEW. After sufficient data were obtained, they gathered a team of producers, service providers, and researchers to rank priorities for sustainable production in the field and propose a precision agricultural system to optimize across the multiple objectives. That system was put in place on Field 1 in 2004, and the data await the completion of the current field crop rotation cycle to analyze the accumulated environmental and economic benefits of this proposed best management practice. In the third example, cooperative research indicated that the eroded sideslope areas of the landscape had not only suffered the most erosion, but that the processes were still active, meaning that these areas contributed disproportionately to the runoff, erosion, and off-site transport of both pesticides and nutrients. Further research had shown that establishing perennial grasses on the areas improved hydraulic conductivity in addition to the expected benefits to erosion prevention. From that knowledge, plus the economic information from the precision agriculture studies, the group proposed sideslope buffers as a combined-benefit BMP to eliminate economic loss from row-crop operations on unproductive areas, essentially eliminate those areas as sources of nutrients and pesticides, substantially reduce erosion, and remediate the degraded soils. Further, through collateral research on the Soil Productivity Assessment for Renewable Energy and Conservation (SPARC) project, it appears that the perennials are much less dependent on topsoil depth than row-crops, increasing hopes that biofuel feedstock production on these areas could actually provide an economic return if cellulosic feedstocks develop a regional market. Thus, the process-level understanding of the entire soil/climate/cropping system enabled a proposed BMP , which is now being evaluated on the GCEW research plot area. These examples document not only process level understanding, they show how the staff and cooperators have used this knowledge to develop solutions.

2) **Infrastructure Capacity**—*the presence of an instrumented watershed or other long-term research facility (e.g., experimental range) of sufficient size to capture landscape-scale processes, heterogeneity, and to integrate across small plot, watershed, and landscape scales; the availability of land to support crop and/or livestock production; and critical infrastructure (e.g., field and analytical laboratory facilities; storage capacity; IT support; housing for visiting researchers);*

The core research infrastructure is the 72 $km^2$ GCEW, located approximately 50 km NNE of the laboratories in Columbia MO. This watershed represents surface-runoff-prone soils found in several Midwest and central states (IL, MO, IA, NE, and KS), and is likely the most runoff-prone watershed in the ARS portfolio. The common soil characteristic is a high-clay layer that restricts water flow and contributes to high surface runoff. Data have been collected in GCEW since 1969 in a rain gauge network and starting in 1971 on streamflow and sediment load at 12, 28, and 72 $km^2$ scales. In 1991, water quality measurements were added at those and smaller scales for surface water and a number of groundwater well nests. The smallest scale was 0.34 ha, at which 3 replicates of 10 plots were established down a gentle landscape slope, representing summit, side, and footslope positions. The plot site has been used to simultaneously evaluate both grain production and soil and water quality of management systems. Various crop management systems that include corn, soybean, wheat, and cover crops with conventional, minimum, or no-tillage practices have been maintained continuously for two decades. Recently, switchgrass and willow bioenergy crops have been adapted into some of the crop management treatments, both for biofuel feedstock production and for environmental benefits. The next scale was whole fields, ranging from 12 to 35 ha, at the outlets of which were sited 3:1 broadcrested V-notch weirs with autosamplers. An automated weather station was added in 1993. In 2004, 12 additional larger-scale basins (200 to 1200 $km^2$) were instrumented, eight of these co-located with USGS flow sites. Since 2010, 6 of the 12 have been retained to provide a combination nested and parallel design from 12 to 750 $km^2$.

Field support infrastructure includes a 2,000 sqft building at the plot and 35-ha field site that includes equipment storage and some shop capabilities. Support buildings in the vicinity of the Columbia offices and laboratories include well-outfitted machine, equipment, and wood shops in a 4,000 sqft field research building (built in 2003), and 6,000 sqft of equipment storage joined to 6,000 sqft of soil and hydrology laboratory space, conditioned storage and walk-in cold storage (built in 2010). A full suite of field equipment is available for agricultural and research operations and transport to the plot and field and on-farm cooperators' sites. The unit maintains a fleet of mixed type vehicles, including road vehicles and both light- and heavy-duty trucks.

Laboratory facilities at the Columbia offices include a water quality laboratory with flow injection analysis, GC-MS, HPLC, flow through (coupled to HPLC) and bench top scintillation counters, and other capabilities to measure dissolved and total nutrients, sediment, and a broad range of pesticides, with emphasis on herbicides. Analytical methods employed meet EPA standards for known compounds, and the staff have developed methods for pesticide metabolites and degradates that previously had none. Laboratory quality assurance includes calibration standards, lab and field blanks, and lab and field spikes that are routinely used to confirm data quality. Modern electronic lab facilities enable fabrication, calibration, and interfacing of instruments to dataloggers and computers. Adjacent to these facilities is a university cooperator's lab with facilities for soil hydraulic property measurements. Nearby is the microbiological laboratory, which provides bacterial enumeration, DNA extraction and storage, a BIOLOG system, and necessary instruments for PCR and DGGE work in detection and characterization of waterborne pathogens and soil microbial ecology. Also available are a carbon-nitrogen analyzer and chromatography systems including a GC-MS configured for greenhouse gas analysis. Numerous other university facilities are available for cooperative research.

Extensive data analysis, computation, GIS, and database infrastructure is available for staff and cooperators. Data storage is backed up daily to a multi-TB RAID array locally with off-site backup as well. Internet communication to the desktop PCs is at 1-GB speeds or greater. Smaller shared storage needs are met with secure server drives; larger, more structured database needs are served by an Oracle database server. Public access to hydrologic data is through the ARS STEWARDS database system.

Staff IT expertise includes 3 IT Specialists and substantial expertise in IT by several technicians, a Cat 3 Ag Engineer, and three Cat 1 scientists. Knowledge encompasses platforms, programming and database languages, and several widely used models. Platforms include standard PC hardware, operating system, security, and the usual suite of applications. Expertise exists in FORTRAN, SAS, Delphi, Visual Basic, C++ and some other programming languages. General database expertise exists in Access, Oracle, dBase and SAS. Spatial data analysis capabilities include GIS (ESRI), CAD, and image analysis (ESRI and ERDAS) software packages. Staff have experience with specialty analysis software as well, including the Stuttgart Neural Network Simulator, and for large hyperspectral datasets, Unscrambler and ParLeS. Staff have written software for a number of data acquisition and/or control applications (e.g. real-time variable-rate N application of based upon canopy and position sensors). They are familiar with most common sampler and datalogger interfacing packages, and have developed specialized acquisition software to collect data from analog, digital, serial and CANbus sensor types. Staff developed and publicly distributed software packages “Yield Editor v.2” and “Management Zone Analyst” available for download from our web site. Modeling experience includes acknowledged expertise both in use and development of the basin- and field-scale hydrologic models SWAT and the Agricultural Policy Environmental Extender (APEX). It is difficult to envision a shortfall in IT capabilities, but if it should happen, the university computer science faculty are available as resources.

Surrounding the GCEW are numerous collateral facilities for cooperative research. Research from these provides substantial data that have been critical for understanding the processes active in transport within and out of the GCEW. These include small watershed agroforestry infrastructure at the MU Horticulture and Agroforestry Research Center (HARC) in New Franklin, the Agroforestry small watershed plots at Novelty, the SPARC biofuel feedstock production plots at MU’s South Farm and a Vegetative Buffer study at MU’s Bradford Farm, both near Columbia, and the Tucker Prairie research site east of Columbia. At many of these sites, controlled studies are possible at smaller or intermediate scales. The Tucker Prairie research site is untilled, and represents the original landscape to contrast the cumulative effects of agricultural operations for the 100-150 years they have occurred. Distributed across the entire state is the MU weather station network, providing internet-accessible data comparable to the GCEW weather station at 29 sites in 20 counties, 10 of which are within 100 km of the GCEW or surrounding sampling stations.

There are no ARS housing facilities for visiting scientists. However, Columbia has more than 3700 rooms in 38 hotels, some of which provide lower-cost extended stay possibilities, so that housing is not an issue.

3) **Data Richness**—*the length, breadth, depth, and overall quality of the existing data record;*

GCEW data for rainfall and streamflow at three scales extend 40+ years, with extensive water quality data spanning the latter half of the period of record. The Conservation Effect Assessment Project (CEAP) added 12 additional larger scale watershed sampling sites for streamflow and water quality during the 2005-2011 period, with about half of those retained for the foreseeable future. These latter provide a parallel structure with contrasting land use and nested structure with similar land use. Thus, they are critical for scaling up from GCEW’s HUC 12 to HUC 10 and HUC 8 scales. Methods are documented in the STEWARDS format, with methods tables, GIS layer metadata, and watershed descriptions. A dataset documentation series is being written. The table of contents is appended to this application for scope, and the preface and overview papers are available if needed. Extensive retrospective QA has been done, and the certainty of the measurements is known and documented in the metadata.

The GCEW database totals 53MB of space, including ~2.9M breakpoint streamflow records, ~890k breakpoint rainfall records, ~15k daily weather records, and ~149k hourly weather observations. It also includes ~137k analyte concentrations from 16,400 samples. These analytes include nutrients (dissolved ammonia, dissolved nitrate, dissolved phosphate, total N, and total P), pesticides and metabolites (acetochlor, alachlor, atrazine, cyanazine, cyanazine amide, deethylatrazine, deisoatrazine, , hydroxyatrazine, metolachlor, metribuzin), and sediment. A further indication of the scope of the dataset is provided in Table 1 (next page).

4) **Data Availability (Accessibility)**—*the state of organization and accessibility of existing data sets (e.g., data in STEWARDS or some other publically-accessible database);*

Daily flow data, daily and hourly weather data and all concentration data from GCEW and related watersheds are resident in STEWARDS, with commitment to stay current within 2 years of collection. When the dataset documentation series is submitted to the journal, the STEWARDS web presence will be the permanent publically accessible site published in the series, to comply with the journal's requirement that datasets be permanently accessible. Sub-daily flow data and sub-hourly weather data can be obtained upon request by contacting our unit. The STEWARDS website is http://www.nrrig.mwa.ars.usda.gov/stewards/stewards.html for reference.

5) **Geographic Coverage at Various Scales**—*How does the site fit within the overall network, and/or complement other potential network sites in terms of the 10 major US agro-ecosystems (http://www.usda.gov/news/pubs/factbook/002a.pdf), the 21 HUC-2 watersheds comprising the lower 48 US states (http://water.usgs.gov/GIS/huc.html), the 20 NEON Domains (http://www.neoninc.org/domains/overview), etc.? LTAR sites should complement both existing networks and other potential LTAR sites by filling geographic gaps. Where there is geographic overlap, each site should provide unique data (e.g., long-term datasets) or data collection opportunities not possible at other sites (this information will be used to assess network overlap and/or redundancies now as well as existing gaps to be filled later; LTAR sites should be representative of their region, however defined—i.e., LTAR sites would be focal points for research in that region);*

GCEW is considered within the Corn Belt agro-ecosystem, and is part of the Upper Mississippi HUC region 07. Of the five corn belt states and the whole of region 07, the Missouri context is the only area not drained by tiles. Most of both those regions, as well as GCEW and the surrounding instrumented watersheds, are in the NEON domain 6 – Prairie Peninsula. The geographic setting, although not far removed from other instrumented watersheds in Iowa also in NEON domain 6, differs substantially from those, or for that matter, the NEON site chosen to represent domain 6, which is centered on the Konza Prairie site in eastern Kansas. Agriculture near the prairie site is radically different than in the corn belt, which comprises most of domain 6, and while the Iowa watersheds are tile drained, GCEW is not. The presence of the restrictive clay layer also makes GCEW one of the most, if not the most, runoff-prone watershed in the ARS watershed portfolio. The 40-year dataset in GCEW complemented by the flow and water quality datasets from the relatively larger-scale CEAP project represent an important ARS resource representing a region documented to behave uniquely in regards to offsite environmental impacts.

**Table 1--Period of record for main instruments in Goodwater Creek Experimental Watershed and related watersheds**

| Description | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | # sites |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precipitation | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 10-39 |
| Runoff | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W-1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 1 |
| W-9 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | 1 |
| W-11 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | X | 1 |
| CEAP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | x | x | 12, 6 |
| F-1 | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 1 |
| F-2 | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | 1 |
| F-3 | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | 1 |
| Plots (vary per year) | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | | | | | | | | | | X | vary |
| Groundwater elevations | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Piezometers | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | |
| Sample wells | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 111 |
| Temperature/humidity* | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | 1 |
| Pan evaporation | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | 1 |
| Water quality (all) | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 55 |
| Plot yields | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 30 |
| Field yields | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 3, 1 |
| Weather station | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 1 |

*Temperature/humidity was co-located with pan evaporation, which was ended in 2003. The automated weather station installed in 1993 became the official GCEW temperature/humidity record.

6) **Partnerships**—*The strength of existing external partnerships with producers, other stakeholders, local universities, etc., including the potential for education and outreach (responses should be more than a series of lists, and should include descriptions of the various activities--research; education; outreach—as well as their strengths and weaknesses;*

The Cropping Systems and Water Quality Research Unit enjoys an exceptional cooperative research relationship with a number of partners, most notably the University of Missouri College of Agriculture, Food, and Natural Resources (CAFNR). This relationship can be traced to roots dating to the 1920's in USDA-MU cooperative research in erosion control, including the 60-year collaboration in the Midwest Claypan Research site at McCredie that contributed data to the USLE. More-recent cooperation emerged with the 1990 initiation of the Management Systems Evaluation Area (MSEA) project, which involved several MU academic and extension entities: MU Water Quality Extension; Soil, Environmental, and Atmospheric Sciences (SEAS); Agricultural Economics; Rural Sociology; Plant Sciences; Agricultural Systems Management; and Biological Engineering. Other cooperators in that project included NRCS, US EPA, and USGS. The breadth of documented cooperators has expanded since then to also include the MU Center for Agroforestry, The Environmental Resource Coalition (affiliated with Missouri Corn Growers Association), Lincoln University, the University of Nebraska, Iowa State University, Western Kentucky University, the Audrain County Soil and Water Conservation District, the Northeast Missouri RC&D Council, and the MFA Inc. agricultural cooperative. On-farm research has been conducted within GCEW and in the broader region with a number of producers on multiple grants, virtually all in cooperation with university staff.

The depth of cooperation is easily documented by co-authorship on grant proposals, specific cooperative agreements, interagency agreements, and co-authorship of publications resulting from the work. A recent review (Paper #2 of a data documentation series being written in 2011-2012, see table of contents in appendix) of publications from research in GCEW or in nearby areas to answer specific research questions to explain phenomena observed in or to provide beneficial management practices for GCEW showed >65% co-authored with cooperators. A similar proportion of co-authorships exists for research unrelated to the watershed. Many of the papers are with graduate students co-advised by ARS scientists.

In cooperation with other government agencies, scientists have consulted with US EPA on 3 Scientific Advisory panels, twice for the re-registration of atrazine, and have contributed important data toward that topic for both US EPA and USGS. Several of the larger-scale water quality sampling sites are co-located with USGS flow stations. Staff interact with NRCS at national, state, and district levels on the CEAP and Mississippi River Basin Initiative (MRBI – see more details on this ongoing project below) projects, several Conservation Innovation Grants (CIG) in cooperation with MU co-PIs, a Missouri Environmental Quality Incentives Program (EQIP) practice, and evaluations of plant materials with the Plant Materials Center located in Elsberry, MO.

Missouri NRCS and ARS have collaborated to address multiple Mississippi River Basin Initiative issues. Staff worked together to develop a sampling protocol to be used at MRBI edge-of-field monitoring sites, as well as collaborating on the locations of these sites to be used for monitoring in the Salt River watersheds in order to complement stream monitoring efforts in those watersheds. These collaborations have later been the basis for design of MRBI monitoring efforts in other watersheds.

University of Missouri and other cooperators who have expressed support during the development of this LTAR nomination include:

- Water Quality Extension
    - Bob Broz, Extension Assistant Professor

        - Extension Agricultural Engineering
        - Water Quality Program Director
- Soil, Environmental, and Atmospheric Sciences
    - Stephen Anderson, William A. Albrecht Distinguished Professor of Soil Science
        - Environmental Soil Physics
        - Vadose zone hydrology, soil hydraulic properties, X-ray computed tomographic and microtomographic imaging for assessment of pore-scale soil properties and processes
    - Randy Miles, Associate Professor
        - Soil Science
        - Director, Sanborn Field and Duley-Miller Research Plots
        - Director, Missouri Wastewater Small Flow Research and Training Center
    - Keith Goyne, Associate Professor
        - Environmental Soil Chemistry
    - Pat Guinan, Extension Assistant Professor, Climatology
        - Missouri State Climatologist
        - Director, Missouri Climate Center
- Biological Engineering
    - Allen Thompson, Associate Professor
        - Hydrology of submerged flow constructed wetlands
        - Water droplet mechanics and soil erosion mechanics
        - Site Specific Irrigation (VRI) scheduling
        - Switchgrass production for bioenergy
- Department of Forestry
    - Hank Stelzer, Associate Professor
        - Dedicated Woody Biomass Energy Crops
    - Jason Hubbart, Assistant Professor
        - Forest Hydrology, Watershed Management, Water Quality, Environmental Biophysics.
- Center for Agroforestry
    - Shibu Jose, H.E. Garrett Endowed Professor
        - Director, Center for Agroforestry
        - Ecological sustainability, agroforestry
        - Forestry
    - Chung-Ho Lin, Research Assistant Professor
        - Phytoremediation and bioremediation in agroforestry
        - Forestry
    - Ranjith Udawatta, Research Associate Professor
        - Water quality, Agroforestry, Watershed management
        - SEAS
- Lincoln University
    - Fengjing Liu, Hydrologist

Nearly all of the above-listed cooperators have co-authored competitive grant proposals, shared graduate students, and co-authored peer-reviewed journal articles with ARS staff. It is expected that these cooperators would be excellent candidates for the initial steering committee for the LTAR if this application is successful.

*Leveraging GCEW for Cooperative Research*

Our approach in cooperative research has been and would continue to be to leverage our infrastructure to make competitive grant proposals stronger. For illustration, a recent USDA-NIFA Capacity Building Grant entitled, Hydrologic Processes Controlling Stream Water Quality in a Missouri Claypan Watershed, represents a cooperrative effort between ARS and Lincoln University (1890 Land-Grant university in Jefferson City, MO) in which the GCEW infrastructure plays a crucial role. The project funded for $306,000 over three years (2011-2014) will look at the contribution of interflow to atrazine and nitrate transport in GCEW. To scale field experimental data to the watershed scale requires sampling of source waters (e.g., rain water, runoff, groundwater, etc…) that utilize existing sampling infrastructure within GCEW. Unique chemical signatures of the source waters can then be used to de-construct the sources of water to Goodwater Creek to determine if interflow is a significant source of atrazine transport under baseflow conditions. The project PI is Dr. Fengjing Liu, Hydrologist with the Department of Agriculture and Environmental Sciences at Lincoln University. Drs. Lerch and Baffaut are serving as project co-PIs.

7) **Institutional Commitment**—*Is there an institutional commitment to support the continued operation of the site for the next 30-50 years (a letter of support from the appropriate ARS Area Office is strongly recommended)? How well-integrated are the existing CRIS projects and/or research units currently at the site? Are scientists and support staff committed to this effort?*

CSWQRU staff have demonstrated a 40-year commitment to the GCEW, indicating that procedures are in place to sustain a research investment beyond the career of any one scientist, or even the aggregate institutional memory. Current staff are committed to the GCEW, and intellectual capabilities are well-suited to leveraging the long-term dataset toward answering questions regarding agriculture sustainability, climate change, and bioenergy. Two of our current research project plans integrate GCEW infrastructure and leverage existing data and understanding of transport and agronomic processes to investigate new management systems. ARS support for the sustained commitment is also seen in the letter from Midwest Area Director Larry Chandler, attached.

Appendix

Table of contents of data documentation series to be submitted to Water Resources Research by 30 September 2012.

**Data documentation papers**

1. Sadler, E. J., R. N. Lerch, N. R. Kitchen, S.H. Anderson, C. Baffaut, K. A. Sudduth, R. J. Kremer, and E. D. Vories. Long-term Agricultural Research at Goodwater Creek Experimental Watershed, Missouri, USA - Preface.
2. Sadler, E. J., R. N. Lerch, N. R. Kitchen, S.H. Anderson, C. Baffaut, K. A. Sudduth, A. A. Prato, R. J. Kremer, and E. D. Vories. Long-term Agricultural Research at Goodwater Creek Experimental Watershed, Missouri, USA - GCEW establishment, history, and overview.
3. Myers, D.B., F. Young, and R.J. Miles. Long-term Agricultural Research at Goodwater Creek Experimental Watershed, Missouri, USA - Physiographic Context and Genesis of the Landscape.
4. Kitchen, N.R., D.B. Myers, and S.H. Anderson. Long-term agricultural research in Goodwater Creek Experimental Watershed, Missouri USA: Regional anthropogenic impact and activity to modern times.
5. Sudduth, K.A., E.J. Sadler, C. Baffaut, N. R. Kitchen, D.B. Myers, and E.D. Vories. Long-term Agricultural Research at Goodwater Creek Experimental Watershed, Missouri, USA - GCEW geospatial database.
6. Sadler, E.J., Baffaut, C., Oster, T., and Lerch, R. N. Long-term Agricultural Research at Goodwater Creek Experimental Watershed, Missouri, USA - GCEW time series data structure.
7. Sadler, E. J., K. A. Sudduth, S.T. Drummond, and E.D. Vories. Long-term Agricultural Research at Goodwater Creek Experimental Watershed, Missouri, USA - GCEW weather data.
8. Baffaut, C., E.J. Sadler, and F. Ghidey. Long-term Agricultural Research at Goodwater Creek Experimental Watershed, Missouri, USA - GCEW flow data.
9. Baffaut, C., F. Ghidey, and K.A. Sudduth. Long-term Agricultural Research at Goodwater Creek Experimental Watershed, Missouri, USA - GCEW sediment data.
10. Lerch, R.N., N.R. Kitchen, C. Baffaut, and E.D. Vories. Long-Term Agricultural Research in Goodwater Creek Experimental Watershed, Missouri, USA – GCEW Nutrient Water Quality Data.
11. Lerch, R.N., C. Baffaut, E.J. Sadler, and R.J. Kremer. Long-Term Agricultural Research in Goodwater Creek Experimental Watershed, Missouri, USA – GCEW Herbicide Water Quality Data.
12. Baffaut, C., B.E. Murphy, J.S. Rikoon, S.H. Anderson, and R. Broz. Long-Term Agricultural Research in Goodwater Creek Experimental Watershed, Missouri, USA – Socio-economic Characteristics of Farm Managers.

**Research Papers**

13. Lerch, R.N., N.R. Kitchen, E.J. Sadler, and E.E. Alberts. Dissolved Nitrogen and Phosphorus Losses in Surface Runoff from the Corn Phase of Three Cropping Systems.
14. Baffaut, C., F. Ghidey, N.L. Lerch, E.E. Alberts, and N.R. Kitchen. Nutrient losses in surface runoff: from plot to field scales.
15. Lerch, R.N., C. Baffaut, N.R. Kitchen, and E.J. Sadler. Dissolved Nitrogen and Phosphorus transport in a High Runoff Potential Watershed.
16. Kitchen, N.R., Lerch, R.N., and Blanchard, P.E. Nitrate levels and hydrogeologic controls in loess and fractured glacial till.
17. Sudduth, K.A., Jang, G., Lerch, R.N., Sadler, E.J. Hyperspectral Remote Sensing Estimates of Reservoir Water Quality in Northeast Missouri, USA.
18. Baffaut, C., F. Ghidey, E.J. Sadler, and S.H. Anderson. SWAT Simulation of Flow and Water Quality in the Goodwater Creek Experimental Watershed.
19. Baffaut, C., F. Ghidey, and E.J. Sadler. Scale Effects on SWAT Model Parameterization for Flow and Water Quality in Nested Watersheds in Northeast Missouri.

United States Department of Agriculture
Research, Education and Economics
Agricultural Research Service

November 14, 2011

SUBJECT: Long-Term Agro-ecosystem Research (LTAR) Network
Cropping Systems and Water Quality Research Unit

TO: Steven R. Shafer, Deputy Administrator
Natural Resources and Sustainable Agricultural Systems

Mark Walbridge, National Program Leader
Natural Resources and Sustainable Agricultural Systems

FROM: Laurence D. Chandler, Director /s/ 11/14/11

The USDA-ARS Cropping Systems and Water Quality Research Unit (CSWQRU) has expressed an interest in formally affiliating with the ARS Long-Term Agro-Ecosystem Research (LTAR) Network. The Midwest Area Office supports their application to be a part of this new opportunity and feels that the CSWQRU could play an important role in the overall success of the LTAR efforts.

The CSWQRU has been integrally involved in research at the Goodwater Creek Experimental Watershed (GCEW) in the Salt River basin of northeastern Missouri for approximately 40 years. Over that time CSWQRU management and scientists have committed both time and resources that have resulted in development of an expansive database related to hydrology, water quality, soil resource variability, and economic/sociological information. The existing staff of 7 research scientists and related technical support staff have an excellent record of productivity and conduct of science and we expect this productivity to continue into the future. The scientific staff has developed excellent scientific collaborations outside of the management unit and also has gained substantial stakeholder interest and support of their research activities. We expect these partnerships to be maintained, if not enhanced, over the coming years.

The GCEW is approximated 72 $km^2$ size which provides an excellent site for comprehensive watershed research. The CSWQRU has invested substantial amounts of funds to maintain a robust infrastructure needed to support their program efforts. The watershed is well instrumented and investments for needed upgrades are made as funds allow. The unit also has excellent laboratory and office space, a robust IT infrastructure, and access to numerous analytical tools due to their location on the campus of the University of Missouri.

Although no one can guarantee that the CSWQRU and the associated work at GCEW will be around for the next 40 years, it is obvious that they are well positioned to maintain their current program, continue to conduct high quality research and collect important data needed to support the LTAR endeavor. Long term funding guarantees will remain an issue, but if current funding remains somewhat predictable over the coming years the CSWQRU should continue to be a viable research entity in landscape scale research efforts. I strongly support inclusion of the CSWQRU in the LTAR Network.