Big Creek Research and Extension Team

University of Arkansas System Division of Agriculture

Quarterly Report – April 1 to June 30, 2017

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

Mission of the University of Arkansas System Division of Agriculture

The mission of the **Division of Agriculture** is to advance the stewardship of natural resources and the environment, cultivate the improvement of agriculture and agribusiness, develop leadership skills and productive citizenship among youth and adults, enhance economic security and financial responsibility among the citizens of the state, ensure a safe, nutritious food supply, improve the quality of life in communities across Arkansas, and strengthen Arkansas families.

Dr. Mark J. Cochran
Vice President for Agriculture

Executive Summary

This is the second Quarterly Report of 2017 for the Big Creek Research and Extension Team that details activities and progress made from April 1 through June 01, 2017.

1. We continue to collect weekly base flow and periodic stormflow water samples from Big Creek above and below the C&H Farm, along with water from a spring, ephemeral stream, surface runoff sites on Fields 1, 5a, and 12, two interceptor trenches below the slurry holding ponds, and house well for chemical and bacterial analysis.

2. Flows at the downstream site are now available at 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. Information on development of the rating curve by USGS at this site is available at 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.

3. In the Ozark Mountain karst region, nutrient concentrations in streams of the Buffalo, Upper Illinois, and Upper White River Watersheds increase as the percent of land in pasture and urban use increases. Averaged over the last three years, nutrient concentrations in Big Creek above and below the C&H Farm are similar to concentrations found in other watersheds where there is a similar amount of pasture and urban land use.

Big Creek Science Team

Andrew Sharpley, Ph.D., TEAM LEADER – Distinguished Professor - Soil science, water quality, soil phosphorus chemistry, agricultural management

Brian Breaker, M.Sc., Surface-Water Specialist, stream flow and constituent collection, analysis, and statistical evaluation of trends.

Kris Brye, Ph.D., Professor - Effects of land application of poultry litter on in-situ nutrient leaching, effects of land use and management practices on soil physical, chemical, and biological properties related to soil quality and sustainability

Mike Daniels, Ph.D., Professor – Extension water quality and nutrient management specialist

Ed Gbur, Ph.D., Professor and Director, Agricultural Statistics Laboratory - Experimental design, linear and generalized linear mixed models, regression, agricultural applications of statistics.

Brian Haggard, Ph.D., Professor - Ecological engineering, environmental soil and water sciences, water quality chemistry, water quality monitoring and modeling, algal nutrient limitation, pollutant transport in aquatic systems

Phil Hays, Ph.D. Ground Water Specialist, U.S. Geological Survey and Research Professor with Geosciences Dept., University of Arkansas, application of stable isotopes and other geochemical indicators in delineating movement and behavior of contaminants in ground-water systems

Mary Savin, Ph.D. - Structure and function of microbial communities in natural and managed ecosystems, microorganisms in nutrient cycling, contaminant degradation

Karl VanDevender, Ph.D. and P.E., Professor - Extension Engineer, Livestock and poultry manure and mortality management, nutrient management planning

Jun Zhu, PhD., Professor - Biological and agricultural engineering, agricultural sustainability, manure treatment technologies

Adam Willis, M.Sc., Newton County Extension Agent - Agriculture

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

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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 8. Left Fork downstream of the C&H Farm operation.

Site 9. North interceptor trench below the manure holding ponds.

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

Site 11. House well at animal facility.

Table 1. Location of sampling sites on the Big Creek Research and Extension Team project.

Site description	Latitude	Longitude	Elevation, ft
Field 1	35 55’ 06.42”	93 03’ 38.34”	984
Field 5a	35 56’03.01”	93 04’ 25.85”	778
Field 12	35 54’ 13.57”	93 04’ 04.76”	838
Ephemeral stream	35 55’ 25.89”	93 04’ 14.94”	824
Spring	35 54’ 57.06”	93 03’ 34.64”	977
Big Creek upstream of farm	35 53’ 32.28”	93 04’ 06.38”	857
Big Creek downstream of farm	35 56’ 18.98”	93 04’ 21.81”	769
Left Fork	35 5’”48.04”	93 04” 02.02”	760
Trench 1 (south)	35 55’ 19.24”	93 04’ 23.04”	896
Trench 2 (north)	35 55’ 21.39”	93 04’ 19.93”	883
House well	35 55’ 27.02”	93 04’ 22.71”	915

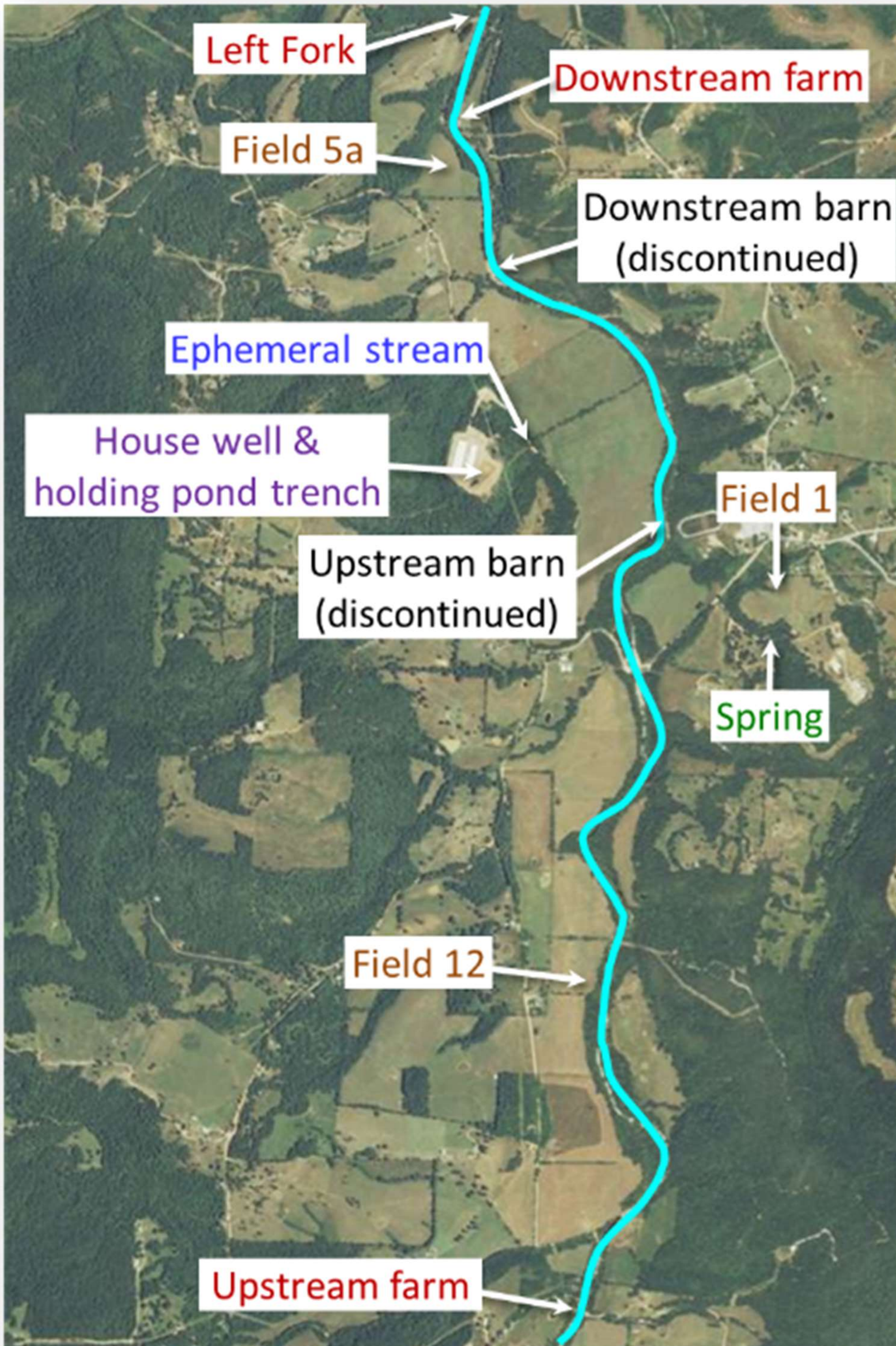

Figure 1. Location of sampling sites for the Big Creek Research and Extension Team project.

Sampling Protocols and Analyses

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

1. One-liter acid-washed bottles were used to collect the stream samples for nutrient analyses.
2. Water was collected from just beneath the surface, where the stream was actively moving and well-mixed.
3. The bottle was rinsed with stream water before collecting the sample.
4. Sterilized specimen cups were used to collect samples for bacterial evaluation.
5. Time of collection was 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.
6. Analyses included Alkalinity (APHA 2320-B), Ammonia (EPA 351.2), Chloride (EPA 300.0), Dissolved Phosphorus (EPA 365.2), E. coli (APHA 9223-B), Electrical Conductivity (EPA 120.1), Nitrate (EPA 300.0), pH (EPA 150.1), Total Coliforms (APHA 9223-B), Total Dissolved Solids (EPA 160.1), Total Nitrogen (APHA 4500-P J), Total Phosphorus (APHA 4500-P J), and Total Suspended Solids (EPA 160.2). 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
7. Prior to collection of a house well water sample, the well is purged and water temperature, pH, and electrical conductivity measured on-site every 30 seconds until all values stabilize (primarily water temperature). 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 file:///U:/Words/C&H%20Farm/Publications/Planning/USGS%20National%20Field%20Mannual_complete%202015.pdf

   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
8. Minimum detection limits (MDLs) for each chemical and biological constituent are listed in Table 1. 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.
9. Chemical and biological analyses of samples collected from the beginning of 2017 to May 31, 2017 are given in Tables 3, 4, 5, and 6.

Table 2. Minimum detection limits (MDLs) for each chemical and biological constituent.

Constituent	Minimum detection limit [1]
Alkalinity, mg/L as $CaCO_3$	2
Chloride, mg/L	0.093
Dissolved P, mg/L	0.002
Conductivity, uS/cm	1
Ammonia-N, mg/L	0.03
Dissolved organic carbon, mg/L	0.18
E. coli, MPN/100 mL	1
Nitrate-N, mg/L	0.004
pH	0.1
Total coliform, MPN/100 mL	1
Total dissolved solids, mg/L	15.22
Total N, mg/L	0.006
Total P, mg/L	0.012
Total suspended solids, mg/L	6.58

[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

Big Creek Research and Extension Team Monitoring Data

Nutrients, Sediment, and Bacteria by Date of Sampling

Table 3. Water quality analyses at each sample site since January 2017, with those collected since the last report noted. Coliform units are Most Probable Number (MPN) per 100 mL of water.

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
			- mg/L -							- - MPN/100 mL - -	
1/5/2017	**1/25/2017**	**Grab sample**									
12:28	15:25	Spring	0.004	0.026	0.04	0.276	0.39	9.5	0.94	74.4	1413.6
13:12	15:25	Upstream farm	0.009	0.014	0.02	0.059	0.09	0.7	0.66	52.0	2419.2
12:00	15:25	Downstream farm	0.012	0.019	0.04	0.257	0.31	1.3	0.55	5.2	1986.3
11:42	15:25	Left Fork	0.006	0.011	0.03	0.229	0.26	0.7	0.85	6.2	1732.9
12:47	15:25	House well	0.008	0.014	0.04	0.610	0.66	0.3	0.30	<1.0	<1.0
1/19/2017	**1/19/2017**	**Grab sample**									
10:41	14:30	Spring	0.009	0.017	0.04	0.286	0.60	33.0	13.31	<1.0	2260.0
11:27	14:30	Upstream farm	0.010	0.016	0.03	0.050	0.14	1.9	4.22	137.6	>2419.2
10:30	14:30	Downstream farm	0.014	0.024	0.02	0.121	0.21	2.5	3.19	60.1	3990.0
10:10	14:30	Left Fork	0.010	0.019	0.03	0.243	0.36	2.6	4.25	55.4	>2419.2
11:00	14:30	House well	0.009	0.013	0.03	0.617	0.69	0.9	7.87	<1.0	<1.0

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
2/2/2017	**2/2/2017**	**Grab sample**									
10:45	14:30	Spring	0.011	0.030	<0.03	0.823	0.89	7.3	5.06	6.3	1732.9
11:20	14:30	Upstream farm	0.009	0.017	<0.03	0.056	0.07	1.1	1.72	41.9	>2419.2
10:30	14:30	Downstream farm	0.014	0.026	0.01	0.160	0.21	5.1	2.21	41.3	>2419.2
10:15	14:30	Left Fork	0.008	0.019	0.01	0.139	0.18	1.1	1.69	17.1	>2419.2
10:57	14:30	House well	0.011	0.031	0.01	0.614	0.78	0.4	2.22	<1.0	<1.0
2/15/2017	**2/15/2017**	**Grab sample**									
11:50	15:35	Spring	0.013	0.093	0.02	0.201	0.57	12.7	8.76	178.5	4350.0
13:30	15:35	Upstream farm	0.009	0.060	0.01	0.132	0.30	5.0	3.04	1986.3	6570.0
11:24	15:35	Downstream farm	0.012	0.082	0.03	0.159	0.42	9.0	3.46	1732.9	11000.0
12:08	15:35	Ephemeral stream	0.020	0.064	0.02	1.323	1.45	3.1	5.06	166.9	5630.0
11:11	15:35	Left Fork	0.015	0.080	0.03	0.314	0.60	17.7	4.66	648.8	11060.0
12:46	15:35	Trench 1	0.004	0.023	0.01	0.141	0.20	1.3	0.45	1.0	1299.7
12:56	15:35	Trench 2	0.004	0.087	0.04	0.486	1.12	6.1	5.99	19.7	42860.0
12:25	15:35	House well	0.008	0.023	0.02	0.649	0.72	0.5	2.07	<1.0	<1.0
Samples analyzed since the last quarterly report											
3/1/2017	**3/1/2017**	**Grab sample**									

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
12:38	14:55	Upstream farm	0.009	0.044	0.03	0.069	0.24	4.7	3.93	2590.0	7940.0
11:18	14:55	Downstream farm	0.005	0.016	0.03	0.148	0.27	2.6	3.24	71.7	2430.0
11:43	14:55	Ephemeral stream	0.011	0.016	0.02	0.659	0.71	1.5	6.75	195.6	5730.0
11:00	14:55	Left Fork	0.008	0.024	0.02	0.136	0.28	4.3	2.46	1119.9	4260.0
12:16	14:55	Trench 2	0.002	0.050	0.04	0.345	0.76	11.6	4.90	98.8	34480.0
11:52	14:55	House well	0.012	0.040	0.03	0.620	0.72	0.5	5.85	<1.0	<1.0
3/16/2017	**3/16/2017**	**Grab sample**									
7:30	11:45	Spring	0.009	0.061	<0.03	0.729	0.99	15.5	2.69	24.0	>2419.2
8:38	11:45	Upstream farm	0.006	0.046	<0.03	0.118	0.29	1.7	1.08	75.9	1299.7
7:13	11:45	Downstream farm	0.010	0.031	<0.03	0.266	0.30	2.9	0.97	68.3	1986.3
7:38	11:45	Ephemeral stream	0.005	0.021	<0.03	0.738	0.800	0.8	2.99	14.8	2419.2
7:00	11:45	Left Fork	0.009	0.043	<0.03	0.300	0.41	3.1	1.77	45.5	>2419.2
8:00	11:45	Trench 1	0.006	0.020	<0.03	0.083	0.11	1.1	1.87	<1.0	179.3
7:46	11:45	House well	0.009	0.023	<0.03	0.856	0.88	0.1	1.52	<1.0	1.0
3/27/2017	**3/27/2017**	**Grab sample**									
11:27	15:40	Spring	0.007	0.044	0.00	0.213	0.60	7.2	9.58	770.1	8800.0

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
12:51	15:40	Upstream farm	0.012	0.122	0.06	0.181	0.74	131.4	5.72	1986.3	17850.0
10:51	15:40	Downstream farm	0.047	0.096	0.20	0.173	1.49	321.9	6.68	9840.0	72150.0
10:37	15:40	Left Fork	0.058	0.164	0.17	0.206	1.50	1005.1	8.51	9330.0	38770.0
11:50	15:40	Trench 1	0.004	0.048	0.03	0.129	0.39	3.1	4.36	387.3	17230.0
11:55	15:40	Trench 2	0.009	0.102	0.13	0.060	0.82	7.0	7.13	488.4	29240.0
12:38	15:40	House well	0.007	0.038	0.02	0.573	0.63	1.6	3.83	18.1	261.3
3/27/2017	**3/27/2017**	**Storm sample**									
11:40	15:40	Ephemeral stream	0.151	0.268	0.29	1.704	3.30	448.3	16.47	18500.0	66530.0
11:05	15:40	Field 1	0.420	0.670	0.43	0.090	18.70	124.4	9.29	8390.0	45690.0
12:15	15:40	Field 5a	2.980	3.232	1.40	0.122	1.80	30.2	32.01	2419.2	69100.0
13:06	15:40	Field 12	0.800	1.276	2.02	2.798	6.04	134.2	9.35	7120.0	96060.0
3/30/2017	**3/30/2017**	**Storm sample**									
11:15	14:15	Ephemeral stream	0.005	0.032	0.01	0.796	0.86	8.6	1.89	2.7	224.0
4/6/2017	**4/6/2017**	**Grab sample**									
11:40	15:25	Spring	0.009	0.032	0.01	0.265	0.42	5.2	6.36	1413.6	1413.6
11:30	15:25	Upstream farm	0.007	0.038	0.01	0.099	0.21	2.3	2.53	72.0	>2419.2

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
11:55	15:25	Downstream farm	0.009	0.034	0.01	0.173	0.26	3.1	1.96	107.6	>2419.2
11:20	15:25	Ephemeral stream	0.008	0.022	<0.03	0.717	0.76	1.6	1.69	148.3	1986.3
11:50	15:25	Left Fork	0.010	0.048	0.01	0.222	0.41	4.7	2.32	135.4	2780.0
10:20	15:25	Trench 1	0.004	0.022	0.03	0.165	0.30	17.2	1.98	47.2	2750.0
4/6/2017	**4/6/2017**	**Storm sample**									
11:15	15:25	Ephemeral stream	0.018	0.080	0.06	0.807	1.14	19.9	4.14	ND	ND
4/13/2017	**4/13/2017**	**Grab sample**									
12:22	15:30	Spring	0.011	0.022	<0.03	0.600	0.63	3.6	15.57	8.6	816.4
13:05	15:30	Upstream farm	0.008	0.054	<0.03	0.026	0.11	2.5	4.64	83.6	2419.2
11:56	15:30	Downstream farm	0.009	0.028	0.01	0.092	0.17	1.1	2.33	135.4	>2419.2
12:50	15:30	Ephemeral stream	0.010	0.018	<0.03	0.593	0.60	1.5	7.73	71.7	6700.0
11:33	15:30	Left Fork	0.010	0.024	<0.03	0.123	0.21	1.6	2.75	22.3	>2419.2
12:35	15:30	House well	0.011	0.020	<0.03	0.564	0.59	0.1	6.22	<1.0	1.0
4/17/2017	**4/17/2017**	**Grab sample**									
12:02	14:55	Spring	0.007	0.044	0.02	0.154	0.40	5.3	6.46	1413.6	18420.0
11:45	14:55	Upstream farm	0.019	0.054	<0.03	0.025	0.12	5.3	1.55	1553.1	9330.0

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
10:51	14:55	Downstream farm	0.011	0.046	0.01	0.129	0.24	3.3	1.51	866.4	8360.0
11:10	14:55	Ephemeral stream	0.005	0.018	<0.03	0.651	0.68	0.9	1.71	410.6	7270.0
10:40	14:55	Left Fork	0.040	0.112	0.02	0.173	0.46	19.5	4.55	9090.0	129970.0
11:25	14:55	House well	0.006	0.016	0.01	0.563	0.57	0.2	1.94	<1.0	12.1
4/24/2017	**4/24/2017**	**Storm sample**									
11:50	15:30	Ephemeral stream	0.007	0.128	0.04	0.000	1.83	318.0	7.35	ND	ND
11:15	15:30	Field 1	0.395	0.592	0.13	0.143	1.50	43.1	7.25	ND	ND
11:35	15:30	Field 5a	0.961	1.212	0.12	0.321	1.53	11.7	11.53	ND	ND
12:15	15:30	Trench 1	0.005	0.040	0.20	0.133	1.76	18.5	7.04	ND	ND
12:20	15:30	Trench 2	0.010	0.084	0.04	0.087	0.93	8.2	8.78	ND	ND
4/27/2017	**4/27/2017**	**Grab sample**									
11:05	16:25	Spring	0.011	0.022	<0.03	0.380	0.44	3.1	2.58	165.8	>2419.2
12:10	16:25	Upstream farm	0.010	0.036	<0.03	0.117	0.12	7.1	1.34	172.3	2430.0
10:35	16:25	Downstream farm	0.014	0.042	<0.03	0.231	0.24	10.7	1.70	214.3	6090.0
10:20	16:25	Left Fork	0.016	0.046	<0.03	0.306	0.32	16.4	2.08	275.5	7230.0
11:30	16:25	House well	0.011	0.014	<0.03	0.532	0.49	0.1	0.69	5.1	52.8
11:43	16:25	Trench 2	0.006	0.046	0.04	0.029	0.42	2.4	4.95	115.3	2419.2

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
4/27/2017	**4/27/2017**	**Storm sample**									
11:52	16:25	Ephemeral stream	0.042	0.253	0.01	0.302	2.57	734.5	8.29	186.0	>2419.2
10:50	16:25	Field 1	0.550	0.784	0.08	0.107	1.32	52.2	8.46	ND	ND
11:15	16:25	Field 5a	0.686	0.846	0.07	0.063	0.86	11.3	7.26	ND	ND
13:40	16:25	Field 12	0.326	0.544	0.02	0.105	0.71	102.3	5.64	ND	ND
11:40	16:25	Trench 1	0.006	0.048	1.04	0.081	1.43	7.2	4.04	40.4	3990.0
5/18/2017	**5/18/2017**	**Grab sample**									
10:55	15:00	Spring	0.006	0.018	<0.03	0.220	0.34	0.4	4.91	88.0	2419.2
11:40	15:00	Upstream farm	0.006	0.048	<0.03	0.067	0.19	2.9	1.50	260.2	>2419.2
10:45	15:00	Downstream farm	0.008	0.024	<0.03	0.189	0.30	1.9	1.10	129.6	3690.0
11:05	15:00	Ephemeral stream	0.012	0.020	<0.03	0.692	0.75	1.7	1.76	49.6	2419.2
10:30	15:00	Left Fork	0.009	0.022	<0.03	0.167	0.26	1.9	1.54	50.4	2419.2
11:15	15:00	House well	0.011	0.020	<0.03	0.431	0.60	0.6	5.05	1.0	3.1
5/31/2017	**5/31/2017**	**Grab sample**									
10:38	13:50	Spring	0.007	0.036	0.00	0.163	0.32	13.2	3.81	235.9	4280.0
11:05	13:50	Upstream farm	0.009	0.020	0.00	0.053	0.14	1.9	1.34	157.6	2419.2

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
10:30	13:50	Downstream farm	0.008	0.052	0.00	0.188	0.25	1.6	1.33	150.0	2419.2
10:55	13:50	Ephemeral stream	0.009	0.020	0.00	0.769	0.79	2.5	1.53	275.5	3500.0
10:20	13:50	Left Fork	0.008	0.020	0.00	0.156	0.22	1.5	1.58	260.2	4720.0
10:51	13:50	House well	0.019	0.026	0.00	0.605	0.92	0.4	1.86	<1.0	22.1

¶ Values proceeded by ‘<’ were reported by the analytical laboratory as zero and the minimum detection limit is given.
§ N.S. is No Sample.

Nutrients, Sediment, and Bacteria by Date Spring, Upstream, and Downstream Sites

Table 4. Water quality analyses in Big Creek upstream and downstream of the C&H Farm boundary of permitted land application since January 2017, with those collected since the last report noted.

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
	- mg/L	- -						- - - MPN/100 mL - - -	
1/5/2017									
Upstream	0.009	0.014	0.02	0.059	0.09	0.7	0.66	52.0	2419.2
Downstream	0.012	0.019	0.04	0.257	0.31	1.3	0.55	5.2	1986.3
1/19/2017									
Upstream	0.010	0.016	0.03	0.050	0.14	1.9	4.22	137.6	2419.2
Downstream	0.014	0.024	0.02	0.121	0.21	2.5	3.19	60.1	3990.0
2/2/2017									
Upstream	0.009	0.017	<0.03	0.056	0.07	1.1	1.72	41.9	>2419.2
Downstream	0.014	0.026	0.01	0.160	0.21	5.1	2.21	41.3	>2419.2
2/15/2017									
Upstream	0.009	0.060	0.01	0.132	0.30	5.0	3.04	1986.3	6570.0
Downstream	0.012	0.082	0.03	0.159	0.42	9.0	3.46	1732.9	11000.0
Samples analyzed since the last Quarterly Report									
3/1/2017									

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Upstream	0.009	0.044	0.03	0.069	0.24	4.7	3.93	2590.0	7940.0
Downstream	0.005	0.016	0.03	0.148	0.27	2.6	3.24	71.7	2430.0
3/16/2017									
Upstream	0.006	0.046	<0.03	0.118	0.29	1.7	1.08	75.9	1299.7
Downstream	0.010	0.031	<0.03	0.266	0.30	2.9	0.97	68.3	1986.3
3/27/2017									
Upstream	0.012	0.122	0.06	0.181	0.74	131.4	5.72	1986.3	17850.0
Downstream	0.047	0.096	0.20	0.173	1.49	321.9	6.68	9840.0	72150.0
4/6/2017									
Upstream	0.007	0.038	0.01	0.099	0.21	2.3	2.53	72.0	>2419.2
Downstream	0.009	0.034	0.01	0.173	0.26	3.1	1.96	107.6	>2419.2
4/13/2017									
Upstream	0.008	0.054	<0.03	0.026	0.11	2.5	4.64	83.6	2419.2
Downstream	0.009	0.028	0.01	0.092	0.17	1.1	2.33	135.4	>2419.2
4/17/2017									
Upstream	0.019	0.054	<0.03	0.025	0.12	5.3	1.55	1553.1	9330.0
Downstream	0.011	0.046	0.01	0.129	0.24	3.3	1.51	866.4	8360.0
4/27/2017									

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Upstream	0.010	0.036	<0.03	0.117	0.12	7.1	1.34	172.3	2430.0
Downstream	0.014	0.042	<0.03	0.231	0.24	10.7	1.70	214.3	6090.0
5/18/2017									
Upstream	0.006	0.048	<0.03	0.067	0.19	2.9	1.50	260.2	>2419.2
Downstream	0.008	0.024	<0.03	0.189	0.30	1.9	1.10	129.6	3690.0
5/31/2017									
Upstream	0.009	0.020	0.00	0.053	0.14	1.9	1.34	157.6	2419.2
Downstream	0.008	0.052	0.00	0.188	0.25	1.6	1.33	150.0	2419.2

¶ Values proceeded by ‘<’ were reported by the analytical laboratory as zero and the Minimum detection limit is given.

§ N.S. is No Sample.

† N.D. is No Data.

Nutrients, Sediment, and Bacteria by Site for Ephemeral Stream, Trenches, Left Fork and Field Runoff

Table 5. Water quality analyses at the ephemeral stream draining the subwatershed containing the production houses and manure holding ponds, and surface runoff from Fields 1, 5a, and 12 since January, 2017, with those collected since the last report noted.

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
	- -			mg/L	- -			- - - MPN/100 mL - - -	
Ephemeral stream									
2/15/2017	0.020	0.064	0.02	1.323	1.45	3.1	5.06	166.9	5630.0
Samples analyzed since the last quarterly report									
3/1/2017	0.011	0.016	0.02	0.659	0.71	1.5	6.75	195.6	5730.0
3/16/2017	0.005	0.021	0.00	0.738	0.800	0.8	2.99	14.8	2419.2
3/27/2017	0.151	0.268	0.29	1.704	3.30	448.3	16.47	18500.0	66530.0
3/30/2017	0.005	0.032	0.01	0.796	0.86	8.6	1.89	2.7	224.0
4/6/2017	0.008	0.022	<0.03	0.717	0.76	1.6	1.69	148.3	1986.3
4/6/2017	0.018	0.080	0.06	0.807	1.14	19.9	4.14	ND	ND
4/17/2017	0.005	0.018	<0.03	0.651	0.68	0.9	1.71	410.6	7270.0
4/24/2017	0.007	0.128	0.04	0.000	1.83	318.0	7.35	ND	ND
4/27/2017	0.042	0.253	0.01	0.302	2.57	734.5	8.29	186.0	>2419.2
5/18/2017	0.012	0.020	<0.03	0.692	0.75	1.7	1.76	49.6	2419.2

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
5/31/2017	0.009	0.020	0.00	0.769	0.79	2.5	1.53	275.5	3500.0
House well									
1/5/2017	0.008	0.014	0.04	0.610	0.66	0.3	0.30	<1.0	<1.0
1/19/2017	0.009	0.013	0.03	0.617	0.69	0.9	7.87	<1.0	<1.0
2/2/2017	0.011	0.031	0.01	0.614	0.78	0.4	2.22	<1.0	<1.0
2/15/2017	0.008	0.023	0.02	0.649	0.72	0.5	2.07	<1.0	<1.0
Samples analyzed since the last quarterly report									
3/1/2017	0.012	0.040	0.03	0.620	0.72	0.5	5.85	<1.0	<1.0
3/16/2017	0.009	0.023	<0.03	0.856	0.88	0.1	1.52	<1.0	1.0
3/27/2017	0.007	0.038	0.02	0.573	0.63	1.6	3.83	18.1	261.3
4/13/2017	0.011	0.020	<0.03	0.564	0.59	0.1	6.22	<1.0	1.0
4/17/2017	0.006	0.016	0.01	0.563	0.57	0.2	1.94	<1.0	12.1
4/27/2017	0.011	0.014	<0.03	0.532	0.49	0.1	0.69	5.1	52.8
5/18/2017	0.011	0.020	<0.03	0.431	0.60	0.6	5.05	1.0	3.1
5/31/2017	0.019	0.026	0.00	0.605	0.92	0.4	1.86	<1.0	22.1
Interceptor Trench 1 (South)									
2/15/2017	0.004	0.023	0.01	0.141	0.20	1.3	0.45	1.0	1299.7

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Samples analyzed since the last quarterly report									
3/16/2017	0.006	0.020	0.00	0.083	0.11	1.1	1.87	<1.0	179.3
3/27/2017	0.004	0.048	0.03	0.129	0.39	3.1	4.36	387.3	17230.0
4/6/2017	0.004	0.022	0.03	0.165	0.30	17.2	1.98	47.2	2750.0
4/24/2017	0.005	0.040	0.20	0.133	1.76	18.5	7.04	ND	ND
4/27/2017	0.006	0.048	1.04	0.081	1.43	7.2	4.04	40.4	3990.0
Interceptor Trench 2 (North)									
2/15/2017	0.004	0.087	0.04	0.486	1.12	6.1	5.99	19.7	42860.0
Samples analyzed since the last quarterly report									
3/1/2017	0.002	0.050	0.04	0.345	0.76	11.6	4.90	98.8	34480.0
3/27/2017	0.009	0.102	0.13	0.060	0.82	7.0	7.13	488.4	29240.0
4/24/2017	0.010	0.084	0.04	0.087	0.93	8.2	8.78	ND	ND
4/27/2017	0.006	0.046	0.04	0.029	0.42	2.4	4.95	115.3	2419.2
Left Fork									
1/5/2017	0.006	0.011	0.03	0.229	0.26	0.7	0.85	6.2	1732.9
1/19/2017	0.010	0.019	0.03	0.243	1.00	2.6	4.25	55.4	>2419.2

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
2/2/2017	0.008	0.019	0.01	0.139	0.18	1.1	1.69	17.1	>2419.2
2/15/2017	0.015	0.080	0.03	0.314	0.60	17.7	4.66	648.8	11060.0
Samples analyzed since the last quarterly report									
3/1/2017	0.008	0.024	0.02	0.136	0.28	4.3	2.46	1119.9	4260.0
3/16/2017	0.009	0.043	<0.03	0.300	0.41	3.1	1.77	45.5	>2419.2
3/27/2017	0.058	0.164	0.17	0.206	1.50	1005.1	8.51	9330.0	38770.0
4/6/2017	0.010	0.048	0.01	0.222	0.41	4.7	2.32	135.4	2780.0
4/13/2017	0.010	0.024	<0.03	0.123	0.21	1.6	2.75	22.3	>2419.2
4/17/2017	0.040	0.112	0.02	0.173	0.46	19.5	4.55	9090.0	129970.0
4/27/2017	0.016	0.046	<0.03	0.306	0.32	16.4	2.08	275.5	7230.0
5/18/2017	0.009	0.022	<0.03	0.167	0.26	1.9	1.54	50.4	2419.2
5/31/2017	0.008	0.020	0.00	0.156	0.22	1.5	1.58	260.2	4720.0
Field 1									
10/13/2016	0.940	1.231	0.13	0.335	2.36	59.0	16.67	N.S.	N.S.
No samples analyzed since the last quarterly report									
3/27/2017	0.420	0.670	0.43	0.090	18.70	124.4	9.29	8390.0	45690.0

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
4/24/2017	0.395	0.592	0.13	0.143	1.50	43.1	7.25	ND	ND
4/27/2017	0.550	0.784	0.08	0.107	1.32	52.2	8.46	ND	ND
Field 5a									
3/31/2016	1.154	1.352	0.27	0.302	1.67	26.5	32.74	N.S.	N.S.
5/10/2016	1.114	1.458	1.69	2.894	6.35	79.9	12.82	N.S.	N.S.
No samples analyzed since the last quarterly report									
3/27/2017	2.980	3.232	1.40	0.122	1.80	30.2	32.01	2419.2	69100.0
4/24/2017	0.961	1.212	0.12	0.321	1.53	11.7	11.53	ND	ND
4/27/2017	0.686	0.846	0.07	0.063	0.86	11.3	7.26	ND	ND
Field 12									
3/10/2016	0.411	0.522	1.17	0.852	4.49	621.5	12.58	N.S.	N.S.
5/10/2016	0.370	0.666	0.12	0.062	1.03	96.7	6.92	N.S.	N.S.
No samples analyzed since the last quarterly report									
3/27/2017	0.800	1.276	2.02	2.798	6.04	134.2	9.35	7120.0	96060.0
4/27/2017	0.326	0.544	0.02	0.105	0.71	102.3	5.64	ND	ND

¶ Values proceeded by ‘<’ were reported by the analytical laboratory as zero and the minimum detection limit is given.

§ N.S. is No Sample. E. coli and total coliform were not measured on surface runoff samples collected by ISCO samplers when sample holding time exceeded the required 8-hour threshold.

† N.D. is No Data.

Water pH, Alkalinity, Chloride, Electrical Conductivity, and Total Dissolved Solids for Several Big Creek Sites

At the beginning of 2015, the pH, alkalinity, chloride concentration, electrical conductivity and total dissolved solids were determined on water samples collected at the upstream and downstream sites, spring, house well, and trenches, to build a data base that will enable to eventually source track the major water source pathways at these sites. These values are given below in Table 6.

Table 6. The pH, Chloride concentration, and electrical conducting of water samples collected at upstream, downstream, spring, ephemeral stream, house well and trench sites, initiated at the beginning of 2017, with those collected since the last report noted.

Date	pH	Chloride	Electrical conductivity
		mg/L	µS/cm
Upstream			
1/5/2017	8.8	2.264	142.0
1/19/2017	7.9	2.089	
2/2/2017	8.4	2.044	112.0
2/15/2017	7.9	2.022	128.0
Samples analyzed since the last quarterly report			
3/1/2017	8.4	1.696	115.0
3/16/2017	7.8	1.508	88.0
3/27/2017	7.6	0.997	50.0
4/6/2017	7.5	1.436	72.0
4/13/2017	7.8	1.392	76.0
4/17/2017	7.9	1.372	95.8
4/27/2017	7.7	1.003	68.0
5/18/2017	8.3	1.518	110.0
5/31/2017	8.0	1.296	122.0
Downstream			

Date	pH	Chloride	Electrical conductivity
1/5/2017	8.1	5.692	220.0
1/19/2017	7.6	2.390	
2/2/2017	7.9	2.414	171.0
2/15/2017	8.2	2.199	119.0
Samples analyzed since the last quarterly report			
3/1/2017	7.8	2.926	162.0
3/16/2017	7.5	1.792	128.0
3/27/2017	7.5	1.113	69.0
4/6/2017	7.5	1.649	106.0
4/13/2017	7.7	1.665	114.0
4/17/2017	7.8	1.849	162.9
4/27/2017	7.6	1.160	102.0
5/18/2017	7.7	2.009	172.0
5/31/2017	8.0	1.714	171.0
Spring			
1/5/2017	7.2	2.462	504.0
1/19/2017	7.1	2.397	
2/2/2017	7.1	3.099	546.0
2/15/2017	7.3	2.305	353.0
Samples analyzed since the last quarterly report			
3/16/2017	7.4	2.618	602.0
3/27/2017	7.3	1.223	373.0
4/6/2017	7.1	2.010	486.0
4/13/2017	7.1	2.810	547.0
4/17/2017	7.2	1.720	445.0
4/27/2017	7.4	1.565	476.0

Date	pH	Chloride	Electrical conductivity
5/18/2017	7.0	1.988	474.0
5/31/2017	7.5	1.305	471.0
Ephemeral Stream			
2/15/2017	7.7	3.366	270.0
3/1/2017	7.8	4.328	396.0
3/16/2017	7.5	3.415	354.0
3/27/2017	7.4	4.373	180.0
3/30/2017	7.8	2.705	224.0
4/6/2017	7.3	3.154	223.0
4/13/2017	7.7	3.585	377.0
4/17/2017	7.5	3.997	394.0
4/23/2017	7.5	2.221	321.0
4/27/2017	7.5	1.414	109.0
5/18/2017	7.6	3.247	346.0
5/31/2017	8.0	3.161	380.0
House Well			
1/5/2017	7.8	5.371	421.0
1/19/2017	7.4	5.234	420.0
2/2/2017	7.5	5.290	420.0
2/15/2017	7.6	5.401	397.0
Samples analyzed since the last quarterly report			
3/1/2017	7.5	5.162	432.0
3/16/2017	7.5	5.453	416.0
3/27/2017	7.8	5.192	438.0
4/13/2017	7.4	5.508	445.0
4/17/2017	7.5	5.315	285.0

Date	pH	Chloride	Electrical conductivity
4/27/2017	7.5	5.000	429.0
5/1/2017	7.6	5.021	436.0
5/11/2017	7.4	6.819	433.0
5/18/2017	7.4	5.024	406.0
5/25/2017	7.7	4.124	442.0
5/31/2017	7.7	4.859	327.0
Trench 1			
2/15/2017	8.0	2.344	397.0
Samples analyzed since the last quarterly report			
3/16/2017	7.8	1.483	164.0
3/27/2017	7.4	1.018	164.0
4/6/2017	7.4	1.877	168.0
4/24/2017	7.4	0.895	160.0
4/27/2017	7.8	0.557	150.0
5/1/2017	7.7	1.193	172.0
Trench 2			
2/15/2017	8.0	1.164	135.0
Samples analyzed since the last quarterly report			
3/1/2017	7.3	0.808	159.0
3/27/2017	7.1	0.376	90.0
4/6/2017	7.0	0.325	175.0
4/24/2017	7.3	0.322	134.0
4/27/2017	7.5	0.217	129.0
5/1/2017	7.7	0.340	157.0

Discharge at USGS 07055790 Site Downstream of C&H Operation

Discharge downstream of the C&H Farm (USGS station 07055790 Big Creek near Mt. Judea, AR) is available at 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

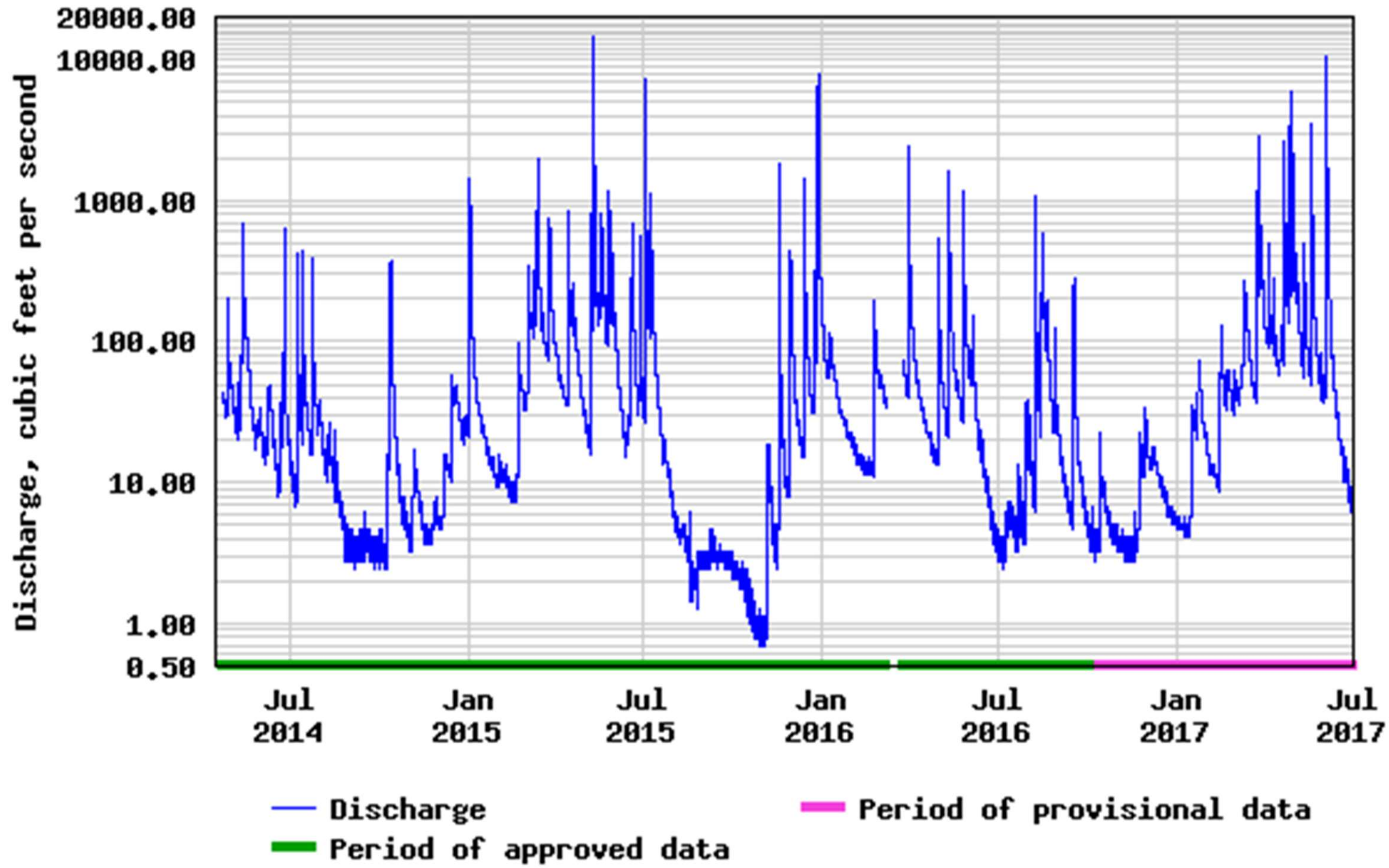

Figure 2. Discharge in Big Creek downstream of the C&H Farm for the period of monitoring; April 2014 to July 2017.

Temporal Trends in Phosphorus, Nitrogen, Bacteria, and Chloride in Big Creek Above and Below the C&H Farm

The concentration of dissolved P, total P, nitrate-N, total N, bacteria and chloride in Big Creek above and below the C&H Farm are presented in subsequent figures to show the season / temporal trends in measured concentrations (Figures 3, 4, 5, 6, 7, 8, and 9).

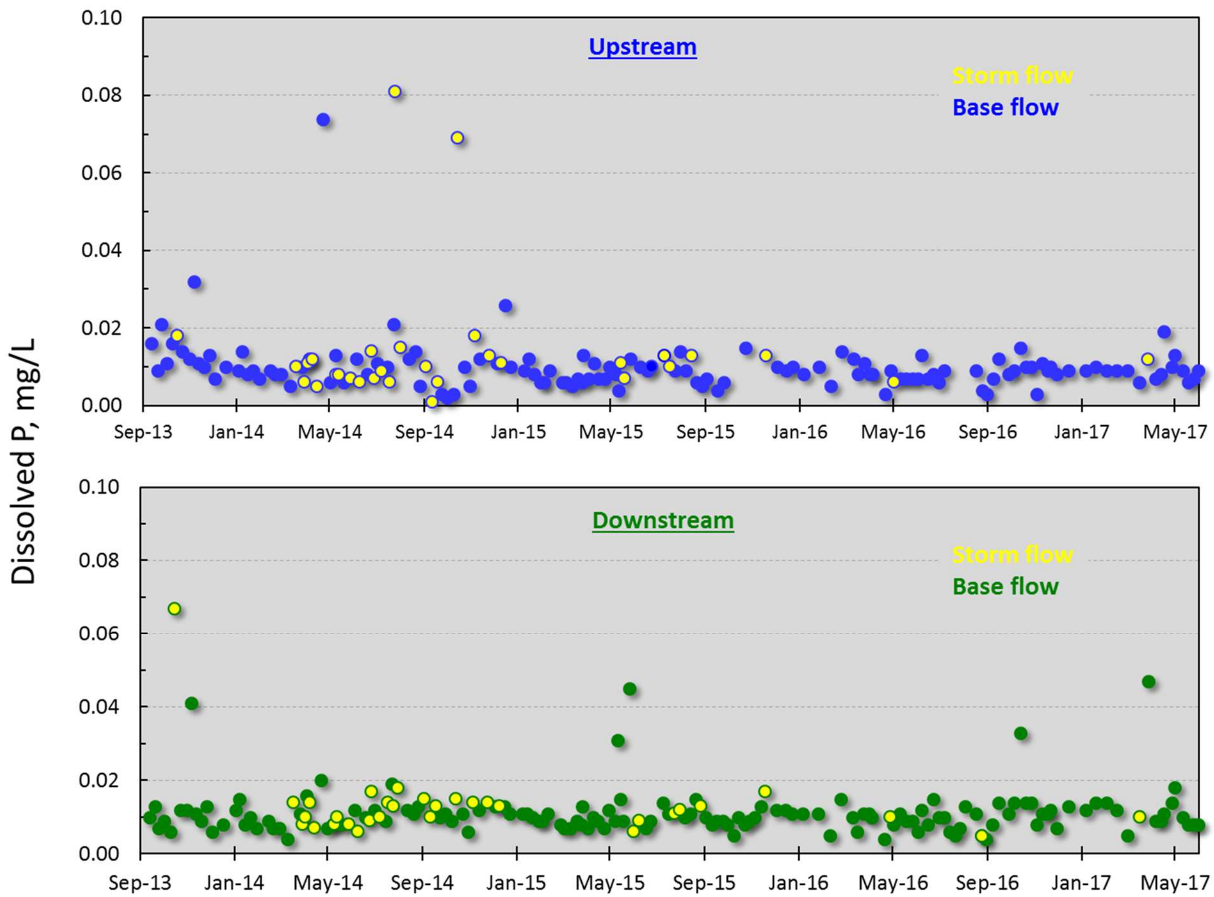

Figure 3. Dissolved P concentration at the Big Creek monitoring site up- and downstream of the C&H Farm, Newton County, AR.

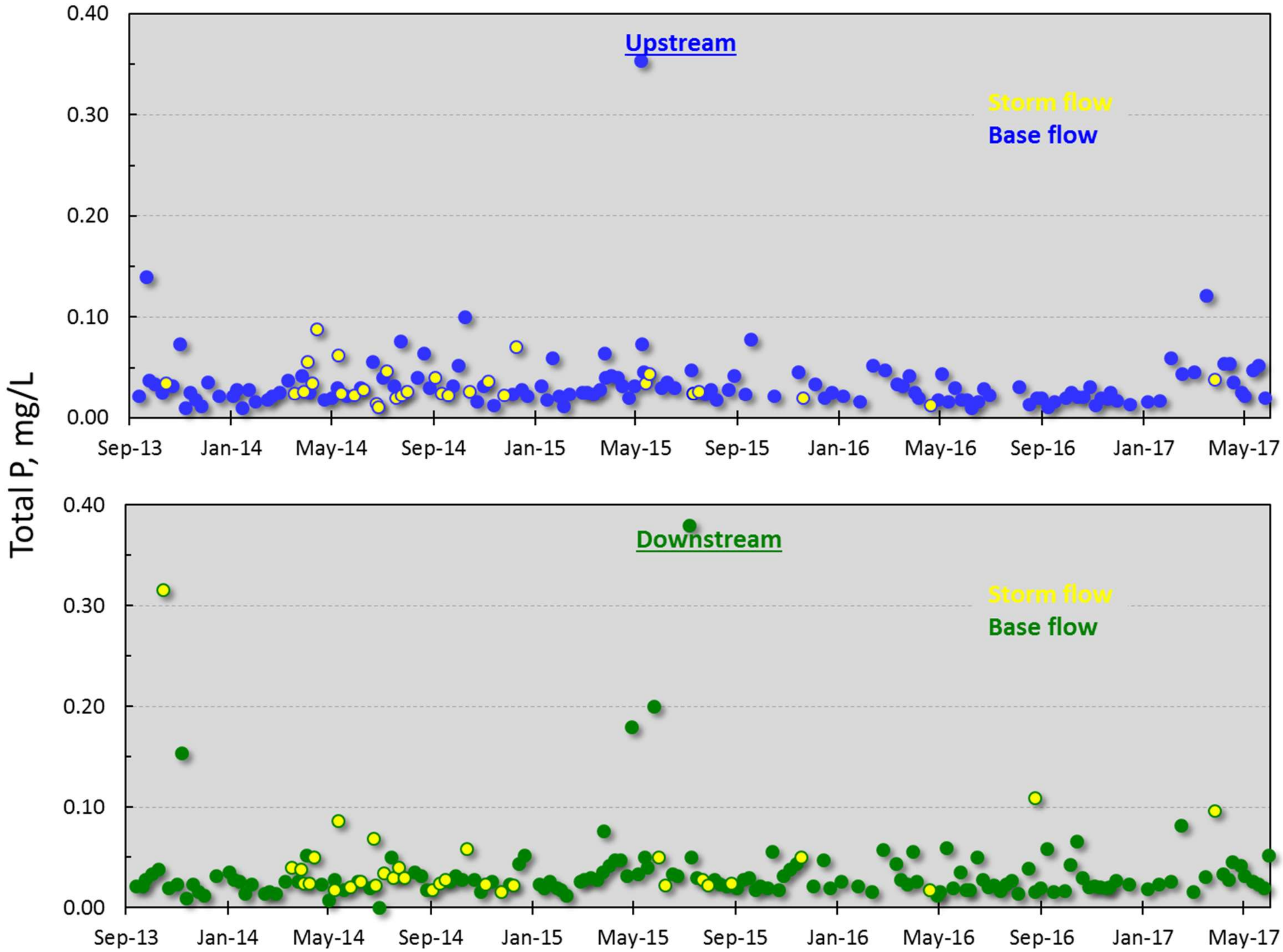

Figure 4. Total P concentration at the Big Creek monitoring site up- and downstream of the C&H Farm, Newton County, AR.

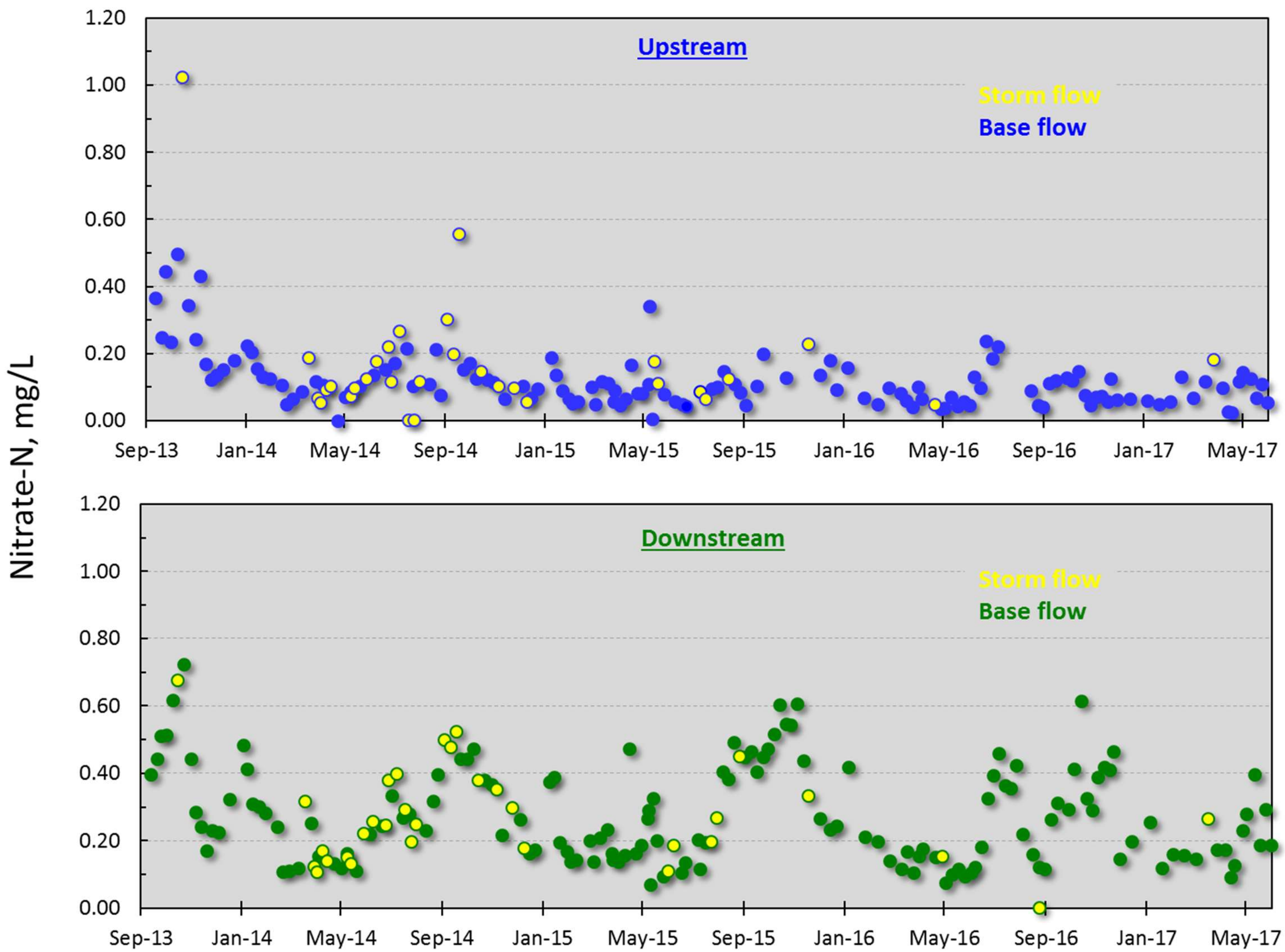

Figure 5. Nitrate-N concentration at the Big Creek monitoring site up- and downstream of the C&H Farm, Newton County, AR.

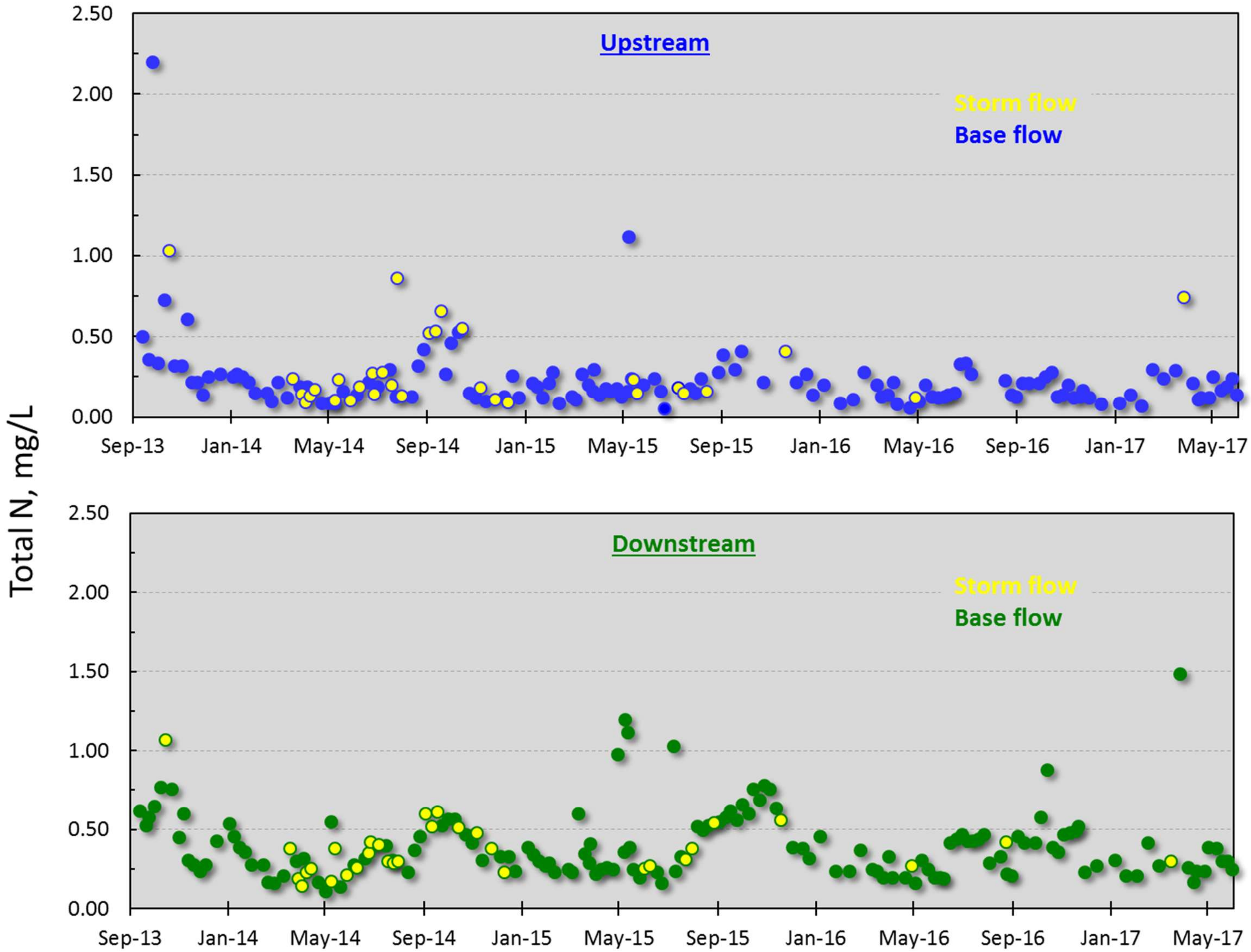

Figure 6. Total N concentration at **the Big Creek monitoring site up- and downstream of the C&H Farm, Newton County, AR.**

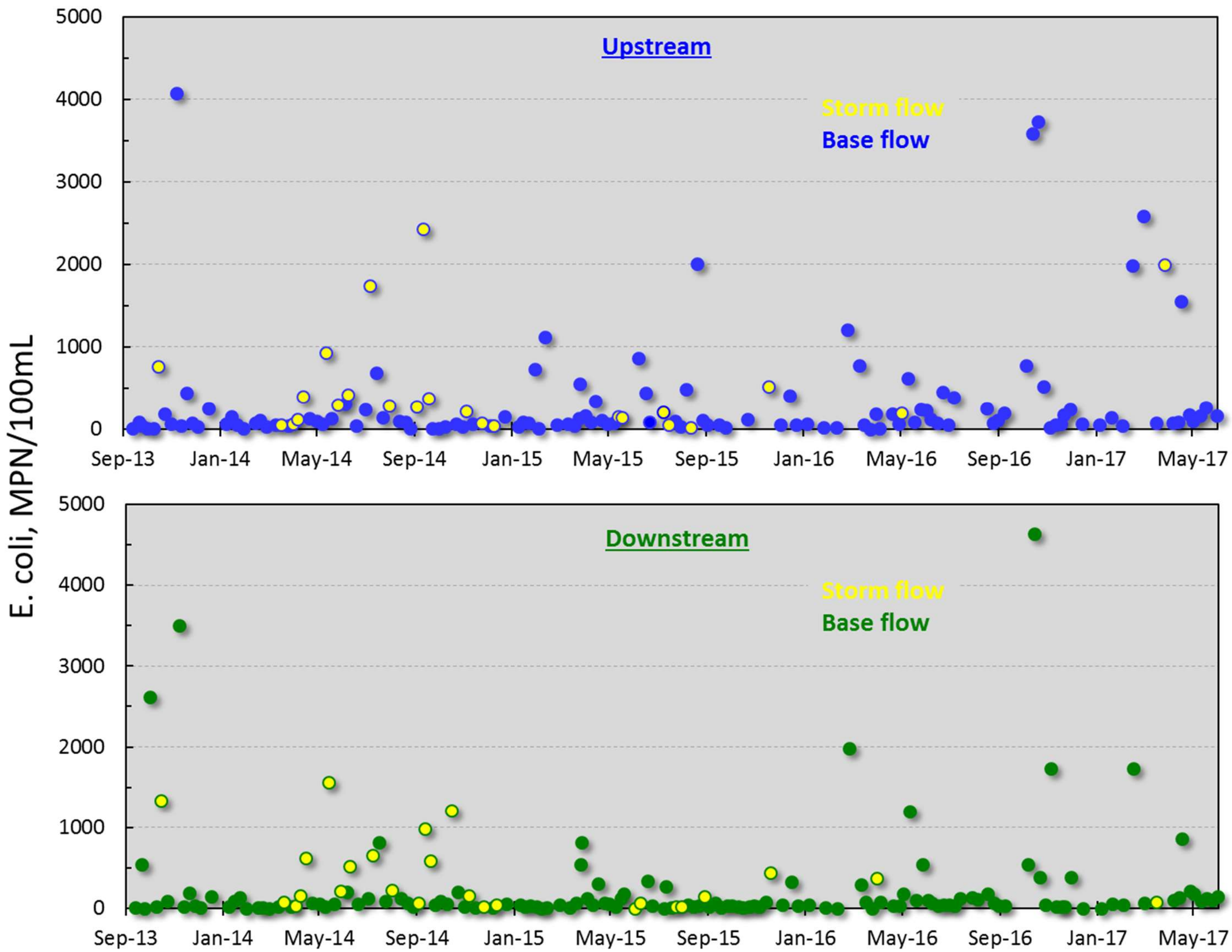

Figure 7. E. coli numbers at the Big Creek monitoring site up- and downstream of the C&H Farm, Newton County, AR.

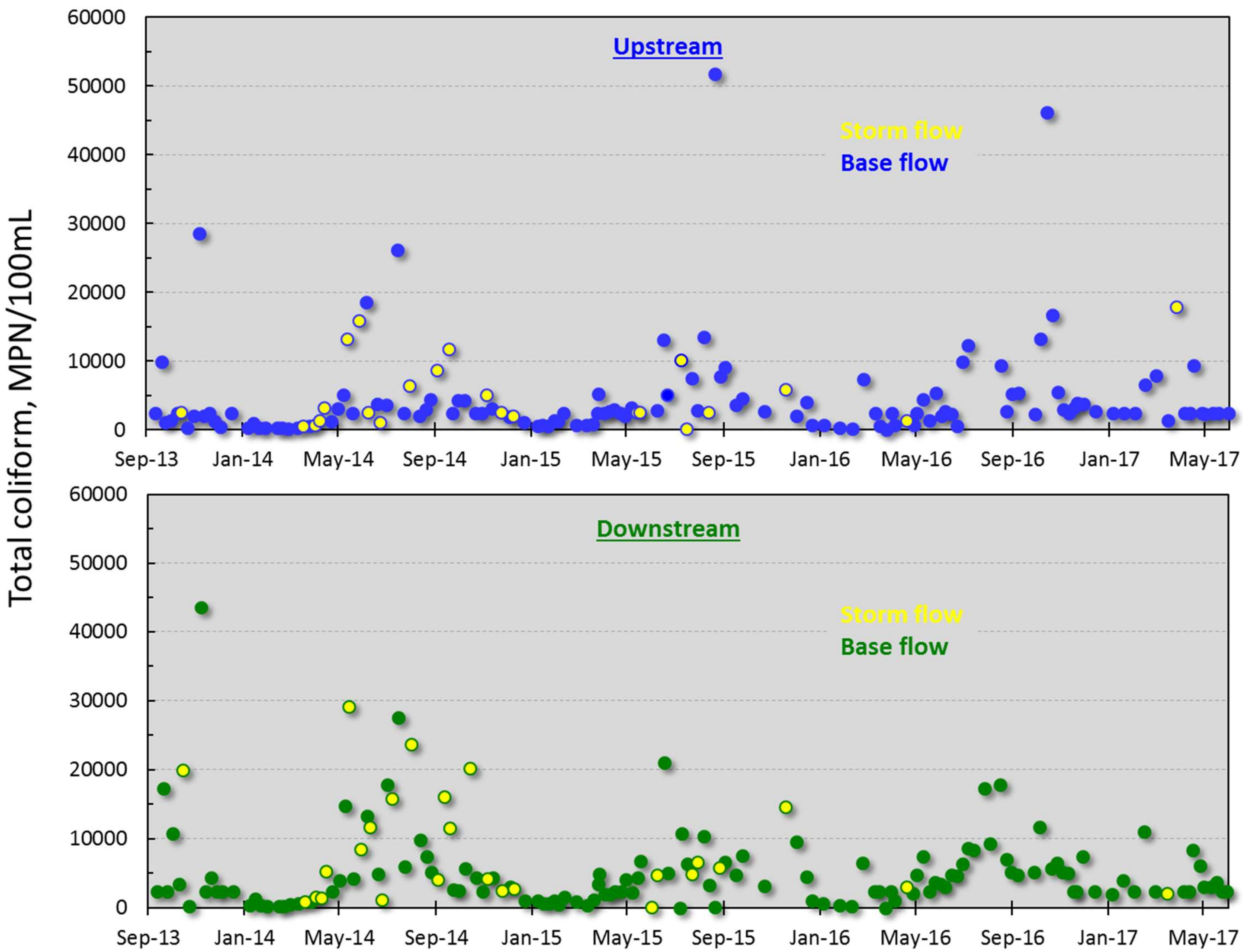

Figure 8. Total coliform numbers at the Big Creek monitoring site up- and downstream of the C&H Farm, Newton County, AR.

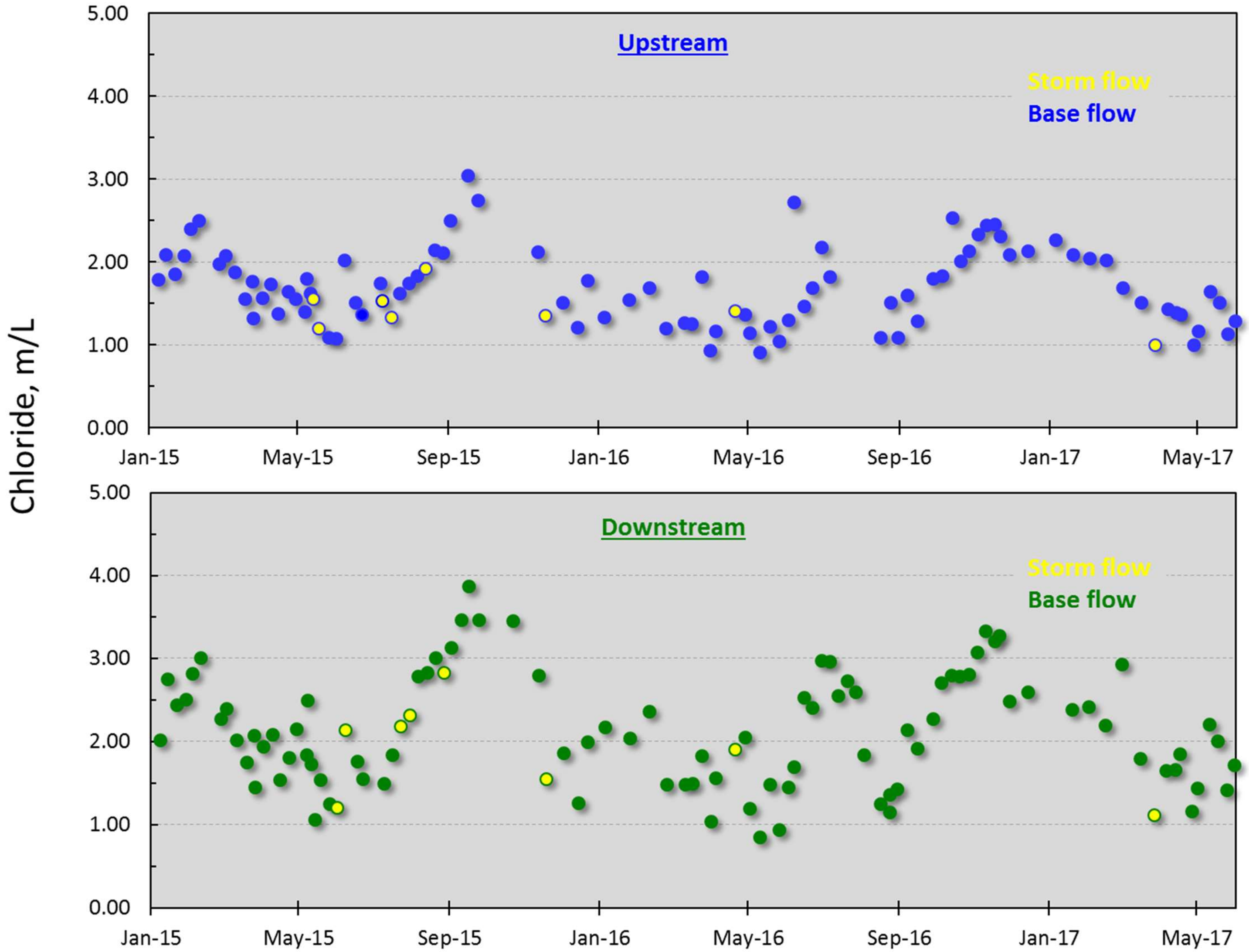

Figure 9. Chloride concentration at the Big Creek monitoring site up- and downstream of the C&H Farm, Newton County, AR.

Relating Land Use and Nutrient Concentrations in Streams of Ozark Mountain Watersheds

Background

Nutrient impairment of surface waters continues despite widespread conservation efforts to reduce losses from urban and rural, specifically agricultural, land uses (Scavia et al., 2014; U.S. Environmental Protection Agency, 2015). Land use within watersheds influences the quantity and quality of water draining from a watershed. In fact, as land disturbance increases and use intensifies, there is a general increase in stormwater runoff and nutrient inputs that lead to a greater potential for nutrient discharge to receiving waters (Dubrovsky et al., 2010; Rebich et al., 2011). For instance, with urban growth, more impervious surfaces increase the flashiness of water runoff, alter the hydrologic response of watersheds, and increase wastewater treatment discharge (Alexander et al., 2008; Dale et al., 2008). As areas of agricultural production grow, more nutrients are often land applied as fertilizer nitrogen (N) and phosphorus (P) that are required for optimum production (Reddy et al., 2010).

Numerous factors determine the relationship between land use in a given watershed and nutrient discharge from that watershed. With an increase in the percent of a watershed drainage area in pasture, row crop, or urban use, a general increase in nutrient concentrations in storm and base flows (Buck et al., 2004; McCarty and Haggard, 2016). In forested watersheds, little nutrient input and land disturbance is usually observed, unless trees are harvested. Thus, nutrient concentrations in streams draining forested watersheds tend to be lower than in watersheds with considerable anthropogenic land use (Dodds, 2007; Haggard, 2010).

Here we assess the affect of land use on stream N and P concentrations in the Ozark Highlands and Boston Mountains ecoregions of northwest Arkansas by combining previously published data for the Upper Illinois River Watershed (Haggard et al., 2010), Upper White River Watershed (Giovannetti et al., 2013), and ongoing monitoring in the Buffalo River Watershed.

For a range of reasons, a great deal of interest has been expressed in N and P concentrations in several streams of the Boston and Ozark Mountains regions. The Upper Illinois River Watershed is the subject of several ongoing nutrient-related strategies, which include development of numeric nutrient criteria, and litigation between downstream receivers of water and upstream users. The Upper White River Watershed is the main source of drinking water for over 330,000 residents of northwest Arkansas and several strategies are in place to protect nutrient-related water quality in the watershed.

The Ozark region includes the first National Scenic River, the Buffalo River, which, together with its tributaries, drain the Buffalo River Watershed. The location of these watersheds are designated on Figure 1. The relationship between stream nutrient concentrations and land use for the region are used to determine if a permitted concentrated animal feeding operation (CAFO) in Big Creek Watershed, a sub-watershed of the Buffalo River Watershed, has affected stream water quality.

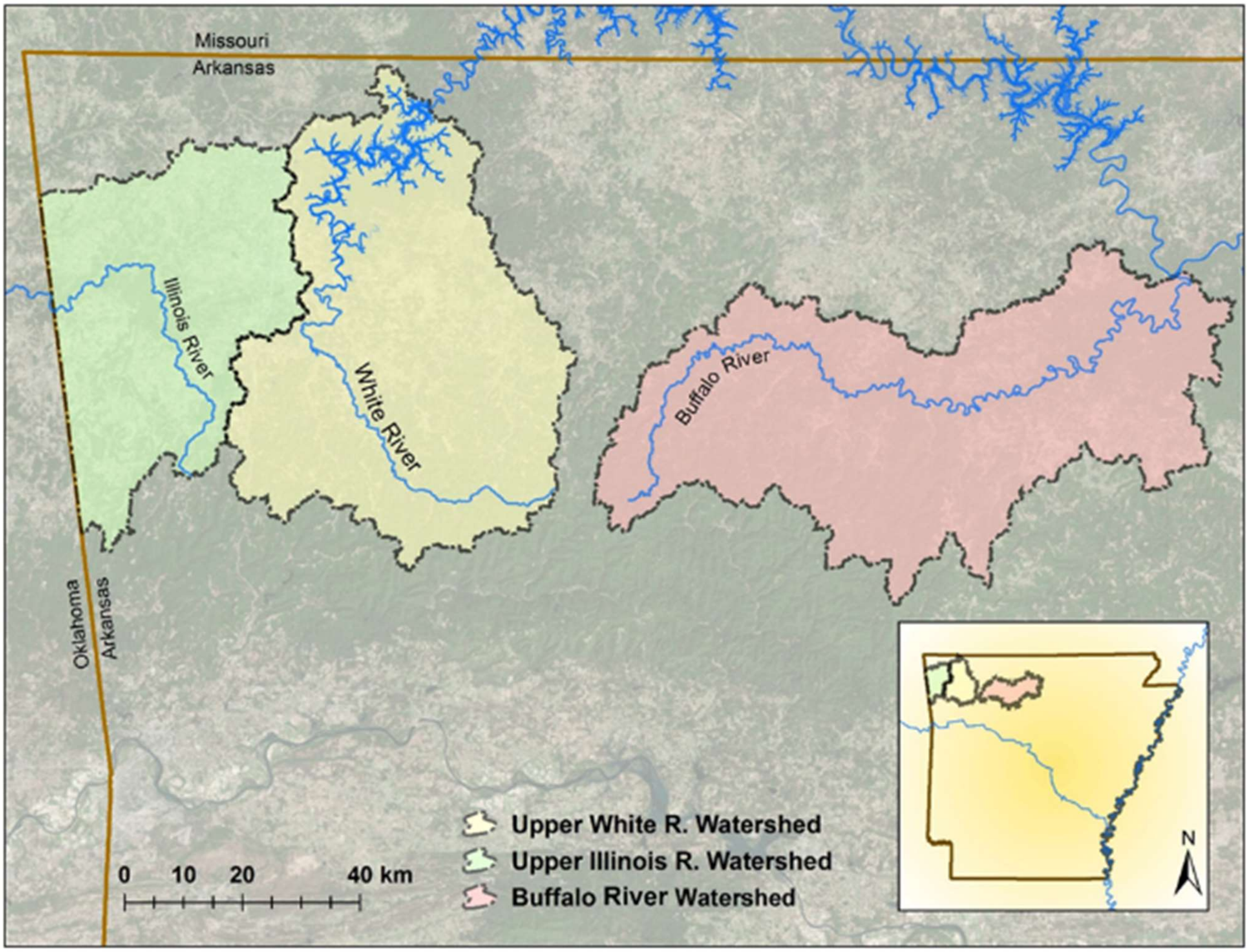

Figure 10. The location of Buffalo River, Upper Illinois, and Upper White River Watershed in northwestern Arkansas. Information from U.S. Geological Survey (USGS), Environmental Systems Research Institute (ESRI), and Aeronautics and Space Administration (NASA).

Sites and Water Quality Data Collection

The concentration of nitrate-N and total N and dissolved and total P have been measured over varying periods in base flow at the outlet of sub-watersheds of the Buffalo (Figure 2), Upper Illinois, and Upper White River Watersheds (Figure 3). In the Buffalo River Watershed, the National Park Service, in partnership with the U.S. Geological Survey and Arkansas Department of Environmental Quality, periodically measured nutrient concentrations at 20 stream locations from 1985-2015 and reported various relationships between land use and nutrient concentrations (Mott and Laurans, 2004; Petersen et al., 1998).

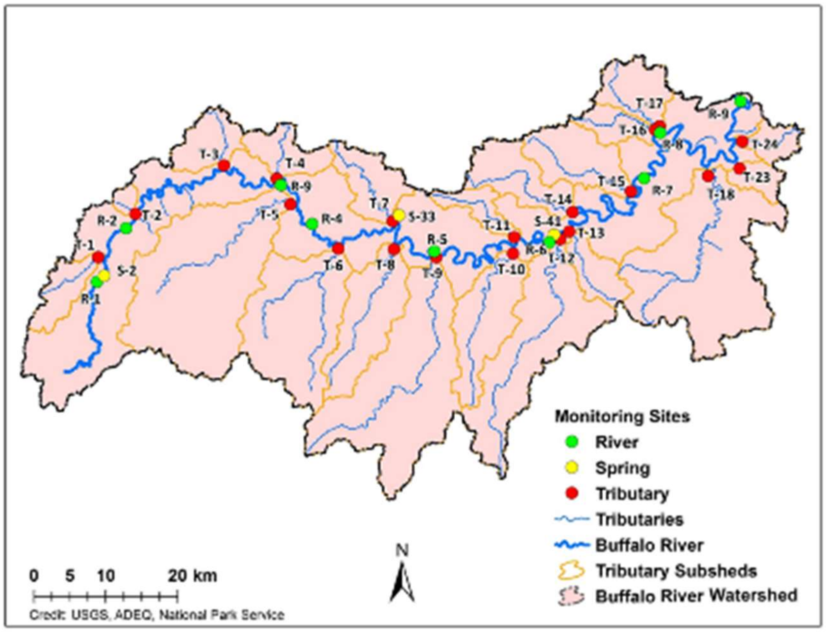

Figure 11. Monitoring sites established in the Buffalo River Watershed in northwest Arkansas, whose tributaries drain forested uplands and agricultural lowlands with poultry and beef cattle operations. Data is from the Arkansas Department of Environmental Quality (1985-2015).

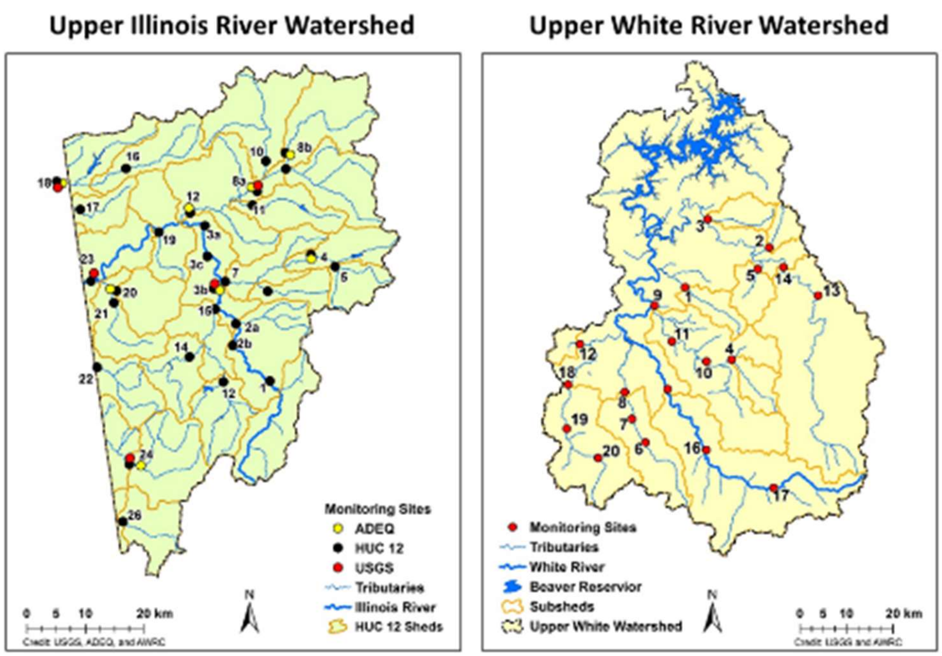

Figure 12. Monitoring sites established in the Upper Illinois (left) and Upper White River Watersheds (right) in northwest Arkansas, whose tributaries drain forested uplands and agricultural lowlands with poultry and beef cattle operations. Data are from Haggard et al. (2010) and Giovannetti et al. (2013), respectively.

In the Upper Illinois River Watershed, Haggard et al. (2010) measured N and P concentrations during baseflow at monthly intervals during 2009 at 29 stream locations. In the Upper White Watershed, Giovannetti et al. (2013) monitored N and P concentrations at 20 stream locations for one year (June 2005 to July 2006) by collecting monthly samples from each location during base flow. While samples were also collected during or immediately following rainfall that produced enough runoff to increase stream flow in both the Upper Illinois River and Upper White Watershed studies, stream-flow values were not included in this analysis.

Forest, pasture, and urban land-use areas, which are the three main land uses in each of the sub-watersheds, are summarized in Tables 1, 2, and 3 for the Buffalo, Upper Illinois, and Upper White River Watersheds, respectively. High-resolution (4 m), land use-land cover depiction was created using 2006 imagery. The range in land-use distribution in the three watersheds is summarized in Table 4.

Information for the permitted swine CAFO, publicly available permit, and manure application records were obtained from the Arkansas Department of Environmental Quality (2017a). The farm was initially permitted for 3 Boars (450 lbs), 2100 Gestating Sows (375 lbs), 400 Lactation Sows (475 lbs), and 4,000 Nursery Pigs (10 lbs). The original permit included 17 land application fields for a total of 630 acres available for land application (Figure 4). All of the fields were established pastures grazed and/or cut for hay with a history of inorganic fertilizer and poultry litter applications.

The planned swine manure applications replaced future poultry litter applications. Table 5 summarizes the manure applications from 2013 to 2016. The 630 acres available for land application does not include additional fields that could not receive manure due to permit constraints, such as setbacks adjacent to stream and other water bodies, rock outcrops, sink holes, adjacent property and residences, and slopes greater than 8%. As indicated on Figure 4 some fields are adjacent to Big Creek or a tributary to it, while others are more distant from the creek.

Relating Stream Nutrient Concentrations and Land Use

Geometric mean stream nutrient concentrations are related to the percentage of the watershed in pasture and urban land use for the Buffalo, Upper Illinois, and Upper White River Watersheds (Figures 5 and 6). The dashed lines on Figures 5 and 6 represent the upper and lower thresholds concentrations, where there is a 95% confidence that a stream draining a watershed with a specific percent pasture and urban land use will have a P and N concentration within those thresholds.

As the percent pasture and urban (i.e., land use intensity) increases, so does stream nutrient concentration. The general increase in nutrient concentrations is consistent with the fact that fertilizer (as mineral and manure sources) is routinely applied to pastures to maintain forage production, as well as deposition of nutrients by grazing cattle.

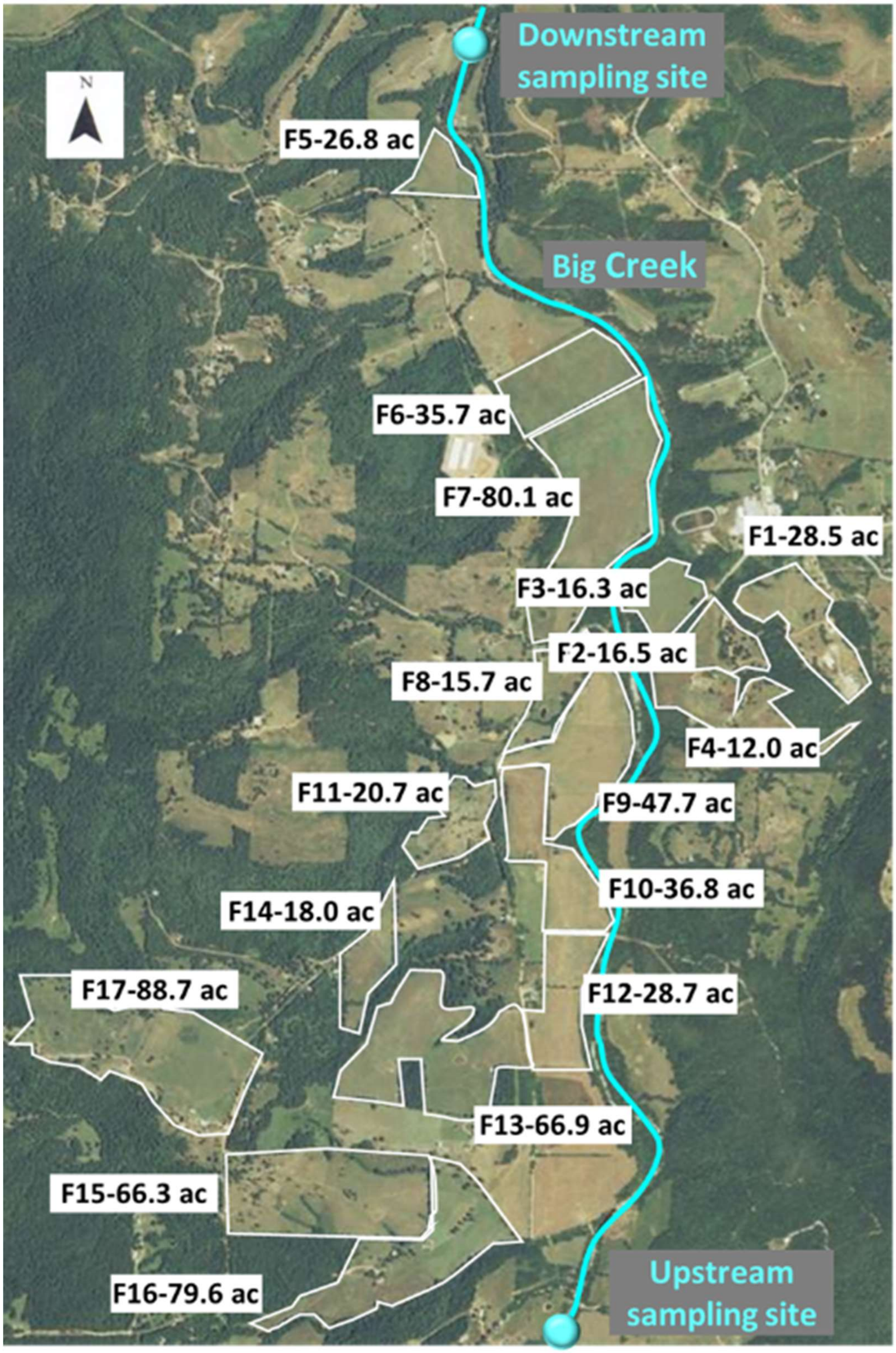

Figure 13. Location of field permitted to receive swine slurry on the C&H Farm and water quality sampling sites on Big Creek up and downstream of the C&H operation.

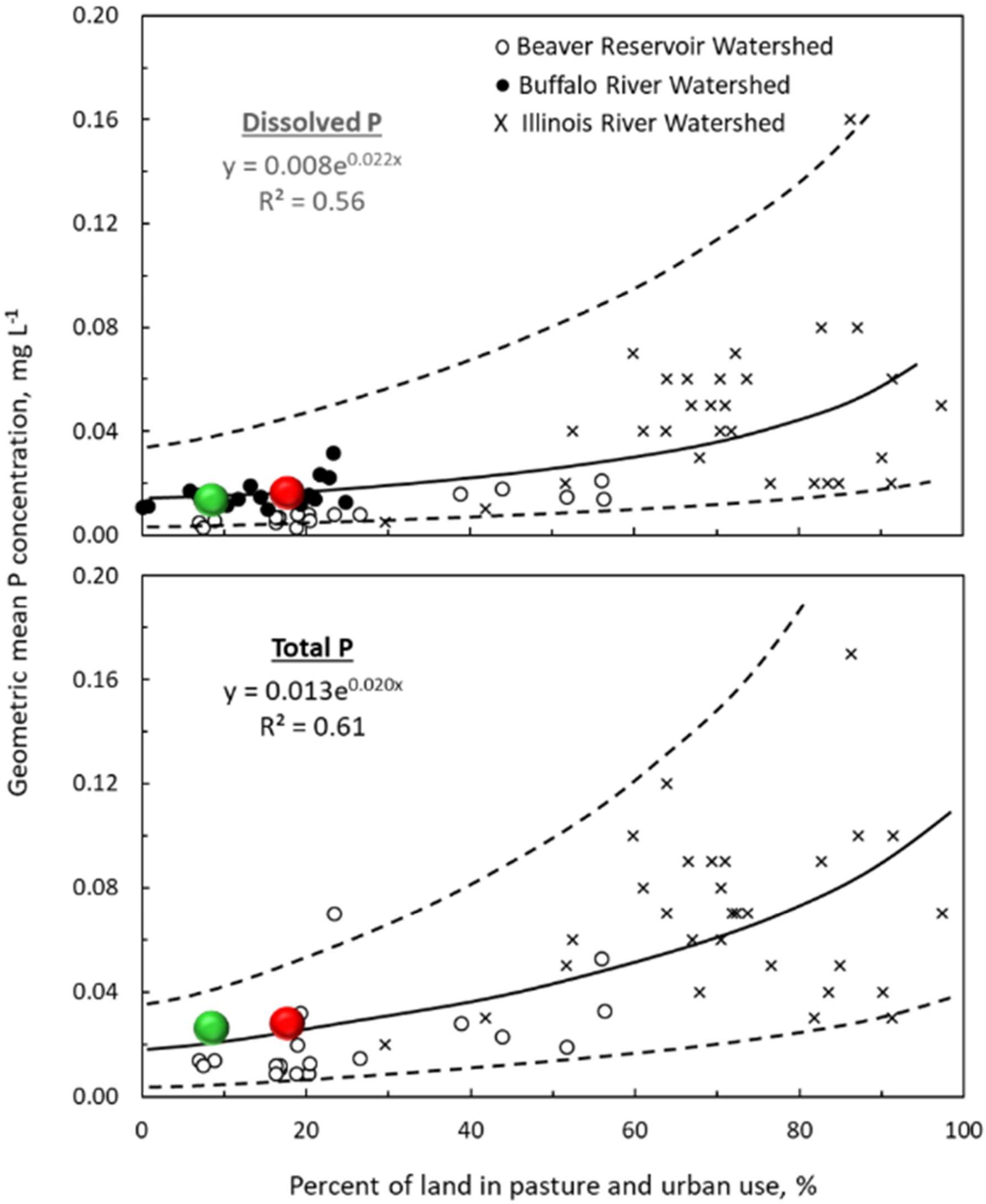

Figure 14. Relationship between land use and the geometric mean dissolved and total P concentrations (mg L^{-1}) in the Buffalo, Upper Illinois, and Upper White River Watersheds. Dashed lines represent the 95% confidence intervals for observed values. Green and red points represent Big Creek geometric means for September 2013 to April 2017 upstream and downstream the swine production facility, respectively.

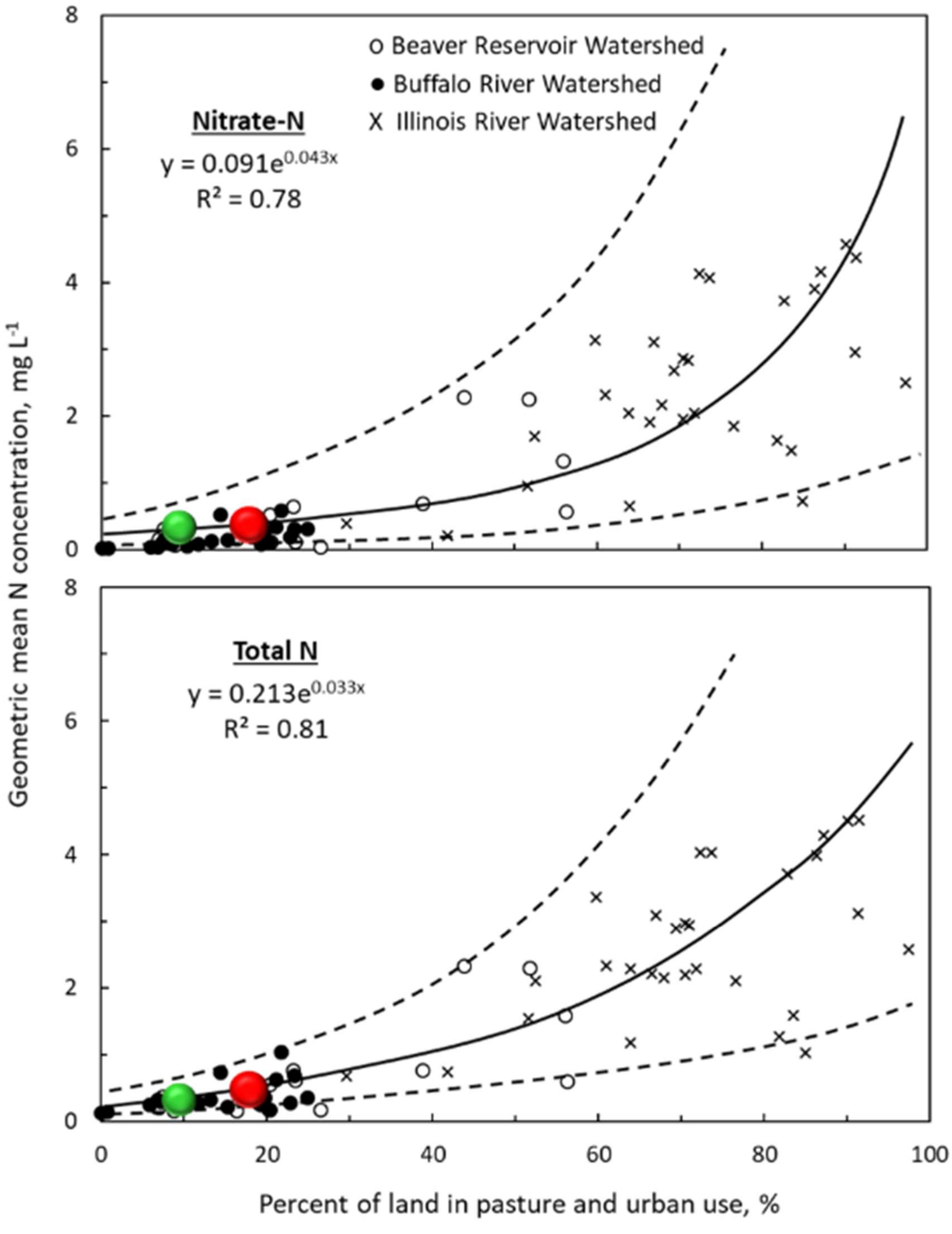

Figure 15. Relationship between land use and the geometric mean nitrate-N and total N concentrations in (mg L^{-1}) in the Buffalo River, Upper Illinois, and Upper White River Watersheds. Dashed lines represent the 95% confidence intervals for the estimated mean (solid line). Green and red points represent Big Creek geometric means for September 2013 to April 2017 upstream and downstream the swine production facility, respectively.

In Big Creek, upstream of the swine production CAFO in the Buffalo River Watershed, the geometric mean concentration of dissolved P, total P, nitrate-N, and total N were 0.009, 0.030, 0.10 and 0.20 mg L^{-1}, respectively, between September 2013 and April 2017. Directly downstream of the CAFO, geometric mean concentrations in Big Creek during base flow over the same period were 0.011, 0.031, 0.23, and 0.36 mg L^{-1} for dissolved P, total P, nitrate-N, and total N, respectively. Relative to water quality standards, the total P concentrations are below the Oklahoma standard of 0.037 mg L^{-1} for the Illinois River (Oklahoma Water Resources Board, 2017) and nitrate-N is below the EPA drinking water standard of 10 mg L^{-1} (U.S. Environmental Protection Agency, 2017).

Geometric mean nutrient concentrations in Big Creek above and below the swine production CAFO and its current potential sphere of influence from slurry applications are similar to or lower than concentrations measured in rivers draining other sub-watersheds in the Upper Illinois and Upper White River Watersheds with similar proportions of agricultural land use (Figures 5 and 6). The proportion of pasture and urban land use in Big Creek up and downstream of the CAFO is 10.6 and 20.5%, respectively, and are in the low range of level of human development in the Buffalo, Upper Illinois, and Upper White River Watersheds.

At the present time, nutrient concentrations in Big Creek above and below the CAFO are consistent with the range seen for other watersheds with similar pasture and urban land-use characteristics. However, this does not preclude the possibility that nutrient concentrations in Big Creek may increase in the future with continued farming operations. Use of these relationships provides a method to determine if nutrient concentrations in a given watershed are changing over time, relative to observed nutrient concentration-land use gradients in other watersheds of the Ozark Highlands and Boston Mountains.

References

Alexander, R.B., R.A. Smith, G.E. Schwarz, E.W. Boyer, J.V. Nolan, and J.W. Brakebill. 2008. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River. Environ. Sci. Technol. 42:822-830.

Arkansas Department of Environmental Quality. 2017a. Specific National Pollutant Discharge Elimination System water permit details: Permit number ARG 590001. Available at https://www.adeq.state.ar.us/home/pdssql/p_permit_details_water_npdes.aspx?AFINDash=51-00164&AFIN=5100164&PmtNbr=ARG590001 Last accessed May 15, 2017.

Buck, O., D.K. Niyogi, and C.R. Townsend. 2004. Scale-dependence of land use effects on water quality of streams in agricultural catchments. Environ. Poll. 130(2):287-299.

Dale, V.H., C.L. Kling, J.L. Meyer, J. Sanders, H. Stallworth, T. Armitage, D. Wangsness, T.S. Bianchi, A. Blumberg, W. Boynton, D.J. Conley, W. Crumpton, M.B. David, D. Gilbert, R.W. Howarth, R. Lowrance, K.R. Mankin, J. Opaluch, H.W. Paerl, K. Reckhow, A.N. Sharpley, T.W. Simpson, C. Snyder, and D. Wright. 2010. Hypoxia in the Northern Gulf of Mexico. Springer Series on Environmental Management. New York, NY: Springer Science.

Dodds, W.K. 2007. Trophic state, eutrophication and nutrient criteria in streams. Trends in Ecol. & Evolution 22:669-676.

Dubrovsky, N.M., K.R. Burow, G.M. Clark, J.M. Gronberg, P.A. Hamilton, K.J. Hitt, D.K. Mueller, and M.D. Munn. 2010. The quality of our Nation's waters—Nutrients in the Nation's streams and groundwater, 1992–2004: U.S. Geological Survey Circular 1350. 174 pages. Available at: http://water.usgs.gov/nawqa/nutrients/pubs/circ1350 Last accessed May 15, 2017.

Giovannetti, J., L.B. Massey, B.E. Haggard, and R.A. Morgan. 2013. Land use effects on stream nutrients at Beaver Lake Watershed. J. Am. Water Works Assoc. 105:E1–E10. E1 – E10. Available at: http://www.awwa.org/publications/journal-awwa/abstract/articleid/34406246.aspx Last accessed May 15, 2017.

Haggard, B.E. 2010. Phosphorus concentrations, loads, and sources within the Illinois River drainage area, northwest Arkansas, 1997–2008. J. Environ. Qual. 39:2113–2120.

Haggard, B.E., P.A. Moore, Jr., I. Chaubey, and E.H. Stanley. 2003. Nitrogen and phosphorus concentrations and export from an Ozark Plateau Catchment in the United States. Biosys. Eng. 86(1):75-85.

Haggard, B.E., A.N. Sharpley, L. Massey, and K. Teague. 2010. Final report to the Illinois River Watershed Partnership: Recommended watershed based strategy for the Upper Illinois River Watershed, Northwest Arkansas, Arkansas. Water Resources Center, University of Arkansas. Technical Publication Number MSC 355. 126 pages. Available at: http://arkansas-water-center.uark.edu/publications/msc/MSC355.pdf Last accessed May 15, 2017.

McCarty, J.A., and B.E. Haggard. 2016. Can we manage nonpoint-source pollution using nutrient concentrations during seasonal baseflow? Agric. Envrion. Letters 1:160015. doi:10.2134/ael2016.03.0015.

Mott, D.N., and J. Laurans. 2004. Water resources management plan: Buffalo National River, Arkansas. U.S. Department of Interior, National Park Service. 160 pages. Available at: https://www.nps.gov/buff/learn/nature/upload/Mott-and-Lauras-2004-Water-Resources-Mgmt-Plan.pdf Last accessed May 15, 2017.

Oklahoma Water Resources Board. 2017. Oklahoma scenic rivers phosphorus criteria review. Available at http://www.owrb.ok.gov/quality/standards/scenicrivers.php/pdf_standards/pdf_standards/pdf_standards/pdf_standards/PCriteriaReview_2012_FinalReport.pdf Last accessed May 15, 2017.

Petersen, J.C., J.C. Adamski, R.W. Bell, J.V. Davis, S.R. Femmer, D.A. Freiwald, and R.L. Joseph. 1998. Water quality in the Ozark Plateaus, Arkansas, Kansas, Missouri, and Oklahoma, 1992-95. U.S. Geological Survey Circular 1158. Fort Collins, CO. Available at: https://pubs.usgs.gov/circ/circ1158/circ1158.pdf Last accessed May 15, 2017.

Rebich, R.A., N.A. Houston, S.V. Mize, D.K. Pearson, P.B. Ging, and C.E. Hornig. 2011. Sources and delivery of nutrients to the northwestern Gulf of Mexico from streams in the south-central United States. J. Am. Water Res. Assoc. 47(5):1062-1086.

Reckhow, K.H., P.E. Norris, R.J. Budell, D.M. Di Toro, J.N. Galloway, H. Greening, A.N. Sharpley, A. Shirmhhammadi, and P.E. Stacey. 2011. Achieving nutrient and sediment reduction goals in the Chesapeake Bay: An evaluation of program strategies and implementation. The National Academies Press, Washington, DC. 258 pages.

Reddy, K.R., S. Newman, T.Z. Osborne, J.R. White, and H.C. Fitz. 2011. Phosphorus cycling in the Greater Everglades Ecosystem: Legacy phosphorus implications for management and restoration. Crit. Reviews Environ. Sci. Technol. 41(6):149-186.

Scavia, D., J.D. Allan, K.K. Arend, S. Bartell, D. Beletsky, N.S. Bosch, S.B. Brandt, R.D. Briland, I. Daloglu, J.V. DePinto, D.M. Dolan, M.A. Evans, T.M Farmer, D. Goto, H. Han, T.O. Hoeoek, R. Knight, S.A. Ludsin, D. Mason, A.M. Michalak, R.P. Richards, J.J. Roberts, D.K. Rucinski, E. Rutherford, D.J. Schwab, T.M. Sesterhenn, H. Zhang, and Y. Zhou. 2014. Assessing and addressing the re-eutrophication of Lake Erie: Central basin hypoxia. J. Great Lakes Res. 40:226-246.

U.S. Environmental Protection Agency. 2015. Watershed assessment, tracking & environmental results. National Probable Sources Contribution to Impairments. Available at http://iaspub.epa.gov/waters10/attains_nation_cy.control#prob_source Last accessed May 15, 2017.

U.S. Environmental Protection Agency. 2017. National primary drinking water regulations: Ground and drinking water. Available at https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations Last accessed May 15, 2017.

U.S. Environmental Protection Agency - Scientific Advisory Board. 2011. Review of EPA's draft Approaches for deriving numeric nutrient criteria for Florida's estuaries, coastal waters, and southern inland flowing waters. EPA Scientific Advisory Board, Washington, DC. 67 pages. Available at http://yosemite.epa.gov/sab/sabproduct.nsf/DCC3488B67473BDA852578D20058F3C9/$File/EPA-SAB-11-010-unsigned.pdf Last accessed May 15, 2017.

Table 7. Land use in the sub-watersheds of the Buffalo River Watershed sampled from 1985-2015. See Figure 2 for site location.

Site #	Stream description	Area	Land use			Geometric mean base-flow concentration			
			Forest	Pasture	Urban	Dissolved P	Total P	Nitrate-N	Total N
		km^2	----------- % -----------			--------------- mg L^{-1} --------------			
T1	Brush Creek at Hwy 21	53.9	85.3	6.8	0.0	0.016	0.020	0.05	0.34
T2	Ponca Creek at Hwy 74	12.6	82.8	7.2	0.0	0.013	0.017	0.11	0.31
T3	Cecil Creek	65.5	75.5	10.3	0.0	0.012	0.010	0.06	0.24
T4	Mill Creek near Pruitt	64.2	68.0	14.4	0.0	0.015	0.025	0.53	0.75
T5	Little Buffalo River	405.0	80.2	8.4	0.1	0.015	0.015	0.09	0.34
T6	Big Creek near Carver	268.7	71.5	13.2	0.0	0.019	0.021	0.13	0.34
T7	Davis Creek	91.7	55.7	21.0	0.0	0.014	0.025	0.35	0.64
T8	Cave Creek	153.8	74.8	11.7	0.0	0.014	0.019	0.09	0.29
T9	Richland Creek	354.6	86.4	5.8	0.0	0.017	0.027	0.05	0.26
T10	Calf Creek	161.8	51.5	23.2	0.0	0.032	0.033	0.32	0.70
T11	Mill Creek at Tyler Bend	45.7	58.2	19.6	0.1	0.015	0.012	0.28	0.37
T12	Bear Creek	308.9	52.1	22.4	0.4	0.023	0.025	0.20	0.29
T13	Brush Creek	64.5	53.9	20.5	1.1	0.024	0.032	0.59	1.05
T14	Tomahawk Creek	117.1	48.5	24.5	0.0	0.013	0.016	0.31	0.37
T15	Water Creek	116.9	67.1	15.2	0.0	0.010	0.008	0.16	0.22
T16	Rush Creek	42.2	82.5	7.6	0.0	0.012	0.027	0.17	0.30
T17	Clabber Creek	84.9	60.0	19.2	0.0	0.012	0.026	0.10	0.26
T18	Big Creek in Lower Wilderness	435.3	56.9	20.3	0.0	0.016	0.019	0.13	0.18
T23	Leatherwood Creek	27.8	98.6	0.0	0.0	0.011	0.031	0.03	0.14
T24	Cow Creek	33.1	97.1	0.7	0.0	0.011	0.015	0.04	0.16

Table 8. Land use in the sub-watersheds of the Upper Illinois River Watershed sampled as part of the one-year monitoring program in 2011. See Figure 3 for site location.

Site #	Sub-watershed name	Area	Land use			Geometric mean base-flow concentration			
			Forest	Pasture	Urban	Dissolved P	Total P	Nitrate-N	Total N
		km^2	----------- % -----------			--------------- mg L^{-1} --------------			
1	Headwaters Illinois	95.8	57.9	37.0	4.7	0.01	0.03	0.21	0.74
2a	Goose Creek-Illinois River	114.0	39.7	50.0	9.7	0.07	0.10	3.13	3.37
2b	Goose Creek-Illinois River	114.0	14.5	72.9	10.6	0.02	0.04	1.49	1.59
3a	Lake Wedington-Illinois River	82.9	28.5	49.5	20.9	0.04	0.06	1.95	2.20
3b	Lake Wedington-Illinois River	82.9	38.1	52.7	8.2	0.04	0.08	2.32	2.34
3c	Lake Wedington-Illinois River	82.9	35.1	47.6	16.1	0.04	0.07	2.04	2.29
4	Lake Fayetteville-Clear Creek	59.6	16.6	30.6	51.2	0.02	0.03	1.63	1.28
5	Mud Creek-Clear Creek	44.0	11.2	50.2	34.8	0.02	0.05	0.72	1.03
6	Hamstring Creek	38.9	22.6	36.6	39.6	0.02	0.05	1.85	2.11
7	Little Wildcat-Clear Creek	59.6	26.9	37.6	34.1	0.04	0.07	2.04	2.29
8a	Headwaters Osage Creek-Illinois River	121.7	12.0	50.2	36.7	0.08	0.10	4.16	4.29
8b	Headwaters Osage Creek-Illinois River	121.7	7.4	30.8	60.5	0.06	0.10	4.38	4.52
9	Spring Creek-Osage Creek	95.8	12.3	42.3	44.0	0.16	0.17	3.9	3.99
10	Little Osage Creek	121.7	9.5	69.4	20.4	0.03	0.04	4.58	4.50
11	Brush Creek-Osage Creek	62.2	7.3	52.9	38.4	0.02	0.03	2.96	3.13
12	Osage Creek-Illinois River	137.3	16.4	54.1	28.6	0.08	0.09	3.73	3.72

Site #	Sub-watershed name	Area	Land use			Geometric mean base-flow concentration			
			Forest	Pasture	Urban	Dissolved P	Total P	Nitrate-N	Total N
13	Upper Muddy Fork-Illinois River	72.5	46.9	45.2	6.4	0.02	0.05	0.96	1.55
14	Moore’s Creek-Muddy Fork	64.8	34.6	55.9	7.9	0.06	0.12	0.65	1.18
15	Lower Muddy Fork-Illinois River	54.4	32.5	59.2	7.1	0.06	0.09	1.91	2.22
16	Headwaters Flint Creek	75.1	26.9	66.6	5.7	0.07	0.07	4.13	4.04
17	Sager Creek	38.9	2.4	61.4	36.0	0.05	0.07	2.50	2.58
18	Middle Flint Creek	64.8	30.2	58.5	9.3	0.03	0.04	2.17	2.15
19	Chambers Hollow-Illinois River	80.3	28.6	49.4	20.9	0.06	0.08	2.86	2.97
20	Wedington Creek	59.6	26.2	69.1	4.3	0.06	0.07	4.08	4.04
21	Cincinnati Creek	67.3	32.7	61.8	5.1	0.05	0.06	3.11	3.09
22	Upper Ballard Creek	62.2	28.9	62.8	8.1	0.05	0.09	2.83	2.94
23	Lake Frances-Illinois River	77.7	29.7	50.8	18.4	0.05	0.09	2.68	2.89
24	Upper Baron Fork	106.2	47.3	48.2	4.2	0.04	0.06	1.70	2.10
26	Upper Evansville Creek	62.2	69.9	26.9	2.7	0.00	0.02	0.40	0.68

Table 9. Land use in the sub-watersheds of the stream sites sampled in the Upper White River Watershed as part of the June 2005 to July 2006 monitoring program. See Figure 3 for site location. From Giovannetti et al., (2013).

Site #	Stream description	Area	Land use			Geometric mean base-flow concentration			
			Forest	Pasture	Urban	Dissolved P	Total P	Nitrate-N	Total N
		km^2	----------- % -----------			--------------- mg L^{-1} --------------			
1	Brush Creek at Hwy 45	51.8	50.9	38.5	0.3	0.016	0.028	0.69	0.78
2	Clear Creek at CR 8516	32.0	40.1	43.8	0.0	0.018	0.023	2.28	2.33
3	Clift Creek at CR 751 and Hwy 12	48.5	36.1	51.7	0.0	0.015	0.019	2.26	2.3
4	Drakes Creek at CR 6245	52.4	69.9	20.3	0.0	0.008	0.009	0.53	0.56
5	Glade Creek at CR 8500	56.4	34	54.8	1.1	0.021	0.053	1.34	1.59
6	Middle Fork, White River at CR 119	73.2	75.6	16.7	0.0	0.007	0.011	0.48	0.5
7	Middle Fork, White River at CR 43	104.5	75.8	16.7	0.0	0.007	0.012	0.46	0.48
8	Middle Fork, White River at CR 57	148.8	76.5	16.3	0.0	0.005	0.012	0.17	0.25
9	Richland Creek Hwy 45	361.0	64.8	26.1	0.4	0.008	0.015	0.05	0.18
10	Richland Creek Hwy 74	239.2	72.4	19.3	0.0	0.015	0.032	0.34	0.52
11	Richland Creek Hwy 79	306.9	68	23.4	0.0	0.008	0.07	0.12	0.62
12	Town Branch at Armstrong Road East of Hwy 156	25.6	36.5	11.9	44.3	0.014	0.033	0.57	0.6
13	War Eagle at Hwy 412	425.8	74.6	18.7	0.2	0.008	0.02	0.21	0.29
14	War Eagle at CR 8500	534.7	69.5	21.9	1.2	--	--	0.65	0.77
15	White River at Springston Ford on CR 49	437.1	86.9	8.7	0.1	0.006	0.014	0.07	0.17
16	White River at CR 5430	344.0	89.4	6.7	0.2	0.005	0.014	0.17	0.22

Site #	Stream description	Area	Land use			Geometric mean base-flow concentration			
			Forest	Pasture	Urban	Dissolved P	Total P	Nitrate-N	Total N
17	White River at CR 5640	104.4	89.6	6.9	0.5	0.003	0.012	0.32	0.38
18	West Fork, White River at CR 1192	211.2	71.6	15.7	4.7	0.006	0.013	0.12	0.19
19	West Fork, White River at Hwy 71 South of West Fork	150.1	76.3	13.7	2.6	0.007	0.009	0.16	0.17
20	West Fork, White River at Hwy 71 Rest Area	64.9	73.1	16.5	2.3	0.003	0.009	0.38	0.4

Table 10. Range percent forest pasture, and urban land use in the Big Creek, Buffalo River, Upper Illinois, and Upper White Watersheds.

Watershed	Forest	Pasture	Urban
	---------------- % ----------------		
Big Creek [1]			
Upstream	89.5	8.0	2.6
Downstream	79.5	17.0	3.5
Buffalo River	52 - 99	0 - 25	0 - 1
Upper White River	34 - 90	7 - 55	0 – 44
Upper Illinois River	2 - 70	27 – 69	3 – 61

Table 11. Big Creek swine manure application summary information for 2013 to 2016.

Year	Number of Fields	Total Area	Total Volume	Average Rate	Average Depth
		ha	m^3	L ha^{-1}	mm
2013	1	4.9	136.3	28,061	2.8
2014	15	231.6	8,961.6	38,686	3.9
2015	15	231.6	12,208.0	52,701	5.3
2016	14	197.9	10,254.7	51,808	5.2

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