Big Creek Research and Extension Team
University of Arkansas System Division of Agriculture

MONITORING THE SUSTAINABLE MANAGEMENT OF NUTRIENTS ON C&H FARM IN BIG CREEK WATERSHED

FINAL REPORT

BIG CREEK FINAL REPORT: OUTLINE

EXECUTIVE SUMMARY

The main results, conclusions, and interpretations of the Big Creek Research and Extension Team's monitoring of the impact of the C&H Farm's operation on soil and water resources of the Big Creek Watershed, within the Buffalo River Watershed, are summarized below. Monitoring started in September 2013 and finished July 2019 and focused on five main outcomes: the impact of slurry and field management on soil fertility; the slurry and field management on nutrient runoff; trends in the quality of water in well, interceptor trench, and ephemeral stream water; nutrient loads in Big Creek as a function of time, flow regime, and location; and trends in nutrient and bacteria concentrations up and downstream of the C&H Farm.

1. **SOILS AND LAND MANAGEMENT:** Soil survey and ground penetrating radar (GPR; conducted by NRCS) of Fields 1, 5a, and 12 showed soils varied in depth across and among fields. Field 1 had an overlying layer of soil that varied from zero (rock outcrops) to 50 cm (20 inches). Fields 5a and 12 adjacent to Big Creek had soils varying in depth from 80 to 150 cm deep (30 to 60 inches). The deeper soil profiles for Fields 5a and 12 were adjacent to Big Creek, with the thinner soils at a higher elevation on the side of a hill, on the field further from the Creek. This is typical of periodic flooding of Big Creek depositing alluvial material adjacent to the stream bank over the last century following land settlement creating thicker soils at lower elevations with soils thinning as you move away from flood plains and terraces and onto hillsides.
2. The nutrient distribution in soils of three fields (Fields 1, 5a, and 12) was determined by repeating soil sampling on a 0.25-acre grid in 2014, 2016, and 2018. Using GPS to locate the initial soil sample locations in 2014, subsequent sampling in 2016 and 2018 was made at the same point (with +/-1-m accuracy). Slurry was not applied to Field 5a, thus, data from this field provided a reference point for normal pasture management in the region.
3. On a whole-field basis (mathematical average of all grid samples) at the 0 to 4 inch depth, there was a statistically significant increase (at 0.05 level of probability) in Mehlich-3 P (59 – 91 mg/kg) for Field 1 between 2014 and 2018. For Field 5a, there was little change in Mehlich-3 P from 2014 to 2018 (45 – 47 mg/kg). Mehlich-3 P for Field 12 increased two-fold between 2014 and 2018 (63 to 122 mg/kg).
4. An accelerated accumulation of P occurred in Field 12 adjacent to the gate where cattle are consistently fed and thus, loaf, with levels as high as 275 mg/kg in the 0 to 4 inch depth. However, it should be noted that the accumulation of Mehlich-3 P in Field 12 was evident in the 2014 grid-soil sampling, conducted prior to the first application of swine slurry to Field 12.
5. Findings from the 2014 to 2018 grid-soil sampling reinforce the current nutrient management understanding, that the continued, long-term application of P (as fertilizer or manure) in amounts greater than pasture offtake (removal in cut hay), result in an accumulation of P at the soil surface and thus, potential for runoff. Where the accumulation rate, is largely determined by the magnitude of the P application above P removal. Increases in soil test P will eventually elevate the P-Index risk value to high and further limit P additions as fertilizer or manure in future iterations of nutrient management planning.

6. Future additions of any nutrients (i.e., as mineral fertilizer, swine slurry, or poultry litter) to fields, which received slurry from C&H Farms, should be carefully managed, so as not to lead further increases in soil test P. This can be achieved by application of nitrogen (N) fertilizer or slurry and poultry litter at P-based rates, where P applied is equivalent to expected forage uptake of P.
7. **MANURE MANAGEMENT AND NUTRIENT RUNOFF**: The annual loss of P and N in surface runoff from Field 1 for the five years of monitoring, averaged 0.8% and 1.8%, respectively, of that applied in slurry; for Field 12 losses were 2.2% and 4.5% of applied slurry P and N. For Field 5a, loss of P and N was an average 6.6 and 4.4%, respectively, of that applied annually in mineral fertilizer. The runoff collection station for Field 1 was located at the base of a hill. The existing nutrient management plan for this field restricted slurry application to the flat hilltop only and slurry was not directly applied to the slope. Effectively, the slope served as a vegetated buffer.
8. The greater nutrient runoff from Fields 5a and 12 and proportion of that applied in slurry or mineral fertilizer was dominated by major storm events in 2015, which resulted in more than twice the volume of runoff in 2015 (5.4 and 0.9 million gallons) than the other four years combined (1.3 and 0.4 million gallons). Additionally, Fields 5a and 12 are adjacent to Big Creek, which breached its banks and flooded these fields in May and December 2015. The higher percentage of nutrient loss from Field 5a relative to Field 12 may have been a combination of commercial mineral fertilizer P being more soluble than that in slurry and differences in surface hydrology. As these are permanent pastures, commercial fertilizer may settle at the soil surface and be unincorporated within the soil itself until rainfall occurs, while infiltration of slurry may help to rapidly incorporate the soluble portions of P into the soil.
9. Grazing, slurry, and fertilizer management of Fields 1, 5a, and 12 over the 5 years of monitoring, may have resulted in an increase in the potential loss of P and N to Big Creek. However, baseline data of P and N loss in runoff were not available for these fields prior to slurry application. Accurate historical nutrient management and nutrient applications were not available or were previous application rates known before the study.
10. **TRENDS IN WATER QUALITY ADJACENT TO C&H PRODUCTION FACILITY**: There was a statistically significant (probability <0.0001) increase in nitrate-N concentrations in ephemeral stream (annual mean of 0.760 to 1.152 mg/L for 2014 and 2019) and well samples (annual mean of 0.474 and 0.799 mg/L for 2014 and 2019) over the monitoring period (April 2014 to June 2019), as determined by the Seasonal Kendall's test for trends in nutrient concentrations, at sites adjacent to the swine production facility and holding ponds.
11. In contrast, chloride and electrical conductivity did not exhibit any statistically significant change over the monitoring period in well, ephemeral stream, and trench samples (April 2015 to June 2019), which suggests elevated nitrate-N concentrations in well and ephemeral stream samples may be influenced by sources other than the holding ponds (i.e., sources that have low chloride and electrical conductivity values).
12. Flow in the interceptor trenches (T1 and T2) was highly responsive to rainfall, indicating the trenches were mainly capturing shallow subsurface flows initiated by rainfall, indicating little to no mixing or contact with liquids in holding ponds.

13. **NUTRIENT LOADS**: The two largest storms occurring during each of the 5-year monitoring accounted for 44, 49, 37, and 42% of the total 5-year load of dissolved P, total P, nitrate-N, and total N, respectively, and 43% of discharge measured at BC7. Conservation measures that minimize the potential for loss during large storm events will need to focus on nutrient (i.e., rate, timing, source, and method of application) rather than transport management (i.e., runoff and erosion control).
14. **TRENDS IN WATER QUALITY IN BIG CREEK UPSTREAM AND DOWNSTREAM OF C&H**: Phosphorus and N concentrations in Big Creek were greater downstream than upstream of the C&H Farm. For example, the 5-year mean nitrate-N concentration was 0.13 mg/L at the upstream site and 0.29 mg/L at the downstream site. This difference was greater at low base flow conditions in Big Creek.
15. The was no consistent increase or decrease in P, N, and E. coli analyte concentrations between September 1 and December 31, 2013 when no slurry had been land applied, compared to the same four-month period for years following land application.
16. Use of WRTDS to estimate flow- adjusted concentrations of nutrients and E. coli over five water years (i.e., May 1, 2014 to April 30, 2019), removed the effect of inter- and intra-annual stream flow variability. This provided a more reliable representation of the effects of changes in source inputs, land use, and watershed response to management.
17. Based on WRTDS analysis, flow-adjusted N concentration increased slightly upstream and downstream (R^2 of 0.022 and 0.015 for 210 and 243 observations, respectively, not significant at 0.05 level of probability) of the C&H Farm between 2014 and 2019. In contrast, dissolved P (R^2 of 0.035 and 0.043, not significant at 0.05 level of probability) and total P concentrations decreased (R^2 of 0.170 and 0.154).
18. Differences in nitrate-N concentrations between down and upstream sites were strongly influenced by stream flow, where the difference (i.e., downstream was greater than upstream) is very large at low flow and small at high flow. This suggests that at low flows, base flow nitrate-N emerges into Big Creek between upstream and downstream sites and that this base flow has a higher nitrate-N concentration than in base flow above the upstream site. However, at high flows it appears that water entering Big Creek from both the subwatershed above the upstream site and the intervening subwatershed between the downstream site, is similar.
19. Despite higher nitrate-N concentrations at the down than upstream site on Big Creek, the relationship between upstream and downstream concentrations is unchanged over time, suggesting that over the 5 years of monitoring, the input of nitrate-N into Big Creek between up and downstream sites did not change (i.e., no increase or decrease).
20. **NUTRIENT CONTEXT**: Nutrient concentrations in streams draining the Boston and Ozark Mountains regions were related to the intensity of watershed land use, as represented by land in pasture and urban settings. Concentrations in Big Creek were similar to other watersheds in this region with similar land use, suggesting limited impact of the CAFO on Big Creek at the present time. However, this does not preclude future impacts of agricultural and urban operations in the watershed.

BIG CREEK SCIENCE TEAM

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Field Technicians, The Big Creek Research and Extension Team are supported by several Program Technicians based in Fayetteville and Little Rock.

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Introduction

Nutrient impairment of surface waters continues despite widespread conservation efforts to reduce losses from urban, rural, and agricultural land uses (Scavia et al., 2014). Land use within watersheds influences the quality and quantity of water in streams draining the landscape. As land disturbance increases and use intensifies, an increase in stormwater runoff and nutrient inputs that lead to a greater potential for transport to receiving water is generally observed (Dubrovsky et al., 2010; Rebich et al., 2011). This has led to efforts to identify and quantify nutrient sources within watersheds, strategically target, and apportion nutrient loss reduction (Reckhow et al., 2011).

Numerous factors influence the relationship between land use in a given watershed and nutrient transport downstream from that watershed. With an increase in drainage area percentage in pasture, row crop, and/or urban use, a general trend of increasing nutrient concentrations in storm and base flows will be manifested (Buck et al., 2004; Giovannetti et al., 2013; Haggard et al., 2003; Migliaccio et al., 2007). Thus, nutrient concentrations in streams draining forested lands tend to be less than in watersheds with considerable anthropogenic land use.

For a range of reasons, great interest has been expressed in nutrient concentrations in several streams of the Boston and Ozark Mountains regions of northwest Arkansas, including the Buffalo National River and its tributaries. In particular, Big Creek has been the center of attention within the Buffalo National River Watershed because of a permitted concentrated animal feeding operation (CAFO).

Big Creek was monitored by the Big Creek Research and Extension Team (BCRET), a partnership between the University of Arkansas System's Division of Agriculture and USGS. Water samples were collected upstream and downstream of the swine CAFO on a near weekly basis since September 2013 (Figure 1).

The water samples were analyzed at an Arkansas Department of Environmental Quality certified water quality laboratory. The data collected is publicly available at https://bigcreekresearch.org/.

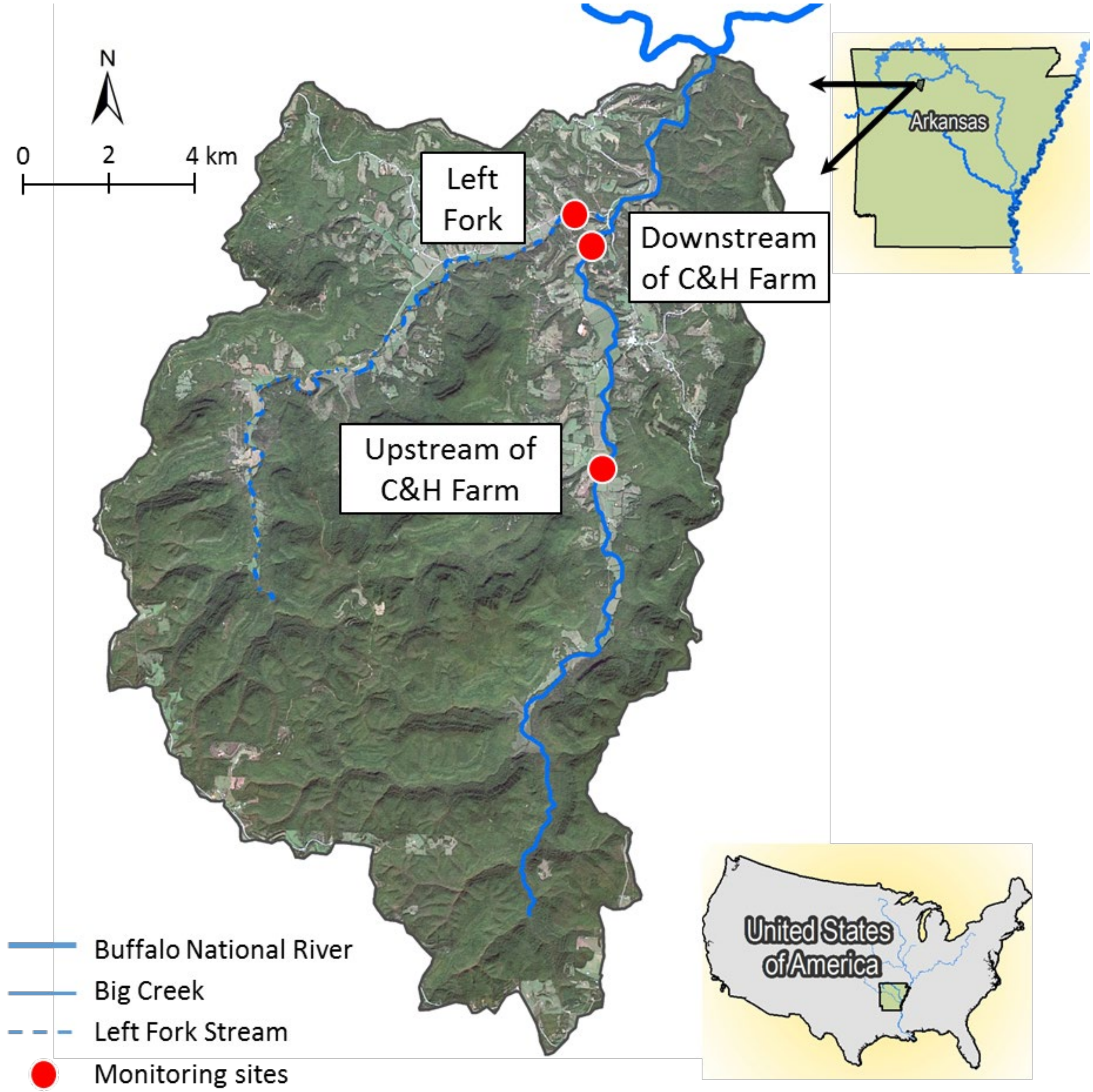

Figure 1. Map of Big Creek Watershed and its location. Watershed image credit: NASA and USGS Landsat 8 Image taken 10-20-2013.

Plan of Work

Summary

1. Collection of water samples for analysis was initiated in September 2013 and continued through June 2019 on a weekly basis for most sites (except when winter storms restricted access to sites and during extended periods of drought) and are included this final report at the following sites:
   a. base flow and periodic stormflow water samples from Big Creek above and below the C&H Farm;
   b. water from a spring (reflecting shallow aquifer flow);
   c. ephemeral stream (reflecting landscape drainage from the area of the holding ponds and operation facilities);
   d. surface runoff from Fields 1, 5a, and 12;
   e. two interceptor trenches below the slurry holding ponds (reflecting subsurface flow below the holding ponds); and
   f. house well (reflecting deeper ground water).
2. Grid-soil sampling (i.e., one-sample per 0.25 acre grid) of Fields 1, 5a, and 12 was conducted between December and February of 2014 prior to slurry application (i.e., Fields 1 and 12), in 2016 and in 2018.
3. Ground penetrating radar was completed in early 2014 on Fields 1, 5a, and 12 by NRCS to investigate below ground features that might accelerate water infiltration and flows. See Appendix C for details.
4. Due to difficulty in maintaining belowground piezometer stations on Fields 5a and 12 watertight, along with restricted access by the landowner to the stations during pasture growth (May through October), limited subsurface water depth information was obtained and thus, not included in this report.
5. Investigation of physical and chemical treatment of slurry from the holding ponds was conducted in 2013 and 2014 to explore potential long-term and economically viable options in order to modify to modify current manure management practices. Neither locally sourced limestone nor purchased slaked lime provided sufficient flocculation of slurry solids and precipitation of phosphorus (P), for on-site treatment of slurry to be an economically viable management option for the farm.
6. Vandalism was not a major problem during the project, except for:
   a. destruction of the sampler unit stand where Dry Creek enters Big Creek (November 2014) and was not replaced (a site recommended by initial Review Panel);
   b. solar panels from two sites were stolen for stream-side stations (October 2017); and
   c. animal carcasses dumped in the ephemeral stream upstream of our sampling unit (November 2017).

Overarching Goals

The overarching goal of the research and monitoring described in this Final Report was to understand if, how, and why stream nutrient concentrations change downstream at Big Creek and whether the permitted swine CAFO, C&H Farms has influenced water quality since extensive monitoring began in September 2013. See Appendix A for Memorandum of Agreement details.

This research and monitoring project evaluated the sustainable management of nutrients from the C&H Farm operation (subsequently referred to as C&H, to include animal facilities and fields permitted to receive land applications of slurry). The study included the following major tasks:

1. Monitor the fate and transport of nutrients and bacteria from land-applied swine effluent to pastures.
2. Assess the impact of farming operations (effluent holding ponds and land-application of effluent) on the quality of critical water features on and surrounding the farm including springs, ephemeral streams, creeks and ground water.
3. Determine the effectiveness and sustainability of alternative manure management techniques, including solid separation, which may enhance transport and export of nutrients out of the watershed.

To address the long-term sustainability of C&H, we grid-soil sampled every two years (2014, 2016 and 2018) to measure soil fertility levels of three fields (i.e., Fields 1, 5a, and 12), which we have a Memorandum of Understanding with landowners to access sampling sites (see Appendix A or details). This combined with nutrient levels in monitored wells will inform manure management decisions and ensure they remain environmentally sustainable. The project will assess the feasibility of manure treatment, which is regarded as addressing nutrient imbalance concerns and has the potential to provide the farm with cost-beneficial alternatives for the sustainable use and export of treated manures.

The plan of research meets the level of funding available. We deferred to Dr. Van Brahana on the use of dye-tracer tests to investigate the presence of possible rapid by-pass flow pathways common in karst-dominated areas. Dr. Brahana is an expert on dye-tracer studies and deferring to him avoided duplicative efforts and saved limited resources, which were used to pay for water sample analysis. A broad pool of expertise from the partner organizations will be brought together for work plan implementation and periodic review.

We believe the monitoring outlined in objectives I and 2 must continue for a minimum of five years, so that reliable conclusions and recommendations of the impact of operation of the C&H Farm on area soils and water quality can be made. This timeframe is recognized by NRCS, EPA, and general scientific community to be the minimum required to accurately assess any impacts and overcome annual weather fluctuations.

Field Evaluation - Land Application Sites

Assess water flow directions and risk of nutrient and bacteria losses from three fields (Fields 1, 5a, and 12) that will be used to land apply manure (Map 1 and Table 1). On each field;

1. Conduct a detailed topographic survey of the application fields to better understand surface water flow patterns and the most appropriate location for surface runoff collection and monitoring wells / piezometer devices.
2. Utilize GIS/GPS and grid soil sampling to develop initial soil nutrient maps for all application fields. Use results to develop strategic soil fertility sampling that will be repeated every two years to track changes in nutrient levels.
3. Conduct inventory of soil physical properties (surface infiltration, subsurface hydraulic conductivity, bulk density, P sorption isotherms, and particle size analysis) of the three application fields.
4. Install bermed surface runoff area (>2 acres) to collect and monitor surface runoff, with weather station.
5. Install two transects of monitoring wells / piezometers across the two stream-side fields (i.e., 5a and 12) to automatically and continuously determine if subsurface water is moving to or away from the adjacent river. Piezometers will be installed so that there is minimal piping or equipment above ground that could interfere or influence with day-to-day farm operations on that field.
6. Collect samples after each rainfall event from the surface runoff areas and monitoring wells, and from monitoring wells at monthly intervals, filter on site, store on ice and ship to the AWRC Laboratory for nitrogen (N), P, pH, sediment, and bacteria (E. coli) analysis for one year.
7. Annually measure soil nutrient fertility on every permitted field of C&H by state approved methods to assess the long-term sustainability of implemented measures.
8. Obtain nutrient application rates from farm records provided annually to the Arkansas Department of Environmental Quality (ADEQ), as part of the permitting requirements.

Water Quality Assessment of Springs, Ephemeral Streams, and Ephemeral Creeks in the Vicinity of the CAFO Production Facility

Measure nutrient, bacteria, and sediment concentrations in: a) an ephemeral stream that drains runoff from around the animal production facility and slurry holding ponds, b) springs connected to land-application fields, and c) Big Creek upstream and downstream of the C&H Farm.

1. Install two observation wells adjacent to the holding ponds and upslope of the holding ponds to determine any potential nutrient seepage.

3. Continuously monitor flow and automatically collect water samples at the road culvert draining the subwatershed containing the animal houses and manure holding ponds.

4. Install a calibrated stream gauge for continuous flow measurement and collect Big Creek water samples on a monthly basis.

5. Deploy sondes at the spring and Big Creek sampling locations to continuously determine dissolved oxygen (DO), excess partial pressure of carbon dioxide ($EpCO_2$), electrical conductivity (EC), and temperature of the water.

Manure Treatment via Solids and Chemical Separation: A Case Study to Evaluate Cost Benefits of Alternative Manure Management Options

Work with the owners of the C&H Farm to explore potential long-term, economically viable, options to modify current manure management practices in the general areas of:

1. Separating manure liquids and solids along with their differential management;
2. Retaining sufficient N to meet crop needs;
3. Exporting excess P off the farm;
4. Mitigating off site odor; and
5. Not exceeding the current economic, labor, and management resources of the farm.

The project will identify management options to meet the above objectives. It is anticipated that the options will include but not be limited to:

1. Mechanical separation of manure solids from liquids with or without chemicals as a precursor for off- farm transport of separated solids; and
2. Selective application of higher P content solids and lower P content liquids to different fields that minimizes any loss of nutrient loss.

For the management options identified, their initial and long-term costs will be estimated and an assessment of their implementation impacts made. Available literature and other information resources will be utilized in this process. However, there will be a need for laboratory and onsite tests/trials. This is especially true when evaluating manure solid-liquid separation and/or chemical use.

Land Use and Soils in the Big Creek Watershed and the Monitored Sub-Watershed

The Buffalo River Watershed is located in north central Arkansas (Figure 4). The location of the Big Creek watershed in the Buffalo River Watershed is depicted in Figure 5. Land use of the watershed drainage area was determined for several segments of the Big Creek Watershed (Table 1). This was accomplished using data from the USDA-NRCS Geospatial Data Gateway for Newton Co., AR http://datagateway.nrcs.usda.gov/; national land cover dataset by State for 2006; cropland data layer by State for 2006; and hydrography data layer for streams and HUC 12 watershed boundaries for 2007 to present. The following drainage areas were delineated; Big Creek (Figure 6), Big Creek upstream of the C&H (Figure 7), downstream of the C&H Farm to the Buffalo River (Figure 8), and the monitored land area encompassing fields permitted to receive manure slurry (Figure 9).

Overall, land use of the area of the monitored watershed encompassing the C&H Farm (18% pasture and 78% forest) was similar to the land area downstream of the C&H Farm to the Buffalo River (17% pasture and 80% forest) (Table 2). Upstream of the C&H Farm there was less pasture (8%) and more forest (90%; Table 2).

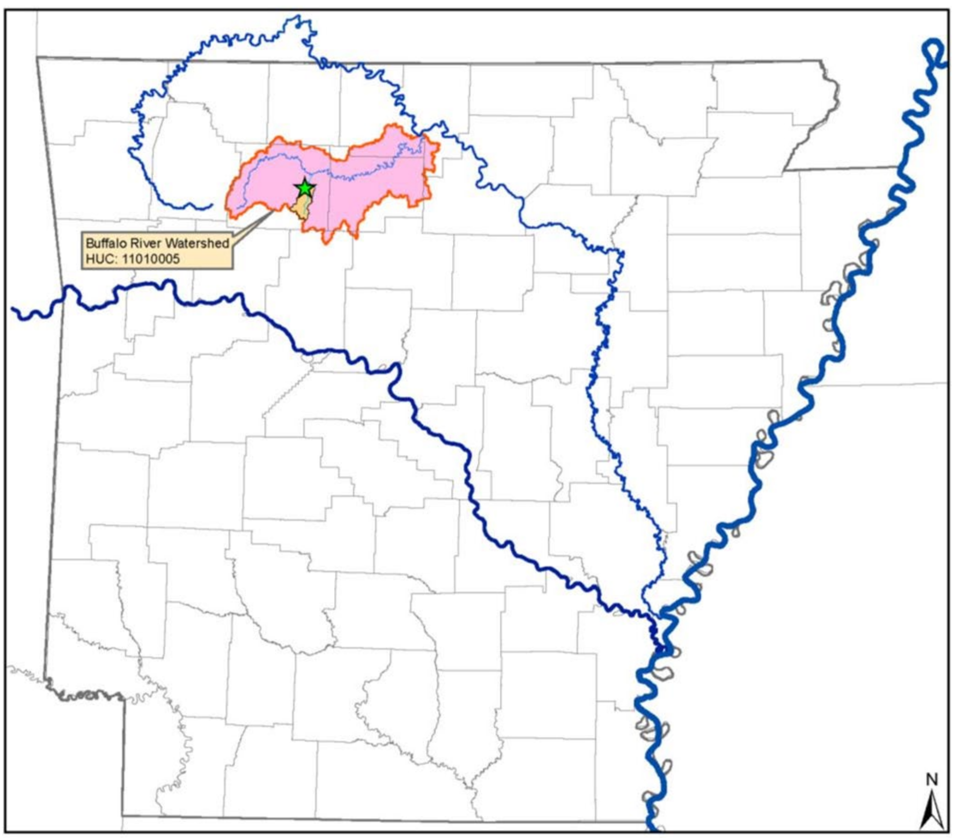

Figure 2. Location of the Buffalo River Watershed in Arkansas

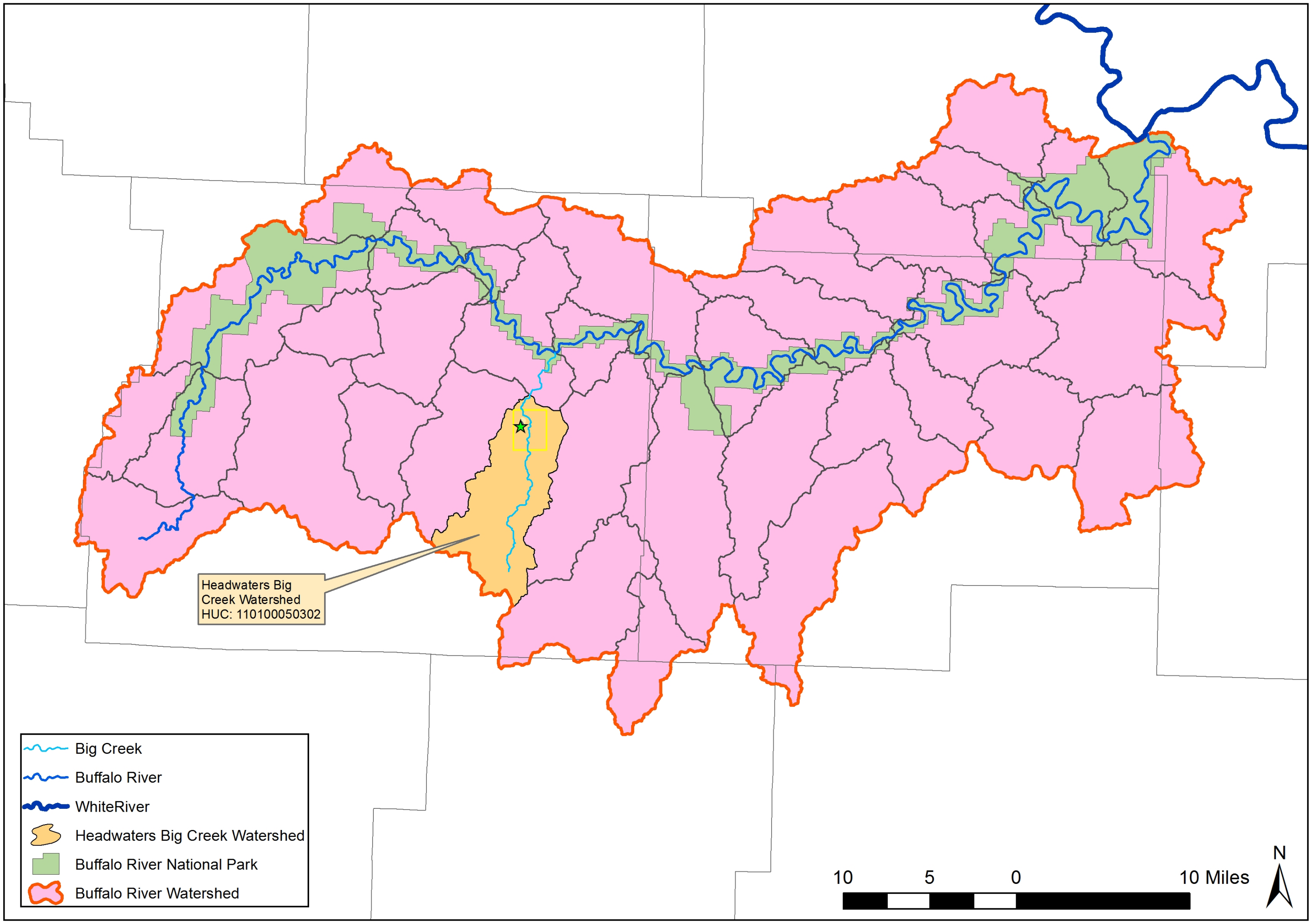

Figure 3. Location of Big Creek Watershed within the Buffalo River Watershed, Arkansas.

Table 1. Land use classification of the monitored watershed, upstream of C&H, downstream of C&H and Big Creek Watersheds. [1]

Land use/Land cover	Big Creek Watershed (Figure 4)		Upstream of C&H (Figure 5)		Downstream of C&H (Figure 6)		Monitored watershed (Figure 7)	
	Area (acres)	% of total area	Area (acres)	% of total area	Area (acres)	% of total area	Area (acres)	% of total area
Grassland/Pasture	8,381	14.4	1,389	8.0	5,431	17.0	1,561	17.8
Deciduous forest	45,977	79.0	15,110	86.5	24,297	75.9	6,570	75.1
Evergreen forest	1,858	3.2	514	2.9	1,094	3.4	250	2.9
Mixed forest	69	0.1	4	0.0	54	0.2	11	0.1
Shrubland	9	0.0	5	0.0	2	0.0	- - [2]	- -
Woody wetlands	2	0.0	0.4	0.0	0.7	0.00	0.7	0.0
Developed/Open space	1,800	3.1	435	2.5	1,038	3.2	327	3.7
Developed/Low intensity	113	0.2	13	0.1	77	0.2	23	0.3
Developed/Medium intensity	6	0.0	0.2	0.0	2	0.0	4	0.1
Developed/High intensity	1	0.0	- -	- -	- -	- -	1	0.1
Open water	1	0.0	- -	- -	0.9	0.0	- -	- -
TOTAL	**58,218**		**17,471**		**31,997**		**8,750**	

[1] Obtained the following data from the USDA:NRCS Geospatial Data Gateway for Newton Co., AR http://datagateway.nrcs.usda.gov/. National land cover dataset by State, 2006. Cropland data layer by State, 2006. Hydrography (streams and HUC 12 watershed boundaries), 2007-present.

[2] None measured.

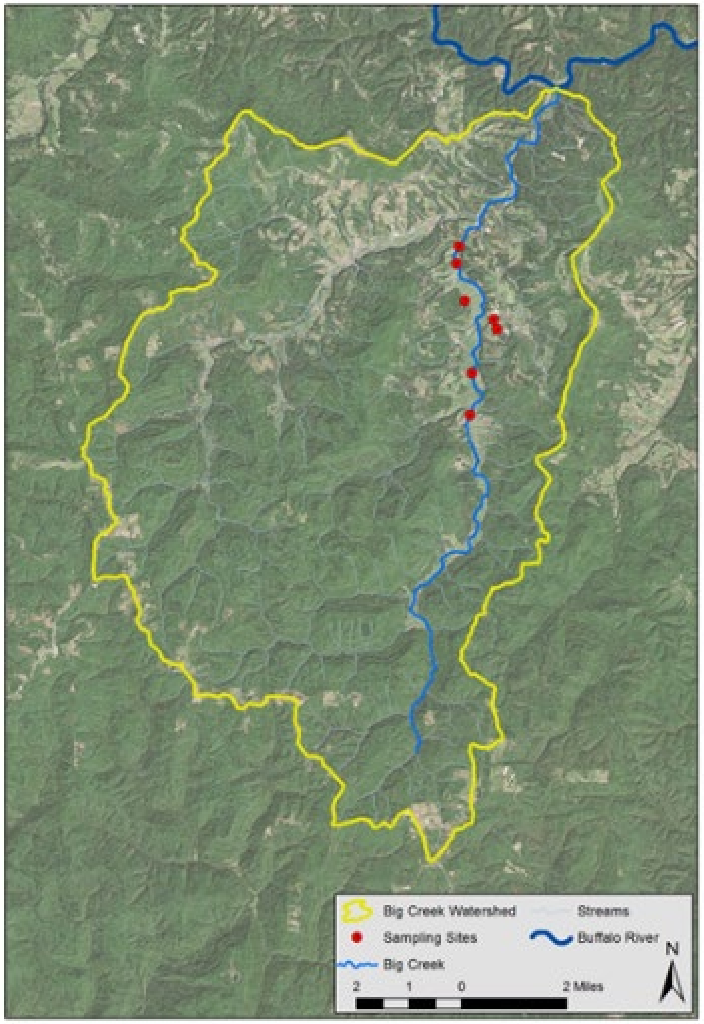

Figure 4. Big Creek Watershed with sampling sites.

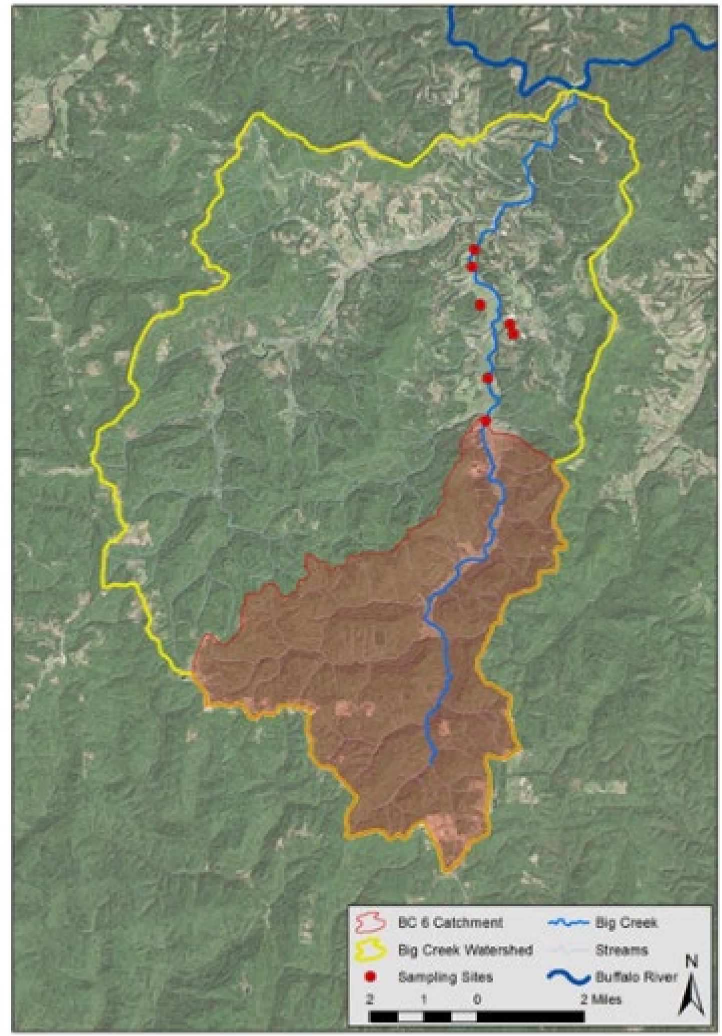

Figure 5. Watershed delineated by the sampling site upstream of the C&H farm.

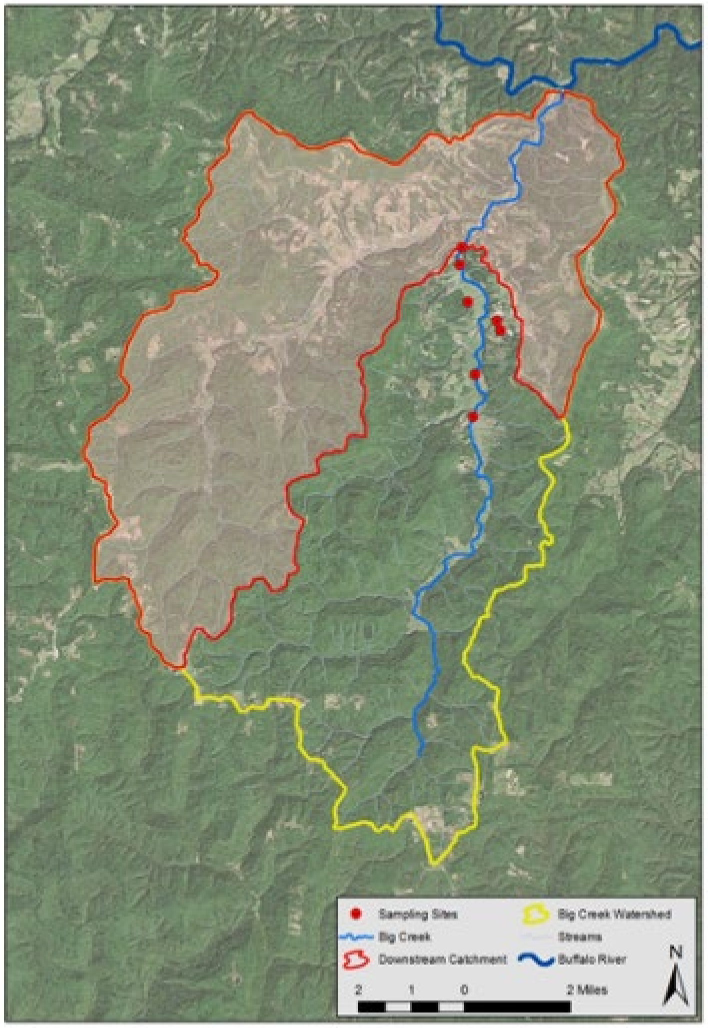

Figure 6. Watershed delineated by the sampling site downstream of the C&H farm to the Buffalo River.

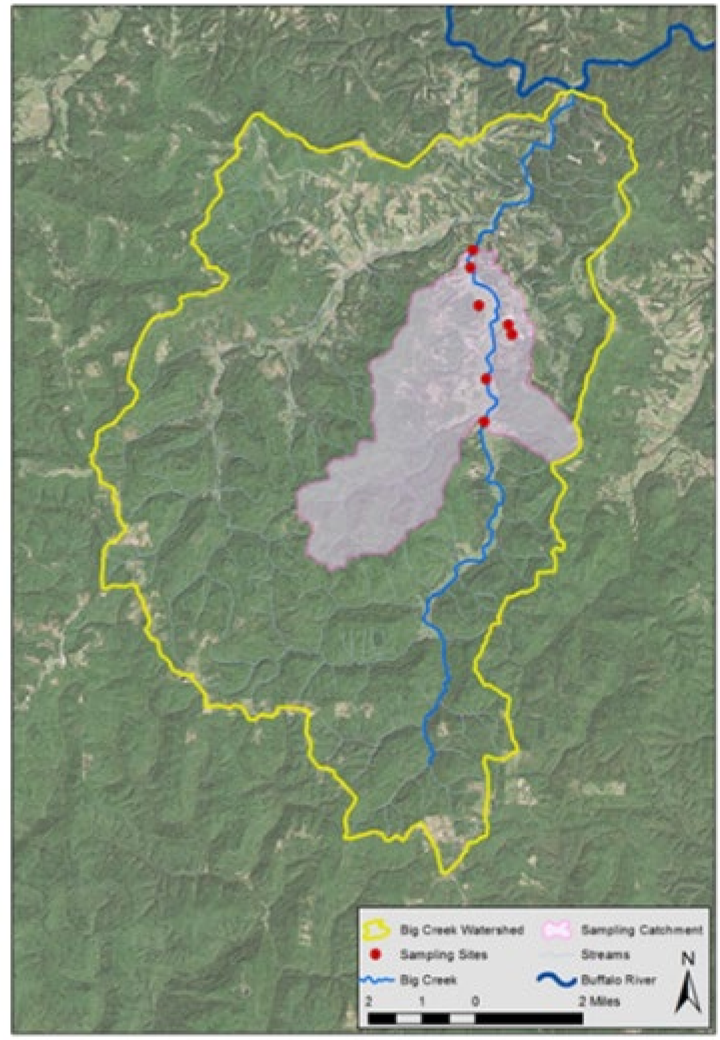

Figure 7. Watershed delineated by sampling sites upstream and downstream of the C&H Farm.

Table 2. Area as pasture, forest and urban for the monitored watershed, upstream of C&H, downstream of C&H and the Big Creek Watersheds.

Land use/Land cover	Big Creek Watershed		Upstream of C&H		Downstream of C&H		Monitored watershed	
	Area (acres)	% of total area	Area (acres)	% of total area	Area (acres)	% of total area	Area (acres)	% of total area
Pasture	8,381	14.4	1,389	8.0	5,431	17.0	1,561	17.8
Forest	47,915	82.3	15,633	89.5	25,448	79.5	6,834	78.1
Urban	1,920	3.3	448	2.6	1,117	3.5	355	4.1
Other	2	0.0	0	0.0	1	0.0	0	0.0

Sampling Locations

Water-quality monitoring sites detailed in Table 3 and Figure 10 are:

Site 1. Edge-of-field monitoring on Field 1 permitted to receive slurry.

Site 2. Edge-of-field monitoring on Field 5a excluded from receiving slurry.

Site 3. Edge-of-field monitoring on Field 12 permitted to receive slurry.

Site 4. Ephemeral stream flow draining a subwatershed containing the production facilities.

Site 5. Spring below Field 1.

Site 6. Big Creek upstream of the C&H Farm operation.

Site 7. Big Creak downstream of the C&H Farm operation.

Site 9. Left Fork downstream of the C&H Farm operation.

Site 10. North interceptor trench below the manure holding ponds.

Site 11. South interceptor trench below the manure holding ponds.

Site 12. House well at animal facility.

Table 3. Location of sampling sites on the Big Creek Research and Extension Team monitoring project.

Site description	Site	Latitude	Longitude	Elevation, ft
Field 1	BC1	35 55’ 06.42”	93 03’ 38.34”	984
Field 5a	BC2	35 56’03.01”	93 04’ 25.85”	778
Field 12	BC3	35 54’ 13.57”	93 04’ 04.76”	838

Site description	Site	Latitude	Longitude	Elevation, ft
Ephemeral stream	BC4	35 55’ 25.89”	93 04’ 14.94”	824
Spring	BC5	35 54’ 57.06”	93 03’ 34.64”	977
Big Creek upstream of farm	BC6	35 53’ 32.28”	93 04’ 06.38”	857
Big Creek downstream of farm	BC7	35 56’ 18.98”	93 04’ 21.81”	769
Left Fork	BC9	35 56’ 48.33”	93 04” 0.92”	760
Trench 1 (south)	T1	35 55’ 19.24”	93 04’ 23.04”	890
Trench 2 (north)	T2	35 55’ 21.39”	93 04’ 19.93”	882
House well	W1	35 55’ 27.02”	93 04’ 22.71”	915
Well water depth		35 55’ 27.02”	93 04’ 22.71”	590
Pond 1 base		35 55’ 20.36”	93 04’ 23.58”	900
Pond 2 base		35 55’ 22.27”	93 04’ 21.61”	892

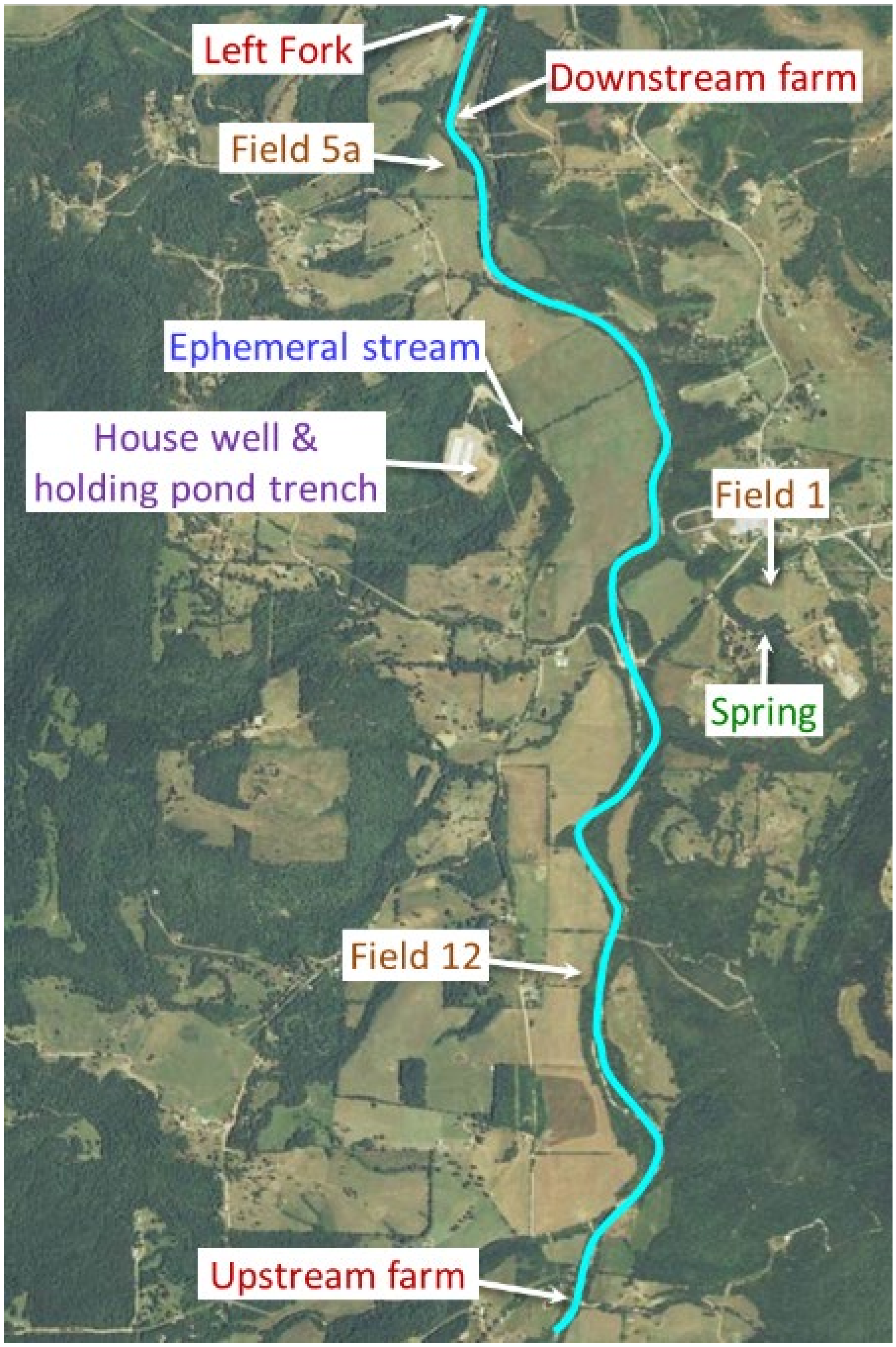

Figure 8. Location of sampling sites for the Big Creek Research and Extension Team project.

Soil Mapping Unit Description from NRCS, Newton Co., AR

For detailed soil survey information of the monitored portion of the Big Creek Watershed, see Appendix B.

Figure 9. Soil type distribution in the vicinity of the C&H Farm operation Mt. Judea, Newton Co., AR. Minor map unit components are excluded from this report.

Methods of Water Flow Measurement, Sample Collection, and Constituent Analysis

Sample Collection

Manual grab sample

The following protocols were used to collect, prepare, and analyze all water samples:

1. One-liter acid-washed bottles are used to collect grab stream samples for analysis.
2. Water is collected from just beneath the surface, where the stream was actively moving and well mixed.
3. The bottle is rinsed with stream water before collecting the sample.
4. Sterilized specimen cups are used to collect samples for bacterial evaluation.
5. Time of collection is noted, and samples placed in a cooler on ice to preserve them until processed and were submitted to the Arkansas Water Resources Center Water Quality Lab on the day of collection for analyses.

ISCO-autosampler collection

ISCO autosamplers collected storm flow samples at up and down stream of the C&H Farm (BC6 and BC7, respectively), ephemeral stream (BC4), Left Fork (BC9), trench (T1 and T2), and edge-of-field runoff sites (BC1, BC5a, and BC12). Each ISCO autosampler is programed to initiate sample collection when a critical stage height is exceeded (Tables 4 and 5). Pacing of sample collection is subsequently programmed to a specific volume of flow, as detailed in Tables 4 and 5.

Water samples during a storm event are composited in a 10 L bottle encased in the ISCO sampler, providing a flow-weighted composite sample for each event. Water collected in the sampler bottle is thoroughly agitated and transferred to a 1-L acid washed bottle. This rinsing process is repeated twice prior to final collection of a 1 L sample. Time of sample collection from the ISCO is noted, and samples placed in a cooler on ice to preserve them until processed. All samples are submitted to the Arkansas Water Resources Center Water Quality Lab on the day of collection for analysis.

Bacteria analysis is not conducted on ISCO collected samples as the tubing and other ISCO components contacting water (except for the acid-washed bottle) could not be isolated and thus, bacterial contamination during ISCO sample collection could not be guaranteed.

Table 4. Parameters used to enable ISCO auto-samplers at BCRET stream sites BC4, BC6, and BC7.

Site	Identifier	ISCO enabled when, over a 30-minute period, stage height (inches) increases	Volume pacing, 100 mL water collected per gallon of water		
			Rainfall, inches		
			<2.5	2.5 to 4	>4
Ephemeral stream	BC4	> 2.0 *	25,000	50,000	100,000
Upstream Big Creek	BC6	1.2	40,000,000	50,000,000	70,000,000
Downstream Big Creek	BC7	1.8	60,000,000	80,000,000	100,000,000

* For ephemeral stream stage height increases >2.0 inches over a 30-min period.

Table 5. Parameters used to enable ISCO auto-samplers at BCRET edge-of-field sites Field 1, 5a, and 12.

Site	Identifier	ISCO enabled when stage height (inches) above	Volume pacing, 100 mL water collected per gallon of water		
			Rainfall, inches		
			<2.5	2.5 to 4	>4
Field 1	BC1	> 0.75	500	1,000	5,000
Field 5a	BC2	> 0.75	5,000	10,000	50,000
Field 12	BC3	> 0.75	500	1,000	5,000

Discharge measurement at gaged sites

The rating curve providing discharge at the downstream site (BC7) is available from USGS via the BCRET website (see https://nwis.waterdata.usgs.gov/ar/nwis/uv/?cb_00065=on&cb_00045=on&cb_00010=on&format=gif_default&period=&begin_date=2014-04-16&end_date=2014-04-23&site_no=07055790) and provided here in Figure 10. USGS has not completed development of a rating curve for the Left Fork site and only concentrations will be given in this report.

Discharge at the ephemeral stream is calculated from water velocity and height of water in the culvert pipe where samples are collected, as measured by the velocity flow meter in the culvert opening and recovered by the ISCO sampler. This data along with diameter of the culver pipe is then used to determine discharge at this site.

Discharge at the edge-of-field sites, BC1, BC5a, and BC12, is calculated from water height in the flume's stilling well with a pressure transducer connected to the ISCO sampler. This recorded data along with dimensions of the 1.5 ft H flume at BC1 and 1.0 ft H flume at BC5a and 12 is used to determine discharge. The H flume at BC1 is larger than BC5a and 12, due to the larger drainage area and greater volume of surface runoff expected at BC1 than at 5a or 12.

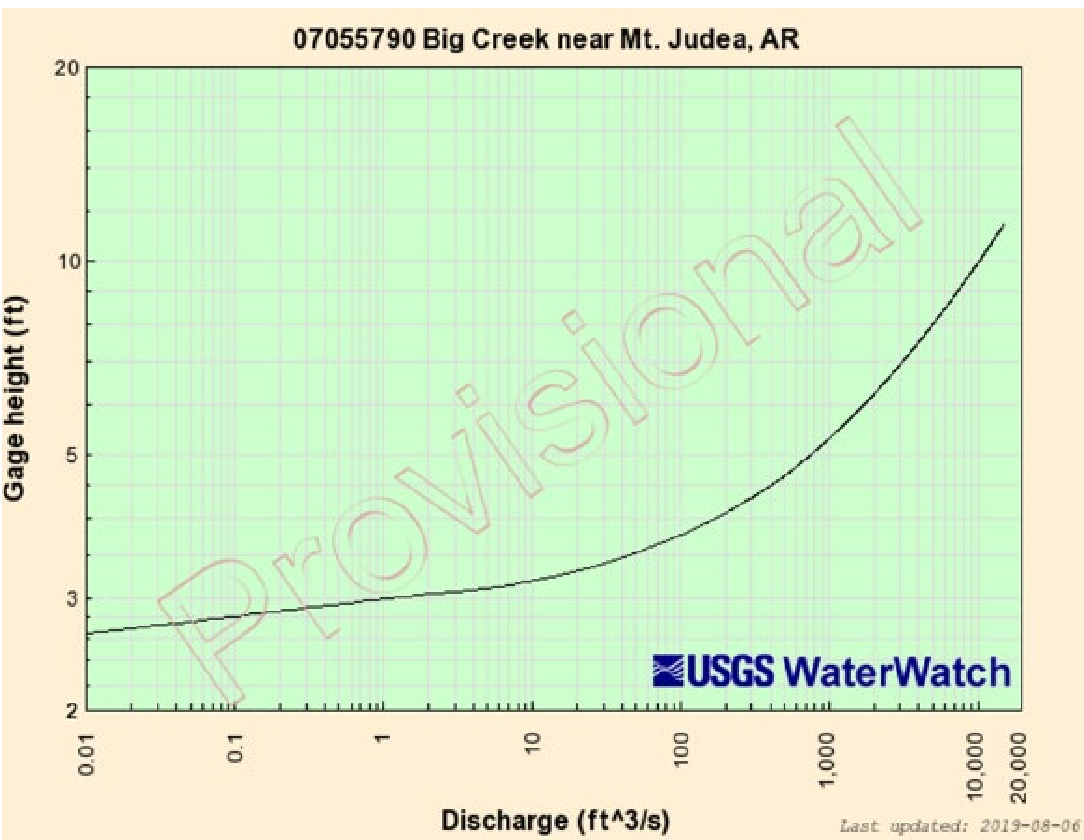

Figure 10. Rating curve developed by USGS for Big Creek downstream of the C&H Farm.

The ISCO area velocity flow module sensors use Doppler technology to directly measure average velocity in the flow stream. A pressure transducer measures liquid depth to determine flow area. The ISCO autosampler then calculates discharge by multiplying the area of the flow stream by its average velocity. For more detail, see https://www.teledyneisco.com/en-us/waterandwastewater/Sampler%20Documents/Datasheets/Isco%20750%20Area%20Velocity%20Flow%20Module%20Datasheet.pdf.

Note USGS states that Stage-discharge relations (ratings) are usually developed from a graphical analysis of numerous discharge measurements. Measurements are made on various schedules and sometimes for different purposes. All discharge measurements are compiled and maintained in a database. Each measurement is carefully made, and undergoes quality assurance review. Some measurements indicate a temporary change in the rating, often due to a change in the streambed (for example, erosion, or deposition) or growth of riparian vegetation. Such changes are called shifts; they may indicate a short- or long-term change in the rating for the gage. In normal usage, the measured shifts (or corrections) are applied mathematically to a defined rating.

Nutrient Load Estimation Using LOADEST

Nutrient loads in Big Creek were determined by the USGS tool LOAD ESTimator (LOADEST), which uses RStudio to estimate constituent loads in streams and rivers (https://water.usgs.gov/software/loadest/; Runkel, 2013; Runkel et al., 2004). LOADEST is based on two previously undocumented software programs known unofficially as LOADEST2 and ESTIMATOR [see Crawford (1996) and Cohn (1988) for relevant details]. Given a time series of streamflow, additional data variables, and constituent concentration, LOADEST assists the user in developing a regression model for the estimation of constituent load (calibration).

The calibration and estimation procedures within LOADEST are based on three statistical estimation methods. The first two methods, Adjusted Maximum Likelihood Estimation (AMLE) and Maximum Likelihood Estimation (MLE), are appropriate when the calibration model errors (residuals) are normally distributed (Runkel et al., 2004). Of the two, AMLE is the method of choice when the calibration data set (time series of streamflow, additional data variables, and concentration) contains censored data. The third method, Least Absolute Deviation (LAD), is an alternative to maximum likelihood estimation when the residuals are not normally distributed. LOADEST output includes diagnostic tests and warnings to assist the user in determining the appropriate estimation method and in interpreting the estimated loads. The LOADEST package tests many different regression models with different combinations of explanatory variables and selects the best model by minimization of the Akaike Information Criterion (AIC) (Runkel et al., 2004).

Explanatory variables within the regression model include various functions of streamflow, decimal time, and additional user-specified data variables. The formulated regression model is then used to estimate loads over a user-specified time interval (estimation) (Runkel et al., 2004). Mean load estimates, standard errors, and 95 percent confidence intervals are developed on a monthly and (or) seasonal basis.

We worked with USGS personnel in Little Rock, AR to develop and implement the R script used at the Carver site (USGS site 07055814 Big Creek at Carver, AR: https://waterdata.usgs.gov/ar/nwis/uv?site_no=07055814) for the BCRET downstream (BC7) site (i.e., USGS site 07055790 Big Creek near Mt. Judea, AR: https://waterdata.usgs.gov/ar/nwis/uv?site_no=07055790).

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The Big Creek Research and Extension Team acknowledge and are extremely grateful to Brian Breaker (formerly U.S. Geological Survey) for advice and help in conducting, analyzing, and interpreting nutrient load estimations for Big Creek using LOADEST and Rscript. His vast experience informed and provided state of the science estimation of constituent loads.

Sample Analysis

1. Analyses included Alkalinity (APHA 2320-B), Chloride (EPA 300.0), Dissolved P (EPA 365.2), E. coli (APHA 9223-B), Electrical Conductivity (EPA 120.1), Nitrate-N (EPA 300.0), pH (EPA 150.1), Total N (APHA 4500-P J), and Total P (APHA 4500-P J) and are listed in Table 6. APHA is American Public Health Association from the Wadeable Streams Assessment, Water Chemistry Laboratory Manual http://www.epa.gov/owow/monitoring/wsa/WRS_lab_manual.pdf

2. Prior to collection of a house-well water sample, the well is purged and water temperature, pH, and electrical conductivity is measured on-site every 30 seconds until all values stabilize. At that point, a sample of water is collected in a 1-L acid-washed bottle. This method is taken from USGS and EPA well water sampling protocols. See USGS methods for sampling at https://water.usgs.gov/owq/FieldManual/chapter4/pdf/Chap4_v2.pdf. Specific and detailed guidance on the collected of water quality data can be found in the USGS National Field Manual at https://water.usgs.gov/owq/FieldManual/.

   The U.S. EPA also recommend that selected water quality parameters can be monitored during low-rate purging, with stabilization of these parameters indicating when the discharge water represents aquifer water or source well water. See: http://www.csus.edu/indiv/h/hornert/Geol_210_Summer_2012/Week%202%20readings/Puls%20and%20Barcelona%201996%20Low%20flow%20sampling.pdf and https://in-situ.com/wp-content/uploads/2015/01/Low-Flow-Groundwater-Sampling-Techniques-Improve-Sample-Quality-and-Reduce-Monitoring-Program-Costs-Case-Study.pdf

3. Minimum detection limits (MDLs) for each chemical and biological constituent are listed in Table 6. Some constituent concentrations were reported by the laboratory as less than the MDL but greater

than zero. Those values are given in subsequent tables but have less confidence in their accuracy than concentrations above the MDL.

Table 6. Minimum detection limits (MDLs) for each chemical and biological constituent.

Constituent	Method of analysis	Minimum detection limit [1]	Reporting limit [2]
Alkalinity, mg/L as $CaCO_3$	APHA 2320-B	2	- -
Chloride, mg/L	EPA 300.0	0.093	0.300
Dissolved P, mg/L	EPA 365.2	0.002	0.010
Conductivity, uS/cm	EPA 120.1	1	- -
Ammonia-N, mg/L	EPA 351.2	0.03	0.046
Dissolved organic carbon, mg/L	EPA 412.1	0.18	0.500
E. coli, MPN/100 mL	APHA 9223-B	1	<1
Nitrate-N, mg/L	EPA 300.0	0.004	0.050
pH	EPA 150.1	0.1	- -
Total coliform, MPN/100 mL	APHA 9223-B	1	<1
Total dissolved solids, mg/L	EPA 160.1	15.22	48.5
Total N, mg/L	APHA 4500-P J	0.006	0.050
Total P, mg/L	APHA 4500-P J	0.012	0.020
Total suspended solids, mg/L	EPA 160.2	6.58	10

[1] MDL the Minimum Detection Limit of an analyte that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. Further information is available at http://water.usgs.gov/owq/OFR_99-193/detection.html

[2] The Reporting limit is the least (non-zero) calibrated standard used in analysis.

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